Program

21–26 Sept 2025

European Nuclear Physics Conference 2025

Moho
16 bis Quai Hamelin 14000 CAEN

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Registration

Session | **Location:** MoHo, Lobby, 16 bis Quai Hamelin 14000 CAEN

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Monday 22 September

09:00–10:00

Plenary Session: Welcome and opening session

Session | **Location:** MohoPIP, Plenary room | **Conveners:**
Marek Lewitowicz (GANIL), Alessandra Fantoni (INFN Laboratori Nazionali di Frascati)

Description

Plenary Session

10:00

10:00

Monday 22 September

10:00–10:30

Plenary Session: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Marek Lewitowicz (GANIL)

Description

Plenary Session

10:00–10:30 **Probing nuclear physics with gravitational waves**

Speaker

Tanja Hinderer (Utrecht University)

Description

The gravitational waves from merging binary systems carry unique information about the nature and internal structure of compact objects. This is of key interest for neutron stars, whose material is compressed by strong gravity to supra-nuclear densities, leading to unique states of matter. I will describe examples of resulting gravitational-wave signatures and associated characteristic parameters, and their link to properties of dense matter. I will also highlight insights gained from recent gravitational-wave discoveries, and conclude with an outlook onto the remaining challenges and exciting prospects for the next years, as gravitational-wave science continues to move towards an era of precision physics.

10:30

10:30

11:00

Monday 22 September

10:30–11:00

Cofee Break

Break | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

11:00

Monday 22 September

11:00–13:00

Plenary Session: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Prof. Muhsin Harakeh (University of Groningen, Groningen, the Netherlands)

Description

Plenary Session

11:00–11:30 **High Precision Measurements with Stored Highly Charged Radioactive Ions**

Speaker

Yury Litvinov (GSI Darmstadt)

Description

Employing storage rings for precision physics experiments with highly-charged ions (HCI) at the intersection of atomic, nuclear, plasma and astrophysics is a rapidly developing field of research. Storage of freshly produced secondary particles in a storage ring is a straightforward way to achieve the most efficient use of the rare species. It allows for determining the mass of the species through the revolution frequency measurement as well as its lifetime by waiting until it decays and often also the decay branching. Furthermore, in reaction studies it allows for using the same secondary ion multiple times thus increasing the reaction luminosity. The number of physics cases is enormous. In the focus of this presentation will be the most recent results obtained at the cooler storage rings ESR of GSI in Darmstadt and CSRe of IMP in Lanzhou.

Both the ESR and CSRe rings are coupled to in-flight fragment separators and are employed for precision mass spectrometry of short-lived rare nuclei. At the CSRe, the enabled measurement of the velocity of every stored particle—in addition to its revolution frequency—has boosted the sensitivity and precision of mass measurements. One of the highlight recent results are the mass determinations around the 64Ge waiting point in the rp-process nucleosynthesis and the mass of 22Si.

The ESR is presently the only instrument dedicatedly utilized for precision studies of decays of HCIs. Radioactive decays of HCIs can be very different as those known in neutral atoms. One of the exotic decay modes is bound-state beta decay, where the beta electron is created in the free electron orbital. The recent measurement of the half-life of 205Tl of about 1 year, which is stable as atom, provided new insights into the origin of the Solar system and strict constraints on the geochemical neutrino project LOREX. Regarding short-lived systems, the application of highly sensitive non-destructive cavity-based Schottky detectors enabled mass-resolved decay studies in the millisecond range. In the absence of bound electrons, the electron conversion is disabled leading to longer lifetimes. Thus, isolated two-photon decays of first excited 0+ states in 72Ge as well as 98Zr and 98Mo could be addressed.

The experiments performed at the ESR and CSRe will be put in the context of the present research programs in a worldwide context, where, thanks to fascinating results obtained at the presently operating storage rings, a number of projects is planned. Several experiments are planned in Spring 2025 at the ESR, CSRe and the dedicated low-energy CRYRING. Dependent on the progress of these experiment, some fresh results might be available to be reported at the conference.

11:30–12:00 **What's new in radionuclides for medical applications?**

Speaker

Prof. Ferid Haddad (Subatech / GIP Arronax)

Description

For many years, nuclear medicine was focus mainly on imaging using Technecium-99m. Some therapy was conducted using Iodine-131 mainly to treat thyroid cancer. In the 2000's, positron emission tomography (PET) imaging arrived leading to a new wave of applications for nuclear medicine especially in cancer imaging using Flurodesoxyglucose labelled with fluorine-18 (18F-FDG). Several attempt to develop therapeutic agents failed to reach the market despite some efficacy as for example the Zevalin, an antibody labelled with Yttrium-90 for some lymphomas. Since 2013, the third wave of applications has started, focused on therapeutic agent using the peptide receptor radionuclide therapy and coupling imaging and therapy in the so-called theranostics approach. This has resulted in the approval of several new products for routine use including 2 therapeutic radiophamarmaceuticals labelled with Lutecium-177: 177Lu-DOTATATE for neuroendocrine tumors approved in 2018 and 177Lu-PSMA for metastatic prostate cancers (2021). Nowadays, almost all pharmaceutical groups have launched a nuclear medicine program leading to more than 45 different radiopharmaceuticals products in clinical trials.
This new wave use new radionuclides for therapy such as Lutecium-177, Copper-67, Terbium-161… for targeted beta-therapy and Actinium-225, Lead-212/Bismuth-212, Astatine-211 … for targeted alpha therapy. New imaging radionuclides are also developed to be used as imaging counterparts to apply the theranostics approach using PET such as Gallium-68 or Copper-64 or using SPECT such as Lead-203 for example. At the same time people are looking not only to the tumor but also to its microenvironement and starts to explore the potential of Auger emission.
This talk will present the current use of radionuclides for nuclear medicine

12:00–12:30 **Experimental Overview of Heavy Ion Collisions**

Speaker

Kara Mattioli (Laboratoire Leprince Ringuet (LLR), CNRS)

Description

Heavy ion collisions provide a unique laboratory for exploring the dynamics of the strong nuclear force, governed by Quantum Chromodynamics (QCD). These collisions probe strongly interacting matter across different regimes, from the partonic structure of nuclei to the quark-gluon plasma (QGP)—a deconfined state of quarks and gluons that existed in the early universe. Experiments spanning a range of beam energies and collision systems deepen our understanding of QGP properties, fundamental QCD interactions, and their interplay. In this talk, I will present an overview of recent experimental results, their implications for our understanding of these strongly interacting systems, and prospects for future studies.

12:30–13:00 **Hadron-hadron interactions from femtoscopy**

Speaker

Valentina Mantovani Sarti (TUM)

Description

In the last years the correlation measurements at LHC, particularly performed in small colliding systems such as proton-proton collisions, proved to be a powerful experimental tool to access the strong force between hadrons. A large amount of interactions among stable or unstable hadrons have not been measured yet and theoretical calculations based on effective lagrangians and/ or starting from first principles, with quarks and gluons as degrees of freedom, are constantly under development and in need of more experimental data. In this talk I will present an overview on recent correlation measurements involving hadrons with strange and charm quarks representing pivotal examples on how such novel technique can help providing input for a more realistic equation of state for neutron stars and how femtoscopy can contribute to the search and understanding of exotic states. For the latter, I will focus on the recent results obtained in the meson-baryon $S=-1$ and $S=-2$ with the measurements of $\Lambda\pi$, ΞK, $\Lambda\bar{K}$ and $\Xi\pi$ correlations. Latest results on the correlation of D mesons with light hadrons will be shown. Finally, future perspectives will also be presented on how to employ femtoscopy to shed light in the charm and many-body sector.

13:00

13:00

14:00

Monday 22 September

13:00–14:00

Lunch

Break | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:00

Monday 22 September

14:00–16:30

Accelerators and Instrumentation: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Constantin Mihai (IFIN-HH)

14:00–14:25 Exclusive physics at the EIC

Speaker
Charlotte Van Hulse (UAH)

Description

The electron-ion collider is a future, US-based, facility dedicated to the investigation of the hadron structure and hadron formation. One of its key deliverables involves the study of the three-dimensional nucleon and nucleus structure in momentum and position space, accessible through the measurement of exclusive processes. A presentation of how exclusive processes will be studied at the EIC will be given. Where applicable, parallels with measurements in hadron-hadron interactions will be highlighted.

14:25–14:50 Lepton Facilities in Europe - Status and Perspectives

Speaker
Achim Denig

Description

We present the status of European lepton accelerators, which are operated successfully for the fields of nuclear, hadron and low-energy particle physics. A special emphasis is given to the GeV-scale fixed-target accelerators ELSA in Bonn and MAMI in Mainz. Furthermore, the physics programme of the upcoming new MESA accelerator is discussed. At MESA, the innovative concept of energy-recovery (ERL) is combined with a light internal gas target, which opens new avenues for precision physics.

14:50–15:10 STRASSE: a new silicon tracker for quasi-free scattering measurements at RIBF

Speaker
Freddy FLAVIGNY (LPC Caen)

Description

In-beam γ-ray spectroscopy and invariant/missing mass studies from quasi-free scattering or knockout reactions on secondary fragmentation beams are often the preferable techniques to give access to the most exotic nuclei and perform their first spectroscopy. Illustratively, such studies have recently enabled to quantify the magic character of 54Ca [1,2], 78Ni[3], but as importantly to characterize the increase of collectivity when departing from shell or subshell closures (ex: 28F[4], 52Ar[5], 66Cr, 70-72Fe[6]) sometimes leading to islands of inversion.
The technical challenge of these experiments is to maintain the best energy resolution possible while maximizing the luminosity and by consequence the target thickness. The above-mentioned results with beams down to a few particles per second have been obtained with the MINOS setup [7] allowing the use of a thick LH2 target (up to 15 cm long) via its combination with a TPC for vertex tracking of (p,2p)-like reactions. While pioneering in several aspects, the overall energy resolution using the MINOS device (either for doppler-correction of γ-ray energies or from recoil protons for missing mass) was limited by its vertex resolution (~5 mm FWHM) and its combination with scintillator arrays (high efficiency but limited resolving power).

In this presentation, we will present a new system in development called STRASSE to go above these performances and enable: (i) high-resolution γ-spectroscopy from an optimal coupling with state-of-the-art germanium tracking detectors and (ii) missing mass measurements with a moderate resolution sufficient to determine the absolute energy of the states populated (σ~ 2 MeV). The STRASSE system consists of a compact silicon tracker (Fig.1) placed in vacuum and a thick LH2 target (up to 150 mm long) with a small diameter of 30 mm to minimize the angular straggling of recoil protons. With about seventeen thousand strips and associated electronics channels in a cylinder of only 36 cm, the tracker aims at reaching a vertex resolution of about 0.5 mm (FWHM).
More precisely, this contribution will focus on the description of this new detection system (principle, electronics, integration) including simulations, first tests and perspectives of physics cases at the RIBF.

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15:10–15:30 New developments in the analysis of the hypernuclear experiment WASA-FRS with machine learning

Speaker
DAVID CALONGE GONZALEZ (CSIC)

Description

The WASA-FRS HypHI Experiment focuses on the study of light hypernuclei by means of heavy-ion induced reactions in 6Li collisions with 12C at 1.96GeV/u. It is part of the WASA-FRS experimental campaign, and so is the eta-prime experiment [1]. The distinctive combination of the high-resolution spectrometer FRagment Separator (FRS) [2] and the high-acceptance detector system WASA [3] is used. The experiment was successfully conducted at GSI-FAIR in Germany in March 2022 as a component of the FAIR Phase-0 Physics Program, within the Super-FRS Experiment Collaboration. The primary objectives of this experiment are twofold: to shed light on the hypertriton puzzle [4] and to investigate the existence of the previously proposed nnΛ bound state [5]. Currently, the data from the experiment is under analysis.

Part of the data analysis is to provide a precise ion-optics of the measurement of the fragment originated from the mesonic weak decay of the hypernuclei of interest. The reconstruction the ion-optics of fragments is based on the calibration run of FRS optics. We have proposed to implement machine learning models and neural networks to represent the ion-optics of FRS: While the current state of the problem involves solving equations of motion of particles in non-ideal magnetic fields - which leads to the application of approximations in the calculations - the implementation of data-driven models allows us to obtain accurate results with possible better momentum and angular resolution.
Another important contribution to the analysis would be the correct identification of signal versus background in the experimental data. For this purpose, we present an analysis using ML techniques as opposed to typical selection conditions methods. The interest of this new approach comes from the fact that the models interpret the physics behind the data by making more accurate cuts and more consistent with the experiment.

In this presentation, we will show two different results of the current status of the R&D in machine learning model of the ion-optics and the prospect of the inference of the track parameters of the fragments based on the calibration data recorded during the WASA-FRS experimental campaign of 2022 and the signal to background ratio enhancement with ML. For the ion optics part: our model selection optimization follows this approach: we utilize AutoML environments [6], to determine the best pipeline for our data. Once identified, this optimized pipeline is implemented in a PyTorch model. Regarding the signal to background ratio enhancement, we will make use of autoML libraries such as autogluon [7] to identify the H3Λ hypernuclei present in the experimental datafile.

The results of this study demonstrate a robust reconstruction of the track angles in the FRS mid-focal plane, achieving an improvement of up to a ~40%. A resolution of 0.65 mrad and 0.46 mrad was achieved for the horizontal and vertical angular track plane, respectively. Additionally, the reconstruction of the magnetic rigidity in the final focal plane attained a resolution Δp/p of 5 10^{-4}. From these results, we demonstrated that a data-driven model of non-linear ion optics is feasible. We also observed that training the full model can be achieved very quickly, paving the way for online training during data collection at the FRS. This capability will enable more accurate real-time analysis of fragment identification and improve the quality of the exotic beam obtained from the fragment separator.
Also, a correct identification of signal events in the experimental data has also been carried out, which allows a precise analysis of the properties of the H3Λ from the experimental data, such as the lifetime of the hypernuclei.

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[2] H. Geissel et al., Nucl. Instr. and Meth. B 70 (1992) 286-297.
[3] C. Bargholtz et al., Nucl. Instr. and Meth. A 594 (2008) 339-350.
[4] T.R. Saito et al., Nature Reviews Physics 3 (2021) 803-813.
[5] C. Rappold et al., Phys. Rev. C 88 (2013) 041001.
[6] M. Feurer et al., JMLR 23 261 (2022) 1-61.
[7] N. Erickso et al., 7th ICML Workshop on AutoML (2020).

15:30–15:50

The dRICH at ePIC: first SiPM based cherenkov detector for frontier QCD studies at the EIC

Speaker

Simone Vallarino (INFN Genova)

Description

The dual-radiator RICH (dRICH) detector of the ePIC experiment at the future Electron-Ion Collider (EIC) will employ Silicon Photomultipliers (SiPMs) for Cherenkov light detection. The photodetector system will cover an area of approximately 3 m², using 3x3 mm² pixel sensors and exceeding 300,000 readout channels, marking the first use of SiPMs for single-photon detection in a high-energy physics (HEP) experiment. SiPMs are favored for their cost-effectiveness and high performance in magnetic fields (~1 T at the dRICH location). The dRICH will cover a broad momentum range, from 1 to 50 GeV/c in the hadronic endcap, providing essential hadron PID for the physics programme. However, due to their limited radiation tolerance, extensive testing is essential to ensure sustained single-photon detection capabilities and to control dark count rates (DCR) throughout the ePIC experiment's operational period.
This work provides an overview of the ePIC-dRICH detector system and details the ongoing R&D efforts for the SiPM-based optical readout subsystem. Particular emphasis is placed on the latest beam test results from a large-area prototype SiPM readout plane, comprising up to 2048 sensors with 3x3 mm² pixels. The modular prototype utilizes an innovative photodetection unit (PDU) developed by INFN for the EIC, integrating 256 SiPM sensors, cooling systems, and time-to-digital conversion (TDC) electronics within a compact ~5x5x14 cm³ package. Multiple PDU modules were successfully tested at CERN-PS in October 2023 and May 2024, using a complete front-end and readout electronics chain based on the ALCOR chip, developed by INFN Torino.

15:50–16:10

First performances of EICROC ASIC to read-out pixelated AC-LGAD sensors for the Electron-Ion Collider (EIC)

Speaker

Arzoo SHARMA (IJCLab, Université Paris-Saclay, CNRS/IN2P3, Orsay)

Description

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Finding the answers to the long-standing questions, such as, emergence of mass and spin of the proton from partons, saturation of gluon density, and gluon momentum distribution inside the proton and nuclei, motivated the EIC [1] to be developed at Brookhaven National Laboratory, USA. The first EIC detector, ePIC (electron Proton-Ion Collision experiment), is comprised of a central barrel detector, as well as extensive beamline detectors in the outgoing electron (far-backward) and hadron (far-forward) beam directions. The far-forward (FF) detectors include Roman pots, which are placed inside vacuum and are intended to detect protons and ions scattered at very small angles (~ 5 mrad) in the forward direction, at ~30m downstream from the interaction point. The main goal of the FF detectors is to tag exclusive and diffractive events and to reconstruct their transverse momentum with a resolution of ~ 10 MeV/c. This is obtained by developing a new generation of 4D tracking sensors, pixelated AC-LGADs (capacitively-coupled Low-Gain Avalanche Diode, pixel of 500x500 μm^2) [2][3] capable of providing the required spatial (less than 50 μm relying on charge sharing among pixels) and timing (~ 30 ps) resolutions. After these AC-LGADs have been read-out using ALTIROC0 [4] as a first attempt, an optimized read-out chip, EICROC (32x32 pads), is being designed by OMEGA and the characterization of the first prototype, EICROC0 (4x4 pads) [5], coupled to an AC-LGAD sensor is being performed at IJCLab. The EICROC0 is a system-on-chip with analog and digital processing including for each of the 16 channels a fast low-noise trans-impedance preamplifier, followed by two paths: a fast path with a discriminator connected to a 10-bit Time-to-Digital Converter (CEA/Irfu) for time measurement (ToA) with a 25 ps accuracy; and a slow path with shaper connected to an 8-bit 40 MHz successive approximation Analog-to-Digital Converter (AGH Krakow) providing amplitudes. The performances of pixelated AC-LGAD sensors read-out by EICROC0, obtained from preamplifier as well as digital (TDC and ADC) data and relying on measurements with the internal charge injection system, a Beta source and an infrared laser, will be presented.

Acknowledgement:
This work is benefitting from support from the French Agence Nationale de la Recherche (ANR), under grant ANR-24-CE31-5571 (project ROAD_4_EIC).

References:
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[5] A. Verplancke et al., "EICROC: an ASIC to read-out the AC-LGAD sensors for the Electron-Ion Collider (EIC)", contribution to the proceedings of the Topical Workshop on Electronics for Particle Physics, Sept. 30th – Oct. 04th, 2024, Glasgow, UK, to be published in JINST 2025.

16:30

14:00 **Monday 22 September** 14:00–16:35

Few-Body Systems: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Francisco-Miguel MARQUES (LPC-Caen)

14:00–14:25 few-body structure of hypernuclei

Speaker

Prof. Emiko Hiyama (Tohoku Univ./RIKEN)

Description

In hypernuclear physics, it is important to study structure of light hypernuclei to extract information on hyperon-nucleon interaction. Recently, observed bound Ξ hypernuclei such as $^{14}{\rm N}+\Xi$ and $^{11}{\rm B}+\Xi$ systems have been observed. Along this line, it is requested to predict what kind of Ξ hypernuclei should be observed theoretically. In this talk, I will review recent progress of Ξ hypernuclei.

14:25–14:50 Neutron-Rich Systems and Neutron Correlations

Speaker

Dr Rimantas Lazauskas (IPHC Strasbourg)

Description

In this contribution, I present our latest developments in the study of neutron-rich nuclei. In particular, recent observations of a sharp low-energy structure in the four-neutron missing mass distribution [1] —following the fast removal of the ^{4}He core from ^{8}He nucleus—have sparked considerable interest. We have been able to explain this phenomenon as a consequence of neutron correlations arising from the emission of neutrons in a diffuse, weakly bound system.

Our earlier work relied on a simplified model of the neutron distribution within the ^{8}He nucleus. In the present study, we aim to build on these foundations by developing a more realistic model of the ^{8}He structure.

Additionally, we will discuss other neutron-rich systems, including neutron-rich hydrogen [3] and the $^{18-21}$B isotopes.

14:50–15:15 Understanding two- and three-body hadronic interactions using femtoscopy

Speaker

Raffaele Del Grande (Czech Technical University in Prague)

Description

The femtoscopy technique at the Large Hadron Collider has proven capable of providing unprecedented precision information on the low-energy interaction between nucleons and strange hadrons. The experimental methodology exploits the emission of particle pairs at the femtometer scale in the collisions and analyzes the momentum correlation induced by free scattering of the produced hadrons. The measurements of the p-Λ and p-Ξ^- correlation functions by the ALICE collaboration have been used to challenge effective field theory results and to test for the first time lattice QCD calculations. Recently, the same experimental technique has been used to access the dynamics of three hadrons and three-nucleon (N-N-N) as well as N-N-Λ correlation measurements became available. Phenomenological calculations indicate that the effect of the three-body forces in the N-N-Λ correlation function is pronounced, demonstrating that correlation function analyses can be used to access the dynamics of few-body systems. In this contribution, I will discuss the impact of the femtoscopy method on the understanding of the two- and three-body interactions with hadrons.

15:15–15:35 Results on light hypernuclei in the WASA-FRS and E07 emulsion experiments

Speaker

Dr Christophe Rappold (Instituto de Estructura de la Materia - CSIC)

Description

The study of light hypernuclei, subatomic nuclei containing strange quarks, is an active area of research explored by multiple collaborations [1,2,3,4,5,6]. Recent investigations using high energy heavy ion collisions have yielded surprising insights into the three body hypernuclear state, Λ3H (hypertriton). Experimental measurements of its lifetime [1,2,3,7,8,9,10] and binding energy [4,11,12] have led to the so called "hypertriton puzzle", still an open topic in hypernuclear physics. Addressing this issue, our European-Japanese collaboration, including CSIC (Spain), GSI-FAIR (Germany), and RIKEN (Japan), focuses on data analysis from the WASA-FRS HypHI experiment at GSI-FAIR and the E07 experiment at J-PARC.
As part of the WASA-FRS collaboration within the Super-FRS Experiment collaboration, we investigate light hypernuclei produced in heavy-ion collisions at 1.96 GeV/u on a fixed carbon target. This experiment, conducted in early 2022 using the WASA detector and the Fragment Separator (FRS) at GSI-FAIR [6], is currently undergoing data analysis. Additionally, in the J-PARC E07 experiment [13], we lead efforts to identify and analyze hypernuclei using deep learning techniques applied to nuclear emulsions irradiated by kaon beams. Our primary objective is to measure the hypertriton binding energy with unprecedented precision [6].
This presentation will provide an overview of our hypernuclear research, focusing on the ongoing analysis of the WASA-FRS HypHI experiment and the first observation of a hypernuclear signal. We will then discuss the measurement of the hypertriton binding energy using nuclear emulsion analysis and deep learning techniques [14], presenting our first results for Λ3H and Λ4H binding energies with statistical and systematic uncertainties of 100 keV and 50 keV, respectively [15]. Finally, we will highlight the first double-strangeness hypernucleus uniquely identified by our AI analysis pipeline [16] in the E07 emulsion experiment. This discovery provides only the second experimental measurement of binding energy of 2Λ, BΛΛ, and of ΛΛ interaction energy, ΔBΛΛ, offering new perspectives on the potential of AI in advancing a "Double-Strangeness Factory".

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15:35–15:55 Multineutron correlations in the decay of heavy Helium isotopes

Speaker
Audrey ANNE

Description

Since the discovery of the neutron in 1932 [1], extensive experimental campaigns and calculations have been carried out to explore the possible existence of multineutron systems [2]. The dineutron being unbound, particular attention has been paid to the next even candidate, the tetraneutron, a system made up of four neutrons. Its few-body character and the absence of Coulomb interaction make of this system a perfect case to test nuclear models and the nucleon-nucleon nuclear force. After sixty years of experimental search, with only two promising signals [3,4], the observation of a resonance-like four-neutron structure using a missing-mass approach [5] has rekindled the interest in this field. In this context, the SAMURAI34 experiment aimed at measuring the invariant mass of the four-neutron system using several breakup reactions of an ^{8}He beam. The direct detection of the four neutrons in different reaction channels will be presented. Preliminary results of several four-neutron observables, and their potential implications, will be discussed.

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15:55–16:15 Four Neutron Point-Production within pionless EFT

Speaker
Timothy George Backert (Technische Universität Darmstadt)

Description

Recent experiments [Duer et al., Nature 606 (2022)] suggest a resonance-like structure in the $^8\text{He(p,p}\alpha\text{)4n}$ reaction. To investigate this, we analyze four-neutron point-creation using pionless effective field theory (EFT) within the Faddeev-Yakubovsky formalism, which enables a decomposition into the 2+2 and 3+1 channel. This is particularly relevant given that dineutron-dineutron correlations (2+2 channel) may drive the observed structure [Lazauskas et al., PRL 130 (2023)].

Within this framework, we present results for the four-neutron point-creation rate, proportional to the cross section. These results are checked to be consistent, at both low and high energies, with conformal field theory (CFT), which treats the multi-neutron state as an 'unnucleus' [Hammer et Son, PNAS 118.35 (2021)]. This analysis aims to provide insight into the possible existence of a tetra-neutron resonance-like structure.

16:15–16:35 The two- and three-nucleon correlation functions

Speaker
alejandro kievsky (INFN)

Description

The interest in the correlation function is based in the use of the femtoscopy technique in experiments at the Large Hadron Collider (LHC) to perform new high-precision studies of the low-energy interactions between hadrons. This experimental method exploits the production and emission of hadrons at relative distances of the order of a femtometer in pp and p-nucleus collisions, to study their final state interaction. The interaction between hadrons appears as a correlation signal in the momentum distributions of the detected particles which can be measured in the form of a correlation function. This function depends on the emission process, which is the source of hadrons, as well as on the final state interaction of the emitted particles. By measuring correlated particle pairs or triplets at low relative energies and comparing the results of the measurements to theoretical predictions, it is possible to extract information on the two-body hadron-hadron interaction and, eventually, on the three-body interaction. In this contribution I will present the latest results in the theoretical computation of the $p-p\,$, $p-p-p$, $p-\Lambda$ and $p-p-\Lambda$ correlation functions. In the three-body case the full dynamics has been solved using the Hyprspherical Adiabatic method. Different models of two-body and three-body interaction has been used to analyze the information captured in the correlation functions.

16:35

14:00 **Monday 22 September** 14:00–16:25

Fundamental Symmetries and Interactions

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Pierre DELAHAYE (GANIL)

14:00–14:25 Search for a neutron dark decay in 6He

Speaker

Hervé Savajols (GANIL/CNRS)

Description

Neutron dark decays have been suggested as a solution to the discrepancy between bottle and beam experiments, providing a dark matter candidate that can be searched for in halo nuclei. The free neutron in the final state following the decay of ^{6}He into ^{4}He + n + χ provides an exceptionally clean detection signature when combined with a high efficiency neutron detector. We will report on on the results of an experiment performed at GANIL using the unique neutron detector TETRA and the high-intensity 6He+ beam. A search for a coincident neutron signal resulted in an upper limit on a dark decay branching ratio of Brχ ≤ 4.0 × 10^{-10} (95% C.L.). Using the dark neutron decay model proposed originally by Fornal and Grinstein [1], we translate this into an upper bound on a dark neutron branching ratio of $\mathcal{O}$(10^{-5}), improving over global constraints by one to several orders of magnitude depending on mχ [2].

References

[1] B. Fornal and and B. Grinstein, Phys. Rev. Lett. 120 (2018) 191801.

[2] L. Lejoubioux et al., Phys. Rev. Lett. 132 (2024) 132501.

14:25–14:45 Next measurement of the neutron electric dipole moment: n2EDM at PSI

Speaker

Efrain Patrick Segarra (Paul Scherrer Institut (PSI))

Description

The world's leading measurement of the neutron's electric dipole moment (EDM) is currently ongoing at the Paul Scherrer Institute (PSI): the n2EDM experiment. n2EDM will deliver, at minimum, an order of magnitude better sensitivity as compared to current limits on the neutron EDM. This increased sensitivity on the neutron EDM will provide stringent constraints on time-reversal violating processes and deeply probe physics beyond the Standard Model (BSM), furthering our understanding on the origins of the baryon asymmetry of the universe.

This talk will highlight the recent achievements and successes during commissioning – from high-voltage operation to magnetic-field uniformity. I will also introduce new techniques we have developed to characterize our apparatus, and emphasize how n2EDM will reach a ground-breaking sensitivity of 10^-27 e.cm.

14:45–15:05 First ultracold neutrons for TUCAN

Speaker

Alexis Brossard (TRIUMF)

Description

The TRIUMF UltraCold Advanced Neutron (TUCAN) collaboration is completing a new ultracold neutron (UCN) source, which aims to be the world's strongest, with an instantaneous production rate of 1.6 × 10^7 UCN/s.
High-energy neutrons are produced by a spallation target irradiated by a proton beam from the TRIUMF cyclotron, then moderated in heavy water and liquid deuterium. UCNs are subsequently produced in superfluid helium-4 by phonon production. The source was commissioned and produced its first detectable UCNs in June 2025, and the results were found to be in reasonable agreement with expectations. Additional data-taking campaigns are planned over the course of the year.
I'll present the results of these campaigns, including UCN production, source UCN storage time, and source performance under different beam currents and heat loads. The results bode well for the completion of a neutron electric dipole moment experiment, the flagship physics project for the source.

15:05–15:25 Measuring the electric dipole moment the muon at PSI

Speaker

Mr Pranas Juknevicius (Paul Scherrer Instute, Forschungsstrasse 111, 5232 Villigen PSI, Switzerland and ETH Zürich, Switzerland)

Description

The Standard Model of particle physics is a widely accepted and well-established theory that is able to describe electromagnetic, weak, and strong interactions using a common framework. However, phenomena such as masses of the neutrinos, the matter–antimatter asymmetry and the nature of dark matter and dark energy remain unexplained. At the Paul Scherrer Institut (PSI) we are setting up an experiment to search for the electric dipole moment (EDM) of muons. A non-zero EDM would indicate a violation of charge-parity (CP) symmetry, thus might help understand the baryon asymmetry in the universe and would be a signal of beyond Standard Model (BSM) physics.

The EDM of elementary particles such as electrons or muons are the simplest systems, where the violation of CP symmetry can be probed. However, the EDM of an electron is measured in molecules or ions, thus different CP violating sources might affect the observable effective EDM. In contrast, our measurement will directly measure unbound muons, thus the only CP violating source is the EDM of the muon. The current best direct limit of the muEDM, established by the g-2 collaboration at the Brookhaven National Laboratory, is $d_\mu < 1.8 \cdot 10^{-19}$ e$\cdot$cm.

At the Paul Scherrer Institut, we are setting up a compact, high-precision experiment to measure the EDM of muons using the frozen-spin technique. The muEDM experiment is carried out in two phases, where in Phase 1 the collaboration is aiming at a sensitivity of $\sigma (d_\mu) =4 \cdot 10^{-21}$ e$\cdot$cm using muons with 23 MeV/c momentum. During Phase 2 the objective is to achieve a sensitivity of $\sigma (d_\mu) = 6 \cdot 10^{-23}$ e$\cdot$cm using muons with momentum 125 MeV/c.

15:25–15:45 Polarization of trapped ions in MORA at IGISOL

Speaker

Luis Miguel Motilla Martinez (University of Jyväskylä / GANIL)

Description

Around us we see an universe filled with galaxies, stars and planets like ours. But when we look back to the Big Bang and the processes that created the matter in it, at first we observe that there should have been created the same amount of matter and antimatter, thus the universe would be empty or different than it is. Sakharov suggested several conditions to explain the matter-antimatter asymmetry, one of them being the violation of the CP symmetry.

In the MORA experiment, we aim to measure the D correlation, which is non zero for violation of T symmetry in polarized nuclei, thus it can be related to CPV. For this we use a detector setup made of MCP's, Phoswiches and Si detectors, to measure coincidences between beta emissions and recoil ions, product of the beta decay of trapped 23Mg ions.

In this talk I will show the latest progress of MORA at IGISOL, the challenges we have overcome, like the 23Na+ contamination, and the latest measurements of the polarization degree and D correlation.

15:45–16:05 Precision Test of CPT Symmetry via Ground State Hyperfine Spectroscopy in Antihydrogen at ALPHA

Speaker

Mr ADRIANO DEL VINCIO (University of Brescia)

Description

On Behalf of ALPHA Collaboration

CPT symmetry is a fundamental principle in the Standard Model of particle physics. Antihydrogen, the simplest atom of antimatter, is ideal for testing CPT invariance by comparing its properties with those, very well known, of hydrogen. The ALPHA experiment at CERN focuses on producing, confining, and studying antihydrogen. Antihydrogen is synthesized by merging positrons and antiprotons in a Penning–Malmberg trap, with magnetic confinement achieved using a superconducting solenoid and octupole magnets.
We report on the techniques used to measure the hyperfine levels of the antihydrogen 1S state at ALPHA. This measurement is conducted in a non-zero magnetic field configuration, where the energy state degeneracy is fully resolved by the ≈ 1 T field used for antihydrogen confinement. Of the four hyperfine spectral lines, which differ according to the relative spin orientations of the positron and antiproton, only two correspond to trappable states. The hyperfine levels are measured by inducing positron spin-flip transitions from trappable to untrappable states using microwave radiation directed into the trap. Detection of antihydrogen annihilation is performed using a multilayer Silicon Vertex Detector (SVD), capable of reconstructing pion tracks and determining the annihilation vertex. The results obtained during the 2023 and 2024 data-taking campaigns will be presented.

16:05–16:25 First measurement of a charge-exchange reaction cross-section for antihydrogen

Speaker

Sarah GEFFROY

Description

On behalf of the GBAR collaboration

The properties of antimatter with respect to matter have been explored with utmost accuracy, except for its gravitational behaviour. The GBAR experiment, based at CERN's AD/ELENA facility, is designed to investigate the weak equivalence principle by measuring the free-fall acceleration of antihydrogen in the Earth gravitational field.

To achieve this, the goal is to produce antihydrogen ions through two successive charge-exchange reactions:

$\overline{p}+ \text{Ps} \rightarrow \overline{H} + e^-$

$\overline{H} + \text{Ps} \rightarrow \overline{H}^+ + e^-$

After cooling down to a very low velocity, one positron from the ion is laser-detached and the remaining neutral $\overline{H}$ is left for a free fall measurement.
The production of $\overline{H}^+$ [2] depends on the cross section of the second charge-exchange reaction — which is unknown. To address this, an experiment is being conducted in 2025 to measure the cross section of the matter-equivalent reaction, known as SPHINX..

In 2022, the successful production of 6 keV antihydrogen atoms was demonstrated for the first time [1] [3]. Building on this, the 2024 beam time led to more than a tenfold increase in the $\overline{H}$ production rate, making it possible to measure the antihydrogen production cross section at two different energies.

In this presentation, I will describe the experimental setup and its operation, and show the first results obtained for the antihydrogen production cross section.

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16:25

14:00 **Monday 22 September** 14:00–16:35

Heavy Ion Collisions and QCD Phases: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Conveners:**
Alessandra Fantoni (INFN Laboratori Nazionali di Frascati), Michael Winn (DPhN/IRFU/DRF/CEA Paris-Saclay)

14:00–14:25 Soft probes of collectivity, from hadrons to nuclei

Speaker
Nicolo Valle (INFN, Pavia)

Description

Understanding the collective behavior emerging in high-energy collisions is a central goal of contemporary heavy-ion physics. Using recent results from the LHC, this talk will present an experimental overview of how light and strange hadrons, as well as (hyper)nuclei, serve as soft probes of the dynamics and hadronization of the Quark-Gluon Plasma.
The presentation will cover selected experimental signatures across multiple collision systems, ranging from pp to Pb–Pb, and explore how features typically associated with collectivity evolve with system size and multiplicity. Special attention will be given to the role of nuclei and hypernuclei as sensitive tools to probe the late-stage dynamics and the nature of hadron formation.

14:25–14:50 The unexpected uses of a bowling pin: exploiting Ne-20 isotopes for precision characterizations of collectivity in small systems

Speaker
Govert Nijs (CERN)

Description

Whether or not femto-scale droplets of quark-gluon plasma (QGP) are formed in so-called small systems at high-energy colliders is a pressing question in the phenomenology of the strong interaction. For proton-proton or proton-nucleus collisions the answer is inconclusive due to the large theoretical uncertainties plaguing the description of these processes. While upcoming data on collisions of O-16 nuclei may mitigate these uncertainties in the near future, here we demonstrate the unique possibilities offered by complementing OO data with collisions of Ne-20 ions. We couple both NLEFT and PGCM ab initio descriptions of the structure of Ne-20 and O-16 to hydrodynamic simulations of OO and NeNe collisions at high energy. We isolate the imprints of the bowling-pin shape of Ne-20 on the collective flow of hadrons, which can be used to perform quantitative tests of the hydrodynamic QGP paradigm. In particular, we predict that the elliptic flow of NeNe collisions is enhanced by as much as 1.170(8)(30) for NLEFT and 1.139(6)(39) for PGCM relative to OO collisions for the 1% most central events. At the same time, theoretical uncertainties largely cancel when studying relative variations of observables between two systems. This demonstrates a method based on experiments with two light-ion species for precision characterizations of the collective dynamics and its emergence in a small system.

14:50–15:15 Fluctuation measurements as a probe of hot QCD matter

Speaker
Mesut Arslandok (Yale University)

Description

Quantum chromodynamics (QCD), the fundamental theory of the strong interaction, predicts that at sufficiently high energy densities, nuclear matter undergoes a phase transition into a deconfined state known as the quark–gluon plasma (QGP). Ultrarelativistic heavy-ion collisions provide ideal conditions to explore the QCD phase diagram and investigate the properties of the QGP as a function of temperature and baryon chemical potential. At very high energies, such as those achieved at the Large Hadron Collider (LHC), and near vanishing baryon chemical potential, the transition from hadronic matter to the QGP is expected to be a smooth crossover. At larger values of baryon chemical potential, this crossover may terminate at a critical endpoint (CEP), beyond which the transition becomes first order. Identifying the CEP is a key objective of current and future beam energy scan programs at RHIC, the CERN SPS, and FAIR.
Fluctuation measurements are essential tools for probing the QCD phase structure and the nature of the QGP. In this talk, I will present an overview of recent experimental results across a wide range of collision energies and discuss their implications for our understanding of the QCD phase diagram.

15:15–15:35 The ASY-EOS-II experiment (S122) at GSI/FAIR: studying the EoS (Equation-of-State) of neutron rich matter at high baryon densities.

Speaker
Enrico De Filippo (INFN Catania, Italy)

Description

Enrico De Filippo (INFN Catania)
for the R3B Collaboration

Constraining the asymmetry term of the EoS is important, among other reasons, for its strict connection with multi-messenger astrophysics, such as compact stars and core collapse supernovae phenomena. By using as main observable the elliptic flow ratio of neutrons and charged particles [1,2], the ASY-EOS experiment probed the isospin dependent component (asymmetry term) of the EoS at densities slightly above ρ$_0$ in
Au + Au reactions at 400 MeV/A. The ASY-EOS-II experiment was performed in March 2025 at GSI/FAIR by using gold beam energies at 280, 400, 600, 1000 MeV/A and proposes to extend the knowledge of the symmetry energy to higher densities near to 2ρ$_0$ and to improve the measurement precision with respect to the previous one. This last aspect can be reached by using innovative and powerful detectors inside the R3B cave. KRAB is a new detector, developed at IFJ PAN, Krakow, constituted by 5 rings of 4x4 mm^2 fast scintillating fibers placed around the target. It provides a fast trigger based on multiplicity and charged particles azimuthal distributions for event-by-event reaction plane reconstruction together with four rings (320 CsI(Tl) telescopes) of the CHIMERA array. Among the R3B collaboration devices, the NeuLAND detector for high efficiency neutrons and H isotopes detection and two frames of the time-of-flight ToFD, made by plastic scintillator paddles, were used. The first ToFD frame in order to measure particles velocity and charge at very forward angles, and the second one as a charged particles veto for the NeuLAND detector. A description and first preliminary results of the S122 experiment will be shown.

[1] P. Russotto et al. Phys. Rev. C94, 034608 (2016).
[2] P. Russotto, M.D. Cozma, E. De Filippo, A. Le Fèvre, Y. Leifels and J. Łukasik, La Riv. del Nuovo Cimento, 46, 1-70 (2023).

15:35–15:55 **Flow phenomena at high nuclear densities with HADES**

Speaker
Behruz Kardan (Goethe-University Frankfurt (IKF))

Description

Heavy-ion collisions in the few-GeV energy range allow the creation of strongly interacting matter under extreme net-baryon densities, conditions which are comparable to the ones in neutron star mergers. The precise investigation of the Equation-of-State (EoS) of this kind of matter is therefore of high relevance for the understanding of neutron stars.

In this contribution, we present new measurements by HADES, the \textit{High-Acceptance Dielectron Spectrometer} located at the SIS18 at GSI in Darmstadt, which is currently the only experimental setup with the unique ability to measure rare and penetrating probes at the high-μ_B frontier of the QCD phase diagram.

We discuss recent high statistics results on collective flow phenomena of protons and light nuclei in Au+Au and Ag+Ag collisions at $\sqrt{s_{\rm{NN}}} = 2.42$ and $2.55\;$GeV. In addition to the commonly discussed directed and elliptic flow, flow coefficients v_{n} up to the 6th order are investigated for the first time in this energy regime. Their combined information allows to construct for the first time a full 3D picture of the angular particle emission in momentum space and can provide more stringent constraints on the \textit{Equation-of-State} (EOS). Furthermore, the event-by-event correlations between the different flow coefficients can be exploited for this purpose and will also be presented.

The multi-differential HADES flow data are confronted with various transport model approaches relevant for this energy region and current constraints e.g. derived via a Bayesian analysis on the EoS are discussed.

Supported by the Helmholtz Forschungsakademie HFHF and the BMBF grant 05P21RFFC3.

15:55–16:15 **Nuclear symmetry energy constraint from isospin diffusion with INDRA-FAZIA**

Speaker
Caterina Ciampi (GANIL)

Description

Heavy-ion collisions offer a unique opportunity to probe the equation of state (EoS) of baryonic matter across a range of densities. However, extracting quantitative constraints from comparisons with transport model predictions requires careful consideration of several factors, such as the choice of observables and ensuring comparable conditions between experimental and simulated data. In particular, an accurate treatment of reaction centrality is crucial to properly account for the latter aspect.

In this contribution, we present a model-independent experimental determination of isospin diffusion effects in ^{58,64}Ni+ ^{58,64}Ni collisions at 32 MeV/nucleon, directly reported as a function of the impact parameter. This result is obtained by combining two datasets with common characteristics, but that include complementary information. The first, collected with the INDRA detector [1], was used to implement a model-independent impact parameter reconstruction employing the method of Ref.[2]. The second dataset, acquired during the first experimental campaign of the INDRA-FAZIA setup at GANIL [3-5], provides neutron-to-proton ratio measurements of the quasiprojectile remnant thanks to FAZIA's identification performance [6,7]. The isospin transport ratio technique [8] was applied to quantify isospin diffusion, revealing a clear evolution toward equilibration as a function of impact parameter [9].

The experimental result is then compared with predictions from the BUU@VECC-McGill transport model [10], which, through the metamodeling approach of Ref. [11], employs various nuclear equation of state parametrizations from the literature. In particular, two extreme χ-EFT interactions were tested, a good agreement is found within the chiral constraint [12]. Additionally, the BUU@VECC-McGill model was used to study the isospin current and baryonic densities evolution during the collision, in order to provide a consistent determination of the density region significantly probed by the experiment.
Finally, we present the resulting symmetry energy constraint from the new INDRA-FAZIA isospin diffusion experimental assessment, which can be used to inform Bayesian inference of the neutron star EoS.

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16:15–16:35 **Effective chiral lagrangian with thermal field fluctuations and broken scale invariance**

Speaker

Luca Passarella (Politecnico di Torino)

Description

We investigate the finite-temperature equation of state (EOS) within an effective Lagrangian framework, where a dilaton field accounts for the breaking of scale symmetry in QCD. We start by extending a previous investigation in the pure gauge $SU(3)_c$ sector [1], describing the dynamics of the gluon condensate in terms of a dilaton Lagrangian. Below the critical temperature, the condensate is dominated by the dilaton field, whereas at higher temperatures, it evaporates in the form of quasi-free gluons. Additionally, for the first time, we incorporate into the calculations the lightest glueballs, i.e. J = 2, 4, 6, assuming that their masses lie on a linear Regge trajectory, as suggested in Ref. [2]. The masses of the exciteted glueballs are affected by the presence of a string tension term [3]. In this context, we explore the role of thermal fluctuations of the dilaton field using the technique proposed in Refs. [4, 5], which successfully reproduces lattice QCD results for thermodynamic quantities such as pressure and energy density [6]. Furthermore, we extend our study to an EOS that includes additional degrees of freedom, namely the σ, π, ω and ρ mesons, along with nucleons, at finite chemical potential. This is achieved through an effective Lagrangian incorporating both broken scale symmetry and explicitly broken chiral symmetry [7, 8]. Beyond the mean-field approximation, we consider the effects of thermal fluctuations of the scalar glueball, other than the contributions of the σ, π, ω and ρ meson fields, to gain insights of the thermodynamic properties of the phase transition.

References

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16:35

14:00

Monday 22 September

14:00–16:30

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Vincent Tatischeff (CSNSM)

14:00–14:25 Experimental studies of explosive nucleosynthesis

Speaker

Alison Laird (University of York)

Description

Exotic nuclei play a critical role in explosive astrophysical scenarios. As well as driving nucleosynthesis, their production and subsequent observation provides signatures of underlying explosion mechanisms or stellar progenitors. Such observations include light curves, such as from supernovae or X-ray bursts, or gamma-ray lines or evidence of their decay in solar and pre-solar material. There is a wealth of observational data that cannot be fully interpreted therefore until the nuclear physics is sufficiently constrained. Developments in radioactive beam production are now enabling new experiments to be performed, using novel techniques, to address these uncertainties. This talk will present recent experimental studies that illuminate these observations of explosive stellar systems.

14:25–14:50 New decay studies along the proton drip line between Mg and P at FRIB

Speaker

Hans Otto Uldall Fynbo (Department of Physics and Astronomy, Aarhus University, Denmark)

Description

13 beta-delayed two-proton (β2p) emitters are known today: ^{22}Al, ^{22,23}Si, ^{26}P, ^{27}S, ^{31}Ar, ^{35}Ca, ^{39}Ti, ^{43}Cr, ^{45,46}Fe, and ^{50,51}Ni. The Q-value (the energy released in the decay) is a major determining factor for what type of beta-delayed decays occur, and therefore two-proton emitters are found at or close to the dripline. Nuclear structure also plays a role as clustering in light nuclei evolves into competition between single particle and collective (rotational and vibrational) degrees of freedom. The cross-over happens in this interesting region of the chart of nuclei where the known β2p emitters are found. The relation between two-proton emission and many-body nuclear structure is still poorly understood.
Of the 13 known cases, only ^{31}Ar has been studied with sufficient statistics and beam quality to provide a deep study of the mechanism of the two-proton emission, this being the only case possible to produce at an ISOL facility (ISOLDE-CERN). Short-lived isotopes of the elements between Mg and Cl are difficult, or impossible, to produce at ISOL facilities due to the chemical properties of those elements.
With FRIB coming on-line and the Gas Stopping Area working excellently it is now possible to make low energy beams of most of these isotopes with unprecedented yields. With FRIB Experiment 21010 on the decays of ^{22}Al and ^{26}P we have initiated the exploration of this fertile region of nuclear structure and decay phenomena. The experiment is the first successful FRIB Experiment conducted in the Stopped Beam Area with yields of the two species of respectively 10 and 60 particles per second. The experiment provided much improved data both in quality and quantity not only for ^{22}Al and ^{26}P, but also for ^{21}Mg and ^{25}Si (beta-delayed one-proton emitters), which were present as contaminants and/or were used for calibration purposes.
In this contribution I will present results from FRIB Experiment 21010 including a clarification of the mechanism of two-proton emission in the decays of ^{22}Al and ^{26}P. Plans for future studies at FRIB to address more of the 13 known cases of beta-delayed two-proton emitters will also be presented.

14:50–15:10 Resonant elastic scattering experiments with active and non-active targets

Speaker

Laurie Dienis (GANIL - Université de Caen Normandie)

Description

This talk will present two resonant elastic scattering experiments addressing questions in nuclear astrophysics and nuclear structure. The first experiment focuses on the production of 18F in classical novae, critical for gamma-ray emissions from β+ decay. The reaction 18F(p, α)15O, which destroys 18F, remains uncertain due to limited spectroscopic data for 19Ne in the Gamow window. To address this, the α(15O, α)15O reaction was studied to measure excitation energies, spins, and α-widths of 19Ne levels near the proton threshold. The experiment, conducted at GANIL with a SPIRAL1 beam, a gaseous target, and silicon detectors, achieved <17 keV FWHM resolution and could refine 18F production rates by up to 3.5 times.

The second experiment explored clustering phenomena in 12Be through the 4He(8He,8 He)4He reaction. Earlier studies identified a resonance at 12.1 MeV near key particle thresholds. Using ACTAR TPC, filled with helium gas and isobutane, excitation energies between 11.5 and 13 MeV were probed with <100 keV resolution, significantly improving on previous work. This approach also enabled the measurement of angular distributions and resonance spin-parity characterization. These results provide insight into clustering dynamics in light nuclei near multi-particle thresholds, which have implications for understanding nuclear structure and reaction mechanisms.

15:10–15:30 Solar fusion cross sections III - a nuclear physics perspective

Speaker

Daniel Bemmerer (Helmholtz-Zentrum Dresden-Rossendorf (HZDR))

Description

The third decadal review of solar fusion cross sections (SF-III) is based on a community consensus formed in a workshop in July 2022 in Berkeley with 50 participants representing many of the groups active in the field. It is now available online (https://arxiv.org/abs/2405.06470 , and Rev. Mod. Phys. in press).

I will present a nuclear physics based perspective on the SF-III recommended astrophysical S-factors for the main hydrogen burning reactions. Further, I will discuss the recommendations for future work included in the SF-III paper, and reflect on possible updates based on more recent developments.

In particular, it emerges from SF-III that while the ^{7}Be, ^{8}B, and CNO neutrino fluxes are by now well measured (<2% precision for ^{7}Be and ^{8}B) assuming flavour mixing, the model predictions for these fluxes are much less precise (8-17% error bar). I will discuss what is needed to close this gap.

15:30–15:50

Constraining neutron-induced processes with surrogate reactions in heavy-ion storage rings

Speaker

Guy LECKENBY (LP2i Bordeaux)

Description

Neutron-induced reaction cross sections of short-lived nuclei are essential in nuclear astrophysics and for applications in nuclear technology. However, these cross sections are very difficult or impossible to measure due to the difficulty in producing and handling the necessary radioactive targets. We are developing a project that uses for the first time surrogate reactions in inverse kinematics at a heavy-ion storage ring. This allows us to measure all the de-excitation probabilities as a function of the excitation energy of the nuclei formed through the surrogate reaction with unrivalled precision and indirectly determine the aforementioned cross sections.

In this contribution, I will present our new methodology and the results of the first two surrogate-reaction experiments that we have successfully performed at the ESR storage ring of the GSI/FAIR facility in Darmstadt, Germany. In these experiments we have investigated the (p,p'), (d,p) and (d,d') surrogate reactions and have achieved a significant breakthrough by measuring for the first time the fission, gamma-ray, neutron and even two- and three-neutron emission probabilities simultaneously. The measurement of all competing decay channels enables the precise determination of fundamental quantities, including fission barriers, particle transmission coefficients, gamma-ray strength functions, and nuclear level densities and employ them to infer (n,f), (n,gamma), (n,n'), (n,2n), and (n,3n) cross sections.

15:50–16:10

Neutron-star-crust properties at zero and finite temperature

Speaker

Theau DIVERRES (GANIL)

Description

The crust of a neutron star is important for many astrophysical phenomena such as the cooling of the star and its transport properties. I will present calculations of the neutron-star crust within a compressible liquid drop model both at zero and finite temperature. I will also discuss results for neutron-star-crust elastic properties, such as the shear modulus, and their associated uncertainties, obtained within a bayesian analysis.

16:10–16:30

Direct measurement of the 7Li(p, α)4He reaction at astrophysical energies using the ELISSA array

Speakers

Dr C. Matei (Extreme Light Infrastructure - Nuclear Physics, "Horia Hulubei" National Institute for R&D in Physics and Nuclear Engineering, 30 Reactorului Street, 077125 Magurele, Romania), Dr Haridas Pai (Extreme Light Infrastructure - Nuclear Physics, "Horia Hulubei" National Institute for R&D in Physics and Nuclear Engineering)

Description

Direct measurement of the 7Li(p, α)4He reaction at astrophysical energies using the ELISSA array has been performed at IFIN-HH with the 3 MV Tandem. This reaction is intimately linked with the so-called "Cosmological Lithium Problem". The existing 7Li(p, α)4He direct measurement data suffer from large uncertainty, particularly at energies below 500 keV (in the center-of-mass system). Thus, a new direct measurement of the 7Li(p, α)4He reactions at low energies, from 59.5 keV to 990 keV (10 different beam energies) in the center-of-mass system has been carried out to reduce the uncertainty in the S(E) factor.
In this experiment, ∼ 2 - 4 pnA beam intensity and self-supported thin polyethylene targets (CH2, about 70 μg/cm2 thick, placed at 90° with respect to the beam axis) were used. The spot size of the 7Li beam on the target was ∼ 1 mm. The ELISSA array, having 12 X3 position-sensitive strip detectors arranged in a barrel-like configuration, was used to detect the transfer alpha. The solid angles of the X3 detectors have been determined from the NPTool simulation. The absolute differential cross-section of the 7Li(p, α)4He reaction has been determined by normalising to the 7Li(p, p)7Li Rutherford scattering cross-section measured in the monitor detector. The total cross-sections (σtotal) of 7Li+p were obtained by fitting the angular distributions of the present data with DWBA calculations. The S(0) value is obtained from the present DWBA and polynomial fits. Reaction rates have also been calculated.

In this talk, measurement of the 7Li(p, α)4He reaction using the ELISSA array will be presented.
Authors: H. Pai, G. L. Guardo, I. Kuncser, D. Lattuada, A. Lupoae, T. Petruse, C. Matei, A. Pappalardo, Y. Xu, D.L. Balabanski, and the ELISSA collaboration

Acknowledgment: This work was supported by the Romanian Ministry of Research and Innovation under research contract PN 23 21 01 06 and partially supported by ELI-RO-RDI-2024-008 of the Romanian Government.

16:30

14:00

Monday 22 September 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 1

Session | **Location:** MoHo, Inspire 1, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Alison Bruce (University of Brighton)

14:00–14:25

Advancements in Gamma-ray Spectroscopy: Expanding Sensitivity and Experimental Capabilities

Speaker

Daniele Mengoni (University and INFN - Padova)

Description

In recent decades, γ-ray spectroscopy has experienced a significant technological advancement through the technique of γ-ray tracking, achieving a sensitivity almost two orders of magnitude greater than previous Compton-shielded arrays. This leap forward rivals the milestones achieved since the beginning of γ-ray spectroscopy. Combining γ-ray spectrometers with detectors recording complementary reaction products, such as light-charged particles for transfer reactions and scattered ions for Coulomb excitation measurements, further enhances sensitivity.

Nucleon transfer reactions provide a valuable means to explore the energies of shell model single-particle orbitals and study their energy migration away from stability. Additionally, such measurements permit the estimation of cross sections relevant to stellar evolution and nucleosynthesis. Coincident γ-ray and particle measurements offer insights into decay channels for unbound systems, crucial for astrophysics and nuclear structure near drip-lines.

In this contribution, results and prospects for transfer-reaction experiments utilizing newly developed complementary devices and other detectors will be outlined, paving the way for further advancements in γ-ray spectroscopy and nuclear structure studies.

14:25–14:45

Exotic cross-shell interactions at $N=28$ with single-neutron transfer on ^{47}K

Speaker

Charlie James PAXMAN (GANIL)

Description

Shell evolution in nuclei far from stability, such as those in the region of $N\geq28$ and $Z<20$, is understood to arise from the complex interplay of orbital interactions, with different interactions accessible in unstable nuclei compared to stability. Experimental studies of these exotic regions provide stringent tests of modern shell model interactions, but are difficult to access experimentally. In this regard, the transfer reaction ^{47}K(d,p)^{48}K provides a unique opportunity to study the exotic $\pi s_{1/2}$-νfp interaction in a near-doubly magic nucleus, owing to the $\pi s^{-1}_{1/2}$ ground state structure of ^{47}K, which is near-degenerate with the `standard' $\pi d^{-1}_{3/2}$ proton configuration in this region.

The first measurement of the ^{47}K(d,pγ)^{48}K transfer reaction has been performed at GANIL, in inverse kinematics using a reaccelerated radioactive isotope beam. The level scheme of ^{48}K has been greatly extended with nine new bound excited states identified and spectroscopic factors deduced. Detailed comparisons with SDPF-U and SDPF-MU shell-model calculations reveal a number of discrepancies between theory and experiment. Intriguingly, an apparent systematic overestimation of spectroscopic factors and a poor reproduction of the energies for 1$^-$ states suggests that the mixing between the $\pi s^{-1}_{1/2}$ and $\pi d^{-1}_{3/2}$ proton configurations in ^{48}K is not correctly described using current interactions, challenging our descriptions of light nuclei around the N=28 island of inversion.

A complete analysis and discussion of the ^{47}K(d,pγ) reaction, and the complementary ^{47}K(d,tγ) reaction, will be presented.

14:45–15:05

Low-lying spectroscopy of 20O and 19O with ACTAR TPC

Speaker

MIGUEL LOZANO GONZALEZ (IGFAE-USC)

Description

Neutron-rich oxygen isotopes provide a unique probe to test state-of-the-art shell-model interactions such as SFO-tls [1] and YSOX [2]. In particular, 19O and 20O isotopes can be further employed to constrain shell evolution near the drip-lines, a crucial step towards a universal interaction. In this regard, single-nucleon transfer reactions are suitable tools to study the single-particle nature of the populated states, enabling the extraction of valuable model inputs, such as spectroscopic factors and excitation energies.

To this end, neutron pick-up reactions 20O(p, d) and 20O(d, t) were performed at a beam energy of 35 AMeV at GANIL. The experimental setup featured the active target ACTAR TPC [3, 4], serving both as a thick gaseous target and as a detection medium for particle tracking, resulting in an overall enhancement of the experimental resolution compared to a conventional thick-target experiment. Additional silicon detectors surrounding the active volume measured the residual energy of the light reaction products, enabling unambiguous particle identification (PID) [5].

This talk will present preliminary results on the low-lying spectroscopy of 19O, along with a comparison to theoretical shell-model calculations and an analysis of the N = 8 shell gap behaviour. Additionally, the inelastic scattering 20O(d, d′) data have been analyzed, and early results on the inelastic excitations will also be discussed.

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15:05–15:25 **Is ^{14}C nuclear chain puzzle solved?**

Speaker

Alessia Francesca Di Pietro (INFN Laboratori Nazionali del Sud)

Description

A. Di Pietro^1, N. Szegedi^1, P. Figuera^1, S. Cherubini^{1,2},M. La Cognata^1, L. Guardo^1, M. Gulino^{1,3},L. Lamia^{1,2}, A. Oliva^1, G. Pizzone^{1,2}, G. Rapisarda^{1,2}, R. Sparta'^{1,3}, M.L. Sergi^{1,2}, D. Torresi^1, A. Tumino^{1,2}, T. Davinson^4, N. Duy^5, J.P. Fernandez Garcia^6, S. Heinitz^7, S. Hayakawa^8, E.A. Maugeri^7, M. Milin^9, H. Shimizu^8, D. Schumann^7, A. Shotter^4, N. Soic^{10}, H. Yamaguchi^8, L. Yang^8
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8 CNS, University of Tokyo, Wako, Japan
9 University of Zagreb, Zagreb, Croatia
10 Ruđer Bošković Institute, Zagreb, Croatia

Some nuclear properties can be understood by modeling nuclei as loosely interacting clusters. Among the various cluster phenomena observed in light unstable nuclei, particularly neutron-rich ones, is a unique form of clustering where an alpha-cluster structure is held together by neutron exchange, akin to covalent bonding in molecules. In the case of neutron-rich nuclei, theoretical predictions by Suhara and Kanada-En'yo [1-3] using antisymmetrized molecular dynamics (AMD) suggest the existence of a linear chain configuration in ^{14}C, where α-particles are bound by neutrons. This configuration is expected to be associated with a rotational band (J = 0$^+$, 2$^+$, 4$^+$) appearing a few MeV above the ^{10}Be+α threshold.
The spectroscopy of ^{14}C has been extensively investigated and, specifically, studies have been conducted to search for the alpha-chain structure by measuring the ^{10}Be+^{4}He elastic scattering excitation function [4-6] and, more recently, ^{14}C breakup reaction [7]. These publication do suggest that states which may be associated to a linear chain configuration of ^{14}C are, indeed, being observed. These claims, however, suffers, on one hand of a poor time resolution that does not allow the separation of the elastic from the inelastic scattering [4,6], on the other, of a poor energy resolution of the ^{14}C excitation energy spectrum [7]. As reported in [8], in fact, ^{14}C posses a large number of states in the excitation energy region of interest.
In this presentation we will report on the results of an elastic scattering ^{10}Be+^{4}He excitation function experiment, performed at INFN-Laboratori Nazionali del Sud using the most intense ^{10}Be radioactive beam available worldwide (10^9 pps). In this measurement the limitations of the previous experiments have been overcome. The elastic scattering excitation function is unambiguously measured in a broad ^{14}C excitation energy region (13 MeV-23 MeV) and large c.m. angular range (90° -180°), with a c.m. energy resolution of about 50 keV. The inelastic scattering channels to both, the 2$_1^+$ and 0$_2^+$ states in ^{10}Be, have also been measured. The theoretical analysis has been performed using R-matrix. The possible evidence (or lack of) linear chain in ^{14}C will be critically discussed.
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15:25–15:45

Exploring unbound states of ^{18}C in inverse kinematics with the R^{3}B experimental setup

Speaker

Martina Feijoo-Fontán (USC)

Description

Since the advent of radioactive ion beam facilities, excited states in exotic neutron-rich carbon isotopes have been an interesting object of study. In the late 90's, three ^{17}C resonant states above the ^{16}C+n threshold were observed using the beta-delayed neutron decay of ^{17}B [Raimann96]. More resonances were observed in later works using transfer [Bohlen07], proton inelastic scattering [Satou07] and neutron-removal [Kim23] reactions. More recently, other studies have started investigating ^{18}C unbound states [Revel18, Murillo22], both via proton knockout reactions in the R3B/LAND setup. This work aims to extend the aforementioned analysis by using the new state-of-the-art R3B setup, which offers higher neutron-detection efficiency.
Moreover, by using ^{X}N(p,2p)$^{X-1}$C reactions, with protons being removed from the $1p_{1/2}$ or $1p_{3/2}$ orbitals, and comparing the energy difference between the centroids of the resulting states in ^{14}C and ^{18}C, provides insight into a potential reduction of the Z=6 gap caused by the p-splitting towards the neutron dripline. While some studies suggest a constant gap along the isotopic carbon chain [Tran18], a previous R3B/LAND work [Syndikus20] has found an increase in the proton component and moderate quenching of the Z=6 gap towards the neutron dripline, which could be explained within a seniority-inspired scheme to the neutron component [Machiavelli14]. However, both experiments are indirect observations of the evolution of the gap.
The GSI/FAIR facility was used to produce a beam of neutron-rich light isotopes near nitrogen at a relativistic kinetic energy of 540 MeV/u. The projectiles, impinging on a 5 cm liquid hydrogen target, populate unbound states of neutron-rich carbon isotopes, including as ^{18}C, which are produced via a quasi-free (p,2p) scattering reaction. The 1n and 2n decaying system ^{18}C* is studied by detecting the evaporated neutron(s), the fragment, and emitted gamma-rays in coincidence. The invariant mass method in inverse kinematics is employed to reconstruct the excitation energy spectrum above S$_n$ and S$_{2n}$. The study is conducted using the R3B setup, which provides high efficiency, acceptance, and resolution for kinematically complete measurements. Key detectors include the CALIFA calorimeter [Califa14] made of CsI(Tl) crystals and the NeuLAND neutron detector [Neuland21], along with tracking detectors for both incoming isotopes and fragments [Tofd22].
Preliminary results reveal that the (p,2p) strength can be extracted up to E*(^{18}C) ~ 15 MeV, observing from the one-neutron emission new unbound states at high energies. The discussion will be based on the correlation of the gamma-ray energies with the reconstructed relative energies between the evaporated neutron and the final fragment. The distribution of the unbound populated states can be compared to those observed in the selective ^{15}N(d,^{3}He)^{14}C reaction [Ajzenberg76], bringing direct information about the change of the amplitude of the p-splitting. Results from the two-neutron unbound system will be discussed as well, particularly exploring the sequential vs. direct emission of the two emitted neutrons.

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15:45–16:05 **Short-range correlations in stable and asymmetric nuclei investigated at R³B**

Speaker

ANDREA LAGNI - (Universidad de Santiago de Compostela)

Description

The formation of short-range correlated nucleon-nucleon pairs (SRCs), primarily composed of neutron-proton pairs [1], appears to be a universal feature in atomic nuclei [2]. Interestingly, measurements in electron scattering indicate that protons become significantly more correlated in asymmetric nuclei as a function of neutron excess. This has potential implications for the description of cold dense nuclear matter as for neutron stars. However, data have been so far restricted to stable nuclei for which the N/Z asymmetry, at maximum ~1.6, is strongly correlated to the mass number, leaving open the question of the origin of the evolution of proton-neutron short range correlations with N/Z. To overcome this ambiguity, we performed an experiment at the R³B setup at GSI-FAIR [3] as part of the FAIR Phase-0 experimental program to measure SRC in the most neutron-rich nucleus yet, 16C, with N/Z=1.67, that is slightly larger than the one of 208Pb (1.53). We employ hard proton knockout reactions in inverse kinematics of 16C beam at 1.25 GeV/nucleon, as well as 12C beam as reference, to study SRC behavior. In this talk, I will discuss the final results of the SRC behavior investigation in stable and neutron-rich nuclei (12C and 16C) based on the study of kinematical variables and comparison with QFS and GCF based calculations [4;5]. In conclusion, I will present prospects for the follow-up research program at FAIR.

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16:05–16:25 **alpha-cluster structures in 14C and 16O**

Speaker

David Palacios Suárez-Bustamante (IGFAE - USC (Spain))

Description

Well-bound spherical nuclei can be considered as closed quantum systems that can be described by state-of-the-art versions of the shell model, where nucleons occupy well-localized single-particle states. However, when we move towards the dripline or inject enough excitation energy into the system, the coupling to the continuum and reaction channels becomes more important, forcing the nucleus to behave like a many-body open quantum system. This complex interplay between reaction and structure leads to intriguing phenomena, where weakly bound or unbound systems exhibit features such as halos, particle emission near decay thresholds, and alpha clustering. Inferring the relevant observables to investigate such phenomena requires the use of efficient detection systems for experiments in inverse kinematics. Solenoidal spectrometers are precisely engineered to effectively analyze various reactions resulting in the formation of clustered states. SOLARIS [1], a next-generation solenoidal spectrometer, offers versatile functionality with its two distinct modes of operation: Si-array and Active Target mode.

In this talk, we will discuss the cluster structure of ^{14}C and ^{16}O, as explored through various experiments conducted using SOLARIS in Active Target mode with the Active Target Time Projection Chamber (AT-TPC). For the ^{14}C, some of the states within the two rotational bands (π-bond and σ-bond) of the linear-chain cluster state (LCCS) remain unresolved [2-7]. We have used resonant scattering of ^{10}Be + ^{4}He as the reaction to explore this nucleus. We present the cross sections, the angular distributions and the spin-parity of several ^{14}C resonances, including states belonging to the rotational bands. In the case of the ^{16}O, we aim to search for resonances near the 4-α emission threshold, where the α condensate states are more likely to manifest [8], with an ^{16}O + ^{4}He reaction. We also calculate the branching ratios of the ^{12}C + ^{4}He and $^{12}C(0_{2^+})$ + ^{4}He exit channels.

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16:30

14:00 **Monday 22 September** 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 2

Session | **Location:** MoHo, Inspire 2, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr Emmanuel CLEMENT (GANIL)

14:00–14:25

Dense-matter equation of state and neutron stars: nuclear-physics and multi-messenger constraints

Speaker

Anthea FANTINA (GANIL ({CNRS}UPR3266))

Description

Neutron stars are unique laboratories to probe matter in extreme conditions that cannot be currently reproduced on Earth. The determination of their equation of state (EoS) is a challenge, but it is particularly important since it allows to relate different global neutron-star properties and to link the prediction of astrophysical observables to microphysical properties of dense matter.

