Excited Hyperons at CLAS/CLAS12

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Motivation

- Compared with the N* sector, the spectrum of hyperons receives less attention
  - For S=-1 sector, only 14 Λ, and 10 Σ states have been established
  - For S=-2 sector, only 6 Ξ states have been established
  - For S=-3 sector, only 2 Ω states have been established
- Most hyperon data came from kaon-beam experiments
- Photoproduction is a great alternative for strangeness production
  - Photon beam has intrinsic $s\bar{s}$ component
  - CLAS, CLAS12 and GlueX offers great opportunities in all hyperon sectors

QM predictions for S=-1 Hyeprons (>2.0GeV)

Λ	$1/2^-$	2015, 2095, 2160, 2195, 2235, 2280
Λ	$3/2^-$	2030, 2110, 2185, 2230, 2290
Λ	$5/2^-$	2180, 2225, 2240, 2295
Λ	$7/2^-$	2150, 2230
Σ	$1/2^-$	2110, 2155, 2165, 2205, 2260, 2275
Σ	$3/2^-$	2120, 2185, 2200, 2215, 2265, 2290
Σ	$5/2^-$	2205, 2250, 2270, 2280
Σ	$7/2^-$	2245

S. Capstick et al., PRD34, 2809 (1986)

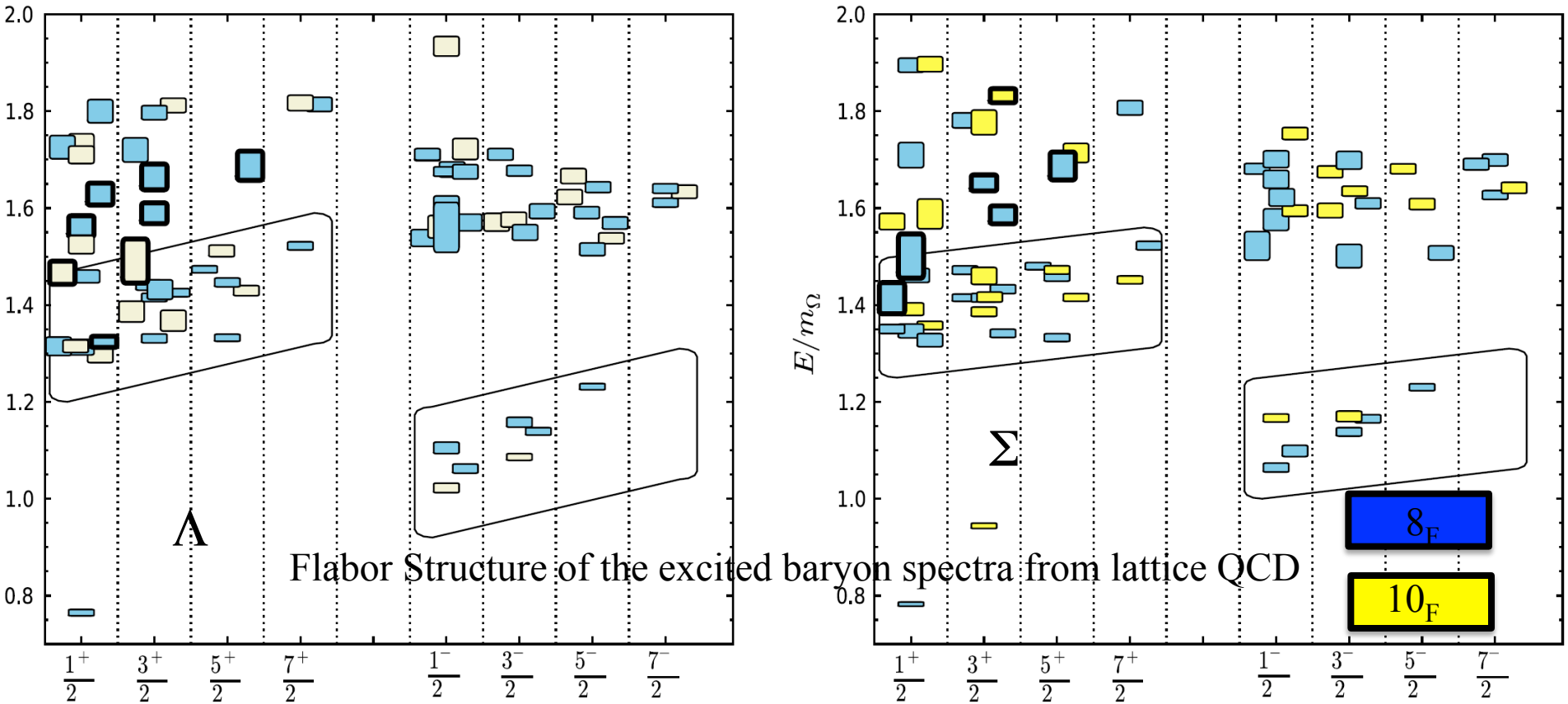
What have been established?

State	Rating
Λ(2100) 7/2-	****
Λ(2110) 5/2+	****
Λ(2350) 9/2+	***
Σ(2030) 7/2+	****
Σ(2250) ??	***

J. Beringer et al, (PDG), PRD86 , 010001, (2012)

Plenty are missing;
Can we discover at least one new state?

LQCD calculation for the S=-1 Hyperon Spectra



Flabor Structure of the excited baryon spectra from lattice QCD

Number of states compatible with QM predictions: Just as many missing states!

S=-1 Hyperons can be also probed via the ΞK channel!

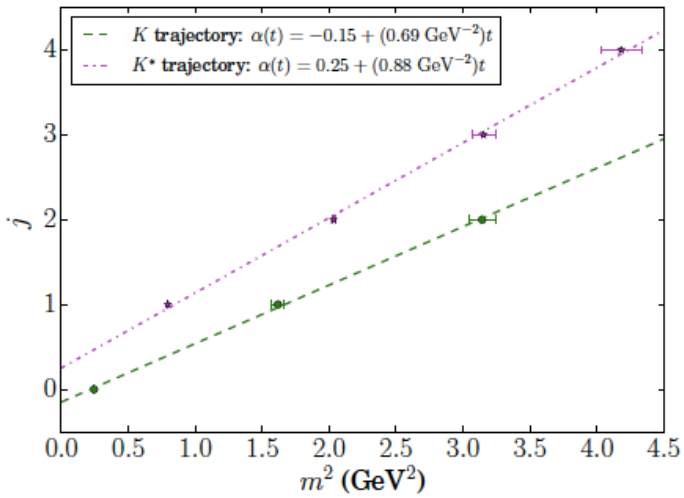
R. Edwards *et al.* "Flavor structure of the excited baryon spectra from lattice QCD",PRD 87, 054506(2013)

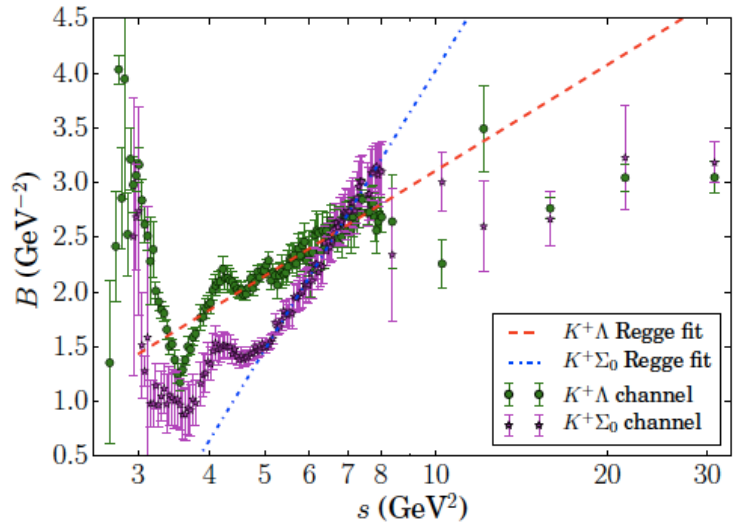
Various Unseen/Rare Decay Modes of Hyperons

