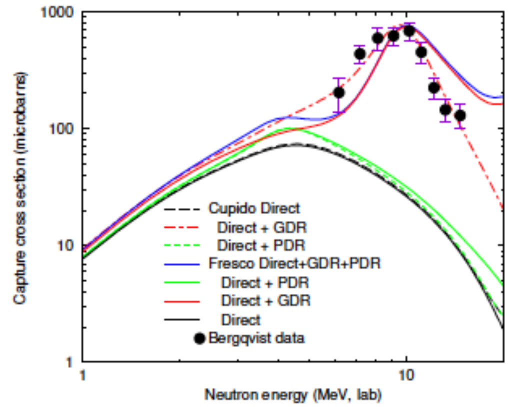
Compound-Nuclear Reactions

Full understanding of a reaction requires description of underlying microscopic processes

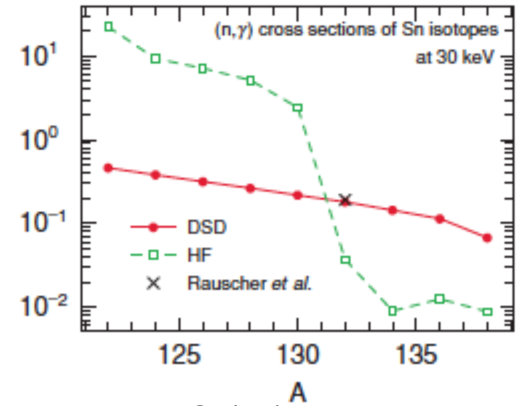
- Direct, semidirect, pre-equilibrium, and compound processes can contribute in the same reaction

Cross sections of compound reactions are needed for nuclear astrophysics, nuclear energy, and stockpile stewardship

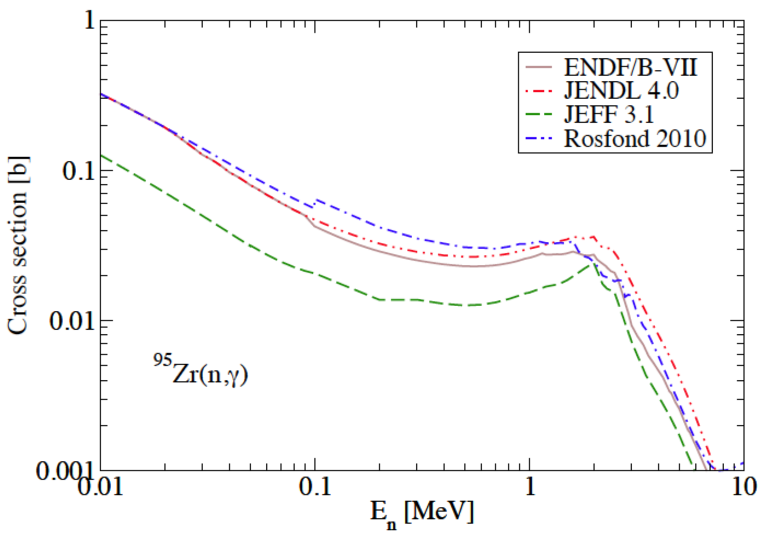
- (n,γ) for s-process branch points
- (n,f) for nuclear energy, waste transmutation



