Study of negative parity bands in ^{165}Yb

Mohd Faisal* and Rani Devi
Department of Physics, University of Jammu, Jammu-180006, India
**Email: mf068183@gmail.com*

Introduction

The study of high spin spectroscopy in rare-earth nuclei, particularly ytterbium (Yb) isotopes, has been a major focus of both experimental and theoretical research. Extensive data has been collected on Yb isotopes with mass numbers ranging from A=156 to 171, making it the most thoroughly studied isotopic mass chain in the A≈160 mass region. Roy et al. [1] expanded the previously known level schemes for ^{165}Yb and assigned the [523]5/2$^-$ Nilsson configuration to the negative parity ground state band and extended it up to I=53/2$^-$. They have also extended the positive parity band, which is based on the Nilsson orbital [642]5/2$^+$, up to I=49/2$^+$ and I=39/2$^+$ for α=+1/2 and α=−1/2 signature partners, respectively. Subsequently, Beck et al. [2] obtained the complete level scheme of ^{165}Yb by incorporating all the previous studies. To interpret the negative parity bands in ^{165}Yb, the Projected Shell Model (PSM) [3] has been employed.

The Model

The Projected Shell Model (PSM) employs the deformed Nilsson model to generate deformed single-particle states, and pairing correlations are incorporated through BCS method. This approach defines a set of deformed quasiparticles (qp) using the Nilsson+BCS framework. Three major harmonic oscillator shells N=3, 4, and 5 for protons, and N=4, 5, and 6 for neutrons are taken. The Hamiltonian used in the present work is

$$\hat{H} = \hat{H}_0 - \frac{1}{2}\chi \sum_{\mu} \hat{Q}^{\dagger}_{2\mu}\hat{Q}_{2\mu} - G_M \hat{P}^{\dagger}\hat{P} - G_Q \sum_{\mu} \hat{P}^{\dagger}_{2\mu}\hat{P}_{2\mu} ,$$

The monopole pairing interaction G_M is taken as $G_M = \left(G_1 \mp G_2 \frac{N-Z}{A}\right)\frac{1}{A}$ MeV,

where G_1 and G_2 are taken as 20.12 and 13.13, respectively. The quadrupole pairing $G_Q = \gamma G_M$, where γ is the proportionality constant and is taken as 0.14 for present calculations.

Results and discussion

The yrast negative parity band of this nucleus is known for both signature partners up to high spins. The Nilsson configuration assigned for this band is [523]5/2$^-$. The PSM calculations have been performed by taking quadrupole deformation parameter (ε_2)=0.240 and hexadecapole deformation parameter (ε_4)=0.008. The band diagram for negative parity bands is shown in Fig. 1. This figure indicates that the 1-qp neutron 1ν1$h_{9/2}$[512]5/2$^-$ band is the lowest up to I=37/2$^-$, with weight factors ranging from 0.982 to 0.486. The band head spin I=5/2$^-$ is consistent with the spin assigned by the authors of reference [1]. From the spin I= 13/2$^-$ onwards, an admixture of 1-qp neutron band based on the Nilsson configuration 1ν2$f_{7/2}$[532]3/2$^-$, is seen to be contributing to the yrast band. The weight factors of this band are less than equal to 0.250. At I = 39/2$^-$, this band is mixed with and crossed by 3-qp bands resulting from the coupling of 1-qp neutron band 1ν1$h_{9/2}$[512]5/2$^-$ with the 5/2, 7/2, and 9/2 components of 1π1$h_{11/2}$ proton orbital, with weight factors ranging from 0.100 to 0.198. The subsequent lowest 1-qp neutron band is 1ν2$f_{7/2}$[532]3/2$^-$ extending to I= 35/2$^-$. The weight factors of this band are less than 0.930. From the spin, I=11/2$^-$ onwards, 1-qp neutron 1ν1$h_{9/2}$[512]5/2$^-$ and 1ν2$f_{7/2}$ [523]5/2$^-$ bands are also contributing to 1ν2$f_{7/2}$[532]3/2$^-$ band. The weight factors of these bands are less than equal to 0.277. At spin I = 37/2$^-$, this band is mixed with and crossed by 3-qp bands resulting from the coupling of 1-qp neutron bands 1ν1$h_{9/2}$ [512]5/2$^-$ with the 5/2, 7/2, and 9/2 components of 1π1$h_{11/2}$ proton orbital, with weight factors ranging from 0.102 to 0.147.