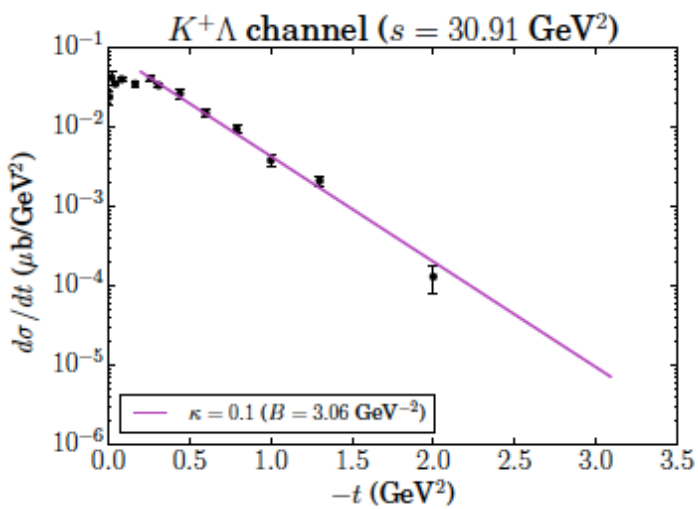
- $Y^* \rightarrow \Xi K$
  - Believed to be the leading contributor to Ξ photoproduction (Oh, Nakayama et al)
  - Never been established;
  - Upper Limit was set for $\Lambda(2100)$ and $\Sigma(2030)$
- $Y^* \rightarrow \Lambda/\Sigma + \eta$

  $\Lambda(1670) \rightarrow \Lambda\eta$, $\Sigma(1750) \rightarrow \Sigma\eta$
- Radiative Decay of exited hyperons
  - Only two have been measured
    - $\Sigma(1385)$, and $\Lambda(1520)$
- $Y^* \rightarrow \Lambda/\Sigma + \eta'$
  - Never been seen

Production Mechanism for Ground States:







Most data from CLAS

Λ seems to follow a single K trajectory

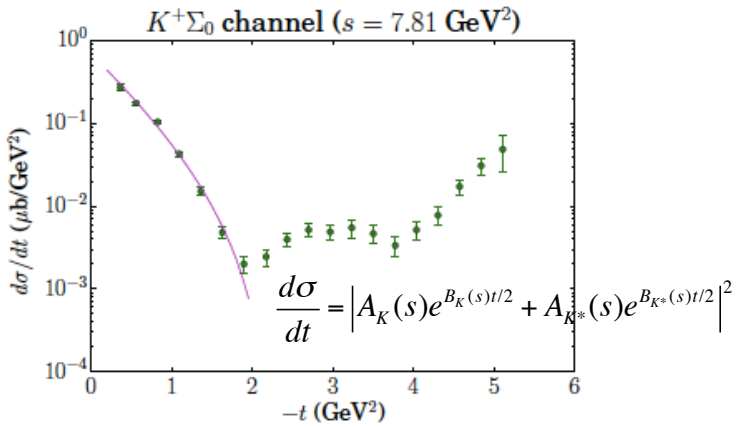
Σ cannot be explained by Kaon exchange

Higher energy data missing (GlueX/CLAS12)

arXiv:1609.03879v2 hep-ph

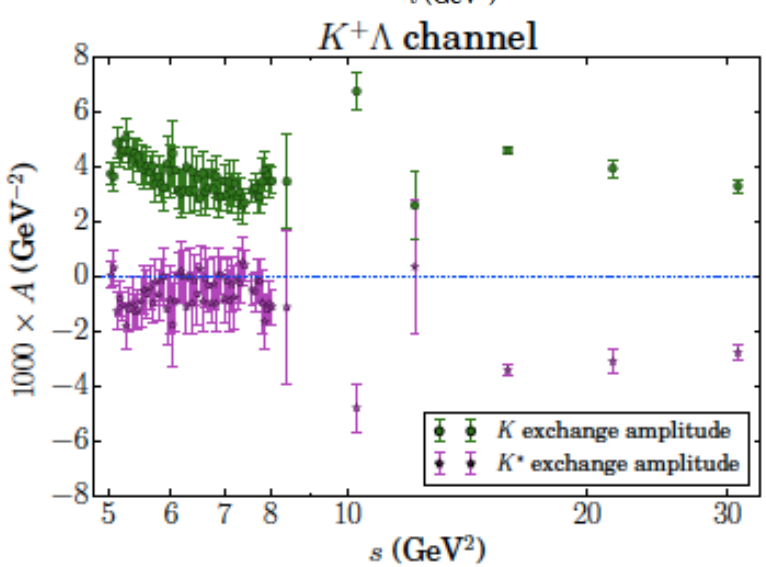
Freese et al. (2016)

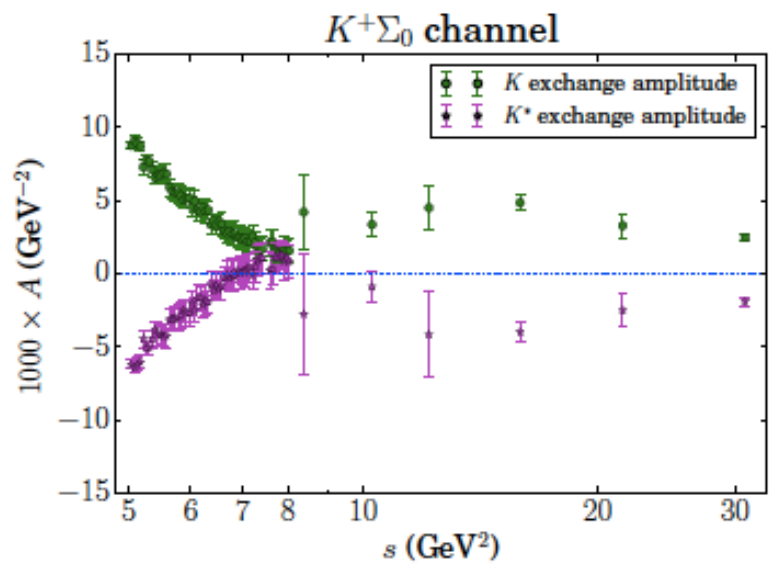
Production Mechanism for Ground States: Double-Exponential Fits



- Λ Photoproduction dominated by K exchange;
- Σ photoproduction: comaprable contributions from K and K* exchange

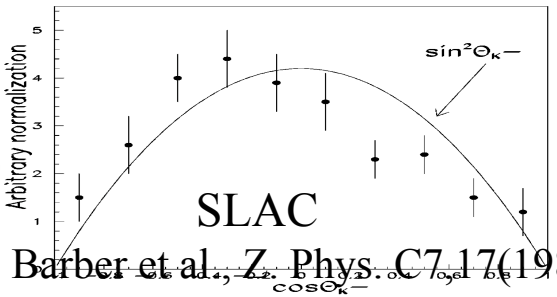
Excited hyperons?



