Photoproduction of hyperon resonances at SPring-8/LEPS

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Differential cross sections for $\gamma p \to K^+\Lambda(1405)$ and $\gamma p \to K^+\Sigma^0(1385)$ reactions have been measured in the photon energy range from 1.5 to 2.4 GeV and the angular range of $0.8 < \cos(\Theta) < 1.0$ for the K^+ scattering angle in the center-of-mass system. This data is the first measurement of the $\Lambda(1405)$ photoproduction cross section.

The data were collected using two different experimental setups, referred to as data set (I) and data set (II). Forward going K^+'s from the $\gamma p \to K^+X$ reaction were detected in the LEPS spectrometer, which consisted of a dipole magnet, a silicon-strip vertex detector, three multiwire drift chambers, a start counter (SC) just downstream of the target, and a time-of-flight (TOF) hodoscope. In order to distinguish $\Lambda(1405)$ and $\Sigma^0(1385)$, a time projection chamber (TPC) was used together with the LEPS spectrometer to facilitate the detection of the decay products of these hyperon resonances. Using this data (data set (II)), the production ratio between $\Sigma^0(1385)$ and $\Lambda(1405)$ was fixed from the yields of $\Sigma^0(1385)$ and $\Lambda(1405)$ measured from their $\Lambda\pi^0$ and $\Sigma^\pm\pi^\mp$ decay modes, respectively. The data for carbon was measured independently and subtracted from the CH_2 spectrum. The absolute values of the differential cross sections were then obtained from the $MM(K^+)$ distribution measured in the previous data (data set (I)) which was taken with a liquid hydrogen target with the input of the production ratio between $\Sigma^0(1385)$ and $\Lambda(1405)$ in the common detector acceptance of the two data sets.

Fig. 1 (a) and (b) show the $MM(K^+)$ spectrum for free protons in CH_2 for two photon energy bins: $1.5 < E_\gamma < 2.0$ GeV and $2.0 < E_\gamma < 2.4$ GeV, respectively. For the resonance around 1.4 GeV/c^2, we assumed a Breit-Wigner shape, neglecting any distortion due to the small contamination of $\Lambda(1405)$. The yields of $\Sigma^0(1385)$ were obtained to be 255 ± 55 events and 525 ± 111 events for $1.5 < E_\gamma < 2.0$ GeV and $2.0 < E_\gamma < 2.4$ GeV, respectively, after subtracting the background of $\gamma p \to K^+\Lambda(1405) \to K^+\Sigma^0\pi^0 \to K^+\Lambda\gamma\pi^0 \to K^+p\pi^-\gamma\pi^0$ reaction and $\gamma p \to K^+\Lambda(1405)/\Sigma^0(1385) \to K^+\Sigma^+\pi^- \to K^+p\pi^0\pi^-$ reaction.

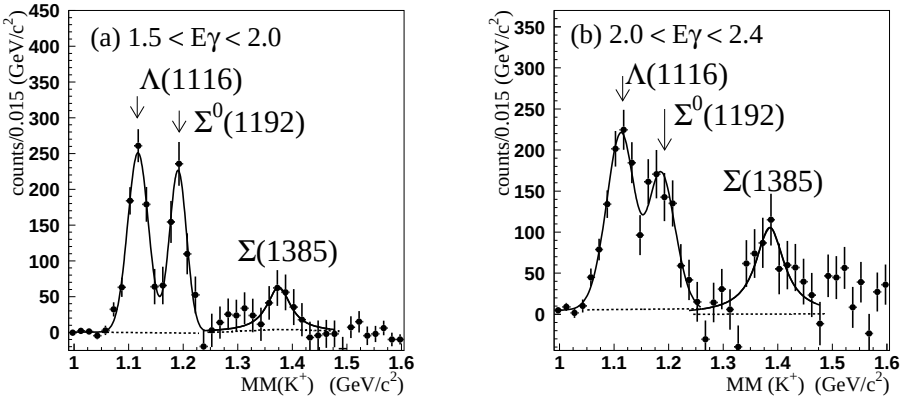

Figure 1: $MM(K^+)$ distribution after the Λ selection cut for two photon energy bins: (a) $1.5 < E_\gamma < 2.0$ GeV and (b) $2.0 < E_\gamma < 2.4$ GeV, respectively.

