Excited Hyperons and the CLAS12 Very Strange Experiment

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for CLAS Collaboration

Outline

- Motivation
- Existing CLAS data in S=-1 and S=-2 sector
  - High mass S=-1 hyperons
  - Cascade polarization
- Future: CLAS12 Vey Strange Exeperiment
  - Excited Cascades
  - Ω^- photoproduction

Motivation: Why study hyperons

- Compared with the N* sector, the spectra of hyperons are less understood
  - For S=-1 sector, only 14 Λ, and 10 Σ states established
  - For S=-2 sector, only 6 Ξ states have been established
  - For S=-3 sector, only 2 Ω states have been established
    - Production mechanism poorly understood
- Investigate how the quark mass changes the effective degrees of freedom of hadron spectra
  - Comparison with QM and Lattice QCD predictions
- Hyperons play important role not just on earth and in the present world
  - neutron star, supernova evolution and early universe

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

State	J^P	Masses (MeV)
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)
(Negative Parity States only)

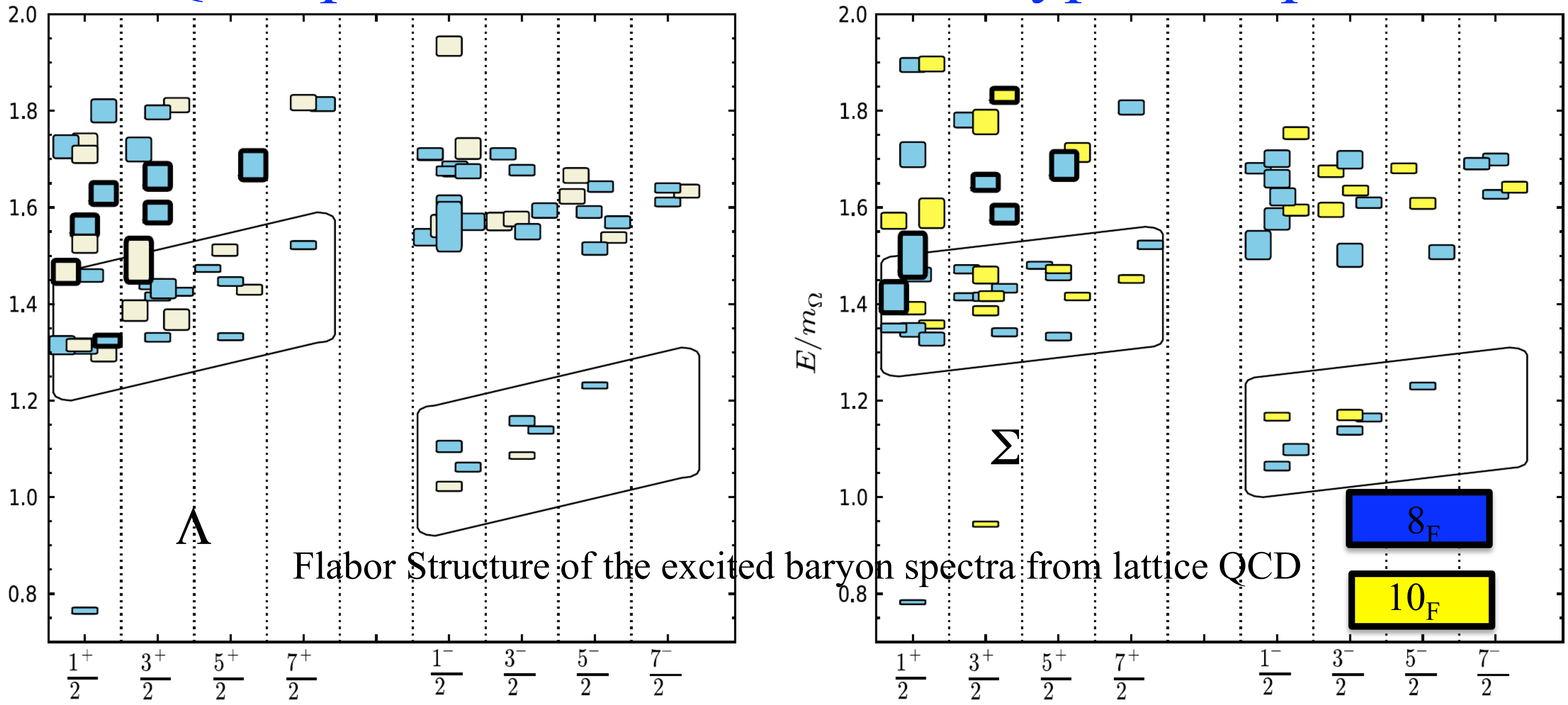
What have been established?

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

K. A. Olive *et al*, (PDG),
Chin.Phys.C38 , 090001, (2014)

Only one state, Λ(1520) , has pole position determined recently

Motivation:
LQCD prediction for the S=-1 Hyperon Spectra



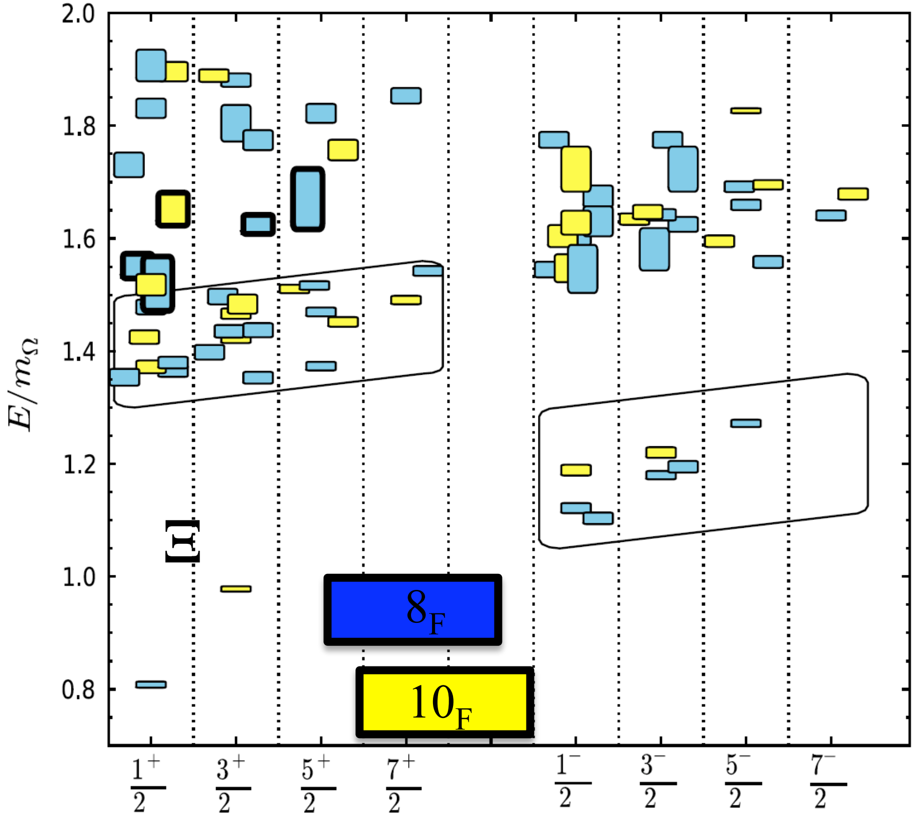
Number of states compatible with QM predictions

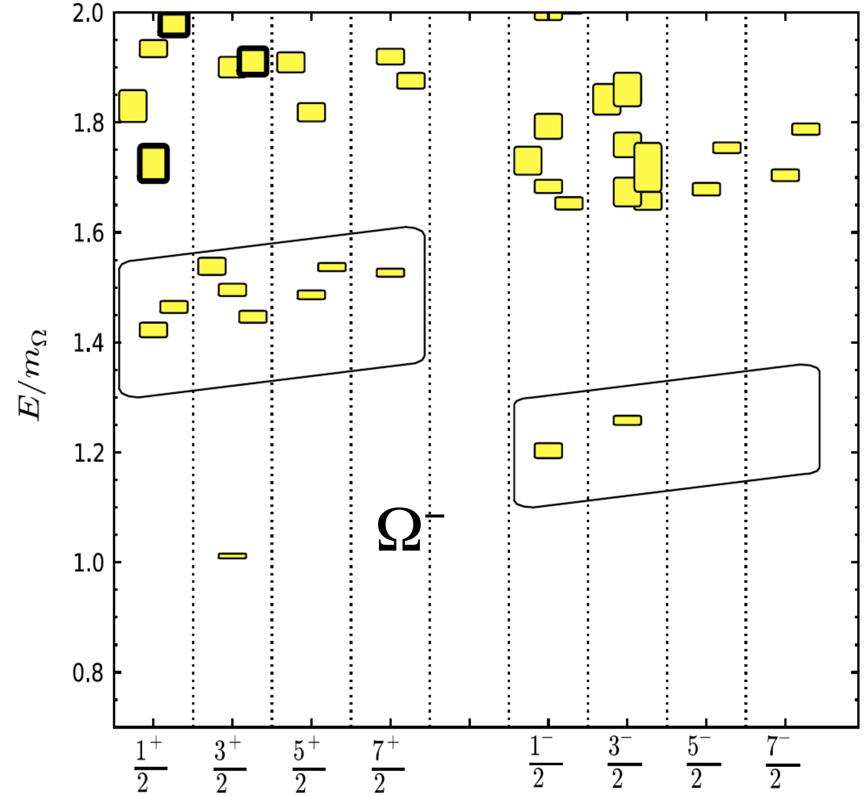
R. Edwards *et al.*

"Flavor structure of the excited baryon spectra from lattice QCD",PRD 87, 054506(2013)