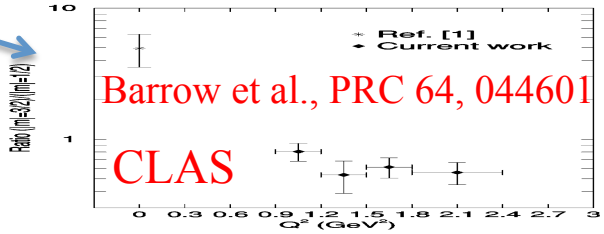


Production Mechanisms of Hyperons

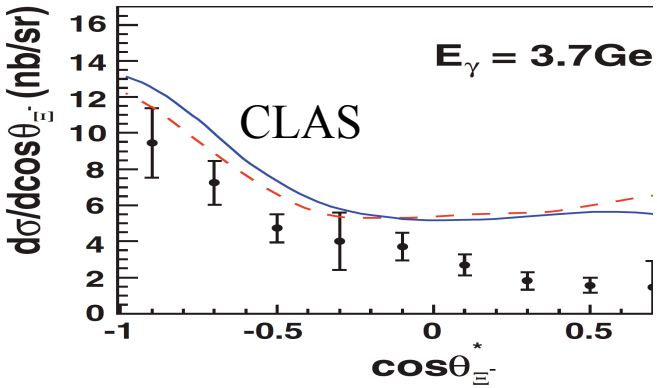
- Λ(1520) photoproduction
  dominated by K* exchange
- Λ(1520) elctroproduction:
  more K exchange
- Exchange particle information can be extracted via angular distribution/PWA
- Other exited hyperons?
  unknown!
- Ξ: photoproudced
  via intermediate hyperons?



Barber et al., Z. Phys. C7,17(1980)

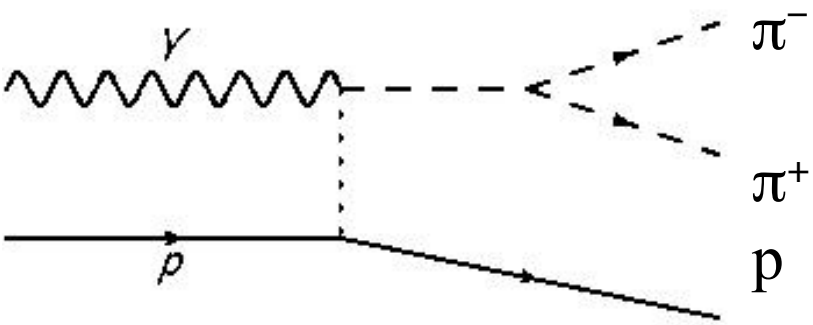


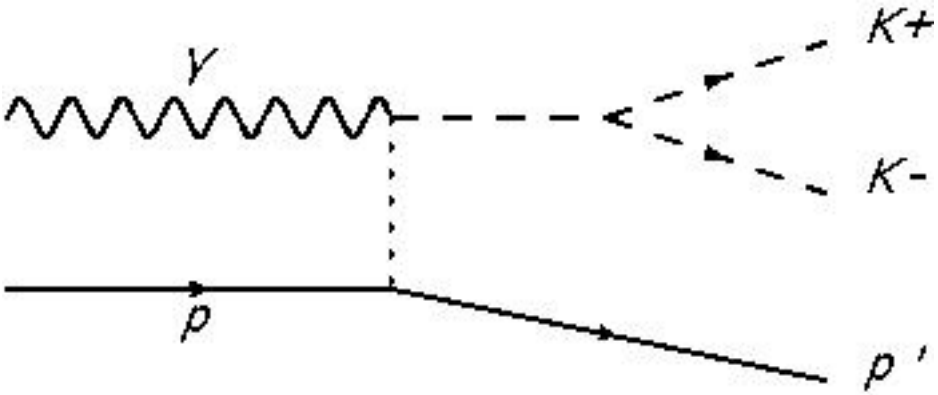
Barrow et al., PRC 64, 044601 (2001)

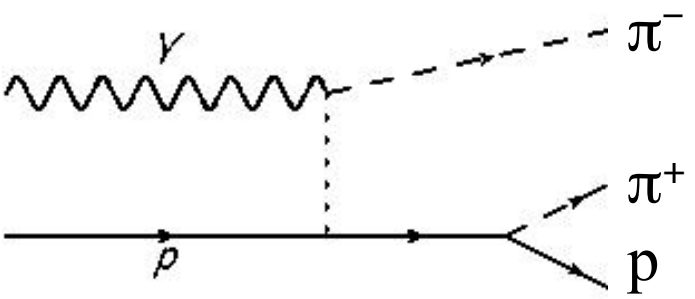


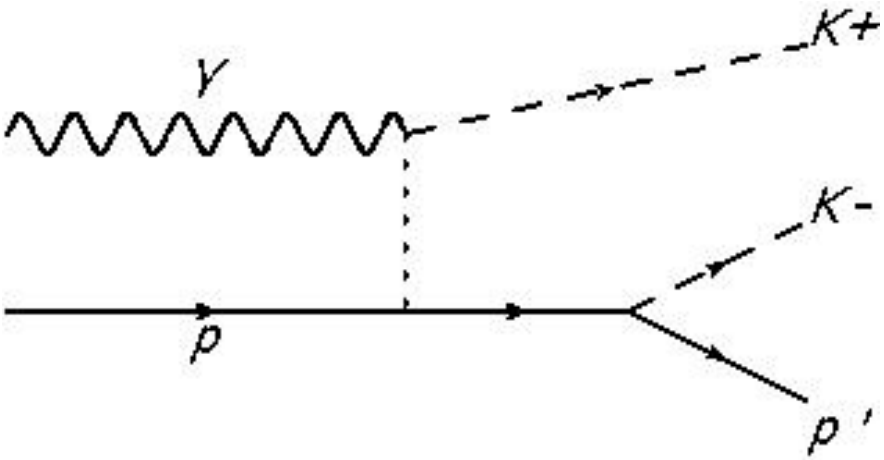
Guo et al., PRC76, 025208 (2007)

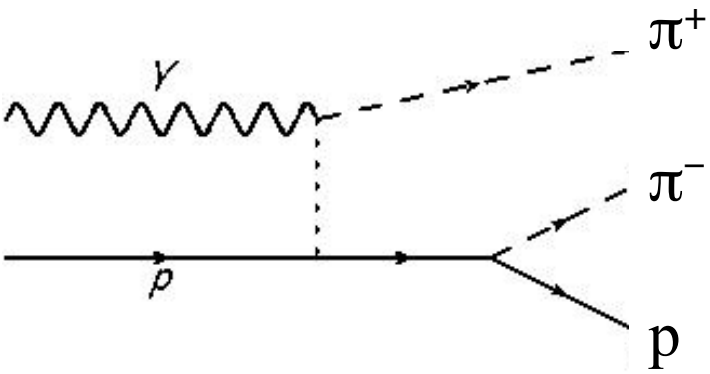
Two Pseudoscalar Meson Photproduction: ππ VS KK (non-resonance region)







