Beam Asymmetry Measurements from g8b for $\gamma p \rightarrow p \pi^+ \pi^-$

Charles Hanretty (Advisor: Dr. Volker Credé)
Florida State University
On behalf of the CLAS Collaboration
Funding provided by DOE
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Tallahassee, FL

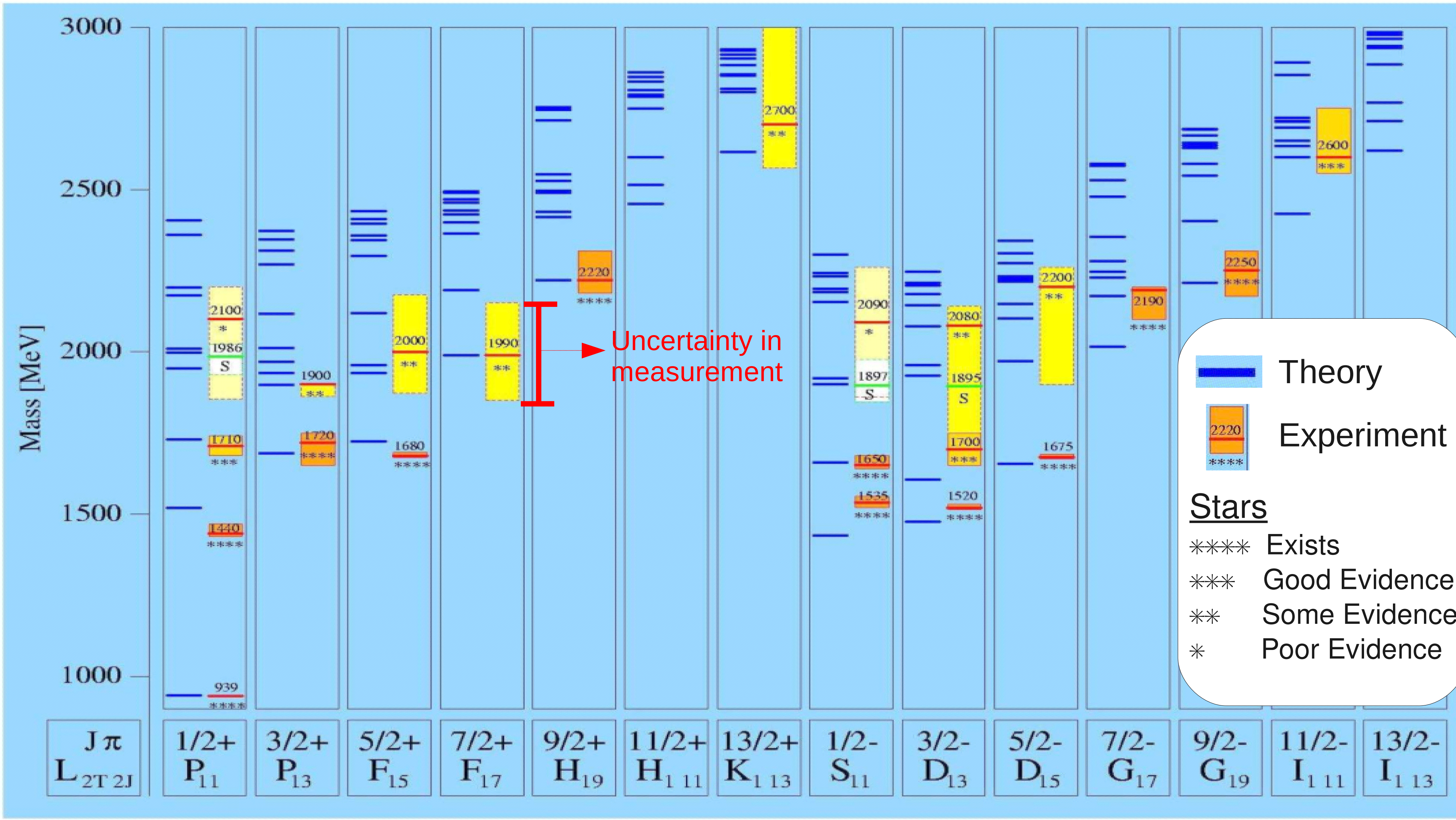
Outline

- Introduction:
  - Problems in Hadron Spectroscopy
- Experimental Facility
- Analysis
  - Final State Equations
  - Coordinate system
  - Preliminary Results from g8b (first measurements of I^s and I^c for $\gamma p \rightarrow p\, \pi^+\pi^-$)

Constituent Quark Model

U. Loring

N* Resonances (Isospin = 1/2 states)



