CEBAF Large Acceptance Spectrometer

PHYSICS WITH NEUTRAL KAON BEAM AT JLAB
KL2016

Strangeness Physics at CLAS in the 6 GeV Era

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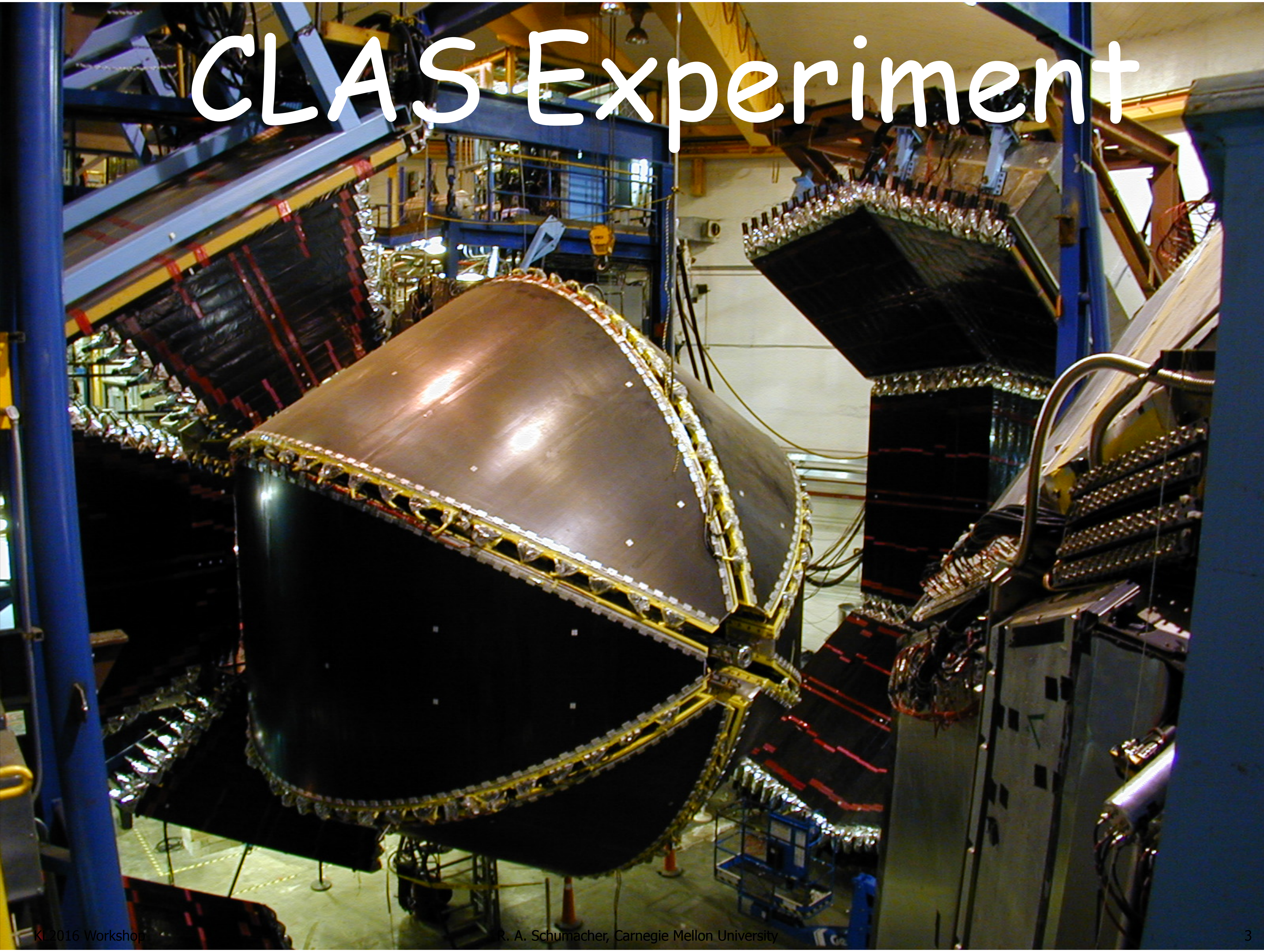
Outline /Overview

- The N* spectrum of states via hyperon photo- and electro- production
- Dimensional scaling of $K\Lambda$ photoproduction
- Excited Y* cross sections measured at CLAS
  - $\Sigma^0(1385)$ ($J^P = 3/2^+$); $\Lambda(1405)$ ($J^P = 1/2^-$); $\Lambda(1520)$ ($J^P = 3/2^-$)
- Structure of the $\Lambda(1405)$: $\Sigma\,\pi$ line shapes; J^P
- Strangeness suppression in exclusive electro-production
- Cascade photoproduction

- One new idea for K_L Beam at GlueX re $\Lambda(1405)$

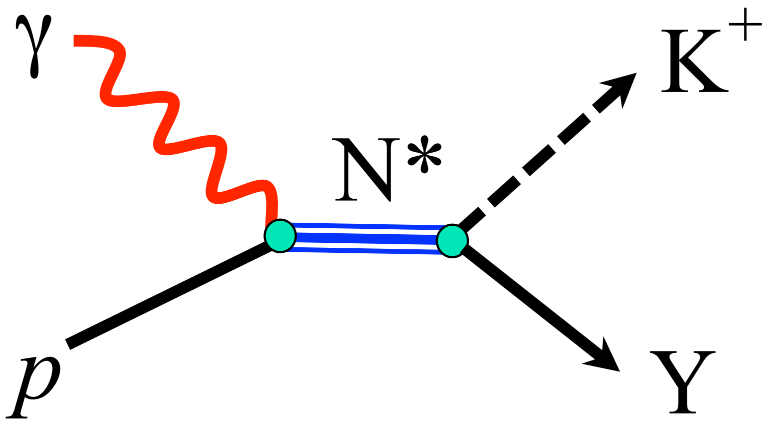
CLAS Experiment



CLAS Experiment

- Photoproduction:
  - Targets: unpolarized LH_2, polarized p, & HD-ice
  - Beams: unpolarized, circular, linear, to ~5 GeV
  - Reconstructed $K^+p\pi^-(\pi^0)$ or $K^+\pi^+\pi^-(n)$
  - 20×10^9 triggers → 1.41×10^6 $KY\pi$ events in *g11a*
- Electroproduction:
  - Q^2 from ~0.5 to ~3 $(GeV/c)^2$
  - Structure functions from Rosenbluth and beam-helicity separations

The N* Spectrum
Photoproduction



Strangeness in N* Physics: Status

Table 8. Star rating suggested for baryon resonances and their decays. Ratings of the Particle Data Group are given as *; additional stars suggested from this analysis are represented by ★; (*) stands for stars which should be removed.

S_{11}

P_{13}

D_{13}

G_{17}

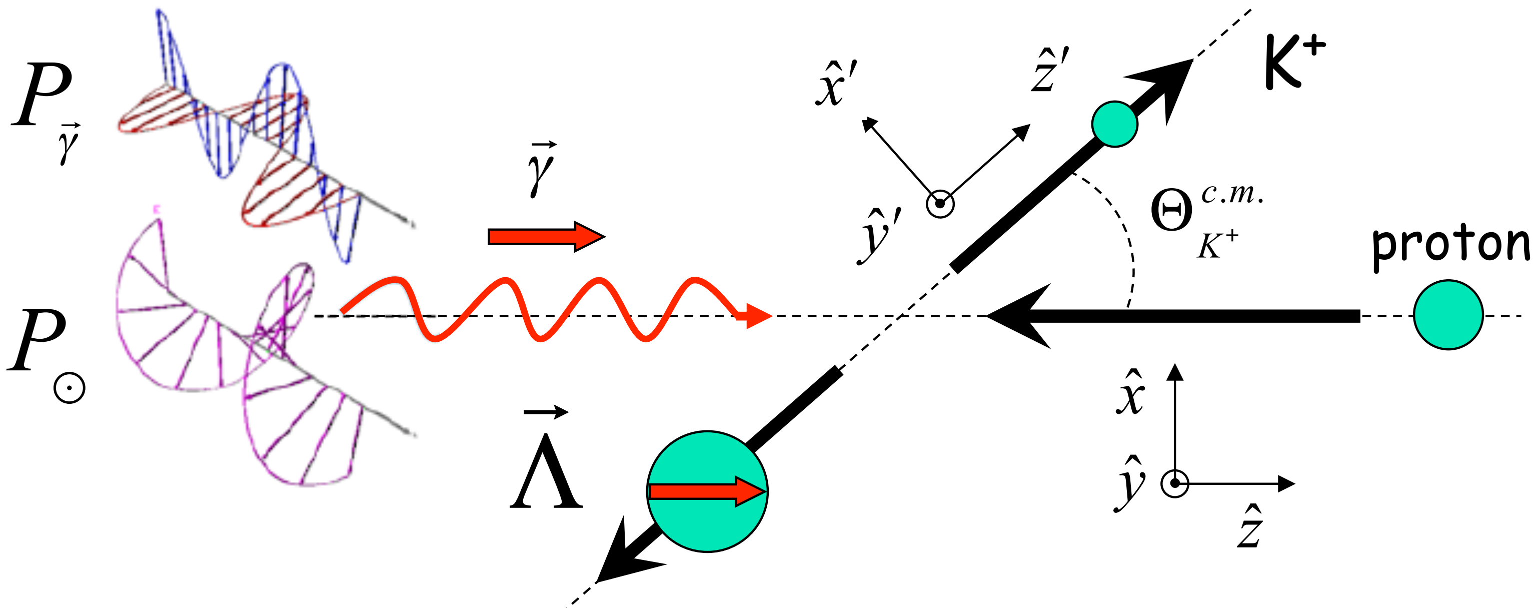
	all	πN	γN	$N\eta$	ΛK	ΣK	$\Delta\pi$	$N\sigma$
$N(1440)\frac{1}{2}^+$	****	****	***★	(*)			***	★★★
$N(1710)\frac{1}{2}^+$	***	***	***	**★	★★★	★★	*(*)	
$N(1880)\frac{1}{2}^+$	★★	★	★		★★	★		
$N(1535)\frac{1}{2}^-$	****	****	****	****			*	
$N(1650)\frac{1}{2}^-$	****	****	***	*★★	***	**	**(*)	
$N(1895)\frac{1}{2}^-$	★★	★	★★	★★	★★	★		
$N(1720)\frac{3}{2}^+$	****	****	****	****	**	**	***	
$N(1900)\frac{3}{2}^+$	**★	**	★★★	★★	★★★	★★	★★	
$N(1520)\frac{3}{2}^-$	****	****	****	***			****	
$N(1700)\frac{3}{2}^-$	**★	**	**	*	*(*)	*	**★	
$N(1875)\frac{3}{2}^-$	★★★	★	★★★		★★★	★★		★★★
$N(2150)\frac{3}{2}^-$	★★	★★	★★		★★		★★	
$N(1680)\frac{5}{2}^+$	****	****	****	*			**(*)	★★
$N(1860)\frac{5}{2}^+$	★	★	★					
$N(2000)\frac{5}{2}^+$	*★★	*(*)	★★	★★	★★	★		
$N(1675)\frac{5}{2}^-$	****	****	***(*)	*	*		***(*)	★
$N(2060)\frac{5}{2}^-$	★★★	★★	★★★	★		★★		
$N(1990)\frac{7}{2}^+$	**	*(*)	★★					
$N(2190)\frac{7}{2}^-$	****	****	*★★		★★			
$N(2220)\frac{9}{2}^+$	****	****						
$N(2250)\frac{9}{2}^-$	****	****						
$\Delta(1910)\frac{1}{2}^+$	****	****	*★			*★	*★	
$\Delta(1620)\frac{1}{2}^-$	****	****	***				****	
$\Delta(1900)\frac{1}{2}^-$	**	**	*★			*★	*★	
$\Delta(1232)\frac{3}{2}^+$	****	****	****					
$\Delta(1600)\frac{3}{2}^+$	***	***	**★				***	
$\Delta(1920)\frac{3}{2}^+$	***	***	*★			*★★	**	
$\Delta(1700)\frac{3}{2}^-$	***	***	***				**	
$\Delta(1940)\frac{3}{2}^-$	*	*	★★				$\vert{}^\star$ from $\Delta\eta\vert$	
$\Delta(1905)\frac{5}{2}^+$	****	****	****			*★★	**(**)	
$\Delta(1950)\frac{7}{2}^+$	****	****	***			*★★	**★	

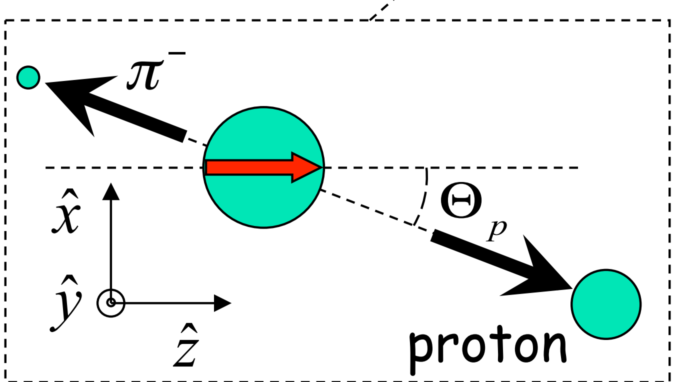
- Role of JLab/CLAS strangeness physics in unraveling properties of N* and Δ states?
- Worldwide effort to determine resonance poles, branching fractions, helicity couplings, etc.
- <u>Bottom line</u>: “Stars” & new resonances added to world database

A. V. Anisovich (BoGa) et al., Eur.Phys. J. A **48**, 15 (2012)

Define the Spin Observables

(for unpolarized nucleon)





$$\frac{d\sigma}{d\Omega} = \sigma_0 \left\{ \begin{array}{l} 1 - P_{\vec{\gamma}} \Sigma \cos 2\phi \\ -\alpha \cos\theta_{x'} \sin 2\phi P_{\vec{\gamma}} O_{x'} - \alpha \cos\theta_{x'} P_{\odot} C_{x'} \\ -\alpha \cos\theta_{z'} \sin 2\phi P_{\vec{\gamma}} O_{z'} - \alpha \cos\theta_{z'} P_{\odot} C_{z'} \\ +\alpha \cos\theta_{y'} P - \alpha \cos\theta_{y'} P_{\vec{\gamma}} T \cos 2\phi \end{array} \right\}$$

Theory: Bonn Gatchina Model

(Just one of several models on the market)

