08:30 - 10:00 **Hadron Spectroscopy Working Group - I**

Bluejeans link: https://bluejeans.com/906158081

Convener: Dr. Marco Battaglieri (INFN-GE)

Location: L102

08:40 **HSWG business** *20'*
Speaker: Dr. Marco Battaglieri (INFN-GE)

09:00 **JPac updates** *30'*
Speaker: Prof. Adam Szczepaniak (Indiana Univeristy/JLab)

09:30 **Homework for HSWG: Light Nucleon Resonance Revival** *30'*
Speaker: Prof. Igor Strakovsky (The George Washington University)
Material: **Slides**

10:30 - 12:30 **Hadron Spectroscopy Working Group - II**

Convener: Dr. Marco Battaglieri (INFN-GE)

Location: L102

10:30 **Measurement of the G Double-Polarisation Observable in Positive Pion Photoproduction** *25'*
Speaker: Dr. Nicholas Zachariou (University of Edinburgh)

10:55 **The eta cross section and further publication plans for CLAS-g12 cross section measurements** *25'*
Speaker: Tianqi Hu (FSU)

11:20 **The polarization observables P, C(x), and C(z) for the reaction K(0)Sigma(+) using CLAS-g12 data** *25'*
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HSWG

CLAS

Collaboration Meeting

JLab, Jun 20 2019

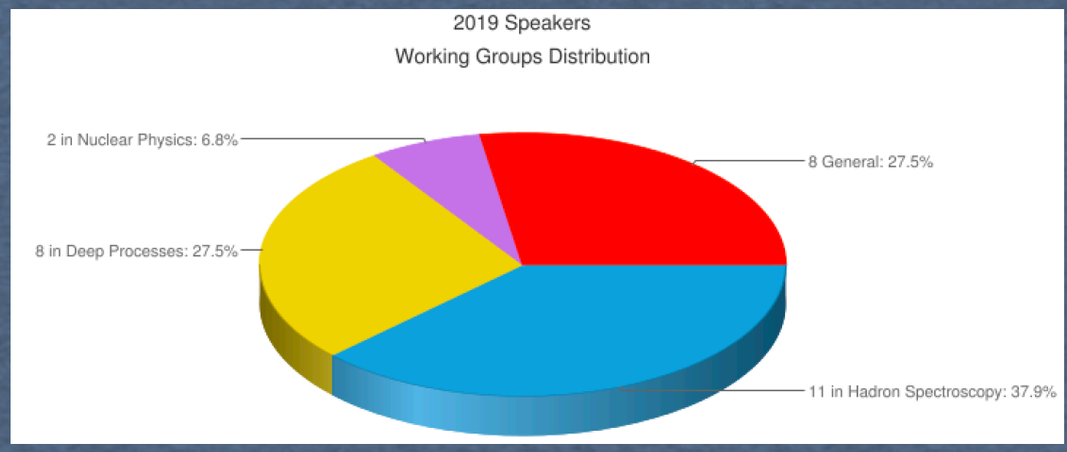
+ HS/Deep/ Nuclear CLAS12 analyses joint session

Agenda

- ✳ CLAS6 data analysis
- ✳ Status of ongoing analysis (update from previous collaboration meeting)
- ✳ Dedicated (joint) session for CLAS12
  - Hadron structure group report (Dan)
  - Update on J/Psi analysis (Joseph)

Talks

- ✳ Over all CLAS contributions, HSWG-related are 38% in 2019 (partial)
- ✳ HSWG representatives in the CSC
  - A.d'Angelo (currently CSC chair)
  - L.Guo
- ✳ JSA-TFC $18k granted for 2019



✳ Review of the "Quasi-real Photoproduction of Hadrons on Deuterium" PI W.Phelps F. Hauenstein, (Y.Ilieva,B.McKinnon)

✳ HSWG chairman nominating committee
- Open for nominations!
- vote in July, term starts in September '19 for 3 years

✳ List of ongoing analysis on HSWG wiki page

Reaction	CLAS running period	Principal Investigator(s)	Graduate Student	Adviser(s)	Contact person(s)	Status
$\gamma^* p \to \pi^0 p$ and eta p	RG-A	Andrea Bianconi, Luca Venturelli			mailto:andrea.bianconi@unibs.it	
Q^2-dependent cross sections for $\gamma^* p \to \pi^+ \pi^- p$ at $Q^2 > 2$ GeV2	RG-A	Krishna Neupane		Ralf Gothe		Underway
$\gamma^* p \to \pi^+ \pi^- p$	RG-A	Adam Thornton		Derek Glazier		Underway
3pi	RG-A	Derek Glazier		Derek Glazier		No Signal Yet
rho beam asymmetry	RG-A	Michael Dugger		Michael Dugger		Underway
Survey of photoproduced cascade states	RG-A	Michael Dugger		Michael Dugger		No Signal Yet
survey of Cascade and Omega baryons	RG-A	Nicholas Zachariou		Nicholas Zachariou		Underway
Omega- cross section	RG-A	Will Phelps				Underway
Inclusive and elastic cross section studies	RG-A	Nikolay Markov			Nikolay Markov	Under way
Single pion electroproduction in the resonance region	RG-A	Nikolay Markov			Nikolay Markov	Under way
Single pion exclusive structure functions at Q2 > 5 GeV2	RG-A	Evgeny Isupov			Evgeny Isupov	Under way
$\gamma^* p \to \pi^+ \pi^- p$ cross sections at Q2 > 5 GeV2	RG-A	Evgeny Golovach			Evgeny Golovach	Under way
Exclusive Two K-short electroproduction cross sections	RG-A	Ken Hicks			Ken Hicks	Just started
N* structure: KY cross section, pol. transfer at Q2 > 1 GeV2	RG-A	Daniel S. Carman			Daniel S. Carman	Under way
Extraction of the nucleon resonance electroexcitation amplitude from $\gamma^* p \to \pi^+ \pi^- p$ electroproduciton off protons with the CLAS12.	RG-A	Viktor Mokeev			Viktor Mokeev	Under way
Evaluation of the resonant contribution into inclusive structure functions.	RG-A	Astrid Hiller Blin			Astrid Hiller Blin	Under way
eta.pi	RG-A	Carlos Salgado		Carlos Salgado		Did not start Yet (in January)
J/psi photoproduciton near threshold	RG-A	Stepan Stepanya	Joseph Newton	Nathan Baltzell, Rafayel Paremuzyan, Valery Kubarovsky		Analysis started
η' and ω decays					Susan Schadmand	Did not start yet

- CLAS12 data analysis
- List on HSWG wiki (https://www.jlab.org/Hall-B/secure/hadron/wiki/index.php/CLAS12_Analysis_projects)
- Keep it updated

WG Reviews status

Released

Polarization Observables T and F in the $\vec{p}(\vec{\gamma},\pi 0)p$ Reaction
PI:H.Jiang
RC: Barry Ritchie (Chair), Volker Crede , Bryan McKinnon
Status: the group is working on major issue, after a thorough review, it is almost done

About to start (searching panelists)

Eta pi and eta' pi photo production (g12)
PI: A.Celentano

p p-bar (g12)
PI:W.Phelps

WG Reviews status

In progress

Analysis of the polarization observables H and P from the reaction gamma p -> pi+ n
PI: R.Lee (M.Dugger)
RC: A.d.Angelo (Chair),B.McKinnon, E.Golovach
Status: in progress but requires some iterations with the leading authors

Measurement of the G Double-Polarisation Observable in Positive Pion Photoproduction
PI: N.Zachariou (L.Zana)
RC: S.Strauch (Chair), P.Cole, D.Sokhan
Status: restarted from scratch: new analysis for the same committee

WG Reviews status

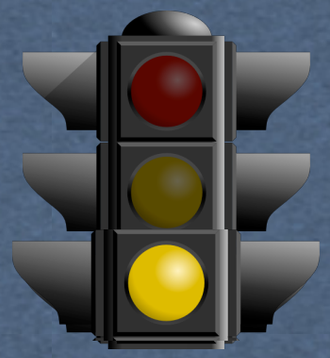
In progress

Exclusive pi- Electroproduction off the Neutron in Deuterium in the Resonance Region

PI: Y. Tian

RC: Nikolay Markov (Chair), Mikhail Bashkanov , Eugene Isupov

Status: 1st round in August, waiting for response from PI, response received, II round uploaded on Feb 8, still working on it. NEEDS SOME ACTIONS



Dalitz Plot Analysis of eta' to eta pi pi − from CLAS g12 Data Set

PI:S.Ghosh

RC:V.Crede (chair), A.Rizzo, E.Pasyuk

Status: Started in July'17; first round of comments on Sept 17: no response from the PI since then.

Scarce communication with the review committee. Is the analysis dead ?????

Ankhi is taking over but a lot of work needs to be done

new message sent to Ankhi: not aware of the response …

Many interactions between S.Schadmand Sudeep and Ankhi

Waiting for a while

WG Reviews status

Resurrected

Photoproduction of the 3π mesons in the reaction $\gamma p \rightarrow \pi+\pi+\pi-n$ with CLAS detector at 6 GeV/c2

PI:P.Eugenio
RC: D.Glazier (chair), A.Filippi, M.Dugger
Status: 2nd round, response received, almost done

Dismissed

Exclusive Photo-Production Measurement of K+Sigma*- off Quasi-Free Neutrons in Deuterium

PI: H.Lu (SCU) et al.
RC: N.Zachariou, M.Dugger, D.MacGregor
Started in 2012 (!)
Status: ?????????????

Actions

- Remove these analyses from the list of active analyses
- Share this information to the whole HSWG to see if ay resources could be allocated to continue (assuming full collaboration from the former PI!)

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How to reconstruct resonances (and determine where they come from) JPAC update

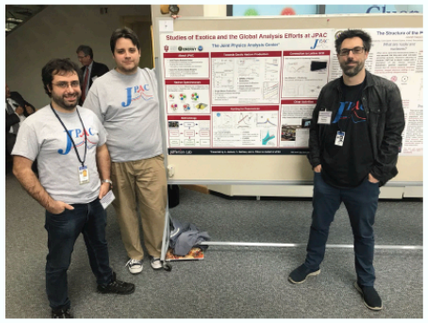
Adam Szczepaniak, Indiana University/Jefferson Lab

Joint Physics Analysis Center

- JPAC: theory, phenomenology and analysis tools in support of experimental data from JLab12 and other accelerator laboratories: one meeting/week + working groups
- Contribute to education of new generation of practitioners in physics of strong interactions : NEW: Graduate course on reaction theory

https://jpac.jlab.org

http://www.indiana.edu/~jpac/



Amplitude analysis : connecting data to QCD

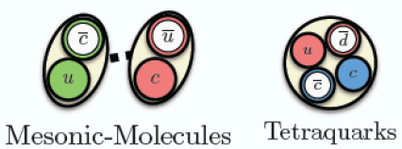
Bottom → Up

Amplitudes

Rules (bubbles, regularization, renormalization, etc.)

Data

Microscopic model



Mesonic-Molecules Tetraquarks

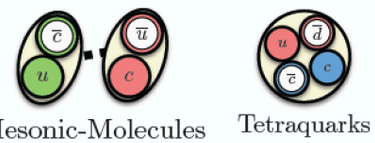
Top → Bottom

Amplitudes

Data

Physical interpretation of poles, cuts,

Microscopic model



Mesonic-Molecules Tetraquarks

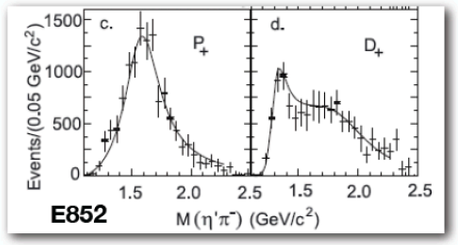
- Reconstruct amplitudes from its singularities (poles, cuts) Recall that each singularity has its own physical interpretation
- Use data to determine best hypothesis
- Test how singularities depend on parameters (channel couplings, thresholds, etc.) to infer their microscopic origins.

