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# Energy dependence of charge changing cross sections of 46Ti on carbon from intermediate to high energies

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The charge radius or point-proton radius is an important quantity for investigating nuclear structure. Although electron scattering experiments and isotope-shift measurements have provided many precise data on charge radii, these methods are limited to long-lived and abundantly produced nuclei. Therefore, we proposed an applicability of the charge changing cross section ($\sigma_{cc}$) to derive the point-proton radii of short-lived exotic nuclei. The $\sigma_{cc}$ is defined as the probability that a projectile nucleus decreases its atomic number due to a high-energy interaction with a target. Applying the Glauber model, which describes reaction cross sections and nucleon density distributions, may enable to derive the point-proton radius from $\sigma_{cc}$ measurements. A modified Glauber model analysis taking into account the energy dependence of the projectile nucleus successfully provided several point-proton radii of light neutron-rich nuclei [1]. However, the point-proton radii deduced by using the $\sigma_{cc}$ and the modified Glauber model analysis showed a systematic deviation from the known charge radii of medium-heavy nuclei. This is due to an evaporation effect, in which protons are statistically emitted from the excited core after direct neutron removal at the initial stage [2]. An updated Glauber analysis taking into account the evaporation effect reproduced experimental cross sections well. A new scaling factor for $\sigma_{cc}$ was also proposed based on this finding [3].
The previous studies conducted in the worldwide facilities assumed the energy dependence of the original Glauber model which needs to be tested. Thus, we precisely measured the energy dependence of charge changing cross sections in a broad energy range by employing $^{46}$Ti with a known charge radius. The experiment was conducted at the Heavy Ion Medical Accelerator in Chiba (HIMAC) facility of the National Institutes for Quantum Science and Technology. A $^{46}$Ti beam of 450 MeV/nucleon was used to irradiate carbon targets of various thicknesses, and several $\sigma_{cc}$ values were measured using the transmission method from 200 to 400 MeV/nucleon. With our previous results, the precise $\sigma_{cc}$ values of $^{46}$Ti on carbon have been obtained from 300 to 700 MeV/nucleon. This is the first time such systematic data have been measured. The results were compared with the updated Glauber calculations with variable core excitation energies. The present study will be a cornerstone in establishing the method of charge radius determination and heavy-ion reaction theory.

References
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