Hartree-Fock-Bogoliubov Calculations in the UCOM Framework*

H. Hergert and R. Roth

Institut für Kernphysik, TU Darmstadt, Schlossgartenstr. 9, 64289 Darmstadt, Germany

With the advent of new radioactive beam facilities like FAIR, the structure of exotic nuclei far beyond the valley of stability can be probed experimentally, providing a strong motivation for theoretical studies using ab initio approaches and interactions which provide a stringent link to QCD as the fundamental theory of the strong interaction.

To this end, we apply second-generation V_{UCOM} interactions [1] derived from the realistic AV18 interaction for the description of open-shell nuclei in a Hartree-Fock-Bogoliubov framework. To disentangle the effects of the particle-hole (ph) and particle-particle (pp) channels, we first use V_{UCOM} as a pairing force in conjunction with the Gogny D1S interaction providing the ph-mean-field. In Fig. 1, the resulting gaps Δ_μ of the canonical state with the lowest quasiparticle energy $\mathcal{E}_\mu = \sqrt{(\varepsilon_\mu - \lambda)^2 + \Delta_\mu^2}$, with the canonical single-particle energy ε_μ and Fermi energy λ, are compared to the odd-centered three-point formula $\Delta^{(3)}(N) = -\frac{1}{2}\left(E(N+1) - 2E(N) + E(N-1)\right)$, where $E(N)$ are experimental ground-state energies. The resulting gaps are stable over a wide range of UCOM interactions characterized by the parameter $\bar{\alpha}$. Only the long-ranged UCOM transformation with $\bar{\alpha} = 0.1\ \mathrm{fm}^4$ exhibits a significant reduction. While the relative $^1S_0$ matrix elements dominating the pairing remain almost unchanged from $\bar{\alpha} = 0.05\ \mathrm{fm}^4$ onward, they mix with higher partial waves due to a Talmi transformation from relative two-particle to decoupled single-particle states. These higher partial waves are predominantly repulsive, hence the reduction of the gap. We have also considered the effect of the commonly used one-body approximation to the intrinsic kinetic energy $\mathrm{T}_{\mathrm{int}} = \mathrm{T} - \mathrm{T}_{\mathrm{cm}}$ in Fig. 1, which produces significantly larger gaps, illustrating the sizable reduction caused by the repulsive two-body contribution of $\mathrm{T}_{\mathrm{int}}$ to the pairing field in an HFB scheme based on an intrisic Hamiltonian.

In line with our general goal, we now switch to a fully self-consistent approach, using V_{UCOM} in the ph and pp channels. In Fig. 2, we display the corresponding theoretical gaps for the tin isotopes. In these calculations, we check another approximation frequently used in HFB calculations, namely the restriction of the pairing interaction to the $^1S_0$ wave. This approximation produces gaps which are considerably larger than when the full interaction is used, irrespective of the parameter $\bar{\alpha}$.

We also observe important effects resulting from the tensor structure of V_{UCOM}. For the restricted pairing interaction, the canonical gaps are very similar to the average gap over paired states $\langle \Delta \rangle = \sum_\mu \Delta_\mu u_\mu v_\mu / \sum_\mu u_\mu v_\mu$, where u_μ, v_μ are the canonical occupation coefficients. When the full V_{UCOM} is used in the pp-channel, the canonical gaps are significantly reduced as the angular momentum of the nucleon increases. This effect is most visible for the $g_{7/2}$ and $h_{11/2}$ subshells which are filled over the tin chain, whereas the s- and $p-$subshells which are filled in the mid-shell tin isotopes are hardly affected.

* Supported by DFG through SFB 634 and the Helmholtz International Center for FAIR.

References

[1] R. Roth *et al.*, Phys. Rev. **C77**, 064003 (2008).

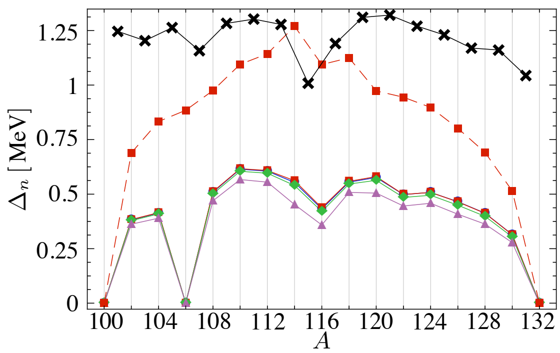

Figure 1: Canonical neutron gaps in the tin isotopes for Gogny D1S + V_{UCOM} with $\bar{\alpha} = 0.03$(●), 0.04(■), 0.06(♦), 0.1 fm^4(▲). Experimental $\Delta^{(3)}(N)$ are indicated by black crosses. Solid lines: full intrinsic kinetic energy, dashed line: one-body approximation.

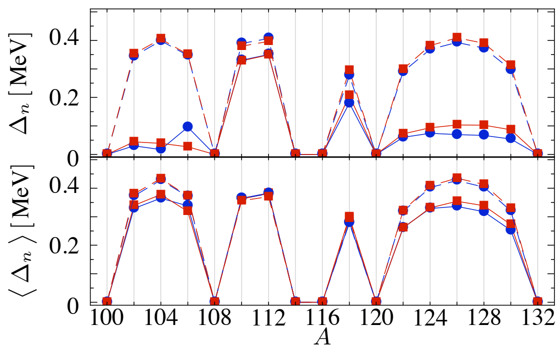

Figure 2: Canonical (top) and average (bottom) neutron gaps in the tin isotopes from fully self-consistent calculations using V_{UCOM} with $\bar{\alpha} = 0.04$(●), 0.1 fm^4(■). Solid lines: full interaction in the pp channel, dashed lines: restriction to relative $^1S_0$ wave.