Electromagnetic Production of Hyperon Resonances

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MENU 2010 Meeting

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Outline

- Motivation: why study the strange baryons?
  - Data on Λ and Σ photoproduction (plenary session)
  - New N* resonances required
- $K^+\Sigma^{*-}$ photoproduction from the neutron
- Radiative decay of the $\Sigma^0(1385)$ resonance
- $K^{*+}\Lambda$ photoproduction
- Note: $\Lambda(1405)$ will be presented by K. Moira.

Theory and the s-quark

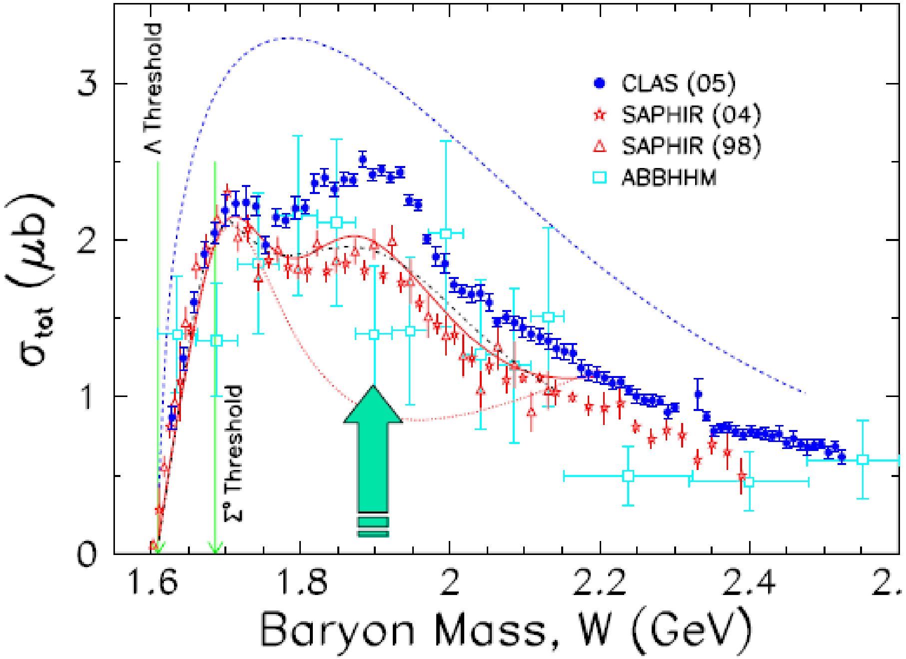
- The u- and d-quarks are light (few MeV)
  - Constituent masses are ~300 MeV.
  - Chiral symmetry breaking is important!
  - Chiral perturbation theory (ChPT) often used.
- The c, b, t-quarks are heavy (>1500 MeV)
  - Heavy quark effective theory works well.
- The s-quark is in the middle (~100 MeV)
  - Neither ChPT nor HQET are appropriate.

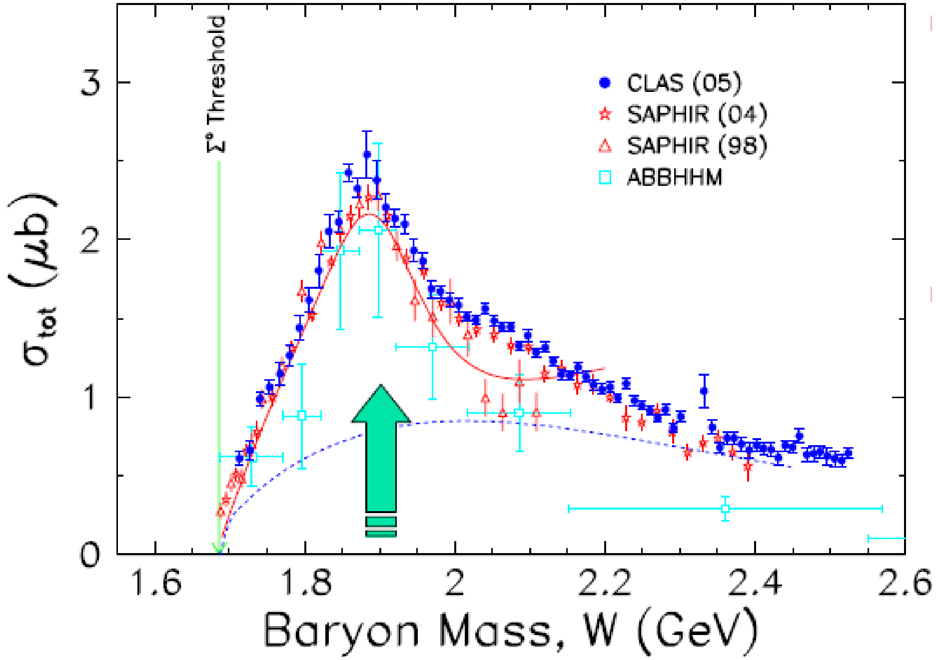
Why Strange Reonances?

- Standard theoretical models methods fail
  - Need experimental data to guide theory.
- Experimentally, Y* widths are smaller
  - N* and Δ* widths typically ~200 MeV.
  - Y* widths typically ~15-50 MeV.
  - Ξ* widths typically ~10-20 MeV.

$\gamma p \rightarrow K^{+}Y$ at CLAS (Schumacher's plenary talk)

Bradford et al., PRC 73, 035202 (2006).





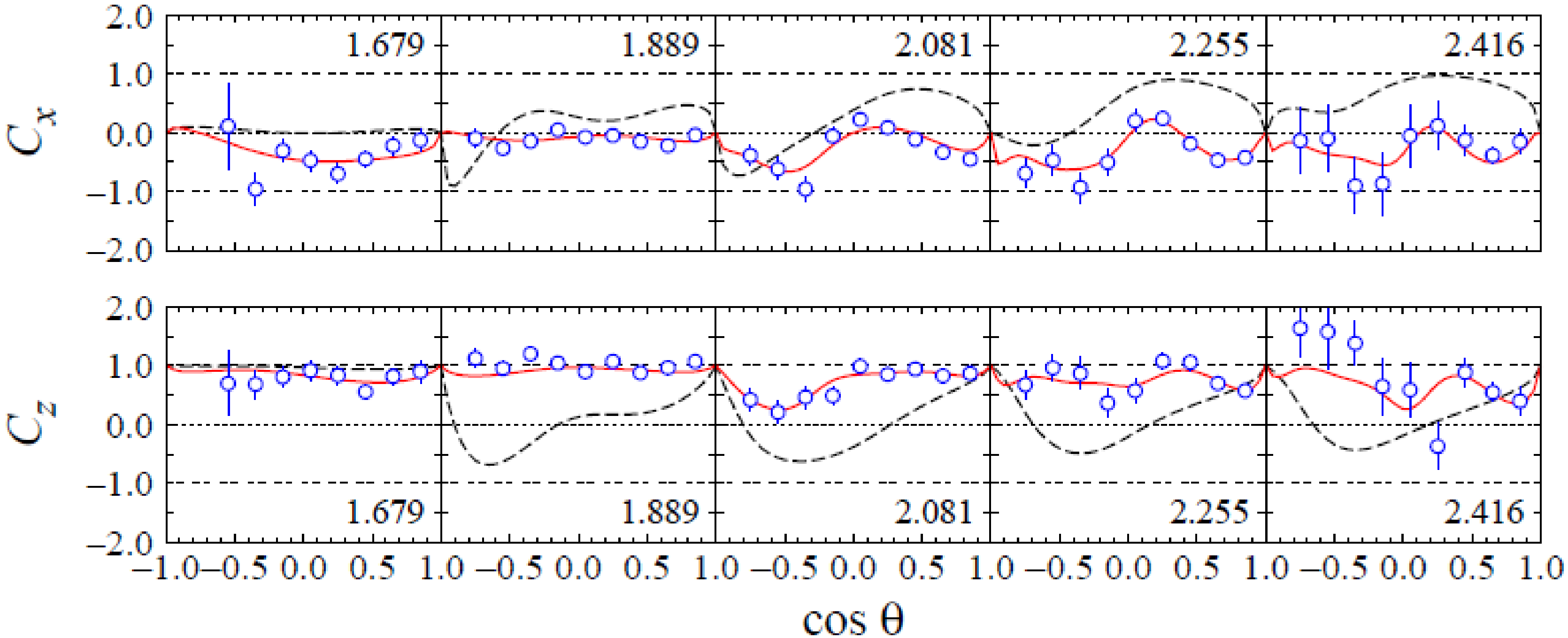
Resonance-like structure near 1.90 GeV:

Is it a new N* state? Bennhold & Mart: D_{13}(1900)?? (new N*).

Or perhaps a KKN bound state?? arXiv:0902:3633 [nucl-th].

Polarization Transfer in K$^+\Lambda$.

Data: Bradford et al., PRC 75, 035205 (2007), Curves: T. Mart, arXiv:0808.0771.



