Superdeformed GIB phenomenon in A=60 and A=80 mass regions

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Introduction

The discovery of identical band (IB) phenomenon implies that the valence particles beyond the superdeformed (SD) shell closure do not influence the core as much as they do in normal deformed (ND) nuclei. In other words, the valence particles remain decoupled from the core and therefore a simple interpretation of the IB phenomenon may be sought in terms of an aligned or decoupled structure. This premise forms the basis of several explanation including the one based on pseudo spin alignment [1]. The role of high-N intruder orbitals appears to be crucial in deciding the identicity of the bands. A number of criteria have been used in the literature for defining two bands as identical bands [2]. These criteria are based on the closeness of gamma ray energies in the two bands or matching of dynamical or kinematic moment of inertia. The analysis for SD General Identical Band (GIB) phenomenon has been done for A=130, 140, 150, 190 mass regions [3]. In this paper, we show that a substantial number of SD bands come very close to a reference band in A=60 and A=80 mass region and give rise to (GIB) phenomenon.

GIB phenomenon

To identify the identical bands, one tries to bring the transition energies of a SD band as close as possible to the transition energies of another SD band in a neighboring nucleus. This is achieved by suitably displacing the angular momentum of one across the other. Let the two bands A and B having gamma ray energies represented by $E_\gamma(I_A)$ and $E_\gamma(I_B)$ respectively. These two bands belong to two different nuclei may be said to have an IB pattern if the difference in gamma ray energies ΔE tends to vanish.

$$\Delta E = E_\gamma(I_A) - E_\gamma(I_B) \approx 0 \quad (1)$$

This criteria may be further extended to include half average, (1/4, 3/4) average of gamma ray energies becoming identical to gamma ray energies of reference band as defined below [4].

$$\Delta E \equiv E_\gamma(I_A) - \frac{1}{2}[E_\gamma(I_{B+2}) + E_\gamma(I_B)] \quad (2)$$

$$\Delta E \equiv E_\gamma(I_A) - \frac{1}{4}[E_\gamma(I_{B+2}) + 3E_\gamma(I_B)] \quad (3)$$

$$\Delta E \equiv E_\gamma(I_A) - \frac{1}{4}[3E_\gamma(I_{B+2}) + E_\gamma(I_B)] \quad (4)$$

The generalized expression for average gamma ray energies $E'_\gamma(I_B)$ can be written as [5]

$$E'_\gamma(I_B) = xE_\gamma(I_B) + (1-x)E_\gamma(I_{B+2}) \quad (5)$$

Here, x is a parameter which may be continuously varied in the interval [0,1]. The $E'_\gamma(I_B)$ may be compared with $E_\gamma(I_A)$ to check the smallness of the quantity i.e.

$$\Delta E = E_\gamma(I_A) - E'_\gamma(I_B) \quad (6)$$

The point to be decided in making this comparison is the relative displacement of band B w.r.t. band A. According to an empirical model [3], the spectrum of a classical rotor with rotational angular momentum $\vec{R}$ and a decoupled particle with an aligned angular momentum i may be written as

$$E_{rot}(I) = \frac{\hbar^2}{2\vartheta}[I(I+1) - 2iI + i(i+1)] \quad (7)$$

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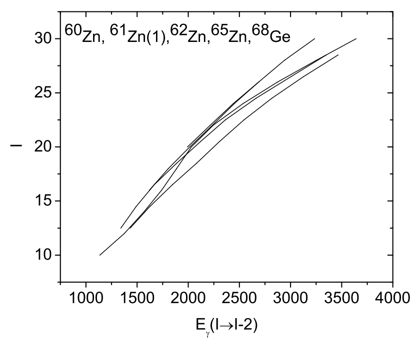

FIG. 1: Plot of I vs. $E_\gamma(I \to I-2)$ showing General Identical Band (GIB) feature in A=60 mass region.

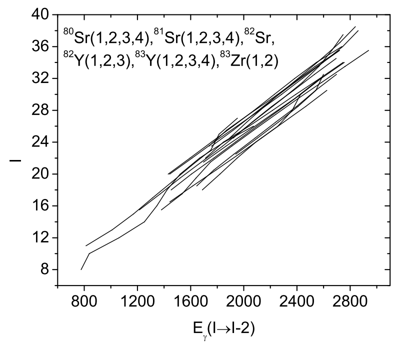

FIG. 2: Plot of I vs. $E_\gamma(I \to I-2)$ showing General Identical Band (GIB) feature in A=80 mass region.

$$E_\gamma(I \to I-2) = \frac{\hbar^2}{2\vartheta} 2[(2I-1) - 2i] \quad (8)$$

According to equation (8)

$$E_\gamma(I_A) = 2C[(2I_A - 1) - 2i_A] \quad (9)$$

$$E_\gamma(I_B) = 2C[(2I_B - 1) - 2i_B] \quad (10)$$

$$\Delta E = 4C[I_A - I_B - 2(1-x) - (i_A - i_B)] \quad (11)$$

In the ideal situation $\Delta E \approx 0$ which implies that

$$\Delta I = 2(1-x) + \Delta i \quad (12)$$

One can calculate Δi from the least square fitting of data. The quantity x is obtained by a procedure of minimizing the difference ΔE in equation (8). Using the value of x, one can obtain ΔI by which the band B should be shifted with respect to band A in order to make them identical.

Results and Discussions

Following the same procedure as outlined above, we carried out an analysis for SD bands in A=60 and A=80 mass regions by using the data from Table of SD bands [6] and continously updated ENSDF data base [7]. In this analysis we choose $^{61}Zn(1)$ and $^{80}Sr(1)$ as reference band A for A=60 and A=80 mass regions respectively and treat all other SD bands as B. We find that in A=60 mass region 5 out of 6 SD bands gives the criteria of identical bands. The corresponding I vs. $E_\gamma(I \to I-2)$ plot is shown in Fig. 1. In A=80 mass region 17 out of 27 SD bands gives the criteria of identical bands; corresponding plot of I vs. $E_\gamma(I \to I-2)$ is shown in Fig. 2. It is clear from the figures that GIB pattern is observed in A=60 and A=80 mass regions but deviations are slightly larger.

References

[1] F.S. Stephens et al., Phys. Rev. C**57**, R1565 (1998).

[2] C. Baktash, B. Hass and W. Nazarewicz, Annu. Rev. Nucl. Part. Sc., **45**, 485 (1995).

[3] M. Dudeja, S.S. Malik and A.K. Jain. Phys. Lett. B**412**, 14 (1997).

[4] El-Aouad et al., Phys. Rev. C**49**, R1246 (1994).

[5] Shen Caiwen, Luo Wendong and Y.S. Chen. Phys. Rev. C**55**, 1762 (1997).

[6] B. Singh, R. Zywina and R. B. Firestone, Table of Superdeformed Nuclear Bands and Fission Isomers, Nuclear Data Sheets **97**, 241 (2002).

[7] http://www.nndc.bnl.gov.