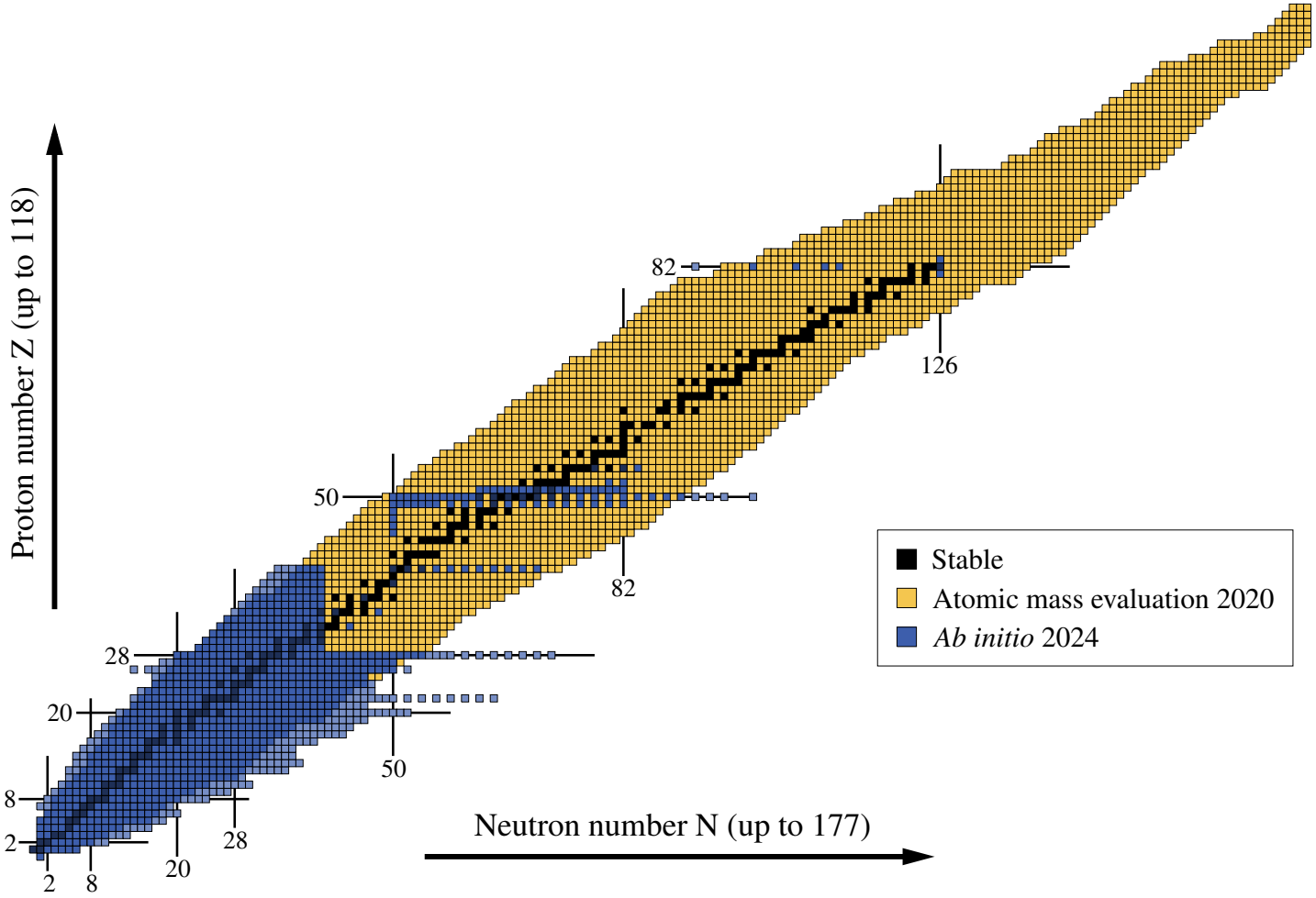
NOVEL CHIRAL LOW-RESOLUTION INTERACTIONS

Pierre Arthuis

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]

