Studies of kaon bound states with FINUDA

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Abstract

By using the FINUDA spectrometer, we are investigating the kaon bound states both in missing-mass spectroscopy and invariant-mass spectroscopy in the stopped K^- absorption reactions. The

large acceptance and good momentum resolution of the spectrometer enabled us to conduct such studies at the same time. Evidence for a K^-pp bound state is reported.

Key words: kaon absorption in nuclei, deeply bound kaonic nuclei, FINUDA experiment
PACS: 21.30.Fe, 21.45.-v, 21.85.+d, 25.80.Nv

1. Introduction

Recently, a kaonic nucleus, a strongly bound state of an antikaon inside a nucleus, is one of hot topics in strangeness nuclear physics. The recent intensive discussions have been triggered by Akaishi and Yamazaki's prediction on the existence of light kaonic nuclei with a phenomenological potential, such as K^-pp, K^-ppn and K^-ppnn [1,2]. Their potential was derived by using $\overline{K}N$ scattering length, and the shift of the ground state of a kaonic hydrogen. They regarded $\Lambda(1405)$ as an $I = 0$ $\overline{K}N$ bound state.

2. FINUDA experiment

The main aim of the FINUDA experiment is to study hypernuclear physics with stopped K^- reaction. Kaons are supplied as the decay products of $\phi(1020)$ mesons, which are produced in the center of the spectrometer by the electron-positron collider DAΦNE. Since the kaons are very slow ($\sim 127\,\mathrm{MeV}/c$), it can be stopped in a thin target (0.2–$0.3\,\mathrm{g/cm^2}$). In the first data taking in 2003–2004, we put five kinds of targets (^{6}Li, ^{7}Li, ^{12}C, ^{27}Al and ^{51}V) around the beam pipe.

3. Missing-mass spectroscopy and invariant-mass spectroscopy

Thanks to good momentum resolution (for charged particles) and large acceptance of the FINUDA spectrometer, we can explore the formation and/or decay of some kaon bound states by detecting multiple particles emitted from a stopped K^- vertex. The missing-mass spectroscopy can be done by detecting nuclear Auger protons/neutrons with the (K^-_{stop}, p/n) reactions. By tagging the decay particles, we can reduce backgrounds. On the other hand, when all the decay particles from a kaonic nucleus are detected, we can apply the invariant-mass spectroscopy for them. Both of the techniques are discussed in the next section.

As shown in Fig. 1 [3], we observed a peak structure around $500\,\mathrm{MeV}/c$ in the proton spectrum for the ^{6}Li target, but not for the ^{12}C target. The peak was seen even in the inclusive spectrum, and it was prominent in coincidence with back-to-back π^-'s in high momentum, which are considered to come from Σ^- decay. Due to strong angular correlation between the proton and the pion, we concluded that the peak was due to kaon absorption by a quasi-deuteron inside a ^{6}Li nucleus almost at rest ($K^- + d \to p + \Sigma^-$). Light kaon bound states with a few nucleons may be produced with stopped K^- absorption. For example, in the following decay modes ($K^-pp \to \Lambda + p$, $K^-pp \to \Lambda + n$, $\Sigma^- + p$,

[1] deceased

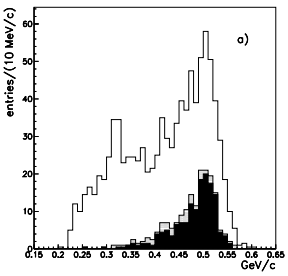

Fig. 1. Proton momentum spectrum in coincidence with a π^- for ^{6}Li target. The shaded spectrum corresponds to the coincidence with high momentum π^- ($> 275\,\mathrm{MeV}/c$). The black spectrum the result for back-to-back event selection ($\cos\theta(p\pi^-) < -0.8$).

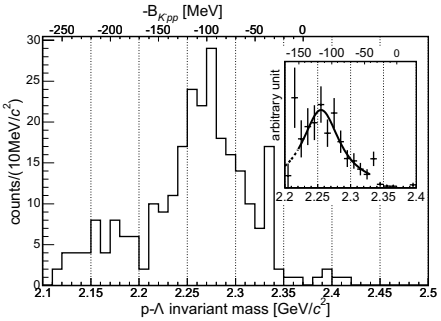

Fig. 2. Invariant mass spectra of back-to-back $\Lambda - p$ pairs for the ^{6}Li, ^{7}Li and ^{12}C targets. The inset shows the result after the acceptance correction.

$K^-ppn \to \Lambda + d$), rather high-momentum hyperon and nucleon (or deuteron) emitted in back-to-back kinematics could be good signatures to detect them. In fact, we observed strong back-to-back correlations in each decay mode. For back-to-back Λ and proton pairs from the ^{6}Li, ^{7}Li and ^{12}C targets, significant mass decrease from the threshold ($m_{K^-} + 2m_p = 2.370\,\mathrm{GeV}/c^2$) was seen in the invariant mass spectrum. If we interpret the Λ and the proton are coming from the decay of lightest kaonic nuclei K^-pp, we obtain the binding energy (B) and the decay width (Γ) by fitting the spectrum with a Lorentzian function, as $B = 115^{+6}_{-5}(\mathrm{stat})^{+3}_{-4}(\mathrm{stat})\,\mathrm{MeV}$ and $\Gamma = 67^{+14}_{-11}(\mathrm{stat})^{+2}_{-3}(\mathrm{syst})\,\mathrm{MeV}$, respectively [6]. Similarly, the Λ and deuteron pairs are observed in back-to-back correlation. Their invariant mass distribution shows a bump below the K^-ppn threshold [7].

4. Summary and Perspective

We exploit both missing-mass and invariant-mass spectroscopy in searching for kaon bound state in the FINUDA experiment. The possible existence of the lightest K^-pp bound state is indicated in the $\Lambda - p$ invariant-mass spectrum.

The second data taking finished in June 2007, with much higher beam luminosity. As well as the $\Lambda + p$ mode, the modes with neutrons ($\Lambda + n$ and $\Sigma^- + p$) will be able to be analyzed in detail. The comparison of these modes will be important in discussing the isospin dependence, because the $\overline{K}N$ interaction has a strong isospin dependence.

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