

NEUTRON-RICH NUCLEI AND NEUTRON SKINS FROM CHIRAL LOW-RESOLUTION INTERACTIONS

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[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



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Low-energy ab initio nuclear theory

A-body system with:

Z protons

N neutrons

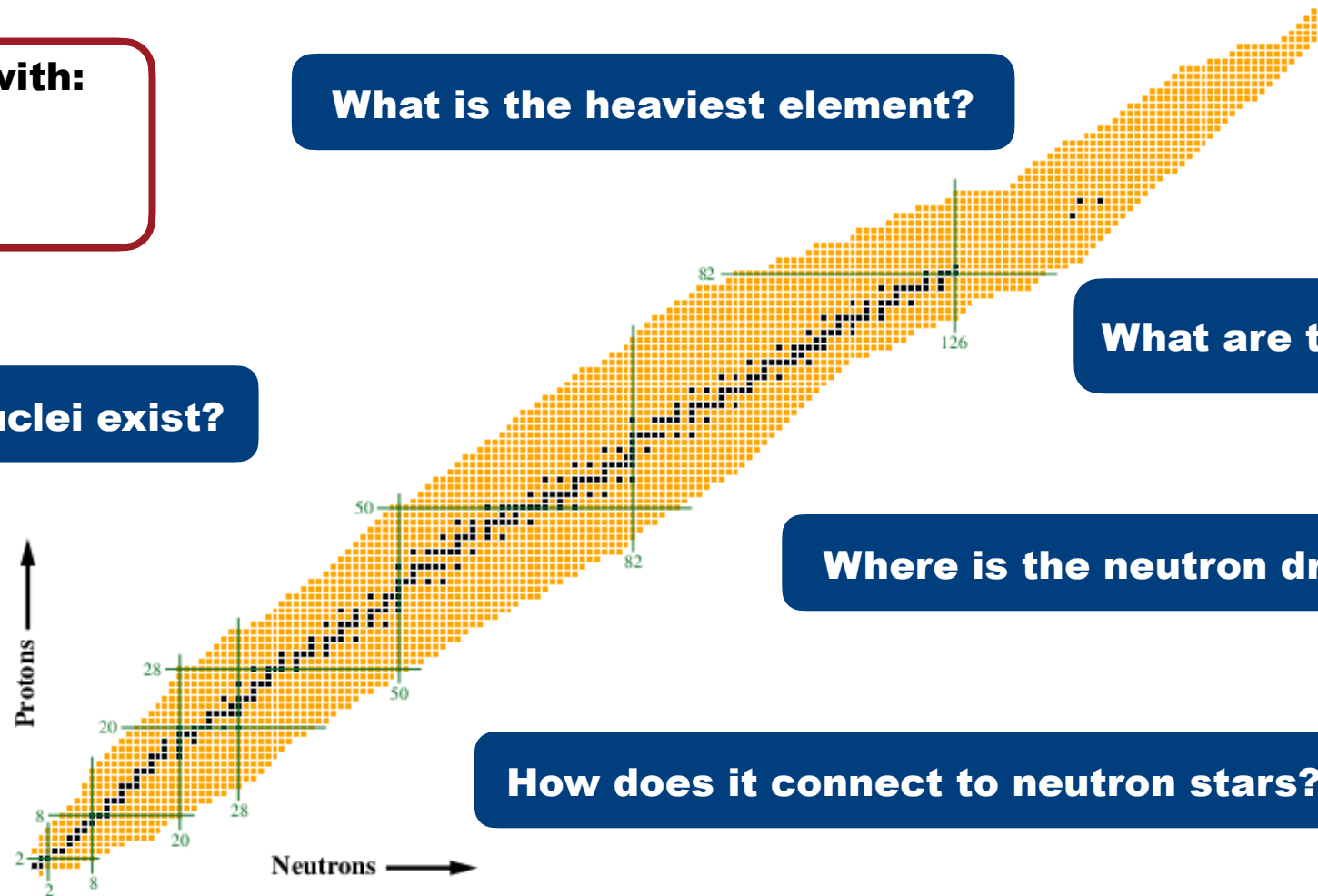
What is the heaviest element?

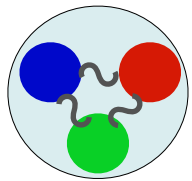
How many nuclei exist?

What are the magic numbers?

Where is the neutron dripline?

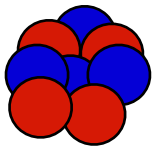
How does it connect to neutron stars?