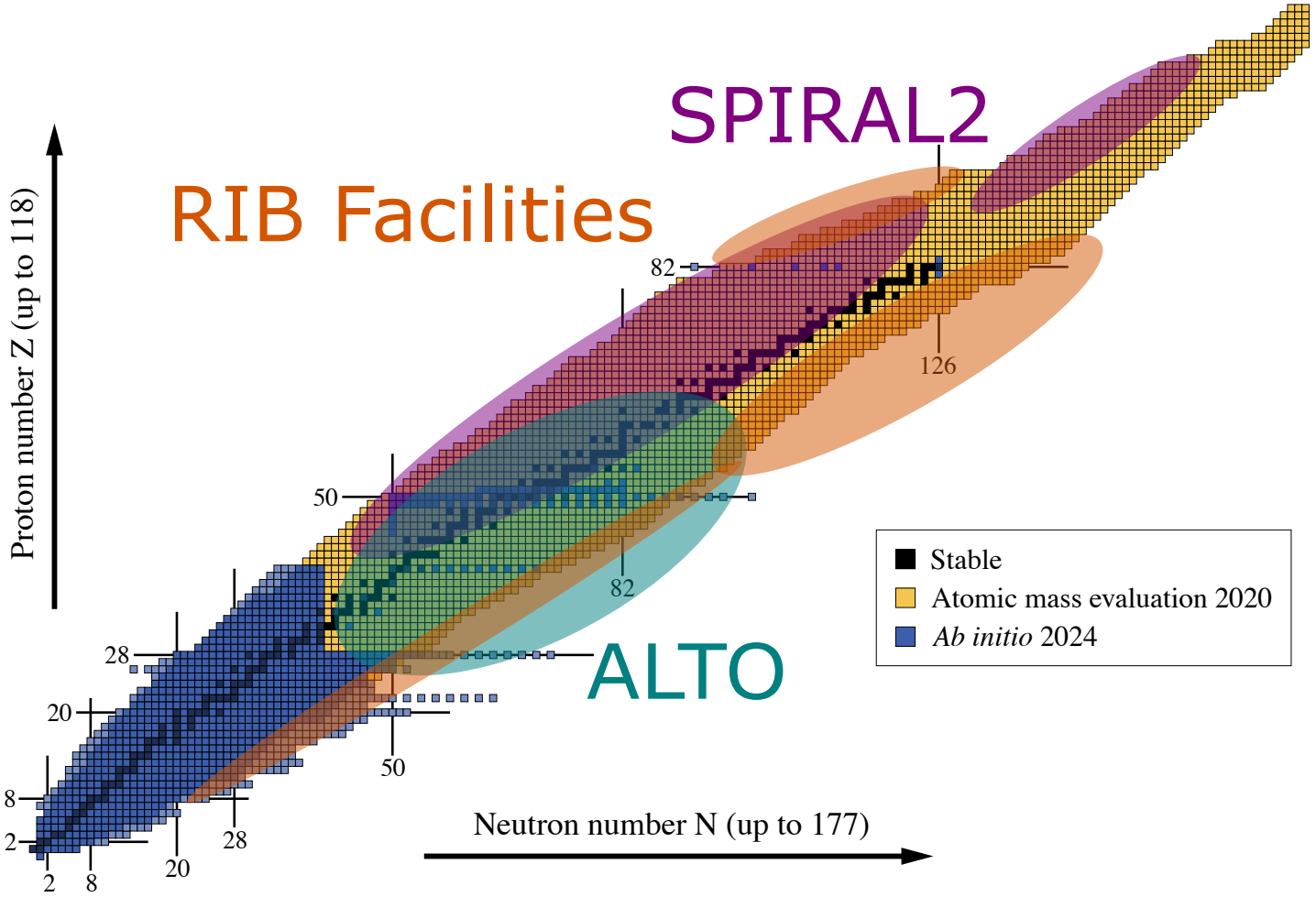
Funded by
the European Union

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

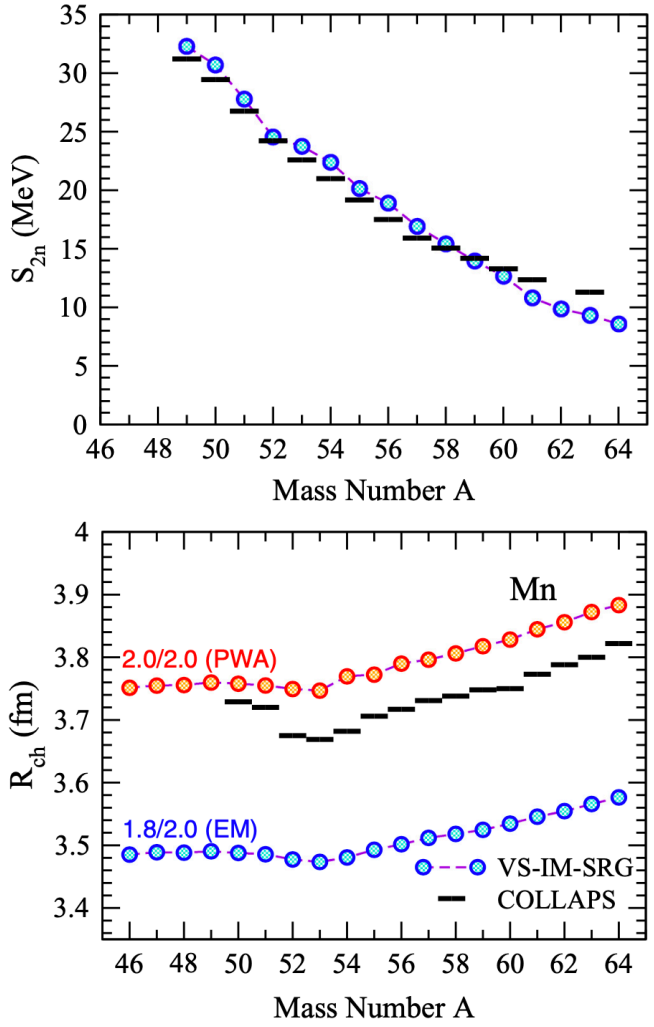
- Better convergence properties through softened interaction
- Proved successful for binding energies with the 1.8/2.0 (EM)
  [Hebeler *et al.*, *PRC* **83** (2011)]

The 1.8/2.0 approach

- NN force SRG-evolved to 1.8 fm^{-1}
- 3N force with c_D, c_E refitted with a cutoff of 2.0 fm^{-1}

Revisit this approach

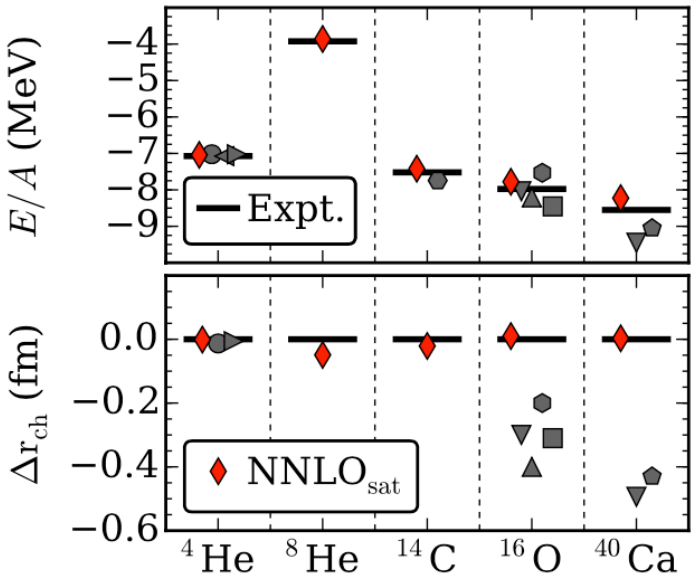
- Goal: Obtain good description of binding energy and radii
- Target: From light to heavy systems



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

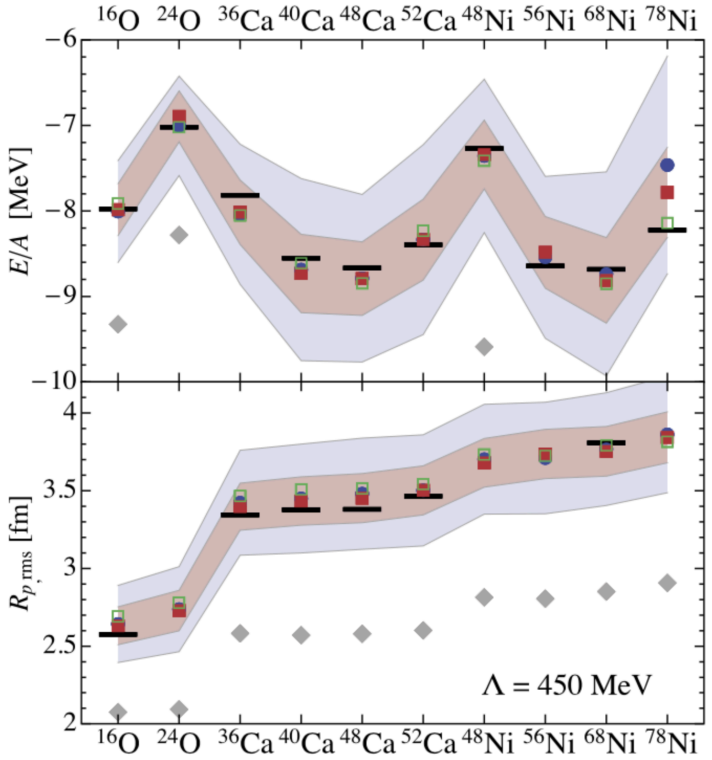
Interactions anchored in many-body data

NNLOsat



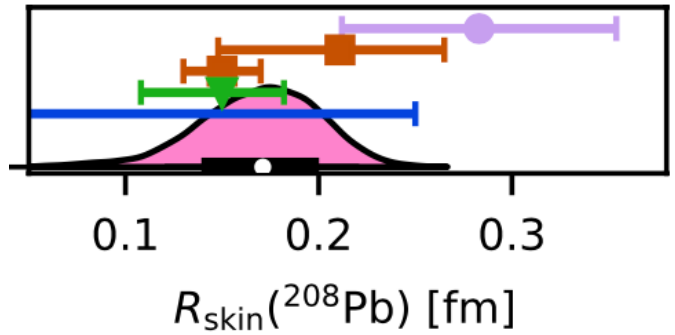
[Ekström *et al.*, *PRC* **91** (2015)]