In this presentation, I will give a brief introduction on the dense-matter EoS, and specifically on the EoS for neutron stars. Various constraints coming from both nuclear physics (theory and experiments) and astrophysics will be discussed. The prediction for the dense-matter EoS and neutron-star observables obtained with a large variety of EoSs, together with a perspectives on future constraints, will be presented in connection with (multi-messenger) observations.

14:25–14:45

Search for double alpha decay

Speaker

Louis Heitz (IJCLab & CEA/Irfu/DPhN)

Description

Alpha decay is known for more than a century, however a global microscopic description of this process has only been successfully developed recently by Mercier et al. [1]. Within the framework of covariant energy density functional, using a least action principle, the half-life of medium and heavy nuclei agree within one order of magnitude with experimental value [2].

Moreover, a new type of decay was predicted: the double alpha decay, where two alpha particles are emitted simultaneously with a large relative angle. Their typical branching ratio (BR) of ~10-7 with respect to the single alpha decay, makes it experimentally accessible, these values of BR being those of well-known cluster decays already detected.

A dedicated experiment was held at Isolde in June 2023. A radioactive beam of 220-222Ra has been used to probe for possible double alpha decay of 220-222Ra as well as 216-218Rn. The setup consisted in 4 DSSD, which allows to make accurate spatial (and temporal) coincidences and therefore to drastically reduce the background due to single alpha decays. Results on this hunt will be shown.

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14:45–15:05

Study of exotic nuclei of interest for applied and fundamental nuclear physics with Total Absorption Gamma-ray Spectroscopy (TAGS)

Speaker

Julien PEPIN (Subatech/IFIC)

Description

The study of beta decay of neutron rich nuclei is particularly important for many fields in fundamental and applied physics [1]. In nuclear reactors, fission products, through their decays, produce an additional energy called decay heat [2]. The assesment of this energy is essential for nuclear safety since it represents around 7% of the power in an operating reactor and these decays continue after reactor shutdown. Beta decay also leads to antineutrino emmission and is thus a good tool for exploring fundamental neutrino physics [3] such as reactor antineutrino anomalies (RAA). This flux anomaly is a deviation of ~6% in the measured number of antineutrino compared to the predicted one. The shape anomaly is an excess of events in the 5 MeV region observed by short baseline and
high precision reactor experiments [4]. In nuclear astrophysics, the r-process is a nucleo-synthesis process [5] at the origin of half of the nuclei heavier than iron. It takes place in hot (T~10^9K) and highly neutron-dense environments. This process is based on the competition between neutron capture (n,γ), photo-dissociation (γ,n) and beta decay. A
precise knowledge of beta strength functions S B (E) can constrain the theoretical models used to understand this nucleo-synthesis process. Some of the existing data of the beta decay properties of fission products involved in these fields of nuclear physics are affected by the pandemonium effect [6]: due to the low efficiency at high energy of
high-resolution detectors, such as Germanium (HPGe), some gamma-rays and the corresponding high energy levels can be missed in the decay data leading to a distortion of the beta decay feeding calculation.
New measurements of relevant nuclei for the above mentioned topics have been performed at the IGISOL facility (Jyväskylä, Finland) in September 2022, using the Total Absorption Gamma-ray Spectroscopy (TAGS) technique [7]. TAGS is complementary to high resolution gamma-ray spectroscopy and employs a calorimeter to measure the gamma cascades de-exciting each level of the daughter nucleus providing a direct measurement of the beta feeding I B . The deduced beta feeding is then used to calculate the beta strength used in the fields of research mentioned above.
In the proposed talk, we will present the TAGS technique and preliminary results of the analysis of the 85 Se and 136 I, two nuclei interesting for their contributions in the calculation of the reactor decay heat. The 136 I and its isomeric state 136m I are also involved in the r-process calculations.

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15:05–15:25

Study of proton and neutron contributions to the excitation of the 2+ states in Si isotopes between N=20 and N=28

Speaker

Dr Stephane Grevy (LP2I Bordeaux)

Description

Studying the structure of exotic nuclei near shell closures is a powerful tool to investigate the underlying nuclear forces. The regions around N=20N=20 and N=28N=28 are known to exhibit significant shape transitions arising from a subtle interplay between monopole evolution—such as the tensor force—and quadrupole excitations leading to deformation.

Previous studies have shown that the deformation around 32Mg32Mg is primarily driven by neutron excitations across the N=20N=20 shell gap, whereas in the N=28N=28 region, deformation arises from both proton excitations within the sdsd shell and neutron excitations above N=28N=28. However, the relative contributions of protons and neutrons remain unclear, and spectroscopic data are still lacking to more tightly constrain theoretical models.

To address this, we conducted combined experiments at LISE aimed at measuring both the B(E2;0+→2+) transition probabilities and the inelastic proton scattering cross-sections for the 2+ states in silicon isotopes between N=20 and N=28. The experiment took place during the 2022 campaign at the LISE spectrometer, utilizing two independent and complementary experimental setups:

The first setup employed the active target ACTAR to measure inelastic scattering on a gaseous proton target. The second was dedicated to Coulomb excitation measurements using EXOGAM, PARIS, and the newly developed Zero Degree Detector (ZDD).

The collected data are currently under analysis. Preliminary results from both setups will be presented, along with new shell model calculations carried out by F. Nowacki and collaborators.

15:25–15:45

MIRACLS: Laser spectroscopy in an MR-ToF device and the charge radii of exotic magnesium isotopes

Speaker

Anthony Roitman (McGill University)

Description

Over the last decade, remarkable advances have been made in the theoretical description of electromagnetic properties of atomic nuclei, stimulated by a wealth of high-quality experimental data on short-lived radionuclides (see references [1-6]). In particular, nuclear charge radii have proven to be highly sensitive probes of phenomena such as pairing, deformation, or shell closures, and thus represent intriguing experimental benchmarks for modern nuclear structure theory.

Collinear Laser Spectroscopy (CLS) is a highly effective, nuclear model-independent tool to experimentally access properties such as nuclear spin, electromagnetic moments, and charge radii with high accuracy and precision. In order to improve the sensitivity of conventional CLS, the Multi Ion Reflection Apparatus for Collinear Laser Spectroscopy (MIRACLS) exploits a new experimental approach by conducting CLS in a high-energy (> 10 keV) multi-reflection time-of-flight (MR-ToF) device [7, 8]. This is a type of ion trap which utilizes two electrostatic mirrors to reflect ion bunches back and forth for several thousands of revolutions. Hence, the ion bunches can be probed by the laser multiple times per measurement cycle to obtain higher statistics than with conventional CLS, which can study each ion bunch only once. In the most favourable spectroscopy schemes, offline measurements have demonstrated a sensitivity for yields as low as ~5 ions per second delivered to MIRACLS.

Building on these advances, a newly-built MIRACLS setup has been coupled to ISOLDE which has recently been exploited for the first time to determine nuclear charge radii of neutron-rich magnesium isotopes in the "island of inversion", extending previous measurements by COLLAPS [9].

In this contribution, I will describe the recent advances in the MIRACLS technique, present the results of the successful Mg online campaign, and discuss their physics implications. An outlook on the next physics goals at MIRACLS will be given, especially the laser-spectroscopy measurements of cadmium isotopes.

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15:45–16:05 Mass Measurements of Exotic Neutron-Deficient Nuclides at IGISOL

Speaker

Dr Zhuang GE (University of Jyväskylä)

Description

The neutron-deficient nuclides surrounding ^{100}Sn, the heaviest doubly magic self-conjugate nucleus, presents a variety of fascinating nuclear structure phenomena. Key nuclear properties, such as atomic masses of exotic nuclei in this area, are crucial for assessing the stability of shell closures and the evolution of single-particle energy levels. Additionally, atomic masses also contribute to understanding proton-neutron interactions in long-lived isomers and the vicinity of the proton drip line. Moreover, the atomic masses of nuclei provide crucial insights for accurately modeling astrophysical processes like rapid proton capture (rp) and νp processes [1–3]. Reliable nuclear data serves as an indispensable reference point for validating theoretical predictions in nuclear physics, ensuring the precision and credibility of such models.

High-precision mass measurements of the ground-state nuclei $^{95-97}$Ag and the isomeric state of ^{96}Ag have been recently conducted at the IGISOL facility in Finland [4, 5]. These measurements leveraged the phase-imaging ion-cyclotron resonance (PI-ICR) method, implemented with the JYFLTRAP double Penning trap [5–7], in conjunction with the newly developed inductively heated hot-cavity catcher laser ion source at IGISOL [4,8]. This setup allows the creation of extremely exotic neutron-deficient nuclides. Notably, the atomic mass of ^{95}Ag was directly determined for the first time. Additionally, the atomic masses of β-decaying 2^{+} and 8^{+} states in ^{96}Ag were identified and measured for the first time, while the precision of the ^{97}Ag mass was significantly improved. These newly measured masses obtained with JYFLTRAP [5–7], with a precision of approximately 1 keV/c^{2}, have been employed to investigate the robustness of the ${N}$ = 50 neutron shell closure. Empirical shell-gap and pairing energies derived from these ground-state mass data were compared with state-of-the-art ab initio calculations, density functional theory calculations, and configuration-interaction shell-model calculations. It was observed that theoretical approaches face challenges in accurately reproducing trends in nuclear ground-state properties along the silver isotopic chain across the ${N}$ = 50 neutron shell and towards the proton dripline. The precise determination of the excitation energy of the ^{96m}Ag isomer serves as a critical benchmark for ab initio predictions of nuclear properties beyond the ground state, particularly for odd-odd nuclei near the proton dripline below ^{100}Sn. Moreover, the first accurate measurement of the excitation energy of the ^{96}Ag isomer allows its ground and isomeric states to be treated as separate species in astrophysical modeling.

In addtion, ions in the A = 84 region were generated using a fusion-evaporation technique, employing a ^{58}Ni primary beam and a ^{28}Si target. Their masses were subsequently measured with a Multi-Reflection Time-of-Flight Mass Spectrometer (MR-TOF MS). These measurements are anticipated to shed light on the Zr-Nb cycle within the rp process [1] and address uncertainties associated with the νp process. Preliminary results from this experiment will be presented.

In this contribution, we report the latest advancements and results from our mass measurement campaigns of exotic neutron-deficient nuclides, conducted using MR-TOF MS and JYFLTRAP at the IGISOL facility.

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16:05–16:25 Isotopic fission yields of 240Pu around the fission barrier from 2p-transfer reactions

Speaker

Dr Diego RAMOS DOVAL (GANIL)

Description

Complete isotopic fission-fragment distributions of 240Pu have been measured, for the first time, as a function of the initial excitation energy. The 240Pu fissioning system was produced through the two-proton transfer reaction between a 238U beam and a 12C target, a surrogate reaction for the neutron-induced fission 239Pu(n,f).

The reaction was measured in inverse kinematics, allowing the fission fragments to be fully identified with the VAMOS Spectrometer and the target-like recoil, 10Be, with a silicon telescope surrounding the target. This technique gives access to new correlations such as the evolution of the neutron content and the proton even-odd staggering of fission fragments with the excitation energy. This new information allows for the experimental determination of the dissipation energy in fission as a function of the fragment split.

When compared to neutron-induced fission, the observed prompt-neutron multiplicity shows a clear reduction in the surrogate two-proton transfer, revealing an unexpected influence of the entrance channel in the fission output, driven by the additional angular momentum induced in the multi-nucleon transfer reactions, which excites the fissioning system to higher-spin states, increasing the probability of the gamma emission that competes with neutron evaporation, in particular from the fission barrier to the scission point.

16:30

14:00 **Monday 22 September** 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 3

Session | **Location:** MoHo, Inspire 3, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** David Boilley (GANIL)

14:00–14:25 Entanglement, Complexity and Quantum Computations of Nuclear Many-Body Systems

Speaker

Caroline Elisa Pauline Robin

Description

Advances in quantum information science have provided new tools and concepts that shed further light on the structure and dynamics of quantum many-body systems and on the underlying forces that govern them. These new insights, together with cross-fertilization and exchange of ideas between fields, are enabling the development of improved methods and algorithms for simulating many-body physics.

I will discuss recent explorations of entanglement and quantum complexity in the structure of nuclei and their connection with the emergence of collectivity. The findings are further utilized to guide simulations of nuclear and related many-body systems, that leverage the potential of hybrid classical-quantum computing environments.

14:25–14:45 Quantum computation approach to nuclear ground and excited state calculation

Speaker

Paul Stevenson (University of Surrey)

Description

Quantum computers offer the promise of efficiently solving problems which suffer exponential scaling with problem size on classical computers. In application to the simulation of physical systems, quantum computers may be able to overcome the explosion of Hilbert space size with particle number, and to deal efficiently with entangled states.

In this contribution, we show some applications of quantum algorithms to solving sample problems in nuclear structure: The preparation of ground states in a shell-model [1,2] and density functional picture [3], and the generation of excited states using a novel variational quantum algorithm [4].
We finish by giving prospects for future work as quantum computing technology moves towards the era of fault-tolerant machines.

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14:45–15:05 Nuclear shell model in a quantum computer

Speaker

Arnau Rios Huguet (Institut de Ciencies del Cosmos, Universitat de Barcelona)

Description

Quantum computing has the potential to provide new algorithms to solve problems that are otherwise untractable classically. Among these problems, one can employ quantum computers to solve quantum many-body problem. In this talk, I will review two different algorithms to attempt and solve the nuclear shell model in quantum computers. One approach is based on variational quantum eigensolvers, a well-known approach for which we have quantified the required resources for nuclear physics applications [1,2,3]. The other approach looks into quantum annealers as many-body solvers, which have surprisingly good scaling properties in mid-shell isotopes [4].

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15:05–15:25 A Diagrammatic Monte Carlo approach for nuclear structure and reactions

Speaker

Mr Stefano Brolli (Università degli Studi di Milano, INFN - Sezione di Milano)

Description

The calculation of many-body correlations in atomic nuclei using ab initio approaches requires accounting for virtual excitations, whose number grows factorially with the perturbative order.
Diagrammatic Monte Carlo (DiagMC) is a promising method that efficiently includes high-order excitations. It has been particularly successful in condensed matter physics [1, 2], where it enables the resummation of contributions in infinite systems at finite temperature.
I will present the first application of DiagMC to a nuclear structure problem: the pure pairing Richardson model. Our results surpass the precision of the state-of-the-art ADC(3) approximation, incorporating diagrams up to eighth order in the ladder expansion [3].
The extension of this approach to realistic Hamiltonians is under development and will be discussed. This will allow the calculation of reliable optical potentials with minimal use of phenomenology, providing more robust results in the study of reactions with radioactive ion beams.

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15:25–15:45

Improved modelling of fission dynamics with the Time-Dependent Generator Coordinate Method

Speaker

Ngee Wein Lau (L2I Toulouse, CNRS/IN2P3, Université de Toulouse)

Description

As experimental measurements and industrial applications of nuclear fission continue to develop, there is an increasing demand for theoretical models to simulate fission processes with high precision, including both reactions commonly used in applications today and exotic processes involving superheavy nuclei which have not yet been observed. The construction of such a model remains a formidable challenge due to computational limitations as well as the complexity of the underlying subatomic interactions.

This presentation will introduce an approach to describing fission based on the Time-Dependent Generator Coordinate Method (TDGCM). While models in this category have improved considerably over the past few decades, significant corrections and extensions are required to achieve the predictive power needed by modern laboratories and industrial applications. A particular focus will be the removal of the Gaussian Overlap Approximation (GOA) from the method, and the modifications to the theory that this requires, with the aim of better simulating the dynamics of extremely deformed compound nuclei approaching scission (splitting into fragments). The new model is compatible with further improvements which allow for the restoration of broken symmetries, with the potential to include previously neglected degrees of freedom such as internal excitations.

15:45–16:05

Extending the reach of nuclear ab initio calculations via dimensionality reduction techniques

Speaker

Lars Zurek (CEA, DAM, DIF)

Description

The so-called ab initio approach to nuclear structure allows to describe atomic nuclei with controlled and systematically improvable approximations.
Such nuclear structure calculations employing interactions derived from chiral effective field theory are nowadays routinely performed in heavy or open-shell systems.
But describing nuclei that are at the same time both heavy and open-shell is still limited by the computational cost of handling very large tensors, especially when breaking rotational symmetry in the calculations.
We apply dimensionality reduction techniques based on a randomized singular value decomposition to Bogoliubov many-body perturbation theory, one of the nuclear ab initio methods.
This requires reformulation of the computational method used to solve the many-body Schrödinger equation.
By employing modern linear algebra algorithms and avoiding the construction of large many-body tensors in the first place, we are able to extend the reach of the method to nuclei where standard approaches would be too expensive to run.

16:05–16:25

Emission processes in a self-consistent field

Speaker

Alexandru Dumitrescu (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering)

Description

A self-consistent description of cluster emission processes in terms of nucleonic degrees of freedom is presented. The starting point is a Woods-Saxon mean field with spin-orbit and Coulomb terms where pairing is treated through standard Bardeen-Cooper-Schrieffer quasiparticles. A residual two-body interaction is introduced in terms of a density-dependent Wigner force having a Gaussian shape with a center of mass correction localized in a region of low nuclear density slightly beyond the geometrical contact radius of a system comprised from a nucleus and a surface cluster. Self-consistency is achieved through a Hartree-Fock iterative procedure that includes these cluster surface corrections. It is shown that such a description adequately reproduces the ground state properties of a spherical nucleus while the surface corrections enhance the tail of single particle orbitals, thus allowing for a good description of the decay width for unstable systems.

16:30

16:35

17:00

Monday 22 September

16:35–17:00

Coffee Break

Break | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

17:00

Monday 22 September 17:00–19:30

Accelerators and Instrumentation: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Achim Denig

17:00–17:20 ALICE upgrades for LHC Run 4 and beyond

Speaker

Domenico Colella (INFN and University of Bari)

Description

The primary objective of the ALICE physics program is to investigate the properties of the quark-gluon plasma (QGP), the deconfined state of strongly interacting matter, and to understand how these properties emerge from the fundamental interactions governed by quantum chromodynamics (QCD). By colliding heavy nuclei, the LHC generates quark-gluon plasma with record-breaking temperature and lifespan, allowing for in-depth study.
A major upgrade was performed on ALICE during the LHC Long Shutdown 2 (2019–2022), and further improvements, including the upgrade of the inner tracker (ITS3) and the installation of a forward calorimeter (FoCal), are planned for Long Shutdown 3 (2026-2029).
For the future, beyond LHC Run 4, the ALICE Collaboration has put forward a proposal for a next-generation, fully silicon-based detector optimized for high-precision tracking and particle identification in heavy-ion collisions (LoI, arXiv:2211.02491). Cutting-edge technologies are under development to pursue a track-pointing resolution better than 10 microns for particles with transverse momentum above 200 MeV/c.
The ALICE 3 experiment will drive significant progress in QGP research while also enabling novel studies in other areas of QCD and fundamental physics. Core QGP investigations will focus on low-pT heavy-flavor production, notably beauty hadrons, multi-charm baryons, charm-charm correlations, and high-precision dielectron emission measurements. Furthermore, ALICE 3 will uniquely contribute to hadronic physics through femtoscopic studies and searches for charmed nuclei, and to fundamental physics by testing the Low theorem for ultra-soft photon emission
This presentation will provide an overview of all the future ALICE upgrades, giving physics motivations and focusing on the status of the R&D for the chosen technologies of the different detectors.

17:20–17:40 ITS3 in ALICE: pioneering bendable wafer-scale sensors for LHC Run 4

Speaker

Paola La Rocca (INFN and University of Catania)

Description

The ALICE experiment at the Large Hadron Collider (LHC) is preparing for an upgrade during Long Shutdown 3 (LS3, 2026-2030), which includes replacing the three innermost layers of the Inner Tracking System (ITS2). The new ITS3 detector will introduce an innovative design featuring wafer-scale monolithic pixel sensors in 65 nm CMOS technology, thinned to 50 $ \mu$m and bent into truly cylindrical layers. This breakthrough allows for an ultra-light detector with a material budget of only 0.07% X$_0$ per layer and a reduced radial distance to the interaction point (19 mm), significantly enhancing tracking performance by a factor of 2, especially for low-momentum particles.
The ITS3 sensors are fabricated using a stitching technique to produce 27 cm-long monolithic detectors without the need for flexible printed circuits placed on top of the sensors. Extensive R&D efforts have demonstrated the feasibility of these sensors, confirming high resolution ($\sim$5 μm), high efficiency (>99%), low fake hit rate (<10^6 /pixel/event), and excellent radiation tolerance (up to 10^{15} 1 MeV n$_{eq}$ cm^{-2}). Additionally, mechanical prototypes have validated the stability of bent sensors under operational conditions, including realistic air cooling and interconnection scheme.
This contribution will present an overview of the ALICE ITS3 upgrade project, together with the latest advancements in its development, covering sensor design and characterization, mechanical integration, and the progress toward the final MOSAIX prototype. Results from laboratory and beam tests will be discussed, highlighting the potential of ITS3 to redefine silicon tracking technology for future collider experiments.

17:40–18:00 A new large-area Micromegas detector and its readout electronics for AMBER experiment at CERN

Speaker

Dr Maxim Alexeev (INFN e Univ. Torino)

Description

The Apparatus for Mesons and Baryon Experimental Research (AMBER, NA66) is a high-energy physics experiment at CERN's M2 beam line, with a broad physics program extending beyond 2032. It includes studies on: antiproton production cross-sections on protons, helium and deuterium; the charge radius of the proton, and Kaon and Pion PDFs via the Drell-Yan process.
As part of medium- and long-term upgrades, aging Multi-Wire Proportional Chambers (MWPCs) will be replaced with Micro-Pattern Gaseous Detectors (MPGD). The replacement technology is the resistive bulk MICRO-MEsh-Gaseous Structure (Micromegas or MM) detector. The MM detector composed of three independent modules will cover an acceptance similar to the present MWPC. The large area of the present MWPC will be covered by three independent micromegas detector modules. Each module has an active area of 1x0.5 m^2, and together the three modules adjacent modules will cover 1x1.5 m^2 in total. Each detector has includes two readout planes in a face-to-face configuration enabling XUV coordinate measurements, the cathode cathodes are implemented on a thinner central PCB. For lateral modules A uniform 10 MΩ/sq Diamond-Like Carbon (DLC) resistive layer is applied on top of the readout strips for lateral modules.
The mechanical structure and readout planes have been designed, and the first detector was produced in October 2024. First tests comprising in-beam operation beam tests are currently ongoing both at CERN and in Torino. In parallel, a 64-channel mixed-signal front-end ASIC, named ToRA (Torino Readout for AMBER), is being developed at INFN Torino. It is optimized for time and energy measurements leveraging results from simulations and from earlier tests with Micromegas prototypes and TIGER-based electronics. Current efforts focus on characterizing detector performance, noise behavior, and integration with the ToRA ASIC. Both the detector and readout system developments will be presented.

18:00–18:20 **The Silicon Tracking System (STS) of the CBM experiment at FAIR**

Speaker

Irakli Keshelashvili (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Description

The Compressed Baryonic Matter (CBM) experiment at the Facility for Antiproton and Ion Research (FAIR) aims to explore the phase diagram of strongly interacting matter at high baryon densities. It is designed to study heavy-ion collisions at beam energies of up to 11 AGeV using the SIS100 synchrotron. The CBM will explore collisions of high-intensity nuclear beams with thick fixed targets achieving high luminosity. Due to the extended beam extraction technique used at the SIS100 synchrotron, CBM data collection will be based on streaming time-stamped detector data into a super-computer. Event detection and physics analysis will be performed online at collision rates up to 10 MHz, demonstrating modern experiments' dynamic and real-time nature. The basic principles of the CBM experiment and its STS detector will be presented. In addition, in the following presentation, I will discuss step by step how the detector components are rigorously selected and prepared for assembly. This process involves a high level of precision and care to ensure the quality and reliability of the detector. It all starts with careful testing of the readout ASIC at the wafer level or in the manual process. The next step is to test the bonding to the micro cables and, later, the 16-chip cables that are bonded to the silicon strip sensor. All test results are stored and made available via a web interface for later use in a specially designed database using custom software applied to each assembly step. This custom software tests the quality and functionality of each detector part, ensures a seamless Q&A procedure, and stores data online from two assembly sites at GSI and KIT. More than 50 percent of the modules will be produced, and the overview will be made by the time of the presentation.

18:20–18:40 **Applications of monolithic CMOS pixel sensor to medical physics**

Speaker

Domenico Colella (INFN and University, Bari)

Description

In recent years, significant advancements in CMOS silicon pixel detectors have led to their widespread adoption across various fields of physics, driving substantial progress in particle detection technologies. A notable example is the ALTAI chip, a CMOS Monolithic Active Pixel Sensor developed as part of the ALICE (A Large Ion Collider Experiment) ITS sensor studies.

The ALTAI chip offers excellent spatial resolution, high charged-particle detection efficiency, minimal noise and fake-hit rate, and reduced sensitivity to photons, making it well-suited for applications in medical physics.

In this contribution, we present recent developments in two ongoing applications within this field. Specifically, we will discuss the concept of a Compton chamber, where multiple stacks of ALTAI chips serve as scatterer elements to form a sufficiently large sensitive volume, enabling real-time monitoring of proton and ion beams in hadron therapy. Additionally, we will explore the prospects for developing an intraoperative probe incorporating an ALTAI chip as a sensitive element, equipped with real-time imaging capabilities for use in radioguided surgery with beta-emitting radiotracers.

18:40–19:00

New timing Multi-Strip Multi-Gap Resistive Plate Chamber architecture with aging suppression for high counting rate experiments

Speaker

Mariana Petris (Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH))

Description

A long time operation of Multi-Gap Resistive Plate Chambers with gas mixtures based on C$_2$H$_2$F$_4$ and SF$_6$ leads to aging effects reflected in an increase of the dark current and dark counting rate, with impact on the chamber performance. Moreover, the higher noise rate leads to an artificial increase of the data volume in a free-streaming data acquisition operation used in high counting rate experiments.
For the mitigation of the gas pollution effects observed in high counting rate Multi-Strip Multi-Gap Resistive Plate Chambers (MSMGRPCs) exposed to high irradiation doses, a new MSMGRPC architecture based on discrete spacers and direct flow of the gas mixture through the gas gaps was designed and assembled. The aging investigations of the chambers with the new design demonstrated negligible aging effects even for rather low gas flow rate. Prototypes with such a direct flow architecture were tested in real operation conditions, in an in-beam test performed at the SIS18 accelerator of GSI Darmstadt with reaction products. The obtained results demonstrate the performance of the prototypes in terms of efficiency (>95%) and time resolution (~55 ps). Therefore, such direct flow MSMGRPCs will be implemented in the modular configuration of the low polar angle region of the TOF wall (inner wall) of the CBM experiment at the FAIR facility in Darmstadt, where a challenging counting rate up to 30 kHz/cm^2 is anticipated. The modular architecture of the CBM-TOF inner wall encompasses 12 modules staggered in space such to assure an uniform detection area. Details about the implementation of the direct flow MSMGRPCs of different granularities in the first module of CBM-TOF inner wall, the most complex one whose assembling is in progress, are included.

19:30

17:00

Monday 22 September 17:00–19:30

Hadron Structure, Spectroscopy and Dynamics: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Bryan McKinnon (University of Glasgow)

17:00–17:25 Deeply Virtual Compton Scattering with CLAS12 at Jefferson Lab

Speaker

Adam HOBALLAH (Hobart) (IJCLab CNRS-IN2P3)

Description

A key step toward a better understanding of the nucleon structure is the study of Generalized Parton Distributions (GPDs). GPDs are nowadays the object of an intense effort of research since they convey an image of the nucleon structure where the longitudinal momentum and the transverse spatial position of the partons inside the nucleon are correlated. Moreover, GPDs give access, via Ji's sum rule, to the contribution of the orbital angular momentum of the quarks to the nucleon spin. Deeply Virtual Compton scattering (DVCS), the electroproduction of a real photon off the nucleon at the quark level, is the golden process directly interpretable in terms of GPDs of the nucleon. The GPDs are accessed in DVCS mainly through the measurements of spin-dependent asymmetries. Combining measurements of asymmetries from DVCS experiments on both the neutron and the proton will allow performing the flavor separation of relevant quark GPDs via linear combinations of proton and neutron GPDs. This talk will mainly focus on recent DVCS measurements from the CLAS12 experiment at Jefferson Lab with the upgraded ~11 GeV CEBAF polarized electron beam. In particular, details on the recent published results of the measurement of Beam Spin Asymmetries from neutron-DVCS will be presented. The impact of the measurement on the extraction of the Compton form factor (CFF) E related to the GPD E of the neutron will be discussed. Further discussion will motivate the foreseen measurements on a transversly polarized proton target aiming to extract the CFF E of the proton.

17:25–17:50 Hadron spectroscopy at BESIII

Speaker

Nils Huesken

Description

Using e+e- annihilation in the tau-charm energy region, the BESIII experiment plays a key role in the spectroscopy of both hadrons made from the light up, down and strange quarks and of charmonium(-like) states.
World-record datasets on the J/psi and psi(2S) states allow for highly precise studies of glueball and hybrid meson candidates, whereas dedicated data above the open-charm threshold enable detailed investigations of the XYZ states.
In this contribution, recent highlights of the BESIII hadron spectroscopy program will be presented.

17:50–18:10 Measurements of transverse momentum dependent effects in SIDIS at COMPASS

Description

An important part of the physics programme of the COMPASS experiment at CERN consists in the measurement of transverse spin and transverse momentum effects in Semi-Inclusive Deep Inelastic Scattering (SIDIS) of high energy muons off unpolarised and transversely polarised nucleons.
In this talk, the most relevant new results on SIDIS off unpolarised protons and transversely polarised deuterons will be reviewed.
The perspectives and the implications for the extraction of transversity and of the transverse momentum-dependent parton distribution functions will also be discussed.

18:10–18:30 Hadronization Dynamics in the Nuclear Medium: Preliminary Insights from the CLAS12 RGE Experiment at Jefferson Lab

Speaker

Prof. Hayk Hakobyan (Universidad Tecnica Federico Santa Maria)

Description

Studying hadronization - the process by which quarks and gluons transition into hadrons -is fundamental to understanding the strong interaction dynamics within quantum chromodynamics (QCD). Using the CLAS12 detector at Jefferson Lab, the Run Group E (RGE) experiment offers unprecedented insights into hadronization in the nuclear medium. This talk will present preliminary results from the experiment, focusing on the behavior of hadrons produced in 11-GeV electron-nucleus scattering. The experiment employs various nuclear targets, enabling a comparative study of medium effects on hadron formation and propagation. By analyzing observables such as hadron multiplicity ratios, transverse momentum broadening, and energy loss, we explore the interaction of quarks and hadrons with the nuclear environment. These measurements provide critical data for understanding color confinement and hadronization timescales, shedding light on QCD processes in dense media. The talk will also highlight the innovative Double-Target system developed for RGE, which facilitates rapid target switching to enhance data collection efficiency.

18:30–18:50 Investigating the proton structure with the FAMU experiment

Speaker

Cecilia Pizzolotto (Istituto Nazionale di Fisica Nucleare, Sezione di Trieste)

Description

The FAMU collaboration aims to measure the hyperfine splitting (hfs) of the muonic hydrogen in the ground state, contributing to the understanding of the proton magnetic structure. The Zemach radius of the proton can be estimated from the hfs measurement with an accuracy better than 1%.

The experiment is conducted at the ISIS facility of the Rutherford Appleton Laboratory (UK) at the RIKEN Port1 beamline, where a pulsed muon beam is directed into an 8-bar hydrogen gas target. The 1S hyperfine splitting (hfs) transition is stimulated irradiating the muonic hydrogen with a tunable mid-infrared laser (~6788 pm). The target also contains a small amount of oxygen, and if the hfs transition occurs, an increase in characteristic X-rays from muonic oxygen is detected. This increase is caused by the increased transfer of the muon from hydrogen to oxygen.

The core of the experiment is the pulsed laser, specially developed by INFN Trieste for this application. This laser is unique worldwide because of its tunability, energy, and spectral purity.
The detector system consists of 34 LaBr scintillating crystals read by photomultiplier tubes and silicon photomultipliers and combines excellent timing performance with high energy resolution. A dedicated muon beam monitor ensures accurate beam diagnostics and data normalization.

This contribution will offer an update on current status of the experiment, its performance, and the progresses made in data analysis.

18:50–19:10 **Neutron DVCS Cross Section Extraction at the CLAS12 Experiment**

Speaker
Li XU

Description

Understanding the internal structure of nucleons remains one of the important challenges in hadronic physics. The measurement of Deeply Virtual Compton Scattering (DVCS) from the neutron provides unique information on Generalized Parton Distributions (GPDs), offering a three-dimensional picture of the neutron's partonic structure. This talk will detail the extraction of the neutron DVCS cross-section from the CLAS12 experiment at the Jefferson Lab, with the electron beam about 10.4 GeV scattering off a liquid deuterium target. We will discuss the analysis strategies, including the selection of neutron DVCS events, the determination of the acceptance and the estimation of systematic uncertainties. The preliminary cross-section results will be presented as a function of relevant kinematic variables, providing valuable inputs for GPD models and furthering our understanding of the neutron's internal structure.

19:10–19:30 **Probing the proton Axial Vector Form Factor with an inverse β– decay experiment**

Speaker
Roberto Perrino (INFN)

Description

The Axial-Vector Form Factor (AVFF) is so far largely unknown compared to the other form factors of the nucleon. Only its normalisation at $Q^2=0$ is experimentally well known from β decay.

Most AVFF experimental knowledge at $Q^2>0$ is owing to ν quasi-elastic scattering on nuclei, and is therefore strongly affected by the determination of ν beam energy; low statistics; also need of nuclear models, as recently shown by results of the Minerνa collaboration. The ν experiments interpretation (e.g. DUNE) would greatly benefit of more accurate and independent AVFF knowledge.
On the other hand, the AVFF is also very important in the picture of the nucleon dynamics degrees of freedom scarcely accessible by electromagnetic probes.

We envisage a direct measurement of the AVFF by means of the inverse β^- decay process $e^-+p\rightarrow n+\nu$ using an intense and highly polarized beam at Jefferson Lab.

Despite of the extremely low cross section, this would stem from a high time resolution neutron arm and a highly suppressive e,π veto arm and advantage of the helicity flipping of 85% polarized beam, all aiming at a very high enhancement of the S/B ratio.

19:30

17:00 **Monday 22 September** 17:00–19:30

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Lynda Achouri (LPC Caen)

17:00–17:25 Nucleosynthesis in zero and extremely low metallicity rotating massive stars

Speaker

Lorenzo Roberti (INFN - Laboratori Nazionali del Sud)

Description

The s-process is responsible for producing roughly half of the elements heavier than iron in the periodic table. While the dominant contribution to s-process nucleosynthesis in galactic chemical evolution (GCE) is typically attributed to the late evolutionary stages of low-mass stars, their long lifetimes make them unlikely sources for explaining the presence of heavy elements observed in the spectra of extremely metal-poor (EMP) low-mass stars, which formed shortly after the Big Bang. In contrast, massive stars ($\rm M\geq \sim8-9 M_{\odot}$) are limited to producing only the weak component of the s-process, especially at low metallicity due to the lack of seeds.

A possible scenario which aims to explain this unexpected presence of heavy elements in EMP stars is that they formed out from gas clouds polluted by the supernova yields of rotating massive progenitors. Rotation at low metallicity, in fact, can considerably boost the neutron capture nucleosynthesis in massive stars through an efficient activation of the neutron sources during He and C burning stages. In this talk, I will present the main results of my recent work, discussing the effect of fast rotation in core-collapse supernova progenitors at zero and very low metallicity, with a particular focus on the nuclear reactions leading to the production of F and of the nuclei beyond Zn.

17:25–17:50 Propagation of Cosmic Rays and nuclear cross sections

Speaker

Karl-Heinz Kampert (University of Wuppertal)

Description

To be added here

17:50–18:10 Direct Measurement of the ^{59}Cu(p,α)^{56}Ni reaction with the Multi Sampling Ionization Chamber Detector (MUSIC)

Speaker

Eilens Lopez Saavedra (Argonne National Laboratory)

Description

We report the preliminary results from a direct cross-section measurement of the ^{59}Cu(p, α) ^{56}Ni reaction, performed in inverse kinematics using the high-efficiency MUSIC active-target detector at the ReA6 facility at FRIB. This reaction is critical in explosive astrophysical environments. In type I X-ray bursts, where rapid proton capture and α-induced processes drive the thermonuclear runaway, the competition between the ^{59}Cu(p, α) and ^{59}Cu(p, γ) reactions governs the breakout from the NiCu cycle. This breakout is essential for synthesizing heavier nuclei and ultimately shapes the X-ray burst light curves and the composition of burst ashes. Similarly, in the νp-process—operating in the proton-rich ejecta of core-collapse supernovae—the ^{59}Cu(p, α) reaction rate strongly influences the formation of heavy, proton-rich isotopes that are observed in the aftermath of these stellar explosions.

Our measurement used a ^{59}Cu beam delivered at 8.41 MeV/u with an intensity of ~1×10^{4} pps, covering the center-of-mass energy range from 2.38 to 5.57 MeV. This energy window lies within the Gamow range for temperatures above 2 GK—a regime critically relevant for both X-ray bursts and the νp-process. The experiment employed methane gas in the MUSIC chamber to enable high-rate detection and event-by-event identification was achieved through characteristic energy-loss patterns, allowing a clear separation of (p, α) events from potential contaminants.

18:10–18:30 Neutron capture and total cross-section measurements on Mo isotopes at n_TOF and GELINA

Speaker

Riccardo Mucciola (INFN Bari)

Description

The neutron-induced reaction cross-sections for molybdenum, particularly the capture cross-sections, are relevant across various scientific fields, from nuclear astrophysics to nuclear technologies. Molybdenum isotopes are present as fission products in conventional nuclear reactors and its use is under study for potential applications in next-generation fission and fusion reactors. Additionally, molybdenum isotopes are observed in pre-solar silicon carbide (SiC) grains, where precise neutron capture cross-sections are essential for constraining models of stellar nucleosynthesis, especially in Asymptotic Giant Branch (AGB) stars where the s-process is active. Discrepancies in model predictions of isotopic compositions in SiC grains have emerged when using Mo cross-section data from the two primary KADoNiS database versions. This shows the importance of an accurate knowledge of the total and capture cross-section for molybdenum isotopes.

However, available experimental data for neutron capture cross-sections of Mo isotopes exhibit substantial uncertainties. This is also reflected in the large uncertainties of the cross-sections recommended in the ENDF/B-VIII.0 library, where uncertainty levels can reach up to 40% for certain isotopes. The uncertainty on the data in the literature has an effect in the uncertainty of the MACS (Maxwellian Averaged Cross Section) found in the latest version of KADoNiS, which presents uncertainties on the level of 10% in the MACS at 30 keV for all the molybdenum isotopes. One of the reasons for these large uncertainties is related to the absence of transmission data for enriched samples.

For these reasons a series of neutron induced cross section measurements were performed on all the natural occurring isotopes of molybdenum. The measurements were performed in two different neutron time-of-flight facilities n_TOF (CERN, Switzerland) and GELINA (EC-JRC Geel, Belgium). This work presents preliminary results from transmission and radiative neutron capture measurements conducted at n_TOF and GELINA for the isotopes ^{94}Mo, ^{95}Mo, and ^{96}Mo. Moreover, the first results of the latest capture measurements performed at both experimental areas of n_TOF on ^{92}Mo,^{97}Mo, ^{98}Mo, and ^{100}Mo will be presented.

18:30–18:50

Novel results on experimental studies of the 46Mn β+ decay channel and its connection to CCSN

Speaker

David Godos Valencia (Instituto de Fisica - UNAM, CEAFMC - University of Huelva)

Description

The ^{44}Ti nucleosynthesis, alongside its characteristic gamma decay chain, is a good gamma tracer of Supernovae events. Specifically for Core Collapse Supernova (CCSN) explosions, the final process experienced by stars with initial mass greater than 8 M$_\odot$, where the nucleosynthesis takes place. Besides, the comparison between observations and models of the synthetized ^{44}Ti in CCSN gives important constraints to the latter, such as the explosion energy and duration as well as the remnant and ejected masses. In this context, reaction networks are used for modelling nucleosynthesis occurring in the last stages of those stars, using thermonuclear reaction rates as its inputs [1,2,3], among others (mass, half-lives, etc.).

In the quest of narrow isolated resonances and the subsequent reaction rates, which are very difficult to study in a direct way by the current nuclear laboratories, indirect methods such as the β-delayed proton emission may help us. This is the case for the ^{45}V(p,γ)^{46}Cr reaction, one of the candidates to which the nucleosynthesis of ^{44}Ti could be sensitive in CCSN explosions [1,4,5].

In this talk we present the analysis of the ^{45}V(p,γ)^{46}Cr reaction rate by means of the ^{46}Mn β^+ decay channel. For that purpose, and to study the excited states of his daughter nucleus ^{46}Cr, the ^{46}Mn was selected among other species in the cocktail beam delivered by LISE fragment separator at GANIL (Caen, France). As part of our preliminary results, we present the proton and gamma emission peaks related to the ^{46}Mn decay and compare them with the work from references [6,7]. Also, we present p-γ and γ-γ coincidence studies used to identify the processes linked to the γ emission. From them we have obtained evidence of a possible larger number of proton transitions from the IAS of ^{46}Cr to ^{45}V excited states than the previously seen at [6].

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18:50–19:10

Neutron background monitoring for the IAXO-D0 detector prototype

Speaker

Víctor Martínez Nouvilas (Universidad Complutense de Madrid)

Description

The International Axion Observatory (IAXO) is a planned gaseous detector helioscope designed to detect axions, theorised to be dark matter candidates. A baseline detector prototype, IAXO-D0, is at present undergoing tests in Zaragoza. This prototype is sensitive to background high-energy neutrons that could induce false positive axion detections.

A neutron monitor has been proposed as a way to provide a continuous measurement of ambient neutrons. A prototype neutron monitor was designed and assembled. It consists of three He-3 proportional counter tubes surrounded by several layers of HDPE and lead. It has been in operation since March 2024 inside the laboratory where IAXO-D0 is being commissioned.

We present Monte Carlo simulations performed to characterise the monitor and the first results of the neutron count rate during the Forbush decrease observed in May 2024, once noise and pile-up have been taken care of, and atmospheric pressure effects have been corrected for.

19:10–19:30

Elastic α-scattering with exotic nuclei: pushing forward on p-process understanding

Speaker

Francisco Maria Santos Lima Geraldes Barba (LIP - Laboratório de Instrumentação e Partículas)

Description

The production of p-nuclei remains a significant open problem in nuclear astrophysics, representing one of the most challenging research frontiers in the field. The α-nuclear potential serves as a critical parameter for modulating p-nuclei synthesis, being known as one of the key parameters to reduce uncertainties in the high atomic mass region of the p-process network. [1,2]

In this contribution, I will present the first experimental measurement of α-particle scattering on exotic heavy nuclei. The experiment was conducted at the HIE-ISOLDE facility at CERN, utilizing Sn isotopes with masses A = 108, 109, 110, and 112. I will discuss the experimental setup, highlighting the innovative Si:He targets [3] that enabled this experiment. The data will be compared to global α-potential models from the literature, highlighting the need to further experimentally explore the unstable isotope regions of the astrophysical p-process.

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19:30

17:00 **Monday 22 September** 17:00–19:05

Nuclear Physics Applications: 1

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Eric Dumonteil (CEA)

17:00–17:25

Developments of Compact Accelerator driven Neutron Sources, news from SATELIT, the Saclay Target with liquid Lithium

Speaker

Loïc THULLIEZ (CEA-Saclay)

Description

Facilities that provide bright thermal neutron beams are crucial for a wide range of research areas, including condensed matter experiments, neutron imaging, and medical applications. Currently, these beams are primarily generated by spallation sources and nuclear research reactors. However, many of these facilities are aging, and the current political climate does not favor the construction of new ones. For instance, the Orphee reactor at CEA-Saclay in France was shut down in 2019. Consequently, there is a need for an alternative, affordable facility that can be built by a single country and is capable of producing high-brilliance neutron beams.At CEA-Saclay, a compact accelerator driven neutron source is investigated in levaraging the IPHI accelerator, which can deliver a 3 MeV proton beam with an intensity of up to 100 mA. The high-energy primary neutrons (~MeV) produced by the interaction between the beam and the target are then slowed down in a moderator to room temperature (~25 meV) and subsequently directed to an experimental setup for use.

Since 2016, an experimental program has been underway to demonstrate the feasability of operating a high power beryllium target of 50 kW for
In parallel with the development of beryllium targets, a liquid lithium target named SATELIT (Saclay Target with Liquid Lithium) has been under de

The European context of the CANS developments, along with the progress made at CEA-Saclay, will be discussed. The focus will be on the latest

References :

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17:25–17:45

Re-TOF: A novel detector for the measurement of the fission cross section induced by high energy neutrons

Speaker

Roberto Zarrella (University of Bologna, INFN section of Bologna)

Description

Neutron-induced fission reaction cross sections are crucial in various fields of nuclear science and technology. Experimental data from these reactions play a key role in understanding nuclear processes at high excitation energies, contributing to the development and refinement of models describing spallation, nuclear fragmentation, and binary fission. Moreover, accurate cross-section data are essential for numerous technological applications. The enhancement of safety in current nuclear reactors and the development of next-generation systems, such as Accelerator Driven Systems (ADS) and Generation IV Fast Neutron Reactors, require precise data across a broad energy spectrum, from thermal energies to several tens of MeV. Additionally, a deeper understanding and modeling of nuclear fission, including nuclear matter properties like viscosity, are necessary for accurately describing fission dynamics. These considerations extend the relevant energy range into the hundreds of MeV, where such phenomena can be more directly characterized.

The neutron time-of-flight facility n_TOF at CERN offers the possibility to study neutron-induced reactions over an extensive energy range, from sub-meV to GeV of neutron kinetic energy. The key features of the facility, such as high energy resolution and the intense instantaneous neutron flux, make it particularly well-suited for high-accuracy, high-resolution fission cross-section measurements.

Recently, a dedicated measurement campaign was conducted to obtain precise cross-section data for the ^{235}U(n,f) reaction, covering the entire energy range from thermal up to several hundreds of MeV. This included the first experimental data above 200 MeV, extending to 440 MeV. Fission yields were measured simultaneously with the neutron flux, which was determined relative to neutron-proton elastic scattering, the main reference for nuclear reactions induced by high energy neutrons. The upper energy limit was constrained by the setup used for the reconstruction of the incident neutron flux. To overcome this limitation, a novel detection system using fast plastic scintillators for recoil proton detection via the time-of-flight (TOF) technique is under development. This advanced detector is designed to extend the energy range up to 1 GeV, enabling a new series of measurements to determine fission cross sections relative to n-p elastic scattering across a continuous spectrum from a few tens of MeV to the GeV region.

This contribution presents a review of the current status and preliminary results from the first detector tests performed in the first experimental area at n_TOF. The potential of this new system for neutron flux determination at very high neutron energies will be discussed.

17:45–18:05

Enhancing Target Development at GANIL for Nuclear Research: Optimization of the Deposition Technique for Lanthanide Targets

Speaker

Radia RAHALI (GANIL - CNRS)

Description

The GANIL (Grand Accélérateur National d'Ions Lourds) facility plays a crucial role in nuclear physics, astrophysics, and materials science by providing high-quality ion beams for cutting-edge research. A key component of these experiments is the production of high-quality targets, which are essential for obtaining accurate and reproducible results. With the development of the SPIRAL2 facility, including the superconducting linear accelerator (LINAC) and experimental areas such as Neutrons for Science (NFS) and the Super Separator Spectrometer (S3), the demand for robust and precisely engineered targets has increased. To support this expanding experimental program, the GANIL target laboratory is undergoing a major upgrade to enhance its production and characterization capabilities, focusing particularly on isotopically enriched targets capable of withstanding high beam intensities.
To meet these challenges, various fabrication techniques, including physical vapor deposition (PVD), electrodeposition, and mechanical rolling, are employed to tailor targets with controlled thickness, composition, and mechanical stability. This work focuses on the development of lanthanide targets (Yb, Gd, Hf, etc.) using PVD techniques. The deposition process was optimized to ensure high-quality thin-film targets on ultra-thin carbon foils (35 $\mu g/cm^2$), which require careful handling to prevent damage. The high melting point of the oxide form of some elements, combined with the need for uniform deposition over large surfaces (16 cm^2), presents significant challenges. To overcome these, a rotation system was integrated into the deposition chamber, ensuring homogeneity. The fabricated targets undergo characterization through X-ray fluorescence (XRF) and scanning electron microscopy with energy dispersive X-ray spectroscopy (SEM-EDX) to assess their uniformity and purity, ensuring they meet experimental requirements.
Preliminary results indicate promising advances in lanthanide target fabrication, with ytterbium targets exhibiting excellent adhesion and homogeneity. The achieved thickness range, from a few $\mu g/cm^2$ to mg/cm^2, fulfills the diverse needs of nuclear physics experiments.

18:25–18:45

Enhancing charge collection efficiency in radiation-damaged unmetallized 4H-SiC detectors via LED Illumination

Speaker

Mauricio Rodríguez Ramos (Centro Nacional de Aceleradores (CNA). University of Seville.)

Description

A new generation of 4H-SiC detectors has demonstrated the capability to operate at temperatures up to 450°C, offering excellent spectroscopic response and energy resolution (≲2%) [1]. This advancement paves the way for the development of silicon carbide detectors designed to measure suprathermal ions (He++ at 3.5 MeV) in extreme radiation and temperature environments, such as those expected in future nuclear fusion reactors like ITER. One of the key challenges to address is the radiation-induced damage. Radiation creates localized defects (trapping centers) in the lattice structure, which capture free charge carriers and lead to charge collection efficiency (CCE) degradation. In this study, we investigate the effect of optical excitation using visible light illumination on the detrapping process of radiation-induced trapped carriers in a 4H-SiC p-n junction unmetallized detector developed by the Institute of Microelectronics of Barcelona (IMB-CNM). The recovery of CCE performance in damaged regions under standard light illumination has been observed in other materials, such as diamond [2]. The detector analyzed in this work was previously irradiated with He beams at 3.5 MeV, creating different damaged regions with cumulative fluences ranging from 1×10^{11} to 1×10^{13} $ions/cm^2$ at three different temperatures (from room temperature up to 400°C) [3]. The spectroscopic response was analyzed at the ion beam nuclear microprobe of the National Accelerator Center (Seville, Spain) using the Ion Beam Induced Charge (IBIC) technique under Light Emission Diodes (LEDs) illumination at different wavelengths to study the influence of light-assisted detrapping on CCE recovery. Our results reveal that illumination induces a significant detrapping process, with higher efficiency in regions of increased trap density. Furthermore, the detrapping effect is intensity-dependent, suggesting a controllable mechanism for performance enhancement. These findings propose a simple yet effective approach to mitigate radiation damage effects, offering a potential strategy to optimize the functionality of SiC-based detectors in harsh fusion environments.

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18:45–19:05

Retention effects in the Szilard-Chalmers reaction for solutions of ethyl iodide and ethanol

Speaker

Dr Antonio Massara (INFN - Laboratori Nazionali del Sud)

Description

This work explores the effects of dilution on the retention phenomena of radioactive atoms produced in the Szilard-Chalmers reaction, with a minimum level of gamma radiation coming from the Am-Be source. For the first time, we demonstrate that the 128-I extraction yield, after a sizable post-irradiation time, can be maximized with a suitable dilution. The origin of this curious effect is still unclear; while a role played by some contaminant can not be excluded, an alternative suggestion could originate from evolution of intermolecular interactions recently observed when alkyl-iodides are mixed with ethanol.

19:05

17:00 **Monday 22 September** 17:00–18:20

Nuclear Physics Applications: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Eric Dumonteil (CEA)

17:00–17:20

Deep Learning–Driven Differentiable Autoplanning for Proton Therapy: A Proof-of-Concept

Speaker

Lorenzo Arsini (Sapienza University of Rome)

Description

Proton therapy is widely recognized for its superior dose conformity and enhanced protection of healthy tissues compared to conventional photon-based radiotherapy, making it an increasingly valuable modality for treating complex cancers. However, fully realizing its potential is constrained by the computational demands of high-fidelity dose calculation and plan optimization. Although Monte Carlo (MC) simulations are the gold standard for dose estimation, their computational expense renders them impractical for iterative treatment plan optimization.
In this work, we introduce a deep-learning (DL)–based dose engine that achieves MC-level accuracy in a few milliseconds. Our approach employs a Graph Neural Network (GNN) architecture trained on MC-generated proton pencil beam dose distributions. This design features a cylindrical geometry—chosen for its alignment with rotational delivery systems—and optimizes computational efficiency. Moreover, the architecture affords fine control of spatial resolution near the Bragg peak, balancing precision with memory requirements.
Crucially, this solution is intended for treatment plan optimization. The network is trained over a broad range of beam parameters—energy, lateral position, and incidence angle—enabling continuous, fully differentiable dose prediction in real time. This capability allows direct gradient computation, making it straightforward to embed the dose engine into gradient-based optimization workflows. Consequently, plan optimization becomes a unified, differentiable process, where beam orientations, energies, and fluences can be jointly optimized via efficient gradient-based methods.
We will present validation results confirming the dose engine's accuracy against MC benchmarks, along with proof-of-concept single-field and multi-field proton therapy treatment plan outcomes. The ability to compute dose and its gradients in milliseconds opens the door to real-time, fully automated plan optimization, in which intricate physical and biological constraints can be directly incorporated into the objective function. Furthermore, by managing continuous degrees of freedom effectively, this framework shows substantial potential for advanced delivery strategies such as proton arc therapy, where dynamic modulation of beam parameters is paramount.

17:20–17:40

Model bias and parameter optimisation with the example of INCL/ABLA

Speaker

Jason Hirtz (CEA-Saclay)

Description

The accuracy (the bias) and precision (the uncertainties) of high-energy spallation models is a key issue for the design and development of new applications and experiments. In the case of the combination of the IntraNuclear Cascade model of Liège (INCL) [1, 2] and the Ablation model (ABLA) [3, 4], we address the problem through two orthogonal approaches, both based on a Bayesian framework.

In the framework of the joined project NURBS, shared between the Swiss National Science Foundation (SNF) and the French National Agency for Research (ANR), we developed an approach to optimise the internal parameter of the model [5] and, on the other hand, we developed a method to estimate the bias of the model [6]. The first approach improve the accuracy and the second quantify the accuracy and the precision of model combination. This will be used to study observable ranging from the double differential neutron production to the hypernuclei fission cross section.

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17:40–18:00

Bayesian optimization on FIFRELIN Monte-Carlo code to fit neutron and gamma multiplicities

Speaker

Guillaume Bazelaire (CEA/DES/IRESNE/DER/SPRC/LEPh)

Description

Bayesian optimization on FIFRELIN Monte-Carlo code to fit neutron and gamma multiplicities

Guillaume BAZELAIRE, *Abdelhazize CHEBBOUBI*, David BERNARD, *Geoffrey DANIEL*, *Jean-Baptiste BLANCHARD**

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Abstract : FIFRELIN (Fission FRagments Evaporation moedLINg) is a Monte-Carlo code based on Hauser-Fesbach formalism [1]. Its purpose is to simulate the de-excitation process of fission fragments. Firstly, fission fragments are generated using a sampling over model and experimental data. Some models depend on free parameters that the user can adjust. After the fission fragments are generated, a cascade over a level scheme is simulated. The free parameters selected no longer interfere with this second step. Numerous quantities of interest are calculated (mass yields, prompt particle spectra, multiplicities …). Up to now, the code relies on four free parameters which mainly control the initial excitation and total angular momentum of fission fragment. Up to now, the main limitation of the code is the capacity to explore the 4D input space. For instance, one FIFRELIN simulation takes seven minutes to get the uncertainties in the order of experimental precision for neutron and gamma multiplicities. It corresponds to 24h of computational time for barely 3 or 4 points in each dimension of the input space. Therefore, it is unrealistic to use a direct exploration of the input space, in order to find a solution that align with the experimental data [2] [3]. To do so, we propose to use Bayesian optimization, supported by the use of Gaussian Process [4]. An independent Gaussian Process models each physical observable, in order to reach global solution that minimize the distance between FIFRELIN response and the experimental target [5]. Starting from scratch, using 20 CPUs, we find inputs that correctly fit the neutron and gamma multiplicities in less than one hour. Neutron emission probability is well fitted also. Other observables can be added, such as the neutron multiplicity as a function of mass. This induces constraint on potential values of temperature ratios, defined for each fragmentation this time. Physical interpretation of this new input model of FIFRELIN will also be presented.

[1] O. Litaize, O. Serot, et L. Berge, « Fission modelling with FIFRELIN »
[2] V. Piau, O. Litaize, A. Chebboubi, S. Oberstedt, A. Göök, et A. Oberstedt, « Neutron and gamma multiplicities calculated in the consistent framework of the Hauser-Feshbach Monte Carlo code FIFRELIN »
[3] P. Santi et M. Miller, « Reevaluation of Prompt Neutron Emission Multiplicity Distributions for Spontaneous Fission »
[4] J. Snoek, H. Larochelle, et R. P. Adams, « Practical Bayesian Optimization of Machine Learning Algorithms »
[5] A. K. Uhrenholt et B. S. Jensen, « Efficient Bayesian Optimization for Target Vector Estimation »

18:00–18:20 **Hybrid Nuclear Interaction Models for Improved Fragmentation Modeling in Ion Therapy**

Speaker

Dr Lorenzo Arsini (Sapienza University of Rome)

Description

Ion therapy employs protons and heavier ions (e.g., helium, carbon, oxygen) for cancer treatment due to their advantageous physical and biological properties, particularly effective against radio-resistant tumors. However, precise modeling of nuclear fragmentation processes, which critically influence dose distributions, biological effectiveness, and overall treatment accuracy—especially with heavier ions—remains challenging. Monte Carlo (MC) simulations are considered the gold standard for dose calculation in ion therapy, with Geant4 being one of the most widely used tools. Nonetheless, Geant4 currently lacks dedicated nuclear interaction models for energies below 100 MeV/u, leading to discrepancies compared to experimental data. Advanced nuclear interaction models, such as the Boltzmann-Langevin One Body (BLOB) model, when interfaced with Geant4, provide improved accuracy but are prohibitively computationally intensive (~4 minutes per interaction), thus impractical for routine clinical use.
To address these limitations, we propose a hybrid modeling approach combining deep learning (DL) techniques with classical nuclear interaction models. Specifically, we developed a physics-informed neural network explicitly designed to incorporate interaction symmetries within its architecture and process nucleons as batch inputs, enabling general applicability across various nuclear reactions. As a proof-of-concept, our model was trained on two computationally demanding tasks: calculating the mean-field potential and computing Hamiltonian derivatives with respect to generalized coordinates in two nuclear interaction models implemented in Geant4—Quantum Molecular Dynamics (QMD) and Light Ion QMD (LiQMD).
We trained our DL models on extensive datasets generated by Geant4 simulations, encompassing multiple ion species and clinically relevant energies (90–130 MeV/u), achieving highly accurate emulation of both potential and Hamiltonian derivatives (Median Relative Error ≤ 0.84%). Integrating the DL models into Geant4, we replaced their corresponding classical methods and conducted several fragmentation simulations. Comparisons of double-differential cross sections for fragment production between classical and hybrid simulations showed that while potential emulation primarily yielded accurate cross sections for lighter fragments, Hamiltonian derivative emulation provided high accuracy across all fragment species, demonstrating strong generalization, interpolation, and extrapolation capabilities.
This study demonstrates the feasibility and potential of our approach, paving the way for future developments. Upcoming work includes increasing computational efficiency through an optimized implementation that leverages GPU acceleration and extending this hybrid methodology to more complex models, such as BLOB, ultimately aiming at precise and rapid nuclear fragmentation modeling for clinical ion therapy planning and validation.

18:20

17:00 **Monday 22 September** 17:00–19:25

Nuclear Structure, Spectroscopy and Dynamics: 4

Session | **Location:** MoHo, Inspire 1, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Araceli LOPEZ-MARTENS (IJCLab)

17:00–17:25 Shell model: recent advances from mid-mass to superheavy elements

Speaker

Dr Frederic NOWACKI (IPHC Strasbourg)

Description

In this presentation, I will expose some of the latest developments in microscopic nuclear structure calculations from mid-mass to superheavy elements. In a first part, I will present developments and applications for the diagonalisation of shell-model hamiltonians in a Discrete Non-Orthogonal Shell Model (DNO-SM)[1] and its latest implementation DNO-SM(VAP)[2]. The method is based on mean-field and beyond-mean field techniques with focus on basis states optimization within a double variation after projection approach. Numerical applications are benchmarked and illustrated against Large Scale Shell Model diagonalisations.
In a second part, this new development will be used to address the subject of high collectivity along the N=Z line. In particular, heavy N=Z nuclei in the mass region A=80 are expected to be some of the most deformed ground states which have been found[3] in mid-mass nuclei, typically 8p-8h,12p-12h for e.g. the cases of 76Sr, 80Zr and more recently extended to 84Mo and 86Mo. This strong enhancement of collectivity with respect to lighter N=Z nuclei has its origin in cross shell excitations across the N=40 shell gap to g9/2, d5/2 and s1/2 which are intruder quadrupole partners generating deformations. I will interpret these structures in terms of the simple Nilsson-SU3 algebraic model[4]. New theoretical calculations for the very region of 80Zr will be presented within the interacting shell model framework from both exact Shell Model diagonalisations and DNO-SM(VAP) approaches[5]. This whole region of collectivity is identified as a new Island of Inversion at the N=Z line.

The DNO-SM(VAP) approach also allows to study superheavy systems within the Shell Model framework and I will present and discuss the first complete description of low-lying spectroscopy in 254No[2].

Finally I will discuss the new perspectives opened with these recent advances.

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17:25–17:45 Probing nuclear structures with fast neutrons at NFS

Speaker

Hemantika Sengar (University of Caen)

Description

Understanding and predicting the evolution of nuclear structure and the novel phenomena in nuclei has long been a pursuit of scientific curiosity.
Conventional methods such as charged particle probes, β-decay, Coulombic-excitation, and heavy-ion fusion evaporation reactions have been employed so far in the phase space of Shell structure, magic numbers, angular momentum, and excitation energy. However, the horizon of possibilities expands when we delve into the uncharted territories of fast-neutron probes. The (n,xn) reactions are a long-standing reaction mechanism used in the cross-section data evaluation, but rarely used in the framework of nuclear structure. This might unveil a treasure trove of reactions, particularly the (n,xn) reactions with high production thresholds, which, until now, have not been looked at from the eye of nuclear structures. As a result, we know very little about their reaction mechanisms.

While the structure of ^{56}Ni has been previously investigated using charged particle and heavy ions collisions as shown in Fig.1, a pure neutron probe was never used. Fig.1: ^{56}Ni Yrast diagram
For the first time, using the unprecedented neutron flux at $\sim$20 -- 40 MeV at the Neutrons for Science (NFS) facility of GANIL--Spiral2, ^{56}Ni can be populated from ^{58}Ni in a (n,3n) reaction which has a cross-section of 2 mb at $\sim$30 MeV, opening a new probe and possibly new aspects of the nuclear structure of this doubly magic nucleus.
The TALYS cross-section calculation as a function of incident neutron energy is shown in Fig.2.The maximum cross-section is predicted to be at 40 MeV, slightly higher than the end-point of NFS. With ^{58}Ni target, studying pure neutron channels is the main interest alongside Co isotopes that are produced from (n,p/d/t) reaction. Fig.2: ^{58}Ni (n,3n)^{56}Ni cross-section.

The nuclei near ^{56}Ni are of particular interest as they are amenable to different microscopic theoretical treatments while studying the competition between single-particle and collective excitations. The collective states in ^{56}Ni involve multiparticle multi-hole excitations across the $N=Z=28$ shell gap from the 1f$_{7/2}$ shell to the 2p$_{3/2}$, 1f$_{5/2}$, and 2p$_{1/2}$ orbits. Excitation to the higher lying 1g$_{9/2}$ orbit are necessary to explain the observed rotational bands in Cu and Zn. At high excitation energies, reaction studies have revealed evidence for hyper-deformed resonances in the ^{56}Ni compound. In this project, we performed prompt-γ spectroscopy of ^{56}Ni using the EXOGAM array at NFS. From nuclear structure's point of view, the main motivation is the search for low spin (J=2 or 4) states from 3 to 10 MeV excitation energy possibly populating the 0^{+} states at 3956 keV, 6654 keV and 7903 keV observed only in ^{58}Ni(p,t)^{56}Ni and ^{58}Ni(^{3}He,n)^{56}Ni reactions. The new new spectroscopic information that will be collected is also relevant for nuclear reaction mechanism formalism (like TALYS) and nuclear data evaluation libraries.

The experiment was carried out in October 2023. The prompt gamma rays selected on the fastest neutron using the Time-of-Flight information have been detected by 12 EXOGAM clovers placed at 15 cm off the beam axis.
Approximately 1.6×10^{10} $\gamma\gamma$ coincidences have been sorted after the AddBack procedure. The ^{56} Ni de-excitation was observed and a large number of $\gamma\gamma$ coincidences for the ^{57} Ni and Co isotopes were sorted. Preliminary analysis of the experiment, focusing mainly on the pure neutron channels, will be presented. The channel (n, 2n) that produces ^{57} Ni has a much larger cross section, reaching a maximum of $\sim$90 mb at around 23 MeV, making it easier to study. Furthermore, ~^{57} Ni is only one neutron away from the doubly magic ^{56}Ni, making spectroscopy of single particle, core-coupled, and collective states of great interest. The primary focus of the talk will be to provide a comprehensive description of its level scheme and excitation functions. This isotope has a half-life of 35.6 hours and undergoes β^{+} decay to produce ^{57}Co in the system, which is interestingly also populated by the (n,d) and (n,n'p) channels. A concise summary of our current understanding of ^{57}Co will also be provided. The question of whether large germanium volume detectors can be used for γ-ray spectroscopy in a high flux, high neutron energy environment will also be addressed.

This experiment is a pioneering work in the study of the nuclear structure studies using large gamma array and fast neutrons and is only possible at GANIL--Spiral2 as of today.
If successful, this program will open a new door for nuclear structure studies.

17:45–18:05

Bayesian inference on nuclear data and neutron star observations for the nuclear equation of state

Speaker

Pietro Klausner (Université de Normandie - Caen / LPC / Università degli studi di Milano)

Description

The Equation of State (EoS) of nuclear matter is related to many topics in nuclear physics. In particular, it is crucial for understanding the structure of compact objects such as neutron stars. In the conservative hypothesis of a purely nucleonic composition of neutron star matter, the EoS is fully determined in terms of the so-called nuclear matter parameters (NMPs), which, in principle, can be determined from nuclear theory and experiments, though with error bars. However, analyses that try to infer the NMPs from nuclear experiments often present one of the following limitations: (i) the control over the quality of the simultaneous reproduction of different observables is limited; (ii) independent inferences of single NMPs give poor knowledge of the correlations among parameters.

The main objective of our work is to address both limitations. Within the standard Skyrme functional ansatz, we build a reliable probability distribution for a combination of nuclear matter parameters and Skyrme parameters (which are needed to constrain all the terms of the functional) using a combined Bayesian inference of a large set of EoS-sensitive nuclear structure data. Beyond the usual ground state properties like binding energies and charge radii, we also included the much-discussed polarizabilities and parity-violating asymmetries of ^{208}Pb and ^{48}Ca, which put stringent constraints on the NMPs J and L, both crucial for the symmetry energy.

The Bayesian analysis final result is a 10-dimensional multivariate probability distribution for the NMPs and Skyrme parameters. Marginalizing the distribution over all parameters but one allows for comparison with previous simpler analyses in the literature, which will be presented during the talk.

Furthermore, the posterior distribution can be used as a prior distribution in a successive Bayesian analysis, this time using astrophysical observations as constraints. This way, this second posterior distribution of NMPs will be informed by both nuclear physics and astrophysics. We will show that the constraints from nuclear experiments are well compatible with the theoretical predictions for infinite pure neutron matter from ab initio modelling, and those constraints additionally indicate the existence of interesting structures in the EoS of neutron stars. We will discuss the final predictions on some selected static properties of neutron stars, which can be computed from the distribution of NMPs. We will devote further attention to the composition of the star crust, which is computed consistently with the star EoS within the extended Thomas-Fermi formalism.

