New measurement of $^8$Li($\alpha$,n)$^{11}$B reactions

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1. Introduction

The $^8$Li($\alpha$,n)$^{11}$B reaction is considered to be the key reaction in the inhomogeneous Big Bang [1–3] and type-II supernova nucleosynthesis [4, 5], and have been studied in experiments [6–13] for thirty years. Especially, we have been providing cross-section data [7–13] on this reaction for more than twenty years with using $^8$Li RI beams.

The previous results [7–13] are summarized in Fig. 1. The Gamow-peak widths, whose energy regions of $T_9 = 1$ and $T_9 = 2$ are important for the Big Bang and supernova nucleosynthesis, respectively, are also indicated in Fig. 1.

We can see in Fig. 1 that the cross-sections obtained by the previous experiments have large differences around $E_{cm} = 1.0$ MeV. The previous experiments were performed by two different methods: inclusive and exclusive. The former detected either $^{11}$B [7, 8] or neutron [10, 12] and the latter [9, 11, 13] detected both $^{11}$B and neutron by measuring their kinetic energies and angles. The cross-sections of the former results are larger than the latter ones systematically. The largest discrepancy appears the center energy of $T_9 = 2$ region and its value is a factor of five. We could presume that the sources of the discrepancies might originate from the experimental methods, but we have no experimental fact to investigate them.

2. Experiment

In order to solve this problem, we proposed a new inclusive measurement. Figure 2 shows the level schemes relevant to the $^8$Li($\alpha$, n)$^{11}$B reaction. As shown in Fig. 2, we could expect that the highly-excited states of $^{11}$B might be produced by this reaction, however the previous experiments did not measure the $\gamma$-rays. Thus we performed a new experiment to measure the $\gamma$-rays emitted from $^{11}$B$^*$.s.

Considering that the expected $\gamma$-ray energies are between 2 and 8 MeV, we employed a large volume $3.5'' \times 8''$ LaBr$_3$:Ce detector [14] provided by INFN Milano. We also installed 850 mm × 150 mm × 50 mm plastic and 50 mm$^6 \times 10$ mm $^6$Li-glass scintillators to detect neutrons by covering wide energy ranges between a few ten keV to 10 MeV for reference to the previous experiments. The plastic scintillator
has an energy threshold of a few hundred keV for detecting neutrons. The $^6$Li-glass scintillator has good detection efficiencies for neutrons whose energies are below a few hundred keV.

This experiment was performed at CRIB in September 2018. We placed a gas-target cell at F3, in which $^4$He gas was filled at a pressure of 1.0 atm. Two LaBr$_3$:Ce detectors were placed close to the $^4$He-gas-target cell. Ten $^6$Li-glass and six plastic scintillators were placed downstream of the gas-target cell with mean distances of 50 cm and 150 cm, respectively. The $^8$Li beam, whose intensity was typically 300 kHz, was produced by the $^7$Li($d,p$)$^8$Li reaction. The primary $^7$Li beam had an energy of 6.0 MeV/nucleon and an intensity of 250 particle nA. The $D_2$-gas production target had a thickness of 1.9 mg/cm$^2$. The energies of $^8$Li particles measured inside the $^4$He-gas target were between $E_{cm} = 0.9$ and 1.9 MeV.

3. Preliminary result

We successfully obtained data with sufficient statistics. Although we faced difficulties in data analysis owing to the large background originating from thermal neutrons, we could identify the $\gamma$-rays emitted from $^{11}$B's. Figure 3 shows the preliminary result of the $\gamma$-ray spectrum. By subtracting the huge background with considering timing information, we could derive this spectrum. We can observe some peak-like structures corresponding to the $\gamma$-ray energies from $^{11}$B's.

4. Future outlook

For obtaining the $\gamma$-ray spectrum with rational quality, we should perform much more careful analysis. Due to the vast thermal-neutron background, we have difficulties to analyzed data of neutron detectors. We should do further research and development to resolve this problem. We are also doing computer simulations for determining efficiencies of detectors to derive absolute values of reaction cross section and branching ratios of the final states of $^{11}$B. We expect that this experiment will provide new data to understand mechanism of the $^8$Li($\alpha,n$)$^{11}$B reaction and dynamics of the excited states of $^{11}$B produced by this reaction.

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