Ab initio evaluations of light-ion reactions and their uncertainties

TRIUMF Science Week 2022

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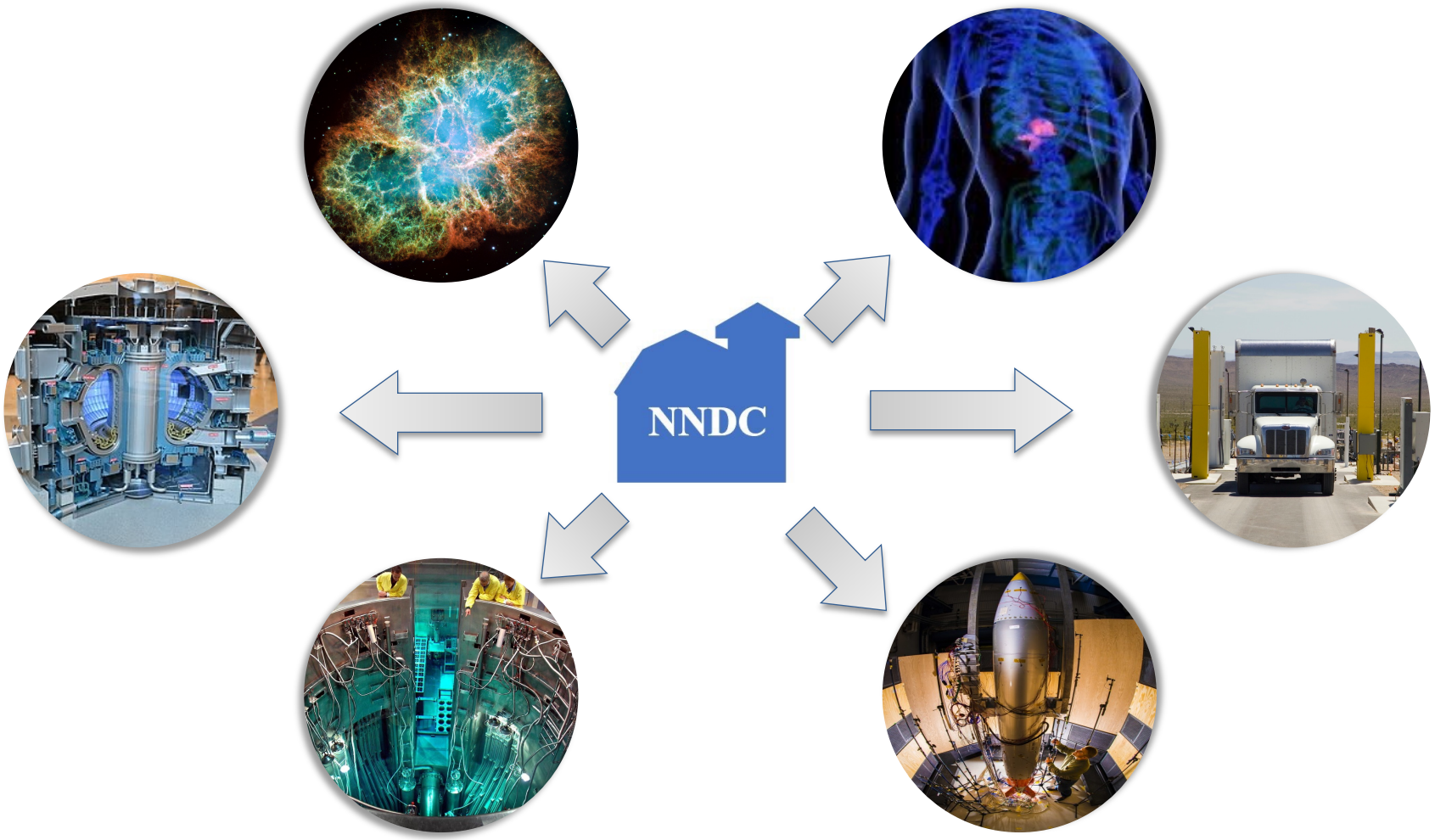
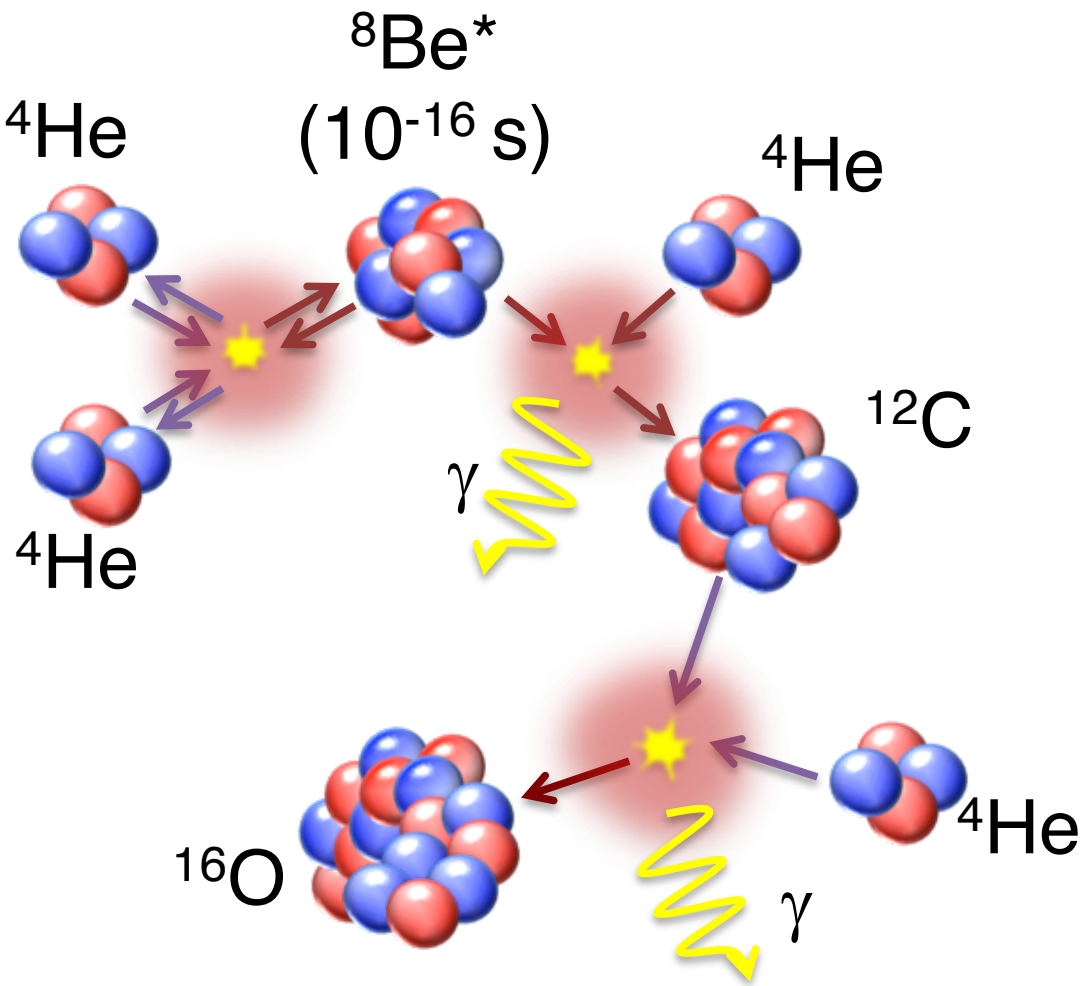
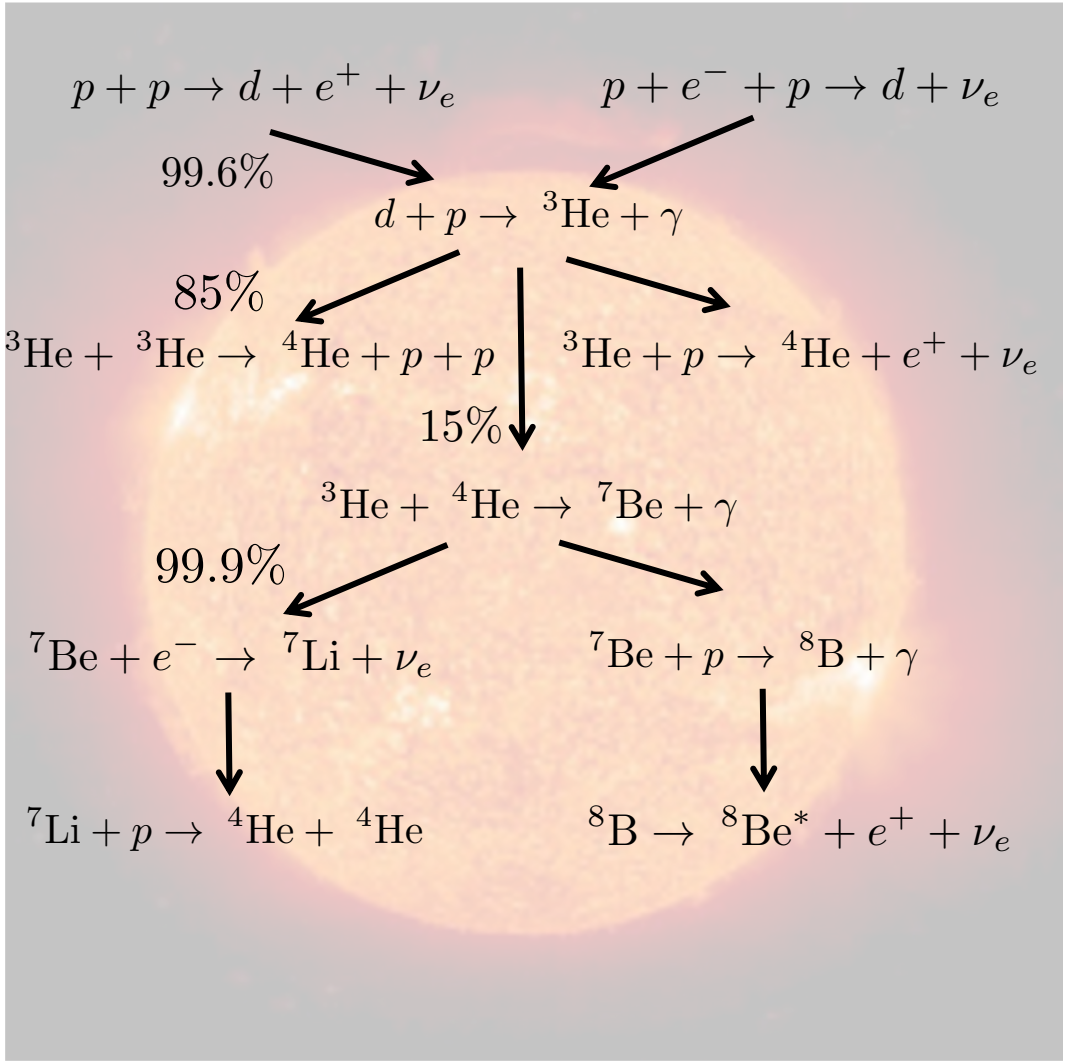
Nuclear data is ubiquitous in basic science and applications

