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

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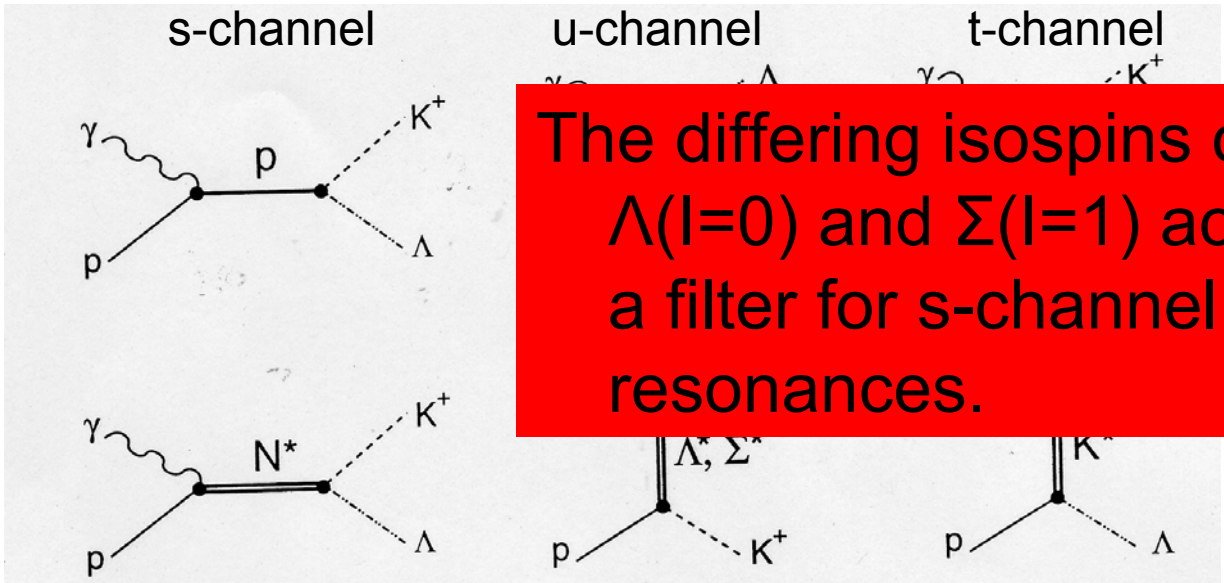
K Hyperon Production Mechanisms

Depend upon phenomenological calculations



The differing isospins of the Λ(I=0) and Σ(I=1) act as a filter for s-channel resonances.

Nucleon resonances: "Missing" baryon searches

Hyperon resonances: Backward peaking

Meson & Reggeon exchange: Forward peaking

Model Comparisons

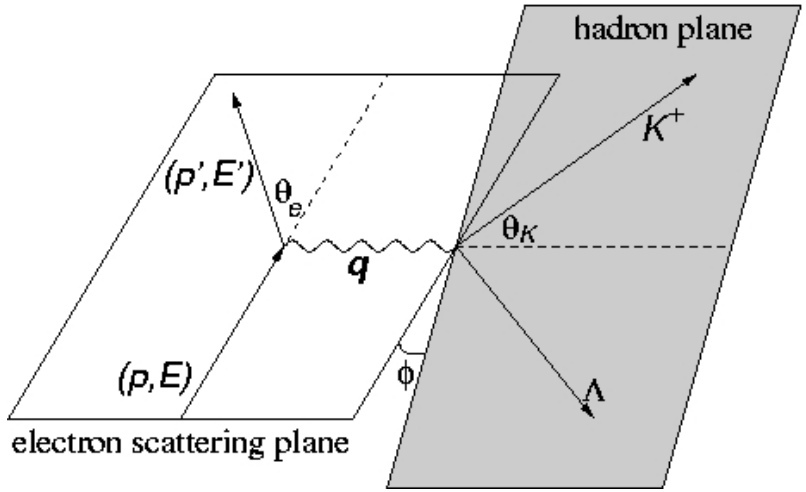
- Effective Lagrangian Models
  - T. Mart, C. Bennhold *et al.* (KAON-MAID) *PRC* ***61****, 012201 (2000)*
    - $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1895)$
    - $K^*(892)$, $K_1(1270)$
  - S. Janssen, J. Ryckebusch *et al.*, *PRC* ***65****, 015201 (2001)*
    - $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$, $D_{13}(1895)$
    - $K^*(892)$
    - $\Lambda^*(1800)$, $\Lambda^*(1810)$

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
    NPA ***627****, 645 (1997); PRC* ***61****, 025204 (2000)*
    - K and $K^*(892)$ trajectories exchanged

Cross Section for Electroproduction

$$\frac{d^5\sigma}{dE'\,d\Omega_e\,d\Omega_K^*} = \Gamma \frac{d^2\sigma_\nu}{d\Omega_K^*}$$



Unpolarized beam/target/recoil

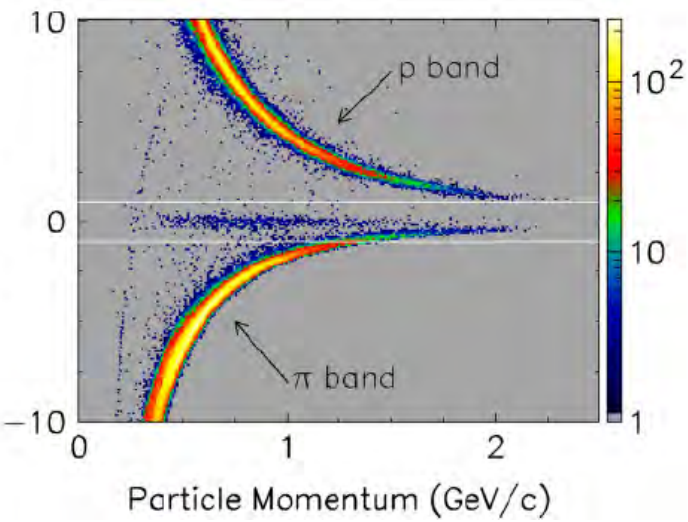
$$\frac{d^2\sigma_\nu}{d\Omega_m^*} = \sigma_T + \varepsilon\sigma_L + \varepsilon\sigma_{TT}\cos 2\phi + \sqrt{2\varepsilon(\varepsilon+1)}\,\sigma_{LT}\cos\phi$$

