Search of Asymmetric Rotors in some even-even Ru-isotopes

Mani Varshney[1], *M. Singh[2], Yuvraj Singh[3], Chhail Bihari[4], A. K. Varshney[5], K. K. Gupta[3] and D. K. Gupta[1]

1. *S. V. College, Aligarh – 202001, U.P., India.*
2. *S. S. L. D. Varshney girls Engg., College, Aligarh-202001, (U. P.), India.*
3. *Govt. College, Dhaliara (H.P), India.*
4. *Bon Maharaj Engineering College, Vrindavan (U.P), India.*
5. *Govt. College, Jojandrapur, (H.P.), India.*

* Email: singh.moti@gmail.com

In the neutron rich nuclei A ≥ 100, the nuclear shape changes rapidly as the valence nucleons fill the $g_{9/2}$ protons and $h_{11/2}$ neutrons orbitals. An empirical relation for computing rotational energies in neutron rich transional nuclei around A ~100 has recently been put forward by Mani et al [1] that based on rigid rotor model of Davydov – Filippov [2] works very well not only for ground band but also for so called gamma band. The purpose of the present work is an extension of the previous work in which the odd – even staggering in - γ band is studied. The staggering indices *S (I, I-1, I-2)* is defined as-

$$S(I, I-1, I-2) = \frac{(E_I - E_{I-1}) - (E_{I-1} - E_{I-2})}{E(2_1^+)} \quad \text{.......... ....(1)}$$

have been used as signature to distinguish the γ – soft and γ – rigid shapes of nuclei [3].

In the present work some even – Ru nuclei are considered to study their nuclear shapes in ground state. The basic results of fundamental models of Wilet–Jean [4] and Davydov - Filippov [2] connecting the band head energies are of immense significance since no perturbation taken place in them because of any physical effects. According to these models $E3_1^+ = E2_1^+ + E2_2^+$ (γ-rigid) and $E3_1^+ = 2E2_1^+ + E4_1^+$ (γ-soft). We calculate $\Delta E_1 = E3_1^+ - (E2_1^+ + E2_2^+)$ and $\Delta E_2 = E3_1^+ - (2E2_1^+ + E4_1^+)$ and one can safely take $\Delta E_1 \rangle\rangle \Delta E_2 \approx 0$ for γ-rigid and $\Delta E_2 \rangle\rangle \Delta E_1 \approx 0$ for γ-soft shapes. The values of γ calculated from relations of ref. 1 and ΔE_1 & ΔE_2 for experiment are listed in Table-I for some even Ru nuclei. The values of S (I) versus I of $^{98-112}$Ru nuclei have been plotted using exp. & empirical values in fig-1. The axial rotor model with rotation – vibration interaction has the energy spectra –

$$E = A\, I\,(I+1) - B\, I^2 (I+1)^2 \qquad (1)$$

It must be emphasized from the above relation that for the axial rotor all the *S (I)* are positive and small in magnitudes & show no zigzag behavior, but increase slowly with increase in *I* of course *S (I) = 0* for all values of *I* if *B=0* but in case of γ - static rotor, the *S (I)* versus *I* plot is a zigzag one however this must be kept in mind that for both rotors whether axial or triaxial value of ΔE_1 is small. Thus, for $\Delta E_1 \approx 0$ & ΔE_2 large, axial rotors will be distinguished from triaxial rotors having small positive values of S (I) while the later will have all positive and negative values of S (I) may not be alternatively but theory should tally exactly with experiment in the plot of S (I) versus I [5].

1. **^{98}Ru:** ΔE_1=271, ΔE_2=907, $\gamma = 26.8^0$ sign of S (4, 3, 2) are opposite in Exp. & ARM. Nothing can be said.
2. **^{100}Ru:** ΔE_1=21, ΔE_2=425, S (I) are large & tallies in ARM with completely to large extent. Therefore, nucleus may be γ-rigid.
3. **^{102}Ru:** S (I) are small and opposite in sign for S (6, 5, 4), S (7, 6, 5), and S (8, 7, 6) but tally S (4, 3, 2), S (5, 4, 3) in exp. and ARM, ΔE_1=571, ΔE_2=535. The nucleus may be γ - soft.
4. **^{104}Ru:** S (I) are large and similar in exp. & ARM, ΔE_1=9, ΔE_2=362, $\gamma=24.5^0$, Thus, nucleus may be γ-rigid.
5. **^{106}Ru:** S (I) are large and similar in exp. and ARM, ΔE_1=291, ΔE_2=164, $\gamma=22.7^0$, nucleus may be γ-rigid.
6. **^{108}Ru:** The value of S (I) are large and similar in exp. and ARM, ΔE_1=4, ΔE_2=175,

γ=22.8^0, Therefore, the nucleus may be γ-rigid.

