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Triaxial projected shell model study of γ-bands in atomic nuclei

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Abstract A systematic study of γ-bands observed in atomic nuclei is performed using the triaxial projected shell model (TPSM) approach. The staggering phase between the even and odd spin members of the γ-band for most of the nuclei investigated in the present work is found to have even-I-below-odd-I, which in the framework of the collective model is considered as a signature of γ-softness. It is observed that out of twenty-three systems studied, only four nuclei, namely, ^{76}Ge, ^{112}Ru, ^{170}Er and ^{232}Th depict staggering phase with odd-I-below-even-I, which is regarded as an indication of the static γ-deformation in the collective model picture. The inclusion of the quasiparticle excitations in the framework of configuration mixing is shown to reverse the staggering phase from odd-I-down to the even-I-down for all the studied nuclei, except for the aforementioned four nuclei. Furthermore, by fitting a collective Bohr Hamiltonian to the TPSM energies, the differences between the two models are delineated through a comparison of the transition probabilities.

1 Introduction

Spontaneous breaking of rotational symmetry that leads to the deformation of a quantum system in the intrinsic frame, has played a pivotal role to unravel the underlying shapes and structures of atomic nuclei [1]. The properties of deformed nuclei are elucidated by considering the ellipsoidal shape, which is conveniently parameterized in terms of axial and non-axial deformation parameters of β and γ. The majority of the deformed nuclei are axially-symmetric ($\gamma = 0$) with angular-momentum projection along the symmetry axis, K, a conserved quantum number with the electromagnetic transition probabilities obeying the selection rules based on this quantum number [2,3]. There are also regions in the nuclear periodic table, referred to as transitional, where the axial symmetry is broken and the non-axial degree of freedom plays an essential role to determine the properties of these nuclei.

In the traditional picture, atomic nuclei may have either a localized minimum or a flat potential energy surface along the γ-degree of freedom, corresponding to γ-rigid and γ-soft nuclei, respectively [4–8]. How to distinguish between the two kinds of shapes from the observable properties has been of considerable interest in nuclear physics for more than sixty years. To address the question properly one needs to complement the potential by inertial parameters to estimate the spread of the wave around the minimum, which is accomplished in various ways. The phenomenological Bohr Hamiltonian [3,9] assumes irrotational-flow inertia and has the two limiting cases. The one limiting case, referred to as the Davydov-Filippov model [10] describes a rigid triaxial shape, which corresponds to a deep potential minimum with respect to both β and γ. The second case, called as Wilets-Jean model [11], describes the completely γ-soft limit and corresponds to a deep potential minimum with respect to β and no γ-dependence. Both limiting cases give rise to similar excitation spectrum for the ground-state band [10,11]. This holds as well for intermediate cases studied in Ref. [9], where the author found that the average energy of the $\gamma-$band is insensitive to the rigidity of the γ-degree of freedom. It is, therefore, impossible to distinguish between soft- and rigid-triaxiality from rich data of this kind that is available for most of the nuclei.

The energy staggering in the γ-band, on the other hand, is sensitive to the softness of the γ-degree of freedom [4]. For γ-soft nuclei (Wilets-Jean limit), the energies of the γ-band

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