Signature effects in $3/2[521]_\nu \otimes 1/2[660]_\nu \otimes 1/2[660]_\nu$ rotational band of ^{155}Dy

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Introduction

In odd-A nuclei, for excitation energy greater than proton or neutron pairing gaps, either a proton-proton or a neutron-neutron pair can break to generate a three-quasiparticle (3qp) quadruplet, on each member of which one rotational band is formed. These rotational generally shows various physical phenomena such as signature effects, back-bending, band-crossing at moderate to high angular momenta In present work, we explored one of these high-spin phenomena namely signature effects observed in 3qp rotational bands of ^{155}Dy. The signature effects refer to splitting of one rotational band (ΔI=1) into two rotational spin sequences with ΔI=2 which characterized as favored and unfavored branches. To identify the underlaying mechanism behind such splitting, we employed the Three Quasiparticle Plus Rotor Model (3QPPRM) [1] approach which relies on Coriolis and particle-particle band mixing calculations.

Theoretical Framework

The total Hamiltonian of an odd-A nuclei can be divided into two parts of which one represents intrinsic and other, the collective degree of freedom [1]:

$$H = H_{av} + H_{pair} + H_{res} + H^{o}_{rot} + H_{irrot} + H_{ppc} + H_{rpc} \quad (1)$$

where, the terms H_{av}, H_{pair}, H_{res} terms represents the contribution of deformed axially symmetric mean field potential, the pairing interactions and the residual neutron-proton interactions, remaining terms represents the contributions appeared from collective degree of freedom. The H^{o}_{rot} is purely rotational contribution, H_{irrot} is the purely intrinsic contribution known as irrotational part, H_{ppc} is the contribution from the couplings of particles among themselves known as the particle-particle coupling term, and H_{rpc} is the contribution from the coupling of particles with even-even core known as the rotor-particle coupling term. The wave functions corresponding to the total Hamiltonian can be written as:

$$\left|IMK\alpha\right\rangle = \sqrt{\frac{2I+1}{16\pi^2}}\begin{bmatrix}\left|D^{I}_{MK}\right\rangle\left|K\alpha\right\rangle + (-1)^{I+K} \\ \times\left|D^{I}_{M-K}\right\rangle R_x(\pi)\left|K\alpha\right\rangle\end{bmatrix} \quad (2)$$

where, the index α characterizes the configuration of the unpaired particles and K is the projection of the intrinsic angular momentum of particles on the symmetry axis.

Results and Discussion

To confirm the validity of present calculations, we choose an unassigned hanging rotational band built over three quasiparticle (3qp) configuration $3/2[521]_\nu \otimes 1/2[660]_\nu \otimes 1/2[660]_\nu$ observed in ^{155}Dy [2]. For this 3qp configuration, there are four possible bandheads namely $K^\pi=5/2^-$, $3/2^-$, $3/2^-$ and 1/2. From the available experimental indicators, it was not possible to assign to which bandhead (out of above four) the experimentally observed band corresponds. To predict the correct bandhead and also to as well as to reproduce the experimentally observed signature effects, we have carried out the complete Coriolis mixing calculations. The results of present calculations are depicted in Figure 1(a-d), from this figures, it is clear that the observed regular pattern as well as magnitude of signature splitting can be theoretically reproduced for K^π: $3/2^-$: $3/2[521]_\nu\uparrow \otimes 1/2[660]_\nu\uparrow \otimes 1/2[660]_\nu\downarrow$ member of the quadruplet (shown in Figure1(a)). The optimized parameters are listed in Table 1. Present assignment is also supported by reasonable RMS deviation (i.e. 115.5 keV) between calculated and experimental level energies. On the basis of present calculations, we successfully resolved the uncertain assignment of bandhead for the rotational band built over 3/2[521]$_{\nu}$↑⊗1/2[660]$_{\nu}$↑⊗1/2[660]$_{\nu}$↓ three quasiparticle configuration observed in ^{155}Dy.