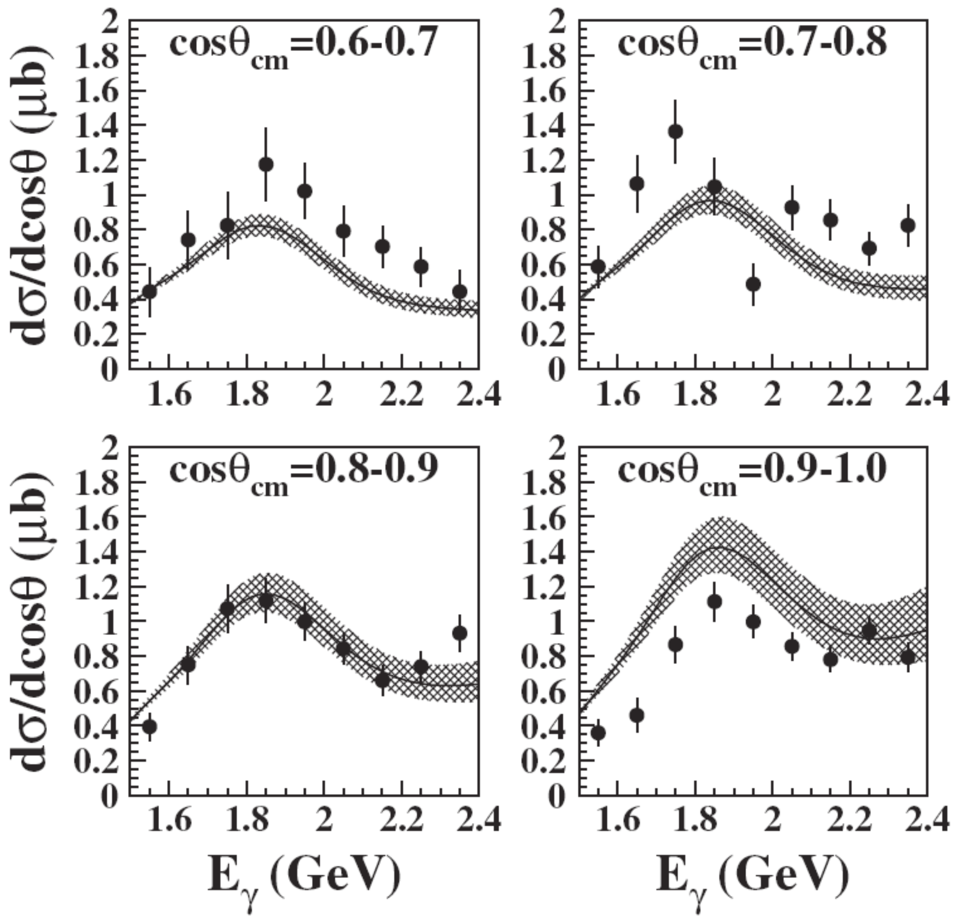
C_x and C_z are for transfer of circular beam polarization to the Λ.

Curves include: S_{11}(1650), P_{11}(1710), P_{13}(1720), P_{13}(1900).

Polarization is a powerful tool to sort out model dependence!

LEPS: $\gamma n \rightarrow K^+\Sigma^{*-}$ cross sections

K. Hicks, D. Keller et al. (LEPS Collaboration), PRL 102, 012501 (2009)

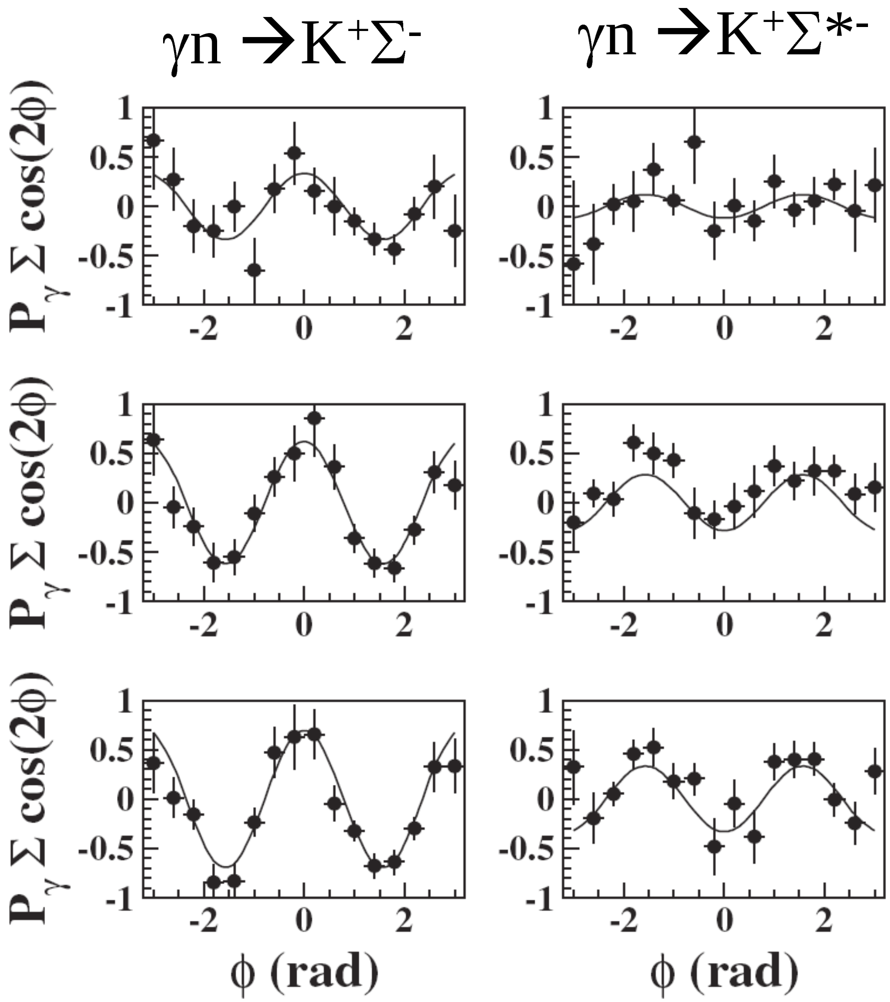


Calculations are from Oh, Ko & Nakayama, averaged over the bin size shown.

- Cross sections are only measured at forward angles: complementary to the CLAS data.

- CLAS data will be available shortly

LEPS: Σ^- and Σ^{*-} beam asymm.

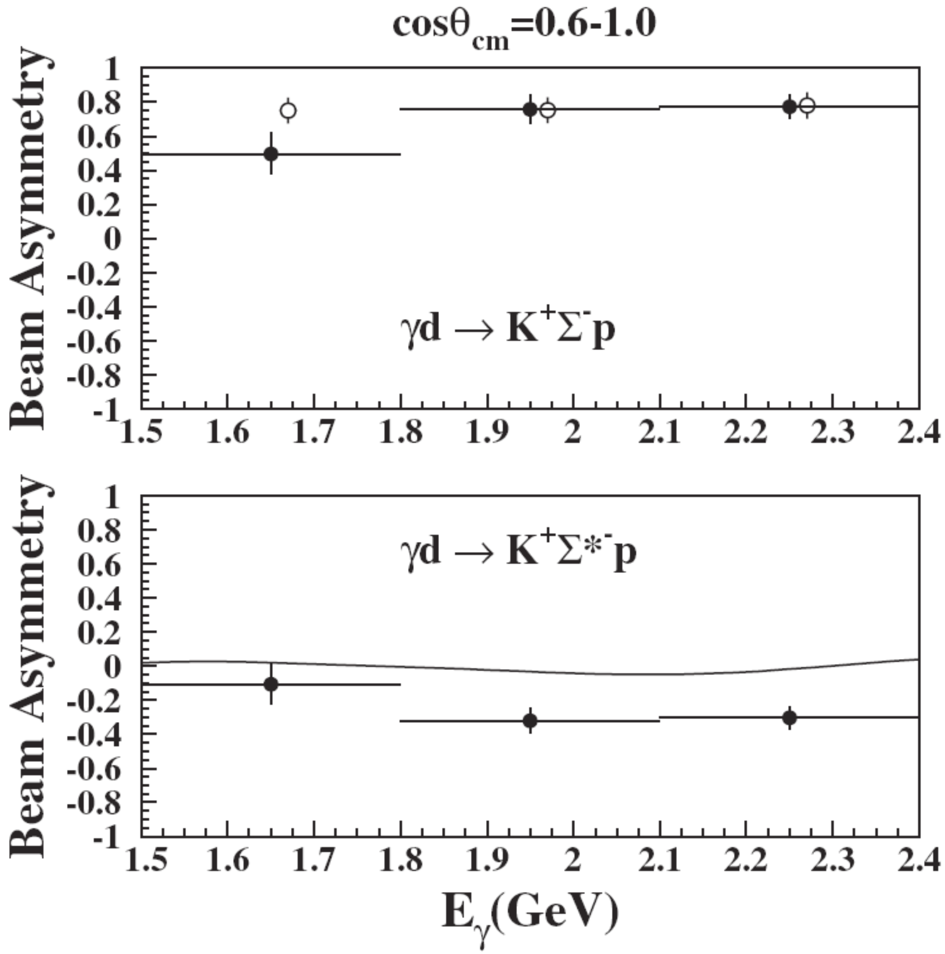


Due to statistics, only three bins in beam energy (1.5-1.8, 1.8-2.1, 2.1-2.4 GeV) were used for the beam asymmetry fits.