- Coupled channels (K-matrix) framework
  - Input: from π N, K N elastic; γ N, π N inelastic to $\pi^{\pm 0}$ N, ηN, η'N, $K^{\pm 0}$ Y, $\pi\pi$ N
    - Use ALL experimental channels, including the strangeness channels & spin observables
  - Partial Wave Analysis
    - First extract each J^P wave
    - Fit N* and Δ resonance pole parameters

Short list of References:

A. Sarantsev, V. Nikonov, A. Anisovich, E. Klempt, U. Thoma; Eur. Phys. J. A **25**, 441 (2005)

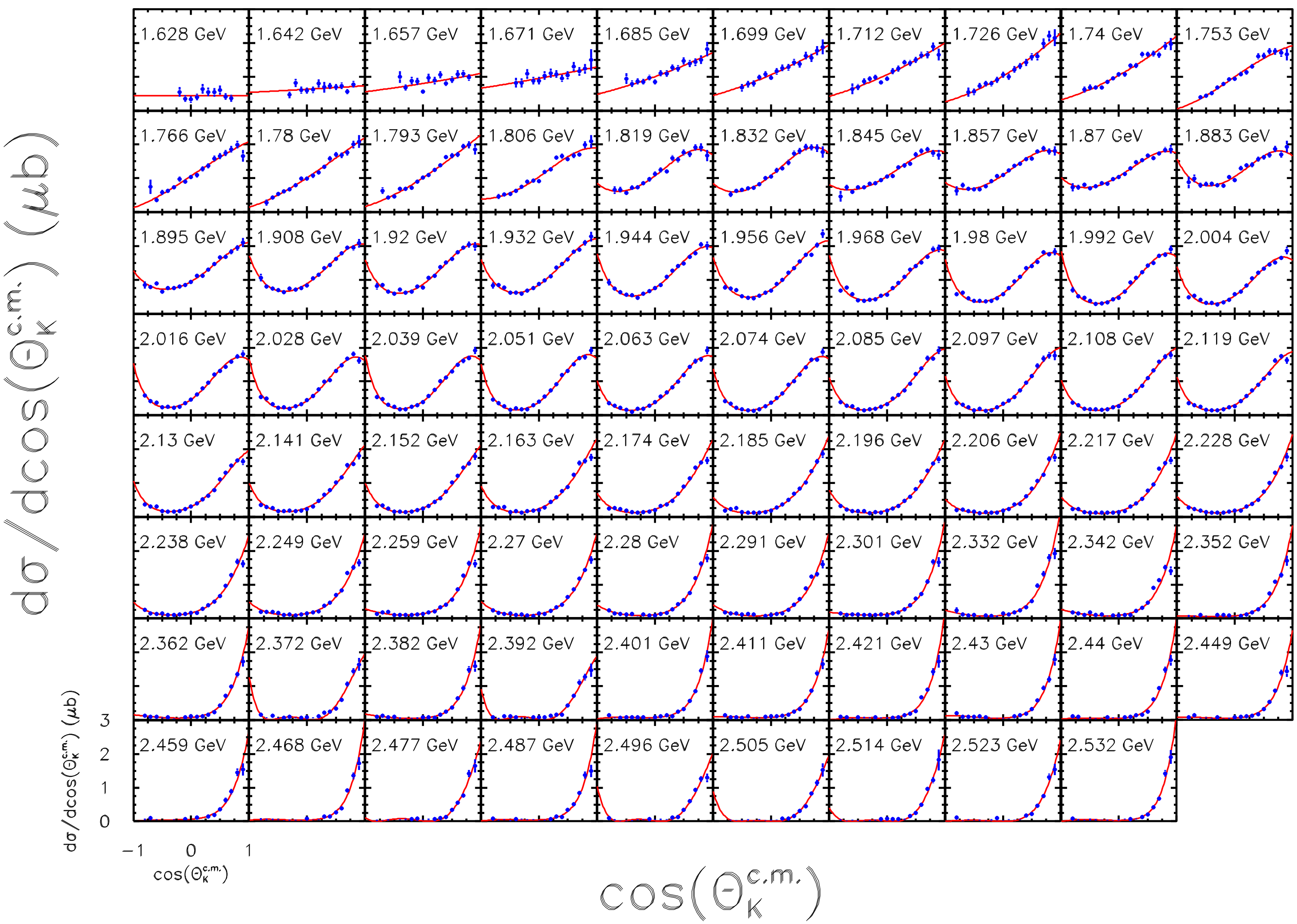
A.V. Anisovich *et al.*, Eur. Phys J. A **25** 427 (2005); Eur. Phys J. A **24,** 111 (2005);

V. A. Nikonov *et al.*, Phys Lett. B **662**, 246 (2008).

A. Anisovich, E. Klempt, V. Nikonov, A. Sarantsev, U. Thoma; Eur. Phys. J. A **47**, 153 (2011).

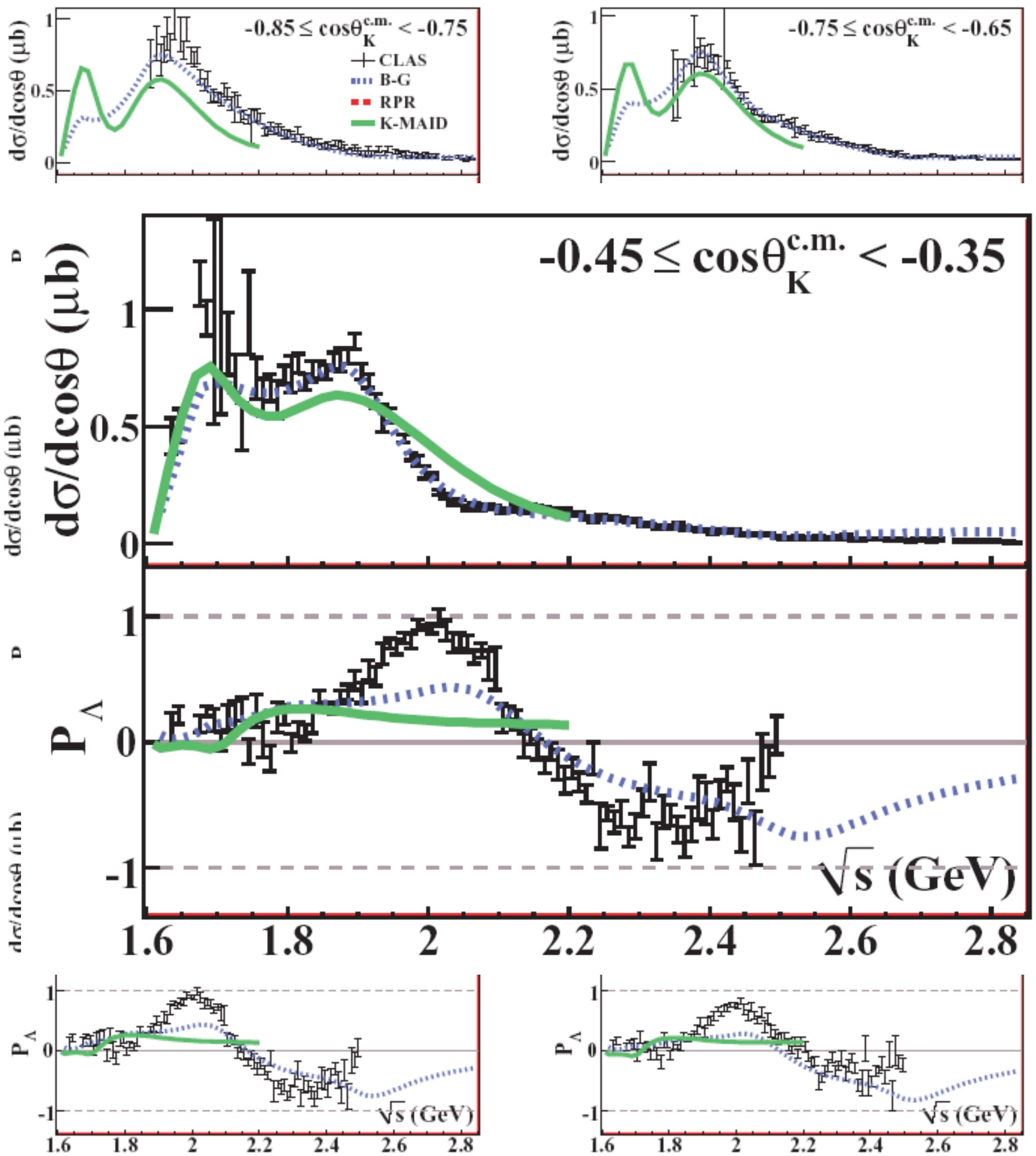
γp→K⁺Λ: cross section

R. Bradford *et al.*, Phys.Rev. C **73**, 035202 (2006)



- Forward peaking indicates t-channel processes at high W
- Angular dependence at lower W consistent with s- and u-channel processes.

$\gamma p \rightarrow K^+\Lambda$: recoil polarization $\vec{P}$



- Kaon-MAID model (green)
  - F.X. Lee *et al.*, Nucl. Phys. **A695**, 237 (2001).
  - Single-channel BW resonance fits
  - No longer up-to-date
- Bonn-Gatchina model (blue)
  - Multi-channel, unitary, BW resonance fit
  - Large suite of N* contributions
  - Was not predictive for recoil polarization

A.V. Sarantsev et al., Eur. Phys. J., A **25**, 441 (2005).

M. McCracken et al, (CLAS) Phys. Rev. C **81**, 025201 (2010).

CLAS Output vs. the World

TABLE II. Measurements performed by the different experiments.

Experiment	Ref(s)	Final State	W range (GeV)	Σ	P	C_x	C_z	T	O_x	O_z
CLAS g11	[12]	$K\Lambda$	1.62–2.84		$\star$					
	[13]	$K\Sigma^0$	1.69–2.84		$\star$					
CLAS g1c	[9, 11]	$K\Lambda$	1.68–2.74		$\star$	$\star$	$\star$			
	[9, 11]	$K\Sigma^0$	1.79–2.74		$\star$	$\star$	$\star$			
LEPS	[14]	$K\Lambda$	1.94–2.30	$\star$						
	[14]	$K\Sigma^0$	1.94–2.30	$\star$						
GRAAL	[15, 16]	$K\Lambda$	1.64–1.92	$\star$	$\star$			$\star$	$\star$	$\star$
	[15]	$K\Sigma^0$	1.74–1.92	$\star$	$\star$					
CLAS g8		$K\Lambda$	1.71–2.19	$\star$	$\star$			$\star$	$\star$	$\star$
		$K\Sigma^0$	1.75–2.19	$\star$	$\star$			$\star$	$\star$	$\star$

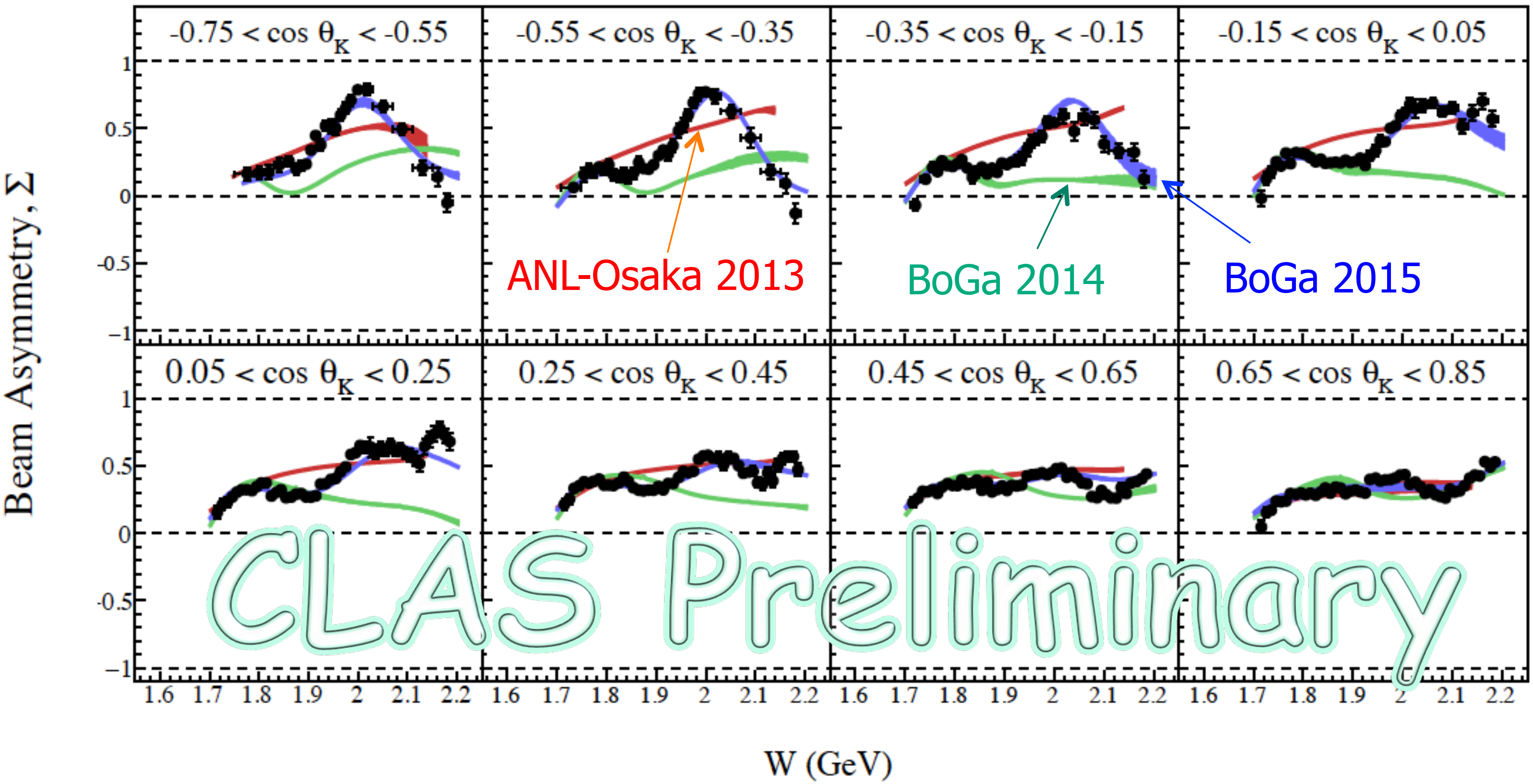
Spin Observables with linear and circular polarized photons

Hyperon recoil polarization is easy to measure:
Competitive advantage over non-strange baryon channels

