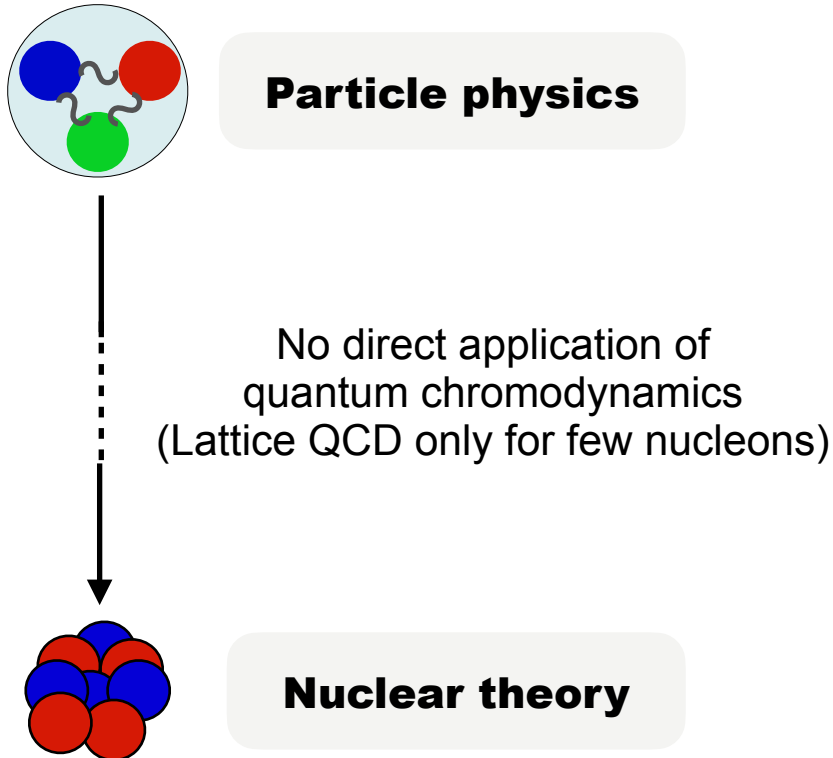


NEUTRON-RICH NUCLEI AND NEUTRON SKINS FROM CHIRAL LOW-RESOLUTION INTERACTIONS

Pierre Arthuis, Kai Hebeler and Achim Schwenk

[Arthuis, Hebeler, Schwenk, arXiv:2401.06675]

WHAT IS AB INITIO?



Effective Field Theory in the A-body sector

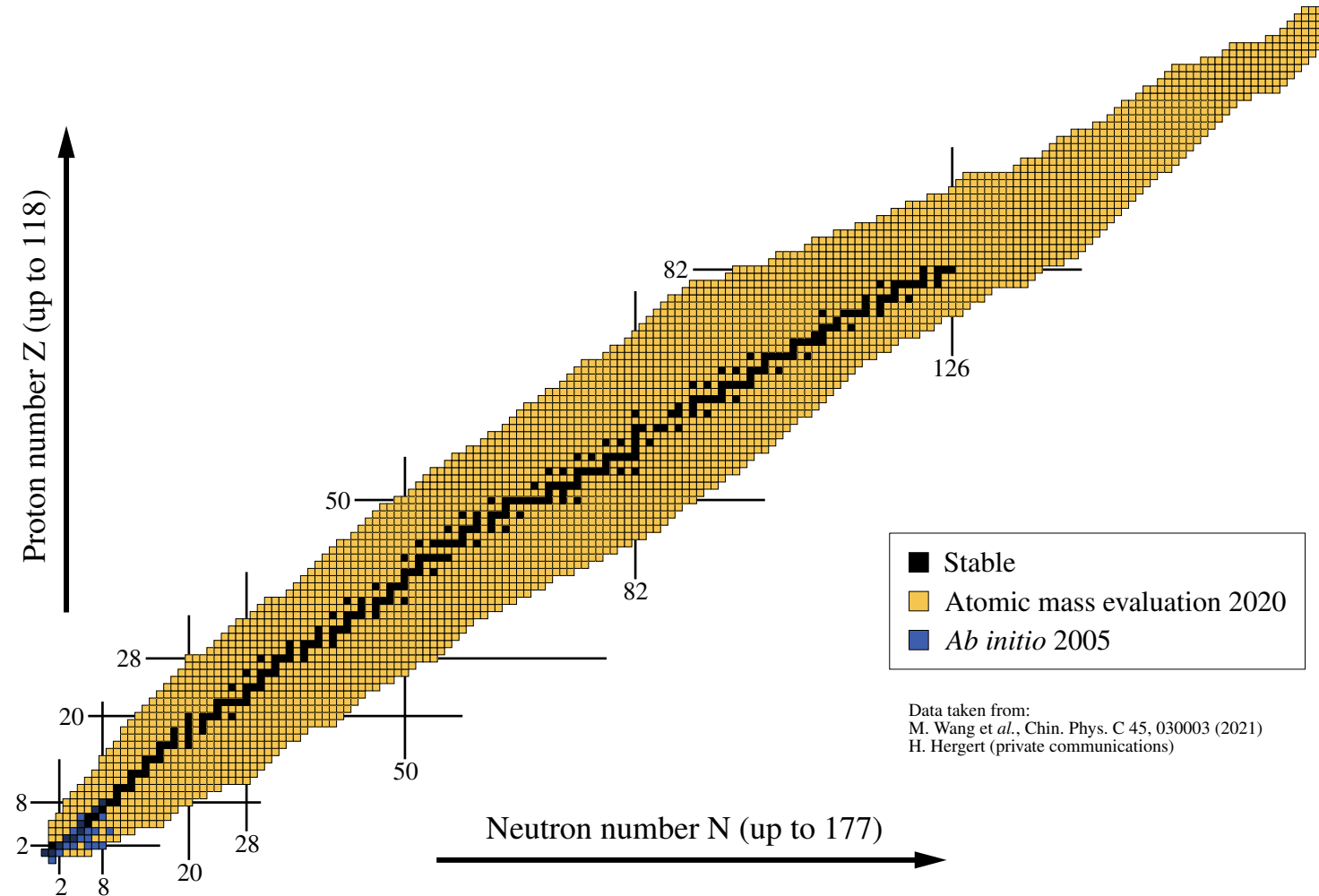
A-body Schrödinger equation

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

Obtain a description that is:

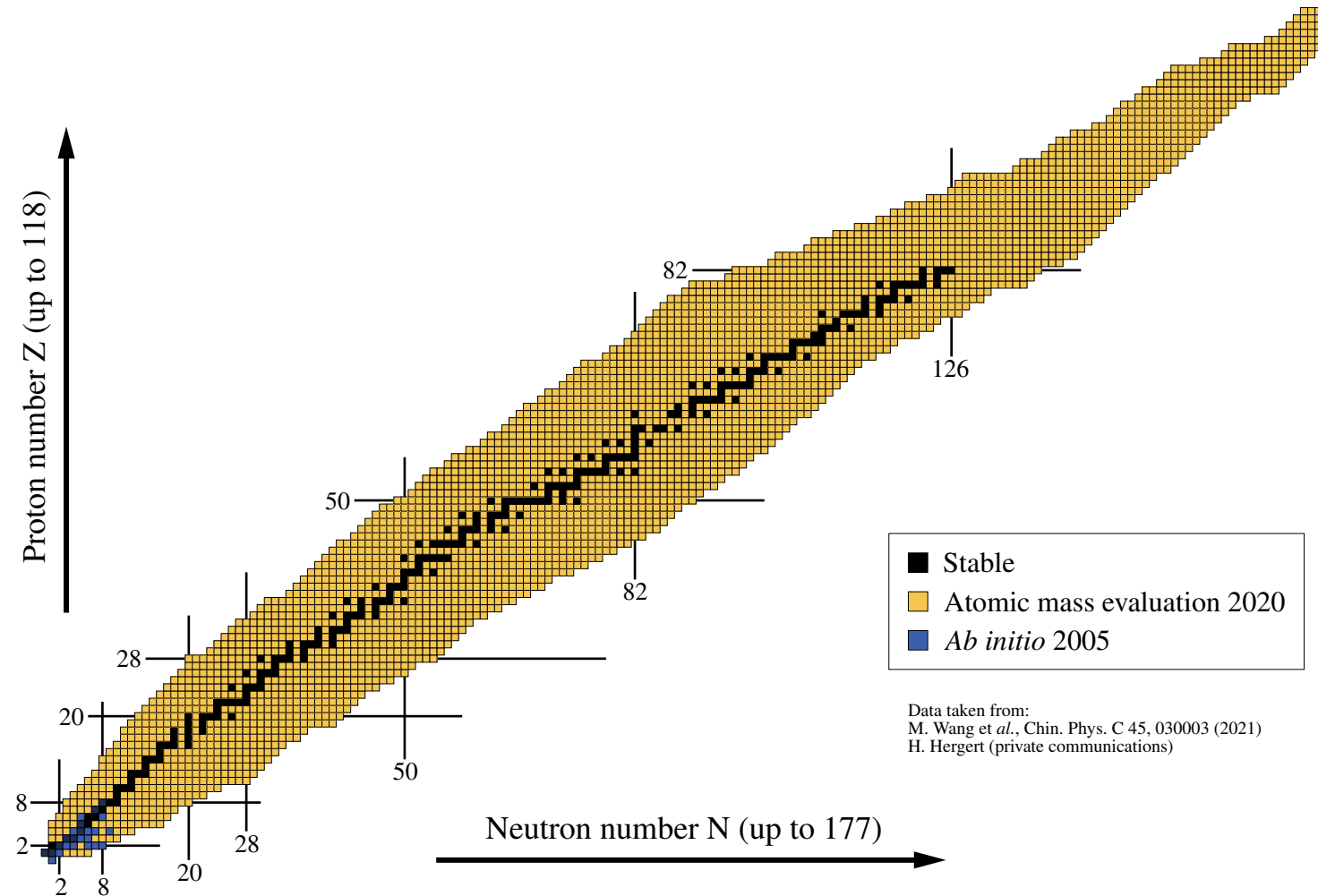
- Consistent
- Systematic
- Accurate enough
- From inter-nucleon interaction
- Rooted in quantum chromodynamics

FROM THE LIGHTEST NUCLEI...