Next, the production of $\Lambda(1405)$ was measured using the $\gamma p \to K^+\Lambda(1405) \to K^+\Sigma^\pm\pi^\mp \to K^+\pi^+\pi^- n$ reaction. Neutrons were identified from the missing mass of the $\gamma p \to K^+\pi^+\pi^- X$ reaction. A kinematic fit

with two constraints (C2-fit), $MM(K^+\pi^+\pi^-) = M(n)$ and $MM(K^+\pi^\pm) = M(\Sigma^\mp)$, was applied to purify the $\Lambda(1405)$ production events and to separate its $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ decay modes. The yield of $\Lambda(1405)$ was extracted by fitting the theoretical spectrum of Nacher *et al.* [2] to the peak in the combined spectrum of the $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ modes. The combined spectrum is shown as closed circles in Fig. 2 for $0.8 < \cos(\Theta_{K_{CM}}) < 1.0$ and two photon energy ranges: $1.5 < E_\gamma < 2.0$ GeV (a) and $2.0 < E_\gamma < 2.4$ GeV (b). The spectra were corrected for the detector acceptance and were normalized using the differential cross section of $K^+\Lambda(1116)$ production measured from data set (I) [1] in each photon energy bin. After correcting for the detector acceptance and decay branches of the hyperon resonances, the production ratios of $\Lambda(1405)$ to $\Sigma^0(1385)$ were obtained as $\Lambda^*/\Sigma^* = 0.54 \pm 0.17$ and 0.084 ± 0.076 for $1.5 < E_\gamma < 2.0$ GeV and $2.0 < E_\gamma < 2.4$ GeV, respectively. The production ratio of $\Lambda(1405)$ to $\Sigma^0(1385)$ is decreased in the high photon energy bin, suggesting the production mechanisms for these two hyperons are quite different.

Finally, the absolute values of the differential cross sections of $\Lambda(1405)$ and $\Sigma^0(1385)$ production off protons were measured from the data set (I) using the production ratio of these two hyperons determined above. The differential cross sections of $\Lambda(1405)$ production were found to be $d\sigma/d(\cos\theta) = 0.43 \pm 0.088(stat.)^{+0.034}_{-0.14}(syst.)$ μb and $0.072 \pm 0.061(stat.)^{+0.011}_{-0.0056}(syst.)$ μb for $1.5 < E_\gamma < 2.0$ GeV and $2.0 < E_\gamma < 2.4$ GeV, respectively. Those of $\Sigma^0(1385)$ production were $0.80 \pm 0.092(stat.)^{+0.062}_{-0.27}(syst.)$ μb and $0.87 \pm 0.064(stat.)^{+0.13}_{-0.067}(syst.)$ μb for $1.5 < E_\gamma < 2.0$ GeV and $2.0 < E_\gamma < 2.4$ GeV, respectively.

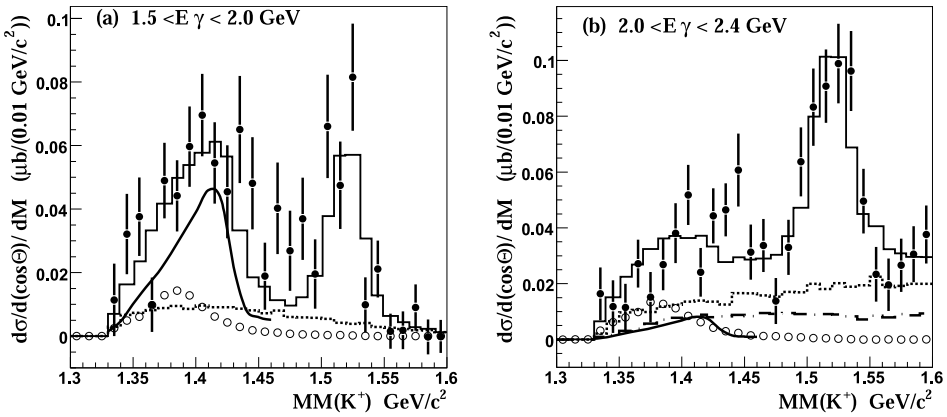

Figure 2: Missing mass of the $\gamma p \to K^+X$ reaction with $\Sigma^+\pi^-$ and $\Sigma^-\pi^+$ decays in data set (II) in two photon energy ranges: (a) $1.5 < E_\gamma < 2.0$ GeV and (b) $2.0 < E_\gamma < 2.4$ GeV. The experimental data are shown as closed circles. The data were fitted with spectra determined by MC simulation of $K^+\Lambda(1405)$, $K^+\Sigma^0(1385)$, $K^+\Lambda(1520)$, nonresonant $(K^+\Sigma\pi)$ and $K^{*0}\Sigma^+$ production. The solid histograms show fit results. The solid lines, open circles, dashed lines and dot-dashed line show spectra of $K^+\Lambda(1405)$, $K^+\Sigma^0(1385)$, nonresonant $(K^+\Sigma\pi)$ and $K^{*0}\Sigma^+$ production, respectively.

References

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