18:05–18:25

Ab initio calculations of beta-decay half-lives for N=50 neutron-rich nuclei

Speaker

Dr Zhen Li (Technische Universität Darmstadt & ExtreMe Matter Institute & Max-Planck-Institut für Kernphysik)

Description

The total beta-decay half-lives of neutron-rich nuclei along magic neutron numbers remain largely unknown experimentally, while they are critical inputs for r-process simulations. In this talk, I will discuss our ab initio calculations for the half-lives of $N=50$ isotones. Starting from two- and three-nucleon interactions derived from chiral effective-field theory, we solve the many-body Schrödinger equation with valence-space in-medium similarity renormalization group, a powerful method to address ground and excited states of closed- and open-shell systems. The Gamow-Teller transitions are calculated with the inclusion of consistent two-body currents, which were recently found to be a key input for explaining the g_A quenching puzzle. In addition, we consider the effects of first-forbidden transitions. Our results agree well with the existing experimental data, validating the predictive power of our approach.

18:25–18:45

Absolute electromagnetic transition rates in semi-magic N = 50 isotones as a test for $(\pi g_{9/2})^n$ single-particle calculations.

Speaker

Jan Jolie (Institut für Kernphysik, Universität zu Köln, Deutschland)

Description

Single-j calculations for $(j)^n$ configurations with n = 3,..,2j+1 can be performed using a semi-empirical approach, provided that the energies and absolute electromagnetic transition rates are known for the two-particle (hole) nucleus. This approach was already successfully applied in the case of protons in the $(\pi g_{9/2})^3$ nucleus ^{211}At [1]. At the Cologne Tandem Accelerator of the Institute for Nuclear Physics we have tested these relations by measuring lifetimes of excited states in the $(\pi g_{9/2})^n$ isotones with N = 50. We started the studies in the two proton nucleus ^{92}Mo where the previously unknown $B(E2:4^+_1 \rightarrow 2^+_1)$ value, was measured with high precision using the electronic $\gamma - \gamma$ fast timing technique [2]. Subsequently we applied the same technique in ^{93}Tc and ^{94}Ru [3] and ^{95}Rh [4]. Emphasis will be made on the comparison with recent radioactive ion beam experiments.
Work supported by DFG Grant JO391/18-2.

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18:45–19:05

Exploring the N=20 island of inversion through lifetime measurements

Speaker

Raquel Nicolás Del Álamo (INFN Padova and Università degli studi di Padova)

Description

The region around ^{32}Mg has become a focus of nuclear structure studies due to the disappearance of the $N = 20$ shell closure, giving rise to a so-called island of inversion. As a result of multi-nucleon correlations, the isotopes in this region exhibit ground states dominated by $2p - 2h$ excitations into the fp shell, deviating from the predictions of a harmonic oscillator potential combined with spin-orbit interaction. ^{34}Si is located only two protons above ^{32}Mg, yet it displays properties characteristic of a doubly magic nucleus and is considered the last even-even isotope at the edge of the island of inversion. Previous studies have revealed the presence of intruder states among the excited states of ^{34}Si and other isotopes along the $N = 20$ line. However, the intruder band remains unseen in ^{35}P.

The measurement of nuclear lifetimes, along with the determination of reduced transition probabilities, provides a sensitive method for probing the nature of nuclear states. Knowledge of the transition probabilities for low-lying excited states in isotopes located at the edge of the island of inversion is crucial for assessing the interplay of spherical and intruder configurations in this region, and the shell evolution towards the island of inversion.

An experiment was performed at the Legnaro National Laboratories (LNL) aiming to measure the lifetimes of excited states in ^{35}P, ^{34}Si, and other isotopes in the region. The measurement was performed using the Doppler Shift Attenuation Method (DSAM). The isotopes of interest were produced through multi-nucleon transfer reactions between a ^{36}S beam and a ^{208}Pb target. The set-up consisted of the AGATA high-purity germanium array and the PRISMA spectrometer, used to identify the recoiling nuclei. The precise Doppler correction allowed by this setup provided the sensitivity needed to measure lifetimes within the range of tens to hundreds of femtoseconds.

19:05–19:25

High-Resolution Gamma-Ray Spectroscopy of ^{136}Ba: Implications for Neutrinoless Double Beta Decay

Speaker

Jelena Bardak

Description

Neutrinoless double beta decay (0νββ) is a rare nuclear process predicted by beyond-Standard Model theories, offering crucial insights into the nature of neutrinos and lepton number violation. A confirmed observation of 0νββ would establish the Majorana nature of neutrinos and provide constraints on their absolute mass scale. Among candidate isotopes, the decay of ^{136}Xe to ^{136}Ba is extensively studied in large-scale experiments such as EXO, KamLAND-Zen, nEXO, and PandaX. However, to date, experiments have only set lower limits on the decay lifetimes [1].
A significant challenge remains in the precise determination of nuclear matrix elements (NMEs), which introduce uncertainties in extracting neutrino properties from measured decay rates. Theoretical predictions of NMEs vary considerably [2], highlighting the need for improved nuclear structure data.
This study investigates the nuclear structure of ^{136}Ba, the daughter nucleus of ^{136}Xe, through high-resolution gamma-ray spectroscopy using the FIPPS array at ILL. The focus is on low-spin states in ^{136}Ba populated via the ^{135}Ba(n,γ)^{136}Ba reaction, with particular emphasis on the characterization of low-spin 0^+ states. These states play a fundamental role in 0νββ decay transitions but remain incompletely understood.
The level scheme of ^{136}Ba has been studied through ^{136}Cs β decay and ^{135}Ba(n, γ) reaction experiments. Although several (n, γ) studies have been conducted, the only published data dates back to 1969 [3].
More recently, a study of the ^{138}Ba(p, t)^{136}Ba reaction [4] identified several previously unknown 0^+ states in ^{136}Ba. The high statistics of this experiment will allow for a significant expansion of the existing data set.
The experimental setup consisted of 16 HPGe clover detectors with anti-Compton shields, achieving an efficiency of 3.5% at 1.4 MeV and an energy resolution of ~2 keV at 1.3 MeV. The experiment employed a thermal neutron beam from the ILL reactor with an intensity of ~10^7 n/s/cm^2 [5]. The results will highlight newly identified transitions and spin assignments for states up to 5 MeV in excitation energy. The coincidence method was used to assign new decay lines by analyzing γγ matrices, while spin assignments were determined through angular correlation analysis of coincident γ rays, referencing existing literature on tentative spin values and mixing ratios.
Additionally, the findings will be compared with theoretical calculations to provide further insights into the nuclear structure of ^{136}Ba. Lifetime measurements will be conducted to reduce uncertainties and provide new data. The vibrational and mixed-symmetry properties of ^{136}Ba (*N=80*) will also be explored to enhance the understanding of its collective dynamics. These results aim to reduce NME uncertainties, advance knowledge of 0νββ, and contribute to broader nuclear structure studies.

References:

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19:25

17:00 **Monday 22 September** 17:00–19:20

Nuclear Structure, Spectroscopy and Dynamics: 5

Session | **Location:** MoHo, Inspire 2, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr Jonathan Wilson (IJC Lab, Orsay, France)

17:00–17:20 Understanding nuclear isomerism through shell model

Speaker

Bhoomika Maheshwari (GANIL)

Description

Nuclear isomers, which are longer-lived excited states of atomic nuclei, emerge due to structural peculiarities that impede their decay processes. Advances in measurement techniques are revealing exotic isomeric properties, leading to an ample amount of data on isomeric states. This information is crucial for both fundamental research and interdisciplinary applications across industry and science. One such application, called as isomer depletion, holds potential for energy storage. A notable example is the ${21/2}^+$ isomeric state in ^{93}Mo, a potential candidate for the nuclear excitation by electronic capture (NEEC). However, the NEEC probabilities suffer limitations due to the lack of knowledge of the involved nuclear electro-magnetic transition rates making theoretical estimates essential. To address this, we investigate the $N=51$ isotones from ^{93}Mo to ^{99}Cd, examining their structural evolution by using an empirically-derived shell-model interaction [1]. The neutron-proton interaction between the $g_{9/2}$ proton and $d_{5/2}$ neutron plays a key role governing the location of the ${21/2}^+$ isomeric state with respect to the possible $E2$ decay branch ${17/2}^+$ state. A detailed quantitative analysis is conducted to explore the role of involved shell model matrix elements connecting the $g_{9/2}$ proton and $d_{5/2}$ neutron. These findings are further compared with the existing interactions in large-scale shell model calculations. This analysis provides insights that may aid in identifying new candidates for the isomeric depletion across different mass regions of nuclear chart.

Since nuclear isomers exist throughout the nuclear landscape, it is valuable to depict their global features and, if any, systematics. A striking example is the $M4$, ${13/2}^+$ isomers in odd-mass $^{197-207}$Pb isotopes, which support nearly constant $B(M4)$ values despite corresponding gamma-energy variations from 200 keV to 1000 keV. We can understand this characteristic behavior using generalized seniority arguments [2]. These results are further supported by full-space large-scale shell-model calculations for the neutron space consisting of $0h_{9/2}$, $1f_{7/2}$, $1f_{5/2}$, $2p_{3/2}$, $2p_{1/2}$ and $0i_{13/2}$ orbitals. While the shell model effectively reproduces the experimental data, interpreting the underlying physics within such huge-dimensional Hamiltonian matrices remains challenging. The generalized seniority offers a simplification to explain these ${13/2}^+$ isomers and their $B(M4)$ values. The calculated results are further verified analytically. Interestingly, similar $M4$ isomers also exist in neighboring odd-mass Pt, Hg and Po isotopes. Ongoing investigations aim to determine whether the generalized-seniority arguments remain valid for the $B(M4)$ values as one moves away from the semi-magic nuclei. Such results are not region-dependent, and so these arguments are also tested in Zr region. Key implications of these findings will be discussed.

Acknowledgements
Financial support from the HORIZON-MSCA-2023-PF-01 project, ISOON, under grant number 101150471 is gratefully acknowledged.

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17:20–17:40 Penning-trap mass measurements of neutron-rich cobalt isotopes at IGISOL

Speaker

Pauline Ascher (LP2iB)

Description

The JYFLTRAP double Penning trap mass spectrometer at the Ion Guide Isotope Separator On-Line (IGISOL) facility offers excellent possibilities for high-precision mass measurements of radioactive ions. Using the new phase imaging technique (PI-ICR), ground and isomeric states can be separated, enabling independent measurements of their binding energies.
Accurate mass measurements of ground and isomeric states of $^{68-70}$Co have been performed at JYFLTRAP. The masses were measured, either for the first time for the isomeric states of ^{68}Co and ^{70}Co or with greatly improved precision for the others. Furthermore, the ordering of the low-spin and high-spin states for ^{68}Co and ^{70}Co could also be established, allowing on one hand to remove ambiguities on the mass surface beyond $N=40$, and on the other hand to demonstrate that the ground state in ^{70}Co corresponds to an intruder configuration. The results of this experiment will be presented as well as their comparison with Large Scale Shell Model calculations.

17:40–18:00 Investigating shape transition in neutron-rich Zr isotopes

Speaker

Guillem Tocabens

Description

The region of neutron-rich nuclei around N = 60 has attracted much interest throughout the years for its unique features, such as the very sudden onset of deformation appearing in several isotopes, precisely at N = 60. Studies of this phenomenon are of great importance in our understanding of shape evolution and shape coexistence [1]. The sudden inversion of weakly and strongly deformed configurations at N = 60 was first proposed by Federman and Pittel within the shell model, invoking the interplay between spin-orbit partners $\pi g_{9/2}$ and $\nu g_{7/2}$ [2]. A more recent interpretation was given in terms of the tensor and central forces operating concurrently in what is known as *type-II shell evolution*, with Monte Carlo shell model calculations being able to quantify the sudden change in deformation, predicting, at the same time, a variety of configurations characterized by different intrinsic shapes appearing at low energy in ^{100}Zr [3]. A large set of experimental spectroscopic data related to the shape transition in the Zr isotopes was also satisfactorily reproduced in the framework of configuration mixing within the interacting boson model (IBM-CM) [4], invoking an intertwined quantum phase transition.

Experimentally, E0 transitions between low-lying 0^+ states in even-even nuclei are a sensitive probe to shape coexistence and shape mixing, being directly related to the charge radius of the nucleus. On the other hand, certain conclusions can already be reached on the basis of level energies, as well as relative and absolute E2 transition strengths obtained via γ-ray spectroscopy following β-decay.

A new device for conversion electron spectroscopy, COeCO (COnversion electron Chasing at Orsay) [5], has recently been built at the ALTO ISOL facility in Orsay, France, and used in a β-decay experiment with ^{98}Rb and ^{100}Rb beams, revealing new insights into shape coexistence in Zr isotopes [6] and opening up new perspectives for conversion electron studies in neutron-rich nuclei at ALTO. A complementary β-decay study at the TRIUMF-ISAC facility with the GRIFFIN HPGe spectrometer and the PACES Si(Li) array resulted in an extension of the level scheme of ^{100}Zr, including, notably, obtaining firm spin assignments for several low-lying 0^+ states, and proposing a candidate for spin-2 level built on the 0^+_4 state [7].

Selected results of these two measurements will be presented, which support a general picture emerging from the MCSM calculations, *i.e.* that of multiple structures with different shapes being present in ^{100}Zr. However, they also point, for the first time, to certain deficiencies in the calculations, as well as important similarities in the structure of N = 60 ^{100}Zr and ^{98}Sr nuclei [8].

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18:00–18:20

Direct identification of actinides in multinucleon transfer reactions and effect of secondary processes

Speaker

Franco Galtarossa (INFN Sezione di Padova)

Description

Multi-nucleon transfer (MNT) reactions between heavy ions at energies close to the Coulomb barrier have been identified as a powerful tool to populate neutron-rich nuclei in the regions of the nuclear chart close to ^{208}Pb and in the actinides [1,2]. The same kind of reactions, but employing neutron-deficient projectiles, can also be envisaged to populate the region of static octupole deformation in the Ra, Th, U chains [3]. These regions are poorly studied due to the difficulty in accessing them with sufficient yields to perform detailed spectroscopy.
Despite the massive effort of different theoretical approaches in predicting absolute and differential cross sections for the production of nuclei in these regions of the nuclear chart [4], experimental information is still scarce. In particular, high-resolution data for such heavy ions (A, Z, Q-value and angular distributions, excitation functions) are largely missing, and the effect on the final yields of secondary processes, such as neutron evaporation and transfer-induced fission, is far from being properly quantified. Since identifying ions with mass $A>200$ at energies of few MeV/u is extremely challenging, most existing studies rely on indirect methods.
Recently, within the AGATA-PRISMA campaign at INFN LNL, we attempted directly identifying the heavy recoils in the ^{129}Xe+^{232}Th MNT reaction at energies slightly above the Coulomb barrier. Thorium-like ions were detected in the PRISMA magnetic spectrometer, placed close to the grazing angle of the reaction, and the coincident γ rays in the AGATA γ-ray tracking array. Although the low kinetic energy did not allow for the identification of the nuclear charge, we could demonstrate for the first time the possibility of reconstructing in PRISMA a high-resolution mass distribution of heavy ions in the actinide region ($A\sim230$). We compared the yields obtained for neutron transfer channels with predictions performed with the GRAZING code, based on a semiclassical approach, and found that GRAZING can follow the trend of the cross sections down to the $-6n$ channel when the effect of neutron evaporation is included.
We will present the results of the analysis and possible applications in view of the forthcoming campaign with Uranium beams foreseen with the PRISMA-AGATA setup at LNL in 2026.

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18:20–18:40

Influence of Exceptional Points on Nuclear Structure and Reactions

Speaker

David CARDONA OCHOA (GANIL)

Description

Exceptional points (EPs) are universal features of non-Hermitian systems, where at least two eigenvalues of an operator coalesce into a single eigenvalue, leading to several non-trivial effects like high sensitivity to parameter changes, unconventional behavior of resonances [1], unconventional time behavior [2], among others[3] . Though long studied in mathematical literature, EPs manifest physically in open quantum systems (OQS), they were first achieved experimentally in microwave cavities [4], but given the ubiquity of non-Hermitian systems, research on EPs spans a wide range of fields in physics such as optics [5], atomic and molecular physics [6], quantum phase transitions [7] and even nuclear physics[8].

The Gamow Shell Model (GSM) [9], as an extension of the traditional shell model into an OQS formulation, provides a natural framework to explore the effects of EPs in nuclear physics. Within this approach, we demonstrate that low-energy EPs emerge for realistic values of the single particle potentials in the 5/2- doublets present in 7Li and 7Be using the Coupled-Channels representation of GSM [10]. Given this, we studied the influence that the presence of EPs has on different reaction and structure quantities, including elastic scattering cross sections, phase shifts, quadrupole and dipole moments and electromagnetic transitions.

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18:40–19:00

Evidence of light multineutron bound systems formation in the 159Tb (p,x)157Dy nuclear reactions

Speaker

Prof. Ihor Kadenko (Taras Shevchenko National University of Kyiv)

Description

In the last few years, we continued to study light multineutron systems [1] in bound states that were predicted by Migdal [2]. Such possibility, for at least the dineutron, is based on the theoretical substantiation that in the outgoing channel as the product of the nuclear reaction a bound system of two identical nucleons exists beyond the volume of the heavy core of the other nucleons of the target nucleus but within the potential well of the core. This prediction has been confirmed in our previously published papers [3-5] by means of the observation of the induced activity of residual nuclei in neutron induced nuclear reactions for energies of impinging neutrons below the threshold of corresponding (n,2n) nuclear reactions. We have extended the scope of our research for other nuclear reaction conditions to make sure that the generation of bound dineutrons is valid not only for one nucleus and one nuclear reaction type.
Therefore, in our new experiment, a stack of Tb, Ti and Cu foils was irradiated by beam of Ep = 17 MeV ± 0.3% energy protons that is below the Eth = 17.14 MeV threshold of the 159Tb(p,3n)157Dy nuclear reaction. The Ti and Cu foils were used for monitoring the proton flux and the energy loss of the protons in the stack. Polyethylene foils were placed in between the metal foils to avoid cross contaminations. After irradiation the induced gamma-activities of the irradiated t = 33 µm thick Tb foils were counted on a Canberra HPGe coaxial detector. In the case of the Tb foil activated in the stack by protons of Ep = (16.23 ± 0.23) MeV energy, the gamma-peak of Eg = 326.3 keV energy was counted for tLIVE = 56,951 seconds live time and net peak area of Snet = (2,154 ± 274) counts was observed due to the decay of 157Dy. This observation can be explained by the presence in the outgoing channel of the 159Tb (p,x)157Dy nuclear reaction beside the 157Dy heavy nucleus either the dineutron in a bound state and one more neutron or a bound trineutron. The estimate for the nuclear reaction cross section of the 159Tb (p,n2+n)157Dy nuclear reaction was obtained as (0.31±0.04) µb. Two other Tb foils irradiated together in the stack with protons of Ep = (16.77 ± 0.23) MeV and Ep = (15.67 ± 0.24) MeV energies were counted on an Ortec Ge planar detector and no any signs of the Eg = 326.3 energy peak. This result actually proves one more prediction in [2] regarding the resonant behaviour of nuclear reactions with the formation of a bound dineutron. Moreover, in [6] under similar conditions but for Ep = (14.86 ± 0.85) MeV proton energy the Eg = 326.3 keV gamma-peak was also observed in the instrumental gamma-spectrum.
As the upper estimate of a bound dineutron is well established as Bdn = 3.01 MeV [7], we also irradiated two Tb foils with Ep = (13.87 ± 0.26 MeV) and Ep = (13.24 ± 0.25) MeV energy protons, correspondingly, followed by counting each foil separately. The measurement of the first foil, again, resulted in appearance of the Eg = 326.3 keV gamma-peak with small statistics while the second Tb foil showed no any signs of the Eg = 326.3 keV peak. This means that we observed a weak but expected sign of the existence of a bound trineutron with the corresponding cross-section estimate of the 159Tb (p,n3)157Dy nuclear reaction being equal (0.45 ± 0.23) µb for Ep = (13.87 ± 0.26) MeV proton energy and an interval binding energy estimate: 3.27 MeV < Btn < 9.26 MeV.
Thus, the trineutron and possible dineutron in bound states were evidenced in this study to be further confirmed.

The research carried out at HUN-REN ATOMKI was supported by the TKP2021-NKTA-42 project financed by the National Research, Development and Innovation Fund of the Ministry for Innovation and Technology, Hungary.
The MGC-20 cyclotron of HUN-REN ATOMKI is a Research Infrastructure of the Cluster of Low Energy Accelerators for Research (CLEAR) of the EURO-LABS project. IKadenko and N.Sakhno were supported by the Transnational Access of the CLEAR EURO-LABS project. The EURO-LABS project has received funding from the European Union's Horizon Europe Research and Innovation programme under Project TA Identifier: CLEAR_ATOMKI_005.

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19:00–19:20 Quadrupole and octupole collectivity in the isotope 106Pd via Coulomb excitation

Speaker

Naomi MArchini (Infn-Florence section)

Description

Shape coexistence is a widespread phenomenon in the nuclide chart. Firstly identified in light nuclei, it has now been observed in several mass regions. Around the shell closure Z=50, shape coexistence has been clearly established in several isotopic chains, particularly in the tin and cadmium isotopes. Intruder states have also been identified in the palladium isotopes. Nevertheless, the coexistence of different shapes has not been firmly established in these nuclei yet. Recent results from our group suggested a different shape of the first excited 0+ state with respect to that of the ground state in 106Pd from E0 measurements. Getting detailed information about the quadrupole shape of the states in this isotope is, therefore, extremely timely. A Coulomb-excitation experiment was performed at the INFN-LNL laboratory with the AGATA-SPIDER setup to investigate the quadrupole collectivity of 106Pd. In this contribution, I will present the first results of this experiment.

19:20

17:00 **Monday 22 September** 17:00–19:05

Nuclear Structure, Spectroscopy and Dynamics: 6

Session | **Location:** MoHo, Inspire 3, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr John Frankland (IN2P3)

17:00–17:25

Demystifying the Fusion Mechanism in Heavy-Ion Collisions Leading to the Formation of Superheavy Nuclei

Speaker

Michal Kowal (National Centre for Nuclear Research)

Description

We discuss the current understanding of the heavy-ion fusion mechanism through the lens of multidimensional stochastic dynamics. Recent developments, including a six-dimensional Langevin formalism with unconstrained motion in mass asymmetry, provide a realistic description of energy dissipation, shape evolution, and angular momentum effects. This approach captures the transition into the overdamped regime, where rapid neck formation and shape equilibration occur, offering excellent agreement with experimental fusion cross-sections and spin distributions. The method has been successfully applied to the formation of heavy and superheavy nuclei [Phys. Lett. B 862 (2025) 139302]. In parallel, a complementary framework based on a four-dimensional biased random walk in deformation space has been developed, where the fusion pathway is guided by the density of available states. By treating the dipole moment as an explicit shape degree of freedom and introducing an auxiliary reference frame located at the neck, this approach enables access to previously unattainable fusion configurations. The method accurately describes fusion probabilities for reactions involving medium-mass projectiles and a 208 Pb target, shedding light on the fusion hindrance mechanism and strengthening predictive models for superheavy element synthesis [Phys. Rev. C 109, L061603 (2024)].

17:25–17:45

Validation of the mechanism in reaching the island of stability

Speaker

Mr Kosuke Kawai (Kindai University)

Description

The existence of ^{298}Fl, the center of the island of stability, has been predicted [1]. To synthesize this nucleus, it is necessary to produce a more neutron-rich compound nucleus than ^{298}Fl, since the excited compound nucleus cools down by emitting neutrons.
According to this paper [2], the compound nucleus ^{304}Fl exhibits some interesting mechanisms. One of them is the effect of neutron emissions. Due to neutron emissions, the neutron number in this nucleus approaches the doubly closed shell, increasing the fission barrier height. This results in the survival probability of ^{304}Fl decreasing quite slowly even at high excitation energy. However, a combination of projectile and target nuclei that can synthesize this nucleus has not yet been found. Therefore, confirming this effect in experiments has been considered difficult.
Recently, experiments were conducted on ^{40}Ar + ^{238}U and ^{48}Ca + ^{232}Th reactions at JINR [3]. We realized that the compound nuclei of these reactions exhibit the same mechanism as ^{304}Fl in terms of the effect of neutron emissions. According to the mass table [4], the shell correction energy, which can be approximated as the fission barrier height, of $^{278, 280}$Ds increases due to neutron emissions. Therefore, we expect the survival probability of $^{278, 280}$Ds to decrease quite slowly even at high excitation energy. In fact, the experimental values of the evaporation residue cross sections do not show large differences between the peak excitation energy (about 40 MeV) and the high excitation energy (over 55 MeV) [3].
We calculate the whole fusion-fission process in the superheavy-mass region in three stages: the projectile-target contact process, the competition between fusion and quasi-fission, and the subsequent decay process. We estimated the evaporation residue cross sections by combining the probabilities of these three processes. We used the coupled-channel method [5, 6] for the first stage, the dynamical model with the multidimensional Langevin approach [6] for the second stage, and the statistical model [7] for the third stage.
In this presentation, we primarily discuss the effect of neutron emissions and the associated increase in the fission barrier height in known fusion reactions. This effect plays a crucial role in reaching the island of stability.

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17:45–18:05

Nuclear Structure Studies of Actinides Using High-Precision Penning-Trap Mass Spectrometry at TRIGA-Trap

Speaker

Tanvir Sayed (Max-Planck-Institut für Kernphysik MPIK)

Description

Penning traps are widely used in high-precision mass spectrometry to determine atomic masses with exceptional precision and accuracy, playing a crucial role in atomic and nuclear physics research [1]. TRIGA-Trap is a high-precision, double Penning-trap mass spectrometer located in the reactor hall of the TRIGA (Training, Research, Isotopes, General Atomic) research reactor in Mainz, Germany [2]. It also serves as one of the development platforms for the planned MATS (Measurements of very short-lived nuclides using an Advanced Trapping System) experiment at FAIR (Facility for Antiproton and Ion Research) which aims to investigate nuclei far from stability in order to enhance our knowledge on their fundamental nuclear properties [3, 4]. While the construction of FAIR is still underway, development platforms such as TRIGA-Trap conduct studies to optimise future experiments and test new emerging ideas.

At TRIGA-Trap, mass measurements of radioactive nuclides $-$ particularly actinides $-$ are performed with the PI-ICR (Phase-Imaging Ion-Cyclotron Resonance) technique [5]. This method offers high sensitivity, resolving power and accuracy, while requiring relatively short measurement times [2]. Recent mass measurements of actinides, including ^{244}Pu, ^{241}Am, ^{243}Am, ^{248}Cm, and ^{249}Cf have achieved uncertainties at the parts-per-billion (ppb) level [6]. These nuclides are in the vicinity of the neutron number $N=152$, a region associated with a deformed sub-shell closure. The precise mass measurements allow the exploration of nuclear structure through trends in mass filters, such as S_{2n} (two-neutron separation energies) and $\delta V_{p,n}$ (average p-n interaction of the most loosely-bound two nucleons), as well as their differentials [6]. Currently, mass measurements in the Pu isotopic chain $-$ including ^{238}Pu, ^{239}Pu, ^{240}Pu, and ^{242}Pu $-$ are in progress. This will enhance the current dataset and contribute to ongoing nuclear structure studies. In particular, the trend in shell evolution with increase in neutron number N towards the $N=152$ sub-shell closure for proton number $Z=94$ can be investigated, and the predictive capabilities of various nuclear shell models for heavy and deformed nuclei can be assessed.

This presentation will provide an overview of the current status of the experiment, including recent mass measurements, their application in nuclear structure evaluation, and an outlook on future directions.

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18:05–18:25

Synthesis of new elements using dynamic effects of nuclear structure in fusion fission processes

Speaker

Yoshihiro Aritomo (Kindai University)

Description

At present, the research into the synthesis of superheavy elements is being pursued under two main goals. One goal is to synthesize elements with larger atomic numbers, and the other is to reach Island of Stability predicted as the next double magic nucleus. The periodic table is currently marked up to element 118, Oganesson (Og) [1], and experiments are being conducted with the aim of synthesizing element 119 as the next new element. Recently, a successful synthesis experiment (54Cr + 238U ▭ 292-xLv) has been carried out using a Cr beam [2].

Here, we discuss the methods using secondary beams with neutron rich nuclei. In the method using a secondary beam, there are concerns about whether a measurable evaporation residual cross section can be obtained because the beam intensity is very small.
However, theoretical analysis suggests that a large evaporation residue cross section can be obtained from the mechanism of the fusion process by the neutron-rich beam and the mechanism of the decay process of the produced nuclei, and that the advantage is sufficient to compensate for the disadvantage of the beam intensity.
In this talk, we will explain and verify the mechanism and discuss the possibility of synthesizing new elements using the secondary beam.

The dynamical and statistical models are used to calculate the production of compound nuclei in the neutron-rich region, their decay processes and to evaluate the evaporation residue cross-sections. To produce neutron-rich compound nuclei, as well as future experimental plans, including the advantage of survival probabilities, are discussed [3]. The possibility of synthesizing new elemental syntheses, exploiting "the dynamic effects of the shell structure", will be discussed.
.
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18:25–18:45

Investigating the nuclear structure of the heaviest elements with the SHIPTRAP mass spectrometer at GSI

Speaker

Francesca Giacoppo (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Description

Investigating the boundaries of the nuclear chart and understanding the structure of the heaviest elements are at the forefront of nuclear physics. The existence of the superheavy nuclei is intimately linked to nuclear shell effects which counteract Coulomb repulsion and therefore hinder spontaneous fission. In the region of heavy deformed nuclei weak shell gaps arise around Z=100 and N=152 as well as around Z=108 and N=162. However, the extension of these gaps and their impact on the structure of these exotic nuclei, especially the most neutron-rich ones, is not yet fully understood, as most of the relevant nuclear systems are not experimentally (well) addressed due to limited production capabilities, i.e. available beam-target combinations and/or corresponding low yields. Moreover, heavy and superheavy nuclides feature often metastable excited states with half-lives that can exceed the one of the ground state. Long-lived isomeric states can have excitation energies of only few tens of keV or below, therefore, their identification is challenging, especially in decay-based measurements.

On the other hand, Penning-trap mass spectrometry allows the experimental determination of the binding energy and, when applied to isotopic chains crossing shell gaps, can provide information concerning the evolution of the shell gap strength without the detailed knowledge of the structure of the nuclei under study. Moreover, mass measurements with Penning traps feature sufficient resolving power to allow the separation of isomeric states when they are populated in the same reaction as the ground state. Their excitation energy can then be measured precisely.

In recent years, we have established tailored and highly sensitive experimental methods allowing us to extend the reach of Penning-trap mass spectrometry with the SHIPTRAP setup to heavy elements well beyond uranium. In this talk a review of the latest mass measurements of nuclides up to rutherfordium will be presented.

18:45–19:05

Analysis of kinetic energy dissipation for the production of neutron-rich nuclei in multi-nucleon transfer reaction

Speaker

Kohta Nakajima (Kindai Univ.)

Description

Synthesis of neutron-rich nuclei is important for the study of Islands of Stability and r-process. However, to produce the neutron-rich nuclei in heavy mass regions will be limited by conventional fusion reactions. Therefore, in recent years, multi-nucleon transfer (MNT) reactions have attracted attention as a method of producing neutron-rich nuclei [1]. However, the reaction mechanism is not yet well understood due to its novelty and complexity. In the future, it will be necessary to estimate the physical quantity of evaporation residue (ER) in the production of neutron-rich nuclei of heavy and superheavy nuclei. In this study, we construct a dynamical model that describes the dynamics of the MNT reaction and verify the model by comparing it with experimental data to clarify the reaction mechanism.

This study aims of deal with the production of neutron-rich nuclei in heavy and superheavy elemental regions. We have been studying the angular momentum of compound nuclei produced in the MNT reaction. The results show that the angular momentum brought into the compound nucleus is affected by the contact time between the projectile and the target. It is also known that the contact time varies with the collision angle between the projectile and target. In this study, we have also included the effect of kinetic energy dissipation that contributes to the reaction of neutron-rich nuclei after their production.

The theoretical model we use is based on the two-center shell model to describe the configuration of nuclei [2]. The time evolution of the configuration is described by the multidimensional Langevin equation [3]. In this presentation, the effect of using deformed target nucleus and the effect of collision angle with deformed target nucleus are discussed from the viewpoint of kinetic energy dissipation, based on the results of dynamical model calculations.

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19:05

19:30

21:30

Monday 22 September

19:30–21:30

Welcome Cocktail

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

Tuesday 23 September

09:00

Tuesday 23 September

09:00–10:30

Plenary Session: 3

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Yvonne Leifels (GSI Helmholtzzentrum für Schwerionenforschung)

Description

Plenary Session

09:00–09:30 **Low-Energy Microscopes of Europe: Revealing the Hidden Features of Atomic Nuclei**

Speaker

Navin Alahari (GANIL)

Description

Throughout science, researchers advance understanding by exploring the extremes of nature. In nuclear physics, this means investigating nuclei under controlled laboratory conditions, as well as studying those that exist only in vast cosmic environments — from stars to galaxies (~10^{25} m) — and connecting these observations to the microscopic realm (~10^{-15} m). Elucidating the behaviour of nuclei requires state-of-the-art accelerators delivering beams of varied lifetimes and energies, coupled with detectors capable of identifying signals as rare as needles in a haystack. Understanding reaction mechanisms and the underlying nuclear structure demands a broad study across many nuclei — much like needing a complete DNA sequence, rather than a single fragment, to fully grasp complex biological systems.
This talk will provide an overview of major European low-energy nuclear physics facilities — both operational and upcoming — highlighting their unique capabilities and complementarities in addressing key questions. These facilities are central to the Horizon Europe EURO-LABS project, which is building, for the first time in Europe, a unified subatomic research community by promoting the sharing of knowledge, technologies, and infrastructure across the fields of subatomic physics. Beyond their scientific contributions, these facilities play a crucial role in training the next generation of researchers and enabling innovations in nuclear applications. However, their central mission remains the advancement of our understanding of the many facets of this complex many-body quantum system — identifying the key variables that govern nuclear dynamics and uncovering the emergence of simplicity within complexity.

09:30–10:00 **On the horizon: the 229mTh nuclear clock**

Speaker

Peter Thirolf (Ludwig-Maximilians-University Munich)

Description

The quest for an optical nuclear frequency standard, the 'nuclear clock' based on the elusive and uniquely low-energetic 'thorium isomer' ^{229m}Th, has increasingly triggered experimental and theoretical research activities in numerous groups worldwide in the last decade. Today's most precise timekeeping is based on optical atomic clocks. However, those could potentially be outperformed by a nuclear clock, based on a nuclear transition instead of an atomic shell transition. Only one nuclear state is known so far that could drive a nuclear clock: the 'Thorium Isomer ^{229m}Th', i.e. the isomeric first excited state of ^{229}Th, representing the lowest nuclear excitation so far reported. Such a nuclear clock promises intriguing applications in applied as well as fundamental physics, ranging from geodesy and seismology to the investigation of possible time variations of fundamental constants and the search for Dark Matter [1].
After years of nuclear-spectroscopy driven identification and characterization activities of ^{229m}Th, the year 2024 witnessed seminal breakthroughs with first laser-driven excitations of the isomeric nuclear resonance in ^{229}Th, both using intense broad-band [2,3] and VUV frequency-comb based narrow-band lasers [4], respectively. Hardly any physical observable experienced an improvement by 11 orders of magnitude within only 5 years, as it was reached for the excitation energy of the thorium isomer. Hence, the question is no longer 'Will there be a nuclear clock?', but rather 'Which types of nuclear clocks with which properties will be realized in the coming years?', driven by the requirements of a variety of fundamental and applied physics applications. While recent progress with optical excitation of ^{229m}Th was achieved via the solid-state approach using doped large-bandgap crystals and thin films [5], the complementary approach using individual laser-cooled trapped ions in vacuum is still under study.
The talk will review the status and perspectives of ongoing activities towards realizing a nuclear frequency standard based on the thorium isomer both in the solid-state and trapped ^{229m}Th^{3+} ion approach.

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10:00–10:30 **Hadron spectroscopy with the GlueX experiment**

Speaker

Farah Afzal

Description

The detailed understanding of how quantum chromodynamics (QCD) gives rise to the spectrum of hadrons is currently one of the biggest open questions in hadron physics. Most of the observed states are classified as quark-antiquark mesons or three-quark baryons. However, QCD allows for a much richer spectrum with more complex configurations. Experimental evidence exists for such non-conventional hadrons like hybrid mesons, in which an excited gluonic field is coupled to a quark-antiquark pair and contributes directly to the meson properties.
Worldwide, different experimental facilities have dedicated and complementary hadron spectroscopy programs. The GlueX experiment, which is located in Hall D at Jefferson Lab, USA, uses a linearly polarized photon beam with energies of up to 12 GeV incident on a liquid hydrogen target and consists of a high-acceptance spectrometer with excellent charged as well as neutral particle detection capabilities. This allows us to study the production mechanisms and decays of a wide range of hadronic resonances.
This talk gives an overview of experimental light hadron spectroscopy with an emphasis on results from the GlueX experiment.

10:30

10:30

11:00

Tuesday 23 September

10:30–11:00

Coffee Break

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

11:00 **Tuesday 23 September** 11:00–13:00

Plenary Session: 4

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:**
Daniel Bemmerer (Helmholtz-Zentrum Dresden-Rossendorf (HZDR))

Description

Plenary Session

11:00–11:30 Direct and Indirect Measurements in Nuclear Astrophysics

Speaker

Aurora Tumino (UKE)

Description

Nuclear astrophysics aims to understand the origin of elements and the energy generation within stars by studying nuclear reactions. Direct experiments attempt to replicate these reactions in laboratory settings, measuring cross-sections at stellar energies. However, these energies are often extremely low, leading to significant experimental challenges. Indirect methods, such as transfer reactions provide alternative routes to extract reaction rates, circumventing the limitations of direct measurements. I will highlight the complementary roles of direct and indirect experiments in advancing our understanding of astrophysical nuclear processes, using the 12C+12C fusion reaction as a key case study. The analysis of this reaction exemplifies the challenges and benefits of both approaches, emphasizing the importance of their combined application for accurate reaction rate determinations crucial for stellar evolution models.

11:30–12:00 Fission: review of recent major advances and selected results

Speaker

christelle schmitt (IPHC Strasbourg)

Description

Nuclear fission owes its name by the fact that, at the macroscopic level, it resembles the division of a living cell, with the nucleus slowly deforming until it breaks into two pieces. This a priori harmless split hides a complex re-arrangement of a many-body quantum system. The excited fragments emerging at scission quickly return to equilibrium by emitting neutrons and gamma-rays. As such, fission is a rich laboratory for studying both fundamental nuclear properties and reaction dynamics. It has a crucial impact in astrophysics and for various societal applications. However, due to its complexity, its understanding still constitutes a challenge for theory.
At the same time, fission is certainly the mechanism with the largest amount of quantities that are observable in the laboratory. These include cross sections, fragment mass, charge, energy and angular distributions, isomeric ratios, as well as neutron and gamma-ray multiplicities, energy and angular distributions. High-fold coincidence measurements between these quantities are the pre-requisite for unambiguously constraining models.
Since a few years, an increasingly huge effort is being invested in Europe to improve the understanding on fission, both on the experimental and theoretical fronts, with an arsenal of approaches, probes and observables. The complete and high-resolution characterization of the fission fragments, and of their de-excitation by neutron and gamma-ray emission is exploited to address longstanding questions pertaining to fission, like the influence of shell effects and pairing correlations, the generation of excitation energy and angular momentum, and their sharing between the fragments at scission, to cite a few. The study of these aspects over the region of the nuclear chart from rare earths to heavy actinides in a comprehensive manner is now within reach. Recent experimental data, combined with innovative theoretical developments, permit to establish a firm step into the direction of a universal understanding of fission. A selection of results from various facilities will be discussed, and some exciting perspectives will be given.

12:00–12:30 Neutrinoless Double Beta Decay: Where We Stand and What Lies Ahead

Speaker

Dr Claudia Nones (CEA/IRFU/DPhP)

Description

Neutrinoless double beta decay ($0\nu\beta\beta$) is a key process in understanding the fundamental nature of neutrinos and their role in the evolution of the Universe. Following the discovery of neutrino flavor oscillations, which demonstrated that neutrinos have mass, the search for $0\nu\beta\beta$ has become one of the most compelling challenges in contemporary particle physics. This talk will begin with an overview of the deep connections between neutrino properties and the mechanism of neutrinoless double beta decay, emphasizing its implications for lepton number violation and the Majorana nature of neutrinos.
The presentation will then survey the most sensitive experimental strategies employed to detect this rare nuclear process, highlighting current efforts across various technologies. A comparative overview of running experiments will be provided, focusing on detector concepts, background suppression techniques, and scalability toward next-generation experiments. The current status of experimental limits on the effective Majorana neutrino mass will be discussed, along with the potential of upcoming projects to cover the inverted mass hierarchy region and a large fraction of the normal one. The talk will conclude with a perspective on future directions and the roadmap toward a definitive discovery.

12:30–13:00 Origin of ultrahigh-energy cosmic rays in Binary Neutron Star Collisions and the crucial roles of Nuclear Physics

Speaker

Glennys Farrar (New York University)

Description

The presentation will begin with a concise overview of the key observational evidence constraining the properties of UHECRs, and why the evidence points to binary neutron star (BNS) mergers as their source. The main topic of the talk is predicting the spectrum and composition of UHECRs in the BNS merger scenario. It is possible to do this in unprecedented specificity thanks to the well-constrained initial conditions after the merger. I will argue that the UHECRs with highest energies are produced in the magnetized outflow away from the jets, contrary to pre-conceived assumptions. I calculate the spectra (including the peak energy) of different A,Z nuclei; the predictions are in good agreement with data. The possible existence of a secondary, higher energy component of protons and/or helium accelerated in the jets is noted and their spectra are predicted.
Nuclear physics plays a critical role in three key aspects of UHECR production:
1) The neutron star equation of state governs the longevity of the transient hyper-massive neutron star, whose lifetime determines the total energy of UHECRs produced.
2) Nucleosynthesis in the expanding ejecta determines the initial distribution of atomic masses. Outside the jets, these are primarily r-process nuclei. After about a day of continued expansion, the conditions for accelerating the highest energy UHECRs are reached.
3) The first stage of acceleration, beginning after 1-10 seconds of expansion, produces a seed population of nuclei with energies above 100 MeV. Its distribution of {Z,A} reflects the r-process abundances and the dependence of initial energization on {Z,A} — however this does not fix the relative amounts of different nuclei in observed UHECRs. Instead, there is a period in which these seed CR nuclei collide with the bulk, unaccelerated nuclear outflow, breaking up into a broad spectrum of lighter CRs. This is then the population which is accelerated to be the UHECRs. So, the nuclear physics of breakup of heavy ions will be critical to predicting the ultimate mix of nuclear masses in UHECRs.

Muiltimessenger consequences and probes of this scenario will also be discussed.

13:00

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Tuesday 23 September

13:00–14:00

Lunch

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

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Tuesday 23 September

14:00–16:30

Accelerators and Instrumentation: 3

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Adam Maj (IFJ PAN)

14:00–14:25

PARIS gamma calorimeter: idea, status and perspectives

Speaker

Michał Ciemała (IFJ PAN Kraków, Polska)

Description

PARIS is an advanced gamma calorimeter designed for high-resolution nuclear spectroscopy, particularly in the study of exotic nuclear properties. The detector system is based on a phoswitch architecture combining high-efficiency scintillators such as LaBr_3(Ce)/CeBr_3 and NaI(Tl), offering good energy and excelent time resolution. The primary goal of PARIS is to enhance the detection capabilities in experiments involving high-energy gamma rays and nuclear structure investigations.

This presentation will outline the fundamental concept behind the PARIS calorimeter, its current development status, and future perspectives. We will discuss the detector design, recent experimental results, and planned upgrades aimed at improving its performance. Additionally, the role of PARIS within large-scale research facilities and collaborations will be highlighted, emphasizing its impact on contemporary nuclear physics.

14:25–14:50

Gamma-Neutron discrimination

Speaker

Franco Ersilio Camera (University of Milano, department of Physics, via Celoria 16 Milano, 20133 Italia and I.N.F.N. Milano section)

Description

The problem to discriminate between gamma-rays and neutrons is a long standing one and it was faced in the past using Time of Flight or PSD techniques as the charge difference technique.

The CLYC (Cs2LiYCl6:Ce) scintillator can easily discriminate between gamma-rays and neutrons induced events but, unfortunately, it has a too low density (only 3.3 g/cm3) and the decay time constant of the scintillation light is too long (the longest is approximately 1000 ns).

Such a long lifetime for the scintillation light makes the crystal unable to sustain high count rates and, in addition, its low density reduces the total full energy peak efficiency making the CLYC crystal not optimal when high efficiency and high counts rates are essential.

The detection and the identification of fast neutrons is performed in CLYC using the nuclear interactions of a neutron with 35Cl (a stable isotope of Cl).
Therefore, a good starting point could be the scintillators which contain 35Cl namely, LaCl3 and CLLBC.

The basic idea is to perform some kind of PSD algorithm or to use (as was already performed in some papers) the FFT and then some kind of PSA on the FFT transformed detector signal to identify neutron events from gamma-ray induced one.

In this presentation, I'll present the status of the research we are performing in Milano on this topic.

14:50–15:10

PISTA, a new detection system for transfer-induced fission in inverse kinematics at VAMOS

Speaker

Lucas Bégué--Guillou (Ganil)

Description

More than 80 years after its discovery, a complete description of the fission process remains a challenge. It is a many-body dynamic problem involving both microscopic and macroscopic aspects of nuclear matter. To further understand the fission process, new experimental data on exotic fissioning systems that cannot be probed using direct neutron-induced fission are needed. Moreover, technological breakthroughs such as the development of Gen-IV reactors and various fundamental aspirations motivate the scientific community to better understand this mechanism.

At GANIL, fission studies using the VAMOS++ large acceptance spectrometer combined with 238U beams at energies around the Coulomb barrier allow to populate exotic fissioning systems. Also, fission induced by transfer or fusion reaction in inverse kinematics allows obtaining isotopic identification (in mass and charge) of fission fragments. Furthermore, the detection and identification of the target-like residue provide the characterization of the fissioning systems in terms of mass, atomic number and excitation energy. Such a combination has been shown to be a powerful tool to extract post-evaporation isotopic yields and neutron content (N/Z) that hold the signature of the shell effects at play in the process [1] as well as the fission barrier [2].

Recently, an upgrade of the target-like residue detection systems has been initiated. For this, the new PISTA (Particle Identification Silicon Telescope Array) detector has been developed. PISTA is an array of eight trapezoidal silicon telescope detectors assembled as in a corolla. Each telescope is composed of two single sided silicon detectors, 100 µm and 1000 µm thick, placed 10 cm from the target. The array covers angles between 30° and 60°. Target-like nuclei are identified using (ΔE, E) technique up to Oxygen isotopes, resulting in the characterisation of the fissioning system. The high angular granularity of the detector allows the reconstruction of the reaction kinematics, thus allowing the reconstruction of the Excitation energy of the fissioning system using two-body kinematics. Thanks to this detection system coupled to VAMOS++, isotopic fission yields with high statistics per energy bin of about 1 MeV in excitation energy from 6 up to 20 MeV are expected.

In this presentation, the results of the first experiment using PISTA will be discussed. This experiment used a 238U beam at 6 A MeV impinging on a 100 µg/cm2 thick 12C target. The characteristics and the performances of the PISTA detection system will be presented.

[1] D. Ramos et al. Phys. Rev. C 101, 034609 (2020)

[2] C. Rodríguez-Tajes et al. Phys. Rev. C 89, 024614 (2014)

[3] Rejmund, M., et al. NIM Section A 646 (2011): 184-191.

15:10–15:30 **Characterization of liquid scintillator detectors for fast neutron detection up to 40 MeV**

Speaker

Dr Alberto Pérez de Rada Fiol (CIEMAT)

Description

Fast neutron detection plays a critical role in nuclear science studies and in a range of nuclear technology applications, from hadron therapy in medicine to neutron monitoring in fusion and spallation technologies. Organic liquid scintillator detectors, such as those based on NE213, are widely used for neutron spectroscopy due to their excellent timing resolution and capability to discriminate neutrons from gamma rays via pulse shape analysis.

In this work, we present a comprehensive characterization of the light output response of two detector systems developed at CIEMAT — MONSTER [1,2] and sTED [3] — covering incident neutron energies from a few MeV up to 40 MeV. Measurements were performed at the NFS facility at GANIL [4] using a quasi-continuous neutron spectrum produced by a 40 MeV deuteron beam impinging on a beryllium target. The detectors were positioned at 30 meters from the source to enable neutron energy determination via the time-of-flight technique, with energy slices selected to extract pulse height distributions across the full energy range.

Special emphasis was placed on the contribution of secondary particles produced via $^{12}C(n,\alpha)$ and $^{12}C(n,n'3\alpha)$ reactions [5,6,7], as well as breakup reactions such as $^{12}C(n,p)$ and $^{12}C(n,d)$ above 20 MeV. Detailed comparisons with Geant4 [8] and PHITS [9] simulations incorporating recent reaction models and evaluated nuclear data were performed to extract the neutron light output functions.

The results provide key input for improving the accuracy of detector response modeling and will enhance the predictive power of simulation tools used in experimental design and data analysis in nuclear physics and technology applications [10,11].

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1. A.R. García *et al.*, *MONSTER: A time of flight spectrometer for β-delayed neutron emission measurements*, JINST **7**, C05012 (2012). doi: 10.1088/1748-0221/7/05/C05012
2. T. Martínez *et al.*, *MONSTER: A TOF Spectrometer for β-delayed neutron spectroscopy*, Nucl. Data Sheets **120**, 78 (2014). doi: 10.1016/j.nds.2014.07.011
3. V. Alcayne *et al.*, *A Segmented Total Energy Detector (sTED) optimized for (n,γ) cross-section measurements at n_TOF EAR2*, Rad. Phys. Chem. **217**, 111525 (2024). doi: 10.1016/j.radphyschem.2024.111525
4. X. Ledoux *et al.*, *First beams at neutrons for science*, Eur. Phys. J. A **57**, 257 (2021). doi: 10.1140/epja/s10050-021-00565-x
5. G. Dietze and H. Klein, *NRESP4 and NEFF4 – Monte Carlo codes for the calculation of neutron response functions and detection efficiencies for NE213 scintillation detectors*, PTB-ND-22, Braunschweig, Germany (1982).
6. E. Mendoza *et al.*, *A new physics model for the charged particle transport with Geant4*, IEEE NSS Conf. Record (2011), 2242. doi: 10.1109/NSSMIC.2011.6154457
7. A.R. García *et al.*, *New physics model in GEANT4 for the simulation of neutron interactions with organic scintillation detectors*, Nucl. Instrum. Methods A **868**, 73 (2017). doi: 10.1016/j.nima.2017.06.021
8. S. Agostinelli *et al.*, *Geant4—a simulation toolkit*, Nucl. Instrum. Methods A **506**, 250 (2003). doi: 10.1016/S0168-9002(03)01368-8
9. T. Sato *et al.*, *Recent improvements of the particle and heavy ion transport code system – PHITS version 3.33*, J. Nucl. Sci. Technol. **61(1)**, 127 (2023). doi: 10.1080/00223131.2023.2275736
10. A. Pérez de Rada Fiol *et al.*, *Analysis of neutron time-of-flight spectra with a Bayesian unfolding methodology*, Rad. Phys. Chem. **226**, 112243 (2025). doi: 10.1016/j.radphyschem.2024.112243
11. A. Pérez de Rada Fiol *et al.*, *β-delayed neutron spectroscopy of ^{85,86}As with MONSTER at IGISOL*, Phys. Rev. C **111**, 044312 (2025). doi: 10.1103/PhysRevC.111.044312

15:30–15:50 Low-energy neutron cross-talk between organic scintillator detectors

Speaker
Franck DELAUNAY (LPC Caen)

Description

Due to high Q-values and low neutron separation energies, β-decay of neutron-rich nuclei can often populate neutron unbound states in the daughter nuclei, and close to the dripline, β-delayed multi-neutron emission becomes possible. Decay schemes are commonly studied via neutron time-of-flight (TOF) spectroscopy using modular arrays based on organic scintillators.
In principle, the use of multi-detector arrays facilitates the detection of events with two or more neutrons. However, of critical importance in such measurements are the effects of cross-talk, whereby a single neutron incident on one detector is detected and scattered to another detector where it is also detected, thus mimicking the detection of two neutrons.
Cross-talk has been reasonably well characterised at intermediate (~10-70 MeV) and high (~100-300 MeV) neutron energies. As evidenced by reaction studies at these energies, a clear and reliable understanding of cross-talk is crucial for planning measurements, for the analysis and for the interpretation of the results. At energies below ~10 MeV, however, there is a lack of data available to enable low-energy cross-talk to be properly characterised and reliably simulated.
In this talk, we present a series of measurements performed with low-energy monoenergetic neutrons to characterise cross-talk between two organic scintillator detectors. Cross-talk time-of-flight spectra and probabilities are determined for neutron energies from 1.4 to 15.5 MeV and effective scattering angles ranging from ~50° to ~100°, and compared to Monte-Carlo simulations incorporating both the active and inactive materials making up the detectors. In the light of the results and simulations, the neutron interaction processes producing cross-talk at the energies explored here are discussed.

15:50–16:10 The neutron Time-Of-Flight facility, n_TOF at CERN: Status and perspectives

Speaker
Alice Manna

Description

n_TOF, at CERN, is the neutron time-of-flight facility dedicated to the study of neutron-induced reactions for fundamental and applied nuclear research. With high-precision neutron cross-section data, n_TOF plays a crucial role in addressing key questions in nuclear astrophysics and for innovation in advanced nuclear technologies. In nuclear astrophysics, experiments performed at n_TOF provide essential insights on the nucleosynthesis processes, such as the s-process responsible for formation of the chemical elements in stars. In nuclear technology, n_TOF contributes to the study of isotopes relevant for reactor design, nuclear waste transmutation, and radiation shielding. Furthermore, the facility investigates aspects linked to medical and space applications, including neutron therapy and radiation effects on electronics.

Established in 2001, n_TOF utilizes a high-intensity, pulsed neutron beam produced by spallation reactions, where 20 GeV/c protons from the CERN Proton Synchrotron (PS) impact on a lead target. The resulting neutron flux spans a wide energy spectrum, from thermal to GeV energies, enabling measurements with high accuracy and resolution over an extensive range.

The facility comprehends two areas suitable for time of flight measurements. EAR1, with a 185-meter flight path, is optimized for high-resolution time-of-flight measurements. EAR2, with the 20-meter beamline, is designed for high-flux applications, fundamental for low mass and short-lived radioactive samples or low cross section reactions. These complementary stations allow for different experimental conditions optimized for specific measurements, such as neutron capture, neutron-induced fission, elastic, inelastic and charged-particle emission reactions. NEAR is the novel experimental area, placed at about 3 meters from the spallation target, designed for spectral-averaged cross section measurements via activation, when a time-of-flight measurement is not possible.

Recent developments at n_TOF include upgrades of the spallation target to enhance neutron production efficiency, improvements in experimental techniques, and expanded research programs addressing emerging scientific challenges.
In this contribution, an overview of the status of the facility, the ongoing experimental activities and the planning of future projects will be presented.

16:10–16:30 **The deep underground "Bellotti Ion Beam Facility" at the Gran Sasso National Laboratories**

Speaker

Matthias Bernhard Junker (INFN - Laboratori Nazionali del Gran Sasso)

Description

The Bellotti Ion Beam Facility (IBF) [1] is located in the deep underground site of Laboratori del Gran Sasso (LNGS), Italy. The facility is named in honor of Enrico Bellotti, the first director of the Laboratori Nazionali del Gran Sasso (LNGS), Italy, who initiated the first installation of an underground accelerator for the study of nuclear reactions of astrophysical interest, following a proposal by C. Rolfs and G. Fiorentini. The facility offers unique opportunities for experiments with intense proton, alpha, and carbon beams in an environment where the cosmic muon flux is reduced by six orders of magnitude compared to the Earth's surface. The primary instrument at the facility is a 3.5 MV Singletron accelerator supplied by High Voltage Engineering Europa in specifications developed at LNGS [2]. The Italian Ministry of Education, University and Research funded the machine on a proposal originated by the LUNA Collaboration.
Since its inauguration in October 2023, Bellotti IBF is being operated as a scientific user facility, available to external users, with the technical management assigned to the Accelerator Service of LNGS. During the first years of operation, the Bellotti IBF has provided ion beams for nuclear astrophysics experiments, whilst concomitant measurements were undertaken for the purpose of precise ion beam energy calibration.
This presentation will provide a comprehensive overview of the characteristics and the perspectives at Bellotti IBF.

[1] The deep underground Bellotti Ion Beam Facility—status and perspectives, M. Junker, G. Imbriani, A. Best, A. Boeltzig, A. Compagnucci, A. Di Leva, F. Ferraro, D. Rapagnani, V. Rigato (2023), The deep underground Bellotti Ion Beam Facility—status and perspectives. Front. Phys. 11:1291113. DOI: 10.3389/fphy.2023.1291113

[2] A High Intensity, High Stability 3.5 MV Singletron™ accelerator, A. Sen , G. Domínguez-Cañizares, N.C. Podaru, .J.W. Mous, M. Junker , G. Imbriani, V. Rigato; Nuclear Instruments and Methods in Physics Research Section B 2019; DOI: 10.1016/j.nimb.2018.09.016

16:30

14:00 **Tuesday 23 September** 14:00–16:35

Few-Body Systems: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Eduardo Garrido (Instituto de Estructura de la Materia, CSIC)

14:00–14:25 Predicting reaction observables at intermediate energies: selected recent developments

Speaker
Hebborn Chloë (IJClab and FRIB)

Description

Nuclear reactions are powerful to probe properties of exotic nuclei located away from stability. The accuracy of the information inferred from reaction measurements rely directly on the quality of the theoretical model used to analyze the experimental data. Reactions at intermediate energies are typically described within few-body models, which sees the reaction as composed of cluster of nucleons, and the few-body dynamics is described within the eikonal method. To make accurate reaction predictions, it is crucial to quantify the uncertainties associated with the few-body method and the inputted effective interaction between the clusters. In this talk, I will discuss recent efforts to constrain these effective interactions and quantify their uncertainties, I will present a systematic study of the validity of the eikonal method, and I will mention recent developments towards describing complex reaction observables involving two-neutron halo nuclei.

14:25–14:50 Ab initio framework for nuclear fusion reactions

Speaker
Guillaume Hupin (CNRS - IJClab)

Description

To advance our understanding of the universe, from physics beyond the Standard Model to cosmic events, a unified approach to nuclear structure and reactions is essential. This requires combining few-body techniques with ab initio many-body calculations of nuclear structure, supported by Effective Field Theory and Uncertainty Quantification. Reaction rates derived from first principles are vital for understanding the synthesis of light elements and terrestrial energy generation, which can power civilization for generations[1].
In this talk, I will outline recent successes in few-body systems aligned with these goals[2, 3]. I will then focus on the No-Core Shell Model with Continuum (NCSMC)[4] and its extensions, tailored to address challenges in heavier systems.
The main challenge is developing precise methods that scale with the number of nucleons A, while accounting for all relevant reaction channels. In a broader physics scope, this includes exotic many-neutron decay channels or processes involving exotic particles subject to the strong force.

[1] Ciullo, G., Engels, R., Büscher, M. & Vasilyev, A. (eds.) Nuclear Fusion with Polarized Fuel, vol. 187, Springer International Publishing (2016).
[2] Deltuva, A. & Fonseca, A. C. Physical Review C 95, 024003 (2017).
[3] Viviani, M., Girlanda, L., Kievsky, A., Logoteta, D. & Marcucci, L. Physical Review Letters 130, 122501 (2023).
[4] Navrátil, P., Quaglioni, S., Hupin, G., Romero-Redondo, C. & Calci, A. Physica Scripta 91, 053002 (2016).

14:50–15:15 Hadronic resonances from lattice QCD

Speaker
Fernando Romero-Lopez (Uni Bern)

Description

Most of the known hadrons in the low-energy QCD spectrum are resonances observed in multiparticle scattering processes. First-principles determination of the properties of these unstable hadrons is a major goal of lattice QCD calculations. Significant progress has been made in the development, implementation and application of theoretical tools that relate finite-volume lattice QCD quantities to scattering amplitudes, allowing the masses and widths of different hadronic resonances to be determined. In this talk I will discuss recent advances in lattice QCD studies of meson-meson, meson-baryon and three-hadron resonances. Examples are σ, $\Lambda(1405)$ and T_{cc}^+.

15:15–15:35 Two-neutron decays within the hyperspherical framework: Application to ^{13}Li, ^{16}Be and ^{21}B

Speaker
JESUS CASAL (Universidad de Sevilla)

Description

Neutron-neutron correlations, specifically in light exotic systems such as two-neutron halo nuclei, is a topic that has attracted a revived interest [1,2]. These correlations are known to play a key role in binding the Borromean system [3,4], thus shaping their properties and dynamics in nuclear collisions. The particular features of these nn correlations extend beyond the driplines and may give rise to two-neutron emitters, such as 26O [5], which exhibit an unbound ground-state resonance. Their main characteristic is being bound with respect to 1n emission but unbound with respect to 2n emission. Therefore, the decay is expected to proceed as a direct two-neutron emission, rather than the sequential decay that may be available for their excited states. The structure properties and decay dynamics of these systems can be studied within the three-body hyperspherical model [6,7], focusing on the relative-energy (or momentum) distributions, which can be then confronted to experimental data.

In Ref. [8] we proposed a method to characterize few-body resonances from the time evolution of the lowest eigenstates of a resonance operator in a discrete basis, with the aim of studying the population of these systems in knockout reactions. The relative-energy distributions in their decay can be computed by solving an inhomogeneus equation with a source term involving the resonance eigenstate [9,10]. In the computed distributions, the mixing of different hypermomenta is found to be crucial for their shape, reflecting different possible asymptotics. The method has been applied to ^{16}Be [11] and ^{13}Li [12], showing signatures of direct two-neutron decay, and in reasonable agreement with recent experimental observations. Calculations for ^{21}B are ongoing.

[1] Kubota et al., Phys. Rev. Lett. 125, 252501 (2020).
[2] Corsi et al., Phys. Lett. B 840, 137875 (2023).
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[4] K. Hagino, H. Sagawa, J. Carbonell and P. Schuck, Phys. Rev. Lett. 99, 022506 (2007).
[5] Z. Kohley, et al., Phys. Rev. Lett. 110, 152501 (2013).
[6] M. V. Zhukov, et al., Phys. Rep. 231, 151 (1993).
[7] A. E. Lovell, F. M. Nunes and I. J. Thompson, Phys. Rev. C 95, 034605 (2017).
[8] J. Casal and J. Gómez-Camacho, Phys. Rev. C 99, 014604 (2019).
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[10] J. Casal and J. Gómez-Camacho, in preparation.
[11] Monteagudo et al., Phys. Rev. Lett. 132, 082501 (2024).
[12] P. André et al., Phys. Lett. B 857, 138977 (2024).

15:35–15:55 **Differential Cross Section for Proton Induced Deuteron Breakup at 108 MeV**

Speaker
Angelina Łobejko

Description

Studies of few-nucleon systems form the basis for understanding nuclear interactions and properties of nuclei. The very accurate theoretical calculations for three-nucleon systems should be confronted with a rich set of precise experimental data. For this purpose, the BINA (Big Instrument for Nuclear-polarization Analysis) detection system has been installed at CCB (Cyclotron Center Bronowice) [1]. The BINA setup is designed to study the elastic and breakup reactions at intermediate energies. It consists of the liquid target facility and the low threshold detector covering nearly 4π solid angle, enabling studies of almost full phase space of these reactions [2,3].
The part of the results of the first experimental run of proton-induced deuteron breakup at a beam energy of 108 MeV have been already published [4, 5]. These data will be supplemented with cross section for breakup reaction in configurations near FSI (Final State Interaction) of pp pairs. The data are normalized to the known cross section for proton-deuteron elastic scattering [6]. Differential cross section determined for a set of over 200 kinematic configurations of proton pairs registered in the forward part of BINA will be compared to state-of-the-art theoretical calculations to study the role of the Three Nucleon Force, Coulomb, and relativistic effects.
Moreover, the research was extended by introducing a new detector, which enabled the determination of pn pairs from the breakup reaction and their direct comparison with the previously determined pp pairs for selected FSI configurations. The data are important for testing the state-of-the-art calculations and the potentials developed within Chiral Effective Field Theory.

[1] A. Łobejko et al., Acta Phys. Pol. B. 50, 3, p.361-366 (2019).
[2] St. Kistryn, E. Stephan, J. Phys. G: Nucl. Part. Phys. 40, 063101 (2013).
[3] A. Ramazani-Moghaddam-Arani, et al., Phys. Rev. C 78, 014006 (2008).
[4] A. Łobejko et al., Few-Body Syst. 65, 2, p.1-7 (2024).
[5] A. Łobejko, E. Stephan et al., arXiv:2407.01582v2 (accepted in PRC) (2025).
[6] K.Ermisch, et al., Phys.Rev.C 68, 051001 (2005).

15:55–16:15 **Experimental studies of the deuteron-proton breakup reaction.**

Speaker
Elżbieta Stephan (Institute of Physics, University of Silesia, Poland)

Description

Scattering in three-nucleon systems at intermediate energies atracts attention due to sensitivity of the observables to subtle effects of the dynamics beyond the pairwise nucleon-nucleon force, so-called three nucleon force (3NF). Recently, the data for nucleon-deuteron collisions have also been considered as a tool for fine-tuning of the 3N Hamiltonian parameters in Chiral EFT. Deuteron breakup in collision with proton is characterised with a 3-body final state, meaning the continuum of kinematic configurations. This creates the conditions for studying contributions to the reaction dynamics (3NF, Coulomb interaction, relativistic effects) in the areas of their greatest visibility, or fit the ChEFT parameters to the large and diverse database. A series of experiments studied the dp breakup with the use of large acceptance detectors: SALAD and BINA at KVI Groningen and CCB PAS Krakow, GeWall and WASA at FZ-Juelich. Differential cross section and, in some cases, vector and tensor analyzing powers were measured over a significant part of the reaction phase space. The results of such experiments conducted over a wide range of beam energies, between 50 and 200 MeV/nucleon, will be discussed.

Polarization observables reveal strong sensitivity to details of the nuclear potential. The breakup reaction provides an opportunity to study many polarization observables beyond the analyzing powers, but the existing database is very limited in this regard. The new project to measure proton polarization induced in the breakup reaction at proton beam energy of 160 MeV has been proposed at CCB PAS Krakow. For this purpose, a polarimeter was designed that, in conjunction with the existing BINA detector, would be used to detect protons from the breakup reaction and determine the induced polarization for a set of kinematic configurations. The current status of the project will be presented.

16:15–16:35

Perturbative Computations of Few-Body Observables in Chiral Effective Field Theory using a Modified Weinberg Power Counting up to N3LO

Speaker

Oliver Thim (Chalmers University of Technology)

Description

Chiral effective field theory (χEFT) promises a systematic approach to describe the force between nucleons as arising from the fundamental principles of quantum chromodynamics. A power counting (PC) quantifies the relative importance of different contributions in the χEFT expansion. The PC ensures that the EFT predictions of observables show order-by-order convergence, which in turn enables robust estimates of the theoretical uncertainty. We investigate a PC where sub-leading interactions are treated perturbatively [1]. We fit unknown low-energy constants in the two-nucleon system and find a good description of both neutron-proton scattering cross sections and S-wave low-energy theorems [2,3]. We have taken the first steps in using this PC for $A>2$ systems beyond first-order perturbation theory. For $^3\mathrm{H}$, we demonstrate reliable computations of the ground-state energy using third-order perturbation theory in the no-core shell model [4].

[1] B. Long, C.J. Yang, Phys. Rev. C 86, 024001 (2012)
[2] O. Thim, A. Ekström, C. Forssén, Phys. Rev. C 109, 064001 (2024)
[3] O. Thim, Few-Body Syst. 65, 69 (2024)
[4] O. Thim, A. Ekström, C. Forssén, in preparation (2025)

16:35

14:00 **Tuesday 23 September** 14:00–16:35

Heavy Ion Collisions and QCD Phases: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:00–14:25 Heavy-flavour measurements in ultra-relativistic heavy-ion collisions

Speaker

Jing Wang (CERN)

Description

Quantum Chromodynamics (QCD) predicts the existence of a deconfined state of quarks and gluons, known as the Quark-Gluon Plasma (QGP), which forms in relativistic heavy-ion collisions. Investigating the transport properties and inner workings of the QGP offers unique insights into the strong interaction. Heavy quarks, produced in the initial hard scatterings of these collisions, serve as powerful probes of the medium. They provide valuable information on in-medium energy loss, diffusion behaviors, and hadronization mechanisms across a wide kinematic regime. With new data and upgraded experiments at the LHC and RHIC, this is an ideal moment to revisit on what we've learned from heavy-flavor studies and to look ahead to future discoveries.