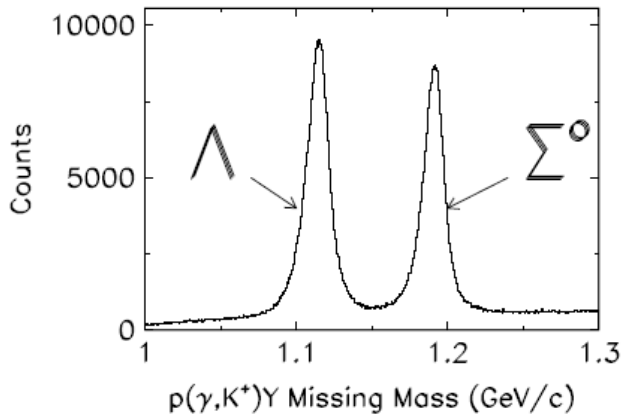
photo-production cross-section

= - Σ σ_T in photoproduction

Kaon and Hyperon Identification

Photoproduction (Bradford)

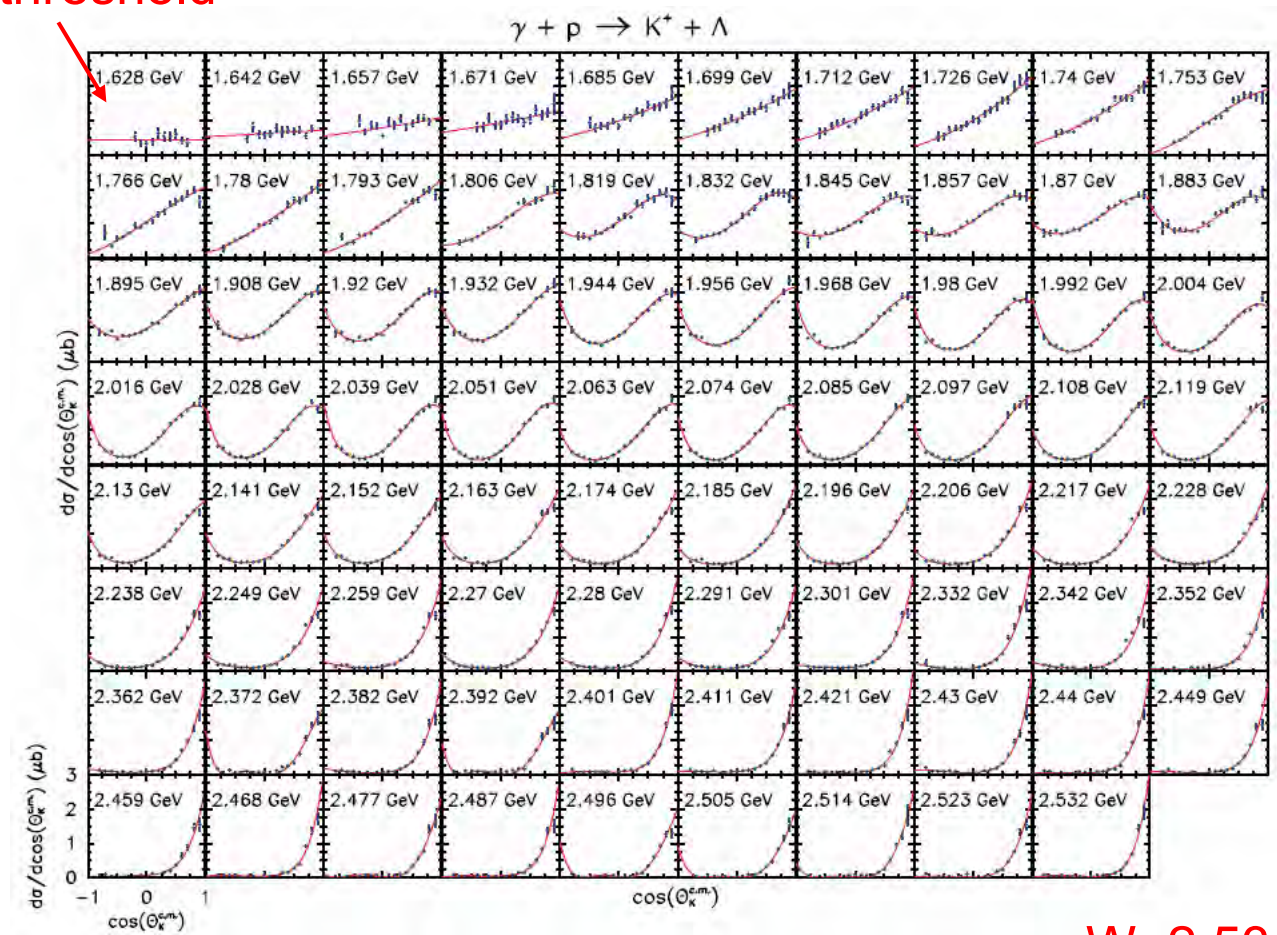




- Kaon identified via time-of-flight (scintillators)
- Electroproduction: detect electron and kaon
- Photoproduction: detect photon (tagger), kaon, and proton
- Exclusive reaction, so use $p(\gamma^{(*)},K^+)$ missing mass to identify the Hyperon
- Background removed under missing-mass distributions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

Λ Photoproduction Differential Cross-sections

threshold



Kinematic coverage:

