Nuclear Physics courses, FRIB theory alliance and Nuclear TALENT

Morten Hjorth-Jensen, National Superconducting Cyclotron Laboratory and Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA & Department of Physics, University of Oslo, Oslo, Norway

February 6 2016

Motivation

- Develop structured courses/modules which will provide our students with a modern education in nuclear physics
- Modules/courses should contain a high-level of synchronization
- A computational perspective is essential
- Can the FRIB theory alliance can function as the national coordinating unit?
- Coordination with the Nuclear TALENT initiative?
- Develop learning outcomes?

What are our needs and how do we contribute to the community as a whole?

Local situation at MSU

We have at MSU a

- basic survey course PHY802 and three basic nuclear physics courses
- structure,
- reactions and dynamics and
- Nuclear Astrophysics.

These basic courses have a duration each of 30-40 hours (2-3 credits).
They are taught as regular one semester courses. There are also experimental courses not discussed here.
We have also an advanced course on Special topics in Nuclear Physics, reaction theory, PHY 989.

Nuclear structure course/module PHY981

- Experimental information
- Single-particle properties and mean-field
- second quantization
- Hartree-Fock theory
- Nuclear forces
- Shell model
- Transitions (EM and β-decays
- Computational elements: build a Hartree-Fock code and/or a shell model code (diagonalization)
- etc

Nuclear dynamics course/module PHY982

- Direct reaction theory and applications
- Reactions of light and heavy ions, from low to relativistic energies
- Single-channel scattering
- Integral forms for scattering. Generalizing to many channels
- Collective couplings. Single-particle couplings. Coupling to the continuum
- Transfer reactions. Breakup reactions
- Adiabatic reaction models. Semiclassical approximations (Eikonal and time-dependent approaches)
- Capture and fusion reactions
- R-matrix methods
- Microscopic models for reactions
- Several computational exercises
- etc

Nuclear astrophysics course/module PHY983

- Neutrinos
- Equation of state for dense matter
- Masses - Stability and Decay
- Reaction Rates
- Beta decay Rates
- The Life of Stars: Stellar burning stages, Hydogen burning, Other burning stages
- The Death of Stars: Supernovae, Neutron Stars and White Dwarfs
- Beyond Iron I: r-process, s- and p-process
- Hydrogen burning at the extremes, the rp process
- etc

Advanced modules and more needs, NSCL

- PHY 989 Special topics in nuclear physics, fall 2015 (Pawel and Bill), advanced reaction theory
- Alex Brown has suggested a special course on Nuclear shell model studies, based on the background (and learning outcomes) from PHY 981, nuclear structure
- We will most likely need an advanced module on field theory (LQCD, electroweak theory, fundamental symmetries)

Student background and our education

- Heterogenous group of students with varying background
  - Only few students have a good training in scientific computing
  - Learn computing by looking at recipes, no deep learning and competence
  - Difficult to transfer to new problems
- Need a more coherent education in computational science and physics
  - FRIB/NSCL adn PA in collaboration with CSME develop strategies for including computational elements in basic education and graduate education.

Computing competence is in general weak or lacks totally.

Courses in computational science and physics

- Computational Physics PHY 480/905(section 002)
- PHY 905 (section 004) High-performance computing"
- Scattered elements of computations here and there (**not a complete list**)
  - PHY 981 Nuclear structure: students write a Hartree-Fock program and a shell-model program
  - PHY 982 Nuclear dynamics: students analyse nuclear reactions using FRESCO

Many possible paths in order to improve the situation:

- Proper graduate course(s) in computational physics
- Computational projects in nuclear physics courses
- Most Nuclear Talent courses have computational projects

Advanced modules, Nuclear Talent

1. Nuclear forces (INT 2013)
2. Many-body methods (GANIL July 2015)
3. Few-body methods for nuclear physics (ECT* July-August 2015)
4. Density functional theory and self-consistent methods
   - ECT* 2014
   - York UK 2016
5. Theory for exploring nuclear structure experiments (GANIL 2014)
6. Theory for exploring nuclear reaction experiments (GANIL 2013)
7. Nuclear theory for astrophysics
   - MSU 2014
   - INT 2015
8. Theoretical approaches to describe exotic nuclei (2016, Chalmers, Gothenburg)

To think of

- How many basic courses can an institution offer, and which courses should be offered?
- How can the coming FRIB theory alliance be used to coordinate an advanced training in nuclear physics?
- How to integrate the (*ad hoc*) Nuclear Talent courses/initiative in our education?
- Most courses offered are theoretical ones. We need a better coordination between theory and experiment.
- Is it possible to integrate material developed in different Talent courses, offering thereby a coherent source for educating the next generation of nuclear physicists? Keyword: Modularization of topics.
- Role of computations.