In this talk, I will present recent experimental advancements in open heavy-flavor measurements in heavy-ion collisions, and discuss the outlook for upcoming research opportunities.

14:25–14:50 Heavy-flavour and quarkonium measurements from pp to AA collisions

Speaker

Stefano Trogolo (Università e INFN - Torino)

Description

Heavy quarks (i.e. charm and beauty), produced in the early stages of high-energy hadronic and nuclear collisions through hard-scattering processes, serve as exceptional probes for investigating Quantum Chromodynamics (QCD) in extreme conditions and for rigorous perturbative QCD (pQCD) tests. Their large masses ensure that the heavy-quark production at the early stage is calculable within pQCD, making them sensitive tools to explore the properties of the Quark-Gluon Plasma (QGP) formed in heavy-ion collisions, as well as cold nuclear matter effects in proton-nucleus (pA) and nucleus-nucleus (AA) collisions.

This invited talk will present a comprehensive overview of recent experimental results on heavy-flavour hadron production and quarkonium measurements across various collision systems, from pp to AA interactions. We will discuss key observables obtained from a wide range of experiments. The presentation will highlight how these measurements shed light on in-medium energy loss, dissociation mechanisms, regeneration, and modification of hadronization processes within the hot and dense medium. We will also explore the opportunities these data offer for refining our understanding of pQCD dynamics, cold nuclear matter effects and those QGP-like phenomena observed in high-multiplicity pp collisions. The discussion will emphasize the critical role of these probes in advancing our knowledge of the strong interaction and the fundamental properties of the QGP.

14:50–15:15 Exploring the phase diagram with electromagnetic probes

Speaker

Alberica Toia (Goethe Uni. Frankfurt & GSI)

Description

Understanding the phase structure of strongly interacting matter is a central goal in high-energy nuclear physics. Electromagnetic probes—such as photons and dileptons—offer a unique window into the space-time evolution of the quark-gluon plasma (QGP) and hadronic matter created in relativistic heavy-ion collisions. Unlike hadrons, these probes interact only electromagnetically and thus carry undistorted information from the entire evolution of the system, including its early, hot stages. In this presentation, we explore how electromagnetic observables can be used to map out the QCD phase diagram, constrain the properties of the QGP, and provide insight into the nature of the phase transition between quark-gluon plasma and hadronic matter. We discuss recent theoretical developments, experimental measurements, and the role of ongoing and future programs in pushing the boundaries of our understanding of the QCD medium.

15:15–15:35 Charm hadron production in fixed-target collisions at the LHC

Speaker

Mr Gabriel Ricart (CEA/Irfu)

Description

Charm production measurements at fixed-target energies at the LHC offer unique opportunities for hadronisation studies sensitive to the beam remnants, constraints on parton distribution functions of the proton and the nucleus including intrinsic charm as well as studies sensitive to deconfinement in nucleus-nucleus collisions.
LHCb pionneered charm production measurements in proton-nucleus and nucleus-nucleus collisions in Run 2. In Run 3, LHCb was upgraded with a dedicated gas injection system, SMOG2. This upgrade features a gas cell to boost fixed-target luminosity and a new system that allows the injection of non-noble gases. SMOG2 enables the collection of large datasets from proton-proton, proton-nucleus and lead-nucleus fixed-target collisions, including high-statistics samples of charm hadrons.

This presentation will cover results from Run 2, the first data collected with the SMOG2 system, as well as future prospects for charm measurements in upcoming fixed-target collisions.

15:35–15:55 **Beauty production in pp collisions at 13.6 TeV with ALICE**

Speaker
Emilie BARREAU (Subatech, Plasma Group)

Description

Charmonium, a bound state of a charm and an anticharm quarks, represents a valuable tool to investigate the properties of the quantum chromo-dynamics (QCD). In particular, charmonium production mechanism involves both perturbative (heavy quark pair production) and non-perturbative (hadronization into the final quarkonium state) aspects, making it an important test ground for the theoretical models. In addition, charmonia production is separated into two parts, the prompt component, from the hadronization of the $c\bar{c}$ pair, and the non-prompt component from the decay of beauty hadrons. Their separation is crucial for the comparison with the various theoretical models currently used in the quarkonia sector.
Thanks to the ALICE upgrade, more precise measurements of the charmonia non-prompt fraction (f_{B}) have been performed at midrapidity (|y| < 0.8), and the installation of the Muon Forward Tracker (MFT) allowed to perform the first measurement of f_{B} at forward rapidity (2.5 < y < 3.6).
The new data-taking paradigm of Run 3 (continuous readout) allowed also to collect a sizable data sample, giving the access to the reconstruction of new beauty hadrons with respect to Run 2, as the $B^{\pm}$ in the J/ψ + $K^{\pm}$ decay channel down to low p_{T} at midrapidity.
In this presentation, the first prompt/non-prompt J/ψ fraction measurement at forward rapidity will be presented, as well as the improved results at midrapidity and the first measurement of $B_{\pm}$ meson production in pp collisions at $\sqrt{s} =13.6$ TeV.

15:55–16:15 **Quarkonium production in pp collisions at $\sqrt{s}$=13.6 TeV with ALICE**

Speaker
Lorenzo Mattei (University Clermont-Auvergne, University of Torino)

Description

Quarkonia are bound states of a heavy quark and an antiquark of the same flavor. In pp collisions, such heavy quark masses require the quark pair to be produced in high-energy scatterings of partons in the colliding protons; once the quark and the antiquark are created, their binding into quarkonium states involves large spatial separations and low momentum scales. The whole production mechanism of quarkonia can therefore be factorized into two parts: the creation of the quark pair, which can be dealt with using a perturbative approach, and the binding of quarks into quarkonia, which is a high-coupling, intrinsically non-perturbative process. Precise measurements of quarkonium production cross sections in pp collisions are essential for enhancing the understanding of charmonium production mechanisms and for testing various theoretical models. Along with probing two different QCD regimes, these measurements provide fundamental benchmarks for investigating the properties of the quark-gluon plasma produced in nucleus-nucleus collisions and for evaluating cold nuclear-matter effects in proton-nucleus collisions. New ALICE measurement of quarkonia in pp collisions at $\sqrt{s}$=13.6 TeV will be presented.
The resonances are reconstructed via their dimuon and dielectron decay at forward and mid-rapidity, respectively.
Ratios of charmonia and bottomonia are discussed as a function of transverse momentum and are compared to the latest theoretical predictions.

16:15–16:35 **Quarkonium collectivity in Pb-Pb collisions at √sNN = 5.36 TeV with ALICE**

Speaker
Rebecca Cerri (Turin University)

Description

Quarkonium production has long been recognized as a key probe for exploring the properties of the quark-gluon plasma (QGP). Among various observables, azimuthal anisotropies in quarkonium production offer valuable insights to investigate its collective behavior in a strongly interacting medium. In particular, the measurement of $\rm{J}/\psi$ elliptic flow (v_2) in Pb–Pb collisions at the LHC provides important evidence for the thermalization of charm quarks in the QGP, supporting the hypothesis of charmonium (re)generation at low transverse momentum ($p_{\rm T}$). In contrast, for the $\Upsilon(1S)$ state, (re)generation is expected to have a negligible impact due to the much larger mass of beauty quarks, which limits their possibilities to thermalize within the medium.
This contribution will present recent ALICE results on quarkonium flow coefficients in Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.36 TeV. New measurements of $\rm{J}/\psi$ v_2 will be discussed, using both the event-plane and the scalar product methods as functions of $p_{\rm T}$ and rapidity. Additionally, the first measurement of the four-particle cumulant $v_2\{4\}$ for $\rm{J}/\psi$ will be presented, providing deeper insight into charm quark thermalization in the QGP. Finally, the first measurement of v_2 for $\Upsilon(\mathrm{1S})$ will be shown, exploring the (re)generation mechanism for beauty quark.

16:35

14:00

Tuesday 23 September 14:00–16:30

Hadron Structure, Spectroscopy and Dynamics: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Silvia Niccolai (IPN Orsay)

14:00–14:25 Hadron Spectroscopy at JLab

Speaker

Bryan McKinnon (University of Glasgow)

Description

While the existence of hadrons such as baryons and mesons is well-established, it is clear that the vast majority of their mass originates not from the constituent quarks themselves, but emerges from the properties of the strong force of nature that binds them. Exploring hadron structure and spectroscopy offers a unique window into Quantum Chromodynamics (QCD, the theory governing the strong force) and provides a route to address fundamental questions such as the origin of hadron mass, the mechanism of quark confinement and the effective degrees of freedom within hadrons. Presented here is an overview of the JLab hadron spectroscopy programme, investigations spanning both structure and spectroscopy and some future possibilities.

14:25–14:50 Insights from the SpinQuest Experiment After the First Commissioning Run

Speaker

Liliet Calero Diaz (Los Alamos National Laboratory)

Description

SpinQuest, a fixed-target experiment at Fermilab, studies the Drell-Yan process by utilizing transversely polarized NH_3 and ND_3 targets alongside an unpolarized 120-GeV proton beam. The primary goal is to measure single spin azimuthal asymmetries that arise from the correlation between the transverse momentum of the struck quark and the spin of the parent nucleon, referred to as Sivers asymmetry. The angular distribution of final-state di-muons from the Drell-Yan process, in relation to the target polarization, is sensitive to one of the eight Transverse Momentum Dependent (TMD) parton distribution functions, the Sivers function, which can only be cleanly accessed in this process. Designed with optimized acceptance and kinematics to capture contributions from the target anti-quarks, SpinQuest seeks to assess the existence of orbital angular momentum (OAM) of sea quarks in the nucleon through the measurement of non-zero Sivers functions, contributing to a broader understanding of individual contributions to proton spin as well as testing the QCD prediction regarding the sign change of the Sivers function in the Drell-Yan process compared to that in semi-inclusive deep inelastic scattering (SIDIS). Additionally, the experiment aims to measure transverse single-spin asymmetries (TSSA) for J/Psi production, which are sensitive to the gluon Sivers function. This presentation will outline the current status of the SpinQuest experiment after the fisrt commissioning run.

14:50–15:10 Implications for Diquark Investigations from the Measurement of Proton Multi-dimensional Multiplicity Ratios

Speaker

Dr Michael Wood (Canisius University)

Description

In the non-perturbative regime of Quantum Chromodynamics, the quark and gluon dynamics in a nuclear medium can be studied through the hadronization process. The deep inelastic electron scattering experiments are a clean way to liberate a bound quark from a nucleon in the medium and study the hadronization process. The E02-104 experiment at the Thomas Jefferson National Accelerator Facility used a 5-GeV electron beam incident on target nuclei of deuterium, carbon, iron, and lead. One observable for investigating the formation of a color-neutral hadron from a free quark (or multiple quarks) is the multiplicity ratio, which represents the normalized yield of hadrons produced in a heavy nucleus relative to that from deuterium. This talk will present results of proton multiplicity ratios in 1D, 2D, and 3D dependencies with respect to Q^{2}, ν, z_{h}, and p_{T}^{2} and discuss possible evidence for direct diquark scattering.

This work is supported in part by the U.S. DOE award #DE-SC0020365.

15:10–15:30 Antiproton-Nucleus Annihilations at Low Energies

Speaker

Viktoria Kraxberger (Austrian Academy of Sciences)

Description

The detection of antimatter is primarily based on its annihilation, thus the understanding of the antiproton-nucleus ($\bar{\mathrm{p}}\mathrm{A}$) interaction is crucial. Despite its significance, current models - compared mainly to experimental results from LEAR - show deviations from low-energy measurements by large factors, suggesting that the annihilation mechanism is not yet fully understood.
This work presents a study of $\bar{\mathrm{p}}\mathrm{A}$ annihilations at rest on a variety of solid targets will provide detailed information on the total multiplicity, energy, and angular distribution of various prongs, as well as their dependence on nuclear mass. The 1-3 μm thick target foils allow heavily ionizing particles to escape, enabling the investigation of possible final state interactions triggered by the primary annihilation mesons and their branching ratios.
The detection system covers most of the solid angle around the 1 cm^2 target and consists of seven Timepix4 ASICs coupled to silicon sensors, allowing for precise tracking, time and energy measurements. A vertex reconstruction algorithm will be applied to tag individual events and discriminate between antiprotons annihilating on target and those elsewhere.
Data collection for the experiment is set to commence in the summer of 2025, and preliminary results will be presented in this talk.

15:30–15:50 **Review of strangeness and dileption production in elementary collisions at HADES**

Speaker
Rafał Lalik (Jagiellonian University in Kraków, Poland)

Description

The HADES (High-Acceptance Di-Electron Spectrometer) detector is a versatile device operating at SIS18 synchrotron at GSI Darmstadt with a vital list of results in the elementary and heavy ion collisions. It combines unique capability of dileptons and hadrons identification. HADES provides a unique platform for investigating elementary reactions, with a particular focus on the strangeness and dilepton production channels. These reactions offer critical insights into the dynamics of hadronic and nuclear matter, hadron structure in non-perturbative QCD regime, as well as the searches for new particles like axions in rare meson decays. The strangeness program at HADES explores the production of strange hadrons in proton-proton, proton-nucleus, and pion-nucleus collisions, serving as a sensitive probe of the underlying production mechanisms and structures. With the recent experiment at 4.5 GeV beam kinetic energy, we enabled more precise studies of heavier mass hyperons like Σ(1385), Λ(1405) and Λ(1520), and double-strangeness like Ξ(1320) particles, and various mesons like omega, eta. Dilepton production serves as a powerful tool to investigate in-medium modifications of hadrons and provides key information on the properties of hot and dense matter, especially in the context of the early stages of hadronic reactions. Thus, the results from dilepton production in the elementary reactions are vital for the current and future heavy ion collisions at SIS100. Dielpton production with pion and proton induced reactions on proton targets in HADES provides unique possibility to study electromagnetic structure of baryons , with the measurements of the electromagnetic transition form factors in the first and second resonance region This talk will present recent results from proton and pion induced elementary collisions from the HADES collaboration, emphasizing the importance of these studies in advancing our understanding of the strong force, hadron structure, and the production mechanisms in various particle collision processes.

15:50–16:10

Proton internal pressure from deeply virtual Compton scattering at the future Electron-Ion Collider

Speaker
Herve Moutarde (CEA-IRFU-SPHN)

Description

As unexpected as it may seem, the past few years revealed that it is possible to ascribe a well-defined meaning to the notion of proton internal pressure, to identify several associated observables that can be measured in contemporary experiments and from them to extract this internal pressure in a theoretically controlled manner. The conceptual breakthrough originates from the definition of generalized parton distributions providing a direct connection between the energy-momentum tensor and exclusive processes measurements accessible at facilities colliding leptons and hadrons.

This unique experimental connection has been highlighted with attempts to extract the nucleon pressure and shear forces distributions. If, in principle, this can be performed in a model-independent way from experimental data, in practice, limited precision and restricted kinematic coverage make such an extraction very challenging. We outline a next-to-leading order formalism allowing a reanalysis of existing global fits with genuine gluonic degrees of freedom. We also provide an estimate of the reduction in uncertainty that could stem from the extended kinematic range relevant for the future Electron-Ion Collider, currently under construction at Brookhaven National Laboratory.

More generally we discuss the impact of future measurements of deeply virtual Compton scattering with the ePIC detector at the Electron-Ion Collider. This provides a reference point for future analyses. In addition to presenting distributions of basic kinematic variables obtained with the latest ePIC design and simulation software, we also examine the impact of future measurements on nucleon tomography. We explain why these developments naturally fit in a versatile software framework, named PARTONS, dedicated to the phenomenology and theory of generalized parton distributions.

16:10–16:30 **DVCS experiment with the Neutral Particle Spectrometer in Hall C at Jefferson Lab**

Speaker
Hao HUANG (IJCLab, CNRS-IN2P3)

Description

The study of the Generalized Parton Distributions (GPDs) is a focal point of hadron physics since they provide rich information about the inner structure of nucleons. Experimentally, measurements of the Compton Form Factors (CFFs) via the Deeply Virtual Compton Scattering (DVCS) process is the simplest approach to access GPDs.
The DVCS experiment in Hall C at the Jefferson Lab was conducted in 2023 and 2024 using an electron beam scattered off liquid hydrogen and deuterium targets. The well-established High Momentum Spectrometer detected the scattered electrons, while the newly installed Neutral Particle Spectrometer captured the emitted photons with high energy resolution. Furthermore, the refined offline calibration of these detectors was performed to achieve a high-precision measurement of the DVCS channel. In this talk, I will present our experimental configuration and the status of the data analysis.

16:30

14:00 **Tuesday 23 September** 14:00–16:30

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 3

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:00–14:25 Recent studies of astrophysical interest using transfer reactions

Speaker

Dr Faïrouz Hammache (CNRS/IJCLab)

Description

Our understanding of stellar evolution has greatly advanced thanks to the synergy between observation, stellar modeling, and nuclear physics. Nuclear reaction rates are fundamental inputs in stellar models, making their study essential for addressing key questions in nuclear astrophysics. Two main experimental approaches are used to determine cross sections: direct measurements and indirect methods such as transfer reactions. However, direct measurements at stellar energies are challenging due to low cross sections, particularly when charged particles or radioactive nuclei are involved. Transfer reactions offer a valuable alternative, allowing the study of both resonant and non-resonant reactions and enabling the extraction of important nuclear structure information such as excitation energies, spin-parity assignments, and decay widths. This talk will present an overview of key astrophysical reactions recently investigated using the transfer reaction method.

14:25–14:50 Origin of Galactic Cosmic Rays: what nuclear physics tells us

Speaker

Vincent Tatischeff (IJCLab)

Description

More than a century after their discovery, galactic cosmic rays remain enigmatic — especially in terms of their astrophysical origins, their propagation through the interstellar medium, and their role in the nucleosynthesis of the light elements lithium, beryllium, and boron. Recent measurements of cosmic-ray composition and energy spectra have yielded valuable insights into these longstanding questions. As a result, nuclear physics now plays a more critical role than ever in interpreting these data and advancing our understanding of cosmic-ray phenomena.

14:50–15:10 Indirect measurement of the 19F(p,αγ)16O and 19F(p,γ)20Ne reactions and direct observation of the 11 keV resonance

Speaker

Dr Marco Salvatore Maria La Cognata (INFN)

Description

The amount of fluorine in stars is a crucial indicator of the internal physical conditions and of the processes taking place within them, such as extra mixing in asymptotic giant branch stars. Also, it is a branching point in proton induced nucleosynthesis, since its proton radiative capture may lead to the synthesis of heavier nuclei (such as Ca in early stars). Recent extrapolated findings on the 19F(p,αγ)16O and 19F(p,γ)20Ne fluorine-destruction channels by the JUNA collaboration indicated a rise in the astrophysical factor by several orders of magnitude below about 100 keV, significantly affecting our comprehension of stellar evolution and nucleosynthesis. Utilizing the Trojan Horse Method (THM), we have indirectly measured the 19F(p,αγ)16O cross section, fully covering astrophysical energies without requiring extrapolations (and with no electron screening enhancement). The strength of the 11-keV resonance was determined, revealing a considerable decrease in the reaction rate compared to earlier studies. The THM results on the αγ channel were also used to rescale the 19F(p,γ)20Ne astrophysical factor, with similar conclusions. Our analysis of its astrophysical significance suggests that this measurement challenges existing models of fluorine and heavier element abundances, reopening unresolved questions in the field, in particular in the case of early stars.

15:10–15:30 Effective mass of a nucleus immersed in superfluid neutrons in the inner crust of a neutron star

Speaker

Dr Daniel Pęcak (Institute of Physics, Polish Academy of Sciences)

Description

Astronomical observations of neutron stars provide data on the kilometer scale, while the nuclear interaction, fundamental for neutron stars, works on the femtometer scale. To describe physical processes across so many orders of magnitude, one needs effective models. The inner crust of a neutron star is a complex system, where a lattice of nuclei strongly interacts with superfluid neutrons. In some situations one can neglect neutron and proton degrees of freedom and capture the essential physical phenomena by parametrizing nuclei with their effective mass, which emerges from the interaction with the background neutrons. We developed the *W-BSk Toolkit* [1], a general-purpose tool that uses time-dependent density functional theory to perform three-dimensional simulations of the inner crust without any geometric constraints. We use generalized Skyrme nuclear energy-density functionals of the Brussels-Montreal family. We study the nonequilibrium dynamics of a nucleus in different layers of the neutron star, which allows us to calculate the effective mass using the microscopic approach. Moreover, we identify, above a threshold velocity, three distinct mechanisms of energy dissipation: phonon emission, Cooper pair breaking, and vortex ring creation. The last mechanism is particularly interesting in the context of a microscopic source of glitches - sudden spin-ups of neutron stars.

[1] D. Pęcak, A. Zdanowicz, N. Chamel, P. Magierski, and G. Wlazłowski
Physical Review X **14**, 041054 (2024)

15:30–15:50 Measurement of the 197Au(γ,n)196Au cross-section with the activation method

Speaker

Giuseppe Gabriele Rapisarda (Dip. di Fisica e Astronomia "E. Majorana" Univ. di Catania & LNS-INFN)

Description

The ^{197}Au(γ,n)^{196}Au reaction is commonly used as a reference process to measure the gamma beam intensity in photonuclear reaction experiments. However, at energies higher than 14.7 MeV, the cross-section values of the ^{197}Au(γ,n)^{196}Au reaction available in the literature (both from experiments and theory) exhibit conflicting values. Thus, we performed a new measurement of the ^{197}Au(γ,n)^{196}Au reaction cross section at the HIγS facility using the activation method. A beam of nearly-monochromatic photons at various energies (10 MeV-20 MeV) was used to activate several gold foils. After irradiation, the number of gamma decays of 196Au (at energies of 333 keV and 356 keV) was measured for each gold foil using a HPGe detector. The intensity of the beam was measured using a dual fission chamber and a thin plastic scintillator. The combined use of these
beam diagnostic systems and the measure of the disintegrations of ^{196}Au, provided a new measurements of the ^{197}Au(γ,n)^{196}Au cross-section reducing the experimental errors with respect to the previous experiments. This result is important to improve the measurement of the gamma-beam intensity for the study of (γ,α) and (γ,p) reactions of interest for the astrophysics.
In this presentation experimental procedure and preliminary results will be shown.

15:50–16:10 Nuclear structure and astrophysics studies with TITAN’s Multiple-Reflection Time-Of-Flight Mass Spectrometer

Speaker

Dr Ali Mollaebrahimi (GSI Helmholtz Centre)

Description

TRIUMF's Ion Trap for Atomic and Nuclear science (TITAN) specializes in high-precision measurements and isobaric separation of exotic nuclei using advanced electromagnetic traps. These precise mass measurements are crucial for investigating nuclear structure and studying astrophysical processes involving isotopes far from the valley of stability.
TITAN’s Multiple-Reflection Time-of-Flight Mass Spectrometer (MR-TOF-MS) enables the study of short-lived and rare nuclei through its fast measurement cycles (on the order of milliseconds) and exceptional sensitivity. This presentation highlights recent developments and experimental results achieved with the MR-TOF-MS at TITAN. The recent results include first-time mass measurement of neutron-rich ^{83}Zn and ^{86}Ga nuclei near neutron shell closure of $N=50$ and $^{136-138}$Sn isotopes near $N=82$ and their implications for studying the 1st and 2nd abundance peaks in the rapid neutron capture process (*r*-process) [1,2].

[1] A. Jacobs et al., Physical Review Letters 134 (2025)
[2] A. Mollaebrahimi et al., Physical Review Letters (under review)

16:10–16:30 Measurements for proton capture cross sections on Sn isotopes

Speaker

Munmun Twisha . (Saha Institute of Nuclear Physics, Kolkata)

Description

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\documentclass[12pt]{article}
% Remove option referee for final version
%
% Remove any % below to load the required packages
%\usepackage{latexsym}
%\usepackage{graphics}
\usepackage{amssymb}
\usepackage{lipsum}
\usepackage{caption}
\usepackage{subcaption}
\usepackage{amsmath}
\usepackage[utf8]{inputenc}
\usepackage{graphicx}

\begin{document}

The synthesis of a p-nuclei encompasses a complex reaction network involving several stable and unstable nuclei
interconnected by numerous reactions. Measurement of cross sections of all these reactions in terrestrial laboratories is not
always possible. Consequently, statistical models are employed to calculate reaction cross sections. However, experimental data
remain indispensable for validating these models and fine-tuning their parameters, making it crucial to measure as many
reactions as possible. Tin (Sn) isotopes, with a large number of stable isotopes and a proton shell closure at Z=50 that
significantly impacts their nuclear structure and reaction rates, serve as an ideal test case for benchmarking nuclear reaction
models. Isotopes of Sn has contributions from all three, s-, r- and p-processes. The isotopes $^{112,114}$Sn are p-only nuclei,
while $^{115}$Sn likely has contributions from all p-, r- and s-processes. Discrepancies in the solar abundances of $^{115}$Sn
and $^{116}$Sn [1] highlight the necessity of precise experimental data to refine astrophysical models. The case of $^{115}$Sn
is particularly intriguing, as it is one of only two odd-A p-nuclei. Odd-A nuclei are generally more susceptible to destruction via
($\gamma$,n) reactions compared to even-A nuclei [2], adding further complexity to understanding its astrophysical origin. \
The proton capture cross sections for the reactions $^{115}$Sn(p,$\gamma$)$^{116}$Sb and $^{119}$Sn(p,$\gamma$)
$^{120}$Sb were measured at the BARC-TIFR Pelletron facility in Mumbai. Since the lowest available proton beam energy at
the Pelletron is 8 MeV, graphite degraders of varying thicknesses were used to achieve energies down to 2.5 MeV. The
$^{119}$Sn(p,$\gamma$)$^{120}$Sb reaction, previously measured by F.R. Chloupek et al. (1999) [3], was repeated at few
energies and extended the energy range up to 8 MeV. Enriched Sn targets were prepared using the rolling method at TIFR, with
final thicknesses of 1.9±0.34 mg/cm$^2$ for $^{115}$Sn (69\% abundance) and 1.7±0.41 mg/cm$^2$ for $^{119}$Sn (97\%
abundance). The target setup included Graphite(1/0.5/0.25 mm) + Enriched Sn ($^{115}$Sn and $^{119}$Sn) + Cu (monitor
foils) and was irradiated with a proton beam with beam current of 80 nA over an energy range of 2.5 –8 MeV. Targets were
irradiated for four half-lives (1 hour) at each energy, and daughter nuclei ($^{116}$Sb and $^{120}$Sb) were counted using two
HPGe detectors with graded shielding. Detector efficiency was calibrated using $^{152}$Eu before counting the irradiated
targets. Data acquisition was performed using a digitizer and processed with COMPASS software. Half-life calculations were
consistent with literature values within the reported error margins. To validate the procedure and analysis, the measurement was
repeated at the FOTIA facility ( energy of proton beam: 1-5 MeV) in BARC at two energy points, 3.5 MeV and 5 MeV, without
using degraders. Total cross sections for the $^{115}$Sn(p,$\gamma$)$^{116}$Sb and $^{119}$Sn(p,$\gamma$)$^{120}$Sb
reactions were measured over an energy range of 2.5 to 8 MeV, nearly covering the entire Gamow window (1.8–4.2 MeV)
relevant to p-process nucleosynthesis for these reactions. Since Sn has various isotopes, so the residual nucleus,
$^{116,120}$Sb were also populated via (p,n) channel and these contributions have been appropriately subtracted. The
measured cross sections were compared with TALYS [4] predictions. the results will be presented at the conference.

References:
[1] K. Wisshak et al.,J, PR/C, 54, (3), 1451, 199609
[2] F.R. Chloupek et al., Nuclear Physics A652, 391-405 (1999).
[3] A. Koning, S. Hilaire, and S. Goriely, TALYS 1.8, A Nuclear Reaction Program, User Manual,
1st ed. (NRG, Netherlands, 2015).

\end{document}
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16:30

14:00 **Tuesday 23 September** 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 7

Session | **Location:** MoHo, Inspire 1, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr Emmanuel CLEMENT (GANIL)

14:00–14:25 Scalable ab initio approaches

Speaker

Vittorio Somà (CEA Paris-Saclay)

Description

Ab initio calculations of atomic nuclei aim at describing their structure and reaction properties starting solely from the basic interactions between nucleons. In the past decade, thanks to developments in many-body theory and in the modelling of nuclear forces, ab initio techniques have steadily progressed and are now able to reach several tens of isotopes up to mass A~100, as well as selected heavy nuclei. The long-term goal is to eventually extend such calculations to the whole nuclear chart, i.e. to several thousands of nuclei up to mass A~300. In this context, one of the main challenges consists in devising computational schemes that can tackle complex, i.e. doubly open-shell, systems and at the same time scale gently with mass number. I will discuss current efforts towards this objective, present recent examples of ab initio calculations of doubly open-shell nuclei and address future perspectives.

14:25–14:45 Measurement of the Hoyle state radius using double excitation inelastic scattering

Speaker

Ilham DEKHISSI

Description

The second 0_{2}^+ state of ^{12}C at an excitation energy of 7.654 MeV, known as the Hoyle state [1], is crucial for understanding how ^{12}C is formed in stellar nucleosynthesis. Despite extensive studies, the Hoyle state characteristics remain a challenging topic for nuclear structure theories: many theoretical models predict very different radii and spatial arrangements of this state [2,3].

Experimentally, only few attempts have been made in order to measure the radius of the Hoyle state, mostly using inelastic scattering angular cross sections. The most frequently cited study reported a 0.5 fm larger Hoyle state radius than the ground state radius [4] from ^{12}C + ^{12}C diffusion at 121.5 MeV. However, the extraction of the Hoyle state radius was based on a simple diffusion model and relied on strong assumptions. Moreover, the cross section was measured at large angles, leading to the first minimum expected at a smaller angle being missed.

To get rid of these limitations, a new experiment was conducted at GANIL in 2025 to measure the Hoyle state radius by comparing single- and double- excitation in ^{12}C + ^{12}C inelastic scattering using the multi-detector FAZIA [5]. This comparative analysis eliminates many of the assumptions that were previously required, allowing for more accurate comparisons with modern scattering theory that incorporates realistic nuclear potentials.

In this talk, I will present this new experiment as well as the first results.

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14:45–15:05 Clustering in ^{16}O investigated with ^{3}He+^{13}C collisions

Speaker

Daniele Dell'Aquila (University of Naples "Federico II" & INFN-Naples)

Description

We investigate the occurrence of α clustered states in ^{16}O at high excitation energies by analyzing ^{3}He + ^{13}C reactions in the 1.4 - 2.2 MeV energy range. We produce refined angular distributions of the differential cross section in absolute units, allowing us to investigate the competition between the α decays leading to ^{12}C in the Hoyle state and those leading to the ground state. The Hoyle branching ratio turns out to be larger than that predicted by theoretical calculations based on barrier penetration models, suggesting the existence of states with large cluster components in the parent nucleus.

15:05–15:25 Experimental Study of Low-Spin States in ^{42}Ca and ^{44}Ca as a Probe for Shape Coexistence

Speaker

Massimiliano Luciani (INF Sezione di Milano, Università degli Studi di Milano)

Description

Nuclear shape coexistence is essential for exploring the microscopic origins of nuclear deformation [1-4].
The Ca isotopic chain between the two shell closures at N=20 and N=28 is an optimal test
area that can provide key insights into this phenomenon [5-7].
The aim of this work is to perform complete low-spin spectroscopy of even-even ^{42,44}Ca and odd-even ^{43,45}Ca isotopes, complementary to the already existing data on ^{41,47,49}Ca, and to search for evidences of shape coexistence phenomena in the $A \sim 40$ region.
As a first step, we focused on the two even-even cases of the isotopic chain, where the presence of 0^+ excitations associated with deformed and superdeformed structures have already been demonstrated [8,9].
Both ^{42}Ca and ^{44}Ca nuclei were populated with a (n$_{th}$, γ) reaction on two CaCo$_3$ targets, the first one being enriched with the ^{41}Ca radioactive isotope.
In both cases, the γ cascades emitted from the S$_n$ capture states were detected using the 32 HPGe crystals array FIPPS [10], at ILL (Grenoble).
The results of this work are complex level schemes that will be presented together with preliminary angular correlation studies made to establish the spin and parities of several excited states of ^{42}Ca and ^{44}Ca nuclei.

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15:25–15:45

Quadrupole-octupole-coupled states in 112Cd via Coulomb excitation with AGATA and SPIDER

Speaker

Tommaso La Marca (INFN - Firenze)

Description

Cadmium isotopes have been thought to be prime examples of nearly harmonic vibrational nuclei. However, recent studies have started depicting a much more complex picture of their structure, highlighting the possibility of multiple shape coexistence. In particular, advanced beyond-mean-field calculations performed for the 110,112Cd isotopes predict a prolate ground state coexisting with three excited 0+ states, each with a different shape. The coupling of the low-energy quadrupole and octupole vibrations is a subject of particular interest in this context. Indeed, if cadmium isotopes are vibrational, quadrupole-octupole-coupled (QOC) states should manifest at low excitation energy with specific features. In this contribution, I will present the first results regarding QOC states in 112Cd from a Coulomb-excitation experiment performed at the INFN-LNL with the state-of-the-art AGATA spectrometer coupled to the heavy ion silicon detector SPIDER.

15:45–16:05

Searching for Alpha-cluster Condensed State in 20Ne

Speaker

Sandro Barlini (Università degli Studi di Firenze ed INFN-Fi)

Description

The search for Alpha-Cluster Condensate State (ACS) in always more heavy nuclei is one of the most intriguing puzzles of nuclear structure. In particular, in2021, Adachi et al. observed three states in ^{20}Ne at 21.2, 21.8, and 23.6 MeV [1]. Such states have been suggested to be realistic candidates, being their decay well correlated with the underlying ACSs in lighter nuclei [2].In this contribution, we attempt to shed light on this topic, populating the excitation energy window of interest via alpha-transfer ^{16}O(^{6}Li, d)^{20}Ne* at 13.5 MeV/nucleon in inverse kinematics.
This exclusive measurement has been performed in summer 2024 and it consists in the detection of the target recoil deuteron with two OSCAR modules [3] placed backward in the laboratory frame, while the ^{20}Ne decay products were collected thanks to the GARFIELD+RCo apparatus[4]. The large coverage of our apparatus and its identification capability permits to disentangle the different reaction channels involving the weakly bound Li-ions [5]. To confirm the ACS candidate states of ^{20}Ne, we will report on events selected by the presence of the transfer deuteron in coincidence with four (out of five)alpha particles from the excited ^{20}Ne detected, to fully reconstruct the kinematics of its decays for different excitation energy gates.

Preliminary results of this experimental search will presented.

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[5] M.L. Wang et al, Nucl. Phys. A 1049 (2024) 122914

16:05–16:25

Study of shape coexistence in Sn isotopes around A=110

Speaker

Giacomo Corbari (Università degli Studi di Milano and INFN Milano)

Description

The shape coexistence phenomenon was investigated in the Sn isotopes region around A=110, by means of γ-ray spectroscopy and lifetime measurements of low-spin states. Recent observations of prolate axially deformed 0^+ states in ^{64,66}Ni isotopes, with a strongly hindered decay to the first 2^+ excited state of spherical nature (shape-isomer-like excitations), were reported [1,2,3]. Similar excitations were suggested in the stable Sn isotopes, across the $Z=50$ shell gap, due to analogies in the orbital configuration. Such hypothesis is corroborated by Monte Carlo Shell Model (MCSM) calculations, performed with the interaction of Ref. [4], whose potential energy surfaces of $^{110-118}$Sn exhibit a well-separated prolate secondary minimum, as in the Ni case.\
Experimentally, several excited 0^+ states have been observed in even-even $^{110-120}$Sn, mainly via particle spectroscopy (e.g. [5,6]), however limited information on their lifetimes is available. To address this issue, a series of complementary experiments was carried out by our collaboration between LNL and IFIN-HH, employing the ROSPHERE-SORCERER and the AGATA-PRISMA setup, respectively. In particular, even-even ^{112,114,116,118,120}Sn isotopes were studied via low-energy multi-nucleon transfer reactions and several lifetimes of excited 0^+_2, 0^+_3 and 0^+_4 states were measured for the first time with the RDDS and the DSAM methods. Preliminary results will be compared with MCSM calculations, giving an insight into the microscopic mechanism leading to the onset of deformation in this region.

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16:30

14:00 **Tuesday 23 September** 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 8

Session | **Location:** MoHo, Inspire 2, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Araceli LOPEZ-MARTENS (IJCLab)

14:00–14:25

Atomic and molecular In-gas-jet laser spectroscopy studies: Revealing the configuration of the K^\pi=8^- isomer in ^{254}No with JetRIS

Speaker

Dr Rafael Ferrer (KU Leuven - IKS)

Description

The In-Gas Laser Ionization and Spectroscopy (IGLIS) technique is a powerful tool to study atomic and nuclear properties of short-lived actinides [1]. Such studies are important to understand the atomic level scheme of these heavy elements, strongly influenced by electron correlations and relativistic effects. Laser spectroscopy in a collimated and low-temperature supersonic gas jet produced by a convergent-divergent contoured nozzle [2] can be used for high precision determination of fundamental nuclear properties still unknown for most of these nuclei, such as moments, spins and differences in mean-square charge radii independently of nuclear model assumptions [3]. Thus, IGLIS studies provide experimental data that are crucial for testing and improving the predictions of state-of-the-art atomic and nuclear theoretical models.
The in-gas-Jet Resonance Ionization Spectroscopy (JetRIS) setup [4] has been designed to perform high-precision IGLIS studies of heavy actinides. JetRIS has recently been commissioned at the focal plane of the SHIP spectrometer in GSI to perform laser spectroscopy on the 254No nuclear ground state [5]. Combining an improved overall efficiency with a fast atom extraction, laser spectroscopy studies of the K^{\pi}=8^- isomer in ^{254}No (T_{1/2} = 265 ms) have been performed in a follow up online campaign. The obtained hyperfine structure has been used to extract the magnetic moment (gK-factor) providing a direct determination of the two quasi-particle configuration of the K-isomer.
In this contribution we will present the nuclear moments and isomer shift of the K-isomer as well as recent results on atomic and molecular IGLIS studies of Th species obtained in offline measurements at KU Leuven.

14:25–14:45

Essential steps towards a nuclear clock: decay-fraction measurements of the radiative decay of 229mTh in solid-state hosts

Speaker

Yens Elskens (KU Leuven)

Description

Due to its low excitation energy around 8.4 eV, the unique ^{229}Th isomer is the ideal candidate for developing a nuclear clock [1]. Such a clock would be particularly suited for fundamental physics studies [1]. In the past, measuring the isomer's radiative decay from a large-bandgap crystal doped with $^{229\mathrm{m}}$Th, has proven difficult: the commonly used population of the isomer via the ^{233}U α-decay has a limited branching ratio towards the isomer and creates a high-radioluminescence background [2, 3]. However, recently, a new approach to populate the isomer through the β-decay of ^{229}Ac was proposed [2]. This approach made it possible to observe, for the first time, the radiative decay of the ^{229}Th isomer with vacuum-ultraviolet (VUV) spectroscopy, which allowed to successfully determine the resulting photon's wavelength at a value of $\lambda = 148.7 \pm 0.4$ nm ($E = 8.338 \pm 0.024$ eV) and the isomer's radiative half-life in a MgF$_2$ crystal at a value of $t_{1/2} = 670 \pm 102$ s [4, 5]. Based on this work, narrow-band laser excitation of the nuclear isomer was achieved [6] with a frequency comb, determining the energy to 10^{-12} precision, boosting the development of a solid-state nuclear clock. A new measurement campaign in July 2023 took place at CERN-ISOLDE, aimed at investigating different large-bandgap crystals and accurately determining the time behaviour of the radiative decay of $^{229\mathrm{m}}$Th, embedded in different crystal materials. This allowed to (1) observe, for the first time, the radiative decay in a LiSrAlF$_6$ crystal, (2) determine the radiative decay fraction of the isomer in different crystals [7], and (3) study the time behaviour of an ensemble of ^{229}Th isomers. These studies revealed the presence of a crystal-material-dependent quenching mechanism induced by the β-decay of the precursor isotopes. Results will be presented, as well as the scope of a new measurement campaign which is expected to take place in May 2025. This campaign aims to extend the earlier radiative-decay fraction measurements with new crystalline materials, and investigate the β-decay-induced quenching mechanism in order to link it to laser- and X-ray-induced quenching as reported in [8, 9].

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14:45–15:05

Isomeric Decays in Neutron-Rich ^{183,184}Hf isotopes at the KISS facility

Speaker

Siddharth Doshi (University of Brighton)

Description

The neutron-rich region of the nuclear chart, around mass numbers A∼180–190, is of great interest for investigating nuclear shape transitions and isomerism in deformed nuclei. Isotopes like ^{183,184}Hf are predicted to host long lived isomeric states and approach a prolate-to-oblate shape/phase transition, which is expected to result in prolate high-K isomers decaying to oblate low-K states[1,2]. Despite good theoretical background, exploring this region is difficult due to the low production rates of neutron-rich isotopes and the refractory nature of elements, especially in the hafnium (Z=72) to platinum (Z=78) range, constraining possibilities for comprehensive studies.

We report on the study of isomeric transitions in neutron rich 183,184Ta populated via β-decay of ^{183,184}Hf, respectively. The experiment was conducted at the KEK Isotope Separation System (KISS) facility at RIKEN[3], using multi-nucleon transfer reactions. A 136Xe beam at 7.2 MeV/nucleon was directed onto a tungsten target, yielding neutron-rich isotopes that were slowed, neutralised, and transported in a gas cell. Laser resonance ionisation was used to selectively ionise hafnium isotopes, followed by mass separation using Isotope Separation On-Line techniques. The isotopes were implanted onto Mylar tape surrounded by a detector system consisting of a multi-segmented proportional gas counter for beta spectroscopy and high-purity-germanium clover detectors for gamma-ray spectroscopy, with measurements taken under precise timing conditions to separate isomeric and prompt events.

Time-correlated β–γ spectroscopy enabled the observation of delayed transitions consistent with the decay of isomeric states. A well-known isomer was used to check and confirm the timing setup and event selection. Other delayed transitions, which were strongly hindered, point to the presence of long-lived isomeric states related to specific nuclear configurations. These findings are interpreted in the context of neighbouring isotopic systematics and transition probability calculations.

This study highlights the capabilities of the KISS facility for probing isomeric phenomena in refactory, neutron-rich nuclei and provides insights into the isomeric and ground state decays of ^{183,184}Hf into ^{183,184}Ta, respectively.

References:

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15:05–15:25

Beta Strength of 92 and 93Rb Measured with the Total Absorption Spectroscopy Technique

Speaker

Amanda Porta (Subatech laboratory)

Description

Beta decay of fission products is at the origin of decay heat and antineutrino emission in nuclear reactors. Decay heat strongly impacts reactor safety since it is about 7% of the nominal reactor power during operation and the only power after reactor stop. Reactor antineutrino detection is used in several fundamental neutrino physics experiments and it can also be used for reactor monitoring and non-proliferation purposes since this flux is directly proportional to reactor power and fuel composition.
92 and 93Rb are two fission products highly impacting reactor antineutrino spectra and decay heat. 92Rb is the most important contributor in reactor antineutrino spectrum between 5 and 8 MeV and 93Rb is in the top five contributors [1]. Moreover, 92Rb is indicated as measurement priority 2 for decay heat calculation of U/Pu cycle and priority 1 for the Th/U cycle [2].

They are candidates for the 'Pandemonium' effect [3] which arises from the difficulty that can occur in reconstructing nuclear level patterns for complex decays via measurements with Germanium detectors, especially when transitions are of high-energy or in regions of high-level density, leading to a distortion in the beta decay feeding.

Measurements of 92 and 93Rb β-decay have been performed at the IGISOL facility (Jyväskylä, Finland) using Total Absorption Gamma-Ray Spectroscopy (TAGS). TAGS is complementary to Germanium technique and uses a calorimeter to measure the total gamma intensity de-exciting each level of the daughter nucleus providing a direct measurement of the beta feeding. Results of 92Rb measurements have been discussed in [4]. At this conference we will present a new ground state to ground state feeding estimation for 92Rb, the measured beta feedings for 93Rb and show the impact of these results on reactor antineutrino spectra.

[1] Total Absorption Gamma-ray Spectroscopy for Decay Heat Calculations and Other Applications (INDC(NDS)-0676)
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15:25–15:45

Recent results from the NUMEN project

Speaker

Diana Carbone (INFN-LNS)

Description

The physics of neutrinoless double beta (0νββ) decay has important implications on particle physics, cosmology and fundamental physics. It is the most promising process to access the effective neutrino mass. To determine quantitative information from the possible measurement of the 0νββ decay half-lives, the knowledge of the Nuclear Matrix Elements (NME) involved in the transition is mandatory. The possibility of using heavy-ion induced double charge exchange (DCE) reactions as tools toward the determination of the NME is at the basis of the NUMEN project [1]. The basic points are that the initial and final state wave functions in the two processes are the same and the transition operators are similar, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components. Full understanding of the DCE reaction mechanism is fundamental to disentangle the reaction part from the nuclear structure aspects relevant for the 0νββ decay NMEs. One of the most debated aspect in the DCE and SCE nuclear reactions is the competition between the direct process, proceeding via the meson-exchange paths, and the sequential ones proceeding through the transfer of several nucleons.
The availability of the MAGNEX large acceptance magnetic spectrometer [2] for high resolution measurements of the DCE reactions is essential to obtain high resolution energy spectra and accurate cross sections at very forward angles, including zero degree, and allows the concurrent measurement of the other relevant reaction channels (elastic and inelastic scattering, one- and two-nucleon transfer and single charge exchange reactions). The strategy applied to study such a full net of reactions is to measure the experimental data in the same experimental conditions and analyze them using state-of-the-art nuclear structure and reaction theories in a unique comprehensive and coherent theoretical framework. This multichannel approach has been recently applied to analyze some nets of nuclear reactions, for example involving the ^{18}O + ^{40}Ca and ^{18}O + ^{12}C systems. Moreover, the absolute cross sections of some DCE reactions populating nuclei of interest for the 0νββ decay have been measured for the first time. These results will be presented and discussed at the Conference.

[1] F.Cappuzzello et al., Eur. Phys. J. A 54 (2018) 72.
[2] F.Cappuzzello et al., Eur. Phys. J. A 52 (2016) 167.

15:45–16:05

Muonic x-ray spectroscopy on La and Lu: measurement techniques and target preparations

Speaker

War War Myint Myat Phyo (KU Leuven)

Description

Lanthanum ($Z = 57$) and lutetium ($Z = 71$) serve as ideal candidates to study proton-emission effects. Lutetium proton-emitting isotopes, showing oblate deformations, are positioned near the $N = 82$ shell closure while lanthanum proton-emitting isotopes, which exhibit significant prolate deformation, are located far from any shell closures. Comparing these two cases helps disentangle proton-emission effects from nuclear shape effects. The precision of mean square charge radii extraction for these proton-emitting isotopes from laser spectroscopy can be improved by incorporating experimental benchmarks for mass and field shift parameters. Such benchmarks can be established through absolute charge radii measurements of stable and long-lived lanthanum and lutetium isotopes using muonic x-ray spectroscopy, combined with the King-Plot analysis method. In muonic x-ray spectroscopy, muons are shot on the target material, where they are captured at a high principal quantum number shell forming the muonic atoms. When this captured muon cascades down to the lower shells, it emits x-rays whose energies are studied and interpreted in terms of nuclear properties. One of the several limiting factors of this technique is the requirement of sufficiently large and isotopically pure targets (at least hundreds of milligrams) to effectively stop and capture muons. For certain radioactive elements, for example ^{138}La, it is impractical to have such large quantities with high purity due to either their availability or radiation safety regulations. To overcome this, the muX collaboration developed an indirect muon capture method, enabling measurements with microgram-scale targets. The purity of the microscopic lanthanum target is enhanced using mass separation techniques. In this poster presentation, the key aspects of muonic x-ray spectroscopy measurements for lanthanum and lutetium will be discussed, including the measurement techniques, the production of microscopic lanthanum and macroscopic lutetium targets, and the preliminary data analysis from the lutetium measurement.

16:05–16:25

Towards the limits of stability - new decay data for the lightest mendelevium isotopes

Speaker

Shayan Kumar (GANIL)

Description

The exploration of neutron-deficient isotopes in the vicinity of the Z = 100 shell gap, offers valuable insight into the nuclear structure and the boundaries of stability for nuclei with extreme neutron-to-proton ratios. To investigate the limits of stability and also the effects of the single-particle states on the decay modes of these nuclei, the neutron-deficient isotopes of mendelevium (^{244,245}Md) were the subject of study in two recent experiments at GSI[1] and Lawrence Berkeley National Laboratory (LBNL)[2,3]. The results of the two experiments initiated a debate[4] on the mass assignment to the observed alpha (α) decay chains of the mendelevium isotope.

The α-decay energies of the reported ^{244}Md events in the experiment at Berkeley were assigned to the neighboring isotope ^{245}Md in a contemporaneous as well as an earlier experiment at GSI[5]. To resolve the disparity between the results from LBNL and GSI, a new experiment was conducted in May-June, 2024 at the Fragment Mass Analyzer (FMA)[6] located at the Argonne Tandem Linear Accelerator System (ATLAS) facility of Argonne National Laboratory (ANL). In this experiment, instead of the two-step procedure applied at Berkeley[2,3], the mass (A) and α-decay energies (E$_\alpha$) of the evaporation residues (ERs) were measured simultaneously. This was achieved using the mass-separation capability of FMA in conjunction with the focal plane decay station, consisting of silicon detectors arranged in a box configuration surrounded by five germanium clover detectors.

The aim of this experiment was to resolve the discrepancy and assign proper α-decay energies to the mass-identified isotopes of mendelevium, and to establish a production cross-section for the isotope of mendelevium in question. The first analysis of the experimental data indicates the occurrence of events at the utilized beam energy that correspond to the reported E$_\alpha$ of ^{245}Md [1]. In this contribution, the results from the experimental data analysis will be presented.

References

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16:30

14:00 **Tuesday 23 September** 14:00–16:30

Nuclear Structure, Spectroscopy and Dynamics: 9

Session | **Location:** MoHo, Inspire 3, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr John Frankland (IN2P3)

14:00–14:20 Scission Deformation of the 120Cd/132Sn Neutronless Fragmentation in 252Cf(sf)

Speaker

Alexis FRANCHETEAU

Description

The generation of the fission fragments spins is one of the least understood mechanism and its theoretical description has been subject to renewed interest following Wilson \textit{et al.} [Nature 590, 566 (2021)]. We report on a study of the radiative decay of fission fragments populated via neutronless fission of ^{252}Cf(sf). In such rare events the fragments are populated below their neutron separation energy, meaning that the radiative decay holds all the information on the generated angular momentum and excitation energy repartition of the fragments. Applying the double-energy method allows for a perfect mass identification of the neutronless fragmentations. In the case of the specific ^{120}Cd/^{132}Sn fragmentation, investigation of the coincident prompt γ-spectrum showed that ^{132}Sn was systematically populated in its ground state, hence the excitation energy is solely given to ^{120}Cd and can be measured. The reproduction of the coincident prompt γ-spectrum is sensitive to the angular momentum distribution of the studied primary fragment. The latter was estimated using a time-dependent collective Hamilton model [Phys. Rev. C 108, 034616 (2023)], allowing us to constrain for the first time the deformation ($\beta\simeq0.4$) of the studied fission fragment at scission.

14:40–15:00 Probing the fluctuation of fission observables

Speaker

David Regnier (CEA)

Description

The nuclear energy-density-functional (EDF) is a successful theoretical tool to describe many properties of a fissioning nucleus up to the generation of the primary fragments [1]. A core ingredient in the EDF-based many-body approaches is the Bogoliubov vacuum wavefunction. Expectation values of observables such as total binding energies or primary fragments mass are widely computed on Bogoliubov vacuua. On the other hand, only a few papers report the whole probability distributions of such observables. Recent studies involving their computation include efforts toward the prediction of the primary fragments number of protons and neutrons [2] and their spin distribution [3]. Yet the computational cost of such a task quickly becomes prohibitive.
In this presentation, I will present the development of a Monte-Carlo method to compute the whole probability distribution of some observables when the system of interest is described by a Bogoliubov vacuum. I will first show the algorithmic and numerical aspects of the method and then emphasize a first application to the fission of 252Cf. We will finally discuss the current limitations and future prospects of the method.

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15:00–15:20 Fission studies with the nu-Ball2 array

Speaker

Dr Jonathan Wilson (IJC Lab, Orsay, France)

Description

A series of recent experiments to perform high resolution gamma ray spectroscopy of nuclear fission have been carried out with the v-Ball2 spectrometer [1]. Nu-Ball2 is a state-of-the-art hybrid gamma-ray spectrometer that was developed and constructed at the ALTO facility of IJC Lab in Orsay. Several open questions are currently being addressed such as the evolution of evolution of fragment yield distributions in the sub-actinide region [2], the emission of high energy gamma rays in nuclear fission with potential population of collective excitations (PDR, GDR, etc.) in the emerging fragments [3]. The experiments have also explored other outstanding questions, such as the angular momentum carried away be neutron emission [4] and potential angular correlations between the spins of fission fragment partners [5]. Finally, the potential energy landscape before fission occurs can also be studied via gamma spectroscopy of fission shape isomers [6][7]. An overview of these new studies during the v-Ball2 experimental campaign will be given and selected results will be presented along with future perspectives.

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15:20–15:40 Probing the Fission Barrier of ^{230}Ac with the ISOLDE Solenoidal Spectrometer

Speaker

Maria Vittoria Managlia (Chalmers University of Technology)

Description

The study of nuclear fission remains a critical area of research, not only for understanding fundamental nuclear properties but also for its implications in the production of heavy elements in astrophysical environments. In r-process nucleosynthesis, fission barriers play a crucial role as they ultimately limit the mass of nuclei that can be produced. Currently, very limited data on fission barriers of neutron-rich nuclei are available. Moreover, studying fission barriers is essential for investigating the effects governing fission dynamics, such as shell structure and collective excitations.

At ISOLDE-CERN, the ISOLDE Solenoidal Spectrometer (ISS) is used to investigate the fission probabilities of neutron-rich actinides via (d,pF) reactions using Radioactive Ion Beams. This approach utilizes a novel setup designed to enhance the detection efficiency for fission fragments in coincidence with transfer-like protons in the 2T solenoidal field. This optimized method will provide access to fission barrier heights as a function of excitation energy. Additionally, complementary γ-ray measurements will offer insight into the total energy and multiplicity of γ-rays emitted during the fission process.

In this context, the first-ever measurement of the fission barrier of ^{230}Ac is being performed, further extending our understanding of fission in neutron-rich actinides.

In this contribution, this novel experimental setup will be presented, and the status of the experiment will be discussed, highlighting its potential for advancing our understanding of neutron-rich fission.
Beyond this study, the method can be extended to investigate even more exotic nuclei farther from the valley of stability, opening new opportunities to explore fission in regions of the nuclear chart that have so far remained experimentally inaccessible.

15:40–16:00 Fission dynamics Investigation using VAMOS++ spectrometer and Second Arm

Speaker

Indu Jangid (GANIL)

Description

The fission process is strongly determined by both the nuclear structure and the nuclear dynamics, which drives the system from its initial state to final break-up through various stages of extreme deformation. The resultant fission fragments, along with the neutron evaporation emerge as promising parameters for elucidating the underlying mechanisms governing the fission process. The VAMOS++ [1, 2] spectrometer is a large solid-angle, ray-tracing magnetic spectrometer, that benefits from inverse kinematics to provide complete isotopic identification of the fission fragments. Conversely, The FALSTAFF [3, 4] spectrometer, employing low-pressure gaseous detectors, is designed to provide constraining data from neutron-induced fission. An experiment was conducted at GANIL with VAMOS++ spectrometer in conjunction with the Second arm (Modified version of FALSTAFF for inverse kinematics) -- to simultaneously measure both fission fragments in coincidence. In this experiment, a 238U beam at coulomb energies was impinged on the beryllium (9Be) target to produce different fissioning systems via fusion and transfer reactions. This study accomplished full isotopic identification of fission fragments from Cm, Pu, and U fissioning systems, with the identification of fissioning systems based on coincident nuclear charge measurements from the two arms. The masses of the fragments before and after neutron evaporation, along with their kinetic energy and proton content, will be presented. Additionally, a comparison of the neutron excess across different isotopes of Cm will be discussed. These results will be compared with state-of-the-art fission models and analyzed in terms of fission modes and nuclear structure.

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16:00–16:20 Fission studies of ^{197}Tl

Speaker

Golda Komalan Satheedas (Inter-University Accelerator Centre, New Delhi, India)

Description

Asymmetric fission in mass pre-actinide region is a topic of current interest in fission studies. The important observation in this mass region is the asymmetric fission of neutron deficient nuclei. Andreyev et al. [1] have reported asymmetric fission fragment mass distribution in the β delayed fission of 180 Hg nucleus about a decade ago. The observed asymmetric mass distribution has been satisfactorily explained by the evolution of multi-dimensional potential energy surface as a function of time [2–4]. However the role of shell structure of the nascent fragments could not be well explained by the existing theoretical models. Further more the studies in this direction have revealed that the asymmetric fission in this mass region is not only governed by the N/Z and excitation energy of the fissioning nucleus but also on the dynamics of the entrance channel before forming the CN. It have also been observed that the presence of non-compound nuclear reactions cannot be ruled out at below barrier energies which also contribute to the wider mass distribution. The low excitation energy at which such phenomenon normally occurs is very difficult to achieve using heavy ion induced reactions. β delayed and electromagnetic induced fission [1] are the only ways to reach such low excitation energies experimentally. The difficulty in such reactions in the Mercury region and low statistics of the data obtained makes it difficult to get any conclusive statement regarding the occurrence of asymmetric mass fission and various factors that influences it. Nevertheless quite a few number of experiments have been carried out using heavy ion induced fusion reaction to produce neutron deficient nuclei in this mass region [5–7]. It has been observed that at very low excitation energies the measured fission fragment mass distribution could be explained only by evoking asymmetric fission mode along with symmetric fission mode. However it is not true for all the cases and considerable low statistics obtained in these measurements makes it difficult to draw a definite conclusion. In this scenario a systematic study of fragment mass distribution near the fission barrier is of utmost importance.

In order to understand the dynamical and entrance channel effects of this phenomenon, we have carried out studies on ^{197}Tl. ^{197}Tl is a potential candidate for looking for asymmetric fission and it was reported earlier that another isotope of Thallium, ^{201}Tl goes through the asymmetric fission path at lower excitation energies [8–10]. ^{197}Tl was populated through two reactions (^{16}O + ^{181}Ta and ^{19}F + ^{178}Hf) which are lying on either side of Businnaro-Gallone critical mass asymmetry. The study was carried out at the reduced beam energies in the range of 0.85 to 1.15. The fission fragment mass distribution, mass-angle correlation and total kinetic energy distribution were measured and these are considered as reliable probes to study the dynamics of heavy-ion induced fission reactions. It was observed that the width of the FF mass distribution measured agreed with the theoretical predictions based on standard saddle point model till near Coulomb barrier and was found to the slightly higher than theoretical predictions, when the excitation energy is further reduced. The broadening of the mass distribution can also be an indication of quasi-fission especially at below Coulomb barrier. However, the mass-angle correlations does not show any asymmetry with respect to 90 degree in the centre of mass and this indicates absence of quasi-fission. The results of the this study will be presented in detail in the conference.

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16:30

16:35

17:00

Tuesday 23 September

16:35–17:00

Coffee Break

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

17:00 **Tuesday 23 September** 17:00–19:35

Accelerators and Instrumentation: 4

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Marek Lewitowicz (GANIL)

17:00–17:20 The ALTO research platform of IJCLab

Speaker

Dr Enrique Minaya Ramirez (IJCLab)

Description

ALTO (Accélérateur Linéaire et Tandem à Orsay) is the two-accelerator research platform of IJCLab (alto.ijclab.in2p3.fr). The first is a 15 MV Tandem accelerator which produces a wide range of heavy ion beams, from proton up to gold. ALTO is also unique in its capacity to provide high-flux naturally directional neutron beams with the LICORNE neutron converter in inverse kinematics. The second machine is a Linear accelerator (LINAC) for electrons up to 50 MeV 10µA that bombard an uranium carbide target as a driver to produce neutron-rich radioactive beams via the photo-fission process. With the delivery of a broad range stable and radioactive beams, its 10 beam lines and experimental halls equipped with diverse instrumentation, spectrometers and detectors, a wide-ranging research if available at ALTO from the study of the fundamental properties of nuclei, key processes for nuclear astrophysics, interaction of ions with matter to the developments in dosimetry and radiobiology. Several projects carried out at ALTO, such as the laser spectroscopy, ion trapping will be pursued at GANIL in the future low energy experimental hall DESIR. The general characteristic of the current development, SPACE ALTO, to increase the added value of ALTO for industrials will be described. And a brief description of the ALTO facility as well as some of the latest results and on-going research program will be presented.

17:20–17:40 Facile production of atomic and molecular actinide ions

Speaker

Jonas Stricker (JGU / HIM Mainz)

Description

J. Stricker(1, 2), K. Gaul(1,2), L. M. Arndt(1), Ch. E. Duellmann(1, 2, 3), D. Renisch(1,2), J. Velten(1) and the TACTICa Collaboration(1, 2, 3). (1) Johannes Gutenberg-University Mainz, 55099 Mainz, Germany. (2) Helmholtz Institute Mainz, 55099 Mainz, Germany. (3) GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany.

Trapped atomic and molecular actinide ions are considered to be ideal for a variety of fundamental physics experiments designed to explore physics beyond the standard model [1]. Molecular actinide ions with one unpaired electron are promising probes of fundamental physics, for example in the search of parity and time-reversal symmetry violations [1]. These molecules can also be used as quantum sensors in the search for ultra-light bosonic dark matter [2].

Laser ablation is one of the most common ion-production methods. We report on the production of ions of thorium- and uranium-containing species in different charge states by laser ablation using a modified commercial ion gun. The produced ions are extracted and analyzed by a time-of-flight mass spectrometer. The modularity of the setup facilitates easy coupling with ion traps, where it is possible to investigate trapped actinide ions of interest using precise spectroscopy. This approach allows us to study signatures that may hint at novel physics. We performed a systematic study on the dependence of the generated ion species, ranging from atomic to tetratomic actinide ions. For this purpose, different chemical actinide compounds were used as target materials for laser ablation in combination with specific laser ablation fluences.
Our systematic approach enables a selective production of tailored actinide ion species. We successfully generated thorium fluoride ions (ThF$_x$$^{n+}$, where x = 0–3, n = 1–3) [3] and uranium oxide ions (UO$_x$$^{n+}$, where x = 0–1, n = 1–4) [4]. Of these molecular ions, the species with a single unpaired electron (ThF^{2+}, UO^{3+}) or closed electronic shells (ThF^3$^+$, UO^4$^+$) may be particularly interesting for precision spectroscopy and tests of fundamental physics.

We will apply this method to produce oxides and fluorides of further actinides in the future. Once coupled to an ion trap we will focus on the investigation of physics beyond the standard model with the produced ions using precision laser spectroscopy.

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17:40–18:05 The ISOLDE Decay Station: current status and perspectives

Speaker

James Cubiss (University of Edinburgh)

Description

The ISOLDE Decay Station (IDS) [1] is a permanent experiment at CERN's ISOLDE facility. The device provides a versatile and flexible tool for studying the wide range of radioactive beams available at the laboratory, and consists of a recently upgraded array of clover detectors surrounding a movable tape system. This core setup is complemented by arrays of ancillary detector for charged particle (silicon, DSSDs, plastic scintillators), neutron (INDiE and OGS) and fast-timing (LaBr:Ce and plastic scintillators) measurements. In this contribution an overview of the setup with recent highlights from the collaboration will be given, along with plans for the future.

References
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18:05–18:25 SIRIUS (Spectroscopy and Identification of Rare Isotopes Using S3) at GANIL

Speaker
Armand BAHINI (GANIL)

Description

The stability of nuclei beyond the spherical double shell closure of ^{208}Pb rapidly decreases because of the disappearance of the macroscopic fission barrier. This phenomenon is however compensated by quantum shell effects caused by alternating zones of high and low densities caused by deformation. The island of superheavy stability is foreseen as a doubly spherical gap whose position varies depending on the model used. Spectroscopy in the region of high masses is very close to the limits of the existing detection systems. The extension of the investigation on nuclear structure to heavier nuclei is governed by an improvement in the efficiency of the transport and selection of the nuclei of interest as well as in the detection systems. The very high intensity beams provided by the NEW GAnil INjector (NEWGAIN) and the LINear ACcelerator (LINAC), combined with the high transmission and selection power of the Super Separator Spectrometer (S^3) will offer unprecedented production rates of nuclei in the picoobarns region.

SIRIUS (Spectroscopy and Identification of Rare Isotopes Using S^3) will be the detection system dedicated to spectroscopy experiments for superheavy nuclei with S^3. SIRIUS consists of five segmented silicon detectors optimized for precision spectroscopy of alpha, beta and fission decay, surrounded by five EXOGAM high-purity germanium detectors for gamma-rays, and a Secondary Emission Detector (SED) placed upstream to track the ions and measure their time of flight. The conjunction of these detectors with the mass resolving power and the transmission of S^3 will make it a unique instrument for the study of superheavy nuclei.

In this contribution, after a brief review of the current status of S^3, we will report on the offline tests of SIRIUS and the performances of its detectors.

18:25–18:45 Results in the characterization of SiC-based devices for radioactive ion beams detection

Speaker
Nunzia Simona Martorana (INFN-Sezione di Catania)

Description

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This contribution discusses the characterization of new-generation Silicon Carbide (SiC) detectors, which are increasingly recognized as an excellent choice for charged particle detection in both medical applications and nuclear physics research [1-7]. Leveraging the SAMOTHRACE ecosystem [8], a SiC detector array is currently being developed for the detection of Radioactive Ion Beams (RIBs) - a cutting-edge tool in both medical and nuclear physics fields [3,6,7]. The array in development, integrated with a fast front end electronics [9-10], is designed to be compact, versatile, and capable of delivering detailed information on RIBs, specifically those produced via the in-flight technique [3]. An important feature of this detection system is its high timing performance, which enhances experimental studies involving RIBs. The results focus on evaluating the energy resolution and timing performances of SiC detectors, composed of 2x2 pixels, with a total surface of 1 cm2 and a thickness of 100 µm. Measurements have been conducted using radioactive α sources as well as accelerated proton and α beams. Furthermore, a new method based on the crossing time and signal-sharing analyses has been employed to determine the time resolution of individual SiC pixels. Additionally, a comparative analysis of the timing resolution achieved using a micro-channel plate detector in coincidence with the SiC will be presented.

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18:45–19:05 Study of superheavy nuclei with S3

Speaker
Julien PIOT (GANIL)

Description

The study of superheavy nuclei has progressed in the last decade with new techniques. In addition to the findings of decay spectroscopy studies [1], the measurement of masses [2] and charge radii [3] have become possible in the fermium-nobelium region, providing new information necessary for the comprehension of the heaviest nuclei. In parallel, a strong international competition is ongoing to produce elements 119 and 120.

However, spectroscopy in the region of high masses is still very close to the limits of the existing detection systems. The isotopes investigated are still the same since the beginning of the investigation of 254No. In order to extend the study to higher Z and A, increasing the production and detection rates of transfermium isotopes, the efficiency of the separator and detection instrumentation must be improved.

This is the goal of the Super Separator Spectrometer S3 [4]. It is currently under completion at the LINAC of SPIRAL2. The LINAC will provide very high intensity stable beams with its upcoming injector NEWGAIN [4], and S3 is designed to efficiently use these beams. Its mass resolving power associated with a high transmission make it a unique tool for identification and decay spectroscopy of superheavy nuclei. The increased sensitivity will allow to study single particle excited states in heavier nuclei, closer to the limits in mass.

This contribution will develop the physics program envisaged for the study of superheavy nuclei at S3 its various instruments, coming online in the next years. An update on the actual status of S3 and its detection instrumentation will be given.

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19:35

17:00 **Tuesday 23 September** 17:00–19:40

Fundamental Symmetries and Interactions: 2

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

17:00–17:20 Latest results from the CUORE experiment

Speaker

Dr Irene Nutini (INFN)

Description

The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has successfully reached the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO$_2$ crystals arranged in a compact cylindrical structure of 19 towers. CUORE has been collecting data continuously at ~10 mK since 2017, achieving a 90% uptime and amassing over 2.5 tonne-years of TeO$_2$ exposure. In March 2024 the collaboration released the most recent result of the search for 0νββ, corresponding to two tonne-year TeO$_2$ exposure. This is the largest amount of data ever acquired with a solid state cryogenic detector, which allows for further improvement in the CUORE sensitivity. In this talk, we will present the current status of the CUORE search for 0νββ with the updated statistics of two tonne yr exposure and further updated results including the CUORE background model, enabling a precision measurement of the ^{130}Te 2νββ decay half-life.

