

HFB Calculations with the Gogny Force in a Basis Embedding Discretized Continuum States

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Motivations

- **Nuclear structure** near the drip- lines: Two reasons why one may get it wrong:
 - Incorrect (or absent) **treatment of the continuum** within a given framework : HFB, RMF, Shell Model, etc.
 - Incorrect **physics input** in effective interaction or Lagrangian: Wrong isospin dependence, missing terms (tensor), etc.
- **Crucial role of pairing interaction** in mean field approaches
- Strategies:
 - HFB/RHB calculations in coordinate space with box-boundary conditions (restricted to Skyrme functionals)
 - HFB/Shell model in a basis:
 - Transformed harmonic oscillator
 - Gamow basis

Outline of the method

- Aim: nuclear structure in neutron or proton rich nuclei
- Best possible pairing interaction \Rightarrow Finite range (Gogny)
 - Particle-hole and particle-particle channel treated on the same footing
 - No divergence problem
- Beyond mean field correlations: PNP (after variation)
- Basis embedding discretized continuum states
 - Suitable to extend to deformed systems
 - Flexible to study the influence of the basis
- Box boundary conditions and spherical symmetry:
Benchmark

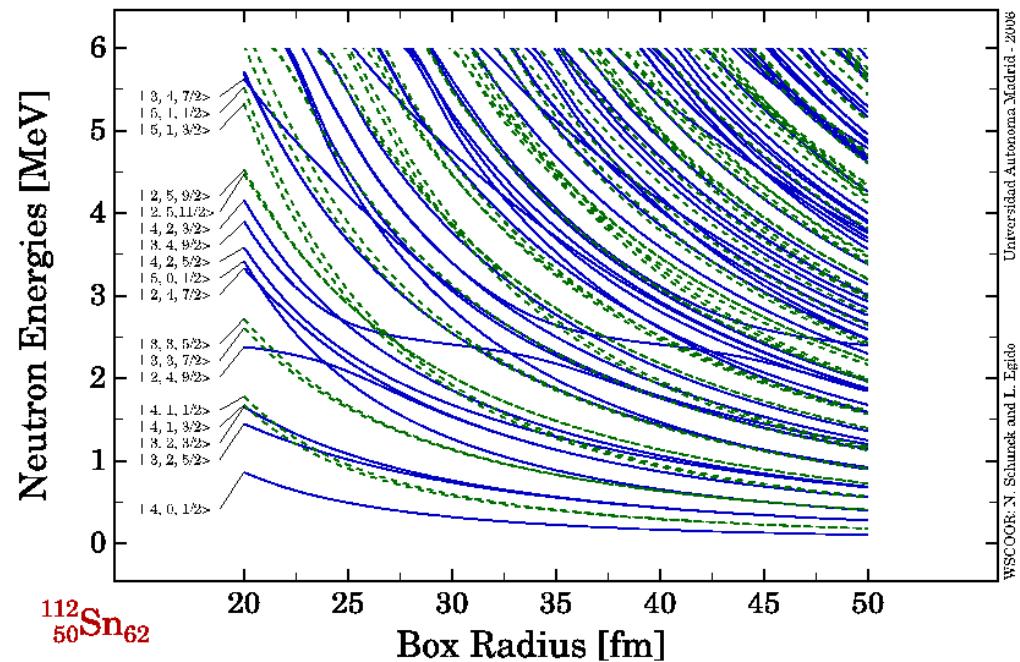
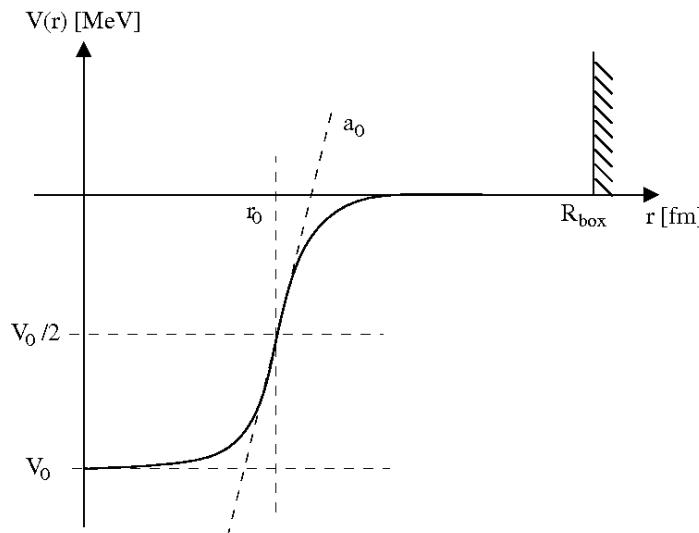
**Microscopic
Description**



**Treatment of
the continuum**

The Basis

- Eigenstates of a Woods Saxon potential
- Numerical integration of the Schrödinger equation (shooting method)
- Any type of realistic one body potential possible



HFB Calculations with the Gogny
Force...

