Spectra and E2-M1 transition properties for the Ground band and K=6$^+$ isomers of ^{172}Er

C.R. Praharaj[1],* B. B. Sahu[2], S. K. Patra[1], and Z. Naik[3†]
[1]*Institute of Physics, Sainik School, Bhubaneswar - 751005, INDIA*
[2]*School of applied Science, KIIT Deemed to be University, Bhubaneswar-751 024, INDIA*
[3]*School of Physics, Sambalpur University, Jyoti Vihar, 768 019, India*

Introduction

In the present work, we have studied the Electromagnetic Properties of neutron-rich ^{172}Er nuclei using a Microscopic model known as 'Deformed Hartree-Fock and Angular Momentum Projection [1]. The ^{172}Er isotope is investigated experimentally by few-nucleon transfer reactions, by several experimental groups in last decay, and established five bands upto high spin J=(22$^+$) (for the Ground band) with excitation energy 5.528 MeV [2, 3]. The band structures include two isomeric bands with K=(6$^+$) and K=(4$^-$). The half-life of 0.57μS and 39.5NS respectively. Except the Ground state band, the spin and parity of the rest bands are kept tentative.

This isotope is also important as the proton number is near the middle of 50 and 82 magic numbers, similarly neutron number is in the middle of 82 and 126 magic numbers. The ^{172}Er is well deformed nuclei and collectivity play a important role in the high spin structure. These call for investigation of the structural properties of ^{172}Er with a microscopic model, so that the various features of bands are understood basis on their microscopic structures.

Theoretical Framework

We start the HF calculation with the model space which consists of $2s_{1/2}$, $1d_{3/2}$, $1d_{5/2}$, $0g_{7/2}$, $0h_{9/2}$ $0h_{11/2}$, orbits for protons with spherical single energies 3.654, 3.288, 0.731, 0.0, 6.460 and 1.705 MeV respectively, and orbits $2p_{1/2}$, $2p_{3/2}$, $1f_{5/2}$, $1f_{7/2}$, $0h_{9/2}$, $0i_{13/2}$ are used for neutrons with spherical single particle energies 4.462, 2.974, 3.432, 0.0, 0.686 and 1.487 MeV respective. The model is consider above the inert ^{132}Sn shell closer. The microscopic model of Hartree-Fock comprises of self consistent deformed Hartree- Fock mean field calculation with surface-δ residual interaction. The force strength of 0.3 MeV is consider among active nucleons (V$_{pp}$ =V$_{pn}$ =V$_{nn}$). To get states of good J, angular momentum projection is done with the help of projection operator

$$P^{JM}_K = \frac{2J+1}{8\pi^2}\int d\Omega\ D^{J\ *}_{MK}(\Omega)\ R(\Omega), \quad (1)$$

where $R(\Omega)$ is the rotation operator and Ω stands for the Euler angles (α, β, γ).

The energies and electromagnetic transition operators are calculated by finding out their matrix elements, which consists of integration over Euler angles. Reduced matrix elements of tensor operator T^L of rank L are given by,

$$\langle\Psi^{J_1}_{K_1}||\ \ T^L\ \ ||\Psi^{J_2}_{K_2}\rangle = \frac{1}{2}\frac{(2J_2+1)(2J_1+1)^{1/2}}{(N^{J_1}_{K_1K_1}N^{J_2}_{K_2K_2})^{1/2}} \sum_{\mu\nu} C^{J_2LJ_1}_{\mu\nu K_1}\int_0^\pi d\beta\ \sin(\beta) d^{J_2}_{\mu K_2}(\beta) \langle\phi_{K_1}|T^L_\nu e^{-i\beta J_y}|\phi_{K_2}\rangle \quad (2)$$

where T^L is an electromagnetic operator (E2, M1 etc). Here $N^J_{K_1K_2}$ is the normalisation constant [1, 4? , 5].