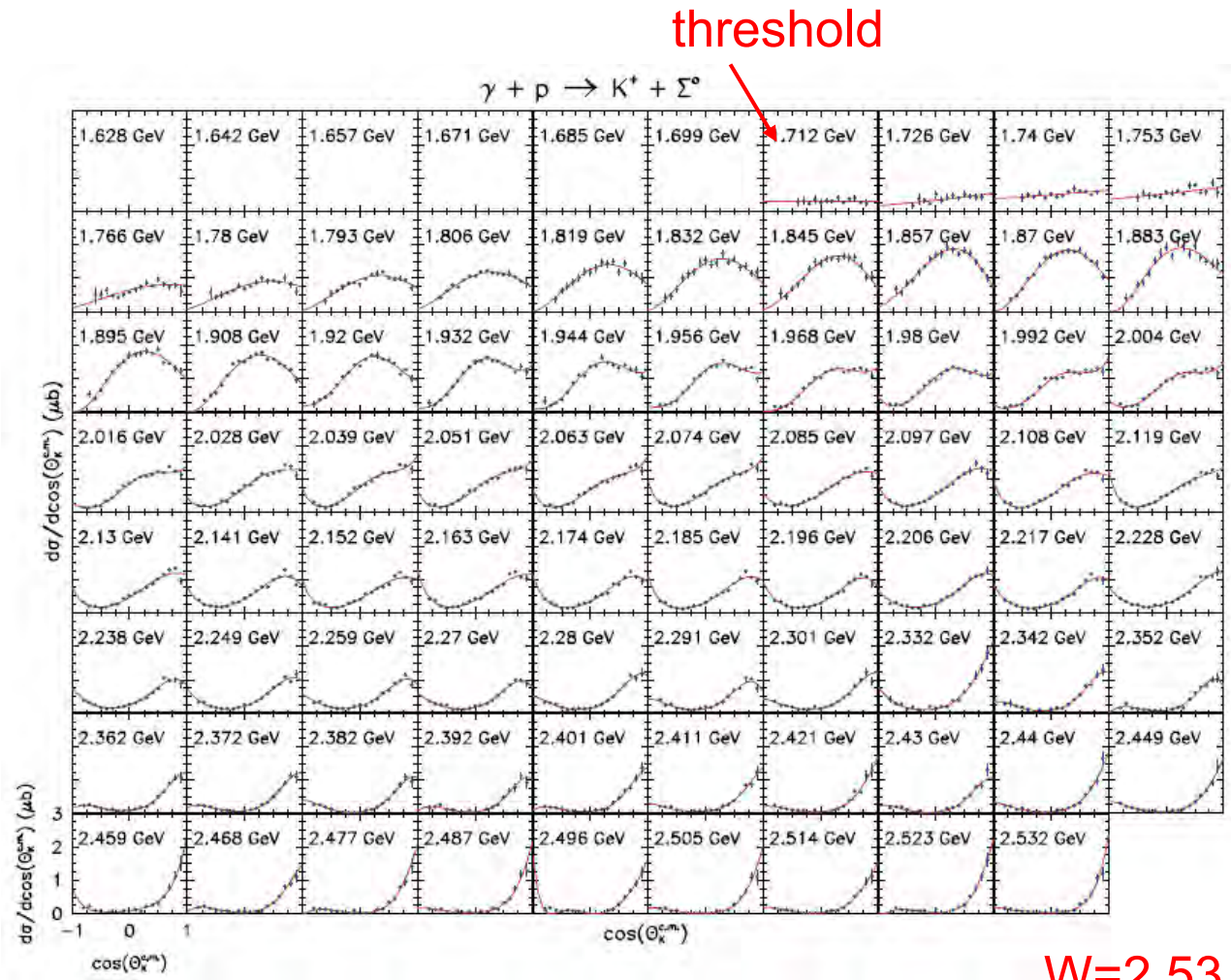
- 25 MeV wide bins
- Δcosθ=0.1
- 1377 data points

Forward peaking.

W=2.53 GeV

Bradford *et al* (CLAS), PRC **73**,035202 (2006)

Σ^0 Photoproduction Differential Cross-sections



Kinematic coverage:

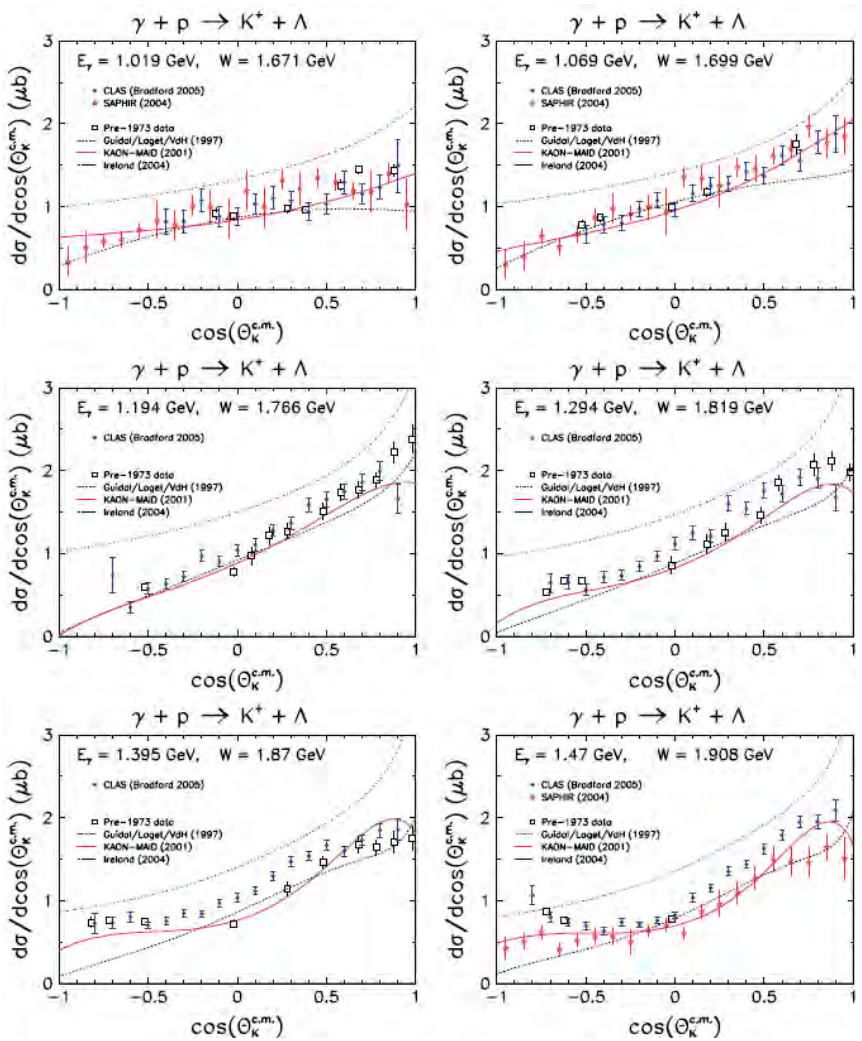
- 25 MeV wide bins
- $\Delta\cos\theta=0.1$
- 1280 data points

Evolving angular distribution as W increases.