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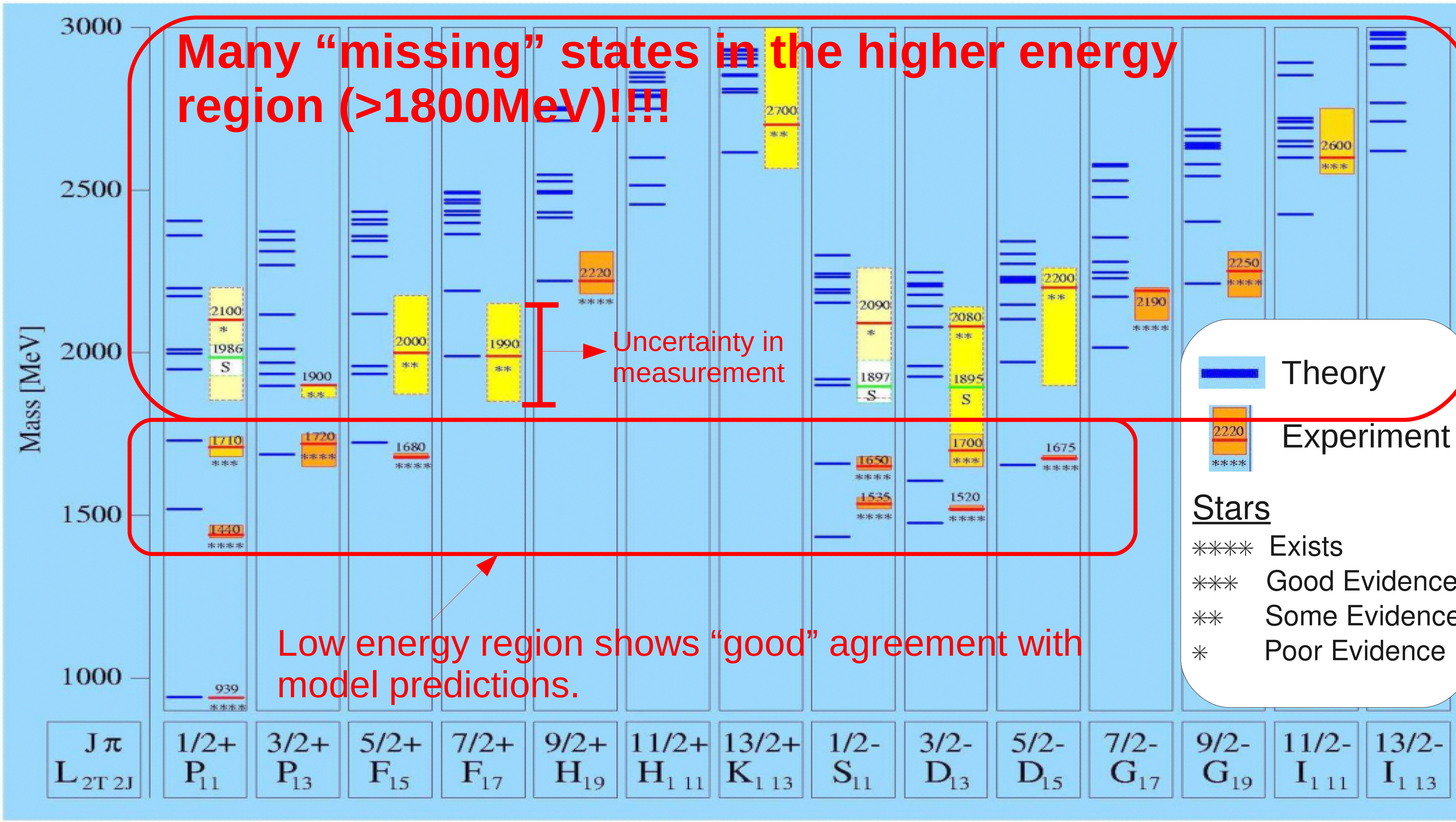
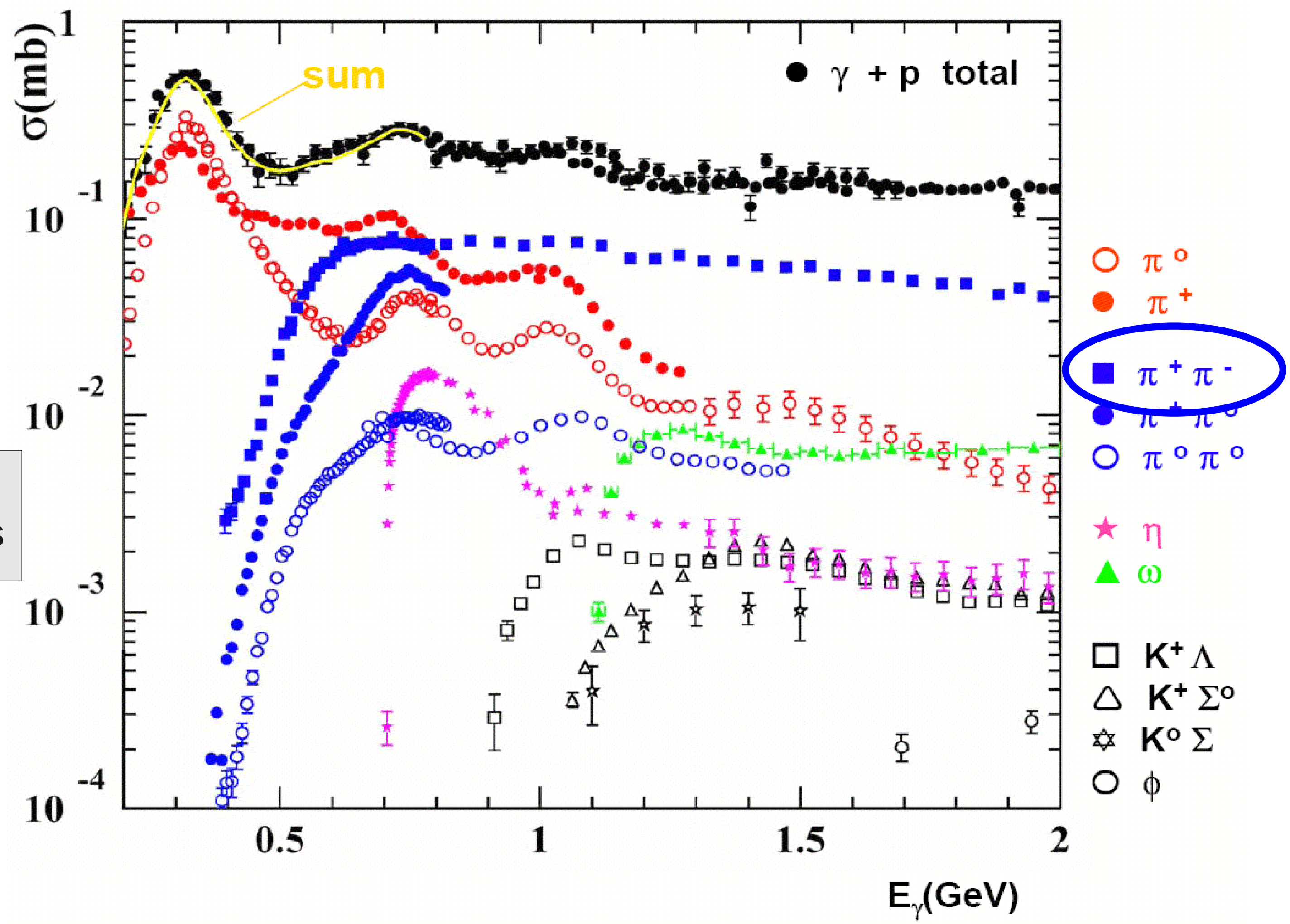