Motivation:

LQCD prediction for the Ξ and Ω spectra

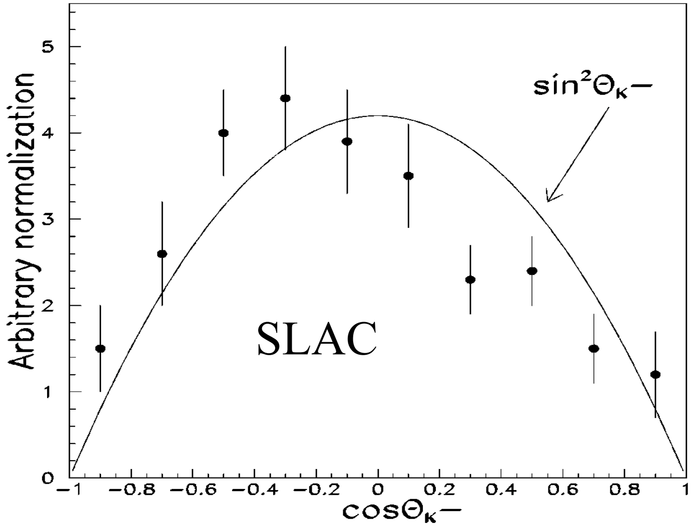




Very few (only four) Ξ states has J^P measured

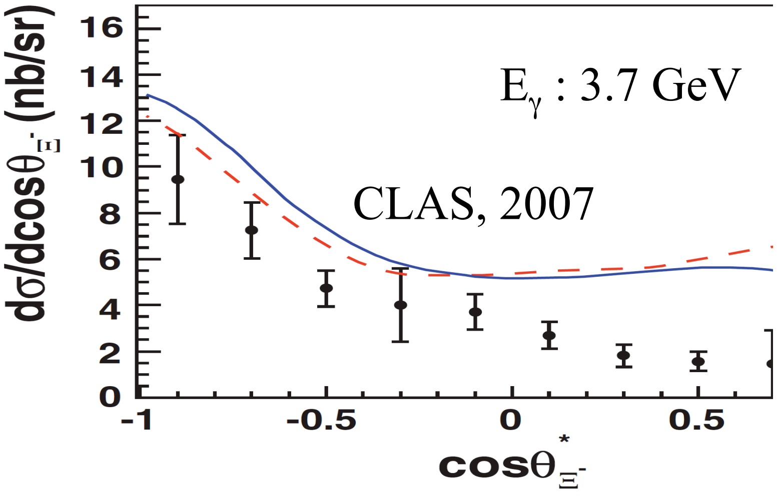
Motivation:
Production Mechanisms of S=-1/, -2 hyperons

- Λ(1520) photoproduction dominated by K* exchange



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

- Ξ: photoproudced via intermediate hyperons?
  - Polarization observables also are important

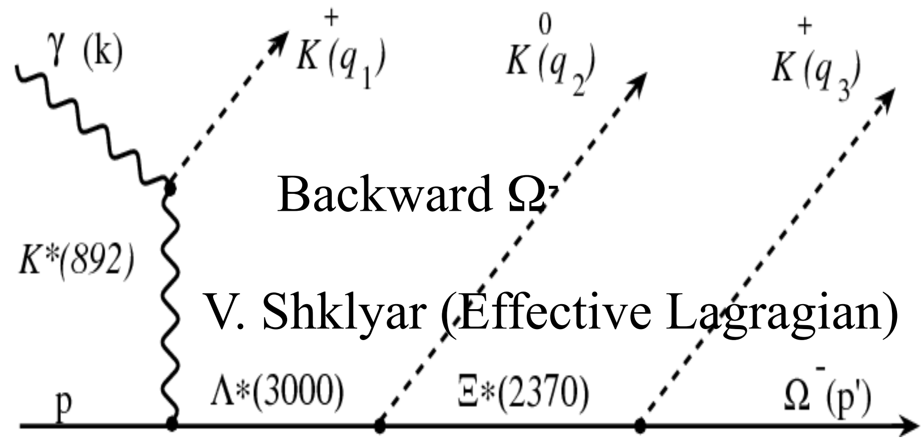


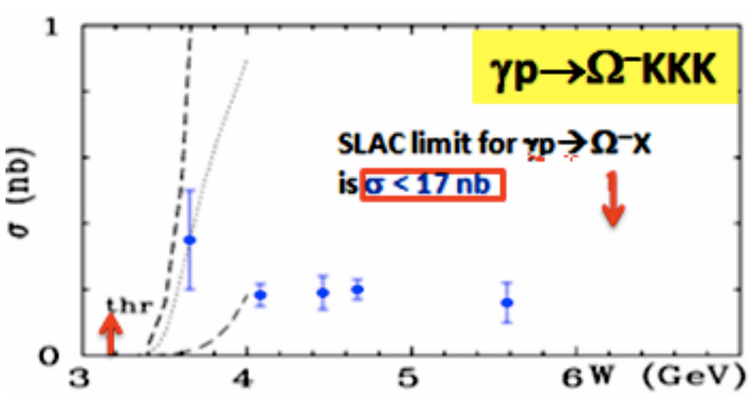
Guo *et al*., PRC76, 025208

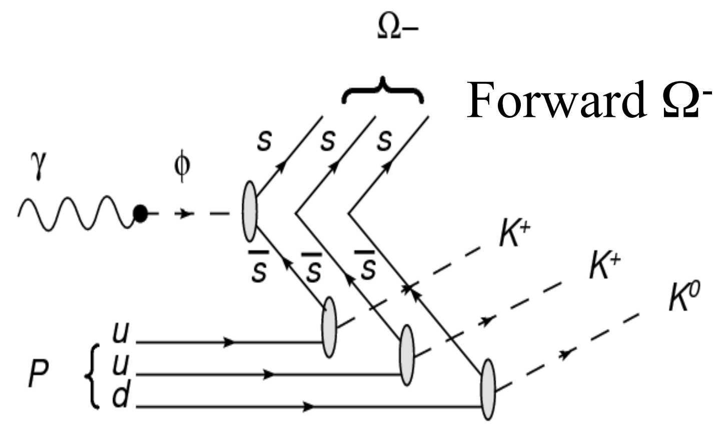
Motivation:
photoproduction mechanism of the very strangest baryon: Ω^-

What is so "strange" about Ω^- photoproduction?

