Direct measurement of the ^{26}Si(α, p)^{29}P reaction at CRIB for the nucleosynthesis in the X-ray bursts

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Abstract. Several (α, p) reactions with radioactive-ions (RI) in the αp-process are important to characterize X-ray bursts. However, some of them do not have sufficient experimental data, and the ^{26}Si(α, p)^{29}P reaction is one of such reactions. We performed a direct measurement of the reaction in inverse kinematics with a thick target at the CNS RI beam separator (CRIB). We used a multiplexer circuit, Mesytec MUX, to acquire data from many channels of silicon detectors. In this experimental setup, a resonant elastic scattering was measured simultaneously. The details of the experimental conditions and the preliminary results of the analysis are discussed.

1 Introduction

The ^{26}Si(α, p)^{29}P reaction is one of the most influential reactions in X-ray bursts (XRBs). In the XRBs, the nucleosynthesis proceeds mainly by the rp-process, the rapid proton capture process. However, in the high temperature condition of XRBs (1–3 GK), the αp-process, the sequence of (α, p) and (p, γ) reactions, competes with proton capture reactions in the region of the nuclei that have atomic numbers of 20–50. The main observable of the XRBs is its light curve and Cyburt *et al.* [1] studied the sensitivity of the nuclear reactions on the light curve. This work classified the ^{26}Si(α, p)^{29}P reaction as "Category 1" in the single-zone model, which contains the reactions that have the greatest impact on the light curve. In addition, according to Parikh *et al.* [2], the reaction rate has some sensitivity on the galactic ^{26}Al abundance. The 1.808 MeV γ-ray line from ^{26}Al provides important information for the nucleosynthesis in the universe. Therefore, the nuclear data of the ^{26}Si(α, p)^{29}P reaction are essential for understanding the XRBs.

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However, experimental data for this reaction are still insufficient and no direct measurement have been reported. Its reaction rate has been evaluated once before by Almaraz-Calderon *et al.* [3] based on the resonance information from the ^{28}Si(^{3}He, n) and ^{32}S(p, t) reactions. However, only in a limited excitation energy region up to 12.04 MeV and resonance parameters just above the α-threshold (9.343 MeV) were not definitely determined. Therefore, we performed direct measurements of the ^{26}Si(α, p)^{29}P reaction and resonant elastic scattering in excitation energies above 12 MeV simultaneously.

2 Experiment and Result

The experiment was performed at the RI Beam Factory operated by RIKEN Nishina Center and Center for Nuclear Study (CNS), the University of Tokyo. We used the CNS Radioisotope Beam Separator (CRIB) [4]. As shown in Figure 1, a ^{24}Mg^{8+} primary beam at 7.55 MeV/u and 3 eμA was irradiated at the ^{3}He primary target at 250 Torr, and a ^{26}Si RI beam was produced by the ^{3}He(^{24}Mg,^{26}Si)n reaction. The ^{26}Si beam purity was typically 29.0% after the two dipole magnets and the Wien filter, and the beam hits the ^{4}He gas secondary target at 250 Torr and room temperature (0.053 mg/cm^{3}). The typical intensity of the ^{26}Si beam was 32 kcps, and the beam energy was 4.5 MeV/u just after the Wien filter.