7. **^{110}Ru:** S (4, 3, 2) & S (6, 5, 4) small and opposite in sign in exp. & ARM, ΔE_1=6,ΔE_2=285, nucleus may be axial.
8. **^{112}Ru:** S (4, 3, 2), S (5, 4, 3), S (6, 5, 4) are small & positive, S (7, 6, 5) negative, S (8, 7, 6) large & equal in both, ΔE_1=13, ΔE_2=371, γ=26^0. Thus, the nucleus may be axial in nature.

Asymmetry in even transitional nuclei is a well established phenomenon. The question of whether asymmetric atomic nuclei are γ-soft or γ-rigid (triaxial) has been an ongoing and active issue in nuclear structure physics for over half a century. Strictly speaking, rigid triaxiality is an imaginary concept which was long back introduced by Davydov-Fillipov [2]. Zamfir & Casten [3] on the basis of γ-band level spacing had already ruled out any possibility of such concept to exist. However, in a broader perspective much work has been done on general triaxiality to be static if not to a full extent but to a limited extent. Davydov-Flippov model energies with various types of modifications and one which has been put forward by authors of ref. 1 had been of much significance. A detailed study of Mo, Ru, Pd – nuclei in mass region $A\sim100$ have already been sent for publication [6]. In a broader perspective, we conclude that ^{100}Ru, ^{104}Ru, ^{106}Ru, ^{108}Ru, ^{112}Ru are very good candidate for γ-rigid shape while ^{102}Ru is γ-soft and ^{110}Ru is axial one whereas ^{98}Ru need some more experimental study for useful comments. These may be γ-soft if not covered by the first two categories.

Table –I

The experimental $\Delta E_1, \Delta E_2$ and calculated value of asymmetry parameter (γ)

Nucleus	γ (in deg.)	ΔE_1	ΔE_2
^{98}Ru	26.8	271	907
^{100}Ru	21.0	21	425
^{102}Ru	22.5	57	535
^{104}Ru	24.5	9	362
^{106}Ru	22.7	29	164
^{108}Ru	22.8	24	175
^{110}Ru	24.2	6	285
^{112}Ru	26.3	13	371

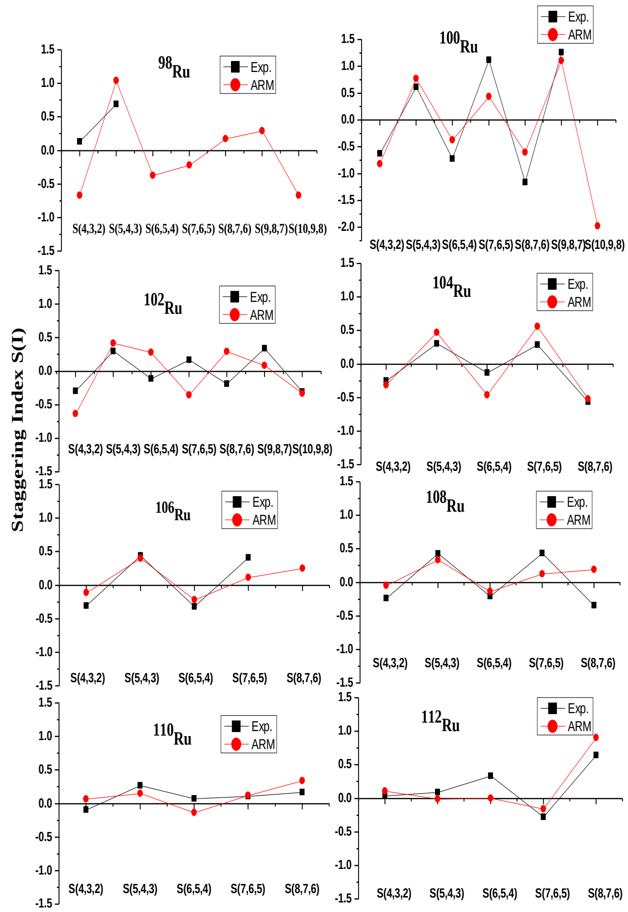

Fig. 1 (b) Staggering Indices S (I) vs Spin (I) in some Ru-isotopes.

References:

1. Mani et.al; Physica Scripta **75** (2007) 451.
2. Davydov A. S. and Filippov G. F.; Nucl. Phys. **8** (1958) 237.
3. Casten R. F. and Zamfir N. V.; Phys. Lett **152** (1985)22.
4. Wilet J. and Jean M.; Phys. Rev.**102** (1956) 788.
5. Fransen C. et al; Phys. Rev. C **67** (2003) 024307.
6. Varshney Mani, et ai ; Physica Scripta, 2010 (Communicated)

Acknowledgement: Principal, S. V. College, Aligarh is gratefully acknowledged for providing working facilities. One of the authors, namely, M.Singh is grateful to **Director**, SSLD Varshney Girls Engg. College, Aligarh.