Development of a high density ^{7}Be beam at CRIB

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The ^{7}Li problem is a discrepancy between the standard Big-Bang Nucleosynthesis (BBN) model and observations. Our research goal is to measure the cross section of the ^{7}Be(d, p) reaction to solve this ^{7}Li problem. A recent theoretical BBN model predicts a primordial ^{7}Li abundance that is 3 times larger than the recent precise observation.[1)] This difference is quite large, while the theoretical calculation reproduces the abundance of the other light nuclei well. One possible scenario to solve the problem, which has not been included yet in the BBN model, is that ^{7}Be was destroyed in the nuclear reaction after the Big Bang. The ^{7}Be(d,p)^{8}Be and the ^{7}Be(n, α)^{4}He reactions are two promising processes for destroying ^{7}Be. We are focusing on the ^{7}Be(d, p)^{8}Be reaction since the contribution from ^{7}Be(d, p)^{8}Be is suggested to be larger that from ^{7}Be(n, α)^{4}He.[2,3)]

We are developing an unstable ^{7}Be target for high-resolution measurement of the ^{7}Be(d, p)^{8}Be reaction in normal kinematics. This is a big technical challenge since ^{7}Be is an unstable nucleus. We suggested to make the ^{7}Be target by implantation in a host material. This is called the *Implantation method*. The development is ongoing at CRIB, Center for Nuclear Study (CNS), University of Tokyo. The first experiment was performed in June 2016. 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 by employing a cryogenic hydrogen gas target. The gas thickness is 8 cm and the gas pressure was 760 Torr. The secondary beam energy was 4.0 MeV/nucleon. A 10-μm thick gold foil as a host target was irradiated with the ^{7}Be beam after an energy degrader made of gold with a thickness of 15 μm and a collimator with a diameter of 3 mm. We evaluated the amount of the implanted ^{7}Be by detecting 477 keV γ rays with a LaBr$_3$ detector after the implantation. The γ ray is emitted through the electron capture decay of ^{7}Be with a branching ratio of 10.4%. We obtained 1.3×10^{11} (4.3×10^{10}/mm^2) ^{7}Be particles after 19 hours of irradiation. The average beam intensity was 6.3 $\times10^5$/mm^2. However, the number of the ^{7}Be particles is almost 10 times smaller than our estimation from the maximum intensity ($\sim10^6$/mm^2) of CRIB's previous performance. We suspect that the beam spot size and the beam profile at F2 were not fully optimized for the high-intensity ^{7}Be beam downstream of the collimator and not maintained at a fixed position during the long irradiation time since we did not check the ^{7}Be beam profile when the beam intensity was increased. This is because it was not possible to count such a high intensity beam directly.

Based on the result of the experiment in 2016, we performed a development experiment at CRIB to optimize the beam line optics and obtain an intense beam of ^{7}Be, in April 2017. Previously, the beam profile was checked with the PPAC detector at CRIB. However the PPAC detector is not a detector for such a high rate, so we could not count the high intensity beam with the existing detector. To solve this issue, we installed a metal mesh at F1 and a plastic scintillator at F2 to count the beam intensity. This was a new trial at CRIB. The metal mesh was used to reduce the ^{7}Be beam intensity, and hence we could count the ^{7}Be beam intensity directly by the plastic scintillator. In this experiment, we tuned the ion-optical parameters and the steerer on the beam line for the best-positioning and focusing of the secondary ^{7}Be, by counting the intensity with the plastic scintillator. We achieved 6.8×10^6/mm^2 as the average beam intensity after the optimization of the settings of beam-line optics. We obtained 1.2×10^{12} (1.7×10^{11}/mm^2) ^{7}Be particles with 7-hours irradiation. As the next step, we plan to measure the ^{7}Be(d, p) reaction at Japan Atomic Energy Agency, tandem facility. The ^{7}Be target will be produced at CRIB before the (d, p) reaction measurement, planned for 2018. About 8.2×10^{12} (2.6×10^{12}/mm^2) ^{7}Be ions will be implanted in 2 days of irradiation.

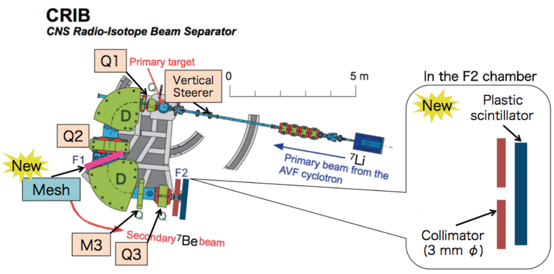

Fig. 1. Plane view of CRIB, where the Q1, Q2, Q3, and M3 magnets and the steerer were optimized in the present work. The installation of the mesh at F1 and the plastic scintillator at F2 was a new trial at CRIB to count the high intensity beam. The ^{7}Be beam was counted after the 3 mm diameter collimator.

References
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