Degenerate doublet bands in ^{141}Sm

G. Manna[1,2], S. Rajbanshi[3],* Habibur Rahaman[3,4], Rahul Biswas[3], R. Palit[5], S. Bhattacharya[6], B. Das[5], Atreyee Dey[7], P. Dey[5], Nidhi Goel[8], A. Kundu[5], V. Malik[5], Mamta Prajapati[8], Rajat Roy[9], Sahab Singh[9], Sajad Ali[10], Deepika Chowdhury[9], G. Mukherjee[11], Somnath Nag[8], A. K. Singh[7], S. K. Jadhav[5], B. S. Naidu[5], and A. T. Vazhappilly[5]

[1] *Department of Physics, Bankura University, Bankura 722155, India*
[2] *Mugberia Gangadhar Mahavidyalaya, Purba Medinipur 721425, INDIA*
[3] *Presidency University, Kolkata 700073, INDIA*
[4] *Indian Institute of Engineering Science and Technology, Shibpur, Howrah 711103, India*
[5] *Tata Institute of Fundamental Research, Mumbai 400085, INDIA*
[6] *The Hebrew University of Jerusalem, Jerusalem 91904, ISRAEL*
[7] *Indian Institute of Technology, Kharagpur, Kharagpur 721302, INDIA*
[8] *Indian Institute of Technology (BHU), Varanasi 221005, INDIA*
[9] *Indian Institute of Technology Ropar, Ropar 140001, INDIA*
[10] *Government General Degree College at Pedong, Kalimpong 734311, INDIA and*
[11] *Variable Energy Cyclotron Center, Kolkata 700064, INDIA*

1. INTRODUCTION

The rotational breakup and alignment of pairs of particles in the $A \sim 140$ mass region occur most easily for particles from the low Ω $h_{11/2}$ protons and the high Ω $h_{11/2}$ neutrons orbitals. Therefore, when both a proton and a neutron from opposite-shape-driving orbits are added to a γ-soft core, it is expected that the resulting equilibrium shape of the nucleus will have a relatively stable triaxial [1].

Considerable effort has been made over the last 30 years to obtain conclusive evidence for the existence of triaxial nuclear shapes. Experimental signatures of triaxility are the chirality and wobbling mode in nuclei. Nuclear chirality results when the angular momenta of the valence proton, the valence neutron, and the core rotation tend to be mutually perpendicular. This occurs when high-j particlelike and holelike orbitals align their angular momenta along the short and long axes of nuclear deformation, respectively, minimizing the interaction energy, and the core-rotation angular momentum is oriented along the intermediate axis because it has the largest (irrotational flow) moment of inertia. The resulting aplanar total angular momentum can be arranged into a left- or a right-handed system, which differs by intrinsic chirality; the two systems are related by the chiral operator, a combination of time reversal and rotation by 180°. When chiral symmetry is thus broken in the intrinsic frame, the necessary restoration of the symmetry in the laboratory frame manifests itself as degenerate doublet $\Delta I = 1$ bands from the doubling of states [2]. The merged states combine the left- and right-handed systems in a way that satisfies the laboratory chiral symmetry requirement.

The present investigation is primarily aimed at observation of the triaxial deformed shape in the ^{141}Sm nucleus through observation of the degenerate doublet bands. In fact, the existence of the well-nigh degenerate $\Delta I = 1$ doublet bands DB2 and DB3 at end of the DB1 in ^{141}Sm stimulate the additinal quest of evolution of the axial to triaxial nuclear shape of the same.