W=2.53 GeV

Bradford *et al* (CLAS), PRC **73**,035202 (2006)

Angular distributions: Λ and Σ^0 comparison



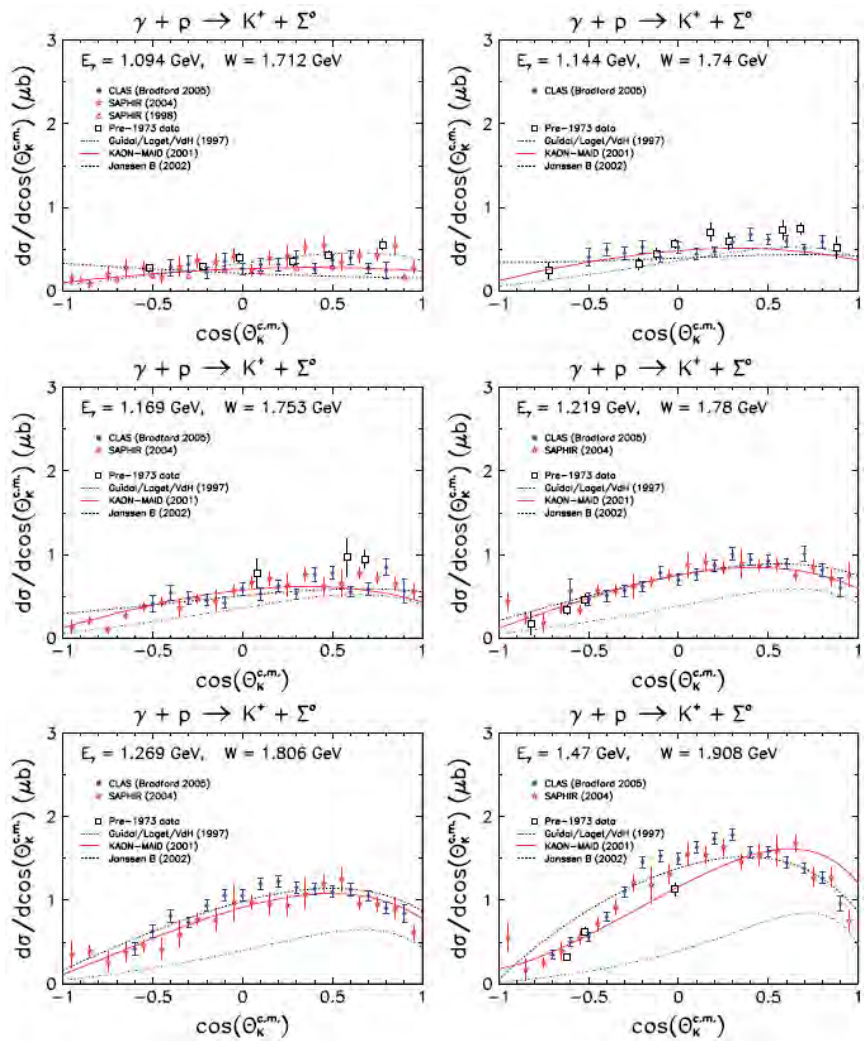
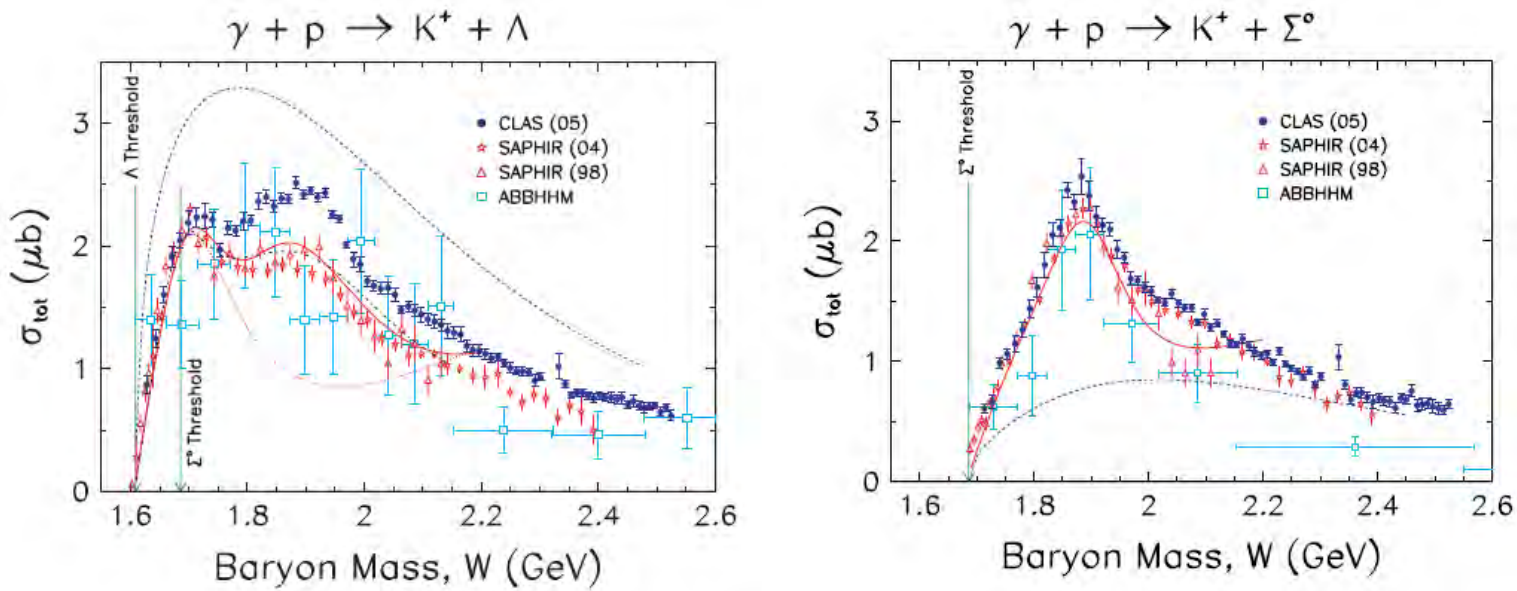


