K$^+$ photoproduction at SPring-8/LEPS

M. Sumihama (for the LEPS Collaboration)
Department of Physics, Osaka University, 1-1 Machikane-Yama, Toyonaka, Osaka 560-0043, Japan

A series of experiments have been carried out by using a linearly polarized photon beam at the SPring-8/LEPS facility from December 2000 to June 2001. The photon beam asymmetries and differential cross sections of the $p(\vec{\gamma},K^+)^\Lambda$ and $p(\vec{\gamma},K^+)^\Sigma^0$ reactions have been measured in the photon energy range from 1.5 GeV to 2.4 GeV at forward angles, $0^\circ < \Theta_{em}^K < 60^\circ$. We report preliminary results of the photon beam asymmetries.

1. INTRODUCTION

Experimental information on nucleon resonances, $N^*$ and $\Delta^*$, has mainly come from studies of the $\pi N$ and $N(\gamma,\pi)$ reactions. However, considerably large number of nucleon resonances predicted by quark models have not been observed in the pionic reactions. Quark model studies suggest that a part of these missing resonances may couple to strangeness channels, such as $K\Lambda$ and $K\Sigma$ channels [9]. The $p(\gamma,K^+)^\Lambda$ and $p(\gamma,K^+)^\Sigma^0$ reactions give good means to search for such nucleon resonances. In fact, indications of new resonance contributions were seen around $E_\gamma = 1.5$ GeV ($W = 1.9$ GeV in total energy) in the cross section data of the $p(\gamma,K^+)^\Lambda$ reaction measured by the SAPHIR [4] and CLAS [5] collaborations. To reproduce the experimental data, missing resonances like $D_{13}(1900)$, were included in several theoretical calculations [6-8]. However, there still remains a controversy in the theoretical description of the cross sections [9], because there are ambiguities of meson-hadron couplings and form factors at hadronic vertices together with the ambiguity of nucleon resonance amplitudes. Therefore, additional observables are necessary to examine the theoretical models. The photon beam asymmetry is one of good candidates for the studies because the observable is quite sensitive to model differences.

The contribution of the t-channel meson exchange is expected to become large at forward angles above the resonance region ($E_\gamma > 2$ GeV). Mesons exchanged in the kaon photoproduction are K, K*, K$_1$, etc. The dominance of the unnatural parity exchange (K and K$_1$) leads to the photon beam asymmetry equal to $-1$ while the natural parity exchange (K$^*$) leads to the photon beam asymmetry equal to $+1$ [9-10]. Therefore, we may provide information on the t-channel meson exchange by measuring the photon beam asymmetries. Since the LEPS spectrometer covers forward angles, the experimental data in the kinematical regions which cannot be accessed at other facilities can be studied with good accuracy and statistics.
2. EXPERIMENTAL PROCEDURE

At the SPring-8/LEPS facility, linearly polarized photons are produced by the backward-
Compton-scattering process of laser photons on the 8-GeV circulating electrons in the
storage ring [9]. In the present measurement, the maximum energy of the produced pho-
ton was 2.4 GeV since an Ar laser (351 nm) was used. The photon energy ranged from
1.5 GeV to 2.4 GeV was measured by the tagging counter with the energy resolution of
15 MeV (RMS). The polarization of the laser photons was typically 98%, and the po-
larization of the produced photons was about 92% at the maximum photon energy. A
half of data was taken by the vertically polarized photons and another half was taken
by the horizontally polarized photons to measure the photon beam asymmetries. The
target was liquid hydrogen with a thickness of 5 cm. The LEPS magnetic spectrometer
has been used to identify charged particles by the momentum and time-of-flight mea-
surement. Figure 1 shows the mass spectrum measured by the LEPS spectrometer with
the liquid hydrogen target. Protons, kaons and pions are identified. A missing mass was
calculated after selecting the K+ events. Figure 2 shows the missing mass spectrum of the
p(γ,K+)X reaction. One can see clearly separated Λ(1116) and Σ0(1193) samples, and
hyperon resonances, Σ(1385)/Λ(1405) and Λ(1520). About 75,000 K+ Λ and 50,000 K+
Σ0 events were detected in the photon energy range 1.5 GeV < Eγ < 2.4 GeV and the
angular range, 0° < Θcm < 60°.

