Change over from Chiral to Shears geometry in Cs isotopes

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Introduction

The nuclei in mass region A = 130 is a rich testing ground for many nuclear symmetries. Apart from the well known collective and single particle excitations, the other exotic modes of nuclear excitations typical for a near spherical and non-axial deformation, like Magnetic rotation (MR) and Chirality [1, 2], have been experimentally observed in many of the nuclei in this region. The MR bands are generated, for near spherical nuclei, when the angular momentum vectors of proton particle and neutron hole, both in high-j orbital, are nearly perpendicular at the band head. The angular momenta are generated by the, so called, shears mechanism in MR bands. The Chiral symmetry in a nucleus is realized for triaxial deformation when the angular momentum vectors of valence proton, neutron (hole) and the core are directed along the three principal axes of the triaxial core. The shears bands are characterized by strong $\Delta I = 1$ M1 with very weak or no crossover E2 transitions. The chiral symmetry breaking in a nucleus is manifested in the occurrence of chiral partner bands - the nearly degenerate doublet bands. The odd-odd nuclei of Cesium (Z = 55) isotopes around A ~ 130, in the unique parity configuration of $\pi h_{11/2} \otimes \nu h_{11/2}$, favors both the conditions. Chiral partner bands have been reported in $^{126\text{-}132}$Cs isotopes [3, 4] by the observation of strongly coupled band with a partner side band. However, in ^{134}Cs, the band based on this same configuration does not show any evidence of chirality [5]. Instead, the states in this band are connected by strong $\Delta I = 1$ M1 transitions with no E2 crossovers, characteristics of shears band. It indicates that there is a sudden change over from chiral to shears geometry in Cs isotopes at N = 79.

We have tried to understand this phenomenon in Cs isotopes by microscopic-macroscopic shell correction calculations.

Procedure of the calculations

The deformation and the gamma softness play important roles in determining the methods of generation of angular momentum in a nucleus. Chiral symmetry breaking is best realized in a stable triaxially deformed nucleus while shears mechanism dominates in a near spherical nucleus. Large amount of gamma softness can destroy the chiral symmetry while for large deformation, the quadrupole rotation dominates over magnetic rotation. Therefore, the shapes of the Cs isotopes in $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration have been studied by calculating the total routhian surfaces (TRS). The Hartee-Fock-Bogoliubov code of Nazarewicz et al. [6] was used for the calculations. The procedure has been outlined in reference [7, 8]. Deformed Woods-Saxon potential and pairing interaction was used with Strutinsky shell corrections method. The TRS were calculated in $\beta_2 - \gamma$ deformation mesh points and minimized in β_4.

Results and Discussion

The deformation parameters β_2 and γ were obtained from the minimum of the TRS for the odd-odd isotopes of $^{126\text{-}136}$Cs nuclei in $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration. These isotopes correspond to the occupation of $\nu h_{11/2}$ orbital.

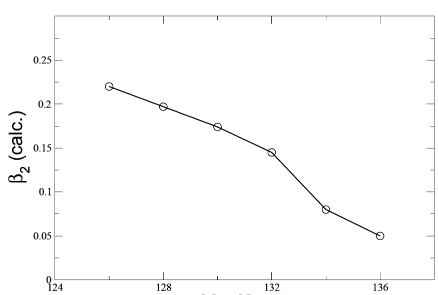

Fig. 1: variation of calculated β_2 of odd-odd Cs isotopes, in $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration, with mass number A.

The variation of the deformation β_2 with mass number is shown in Fig. 1 for these nuclei. It is observed that the deformation gradually decreases as the neutron number increases in the $\nu h_{11/2}$ orbital and as the neutron Fermi surface approaches the N = 82 spherical shell closure. Similar features were obtained for protons approaching the Z = 50 shell closure in this region for N = 79 isotones [9].

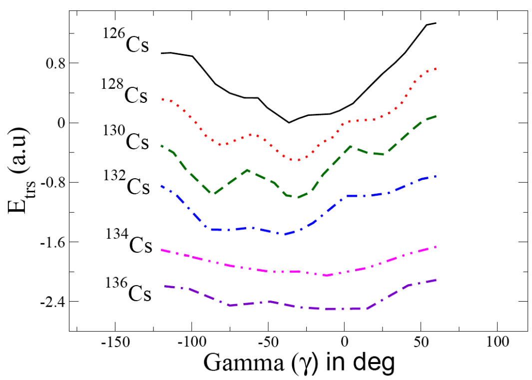

Fig. 2: variation of TRS energy (E_{trs}) with γ for Cs isotopes in $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration.

The variation of the TRS energies, E_{trs}, (relative to minimum) with deformation parameter γ is shown in Fig. 2 for the odd-odd Cs isotopes, in the same configuration for the β_2 values close to the minimum of the TRS. $\gamma = 0^o$ corresponds to a prolate shape and $\gamma = -60^o$ to an oblate shape. For a traixial shape γ is in between these values.

It can be seen from Fig. 2 that ^{126}Cs has a minimum at $\gamma \sim -30^o$ which corresponds to maximum triaxiality. As the neutron number increases, another minimum close to $\gamma \sim -90^o$ appears. The two minima, however, are separated by a well defined barrier which vanishes for ^{134}Cs and ^{136}Cs. In other words, while there are stable triaxial shapes for lighter isotopes, as the neutron number increases, the energy surfaces become more and more γ-soft.

The β_2 values (see Fig. 1) for the ^{126,128,130,132}Cs are between 0.22 and 0.15. The stable triaxial deformation together with this relatively large β_2 values seem to favor the chirality to dominate in these isotopes as observed experimentally. On the other hand, for ^{134,136}Cs nuclei, $\beta_2 < 0.1$ and also they are very γ-soft. Moreover, as the neutron number increases, neutron Fermi level moves towards the upper part of the $h_{11/2}$ level and neutron holes are created in the high-Ω orbital. These are favorable condition for the shears mechanism to dominate for ^{134}Cs and ^{136}Cs. These seem to explain the sudden change of character from chiral partner band to MR like band for the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration at N = 79 in ^{134}Cs compared to the lighter odd-odd isotopes. Similar MR band is predicted to occur in ^{136}Cs as well.

Summary

In summary, we have investigated the sudden change over observed from chiral doublet band to magnetic rotation like band for the $\pi h_{11/2} \otimes \nu h_{11/2}$ configuration in ^{134}Cs by calculating the shape of the odd-odd Cs nuclei in the frame work of shell corrected microscopic-macroscopic method. The decrease of β_2 and increase of the γ-softness seem to be destroying the chirality and favoring the shears mechanism to dominate in heavier Cs isotopes with N > 77. Experimental data on ^{136}Cs will be interesting to compare with the prediction.

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