Study of ^{116}Sb: an ensemble of single particle as well as collective structure

Shabir Dar[1,2], Soumik Bhattacharya[1,2*], S. Bhattacharyya[1,2], R. Banik[1,2], S. Nandi[1,2], G. Mukherjee[1,2], S. Das Gupta[3], Sajad.Ali[4,2], S. Chatterjee[5], S. Das[5], A.Dhal[1], S. S. Ghugre[5], A. Goswami[4], D. Mondal[1,2], S. Mukhopadhyay[1,2], S. Pal[1,2], D. Pandit[1], R. Raut[5], P. Ray[4], S. Samanta[5]

[1]*Variable Energy Cyclotron Center, Kolkata, India*
[2]*HBNI, Anushaktinagar, Mumbai, India*
[3]*Victoria Institution (College), Kolkata, India*
[4]*Saha Institute of Nuclear Physics, Kolkata, India*
[5]*UGC-DAE CSR, Kolkata Centre, Kolkata, India*
** email: soumik@vecc.gov.in*

Introduction

The studies of Antimony have provided a lot of interesting physics because of its proximity to magic nucleus (Z = 50) and the coexistence of single-particle and collective levels side by side. As the odd proton resides in the $g_{9/2}$ β-upsloping orbital near to the shell closure, it will mainly posses single-particle levels at low excitation energy and less deformation. With increasing excitation energy the single proton will occupy $g_{7/2}$ orbital and for the β-downsloping effect of $g_{7/2}$ orbital the nucleus is dragged towards deformation and may exhibit collective structure [1-2]. The same type of behavior has also been observed in the odd mass ^{117}Sb nucleus where the structure is mainly obtained from the coupling of the odd valence proton occupying the available valence orbitals to the corresponding core [3]. Along with that, for ^{116}Sb (N=65), due to the presence of odd valance neutron near mid shell region, the collectivity in this nucleus can be enhanced. Moreover, an indication of magnetic rotational structure has also been reported earlier in ^{116}Sb. Thus the nucleus can be used to explore the competition between single-particle and collective excitations. Present work is aimed to establish the magnetic rotational structure and other yrast and near-yrast single particle excitations.

Experiment

The excited states of the ^{116}Sb has been populated by using the reaction ^{115}In(α, 3n)^{116}Sb at a beam energy of 40 MeV from the K-130 cyclotron at VECC, Kolkata. We have used the natural Indium (^{113,115}In) self-supporting foil as target. The γ-rays emitted from the decaying nucleus were detected by the INGA array at VECC, which comprised of 7 Compton suppressed Clover HPGe detectors at different angles with respect to the beam direction. Out of 7 detectors, 4 detectors were placed at 90°, 2 in backward 55° and 1 in forward at 40° angles with respect to beam direction. The target was placed 25 cm away from the aluminum face of the Clover detectors of the array.

Pre-amplifier pulse has been processed using PIXIE-16 digitizer based pulse processing and data acquisition system [4] and the data were collected in singles as well as in γ–γ coincidence mode. The backward and 90° detectors are used to determine the DCO ratio as well as the polarization asymmetry. Standard ^{152}Eu and ^{133}Ba source were used for calibration of the detectors and to measure the efficiency of each Clover detector as well as the INGA array. Data were sorted using a set of programs, IUCPIX [4] developed at UGC-DAE CSR, Kolkata.

Analysis and Results

The Compton suppressed time stamped data was analyzed using the Radware software package. A γ–γ coincidence matrix has been formed with the addbacks of all the 7 Clover detectors to obtain the coincidence relations between different γ-rays. A total of $2*10^8$ events were acquired in the experiment and the total projection spectrum of the γ–γ matrix are shown in the Fig. 1. The red color marked transitions

are from the ^{116}Sb nucleus while the black color marked transitions are the contribution from the other populated nuclei from natural indium.