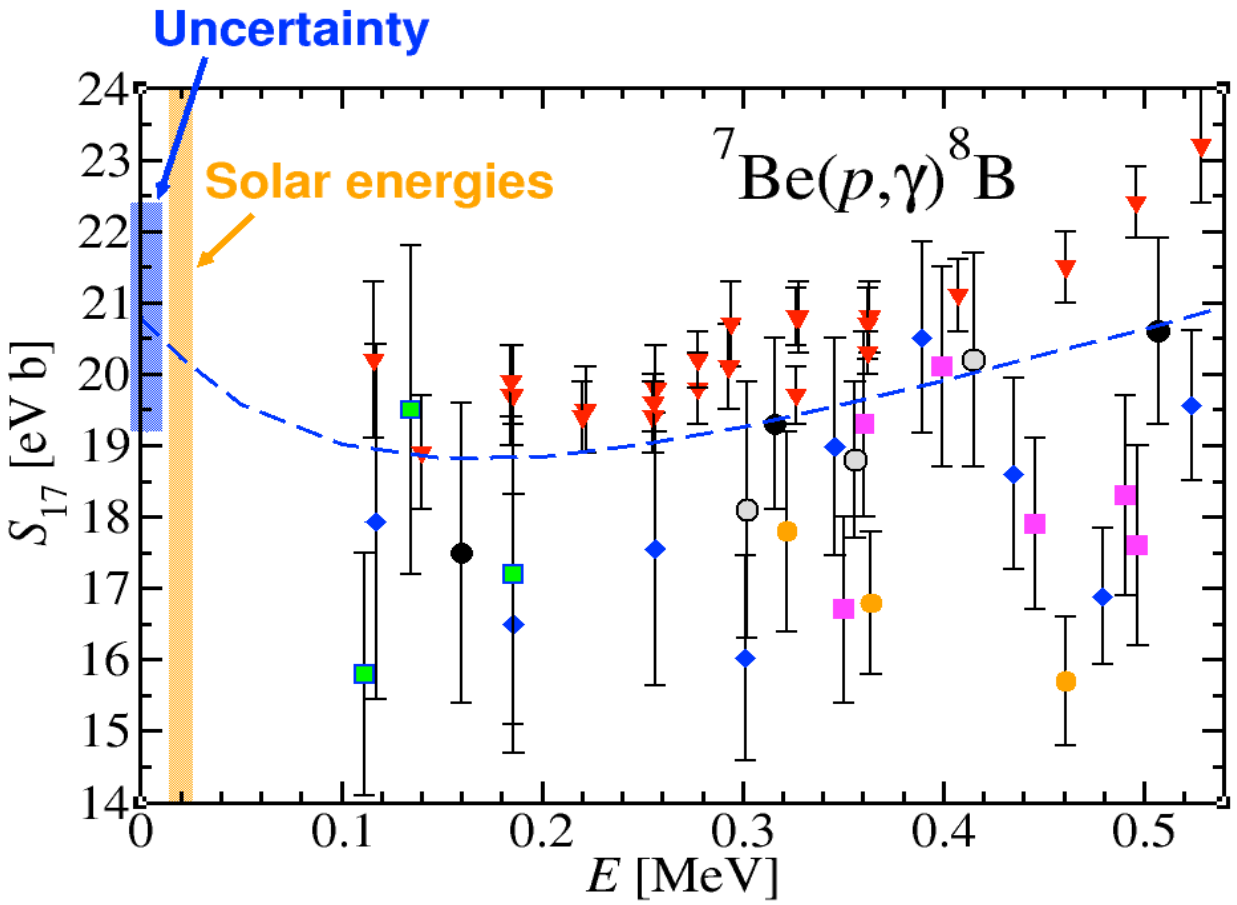


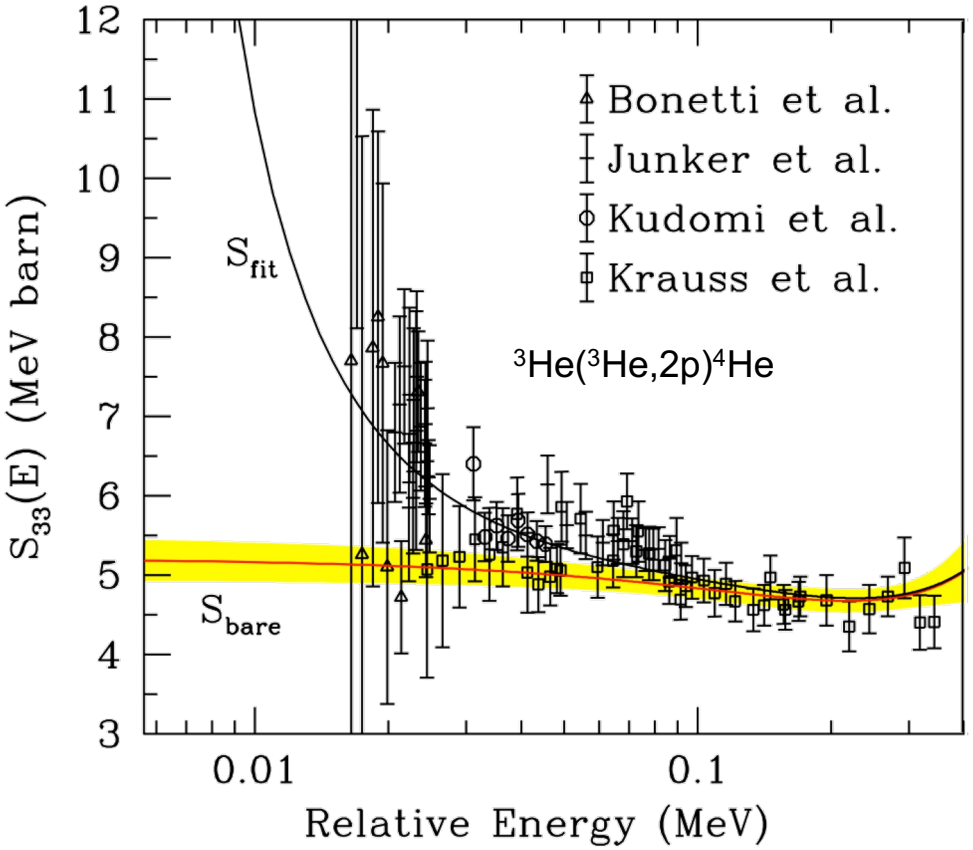
From hydrogen to carbon, nuclei are the powerhouse of stars