Particle physics

No direct application of
quantum chromodynamics
(Lattice QCD only for few nucleons)



Nuclear theory

Interactions anchored in Effective Field Theory

A-body Schrödinger equation

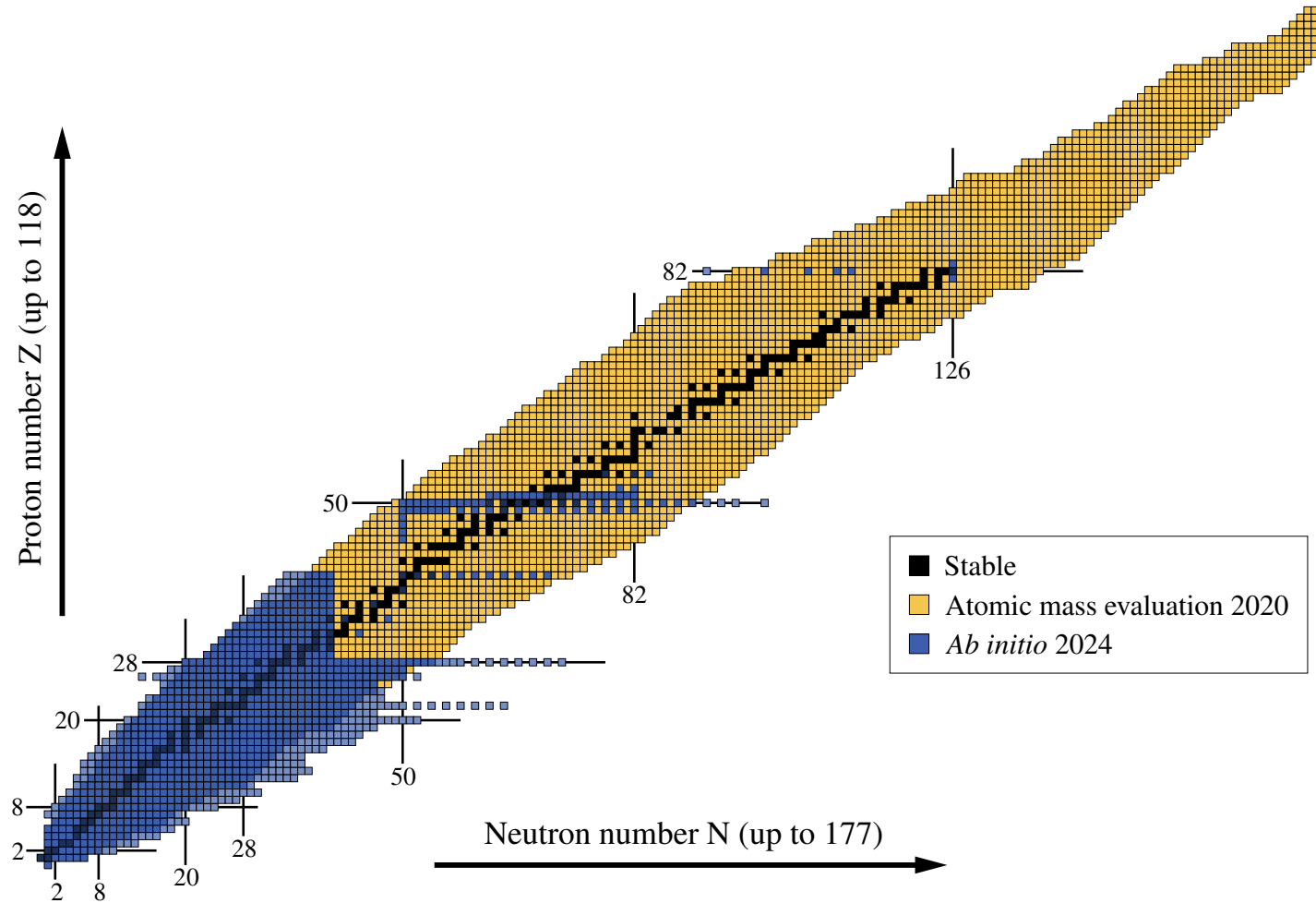
$$H|\Psi^A\rangle = E^A|\Psi^A\rangle$$

Obtain a description that is:

- Consistent
- Systematic
- Accurate enough
- From inter-nucleon interactions
- Rooted in quantum chromodynamics



