Investigation of triaxiality in the Ba nuclei near N=82 shell closure

Suresh Kumar*
Department of Physics and Astrophysics,
University of Delhi, Delhi-110007, India

Spectroscopy study of Ba nuclei in mass A=135 region performed with INGA array to look insight into phenomena like triaxiality and magnetic rotation. In present contribution, I will review the results obtained with INGA array to investigation of triaxiality in the ^{133,134,135}Ba nuclei.

The nuclei around the $A = 135$ mass region are transitional in nature with a moderate deformation and softness with respect to triaxialty. Several interesting phenomena, such as shape coexistence of prolate and oblate deformations [1, 2], high spin structures based on isomers and excited states with multi-quasi-particle configurations have been observed [2–4] in the nuclei from Xe to Nd. Further, nuclear triaxiality is also expressed as wobbling motion and have been discussed by Bohr and Mottelson [5]. Recently, the wobbling motion has also been reported in the ^{135}Pr [6] and ^{133}La [7] nuclei, which further supports triaxiality in this mass region. In addition to it, the observation of $I^{\pi} = 10^{+}, 7^{-}$, 5^{-}, $19/2^{+}$ and $25/2^{-}$ isomeric states is a typical feature in most of the nuclei. The ^{133,134,135}Ba nuclei lie near the neutron shell closure at N = 82 and in the proton mid-shell between Z = 50 and 64 shell closures. In these nuclei, an interplay of quadrupole collectivity and single-particle degrees of freedom could exist even in the relatively low-lying states and have possibility to demonstrate the excitation modes of a triaxial nucleus.

The high spin states of ^{135}Ba were populated by about 54 percent of the total cross-section in the ^{130}Te(^{9}Be,4n)^{135}Ba reaction at a beam energy of 42.5 MeV and detail of experimental set-up and data analysis is given in Ref [1]. The excited states of the $^{133,134}Ba$ nucleus were populated using the $^{124}Sn(^{13}C$, xn)$^{133,134}Ba$ reaction at a beam energy of 48 MeV (INGA TIFR). Details on Data analysis and the measurement of both polarization asymmetry and DCO ratio can be found in Ref. [8, 9].

From the systematics of the energy levels belonging to the this band [1], it appears that it is more regular in ^{135}Ba than in other N = 79 higher even-Z nuclei. A 3qp configuration $\pi(h_{11/2}g_{7/2}) \otimes \nu(h_{11/2})^{-1}$ was used in the TAC calculations for the positive parity dipole band. The pairing parameter Δ_p and Δ_n calculated as 80% of the odd-even mass difference are 0.896 MeV and 0.926 MeV, respectively. A minimum was found at the deformation parameters $\epsilon_2 = 0.095, \epsilon_4 = -0.013, \gamma = 26^o$ with an average tilt angle $\approx 56.4^o$ which corresponds to a triaxial shape. The calculations based on this configuration seem to explain the observed behaviour of $E\ vs.\ I(\hbar)$ as shown in Fig. 1. The calculated results match reasonably well with the measured values. The calculated B(M1) values also decrease with increase in $\hbar\omega$ i.e. from 2.9 to 1.2 μ_N^2 while B(E2) value increase with with increase in $\hbar\omega$ i.e. form 0.010 to 0.025 $(eb)^2$. Thus, based on the systematics and the TAC calculations, we suggest that the positive parity dipole band built on the 3082.8 keV state has the $\pi(h_{11/2}g_{7/2}) \otimes \nu h^{-1}_{11/2}$ 3qp configuration. This comparison with calculated results suggests that this band may have magnetic rotation nature.

