Brückner-Hartree-Fock with Realistic Nucleon-Nucleon Potentials

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Overview

- Realistic Potentials & Effective Interactions
- Unitary Correlation Operator Method (UCOM)
- Hartree-Fock + Perturbation Theory
- Brückner-Hartree-Fock (BHF)
- Summary & Outlook

Realistic Potentials & Effective Interactions

Realistic Potentials

- QCD motivated: based on meson exchange picture or chiral effective field theory
- fitted to properties of the deuteron and phase shifts
- need a short-range repulsion and tensor force
  Examples: AV18, CD Bonn, Chiral $\mathrm{N^3LO}$ ...

Effective Interactions

- simple model spaces cannot describe short-range correlations
- adapt realistic potentials to
  model spaces while conserving phase shifts of the realistic potential

Unitary Correlation Operator Method

Correlation Operator

introduce short-range correlations by means of a unitary transformation with respect to the relative coordinates of all pairs

$$\mathrm{C} = \exp[-\mathrm{i}\,\mathrm{G}] = \exp\Big[-\,\mathrm{i}\sum_{i<j} \mathrm{g}_{ij}\Big]$$

$$\mathrm{G}^\dagger = \mathrm{G}$$
$$\mathrm{C}^\dagger \mathrm{C} = 1$$

Correlated States

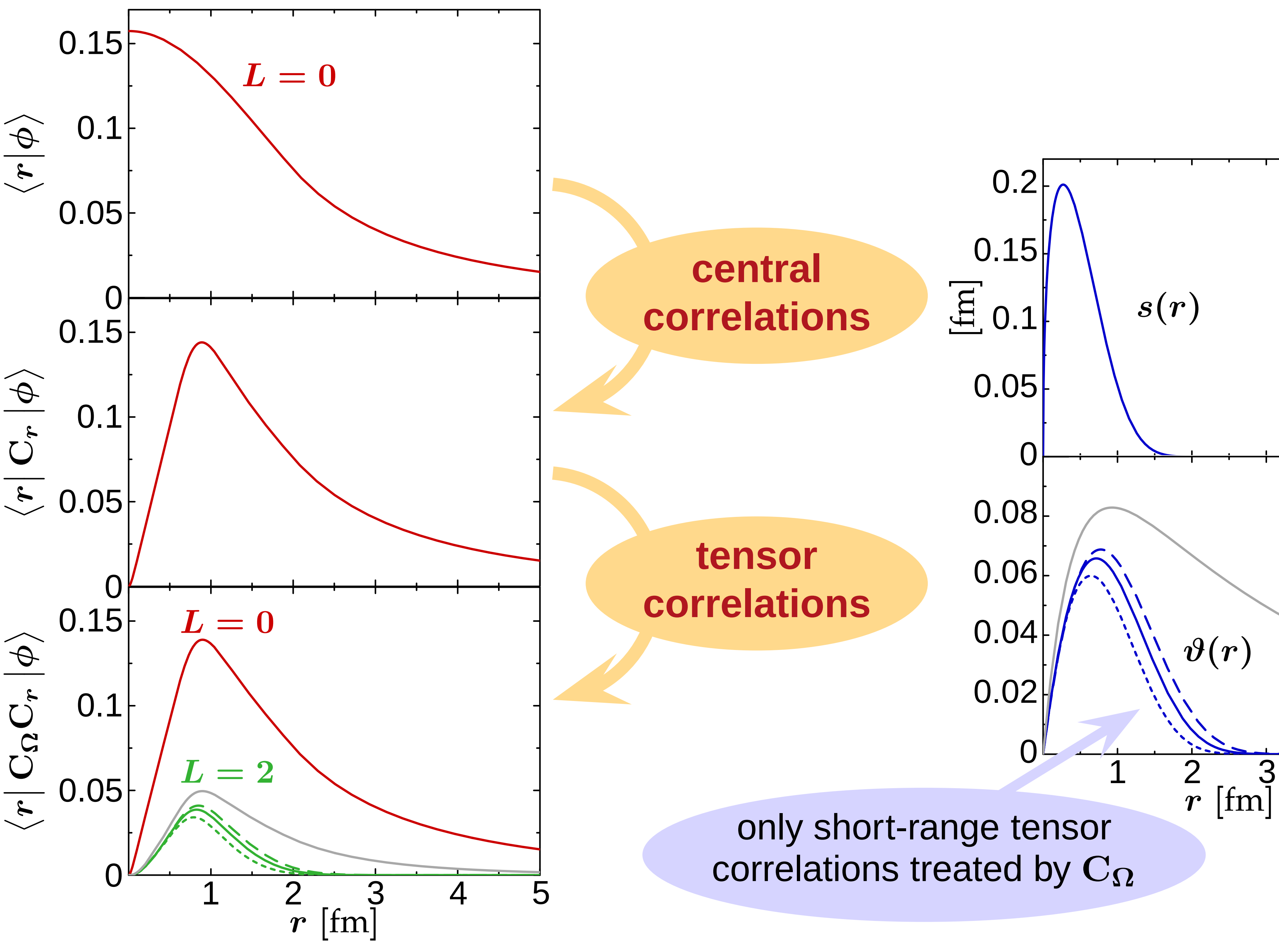
$$|\widetilde{\psi}\rangle = \mathrm{C}\ |\psi\rangle$$