17:20–17:40 The LEGEND Program to Search for Neutrinoless Double Beta Decay

Speaker

Alexander Leder (Los Alamos National Laboratory)

Description

The observation of neutrinoless double beta (0$\nu\beta\beta$) decay would have profound implications on the field of neutrino physics, giving key insights into multiple questions simultaneously. It would prove the existence of a lepton number violating process, determining if neutrinos are Majorana particles as well as constraining the overall mass hierarchy and the absolute mass scale of the neutrino. The multiphase LEGEND (Large Enriched Germanium Detector for Neutrinoless $\beta\beta$ Decay) suite of experiments seeks to build upon the previous successes of the GERDA and MAJORANA 0$\nu\beta\beta$ search experiments to fully span the inverted neutrino mass ordering region. In the first phase, LEGEND-200, has already deployed 142 kg of enriched germanium detectors working towards deploying 200 kg with a total exposure of 1 tonne year and a background index of $\approx 10^{-4}$ cts/(keV*kg*year) with the aim of reaching a 0$\nu\beta\beta$ half-life sensitivity of 10^{27} years at 90% CL. In the following phase, LEGEND-1000, the enriched germanium mass will be increased to 1000 kg, with a background index of $\approx 10^{-5}$ cts/(keV*kg*year) and an exposure of 10 tonne-years, allowing for a projected 3σ half-life discovery sensitivity of 1.3*10^{28} years. In this talk, we will present the current operation status and an overview of the ongoing LEGEND-200 0$\nu\beta\beta$ search results as well discussing the road ahead for the LEGEND-1000 0$\nu\beta\beta$ experiment.

This work is supported by the U.S. DOE and the NSF, the LANL, ORNL and LBNL LDRD programs; the European ERC and Horizon programs; the German DFG, BMBF, and MPG; the Italian INFN; the Polish NCN and MNiSW; the Czech MEYS; the Slovak RDA; the Swiss SNF; the UK STFC; the Canadian NSERC and CFI; the LNGS and SURF facilities.

17:40–18:00 Ultra-low Q$_\beta$ value for the allowed decay of ^{110}Ag^m confirmed via mass measurements

Speaker

Jouni Ruotsalainen (University of Jyväskylä)

Description

The existence of the three flavours of neutrinos, electron, muon and tau neutrino, predicted by the Standard Model of particle physics has been experimentally proven decades ago. Contrary to the Standard Model however, neutrino oscillation experiments [1] have shown that they are massive particles, making neutrino mass measurements a gateway to physics beyond the Standard Model. As these experiments can only determine the squared mass difference of the flavours, the absolute mass has to be determined through other means, such as studying the kinematics of β-decay reaction products. As per $E=mc^2$, some energy released in the decay (Q-value) is transformed into the (anti-)neutrino created in the decay, and thus the mass of the neutrino can be determined from the difference between the energy left with the other decay products and the Q-value of the decay, as the neutrino is unlikely to interact with the detector. Since the mass is expected to be minuscule, the difference is easier to observe in a decay with ultra-low Q-value ($<$ 1 keV).

In our work [2], we have determined the Q-value of the β^- decay of the 117.59 keV isomer of ^{110}Ag into the excited state at 3008.41 keV in ^{110}Cd. This determination was done by combining our precise Penning trap measurement of the mass difference of ^{110}Cd and ^{109}Ag with previously published measurements of ^{109}Ag(n,γ)^{110}Ag [3] and the excitation energies [4]. The obtained Q-value of 405(135) eV is notable. It is the lowest measured Q value for an allowed transition and, as such, is an excellent candidate for an experiment searching for the neutrino mass. In addition, the partial half-life and the branching ratio of this transition were calculated. In my contribution, I will present the JYFLTRAP double Penning trap [5] measurement setup at the IGISOL facility [6] at the University of Jyväskylä, and the results of our measurement.

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18:00–18:20 Emerging quantum sensing technology for new physics searches

Speaker

Leendert HAYEN (LPC Caen)

Description

The advent of novel cryogenic sensors is opening up new paths in the search for Beyond Standard Model physics, promising to shed light on open questions such as the neutrino mass scale and even fundamental aspects of quantum mechanics. Searches in nuclear beta decays are at the forefront of new physics searches in the electroweak sector, and several efforts are currently ongoing to take advantage of new detection capabilities. Recently, the BeEST experiment demonstrated direct spectroscopy of recoiling 7Li nucleus after electron capture in 7Be with eV-scale resolution using superconducting tunnel junction detectors, constraining sterile neutrino searches [1] and the wave packet size of the emitted neutrino [2]. We will present these results and highlight current efforts to significantly expand the reach of these emerging technologies, focusing on their deployment at radioactive ion beam facilities with the SALER (FRIB) and ASGARD (GANIL) experiments.

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18:20–18:40 Precision measurements in superallowed 0+ → 0+ β decays at GANIL and upcoming opportunities

Speaker

Dr Bernadette Rebeiro (GANIL)

Description

Corrected transition rates ($\mathcal{F}t^{0^+ \to 0^+}$ values) of superallowed $0^+ \to 0^+$ beta decays have served as a benchmark for validating the conserved vector current (CVC) hypothesis in weak interactions. They now provide the most precise value of V_{ud}, the dominant top-row element of the Cabibbo-Kobayashi-Maskawa (CKM) quark mixing matrix. By imposing stringent constrains on the CKM unitarity, these decays enable probing physics beyond the Standard Model in the electroweak sector. Recent reevaluation of the superallowed $\mathcal{F}t^{0^+ \to 0^+}$ values have resulted in a value of V_{ud} that challenges the unitarity of the CKM matrix.

In this presentation, I will briefly discuss this current situation and the experimental program at GANIL, which aims to constrain isospin symmetry-breaking (ISB) corrections. Together with radiative corrections, this allows to extract nuclear medium-independent $\mathcal{F}t^{0^+ \to 0^+}$ values from the experimentally measured transition rates ($ft^{0^+ \to 0^+}$). In this context, I will also present preliminary results for the SA emitters ^{18}Ne and ^{30}S. Finally, I will highlight the opportunities available for high-precision measurements of these SA observables at DESIR and S^3-LEB, the upcoming low-energy radioactive ion beam facilities at GANIL.

18:40–19:00 Nuclear radii and V_{ud}

Speaker

Dr Mikhail Gorshteyn (Universität Mainz)

Description

Tests of CKM unitarity are a rigorous tool for constraining possible extensions of the Standard Model. The top-row CKM unitarity test--at the current precision level, a simpler two-flavor Cabibbo unitarity--relies on a combination of kaon, neutron and superallowed nuclear decays. The latter presently give the most precise value of V_{ud} and lead to an apparent 2-3σ unitarity deficit. Recent developments in the theory of superallowed nuclear β decays regarded the interplay of precise nuclear radii with V_{ud}. This connection involves Coulomb corrections, the isospin-breaking correction δ_C and nuclear structure corrections: δ_{NS} to β decay rates and nuclear polarization correction to charge radii in muonic atoms.

19:00–19:20

Reviving muonic atom spectroscopy to extract absolute nuclear charge radii in rare and radioactive targets

Speaker

Stergiani Marina Vogiatzi (KU Leuven)

Description

The knowledge of absolute nuclear charge radii has a significant scientific impact, from testing nuclear theories to beyond standard model physics. The absolute charge radii of almost all stable isotopes were extracted till the late 1990s, using the muonic atom spectroscopy method. In this method, a negatively charged muon beam is shot on target, the muon stops and is captured at a high principle quantum number. From there on, the muon will cascade down to the ground state of the atom, emitting muonic x rays at the later stage of the cascade. Due to the heavy mass of the muon, there is a large overlap between the low-lying muonic states and the nuclear charge distribution making the muonic 2p-1s x rays highly sensitive to the nuclear properties, such as the charge radius. However, to stop and capture the muon directly in the target, tenths to hundreds of milligrams of target material are typically needed, limiting past muonic measurements to stable or abundant targets. Since then, we have developed a method in which muon captures in microgram targets are realized through subsequent transfers of the muon in a high pressure $\mathrm{H_2/D_2}$ gas, and thus we have extended the muonic measurements to radioactive and rare isotopes across the nuclear chart. In this contribution, an overview of the experiment and the current stage of charge radii extraction of isotopes spanning from Si to Cm will be discussed, highlighting the experimental and theoretical principles and challenges in that process.

19:20–19:40

Testing fundamental symmetries in hyperon decays with BESIII

Speaker

Prof. Karin Schoenning (Uppsala Universitet)

Description

Decays of spin-polarised and quantum-entangled hyperon-antihyperon pairs have recently presented themselves as promising hunting grounds for processes that violate fundamental symmetries, such as charge conjugation (C) and charge conjugation and parity (CP). When hyperons are produced in electron-positron annihilations, the quantum numbers of the initial state are well-known. This enables a full spin decomposition of the multi-step decay process from which we can construct precise symmetry tests. In particular, sequential decays of multi-strange hyperons allow for a separation of strong and weak amplitudes, resulting in a better sensitivity to CP violation.

The world-record sample of 10^10 J/Psi from the Beijing Spectrometer (BESIII) provides a unique source of almost background-free
hyperon-antihyperon pairs. From this, several stringent symmetry tests in hyperon decays have emerged. In this talk, I will present an overview of BESIII hyperon decay studies, with focus on recent results.

19:40

17:00 **Tuesday 23 September** 17:00–19:30

Hadron Structure, Spectroscopy and Dynamics: 3

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Adam HOBALLAH (IJCLab CNRS-IN2P3)

17:00–17:25 Timelike Form Factors of Baryons

Speaker

Weiping Wang (JGU Mainz)

Description

The electromagnetic structure of baryons, parametrized in terms of electromagnetic form factors (EMFFs), provides a key to understanding quantum chromodynamics effects in bound states. While spacelike form factors for the proton and neutron are accessible through the elastic electron scattering, the most viable option for unstable hadrons is the timelike EMFFs. Recently, precise measurements of pair production of proton, neutron, strange and charmed hyperons in the annihilation of electron and positron has brought renewed insights into the electromagnetic structure of the baryons. In this talk, I will introduce you the latest experimental results on the study of baryon EMFFs and discuss the possible theoretic interpretations for the non-trivial properties of the baryon EMFFs.

17:25–17:50 Status of TMD studies at CLAS12

Speaker

Timothy Hayward (MIT)

Description

The status of several CLAS12 semi-inclusive deep inelastic scattering measurements sensitive to TMDs, including several new results from a 10.5 GeV longitudinally polarized electron beam incident on a longitudinally polarized target, will be discussed. These measurements will be placed into context of the global study of TMDs with a particular focus on areas where CLAS12 and other fixed target experiments may be in friction with phenomenology, including effects from longitudinally polarized virtual photons, current vs target fragmentation and the contribution of diffractive vector mesons.

17:50–18:10 Nucleon resonance studies from KY electroproduction at CLAS12

Speaker

Lucilla Lanza (University of Rome Tor Vergata)

Description

An experimental program has been approved at the Thomas Jefferson National Accelerator Facility to measure the (ep,e'K+)Y reactions to study the spectrum and structure of excited nucleon states. New data from CLAS12 on πN, $\pi\pi N$, and KY electroproduction have been obtained using electron beams with energies of 6.5 and 7.5 impinging upon a liquid hydrogen target. Scattered electrons have been detected in a polar angle range of 2.5° to 4.5° by the Forward Tagger (FT) and at angles greater than 6° in the CLAS12 Forward Detector, allowing to measure the KY electro-production differential cross section and to probe the Q2 evolution of the nucleon resonances electro-couplings in the Q2 range from 0.05 GeV2 to 3 GeV2. The Q2 dependence of excited baryons electro-couplings allows to probe the dressed quark mass over the full range of distances where the dominant part of hadron mass emerges from QCD. By studying the Q2 evolution of electroexcitation amplitudes it will be also possible to distinguish between regular N states and possible additional hybrid baryon states in the mass range of 2.0 GeV < W < 2.5 GeV where the lightest hybrid baryons are expected to be located based on LQCD studies of the N* spectrum. This presentation will report results from ongoing analyses for KY electroproduction and prospects for future studies will be discussed.

18:10–18:30 Improved dispersion relation and extraction of the D-term

Speaker

Victor Martinez-Fernandez (Institute for Research on the Fundamental Laws of the Universe (IRFU/CEA))

Description

Quantum Chromodynamics (QCD) is the theoretical framework to study hadrons by means of their fundamental degrees of freedom, i.e. quarks and gluons, collectively referred to as partons. QCD defines many types of distributions describing a given hadron in terms of partons. For the purposes of this talk, we are interested in the so-called generalized parton distributions (GPDs) which are off-forward matrix elements of quark and gluon operators. These ones are typically accessed in exclusive Compton scattering and parameterized by 2 functions named *double distributions*: $F(\beta,\alpha,t)$ and $D(\alpha,t)$ (the D-term). The latter is of special interest in hadron physics as it is connected to the internal distribution of pressure in the hadron through its connection to the gravitational form factor (GFF) C.

Convolutions of GPDs with coefficient functions describing the interaction of photons with the partons in the hadron are named Compton form factors (CFFs). Real and imaginary parts of CFFs are related by "subtracted" dispersion relations, i.e. the difference between the real and imaginary parts is given by a constant. At leading twist ($|t|/Q^2\to 0$), this subtraction constant is solely given by the D-term. In this talk, we will show how the inclusion of kinematic twist corrections makes the subtraction constant to be dependent on the other double distribution, $F(\beta,\alpha,t)$, affecting the determination of the D-term from data on CFFs. We will present an extraction of the D-term at different accuracies describing the impact of different types of corrections.

18:30–18:50 **Deeply Virtual Compton Scattering measurements with $e\gamma$ detection @ CLAS12**

Speaker

Mr Juan Sebastian ALVARADO (Université Paris-Saclay - IJCLab)

Description

Generalized Parton Distributions (GPDs) are probability functions describing spatial and momentum distributions of partons in nucleon structure studies. They are crucial for understanding the correlation between the longitudinal momentum and the transverse position of partons inside the nucleon. The Deeply Virtual Compton Scattering (DVCS) is a privileged channel for GPD studies, as chiral-even GPDs can be accessed through spin-dependent asymmetries. Although detecting all final state particles is preferred for selecting DVCS events, DVCS identification only requires the detection of two final state particles, given the missing particle reconstructed from conservation laws. In this work, we present new Beam Spin Asymmetry and preliminary cross-section measurements of proton-DVCS in the topology from experimental data taken by the CLAS12 detector at Jefferson Lab. We show that Machine Learning techniques allow a suitable channel selection in the final state, boosting statistics and giving access to a larger phase space than the proton-detected topology.

18:50–19:10 **The bound-state of a phi-meson (ϕ) and three nucleons (NNN)**

Speaker

Dr Shalva Tsiklauri (The City University of New York-BMCC)

Description

The four-body Schrödinger equations in momentum representation are solved to investigate the bound-state solutions for a system consisting of a phi-meson (ϕ) and three nucleons (NNN). The analysis uses a new spin-3/2 N−ϕ potential derived from lattice QCD simulations near the physical point and the realistic NN Malfliet-Tjon (MT) potential. Our numerical calculations for the ϕppn system in maximum spin result in a ground state binding energy of approximately 12 MeV. These findings indicate the potential for the formation of novel nuclear clusters.

19:30

17:00

Tuesday 23 September 17:00–19:00

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 4

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Dr Marco Salvatore Maria La Cognata (INFN)

17:00–17:20

Measurements of hadron production in LHCb and their impact on modeling of extensive air showers

Speaker
felix riehn (TU Dortmund)

Description

The LHCb experiment at CERN employs a general-purpose forward spectrometer designed to study heavy flavour physics at the LHC. The acceptance of the spectrometer covers the pseudorapidity range $2 < \eta < 5$ and provides full tracking and particle identification down to very small transverse momenta. This makes LHCb also ideal to study hadronic interactions similar to those that occur in extensive air showers initiated by cosmic rays. In addition, the operation of the LHC with oxygen beams this summer will for the first time allow us to probe the exact conditions of the interactions in air showers. In this contribution I will summarize measurements of hadronic particle production done at LHCb, discuss their implication for models of interactions in air showers and which measurements should be performed in the future to provide better constraints.

17:20–17:40

Measurements of the $^{14, 15}$N(α, γ)$^{18, 19}$F reactions and prospect for other helium burning studies at Felsenkeller lab

Speaker
Eliana Masha

Description

Helium burning is a crucial phase for stellar evolution, playing a key role in the production of elements like carbon, oxygen, and fluorine, which significantly impact the chemical evolution of the Universe.
Precise measurements of nuclear reaction rates at helium-burning astrophysical energies are challenging and essential for constraining stellar models and understanding nucleosynthesis pathways. We report on new measurements of the ^{14}N(α,γ)^{18}F and ^{15}N(α,γ)^{19}F reactions, performed at the Felsenkeller 5 MV accelerator laboratory in Dresden, Germany. These reactions contribute to fluorine production, an element whose origin remains a long-standing puzzle in nuclear astrophysics. Details on the experimental setup, preliminary results, and future plans for studying other key helium-burning reactions will be presented.

17:40–18:00

Direct measurement of 12C+12C at LUNA

Speaker
Gianluca Imbriani (university of Naples Federico II)

Description

Carbon burning is the third stage of stellar evolution, influencing the fate of both massive stars and low-mass stars in binary systems.
Stellar carbon burning primarily occurs through the 12C(12C, α)20Ne and 12C(12C, p)23Na reactions. While these reactions have been studied over a wide energy range, direct measurements below 2.1 MeV (the astrophysical range) are lacking. Indirect data, such as those from the Trojan Horse approach, are available at astrophysical energies but carry uncertainties in renormalization. Thus, direct measurements are crucial for stellar evolution models and interpreting indirect results.
Currently, the LUNA collaboration is conducting direct studies at the Bellotti ion beam facility in the Laboratori Nazionali del Gran Sasso (LNGS), Italy, using intense carbon beams with excellent energy resolution. The goal is to directly measure the 12C+12C cross-section at astrophysical energies using γ-ray spectroscopy. The detection setup includes NaI scintillators surrounding a 150% HPGe detector ensuring high efficiency and preserving HPGe resolution (1.2 keV at 1.33 MeV). The NaI array also acts as a veto for background radiation. The detectors are shielded with 2 cm of copper and 25 cm of lead to reduce environmental background by over two orders of magnitude.
This setup will achieve unprecedented sensitivity, with an expected background four orders of magnitude lower than previous direct measurements at low energies. It will also allow exploration of the 24Mg level density through de-excitation of 20Ne and 23Na nuclei, potentially revealing cluster structures in the 24Mg nucleus. In particular, we will focus on the 1.5-3.5 MeV energy range (15.44 MeV to 17.94 MeV in the Q-value window), where cluster states might influence the 12C+12C reaction rate.
I will present recent developments in the setup, including simulations and detailed characterization of the HPGe detector's active volume, as well as preliminary results from beam-on-target tests for target characterization, detector efficiency, and 12C+12C measurements at higher energies (Ep > 2 MeV).

18:00–18:20

Investigating Δ-Resonances in Neutron Stars: Insights from Nuclear and Astrophysical Observations

Speaker
Vivek Baruah Thapa (Bhawanipur Anchalik College, Assam, India)

Description

This work conducts a thorough Bayesian analysis of neutron star matter, incorporating (Δ)-resonances alongside hyperons and nucleons within a density-dependent relativistic hadron (DDRH) model. By leveraging constraints from nuclear saturation properties, chiral effective field theory (χEFT), NICER radius measurements, and tidal deformability data from GW170817, we systematically examine the role of $(\Delta$)-resonances in shaping the equation of state (EoS) and neutron star observables. Our findings indicate that while (Δ)-baryons soften the EoS at lower densities, they ensure sufficient stiffness at higher densities to sustain neutron stars with masses up to $(2M_{\odot})$. This provides a natural resolution to neutron star radius constraints and aligns well with the observed low-mass compact object in HESS J1731-347 while remaining consistent with GW170817 tidal deformability limits. Furthermore, we find that (Δ)-resonances preferentially populate the outer core of neutron stars, potentially influencing neutron star merger dynamics. Their presence could also play a significant role in neutron star cooling through the direct Urca process. Additionally, we explore quasi-normal (f)-mode oscillations within a fully relativistic framework, uncovering strong correlations between the (f)-mode frequency, neutron star compactness, and tidal deformability. By incorporating (Δ)-resonances and adhering to astrophysical constraints, we determine $(f_{1.4} = 1.97^{+0.17}_{-0.22})$ KHz and a damping time of $(\tau_{f_{1.4}} = 0.19^{+0.05}_{-0.03})$ s at the (1σ) confidence level.

18:20–18:40 Understanding 26Al production in classical novae: search for new states in 26Si

Speaker

Ignasio WAKUDYANAYE

Description

The 25Al(p, γ)26Si reaction plays a crucial role in the production of the 26Al radioisotope in the Galaxy. To accurately model the thermonuclear reaction rates for the production of 26Al in astrophysical environments, spectroscopic information about the nature of the states (Iπ , Ex ,..) close to the proton threshold is needed. Theoretical calculations predict three resonances in 26Si with Iπ = 3+, Iπ = 1+ and Iπ = 0+, lying close to the proton threshold that dominate the reaction rate. An experiment using the 24Mg(3He, nγ)26Si reaction at a beam energy of 7.9 MeV was conducted. Neutron-gamma coincidence measurements were performed using the EDEN Array for the neutrons and Germanium detectors for the gamma-rays. States lying close to the proton threshold were populated. I'm going to present the first results of my analysis.

18:40–19:00 Gamow Shell Model description of near-threshold resonances in 11C

Speaker

Alan Cruz Dassie (Grand Accélérateur National d'Ions Lourds (GANIL), CEA/DSM - CNRS/IN2P3, BP 55027, F-14000 Caen, France)

Description

The Carbon-11 nucleus plays an important role in first start nucleosynthesis patterns [1] as a composite of the reaction $^{10}\mathrm{B}(p,\alpha)^{7}\mathrm{Be}$, which act in the hot pp-chains [2] by back processing material branching across the mass $A = 5$ and $A = 8$ mass gap towards $^{10}\mathrm{B}$. The $^{11}\mathrm{C}$ resonances $J^\pi = 5/2^+_2$ and $J^\pi = 7/2^+_1$, 10 keV above and 40 keV below the proton-threshold [3,4], respectively, may impact on the $^{10}\mathrm{B}(p,\alpha)^{7}\mathrm{Be}$ reaction. A shell-model embed in the continuum analysis [5] found that the strong coupling to the one-proton channel $\left[^{10}\mathrm{B}(3^+)\otimes p(lj)\right]^{J^+}$ changes their structure significantly.

To deepen the theoretical analysis, we propose the Gamow shell model (GSM) [6,7] approach. GSM offers a unifying framework with the open quantum system formulation thanks to couplings between discrete and scattering states, as it makes use of the Berggren ensemble [8] of single-particle states. In order describe the scattering properties and reactions, we formulate the GSM in the couple-channel representation (GSM-CC) [9]. Then, the Hamiltonian matrix becomes complex symmetric since the resonances are calculated using the Berggren basis.

Using different mass partitions in the coupled-channel representation, we applied the GSM-CC to reproduce the energies and widths of the $^{11}\mathrm{C}$ excited states above the alpha-threshold. We were able to identify how the excited channel of $\left[^{10}\mathrm{B}\otimes p\right]^{J^+}$ and the presence of the alpha-channels affects the near threshold resonances. Furthermore, we applied the GSM-CC to describe the cross-sections of different types of elastic ($^{10}\mathrm{B}(p,p)^{10}\mathrm{B}$, $^{11}\mathrm{C}(\alpha,\alpha)^{11}\mathrm{C}$), radiative capture ($^{10}\mathrm{B}(p,\gamma)^{11}\mathrm{C}$, $^{7}\mathrm{Be}(\alpha,\gamma)^{11}\mathrm{C}$) and transfer ($^{10}\mathrm{B}(p,\alpha)^{7}\mathrm{Be}$) reactions.

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19:00

17:00 **Tuesday 23 September** 17:00–19:10

Nuclear Physics Applications: 3

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

17:00–17:25 Recent Advances in Hadron Therapy

Speaker

Charlot Vandevoorde (GSI Helmholtz Center for Heavy Ion Research)

Description

Recent advances in hadron therapy, particularly proton and carbon ion therapy, are reshaping the landscape of cancer treatment by offering increased precision, reduced toxicity, and expanded clinical indications. Technological innovations in beam delivery systems, adaptive treatment planning, and real-time imaging have significantly enhanced dose conformality while minimizing exposure to surrounding healthy tissue. These developments are particularly impactful for treating tumours in complex anatomical regions or radioresistant cancers, where conventional X-ray therapy often falls short. The emergence of compact and cost-effective facility designs is addressing long-standing concerns about infrastructure complexity and expense, making hadron therapy more accessible. Furthermore, accelerator-driven Boron Neutron Capture Therapy (BNCT) is re-emerging as a promising modality, benefiting from advancements in accelerator technology and boron compound development.
Another innovative frontier is FLASH therapy, an experimental but highly promising technique in hadron therapy involving ultra-high dose rate irradiation, which has shown potential to reduce normal tissue toxicity while maintaining tumour control in preclinical settings. High-intensity particle beams, essential for translating FLASH into clinical hadron therapy, are driving the next generation of facility designs. Looking further ahead, the promising results of preclinical research in radioactive ion beams, mini-beam therapy, and alternative ion species (beyond protons and carbon) is opening new avenues for optimizing the precision and biological effectiveness of hadron therapy.
Beyond physics and engineering, biology is poised to drive the next leap in hadron therapy. The generation of complex DNA damage by high linear energy transfer (LET) particles is linked to the accumulation of cytosolic DNA, which in turn activates innate immune responses. This raises the prospect of synergistic effects between hadron therapy and immunotherapy. In parallel, insights into DNA repair pathway choice are revealing promising biomarkers for treatment selection and novel targets for radiosensitization. As these multidisciplinary advances converge, hadron therapy is transitioning from a niche modality to a cornerstone of precision oncology.

17:25–17:45 Dosimetry and cellular mechanisms of carbon ion FLASH irradiations

Speaker

Mateusz Sitarz (CIMAP, GANIL)

Description

Introduction
Conventional radiotherapy (CONV) delivers a radiation treatment dose in order of minutes, resulting in dose rate of about 2 Gy/min. However, multiple recent preclinical studies demonstrated substantial healthy tissue sparing effect if the ultra-high dose rate, FLASH (> 40 Gy/s), is employed instead. At the same time, radiobiological effect on tumor remains unchanged. However, precise explanation of FLASH effect is still unclear, and dose measurements at high beam currents remains challenging.
The aims of this study are therefore to develop a reliable dosimetry setup and employ it to investigate cellular mechanisms involved in FLASH effect during irradiations with carbon ions. Carbon ions are gaining interest in radiotherapy as they offer superior treatment possibilities and a wide range of Linear Energy Transfer (LET) suitable for mechanistic investigations.
Methodology
In this study, we adapted a passively scattered carbon ion beamline at GANIL to deliver FLASH (40-60 Gy/s) and CONV (1.5-2.5 Gy/min) dose rates in the same conditions. The dose rate and the radiation field of 1.8 x 1.8 cm^2 is monitored with secondary electron detector, X-ray detector, multi-strip ionization chamber DOSION, and gafchromic films, as well as verified in GATE Monte Carlo environment.
The setup was employed to irradiate two cell lines (in monolayers): lung cancer cells (A549) and healthy fibroblasts (AG01522), at LET of either 30 or 80 keV/µm, and in either normoxia (21% pO$_2$) or hypoxia (1% pO$_2$) conditions. Biological endpoints included cell survival, cell cycle arrest, DNA damage, and Reactive Oxygen Species (ROS) in mitochondria.
Results
Radiochromic films and Monte Carlo simulations have shown a radiation fields of at least 90% homogeneity. Dose read-out from films, DOSION, X-ray detector, and secondary electron detector were found consistent within 90%. Additionally, we were able to observe beam spatial (~0.1 mm) and time (~0.02 ms) structures with DOSION. LET values obtained in GATE were in good agreement with independent calculations in SRIM software.
Regarding cell responses, we observed a reduced cell death of fibroblast in FLASH in hypoxia. The effect was dependent on dose and LET, up to around 50% (isoeffect at 15% survival). The mechanistic model of radiologic oxygen depletion (one of FLASH explanation hypotheses) was not able to explain observed differences. Changing the dose rate did not change the response of lung carcinoma, as expected. Other endpoints will also be discussed.
Conclusions
This preliminary study validates the sparing effect of carbon FLASH in vitro in AG01522 fibroblasts as well as unaltered response of tumor A549 cells, for different doses, LET, and oxygen concentrations. We also demonstrated a reliable dosimetry solution for preclinical ^{12}C-FLASH studies. We plan to pursuit this research to potentially unravel new treatment solutions with heavy ions and FLASH.

17:45–18:05 A new model for p +9Be reaction as BNCT neutron source

Speaker

Alessandro Colombi (INFN - Pavia)

Description

The production of a neutron beam with suitable energy and angular distributions is fundamental for different scientific applications and particularly for Boron Neutron Capture Therapy (BNCT). Nowadays, two accelerator based nuclear reactions are studied and used worldwide as BNCT neutron sources: ^{7}Li(p,n) and ^{9}Be(p,xn).

The former is commercially available but is affected by important limitations, as the low melting point of lithium and the formation of ^{7}Be, a radioactive nuclide that requires adequate precautions in hospitals. The latter allows to overcome these limits, but is more complex to be described due to the presence of more open reaction channels: they are not always all considered in state-of-art codes and it is important to estimate their contribution to the total neutron yield.

We have developed a new model for the calculation of the double differential neutron yield of the ^{9}Be(p,xn) reaction at low energies (E≤5 MeV), based on the existing data and on previous analyses for the total cross sections. We present the new results of our work that show a significant improvement with respect to the currently available models and also allow to estimate neutron yields at higher energies.

18:05–18:25

Secondary fragment production in ion Beam therapy: experimental measurements for nuclear model improvement

Speaker

Lévana Gesson

Description

Accurate modelling of nuclear fragmentation is essential in ion beam therapy, where secondary ions contribute significantly to dose deposition and biological effects. However, the predictive capabilities of current Monte Carlo models remain limited in the energy range of therapeutic beam, especially for light fragment production (Z = 1–6), due to a lack of experimental data.

Within the CLINM (Cross-sections Light Ions and Neutron Measurements) project, we performed detailed measurements of secondary charged particles produced by carbon beams (120–400 MeV/u) on thick RW3 targets at the CNAO facility, using a ΔE–E scintillation telescope. This telescope enabled particle identification and energy reconstruction over multiple emission angles and irradiation configurations.

The measured yields and energy spectra were benchmarked against Geant4 simulations using the INCL++ physics list. Systematic discrepancies were observed across all ion species, particularly for helium and beryllium fragments, where both yield and spectral shape were misestimated. In several cases, model predictions underestimated light ion production by more than 30%, or failed to reproduce the angular dependence of energy distributions.

These results highlight the limitations of current hadronic models for therapy-relevant ion beams, and provide new statistics data to guide their refinement. This work reinforces the need for dedicated experimental campaigns to ensure the reliability of Monte Carlo simulations in clinical contexts.

18:25–18:50

CYCLHAD and the C400 accelerator for ion therapy and research

Speaker

Mr GABRIEL GAUBERT (CYCLHAD)

Description

Since 2018, CYCLHAD has been engaged in treatments, research and development activities in proton therapy. Operating a single cancer treatment room using a Proteus®One commercial superconducting synchrocyclotron from IBA company, CYCLHAD is going to broaden its offer. A new milestone is currently underway to enable expanded heavy ions like carbon ion therapy capabilities by 2028, promising even more precise and effective cancer treatments. The unique set-up combining access to proton, helium and carbon ion, thanks to the C400 superconducting cyclotron from NHa, will bring for the first time in France cutting edge treatment for patients in partnership with a clinical institution and research laboratories. Moreover, the facility will make possible radio-biology and material sciences R&D as well as microelectronic hardness testing under irradiation.
This presentation is describing the whole CYCLHAD facility with its accelerators and irradiation rooms equipments feature.

19:10

17:00 **Tuesday 23 September** 17:00–19:00

Nuclear Physics Applications: 4

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

17:00–17:20

VENDETA: VErsatile Neutron DETector Array, a new high-resolution neutron time-of-flight measurement array

Speaker

Owen Syrett (CEA)

Description

Prompt neutrons are emitted by fission fragments during the nuclear fission process. These neutrons play a crucial role for applications as they drive the chain reaction in nuclear fuel by inducing new fissions. The measurement of Prompt Fission Neutron Spectra (PFNS), which are the energy distributions of these neutrons, need to be done with high precision. Neutron multiplicity and average energy can be derived from the PFNS. These data are critical for applications, necessitating measurements with uncertainties well below 1%.
The importance of this data motivated the development of the VErsatile Neutron DETector Array (VENDETA), which is a high-resolution time-of-flight array for neutron detection. VENDETA's liquid scintillator detectors offer a high intrinsic efficiency, exceeding 20% over a range of 100 keV to 20 MeV, with a peak efficiency of 65% for 650 keV neutrons. For low energies, neutron-gamma discrimination capabilities are preserved down to 30 keVee. Additionally, its excellent time resolution (< 500 ps) enables fine energy resolution for fast neutrons.
This work will present the VENDETA set-up as it was operated at the Los Alamos Neutron Science CEnter (LANSCE) and its characterization with a 252Cf(sf) source. A measurement was run in 2024 for 240Pu(sf), an actinide of interest invariably present in small quantities in nuclear fuel. High statistics results on the PFNS and neutron multiplicity with high accuracy will be shown and demonstrate VENDETA's capabilities.

17:20–17:40

Measurement of ^{63,65}Cu neutron capture cross sections at the n$_$TOF facility

Speaker

Nicholas Pieretti (INFN, University of Bologna)

Description

Neutron-induced reactions on Copper are of great relevance for both nuclear technologies and astrophysics. Copper is a key structural material in the TAPIRO research reactor, which plays a crucial role in validating nuclear data and materials for fast Generation IV reactors. Recent sensitivity and uncertainty studies on TAPIRO have highlighted the need for improved Copper cross section data due to inconsistencies in current evaluations. In stellar nucleosynthesis, Copper is an important iron-peak element, and its neutron capture cross section significantly influences s-process modeling in massive stars.
To address this need for improved Copper cross section data, the n$_$TOF collaboration is conducting a dedicated measurement campaign on ^{63,65}Cu$(\mathrm{n,} \gamma)$ and ^{63,65}Cu$(\mathrm{n, tot})$ cross sections. n$_$TOF is a high-resolution time-of-flight facility at CERN, covering a wide neutron energy range (meV - GeV) with a high flux and low duty cycle. Measurements are performed at EAR1, located 185 meters from the spallation target, offering optimal conditions for high-precision resonance parameter extraction. The combination of capture and transmission data allows the determination of the elastic cross section.
This contribution will present preliminary results from the ongoing analysis of the 2024 capture measurement campaign.

This presentation is given on behalf of the n_TOF Collaboration.

17:40–18:00

First Fragmentation Cross Section Measurements with the Full FOOT setup

Speaker

Giacomo Ubaldi (INFN Bologna)

Description

The main goal of FOOT is to measure double differential fragmentation cross sections of light elements (Z $\le$ 10) in the energy range of 100–1000 MeV/nucleon, of interest both in medical and space-related fields. Particle Therapy is a medical treatment that uses charged particles with a tuned Bragg Peak to maximize the dose to tumors while minimizing damage to healthy tissue. However, ion fragmentation along the beam path can alter dose distribution, making precise cross section measurements for accurate treatment planning. In space, cosmic rays interact with spacecraft materials, producing secondary radiation that can affect astronauts and electronics. Thus, accurate cross section measurements are crucial also for improving shielding strategies in Space Radioprotection.

The FOOT electronic setup is a multi-detector system designed for precise fragment identification. In addition to measuring energy loss (ΔE), time of flight (TOF), and kinetic energy (E_k), its core component is a magnetic spectrometer that combines permanent magnets with silicon detectors. A Kalman filter algorithm is employed to reconstruct fragment tracks and compute their momentum (p) from track deflections. This identification method improves the scintillator-based techniques previously used by FOOT, which did not include a magnetic field. In particular, it reduces erroneous reconstructions caused by secondary fragmentation in air, accounts for multiple scattering effects and improves resolution without requiring dedicated background data acquisition.

After an overview of the apparatus, the full tracking procedure is described, focusing on experimental data from the 2024 CNAO campaign. Results on resolution are then presented, followed by preliminary cross section measurements, enabling a comparison between the potential of this method and that of the conventional scintillator-based approach.

18:00–18:20

Elemental and angular differential fragmentation cross section measurements with the FOOT experiment

Speaker
Matilde Dondi (University of Bologna - INFN Bologna)

Description

Nuclear fragmentation cross section measurements hold significant importance in both hadrontherapy and space radioprotection. Hadrontherapy is an external radiation therapy that employs beams of protons and heavier ions to target deep-seated tumors. These particles exhibit a favorable depth-dose distribution in tissues, featuring a low dose at the entrance and a maximum release at the end of their trajectory (Bragg peak). In these treatments, nuclear interactions between the beam and human body nuclei have also to be considered, since they can produce fragments that modify the profile of the dose delivered to healthy tissues.
In the context of space radioprotection, the growing interest in human missions beyond low Earth orbit requires a deep understanding of radiation risks, highlighting the need for precise nuclear fragmentation cross section data. Unfortunately, in the relevant energy range for these purposes, there are very few data available in the literature regarding nuclear fragmentation measurements.
The FOOT (FragmentatiOn Of Target) experiment was proposed to fill the gap in nuclear fragmentation cross section measurements and aims to provide measurements of double-differential cross sections in both angle and kinetic energy of nuclear fragments produced with a precision within 5% for light nuclei (Z $\leq$ 8) in the kinetic energy range between 200 MeV/nucleon up to 800 MeV/nucleon.
In this contribution, the fragmentation cross section measurement of a 400 MeV/nucleon ^{16}O beam interacting with a graphite and a polyethylene target will be discussed, with data collected at the GSI accelerator facility in Darmstadt, Germany. The evaluation of the fragmentation cross sections on a Hydrogen target is also presented.

This presentation is given on behalf of the FOOT Collaboration.

18:20–18:40

Experimental insights into neutron-induced fission of ^{235}U and ^{237}Np using the FALSTAFF spectrometer at NFS

Speaker
Deby Treasa Kattikat Melcom (Post Doctoral Fellow)

Description

The FALSTAFF spectrometer [1], designed to detect fission fragments produced in direct kinematics, is a key tool in advancing the understanding of neutron-induced fission, particularly in the MeV energy range. Fission models, both phenomenological and microscopic, have seen significant development over the past decade. However, their ability to accurately predict fission observables such as fragment masses, charges, kinetic energies, and neutrons/gammas, remains an area of active investigation.
FALSTAFF employs a 2V-2EV measurement technique to determine the velocity and residual kinetic energy of fission fragments on an event-by-event basis. The velocity is obtained using time-of-flight measurements with a pair Secondary Electron Detectors (SEDs) [3], while the residual energy is measured by calorimetry in an axial ionization chamber.
Recent experiments were conducted at the Neutron For Science (NFS) facility of GANIL/SPIRAL2 [2], focusing on 235 U and 237 Np fission. These experiments spanned a neutron energy range from 0.5 to 40 MeV, providing valuable data on fission fragment mass distributions (FFMDs) and kinetic energies. In this presentation, we will present the results from the 235 U experiments and preliminary data from the 237 Np experiment, taken in October 2024. Comparisons with GEANT4 simulations will be discussed, and
the talk will conclude with an overview of the future FALSTAFF scientific program, which includes the commissioning of the second arm of the spectrometer for coincident detection of both fission fragments. These ongoing developments are expected to significantly enhance the capability of FALSTAFF and contribute to the improvement of nuclear data essential for the simulation of next-generation reactors and hence their design.
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18:40–19:00

Investing Quasi Fission Dynamics of ^{35} Cl + ^{181} Ta and ^{35} Cl + ^{205} Tl

Speaker
Ajmira Sultana (Variable Energy Cyclotron Centre)

Description

Quasi-fission (QF) and fusion fission (FF) are two competing processes that affects formation probability of Super Heavy Element (SHE). To optimize the exploration of the SHE landscape, it is important to understand the competition between QF and FF. Several experiments are being carried out by us [1-2] to understand the dynamics of QF and FF, particularly to understand the role of entrance channel parameters. There are scarcity of reliable theoretical models too that efficiently predicts the amount of QF in a reaction. However, any new models [3] that are being developed, needs to be tested experimentally.
We have an ongoing research program [4-8] to systematically measure the fission fragment mass and energy distributions for several target projectile systems using large area MWPC at the Indian accelerator facilities [e.g; Kolkata Cyclotron, Mumbai and New Delhi Pelletron]. Non equilibration of mass and total kinetic energy are the signature of the presence of QF in a reactions.
In the conference we will report on our recent measurements of the fission fragment mass distributions in the ^{35}Cl + ^{181}Ta and ^{35}Cl + ^{205}Tl reactions with beam energies ranging from 167 to 180 MeV. For both the reactions, the mass distributions of fission fragments, analysed as a function of the canter-of-mass scattering angle θc.m., revealed distinct signatures of QF. A parabolic variation of the average total kinetic energy (TKE) with mass was observed, deviating from the liquid drop model and indicating an admixture of non-compound nuclear fission. For both reactions, the measured mass distributions were well reproduced using a three-Gaussian fitting approach, where one component corresponds to fusion-fission and the remaining two represent quasi-fission. The measured TKE distributions also show a deviation from a single Gaussian on the higher energy side. To decompose the experimental TKE distribution, two components are required: one corresponding to fusion-fission, with its peak value following the Viola systematics, and another corresponding to quasi-fission. The percentage of QF was consistently reproduced across both mass and TKE distributions. Thus, quasi-fission is observed in both the ^{35}Cl + ^{181}Ta and ^{35}Cl + ^{205}Tl reactions. To further elucidate the role of entrance-channel parameters in quasi-fission dynamics, a comparative analysis of these two reactions are being conducted and evaluated against theoretical model calculations to enhance our understanding of the underlying reaction mechanisms.

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19:00

17:00 **Tuesday 23 September** 17:00–19:25

Nuclear Structure, Spectroscopy and Dynamics: 10

Session | **Location:** MoHo, Inspire 1, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Alison Bruce (University of Brighton)

17:00–17:25 Ab initio description of monopole resonances

Speaker
Andrea Porro (TU Darmstadt)

Description

Giant monopole resonances, and in particular the nuclear breathing mode, play a central role in constraining the incompressibility of nuclear matter - an essential parameter in the nuclear equation of state. Traditionally, these modes have been studied within the Random Phase Approximation (RPA) using phenomenological Energy Density Functionals (EDF), establishing a well-known framework for exploring collective excitations.

However, a comprehensive, systematic treatment of monopole resonances within the ab initio paradigm remains largely unexplored. Ab initio many-body methods, despite their remarkable progress over the past two decades, still face challenges in addressing excited-state phenomena.

In this talk, I will present systematic ab initio predictions of (giant) monopole resonances across light- and mid-mass nuclei, including both closed- and open-shell systems. Using the Projected Generator Coordinate Method (PGCM) and the In-Medium Similarity Renormalization Group (IMSRG), we explore key aspects of the monopole response, highlighting novel insights into the structure and dynamics of nuclear matter from first principles.

17:25–17:45 Probing the Isospin Mixing in the ^{72}Kr Compound Nucleus via GDR γ Decay

Speaker
Agnese Giaz (INFN-Milano)

Description

The isospin symmetry is a consequence of the charge-independence of the nucleon-nucleon nuclear interaction. However, the Coulomb interaction breaks the isospin symmetry. Despite the small size of the isospin breaking, it is fundamental to know its value in the best possible way to understand the properties of the isobaric analog state and its role in Fermi β decay.
In the case of self-conjugated nuclei with N=Z, the selection rules for electromagnetic transition forbid the γ decay of electric dipole type. The presence of E1 decay and the measurement of its intensity is a tool to deduce isospin mixing. The giant dipole resonance (GDR)is an E1 decay that can be used as a probe to measure the value of the isospin mixing [1-3].
We used this approach to measure the E1 decay of the GDR in nuclei produced with N=Z. In this framework, we deduced the isospin mixing in the compound nucleus ^{72}Kr at a low nuclear temperature, around 1.3 MeV, from the γ decay of the GDR. The γ rays from two compound-nucleus reactions were measured: from the ^{32}S + ^{40}Ca at bombarding energy of 90 MeV characterized by isospin I = 0, and from the ^{31}P + ^{40}Ca at 82 MeV used as a reference (I $\neq$ 0). We employed the ELIGANT array at the Bucharest Tandem Laboratory, consisting of Compton-suppressed large-volume scintillator detectors (LaBr$_3$:Ce and CeBr$_3$) [4].
The statistical-model analysis of the measured spectra provided a mixing parameter of $(3.5\,\pm\,0.8)\%$ [5]. This datum, being at the lowest temperature compared with the few other existing ones, validates the predictions of the temperature dependence of the isospin mixing. Moreover, we studied the isospin mixing parameter, measured via GDR, as a function of nucleus mass and temperature.
We extracted the isospin-symmetry-breaking correction, δ_c, from the isopin mixing parameter used for the Fermi super-allowed transitions. It is consistent with β decay data, theoretical predictions, and previous experimental results [5].

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17:45–18:05 Photographing the Nucleus: Photon-Scattering on its Giant Dipole Resonance

Speaker
Norbert Pietralla (TU Darmstadt, IKP)

Description

The response of atomic nuclei to external, harmonically oscillating electric fields, i.e., their photoresponse [1], is dominated by their isovector Giant Dipole Resonance (GDR). The existence of the GDR is known for almost a century [2]. Although it is often considered as the archetype of a collective nuclear mode, a variety of fundamental questions to its very nature is still unanswered: What is the lifetime of the GDR? What is the relation of its width to the probability for photon emission? How does the branching ratio between electromagnetic and hadronic decay evolve with energy over the GDR?

We will address these fundamental questions in our presentation. We will discuss our recent data from photonuclear reactions that provide new evidences. The GDRs of the nuclides 140Ce, 154Sm, 164Dy, 208Pb, and 232Th have been studied with quasimonochromatic photon beams of energies between 11 and 17 MeV at the High Intensity γ-ray Source (HIγS) at the Triangle Universities Nuclear Laboratory (TUNL). Nuclear Resonance Fluorescence of the GDR and Smekal-Raman scattering to the first excited state have been measured quantitatively and first results have been published already [3].
* *This work is supported by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) under grant No. GRK 2891 'Nuclear Photonics' – Project-ID 499256822.*

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18:05–18:25 **First study of the PDR via neutron inelastic scattering at GANIL-SPIRAL2/NFS**

Speaker
Périne Miriot-Jaubert (CEA Saclay / IRFU / DPhN)

Description

The pygmy dipole resonance (PDR) refers to a low-lying strength in the dipole response of nuclei, located around the neutron separation energy [1] and associated with neutron excess in nuclei. As of today, the available experimental data do not provide an accurate picture of the fine structure of the PDR. These open questions on its structure and its potential implications on neutron capture-rates in the r-process [2] or as a tool to constrain the symmetry energy in the nuclear equation of state [3] convey a clear need for more experimental data to pin down its nature and refine theoretical models.

In experimental studies of the PDR via inelastic scattering, the so-called "multi-messenger investigation" [4] of the PDR shows a clear advantage to extract complementary information on its nature, depending on the probe used. The experiment I will present fits into this context and offers, for the first time, a study of the PDR using a neutron probe.

The experiment dedicated to the study of the PDR in the 140Ce nucleus via neutron inelastic scattering (n,n'γ) took place in 2022 at the Neutrons For Science facility at GANIL-SPIRAL2 [5]. The ~30 MeV quasi-monoenergetic neutron beams available at the facility, which are unique in terms of intensity, made this study possible. The PARIS [6] and the MONSTER [7] arrays were used for the γ and scattered neutron detection respectively. The detection setup offers very good timing characteristics and a high γ-ray efficiency in the PDR region.

The talk will first present the results for the elastic and inelastic scattering reactions on 12C target used as a benchmark. The presentation will then focus on the results of the study with the 140Ce target, with the extraction of the PDR strength. Finally, conclusions on the interest of the neutron probe and perspectives will be discussed.

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18:25–18:45 **Studying collective excitations at CCB of IFJ PAN Krakow**

Speaker
Maria Kmiecik (IFJ PAN Krakow)

Description

The Cyclotron Centre Bronowice (CCB) of the Institute of Nuclear Physics of the Polish Academy of Sciences (IFJ PAN) in Kraków is a proton therapy center built in the previous decade, where in addition to therapy, the proton beam is used for scientific research. One of the first measurements performed at the Cyclotron Centre Bronowice (CCB) were studies of collective excitations induced using proton inelastic scattering reaction.
The employed experimental method was based on coincidence measurement of scattered protons and gamma rays emitted from the decay of excited nuclei. A series of experiments have been conducted using experimental setup consisting of the KRATTA [1] array to register scattered protons and HECTOR [2] or LaBr3 detectors together with PARIS [3] phoswiches for gamma rays measurement. As a result the gamma decay of excited 208Pb, 120Sn, 58Ni and 62Ni nuclei has been investigated. In the first experiment it was measured the gamma decay of Isoscalar Giant Quadrupole Resonance (ISGQR) from 208Pb [4], which was the confirmation of the only previous observation [5]. Similar investigations have been performed also for 120Sn. The gamma decay from Ni isotopes have been measured in order study the pygmy strength with increasing neutron number. In the talk the experimental method as well as selected results will be presented.

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18:45–19:05
New perspectives to study Neutronrich, EXotic, heavy nuclei produced in multinucleon Transfer reactions with NEXT

Speaker

Julia Even (University of Groningen)

Description

Neutron-rich, heavy, EXotic nuclei around the neutron shell closure at N=126 and in the transfermium region are accessible via multinucleon Transfer reactions which feature relatively high cross sections. The wide angular distributions of the multinucleon transfer products lead to experimental challenges in their separation and identification.
We will overcome these challenges with the new NEXT experiment at the PARTREC facility in Groningen. NEXT is designed in such a way that a large fraction of the target-like transfer products emitted in a forward angel of 10° to 40° from the target will be separated and focuses towards a gas-catcher within a field of a 3 Tesla solenoid magnet. After thermalization the heavy transfer products are injected into a MultiReflection Time-of-Flight Mass Spectrometer for precision mass measurement and sample preparation for back-ground free mass spectrometry. Thus, even very long-lived, heavy transfer products can be identified and studied with NEXT. NEXT is currently undergoing commissioning.
In my contribution I will give an overview of the NEXT setup and report on the first beam on target experiments.

19:05–19:25 Decay of the stretched resonance at 19.6 MeV in 12C investigated via (p,p') reactions

Speaker

Natalia Cieplicka-Orynczak (Institute of Nuclear Physics Polish Academy of Sciences)

Description

Stretched resonances are rather simple nuclear excitations, even though in light nuclei they appear in the continuum energy region. The structures of these states are dominated by a single particle-hole component for which the excited particle and the residual hole couple to the maximal possible spin value available on their respective shells. The simplicity of their configurations results from the expected low density of other one-particle-one-hole configurations of high angular momenta in this energy region. Therefore, their theoretical description could provide clean information about the role of continuum couplings in stretched states.

In p-shell nuclei, these excitations are realized through the p$_{3/2}$ → d$_{5/2}$ stretched transitions [1] and are observed in high-energy regions above the nucleon separation energies. Therefore, the decays of stretched resonances are expected to be dominated by the proton and neutron emission, however, the knowledge about their decay patterns is rather scarce. The direct measurement of stretched states decay paths should provide data which can be used as a very demanding test of state-of-the-art theory approaches – such as, for example, Gamow Shell Model (GSM) [2] - which is an adequate tool for describing these excitations. Recently, experimental findings on the proton and neutron decay branches from the 21.47-MeV stretched state in the ^{13}C nucleus were compared with theoretical calculations from the GSM, extended to describe stretched resonances in p-shell nuclei [3]. A very good agreement obtained between the measured and predicted decay properties of the 21.47-MeV state in ^{13}C demonstrated the high quality of the GSM calculations.

Preliminary results from an experiment performed at the Cyclotron Centre Bronowice (CCB) at IFJ PAN in Kraków (Poland), aiming at the first experimental investigation of the decay of the 19.6-MeV stretched resonance in ^{12}C, will be presented. The state of interest in ^{12}C was populated in the proton inelastic scattering reaction ^{12}C(p,p') at 135 MeV proton energy. The detection setup consisted of: i) the KRATTA telescope array for detection of scattered protons, ii) two clusters of the PARIS scintillator array and four LaBr$_3$ detectors for γ-ray measurement, and iii) four thick DSSD units for light charged particles detection. Information on the decay paths from the 19.6-MeV stretched state in ^{12}C was obtained by measuring the protons inelastically scattered off a ^{12}C target in coincidence with γ rays from daughter nuclei and charged particles emitted in the decay of the resonance.

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19:25

17:00 **Tuesday 23 September** 17:00–19:25

Nuclear Structure, Spectroscopy and Dynamics: 11

Session | **Location:** MoHo, Inspire 2, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Zsolt Podolyak (University of Surrey)

17:00–17:25 Highlights from the ISOLDE Solenoidal Spectrometer

Speaker

Andreas Heinz (Chalmers University of Technology)

Description

Spectroscopy based on nuclear transfer reactions has been a workhorse for the investigation of nuclear structure for decades and motivated the construction of many high-resolution spectrometers around the world. However, extending this approach to reactions in inverse kinematics, required for most radioactive beams, comes with a loss of resolution due to kinematic compression and kinematic broadening. These problems can be overcome if the transfer reaction occurs inside a strong solenoidal field, which forces the ejectile on helical trajectories. By measuring the position as well as the energy of the ejectile, the excitation energy as well as the center-of-mass emission angle can be extracted. Angular distributions can be used to determine the amount of transferred angular momentum.

The ISOLDE Solenoidal Spectrometer (ISS) is making use of this highly versatile approach, allowing for a broad range of experiments motivated by, e.g., the evolution of nuclear shell structure, shape coexistence, nuclear astrophysics, and nuclear fission. In this presentation the experimental approach, available detectors as well as recent results will be discussed.

17:25–17:45 Catching the spin - Isomeric yield ratios by direct ion counting for studies in fission dynamics

Speaker

Stephan Pomp (Uppsala University)

Description

The fission process forms highly excited fragments carrying significant amounts of angular momentum. This formation is generally described via a shape evolution on the potential energy landscape of the fissioning system. Among the aspects that are still hard to describe in this process is the generation of the fragment angular momenta, highlighted by the work of Wilhelmy et al. in the early 1970s. Isomeric yield ratios (IYR) offer the possibility to address this question.

Traditionally, gamma-spectrometry has been used to measure IYR but risk suffering from incomplete information on the nuclear level scheme and decay branching ratios. To avoid this problem, we employ direct ion counting using mass measurement techniques and unambiguously determine IYR from fission. With recent advances such as the Phase-Imaging Ion-Cyclotron-Resonance (PI-ICR) technique [1], isomers with mass differences as low as a few tens of keV can be resolved. Over the past years, IYR for a total of 40 different isotopes produced from 232Th(p,f), 232Th(a,f), and 238U(p,f) could be obtained using JYFLTRAP at IGISOL of the University of Jyväskylä [2-5].

To interpret the data with respect to the quest for the fragment angular momentum generation, the average angular momentum of a specific fragment can be derived via extensive modeling of the de-excitation process of the neutron rich nuclei [4]. An important ingredient is the spin distribution in the nuclear level density which has to be significantly narrower than generally employed [6].

We have been able to extend the observations by Wilson et al. [7] to the symmetry region. While a sawtooth-like picture of the dependence of fragment angular momenta on mass emerges, it seems not possible to explain the data with the rubber-band model proposed by Wilson et al. [4]. We also provide evidence that at least 30% of an increase of the spin of compound fissioning system is transmitted to the fragment angular momenta [6].

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17:45–18:05 Insights on fission from the neutronless channel and perspectives

Speaker

Laurent Gaudefroy (CEA-France)

Description

I will present part of the results recently obtained by studying the radiative decay of fission fragments populated in 252Cf(sf). Fission fragments were detected and their kinetic energies measured using a twin Frisch grid ionization chamber. This compact detector was surrounded by an array of 54 large volume NaI detectors. For the particular event without neutron emission, the fragments' mass identification is very good (0.68 a.m.u.) and we are able to isolate specific fragments from the rest of the data. In this case, our data allows us to determine the total excitation energy distribution of the fragmentation. The gamma-ray spectrum measured in coincidence with that TXE distribution can be used in order to constrain the properties of the fragments at scission. I will discuss the case of the 118Pd/134Te fragmentation where we determine the excitation energy distribution between the fragments and show that it is associated with shape fluctuations at scission.

In addition, if enough time is allocated, i propose to present the future experimental program, DEFFI, we plan to perform at GANIL/NFS in order to study the radiative decay of the fission fragments produced in neutron induced fission.

18:05–18:25

Isotopic fission fragments yields in the Thorium region produced in inverse-kinematics with a 232Th beam.

Speaker

Alex Cobo Zarzuelo (GANIL)

Description

A general description of the fission mechanism considers both microscopical quantities, such as nuclear structure of the fission fragments, and macroscopic effects, like the Coulomb repulsion between the nuclei. The interplay between both quantities prevents, so far, from a fully microscopical description of the interaction. Despite the development of different theoretical models [1] and simulation codes based on experimental data, such as GEF [2], the fission process is not reproduced with enough accuracy along the nuclear chart. A large set of experimental data is needed in order to constrain the models.

Using the inverse-kinematics technique and multi-nucleon transfer reactions, the fission process is studied at GANIL with the VAMOS++ spectrometer [3]. This enables the isotopic identification of complete fission fragment distributions [4]. Moreover, the coupling of this spectrometer to a highly stripped silicon detector (PISTA) allows the identification of the fissioning system and the reconstruction of its excitation energy with high resolution.

A new experiment was conducted at VAMOS++ with the newly accelerated ^{232}Th beam at Coulomb energies. Transfer reactions performed with a ^{12}C target permitted to populate fissioning systems from ^{230}Th up to ^{244}Cm. The produced nuclei lay on a region closer to the known transition between asymmetric to symmetric fission in the actinides [5]. This allows the systematic study of the shell-closure effects occurring for different deformation parameters, like octupolar deformation, recently proposed to be responsible for the asymmetric fission in the actinides region [6]. Moreover, experimental results show that the isotopic distributions around Th isotopes deviate from the general actinide behaviour [7].

The experimental setup included the VAMOS++ spectrometer, which was composed of a pair of magnetic quadrupoles and a dipole, and a set of Multi-Wire Proportional Counters (MWPCs) before and after the optical modules. An Ionization Chamber (IC) was also positioned at the end of the focal plane. Moreover, around the target position, PISTA detector was located, as well as another MWPC placed at 40° with respect to the VAMOS axis. This detector was included for the simultaneous measurement of the velocity of both fission fragments on an event by event basis. In this work, the isotopic and mass fission fragment yields will be presented as a function of the excitation energy of the fissioning system. On top of this, neutron excess of the fragments will be shown, as well as some correlations between both fission fragments.

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18:25–18:45

Investigation of Shell Effect Damping in Nuclear Fission Using VAMOS and PISTA

Speaker

Theodore Efremov (CEA)

Description

Studying nuclear fission provides insight into the interplay between the dynamic evolution of the compound nucleus and microscopic effects such as shell structure and pairing correlations. Measuring fission fragment yields not only advances our understanding of nuclear structure but also has important applications in nuclear reactor physics.

This work focuses on the evolution of fission fragment yields as a function of the excitation energy (E*) of the fissioning system. As E* increases, the symmetric component of the yield becomes more pronounced, indicating the gradual suppression of nuclear structure effects. Precise measurements of this effect are crucial for constraining state-of-the-art fission models and have direct implications for the development of Generation-IV fast neutron nuclear reactors.

To precisely investigate the evolution of fission yield with the excitation energy, a dedicated experimental campaign was conducted, integrating the Particle Identification Silicon Telescope Array (PISTA), alongside enhancements to the VAMOS++ spectrometer at GANIL. The experiment employed the inverse kinematics technique, where a beam of ^{238}U impinged on a ^{12}C target, inducing transfer reactions that populated various fissioning systems alongside their associated light recoils. This setup allows for the study of shell effect damping in nuclei near ^{238}U within an excitation energy range of 6 to 20 MeV, achieving an excitation energy resolution of $\sim$700 keV (FWHM).

This work presents the experimental setup as implemented at GANIL with a particular focus on the first-time use of the PISTA array. We will discuss the ongoing data analysis from two acquisition campaigns conducted between 2023 and 2024. Particular focus will be given to the ^{242}Pu fissioning system, populated via the ^{12}C(^{238}U,^{242}Pu)^{8}Be$\rightarrow$2α reaction, as PISTA is highly efficient at detecting these events due to its high granularity. Preliminary results on the evolution of mass and charge distributions will also be presented.

18:45–19:05

HFB3+CHICON: Large-scale PES generation with an axial HFB solver for structure and fission studies.

Speaker

Junah Newsome (CEA DAM DIF)

Description

In this talk, a new open-source solver for the nuclear Hartree-Fock-Bogoliubov (HFB) equations will be presented. This solver uses a double set of HO solutions as its basis, allowing an accurate description of highly elongated nuclear states using a relatively small number of basis states. The implemented nucleon-nucleon effective interactions are of D1x, D2x Gogny types. The solver is written in C++, and can be used from the command line or from Python scripts.

Then the new CHICON tool will be presented. This tool computes large-scale Potential Energy Surfaces (PES) for any number of collective coordinates. PESs with up to 3 collective coordinates generated on CEA's supercomputers will be showcased.

Finally, we will discuss the physical results concerning the microscopic description of nuclear fission: static results related to the PES itself (barrier heights, fission paths, fragment properties, …) and dynamical ones computed using the TDGCM+GOA method with the FELIX code (fission yields, …).

This toolchain has been used to interpret some of the experimental results obtained during SOFIA's latest measurement campaign.

19:05–19:25 Mapping the new asymmetric fission island with the R3B/SOFIA setup

Speaker

Dr Pierre Morfouace (CEA, DAM, DIF)

Description

The low energy fission in the actinide region is known to be mainly asymmetric, driven by structure effects of the nascent fragments. Moreover, we know that there is a transition from asymmetric to symmetric splitting for Thorium isotopes. It was assumed that this latter split would be the main fission mode for lighter nuclei. However, unexpected asymmetric splits have been observed again in neutron-deficient exotic nuclei. This observation triggered a lot of theoretical and experimental work, and further studies in this region confirmed the unexpected asymmetric fission mode, which seems to characterize the fission of neutron-deficient nuclei in the sub-lead region.

To explore this newly identified island of asymmetric fission, a dedicated experiment was conducted at GSI, Darmstadt, Germany, using inverse kinematics at relativistic energies with the state-of-the-art R^{3}B/SOFIA setup. We present measurements of fission fragment charge distribution from 100 exotic fissioning systems, establishing a connection between the neutron-deficient sub-lead region and the well-known actinide region. These new data provide a comprehensive mapping of the asymmetric fission island, offering clear experimental evidence of the important role played by the deformed $Z=36$ proton shell in the fission of sub-lead nuclei.

Following a detailed description of the experimental apparatus, we will discuss the fission-fragment charge yields, highlighting the significant role of $Z=36$ in the light fragment in the splitting process within this region. Additionally, we will compare our findings with both microscopic and phenomenological models.

19:25

19:40 **Tuesday 23 September** 19:40–21:40

Poster session: 1 with refreshments

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

19:40–19:41 Cross-sections of the 127I (n, n2) 126I nuclear reactions

Speaker

Prof. Ihor Kadenko (Taras Shevchenko National University of Kyiv)

Description

An experimental search for a bound dineutron has been ongoing for decades, presenting the experiments for light and heavier nuclei masses as target nuclei. Our approach to indirectly observe a bound dineutron is based on the theoretical prediction by Migdal [1] and considers not light, but heavier nuclei in nuclear reactions, near which a bound dineutron can be formed in the outgoing channels as a product of (n,n2) nuclear reactions [2-4]. The possibility for two neutrons to populate a certain energy level comes from the solution of the quantum-mechanical problem in [1], resulted in the appearance of real levels within the potential well of some heavy nuclei outside of their volume in order to bind two identical particles in one nucleus. In our article [5], a set of medium and heavy weight target nuclei (90 < A < 210) was considered and ranked according to the criteria in [5, 6] to identify those of them that are acceptable for the (n,n2) nuclear reaction in order to form another heavy nucleus in the outgoing channel that is more susceptible to host a bound dineutron. With our earlier experiments [2-4], we mainly targeted at heavier nuclei like 159Tb, 175Lu, 197Au, while this phenomenon may also take place for nuclei with smaller masses, for instance, 127I. According to the ranking in [5], this isotope, like 174Lu nucleus, belongs to the "less-likely" category because only two criteria out of four are met. However, 127I is included in the “0”-category, for which none of the criteria reaches the required value, but can be considered as a candidate with, probably, lesser cross-sections, going down in the hierarchy of atomic masses. Then we may expand the boundaries, within which the dineutron can be observed with necessary statistical significance. Thus, it was our decision to design and perform experiments with neutron irradiation of potassium iodine (KI) samples in order to observe the formation of bound dineutrons under conditions that are not optimal, and to determine the cross-sections for the 127I(n,n2) nuclear reaction.
Therefore, in our new experiment to identify the potential nuclear reaction channel 127I(n,n2)126I within the energy range below the Eth = 9.217 MeV threshold energy of the 127I(n,2n)126I nuclear reaction, two KI samples were irradiated by neutrons generated via the DD reaction:
- with deuterons of Ed = 5.429 MeV that induced neutrons in the En = 7.20+0.13/-0.11 MeV neutron energy range with ㄹㅂn = 1.12E+06 +18%/-27% n/(cm2•s) fluence rate;
- with deuterons of Ed = 6.812 MeV that induced neutrons in the En = 8.78+0.09/-0.09 MeV neutron energy range with ㄹㅂn = 1.38E+06 +18%/-27% n/(cm2•s) fluence rate.
In both irradiations Nb foils were attached to the rear sides of the KI samples in order to check the presence of neutrons above the Eth = 8.927 MeV threshold energy of the 93Nb(n,2n)92mNb nuclear reaction.
After completion of the irradiations lasted about 36,000 s for each case, the KI samples as well as the Nb foils were counted on an HPGe Canberra detector. Both Nb foils showed no induced activity of 92mNb, but in both KI samples the full absorption peaks at Eg = 388 keV and Eg = 666 keV gamma-ray energies were detected due to the decay of 126I with peak areas from hundreds to several thousands of counts.
Taking the expression for cross-section calculations from [4], the estimated cross-sections are (0.25 ± 0.08) mb and (0.24 ± 0.07) mb for the first and second irradiations, respectively.
Thus, the dineutron in bound state was clearly observed in this study for the 127I (n, n2)126I nuclear reaction with corresponding cross-section estimates.
The research carried out at HUN-REN ATOMKI was supported by the TKP2021-NKTA-42 project financed by the National Research, Development and Innovation Fund of the Ministry for Innovation and Technology, Hungary.
The MGC-20 cyclotron of HUN-REN ATOMKI is a Research Infrastructure of the Cluster of Low Energy Accelerators for Research (CLEAR) of the EURO-LABS project. I.M.Kadenko was supported by the Transnational Access of the CLEAR EURO-LABS project. The EURO-LABS project has received funding from the European Union's Horizon Europe Research and Innovation programme under Project TA Identifier: CLEAR_ATOMKI_001.

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19:41–19:42 Towards Precise Reference Quadrupole Moment Measurements in Transition Metals

Speaker

Shikha Rathi (Technion – Israel Institute of Technology, Haifa 3200003, Israel)

Description

The spectroscopic quadrupole moment (Q) is a fundamental property that provides information about nuclear deformation. However, its precise extraction for the transition elements remains challenging due to their complex atomic structures. Meanwhile, muonic atoms offer a simpler hydrogen-like structure with amplified hyperfine interaction effects. Recent efforts have revived this technique, successfully measuring the Q of $^{185-187}$Re $[1]$. Unfortunately, in the mid-Z region, these measurements remain limited by low detection efficiency $[2]$ or poor resolving power $[3]$.
In this talk, I will present a new approach to measuring the reference Q values of transition elements by combining muonic atom spectroscopy with the high efficiency and resolving power of a cryogenic microcalorimeter (MC) detector $[4]$. I will discuss the associated challenges and feasibility of this measurement based on simulations, using ^{63}Cu as a test case, along with its detailed theoretical hyperfine interaction calculations using the mcdfgme Dirac-Fock code $[5]$. Our method aims to overcome the current limitations in precision, reducing the uncertainty in Q by up to a factor of 30. An improved reference quadrupole moment will allow the calibration of entire isotopic chains (including isomers and short-lived excited states), offering a deeper understanding of the nuclear structure.
Current fractional accuracy in reference quadrupole moments [6] and our accuracy goals for transition metal nuclei

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19:42–19:43

Field-theoretical treatment of the deuteron breakup in the reaction $e+d \to e'+p+n$ on $e'p$-coincidence

Speaker

Yan Kostylenko (National Science Center "Kharkiv Institute of Physics and Technology")

Description

This research is the field-theoretical description of the deuteron breakup by fast electrons, being a prolongation of the studies carried out [1] at the Kharkiv Institute of Physics & Technology. As in our recent works [2,3], key features of the approach proposed embody gauge-independent calculations of the reaction amplitudes, as well as, a fresh look at the construction of the one-nucleon current operator and a new family of isovector meson exchange currents. The latter is acquired by starting from the Noether current and reformulating it in the clothed particle representation.