Exact methods (80's)

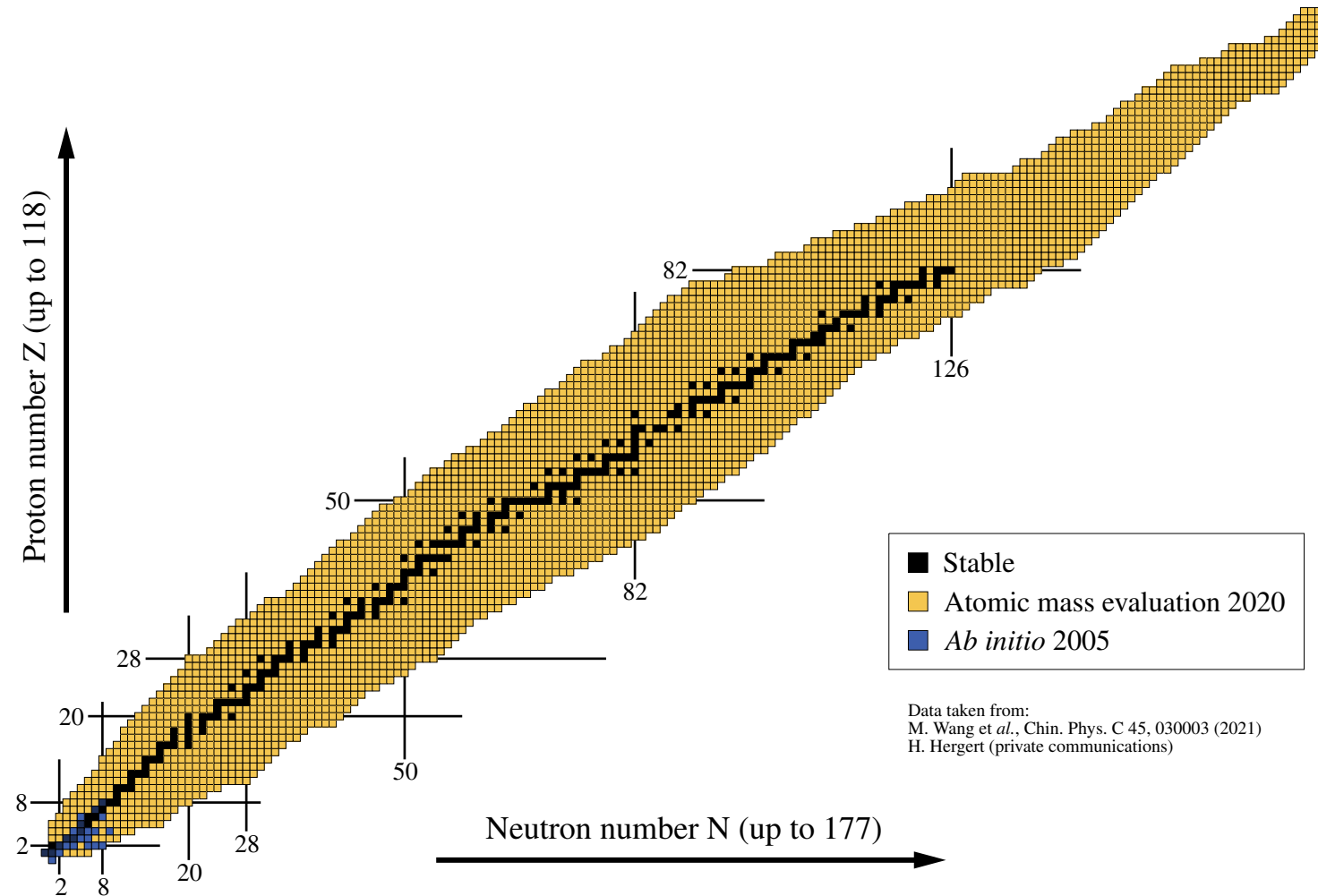
FROM THE LIGHTEST NUCLEI...



Exact methods (80's)

Closed-shell methods (00's)

FROM THE LIGHTEST NUCLEI...

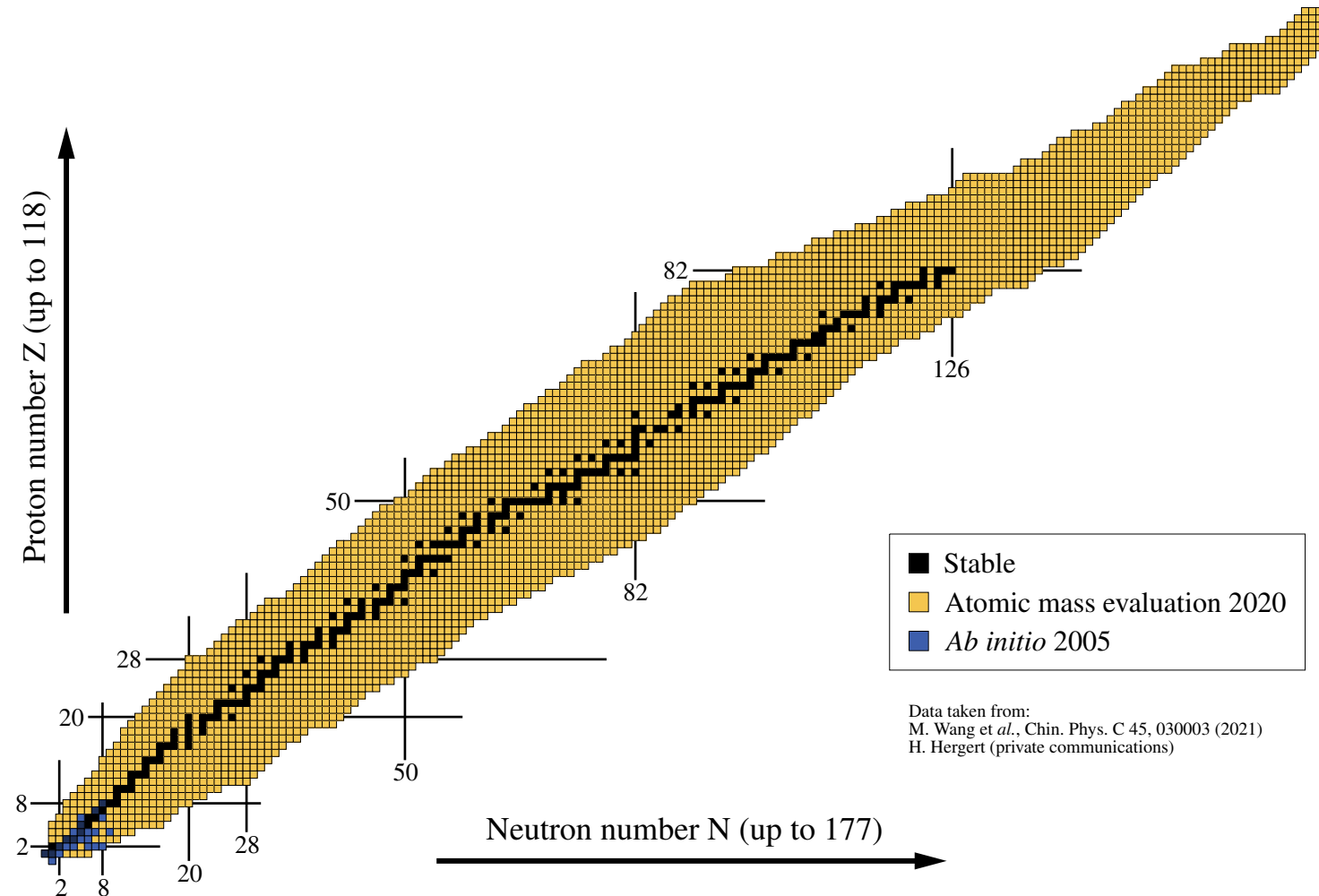


Exact methods (80's)

Closed-shell methods (00's)

Open-shell methods (10's)

FROM THE LIGHTEST NUCLEI...



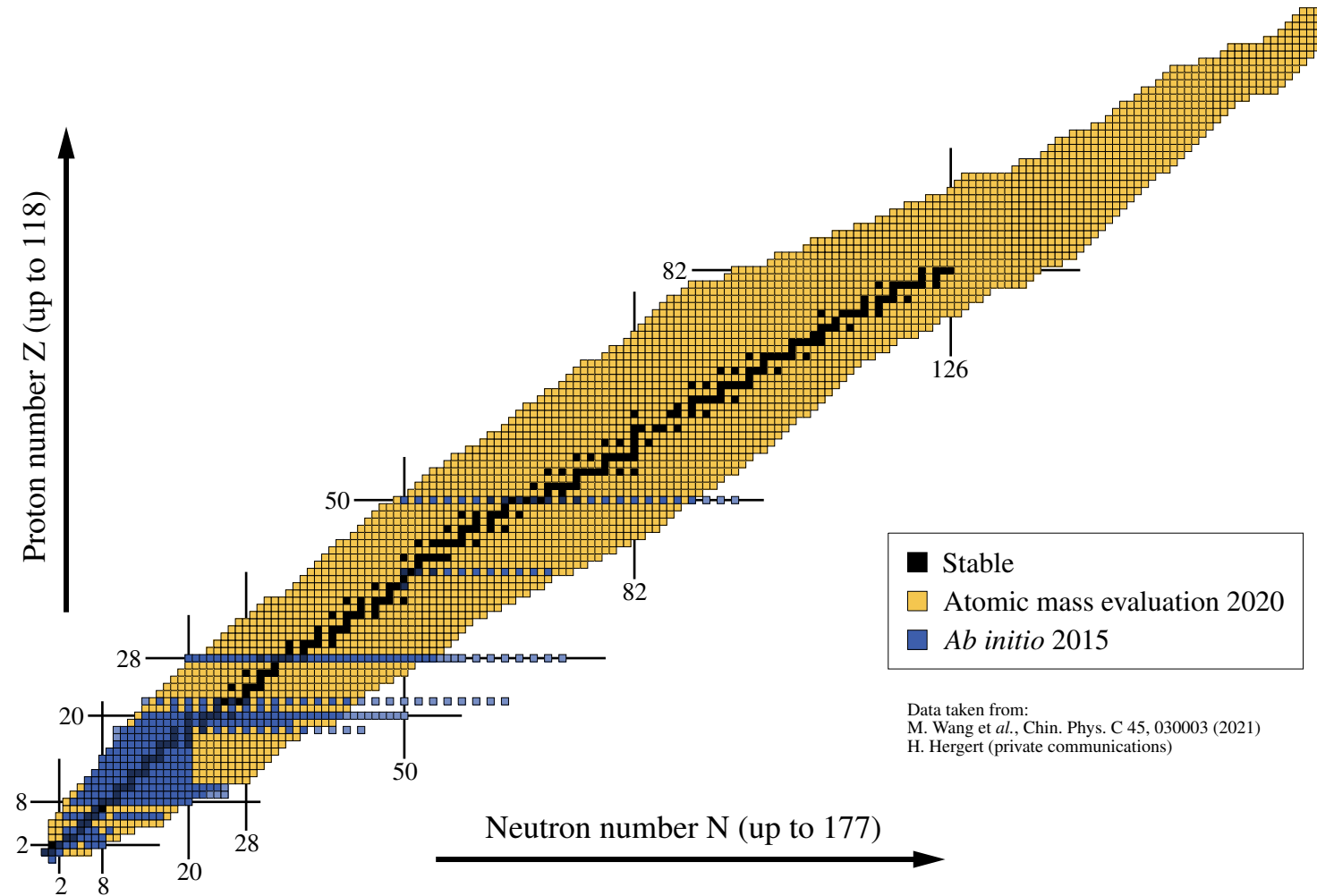
Exact methods (80's)

Closed-shell methods (00's)

Open-shell methods (10's)

Ab initio valence space (2014)

FROM THE LIGHTEST NUCLEI...