- Three s quark in Ω^-;
  None in the initial state
- Mechanism totally unknown
- Different models predicts opposite angular preferences
- Cross section predictions are consistent:
  $\sigma \sim$1nb at CLAS12 energy range

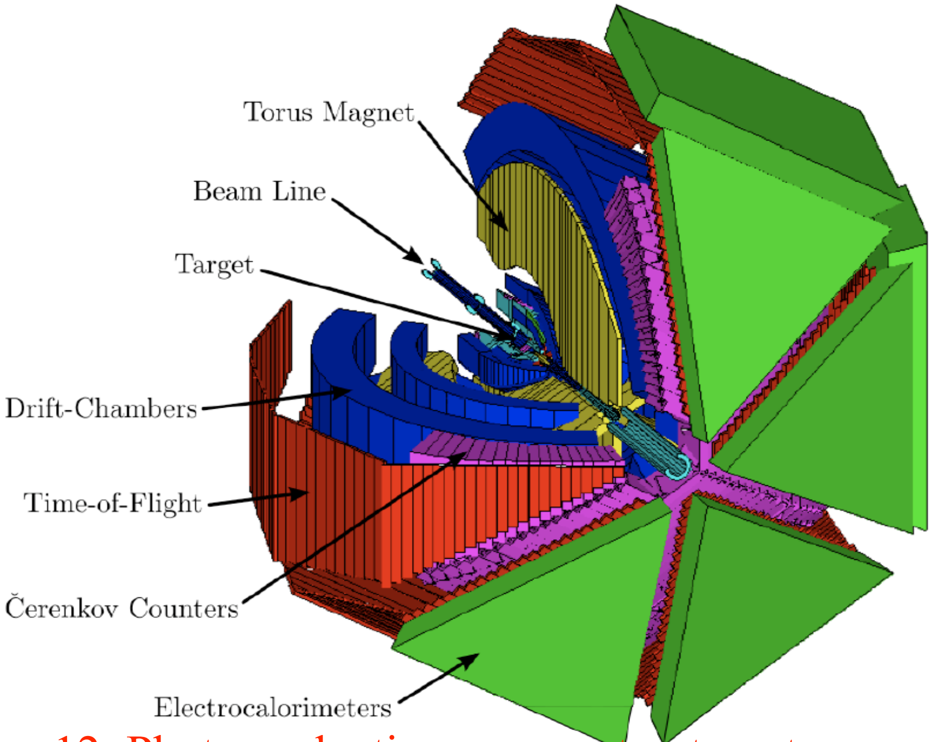






A. Afanasev (VMD)

Existing data: CLAS g12 experiment



g12: Photoproduction on a proton target
Integrated luminosity: 68pb-1
Eg: up to 1.3-5.5GeV
Circular polarization: ~70%
Target: Unpolarized
Channels for hyperon spectroscopy:

$\gamma p \rightarrow pK^+K^-$

- Hyperon production is the background for strangeonia
- Beam helicity Asymmetry
- Y*→ pK⁻ PWA

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

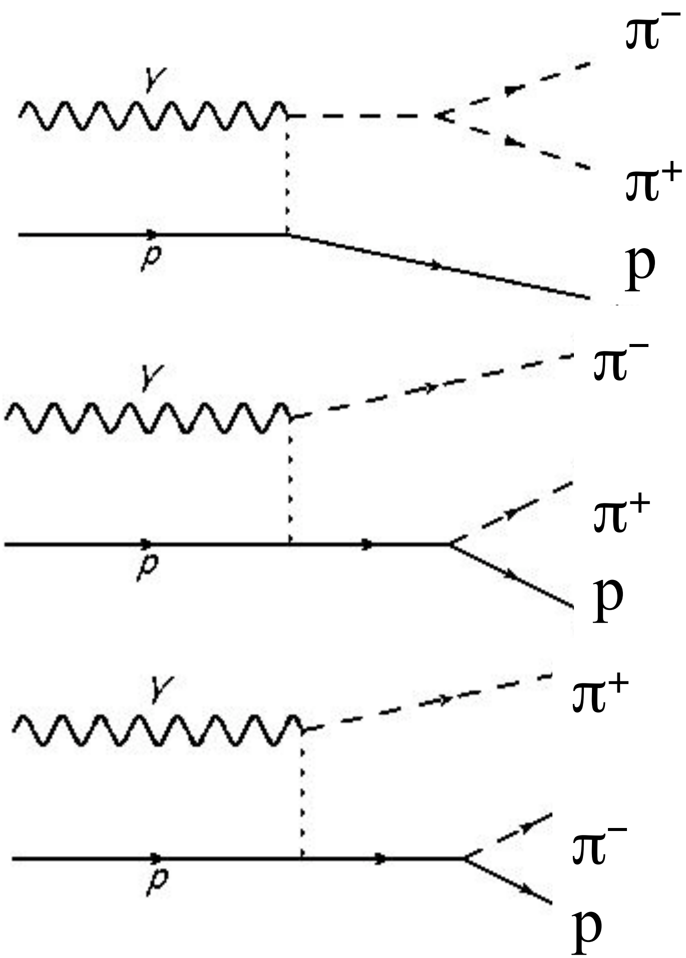
- K*Y and KΣ(1385) important for high-mass N* (P, Cx, Cz, I^C)

$\gamma p \rightarrow K^+K^+\Xi^-, \Xi^- \rightarrow \pi^-\Lambda$

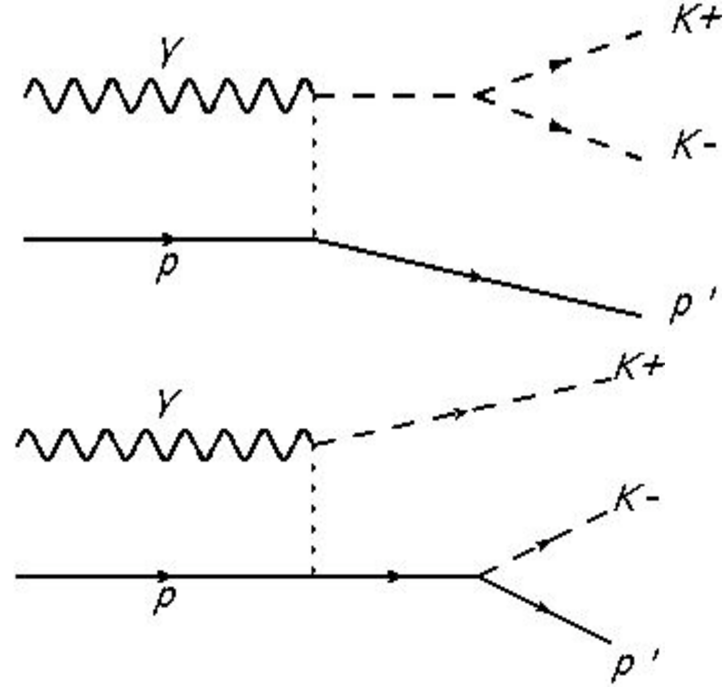
Use polarization observables to probe possible intermediate Y*

Existing data:

Two Pseudoscalar Meson Photproduction: ππ VS KK



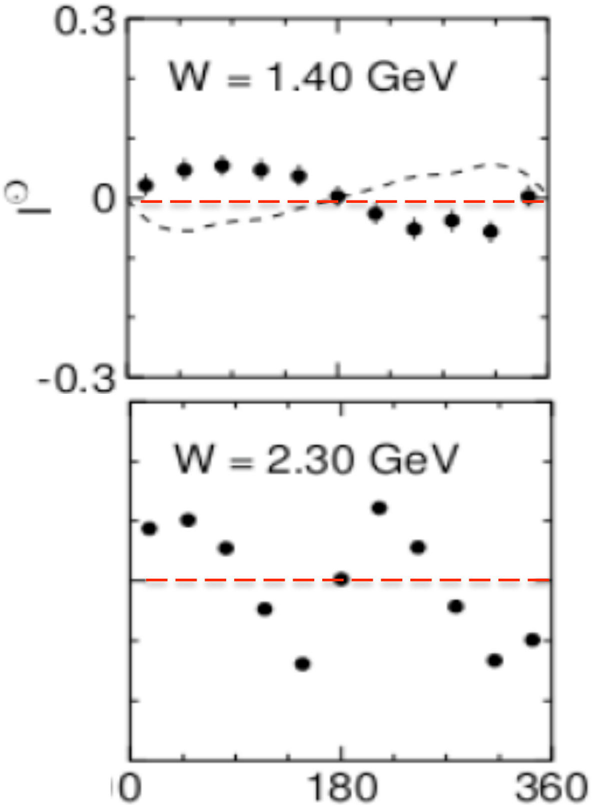
Non-resonance region ππ photoproduction



Lack of pK^{+} resonances:
reduction of one major diagram

Different interference pattern expected

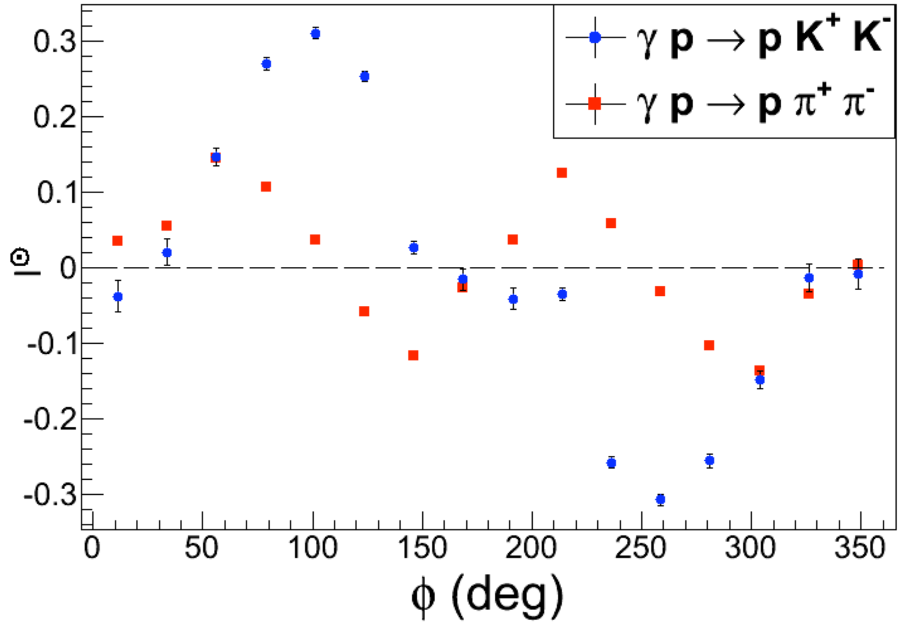
Existing data: Beam Helicity Asymmetry:ππ VS KK



