The study of the core-excited component in ^{11}Li

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^{11}Li is one of the most well-known drip-line nuclei in nuclear physics. The discovery of a spatially extended structure of neutrons in ^{11}Li, which is now widely known as "halo" structure, opened the very active field of research with unstable nuclear beams.1) ^{11}Li has the Borromean nature, generally considered as a 3-body system of ^{9}Li plus 2 well-decoupled valence neutrons. However, recent theoretical studies pointed out that contribution of the excited ^{9}Li core could also be significant2,3) in the ground state of ^{11}Li. But no experiment has hitherto succeeded in providing a direct information about the excited-core in ^{11}Li.

The SAMURAI18 experiment performed at the Radioactive Isotope Beam Factory (RIBF) in RIKEN employed the quasi-free (p, pn) reaction. Kubota *et al.*4) reported the dineutron correlation localized radially on the ^{11}Li surface with the data of the ^{11}Li$(p, pn)^{9}$Li$(g.s) + n$ channel. The core-excited component associated with bound excited states of ^{9}Li ($J^{\pi} = 1/2^{-}$, $E_x = 2.69$ MeV) was also studied from coincident gamma-ray measurement and no significant contribution of this component was observed, which can be attributed to the spin-parity constraints.5) Thus, it can be expected that the core-excited component in ^{11}Li that we are interested in should be associated with a ^{9}Li excited state with $J^{\pi} = 3/2^{-}$ and with a higher excitation energy above the ^{8}Li $+ n$ breakup threshold. By looking into the ^{8}Li $+ 2n$ channel of the SAMURAI18 experiment, we will be able to probe the ^{9}Li*(unbound) $+ n$ component in ^{11}Li.

Secondary ^{11}Li beams ($\sim 1 \times 10^{5}$ pps, ~246 MeV/nucleon) were produced from the fragmentation of ^{48}Ca beam at 345 MeV/nucleon and selected by the BigRIPS fragment separator. They were then tracked onto the 150-mm-thick MINOS target using two multiwire drift chambers. After a (p, pn) reaction, the target proton and one of the neutron of ^{11}Li were scattered to large polar angles. The recoil particle detector (RPD) was composed of a multiwire drift chamber and a plastic scintillator hodoscope. The neutron detector array WINDS was installed to measure the scattering angle and the time of flight of the knockout neutron. The beam-like residues—the charged fragment ^{8}Li and two neutrons—were analyzed by the SAMURAI spectrometer and the neutron detector array NEBULA, respectively. Single incoming neutron could induce signals in multiple detectors of NEBULA, a phenomenon commonly called cross-talk. The time-space-separation cuts and the causality cuts of velocity were applied to eliminate these fake two-neutron events.6)

The relative energy spectrum of ^{10}Li is reconstructed from coincident ^{8}Li $+ n + n$ events using the invariant-mass method and is presented in Fig. 1. Two resonance-like structures are observed at $E_{\rm rel} \sim 0.3$ MeV and at $E_{\rm rel} \sim 1.6$ MeV. The spectrum can be well fitted using a sum of an Is-wave virtual state for the first peak and a p-wave resonance for the second peak. Figure 2 shows the Dalitz plot of the relative energy of the subsystem ^{8}Li $+ n$ ($E_{\rm fn}$) versus that of ^{8}Li $+ n + n$ ($E_{\rm rel}$). The correlation pattern in the $E_{\rm rel}$ range of 1.3–1.7 MeV is consistent with the sequential two-neutron emission via an intermediate ^{9}Li resonant state with $E_{\rm fn} \sim 0.3$ MeV, and

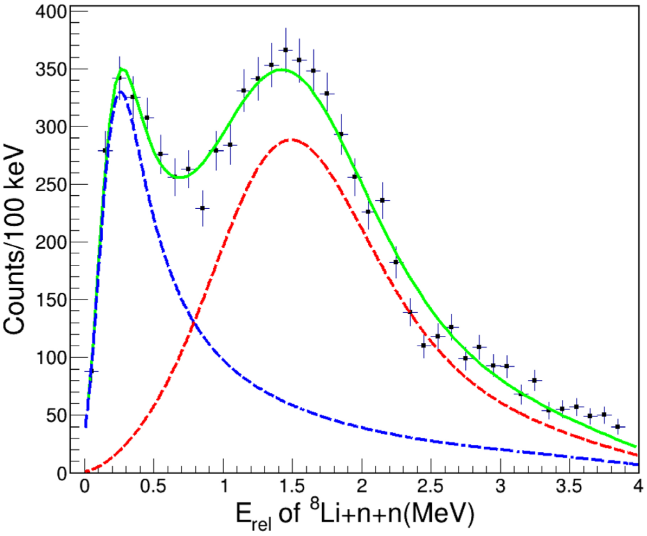

Fig. 1. Relative energy spectrum for ^{8}Li $+ 2n$. The blue dashed line, red dashed line and the green line represent the the s-wave virtual state fit, p-wave resonance fit and sum of these two components, respectively.

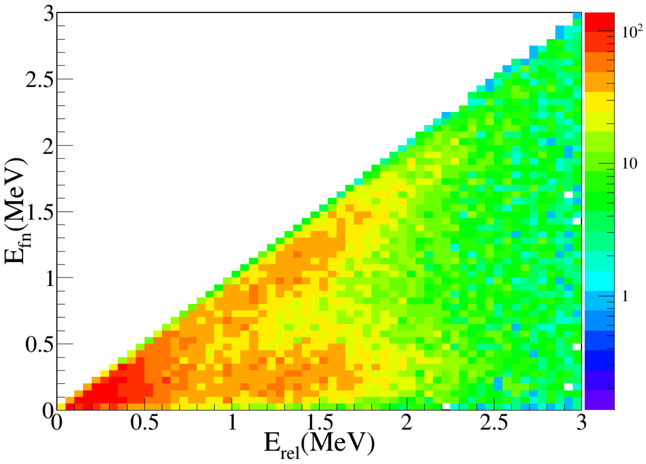

Fig. 2. Dalitz plot of the relative energy. The horizontal axis represents the relative energy of ^{8}Li $+ n + n$ ($E_{\rm rel}$) and vertical axis represents the relative energy of ^{8}Li $+ n$ ($E_{\rm fn}$).

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this component should thus be assigned to the excited-core configuration in the ground state of ^{11}Li. For the next step, we will analyze the momentum distribution of the knockout neutron to determine its single-particle orbital occupation. By combining with the theoretical calculation that is now in progress we will be able to pin down the excited-core component in ^{11}Li.

References

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