Study of multi-quasiparticle band structures in ^{197}Tl using α beam

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Introduction

Study of the multi-quasiparticle (qp) states and the band structures built on them in the neutron deficient Tl nuclei in A ~ 190 mass region provides useful information on particle-hole interaction in the heavy nuclei. The ground states of the odd-A Tl nuclei are $1/2^+$ [1, 2, 3] corresponding to the proton hole in the $3s_{1/2}$ orbital below the Z = 82 spherical shell closure. However, the shape driving high-j $\pi h_{9/2}$ and $\pi i_{13/2}$ orbitals come down in energy with deformation and intrude into the region of proton Fermi level. On the other hand, the high-j $\nu i_{13/2}$ orbital becomes available for neutrons for the neutron number N < 114. Therefore, competing shape driving effects of the high-j proton and neutron orbitals and the spherical shell closures play crucial roles for the structure of the high-spin multi-qp states in neutron deficient Tl nuclei in A = 190 mass region.

Rotational bands based on the intruder ´[505]9/2ˉ Nilsson state have been observed in the chain of $^{189\text{-}197}$Tl isotopes with different types of particle-core couplings [4-8]. The moments of inertia (MoI) of Tl isotopes, deduced by fitting these bands by rotational model formula, are shown in Fig.1. An abrupt change, seen at N = 108, is associated with the transformation from decoupled to strongly coupled band. Another small change at N = 114 may be associated with the availability of $\nu i_{13/2}$ orbital for neutrons. Data on multi-qp states in these Tl isotopes are scarce. In ^{197}Tl, which falls in the third region in Fig.1 with relatively low MoI, two 3-qp bands are reported [9]. The 2nd (new) one of those, had very low statistics and the coincidence relation was not verified.

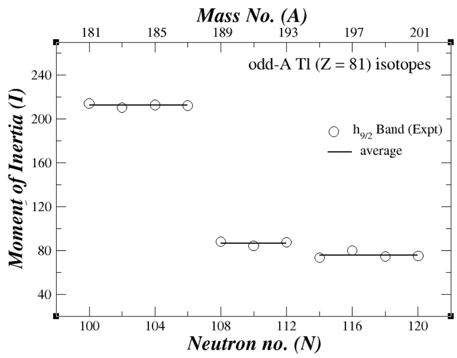

Fig.1: Moments of Inertia in Tl isotopes deduced from the observed rotational bands based on $\pi h_{9/2}$ orbital.

In order to investigate the multi-qp band structures we have studied the excited states in ^{197}Tl by gamma ray spectroscopy.

Experimental Details

Excited states in ^{197}Tl were populated by the α-induced fusion-evaporation reaction ^{197}Au(^{4}He, 4n)^{197}Tl at 50 MeV of beam energy from the K-130 Cyclotron at VECC, Kolkata. The target was a self-supporting 5 mg/cm^2 gold foil. The emitted ɔ rays were detected using the VENUS array consists of 6 Compton-suppressed clover Ge detectors. The detectors were in 6 angles with 2 each at ±30^o (backward) and ±90^o, other two were at the forward 45^o and 55^o angles with respect to the beam direction in median plane. A VME data acquisition system was used.

To construct the level scheme, a total ɔ-γ matrix was made with coincidence time window of ±25 ns from the prompt peak of RF-ɔ TAC and γ–γ TAC. The matrix contained about 3.4 × 10^8 γ–γ coincidence events. DCO and the polarization (IPDCO) matrices were constructed to assign spin and parity (J^{π}) of the states from the multipolarity (λ) and the type (E/M) of the emitted γ-rays. The LAMPS and the RADWARE codes were used for the analysis. Fig. 2 shows a total projection spectrum from the γ–γ matrix. All the known γ-rays in ^{197}Tl (marked) including the ones with low statistics in band B3 in Ref. [9] are clearly observed in this spectrum. Several new transitions are also seen in this spectrum most of which belong to ^{197}Tl.

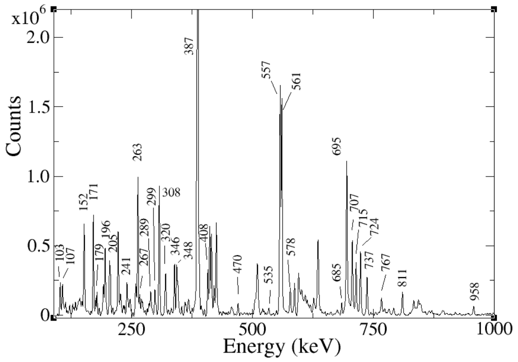

Fig.2: Total projection spectrum from the γ–γ matrix. Known γ-lines of ^{197}Tl are marked.

Results and Discussion

Out of the two 3-qp band-like structures reported in Ref. [9] as B2 (built on $15/2^{-}$) and B3 (built on $17/2^{(-)}$) the later was produced with low statistics with tentative placement of the levels and their J^{π} values, as the coincidence relation among the γ-rays could not be established.

The coincidence relation in this band could be established with much better statistics in our work,. The gated spectra with gates put on 179-keV and 241-keV γ-rays belonging to the band B3 in ^{197}Tl are shown in Fig. 3. The bunch of γ-lines belonging to this band along with the other known γ-lines in ^{197}Tl are seen in these spectra which establishes that these γ-rays indeed belong to ^{197}Tl. The 361-keV γ-ray was earlier placed in such a way that it was supposed to be in coincidence with both 179 and 241 keV γ-rays. But it is seen from Fig. 3 that 361-keV is in coincidence with 241-keV but not with 179-keV. This clearly suggests a modification of the band B3. Moreover, a few new transitions in the $\pi h_{9/2}$ band are also observed indicating band-crossing and 3-qp structure in this band as well.

Summary and Conclusion

γ-ray spectroscopy of ^{197}Tl was performed at VECC using α-beam and the VENUS setup. Proper coincidence relation could be established from the higher γ–γ statistics in this experiment which indicates that a modification of the band B3 is required. The detailed analysis is in progress to establish a correct level scheme and to assign spin and parity of the levels.

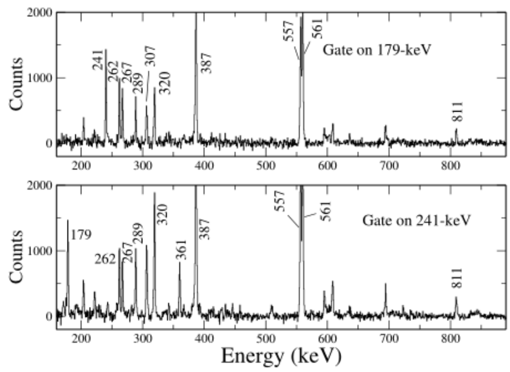

Fig. 3 Single gated spectra of ^{197}Tl gated by 179-keV and 241-keV transitions in band B3 [9].

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