Measuring reaction rates is remarkably challenging





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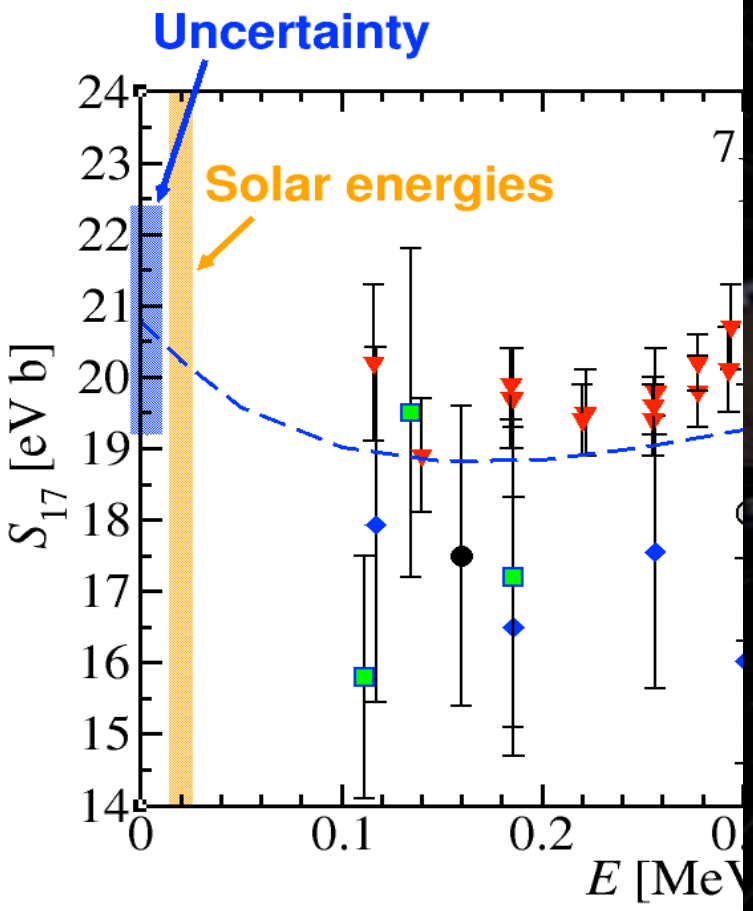
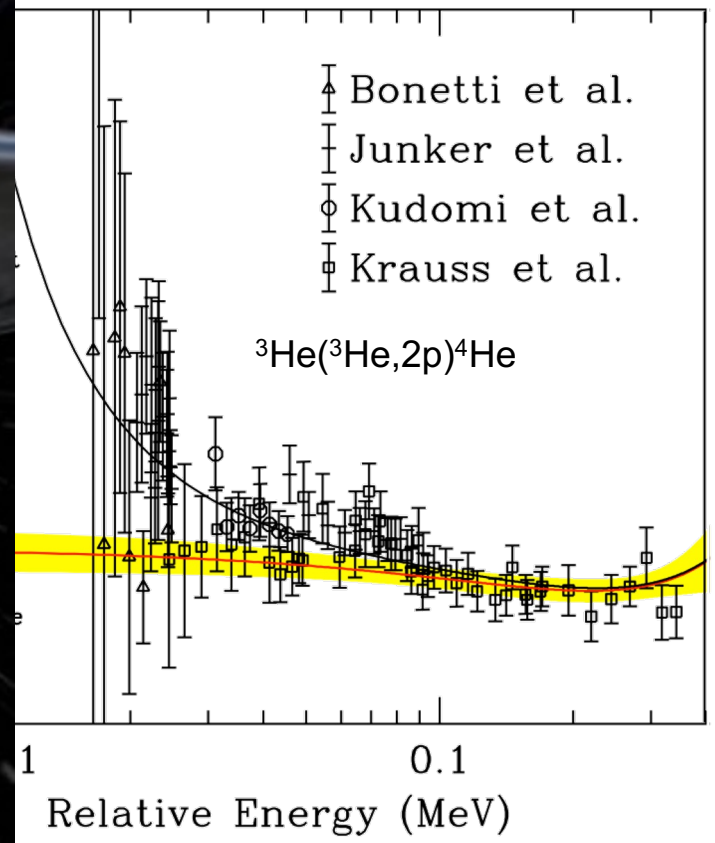
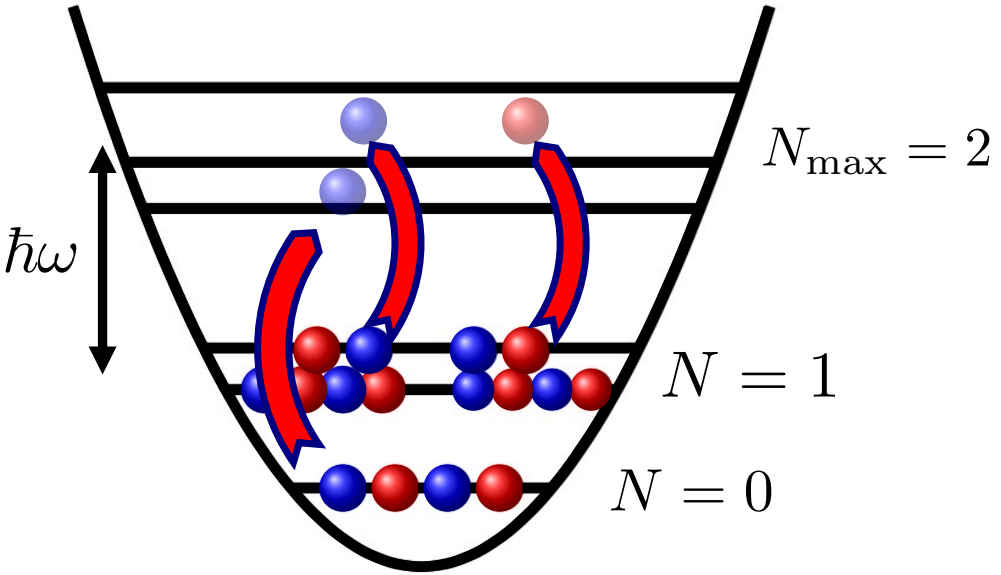
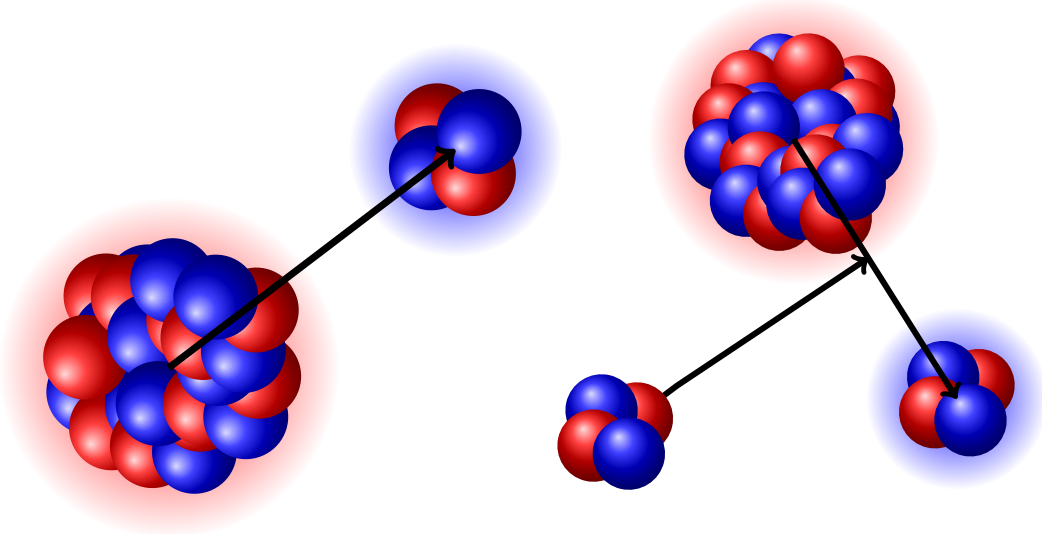




For a complete ab initio description, we need to include both structure and reaction dynamics



Configuration Interaction
No Core Shell Model (NCSM)



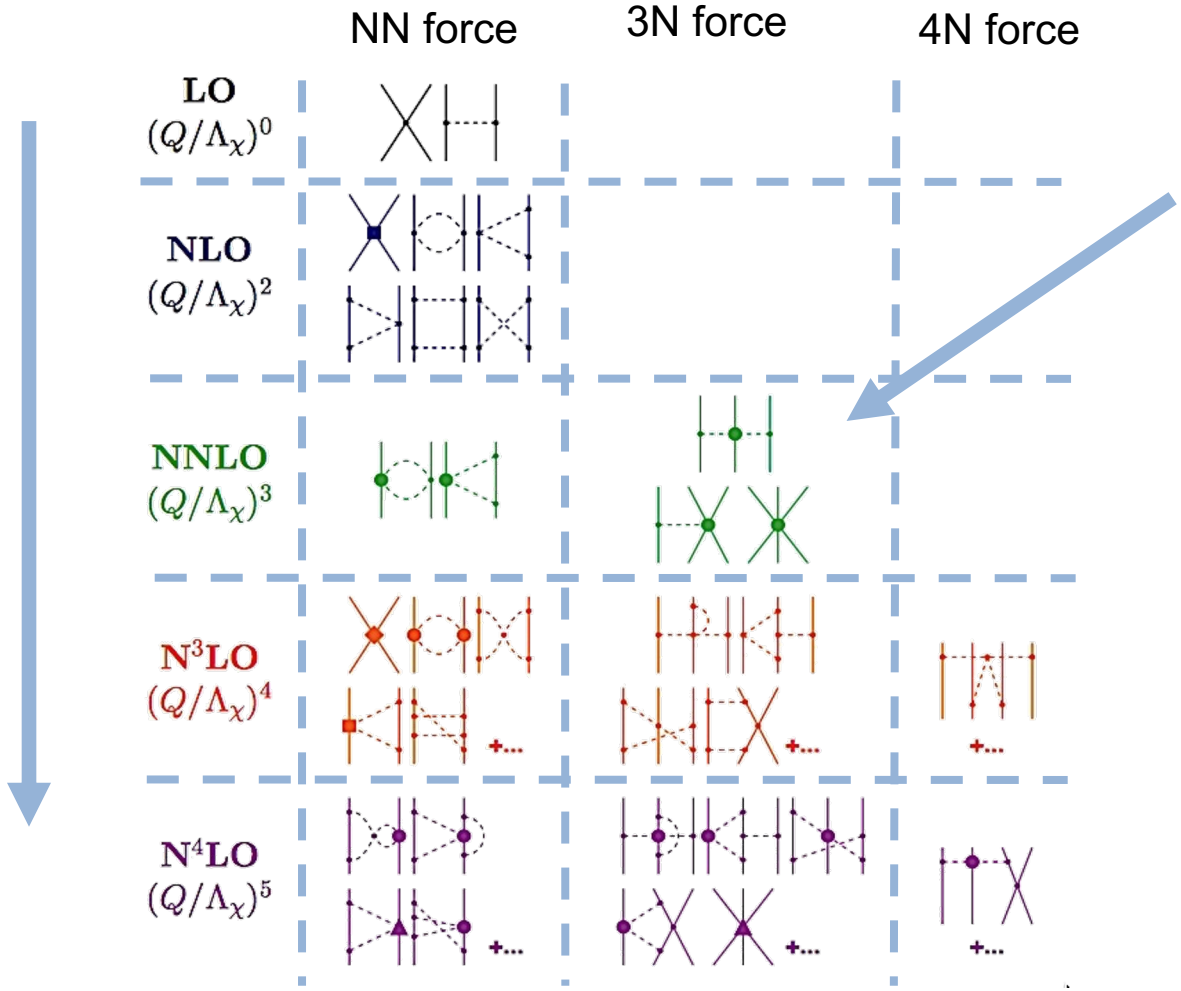
Discrete structure information input

Continuous dynamical input (clustering/reactions)

$$\Psi = \sum_{\lambda} c_{\lambda} \left| \quad \right\rangle + \sum_{\nu} \int dr u_{\nu}(r) \left| \quad \right\rangle$$

Chiral effective field theory interactions provide a direct link between the nuclear interactions and QCD.