Following [4], we have focused on angular distributions and polarization of the knocked-out protons that are expressed through the structure functions W_i and $\vec{\Sigma}_i$ ($i=C,T,S,I$), respectively, taking into account the final state interaction (FSI). We emphasize the latter since this polarization takes zero values without FSI included. We use the deuteron wave function in the momentum space that has been calculated in the clothed particle representation [5], and the "distorted" wave functions of the np-pair obtained by solving the R-matrix equation with the so-called Kharkiv potential. Our calculations are essentially relativistic. We avoid any nonrelativistic reduction.

Special attention is paid to predicting observables at kinematics forbidden in the electron scattering on free nucleons (cf. [6]), viz., the region corresponding to proton emission into the backward hemisphere.
It is implied that our approach can be extended to the theory of the neutrino scattering off few-nucleon nuclei.

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19:43–19:44

Collectivity and vibrational-octupole instability in ^{220}Rn and ^{226}Ra

Speaker

Katarzyna Mazurek (Institute of Nuclear Physics PAN)

Description

The vibration and rotation modes shed light on collective properties of nuclei. The rotational level patterns in ^{220}Rn and ^{226}Ra nuclei have been obtain in a collective quadrupole+octupole approach with microscopic mass tensor and moments of inertia dependent on deformation and pairing degrees of freedom. However, the main objective is to quantitatively confirm the known experimental facts that the Rn nucleus passes from octupole vibrational to octupole deformed with external rotation, while the Ra nucleus is hardly affected by rotation, being octupole deformed from the beginning.
The collective potential calculated in a nine-dimensional collective coordinate space is determined using the macroscopic-microscopic method with Strutinsky shell correction and the BCS method with particle number projection. The corresponding Hamiltonian is diagonalized based on the projected solutions of the harmonic oscillators coupled with the corresponding Wigner functions. Such an orthogonalised basis is additionally symmetrised with respect to the so-called internal symmetry group, specifically dedicated to the collective space used, to ensure the uniqueness of the solutions of the Hamiltonian with respect to the laboratory frame.
The response of the pairing and deformation degrees of freedom to external rotation is discussed in the variational approach (the total energy is minimised by the pairing and deformation variables). As the nuclear spin increases, the pairing gaps of protons and neutrons decrease from equilibrium values to zero (no superfluid solution). Consequently, the corresponding microscopic moments of inertia increase with increasing collective spin (Coriolis antiparity effect), resulting in effectively lower rotational energy levels Iπ with respect to pure rigid-rotor solution I(I+1) pattern. The overall comparison of experimental and theoretical rotational energy level schemes, dipole, quadrupole and octupole transition probabilities of BE(λ) in ^{220}Rn and ^{226}Ra is satisfactory.

19:44–19:45

A Novel Approach for the Calculation of Few-body Response Functions

Speaker

Dr JAGJIT SINGH (The University of Manchester, UK)

Description

There are two common approaches for calculating cross-sections for weak probes: one involves using square-integrable basis functions [1-5], while the other relies on response functions (dynamical polarizabilities) [6]. For multi-open-channel problems, all methods struggle to some extent. Considering these issues, we develop a powerful novel alternative which takes advantage of the randomness of the Stochastic Variational Method (SVM) [7].

Our method extracts response functions (dynamical polarisabilities) directly from a bound-state approach for perturbation-induced reactions [7]. Explicitly, we express the response as a sum of δ functions (inspired by the Lorentz integral transform (LIT) method [2, 8, 9]). In the LIT formalism, an analogous sum is convoluted with a Lorentzian, yielding a smooth function, which then gives the response function after a numerical inversion. We determine this latter function directly by solving an inhomogeneous bound-state problem while avoiding the problems that the inversion can ill-pose.

Instead of folding the response with a smearing function as in the LIT, we use the integrated response, that is, the integral up to some energy of a response function. Hence, the sum of δ distributions becomes a stepwise continuous function of energy, which we fit with a differentiable function. This facilitates a robust derivation of the smooth physical response function. Ostensibly, we have replaced one hard problem (robust inversion of the LIT) with another (fitting of a function). However, the fitting procedure seems to be very robust. We will demonstrate this advantage by using a stochastic basis choice that covers the dominant important areas of the spectrum. We benchmark our method with both an analytically solvable model and results from the LIT for photo-dissociation of the deuteron. We also intend to discuss our preliminary results for the photo-dissociation of 3He.

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19:45–19:46

Toward 238U(n, γ) cross sections from measured γ-strength function and nuclear level density with SFγNCS

Speaker

Chloe Fougeres (CEA/DIF)

Description

A neutron capture by a nucleus results in a compound nucleus that quickly desexcites while emitting γ-rays if its excitation energy is less than a few MeV. This process, known as a radiative capture, occurs in many stellar nucleosynthesis. The reaction cross sections can be measured precisely for stable nuclei or nuclei close to the valley of stability but this becomes challenging for more exotic nuclei [1]. Nuclear reaction models based on stable nuclei struggle to provide reliable predictions for these exotic nuclei. Some progress has been made by looking at microscopic ingredients that are experimentally accessible: the nuclear level density and the γ strength function. These describe the γ-ray cascade and the structure of the nucleus at high excitation energies. Measuring them allows us to improve the precision of evaluated radiative capture cross sections of unstable nuclei.
A detection system SFγNCS (γ Strength function for Neutron Capture Simulations) [2] has recently been developed to measure these ingredients of the radiative decay. In SFγNCS experiments, aimed nuclei are populated in direct kinematics by (d, p) transfer reactions close to the neutron radiative captures of interest. From the light ejectiles detected in a ΔE-E silicon telescope,the excitation energy Ex is identified. The γ-rays emitted throughout the cascade are measured with an array of 60 NaI detectors with an excellent efficiency. Following the Oslo method, the [Eγ ,Ex] measured matrix is analysed to extract the [Eγ , Ex] primary matrix, i.e. the first-generation γ-rays in the cascade which are described by the γ-strength function and nuclear level density. A benchmark experiment of SFγNCS will be reported here. The γ-strength function and nuclear level density of 239U were recently measured [2]. Furthermore, a new evaluation of the 238U(n, γ) cross sections will be discussed.

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19:46–19:47

Antikaon condensed dense matter in neutron star with SU(3) flavour symmetry

Speaker

Athira S (Indian Institute of Technology Jodhpur 342037 India)

Description

Massive pulsar observations indicate that compact stars' central densities can significantly surpass nuclear saturation densities, which could lead to the formation of exotic matter such as quark matter, meson condensates, and hyperons. One important contender among meson condensates, anti-kaon (K^-) condensation, is not well understood in terms of kaon-meson interactions. We refine previous quark model approaches by calculating hadronic couplings in the mesonic sector using SU(3) flavor symmetry. The symmetric-antisymmetric weight factor (α_v), octet-to-singlet coupling ratio (z), and mixing angle (θ_v) are identified as key parameters, with α_v being considered as a free parameter. According to our findings, greater α_v values increase neutron star masses, delay K^- condensation, and stiffen the equation of state. The onset of K^- condensation is extremely sensitive to α_v and happens through a second-order phase transition.

19:47–19:48

Overview of unstable nuclear state studies in dissociation of relativistic nuclei

Speaker

Andrei Zaitsev (JINR)

Description

Ensembles of He and H isotopes can be studied with unique completeness and resolution in nuclear emulsion layers longitudinally exposed to relativistic nuclei [1,2]. Determination of the invariant mass of their pairs or triplets by emission angles in the velocity conservation approximation is sufficient to identify a number of unstable states – ^{8}Be(0$^+$), ^{8}Be(2$^+ $), ^{9}B, ^{12}C(0$^+_2$), ^{12}C(3$^−$), ^{6}Be [3].
The BECQUEREL experiment [4,5], using this approach, is aimed at searching for the α-particle Bose-Einstein condensate (αBEC), an unstable of S-wave α-particle state. The ^{8}Be(0$^+$) is associated with 2$ \alpha$BEC, and ^{12}C(0$^+_2$) or the Hoyle state with 3αBEC. In the relativistic fragmentation of heavy nuclei, an enhancement of ^{8}Be, ^{9}B and ^{12}C(0$^+_2$) is detected, suggesting their synthesis in the fusion of associated $ \alpha$-particles. The focus of the search is the 4αBEC state of ^{16}O(0$^+_6$) at 660 keV above the 4α threshold, decaying into α^{12}C(0$^+_2$) or 2^{8}Be. In this context, the status of the analysis of α-particle fragmentation in a nuclear emulsion exposed to ^{84}Kr nuclei at 950 MeV per nucleon is presented. Secondary stars produced by relativistic neutrons are observed in the nucleus fragmentation cone [4]. The neutron average energy in the parent nucleus system is estimated to be 1.3 MeV [6].
The αBEC search leads to the study of nuclear matter in the region of temperature and density from red giants to supernova. It is characterized by the ratios of ^{1,2,3}H and ^{3,4}He. Nuclear emulsion layers exposed to heavy nuclei of several GeV per nucleon at the NICA accelerator complex are optimal for identifying H and He isotopes by multiple scattering, searching for unstable states, and assessing neutron accompaniment. An exposure to ^{124}Xe nuclei of 3.8 GeV per nucleon, performed at the NICA accelerator complex, allows the use of proven approaches. Parameters of the beam are determined by using the CR-39 track detector by direct crater counting on the Olympus BX63 microscope.

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19:48–19:49

Status of the b-STILED project

Speaker

Mr Romain Garreau (LPC Caen)

Description

Precision measurements in beta decay play an essential role in the search for new physics beyond the standard model (SM) by probing “exotic” phenomena such as scalar and tensor interactions. The presence of these interactions would lead to deviations in specific observables from their SM predictions. The study of the full beta energy spectrum offers a sensitive mean to probe these exotic interactions.
The goal of the b-STILED (b: Search of Tensor Interactions in nucLear bEta Decay) project is to perform the most precise measurement of the beta-energy spectrum in 6He decay. The objective is to extract the Fierz interference term b with a precision in the order of 4.10-3. This term depends linearly on tensor interaction.
A limiting instrumental effect in previous measurements of the beta energy spectrum is the partial energy loss due to electron backscattering outside the detector volume. The present project used two techniques to mitigate this effect. The first uses a low energy beam of 6He+ ions (25 keV) implanted between two scintillation detectors, whereas the second uses a high energy beam of 6He+ ions (312 MeV) implanted inside one scintillation detector to form a 4π calorimeter. Both techniques ensure the deposition of the entire energy of the beta particles. Both measurements were performed at GANIL.
This contribution will present the overall context of the project, centering on the second experimental setup, and will report on the status of the data analysis.

19:49–19:50

Examination of systematic uncertainties in the extraction of Fierz interference term within the bSTILED project

Speaker

Anjli Rani (LPC CAEN)

Description

The Standard Model (SM) of electroweak interactions has been remarkably successful in describing fundamental particle interactions. However, compelling observational and theoretical indications suggest that it is an incomplete framework, necessitating an extended theoretical formulation. Searches for ***New Physics (NP)*** beyond the SM are actively pursued along three primary frontiers: the high-energy frontier, which probes unexplored energy scales using advanced particle accelerators such as the Large Hadron Collider (LHC); the cosmological frontier, which investigates fundamental questions related to dark matter and the cosmic microwave background; and the high-precision frontier, which employs ultra-sensitive measurements of atomic, nuclear, and particle processes to uncover deviations from SM predictions. Within this precision frontier, the ***extraction of the Fierz interference term (b$_{F}$)*** from beta decay experiments serves as a highly sensitive probe for physics beyond the SM. A nonzero value of *b$_{F}$* would indicate the presence of exotic ***scalar or tensor interactions***, providing direct evidence for non-Standard Model weak interactions. However, achieving a precise determination of *b$_{F}$* is experimentally challenging due to statistical and systematic uncertainties that stem from electron back-scattering, detector calibration errors, theoretical modeling approximations, and acquisition system limitations. In this work, we present a comprehensive mitigation strategy for systematic uncertainties affecting the precise extraction of the Fierz interference term. Key aspects include corrections for ***non-linearity in energy calibration, gain and baseline fluctuations, detector response function, light collection effects, acquisition module characteristics, and spectral fitting methodologies***. To enhance the reliability of the analysis, we incorporate ***Geant4-based Monte Carlo simulations***, enabling a refined quantification of systematic uncertainties. Position-dependent variations in optical photon collection have been observed to introduce systematic uncertainties in energy calibration. Imperfect light collection can result in non-uniform energy reconstruction, leading to distortions in the spectral shape. Additionally, reduced light yield can degrade energy resolution, thereby increasing uncertainties in spectral measurements. To mitigate these effects, corrections have been implemented through detailed simulations of light transport to account for collection variations, event-by-event corrections based on optical response maps, and calibration using well-characterized gamma and beta sources to benchmark detector response. These developments significantly improve the robustness of Fierz interference measurements and strengthen their role as a precision test for NP.

19:50–19:51

Probing Beyond the Standard Model with Beta Decay and Electron Capture

Speaker

Mr Victor Dumenil (LPC Caen)

Description

Nuclear beta decay and electron capture allow us to probe the Standard Model (SM) and search for new physics in competitive and complementary ways to the LHC. In particular, beta decay can be extremely sensitive to exotic scalar and tensor currents at the TeV scale through precision measurements. This sensitivity shows up most clearly in the Fierz interference term, b_F, which is linearly dependent on these exotic currents.
Electron capture and beta-+ decay show an opposite dependence to b_F but probe the same nuclear matrix element, such that their ratio becomes a very sensitive probe to new physics with reduced nuclear structure contributions. The remaining nucleus-sensitive corrections depend on the shape factor, C, for both. The latter can be expressed as a combination of form factors, which will contain the nuclear structure information and the convolution of the lepton wave functions. We will report on the calculation of these residual nuclear structure corrections using the Behrens-Bühring formalism and shell model calculations.

19:51–19:52 Nuclear reactions studies around the Coulomb barrier with light nuclei at CNA.

Speaker

Alejandro Vegas Díaz (Universidad de Sevilla)

Description

The study of nuclear reactions involving light nuclei at low incident energies is essential for the development and corroboration of different theories and models applied to astrophysical environments [1,2]. The experimental Basic Nuclear Physics (FNB) line, installed at the 3 MV tandem accelerator of the National Accelerators Center (CNA), is being adapted and prepared to study these kinds of reactions at energies around the Coulomb barrier, leveraging the target development and characterization capabilities at the CNA and its collaborating facilities.

A new experimental setup, composed by two large area segmented silicon detectors in telescope configuration, has been mounted at the FNB beam line. The segmentation of the detectors, along with the facility's capabilities, will allow us to obtain a precise energy distribution of the reaction fragments, with high angular resolution covering a 25° angular range. This work will outline the characterization of the detection system and the overall experimental setup. In addition, preliminary results for the ^{6}Li+^{12}C reaction at incident energies from 3 to 8 MeV, with particular emphasis on the dissociation channels of the projectile, will be presented.

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19:53–19:54 Hypernuclei in Gamow Shell Model

Speaker

Alan Cruz DASSIE (Grand Accélérateur National d'Ions Lourds (GANIL), CEA/DSM - CNRS/IN2P3, BP 55027, F-14000 Caen, France)

Description

One of goals of hypernuclear physics is to obtain information on baryon-baryon interaction in a unified way. Especially, it becomes an important issue to obtain information on hyperon(Y)-nucleon(N) interaction. For this purpose, hyperon-nucleon scattering experiments are planned at JLab and J-PARC facilities [1].

The physics of strangeness $S=-1$ hypernuclei bears a fundamental difference from nucleonic systems: the number of protons, neutrons, Λ, and $\Sigma^{-,0,+}$ particles is not conserved, as only total charge, strangeness, and baryon number are good quantum numbers [2]. Concerning the YN interactions, one can have the direct $\Lambda N - \Lambda N$ part and the $\Lambda N - \Sigma N$ conversion couplings. The conversion couplings are expected to play an important role in the structure of heavier neutron-rich Λ-hypernuclei [3]. In fact, $\Lambda N - \Sigma N$ conversions are necessary to understand the binding energies of known hypernuclei [4,5], and is also important for understanding the equation of state that governs the size and mass of neutron stars [6].

Description of an hyperon in the nuclear medium is a many-body problem, and therefore, hypernuclei have to be treated using microscopic nuclear theory models. An extension of the Gamow shell model (GSM) formalism [7,8] has been done to the study of hypernuclei (GSM-H), extending the nucleon space to a more general baryon space, with applications for the structure of single-strangeness hypernuclei. The GSM makes use of Slater determinants defined in the Berggren [9] ensemble of single-particle (s.p.) states, which includes bound states, resonances, and (complex-energy) scattering states, to define the many-body basis in which the GSM Hamiltonian is diagonalized. In this way, one obtains the theory which preserves unitarity in all regimes of binding energy, since bound, resonance, and scattering states are treated on equal footing [7,8].

Motivated by the proposed and approved experiment at JLab to investigate the isospin dependence of medium-heavy hypernuclei $^{40,48}_{\;\;\;\;\Lambda}$K ($^{39,47}\mathrm{K}+\Lambda$), we have applied the GSM-H to determine the binding energies of the Λ hyperon and excited spectra of $^{40,48}_{\;\;\;\;\Lambda}$Ca ($^{39,47}\mathrm{Ca}+\Lambda$) and $^{40,48}_{\;\;\;\;\Lambda}$K isotopes. Moreover, a careful analysis of the $\Lambda N - \Sigma N$ coupling and its effects on spectra and binding energy has been done. Finally, we determined the nucleon number dependence of the YN effective interaction and the differences between neutron-Λ and proton-Λ interactions when increasing the number of valence neutrons.

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19:54–19:55

First tests from the Fast Radioactive Ion Extraction and Neutralization Device for S^{3} project

Speaker

Valentin MARCHAND (Université Paris-Saclay, CNRS/IN2P3, IJCLab, 91405 Orsay, France)

Description

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The GANIL accelerator complex in Caen, France recently commissioned a new superconducting linear accelerator as part of the SPIRAL2 facility. This facility will enable the production of heavy and super-heavy radionuclides via fusion-evaporation at the entrance of the Super Separator Spectrometer (S^{3}) experimental area. There, the secondary beam undergoes several stages of mass separation and focusing to be finally delivered to a focal plane experiment [1]. Located at S^{3} focal point, the S^{3} Low Energy Branch (S^{3}-LEB) is a low-energy experiment dedicated to the study of nuclides using the In-Gas Laser Ionization Spectroscopy (IGLIS) technique, as well as decay spectroscopy and mass spectrometry [2]. These techniques allow to probe the structure of exotic nuclei, providing access to properties such as the charge radius, the spin and the magnetic and quadrupole moments.

The reaction products from S^{3} enter the S^{3}-LEB gas cell by passing through a thin window. They are stopped and neutralized by collisions with the buffer gas before being extracted by the argon gas flow in a supersonic jet. In the gas jet, a two-step ionization of the isotopes is performed using wavelength-tunable titanium:sapphire (Ti:sa) lasers. The supersonic jet ensures a minimization of the pressure and temperature and, consequently, maximizes the spectral resolution.

The current S^{3}-LEB gas cell allows only the study of nuclides with a half-life superior to 600 ms. In order to speed up the extraction process for shorter species, the Fast Radioactive Ion Extraction and Neutralization Device for S^{3} (FRIENDS^{3}) project aims to design a new gas cell. The latter needs to minimize the extraction time, maximize the extraction and neutralization efficiency while minimizing the neutralization time. In the new design, the beam would enter through the window and be guided and extracted toward a neutralization tube using an electric field [3]. In the second part of the setup, the ions will then undergo neutralization by recombination with free electrons. The FRIENDS^{3} setup has been designed and constructed, and is currently in the test phase, first at Orsay, then at GANIL. This work will present the status of the FRIENDS^{3} project, as well as recent results from the commissioning phase.

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19:55–19:56 **Intruder band structures in neutron deficient odd-odd Tl nuclei**

Speaker

SNIGDHA PAL (Variable Energy Cyclotron Centre, Kolkata, India,)

Description

The investigation of nuclei near the proton shell closure at (Z = 82) remains a vibrant field of research, as these nuclei exhibit a rich interplay of shapes driven by shape coexistence, and proton-neutron interactions. In the (A $\sim$ 190) mass region, odd-odd thallium (Tl) isotopes serve as an exemplary testing ground where both symmetric oblate and triaxial configurations have been identified. While the proton Fermi level in these nuclei is nominally positioned near the 3s$_{1/2}$ orbital, the emergence of the strongly shape-driving h$_{9/2}$ and i$_{13/2}$ Nilsson orbitals at moderate deformations adds layers of complexity to the nuclear structure. The neutron Fermi level, located near the i$_{13/2}$ orbital above the (N = 100) semi-magic shell closure, plays a pivotal role in shaping the observed band structures.

Our comprehensive study was designed to investigate the structural evolution in Tl isotopes, particularly focusing on the relatively unexplored odd-odd nuclei ^{190}Tl and ^{192}Tl. Previous work in this mass region has revealed that while neutron-rich ^{202,204}Tl [1,2] nuclei tend toward near sphericity, their neutron-deficient counterparts display a spectrum of deformed shapes, including signatures of triaxiality manifested as chiral and t-band structures in nuclei such as ^{193,194,195,198}Tl [3,4,5,6]. In addition, Magnetic Rotational (MR) bands have been observed in ^{194,197}Tl [7,8], and the coexistence of prolate-oblate shapes is clearly observed in ^{189,191}Tl [9]. The scant experimental information on ^{190,192}Tl, however, has left its nuclear structure, particularly its transitional behaviour between axial and non-axial configurations, largely unresolved.

To address these uncertainties, we conducted two complementary fusion evaporation experiments. The first used ^{30}Si beam of 157 MeV energy delivered by the BARC-TIFR Pelletron LINAC in Mumbai, while the second used ^{16}O beam of 142 MeV energy from the K-130 cyclotron at VECC, India. Both experiments successfully populated high-spin states in the nuclei of interest, with prompt gamma-ray detection achieved using the INGA array equipped with up to 17 clover HPGe detectors. Through meticulous measurements of directional correlation ratios (R$_{DCO}$) and linear polarization asymmetry (Δ_{IPDCO}), we were able to establish definitive spin and parity assignments.

In our study, in ^{190}Tl the $\pi h_{9/2}$ $\otimes$ $\nu i_{13/2}$ oblate band has been expanded upto 21$\hbar$ i.e beyond the band crossing which can be compared with its neighbours. In addition, a new positive parity band, with a 4-quasiparticle configuration, has also been identified. It is characterised as MR band with a proposed particle-hole configuration of $\pi i_{13/2}$ $\otimes$ $\nu (i_{13/2})^{-1}(p_{3/2})^{-2}$ and described using a semi-classical framework [10]. In ^{192}Tl an updated levelscheme is constructed in which indications of octuple correlations have been observed. These findings offer critical insights into the evolution of nuclear shapes near the (Z = 82) shell closure. Further analysis and theoretical modelling are underway to explore the potential presence of chiral bands in these nuclei. We look forward to discussing these results and their implications at the conference.

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19:56–19:57 **Monte Carlo Simulation Studies for the BRAND Experiment**

Speaker

Mr Prateek Hegde (M. Smoluchowski Institute of Physics, Jagiellonian University in Krakow, Poland)

Description

The Standard Model (SM) of electroweak interactions relies on key assumptions, such as the vector and axial-vector nature of the weak force, parity violation, and the masslessness of neutrinos, which were initially inferred from neutron beta decay. Nowadays, precision experiments with slow neutrons are involved in searches of physics beyond SM (BSM). The BRAND experiment is one of them. It aims to measure eleven neutron beta decay correlation coefficients simultaneously, with seven of them—H, L, N, R, S, U, and V—being accessible through the transverse polarization of scattered electrons which will be measured using Mott-scattering. Beta decay events of polarized cold neutrons will be identified through the reconstruction of the three-body kinematics.

The current experimental setup for BRAND-II consists of two main components: the electron detection system (EDS) and the proton detection system (PDS). The EDS includes a Mott polarimeter equipped with plastic scintillators for measuring energy and a low-mass multiwire gas chamber for accessing their tracks. The PDS consists of an accelerating electric field, a proton-electron converter, and scintillation detectors for measuring proton time-of-flight and hit position. A Geant4-based Monte Carlo model of the setup has been developed for simulation studies of critical aspects of the experiment.

Very few experimental studies have focused on polarized electrons with energies below 1 MeV. Therefore, extensive Monte Carlo simulations are necessary in order to optimize the experimental setup. This work presents preliminary Monte Carlo results for Mott scattering, focusing on optimizing the target thickness and evaluating the detector setup's figure of merit for BRAND-II. Depolarization effects from multiple and plural scattering as the dominating destructive effects are examined. Additionally, the sensitivity of selected correlation coefficients is studied using energy and geometric cuts imposed by Mott polarimeter geometry using Monte Carlo simulations.

19:57–19:58 **Pre-neutron yields with the VAMOS++ spectrometer and its second arm**

Speaker

Alexis FRANCHETEAU

Description

We report on the pre-neutron mass yields of actinides near ^{232}Th measured in inverse kinematics at the VAMOS++ spectrometer and its newly developed second arm. The experiment used a ^{232}Th beam accelerated for the first time at GANIL, impinging on a carbon target (100 $\mu g\cdot cm^{-2}$) inducing fission of a few actinides from multi-nucleon transfer. The VAMOS++ spectrometer allows to measure the isotopic yields after neutron evaporation with a few percents of resolution. It is coupled with the PISTA detector, an array of DSSD detecting and identifying the target-like recoil at forward angles. This allows a better control of the excitation energy of the fissioning system. We present the new detection setup added to the VAMOS++ spectrometer to measure the second fragment. It is composed of two Multi-Wire Proportional Counters (MWPC) separated by 1.6~m, at 40° from the VAMOS++ spectrometer. This allows a precise velocity measurement of the second fragment which, coupled to the VAMOS identification, give access to the pre-neutron masses and therefore to the neutron evaporation of the fragment detected in VAMOS, event by event.

19:58–19:59

Study of the isospin dependence of the temperature of different sources in the 78Kr+40 and 86Kr+48Ca reactions

Speaker

Brunilde Gnoffo (Università degli Studi di Catania)

Description

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The influence of isospin on thermometric properties is examined in the reactions 78Kr + 40Ca and 86Kr + 48Ca at 10 AMeV. These reactions were realized as part of the ISODEC experiment at INFN-LNS (Laboratori Nazionali del Sud) in Catania, utilizing the 4π CHIMERA multidetector. The analysis of the collected data indicates a correlation between temperature and the N/Z ratio. Two thermometric approaches were employed to determine the temperature of different sources: the slope thermometer using alpha particles as a probe and the double isotope yield ratio method. The findings reveal that depending on the source, isospin affects the temperature differently. For example, for the compound nucleus source, the neutron-rich system exhibits higher temperatures compared to the neutron-poor one and this trend is further validated through comparisons with the GEMINI++ statistical model.

19:59–20:00

Study of Isotopic dependence of IVGDR width at low temperature near Sn region

Speaker

SAUMANTI SADHUKHAN (Variable Energy Cyclotron Centre (VECC), Kolkata, India)

Description

The isovector giant dipole resonance (IVGDR)—a macroscopic oscillation where neutrons and protons move out of phase—serves as a key probe for studying the structure of many-body quantum systems. Generally, the width (Γ_G) of IVGDR is related to the various damping mechanism of this collective vibration and is an important observable to understand the structural details of excited nuclei. Experimentally, it has been observed that Γ_G increases with temperature (T) within the range of 1 MeV $\le$ T $\le$ 3 MeV and further increase in T beyond this range may lead to the saturation in Γ_G [1]. However, exploring the low-temperature regime (T $\le$ 1 MeV) remains challenging due to difficulties in populating nuclei at such energies, primarily because of the Coulomb barrier in the entrance channel. Only a few studies exist in this regime and they reveal that microscopic effects such as shell structure and pairing fluctuations suppress the thermal broadening of Γ_G at low temperatures [2-6]. The Thermal Shape Fluctuation Model (TSFM) [7] is widely used to explain the mid-temperature behavior of Γ_G, while the Phonon Damping Model (PDM) [8] and the Critical Temperature Fluctuation Model (CTFM) [5] successfully describe the suppression at low temperatures. This suppression appears to be a general trend across a broad mass range (A $\approx$ 30–208), though an exception has been reported in ^{114}Sn [9]. In a recent experiment, measurement of high-energy γ -rays have been performed for ^{124,136}Ba at temperature around 1.1 MeV to study the properties of IVGDR over a wide N/Z range [10]. It has been observed that for ^{124}Ba, Γ_G shows little sensitivity to temperature, whereas for ^{136}Ba, it increases significantly. This difference suggests a dominant role of shell-closure effects in ^{136}Ba. A more systematic investigation across a wider mass range is needed to fully understand the influence of N/Z asymmetry and other microscopic properties on the variation of Γ_G with temperature.

Motivated by the need to explore the temperature dependence of the IVGDR width (Γ_G) in systems where shell effects are minimal, we conducted a systematic study across an isotopic chain of tellurium (Te) nuclei. The isotopes ^{116,120,128}Te were populated in the low-temperature regime (T $\approx$ 0.8–1.2 MeV) via α-induced fusion reactions using the K-130 cyclotron at VECC, India. The high-energy γ-rays (E$_\gamma$ $\ge$ 4 MeV) emitted from the decay of the excited Te isotopes were detected using the Large Area Modular BaF$_2$ Detector Array (LAMBDA) [11]. A multiplicity filter [12], comprising 50 BaF$_2$ elements (each 3.5×3.5×5 cm^3), was employed to measure the angular momentum (J) of the compound nucleus on an event-by-event basis. A detailed offline analysis was performed within the CERN ROOT framework to extract the GDR spectra from raw data after applying necessary corrections and selection cuts. The measured spectra were analyzed using the statistical model code TALYS. Our results indicate that Γ_G remains nearly constant up to T $\approx$ 1 MeV for all studied isotopes, beyond which it exhibits a clear increase with temperature. A complementary theoretical analysis was performed using Thermal Shape Fluctuation Model (TSFM), incorporating microscopic inputs derived from nuclear energy density functional calculations. This approach enables a self-consistent treatment of temperature-dependent nuclear properties while maintaining crucial connections to the underlying microscopic structure. Further details and implications of these findings will be presented at the conference.

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20:00–20:01 **Observation of gamma vibrational bands in even-Xe isotopes**

Speaker

Suchorita Paul (Variable Energy Cyclotrone Centre, Kolkata)

Description

The nuclei with few valence protons above Z=50 major shell closure, disclose a diverse structural phenomena, which are worth exploring. In these nuclei of A~120-130 region, the valence neutrons mainly promote the collectivity, whereas, the valence protons dominates the single particle structures in the nuclear structures. The available orbitals for both the protons and neutrons are, viz., 2d$_{5/2}$, 1g$_{7/2}$, 3s$_{1/2}$, 1h$_{11/2}$, 2d$_{3/2}$. The shape driving effects are promoted by low-Ω as well as medium to high-Ω ν unique parity h$_{11/2}$ orbital.
The Xe (Z=54) isotopes have valence protons in paired condition outside Z=50 shell closure and these isotopes in A~130 mass region lie in the transitional region between γ-soft rotor to vibrational nature near the N=82 shell closure [1, 2]. The different structural effects [3,4], such as, signature splitting, wobbling, chirality, γ-vibrational bands are the key indicators of triaxiality, depicted by different Xe isotopes. For quasi-γ band, the sequence of 2$_{2}$+, 3+, 4$_{2}$+, 5+, 6$_{2}$+ etc states and their decaying transitions to ground state bands are the main features. The yrast and near-yrast level structures of $^{128, 130}$Xe have been investigated via two complimentary reactions using heavy and light ion beams. The experiment was carried out at Variable Energy Cyclotron Centre (VECC), Kolkata, using 43 MeV α-beam from K-130 Cyclotron to populate ^{130}Xe on 2 mg/cm^{2} thick ^{130}Te two targets back to back, evaporated on a 600 μg/cm^{2} Myler backing at VECC, Kolkata (India). The de-exciting gamma rays are detected by 11 Compton suppressed HPGe Clover detectors and 1 Low-Energy Photon Spectrometer (LEPS) of INGA setup at VECC, Kolkata coupled to PIXIE-16 based digital data acquisition system [5]. The experiment to populate ^{128}Xe, was performed at BARC-TIFR Pelletron LINAC Facility, Mumbai using ^{124}Sn(^{9}Be,6n) fusion evaporation reaction at 40 MeV beam energy. Indian National Gamma Array (INGA) setup at TIFR, Mumbai in this experiment were consisted of 18 Compton suppressed Clover High Purity Ge (HPGe) detectors. The systematics γ-vibrational band in ^{128,130}Xe are observed from both the experiments. The theoretical calculation using TPSM has been done and the experimental observations are in good agreement with the theoretical results. The detailed results will be presented.
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20:02–20:03

Spectroscopy of even-even open-shell nuclei via self-consistent Gorkov-Green's function calculations

Speaker

Gianluca STELLIN (IJCLab, Université Paris-Saclay)

Description

In the last decade, the *ab-initio* self-consistent Gorkov Green's function (SCGGF) [1,2] approach has marked a step forward in the knowledge of bulk nuclear properties of even-even open-shell nuclei, such as the ones lying along the Ar-Cr isotopic chains [3,4]. The access to the one-particle propagator has allowed the study of ground and excited states of neighbouring odd-A isotopes [5-7].

Nevertheless, the prediction of excited energy levels and reduced electric and magnetic multipole transition probabilities calls for the introduction of the polarization propagator, previously not embedded in the $\mathrm{U}(1)_Z \times \mathrm{U}(1)_N$ symmetry breaking formalism.

In quantum chemistry, present-day approaches for the description of the spectrum of medium-sized organic molecules [8,9] are based on diagrammatic many-body Green's function theory applied to the polarization propagator at third order in the *algebraic diagrammatic construction* (ADC) approach [10-13]. The implementation of the ADC formalism to Gokov's polarization propagator is currently in progress and takes advantage from the output of the recently developed automated implementation of Wick's theorem (AIWT) code [14].

Another return of this is study will be provided by the prediction of new shell closures in neutron-rich even-even nuclei, identified through the local maxima in the energy of the 2_1^+ state and in the related electric quadrupole transition probability, $B(E2,0_1^+\rightarrow 2_1^+)$ [15].

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20:03–20:04

First measurement of the quadrupole moment of the 2^{+}_{1} state in ^{108}Sn and ^{110}Sn

Speaker

Rafael Antonio Lopez (Lund University)

Description

Recent Monte Carlo Shell Model (MCSM) calculations made by T. Togashi et. al. [Phys. Rev. Lett. 121, 062501 (2018)] attempt to account for discrepancies observed between measurements and previous theoretical calculations of the reduced transition probability B(E2;$2^{+}_{1} \rightarrow 0^{+}_{1}$) in the neutron deficient Sn isotopes. One of the predictions of the MCSM calculation is that a shape change should occur for the 2^{+}_{1} state between ^{108}Sn and ^{110}Sn. In this work we present the first experimental results for the quadrupole moment for this state in ^{108}Sn and ^{110}Sn, along with a more precise determination of the reduced transition probability B(E2;$2^{+}_{1} \rightarrow 0^{+}_{1}$) in order to address this question.The measurement results were obtained through a safe Coulomb excitation experiment at HIE-ISOLDE, using the Miniball setup. A novel analysis approach combining GOSIA and GOSIA2 codes with a DSAM measurement was used to calculate both diagonal and transitional matrix elements. Preliminary results are compared to MCSM calculations and observations regarding a shape change in the 2^{+}_{1} state are discussed.

20:04–20:05

The Search for Double Alpha Decay at the FRS Ion Catcher, GSI: Ra-224 Data Analysis Status

Speaker

Mr Makar Simonov (Justus Liebig University Giessen)

Description

The idea of the capability of nuclei to emit two alpha particles simultaneously dates back to the late 1970s, inspired by the concept of two-proton radioactivity. Subsequently, observation of the exotic decay was considered unfeasible due to the extremely low branching ratio, which was calculated to be on the order of 10^{-20} or less. Recent theoretical work by Mercier *et al.* (PRL **127**, 012501 (2021)) raised the estimate to 10^{-8}, which triggered several experiments to search for the double alpha decay at GSI, CERN, and MSU.

In this report, we will focus on the results of an experiment on the search for Ra-224 double alpha decay, which was conducted at the FRS Ion Catcher (GSI). The offline production of Ra-224 from a Th-228 source provides a clean spectrum of decay products and reduces the contribution of random coincidences. To allow onward filtering of candidate double alpha-decay events, a Monte Carlo-based simulation and analytical data handling procedures have been developed. Background simulation results will be shown, and estimates of the time and energy resolution of the DSSD detectors will be presented.

20:05–20:06

Fusion Hindrance using a Markov Chain Method

Speaker

Mr Filip Agert (Lund University and GANIL and UNICAEN)

Description

The synthesis of superheavy nuclei (SHN) with heavy ion collisions is modelled as a three staged model: *capture*, *formation* and *s urvival*, where this presentation explores the first two stages. Starting from the model in [1], the memoryless Brownian random walk was replaced by a Markov chain approach yielding significantly faster calculations which was then used to determine the cross sections in the production of SHN with deformed nuclei as targets [2]. In the presentation I show the results of this work that is presently being extended to yield systematic cross section predictions for different combinations of targets and projectiles [3]. To be able to present preliminary cross section results, the KEWPIE2 code is used for computing the survival probability [4].

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20:06–20:07

Imprint of alpha-clustering on nucleon-nucleon correlations in relativistic light ion collisions

Speaker

Dr Hadi Mehrabpour (Peking Univresity)

Description

This study investigates the influence of α-cluster structures in relativistic light nuclear collisions. Using a cluster framework, the characteristics of the nucleonic configurations of ^{16} O and ^{20} Ne are extracted as predicted by various \textit{ab initio} models, including Nuclear Lattice Effective Field Theory (NLEFT), Variational Monte Carlo (VMC), and the Projected Generator Coordinate Method (PGCM). Additionally, I analyze configurations derived from a three-parameter Fermi (3pF) density function. The investigation focuses on the effects of cluster parameters on two-point correlators using a rotor model for symmetric collisions (^{16}O+^{16}O and ^{20}Ne+^{20}Ne) and asymmetric collisions (^{208}Pb+^{16}O and ^{208}Pb+^{20}Ne). The cluster parameters are determined by minimizing the \textit{chi-square} statistic to align the nucleon distributions with those predicted by the mentioned theories. The results reveal that perturbative calculations effectively capture the structural features of these nuclei, while comparisons with Monte Carlo simulations validate these findings. Furthermore, The analysis reveals distinct cluster geometries: VMC suggests tetrahedral shapes, while NLEFT, PGCM, and 3pF indicate irregular triangular pyramids. Notably, NLEFT shows a bowling pin-like α cluster structure for ^{20}Ne. The study also identifies constraints on cluster parameters in the ground and excited oxygen states, with a gradual increase in $\varepsilon_2\{2\}$ for excited states. Accurate modeling of asymmetric collisions requires a range of nucleons from heavy spherical nuclei, leading to weighted correlators in perturbative calculations. I demonstrate consistency between perturbative calculations and Monte Carlo models, with analytical calculations providing more insights into asymmetric than symmetric collisions.

20:07–20:08

Proton-induced fission of 232Th and 238U for RI beam production at RAON

Speaker

Chang-hoon Song (Pusan National University)

Description

Proton-induced fission of ^{232}Th and ^{238}U at tens-of-MeV energies has been studied. This type of reactions is commonly used in the isotope separation on-line (ISOL) technique, which provides high-quality and intense rare isotope (RI) beams. This work aims to estimate RI beam yields for application at RAON, Korea's heavy-ion accelerator. A stochastic model based on the Langevin approach is employed to describe the shape evolution of excited compound nuclei (^{233}Pa and ^{239}Np), incorporating the fluctuation-dissipation theorem. Shell correction energies, which vary with excitation energy, are included in a potential energy surface (PES) based on the liquid-drop model. A multi-chance fission (MCF) framework, utilizing the Fermi gas model, accounts for the persistence of shell effects at high excitation energies, which prevent the mass distribution of fission fragments from becoming symmetric. The contribution of each fission chance in the MCF is compared with the GEF, and both sets of results were further compared with experimental data, confirming the accuracy of the proposed method for estimating RI production yields.

20:08–20:09

Study of Release Properties of Sn, Ag, and Pd in an Upgraded Inductively Heated Hot Cavity Laser Ion Source

Speaker

Saikumar Chinthakayala (University of Caen)

Description

The region surrounding the doubly magic nucleus ^{100}Sn, particularly on the proton-rich side beyond the (N=50) shell closure, provides a crucial test ground for modern nuclear structure models. It offers access to fundamental phenomena such as isospin symmetry breaking, nucleon pairing, shell evolution, and the influence of the tensor force and Wigner energy [1]. Despite its importance, this region remains experimentally underexplored due to the significant challenges associated with producing and extracting short-lived, proton-rich isotopes with high efficiency.

To address these challenges, we conducted systematic studies of the production and release of Ag, Sn, and Pd isotopes using an upgraded inductively heated hot-cavity laser ion source (HCLIS) at the IGISOL facility. These investigations serve as essential precursors to precision laser spectroscopy and high-resolution mass measurements of isotopes near the (N=Z) line.

In the experimental setup, stable beams of Ag and Sn at 495 MeV from the K130 cyclotron were implanted in the HCLIS, evaporated, and resonantly ionized via multistep laser excitation. The resulting ions were accelerated to 30 kV, mass separated, and detected at the focal plane using either a Faraday cup or a microchannel plate (MCP) detector. Overall ionization and extraction efficiency was quantified by comparing the implanted beam current to the yield of mass-separated ions. Ion time profiles were recorded using a time-to-digital converter (TDC), synchronized via pulsed primary beam control.

For Pd, the release results were obtained from radioactive ^{99}Pd, which was produced via fusion-evaporation reactions. In the same experimental campaign, ^{92}Pd at the (N=Z) line was produced and its mass was measured directly for the first time with a MR-ToF mass spectrometer. Complementary COMSOL and Monte Carlo simulations are underway to model isotope effusion and transport dynamics within the HCLIS system.

The preliminary results demonstrate a total release and ionization efficiency of approximately 10% for Ag, with extraction times on the order of a few milliseconds. The efficiencies for Sn and Pd were around 5%, with Sn released within 350 ms and Pd within several seconds. These findings validate the performance of the HCLIS system and demonstrate its suitability for future spectroscopic studies in the proton-rich (N=Z) region near ^{100}Sn. Moreover, the measurements provide essential input for optimizing the design of target-ion source systems in upcoming experimental campaigns.

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20:09–20:10 **Low-Energy Fusion of Magic Nuclei: the Case of 16O+48Ca**

Speaker
Lorenzo Corradi (INFN-LNL)

Description

Motivated by the doubly magic nature of the system ^{16}O + ^{48}Ca, we have measured [1] its fusion excitation function from above to far below the barrier at the Laboratori Nationali di Legnaro of INFN. We have used the ^{16}O beams from the XTU Tandem accelerator. The fusion cross sections were measured down to a few µb by identifying the evaporation residues in a detector telescope, downstream of an electrostatic beam deflector.
Coupled-channel calculations with the Akyuz-Winther potential, including the lowest 2$^+$ and 3$^−$ states of ^{48}Ca, well fit the data down to σ_{fus}≈ 0.8 mb. At lower energies, the hindrance effect shows up. The fusion barrier distribution has a single main peak.
At lower energies, the data are consistent with pure one-dimensional tunnelling, as observed for ^{12}C + ^{24}Mg, ^{30}Si [2].
The logarithmic slope reaches the L$_{CS}$ value, and the S factor develops a maximum vs energy. The low-energy data are well fit by an empirical approach simulating the coupling strength damping (adiabatic model), while the hindrance model fits the S factor maximum but not its increase at the lowest energies.
Doubly-magic systems were previously investigated, and the present case ^{16}O + ^{48}Ca confirms their common trend when the various Coulomb barriers are considered.
The phenomenological systematics proposed for heavier, stiff systems several years ago [3] have required adjusting the fit parameters, leading to updated hindrance predictions for the light systems of astrophysical interest.

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20:10–20:11 **Influence of pure isoscalar neutron-proton pairing on nuclear statistical quantities.**

Speaker
Dr Djamila Mokhtari (USTHB)

Description

Abstract
Pairing correlations are an essential feature in the understanding of nuclear structure. Recently, renewed interest in the study of these correlations occurred [1-2] due to the development of the radioactive beam facilities that made the experimental study of medium mass nuclei such as N≈ Z possible.
In the isospin formalism, the pairing effect can exist in the isovector case (T=1) which corresponds both the pairing between like-particles and the neutron-proton pairing, and the isoscalar case (T=0) which corresponds to only neutron-proton pairing. T being the isospin quantum number.
It's shown from both theoretical and experimental studies that, besides the isovector pairing, isoscalar one may also be of importance in N≈Z nuclei [3-4]
On the other hand, the study of the temperature effect on pairing correlations at finite temperature have been the subject of many efforts since the sixties and is still a relevant subject [5- 7].
In the present work, expressions of the various statistical quantities, i. e. , the energy, the entropy and the heat capacity are deduced using a path integral approach in the pure isoscalar pairing (T=0). A numerical study is then performed using the schematic one level model.
It's shown that the behavior of the various statistical quantities as a function of the temperature is similar to that obtained using the conventional FTBCS theory in the pairing between like-particles case. An increase in the energy value is noted compared with other types of pairing.

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20:11–20:12 **Double-beta decay Q-value measurements with the JYFLTRAP Penning trap**

Speaker

Jouni Ruotsalainen (University of Jyväskylä)

Description

The observation of double-beta decays and double-electron captures have become an important tool in the search for physics beyond the Standard Model (SM). These decays have been proposed to decay by emitting either two neutrinos or no neutrinos. While the two neutrino mode has been observed [1], the proposed neutrinoless decay mode requires the neutrino to be its own antiparticle (a Majorana particle), which would be a violation of the SM. To determine the suitability of an isotope for these observations, the energy released in the decay (Q-value) needs to be known precisely in order to calculate its half-life (generally $\geq10^{25}$ a [1]), and thus the feasibility of observing the neutrinoless decay mode and to separate the decay signal from background.

In three recent measurements at the Ion Guide Isotope Separator On-Line (IGISOL) facility [2] in the University of Jyväskylä, the JYFLTRAP double Penning trap [3] employing the Phase-Imaging Ion-Cyclotron Resonance (PI-ICR) method [4] was used to determine the $Q_{\beta^-\beta^-}$ of ^{104}Ru [5], ^{122}Sn, ^{142}Ce and ^{148}Nd, and Q_{ECEC} of ^{120}Te. In addition, the precisely known Q_{ECEC} of ^{102}Pd [5] and ^{150}Nd, and $Q_{\beta^-\beta^-}$ of ^{124}Sn were re-measured. The ions were produced using two electric discharge ion sources. A precision of $\sim$100 eVs was reached for the Q-values. Most of our measurements are in agreement with their literature values in the Atomic Mass Evaluation [6]. In my contribution, I will present the JYFLTRAP measurement setup, the PI-ICR measurement technique and the results of our measurements.

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20:12–20:13

The spectrum of ^{18}O and ^{40}Ca nuclei in terms of the multiconfigurational dynamical symmetry

Speaker

Chandra Sekhar Panda (HUN-REN Institute for Nuclear Research, 4001 Debrecen, P. O. Box 51, Hungary, and Doctoral School of Physics, University of Debrecen, 4026 Debrecen, Bem tér 18/B, Hungary)

Description

The multi-configurational dynamical symmetry (MUSY) serves as a unifying framework that links the fundamental structure models of atomic nuclei: the shell, collective, and cluster models [1, 2]. It constitutes a composite symmetry where each configuration possesses a usual [U(3)] dynamical symmetry and an additional symmetry that connects these configurations among themselves. As a consequence of the latter feature, it enables the connection between wave functions of different configurations, such as shell, quartet, or cluster configurations.
We have applied MUSY to the ^{18}O and ^{40}Ca nuclei for the unified description of the complete spectrum, including different configurations and energy valleys. Furthermore, we have obtained shape isomers from the study of the Stability and self-Consistency of SU(3) Symmetry (SCS) [3].

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20:13–20:14 **Resonance Effects on Breakup and Fusion Cross Sections in 6,7Li + 209Bi Reactions**

Speaker
Dr Lucas Vusi Ndala (University of South Africa)

Description

We employ the Continuum Discretized Coupled Channels (CDCC) method to investigate the breakup and total fusion cross sections for the weakly bound nuclei 6Li and 7Li on a 209Bi target at energies below, around and above the Coulomb barrier. Our analysis reveals that the inclusion of projectile resonances enhances breakup cross sections while suppressing fusion cross sections. These resonances exhibit opposite and slightly pronounced effects on the integrated breakup and fusion cross sections,
emphasizing their role in reaction dynamics. These findings contribute to a deeper understanding of the influence of projectile structure on nuclear reactions below, around and above the Coulomb barrier.

20:14–20:15
PROBING SHORT RANGE CORRELATIONS IN HEAVY-ION DOUBLE CHARGE EXCHANGE REACTIONS

Speaker
Diana Carbone (INFN-LNS)

Description

The high momentum transfer encountered in heavy ion Double Charge Exchange (DCE) reactions provides an ideal environment for studying correlation phenomena beyond mean-field in Nuclear Matrix Elements (NMEs). This investigation is of paramount interest for probing the nuclear counterpart of the elusive neutrinoless double beta ($0\nu\beta\beta$) decay. Currently, the NMEs for such a decay are embedded in a complex puzzle due to the large uncertainty in their determination [1]. Knowing with high precision the NMEs, the neutrino Majorana mass might be determined, provided the $0\nu\beta\beta$ lifetimes [2]. In this respect, the NUMEN [3] project aims to study a wide range of heavy-ion induced DCE reactions in order to provide constraints in the calculation of the NMEs [2].
The DCE reaction is mainly fed through three main competitive processes, namely multi-nucleon Transfer Double Charge Exchange (TDCE) [4], the Double Single Charge Exchange (DSCE) [5] and the Majorana Double Charge Exchange (MDCE) [6]. The latter is a meson exchange process mediated by an effective rank-2 isotensor interaction, coming from the off-shell pion-nucleon DCE scattering. It presents a pronounced short-range character, ranging from the dimension of about 1 fm. Microscopic calculations of MDCE-NMEs have been performed, where the pion potentials play the role of the strong interaction counterparts to the $0\nu\beta\beta$ neutrino potentials. The strong short-range correlations induced by the pion potentials leading to a new type of two-body transition form factors, which are of central importance and highest interest for nuclear spectroscopy. The multipole structure of pion potentials and NMEs will be discussed and first preliminary results for the theoretical cross section angular distributions will be presented and compared with experimental data.

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20:15–20:16 **Role of the effective interaction on Bohr Hamiltonian calculations**

Speaker
Clementine Azam

Description

The Bohr-Hamiltonian (BH) method [1,2], based on microscopic Hartree-Fock-Bogoliubov calculations, is the tool of choice to perform systematic calculations of the properties of low-energy states along the nuclear chart with a good degree of accuracy [3].
A first systematic study [4] shows that, despite the cranking approximation used to calculate the mass parameters, the BH is able to reproduce the energy of the first 2^+ for more than 500 nuclei with an accuracy of $\approx$ 20 \%.

Although the effective nucleon-nucleon (NN) interaction is not explicitly included in the expressions of the generalised BH, it explicitly contributes to the determination of the deformation landscape as well as the single particle shell structure.
In Ref.[5], a limited study on krypton isotopes has shown that a small adjustment of the spin orbit term can lead to remarkable differences in the observed energies and electromagnetic transitions of low-energy collective states.

In recent years, several groups have worked to further improve the Gogny interactions, and since Gogny's original work in the 1980s, great advances have been made to improve on well-known shortcomings of the original force. For example, the D1M [1] interaction has been adapted to include the so-called zero point energy arising from coupling to collective vibrations, while the D3G3M [7] has been adapted to further improve the infinite matter properties of the D1M.
It is therefore important to study the performance of these new interactions on the energy spectra obtained by the BH method.

In this talk, I will present the results of the BH using a variety of Gogny interactions to perform a sensitivity study of the role of the different terms on the position of the low energy states. In particular, I will discuss how the inclusion of additional beyond mean field corrections can affect the calculations.

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20:16–20:17 Exploring Clustering in Exotic Nucleus

Speaker

Gokul Arakkal (Cochin University of Science and Technology)

Description

The study of atomic nuclei presents a compelling example of the challenges involved in solving many-body systems. Understanding these complexities reveals one of the most intriguing mysteries of the Universe: the fundamental information of atomic nuclei. The first theoretical models of molecular states and nucleon clustering in atomic nuclei were proposed in the 1930s [1]. In this context, we employ the relativistic Hartree-Bogoliubov (RHB) framework to explore these phenomena, which naturally incorporates critical relativistic effects such as spin-orbit interactions and scalar and vector potentials [2]. This study utilizes the RHB method to investigate nucleon clustering in nuclei near the neutron drip line, particularly at extreme conditions [3, 4]. Key insights are drawn from parameters such as the density profile and nucleon-nucleon correlation functions.

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20:17–20:18 Generative machine learning improves microscopic description of dissociation reactions

Speaker

Alice Bernard

Description

Over the last five years, generative machine learning has proven to be incredibly powerful in various domains: communications, image processing, graph analysis… The question now is: how can it help improve the microscopic description of complex physical phenomena, such as nuclear fission? In fact, there is currently no theoretical model capable of predicting fission half-lives, yields and de-excitation of the fragments over the entire the nuclear chart. Nevertheless, thanks to the increasing power of supercomputers, the energy density functional is now able to describe dissociation reactions from alpha-emission to actinide fission. In particular, the Time Dependent Generator Coordinate Method is a successful method to obtain fission yields and half-lives.
This approach relies on the computation of potential energy surfaces, which are currently determined by minimizing the energy of the system given some constraints on its shape [1].
In theory, these constraints should be representative of the deformations that the nucleus undergoes during fission. However, the minimization procedure often leads to the presence of “discontinuities" in the potential energy surfaces [2]. A discontinuity is the fact that two states that should occur immediately after each other are very different. In such cases, some information is missing, preventing sound studies of the fission dynamics, especially after and close to the point of scission.
In this talk I will present a method to get rid of discontinuities in potential energy surfaces. This method builds new coordinates based on a generative machine learning algorithm. These new coordinates are more representative of the evolution of the nucleus and allows to describe states that were not accessible within the previous description. This leads, for example, to new potential energy wells and barriers that affect the calculation of half-lives. I will emphasize the first applications of this method to superfluid systems: a study of the 20Ne quadrupole deformation and the alpha emission of 104Te. Eventually, I will discuss its perspectives in the context of fission.

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20:18–20:19

Study of the structure of neutron-rich isotopes 22, 23, 24O in inverse kinematics with the R3B experimental setup at GSI/FAIR

Speaker

pablo González Rusell (USC and UDC)

Description

Pablo González Rusell for the R^{3}B collaboration

The atomic nuclear structure is still one of the most complex problems in modern physics. This is due to the fact that many-body correlations beyond the symmetries of the nucleon-nucleon potential leads to the existence of a large number of nuclear systems whose properties differ significantly from what can be expected based on the simple addition of nucleons. An example of these phenomena is the drastic extension of the neutron drip line for $Z=9$ compared with $Z=8$ isotopes [1, 2]. The neutron drip line is the limit of nuclear binding from which adding more neutrons is no longer possible, resulting in the spontaneous emission of neutrons (dripping). In order to understand the drip line phenomena, studying and characterizing the structure of $Z=8$ and $Z=9$ isotopes through one nucleon removal reactions is fundamental.

In particular, our study aims to deploy the reaction ^{25}F(p,2p)^{24}O, in inverse kinematics, in order to characterize the final states of the residual ^{24}O core, similar to what was done in [3], but with significantly higher resolution, statistics, and acceptance provided by the R3B (Reactions with Relativistic Radioactive Beams) experimental setup at GSI/FAIR. More thoroughly, an incoming ^{25}F-beam with an energy of 650 MeV/nucleon will impinge onto a LH$_{2}$-target of 15 cm length. The outgoing heavy fragments of $^{22,\; 23,\; 24}$O will be measured in coincidence with the (p,2p) reaction, providing an indication of populated excited or ground states of ^{24}O. Furthermore, since there are no bound excited states of $^{23,\; 24}$O, the de-excitation process will proceed through one or two neutron emissions, which will be measured with high resolution in the neutron detector NeuLAND, allowing us to resolve and study the excited states of ^{24}O. The cross-sections to populate individual final states together with the reconstructed momentum distribution of the decaying ^{24}O system would help to accurately determine the configuration of the excited ^{24}O core in ^{25}F.

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20:19–20:20

SU*(3) limit of the Interacting Boson Model and its relation to the realistic shell model

Speaker

Prof. Takahiro MIZUSAKI (Senshu univeristy)

Description

In the neutron-proton interacting boson model (IBM-2) [1], the SU*(3) limit appears, which has a triaxial nature. It was first clarified by A.E.L. Dieperink and R. Bijker [2] with group theory and with coherent state analysis. This triaxiality has been also suggested from the correspondence between shape variables (β, γ) and SU(3) irrep label (λ, μ) by Ref. [3]. Moreover, the SU*(3) limit corresponds to one of the corners in IBM-2's extended symmetry triangle, where quantum phase transition lines (surfaces) and quantum critical points between spherical and triaxial shapes have been reported in Refs [4,5].
Here, we investigate the ground state and the excited state properties of the SU*(3) limit with angular momentum projected coherent state beyond mean field picture. We will discuss the relationship between intrinsic pictures and group theory, and will clarify the characteristics of the SU*(3) limit.
IBM-2 has given us various useful concepts to understand interacting nucleon systems. However, it is limited in the quantitative description because complex dynamics of fermion pairs are treated by boson approximation. The IBM concepts should be reinvestigated within the realistic shell model with the help of modern computational many-body methods.
Recently, we found a shell-model counterpart of the IBM-2 extended symmetry triangle by large-scale shell model calculation. Here we use the angular momentum projected Generator Coordinate Method (GCM) based on the Hartree-Fock-Bogoliubov (HFB) states with the realistic shell model (PMMU) interaction [6]. We will report it.

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20:20–20:21

Developments for the S3 Low Energy Branch at the GISELE laser laboratory

Speaker

Andres Felipe LOPEZ (PhD GANIL CNRS)

Description

Laser spectroscopy for studying the ground and isomeric state properties of exotic nuclei has established itself as a versatile and powerful tool, with the capabilities of providing access to nuclear model-independent data about charge radii, electromagnetic moments and spins [1]. Part of this achievement is owed to the possibility of having narrow-bandwidth (60 MHz), high power and tunable laser sources, which allow measuring the hyperfine structure and isotope shift along isotopic chains.

The Low-Energy-Branch (LEB) joined to The Super Spectrometer Separator (S3) facility at GANIL-SPIRAL2 will enable high-resolution in-gas-jet laser spectroscopy of radioactive nuclei produced with extremely low cross sections [2-3]. The online commissioning plan for S3 (and thus S3-LEB) has been established, and the first fusion-evaporation reaction used will give the opportunity to obtain nuclear and atomic information of neutron-deficient isotopes around erbium, towards the N=82 shell closure.

As part of the preparation for the first experiments, offline tests of full Ti:sapphire laser system and required laser spectroscopic schemes are carried out at the GISELE laser laboratory on elements of interest such as dysprosium and erbium [4]. The results of these offline measurements and related technical developments will be presented in this contribution.

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20:21–20:22

Energy and Deformation Dependence of Collective Enhancement in Nuclear Level Densities

Speaker

Parvathi V Nair (Cochin University of Science and Technology, Kochi, Kerala, India)

Description

The nuclear level density (NLD) represents the number of accessible energy states in a nucleus at a given excitation energy and is vital for modeling nuclear reactions and decay processes. At lower excitation energies, NLD is significantly enhanced by collective effects, rotational and vibrational motions, which are prominent in deformed nuclei. This phenomenon, referred to as collective enhancement (CELD), is often quantified by a deformation-dependent factor. As excitation energy rises, the ordered nature of collective motion breaks down, marking a shift from a collective to intrinsic single-particle excitation regime. Additionally, nuclear pairing interactions, which suppress level density at low energies, weaken with increasing temperature, further influencing the NLD behavior.
Experimental data across different mass regions consistently support the existence and subsequent fadeout of collective enhancement with rising excitation energy. These observations emphasize the need to incorporate both collective and pairing effects, along with their dependence on energy and deformation, for realistic and predictive NLD models. In the present study, we investigate the behavior of CELD and its fadeout in excited nuclei, emphasizing the correlation with nuclear deformation and excitation energy.

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20:22–20:23

Multipolarity and Mixing ratio of γ-ray in ^{67}Ga

Speaker

Nandini Patel (University of Delhi)

Description

In the light odd-mass $^{65-69}$Ga isotopes ($Z = 31$), the excited states have several bands arising from the weak coupling of a quasi-particle occupying the $\pi f_{5/2}$, $\pi p_{3/2}$, and $\pi g_{9/2}$ orbitals [1]. In the present study, the excited states of ^{67}Ga were populated via ^{56,57}Fe(^{13}C, p2nγ/pnγ) fusion-evaporation reaction at 45 MeV beam energy. The ^{13}C beam was obtained from the 14 UD Pelletron accelerator at the Tata Institute of Fundamental Research (TIFR), Mumbai, India. The Indian National Gamma Array (INGA), equipped with 15 Compton-suppressed HPGe clover detectors (at the time of the experiment), was used to detect the de-excited γ-rays. The level scheme analysis was performed using the RADWARE package [2] and Cubix software [3].

In the present work, the low-lying γ-ray transitions were reinvestigated using two-fold and three-fold coincidences. The spin and parity of the levels were assigned based on the R_{DCO} and linear polarization asymmetry (Δ) values. In our measurements, the 342.5-, 416.6-, 554.4-, 712.4-, 824.0-, 888.4-, 958.0-, 1159.8-, 1202.0-, 1239.8-, 1317.9-, 1330.7-, and 1641.5 keV γ-ray transitions exhibit quadrupole character with $\Delta I = 2$ or $\Delta I = 0$. The 358.9-, 546.1-, 842.9-, 871.3-, 935.2-, and 1343.4 keV γ-ray transitions have been identified as dipole transitions. Based on polarization asymmetry (Δ) measurements, the 712.4-, 824.0-, 888.4-, 958.0-, 1159.8-, and 1202.0 keV γ-ray transitions are of $E2$ character, while the 871.3 keV γ-ray transition is of $E1$ character. The 554.4 keV γ-ray transition has a negative polarization asymmetry (Δ) value and exhibits $E1$ ($\Delta I = 0$) character. Other transitions, such as 358.9-, 546.1-, and 842.9 keV, have $M1/E2$ character.

The relative intensities of the measured γ-ray energies are also reported in our work. The multipolarity of the γ-rays agrees with a recently published paper; however, due to limited statistics, we did not observe the newly reported $E3$ transition [4]. To determine the mixing ratio of the γ-rays, further analysis is in progress, and more results will be presented during the conference.

Acknowledgment
We thank the INGA group and the Pelletron staff at the Tata Institute of Fundamental Research for their assistance. One of the authors, Nandini Patel, acknowledges the financial support from the University Grants Commission (UGC), India, through a research fellowship at the University of Delhi, New Delhi 110007, India.

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20:23–20:24

Unbound states in 19O(d,p)20O to understand the oxygen dripline

Speaker

Charlie James PAXMAN (GANIL)

Description

The neutron dripline in oxygen isotopes presents a clear challenge and unique opportunity for studies of shell evolution and nuclear structure. The heaviest observed bound isotope of fluorine ($Z=9$) has 22 neutrons, whereas oxygen -- with only one fewer proton, $Z=8$ -- can only bind 16 neutrons. This striking anomaly is a result of an increase in the spacing between the ν($d_{3/2}$) orbital and the ν($s_{1/2} d_{5/2}$) orbitals, which could only be explained by the inclusion of three-body forces. As such, measurements relating to the ν($d_{3/2}$) orbital in oxygen isotopes are of significant interest, in order to test our current models. Unfortunately, comprehensive spectroscopy close to the dripline is limited by the intensity and quality of radioactive isotope beams. In this work, we instead search for ν($d_{3/2}$) orbital occupation in the the high-energy states of a less-exotic isotope.

The single-neutron transfer reaction ^{19}O(d,p)^{20}O has been performed at GANIL using a high-quality radioactive beam of ^{19}O impinged on a solid CD$_2$ target (both with and without gold foil backing). States up to and above the neutron separation energy were populated. The resulting ^{20}O heavy recoil, ejected proton, and prompt γ-ray emissions were detected using the state-of-the-art MUGAST+AGATA+VAMOS triple-coincidence experimental set-up. Bound states populated by s-wave and d-wave transfer have been identified, and angular distributions of at least three unbound states between 7.6 MeV and 9.0 MeV have been observed, accessed for the first time through the ^{19}O(d,p) channel.

20:24–20:25

Preliminary Results on the Gamma-Spectroscopy of 229Ac Following the Beta Decay of 229Ra

Speaker

Dr Magda Satrazani (KU Leuven)

Description

The isotope ^{229}Th is of particular interest due to its exceptionally low-energy isomeric state ($\sim$ 8.2 eV), which can be studied via vacuum ultraviolet (VUV) spectroscopy, and holds great potential for the development of a nuclear clock [1,2]. Understanding this isomer's properties, including its excitation and decay modes, is hereby essential and involves investigating the nuclear structure in the actinide region. In recent work at ISOLDE the isomer was populated via the beta-decay of ^{229}Ac and allowed to observe its radiative decay [2,3]. The odd-even nucleus ^{229}Ac, as the part of the beta-decay chain from ^{229}Ra to ^{229}Th, is directly linked to the population and depopulation of nuclear states that influence the feeding of the isomer. However, despite its relevance, the structure of ^{229}Ac remains poorly studied, with little experimental data available.

To address this, we have performed a gamma-spectroscopy study of ^{229}Ac following the beta-decay of ^{229}Ra. The data were collected at the ISOLDE facility at CERN using the ISOLDE Decay Station (IDS) [4], which provides high-resolution gamma-ray detection capabilities. This study aims to refine the level scheme of ^{229}Ac, identify key transitions, and improve our understanding of the nuclear structure in this region. The preliminary results presented in this work, aim to contribute to a more comprehensive picture of the nuclear properties of the actinide region of the nuclear chart.

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20:25–20:26

Effects of neutron emission during fission on fragment mass distribution calculated with dynamical model

Speaker

Shinya Takagi (Kindai University)

Description

Fission is one of the most complex reactions. The mass asymmetry of the fission fragments depends on the shell structure of the fissioning nucleus. It is generally believed that mass-asymmetric fission disappeared due to the annihilation of the shell structure in high excitation energy. Recently, however, fissioning over a wide range of excitation energies has been experimentally observed by producing fissioning nuclei through multi-nucleon transfer reactions [1,2]. In that experiment, it was found that the fission fragment mass distributions (FFMDs) maintain a double-humped structure even at high excitation energies such as 50 MeV. It can be explained by using the concept of multi-chance fission. In the general concept of multi-chance fission, fissioning nuclides changes by multiple emissions of neutrons before fission. The neutron emission lowers the excitation energy of fissioning nucleus, which restores the shell structure, thus reviving mass-asymmetric fission.
The purpose of this study is to introduce neutron emission during fission in the dynamical model, in contrast to the general approach that neutron can be emitted at the compound nucleus shape. In our model the shell structure can revive at any step of nuclear shape evolution. We observed the effect of neutron emission in FFMDs also in this approach. Effects of neutron emission, such as isotope dependence of pre-scission neutron multiplicity for fissioning nuclides, are discussed.