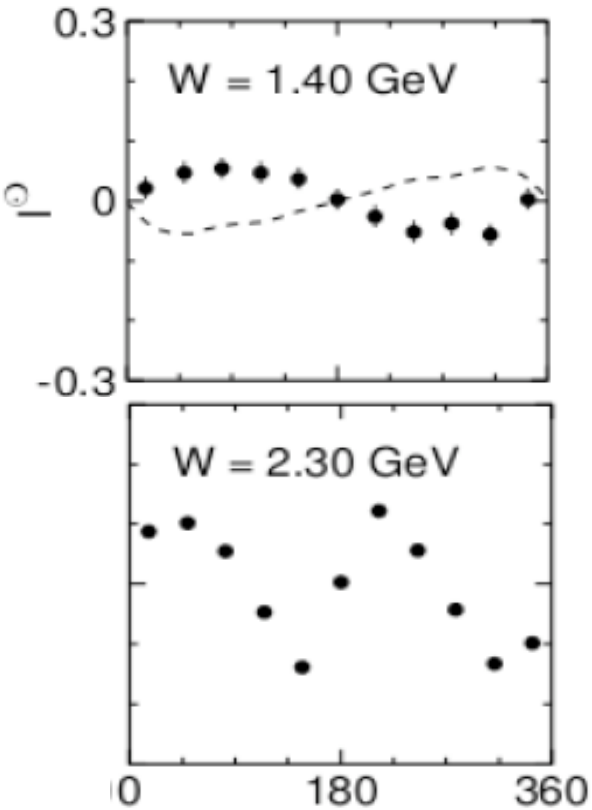




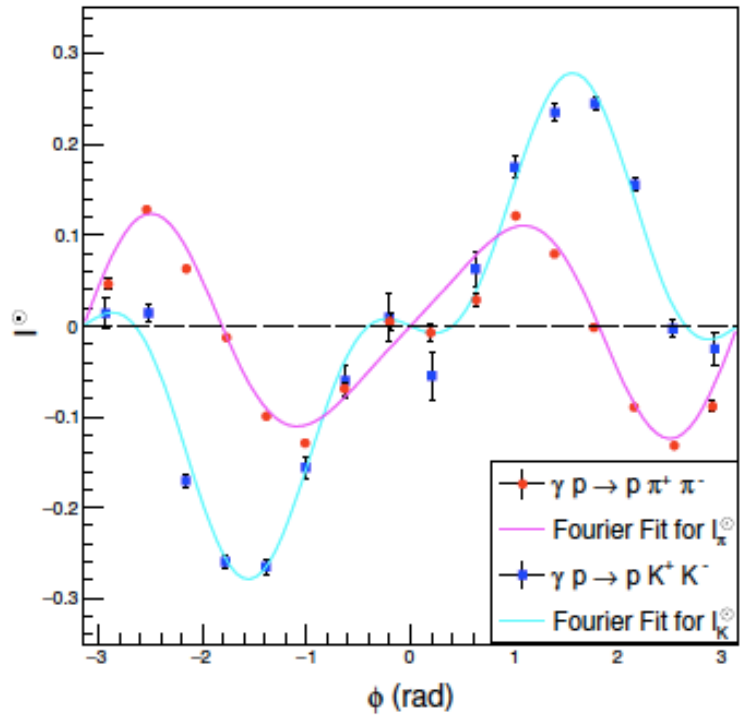
Lack of pK+ resonances → reduction of one major diagram

Different interference pattern?

Beam Helicity Asymmetry:ππ VS KK



$\gamma p \rightarrow p\pi^+\pi^-$



R.

ϕ: Angle between the two-meson plane/production plane

Eg: 2.8-5.5 GeV

Key difference:

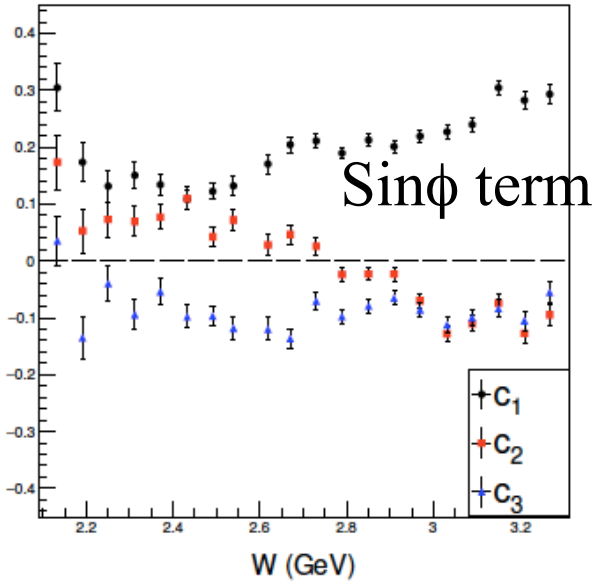
sin2ϕ vs sinϕ

Different strengths

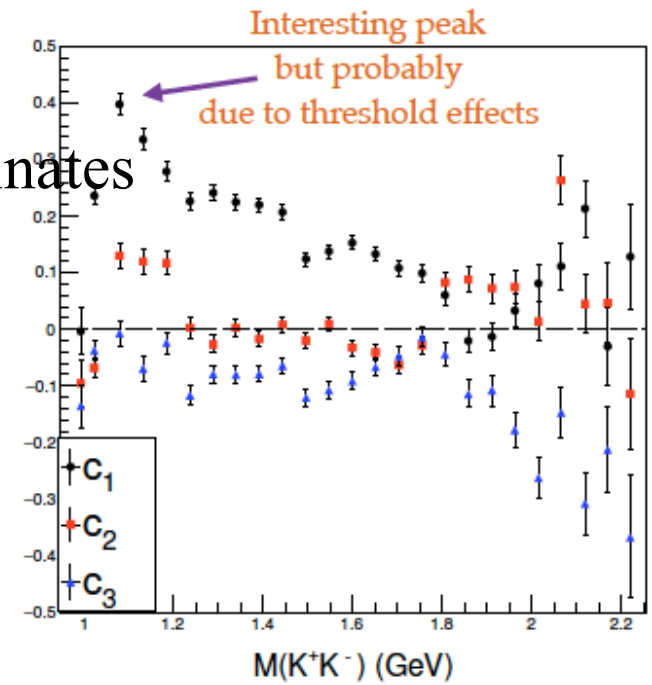
(not necessarily fair comparisons)

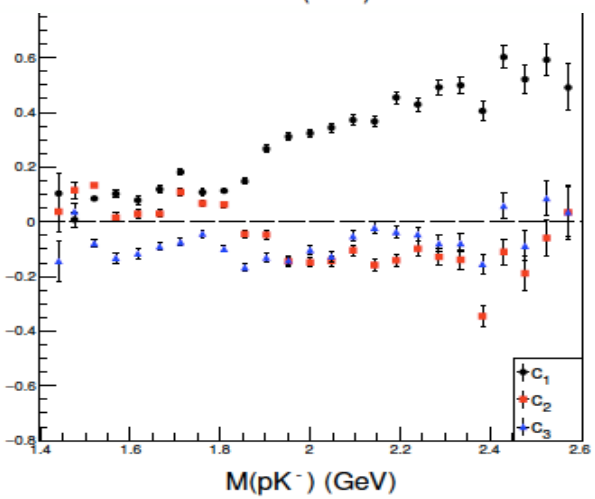
Strautch et al., PRL 95, 162003 (2005)