The partial level scheme above the 2957.1 keV isomer with spin $I^{\pi} = 10^{+}$ is extended up to 7712.9 keV level with maximum spin I^{π} = (20^{-}) [9]. A negative parity band labeled as band D1 is established above the 5677.9 keV level. The 171.3-, 176.6-, 278.9-, 388.7-,

*Electronic address: `sursvmk123@gmail.com`

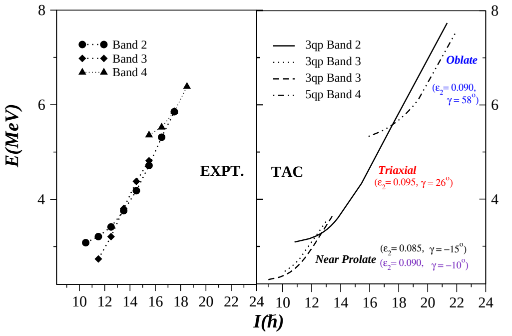

FIG. 1: Plot showing the E *vs.* $I(\hbar)$ behaviour for the measured (right panel) and the calculated (left panel) values of bands 2, 3 and 4.

448.0- and 571.4 keV γ-ray transitions constituting this band. The TAC calculations were performed using the 4-qp $\pi[h_{11/2}(g_{7/2}/d_{5/2})] \otimes \nu[h_{11/2}]^2$ configuration and results a minimum at $\epsilon_2 = 0.090$ and $\gamma = 60$ with an average tilted angle $\theta = 40$. The calculated B(M1) and B(M1)/B(E2) ratios along with the systematic studies in the neighboring nuclei shows the magnetic rotational character of the dipole band D1.

A partial level scheme of the ^{133}Ba nucleus [8], comprises - Band A, Band B, Band C, Band D and the inter connecting transitions and is shown in Fig. 2. The structure of the Band D is very similar to the band structure which is reported in the ^{135}Ba nucleus. For a wobbler band named as Band B, the $\Delta I = 1$ should, linking transitions should have strong E2 nature. The RDCO and polarization asymmetry values of the interlinking transitions between Band A and Band B are compared with the values of linking transitions of the wobbler bands in the ^{135}Pr [6] and ^{133}La [7] nuclei. The wobbling energies E_{wob}(MeV)show decreasing behaviour with spin(I$\hbar$). This trends of E_{wob}(MeV) along with electric nature of linking transition confirms that Band A and Band B arises from $n_\omega = 0$ and $n_\omega = 1$, may have transverse wobbling in the ^{133}Ba nucleus. Also, same is also true from the alignment plot.

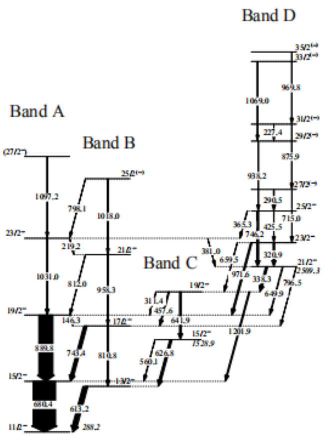

FIG. 2: Partial level scheme of the ^{133}Ba nucleus obtained in the present work.

The structure of the $^{135,134,133}Ba$ nucleus has been investigated using the ^{130}Te(^{9}Be,xn) and $^{124}Sn(^{13}C$, xn) reactions and more results will be present during the talk.

The financial assistance received (IUAC project (UFR - 51320) and INGA project (No. IR/S2/PF-03/2003-I)) and support/help by the Petletton and target Lab at at TIFR, Mumbai and IUAC, New Delhi are highly appreciated and acknowledged.

References

[1] Suresh Kumar *et al.*,Phys. Rev. C **81**, 067304 (2010).
[2] E.S. Paul, D.B. Fossan, Y. Liang, R. Ma, and N. Xu, Phys. Rev. C **40**, 1255 (1989).
[3] C.M. Petrache *et al.*, Phys. Rev. C **86**, 044321 (2012).
[4] A. Granderath, P.F. Mantica, R. Bengtsson, R. Wyss, P. Von Brentano, A. Gelberg, and F. Seiffert, Nucl. Phys. **A597**, 427 (1996).
[5] A. Bohr and B. Mottelson, Nuclear Structure Volume II (W. A. Benjamin, New York,1975).
[6] J.T Matta *et al.*, Phys. Rev. Lett. **114**, 082501 (2015)
[7] S. Biswas *et al.*, Eur. Phys. J A **55** , 159, (2019).
[8] R. Devi, Ph.D. Thesis 2018, University of Delhi.
[9] Neelam, Ph.D. Thesis to be submit, University of Delhi.