C.A. Paterson et al. (CLAS Collaboration) to be published, 2016

$\gamma p \rightarrow K^+\Lambda$: beam asymmetry Σ

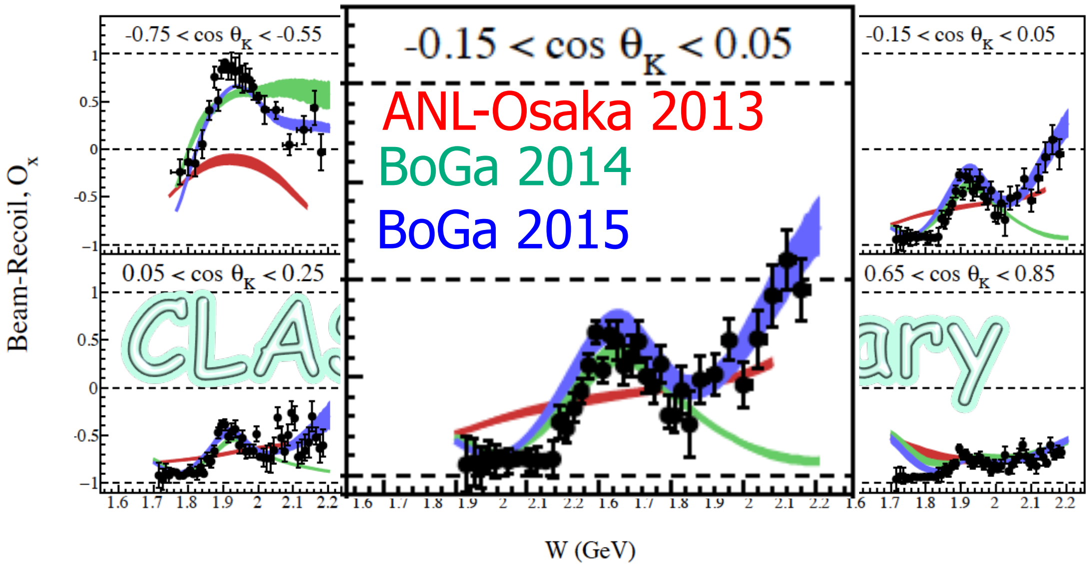
$$\frac{d\sigma}{d\Omega_{K^+}} = \frac{d\sigma}{d\Omega_{K^+}}\bigg|_{unpol.}\left\{1+\Sigma P_\gamma \cos 2\phi\right\}$$



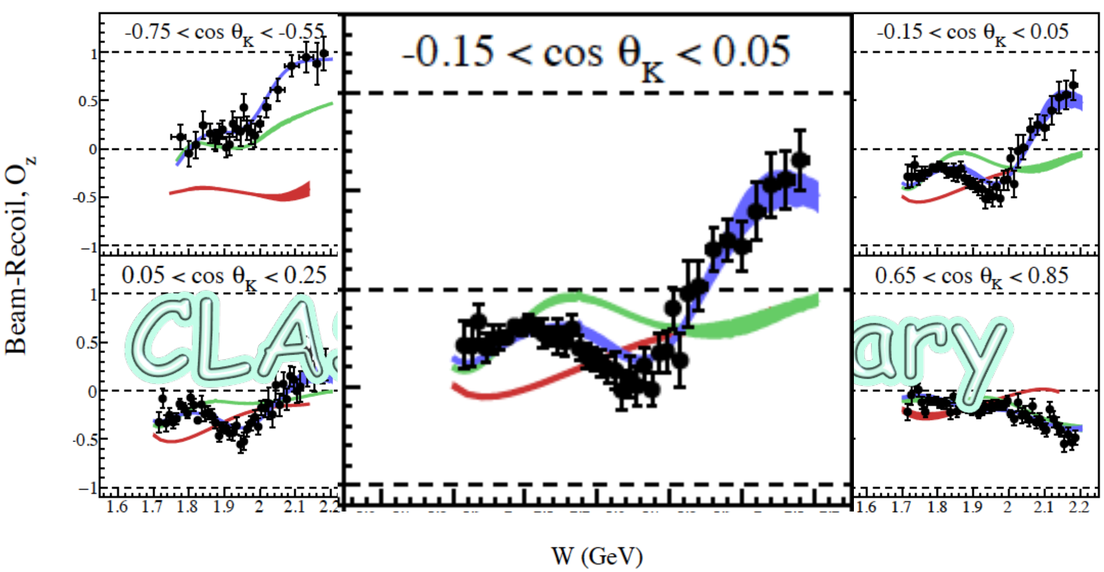
Bonn-Gatchina 2014 model was not predictive in newly-measured kinematics & observables

C.A. Paterson et al. (CLAS Collaboration) to be published, 2016

$\vec{\gamma} p \rightarrow K^+ \vec{\Lambda}$ Beam-Recoil O_x and O_z



O_x



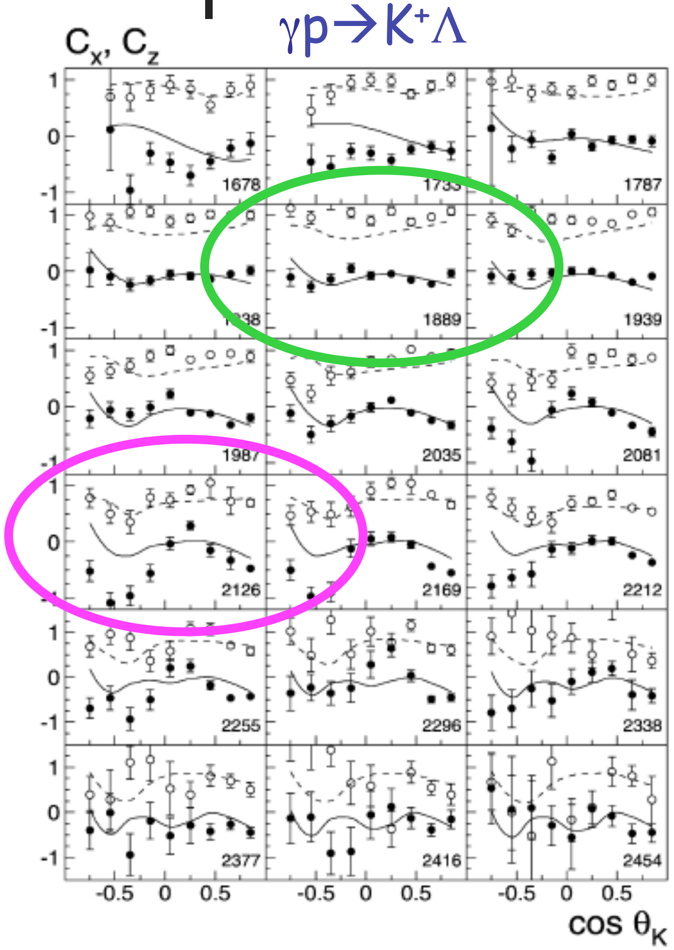
O_z

Bonn-Gatchina 2014 model was not predictive in newly-measured kinematics & observables:

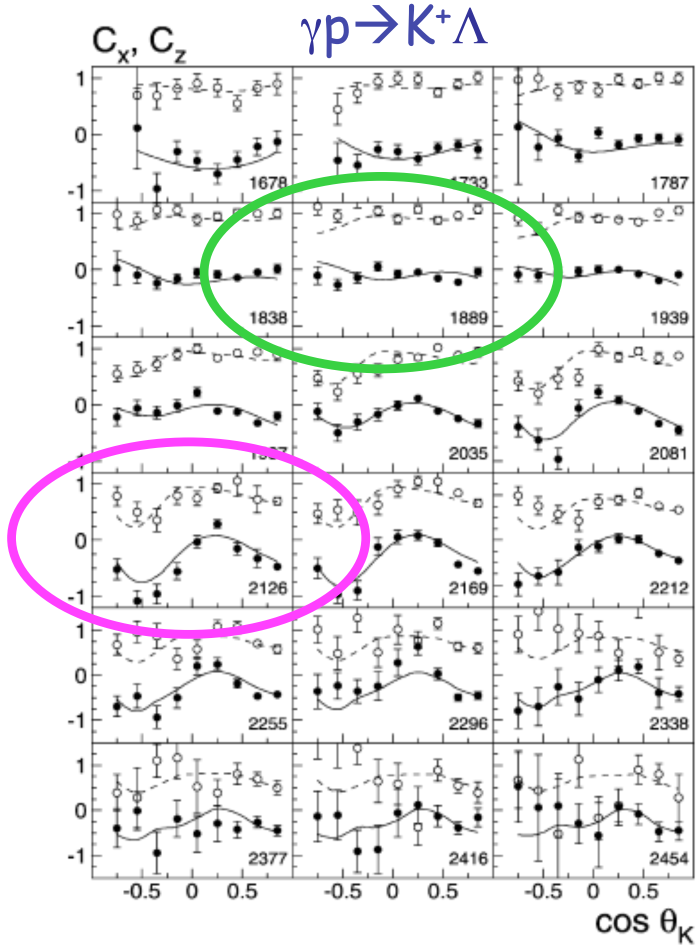
The model is descriptive but not predictive: lots of high quality data needed to pin down the resonance content of the reaction.

C.A. Paterson et al. (CLAS Collaboration) to be published, 2016

$\vec{\gamma} p \rightarrow K^+ \vec{\Lambda}$ Beam-Recoil C_x and C_z

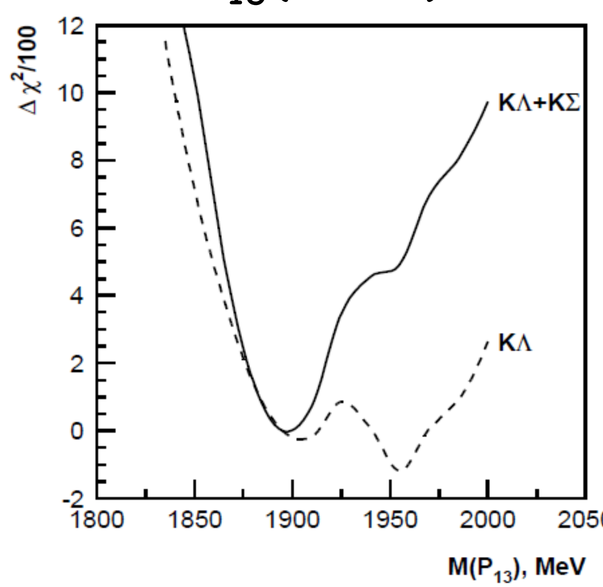


C_xC_z without N*(1900)P_{13}



C_xC_z with N*(1900)P_{13}

- Nikanov *et al*.'s refit of Bonn-Gatchina coupled-channel isobar model
- mix includes: S_{11}-wave, $P_{13}(1720)$, $P_{13}(1900)$, $P_{11}(1840)$
- $K^+\Sigma^0$ cross sections also better described with $P_{13}(1900)$



R. Bradford *et al.*, (CLAS Collaboration) Phys. Rev. C **75**, 035205 (2007).
V. A. Nikanov *et al.*, Phys Lett. B **662**, 246 (2008).
see also: A.V. Anisovich *et al.*, Eur. Phys J. A **25** 427 (2005).

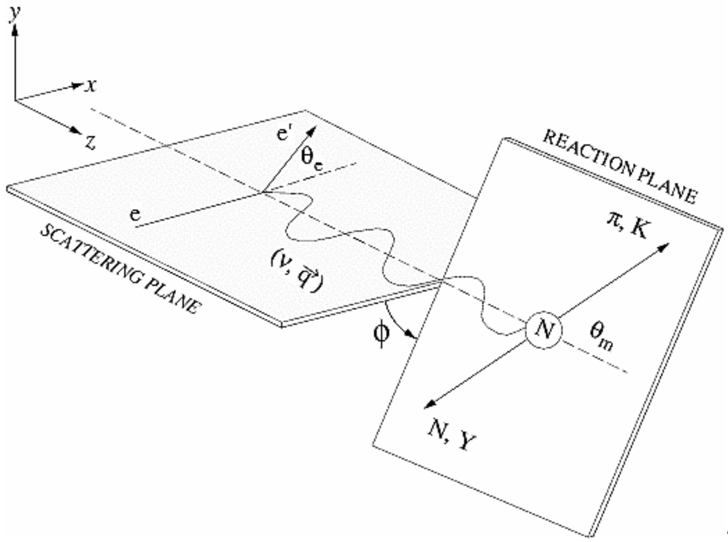
Lots more could be said…

- Omit results for Σ photoproduction
- Omit discussion of reactions on the neutron (deuteron), which accesses photon coupling isospin dependence.
- Overall goal: measure enough observ-ables for "complete" determination of amplitudes $\Rightarrow$ extract N^* and Δ content

Strangeness and the N* Spectrum of States - Electroproduction

Structure Functions

For unpolarized target & polarized e^- beam:



$$\frac{d^4\sigma}{dQ^2 dW\, d\Omega_K} = \Gamma(Q^2, W) \times \frac{d\sigma}{d\Omega_K}\left(Q^2, W, \Theta_K, \varepsilon, \phi\right)$$

