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

Y. K. Tanaka[1] *and the η-PRiME collaboration*

[1]The University of Tokyo, Tokyo, Japan

We report an inclusive measurement of the ^{12}C(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 $U_A(1)$ 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 ^{12}C(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/cm^2 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 scintillation counters (SC2H, SC2V, SC41, SC42) were used for time-of-flight (TOF) measurements. Cherenkov counters (mini-HIRAC, HIRAC, TORCH) were installed to tune a DAQ trigger.

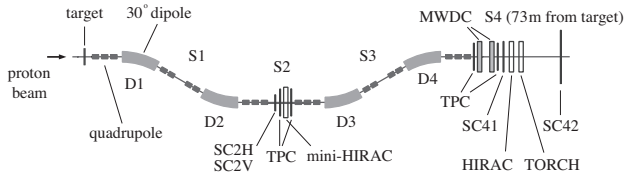

Figure 1: A schematic view of the experimental setup at the FRS.

At the S4 focal plane, protons are observed as background with a rate of about 2×10^5/s, while the rate of the deuterons is about 1×10^3/s. The deuterons are identified by the TOF between S2 and S4, since the velocities of the deuterons ($\beta_d \sim 0.84$) are different from those of the protons ($\beta_p \sim 0.95$). 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.

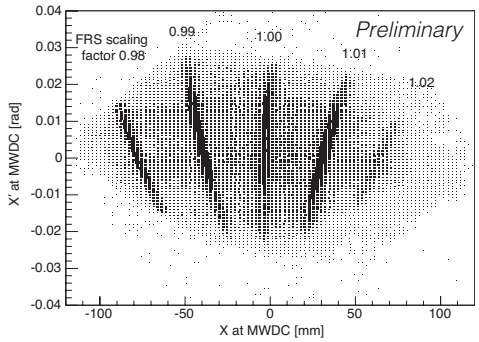

Figure 2: The horizontal position and angle measured by the MWDCs in the calibration. The figure is overlaid for five scaling factors of the FRS magnetic fields.

The measurement of the ^{12}C(p,d) reaction was performed for about 75 hours. The region of the excitation energy from -90 MeV to +40 MeV from the η' production threshold was investigated by scaling the FRS magnetic fields from 0.98 to 1.02. High statistical sensitivity was achieved by accumulating about (5-10)$\times10^6$ deuterons for each FRS setting. The analysis of the missing-mass spectra is presently ongoing.

For FAIR, we plan a semi-exclusive measurement of the (p,dp) reaction by tagging protons emitted in the decay of the η' mesic nuclei. An inclusive measurement of the (p,d) reaction with better statistics is planned as well.

References

[1] K. Itahashi *et al.*, Prog. Theor. Phys. **128**, 601 (2012).

[2] D. Jido *et al.*, Phys. Rev. C **85**, 032201(R) (2012).

[3] S. H. Lee and T. Hatsuda, Phys. Rev. D **54**, 1871 (1996).

[4] H. Nagahiro *et al.*, Phys. Rev. C **87**, 045201 (2013).

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

DOI:10.15120/GR-2015-1-MU-HADRONS-14