Beam Helicity Asymmetry: Dependence on invariant masses



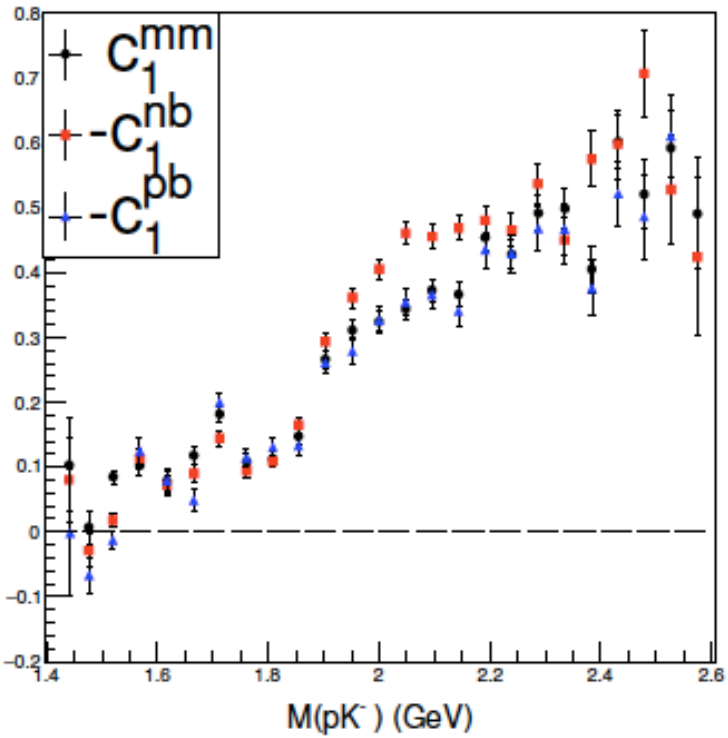
Sinϕ term dominates

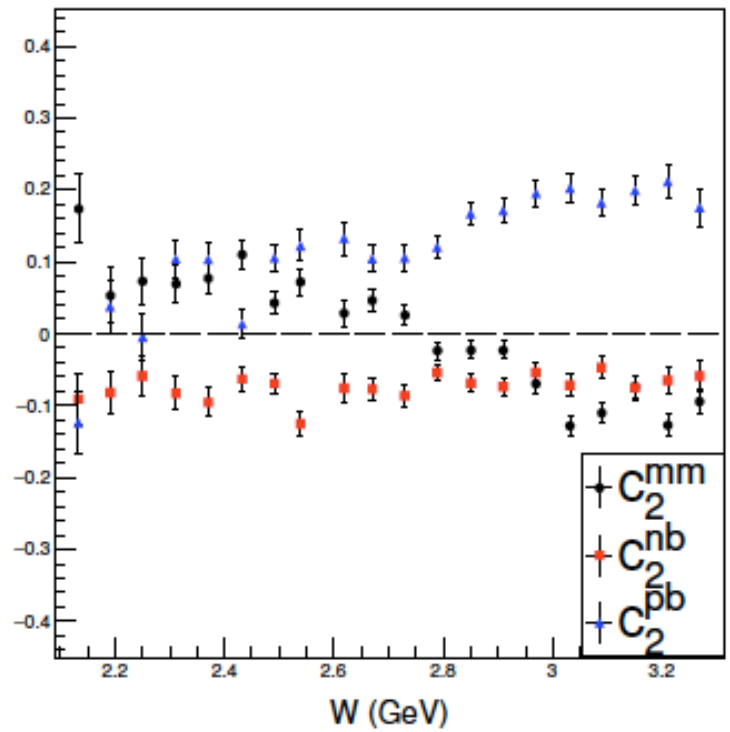




- Strong dependence on pK^- invariant mass
  -- higher mass hyperons?
- Need theoretical predictions for comparison

Fourier Coefficient dependence on the plane definitions





The dominant term (sinϕ) coefficient seems independent on the planne defintion
Similar observation for the ππ chanel
Higher terms do not exhibit this independence

Radiative Decay of Excited Hyperons

CLAS Results in PDG

$\Sigma(1385) \rightarrow \Lambda\gamma$

$$\Gamma(\Lambda\gamma)/\Gamma(\Lambda\pi)$$

$1.42 \pm 0.12^{+0.11}_{-0.07}$	624 ± 25	KELLER	11	CLAS
$1.53 \pm 0.39^{+0.15}_{-0.24}$	61	TAYLOR	05	CLAS

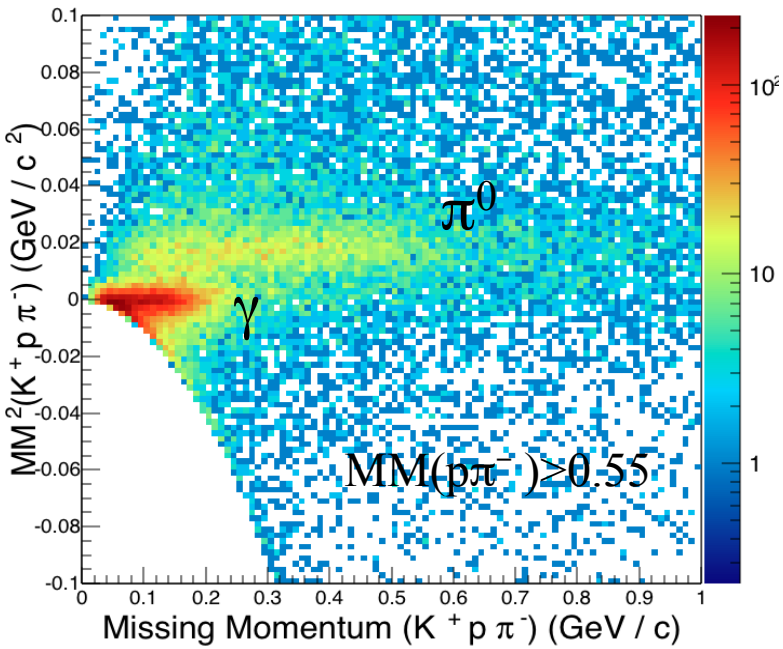
$\Lambda(1520) \rightarrow \Lambda\gamma$ PRC **71**, 054609 (2005)

$$\Gamma(\Lambda\gamma)/\Gamma_{total}$$

$10.7 \pm 2.9^{+1.5}_{-0.4}$	32	TAYLOR	05	CLAS

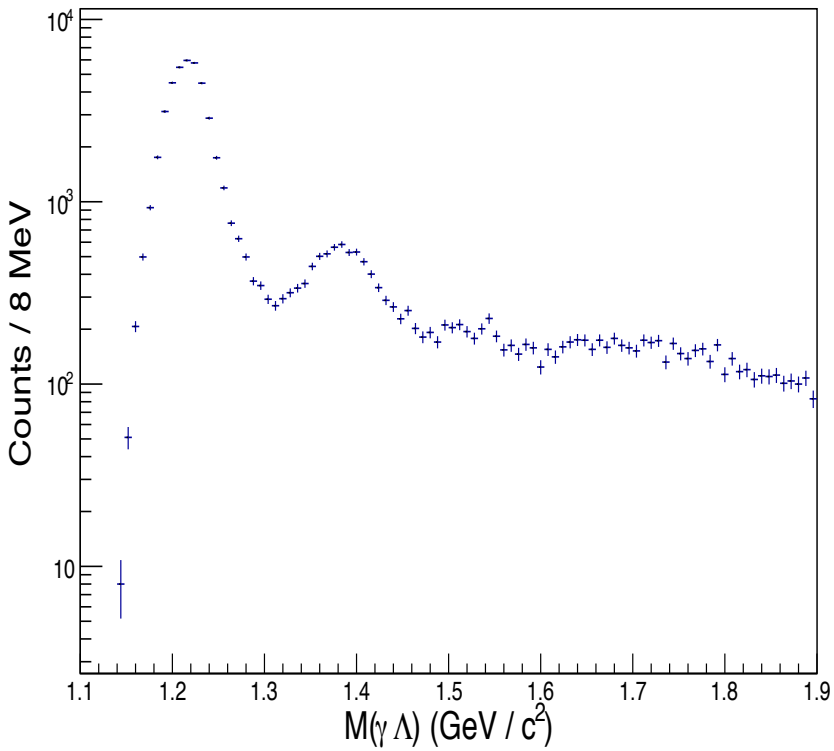
The radiative decay is related to the meson Cloud effect on the magnetic moment, and the quark wavefunctions of hyperons

