Study of proton distribution of neutron-rich nitrogen isotopes through charge-changing cross section measurements

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With large neutron-to-proton ratios far from the line of stability, nuclei develop exotic structures such as neutron skin and halo. Charge radius which is a fundamental nuclear ground-state property, seems to be changing with the increase of valence neutrons. As an example, the charge radius of ^{11}Li, where there are two valence neutrons in addition to the core ^{9}Li nucleus, is larger than that of ^{9}Li [1]. Therefore, to understand the structure of neutron-rich nuclei, it is important to know how the proton distribution of a nucleus is affected with large neutron-to-proton ratios. Furthermore, proton radius is crucial for determining the neutron-skin thickness if the matter radius is known. The proton radius is also necessary to understand the spatial correlation between the halo and the core. Complimentary to the traditional methods for determining the charge radius (or proton radius) which are isotope shift measurements and electron scattering measurements, charge-changing cross section measurement is a new tool which can be applied very well for stable nuclei and as well as for exotic nuclei far from the β-stability line.

Charge-changing cross section (σ_{cc}) is the sum of all interactions of the protons in the projectile due to the collision with the nucleons of the target nucleus that changes the proton number of the projectile. Thus it can be used as a probe to measure the extent of the proton distribution in exotic nuclei through Glauber model analysis of the reaction. Measurements to determine the charge-changing cross section have been done for neutron-rich $^{8-11}$Li [2], $^{9-14}$Be [3], $^{14-16}$C [4] and $^{10-17}$B [5] isotopes, although there was no attempt to derive the proton radii in Ref [2]. Here, we focus on systematic studies of σ_{cc} and proton distribution for neutron-rich nitrogen isotopes.

We performed the experiment using the FRagment Separator (FRS) [6] at GSI, Germany. Beams of ^{14,15}N and $^{17-22}$N were

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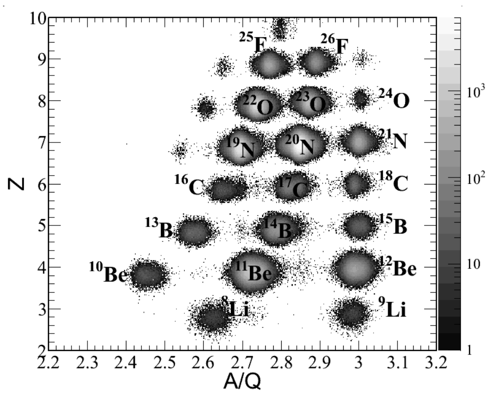

FIG. 1: Particle identification spectrum before the reaction target at the final focus of the FRS. Particle identification was performed using Bρ-ToF-ΔE measurement.

produced by fragmentation of primary beams ^{22}Ne and ^{40}Ar impinging on a 6.3 g/cm^2 thick Be target. The primary beam energy was about 1 GeV/u. The beams of interest were identified and separated using their magnetic rigidity (Bρ), time of flight (ToF) between two focal planes of the FRS, and by the energy loss (ΔE) measurement in a multisampling ionization chamber (MUSIC). The σ_{cc} was measured with a 4.010 g/cm^2 thick carbon target placed at the final focus of the FRS.

Figure 1 shows an example of the particle identification before the reaction target. The Z-resolution (σ) of the nitrogen isotopes is around 1.6%.

The proton radii can be obtained from the finite-range Glauber model analysis of the measured σ_{cc}. Similarly, the matter radii can be obtained from the interaction cross section measurements. Figure 2 shows the interaction cross section, obtained with C target, for $^{14-22}$N [7]. Interaction cross section increases from ^{18}N to ^{22}N. From the combined values of matter and proton radii one can evaluate the neutron-skin thickness for neutron-rich nuclei.

Details of the experimental setup, analysis procedures and new results for neutron-rich nitrogen isotopes will be presented during the symposium.

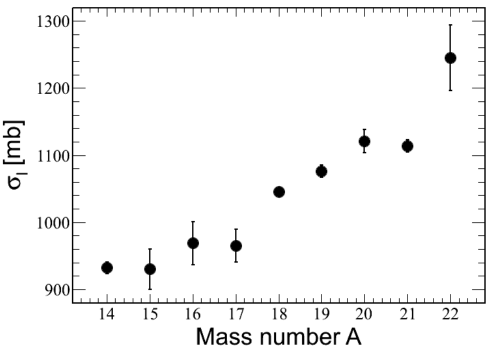

FIG. 2: Interaction cross section for nitrogen isotopes [7].

References

[1] R. Sánchez, *et al.*, Phys. Rev. Lett. **96**, 033002 (2006).

[2] B. Blank, *et al.*, Z. Phys. A - Hadrons and Nuclei. **343**, 375 (1992).

[3] S. Terashima, *et al.*, Prog. Theor. Exp. Phys. **101D02** (2014).

[4] T. Yamaguchi, *et al.*, Phys. Rev. Lett. **107**, 032502 (2011).

[5] A. Estradé, *et al.*, Phys. Rev. Lett. **113**, 132501 (2014).

[6] H. Geissel *et al.*, Nucl. Instrum. Methods Phys. Res., Sect. B **70**, 286 (1992).

[7] A. Ozawa, T. Suzuki and I. Tanihata, Nucl. Phys. A **693**, 32 (2001).