Systematic expansion of the nuclear force means quantifiable uncertainties!

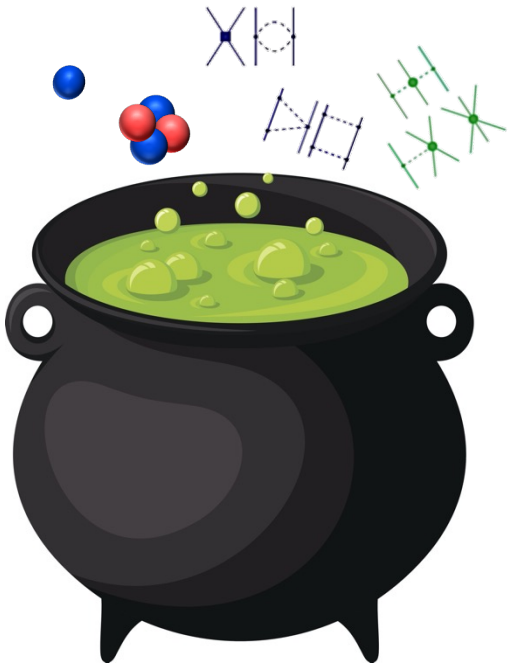


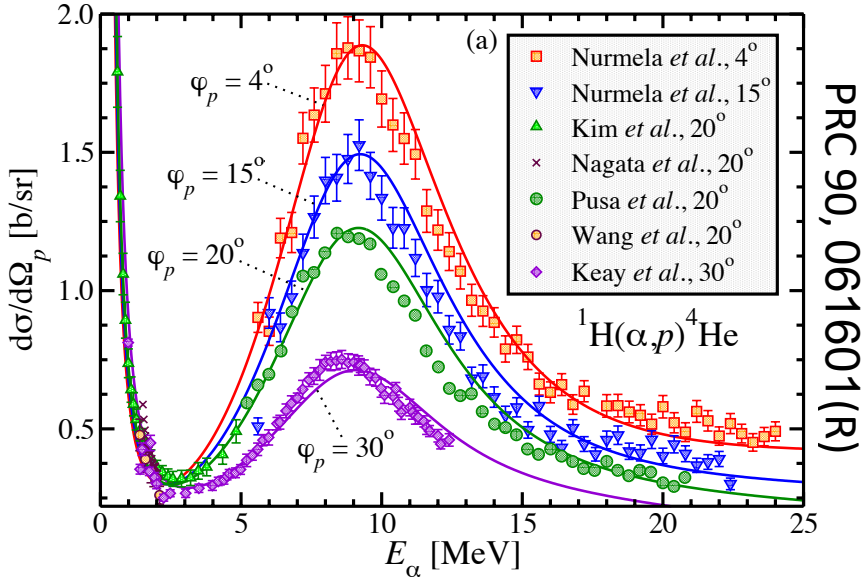
Few diagrams means few parameters that must be constrained from experiments.

Many-nucleon forces appear organically.

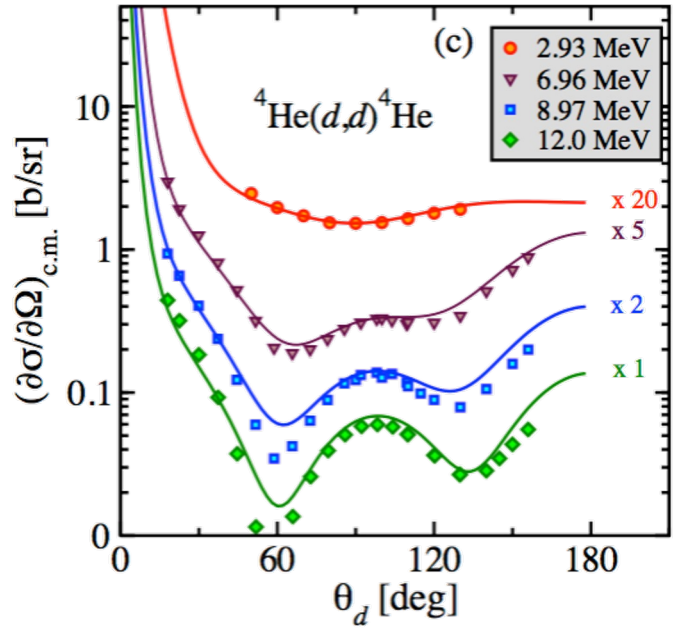
Three-Nucleon forces make calculations order-of-magnitude more expensive.

High Performance Computing is an essential tool for an ab initio theory of nuclear reactions.





PRC 90, 061601(R)



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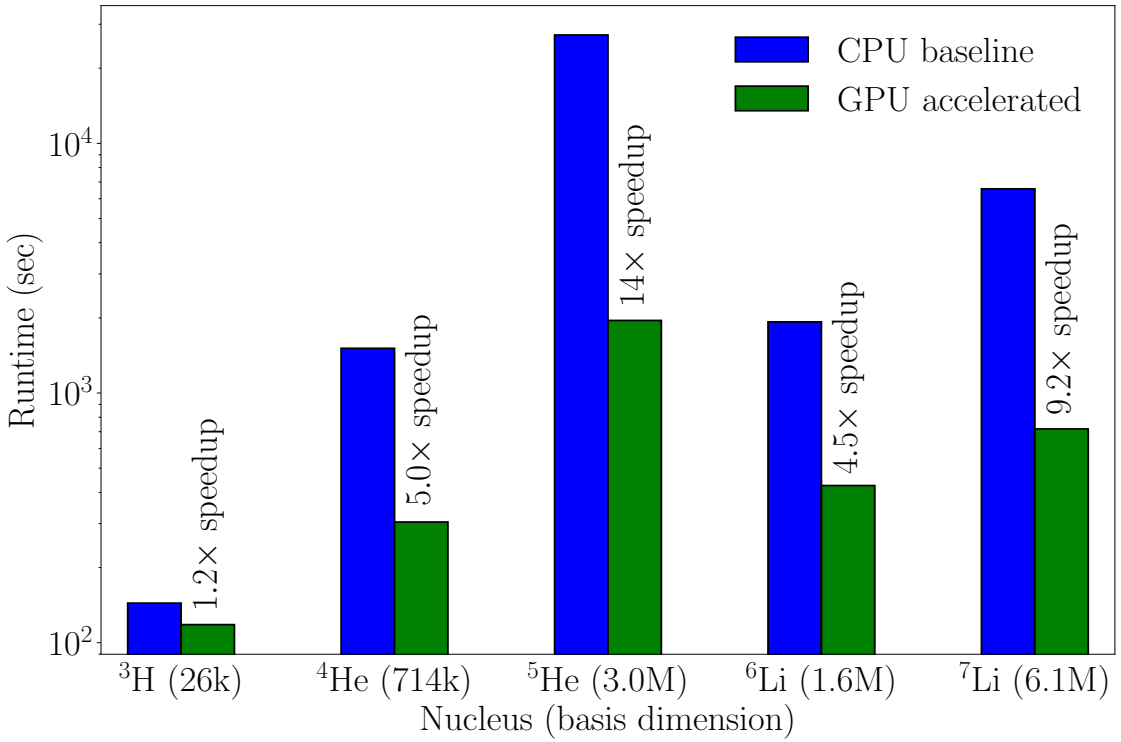
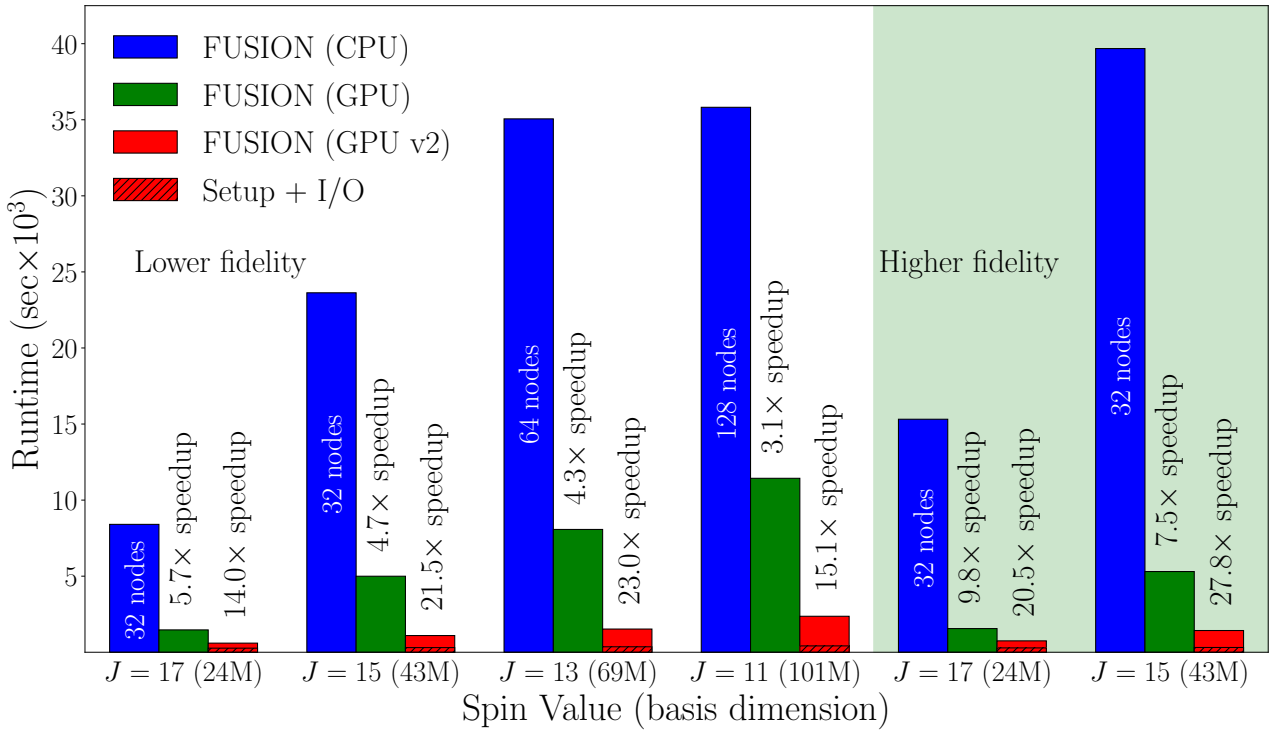
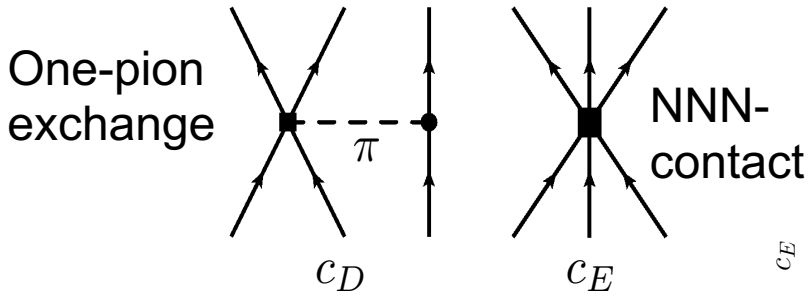
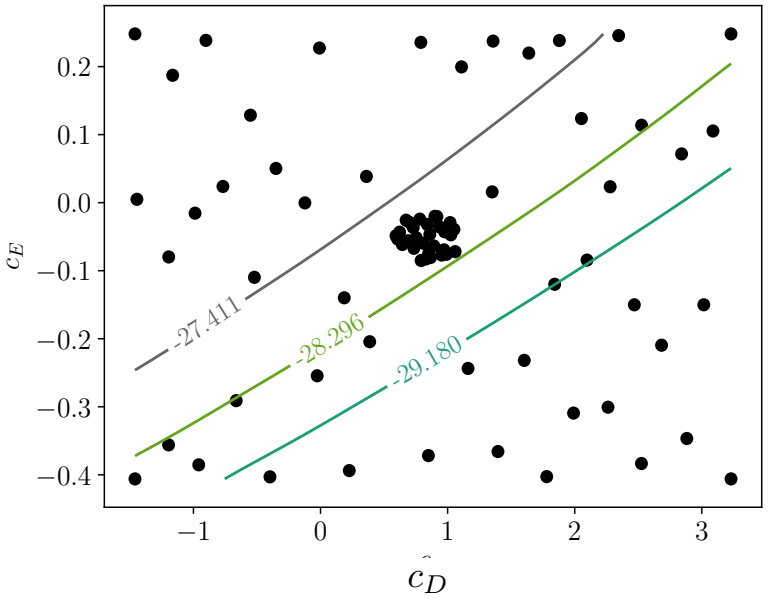
High-Performance Computing is essential for ab initio theory. Novel architectures allow for previously impossible calculations.

