Measurement of the Photon Beam Asymmetry $\Sigma$ for

$$\gamma + p \rightarrow K^+ \Sigma^0 \text{ at } E_\gamma = 8.5 \text{ GeV}$$

in GlueX

Nilanga Wickramaraarachchi and Moskov Amaryan

On behalf of the GlueX Collaboration

MENU-2019, Pittsburgh, PA 06/06/2019
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
Regge Model

- Scattering amplitude $\Rightarrow$ exchange of Regge trajectories at high energies
- Regge trajectory $\Rightarrow$ resonances with identical internal quantum numbers but different spins $J$
- Have relation $J_i = \alpha(m_i^2)$ for different masses
Regge Plus Resonance Model


\[ M_{RPR} = \sum_{K^*} \left( \begin{array}{c} \gamma \\
\rightarrow K \\
\end{array} \right) + \sum_{R} \left( \begin{array}{c} \gamma \\
(\gamma p) \rightarrow R \\
\end{array} \right) \]

• \( t \)-channel ➔ \( K^* \) trajectories

• For photon lab energies \( \geq 4 \) GeV resonant contribution vanish

• GlueX energies ➔ only Regge part of amplitude
Previous Measurements

LEPS 1.5-3.0 GeV

SLAC 16 GeV
Phys. Rev. D 20 1553 (1979)
Physics Motivation

- Linearly polarized photon beam to study exchange of parity
  - natural-parity \( P = (-1)^J \) (e.g. K*(892))
  - unnatural-parity \( P = (-1)^{J+1} \) (e.g. K(494))

- "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 orthogonal polarization modes: PERP, PARA → (0/90 and 45/135)
Event Selection

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

\[ \gamma p \rightarrow K^+ \Lambda \gamma \ (\Lambda \rightarrow \pi^- p) \]

- Two positive tracks, one negative track and one neutral shower in final state
- Missing Mass Squared cut (exclusive reaction)
- Kinematic fit satisfying the conservation of energy and momentum
- Vertex cuts to select kaons within the target region
- PID using TOF
- dE/dx cut for proton selection
- FCAL shower quality > 0.5
Event Selection

Counts/0.1 ns

Counts/0.5 cm

Counts/0.2 (MeV/c²)

π⁺/K⁺/e⁺

protons
Invariant Mass of $\pi^- p$

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

- Accidentals are scaled by the time window

![Graph showing counts vs. invariant mass for $\pi^- p$ with peaks and labeled $\Lambda(1116)$]
Invariant Mass of $\pi^- p \gamma$

- Events within $1.107 < M_{\pi^- p} < 1.125$ GeV/$c^2$

- Very clean $\Sigma^0$ peak
-t distribution

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

- $t = (p_{\text{beam}} - p_{K^+})^2$

- 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

\[
\frac{Y_\perp - F_R Y_\parallel}{Y_\perp + F_R Y_\parallel} = \frac{(P_\perp + P_\parallel)\Sigma \cos 2\phi}{2 + (P_\perp - P_\parallel)\Sigma \cos 2\phi}
\]

Cancels acceptance effects

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

\[ \chi^2 / \text{ndf} \quad 22.02 / 19 \]

\[ \text{Prob} \quad 0.2831 \]

\[ p_0 \quad 0.9201 \pm 0.0538 \]
Yield Asymmetry for u-channel

\[ \chi^2 / \text{ndf} \quad 13.21 / 9 \]

Prob 0.1532

p0 0.3901 ± 0.1097
Beam Asymmetry of $\gamma p \to K^+ \Sigma^0$

- Combined result from two orientation sets
- Errors are statistical $\oplus$ systematic

$\Sigma \sim 1$

Natural parity exchange ($K^*(892)$)

First ever measurement for beam asymmetry vs. $-u$


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

• Photon beam asymmetry above resonance region in t-channel is measured with much higher precision than at SLAC

• It is well described by RPR model and confirms dominance of natural parity exchange

• Photon Beam Asymmetry for u-channel has been measured for the first time and there are no theory model predictions yet to perform any comparison

• Presented results have been released by the GlueX Collaboration as preliminary and soon will be submitted for a publication
Backup: \(-t\) and \(-u\) distributions

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

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

- Both \(t\)- and \(u\)-channel contributions
t-channel and u-channel separate MC

sum of all MC
Yield Asymmetry (0/90) for $t$ bins

- $t=0.1-0.35 (GeV/c)^2$

- $t=0.35-0.50 (GeV/c)^2$

- $t=0.50-0.70 (GeV/c)^2$

- $t=0.70-1.40 (GeV/c)^2$
Yield Asymmetry (45/135) for $t$ bins

$-t=0.1-0.35 \ (GeV/c)^2$

$-t=0.35-0.50 \ (GeV/c)^2$

$-t=0.50-0.70 \ (GeV/c)^2$

$-t=0.70-1.40 \ (GeV/c)^2$
Yield Asymmetry (0/90) for $u$ bins

- $u=0.1-0.5 \ (GeV/c)^2$
- $u=0.5-0.65 \ (GeV/c)^2$
- $u=0.65-1.1 \ (GeV/c)^2$
Yield Asymmetry (45/135) for $u$ bins

- $u=0.1-0.5 \ (GeV/c)^2$
- $u=0.5-0.65 \ (GeV/c)^2$
- $u=0.65-1.1 \ (GeV/c)^2$
$\Lambda$ peak within $\Sigma$ region

$M_{\pi^- p}$

- Very clean $\Lambda$ peak!