Super rigid nature of super-deformed bands

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Introduction

The phenomenon of high-spin super-deformation represents one of the most remarkable discoveries in nuclear physics. A large number of SD bands have been observed in A=60, 80, 130, 150, 190 mass regions [1, 2]. The cascades of SD bands are known to be connected by electric quadruple E2 transitions. Because of absence of linking transitions between super-deformed (SD) and normal deformed (ND) levels, the spin assignments of most of these bands carry a minimum uncertainty ≈ 1-2$\hbar$. It was found in an analysis of SD bands in the context of semi classical approach that moment of inertia comes close to the rigid body value in most of the cases [3,4]. Lack of knowledge of spins has led to an emphasis on the study of dynamical moment of inertia of SD bands and systematic of kinematic moment of inertia has not been examined so far. In this paper, we extract the band moment of inertia J_0 and softness parameter (σ) of all the SD bands corresponding to axes ratio (x) = 1.5 and present their systematic.

Results and Discussions

We discuss the results for SD bands corresponding to deformation or ratio of major to minor axes (x) = 1.5. This deformation is also based on measured transition quadruple moments (Q_t), which are used to obtain the x-values for a number of SD bands. The band moment of inertia J_0 for rigid prolate shape $J_{prolate}$ may be obtained by using the relation [5].

$$J_{prolate} = \left\{\frac{A^{5/3}}{72}\frac{1+x^2}{2x^{2/3}}\right\}$$

The four parameter formula [6] has been used to fit the gamma ray energies of all the SD bands corresponding to x=1.5 shape in the Table of SD bands [1] and continuously updated ENSDF [2] database. In 1.5:1 category, a total of 59 SD bands have been fitted by using four parameter formula. The J_0 values from fitting of SD bands are plotted as a function of mass number A in the Fig. 1; these are compared with the moment of inertia values of a prolate ellipsoid having x=1.5 and with that of rigid sphere. We note that J_0 values follow the general trend of the prolate rigid rotor as a function of the mass number A. Many values come close to the prolate rigid rotor curve and many of them are much below the prolate rigid rotor curve. It is surprising to note that few of them are much higher than the prolate rigid rotor curve and we term these bands as "super rigid" rotor bands.

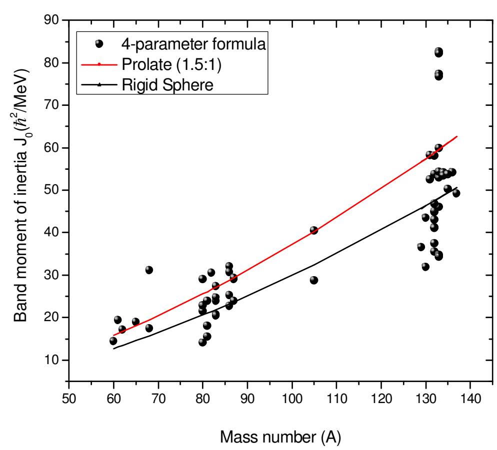

Fig. 1 Band moment of inertia J_0 as a function of mass number A for all SD bands with deformation (1.5:1) obtained by using the four parameter formula. The black line is the moment of inertia value for rigid sphere and red line for prolate ellipsoid with deformation (1.5:1).

Further insight into the behavior of band moment of inertia may be obtained by a comparison of the J_0 values from the band fitting with those obtained from the Q_t measurements [see Fig. 2]. In Fig. 2, J_0 values of those SD bands are compared in which Q_t measurements are available. There are many cases where J_0 values nearly match with those obtained from the Q_t values and also with the rigid rotor estimates. The most interesting point to note that there are several values of J_0 in A=60 and A=80 mass region which are much higher than those obtained from the measured Q_t measurements. We term these cases as "super rigid" bands. We can only contemplate that such cases may be examples of enhanced "nuclear magnetism" in SD bands [7].

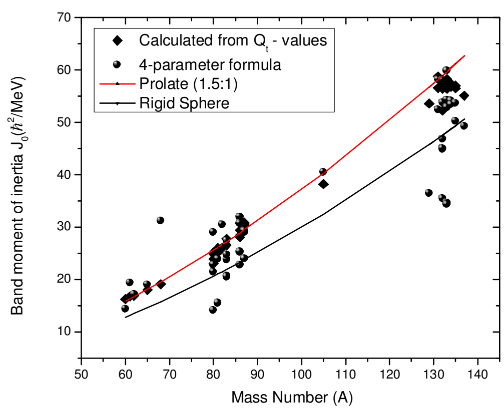

Fig. 2 Individual values of the band moment of inertia J_0 as obtained from the measured Q_t values are compared with the values obtained from the four parameter formula fits. Also the curves are shown for the 1.5:1 and 1:1 shapes.

The value of softness parameter (σ) from fitting are observed to lie in the range of $0.59*10^{-5}$ to $91.1*10^{-5}$ [see Fig. 3]. These values are much smaller than those of the ND bands. Therefore, SD bands are much more rigid than ND bands. The bulk of the cases comprising the SD bands in 1.5:1 category comes from the A=130, 80 mass regions in that order, which have an average σ=51 and $46*(10^{-5})$ respectively. However, there is some spread in the σ values within the SD bands of given mass region.

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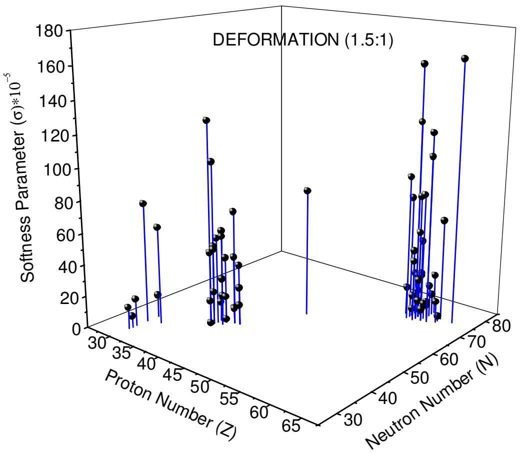

Fig. 3 Softness parameter σ as a function of proton number and neutron number obtained by using the four parameter formula for SD bands having a deformation about (1.5:1).

Conclusions

The systematic of J_0 and σ is presented for x=1.5 shape. We note that some values of J_0 are much higher than prolate rigid rotor curve and those obtained from Q_t measurements. We term these bands as "super rigid" bands. The results for other SD bands corresponding to x=1.7 shape and x=2 shape will also be presented.

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