Predictive theory for tritium breeding: needs and opportunities

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Blankets can be made from multiple materials each of which has its own data needs

The blanket is one of the most important components of a fusion reactor because it deals directly with the issues of energy extraction and fuel breeding, which represent major technical feasibility questions for the practical development of fusion power. In addition, the blanket substantially influences the reactor economics and safety. Demonstrating the engineering feasibility of the blanket will require extensive research and development.

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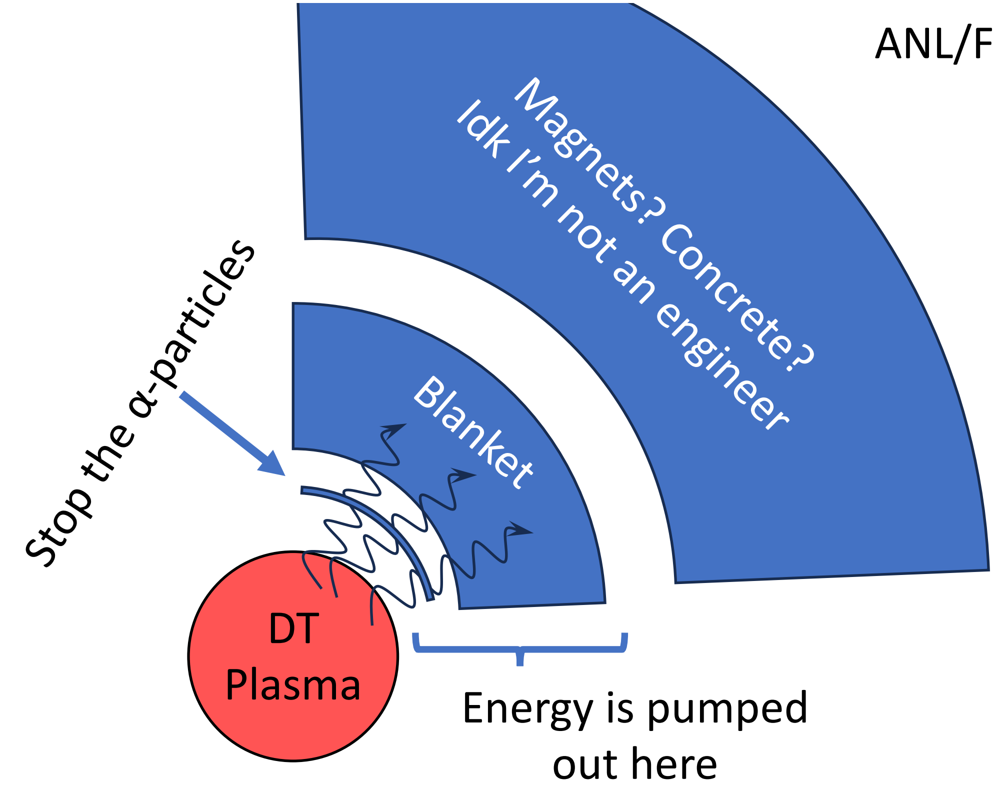
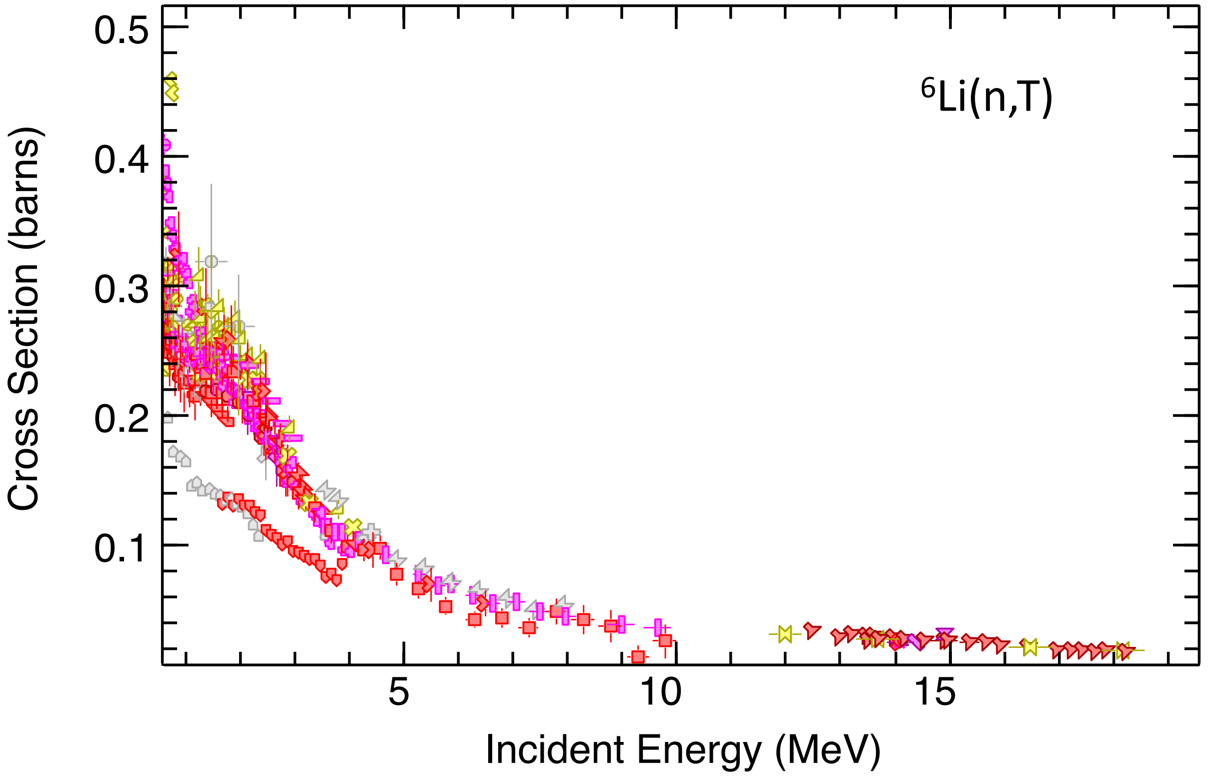
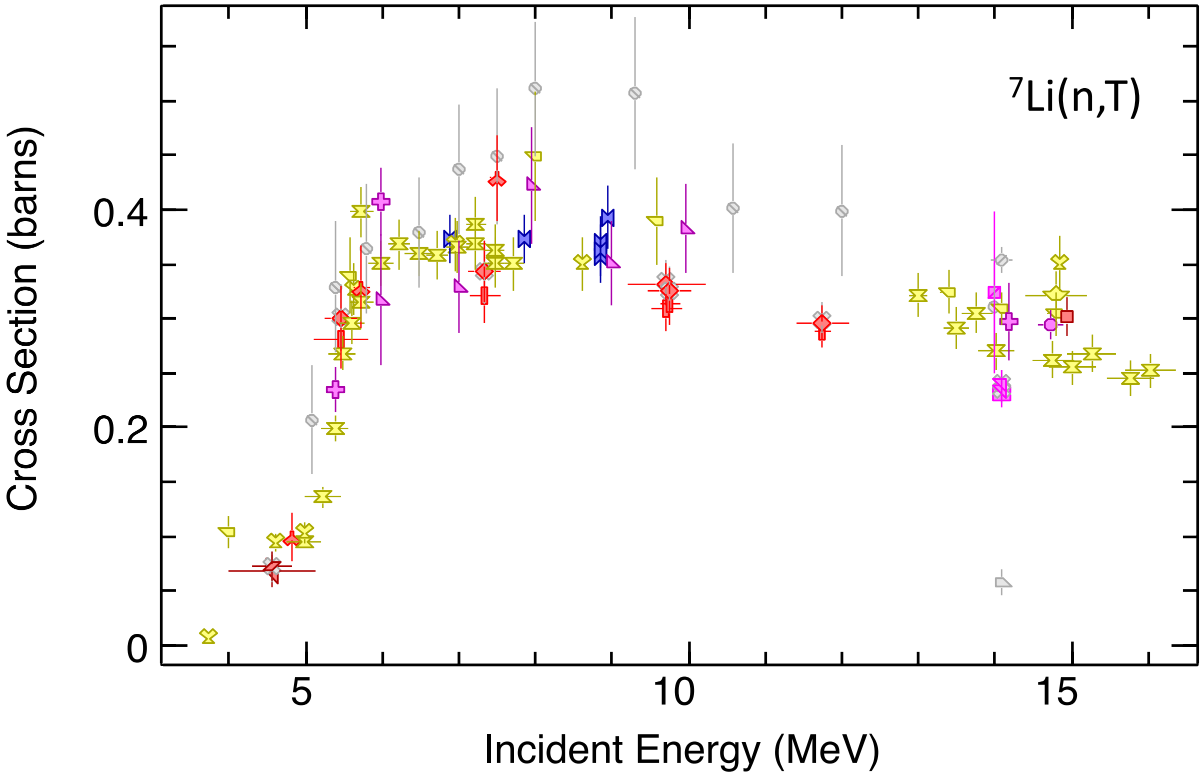


