Search for $^{6}_{\Lambda}$H hypernucleus by the (π^-, K$^+$) reaction at p_{π^-}=1.2GeV/c

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The study of neutron-rich hypernuclei is one of the most important topics in the strangeness nuclear physics. The glue-like role of the Λ hyperon is expected to be critical in nuclei beyond the neutron-drip line. The knowledge of the behavior of hyperons in a neutron-excess environment will significantly affect our understanding of neutron stars because the addition of hyperons softens the Equation of State of matter at the core. To study its effects, we selected the $^{6}_{\Lambda}$H hypernucleus which consists of one proton, four neutrons, and one Λ hyperon. Theoretical calculations of binding energy of $^{6}_{\Lambda}$H were performed with several models, and these mass differences were more than 3MeV. Therefore, it is important to measure the Λ binding energy experimentally. On the other hand, theoretical calculation of production cross section cannot be investigated because production mechanisms of neutron-rich hypernuclei are not well known. It would be a key to get information of production mechanism if the cross section is measured precisely.

An experiment was proposed aiming at a precise spectroscopic study of the light neutron-rich Λ hypernucleus $^{6}_{\Lambda}$H via the ^{6}Li(π^-,K$^+$) reaction at the π^- beam momentum of 1.2 GeV/c [1]. The (π^-,K$^+$) reaction is good tool to access the neutron-rich region because two protons are changed to one neutron and one Λ hyperon. However, the production cross section of the (π^-,K$^+$) reaction is considerably small, roughly 10^{-3} of that of the non-charge-exchange (π^+,K$^+$) reaction. Therefore, we planned to use 10^7 pion beams to observe more than 100 events of $^{6}_{\Lambda}$H and to determine the binding energy in a good statistical accuracy. To accept such a high rate beam, the Silicon Strip Detector and Scintillating Fiber Tracker were developed. They have sufficient tolerance to high rate beams up to 10^8 Hz.

The experiment was performed at the K1.8 beam line of the J-PARC Hadron Experimental Facility. The K1.8 beam line spectrometer and the Superconducting Kaon Spectrometer (SKS) were used as shown in Fig.1. We used high intensity pion beams of 1.2-1.4$\times10^7$spill (2s spill). The total number of pion irradiated on a ^{6}Li target was 1.4×10^{12}.

Mass scale was calibrated using $p(\pi^\pm$,K$^+)\Sigma^\pm$ reactions with an accuracy of 1.26 MeV/c^2. Missing-mass resolution was estimated to be 3.2 MeV (FWHM) from the observed energy spectrum of ^{12}C(π^+,K$^+$)$^{12}_{\Lambda}$C reaction.

Figure 2 shows the missing-mass spectrum of the ^{6}Li(π^-,K$^+$) reaction [2]. The vertical axis shows the double differential cross section in the laboratory frame. A magnified view around the Λ bound region is shown in the inset. The arrow labeled as $^{4}_{\Lambda}$H+2n shows the particle decay threshold. No significant peak structure was observed around the shown arrow.

An upper limit was estimated from the number of events around the particle decay threshold. There were 3 events in the threshold region within the missing-mass window. The upper limit of the number of signal events is estimated to be 6.68 events at the 90% confidence level which corresponds to 1.2nb/sr.

The present result suggests either there is no bound or no narrow resonance state in $^{6}_{\Lambda}$H or the production cross section is much less than we expected. Quantitative theoretical calculation of the production cross section which explains the present result is necessary for further studies of the $^{6}_{\Lambda}$H structure.

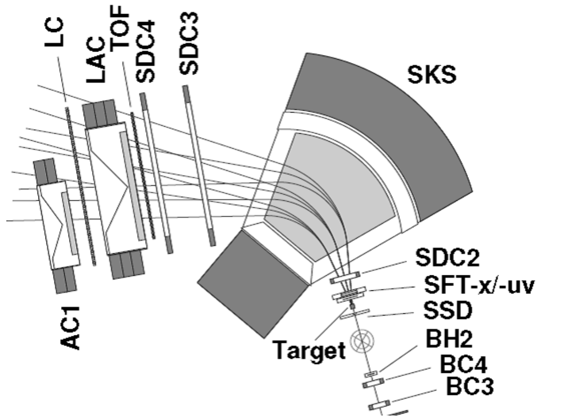

Fig.1 The setup of $^{6}_{\Lambda}$H production experiment. The silicon strip detector (SSD) and Scintillating Fiber Tracker are located upstream and downstream of the target, respectively.

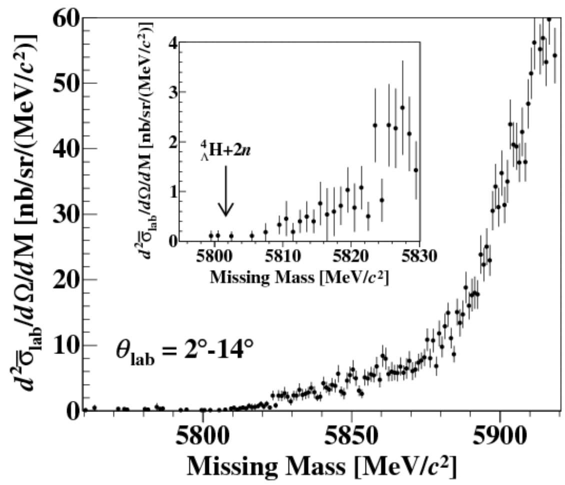

Fig.2 Missing-mass spectrum of the ^{6}Li(π^-,K$^+$) reaction at the momentum of 1.2 GeV/c. A magnified view around the Λ bound region is shown in the inset. The arrow labelled as $^{4}_{\Lambda}$H+2n shows the particle decay threshold.

References

[1] A. Sakaguchi *et al*., J-PARC Proposal E10.
[2] H. Sugimura *et al*., Phys. Lett. **B729**, 39 (2014).