Systematic study of nuclear softness of superdeformed bands with $N_P N_n$ scheme in A=190 mass region

Neha Sharma[1,2,3],* H.M. Mittal[2], and A.K. Jain[3]
[1] *CT Group of Institutions, Shahpur Campus, Jalandhar-144020, INDIA*
[2] *Dr. B.R. Ambedkar National Institute of Technology, Jalandhar-144011, INDIA and*
[3] *Deptartment of Physics, Indian Institute of Technology, Roorkee-247667, INDIA*

Introduction

A critical role of the proton-neutron (p-n) interaction in developing mixed configurations in nuclei has been recognized half a century ago by de-Shalit and Goldhaber [1], the importance of the valence p-n interaction in the evolution of nuclear structure have also been asserted by many authors. Talmi [2] was the first to emphasize that the p-n interaction may give rise to deformed nuclei. A simple pattern appeared whenever nuclear data concerning nuclear deformation was plotted against the product N_pN_n between the valence proton number N_p and the valence neutron number N_n [3]. This phenomenon has been referred to as "the N_pN_n scheme" in the literature [4]. More than two decades ago, a lead has been taken by many authors, in regarding the N_pN_n scheme as clear evidence of the p-n interaction being the dominant factor of inducing the nuclear deformation. Gupta et al. [5] studied the variation of softness parameter with the increasing deformation for deformed nuclei by using variable moment of inertia nuclear softness model. This study motivated us to study the softness parameter with N_pN_n for SD nuclei. Here, in this paper, we extend the same idea by studying the nuclear softness parameter with N_pN_n for the SD bands in A=190 mass region.

In the present work, we use a 4-parameter formula based on the prescription of Bohr and Mottelson [6, 7] to obtain the nuclear softness parameter σ for SD bands in A=190 mass region. We present the systematics of the softness parameter of the SD bands in A=190 mass region with the gamma ray energy ratio R(I)=$E_\gamma(I \rightarrow (I-2))/E_\gamma((I-2) \rightarrow (I-4))$ and N_pN_n .

*Electronic address: nsharma.nitj@gmail.com

Results and Discussions

The 4-parameter formula has been used to fit the E2 gamma ray energies of all the SD bands in A=190 mass region. The experimental data are taken from Ref. [8] and the continuously updated ENSDF and XUNDL databases [9]. We have considered only those SD bands for which some kind of estimates of spin assignments are available. A total 71 SD bands have been fitted in this mass region.

There is a close relation between the nuclear deformation and the p-n interaction and also between the N_pN_n scheme and the nuclear deformation. As already discussed, that whenever a nuclear data related to nuclear deformation plotted against N_pN_n, a simple pattern had appeared [3]. But in our case, the values of σ are found to be very scattered. Because some SD bands have large values of σ and some SD bands have small values of σ. One reason for large values of σ is that pairing correlations are dominant in those cases; however, the SD phenomenon is high spin phenomenon. In general, the value of softness parameter increases with increasing value of N_pN_n.

One thing which is to be noted that $^{195}Hg(1)$ and $^{195}Hg(2)$ have same value of softness parameter. Similarly, $^{194}Hg(2)$ and $^{194}Hg(3)$, $^{193}Hg(3)$ and $^{193}Hg(5)$, $^{192}Hg(1)$ and $^{192}Hg(2)$, $^{191}Hg(1)$ and $^{191}Hg(4)$ have also the same value of σ versus the same value of N_pN_n respectively. Similarly, the value of the softness parameter increases as the value of N_pN_n increases in other bands of A=190 mass region. The σ for $^{194}Tl(4)$ and $^{194}Tl(5)$,

$^{193}Tl(1)$ and $^{193}Tl(2)$, $^{192}Tl(3)$ and $^{192}Tl(4)$, $^{191}Tl(1)$ and $^{191}Tl(2)$ have same value with the same value of N_pN_n respectively. It has been observed that majority of SD bands in A=190 mass region in odd-A nuclei, odd-odd nuclei and excited SD bands in even-even nuclei are signature partner SD bands [10]. It has also been observed that the value of band moment of inertia J_0 of each signature partner SD bands in A=190 mass region are almost identical [11, 12]. It is highly interesting to note that the value of the softness parameter σ of the signature partner SD bands is also the same

Conclusions

In this present work, we calculate the nuclear softness parameter (σ) for SD bands in A=190 mass region by using 4-parameter formula and present their systematics in the scheme of N_pN_n. 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. In general, the value of σ increases as the value of N_pN_n increases, which suggests that rigidity decreases as the value of N_pN_n increases. It is highly interesting to note that the signature partner SD bands observed in A=190 mass region have identical value of softness parameter (σ).

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References

[1] A de-Shalit and M Goldhaber, Phys. Rev. **92**, 1211 (1953).
[2] I Talmi, Rev. Mod. Phys. **34**, 704 (1962).
[3] R F Casten, Nucl. Phys. A **443**, 1 (1985).
[4] R F Casten and N V Zamfir, J. Phys. G: Nucl. Part.Phys. **22**, 1521 (1996).
[5] J B Gupta, A K Kavathekar and Y P Sabharwal, Phys. Rev. C **56**, 3417 (1997).
[6] A. Bohr and B. R. Mottelson, Nuclear Structure, Vol.II(Benjamin, New York, 1975).
[7] B. R. Mottelson, Proceeding of the Nuclear Structure Symposium of the Thousands Lakes, Jousta, 1970 [Nordisk Institut for Theoretisk Atomfysik, Nordita, Report No. 417, 1971(unpublished).
[8] B. Singh, R. Zywina and R. B. Firestone, Table of superdeformed Nuclear Bands and Fission Isomers, Nuclear Data Sheets **97**, 241 (2002) and references therein.
[9] Evaluated Nuclear Structure Data File (ENSDF) and Experimental Unevaluated Nuclear Data List (XUNDL) databases maintained at the National Nuclear Data Centre, Brookhaven National Labortary, Upton, NY.
[10] S X Liu and J Y Zeng, Phys. Rev. C **58**, 3266 (1998).
[11] Neha Sharma and H M Mittal and A K Jain, Proc. DAE Symp. on Nucl. Phys. **56**, 332 (2011).
[12] H M Mittal and Neha Sharma, International Journal of Nuclear Energy Science and Technology **7**, 368 (2013).