Hüther et al. family



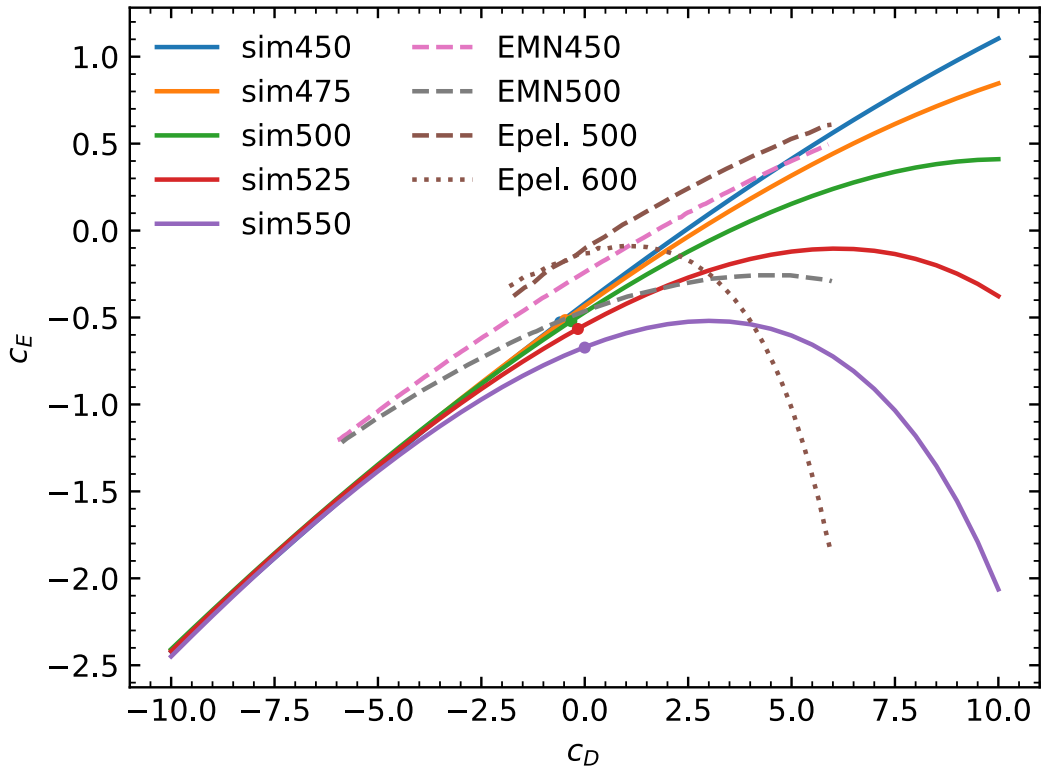
[Hüther *et al.*, *PLB* **808** (2020)]

Non-implausible, ΔNNLO$_{GO}$

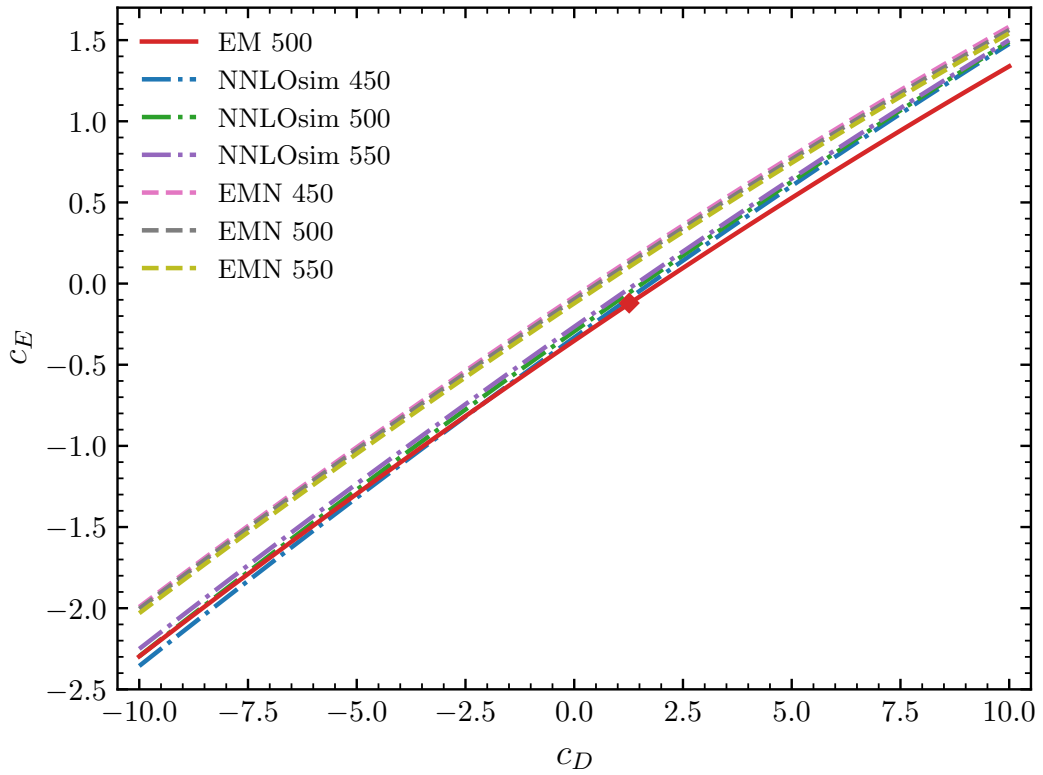


[Hu *et al.*, *Nat. Phys.* **18** (2022)]

The 1.8/2.0 and triton binding energy



Epel. data: [Epelbaum et al., *PRC* **66** (2002)]