Virtual photon flux

Meson cross section

Transverse

Transverse-transverse interference

Helicity structure

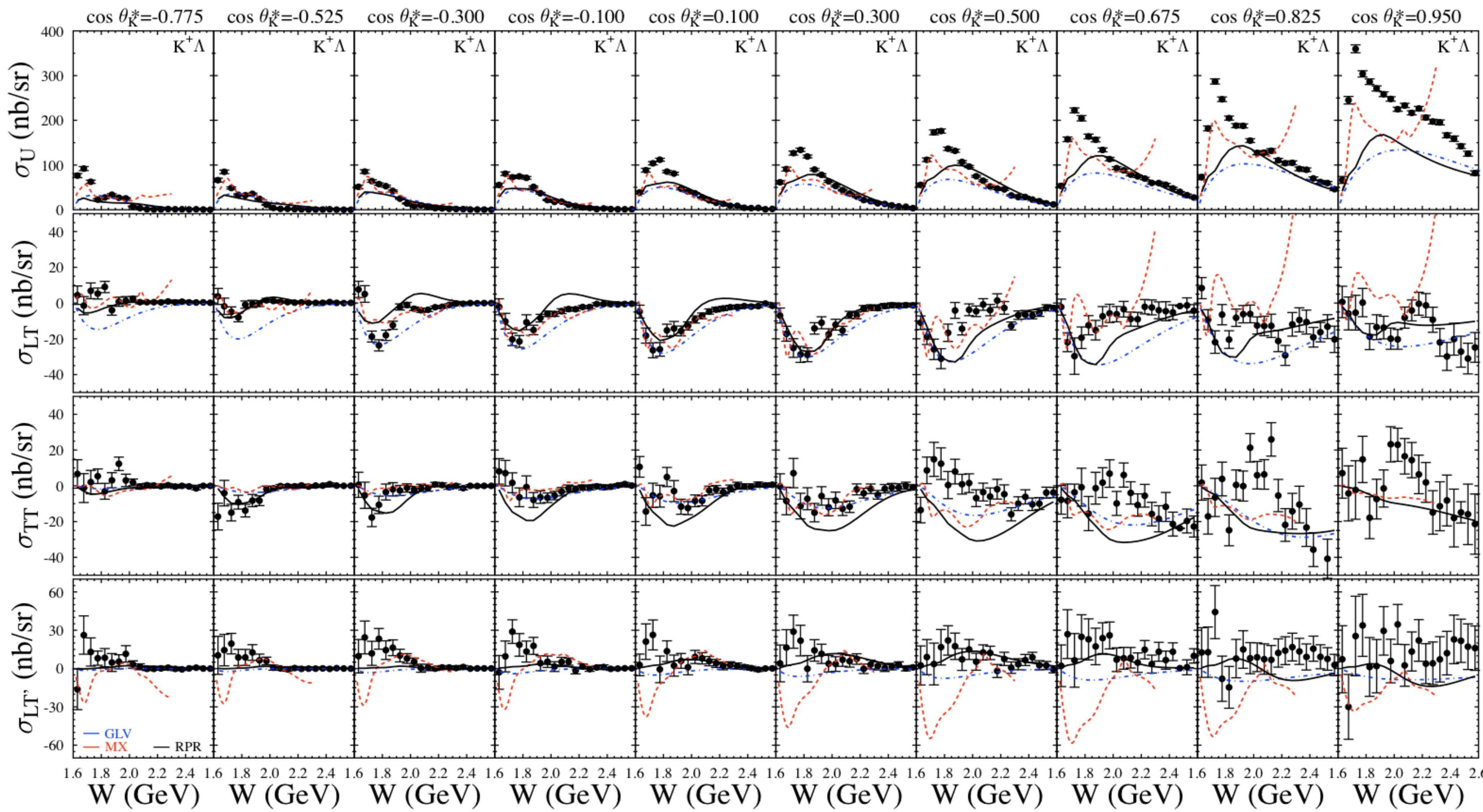
$$\frac{d\sigma}{d\Omega_K} = \sigma_T + \varepsilon_L \sigma_L + \varepsilon \sigma_{TT} \cos(2\phi) + \sqrt{2\varepsilon_L(\varepsilon+1)}\,\sigma_{LT} \cos(\phi) + h\sqrt{2\varepsilon_L(1-\varepsilon)}\,\sigma_{LT'}$$

σ_u
"Unseparated"

Longitudinal (sensitive to J=0± exchange in t-channel: kaons, diquarks)

Transverse-longitudinal interference

$K^+\Lambda$ Structure Functions



E = 5.5 GeV, W: thr – 2.6 GeV, Q² = 1.80, 2.60, 3.45 GeV² [Carman *et al.*, PR C **87**, 025204 (2013)]

CLAS *ep* Data Set Overview

#	Period	E_b (GeV)	Events (M)
1	e1c	2.567	900
2	e1c	4.056	370
3	e1c	4.247	620
4	e1c	4.462	420
5	e1d	4.817	300
6	e1-6	5.754	4500
7	e1f	5.499	5000
8	e1g	3.178	2500

- $K^+\Lambda$ recoil polariazation
  - *W=1.6-2.7 GeV, <Q^2>=1.9 GeV^2*

    [Gabrielyan *et al.*, PR C **90**, 035202 (2014)]

Publications:

- $K^+\Lambda$ beam-recoil pol. transfer
  - *W=1.6-2.15 GeV, Q^2=0.3 – 1.5 GeV^2*

    [Carman *et al.*, PRL **90**, 131804 (2003)]
- $K^+\Lambda$ σ_L/σ_T ratio from pol. transfer data
  - *W=1.72-1.98 GeV, Q^2~0.7 GeV^2*

    [Raue & Carman, PR C **71**, 065209 (2005)]
- $K^+\Lambda$, $K^+\Sigma^0$ separated structure functions
  - *W=thr-2.4 GeV, Q^2=0.5-2.8 GeV^2*
  - σ_U, σ_{LT}, σ_{TT}, σ_L, σ_T - $K^+\Lambda$, $K^+\Sigma^0$

    [Ambrozewicz *et al.*, PR C **75**, 045203 (2007)]
  - *W=thr-2.6 GeV, Q^2=1.4-3.9 GeV^2*
  - σ_U, σ_{LT}, σ_{TT}, $\sigma_{LT'}$ – $K^+\Lambda$, $K^+\Sigma^0$

    [Carman *et al.*, PRC **87**, 025204 (2013)]
- $K^+\Lambda$ fifth structure function $\sigma_{LT'}$
  - *W=1.6-2.1 GeV, Q^2=0.65, 1.0 GeV^2*

    [Nasseripour *et al.*, PR C **77**, 065208 (2008)]
- $K^+\Lambda$, $K^+\Sigma^0$ beam-recoil pol. transfer
  - *W=thr-2.6 GeV, Q^2=1.6-2.6 GeV^2*

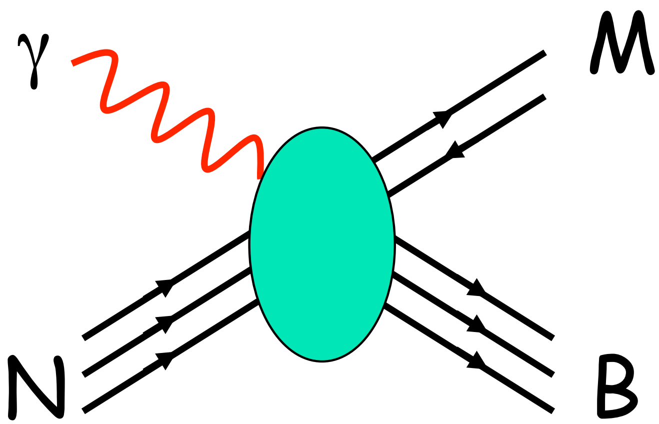
    [Carman *et al.*, PR C **79**, 065205 (2009)]

Dimensional Scaling of $K\Lambda$

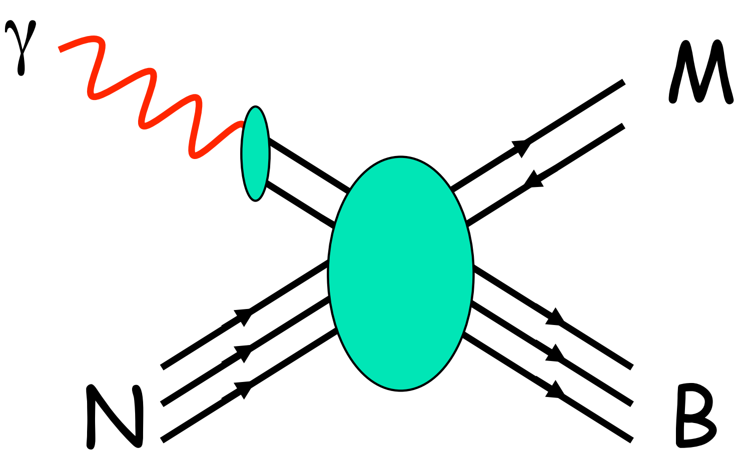
Publication: Scaling and Resonances in Elementary $K^+\Lambda$ Photo-production, R.A.Sch. and M.M. Sargsian Phys.Rev.C**83** 025207 (2011).

Constituent-Counting Scaling

$$\frac{d\sigma}{dt} = f\left(\frac{t}{s}\right) s^{2-n}$$



$n=9$

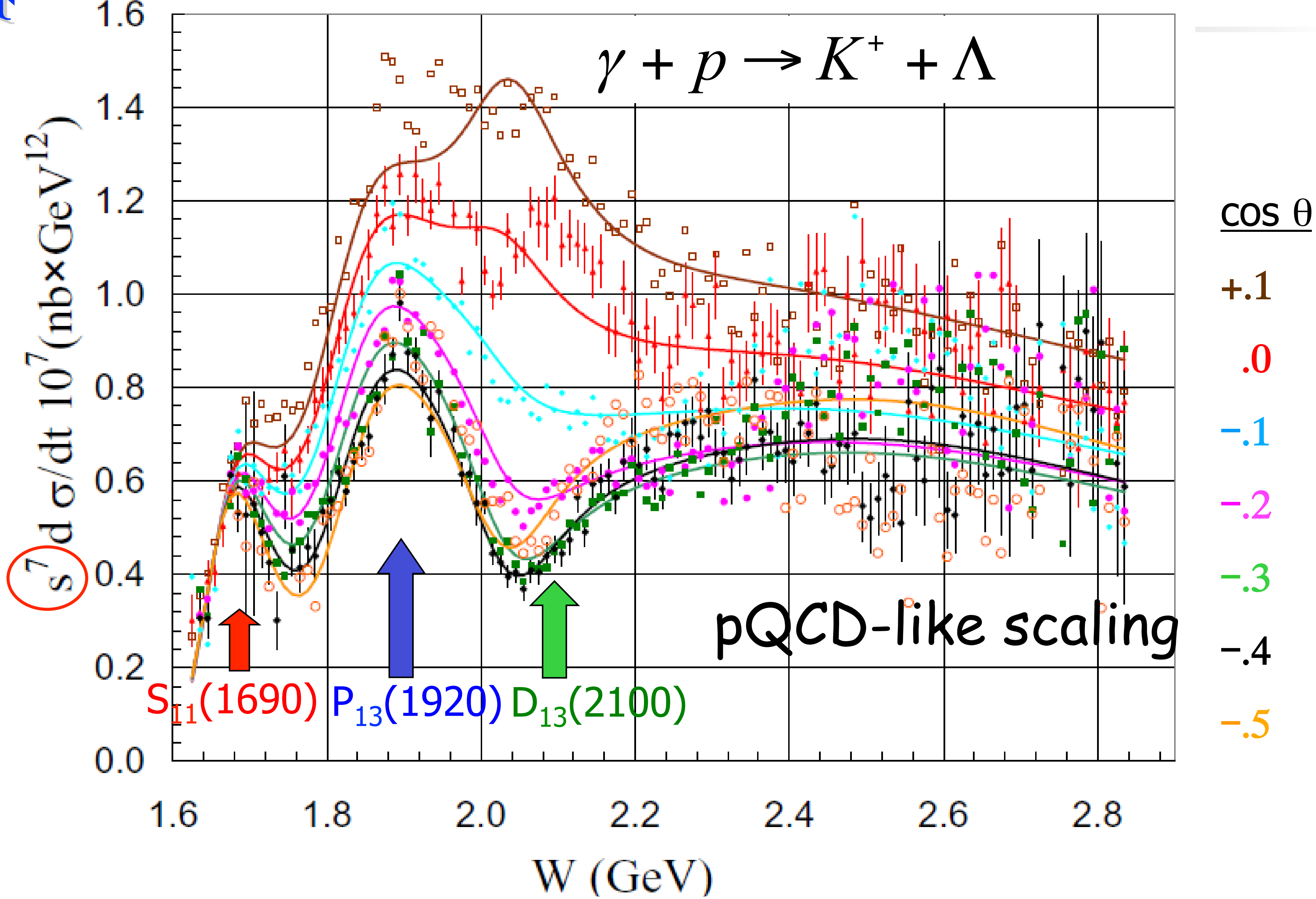


$n=10$

- Constituent counting rules for exclusive scattering
- Valid for $s \rightarrow \infty$ and t/s fixed
  - $t/s \sim \cos(\theta_{cm})$ as $s \rightarrow \infty$
- n = number of point-like constituents
- Follows from pQCD… but also other models
- Does it work for $K\Lambda$?

S. J. Brodsky and G. R. Farrar, PRL **31**, 1153 (1973)

Resonance Fit to Cross Section

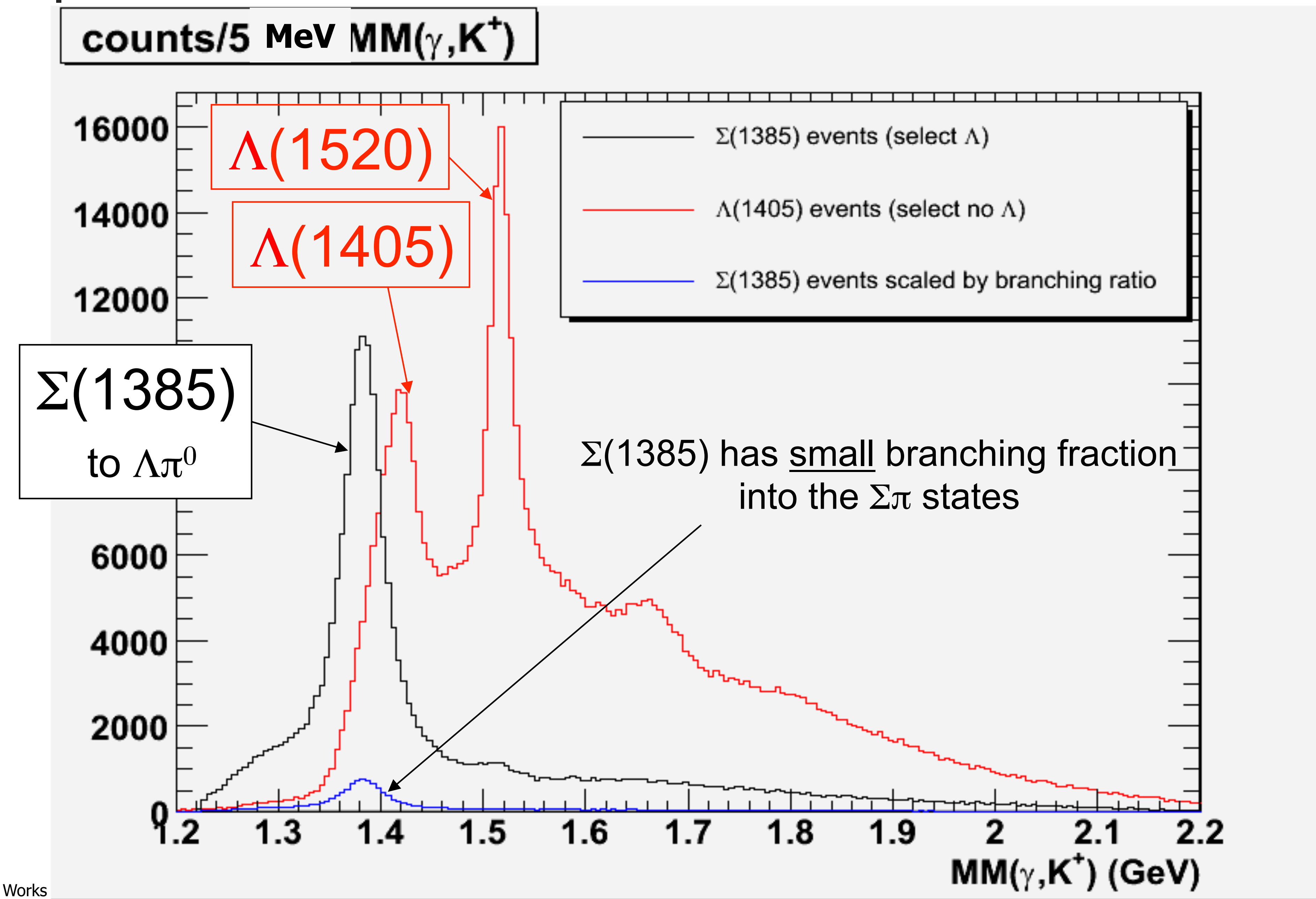


R.A. Schumacher and M.M. Sargsian Phys. Rev. C **83** 025207 (2011).