The $K^+\Sigma^-$ final state (left), shows the opposite sign for the beam asymmetry when compared with the $K^+\Sigma^{*-}$ final state (right).

LEPS: Σ^{*-} beam asymmetries

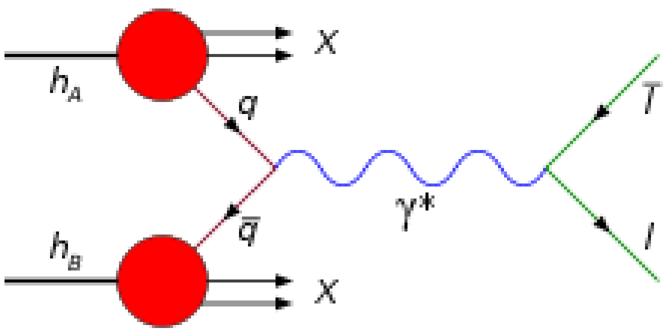
K. Hicks, D. Keller et al. (LEPS Collaboration), PRL 102, 012501 (2009)



Present results (solid points) compared with previously published data (open points) from Kohri *et al.* (PRL, 2006)

Curve (Oh, Ko, Nakanyama) assumes 3-quark structure to the Σ^*. A 5-quark component would have asymmetry of -1 (model of B.-S. Zou).

Drell-Yan: nucleon has pion cloud

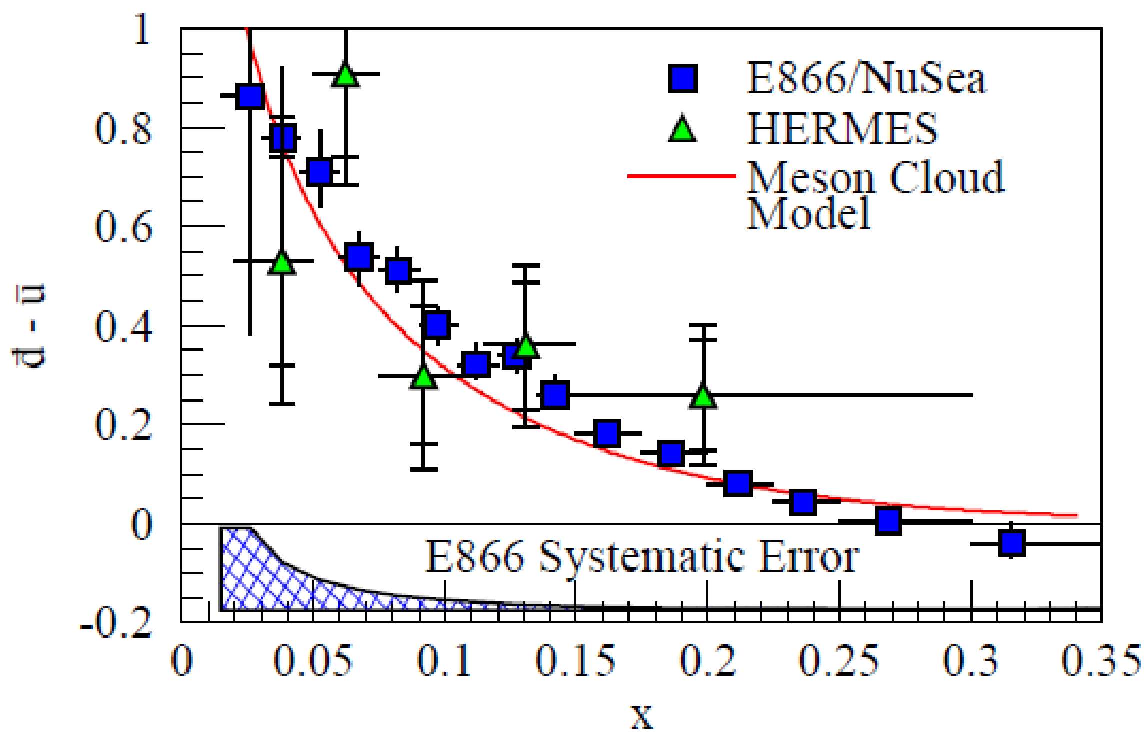


The Drell-Yan process measures the antiquark sea in the nucleon.

The results show that there is an asymmetry to the u* and d* sea in the proton.

The nucleon has an admixture of qqq(qq^{bar}).

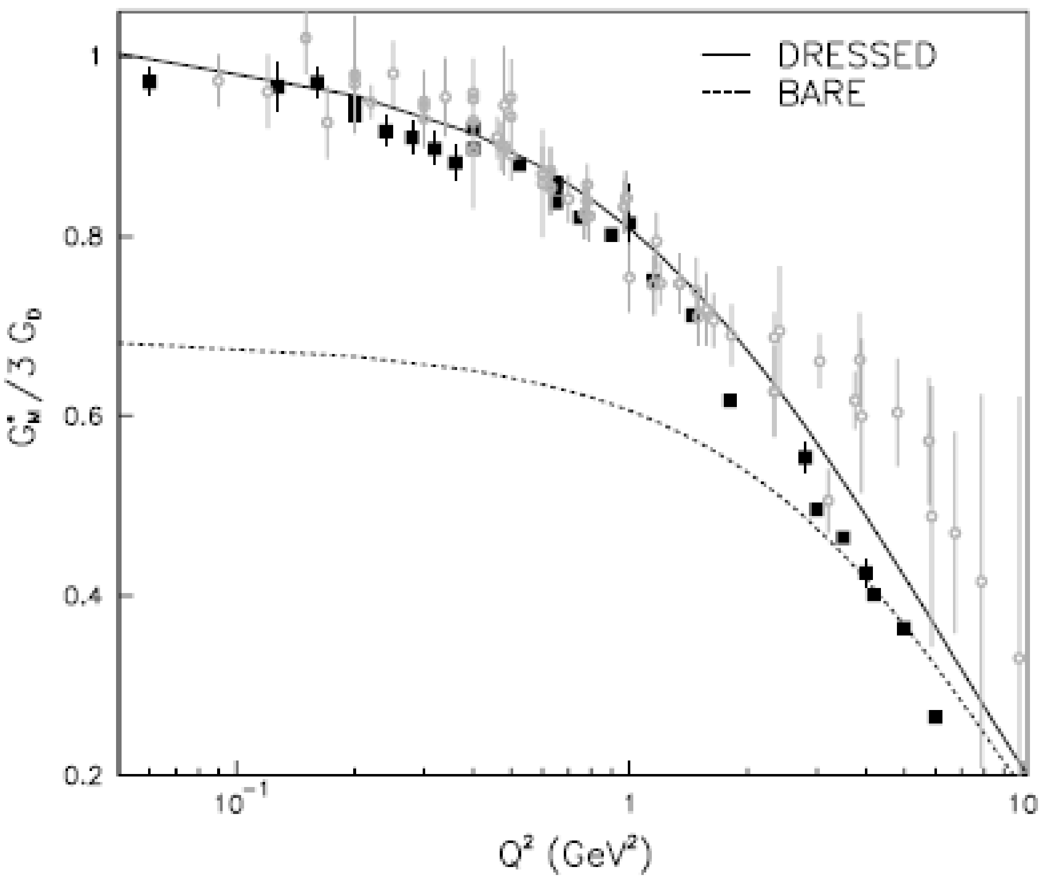
From: P. Reimer, arXiv:0704.3621.



K. Hicks (Ohio)

The NΔ magnetic form factor

Data from Bates, MAMI, and JLab.
Curves from Julia-Diaz et al. PRC 75, 015205 (2007).