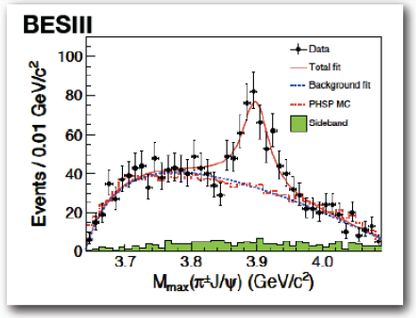
- $J^{PC}=1^{-+}$ I=1, light exotic hybrid ?

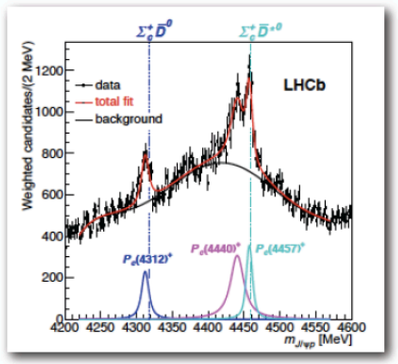
  Yes : "Normal resonance"

- $Z_c(3900)$ in J/ψ π π, $\bar{D}D^*$?

  Inconclusive

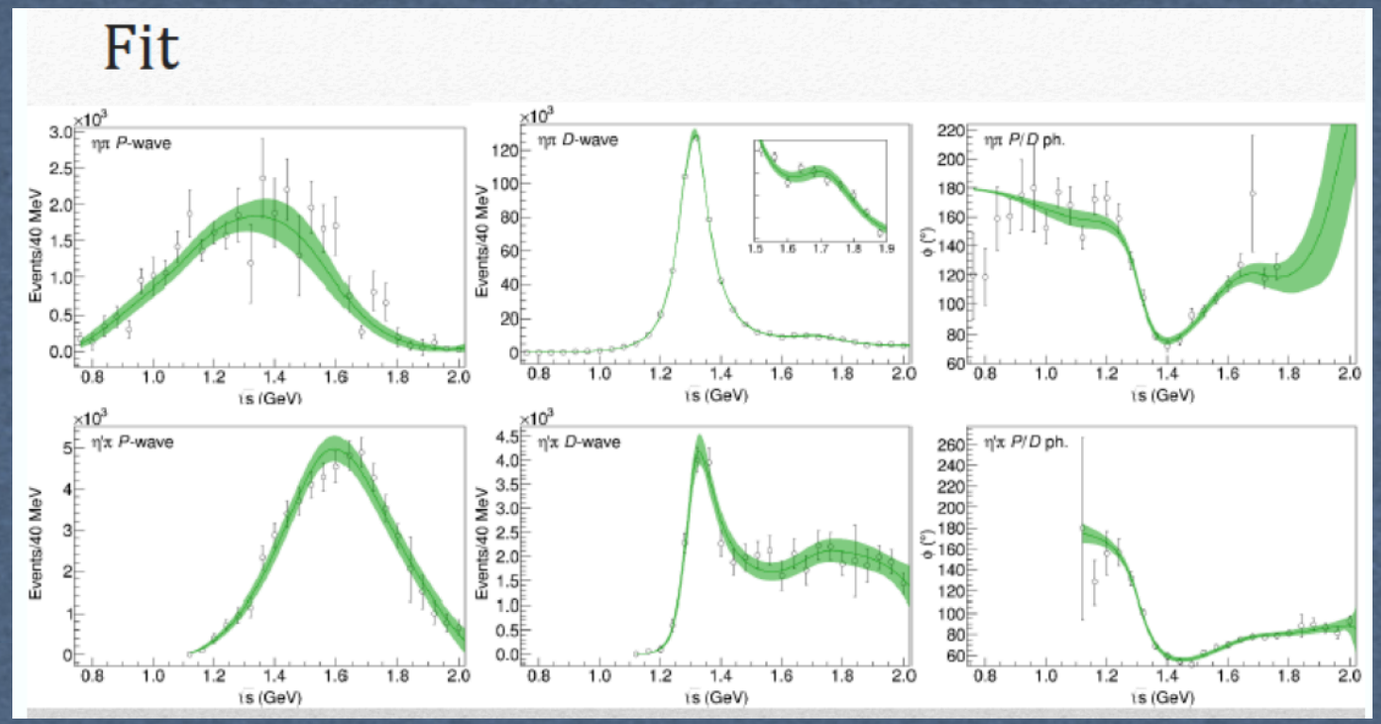


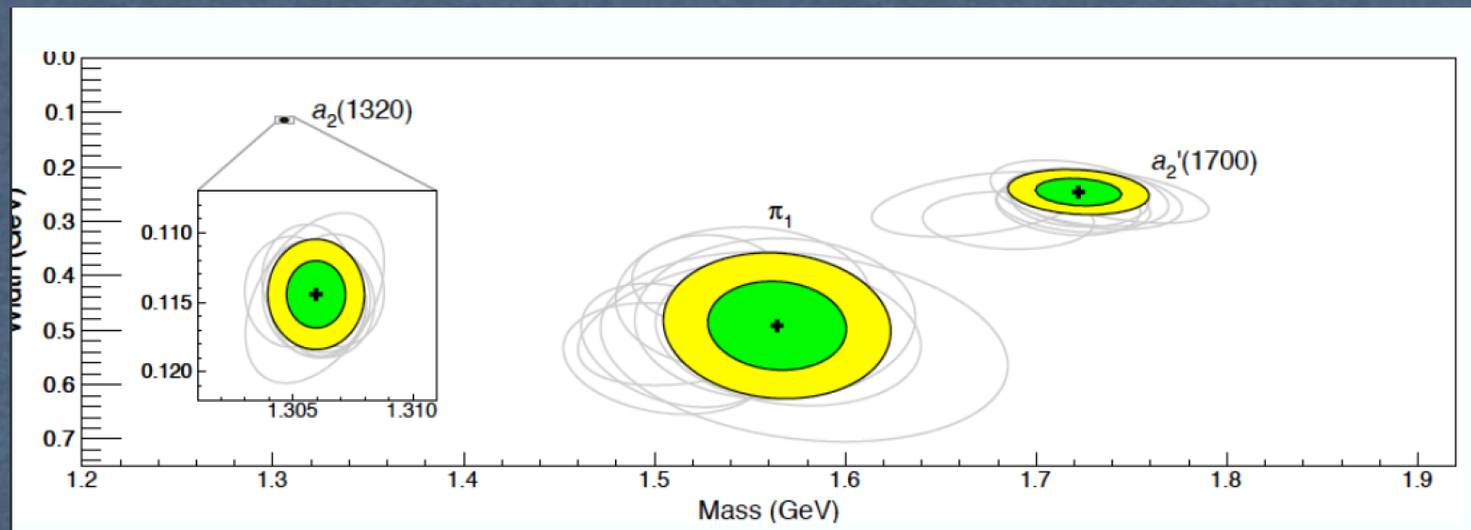




- $P_c(4312)$ in $\Lambda_b \rightarrow$ J/ψ p K

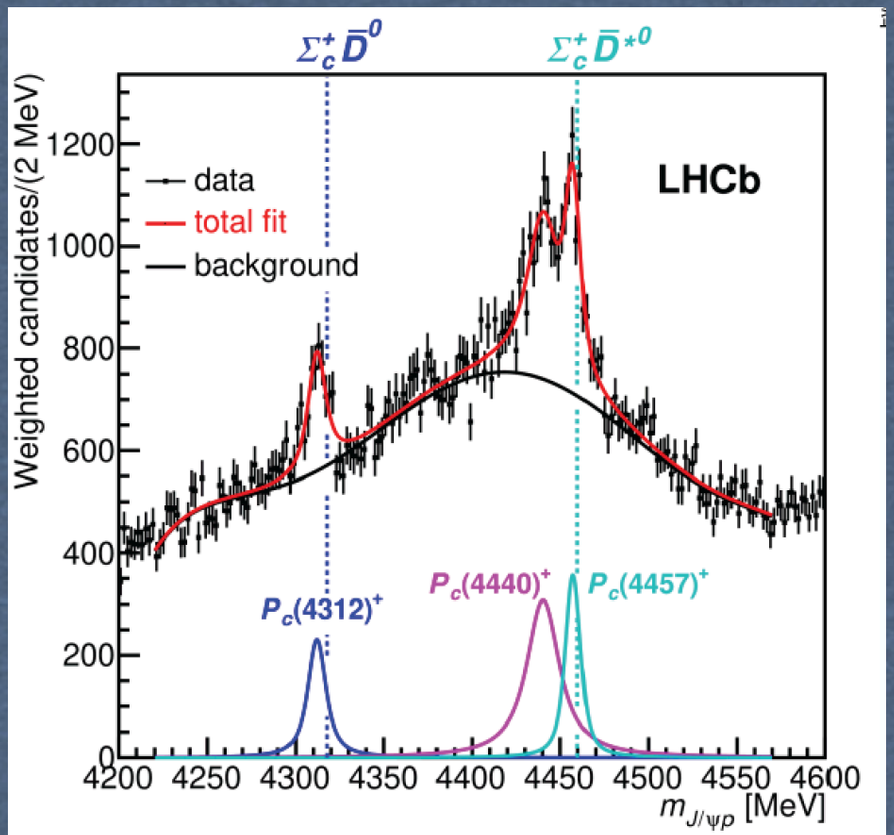
  No : Unbound

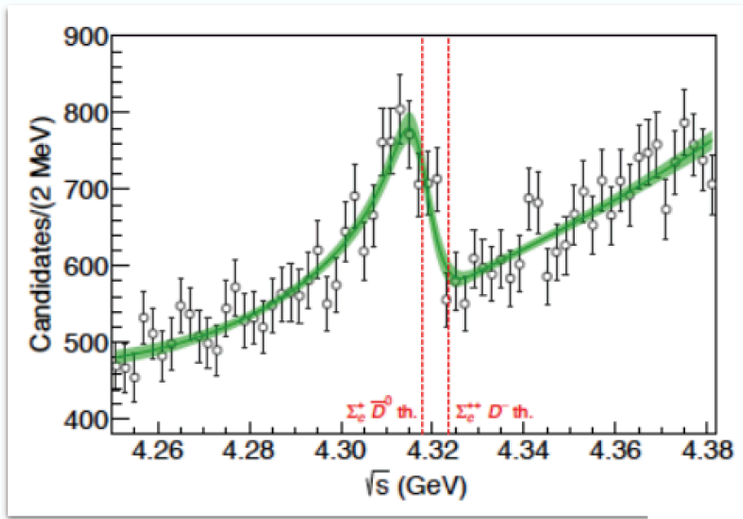




The variance of the bootstrapped poles gives the statistical error

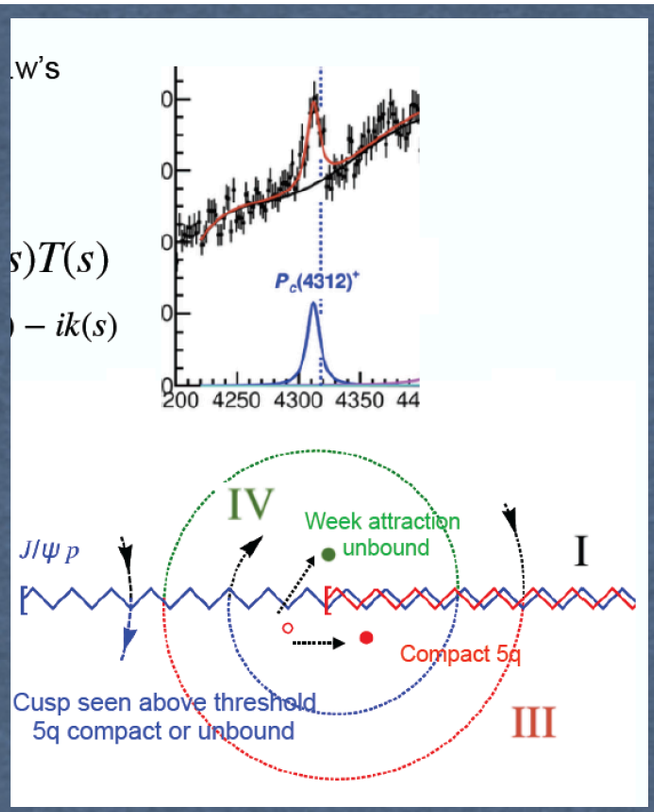
Poles	Mass (MeV)	Width (MeV)
$a_2(1320)$	1306.0 ± 0.8	114.4 ± 1.6
$a_2'(1700)$	1722 ± 15	247 ± 17
π_1	1564 ± 24	492 ± 54





