Missing-mass spectroscopy of tetra-neutron system via exothermic double-charge exchange reaction ^{4}He(^{8}He,^{8}Be)4n

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Since the report on candidates of a bound tetra-neutron system[1], multi-neutron systems in nuclei have attracted considerable attention on both the experimental and theoretical fronts. On the other hand, later theoretical studies using *ab-initio* calculations[2] have suggested that the tetra-neutron cannot exist as a bound system but possibly as a resonance system.

We performed missing-mass spectroscopy of the 4n system via the exothermic double-charge exchange reaction ^{4}He(^{8}He,^{8}Be)4n[3]. The primary goal of the experiment was to determine the energy level and its width of the 4n system. In order to produce the 4n system with a small momentum transfer of less than 20 MeV/c, a secondary beam of ^{8}He with a large internal energy was used.

The experiment was performed at the RIKEN RI Beam Factory (RIBF) using the SHARAQ spectrometer and a liquid He target system[4]. We measured the momentum of the ^{8}He beam at BigRIPS-F6 with the High-Resolution Beamline and the momenta of two alpha particles, which were the decay products of the ^{8}Be ejectile, with the SHARAQ spectrometer. The incident beam energy of ^{8}He was 186 MeV/u.

Events resulting from the ^{4}He(^{8}He,^{8}Be)4n reaction were selected. Two α particles from the ^{8}Be ejectile were detected simultaneously at the final focal plane of the SHARAQ spectrometer. Furthermore, a method to reconstruct trajectories for more than two particles under a high-intensity beam ($\sim$2 MHz) was developed [5]. In order to a obtain good signal-to-noise ratio, it was important to identify multi-particles in one bunch, which have the possibility to create the background events. These events were rejected using the Multi-Wire Drift Chamber (MWDC) at F6.

We obtained the missing-mass spectrum of a tetra-neutron system, as shown in Fig. 1. The spectrum contains 28 events including background events. The background events were estimated from the the number of events that was not identified as multi-particle in one bunch in the MWDC at F6. There were only 2.2 ± 1.0 events in the whole spectrum region, which is almost negligible compared to the selected 28 events. The excitation energy (E_{4n}) of the spectrum was calibrated using the peak position of the ^{8}Li(1^+) state and the scale of magnetic rigidity of the SHARAQ spectrometer. ^{8}Li was produced by the inverse kinematics of the (p,n) reaction of ^{8}He. The uncertainty of the energy determination accuracy was 1.25 MeV at the one sigma level. The resolution of the spectrum was 1.16 MeV at the one sigma level.

The events were concentrated in the low-excitation-energy region of $0 < E_{4n} < 2$ MeV and a continuum were observed at a region of $E_{4n} > 2$ MeV. The mean of the four events at $0 < E_{4n} < 2$ MeV was 0.83 ± 0.25 MeV. The possibility of the resonance state at the low-energy region and the shape of the continuum will be discussed in comparison with results of a theoretical calculation assuming the correlation of di-neutron clusters.

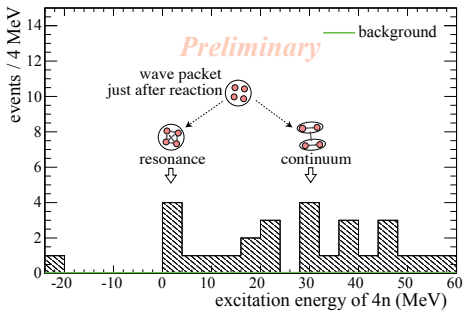

Fig. 1. Missing-mass spectrum of tetra-neutron system.

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