Search for a K^-pp Bound State by Using the $\pi^+ + d \to K^+ + X$ Reaction

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The strange dibaryons (strangeness $S = -1$ and baryon number $B = 2$) such as $\bar{K}NN$ system, in which a bound state of K^-pp is expected, are experimentally not well revealed yet. We have searched for a K^-pp bound state by using the $\pi^+ + d \to K^+ + X$ reaction at pion incident momentum of 1.69 GeV/c in the laboratory angles between 2° and 16°.

The present experiment, J-PARC E27, has been carried out at the K1.8 beam line of the hadron experimental hall at J-PARC. The K1.8 beam line and the SKS spectrometer have been used with a good momentum resolution of $\Delta p/p \sim 10^{-3}$ to measure π^+ and K^+ momenta. Since the SKS has a wide acceptance (about 100 msr) and good momentum resolution, we could measure the missing mass spectrum with the good energy resolution of 3 MeV (FWHM) and wide missing-mass region from the production of a quasi-free Λ to a quasi-free hyperon resonances, $\Lambda(1405)$ and $\Sigma(1385)$. The elementary process of $\pi^+ + [p|n] \to K^+X$ reaction has already been measured by using the hydrogen bubble chamber. Thus, we can explore exotic states in the wide energy range.

In this reaction $\Lambda(1405)$ hyperon resonance, which is considered as the bound state of $\bar{K}N$ system, is expected to be produced as a doorway to form the K^-pp bound state through the $\Lambda(1405) + p \to K^-pp$ process. However, most of the produced $\Lambda(1405)$'s would escape from deuterons without secondary reactions. Therefore, coincidence of high-momentum ($> 250\ \mathrm{MeV}/c$) proton(s) in large emission angles ($39° < \theta_{\mathrm{lab}} < 122°$) was required to enhance the signal-to-noise ratio.

We have measured the inclusive missing-mass spectra at this momentum in high statistics and high energy resolution for the first time [1]. The overall structure was understood with a simple quasi-free picture based on the known elementary processes. However, we have observed two distinct deviations from this picture. One is the ΣN cusp, of which mass was found to be $2130.5 \pm 0.4(\mathrm{stat.}) \pm 0.9(\mathrm{syst.})\ \mathrm{MeV}/c^2$ with the decay width of $\Gamma = 5.3^{+1.4}_{-1.2}(\mathrm{stat.})^{+0.6}_{-0.3}(\mathrm{syst.})$ MeV. The peak position is consistent within the error of the previous measurements. Since this result is the first measurement of the ΣN cusp structure in the inclusive spectrum of the $\pi^+ + d \to K^+ + X$ reaction, further detailed theoretical studies including the present data would reveal the information on the ΣN-ΛN coupling strength and the pole position. The other notable feature is that the centroid of the broad bump structure in the region of hyperon resonance production was significantly shifted to the low-mass side as compared with a simple quasi-free simulation. The observed "shift" values are $32.4 \pm 0.5(\mathrm{stat.})^{+2.9}_{-1.7}(\mathrm{syst.})$ $(22.4 \pm 0.4(\mathrm{stat.})^{+2.7}_{-1.7}(\mathrm{syst.}))\mathrm{MeV}/c^2$, which are the calculated missing mass in the kinematics of a deuteron (proton) at rest as a target. In order to clarify the origin of the peak "shift", further theoretical and experimental studies to measure the invariant mass spectra of the decay particle are necessary.

We have measured a mass distribution of a "K^-pp"-like structure as Fig. 1 in the $\pi^+ + d \to K^+ +$ "K^-pp", "K^-pp"$\to \Sigma^0 + p$ mode in the scattering angles between 2° and 14° for the first time [2]. Here, the final state of $\Sigma^0 p$ was identified using the missing–mass square M_X^2 distribution of $\pi^+ + d \to K^+pp + X$ reaction by measuring the two protons in the Range Counter Array (RCA). A broad enhancement has been observed in the missing mass spectrum around 2.27 GeV/c^2. By fitting with the relativistic Breit-Wigner function, the mass and decay width of "K^-pp"-like structure have been evaluated to be $2275\,^{+17}_{-18}(\mathrm{stat.})\,^{+21}_{-30}(\mathrm{syst.})\ \mathrm{MeV}/c^2$ and $\Gamma = 162\,^{+87}_{-45}(\mathrm{stat.})\,^{+66}_{-78}(\mathrm{syst.})$ MeV, respectively. These obtained mass and width are not inconsistent with the values of the past experiments (FINUDA [3] and DISTO [4] experiments) within the errors, although our statistical and systematic errors are large. If the observed structure originates from the K^-pp bound state, its binding energy is $95^{+18}_{-17}(\mathrm{stat.})^{+30}_{-21}(\mathrm{syst.})$ MeV. Such a large binding energy together with a large width is difficult to reproduce in the present theoretical models. Thus, the observed enhancement might not be the simple K^-pp bound state but the other probabilities such as a $\pi\Lambda N$-$\pi\Sigma N$ dibaryon [5] and a lower pole of the K^-pp [6].

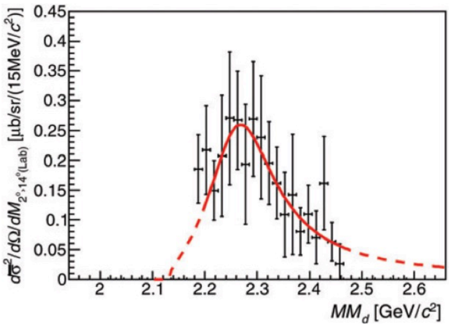

Fig. 1 Missing mass spectrum of the $\pi^+ + d \to K^+ + X$ reaction for two-proton coincidence and the $\Sigma^0 p$ decay branch events [2].

References

[1] Y. Ichikawa *et al.*, Prog. Theor. Exp. Phys. **2014**, 101D03 (2014).

[2] Y. Ichikawa *et al.*, Prog. Theor. Exp. Phys. **2015**, 021D01 (2015).

[3] M. Agnelo *et al.*, Phys. Rev. Lett. **94**, 212305 (2005).

[4] T. Yamazaki *et al.*, Phys. Rev. Lett. **104**, 132502 (2010).

[5] H. Garcilazo and A. Gal, Nucl. Phys. A **897**, 167 (2013).

[6] A. Dote *et al.*, Prog. Theor. Exp. Phys. **2015**, 043D02 (2015).