$$T^{-1} = M - i\rho(s)$$

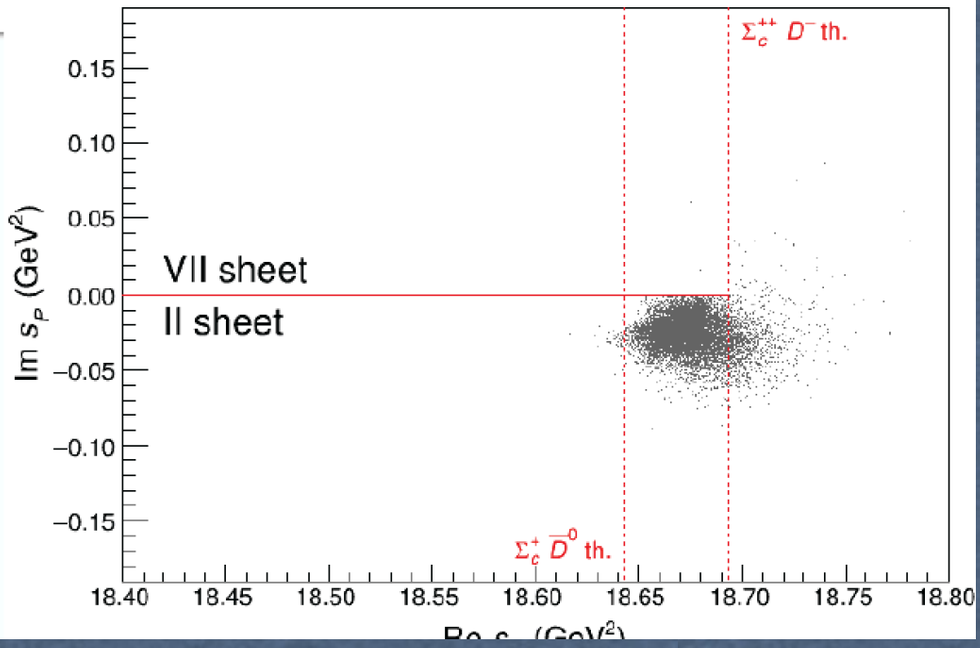
M = 3 x 3 scattering lengt matrix



Decrease coupling between J/ψ p and $\Sigma^+\bar{D}$ channels

Remove imaginary parts

Consistent with unbound state



Homework for HDWG: Light Nucleon Resonance Revival

Igor Strakovsky
The George Washington University

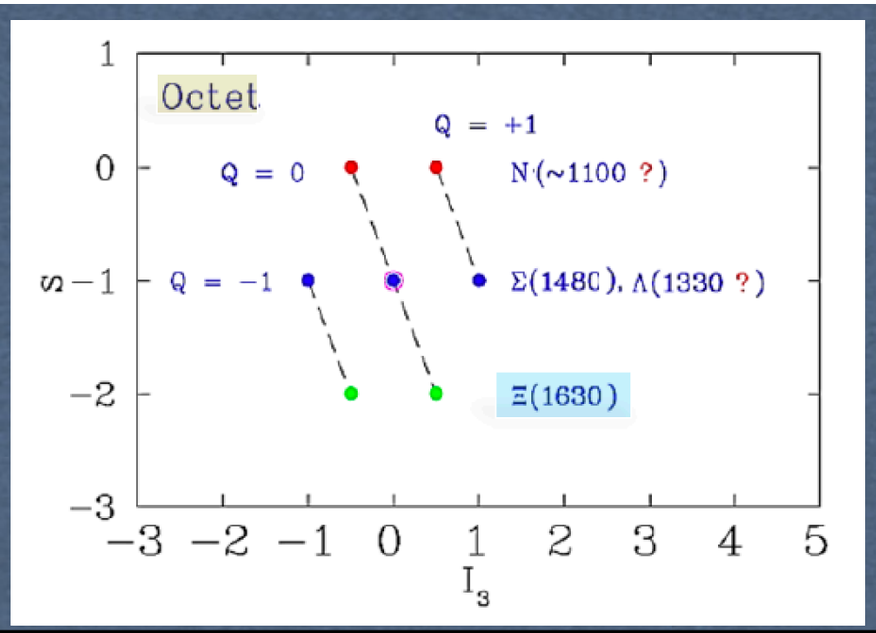
- Baryon spectroscopy continues to motivate **extensive experimental program**, with most studies focused on **missing resonance problem**.
- Given **underpopulation** of conventional **3-q** states, it is difficult to identify unconventional states.
- If, however, **N′** state was to be found with **mass** between **N** & **Δ**, it would **undoubtedly** have exotic structure.

- Such baryon state (called here **N′**, for brevity and according to tradition, though its **isospin** could be **1/2**) was suggested to complete **unitary multiplet** of hyperon resonance states **Σ(1480)** & **Ξ(1620)**, considered now to have **1*** status according to PDG.

Unitarity Partners (?)

State	Mass (MeV)	Width (MeV)	Decay Modes	Hadron Production Xsections
N′	∼1100 ?	<0.05	Nγ ?	$< 10^{-4}$ of "normal"
Λ	1330 ?		Λγ	$\sim 10\mu b$
Σ	1480	30-80 ?	Λπ, Σπ, N$\bar{K}$	$\sim 1\mu b$
Ξ	1630	20-50 ?	Ξπ	$\sim 1\mu b$

On base of positive observations.



$\Xi(1620)1/2(?^?)$ ☆

Ξ(1620) MASS

VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
≈ 1620 OUR ESTIMATE					
1624± 3	31	BRIEFEL	77	HBC	K^-p 2.87 GeV/c
1633±12	34	DEBELLEFON	75B	HBC	$K^-p \to \Xi^-\overline{K}\pi$
1606± 6	29	ROSS	72	HBC	K^-p 3.1–3.7 GeV/c

Ξ(1620) WIDTH

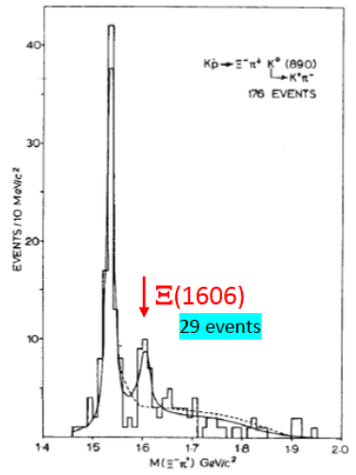
VALUE (MeV)	EVTS	DOCUMENT ID		TECN	COMMENT
22.5	31	[1] BRIEFEL	77	HBC	K^-p 2.87 GeV/c
40 ±15	34	DEBELLEFON	75B	HBC	$K^-p \to \Xi^-\overline{K}\pi$
21 ± 7	29	ROSS	72	HBC	$K^-p \to \Xi^-\pi^+K^{*0}(892)$

$\Xi(1606)$ via $K^-p \to \Xi^-\pi^+K^{*0}(892)$ from CERN

$\Xi(1620)$ via $K^-p \to \Xi^-\pi^+K^0$ from BROOKHAVEN NATIONAL LABORATORY

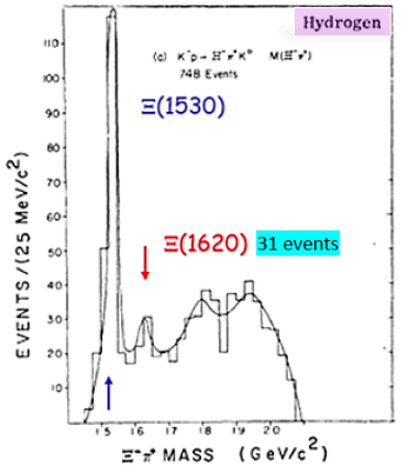
$\Xi(1620)$ via $\Xi^-Cu \to \Xi^-\pi^+X$ from WA89

Ξ(1530)



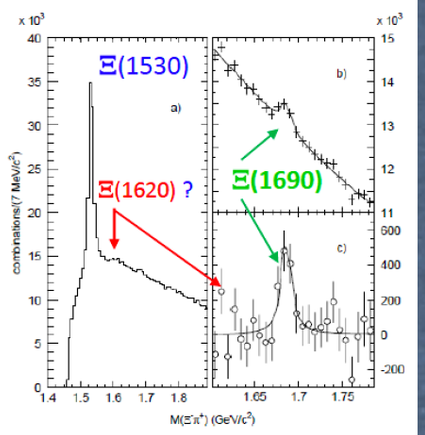
M = 1605.5±5.6 MeV
Γ = 20.8±7.4 MeV

R.T. Ross *et al*, Phys Lett **38B**, 177 (1972)



M = 1624±3 MeV
Γ = 22.5 MeV

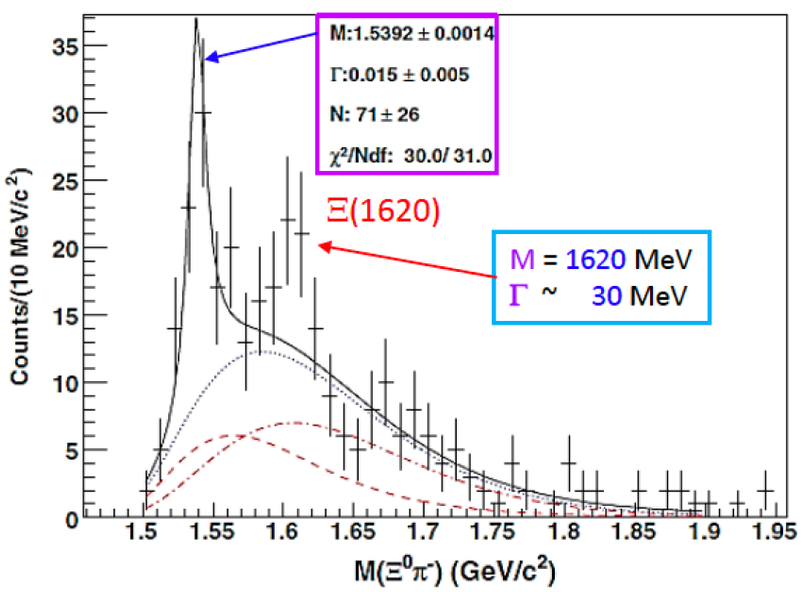
E. Briefel *et al*, Phys Rev D **16**, 2706 (1977)