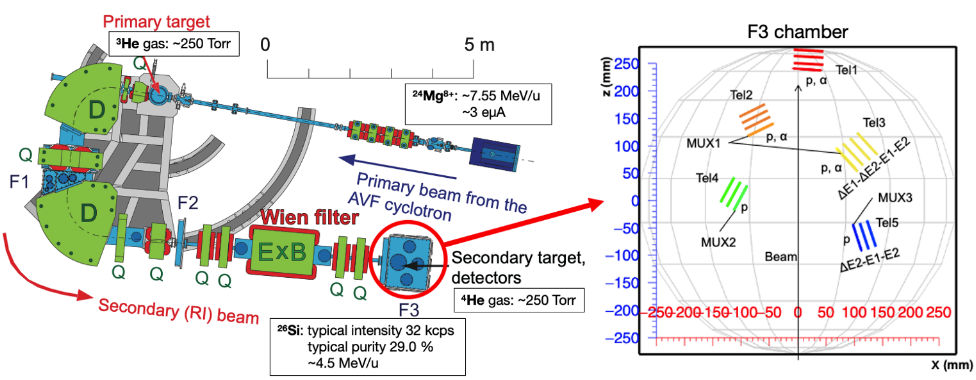

Figure 1. The left part shows the structure of CRIB facility and the parameters of the beam and the target. The right part shows the setup of the detectors in the target chamber. Note that the beam direction is from bottom to top. The three lower angle telescopes (Tel1, Tel2 and Tel3) consisted of two single-sided silicon strip detectors (SSSD) and two single-pad silicon detectors (SSD) and the two higher angle telescopes (Tel4 and Tel5) consisted of one double-sided silicon strip detector (DSSD) and two SSDs.

The thick target method [5] was used in this experiment in order to obtain the data of a wide range of scattering energy. The detectable range of the center-of-mass energy ($E_{\mathrm{c.m.}}$) was between 3.0 and 8.0 MeV. The longer the beam particles traveled to react, the smaller the $E_{\mathrm{c.m.}}$ of the reaction became. Therefore, it was possible to measure a wide energy range without changing the beam energy. The reaction products of p and α from the ^{26}Si(α, p)^{29}P reaction and the elastic scattering were identified by silicon ΔE-E telescopes. The configuration of the detectors is shown in Figure 1.

Compared to previous CRIB experiments, the number of the channels was larger in the present work and the original standard circuits could not handle all the channels. Therefore, multiplexer modules, Mesytec MUX [6], were introduced into the CRIB circuit for the first time. The inputs of the module are the 16 signals from a silicon strip detector and the outputs are two energies, two positions and one trigger (timing), and the module can handle up to two

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simultaneous hits. Three MUX modules with 32 input channels were used, and 192 channels were reduced to 30 channels in total including the energy and timing signals. The strip number can be known from the position output for each event, therefore it can process events in the same way as standard circuits. An energy resolution of the MUX circuits was equivalent to that of the original standard circuits.

Figure 2 shows the particle identification of one of the ΔE-E silicon telescopes (Tel2). This telescope consisted of 20 μm SSSD (dE1), 300 μm SSSD (dE2), 1494 μm SSD and 1485 μm SSD. The locus of the left and right panel in Figure 2 shows α and p respectively. These plots show that the ^{26}Si(α, p)^{29}P and elastic scattering were successfully detected in this telescope. A futher analysis is ongoing.

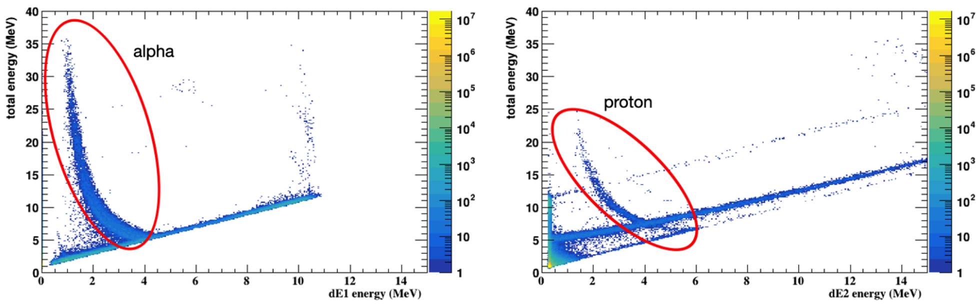

Figure 2. The particle identification using ΔE-E method. This data are from one of the lower angle telescope (Tel2). The left panel shows the total energy vs. the energy detected at dE1 and the right panel shows the total energy vs. the energy detected at dE2. The left and right loci indicate the α and p, respectively.

3 Summary

We performed direct measurements of the ^{26}Si(α, p)^{29}P and the ^{26}Si + α resonant elastic scattering simultaneously at CRIB. Because many detectors were required in this experiment, the multiplexer modules, mesytec MUX, were used first in CRIB. We succeeded in handling a large number of channels in limited feedthroughs with almost the same energy resolution as the original standard circuits. By using the ΔE-E method, the reaction products of α and p were identified. The reaction cross section of these reactions will be obtained in a future analysis.

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