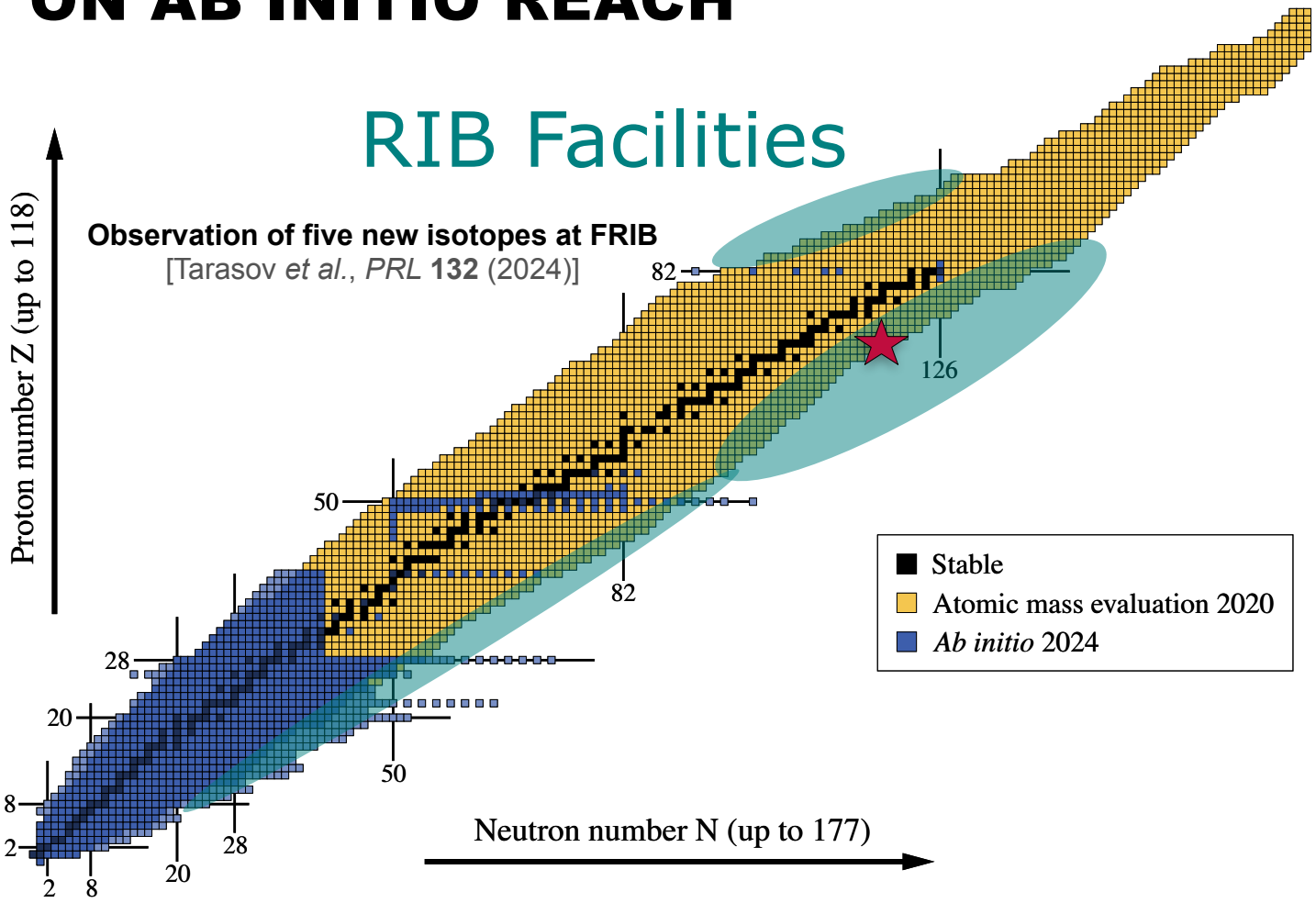
NEUTRON-RICH NUCLEI AND NEUTRON SKINS FROM CHIRAL LOW-RESOLUTION INTERACTIONS

Pierre Arthuis

[Arthuis, Hebeler, Schwenk, arXiv:2401.06675]

ON AB INITIO REACH

RIB Facilities



Adapted from B. Bally

What theory needs

Efficient many-body methods

Accurate interactions

WHY LOW-RESOLUTION INTERACTIONS?

Sufficient to describe bulk properties of nuclei

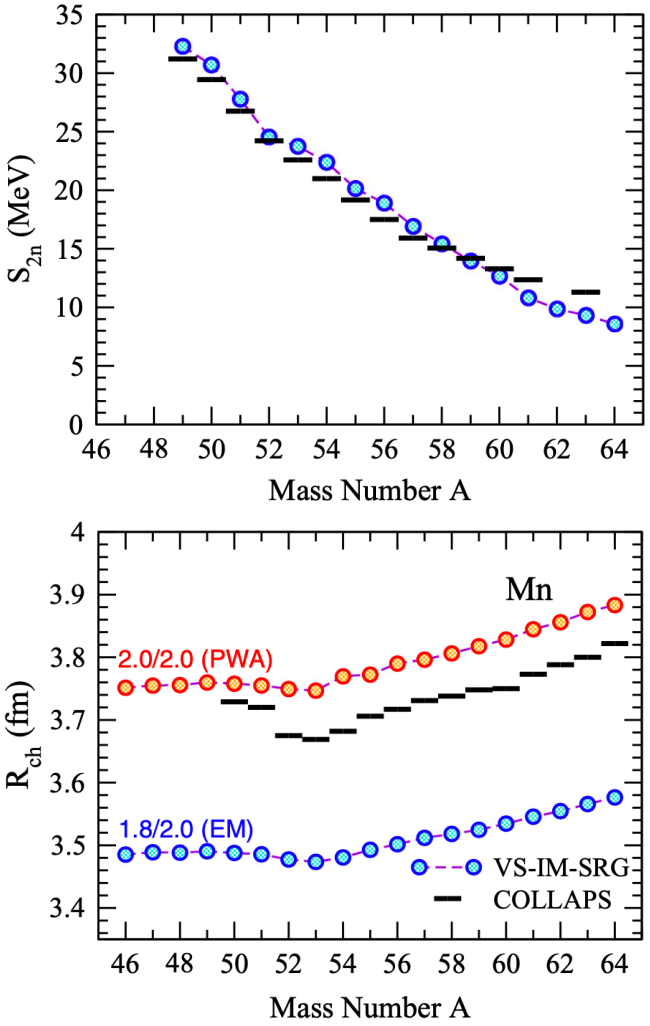
- Better convergence properties through softened interaction
- Proved successful for binding energies with the 1.8/2.0 (EM)
  [Hebeler *et al.*, *PRC* **83** (2011)]

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

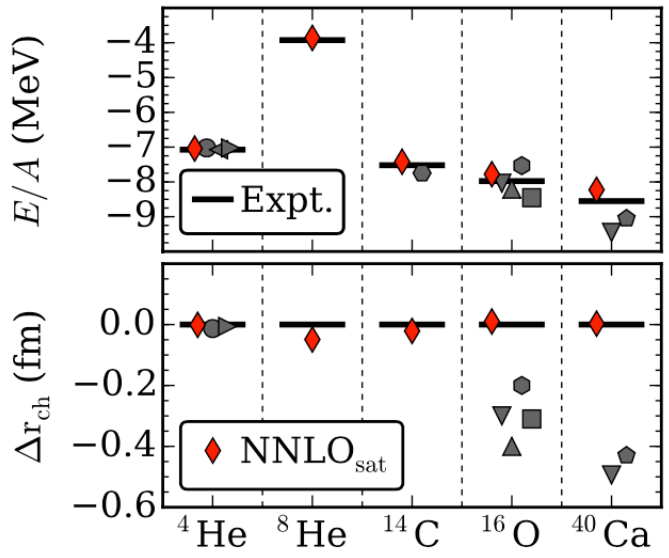
- Goal: Obtain good description of binding energy and radii
- Target: From light to heavy systems