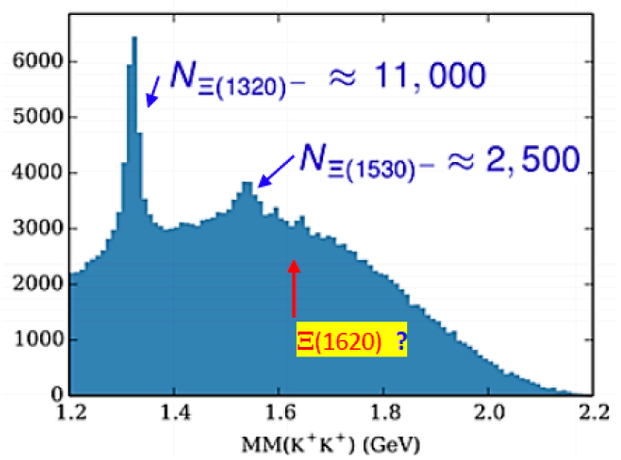
M.I. Adamovich *et al*, Eur Phys J C **5**, 621 (1998)

$\Xi(1620)$ via $\gamma p \to K^+K^{*0}\Xi^0$ & $K^+K^+\Xi^-$ from CLAS

Ξ⁻(1530)

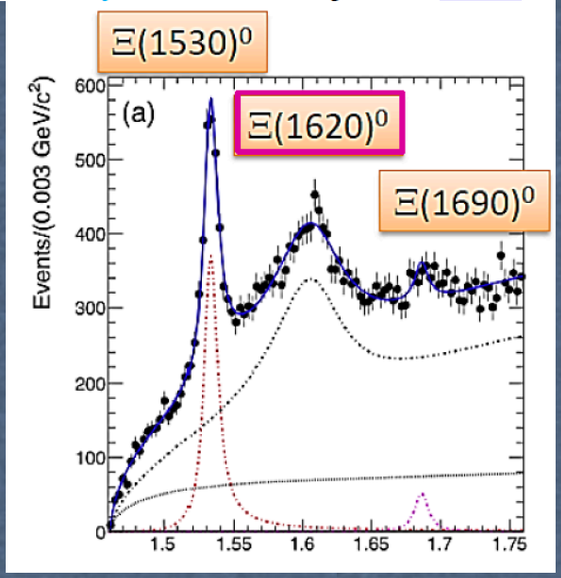


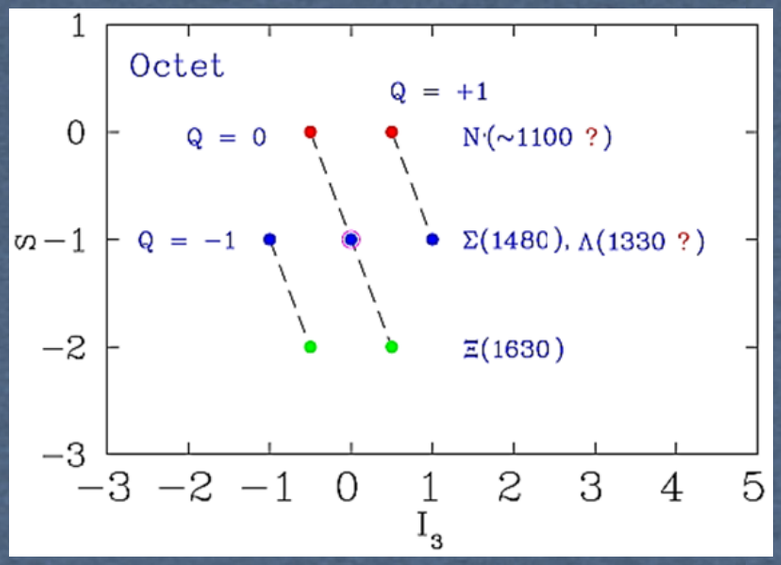
L. Guo *et al*, Phys Rev C **76**, 025208 (2007)

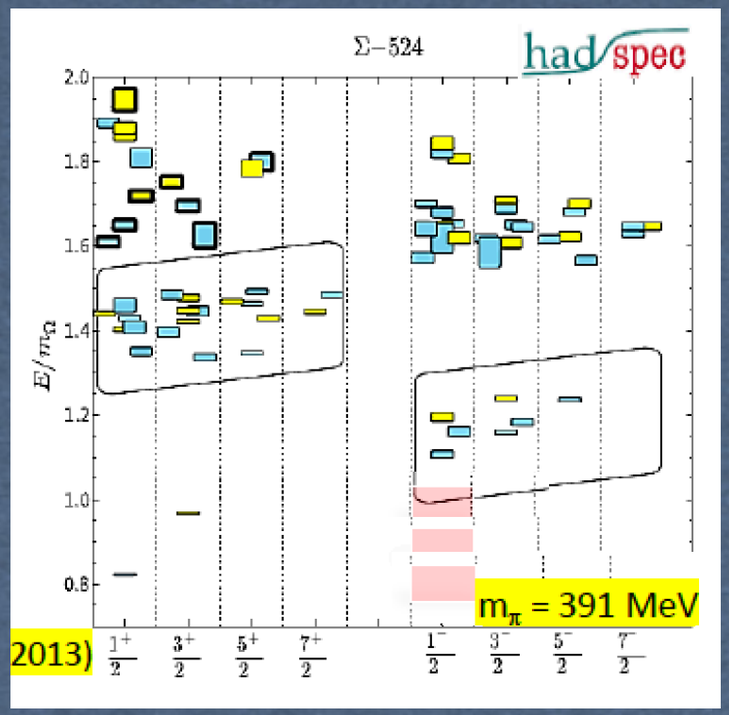


J.T. Goetz *et al*, Phys Rev C **98**, 062201 (2018)

$\Xi(1620)$ via $\Xi_c^+ \to \Xi^-\pi^+\pi^+$ from BELLE



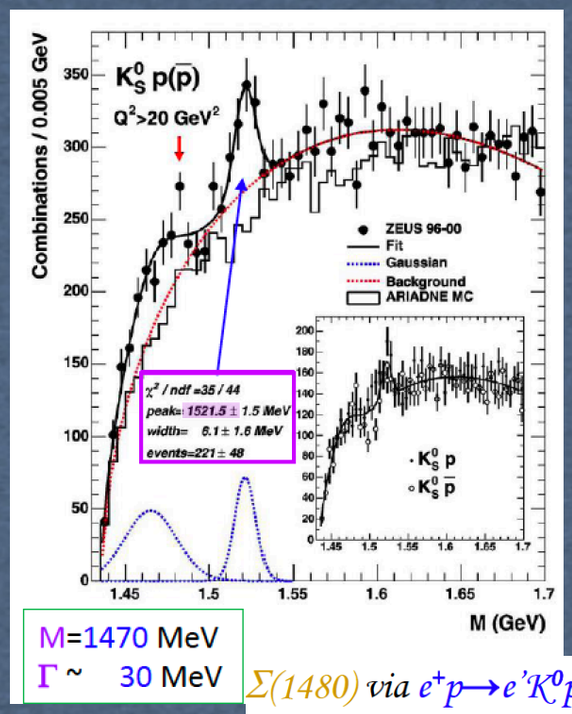




N' below Pion Threshold for (Quasi) Bound States of πN

- We find no evidence for elastic πN resonances in region between πN thr & 1300 MeV having width Γ > 50 keV.
- Present πN data cannot exclude even purely elastic (or inelastic) narrow resonances with Γ < 50 keV.

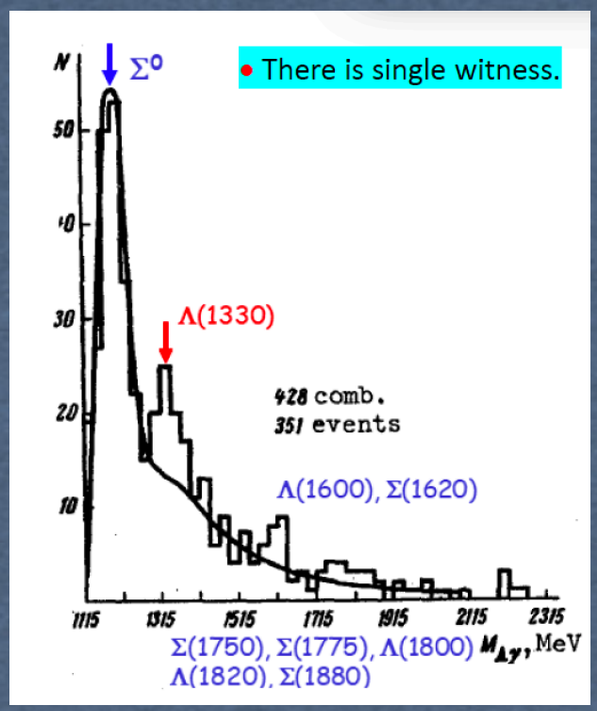
Σ(1480)1(?²) ☆



M=1470 MeV
Γ ~ 30 MeV

Σ(1480) via $e^+p \to e'K^0pX$ from ZEUS

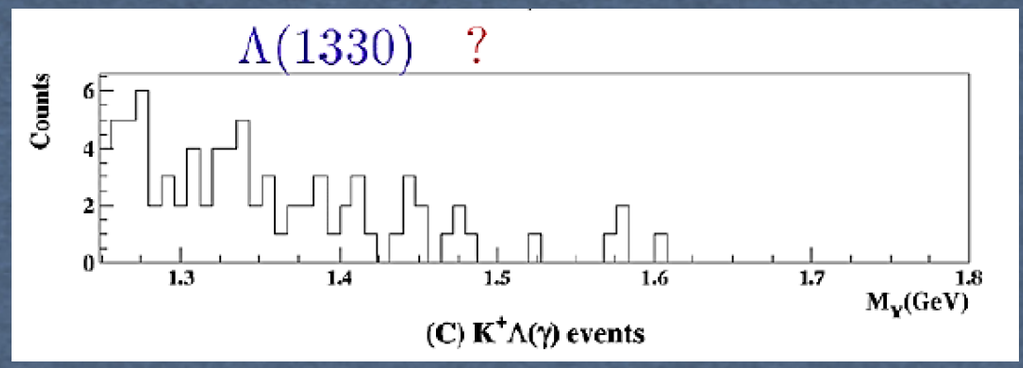
Λ(1330) via $\pi^- p \to \Lambda\gamma X^0$ from



- There is single witness.

