Differential Cross-Sections and Recoil Polarizations for $\gamma p \rightarrow K^+\Sigma^0$ from CLAS at Jefferson Lab

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# Outline

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Search for “Missing” Baryons in the Strange Sector

- Constituent quark models predict many more nucleon resonances than observed in $N\pi$ partial wave analyses
- Koniuk & Isgur (1980) – “missing” resonances exist, but don’t couple to $N\pi$
- Study non-$N\pi$ channels ($N\eta, N\omega, \Delta\pi, K\Lambda, K\Sigma, \ldots$)
- Capstick & Roberts (1998) – appreciable strength for several un-observed negative parity baryons decaying into the strange sector
- Experiments at Jefferson Lab (CLAS), Bonn (SAPHIR), Grenoble (GRAAL), Osaka (LEPS) are looking for these “missing” baryons in Kaon electro- and photo-production
Search for “Missing” Baryons in the Strange Sector

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We report new measurements for $\gamma p \rightarrow K^+\Sigma^0$ from CLAS (g11a dataset) at Jefferson Lab
Event Selection Overview

\( \gamma p \rightarrow K^+ \Sigma^0 \) event selection utilizes the \( \Sigma^0 \rightarrow \gamma_{out} \Lambda \rightarrow \gamma_{out} p \pi^- \) decay

- **Three-track topology:** \( \gamma p \rightarrow K^+ p \pi^- (\gamma) \)
  - detect all charged tracks \( (K^+ p \pi^-) \)
  - \( \gamma_{out} \) from missing momentum (via kinematic fitting)
  - Excellent PID

- **Two-track topology:** \( \gamma p \rightarrow K^+ p (\pi^- \gamma) \)
  - detect \( K^+ p \)
  - \( \gamma_{out} \) and \( \pi^- \) momenta remain unknown
  - Larger Acceptance (esp. in Backward Angles)
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- **Timing cuts**
- Select \( \Sigma \)'s using an *event-based* background separation method
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  - $\sim 0.65 \text{million}$ events

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  - $\sim 1.61 \text{million}$ events

- Timing cuts

- Select $\Sigma$'s using an event-based background separation method
COMPARE: TWO- AND THREE-TRACK RESULTS

Different event-selection, particle identification, analysis techniques. No Kinematic Fitting in two-track topology. Agreement is very satisfactory.

Final $g_{11a}$ cross-sections: weighted average of two results
**CROSS-SECTIONS – BACKWARD ANGLES**

\[-0.85 < \cos \theta_{CM}^{K^+} < -0.75\]

- **CLAS g11a**
- **CLAS g1c (2005)**
- **SAPHIR (2004)**

\[g11a \text{ and } g1c – \text{very good agreement}\]

SAPHIR does not show “hump” at $\sim 2.2$ GeV
**Differential Cross-sections**

**Cross-sections – Mid Angles**

\[-0.05 < \cos \theta_{CM}^{K^+} < 0.05\]

- \(\text{CLAS g11a}\)
- \(\text{CLAS g1c (2005)}\)
- \(\text{SAPHIR (2004)}\)

\(g_{11a}\) and \(g_{1c}\) – very good agreement

SAPHIR “slightly” low
CROSS-SECTIONS – FORWARD ANGLES

\[ 0.65 < \cos \theta^{K^+}_{CM} < 0.75 \]

- CLAS g11a
- CLAS g1c (2005)
- SAPHIR (2004)
- LEPS (2005)

\( g_{11a} \) “slightly” lower than both \( g_{1c} \) and SAPHIR
LEPS doesn’t really resolve the discrepancy
Recoil Polarizations

- full characterization of $\gamma p \rightarrow K^+ \Sigma^0$ require differential cross sections plus 7 polarization measurements

- polarizations measurable from the self-analysing nature of $\Sigma^0$ and $\Lambda$ decays

- $g11a$ had unpolarized beam and unpolarized target: recoil polarization ($P_\Sigma$) only. (others will be available from FROST)

- previous $P_\Sigma$ world data is scarce: present analysis offers wide kinematic coverage and a many fold increase in statistics

- additional precision: $\Sigma^0-\Lambda$ spin transfer correlation is preserved in this analysis
### Recoil Polarizations

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**Preliminary**
Summary

- \( \frac{d\sigma}{\cos \theta_{CM}^{K^+}} \) measured for \( \gamma p \rightarrow K^+\Sigma^0 \) from threshold till 2.84 GeV with wide angular coverage from the CLAS \( g11a \) dataset.

- Two-track analysis allows us to confirm structure around \( \sim 2.2 \) GeV earlier seen in CLAS \( g1c \) at backward angles.

- *Slightly* lower than CLAS \( g1c \) and SAPHIR in a few mid-forward mid-energy bins.

- \( P_\Sigma \) measured for \( \sqrt{s} \) from 1.8 to 2.85 GeV and \( \cos \theta_{CM}^{K^+} > -0.5 \). *Greatly extends* \( P_\Sigma \) world data in both precision and kinematic coverage.
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- PWA for missing baryon resonance searches using these measurements is in progress

- Simultaneously, publish present results
Timing Cuts

Three-track  Two-track

PWA Group  (CMU)  CLAS g11a analysis  May 2
Signal-background Separation

Three-track

1.9 GeV/c^2 ≤ √s ≤ 2.1 GeV/c^2

2.3 GeV/c^2 ≤ √s ≤ 2.5 GeV/c^2

2.7 GeV/c^2 ≤ √s ≤ 2.84 GeV/c^2
**Signal-background Separation**

Two-track

1.9 GeV/c² ≤ √s ≤ 2.1 GeV/c²

2.3 GeV/c² ≤ √s ≤ 2.5 GeV/c²

2.7 GeV/c² ≤ √s ≤ 2.84 GeV/c²

Signal  Background
Quality of PWA fits

\[ \sqrt{s} = 2.005 \text{ GeV/c}^2 \]

\[ \sqrt{s} = 2.705 \text{ GeV/c}^2 \]

(Three-track topology only)
**Extraction of $P_\Sigma$**

**CM frame**

Similarly, next, go to the $\Lambda$ Helicity Frame

$C \propto 1 + \alpha \langle \vec{P}_\Lambda \rangle \cos \theta_{\Lambda HF}^p = 1 + \alpha \left( -\langle \vec{P}_{\Sigma^0} \rangle \cos \theta_{\Sigma HF}^\Lambda \right) \cos \theta_{\Lambda HF}^p$

If $\gamma$ not observed,

$P_\Lambda = -P_{\Sigma} \cos \theta_{\Sigma HF}^\Lambda$

$\Lambda$ decay is *self-analysing*