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

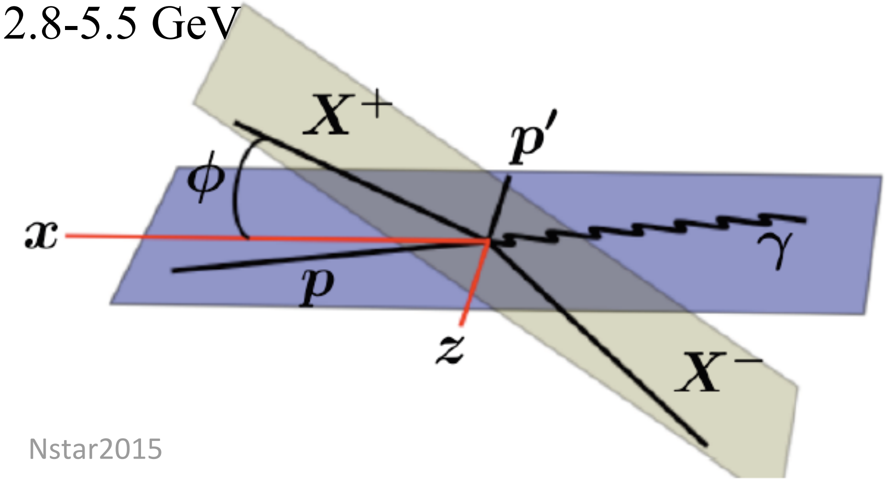
$$\gamma p \rightarrow p\pi^+\pi^-$$

- Strong w-dependence
- Amplitude/Frequency change



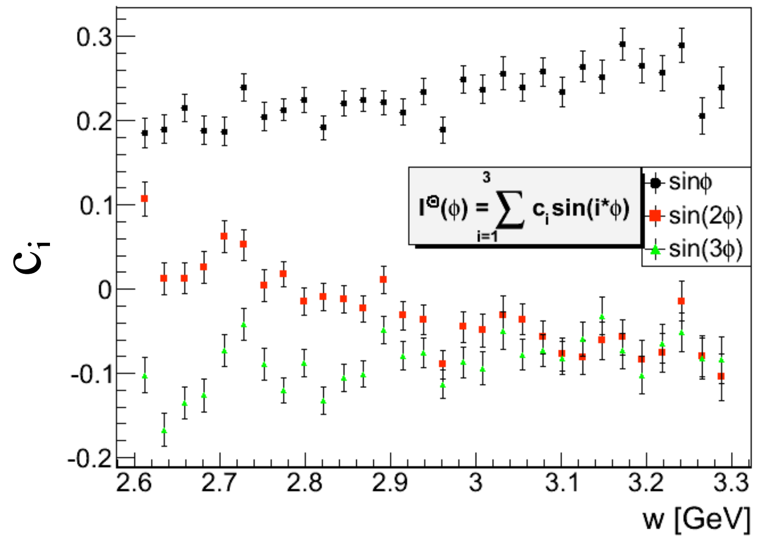
ϕ: Angle between the two-meson plane/production plane

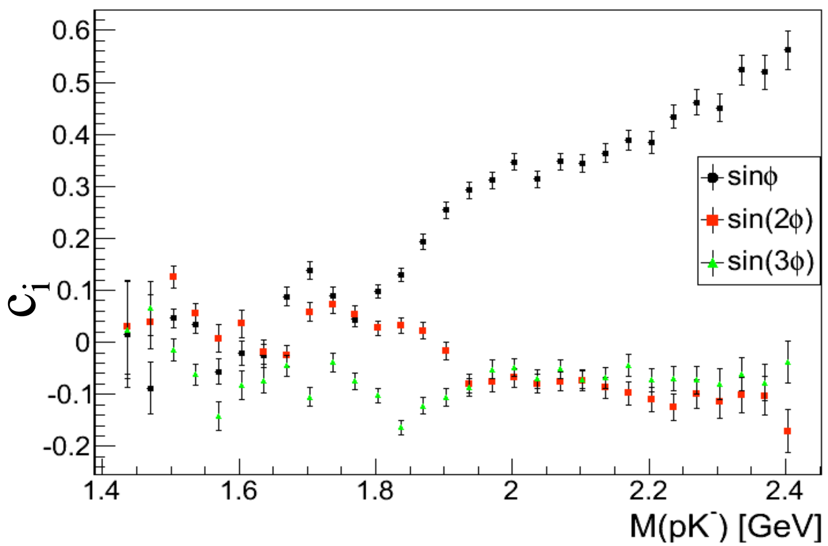
Eg: 2.8-5.5 GeV

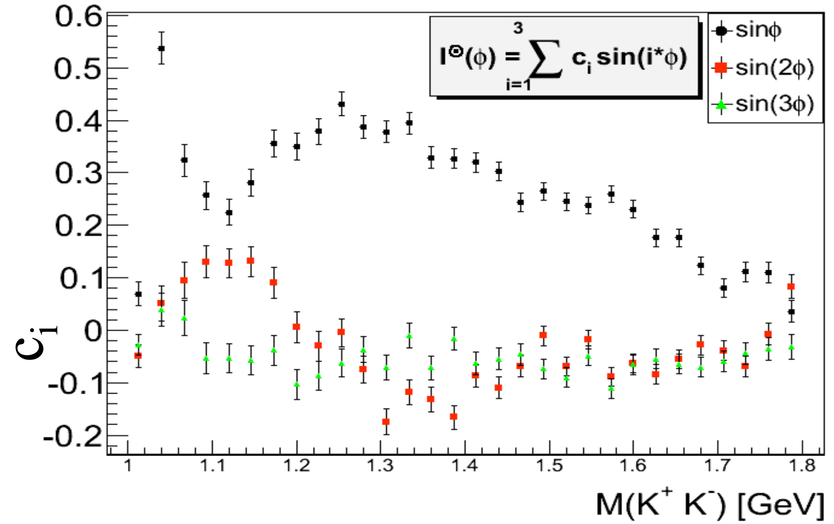


Existing data: $\gamma p \rightarrow pK^+K^-$ Beam Helicity Asymmetry

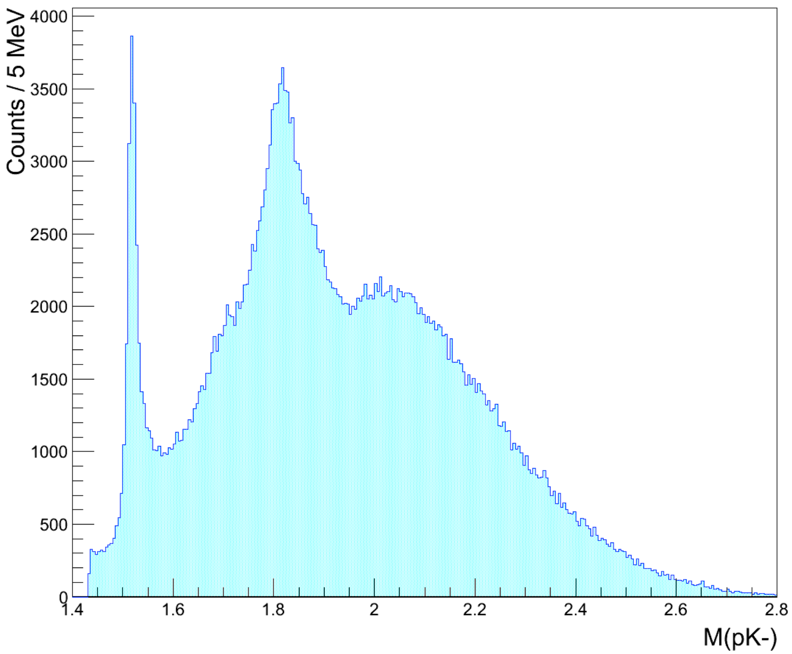
- Fit with Fourier series
- Dominant term is sinϕ
- Asymmetry mmplitude (c_i) changes with pK$^-$/KK masses
- Offers important constraint for production model and PWA