Correlated Operators

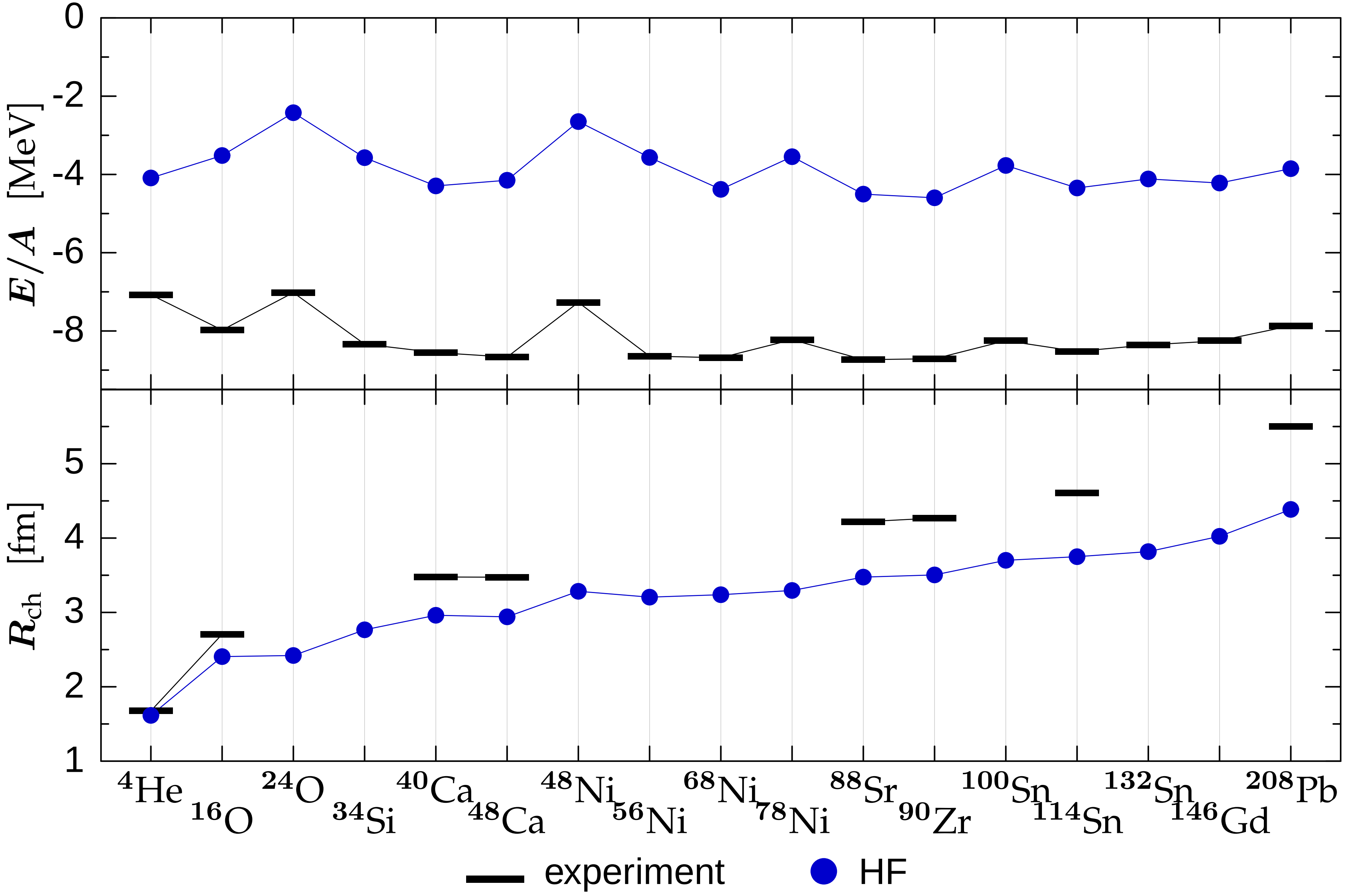
$$\widetilde{\mathrm{O}} = \mathrm{C}^\dagger\ \mathrm{O}\ \mathrm{C}$$