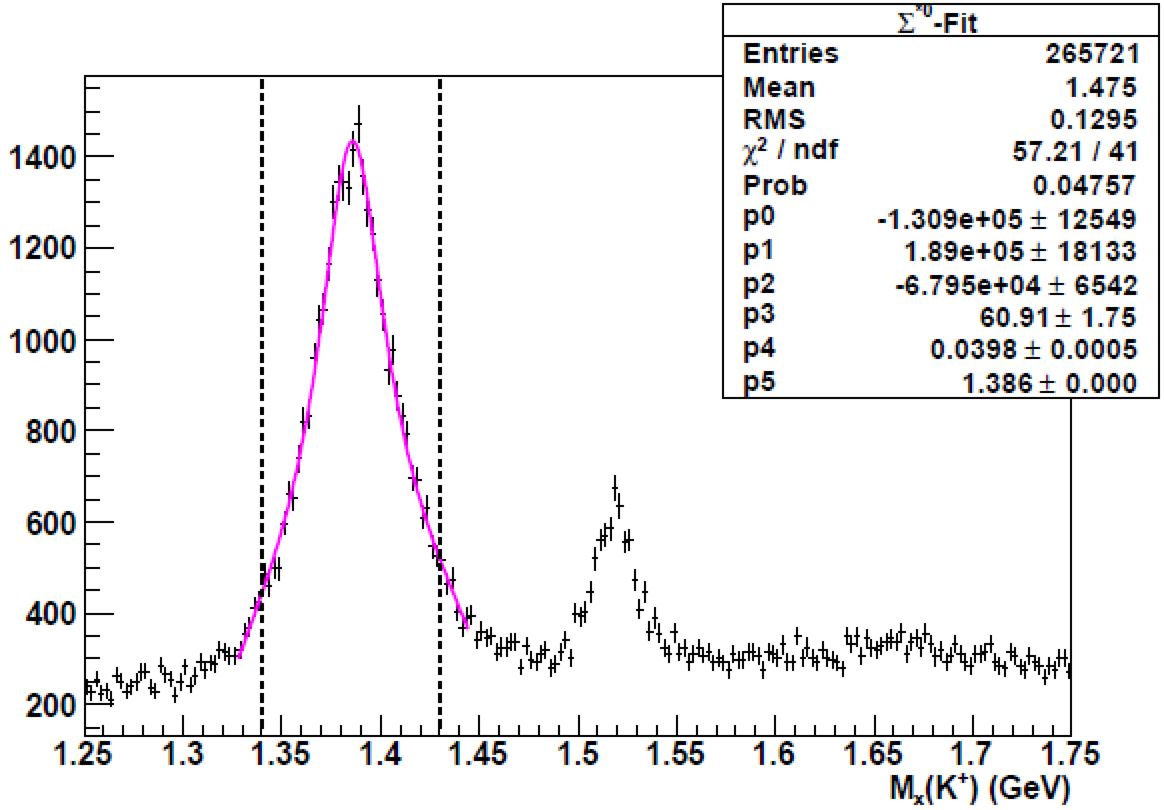
Quark model for $\gamma N \rightarrow \Delta$ does not fit the data.

Dressed with a meson cloud, theory fits the data. <u>The effect is not small</u>.

What about $\Sigma^* \rightarrow \Sigma\gamma$?
This is being measured now using JLab data.
(Thesis of D. Keller)

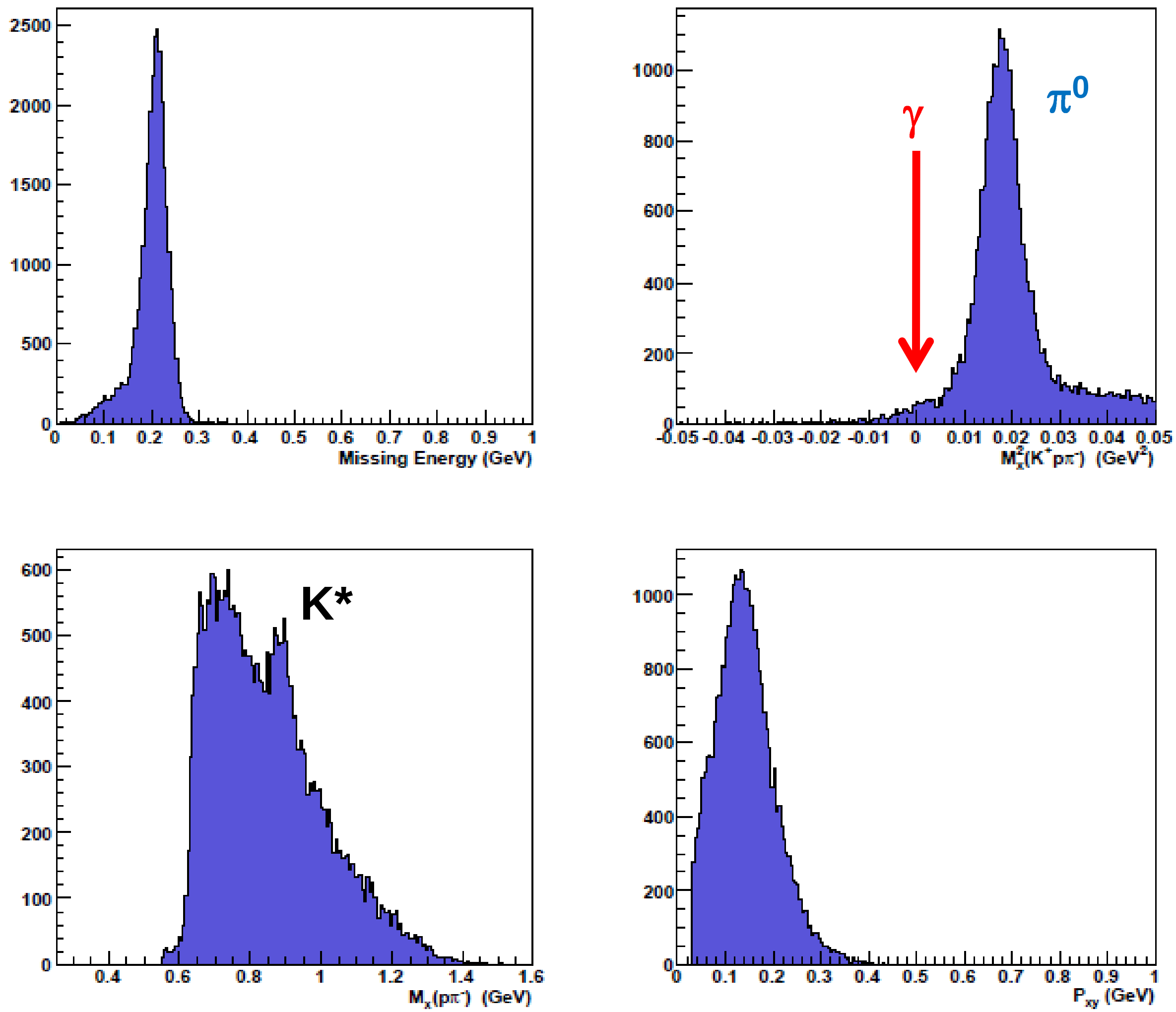
$\gamma\, p \rightarrow K^+\, \Sigma^0(1385) \rightarrow K^+\, \Lambda\, X$

Preliminary CLAS analysis by Dustin Keller (Ohio U.)



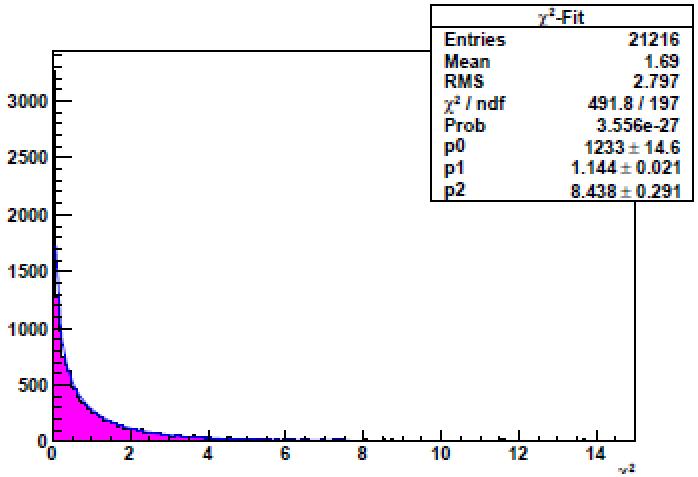
Need Kinematic Fitting

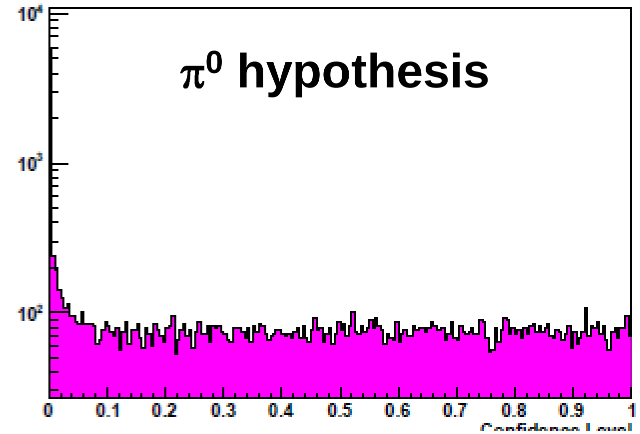
CLAS preliminary: mass spectra after cut on Σ* peak.

