Measurement of $^4$He($^8$He,$^8$Be) reaction for verifying tetra-neutron resonance

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The existence of nuclei composed only of neutrons has been discussed for over half a century, but it has not been confirmed yet. In 2002, a candidate bound state of the tetra-neutron, which consists of four neutrons, was reported.1 An ab-initio calculation suggested that there might be a tetra-neutron (4\text{n}) resonance, but a bound 4\text{n} was not reproduced.2 An experimental search for the 4\text{n} resonance state conducted using the exothermic double charge exchange (DCX) $^4$He($^8$He,$^8$Be)4\text{n} reaction was performed at the SHARAQ spectrometer in RIBF.3 As a result, four candidate events were found with a 4.9\text{\textsigma} significance level, and the energy of the 4\text{n} resonance was determined as $E_{4\text{n}} = 0.83 \pm 0.65$ (stat.) $\pm 1.25$ (syst.) MeV. To confirm the existence of 4\text{n} resonance, we performed a new measurement with higher statistics and with smaller energy uncertainty.

Fig. 1. Detector setup of BigRIPS/SHARAQ beam line.

Figure 1 shows a schematic view of the setup for this experiment. A primary $^{18}$O beam was accelerated to about 230 MeV/nucleon by AVF+RRC+SRC. The intensity of the primary beam was about 700 particles. The energy of the secondary $^8$He beam was about 186 MeV/nucleon. The beam intensity was increased from that in the previous experiment. The rate of the secondary beam at F3 was increased from about 2.0 MHz to 3.5 MHz. Six low-pressure multiwire drift chambers (LP-MWDCs) were installed for tracking the beam. “F6” was set as a dispersive focal plane, so that the momentum of the beam could be measured by the focus position. At “S0,” a liquid He target system (CRYPTA) was installed. At the final focal plane, “S2,” 2 α particles from the decay of outgoing $^8$Be were detected using 2 cathode readout drift chambers (CRDCs).

Fig. 2. A preliminary hit pattern of the $^1$H(t,$^3$He) reaction at S2 for the energy calibration with a reaction kinematics curve. The X and Y axes represent the missing momentum and the vertical scattering angle, respectively.

In the present experiment, the method of missing-momentum calibration was changed to reduce the systematic error of the 4\text{n} energy. As a reference for the energy, the $^1$H(t,$^3$He) reaction was measured with a triton beam that has the same magnetic rigidity as the $^8$He beam (8.3 Tm). The energy can be calibrated without changing the magnetic settings. Figure 2 shows an S2 image of outgoing $^3$He particles from the $^1$H(t,$^3$He) reaction. The red line indicates the fitted kinematics curve of the reaction. The threshold energy of the 4\text{n} state can be determined from the curve. Further analysis is now in progress.

References