Precise measurement of the ^{4}He(^{8}He,^{8}Be) reaction

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Nuclei composed of only neutrons have been discussed for over a half century. However, their existence has not been confirmed. 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 ($4n$) resonance, but a bound $4n$ was not reproduced.[2)] An experimental search for the $4n$ resonance state conducted using the exothermic double charge exchange (DCX) ^{4}He(^{8}He,^{8}Be)$4n$ reaction was performed at the SHARAQ spectrometer in RIBF.[3)] As a result, four candidate events of the resonance state were found with a 4.9σ significance level, and the excitation energy of $4n$ was determined as $E_{4n} = 0.83 \pm 0.65$ (stat.) $\pm$ 1.25 (syst.) MeV, which is close to the threshold.

To decide that the tetra-neutron state is a bound ($E_{4n} < 0$) or resonance ($E_{4n} > 0$) state, it is necessary to reduce the systematic uncertainty for the excitation energy of $4n$. Then, we performed a new measurement to obtain more statistics than the previous experiment and reduce the uncertainty of the energy of the $4n$ state.

The ^{1}H(^{3}H,^{3}He) reaction with the same magnetic rigidity of the ^{8}He beam (8.3 Tm) was used to determine a missing-mass calibration. Thus, the energy can be calibrated without changing the magnet settings. This is the reason why we do not have to consider the scaling errors of magnetic fields. The accuracy of the excitation energy of $4n$ is evaluated to be approximately 100 keV, which originated from the uncertaintly of the energy reference.

In order to obtain more statistics than the previous experiment, the intensity of the ^{8}He secondary beam of 186 MeV/nucleon was approximately twice that in the previous experiment (3.5×10^6 cps at F3 focal plane).[4)] At the "F3 (achromatic focus for beam trigger)," "F6 (dispersive focus)," and "S0 (achromatic focus for the secondary target)," low-pressure multi-wired drift chambers (LP-MWDCs) were used for tracking the beam. Events for the physics run were triggered by the S2 plastic scintillator at the focal plane of the SHARAQ spectrometer. Because of the high-rate beam condition, a single event may contain multiple hits at the drift chambers over several beam bunches of 13.7 MHz (RF frequency), considering the maximum drift time for the MWDCs is comparable to the interval of the beam bunch. Hence it is necessary to treat information of the redundant planes and other detectors.

In order to estimate the number of true four-neutron events, a strict cut satisfying the condition that the two clusters at the cathode planes of S2 have consistent energy signals with 2 α particles oeiginating in the ^{8}Be is analyzed. A preliminary analysis shows an similar event pattern in a spectrum as a function of the momenta of ^{8}He and ^{8}Be that is similar to the previous experiment. Considering the analyzed area of the decay cone of ^{8}Be, we expect approximately 2–3 times more statistics than the previous experiment.

A more precise calibration for the missing-mass spectrum taking into account the energy loss and straggling at the detectors and the target to reduce systematic errors will be performed concurrently.

In summary, we are still attempting to purify true events for increasing statistics with careful rejection conditions for the background. In parallel, missing-mass calibration will be tuned up to increase the accuracy of the $4n$ energy. Further analysis is ongoing.

References
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