Signature dependent shape evolution in nuclei in A ~ 130 region

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Introduction

The shape of a nucleus largely depends on the shape driving effects of the nucleons near the Fermi level. For an axially deformed nucleus, Ω (the projection of the single particle angular momentum on to the symmetry axis) is a good quantum number. The high- and low-Ω Nilsson orbitals have opposite shape driving effects. The energies of the low-Ω orbitals tend to decrease with the deformation (β_2) for prolate shape ($\gamma = 0^o$) while for the high-Ω orbitals, the energies decrease with the increase in the oblate ($\gamma = -60^o$) deformation. For the nuclei in the mass region A ~ 130, the valence orbitals of protons and neutrons have different shape driving tendencies and hence, these nuclei exhibit many interesting shape properties. Because of the opposing shape driving effects of the proton and the neutron orbitals, the ground state shape of many of the nuclei in this region are γ soft and triaxial. When external perturbations are imparted in such nuclei, the energies may distribute in such a way so that the minimum may occur at a stable deformation. The effect of such perturbation, e.g. rotation, on the energy surfaces of a nucleus depends on the response of the valence orbitals to such perturbations. For a rotating nucleus, only the parity (π) and the signature (α) are the good quantum numbers. Therefore, from the study of the evolution of nuclear shape with the rotational frequency, one can get the information about the shape driving effects of the different signature partners of the Nilsson orbitals. Many interesting phenomena, like chiral symmetry breaking in nucleus, have been observed in the Cs nuclei in this region [1]. However, as the neutron number increases towards the neutron shell closure, the effect of the spherical magic number N = 82 starts dominating and the shape changes. Recently, it has been observed that N = 77 defines the border of the deformed shape for the Cs isotopes [2]. Therefore, to study the evolution of deformed shape, one needs to be confined to the neutron number below N = 77.

In this work, the shape of the odd-A isotones with neutron number N = 75 have been studied in the frame work of cranked shell model to investigate the shape evolution with rotational frequency in Ba (Z = 56) and Ce (Z = 58) nuclei in mass region A = 130.

Method

The total Routhian surfaces (TRS) are calculated, in the present work, using the Hartee-Fock-Bogoliubov code of Nazarewicz et al. [3]. A deformed Woods-Saxon potential and a pairing interaction was used with Strutinsky shell corrections method. The energies are calculated in the β_2-γ deformation mesh points and were minimized in β_4 at each value of the mesh points. These are calculated at different rotational frequencies $\hbar\omega$ and for different configurations.

Results and Discussion

The TRS calculations, done for the 1-qp configuration of ^{131}Ba and ^{133}Ce, are reported here. The odd neutron in these N = 75 isotones, occupy the unique parity $h_{11/2}$ orbital. Therefore, the negative parity configuration of these nuclei would be pure and unperturbed. In the present work, the calculations were performed for odd-neutron in the $\alpha = +1$ and in $\alpha = -1$ signatures of the negative parity orbital at the rotational frequencies $\hbar\omega$ from about 0.1 MeV to 0.5 MeV, encompassing the band crossing region. The TRSs for ^{131}Ba with negative parity, negative signature (π = -, $\alpha = -1$) configuration are shown in Fig. 1, calculated at two different rotational frequencies $\hbar\omega = 0.21$ MeV (top) and 0.31 MeV (bottom), corresponding to the situations before and after the band crossing in this nucleus. The shaded region corresponds to the minimum of the TRS and hence, the β_2 and γ values for this minimum correspond to the shape of the nucleus. The TRSs for the same configuration but for α =

+1 has been shown in Fig. 2 at the same ħω values.

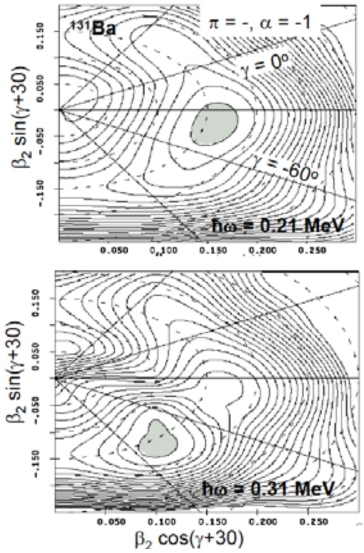

Fig. 1 Calculated TRSs at ħω = 0.21 MeV (top) and 0.31 MeV (bottom) for ^{131}Ba in the –ve parity, -ve signature configuration.

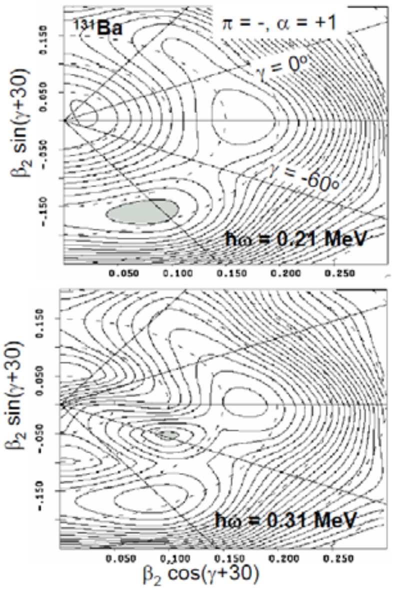

Fig. 2 Same as Fig. 1 but for the –ve parity, +ve signature configuration.

It can be seen from these two figures that α = -1 and α = +1 gives different shapes, particularly in the γ-degrees of freedom, before as well as after the band crossing. In other words, the particle alignment induces different change in shape for the two signature partners.

The calculations are also performed for the negative parity 1-qp band in ^{133}Ce which give similar results. The evolution of shape as a function of rotational frequency has been studied for both the nuclei. Since, the effect is more prominent in the γ-plane, the TRS energies (E_{TRS}) are plotted as a function of γ in Fig. 3 for ^{133}Ce in the α = +1 and α = -1 configuration at different ħω. The figure clearly suggests different shape evolution in this nucleus for the two signature partners.

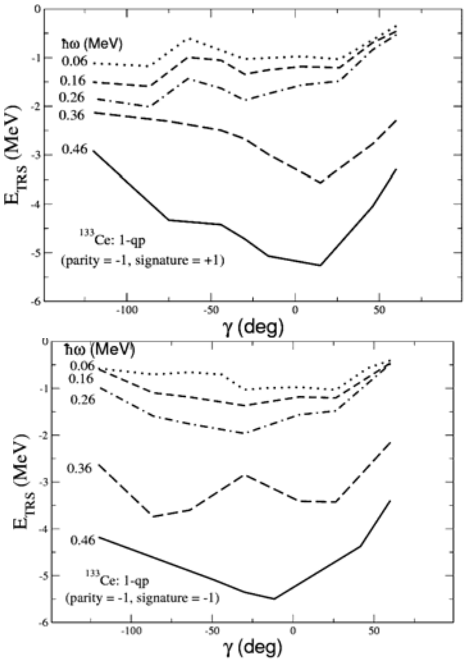

Fig. 3 The calculated TRS energy as a function of triaxiality γ for the –ve parity band of ^{133}Ce with signature α = +1 (top) and α = -1 (bottom).

In conclusion, the TRS calculations suggest that the two signature partners of the same orbital induces different shapes and shape evolution in the N = 75 isotones. Interestingly, it also appears that the α = +1 and α = -1 induce a change in shape towards +ve and –ve values of γ, respectively, similar to that observed in mass A ~ 70 region [4].

References

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