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

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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 triaxiality. 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-quasiparticle 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 $^{139}$Pr [6] and $^{133}$La [7] nuclei, which further supports triaxiality in this mass region. In addition to it, the observation of $I^π = 10^−, 7^−, 5^−, 19/2^+$ 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 $^{139}$Te($^{12}$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 $\Delta_\pi$ and $\Delta_\nu$ 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 $\epsilon_2 = 0.095, \epsilon_4 = -0.013, \gamma = 26^\circ$ with an average tilt angle $\angle = 56.4^\circ$ which corresponds to a triaxial shape. The calculations based on this configuration seem to explain the observed behaviour of $E$ vs. $I(h)$ 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 $h_\omega$ i.e. from 2.9 to 1.2 $\mu_N^2$, while B(E2) value increase with with increase in $h_\omega$ 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 $\pi(h_{11/2}g_{7/2}) \otimes \nu^{h_{11/2}}$ 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 $I^\pi = (20^-)$ [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–,

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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 $\theta = 40^\circ$. 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 interconnecting 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)$h$. 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.

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.

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