Systematic study of near-yrast band structures in odd-mass $^{125-137}$Pr and $^{127-139}$Pm isotopes

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In the present work, the basis space in the triaxial projected shell-model approach is expanded to include three and five quasiparticle configurations for odd-proton systems. This extension allows us to investigate the high-spin band structures observed in odd-proton systems up to and including the second band-crossing region and, as a first major application of this development, the high-spin properties are investigated for odd-mass $^{125-137}$Pr and $^{127-139}$Pm isotopes. It is shown that band crossings in the studied isotopes have mixed structures with the first crossing dominated by one-proton coupled to two-neutron configuration for the lighter isotopes which then changes to three-proton configuration with increasing neutron number. Furthermore, γ bands based on quasiparticle states are also delineated in the present work, and it is predicted that these band structures built on three-quasiparticle configurations become favored in energy for heavier systems in the high-spin region.

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I. INTRODUCTION

Nuclei in the mass ≈130 region are known to exhibit a rich variety of shapes and structures. In this region, interesting phenomena of shape coexistence [1,2], strongly deformed [3] to superdeformed [4,5] shapes, chiral doublet bands [6,7], and γ bands built on quasiparticle states [8–10] have been observed. This is the heaviest mass region with valence neutrons and protons occupying the same intruder orbital, $1h_{11/2}$. For the neutron-deficient isotopic chains in this mass region, protons occupy the low-Ω orbitals, whereas neutron occupancy changes from mid-Ω to high-Ω orbitals of $1h_{11/2}$. Due to the competing shape polarizing effects of low-Ω and high-Ω orbitals, the neutron-deficient nuclei in this region are expected to have, in general, triaxial shapes [11,12].

The interplay between proton and neutron configurations also plays an important role in the elucidation of the high-spin band structures observed in this mass region. Band structures have been observed up to quite high spin, and band-crossing features have attracted considerable attention [13–15]. In particular, the nature of the band crossings in odd-proton Pr and Pm isotopes has been extensively studied in recent years [16–20]. It has been shown that the standard cranked shell-model (CSM) approach with fixed pairing and deformation fields can describe the band-crossing features reasonably well for heavier Pr and Pm isotopes. However, for lighter isotopes of ^{127}Pr and ^{131}Pm, the gain in alignment is substantially underpredicted using this approach [21]. The band crossings in these nuclei have also been investigated using the extended version of total Routhian surface (TRS) approach [21], in which pairing and deformation fields are determined self-consistently. The observed band crossing features have been reproduced in this more realistic approach, and it has been demonstrated that the nature of the first band crossing is quite different from that predicted using the standard CSM approach. It has been shown that, for lighter isotopes, band crossings for these isotopes have a dominant contribution from the neutron configuration. This is in contradiction with the standard CSM results which predict proton BC crossing earlier than the neutron AB crossing for these nuclei.

Furthermore, band-crossing features in odd-proton isotopes have been investigated using the projected shell model (PSM) approach. In this model, basis states are constructed from the solutions of the Nilsson potential with axial symmetry [22]. In the study of odd-proton nuclei, the basis space in PSM is comprised of one-proton and one-proton coupled to two-neutron configurations. It has been shown using this approach that band crossing features of lighter isotopes of promethium could be described well. However, for heavier isotopes, discrepancies were observed between the PSM prediction and the experimental data. The major reason for this discrepancy is due to neglect of the proton aligning configurations in the basis space of PSM since it is evident from the CSM analysis [21] that the proton contribution becomes more dominant for heavier Pr and Pm isotopes. To elucidate the band crossing features for these isotopes, it is imperative to include both neutron- and proton-aligning configurations in the basis space. In the present work, we have generalized the basis space of the projected shell model for odd-proton systems by including proton aligning configurations in addition to the neutron states. The generalized basis configuration space has been implemented in the three-dimensional version