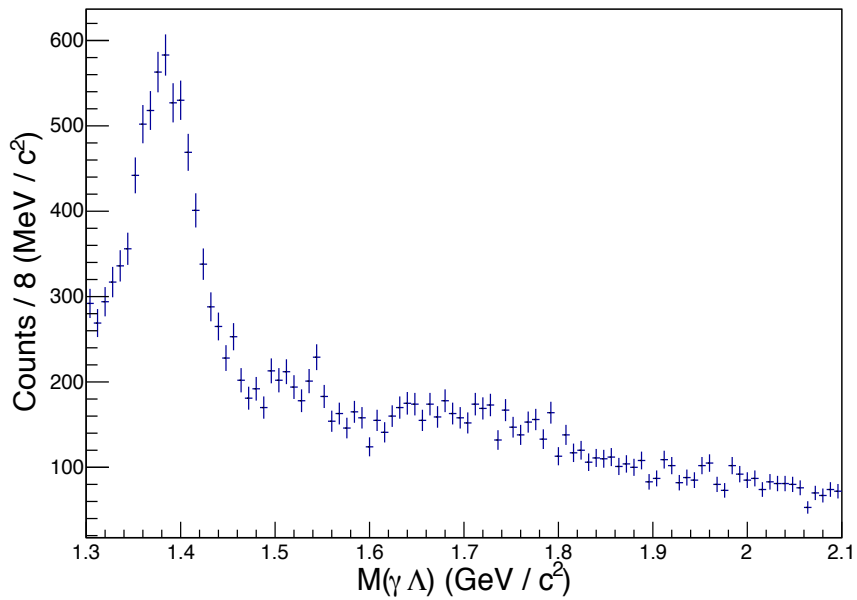
Others? None observed



g12 prospect

Radiative Decay of Excited Hyperons

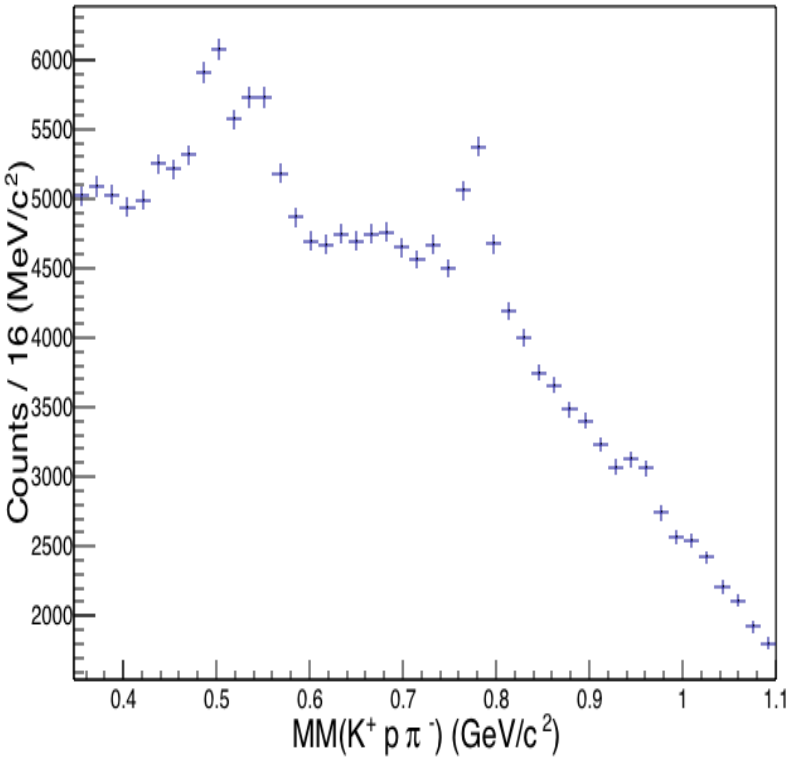




$$\gamma p \rightarrow K^{+}\Lambda(\gamma)$$

- Preliminary studies: Puentes et al, FIU
- π^0 contamination needs to be estimated
- Kinematic fitting to be used
- 25% statistics shown
- Data promising
  - Multiple background processes

$\gamma p \rightarrow K^{+}\Lambda(\eta/\omega/\eta')$? A tentative look



Y* → Λ/Σ+η

Two states reported

Y* → Λ/Σ+ω

Some limits established

Y* → Λ/Σ+η'

Never been seen

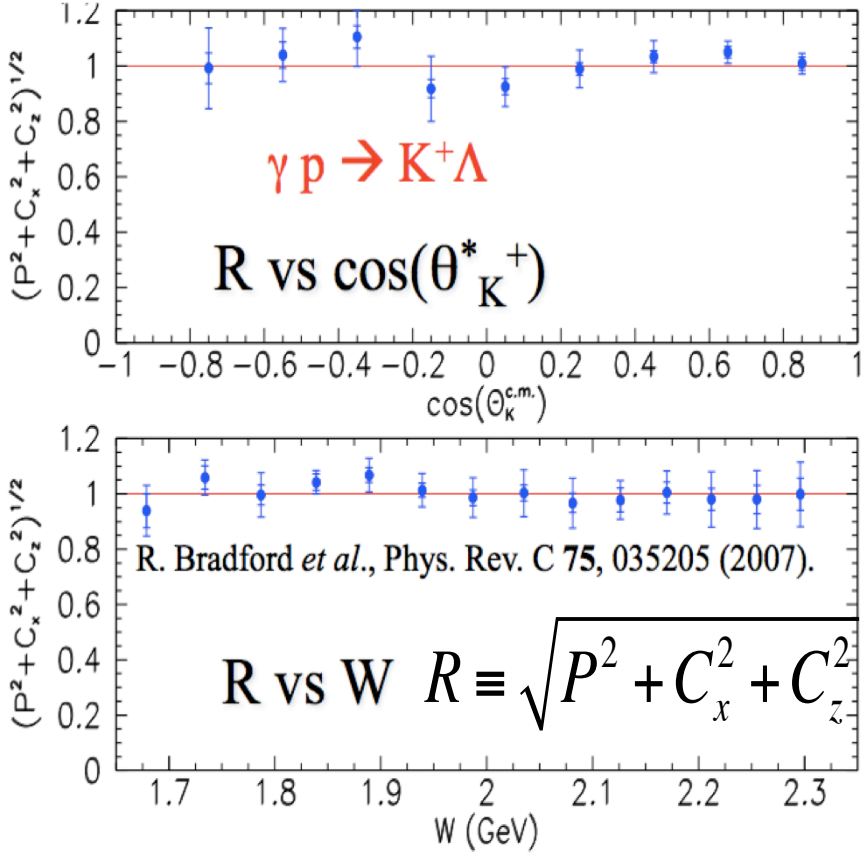
Beam helicity asymmetry could be studied

