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JRC TECHNICAL REPORT

JRC-CEA collaboration agreement on cooperation in the field of research and development in Nuclear Safety

Final Report - Period 2016-2021

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Abstract

This report presents the achievements accomplished in the framework of the collaboration agreement on cooperation in the field of research and development in Nuclear Safety signed between the JRC and the CEA in 2016 for a period of 5 years (2016-2021). Out of the 23 projects approved, 11 projects have been completed, 10 are still ongoing and 2 were not able to start.

Projects were defined in project sheets and each project was assigned a lead researcher from both institutes. The umbrella of the collaboration agreement made it easy for scientists to visit the other institute and use the available facilities.

In addition, this report also highlights the extensive collaboration between the two parties beyond this collaboration agreement, in particular: in H2020 and Euratom indirect actions, through the Open access programme and collaborative work, the collaboration agreement on Security Research, the Jules Horowitz Reactor and in other multilateral frameworks.

Based on the success of this collaboration agreement, and the extent to which both parties collaborate in other frameworks, measurable in the amount of scientific publications and in an increased awareness among the scientists of both institutes of available know-how and infrastructure, JRC and CEA management decided to renew this collaboration for 5 more years. New projects are already in the process of being defined for the next period.

1 Introduction

1.1 Descriptions of the parties

Major player in Research, Development and Innovation, the **CEA** intervenes in 6 prominent fields: Defence and National Security, Nuclear and Renewable Energies, Biotechnological and Medical Research, Technological Research for Industry, Fundamental Research (Material and Life Sciences) and Decommissioning / Dismantling of nuclear facilities. The CEA relies on 4 Operational Directorates, supported by Functional Directorates, whose activities are deployed on 9 locations in France, to carry out the missions entrusted by Public Authorities (PAs):

- Defence and Security: Respond to the challenges of nuclear deterrence; bring technical support to PAs in the fight against terrorism, tsunami warning and support for conventional defence.
- Energies (Nuclear and Renewable): The CEA is at the forefront of the implementation of the energy transition, necessary to fight against global warming. In this perspective, CEA conducts research on the means of producing energy (nuclear, renewable) as well as on energy efficiency and performance.
- Digital Transition: Over time, the CEA has acquired cutting-edge skills in electronics and digital technology. CEA has a unique ability to design, build and manage innovative technological platforms, for the benefit of the scientific and industrial community.
- Technology for the Medicine of the Future: The CEA has been involved since its creation in research in biology and health. Over the years, it has also become a central player in France for the design and integration of innovative technologies in the field of medicine of the future.
- Fundamental Research: In addition to its other missions, the CEA invests in fundamental research of excellence at the forefront of Science, at the origin of a very extensive knowledge and know-how.
- Decommissioning / Dismantling: With a general strategy validated by the safety authorities in 2019, the CEA is leading projects and R&D simultaneously for safer, technically and economically optimized operations (36 installations being dismantled, more than 1,000 employees mobilized and real expertise in the field).

As the science and knowledge service of the European Commission, the mission of the **Joint Research Centre (JRC)** is to support EU policies with independent evidence throughout the whole policy cycle. Through its Directorate for Nuclear Safety and Security located in Geel (Belgium), Ispra (Italy), Karlsruhe (Germany) and Petten (the Netherlands), the JRC conducts research in the fields of nuclear reactor and fuel safety; radioactive waste and spent fuel management, nuclear data for reactor and other applications; nuclear safeguards and security; emergency preparedness; radioprotection, dosimetry, decommissioning and nuclear science applications. JRC structures its collaboration with relevant nuclear research organisations in Member States under appropriate collaboration instruments, in order to ensure that JRC's research and training activities are aligned as appropriate with the national ones. Bringing scattered cooperation or joint projects under wider scope, more comprehensive frameworks allows for higher efficiency, easier follow-up, and appropriate visibility.

1.2 Objectives of the report

The JRC had long standing cooperation with the CEA in the field of nuclear energy since the creation of the JRC. The first collaboration agreement on cooperation in the field of research and development in Nuclear Safety, signed on 12 October 2016 by the Director General of the JRC, Vladimir Šucha, and the Administrator General of CEA, Daniel Verwaerde, constitutes a major step that provided a solid framework and more consistent structure to this cooperation.

After a 5-year implementation period and in line with the article 6.1[1] of the Collaboration Agreement, this report aims to take stock of the achievements and to consolidate cooperation on research in nuclear safety between the two entities.

[1] The Parties shall consult each other to establish together the following reports/presentations for each joint project undertaken under this Collaboration Agreement or the specific agreement. In the absence of agreement, therein each Party shall draw up separate reports.

- Presentations for Steering Committee Meetings on status of the project or of the collaborations
- Final Report: description of work and research carried out. The final report may be a scientific article.

1.3 Scope

This report addresses mainly direct cooperation in the framework of the collaboration agreement on Nuclear Safety (chapter 2), including projects and exchanges of staff.

Nonetheless, it also includes additional information about existing cooperation taking place in other areas and frameworks (chapter 3) with the aim to provide a global picture of the extensive collaboration between the two parties and to underline its strength.

In that sense, information will also be provided regarding:

— Projects with JRC and CEA presence in the framework of Indirect Actions – EU projects in Horizon 2020 and Euratom where both JRC and CEA are present covering multiple domains (3.1);

— Open Access to JRC research infrastructures and collaborative work (3.2);

— Collaboration agreement in the field of Security research (3.3);

— Cooperation in the frame of the Jules Horowitz Reactor (3.4);

— Other frameworks of cooperation (3.5).

2 Cooperation in the framework of the collaboration agreement on Nuclear Safety

This chapter aims to report on the achievements accomplished under this collaboration agreement during the period 2016-2021, particularly in what regards the 23 projects initiated. This is the main objective of this report as provided in article 6.1 of the agreement.

2.1 Main aspects of the collaboration agreement

As provided in article 1 of the agreement, the objective of the collaboration agreement is "to contribute more effectively to understanding and resolving scientific issues in the field of nuclear safety and to ensure that discoveries, inventions and creations generated under this collaboration agreement are utilized in ways most likely to benefit the public" (article 1.1).

In particular, it aims to "improve the coordination and effectiveness of cooperation efforts between the CEA and the JRC (article 1.2) in a wide range of topics:

- nuclear data
- conventional and advanced nuclear fuel safety
- nuclear fuel cycle safety
- nuclear materials
- LWR nuclear reactor safety
- safety of spent fuel and radioactive waste
- decommissioning
- emergency preparedness and response
- environmental monitoring
- radiation protection.

The following crosscutting topics are also covered by this agreement: modelling tools/computer codes, training and education, infrastructure, and standardization.

The research work is coordinated by a Steering Committee that shall meet once a year to "evaluate past activities, develop detailed plans for future co-operative projects, and discuss any matter concerning the implementation of this Collaboration Agreement" (article 4.1). During the period covered by this report, one steering committee took place on 12 April 2018 and was organised jointly with the steering committee dedicated to the collaboration agreement on Security Research.

2.2 Joint projects

During the reporting period, 23 projects were developed under this collaboration agreement between the JRC and the CEA in several domains. Almost half of the projects (11) deals with nuclear data, which appears as the most important topic of collaboration in the framework of this agreement. Out of the 23 projects approved, 11 projects have been completed, 10 are still ongoing and 2 were not able to start.

The methodology of implementation based on specific project descriptions with defined deliverables and time schedules using harmonised project sheets with reference to the scientific topics covered by the agreement has proven to be very effective.

This section provides a list of projects (Table1) with their relative topic and status at the end of the cooperation period. A brief summary of each project can be found in Annex 1.

In order to facilitate the identification of the different projects and for the sake of clarity in this report, the projects have been numbered a posteriori (P1, P2…). Such a numbering should be considered for future joint projects in order to facilitate coordination and reporting.

Table 1. List of approved project sheets for the period 2016 - 2021

Research Area Project	Status
Nuclear data	
P1- Development of an experimental set-up dedicated to the capture cross section measurements of fissile nuclides	Ongoing
P2- Delayed Neutron Data Measurements at JRC	Did not start
P3- Fission cross section measurement of 235U from thermal energy region to several keV	Ongoing
P4- INTEGRAAL, integral measurement at JRC	Ongoing
P5- Transmission measurements of the MINERVE samples at the time-of-flight facility GELINA	Closed
P6- Magnet system for alpha spectrometry	Closed
P8- Production of a molecular plating cell	Closed
P9- Fission fragment spectrometers	Ongoing
P10- FIFRELIN/VESPA – measurement of reference data as input to improve and/or validate the FIFRELIN code	Closed
P22- Provide training in low-level gamma-ray spectrometry	Closed
P23- Production and characterisation of 235,238U and Pu thin target layers	Ongoing
Emergency preparedness and response P7- Reference value determination for Proficiency Test of environmental monitoring laboratories in the EU	Closed
Conventional and Advanced Nuclear fuel Safety - current systems P11- Laser heating of irradiated fuels	Ongoing
P15- Thermodynamic data for severe accidents	Ongoing
P16- Assessment of Volatile Fission Product Behaviour via Simulated Fuels	Closed
P17- Creep and solid state diffusion in UO2 as a function of grain size	Closed
Conventional and Advanced Nuclear fuel Safety - innovative systems P12- B4C+MOX thermodynamic behaviour	Ongoing
P13 - Sodium+MOX thermodynamic behaviour	Closed
P14- Uranium-americium MABB	Closed
P21- Kinetics of Sodium-MOX interaction	Closed
Conventional and Advanced Nuclear fuel Safety : In-pile behaviour of the nuclear fuel or spent fuel regarding over-pressurization of rods or pins P19- A study of the Helium behavior in saturated-UO2+x and (U,Ce)O2 solid solutions	Ongoing
Nuclear materials P18- Irradiation behavior of B4C neutron-absorber material for ASTRID	Did not start
Safety of spent fuel and radioactive waste : HLW conditioning P20- Helium solubility in HLW model glass	Ongoing

2.3 Exchanges of staff

In view of the implementation of the projects mentioned above and in line with articles 2.2 and 2.3, this collaboration agreement enables exchanges of staff between the two parties. Exchanging of staff is highly beneficial to strengthen collaboration but also to contribute to capacity building and mobility in nuclear expertise and competences. To illustrate this component of the agreement, exchanges of staff that took place during this period are summarized in Table 2 for those hosted at JRC.

Table 2. Exchanges of staff (hosted at JRC)

CEA staff hosted at JRC Karlsruhe	6 PhD students 3 trainees
CEA staff hosted at JRC Geel	16 staff visiting JRC-Geel 3 PhD students

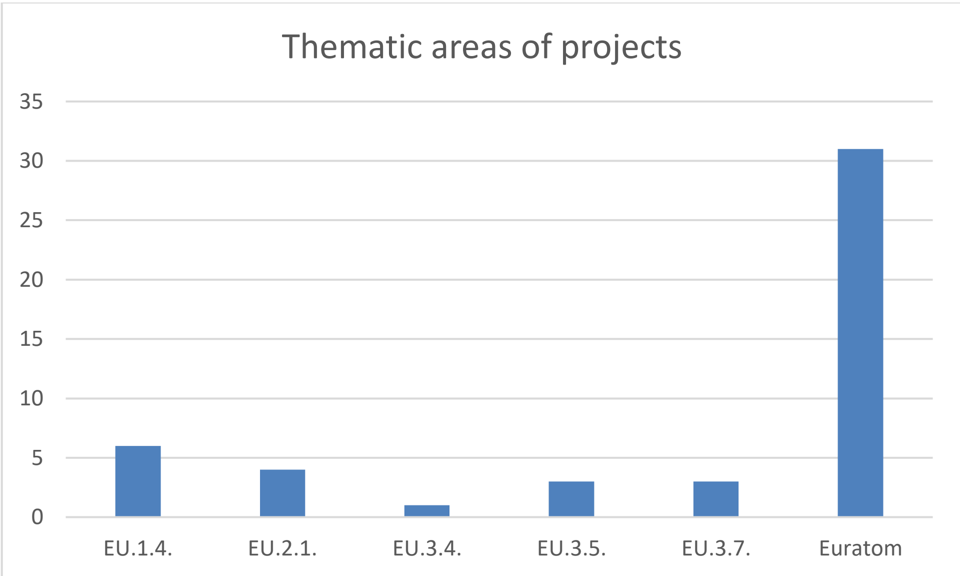
3 Cooperation in other frameworks

As explained in the introduction, it has been decided to extend the scope of this report to other frameworks of collaboration in order to give a more global outlook, underlining the extent of the existing collaboration between the JRC and the CEA. This chapter will therefore present collaborations in the framework of indirect actions (H2020 and Euratom), the Open Access to JRC infrastructures and collaborative work, the collaboration agreement on Security Research, the Jules Horowitz Reactor and other multilateral frameworks of cooperation such as SNETP.

3.1 Projects with JRC and CEA presence in the framework of Indirect Actions (H2020 and Euratom)

During the reporting period, 48 ongoing common projects involved JRC and CEA's teams in the frame of the H2020 and Euratom programmes. Among these projects, **31 projects** (two-thirds) took place in the Euratom programme, covering a wide range of subjects, what makes the CEA the main partner institution of the JRC in the framework of Euratom indirect actions.