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

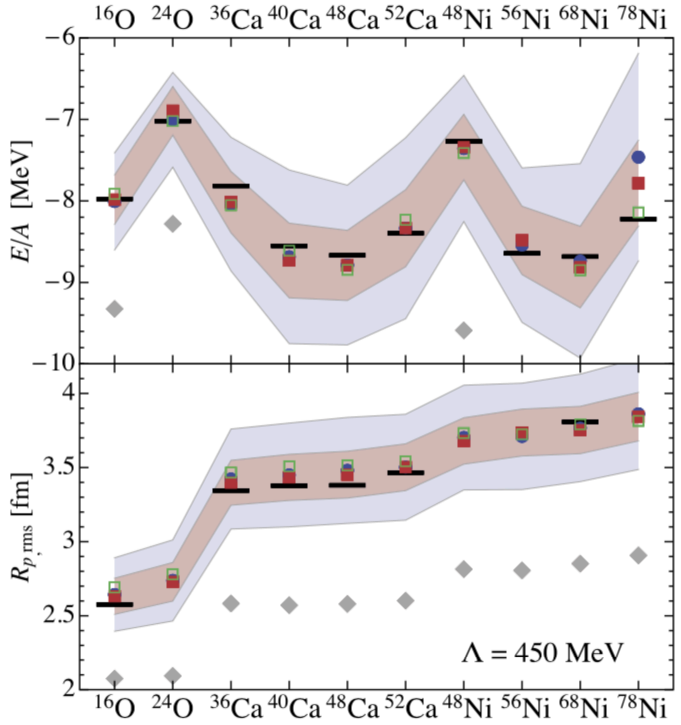
INTERACTIONS ANCHORED IN MANY-BODY DATA

NNLOsat



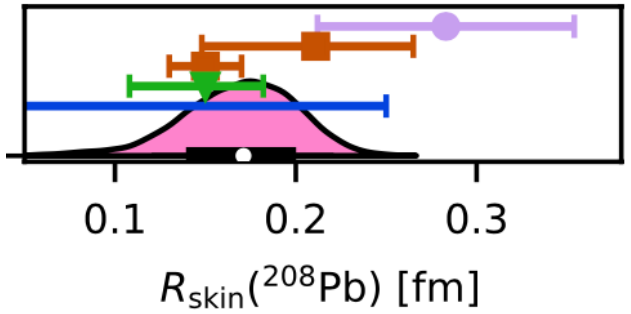
[Ekström *et al.*, *PRC* **91** (2015)]

Hüther et al. family



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

Non-implausible, ΔNNLO$_{GO}$



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

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

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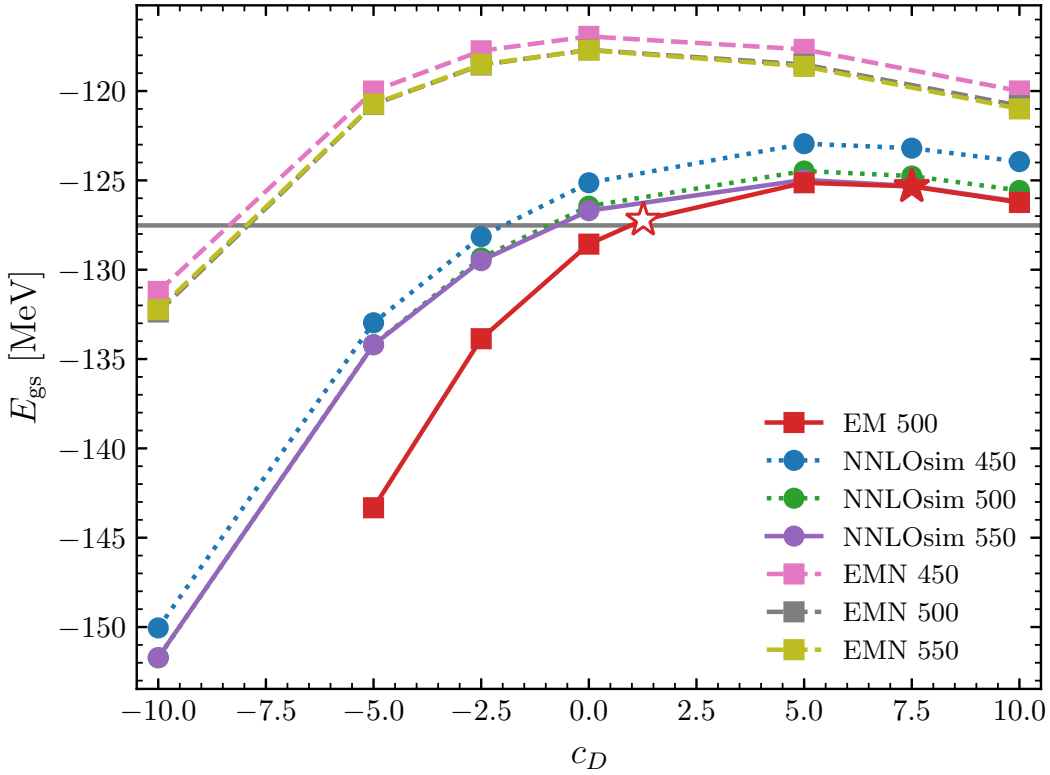
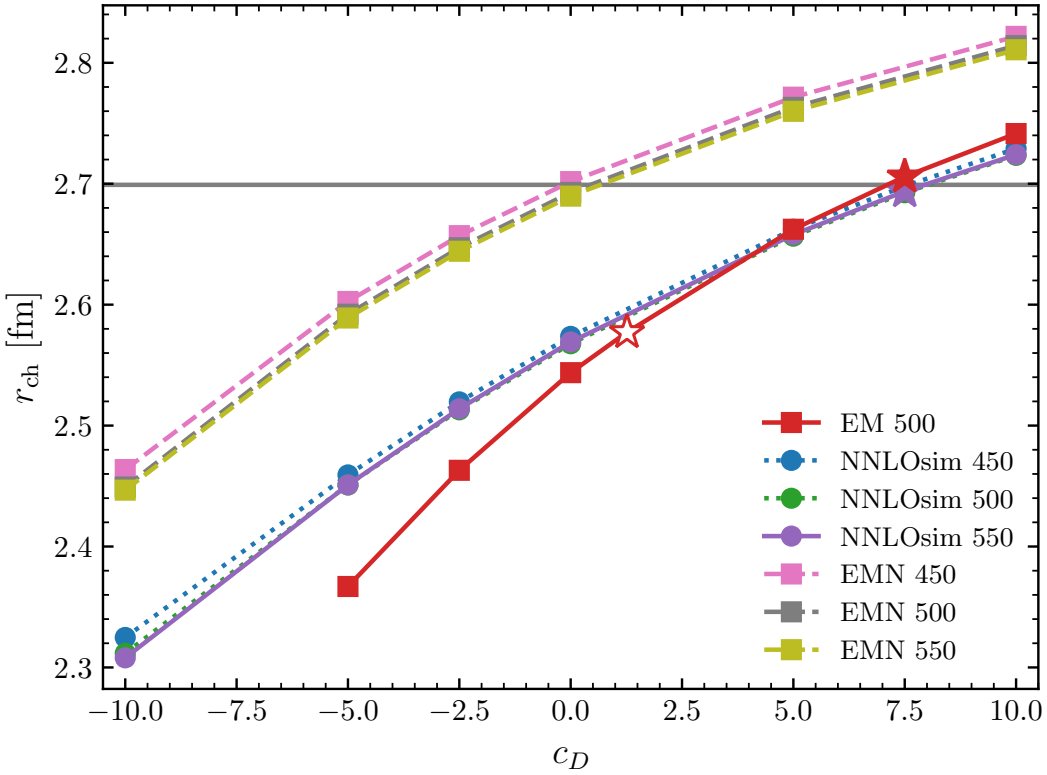
ANCHORING THE INTERACTIONS ON 16O