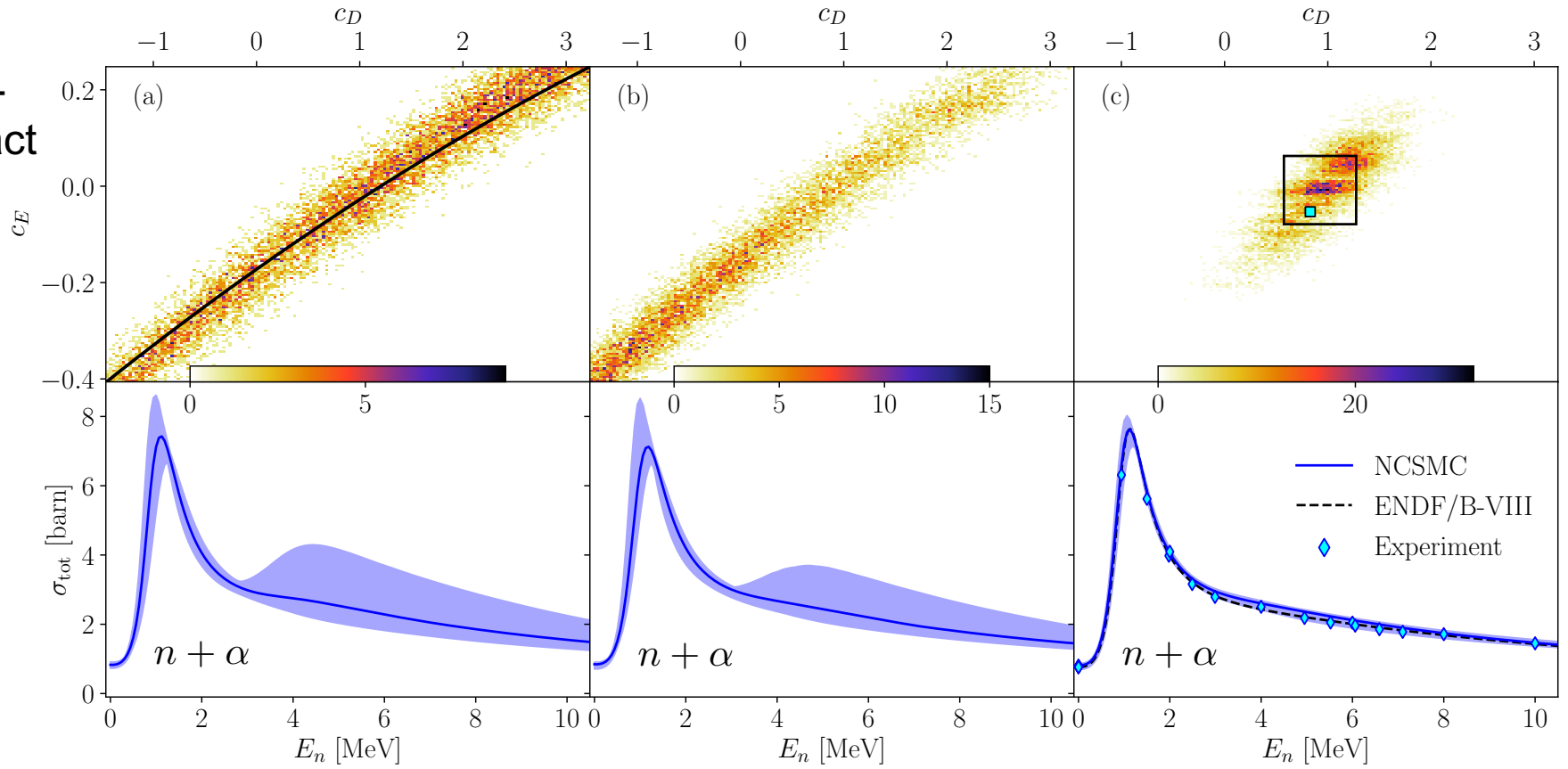




Significant speedups coupled with efficient emulators make uncertainty quantification of theoretical predictions possible.

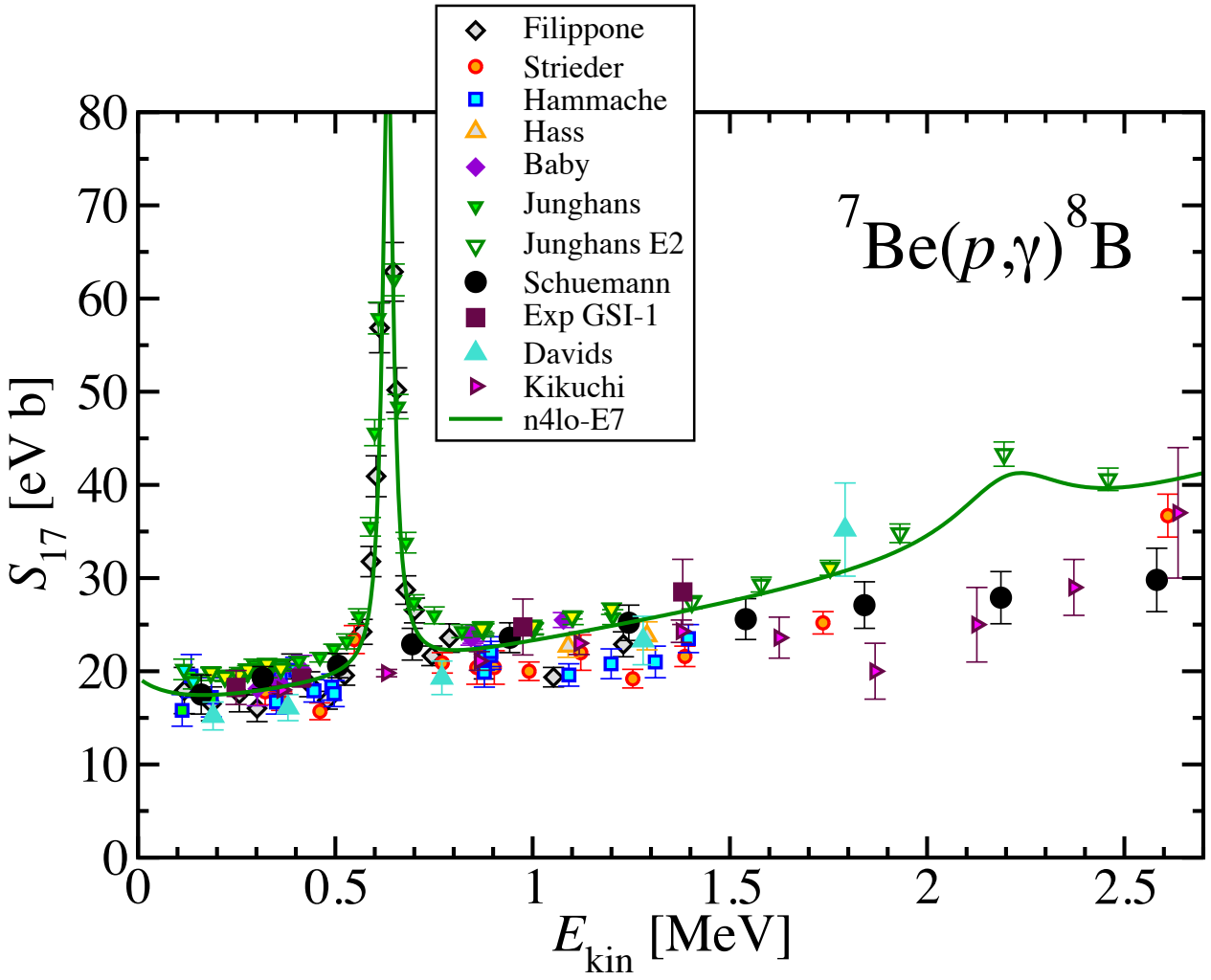






Phys. Rev. C **102**, 024616 (2020)