- Relevant nuclei:
  - Definitely Lithium (probably)
  - Titanium/Silicon/Oxygen for blanket
  - Beryllium/Lead for multiplication
  - Boron (see also yesterday's talk)
- Neutron energies needed can vary from 14 MeV down to few MeV as produced by the multiplication spectra

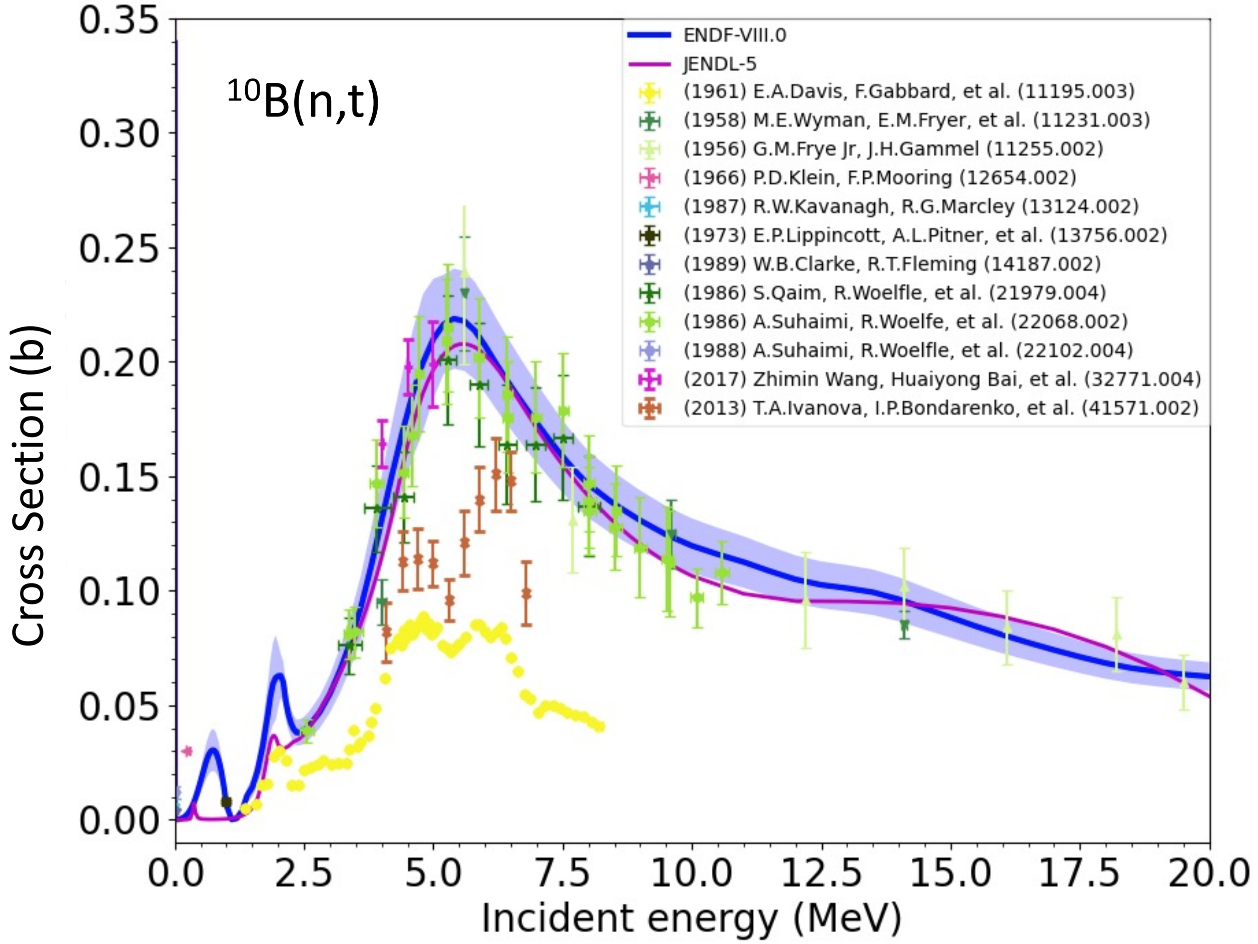
Measurements exist for tritium production from lithium. Evaluations lack covariances at all energies