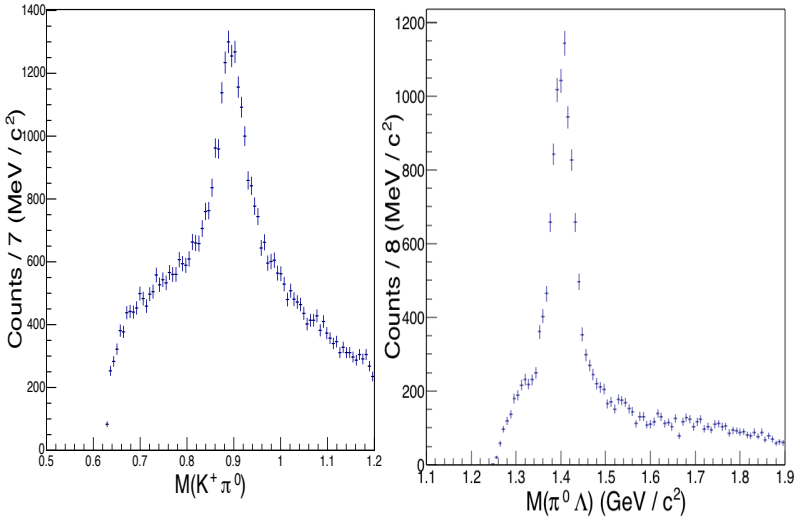
Statistics limited for (PWA)

Future experiments (CLAS12/GlueX)

Could also be due to strange meson's decay to $K^{+}\eta/\omega/\eta'$

Λ polarization in $K^+\Lambda/K^{*+}\Lambda$ photoproduction



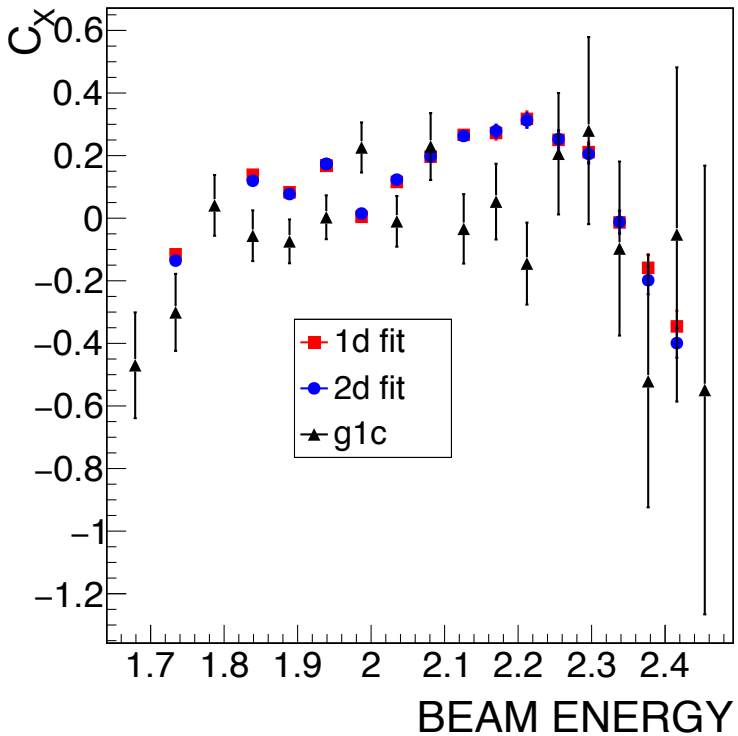


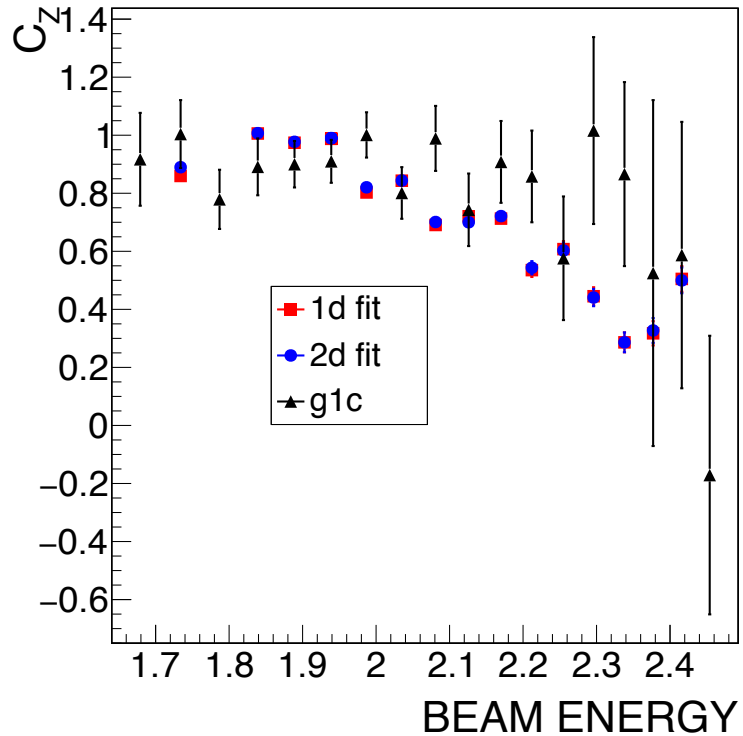
$$\gamma p \rightarrow K^+\Lambda(\pi^0)$$

Prior CLAS results (Tang et al, PRC 87, 065204 (2013)) did not publish polarization results

- 100% polarization in $K^+\Lambda$ photoproduction
- Various models suggest similar behavior in
- $K^{*+}\Lambda$ photoproduction

Extending the Λ polarization measurements





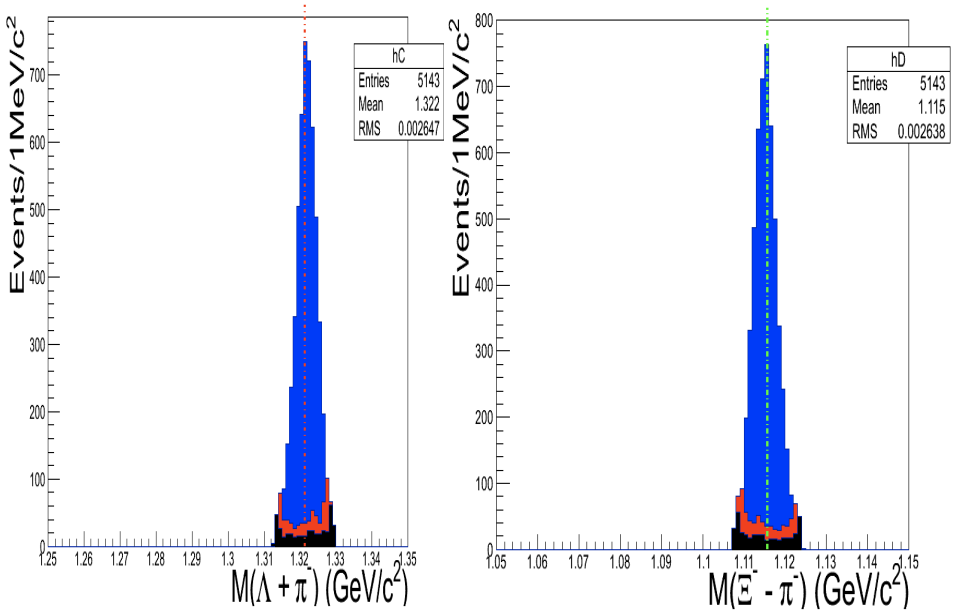
Polarization observables important to extract the missing nucleon resonances