Photo-production total cross-sections

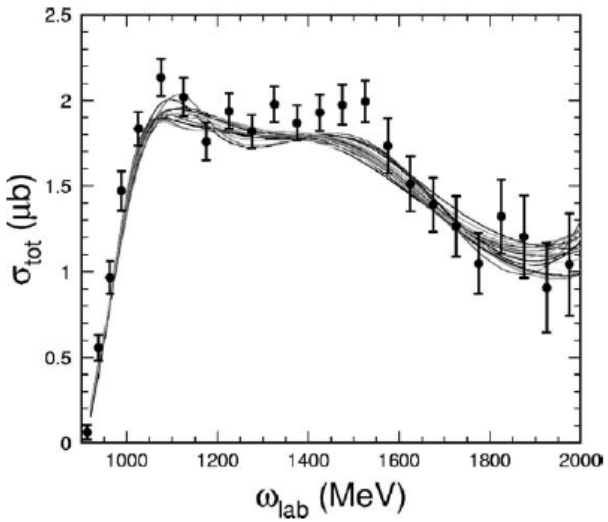


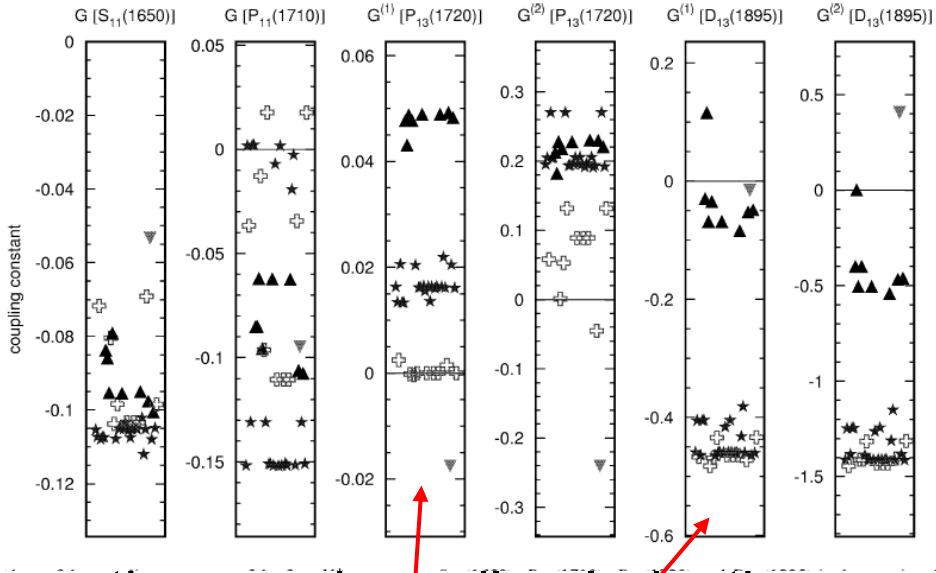
Bradford *et al* (CLAS), PRC **73**,035202 (2006)

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

What is needed to make an impact?

S. Janssen *et al.* PLB **562**, 51 (2003)



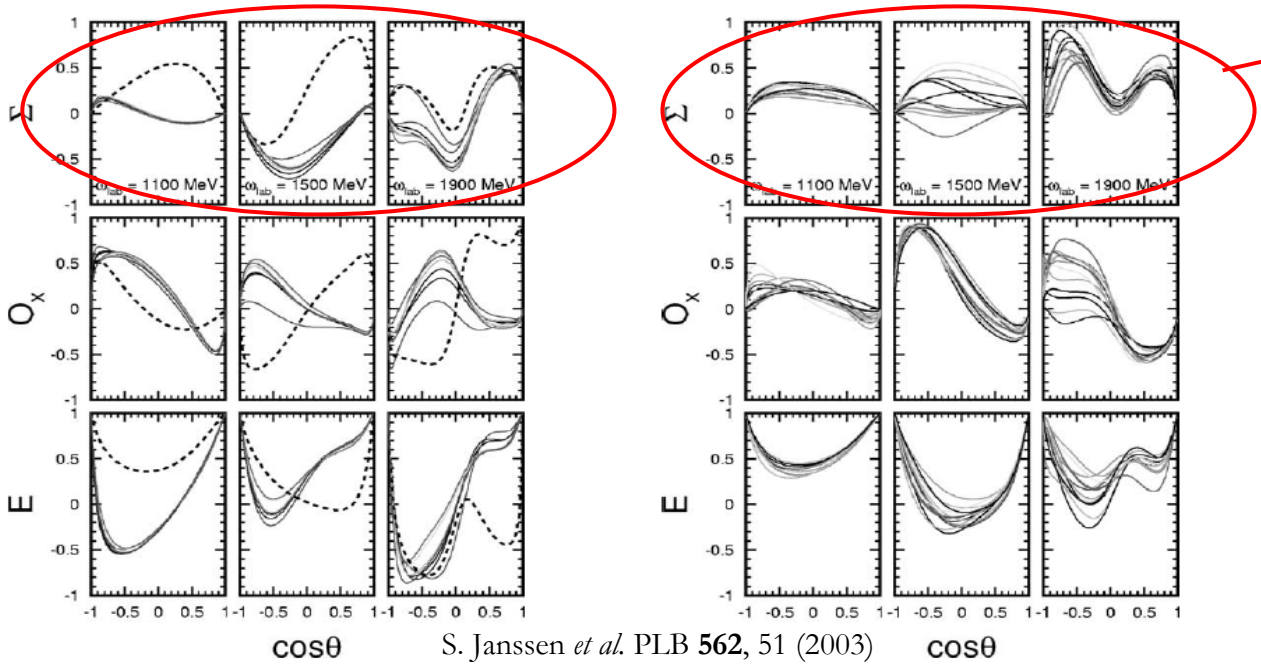


- Fits to differential cross-sections and recoil polarizations (SAPHIR data) found many solutions of similar quality.
- The solutions fell into families… (see $P_{13,}$ D_{13})
- … but we need observables that are sensitive to the differences.

Sensitive observables

Weak D_{13}

Stronger D_{13}



$$\Sigma = -\frac{\sigma_{TT}}{\sigma_T}$$

ω_{lab}=1.5 GeV is W=1.92 GeV

S. Janssen *et al.* PLB **562**, 51 (2003)

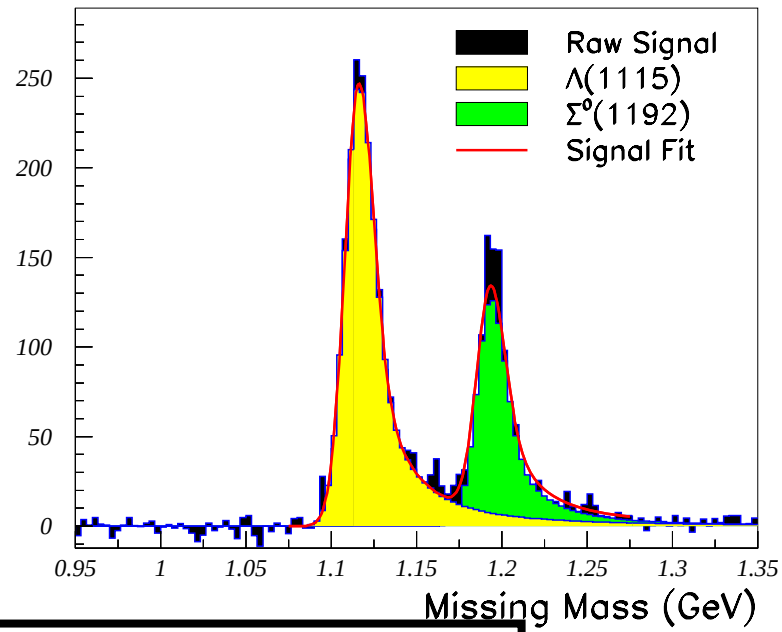
- Photoproduction polarization observables are sensitive to the different sets.

