Band structure of low lying bands of some neutron rich odd-odd Eu isotopes

*Rakesh K. Pandit[1], Rani Devi[1] and S.K.Khosa[2]
[1]*Department of Physics, University of Jammu, Jammu-180006*
[2]*Department of Physics and Astronomical Sciences, Central University of Jammu, Jammu-181143*
**email: panditrakesh7@yahoo.com*

Introduction

The odd odd Eu isotopes in the mass region A=150-160 provide an interesting possibility to study the low lying rotational band structure of these isotopes. The experimental data available on properties and characteristics of band levels of these doubly odd Eu isotopes in the mass region (A=150-160) pose a challenge to theorists to reproduce the extremely complex band spectra of these nuclei. It should be noted that from the neutron number N=89, these isotopes show emergence of deformation and rotational band spectra. In this work, an attempt has been made to study the low spin complex spectroscopy of these nuclei to understand the structure of yrast band and the low lying excited bands in these isotopes.

Brief description of theory

In the present work, Projected Shell Model [1] has been employed to study the yrast and excited bands of $^{152\text{-}156}$Eu nuclei. In the present study, three major harmonic oscillator shells with N=3,4,5 for protons and N=4,5,6 for neutrons are taken. The Hamiltonian that has been used in the present calculation contains the single particle energies, quadrupole-quadrupole interaction, monopole pairing between like particles, and quadrupole pairing interactions. The monopole pairing strength G_M takes the form

$$G_M = \left[G_1 \pm G_2 \frac{N-Z}{A}\right] A^{-1}$$

where plus (minus) is for protons (neutrons). For these isotopes G_1 and G_2 are taken as 20.00 and 13.00. The quadrupole(ε_2) and hexadecapole (ε_4) parameters used in the present calculations are 0.300 and -0.050, respectively for $^{152\text{-}154}$Eu and 0.355 and 0.030, respectively for ^{156}Eu.

Results and discussion

In the case of ^{152}Eu isotope, the observed yrast energy spectra is nicely reproduced as can be seen in figure 1. For ^{154}Eu, the calculated yrast energy spectra are well reproduced up to I=5$^-$. From I=6$^-$ to I=10$^-$, the observed trends have been reasonably reproduced. In the case of ^{156}Eu isotope, the agreement between experimental and calculated yrast energy spectra are good except at the spin I=5$^+$, where the calculated value is small as compared to the observed one. From the band diagram in the figure 2, it can be seen that the 2-qp band built on K=3 and having configuration $1\nu1h_{11/2}[11/2]+1\pi1g_{7/2}[5/2]$, K=3 is lowest in energy from band head spin I=3$^-$ to I=5$^-$ This is consistent with the observed band head spin and configuration of Ref.[2]. Our calculations predicted two 2-quasiparticle (qp) intruder bands based on I=6$^-$ and I=7$^-$ in ^{152}Eu. From the spin I=8$^-$ to I=13$^-$, only one 2-qp band having configuration $1\nu1h_{11/2}[11/2]+1\pi1g_{7/2}[5/2]$, K=8 is predicted to contribute in the formation of the yrast band. This calculation is very much consistent with the observation of the authors of Refs. [3,4]. From the comparison of the results in figure 3, it is clear that the energy states of the ground state band 1, excited bands 3and 4, are well reproduced with respect to their band head energies and energy difference between two adjacent energy levels. For the band 1, the energy difference between calculated and observed values at the highest known spin I=7$^-$ is 0.027 MeV. For the band 3, the energy difference between calculated and observed values at the highest known spin I=4$^-$ is 0.024 MeV and the difference between experimental and calculated band head energies is 0.006 MeV.

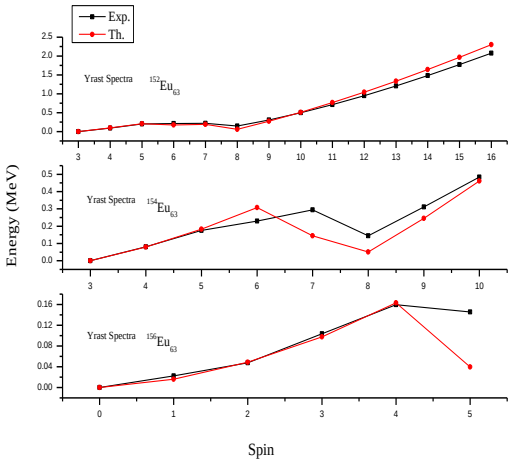

Fig.1 Comparison of experimental (Exp.) and theoretical (Th.) yrast energy spectra of $^{152\text{-}156}$Eu.

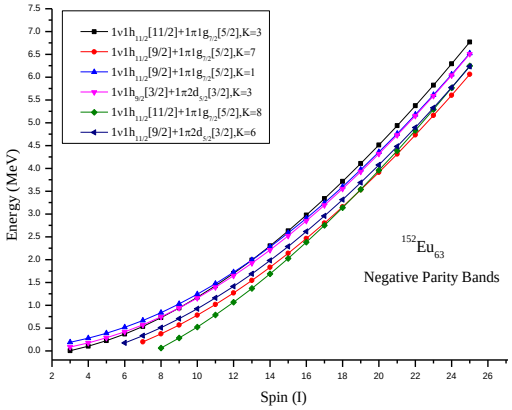

Fig.2 Band diagram for negative parity bands of ^{152}Eu.

For the band 4, the energy difference between calculated and observed values at the highest known spin $I=3^-$ is 0.013 MeV and the difference between experimental and calculated band head energies is 0.002 MeV. In case of band 2 built on $K=8^-$, the difference between experimental and calculated band head energies is 0.089 MeV and the difference between calculated and observed values at the highest known spin $I=16^-$ is 0.224 MeV. The transition energies of these bands in ^{152}Eu are also reasonably reproduced, except for the band 2, where calculated values are found to be slightly higher than the observed values.

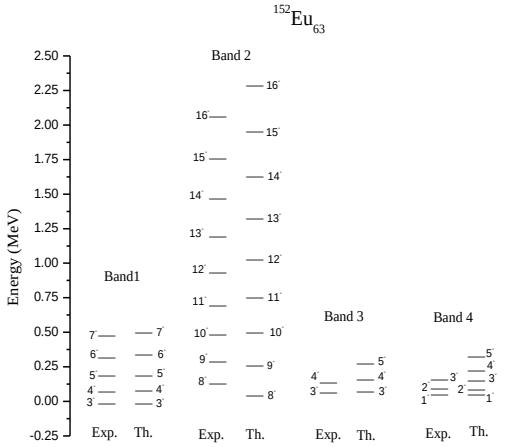

Fig.3 Comparison of experimental (Exp.) [2,4] and theoretical (Th.) energy levels of negative parity bands of ^{152}Eu.

Conclusions

The projected shell model has been able to reproduce successfully the formation of negative parity ground state band structure based on configuration $1\nu1h_{11/2}[11/2]+1\pi1g_{7/2}[5/2]$, K=3 for both ^{152,154}Eu isotopes. Our calculations predicted two 2-quasiparticle (qp) intruder bands based on $I=6^-$ and $I=7^-$ in ^{152}Eu and one 2-qp intruder band based on $I=7^-$ in ^{154}Eu. Further, the PSM has been completely successful in reproducing the formation of positive parity ground state band based on configuration $1\nu1i_{13/2}$ $[5/2]+1\pi1g_{7/2}[5/2]$,K=0 in ^{156}Eu isotope. Moreover, the ground state energy spectra and energy spectra of other 2-qp rotational bands have also been reasonably reproduced in isotopic mass chain of $^{152\text{-}156}$Eu.

References

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