$$\langle\widetilde{\psi}|\,\mathrm{O}\,|\widetilde{\psi}'\rangle = \langle\psi|\,\mathrm{C}^\dagger\ \mathrm{O}\ \mathrm{C}\,|\psi'\rangle = \langle\psi|\,\widetilde{\mathrm{O}}\,|\psi'\rangle$$

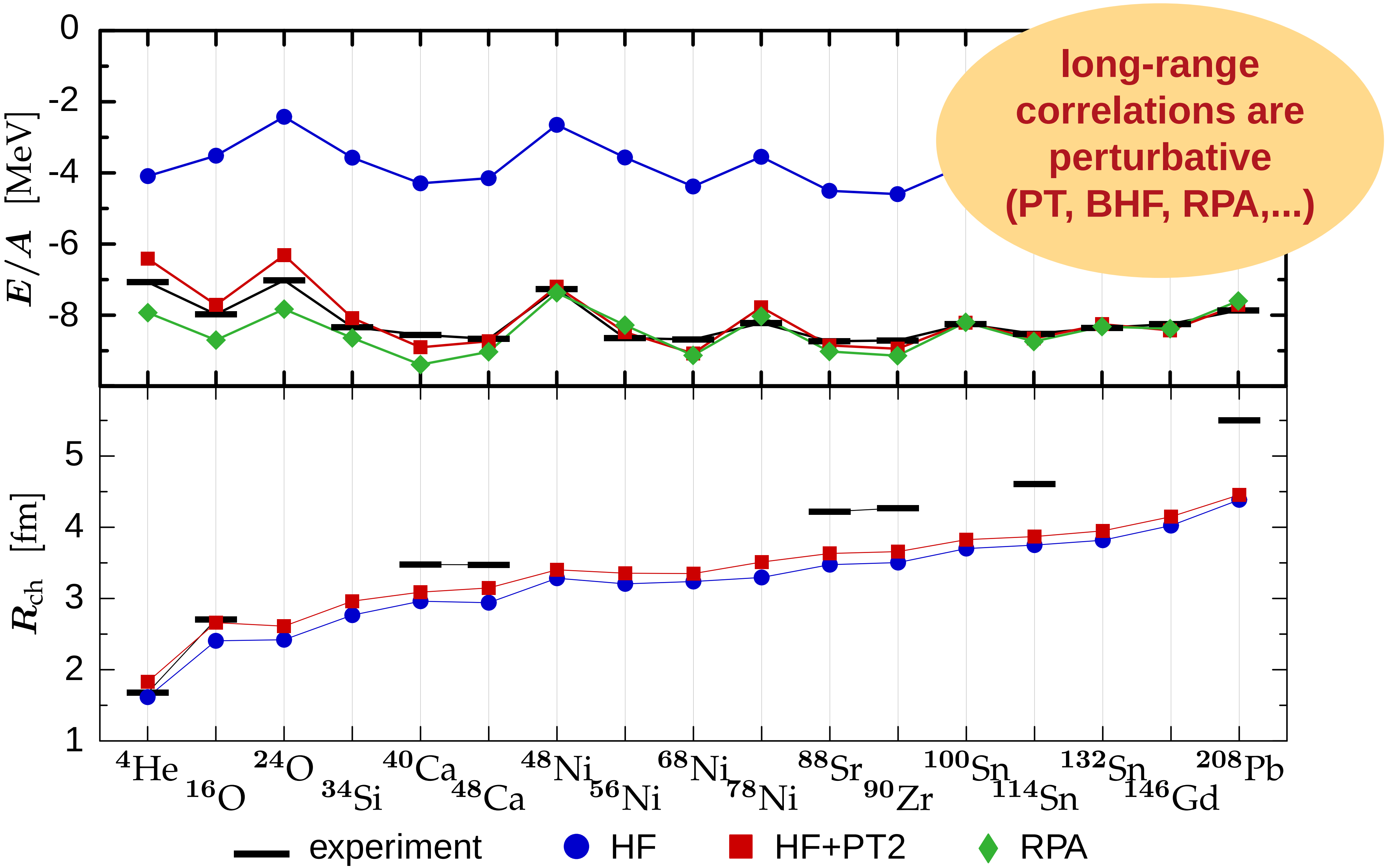
Correlated States: The Deuteron



Binding Energies & Radii



Binding Energies & Radii



Bethe-Goldstone-Equation

Equation

$$G^{\omega} = W + W \frac{1}{2} \frac{Q}{\omega - H_0} G$$

