Measurements of charge-changing and reaction cross sections of neutron-rich Ca isotopes

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In the neutron-rich region of the nuclear landscape, nuclei exhibit many surprising properties. The formation of exotic structures such as neutron skins and halos have been observed,[1)] and evolutions of nuclear shell structure have been reported in light exotic nuclei.[2)] Experimental findings of such new phenomena are essential to elucidating the underlying mechanisms and refining the nuclear models. The evolution of the shell structure of neutron-rich nuclei is of particular interest owing to new shell closures appearing and conventional ones disappearing.

The $N = 32$ and 34 new shell closures are prominent in neutron-rich Ca isotopes from the mass measurements of $^{52–54}$Ca[3)] and the observed large excitation energy of the first 2^+ state in ^{54}Ca.[4)] However, recent measurements of the proton (charge) root-mean-square (rms) radii of ^{49,51,52}Ca[5)] have raised questions on the proposed $N = 32$ shell closure. The measurement of masses of $^{55–57}$Ca[6)] also suggests a shell closure at $N = 34$.

The size of a nucleus, which can be defined as the rms radius of its nucleon density distribution, can provide important insights on the evolution of the shell structure. Extensive studies[7)] on the isotopic and isotonic trends of nuclear charge radii have shown that strong correlations exist between the charge radii and other ground and excited state observables of closed-shell nuclei. Along an isotopic chain, the charge (proton) rms radius (denoted as the proton radius hereinafter) exhibits a decrease at neutron shell closure. While such a decrease is seen for ^{48}Ca related to the $N = 28$ shell closure, the proton radius of ^{52}Ca measured by isotope shift shows an increase compared with ^{50}Ca.[5)] In a recent experiment performed at the RIKEN RIBF facility, we investigated the interaction and charge changing cross sections of $^{48–55}$Ca with energies of approximately 250 MeV/nucleon reacting with a C target of thickness of approximately 1 g/cm^2. The measurement was based on the transmission technique, where the ratio of

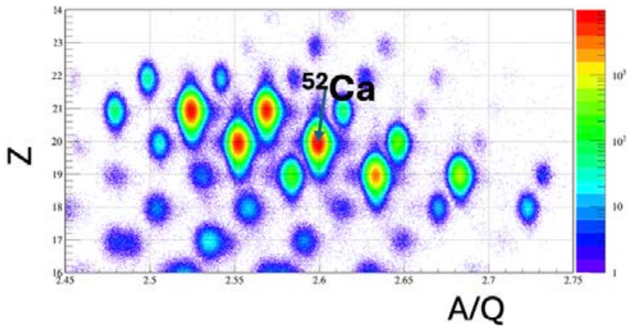

Fig. 1. Particle identification (preliminary) before the reaction target at the F8 focal plane of BigRIPS.

the number of outgoing un-reacted nuclei to the number of incident particles provides the interaction cross section. The charge changing cross section was measured from the ratio of the number of particles with $Z \geq Z_{\mathrm{incident}}$ to the number of incoming particles for the nucleus of interest. These isotopes were produced from the fragmentation of a ^{70}Zn primary beam with a ^{9}Be production target. The isotopes were identified (Fig. 1) using the ΔE-$B\rho$-TOF method using the BigRIPS fragment separator. The reaction target was located at the F8 achromatic focal plane. The energy-loss (ΔE) was measured via multi-anode ionization chambers placed before the reaction target at F7 focal plane and after the target at F8. Fast timing plastic scintillators located at the different focal planes from F3–F11 measured the time of flight of the ions. The magnetic rigidity was derived from the positions measured using parallel plate avalanche counters (PPAC) and the magnetic field of the dipoles. The charge changing cross sections were determined from the energy deposit in the ionization chamber for nuclei with $Z \geq 20$, after the target at F8. The unreacted Ca isotope of interest was transported to the F11 focal plane through the zero-degree spectrometer. The analysis of the data is currently in progress.

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