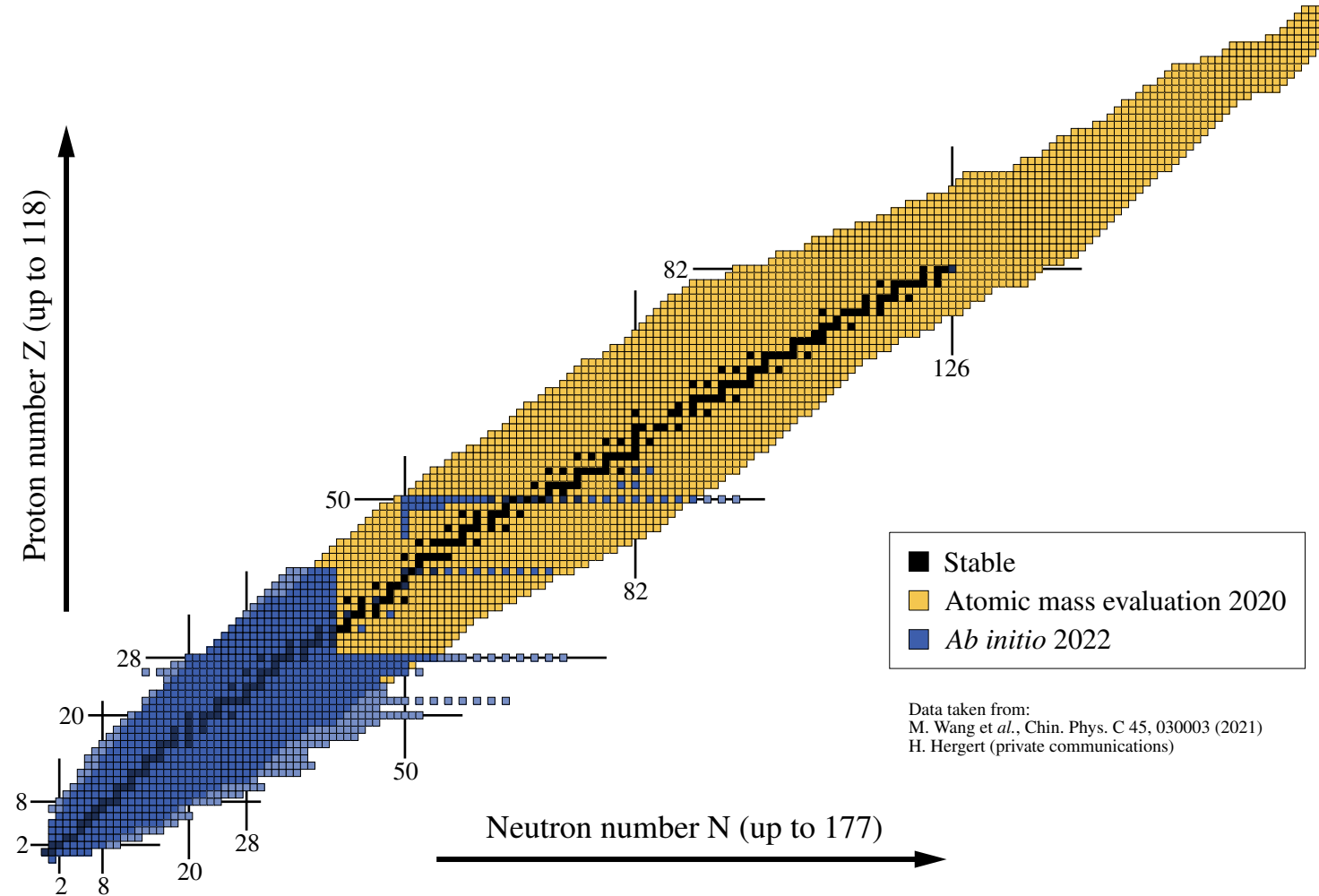
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Closed-shell methods (00's)

Open-shell methods (10's)

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FROM THE LIGHTEST NUCLEI...



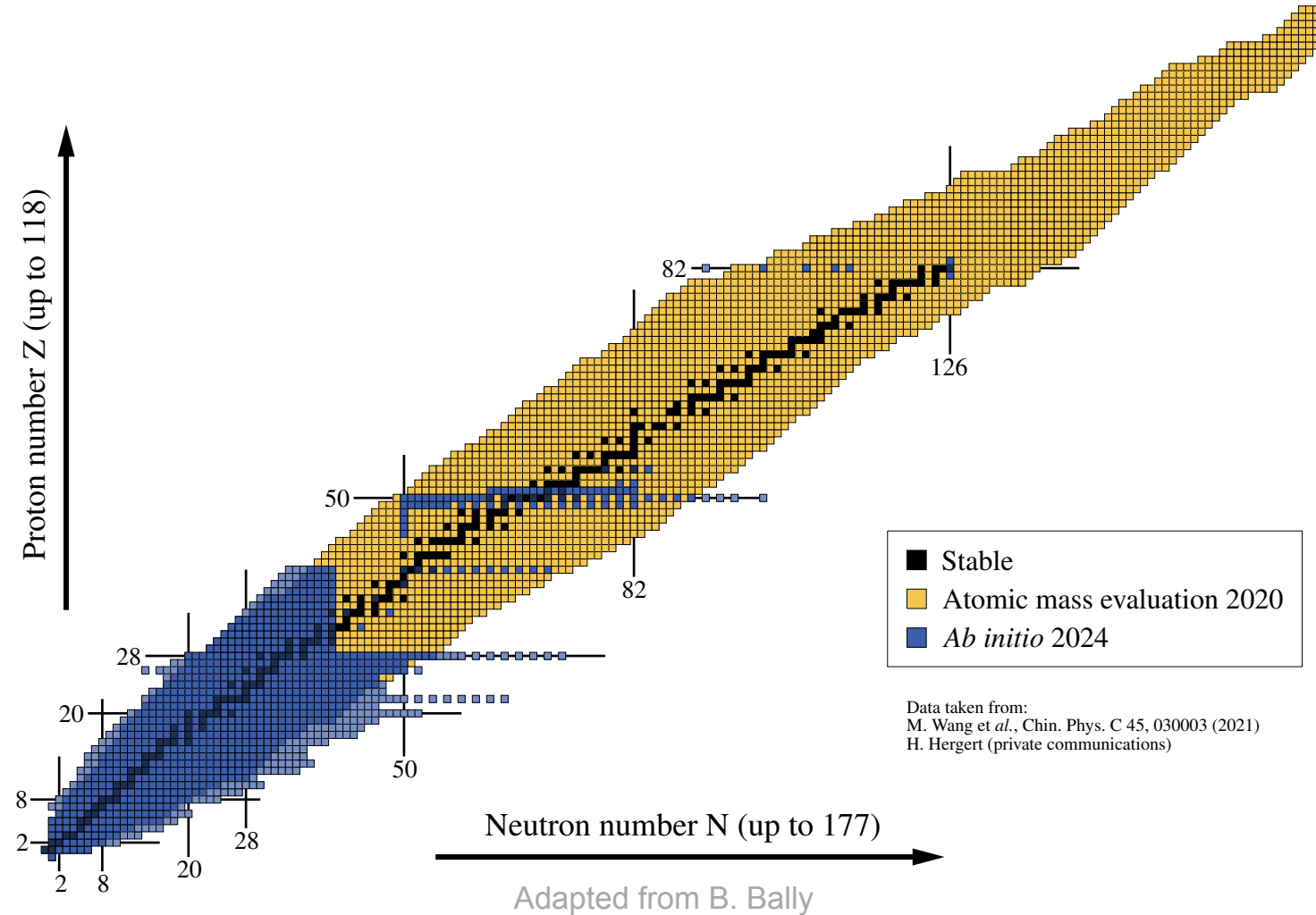
Exact methods (80's)

Closed-shell methods (00's)

Open-shell methods (10's)

Ab initio valence space (2014)