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

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

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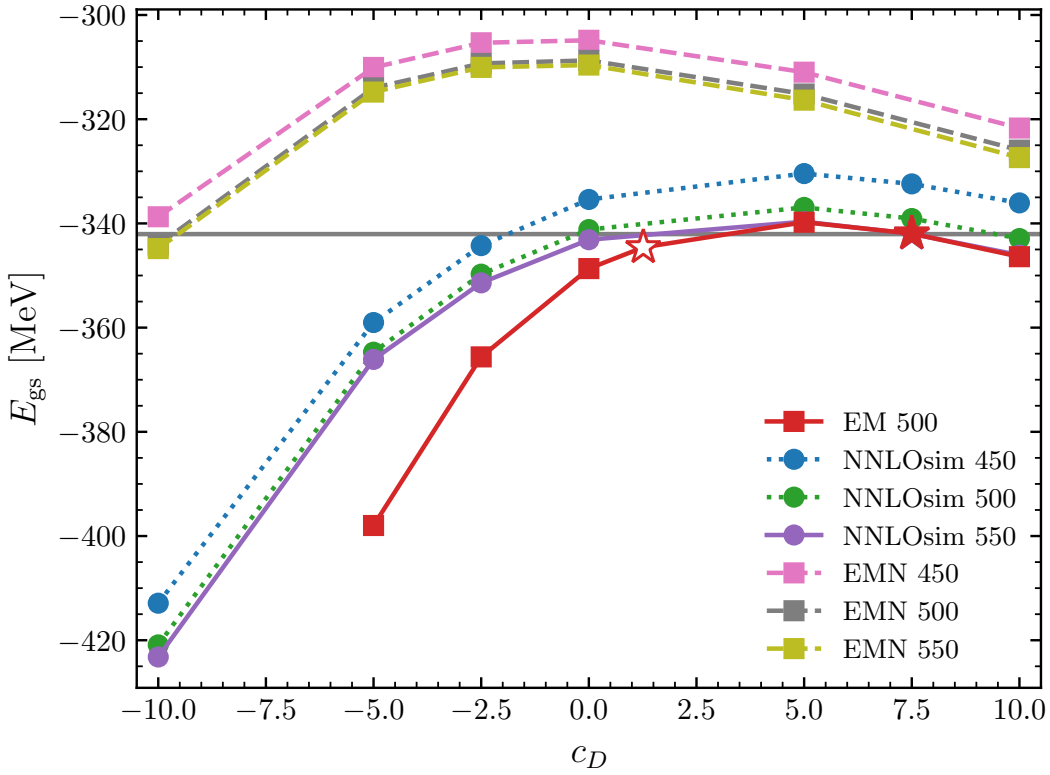
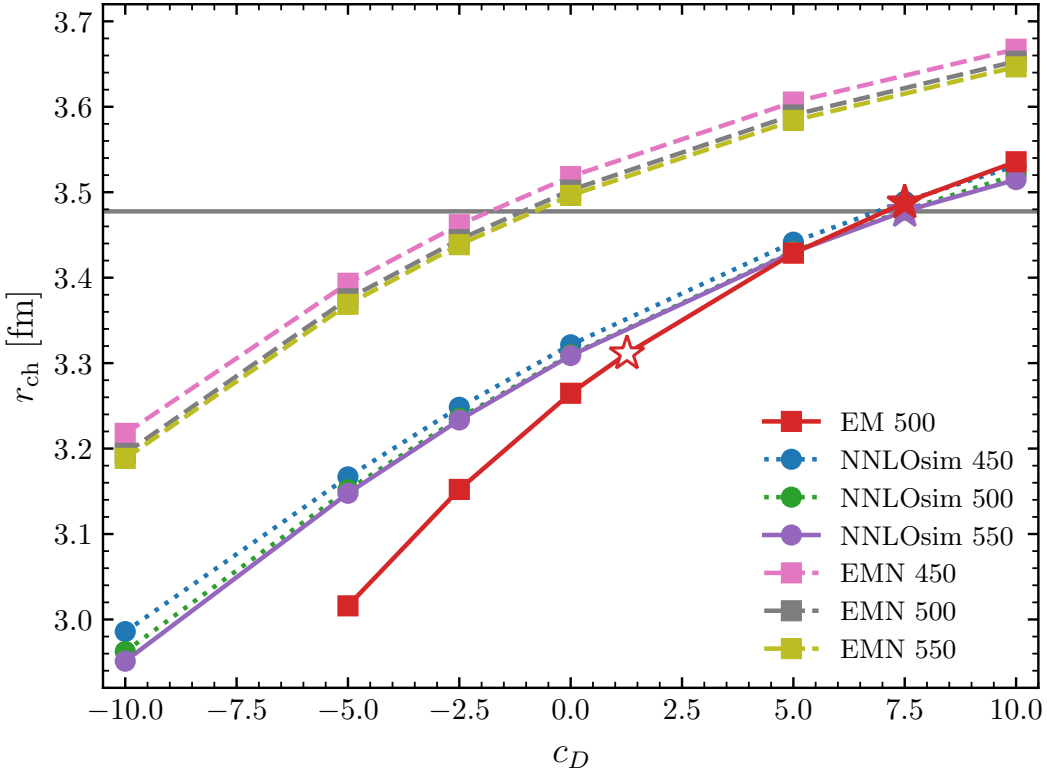
A CHECK AGAINST 40CA