"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).

CLAS Kaon Electroproduction

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.

$0.5 \leq Q^2 \leq 2.6$ GeV^2 $\quad 1.6 \leq W \leq 2.4$ 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

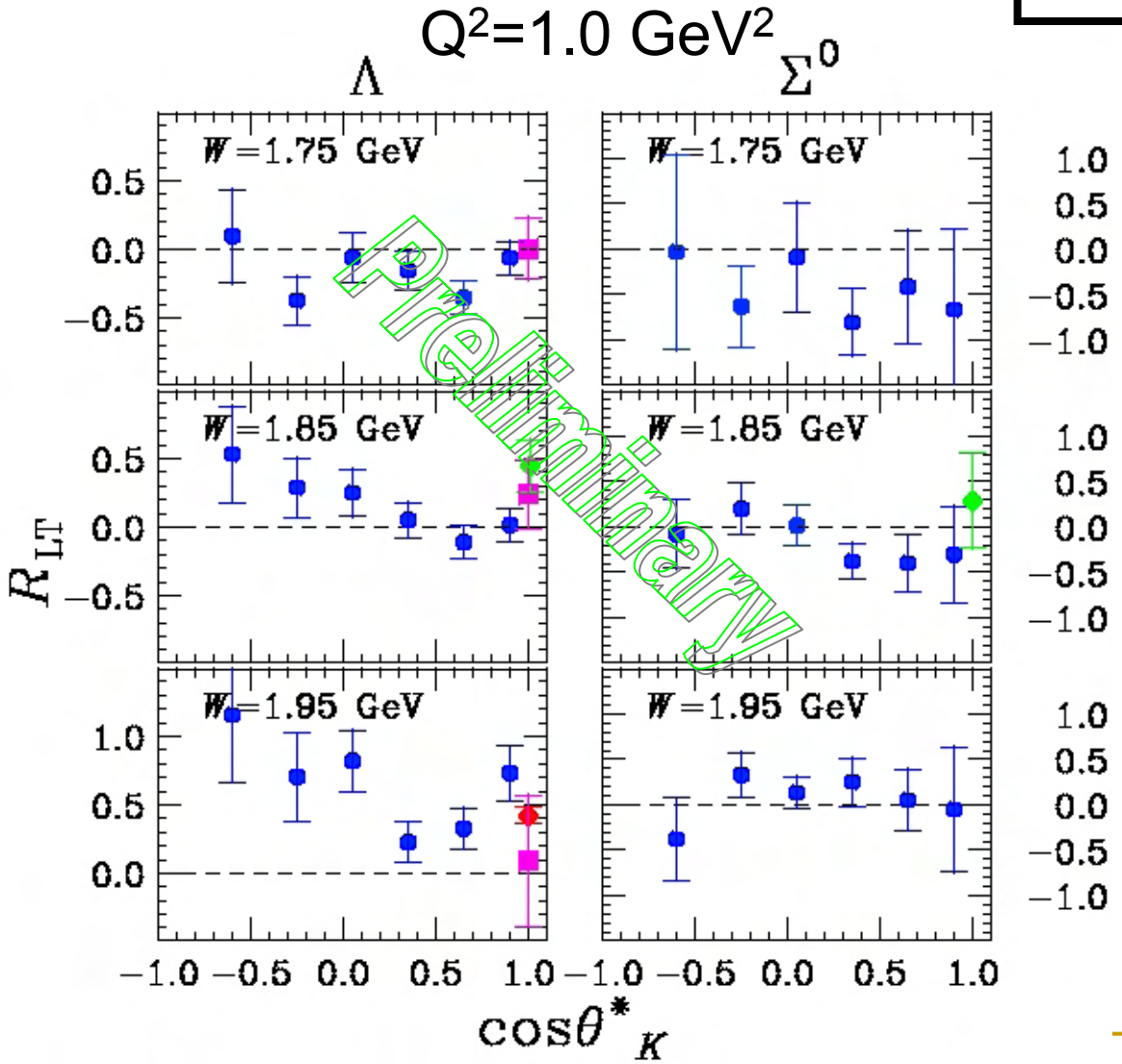
Category	Type	Sources	Avg. Size
Event Reconstruction	scaling	Trigger+tracking efficiency	1%
	Φ-dep	Elec. fiducial cut $(\phi - \theta)$	0.6%
	Φ-dep.	Kaon fiducial cut $(\phi - \theta)$	4.1%
	Φ-dep.	Elec. fiducial cut $(\theta - P_e)$	3.6%
	Φ-dep.	Kaon fiducial cut $(\theta - P_K)$	1.9%
	scaling	Electron PID efficiency	1.5%
	scaling	Kaon PID efficiency	1.0%
Yield Extraction	stat.	Signal templates PID background subtraction	25% · stat
Acceptance, radcorr, & bin size	Φ-dep.	Model dep. of accep. calcs. Model dep. of radcorr. calcs. Model dep. of bin size corr.	8.0%
RadCorr: theory	scaling	VEGAS vs. EXCLURAD	3.4%
Photon flux-factor	scaling	From mom. and angle errors	3.0%
Luminosity	scaling	Live time corr.	0.5%
	scaling	Overall stability	1.5%
	scaling	Electron flux norm.	3.0%
Total			11.6%+25% · stat

9.9% pt-to-pt

6.0% scale

Ratio results: σ_L/σ_T

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)
- Raue & Carman PRC **71,** (2006) (Polarization transfer)

