# THE SYSTEMATIC DEPENDENCE OF (E2;4G→2G)/B(E2;2G→0G) RATIO ON N AND Z FOR ND-HG NUCLEI

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## ABSTRACT

*The systematic dependence of experimental B(E2; 4g→2g)/ B(E2;2g→0g) branching ratio with N and Z is carried out for Nd- Hg even –even nuclei. The SU(5) and SU(3) limits of interacting boson model are also discussed. The N and Z dependence of B(E2) branching ratio has been observed. The Z=64 subshell effect is also seen for N≤ 90 region.*

***Keywords: B(E2; 4g→2g)/ B(E2;2g→0g) branching ratio, nuclear structure, Nd –Hg nuclei, SU(5), SU(3), Z=64 subshell effect***

## I. INTRODUCTION

The concept of collectivity in nuclei is one of the most fundamental findings in history of nuclear physics. Various nuclear models have been applied to describe this collective behaviour of atomic nuclei. The geometrical models depicting the nucleus as a liquid drop with a given nuclear shape and algebraic models, take into account the pairs of proton and/or neutron only. Despite the often very dissimilar theoretical approaches, most of the collective models have some common basic features, such as predictions of energies rotational, vibrational and other higher multi-phonon bands or B(E2) ratios for inter and intra band transitions, which have been observed in a wealth of non- magic atomic nuclei.

The energy ratio $R_4$ is a key observables which can be used to assess the collectivity of nuclei and it is equal to 2 for an ideal spherical harmonic vibrator or SU(5) limit and 10/3 in an axially symmetric deformed rotor or SU(3) limit of interacting boson model (IBM)[1]. The transition rates also provide another good measure of nuclear collectivity [2], which is less sensitive to anharmonicities than energies of various bands. The $B(E2;4_g\rightarrow2_g)/B(E2;2_g\rightarrow0_g)$ branching ratio is a particularly good example, which is equal to 2 in the spherical limit or SU(5) and 1.4 in the deformed limit or SU(3)[1]. Significant deviations from these two limiting values can be found; if one moves away from the closed shell.

In the present work, we have compiled the observed data of $B(E2;4_g\rightarrow2_g)/B(E2;2_g\rightarrow0_g)$ branching ratio from the website of Brookhaven National Laboratory[3] for Nd – Hg nuclei. The variation of this B(E2) ratio with N and Z has been studied. The SU(3) and SU(5) limits are also included for useful comparison. The result & discussions and conclusion are given in § II and III respectively.

## II.RESULT AND DISCUSSIONS

### 2.1 The variation of experimental B(E2;4g→2g)/ B(E2; 2g→0g) ratio verses neutron number (N)

To avoid the overlapping of experimental data of the nuclei and to have a clear picture for a definite conclusion about the dependence of B(E2;4g→2g)/B(E2;2g→0g) ratio on N, the whole data is divided into two parts and shown in two figures i.e. Fig. 1 for Nd- Er nuclei and in Fig. 2 for Yb- Hg nuclei. The vibrational model or SU(5) limit at 2 and rotational model or SU(3) limit at 1.4 are shown in the Fig 1 and Fig. 2. The data points are joined for same value of Z, so that the effect of N will be visible.

For Nd, this ratio increases sharply from 0.73 to 1.61(maximum value at N=88) as N increases from 84 to 88 and if N is further increased from 88 to 92 it decreases slowly from 1.61 to 1.31(see Fig. 1). The same feature is observed for Sm, where this ratio increases from 1.65 to 1.9 on increasing N from 86 to 88 and beyond N=88 it drops sharply and approaches to Alaga value of 1.4 for N=92. In case of Gd, the BE(2) ratio decreases from 1.82 to 1.46 as N increases from 88 to 94. Also in Er, this ratio decreases from 1.78 to 1.5 as N increases from 88 to 100 and minimum value of 1.18 at N=96. Therefore, for N=88 (Sm, Gd and Er) isotones, this ratio ≈1.8 is very close to the VM limit of 2.0 indication vibrational nature. However for Dy (N=88, 92, 94, 96) this ratio is close to Alaga value indication deformed rotor nature and for N=90; Dy indicating transitional nature because this ratio (=1.63) is lying in between SU(5) and SU(3) limiting value (see Fig. 1).

For Yb and Hf nuclei, BE(2) ratio is ranging between 1.4 to 1.6 for different values of N and close to SU(3) limit (see Fig. 2). In case of W, the ratio increases sharply from 1.1(3) to 1.74(15) on increasing N from 94 to 100 and decreases very slowly on increasing N from 108 to 112 (almost remains around Alaga value).