Figure 1. Number of projects with JRC and CEA presence in the framework of Euratom indirect actions and H2020



Source: ECorda database, release 20210505

Their thematic breakdown is the following:

— Euratom: 31 projects
— Excellent Science (Pillar 1):
  - Infrastructures (EU 1.4): 6 projects
— Industrial Leadership (Pillar 2):
  - Leadership in enabling & industrial technologies (EU 2.1): 4 projects
— Societal Challenges (Pillar 3):
  - Smart, green & integrated transport (EU 3.4): 1 project
  - Climate action, environment, resource efficiency & raw materials (EU 3.5): 3 projects
  - Secure societies (EU 3.7): 3 projects

See Annexes 2 & 3 for more details.

3.2 Open Access to JRC research infrastructures and collaborative work

3.2.1 Open Access

The European Commission's Joint Research Centre (JRC) opens its scientific laboratories and facilities to people working in academia and research organisations, industry, small and medium enterprises (SMEs), and more in general to the public and private sector. Concerning more specifically its nuclear facilities, the JRC offers access to EU Member States and to countries associated to the Euratom Research Programme[2].

Among the JRC 56 research infrastructures, 39 can open access to external users in various fields of science (nuclear and radiological; chemistry; biosciences and life sciences; physic al sciences and ICT) on the different JRC sites in Ispra (Italy), Geel (Belgium), Karlsruhe (Germany) and Petten (The Netherlands)[3].

In particular, the JRC is opening access to the following groups of Nuclear Research Infrastructures:

- Actinide User Laboratory (ActUsLab, Karlsruhe- Germany)
- Laboratory of the Environmental & Mechanical Materials Assessment (EMMA, Petten - The Netherlands)
- European research infrastructure for nuclear reaction, radioactivity, radiation and technology studies in science and applications (EUFRAT, Geel- Belgium)

In the framework of this programme, CEA is one of the user institutions of the High-resolution neutron time-of-flight facility GELINA and the FMR (Fuels and material research) laboratories which provide the scientific basis for the objective assessment and modelling of the safety-related behaviour of nuclear materials.

3.2.2 Collaborative work

Besides the activities defined under the collaboration agreement through project sheets, other collaborative projects between the JRC and the CEA were carried out, in particular in the following areas:

- production of nuclear data
- development of innovative detectors and measurement techniques
- production and characterisation of reference materials

More details on these activities can be found in Annex 4.

3.3 Cooperation in the field of Security Research

A collaboration agreement in the field of Security research signed by the Director General of the JRC, Vladimir Šucha, and the Administrator General of CEA, François Jacq, entered into force on 1st July 2017 for a period of 5 years. The main topics covered by this agreement are the following:

- nuclear security
- chemical, biological and explosive detection
- critical infrastructure protection
- cybersecurity

[2] https://joint-research-centre.ec.europa.eu/knowledge-research/open-access-jrc-research-infrastructures_en

[3] Jenet, A ., B . Acosta-Iborra, L . Aldave de la Heras, Y . Aregbe, J . Barrero, K . Boboridis, S . Bremer-Hoffman, M . Bruchhausen, R . Caciuffo, E . Colineau, P . Colpo, R . Eloirdi, D . Gilliland, J . Heyse, M . Hult, M. Lamperti Tornaghi, T . Malkow, F .J . Molina, C . Nieuweling, K .-F . Nilsson, R . Novotny, S . Oberstedt, P . Pegon, M . Peroni, A . Pfrang, A. Plompen, A. Ruiz-Moreno, P. Schillebeeckx, S.-Z. Schmidtler, B. Sokull-Kluettgen,F. Taucer, G. Tsionis, K. Tuček and S . Vegro . ***Open access to JRC research infrastructures*** . Publications Office of the European Union, Luxembourg, 2021 . ISBN 978-92-76-34190-1, doi:10 .2760/562421, JRC123699

Two crosscutting topics are also covered:

- training and education
- other elements in connection with new challenges for security

Three common projects took place under the third pillar of H2020 in the area « Secure societies »:

Table 3. CEA-JRC common projects – H2020 – « Secure societies »

Title	Project's number	Short description
C-BORD	653323	effective Container inspection at BORDer control points
EuroBioTox	740189	European programme for the establishment of validated procedures for the detection and identification of biological toxins
ENTRANCE	883424	EfficieNT Risk-bAsed iNspection of freight Crossing bordErs without disrupting business

See Annex 5 for more details on each project.

3.4 Jules Horowitz Reactor (JHR)

The Jules Horowitz Reactor (JHR), a project conducted by the CEA Nuclear Energy Division, is a materials testing reactor currently under construction in France, which will be used for testing fuel and materials behaviour under irradiation, enhancing the safety of current and future nuclear reactors. The JHR will also produce radioisotopes for nuclear medicine and non-nuclear industrial applications.

Considering necessary to secure future research capabilities, the CEA and the JRC signed a contract in 2010, agreeing that JRC will get the reserved and secured access rights to 1 % of the JHR experimental capacity for its own use or contracts with third parties. The duration agreed is for the first 30 years of operation, with the possibility of extension under the conditions in the contract. Other conditions as price, payment modalities, IPR, mode of use, etc. are detailed in the contract.

Moreover, the Commission's DG RTD owns, in similar terms, 5% of such access rights to the reactor, to be used by the indirect actions of the Euratom research and training programmes. Therefore, Euratom programmes (both direct and indirect actions) owns 6% of access rights to the JHR reactor.

In addition, in 2020, the project JH OP 2040 was launched to develop an operation plan for the first 15 year of operation of the reactor. The project will develop a detailed irradiation plan for the first 4 years of operation, a research agenda for the following 11 years, as well as a governance and financial model for funding the experiments and a communication plan. The JRC participates in this action to ensure that it covers the full use of the Euratom access right while taking into account the JRC planned activities.

In the near future, other projects related to the JHR could also be potentially developed, and directly under the collaboration agreement on Nuclear Safety, in particular concerning experimental tools.

3.5 Other frameworks of cooperation such as SNETP, EERA, TTO Circle

JRC and CEA individually participate in a number of multilateral cooperation frameworks of different nature that include various and different stakeholders. In this context, both entities also work together and reinforce directly and/or indirectly their ties. This kind of collaboration can be illustrated by the following examples: SNETP, EERA, and TTO circle.

3.5.1 SNETP (Sustainable Nuclear Energy Technology Platform)

The SNETP was established in September 2007 as a R&D&I platform to support and promote the safe, reliable and efficient operation of Generation II, III and IV civil nuclear systems. The 108 international members include industrial actors, research and development organisations, academia, technical and safety organisations, SMEs as well as non-governmental bodies.

CEA and JRC are members and both contribute to the three pillars of SNETP: Nuclear Generation II&III Alliance (NUGENIA); European Sustainable Nuclear Industrial Initiative (ESNII); and Nuclear Cogeneration Industrial Initiative (NC2I).

In addition, this platform is considered as a privileged networking environment that contribute to the emergence of new common projects between the Parties.

3.5.2 EERA (European Energy Research Alliance): the particular case of the SUPEERA project

In the course of the SUPEERA project's implementation, more specifically of its task 1.1, SUPEERA Partners (including CEA as WP1 leader among five linked third parties) and SETIS have worked in close collaboration, in order to further the complementarity of their work, leading notably to an amendment of SUPEERA's grant agreement in 2021.

The SUPEERA project (SUPport to the coordination of national research and innovation programmes in areas of activities of the European Energy Research Alliance) is a European coordination and support action (CSA) project which was granted to the European Energy Research Alliance (EERA.aisbl) in 2020.

In particular, SUPEERA's first work package (WP1) aims at facilitating the execution of the SET-Plan Implementations plans, based on the monitoring of the progress and challenges related to each of them.

The first two deliverables of this work package task (D1.1, D1.2), approved by the European Commission in March and October 2021, strongly relied on the data made available by SETIS. Moreover, the amendment to the Grant Agreement and the subsequent revision of this specific task of SUPEERA proved to be beneficial to all parties involved in the monitoring and reporting process. It allowed SUPEERA to further its analysis of the state of play of the activities of the SET Plan, building upon SETIS' yearly assessment report in a more complementary way and therefore avoiding overlaps as well as to apply more methodological flexibility to reflect new priorities and targets originated from the European Green Deal, Next Generation EU, and other relevant EU policies and strategies and. Finally, it consented to deliver a very first attempt of the consolidated overview of the factors that by SIs are perceived as the obstacles for the execution of SET Plan IPs actions still lagging behind.

3.5.3 TTO Circle (European Technology Transfert Offices Circle)

In the frame of a study commissioned by the TTO Circle[4], regarding "State Aid Rules in Research, Development & Innovation", the CEA provided a legal expertise during the first semester 2019[5].

The European Association of Research and Technology Organisations (EARTO) endorsed this study through its Legal Working Group and published its response to the EC consultation in June 2021[6]. EARTO gathers 350 RTOs from 23 countries. CEA is a member of EARTO and its executive Board. The JRC contributes to its Working Groups. In the past years, representatives of both sides participated notably to the WG Legal Experts, chaired by CEA.

[4] The European Technology Transfer Offices circle is a network established with the aim to bring together the major public research organisations in order to share best practices, knowledge and expertise, perform joint activities and develop a common approach towards international standards for the professionalization of technology transfer.
[5] The report is accessible hereafter: https://publications.jrc.ec.europa.eu/repository/handle/JRC122304
[6] https://www.earto.eu/wp-content/uploads/EARTO-Report-on-State-Aid-on-RDI-The-Right-Way-Final.pdf

4 Publications

Since 2017, we identified 169 published articles covering all fields of collaboration (essentially nuclear related activities) in which both CEA and JRC researchers are involved. Apart of that, 41 documents such as book chapters, proceeding papers or meeting abstracts were found in international database, but not considered in our bibliometric analysis.

See Annex 6 for more details.

Table 4. Main areas of publications / number of publications

Area of publication	***Number of publications***
Chemistry, Multidisciplinary	39
Geosciences	8
Instruments & Instrumentation	8
Materials Science	17
Multidisciplinary Sciences	15
Nuclear Science & Technology	11
Physics, Multidisciplinary	27
Miscellaneous	44

Source: CEA IST (CEA Technical and Scientific Information)

5 Conclusions

This Final Report summarized the projects coordinated by CEA and JRC under the collaboration agreement No. 34351 on cooperation in the field of research and development in Nuclear Safety running from 2016 to 2021.

The majority of projects were defined in project sheets and each project was assigned a lead researcher from both institutes.

The umbrella of the collaboration agreement made easier for researchers from both institutes to reach out to each other and we believe that the awareness of availabilities in know-how and infrastructure at both parties has increased.

The projects covered scientific research and education and training, in the following areas:

- Nuclear data for nuclear science and technology
- Emergency preparedness
- Conventional and advanced nuclear fuel safety for both current and innovative systems
- Production of nuclear reference materials
- Safety of spent fuel and radioactive waste.

They demonstrate the complementary nature of the competences and nuclear infrastructure of the JRC and the CEA.

In addition, this report highlighted that collaboration between the JRC and the CEA is not limited to this collaboration agreement on Nuclear Safety but that there is collaboration through many other activities carried out in various frameworks, contributing to reinforce the ties and culture of collaboration between the parties.

Based on the success of this extensive collaboration, JRC and CEA management decided to renew the collaboration agreement and new projects are already in the process of being defined for the next period.

The amendment n°1 to the collaboration agreement entered into force on 12 October 2021 and was signed by Mr François Jacq, Administrateur Général du CEA, and Mr Stephen Quest, Director-General of the JRC. This amendment extends the duration of the agreement for 5 more years. In addition, it enlarges article 1.2 of the agreement by adding the following two key cross-cutting fields of interest for JRC and CEA: SMR – Cogeneration and Circular Economy.

The names of coordinators have been updated. For the JRC, the coordinator is Dr Margarida GOULART, Head of the Euratom Coordination Unit. For the CEA, the coordinator is Dr Stéphane SARRADE, Director of Energy Programs, Energy Division.

Based on this extended agreement, the CEA and the JRC will be able to pursue this excellent collaboration and to launch new activities, in line with the challenges and priorities identified on both sides.

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Jules Horowitz Operation Plan 2040:

- **https://cordis.europa.eu/project/id/899360**
- **https://www.jhop2040-h2020.eu/**

Open access to JRC Research Infrastructures

- **European Commission website: https://joint-research-centre.ec.europa.eu/knowledge-research/open-access-jrc-research-infrastructures_en**

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List of abbreviations

CEA	Commissariat à l'énergie atomique et aux énergies alternatives
DG RTD	Directorate General for Research and innovation
EERA	European Energy Research Alliance
H2020	Horizon 2020
HLW	High Level Waste
IPR	Intellectual Property Rights
JHR	Jules Horowitz Reactor
JRC	Joint Research Centre
MOX	Mixed Oxide Fuel
PAs	Public Authorities
RTO	Research and Technology Organisation
SNETP	Sustainable Nuclear Energy Technology Platform

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Annexes

Annex 1. Joint projects under the collaboration agreement on Nuclear Safety– details

P1- Development of an experimental set-up dedicated to the capture cross section measurements of fissile nuclides

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: O. Serot (CEA/DEN Cadarache)
Euratom Principal Investigator : P. Schillebeeckx (JRC.G.2)
Timeframe: started in September 2017 - ongoing

Background

Neutron capture cross sections $\sigma_{n\gamma}$ of fissile nuclides are of high interest for the design of advanced reactors, safety assessment of critical systems and management of nuclear fuel. The most common method to measure $\sigma_{n\gamma}$ is based on detecting of prompt γ-rays after (n,γ) reaction. In case of a fissile nucleus such measurements are complicated by the presence of prompt fission γ-rays. Hence, a separation between the contribution due to prompt capture and fission γ-rays is required. In this project a new detection system based on a fission tagging detector combined with the total energy detection principle will be developed for future measurements at the GELINA neutron time-of-flight facility of JRC-Geel.