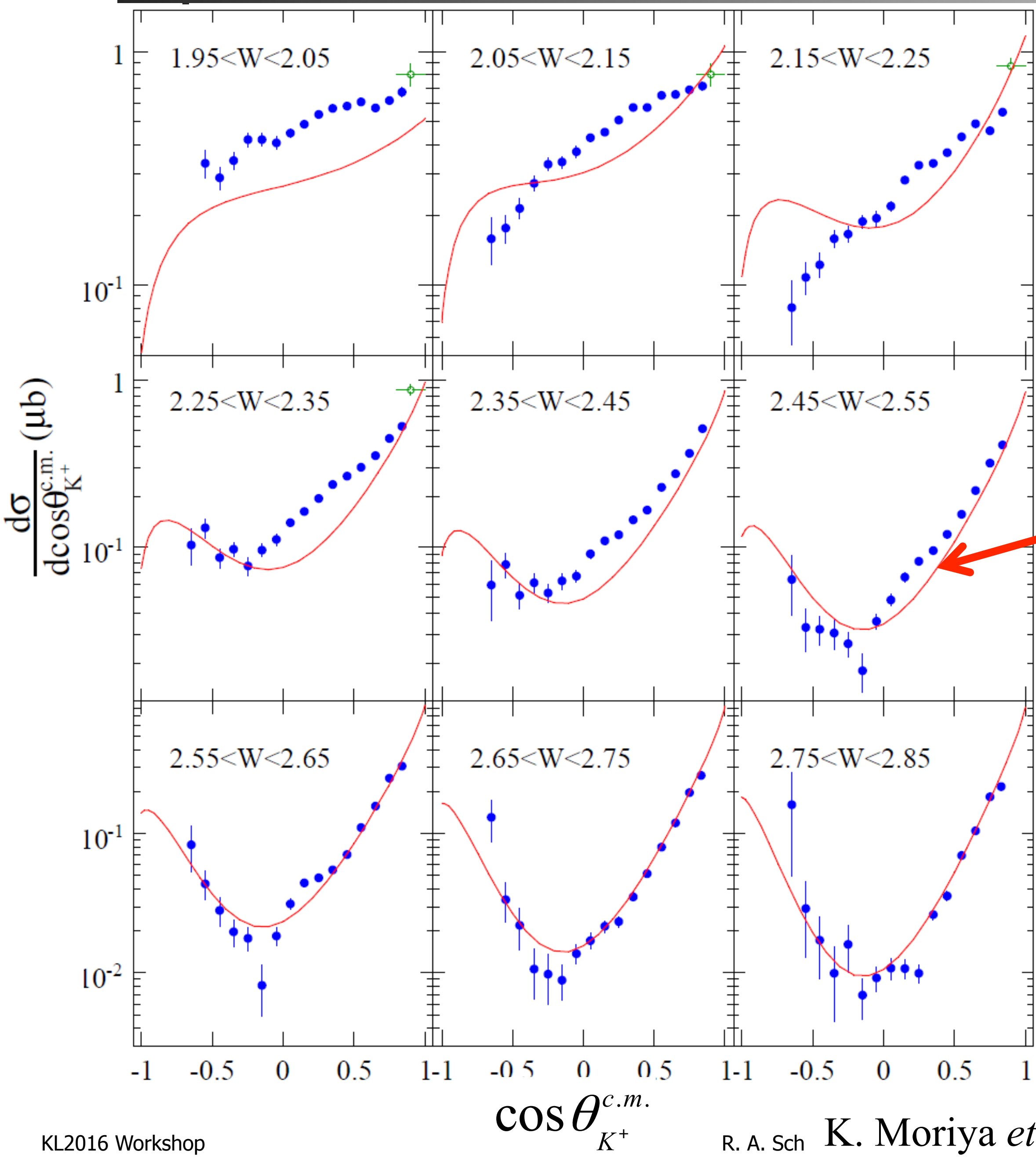
Excited Y* Cross Sections

Publication: Differential Photoproduction Cross Sections of Σ^0(1385), Λ(1405) and Λ(1520) , K. Moriya *et al.* (CLAS Collaboration), Phys. Rev. C **88**, 045201 (2013).

Detect $K^+p\pi^-(\pi^0)$ or $K^+\pi^+\pi^-(n)$



Differential $\Sigma^0(1385)$ Cross Section

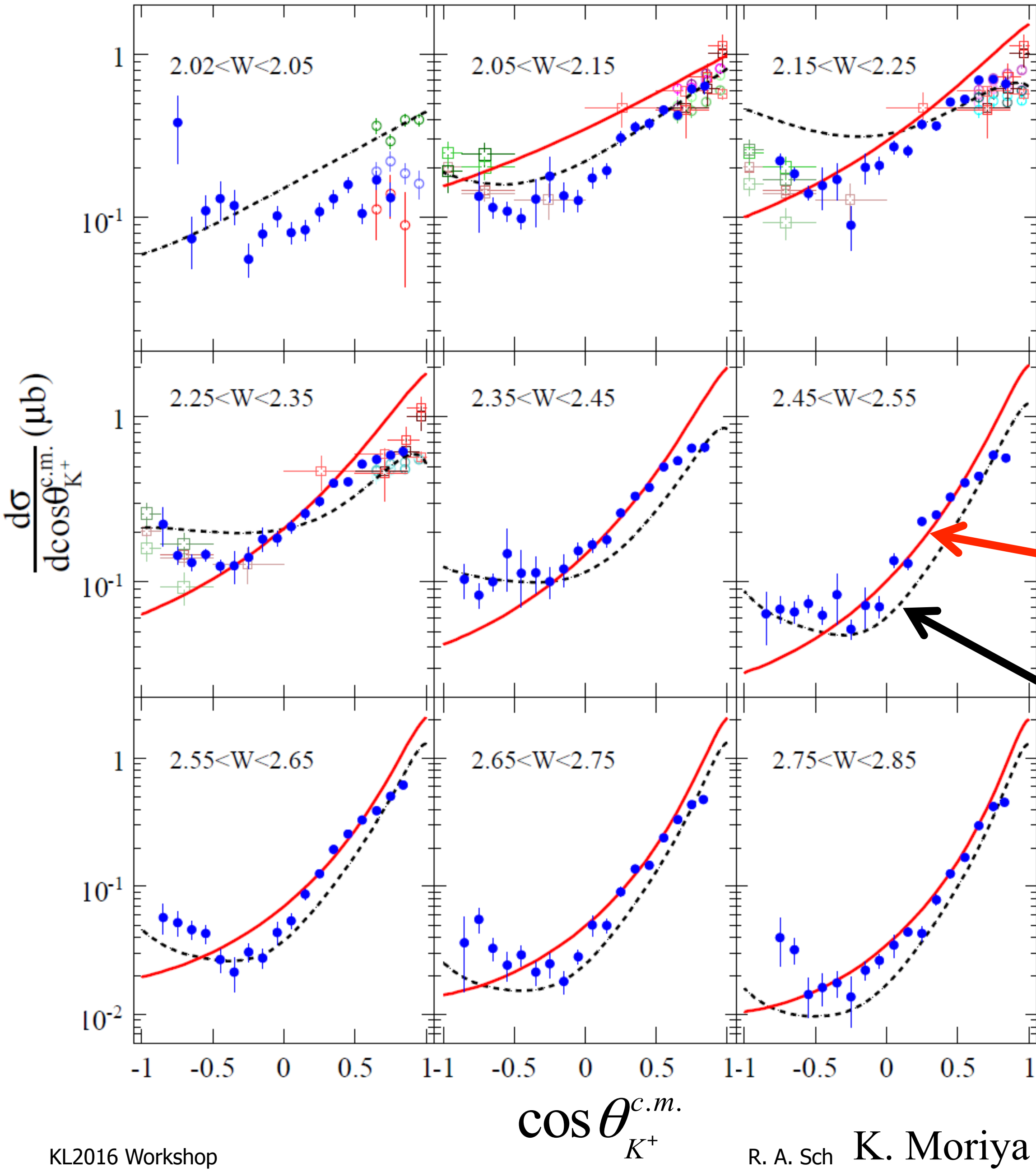


- $\gamma + p \rightarrow K^+ + \Sigma^0(1385)$
- Experiment: see t-channel-like forward peaking & u-channel backward rise
  - Agreement with LEPS
- Theory by Oh et al.[1]: contact term dominant; included four high-mass N^* and Δ resonances
  - Prediction was fitted to preliminary CLAS total cross section (years ago)

1. Y. Oh, C. M. Ko, K. Nakayama, Phys. Rev. **C 77**, 045204 (2008)

K. Moriya *et al.* (CLAS), Phys. Rev. C **88**, 045201 (2013).

Differential $\Lambda(1520)$ Cross Section

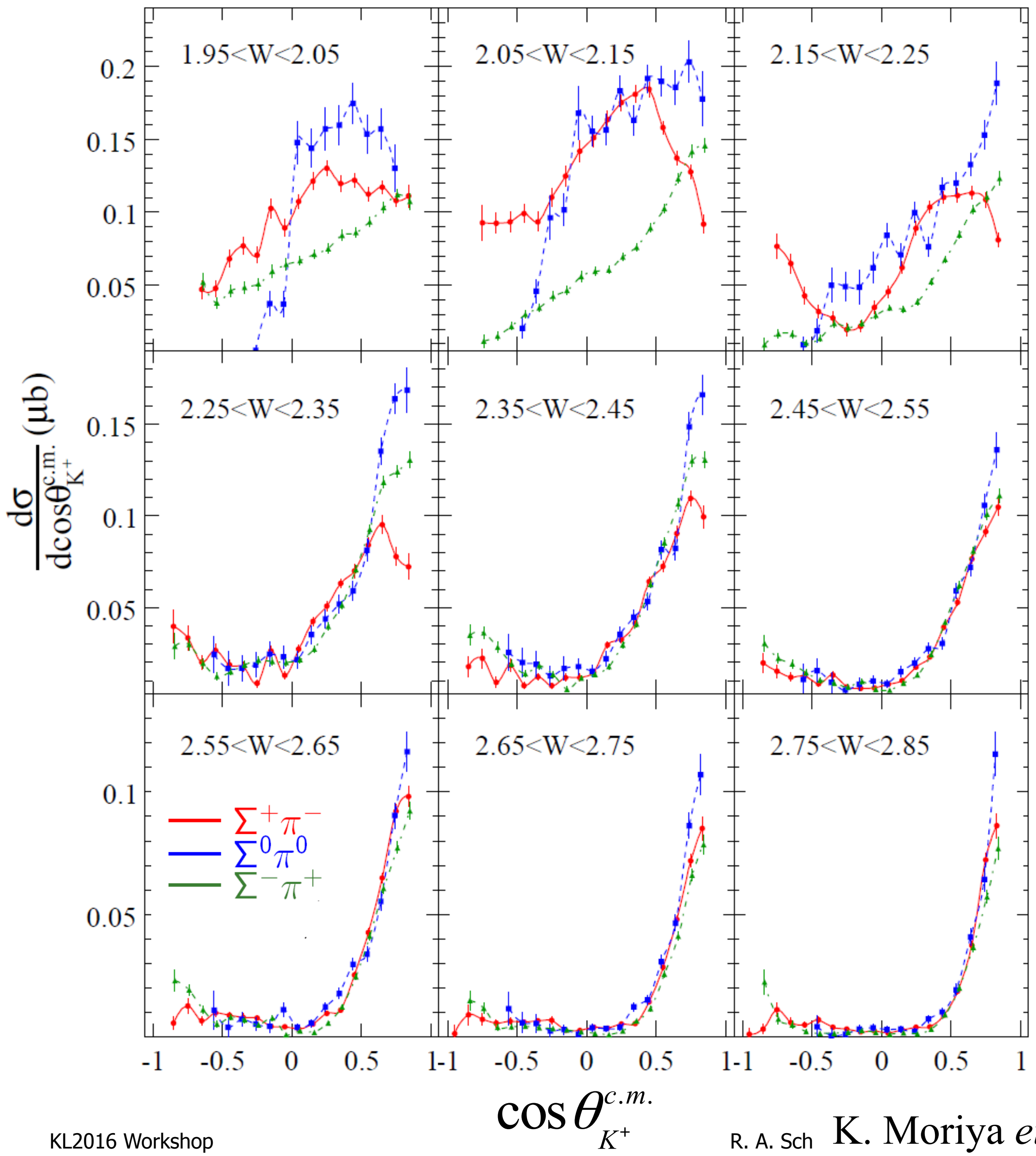


- $\gamma + p \to K^+ + \Lambda(1520)$
- Experiment: see t-channel-like forward peaking & u-channel backward rise
  - Agreement with LEPS[1,2]
- Theories:
  - Nam & Kao[3]: contact term dominant; no K^* or u-channel exchanges
  - He & Chen[4]: K^* and $N(2080)D_{13}$ $J^P=3/2^-$ added