2. EXPERIMENTAL DETAILS

High-spin states of ^{141}Sm were populated using ^{116}Cd(^{30}Si,5n) reaction at E_{lab} = 149 MeV. The target was 2.4 mg/cm^2 ^{116}Cd (99%

*Electronic address: subhendu.physics@presiuniv.ac.in

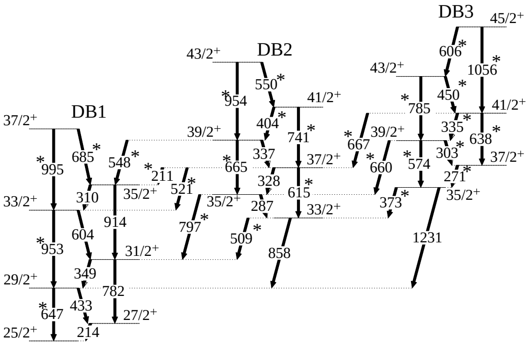

FIG. 1: Partial level scheme of ^{141}Sm obtained from the present work. Newly observed transitions are marked by asterisk.

enriched) on a 14.5 mg/cm^2 thick lead backing. The de-exciting γ-ray transitions were detected by the Indian National Gamma Array (INGA) which was consisted of seventeen Compton-suppressed clover detectors at the time of experiment [4]. The data were sorted into γ-γ matrices, symmetric as well as angle dependent, and γ-γ-γ cube using the **MARCOS** code and analyzed using the **INGASORT** and the **RADWARE** packages.

3. RESULTS AND DISCUSSION

The principal objective of the present work has been to investigate the origin of the dipole structures above the 2978-keV, $25/2^+$ state in the level scheme of ^{141}Sm that have pre-

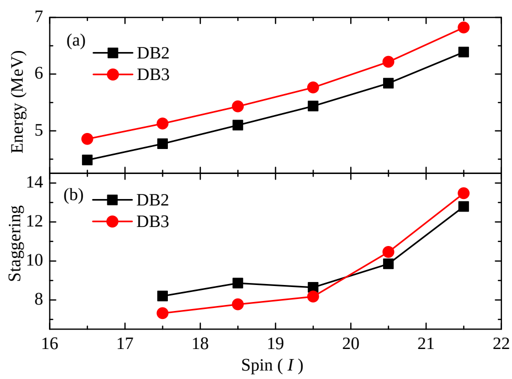

FIG. 2: The experimental (a) energy, and (b) staggering of the bands DB2 and DB3 in ^{141}Sm.

viously been reported by the Cardona *et al.* [3]. The Cardona *et al.* [3] was observed another dipole band-like structure consisted by the γ -ray transitions of energies 287, 328 and 337-keV and connected to the lower lying 29/2 state via the 858-keV dipole transition. In the coincidence spectrum, we have observed 27 new gamma transitions and arranged then in the form of three dipole band structures DB1, DB2 and DB3.

The excitation energy [E(I)] and the energy staggering S(I) values for the bands DB2 and DB3 in ^{141}Sm are plotted as a function of spin (Fig. 2). The absence of staggering of the S(I) values for both the bands indicates weak Coriolis interactions resulting from perpendicular angular momenta coupling of the single particle to that of the core. The energy degeneracy (Fig. 2) shows almost identical behavior indicating the strong influence of the core rather than the valence particles. Such observations strongly indicate that these bands are chiral partners owing to their characteristics, irrespective of their origin. The proposition needs to be stringently tested in the light of the electromagnetic properties of the observed bands. The observation of this doublet structure in near shell closure nucleus ^{141}Sm reveals breakdown of a symmetry with resemblance to chirality. The detailed calculations will be presented to unravel the intrinsic stucture of the nearly degenerate doublet bands.

ACKNOWLEDGMENTS

We acknowledge the help and support from the **INGA** collaboration. We are thankful to the staff at the **Pelletron LINAC Facility** in **TIFR**, Mumbai for their efforts in delivering steady and uninterrupted ^{30}Si beam.

References

[1] S. Frauendorf and J. Meng, Nucl. Phys. A **617**, 131 (1997).

[2] J. Meng and S. Q. Zhang, J. Phys. G **37**, 064025 (2010).

[3] M. A. Cardona, *et al.*, Z. Phys. A **340**, 345 (1991).

[4] R. Palit *et al.*, Nucl. Instrum. Methods A **680**, 90 (2012).