Summary

The development of a new detection system based on a fission tagging detector combined with the total energy detection principle did not start due to problems related with a PhD student (see comment).

An alternative measurement technique was proposed and applied to determine spectrum averaged cross section data for the $^{235}U(n,\gamma)$ reaction. This technique, which is based on a combination of neutron activation and atom counting of the reaction products using accelerator mass spectrometry, was applied for measurements at a cold neutron beam of the ILL Grenoble and FRM II Munich reactors and at the thermal neutron field in the BR1 reactor at SCK CEN. By combining measurements at facilities with different neutron spectra the energy dependence of the cross section can be obtained. The results of these measurement previous measurements at a beam with a Maxwellian spectrum with kT = 25 keV and 426 keV.

The experiments are finalised:

- samples were prepared at JRC-Geel
- irradiation of a 235U samples and 197Au foils were carried out at the BR1, FRM II and BR1 reactor
- irradiated 235U samples together with additional reference materials from JRC Geel to calibrate the mass spectrometers were send to the University of Vienna for an AMS analysis

The analysis of the AMS data is ongoing.

Comment

These activities were scheduled to be part of the PhD work of Mr. A. Belkache supervised by O. Serot of CEA. However, early in his contract, Mr. A. Belkache decided to stop his PhD activities. Unfortunately, there were not enough resources to continue the work at GELINA. However, we intend to finalise the work on the spectrum averaged capture cross section measurements at the BR1, ILL and FRMII facilities.

Publications

none

P2- Development of an experimental set-up dedicated to the capture cross section measurements of fissile nuclides

Project Domain (Research Field): nuclear data
CEA Principal Investigator : Pierre Leconte
Euratom Principal Investigator : A. Plompen

The project did not start since there was a delay in the licence of MONNET. A new project is under discussion.

P3-Fission cross section measurement of 235U from thermal energy region to several keV

Project Domain (Research Field): Nuclear data
CEA Principal Investigator : O. Serot (CEA/DEN Cadarache)
Euratom Principal Investigator: P. Schillebeeckx (JRC.G.2)
Timeframe: started in June 2017 - ongoing

Background

^{235}U is the most common fissile nuclide used worldwide. An accurate knowledge of its neutron-induced fission cross sections σ_{nf} highly influences the quality of results obtained from numerical simulations. The ^{235}U fission cross section σ_{nf} at 2200 m/s, the cross section integral between 7.8 eV and 11 eV and the point-wise cross section above a neutron energy of 150 keV are used as a reference or neutron standard for measuring cross sections of other reactions. Unfortunately, experimental data in the resonance region to determine a standard for the resonance integral are rather scarce. This work aims at extending the data base to establish such a standard with a reduced uncertainty.

Summary

Fission cross section measurements were carried out at the time-of-flight facility GELINA. The measurements were performed at a 9 m station of flight path 2 using a double Frisch-Gridded ionisation chamber with a common aluminium cathode with a thin layer of ^{235}U and ^{10}B deposited on apposite sites. To cover the full resolved resonance including the thermal energy region two experimental campaigns were organised with the accelerator operating at 50 Hz and 400 Hz. The 50 Hz campaign lasted about 3 months and the 400 Hz campaign 1 week. The TOF and the pulse height of detected events were recorded in list mode using a data acquisition system developed at JRC Geel. The data reduction and analysis is in progress.

Comment

This activity was scheduled to be part of the PhD work of Mr. A. Belkache supervised by O. Serot of CEA. However, early in his contract, Mr. A. Belkache decided to stop his PhD activities. Therefore, the expected time schedule could not be followed. Nevertheless, we intend to proceed with the analysis of the data, produce data for the EXFOR data library and report the results in a journal paper.

Publications

none

P4– INTEGRAAL, integral measurement at JRC

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: P. Leconte (CEA/DEN Cadarache)
Euratom Principal Investigator : A. Plompen (JRC.G.2)
Timeframe: started in January 2017 – ongoing

Background

Results of shielding experiments are valuable input data to validate evaluated cross section data, in particular cross sections for neutron elastic and inelastic reactions. In this project the possibility to perform for the first time neutron shielding experiments in the target hall of the GELINA facility is investigated and a verified by experiments through thick slab of depleted uranium.

Summary

The possibility to perform shielding experiments in the target hall of GELINA was investigated. The work included:

- a feasibility study based on Monte Carlo simulations
- first experiments using slabs of depleted uranium
- improve experimental conditions based on the results of the first experiments
- design and construction of an improved set-up for new experiments.

The main objective is to design an experiment which maximizes the sensitivity to the inelastic scattering cross section of ^{238}U.

Results of Monte Carlo simulations with TRIPOLI and MCNP6 showed that GELINA has the potential to perform integral experiments:

- the total neutron emission rate is equivalent to the one used in the other experiments such as those at the CALIBAN critical facility in Valduc (FR).
- The depleted uranium disks available at JRC Geel have suitable characteristics for such experiments

The results of these calculations were used to design a first experiment which carried out in 2017. Five metallic depleted uranium disks (33 mm thickness) and one 5-mm thick disk, all canned in Al, were stacked together to have total uranium thickness of 155 mm. The employed neutron dosimetry reactions were ^{103}Rh(n,n'g), ^{115}In(n,n'g), ^{58}Ni(n,p), ^{27}Al(n,a), ^{47}Ti(n,p), ^{56}Fe(n,p), ^{54}Fe(n,p), ^{24}Mg(n,p), ^{59}Co(n,a), $^{235+238}$U(n,f), ^{46}Ti(n,p), ^{48}Ti(n,p). The primary experimental result is the reaction rate at a given depth divided by the reaction rate at the front of the block. The observed reaction rates were compared to detailed Monte Carlo calculations using the code TRIPOLI4. Very reasonable results are obtained from first trial runs and optimizations emerge that are of relevance to arrive at benchmark quality shielding experiments that are suitable for validating transport cross sections. A study was made to improve the integral experiment with an effective shield against room return. Shield parameters were determined at CEA and an improved set-up following the design specifications of CEA was constructed by JRC.

The project continues as part of the INTEGRAAL/2 project which was accepted by the EUFRAT User Selection Committee. In addition, the results of this project will benefit from another open access proposal, i.e. URANIUM_NRTA, for which the measurements at GELINA started in 2020. This proposal aims at characterizing the depleted uranium discs by NRTA for the presence of high neutron absorbing elements.

Publications

Contributions to conference proceedings and workshops

Leconte et al., "On the feasibility to perform integral transmission experiments in the GELINA target hall at IRMM", European Physics Journal Web of Conferences 153 (2017) 01023

Technical Reports

Nyman et al., "Integral Experiments in the GELINA Target Hall – ^{238}U and ^{nat}Cu", JRC Technical Reports, JRC104092, EUR28241 EN (2016)
Plompen et al., "Towards neutron benchmark experiments with GELINA", JRC Technical Reports, JRC109785 (2017)

P5 – Transmission measurements of the MINERVE samples at the TOF facility GELINA

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: G. Noguere (CEA/DEN Cadarache)
Euratom Principal Investigator : S. Kopecky (JRC.G.2)
Timeframe: started in September 2017 – closed in November 2020

This work is part of the PhD thesis of Lino Šalamon (CEA/DEN Cadarache)

Background

Various UO_2 samples containing different nuclides (fission products and actinides) were used for oscillation measurements in the MINERVE reactor (CEA Cadarache) in the frame of the Burn-Up Credit (BUC) and OSMOSE experiments. A correct interpretation of these integral experiments requires an accurate knowledge of the sample composition in particular the presence of strong neutron absorbing material. In this project the use of transmission measurements at GELINA to characterise the MINERVE samples and to provide additional experimental data for an improved evaluation of resonance parameters is investigated. The work is part of the PhD thesis of L. Šalamon. Part of the work was performed within the EUFRAT open access project of the JRC.G.2.

Summary

An analytical model to analyse transmission data of samples with a cylindrical geometry (like the MINERVE samples) was developed. For such samples the basic Lambert-Beer law cannot be applied. The model was validated experimentally by transmission experiments using samples containing natural silver. To avoid bias effects in the interpretation of the data, the resonance parameters of ^{107}Ag and ^{109}Ag isotopes were first reviewed and improved based on dedicated transmission and capture cross section measurements at GELINA. This resulted in a new the evaluation of resonance parameters for neutron interactions with these Ag isotopes.

To validate the analytical model NRTA experiments were carried out at a 10 m transmission station of GELINA that was especially designed for such applications. NRTA was applied to determine the nuclide composition of UO_2, AL_2O_3 and liquid samples doped with natural silved. Applying the new analytical model the volume number densities of ^{238}U, ^{107}Ag and ^{109}Ag were within 2% fully consistent with the values quoted by the manufacturer. In addition, the NRTA data revealed a tungsten contamination which was not reported by the provider.

Finally, transmission measurement on a cylindrical or containing ten UO_2 pellets doped with ^{99}Tc were carried out. This sample is one of the samples which were especially designed for pile-oscillation measurements at the MINERVE reactor. The results of these measurements were used to produce an improved set of resolved and average resonance parameters for neutron interactions with ^{99}TC.

The parameters for ^{107,109}Ag and ^{99}Tc are the basis of a new evaluated data file for ^{99}Tc to be adopted in the JEFF library. Most of the experimental data were delivered to the EXFOR library. The project continues as part of the MINERVE_UO2GD project which was accepted by the EUFRAT User Selection Committee.

Publications

Journal papers

Šalamon et al., "107Ag and 109Ag resonance parameters for neutron induced reactions below 1 keV", Nuclear Instruments and Methods B446 (2019) 19
Šalamon et al., "Neutron resonance transmission analysis of cylindrical samples used for reactivity worth measurements", Journal of Radioanalytical and Nuclear Chemistry 321 (2019) 519
Ma Fei et al., "Non-destructive analysis of samples with a complex geometry by NRTA", Journal of Archaeological Science, 33 (2020) 10521
Noguere et al., "Average neutron cross sections of 99Tc", Physical Review C102 (2020) 015807

Contributions to conference proceedings and workshops

Šalamon et al., "Neutron resonance transmission analysis of cylindrical samples used for reactivity worth measurements", EPJ Web of Conferences 239 (2020) 102521

Technical Reports

Šalamon et al., "Results of TOF transmission measurements for ^{nat}Ag at a 10 m station of GELINA", INDC International Nuclear Data Committee, INDC(EUR)-0036 (2020)

6 – Magnet system for alpha spectrometry

Project Domain (Research Field): Nuclear data
CEA Principal Investigator : Sylvie Pierre (CEA/LNHB)
Euratom Principal Investigator:Jan Paepen (JRC.G.2)
Timeframe: started in June 2016 –closed in August 2018

Background

Some alpha-particle emission intensities are known with large uncertainties. These intensities can be calculated from spectra measured with silicon detectors and for accurate results, it is necessary to have a large number of pulses in the alpha peaks. If the emission intensity is low, there is a big advantage to increase the detection solid angle, thus to place the detector close to the source. However, this also increases the probability to detect alpha particles in coincidence with conversion electrons, leading to a distortion of the spectrum. The resulting effects are peak shape deformation, summing-out of the low-energy peaks, summing-in of the high-energy peaks and as a consequence erroneous peak fitting and emission probability assignments. An effective way to mitigate these effects is the application of a magnetic field to bend away the conversion electrons from their path towards the detector, as demonstrated by Paepen et al.0. The determination of some low-intensity alpha peaks can be time-consuming and so it is interesting to share the work and to compare the results obtained in different laboratories.

The design and production of tailor-made magnet systems that accommodate the alpha spectrometry measurement setups of CEA-LNHB is the subject of this project. The design should maximise the magnetic field in order to deflect as much as possible the electrons, but should minimise the deflection on the alpha particles, and should physically fit into the measurement setups.

Summary

Based on previous experience0, JRC designed and produced a magnet systems taking into account the constraints determined by CEA (conversion electron energy to deflect, alpha energy, dimensions of chamber and source, etc.) The constraints were discussed at a meeting on 23/06/2016 at JRC-Geel, attended by Sylvie Pierre and Benoit Sabot (CEA) and Jan Paepen and Maria Marouli (JRC). From 02/08/2018 until 04/08/2018, Maria Marouli (JRC) visited LNHB and provided training on the use of the magnet systems and the optimisation of alpha spectrometry measurements in general. The magnet system, the technical drawings and safety instructions were provided to CEA. The project is closed.

Publications

Journal papers: N.A.

Contributions to conference proceedings and workshops: N.A.

Technical Reports:

- Technical drawings of the magnet system
- Safety instructions

References

Paepen et al., A magnet system for the suppression of conversion electrons in alpha spectrometry, Applied Radiation and Isotopes 87 (2014) 320-324

P7- Reference value determination for Proficiency Test of environmental monitoring laboratories in the EU

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: Thierry Branger (CEA/LNHB)
Euratom Principal Investigator: Katarzyna Sobiech-Matura (JRC.G.2)
Timeframe: started in February 2017 – closed in November 2017

Background

This project aims to provide proficiency testing of radionuclide measurements in environmental matrices and foodstuff for Member States' laboratories which monitor radionuclides in the environment and food. Periodical participation in such tests improve the comparability and reliability of measurement results reported to the Commission by the Member States as laid down in Commission Recommendation COM/2000/473 and Articles 35 and 36 of the Euratom Treaty.

