Coulomb Breakup of the One-Neutron Halo Nucleus ^{11}Be

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One-neutron-removal reactions have been proven to be very useful to study the reaction mechanism and the structure of exotic nuclei. In the present work, the electromagnetic and nuclear contributions to the breakup of ^{11}Be have been investigated with a secondary beam of ^{11}Be (520 MeV/u) on lead and carbon targets.

The secondary beam of ^{11}Be ions was produced by fragmentation of a primary ^{40}Ar beam delivered by the synchrotron SIS at GSI and was separated by the Fragment Separator (FRS). The projectiles were identified uniquely by means of energy loss and time of flight measurements. Behind the target, the fragments were deflected by a large-gap dipole magnet (ALADIN). By using energy-loss and time-of-flight measurements as well as position measurements before and after the dipole magnet, the charge, velocity, scattering angle and the mass of the fragments were determined. Neutrons and γ-rays were detected by the LAND and the 4π- Crystal Ball spectrometer, respectively. The γ-spectra show that the 0^+, 2^+, 1^- and 2^- levels of ^{10}Be were populated in one-neutron-removal reactions, both with the carbon target and with the lead target (see Fig. 1). The detector response functions corresponding to the individual γ-rays were generated with the Monte Carlo code GEANT in a simulation procedure that took into account the Doppler shift. The calculated line shapes, together with a smooth background, were fitted to the measured spectra and thus determine the relative population of excited states and ground state of the ^{10}Be core.

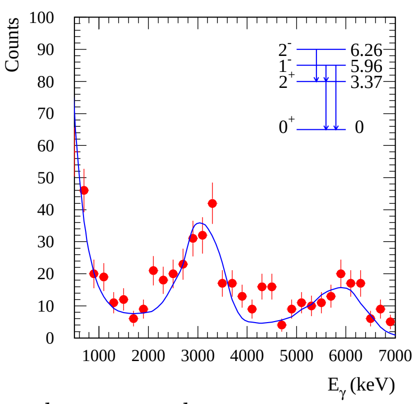

Figure 1: Doppler corrected γ-energy spectrum measured with the Crystal Ball in coincidence with ^{10}Be and one neutron (Pb target). The fitted spectrum is shown by solid line.

The observed γ-spectrum from the ^{10}Be fragment indicates that not only the halo neutron, but also neutrons from the core are removed. For the further analysis, the excitation energy spectrum of ^{11}Be was reconstructed from the measured momenta of the ^{10}Be fragment and the emitted neutron. These spectra were differentiated according to the ground state or the excited states in the ^{10}Be fragment. By comparing these differential cross sections in case of electromagnetic excitation (Pb-target) with the cross sections calculated on the basis of the direct-breakup model, one can deduce information about the ground state structure [1]. The ground state of ^{11}Be with spin $I^\pi = 1/2^+$ can be represented as $|^{11}Be>= \sqrt{S_1}|2s_{1/2}\nu \otimes 0^+ > + \sqrt{S_2}|1d_{5/2}\nu \otimes 2^+ > + ...,$ where S_1 and S_2 represent the spectroscopic factors for the two configurations with neutrons in the $2s_{1/2}$ and $1d_{5/2}$ orbits, respectively.

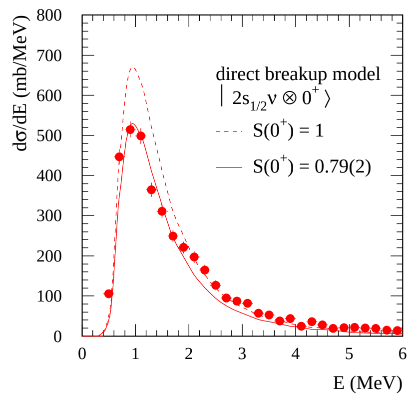

Figure 2: Excitation energy spectrum of ^{11}Be obtained with the Pb target requiring the ^{10}Be fragment to be in its ground state. Calculations within the direct breakup model are also shown.

By subtracting contributions of the excited states as well as nuclear contributions from the measured differential cross section obtained with Pb target, we extract the decay spectrum explicitly for the $2s_{1/2}$ neutron coupled to the ^{10}Be ground state as shown in Fig. 2. By comparing to the direct breakup model we obtain a spectroscopic factor of 0.79(2) for the $2s_{1/2}$ neutron halo configuration, which is consistent with the previous measurements of knockout reactions [2], transfer reactions [3] and with shell model calculations [4].

The excited-state partial cross sections for pure Coulomb and nuclear processes were determined. While in the case of Coulomb dissociation only a few percent of the total breakup cross section is accounted for the ^{10}Be excited state population, about 20% of the nuclear cross section is due to population of the excited states. This is understood due to the strong dependence of the Coulomb breakup cross section on the spatial extension of the neutron wave function.

References

[1] T. Nakamura *et al.* Phys. Lett. B **331** (1994) 296.
[2] T. Aumann *et al.* Phys. Rev. Lett. **84** (2000) 35.
[3] S. Fortier *et al.* Phys. Lett. B 461, (1999) 22.
[4] E. K. Warburton and B. A. Brown, Phys. Rev. C **46** (1992) 923.