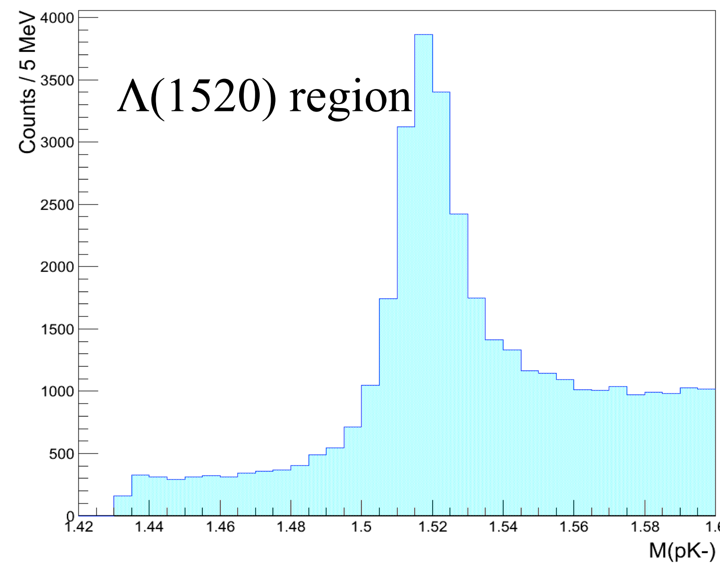


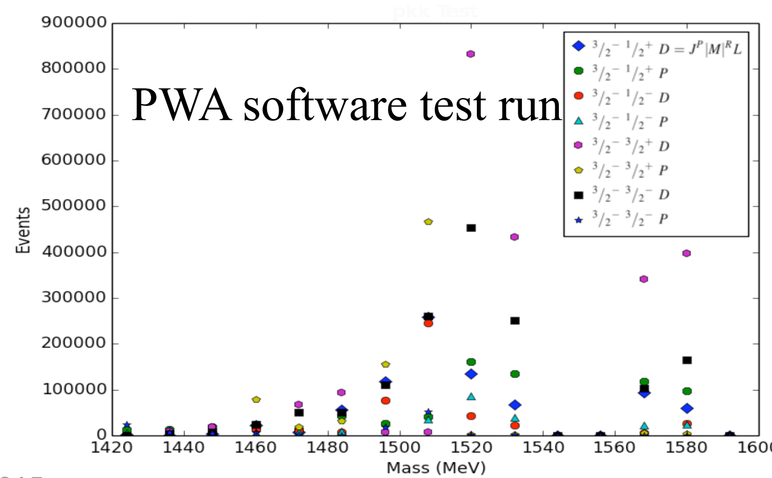




Existing data: PWA plan for Y*→pK$^-$



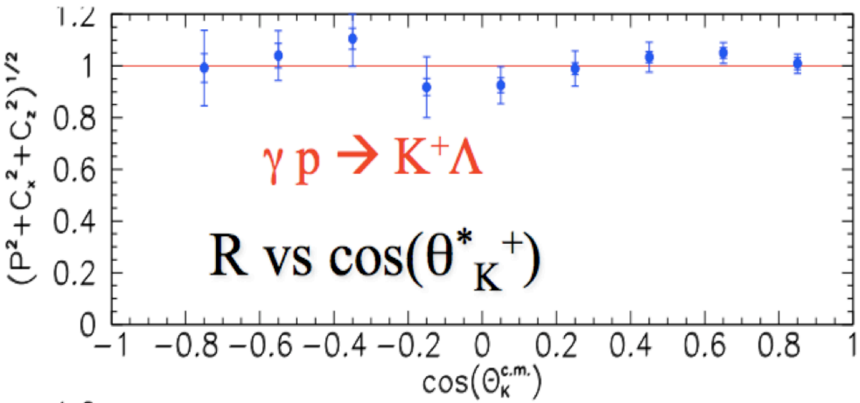


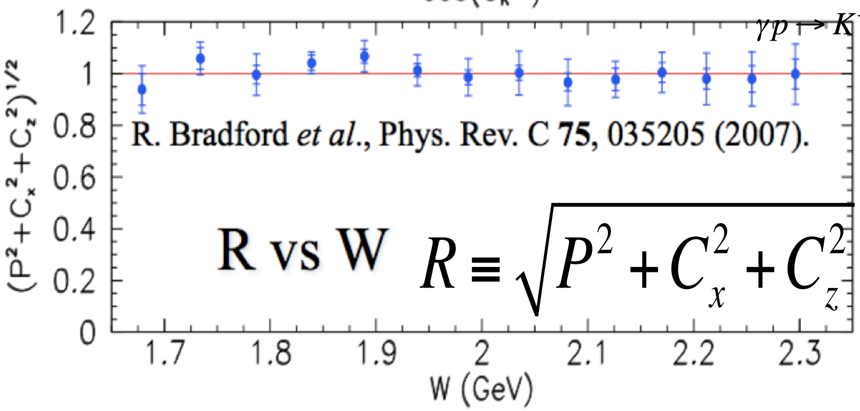


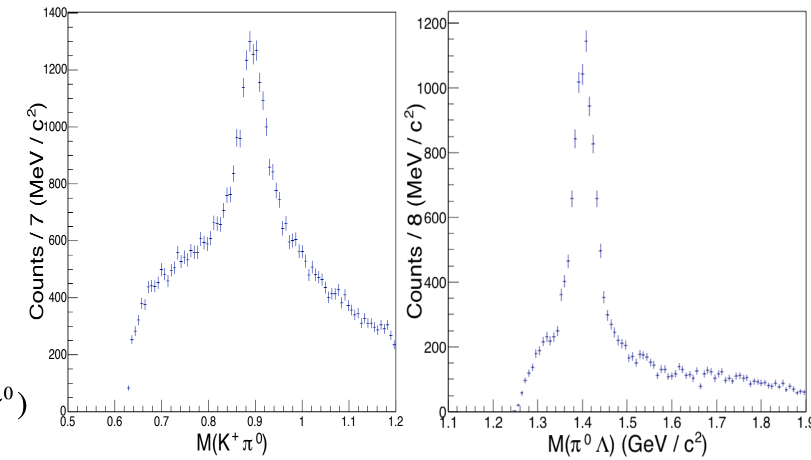
PWA: Isobar model/No meson waves
included yet