Bare interactions

- Similar parabolic curves
- Larger cutoff means stronger bend

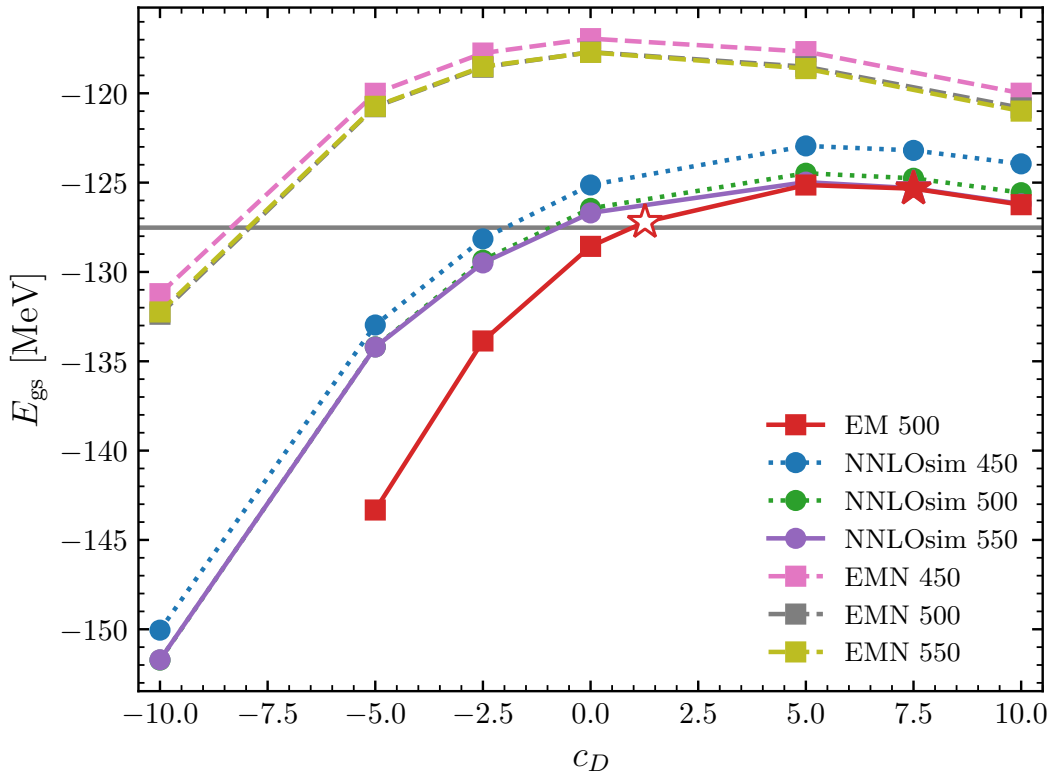
'1.8/2.0' interactions

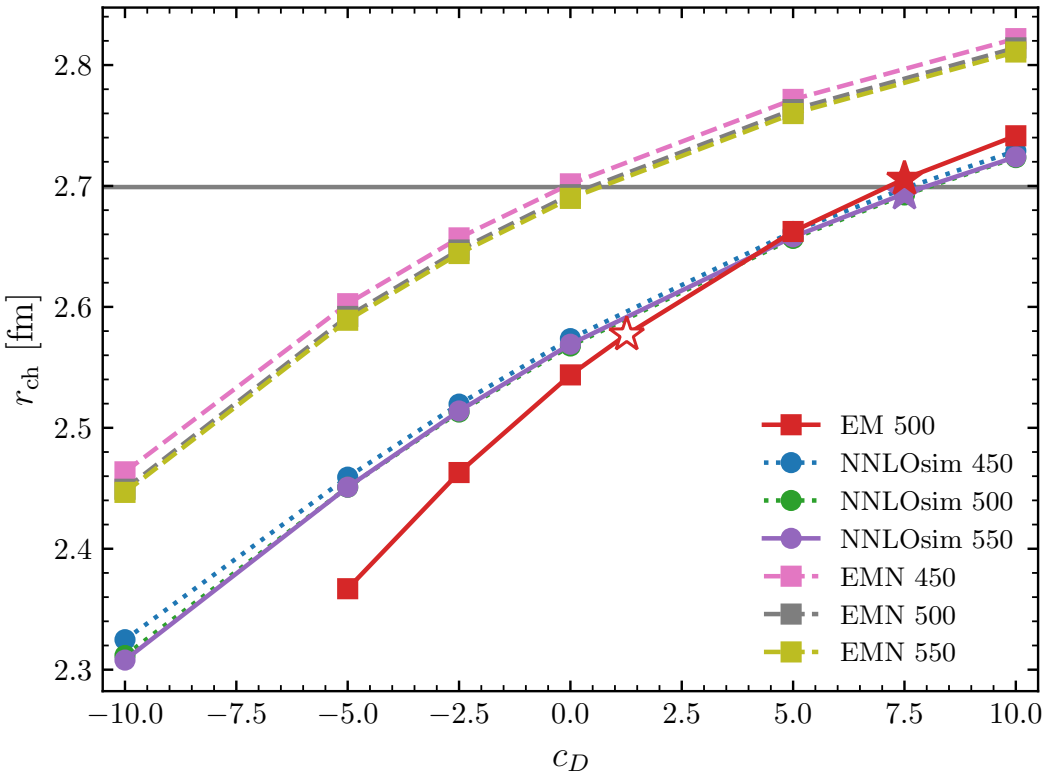
- Very similar, quasi-linear dependence
- Mild dependence on original LECs

EMN: [Entem *et al.*, *PRC* **96** (2017)] NNLOsim: [Carlsson *et al.*, *PRX* **6** (2016)] EM: [Entem, Machleidt, *PRC* **68** (2003)]

Anchoring the interaction on ^{16}O

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]





Binding energy

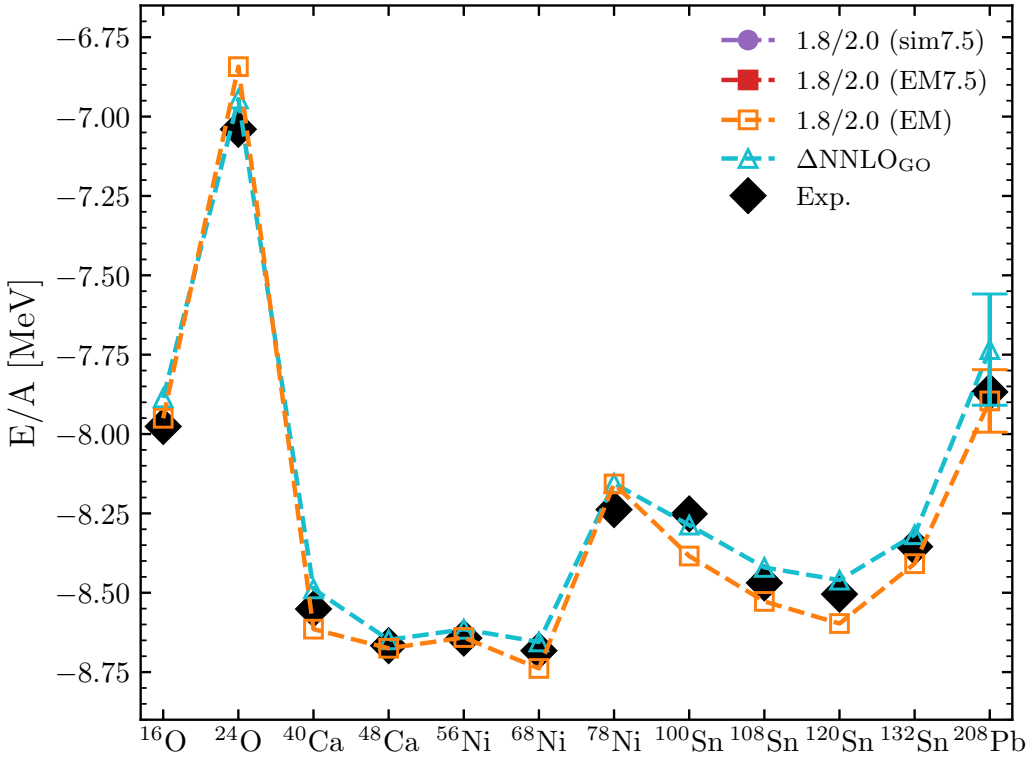
- NNLOsims and EM 500 stay close to exp. value
- EMNs only close for very negative c_D

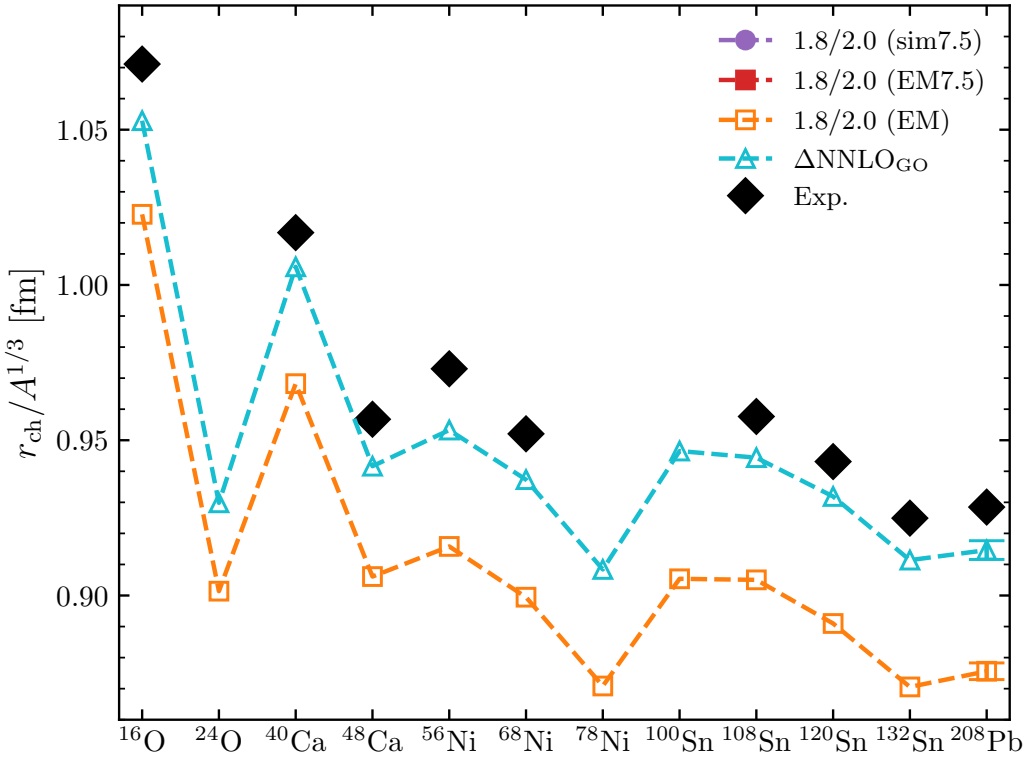
Charge radius

- Quasi-linear evolution with c_D
- $c_D = 7.5$ yields very good radius for NNLOsims and EM