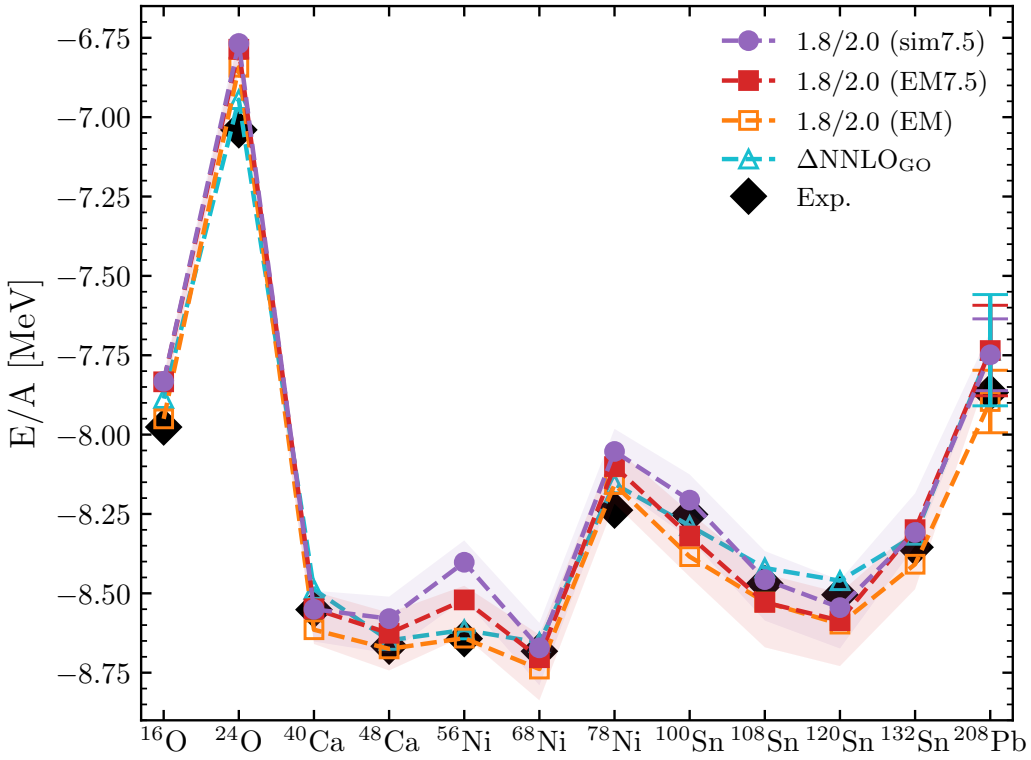


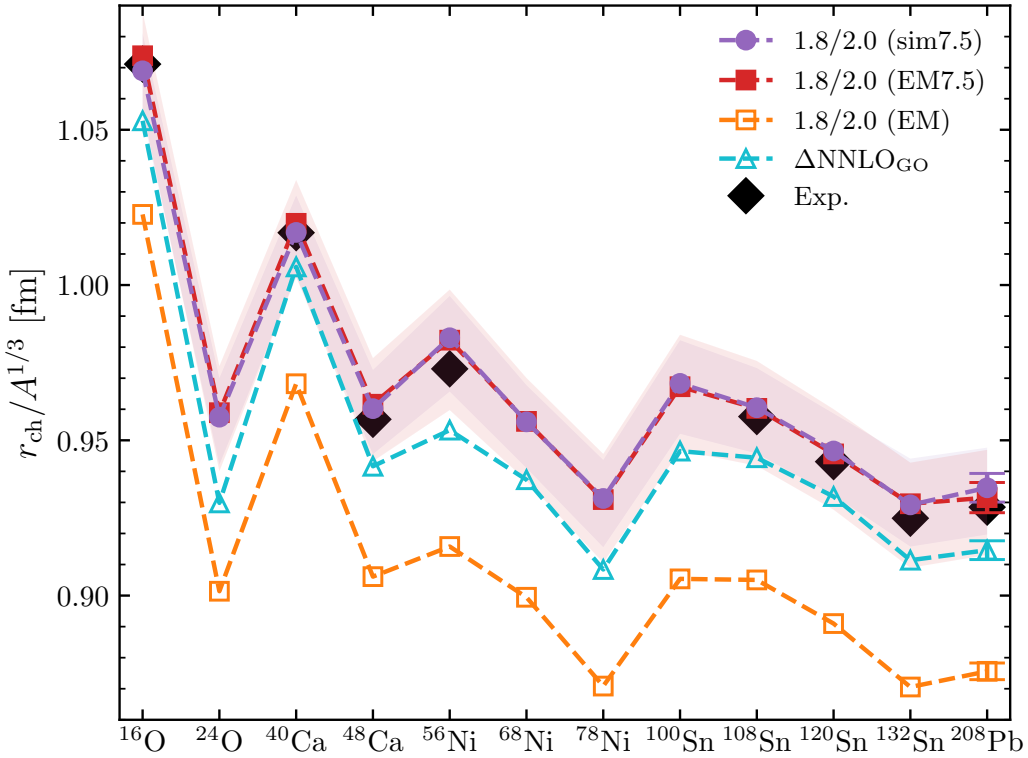
Similar reproduction

- Excellent reproduction of binding energy for c_D = 7.5
- Almost unchanged picture for the charge radius

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

GROUND-STATE ACCURACY TOWARDS HEAVY SYSTEMS





Binding energy

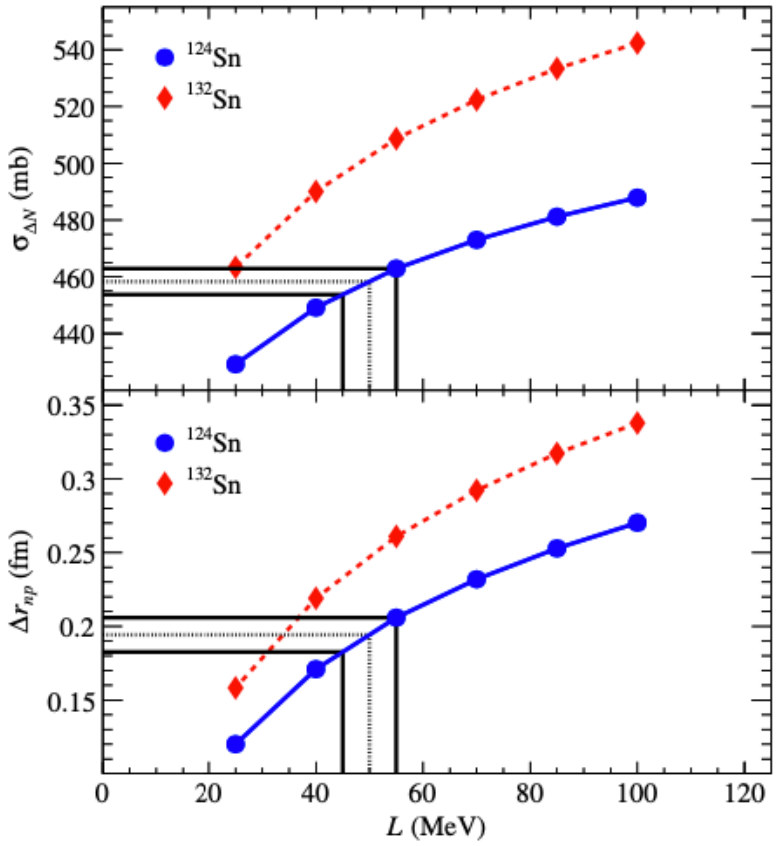
- Reasonable reproduction of experimental values
- Slight improvement for heavy systems w.r.t. 1.8/2.0 (EM)

