^{7}Be$(n,p)^7$Li and ^{7}Be$(n,\alpha)^4$He reaction measurements at CRIB using the Trojan Horse method

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It has been known that the primordial ^{7}Li abundance predicted by the standard Big-Bang Nucleosynthesis (BBN) model[1)] is about three times larger than the observation, which is the cosmological ^{7}Li problem. The ^{7}Be$(n,p)^7$Li reaction is considered as the main process to destruct ^{7}Be during the BBN, which is also crucial in determining the ^{7}Li abundance. The resonance structure of the ^{7}Be$(n,p)^7$Li reaction was well investigated by the R-matrix analysis[2)] on several experimental data. However, the contribution of the transition to the first excited state of ^{7}Li at the BBN energies ($\sim$ 25 keV–1 MeV) has never been discussed. The other interesting reaction channel of the neutron induced reaction, ^{7}Be$(n,\alpha)^4$He, has not been investigated until recently[3,4)] in terms of the relevance to the BBN scenario. Note that the new measurement[4)] was limited and carried out at very low energies, which thus lacks the information on the total ^{7}Be$(n,\alpha)^4$He cross section in the BBN energy region.

We performed indirect measurements of the ^{7}Be$(n,p)^7$Li and ^{7}Be$(n,\alpha)^4$He reactions simultaneously by the Trojan horse method (THM)[5)] at the Center for Nuclear Study Radioactive Ion Beam (CRIB) separator[6)]. The THM is an indirect technique that allows us to approach a two-body reaction at astrophysical energies via a three-body reaction by selecting the quasi-free (QF) kinematics. Moreover, the THM is useful as a "virtual neutron source" for neutron-induced reactions by using a deuteron target[7)]. Similar to the first application of THM to the RI+n reaction[8)], which was performed in collaboration with our group, we used a ^{7}Be beam and a deuteron target that induce the ^{7}Be$(d,^7$Li$p)^1$H and ^{7}Be$(d,\alpha\alpha)^1$H reactions in inverse kinematics to study the ^{7}Be$(n,p)^7$Li and ^{7}Be$(n,\alpha)^4$He reactions, respectively. We produced a ^{7}Be beam at 22.1$\pm$0.14 MeV with an intensity of 1×10^6 pps on target. The experimental setup consisted of two parallel-plate avalanche counters (PPACs) for beam tracking, a CD_2 target, and six ΔE-E position-sensitive silicon-detector telescopes at $\pm12°$, $\pm34°$ and $\pm56°$. The thickness of the CD_2 target was 64 μg/cm^2. A use of such a thin target allows reducing the energy spread to about 120 keV. This helps to identify the first excited state of ^{7}Li (478 keV) in the reconstructed Q-value spectrum. We observed p-^{7}Li and α-α coincidental events, and confirmed that they were kinematically correct as the expected three-body exit channels. Figure 1 shows three-body Q-value spectra of those channels. The peaks are fitted by Gaussian functions with mean values of -0.67 MeV and 16.64 MeV, respectively, which are consistent with the known Q values of -0.580 MeV and 16.766 MeV within the resolution of about 600 keV (rms). This resolution is expected to be improved to 150–200 keV with more precise energy and angular calibrations and further corrections. Accordingly, one can resolve both the ground and the first excited state of ^{7}Li. By selecting the corresponding kinematic region, we estimate about 3000 QF events for the ^{7}Be$(n,p)^7$Li channel in total.

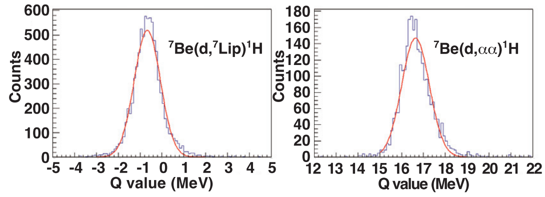

Fig. 1. Q-value spectra of the ^{7}Be$(d,^7$Li$p)^1$H (left) and the ^{7}Be$(d,\alpha\alpha)^1$H (right) reactions.

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