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Disentangling collective and single-particle structures in neutron-rich Se isotopes

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The quadrant of the nuclear chart north-east of the doubly magic ^{78}Ni is expected to be rife with competition between single-particle and collective degrees of freedom. Of the nuclei in the $28Z < 50$ and $50N < 82$ valence spaces, the neutron-rich Se isotopes have been suggested by theory and experiment to exhibit shape co-existence of spherical, prolate and oblate shapes, and prone to gamma-softness [1, 2]. In addition, in-elastic scattering studies of ^{90,92}Se indicate a lowering of the 3^- state, in-line with global systematics [3]. This observation is coincident with the correspondence of these nuclei to the predicted "octupole magic numbers", $Z = 34$ and $N = 56$, leaving open the possibility of strong octupole correlations. From an astrophysical perspective, electron capture on nuclei with $Z < 40$ and $N > 40$ in type II supernovae collapse is expected to be strongly suppressed as the equivalent neutron orbitals of the proton valence space are fully occupied. Should, however, there be a significant mixing between the pf and sdg neutron shells, the Fermi-blocking effect could be diminished shell causing nuclear electron captures to dominate over free proton electron capture [4]. To shine light on these matters, we propose the study of the Se isotopic chain with $53\ N\ 58$.

In the odd-mass Se isotopes the locations of the states of which comprise of single-particle configuration, as part of a multiplet or purely single-nucleon, how they evolve, and their composition shall be studied through the single-nucleon knockouts of the respective even-mass isotopes. The locations of these orbits will guide shell model calculations and help disentangle the collective and single-particle contributions, as well as provide evidence for the pf-sdg mixing relevant for the electron captures in novae. A previous study [5] claims to have located 3 such states in ^{87}Se belonging to the $\mathrm{f}^3_{5/2}$ multiplet, the verification of these states can be carried out more robustly in the work proposed here. The importance of a $\mathrm{s}_{1/2}$ neutron state, predicted in ^{87}Se to be 0.97 MeV, is highlighted in Ref. [5], with knockout reactions, this and other single-particle states will be populated for study. To probe in a more experimentally quantifiable way the shapes of the even-even nuclei inferred from a previous study [1] , Coulomb excitation of the even-mass isotopes on a high-Z target is proposed to obtain reliable $B(E2)$ values. In addition to the population of the 2^+ states, the yrast 3^- states, are expected to be populated. The extraction of the $B(E3)$ values to these states will provide a direct measurement of the octupole correlations present in this supposedly doubly ocuptole-magic region.

To address the issues above, very specific experimental conditions are required. Due to the exotic nature of the nuclei proposed for study here, high-intensity RI beams are required. Additionally, since excitation states in the odd-even nuclei are expected to be of high level-density with some transitions having rather similar energy, excellent γ-ray resolution is required. This will also allow unambiguous measurement of parallel momentum distributions in coincidence with the de-excitation γ rays allowing for firm classification of the orbital configuration of the state populated. From these constraints, it is evident that the optimum configuration to perform these experiments will be with the proposed hybrid array of HPGe detectors at the RIBF.

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[5] T. Rząca-Urban *et al.* Phys. Rev. C **88**, 034302 (2013).

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