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20:26–20:27

Simulation experiments for direct dineutron decay observation

Speaker

Nadiia Sakhno (International Nuclear Safety Center of Ukraine of Taras Shevchenko National University of Kyiv)

Description

In our previous studies, possible and statistically significant observations of a bound dineutron in nucler reactions with fast neutrons on 159Tb [1] and 197Au [2] nuclei was investigated, that coincides with the Migdal's and Dyugaev's [3, 4] predictions about bound dineutron existence. To directly observe the decay of bound dineutrons, the estimation of half-life and the end-point energy for the dineutron decay was made [5, 6]. In addition, some suggestions for the future experiment for direct observation of bound dineutron decay were discussed in [7] along with the list of the nuclei as possible candidates, on which a bound dineutron could be observed in future experiments [8, 9].
In this work, we develop and test the simulation model for the future experiments proposed in [7] for the observation of bound dineutrons in neutron induced nuclear reactions on nuclei from the list defined in [8, 9]. The "irradiated" samples were placed between two thin plastic organic scintillators for detection of electrons due to dineuron decay and surrounded by two BGO detectors for detection of the emitted gamma-rays by nuclear reaction products. Detectors and corresponding circuits may operate both in coincidence and anticoincidence modes. The difference between the detected beta-spectrum with and without formation of dineutrons with thorough consideration of gamma-rays emitted from residual nuclei, can be the directly treated as the sign of the formation of a bound dineutron. The scheme of the decay of dineutron caused by the Gamov-Teller of Fermi transitions with the known decay schemes of residual nuclei are used for the simulation. The dineutron decay was emulated via 90Sr decay with a modified half-life. The predictions about the cross-sections of bound dineutrons formation were also taken into account. The list of the sample nuclei, on which the formation of bound dineutron is expected, was defined. Among them, 169Tm is considered as one of the most promising target nuclei. On the basis of the simulated experiment results, the future real experiment with a more precise estimate of reaction cross-sections will be defined and the corrections to the model of bound dineutron formation in nuclear reactions will be made.

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20:27–20:28 SEASON: a powerful decay-station for the study of (super)-heavy nuclei

Speaker

Mathilde Ragot (CEA)

Description

SEASON (Spectroscopy of Electron and Alpha in Silicon bOx couNter) is a decay station developed at CEA-IRFU and currently being commissioned. SEASON is designed to meet the constraints of a high energy-resolution decay station and an efficient counter for laser spectroscopy for the study of heavy and superheavy nuclei. The detection system is made of 7 DSSD (Double-sided Silicon Stripped Detector) for the detection of alpha particles and electrons, and will be coupled with 2 HPGe (High Purity Germanium) detectors for the gamma-rays. The low energy beam (< 30 keV) of nuclei under study will be implanted in very thin (90 nm) carbon foils, evenly distributed on a rotating wheel. This will allow for a detailed decay spectroscopy, the summing effect being reduced thanks to the stripping of the detector, but also to remove the accumulated radioactivity by rotating the wheel to start a contamination-free measurement.

The offline (source) commissioning is taking place from February to May 2025 at GANIL and the online (beam) commissioning is planned at IGISOL (Jyväskyla – Finland) in the Fall of 2025. An experimental campaign is then foreseen up to the end of the year 2026, when SEASON will come back to France at GANIL to be set up at the end of S3-LEB (Low Energy Branch of S3).

In this poster, after having recalled the physics cases that we want to study with SEASON, we will present the SEASON detector. Then the results of the offline commissioning will be shown, with a focus on SEASON's characteristics such as resolution, efficiency, … A comparison to GEANT4 simulation will be added. Finally, the upcoming schedule and opportunities with SEASON will be presented.

20:28–20:29 Deformation in one-neutron halo nuclei using halo effective field theory

Speaker

Live-Palm Kubushishi (Ohio University)

Description

Halo nuclei are exotic nuclear structures found far from stability near the dripline. Unlike stable nuclei, halo nuclei exhibit a large matter radius. This peculiar feature is the result of their strongly clusterised structure. They can be seen as a compact core to which one or two valence neutrons are loosely bound. Due to the quantum tunnel effect, they exhibit a high presence probability at a large distance from the other nucleons. Being located far from stability halo nuclei are mostly studied through reactions. To describe these reactions, it is essential to have reliable few body models of halo nuclei. This can be achieved by resorting to the halo effective field theory (Halo-EFT).

In this talk, I propose a simple structure model to account for deformation in one-neutron halo nuclei. I develop the Halo-EFT particle-rotor model to describe one-neutron halo nuclei, which takes core excitation into account. I solve the resulting coupled-channel equations, using the R-matrix method on a Lagrange mesh. Last, I study the impact of core excitation on the wave functions and scattering phaseshifts for bound and resonant states. Depending on the studied nucleus, a comparison between my results and some high-precision ab initio or microscopic calculations is also provided. Structure and reaction calculations for 11Be, 17C and 19C will be presented.

20:29–20:30 The ePIC Silicon Vertex Tracker Barrel: design and thermal-mechanical tests

Speaker

Domenico Colella (INFN and University of Bari)

Description

The future Electron Ion Collider (EIC) will offer a unique opportunity to explore the parton distributions inside nucleons and nuclei thanks to an unprecedented luminosity, a wide range of energies, a large choice of nuclei and polarization of both beams.
The electron Proton-Ion Collider collaboration (ePIC) detector will be capable of precise determination of the position of primary and secondary vertexes, essential e.g. for the identification of charm hadrons, which have typical decay lengths of the order of 100 microns, via topological cuts, giving access to the gluon distribution inside hadrons.
This measurement capability is achieved with a Silicon Vertex Tracker (SVT) placed as the innermost device in the ePIC experiment.
The SVT Inner and Outer Barrel (IB,OB), developed by a collaboration of Italy-UK-USA institutes, provide five detecting layers made of silicon detectors, using the 65 nm MAPS technology with stitching, pioneered by the ALICE collaboration for the ITS3 upgrade.
The IB main focus is on vertexing performance. It is made of three layers of wafer-scale sensors bent to a cylindrical shape.
The OB, composed of two layers, mainly contributes to the particle momentum measurement and it is equipped with a smaller version of the IB sensor mounted in a typical stave configuration.
The status of the design and results of tests performed on thermal-mechanical mock-ups of the detector will be presented.

20:31–20:32 Estimation of the Uncertainty of Energy Measurements in Charged Particle Beams using Radiochromic Films

Speaker

Radu Alin Vasilache (University of Bucharest, Faculty of Physics)

Description

A few years ago, our group has developed anew method for measuring doses in ultra high dose rate charged particle beams, based on multivolume ion chambers - the QUADDRO detector. The measurement, however, did not account for the energy of the particles in the beam and such a measurement was done using radiocheromic films pklaced axially in the beam.
While performimg energy measurements in 10 MeV proton beams it became apparent that the accuracy of the energy measurement is very sensitive to the accuracy of the axial allignment of the film.
The present work is meant to estimate the errors due to missalignment. Several experiment have been made using Gafchromic EBT4 films in axial presentation. The films have been irradiated to electron beam of energies varying from 5 MeV to 19 MeV and the deviation from the collinearity between the beam axis and the films was set between 0 and 5 degrees.
Similar measurements were performed in 19 MeV proton beams.
We present here the error estimations resulting from these measurements, as well as their impact of the dose measurements using the QUADDRIL detector.

20:32–20:33 Study of Beta Delayed Proton Emissions in 20Mg

Speaker

Alexandru Silviu Pencu (National Institute for Nuclear Physics and Engineering Horia Hulubei (IFIN-HH), DTF)

Description

The study of delayed emissions in proton-rich nuclei provides valuable new insights into nuclear structure and enables the investigation of open quantum systems. We present a comprehensive analysis of the resonant Gamow states of 20Na, populated via the β^+ decay of 20Mg, with particular focus on the decay widths associated with the proton emission process. Moreover, by employing several mean-field parametrisations, we study the limits of the WKB approximation in describing resonances that are close to the potential barrier and compare the results with those obtained by using Gamow-state methods.

20:33–20:34 Performance and upgrade of the ATLAS Hadronic Tile Calorimeter

Speaker

Marina Kholodenko (Laboratory of Instrumentation and Experimental Particle Physics, Portugal)

Description

The Tile Calorimeter (TileCal) is a central hadronic calorimeter of the ATLAS experiment at the LHC. The TileCal plays an important role in the reconstruction of jets, hadronically decaying tau leptons, missing transverse energy, in the muon identification and provides information to the dedicated calorimeter trigger. This sampling calorimeter is composed by the plastic scintillating tiles and steel absorbers. The scintillating light is read-out by the wavelength shifting fibres coupled to the photomultiplier tubes.
The upcoming High-Luminosity phase of the LHC (HL-LHC), starting in 2030, will increase the nominal instantaneous luminosity by a factor of 5 to 7.5, alongside an upgraded ATLAS Trigger and Data Acquisition architecture. This upgrade necessitates a complete redesign of the readout electronics and power systems of TileCal. New electronics of the TileCal is needed to meet the requirements of a 1 MHz trigger, higher ambient radiation, and to ensure better performance under high pile-up conditions at the HL-LHC. Both the on- and off-detector TileCal electronics will be replaced during the shutdown of 2026-2030. PMT signals from every TileCal channel will be digitized and sent directly to the back-end electronics, where the signals are reconstructed, stored, and sent to the first level of trigger at a rate of 40 MHz. This will provide better precision of the calorimeter signals used by the trigger system and will allow the development of more complex trigger algorithms.
The TileCal upgrade program has included extensive research and development, including test beam studies and the construction of a Demonstrator module. This Demonstrator module with reverse compatibility with the existing system was inserted in ATLAS in July 2019 for operating in actual detector conditions.
A summary of first LHC Run 3 performance results including the calibration, stability, absolute energy scale, uniformity and time resolution will be presented. This talk will also include the ongoing developments for on- and off-detector systems, together with expected performance characteristics and results of test-beam campaigns with the electronics prototypes.

20:34–20:35

Bayesian inference of maximum density in central collisions and contribution to compression energy between 40 to 100 MeV/nucleon

Speaker

Antonin Valente (LPC Caen)

Description

This study introduces an innovative method for characterizing the nuclear equation of state (EOS) through the analysis of central heavy-ion collisions within the Fermi energy range. We examine experimental data from Nickel-Nickel and Xenon-Tin collisions at energies of 32–100 MeV/nucleon, collected using the INDRA 4π array at GANIL. By leveraging Artificial Intelligence (AI) and Machine Learning (ML) techniques, we enhance the precision of our analysis. Our approach features a neural-network-based reconstruction of the impact parameter, trained on HIPSE and ELIE simulations, which achieves sub-femtometer accuracy. This high precision facilitates the accurate selection of central collision events for detailed investigation.
We further employ a Bayesian inference framework to estimate in-medium nucleon-nucleon cross-sections and maximal density, drawing on probabilities derived from a comprehensive set of global observables. Our findings align with prior phenomenological studies, particularly for reactions below 100 MeV/nucleon, while the Bayesian method provides both mean values and their associated uncertainties, yielding a more robust depiction of nuclear medium effects. We also provide estimates of compression energy and freeze-out time, using experimental insights from our inference analysis. These advancements offer refined constraints on the nuclear EOS across a spectrum of densities and isospin asymmetries, enhancing our understanding of nuclear matter properties in both laboratory and astrophysical scenarios.

20:35–20:36

Thermal Release studies from Activated nat-Ti, nat-V and nat-Ta Target Materials - Investigation of Parameters Relevant for Isotope Mass Separation

Speaker

Patricija Kalnina (CERN)

Description

Scandium (Sc) and Terbium (Tb) have gained significant interest in nuclear medicine due to their radioactive isotopes being suitable for cancer diagnostics and therapy, offering a promising avenue for theranostics. However, challenges persist in achieving high molar activity and radiochemical purity for medical applications. The physical isotope mass separation technique presents an interest to increase the purity of such samples for medical applications. Despite recent advancements in mass separation at CERN-MEDICIS and other different facilities, the efficiency and yield for some radionuclides known as "difficult to extract" such as Sc and Tb, remain sub-optimal to produce medically relevant activities.
This study aims to systematically investigate the thermal release kinetics of Sc radionuclides from activated natural titanium and vanadium foils, and of Tb radionuclides in tantalum, all studied in tantalum (Ta) environments of typical ISOL (Isotope Separation On-Line) target units. By elucidating the combination of target material structure and temperature conditions, enhanced release parameters were identified. Maximum Sc release from a non-embossed nat-Ti foil samples was achieved at 1200 °C, for embossed nat-Ti foil samples at 1450 °C and for nat-V foil samples at 1600 °C, within an hour of reaching the set temperature. However, maximum Tb release from a non-embossed nat-Ta foil samples was achieved at 2300 °C, for embossed nat-Ta foil samples at 2300 °C Tb release reached only 80% and for natTa double folded samples maximum release was achieved at 1900 °C, within an hour of reaching the set temperature.
Theoretical estimations were done to estimate radionuclide production in target materials and to identify the possible limiting factors during thermal release. A proof of concept for the methodology to study MEDICIS and ISOLDE-produced radionuclide release kinetics and behaviour from various target materials and structures is presented. This work also aims to complement radionuclide release studies in case of fire accidents for radiation protection purposes and provide a way to benchmark theoretical codes.
Additionally, due to the large number of radionuclides that are produced from high-energy proton irradiation of nat-Ta foils, several release curves were obtained for radionuclides, including some of interest in nuclear medicine. These findings offer insights into optimizing the mass separation process to improve the efficiency of radionuclide production by mass-separation both for fundamental physics and for medical applications.

20:36–20:37

Study of transverse momentum spectra and nuclear modification factors of Heavy Hadrons in Au+Au collision at centre-of-mass energy of 200 GeV.

Speaker

Sunidhi Saxena (Banaras Hindu University)

Description

In ultrarelativistic heavy-ion collisions, a hot and dense state of deconfined color-conducting matter, known as Quark-Gluon Plasma, is produced at extremely high temperature and density. This state allows the exploration of Quantum Chromodynamics properties. In particular, Heavy quarks are primarily produced in the initial hard scattering and traverse the QGP throughout its evolution. As a result, heavy quarks serve as essential probes for examining the pre-equilibrium phase and the transport properties of dense nuclear matter, using perturbative calculations of their production cross-sections. Some key observables for studying the QGP medium include the transverse momentum (p_{T}) distributions and nuclear modification factors (R_{AA} and R_{CP}) of final-state hadrons. In this study, we employed the Monte Carlo based HYDJET++ event generator to simulate the production of heavy hadrons (D^{0}, $\bar{D^{0}}$, Λ_{c}, D^{+}, and D^{-}) in Au+Au collision at $\sqrt{s_{NN}}$ = 200 GeV. We analyzed p_{T} spectra and observed that the slope of the p_{T} spectra decreases from the peripheral collisions to central collisions, indicating a higher temperature in central collisions, which is consistent with STAR experimental data. The HYDJET++ model reproduces experimental results well at low and intermediate p_{T}; however, at high p_{T}, it overestimates the data. Further insights are gained by analyzing the nuclear modification factors. The observed suppression in R_{AA} at high p_{T} is attributed to radiative energy loss within the QGP, and this suppression weakens in peripheral collisions due to the smaller overlap region of the colliding nuclei. At low p_{T} , a slight suppression is observed, likely due to the coalescence of heavy quarks with in-medium constituents. Similarly, R_{CP} reflects the centrality dependence of energy loss effects. This behaviour of R_{AA} and R_{CP} matches the experimental data well. Overall, this study highlights the capability of the HYDJET++ model in describing charm hadron production, the centrality dependence of momentum distributions, and the energy loss effects in heavy-ion collisions.

20:37–20:38

Dynamical Evolution of Stochastic Fluctuations

Speaker

Sahr Alzhrani (Jazan University)

Description

Develops a theoretical framework to study stochastic fluctuations in relativistic heavy-ion collisions, with a focus on their evolution near the QCD critical point. We begin by introducing thermal and critical fluctuations and their impact on the hydrodynamic evolution of the system. The "Hydro+" formulation is explored as a means of incorporating critical fluctuations into hydrodynamic simulations. Various critical models are compared, including Models A, B, and H, to assess their influence on fluctuation dynamics.
We utilize a realistic QCD equation of state (EOS) from the BEST collaboration, which incorporates a tunable critical point, to analyze the impact of critical behavior on the system's evolution. Bjorken (1+1)D simulations provide insights into the effects of different critical models, while (3+1)D simulations track the fireball's phase diagram trajectory and the full 3D evolution of the two-point function C_(ŝŝ) (Q). Additionally, we examine out-of-equilibrium corrections to entropy, highlighting the significant deviations from equilibrium in regions near the critical point.
Our findings provide theoretical guidance for experimental efforts to locate the QCD critical point in the RHIC Beam Energy Scan program. The results illustrate the importance of including stochastic fluctuations in hydrodynamic modeling and set the stage for future studies on nonequilibrium dynamics in high-energy nuclear collisions.

20:38–20:39

Nuclear-Powered Plasma CO_2 Dissociation for Deep-Space Electrostatic and Electrothermal Propulsion

Speaker

Natalia Lopez (Harvard University)

Description

Plasma-assisted CO_2 dissociation has been widely studied for in-situ resource utilization (ISRU) on Mars, where it is used to generate oxygen and fuel from the Martian CO_2-rich atmosphere. On Earth, the process has been explored for carbon capture and utilization, where CO_2 is utilized to produce valuable fuels and chemicals. Its application to space propulsion, however, is nearly unexplored despite the potential for enhancing the sustainability and autonomy of deep-space missions.

The feasibility of nuclear-powered plasma-aided CO_2 dissociation as a source of propellants in electric propulsion and as a route to in-space fuel manufacturing is investigated in this research. By combining high-power NEP reactors or fusion plasma sources with plasma dissociation, CO_2 dissociation byproducts, carbon monoxide (CO) and oxygen (O_2), can be efficiently ionized for propulsion. These ionized ions can then be utilized in Hall-effect thrusters, radiofrequency (RF) ion thrusters, and arcjet thrusters, which give a scalable, very efficient paradigm for propulsion in deep-space long-term exploration.

20:39–20:40

Studying properties of hot and dense baryonic matter with the HADES experiment

Speaker

Szymon HARABASZ (IJCLab Orsay)

Description

Collisions of heavy-ions at relativistic energies provide an essential tool to study the behavior of strongly interacting matter at elevated temperature and density.
In the regime of few GeV per nucleon, quark deconfinement does not occur, but a non-trivial dynamics of the system is driven by moderate temperatures (few tens MeV) and baryon densities (2-3 nuclear saturation density), which lead to abundant excitation of baryonic resonances.
Currently, understanding of such hot and dense medium is not yet full.

HADES (High-Acceptance Di-Electron Spectrometer) is a multi-purpose particle detector setup designed specifically to perform such studies. It has been used in experiments with heavy-ion collisions as well as in proton- and pion-induced reactions on a fixed target with beams in the energy range of a few GeV, received from the SIS18 accelerator located in Darmstadt, Germany.

In this contribution, we give an overview of HADES results from Au+Au collisions at $\sqrt{s_{NN}}$ = 2.42 GeV and Ag+Ag collisions at $\sqrt{s_{NN}}$ = 2.55 and 2.42 GeV. The observables under investigation include electromagnetic probes, strangeness production, light flavor hadrons flow and fluctuations, as well as correlation observables.

We also give an outlook to the sensitivity to the phase structure of baryon-dominated matter with the new HADES program at further lowered beam energies.

21:40

Wednesday 24 September

09:00 **Wednesday 24 September** 09:00–10:30

Plenary Session: 5

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Fanny Farget (GANIL)

Description

Plenary Session

09:00–09:30

Probing the Proton's Internal Structure with Generalized Parton Distributions: From Jefferson Lab to the EIC

Speaker

Pierre Chatagnon (CEA Saclay)

Description

Quantum Chromodynamics (QCD) reveals its complexity at large distances and low energies. Understanding the internal structure of the nucleons is therefore essential for a complete understanding of QCD in this regime. Generalized Parton Distributions (GPDs) play a crucial role in this effort, as they provide a means to map both the spatial and the longitudinal momentum distributions of partons in the nucleons. Beyond offering a three-dimensional view of the proton's internal structure, GPDs are also closely linked to the nucleon's spin structure and its internal force distribution. As a result, GPDs have been the focus of intense global experimental efforts.
At Jefferson Lab, extensive measurements have been conducted to study GPDs, primarily through exclusive reactions such as Deeply Virtual Compton Scattering (DVCS)—the exclusive electroproduction of a real photon at the partonic level. In addition to DVCS, other exclusive processes, including Timelike Compton Scattering, Double DVCS, and the exclusive electroproduction of mesons, have been investigated. These results provide a detailed picture of the valence structure of the nucleon.
Looking ahead, future experiments at Jefferson Lab will further leverage the capabilities of the CEBAF accelerator, while the upcoming Electron-Ion Collider (EIC) will significantly enhance our understanding of the gluon content of nucleons.

09:30–10:00

Progress in the development of nuclear models for astrophysical applications

Speaker

Stephane Goriely (Université Libre de Bruxelles)

Description

Though the origin of most of the nuclides lighter than iron is now quite well understood, the synthesis of the heavy elements (i.e. heavier than iron) remains puzzling in many respects. The major mechanisms called for to explain the production of the heavy nuclei are the slow neutron-capture process (or s-process), occurring during the hydrostatic stellar burning phases, the rapid neutron-capture process (or r-process) believed to develop during the explosion of a star as a supernova or the coalescence of two binary neutron stars. In addition, the origin of the neutron-deficient nuclides observed in the solar system is attributed to the so-called p-process taking place in supernovae. Recently, the intermediate neutron-capture process (or i-process) has been called for to explain the surface enrichment of specific metal-poor stars.

All these nuclear processes are due to nuclear reactions taking place in conditions of locally established thermodynamic equilibrium. Composition changes in the cosmos can also be the result of nuclear transformations in too dilute and/or too cold media to establish thermodynamic equilibrium between the reaction partners. This is the case for stellar/solar energetic particles interacting with circumstellar media and for Galactic cosmic rays bombarding the interstellar medium. This is referred to as "non-thermal nucleosynthesis". While almost all the existing nucleosynthesis models are based on thermal processes, non-thermal processes have been called for to explain specific species or chemically peculiar stars.

Both thermal and non-thermal nucleosynthesis require a detailed knowledge not only of the astrophysical sites and physical conditions in which the processes take place, but also of accurate and reliable nuclear data. The present talk will critically review the different astrophysical models as well as the enormous theoretical challenges in nuclear physics. These include the reaction model needed to describe the captures by exotic nuclei, as well as the nuclear ingredients needed to estimate the corresponding reaction rates, namely nuclear structure properties, level densities, photon strength functions, as well as fission properties. New progress based on mean-field and beyond-mean-field models will be described and their impact on nucleosynthesis processes illustrated.

10:00–10:30

Matter-Antimatter Asymmetry in the Universe: Spectroscopy of Trapped Antihydrogen and Method for Direct Comparison with Hydrogen

Speaker

Claudio Lenz Cesar (CERN)

Description

We describe laser spectroscopy of the 1S-2S transition in trapped [1] and laser cooled [2] antihydrogen to 13 significant figures [3] and a lineshape theory [4] for its analysis. This is an order of magnitude improvement over our last results [5]. We discuss the extension of the methods to allow spectroscopy of hydrogen in the same apparatus as proposed in [6] and with a proof-of-principle with antihydrogen [7]. Addressing both atoms under the same conditions will minimize many systematic effects — such as the AC Stark shift and magnetic and electric fields besides sidereal localization — and will allow a direct comparison of the CPT conjugated species to 15 or more digits. The techniques have direct implications on tests of the Charge-Parity-Time (CPT) Symmetry, searching for explanations on the mystery of matter-antimatter asymmetry in the universe. The gravitational fall of antihydrogen [8], following an original proposal by the speaker [9] will be briefly discussed.

[1] G. Andresen et al. [ALPHA Collab.],Trapped antihydrogen, Nature 468, 673(2010)
[2] C. Baker et al. [ALPHA Collab.], Laser cooling of antihydrogen atoms, Nature 592, 35(2021)
[3] [ALPHA Collab.], manuscript under preparation
[4] L. Azevedo and C. Lenz Cesar, Quasianalytical line shape for the 1S-2S laser spectroscopy of antihydrogen and hydrogen, Phys. Rev. A 111, 012807 (2025)
[5] M. Ahmadi et al. [ALPHA Collab.], Characterization of the 1S–2S transition in antihydrogen, Nature 557, 71 (2018)
[6] C. Lenz Cesar, A sensitive detection method for high resolution spectroscopy of trapped antihydrogen, hydrogen and other trapped species, J. Phys. B: At., Mol. Opt. Phys. 49, 074001 (2016)
[7] [ALPHA Collab.], manuscript under preparation
[8] E. K. Anderson, et al. [ALPHA Collab.], Observation of the effect of gravity on the motion of antimatter, Nature 621, 716 (2023)
[9] C. L. Cesar, Trapping and spectroscopy of hydrogen. Hyp. Interact. 109, 293 (1997)

10:30

10:30

11:00

Wednesday 24 September

10:30–11:00

Coffee Break

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

11:00

Wednesday 24 September

11:00–13:00

Plenary Session: 6

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Navin Alahari (GANIL)

Description

Plenary Session

11:00–11:30 **Results from Nuclear Structure Studies at FRIB**

Speaker

Alexandra Gade (Facility for Rare Isotope Beams (MSU))

Description

There are approximately 300 stable and 3,000 known unstable (rare) isotopes. Estimates are that over 7,000 different isotopes are bound by the nuclear force. It is now recognized that the properties of many, sometimes undiscovered, rare isotopes hold the key to understanding how to develop a comprehensive and predictive model of atomic nuclei, to accurately model a variety of astrophysical environments, and to understand the origin and history of elements in the Universe. Some of these isotopes also offer the possibility to study nature's underlying fundamental symmetries and to explore new societal applications of rare isotopes. This presentation will give a glimpse of the opportunities that arise at the Facility for Rare Isotope Beams (FRIB) that started operations at Michigan State University in 2022, with a focus on results from nuclear structure studies.

A.G. is supported by the U.S. Department of Energy (DOE), Office of Science, Office of Nuclear Physics, under Award No. DESC0023633

11:30–12:00 **Particle and Nuclear Physics at PSI**

Speaker

Klaus Kirch (PSI - ETH Zurich)

Description

CHRISP is the Swiss Research Infrastructure for Particle Physics at PSI. The High Intensity Proton Accelerator complex HIPA provides a beam of 590 MeV protons at 50 MHz from its ring cyclotron to targets. The beam with an average current of up to 2.4 mA, corresponding to 1.4 MW average beam power, simultaneously serves nuclear and particle physics experiments with pions, muons and ultracold neutrons (UCN), as well as two other large communities for materials research with muons at the Swiss muon Source, S⌙ S, and neutrons at the Swiss spallation source, SINQ, respectively. The pion, muon and UCN beams are some of the highest intensity, low momentum beams available worldwide offering unique opportunities, see [1] for the latest review. In addition, particle beams are also used for test purposes, for detector development or radiation hardness. Within CHRISP and using a beam of up to 230 MeV from the medical cyclotron COMET, the proton irradiation facility PIF serves a large community from industry, universities, CERN and ESA.

The experiments carried out in nuclear and particle physics cover a broad range of questions from fundamental symmetry tests, e.g. regarding charged lepton flavor, lepton universality and CP violation, to precision measurements of parameters and benchmarks of the Standard Model of particle physics and modern nuclear theory, such as particle masses or nuclear charge radii. The talk will present an overview of the ongoing efforts and discuss the planned upgrade of the facility to even higher intensity muon beams.

[1] A. Signer, K. Kirch, C.M. Hoffman, Review of Particle Physics at PSI, SciPost Phys. Proc. 5 (2021), doi:10.21468/SciPostPhysProc.5

12:00–12:30 **From nuclear data to nuclear energy applications**

Speaker

Prof. Arjan Koning (IAEA)

Description

An overview is given of the current nuclear data libraries which are used for nuclear technology, in particular nuclear energy. These nuclear data libraries are filled with fundamental nuclear reaction and nuclear structure data, coming from a mixture of measurements and nuclear model calculations, and are used in Monte Carlo or deterministic application codes for the analysis of nuclear reactors and other devices.
A special focus will be given on nuclear data development projects and the modernization of various data dissemination methods at the IAEA, which allows users to make more automated use of data, among others for AI/ML applications. Important nuclear databases which will be mentioned are EXFOR, ENSDF and ENDF.
Finally the use of the TALYS nuclear reaction model code for nuclear data generation will be outlined. The general nuclear reaction mechanisms described are the optical model, direct reactions, compound nucleus model, pre-equilibrium reactions and fission. The most important nuclear structure models are those for masses, discrete levels, level densities, photon strength functions and fission barriers.

12:30–13:00 **Advances on Nucleon Structure from Lattice QCD**

Speaker

Simone Bacchio (The Cyprus Institute)

Description

Understanding the internal structure of the nucleon remains a fundamental challenge in nuclear and particle physics. Lattice Quantum Chromodynamics (LQCD) provides a rigorous, first-principles framework to study key nucleon properties, including parton distributions, form factors, and moments of generalized parton distributions. Recent advancements in computational algorithms, renormalization techniques, and statistical precision have significantly improved our ability to extract nucleon observables with controlled systematic uncertainties.

In this talk, I will present recent progress in LQCD calculations of nucleon structure, highlighting results on the axial charge, electromagnetic form factors, and partonic distributions. I will discuss the role of novel approaches, such as large-momentum effective theory (LaMET) and pseudo-distributions, in accessing partonic structure directly from lattice simulations. Additionally, I will address challenges related to excited-state contamination, finite-volume effects, and discretization artifacts, and how they are being systematically controlled in state-of-the-art calculations.

13:00

13:00

14:00

Wednesday 24 September

13:00–14:00

Lunch

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:00
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Wednesday 24 September 14:00–21:00

Guided Tours

Session

Thursday 25 September

09:00

Thursday 25 September 09:00–10:30

Plenary Session: 7

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** BARBARA ERAZMUS (IN2P3/CNRS)

Description

Plenary Session

09:00–09:30 Future physics programme and facilities for relativistic heavy-ion collisions

Speaker

David Dobrigkeit Chinellato (Austrian Academy of Sciences)

Description

Relativistic heavy-ion collisions are essential to advancing our understanding of Quantum Chromodynamics (QCD) under extreme conditions of temperature and density. These experiments recreate the quark-gluon plasma (QGP), a state of matter that dominated the early universe, providing critical insights into the emergent phenomena of QCD such as strangeness enhancement and collective particle emission. The upcoming upgrades to the ALICE experiment at the CERN LHC, culminating in the next-generation ALICE 3 detector, are designed to deliver unprecedented precision in heavy-flavor and electromagnetic probe measurements, enabling differential studies of QGP properties with high statistics and low backgrounds. Complementarily, the FAIR facility at GSI will probe the QCD phase diagram at lower collision energies, where the net baryon density is highest and signals of a first-order phase transition or critical point may emerge. Together, these experimental programs will provide a multi-dimensional map of strongly interacting matter across a wide range of conditions, shaping the future of relativistic heavy-ion physics and our comprehension of the strong force.

09:30–10:00 Three-nucleon systems and three-nucleon interactions

Speaker

Prof. Luca Girlanda (University of Salento and Istituto Nazionale di Fisica Nucleare)

Description

The nuclear interaction problem can nowadays be addressed within the systematic framework of effective field theories, rooted in the underlying quantum chromodynamics through its approximate and dynamically broken chiral symmetry. Nevertheless, despite tremendous progress, long-standing discrepancies between theory and experiment persist in the A=3 continuum, most notably the so-called Ay puzzle, due to the poorly known three-nucleon force. We will review its status and the perspectives to solve it using the freedom to parametrize the off-shell nucleon-nucleon contact interaction arising at the fourth order of the low-energy expansion.

10:00–10:30 Searches for exotic currents in nuclear beta decay

Speaker

Prof. Oscar Naviliat-Cuncic (FRIB - Michigan State University)

Description

Searches for signatures of new physics involve many probes, in particular at low energies, beyond those accessible at high-energy colliders. Those searches also include charged current processes such as nuclear beta decay and electron capture.
In this presentation, I will review current efforts searching for new physics in nuclear beta decay and I will retrace the progress achieved so far in terms of constraints on exotic couplings.

10:30

10:30

11:00

Thursday 25 September

10:30–11:00

Coffee Break: Conference Photo & Coffee Break

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

10:30–10:55 **Conference Photo & Coffee Break**

11:00 **Thursday 25 September** 11:00–12:10

12:10

Round Table - Open Science & Data

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Conveners:** Dr Antoine Lemasson (GANIL / CNRS), Olivier Lopez

12:10 **Thursday 25 September** 12:10–13:20

13:20

Round Table - Nuclear Physics & Society

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Maria José Garcia Borge (IEM-CSIC)

13:20

14:20

Thursday 25 September

13:20–14:20

Lunch

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:20 **Thursday 25 September** 14:20–16:50

Accelerators and Instrumentation: 5

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Norbert Pietralla (TU Darmstadt, IKP)

14:20–14:45 ePIC's physics and detector overview

Speaker
Francesco Bossu (CEA-Saclay)

Description

On behalf of the ePIC collaboration.
The Electron-Ion Collider (EIC) is a next-generation facility to explore quantum chromodynamics (QCD) by colliding polarized electrons with polarized protons and heavy ions. The ePIC detector at the EIC will study the 3D structure of nucleons, the spin-momentum correlations of quarks and gluons, and the emergent properties of dense gluon fields. Leveraging cutting-edge technologies, ePIC aims to deliver unprecedented precision in imaging hadron structure and probing QCD in extreme conditions. This talk will highlight the EIC's physics goals and ePIC's innovative detector design.

14:45–15:05 CRYRING@ESR Facility for Low-Energy Ion Beams

Speaker
Zoran Andelkovic (GSI GmbH)

Description

As a Swedish in-kind contribution to FAIR, the storage ring CRYRING@ESR was delivered to GSI in 2014, assembled in the following years and commissioned in 2018. With a relatively compact circumference of 54 m and the maximal magnetic rigidity of 1.44 Tm, CRYRING is suitable for precision experiments with highly charged ion beams at low energies. It consists out of 12 sections, including electron cooling, acceleration/deceleration, injection/extraction, various detectors and alternating experimental setups.

In the past years CRYRING@ESR has served several tens of experiments approved by the General Program Advisory Committee (G-PAC) and developed stored beams ranging from light, locally produced ions at several keV/u, up to heavy highly charged ions delivered at several MeV/u from the GSI accelerator chain. A special feature of CRYRING@ESR is an ultra-cold electron cooler, achieved by overlapping the ion beam with an electron beam which is produced inside a superconducting magnet and adiabatically expanded by a factor of 100. We will present the recent performance and capabilities of the storage ring and the expansion plans for the upcoming years.

15:05–15:25 The new PID equipment of the Super-FRS

Speaker
Chiara Nociforo (GSI Helmholtzzentrum für Schwerionenforschung GmbH)

Description

The new PID equipment of the Super-FRS [1], presently under construction at FAIR, was qualified using SIS18 beams (C, Ag, U) delivered at different energies 400-1000 MeV/nucleon.
The absence at GSI of a beam line suitable to be equipped with Super-FRS vacuum detectors, due the large acceptance in momentum of the Super-FRS, enforced to install the first equipped Super-FRS diagnostic chamber in Cave C and use it like a compact and standard PID set up.
The overall system design for Super-FRS PID will be presented. The successful test runs together with their results will be presented.
[1] M. Winkler et al., Nucl. Instr. Meth. B 266 (2008) 4183

15:25–15:45 Achievements on Targets and Target Station for the study of heavy and super heavy nuclei with the Super-Separator-Spectrometer, S3 at GANIL

Speaker
Christelle STODEL (GANIL)

Description

GANIL facility was upgraded with a superconducting linear accelerator, which delivers highly intense stable beams. Light ions are used at the Neutron for Science (NFS) experimental hall [1] and heavier ions are essential to produce exotic nuclei, like heavy neutron-deficient isotopes and super heavy nuclei, in the Super Separator Spectrometer (S3) [2, 3].
By combining the intense heavy ion beams with the fully instrumented target station, the various electromagnetic components, the fixed and movable beam dumps, S3 is a powerful tool to purify the elements of interest produced in the target from the primary intense ion beam, and retrieving them at the focal plane with a high transmission. The detection setups, SIRIUS implantation-decay spectroscopy station [4] and S3-LEB (Low Energy Branch) [5] are unique tools designed to study in detail the rare nuclei produced by fusion-evaporation

To achieve the planned extensive experimental program, for instance the study of heavy and super-heavy elements (SHE with Z>103), specific research and developments on targets and their environment are conducted. High-quality targets are an essential element in the experimental setup as they play a key role in the accuracy of obtained observables. To sustain intense beams for a long period, targets are mounted on a rotating wheel and their integrity has to be controlled regularly. S3 will be equipped with two specific target stations, either for stable or actinide targets. They are designed to include fast rotating wheels on which several targets are mounted, and a versatile set of diagnostics and survey tools. The first S3 target station specific for stable targets was commissioned in 2023 with various targets irradiated with a heavy-ion beam and used during the first step of the S3 commissioning conducted in 2024. The instrumentation proved to be efficient in synchronizing the beam with the rotation and in checking the target areal thickness.

After introducing the S3 spectrometer with its scientific programs and technical achievements, we will detail achieved technical developments on S3 the target stations mentioned above. In addition, we propose to report on current targets development at GANIL.

References
[1] X. Ledoux et al., Eur. Phys. J. A57, 25 (2021).
[2] H. Savajols et al., AIP Conf. Proc. 1238, 251 (2010).
[3] F. Dechery et al, Eur. Phys. J. A (2015) 51: 66.
[4] J. Piot and the S3 collaboration, Acta Phys. Pol. B 43 (2012) 285.
[5] R. Ferrer et al. Nucl. Inst. and Meth. B, Volume 317 (2013) 570.

S3 has been funded by the French Research Ministry, National Research Agency (ANR), through the EQUIPEX (EQUIPment of EXcellence) reference ANR-10EQPX-46, the FEDER (Fonds Europeen de Developpement Economique et Regional), the CPER (Contrat Plan Etat Region), and supported by the U.S. Department of Energy, Office of Nuclear Physics, under contract No. DE-AC02-06CH11357 and by the E.C.FP7-INFRASTRUCTURES 2007, SPIRAL2 Preparatory Phase, Grant Agreement No.: 212692

15:45–16:05 **Recent advances of the S3-Low Energy Branch**

Speaker

Sarina Geldhof (GANIL)

Description

The SPIRAL2 facility of GANIL will significantly extend the capability to study short-lived nuclei by producing beams of rare isotopes at unprecedented intensities. The SPIRAL2-LINAC coupled with the Super Separator Spectrometer (S3) recoil separator will facilitate the production of neutron-deficient nuclei close to the proton dripline as well as super heavy nuclei via fusion-evaporation reactions, with an efficient separation from the intense background contamination [1]. At the focal plane of S3, the Low Energy Branch (S3-LEB) will enable low-energy nuclear physics experiments by thermalising and neutralising the nuclei in a gas cell before extraction in a supersonic gas jet. In the jet, resonant laser ionisation can serve as both a selective ion source and a method of spectroscopy.

Resonant laser ionisation spectroscopy in the low density and low temperature environment of the supersonic jet will boost the spectral resolution by an order of magnitude, while maintaining the typical efficiency of in-source laser spectroscopy [2]. The technique allows the precise investigation of isotope shifts and hyperfine structures at the extremes of the nuclear chart. This will give access to ground-state properties such as spins, charge radii and electromagnetic moments in a nuclear-model-independent framework. Combined with the PILGRIM MR-TOF and the SEASON decay station, mass and decay measurements will also be performed. The S3-LEB setup has been commissioned offline in a dedicated laboratory [3, 4], and is now installed at the focal plane of S3, in preparation for online commissioning.

We present the latest results of the offline commissioning of the setup, including a detailed characterisation of the gas jet combined with series of mass measurements using PILGRIM using, e.g., erbium isotopes. The preparation for online experiments at S3 and the first scientific objectives with short-lived nuclei in the coming years will be shown. In addition, we will present the results and perspectives of ongoing related projects, such as FRIENDS3, which aims at improving the extraction speed and neutralisation of the gas cell, and IDEAS3, a tape-based identification station under development.

[1] F. Déchery et al., Nucl. Instrum. Meth. B 376, 125-130 (2016)
[2] R. Ferrer et al., Nat. Comm. 8, 14520 (2017)
[3] J. Romans, et al., Atoms 10(1), 21 (2022)
[4] A. Ajayakumar, et al., Nucl. Instrum. Meth. B 539, 102 (2023)

16:05–16:25 **Implementation of Laser Resonance Chromatography at S3**

Speaker

Mustapha Laatiaoui (GANIL)

Description

Atoms of different chemical elements possess spectra that serve as their unique fingerprints. Our knowledge of their spectra has allowed the identification of heavy elements in extragalactic stars, and even in neutron star mergers where half of the elements are thought to be produced.
Till date, very little is known about the atomic structure of the heaviest elements, which can only be synthesized in trace amounts in nuclear fusion-evaporation reactions. With such scarce yields, spectroscopy must be done "one atom at a time", for which traditional fluorescence methods lack sensitivity. Similarly, and despite the fact that resonance ionization spectroscopy has been successfully applied to a few atoms of nobelium (Z=102) [1] and, more recently, to fermium (Z=100) [2], it would still require groundbreaking developments before it can be applied to refractory metals of the d-block elements, which lay ahead.
The recently developed Laser Resonance Chromatography (LRC) technique could remedy this [3]. It exploits electronic state-resolved chromatography to measure the change in the ground state population by laser resonance excitation of sample ions to their higher excited levels, so that neither fluorescence detection nor resonance ionization is required for spectroscopy. The spectral precision of the method, combined with its high sensitivity, will enable the study of the atomic structure of the heaviest elements, in particular those beyond nobelium, and additionally will help to elucidate the evolution of nuclear charge radii and deformation in neutron-deficient isotopes of many transition metals that are so far out of reach or more challenging for conventional techniques.
In my contribution I will explain the LRC technique and show the future prospects for its implementation at the S3 installation of GANIL/SPIRAL2 for the spectroscopy of neutron-deficient actinium (Z=89) and lawrencium (Z=103) isotopes.

References:
[1] M. Laatiaoui et al., Nature 538 (2016) 495.
[2] J. Warbinek et al., Nature 634 (2024) 1075.
[3] M. Laatiaoui et al., PRL 125 (2020) 023002.

16:50

14:20 **Thursday 25 September** 14:20–16:50

Accelerators and Instrumentation: 6

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Dieter Ackermann (GANIL)

14:20–14:40

The (NA)2STARS: Neutrinos, Applications and Nuclear Astrophysics with a Segmented Total Absorption with higher Resolution Spectrometer, a combination of calorimetric and spectroscopic tools for beta decay and in-beam measurements

Speaker

Muriel FALLOT (Subatech)

Description

The international collaboration constituted based on the Total Absorption Gamma-ray Spectroscopy technique (TAGS) in Europe is aiming to build a Total Absorption Spectrometer (TAS) of the next generation. TAGS is a calorimetric technique using large monolithic or segmented scintillators that cover more than 80% of 4ᅳ, but with limited energy resolution. It complements high-resolution spectroscopy using Germanium crystals. It is particularly well suited to physics themes requiring the detection of high-energy or multiple gamma photons, as in the case of beta decay of short-lived nuclei, or the measurement of reaction cross sections useful in certain nucleosynthesis processes. Indeed, in the case of beta decay of nuclei with large Q-values, the excitation energy states of the daughter nucleus are located at high energy and de-excited by multiple gamma lines or very energetic gamma-rays. A systematic error known as the Pandemonium effect [1] can affect data due to the low intrinsic or geometric efficiency of devices based on HPGe-type detectors. This effect results in poor determination of beta intensity distributions, and has far-reaching consequences for topics involving good knowledge of these intensity distributions.
The new instrument, called STARS (Segmented Total Absorption with higher Resolution Spectrometer), will ally efficiency with a higher segmentation and energy resolution than the existing spectrometers thanks to the addition of 16 LaBr3 crystals. The two segmented TAS that exist in Europe that will benefit from this upgrade are DTAS detector (18 NaI crystals [2]) and the Rocinante detector (12 BaF2 crystals [3]). The scientific advances that will be made possible will concern nuclear structure, nuclear astrophysics, neutrino and reactor physics, topics to which the TAGS technique has proven to bring significant advances [4]. The research objectives span a wide physics program that will bring together a wide international community of users around the proposed advanced TAS.

[1] J. C. Hardy et al., Phys. Lett. 71 B, 307 (1977).
[2] V. Guadilla et al., Nucl. Instr. Meth. A910, 79-89 (2018).
[3] E. Valencia et al., Phys. Rev. C 95, 024320 (2017).
[4] A. Algora, B. Rubio, J.-L. Tain, M. Fallot, W. Gelletly, Eur. Phys. J. A 57, 85 (2021) and references therein.

14:40–15:00

Enhanced laser-driven proton acceleration through Formvar film production

Speaker

Afonso Vicente (Laboratório de Instrumentação e Física Experimental de Partículas (LIP))

Description

Conventional accelerators, which use radio-frequency fields, can only reach maximum acceleration field strengths on the order of 1 MV/cm [1], resulting in large footprints and high associated costs, especially for low-energy (MeV range) applications. In contrast, laser-driven accelerators have consistently reached acceleration field gradients on the order of GV/cm to TV/cm, rendering them a promising, more compact alternative [1,2].
While in the last decade developments in ultra-short-pulse high-intensity lasers have made laser-driven acceleration an emerging alternative [1,2], several challenges are yet to be overcome to produce stable beams, capable of operating for prolonged periods of time, with optimum fluxes and energies. For laser-driven proton acceleration specifically, one crucial area for further improvements is target production, as targets are the site where high-intensity laser-plasma interactions occur [1]. At the Laser Laboratory for Acceleration and Applications (L2A2) facility, the use of 8 μm Al foils in multi-shot operation has produced proton beams with energies on the order of ~1.2 MeV [3]. However, most foreseen applications, such as radionuclides-based medical imaging, can require energy of tens of MeV.
Our work addresses this challenge by developing ultrathin (below 1 μm) plastic films, with and without silver-coatings, to improve the performance of laser-driven proton acceleration at the L2A2 facility. Protocols were developed to produce films as thin as 250 nm using Polyvinyl formal, also known as Formvar. The silver-coatings were produced via vacuum thermal evaporation, a well-known physical vapor deposition technique [4]. The films were characterised by two previously established techniques, transmission alpha-energy loss and Rutherford backscattering spectrometry, as well as a new X-ray attenuation technique, which was benchmarked in this work. At the L2A2 facility, protons were accelerated by the Target Normal Sheath Acceleration (TNSA) mechanism. Results from time-of-flight beam diagnostics show that plain Formvar films performed better than the silver-coated one, with achieved energies more than doubled when compared to previous reported values [3]. Thinner films reached peak energies of 3.5 MeV, and increased the proton flux as well, reaching orders of ~10^10 MeV−1·srad−1.
Our results demonstrate the significant impact that improvements on film production can have on laser-driven proton acceleration, leaving the door open for further improvements, to increase the feasibility of laser-driven proton acceleration as an alternative to conventional acceleration.

[1] J. Badziak, J. Physics: Conference Series 959.1 (2018)
[2] Wim Leemans and Eric Esarey, Physics Today 62.3, 44-49 (2009)
[3] J. Peñas et al, High Power Laser Science and Engineering 12 (2024)
[4] A. Muggleton, J. Physics E 12.9 (1979)

15:00–15:20

Technical progress at the double Penning Trap PIPERADE

Speaker

Dr Emmanuel Rey-herme (LP2IB)

Description

The construction of the DESIR facility at GANIL-SPIRAL2 is almost completed and soon the installation of the experimental setups will start. The experimental hall will feature state-of-the-art setups for decay and laser spectroscopy, as well as trap-based experiments. With the beams produced at SPIRAL1 and S3, DESIR will provide unique opportunities for high-precision low-energy nuclear physics. However, to make the most of those production capacities, high beam purification capacities are crucial.

In this context, the LP2iB has devised several complex devices that will be the backbone of the facility. In this presentation, I will focus on the progress on PIPERADE (Plèges de PEnning pour les RAdionucléides à DESIR). This double Penning trap spectrometer has been designed for high-resolution mass purification of strongly contaminated ion beams and high-precision mass measurements.

With its high-capacity purification trap, PIPERADE aims to separate up to 105 ions per bunch. Moreover, using state-of-the-art phase cleaning techniques, resolving powers up to 107 are expected, enabling the separation of low-lying isomeric states from their ground states. This allows to re-inject isomerically-pure beam in the main DESIR beam line to perform trap-assisted spectroscopy with the downstream setups.

In addition to its purification capabilities, PIPERADE is designed for high-precision mass measurements using the ToF-ICR (Time-of-Flight Ion-Cylotron-Resonance) and PI-ICR (Phase-Imaging Ion-Cyclotron-Resonance) techniques. A relative precision δm/m of 10-9 has already been reached for the first ToF-ICR measurements. Furthermore, the first PI-ICR mass measurements with PIPERADE have been performed in the past year, a crucial step towards the aimed precision and sensitivity.

In this oral contribution, I will present these recent upgrades and show the results obtained with PIPERADE, as well as outline the perspectives on its installation at DESIR and the future experimental program.

15:20–15:40 Results on the CROSSTEST@LNL experiment for NArCoS: the Cross-talk problem

Speaker

Brunilde Gnoffo (Università degli Studi di Catania)

Description

The advent of new facilities for radioactive ion beams mainly rich in neutrons, like SPES @ LNL, FRAISE @ LNS and FAIR @ GSI only to give some examples, imposes the joint detection and discrimination of neutrons and charged particles in Heavy radioactive Ion collisions, with high angular and energy resolution. The construction of novel detection systems suitable for this experimental task is both a scientific and a technological challenge.
The contribution will illustrate the results of recent tests performed on a recently introduced plastic scintillator material, the EJ276, both in the "green-shifted" and in the base version, coupled with SiPMs. The contribution will also present results on the CROSSTEST experiment performed at LNL-INFN in November 2023. The goal of the experiment was the study of the crosstalk among the elementary cells of NArCoS (Neutron Array for Correlation Studies) at low neutron energy of 4.5 MeV, a novel detector for neutrons and charged particles with high energy and angular resolution, based on a 3D cluster of the EJ276 scintillation units. This project is also funded by the Italian PRIN ANCHISE Project (2020H8YFRE) and the CHIRONE experiment of the INFN.

15:40–16:00 Measuring Variation of β-Decay Rates in Laboratory Plasmas: the PANDORA Facility

Speaker

Bharat Mishra (INFN - LNS)

Description

The PANDORA (Plasmas for Astrophysics, Nuclear Decay Observation and Radiation for Archaeometry) facility aims to investigate the variation of nuclear and atomic properties inside a laboratory magnetoplasma emulating some aspects of the stellar interior [1]. The main goals of the facility are to use an electron cyclotron resonance (ECR) ion trap to measure β-decay rates and optical opacities of isotopes in a hot plasma for application to s- and r-process nucleosynthesis, respectively. The measurements will serve as a crucial benchmark of model-predictions [2, 3], which can then be applied to nucleosynthesis codes. The facility is currently under realisation at INFN-LNS in Catania, Italy, and the first plasma is expected to be ignited in 2026. While initial runs will be performed with isotopes that can be injected into the trap with relative ease, phase-2 operations will couple the plasma with an RIB line to study decay dynamics of short-lived isotopes through in-flight injection or charge breeding techniques.

Measuring decay rates inside magnetoplasmas requires a robust detection methodology complemented by detailed plasma simulations. We present here an overview of the physics and technology behind PANDORA, starting from a systematics-based model of in-plasma decay [3]. We will use the model to calculate decay rates of ^{7}Be and ^{134}Cs in a general plasma and then couple the results with an in-house Particle-in-Cell Monte Carlo (PIC-MC) code to predict spatial trends of decay rates in the PANDORA trap. These isotopes are among the first cases to be studied, based on their feasibility and astrophysical relevance. We will then describe the detection methodology, which is based on counting secondary γ-rays emitted during the decay using 14 HPGe detectors placed around the plasma trap. We will conclude by presenting a “virtual experiment” of PANDORA, outlining the various steps of a typical measurement such as isotope injection, plasma characterization and monitoring, and data interpretation.

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[2] Pidatella, A. et al. *Experimental and numerical investigation of magneto-plasma optical properties towards measurements of opacity relevant for compact binary objects*. Frontiers in Space Science and Astronomy. DOI: **10.3389/fspas.2022.931744**

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16:00–16:20 ARIES: A High-Efficiency, High-Granularity Beta-Tagging Scintillator Array with Ultra-Fast Timing for Decay Spectroscopy Studies

Speaker

Victoria Vedia (TRIUMF)

Description

The combination of large arrays of high-purity germanium (HPGe) detectors with auxiliary particle detection systems is among the most powerful methods for studying atomic nuclei. It is done through nuclear spectroscopy at radioactive ion beam facilities such as TRIUMF-ISAC [1] together with the use of high-efficiency gamma-ray spectrometers like GRIFFIN (The Gamma-Ray Infrastructure For Fundamental Investigations of Nuclei) [2].
The use of ancillary detectors is key for disentangling complex level schemes, providing high isotopic selectivity and giving access to physics observables which give direct insight to the nuclear structure.
The ARIES detector (Ancillary Detector for Rare-Isotope Event Selection) is a high-efficiency ultra-fast β-particles detector designed to operate as the main ancillary detector at the GRIFFIN spectrometer. Its design matches 1:1 the GRIFFIN geometry, allowing ㄴㅈ-ㄹㅅ angular correlations with more than 114 unique angles. ARIES entails low g-ray attenuation, superior counting rate greater than 20MBq and Fast Timing capabilities allowing lifetime measurement down to the few ps range.
In addition to its novel design, ARIES includes leverage technologies such as flex-circuit electronics, magnetron sputtering for coating plastic scintillators, and many more. The design, performance, and status of ARIES, along with an overview of the scientific opportunities, will be presented.

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16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 5

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Eugenio Scapparone (INFN-Bologna)

14:20–14:45

Neutrino mass measurements with KATRIN and atomic source development for future experiments

Speaker

Caroline Rodenbeck (Karlsruher Institut für Technologie)

Description

From the observation of oscillations, neutrinos are known to have a mass. However, it remains an open question as to how large that mass is. One way of determining the neutrino mass is the investigation of weak decay kinematics. Especially suited is the beta decay of tritium, mainly due to its simple structure, high activity, and comparatively low endpoint value.

KATRIN, the Karlsruhe Tritium Neutrino Experiment, measures the imprint of the neutrino mass on the endpoint region of the tritium beta-decay spectrum. KATRIN sets the most stringent upper limit on the neutrino mass, at a value of below 0.45 eV (90% CL), and its final sensitivity will be below 0.3 eV.

To go beyond KATRIN, future experiments will require improvements in detector technology. This is currently being investigated in the form of e.g. time-of-flight techniques and quantum sensors. Once significant advancements in this area are made, however, the molecular tritium source will become a limiting factor. An atomic tritium source will therefore be needed.

Such an atomic source can be implemented by trapping mK-cold atoms in a magnetic field. Within the Karlsruhe Mainz Atomic Tritium Experiment (KAMATE), the production and cooling of tritium atoms is being studied.

The talk will present the current KATRIN results and provide an overview of the ongoing efforts for the development of an atomic tritium source within KAMATE and beyond.

14:45–15:10

Helium burning and nuclear clustering: recent studies and constraints from direct reactions

Speaker

Dr Kevin Ching Wei Li (University of Oslo)

Description

Understanding stellar nucleosynthesis remains a forefront challenge in physics and relies on detailed knowledge of helium burning, whose pivotal triple-α and $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ reactions set the carbon–oxygen balance in stars. This talk will present recently published precision data on the triple-α reaction and a new direct measurement of $^{12}\mathrm{C}(\alpha,\gamma)^{16}\mathrm{O}$ performed at iThemba LABS. Finally, it will introduce a framework for analysing direct-reaction data that treats sub-threshold states and resonances in a manner consistent with R-matrix scattering analyses. This enables more stringent tests of nuclear clustering and yields parameters that are more model-independent and comparable across different studies. These parameters may ultimately support improved constraints on astrophysical reaction rates.

15:10–15:30

Electron screening: answer to an old problem from a new perspective

Speaker

Aleksandra Cvetinović (Jožef Stefan Institute)

Description

In nuclear reactions induced by low-energy charged particles, atomic electrons can participate in the process by screening the nuclear charge and so, effectively reducing the repulsive Coulomb barrier. Consequently, the measured cross section is enhanced by an effect called electron screening. There are several theoretical models, based on a static approach, describing this effect. However, in numerous experiments, different research groups obtained extremely high values of electron screening that theories failed to describe. Instead, supported by our experimental findings, we proposed a new, dynamic approach to the problem, where screening is influenced by valence electrons present in the hosting material crystal lattice. Our latest experimental results will be discussed.

15:30–15:50

The study of the 21Ne(p,γ)22Na reaction at LUNA and its astrophysical impact

Speaker

Antonio Caciolli (University and INFN Padova)

Description

The production and abundances of neon and sodium isotopes in massive stars, novae and supernovae is strictly connected to the cross section of proton reactions with Ne isotopes. In particular, the 21Ne(p,γ)22Na reaction has a relevant role in the production of the radioactive isotope 22Na in novae and supernovae. At T~0.1-0.7GK, the main contributions to the stellar rate are provided by several resonances (Ep=126, 271, 272, 290 and 352 keV). The reaction has been recently studied at LUNA (Laboratory for Underground Nuclear Astrophysics) using the intense proton beam delivered by the LUNA 400 kV accelerator and a windowless differential-pumping gas target coupled with two high-purity germanium detectors. The resonance strengths and branching ratios have been determined for all the resonances of interest and in the case the strength of the 272.3 keV resonance a > 3σ tension with an earlier measurement was found. Several new transitions have also been observed for 22Na excited states. The contribution is aimed to summarize the new results and to highlight their impact on 1.05-1.25 M/M novae scenarios.

15:50–16:10

miniTRASGO: A Compact Muon Detector for Global Cosmic Ray Monitoring and Space Weather Studies

Speaker

CAYETANO SONEIRA LANDIN (Complutense University of Madrid)

Description

The miniTRASGO is a compact, cost-effective secondary cosmic ray detector optimized for studies in solar activity, cosmic rays, and atmospheric physics. Based on Resistive Plate Chambers (RPCs), it provides stable detection rates and high sensitivity. This was demonstrated by its successful measurement of Forbush Decreases in March and May 2024 at the Madrid station, which, at the time, hosted the only deployed miniTRASGO unit. These results highlight the detector's reliability despite its limited active area.

Due to its design and location, miniTRASGO also complements nearby neutron monitor stations from the NMDB, such as CaLMa, which is geographically close to Madrid. By detecting the secondary muon component of cosmic rays, it adds a valuable observational channel to conventional cosmic ray monitoring.

By early 2025, additional units are deployed in Warsaw, Puebla, and Monterrey, each situated at distinct latitudes and characterized by different geomagnetic cutoff rigidities. This expansion establishes miniTRASGO as a scalable platform for a global muon monitoring network, enabling detailed studies of cosmic ray modulation and space weather phenomena.

In addition to global flux monitoring, miniTRASGO supports angular-resolved studies of cosmic ray variability. It applies atmospheric corrections and analyzes rate dependence on arrival direction, facilitating investigations into geomagnetic effects, solar modulation, and cosmic ray–atmosphere interactions. These capabilities significantly enhance its utility for coordinated, multi-site cosmic ray research.

16:10–16:30

Hybrid star properties with the NJL and mean field approximation of QCD models: A Bayesian approach

Speaker

Milena Albino (University of Coimbra)

Description

Neutron stars are the most compact objects in the Universe. The core of these extremely compact objects has such high densities that it reaches regions of the QCD phase diagram that are still unknown. In this work we explore the possibility of deconfined quark matter inside neutron stars. For this purpose, we generated eight sets of hybrid equations of state. For the hadron phase, we used the relativistic mean-field model with nonlinear meson terms. The quark phase is described by two different models: the Nambu-Jona-Lasinio model with multiquark interactions and the mean-field theory of QCD, a model similar to the vectorial MIT bag model. The phase transition is obtained by applying Maxwell's construction. Bayesian inference was used to reproduce the observational data of neutron stars. In half of the sets we also imposed the constraint imposed by the pQCD calculations. The results show that the hybrid stars are compatible with the observational data. Although the pQCD calculation reduces the maximum mass, these models were able to reach $M_\text{max} = 2.1-2.3 M_\odot$. Other consequences of the imposed constraints and the chosen model will be discussed.

16:30–16:50

Measurements of neutron capture cross sections for nucleosynthesis at n_TOF: the cases of 64Ni(n, γ) and 30Si(n, γ)

Speaker

Michele Spelta (University of Trieste. INFN - Sez. di Trieste. CERN)

Description

Neutron capture reactions play an important role in nuclear astrophysics as they are at the base of the s-process and the r-process, the two main mechanisms of nucleosynthesis beyond the iron peak.
Neutron capture cross sections are therefore important inputs of stellar models. Their accurate knowledge is crucial to predict reliable stellar yields and isotopic abundances that, compared with the observations, can eventually constrain stellar properties not directly experimentally accessible.
For example, ^{64}Ni is among the seeds of the s-process and its capture cross section was found to significantly affect the predicted abundance of many isotopes produced afterwards in the s-process chain both in massive and in AGB stars. On the other hand, the neutron capture cross section of ^{30}Si is extremely important to explain the abundance of the Silicon isotopes measured in presolar SiC grains, disentangling the contributions of neutron-capture nucleosynthesis and galactic chemical evolution.
Since the data available in literature were scarce and discrepant for both isotopes, new time-of-flight measurements of ^{64}Ni(n, γ) and ^{30}Si(n, γ) have been performed at n_TOF facility, a pulsed white neutron source at CERN characterized by a wide neutron energy range, high instantaneous neutron flux and excellent energy resolution. Highly enriched samples have been used in the measurements.
The preliminary results show interesting discrepancies with respect to the cross sections recommended in the most recent releases of the evaluated nuclear data libraries. In particular, in both isotopes, huge resonances expected in the energy range of astrophysical interest are not observed. Therefore, a significant impact on the Maxwellian Averaged Cross Section (MACS) for astrophysical applications is expected.

16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Astrophysics, Astroparticle Physics and Synergies with Nuclear Physics: 6

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:20–14:45 Nucleosynthesis in First Stars and Other Puzzles: Experimental Prospects at LUNA

Speaker

Marialuisa Aliotta (University of Edinburgh)

Description

First stars played a key role in shaping the chemical evolution of the universe, acting as the earliest sites of nucleosynthesis beyond the Big Bang. Yet, key aspects of their nuclear burning processes—particularly the formation of CNO nuclei from primordial material—remain among the long-standing puzzles in nuclear astrophysics.

Recent studies suggest that previously overlooked reaction paths, involving alpha-induced reactions on lithium and boron isotopes, may provide a crucial link. If enhanced by nuclear clustering effects, these reactions could also shed light on the persistent cosmological lithium problem and the anomalous electron screening observed in laboratory experiments.

In this talk, I will present ongoing efforts at the Laboratory for Underground Nuclear Astrophysics (LUNA), located deep underground at LNGS, Italy, to measure alpha-induced reactions at astrophysical energies. Thanks to LUNA's ultra-low background environment, these studies can achieve unprecedented precision, offering new insights into stellar evolution and the nuclear processes that shaped the cosmos.

This work is part of the NUCLEAR research programme supported by an ERC Advanced Grant (UKRI-funded, EP/Z534626/1), aimed at addressing open questions about the origin of the elements and the early universe.

14:45–15:10 Recent experimental efforts for the astrophysical p-process

Speaker

Daniel Galaviz Redondo (LIP / FCUL)

Description

The astrophysical p-process is the crucial mechanism responsible for the synthesis of a sub-set of proton-rich isotopes, known as p-nuclei, which cannot be produced by the s- and r-processes. Despite the several astrophysical environments considered in the literature [1-3] photodisintegration reactions are identified as the dominant mechanism for the production of these rather weakly naturally existing isotopes. Despite its significance, the exact conditions and reaction rates involved in the p-process remain poorly understood, necessitating precise experimental data to refine theoretical models.

In this talk I will provide an overview on the current understanding of the astrophysical p-process, which are the presently identified uncertainties from the nuclear physics perspective, and which are the efforts that the Lisbon group has recently performed to experimentaly advance in the understanding of the properties of nuclei involved in this nucleosynthesis process, ranging from new techniques to determine reaction cross sections to innovative studies of α nuclear potentials with radioactive isotopes.

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15:10–15:30 Direct measurement of the 12C+12C fusion reaction at astrophysical energies

Speaker

Prof. Sandrine Courtin (IPHC-CNRS and University of Strasbourg)

Description

Only a handful of the most energetic reactions involving the most abundant elements are driving the evolution and chemical structure of massive stars. Among these, the fusion of two carbon nuclei is a key process during the late stages of the evolution such stars, in explosive nucleosynthesis in Type 1a supernovae and superbursts in x-ray binary systems [1]. The precise measurement of the ultra-low oscillating carbon fusion cross sections is extremely challenging so that the quantification of this critical reaction still lacks the necessary accuracy to constrain astrophysical models. Current data from direct measurements span from above the Coulomb barrier to the region of astrophysics interest, but with large uncertainty towards low relative energies so that extrapolations into the Gamow window can differ by orders of magnitude.
The STELar LAboratory (STELLA) experiment has been developed to increase the accuracy of direct carbon fusion reaction measurements, as compared to conventional experiments, by using the coincident detection of the evaporation residues characteristic gamma rays and the emitted charged light particles, which drastically suppresses the backgrounds [2]. STELLA furthermore combines nano seconds timing with this approach for unambigious exit channel identification with timing gates of tens of nanoseconds. The setup employs thin large self-supporting rotating carbon targets and is designed for reliable and stable fusion measurements during weeks of bombardment with beam of an intensity of up to ten µA.
We will present recent ^{12}C+^{12}C measurements with STELLA, right in the astrophysics region of interest of 25 M$_{\odot}$ stars. These data complement an earlier experiment at the lowest-energy direct measurement carried out so far [3], where partly only limits could be established, and largely improves the understanding of the fusion excitation function. The results will be discussed on terms of molecular resonances in the ^{24}Mg(^{12}C-^{12}C) compound nucleus as well as hindrance of the fusion process at the lowest energies.
The impact of the STELLA results on the chemical structure and evolution scenarios of massive stars will be discussed, based on novel hydrodynamics calculations using the GENEC code.

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15:30–15:50 Stopping Power of ions in laser-induced plasmas for nuclear astrophysics studies

Speaker

Dr Giorgio Lo Presti (INFN)

Description

Stopping power (SP) refers to the rate at which a charged particle loses energy as it moves through a medium; however, it is substantially different between ordinary (cold) and plasma matter. As a consequence, a precise determination of SP in plasmas is essential for nuclear astrophysics [Ber04, ADGL99] and energy production [LP93, ZZZ+22], because it plays a central role in determining nuclear reaction rates both in stellar and reactor environments. In addition, deviations of SP expectations on Big-Bang Nucleosynthesis and supernova explosions are significant because the proportion of nuclear product content is influenced by the photon production rates resulting from ion braking.

The main components of stopping power are: "electronic SP" and "nuclear SP". Electronic SP is the energy loss due to interactions with electrons, while nuclear SP is the energy loss due to collisions with nuclei. In plasma, electronic SP is significantly influenced by electronic screening, where free negative charges modify the potential between ions, facilitating the overcoming of the Coulomb barrier and enhancing fusion probabilities. Since the electronic distribution affects the energy loss of projectile nuclei, screening also alters the stopping power itself [CFJ+00]. Investigating this phenomenon is essential to resolve the discrepancies between theoretical predictions and laboratory data, ultimately improving the understanding of nuclear fusion processes in stellar and reactor environments.

Further experimental and theoretical SP studies are thus necessary to gain more and more detailed information on entire universe, even though the conditions of these environments are typically difficult-to-access and critical in terms of high temperature and density. Hence, it is useful to develop experimental setups and theoretical approaches that simplify the study of the SP. In this framework, our collaboration, named SPILL (by INFN), aims to study the SP under conditions of astrophysical interest by means of laser produced plasmas (LPP) [Alt17]. Through high intensity lasers and short duration pulses, it is, in fact, possible to generate non stationary and highly concentrated plasmas [Gil96].

Our simulations implement SP through the electrodynamical characterization of a non-thermalized LPP in such a kind of complex environment. In this contribution, the preliminary performances and results of our experimental apparatus, designed to measure the energy loss of light and heavy ions passing through an LPP, will be presented together with a theoretical model accounting for the SP effects in a simplified nucleosynthesis scenario.