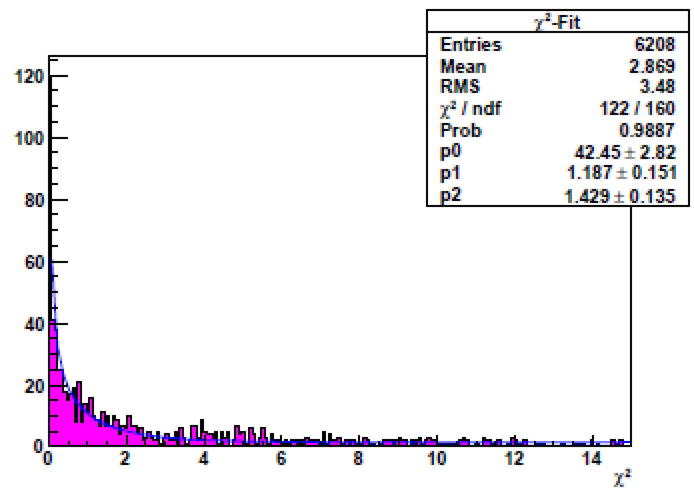


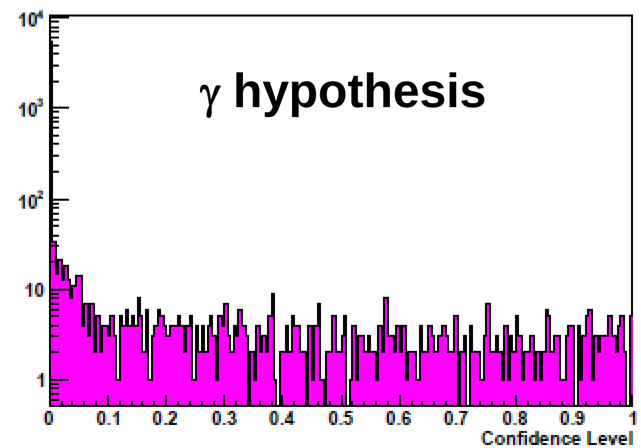
Confidence Level Plots

CLAS preliminary: analysis by Dustin Keller (Ohio U.)









Preliminary results (ratio)

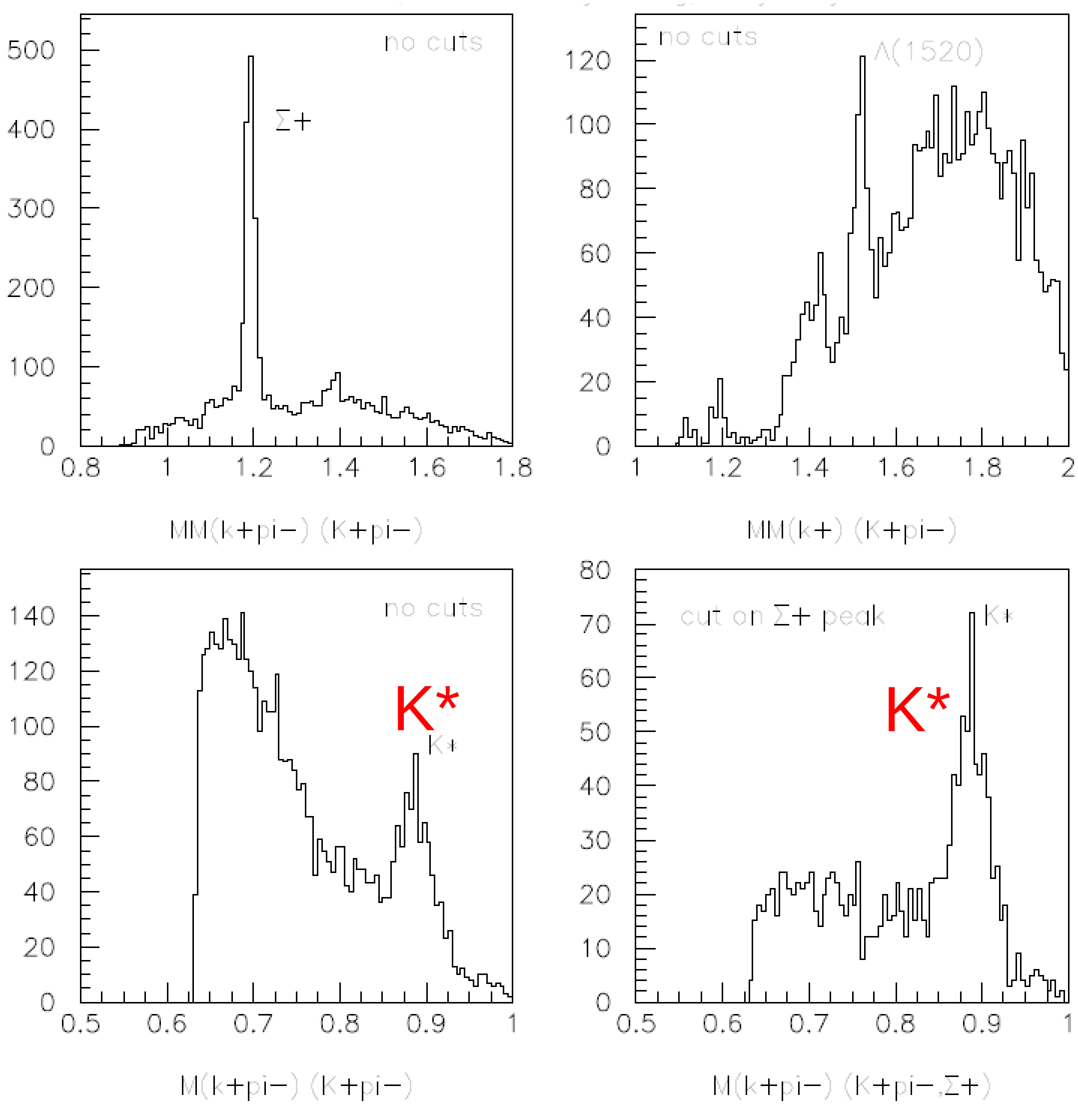
CLAS analysis by D. Keller (Ohio U.)

$$R_{\Lambda\pi}^{\Lambda\gamma} = \frac{\Gamma[\Sigma^0(1385) \to \Lambda\gamma]}{\Gamma[\Sigma^0(1385) \to \Lambda\pi^0]} = 1.42 \pm 0.11(stat)^{0.14}_{-0.13}(sys).$$ **%**

Preliminary systematic studies of cut points on the confidence level (%).

$P_{\pi^0}(\%)$	$P_\gamma(\%)$	R(%)
1	1	1.38± 0.11
5	5	1.39± 0.11
10	10	1.42± 0.11
15	15	1.43± 0.11
10	1	1.40± 0.11
1	10	1.42± 0.12
1	15	1.44± 0.11
1	20	1.44± 0.13
1	25	1.44± 0.14

LEPS: K^{*0} photoproduction

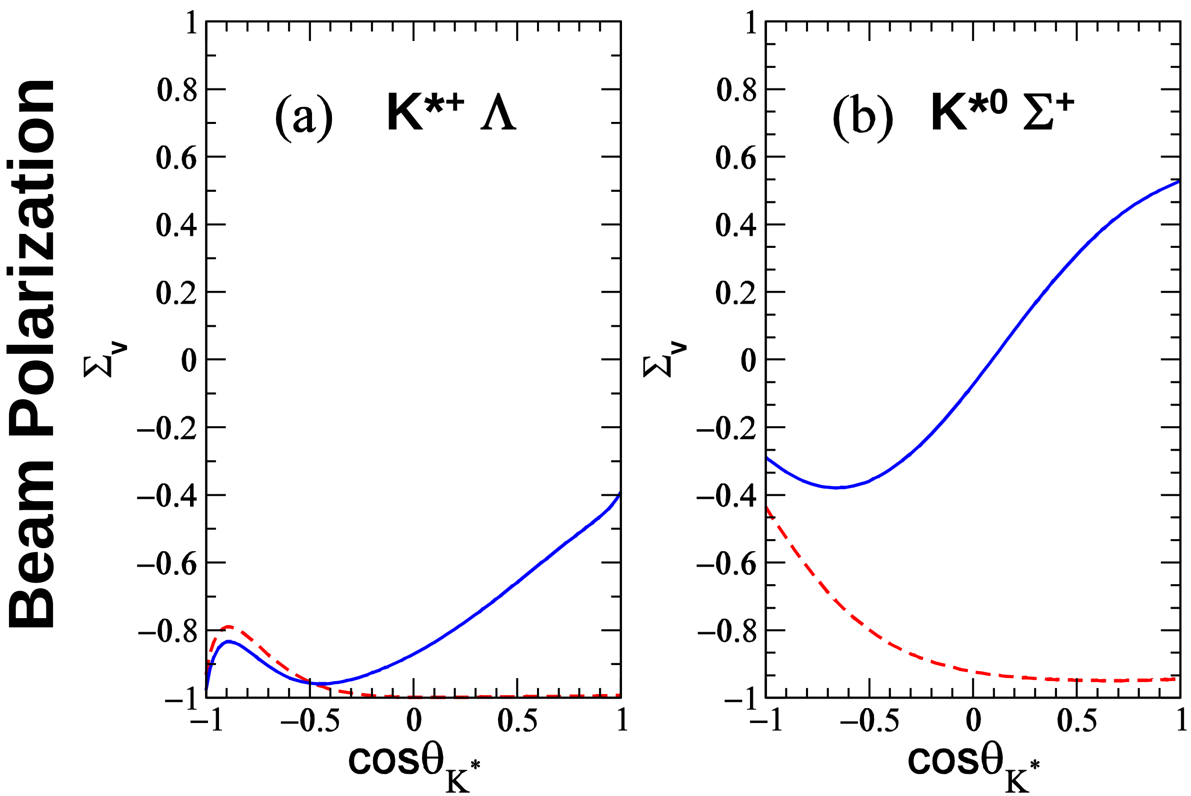


The beam energy for this experiment was 2.0-3.0 GeV (using a new laser)

The physics is that the beam asymm. is very sensitive to the kappa-meson, partner to $f_0(600)$.