Explanation

$W = T - T_{\text{cm}} + V_{\text{UCOM}} + V_C$

ω : starting energy

Q : Pauli operator

H_0 : single particle Hamiltonian

Implementation

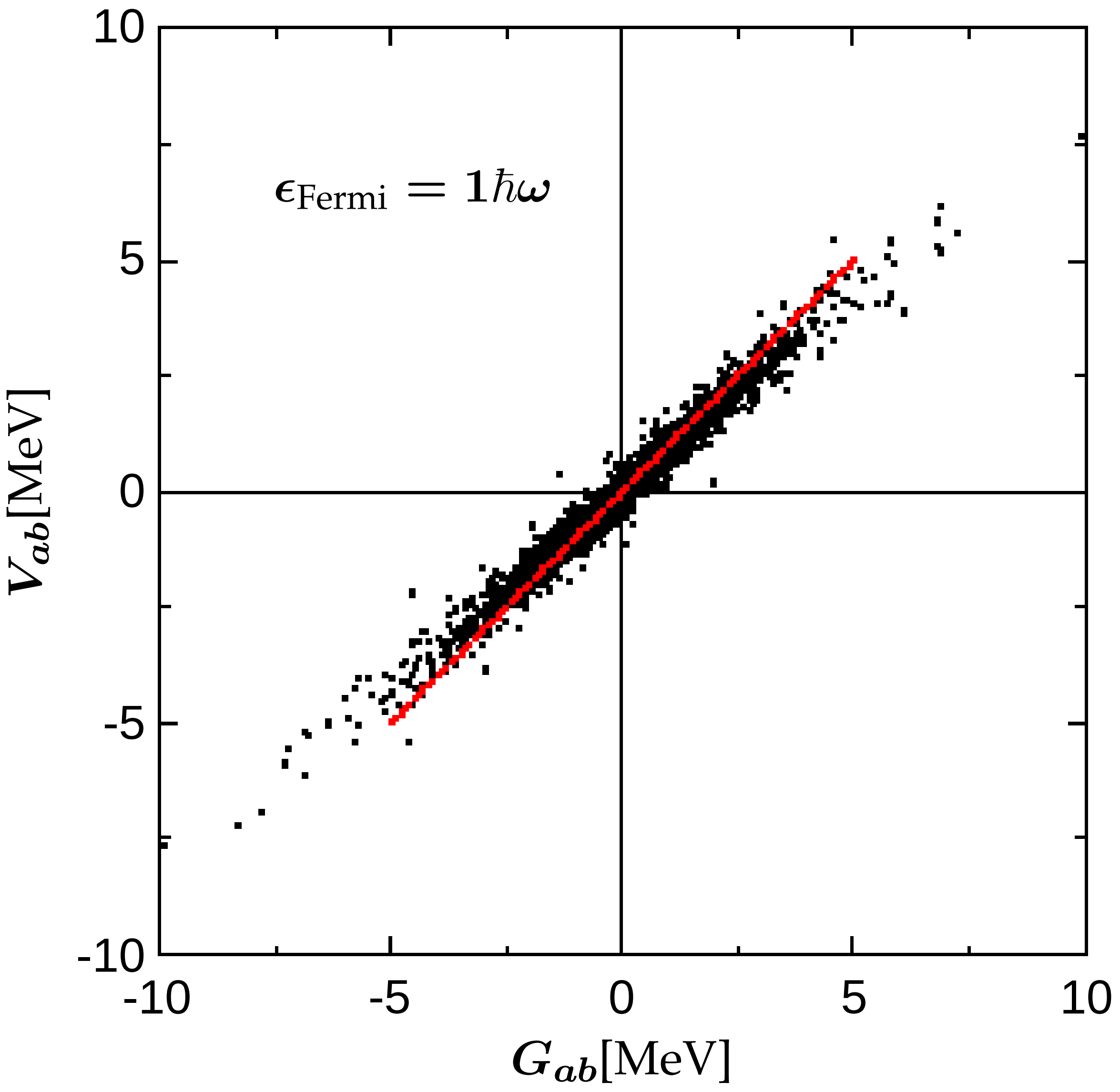
Inversion

$$G^{\omega} = [\mathbb{1} - \frac{1}{2} \frac{Q}{\omega - H_0} W]^{-1} W$$

Iteration

$$G^{\omega} = W + W \frac{1}{2} \frac{Q}{\omega - H_0} W + W \frac{1}{4} \frac{Q}{\omega - H_0} W \frac{Q}{\omega - H_0} W + \ldots$$