Summary

JRC Geel prepared proficiency testing samples from maize. It was spiked with I-131, Cs-134, and Cs-137. The estimated activity level were 0.2-0.5 Bq/g per radionuclide. In the second half of May 2017 the material was prepared, homogenized and packed in amber glass bottles (~100 g each) and shipped to CEA for gamma-ray measurements together with a template of a report on the measurement results. CEA provided JRC with results and other relevant information as described in the template report.

Publications

none

P8- Production of a molecular plating cell

Project Domain (Research Field): Fission studies
CEA Principal investigator: J. Taieb (CEA/DAM Bruyères-le-Châtel)
Euratom Principal investigator: G. Sibbens (JRC.G.2)
Timeframe: started in march 2017-closed in June 2017

Background

JRC.G.2 prepared 22 ^{239}Pu deposits through the EUFRAT project (EUFRAT 02-16 TP) for Prompt Fission Neutron Spectra measurements at LANSCE/WNR (Los Alamos, USA) [1]. These deposits were used in a dedicated fission chamber developed by the CEA group, in charge of the experiments at LANSCE. A dedicated molecular plating cell was prepared to deposit the ^{239}Pu layers on a frame developed by CEA. The CEA group intends to produce ^{252}Cf deposits on the same frame at their laboratories. Therefore, a similar molecular plating cell is needed.

Summary

Based on the design of the molecular plating cell that was used for the preparation of the ^{239}Pu deposits on the CEA frames, JRC produced and tested a similar cell for CEA. The molecular plating cell including the anode motor and work instructions were provided to CEA. The project is closed.

References:

[1] P. Marini et al., Prompt-fission-neutron spectra in the ^{239}Pu(n, f) reaction, Physical Review C 101, 044614 (2020).

Publications

none

P9- Fission fragment spectrometers (FALSTAFF VERDI)

Project Domain (Research Field): Fission
CEA Principal Investigator: D. Doré (CEA/DSM Saclay)
Euratom Principal Investigator: S. Oberstedt (JRC.G.2)
Timeframe started in January 2017 – ongoing

Other Collaborating Organizations/Scientists: S. Pomp (Uppsala University)

Background

Some years ago, CEA and JRC started a technical exchange to optimize the different components of their 2v-2E spectrometers, respectively FALSTAFF and VERDI setups. The goal of these setups is to provide fragment yields and correlated average neutron multiplicity for different major and minor actinides in the neutron energy domain below the threshold for the second-chance fission. In addition, FALSTAFF will allow studying the evolution of the post-neutron fission-fragment mass distribution over a large energy domain, from some hundreds of keV up to 30 MeV. All data will serve as input to nuclear fission models to improve the data libraries needed for new reactor concepts, developed to create a carbon-free and sustainable energy supply.

The VERDI spectrometer is based on the combination of micro-channel plate detectors and an array of silicon detectors for time-of-flight (TOF) and kinetic energy measurements, whereas FALSTAFF employs secondary electron detectors (SED) for the TOF measurement and axial ionisation chambers to measure the fragment residual kinetic energy, placed behind the stop detector. Both systems achieve timing resolutions close to 100 ps (sigma) and an energy resolution of 1% or better.

Summary

FALSTAFF

The first arm of the FALSTAFF spectrometer was tested in 2018 with a thermal neutron beam at the Orphee reactor (CEA/Saclay). These tests revealed that there FALSTAFF can be used for studies with a neutron beam. In 2019 a new ToF detector was installed and more tests with a Cf-252 source were performed. With the previous detector, a high threshold was necessary to cut the noise which implies a cut in the heavy fragment mass distribution. The 2019 detector restored the proportion of light and heavy fragments. Recently another new Tof detector has been delivered and is under tests. The DAQ system has also been updated.

In parallel to the experimental work, the energy loss correction has been investigated. Indeed, the energy loss of fragments in the different layers of the FALSTAFF setup has to be calculated and data have to be corrected. In order to verify the stopping powers for such heavy ions, an experimental campaign was achieved in 2019. Results showed that the DPASS library was more appropriate than the well-known SRIM calculations for the fission fragments in the energy range of interest. This library has been implemented in our version of GEANT4 and in the analysis code.

In 2020, the Ganil PAC accepted a CEA proposal for an experiment at NFS with a ^{235}U target. JRC.G.2 will participate to the experiment and provide the ^{235}U target. In addition, FALSTAFF has recently welcomed new collaborators from GANIL. It has been decided to move FALSTAFF at Ganil in Fall 2021. A test experiment will be performed (beginning 2022) combining FALSTAFF with VAMOS spectrometer in order to investigate the charge determination thanks to the energy loss profile in the ionization chamber.

VERDI

The VERDI spectrometer is operational as two-arm time-of-flight spectrometer. Its time and energy resolution was tested with the spontaneous fission of ^{252}Cf leading to satisfactory results for the pre-neutron mass distribution. The post-neutron mass distribution showed the effect of a limited signal-to-noise ratio. Further data analysis lead to the mass-dependent average neutron multiplicity, deduced from the event-wise difference of the pre- and post-neutron masses. The correlation of the average neutron multiplicity with the fragments total kinetic energy showed the wrong slope and revealed the impact of prompt neutron emission on the fragment velocity, which is in first-order assumed to be unchanged after prompt neutron emission, a key assumption to obtain pre-neutron masses from a double-velocity measurement. A first order correction was suggested and successfully implemented.

The time resolution turned out to be worse than expected due to the plasma-delay time (PDT) occurring in silicon detectors, when detecting high-charge particles. This quantity is now being measured with the ILL LOHENGRIN spectrometer in conjunction with an MCP start detector. The velocity of selected fragment masses with well-defined kinetic energies is measured. The difference of measured and calculated velocity allows determining the PDT as a function of mass and nuclear charge of the fragment. The expected improvement in time resolution, i.e. mass resolution, will be verified in an upcoming measurement campaign with a ^{252}Cf spontaneous fission source, which is tentatively scheduled for the second half of 2022.

Publications

Contributions to conference proceedings and workshops

Jansson et al., "The new double energy-velocity spectrometer VERD", EPJ Web of Conferences, 146 (2017) 04016

Al-Adili et al., "Studying fission neutrons with 2E-2v and 2E", EPJ Web of Conferences, 169 (2018) 00002

Doré et al., "Performance validation of the first arm of FALSTAFF: ^{252}Cf and ^{235}U fission fragment characterisation", EPJ Web of Conferences, 211 (2019) 04002

10 – FIFRELIN/VESPA – measurement of reference data as input to improve and/or validate the FIFRELIN code (progress report 2021)

Project Domain (Research Field): Nuclear data
CEA Principal Investigator : O. Litaize (CEA/DES Cadarache)
Euratom Principal Investigator :S. Oberstedt (JRC.G.2)
Timeframe: started January 2017 – closed 2021

Other Collaborating Organizations/Scientists: European Light Infrastructure – Nuclear Physics (Andreas Oberstedt)

This work is part of the PhD thesis of Valentin Piau (CEA/DEN Cadarache)

Background

Aiming at a carbon-free and sustainable energy supply triggered new, fast-neutron based reactor concepts. One ingredient for the safety assessment of such contemplated devices is the knowledge about the de-excitation mechanism, taking place after fission fragments were produced in a highly excited state. Such cooling down is achieved through the subsequent emission of neutrons and gamma rays and, at a later state, by beta-decay. In order to arrive at a realistic description of this process experimental data are needed to better confine the range of the, sometimes many model parameters.

The goal here is to produce high-quality prompt fission gamma-ray spectral data as input to state-of-the-art nuclear fission model, the CEA FIFRELIN Monte-Carlo code. The aim of this code is to simulate the whole set of fission observables including prompt fission neutrons and gamma rays. Four free input parameters govern the excitation energy and spin/parity entry zone of the primary fragments. These parameters are chosen to reproduce a targeted fission observable such as, for example, total mean gamma-ray multiplicity, average total gamma-ray energy or the prompt neutron multiplicity (nu-bar).

The experimental work was performed at the JRC.G.2 MONNET laboratory.

Summary

With the VESPA spectrometer the prompt fission γ-ray (PFG) and neutron (PFN) correlations with fission-fragment mass (A*) and total kinetic energy (TKE) were measured for the spontaneous fission of ^{252}Cf. A position-sensitive twin Frisch-grid ionization chamber and several neutron detectors complemented the VESPA spectrometer. The experimental work was performed at the MONNET laboratory of JRC-Geel. The data analysis focused on the following topics:

- Average prompt fission γ-ray quantities were measured to validate the set-up and to determine the detectors' response matrices using the GEANT4 code.
- Mass-pair resolved prompt fission γ-ray spectra were obtained. Those spectra await comparison with FIFRELIN-generated data.
- Mass- and energy-dependent average PFG multiplicity were measured, unequivocally proving the sawtooth like dependence of average number of PFGs as a function of fragment mass hitherto debated within the community. The measured energy dependence confirms the only results existing in literature.
- Time dependence of γ-ray emission up to 30 μs.
- Investigation of fission-fragment isomer decay measuring level life-times and isomeric ratios.

Pre-neutron mass and kinetic energy yields measured with VESPA are of fundamental importance for the FIFRELIN code to initialize the de-excitation process. The measured fission-fragment isomeric state life times and yields will be used to complement the information related to level schemes coming from the RIPL-3 database. The recently measured average number of PFGs as a function of fragment mass allowed to determine, which primary fission fragment spin distribution model is the best to describe the shape of this observable. Ongoing calculations based on microscopic level densities and photon strength functions seem to reproduce even better the experimental data (to be published) especially in the heavy mass range.

Presently, the VESPA spectrometer is upgraded with an array of CeBr3 detectors to increase the efficiency. Additionally, we are working on a new technique to produce spectroscopic actinide targets. Then, the PFGS and PFNS measurements on spontaneous fissioning ^{246}Cm and ^{248}Cm actinides will be pursued

Publications

Journal papers

Chebboubi et al., "Kinetic energy dependence of fission fragment isomeric ratios for spherical nuclei Sn-132", Physics Letters B 175, (2017) 190
Oberstedt et al., "Predictions of characteristics of prompt-fission γ-ray spectra from the n + ^{238}U reaction up to En = 20 MeV",

Physical Review C96 (2017) 034612
Choudhury et al., “High-Precision Prompt Fission Gamma-Ray Studies For Nuclear Reactor Safety”, Journal Nuclear Research and Development 14 (2017) 3
Thulliez et al., “Neutron and γ multiplicities as a function of neutron energy for the $^{237}Np(n,f)$ reaction”, Physical Review C 100 (2019) 044616
Almazán et al., “Improved STEREO simulation with a new gamma ray spectrum of excited gadolinium isotopes using FIFRELIN”, European Physical Journal A55 (2019) 183
Travar et al., “Experimental information on mass- and TKE-dependence of the prompt fission γ-ray multiplicity”, Physics Letters B 817 (2021) 136293
Gupta et al., “Fission fragment yield distribution in the heavy-mass region from the $^{239}Pu(n_{th},f)$ reaction”, Physical Review C96 (2017) 014608

Contributions to conference proceedings and workshops

Choudhury et al., “Recent results from prompt fission gamma-ray measurements”, “AIP Conference Proceedings 2076, 060002 (2019)
Serot et al., “Calculation of the Fission Observables in the Resolved Resonance energy Region of the $^{235}U(n,f)$ reaction”, EPJ Web of Conference. 239 (2020) 05002

P11- Laser heating of irradiated fuels

Project Domain (Research Field): Safety of Current Systems
CEA Principal Investigator: Y. Pontillon
Euratom Principal Investigator: L. Vlahovic

In the period 2017-2019 exchange meetings for the project were organised, and a technical meeting between the JRC and CEA teams and a team of Institut Fresnel, with which CEA works closely on this topic, was planned as the next step. Due to the COVID restrictions of the last two years, this has not yet taken place, and will be done as soon as the situation allows.

P12 – B4C+MOX thermodynamic behaviour

Project Domain (Research Field): Safety of Innovative Systems
CEA Principal Investigator: C. Gueneau
Euratom Principal Investigator: J.-F. Vigier
Timeframe: started in 2018 - ongoing (the major part of the experimental work in JRC laboratories is completed. The PhD thesis will be finalised and submitted by the end of September 2021.)

Summary

The study of severe accident is a key step to assess the safety of Sodium Fast Reactors (SFR). In the potential event of a severe accident, the fast rise of temperature could lead to the formation of "corium" which is the complex mixture forming during the core materials chemical interaction at very high temperature. This activity deals with the study of the chemical interaction between MOX fuel and B_4C, which is of upmost importance to assess the efficiency of the mitigation effect of B_4C. The project was conducted in the frame of the PhD thesis of Mathieu Garrigue, who will submit his PhD thesis end of September 2021. A one-year exchange visit of Mathieu Garrigue to JRC KA was arranged in the frame of the CRA between the Joint Research Center (JRC) and the Commissariat à l'Energie Atomique et aux énergies alternatives (CEA) on cooperation in the field of research and development in Nuclear Safety.

Experiments using UO_2 were performed in CEA Saclay during his PhD first year (Oct. 2018 - Oct. 2019). Handling MOX required performing experiments in specific laboratories available at JRC Karlsruhe, during which chemical interaction involving MOX fuel was studied, and thereby to fill the lack of experimental data needed to build a thermodynamic model using the CALPHAD method on corium for SFR reactors.

The main goal of this exchange was to get knowledge about interactions between MOX and B_4C at high temperature. Also, the acquisition of thermodynamic data on mixed uranium and plutonium borides is required in order to build a CALPHAD database. Moreover, taking into account the steel cladding in the system also bring relevant information on the thermochemical corium behaviour.

Status

Even though, and due to the COVID pandemic, not all planned activities could be realised, the major part of the experimental work in JRC laboratories is completed. The PhD thesis will be finalised and submitted by the end of September 2021.