...TOWARDS MEDIUM- AND HEAVY-MASS SYSTEMS



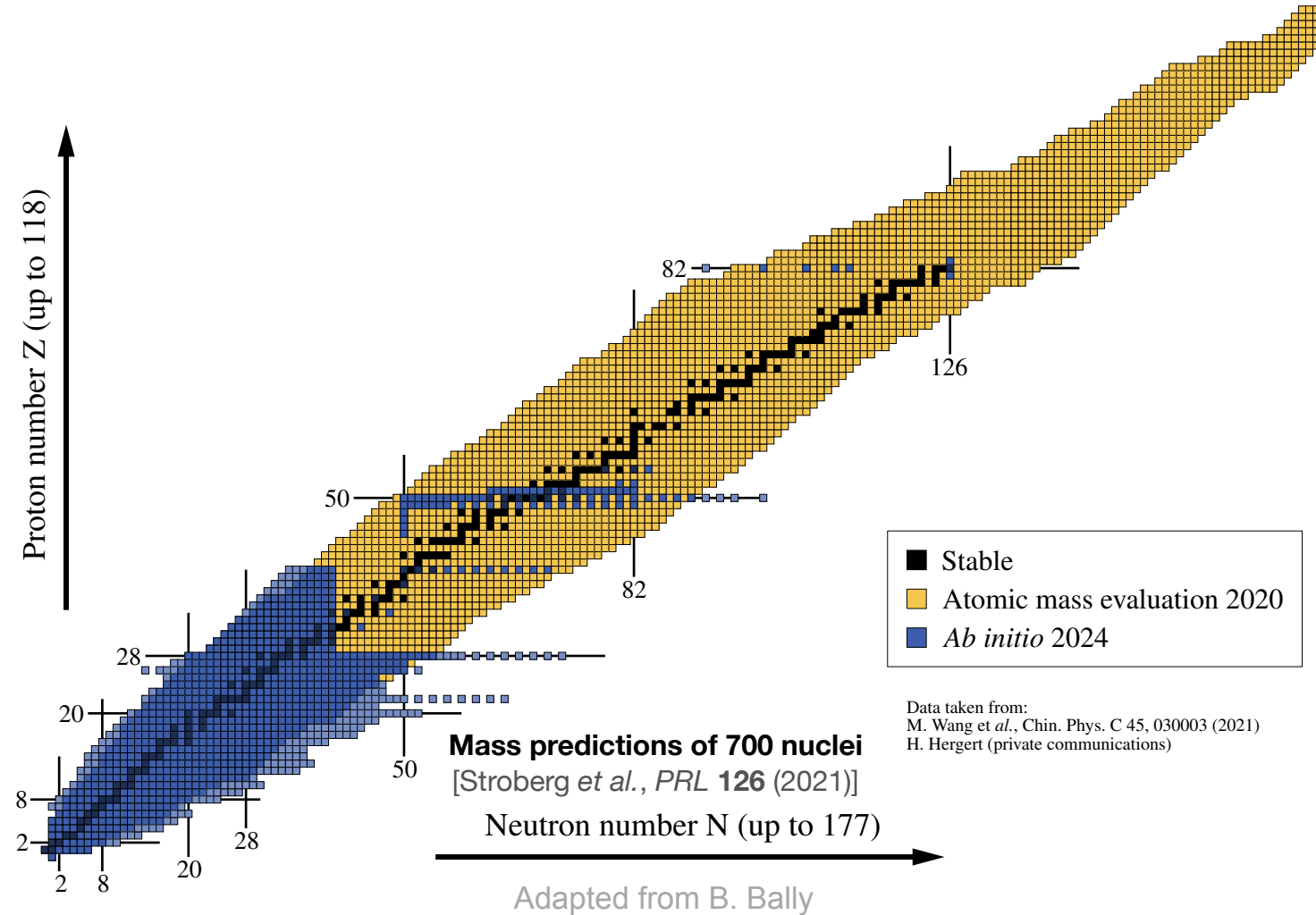
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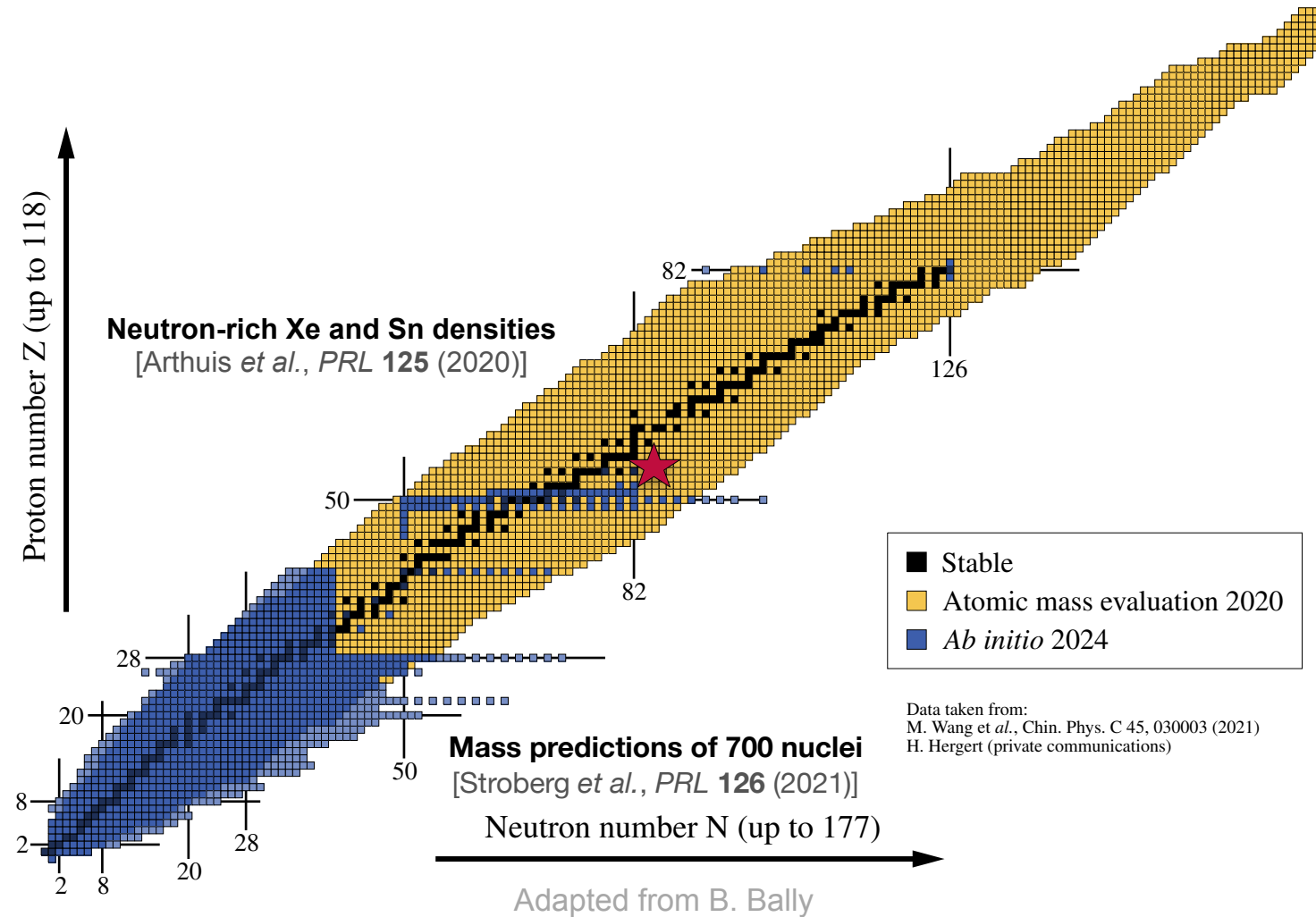
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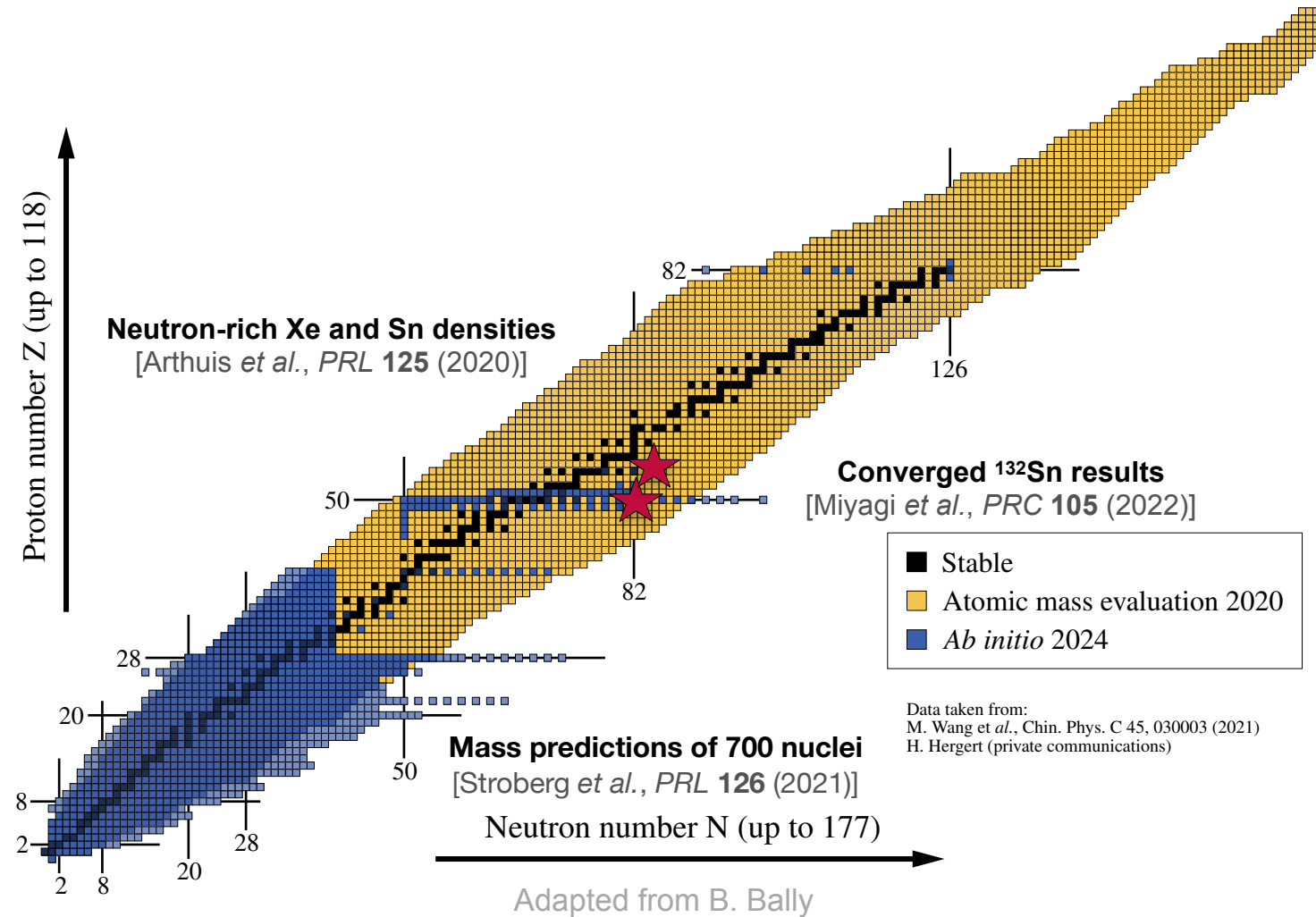
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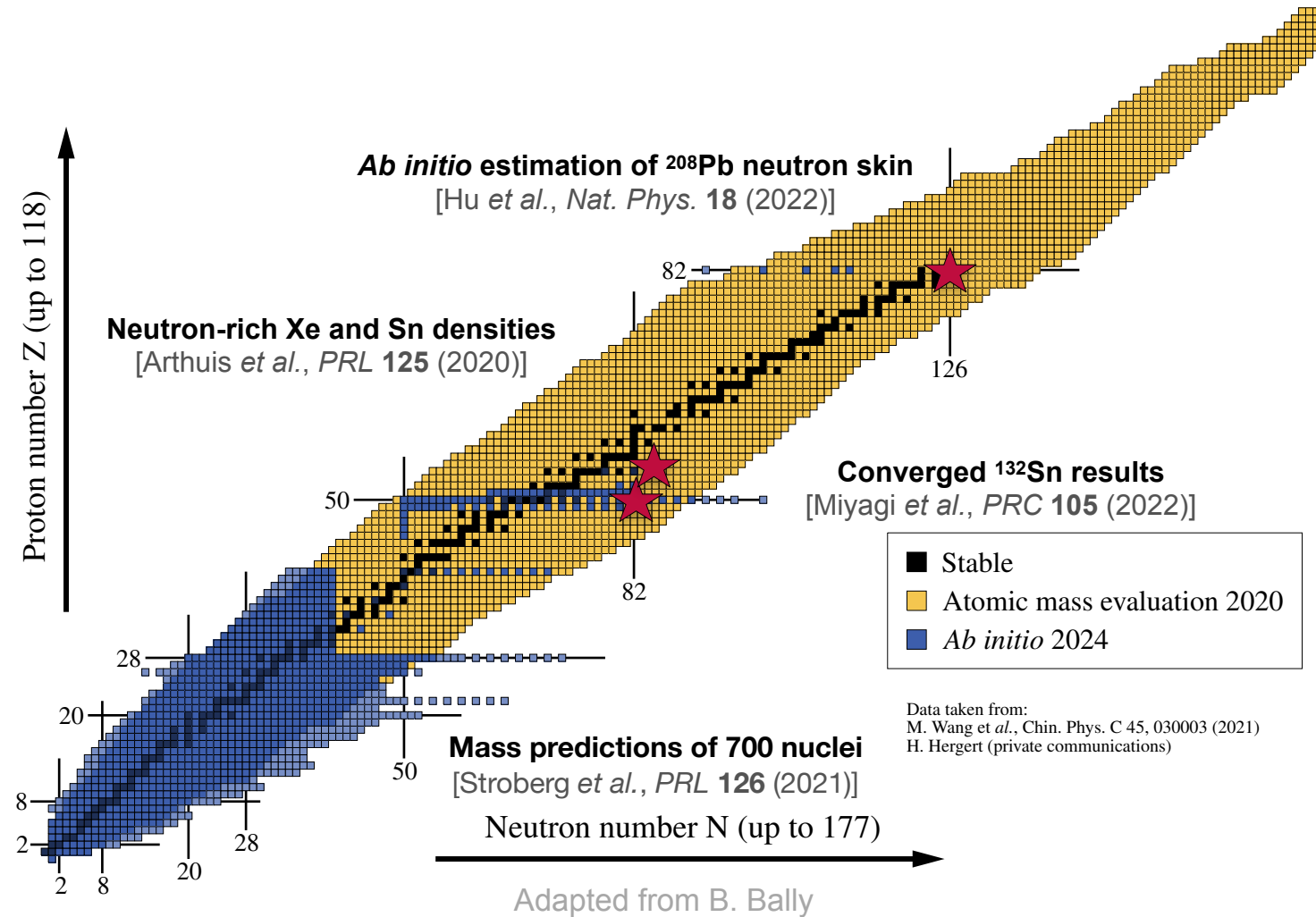
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Exact methods (80's)