Practical Details

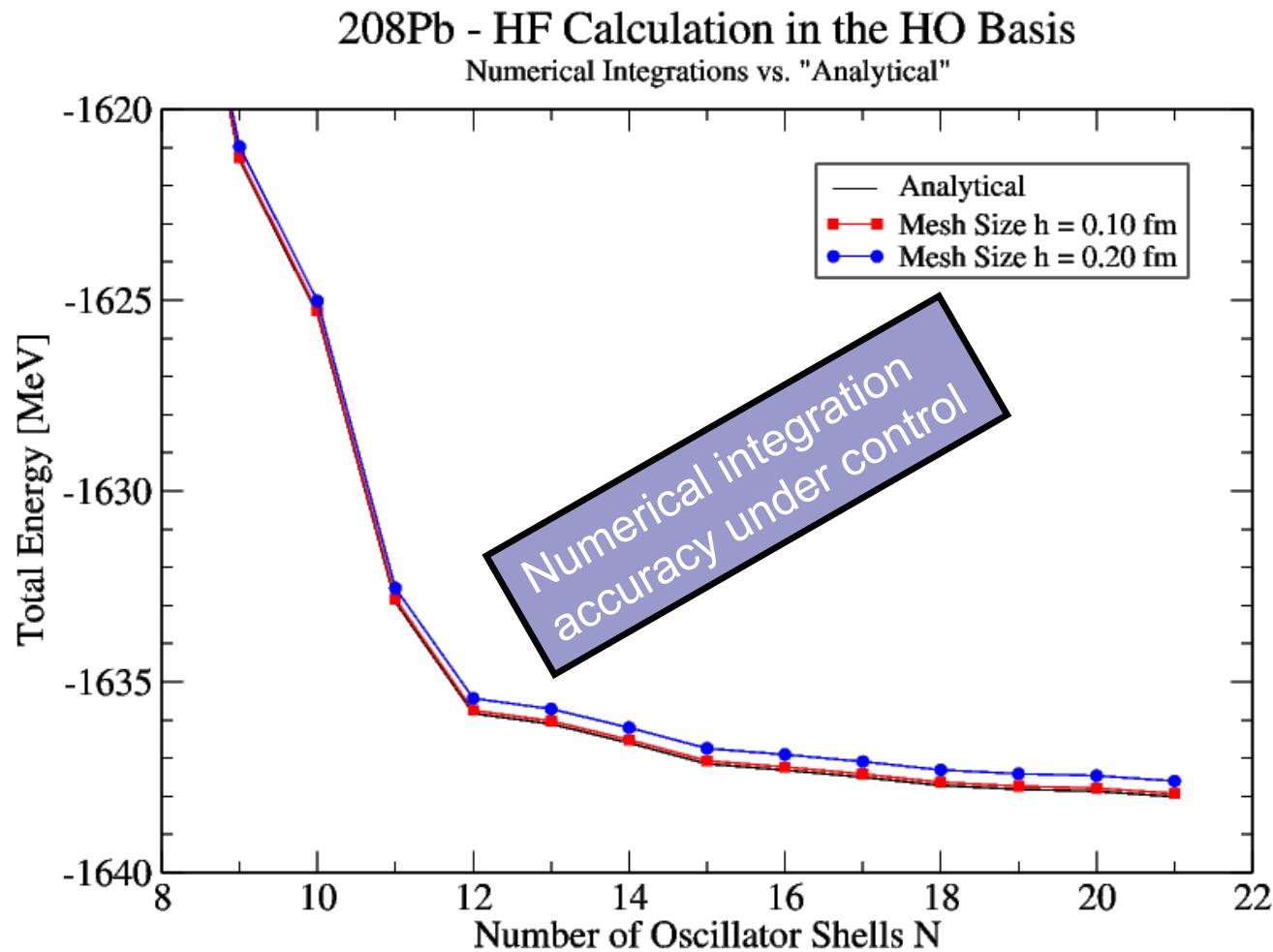
- Initial architecture: spherical HFB code in the HO basis:
Only the **radial part** of the matrix elements need be re-calculated