1. H. Kohri et al. (LEPS) Phys Rev Lett **104**, 172001 (2010)
2. N. Muramatsu et al. (LEPS) Phys Rev **103**, 012001 (2009)
3. S.I. Nam & C.W. Kao, Phys. Rev. **C 81**, 055206 (2010)
4. J. He & X.R. Chen, Phys. Rev. **C 86**, 035204 (2012)

K. Moriya *et al.* (CLAS), Phys. Rev. C **88**, 045201 (2013).

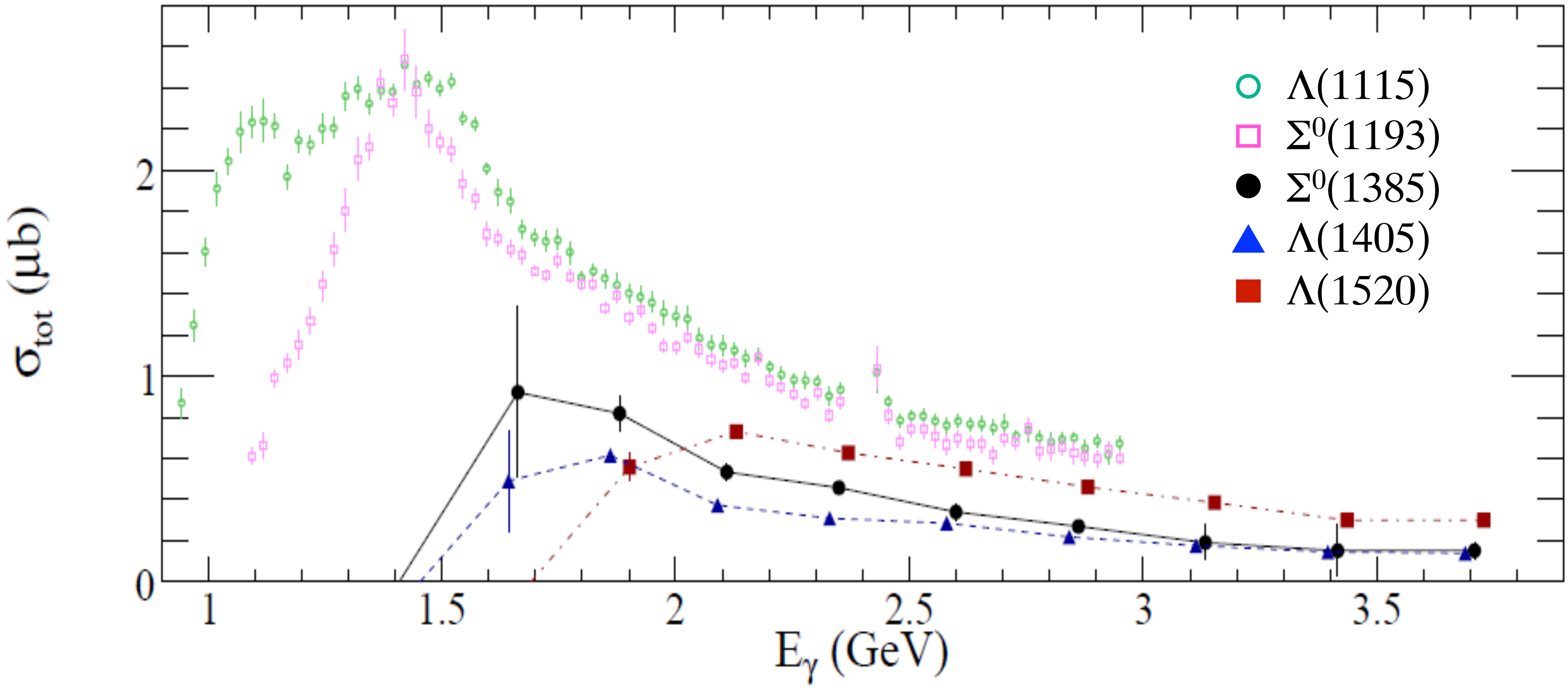
Differential $\Lambda(1405)$ Cross Section



- $\gamma + p \to K^+ + \Lambda(1405)$
- Experiment: first-ever measurements
- Low W: See strong isospin dependence
  - Charge channels differ
  - WHY?!?
- High W: See t-channel-like forward peaking & u-channel backward rise at high W
- Channels merge together at high W

K. Moriya *et al.* (CLAS), Phys. Rev. C **88**, 045201 (2013).

Total Cross Sections Comparison



- $\gamma + p \rightarrow K^+ + Y^{(*)}$
- All three Y^*s have similar total cross sections
- Ground state Λ and Σ^0 are comparable to Y^* in size[1]

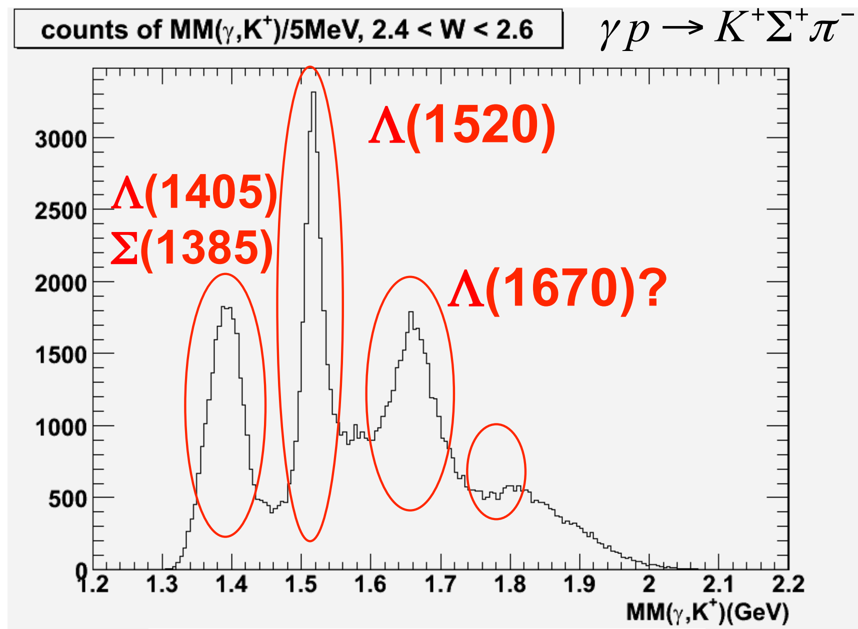
1. R. Bradford et al. (CLAS) Phys. Rev. **C 73**, 035202 (2006)
   K. Moriya *et al.* (CLAS), Phys. Rev. C **88**, 045201 (2013).

Λ(1405) Structure

Publications: Measurement of the Σπ Photo-production Line Shapes Near the Λ(1405), K. Moriya *et al.* (CLAS Collaboration), Phys. Rev. C **87**, 035206 (2013);
Isospin Decomposition of the Photoproduced Σπ System near the Λ(1405), R. A. Sch. & K. Moriya, Nucl. Phys A **914**, 51 (2013) .

What "is" the Λ(1405)?

- An issue since its prediction/discovery
  - Dynamically generated resonance, via unitary meson-baryon channel coupling
    - R. Dalitz & S.F.Tuan, Phys. Rev. Lett. **2**, 425 (1959), Ann. Phys. **10**, 307 (1960).
    - Chiral unitary models (present-day theoretical industry!)
  - SU(3) singlet 3q state, I=0, $J^{\pi} = \frac{1}{2}^{-}$
  - $\bar{K}N$ sub-threshold state
    - Recent first Lattice QCD result: J. Hall *et al.*, Phys Rev Lett **114**, 132002 (2015)
  - Signal may be an overlay of I=0 and I=1 states



(γ,K) Missing Mass (GeV)

Chiral Unitary Models

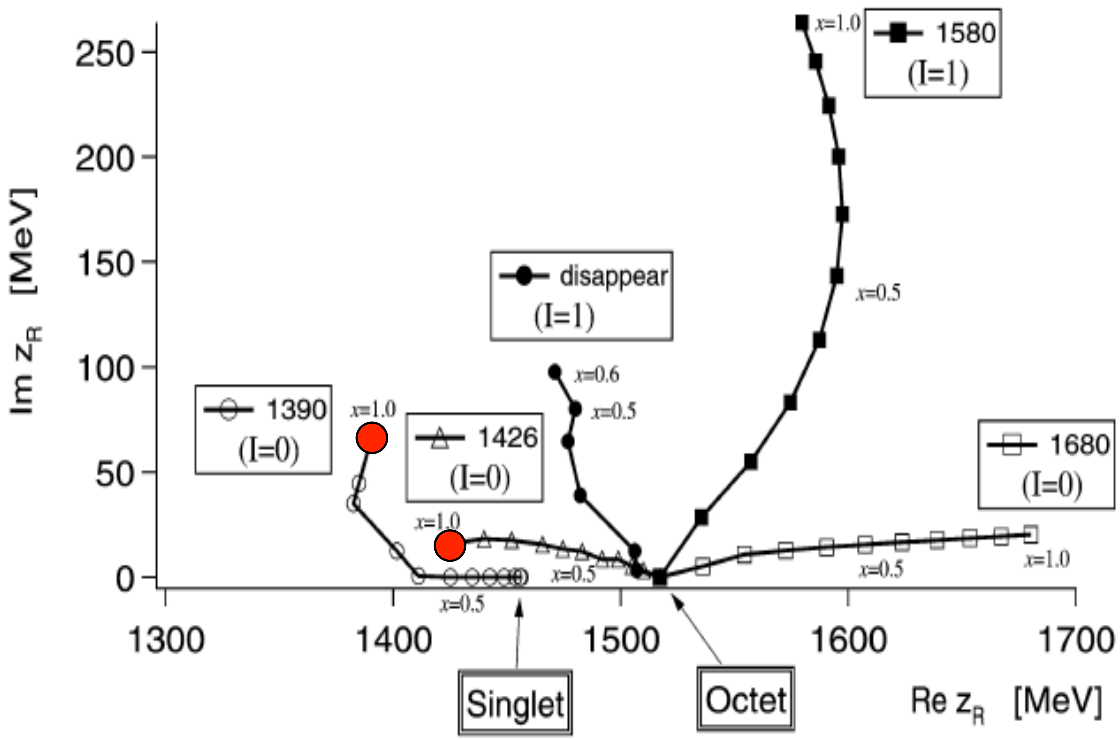
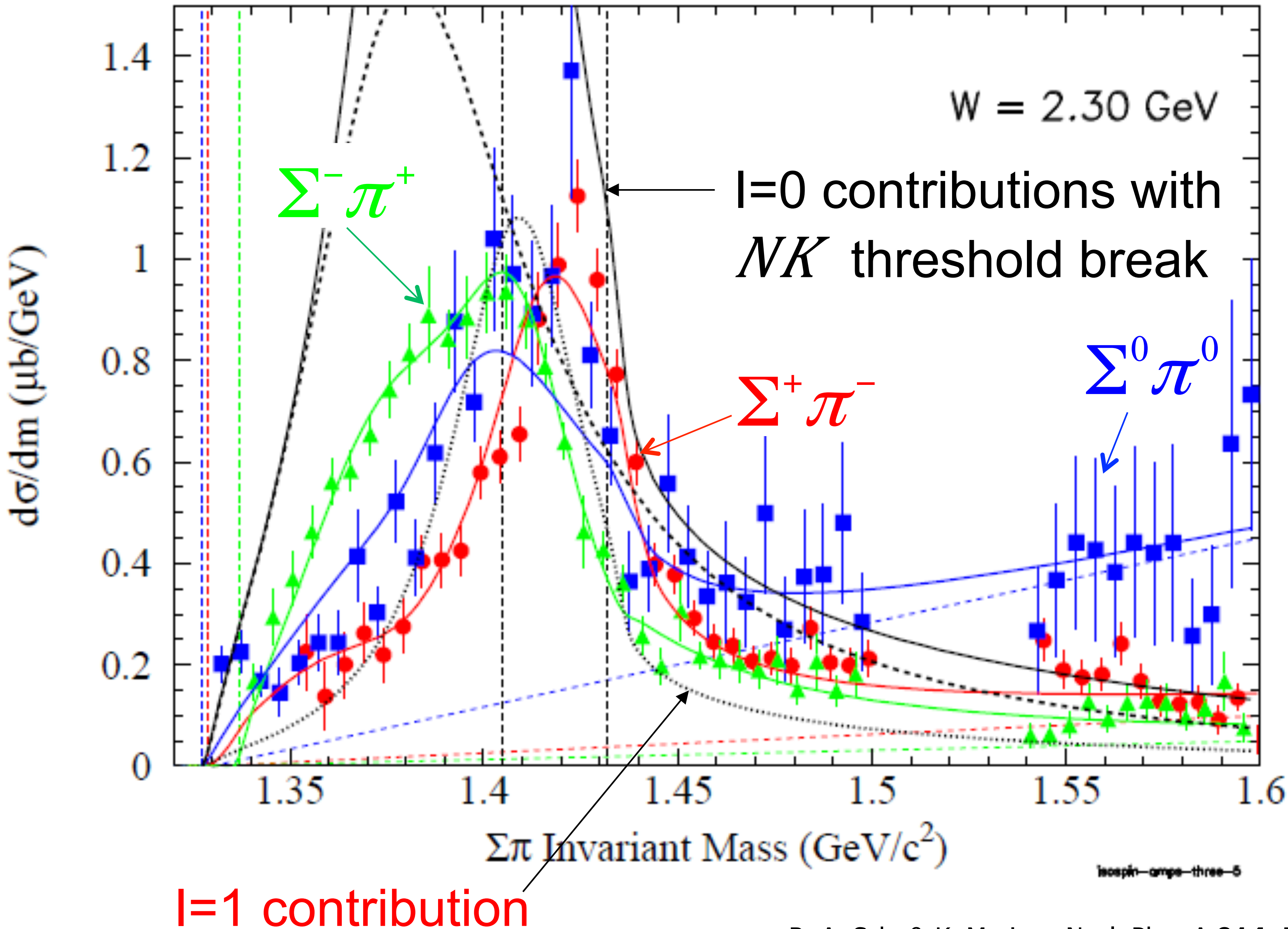


Fig. 1. Trajectories of the poles in the scattering amplitudes obtained by changing the SU(3) breaking parameter x gradually. At the SU(3) symmetric limit ($x = 0$), only two poles appear, one is for the singlet and the other for the octets. The symbols correspond to the step size $\delta x = 0.1$.