Waves for different M values:
Offer decay/exchange information

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







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

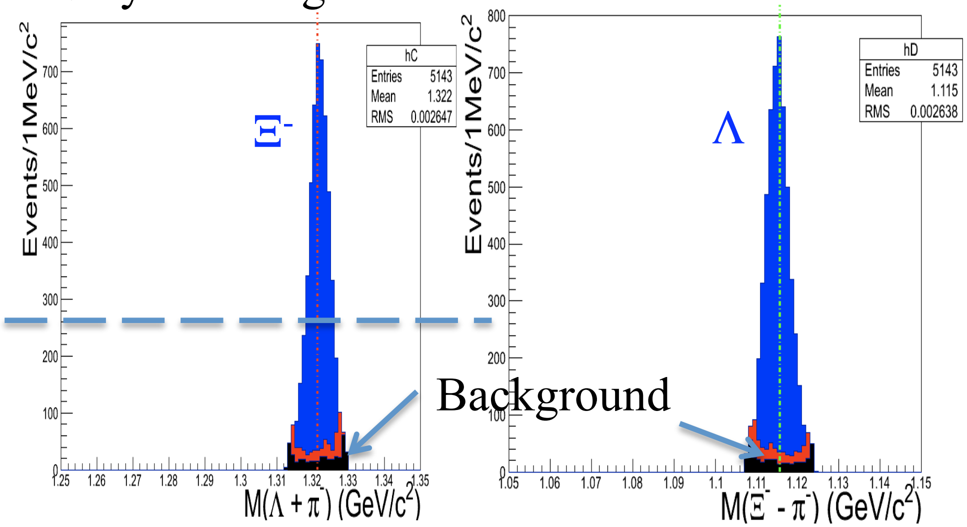
CLAS g12 data
Yero *et al.*, FIU

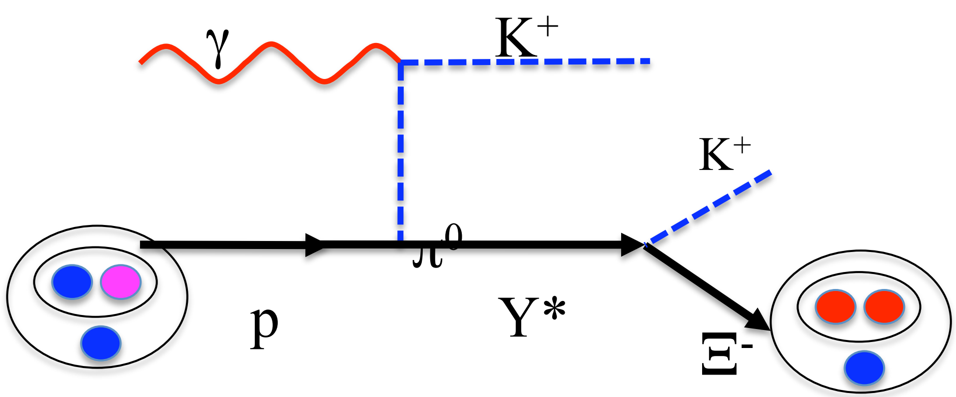
Prior CLAS results (Tang *et al.*, PRC 87, 065204 (2013)) did not publish polarization results

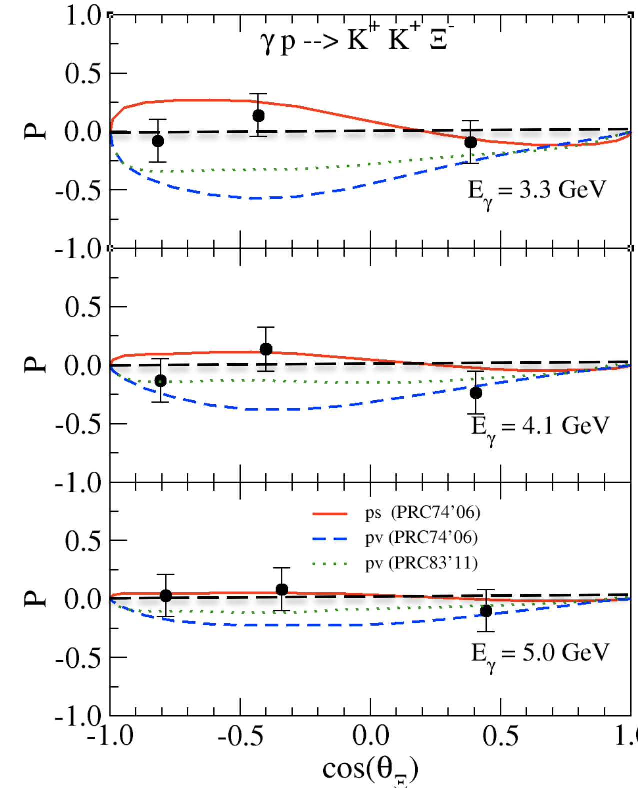
- 100% polarization in $K^+\Lambda$ photoproduction
- Various models suggest similar behavior in
- Several high-mass N* expected to couple to $K^*\Lambda/K\Sigma(1385)$ strongly

Existing data:
Ξ^- induced olarization in photoproduction

Very clean signals:

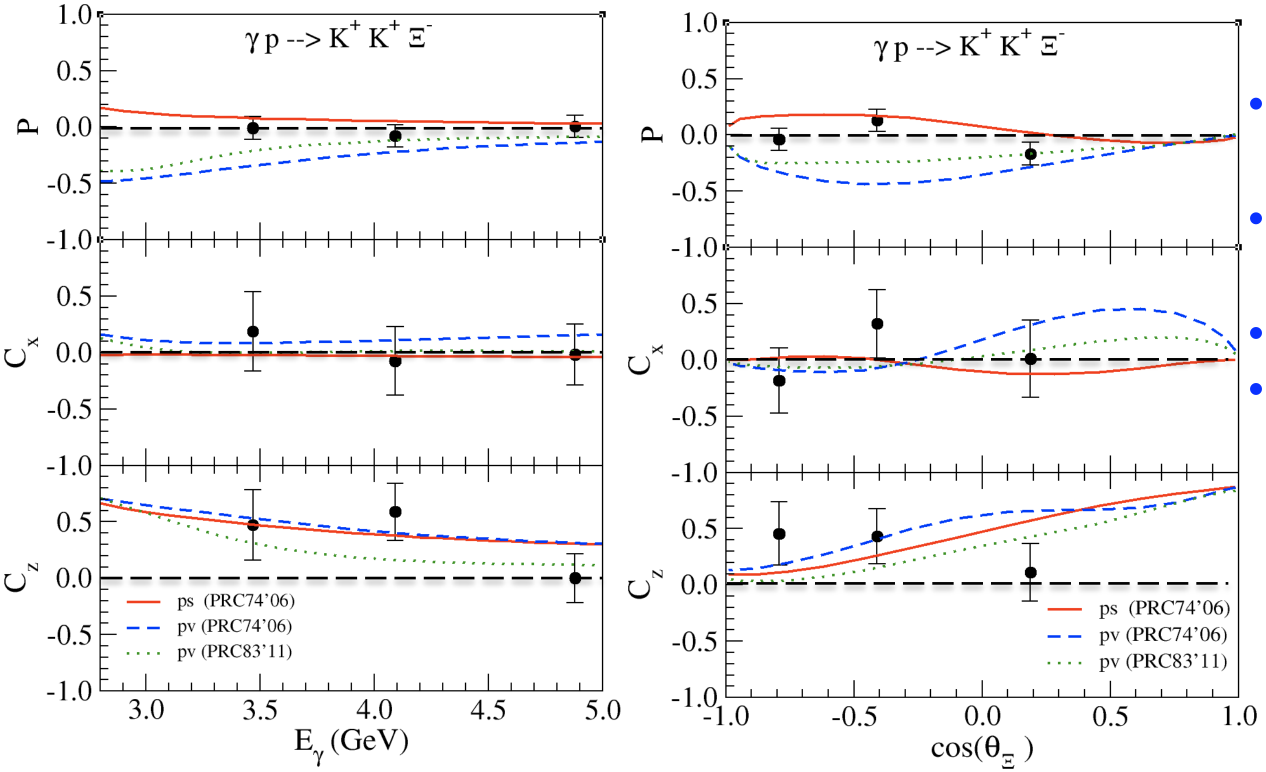






First time measurement!
(Bono Ph.D Thesis, 2014)

Existing data: 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 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)

