Differential cross section and photon beam asymmetry for the $\vec{\gamma}n \to K^+\Sigma^-$ reaction at E_γ=1.5-2.4 GeV

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The reaction mechanism of strangeness photoproduction is important to study in order to understand the role of nucleon resonances, the hyperon resonances, and their decay branching ratios. In the past, experimental data were limited to $K^+\Lambda$ and $K^+\Sigma^0$ productions off the proton. We measured, for the first time, differential cross sections and photon beam asymmetries for the $\vec{\gamma}n \to K^+\Sigma^-$ reaction and compare with the $\vec{\gamma}p \to K^+\Sigma^0$ reaction.

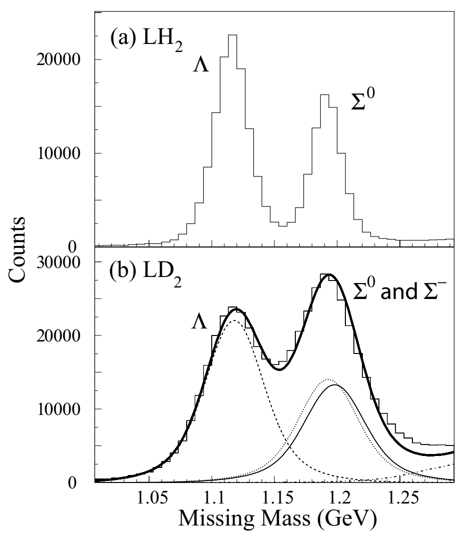

Figure 1: Missing mass spectra obtained for K^+ photoproduction off LH$_2$ (a) and LD$_2$ (b) targets. The dashed, dotted, and solid curves correspond to Λ, Σ^0, and Σ^- production, respectively. The dot-dashed curve is the estimated background. The thick solid curve is the sum of all contributions.

The experiment was carried out using the laser-electron photon facility at SPring-8 (LEPS). The experimental setup was described in detail elsewhere [1]. Liquid hydrogen (LH$_2$) and deuterium (LD$_2$) targets with an effective length of 16 cm were employed [2]. Figure 1 shows the missing mass ($MM_{\gamma K^+}$) spectra for E_γ=1.5-2.4 GeV and 0.6< $\cos\Theta_{\rm cm}$ <1. Λ and Σ^0 particles are produced on the proton, while the Σ^- particle is produced on the neutron. Therefore, the ratio $N(\Sigma)/N(\Lambda)$ in the LD$_2$ data is larger than the ratio $N(\Sigma^0)/N(\Lambda)$ in the LH$_2$ data. In this analysis, the ratio $N(\Sigma^0)/N(\Lambda)$ for the LD$_2$ data was assumed to be the same as for the LH$_2$ data. The $K^+\Sigma^-$ cross section can be obtained from the difference between the production yield ratios of $N(\Sigma)/N(\Lambda)$ in the LD$_2$ data and $N(\Sigma^0)/N(\Lambda)$ in the LH$_2$ data. As a result of the fit to the missing mass spectrum, the production yield ratio $N(\Sigma^-)/N(\Sigma^0)$ was obtained. The $K^+\Sigma^-$ cross section was calculated by using the ratio,

$$\frac{d\sigma_{\Sigma^-}}{d\cos\Theta_{\rm cm}} = \frac{d\sigma_{\Sigma^0}}{d\cos\Theta_{\rm cm}} \times \frac{N(\Sigma^-)}{N(\Sigma^0)}. \quad (1)$$

In Fig. 2 the differential cross sections for $K^+\Sigma^-$ and $K^+\Sigma^0$ are shown. In the center-of-mass energy (W=$\sqrt{s}$) region above 2.1 GeV at 0.8< $\cos\Theta_{\rm cm}$, the cross sections for the two reactions are similar. This result is inconsistent with a model based on the exchange of pure isospin 1/2, dominantly due to K and K^* mesons, where the cross section ratio of $\sigma_{K^+\Sigma^-}/\sigma_{K^+\Sigma^0}$ is expected to be 2. Regge model calculations agree with the data for $K^+\Sigma^0$, but largely overestimate the $K^+\Sigma^-$ data. The Δ^* contribution is considered to be the most reasonable explanation for the similar cross sections. If the isospin 3/2 amplitude is 10% of the isospin

