Nature of adiabatic crossing of degenerate doublet bands in ^{106}Ag

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In the last decade, a number of nearly degenerate pairs of rotational bands with same parity have been reported in nuclei of mass A∼130 [1] and A∼100 [2] regions. These bands are known to be strongly connected to each other. It has been proposed that a possible reason for the occurrence of these doublet bands is spontaneous breaking of chiral symmetry in triaxial nuclei due to the presence of three orthogonal angular momenta of the valence protons, valence neutrons and the core. However, for the two bands to be chiral partners, the near degeneracy in level energy and spin is a necessary but not a sufficient condition. In addition, these bands should exhibit nearly similar moment of inertia, quasiparticle alignment, signature staggering behaviour and more importantly, the transition probabilities.

Indeed the nuclei ^{134}Pr [1] and ^{104}Rh [2] exhibit the best overall energy degeneracy. However, in both cases the quasi-particle alignment behaviour has been found to be different which indicates different shapes associated with the two bands. This has been supported by dissimilar behaviour of the measured B(E2) rates of the main band are a factor of 2-3 larger than that of the partner band, which rules out the possibility of static chirality. In mass $\sim$ 106 region, the doublet bands observed in ^{106}Ag nucleus that are built on $\pi g_{9/2} \times \nu h^2_{11/2}$ are being proposed as resulting from the chiral symmetry. The observed B(E2) rates for the two bands are nearly same, except around the band crossing spin, while their moments of inertia are quite different. Thus, the interpretation of observed doublet bands in this nucleus as chiral partners needs to be substantiated by theoretical models. Different theoretical models have been used to study nuclear chirality with varying degree of success. However, for ^{106}Ag nucleus the observed degenrate energies are available up to I=20 for both yrast and the partner band and the data clearly depicts the crossing of the two bands. This crossing of the two bands in ^{106}Ag has been an unsolved problem in nuclear structure physics. A comparison with the calculated values using triaxial projected shell model (TPSM) approach indicates that these bands originate from two different quasi-particle configurations but constructed from the same mean-field deformation. The deformation parameters employed by TPSM are $\beta = 0.149$ and $\gamma = 30^0$. The triaxial basis generated by Nilsson potential are projected onto good angular-momentum states through three-dimensional angular-momentum projection formalism. These projected basis are then employed to diagonalize the shell model Hamiltonian. The main aim of the present letter is to dig more physics on the nature of adiabatic crossing on degenrate doublet bands in in ^{106}Ag nucleus.

In order to probe further the adiabatic crossing of the two degenrate doublet bands in ^{106}Ag nucleus, we have evaluated the K-distributions of the wavefunctions for the doublet bands. The projections along the quantization axis of intermediate, $i-$ and short, $s-$ are simply obtained by using the γ-values of 90^0 and 150^0. In the present TPSM approach, as compared to the particle-rotor, the projected basis are not orthogonal and in Figs. 1, only the diagonal components of the expression : $P(K,K') = \sum_{\nu\nu'} c_{K\nu} < \nu|P^I_{KK'}|\nu' > c_{K\nu'}$ are shown. In the above equation, $c_{K\nu}$ are the amplitudes of the yrast- and the partner-band wavefunctions. Figs. 1 provide the diagonal K-distributions $P_K = P(K,K)$ for the projection of the total angular momentum along the intermediate $(i)-$, long $(l-)$ and short $(s-)$ quantization axis for odd- and even- angular-momentum states, respectively. We interpret P_K as a measure for the probability of the projection of the total angular momentum on the respective axis and its distributions in the following manner. The $g_{9/2}$ proton hole tends to align its $\vec{j}$ with the l-axis and the $h_{11/2}$ neutron particle tends to align its $\vec{j}$ with the s-axis. The projections of $\vec{j}$ of the two quasiparticles generate part of K_l and K_s, respec-

