Extended triaxial projected shell model approach for odd-neutron nuclei

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In an effort to elucidate the rich band structures observed in odd-neutron systems, the triaxial projected shell model approach is extended to include three-quasineutron and five-quasiparticle configurations. This extension makes it possible to investigate the high-spin states up to and including the second band crossing. Detailed investigation has been performed for odd-mass Xe isotopes with the extended basis, and it is shown that the character of the band crossing along the yrast line changes with shell filling of the $1h_{11/2}$ orbital. Further, it is observed that the three-quasiparticle state that crosses the ground-state configuration, leading to the normal band crossing phenomenon along the yrast line, first crosses the γ band based on the ground-state configuration at an earlier spin value. This crossing feature explains the occurrence of the signature inversion observed in the γ bands for some of the studied isotopes.

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I. INTRODUCTION

In recent years, some major advancements in spectroscopic techniques have made it feasible to populate the high-spin band structures in atomic nuclei to the extremes of angular-momentum, excitation energy, and isospin [1–18]. In some nuclei, the high-spin states have been studied up to angular momentum $I \approx 60\hbar$, and as many as 20 sidebands have been identified [9–12,14]. The observation of these rich band structures poses a tremendous challenge to theoretical models to elucidate the properties of these structures. During the last several decades, the standard approach to describe the high-spin properties of deformed nuclei has been the cranked shell model (CSM) based on a modified harmonic oscillator [19,20] or Woods-Saxon potential [21]. Although this approach has provided some new insights into the structure of the high-spin states, it is known to have limited applicability. For instance, it is suited only for rotating systems, and the study of vibrational modes is beyond the scope of the basic CSM approach. Further, the CSM wave functions do not have well defined value of the angular momentum, and the evaluation of the transition probabilities using this approach becomes questionable [22].

The spherical shell model (SSM) approach has made great strides in recent years to explore the medium and heavier mass regions, and it has become possible to investigate the properties of nuclei in the mass region, $A \approx 120$–130 [23–30]. However, in order to study the high-spin band structures, it is essential to include, at least, the configuration space of two oscillator shells, which seems to be impossible with the existing computational facilities. The modern mean-field approaches based on Skyrme, Gogny, and relativistic density functionals, on the other hand, reproduce the known binding energies of nuclei all across the Segrè chart with a remarkable accuracy [31–36]. The problem with these approaches is that they are mostly limited to investigate the ground-state properties, as beyond-mean-field extensions using the projection methods lead to singularities [37–40], and further one encounters the conceptual problem of how to treat the density-dependent terms in the functionals of these approaches. In recent years, alternative approaches have been developed to map the energy surfaces obtained from the density functional onto Bohr [41–43] and interacting boson model (IBM) [44,45] Hamiltonians, and fit the parameters of these phenomenological approaches. These model Hamiltonians are then solved using the standard techniques to obtain the energies and electromagnetic properties of the nuclear systems. However, these alternative approaches are restricted, at the moment, to investigating ground-state band structures only.

In recent years, the triaxial projected shell model (TPSM) approach has been demonstrated to provide a unified description of the high-spin band structures of rotational and transitional nuclei with remarkable accuracy [56–58]. The advantage of this model is that basis space is composed of angular-momentum projected multiquasiparticle states which allows one to investigate the band structures up to quite high spin. The basic tenet of the TPSM approach is quite similar to that of the SSM approach with the only exception that

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