Charge radius

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

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

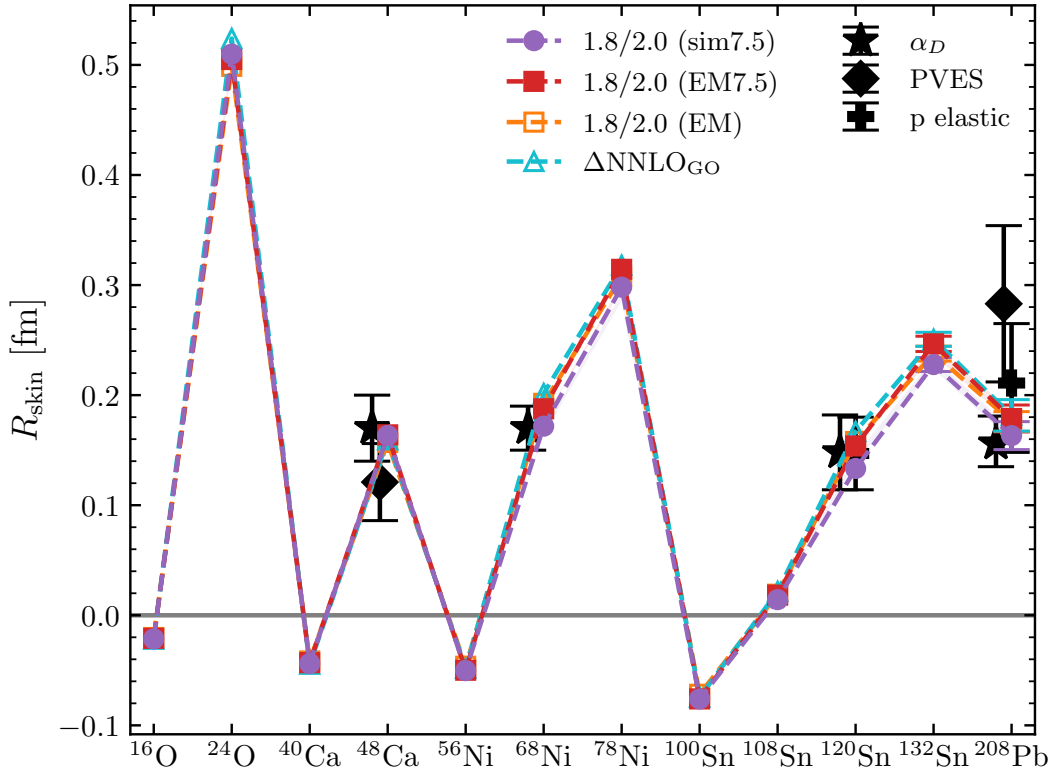
NEUTRON SKIN AND HEAVY SYSTEMS



[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



[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

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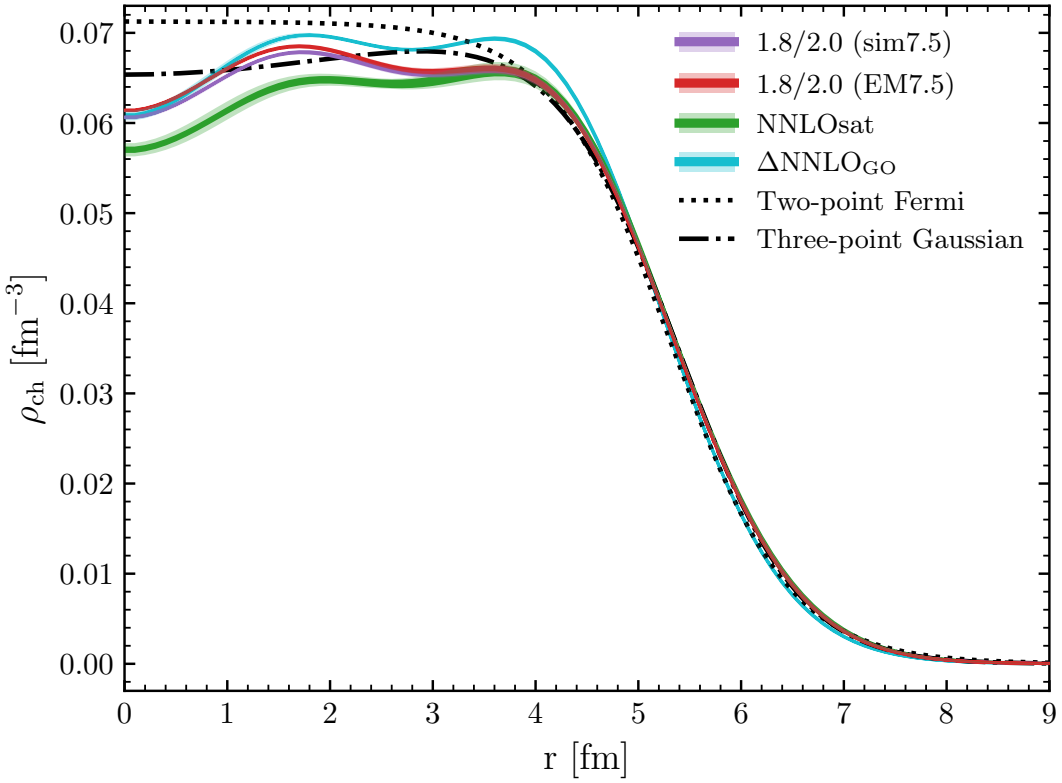
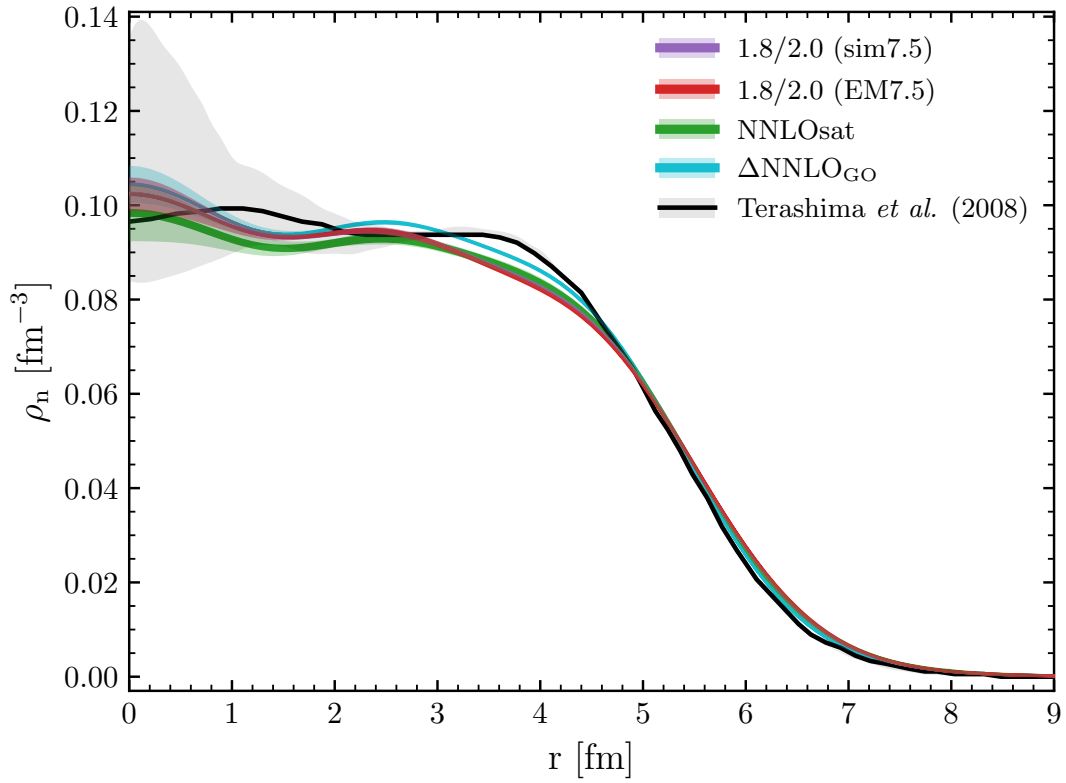
AB INITIO DENSITIES FOR HEAVY SYSTEMS: 120SN



