Study of $\bar{K}NN$ bound state via $^{3}\mathrm{He}\,(K^{-},\Lambda p)\,n$ reaction at J-PARC

T. Yamaga, for the J-PARC E15 collaboration
RIKEN, Wako, Saitama 351-0198, Japan

A bound system of a nucleus and an anti-kaon($\bar{K}$), so-called kaonic nucleus, has been studied for long time to establish a possibility that a meson could be a component of a nucleus. Theoretically, the existence of kaonic nucleus system is strongly supported, however, the binding energy and width has not been uniquely predicted yet due to lack of understanding of $\bar{K}N$ interaction below the $\bar{K}N$ mass threshold. In order to investigate the property of the kaonic nucleus, many experiments have been performed with varied reactions. Some of the m found a resonant state which might be a kaonic nucleus, but its binding energy and width are not consistent with theoretical predictions. Furthermore, some experiments reported no evidence of the kaonic nucleus, even though the production reaction is the same as the experiment reporting the resonant state. Therefore, studying for kaonic nucleus system is still not concluded yet even for the simplest system, the $\bar{K}NN$ bound state.

We performed an experiment to study the $\bar{K}NN$ bound state via in-flight (K^{-},n) reaction on ^{3}He target at the J-PARC hadron experimental facility (J-PARC E15 experiment [1]). In this reaction, the neutron inside the ^{3}He target is kicked out in forward direction, taking the momentum of the incident kaon, then, the kaon "stands around" with two residual protons with low momentum transfer of about 200 MeV/c. Consequently, the $\bar{K}NN$ bound state is expected to be formed with relatively large cross section compared to other experiments owing to high sticking probability of low momentum kaon. Furthermore, the kinematics of the in-flight reaction and exclusive decay analysis help to reduce the background such as other nucleon or hyperon resonance production reactions, and one- or two-nucleon absorption processes. The produced state is reconstructed by invariant-mass of expected decay mode of $\bar{K}NN$ bound state, Λp mode, by using a cylindrical detector system (CDS) surrounding the ^{3}He target. The kicked out neutron is not directly detected but kinematically identified by using missing-mass technique.

In the analysis, three charged tracks from two protons and one π^{-} are required in the CDS. Then, invariant-mass of two $p\pi^{-}$ pairs, and distances of closest approach (DCA) of each tracks are used to identify Λ-production. After reconstructing Λ, Λpn final state is identified by using log-likelihood method which contains DCA informations and result of kinematical fitting based on "*KinFitter*"[2].

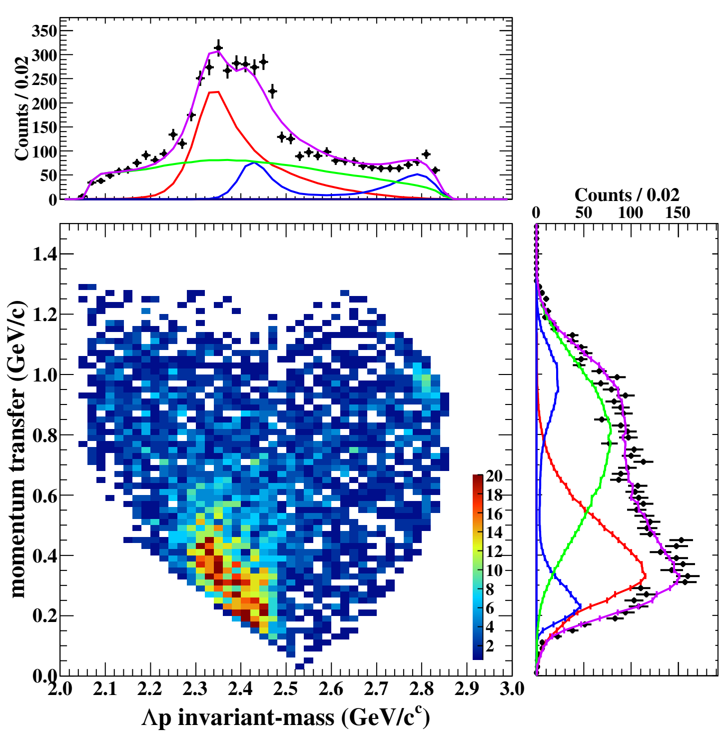

Figure 1: 2D plot of invariant-mass of Λp versus momentum transfer. Black points and solid lines show experimental data and fitting result consists of $\bar{K}NN$ bound state (red), quasi-elastic process (blue), continuum background (green), and their total (purple).

Figure 1 shows observed Λp invariant-mass versus momentum transfer ($q = |\vec{p}_{K^-} - \vec{p_n}|$) distribution of selected Λpn final state. A peak structure can be seen around K^-pp mass-threshold ($M_{K^-pp} = 2.37$ GeV/c^2). We tried to reproduce the observed distribution by following three components.

1. $\bar{K}NN$ bound state: This component comes from $\bar{K}NN$ bound state production. It has Breit-Wigner shape on Λp invariant-mass, and S-wave form factor on momentum transfer.
2. Kinematical structure: This component is made by two step reaction that quasi-elastic kaon scattering with one of nucleon in ^{3}He, followed by kaon absorption by residual one or two nucleon. We assume Gaussian peak structure whose peak position depends on momentum transfer.
3. Broad background All of reaction except above two reactions are included in this component. We used Breit-Wigner shape with large Γ to reproduce this broad background.

The fitting result is also shown in Fig.1 by colored solid lines. Both of Λp invariant-mass and momentum transfer distributions are well reproduced by these three components. We found that observed $\bar{K}NN$ bound state has the binding energy of $47 \pm 3(\text{stat.})^{+3}_{-6}(\text{syst.})$ MeV, and the decay width of $115 \pm 7(\text{stat.})^{+10}_{-20}(\text{syst.})$ MeV [3].

References

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