K* Photoproduction: Theory

Y. Oh and H. Kim, Phys. Rev. C74, 015208 (2006).

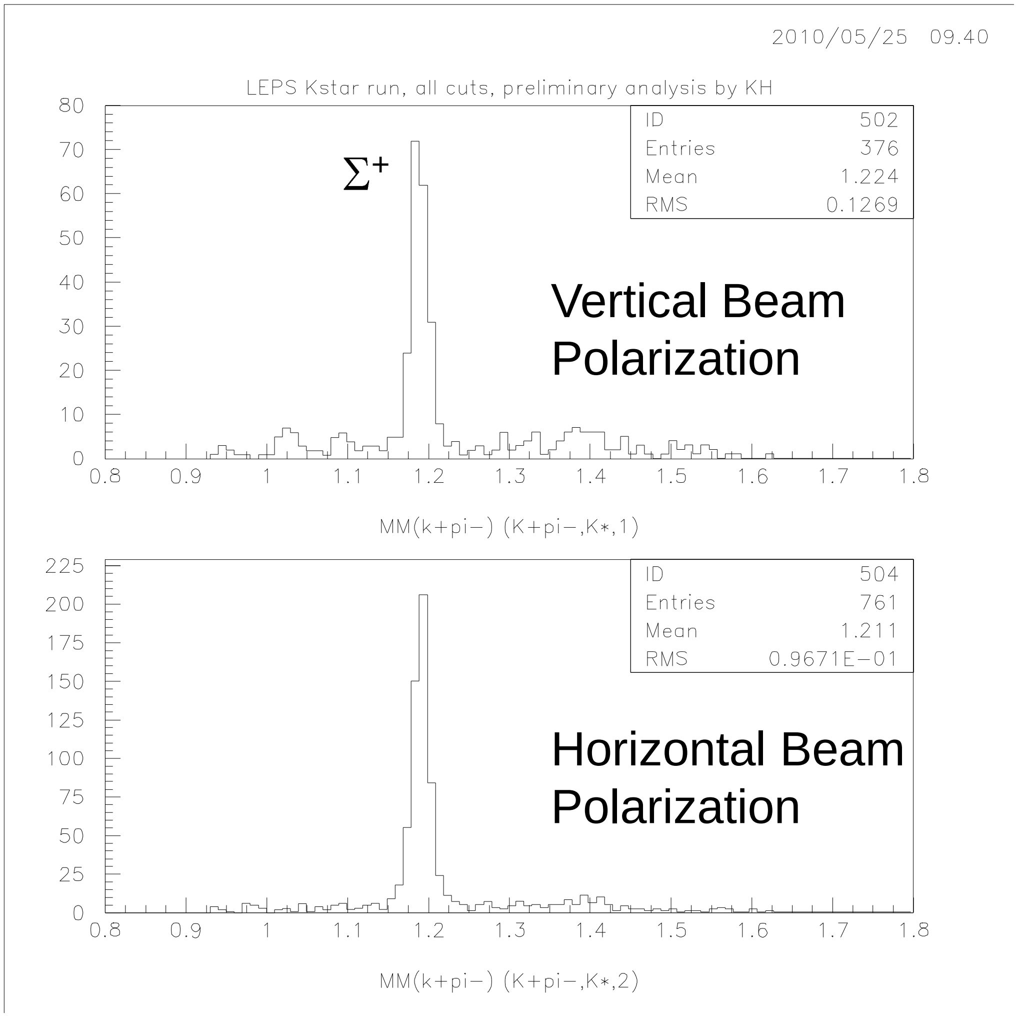


Solid line: with Kappa meson exchange.

Dashed line: no Kappa exchange diagrams

There is a large effect on the beam polarization when the $K_0(700)$ meson (0^{++}) is included. This could be definitive evidence for the existence of the $K_0(700)$, which cannot be seen directly due to its wide width

LEPS: $K^{*0}\ \Sigma^+$ Preliminary



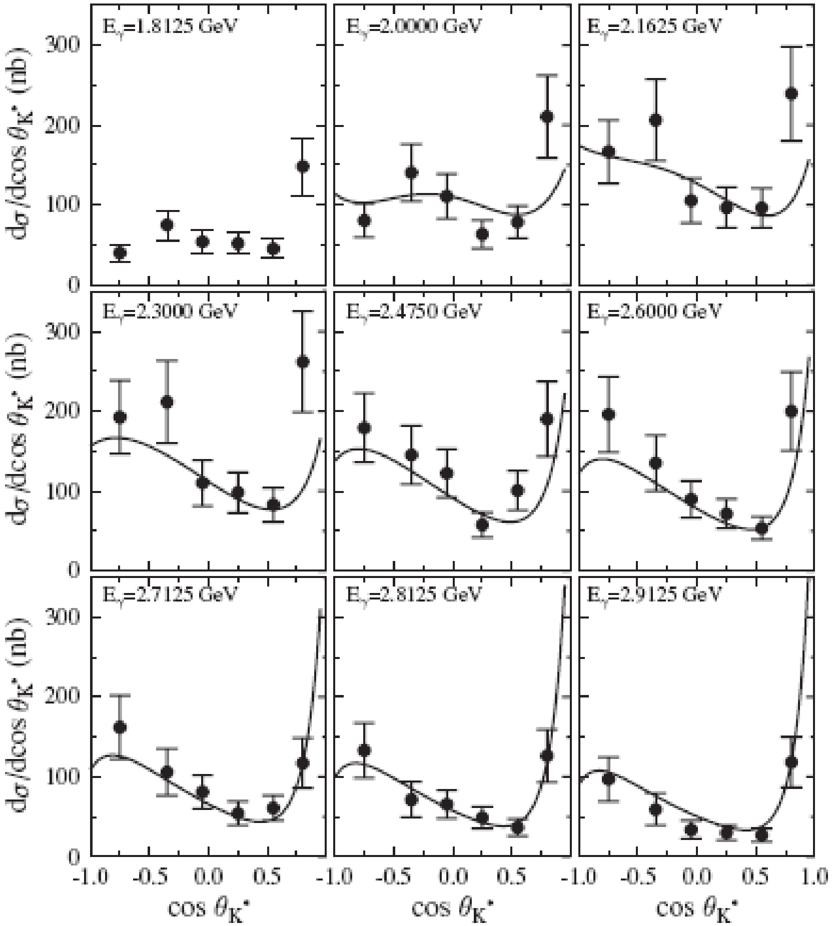
Analysis being done by KH & S.H. Hwang (Pusan University)

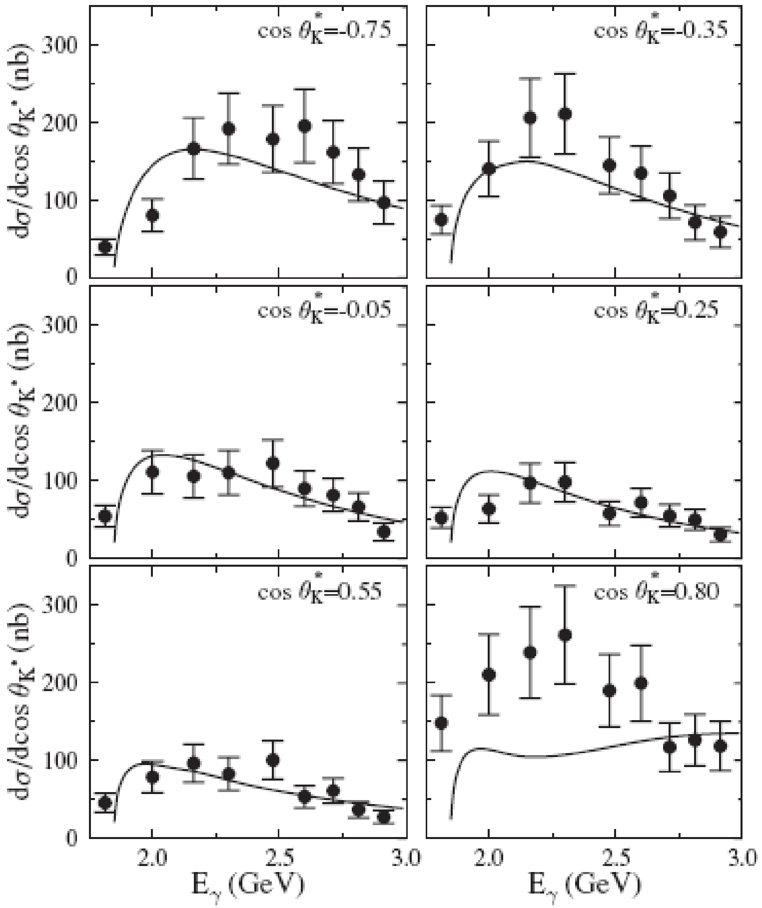
Because the LEPS detector has a larger acceptance in the horizontal plane than in the vertical plane, this result suggests that the K* is produced preferentially in the direction of the photon beam linear polarization direction.