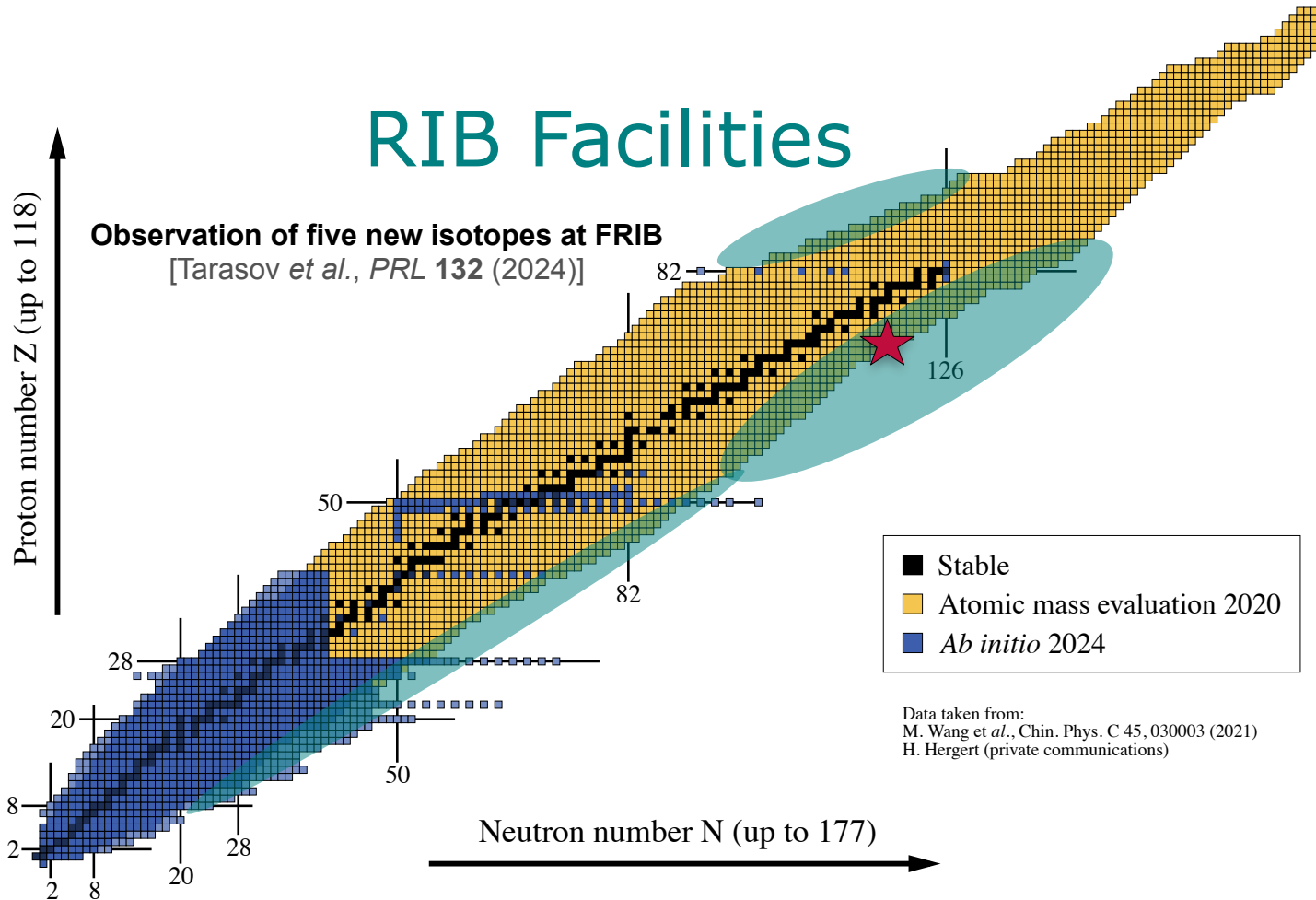
Closed-shell methods (00's)

Open-shell methods (10's)

Ab initio valence space (2014)

...TOWARDS MEDIUM- AND HEAVY-MASS SYSTEMS

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

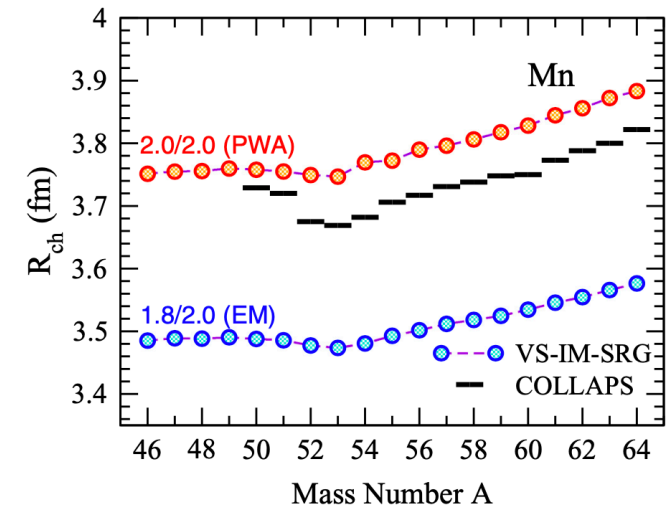
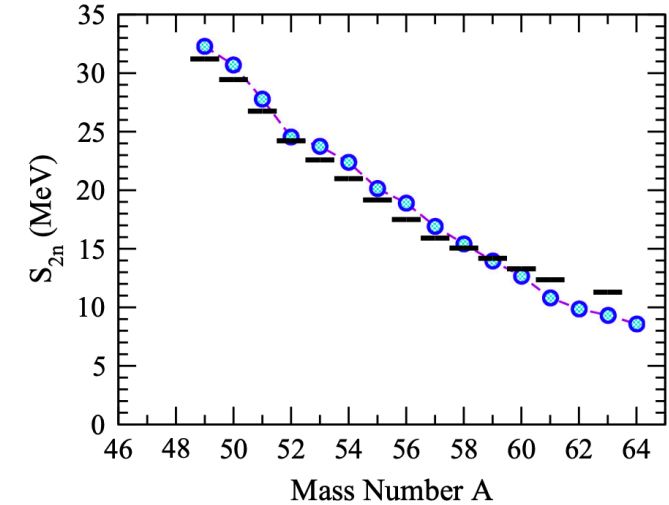
- Better convergence properties through softened interaction
- Proved successful for binding energies with the 1.8/2.0 (EM)
[Hebeler *et al.*, *PRC* 83 (2011)]