Ground-state accuracy towards heavy systems

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]





Ground-state accuracy towards heavy systems

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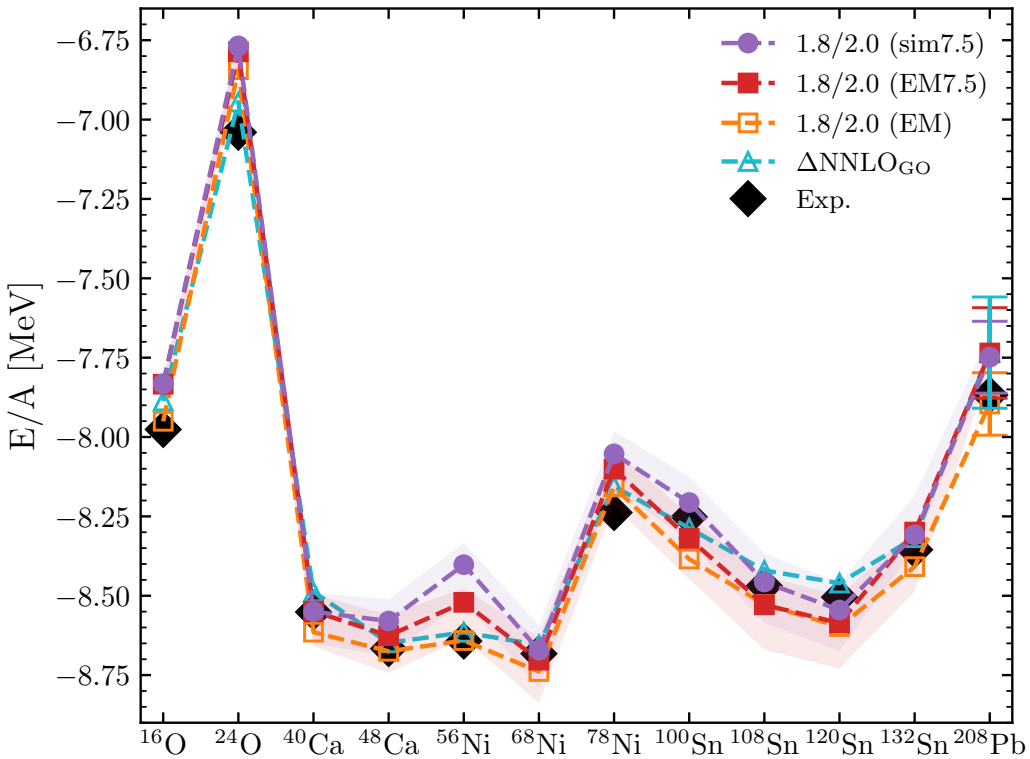
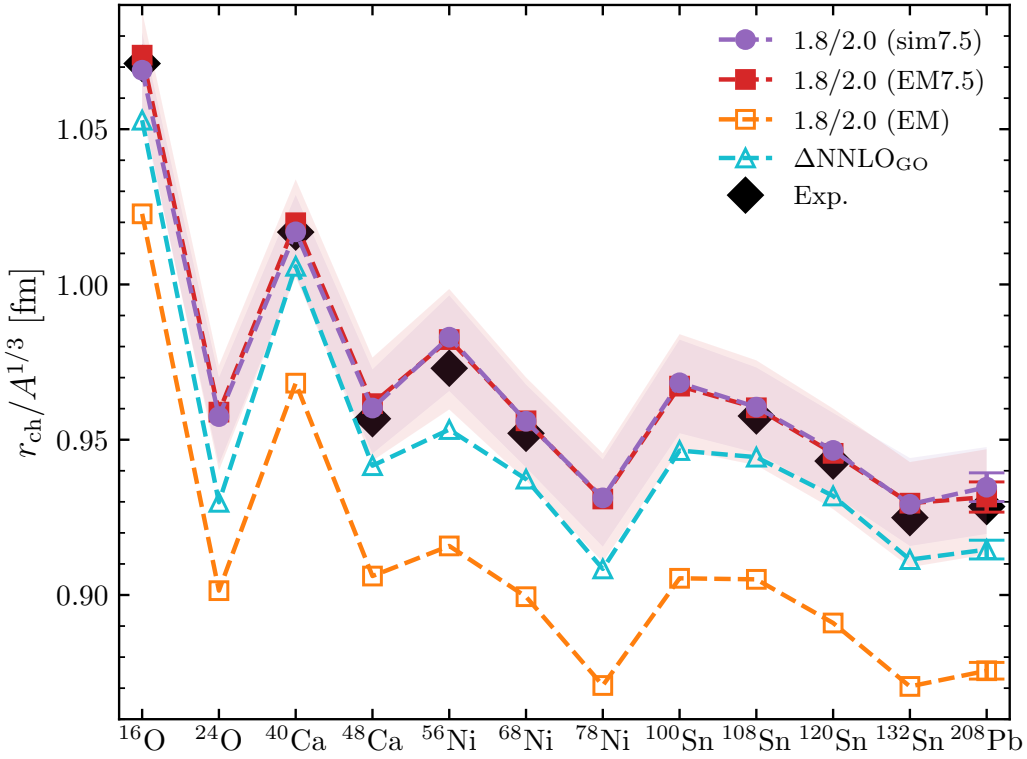




Binding energy

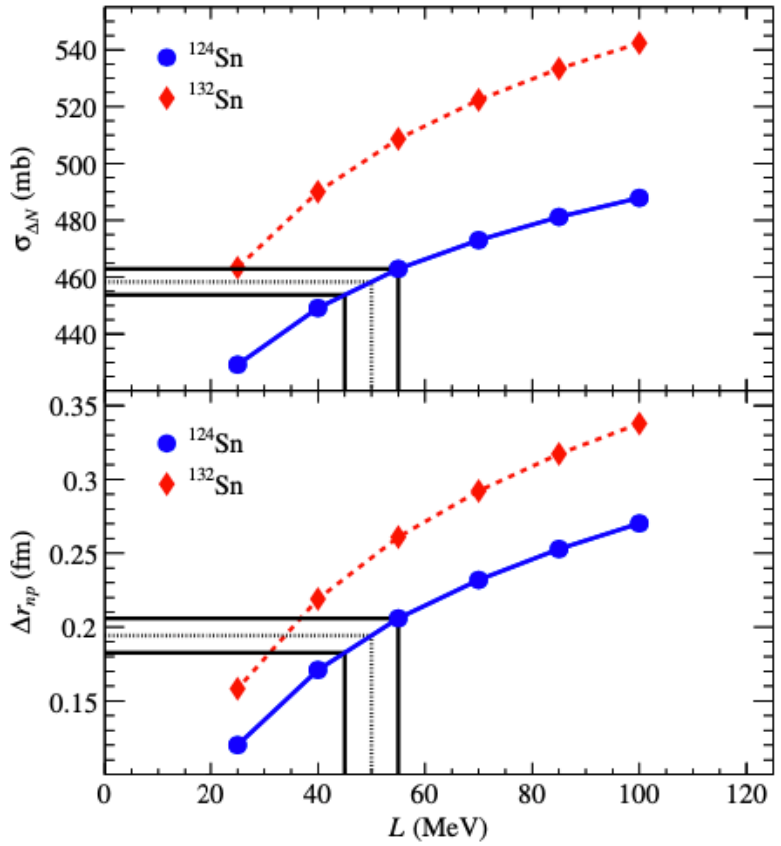
- Reasonable reproduction of experimental values
- Slight improvement for heavy systems w.r.t. 1.8/2.0 (EM)