Publication

Mathieu Garrigue, Jean-François Vigier, Jean-Yves Colle, Andrea Quaini, Christine Guéneau, Characterization of MOx-B_4C interactions at high temperature through RADES experimental setup - Application to severe accident in Sodium Fast Reactor, NuMat 2020 Conference, 26-29 October 2020.

P13- Sodium+MOX thermodynamic behaviour

Project Domain (Research Field): Safety of Innovative Systems
CEA Principal Investigator : C. Gueneau
Euratom Principal Investigator : K. Popa
Timeframe: started in 2018 – closed in November 2020

Summary

The interaction of liquid sodium with MOX fuel is of high significance for the safety assessment of Sodium-cooled Fast Reactors (SFR). In a severe accident, the fuel could be partially or fully molten and interact with the sodium coolant at high temperatures. The fission products that are released from the irradiated MOX fuel could also interact with sodium. A thorough knowledge of the interaction products is essential to predict the aftermath on safety, and therefore the nature of the phases that could form in such situation needs to be determined.

The aim of the project was to investigate the thermodynamic properties of these complex systems to better understand and predict the phases that would form in case of a chemical reaction between sodium and the irradiated MOX fuel containing fission products. For this purpose, structural and thermodynamic properties of two representative chemical systems, the Na-O-Pu-U system and the Ba-Cs-I-Mo-O-Te system, were assessed. The gained data were then used to start the development of a thermodynamic database by thermodynamic modelling of the systems using the CALPHAD method.

The project was conducted and concluded in the frame of the PhD thesis of Guilhem Kauric, which he successfully defended at University Paris-Saclay on 20th of November 2020.

Status

Completed. The project was concluded with the successful PhD defence of Guilhem Kauric in November 2020.

Publications

Kauric, Guilhem. Contribution to the investigation of the chemical interaction between sodium and irradiated MOX fuel for the safety of Sodium-cooled Fast Reactors. Diss. Université Paris-Saclay, 2020.

Kauric, Guilhem, et al. "Structural and Thermodynamic Investigation of the Perovskite Ba2NaMoO5. 5." Inorganic chemistry 59 (2020) 6120-6130.

Kauric, G., et al. "Synthesis and characterization of nanocrystalline U1-xPuxO2(+y) mixed oxides." Materials Today Advances 8 (2020) 100105.

P14- Uranium-americium MABB

Project Domain (Research Field): Safety of Innovative Systems
CEA Principal Investigator: P. Martin
Euratom Principal Investigator : T. Wiss
Timeframe: 2018-2021 : closed

Summary

- Melting point determination of selected compositions using laser flash technique
- Structural analysis using SEM/TEM techniques
- Heat capacity measurements on selected samples
- KEMS measurements on selected samples with the aim to determine partial vapour pressures of actinide oxide gaseous species.
- KEMS and Q-GAMES measurements to quantify helium release from aged americium containing samples

Highlights

- The very high melting temperatures of (U,Am)-oxides ($T > 2500$ K) were measured.
- The effect of the oxidation on the melting behaviour was studied.
- Extensive post-melting characterizations were performed (SEM, XAS).
- A CALPHAD thermodynamic modeling of the liquid in the U-Am-O system was obtained.

Deliverables

Epifano, D. Prieur, P.M. Martin, C. Guéneau, K. Dardenne, J. Rothe, T. Vitova, O. Dieste, T. Wiss, R.J.M. Konings, D. Manara, Melting behaviour of uranium-americium mixed oxides under different atmospheres, The Journal of Chemical Thermodynamics, Volume 140, 2020, 105896,

P15- Thermodynamic data for severe accidents

Project Domain (Research Field): Nuclear fuel safety
CEA Principal Investigator : C. Gueneau (CEA/DES Saclay)
Euratom Principal Investigator: JRC.G.I.3
Timeframe: started in June 2017 - ongoing

Background

The goal of this research is to provide data for the safety assessment of current and future nuclear fuels, particularly during accident scenarios may, with a low probability, result in severe accident, as emphasized by the Fukushima-Daiichi accident in Japan. In a typical case of failure of the cooling system in a nuclear reactor, overheating of a fuel element can take place, leading to failure of fuel rods. Subsequently, numerous processes can take place, from interaction between fuel and coolant, control rod materials, to the melting of the core components leading to "corium", a lava-like liquid. This hot, highly radioactive mixture can diffuse outside the primary containment if the steel wall is melted through, and end up reacting even with the concrete constituting the most external barrier. The study of thermodynamic and thermophysical properties of corium subsystems constitutes the main object of this project. Particular emphasis will be given to the systems mixed oxide (MOX) fuels – zirconium and mixed oxide fuels-steel. Analyses will be extended to high-Pu MOX also containing minor-actinide (Np, Am) representative for GEN IV nuclear reactors.

Summary

The following joint studies were performed in the reporting period:

- The Fe_3O_4-PuO_2 phase diagram was studied by the laser melting technique at JRC-Karlsruhe combined with CALPHAD caculations by the CEA-Saclay team. This work was done in the frame of a traineeship of Mr. L. Cassini (PoliMi).
- The margin to the melting of MOX fuel containing Am and of $(Pu,Am)O_2$ mixed oxides was measured by the laser melting technique in the frame of the PhD work of Mrs. P. Fouquet-Métivier (CEA), who stayed as visiting scientist at JRC-Karlsruhe for period of one year. These experimental data were used to improve the thermodynamic modelling of $(U,Pu,Am)O_2$ oxides.

Comment

This work was strongly affected by the COVID pandemic during the last two years. The visit of M. Cassini to Saclay for the thermodynamic modelling could not take place in 2020.

Publications

none

P16- Assessment of Volatile Fission Product Behaviour via Simulated Fuels

Project Domain (Research Field): Conventional and Advanced Nuclear fuel Safety: Current Systems
CEA Principal Investigator: Fabienne Audubert
Euratom Principal Investigator: Marco Cologna (JRC)
Timeframe: started in 2018- closed in 2020

Summary

Aim of the project was to complement the data on the behaviour of fission products in normal and severe accident conditions, typically obtained by studying the behaviour of real irradiated fuels, by synthetizing and studying simulated spent fuels (SIMFUELS).

The focus was on different volatile and non-volatile fission product phases, e.g. Cs_2MoO_4, Cs_2UO_4, $BaZrO_3$, $BaMoO_4$, BaO, MoO_3 and ZrO_2, in concentration representative of those found in an irradiated UO_2.

The synthesis of the SIMFUELS and basic characterisation took place at JRC. Two batches of UO_2 samples were transported from JRC to CEA, where further annealing studies, advanced characterisation and thermodynamic modelling were performed.

The project involved the exchange of four students (Two PhD Students and two trainees) that had the opportunity to perform work both at CEA as well as JRC.

Follow-up project submitted.

The results are summarised in following publications:

[1] C. Le Gall, "Contribution to the study of fission products release from nuclear fuels in severe accident conditions: effect of the pO2 on Cs, Mo and Ba speciation" PhD Thesis, Université Grenoble Alpes, 2018.

[2] L. Balice, PhD Thesis, PhD Thesis, Université Grenoble Alpes, in preparation.

[3] C. Le Gall, M. Cologna, M. Holzhäuser, K. Popa, J. Boshoven, H. Hein, J.-L. Hazemannc O. Proux, C. Riglet Martial, J. Léchelle, F. Audubert, Y. Pontillon "An innovative Method to study Volatile Fission Products speciation in nuclear fuels under Severe Accident Conditions." 8th European Review Meeting on Severe Accident Research (ERMSAR - 2017), May 2017, Varsovie, Poland. ffcea-02434559

[4] L Balice, M Cologna, F Audubert, JL Hazemann, "Densification mechanisms of UO2 consolidated by spark plasma sintering", Journal of the European Ceramic Society 41 (1), 719-728 (2021)

[5] C. Le Gall, C. Riglet Martial, J. Léchelle, F. Audubert, Y. Pontillon, M. Cologna, M. Holzhäuser, K. Popa, J. Boshoven, H. Hein, 2017, Synthesis of SIMFUEL samples by Spark Plasma Sintering to study Volatile Fission Products speciation in Severe Accident conditions, NUFUEL, Italie, 04/09/2017

[6] C. Le Gall, P. Taupin, M. Cologna, M. Holzhäuser, K. Popa, J. Boshoven, H. Hein, F. Audubert, 2018, SPS synthesis of UO2 samples containing Cs, Mo, Ba and Zr bearing phases, Fourth International Workshop on SPS, Cagliari (Italie), 23-25/05/2018 (poster)

P17 – Creep and solid state diffusion in UO_2 as a function of grain size

Project Domain (Research Field): Conventional and Advanced Nuclear fuel Safety: Current Systems
CEA Principal Investigator: Philippe Garcia
Euratom Principal Investigator: Marco Cologna
Project Timeframe: started in 2018 – closed in 2020

Summary

The grain size has a major effect on virtually all the processes governed by solid state diffusion, such as grain growth, densification and high temperature plastic deformation. The effect of the grain size on such phenomena for UO_2 needs still to be clearly assessed. This is particularly relevant because in nuclear fuels the microstructure is evolving during operation.

The main aim of this project was to study the behaviour of the microstructure and oxygen partial pressure in terms of grain growth kinetics and mechanical properties. In order to achieve this aim, JRC studied the synthesis of dense pellets of UO2 with different grain sizes (from few tenths of nanometres to few micrometres), while CEA performed high temperature compression tests as a function of the grain size and oxygen potential.

A technique was developed to achieve UO2 dense disks with grain sizes in the sub-micrometre range [1]. In case of macroscopic pellets with high aspect ratios, as needed for creep testing, the grain growth during sintering could not be suppressed, and only grain sizes down to about 3 micrometers were achieved. Two batches of UO_2 samples with different microstructures were transported to CEA for creep testing. It was found that that the creep mechanism and rate depend strongly on the grain size and oxygen partial pressure, and a relation was proposed [2].

The results are summarised in following publications:

[1] E De Bona, L Balice, L Cognini, M Holzhäuser, K Popa, O Walter, M Cologna, D Prieur, T Wiss, G. Baldinozzi, “Single-step, high pressure, and two-step spark plasma sintering of UO2 nanopowders”, Journal of the European Ceramic Society, 41 (6), 3655-3663 (2021)

[2] Jean-Baptiste Parise, “A study of viscoplastic deformation processes in polycrystalline uranium dioxide in the near stoichiometric region: influence of oxygen activity and microstructure.” PhD Thesis, Université de Limoges, 2021.

P18 - Irradiation behavior of B_4C neutron-absorber material for ASTRID

Project Domain (Research Field): Core materials for fast reactors
CEA Principal Investigator: Caroline Bisor, Scientist
Euratom Principal Investigator: Thierry Wiss, scientific officer
Timeframe: The project did not start.

Summary

Several discussions and iterations of documentation to support SPECIFIC AGREEMENT ON POST-IRRADIATION EXAMINATIONS ON B_4C SAMPLES FROM PHENIX were performed. The samples, transfert/transport modalities, working plan was elaborated. After the decision of CEA to stop the ASTRID project the agreement needed some revision of the preamble and was since in stand-by because of the pandemic.

P19- A study of the Helium behavior in saturated-UO2+x and (U,Ce)O2 solid solutions

Project Domain (Research Field): In-pile behaviour of the nuclear fuel or spent fuel regarding over-pressurization of rods or pins.

CEA Principal Investigator : Jacques Lechelle
Euratom Principal Investigator: Thierry Wiss
Timeframe : 2017-2019 : ongoing

Summary

Helium incorporated in fluorite structure can impact the behavior of nuclear fuel in operation or storage conditions. Several experiment to assess this behavior were envisaged.

- Fabrication of $UO_{2.03}$, $UO_{2.16}$, U_4O_9, $(U_{0.554}Ce_{0.446})O_2$ and CeO_2 samples and preparation to extract relevant samples for the infusion device (CEA)
- Samples to be saturated with Helium at CEA Cadarache Center or implanted with He (CEA)
- He infusion experiments by varying the infusion pressure (JRC)
- Measurements of the He infused concentration for each infusion condition (JRC)

Not all the experiments were performed but the project has contributed to develop and apply methodologies that are currently used in the H2020 project "Inspyre" in which this scientific collaboration is pursued.

For example:
the feasibility of a High Resolution X-Ray Diffraction experiment working up to 800°C with depleted UO_2 under an atmosphere with a controlled oxygen partial pressure on BM25A beamline at ESRF has been demonstrated (see deliverable).
The infusion device developed at JRC is now in use and has been part of a PhD work in the frame of Inspyre. The collaboration with J. Lechelle is going on and samples studied at CEA-Cadarache will be shipped to JRC-Ka in the coming weeks for studies on helium behavior.

Deliverable

Jacques Léchelle, Adrien Michel, Gaëlle Carlot, Vincent Klosek, Thierry Wiss, Helium solubility study by High Resolution Powder Diffraction in hyper-stoichiometric uranium dioxide (UO_{2+x}), mixed uranium cerium oxide $(U,Ce)O_2$ and CeO_2, ESRF report experiment esrf report MA-3450, 2017

P20 – Helium solubility in HLW model glass

Project Domain (Research Field): Backend of the fuel cycle. HLW conditionning
CEA Principal Investigator: Sylvain Peuget
Euratom Principal Investigator: Thierry Wiss
Timeframe : 2017- ongoing

Summary

The nuclear waste glass will incorporate alpha emitters and solubility and behavior of radiogenic helium needs to be assessed.

