Measurement of momentum distribution and reaction cross section for proton-rich nucleus ^{23}Al

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Measurements of the momentum distribution ($P_{//}$) have confirmed the existence of a proton halo in ^{26,27,28}P [1]. Reaction cross sections (σ_R) of $N = 10 \sim 15$ isotones have been measured on HIRFL-RIBLL in Lanzhou [2]. A remarkable enhancement of σ_R for ^{27}P and ^{23}Al is observed as compared with their neighboring nuclei. This result strongly suggests the existence of a proton halo in ^{27}P and ^{23}Al [2,3]. For ^{23}Al, it is interesting to investigate the possible cause for the appearance of the proton halo. In the ground state of ^{23}Al, the last proton may occupy the level $1d_{5/2}$ or $2s_{1/2}$ in the spherical shell model. When the last proton occupies $1d_{5/2}$, a large centrifugal barrier tends to suppress the formation of a halo. If there exist deformations in the nuclei, the situation may become more complex. Here it is unclear which case the nucleus ^{23}Al will belong to. Thus a correct description of the proton halo in ^{23}Al may present a new challenge to the existing theoretical models. ^{23}Al is between the halo nuclei ^{17}Ne and ^{26,27}P. It may play an important role for the study of proton halos in $2s$-$1d$ shell nuclei. Since $P_{//}$ and σ_R measurements are very useful methods for halo structure investigations, we have performed this experiment for further clarification of the halo structure in ^{23}Al.

The experiment was performed at the Riken Projectile Fragment Separator (RIPS). The primary beam of 135 A MeV ^{28}Si was used to produce the secondary beams of ^{23}Al. Before the carbon target (377 mg/cm^2) installed at F2, particle identification was carried out by using the $B\rho-\Delta E-$TOF method. The TOF was determined from a delay-line PPAC at F1 and a plastic scintillator (0.5 mm thick) at F2. ΔE was measured using the newly constructed Ion Chamber (200$\phi \times 780$mm). After the carbon target, the TOF$-\Delta E - E$ method was used for particle identification. Another plastic scintillator (1.5 mm thick) at F3 gave the stop signal of the TOF from F2 to F3. The Ion Chamber (90$\phi \times 650$mm) was used to measure ΔE. E was measured by the 3"$\phi \times$ 6cm NaI(Tl) detector with veto counters.

The measurement of σ_R was carried out by using a transmission-type method. σ_R was determined by the ratios between incident and outgoing particles without reaction from both target-in and target-out measurements. $P_{//}$ of fragment from breakup reactions was determined from the TOF between the two plastic scintillators installed at F2 and F3. The position information from F1-PPAC was used to derive the incident momentum [4]. An enhancement is observed in σ_R for ^{23}Al compared to its neighbors. The $P_{//}$ of ^{22}Mg fragments from ^{23}Al breakup have been obtain. The width of the distributions is found to be consistent with prediction by the Goldhaber Model. The experimental data are discussed in the framework of the few-body Glauber model. The analysis of $P_{//}$ indicates a dominant d-wave component in the ground state of ^{23}Al. This confirms the result of a recent magnetic moment measurement which indicates that the valence proton is in d-wave [5]. In order to explain the data of both σ_R and $P_{//}$, the configuration of an enlarged core plus the valence proton for ^{23}Al is necessary.

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