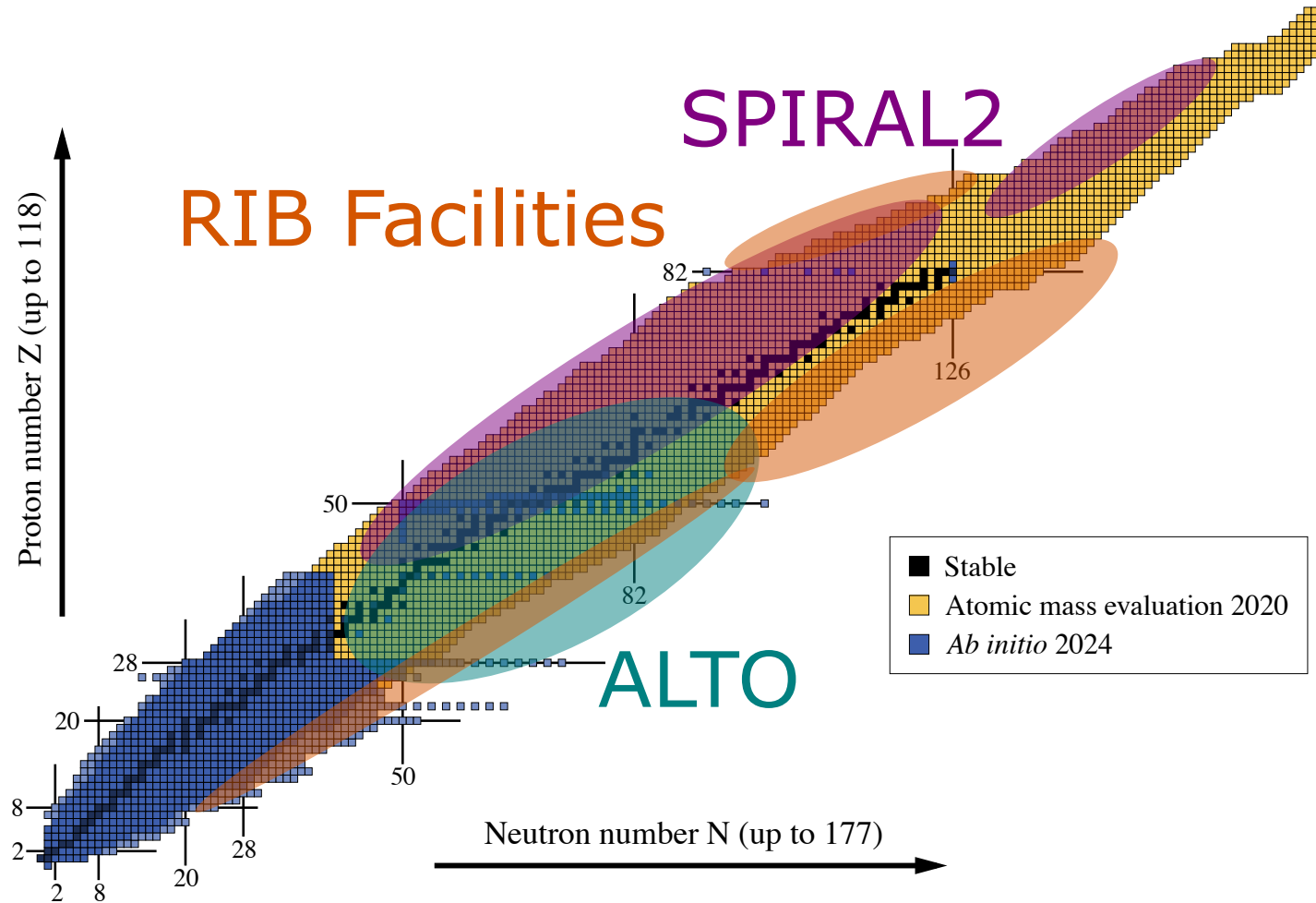
A look at experimental facilities



Adapted from B. Bally



A look at experimental facilities



Adapted from B. Bally

New era of shared effort

Heavier nuclei

More exotic nuclei



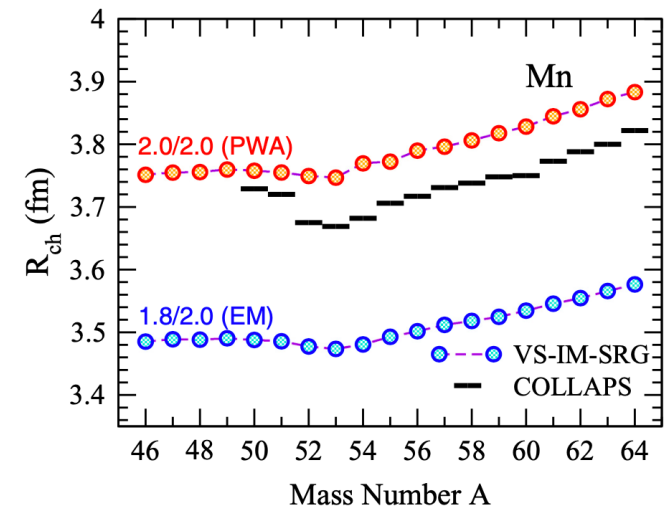
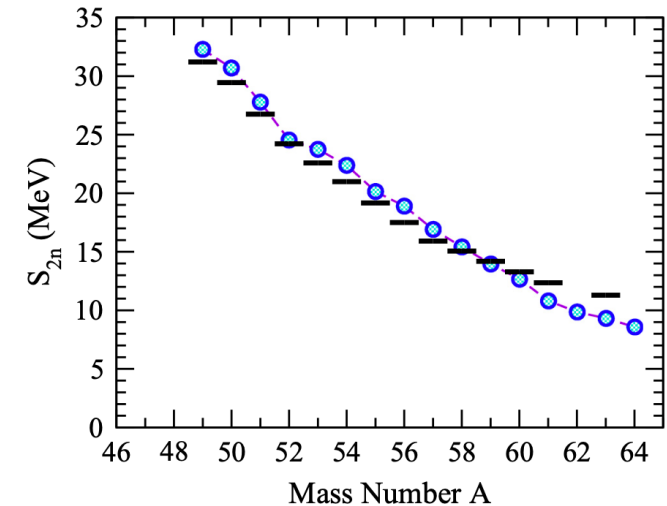
Why low-resolution interactions?

