

Nuclear Physics courses, FRIB theory center 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

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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.