Gogny Central term: **finite-range**

$$\hat{V}_{cen}(\hat{\mathbf{H}}_{cen}, \mathbf{r}_1, \mathbf{r}_2) = x \sum_i P_\sigma \delta((\mathbf{r}_1 - \mathbf{r}_2)^2 / \mu_i^2) \frac{1}{2} \left(t W_i + x B_i \hat{P}_\sigma (\hat{\mathbf{k}}^\dagger)^2 \hat{H}_i \hat{\mathbf{R}}_1 \cdot \mathbf{r}_2 M_i \hat{P}_\sigma \hat{\mathbf{P}}_2 \right)_2 \hat{\mathbf{k}}^2$$

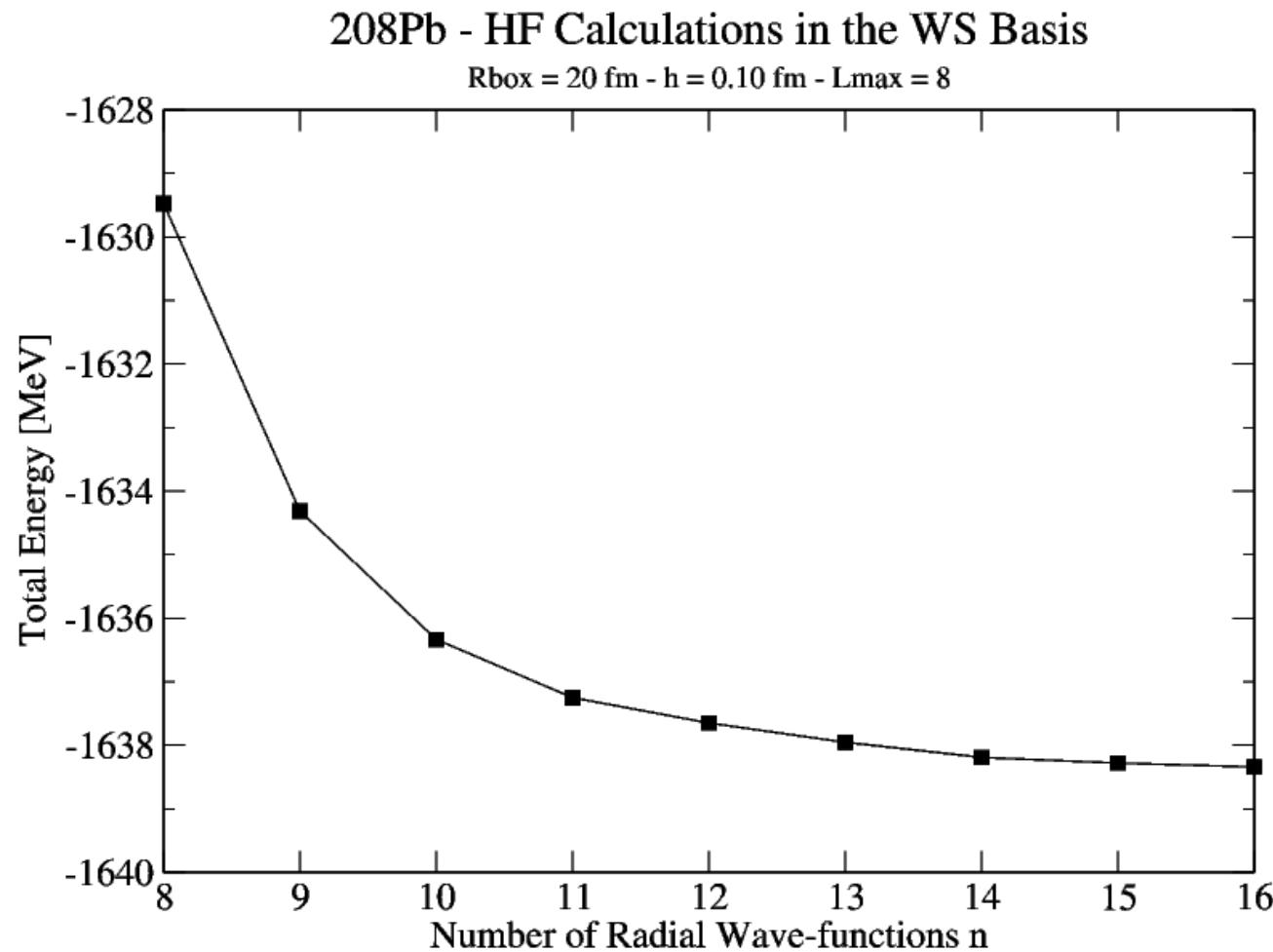
- HO Basis: can be computed analytically $\hat{\mathbf{R}}_1 \cdot \hat{\mathbf{R}}_2 (\mathbf{r}_1 - \mathbf{r}_2) \hat{\mathbf{k}}$
 - Numerical Basis: must be calculated approximately
- All exchange terms taken into account
 - Coulomb potential calculated exactly