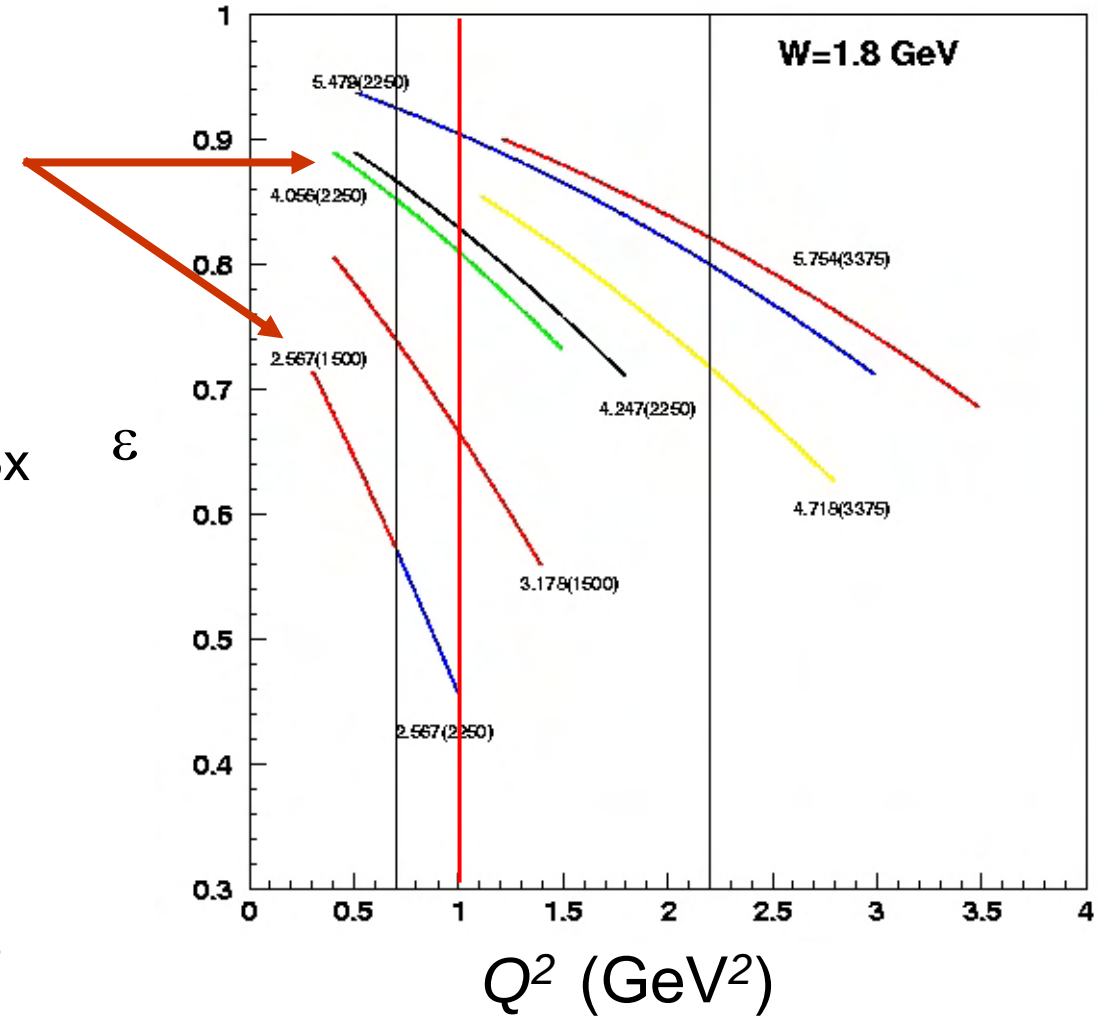
statistical uncertainties only

Improvements in L/T Separations

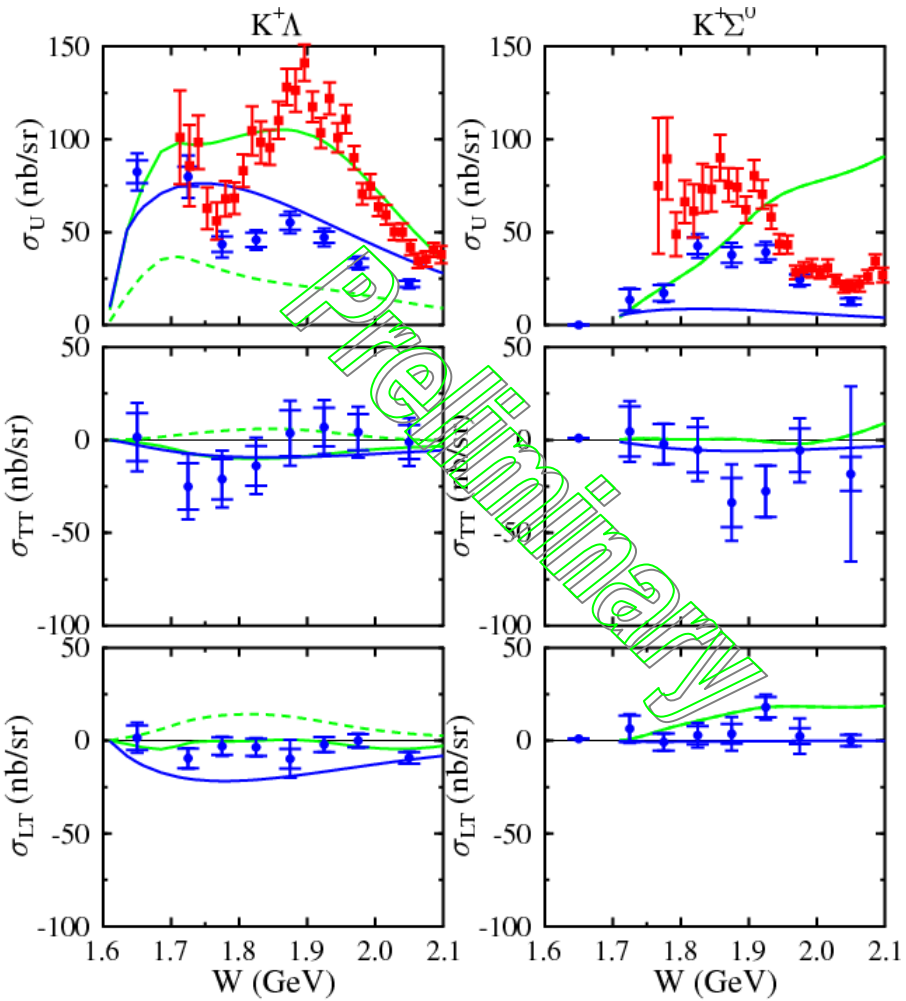
- Currently only have two ε values from two beam energies.
- There are FIVE more data sets at different beam energies to analyze. The 3.2 and >5 GeV datasets have 3x greater statistics.

