A Study of Neutron Skin Thickness at neutron magic 28, 50 and 82 within Relativistic Hartree Bogoliubov Approximation

Smriti Thakur* and Shashi K. Dhiman†
Department of Physics, Himachal Pradesh University, Shimla - 171005, INDIA

Introduction: The nucleon density distribution is one of the most basic properties of nuclei. To determine the nature of the neutron distribution accurately in a nuclei has received considerable attention in recent years. As neutron number increases, the radius of the neutron density distribution becomes larger than that of the protons, reflecting the pressure of the symmetry energy. For large neutron excess, the bulk of neutron density is believed to extend beyond the proton density creating a sort of "neutron skin"[1, 2]. We present our theoretical results of neutron skin thickness Δr_{np} for neutron-rich and double-magic nuclear system.

Methods: We employed Covariant Relativistic self-consistent mean field models analogous to Kohn-Sham density functional theory to construct the Nuclear Density Functionals from Lagrangian densities based on mesons exchange and point coupling models. The pairing correlations of nucleons are considered by the relativistic Hartree-Bogoliubov functional based on quasi-particle operators of Bogoliubov transformations. The nuclear energy density functionals are constructed by using meson coupling model with DDME parameterizations and point coupling model with DDPC parameterizations with a separable pairing interaction. The Δr_{np} is defined as the difference between the nuclear rms radii obtained using the density distributions for point neutrons r_n and point protons r_p; $\Delta r_{np} = \sqrt{r_n^2} - \sqrt{r_p^2}$.

Results and Discussions In this reserach paper, we compare theoretical computed results with available experimental data for neutron skin for even-even nuclides have neutrons at magic numbers 28, 50 and 82 with protons number varies as, respectively, 12-24, 28-44, and 46-68. In Fig.(1), we present Δr_{np} in fm, plotted as a function of atomic number Z, for even-even isotones of neutron shell closure at N = 28 for ^{40}Mg, ^{42}Si, ^{44}S, ^{46}Ar, ^{48}Ca, ^{50}Ti and ^{52}Cr. The recent observation of ^{40}Mg provides a significant advancement in

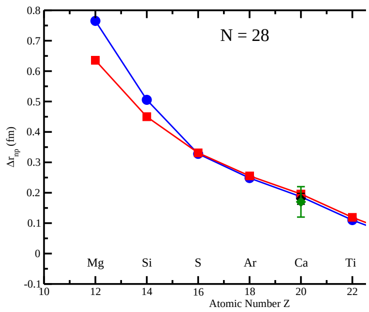

FIG. 1: (color online) The Δr_{np} in fm, plotted as a function of proton number Z, for the isotonic chain at N = 28.

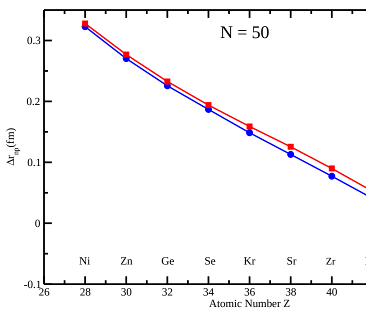

FIG. 2: (color online) Same as 1, but for isotonic chain at N = 50.

*Electronic address: thakursmriti14@gmail.com
†Electronic address: shashi.dhiman@gmail.com

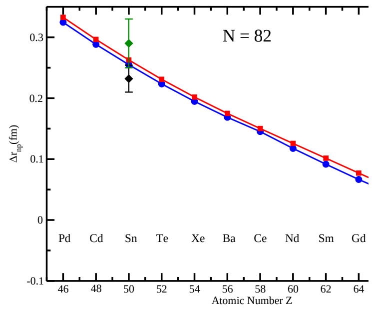

FIG. 3: (color online) Same as 1, but for the isotonic chain at N = 82.

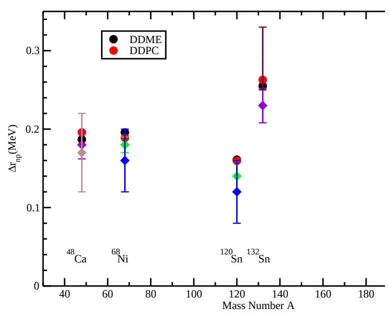

FIG. 4: (color online) The Δr_{np} in fm for double magic nuclei, plotted as a function of Mass number A.

our understanding of where the neutron drip line is likely to go for nuclei with atomic number 12, where the value Δr_{np} ranging as 0.65-0.76 fm. The theoretical results of Δr_{np} for isotonic chain at neutrons number N = 50 are presented in Fig.(2), the values of Δr_{np} varies as from 0.32 fm in ^{78}Ni to 0.05 fm in ^{94}Ru nucleus. Fig.(3) presents the variation in Δr_{np} for isotones from atomic number 46 (^{128}Pd) to 68 (^{150}Er) and, the magnitude of Δr_{np} varies as 0.01 fm in ^{150}Er - 0.33 fm in ^{128}Pd. In general, the values of Δr_{np} decreases as the atomic number Z is increasing in the chain of isotones shown in Figs.(1,2 and 3). The Δr_{np} for neutron-rich and double-magic nuclear system ^{48}Ca,^{68}Ni, ^{120}Sn, ^{132}Sn and ^{208}Pb are presented is Fig.(4), and compared to the recently available experimental data. It can be observed that the ratio Z/N $\approx$ 0.7 in double magic nuclei ^{48}Ca, ^{120}Sn and ^{208}Pb and the value of Δr_{np} lies in close order of 0.16-0.19 fm, whereas for the ratio Z/N $\approx$ 0.5-0.6 in ^{42}Si, ^{44}S and ^{132}Sn, the value of Δr_{np} is more than 0.25 fm. This observation establishes the relationship of ratio Z/N with Δr_{np} in the doubly magic nuclei and neutron rich nuclei indicating shell closures in the recent investigations in ^{42}Si nucleus. The theoretical value of Δr_{np} in doubly magic ^{132}Sn nucleus is 0.25 fm, which is comparable with recent experimental extractions of Δr_{np} 0.23$\pm$0.02 fm and 0.29$\pm$0.04fm. In ^{68}Ni nuclear system, protons are magic numbers and neutrons are semi-magic number. There are many theoretical and experimental investigation focussed on ^{208}Pb, ^{132}Sn, ^{120}Sn, ^{68}Ni and ^{48}Ca nuclei, which have well understood nuclear structure due their closed protons and neutrons shells at the magic numbers. A recent reviews on experimental measurements of Δr_{np} in ^{208}Pb, suggest that its values ranges from 0.15$\pm$0.03 fm to 0.21$\pm$0.06, with analysis of coherent pion photo-production and pion scattering, respectively. Whereas our theoretical results for $\Delta r_{np} = 0.19 - 0.20$fm in ^{208}Pb are reasonable well within the experimental measurements. The double magic ^{48}Ca nucleus is very interesting nuclide and can help to provide information of bulk nuclear matter properties and size of neutron star, our computed value of Δr_{np} = 0.18 fm is comparable with recently experimental measurements[1]. The theoretically computed results are reasonable reproducing the values for Δr_{np} in ^{208}Pb, ^{120}Sn, and ^{68}Ni nuclei are in the ranges 0.13 - 0.19, 0.12 - 0.16, and 0.15 - 0.19 fm, respectively from ref.[2], whereas the in case of ^{48}Ca, our results overestimated by very small value of 0.02 fm only as shown in Fig.(4).

References

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