Staggering in Signature Partners of A~190 Mass Region of Superdeformed Rotational bands

Uma.V.S[1], Alpana Goel[2]*and Archana Yadav[2]

[1]Department of Physics, Amity Institute of Applied Sciences (AIAS), Amity University, Noida -201303, INDIA

[2]Amity Institute of Nuclear Science and Technology (AINST), Amity University, Noida-201303,INDIA

*E-mail: agoel1@amity.edu

Introduction

Past decades have reported many regularly spaced gamma ray sequences, with higher precision, in mass regions A ~ 60, 80, 130, 150 and 190 for superdeformed (SD) nuclei. These studies are facilitated with advancement in technologies and experimental research. There are more than 85 super-deformed (SD) bands have been identified in Au, Hg, Tl, Pb, Bi and Po nuclei of A~190 mass region alone[1-2]. The SD states in A~190 mass region have been observed down to quite low spin also many bands show the smooth rise in the dynamical moment of inertia as rotational frequency increases. A zigzag behaviour was observed as a function of spin which was un-expected in transition energies of superdeformed nuclei. This property was named as odd-even staggering effect. Rotational bands depends upon the signature quantum number r=$e^{i\alpha\pi}$, which defines the admissible spin sequence for a rotational band according to the relation I=α±2n(n=0,1…).Usually two signature partner band with r=+1(α=0)and r = -1 (α=1) in even mass nuclei and r=±1(α=±1/2)in odd mass nuclei, which are separated by a signature splitting energy. Often staggering occur at high rotational frequencies and is associated with ΔI=1 signature splitting. ΔI=1 staggering is relative to displacement of energy levels with odd spin (I = 1,3,5…) and even-spin (I=2,4,6…) in rotational bands. ΔI=1 staggering has been well-known for a long time in normal deformed nuclei however information on signature splitting in SD bands is only partly available. As this shows relative excitation among signature partners [3-4].

This paper discuss about ΔI=1 signature splitting in signature partner pairs of A~190 mass region. Around twenty signature partner pairs(usually called as two bands, each with a fixed signature) have been reported in this mass region. For these signature pairs, band head moment of inertia ($\mathcal{J}_0$) and intrinsic structure of each pair of signature partners have been found as almost identical. Also, these signature partner pairs showed large amplitude signature splitting. As each of the two signature partner forms a regular spin sequence and signature bands are not equivalent in terms of energies. This difference in energies results in signature splitting.

Sketch of the Model

In VMI model equation, the energy levels of rotational bands is given as, [5-6]

$$E_I = E_0 + \frac{1}{2\mathcal{J}_I}[I(I+1) - I_0(I_0+1)] + \frac{1}{2}C(\mathcal{J}_I - \mathcal{J}_0)^2 \ldots.(1)$$

While for SD bands, the transition energy is expressed as

$$E\gamma(I \to I-2) = E(I) \to E(I-2)$$

Therefore, we get [7-8]

$$E\gamma(I \to I-2) = \frac{1}{2\mathcal{J}_0}[I(I+1) - (I-2)(I-1)] + \frac{1}{8C\mathcal{J}_0{}^4}\{[I(I+1)]^2 - [(I-2)(I-1)]^2\} \ldots\ldots\ldots(2)$$

This equation considers both parameters $\mathcal{J}_0$ and C. These two parameters were determined by fitting least square procedures of all the known energies in the observed spectra.

We have predicted the band head spin(I_0) through the observed transition energy ratio[7-8]. The root mean square deviations (rms) of transition energies for different spin values are calculated. The rms value is least for band head spin value. If I_0 shifts away from the accurate value by ±1,rapid shift in rms deviation can be observed.

The rms ($\mathcal{X}$) deviation is expressed as;

$$\mathcal{X} = \left[\frac{1}{n}\sum_{i=1}^{n}\left|\frac{E\gamma^{cal}(I_i) - E\gamma^{exp}(I_i)}{E\gamma^{exp}(I_i)}\right|^2\right]^{1/2}$$

Where n is the total number of transitions involved in the fitting.

It was observed that the rms deviation plots are nearly same for intrinsic structure in the signature partners. For each signature partner pairs of SD bands, the transition energies in one band were very close to the midpoint of other band confirming signature partners in particular nucleus. Most of the signature partners show in the same nucleus expect in signature partner like [^{193}Hg(b1) and ^{193}Pb(b5)].