Stability: Numerical Integration



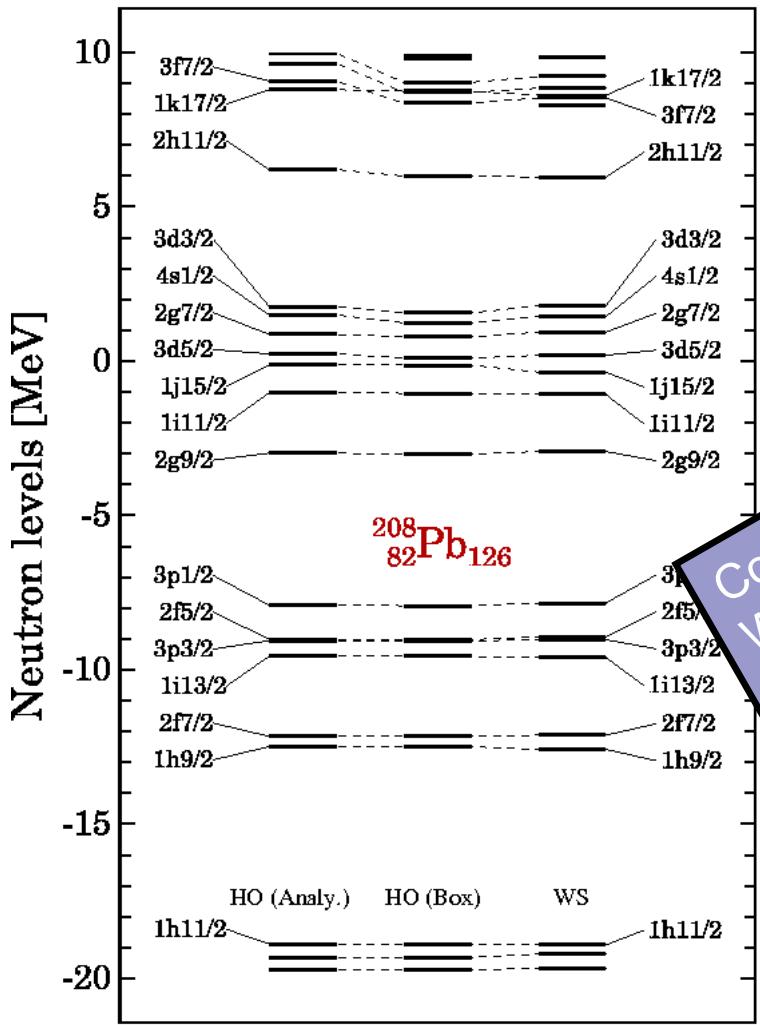
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Stability: Convergence of WS Basis (1. HF)