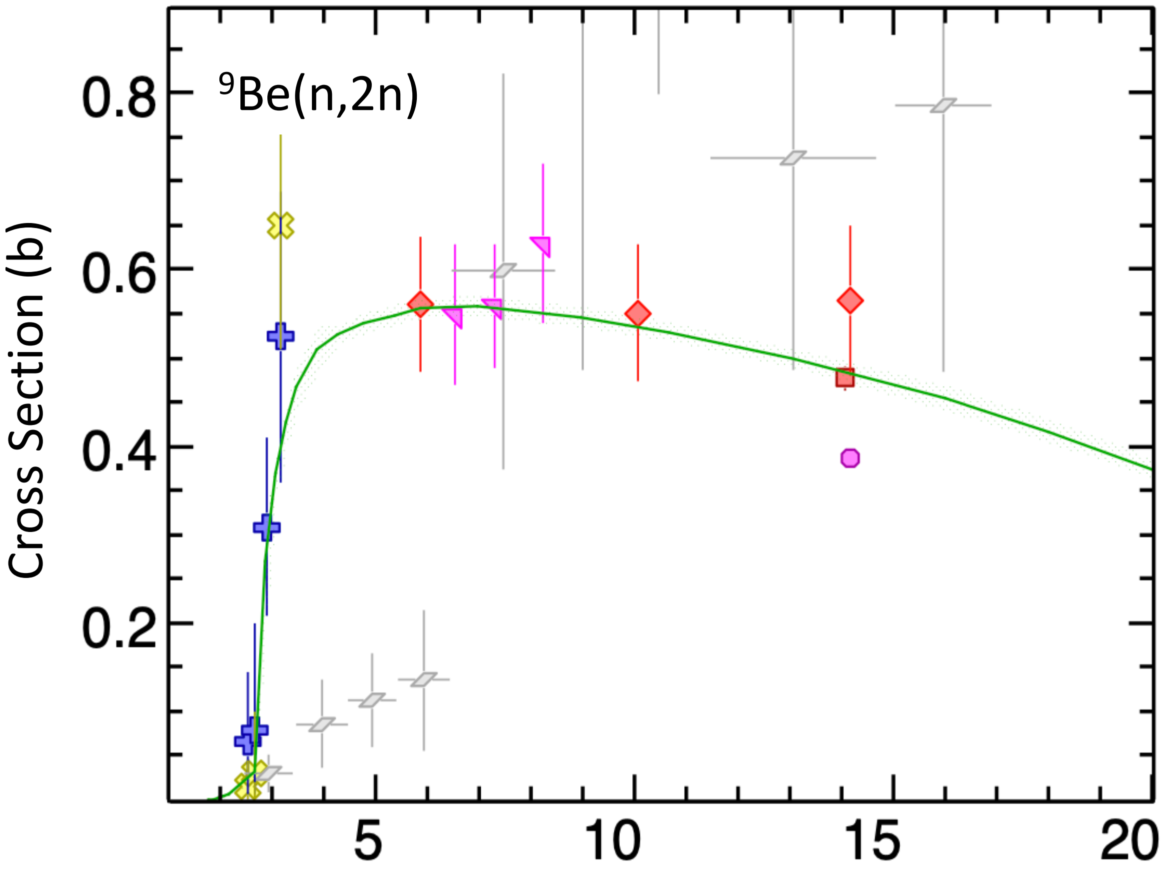




Need: measurements and theory that can link the two evaluations

Predictive theory needs for tritium production and neutron multiplication

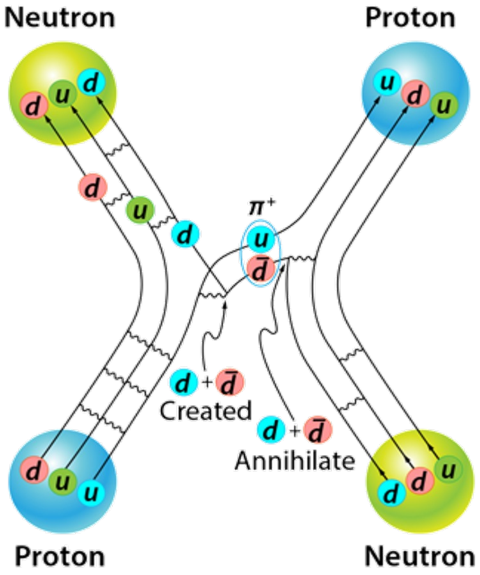




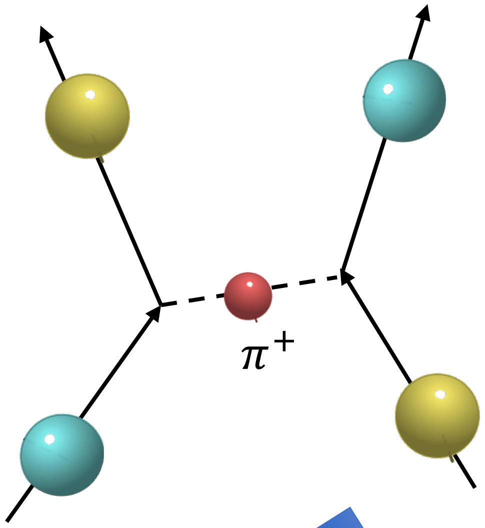
Need: new theoretical tools to describe more complex reactions (3+ fragments)

