Exploring the Origin of Nearly Degenerate Doublet Bands in ^{106}Ag

N. Rather,[1] P. Datta,[2,*] S. Chattopadhyay,[1] S. Rajbanshi,[1] A. Goswami,[1] G. H. Bhat,[3] J. A. Sheikh,[3] S. Roy,[4] R. Palit,[4] S. Pal,[4] S. Saha,[4] J. Sethi,[4] S. Biswas,[4] P. Singh,[4] and H. C. Jain[4]
[1]*Saha Institute of Nuclear Physics, Kolkata 700064, India*
[2]*Ananda Mohan College, Kolkata 700009, India*
[3]*Department of Physics, University of Kashmir, Srinagar 190006, India*
[4]*Tata Institute of Fundamental Research, Mumbai 400005, India*
(Received 28 October 2013; revised manuscript received 16 April 2014; published 20 May 2014)

The lifetimes of the excited levels for the two nearly degenerate bands of ^{106}Ag have been measured using the Doppler-shift attenuation method. The deduced $B(E2)$ and $B(M1)$ rates in the two bands are found to be similar, except around the band crossing spin, while their moments of inertia are quite different. This is a novel observation for a nearly degenerate doublet band.

DOI: 10.1103/PhysRevLett.112.202503 PACS numbers: 27.60.+j, 21.10.Tg, 21.60.Ev

The effects of the shape of a finite fermion system on its collective modes of excitations remain a subject of intense research. This experimental evidence comes from different fields of research. For example, an ultracold cloud of $\sim 4 \times 10^5$ ^{6}Li atoms exhibits collective angular oscillation about a principal axis of the elliptic trap when the angle of the trap is suddenly rotated by $\sim 5°$ [1]. Another piece of evidence is the observation of strong dipole and quadrupole resonances in ultrasmall two-dimensional systems comprised of ~ 20 electrons per quantum dot [2,3], where the system can be described by an effective parabolic potential. However, the most well studied system of this class is the deformed atomic nucleus, which is a classic example of a quantum rotor. The angular momentum (I) and the corresponding energy (E) of the rotational levels are related as $E = AI(I+1)$, where A can be expressed in terms of an effective moment of inertia ($\Im$) defined by $A = \hbar^2/2\Im$. This concept of an average deformed shape for a system of a finite number of interacting nucleons is possible since the motions of the nucleons in a nucleus are fast compared to the rotational frequency. The systematic theoretical studies based on the deformed mean field potential (Nilsson potential) indicate that most of the deformed nuclei have an axially symmetric shape. For these nuclei, the collective rotation is possible only around an axis perpendicular to the symmetry axis. This rotational symmetry implies that the projection of the angular momentum on the symmetry axis (designated as K) is a conserved quantum number.

The extent of the quadrupole deformation (β_2) can be estimated by measuring the electric quadrupole transition rates $B(E2, I \to I-2)$ in the rotational band. However, such direct evidence for a generalized triaxial shape is not possible since the two deformation parameters, namely, β_2 and the extent of departure from the symmetric shape (γ), cannot be determined from a single experimental $B(E2)$ value. It should be noted that the triaxial shape breaks the rotational symmetry since the rotation is possible along any of the three principal axes. Although there is no direct evidence of a stable triaxial deformation in an atomic nucleus, there is a great deal of indirect spectroscopic evidence, such as signature inversion at high spins [4], a wobbling motion [5], and spin chirality [6]. In the case of spin chirality, the chiral symmetry is spontaneously broken in a triaxial nucleus due to the presence of the three orthogonal angular momenta of valence protons, valence neutrons, and the core [7]. The restoration of this broken symmetry in the laboratory frame leads to a pair of nearly degenerate rotational bands with the same parity. Thus, a pair of bands can be experimentally identified as chiral partners, provided that they exhibit nearly similar band structures, moments of inertia (MOI), and, more importantly, the transition probabilities [8]. Such situations have been best realized in ^{128}Cs [9] and ^{135}Nd [10] for the $A \sim 130$ region. In recent years, a number of doublet bands have also been reported in the $A \sim 100$ [11–14] region, but their band structures and MOI have been found to be different. In addition, the transition rates have not been measured. Thus, the origin of these bands of the $A \sim 100$ region could not be established. In the present work, we report the first precise measurement of transition rates in the doublet bands of ^{106}Ag.

In the previous work by Joshi *et al.* [12], it was proposed that the main and partner bands could arise due to the triaxial and the axially symmetric shapes, respectively, which was the reason for the observation of different MOI for the two bands. The origin of the shape transformation for the partner band was attributed to the chiral vibrations of the γ-soft ^{106}Ag. In a recent publication [15], Ma *et al.*. have proposed that these bands in ^{106}Ag may originate due to the two different quasiparticle structures, namely, $\pi(g_{9/2})^1 \otimes \nu(h_{11/2})^1$ for the main band and $\pi(g_{9/2})^1 \otimes \nu(h_{11/2})^3$ for the partner band. Thus, the previous investigations [12,15] on the origin of the doublet bands of ^{106}Ag have indicated two contrasting possibilities, namely, distinct shapes or distinct quasiparticle structures.