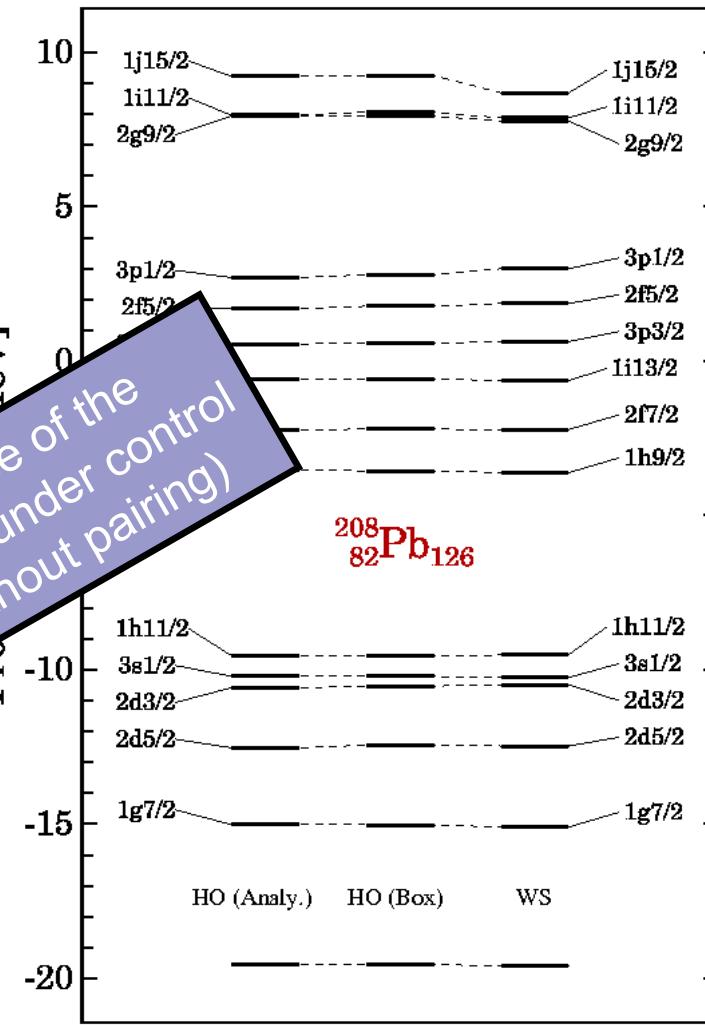


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Stability: Single-particle Levels (2. HF)