Sufficient to describe bulk properties of nuclei

- Better convergence properties through softened interaction
- Proved successful for binding energies with the 1.8/2.0 (EM)
[Hebeler *et al.*, *PRC* **83** (2011)]

Revisit the 1.8/2.0 approach

- Goal: Obtain good description of binding energy and radii
- Target: From light to heavy systems

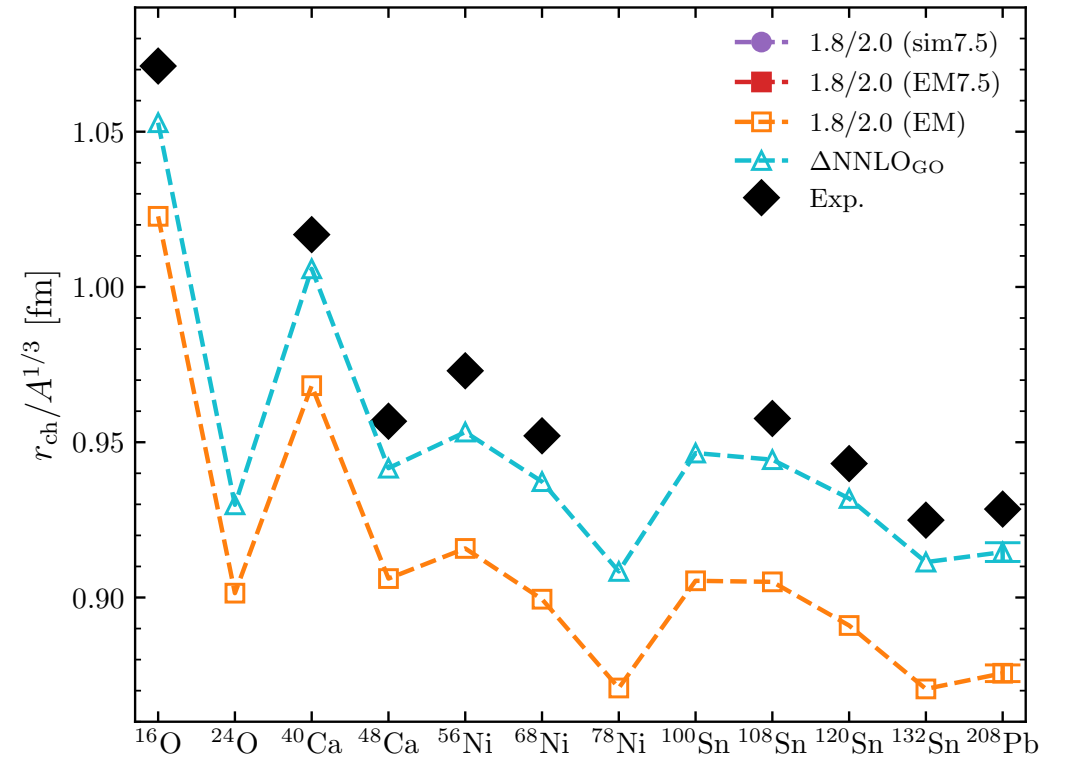
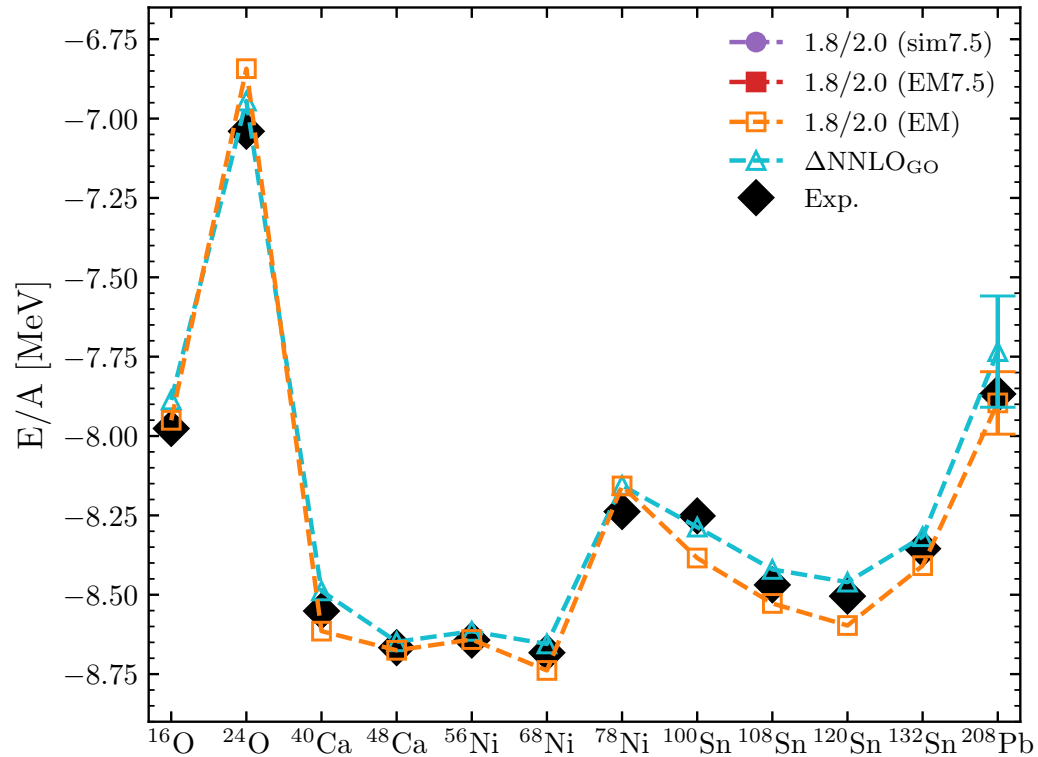


