Nature of γ-band staggering in $^{122-128}$Ba nuclei

G. H. Bhat[1],* J. A. Sheikh[1,2], and R. Palit[4]
[1]*Department of Physics, University of Kashmir, Srinagar,190 006, India and*
[4]*Department of Nuclear and Atomic Physics,*
Tata Institute of Fundamental Research, Colaba, Mumbai, 400 005,India

Quadrupole deformations of atomic nuclei can be of two types: β deformations which preserve axial symmetry and γ-deformations which lead to triaxial shapes. Although the collective model of nuclei introduced these ideas a half decade ago [1], it is still a matter of debate to what extent triaxiality is present in nuclei and, specifically, whether nuclear ground states exhibit stable triaxial deformation. On the other hand, γ-bands, associated with collective vibrations that break axial symmetry, are a well-established feature in the spectroscopy of deformed nuclei.

Bohr-Mottelson represents an anomalous rotation band in the rigid triaxial model (RTR) of Davydov and Filippov [2]. Wilets and Jean [3] used γ-independent potential for the collective structure, which yields a level pattern equivalent to the modified anharmonic oscillator, grouped the level of γ-band as 2_2, 3, 4_2, 5, 6_2, ... in contrast to the RTR pattern of 2_2, 3, 4_2,5, 6_2, 7, , ... This sequence of the energy levels of the γ-bands leads to opposite phase staggering. The opposite phase staggering in γ-bands demonstrates that Davydov and Filippov picture belongs to γ-rigid nature and Wilets and Jean belongs to γ-soft nature.

In the past few years, microscopic triaxial projected shell model (TPSM) approach has been used quite extensively to shed light on some of the outstanding issues related to the triaxility ie., γ-vibrations, Chiral symmetry and wobbling motion in atomic nuclei [5]. In the prsent abstract we have investigated the γ-band phase staggering in even-even Ba isotopes using the TPSM approach [4]. The above mentioned Ba-isotopes were chosen as they have well developed γ-bands observed experimentally and for some of them up to high-spins. The input parameters in the TPSM calculations are the two pair gaps and two deformation parameters. The pair gaps are calculated with the standard pairing factors, it has been checked that they reproduce the pair gaps calculated from the observed odd-even mass differences. The two deformation parameter of ϵ and ϵ' used in the study are ($\epsilon(\epsilon', \gamma^0)$ = 0.250(0.130,27), 0.250(0.120,25), 0.233(0.120,27), 0.200(0.120,30)) for even-even ^{122,124,126,128}Ba isotopes respectively. The corresponding conventional triaxiality parameter γ (in degrees) is also given. The quadrupole deformation ϵ in the table are those of Moller and Nix and ϵ' have been calculated from the minimum of the projected energy surface. TPSM calculations are performed mainly in two stages. In the first stage, the projected states are obtained from the triaxial deformed quasiparticle Nilsson states by using the three dimensional angular-momentum projection operator. The angular-momentum projection is carried out from various intrinsic states close to the Fermi surface. We have performed the angular-momentum projection for all the quasiparticle configurations, which are built by considering the single-particle states that are within 3 MeV from the Fermi surfaces. In the second stage, the shell model Hamiltonian with pairing plus quadrupole-quadrupole interaction is diagonalised with the projected states as the basis configurations. It has been demonstrated that staggering parameter, defined as $S(I) = \frac{[E(I)-E(I-1)]-[E(I-1)-E(I-2)]}{E(2_1^+)}$ can shed light on the nature of the γ-deformation in atomic nuclei. It is known that signature splitting

*Electronic address: gwhr.bhat@gmail.com

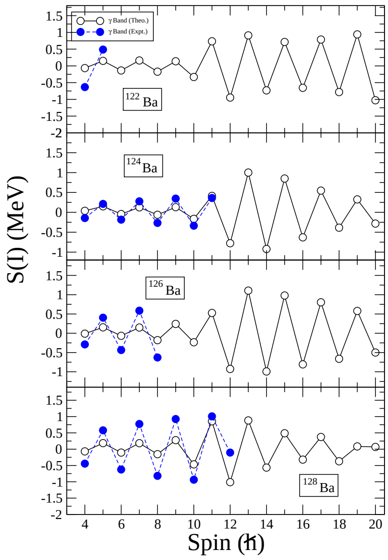

FIG. 1: (Color online) Comparison of experimental and the calculated band energies for ^{122,124,126,128}Ba.

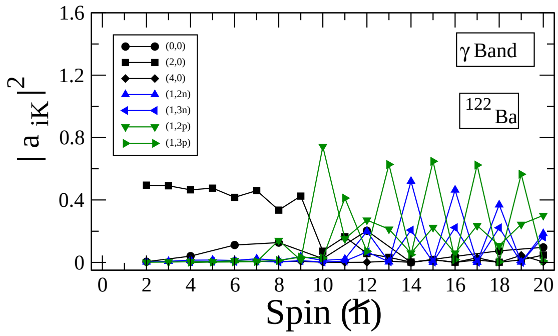

FIG. 2: (Color online) Wavefunction decomposition for ^{122}Ba. a_{iK} denotes the amplitude of the wavefuction in terms of the projected basis states.

or phase staggering in the γ-band is sensitive to the nature of γ deformation. In order to demonstrate that TPSM correctly describes the triaxility of ^{122,124,126,128}Ba isotopes, the staggering parameter, $\S(I)$, calculated from TPSM is compared with the experimental energies in Fig. 1 plotted as a function of angula-momentum. It is noted from the figure that S(I) is quite small at the begining, but then suddenly increases at about I=8-10$\hbar$. This increase in S(I) is related to the importance of the two-neutron aligned configuration above I=8-10$\hbar$. It is also clear from Fig. 1 that TPSM calculations reproduce observed staggering quite accurately and, therefore, correcty describes the γ-deformation of ^{122,124,126,128}Ba isotopes. In order to probe further the structure of the signature splitting of the γ-vibrational bands, the wavefunctions of the γ-band are shown in Fig. 2 for ^{122}Ba as an illustrative example. The γ-band for low spin states is predominantly a K=2 band up to I=9. Above the bandcrossing region, even- and odd-I states have very different intrinsic structures. Even-I states are dominated by the neutron-aligned configuration, $(1, 2n)$ and the odd-I states have maximum $(3, 2p)$ aligned proton contribution. It has been demonstrated that $\gamma-$bands with K=3 built on the two-quasiparticle configurations can modify the band-crossing features in these nuclei and plays central role in the phase staggering of the $\gamma-$bands.

In conclusion the calculations presented in the present abstract have clearly demonstrated that a simple model based on schematic pairing plus quadrupole-quadrupole interaction with three-dimensional angular-momentum projection technique can describe band structures in transitional nuclei in a quantitative manner. Further, the TPSM calculations reproduces the signature splitting of the γ-vibrational bands reasonably quit well.

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