Λ(1330) via $\gamma p \to K^+\Lambda X^0$ from clas

S. Taylor, Ph.D. Thesis, Rice U, May 2000

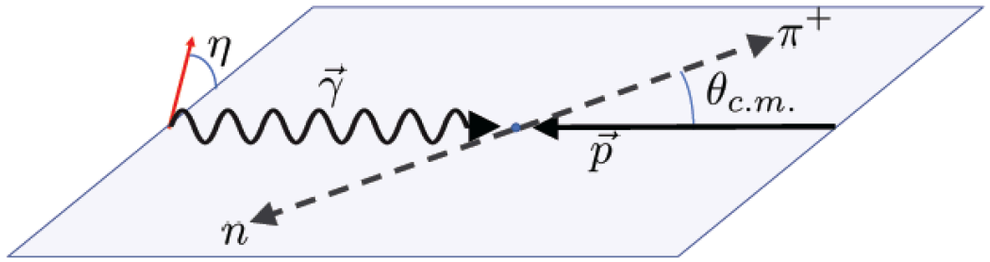


Determination of G for $\gamma p \to \pi^+ n$ from g9

Nicholas Zachariou

- Longitudinally polarized proton target
- Linearly polarized photon beam

$$\frac{d\sigma}{d\Omega} = \left(\frac{d\sigma}{d\Omega}\right)_0 (1 + P_\gamma \Sigma \cos(2\eta) + P_\gamma P_z \mathbb{G} \sin(2\eta))$$



Run Period: g9a Target: Frozen-spin butanol CLAS Torus Field: +1918.6 A		
E_e (GeV)	Nominal coh. edges (GeV)	Run range
2.751	0.70 1.10 1.30 1.50 1.70	55854 - 55938
3.539	0.73 0.93 1.10	55678 - 55844
4.599	1.90 2.10 2.30	55945 - 56152

- Maximum Likelihood method
  - For a given event the likelihood is given by:

$$L_i = c_i \left[1 + P_{\gamma,i} \Sigma \cos(2\eta_i) + P_{\gamma,i} P_{z,i} G \sin(2\eta_i)\right] A$$

c_i : normalization coefficient

Assumption: Acceptance is largely independent of η (φ)

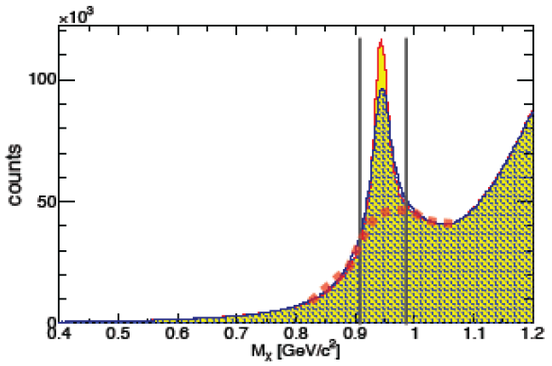
$$\log L = b + \sum_i \log\left[1 + P_{\gamma,i} \Sigma \cos(2\eta_i) + P_{\gamma,i} P_{z,i} G \sin(2\eta_i)\right]$$

$$\eta^{Para} = \phi_{lab} + \phi_0 \qquad \text{Para:} \quad \mathcal{P}_{\gamma,i} = P_{\gamma,i}$$

$$\eta^{Perp} = \phi_{lab} - 90° + \phi_0 \qquad \text{Perp:} \quad \mathcal{P}_{\gamma,i} = -P_{\gamma,i}$$

$$\log L = \sum_i \log\left[1 + \mathcal{P}_{\gamma,i} \Sigma \cos(2\phi_i + 2\phi_0) + \mathcal{P}_{\gamma,i} P_{z,i} G \sin(2\phi_i + 2\phi_0)\right]$$

Contributions from bound protons



$$D_F = 1 - \frac{N_{0,bnd}}{N_{0,T}}$$

$$\mathbb{G}_{sig} = \frac{\mathbb{G}_T}{D_F}$$

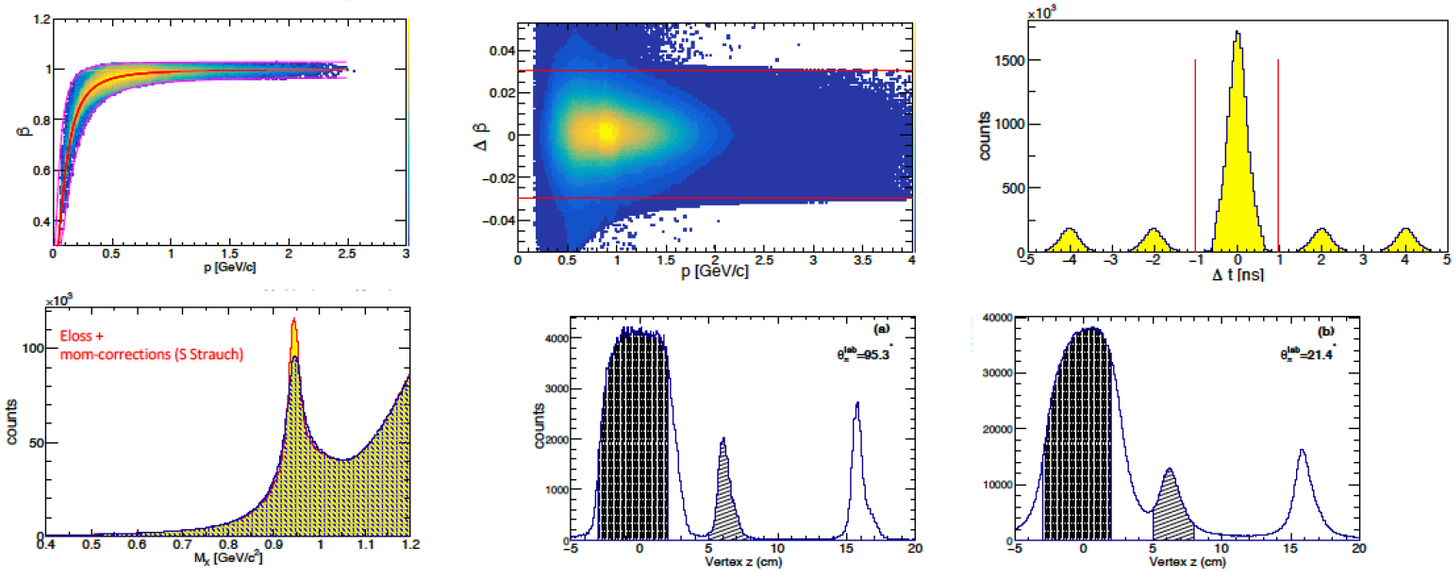
$$\Sigma_{sig} = \frac{\Sigma_T - (1 - D_F)\Sigma_{bnd}}{D_F}$$

Reaction Reconstruction

Skim: Single positively charged-track events (no requirements on neutrals) with a wide beta vs p cut

PID: Δβ (momentum independent) cuts, assuming pion mass

Photon Selection: Δt – coincidence time (pion-photon) at event vertex



Reaction Reconstruction: γp → π⁺ X

Reaction Vertex

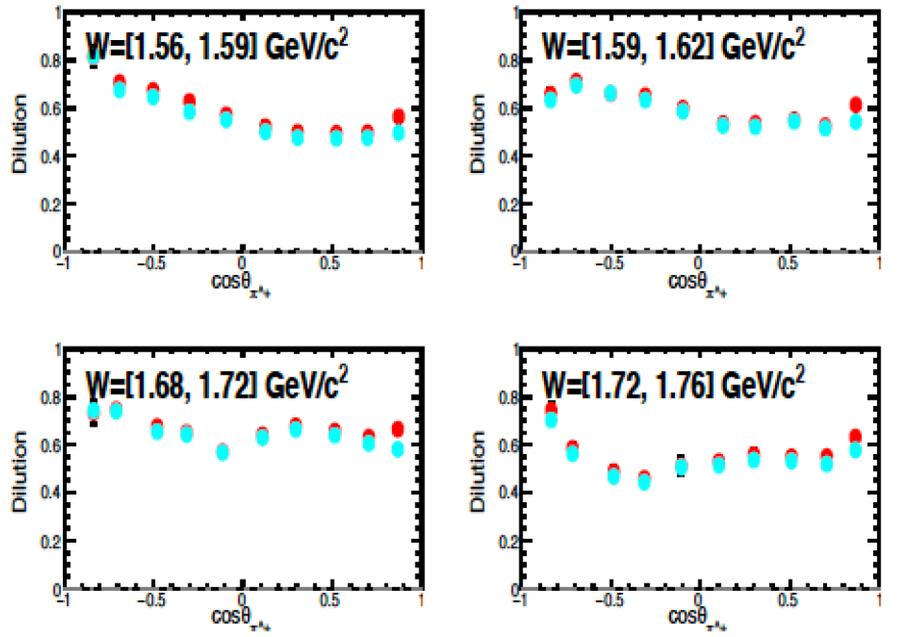
Systematic Studies

Source	σ^{sys}
Maximum Likelihood	negligible
Pion PID	0.0046
Reaction reconstruction	0.0120
ϕ_0 offset	0.0076
Vertex cuts	0.0088
Fiducial cuts	0.0018
Dilution factor (1)	0.0033
Total Absolute Systematic	**0.018**
Photon polarization	6%
Target polarization	6%
Dilution factor (2)	Varies ∼ 4%