Charge radius

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

Neutron skins and heavy systems

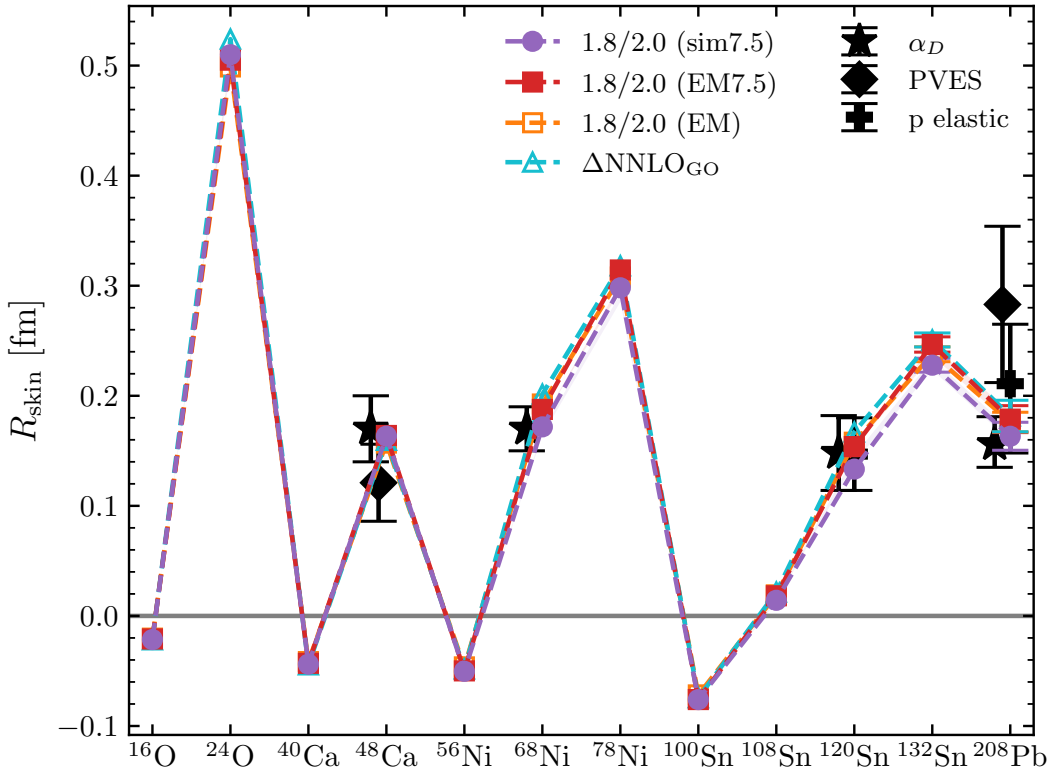
[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



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

Neutron removal off Sn isotopes @ R3B/GSI

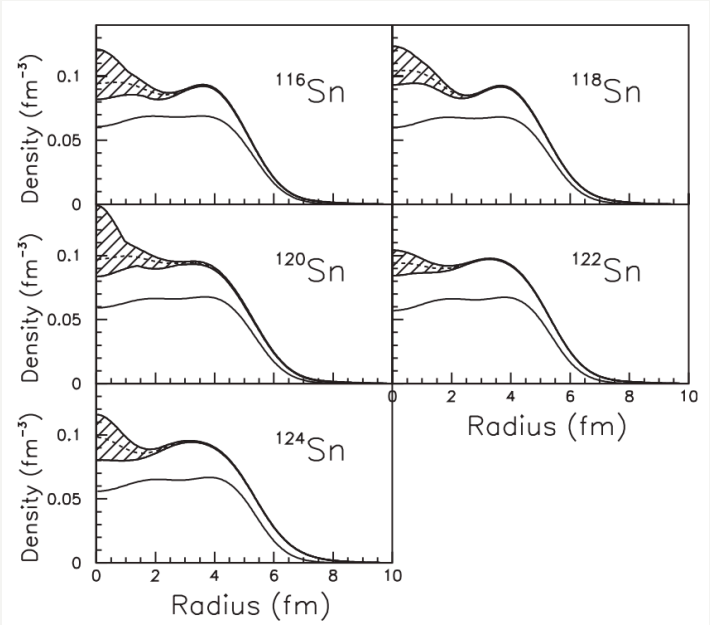
- Access L through the cross-section, need for theory input
- L correlated to neutron skin too: Great test case



On neutron skins

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]

Evolution w.r.t. isospin

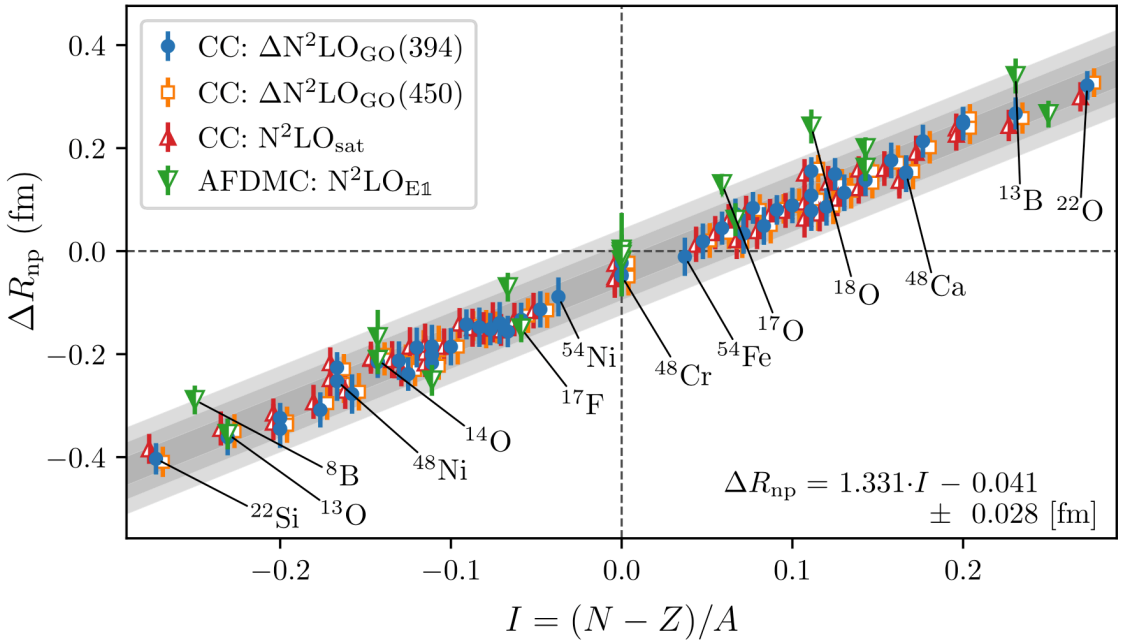


[Terashima *et al.*, *PRC* **77** (2008)]

