

## Oblate band structure based on $\pi h_{9/2}$ orbital in $^{199}\text{Tl}$

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### Introduction

The availability of high-j orbitals both for protons and neutrons near doubly magic shell closure  $^{208}\text{Pb}$  plays an important role to drive the nuclei in this region towards deformations and is also responsible for the presence of a series of low lying spin gap isomers [1]. Thallium nuclei ( $Z=81$ ) with one valance proton hole and few neutron holes outside the  $^{208}\text{Pb}$  core, are expected to have a spherical structure. However, the shape driving effect of intruder  $\pi h_{9/2}$  orbital imposes an oblate shape and a deformed coupled band based on  $\pi h_{9/2}$  configuration has been observed for all odd mass Thallium nuclei [2-4] near  $A\sim 200$  region. Such oblate band structures are known up to  $29/2\hbar$  for both  $^{201}\text{Tl}$  and  $^{197}\text{Tl}$  [2,3]. Oblate band structures built on  $\pi h_{9/2}$  orbital were also reported for  $^{199}\text{Tl}$  [5] but only up to  $19/2\hbar$  with tentative spin-parity assignments for most of the levels. Moreover, the single particle excitation of high-j intruder orbital,  $\pi i_{13/2}$  was observed in  $^{197}\text{Tl}$  [3] at 1953 keV, which also drives the nucleus towards oblate shape. It is interesting to find out whether this state is available also in  $^{199}\text{Tl}$  at low excitation energy.

### Experiment and Analysis:

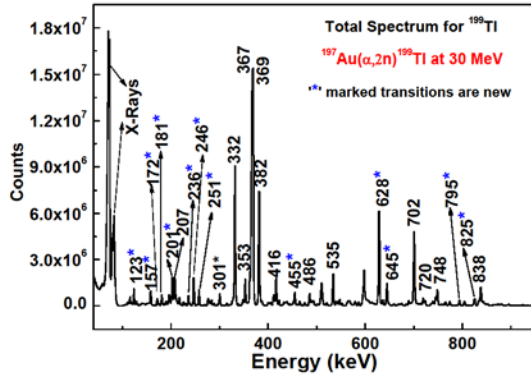
In the present work the excited states of  $^{199}\text{Tl}$  were populated using 30 MeV  $\alpha$  beam from K130 Cyclotron at VECC, Kolkata, with fusion evaporation reaction  $^{197}\text{Au}(\alpha,2n)^{199}\text{Tl}$ . In alpha induced reaction, a unique reaction channel can be populated with large cross section (estimated to be 1050mb for  $^{199}\text{Tl}$  out of 1100mb total cross section in this case) with very little overlap of other neighboring neutron evaporation channels at particular beam energy. The decaying  $\gamma$  rays

from the excited states were detected using **VECC** array for **NUclear Spectroscopy** (VENUS) at VECC, consisting of six Compton suppressed Clover HPGe detectors. Two detectors were placed at forward  $45^\circ$  and  $55^\circ$ , two at  $90^\circ$ , and the rest two at backward  $30^\circ$  angles with respect to the beam direction and at the distance of 26 cm from the target position. To process the signals from Clover detectors, 16 channel Mesytec amplifiers were used and the standard NIM analogue electronics were used for the BGO shields and for other trigger logics. The data were collected with high resolution VME ADCs and VME based data acquisition system using LAMPS. The trigger conditions for the experiment were both, singles mode (for angular distribution measurement) and doubles mode (for  $\gamma$ - $\gamma$  coincidence). TAC spectra were used to select the prompt transitions. Data were sorted using LAMPS, INGASORT and Radware software packages. A  $\gamma$ - $\gamma$  matrix has been formed to verify the coincidence relations of the  $\gamma$  rays. A matrix has also been formed using the data from two detectors at backward  $30^\circ$  in y-axis and other two detectors at  $90^\circ$  in x-axis to find out the Directional Correlation from Oriented states (DCO ratio) for various transitions. The  $90^\circ$  detectors are used for the measurements of Integrated Polarization from Directional Correlation of Oriented states (IPDCO) for assigning the parity of the states.