Future: The Very Strange Collaboration

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[18)] *Rensselaer Polytechnic Institute, USA*
[19)] *Carneige Mellon University, USA*
[20)] *University of Georgia, USA*
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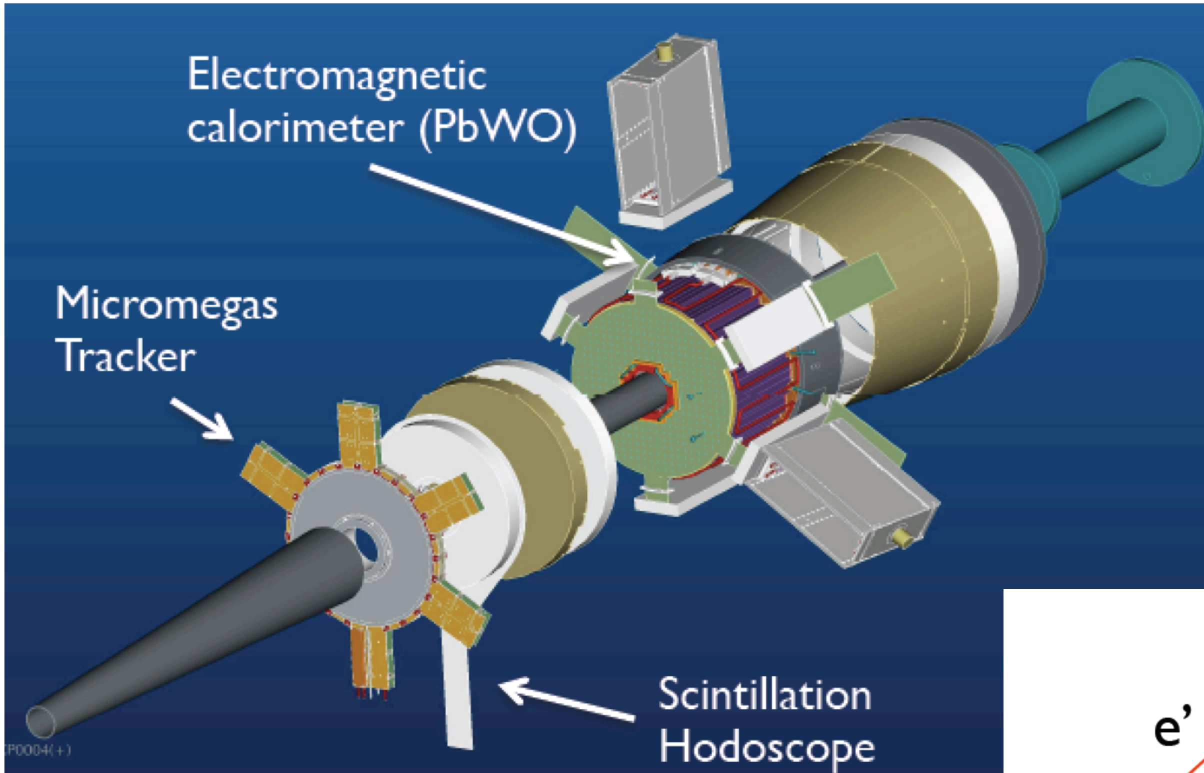
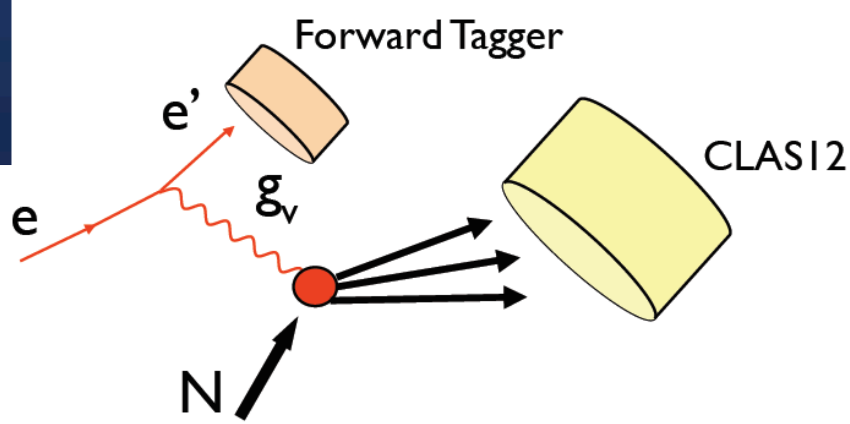
[23)] *California State University, Dominguez Hills, USA*
[24)] *CEA-Saclay, France*
[25)] *Norfolk State University,, USA*
[26)] *Giessen UniversityGermany*

Future: CLAS12 Forward Tagger



FT-Cal: energy/momentum (INFNs)
FT-Hodo: veto for photons (Edinburgh/JMU/NSU)
FT-Trck: electron angles, pol (Saclay/Ohio)

Electron scattering at 2.5-4.5 degrees
Q^2: 0.01-0.3GeV
Quasi-real photon: 6.5-10.5GeV
Polarization: 70%-10%
$N_\gamma \sim 5\text{x}10^8$ on 5cm H_2 target

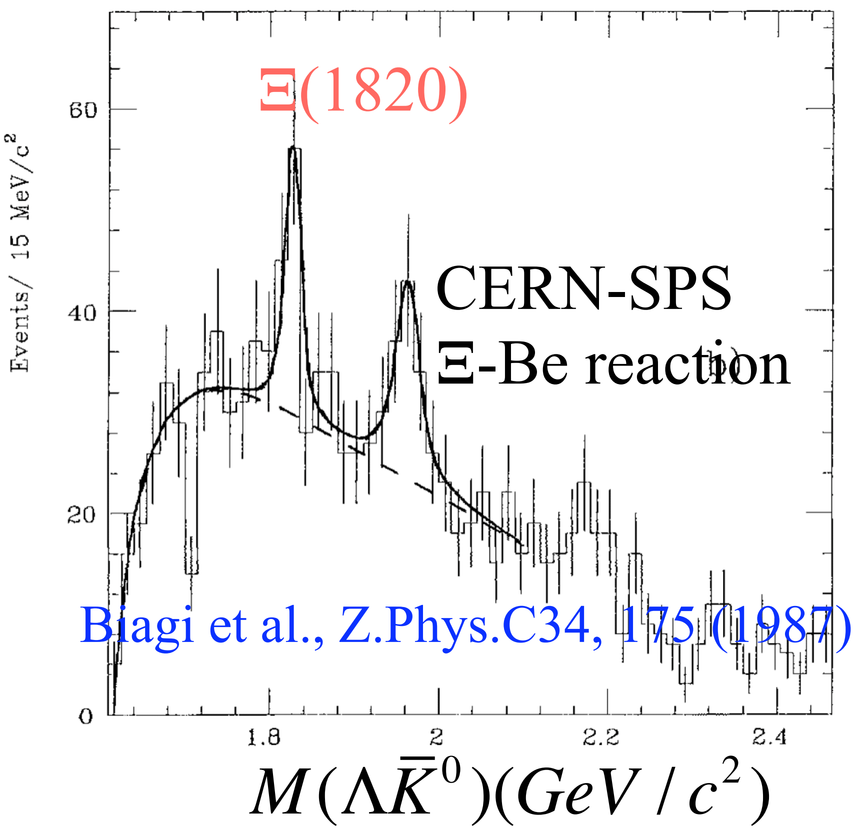


Future: CLAS12 Very Strange Experiment (E12-11-005a)
Expected Particle Rate

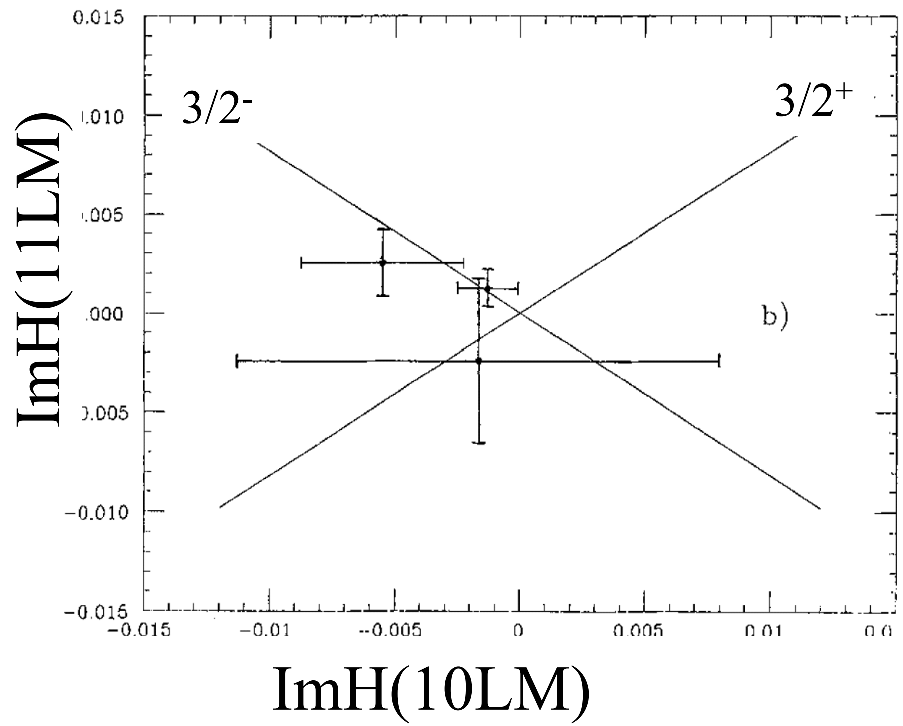
	Detected particles	Measured Decays	Overall Efficiency	Rate/hr	Total Detected
Ω^-	$K^+K^+K^0$		~3.9%	~3.6	~7k
Ω^-	$K^+K^+K^0K^-$	Ω^-	~0.5%	~0.5	~1k
Ξ^-	$K^+K^+\pi^-$	Ξ^-	~9.3%	~440	~0.9M
$\Xi^-(1530)$	$K^+K^+\pi^-$	$\Xi^-(1530)$	~7.4%	~140	~270K
$\Xi^-(1820)$	$K^+K^+K^-p$	$\Xi^-(1820)\Lambda$	~0.63%	~6	~12K

