Measurement of the beam-target double polarisation observable, $E$, for $\gamma(p,K^0)\Sigma^+$

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Measurement of the beam-target double polarisation observable, $E$, for $\gamma(p,K^0)\Sigma^+$

- Polarisation observables and motivation
- CBELSA/TAPS experiment
- Identification of the $\gamma(p,K^0)\Sigma^+$ channel
- The kinematic fit
- Results
Polarisation observables in photoproduction experiments

- Crucial for the determination of baryon resonance structure
- Global effort to determine sufficient single and double polarisation observables for model independent analysis of meson photoproduction

Polarisation observables in strangeness photoproduction

- Measurement of the beam-recoil observables, $C_X$ and $C_Z$ for $\gamma(p,K^+)^\Lambda$

$C_Z \approx 1$, $C_X \approx 0$ for all angles and energy [1].

- “Toy” model proposed [2]:

• $\gamma(p,K^+)\Lambda$ has s-channel and t-channel contributions, for example:

\[
\begin{align*}
\gamma(p,K^+) &\rightarrow K^+ \\
p &\rightarrow \Lambda
\end{align*}
\]

- s-channel

\[
\begin{align*}
\gamma &\rightarrow K^+ \\
\Lambda &\rightarrow K^+
\end{align*}
\]

- t-channel

• $\gamma(p,K^0)\Sigma^+$ does not have the same t-channel process ($\gamma$ cannot couple to $K^0$)

• t-channel with $K^*$ vector mesons can contribute however, for example:

\[
\begin{align*}
\gamma(p,\Sigma^+) &\rightarrow K^0 \\
\Sigma^+ &\rightarrow K^*(892)
\end{align*}
\]

t-channel contributions must be understood for any partial wave analysis which using s-channel resonances
\[ \gamma(p,K^0)\Sigma^+ \] cross sections

- Cross section measurements suggest strong t-channel dependency:


It is predicted that “E” will be particularly sensitive to t-channel contributions.
Identifying t-channel contributions with “E”

• Longitudinally polarised target (butanol), circularly polarised photon beam

\[
E = \frac{\sigma_{1/2} - \sigma_{3/2}}{\sigma_{1/2} + \sigma_{3/2}}
\]

\[
E = \frac{N_{1/2} - N_{3/2}}{N_{1/2} + N_{3/2}} \cdot \frac{1}{P_T P_B f}
\]

• Expect non-zero “E” for s-channel, but zero “E” for entirely t-channel

(Red arrows show spin direction)
The CBELSA/TAPS experiment

ELSA $e^-$ beam (2350 MeV, circularly polarised)

Crystal Barrel.
1380 CsI(Tl) crystals
$30^\circ$ – $160^\circ$

Forward plug.
$30^\circ$ – $12^\circ$

November 2009 beam time:
~ 23 days of data
Circularly polarised beam, longitudinally polarised target

MiniTAPS.
216 BaF$_2$ crystals, < $12^\circ$
Event selection

\[ \gamma p \rightarrow K^0 \Sigma^+ \]
\[ \rightarrow p \pi^0 \quad \Gamma \sim 52\% \]
\[ \pi^0 \pi^0 \quad \Gamma \sim 31\% \]

- 1 charged, 6 neutral hits, with timing cuts
- Reject events with 6\(\gamma\) invariant mass < 600 MeV (remove p\(\eta\) channel)
- Select best of 15 combinations of 6\(\gamma\) into 3\(\pi^0\) (with mass cuts)
Event selection

• Three combinations of constructing $K^0$ and $\Sigma^0$ from $3\pi^0$. Reject combinations where azimuthal angle difference is less than $150^0$

• Reject events where the beam energy is below threshold ($< 1050$ MeV)

• Use prompt / random timing in the tagger to statistically reject background

• Reconstruct proton mass from $3\pi^0$ and cut on mass
- Reconstruct $K^0$ invariant mass and “missing mass”

- Select events where “missing mass” is between 1170 – 1210 MeV.

Conclude that this is insufficient to constrain the reaction channel in the experimental data due to background.
Kinematic fitting

- A least squares fit with constraints (e.g. one reaction vertex, and momentum conservation)

- Use the hypothesis: $\gamma p \rightarrow p \pi^0 \pi^0 \pi^0$ and test on an event by event basis

- Inputted errors for beam energy, photon energy and direction

- Allow variables to shift value and compare to the inputted error

- Pull distributions: a measure of how the shift of variables compares to the known error.

- Confidence level: should be flat for events which match the hypothesis
Present status

- Fit 3\textsuperscript{rd} order polynomial to the background and Gaussian function to the invariant mass peak

- \[ \sigma_{3/2} \] (target – beam spins aligned)
Present status

1050 – 1250 MeV

1250 – 1500 MeV

1500 – 1750 MeV

1750 – 2000 MeV

2000 – 2250 MeV

1050 – 2250 MeV
Future plans

• Implement proton direction into the kinematic fit

• Target length as a further constraint (or K^0 decay length?)

• Extraction of asymmetries

• Dilution factor (compare data on carbon targets)

• Beam and target polarisation
Back up slides
Event selection

- Identify one proton and six photons with CB/ELSA:
  \[ \gamma p \rightarrow K^0 \Sigma^+ \rightarrow p\pi^0 (\Gamma \sim 5\%) \]
  \[ \pi^0\pi^0 (\Gamma \sim 31\%) \]

- 1 charged, 6 neutral hits, with relative timing cuts
  \[ 20.0 < t < 50.0 \text{ ns} \]

- Time difference between neutral hits < 10.0 ns

- Time difference between neutral and charged hit < 20.0 ns
Event selection

- Construct the $K^0$ and $\Sigma^+$ four momentum from decay particles (3 combinations)
- Reject combinations with coplanarity $> 150.0^\circ$
Event selection

- Invariant mass of the 6 neutral hits > 600 MeV (reject $\gamma p r p \eta$)
- Invariant mass of 3 $\pi^0$ from the 6 neutral PEDs (15 combinations)
- Select the lowest $\chi^2$ as the best candidate

$$\chi^2 = \sum \frac{(m_{\gamma\gamma} - m_{\pi^0})^2}{\sigma^2}$$
Event selection

- Construct the $K^0$ and $\Sigma^+$ four momentum from decay particles (3 combinations)
- Reject combinations with coplanarity > 150.0°
Event selection: Beam photon selection cuts

- Reject events where $E_\gamma < 1050$ MeV
- Select two timing regions:
  - "Prompt" hits: $-20.0 < t_p < 25.0$ ns
  - "Random" hits: $-500.0 < t_R < -100.0$ ns; $100.0 < t_R < 500.0$ ns

- Reconstruct proton mass from $3\pi^0$ 4-momentum:
Kinematic fitting

- A least squares fit with constraints

- Use the hypothesis: $\gamma p \parallel p \pi^0 \pi^0 \pi^0$ and test on an event by event basis

- Inputted errors for beam energy, neutral PED energy and direction

Confidence level cut on > 0.1