Calculations using interactions derived from chiral EFT reproduce experimental data.



arxiv:2202.11759

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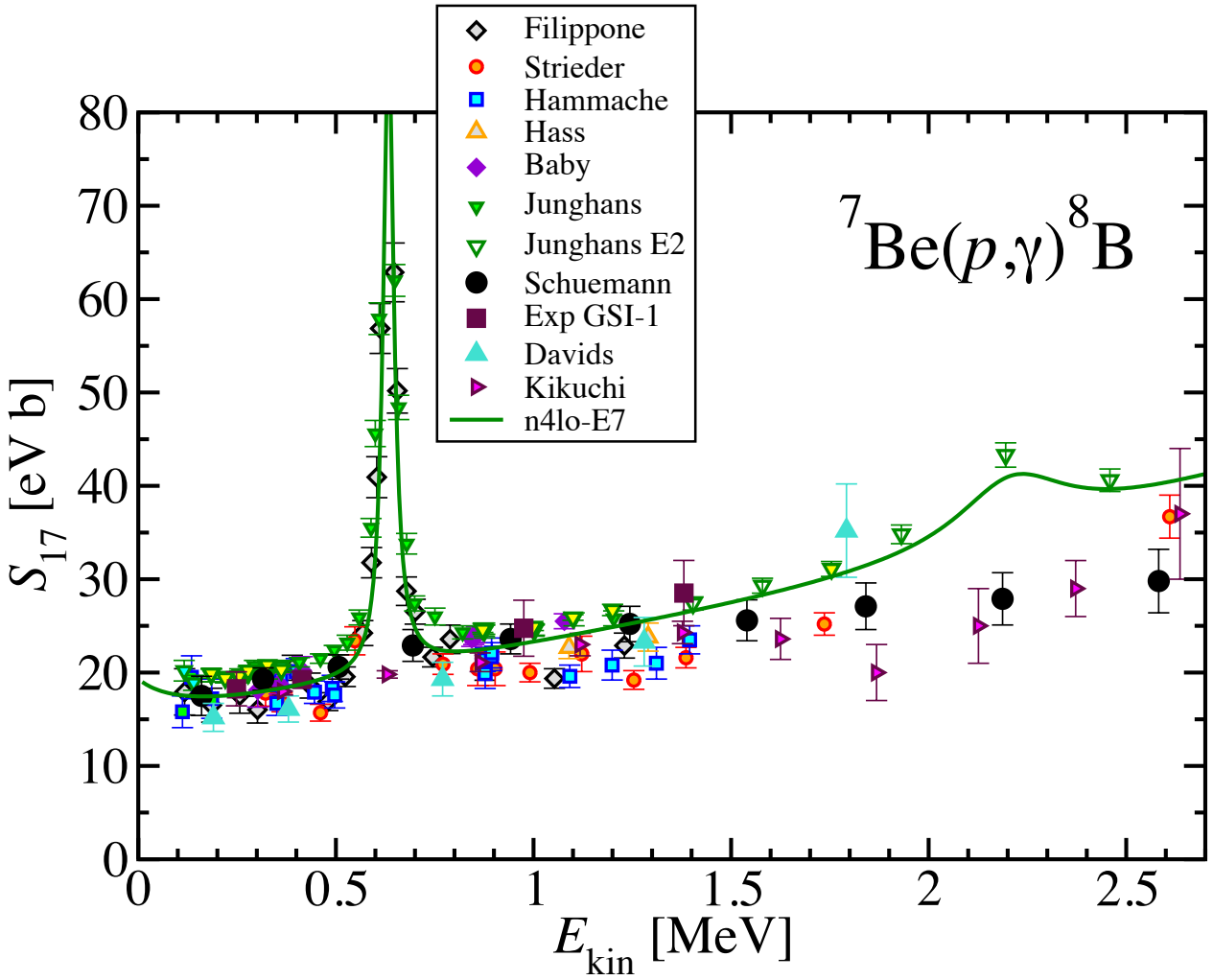

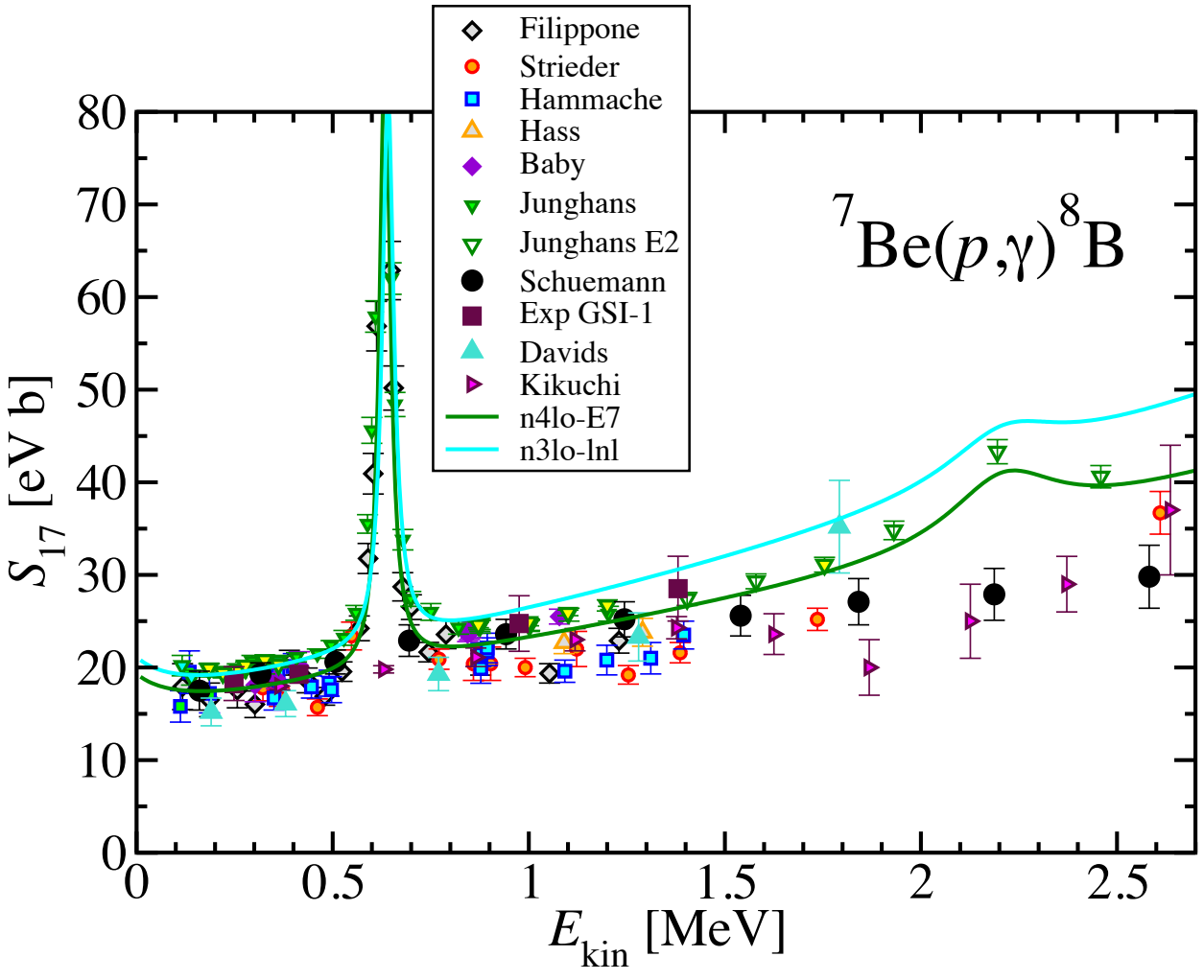

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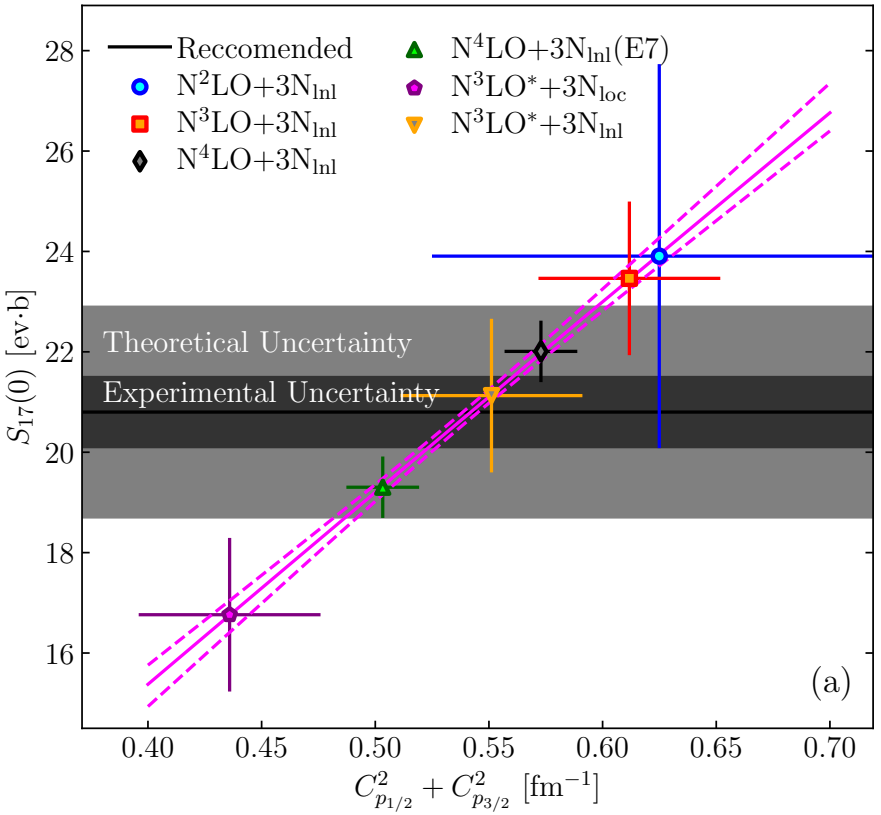
We can extract universal features of the reaction process by leveraging multiple calculations with different interactions



