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Signature Splitting in 7/2 [633]$_\nu$ band of ^{175}Hf

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Abstract. In this paper, we present an explanation of signature splitting observed in the one quasiparticle rotational band (7/2[633]$_\nu$) of ^{175}Hf in terms of one particle plus rotor model (PRM) calculations. The role of angular momentum dependence of the inertia parameter and rotational correction term appearing in Coriolis mixing calculations to explain signature effects is discussed.

1 Introduction

It is well known that the moment of inertia and its dependence on angular momentum is slightly different in case of odd-A nuclides as compared to the neighboring even-even nuclides. This difference in the moment of inertia and its dependency on angular momentum originate from the larger deformation and weaker pairing correlations observed in the case of odd-A nuclides [1]. Coriolis mixing is assumed to be a possible cause for signature effects observed in Odd-A nuclei [2,3]. But in the present calculations, we present a minute inspection of the Coriolis mixing calculation to explore the active role of various terms such as angular momentum dependence of inertia parameter ($A_K\left(I\right)$) and Rotational Correction Term (RCT) in explaining the observed signature splitting in the one-quasineutron ($7/2[633]_\nu$) band of ^{175}Hf [4].We focused on this band in particular because it exhibits almost negligible staggering in the low spin region and pronounced staggering at high spin and hence is a good example for understanding the active role of various terms in explaining negligible and pronounced signature splitting in one quasiparticle (1qp) bands.

2 Formulation

The single particle Hamiltonian in a deformed Odd-A nucleus can be written as

$$H = H_{Nilsson} + H_{Pairing} + H_{Rot} \tag{1}$$

where $H_{Nilsson}$, $H_{Pairing}$ and H_{Rot} are the Hamiltonian's corresponding to odd nucleon, pairing gap and rotor, respectively.

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For an axially symmetric deformed core, H_{Rot} can further be written as

$$H_{Rot} = H_{rot}^{(0)} + H_{rec} + H_{Cor} \tag{2}$$

where $H_{rot}^{(0)}$, H_{rec} and H_{cor} are rotational, recoil and Coriolis terms and are given by

$$H_{rot}^{(0)} = \frac{\hbar^2}{2\Im}(I^2 - I_3^2) \tag{3}$$

$$H_{rec} = \frac{\hbar^2}{2\Im}(j^2 - j_3^2) \tag{4}$$

$$H_{cor} = -2\frac{\hbar^2}{2\Im}(I_1 j_1 + I_2 j_2) = -\frac{\hbar^2}{2\Im}(I_+ j_- + I_- j_+) \tag{5}$$

Thus, the total Hamiltonian given by eq. (1) becomes

$$H = H_{Nilsson} + H_{pairing} + H_{rot}^{(0)} + H_{rec} + H_{Cor} \tag{6}$$

The unperturbed rotational energies which appears from diagonal term of the total Hamiltonian are given as

$$E_k(I) = E_b(K) + A_K(I) \times [I(I+1) - K^2 + \delta_{K,1/2}(-1)^{I+\frac{1}{2}} a(I+\frac{1}{2})] \tag{7}$$

where a is the decoupling parameter and $A_K(I)$ is the rotational parameter for the unmixed bands. The angular momentum dependence of the inertia parameter appearing through $A_K(I)$ is given by [5]

$$A_K(I) = \frac{\hbar^2}{2\Im} + B[I(I+1) - K(K+1)] \tag{8}$$

In the present calculations, we consider $\frac{\hbar^2}{2\Im}$ and B as free parameters. The band head energies can be written

$$E_b(K) = \sqrt{(\varepsilon_K - \lambda)^2 + \Delta^2} - \sqrt{(\varepsilon_{K_0} - \lambda)^2 + \Delta^2} + A_K(K)[f(j,K) - f(j,K_0) - K_0] \tag{9}$$

where $f(j,K)$ and $f(j,K_0)$ are the rotational corrections to the band-head energies and given as

$$f(j,K) = \langle j^2 \rangle - \langle j_3^2 \rangle = \sum_j C_{j,l}^2 j(j+1) - K^2 \tag{10}$$

The single particle energies ε_K of the excited states and ε_{K_0} of ground states as well as the Nilsson coefficients, $C_{j,l}$ are calculated from the Nilsson model with the deformation parameters ε_2 and ε_4 and the potential parameters κ and μ .The Fermi energy λ is a free parameter and the half energy gap Δ is calculated from odd-even mass difference [6].

3 Result &Discussion

We present the PRM calculations for the quasineutron band ($7/2[633]_{\nu}$) observed in ^{175}Hf . The single particle neutron energies were calculated from the Nilsson model with potential parameters, $k = 0.0636$ and $\mu = 0.393$ [7] and with ground state deformations $\varepsilon_2 = 0.258$ and $\varepsilon_4 = 0.060$ [8]. We particularly focused on this band because it exhibits negligible splitting at low spins ($7/2 \le I \le 19/2$) and pronounced signature splitting at high spins ($19/2 \le I \le 33/2$) as shown in Fig. 1(a). For minute inspection of the low and high spin regions of this band, we considered role of various terms such as angular momentum dependence of the inertia parameter and RCT for explaining negligible and pronounced staggering. In order to study the role of various terms, we considered following three possibilities:

(A) angular momentum dependence of the moment of inertia as a free parameter without incorporating the rotational correction term in the total Hamiltonion

(B) without considering the angular momentum dependence of the moment of inertia but with inclusion of a rotational correction term in the total Hamiltonion

(C) angular momentum dependence of the moment of inertia as a free parameter along with a rotational correction term in the total Hamiltonion