For calculation of various Electric transition elements, we have used e_p=1.7e and e_n=0.7e as effective charges for proton and neutron respectively. Similarly g-factors of $g_l = \mu_N$ and $g_s = \frac{1}{2} \times 5.586\ \mu_N$ for protons and g_l=0 and

*Electronic address: crp@iopb.res.in
†Electronic address: z.naik@suniv.ac.in

$g_s = \frac{1}{2} \times (-3.826)\ \mu_N$ for neutrons are used for calculations of Magnetic transition properties.

Our HF calculation gives the deformation (β_2) for ^{172}Er is 0.311, which correspond the intrinsic quadrupole moment 7.13 *eb*. Experimental value is not available for ^{172}Er but the experimental β_2 value of ^{170}Er is 0.33, which is very close to our calculation.

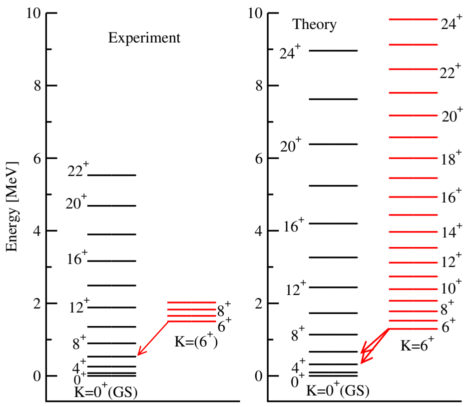

FIG. 1: Comparison of theoretical and experimental spectra of the Ground band and K=6+ isomeric band.

Results and discussions

We have calculated spectra for the available bands. Comparison of spectra of ground state band (GS) and K=(6^+) isomer bands with experimental spectra are given in figure Fig.1. The theoretical band head energy of the K=6^+ is slightly lower than that of experiment. The theoretical level spacings (gamma-energies) are slightly larger than respective experimental level spacings. Our calculation give that, this band is of 2-quasi neutron in nature. We have assigned configuration based on level spacing and band head energy to all excited the bands. Based on our calculation we have suggested 2-quasi proton for K=(4^-) isomeric band and 2-quasi neutron for K=(7^-) high K band. Further investigation is required for K=(3^+) band.

We have also calculated the reduced transition probability B(E2) and B(M1) for various transitions. Our prediction are shown in Fig.2. From the figure, it is observed that the dominance of B(M1) over B(E2) increases with increase of J for $J \to J-1$.

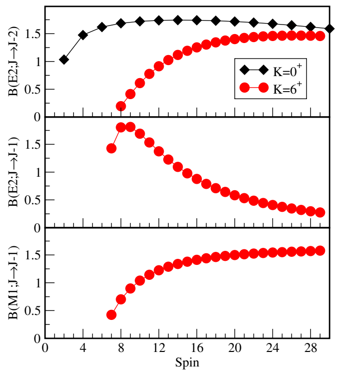

FIG. 2: Prediction of B(E2;$J \to J-2$), B(E2;$J \to J-1$) and B(M1;$J \to J-1$) value for GS and K=6^+ band. The unit of B(E2) and B(M1) values are e^2b^2 and μ_N respectively.

Conclusion

Band structures of neutron-rich ^{172}Er are investigated using deformed HF and J projection formalism. Calculations have also been made for reduced transition probability (B(E2) and B(M1) values). Our model gives, it is a well deformed nucleus, which agrees with experimental value.

References

[1] Zashmir Naik, C. R. Praharaj, Phys. Rev. **C67**, 054318 (2003).

[2] C. Y. Wu et al., Phys. Rev. C 70, 014313 (2004).

[3] G. D. Dracoulis et al., Phys. Rev. C 81, 054313 (2010).

[4] G. Ripka, in Advances in Nuclear Physics, edited by M. Baranger and E. Vogt (Plenum Press, New York, 1966), Vol. 1.

[5] R.E. Peierls and Y. Yoccoz, Proc. Phys. Soc., London, Sect. A70, 381 (1957).