For N=96 the data point of Os is close to the other N=96 isotones (Yb, Hf, W) data points. When N increases from 108 to 112, the ratio for Os increases from 1.4(4) to 1.68(11) and when N is increased from 112 to 116 the B(E2) ratio decreases from 1.68(11) to 1.22(4) indicating prolate to oblate shape-phase-transition as observed by Kumar and Baranger [4].

For N=98, the B(E2) [=1.87(24)] for Pt is close to VM value and for N=102 the ratios is minimum [=0.92(22)]. The B(E2) ratio for Pt decreases from 1.65 to 1.56 when N increases 106 from 114 and again increases from 1.56 to 1.73 as N increases from 114 to 116(attains maximum value =1.73(11) at 116). If N is increased from 116 to 120 this ratio drops linearly with the same slope as observed for Os (N=112 to 116).This indicates the similar nature of Pt and Os nuclei for this region.

For two nuclei; $^{182}$Hg and $^{184}$Hg; the B(E2) ratio is 4.6(3) and 2.8(8) respectively; which are anomalously more than VM limiting value and not included in the Fig.2. The B(E2) ratio is smallest in case of $^{198}$Hg; which is non magic nucleus; has only two vacancy of p+ for Z =82. This ratio is also very small in case of $^{144}Nd_{84}$ [=0.73(9)] (see Fig.1); which is also a non- magic nucleus; which has only two valence $n^0$ outside N=82. It supports the findings of Cakirli et.al. [5], that the B(E2;4g→2g)/B(E2;2g→0g) ratio is anomalously small in non magic nuclei, as it cannot be explained with collective approaches.

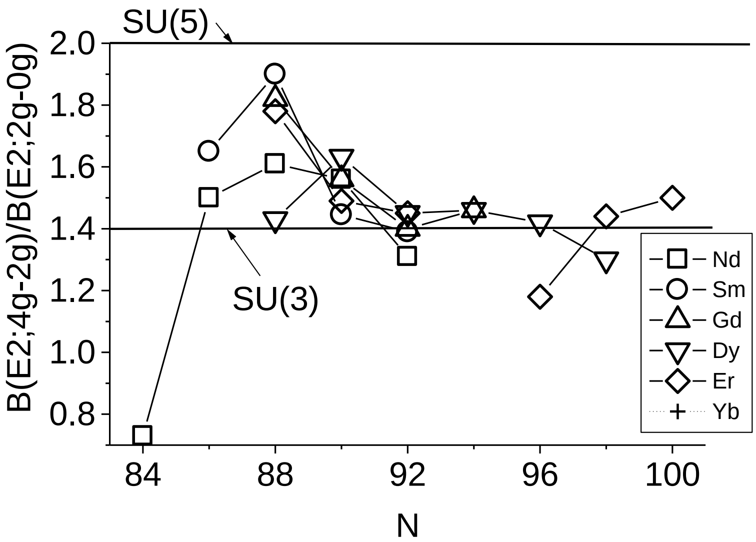


**Fig.1: The variation of experimental B(E2;4g→2g)/B(E2;2g→0g) ratio vs. neutron number (N) for Nd-Er nuclei. The vibrational limit SU(5) at 2.0 and rotational limit SU(3) at 1.4 are shown by dotted lines for comparison.**

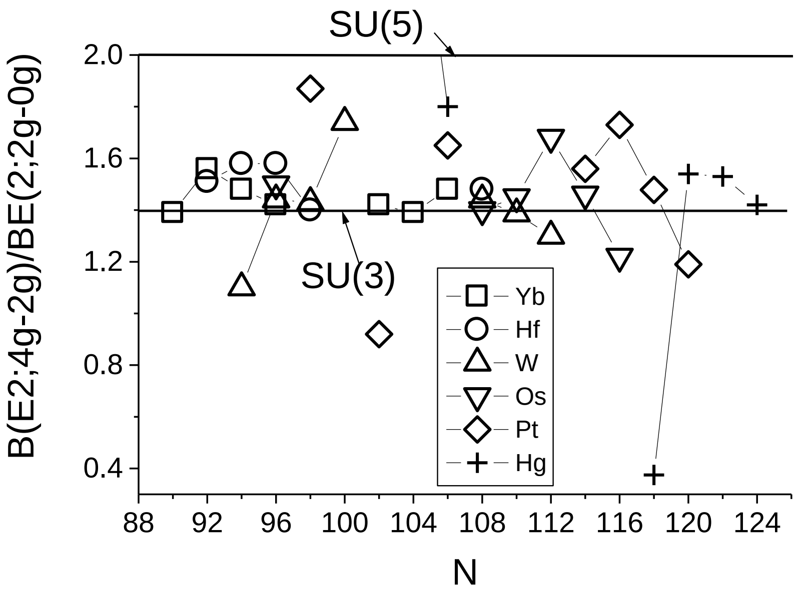


**Fig.2: The variation of experimental B(E2;4g→2g)/B(E2;2g→0g) ratio vs. neutron number (N) for Yb-Hg nuclei. The vibrational limit SU(5) at 2.0 and rotational limit SU(3) at 1.4 are shown by dotted lines for comparison.**

