Search for Pentaquark Baryon Associated with Photoproduction of Λ(1520) from Liquid Deuterium Target

The LEPS collaboration reported the first evidence of the Θ^+ in a reaction $\gamma C \rightarrow \Theta^+ K^- X$ from a plastic counter [1]. A narrow peak of a baryon resonance was observed at 1.54±0.01 GeV/c^2 in the K^- missing mass spectrum from a neutron by applying a correction to get rid of the Fermi motion effect. This peak was identified as a pentaquark state ($uudd\bar{s} = \Theta^+$) because its strangeness quantum number was +1. Positive observations of this resonance were followed by other experiments, namely, DIANA, CLAS, SAPHIR, bubble chamber experiments, HERMES, ZEUS, COSY-TOF, and SVD-2. On the other hand, many high-energy experiments including BaBar, Belle, HERA-B, SPHINX, HyperCP, CDF, and FOCUS have reported null results. Some of them have set upper limits for the production ratio of Θ^+ to Λ(1520) below a few %. Since the statistical significances in a series of positive observations were not high enough, further confirmation with high statistics data continued in the above experiments. Recently, some of new results have appeared as listed in Ref. [2]. While SVD-2 and DIANA showed positive confirmations, CLAS did not support the earlier observation in a reaction $\gamma d \rightarrow \Theta^+ K^- p$ with 30 times more data. The upper limit for the total cross section was set to 0.3 nb at the 95% confidence level.

The LEPS collaboration has also collected further data with a liquid deuterium target, which includes neutrons. A photon beam was produced at **BL33LEP** by the backward Compton scattering of an Ar laser (7 W, ~351 nm) from 8-GeV electrons in SPring-8. The maximum photon energy reached 2.4 GeV, and photons with an energy higher than 1.5 GeV were tagged by detecting recoil electrons. The liquid hydrogen (LH_2) or deuterium (LD_2) target was exposed to the photon beam at an intensity of ~10^6 /sec. Integrated numbers of tagged photons reached ~3×10^{12} for the LH_2 runs and ~4.5×10^{12} for the LD_2 runs in the years 2002 - 2003. The LH_2 data was collected for calibrations and background studies. Charged particles produced in photoreactions were detected using a forward spectrometer, which consisted of a silicon vertex detector, three drift chambers and a dipole magnet (0.7 Tesla). Particle identification was done by measuring the time-of-flight at a plastic scintillator wall 4 m downstream of the target.

Two charged particles were detected at the forward spectrometer in the LD_2 runs. In the case in which K^+ and K^- were detected as performed in Ref. [1], the Θ^+ was searched for in the K^- missing mass spectrum from a neutron with a correction for Fermi motion. In addition to this detection mode, K^- and a proton were detected so that the Θ^+ was identified in their missing mass from a deuteron without any effect due to Fermi motion. In the present study, the reaction $\gamma d \rightarrow \Theta^+\Lambda(1520) \rightarrow \Theta^+ K^- p$ was examined in the forward acceptance not as done by the CLAS experiment. The left panel of Fig. 1 shows the K^-p invariant mass distribution. The quasi-free production of $K^+\Lambda(1520)$ is seen above the spectra from non-resonant K^+K^-p and ϕp photoproductions. The right

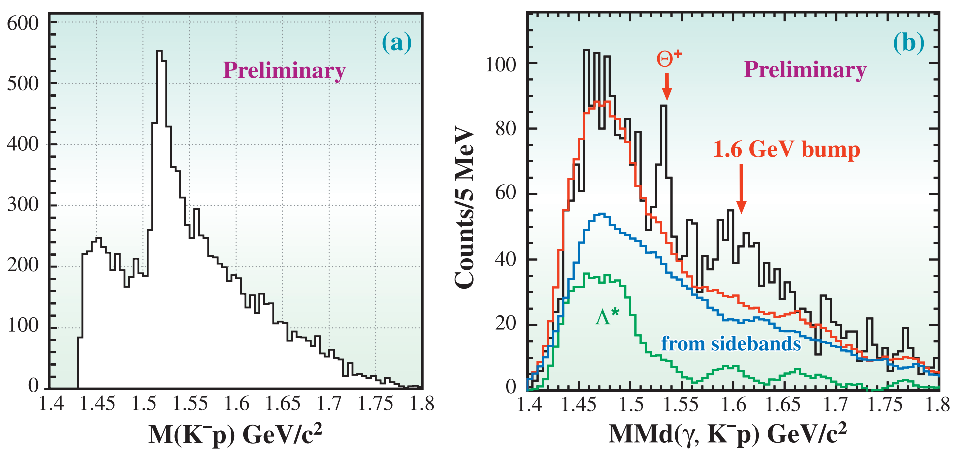

Fig. 1. K^-p invariant mass distribution in LD_2 data and K^-p missing mass spectrum after selecting Λ(1520) production. Background estimates based on side-bands in the real data are overlayed.