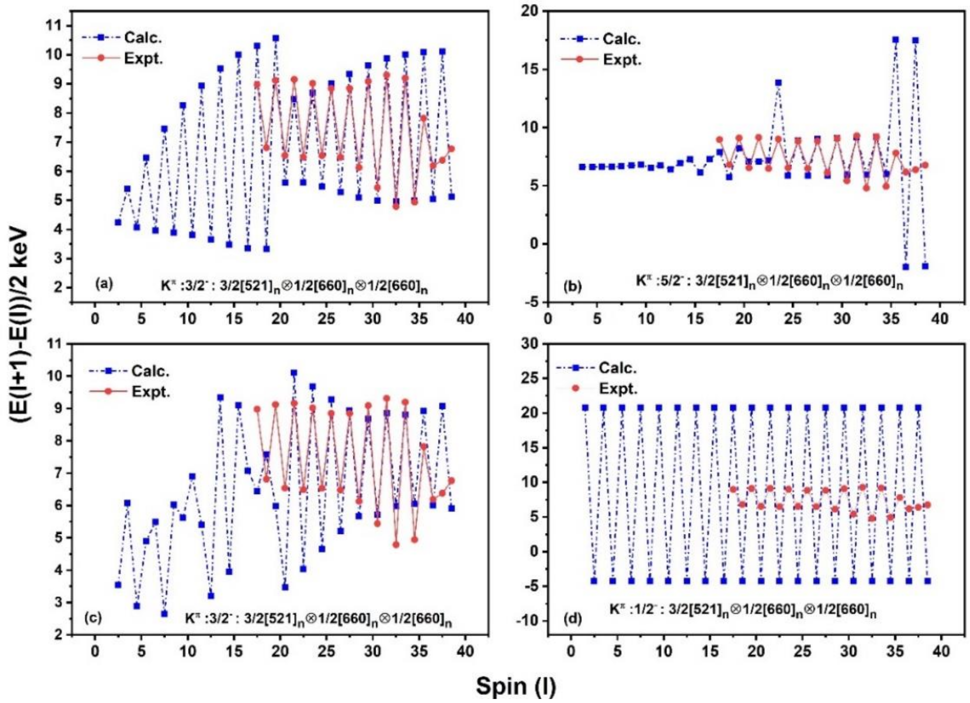

Figure 1: Comparison of theoretical signature splitting with experimental data.

Table 1: List of Optimized parameter using minute minimization subroutine [3].

Nilsson configurations $\Omega[Nn_z\Lambda]\Sigma$	K$^{\pi}$	E_{cal} (keV)	$\hbar^2/2\Im$ ($\hbar^2$/keV^{-1})	E_N (keV)
3/2[521]$_{\nu}$↑⊗1/2[660]$_{\nu}$↑⊗1/2[660]$_{\nu}$↑	5/2^{-}	1107.1	8.82	
3/2[521]$_{\nu}$↑⊗1/2[660]$_{\nu}$↑⊗1/2[660]$_{\nu}$↓	3/2^{-}	1424.0	8.89	-98.57
3/2[521]$_{\nu}$↑⊗1/2[660]$_{\nu}$↓⊗1/2[660]$_{\nu}$↑	3/2^{-}	1597.1	8.27	
3/2[521]$_{\nu}$↓⊗1/2[660]$_{\nu}$↑⊗1/2[660]$_{\nu}$↑	1/2^{-}	1529.1	8.27	
Matrix Elements				
1/2[530]$_{\nu}$⊗1/2[530]$_{\nu}$	0.89			
3/2[521]$_{\nu}$⊗1/2[530]$_{\nu}$	4.39			
5/2[512]$_{\nu}$⊗3/2[521]$_{\nu}$	5.61			
1/2[660]$_{\nu}$⊗1/2[660]$_{\nu}$	0.66			
3/2[651]$_{\nu}$⊗1/2[660]$_{\nu}$	0.92			
1/2[660]$_{\nu}$⊗1/2[660]$_{\nu}$	0.84			

References

[1] S. Singh *et al.*, *Phys. Scr*, *125* (2006) 186-187.

[2] R. Vlastou, *et al.*, *Nuclear Physics A* 580 (1994): 133-155.

[3] James, Fred. *MINUIT:* No. CERNLIB-D506. CERN, 1998.