Rotational band structure of ^{136}Ba nucleus

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Introduction

One of the main aims of the nuclear structure physics is to understand the particle-hole correlations occurring inside the exotic nuclei lying in the transitional region. Thus the transitional region has become a laboratory to test the nuclear structure models. The interplay of strongly shape driving orbitals $\pi g_{9/2}$ and $\nu h_{11/2}$ can influence the overall shape of nucleus and result in variety of shapes with the modest deformation in mass region A~100. In a similar manner, for A~130 mass region, the proton-neutron particle hole excitations include $g_{7/2}$, $d_{5/2}$ and the $g_{9/2}$ extruder orbitals as valence space for protons while for neutrons, valence active nucleon's orbitals are $g_{7/2}$, $d_{5/2}$, $d_{3/2}$ and $s_{1/2}$. In this mass region, the nuclei such as xenon, barium and cerium form a transitional pathway between closed nuclei and strongly deformed nuclei. The low lying states of these even-even nuclei have been studied by various research groups [1-5] and show a rich collective structure. Since, rotation is considered as one of the collective motion in quantum mechanical systems, so the qualitative analysis on the rotational structure of ^{136}Ba nucleus has provided a significant understanding of the feature of collectivity in these nuclei. A comparative study of some high spin characteristics of nuclear structure properties of doubly-even ^{136}Ba nucleus has been made in the present work using two microscopic frameworks - CHFB and PSM.

Formalisms

a) CHFB

Originally, the Cranking Hartree Fock Bogoulibov (CHFB) Model has been introduced phenomenologically by Inglis [6]. In CHFB model, the Hamiltonian is cranked about an axis perpendicular to the symmetry axis of the nucleus.

The Hamiltonian used in the present CHFB approach is

$$H = H_0 - \lambda N - \omega J_x$$

where λ is lagrangian multiplier. ω is the rotational frequency. CHFB is usually carried out by employing large valence space and quadrupole-quadripole plus pairing type of interactions. The valence space spanned by $3s_{1/2}$, $2d_{3/2}$, $2d_{5/2}$, $2f_{7/2}$, $1g_{7/2}$, $1h_{9/2}$ and $1h_{11/2}$ orbits for protons and neutrons has been selected. The strength for the like particles (n-n) as well as neutron-proton (n-p) components of the quadrupole-quadrupole (q-q) interaction and pairing gap parameters for ^{136}Ba isotope were taken as:

$\chi_{nn} = \chi_{pp} = -0.0119$, $\chi_{np} = -0.0229$ and $G_p = -0.27$

b) PSM

Quasi-particles defined in the deformed Nilsson + BCS calculations are the starting point of the Projected Shell Model [7]. The total Hamiltonian used in the present work is of the form

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

where H_0 is the spherical single-particle Hamiltonian. The second, third and fourth terms represent quadrupole-quadrupole, monopole pairing and quadrupole pairing interactions, respectively. χ is the quadrupole-quadrupole coupling constant. In the present study **N** = 3,4,5 major shells are chosen for both neutrons and protons. The strengths of the monopole pairing forces are chosen as $G_1 = 22.20$ and $G_2 = 12.12$. The quadrupole pairing strength G_Q is fixed as $0.16\ G_M$.

Results and their analysis

The present study is devoted to nuclear structure study of ^{136}Ba nucleus. In this work, comparative study of yrast states of even-even ^{136}Ba nucleus has been performed to investigate the important characteristics such as intrinsic quadrupole moments, root mean square radii of protons and neutrons, reduced transition probabilities and back-bending in moment of inertia. A brief account on some of the results analyzed by the present study is discussed here-under whereas the detailed presentation of the results would be made in the conference.

a) Yrast states: The yrast line for ^{136}Ba nucleus is shown in Fig. 1. The calculated CHFB and PSM data is compared with the available experimental data [8] as well as the other theoretical data taken from Ref. [9]. From Fig. 1, it has been seen that the low lying states are very well reproduced by the CHFB technique but the CHFB results show deviation for higher spin states. However, high spin yrast states are accurately obtained by the PSM framework. Thus PSM gives a good description of high spin structure of ^{136}Ba nucleus.

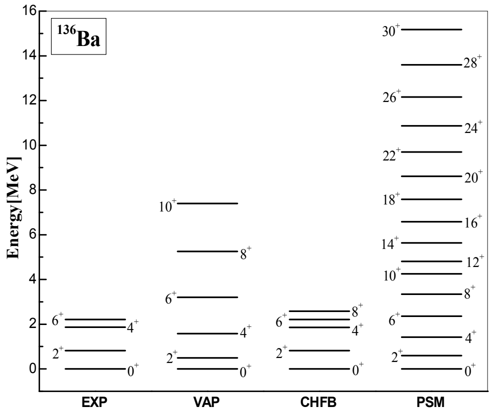

Fig. 1 Comparison of calculated yrast energy levels with the available experimental as well as other theoretical data.

***b) Intrinsic quadrupole moment*:** It is well known from the literature that E_2^+ values give us an idea about the degree of deformation in a nucleus: Smaller the value of E_2^+ for the nucleus, more deformed the nucleus is. Also, the ratio E_4^+/E_2^+ is found to be greater than 2 which means that ^{136}Ba nucleus is well deformed. The intrinsic quadrupole moment of ^{136}Ba nucleus is also calculated.

c) Back-bending in moment of inertia: Fig 2. gives the plot of kinetic moment of inertia and square of the rotational frequency for ^{136}Ba nucleus. Back-bending in moment of inertia is correctly reproduced at the spin value of 4^+ by the present calculations.

Table. 1 Deformation systematic of ^{136}Ba nucleus

Quanities	Exp.	Th.
E_2^+	0.818	0.820
E_4^+	1.866	1.860
E_4^+/E_2^+	2.270	2.26
$\langle Q_0^2 \rangle_\pi$	--	27.11
$\langle Q_0^2 \rangle_\nu$	--	29.43
$\langle Q_0^2 \rangle_{CHFB}$	--	56.55

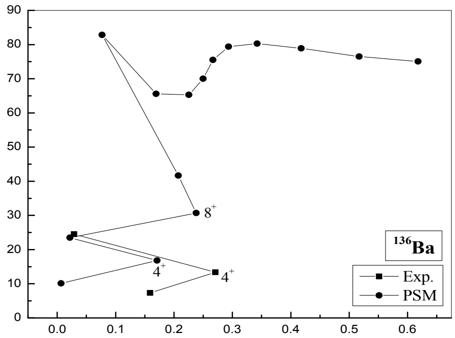

Fig. 2 Back-bending in moment of inertia in ^{136}Ba.

Summary

To summarize, one can say that, CHFB provides a good description of low spin states of ^{136}Ba nucleus, whereas the higher spin states are well reproduced by the PSM. Also, ^{136}Ba nucleus is found to be deformed as E_4/E_2 ratio > 2.

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