Program for Nuclear Talent course on *Many-body methods for nuclear physics, from Structure to Reactions* at Henan Normal University, P.R. China, July 16-August 5 2018

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Motivation and introduction

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 disappearance 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

Aims and Learning Outcomes

This three-week TALENT course on nuclear theory will focus on the Many-body methods for nuclear structure and reactions, focusing on nuclear shell model and/or coupled cluster theory and in-medium SRG with applications to structure and reactions. Via hands-on projects and series of exercise, the participants will have been exposed to the necessary tools and theoretical models used in modern nuclear theory.

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 course starts July 16 (with arrival on July 15) and ends (the course) on August 3. A three days workshop will be organized from August 4 to August 6. The mornings will consist of lectures and the afternoons will be devoted to exercises meant to shed light on the exposed theory, and the computational 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

Teachers and organizers

The local organizers are

1. Chun-Wang Ma at Henan Normal University, Xinxiang, Henan 453007, P.R. China
2. Furong Xu at School of Physics, Peking University, Beijing 100871, P.R. China
3. Shan-Gui Zhou at the Institute of Theoretical Physics, Chinese Academy of Sciences, Beijing 100864, P.R. China

In addition Qiao Chunyuan will help with administrative matters. You can reach her at the email address qiaochunyuan919@126.com.

Thomas Papenbrock and Morten Hjorth-Jensen will also function as student advisors and coordinators.

The teachers are

1. Kevin Fossez at National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA
2. Morten Hjorth-Jensen at National Superconducting Cyclotron

Course Content and detailed plan

Lectures are approximately 45 min each with a small break between each lecture. The morning sessions are scheduled to end around 1230pm. Every Friday we will have presentations from each group, where a summary of what has been achieved is presented.

Lectures and preparatory material on second quantization are all available at the Github address of the course, or go to URL:https://nucleartalent.github.io/ManyBody2018/doc/web/course.htm for an easier read.

Furthermore, we strongly recommend that you read chapter 8 and 10 of Lecture Notes in Physics 936. This text contains also links to all codes we will discuss, in addition to the codes we have placed in the program folder of the course. If you cannot access the pdf file of the above text, you can reach chapters 8 and 10 via their respective arXiv versions, click here for chapter 8 and here for chapter 10.

Furthermore, for Coupled Cluster theory the review of Crawford and Schaefer III, An Introduction to Coupled Cluster Theory for Computational Chemists is highly recommended.

Week 1

Day		Lecture Topics and lecturer
Monday	830am-1230pm	Welcome and introduction (Orga
		Second quantization and Hamiltonia
	1230pm-230pm	Lunch + own activities
	230pm-6pm	Getting started with Pairing Hami
Tuesday	9am-11am	Full configuration interaction theory
	1130am-1230pm	Pairing in Nuclear Physics (YM
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Wednesday	9am-1230am	Full configuration interaction theory and the pairing
	11am-1230pm	Pairing in Nuclear Physics (YM
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Thursday	9am-11pm	Full configuration interaction theory
		Hartree-Fock theory and links to Coupled
	1130am-1230pm	Pairing in Nuclear Physics (YM
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Friday	9am-1230pm	Pairing in nuclear physics and summary of 1
	1230pm-230pm	Lunch + own activities
	230pm-6pm	Group presentations of weekly w

Week 2

Day		Lecture Topics and lecturer
Monday	9am-1230pm	Introduction to Coupled Cluster (CC) theory
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Tuesday	9am-1230pm	Developing a CC code for the pairing model
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Wednesday	9am-11am	CC theory and Infinite Matter (TP)
	1130am-1230pm	Computational CC theory for closed and open shell
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Thursday	9am-1030am	Summary of CC theory and infinite matter (
	11am-1230pm	Machine learning applied to CC theory (W
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Friday	9am-11am	From structure to reaction theory (TP)
	1130am-1230pm	Summary of second week and links to IMSRG
	1230pm-230pm	Lunch + own activities
	230pm-6pm	Group presentations of weekly work

Week 3

Day		Lecture Topics and lecturer
Sunday	9am-1230pm	SRG theory (RS)
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Monday	9am-12:30pm	IMSRG and infinite matter (RS)
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Tuesday	9am-1100am	Bergreen basis, the continuum, and IMSRG (K
	1130am-1230pm	Many-body perturbation theory calculations (B
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Wednesday	9am-1230pm	Bergreen basis, the continuum, and IMSRG (K
	1230pm-230pm	Lunch + own activities
	230pm-6pm	
Thursday	9am-1030am	Summary Bergreen basis, the continuum, and IMSR
	11am-1230pm	Summary of school
	1230pm-230pm	Lunch + own activities
	230pm-6pm	Final group presentations
Friday	All day	Workshop, see own program
Saturday	All day	Workshop, see own program

Teaching and projects

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, with the possibility to complete a final assignment if credits are needed.

The organization of a typical course day is as follows:

Time	Activity
9am-1230pm	Lectures, project relevant information and directed exercises
1230pm-230pm	Lunch
230pm-6pm	Computational projects, exercises and hands-on sessions
6pm-7pm	Wrap-up of the day and eventual student presentations

Audience and Prerequisites

You 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.