Measurement of the Photon Beam Asymmetry $\Sigma$ for $\gamma + p \rightarrow K^+\Sigma^0$ at $E_\gamma = 8.5$ GeV in GlueX

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On behalf of the GlueX Collaboration
Introduction

- Important channels in kaon photoproduction
  \[ \gamma p \rightarrow KY (Y = \Lambda, \Sigma) \]

- Useful to study pair creation of strange and anti-strange quarks

- Different channels can contribute

  - s-channel
  - u-channel
  - t-channel

Physics Motivation

• Linearly polarized photon beam to study exchange of parity

• natural-parity \( P = (-1)^J \)

• unnatural-parity \( P = (-1)^{J+1} \)

• "Stichel's theorem" (Z. Phys. 180, 170 (1964))

• to the leading power in \( s \), cross section for photon polarized \( \perp \) to production plane dominated by natural-parity exchange

• for photon polarized \( \parallel \) to production plane dominated by unnatural-parity exchange

\[
\text{Beam Asymmetry} \quad \Sigma = \frac{(d\sigma_\perp/dt) - (d\sigma_\parallel/dt)}{(d\sigma_\perp/dt) + (d\sigma_\parallel/dt)}
\]
GlueX Detector

- Jefferson Lab, Newport News, VA, USA
- Hall D
- CEBAF ➞ 12 GeV electron beam

- Photons are linearly polarized relative to crystal axes in the diamond
- Coherent bremsstrahlung
- Two polarization modes: PARA ➞ $\vec{E} \parallel$
  PERP ➞ $\vec{E} \perp$
Event Selection

\[ \gamma + p \rightarrow K^+ + \Sigma^0(1193) \Rightarrow \Sigma^0 \rightarrow \Lambda \gamma \]

- Select combinations of particles matching the topology of
  \[ \gamma p \rightarrow K^+ \Lambda \gamma \ (\Lambda \rightarrow \pi^- p) \]
- Two positive tracks, one negative track and one neutral shower in final state
- \(-0.08 \text{ GeV}^2 < M_X^2 < 0.08 \text{ GeV}^2\)
- Kinematic fit satisfying the conservation of energy and momentum
  (confidence level > 0.0001)
- PID for charged tracks was done with TOF and for photons with EM calorimeters
Invariant Mass of $\pi^- p$

- Coherent peak $\Rightarrow 8.2 < E_{beam} < 8.8$ GeV

- Accidentals are scaled by the time window
Invariant Mass of $\pi^- p \gamma$

- Events within $1.107 < M_{\pi^- p} < 1.125$ GeV/c$^2$
$M_{\pi^-, \rho\gamma}$ vs FCAL shower quality

- Cut to remove extra showers from hadrons misidentified as photons in forward calorimeter (FCAL)
- Shower quality variable $\rightarrow$ developed using neural net technology
Cut on shower quality

- Shower quality $>0.5 \Rightarrow$ clean $\Sigma^0$ peak
- Background of uncorrelated photons eliminated
-t distribution

- Events within $1.169 < M_{\pi^- p\gamma} < 1.217 \text{ GeV}/c^2$

\[-t = -[(p_{beam} - p_{K^+})^2]\]

- Both t- and u-channel contributions
Photon Beam Asymmetry

\[
\sigma = \sigma_0[1 - P_\gamma \Sigma \cos 2(\phi_{K^+} - \phi_{\gamma}^{\text{lin}})]
\]

In terms of PARA and PERP yields and polarizations

\[
\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel) \Sigma \cos 2(\phi_{K^+} - \phi_0)}{2 + (P_\perp - P_\parallel) \Sigma \cos 2(\phi_{K^+} - \phi_0)}
\]

- \(\Sigma\) - Beam asymmetry
- \(P_\gamma\) - Degree of photon polarization
- \(\phi_{K^+}\) - Azimuthal angle of production plane
- \(\phi_{\gamma}^{\text{lin}}\) - Azimuthal angle of photon beam linear polarization plane
Yield Asymmetry

\(-t=0.1-0.35\) bin for 45/135

\[ p_0 = \sum \rightarrow \text{Beam asymmetry} \]
Beam Asymmetry of $\gamma p \rightarrow K^+ \Sigma^0$

- Combined result from two orientation sets (errors are statistical only)


SLAC data: Phys. Rev. D 20 1553 (1979)
Outlook

• Work on the systematics

• Finalize the asymmetry measurement for $u$-channel (first time measurement)

• Work on the draft paper
Backup - Effect of the cut on MC

\[ K^+ \Sigma^0 \quad t\text{-channel} \]

\[ K^+ \Lambda \quad t\text{-channel} \]

- FCAL shower quality > 0.5 cut eliminates the background coming from \( K^+ \Lambda \ t\text{-channel} \)
- No loss of signal events due to the cut
Backup-Yield Asymmetry (0/90) for $t$ bins

- $t=0.1-0.35$
- $t=0.35-0.50$
- $t=0.50-0.70$
- $t=0.70-1.40$
Backup-Yield Asymmetry (45/135) for $t$ bins

- $t=0.1-0.35$

- $t=0.35-0.50$

- $t=0.50-0.70$

- $t=0.70-1.40$