### 2.2 The variation of experimental B(E2;4g→2g)/ B(E2; 2g→0g) ratio verses proton number (Z).

The variation of observed B(E2;4g→2g)/ B(E2; 2g→0g) ratio with proton number (Z) is shown in Fig. 3, 4 and 5 for N=84 to 92, N=94 to 102 and N= 104 to 124 isotones respectively and the experimental points are joined for same value of N to observe the effect of Z. The vibrational limit (VM) or SU(5) at 2 and rotational limit or SU(3) at 1.4 are also shown by dotted lines for useful comparison in each figure.

It is evident from Fig. 3, that the BE(2) ratio for N=88 isotones increases on increasing Z from 60 to 62 (attains the maximum values for $Sm_{88}$) and decreases for Gd and Dy (attains minimum value close to SU(3) limit for $Dy_{88}$) and again for Er it increases. For N=88, the B(E2) ratio is close to SU(5) limiting value for Sm, Gd and Er while Dy reflects SU(3) nature and Nd in between these two limits. Also, the $Sm_{88}$ is least deformed and $Dy_{88}$ is most deformed. For N=86 isotones the B(E2) data is available only for two nuclei and it is increasing on increasing N from 60 to 60 as in the case of N=88.

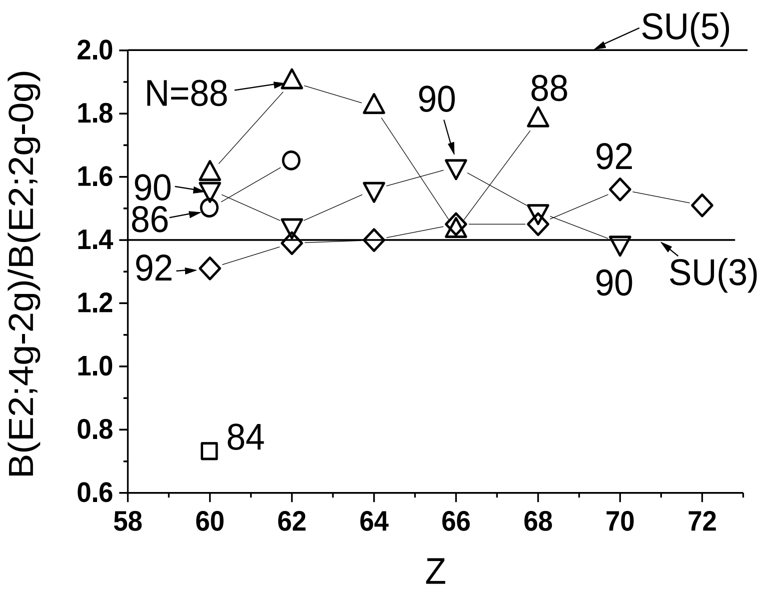


**Fig.3: The variation of experimental B(E2;4g→2g)/ B(E2; 2g→0g) ratio vs. proton number (Z). The vibrational limit SU(5) at 2.0 and rotational limit SU(3) at 1.4 are shown by dotted lines for comparison. The experimental points are joined for same value of N to observe the effect of Z on this B(E2) ratio for each isotones for N=84-92.**

For N=90 isotones the behaviour of B(E2) is just opposite to N=86 and 88; the B(E2) ratio initially decreases as N increases from 60 to 62 and increases as N increases from 62 to 66 just opposite to N=88. It is evident from the figure that the gap is maximum between the two curves for N=88 and 90 around Z= 64 indication the subshell effect at Z=64 for N<90. It is supporting the findings of Casten [6] and Casten and Zamfir [7].

In general, for N=90 isotones, the B(E2) ratio is somewhat independent of Z indicating constant structures because the values of this ratio are ranging between 1.45 to 1.6 and it support the findings of Gupta [8]. For N=90 isotones, this B(E2) ratio initially decreases on increasing Z from 60 to 62 (attains minimum values which is close to SU(3) limiting value for $Sm_{90}$ unlike $Sm_{88}$ for which this ratio is close to SU(5) limiting value) and increases slowly on increasing Z from 62 to 66; and attains maximum value(=1.6) for $Dy_{90}$; and beyond Z=66 the BE(2) decreases linearly on increasing Z from 66 to 70 (and approaches 1.4 value for $Hf_{90}$). It is clear from Fig. 3 that $Sm_{90}$ and $Hf_{90}$ are most deformed in comparison to other N=90 isotones.

