

Triaxial projected shell model study of γ -vibrational bands in $^{122,124}\text{Ba}$ isotopes

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Introduction

Transitional nuclei between spherical and strongly deformed regions of the nuclear chart are usually soft with respect to deformation changes. In the mass region $A \sim 130$, the xenon, barium and cerium nuclei form a transitional path between closed shell structure and strong deformation. Shape changes, including triaxiality, can be induced by the excitation of nucleons into specific deformation-driving orbitals. The even-even nuclei of this region seems to be soft with regard to the γ -deformation at an almost maximum effective triaxiality with $\gamma \sim 30^\circ$ [1,2]. In this region of nuclear chart, the Ba nuclei are known to be axially asymmetric in their ground state [3]. This is due to the different deformation driving forces of the valence protons and neutrons occupying low and high Ω states of the $h_{11/2}$ intruder orbital. It has been shown that nuclei in this mass region ($A \sim 130$) are soft relative to γ -deformation so these nuclei represent good candidates for studying the deformation driving effects of different quasi-partricles. Shape transitions in neutron-deficient barium isotopes have been an attractive topic in nuclear physics [4]. Many methods, both experimental and theoretical, have been employed to study the nuclear structure properties of barium nuclei [5-8]. The evolution of shape and rotational structure along the yrast line in even-even $^{118-128}\text{Ba}$ isotopes has been systematically investigated by means of pairing self-consistent Woods-Saxon-Strutinsky calculations using the total Routhian surface approach by JieYang et al., [9]. H. Sakamoto qualitatively reproduced the energies of the ground-state band and staggering of the quasi- γ band [10]. Further, it has been observed from the review of literature that great effort has been made in the past as well as in the recent time to study the rotational band structure and triaxiality in Barium nuclei. The present work aims to elucidate the band structure and various nuclear structure properties of $^{122,124}\text{Ba}$ isotopes using Triaxial projected shell model

(TPSM) approach [11]. The present results obtained have been found to explain most of the experimental observations quite successfully in these nuclei.

The Theory of the Applied Model

To carry out the nuclear structure calculations for $^{122,124}\text{Ba}$ nuclei, Triaxial Projected Shell Model is employed. In TPSM, apart from 0-qp, the higher quasiparticles like 2- and 4-qp configurations are explicitly included in the basis space. Therefore, it is possible for the model to study high-spin band structures, which emphasizes the interplay between collective and single-particle excitations. To describe the nucleus to be axially and triaxially deformed triaxially-deformed, Nilsson states are employed in TPSM. An explicit three-dimensional angular-momentum projection is then performed for configurations built from the deformed Nilsson states. A triaxial qp configuration is an admixture of different K (projection along the symmetry axis) states, and the vacuum configuration is composed of $K=0,2,4,\dots$ states for an even-even system. It has been shown that the angular-momentum projection from the $K = 0, 2, \text{ and } 4$ states correspond to the ground, γ - and $\gamma\gamma$ -bands, respectively.

The TPSM calculations proceed in several stages. In the first stage, the deformed basis space is constructed by solving the triaxially deformed Nilsson potential. The triaxially deformed single-particle basis is obtained from the Nilsson model [12]. In the second step, the good angular-momentum states are obtained from the deformed basis by employing the three dimensional angular-momentum projection technique. In the third and the final stage, the projected bases are used to diagonalize the shell model Hamiltonian. The set of deformation parameters, axial (ϵ) and triaxial (ϵ') are set as 0.270, 0.165 and 0.255, 0.1375 for $^{122,124}\text{Ba}$ nuclei, respectively.

Results and Discussions

The angular-momentum projected energies from 0-qp, 2-qp, and 4-qp configurations, calculated with deformation parameters given above, are depicted in Fig. 1 for $^{122,124}\text{Ba}$ isotopes studied in the present work. These are called the band diagrams. To extract structural information from the TPSM calculations, it is useful to discuss the energies in terms of band diagram. The projected energies of only the lowest few 2- and 4-qp configurations are plotted for clarity.

It is observed from Fig. 1(a) that the projected bands from two-quasineutron and two quasiproton states having $K = 1$ cross the ground-state band at $I = 12^+$. Further at $I = 16^+$, the projected bands from two-quasineutron and two quasiproton state having $K = 3$ cross the g-band and the 4-qp band (two-quasineutron plus two-quasiproton) having $K = 2$ forms the yrast configuration at $I = 18^+$.

From Fig. 1(b) it is observed that the projected bands from two-quasineutron state having $K = 1$ cross the ground-state band at $I = 12^+$. Further at $I = 14^+$, the projected bands from two-quasineutron state having $K = 3$ and two quasiproton state having $K = 1$ cross the ground-state band and the 4-qp structures (two-quasineutron plus two-quasiproton) having $K = 2$ and $K=4$ form the yrast configuration at $I = 18^+$.

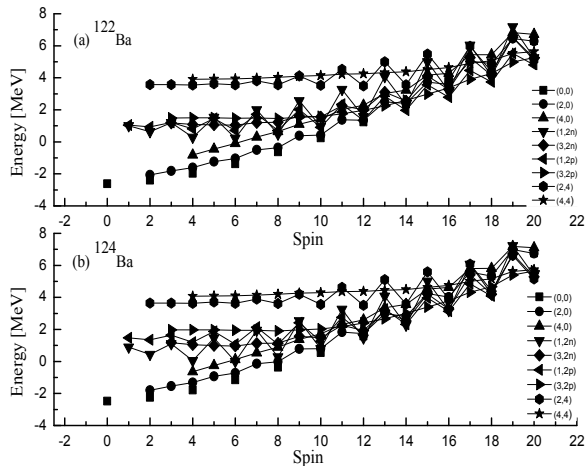


Fig. 1 Band diagrams of (a) ^{122}Ba , (b) ^{124}Ba

The band energies, obtained after diagonalization, are shown in Fig. 2 with the available experimental data. It is evident from the figure that TPSM results are in excellent agreement with the known experimental energies.

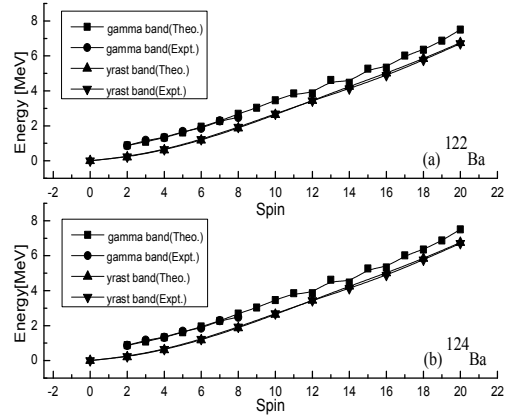


Fig. 2 Comparison of the Experimental and TPSM yrast spectra and γ bands for (a) ^{122}Ba , (b) ^{124}Ba

Summary

The $^{122,124}\text{Ba}$ nuclei have been studied within a theoretical microscopic technique- Triaxial Projected Shell Model. The band structures for these nuclei have been interpreted in terms of multi quasi-particle configurations and the γ band built on the ground-state band is well reproduced by the TPSM. The obtained results are discussed closely in contrast to the available experimental data and an excellent agreement has been obtained between the two.

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