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

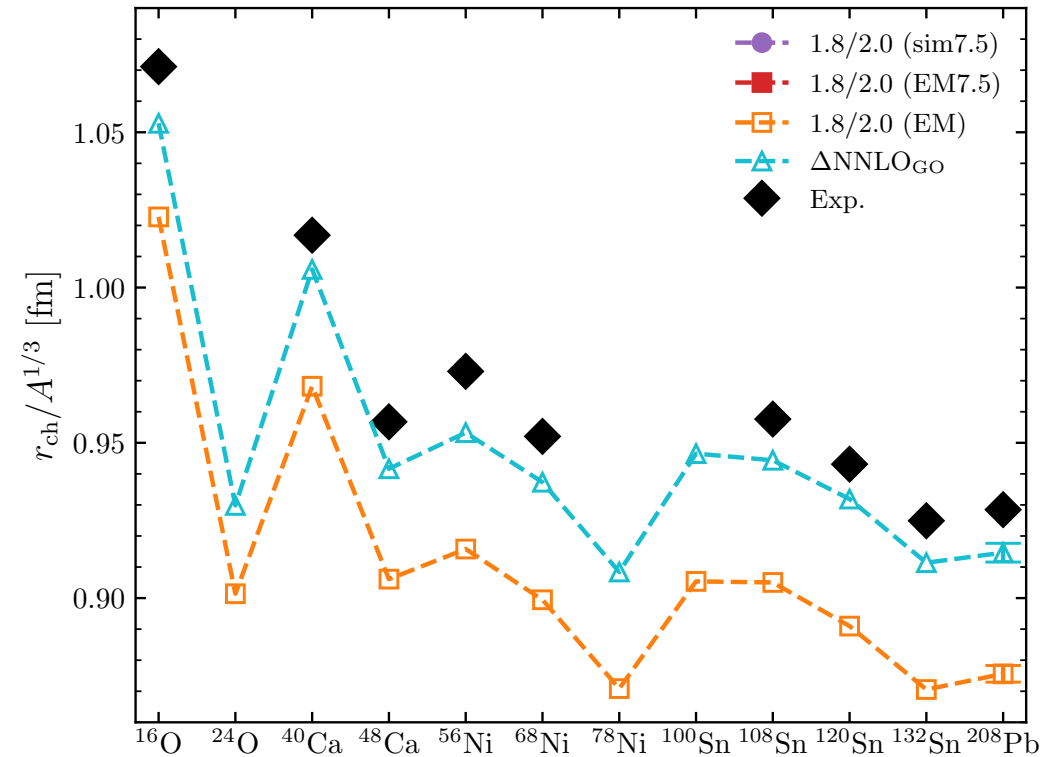
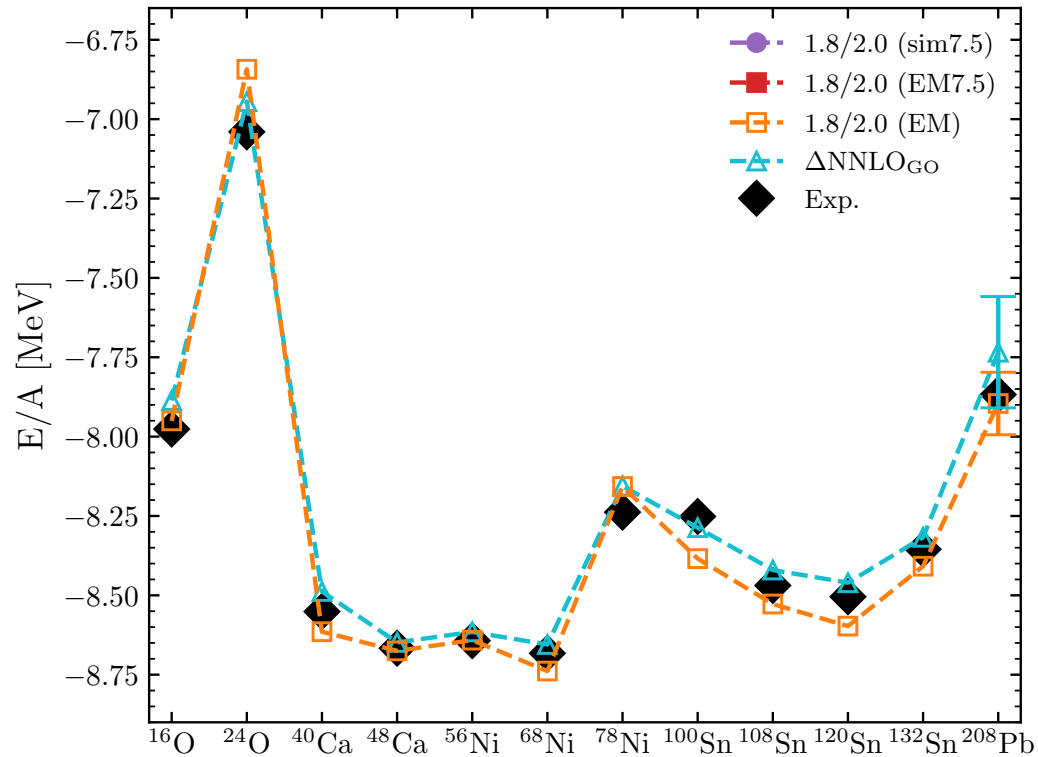
Our new interactions

- Based on EM500 and NNLOsim 550
- Designed to reproduce ¹⁶O radius

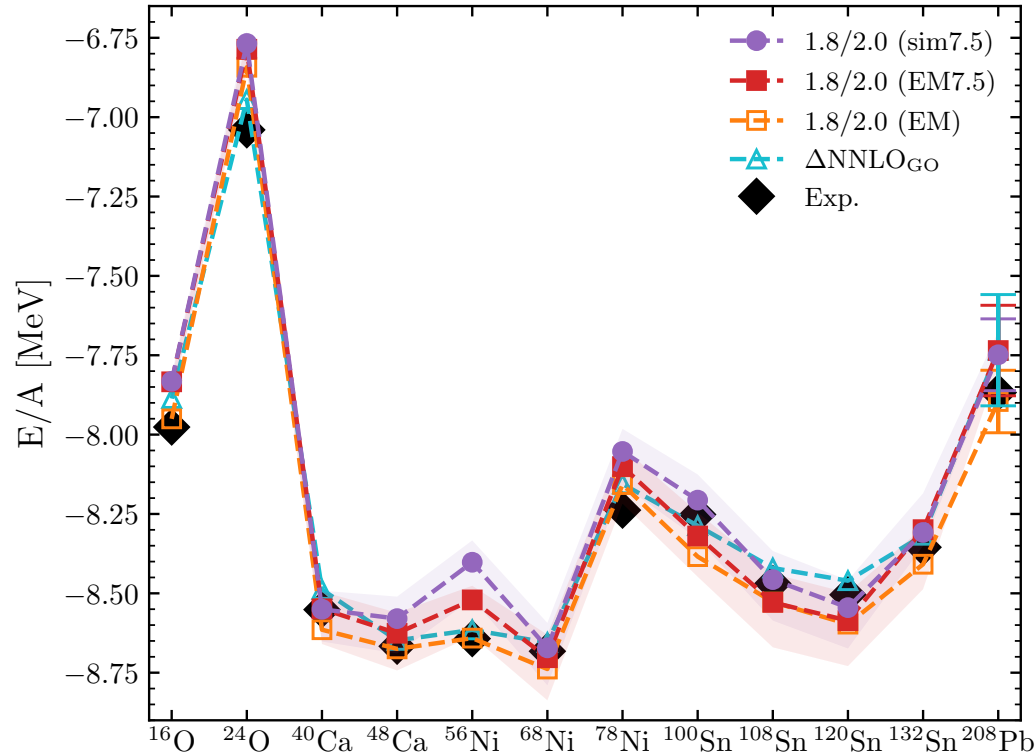


[Simonis *et al.*, *PRC* 96 (2017)]

GROUND-STATE ACCURACY TOWARDS HEAVY SYSTEMS

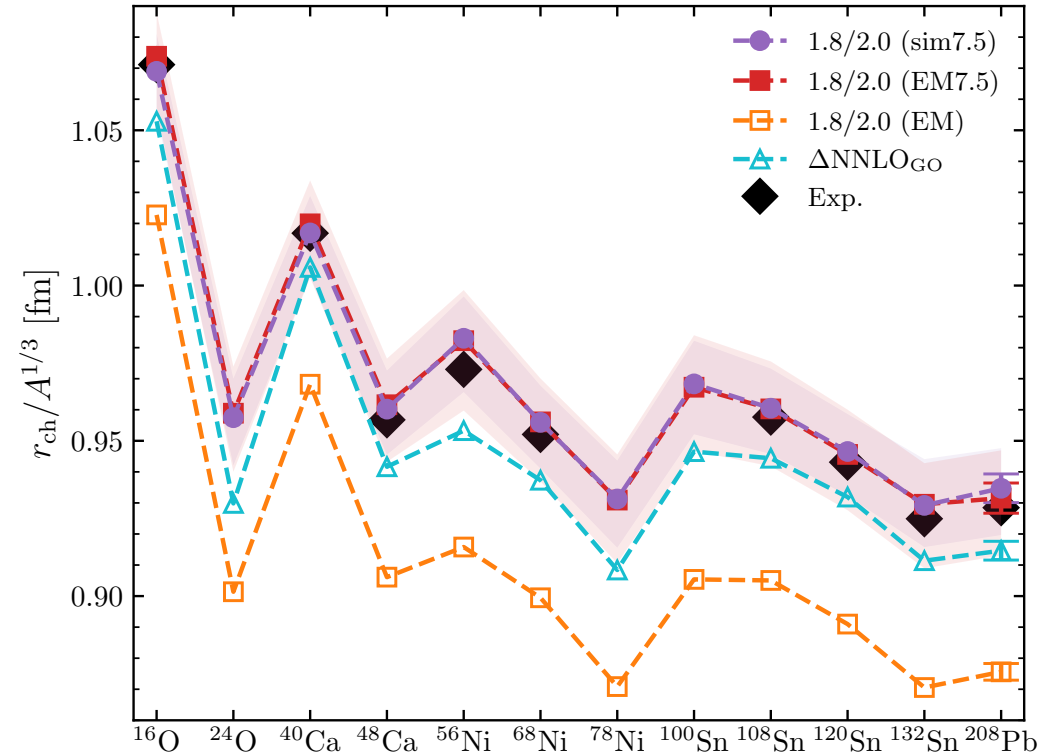


GROUND-STATE ACCURACY TOWARDS HEAVY SYSTEMS



Binding energy

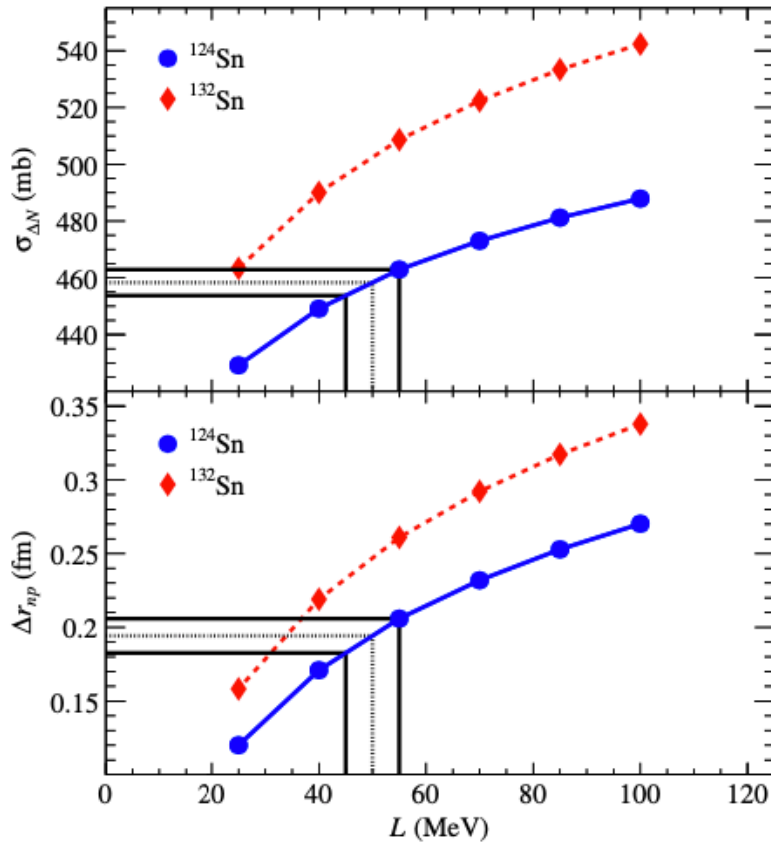
- Reasonable reproduction of experimental values
- Slight improvement for heavy systems w.r.t. 1.8/2.0 (EM)