At LLNL we are developing a predictive light-ion reaction theory that arises from first principles

Quantum Chromodynamics

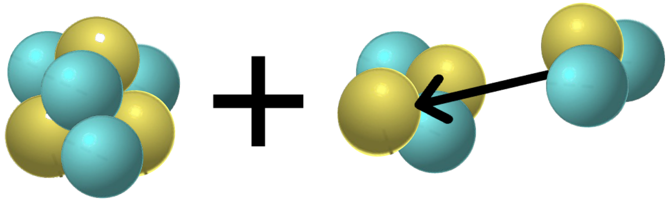


Chiral Effective Field Theory



Two & three-nucleon (NN+3N) forces

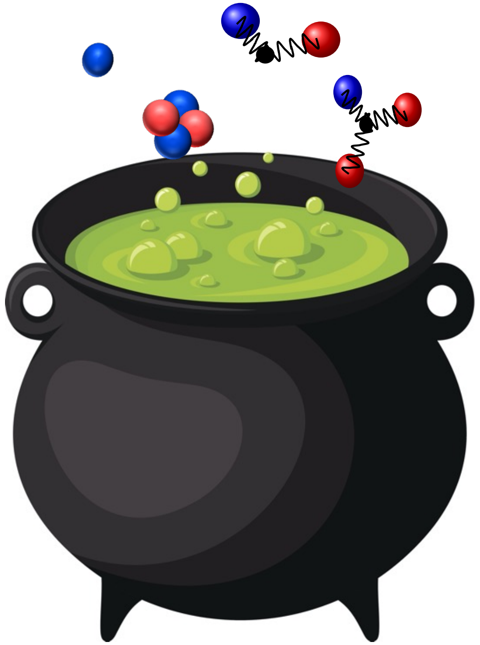
Unified ab initio many-body approach to structure and reactions



All active (point-like) nucleons, non-relativistic quantum mechanics

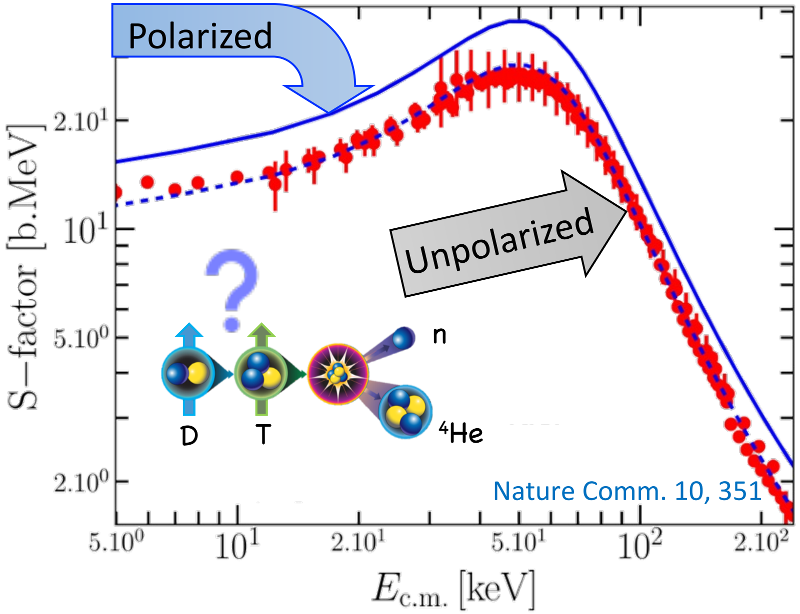
State-of-the art first principle (or *ab initio*) informed evaluations now also becoming possible at LLNL

Sole input is the interaction between the nucleons.