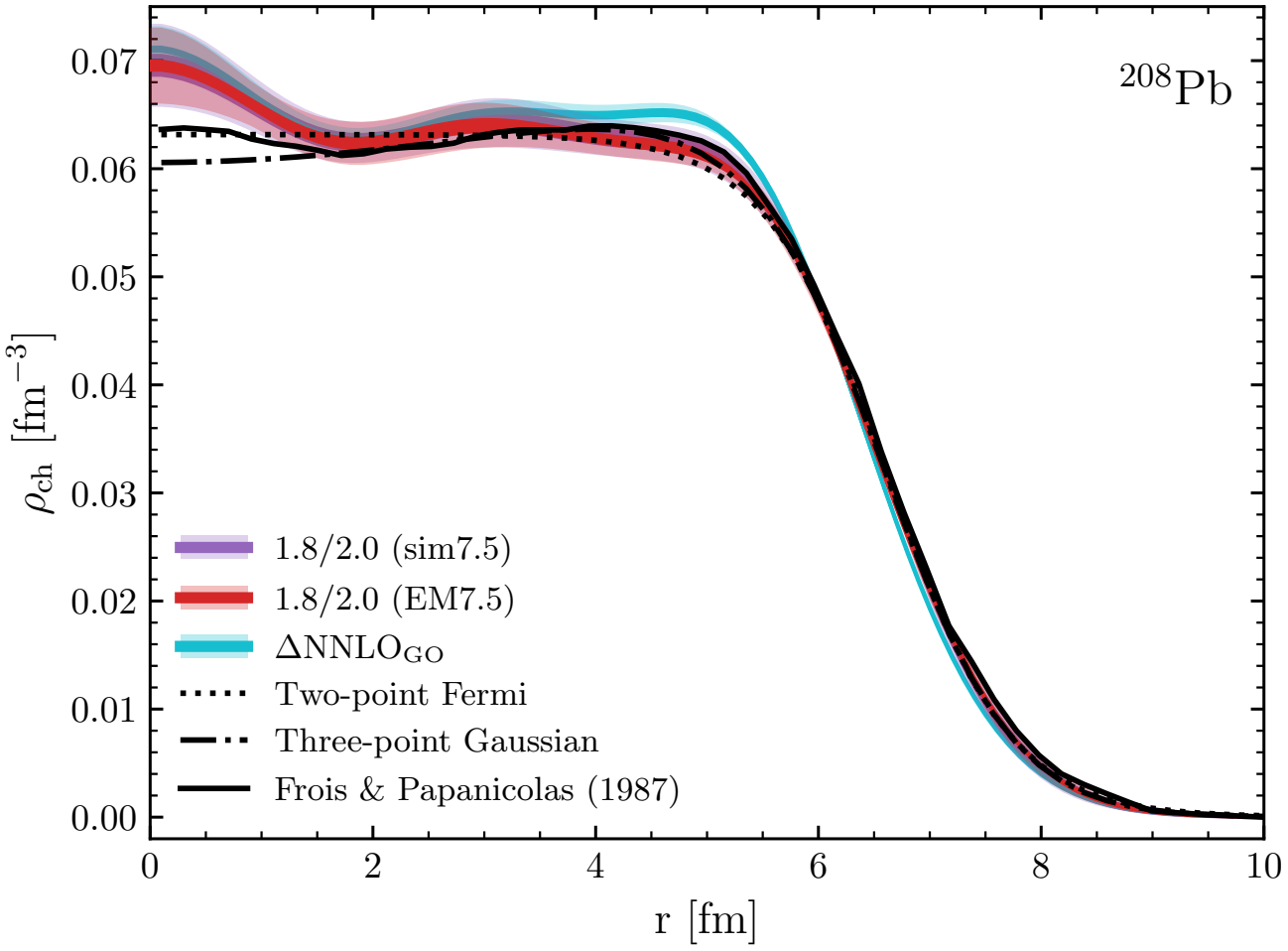


Excellent reproduction of ^{120}Sn densities

- Consistent picture over the different interactions
- Very moderate uncertainties

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

AB INITIO DENSITIES FOR HEAVIER SYSTEMS: 208PB



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

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

ON NEUTRON SKINS

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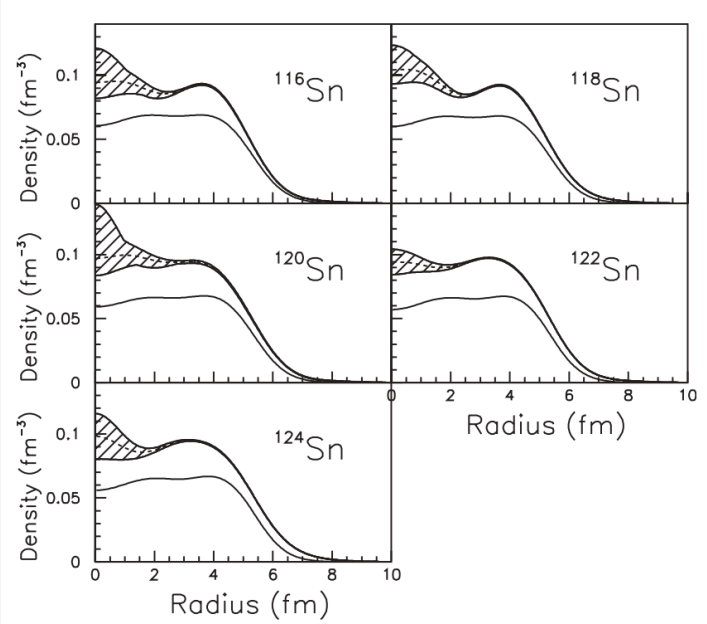
Evolution w.r.t. isospin

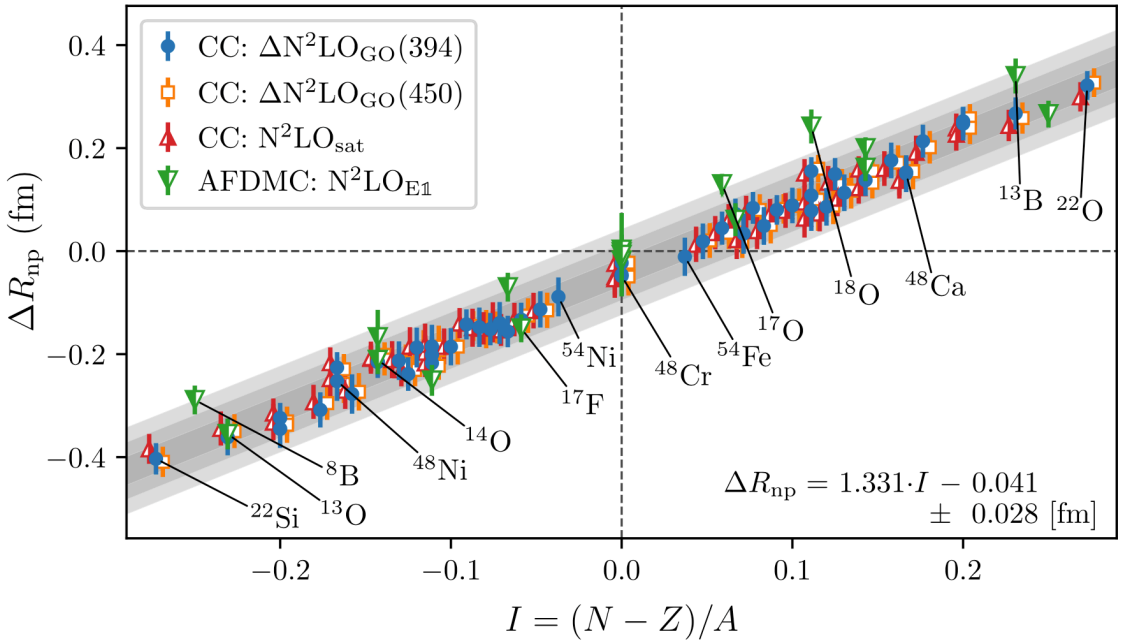


[Terashima *et al.*, *PRC* **77** (2008)]

