Candidate chiral doublet bands in the odd-N ^{135}Nd nucleus

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For substantial triaxiality, the orientation of the rotational axis determines the geometry of the system. For well deformed nuclei, the rotational bands are built through rotation about an axis that is perpendicular to the symmetry axis. While the tilted bands are obtained by rotation about an axis which is tilted with respect to the principle axis and the rotation is still planar. However, the chiral bands are obtained by rotating about an axis which does not lie in a plane and is, therefore, known as aplanar rotation. The three mutually perpendicular angular momenta, formed by short, intermediate and long semi-axis, can be arranged to form two systems with opposite chirality, namely left and right handness. They are transformed into each other by the chiral operator that combines time-reversal and spatial rotation of angle π. Thus planar geometry is the "achiral" and aplanar geometry is "chiral". Besides, energy spectra the life-time measurements play a centre role for identification of the chiral bands. For the ideal chiral critria, the intra-band B(E2) transitions at higher angular momenta should increase with increase in spin while as inter-band B(E2) transitions should decrease with increase in spin. This is due to the reason that chiral doublet bands have strong "M1" and "E2" intra-band transition but weak inter-band transitions [1].

Since the first experimental evidence for chiral doublet bands was found in the odd-Z N = 75 isotones, more than 20 experimental candidates have been reported in the A $\sim$ 100, 130, and 190 mass regions, including odd- odd, odd-A and even-even nuclei. On the theoretical side, many attempts have been made to describe the bands and to investigate the underling physics. These models include one-particle-one-hole-rotor model (PRM), tilted axis cranking (TAC) approximation, realistic TAC approaches, the Strutinsky shell correction method with a hybrid Woods-Saxon and Nilsson potential, the Skyrme Hartree-Fock model and the relativistic mean field model. These models have been developed to investigate this new phenomena with varying degree of success. Within the TAC mean field approximation, the left-handed and right-handed solutions are exactly degenerate. It is not possible to calculate the energy difference between the bands, which is the consequence of quantum tunneling between the two solutions. Particle rotor model (PRM) has been shown to provide a reasonable description of the most of the characteristics of the chiral bands, it is known to depict discrepancies with the observed data. For instance, the measured B(E2) values for the yrast band in ^{128}Cs drop with spin and PRM calculations display opposite trend of increasing B(E2) with spin. Recently triaxial projected shell model (TPSM) gives a slightly better description of the observed data as compared to the PRM approach for ^{128}Cs. In particular, it was shown that TPSM correctly reproduces the observed trend in the measured $B(E2)$ transitions as a function of spin. Quite recently, pair of degenerate bands in ^{108}Ag is studied using the microscopic TPSM. It is shown that the partner band has a different quasiparticle structure as

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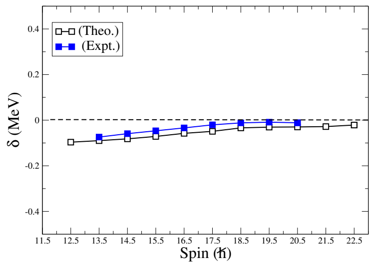

FIG. 1: Comparison of the TPSM and experimental values of δ(E).

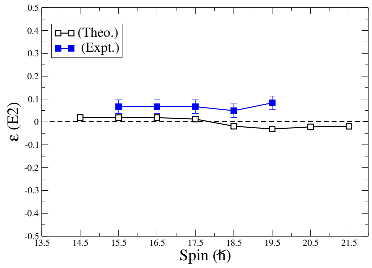

FIG. 2: Comparison of the TPSM and experimental values of ϵ(E2).

compared to the yrast band.

In the TPSM calculations for the doublet bands in ^{135}Nd, the configuration $\pi h_{11/2} \otimes \nu h^{-1}_{11/2}$ is adopted. The deformation parameters ϵ = 0.223 and ϵ'= 0.100 for ^{135}Nd are obtained from the microscopic self-consistent triaxial relativistic mean field calculation. In more detail, the calculated energy spectra well reproduce the experimental results that show

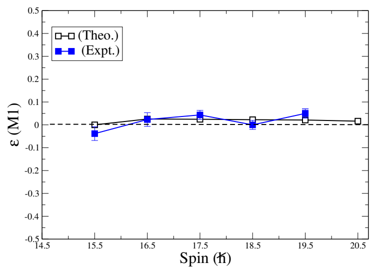

FIG. 3: Comparison of the TPSM and experimental values of ϵ(M1).

a energy separation from 400 keV at I = $29/2\hbar$ decreasing with spin to 100 keV at I = $39/2\hbar$. In this Letter, we want to touch another point, as an odd- nucleus, the chiral bands in ^{135}Nd are not built on the low-lying one-quasiparticle state, but on an excited three-quasiparticle state. In fact, it has been observed that the chiral bands would decay to the ground-state band based on $\nu h^{-1}_{11/2}$. The ground-state band together with the main partner of chiral bands composes the yrast band in ^{135}Nd. It has been shown that in order to probe the chiral nature of the band structures, it is important to investigate both the energy differences and the deviations in the transition probabilities of the doubet bands.It is expected that in the strong chiral limit, both energy differences and the deviations in the transition probabilities should tend to zero and deviations from it correspond to the tunneling between the two solutions. The differences in the energy (δ) is plotted in Fig. 1 and the deviations in the $B(E2)$ [$\epsilon(E2)$] and $B(M1)$ [$\epsilon(M1)$] transition probabilities are displayed in Figs. 2 and 3, respectively. It is evident from the Fig 1 that "δ" calculated from both the TPSM and the experimental energies are close to zero. It is also interesting to note from the figure that this deviation approaches zero with increasing spin, implying that from energy considerations chiral limit is obtained at high-spin. TPSM calculated devations in $B(E2)$ and $B(M1)$, plotted in Figs. 2 and 3, along with data are very well reproduced and both are close to zero in the entire spin regime. In conclusion the observed energies for the two chiral bands are excellently reproduced by 3-qp TPSM calculations in the higher spin region ($I > 23/2\hbar$). Based on the analysis of the angular momentum components, it is illustrated that the yrast band changes from the electric rotation to chiral mode, which is supported meanwhile by the performance of electromagnetic transitions.

References

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