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15:50–16:10 Calibrating the medium effects of light clusters in heavy-ion collisions

Speaker

Tiago Custódio (University of Coimbra)

Description

Light nuclei are found in core-collapse supernova matter and in binary neutron star mergers. Their abundance can affect the dynamics and properties of supernovae [1-3] and binary neutron star mergers [4-8], both directly through their weak reactions with the surrounding medium, and indirectly through their competition with heavy nuclei [9], which can modify the proton fraction and the size of nucleosynthesis seeds [10]. They can also have a significant (indirect) effect on the dynamics of the core-collapse supernova explosion giving rise to a faster shock retreat and an early neutrino luminosity [11], even though, only a negligible (direct) impact from the weak reactions involving the light clusters was obtained. The transport coefficients are determined by the collision rates of electrons and/or neutrinos with clusters, which in turn depend on the cluster abundances and sizes. In binary mergers, the recombination of free nucleons into α particles can generate enough energy to induce mass outflows [12]. Therefore, the study of light nuclei is essential to obtain a good description of these astrophysical events. In particular, in the scope of relativistic mean-field models, their nuclear couplings need to be calibrated to experimental data such as heavy-ion collisions. In this work [15], we propose a Bayesian inference estimation of in-medium modification of the cluster self-energies from light nuclei multiplicities measured in selected samples of central $^{136,124}Xe+^{124,112}Sn$ collisions with the INDRA apparatus. The data are interpreted with a relativistic quasi-particle cluster approach in the mean-field approximation without any prior assumption on the thermal parameters of the model. An excellent reproduction is obtained for H and He isotope multiplicities, and compatible posterior distributions are found for the unknown thermal parameters, for two different nuclear models.

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16:10–16:30

Measurement of the 118Sn(p,γ)119Sb cross-sections with low energy proton beams using the activation technique

Speaker

Ms Margarida Paulino (LIP, FCT-UNL)

Description

The p-process was first proposed as a solution to the formation of proton-rich heavy nuclei between Se and Hg that cannot be produced via the r- and s-processes. The p-nuclei are typically 10-1000 times less abundant than isotopes formed through the r or s-processes, making the study of their reaction cross-sections fundamental for improving current nucleosynthesis models [1]. In this work, I present the measurement of $^{118}\mathrm{Sn}(p,\gamma)^{119}\mathrm{Sb}$ cross-sections with low energy proton beams using for the first time the activation technique. The isotope $^{119}\mathrm{Sb}$ has been identified as a branching point between the (γ,n) and (γ,p) reactions in the p-process chain, presenting high reaction rate uncertainties [2].
Cross-sections were calculated at three different energies by measuring the X-ray and γ photons emitted during the decay of $^{119}\mathrm{Sb}$. Highly enriched targets were used for these measurements, and details will be provided on their production, along with the experimental setup used and the data analysis involved in the calculations. The results obtained were compared to previous literature values [3][4] and theoretical simulations done via TALYS.
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16:30–16:50

Impact of Temperature-Dependent Gamma-Ray Strength Functions on Astrophysical Reaction Rates

Speaker

Tanmoy Ghosh (Dept. of Physics, Faculty of Science, University of Zagreb)

Description

To comprehensively understand nuclear astrophysical network calculations, especially in the context of processes like the r-process, it is crucial to consider astrophysical reaction rates at a fixed temperature which requires Maxwellian-averaged cross-sections across a wide range of energies for radiative neutron capture processes. Determining these cross-sections and reaction rates within a statistical framework [1–3] primarily relies on three key components: (i) Neutron-Nucleus Optical Model Potential (OMP), (ii) Gamma-ray Strength Function (γSF), and (iii) Nuclear Level Density (NLD). While uncertainties in the Neutron-Nucleus Optical Model Potential (OMP) are relatively small, the Gamma-ray Strength Function (γSF) and Nuclear Level Density (NLD) have a more significant impact on shaping the calculated neutron capture rates.
In our recent study, we have calculated temperature effects in electric and magnetic dipole (E1 and M1) transitions using a self-consistent finite-temperature relativistic quasiparticle random phase approximation (FT-RQRPA) based on a relativistic energy density functional with point-coupling interactions [4, 5]. Currently, we examine their impact on crucial astrophysical reaction rate calculations.

[1] W. Hauser et al., Phys. Rev. 87, 366 (1952).
[2] Sangeeta et al., PRC 105, 044320 (2022).
[3] T. Ghosh et al., JPhysG 51, 045105 (2024).
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16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Physics Applications: 5

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

14:20–14:45 New challenges for experimental data dedicated to nuclear reactor physics

Speaker

Maëlle KERVENO (IPHC/CNRS)

Description

Researches on nuclear reactors, both for optimization of current generation or for study of next generations, require simulations. Indeed, reactor operation parameters, fuel burning, waste production, etc. can be studied by simulation with Monte Carlo or deterministic codes. These codes simulate the fundamental interaction of nucleons or ions with the matter and use as inputs nuclear data like reaction cross sections, angular distributions, fission yields, decay information … These inputs are called evaluated nuclear data, they are compiled in evaluated nuclear databases and they are determined from experimental data and state-of-the art nuclear reaction codes. The increase in calculation power allows today precise sensitivity studies, which reveal that the one major limiting factor for accuracy simulations of reactor parameters is the accuracy of evaluated nuclear data used as inputs. The international community is thus continuously working on the improvement of evaluated nuclear data libraries like the European - JEFF (Joint Evaluated Fission and Fusion), the US - ENDF (Evaluated Nuclear Data File) or the Japanese - JENDL (Japanese Evaluated Nuclear Data Library), … The quality of evaluated nuclear data bases can be improved with efforts both from the experimental and theoretical sides as reliance on nuclear models is common today for nuclear data evaluation. In some cases, where experimental data are scarce or known with low precision, new measurements are mandatory to provide new and relevant constraints for nuclear modeling. Moreover, experimental integral data are also used in the evaluation cycle as validation. In this presentation, after the description of the context and issues of nuclear data for reactor physics, I will focus on the new challenges we have to face for microscopic experimental data (used for theoretical modeling improvement and evaluation) in the frame of the development of modern, high performance evaluated data bases.

14:45–15:05 IAEA activities in support of nuclear physics research and applications

Speaker

Dr Danas Ridikas (IAEA)

Description

Facilitation of development and promotion of nuclear applications for peaceful purposes and related capacity building are among the IAEA missions where Physics Section contributes most [1]. The relevant activities fall under the IAEA's program on nuclear science and cover three main thematic areas: research and applications with particle accelerators and neutron sources (incl. research reactors), nuclear instrumentation and capacity building, and controlled fusion research and technology (incl. cooperation with ITER). As a result, the Section helps IAEA's Member States to advance their capabilities and progress in materials research, energy, environment, food, agriculture, medicine, cultural heritage, forensics, and some other fields with a direct socioeconomic impact.

The Section also operates the Nuclear Science and Instrumentation Laboratory (NSIL) at Seibersdorf [2], located 40 km south of Vienna. The NSIL provides expertise, training and support in the effective utilization of nuclear instrumentation and analytical techniques in a broad range of applications, with a focus on mobile radiation monitoring, X-ray spectrometry, and neutron science.

This presentation will illustrate through a number of selected examples how the IAEA supports nuclear physics research and diverse applications in order to address key development priorities in many areas of societal importance and economic growth of the developing countries. Where applicable, direct linkage to the United Nations Sustainable Development Goals (UN SDGs) will be demonstrated. In addition, some future plans on enhancing capabilities of the NSIL as part of Physics Section will be highlighted, in particular by establishment of the ion beam facility (IBF) based on a compact particle accelerator and offering research and applications both with ion beams and neutrons.

[1] https://www.iaea.org/about/organizational-structure/department-of-nuclear-sciences-and-applications/division-of-physical-and-chemical-sciences/physics-section
[2] https://nucleus.iaea.org/sites/nuclear-instrumentation/

15:05–15:25 Modelling γ-spectrum from d-t collisions: potential for industrial applications

Speaker

Natalia Timofeyuk

Description

Motivated by possible industrial fusion applications of the γ-rays accompanying d-t collisions I present the first model calculations of the minor branching ratio of the $d+t$ reaction, $d+t \rightarrow \alpha+n+\gamma$. The model exploits the most relevant physics feature -- spin conservation in electric dipole transitions -- which leads to a peculiar mechanism of this reaction: γ-emission via bremsstrahlung from an intermediate α-n state. As a consequence of the bremsstrahlung, the γ-spectrum contains non-zero contributions at all energies thus making inclusive $dt\gamma$ cross section measurements sensitive to the low-energy cutoff of the detected γ-events. Comparison of the model predictions to existing $d+t \rightarrow \alpha+n+\gamma$ measurements in accelerators, employing cutoffs of 13 and 14 MeV, and inertial confinement fusion facilities, with a low-limit cutoff of 0.4 to 10 MeV, suggests a possible contradiction between results from these two types of experiments. The model predictions agree well with accelerator measurements and corroborate the cutoff dependence observed in inertial confinement experiments. The model predictions are sensitive to the wave function details inside the short-range area of the α-n interaction, with uncertainty comparable to that of available experimental data, but become model-independent below 4-5 MeV. This part of the γ-spectrum features a previously unexpected rise, which below 0.5 MeV surpasses the main 17 MeV γ-peak in strength. The reactivity of the $d+t \rightarrow \alpha+n+\gamma$ branch strongly depends on the d-t plasma temperature, which opens the possibility of advanced plasma temperature diagnostics.

15:25–15:50 **Utilizing beams of MeV ions for measurements of kinetics in materials on the atomic scale**

Speaker

Daniel Primetzhofer (daniel.primetzhofer@physics.uu.se)

Description

To meet the sustainable development goals of the United Nations we have to transform our global economy into energy-smart, sustainable, cyclic societies. The materials we nowadays employ for storage and conversion of energy but also for regulation of energy transport are commonly complex compound systems often containing light chemical elements such as hydrogen, lithium or oxygen, either intentionally, or as contaminations, significantly altering materials properties. Characterization of the above-mentioned systems, during design, manufacturing and operation is challenging, due to the comparably weak electronic signature of these species.
Materials analysis methods based on energetic ions, due to their unique characteristics providing depth-resolved information on material composition and sensitivity also to light chemical species provide a unique toolbox to be exploited for such characterization. They are commonly non-destructive and robust in applicability rendering them excellent probes for studying materials modification processes while they occur, i.e. in in-situ or even in-operando investigations.
In this contribution, several recent studies using keV and MeV ion beam analytical tools for in-situ and in-operando characterization of a number of material systems with high relevance for energy-related applications will be presented.

Experiments were conducted at the 5MV 15-SDH-2 pelletron accelerator at Uppsala University which can provide a broad spectrum of beams in the energy range of 2 to ~50 MeV to multiple end-stations some of which capable of in-situ synthesis or materials modification [1]. The ion-beam based characterization was complemented by atom probe tomography, X-ray diffraction and transmission electron microscopy.

We performed high-resolution depth profiling of Li and O in thin film batteries using primary beams of He and Li at energies up to 10 MeV. By recording transmitted particles in coincidence, we could observe reversible transport of Li and quantify the material transport during charging and discharging of the battery stack [2][3][4].

Oxidized rare-earth metal hydrides can feature reversible photochromism at ambient conditions with huge potential for passive regulation of energy flow. To better understand the nature of the photochromic effect, we combined ion beam analysis with in-situ reactive growth and oxidation [5]. From this work and further complementary studies, a dual-phase nature is proposed and the photochromism is related to high residual stress levels in the films [6].

We furthermore explored the potential of ion beam analytical techniques capable of directly and indirectly sensing hydrogen in real space at a true atomic length scale. As a result, we succeeded to probe the specific lattice location and vibrational amplitude of H in crystalline matrices, specifically investigating Fe/V superlattices as model systems for studying effects of proximity and dimensionality. [7].

References:
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[7] K. Komander et al., Phys. rev. Lett. (2021)

15:50–16:10 **First results of (n,alpha) measurements on F-19 with the SCALP detector**

Speaker

François-René Lecolley (LPC Caen (ENSICAEN - CNRS/IN2P3 - UCN))

Description

The (n,alpha) cross-sections on oxygen 16 and fluorine 19 are of great interest for the improvement and/or development of the nuclear reactors. Significant differences have been observed for those nuclei regarding the (n,alpha) channel:
- on oxygen 16, discrepancies up to 30% between experimental data and/or evaluation are observed and are responsible for an uncertainty of 100 pcm on the keff or reactor using either water and/or oxide fuel [1],
- on fluorine 19, discrepancies up to a factor 3 between experimental data and/or evaluation are observed. Estimated uncertainty on the total neutron interaction cross-section of F-19 bring up to 213 pcm uncertainty on the reactor keff value. The uncertainty on the cross-section of the reaction (n,alpha) alone is responsible for approximately 40 pcm to 130 pcm of uncertainty on keff depending on the type of MSR considered [2].

In view of improving our knowledge on (n,alpha) reactions, the ACE group (Groupe Aval du Cycle Electronucléaire) of the LPC Caen has developed a new detector named SCALP [3] (Scintillating ionization Chamber for ALPha particle detection in neutron induced reactions). This presentation deals with the first experiments carried out with this new detector at the new NFS facility (GANIL, Caen, France) and the nELBE facility (HZDR, Dresden, Germany).

After discussing the needs for new measurements of (n,alpha) reaction on 0-16 and F-19, the operating procedure of the SCALP detector will be presented, as well as the experiments that have been conducted using it. Furthermore, insights into the data acquired during our experiment, as well as the data processing will be provided. First results of the SCALP project will then be discussed and compared with available experimental data and the most recent evaluation of (n,alpha) reaction on F-19.

[1] – M. Salvatores and R. Jacqmin, Uncertainty and Target Accuracy assessment for innovative systems using recent covariance data evaluations (International Evaluation Co-operation, NEA/WPEC-26, 2008)
[2] – Sigfrid Stjarnholm, Nuclear Data Uncertainty Quantification for Reactor Physics Parameters in Fluorine-19 based Molten Salt Reactors (WONDER-2023, Aix-enProvence France, 2023)
[3] – B. Galhaut et al, SCALP: Scintillating ionization Chamber for ALPha particle production in neutron induced reactions, ND 2016, EPJ Web of Conferences 146, 03014 (2017)

16:10–16:30

Performance Evaluation and Simulation of Segmented SiC-Based Particle Detectors for Dosimetry and Real-Time Monitoring

Speaker

GIUSEPPE FERDINANDO D'AGATA (Università degli Studi di Catania - Dipartimento di Fisica e Astronomia "Ettore Majorana" & INFN Sezione di Catania)

Description

In the last decade, SiC-based detectors have emerged as strong candidates for next-generation particle detection. This is due to several advantageous properties of the material, including its high breakdown field, high saturation velocity, wide band-gap, radiation hardness, strong mechanical resistance, and thermal stability [1–3]. Additionally, SiC has been proposed as a promising solution for easy-to-use, high-performance active dosimeters [4,5], thanks to its biocompatibility and relative insensitivity to light [6].
Within this context, as part of the SAMOTHRACE ecosystem [7], studies have been conducted to evaluate the performance of SiC devices for dosimetry and real-time monitoring. This research is part of a collaboration between the University of Catania's Department of Physics and Astronomy, the Laboratori Nazionali del Sud (LNS) of the Istituto Nazionale di Fisica Nucleare (INFN), and the INFN – Sezione di Catania. Proton, alpha beams and radioactive α-sources were used to characterize the performance of a segmented SiC detector, focusing on the interplay between different pads of the detector, as well as cross-talk, inter-pad contributions, and edge effects.
This contribution will focus on the evaluation of these effects from the simulation side, performed using Geant4 tools, modelling the expected behaviour of two different SiC detectors (10 μm and 100 μm thick) with the same 2×2 segmented geometry. The simulations considered variations in manufacturing and detector configurations. This step is crucial for gaining a deeper understanding of the detector's response in different regions, particularly in the inter-pad areas, where weaker signals and electric field interactions can significantly degrade the output, potentially leading to improper—or even missing—event reconstruction. Finally, a comprehensive evaluation of the electric field is currently underway.

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16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Structure, Spectroscopy and Dynamics: 12

Session | **Location:** MoHo, Inspire 1, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** David Boilley (GANIL)

14:20–14:45 Recent advances from ab initio Self-Consistent Green's function computations of nuclei

Speaker

Carlo Barbieri (Università degli Studi di Milano)

Description

Many-body Green's functions stands out among microscopic theories for its capability to encapsulate infromation on ground state properties, response and single particle spectroscopy within the same framework. Different aspects of the many-body correlations and dynamics of a given nucleus can then be investigated simultaneously with the same microscopic approach.

The first part of the talk will focuss on ongoing work to extend self-consistent Green's function (SCGF) theory to desceribe pairing effects in the presence of collective excitations--the so called Gorkov-ADC(3) framework[1]--and the exploitation of diagrammatic Monte Carlo methods [2] for devising first principle optical potentials [3].

The second part of the talk will cover recent results regarding the structure near the Ar and Ca isotopic chains. In particular, I will further discuss the analysis of a recent GANIL experiment that provided evidence for a charge bubble in ^{46}Ar and linked this to an atypical shell closure at Z=18 and N=28 [4].

[1] C. Barbieri, T. Duguet and V. Somà, Phys. rev. C **105**, 044330 (2022).
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14:45–15:05 Nuclear moments of isomeric states around 132Sn

Speaker

Georgi Georgiev (CSNSM, Orsay, France)

Description

The nuclear electromagnetic moments provide an essential information about the structure of the state of interest. They are very stringent tests to the nuclear theory. The magnetic dipole moments are especially sensitive towards the single-particle properties of the nuclear wave functions while the electric quadrupole moments give an insight to the nuclear deformation and collectivity.
Experimental nuclear moments studies of microsecond isomeric states constitute a special challenge for the neutron-rich nuclei far from stability. Often those isomeric states are populated in projectile fragmentation reactions and specific techniques are applied in order to obtain spin-oriented ensembles of nuclei. The peculiarities of those techniques will be touched upon.
From nuclear structure perspective the region around ^{132}Sn represents a special interest and is often considered in a conjunction with the ^{208}Pb region. The nuclear wave functions are expected to demonstrate clear single-particle properties thus the nuclear magnetic moments are expected to be well in agreement with the extreme single-particle shell model. Indeed, this has been observed experimentally for the case of ^{131}In [1], a single proton hole in ^{132}Sn, for which the experimental ground-state magnetic moment has been reproduced by the theory using free-nucleon g factors.
A campaign of two experiments, aiming at magnetic moment studies in ^{132}Sn and ^{130}Sn has been performed at the RIKEN Nishina Center in December 2024. The 10^+ isomeric state in ^{130}Sn (E_x = 2435 keV, $t_{1/2}$ = 1.6 µs) has been populated in a two-step projectile fragmentation reaction following the two-neutron removal from the 132Sn secondary beam. The Time Dependent Perturbed Angular Distribution (TDPAD) technique has been applied. In the second experiment the 6^+ (E_x = 4715 keV, $t_{1/2}$ = 20 ns) isomeric state in ^{132}Sn has been populated following the γ-ray decay of the 8^+ ($t_{1/2}$ = 2.1 µs) isomeric state in the same nucleus. The Time Dependent Perturbed Angular Correlations (TDPAC) technique has been used for the moment study of the short-lived isomeric state.
The experimental details and the status of the data analysis for the two experiments will be presented and the results will be compared to theoretical models. The experimental challenges and the future perspectives will be discussed as well.
[1] A. Vernon et al., Nature 607 (2022) 260

15:05–15:25 Octupole Correlations in the neutron-deficient ^{110}Xe nucleus

Speaker

Illana Sison Andres (Complutense University of Madrid)

Description

Octupole correlations near $N = Z = 56$ are unique in the sense that they occur between particles in the same orbitals for both neutrons and protons. In this region just above ^{100}Sn, it is expected that enhanced octupole correlations will take place at low and medium spins in the light Te ($Z = 52$), I ($Z = 53$), and Xe ($Z = 54$) nuclei [1]. In this region of the nuclear chart, the Fermi surface for both neutrons and protons lies close to orbitals from the $d_{5/2}$ and $h_{11/2}$ subshells; octupole correlations emerge from the interactions of particles in these orbitals with valence neutrons and protons outside the ^{100}Sn core [2, 3]. As a result of the octupole correlations, an enhancement of octupole collectivity is expected to appear. Close to N = Z = 56, a level structure characteristic of octupole correlations, consisting of negative-parity states and enhanced E1 transitions, has been observed in several cases, including ^{112}Xe [4], ^{114}Xe [5, 6, 7], and ^{118}Ba [8].
With the aim to observe for the first time the octupole band in the neutron-deficient ($N = Z + 2$) ^{110}Xe nucleus, an in-beam experiment was performed at the Accelerator Laboratory of the University of Jyväskylä, Finland. The ^{110}Xe nuclei were produced via the ^{54}Fe(^{58}Ni,2n) fusion-evaporation reaction. The emitted γ rays were detected using the JUROGAM3 γ-ray spectrometer [9], while the fusion-evaporation residues were separated with the MARA separator [10]. In this experiment, we were able to prove the existence of the octupole band via the identification of the low-lying 3^{-} and 5^{-} states and their inter-band E1 transitions between the ground-state band and the octupole band [11]. Hence, these new experimental findings will be presented combined with a detailed study of the systematics of the energy levels and the B(E2)/B(E1) ratios in $^{110-114}$Xe and a comparison with state-of-the-art theoretical calculations.

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15:25–15:45

Theoretical nuclear reaction analysis for the ISOLDE Superconducting Recoil Separator (ISRS)

Speaker

Fatemeh Torabi (Departamento de Ciencias Integradas, Facultad de Ciencias Experimentales, Universidad de Huelva, 21071 Huelva, Spain)

Description

The ISOLDE Superconducting Recoil Separator (ISRS) [1] is an innovative high-resolution recoil separator aiming to extend the physics program of HIE-ISOLDE by using gamma-particle correlations and decay spectroscopy at the focal plane detector. The objective of the ISRS´s theory group is to predict direct and compound-nuclei production for selected nuclear reactions, aiming to optimize the performance of the spectrometer. The team has analyzed a selection of physics cases entailing reactions induced by 9Li, 30Mg, 68Ni, 132Sn, 185Hg, and 225Ra beams on a CD_2 target at the energy of 10 MeV/u.

A comprehensive analysis has been undertaken to describe various mechanisms such as elastic breakup, nonelastic breakup, compound-nucleus, and pre-equilibrium processes, as well as transfer reactions, for which we have made use of different codes, particularly a modified version of EMPIRE, PACE4, and FRESCO [2-4]. In our analysis, the use of modified EMPIRE which incorporated the post-form distorted wave Born expression of the Ichimura-Austern-Vincent approach (DWBA-IAV) [5-9] for breakup predictions alongside PACE4 allow us to provide an accurate depiction of reaction dynamics and thorough estimates of the energy and angular distributions of the residual nuclei produced in the selected systems.

Furthermore, for the transfer channels, which play a crucial role in nuclear structure and reaction studies, theoretical calculations for the (d,p) and (d,n) reactions in all the selected cases have been performed using the coupled-channels code FRESCO, providing both angular and energy distributions essential for accurate separator design.

The resulting theoretical angular and energy distributions for residual nuclei through various reaction mechanisms are currently being used in beam dynamics simulations. These simulations provide critical input for optimizing the experimental design, thereby advancing future nuclear-reaction analysis with ISRS.

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15:45–16:05

From Shell Gaps to Shape Coexistence: Probing the Island of Inversion N=40 through the ⁎ decay of 67Mn

Speaker

Victoria Vedia (CERN)

Description

One of the best-known divergences from the independent-particle shell model description of the atomic nucleus is the existence of islands of inversion (IoI) [1]. The N=40 IoI draws particular interest, as 40 was postulated as a non-traditional "magic" number, however, later experimental measurements of B(E2) values and E(2+) energies indicated enhanced collectivity through the N= 40 shell gap, with the clear exception of 68Ni [2,3]. In addition, LNPS shell model calculations predict triple shape coexistence for 67Co (N=40), with three rotational bands [4] and recent experiments on 67Fe (N=41) propose a spin-parity of 5/2+ or 1/2− for its ground state [5], which indicates significant deformation. In addition, shape coexistence is also expected for 67Fe.
To get a better understanding of this region, given the limited experimental data, an experiment was conducted at the TRIUMF-ISAC facility using the GRIFFIN spectrometer [6]. The β and βn decay of 67Mn populated the 67,66Fe, 67,66Co, and 67,66Ni isotopes. This data set contains orders of magnitude more statistics than previous studies, allowing us to build a complete level scheme of 67Fe and 67Ni for the first time and to improve upon the known β- decay level schemes of 67Co. In addition, measurements of level lifetimes down to the picosecond range will allow us to investigate the band structure in these nuclei. For the 67Fe isotope, a good level of statistics will allow us to measure the energy of the identified isomeric state and improve the lifetime measurement.

16:05–16:25

Ground state properties of Chromium isotopes from stability to the N=40 Island of Inversion

Speaker

Louis-Alexandre LALANNE (IPHC)

Description

The Chromium isotopic chain sits half-way in between the magic Ca and Ni isotopic chains and displays the highest level of collectivity of the region [1]. Going from the N = 28 shell closure to the center of the N = 40 Island of Inversion 64Cr, drastic structural changes are observed along the Cr isotopic chain, driven by a complex interplay of single particle and collective behaviors that poses challenges to nuclear theories [2,3,4].
In order to get a comprehensive picture of the evolution from spherical and single particle behavior to deformed and collective structures, the Colinear Resonance Ionization Spectroscopy (CRIS) collaboration performed the first measurement of the evolution of ground state properties of neutron rich Cr isotopes. The ground state spin, magnetic dipole moment and changes in charge radii of 50−63Cr have been measured using high resolution collinear resonance ionization laser spectroscopy and nine isotopes have been measured for the first time with this technique.

The present ground-state spin measurement of 61Cr, differing from literature, has significant consequences on the interpretation of existing beta decay. Its structure and shape are interpreted with state-of-the-art Shell Model calculations, establishing the western border of the N = 40 Island Of Inversion (IoI) [5]. The shape evolution along the Cr isotopic chain is interpreted as a second order quantum phase transition at the entrance of the N=40 IoI.
Discontinuities have been observed in the evolution of charge radii, entering the Island of Inversion. These results provide the first insight into the evolution of the ground state properties of even-Z isotopes from the magical N = 28 to the N = 40 island of inversion.

In this talk, the CRIS experiment will be introduced. Preliminary results will be presented and discussed in relation to the formation of the N = 40 island of inversion.

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16:25–16:45

Study of Shape coexistence and Triaxial deformation in Cr isotopes via lifetime measurements

Speaker

Julgen Pellumaj (University of Padova and INFN Padova)

Description

The appearance of a subshell closure in ^{56}Cr (N=32) is confirmed by the high excitation energy of the 2$_{1}^{+}$ state and the B(E2;2$_1^+\rightarrow$0$_1^+$). Shell model calculations are able to reproduce the energy of the first 2$^+$ state but not the drop of collectivity at N=32 for the Cr isotopes.
The discrepancy between the experimental data and the theoretical calculations for ^{56}Cr may be as a result of coexisting shapes in this nucleus and triaxiality which greatly reduces the B(E2) values. Indeed, calculations performed with the AMD+HFB framework aiming to investigate the triaxial deformation of the states and shape coexistence in this region show coexisting prolate and spherical shapes along the N=32 isotonic chain with the largest deformation in chromium isotopes. Including triaxial deformation in the model lowers the excitation energy of the 2$_1^+$ state a few hundred of keV and reduces the B(E2) values, being able to reproduce the drop of collectivity at N=32 in agreement with experimental data, but still the theoretical values of B(E2) remain much higher than the experimental ones.
Shape coexistence and triaxial deformation were studied in a recent experiment via lifetime measurements of the 0$_2^+$ and 2$_2^+$ states in ^{56}Cr employing the RDDS and the DSAM technique. The states of interest were populated using a transfer reaction: ^{54}Cr(^{18}O,^{16}O)^{56}Cr. The AGATA array was coupled with the SPIDER detector to reach the needed channel selectivity and control the feeding of the states of interest from higher lying states. Experimental results will be discussed in terms of theoretical calculations.

16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Structure, Spectroscopy and Dynamics: 13

Session | **Location:** MoHo, Inspire 2, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr Emmanuel CLEMENT (GANIL)

14:20–14:40 Study of ^{68}Ni by means of (d,p) and (p,d) transfer reactions

Speaker

Mr P. Sharma (Grand Accélérateur National d'Ions Lourds, CEA/DRF - CNRS/IN2P3, B. P. 55027, F-14076 Caen Cedex 5, France)

Description

The evolution of nuclear shell structure in exotic nuclei provides key insights into the fundamental nature of nuclear forces. In nuclei far from stability, conventional magic numbers can disappear, while new ones may emerge, a phenomenon known as shell evolution [1]. A well-known example is the evolution of the N=28 shell gap from ^{40}Ca to ^{48}Ca, which has been successfully explained by three-nucleon (3N) forces [2]. Similarly, the N=14 shell gap in oxygen isotopes shows a comparable trend [3]. These studies highlight the crucial role of many-body interactions in shaping shell structure. To extend our understanding to heavier nuclei, we investigate the evolution of the N=50 shell gap for which the isotopic chain of Ni would be the perfect candidate. An experiment was carried out at GANIL to study ^{68}Ni via (p,d) and (d,p) reactions, as this nucleus is the anchor point to determine the amplitude of the N=50 shell gap in ^{78}Ni, from relatively well known neutron-neutron effective interaction from experimental data. By performing neutron-adding and neutron-removing reactions in ^{68}Ni, we also get a unique access to the spectroscopic strengths and thus, the occupancy of the orbitals below and above N=40. This allows to characterize the magicity at N=40. Indeed, depending on whether a sharp occupancy drop is observed or not, the nucleus can be concluded to have either a magic or a superfluid nature [4]. Moreover, it is also planned to deduce the information on the 2p$_{1/2}$ - 2p$_{3/2}$, 1g$_{7/2}$ - 1g$_{9/2}$ and 1f$_{5/2}$ - 1f$_{7/2}$ spin-orbit splittings.

A primary beam of ^{70}Zn was bombarded on a thick Be target to produce a secondary beam of ^{68}Ni by fragmentation using the LISE spectrometer. With this secondary beam, ^{69}Ni and ^{67}Ni nuclei were populated in inverse kinematics using CD_2 and CH_2 as secondary targets in three separate channels: (1) ^{68}Ni (d,p) ^{69}Ni @ 18 MeV/u, (2) ^{68}Ni (d,t) ^{67}Ni @ 18 MeV/u and, (3) ^{68}Ni (p,d) ^{67}Ni @ 40 MeV/u. The detector setup consisted of two position sensitive gas detectors before target for beam tracking. The transfer-like products (^{67}Ni and ^{69}Ni) are tracked by means of Drift Chambers, and are identified using Ionization chambers and Plastic Scintillators which make the zero-degree detection (ZDD). The light particles produced in the forward direction transfer reactions {(p,d) or (d,t)} are detected by 4 highly segmented Si-CsI array MUST2 and in the backward direction {(d,p)} by another Si detector setup MUGAST to determine the energy loss and angles. A Ge-clover detector array EXOGAM2 is used to detect the in-flight and the isomeric-delayed gamma rays along with one detector at the end of the ZDD to detect the 9/2$^+$ isomeric state populated from the ^{68}Ni (p,d) reaction.

Thanks to such a cover-it-all experimental setup and the selection of kinematics of the outgoing nuclei, the first analysis shows promising data and statistics. The triple coincidence gamma measurements obtained by gating at the light particles in MUST2/MUGAST, the transfer-like products in the ZDD, as well as the correlated gammas are allowing us very precise energy determinations. As is evident, this study addresses a variety of key features related to the understanding of nuclear forces. The analysis of (d,p) part is almost finished and that of (p,d) has been started in parallel. Both will be presented in this contribution.

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14:40–15:00 Exploring the Reaction 64-Ni + 238-U and the Measurement of Isomeric State Lifetimes of Target-Like Transfer Products

Speaker

Mrs Jennifer Brigitte Cipagauta Mora (University of Groningen)

Description

Multi-nucleon transfer (MNT) reactions are a promising method for producing neutron-rich heavy exotic nuclei. Many facilities around the world are studying this process to better understand the reaction mechanisms involved, as well as the competing mechanisms using specific projectile/target combinations [1].

The gas-filled recoil separator RITU [2] at the Jyväskylä Accelerator Laboratory can be used to study a fraction of transfer products emitted close to zero degrees from the beam. By combining RITU with the JUROGAM [3] detector array, transfer products can be identified by their prompt γ-ray emissions at the target position. Furthermore, these γ emissions can be correlated with recoil detection in the focal plane of RITU. This setup provides direct insight into the reaction mechanisms, allowing the study of nuclear structure, reaction kinematics and the determination of differential cross sections.

In this contribution, I will present studies of the reaction ^{64}Ni + ^{238}U, performed at energies near the Coulomb barrier. By employing several correlation methods, we identified both quasifission and MNT products. Quasifission fragments were characterized using recoil-gated $\alpha-\alpha$ correlations, while $\gamma-\gamma-\gamma$ analysis enabled the detection of target-like nuclei. Additionally, for the first time, the lifetimes of isomeric states of MNT products, which are close to the mass and charge of the uranium target, were measured using conversion electron-γ correlations.

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15:00–15:20

Sub barrier transfer reactions and search for signatures of a nuclear Josephson effect with PRISMA+AGATA: the 60Ni+116Sn system

Speaker

Dr Lorenzo Corradi (INFN Laboratori Nazionali di Legnaro)

Description

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1 Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali di Legnaro, Legnaro (PD), Italy
2 Dipartimento di Fisica, Universitá di Padova, Italy
3 Ruder Bošković Institute, Croatia
4 Istituto Nazionale di Fisica Nucleare, Padova, Italy
5 Dipartimento di Fisica e Scienze della Terra, Universitá di Ferrara, Italy
6 Istituto Nazionale di Fisica Nucleare, Milano, Italy
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8 Istituto Nazionale di Fisica Nucleare, Firenze, Italy
9 Universidade de Santiago de Compostela, Spain

A series of sub-barrier transfer experiments have been recently carried out at LNL, with reaction products detected in inverse kinematic and at forward angles with the large solid angle magnetic spectrometer PRISMA. We measured transfer cross sections far below the Coulomb barrier, making excitation functions down to very low bombarding energies [1-5]. For the (well Q-value matched) one and two neutron transfer channels in the system 60Ni+ 116Sn the microscopic calculations very well reproduce the experimental data in the whole energy range [1-2]. Proton transfer channels have been also analyzed [3], showing the presence of strong proton-proton correlations. These kind of studies, where we followed the behaviour of the transfer probabilities by varying the internuclear distance, turned out to be fundamental to probe nucleon-nucleon correlation effects. In this context, the coupling of the AGATA gamma array to PRISMA offered a unique opportunity to study a nuclear (alternating current (AC)) Josephson-like effect [6], with Cooper-pair tunnelling between superfluid nuclei, whose manifestation has been recently proposed [7] using the data of Refs. [1,2] as a stepping stone. Predictions have been made of a specific gamma strength function associated with the dipole oscillations generated by the, mainly successive, two neutron transfer process. In a very recent experiment carried out at LNL with PRISMA+AGATA we directly tested for the first time the possible manifestation of this important effect of Cooper pair behaviour, observed to date only in condensed matter physics. After a general overview on the subject, the talk will focus on new results, addressing the new achievements and the critical issues

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15:20–15:40

Generalised Pandya relations for the neutron-proton interaction

Speaker

Piet Van Isacker (GANIL)

Description

The Pandya relation connects the interaction between two particles (or two holes) with the interaction between a particle and a hole [1], and follows from the action of the particle-hole conjugation operator in the context of the shell model [2]. The relation has been used extensively to correlate spectra of pairs of nuclei, for example 40K and 38Cl [3]. Many other examples are known [4,5].

Another useful symmetry of the shell model is seniority, which refers to the number of nucleons that are not in pairs coupled to angular momentum zero [6]. In semi-magic nuclei seniority is an approximate symmetry of the eigenstates of the nuclear Hamiltonian but, more generally, it is a quantum number that can be used to label basis states.

In this talk it is shown that generic expressions of the neutron-proton interaction in a seniority basis reveal a connection with particle-hole conjugation, leading to generalised Pandya relations in terms of 3nj symbols of angular-momentum recoupling coefficients. Examples of its application in nuclei are presented.

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15:40–16:00

Measurements of the reaction cross sections of neutron-rich Sn isotopes at the R^{3}B setup

Speaker

Eleonora Kudaibergenova (TU Darmstadt, Germany)

Description

The nuclear equation of state (EoS) plays a key role in many different aspects of modern physics, being fundamental for understanding the structure of nuclear matter, the properties of neutron stars, and the synthesis of heavy elements. While the properties of proton-neutron symmetric matter are relatively well known, the study of asymmetric matter via properties of neutron-rich nuclei became a main frontier of investigation. The asymmetry part of the nuclear EoS is characterized by the symmetry energy at saturation density J and its slope L, with L remaining poorly constrained experimentally. It has been identified that a precise determination of the neutron-removal cross section of neutron-rich nuclei, which is directly related to the neutron skin, would provide a possible constraint on L, with an uncertainty of ΔL $\approx$ 10 MeV.

Such studies can be performed at the R^{3}B (Reactions with Relativistic Radioactive Beams) setup, which allows for the kinematically complete measurements of reactions with high resolution, efficiency, and acceptance. The experiment was conducted in the GSI facility as a part of the FAIR Phase-0 program. The reactions are studied in inverse kinematics with neutron-rich tin isotopes in the mass range A=124-134 on carbon targets of different thicknesses. The reaction products have been measured at beam energies of 400-900 AMeV. A main goal of the experiment is to constrain the L parameter from the accurate measurement of the neutron-removal cross section by comparison to density functional theory.

In addition to the neutron-removal cross section, the experiment also provides valuable data on other reaction cross sections, offering a broader picture of the nuclear reaction mechanisms. In particular, the total interaction and charge-changing cross sections are important for the test of the reaction theory based on Glauber model. This communication presents the motivation for the study, the current analysis results, and findings from the comparison with theoretical predictions.

This project was supported by the BMBF project No. 05P21RDFN2, Helmholtz Forschungsakademie Hessen für FAIR (HFHF), and the GSI-TU Darmstadt cooperation.

16:00–16:20

Seniority scheme for j=9/2 orbitals

Speaker

Zsolt Podolyak (University of Surrey)

Description

The seniority scheme assumes that the low lying states in a nucleus can be described considering one single orbital, and there is no seniority mixing. The aim of the present paper is to test the validity of this, by focusing on the reduced B(E2) transition strengths, considered to provide more stringent test of the wave function than the excitation energies.

The largest amount of experimental data on seniority is related to j=9/2 orbitals. The proton g9/2 orbital between the Z=40 sub-shell and the Z=50 shell closures is isolated from other orbitals, therefore the N=50 nuclei with Z=42-48 provide a stringent test of seniority. Similarly, the proton h9/2 orbital is the first one above the Z=82 magic number, while the neutron g9/2 is first above N=126, making the N=126 isotones and the neutron-rich Z=82 Pb isotopes good test cases.

All available data, both on even- and odd-mass nuclei, were considered. The seniority scheme provides a good approximation for all these three regions, with the best fit given by the lead isotopes. In addition, shell model calculations using well established interactions were performed. In the N=50 and Z=82 considering all orbitals within a shell provide only a limited improvement in reproducing the data when compared to the seniority scheme. In contrast, the shell model provides much better agreement for N=126 nuclei, where the proton f7/2 orbital has increasing effect on the transition strengths as the j=9/2 orbital is filled. In order to further test whether the lead isotopes provide the best example of the seniority scheme, and investigate the possible effect of the neutron i11/2 orbital, more experimental information is required, especially for 214,215,216Pb.

16:20–16:40

Theory Predictions of Exotic Nuclear Symmetries and Spontaneous Symmetry Breaking: Identification Methods

Speaker

Irene Dedes (IFJ PAN)

Description

Over the past few years, there has been an increasing interest in exotic nuclear shapes and accompanying symmetries in low energy subatomic physics, both from theory and experimental points of view. We are going to address theoretical calculations employing realistic nuclear structure Hamiltonians to provide trustworthy predictions of the still unknown quantum mechanisms; new concepts are also needed to construct experimental identifications of the predicted effects.

We wish to present new developments in this field resulting from large scale calculations with a realistic *phenomenological mean-field Hamiltonian* based on the so-called universal, deformed *Woods-Saxon potential* - combined with powerful mathematical tools, such as *Inverse Problem Theory* and *Group-, and Group Representation Theories*, which allowed for model parameter and predictive power stabilisation.
Using this approach we were able to provide theory contributions to new experimental proposals related to high-rank symmetries predicted to be present along the whole Nuclear Chart as well as exotic isomer phenomena.

We focussed on Tetrahedral T_d and Octahedral O_h symmetries. They are known to cause vanishing of collective $B(E1)$ and $B(E2)$ transition probabilities at the exact symmetry limits, what produces specific difficulties in feeding of the tetrahedral symmetry states and their decay, Ref.[1]. These properties make the experimental detection of such bands extremely challenging, but at the same time induce the presence of exotic isomeric states which may generally facilitate studies of exotic nuclei. We formulate new methods of identification of these exotic states with the help of rotational bands with the structures never seen before. For example, T_d band sequence is built out of the states mixing parities and odd and even spins $$ A_1 \leftrightarrow I^{\pi}: 0^+, 3^-, 4^+, 6^+, 6^-, 7^-, 8^+, 9^+, 9^-, 10^+, 10^-, ... $$ Following a recent discovery of the simultaneous presence and competition of the *octahedral and tetrahedral symmetries* in ^{152}Sm, Ref.[2], we discuss the newly obtained results, including the world-first identification of a second T_d band in the same nucleus. The new results allow for the interpretation of the obtained spectra in terms of the "spontaneous symmetry breaking", an exotic mechanisms never seen before, cf. Ref.[3].

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16:50

14:20 **Thursday 25 September** 14:20–16:50

Nuclear Structure, Spectroscopy and Dynamics: 14

Session | **Location:** MoHo, Inspire 3, 16 bis Quai Amiral Hamelin, 14000 Caen | **Convener:** Dr Jonathan Wilson (IJC Lab, Orsay, France)

14:20–14:45 Physics of nuclear threshold effects

Speaker

Prof. Marek Ploszajczak (GANIL)

Description

Loosely bound nuclei are currently the focus of interest in low-energy nuclear physics. The deeper understanding of their properties, provided by the open-shell model for quantum systems, changes the understanding of many phenomena and opens new horizons for spectroscopic studies of nuclei from the drop lines to the β-stability valley, as well as for states near and above the particle emission threshold [1,2]. Systematic studies in this broad region of masses and excitation energies will extend and complete our knowledge of atomic nuclei at the edge of stability.

In this lecture I will discuss recent progress in the description of nuclear states using the shell model for open quantum systems. In particular, I will present selected most important generic properties of open quantum systems in examples of (i) the near-threshold collectivity and clustering, (ii) chameleon features of the resonances, (iii) the low-energy reactions of astrophysical importance, (iv) the modification of electromagnetic transitions by the coupling to decay channels, (v) the change of effective NN interactions and shell occupancy in weakly bound/unbound states, (vi) the exceptional point singularities in the scattering continuum and their consequences in the nuclear spectroscopy and reactions. Based on these examples, I will argue that the near-threshold nuclear states constitute a new quantum regime of the atomic nucleus with unique, universal properties.

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14:45–15:05 Evolution of the pygmy dipole resonance in the Sn mass region studied with the Oslo method

Speaker

Maria Markova (University of Oslo)

Description

The pygmy dipole resonance (PDR) is commonly associated with an excess $E1$ strength on top of the low-energy tail of the giant dipole resonance (GDR) close to the neutron-separation energy in stable and unstable heavy nuclei. While its detailed structure, properties, and origin remain a matter of ongoing debates and research, the neutron-skin oscillation picture of this feature still prevails and suggests some dependence of the PDR strength on neutron excess. This might have further consequences for neutron-capture rates relevant for heavy-element nucleosynthesis [1], making a systematic investigation of the PDR and the low-lying $E1$ strength in general in different isotopic chains particularly interesting from the nuclear structure and astrophysical perspectives.

This work presents the most recent update on a consistent systematic study of the low-lying electric dipole strength and the potential PDR in stable and unstable Pd, Cd, In, Sn, and Sb isotopes with the Oslo method [2]. The analysis focuses on dipole γ-ray strength functions (GSF) below the neutron threshold extracted from particle-γ coincidence data from light-ion induced reactions studied at the Oslo Cyclotron Laboratory (OCL). The most recent ($p,p^{\prime}\gamma$) and ($\alpha,p\gamma$) experiments have been performed with a new array of 30 LaBr3(Ce) scintillator detectors (OSCAR) with an improved energy resolution and timing properties for the selection of particle-γ events as compared to the earlier experiments done with the NaI(Tl) detector array CACTUS. All previously published GSFs of the $^{105, 106, 111, 112}$Cd [3] and $^{105-108}$Pd [4] isotopes have been re-analysed to provide a more consistent analysis of the strengths in the Sn mass region.

With a wide span of isotopes (from unstable, neutron-deficient ^{109}In to unstable, neutron-rich ^{127}Sb), these dipole strengths provide an excellent case for investigation of the PDR evolution with increasing proton-neutron asymmetry, comparing it with different theoretical approaches, and revealing a possible impact of this feature on the astrophysical radiative neutron-capture processes. Combining these data with available (γ,n) cross sections and the $E1$ and $M1$ strengths from relativistic Coulomb excitation experiments allows us to extract the low-lying $E1$ component from the total dipole strength in each case. It was found to exhaust $\approx 1-3\%$ of the classical Thomas-Reiche-Kuhn (TRK) sum rule, being nearly constant throughout the whole chain of Sn isotopes and weakly increasing with neutron number in Cd and Pd isotopes. This finding is in contradiction with the majority of theoretical approaches, such as, e.g., relativistic quasi-particle random-phase and time-blocking approximations, predicting a strong, steady increase in the low-lying $E1$ strength with neutron number. Moreover, a presumably isovector component of the PDR was extracted for $^{118-122,124}$Sn. The most neutron-deficient case of ^{109}In studied recently at the OCL, on the contrary, exhibits little to no excess $E1$ strength below the neutron threshold, thus standing out among the neighboring Cd and Sn isotopes.

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15:05–15:30 Isolde Tape Station and future at SPES

Speaker

giovanna benzoni (INFN)

Description

In this contribution recent results obtained at the ISOLDE DECAY STATION (IDS) are discussed, together with an insight on future perspectives.
In addition, the new physics opportunities opening up at the upcoming SPES ISOL facility at LNL (Italy) will also be presented, underlying the complementarity of the two facilities.

15:30–15:50

High resolution studies of multinucleon transfer reactions in the 206Pb+118Sn system from above to below the Coulomb barrier

Speaker

Suzana Szilner (Ruder Boskovic Institute, Zagreb, Croatia)

Description

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8University of Zagreb, Croatia
9Argonne National Laboratory, USA

Multinucleon transfer reactions (MNT) are presently at the focus of intensive investigations in both reaction mechanism and gamma spectroscopy [1-4]. MNT are in fact recognized as a very promising tool for the production of neutron rich heavy nuclei, especially in the N=126 region, relevant for astrophysics. At the same time via MNT one can probe nucleon-nucleon correlations, which are predicted to strongly affect the properties of nuclei with extreme N/Z ratios. In this context we performed a very detailed study of MNT processes in the 206Pb+118Sn system by measuring differential and total cross sections, and Q-value distribution for a variety of neutron and proton pick-up and stripping channels from above [1] to below [2] the Coulomb barrier. The above barrier energy region is connected with the evolution from quasi-elastic to deep inelastic channels, while the lower energy region with the effects of correlations, pairing in particular [5-7]. Data have been obtained making use of the highest capability of the magnetic spectrometer PRISMA [4], whose efficiency and resolution allowed to distinguish mass and nuclear charge for a variety of transfer products, with extracted cross sections spanning a range of two orders of magnitudes. The comparison of data with calculations showed important effects of secondary processes [1,8] at high energy and of pair degrees of freedom at low energy.
A presentation of these experiments will address the most relevant results, also in connection with the new possibilites offered by the availabilty of exotic beams.

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15:50–16:10

Towards the synthesis of new heavy nuclei: multi-nucleon transfer reactions with 136Xe + 238U

Speaker

Jonathan Bequet (CEA/Irfu/DPhN)

Description

Most of the heaviest nuclei synthesized in recent decades have been obtained using fusion-evaporation reactions. Due to neutron evaporation and the limited choice of beam-target combinations, this mechanism tends to produce mainly neutron-deficient nuclei. In addition, the cross-sections are often small, e.g. 0.5 pb at most for the discovery of 294Og [1]. Multi-Nucleon Transfer (MNT) reactions are therefore expected to be a complementary mechanism to fusion-evaporation. Indeed, according to the theory [2], this mechanism is well suited to produce neutron-rich heavy ions with relatively high cross sections at forward angles of the order of µbarns.
An experiment was carried out at Argonne National Laboratory in 2023 using a 136Xe beam on a 238U target with detection of the reaction products at forward angles. The setup consisted of the Gammasphere germanium array to perform prompt γ spectroscopy, the AGFA gas-filled separator (with He gas at 4 Torr) to separate the MNT products. A decay station for decay spectroscopy studies was installed at the focal plane, consisting of a DSSD, a PPAC and silicon detectors in a tunnel configuration surrounded by four Clover germanium detectors.
Few-nucleon transfer channels were successfully identified and their production cross-sections measured. The results of this analysis and their interpretation will be presented in this talk.

16:10–16:30

Update of the summation calculations for reactor antineutrino spectra

Speaker

Magali Estienne

Description

Abstract: The accurate determination of reactor antineutrino spectra remains a very actual research topic for which interrogations have emerged in the past decade. Indeed, after the "reactor anomaly" (RAA) [1] – a deficit of measured antineutrinos at short baseline reactor experiments with respect to spectral predictions – the three international reactor neutrino experiments Double Chooz, Daya Bay and Reno have evidenced spectral distortions in their measurements w.r.t the same spectral predictions (Shape Anomaly)[2]. This puzzle is called the "shape anomaly". The latter predictions were obtained through the conversion of integral beta energy spectra obtained at the ILL research reactor [3]. Several studies have shown that the underlying nuclear physics required for the conversion of these spectra into antineutrino spectra is not totally under control [4]. The unique alternative to converted spectra is a complementary approach consisting in determining the antineutrino spectrum through nuclear data [5,6]. In the past years, the reactor neutrino experiments such as Prospect [7], STEREO [8] and Daya Bay [9] have published in 2023 their analysis with the complete statistics of the measured data. The outcome of these analyses, combined with the work carried out in experimental nuclear physics with the TAGS measurements in particular [10, 11, 12], is that the sterile neutrino hypothesis is strongly disfavored to explain the RAA, but that further efforts remain to be made both theoretically and experimentally to fully understand the origin of RAA and shape anomaly, and that accurate predictions of antineutrino fluxes and spectra are still needed for future discoveries. Indeed the Daya Bay collaboration provided the first measurement of the high energy part of the reactor antineutrino spectrum above 8 MeV. In addition, the Juno-Tao [13] experiment will perform a measurement of reactor antineutrino spectra with unprecedented energy resolution that will allow to tackle the contribution of specific fission products and constrain potentially nuclear data with the measured antineutrinos. The summation method based on the nuclear data will be the privileged tool to interpret these measurements. At this conference, we propose to present an update of our summation calculations with a focus on the impact of the most recent TAGS results and in the context of the afore mentioned reactor neutrino experiments.

[1] G. Mention et al. , Phys. Rev. D 83 , 073006 (2011)
[2] Double Chooz and Reno Collaborations in Proceedings of the Neutrino 2014 Conference, http://neutrino2014.bu.edu/; Daya Bay Collaboration in Proceedings of the ICHEP 2014 Conference, http://ichep2014.es/.
[3] P. Huber, Phys. Rev. C 84, 024617 (2011).
[4] A. C. Hayes et al., Phys. Rev. Lett. 112, 202501 (2014).
[5] M. Fallot et al., Phys. Rev. Lett. 109 , 202504 (2012).
[6] A A. Sonzogni et al. , Phys. Rev. C 91 , 011301 (R) (2015).
[7] M. Andriamirado et al., Prospect Collab. PHYSICAL REVIEW LETTERS 131, 021802 (2023)
[8] F.P. An et al. Daya Bay collab., Phys. Rev. Lett. 130 (2023) 211801 and F.P. An et al. Daya Bay collab., Phys. Rev. Lett. 129 (2022) 041801).
[9] H. Almazan et al., STEREO collab. Nature 613, 257–261 (2023). https://doi.org/10.1038/s41586-022-05568-2.
[10] M.Estienne et al. " Updated Summation Model: An Improved Agreement with the Daya Bay Antineutrino Fluxes". In: Physical Review Letters 123, 022502 (2019).
[11] A. Algora, B. Rubio, J.-L. Tain, M. Fallot, W. Gelletly Review Paper Eur. Phys. J. A 57, 85 (2021)
[12] Chao Zhang a, Xin Qian a, Muriel Fallot bProgress in Particle and Nuclear Physics Volume 136, March 2024, 104106
[13] A. Abusleme, et al., TAO Conceptual Design Report. arXiv:2005.08745.

16:30–16:50

Transfer and breakup reactions of neutron-rich carbon isotopes described within few-body models

Speaker

Pedro Punta (Universidad de Sevilla)

Description

The study of reactions involving weakly bound exotic nuclei is an active field due to advances in radioactive beam facilities. Many of these nuclei can be approximately described by a model consisting of an inert core and one or more valence nucleons. However to properly describe some of these nuclei within few-body models, additional effects must be considered, such as deformations and possible excitations of the core. This is the case of ^{17}C and ^{19}C, which can be approximately described as a deformed core and a weakly-bound neutron.

The carbon isotopes ^{17}C and ^{19}C are studied using the novel NAMD model resulting from the combination of the Nilsson and PAMD models from [Phys. Rev. C 108 (2023) 024613]. The prposed formalism follows the Nilsson model scheme but including microscopic information of the core based on Antisymmetrized Molecular Dynamics (AMD) calculations. Different methods are considered to study the effect of including Pauli blocking of forbidden states and pairing correlations. In our calculations, the continuum spectrum of unbound states of the nucleus is discretized using the transformed harmonic oscillator basis (THO) [Phys. Rev. C 80 (2009) 054605], which has been successfully applied to the analysis of breakup and transfer reactions [Phys. Rev. Lett. 109 (2012) 232502].

The bound states wavefunctions obtained for ^{17}C have been tested by applying them to the ^{16}C(d,p)^{17}C transfer reaction, using as reaction framework the Adiabatic Distorted Wave Approximation (ADWA). The results are consistent with the data from [Phys. Lett. B 811 (2020) 135939], significantly improving the agreement by including Pauli blocking effects. The same transfer reaction is studied also populating unbound states in the continuum of of ^{17}C. The unbound states of ^{17}C and ^{19}C are also studied in breakup reactions with protons. Our obtained wavefunctions are applied to XCDCC calculations [Phys. Rev. C 95 (2017) 044611] and the results are compared with the experimental data from [Phys. Lett. B 660 (2008) 320].

16:50

16:50

18:30

Thursday 25 September 16:50–18:30

Poster Session: 2 - with coffee (See Poster session 1 for the list of posters)

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

19:30

23:30

Thursday 25 September

19:30–23:30

Conference Dinner

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

Friday 26 September

09:00

Friday 26 September

09:00–11:00

Plenary Session: 10

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Herve Moutarde (CEA-IRFU-SPHN)

Description

Plenary Session

09:00–09:30 The FAIR/GSI facility - Status and future perspectives

Speaker

Prof. Thomas Nilsson (GSI/FAIR)

Description

FAIR (Facility for Antiproton and Ion Research) is an international accelerator facility under construction at the site of the GSI Helmholtzzentrum für Schwerionenforschung in Darmstadt.FAIR will deliver a wide range of intense primary and secondary beams at relativistic energies, including radioactive beams of all elements and, in a later stage, antiprotons.

The existing GSI accelerators will become part of the future FAIR facility and serve as the first acceleration stage while simultaneously permitting a cutting-edge scientific programme using the existing installations. Within the currently approved funding scope, the vision of FAIR2028 is being realised, where the new installations such as the SIS100 synchrotron and the Super-FRS fragment separator together with associated experimental caves and instrumentation is being combined with the existing GSI installations into a world-leading facility.

In the coming years, the strategic objectives of FAIR and GSI can be structured as:

- **Construction, installation and commissioning of FAIR**, starting operation of the new facilities in 2028.
- **GSI ready for FAIR:**
- Perform a world-class scientific FAIR Phase-0 program through early physics experiments with FAIR equipment at GSI combined with testing and commissioning of new accelerators and detector instrumentation while maintaining and extending the FAIR science community Upgrade of existing GSI facilities for the FAIR operation
- Build a modern campus with appropriate infrastructure for the employees and international users

An overview of the science made possible with the new and upgraded installations will be made, together with status update of the strategic objectives including recent scientific highlights.

09:30–10:00 Ab initio in nuclear theory: what, why, and how

Speaker

Andreas Ekström (Chalmers University of Technology)

Description

The ab initio method in nuclear theory can be interpreted as a systematically improvable approach for quantitatively describing nuclei using the finest resolution scale possible while maximizing its predictive capabilities. In this talk, I will highlight some recent developments in ab initio nuclear structure calculations, focusing on the use of Bayesian methods for uncertainty quantification. I will also discuss some of the challenges that we are facing.

10:00–10:30 A novel overall view of nuclear shapes, rotations and vibrations

Speaker

Takaharu Otsuka (Department of Physics, University of Tokyo)

Description

The ellipsoidal deformation of nuclear shapes has been one of the central questions of nuclear structure physics. Fully microscopic approaches with a wide range of possible relevant correlations have been naturally difficult. Just recently, such approaches became feasible by using the Monte Carlo Shell Model [1], particularly by its most advanced version Quasiparticle Vacuua Shell Model (QVSM). In parallel to such computational development, there have been some interesting progresses in the studies on the underlying mechanisms and/or the characteristics of collective bands. It will be shown [1] that the prevailing of triaxial shapes occurs for heavy deformed nuclei (i) due to the restoration of rotational symmetry and
(ii) due to particular components of nucleon-nucleon interaction, such as tensor force and hexadecapole part of the central force, between proton and neutron. The gamma (double gamma) band appears not as a vibrational excitation but as a K=2 (K=4) rotation. In fact, the K quantum number is shown to be practically conserved, providing us with a nice classification of collective bands with substantial triaxialities. Beside rotational excitations, vibrational modes are also described, within the quantum many-body framework, for both deformed and near-spherical cases. The former cases show various bands at higher energies, including some relatively low-lying beta bands in some nuclei. The near-spherical case exhibits vibrational excitations from weakly deformed (not spherical) ground states, with characteristic ratios of excitation energies and B(E2) values. However, the interpretation of the so-called two-phonon triplet is very different from the conventional picture. Thus, we present an overall new picture of nuclear quadrupole collectivity as a consequence of nucleon-nucleon interactions in the quantum many-body framework, which shows visible differences from conventional ones.

[1] T. Otsuka, Y. Tsunoda, N. Shimizu, Y. Utsuno, T. Abe, H. Ueno, Eur. Phys. J. A, 61,126 (2025); DOI: 10.1140/epja/s10050-025-01553-1

10:30–11:00

From Nuclear Physics to Isotope Geochemistry: Identifying Anthropogenic Contamination Sources in the Environment

Speaker

Dr Alkiviadis GOURGIOTIS (Autorité de sûreté nucléaire et de radioprotection (ASNR) - PSE/ENV/SPDR/LT2S, F-92260, Fontenay-aux-Roses, France.)

Description

Human activities—whether nuclear (civilian and military) or industrial processes involving naturally radioactive materials (oil and gas production, phosphate mining, and rare earth extraction)—have released and redistributed radionuclides across environmental compartments. This contamination could threaten ecosystems and human health, with risks driven by the persistence, concentration, and geochemical behavior of these radioactive elements and the sensitivity or organisms. Contamination sources can mix, overlap with legacy contamination, or be masked by naturally occurring elements (e.g., ^{238}U). Effective management and remediation of contaminated soils and sites require, first and foremost, a precise identification of these sources.
Isotope geochemistry, at the intersection of geology, chemistry, and nuclear physics, provides relevant methodologies and tools for identifying sources of environmental contamination. By exploring isotopic and elemental "fingerprints," scientists can trace contamination origins and track their evolution across time and space.
This presentation explores the crucial role of nuclear physics—such as nuclear reactions, isotope production, and decay processes—in isotope geochemistry, helping geochemists interpret isotopic signatures associated with various contamination sources. Nuclear physics is essential for characterizing elemental and isotopic endmembers—such as using reactor physics calculations to estimate fuel burn-up and the resulting isotope/elemental ratios. It also plays a key role in developing high-precision experimental methods for isotope analysis, including advanced mass spectrometry techniques (e.g., ICP-MS, TIMS, AMS) and radiation detection methods (e.g., gamma spectroscopy, alpha spectrometry).
Several examples of contamination sources will be discussed, including uranium mining and milling processes, nuclear power plant accidents/incidents, global fallout, and reprocessing facilities. Emphasis will be placed on understanding the geochemical behavior of these tracers, offering valuable insights for tracking radioactive contamination.

11:00

11:00

11:20

Friday 26 September

11:00–11:20

Coffee Break

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN

11:20

Friday 26 September

11:20–11:50

Plenary Session: 11

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Alessandra Fantoni (INFN Laboratori Nazionali di Frascati)

Description

Plenary Session

11:20–11:50 **The Sun as a cornerstone for (stellar) foundation science**

Speaker

Aldo Serenelli

Description

In this talk, I will review the unique place the Sun has as a fundamental laboratory for astrophysics and related fields. I will put the emphasis on current open questions and, in relation to them, on the need for accurate measurements of key nuclear reaction cross sections.

11:50

11:50 **Friday 26 September** 11:50–13:25

EPS Lise Meitner and Best Phd Prize presentations

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Convener:** Alessandra Fantoni (INFN Laboratori Nazionali di Frascati)

11:50–12:15 Isoscalar electric giant resonances: Compression modes and nuclear incompressibility

Speaker

Prof. Muhsin Harakeh (University of Groningen, Groningen, the Netherlands)

Description

A rich spectrum of giant resonances of different multipolarities and spin and isospin structure was expected on theoretical grounds. In the nineteen seventies, the isoscalar giant quadrupole resonance (ISGQR) was discovered in electron scattering followed by the isoscalar giant monopole resonance (ISGMR) in inelastic α scattering. In the last five decades, the compression modes the ISGMR and isoscalar giant dipole resonance (ISGDR) were extensively studied because of their importance for the determination of the nuclear-matter incompressibility and consequently their implications for the equation of state (EOS) of nuclear matter. Though the nuclear matter incompressibility (K_∞) has been reasonably well determined (~ 240 $\pm$ 20 MeV) through comparison of experimental results on several spherical nuclei with microscopic calculations, the asymmetry term was determined with larger uncertainty. This has been addressed in measurements on a series of stable Sn and Cd isotopes, which resulted in a value of K_τ = - 550 $\pm$ 100 MeV for the asymmetry term in the nuclear incompressibility. The nuclear matter incompressibility and the asymmetry term are key parameters of the equation of state (EOS) of nuclear matter.

12:15–12:40 The Scissors Mode: A Building Block of Low-Energy Nuclear Structure

Speaker

Peter von Neumann-Cosel (Institut für Kernphysik, TU Darmstadt)

Description

The magnetic dipole scissors mode and its implications for the low-energy structure of heavy nuclei are discussed. Salient features like its orbital nature, the correlation of the strength with ground-state deformation, the collectivity and a systematic description within a sum-rule approach are reviewed [1]. The scissors mode is also observed in the quasicontinuum and may be related to the phenomenon of an enhancement of the γ strength function at very low energies [2,3]. Finally, the implications of a recent conjecture that the ground states of all heavy deformed nuclei show some degree of triaxiality [4] on the understanding of the scissors mode are investigated.

[1] K. Heyde, P. von Neumann-Cosel and A. Richter, Rev. Mod. Phys. 82, 2365 (2010).
[2] M. Guttormsen et al., Phys. Rev. C 106, 034314 (2022).
[3] F.-Q. Chen et al., Phys. Rev. Lett. 134, 082502 (2025).
[4] T. Otsuka et al., Eur. Phys. J. A 61, 126 (2025).

12:40–12:55 Search for 22Na in novae supported by a novel method for measuring femtosecond nuclear lifetimes.

Speaker

Chloe Fougeres (CEA/DIF)

Description

Simulations of explosive nucleosynthesis in novae predict the production of the radioisotope 22Na. Its half-life of 2.6 yr makes it a very interesting astronomical observable by allowing space and time correlations with the astrophysical object. Its γ-ray line at 1.275 MeV has not been observed yet by γ-ray space observatories. This radioisotope should bring constraints on nova models and help to explain abnormal 22Ne abundance observed in presolar grains. At peak nova temperatures, the main destruction reaction 22Na(p, γ)23Mg is dominated by a resonance at 0.204 MeV associated to the Ex=7.785 MeV excited state in 23Mg. However, the different determinations of the resonance strength disagree, resulting in uncertainties of one order of magnitude for the expected mass of 22Na ejected in novae.
An experiment was performed at GANIL facility to measure both the lifetime and the proton branching ratio of the Ex=7.785 MeV state. The reaction 3He(24Mg,α)23Mg* was measured with particle detectors, magnetic spectrometer VAMOS++ and silicon detector SPIDER, and γ-ray tracking spectrometer AGATA. Lifetimes in 23Mg, down to the femtosecond, were measured with a new approach and protons emitted from unbound states were identified. With a reevaluated thermonuclear rate of 22Na(p, γ)23Mg, stellar modelling was performed. Robust estimates of the detectability limit of 22Na in novae were found promising for the detection the 1.275 MeV γ-ray line over the coming decades.

12:55–13:10 Theory of nuclear matter: ab initio developments and connections to the nuclear energy functional

Speaker

Francesco Marino (Institut für Kernphysik, Johannes Gutenberg Universität, Mainz, Germany)

Description

Infinite nuclear matter lies at the crossroads of nuclear physics investigations, as it connects the microscale of nuclei and the macroscale of compact celestial bodies. On the one hand, nuclear matter properties can be partially constrained by finite nuclei observables and astrophysical observations. On the other hand, nuclear matter can guide the development of both ab initio nuclear interactions and energy density functional (EDF) models for studying finite nuclei.
In this contribution, I will report results obtained with a newly developed ab initio Green's functions method, which provides an accurate picture of the nuclear matter equation of state and single-particle properties. Then, I will discuss the first steps and the prospects of a strategy that aims at improving the EDF approach by grounding it on the nuclear matter predictions.

13:10–13:25

Observation of the radiative decay of the low energy thorium-229 isomer: En route towards a nuclear clock

Speaker

Mr Sandro Kraemer (Instituut voor Kern- en Stralingsfysica, KU Leuven)

Description

The radioisotope thorium-229 features a nuclear isomer with an exceptionally low excitation energy of ≈ 8.4 eV and a favorable coupling to the environment, making it a candidate for a next generation of optical clocks allowing to study fundamental physics such as the variation of the fine structure constant [1,2].
While first indirect experimental evidence for the existence of such a nuclear state dates from almost 50 years ago, the proof of existence has been delivered only recently by observing the isomer's internal electron conversion decay [3]. This discovery triggered a series of successful measurements using the α-decay of uranium-233 of several properties, including its energy, an important input parameter for the development of laser excitation of the nucleus. In spite of recent progress, the difficulties to observe the isomer's radiative decay remained a dark spot of this research field. The development towards a "nuclear clock" was further hindered by a too large uncertainty on the isomer energy.
The study of the β-decay of actinium-229 inside a large-bandgap crystal at the ISOLDE facility at CERN lead to the first observation of the radiative decay [4] and set the scene for direct laser excitation of the thorium-229 nucleus [5].
In this contribution, the nuclear clock concept is introduced and results from vacuum-ultraviolet spectroscopy studies are discussed.

[1] E. Peik et al., Europhys. Lett. 61, 2 (2003).
[2] E. Peik et al. Quantum Sci. Technol. 6 (3), 034002 (2021).
[3] L. von der Wense et al. Nature 533 (7601), 47–51 (2016).
[4] S. Kraemer et al. Nature 617, 706-710 (2023).
[5] J. Tiedau et al. Phys.Rev.Lett. 132 182501 (2024).

13:25

13:25

Friday 26 September

13:25–13:50

Best Poster Prizes and Closure

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN | **Conveners:**
Eberhard Widmann (Stefan Meyer Institute Vienna), Marek Lewitowicz (GANIL), Alessandra Fantoni (INFN Laboratori Nazionali di Frascati)

13:50

13:50

14:50

Friday 26 September

13:50–14:50

Lunch

Session | **Location:** Moho, 16 bis Quai Hamelin 14000 CAEN