Correlations I

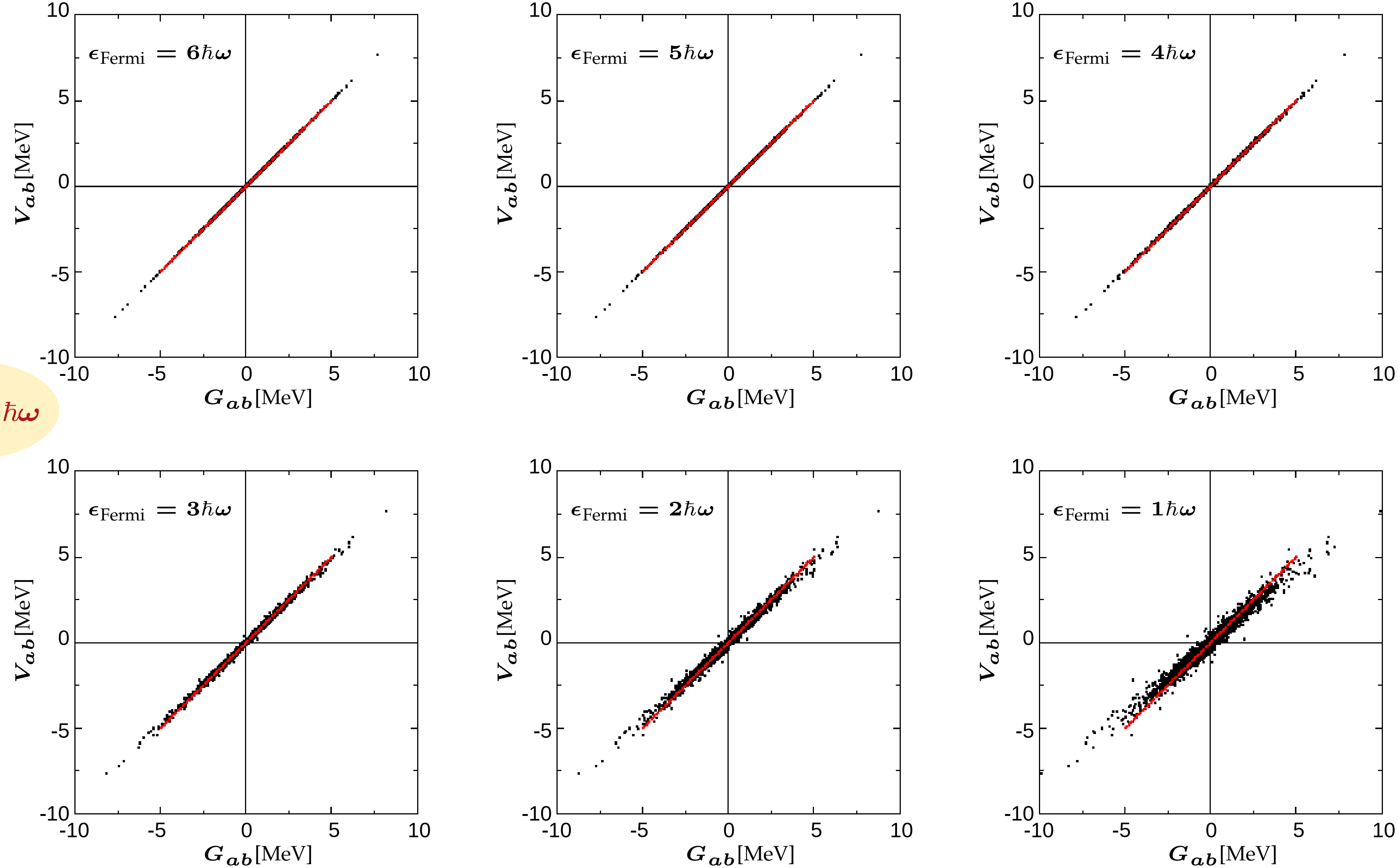


$\epsilon_{\text{max}=6\hbar\omega}$

$J = 1$

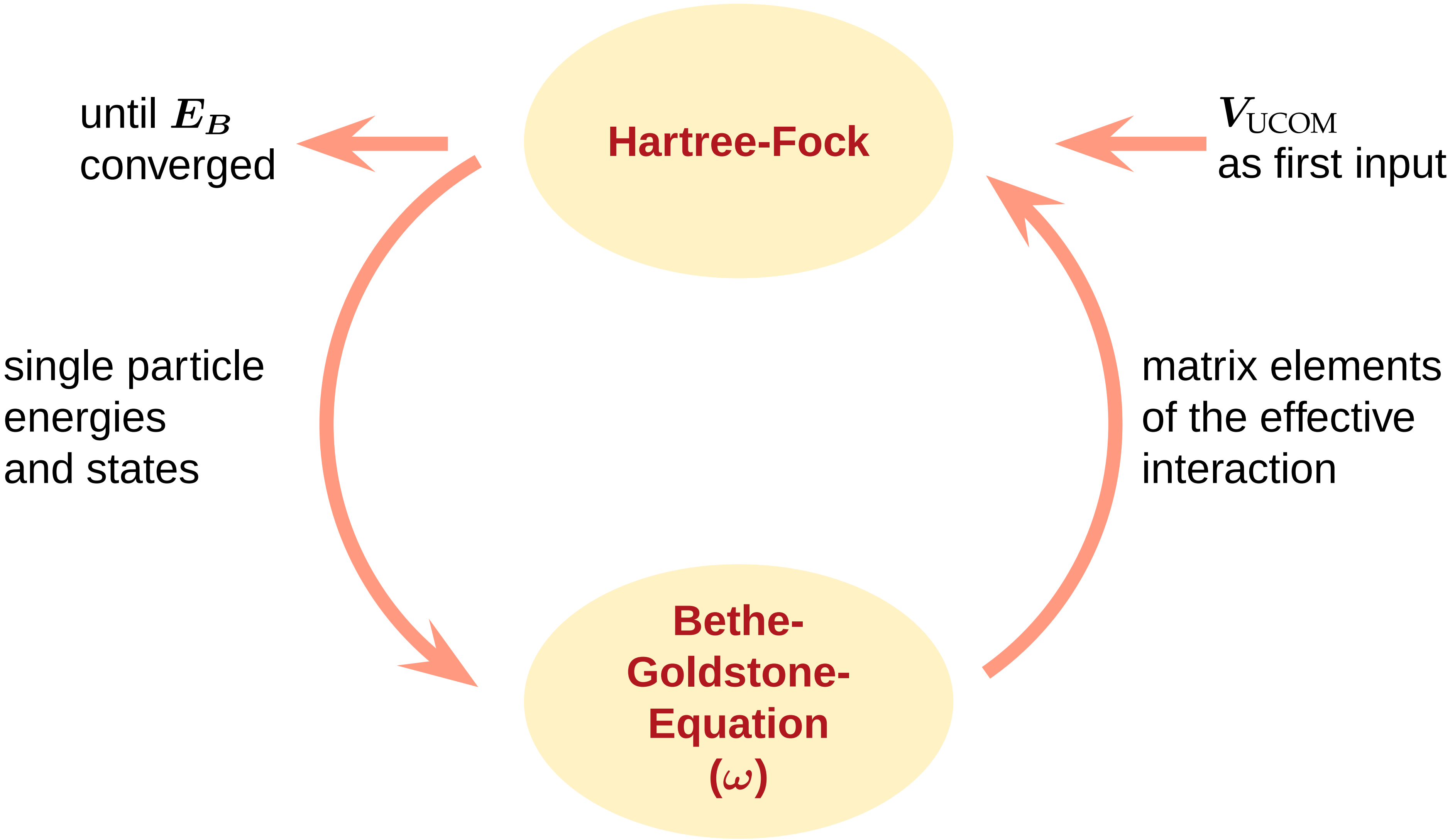
$T = 0$

Correlations II

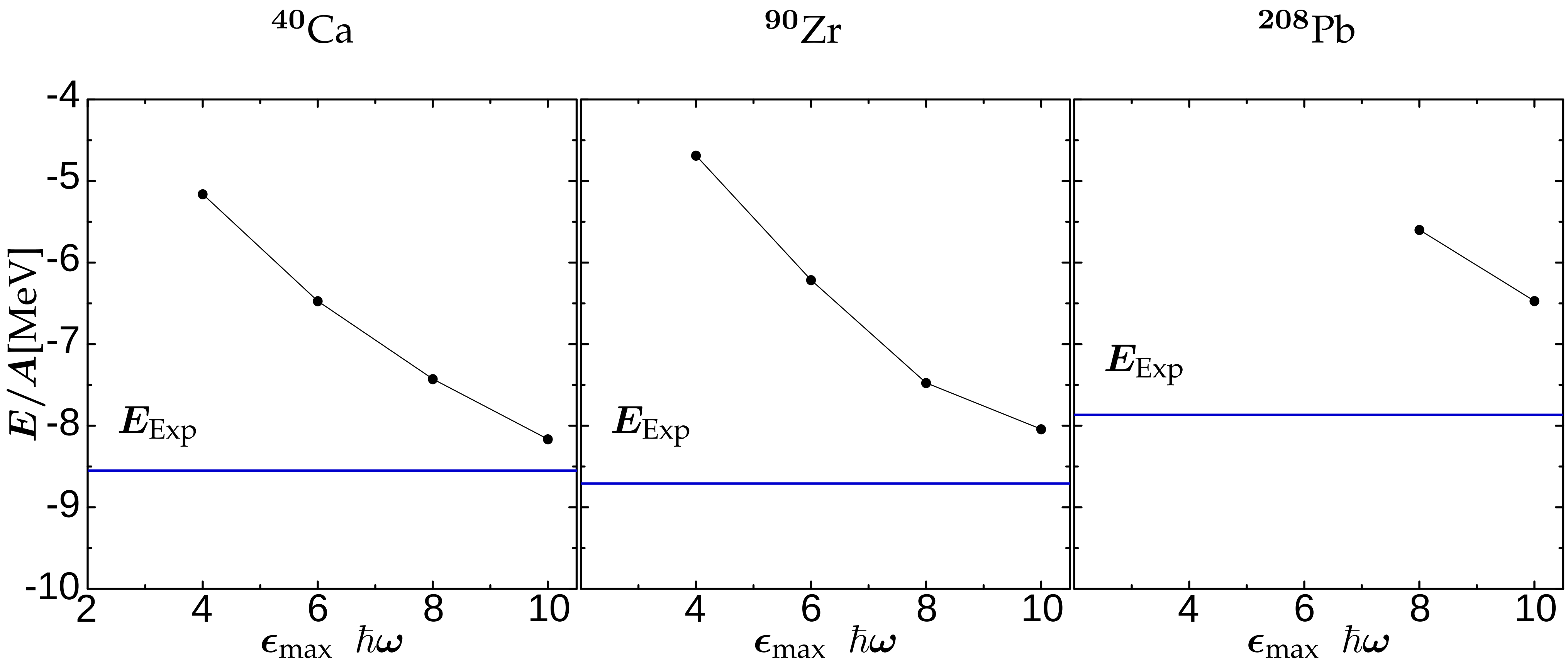


$\epsilon_{\text{max}}=6\hbar\omega$

Fully Self-Consistent BHF