Typically take up significant part of the machine, require multiple runs, can scale up to machine size

Polarized DT Fusion

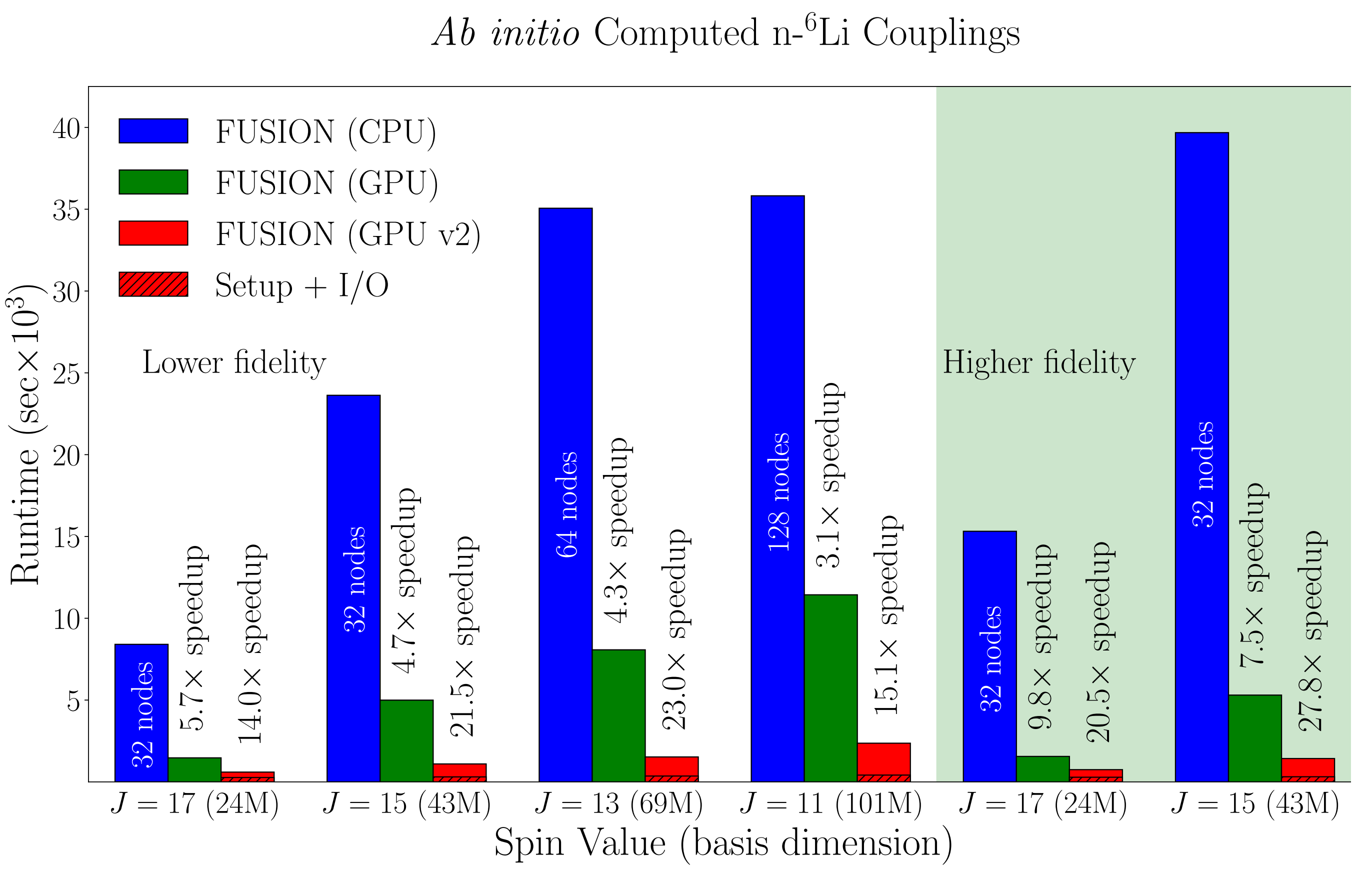


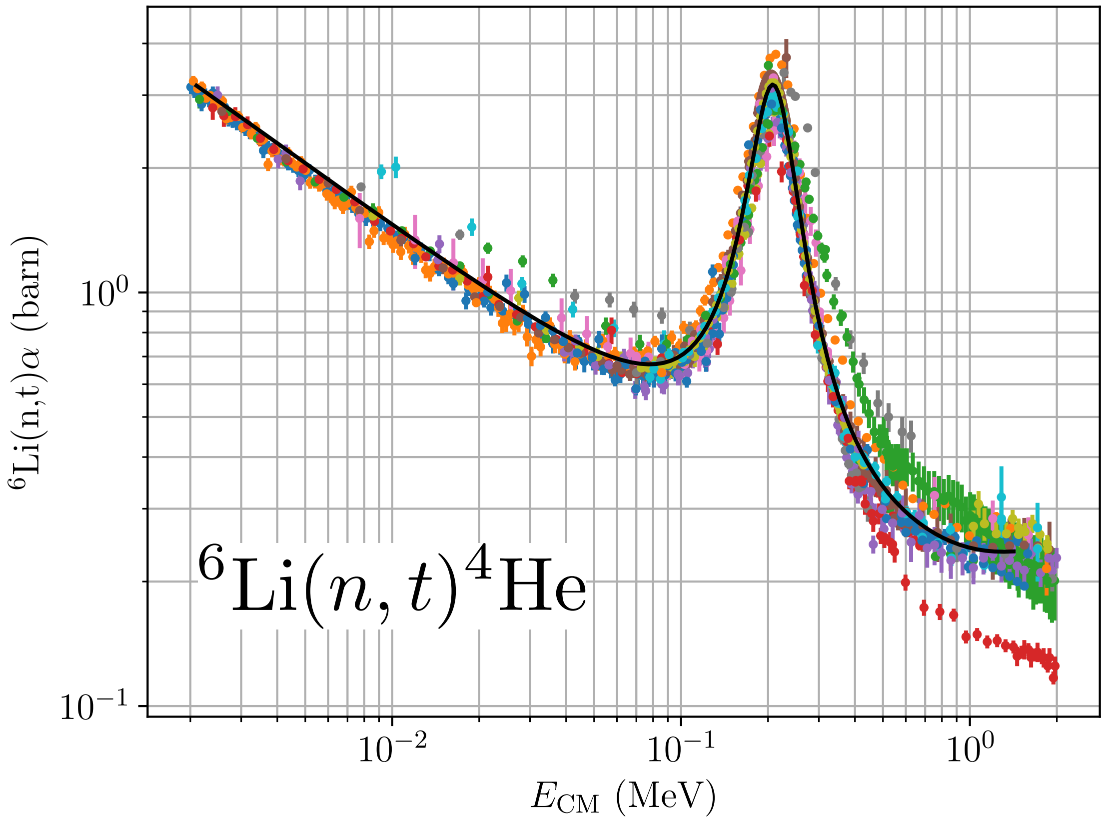
Astrophysical S-factor: nuclear contribution