- Assuming half field and 80 beam days
- Vertex Efficiency/Branching Ratio included

Future: Parity Measurement of Ξ(1820)



Needs corroboration



Ξ(1820) 3/2$^-$ counts: ~50
Need to detect whole decay chain

CLAS12 estimate: ~12k Ξ(1820)
with complete decay chain
At CLAS12 (80 beam days)

Future: CLAS12: Ξ^- Polarization and $\Xi^-(1820)$ Spin-Parity

- Ξ^- polarization measurement:

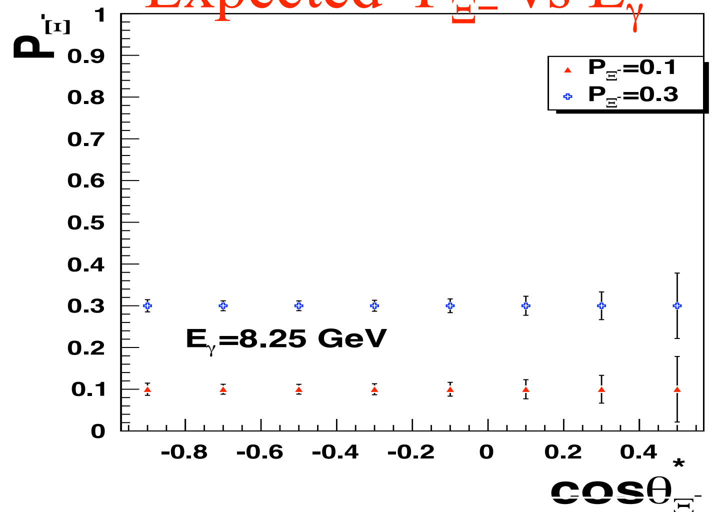
$$\gamma p \to K^+K^+\Xi^- \to K^+K^+\pi^-(\Lambda)$$

- $\Xi^-(1820)$ double moments

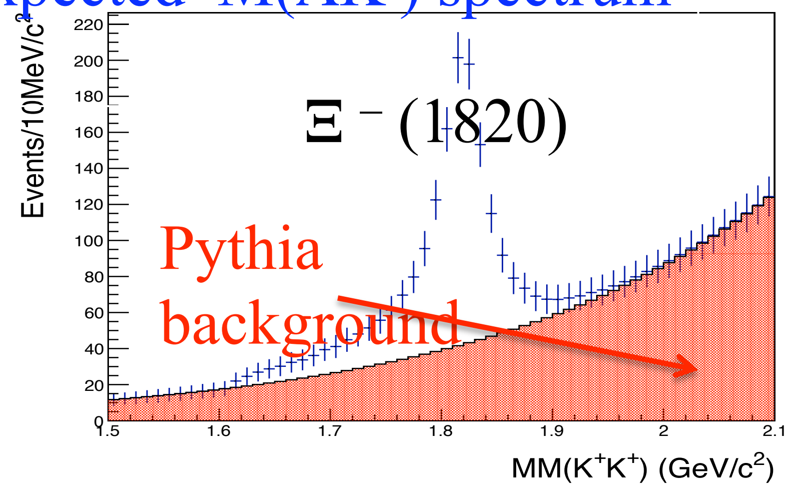
$$\gamma p \to K^+K^+\Xi^-(1820)$$

$$\Xi^-(1820) \to K^-(\Lambda \to \pi^- p)$$

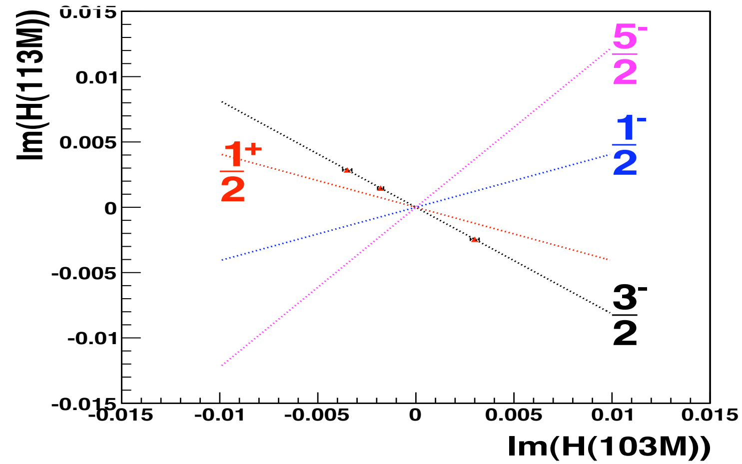
Expected P_{Ξ^-} vs E_γ



Expected $M(\Lambda K^-)$ spectrum

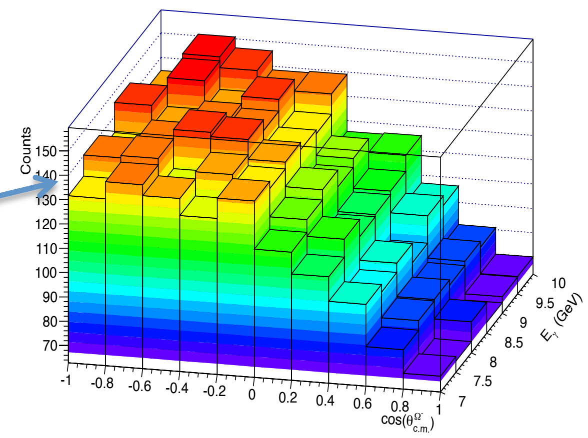


Expected double moments (L=3)



Future:
CLAS12 Ω^- Mass Spectrum and Cross Sections

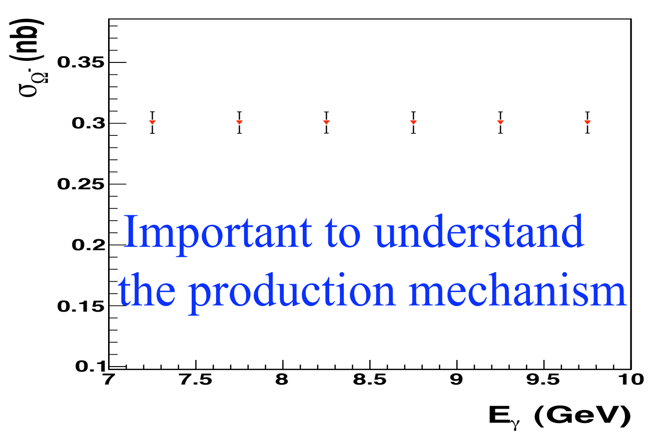
- Ω^- Measurement:
  - When four kaons detected, spectra is expected to be background FREE

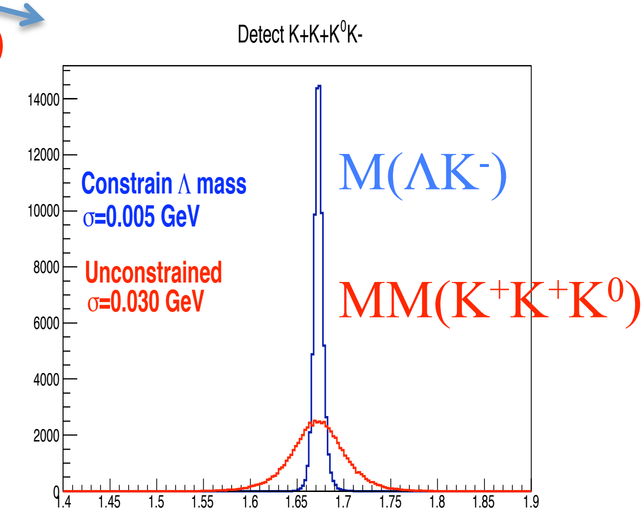


$$\gamma p \rightarrow K^+K^+K^0(\Omega^-)$$

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

Expected Cross section Measurements
(Assuming no energy or angular dependence)





Summary

- CLAS data already has multiple promises
  - pK^+K^- beam helicity asymmetry measurements can be used to constrain production models
  - Ξ^- polarization in photoproduction: intermediate Y*?
  - $K^*\Lambda$ polarization can be investigated and compare the Λ polarization mechanism (with $K\Lambda$ photoproduction)
- CLAS12/GlueX would be gold mines for hyperons
  - Ξ polarization: Much higher statistics;
  - Excited cascades and their quantum numbers
  - Ω^- photoproduction
    - First time the production dynamics can be explored experimentally
    - Excited Ω^- in the "not so distant" future?