Measurement of ^{25}Al+p resonant elastic scattering relevant to the astrophysical reaction ^{22}Mg(α, p)^{25}Al

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Type-I X-ray bursts are the most frequently observed thermonuclear explosions in nature.[1)] They occur on the surface of accreting neutron stars in low-mass X-ray binary systems. The investigation of X-ray bursts can help us understand the properties of a neutron star and the underlying physics.

The bursts are driven by the tripe-α reaction, the αp-process, and the rp-process. After breakout from the hot CNO cycle, the nucleosynthesis path is characterized by the αp-process.[2)] The αp-process is a sequence of α- and proton-induced reactions that transport nuclear material from the CNO cycle toward the region of heavier proton-rich nuclei.

The X-ray light curve is the main direct observable of X-ray bursts and could be affected significantly by the αp-process. According to a recent sensitivity study by Cyburt,[3)] the ^{22}Mg(α, p)^{25}Al reaction is thought to be the most sensitive one during the αp-process and may have a prominent impact on the burst light curve. However, with scarce experimental information on this reaction, the reaction rate in the calculations of X-ray bursts is estimated based on statistical models.

A measurement of ^{25}Al+p resonant elastic scattering has been performed to experimentally examine the ^{22}Mg(α, p)^{25}Al reaction rates. The experiment was performed using the CNS radioactive ion beam separator (CRIB),[4)] installed by the Center for Nuclear Study (CNS), University of Tokyo, in the RIKEN Accelerator Research Facility. A primary beam of ^{24}Mg^{8+} was accelerated up to 8.0 MeV/nucleon by the AVF cyclotron with an average intensity of 1 eμA. The primary beam bombarded a liquid-nitrogen-cooled D_2 gas target to produce a secondary ^{25}Al beam via the ^{24}Mg(d, n)^{25}Al reaction in inverse kinematics. The ^{25}Al beam was separated by the CRIB separator. The ^{25}Al beam, with an average energy of 5.68 MeV/nucleon and an average intensity of 2.0×10^5 pps, was then delivered to the F3 experimental chamber, where it bombarded a 13.95-mg/cm^2-thick $(CH_2)_n$ target and a 18.02-mg/cm^2-thick C target in which the beam was stopped. The C target was used to evaluate the background contributions. After passing through a Wien filter, the ^{25}Al beam purity can be up to 80%.

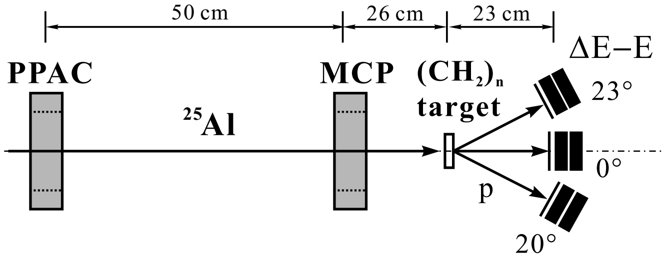

Fig. 1. Schematic diagram (top view) of the experimental setup at the F3 chamber.

The setup at the F3 experimental chamber is shown in Fig. 1. A parallel-plate avalanche counter (PPAC) and a micro channel plate (MCP) were used for measuring the time and position information of the beam particles. The beam particles were identified in an event-by-event mode using the abscissa of MCP and the time of flight between MCP and the RF signal provided by the cyclotron.

The recoiling light particles from the ^{25}Al+p reaction were measured using three sets of Si telescopes at average angles of $\theta_{lab} \approx 0°$, 20°, and 23°, respectively. Each telescope consisted of a 65-μm-thick double-side-strip (16 × 16 strips) silicon detector and two 1500-μm-thick pad detectors. The recoiling particles were clearly identified using the ΔE-E method. An array of ten NaI(Tl) detectors was mounted directly above the target and used to detect the γ rays from the decay of the excited states in ^{25}Al. The data analysis is in progress.

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