Full analysis of the spin-density matrix elements are necessary to get a correct value for the parity asymmetry.

CLAS: $K^{*0}\Sigma^{+}$ data (2007)

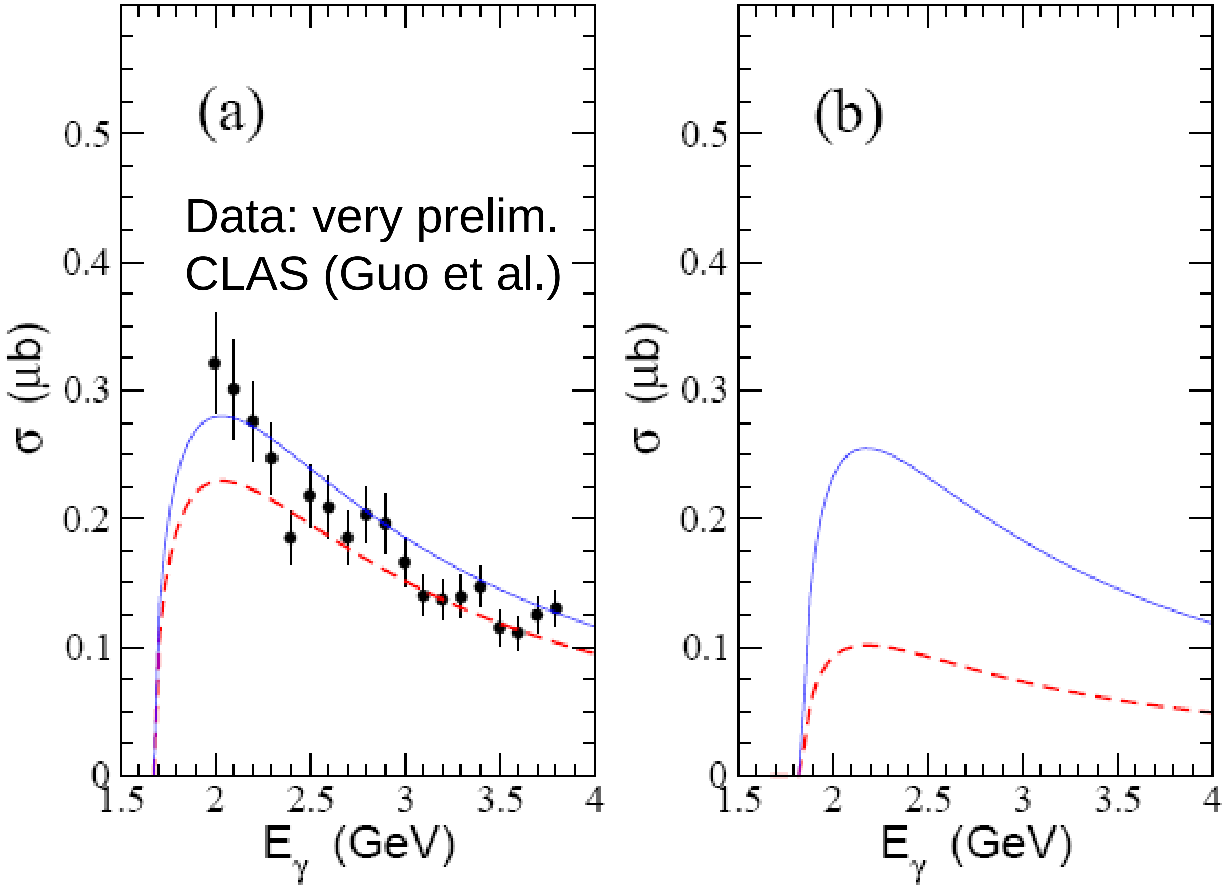
I. Hleiqawi et al., Phys. Rev. C 76 (2007) 039905E.





Theory: a) $K^{*+}\Lambda$, b) $K^{*0}\Sigma^+$

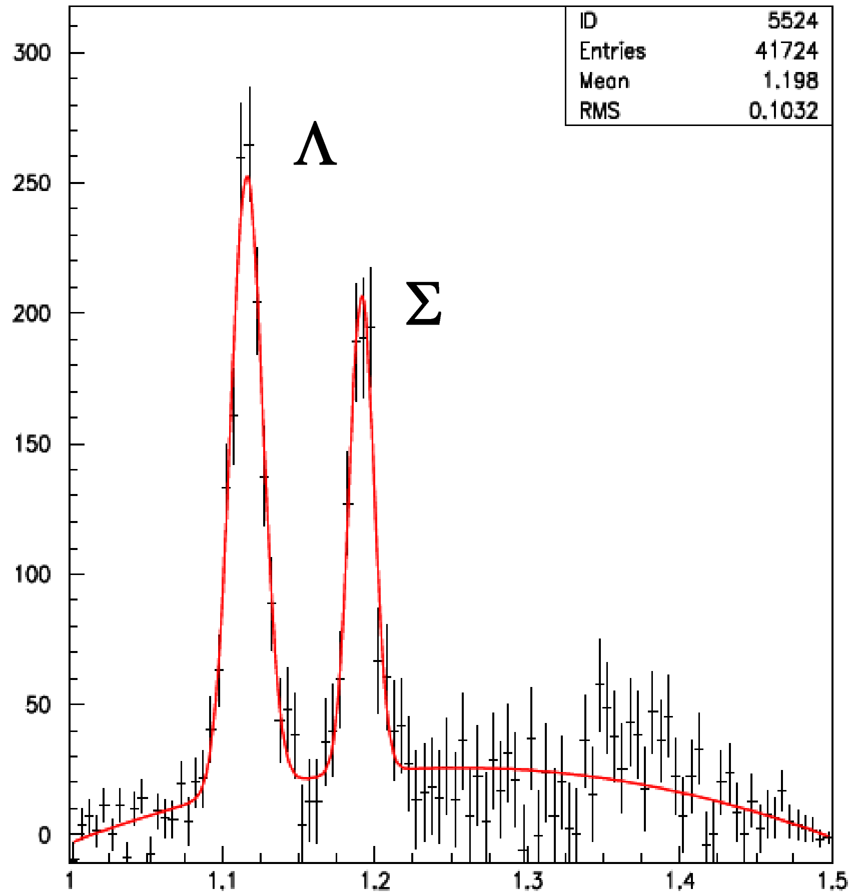
Y. Oh and H. Kim, hep-ph/0605105.



SOLID BLUE: no kappa form factor; DASHED RED: with kappa form factor

$\gamma\, p \rightarrow K^{*+}\, Y \rightarrow K^0\, \pi^+\, Y$

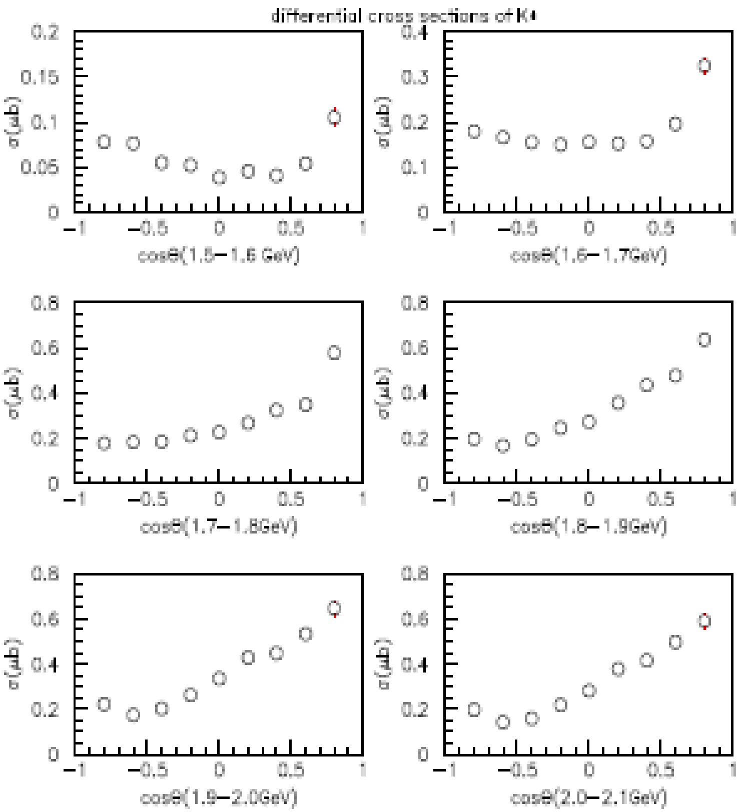
Preliminary CLAS analysis by Wei Tang (Ohio U.)

