Strangeness Production on the Neutron via the Reaction
\[ \gamma n (p) \rightarrow K^+ \Sigma^- (p) \]

- motivation
- experiment
- K+ identification, kinematic corrections
- inclusive/exclusive analysis
- background studies
- acceptance/efficiency
- unfolding the \( \Sigma^- \) cross section

Jörn Langheinrich
NSTAR 2005
Strangeness Photoproduction

Isospin Channels:

\[ \gamma p \rightarrow K^+ \Lambda \]
\[ \gamma p \rightarrow K^+ \Sigma^0 \]
\[ \gamma n \rightarrow K^+ \Sigma^- \]
\[ \gamma n \rightarrow K^0 \Lambda \]
\[ \gamma n \rightarrow K^0 \Sigma^0 \]
\[ \gamma p \rightarrow K^0 \Sigma^+ \]
CEBAF Large Acceptance Spectrometer
g2a experiment

Beam energy $E_0$: 2.5 GeV
Photon energy: 20% - 95% of $E_0$ (tagged region)
Trigger: tagger + 1 charged (or 2 neutral)
Torus current: 87% pos. outbending
Beam current: 10-13 nA $10^{-4}$ radiator
Events recorded: over $2 \times 10^9$

This Analysis:
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Sponsor:
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Contributions:
Bernhard Mecking
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Ulrike Thoma
All nice people doing g2 cooking, calibration, and shifts
$K^+$ cuts
$p_{K^+} = 0.504$ [GeV]

$\sigma_{\text{fit}} = 7.8$ [MeV]

$K^*_\text{MASS}$ [GeV]

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$K^*_\text{MASS}$ [GeV]

$p_{K^+} = 1.031$ [GeV]

$\sigma_{\text{fit}} = 22.8$ [MeV]

$p_{K^+} = 1.515$ [GeV]

$\sigma_{\text{fit}} = 36.9$ [MeV]
K⁺ Mass Peak / Resolution

Data
MC Simulation
Polynomial(3) function

Data
MC Simulation
Several gpp settings
K$^+$ Time-of-Flight Correction

Before

Kaon mass [GeV/c$^2$]

$\Phi$ [deg]
$K^+$ Time-of-Flight Correction

After

Kaon mass [GeV/c$^2$]

$\Phi$ [deg]

... consider fiducial cuts
Inclusive or Exclusive analysis?

\[ \Sigma^- \text{ missing mass} \]

- **High Acceptance**
  - Flat Acceptance
  - High $\theta$, $E_\gamma$ coverage
  - Model independent simulation
  - Background easy to understand

\[ \Sigma^- \rightarrow \pi n \]

- **Separation of $\Sigma^-$**
  - Stand alone analysis
  - High mass resolution
  - Fermi motion correction
  - Low background

Let's do both!

Ana Lima
Jörn Langheinrich

Ioana Niculescu
Gabriel Niculescu
$M_X = \sqrt{M_N^2 + M_K^2 - 2M_N E_K + 2E_Y (M_N - E_K + p_K \cos \theta)}$
Assuming Nucleon Target

![Plot showing the distribution of missing mass against the angle of decay, with peaks indicating the presence of different particles such as n, Λ, Σ, and Σ(1385).]
Other Assumptions

Deuterium target

Misidentified $\pi^+$
Missing mass vs Kaon mass

\[ \Sigma(1385) \]

\[ \Sigma \]

\[ \Lambda \]
Divide missing mass distribution into bins
Fit K+ mass distribution in each bin

Check fit quality!
Hyperon structure in background

$\Sigma$ peak 7695.4 evts

$\Lambda$ peak 6412.61 evts

background 4867.39 evts

miss. mass ($1.362 < E_\gamma < 1.462 \quad 0.7 < \cos \theta_K^{CM} < 0.8$)

Pion contrib. identified by $\gamma p \rightarrow n\pi^+$

Background probability Method:
K⁺ Efficiency / Lab System

MC-simulation using isobar model [T.Mart] as event generator

thrown

reconstr.

background

acceptance
Smear $\Lambda$, $\Sigma^0$ photoproduction cross section measured off proton target [McNabb, Schumacher] by Fermi motion.

Apply phenomenological fit (Legendre Polynom) to get $\Sigma^0 / \Lambda$ ratio

Use this ratio and our measured $\Lambda$ cross section off deuteron target to calculate $\Sigma^0$ cross section

Subtract calculated $\Sigma^0$ cross section from our measured $\Sigma_{\text{TOTAL}}$
Differential Cross Section

Preliminary

\[ \Lambda \]

\[ \frac{d\sigma}{d\cos \theta} \quad [\mu b] \]

\[ \begin{array}{c}
\text{E}_y = 1.012 \\
\sum \\
\text{below threshold}
\end{array} \]

\[ \begin{array}{c}
\text{E}_y = 1.113 \\
\sum
\end{array} \]
Differential Cross Section

Preliminary

Our Analysis
Cross Section off Proton [McNabb, Schumacher]
After Sigma0 Subtraction
Our Analysis

Cross Section off Proton [McNabb, Schumacher]

After Sigma0 Subtraction
Our Analysis
Cross Section off Proton [McNabb, Schumacher]
After Sigma0 Subtraction
Our Analysis
Cross Section off Proton [McNabb, Schumacher]
After Sigma0 Subtraction
Our Analysis
Cross Section off Proton [McNabb, Schumacher]
After Sigma0 Subtraction
$W$ dependence of results

Preliminary

$\cos \Theta_{K}^* = 0.35$

$\Sigma$ after $\Sigma^0$ subtraction

Results from exclusive analysis

Kaon MAID
W dependence of results

Preliminary

$\Sigma$ after $\Sigma^0$ subtraction

Results from exclusive analysis

Kaon MAID
$\Sigma$ after $\Sigma^o$ subtraction

Results from exclusive analysis

Kaon MAID
$W$ dependence of results

$\cos \Theta_K^* = 0.65$

$\Sigma$ after $\Sigma^0$ subtraction

Results from exclusive analysis

Kaon MAID
$W$ dependence of results

Preliminary

$\cos \Theta_K^* = 0.75$

\[ \sigma/d\Omega [\mu b/sr] \]

$W [\text{GeV}]$

$\Sigma$ after $\Sigma^0$ subtraction

Results from exclusive analysis

Kaon MAID
Accomplished:

Robust, model independent analysis
Good/fair reproduction of $\Lambda$ cross section
Surprising result for $\Sigma^-$ cross section
  $\Sigma^-$ cross section lower than expected
cos $\Theta$ structure: minimum at 0.45

To do:

Compare exclusive and inclusive
Discuss systematic errors

Your suggestion goes here

Analysis review process