SAMURAI18: comprehensive study of ^{11}Li

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Since the discovery of the neutron halo, ^{11}Li has been one of the most attractive neutron drip-line nuclei. It is known as a Borromean nucleus, described as a three-body system with two weakly bound valance neutrons around a ^{9}Li core nucleus, with none of the two-body subsystems (^{10}Li or ^{2}n) having bound states. A hypothetical bound state of two neutrons, known as the *dineutron*,[1)] is thought to be closely related to its existence.

The quasi-free knockout reaction in inverse kinematics was employed in this study to reveal the two-neutron correlation in ^{11}Li without breaking quantum coherence.[2)] By introducing the liquid hydrogen target system MINOS[3)] to the RIKEN RIBF, an unprecedentedly high luminosity has been realized. The dedicated (p, pn) setup combined with the SAMURAI spectrometer[4)] allowed kinematically "too" complete measurement resulting in high reliability.

By knocking out a valence neutron, the unbound ^{10}Li was produced, and the decay channel of $^{9}\mathrm{Li}+n$ was investigated. The known low-lying structures of s-wave virtual state and p-wave resonances were identified, and the resonance parameters were significantly improved. Furthermore, an exceptionally narrow resonance with a width of 0.7 MeV at a relative energy of 5.5 MeV was newly found and identified as a d-wave resonance by the multipole decomposition analysis. Recently, the analysis of the decay channel of $^{8}\mathrm{Li}+2n$ has revealed an interesting structure that provides insight into the ^{9}Li core excitation in the ground state of the ^{11}Li.[5)]

The in-nucleus momentum k of the knockout neutron is reconstructed from the measured momentum of the recoil proton and the knockout neutron. This value is used as a measure of the radial position of the dineutron as well as to define the correlation angle θ_{nf}, which is the measure of the dineutron strength. The relationship between θ_{nf} and k reveals that the dineutron is localized at the surface of ^{11}Li and changes its shape in other region, such as near the center of the nucleus and in the tail of the halo.[6)] The same analysis has been carried out for ^{14}Be and ^{17}B, and the universality of the dineutron is becoming apparent.[7)]

Only dineutron in the ground state can be studied with one neutron knockout. In order to overcome this limitation, the proton knockout from ^{12}Be was used

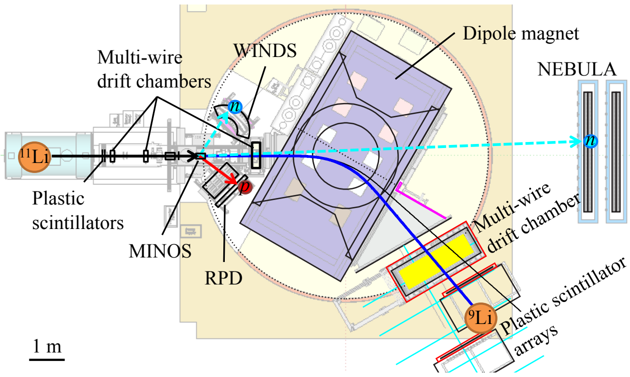

Fig. 1. Schematic of the setup.

to produce the excited ^{11}Li. The decay mode of the $^{9}\mathrm{Li}+2n$ channel was investigated through the energy sharing between the two-body subsystems and it was found that in most cases ^{11}Li decays through ^{10}Li, *i.e.*, emitting the two neutrons sequentially.[8)]

From the interest of the tensor force, the formation of deuteron clusters in ^{11}Li was investigated using the deuteron knockout reaction. Since deuterons are weakly bound systems, approximately half dissociates during the knockout process. However, choosing the appropriate kinematics can distinguish deuteron-originated protons and protons from proton knockout. The deuteron spectroscopic factor could be obtained by comparing it with the distorted-wave impulse approximation (DWIA) calculation, though it contains large systematic uncertainties.[9)]

The proton knockout channel was also investigated for the ^{10}He spectroscopy. A three-body correlation analysis showed convincing result on the long-debated ground state of ^{10}He.[10)]

In summary, ^{11}Li was comprehensively studied using the quasi-free knockout reaction. In addition to two-neutron correlation in the ground and excited states, the structure of unbound subsystems and the formation of deuteron clusters were investigated.

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