Liquid droplet model

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

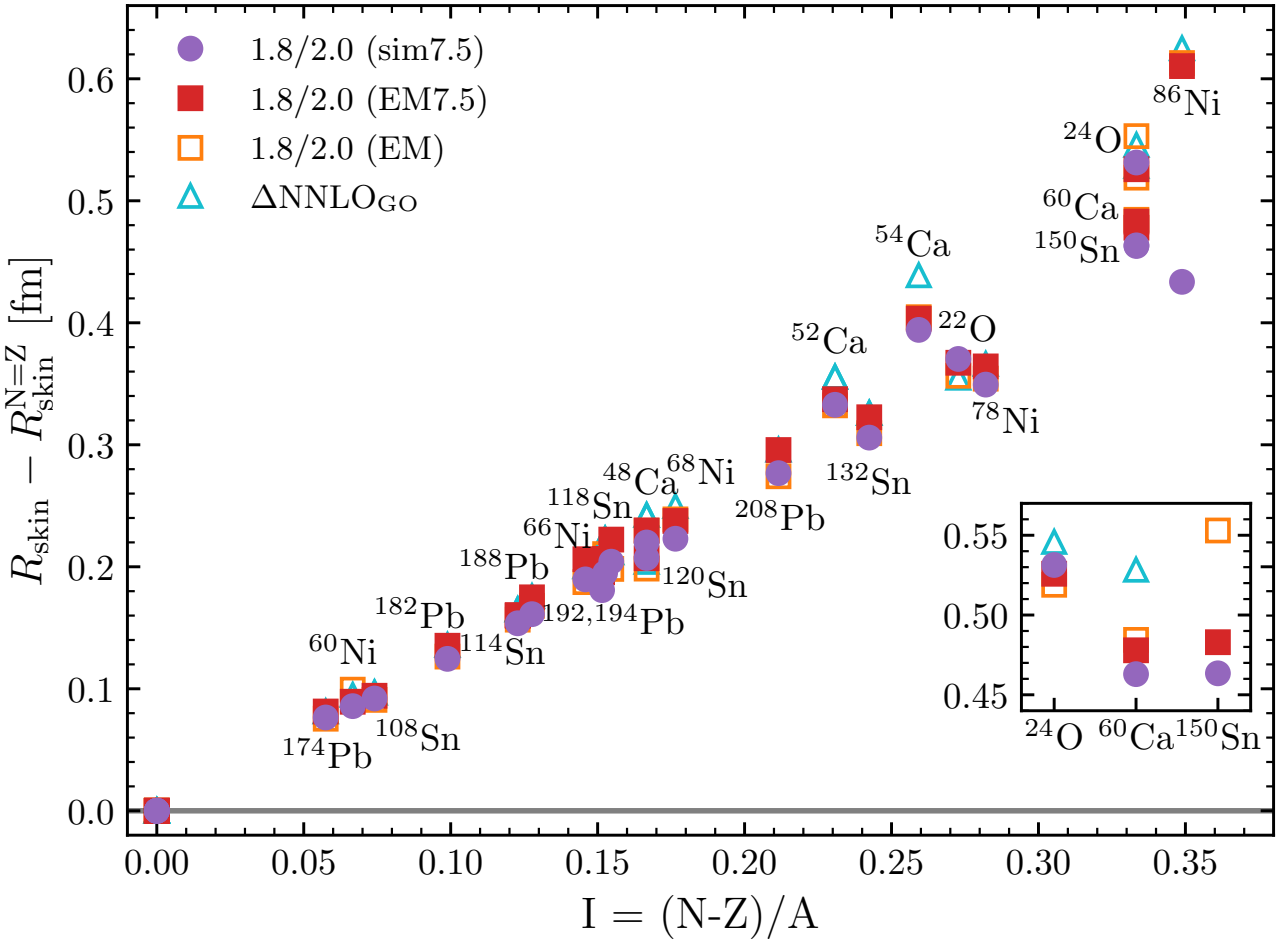
Linear relation confirmed on *ab initio* basis



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

[ARTHUIS, HEBELER, SCHWENK, ARXIV:2401.06675]

NEUTRON SKINS IN NEUTRON-RICH ISOTOPES



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

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[TICHAI, ARTHUIS, HEBELER, HEINZ, HOPPE, MIYAGI, SCHWENK, ZUREK, ARXIV:2307.15572]

LOW-RANK DECOMPOSITION OF THREE-BODY FORCES

[TICHAI, ARTHUIS, HEBELER, HEINZ, HOPPE, SCHWENK, PLB 821 (2021)]

FACTORISATION TECHNIQUES FOR ME STORAGE

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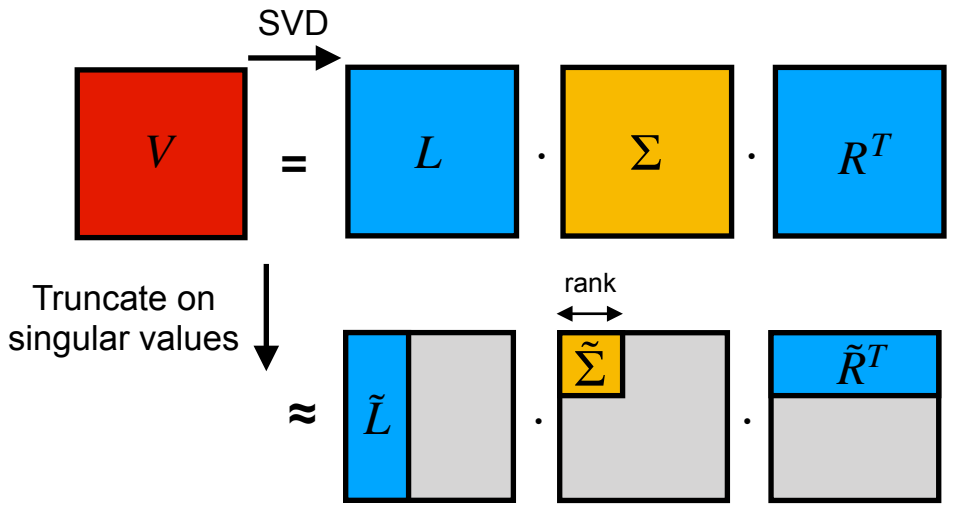
Motivation

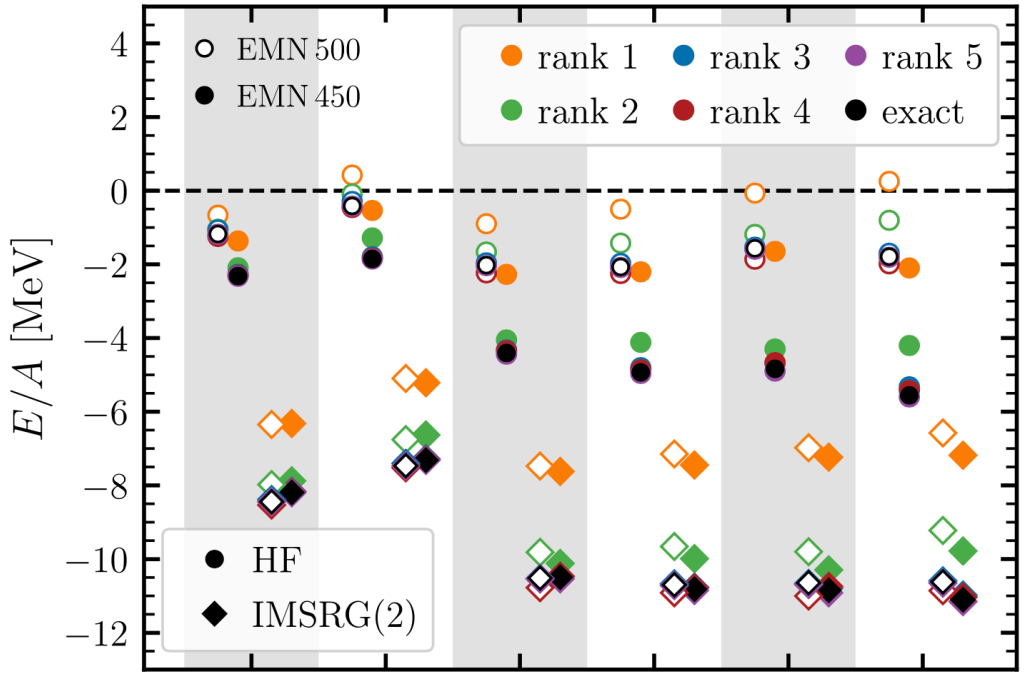
- Matrix element storage: NN costly, 3N bottleneck
- Can we reduce it with a tiny error?