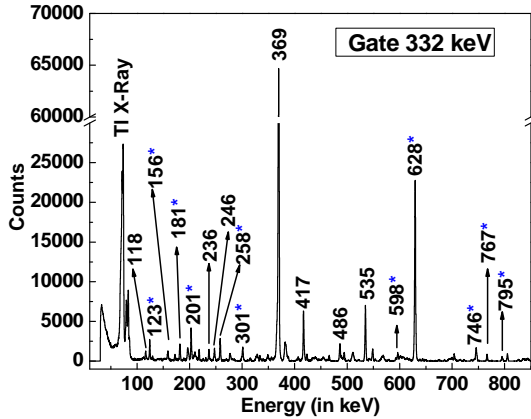
### Results:

The total projection from the  $\gamma$ - $\gamma$  coincidence matrix is shown in Fig.1. It can be seen from Fig.1 that the total spectrum is dominated mainly by the transitions from  $^{199}\text{Tl}$ . The known doublet of 367 and 369 keV can be distinguished clearly

from the spectrum. Gate on 332 keV known transition of  $\pi h_{9/2}$  band shows many new  $\gamma$  rays, as can be seen from Fig.2. The 628 keV transition was tentatively assigned from the previous study of Electron Capture (EC) decay of the 12.2 min isomeric state of  $^{199}\text{Pb}$  [6] and  $^{197}\text{Au}(\alpha,2n\gamma)$  reaction [1]. Presence of a new side band, connected to the main yrast band by 628 keV transition is evident from this coincidence spectrum.



**Fig 1:** Total projection from  $\gamma$ - $\gamma$  matrix, showing transitions in  $^{199}\text{Tl}$ . New transitions are marked with \*.

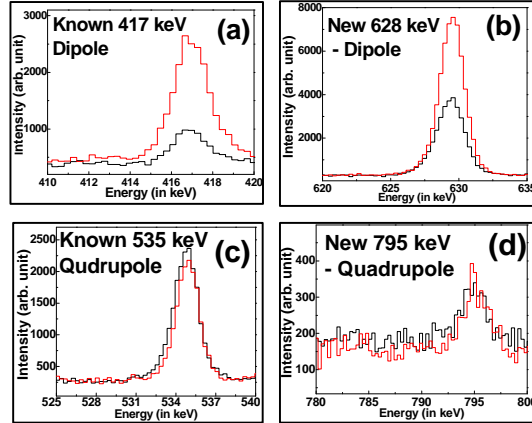


**Fig. 2** Coincidence spectrum of known 332 keV gate. New transitions are marked as ‘\*’.

The preliminary analysis indicates that the main yrast band based on  $\pi h_{9/2}$  orbital can be extended up to higher spins compare to the previous work [5] with the placement of new transitions. The DCO ratio is defined by

$$\text{DCO} = \frac{I_{\gamma_1 \text{ at } \theta_1(150^\circ), \text{ gated by } \gamma_2 \text{ at } \theta_2(90^\circ)}}{I_{\gamma_1 \text{ at } \theta_2(90^\circ), \text{ gated by } \gamma_2 \text{ at } \theta_1(150^\circ)}}$$

The overlap of the spectra according to the DCO ratio definition clearly indicates the multiplicities of some of the known and new transitions, as shown in Fig.3, in a known quadrupole gate of 702 keV.



**Fig. 3:** (Colour online) Projected spectra of DCO matrix for (a) Known dipole (b) New dipole (c) Known quadrupole (d) New quadrupole transitions in  $^{199}\text{Tl}$ . Black (Red) spectrum is the projection at  $30^\circ(90^\circ)$  detectors when gated by known quadrupole transition of 702 keV at  $90^\circ(30^\circ)$  detectors.

### Conclusion:

Preliminary analysis shows several new transitions which can be assigned to  $^{199}\text{Tl}$  from the present data. Two band like structures with  $9/2^-$  and  $1/2^+$  as band heads are observed. The population of  $^{199}\text{Tl}$  with  $\alpha$ -beam opens up a wide possibility to study of both yrast and non-yrast states, as it is observed from the current work. The multiplicities of the transitions are found from the DCO ratio measurements. The analysis of polarization to determine the parity of the states and the angular distribution analysis from the singles data for the calculations of mixing ratios and  $\Delta J$  of the transitions are in progress.

### References

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