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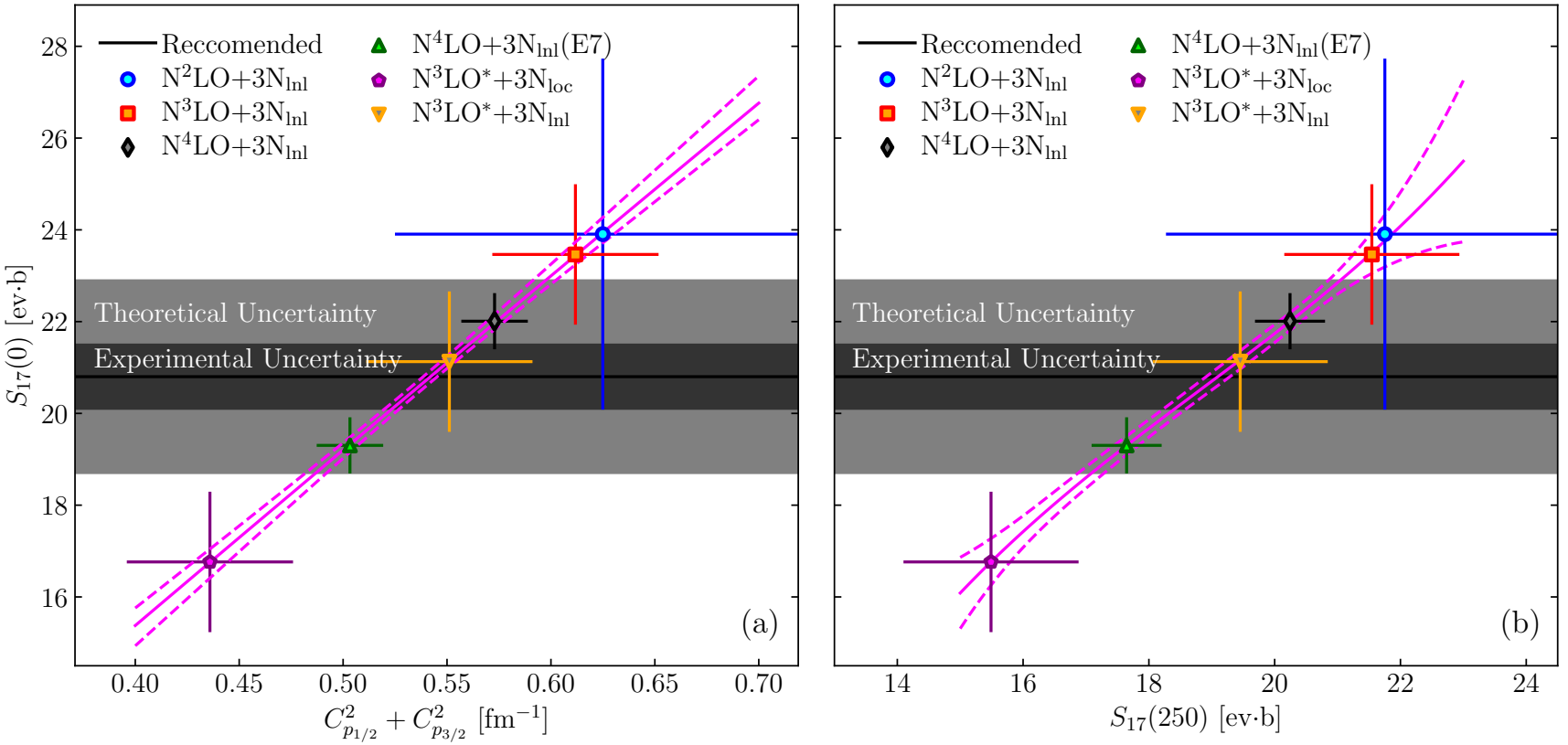

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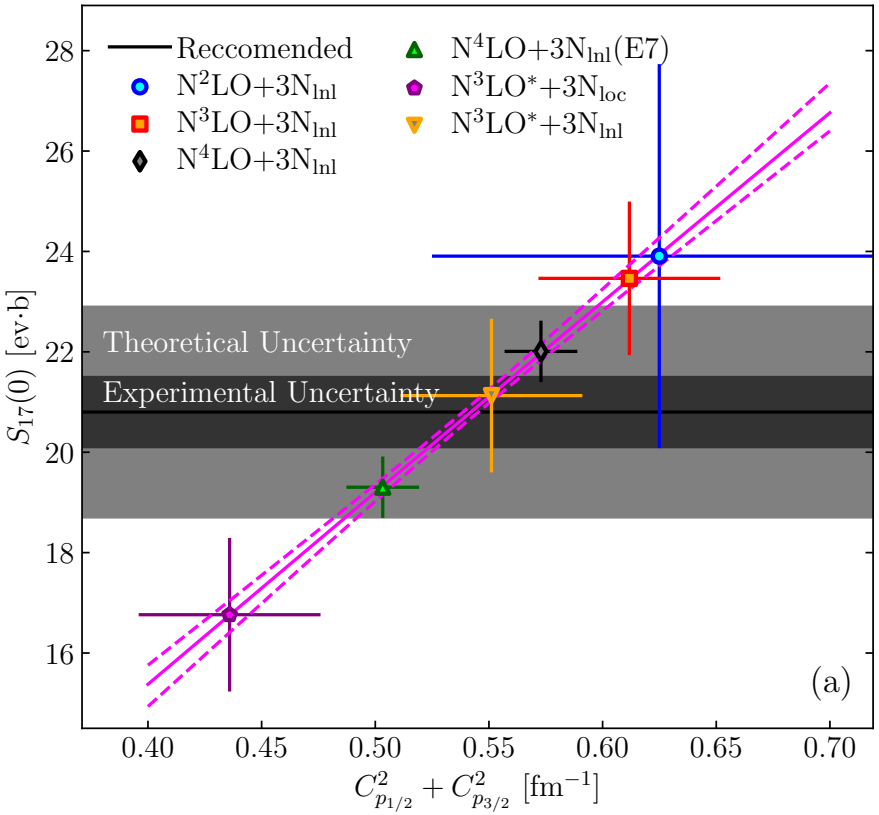

