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

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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 $\sigma$ 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 $R(I)=E_r(I \rightarrow (I - 2))/E_r((I - 2) \rightarrow (I - 4))$ and $N_pN_n$.

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 ENDF 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 $\sigma$ are found to be very scattered. Because some SD bands have large values of $\sigma$ and some SD bands have small values of $\sigma$. One reason for large values of $\sigma$ 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 $\sigma$ 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 $\sigma$ for $^{194}Tl(4)$ and $^{194}Tl(5)$,
$^{193}\text{Tl}(1)$ and $^{193}\text{Tl}(2)$, $^{192}\text{Tl}(3)$ and $^{192}\text{Tl}(4)$,
$^{191}\text{Tl}(1)$ and $^{191}\text{Tl}(2)$ 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 exited SD bands in even-even nu-
clei 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
$\sigma$ of the signature partner SD bands is also the same

**Conclusions**

In this present work, we calculate the nu-
clear softness parameter ($\sigma$) 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 ($\sigma$) 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
$\sigma$ 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 inter-
esting to note that the signature partner SD
bands observed in $A=190$ mass region have
identical value of softness parameter ($\sigma$).

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