Backbending of ^{162}Dy using Nilsson deformed model

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Introduction

Deformed shell model was proposed by Nilsson with phenomenological model potential called modified oscillator potential, in order to investigate the effect of deformation on single particle energy levels and to explain shell structure. The deformed nuclei can show pronounced gaps in the single particle levels much analogous to spherical nuclei. Shell closure or magicity leads to large gaps in the single particle levels, which reveals increased stability of a nucleus. Shell closure is also encountered in deformed nucleus at specific nucleon numbers [1]. Among the approaches to solve nuclear many body problem, there were three potentials such as Nilsson potential, Woods-Saxon potential and Yukawa mean field potential which are used extensively [2]. In Nilsson potential the spin-orbit term is incorporated with a constant κ and ℓ^2 term, to lower the energy of the single-particle states closer to the nuclear surface in order to correct for the steep rise in the harmonic-oscillator potential and is parametrised by the notation μ.

Nilsson deformed model is used to generate single particle energy states. In this model, the potential in Hamiltonian comprises the anisotropic harmonic oscillator potential plus the spin-orbit and centrifugal potentials.

$$H = {H_0}^0 + H_\delta + C\ell.s + D\ell^2 \qquad (1)$$

With all the matrix elements available, Hamiltonian matrix may be written by properly varying the quantum numbers of the basis $|Nl\Lambda\Omega\rangle$. Diagonalization of these matrices will lead to the energy eigen-values which are the single-particle energies of nuclei within the Nilsson model. New parameters κ and μ instead of C and D are given by,

$$\kappa = -\frac{1}{2}C\hbar\omega_0^0 \qquad (2)$$

$$\mu = \frac{2D}{C} \qquad (3)$$

The sudden rise in the moment of inertia around spin $I \geqslant 12\hbar$, commonly known as the backbending phenomenon, due to the backbend in the moment of inertia $(2I/\hbar^2)$ against the rotational frequency squared $(\hbar^2\omega^2)$ plots. Jain *et al* [1] empirically established the correlation between the presence of local gaps in neutron single particle energy levels for a deformed potential and the occurrence of backbending in the yrast bands of the rare-earth even-even nuclei. In the present work, we have attempted to explain backbending phenomena in rare earth nucleus ^{162}Dy using neutron single particle energy levels of Nilsson deformed shell model. Also, we have attempted to study the influence of the Nilsson parameters in deciding the backbending behaviour. The Nilsson Hamiltonian contains no Coulomb term. The effect of that term is incorporated into an appropriate choice of the constants κ and μ. They are actually fitted, such that the observed levels in deformed nuclei are reproduced.

Results and discussion

The quadrupole deformation (ϵ_2) of even-even nucleus ^{162}Dy is 0.281 [3]. In the present work we have used two sets of κ and μ. The first set is κ=0.062 for all N and μ = 0, 0, 0.35, 0.625 and 0.42 for N= 0, 1, 2, 3 and

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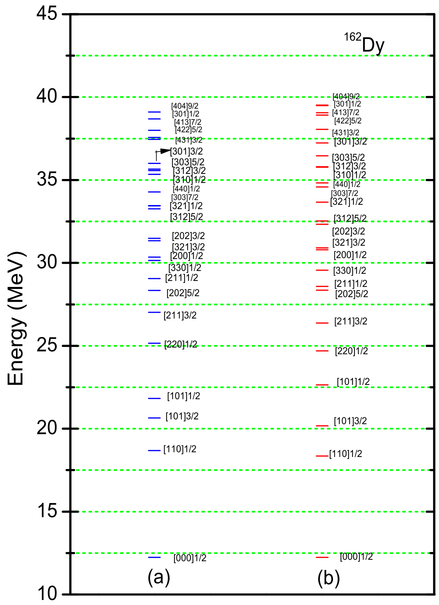

FIG. 1: Single particle energy levels for neutrons of ^{162}Dy for (a) same κ for all N and (b) varied κ for different N.

4 respectively. The second set is κ= 0.120, 0.120, 0.105, 0.09 and 0.07 and μ = 0, 0, 0.25, 0.39 and 0.43 for N= 0, 1, 2, 3 and 4 respectively. Calculated single particle energy levels for neutrons for ^{162}Dy are presented in Fig. 1, with (a) for the use of first set of κ and μ and (b) for the use of second set of κ and μ. In proton levels, only slight variation between energy levels is noted for the two sets of κ and μ, which is not presented here. But for neutron levels, there is an appreciable gap between Fermi levels [301]1/2 and [404]9/2 noticed for the use of first set of κ and μ and the gap between these levels is reduced when the second set of κ and μ is used.

In high spin states, identification of gaps is associated with interesting nuclear phenomena. Jain *et al* [1] correlated these gaps in neutron single particle level for a deformed potential with the occurrence of backbending in the yrast bands of rare-earth nuclei. According to them, there is no gap exist between the levels in the Nilsson level scheme of neutrons for a quadrupole deformation around $\epsilon \simeq 0.3$ for nuclei ^{158,160,162}Dy, ^{160,162,164}Er and ^{162,164,166}Yb with neutron number between 92 to 96. ^{162}Dy with neutron number 96 is said to have no gap and hence predicted to backbend. In Fig. 1(a) there exist a gap between the Fermi levels [301]1/2 and [404]9/2. However this gap is found to disappear for the use of second set of κ and μ. This confirms backbending in ^{162}Dy. Different values of κ for different shells is found to change the gaps between the single particle energies. There is large gap noted between levels [301]3/2 and [431]3/2 for the use of same $\kappa = 0.062$, whereas this gap is reduced in Fig. 1(b) for the use of different κ for different N values. Similarly large spacing between levels [202]3/2 and [312]5/2 is reduced much for the use of different κ. Hence the Nilsson parameters are found to play a significant role in deciding the gaps between single particle energy levels. Further comparison with the experimental results need to be carried out and will be presented.

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