Example: ^{208}Pb(n,γ)
Direct, semi-direct, and compound processes contribute



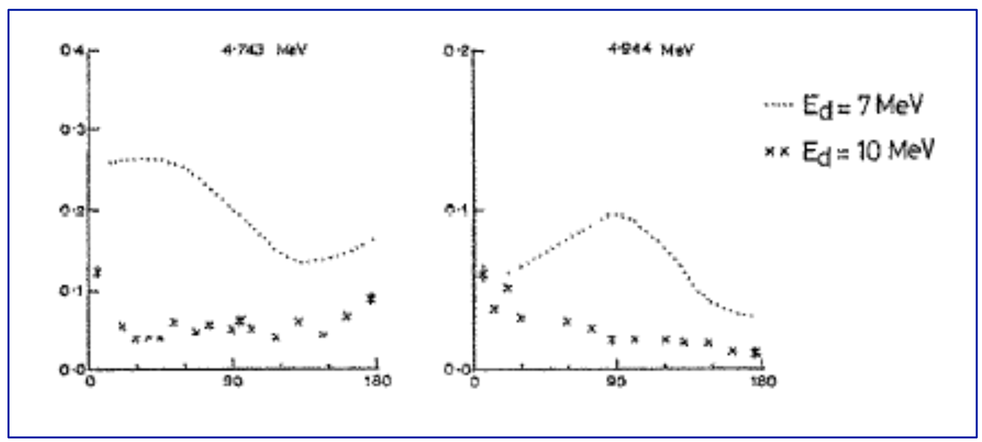
Example: Sn(n,γ)
Relative importance of processes changes with neutron excess



Example: ^{153}Gd(n,g). Lack of experimental constraints leads to large differences between evaluations.

Extract nuclear structure information from experiments

- CN reactions can 'contaminate' direct-reaction measurements; need to be corrected for theoretically



Example: ^{40}Ca(d,p) – no typical direct-reaction pattern

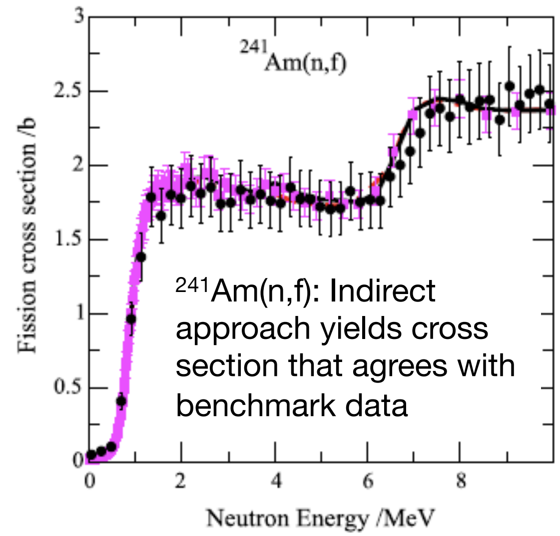
Current status

Descriptions of reactions with combinations of direct, semi-direct, pre-equilibrium, and compound contributions

- Individual processes can be calculated, but are normally not treated in a coherent framework
- Extrapolations away from stability use untested assumptions about nuclear structure and relative importance of the contributions

Indirect approach for obtaining compound cross sections

- Idea: The compound nucleus is created via inelastic scattering or a transfer reaction, and the decay is measured. Theory is used to relate the measurement to the desired cross section
- Approximate implementations have proven useful for obtaining (n,f) cross sections
- Approximations are not valid for all reactions of interest
- Capture reactions require more detailed modeling of the indirect reaction processes



Extracting nuclear structure information from experiments

- Typically, experimental conditions are adjusted to maximize the direct-reaction contributions
- Current exotic-beam experiments have very low center-of-mass energies, which accentuates the problem

Future challenges

Goal: Achieve a comprehensive description of direct, semi-direct, pre-equilibrium, and compound processes for a variety of reactions

Needed:

- State-of-the-art microscopic structure calculations to produce inputs for statistical (Hauser-Feshbach) reaction calculations
- Quantum-mechanical multi-step treatment of pre-equilibrium reactions
- Computationally inexpensive treatment of correlations between reaction channels (width fluctuation corrections)
- Better understanding of energy averages, the role of doorway states, the effect of low level densities
- Proper inclusion of effects of nuclear deformation and isospin conservation
- Theoretical descriptions of the formation of a compound nucleus via inelastic scattering or a transfer reaction

Requirements

- Faculty/staff, postdocs, students
- Close collaboration between theory and experiment, to guide, test and apply the theory developed