

Nuclear Physics courses, FRIB theory center and Nuclear TALENT

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Motivation

- Develop structured 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
- The FRIB theory center can function as the national coordinating unit
- Coordination with the Nuclear TALENT initiative

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 three basic courses have a duration each of 30-40 hours (2-3 credits).

They can be taught as a regular one-semester course or half-semester course. There are also experimental courses not discussed here.

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, Hydrogen 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, Nuclear Talent

- Nuclear forces (INT 2013, new version 2017)
- Many-body methods (GANIL July 2015)
 - Many-body perturbation theory
 - Similarity renormalization group theory
 - Coupled cluster theory
 - Green's function theory
 - FCI (Shell model)

Advanced modules, Nuclear Talent

- Few-body methods for nuclear physics (ECT* July-August 2015)
 - Forces and nuclear models
 - The Faddeev and Faddeev-Yakubowsky Equations
 - Methods based on Basis expansions
 - Few-nucleon reactions with external probes

Advanced modules, Nuclear Talent

- Density functional theory and self-consistent methods (ECT* 2014 and York 2016)
- Theory for exploring nuclear structure experiments (GANIL 2014)
- Theory for exploring nuclear reaction experiments (GANIL 2013)

Advanced modules, Nuclear Talent

- Nuclear theory for astrophysics (MSU 2014 and INT 2015)
 - Stellar evolution, supernova and neutron stars.
 - Observations and basic properties of neutron stars and supernovae.
 - Brief review of nuclear forces and nuclear models.
 - Review of thermodynamics and statistical mechanics.
 - Basic notions in dense matter theory.
 - Simple models, the equation of state, and linear response theory.
 - Homogeneous dense nuclear matter.
 - etc

Advanced modules, Nuclear Talent

- Theoretical approaches to describe exotic nuclei (planned for 2016, Chalmers, Gothenburg)
- High-performance computing and computational tools for nuclear physics
 - ECT* 2012, Shell model and variational Monte Carlo
 - LANL/ORNL in 2016, Monte Carlo methods

To think of

- How many basic courses can an institution offer, and which courses should be offered?
- How can the coming FRIB theory center be used to coordinate an advanced training in nuclear physics?
- Can we integrate the (*ad hoc*) Nuclear Talent courses/initiative in our education?
- **Nuclear Talent initiative and Asia**
- Most courses offered are theoretical ones. We need a better coordination between theory and experiment. Should we think of an experimental Talent initiative?
- 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.