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



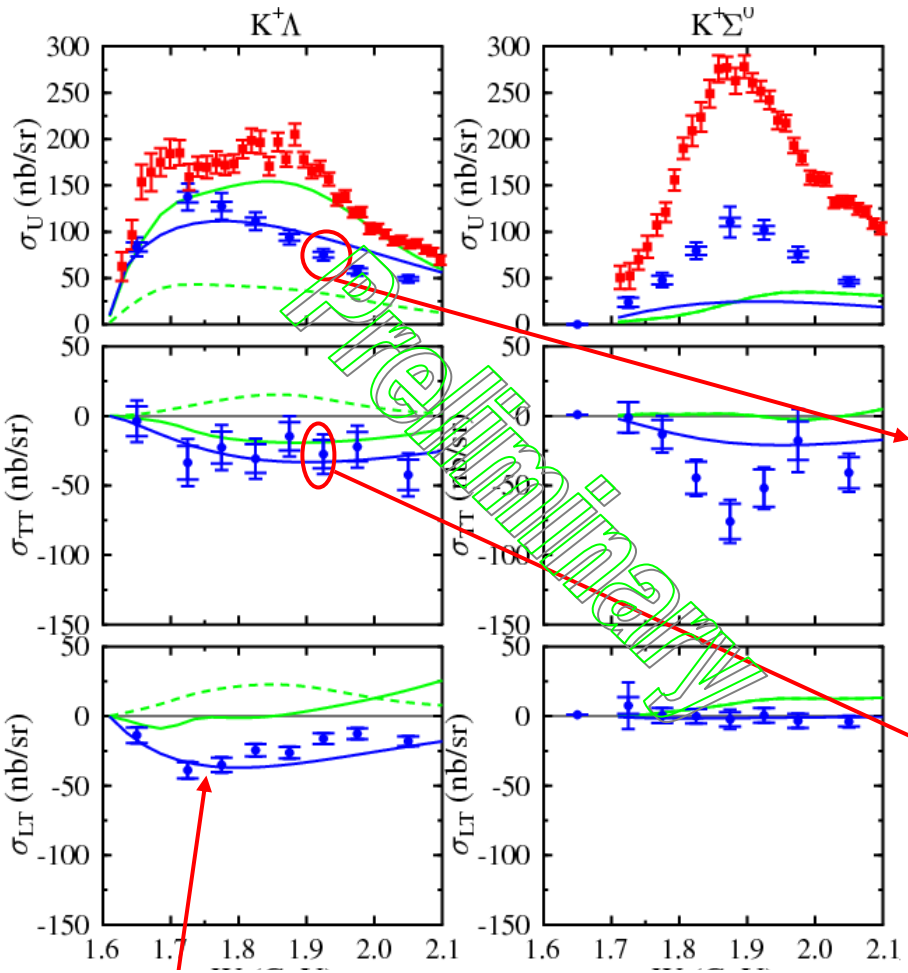
Photoproduction results (Bradford)

Janssen, Ryckebusch *et al*

Guidal, Laget, and Vanderhaeghen

$\cos\theta_K^* = -0.6$, $Q^2 = 0.65$ GeV^2

Hyperon Structure Functions – central angles



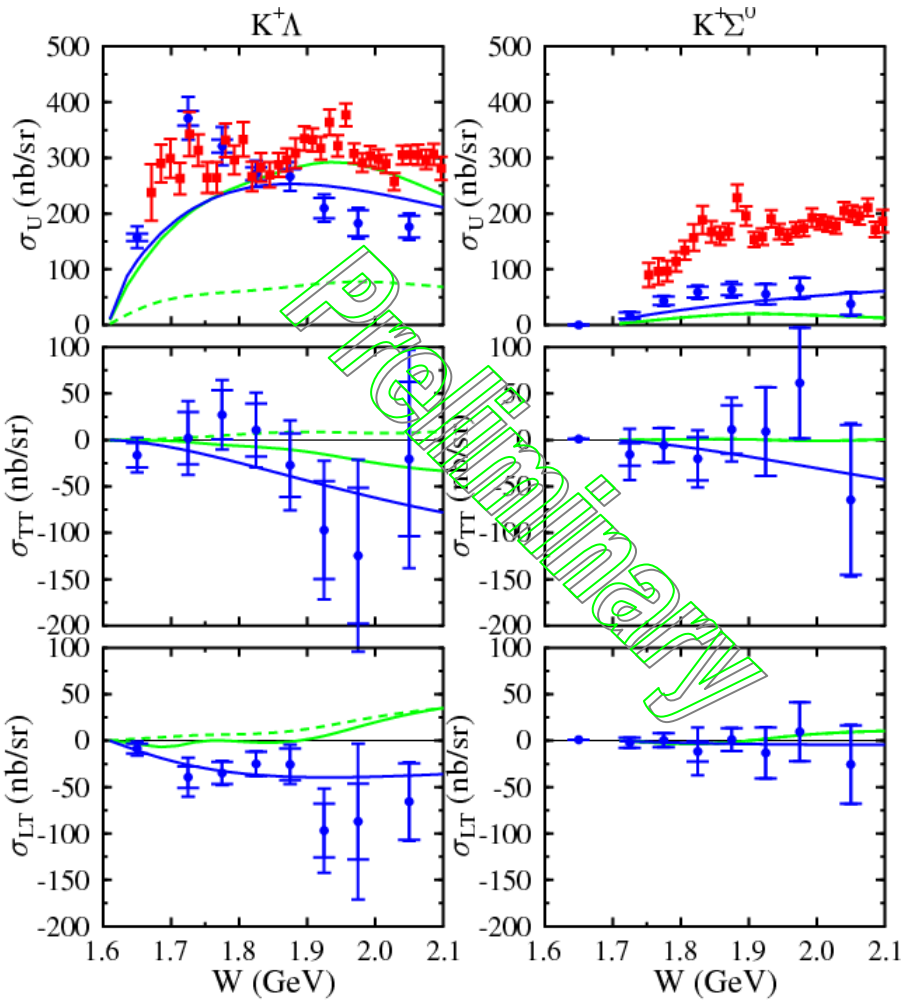
Photoproduction results (Bradford)

Σ-equivalent at W=1.92 GeV:

- R_{LT} was 0.5 to 0.75±0.5, ε ~ 0.43, so σ_T ~ 60±15nb/sr
- $\Sigma^{(*)}$ ~ 0.5±0.2
  - Favors stronger D_{13} coupling

Non-zero σ_{LT} requires $\sigma_L > 0$

Hyperon Structure Functions – forward angles



Photoproduction results (Bradford)

Janssen, Ryckebusch *et al*

Guidal, Laget, and Vanderhaeghen

$\cos\theta_K^* = 0.9$, $Q^2 = 0.65$ GeV^2

Other current or recently completed Strangeness production projects

- Measurement of helicity-correlated structure function σ'_{LT}
- Transferred and induced Hyperon polarization
- Radiative decay of the Λ(1520)
- Line-shape of the Λ(1405)
- Λ photo-production off of deuterium
- "Complete" measurement of the differential cross-section and polarization observables utilizing a polarized beam, frozen-spin polarized target, and self-analyzing decay (in preparation).
- Cascade photo-production off the proton
- Φ-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.

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

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

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

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