Search for η′ mesic nuclei by (p,d) reaction at FRS*

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We report an inclusive measurement of the 12C(p,d) reaction around the η′ emission threshold aiming to search for η′ meson-nucleus bound states (η′ mesic nuclei) [1]. The large mass of the η′ meson is attributed to the U(1) anomaly effect, which contributes to the η′ mass only with spontaneous and/or explicit breaking of chiral symmetry [2, 3]. In a high density medium, due to partial restoration of chiral symmetry, the η′ mass is theoretically expected to be reduced [2]. This leads to an attraction between η′ and a nucleus and to the possible existence of η′ mesic nuclei [4].

In August 2014, we performed a pilot experiment to inclusively measure the missing-mass spectrum of the 12C(p,d) reaction using a 2.5 GeV proton beam accelerated by SIS 18. The proton beam impinged on a carbon target to produce η′ mesic states. The momentum of the ejectile deuteron was analyzed by the FRS to obtain the missing mass of the reaction.

The experimental setup at the FRS is shown in Fig. 1. The proton beam with an intensity of about 10^10/s was incident on a 4 g/cm² thick carbon target. A newly-developed ion optics with a dispersive focal plane at S4 was applied to the FRS so that the momentum of the deuteron can be derived from a measured position at the S4 focal plane. Multi-wire drift chambers (MWDCs) and TPCs were used to measure the particle track, and Cherenkov counters (mini-HIRAC, SC2V, SC41, SC42) were used for time-of-flight (TOF) measurements. Cherenkov counters (mini-HIRAC, HIRAC, TORCH) were installed to tune a DAQ trigger.

At the S4 focal plane, protons are observed as background with a rate of about 2 × 10^7/s, while the rate of the deuterons is about 1 × 10^4/s. The deuterons are identified by the TOF between S2 and S4, since the velocities of the deuterons (β_d ~ 0.84) are different from those of the protons (β_p ~ 0.95). At the trigger level, about 99.5% of the protons are rejected by a DAQ trigger which requires coincidence of the scintillator signals at S2 and at S4 with a time difference corresponding to the deuterons. The remaining 0.5% is due to two or more than two accidental protons which can trigger the DAQ. In the offline analysis, almost all the multi-proton events are removed by selecting single pulses in the scintillator signals recorded by a waveform digitizer.

For the calibration of the spectrometer, the d(p,d)p elastic scattering was measured using a 1.6 GeV proton beam and a CD_2 target. Figure 2 shows the position and the angle measured by the MWDCs overlaid for five scaling factors for the FRS magnetic fields. Ion-optical parameters (focus, dispersion, and higher-order aberrations) are determined by these measurements. Moreover, from the widths of the elastic peaks, the missing-mass resolution in the production measurement is evaluated to be about 2 MeV/c^2 (σ), which is sufficiently smaller than the expected natural width of the η′ mesic nuclei.

The experiment was performed in the framework of the Super-FRS collaboration for FAIR.

References