Observation of a correlated free four-neutron system†

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The high impact potential of multi-neutron systems has led to many experimental searches for such isolated systems starting in the early 60 s, with in particular, the four-neutron system. Till date, only a few indications of its existence have been found.[1)]

This study used the quasi-elastic knockout reaction ^{8}He$(p, p\alpha)$ at maximum momentum transfer, removing the α-core from ^{8}He as fast as possible, to ensure a recoil-less production of the $4n$ as spectators.

The experiment was conducted at SAMURAI, where a 156 MeV/nucleon ^{8}He beam was transported to a liquid-hydrogen target. From the combined selection of charged particles in the reaction, the energy spectrum of the $4n$ system was reconstructed via the missing-mass method, as shown in Fig. 1. Two components are observed: a pronounced peak at low energy which experimentally has a resonance-like structure, and a wide distribution at higher energies attributed to a non-resonant continuum response.[2)] As the non-resonant part cannot explain the sharp low-energy peak, the energy and width of the resonance-like structure was determined assuming a Breit-Wigner shape as $E_{\mathrm{r}} = 2.37 \pm 0.58$ MeV and $\Gamma = 1.75 \pm 0.40$ MeV, respectively, with a striking significance level.

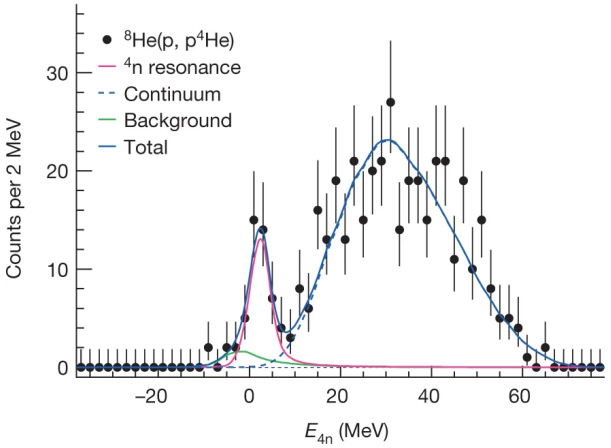

Fig. 1. Missing-mass spectrum of the $4n$ system.

From theoretical perspective there is no consensus among the different studies. While some predict a low-energy resonance,[3)] others exclude this possibility[4)] and even predict that a low-energy structure can appear as a consequence of neutron's final-state interaction, and the reaction mechanism.[5)] Whether our observation is attributed to a tetra-neutron correlation or other correlations between the neutrons in the final state, needs to be clarified by ab initio theories accounting fully for the continuum. Next-generation experiments, foreseen at SAMURAI, using different reaction mechanisms and detecting the four neutrons in coincidence will shed light on the properties of the four-neutron system and the origin of the low-energy peak.

† Condensed from the article in Nature **606**, 678 (2022)
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