# High spin band structure in $^{200}$Tl

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## Introduction

The nuclei of mass 200 region with a few particles and holes configuration near the $^{208}$Pb doubly magic shell closure has drawn considerable experimental and theoretical attention in the past few decades. In this context, band structure of Thallium isotopes (Z=81) with one proton hole to Z=82 shell closure are interesting to investigate as a function of angular momentum to understand the various angular momentum coupling of the valence particles or holes with the underlying core. For the Tl isotopes in mass 190-200 region, the quasiparticle excitation to $\pi h_{9/2}$ and quasi-hole excitation to $\nu i_{13/2}$ orbitals stabilize the nuclei to oblate deformation. A two- quasiparticle rotational band structure based on $\pi h_{9/2}\otimes\nu i_{13/2}$ configuration has been observed in odd-odd Tl nuclei in this mass region [1-5]. Alignment of two more $i_{13/2}$ neutrons, leading to a band structure of four- quasiparticle configuration at higher spin has been observed in $^{194}$Tl [2]. Other than this yrast band, presence of a possible chiral partner band of above configuration have been reported in $^{194}$Tl [2], $^{198}$Tl [4]. In $^{194}$Tl, a band of six-quasiparticle configuration has been also characterized as magnetic rotation band [1]. On the other hand, in heavier isotopes, coupling with octupole vibration states in Pb core becomes important in generating excited states as observed in $^{204}$Tl [5]. With this variety of band structures reported for the odd-odd Tl isotopes, it would be interesting to investigate the detailed band structure of the odd-odd isotope $^{200}$Tl. Knowledge of high spin states in $^{200}$Tl was very limited prior to the present work, except that of Ref.[6], which was carried out with limited numbers of Ge(Li) detectors.

## Experiment and Analysis

The high spin states in $^{200}$Tl have been populated in $^{198}$Pt($^{7}$Li,5n)$^{200}$Tl reaction using 45 MeV of $^{7}$Li beam from the BARC-TIFR Pelletron-LINAC facility at Mumbai. A self supporting enriched $^{198}$Pt foil of thickness 1.3mg/cm$^2$ was used. γ–γ Coincidence data have been taken using digital data acquisition system [7] and 15 Clover HPGe detectors of Indian National Gamma Array (INGA) setup at TIFR. Further details of the experimental setup are given in Ref.[8]. After gain matching of the energy spectra of all the detectors, γ-γ matrices with various time windows and a γ-γ-γ cube were formed to establish the coincidence relationships among the observed gamma transitions using RADWARE and INGASORT analysis packages. To find out the multipolarity of newly placed γ-rays, DCO ratios were deduced from a correlation matrix, formed with data of -23˚ detectors at x-axis and 90$^o$ detectors in the y-axis. For polarization asymmetry ratio, two matrices, corresponding to parallel and perpendicular scattering to the crystals of 90˚ detectors with respect to coincidence gamma rays in all the other detectors, were formed.

## Discussion

Considerable extensions of the main band with many new transitions de-exciting from higher spin states and a new positive parity side band have been observed in $^{200}$Tl from the present work. The $\pi h_{9/2}\otimes\nu i_{13/2}$ yrast band is extended to higher spins upto excitation energy

of 4.3 MeV and spin of 20ħ. The energy staggering, defined as S(I) = [E(I)-E(I-1)]/2I, where E(I) is the energy of the state with spin I, of the yrast band in $^{200}$Tl along with the same band of other odd-odd Tl isotopes are plotted in Fig.1 as a function of spin.

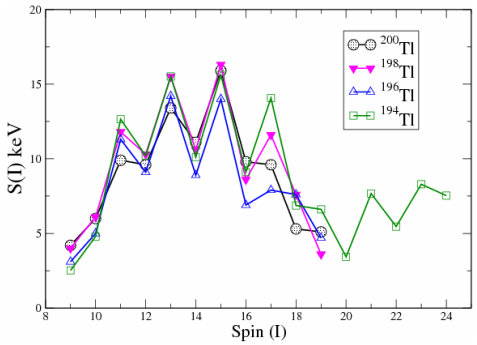


**Fig 1:** Energy staggering of $\pi h_{9/2} \otimes \nu i^{-1}_{13/2}$ band as a function of spin for odd-odd Tl isotopes.

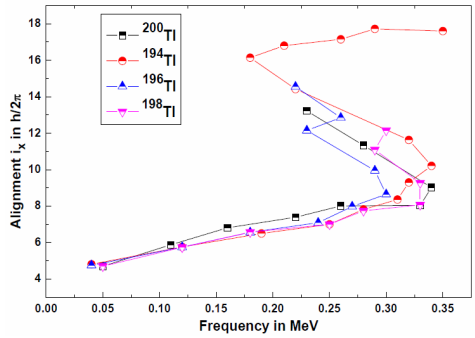


**Fig 2:** Comparison of alignment ($i_x$) as a function of frequency (ħω) of $\pi h_{9/2} \otimes \nu i^{-1}_{13/2}$ band for the odd-odd Tl isotopes.

It can be seen from Fig.1 that the staggering plot of all the odd-odd Tl isotopes have remarkable similarities including that of $^{200}$Tl. The staggering feature shows a low spin signature inversion at I=11 and there is a certain change in the staggering pattern of this band after I=16 for all the even-A Tl isotopes shown in Fig. 1 . This indicate that the similar structure continues to persist for N = 119 in $^{200}$Tl. The plot of aligned angular momentum ($i_x$) is shown in Fig.2. It is found that the alignment of the yrast band in $^{200}$Tl follows the same nature up to the crossing frequency of 0.33 MeV (corresponds to I=16), as in all the neighboring isotopes. A gain in alignment of > 5ħ has been observed after the band crossing. This is interpreted as due to the alignment of a pair of $i_{13/2}$ neutrons, making the band structure beyond the 16$^-$ spin as four quasiparticle configuration $\pi h_{9/2} \otimes \nu i^{-3}_{13/2}$.

The new side band observed in $^{200}$Tl is determined to be of positive parity. This band decays strongly to the main yrast band through the parity changing transitions of either E1 or M2 type. The multipolarity and nature of these connecting transitions are extracted from the DCO ratio and the polarization asymmetry ratio. The plot of excitation energy and staggering pattern of the side band as a function of spin (I) are plotted in fig. 3(a-b) and compared with those of the main band. It is observed that the side band shows very similar excitation energy and staggering pattern as the main band beyond the first crossing. The excitation energy and spin indicate that this band is probably built on a four quasiparticle configuration $\pi h_{9/2} \otimes \nu i^{-2}_{13/2} \nu j$, where j can be either of $f_{5/2}$, $p_{3/2}$, $p_{1/2}$. Further investigation in this regard is in progress.

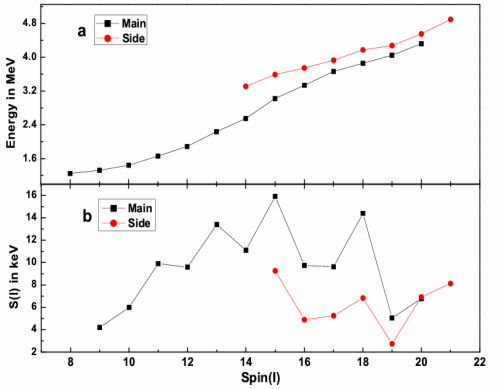


**Fig. 3:** (a) excitation energy and (b) S(I) as a function of spin (I) of the side and main band observed in $^{200}$Tl.

## References

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