Near-Threshold Photoproduction of Λ(1520) from Protons and Deuterons [1]

Λ(1520) is an excited state of baryon resonance composed of up, down, and strange quarks in naive quark models. Its mass and spin have been experimentally determined to be 1519.5 MeV/c^2 and 3/2, respectively. Recently, the study of Λ(1520) has received much attention as a reference state of possible exotic hadrons. For example, the hypothetical pentaquark state Θ^+ (uudd$\bar{s}$) has a similar mass (1530 MeV/c^2) with an opposite strangeness, and it has been observed only in the near-threshold photoproduction from neutrons [2] but not from protons. Theoretically this difference can be explained by the dominant contribution of the contact-term diagram, which is necessary to conserve gauge invariance with t-channel *K*-meson exchange [3]. This theoretical framework also predicts that the near-threshold photoproduction of Λ(1520) from neutrons is much smaller than that from protons. Nevertheless, there are no experimental results of Λ(1520) photoproduction from protons at the near-threshold energies nor from neutrons in any energy region. Another exotic hadron candidate, which has a mass close to Λ(1520), is Λ(1405). This state is considered to be degenerated with Λ(1520) in naive quark models, but their mass difference is larger than that expected from spin-orbit force. Therefore, the importance of the meson-baryon correlation inside Λ(1405) has been intensively discussed. The hadron structure of Λ(1520) is also interesting as a reference state, and it can be studied by the access through the $K^*N\Lambda(1520)$ coupling in photoproduction experiments.

The LEPS collaboration has collected data to investigate Λ(1520) with a linearly polarized photon beam produced at **BL33LEP** by backward Compton scattering of an Ar laser (7 W, ~351 nm) from 8 GeV electrons. Photons in the energy range of 1.5-2.4 GeV were tagged by detecting recoil electrons, and liquid hydrogen (LH_2) or deuterium (LD_2) targets were alternatively exposed to the photon beam at an intensity of ~10^6/s. The integrated numbers of tagged photons reached ~2.8×10^{12} for the LH_2 runs and ~4.6×10^{12} for the LD_2 runs in the years 2002-2003. Charged particles produced at the targets were detected and momentum-analyzed using the LEPS forward spectrometer, which consisted of a silicon vertex detector, three drift chambers and a dipole magnet (0.7 Tesla). Those charged particles were identified by measuring their time-of-flight at a plastic scintillator wall 4 m downstream of the target. We detected two charged particles in the final state of the $\gamma p \rightarrow K^+\Lambda(1520) \rightarrow K^+K^-p$ or $\gamma n \rightarrow K^0\Lambda(1520) \rightarrow K^0K^-p$ reaction. When K^+K^- or K^+p pairs were detected at the forward spectrometer, the backward photoproduction of Λ(1520) at the γp center-of-mass system was kinematically accepted and Λ(1520) was identified in the K^+ missing mass spectrum assuming the proton mass for the target. (See Figs. 1(a) and 1(b).) In contrast, the forward photoproduction of Λ(1520) at the γp or γn center-of-mass system was covered by detecting a K^-p pair at the forward spectrometer, and Λ(1520) was identified in the K^-p invariant mass spectrum, as shown in Figs. 1(c) and 1(d).

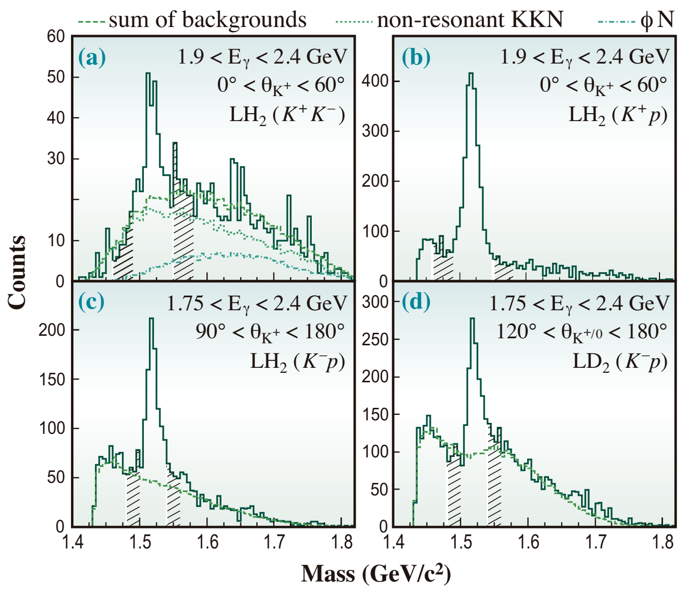

Fig. 1. Panels **(a)** and **(b)** show K^+ missing mass spectra for the LH_2 runs in the K^+K^- and K^+p detection modes, respectively. Panels **(c)** and **(d)** show K^-p invariant mass spectra in the K^-p detection mode for the LH_2 and LD_2 runs, respectively.

