3qp IBs based on different bandhead spin

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Introduction

A comprehensive study of high-K three-quasiparticle rotational bands in odd-A nuclei indicates the similarity in γ-ray energies and dynamic moment of inertia $\Im^{(2)}$. In article [1], specific examples from the experimental data on IBs in 3qp high-K rotational bands based on different band head spin in five pairs of nuclei viz. (^{163}Er,^{175}Ta), (^{163}Er,^{181}Ir), (^{177}Lu,^{179}Ta), (^{171}Hf,^{177}Re) and (^{175}Ta,^{181}Ir) have been discussed. By Tilted-Axis Cranking (TAC) model calculations, it is established that the identical nature between 3qp rotational bands is attributed to the interpaly of structure parameters, pairing correlations and the Nilsson orbital configurations of nuclei.

TAC model and calculations

In this model, the mean field Hamiltonian of a rotating field for either neutrons or protons, is written as:

$$\begin{aligned} h' &= h_{sp} - \Delta(P^+ + P) - \lambda N \\ &- \omega(J_1 \sin\theta + J_3 \cos\theta). \end{aligned}$$

Here, h_{sp} is the single particle Nilsson Hamiltonian in a deformed mean field as given below [2]:

$$h_{sp} = V_{osc} + \kappa \mathbf{l}.\mathbf{s} + \mu(l^2 - < l^2 >),$$

where V_{osc} is a harmonic oscillator potential whose frequencies are parameterized by Nilsson's alternative set of the deformation parameters ϵ and γ:

$$\omega_\nu = \omega_0 \Omega_\nu; \Omega_\nu = \left[1 - \frac{2}{3}\epsilon_2 \cos\left(\gamma - \frac{2\pi\nu}{3}\right)\right]$$

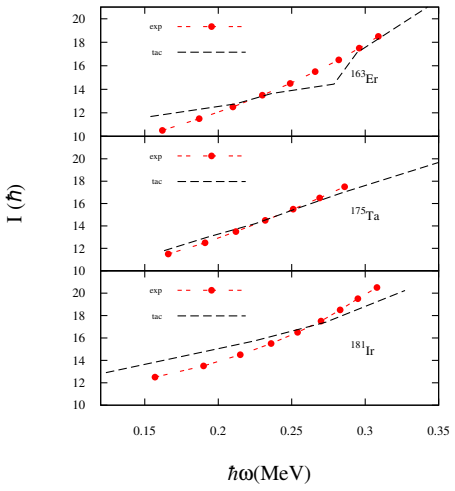

FIG. 1: $I(\hbar)$ vs. $\hbar\omega$(MeV) plot establishing identical nature among the 3qp rotational bands of ^{163}Er, ^{175}Ta and ^{181}Ir nuclei.

with $\nu = 1, 2, 3$ and ω_0 is oscillator's frequency which is fixed by volume conservation condition [2]. The monopole pairing operator P together with the gap parameter Δ determines the pairing field. We have chosen Δ_p and Δ_n as 80% of the odd-even mass difference for protons and neutrons, calculated using the expressions as given in [3]. The chemical potential λ is fixed to reproduce the correct particle number at $\omega = 0$.

We carry out planar TAC calculations by keeping $\phi = 0°$. The angle θ decides the tilt of the cranking axis with respect to the z-axis in the x-z plane of the intrinsic frame of reference and is calculated as

$$\tan\theta = \frac{\omega_1}{\omega_3} = \frac{J_1}{J_3},$$

where J_1 and J_3 are the components of the total angular momentum $\mathbf{I}$ along the 1 and 3