$$\sigma(E) = \frac{S(E)}{E} \exp\left(-\frac{2\pi Z_1 Z_2 e^2}{\hbar\sqrt{2E/m}}\right)$$

'Coulomb' contribution (tunneling)

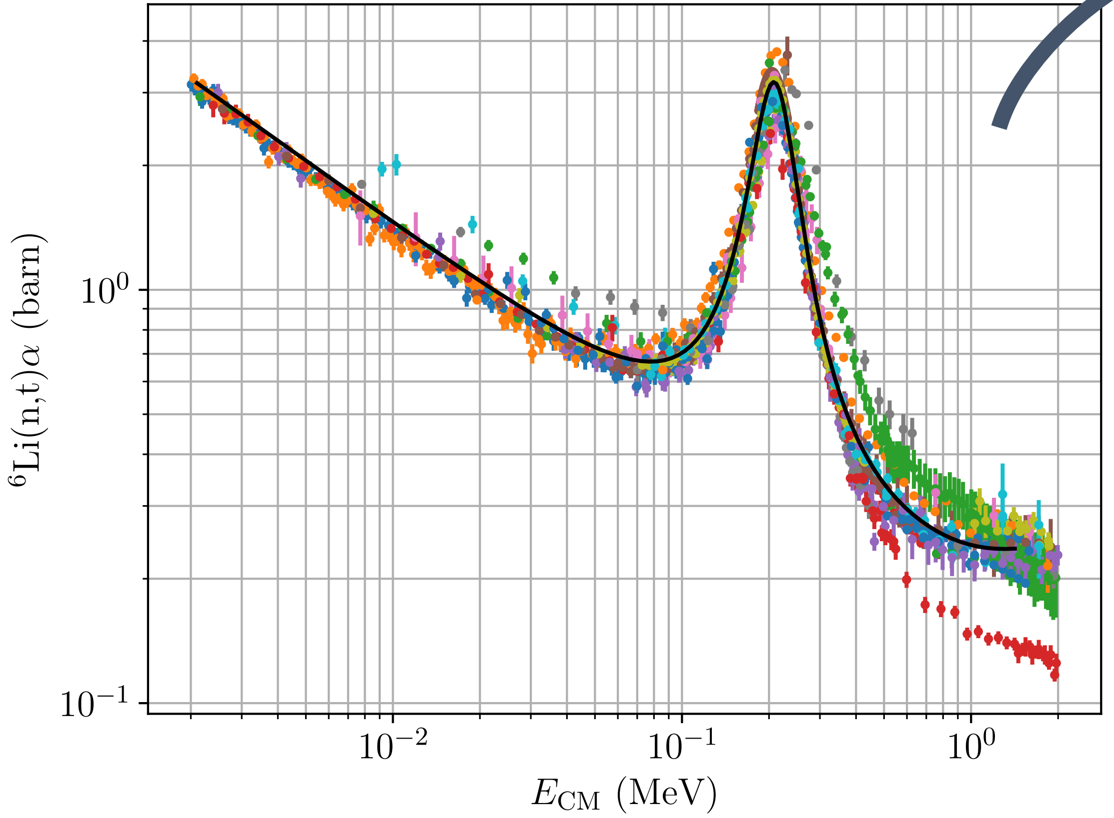
By taking advantage of advanced architectures first principle calculations can reach even further