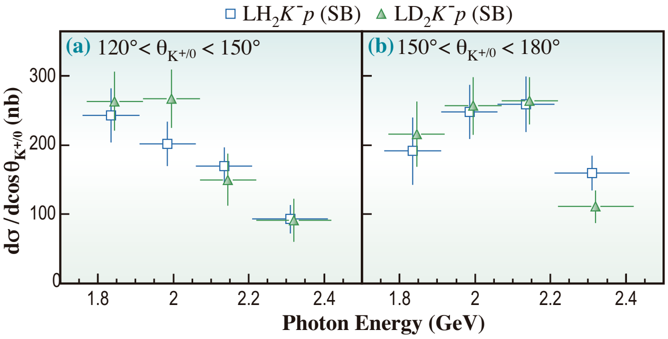

Fig. 2. Differential cross sections of the Λ(1520) photoproduction from protons (□) and deuterons (▲) in the two backward K$^{+/0}$ angular regions.

Figure 2 shows differential cross sections of the forward Λ(1520) photoproduction from protons and deuterons, measured in the K^-p detection mode. The cross sections from deuterons were comparable to those from protons, although the number of nucleons was twofold. Their ratio was measured to be 1.02±0.11 in the range of $1.75<E_\gamma<2.4$ GeV and $120°<\theta_{K+/0}<180°$. The Λ(1520) photoproduction from neutrons was therefore found to be suppressed, as predicted by the theory advocating the importance of contact-term diagram. Figure 3(a) shows differential cross sections of the reaction $\gamma p\rightarrow K^+\Lambda(1520)$, measured in 30° bins of K^+ angle, using all the detection modes. The cross sections at the forward K^+ angles were more than three times larger than those at the backward K^+ angles, and this behavior was consistent with the theoretical prediction based on the dominant contribution of the contact term and K exchange, as shown by the dashed and dotted lines corresponding to E_γ=1.85 and 2.35 GeV, respectively. The cross sections measured at forward K^+ angles were lower than the theoretical predictions calculated on the basis of the old high energy measurement by the LAMP2 Collaboration. (See Fig. 3(b).) The present result suggests new information for theoretical models, including the rescaling with a new cut-off parameter, as done in Fig. 3(a). We also measured the degrees of asymmetry in the $\Lambda(1520)\rightarrow K^-p$ decay angular distribution at the t-channel helicity frame of rest Λ(1520) and in the azimuthal angle distribution of the Λ(1520) production plane relative to the polarization vector of the photon beam. In particular, the latter asymmetry, called photon beam asymmetry (Σ), is sensitive to the strength of the $K^*N\Lambda(1520)$ coupling constant. We found this asymmetry to be close to zero (Σ =-0.01±0.07), and the $K^*N\Lambda(1520)$ coupling constant was therefore small. Although the present measurement is not precise enough to discuss the hadron structure of Λ(1520), our observation suggests that the t-channel K^* exchange contribution is small in Λ(1520) photoproduction. This result is consistent with the theory emphasizing the dominance of contact-term contribution.

In summary, we studied the Λ (1520) photoproduction from protons and deuterons by detecting two charged particles in three different ways that were complementary to each other in acceptance. The present analyses were the first ever measurements near the threshold energy and with a neutron target. The measured differential cross sections and photon beam asymmetry suggested that the contact-term contribution associated with t-channel K exchange is important in Λ(1520) photoproduction and that the $K^*N\Lambda(1520)$ coupling constant is relatively small.

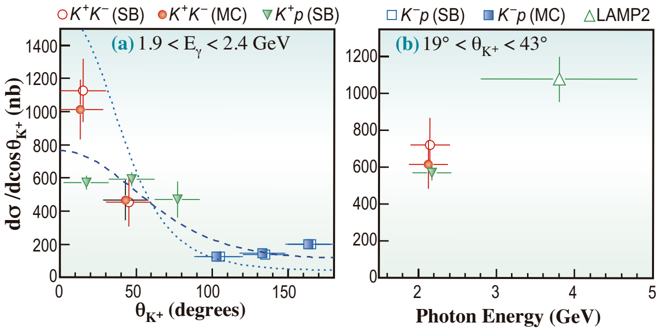

Fig. 3. **(a)** Differential cross sections from protons, measured by three different detection modes. Background spectra under the Λ(1520) resonance peak were subtracted by the two methods using sidebands (SB) and Monte Carlo simulations (MC). **(b)** Differential cross sections of the $\gamma p\rightarrow K^+\Lambda(1520)$ reaction at forward K^+ angles, measured by this work and the LAMP2 Collaboration.

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