Results

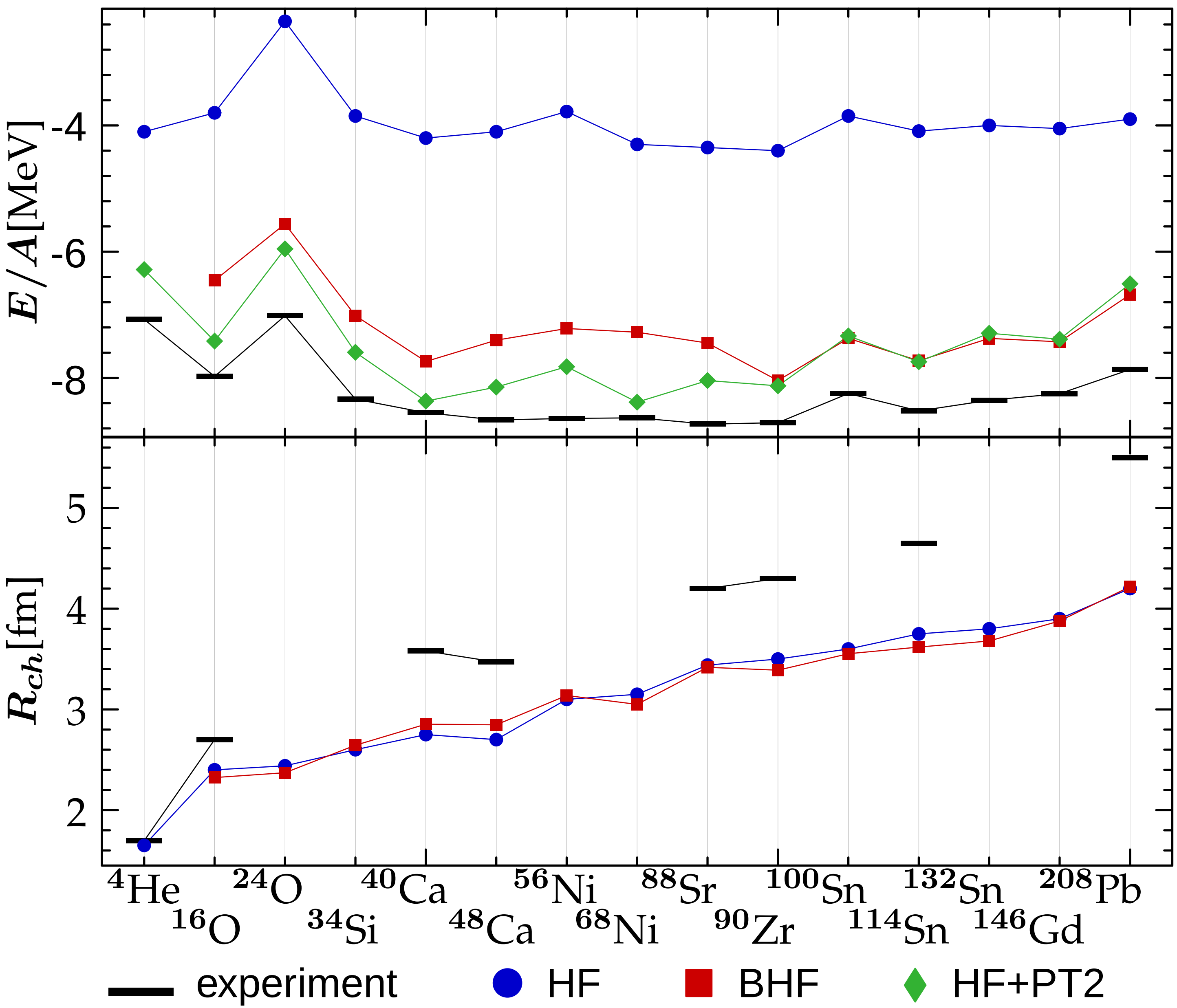


^{40}Ca
^{90}Zr
^{208}Pb
E/A[MeV]
-4
-5
-6
-7
-8
-9
-10
2
4
6
8
10
$E_{\rm Exp}$
$\epsilon_{\rm max}$ $\hbar\omega$

Binding Energy & Radii

$\epsilon_{\max}=10\hbar\omega$

preliminary results



Summary & Outlook

- UCOM describes short-range correlations and ’tames’ the interaction; can be used in HF (BHF, RPA . . .)
- fully self-consistent BHF based on the realistic two body interaction V_{UCOM}
- results for the energy with BHF are in good agreement with experiment and second-order perturbation theory but radii are not much improved
- Outlook: other ’strategies’ for the starting energy, Padè approximants in the iterative scheme

Epilogue...

My Collaborators

- R. Roth, P. Papakonstantinou, H.Hergert, A. Zapp

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