[Simonis *et al.*, *PRC* **96** (2017)]



Ground-state accuracy towards heavy systems

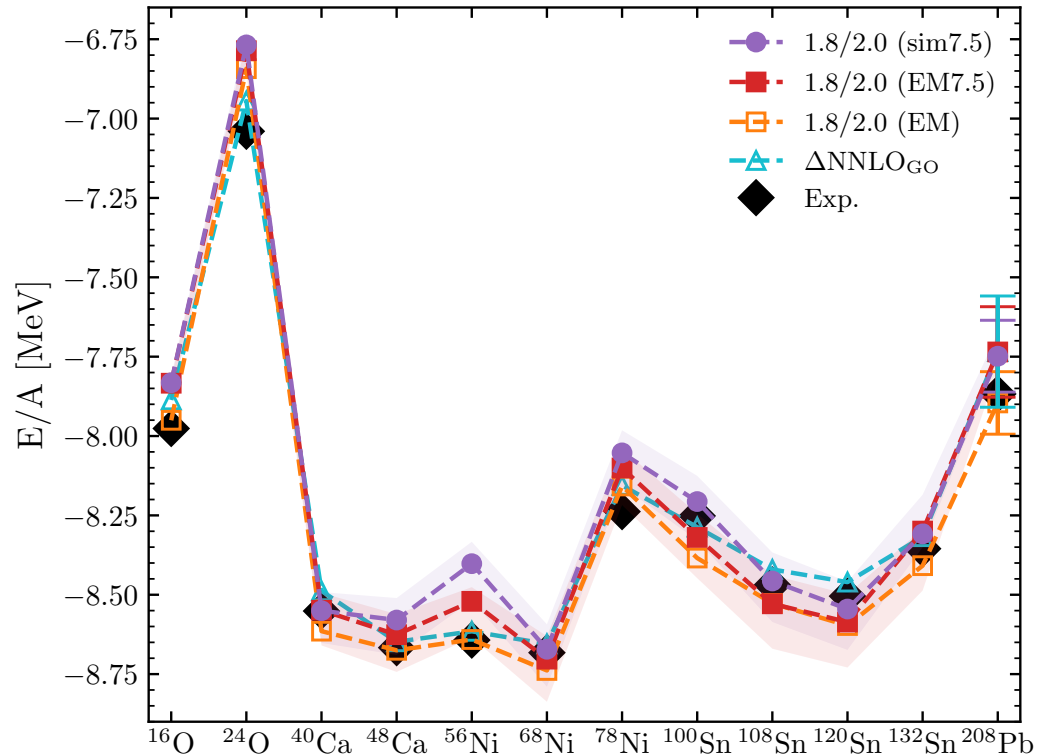
[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]





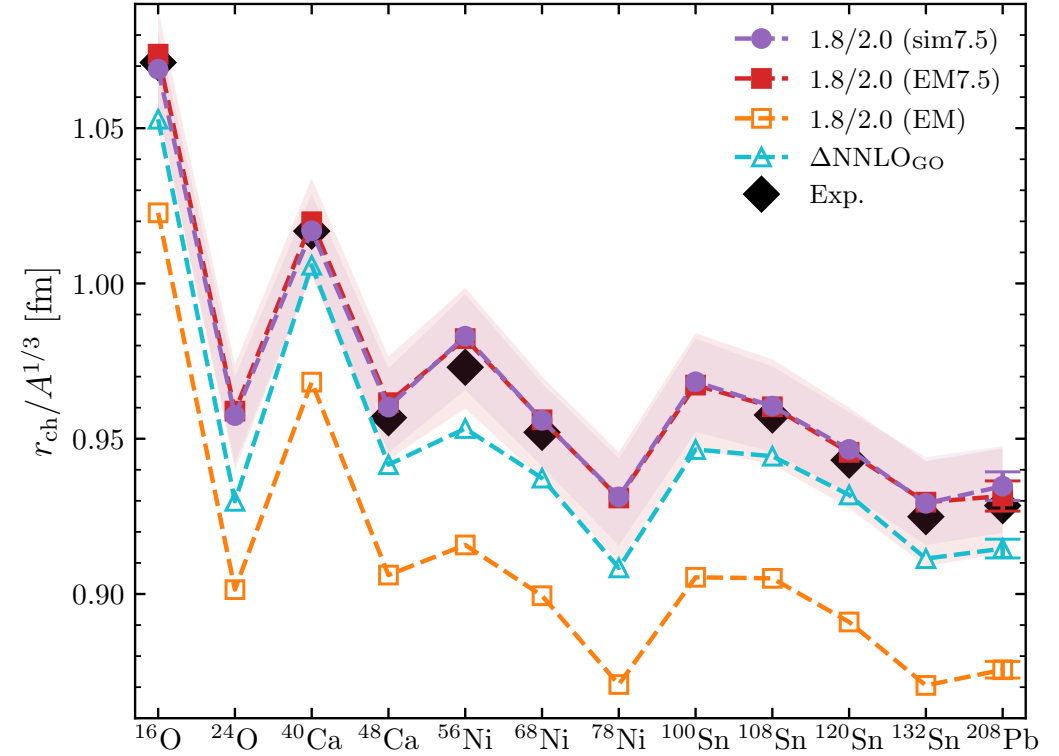
Ground-state accuracy towards heavy systems