In Fig. 1(b), we present particle rotor model calculations for the low spin region of this band. From this Fig. it is clear that the PRM calculation with the angular momentum dependence of inertia as a free parameter without including rotational correction term gives an excellent match with the experimental results. On the other hand, the results with the inclusion of RCT in the total Hamiltonian and without considering angular momentum dependence of inertia, deviates considerably from the experimental data. But if we consider RCT in the total Hamiltonian along with angular momentum dependence of the inertia parameters, the matching of PRM calculations with experimental data lies midway between the results of the two possibilities. Thus, for low spin region of this band having almost negligible staggering, the angular momentum dependence of inertia parameter plays a significant role and the optimized set of parameters corresponding to this calculation is: $\lambda = 6.61$ MeV, $\frac{\hbar^2}{2\Im} = 9.62$ keV, $\alpha = 0.28$ and $A_K(I) = 0.013$ keV. In Fig. 1(c) we present the PRM calculations for the high spin region ($19/2 \le I \le 33/2$) with the three possibilities (A-C). From this Fig. it is clear that inclusion of RCT in the total Hamiltonian but without taking the angular momentum dependence of the inertia parameter gives better agreement with the experimental data compared with the other two possibilities namely (A) and (C). The optimized parameters pertaining to this calculation are: $\lambda = 6.56$ MeV, $\frac{\hbar^2}{2\Im} = 12.57$ keV, and $\alpha = 0.18$. Thus, RCT plays a significant role in explaining the pronounced staggering in 1qp bands, this further strengthens our earlier results on different nuclides [9]. In Fig. 1(d), we present PRM results for whole spin range ($7/2 \le I \le 33/2$). From this Fig. it is clear that the possibilities (A) and (B) stated above have opposite tendencies in reproducing the signature splitting and the best fitted parameters for possibility (C) are: $\lambda = 6.56$ MeV, $\frac{\hbar^2}{2\Im} = 10.21$ keV, $\alpha = 0.26$ and $A_K(I) = 0.004$ keV.

4 Conclusions

We present PRM calculations to explain signature splitting in a one quasineutron band $7/2[633]_{\nu}$ observed in ^{175}Hf . On the basis of the present calculations, we suggest that the angular momentum dependence of the inertia parameter, without considering the RCT in the total Hamiltonian plays an important role in explaining negligible staggering, but the total Hamiltonian with RCT term gives a better agreement for pronounced signature splitting observed in 1qp bands.

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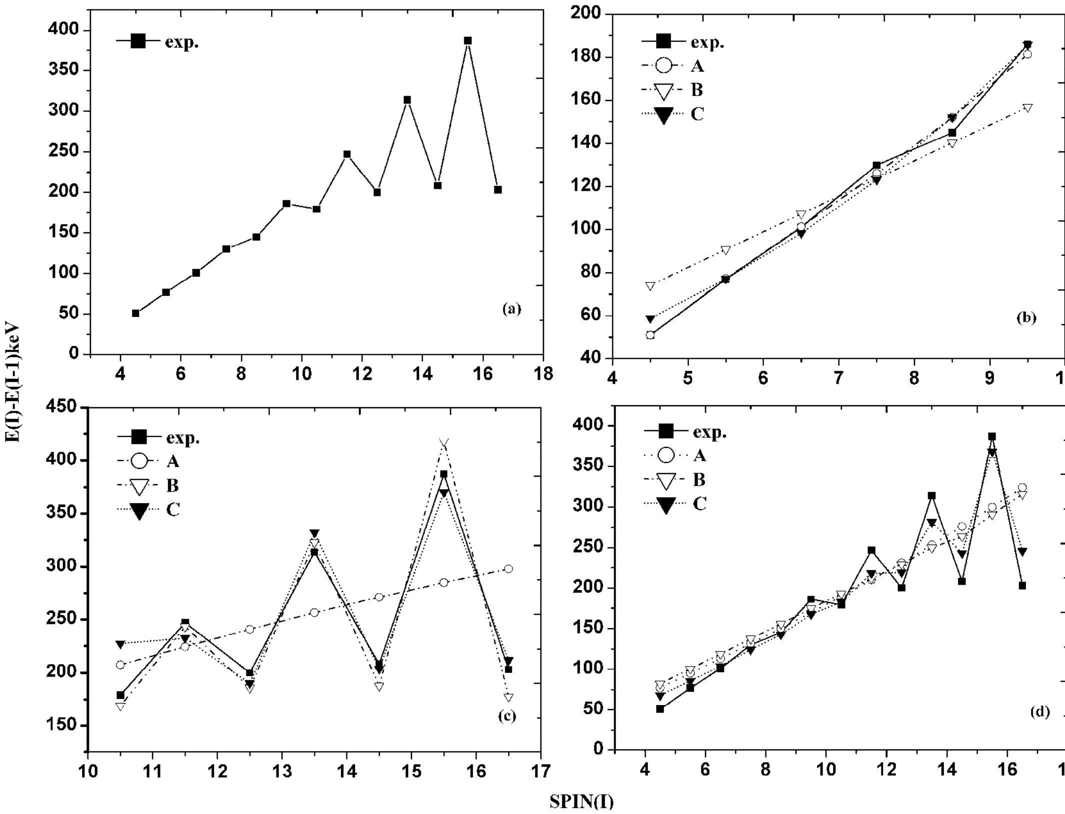

Figure 1. The comparison of PRM calculations with experimental results: (A) angular momentum dependence of moment of inertia as a free parameter without RCT, (B) without considering angular momentum dependence of moment of inertia but with inclusion of RCT in total Hamiltonion, and (C) angular momentum dependence of moment of inertia as a free parameter along with RCT in total Hamiltonion

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