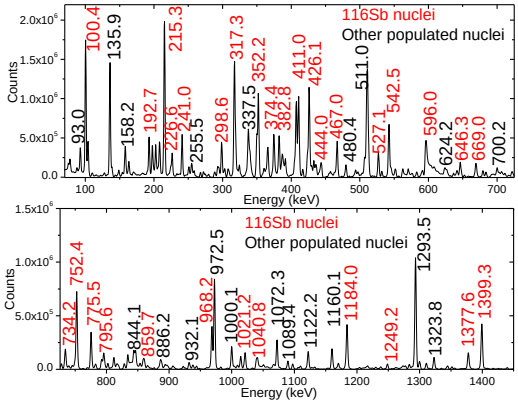

Fig.1: Full projection of γ–γ matrix showing the γ-rays detected in the current reaction.

New γ-transitions have been identified and placed in the level scheme from the preliminary analysis. Assignment of other observed new γ-transitions in the level scheme is in progress.

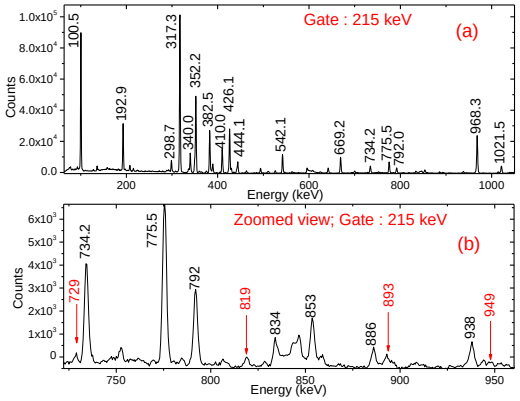

Fig. 2: (a) Gated spectra: gate at 215 keV, (b) Expanded view of 215 keV gate.

Fig. 2(a) represents the gate on 215 keV from E_γ-E_γ matrix which shows all the previously reported γ-rays which are in coincidence with it and Fig. 2(b) is the expanded view of Fig. 2(a), showing some new γ-rays (marked with red) which are identified as crossover transitions of already known dipole band structure. Fig. 3(a) represents the gate on 1399 keV and shows all the previously reported γ-rays which are in coincidence with it and the red marked transitions in the expanded view gated spectra Fig. 3(b) represents the newly observed transitions. The newly observed γ-rays in the gate of 1399 keV transition, connect to two sequences of levels which ultimately establishes a band like structure above the previously seen single particle structure. The multipolarity and the nature (E/M) of the newly placed γ-rays are therefore very important for confirmation of the above fact.

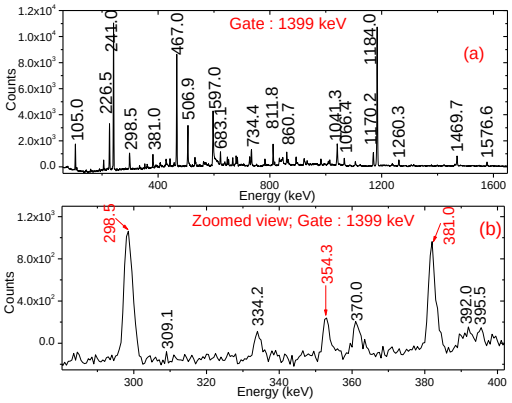

Fig. 3: (a) Gated spectra; gate at 1399 keV (b) Expanded view of 1399 keV gate.

Summary

New γ-rays in ^{116}Sb have been identified from primary analysis and placed in the level scheme from the coincidence relationship of various gates from the γ–γ matrix. The analysis of DCO and IPDCO matrices to find out the nature of these γ-rays as well as to place the observed new transitions in the level scheme is in progress.

Acknowledgement

We would like to thank INGA collaboration for their support and the Cyclotron operators of VECC, Kolkata for their sincere efforts in providing a very good quality Alpha beam. S.D acknowledges the financial support from UGC. INGA is partially funded by DST, Government of India (No. IR/S2/PF-03/2003-II).

References

[1] V. P. Janzen et al., PRL **72,** 1160 (1994).
[2] S. Y. Wang et al., PRC **86**, 064302 (2012).
[3] R. Banik et al., Proceedings of the DAE Symp. on Nucl. Phys. **62**, 124 (2017).
[4] S. Das *et.al.*, NIM A **893**, 138 (2018).