Charge radius of doubly magic ^{56}Ni and reaction cross section for p-Ni

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Introduction

The systematic study of root-mean-square (rms) charge radii, $< r_c^2 >^{1/2}$ for isotopic chains give insight into nuclear shell effects and properties of nuclei. The measurement of $< r_c^2 >^{1/2}$ using laser spectroscopy is challenging and experimental information is scarce in the N=28 region. It is interesting to know whether the Ni isotopic chain has a behavior around N=28 similar to neighboring isotopic chains; also whether removing neutrons from N=28 increases $< r_c^2 >^{1/2}$ in contrast to the decrease expected from the droplet model. The data for charge radii are available in literature for only stable even isotopes of Ni (N=30-36). In this short abstract, we make a prediction of $< r_c^2 >^{1/2}$ for the doubly magic nucleus ^{56}Ni as well as for neutron-deficient and neutron-rich isotopes. Moreover, knowing $< r_c^2 >^{1/2}$ and hence the nuclear matter densities, we can make a prediction of total reaction cross section using the folding model analysis [1, 2]. Elastic scattering differential cross section data for proton scattering at 65 MeV are available for ^{58,60,62,64}Ni [3]. In the present work, ground state properties have been calculated for both neutron-deficient and neutron-rich even Ni isotopes. Inputs to the calculations are from the non-relativistic Hartree-Fock-Bogoliubov (HFB) approach based on Gogny D1S effective interaction [4]. The HFB-D1S calculated target matter densities are folded with the extended Jeukenne, Lejeune, and Mahaux (JLM) energy- and density-dependent nucleon-nucleon interaction [5] to obtain the proton optical potentials for even Ni isotopes. This results in real and imaginary parts of the optical model potential (OMP) which are then used to calculate the reaction and differential cross sections for 65-MeV proton scattering from even Ni isotopes.

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Discussion

The nuclear binding energies, two-neutron separation energies and nuclear charge radii from the HFB-D1S approach and compared with corresponding data [6], and found to be in good agreement with experiment. The calculated rms charge radii for even Ni isotopes are plotted in Fig. 1(a). The available experimental values for ^{58,60,62,64}Ni are also shown in the same figure. From the figure, we observe that calculated charge radii overall agree with data. Experimental $< r_c^2 >^{1/2}$ is not available for N=28 (^{56}Ni). It is clearly seen from the figure that our calculation shows a change of slope at N=28 while the droplet model shows a smooth behavior. It can be seen that removal of neutrons from N=28 reduces the radii of N=22,24,26 nuclei.

Since ground state properties for Ni isotopes from HFB calculations are in good accord with the data, where available, we now proceed to calculate the OMP and hence the differential and reaction cross sections for 65-MeV proton scattering off Ni isotopes. The nuclear matter density distributions from HFB-D1S are used in the folding model analysis. For prediction of the total reaction cross section (σ_R) of unstable isotopes of Ni, first we have to obtain a good fit to the differential cross section data for stable isotopes of Ni. For this purpose, we need to renormalize the real (λ_V) and imaginary (λ_W) part of central potential as well as real part (λ_{Vso}) of spin-orbit potential. Thus a search on λ_V, λ_W and λ_{Vso} was carried out to obtain best-fit values. The σ_R calculated

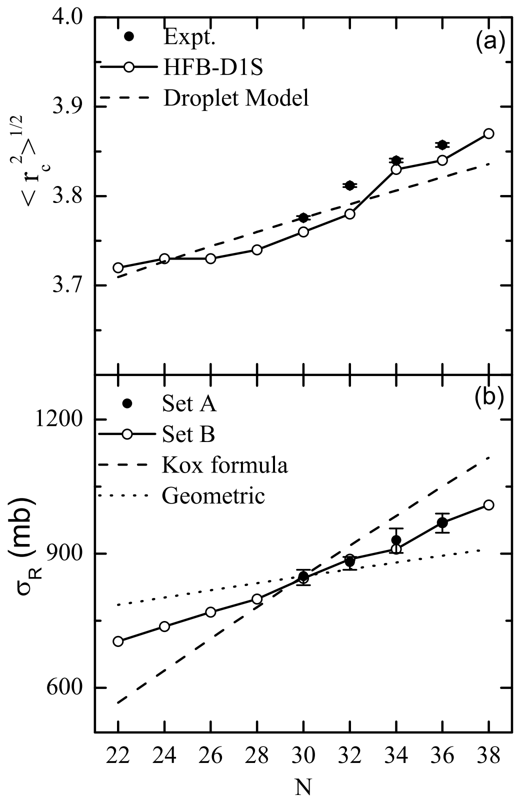

FIG. 1: (a) The HFB-D1S calculated *rms* charge radii for even Ni isotopes and corresponding experimental values [3]. Charge radii calculated using droplet model are also shown. (b) Total reaction cross-section, σ_R, for *p*-Ni at 65 MeV calculated using Set A and Set B. σ_R using Kox formula [7] and geometric cross section are shown for comparison.

using these values are refered to as Set A and are shown in Fig. 1(b). The mass number (A) dependence of λ_V and λ_W for stable isotopes was used to make a prediction of cross sections for unstable isotopes (N=22-38), keeping λ_{Vso}=88. The σ_R calculated, is denoted as Set B and plotted in Fig. 1(b).

For comparison, σ_R calculated using Kox formula [7] (σ_R^{Kox}) and the geometric cross section (σ_R^g) are shown in Fig. 1(b). The σ_R^{Kox} is normalized to N=30 and is shown as a dashed line in Fig. 1(b). σ_R^{Kox} shows a smooth variation from N=22 to N=38. σ_R^g is also shown in the same figure and it is normalized to the σ_R calculated from best-fit values of λ_V and λ_W for ^{58}Ni. The σ_R^g are calculated using the relation $\sigma_R^g = \pi r_0^2 (A_p^{1/3} + A_{Ni}^{1/3})^2$, where A_p and A_{Ni} are the masses of proton projectile and Ni target, respectively. It can be seen that σ_R^g has a smaller slope in comparision with σ_R^{Kox}. Set B calculated σ_R shows a slight change of slope at N=28. However, there is no experimental data for ^{56}Ni (N=28) as well as for neutron-deficient and neutron-rich isotopes to verify this prediction. It would be interesting to verify experimentally if there is a change of slope at N=28 for the *rms* charge radii for Ni isotopic chain as well as for σ_R for scattering of protons from Ni nuclei.

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