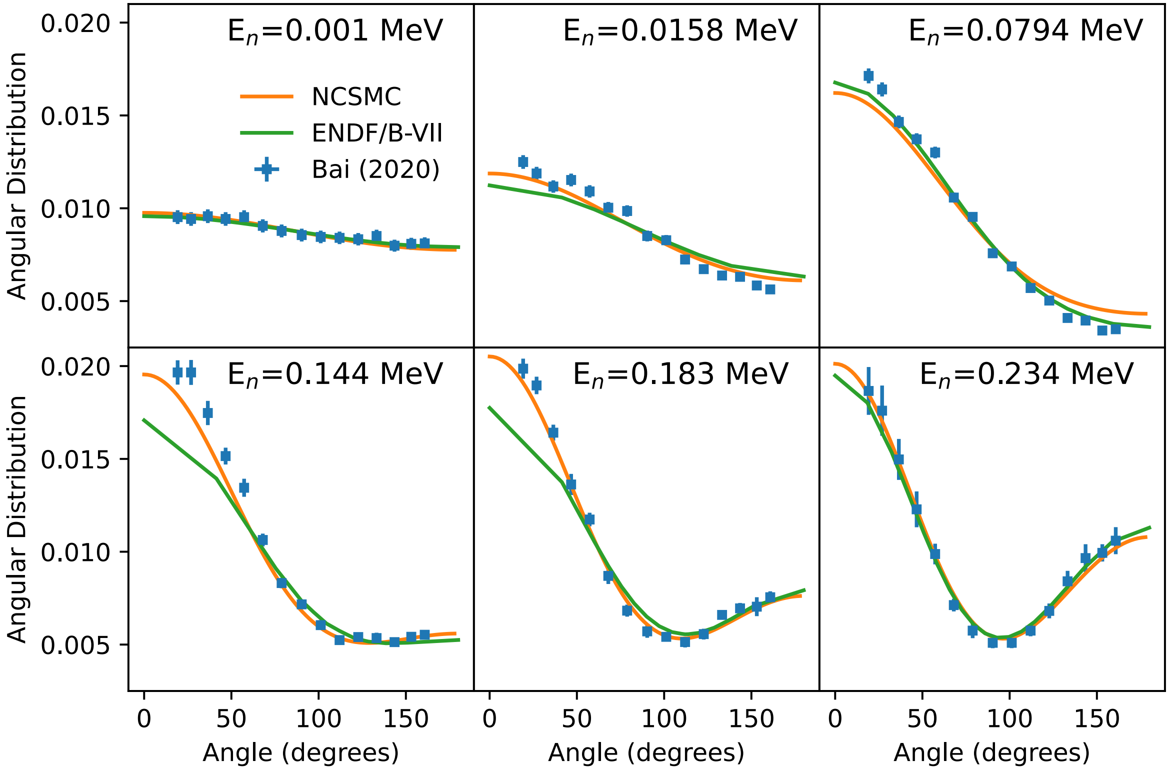


Ab initio nuclear reaction theory can provide an independent method for predicting standards cross sections

NCSMC parameters tuned to reproduce reaction cross section



Angular distributions are predicted with no further experimental input



Reminder Need: theoretical tools for beyond breakup range

Conclusions & Laundry list

- Need: Predictive theories that go beyond traditional forms of evaluation and are better suited to dealing with absent or incomplete data.
- Need: Cross section data for low-energy neutrons emitted from multiplication impinging on the various blanket materials
- Need: Well-evaluated uncertainties of resulting predictions that will be passed on to transport codes

- Opportunity: Leverage advanced simulation & computing for predictive evaluations
- Opportunity: Advanced evaluation methods that will have impact beyond fusion energy production
- Opportunity: Integral experiments combined with predictive theory