Charge radius

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

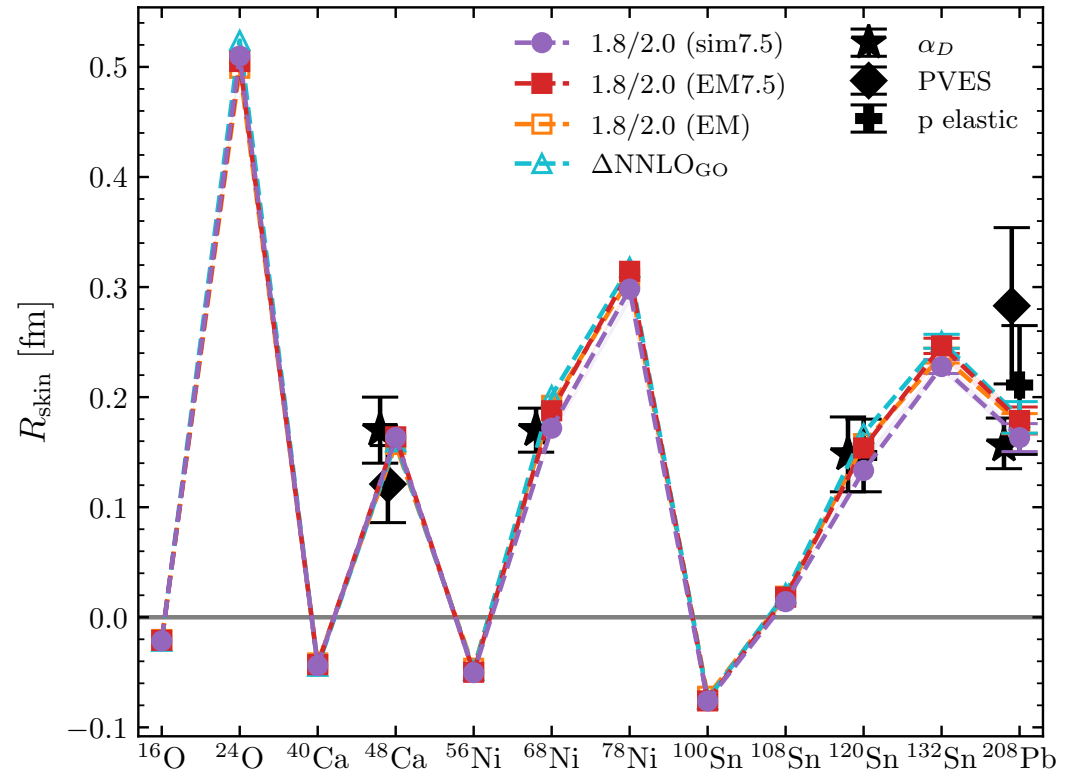
NEUTRON SKIN AND HEAVY SYSTEMS



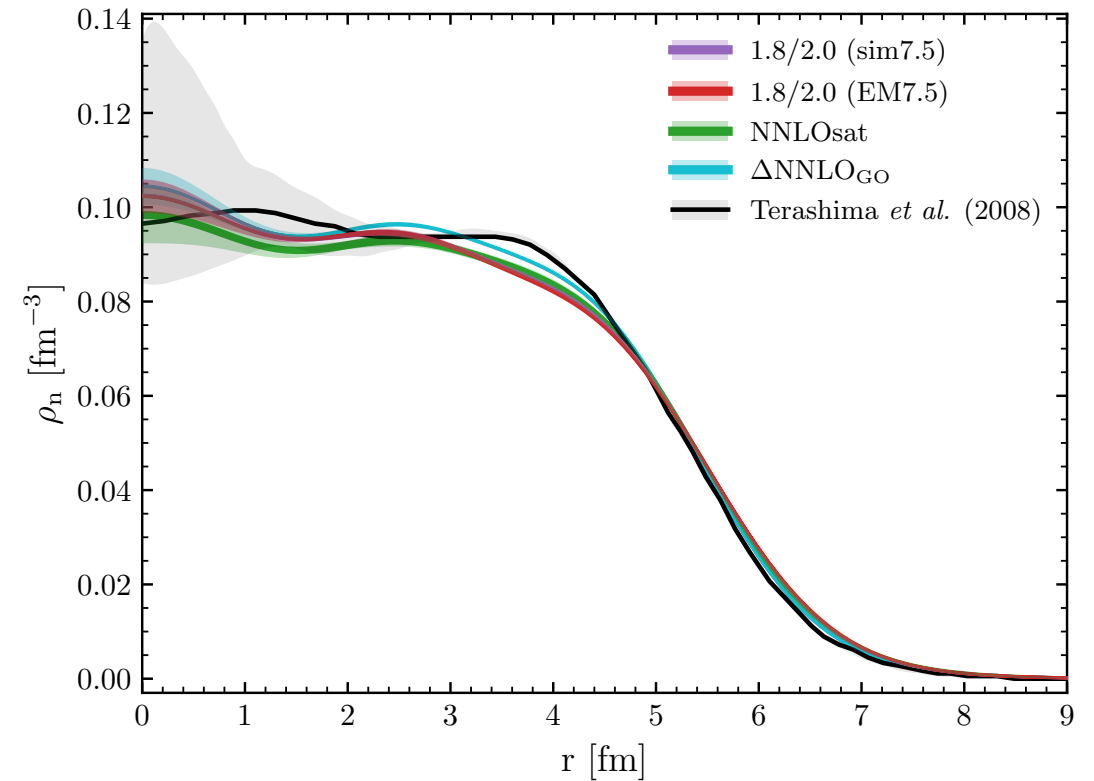
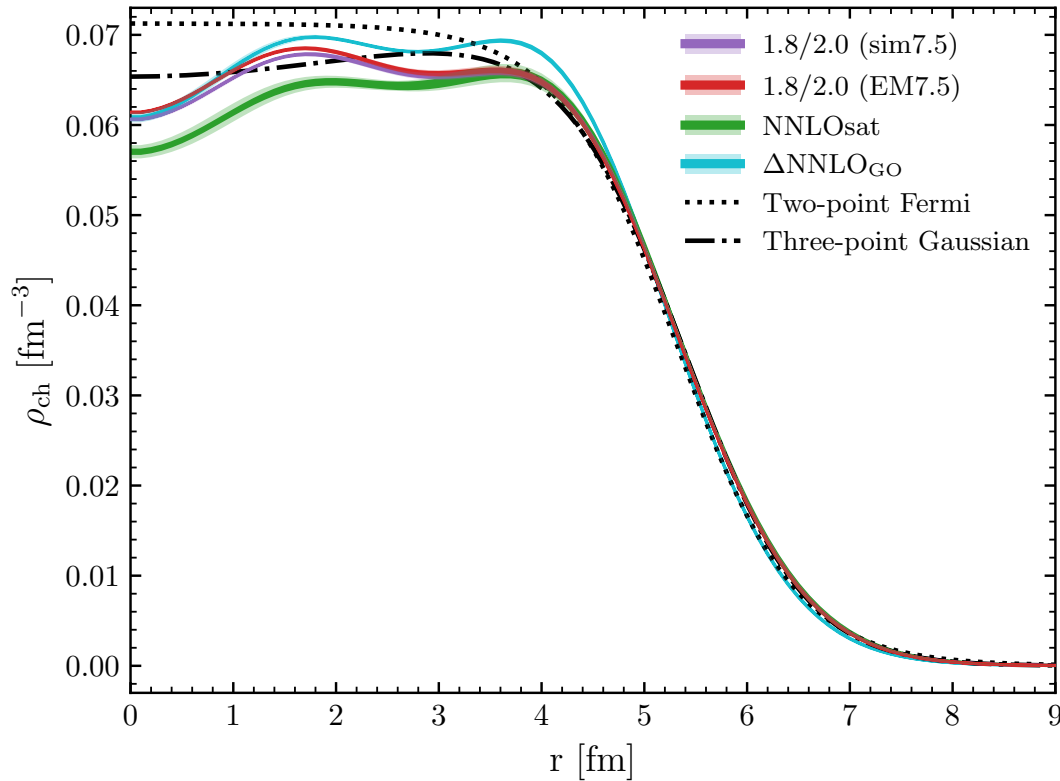
[Aumann *et al.*, *PRL* 119 (2017)]

Neutron removal off Sn isotopes @ R3B/GSI

- Access infinite matter parameter L through the cross-section
- L correlated to neutron skin too: Great test case



AB INITIO DENSITIES FOR HEAVY SYSTEMS: ^{120}Sn



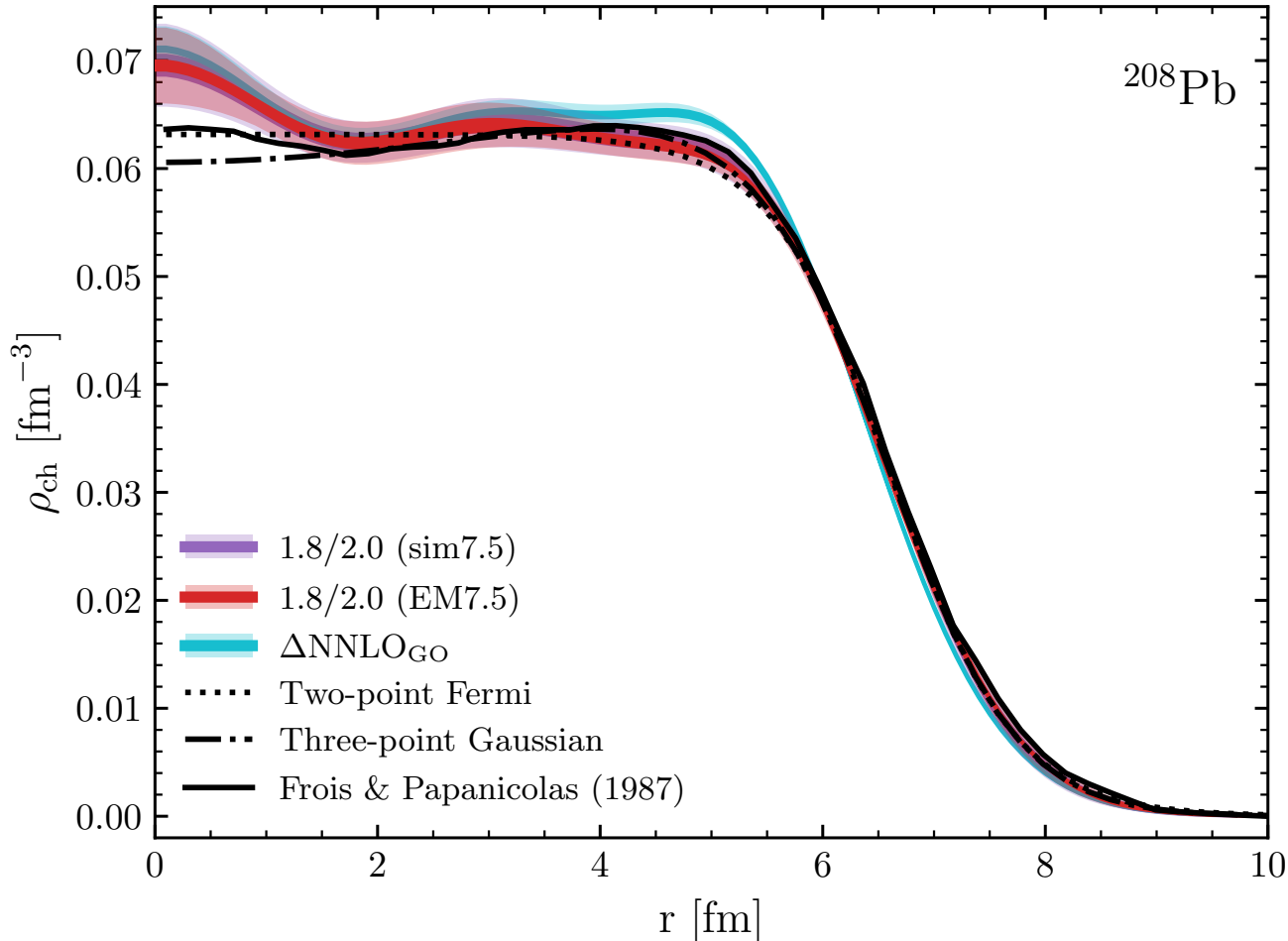
Excellent reproduction of ^{120}Sn densities