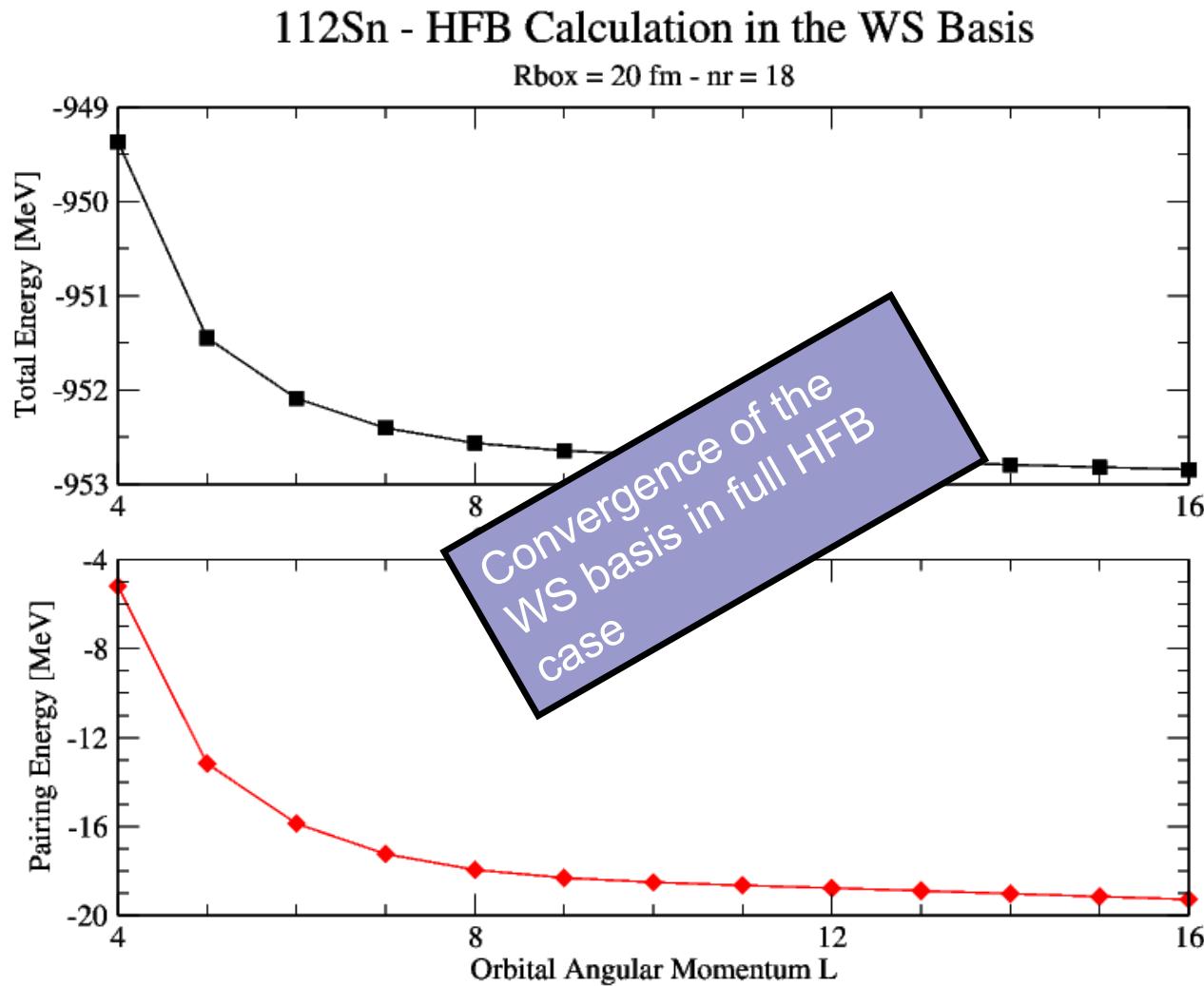


Convergence of the
WS basis under control
(case without pairing)



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Stability: Full Pairing Calculations (3. HFB)

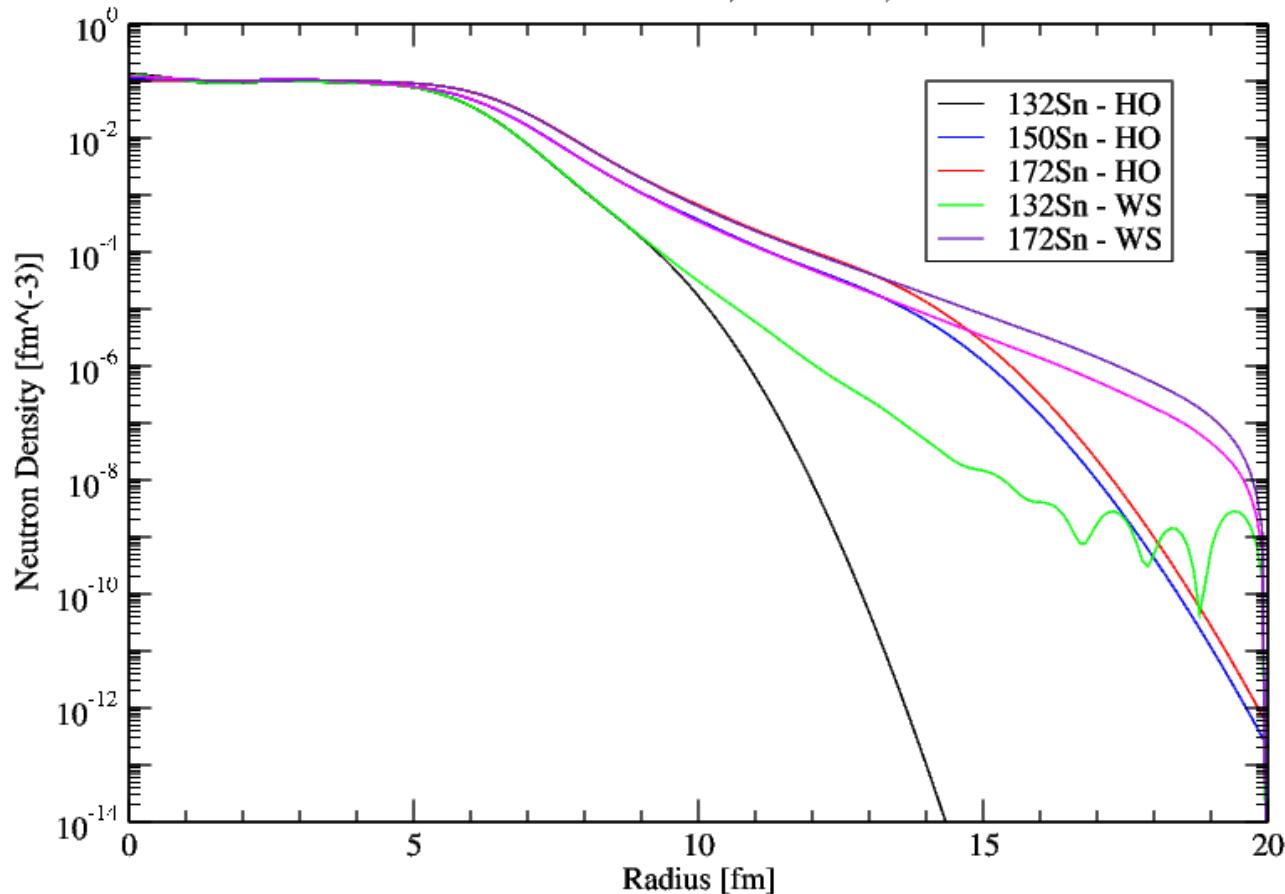


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Towards the drip-lines: Neutron densities