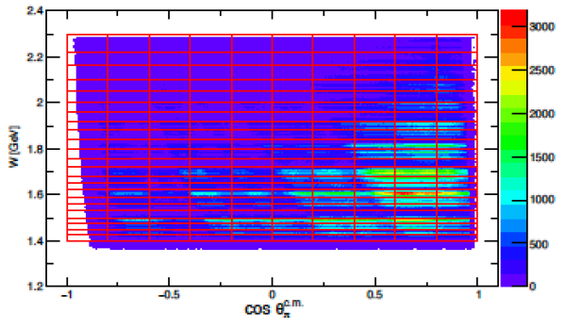
$$D_F = 1 - \frac{N_{0,bnd}}{N_{0,T}}$$

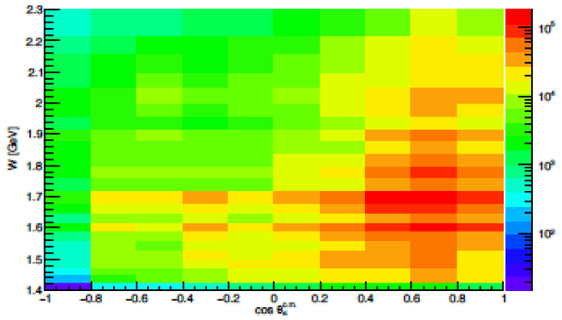
Constrained by Carbon & Butanol

Constrained by Carbon

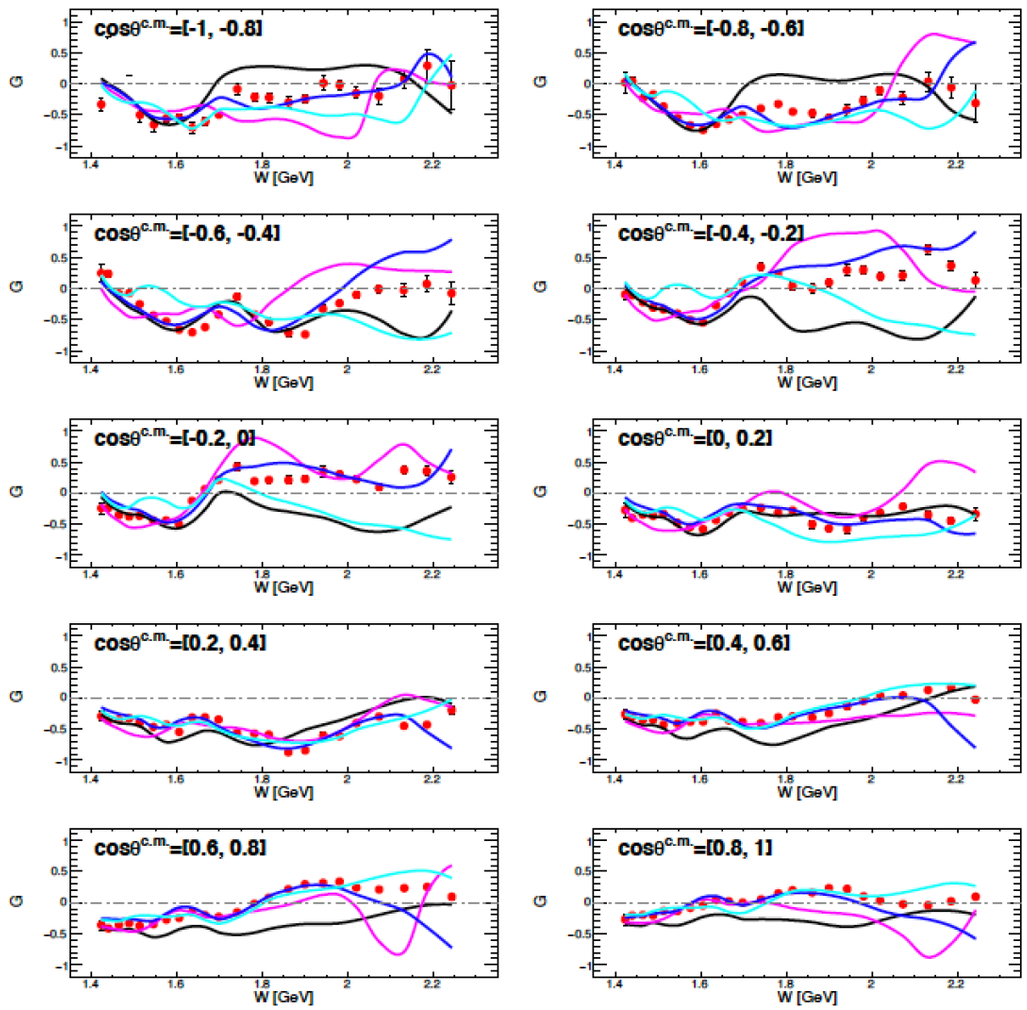


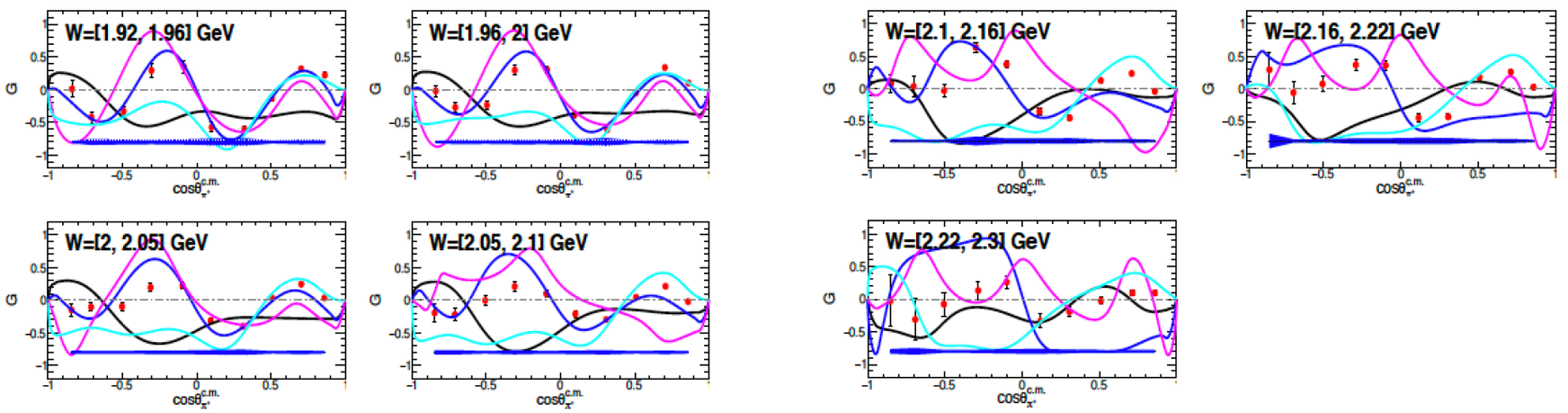
Results





Julich MAID SAID Bonn Gatchina





η cross section measurements with CLAS g12 data

Tianqi Hu

Background Subtraction

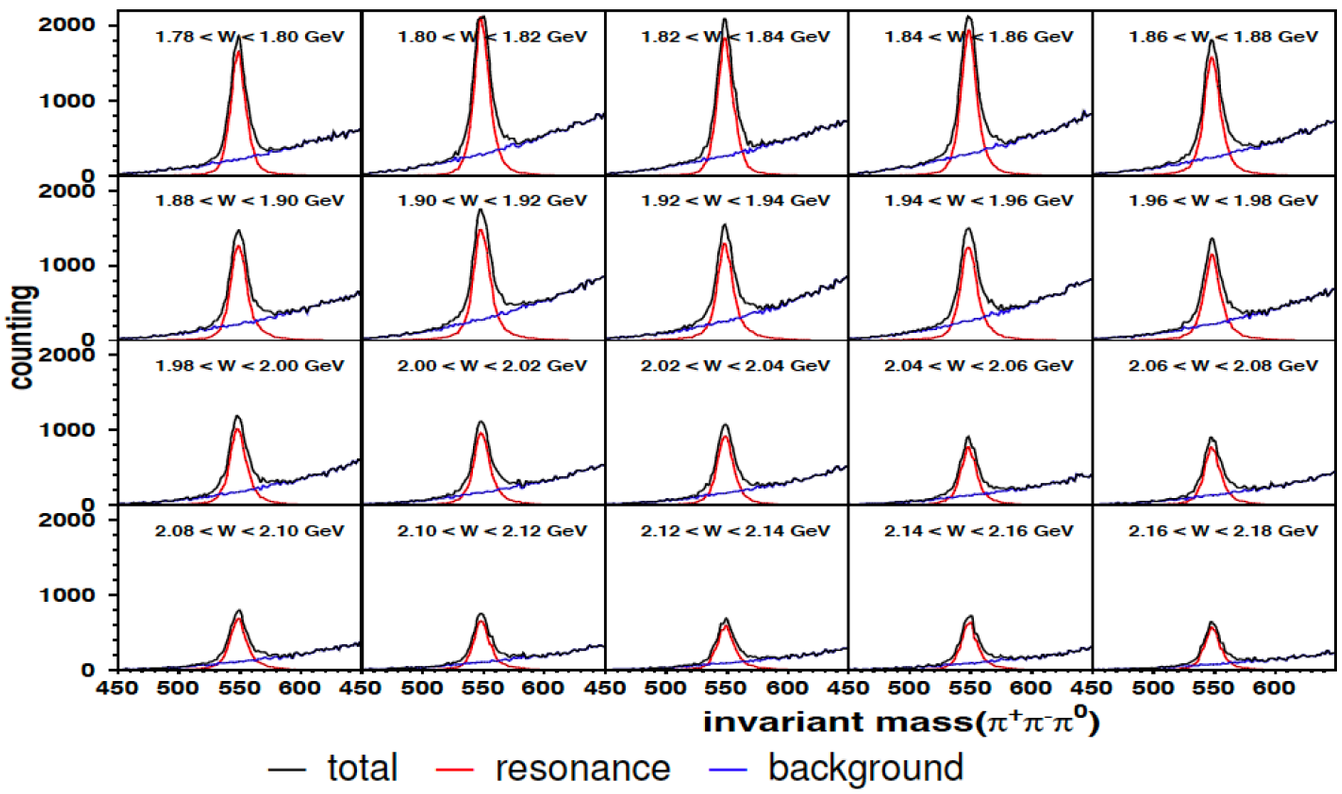
Background subtraction is done by using a probability-based method.

- Resonance tends to be kinematically close to resonance, so for background.
- The proportion of the resonance components among the nearest neighbors of one events give the Bayesian probability of this event to be the resonance.
- This Bayesian probability is called the Q-factor.

If we choose M different kinematic observables $O_k (k = 1, 2, 3, \cdots, M)$ that are normalized by their ranges, the kinematic distance squared between two events that are labeled by i and j can be defined as

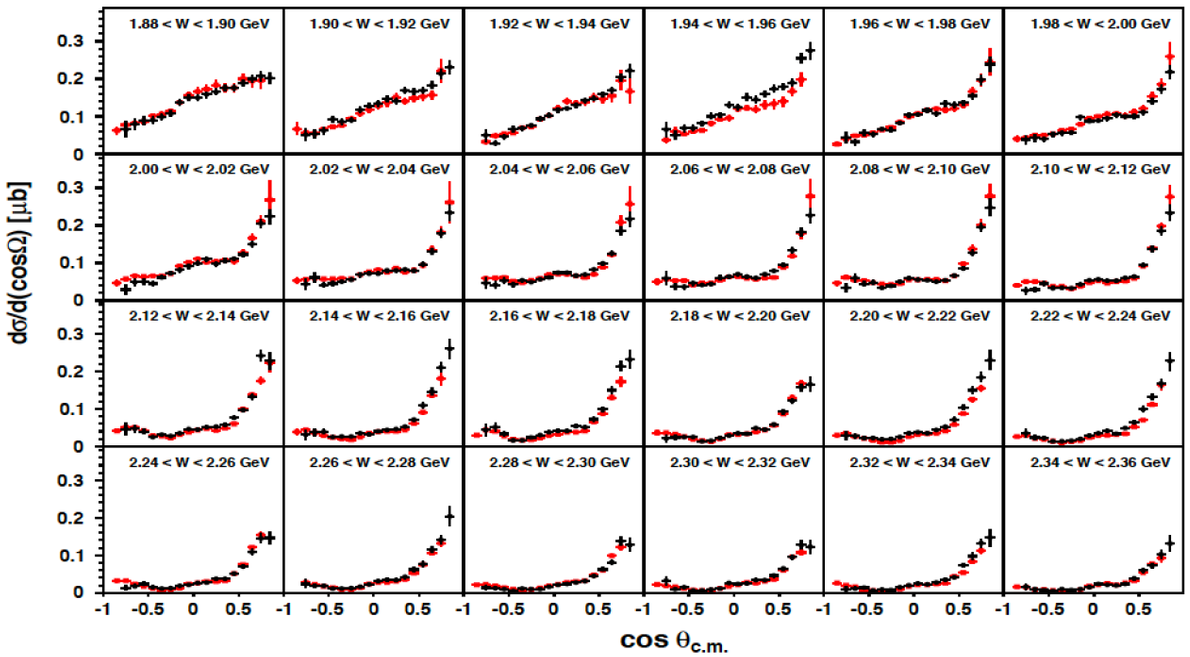
$$d_{ij}^2 = \sum_k (O_k^i - O_k^j)^2 \quad (1)$$

$\pi^+\pi^-\pi^0$ Invariant Mass Distributions

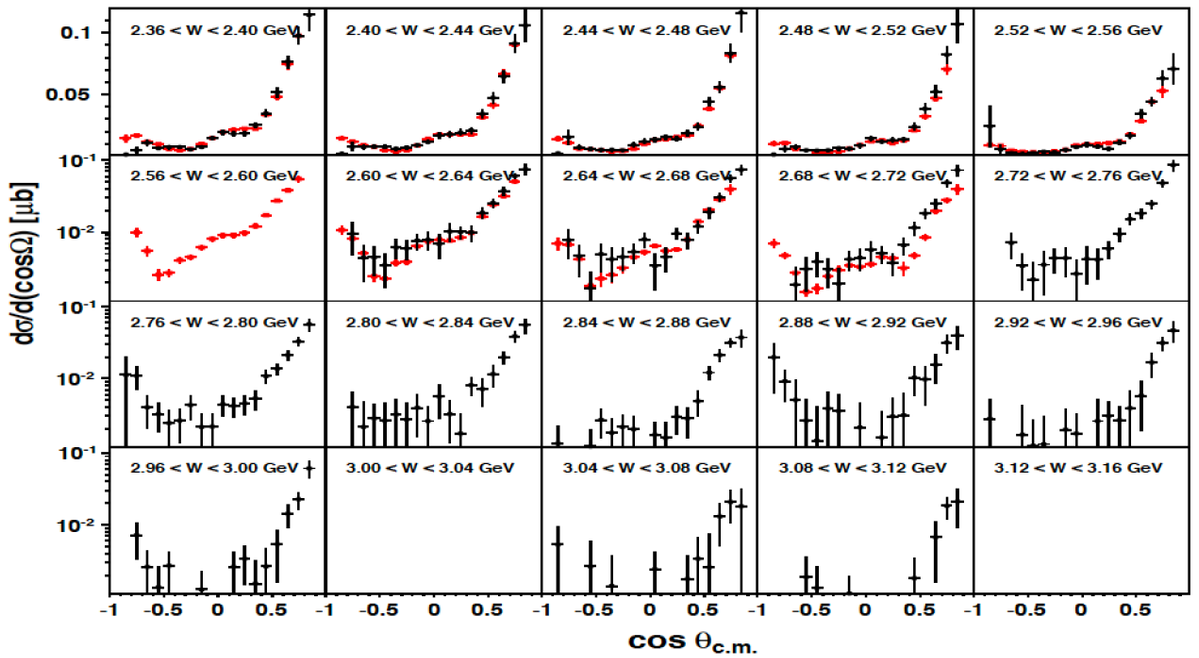


	data & Monte Carlo
confidence level cut	1%
$\Delta\beta$ cut	3σ
vertex cut	$-110 < z < -72$ cm
forward π^0 cut	$\cos\theta_{\pi^0}$<0.99
fiducial cut	yes
trigger cut	yes
trigger simulation	only for MC
bad paddle knock out	yes