ΔI=1 staggering in signature partner of SD bands

Difference between the average transitions I+2 →I→I-2 energies in one band and the transition I+1→I→I-1 energies in its signature partner were calculated for Hg, Tl and Pb isotopes in A~190 region. The ΔI=1 staggering in signature partner pairs among the nucleus is represented as,

$$\Delta^2 E\gamma(I) = [E\gamma(I+2 \rightarrow I)+ E\gamma(I \rightarrow I-2)]/2- E\gamma(I+1 \rightarrow I-1)$$

Results

Twenty signature partner pairs of Hg, Tl and Pb isotopes in A~190 mass region were identified. The band head moment of inertia ($\mathcal{J}_0$) of signature partners were close to each other, which suggested that each pair of signature partner do have the same intrinsic structure. For signature partner SD bands, $\mathcal{J}_0$ and I_0 values are shown in table1.

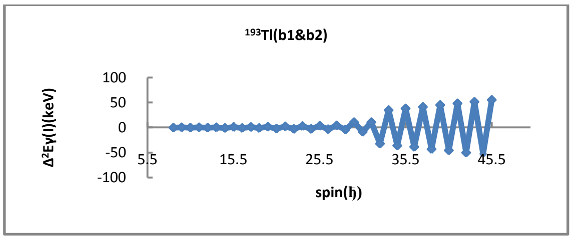
Table1: Band head moment of inertia ($\mathcal{J}_0$) and band head spin (I_0) of signature partner pairs in A~190 region

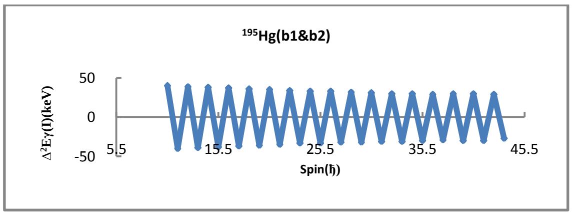
Signature partners	Assigned I_0	$\mathcal{J}_0$ ($\hbar^2$MeV^{-1})
^{191}Hg(band2) ^{191}Hg(band3)	10.5 11.5	95.1 94.3
^{193}Hg(band1) ^{193}Hg(band2)	9.5 10.5	93.0 93.6
^{193}Hg(band3) ^{193}Hg(band4)	9.5 10.5	93.2 93.6
^{194}Hg(band2) ^{194}Hg(band3)	8 9	94.0 94.0
^{195}Hg(band1) ^{195}Hg(band2)	11.5 10.5	93.6 93.4
^{195}Hg(band3) ^{195}Hg(band4)	10.5 11.5	97.9 98.0
^{191}Tl(band1) ^{191}Tl(band2)	11.5 10.5	92.7 92.1
^{193}Tl(band1) ^{193}Tl(band2)	8.5 9.5	96.0 96.1
^{194}Tl(band1) ^{194}Tl(band2)	12 9	98.8 99.9
^{194}Tl(band3) ^{194}Tl(band4)	10 9	94.8 94.8
^{194}Tl(band5) ^{194}Tl(band6)	8 9	100.7 101.0
^{195}Tl(band1) ^{195}Tl(band2)	5.5 6.5	95.5 95.0
^{193}Pb(band3) ^{193}Pb(band4)	10.5 11.5	94.6 94.0
^{193}Pb(band5) ^{193}Pb(band6)	8.5 9.5	93.0 93.0
^{194}Pb(band2) ^{194}Pb(band3)	10 11	94.4 94.4
^{195}Pb(band1) ^{195}Pb(band2)	7.5 6.5	98.7 98.0
^{195}Pb(band3) ^{195}Pb(band4)	7.5 8.5	90.5 92.4
^{196}Pb(band2) ^{196}Pb(band3)	8 9	91.8 91.8
^{197}Pb(band1) ^{197}Pb(band2)	5.5 4.5	98.7 97.5
^{193}Hg(band1) ^{193}Pb(band5)	9.5 8.5	93.0 93.0

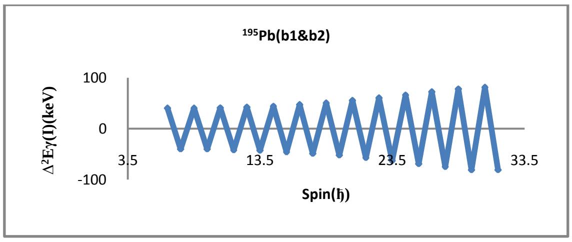
Conclusion

Among signature partner pairs, transition energies vary in regularly pattern with increasing spin values. Most of the signature partners for isotopes of Hg,Tl and Pb in A~190 region show large amplitude ΔI=1 staggering. In this paper, the signature splitting in signature partner pairs are shown.

Figure 1: The ΔI=1 signature splitting in some signature partners of SD nuclei of A~190 region.







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