Effect of γ-deformation on signature splitting of the negative parity band in ^{131}Xe

(A Triaxial Particle Rotor Model study)

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Introduction

Investigation on the rotational properties of triaxial nuclei is a topic of current interest. Several rotational properties in these nuclei deviate from their usual behaviour due to the breaking of axial symmetry. For instance, the *signature* (α) quantum number no longer remains conserved in non-axially deformed nuclei and hence, strong mixing of different single particle orbitals is expected to be occurred. A a consequence, the energy staggering between favoured and unfavoured signature partners, known as signature splitting [$S(I)$], behaved differently.

Xenon isotopes are well-known for their triaxial shapes [1]. The anomalous $S(I)$ of the negative parity bands in $^{119-125}$Xe remains a long-standing puzzle [2] until the 'so-called' unfavoured signature partner of yrast negative parity band in ^{127}Xe reinterpreted in terms of wobbling excitation [3]. In the case of ^{131}Xe$_{77}$, in spite of having association with high-Ω $h_{11/2}$ configuration [4], the $S(I)$ in negative parity band is found large [5], as also reported in the case of ^{133}Ba$_{77}$ [6]. Such an enhanced $S(I)$ was interpreted as a consequence of triaxial deformation. Therefore, in this work the effect of triaxial deformation (γ) on the $S(I)$ of the negative parity band in ^{131}Xe has been studied under the framework of triaxial particle rotor model.

Formalism

The particle-rotor Hamiltonian of an odd-A nucleus can be expressed as:

$$H = H_{core} + H_{sp} + H_{pair}$$

where, H_{core} represents the collective rotation of the even-even core, H_{sp} stands for the single-particle Hamiltonian and the pairing interaction introduced by H_{pair}. Hamiltonian for the core rotation can be written as:

$$H_{core} = \sum_{k=1}^{3} A_k (I_k - j_k)^2$$

The A_k stand for the inertial parameters. The H_{sp} is characterized by the deformation parameters: ϵ_2, ϵ_4 and γ. The pairing term is estimated via standard BCS procedure. Details of this model is available in Refs. [7, 8].

Results

The triaxial particle rotor model is used widely to studying the low-lying rotational properties of an odd-A nucleus theoretically. The particle-rotor calculation, which was reported earlier [1], nicely reproduces the favoured partner of the yrast negative parity band in ^{131}Xe, but, the excitation energy of the newly identified unfavoured partner is underestimated. Thus, it also fails to reporduce the signature splitting, deduced from the experimental level energies. The signature splitting of the negative parity band in ^{125}Xe is found sensitive to the triaxial deformation parameter γ [9]. Hence, to study the effect of the γ parameter on $S(I)$, further calculations were carried out with a fixed $\epsilon_2 = 0.13$ and variable $\gamma = 0° - 60°$. A comparative plot of experimental and calculated signature splitting is shown in FIG. 1. At $\gamma = 0°$, the magnitude of the calculated $S(I)$ is found low as expected for a high-Ω configuration in an axially symmetric nucleus. With increasing γ, the magnitude of $S(I)$ is also found

TABLE I: List of parameters used in calculation.

ϵ_2	γ	E_{2^+}	ξ	A00	# orbital
0.13	33°	0.5	1.0	0.06	14-28

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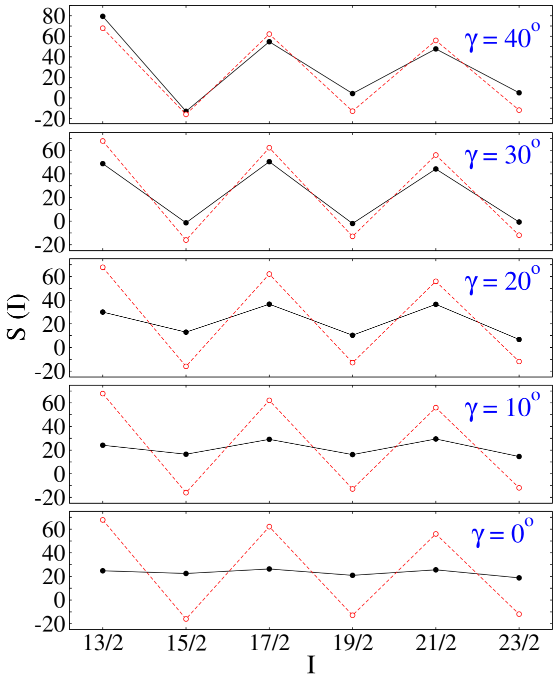