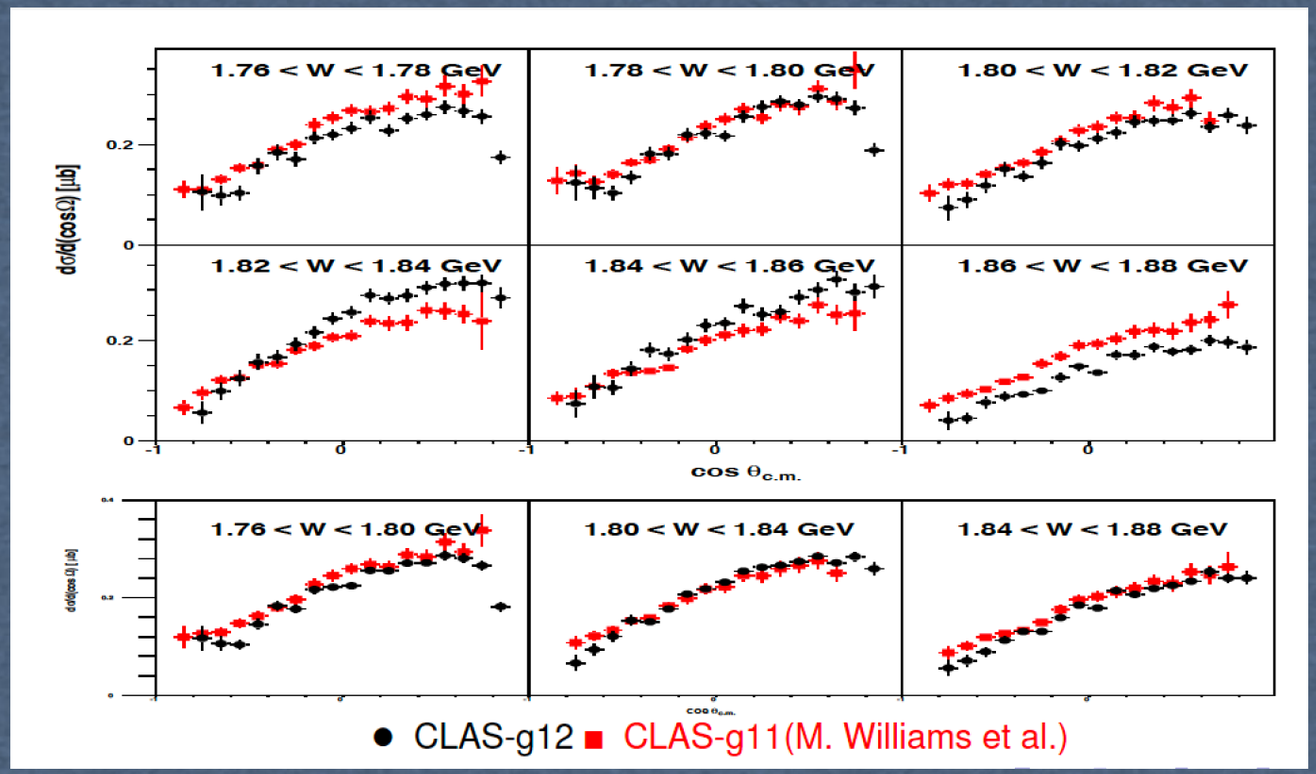
η Differential Cross Sections



● CLAS-g12 ■ CLAS-g11(M. Williams et al.)



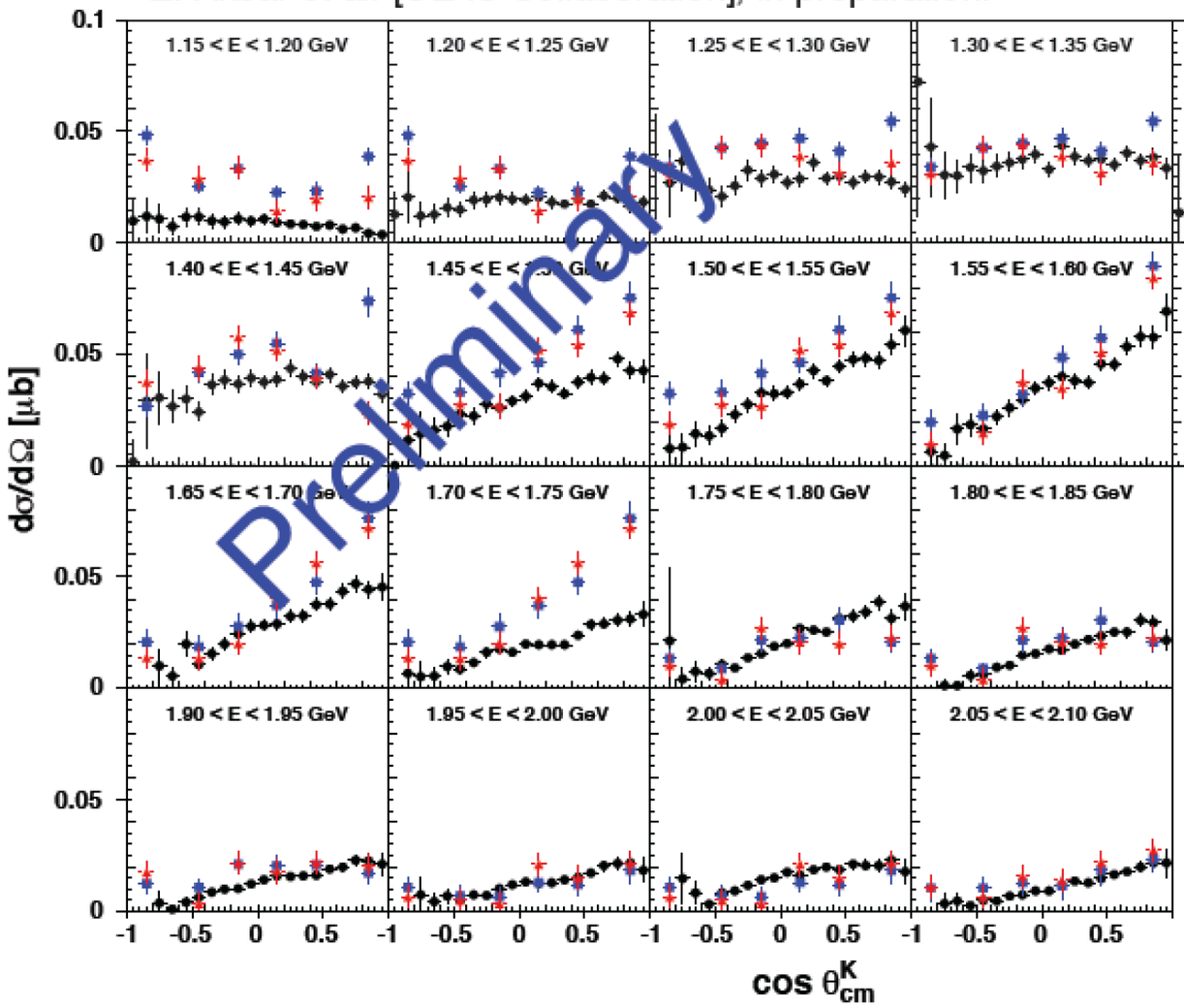
● CLAS-g12 ■ CLAS-g11(M. Williams et al.)



● CLAS-g12 ■ CLAS-g11(M. Williams et al.)

$\gamma p \to K^0\Sigma^+$ Cross Section

Z. Akbar *et al.* [CLAS Collaboration], in preparation.

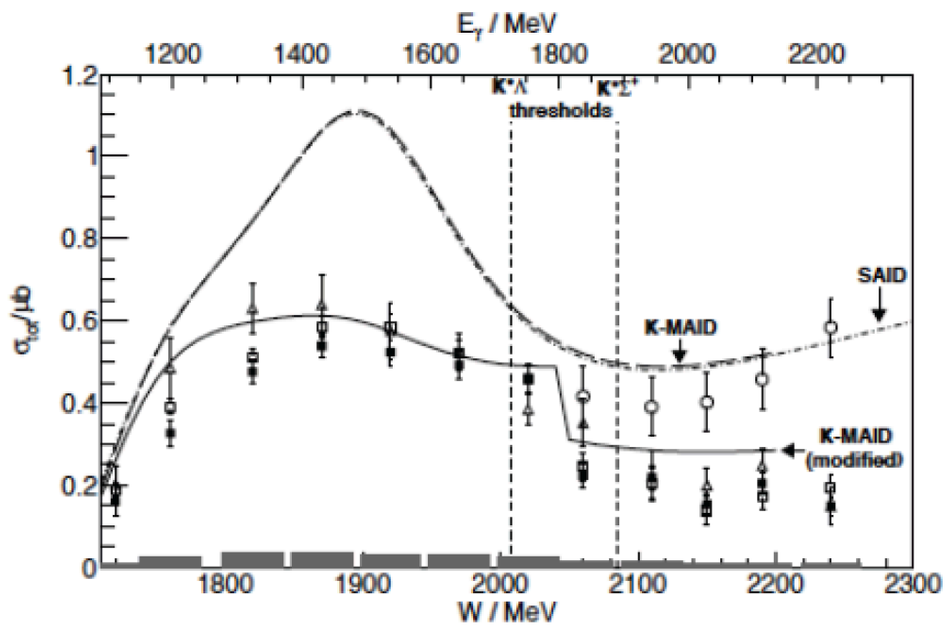


CLAS-g12 • CB-ELSA • CBELSA/TAPS •

New cross section results in 50-MeV-wide E_γ bins for

$1.15 < E_\gamma < 3.0$ GeV

Phys. Lett. B **713**, 180 (2012)



➜ In preparation for $K^0\,\Sigma^+$: $E, \Sigma, T, C_x, C_z, O_x, O_z$

Measurement of Polarization Observables for the Σ^+ Hyperon

Frank Gonzalez

- Photoproduction of neutral kaons offers advantage over charged ones since photons cannot couple directly to (vanishing) charge of the meson.
- Data on isospin related channels $K^0\Sigma^+$ and $K^+\Sigma^0$ allow for disentanglement of contributions from N^* and Δ^* resonances.
- Hyperon decay allows measurement of asymmetries, which allow for the extraction of hyperon recoil polarization P.
- Trade-off however is low cross-sections, leading to less statistics.
- The determination of the polarization observables allows for an understanding of the intermediate steps involved in the reaction.

