Microscopic study of wobbling motion in ^{129}Ba

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Introduction

The majority of the nuclei on the nuclear chart are deformed, with most of these systems exhibiting axial symmetry. There are also a few regions in nuclear chart for which axial symmetry is predicted to be broken. These systems, referred to as triaxial nuclei, possess unequal moments of inertia along the three principle axes (short axis s, medium axis m and long axis l). The emergence of wobbling motion, an excitation mode unique to a triaxial body, is considered as a fingerprint of non-axial nuclear shape. For the yrast state, the nucleus favors the rotation about the axis with the largest moment of inertia (m-axis), and to generate the excited state, some angular momentum is transferred to the other axes (m-axis to s- and l-axis). This results in a sequence of rotational bands built on the same intrinsic structure and characterized by the wobbling quantum number (n_ω).

In this work, we have performed the microscopic investigation of wobbling motion in ^{129}Ba in the framework of microscopic triaxial projected shell model (TPSM) approach [1, 2].

Theoretical Framework

TPSM is a microscopic shell model approach based on the deformed basis, and the calculations are performed in three stages. In the first stage, deformed quasiparticle basis are constructed from the solutions of the triaxially deformed Nilsson potential and BCS. In the next stage, good angular-momentum basis are projected out from the Nilsson + BCS states using the explicit three-dimensional angular-momentum projection operator. In the third and final stage, projected states from the quasiparticle configurations close to the Fermi surface are used to diagonalize the shell model Hamiltonian (quadrupole + pairing) given as:

$$\hat{H} = \hat{H}_0 - \frac{1}{2}\chi \sum_{\mu} \hat{Q}^{\dagger}_{\mu}\hat{Q}_{\mu} - G_M \hat{P}^{\dagger}\hat{P} - G_Q \sum_{\mu} \hat{P}^{\dagger}_{\mu}\hat{P}_{\mu}.$$

The wavefunctions obtained in the diagonalization of the above mentioned Hamiltonian are then used to calculate the electromagnetic transition probabilities, the details of which can be found in [2, 3].

Results and Discussion

In the present work, the band structure in ^{129}Ba are investigated microscopically with the TPSM approach. The numerical calculations using microscopic TPSM have been performed with axial (β)and triaxial (γ) deformation parameters equal to 0.220 and 0.150 respectively. Three major oscillator shells (N = 3,4,5) both for protons and neutrons are employed for the present calculations. The calculated TPSM energies obtained after diagonalization of the shell model Hamiltonian are compared with the available experimental data in Fig. 1. It is evident from Fig. 1 that TPSM reproduces the experimental energies quite accurately in comparison to semiclassical quasiparticle triaxial rotor (QTR) model calculations [4]. This is because of the fact that the moments of inertia in TSPM are calculated in a microscopic way and the antisymmetrization between the odd valence quasineutron and the quasiparticles forming the rotor is fully taken into account.

All the studied negative parity bands in ^{129}Ba have one $h_{11/2}$ quasi-neutron structure. The main focus of the present work is Band 3 in Fig. 1. To ascertain the wobbling nature of this band, we have calculated the wobbling frequency defined as:

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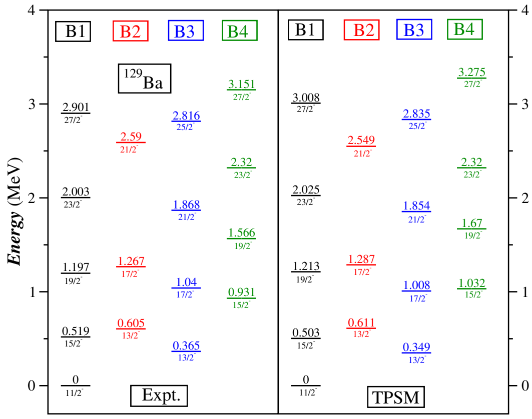

FIG. 1: TPSM energies for the lowest four bands after configuration mixing are plotted along with the available experimental data for the ^{129}Ba isotope. Data is taken from [4].

$$E_{wob}(I) = E_{n_\omega=1}(I) - \frac{[E_{n_\omega=0}(I+1) + E_{n_\omega=0}(I-1)]}{2}, \tag{1}$$

For the longitudinal wobbling motion, the rotational axis is along the long-axis. The wobbling frequency is plotted in Fig. 2 as a function of spin. It is noted from the Fig. 2 that the present calculation reproduces the increasing trend of the wobbling energy and is in fair agreement with the experimental values. Thus Band 3 in Fig. 1 can be identified as a first phonon wobbling band ($n_\omega = 1$) in ^{129}Ba as conjectured experimentally. The $n_\omega = 1$ wobbling bands are obtained when the angular-momentum from m-axis is transferred to l- and s-axis. Since the wobbling frequency in Fig. 2 increases with spin, and it supports the longitudinal nature of this band.

Summary

In the present work, we have performed a microscopic investigation of the wobbling band structures observed in ^{129}Ba isotope using the TPSM approach. This model is now a tool of choice to study the high-spin band structures in deformed and transitional nuclei.The TPSM approach employs the triaxial basis configurations and is well suited to investigate the properties of triaxial nuclei. The wobbling motion is an excitation mode which is unique for triaxial shapes and was originally predicted by Bohr and Mottelson [5] for even-even systems. Thus Band 3 in Fig. 2 is identified as a wobbling band built on $n_\omega = 1$ phonon excitation in ^{129}Ba as conjectured experimentally. The increase in the wobbling frequency with spin shows that this band has a longitudinal nature.

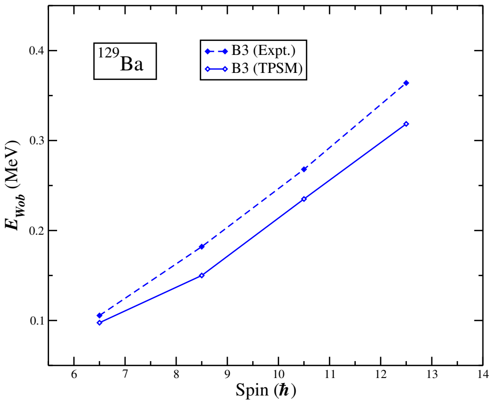

FIG. 2: TPSM wobbling energies are compared with the experimental values obtained from the Band 3 for ^{129}Ba.

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