Neutron Densities of Sn Isotopes - WS vs. HO Basis

Nsh = 22 - Rbox = 20 fm, Lmax = 10, nr = 18

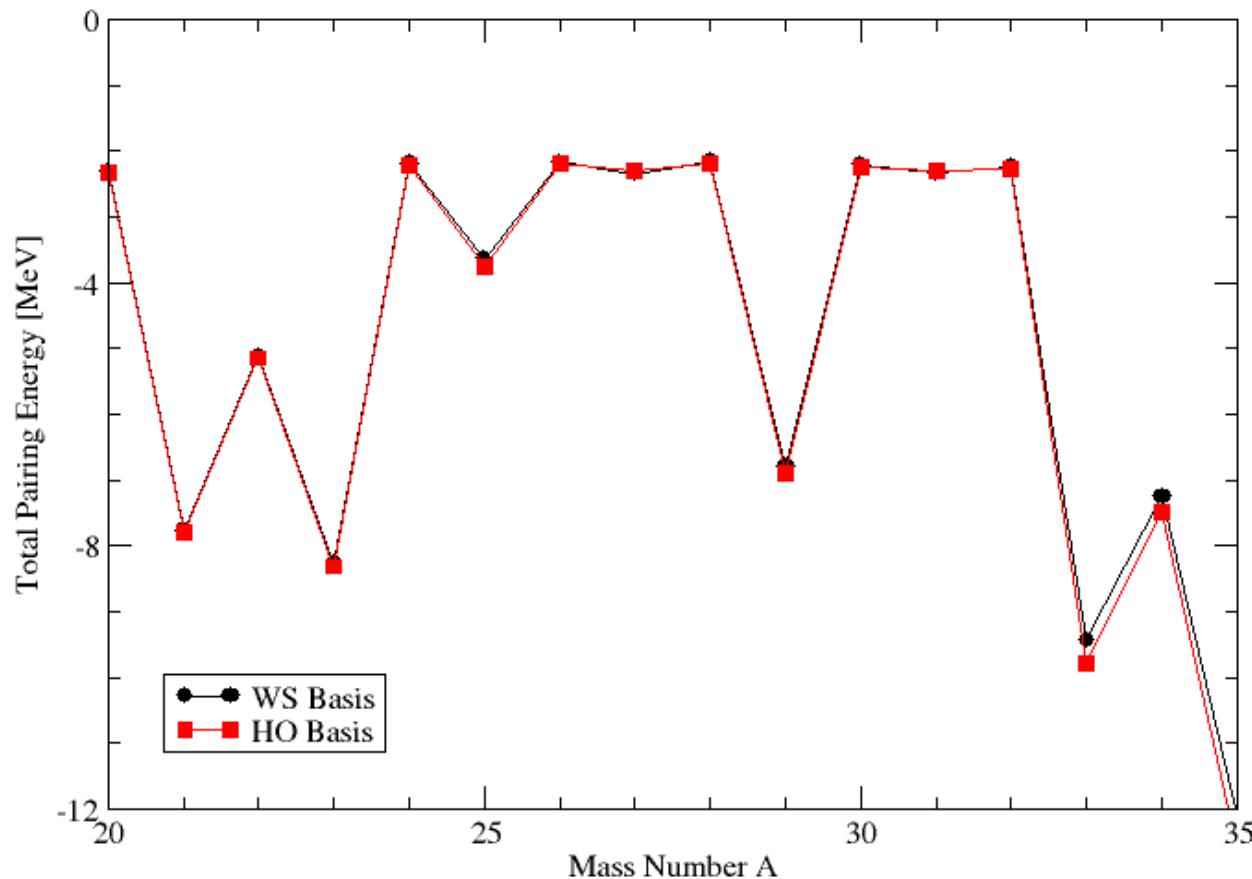


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Influence of the Basis

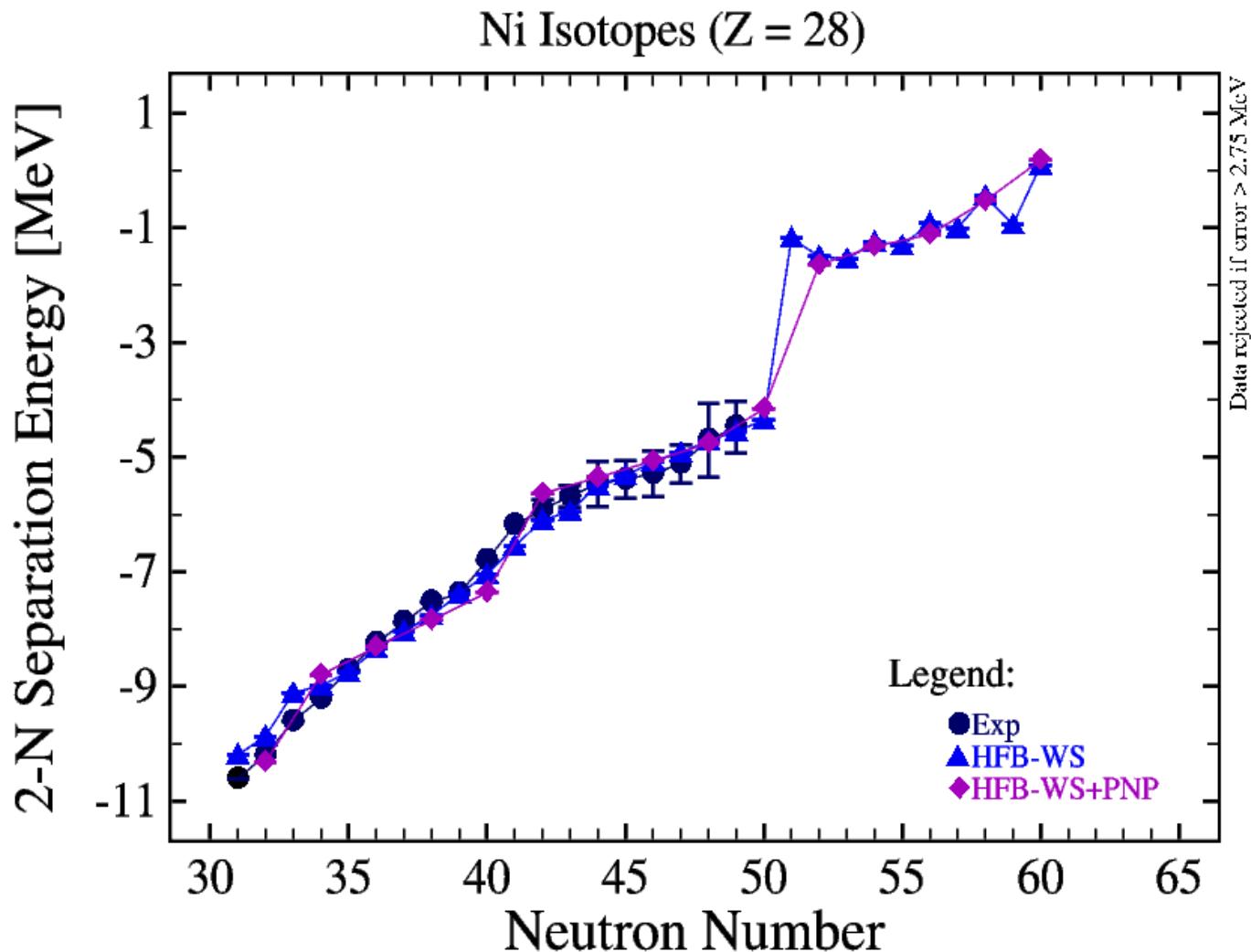
Pairing Energy in Na Isotopes - Gogny D1S

WS Basis ($R_{\text{box}} = 20 \text{ fm}$, $N = 20$) - HO ($N_{\text{sh}} = 20$)



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Particle Number Projection



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Conclusions

- Method to extend mean field calculations with **finite-range forces** to drip line nuclei
- First application with complete treatment of pairing correlations including PNP
- **Ground-state structure properties** (atomic masses, radii, pairing energy, etc.) are not **significantly** affected by the continuum, contrary to **densities**
- Necessity to improve the treatment of the continuum to be able to deal with excited states...