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



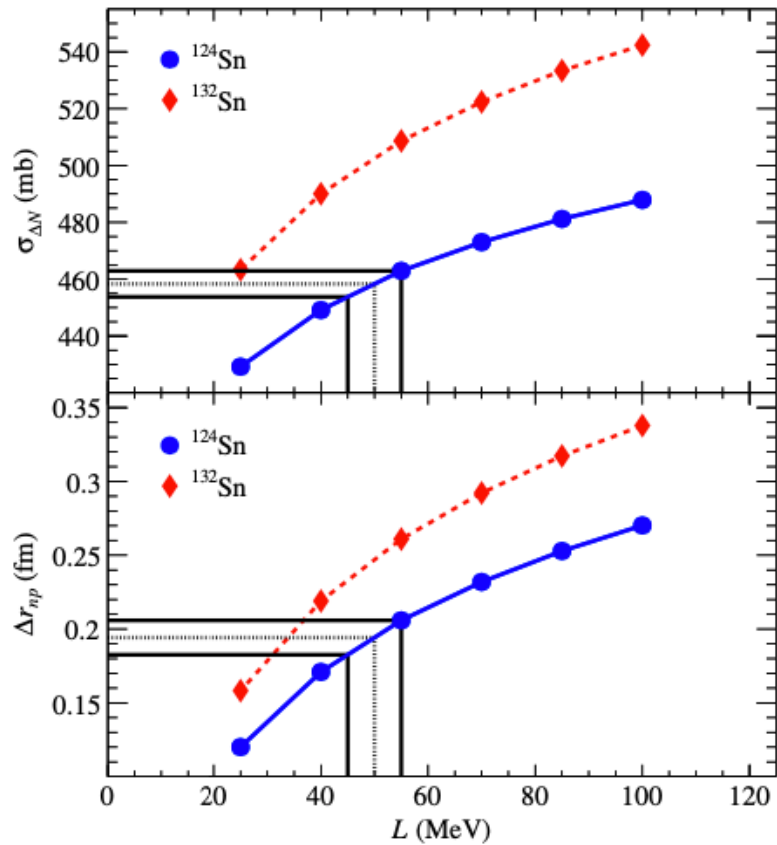
Binding energy

- Reasonable reproduction of experimental values
- Slight improvement for heavy systems w.r.t. 1.8/2.0 (EM)



Charge radius

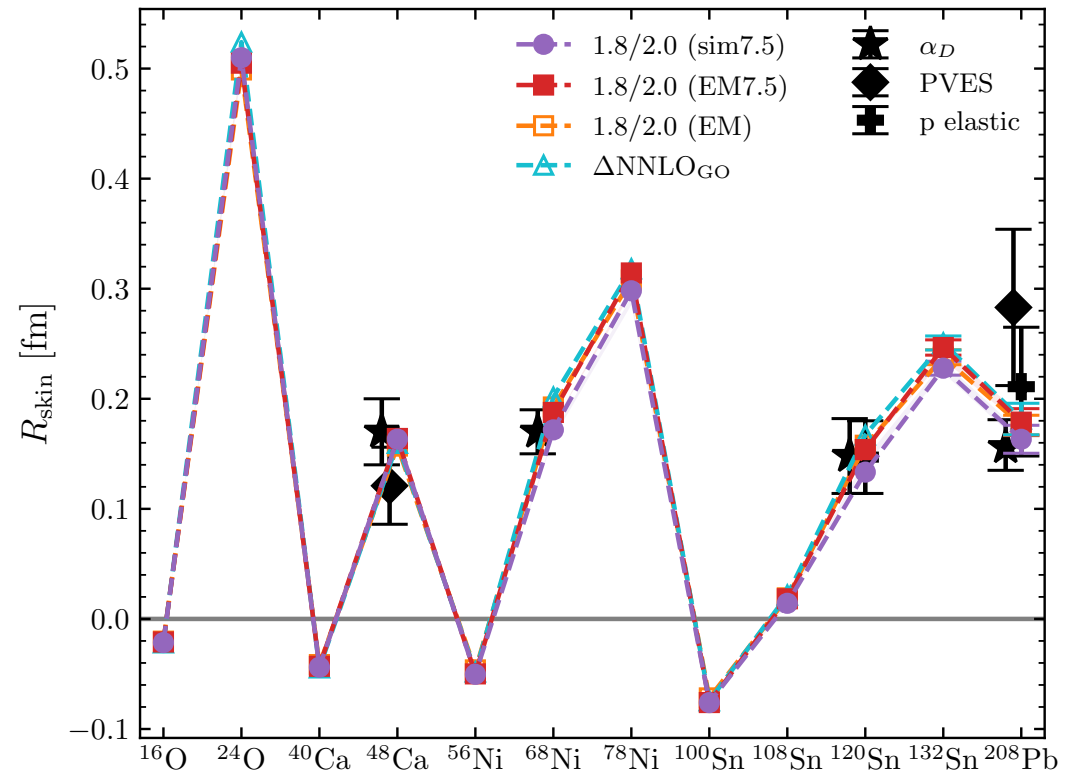
- Quasi-exact reproduction over complete mass range
- Excellent combined reproduction of charge and mass



