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The study of nuclear softness parameter in Hg and Tl Superdeformed nucleus through 2-parameter formula

[1]Honey Sharma, [1]H. M. Mittal, [2]Neha Sharma and [3]Pankaj Arora
[1]*Department of Physics, Dr. B.R. Ambedkar National Institute of Tech., Jalandhar 144011, India.*
[2]*CT Institute of Engineering, Management and Technology, Jalandhar 144020, India.*
[3]*CT Polytechnic College*, Jalandhar 144020, India. *email: honeyshrma777@gmail.com*

*Abstract***—The two parameter formula has been applied on different superdeformed bands of Hg and Tl nucleus. The nuclear softness parameter is related to the rigidity of the nucleus. One of the most common signatures to detect rigidity is $R(I)$ ratios. The variation of nuclear softness parameter versus $R(I) = E_\gamma(I \rightarrow (I-2))/E_\gamma((I-2) \rightarrow (I-4))$ is studied.**

Index Terms— **Superdeformed bands, Nuclear softness parameter, R (I) ratios.**

I. Introduction

THE invention that initiates the research on superdeformation was predicted by Struntinsky [1]. The appearance of high spin superdeformation was later determined by Dudek and Nazarewicz [2]. The experimental verification of which is given by Twin et al. [3]. The superdeformed bands are now observed in so many of the mass regions i.e. A=60, 80, 130, 150, 190. Due to the non-linking transitions between superdeformed bands and normal deformed bands, several puzzles; like exact spin, excitation energies and parties of SD bands remains unknown. Many of the different approaches [4-7] are presented to solve the problem of spin assignment. The discrete γ ray's connecting the states helps experimentally in the projection of spin and excitation energies of all the subscribers of ^{194}Hg(1) [8]. With the help of these predictions spins and excitation energies of yrast SD bands of ^{194}Pb [9-11] and ^{194}Hg(3) [12] are also established. The unique spectroscopic statistics available to explain the phenomenon of superdeformation mainly consists of intraband energies. The characterization of SD nuclei are mainly discussed by two types of MOI i.e. kinematic moment of inertia $J^{(1)}$ which depends upon spin propositions and dynamic moment of inertia $J^{(2)}$ which are independent of spin. For A~150 mass region, the variation in $J^{(2)}$ with rotational frequency is relying upon proton and neutron occupation of high –N intruder orbital [13]. For most of the even-even and odd-A nuclei in A~190 mass region, $J^{(2)}$ displays a regular increase with increasing rotational frequency [14], which is due to the gradual alignment of quasinucleons occupying high-N orbital's (originating from $i_{13/2}$ proton and $j_{15/2}$ neutron sub shells) in the existence of pair correlation while in odd-odd SD nuclei; moment of inertia remains almost constant. In A~190 mass region superdeformation is well demonstrated experimentally with over 30 bands recognized in Hg, Tl, Pb nuclei [14]. These inspections assert the various theoretical previsions of superdeformation for these nuclei [15-18] and have prolonged the analysis of nuclei under extreme condition of large deformations and high angular momentum. Moment of inertia attains rigid values; when spin of the nuclei increases. The increase in the values of moment of inertia per unit change in angular momentum is defined as 'Nuclear softness parameter [19]. Softness parameter generally detects the rigidity of nucleus. The data compiled for nuclear softness parameter by Sharma and Mittal [20] is observed to be in the range of $10^{-4} \leq \sigma \leq 10^{-6}$. With the comparison of data with ND bands ($10^{-2} \leq \sigma \leq 10^{-4}$) it is observed that nuclear softness parameter value for SD bands are 100 times less than that of ND bands; which implies SD are much more rigid than ND bands. We present the systematics of nuclear softness parameter of Hg and Tl nucleus with $E_\gamma\left(I \rightarrow (I-2)\right)/E_\gamma\left((I-2) \rightarrow (I-4)\right)$.