Figure 1. Mass spectrum calculated by
momenta and time-of-flights. The peaks
of protons, kaons and pions are seen.

Figure 2. Missing mass spectrum of the
p(γ,K+)X reaction. The Λ(1116) and
Σ0(1193) peaks are seen clearly.
3. RESULTS OF PHOTON BEAM ASYMMETRIES

By making the vertically and horizontally polarized photons, two sets of data were accumulated to measure the photon beam asymmetries. The relation between the production yields in the two data sets and the photon beam asymmetry (Σ) is given as follows:

\[
\frac{N_v - N_h}{N_v + N_h} = \Sigma P \cos(2\phi_{K^+}),
\]

where \(N_v(N_h)\) is the \(K^+\) photoproduction yield with the vertically (horizontally) polarized photons, \(\phi_{K^+}\) is the \(K^+\) azimuthal angle (angle between the reaction plane and the horizontal plane) and \(P\) is the polarization of the photons. The \(\phi_{K^+}\) dependence of the ratio

![Figure 3](image3.png)

Figure 3. Preliminary photon beam asymmetries Σ of the \(p(\vec{\gamma},K^+)\Lambda\) reaction.

![Figure 4](image4.png)

Figure 4. Preliminary photon beam asymmetries Σ of the \(p(\vec{\gamma},K^+)\Sigma^0\) reaction.
\( \frac{N_v - N_h}{N_v + N_h} \) was fitted by the function \( \cos(2 \phi_{K^+}) \). The amplitude \( \Sigma P \) was estimated by the fitting, and the degree of polarization \( P \) was obtained by using the photon energy \( E_\gamma \). Figures 3 and 4 show preliminary results of the photon beam asymmetries as a function of \( \cos \Theta_{cm}^{K^+} \) for the \( p(\gamma,K^+)\Lambda \) and \( p(\gamma,K^+)\Sigma^0 \) reactions. Only statistical errors are included in the error bars in the data plots. The signs of the beam asymmetries of both reactions are positive in the measured kinematical region. The values of our preliminary asymmetry data for the \( p(\gamma,K^+)\Lambda \) reaction increase as the increase of the photon energy. The photon asymmetry slightly drops at larger angles above \( E_\gamma = 1.7 \) GeV. The photon asymmetry of the \( p(\gamma,K^+)\Sigma^0 \) reaction also increases as the photon energy increases. The angular distributions are flat over all the photon energy range.

4. SUMMARY

In the previous experiments, the cross section data of the \( p(\gamma,K^+)\Lambda \) reaction have been discussed in connection with missing resonances, but the experimental data are not conclusive to confirm the resonances. We measured the photon beam asymmetries for the \( p(\gamma,K^+)\Lambda \) and \( p(\gamma,K^+)\Sigma^0 \) reactions in the photon energy range \( 1.5 \) GeV < \( E_\gamma < 2.4 \) GeV and the angular range \( 0^\circ < \Theta_{cm}^{K^+} < 60^\circ \). Theoretical models can be examined and improved by including our photon beam asymmetry data. Current data will extend our knowledge of the \( K^+ \) photoproduction mechanism including the effect of nucleon resonances.

REFERENCES

1. S. Capstick and W. Roberts, Phys. Rev. D 58 (1998) 074011.
2. M.Q. Tran et al., Phys. Lett. B 445 (1998) 20.
3. R.A. Schumacher, Nucl. Phys. A663&664 (2000) 440.
4. T. Mart and C. Bennhold, Phys. Rev. C 61 (1999) 012201.
5. S. Janssen, J. Ryckebusch, D. Debruyne, and T.V. Cauteren, Phys. Rev. C 65 (2002) 015201.
6. B. Saghai, nucl-th/0105001 (2001).
7. P. Stichel, Z. Phys. 180 (1964) 170.
8. M. Guidal, M. Laget and M. Vanderhaeghen, Nucl. Phys. A627 (1997) 645.
9. T. Nakano, et al., Nucl. Phys. A684 (2001) 71.