[Aumann *et al.*, *PRL* 119 (2017)]

Neutron removal off Sn isotopes @ R3B/GSI

- Access L through the cross-section, need for theory input
- L correlated to neutron skin too: Great test case

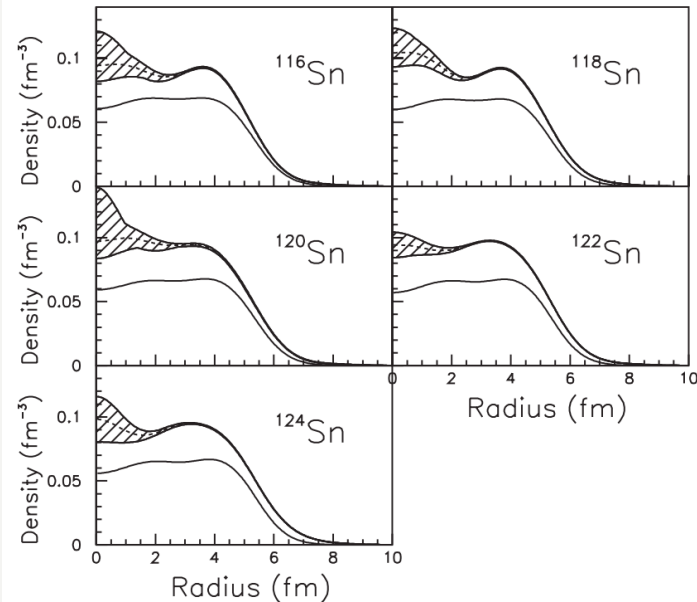




On neutron skins

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]

Evolution w.r.t. isospin

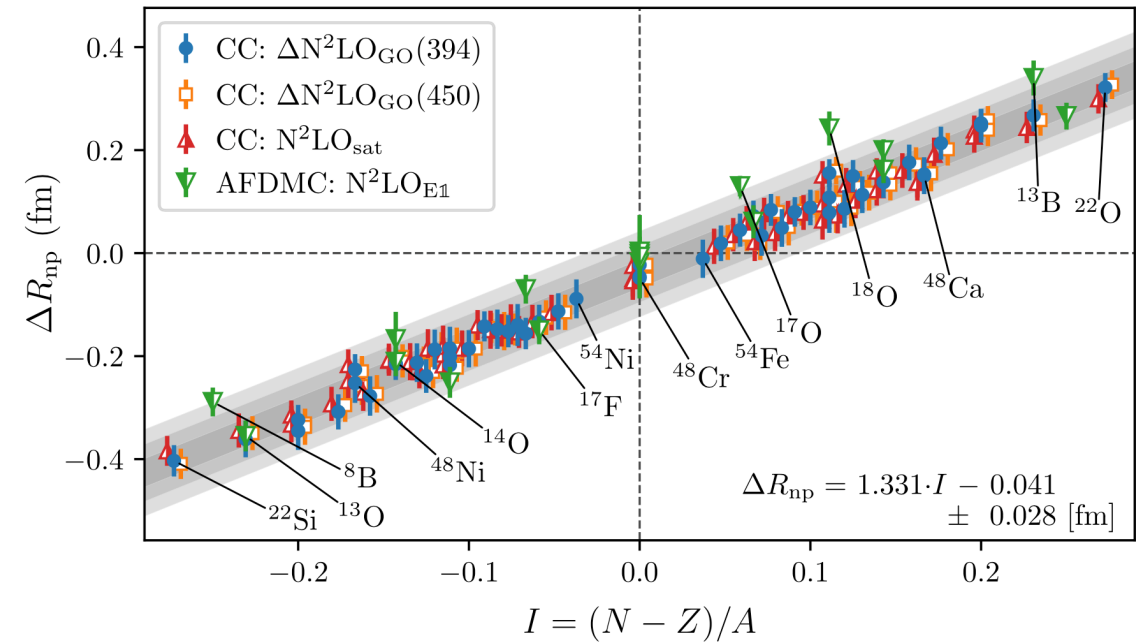


[Terashima et al., PRC 77 (2008)]