- Elaboration of glass rods (CEA)
- Sample preparation to extract relevant samples for the infusion device (CEA)
- Analysis of the experimental data and comparison with the published available data
- He infusion experiments by varying the infusion pressure (JRC)
- Measurements of the He infused concentration for each infusion condition (JRC)

The samples to be infused at JRC have been shipped by CEA. The development of the infusion device was longer than initially planned (several equipment failures).

The device are currently in operation and preliminary infusion tests of CJ1 glass samples took place at the end of 2019. The results were published in the experimental section of the PhD thesis of Luana Cognini (Investigation of helium behaviour in oxide nuclear fuel, PhD thesis, Politecnico di Milano, June 2021). More infusions will be performed, and results exchanged with S. Peuget (CEA).

P21- Kinetics of Sodium-MOX interaction

General

Project Domain (Research Field): Safety of Innovative Systems
CEA Principal Investigator: L. Desgranges
Euratom Principal Investigator: D. Freis
Timeframe: started in 2018- closed in December 2020

Summary

The objective of this study was to create valuable data for the safety assessment of defective fuel pins of a Sodium-cooled Fast Reactor (SFR), which will have to be stored in the reactor vessel for a period of about three years because of their residual power. In case of a cladding rupture, the liquid sodium coolant can penetrate into the fuel pin and interact with the MOX fuel, leading to fuel swelling and release of radioactive material into the primary circuit. Under storage conditions the defective fuel pins should not deteriorate anymore in order to avoid dissemination of fuel in the primary coolant. Therefore, assessing a safe storage criterion requires determining the kinetics of the interaction reaction between liquid sodium and MOX fuel. Because predictions have to be done over periods of time longer than the usually achievable duration of experiments in hot labs, a reliable modelling of the reaction kinetics is needed.

In the frame of this project, extensive experimental investigations and advanced characterisations were performed on the principal interaction mechanisms and kinetics of the interaction reaction between liquid sodium and nuclear fuel (UO_2 and MOX). Besides the pure kinetic data, the experimental work generated a number of original results on the nature of the interaction mechanism, which were not known in the literature before, and which allowed the creation of a comprehensive kinetic model.

The project was conducted and concluded in the frame of the PhD thesis of Concettina Andrello, which she successfully defended at École nationale supérieure des Mines de Saint-Étienne on 7th of December 2020.

Status

Completed. The project was concluded with the successful PhD defence of Concettina Andrello in December 2020. A follow-up project in the frame of the PhD thesis of Tristan Bossert is ongoing.

Publications

Andrello, Concettina. Mechanism and kinetics of the reaction between liquid sodium and nuclear fuel of future fast neutron reactors. Diss. École nationale supérieure des Mines de Saint-Étienne, 2020.

Andrello, Concettina, et al. "New insight of the reaction kinetic between uranium oxide and liquid Sodium: Experimental and modelling." NuMat2020-The Nuclear Materials Conference. 2020.

Andrello, Concettina, et al. "UO2 corrosion by liquid sodium." NuFuel-MMNSF 2019 Workshop. 2019.

P22- Provide training in low-level gamma-ray spectrometry

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: Marie-Christine Lépy (CEA/LNHB)
Euratom Principal Investigator: Mikael Hult (JRC.G.2)
Timeframe:Started in June 2018 – closed in June 2018

Background

CEA organised a training course on gamma-ray spectrometry at their premises June 12-14, 2018. This course was suggested by the ICRM-GS WG (International Committee for radionuclide metrology – Gamma-ray Spectrometry Working Group) with the goal to reach people already knowing gamma ray spectrometry, wishing to get more detailed information on corrective terms, to improve the quality of results.

Summary

Mikael Hult gave three lectures in the training course on gamma-ray spectrometry organised at the CEA-LNE HQ in Paris. There were 30 participants of whom 4 were from outside Europe, 2 from associated EU-countries and 24 from EU-countries. The other lecturers were Marie-Christine Lépy (CEA), Philippe Cassette (CEA) and Octavian Sima (Bucharest Univ.)

At Day-3 of the event was the ICRM (International Committee for Radionuclide Metrology) Gamma-ray Spectrometry Working Group meeting. At this meting: (1) the ongoing actions (involving both CEA and JRC) were presented and discussed: e.g. comparison of Monte Carlo codes for coincidence summing corrections. (2) New developments were presented: e.g. MH presented the work JRC conducted with SCK•CEN and UHasselt on studies of deadlayer thicknesses in HPGe-detectors. (3) New actions were discussed: e.g. implementation of automatic optimisation of computer models for HPGe-detectors.

Publications

Contributions to conference proceedings and workshops

Presentations presented at ICRM GS WG web-site:

GSWG Meetings and Workshops – Laboratoire National Henri Becquerel (lnhb.fr)

P23- Production and characterisation of 235,238U and Pu thin target layers

Project Domain (Research Field): Nuclear data
CEA Principal Investigator: J. Taieb (CEA/DAM Bruyères-le-Châtel)
Euratom Principal Investigator: G. Sibbens (JRC.G.2)
Timeframe: ongoing

Background

CEA developed a fission chamber for measurements of the characteristics of prompt fission neutron emitted after neutron induced fission of ^{235}U, ^{238}U and ^{239}Pu. The chamber was used in 2017 at LANSCE for measurements of prompt fission neutron spectra emitted after a ^{239}Pu(n,f) reaction. For these measurements 22 thin target layers were prepared by JRC.G.2 as part of the EU CHANDA project. The targets were prepared by molecular plating. Similar ^{235,238}U and ^{239}Pu samples are needed for measurements of neutrons emitted after (n,f) and (n,xn) reactions. For these experiments a new detector was designed and constructed. The measurements will be carried out at the NFS facility at GANIL (FR).

Summary

A set of 22 ^{235}U and 22 ^{238}U thin target layers were prepared and characterized at the TARGET laboratory of JRC.G.2. The targets were prepared by molecular plating on a 25 µm thick Al foil mounted on a ring with inner and outer diameter of 64 mm and 74 mm, respectively. The diameter of the deposit is 33 mm. They were characterized by defined low solid-angle alpha-particle counting. The total average areal density of the ^{235}U and ^{238}U deposits is 262 and 258 µg/cm^2 respectively. The isotopic composition of the U material was determined by mass spectrometry. The ^{235}U and ^{238}U targets were provided to CEA.

The production of the ^{239}Pu deposits with a nominal areal density of 100 µg/cm^2 is scheduled for the first half of 2022. For the production of other targets, i.e. ^{238,240,241,242}Pu, the characteristics are required.

Annex 2. Projects in the framework of the Euratom programme indirect actions

SAMOFAR – id 661891

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-03-2014 - New innovative approaches to reactor safety
Short description : A Paradigm Shift in Reactor Safety with the Molten Salt Fast Reactor
Timeframe: started 1 August 2015 – ended 31 July 2019
Overall budget: € 5 235 071,56
EU contribution: € 3 466 896,50

Summary
Imagine an inherently safe reactor that produces all electricity world-wide for thousands of years, and recycles all actinides until fission. The Molten Salt Fast Reactor (MSFR) can reach this goal, delivering indisputable evidence of the excellent safety features of the MSFR, and to enable a consortium of important stakeholders like TSO's and industry, to advance with the MSFR up to the Demonstration phase.

Dissemination
http://samofar.eu/publications/

ANNETTE – id 661910

Programme(s) : H2020-Euratom-1.3.
Topic(s) : NFRP-10-2015 - Education and training (Bologna and Copenhagen processes)
Short description: Advanced Networking for Nuclear Education and Training and Transfer of Expertise
Timeframe: started 1 January 2016 – ended 31 December 2019
Overall budget: € 3 184 447,50
EU contribution: € 2 517 399

Summary
The present situation of nuclear energy in Europe asks for a continuing effort in the field of Education and Training aimed to assure a qualified workforce in the next decades. In this scenario, the present proposal is aimed at enhancing and networking the Europe-wide efforts initiated in the past decades by different organisations belonging to academia, research centres and industry to maintain and develop Education and Training in the nuclear fields.

Dissemination
https://www.annette.eu/about/deliverables/

SOTERIA – id 661913

Programme(s) : H2020-Euratom-1.8. - H2020-Euratom-1.3. - H2020-Euratom-1.1.
Topic(s) : NFRP-01-2014 - Improved safety design and operation of fission reactors
Short description : Safe long term operation of light water reactors based on improved understanding of radiation effects in nuclear structural materials
Timeframe: started 1 September 2015 – ended 31 August 2019
Overall budget: € 13 888 769,25
EU contribution: € 4 971 297

Summary
The overall aim of the SOTERIA project is to improve the understanding of the ageing phenomena occurring in reactor pressure vessel (RPV) steels and in the internal steels (internals) in order to provide crucial information to regulators and operators to ensure safe long-term operation (LTO) of existing European nuclear power plants (NPPs).

Dissemination
http://www.soteria-project.eu/page/en/media-center.php

IVMR – id 662157

Programme(s) : H2020-Euratom-1.8. - H2020-Euratom-1.3. - H2020-Euratom-1.1.
Topic(s) : NFRP-01-2014 - Improved safety design and operation of fission reactors
Short description : In-Vessel Melt Retention Severe Accident Management Strategy for Existing and Future NPPs
Timeframe: started 1 June 2015 – ended 30 November 2019
Overall budget: € 8 262 989,38
EU contribution: € 4 831 454

Summary
The overall aim of the SOTERIA project is to improve the understanding of the ageing phenomena occurring in reactor pressure vessel (RPV) steels and in the internal steels (internals) in order to provide crucial information to regulators and operators to ensure safe long-term operation (LTO) of existing European nuclear power plants (NPPs).

Dissemination
https://gforge.irsn.fr/gf/project/ivmr/docman/Publications/

MYRTE – id 662186

Programme(s) : H2020-Euratom-1.8. - H2020-Euratom-1.3. - H2020-Euratom-1.4. - H2020-Euratom-1.1.
Topic(s) : NFRP-09-2015 - Transmutation of minor actinides (Towards industrial application)
Short description : MYRRHA Research and Transmutation Endeavour
Timeframe: started 1 April 2015 – ended 30 September 2019
Overall budget: € 11 994 609,99
EU contribution: € 8 995 962

Summary
The Strategic Research Agenda of the EU Sustainable Nuclear Energy Technical platform requires new large infrastructures for its successful deployment. MYRRHA has been identified as a long term supporting research facility for all ESNII systems and as such put in the high-priority list of ESFRI. The goal of MYRTE is to perform the necessary research in order to demonstrate the feasibility of transmutation of high-level waste at industrial scale through the development of the MYRRHA research facility.

Dissemination
https://myrte.sckcen.be/en/Deliverables

INCEFA – PLUS – id 662320

Programme(s) : H2020-Euratom-1.8. - H2020-Euratom-1.3. - H2020-Euratom-1.1.
Topic(s) : NFRP-01-2014 - Improved safety design and operation of fission reactors
Short description : INcreasing Safety in NPPs by Covering gaps in Environmental Fatigue Assessment
Timeframe: started 1 July 2015 – ended 31 October 2020
Overall budget: € 6 140 668,75
EU contribution: € 2 550 128

Summary
INCEFA-PLUS delivers new experimental data and new guidelines for assessment of environmental fatigue damage to ensure safe operation of European nuclear power plants. Austenitic stainless steels will be tested for the effects of mean strain, hold time and material roughness on fatigue endurance. Testing will be in nuclear Light Water Reactor environments. The data obtained will be collected and standardised in an online fatigue database with the objective of organising a CEN workshop on this aspect.

Dissemination
https://incefaplus.unican.es/dissemination-and-training/public-documents/

IL TROVATORE – id 740415

Programme(s) :	H2020-Euratom-1.1.
Topic(s) :	NFRP-1 - Continually improving safety and reliability of Generation II and III reactors
Short description :	Innovative cladding materials for advanced accident-tolerant energy systems
Timeframe:	started 1 October 2017 – 31 March 2022
Overall budget:	€ 5 418 893,75
EU contribution:	€ 4 999 999,25

Summary

The Fukushima Daiichi event has demonstrated the need for improved nuclear energy safety, which can be ensured by the development of accident-tolerant fuels (ATFs). The main objective of IL TROVATORE is to identify the best candidate ATF cladding materials for use in Gen-II and Gen-III/III+ LWRs and to validate them in an industrially-relevant environment, i.e. under neutron irradiation in PWR-like water.

Dissemination

https://www.iltrovatore-h2020.eu/en/Publications/Proceedings

INSPYRE – id 754329

Programme(s) :	H2020-Euratom-1.2.
Topic(s) :	NFRP-5 - Materials research for Generation-IV reactors
Short description :	Investigations Supporting MOX Fuel Licensing in ESNII Prototype Reactors
Timeframe:	started 1 September 2017 – 28 February 2022
Overall budget:	€ 8 500 739,70
EU contribution:	€ 3 998 478,80

Summary

INSPYRE, a proposal fully supported and endorsed by the Steering Committee of the EERA Joint Programme on Nuclear Materials, focusses on the investigation of fast reactor MOX fuel to support the licensing of the start-up cores of the ESNII reactor prototypes.