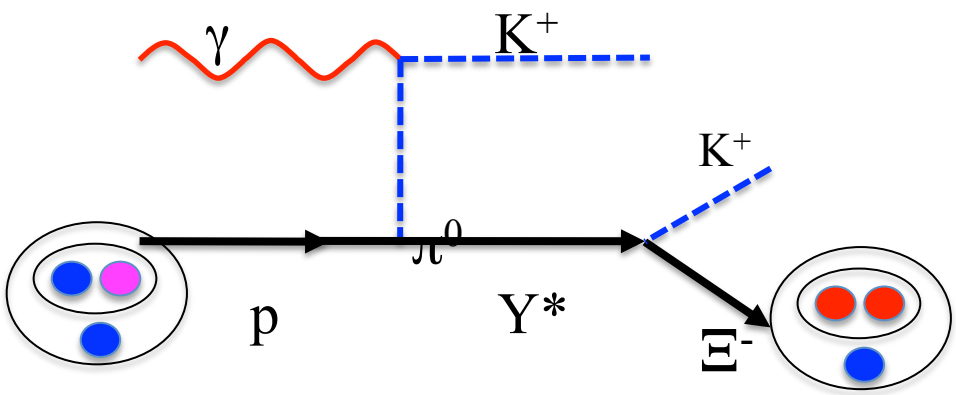
New CLAS data (g12) can reduce the statistical uncertainty by a factor of 3!

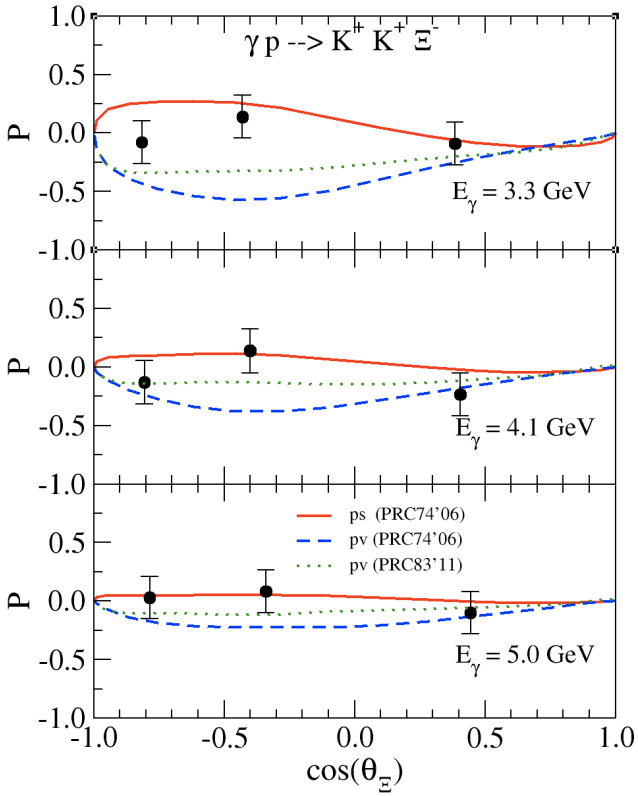
Polarization extraction methods improved (2d Fits/Maximum Log Likelyhood)

Future data can extend the measurement at higher energies

Ξ^- induced olarization in photoproduction

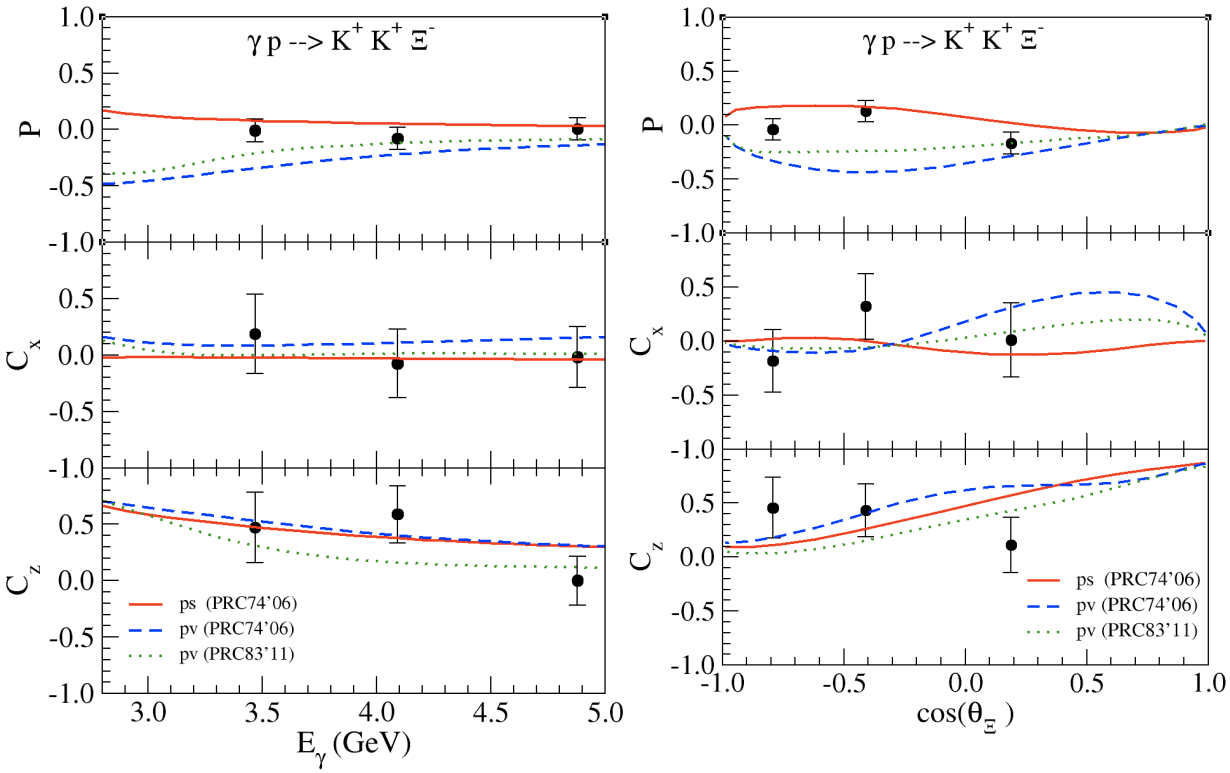






First time measurement!
(Bono Ph.D Thesis, 2014)
Collaboration review in progress.

Ξ^- Polarization in photoproduction



- Results VS prediction: Limited by statistics
- R~0.3
  VS R~1 for Λ results
- Unable to distinguish models
- Future data expects multiple orders of magnitude more statistics
  GlueX
  CLAS12: Very Strange Experiment

Theoretical curves from Nakayama et al

Model variants: Pseudoscalar/Pseudovector coupling/High-mass hyperons

Man et al., PRC83, 055201, (2011)

Nakayama et al., PRC74, 035205 (2006)

Summary

- Hyperon Spectroscopy offers multiple opportunites for S=-1 sector
- CLAS data already has multiple promises
  - First measurement of pK^+K^- beam helicity asymmetry measurements
  - First measurement of Ξ^- polarization in photoproduction
  - Radiative decays of excited hyperons could be extended
- CLAS12/GlueX would be gold mines for hyperons
  - $Y^* \rightarrow \Lambda\eta/\omega/\eta'$
  - Ξ polarization: Much higher statistics; PWA of $Y \rightarrow K\Xi$
  - Extend the measurement for ground states at higher energies

Acknowledgement

- Organizers and Jefferson Lab
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