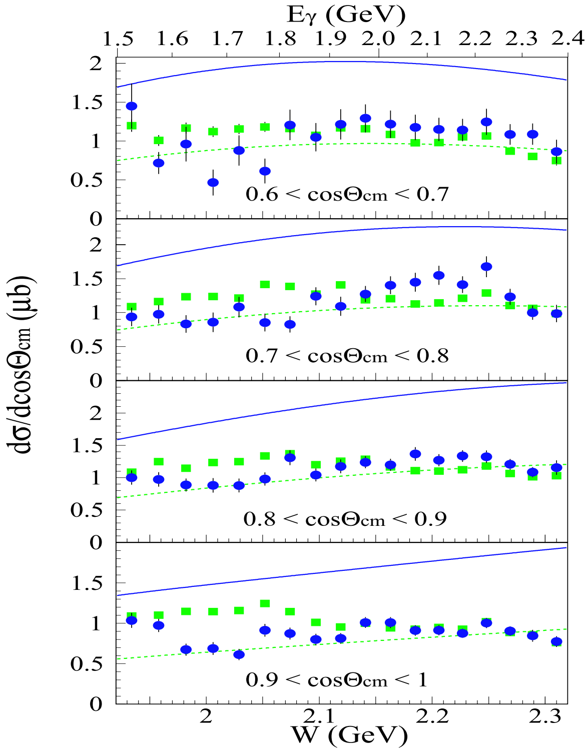

Figure 2: Differential cross sections for $\vec{\gamma}n \rightarrow K^+\Sigma^-$ (circle) and $\vec{\gamma}p \rightarrow K^+\Sigma^0$ (square). Only statistical errors are shown. The solid and dashed curves are the Regge model calculations for the $K^+\Sigma^-$ and $K^+\Sigma^0$, respectively.

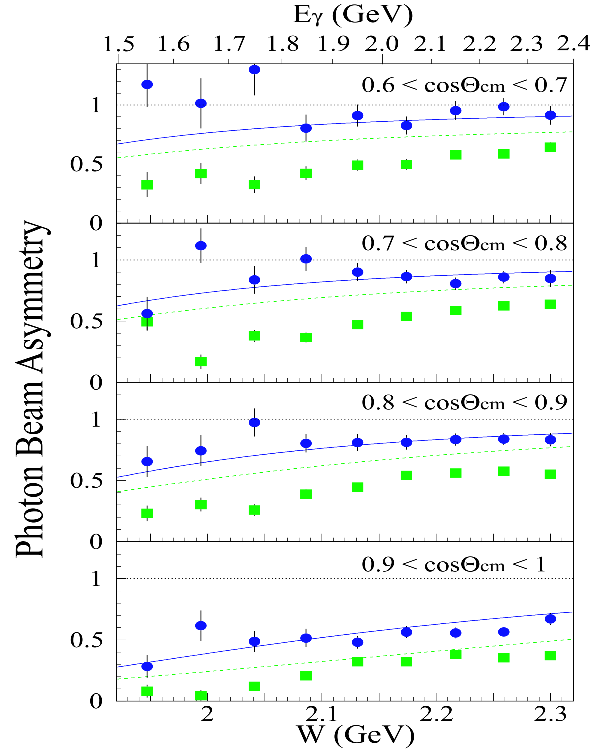

Figure 3: Photon beam asymmetries for $\vec{\gamma}n \rightarrow K^+\Sigma^-$ (circle) and $\vec{\gamma}p \rightarrow K^+\Sigma^0$ (square). Only statistical errors are shown. The solid and dashed curves are the Regge model calculations for the $K^+\Sigma^-$ and $K^+\Sigma^0$, respectively.

1/2 amplitudes, dominantly due to K and K^* exchanges, in the $K^+\Sigma$ cross sections described in Ref.[3], the similarity of the $K^+\Sigma^-$ and $K^+\Sigma^0$ cross sections can be explained.

By using vertically and horizontally polarized photon beams, the photon beam asymmetry (Σ) can be measured without any correction for the spectrometer acceptance [1]. In Fig. 3 the photon beam asymmetries for $K^+\Sigma^-$ and $K^+\Sigma^0$ are shown. For $K^+\Sigma^-$, the asymmetries are positive and are larger than those for $K^+\Sigma^0$. The asymmetries close to +1 at $\cos\Theta_{\rm cm} < 0.9$ indicate the dominance of the K^* exchange in the t-channel. The asymmetries are small at $0.9 < \cos\Theta_{\rm cm}$ because the asymmetries go to zero at $\cos\Theta_{\rm cm}=1$.

The Regge model calculations overestimate the data for the $K^+\Sigma^0$, while the calculations agree with the data for the $K^+\Sigma^-$. This agreement suggests that an additional contribution, which is not included in the calculations, is small in the $K^+\Sigma^-$ channel. As shown above, contributions from Δ^* resonances could explain the $K^+\Sigma^0$ data [4]. However, this Δ^* contribution reduces the $K^+\Sigma^-$ asymmetries and fails to explain the polarization data. A large difference between the asymmetries for the $K^+\Sigma^-$ and $K^+\Sigma^0$ can not be explained by simple theoretical considerations based on Regge model calculations. In the energy region of a few GeV, there is no theoretical calculation which describes the strangeness photoproduction well. The present result may imply the existence of a hidden reaction mechanism, and will provide constrains in the model calculations with the aim to advance our understanding of the $s\bar{s}$ pair production mechanisms.

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