The Mean Field Study of One-neutron and Two-neutron Separation Energies in Gold Isotopes

Anjana A V,* Nicemon Thomas, and Antony Joseph
Department of Physics, University of Calicut, Malappuram - 673635, INDIA

Introduction

There has been large effort for investigating nuclear ground state properties in terms of the self-consistent mean-field approximation. Self consistent mean field theory is one of the most important theories, which helps in understanding medium and heavy mass nuclei. Here, we have used the Hartree-Fock-Bogoliubov (HFB) self-consistent mean-field model with Harmonic Oscillator (HO) single-particle basis to expand quasi-particle wave functions [1]. In the mean field part we have employed the zero range Skyrme interaction and in the pairing part density dependent delta interaction (DDDI) in its mixed form is used. In the present work, we have made an attempt to investigate the one neutron separation energies (S_n) and two neutron separation energies (S_{2n}) of odd-even and odd-odd Gold (Au) isotopes. The odd-even staggering (OES) of nuclear binding energy implies that the masses of odd nuclei are larger than the two nearby even nuclei [2].

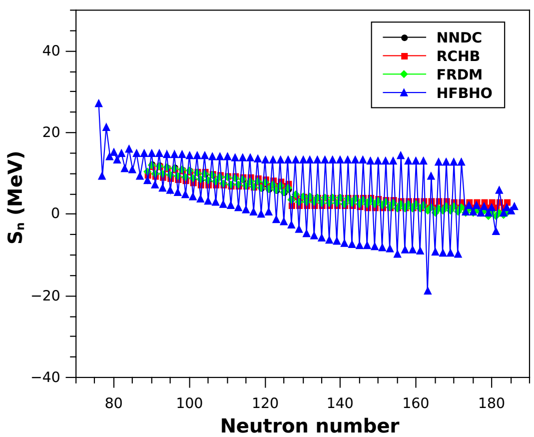

FIG. 1: Variation of the one-neutron separation energy (S_n) with neutron number of Au isotopes.

Theoretical Framework

Here we have performed a numerical analysis based on the HFB approach with the Universal Nuclear Energy Density Skyrme Functional (UNEDF0). Here, the calculations were made by using the HFB solver [3], with Harmonic Oscillator basis (HFBHO) and which iteratively diagonalizes the HFB Hamiltonian until the self-consistent solution is achieved. The computations for odd mass nuclei are made by using the blocking of quasi-particle states. The HFB equation in matrix form is given by,

$$\begin{pmatrix} (h-\lambda) & \Delta \\ -\Delta^* & -(h-\lambda)^* \end{pmatrix} \begin{pmatrix} U_n \\ V_n \end{pmatrix} = E_n \begin{pmatrix} U_n \\ V_n \end{pmatrix} \quad (1)$$

The single neutron separation energy is one of the observables obtained from binding energy BE(N,Z) and plays a significant role in finding the close shell nuclei in the isotopic chain and it is given by the equation

$$S_n(N,Z) = BE(N,Z) - BE(N\text{-}1,Z) \quad (2)$$

The two-neutron separation energy is an important physical property of a nucleus and is playing a significant role in identifying the nuclear shell closures in the isotopic chain. It is expressed as follows,

$$S_{2n}(N,Z) = BE(N,Z) - BE(N\text{-}2,Z) \quad (3)$$

Results and Discussion

In this study, we have calculated the single-neutron and two-neutron separation energies,

*Electronic address: anjanasayoojyam88@gmail.com

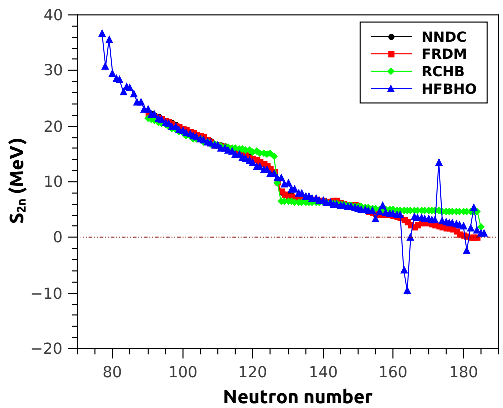

FIG. 2: Variation of the two-neutron separation energy (S_{2n}) with neutron number of Au isotopes.

for the ground state of Au nuclei obtained from the HFB calculations (HFBHO) and compared with the available experimental and theoretical data. The variation of estimated S_n values for Au isotopes with neutron number N is shown in Figure 1. The computed results agrees reasonably well with Finite Range Droplet model (FRDM), Relativistic-Continum-Hartree-Bogoliubov (RCHB)[4] predictions and available experimental data (NNDC). The nucleus having zero separation energy value can be identified as the neutron drip line. This study also implies the influence of pairing correlations in the neutron separation energies. The odd-even staggering of S_n values with neutron number is clearly visible here.

In Figure 2, we display the calculated S_{2n} values of odd–even and odd-odd Au isotopes, as a function of the neutron number. The two-neutron separation energy values of nuclei decreases with increase in N. The decline is smooth except at the magic numbers, where a sharp change in S_{2n} is observed due to the presence of neutron shell closures. The abrupt decline in S_{2n} values for ^{205}Au and ^{263}Au indicate the presence of the magic neutron number N = 126 and N=184. Except for a few data points, the present results agree with the experimental data, RCHB values and FRDM values. The two-neutron separation energies computed for the Au isotopic series were analysed to find the two-neutron dripline. The two-neutron drip line for an isotopic chain can be identified from the presence of nuclei having zero or slightly positive S_{2n} value. Therefore, the change in the sign of S_{2n} as it crosses S_{2n}=0 from positive to negative is used as an indicator for locating the drip line. In the present work, the neutron drip line has been observed for ^{260}Au. Our prediction for the two-neutron drip line in Au isotopic chain is consistent with different theoretical model investigations.

In summary, using HFB theory, we have explored the single-neutron and two-neutron separation energies over a series of isotopic chains of Gold. The computed results are matching well with the available experimental and theoretical data. Our calculations show the neutron number dependence of neutron separation energies. In this analysis we found that the odd even staggering have important influence on neutron separation energies of Au isotopes. This estimation shows that there is considerable effect of pairing correlations in the neutron separation energies. The positive and negative S_{2n} values can be associated with the stability and instability of nuclei against nucleon emission. For a particle-bound nucleus, two-neutron separation energy is positive while it is negative for an unbound nucleus. We can see that, the neutron-rich nuclei ^{260}Au, in the isotopic chain of Au, have a very low value of S_{2n} leading to an unbound system.

Acknowledgments

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