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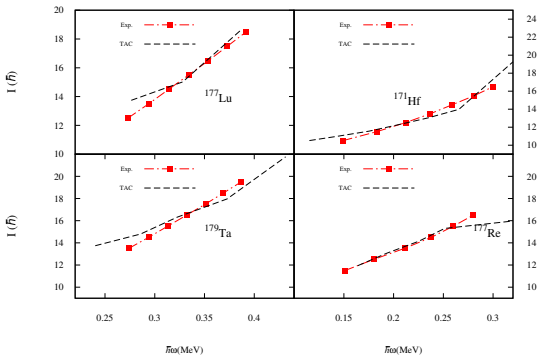

FIG. 2: On left panel, $I(\hbar)$ vs. $\hbar\omega$(MeV) plot for ^{177}Lu, ^{179}Ta nuclei and on right panel between bands of ^{171}Hf,^{177}Re nuclei

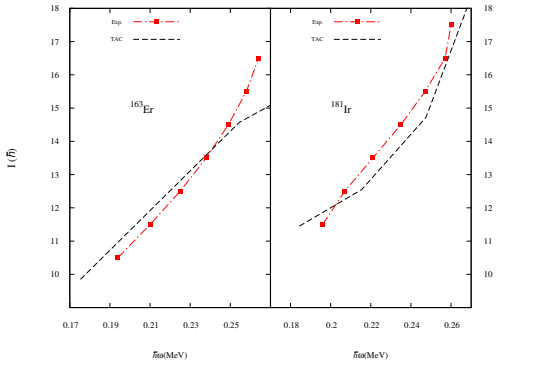

FIG. 3: $I(\hbar)$ vs. $\hbar\omega$(MeV) plot establishing identical nature between the 3qp rotational bands of ^{163}Er and ^{181}Ir

axis, respectively. The total Routhian $E(\omega)$ is calculated by using the Strutinsky renormalization technique [4],

$$E(\omega) = E_{LD} - E_{smooth} + < \omega \mid h' \mid \omega > . \quad (1)$$

The smooth part of the energy E_{smooth} is calculated by the Strutinsky's averaging method [4] and E_{LD} is the liquid drop energy which is given as in:

$$E_{LD} = (B_s - 1)\left[c_1 A^{2/3} + c_2 \frac{(N-Z)^2}{A^{4/3}}\right] + (B_c - 1)\frac{c_3 Z^2}{A^{1/3}}$$

where $c_1 = 17.9439MeV$, $c_2 = -31.9868MeV$ and $c_3 = 0.75031MeV$. The surface integral (B_s) and coulomb integral (B_c) are used as defined in [5].

The total Routhian (1) is then minimized with respect to the deformation parameters (ϵ_2,ϵ_4,γ) to obtain a self consistent minimum in total energy for a chosen configuration and a cranking frequency ω.

We then fix the deformation parameters at these values and calculate the total energy for each ω at the corresponding equilibrium tilt angles. TAC calculates the energy E as a function of rotational frequency. To compare the experimental results with the calculated ones, we transform the experimental energies into the rotational frequency by using the relation:

$$\hbar\omega(I) = E(I) - E(I-1).$$

Considering the bandhead angular momentum and parity, we have taken same configuration of high-K identical rotational bands for our calculations. In FIGs. 1-3, we plot the calculated angular momentum $(I(\hbar))$ vs. the rotational frequency $(\hbar\omega(\text{MeV}))$ for the pairs of nuclei exhibiting IBs and for comparison, we plot in the same figure (curve with solid circles and solid squares) the experimental data for these bands. The calculated bandhead spin-parity matches with the observed ones. A close and almost similar trend justify the identical nature.

References

[1] P. Singh, H. Kaur and S. S. Malik, DAE Symp. **60**, 174 (2015).
[2] I. Ragnarsson and S. G. Nilsson, Shapes and Shells in Nuclear Structure, Cambridge University Press, (2005).
[3] A. Bohr and B. R. Mottelson, Nuclear Structure Vol. 1, World Scientific, (1969).
[4] V. M. Strutinsky, Nuclear Physics A **95**, 420 (1967).
[5] W. D. Myers and W. J. Swiatecki, Nuclear Physics **81**, 1 (1966).