- Consistent picture over the different interactions
- Very moderate uncertainties

Check against NNLOsat

- Able to reproduce electron scattering off Xe at SCRIT (RIKEN) [Arthuis, Barbieri, Vorabbi, Finelli, *PRL* 125 (2020)]

AB INITIO DENSITIES FOR HEAVIER SYSTEMS: ^{208}Pb



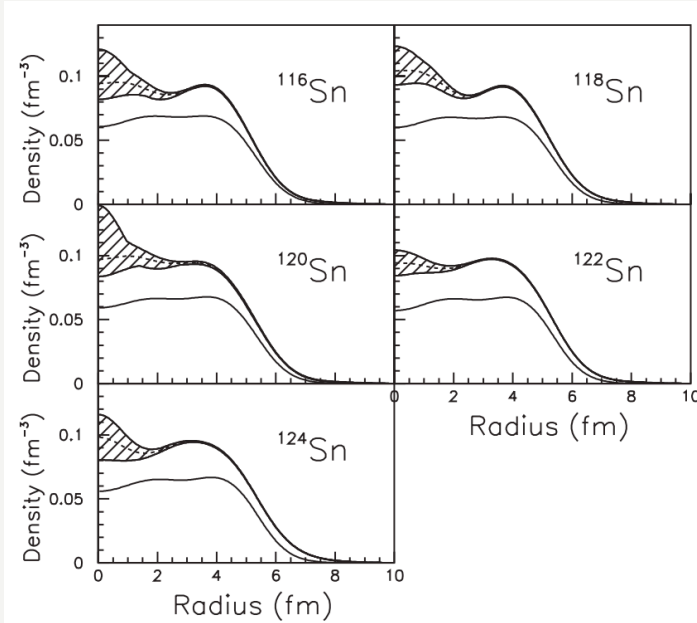
Charge density for ^{208}Pb

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

1.8/2.0s consistent over the nuclear chart

ON NEUTRON SKINS

Evolution w.r.t. isospin

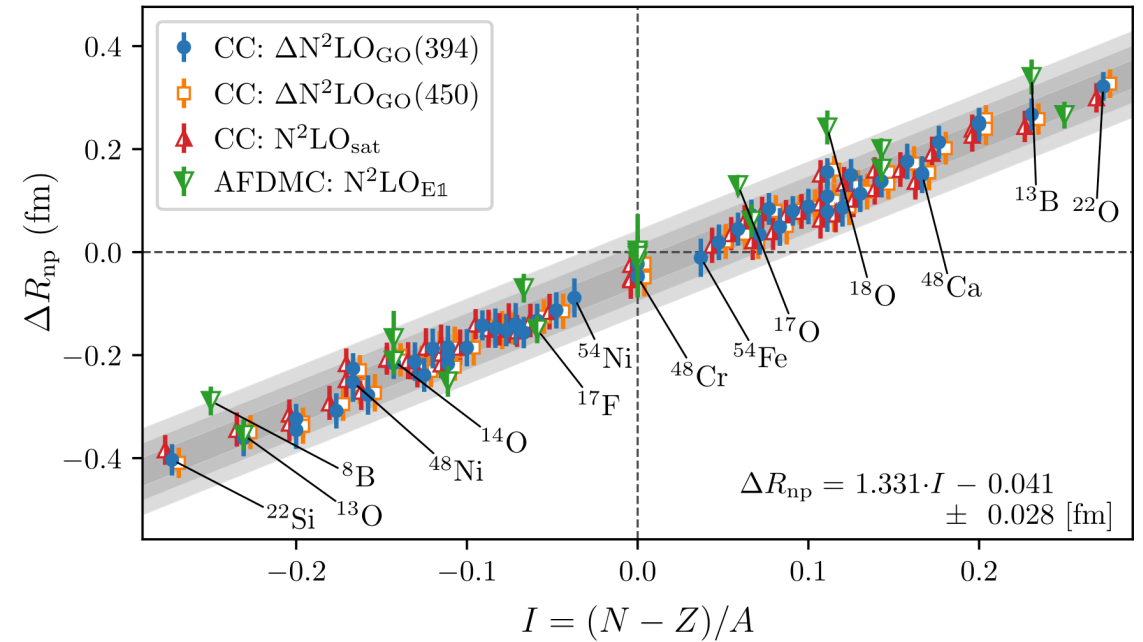


[Terashima et al., PRC 77 (2008)]

Liquid droplet model

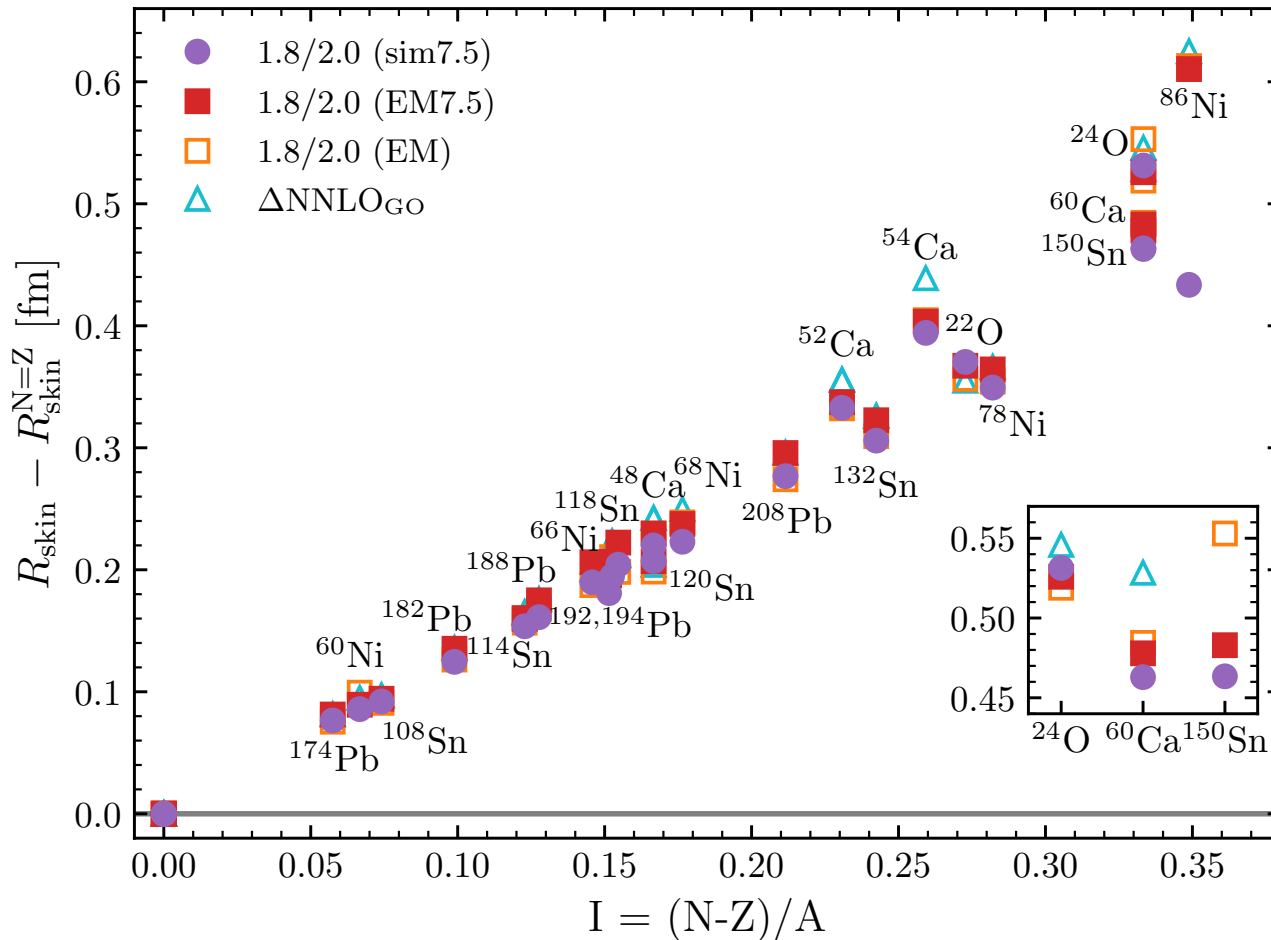
$$R_{\text{skin}} \propto \frac{2r_0}{3} \frac{S_S}{S_V + S_S A^{-1/3}} \frac{N - Z}{A}$$

Linear relation confirmed on *ab initio* basis



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

NEUTRON SKINS IN NEUTRON-RICH ISOTOPES



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

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

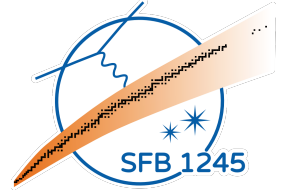
Neutron skin dependence on isospin

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

ACKNOWLEDGMENTS



Thank your for your attention!



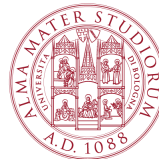
STRONGINT group
C. Brase, M. Companys-Franzke, Y. Dietz,
K. Hebel, M. Heinz, A. Porro, A. Schwenk,
I. Svensson, A. Tichai



UNIVERSITÀ
DEGLI STUDI
DI MILANO



C. Barbieri



P. Finelli



UNIVERSITY OF
SURREY

M. Vorabbi