In Fig. 2, the comparison of experimental and theoretical aligned angular momenta for negative parity 1ν1h$_{9/2}$[512]5/2$^-$ band for α=+1/2 and α=−1/2 signature partners is displayed. This figure illustrates that for the, 1ν1h$_{9/2}$[512]5/2$^-$ band experimentally α=+1/2 signature branch exhibits an upbend at I=29/2$^-$ at a rotational frequency of ħω=0.24 MeV, which is theoretically reproduced at I=33/2$^-$ at a rotational frequency of ħω= 0.39 MeV. For the α=-1/2 signature partner of this band, experimental data is unavailable, and the theoretical prediction for the upbend occurs at I=35/2$^-$ with a rotational frequency of ħω=0.41 MeV. For the 1ν2f$_{7/2}$ [532]3/2$^-$ band, experimental data is not available, but theoretical calculations predict backbends at I=33/2$^-$ and I=35/2$^-$ at rotational frequencies of 0.40 and 0.41 MeV for the α=+1/2 and α=−1/2 signature partners, respectively. At these spins, the 1-qp band is mixed and crossed by 3-qp bands. The backbends or upbends may be ascribed to the alignment of a pair of protons in the proton 1π1$h_{11/2}$ orbital.

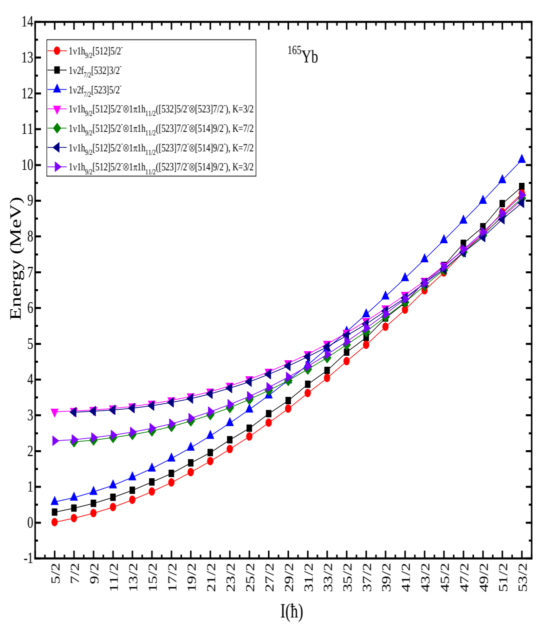

Fig. 1. Band diagram for negative parity bands of ^{165}Yb.

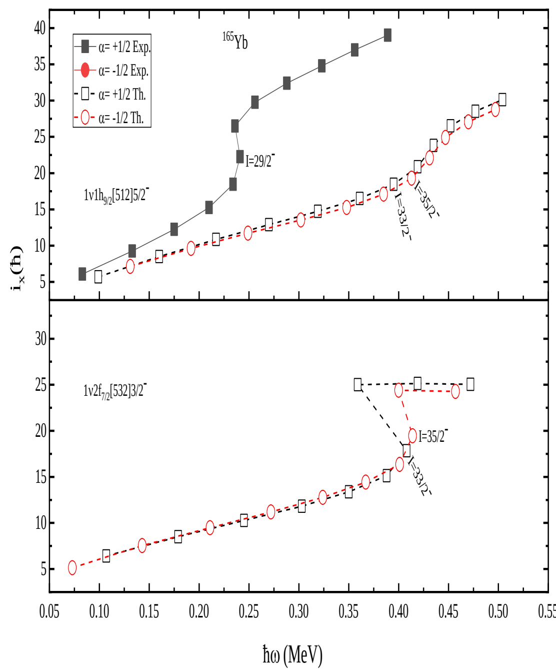

Fig.2. Comparison of theoretical (Th.) aligned angular momenta with available Experimental (Exp.) [1,2] data for negative parity bands of ^{165}Yb.

Conclusions

The projected shell model with monopole pairing plus quadrupole-quadrupole interaction has been employed to study the low-lying negative parity band structures in ^{165}Yb. The observed excitation spectra and backbends or upbends in alignments are nicely reproduced by the present calculations. The backbends or upbends may be ascribed to the alignment of a pair of protons in the proton 1π1$h_{11/2}$ orbital.

Acknowledgements

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References

[1] N.Roy et al., Nuclear Physics A**382** 125-158 (1982).

[2] E.M. Beck et al., Nuclear Physics A**464** 472-496 (1987).

[3] K. Hara and Y. Sun, Int. J. Mod. Phys. E**4**, 637 (1995).