Nuclear Halo Structure Studies via High-Energy Break-up Reactions

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The nuclear halo structure can be efficiently investigated via high-energy breakup reactions. Partial and differential break-up cross section measurements for the removal of valence nucleons and momentum measurements are spectroscopic methods successfully applied at high-energy fragmentation facilities. A narrow momentum distribution of the core fragments can be a clear signature for new halo candidates [1, 2, 3]. In recent experiments at the FRS we measured the momentum distributions of neutron-rich oxygen isotopes isotopes produced via fragmentation of ^{40}Ar projectiles. The fragments were unambiguously identified by magnetic rigidity, time-of-flight and energy-deposition measurements in front of the breakup target placed at the central focal plane of the FRS. Momentum distributions of the secondary fragments after removal of one neutron are shown in fig. 1.

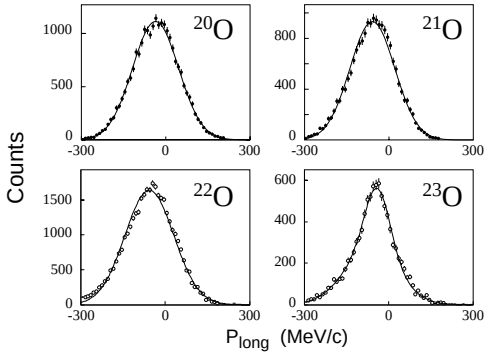

Figure 1: Measured momentum distributions of oxygen isotopes after one-neutron removal reaction in a carbon breakup target placed at the central focal plane of the FRS. The preliminary fwhm values of the distributions are ^{20}O (192 ± 5 MeV/c), ^{21}O (187 ± 9 MeV/c), ^{22}O (203 ± 14 MeV/c) ^{23}O (130 ± 8 MeV/c).

The narrow momentum distribution of the valence neutron in ^{23}O reflects a clear shell structure in accordance to the observation in ref.[4]. From the shape of the measured longitudinal momentum distribution the orbital angular momentum of the removed nucleon can be determined and from the removal cross section the spectroscopic factors. These powerful spectroscopic tools were extended by γ-ray detection to identify the final states of the core fragments after the removal reaction. The gamma detector consisted of an array of 32 NaI units located 80 cm behind of the breakup target (total efficiency (ϵ)= 3 % and energy resolution (ΔE/E)= 12% for E_γ=429 keV).

The method is illustrated by a test measurement of ^{8}B, performed in the beginning of this experimental campaign. In this part, the ^{8}B beam was produced by fragmentation of a primary beam of ^{12}C at 1 GeV/nucleon. The nuclear structure of ^{8}B was studied via one-proton removal reaction in lead and carbon breakup targets and the measured momentum distributions were recorded in coincidence with γ-ray spectroscopy. The corresponding one-proton removal cross section are: σ_{-1p}(C) = (94 ± 9) mb and σ_{-1p}(Pb) = (662 ± 60) mb both in excellent agreement with our earlier measurements [5].
The contributions from the ground and excited state to the ^{7}Be momentum distribution after the p-removal in the carbon target are shown in fig.2. It is clearly seen that the ground-state transition dominates the measured momentum distribution.

The data analysis for the oxygen isotopes is still in progress, however, the preliminary results show that we can extract the above mentioned spectroscopic information. In future, we will extend the measurements to heavier elements and will also use a hydrogen breakup target in combination with an improved γ-setup.

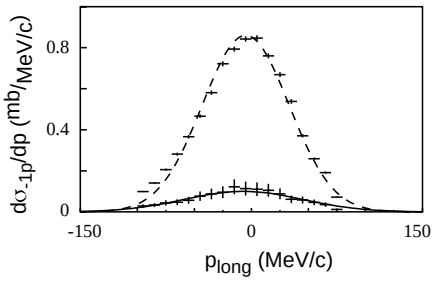

Figure 2: The measured momentum distribution of ^{7}Be. The separate contributions for the transition in the ground-state (dashed line) and first excited state (full line) after the p-removal in the lead target are shown.

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