For N=92 isotones, this ratio goes on increasing very slowly from 1.31 to 1.56 on increasing Z from 60 to 74 and is close to SU(3) limiting value of 1.4. However for N=94, this ratio is almost constant because its values are 1.46±0.05, 1.46±0.07, 1.48±0.07, 1.58±0.10 and 1.1±0.3 for Gd, Dy, Yb, Hf and W isotopes respectively indication Z independency. For N=94, 96 and 98 isotones (see Fig. 4) the ratio is close to SU(3)

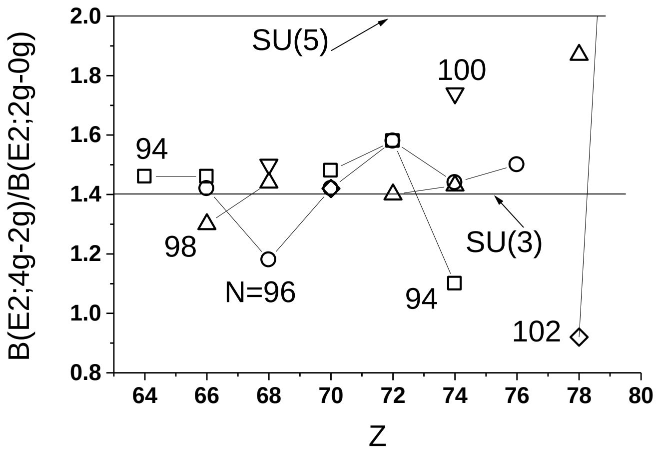


**Fig.4: Same as Fig.3 for N=94 to 102.**

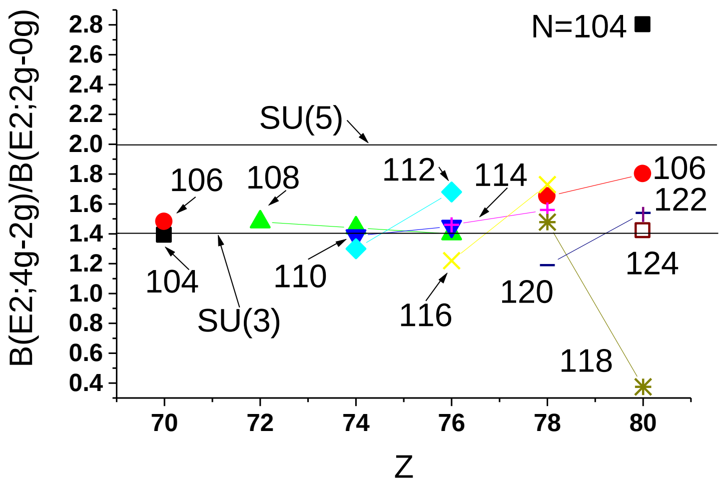


**Fig.5: Same as Fig.3 for N=104 to 124.**

limiting value indicating deformed nature. For other isotones the B(E2) ratio is lying between SU(5) and SU(3) or O(6) limiting values (see Fig.5) as predicted by the asymmetry rotor model [9].

## III. CONCLUSION

The variation of B(E2; 4g→2g)/ B(E2;2g→0g) ratio with N and Z is shown for Nd – Hg nuclei. It is found that the there is shape phase transition for N=88 and 90 isotones (Nd, Sm, Gd, Er) from an ideal spherical harmonic vibrator or SU(5) to an axially symmetric deformed rotor or SU(3). Also B(E2) ratio is anomalously small for two nuclei i.e., $^{198}_{80}Hg_{118}$ (=0.375±0.018) and $^{144}_{60}Nd_{84}$ (=0.73±0.090) with only two vacancy of p+ for Z =82 and two valence $n^0$ outside N=82, respectively; which supports the findings of Cakirli et.al. [5]. The present study supports; the subshell effect around Z=64, for N≤ 90 as observed by Casten [6] and Casten and Zamfir [7]; and the constant nuclear structure of N=90 isotones as pointed out by Gupta [8].

## IV.ACKNOWLEDGEMENTS

One of us (SS) expresses his gratitude to the Prof. Alabi Musa, Vice Chancellor, Yobe State University, Damaturu, Yobe State, Nigeria for encouragement and for providing the facilities for the research work. We are grateful to Professor J. B. Gupta, Ramjas College, University of Delhi for his valuable guidance.

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