FIG. 1: Estimated signature splitting (black line) in $\nu h_{11/2}$ band for different triaxial deformation parameter γ and a fixed axial deformation $\epsilon_2 = 0.13$. Red line represents the experimental value of $S(I)$.

increasing. Another aspect of this study is to understand the effect of triaxiality on the excitation energy of the $I^\pi = 9/2^-$ state. Unlike lighter mass Xe isotopes, the $I^\pi = 9/2^-$ state is found above $I^\pi = 11/2^-$ state in ^{131}Xe. From the present calculation it is found that the $E_{9/2^-} > E_{11/2^-}$ only at $\gamma \approx 30° - 35°$

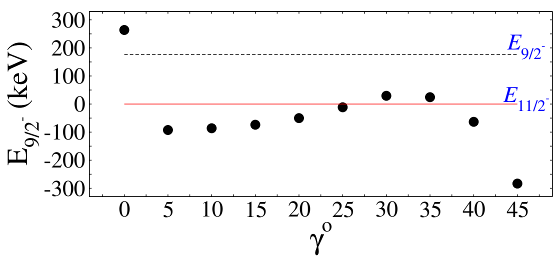

FIG. 2: Calculated energy of the $I^\pi = 9/2^-$ level, for different triaxial deformation parameter γ, in ^{131}Xe. Energies are normalized *w.r.t.* $E_{11/2} = 0$ (red solid line). Experimentally observed relative excitation energy ($E_{9/2} = 177$ keV) of the $I^\pi = 9/2^-$ level is marked by black dotted line.

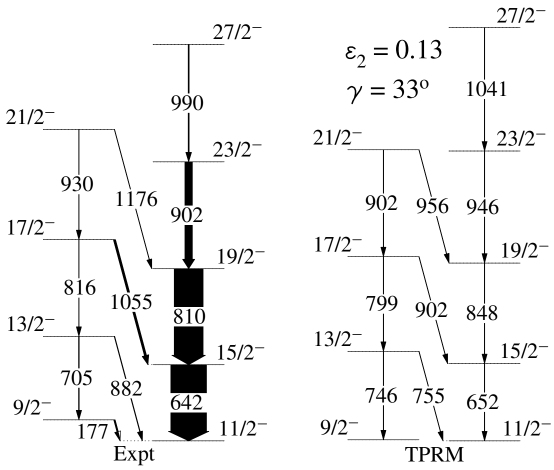

FIG. 3: Experimentally observed and theoretically calculated energy levels of $\nu h_{11/2}$ band in ^{131}Xe.

(FIG. 2). Therefore, to reach a good agreement with the experiment data, the axial and triaxial quadrupole deformations ($\epsilon_2, \gamma = 0.13, 33°$) were taken finally, which could reproduce both favoured and unfavoured signature partners of the $\nu h_{11/2}$ band, as shown in FIG. 3.

Summary

A detailed calculation is carried out under the framework of triaxial particle rotor model to understand the structure of the negative parity bands in ^{131}Xe. From the present investigation it can be concluded that the ^{131}Xe nucleus has a triaxially deformed shape and the observed large signature splitting in negative parity band arises due to this γ deformation primarily.

Acknowledgements

We would like to thank Dr. G. Mukherjee, VECC, Kolkata for his valuable suggestions.

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