Strangeness Production in Hall B
(From a Hyperon-production-centric view)

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K Hyperon Production Mechanisms

Depend upon phenomenological calculations

Nucleon resonances: “Missing” baryon searches

Hyperon resonances: Backward peaking

Meson & Reggeon exchange: Forward peaking

The differing isospins of the $\Lambda(I=0)$ and $\Sigma(I=1)$ act as a filter for s-channel resonances.
Model Comparisons

- **Effective Lagrangian Models**
    - $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1895)$
    - $K^*(892)$, $K_1(1270)$
    - $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1895)$
    - $K^*(892)$
    - $\Lambda^*(1800)$, $\Lambda^*(1810)$

  Quantities such as form factors and coupling constants are free parameters in fits of the data.

- **Regge Exchange Model**
  - M. Guidal, J.M. Laget, and M. Vanderhaeghen
    - $K$ and $K^*(892)$ trajectories exchanged
Cross Section for Electroproduction

\[ \frac{d^5 \sigma}{dE' d\Omega_e d\Omega_K^*} = \Gamma \frac{d^2 \sigma_v}{d\Omega_K^*} \]

Unpolarized beam/target/recoil

\[ \frac{d^2 \sigma_v}{d\Omega_m^*} = \sigma_T + \varepsilon \sigma_L + \varepsilon \sigma_{TT} \cos 2\phi + \sqrt{2\varepsilon(\varepsilon + 1)} \sigma_{LT} \cos \phi \]

photo-production cross-section

= - \Sigma \sigma_T \text{ in photoproduction}
Kaon and Hyperon Identification

- Kaon identified via time-of-flight (scintillators)
- Electroproduction: detect electron and kaon
- Photoproduction: detect photon (tagger), kaon, and proton
- Exclusive reaction, so use $p(\gamma^*, K^+)$ missing mass to identify the Hyperon
- Background removed under missing-mass distributions via fit to the Hyperon peaks.
Λ Photoproduction Differential Cross-sections

threshold

Kinematic coverage:
- 25 MeV wide bins
- Δcosθ=0.1
- 1377 data points

Forward peaking.


W=2.53 GeV
$\Sigma^0$ Photoproduction Differential Cross-sections

Kinematic coverage:
- 25 MeV wide bins
- $\Delta \cos \theta = 0.1$
- 1280 data points

Evolving angular distribution as $W$ increases.


W=2.53 GeV
Angular distributions: Λ and Σ^0 comparison
Photo-production total cross-sections

- Disagreement with SAPHIR total cross-sections for $\Lambda$ but not for $\Sigma^0$
- Features around 1.9 GeV in $\Lambda$, and 1.85 in $\Sigma^0$
- Trends match Regge-model calculations at high $W$.

What is needed to make an impact?


- Fits to differential cross-sections and recoil polarizations (SAPHIR data) found many solutions of similar quality.
- The solutions fell into families… (see $P_{13}$, $D_{13}$)
- … but we need observables that are sensitive to the differences.
Photoproduction polarization observables are sensitive to the different sets. “The clear differences in the asymmetries between the two subsets will require only modest statistical accuracy to distinguish experimentally.”

With CLAS, we have measurements of the electoproduction-equivalent to Σ now (photoproduction analysis is underway).
4 different data sets were analyzed:
- 2.5 GeV, 1500 A torus current
- 2.5 GeV, 2250 A torus current
- 4.1 GeV, 2250 A torus current
- 4.3 GeV, 2250 A torus current

The different energy and torus current data sets have different effective geometric coverage of the CLAS detector.

\[ 0.5 \leq Q^2 \leq 2.6 \text{ GeV}^2 \quad 1.6 \leq W \leq 2.4 \text{ GeV} \]

Within an energy setting, the structure functions could be cross checked.
Electroproduction Structure Functions

- Extracted interference terms from 2.5 and 4.0 GeV datasets separately and with a combined “ε-ϕ fit”.
- Typical systematic uncertainty contributions were

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Total: 9.9% pt-to-pt

6.0% scale
Ratio results: $\sigma_L/\sigma_T$

$Q^2=1.0$ GeV$^2$

First ever L/T separation away from $\cos\theta^*_K=1$

- Mohring et al., (Hall C) PRC 67, 055205 (2003).
- Markowitz et al., (Hall A) unpublished (stat. uncertainties only)

Statistical uncertainties only
Currently only have two \( \varepsilon \) values from two beam energies.

There are FIVE more data sets at different beam energies to analyze. The 3.2 and >5 GeV datasets have 3x greater statistics.

What have we learned?

• Rosenbluth separations are hard, especially with large-acceptance devices.

• Prefer more than two-points to perform the separation.
Hyperon Structure Functions – backward angles

Photoproduction results (Bradford)

\[ \cos \theta_K^* = -0.6 \ , \ Q^2 = 0.65 \text{ GeV}^2 \]
Hyperon Structure Functions – central angles

Photoproduction results (Bradford)

Σ-equivalent at $W=1.92$ GeV:
- $R_{LT}$ was 0.5 to $0.75 \pm 0.5$, $\varepsilon \sim 0.43$, so $\sigma_T \sim 60 \pm 15\text{nb/sr}$
- $\Sigma^{(*)} \sim 0.5 \pm 0.2$
  - Favors stronger $D_{13}$ coupling

Non-zero $\sigma_{LT}$ requires $\sigma_L > 0$
Hyperon Structure Functions – forward angles

Photoproduction results (Bradford)

\[ \cos \theta K^* = 0.9, \ Q^2 = 0.65 \text{ GeV}^2 \]

Janssen, Ryckebusch et al
Guidal, Laget, and Vanderhaeghen
Other current or recently completed
Strangeness production projects

- Measurement of helicity-correlated structure function $\sigma_{LT}'$
- Transferred and induced Hyperon polarization
- Radiative decay of the $\Lambda(1520)$
- Line-shape of the $\Lambda(1405)$
- $\Lambda$ photo-production off of deuterium
- Cascade photo-production off the proton
- $\Phi$-meson photo-production off the proton
Conclusions

- High-quality photoproduction cross-section measurements have been published (McNabb et al, Bradford et al), surpassing the competition in coverage and statistics.

- $\Lambda$ production:
  - $t$-channel and $s$-channel diagrams play a large role
  - $\sigma_L$ remains “small” from small to large angles, though $\sigma_{LT}$ shows that it is non-zero
  - Together, the photo- and electro-production results favor calculations with non-zero coupling to the $D_{13}(1895)$

- $\Sigma^0$ production:
  - $s$-channel diagrams are most important at low energy
  - $t$-channel/Reggeon exchange dominates when $W>2$ GeV (above the resonance region)
  - $\sigma_L$ and $\sigma_{LT}$ for the $\Sigma^0$ remain “small” from small to large angles
  - Strong resonance-like structure in the $\Sigma^0$ at $W=1.9$ GeV.

- CLAS is providing the first measurements of the interference terms and $R_{LT}$ for scattering angles above $15^\circ$

- The strangeness program with CLAS continues, through both new experimental opportunities and a mining of the rich CLAS dataset.