Dissemination

http://www.eera-jpnm.eu/inspyre/filesharer/documents/

ESFR-SMART – id 754501

Programme(s) :	H2020-Euratom-1.1.
Topic(s) :	NFRP-2 - Research on safety of fast neutron Generation-IV reactors
Short description :	European Sodium Fast Reactor Safety Measures Assessment and Research Tools
Timeframe:	started 1 September 2017 – 31 August 2022
Overall budget:	€ 9 911 150
EU contribution:	€ 5 000 000

Summary

To improve the public acceptance of the future nuclear power in Europe we have to demonstrate that the new reactors have significantly higher safety level compared to traditional reactors. The ESFR-SMART project (European Sodium Fast Reactor Safety Measures Assessment and Research Tools) aims at enhancing further the safety of Generation-IV SFRs and in particular of the commercial-size European Sodium Fast Reactor (ESFR) in accordance with the ESNII roadmap and in close cooperation with the ASTRID program.

Dissemination

https://esfr-smart.eu/resources/

M4F – id 755039

Programme(s) : H2020-Euratom-1.6. - H2020-Euratom-1.1.
Topic(s) : NFRP-13 - Fission/fusion cross-cutting research in the area of multi-scale materials modelling
Short description : MULTISCALE MODELLING FOR FUSION AND FISSION MATERIALS
Timeframe: started 1 September 2017 – 31 December 2021
Overall budget: € 6 524 695,88
EU contribution: € 4 000 000

Summary
The main goal of M4F project is to bring together the fusion and fission materials communities working on the prediction of microstructural-induced irradiation damage and deformation mechanisms of irradiated ferritic/martensitic (F/M) steels. M4F project is a multidisciplinary one, were both modelling and experiments at different scales will be integrated to foster the understanding of complex phenomena associated to the formation and evolution of irradiation induced defects and their role on the deformation behaviour.

Dissemination
https://esfr-smart.eu/resources/

McSAFE – id 755097

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-1 - Continually improving safety and reliability of Generation II and III reactors
Short description : High-Performance Monte Carlo Methods for SAFEty Demonstration- From Proof of Concept to realistic Safety Analysis and Industry-like Applications
Timeframe: started 1 September 2017 – ended 31 August 2020
Overall budget: € 3 140 393,75
EU contribution: € 2 981 592,23

Summary
Considering the priority topics of NUGENIA and the achievements of the EU HPMC project, the overall objective of the McSAFE project is to move the Monte Carlo based stand-alone and coupled solution methodologies to become valuable and widespread numerical tools for realistic core design, safety analysis and industry-like applications of LWRs of generation II and III.

Dissemination
https://www.mcsafe-h2020.eu/

GENIORS – id 755171

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-3 - Investigating the safety of closed nuclear fuel cycle options and fuel developments
Short description : GEN IV Integrated Oxide fuels recycling strategies
Timeframe: started 1 June 2017 – ended 31 May 2021
Overall budget: € 7 515 950,34
EU contribution: € 4 999 699,96

Summary
The current open nuclear fuel cycle uses only a few percent of the energy contained in uranium. This efficiency can be greatly improved through the recycling of spent fuel (as done today in France for instance), including, in the longer term, multi-recycling strategies to be deployed in fast reactors. In this context, GENIORS addresses research and innovation in fuel cycle chemistry and physics for the optimisation of fuel design in line with the strategic research and innovation agenda and deployment strategy of SNETP, notably of its ESNII component.

Dissemination
https://www.geniors.eu/results/

GEMMA – id 755269

Programme(s) : H2020-Euratom-1.2.
Topic(s) : NFRP-5 - Materials research for Generation-IV reactors
Short description : GEneration iv Materials MAturity
Timeframe: started 1 June 2017 – ended 30 November 2021
Overall budget: € 6 625 379,38
EU contribution: € 3 999 182

Summary
The general objective of GEMMA Project is to qualify and codify the selected structural materials for the construction of Generation IV reactors, as envisaged within the European Sustainable Nuclear Industrial Initiative (ESNII). The structural materials, to be considered in the GEMMA project, are those selected by the designers of the ESNII systems for fuel cladding and, in some cases, for the main vessel and the internals. Their qualification means that their resistance to harsh exposure conditions of high temperature, highly corrosive environment and intense flux of fast neutrons, will be experimentally verified and/or numerically modelled.

Dissemination
http://www.eera-jpnm.eu/gemma/filesharer/documents/Project_Related_Publications

DISCO – id 755443

Programme(s) : H2020-Euratom-1.2.
Topic(s) : NFRP-6 - Addressing key priority R&I issues for the first-of-the-kind geological repositories
Short description : Modern spent fuel dissolution and chemistry in failed container conditions
Timeframe: started 1 June 2017 – ended 30 November 2021
Overall budget: € 4 692 067,50
EU contribution: € 3 987 675,50

Summary
While the scientific understanding of the dissolution of standard spent uranium oxide fuel has reached a certain mature state, new types of fuels with additives ("doped fuels") have been developed. These fuels are already in use in some reactors, and their use is foreseen to be expanded. Similarly, there is a dearth of dissolution data from MOX fuels, which are also currently in use in several reactors. This project aims to expand the database on spent fuel dissolution with results from dissolution studies performed in truly reducing conditions, with hydrogen present. The effects of dopants will be investigated through experiments using both spent nuclear fuel and synthetic materials specifically designed for the project.

Dissemination
https://www.disco-h2020.eu/Home/Deliverables
https://www.disco-h2020.eu/Home/PublicationsProject

INSIDER – id 755554

Programme(s) : H2020-Euratom-1.2.
Topic(s) : NFRP-7 - Research and innovation on the overall management of radioactive waste other than geological disposal.
Short description : Improved Nuclear SIte characterization for waste minimization in DD operations under constrained EnviRonment
Timeframe: started 1 June 2017 – ended 30 November 2021
Overall budget: € 4 173 870
EU contribution: € 3 781 064,64

Summary
Decommissioning and dismantling (D&D) operations are strongly dependent on the facilities history and the inventory of present radionuclides. The D&D processes are significant source of radioactive waste and their management is a major challenge from technical, economical, financial and societal point of view. This is recognized in a number of reference documents and studies on EU and international level. These challenges are naturally subject for further optimisation and the ambition of INSIDER project is to contribute to it as follows. For constrained environments new methodologies are necessary for more accurate initial estimation of contaminated materials, resulting waste volumes and timely planning.

Dissemination
https://insider-h2020.eu/results/

ENENplus - id 755576

Programme(s) : H2020-Euratom-1.3.
Topic(s) : NFRP-12 - Support for careers in the nuclear field
Short description : Attract, Retain and Develop New Nuclear Talents Beyond Academic Curricula
Timeframe: started 1 October 2017 – ended 30 November 2021
Overall budget: € 3 258 062,50
EU contribution: € 2 986 188

Summary
The primary motivation of the ENEN+ project is to substantially contribute to the revival of the interest of young generations in the careers in nuclear sector. Integration of further nuclear disciplines (e.g. nuclear chemistry, decommissioning, fusion engineering…) and sustainability of the ENEN+ accomplishments beyond the project life of is foreseen within the existing ENEN Association and its members and partnering of ENEN association with ongoing and proposed projects. A mobility fund of more than 1.000.000 EUR for European students researchers and learners is established in the project.

Dissemination
https://plus.enen.eu/

MUSA - id 847441

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-2018-1 - Safety assessments to improve accident management strategies for Generation II & III reactors
Short description : MANAGEMENT AND UNCERTAINTIES OF SEVERE ACCIDENTS
Timeframe: started 1 June 2019 – 31 May 2023
Overall budget: € 5 768 452,50
EU contribution: € 3 186 503,05

Summary
The continuous efforts to raise nuclear safety to the highest standards possible has pointed the need to assess the methodologies used in severe accident simulation. The overall objective of the MUSA project is to assess the capability of severe accident codes when modelling reactor and SFP (Spent Fuel Pool) accident scenarios of Gen II and Gen III reactor designs.

Dissemination
https://musa-h2020.eu/results/

SAMOSAFER - id 847527

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-2018-2 - Model development and safety assessments for Generation IV reactors
Short description : Severe Accident Modeling and Safety Assessment for Fluid-fuel Energy Reactors
Timeframe: started 1 October 2019 – 30 September 2023
Overall budget: € 4 535 245
EU contribution: € 3 498 000

Summary
Molten salt reactors (MSRs) are one of several next-generation (Gen IV) nuclear reactor designs under development today. Efforts to revive older nuclear designs have been bubbling up in the EU, Russia and US, and many start-ups are trying to commercialise the technology. Further work is needed to test the safety of the reactor and the nuclear fuel cycle facilities, and demonstrate the path towards technology licensing and deployment. The EU-funded SAMOSAFER project will use advanced numerical and experimental techniques to prove the safety of MSRs.

Dissemination

https://samosafer.eu/publications/

SANDA - id 847552

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-2018-4 - Improved nuclear data for energy and non-energy modelling applications.
Short description : Supplying Accurate Nuclear Data for energy and non-energy Applications
Timeframe: started 1 September 2019 – 31 August 2023
Overall budget: € 4 666 600
EU contribution: € 3 499 948

Summary
Accurate nuclear data are of fundamental importance in a number of different nuclear and non-nuclear fields. The EU-funded SANDA project aims to produce a data library containing high-quality nuclear measurements on key isotopes and reactions. The project puts special focus on how data is measured, evaluated and validated. SANDA aims to widely and efficiently disseminate its results through the Nuclear Energy Agency (NEA) and the International Atomic Energy Agency (IAEA).

Dissemination
http://www.sanda-nd.eu/access-open-research-data-project

ELSMOR - id 847553

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-2018-3 - Research on the safety of Light Water Small Modular Reactors
Short description : Towards European Licencing of Small Modular Reactors
Timeframe: started 1 September 2019 – 28 February 2023
Overall budget: € 4 279 581
EU contribution: € 3 494 703,56

Summary
Light water small modular reactors (LW-SMRs) are a promising new technology whose features make them a potentially attractive energy source. The EU-funded ELSMOR project seeks to design methods and tools for stakeholders to assess and verify LW-SMRs' safety when installed across Europe. The project will devise procedures to evaluate their safety, enhance European experimental research infrastructure to help in assessing future LW-SMR safety features, and enrich European nuclear safety analysis codes for evaluating future LW-SMR safety. Ultimately, the licensing procedure will be smoother and more complete.

Dissemination
http://www.elsmor.eu/

EURAD - id 847593

Programme(s) : H2020-Euratom-1.2.
Topic(s) : NFRP-2018-6 - European Joint Research Programme in the management and disposal of radioactive waste
Short description : European Joint Programme on Radioactive Waste Management
Timeframe: started 1 June 2019 – 31 May 2024
Overall budget: € 59 922 246,61
EU contribution: € 32 500 000

Summary
EURAD will help the EU member states to implement the Waste Directive by working with their national programmes. It will also coordinate action on joint targets among all related organisations involved at European level, whether in research or technical support. Building on the JOPRAD project, the EURAD project will help member states to obtain the know-how required to implement safe and long-term management of radioactive waste.

Dissemination
https://www.ejp-eurad.eu/publications

ARIEL – id 847594

Programme(s) : H2020-Euratom-1.8.
Topic(s) : NFRP-2018-7 - Availability and use of research infrastructures for education, training and competence building
Short description : AVAILABILITY AND USE OF NUCLEAR DATA RESEARCH INFRASTRUCTURES FOR EDUCATION AND LEARNING
Timeframe: started 1 September 2019 – 29 February 2024
Overall budget: € 1 998 670
EU contribution: € 1 998 670

Summary
Accurate and precise nuclear data are a basis for the development and safety improvement of nuclear technology. The ARIEL project will provide an opportunity for 90 early-stage researchers and technicians to learn from international experts at 23 accelerator- or reactor-based neutron beam facilities. The project will focus on experimental work, adding a minimum total of 3 000 beam-time hours to the experience of applicants.

Dissemination
https://www.ariel-h2020.eu/index.php/en/

SHARE – id 847626

Programme(s) : H2020-Euratom-1.1.
Topic(s) : NFRP-2018-5 - Development of a roadmap for decommissioning research aiming at safety improvement, environmental impact minimisation and cost reduction
Short description : StakeHolder-based Analysis of REsearch for Decommissioning.
Timeframe: started 1 June 2019 – 31 March 2022
Overall budget: € 1 525 925
EU contribution: € 1 413 159,25

Summary
The decommissioning process of nuclear facilities raises concerns related to safety, costs and potential environmental hazards. The EU-funded SHARE project will offer comprehensive guidelines for research allowing stakeholders to address threats and challenges, decrease costs, and improve safety. The project intends to increase confidence in the decommissioning process and support policymakers to determine areas eligible for a financial contribution. In addition, it will encourage synergies between stakeholders and other international foundations and will attract research institutions.

Dissemination
https://share-h2020.eu/

JHOP2040 – id 899360

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-16 - Roadmap for use of Euratom access rights to Jules Horowitz Reactor experimental capacity
Short description : JULES HOROWITZ OPERATION PLAN 2040
Timeframe: started 1 September 2020 – 28 February 2023
Overall budget: € 1 572 117,50
EU contribution: € 1 100 501,20

Summary
The Jules Horowitz Reactor (JHR) is a materials testing reactor currently under construction, which will be used for testing fuel and materials behaviour under irradiation, enhancing the safety of current and future nuclear reactors. The JHR will also produce radioisotopes for nuclear medicine and non-nuclear industrial applications. The plan is to accommodate approximately 20 experiments per year with instrumentation accessing previously impossible analyses. The EU-funded JHOP2040 project is supporting the development of the JHR strategic research roadmap through 2040.

