Results of the K^-pp bound-state search in J-PARC E15[1st]

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The interaction between a nucleon and an anti-kaon ($\bar{K}$), the lightest hadron with a strange quark, is one of the keys to understanding meson-baryon interactions in low energy quantum chromodynamics (QCD) incorporating three flavors in the nuclear system. Precise measurements of elementary $\bar{K}N$ interactions and investigations of $\bar{K}$-nuclear bound systems ($\bar{K}$ nuclei) are currently hot topics. The K^-pp state, a bound system of a negative kaon and two protons, is theoretically considered the simplest $\bar{K}$ nucleus,[1)] and thus it has attracted special interest. We are searching for the K^-pp bound state by using an in-flight reaction as the J-PARC E15 experiment.[2)] The first physics data acquisition (E15^{1st}) was performed in May 2013, with 5×10^9 kaons at 1 GeV/c on a liquid ^{3}He target.

Figure 1 shows the obtained semi-inclusive neutron spectrum at $\theta_n^{lab} = 0°$.[3)] Here, we detected the neutron by using a plastic scintillator array $\sim$ 15 m away from the target. To reconstruct the reaction vertex for the time-of-flight measurement, at least one charged track is required in a cylindrical detector system (CDS) surrounding the target. The K^0-tagged spectrum, shown in the inset of Fig. 1, is attributed to the charge-exchange $K^-p \to K_s^0 n$ reaction, and demonstrates that the detector resolution and the missing-mass scale are well understood.

The observed yield in the deeply bound region, corresponding to K^-pp binding energies larger than 80 MeV, was in good agreement with the evaluated backgrounds originating from 1) accidental hits and neutral particles other than neutrons, 2) reactions on the target cell, and 3) neutrons produced via charged Σ decay. In this mass region, upper limits on the production cross section of a bound state were evaluated, assuming a $K^-pp \to \Lambda p$ isotropic decay. They were determined to be 30-270 μb/sr, depending on the mass and the decay width. The upper limits obtained are much smaller than the theoretical calculation.[4)] The ratios of the upper limits to cross sections of the quasi-elastic channels are (0.5–5)% (quasi-elastic) and (0.3–3)% (charge exchange). These ratios are rather small compared to the sticking probability of the usual hypernucleus formation. On the other hand, a significant excess was observed around the K^-pp binding threshold. However, in spite of the observed large yield corresponding to $\sim$ 1 mb/sr, structures suggested in theoretical spectral functions[4,5)] cannot be identified from only the semi-inclusive measurement.

We also analyzed the Λp events detected using the CDS to investigate the K^-pp decay. A Λ was reconstructed from a $\pi^- p$ pair detected using the CDS to be almost free from the background. Missing-neutron events were identified by the ^{3}He$(K^-, \Lambda p)X$ missing mass, with $\sim$ 20% $\Sigma^0 p$-event contamination ($\Sigma^0 \to \Lambda\gamma$). The preliminary Λp invariant-mass spectrum, obtained with $\sim$ 10 MeV/c^2 resolution, consists of a flat component widely distributed in the three-body phase space and an enhancement around the threshold. The threshold structure mainly originates from events with a low-momentum transfer, and it might be evidence for the K^-pp bound state.

In 2015, we plan to conduct the 2nd-stage physics run with 10 times the number of beam-kaons in the 1st stage, as well as calibration runs with hydrogen and deuteron targets. With the new data set, we will further investigate the structure around the K^-pp binding threshold.

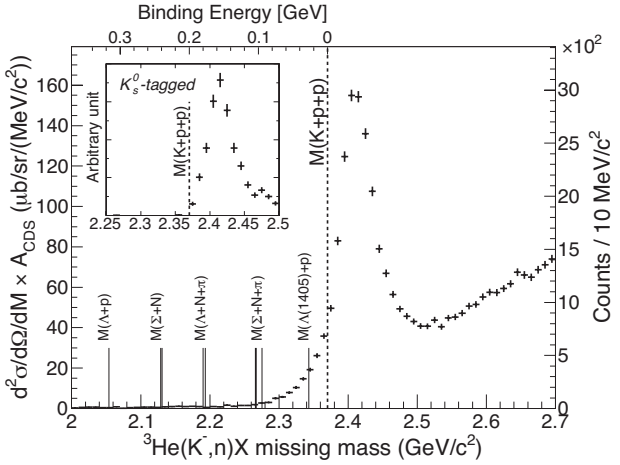

Fig. 1. ^{3}He$(K^-, n)X$ semi-inclusive missing-mass distribution at $\theta_n^{lab} = 0°$[3)]. A_{CDS} denotes the charged-tagging acceptance of the CDS. The inset shows the K_s^0-tagged spectrum.

References

1) T. Yamazaki and Y. Akaishi: Phys. Lett. B **535** (2002) 70.
2) M. Iwasaki et al.: J-PARC proposal P15, "A search for deeply-bound kaonic nuclear states by in-flight ^{3}He(K^-, n) reaction" (2005).
3) T. Hashimoto et al.: arXiv:1408.5637 (2014).
4) T. Koike and T. Harada: Phys. Rev. C **80** (2009) 055208.
5) J. Yamagata-Sekihara, D. Jido, H. Nagahiro, and S. Hirenzaki: Phys. Rev. C **80** (2009) 045204.

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