Neutron skin in neutron-rich nuclei

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Introduction

The study of exotic nuclei has attracted worldwide attention due to their unexpected behaviour very different from stable nuclei such as nuclear halo and skin [1]. The neutron-rich are the class of exotic nuclei having large value of N/Z ratio. The excessive neutrons in neutron-rich nuclei produce a large difference in Fermi energy of neutrons and protons which make a decoupling of neutron and proton distribution and as a result nuclear halo and skin structure is appeared. Generally, halo is considered as a long low density tails in nuclear matter distribution, whereas skin is defined as a significant difference in matter radii for neutrons and protons. Neutron skin plays a significant role in correlation with a number of physical observables in finite nuclei [2], nuclear symmetry energy [3, 4] and infinite nuclear matter to pure neutron matter [5]. Moreover, skin is also beautifully linked with the various constraint found to impose on the equation of state of high density matter in neutron stars [3]. In this regard, we investigate the neutron skin thickness for a series of neutron-rich nuclei starting from stable system to exotic region(N=2Z+4) in order to correlate the various observables within nuclear structure.

Formalism

The present calculations are made on axially deformed Relativistic Mean Field (RMF) model with NL3 parameter set. The RMF formalism is very powerful and well established model to reproduce the structural properties of the nuclei over the whole periodic table from proton drip line to neutron exotic region [8]. For the detailed formalism and numerical techniques, see Ref. [9] and references therein.

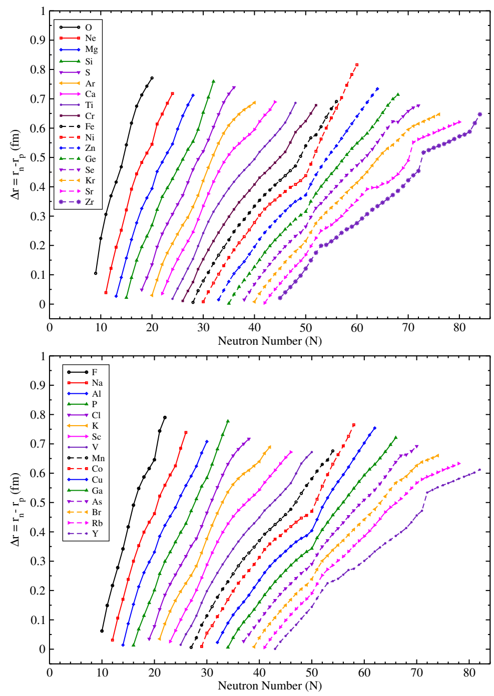

FIG. 1: Neutron skin thickness for even-Z (top) and odd-Z (bottom) neutron-rich nuclei as a function of neutron number.

Results and Discussion

We make the plot for neutron skin thickness $\Delta r = r_n - r_p$ of considered nuclei as a function of neutron number for stable to large exotic region N=2Z+4. The neutron-rich nuclei show the skin thickness of the order of 0.8fm. The magnitude of skin thickness increases gradually with increasing the neutron number in the isotopes. The gradual increase in the neutron skin may be attributed to the redistribution of the nucleons due to addition of neutrons. A sudden increase of neutron thickness is noticed for Co, Ni, Cu, Zn isotopes with neutron

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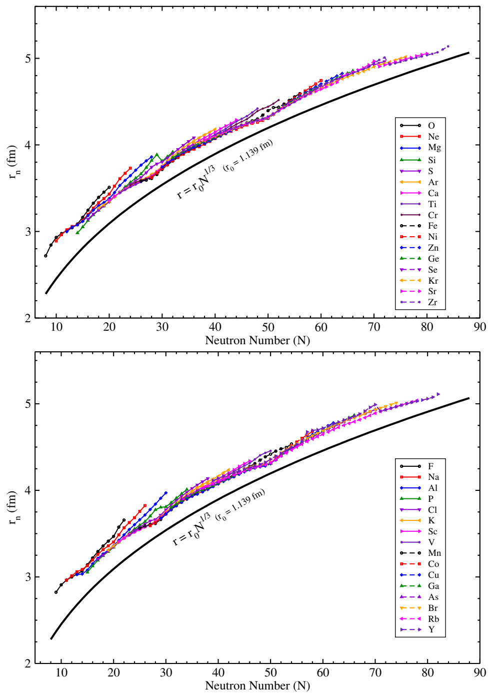

FIG. 2: Rms neutron radii r_n for even-Z (top) and odd-Z (bottom) neutron-rich nuclei as a function of neutron number.

number grater than 50 (N > 50). This type of kink in the skin plot indicates unexpected behaviour of the nuclei and supposed to be halo/skin structure candidates with extended tail and therefore this demand a more careful investigations.

In order to illustrate the probably halo/skin structure, the calculated rms neutron radii r_n as a function of neutron number for considered neutron-rich nuclei are plotted in Fig2. It is very interesting to see that rn follows the stability curve for the stable range of the nuclei, which is computed by using the formula $r = r_0 N^{1/3}$ and makes the deviation for exotic region having large value of N/Z ratio. The increase in the slope of r_n indicates the halo/skin structure. A sharp increase in neutron radius is seen from Fig. 2 for light isotopes O, F, Ne, Na, Mg and Al in large exotic region. Ofcourse these rises in r_n are due to valence neutron adjusted to nuclei and shall form the halo/skin structure. The calculated values of r_n by RMF are compared with available theoretical data [6, 7] and an agreement is noticed. To understand the above result more clearly, we shall go through for separation energy, single particle energy, occupation probability of the valance neutron and specifically density distribution of nucleons around surface region. Work is in progress in this direction in order for detailed investigation of nuclear structure phenomena of neutron-rich nuclei.

In summary, we estimated the neutron skin thickness from rms neutron and proton radii calculated by RMF for exotic neutron-rich nuclei. The theoretical estimations are computed from axially deformed solution of Lagrange equations. To understand the size of the isotopes, the neutron radii are compared with stability curve.

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