^{7}Be target production to measure ^{7}Be(d,p) reaction for the primordial ^{7}Li problem in Big-Bang Nucleosynthesis

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The overestimation of primordial ^{7}Li abundance in the standard Big-Bang nucleosynthesis (BBN) model is one of the known and unresolved problems. A recent theoretical BBN model predicted a primordial ^{7}Li abundance that was approximately three times larger than the recent precise observation.[1)] Light nuclei were produced up to ^{7}Be by nuclear reactions in several hundred seconds following the Big Bang.

^{7}Li nuclei were predominantly produced by the electron capture decay of ^{7}Be in the standard BBN model. The decay half life of ^{7}Be, 53.22 days, is much longer than the timescale of the production of light nuclei after the Big Bang. Thus, one possible scenario to solve the ^{7}Li problem is that ^{7}Be was destroyed in the timescale of the nuclear reactions. There are several possibilities to destroy ^{7}Be, for example, the ^{7}Be(d,p)^{8}Be, ^{7}Be(n,α), or ^{7}Be(n,p) reactions.[2)] We focus on the ^{7}Be(d,p)^{8}Be reaction because its contribution is suggested to be larger than that of ^{7}Be(n,α)^{4}He.[3,4)] The goal of the experiment is to measure the cross-section of the ^{7}Be(d,p)^{8}Be reaction in the BBN energy region of 100–400 keV. We plan to measure the ^{7}Be(d,p)^{8}Be reaction with a ^{7}Be target because the available data are insufficient for the accuracy or energy range.[5,6)] We are also motivated to measure the reaction in direct kinematics because it implements a good energy resolution. The method allows us to reconstruct the kinematics of the reaction by measuring the outgoing proton without measuring the two alpha particles. We apply the *implantation target method* to produce the ^{7}Be target. ^{7}Be particles were implanted by irradiating a gold target with a ^{7}Be beam.

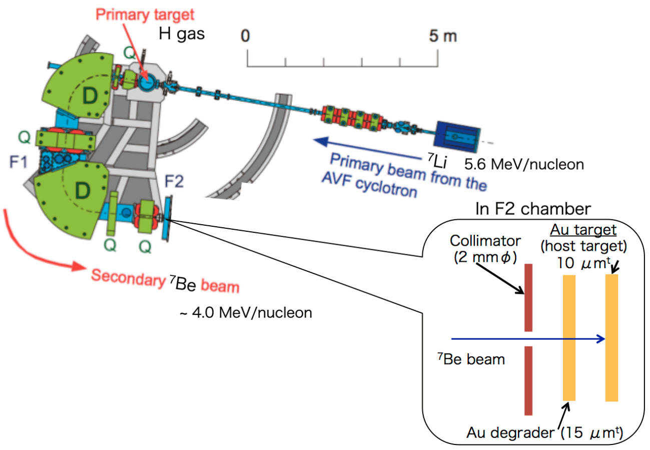

Fig. 1. Experimental setup at CRIB. The enlarged schematic picture shows the inside of the F2 chamber.

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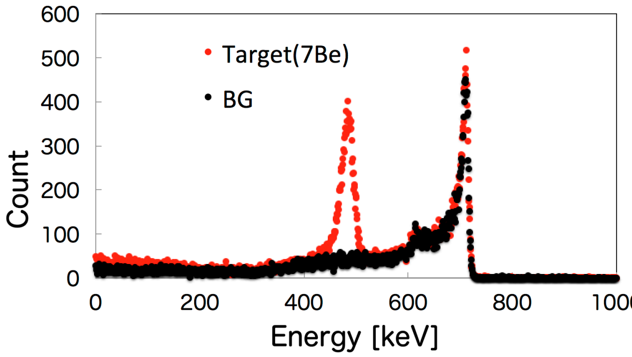

Fig. 2. γ-ray energy spectrum of the implanted ^{7}Be (red dotted plot) and background spectrum (black dotted plot).

We performed an experiment to produce a ^{7}Be implanted target at CRIB, Center for Nuclear Study (CNS) in April, 2018. The experimental setup is shown in Fig. 1.[7)] The primary beam was ^{7}Li^{2+} at 5.6 MeV/nucleon. The secondary beam was produced by the ^{1}H(^{7}Li, ^{7}Be) reaction. The secondary beam energy was 4.0 MeV/nucleon. The ^{7}Be beam was directed on to a 10 μm thick gold target as the host material after an energy degrader made of gold with a thickness of 15 μm and 2 mmϕ collimator determined the implanted beam position.

We evaluated the amount of implanted ^{7}Be by detecting 477 keV γ-rays with a $LaBr_3$ detector after the implantation. The γ-ray is emitted in the electron capture process of ^{7}Be with a branching ratio of 10.5%. We achieved an implantation of 1.9×10^{12} ^{7}Be particles as expected after one day of irradiation. Figure 2 shows the measured γ-ray spectrum. We improved the beam optics for the the high intensity ^{7}Be beam since 2017, which enabled the production of the ^{7}Be target with a high intensity beam.

The ^{7}Be target was carried to the Japan Atomic Energy Agency (JAEA) to measure the (d,p) reaction in June, 2018. The outgoing protons were successfully measured by three layered silicon detectors with the thickness of 500 μm each at 2 different angles, 30° and 45°. Currently, analyses are being conducted to obtain the cross-section of the ^{7}Be(d,p) reaction.

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