

## Shape Co-existence in $^{135}_{56}\text{Ba}_{79}$

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The  $^{135}\text{Ba}$  nucleus lies near the neutron shell closure at  $N = 82$  and in the proton mid-shell between  $Z = 50$  and  $64$  shell closures. For transitional nuclei in the  $A \sim 135$  region, the ground state shape changes rapidly with neutron number, but high spin structure of these nuclei show similarity. The high spin states have a configuration involving protons near the bottom of the  $h_{11/2}$  subshell, while the neutrons lie near the top of the  $h_{11/2}$  subshell. Thus the proton alignment drives the nucleus to prolate shape and the neutron alignment drives it to oblate shape. This has a direct consequence on shape transitions and quasi-particle alignments. Recently, the  $^{139}\text{Nd}$  [1, 2] and  $^{137}\text{Ce}$  [3] nuclei have been studied to obtain the low and high spin states. Both these nuclei have shown multi-quasiparticle configuration based bands and shape co-existence phenomenon at high spin. Thus, a shape co-existence of different shapes is also expected in  $^{135}\text{Ba}$ .

In the earlier works, some low spin states in  $^{135}\text{Ba}$  were observed in Coulomb excitation [4],  $\beta$ -decay,  $(n, \gamma)$  reaction [5] and in

$(^9\text{Be}, xn)$  reaction [6]. More recently, the high spin states in  $^{135}\text{Ba}$  were studied [7] using the  $(^9\text{Be}, xn)$  reaction. In present work, The high spin states of  $^{135}\text{Ba}$  were populated by about 54 percent of the total cross-section in the  $^{130}\text{Te}(^9\text{Be}, 4n)^{135}\text{Ba}$  reaction at a beam energy of 42.5 MeV. The  $^9\text{Be}$  beam was obtained from the 15UD Pelletron Accelerator at Inter University Accelerator Centre (IUAC), New Delhi. The target used was of  $750 \mu\text{g}/\text{cm}^2$  enriched  $^{130}\text{Te}$ , evaporated on a  $6 \text{mg}/\text{cm}^2$   $^{197}\text{Au}$  backing. The  $\gamma$ - $\gamma$  coincidence data were collected by using the Gamma Detector Array (GDA). A total of 20 new  $\gamma$ -rays have been found and placed in the level scheme. we have obtained three new bands at high spins (labelled as band 2, band 3 and band 4). Spins and parities of the levels have been assigned using values of directional correlation of oriented nuclei (DCO) ratios and linear polarisation of the  $\gamma$ -ray determined in this study. The cross-over E2 transitions in two of these bands have been observed for first time. The observation of these cross-over E2 transitions required some modification in the high-spin level scheme reported in ref.[7]. In addition, we have also undertaken theoretical calculations within the frame work of the hybrid version of Tilted Axis Cranking (TAC) model [8].

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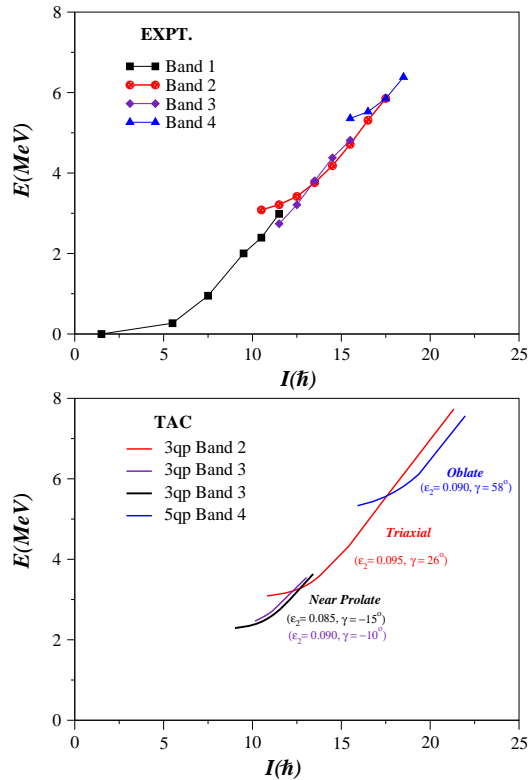


FIG. 1: Plot showing the excitation energy ( $E$ ) as a function of angular momentum  $I(\hbar)$  for the measured (upper panel) and the calculated (lower panel) values of bands 2, 3 and 4.

An interesting result of the present study is the observation of the high spin band structures based on the existence of multiple minima in the  $\gamma$ -deformation at nearly constant  $\epsilon_2 \sim 0.09$  (Fig. 1). The overall view of the measured excitation energy  $E$  vs.  $I(\hbar)$  for all three bands excluding the ground band can be seen in Fig. 1. The band 3 is the first one to become yrast by crossing the ground band (not shown in the in Fig. 1). The band 2 then crosses the band 3 to become yrast followed by the band 4 which crosses the band 2. We plot in lower panel the results of the TAC calcula-

tions for the bands 2, 3, and 4 along with the values of nuclear shape parameters. It may be observed that the excitation energy pattern as well as the crossings are reproduced reasonably well in all the cases. Thus, the  $^{135}\text{Ba}$  nucleus is a  $\gamma$ -soft nucleus and exhibits a shape co-existence of near prolate, triaxial, and oblate shapes at high spins.

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