See Matthias' talk

99% accuracy with 5% of the data

- Systematic convergence w.r.t. rank
- Quality independent of mass number



[TICHAI, ARTHUIS, HEBELER, HEINZ, HOPPE, MIYAGI, SCHWENK, ZUREK, ARXIV:2307.15572]

FACTORISATION TECHNIQUES FOR ME STORAGE

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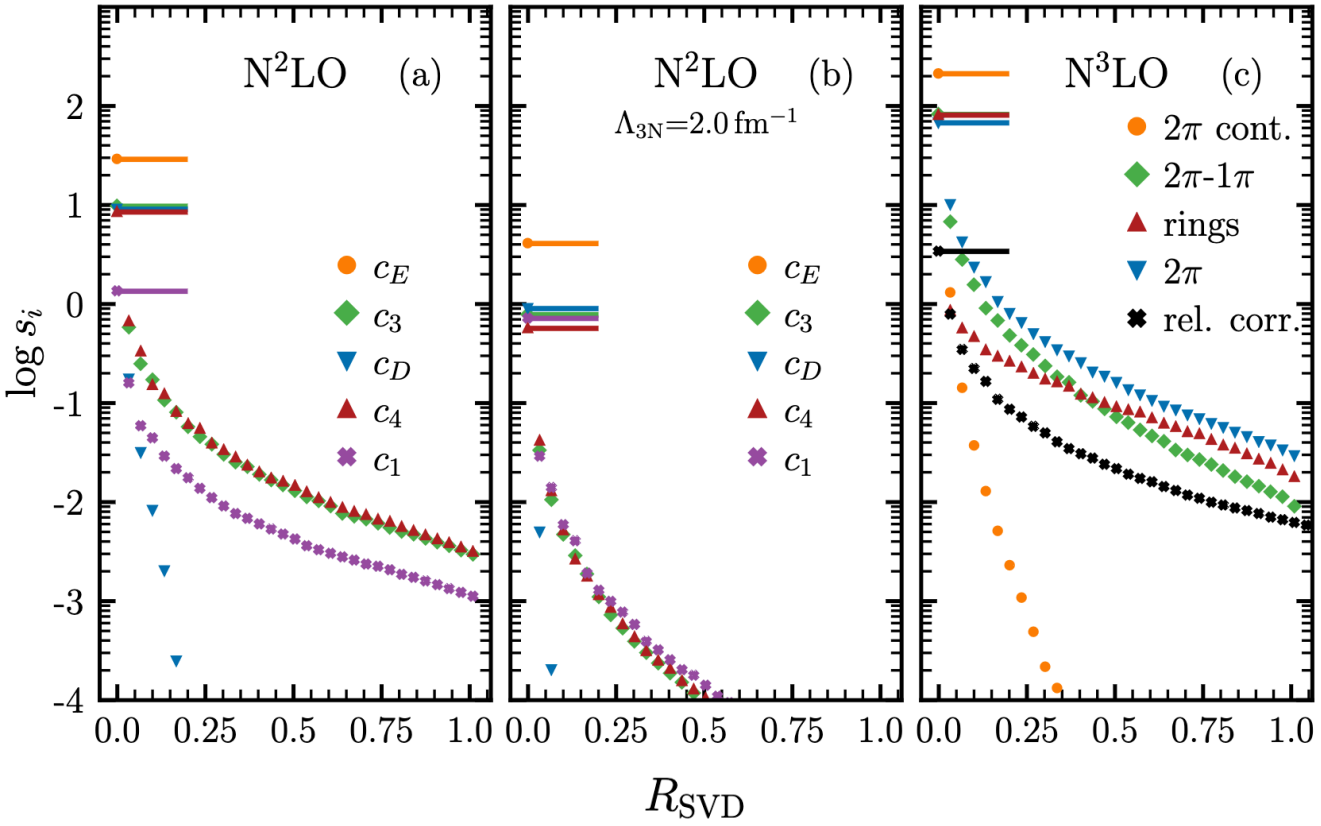
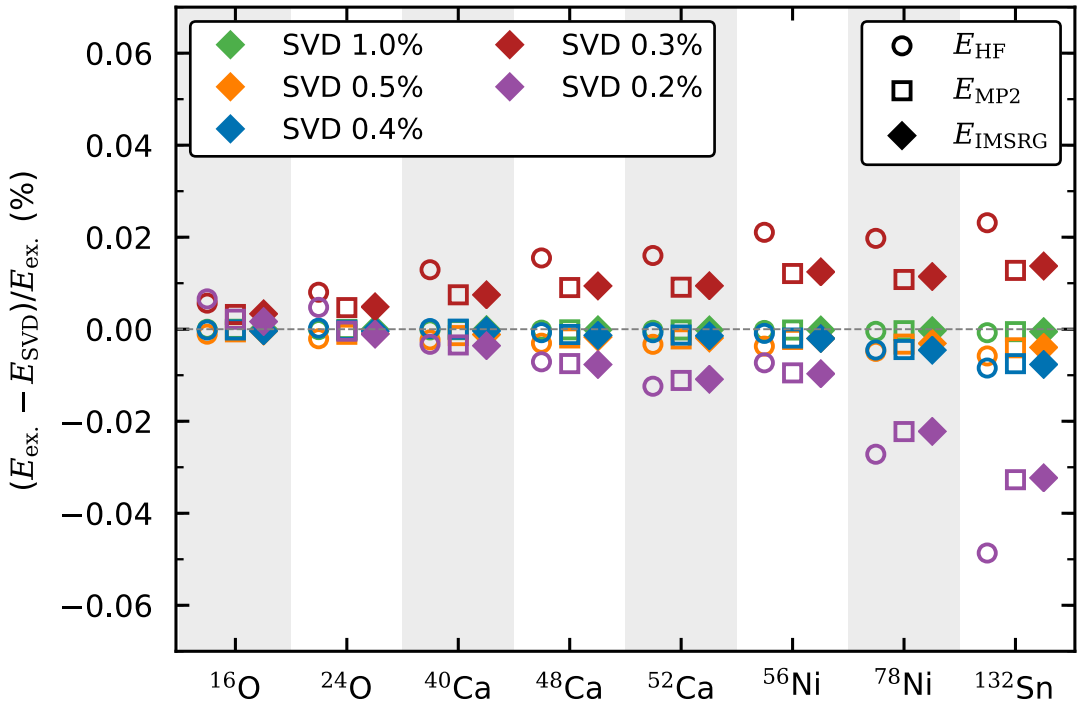
Needs

- Remove bottleneck of 3N matrix elements storage
- Use random projection techniques to tackle larger dimensions





Potential for massive storage gains

- Saving by a factor >100
- Quality preserved in heavier systems

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CONCLUSION AND OUTLOOK

Accurate interactions over the nuclear chart

- Novel interactions with good convergence properties
- Very good reproduction of binding energy, radii, neutron skins
- Now to extend to open-shell nuclei and infinite matter

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

ACKNOWLEDGMENTS

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Thank your for your attention!

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