Candidate resonant tetraneutron state populated by the ^{4}He(^{8}He,^{8}Be) reaction

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The possible existence of a tetraneutron system forming a resonance state is still an open and fascinating question; however, theoretical and experimental studies suggest that the tetraneutron does not exist as a bound state[1,2]. An experiment to search for the tetraneutron state has been performed by measuring the double-charge exchange (DCX) reaction ^{4}He(^{8}He,^{8}Be) at 186 MeV/u at RIBF using the SHARAQ spectrometer. Utilizing the large positive Q-value of the (^{8}He,^{8}Be) reaction, an almost recoil-less condition of the four-neutron system was achieved in order to populate weakly interacting four-neutron systems efficiently. The detail of the experiment and data-analysis have been described in previous reports[3,4].

We obtained the missing-mass spectrum of a tetraneutron system, as shown in Fig. 1 (a). To interpret this spectrum, we assumed two different states: (1) direct decay contributing to the continuum with a final-state interaction between the two correlated neutron pairs; (2) a possible resonant state of the tetraneutron system near the threshold. To demonstrate the significance of the yields near the threshold, we fitted the experimental data with a trial function assuming the absence of the resonant state and estimated the goodness-of-fit with the likelihood ratio test (Fig. 1 (b)). Because of the small contribution from the continuum and experimental background, the significance level of the peak is 4.9 with the analysis of the look elsewhere effect.

In conclusion, the four events in the $0 < E_{4n} < 2$ MeV region are candidates for the resonant state of the tetraneutron system. The mean energy of the events is evaluated to be 0.83±0.65 MeV with an additional systematic uncertainty of 1.25 MeV due to uncertainty in the calibration of the missing-mass energy. These results suggest a possible resonant state of the tetraneutron system, although the possibility of a bound state is not experimentally excluded. The upper limit of the width of the peak is estimated to be 2.6 MeV (FWHM), which is mainly determined by experimental missing-mass resolution. The rather narrow width may be understood by considering a small phase space for the four-body decay.

The result indicating the resonant state may suggest necessity of strong many-body forces, such as isospin T =3/2 three-body force and/or $T = 2$ four-body force, which are incompatible with the present understanding of nuclear interactions[5]. Our results should serve as a basis for further investigations.

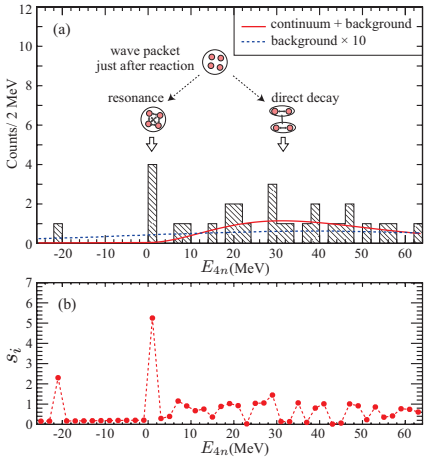

Fig. 1. (a) Missing-mass spectrum of the tetraneutron system. The solid (red) line represents the sum of the direct decay of the correlated two-neutron pairs and the estimated background. The dashed (blue) line represents the estimated background multiplied by a factor of 10. (b) Evaluation of the goodness of fit for each bin.

References

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