Strange dibaryon system produced in the d(π^+, K^+) reaction at J-PARC

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The strange dibaryon systems ($S = -1$, $B = 2$) beyond the octet baryon pair (ΛN, ΣN) are experimentally not well explored, yet. A recently interested system of $\bar{K}NN$ is such an example. In this system, a bound state of K^-pp is expected to exist theoretically, while it may be a broad resonance. On the other hand, the experimental status is still not conclusive although some experimental evidences are reported.

In order to investigate whether the strange dibaryon system such as a K^-pp, we carried out the J-PARC E27 experiment by using the $d(\pi^+, K^+)$ reaction at the pion incident momentum of 1.69 GeV/c. The present experiment was performed at the K1.8 beam line of the hadron experimental hall at J-PARC. In this experiment, the K1.8 beam line spectrometer and the SKS spectrometer were used with a good momentum resolution of $\Delta p/p \sim 10^{-3}$ to measure π^+ and K^+ momenta. Since the SKS had a good momentum resolution and wide acceptance about 100 msr, we could measure the missing mass spectrum of $d(\pi^+, K^+)$ reaction with the good energy resolution of about 3 MeV (FWHM) and wide missing-mass region from quasi-free Λ production region (2.05 GeV/c^2) to quasi-free $\Lambda(1405)$, $\Sigma(1385)$ excited hyperon resonances production region (2.5 GeV/c^2). Here, the elementary processes of the $\pi^+ + p/n$ reactions are rather well known at this energy, so that we can fully explore exotic states in the wide energy range.

In this reaction, the K^-pp is expected to be formed through the $\Lambda(1405)$ production as a doorway [1]. However, most of the produced $\Lambda(1405)$'s would escape from deuterons without secondary reactions. Therefore, coincidence of high-momentum (> 250 MeV/c) proton(s) in large emission angles ($39^\circ < \theta_{lab.} < 122^\circ$) is requested to enhance the signal-to-background ratio.

We obtained the inclusive missing-mass spectrum at the laboratory scattering angle between 2° and 16° in high statistics and high energy resolution for the first time. The overall structure was understood with a simple quasi-free picture based on the known elementary processes. However, there were two peculiar deviations from this picture. One observation is the ΣN cusp, of which mass was found to be 2130.5 ± 0.4 (stat.) $\pm$ 0.9 (syst.) MeV/c^2 with the width of $\Gamma = 5.3\ ^{+1.4}_{-1.2}$ (stat.) $^{+0.6}_{-0.3}$ (syst.) MeV. The peak position is consistent with previous measurements. Further detailed studies including the present data would reveal the information on the ΣN-ΛN coupling strength and the pole position. Another observation is that the centroid of the broad bump structure in the Y^* production region was significantly shifted to low mass side as compared with a simple quasi-free simulation. The obtained "shift" values are

32.4 ± 0.5 (stat.) $^{+2.9}_{-1.7}$ (syst.) (22.4 ± 0.4 (stat.) $^{+2.7}_{-1.7}$ (syst.)) MeV/c^2 , which are calculated the missing mass in the kimematics of a dueteron (proton) at rest as a target. In order to clarify the origin of the peak "shift", further experimental and theoretical studies are necessary.

We have measured the missing-mass distributions of $d^2\bar{\sigma}/d\Omega/dM$ in the $\pi^+ d \rightarrow K^+ W,\ W \rightarrow \Sigma^0(\Lambda)p$ reactions in the scattering angle between 2° and 14° for the first time. Here, the final states of $\Sigma^0 p$ and Λp were identified using the missing-mass squared M_X^2 distribution of $d(\pi^+, K^+ pp)X$ reaction by measuring the two protons in the Range Counter Array (RCA). A broad enhancement have been observed in the missing-mass distribution of the $\Sigma^0 p$ mode around 2.27 GeV/c^2 corresponding to the "$K^- pp$"-like structure. The mass and width of the "$K^- pp$"-like structure were evaluated to be 2275 $^{+17}_{-18}$ (stat.) $^{+21}_{-30}$ (syst.) MeV/c^2 and 162 $^{+87}_{-45}$ (stat.) $^{+66}_{-78}$ (syst.) MeV, respectively, by fitting with the relativistic Breit Wigner function. These obtained mass and width are not inconsistent with the values evaluated from the past experiments (FINUDA and DISTO experiments) within the errors, although our statistical and systematic errors are large. If the observed structure originates from the $K^- pp$ bound state, the binding energy of the $K^- pp$ system corresponds to be 95 $^{+18}_{-17}$ (stat.) $^{+30}_{-21}$ (syst.) MeV. Such a large binding energy together with a large width is difficult to reproduce in the present theoretical models. The other possibilities like a dibaryon as $\pi\Lambda N$–$\pi\Sigma N$ bound states [2], a $\Lambda^* N$ bound states [3], and a lower $\pi\Sigma N$ pole of the $K^- pp$ might be considered as alternatives [4]. In this view, the isospin of the "$K^- pp$"-like structure should be 1/2 not 3/2, while a dibaryon as $\pi\Lambda N$–$\pi\Sigma N$ bound state is expected to be isospin $I = 3/2$. Furthermore, we have measured the branching fraction between the Λp and $\Sigma^0 p$ decay modes of the "$K^- pp$"-like structure to be $\Gamma_{\Lambda p}/\Gamma_{\Sigma^0 p} = 0.92$ $^{+0.16}_{-0.14}$ (stat.) $^{+0.60}_{-0.42}$ (syst.). The obtained branching fraction is not in-consistent with the theoretically predicted value of $\Gamma_{\Lambda p}/\Gamma_{\Sigma^0 p} \sim 1.2$ [5] using the chiral unitary approach within the error, although our error is large. In order to reduce these errors, further experiments with higher statistic and larger acceptance detector system is important.

References

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