Liquid droplet model

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

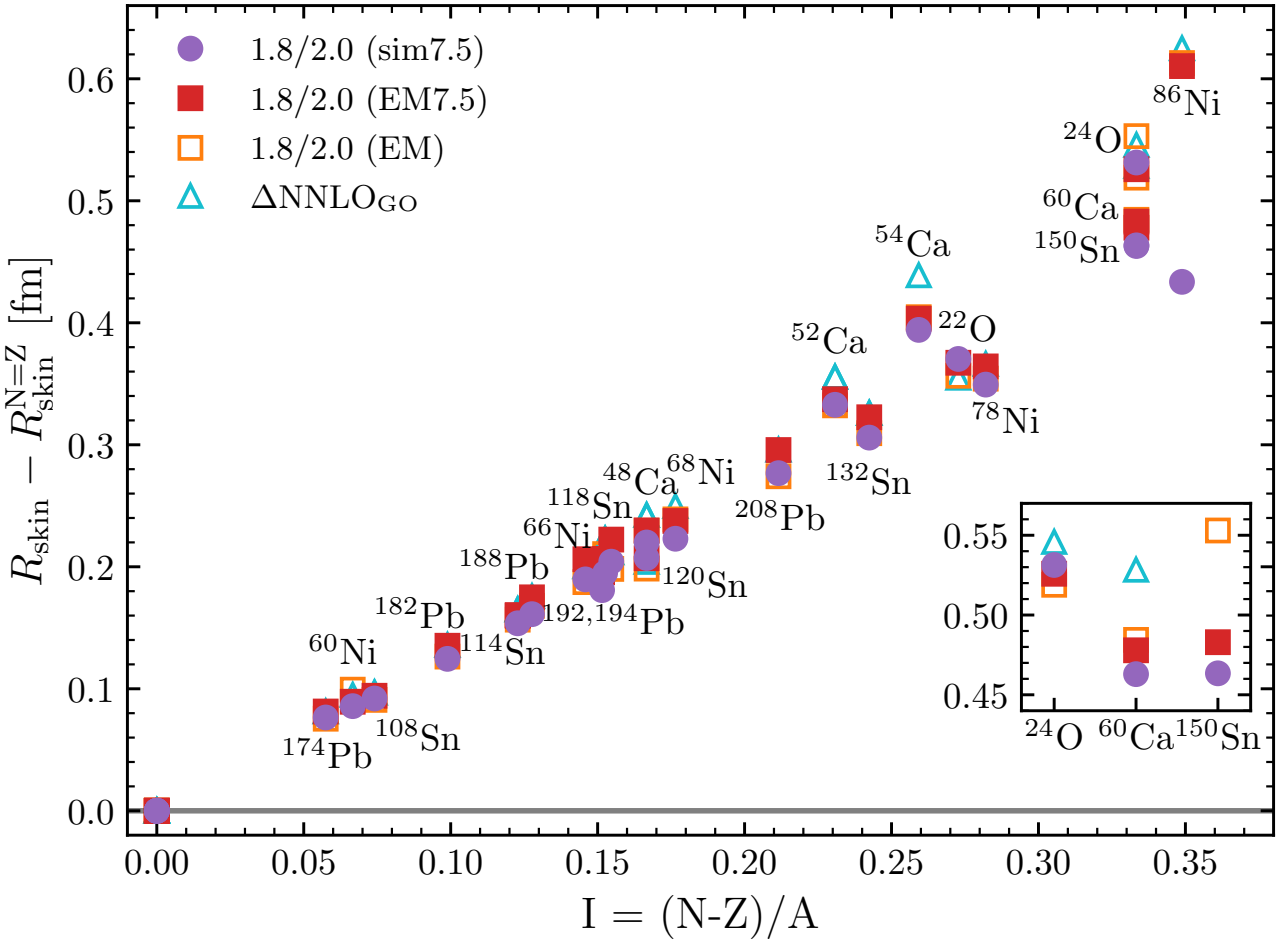
Linear relation confirmed on *ab initio* basis