- SU(3) baryons irreps $1+8_s+8_a$ combine with 0^- Goldstone bosons to generate:
- Two octets and a singlet of $\frac{1}{2}^-$ baryons generated dynamically in SU(3) limit
- SU(3) breaking leads to two $S=-1$ $I=0$ poles near 1405 MeV
  - ~1420 mostly $\bar{K}N$
  - ~1390 mostly $\pi\Sigma$
- Possible weak $I=1$ pole also predicted

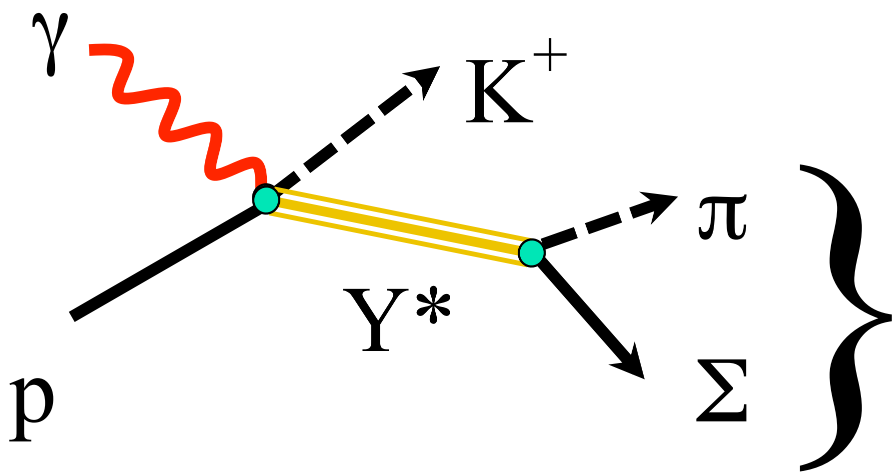
D. Jido, J.A. Oller, E. Oset, A. Ramos, U-G Meissner Nucl. Phys. A **725,** 181 (2003)
J.A. Oller, U.-G. Meissner Phys. Lett B **500**, 263 (2001).

Example at W=2.30 GeV



R. A. Sch. & K. Moriya, Nucl. Phys A **914**, 51 (2013)

Isospin Interference



Final Σπ state

$$\left|I, I_3\right\rangle =$$

$$\left|0,0\right\rangle, \left|1,0\right\rangle$$

$$|t_I|^2 \equiv |\langle I, 0|\hat{T}^{(I)}|\gamma p\rangle|^2$$

Three charge combinations:

$$\begin{aligned}
|T_{\pi^-\Sigma^+}|^2 &= \frac{1}{3}|t_0|^2 + \frac{1}{2}|t_1|^2 - \frac{2}{\sqrt{6}}|t_0||t_1|\cos\phi_{01}, \\
|T_{\pi^0\Sigma^0}|^2 &= \frac{1}{3}|t_0|^2, \\
|T_{\pi^+\Sigma^-}|^2 &= \frac{1}{3}|t_0|^2 + \frac{1}{2}|t_1|^2 + \frac{2}{\sqrt{6}}|t_0||t_1|\cos\phi_{01}.
\end{aligned}$$

What "is" the I=1 piece?

- $\mathrm{I}=1$ resonance? $\mathrm{I}=1$ continuum amplitude?
- L. Roca and E. Oset model[1]:
  - Possible $\mathrm{I}=1$ resonance in vicinity of $N\bar{K}$ threshold
- B.-S. Zou et al. model[2]:
  - $\Sigma\left(\frac{1}{2}\right)^{-}$ is a $\left|[ud][us]\bar{s}\right\rangle$ state: part of a new nonet
- No interference seen in $\Lambda(1520)$ mass range: therefore it's not a continuum amplitude
- More investigation needed !

1. L. Roca, E. Oset "On the isospin 0 and 1 resonances from $\pi\Sigma$ photoproduction data" Phys. Rev. C **88** 055206 (2013).
2. Bing-Song Zou "Five-quark components in baryons", Nucl Phys A 835 199 (2010).

Spin and Parity of $\Lambda(1405)$

Publication: Spin and Parity of the $\Lambda(1405)$ Baryon, K. Moriya *et al.* (CLAS Collaboration), Phys. Rev. Lett. **112**, 082004 (2014).

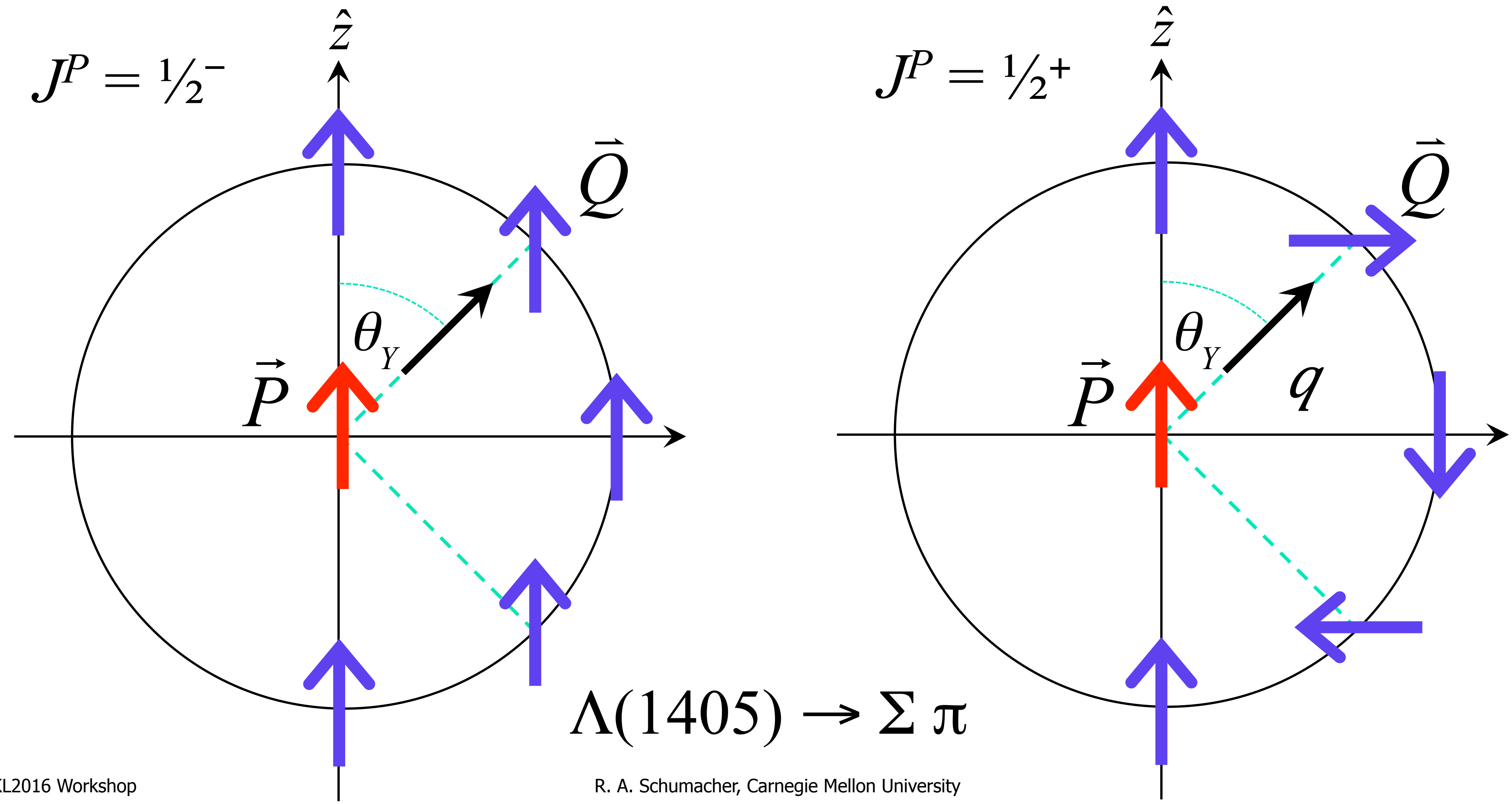
S-wave, P-wave Scenarios

L=0 (s-wave)

$$\vec{Q} = \vec{P}$$

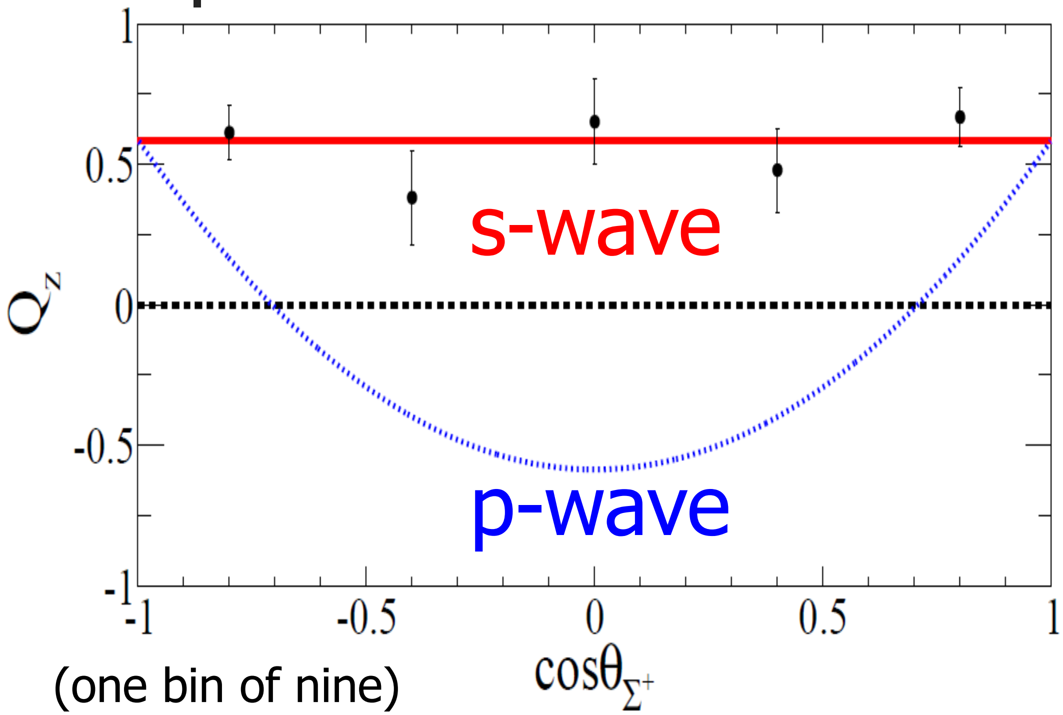
L=1 (p-wave)

$$\vec{Q} = -\vec{P} + 2(\vec{P} \bullet \hat{q})\hat{q}$$



$\Lambda(1405) \to \Sigma\,\pi$

Parity and Spin of $\Lambda(1405)$



(one bin of nine)

- Polarization axis is along $\hat{z} = \hat{\gamma} \times \hat{K}$
- Used W=2.55 to 2.85 GeV, $\cos\theta_K^{c.m.} > 0.6$
- Decay $\Lambda(1405) \to \Sigma^+\pi^-$ is isotropic (p=0.5), so $J \to 1/2$
- Weak decay asymmetry for Σ^+ is $\alpha = -0.98$ (big!)
- Decay is s-wave,

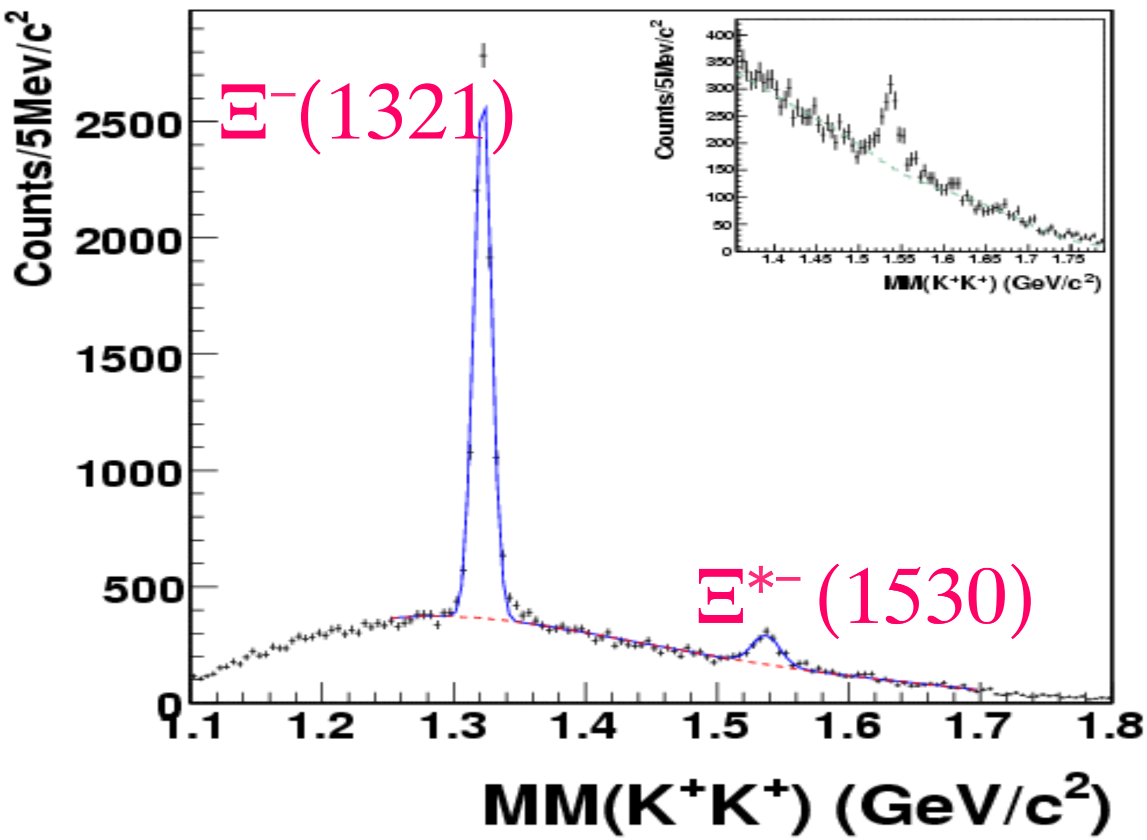
$$\Rightarrow P = \text{"}negative\text{"}$$

