Missing-mass spectroscopy of the 4n system via exothermic double-charge exchange reaction at high beam counting rates

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Since the report on candidates of 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.

We performed missing-mass spectroscopy of the 4n system via an exothermic double-charge exchange reaction ^{4}He(^{8}He,^{8}Be)4n. The purpose of this experiment was to obtain information on few-body forces, such as the T=3/2 three body force, and the correlations between in multi-body scattering states that reflect final state interactions of sub-systems, such as di-neutron correlations. 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, 190 A MeV, was used.

The experiment was performed at the RIKEN RI Beam Factory (RIBF) using the SHARAQ spectrometer and a liquid He target system. The Be target at BigRIPS-F0 was bombarded by a primary beam of ^{18}O at 230 A MeV to produce the ^{8}He secondary beam. We measured the momentum of the ^{8}He beam at BigRIPS-F6 with the High-Resolution Beamline and also measured the momentum of two alpha particles, which were the decay products of the ^{8}Be ejectile, with the SHARAQ spectrometer.

Because a small cross section was expected for this reaction, it was important to achieve a large yield and good S/N ratio. The highest ^{8}He beam intensity in this experiment was 2×10^{6} counts/second, which was produced by the 13.7 MHz AVF cyclotron. The first bunch of triggered particles comprise 14.6 % of the multi-particle event, and the next bunch comprises 12.7 % (the bunch after that comprise 10.6 %). We developed a new analytical framework that contains information of multi particles arranged in a bunch structure as a new dimension. Previous frameworks have assumed that one trigger event corresponds to only one particle.

By reading multi-hit TDCs and assigning bunches in plastic scintillators, we can increase the statistics by 12.1%w. With the multi wire drift chambers(MWDCs) as tracking detectors at the beamline, it is found that other particles in the later bunches of the triggered particle cause tracking errors. By treating the sum of drift times of the planes shifted to the half cell of MWDCs (Fig. 1), we can improve statistics by 10.3% and eliminate multi-particles in each bunch.

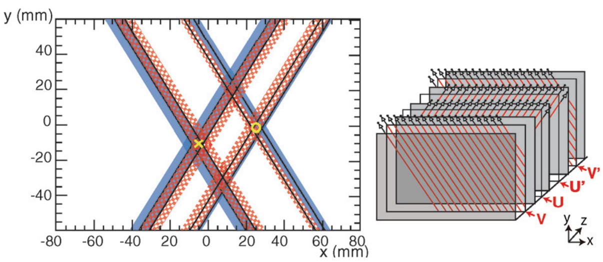

Fig. 1. Example of an event snapshot. The MWDC at F6 consists of 4 planes (U(30°)-U'(30°)-V(60°)-V'(60°)). Solid lines represent hit wires. Blue solid and red meshed bands represent the drift length of U(U') and V(V') planes, respectively. We can track the position (indicated by yellow circle) if there are 4 candidates. The yellow cross denotes the particle in the next bunch of triggered particle.

At the final focal plane of the SHARAQ spectrometer, two-alpha events can be tracked using cathode readout drift chamber[4)] (CRDCs). We identified approximately about a hundred candidate events for the 4n system. We are yet to examine the kinematical conditions and eliminate the background.

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