II. Theory

The methodology of even nuclei gives the approval on Bohr-Mottelson's depiction of deformed rotating nuclei with rotational energies

$$E = \frac{\hbar^2}{2I}J(J+1) = AJ(J+1) \qquad (1)$$

Experimentally; it is noticed that for higher J-states, probably eq.1. with constant moment of inertia, holds only approximately. An enhanced energy formula is of the form

$$E = AJ(J+1) + BJ^2(J+1)^2 \qquad (2)$$

is achieved as a first approximation from classical calculation of centrifugal stretching [21]. However the above stated equations are not suitable to show the experimental spectra with high J- values. Another series form can be [22]

$$E = AJ(J+1) + BJ^2(J+1)^2 + CJ^3(J+1)^3 + \cdots. \qquad (3)$$

The first term is calculated by higher approximation for centrifugal stretching or rotation- vibration interaction. Similarly this series also tends to deviates for high spin and cannot be applicable [23]. Therefore a successful formula i.e. two- parameter formula is obtained from experimental level systematics; or, it can be derived from nuclear hydrodynamics [24]. 2 –parameter formula is used for ground- state rotational bands of deformed even nuclei. The 2- parameter formula can be stated as

$$E = a\left[\sqrt{1 + bI(I+1)} - 1\right] \quad (4)$$

Since intraband energies are the only available data for SD bands; so one may fit E_γ transitions;

$$E_\gamma(I) = E(I) - E(I-2) \quad (5)$$

So, using eqs. (4) and (5), we obtain

$$E_\gamma(I \to I-2) = a\left[\sqrt{1 + bI(I+1)} - \sqrt{1 + b(I-2)(I-1)}\right] \quad (6)$$

The parameter a and b can be obtained by fitting the E_γ transitions for SD cascades. One may obtain the nuclear softness parameter (σ) by using the relation

$$(\sigma) = 0.5b \quad (7)$$

III. Results and Discussion

We used the fitted data of 2-parameter formula from Ref [25] and obtained the nuclear softness parameter for Hg and Tl nucleus in A=190 mass region by using eq. (7). The nuclear softness parameter (σ) basically describes rigidity of the nucleus. To account for rigidity; the foremost signature can be the quantity like (E_4/E_2) ratio in deformed even- even nuclei. After all the band head energies of SD bands are not known; so the energy ratios cannot be used directly ; so as a substitute a ratio of γ ray transition energy can be used which can be defined as $R(I) = E_\gamma\left(I \to (I-2)\right)/E_\gamma\left((I-2) \to (I-4)\right)$. We therefore calculate R (I) ratios by using Ref [26-27] for those SD bands where same set of spins are known. The variation of nuclear softness parameter versus R (I) ratios is studied in Fig. 1. It is observed from Fig.1. that nuclear softness parameter of SD bands in Hg and Tl nucleus decreases with increase in R(I); which indicates decrease of pairing in turn of which deformation in these nuclei increases.

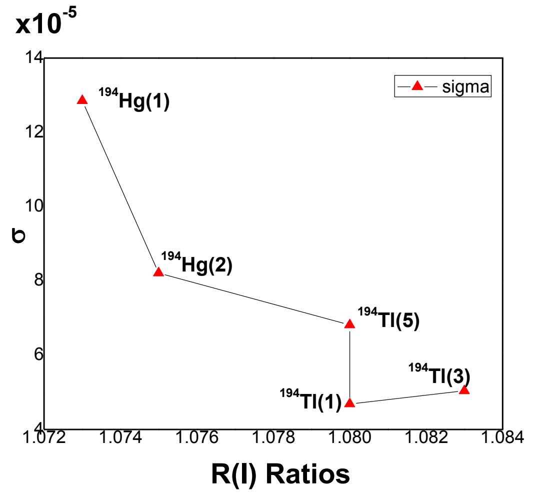

Fig. 1.The variation of nuclear softness parameter versus R (I) ratios of Hg and Tl nucleus.

IV. Conclusion

In this present work, we used 2 parameter fitted data for Hg and Tl SD nucleus and studied the variation of nuclear softness parameter versus R (I) ratios. It is highly interesting to note that smaller is the nuclear softness parameter larger is the deformation; and larger is the rigidity.

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