Further Evidence for Θ^+ from LEPS

Since the LEPS collaboration reported the observation of a narrow baryon resonance-like structure in the nK^+ invariant mass spectrum produced in $\gamma n \rightarrow K^+K^-n$ reactions [1], a considerable number of experiments have been carried out to check the existence of the exotic baryon Θ^+, which is a genuine exotic baryon with the minimum quark configuration of $uudd\bar{s}$.

Although the LEPS result seemed to be supported by several experiments, many experiments at high energies, particularly collider experiments, yielded no positive evidence in the pK_s invariant mass distributions with a good mass resolution and high statistics. The experiment most relevant to the current study was also carried out by the CLAS collaboration [2]. The search was carried out by detecting all charged particles in the final state in $\gamma d \rightarrow K^-K^+n$ reactions. The neutron momentum was reconstructed by the missing momentum technique, and Θ^+ was searched in the nK^+ invariant mass distribution. No narrow peak was observed, and the upper limit (95% CL) for the elementary $\gamma n \rightarrow K^-\Theta^+$ reaction was found to be ~3 nb by using a phenomenological model based on $\Lambda(1520)$ production.

To shed light on the controversial situation, we studied the photoproduction of Θ^+ from a neutron by closely comparing it with the photoproduction of $\Lambda(1520)$ from a proton in a deuteron. Because the LEPS detector has a symmetric acceptance for positive and negative particles, a similar procedure can be applied to both analyses. The validity of corrections and event selection criteria can also be cross-checked. The analysis was performed using the data collected with the LEPS detector in 2002-2003 [3].

A photon beam in the energy range from 1.5 GeV to 2.4 GeV is produced at BL33LEP by Compton backscattering of laser photons from 8 GeV electrons in the storage ring with a typical beam intensity of 10^6 photons/s. The photons were alternatively injected into liquid deuterium (LD_2) or liquid hydrogen (LH_2) targets.

We analyze events of the type $\gamma d \rightarrow K^+K^-X$, where X denotes particles that were not required to be identified by the LEPS detector. Because the momenta of the target nucleons are not measured, the minimum momentum spectator approximation (MMSA) has been developed to obtain the invariant mass of pK^- or nK^+ pairs from $\gamma d \rightarrow K^+K^-pn$ reactions. The processes of interest are sequential processes of quasi-free productions of $\Lambda(1520)$ or Θ^+ and their decays, $\gamma p \rightarrow K^+\,\Lambda(1520) \rightarrow K^+K^-p$ and $\gamma n \rightarrow K^-\Theta^+ \rightarrow K^-K^+n$.

The dominant contribution in the selected K^+K^-

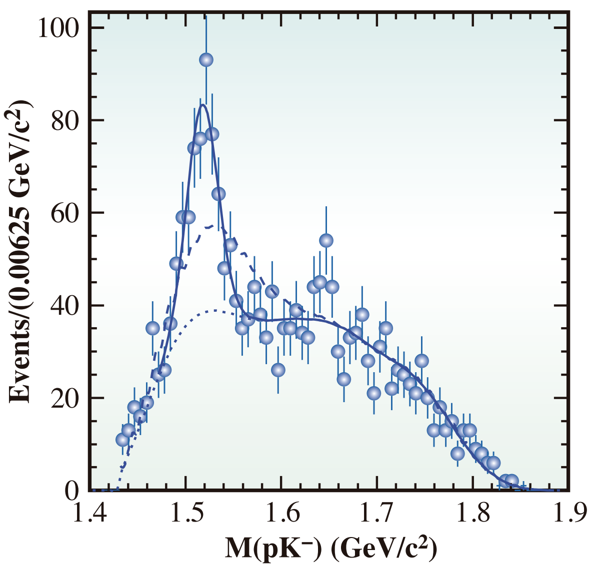

Fig. 1. $M(pK^-)$ distribution with a fit to the background spectrum only (dashed line) and with a Gaussian function (solid line). The dotted line is the background.

events is from φ decays, which are rejected by a cut on the KK invariant mass. Figure 1 shows the $M(pK^-)$ distribution, where the Λ(1520) contribution is clearly identified.

The $M(pK^+)$ distribution for the final candidate events is shown in Fig. 2. There is a narrow peak structure near 1.52-1.53 GeV/c^2. The distribution is fitted to the RMM spectra with and without a Gaussian peak with the estimated width of 11 MeV/c^2 to represent the Θ^+ signals. The statistical significance is 5.2σ, and the differential cross section for the $\gamma n \rightarrow K^-\Theta^+$ reaction is estimated to be 12 ± 2 nb/sr in the LEPS angular range.

There is a contradiction between the upper limit given by CLAS [2] and the differential cross section given here. However, there are differences between the CLAS and the LEPS measurements. If Θ^+ is mainly produced at forward angles, it is possible that CLAS would not see the K^- associated with Θ^+ production because the most forward angle for K^- detection is about 20 degrees in the CLAS measurement, whereas most of the LEPS acceptance is within 20 degrees. In the near future, LEPS will analyze data with a larger acceptance using a time-projection chamber for large angles to provide the Θ^+ angular distribution.

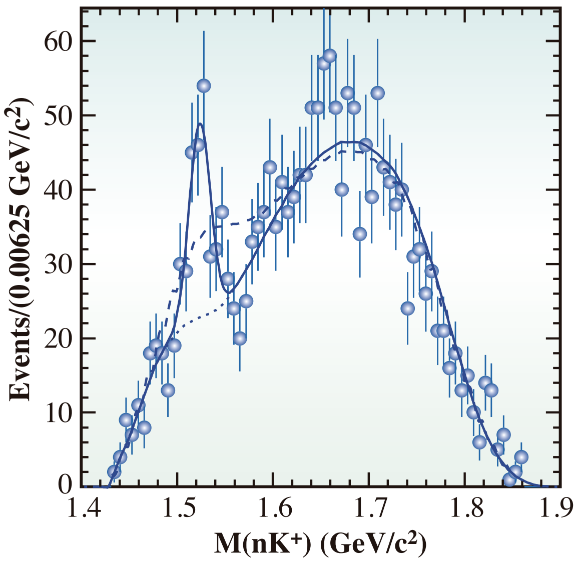

Fig. 2. $M(pK^+)$ distribution with a fit to the background spectrum only (dashed line) and with a Gaussian function (solid line). The dotted line is the background.

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References

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