Matter radii of Be isotopes using 2pF density distribution

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Introduction

The fundamental properties of the nuclear many body systems such as matter radius and matter distribution have drawn considerable attention as this information about the nucleus not only reflects the nuclear structure properties namely shell structure, shape co-existence, and shape transition but also is important for testing, developing, and perfecting nuclear structure models. One of the most exciting features of some of the exotic nuclei is the neutron halo which demonstrates a large spatial extension of neutron distributions. Such a feature was first noticed in ^{11}Li by Tanihata *et al.* [1] who observed a sudden rise in interaction cross section on ^{12}C as compared to its neighboring isotopes. The other good examples for neutron halo nuclei are ^{11}Be, ^{19,22}C and ^{31}Ne.

On the theoretical front, the Glauber model has been quite successful in extracting the matter radii of radioactive nuclei [2] employing the corresponding experimental data on the reaction cross sections. Recently, we have deduced the root-mean-square proton and neutron radii for $4 \leq Z \leq 9$ isotopes from a systematic analysis of experimental charge-changing and interaction cross section in the framework of Glauber model. [3]. These calculations involve the Slater determinant harmonic oscillator single-particle densities (SDHO).

To strengthen our recent findings on matter radii [3], we, in this work undertake the analysis of charge-changing and interaction cross section using 2pF densities;

$$\rho(r) = \frac{\rho_0}{1 + e^{(r-C)/a}}$$

where a is the diffuseness parameter and C is the radius parameter. The central density ρ_0 is obtained by the normalization of $\rho(r)$ to the number of nucleons. Our focus in this study is to see how far the results on matter radii with 2pF densities agree with the SDHO results.

Formulation

In Glauber model, the S- matrix element S_{00} describing the elastic scattering of the projectile nucleus with ground state wave function ψ_B on a target nucleus with ground state wave function ψ_A is written as

$$S_{00}(\vec{b}) = \left(\psi_A \psi_B \,|\, \prod_{i=1}^{A} \prod_{j=1}^{B} [1 - \Gamma_{NN}(\vec{b} - \vec{s_i} + \vec{s_j})] \,|\, \psi_B \psi_A \right) \tag{1}$$

where A(B) is the mass number of the target(projectile) nucleus. $\vec{s_i}$ ($\vec{s_j}$) is the projection of the target(projectile) of i^{th} (j^{th}) nucleon coordinate on a plane perpendicular to the incident direction. The NN profile function Γ_{NN} is related to the NN scattering amplitude f_{NN} as

$$\Gamma_{NN}(\vec{b}) = \frac{1}{2\pi i k} \int d^2q \exp(-i\vec{q}.\vec{b}) f_{NN}(\vec{q}) \tag{2}$$

where k is the incident nucleon momentum corresponding to the projectile kinetic energy per nucleon.

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Following Ahmad [4], the S-matrix element S_{00} upto two-body density term is given by

$$S_{00}(\vec{b}) \approx S_0(\vec{b}) + S_2(\vec{b}) \qquad (3)$$

The reaction(interaction) cross section is given by

$$\sigma_I = \int d^2b[1 - |S_{00}(\vec{b})|^2]$$

The detailed discussion for S_{00} is given in Ref. [4]. Following [3, 5], charge-changing cross section (σ_{CC}) may be written as

$$\sigma_{CC} = \epsilon\, \sigma_{CC}^{p} ,$$

where σ_{CC}^{p} is the contribution to the charge-changing cross section due to the scattering of only projectile protons and $\epsilon = \sigma_{CC}^{exp}/\sigma_{CC}^{p}$ is the correction parameter that takes care of contribution of the presence of projectile neutron.

Results and Discussion

Following the approach outlined above, we have calculated the charge-changing and interaction cross section for $^{7,9\text{-}12,14}$Be isotopes on ^{12}C target using 2pF density distribution at medium energies. As done in Ref. [3], we have first calculated the correction parameter ϵ for those Be isotopes whose experimental charge radii are known. The average value of ϵ is then used to predict the proton radii of $^{7,9\text{-}12,14}$Be isotopes. It is found that (Table 2) the extracted proton radii of Be isotopes using 2pF densities agree well with the corresponding values obtained using SDHO densities.

Table 1: σ_{CC}^{p} reproduces experimental proton charge radius $\langle r_{ch}^2\rangle^{1/2}$ [6].

$Proj.$	E/A (MeV)	σ_{cc}^{exp} (mb) [7]	σ_{CC}^{p} (mb)	ϵ	ϵ_{avg}
^{7}Be	772	706±8	657.87	1.073	1.074
^{9}Be	921	682±30	639.89	1.065	
^{10}Be	946	670±10	617.48	1.085	
^{11}Be	962	681±3	635.85	1.071	
^{12}Be	925	686±3	637.61	1.076	

Using the extracted proton radii, we have calculated the neutron radii by reproducing the experimental σ_I values. In FIG. 1, we have shown our result on neutron and matter radii for $^{7,9\text{-}12,14}$Be isotopes. It is important to note that the sudden increase in the matter radii of ^{11}Be and ^{14}Be indicate their halo structure when coupled with their respective one- and two-neutron separation energies. In summary we find that results with 2pF density are equivalent with SDHO density.

Table 2: Predicted proton radius obtained by fitting the σ_{CC}^{exp} using the average value of correction parameter ϵ_{avg}. Δr_p is the change in proton radii with respect to SDHO predictions.

$Proj.$	r_p(fm)	σ_{cc}^{exp} (mb) [7]	(Δr_p)%
^{7}Be	2.6438	706±8	0.02
^{9}Be	2.4866	682±30	0.004
^{10}Be	2.4052	670±10	0.01
^{11}Be	2.4568	681±3	0.01
^{12}Be	2.5121	686±3	0.01
^{14}Be	2.5617	697 ± 4	0.0001

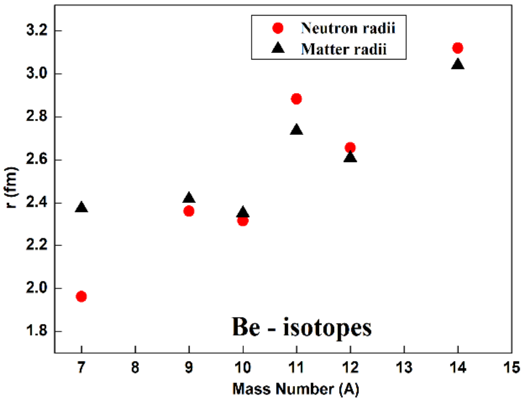

FIG. 1: The extracted neutron and matter radii for Be isotopes.

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