Yrast Spectra of ^{140}Ba in Deformed Hartree-Fock and J Projection Model

Shailesh. K. Singh[1], B. B. Sahu[2],* C. R. Praharaj[1], S. K. Patra[1], Z. Naik[3], and R. K. Bhowmik[4]
[1]Institute of Physics, Sachivalaya Marg, Bhubaneswar-751 005, INDIA
[2]Kalinga Institute of Industrial Technology (KIIT) University, Bhubaneswar-751 024, INDIA
[3]School of Physics, Sambalpur University, Jyotivihar, Sambalpur-768 019, INDIA and
[4]45c Maharaja Tagore Road, Kolkata-700 031, INDIA

Introduction

^{140}Ba is known experimentally to have a negative parity excited band (besides the $K = 0^+$ ground band) at fairly low excitation energy. The ground band shows certain anomaly around $J = 10^+$.

In this work we have studied the structure of ^{140}Ba using deformed Hartree-Fock and Angular Momentum Projection [1, 2]. The $sdg_{7/2}h11/2h9/2$ space for protons and $pfh_{9/2}i_{13/2}$ space for neutrons are used in this study. We use surface delta matrix elements as the residual 2-body interaction elements in this space, which works well for a broad range of nuclei [2, 4]. The prolate Hartree-Fock solution is the lowest in the energy and the orbits for this solution are plotted in Fig. 1. We calculate the spectra of nuclei for various intrinsic states using angular momentum projection techniques. We have the $K = 0^+$ ground state band, $K = 0^+$ excited band (with two-proton excitation to $h_{11/2}$ orbits). We have the $K = 3^-$ band obtained by proton excitation from $5/2^+$ to $1/2^-$ orbits.

Theoretical Framework

The theory for Hartree-Fock and J projection can be seen in Ref. [1–3]. A deformed shape such as one described by Slater determinant of deformed orbits $| \Phi_K >$ is localized in angle and, by the uncertainty principle, is not a state of good angular momentum (J). Thus $| \Phi_K >$ does not have a unique J quantum number and is a superposition of various J states [1–3],

$$| \Phi_K >= \sum_I C_{IK} | \Psi_{IK} > . \quad (1)$$

One needs to project out states of good angular momenta from the intrinsic state Φ_K with the Angular Momentum Projection operator,

$$P^{IM}_K = \frac{2I + 1}{8\pi^2} \int d\Omega {D^I_{MK}}^*(\Omega) R(\Omega). \quad (2)$$

In general two states $| \Psi^{JM}_{K_1} >$ and $| \Psi^{JM}_{K_2} >$ projected from two intrinsic configurations are not orthogonal to each other even if $| \Phi_{K_1} >$ and $| \Phi_{K_2} >$ are orthogonal. Thus, whenever necessary, we do band-mixing using the following equation:

$$\sum_{K'} (H^J_{KK'} - E_J N^J_{KK'}) C^J_{K'} = 0. \quad (3)$$

Results and Discussion

The intrinsic quadrupole deformation parameter β of the prolate Hartree-Fock solution is about 0.2. Since the deformation is modest the ground band does not extend to the large J values and is limited to $J_{max} \sim 14\hbar$. We construct an excited $K = 0^+$ intrinsic state by exciting two protons from $\pm5/2^+$ orbit to the strongly prolate $\pm1/2^-$ orbits of $h_{11/2}$ origin. This intrinsic state quadrupole moment parameter $\sim$ 0.28. Angular momentum projection from this $2h2p$ configuration gives the band which extends to $J_{max} \sim 22\hbar$; and, significantly, crosses the ground band at $J = 10\hbar$, becoming yrast beyond this spin value. Thus the upper part of the yrast

*Electronic address: bbsnou@gmail.com

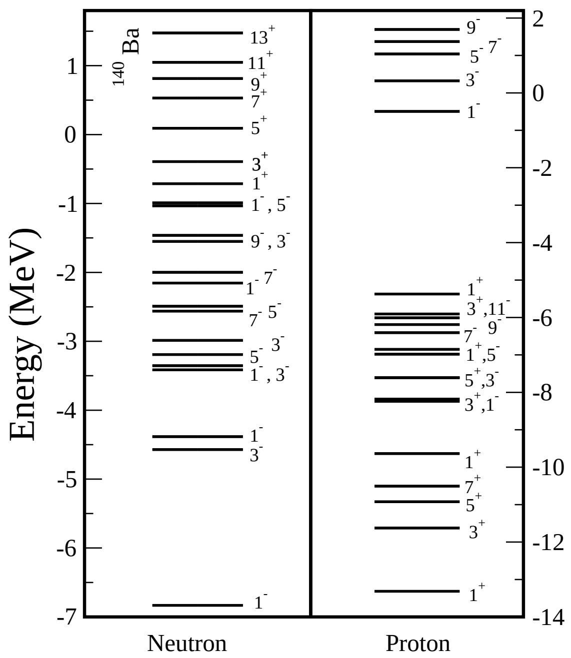

FIG. 1: Prolate deformed HF orbits of ^{140}Ba.

$K = 0^+$ band has considerably more quadrupole deformation.

The $K = 3^-$ intrinsic state is obtained by promoting a proton from the $-5/2^+$ orbit (at the top of the proton Fermi level) to the $1/2^-$ orbit of $h_{11/2}$. This band also has enhanced quadrupole collectivity compared to the low spin members of the ground band. The energy spectra and BE(2) values are shown in Fig. 2,3.

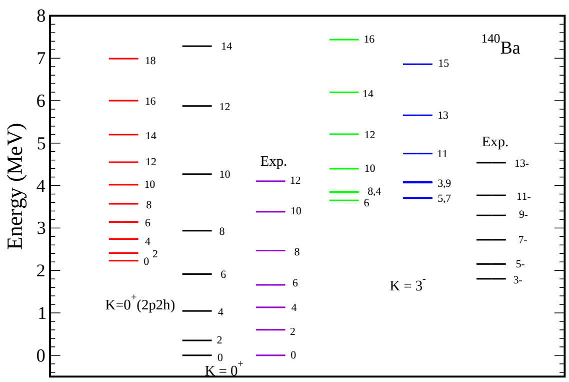

FIG. 2: Energy spectra with deformed HF model of ^{140}Ba. The experimental data are taken from [5].

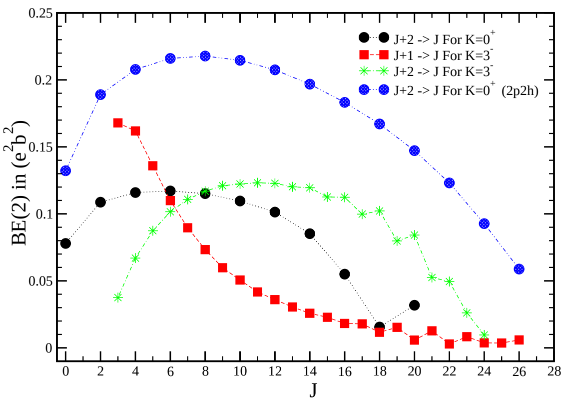

FIG. 3: BE(2) values of various bands of ^{140}Ba.

Conclusions

In conclusion, we studied the band structure of ^{140}Ba nucleus by deformed Hartree-Fock and J projection model. ^{140}Ba is known experimentally to have a negative parity excited band (besides the K=0^+ ground band) at fairly low excitation energy. The ground band anomaly around J=10^+ is explained by the band-crossing caused by the $2p2h$ deformed band. We have also shown the behavior of BE(2) for ground state and excited bands of this nucleus.

Acknowledgments

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