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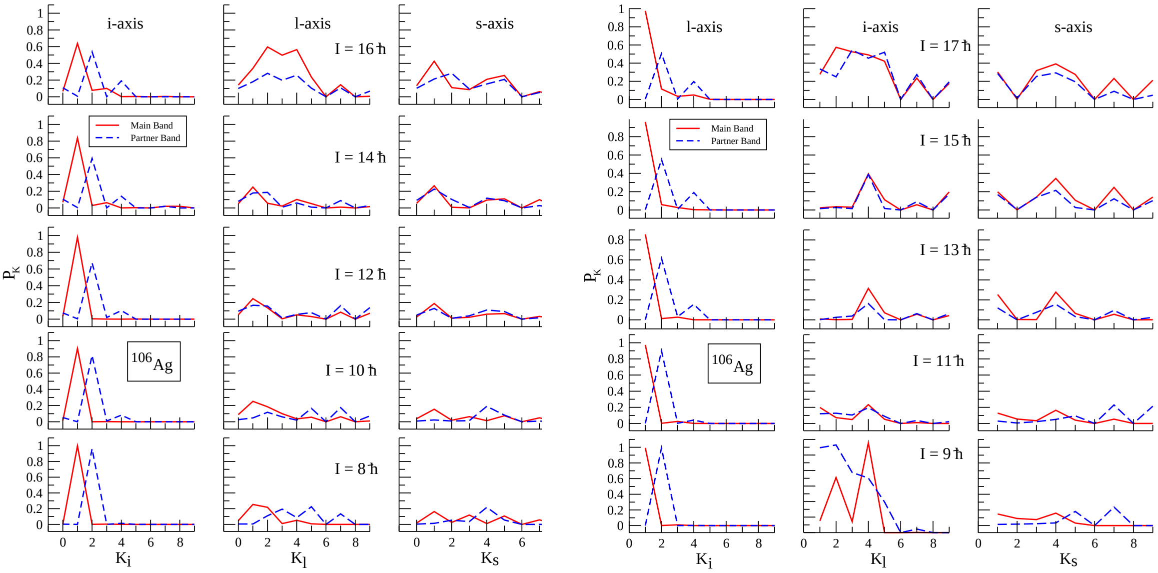

FIG. 1: (Color online) The probability distribution for the projection of total angular momentum, $I^\pi = I^\pi = 8^-, 10^-, 12^- \ldots$ for even members and $I^\pi = 9^-, 11^-, 13^- \ldots$ for odd members on the long $(l-)$, intermediate $(i-)$, and short $(s-)$ axis for the yrast and its degenerate partner band in ^{106}Ag nucleus.

tively. The collective angular momentum provides the other part, which increases with I. Whereas at $I = 7$ the two partner bands (blue and red) look different, they become very similar with increasing I. The K_i distributions are peaked at $K_i = 1$ for the yrast band and $K_i = 2$ for the partner band. For both bands the $K_i = 0$ component is very small. This means that there is no tunneling between the upper and lower hemispheres with respect to the s-l plane, which reflects the fact that the two bands are regular $\Delta I = 1$ sequences. The further discussion can be restricted to the upper hemisphere $K_i > 0$. For $I = 7$ the distributions of the yrast and partner band contain only one component K_i=1 and 2, respectively. This means that the probability does not dependent on the conjugate angle Φ_i, which rotates the vector $\vec{J}$ of the total angular momentum about the i-axis. In the case of partner band, a second component at $K_i = 4$ develops with increasing I. The probability function of the superposition : $A\exp[2i\Phi] + B\exp[4i\Phi]$ with $AB < 0$ [The case $AB > 0$ can be disregarded because the orientation of the $\vec{j}$ of the proton hole and the neutron particle along respective long and short axes causes a preferred orientation of $\vec{J}$ at about $\pi/4$ between these axes.] has maxima at $\Phi = \pi/4,\ 3\pi/4,\ 5\pi/4,\ 7\pi/4$ and minima at $\Phi = 0,\ \pi/2,\ \pi,\ 3\pi/2$. The appearance of these maxima signals that chirality develops [2]. If chiral symmetry is spontaneously broken, the angular momentum vector lies outside the three principal planes of the triaxial density. There are four equivalent orientations in the upper hemisphere, two left-handed and two right-handed. Tunneling between these four positions restores chiral symmetry for eigenstates of the Hamiltonian, which is localized around these positions. The tunneling decreases with the length of the vector $\vec{J}$ and chirality becomes more apparent. It is to be noted that yrast band does not develop the same signature of chirality and only a slight admixture of K_i=3 is seen in the even-I states. The fact that the yrast band contains only odd K_i and the partner band only even K_i explains why the two band cross without mixing and repel each other.

References

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