Dissemination
http://www-rjh.cea.fr/index.html

ORIENT-NM - id 899997

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-08 - Towards joint European effort in area of nuclear materials
Short description : ORGANISATION OF THE EUROPEAN RESEARCH COMMUNITY ON NUCLEAR MATERIALS
Timeframe: started 1 October 2020 – 31 March 2023
Overall budget: € 1 756 380
EU contribution: € 1 099 588,75

Summary
Nuclear power will play a key role in the energy transition. Materials are key for safety, efficiency and economy of nuclear energy. Hence the importance of funding research on nuclear materials through stable and highly cooperative instruments, as in a European Joint Programme, or Co-funded European Partnership (CEP) in HEu. The ORIENT-NM project will set the basis for launching a CEP on nuclear materials. The project will produce a convincing strategic research agenda for materials for all nuclear reactor generations and develop an efficient CEP governance and legal structure, as well as implementation scheme.

Dissemination
http://www.eera-jpnm.eu/orient-nm/filesharer/documents/

PUMMA – id 945022

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-06 - Safety Research and Innovation for advanced nuclear systems
Short description : Plutonium Management for More Agility
Timeframe: started 1 October 2020 – 30 September 2024
Overall budget: € 6 749 591,25
EU contribution: € 3 795 800,50

Summary
Outlining different options for plutonium management in future reactor systems
Current knowledge on how mixed oxide (MOX) fuel behaves in Generation-IV reactors is mainly obtained from feedback on earlier European sodium-cooled fast reactors. However, this knowledge cannot meet future needs regarding reactors, plutonium management or operating regimes. To address this problem, PUMMA project aims to outline various options for plutonium management in Generation-IV systems.

Dissemination
https://pumma-h2020.eu/

McSAFER – id 945063

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-05 - Support for safety research of Small Modular Reactors
Short description : High-Performance Advanced Methods and Experimental Investigations for the Safety Evaluation of Generic Small Modular Reactors
Timeframe: started 1 September 2020 – 31 August 2023
Overall budget: € 4 045 133,75
EU contribution: € 3 995 982,50

Summary
SMRs have the potential to provide safe and flexible nuclear power generation options. To further this potential, McSAFER project aims to improve safety research for SMRs. It will do so by combining dedicated experimental investigations and numerical simulations. It will carry out experiments on European thermal hydraulic test facilities in order to investigate SMR-specific safety-relevant phenomena. Additionally, the project will use advanced computational tools to conduct neutron-physical, thermal hydraulic and thermo-mechanic analyses of the reactor core of different SMR designs.

Dissemination
https://mcsafer-h2020.eu/

PATRICIA – id 945077

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-07 - Safety Research and Innovation for Partitioning and/or Transmutation
Short description : Partitioning And Transmuter Research Initiative in a Collaborative Innovation Action
Timeframe: started 1 September 2020 – 31 August 2024
Overall budget: € 8 489 440,63
EU contribution: € 6 499 979,50

Summary
Nuclear power has low CO_2 emissions and is a sustainable energy source. The solution for achieving reduced nuclear waste is to recycle spent fuel. To address this challenge, the PATRICIA project aims to follow the EU's plan for sustainable nuclear energy that describes the technical needs of fuel recycling. To this end, the project will investigate advanced partitioning to efficiently separate the radioactive chemical americium from spent fuel, and it will study the development of transmutation systems. It will also explore the behaviour of americium-bearing fuel under irradiation and conduct safety-related research.

Dissemination
https://patricia-h2020.eu/

PREDIS – id 945098

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-10 - Developing pre-disposal activities identified in the scope of the European Joint Programme in Radioactive Waste Management
Short description : PRE-DISposal management of radioactive waste
Timeframe: started 1 September 2020 – 31 August 2024
Overall budget: € 23 773 742,75
EU contribution: € 14 000 000

Summary
The PREDIS project aims to develop and carry out activities for the pre-disposal treatment of radioactive waste – not including nuclear fuel and high-level radioactive waste. To this end, it will advance treatment and conditioning methodologies for waste for which no adequate or industrially mature solutions currently exist. It will also test and assess innovations in cemented waste handling and pre-disposal storage. The tools produced by the project will guide decision making on the developed technologies and their impact on waste management and disposal.

Dissemination
https://predis-h2020.eu/

INCEFA-SCALE – id 945300

Programme(s) : H2020-Euratom-1.
Topic(s) : NFRP-2019-2020-01 - Ageing phenomena of components and structures and operational issues
Short description : INcreasing safety in NPPs by Covering gaps in Environmental Fatigue Assessment - focusing on gaps between laboratory data and component SCALE
Timeframe: started 1 October 2020 – 30 September 2025
Overall budget: € 6 807 417,50
EU contribution: € 3 999 999,82

Summary
Effective methods for predicting component lifetimes are needed to ensure that nuclear power plants operate safely and reliably. Component-scale environmental fatigue tests are expected to advance these methods. However, limited test data restricts the transferability of laboratory-scale tests to real component geometries and loadings. To address this challenge, the INCEFA-SCALE project intends to enhance the ability to predict the lifetimes of nuclear plant components when they are subjected to environmentally-assisted fatigue. The project will contribute to the advanced prediction of nuclear power plant component lifetimes.

Dissemination
https://snetp.eu/portfolio-items/incefa-scale/

NUCOBAM – id 945313

Programme(s) :	H2020-Euratom-1.
Topic(s) :	NFRP-2019-2020-04 - Innovation for Generation II and III reactors
Short description :	NUclear COmponents Based on Additive Manufacturing
Timeframe:	started 1 October 2020 – 30 September 2024
Overall budget:	€ 4 067 916,75
EU contribution:	€ 2 999 324,85

Summary
Additive manufacturing (AM) will make it possible for the nuclear industry to tackle the problems related to obsolete components and reactor efficiency and safety. The NUCOBAM project therefore aims to develop the qualification process and evaluate the in-service behaviour of AM materials, allowing the use of additively manufactured components in nuclear installations. To this end, it will research how to implement AM processes in nuclear design codes and standards in order to create components for nuclear power generation equipment.

Dissemination
https://snetp.eu/portfolio-items/nucobam/

Annex 3. Projects in the framework of H2020

Excellent Science	***Infrastructures (EU 1.4)***
EUNCL id 654190	European Nanomedicine Characterization Laboratory
SERA id 730900	Seismology and Earthquake Engineering Research Infrastructure Alliance for Europe
ERIGrid 2.0 id 870620	European Research Infrastructure supporting Smart Grid and Smart Energy Systems Research, Technology Development, Validation and Roll Out - Second Edition
NEP id 101007417	Nanoscience Foundries and Fine Analysis - Europe|PILOT
ATMO-ACCESS id 101008004	Solutions for Sustainable Access to Atmospheric Research Facilities
PRISMAP id 101008571	The European medical isotope programme: Production of high purity isotopes by mass separation

Industrial Leadership	***Leadership in enabling & industrial technologies (EU 2.1)***
NanoREG II id 646221	Development and implementation of Grouping and Safe-by-Design approaches within regulatory frameworks
REFINE id 761104	Regulatory Science Framework for Nano(bio)material-based Medical Products and Devices
CHE id 776186	CO2 Human Emissions
CoCO2 id 958927	Prototype system for a Copernicus CO2 service

Societal Challenges	***Smart, green & integrated transport (EU 3.4)***
SHOW id 875530	SHared automation Operating models for Worldwide adoption
	Climate action, environment, resource efficiency & raw materials (EU 3.5)
SCRREN id 730227	Solutions for CRitical Raw materials - a European Expert Network
VERIFY id 776810	Observation-based system for monitoring and verification of greenhouse gases
SCREEN2 id 958211	Solutions for CRitical Raw materials - a European Expert Network 2

Annex 4. Examples of collaborative work

1. Production of nuclear data

Improved evaluated data files for neutron induced interactions with ^{175}Lu and ^{241}Am in the resonance region were produced. The improved data rely on results of experiments at GELINA as part of the EUFRAT open access project and integral experiments at the MINERVE reactor, which were carried out in a collaborative effort with CEA/DEN Cadarache and CEA/DAM Bruyères-le-Châtel. The results of these evaluations were published in journal papers and adopted in the JEFF-3.3 library.

Publications

Geslot et al. , "Americium-241 integral radiative capture cross section in over-moderated neutron spectrum from pile oscillator measurements in the Minerve reactor", EPJ Journal Web of Conferences 146 (2017) 06016

Noguere et al. , "s-wave average neutron resonance parameters of ^{175}Lu + n", Physical Review C 100 (2019) 065806

Harada et al., "Improving Nuclear Data Accuracy of the ^{241}Am Capture Cross-section", Nuclear Science, NEA/NSC/R(2020)2

Plompen et al., "The Joint Evaluated Fission and Fusion Nuclear Data Library, JEFF-3.3", European Physics Journal A 56 (2020) 181

2. Development of innovative detectors and measurement techniques

The GELINA facility was used to test the performance of two innovative detection systems that were developed at CEA for use at the n_TOF facility at CERN:

- a segmented MICROMEGAS based on the microbulk technology with an embedded XY structure
- an ionisation chamber used as fission tag detector for fission and capture cross sections of actinides

The testing of the ionisation chamber was part of the PhD thesis of M. Bacak (CEA/DSM Saclay).

Publications

Diakaki et al., "Development of a novel segmented mesh MicroMegas detector for neutron beam profiling", Nuclear Instruments and Methods A 903 (2018) 46

Bacak et al., "A compact fission detector for fission-tagging neutron capture experiments with radioactive fissile isotopes", Nuclear Instruments and Methods A 969 (2020) 163981

Bacak et al., "Preliminary results on the ^{233}U α-ratio measurement at n_TOF", EPJ Journal Web of Conferences 146 (2017) 03027

3. Production and characterisation of reference material

JRC.G.2 produced and certified a reference material including 60Co for nuclear decommissioning. CEA/LHNB assisted in the characterisation of the disks and reviewed the certification procedure.

A set of 14 thin ^{233}U layers were produced and characterised at the TARGET laboratory of the JRC.G.2. These layers were used for neutron induced capture and fission cross section measurements at the n_TOF facility at CERN.

In the open access project URANIUM_NRTA the composition of the uranium disks used in the INTEGRAAL project was verified by neutron transmission measurements at the GELINA facility. The experiments are finished and the data analysis is in progress.

4. ANR CEA/JRC – collaborative project approved

A joint research project from CEA/DRF Saclay and JRC.G.2 in response to a call for proposals by the Agence Nationale de la Recherche (ANR) in France was accepted. The proposal entitled "Temporal and spatial detection of charged particles by neutron-induced reactions" aims at developing a neutron-transparent detector based on the Micromegas technology, capable of providing time, position and angular information. The proposal was submitted in the category "Projet de Recherche Collaborative (PRC)" for which the success rate was 15%. The project strongly relies on a collaboration with the JRC and in particular on experimental activities at the GELINA facility and the target preparation laboratory.

Annex 5. Projects in the framework of the collaboration agreement on Security Research

C-BORD – id 653323

Programme(s) : H2020-EU.3.7. - Secure societies - Protecting freedom and security of Europe and its citizens
Topic(s) : BES-09-2014 - Supply Chain Security topic 2: Technologies for inspections of large volume freight
Short description : effective Container inspection at BORDer control points
Timeframe: started 1 June 2015 – ended 30 November 2018
Overall budget: € 11 826 452,50
EU contribution: € 11 826 452,50

Summary
Efficient NII (non-intrusive inspection) of containerised freight is critical to trade and society. Freight containers are potential means for smuggling (e.g. tobacco), illegal immigration, trafficking of drugs, mis-declared goods and dangerous illicit substances, including explosives, nuclear material, chemical and biological warfare agents and radioactively contaminated goods. The C-BORD Toolbox and Framework will address all these targets and enable customs to deploy comprehensive cost-effective container NII solutions to potentially protect all EU sea and land-borders, satisfying a large range of container NII needs.

Dissemination
https://www.cbord-h2020.eu/

EuroBioTox – id 740189

Programme(s) : H2020-EU.3.7. - Secure societies - Protecting freedom and security of Europe and its citizens
Topic(s) : SEC-03-DRS-2016 - Validation of biological toxins measurements after an incident: Development of tools and procedures for quality control
Short description : European programme for the establishment of validated procedures for the detection and identification of biological toxins
Timeframe: started 1 June 2017 – 31 December 2022
Overall budget: € 9 526 721,25
EU contribution: € 7 998 747

Summary
Recent incidents in Europe and worldwide have threatened civil society by the attempted use of different biological toxins and have thereby shown that increased vigilance and adequate preparation is of increasing importance in a world facing growing risks of man-made disasters. Previous studies which the consortium is well acquainted with showed that there is a lack of robustness in European preparedness for biotoxin incidents. There is a need for standard analytical tools and procedures, reference materials, state-of-the-art training and establishment of a European proficiency testing scheme.

Dissemination
https://eurobiotox.eu/

ENTRANCE – id 883424

Programme(s) : H2020-EU.3.7. - Secure societies - Protecting freedom and security of Europe and its citizens
Topic(s) : SU-BES02-2018-2019-2020 - Technologies to enhance border and external security
Short description : EfficieNT Risk-bAsed iNspection of freight Crossing bordErs without disrupting business
Timeframe: started 1 October 2020 – 30 September 2023
Overall budget: € 6 998 686,25
EU contribution: € 6 398 686,25

Summary
The ENTRANCE project aims to develop and validate a comprehensive user-based toolbox for the risk-based non-intrusive inspection of cross-border freight movements, particularly at the EU Customs Union borders. The aim of this toolbox is to enhance the capabilities of border security practitioners, shielding against a wide range of dangerous and illicit materials with minimum disruption in the cross-border flow of goods.

Annex 6. Co-publications

Remarks:

- This list considers publications from 2017 to mid-2021
- Publications are referenced as follows: Review Volume (Issue) (First page) (Article number)

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