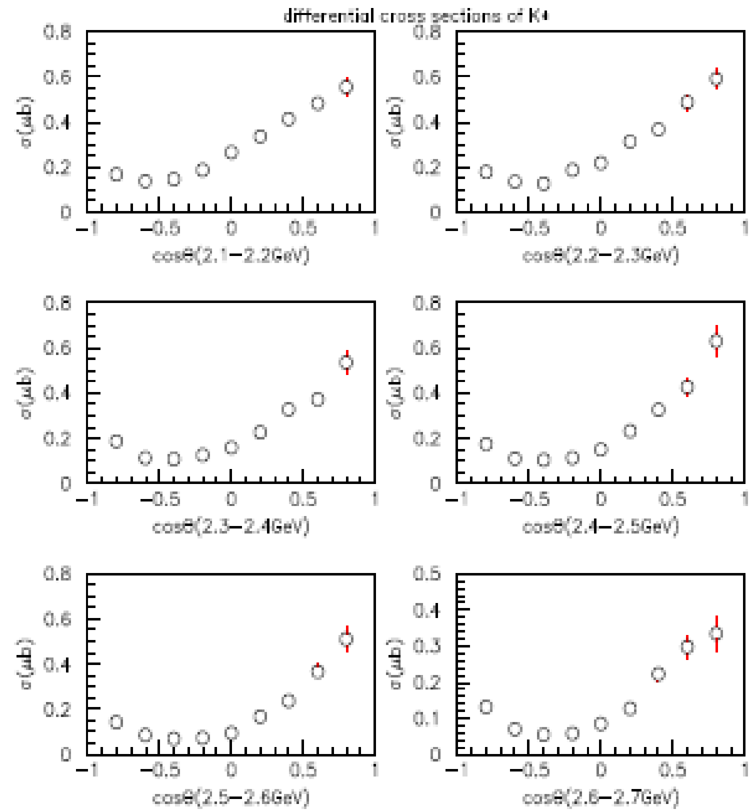


Missing Mass (GeV)

Differential Cross Sections

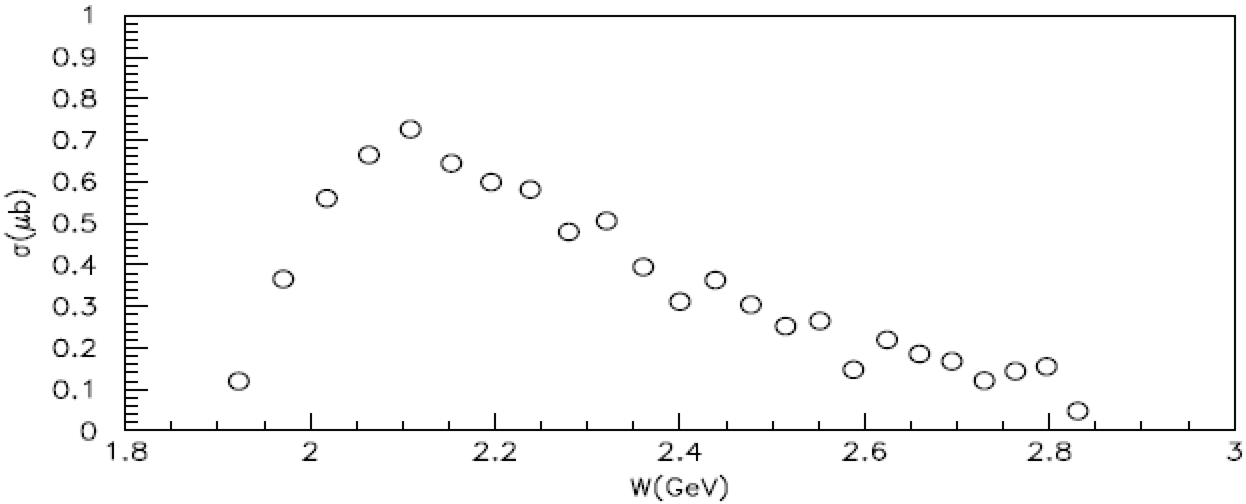
Preliminary CLAS analysis by Wei Tang (Ohio U.)





Total Cross Sections

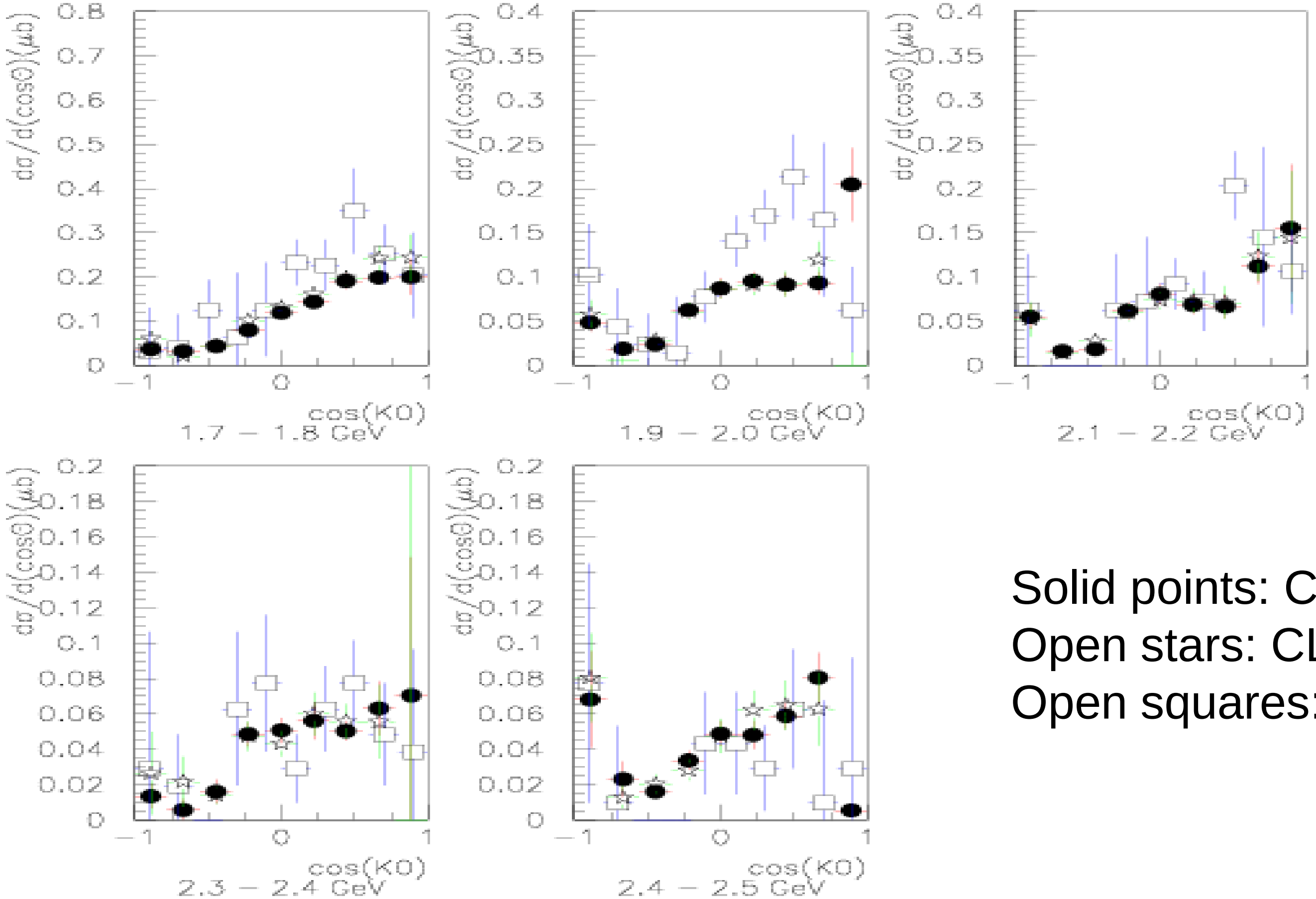
Preliminary CLAS analysis by Wei Tang (Ohio U.)



Although still preliminary, the total cross sections appear to be 2x larger than Guo's analysis.
The procedures used here can be checked using the $K^0\Sigma^+$ cross sections that should agree with world data.

Cross-check: $\gamma\ p \rightarrow K^0\ \Sigma^+$

Preliminary CLAS analysis by Wei Tang (Ohio U.)



Solid points: CLAS
Open stars: CLAS (alt. method)
Open squares: SAPHIR

Future of strangeness analysis

Precise $K^+\Lambda$ (complete set of observables)

Precise $K^{*+}\Lambda$ (including recoil polarization, etc.)

t-channel exchange: K^{*+} K^+

isoscalar

isovector

t-channel

s-channel

Precise $K^0\Sigma^+$ (many spin observables)

Precise $K^{*0}\Sigma^+$ (including some spin observables)

s-channel exchange: S=1/2,S=3/2

Summary

- The s-quark mass is difficult theoretically.
  - Too heavy for ChPT, too light for HQET
  - Need experimental data to guide theory
- New KY, KY* data: meson cloud effects!
  - $K\Lambda$ data show strong s-quark polarization
  - $K^+\Sigma^{*-}(1385)$ beam polarization: why negative?
  - Δ & Σ^* Radiative decays: needs meson cloud
  - K*Y: lots of new, high-quality data: $K_0(700)$?