Liquid droplet model

$$R_{\text{skin}} \propto \frac{2r_0}{3} \frac{S_S}{S_V + S_S A^{-1/3}} \frac{N - Z}{A}$$

Linear relation confirmed on *ab initio* basis

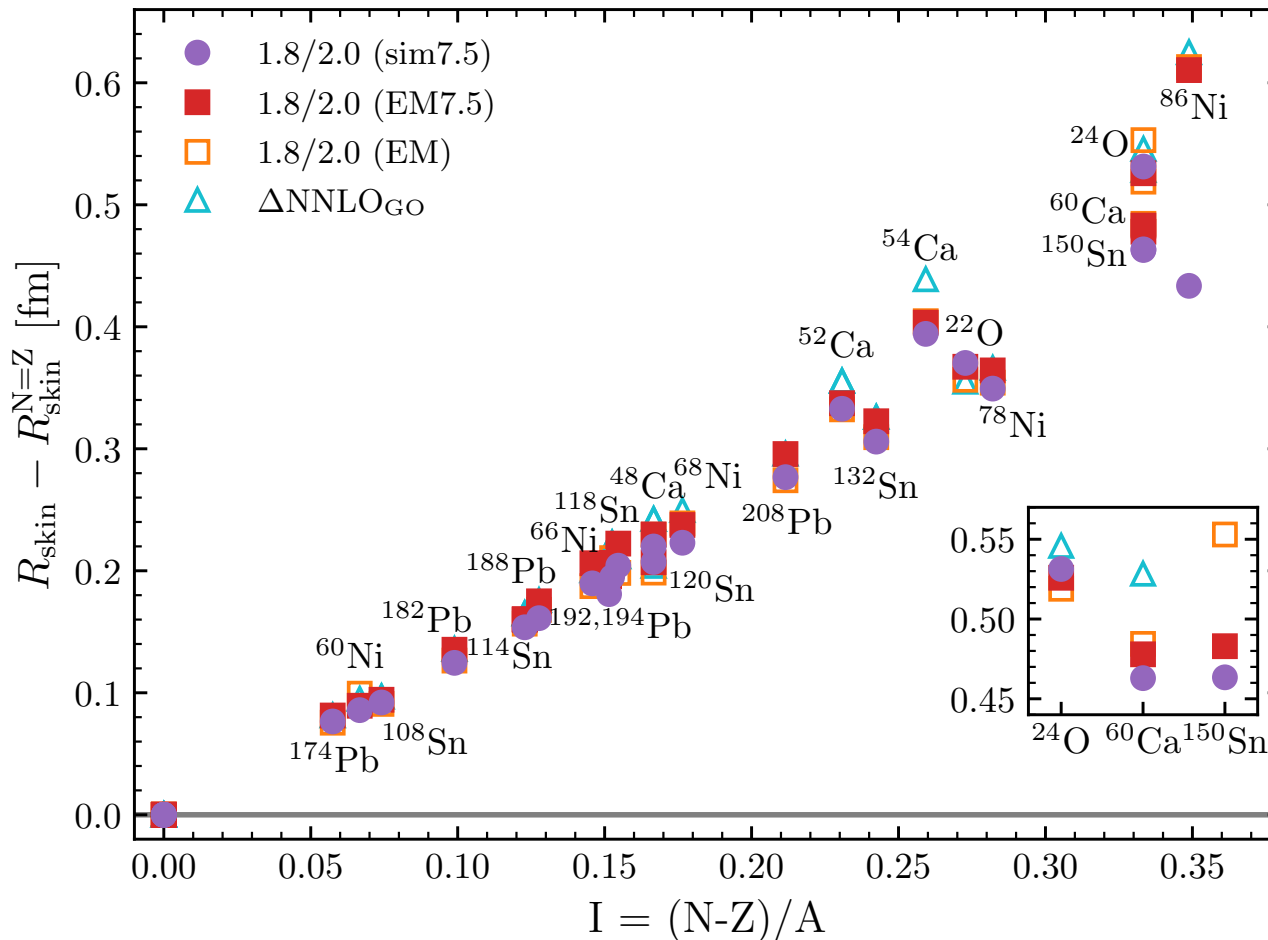


[Novario et al., PRL 130 (2023)]



Neutron skins in neutron-rich isotopes

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



Evolution w.r.t. isospin

- Linear dependence confirmed in valley of stability
- Neutron-rich nuclei exhibit stronger dependence
- Highlight importance of interaction

Good physics cases to explore

Strongly correlated with $\Delta R_{\text{ch}}^{\text{mirror}}$

[N. Koak, B.Sc. Thesis (2024)]



Ab initio methods for nuclear physics

- Offer a systematic approach to nuclear structure and reactions

Novel accurate interactions over the nuclear chart

- Very good reproduction of binding energy, radii, neutron skins

Neutron skin dependence on isospin

- Enhanced dependence on system at the most neutron-rich
- Neutron-rich nuclei to be more accessible with new RIB facilities



Acknowledgments



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