Theoretical Interpretation of Identical bands in normal deformed nuclei

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The striking feature of Identical bands at normal deformation was first pointed out by Jain and interpreted in terms of effective decoupling mechanism [1]. Similarities in γ-ray energies together with kinematic moment of inertia $\mathcal{I}^{(1)}$ and dynamic moment of inertia $\mathcal{I}^{(2)}$ lead to identicity in rotational bands of neighbouring nuclei. In normal defromed nuclei, low spins identical bands between adjacent even even and odd-mass nuclei occur because of the cancellation between the pairing deformation parameter [2].

The positive parity $\Delta I = 1$ bands having same configuration are identical in ^{173}Hf and ^{175}Hf nuclei but the same band of ^{171}Hf nucleus is quite different [3]. In the present work, we study the experimental data on 3qp bands having the configuration $\pi\frac{7}{2}[404] \otimes \pi\frac{5}{2}[402] \otimes \nu\frac{7}{2}[633]$ in normal deformed ^{171}Hf, ^{173}Hf and ^{175}Hf nuclei. This comparative study will help us to find certain factors and circumstances that may be responsible for the emergence of identical bands only in particular nuclei.

The kinematic moment of inertia $\mathcal{I}$ for the normal deformed nuclei in the presence of pairing correlations is aprroximated as follows:

$$\mathcal{I}^{(1)}_{exp} = \mathcal{I}_{\rm rigid}\left\{1 - \frac{ln[x+\sqrt{1+x^2}]}{x\sqrt{1+x^2}}\right\} \quad (1)$$

where $x = \frac{\delta\hbar\omega_0}{2\Delta}$ is a dimensionless quantity, which characterises the compensatory interplay measure between the deformation parameter(δ) and the pairing interactions (measured by gap parameter Δ) and $\hbar\omega_0 = \frac{41}{A^{1/3}}MeV$ [4].

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$\mathcal{I}_{\rm rigid}$ is the classical rigid-rotor moment of inertia and is given by $= \frac{2}{5}AMR^2(1+\frac{\delta}{3})$ where $R = 1.15A^{\frac{1}{3}}$fm. Equation (1) is solved for x i.e. $\frac{\delta\hbar\omega}{2\Delta}$, using deformation parameter (δ) as (0.2495, 0.256, 0.257) for ^{171}Hf, ^{173}Hf and ^{175}Hf [6] nuclei respectively. The values obtained are plotted vs. total angular momentum as shown in fig (1).

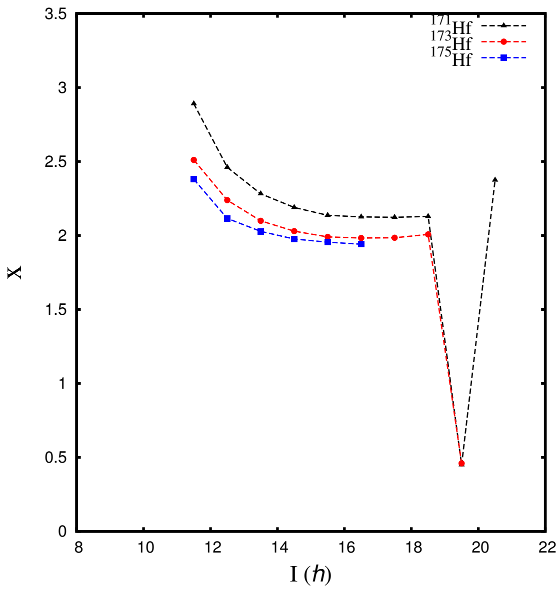

FIG. 1: $x = \frac{\delta\hbar\omega}{2\Delta}$ vs. I for bands of ^{171}Hf,^{173}Hf and ^{175}Hf nuclei.

The nuclei ^{173}Hf and ^{175}Hf, which are having the identical bands, have almost same value of x and it is quite different from that of ^{171}Hf nucleus. Although 3qp band of ^{171}Hf nucleus exhibits the same configuration as that of other two nuclei, yet it does not have identical band structure. This is because of different compensatory interplay between defromation and the pairing interactions. So, defromation and parinig interactions complement each other in similar fashion in identical bands so that the kinematic moment of inertia becomes similar.

Cranked shell model [5] is used to explain the identicity in the positive parity $\Delta I = 1$ band based on prolate shape in ^{173}Hf and ^{175}Hf. The modified oscillator potential has been used with standard parameters for normal deformed configuration of each isotope of Hf nucleus. The values of calculated Δ_p Δ_n and the corresponding values of $(\epsilon_2, \epsilon_4, \gamma)$ for each isotope are given in a table (I).

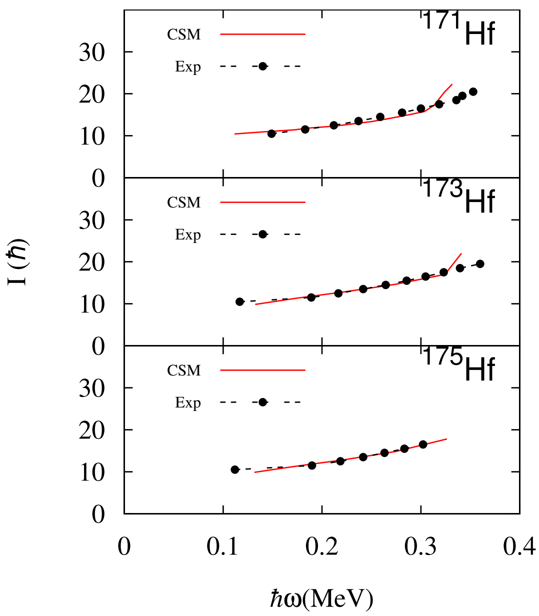

FIG. 2: $I(\hbar)$ vs. $\hbar\omega(MeV)$ for bands of ^{171}Hf, ^{173}Hf and ^{175}Hf nucleus.

It has also been confirmed that inspite of same 3qp configuration ($\pi\frac{7}{2}[404] \otimes \pi\frac{5}{2}[402] \otimes \nu\frac{7}{2}[633]$), rotational band in ^{171}Hf is quite different. The calculated BM1/BE2 values are also in agreement with the experimental ones.

In conclusions, the cranked shell model explains the feature of identicity of positive parity $\Delta I = 1$ band in ^{173}Hf and ^{175}Hf nuclei. Inspite of same 3qp configuration, the band obtained for ^{171}Hf is not identical to bands of other two isotopes. Also, the defromation to pairing interactions ratio is determined. This ratio is similar for Hf Isotopes (^{173}Hf and ^{175}Hf) having identical 3qp bands and quite different from that of ^{171}Hf nucleus. We conclude that compensatory interplay between deformation and pairing interations plays an important role in making the rotational bands of different nuclei identical.

TABLE I:

	$\Delta_p(MeV)$	$\Delta_n(MeV)$	ϵ_2	ϵ_4	γ^0
^{171}Hf	0.8307	0.6843	0.2495	0.0185	0
^{173}Hf	0.6765	0.718	0.256	0.0285	0
^{175}Hf	0.651	0.5844	0.257	0.0385	0

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