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

Neutron skins in neutron-rich isotopes

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



Evolution w.r.t. isospin

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

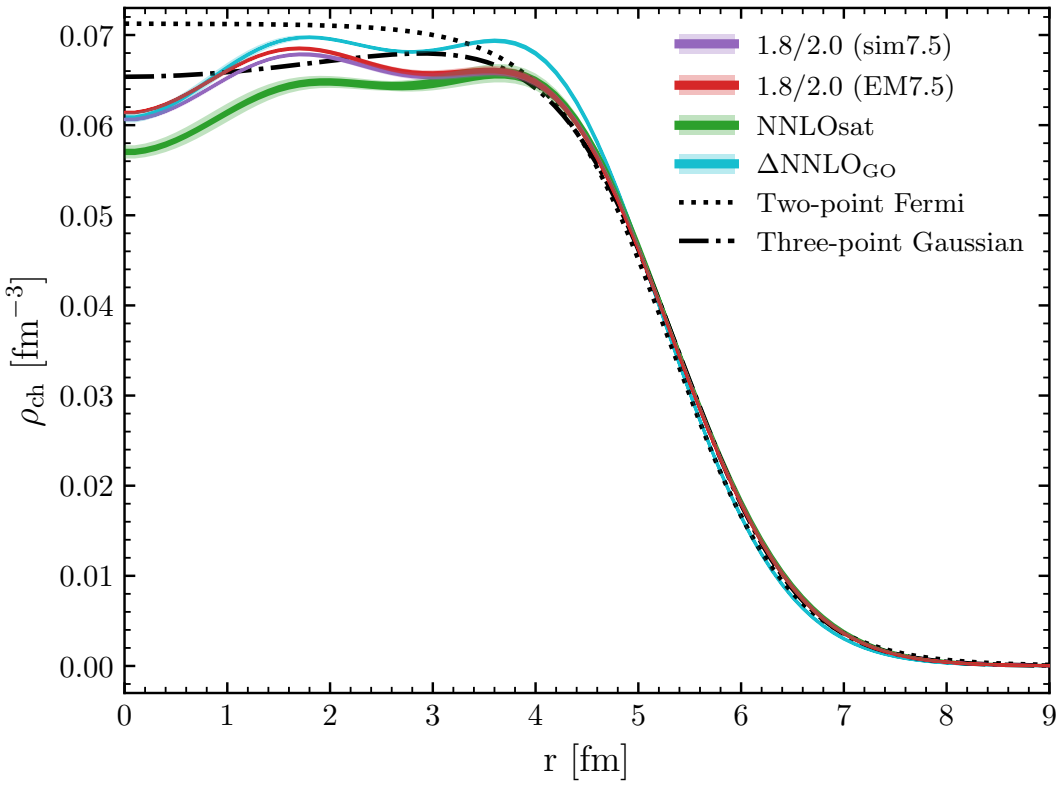
Good physics cases to explore

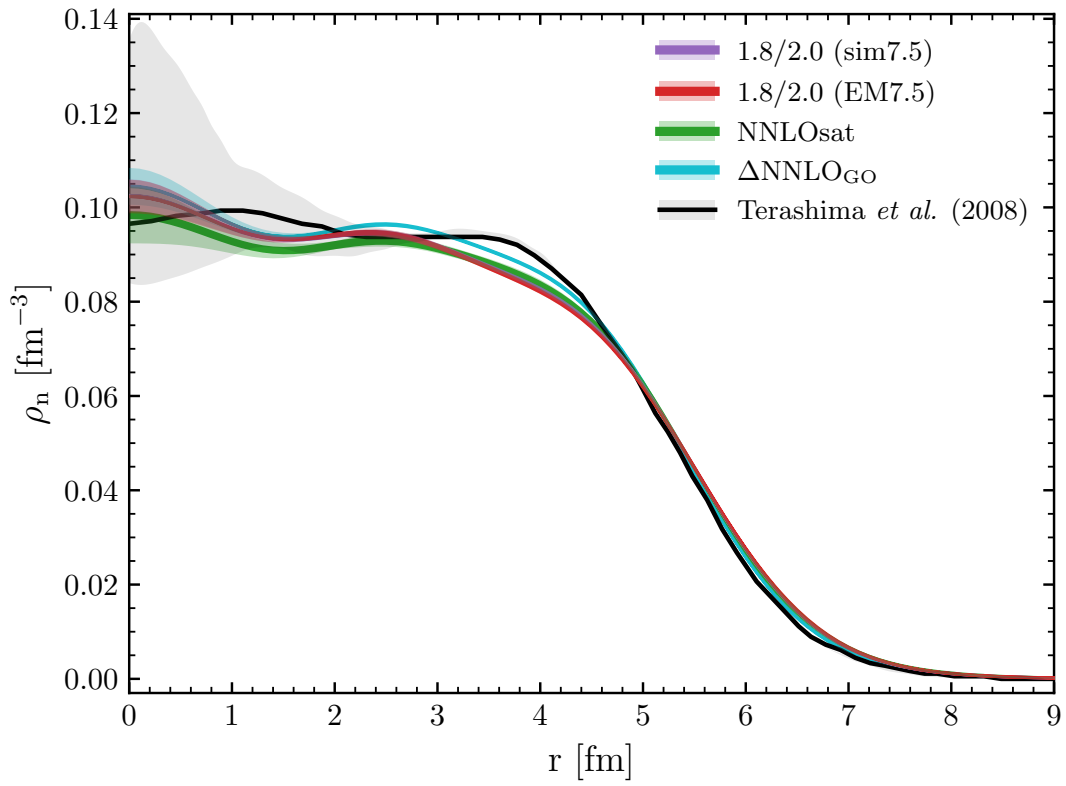
Strongly correlated with ΔR_{ch}^{mirror}

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

Ab initio densities for heavy systems: ^{120}Sn

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



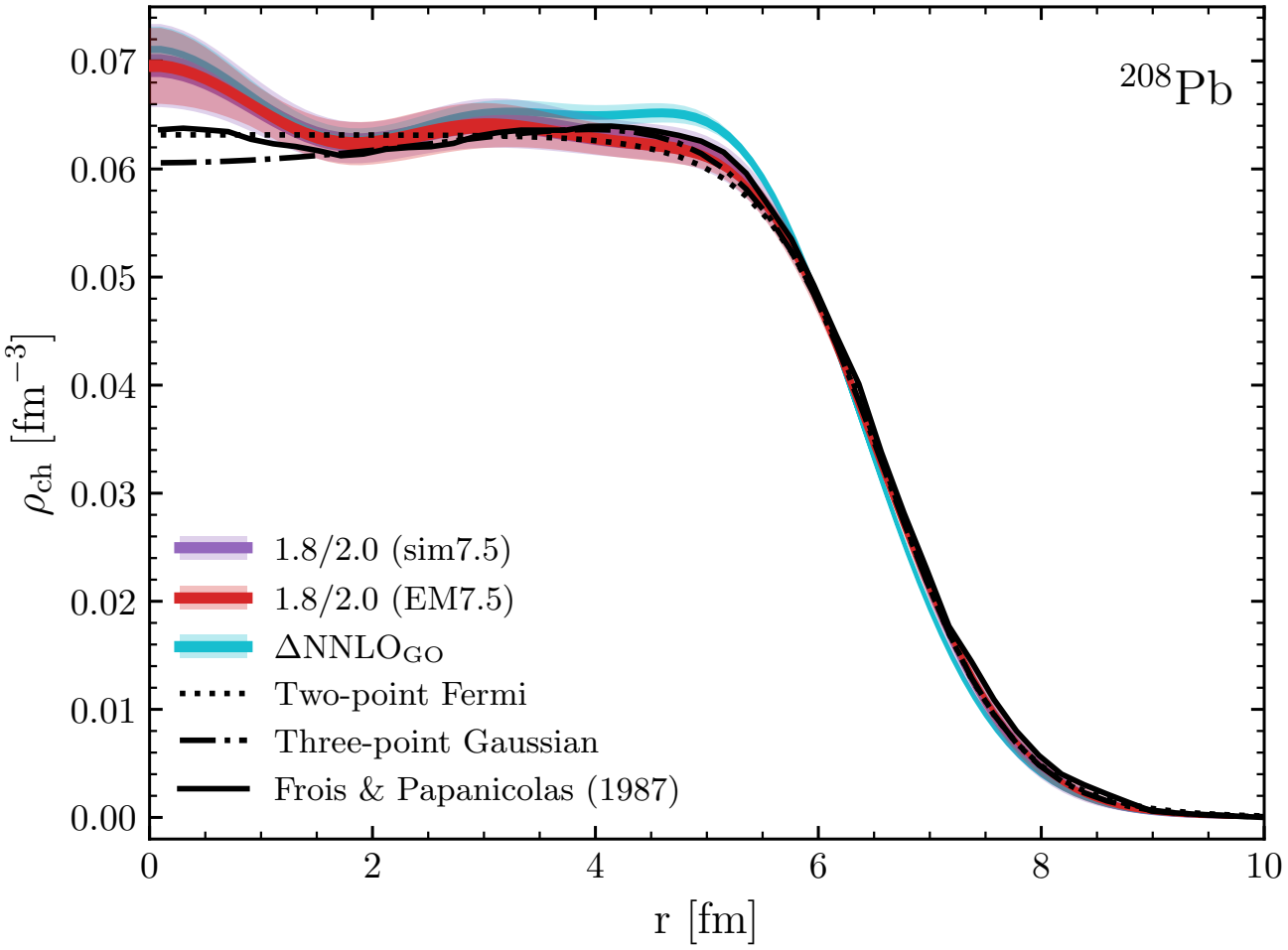


Excellent reproduction of ^{120}Sn densities

- Consistent picture over the different interactions
- Very moderate uncertainties

Ab initio densities for heavier systems: ^{208}Pb

[Arthuis, Hebeler, Schwenk, arxiv:2401.06675]



Charge density for ^{208}Pb

- Consistent picture over the different interactions
- 1.8/2.0s give excellent surface profile

1.8/2.0s consistent over the nuclear chart

Conclusion and outlook

Accurate interactions over the nuclear chart

- Novel interactions with good convergence properties
- Very good reproduction of binding energy, radii, neutron skins

Neutron skin dependence on isospin

- Enhanced dependance on system at the most neutron-rich
- Highlight differences in the interactions
- Neutron-rich nuclei to be more accessible with new RIB facilities
- New generation of scattering experiment off exotic nuclei coming

Food for thought(?)

Strong signs that many-body data helps

- Can we learn from that?
- Is there something we are missing when focusing on the few-body sector?

Other possible quantities to use for fits?

- Not just radii but densities? Signs that it helps for EDFs [Bennaceur (private. comm.)]
- Not just structure but reactions? [Kravvaris, *et al.*, *PRC* **102** (2020)]

Fully exploit potential of 'new' tools

- Emulators for fits at the many-body level
- Bayesian inference and UQ for appropriate exploration of parameter space

Acknowledgments

Thank your for your attention!

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