Global study of softness parameter of superdeformed bands

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Introduction

The superdeformed (SD) shapes whose existence was predicted first by V.M. Strutinsky [1] have been observed experimentally by Twin et al. [2]. They are manifestation of strong deformed shell effects which remain in close analogy to the well known spherical shell closures. The phenomenon of high spin deformation represents one of the most remarkable discoveries in nuclear physics made during the last decade of 20th century. A large number of SD bands have been observed in the mass region A=60, 80, 130, 150, 190 [3, 4]. Also Ideguchi et al. [5, 6] observed SD bands in A=40 mass region.

In this paper, we use a simple 4-parameter formula due to Bohr and Mottelson [7, 8] to obtain the nuclear softness parameter σ for the SD bands covering the whole chart of nuclides. Throughout this study, we have assumed that all the SD bands have a prolate ellipsoidal shape. We have, therefore, discarded those SD bands which have been identified as tri-axial in nature.

Results and Discussions

The 4-parameter formula has been used to fit the E2 gamma ray energies of all the SD bands covering the whole chart of nuclide [11]. The experimental data are taken from Ref. [3] and the continuously updated ENSDF and XUNDL databases [4]. We have considered only those SD bands for which some kind of estimates of spin assignments are available. A total 219 SD bands have been fitted. Since the SD bands are good rotors, so, the fits are generally very good as expected. Most of the σ values are observed to lie in the range of 0.03 $\times 10^{-5}$ to 43.5 $\times 10^{-5}$. These σ values are much smaller than those of normal deformed (ND) bands by a factor of 100 at least. The nuclear softness parameter σ for SD bands lies in the range of $10^{-3} \leq \sigma \leq 10^{-6}$ as compared to ND bands having a range of $10^{-2} \leq \sigma \leq 10^{-4}$. The nuclear softness parameter is related to extent of rigidity of SD bands. Thus, the SD bands are found to be much more rigid than the ND bands.

We plot in Fig. 1, the fitted values of the softness parameter σ for all the SD bands as a function of the axes ratio x, which represents the deformation of the SD bands. This plot brings out two important results. One, the σ-values are strongly correlated to the deformation; larger the deformation, smaller is the softness and, therefore, higher is the rigidity. Two, the spread in the σ-values converges as the deformation increases. The second result is quite dramatic and immediately suggests that the large deformation bands are more rigid and also more similar to each other. Since, nearly all the SD bands in the 2:1 category belong to A=150 mass region, this conclusion has nothing to do with the presence of a larger number of nucleons in the nucleus. It, therefore, appears to be purely a deformation effect. We believe that the variation of level density with deformation may be an important factor causing this dependence. Microscopic calculations should be carried out to understand this feature. Based on the studies of periodic orbits in spheroidal cavities, we suggest a connection between the increasing role of the non-planar 3-dimensional (3D) periodic orbits and the rigidity of the bands as the deformation increases [12].

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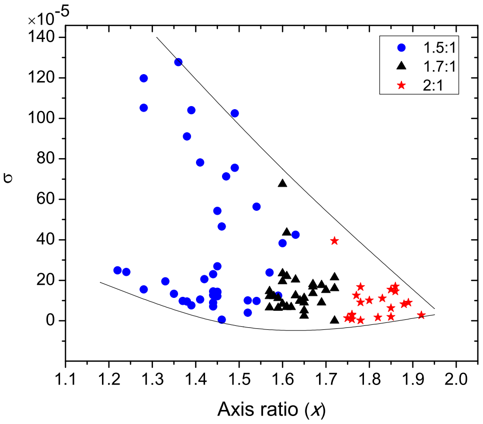

FIG. 1: Softness parameter σ vs. axis ratio (x) obtained from the 4-parameter formula for all the SD bands.

Conclusions

In this present work, we calculate the nuclear softness parameter (σ) for SD bands covering the whole chart of nuclides by using 4-parameter formula and present their systematics in detail. The nuclear softness parameter (σ) for SD bands lies in the range of $10^{-3} \leq \sigma \leq 10^{-6}$ as compared to ND bands having a range of $10^{-2} \leq \sigma \leq 10^{-4}$. Thus, the SD bands are found to be much more rigid than the ND bands. We also find that the softness parameter σ is strongly correlated to deformation. Larger the deformation, smaller is the value of σ and, more significantly, smaller is the spread in the σ-values. Nearly all the SD bands in the 2:1 category belong to A=150 mass region and have σ-values with least spread across the various SD bands. This suggests that the rigidity of the SD bands mostly depends on the magnitude of deformation. We also note that the well celebrated 2:1 shape is not reached in any SD band; the highest x-values are reached in A=150 mass region and it is always less than 1.9.

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