The $\gamma p \rightarrow K^+ \Lambda$ and $\gamma p \rightarrow K^+ \Sigma^0$ reactions at SPring-8/LEPS

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Physics motivation

Missing resonances $N^*$ and $\Delta^*$ in s-channel

- It is essential to fully know $N^*$ and $\Delta^*$ to understand baryon structure.
- Many nucleon resonances predicted by quark model are still missing.
- $D_{13}(1900)$ resonance in SAPHIR / CLAS data was found.

Some resonances should couple to $K\Lambda$ or $K\Sigma$ channel. Kaon photoproduction is good means to search for missing resonances.
**Meson exchange in t-channel**

\[ E_\gamma = 1.5 - 2.4 \text{ GeV} \]

Transition region, s-channel → t-channel

Contribution of t-channel meson exchange becomes large above 2GeV.

\[
\begin{array}{c}
\gamma \\
\rightarrow \\
K^+ \\
\rightarrow \\
K^*, K, K_1 \\
\rightarrow \\
p \\
Y(\Lambda, \Sigma^0)
\end{array}
\]

Photon-beam asymmetry \( \Sigma \)

- natural parity exchange (K*) \( \rightarrow \Sigma = +1 \)
- unnatural parity exchange (K, K1) \( \rightarrow \Sigma = -1 \)

at \( t = 0 \) and large \( E_\gamma \).
LEPS spectrometer - forward acceptance

- Liquid Hydrogen Target (50 mm thick)
- Start counter
- Aerogel Cherenkov (n=1.03)
- Dipole Magnet (0.7 T)
- Silicon Vertex Detector
- MWDC 1
- MWDC 2
- MWDC 3
- TOF wall
- Linearly polarized γ
Particle identification
by time-of-flight and momentum measurements

Momentum resolution
~0.8% for 2GeV/c Kaons.

Time resolution ~150 ps.
$K^+ \text{ Missing mass spectrum}$

$\gamma p \rightarrow K^+\Lambda(1116)$

$\gamma p \rightarrow K^+\Sigma^0(1193)$

Z-vertex distribution

Counts

Counts

$\Lambda(1116)$

$\Sigma^0(1193)$

$\Lambda(1405)/\Sigma(1385)$

$\Lambda(1520)$

$\gamma p \rightarrow K^+\Lambda(1116)$

$\gamma p \rightarrow K^+\Sigma^0(1193)$
Differential cross sections
- Energy dependence

Resonance-like structure

\[ \frac{d\sigma}{d(cos\theta)} \]

\( \cos\theta_{cm}^K = 0.75 \)
\( \cos\theta_{cm}^K = 0.85 \)
\( \cos\theta_{cm}^K = 0.95 \)

\[ \Lambda(1116) \quad W (GeV) \]

\[ \Sigma^0(1193) \quad W (GeV) \]

→ K+K*-exchange by M. Guidal.
→ Isobar + Regge by T. Mart and C. Bennhold.
→ Gent isobar model by T. Corthals
Differential cross sections
- angular dependence

\[ \Lambda(1116) \]
\[ \Sigma^0(1193) \]

\[ \frac{d\sigma}{d(\cos\theta_{cm})} (\mu b) \]

\[ E_r = 1.575 \]
\[ E_r = 1.725 \]
\[ E_r = 1.875 \]
\[ E_r = 2.025 \]
\[ E_r = 2.175 \]
\[ E_r = 2.325 \]

Forward peaking cannot be reproduced by Feynman diagram only, at \( E_\gamma > 2 \text{GeV} \). Need Regge poles.

\[ \rightarrow \text{Regge model } K+K^*\text{-exchange} \]
\[ \rightarrow \text{Isobar (Feynman) only} \]
\[ \rightarrow \text{Isobar + Regge} \]

by T. Mart and C. Bennhold.
Photon-beam asymmetry $\Sigma$
- single polarization observable

* data

Positive sign

Polarization observable is important in order to fix the model parameters (fine optimization) and understand the Kaon Photoproduction, including the existence of a missing resonance $-D_{13}$.

$\rightarrow$ K+K*-exchange by M. Guidal.
$\rightarrow$ Isobar + Regge by T. Mart and C. Bennhold.
$\rightarrow$ Gent isobar model by T. Corthals
Differential cross sections for $\gamma p \rightarrow p\pi^0$

- Check photon normalization factor

LEPS data
Old data
Curves SAID (fit data at $E_\gamma < 2$GeV)

Good agreement with SAID $\rightarrow$ Photon normalization is OK.
Meson photoproduction in u-channel

Detect protons by forward spectrometer.

Measure photon-beam asymmetry at backward angles where no data for $\gamma p \rightarrow p\pi^0$.

Missing mass for $\gamma p \rightarrow pX$

We will obtain differential cross section and photon asymmetry for $\eta$, $\eta'$ and $\omega$.

LEPS data
Old data
Curves SAID
Summary

The $K^+\Lambda$ photoproduction was measured by linearly polarized photons at SPring-8/LEPS.

Photon-beam asymmetry is a good tool to define theoretical models.

Differential cross sections were obtained at very forward angles, up to $\cos\theta_{cm} = 0.975$.

Bump structure was seen at $W=1960$ MeV in the $K^+\Lambda$ mode.

We see a forward peaking in $K^+\Lambda$ while no peaking in $K^+\Sigma^0$.

In order to fit the forward-angle data, a Regge pole is necessary in addition to $s$-channel resonances and $t$-channel $K$ and $K^*$ exchanges.

Combination of isobar (Feynman) and Regge is successful to explain this forward peaking in $K^+\Lambda$.

Photon normalization was checked by $\gamma p \rightarrow p\pi^0$ cross sections. The data show a good agreement with SAID. LEPS photon normalization is OK.

Photon asymmetry data are obtained at backward angles.

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