Spin-Dependent Cross-Section for $K^0\Sigma^+$ Photoproduction

$$\rho_Y \frac{d\sigma}{d\Omega_{K^+}} = \left.\frac{d\sigma}{d\Omega_{K^+}}\right|_{\text{unpol}} \{1 + \sigma_y P + P_\odot(C_x\sigma_x + C_z\sigma_z)\}$$

$$\rho_Y = (1 + \vec{\sigma}\cdot\vec{P}_Y)$$

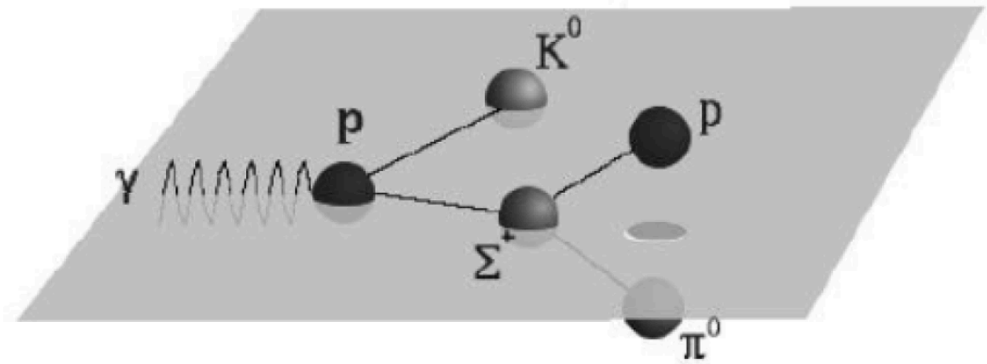
Polarization Components

$$P_{\Sigma_x^+} = P_\odot C_x$$

$$P_{\Sigma_y^+} = P$$

$$P_{\Sigma_z^+} = P_\odot C_z$$

- Transverse (induced) polarization $P_{\Sigma_y^+}$ is equivalent to P observable.
- The $\hat{x}$ and $\hat{z}$ components of hyperon polarization are proportional to C_x, C_z via degree of beam polarization $P_\odot$.



g12 experiment specs

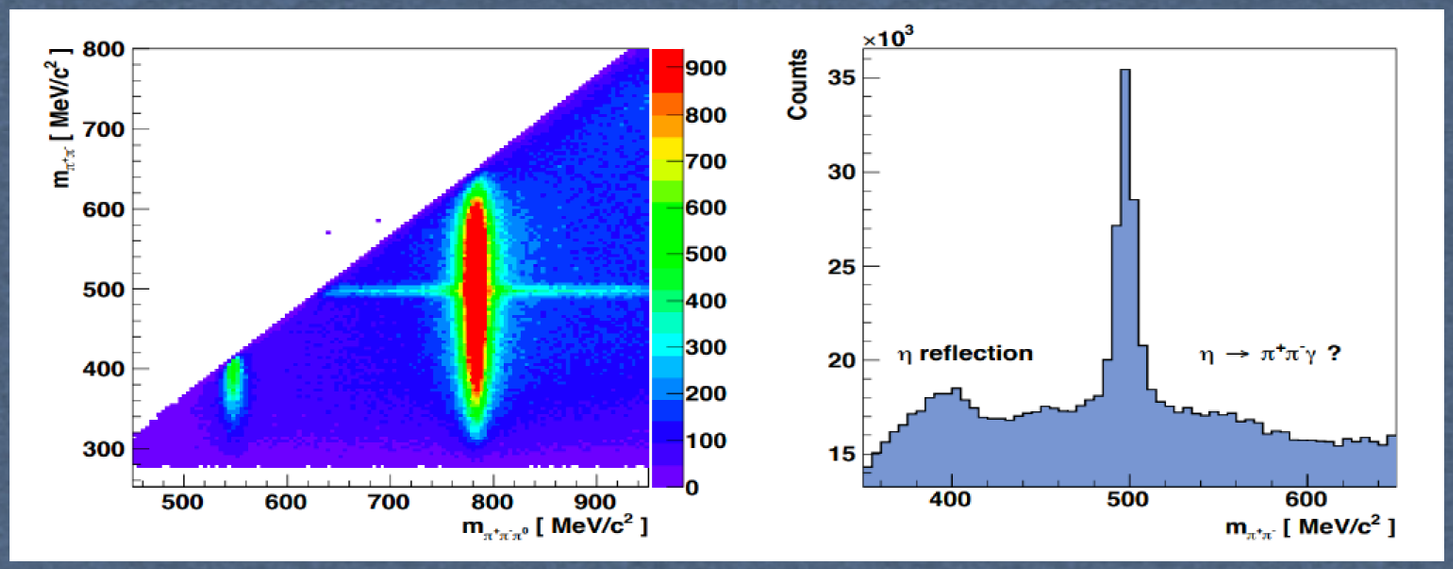
Photon polarization: Circular.
Target Material: Liquid hydrogen.
Target position: 90 cm from CLAS detector center.
Energy range: $1.1 - 5.4$ GeV.

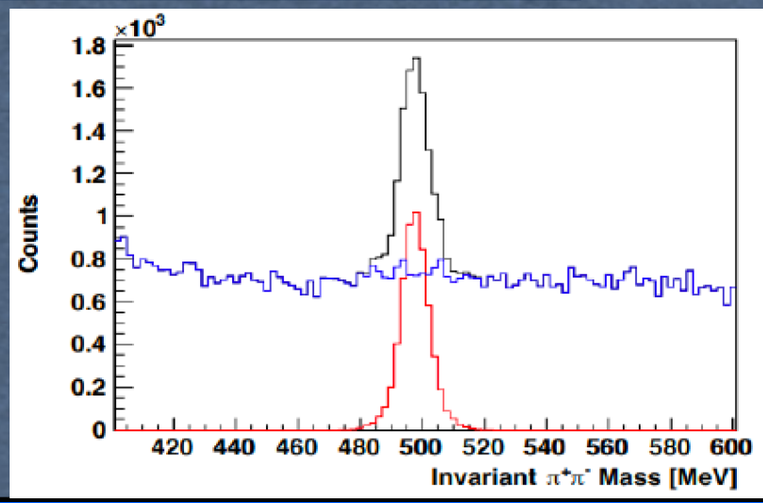
$\gamma p \rightarrow K^0\Sigma^+$

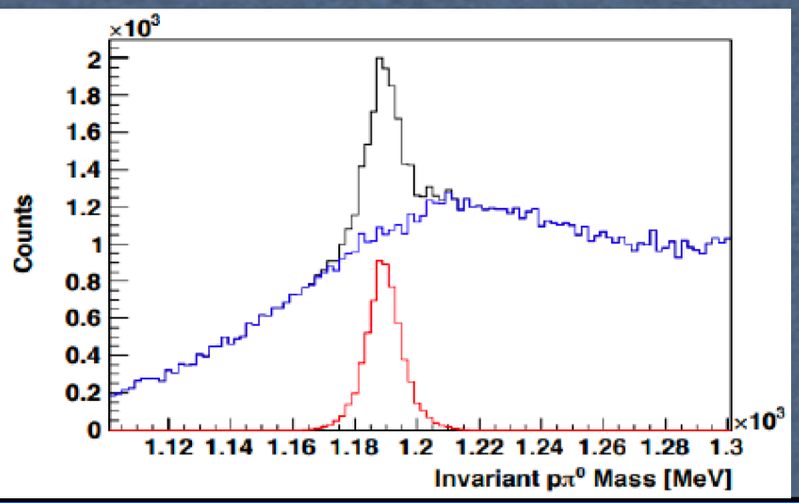
$K^0 \rightarrow \pi^+\pi^-$ and $\Sigma^+ \rightarrow p\pi^0$

g12 Data Cuts

- **Vertex Cut:** -110.0 cm $<$ z-vertex $<$ -70.0 cm.
- **Timing Cut:** $|\Delta_{\mathrm{TBID}}| < 1$ ns.
- **Particle ID Cut:** $\Delta\beta = |\beta_c - \beta_m| \leq 3\sigma$.
- **Fiducial Cut:** nominal scenario.

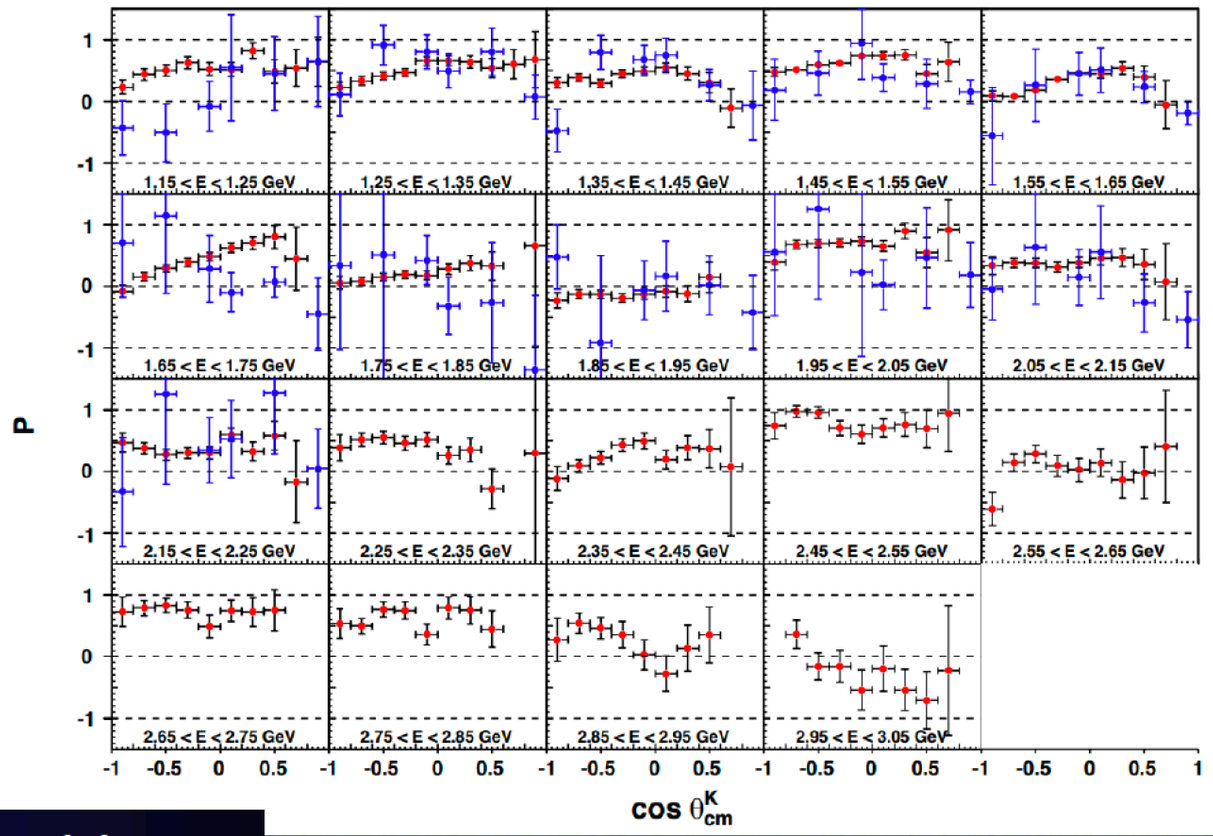






- The measurement of the Σ^+ induced recoil polarization P was thus based on the asymmetry between the proton count rate above and below the reaction plane in the Σ^+ rest-frame.
- P observable does not require beam's polarization data; P can be seen as the "C_y" observable.

Extracting the P Observable, Histograms



Extraction Methods for the C_x & C_z Observables

- Double polarization observables C_x and C_z have not been extracted for $\gamma p \to K^0\Sigma^+$ reaction.

- Three strategies exist in order to extract double polarization observables:
  - **One-dimensional fit:** Individually yields C_x or C_z.
  - **Two-dimensional fit:** Simultaneously yields C_x and C_z.
  - **Maximum-likelihood fit:** Simultaneous extraction of all observables P, C_x and C_z.