panel of Fig. 1 shows the missing mass spectrum of K^-p from a deuteron after requiring that the invariant mass corresponds to the $\Lambda(1520)$ mass (1.50 to 1.54 GeV/c^2). A peak structure was observed at 1.53 GeV/c^2, which corresponds to the Θ^+ signal. MC-based and real-data-based methods, which were complementary to each other, were adopted for reliable estimates of the background spectrum. These methods gave statistical significances of 4-5σ in the missing mass region of 1.520 - 1.545 GeV/c^2. The width of the cut to select $\Lambda(1520)$ production was varied as shown in Fig. 2. The S/N ratio of the peak structure increased with the narrower cut while it dropped with the wider cuts. The peak height was maintained while varying the width. This dependence shows that the peak structure is associated with $\Lambda(1520)$ production. Differential cross sections are being measured in order to compare them with the upper limits from other experiments.

Data collection with a higher intensity photon beam is desired to confirm the existence of the Θ^+ with higher statistics. Currently, additional data is being collected with a beam that is produced by injecting two solid state lasers (8 W, 355 nm) into SPring-8 simultaneously, as shown in Fig. 3. Interference between the two lasers was avoided using 80-MHz quasi-CW lasers. The photon beam intensity has reached 2×10^6 /sec. Five to ten times higher statistics is aimed at using the new data. We also

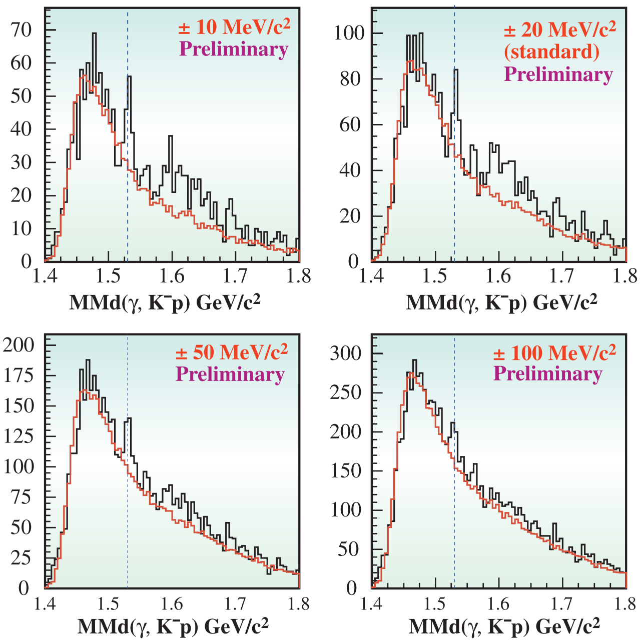

Fig. 2. K^-p missing mass distributions in LD_2 data. The condition to select the $\Lambda(1520)$ photoproduction was varied from ±10 MeV/c^2 to ±100 MeV/c^2. Background spectra from the MC simulations are overlayed.

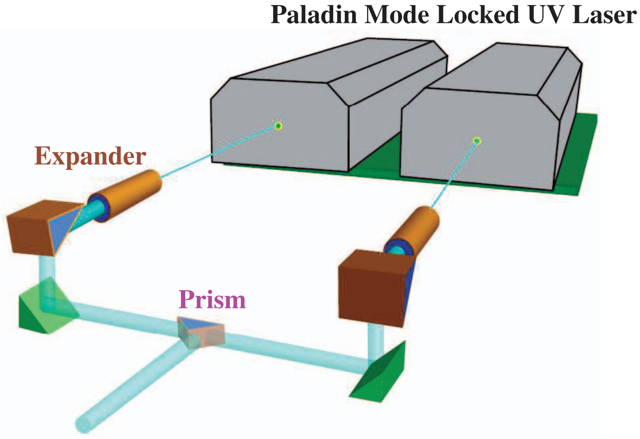

Fig. 3. A schematic view of two lasers injected into SPring-8. Two beam axes were merged at a knife-edge prism after adjusting laser focuses with expanders and mirrors.

plan to cover acceptance regions other than the forward direction. While the final state of the present analysis is similar to that of the CLAS experiment, the acceptance coverage of the K^-p detection is not overlapped. A new time projection chamber has been constructed in order to surround the target, and it is expected to cover both LEPS and CLAS acceptance regions. As a near future project, the construction of a new beamline to produce a higher intensity photon beam has been proposed at BL31ID. We aim to obtain an intensity of ~10^7 /sec by injecting 4 sets of higher power lasers with beam shaping to match the electron beam shape. A good divergence of the electron beam in the straight section will result in better resolution for tagger energy measurement and a well-collimated photon beam to place a large detector system far from the storage ring. High statistics data collection and systematic studies of the Θ^+ photoproduction are expected.

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