

## Inclusive breakup measurement of $N = 20 - 28$ nuclei near neutron drip-line

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One-neutron removal cross sections of Coulomb and nuclear breakup of  $^{29,31}\text{Ne}$ ,  $^{33,35,37}\text{Mg}$ , and  $^{39,41}\text{Si}$  have been measured at around 240 MeV/nucleon at RI Beam Factory (RIBF). Additionally, the fragment momentum distributions for  $^{28,30}\text{Ne}$ ,  $^{32,34,36}\text{Mg}$ , and  $^{38,40}\text{Si}$  after nuclear breakup have been measured. The Coulomb breakup reaction is sensitive to the soft  $E1$  excitation, which have been used to investigate the halo structure. On the other hand, nuclear breakup reaction can tell the configuration of single-particle orbitals. In our analysis, these reactions are utilized in combination to find halo nuclei and obtain the spectroscopic factors, separation energy, and spin parity of the ground state. Namely, we have established a new spectroscopic tool by using both Coulomb and nuclear breakup reactions.

The measured Coulomb breakup cross sections showed significant enhancement for  $^{31}\text{Ne}$  [1] and  $^{37}\text{Mg}$ , which suggests the halo formation in these nuclei. Additionally, the combined analysis of Coulomb and nuclear breakup reactions provided the separation energy and spin-parity of the ground state. We discuss the results and their shell structure of nuclei near the neutron drip-line. We also report the recent results of fragment momentum distributions for one-neutron removal from  $^{19,20}\text{C}$  and two-neutron removal from  $^{20,22}\text{C}$  [2].

[1] T. Nakamura, N. Kobayashi et al., Phys. Rev. Lett. **103**, 262501 (2009).

[2] N. Kobayashi et al., Phys. Rev. C **86**, 054604 (2012).