Shears Band based on a large multi-qp configuration in ^{195}Tl

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Introduction

The data available for shears band in A∼190 region [1, 2] shows the following properties →

1. The bands exihibit ΔI=1 structure and the level energies follow the pattern of E-E_0∼$A_0(I-I_0)^2$ where E_0 and I_0 are the band head energy and spin respectively.

2. The bands consist of strong M1 transitions with only very weak or no E2 crossovers resulting in large B(M1)/B(E2) ratios, ≥20$\mu_N{}^2/(eb)^2$ and B(M1)∼ 2-10$\mu_N{}^2$.

3. They are usually observed in near spherical nuclei, having very small oblate, prolate or triaxial deformation.

4. The bandheads lie at high excitation energy (a few MeV), has a high spin (I∼10-15$\hbar$) and a high value of K, indicative of multi-quasiparticle character involving high j orbitals.

5. The ratio of dynamic moment of inertia $J^{(2)i}$ to the B(E2) is large, $J^{(2)}$/B(E2) > 100 MeV$^{-1}(eb)^{-2}$.

Recently, shears bands built on multi-quasiparticle states with up to 8 quasiparticleis (qp) have been obsrved in odd-odd Tl and Bi isotopes [3, 4]. Recently we have proposed a new and improved level scheme of ^{195}Tl based on the data taken in the recently concluded INGA campaign at TIFR, Mumbai, in which a new band structure was reported at an excitation energy of about 4.2 MeV and a spin of 16.5$\hbar$ [5]. We have analysed this highly excited band in the light of the above criteria of shears bands and argue here that this band might be a magnetic rotatonal band though we do not have the lifetime measurement to substatiate our argument with the measured B(M1) values.

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Results and Discussion

This newly observed band consists of predominently M1 γ transitions and two weak E2 cross-over transitions. The B(M1)/B(E2) ratio ≥ 17 $\mu_N{}^2/(eb)^2$ and the dynamic moment of inertia $J^{(2)} \sim 42\ \hbar^2 MeV^{-1}$ are obtained for this band. The aligned angular momenta

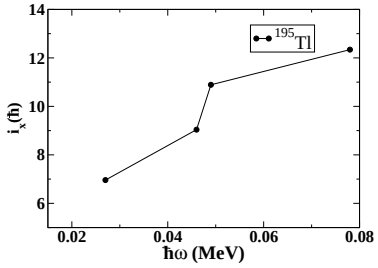

FIG. 1: Plot of aligned angular momentum vs. $\hbar\omega$ of the new band in ^{195}Tl.

are plotted for this band as a function of $\hbar\omega$ in Fig.1. It shows that the initial alignment of this band is about 7$\hbar$, which is quite large compared to the other bands in this nucleus [5], indicating multi-qp configuration for this band. Considering the spin, parity and excitation energy of this band, the available proton and neutron single particle levels and the configuration of similar bands in the neighboring Pb isotopes [6], two possible configurations could be assigned to this band; a 5-qp configuration $\pi s_{\frac{1}{2}}^{-1} h_{\frac{9}{2}} i_{\frac{13}{2}} \otimes i_{\frac{13}{2}}^{-2}$ and a 7-qp configuration $\pi s_{\frac{1}{2}}^{-1} h_{\frac{9}{2}} i_{\frac{13}{2}} \otimes i_{\frac{13}{2}}^{-2} p_{\frac{3}{2}} f_{\frac{5}{2}}$. Considering the fact that for both protons and neutrons high-Ω $\nu i_{13/2}$ orbitals are available for slighly

oblate deformation for this nucleus, the observed aligned angular momentum would not be possible for the 5-qp configuration. Therefore, the 7-qp particle configuratiuon is assigned to this band.

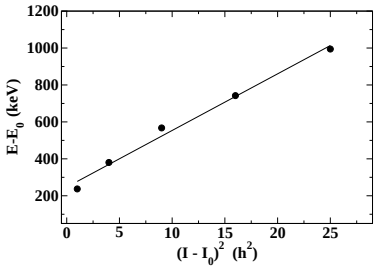

FIG. 2: E-E_0 vs. (I-I_0)^2 curve for the new band build on $\frac{33}{2}^{(-)}$ bandhead in ^{195}Tl.

The level energies of this band relative to the band head energy E-E_0 are plotted as a function of (I-I$_0$)^2, where I$_0$ is the band head spin, in Fig.2 and are fitted with a linear function. The Total Routhian Surface (TRS) calculations for the 7-qp configuration of this nucleus has been performed and it shows the minimum of the TRS corresponds to deformation $\beta_2 \sim 0.1$ and $\gamma \sim -40°$, indicating small deformation which is compatible with the low B(E2) value for the above configuration. Therefore, this band shows the characteristic behaviour of a shears band.

Following the semi-classical model of Macchiavelli et. al.,[2] the shears angle between the proton (j_π=$\frac{21}{2}^{-}\hbar$) and neutron ($j_\nu = 13^{+}\hbar$) spin angular momentum is determined using the semi-classical expression,

$$cos\theta = \frac{j_\pi \cdot j_\nu}{\mid j_\nu \mid\mid j_\nu \mid}$$

$= ((\mathrm{I(I+1)\text{-}j}_\pi(j_\pi+1) - j_\nu(j_\nu+1))/2((j_\pi(j_\pi+1)j_\nu(j_\nu+1))^{1/2}$(1)

where I is the total angular momentum, the gradual alignment of this two blades can give rise to the maximum angular momentum $\frac{47}{2}^{-}$ at the band termination. In the present case the angular momentum upto ($\frac{41}{2}^{-}$) have been observed, which is perhaps limited by the maximum angular momentum that can be populated in the reaction used [5].

The effective interaction strength for the proton particle and neutron hole blades is determined using the equation

$$V(I(\theta)) = E_I - E_b = (3/2)V_2\ cos^2\theta_I \quad (2)$$

where E_I is the energy of the level with angular momentum I, θ_I is the corresponding shears angle as given in Eq.(1), E_b is the bandhead energy, V_2 is the strength of the interaction between the blades of the shears. So V_2 can be calculated by using the experimentally observed energy levels of the shears band. In Fig. 3 $V(I(\theta))$ is plotted as a function of θ and V_2, for this 7-qp configuration, come out to be 2086 keV. This corresponds to an effective interaction of 348 keV per particle hole pair which is in good agreement with the same observed in this mass region [3, 4].

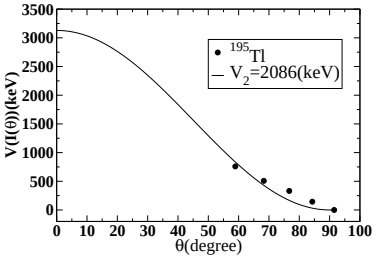

FIG. 3: The effective interaction between the angular momentum vectors, j_π and j_ν as a function of shears angle θ obtained in a semiclassical formalism.

References

[1] Amita, A. K. Jain, and B. Singh, At. Data. Nucl. Data Tables **74**, 283 (2000).

[2] R. M. Clark and A. O. Maccihiavelli, Annu. Rev. Nucl. Part. Sci **50**, 1 (2000).

[3] H. Pai et al., Phys. Rev. **C 88**, 064302 (2013).

[4] H. Pai et al., Phys. Rev. **C 90**, 064314 (2014).

[5] T. Roy et. al., Proc. DAE-BRNS, Symposium on Nuclear Physics. Vol **59**, 88 (2014).

[6] A. K. Singh et al., Nucl. Phys. **A 707**, 3 (2002).