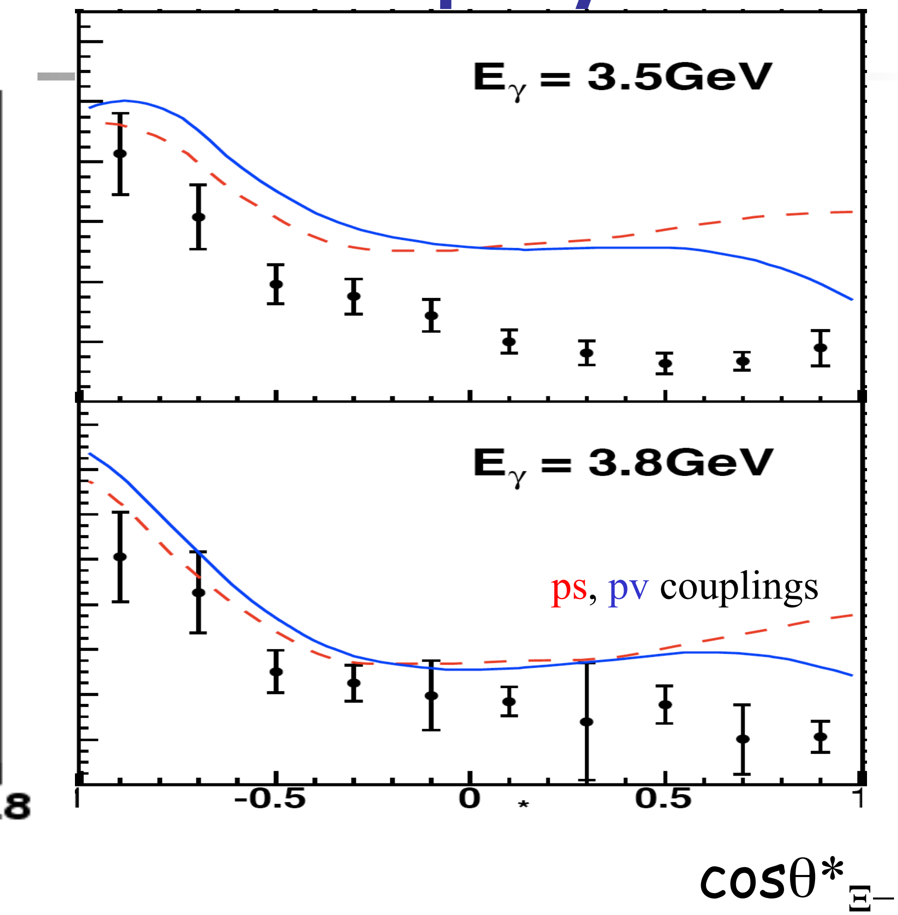
$J^P = ½^-$ confirms quark model expectation

and the $\Lambda(1405)$ is produced ~ +45% polarized

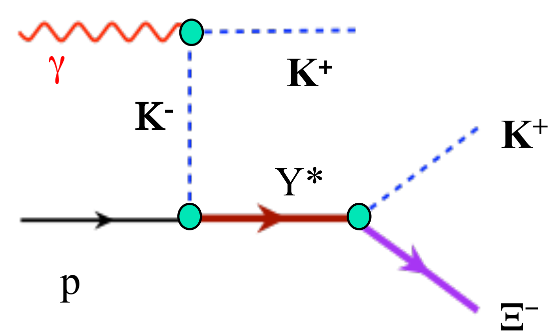
Strangeness -2: Where are the Excited Cascades?

$\Xi^{-(*)}$ Production: $S = -2$ physics





- Detect via $\gamma\, p \rightarrow K^+K^+(\Xi^-)$
- Only two narrow states seen: $\Xi(1321)$, $\Xi(1530)$
- Other states? Failed searches (g12 group)…

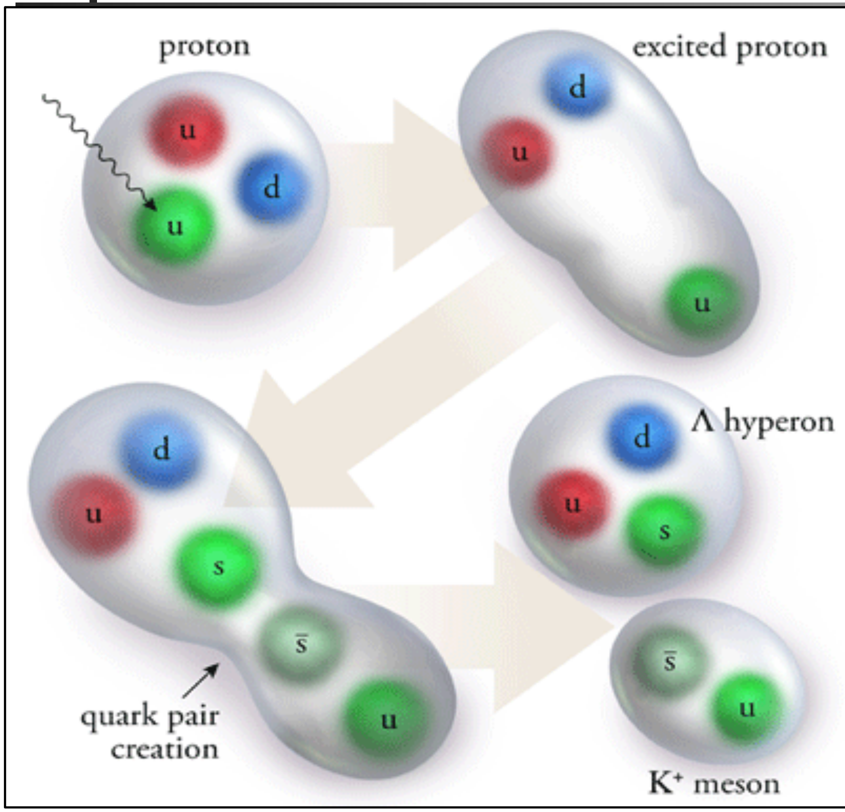


L. Guo et.al. Phys Rev C **76** 025208 (2007)

Strangeness Suppression in $q\bar{q}$ Creation in Exclusive Reactions

Publication: M. D. Mestayer, K. Park *et al.* (CLAS Collaboration), Phys. Rev. Lett. **113**, 152004 (2014).

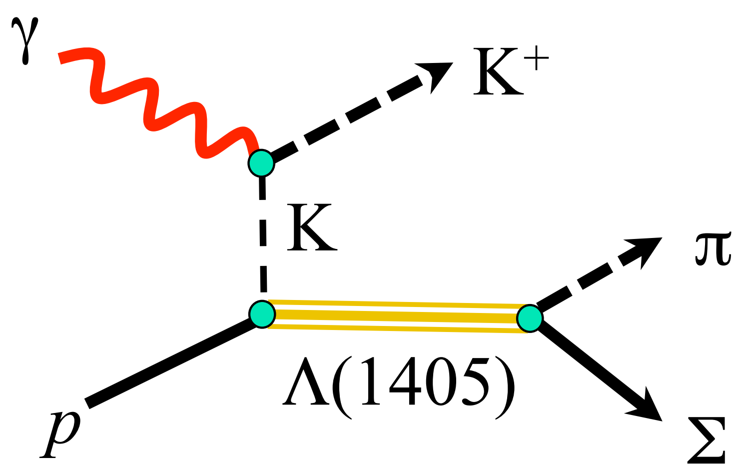
$K^+\Lambda : \pi^+ n : \pi^0 p$ Electroproduction Ratios

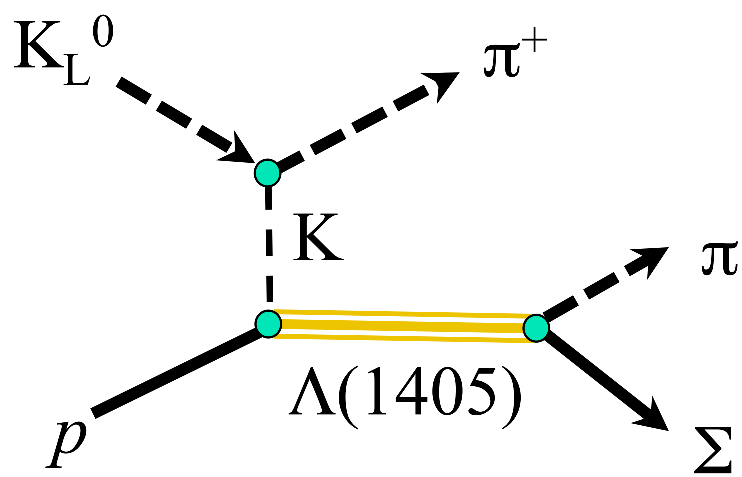


Ratio	$s\bar{s}$ / $d\bar{d}$	$u\bar{u}$ / $d\bar{d}$
$K^+\Lambda/\pi^+n$	0.19 ± 0.03	-
$K^+\Lambda/\pi^0p$	0.22 ± 0.07	-
$K^+\Lambda/\pi^0p$	0.28 ± 0.07	-
π^0p/π^+n	-	0.74 ± 0.18

- Motivation:
  - Quark model picture of quark-pair creation and flux-tube breaking: does it apply in the low-energy exclusive limit?
- Measurements:
  - Ratio of processes in which only one $q\bar{q}$ pair is produced: an $s\bar{s}$, $d\bar{d}$, or $u\bar{u}$, respectively
  - In quark-model picture, ratios are proportional to the relative production rates of $s\bar{s}$, $d\bar{d}$, or $u\bar{u}$
- Physics conclusion:
  - Ratio of $s\bar{s}$ pair creation relative to $u\bar{u}$ or $d\bar{d}$ is suppressed ~0.2 – 0.3
  - Consistent with high-energy results when 100's of particles are produced

Outlook at GlueX for Λ(1405) Line-Shape Measurement



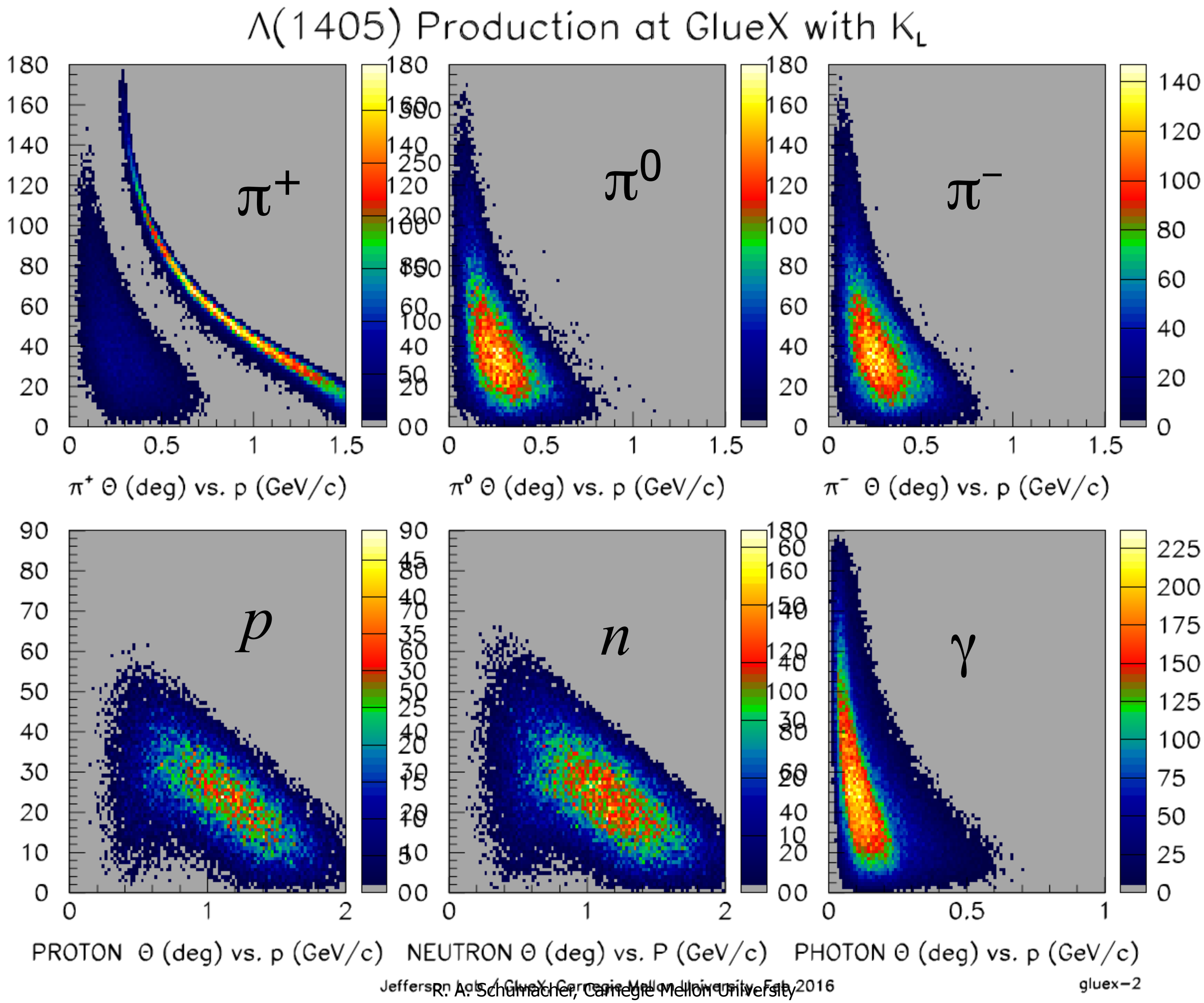


Count rate estimate $\Lambda(1405)$

$$K_L^0 p \rightarrow \Lambda(1405)\pi^+ \rightarrow \Sigma^{+0-}\pi^{-0+}\pi^+$$

- Assume: 10^3 K_L/sec between 1.0 and 2.0 GeV/c
- Target 40 cm LH_2
- Total estimated cross section 250 μb
  - Scale from $K^- p \rightarrow \pi^0 \Lambda(1405)$ … 50% K_L/K_S mixing
- Rate ~ 0.4 / sec (before acceptances)
  - No kaons to detect in final state
  - Measurement may be feasible

At GlueX: $K_L^0 p \to \Lambda(1405)\pi^+$



Summary/Conclusions

- Hyperon photo- and electro-production used to pin down N^* spectrum above 1.6 GeV
- Y^* cross sections compared; $\Lambda(1405)$ "weird"
- Interference effects in $\Lambda(1405)$ line shapes in $\Sigma\,\pi$ demonstrated
- Direct J^P measurement for $\Lambda(1405)$ made: $\frac{1}{2}^-$
- Cross section "scaling" demonstrated
- Strangeness "suppression" seen in exclusive
- GlueX with K_L beam could explore $\Lambda(1405)$ line shapes in more detail