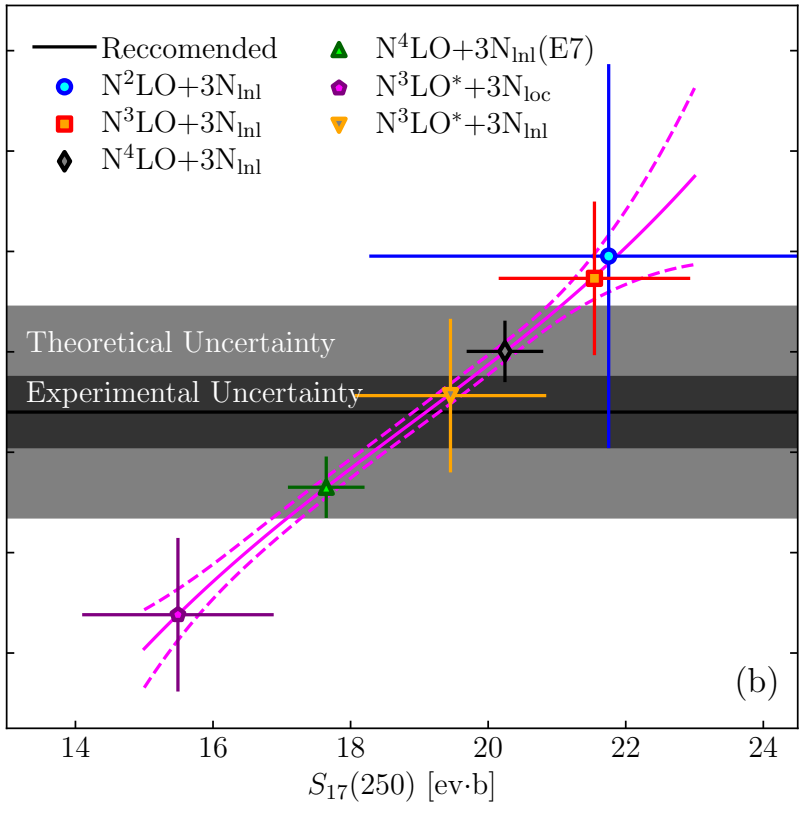

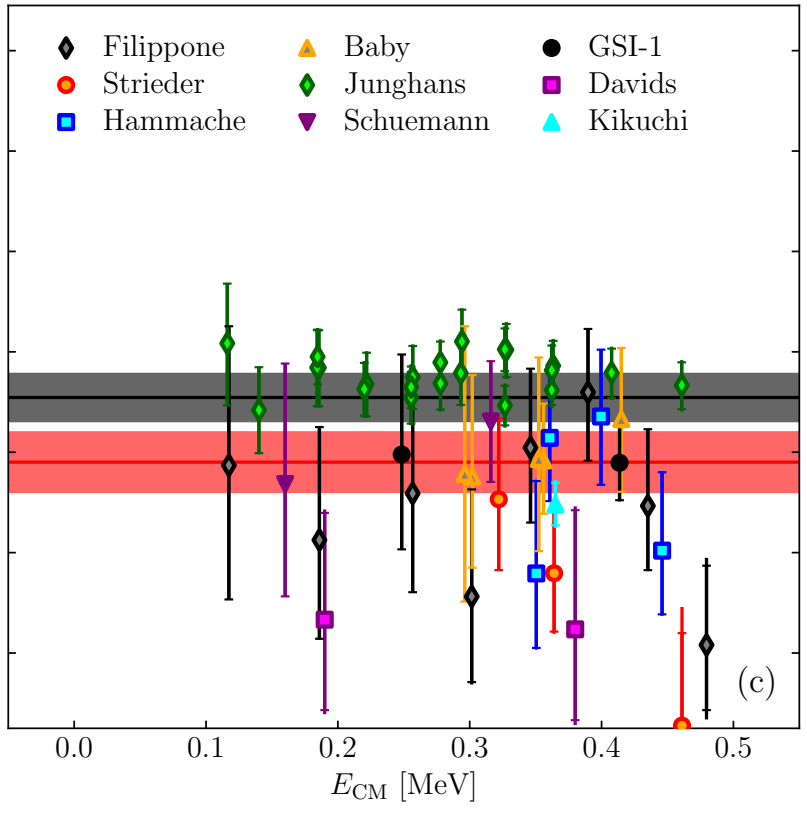

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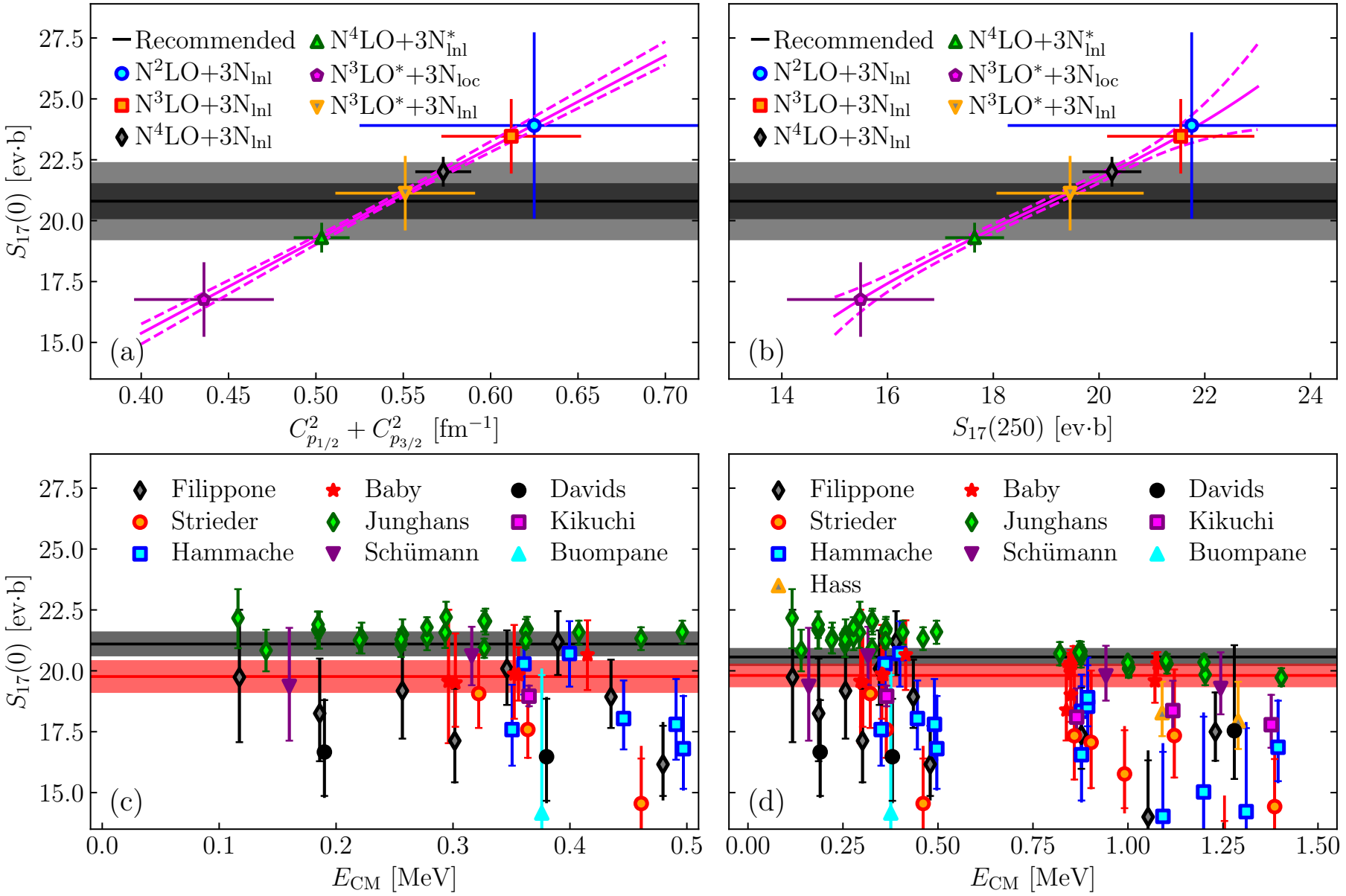

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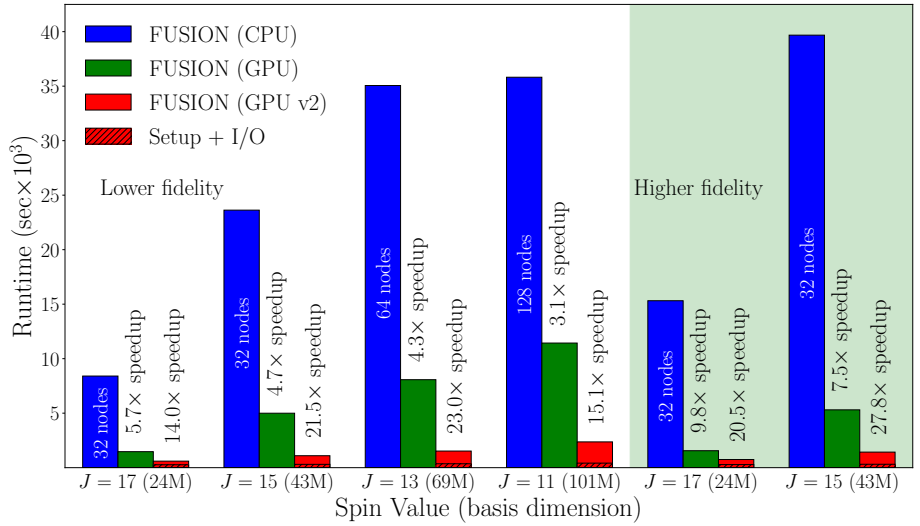
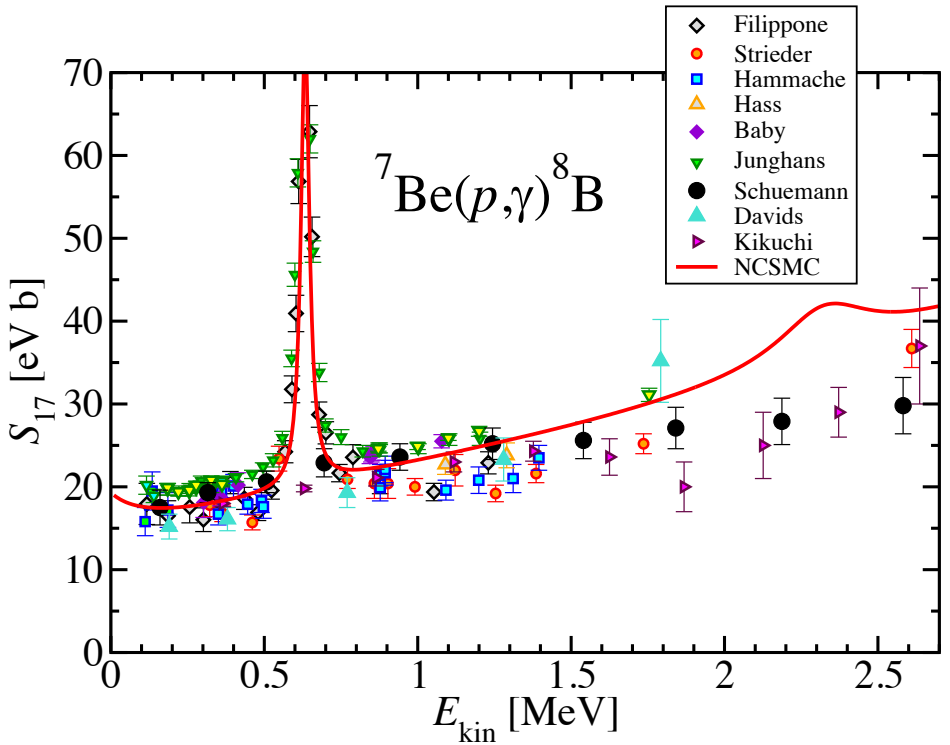
Conclusions & Outlook

- Ab initio reaction theory provides a path forward for the evaluation of nuclear data with increased precision.
- Theoretical uncertainties can now be quantified though more contributions need to be included.
- Theory alone is not the answer! We need high-precision experimental data that will put predictiveness to the test and guide the evaluation.





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