Proposal for a Nuclear Talent course at the ECT* in 2017: Theory for Exploring Nuclear Structure Experiments

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Proposal for a Nuclear Talent course at the ECT* in 2017

We would like to propose a three-week Nuclear Talent course on Theory for exploring nuclear structure experiments at the ECT* for the summer of 2017. A similar course was run and organized at Ganil by Rick Casten and Piet van Isacker in 2014. The course was oversubscribed with more than 60 student applications, clearly demonstrating the need in the community for the selected topics. We believe such a course has a strong potential to attract many students, theorists and experimentalists alike. Since the Nuclear Talent initiative aims at proposing the various courses in cycles of three to four years, it is timely to propose the above course again. This course provides a hands-on approach to experimental data and their interpretations.

Below we give a short motivation for the proposed course and the rationale behind the Nuclear Talent initiative. Thereafter we detail our course plans with learning outcomes, objectives and teaching philosophy, as well as various organizational and practical matters. The teaching teams consists of both theorists and experimentalists. We believe such a mix is important as it gives the students a better

Motivation

To understand why matter is stable, and thereby shed light on the limits of nuclear stability, is one of the overarching aims and intellectual challenges of basic research in nuclear physics. To relate the stability of matter to the underlying fundamental forces and particles of nature as manifested in nuclear matter, is central to present and planned rare isotope facilities.

Important properties of nuclear systems which can reveal information about these topics are for example masses, and thereby binding energies, and density distributions of nuclei. These are quantities which convey important information on the shell structure of nuclei, with their pertinent magic numbers and shell closures or the eventual disappearence of the latter away from the valley of stability.

During the last decade, the study of nuclear structure and the models used to describe atomic nuclei are experiencing a renaissance. This is driven by three technological revolutions: accelerators capable of producing and accelerating exotic nuclei far from stability; instrumentation capable of detecting the resulting

Introduction to the Talent Courses

A recently established initiative, Training in Advanced Low Energy Nuclear Theory, aims at providing an advanced and comprehensive training to graduate students and young researchers in low-energy nuclear theory. The initiative is a multinational network between several European and Northern American institutions and aims at developing a broad curriculum that will provide the platform for a cutting-edge theory for understanding nuclei and nuclear reactions. These objectives will be met by offering series of lectures, commissioned from experienced teachers in nuclear theory. The educational material generated under this program will be collected in the form of WEB-based courses, textbooks, and a variety of modern educational resources. No such all-encompassing material is available at present; its development will allow dispersed university groups to profit from the best expertise available.
The Nuclear Talent initiative has (as of May 2016) organized and run successfully nine advanced courses since the summer of 2012. Three of these courses have been run and organized (in a very successful way) at the premises of the ECT*. We hope thus, if this

Aims and Learning Outcomes

This three-week TALENT course on nuclear theory will focus on the interpretation of data on the structure of nuclei using the Nuclear shell model as main tool.

Format: We propose approximately forty-five hours of lectures over three weeks and a comparable amount of practical computer and exercise sessions, including the setting of individual problems and the organization of various individual projects.

The mornings will consist of lectures and the afternoons will be devoted to exercises meant to shed light on the exposed theory, the computational projects and individual student projects. These components will be coordinated to foster student engagement, maximize learning and create lasting value for the students. For the benefit of the TALENT series and of the community, material (courses, slides, problems and solutions, reports on students' projects) will be made publicly available using version control software like *git* and posted electronically on github.

As with previous TALENT courses, we envision the following features for the afternoon sessions:

Course Content and detailed plan

Week 1.

	Lecture Topics	
Monday	Introduction and discussion of data	Discuss
	Hamiltonians and mean field	D
Tuesday	Mean field models and Hartree-Fock theory	D
Wednesday	Second quantization and shell-model basics	
	Experiments and data that justify a mean-field interpretation	
Thursday	Shell-model code for a simple pairing problem	
	Basic shell-model algorithm	
Friday	Writing a shell-model program for the simple pairing problem	

Week 2.

	Lecture Topics	
Monday	Shell-model Hamiltonians and the *sd*-shell as case	Exte
	Efficient computations of Hamiltonian matrices	
Tuesday	Effective Hamiltonians and angular momentum algebra	Bit representa
Wednesday	Effective Hamiltonians from data	
Thursday	Electromagnetic decays, theory and experiment	Co
	Onebody transitions and what can be measured	
Friday	Electromagnetic decays, theory and experiment	
	Introducing NushellX	Demon

Week 3

Teaching

The course will be taught as an intensive course of duration of three weeks, with a total time of 45 h of lectures, 45 h of exercises and a final assignment of 2 weeks of work. The total load will be approximately 160-170 hours, corresponding to **7 ECTS** in Europe. The final assignment will be graded with marks A, B, C, D, E and failed for Master students and passed/not passed for PhD students. A course certificate will be issued for students requiring it from the University of Trento.

The organization of a typical course day is as follows:

Time	Activity
9am-12pm	Lectures, project relevant information and directed exercises
12pm-2pm	Lunch
2pm-6pm	Computational projects, exercises and hands-on sessions
6pm-7pm	Wrap-up of the day and eventual student presentations

If approved byt the ECT* board of directors, our preferred time slot would be from the second half of June till the second half of July.

Teachers and organizers

The organizers are

1. Alex Brown, National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
2. Morten Hjorth-Jensen, National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA

Morten Hjorth-Jensen will also function as student advisor and coordinator.
The teachers are

1. Alex Brown, National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA
2. Alexandra Gade National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA

Audience and Prerequisites

Students and post-doctoral fellows interested in models for nuclear structure, phenomenological techniques for interpreting and predicting the structure of stable as well as exotic nuclei. The material will be of interest, and accessible, to both theorists and experimentalists, and will include learning the practical use of shell-model approaches in order to interpret and study nuclear structure experiments.

The students are expected to have operating programming skills in in compiled programming languages like Fortran or C++ or alternatively an interpreted language like Python and knowledge of quantum mechanics at an intermediate level. Preparatory modules on second quantization, Wick's theorem, representation of Hamiltonians and calculations of Hamiltonian matrix elements, independent particle models and Hartree-Fock theory are provided at the website of the course. Students who have not studied the above topics are expected to gain this knowledge prior to attendance. Additional modules for self-teaching on Fortran and/or C++ or Python are also provided.

Admission

The target group is Master of Science students, PhD students and early post-doctoral fellows. Also senior staff can attend but they have to be self-supported. The maximum number of students is 20-25, of which only at most 15 can receive full local support. The process of selections of the students will be managed in agreement with the ECT*.

Preliminary budget

We expect to accept between 20-25 students. Local students from the University of Trento are fully self-supported. If approved, we would very much appreciate if the ECT* can sponsor 15 of the selected students with local expenses, that is lodging and meals during weekdays. Any additional funds for sponsoring further students is highly appreciated. All travel expenses will be covered by the respective home institute. Teachers are self-supported. We plan to raise additional funds to cover local support for additional students and the expenses of the teachers.
There is no participation fee. Administrative support from the ECT* in organizing the course and setting up the application procedure is essential for a smooth (as always) outcome. The administrative experience of the staff at the ECT* has been unique and essential in running successully our previous Talent courses (2012, 2014 and 2015). We would thus highly appreciate it if these services are provided if the proposal is approved.