Search for $\bar{K}NN$ bound state at J-PARC

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The possible existence of strongly bound $\bar{K}$ nuclear states has been widely discussed as a consequence of the strongly attractive $\bar{K}N$ interaction in the $I = 0$ channels.[1)] The investigation of those exotic states will provide unique information of the $\bar{K}N$ interaction below the threshold, which is still not fully understood. Among the $\bar{K}$ nuclear-states, the simplest $\bar{K}$-nuclear cluster $\bar{K}NN$, is of special interest because it is the lightest $S = -1$ $\bar{K}$ nucleus. Many theoretical calculations based on the $\bar{K}NN - \pi\Sigma N - \pi\Lambda N$ coupled channels have predicted the existence of the bound state.[2)] However, the calculated properties of the bound state, such as the binding energy (B.E.) and decay width (Γ), strongly depend on $\bar{K}N$ interaction models.

Experimentally, there are several reports on the observation of peak structure with a B.E. of $\sim$ 100 MeV.[3–5)] In contrast, null results were also reported by several experiments,[6,7)] and therefore the existence of the $\bar{K}NN$ bound state has remained controversial. The J-PARC E15 experiment was performed at the K1.8BR beam line using the $K^-+\,^3$He reaction at p_{K^-} = 1.0 GeV/c.[8)] The first physics run of the E15 experiment was conducted in May 2013 with 5.3×10^9 kaons incident on ^{3}He. The results of a semi-inclusive $^3\mathrm{He}(K^-, n)X$ measurement can be found in Ref[9)]. To measure an expected decay mode of $\bar{K}NN \to \Lambda p$, an exclusive $^3\mathrm{He}(K^-, \Lambda p)n$ measurement was also performed by identifying two protons and one negative pion in a cylindrical detector system (CDS) surrounding a liquid ^{3}He target system.[10)] The $p\pi^-$ pair associated with a specific Λ decay in the $pp\pi^-$ event was reconstructed with a log-likelihood method, and a missing neutron was identified kinematically.

The distribution of the Λp invariant mass and the neutron emission angle of the obtained Λpn final state are shown in Fig. 1 (b) and (c), respectively, and a scatter plot of the two is given in Fig. 1 (a). A bump structure is observed at the mass threshold of $K^- + p + p$ in the Λp invariant mass spectrum, which is not reproduced by a global fit based on multi-nucleon absorption processes of K^-. To explain the excess, a simple S-wave Breit-Wigner structure over the three-body phase space of the $K^-\,^3\mathrm{He} \to \Lambda pn$ reaction is assumed. A χ^2 test was performed between the experimental data and the simulated pole together with the multi-nucleon absorption processes, and the minimum χ^2 point was obtained with $M_X = 2355^{+6}_{-8}(stat.) \pm 12(syst.)$ MeV/c^2, $\Gamma_X = 110^{+19}_{-17}(stat.) \pm 27(syst.)$ MeV/c^2.

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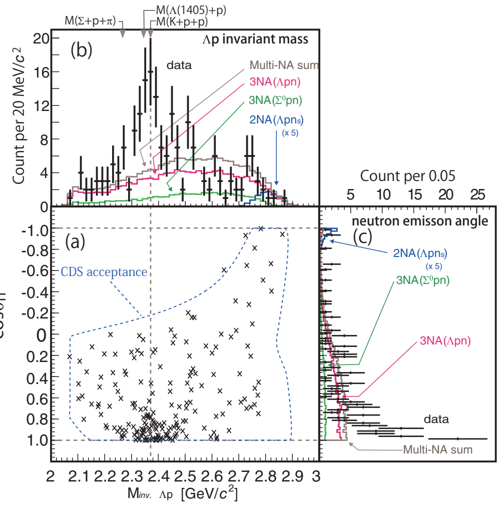

Fig. 1. (a) Distribution of the Λ invariant mass and the emission angle of the missing neutron, (b) Λ invariant mass with simulated spectra obtained by the global fit, and (c) angular distribution of the missing neutron.[10)]

A naive interpretation of the structure would be the $\bar{K}NN$ bound state, since the pole position is located below the mass threshold of K^-+p+p (2370 MeV/c^2). It could also be a shallow bound or unbound resonance of the $\Lambda(1405)p$ system followed by Λp conversion, the threshold of which is located at 2343 MeV/c^2 if the mass of $\Lambda(1405)$ is assumed to be 1405 MeV/c^2. To explore whether or not the observed structure is the $\bar{K}NN$ bound state in more detail, the second run was carried out in 2015 with the accumulation of 30 times more data on the Λpn final state and the analysis is in progress.

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