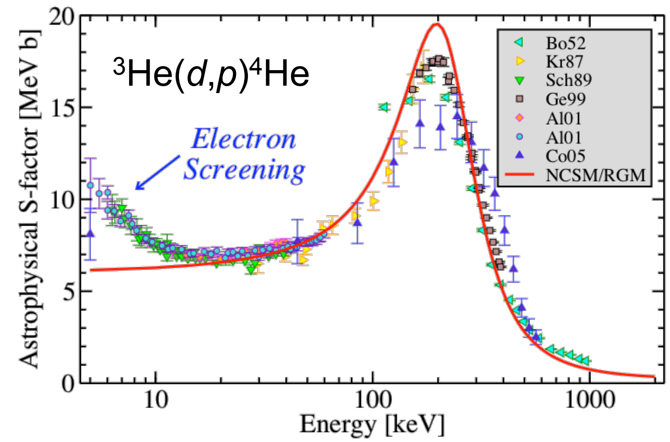
Fundamental theory of scattering and reactions

Developing a fundamental theory of nuclear scattering and reactions is crucial for nuclear science, nuclear astrophysics, and applications

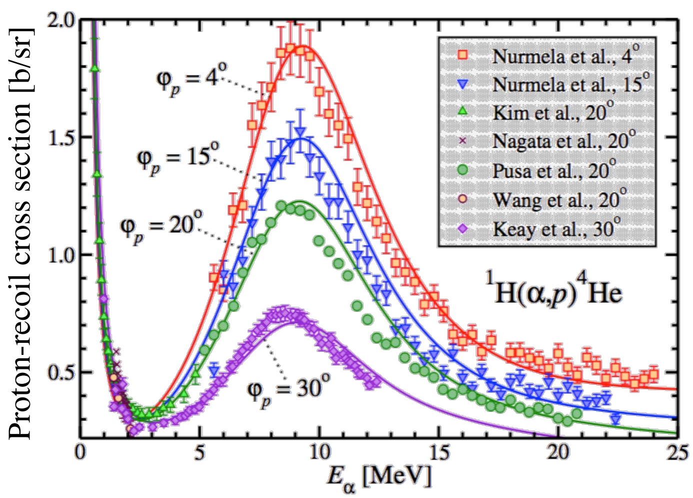
- Exotic nuclei offer an exciting opportunity to test our understanding of nuclear properties in terms of forces emerging from QCD, but:
  - Need theory able to accurately model the reactions used to populate ground states and resonances of exotic nuclei
  - Only with a unified treatment of bound and continuum states can we correctly interpret, e.g., the role of the 3N force in exotic nuclei
- Predictive theory needed at low energies beyond experimental reach, to improve evaluation of important rates for Big Bang Nucleosynthesis, Standard Solar Model, Stellar Nucleosynthesis, fusion energy research

Present status

- *Ab initio* approach with realistic NN forces developed and applied to two-body light-nucleus reactions relevant for astrophysics and fusion research
- *First ab initio* description of ^{4}He+n+n continuum paves the way to fusion reactions with 3-body final states
- Complete *ab initio* descriptions of scattering in the A=5 sector give us initial confidence on the methods and underlying NN+NNN Hamiltonians
- *Ab initio* studies of *N*- and *d*-nucleus scattering give first glimpse of interplay between NNN force and continuum effects in energy spectra

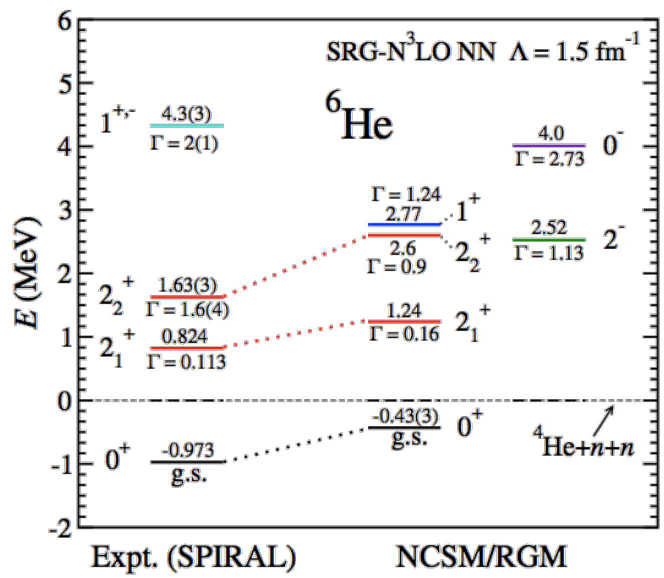


d+^{3}He fusion from ab initio theory with realistic NN interaction vs Expt.



Left: complete ab initio description of proton-^{4}He scattering

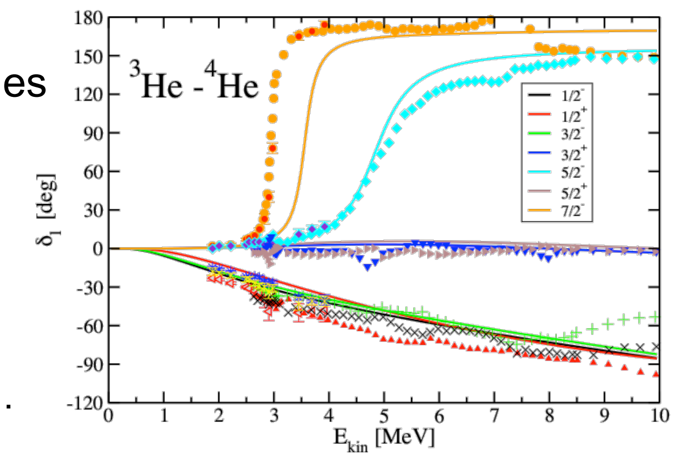
Right: ^{6}He spectrum of states from first ab initio description of ^{4}He+n+n continuum



Future challenges

- Complete validation for our theory/NN+NNN Hamiltonians and deliver accurate predictions for lesser known A=5 cross sections
  - Stringent test on experimentally well-known $^{3}H(d,n)^{4}He$ cross section
  - $d+^{3}H \rightarrow ^{4}He+n+\gamma$ bremsstrahlung (fusion research); $^{3}H(d,p)^{4}He$ (hindered by electron screening)

- Provide *ab initio* description of binary reactions involving p-shell nuclei and/or composite projectiles
  - (d,p) transfer reactions relevant for astrophysics and FRIB (e.g.: $^{7}Li(d,p)^{8}Li$)
  - $^{3}He(\alpha,\gamma)^{7}Be$, $^{7}Be(p,\gamma)^{8}Be$ (standard solar model); $^{6}Li(n,^{3}H)^{4}He$ (fusion research)
  - $^{8}Be(\alpha,\gamma)^{12}C$, $^{12}C(\alpha,\gamma)^{16}O$ (stellar nucleosyntesis), …



^{3}He-^{4}He scattering from ab initio theory with NN pot. vs Expt.

- Deliver high-fidelity simulations complete of both NNN force and multi-fragment dynamics for complex reactions and exotic nuclei
  - Three-cluster resonances and Borromean halo nuclei: ^{5}H, ^{6}He, ^{11}Li, ^{14}Be, …
  - $^{3}He(^{3}He,2p)^{4}He$ (standard solar model), $^{3}H(^{3}H,2n)^{4}He$ (fusion research), …

Requirements: faculties/staff, postdocs, graduate students, high-performance computing