Dynamical symmetries in a doubly odd nuclei: case study of ^{126}I and ^{130}La

Himanshu Kumar Singh*
Department of Physics, Indian Institute Of Technology Bombay, Mumbai - 400076, INDIA

Introduction

The atomic nuclei are a mesoscopic system and have complex structures and dynamics. The investigation of such system gives a vibrant information of underlying symmetries that existed in it. Rotational motion of the nuclei introduces many new symmetries and collective degree of freedom. Consequently, many new phenomena have been observed, e.g. backbending, signature splitting, signature inversion, chirality, etc. With the help of symmetries arguments, many of them can be explained nicely, for example energy degenerate bands of same parity due to chiral symmetry breaking. In mass region $A \approx 130$, a large number of doubly odd nuclei exhibit the possible chiral bands as well as signature partners bands.

The objective of the present work is to investigate these symmetry-based bands in doubly odd nuclei in mass region $A \approx 130$ (specially chiral bands). Additionally, the cause of signature inversion was also addressed. Two nuclei were extensively studied, one is ^{126}I, and another is ^{130}La using the framework of lifetime measurements.

Experimental details

Two experiments were performed to populate the high spin states of these nuclei through the fusion evaporation reactions. The reactions were ^{7}Li(^{124}Sn, $5n$)^{126}I at $E_B = 50$ MeV and ^{19}F(^{116}Cd, $5n$)^{130}La at $E_B = 94$ MeV at IUAC, New Delhi. In both the experiments, the Indian National Gamma Array (INGA) was used containing 15 and 18 Compton suppressed clover detectors respectively. It is noteworthy to mention that we utilized the self-supported thick targets in our experiments for DSAM instead of the conventional backing-based target experiments. The data were acquired in list mode format and further processed and analyzed by `LAMPS, CANDLE, RADWARE` and `LINESHAPE` programs.

Results and discussion

We performed the lifetime measurements via DSAM and evaluated their EM-transition probabilities. We adopted the procedure of gating on the above transitions (GTA) as well as below (GTB). The GTA was crucial for the uppermost levels because they usually have a relatively large contribution from the side-feedings. In both the analysis procedures, we fitted all the levels globally and simultaneously at two angles (32° and 148°) and used 90° spectra to mark contaminations peaks, as shown in Fig 1.

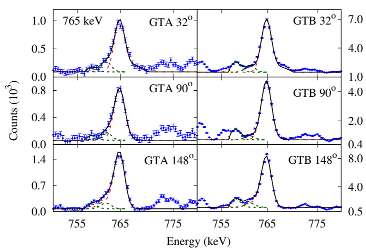

FIG. 1: Illustrative examples of Lineshape fitting (in red) of the Doppler shifted γ-peaks (in blue).

The first lifetime measurements were carried out on the different bands of ^{126}I. The negative parity yrast band exhibits the phenomenon of signature inversion. The reason for the signature inversion was an obscure and debatable subject. However, our lifetime measurements of states below and above the signature inversion and two quasi-particle plus ro-

*Electronic address: `hain.iitb@gmail.com`

tor model rotor calculations able to reproduce signature splitting and B(E2) (see Fig. 2) and suggest some physical picture of the cause of signature inversion in ^{126}I. The cause of signature inversion in ^{126}I is due to the shape change or change in the axis of rotation or a combination of both. We inferred a combination of both because the triaxiality (γ) changed its value as well as the sign. Alternative support of this conclusion is the observation of backbending near the inversion spin, which can change the shape due to particle alignment [1].

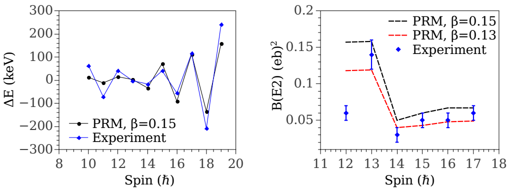

FIG. 2: Comparison of ΔE and B(E2) obtained experimentally and theoretically (PRM) showing the signature splitting and inversion.

Furthermore, the level lifetimes measurements of two positive parity bands of the same particle configurations were done. The trends of transition probabilities are not so far similar as compared to chiral bands in this mass region. In addition to it, the spectroscopic features of both bands are entirely different. The sideband is emerged due to the rotation of a well-deformed core, whereas the main band is more like due to quasi-particle excitation (like many possible backbends) or some sort of vibrating nature. The above observations help us to conclude the absence of chiral symmetry breaking in ^{126}I.

The second work is the lifetime measurements of the proposed chiral bands in ^{130}La. The lifetime measurements and corresponding transition probabilities of the main band have a close resemblance to the chiral bands. But due to the lack of statistics, the lifetime measurements of the partner band are still difficult. However, the contemporary group confirms that degenerate bands are chiral candidates. There is an absence of static chirality but the possibility of chiral vibration can not be ignored. We measured some more lifetimes for the low-lying states because of better recoil velocity in our data compared to them. The low-lying spin states measurements also follow the same transition probabilities selection rules which are theoretically proposed for the chiral bands. The clear observations of staggering in intra-band B(E2) and B(M1) values. The inter-band B(M1) values are in the opposite phase with the intra-band B(E2) and B(M1).

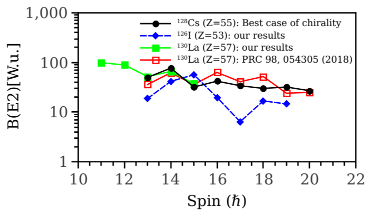

FIG. 3: B(E2) values of the main band and their comparison with other N=73 isotones.

At last, the possible chiral bands for the two nuclei studied are compared with the ^{128}Cs which can be considered as a best-case of chiral symmetry breaking in doubly odd nuclei. The measurements for ^{126}I and ^{130}La, have similar values of B(E2) as reported for ^{128}Cs as shown in Fig. 3. The ^{130}La can be considered as a chiral candidate [2]. But, the chiral phenomenon can be completely excluded in the case of ^{126}I.

Acknowledgments

I would like to thank and show my heartfelt gratitude to my supervisor Professor Pragya Das. I gratefully acknowledge financial support from IIT Bombay and MHRD and thank all my lab mates, the INGA collaboration, and the accelerator staff at IUAC. The Department of Science and Technology (Project Grant No. IR/S2/PF-03/2003-III) is thankfully acknowledged for the Indian Gamma Array collaboration.

References

[1] H. K. Singh, P. Das, *et al.*, Phys. Rev. C 100 (6), 064306, (2019).
[2] P. Das, H. K. Singh, *et al.*, Acta Phys. Pol. B 51 (1) (2020).