A Study of Neutron Skin Thickness in Iridium and Gold Isotopes Using HFB Theory

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Introduction

One of the most basic properties of an atomic nuclei is the distribution of the nucleon density. The density distributions of exotic nuclei are very different from that of stable nuclei. The neutron density profile extend beyond the proton density profile as the excessive neutrons are pushed out against the nuclear surface and therefore creating a sort of neutron skin. Neutron-rich nuclei produce a divergence in the Fermi energies and decoupling of neutron and proton distribution and as a result nuclear halo and skin structure is appeared. Halo is the low density tail in nuclear matter distribution, whereas skin is the difference in matter radii for neutrons and protons. The neutron skin is the significant difference in the values of matter radii for neutrons and protons and it describes the excess of neutrons at the nuclear surface. In the present study we have made an attempt to investigate the rms radii and neutron skin thickness in Iridium(Z=77) and Gold(Z=79) nuclei. The present work is devoted to the study of nuclear skin of odd-even and odd-odd isotopes of Ir and Au, thus it has significance in nuclear structure phenomena of exotic nuclei.

Theoretical Framework

Here, the calculations are made by using the computer code HFBTHO (v2.00d), utilizing Harmonic Oscillator single-particle basis which iteratively diagonalizes the HFB Hamiltonian[1] based on the UNE0 Skyrme functional and zero-range pairing interaction until the self-consistent solution is achieved. HFB equation in matrix form is given by

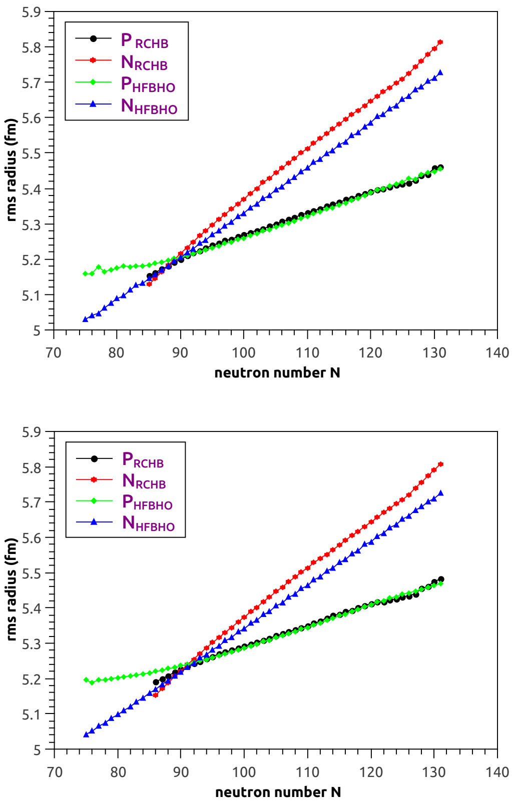

FIG. 1: Variation of rms radius with neutron number of Iridium isotopes (top) and Gold isotopes (bottom)

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

The pairing channel was parameterized by a density-dependent delta interaction in its mixed form, given by the equation

$$V_{pair}^{(n,p)}(\mathbf{r}) = V_0^{(n,p)}\left(1 - \frac{1}{2}\frac{\rho_0(\mathbf{r})}{\rho_c}\right)\delta(\mathbf{r}\text{-}\mathbf{r'}) \quad (2)$$

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The theoretical calculations are difficult for odd mass nuclei since their presence breaks the time reversal symmetry. In the case of odd isotopes, calculations are made by using the blocking of quasi-particle states to take care of the time reversal symmetry in the mean-field model. An approximation to the exact blocking called Equal Filling Approximation (EFA) is used in this case.

The neutron skin thickness mainly appears in heavy nuclei due to unequal number of neutrons and protons. In heavy nuclei, the number of neutrons are found to be more as compared to that of protons which lead to the formation of neutron skin Δr_{np} on its surface.

$$\Delta r_{np} = r_n - r_p \tag{3}$$

The neutron skin thickness is defined as the difference between the nuclear rms radii obtained using the neutron and proton density distributions.

Results and Discussion

For predicting the probable skin structure of the considered isotopic series, we have calculated rms radii and neutron skin thickness. The neutron and proton rms radii determined are plotted against the neutron number for Ir and Au isotopes in figure 1. We can notice the increase of rms radii with neutron number. The sharp increase in the slope of neutron rms radii at the drip line region indicates the larger neutron radius and appearence of skin structure. Here the computed results from HFBHO model[2] are matching almost well with the data available from RCHB theories[3]. It can be seen from figure that difference between the neutron and proton rms radii starts to increase with the increase of neutron number, in favor of developing a neutron skin.

In figure 2, we have presented and compared our results of the neutron skin thickness Δr_{np} as a function of neutron number N for the considered isotopic chains of Ir and Au. Within the given isotopes, the magnitude of skin thickness increases systematically with the number of neutrons. The magnitude of skin thickness gradually increases with neutron number in the isotopes as a result of the redistribution of the nucleons due to addition of neutrons. A linear dependence of neutron skin thickness on mass number is observed in figure with the change in slope is noticed around N=126. This sudden increase of neutron skin thickness may be due to the extra stability and shell closure around the magic number.

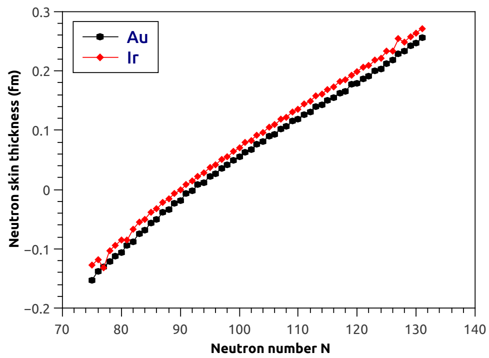

FIG. 2: Variation of neutron skin thickness with neutron number of Iridium and Gold isotopes

In summary, by using HFB theory we have estimated the neutron skin thickness from rms radii for exotic nuclei of Ir and Au. The rms radii and neutron skin over a series of isotopic chains have been explored. To understand the skin structure, proton and neutron radii are plotted as functions of neutron number and compared with available data. These results show that the rms radii and neutron skin thickness are increasing with neutron number.

Acknowledgments

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