Why the lack of evidence? What can we do?

- Most of the existing data regarding N* resonances involves πN elastic scattering.
  - Photoproduction (γp) is predicted to be a promising method for producing these states.
- Existing polarized photoproduction data mainly covers a mass range up to about 1800 MeV with analyses involving a single meson.
  - Go higher in energy; analyze a channel with two or more mesons as it accounts for most of the cross section for $W \geq 2$ GeV
- Analysis of unpolarized data leads to ambiguous results.
  - The inclusion of polarization avoids such ambiguities.

γ+p Cross Section



Experimental Cross Sections

- $\pi^+\pi^-$ cross section is large but devoid of structure. → resonances are broad and overlapping.
- Cannot go "peak hunting".
- Constraints provided by polarization are needed to disentangle and isolate resonance contributions.

The Facility: Jefferson Lab in Newport News, VA

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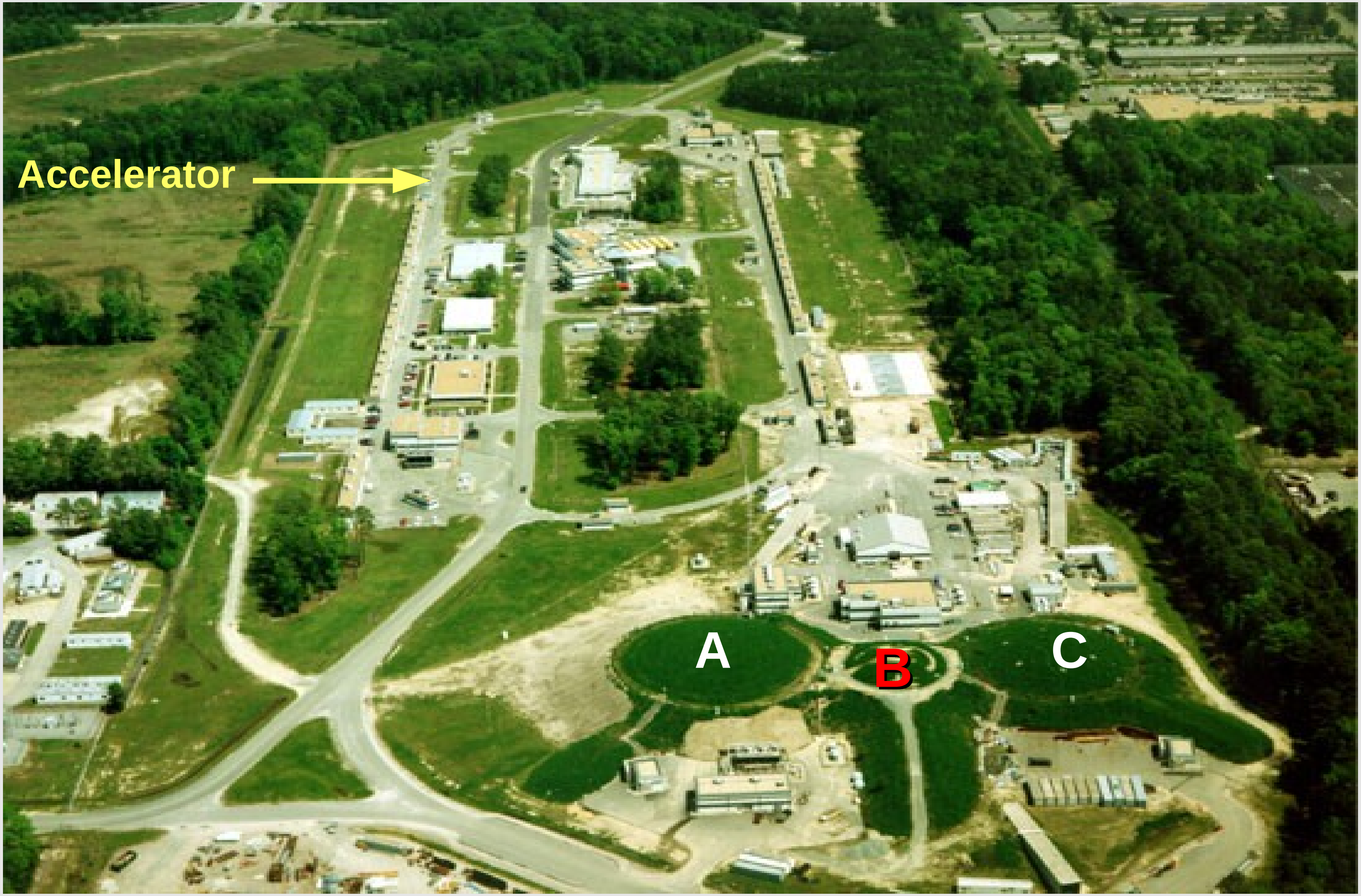
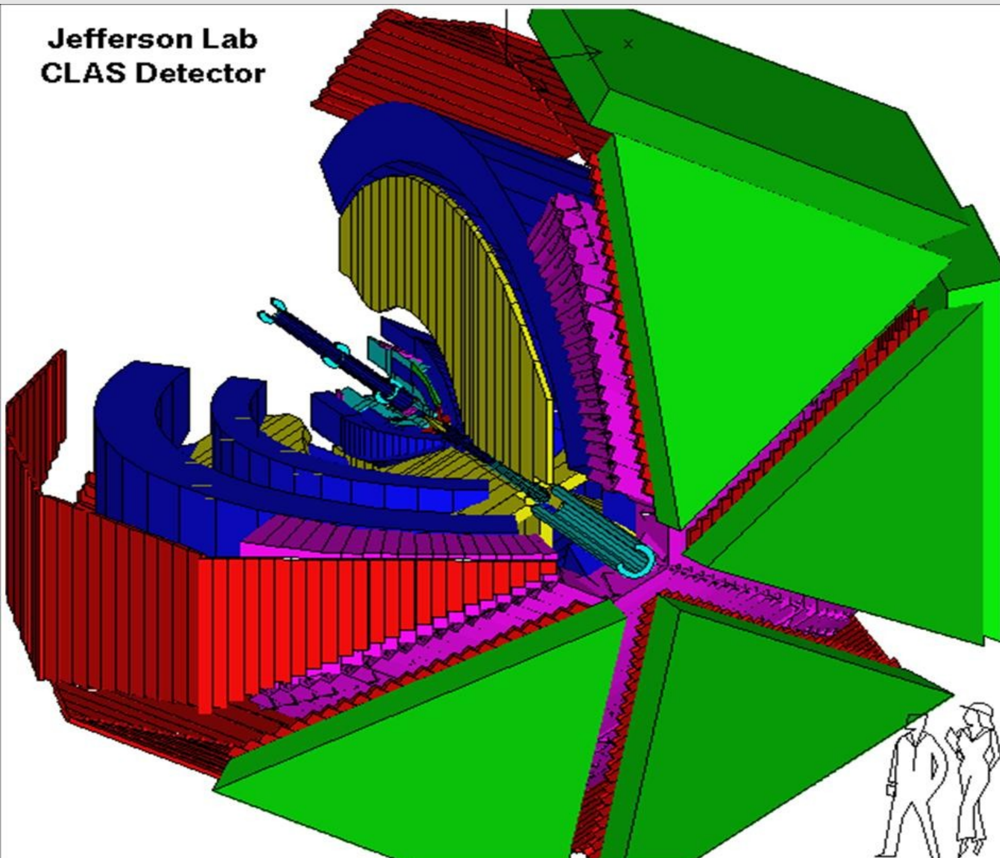
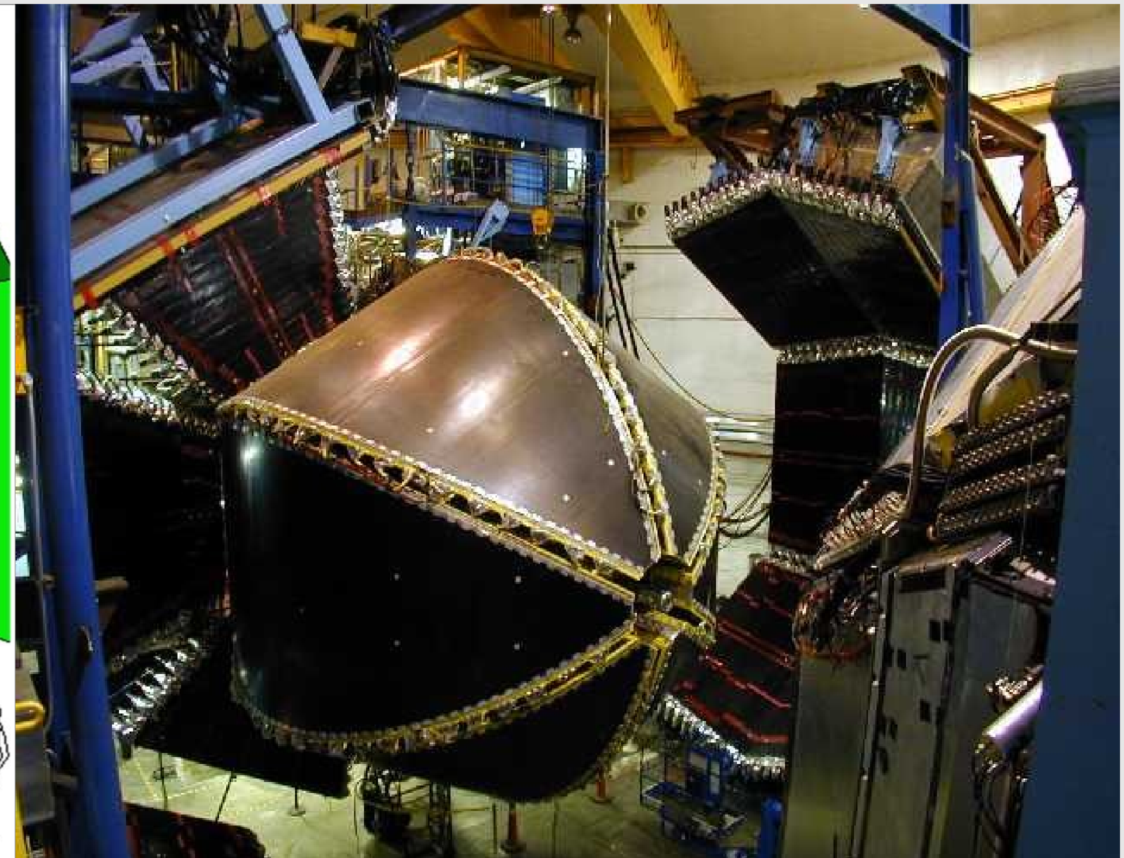


The Hall B Detector : CLAS

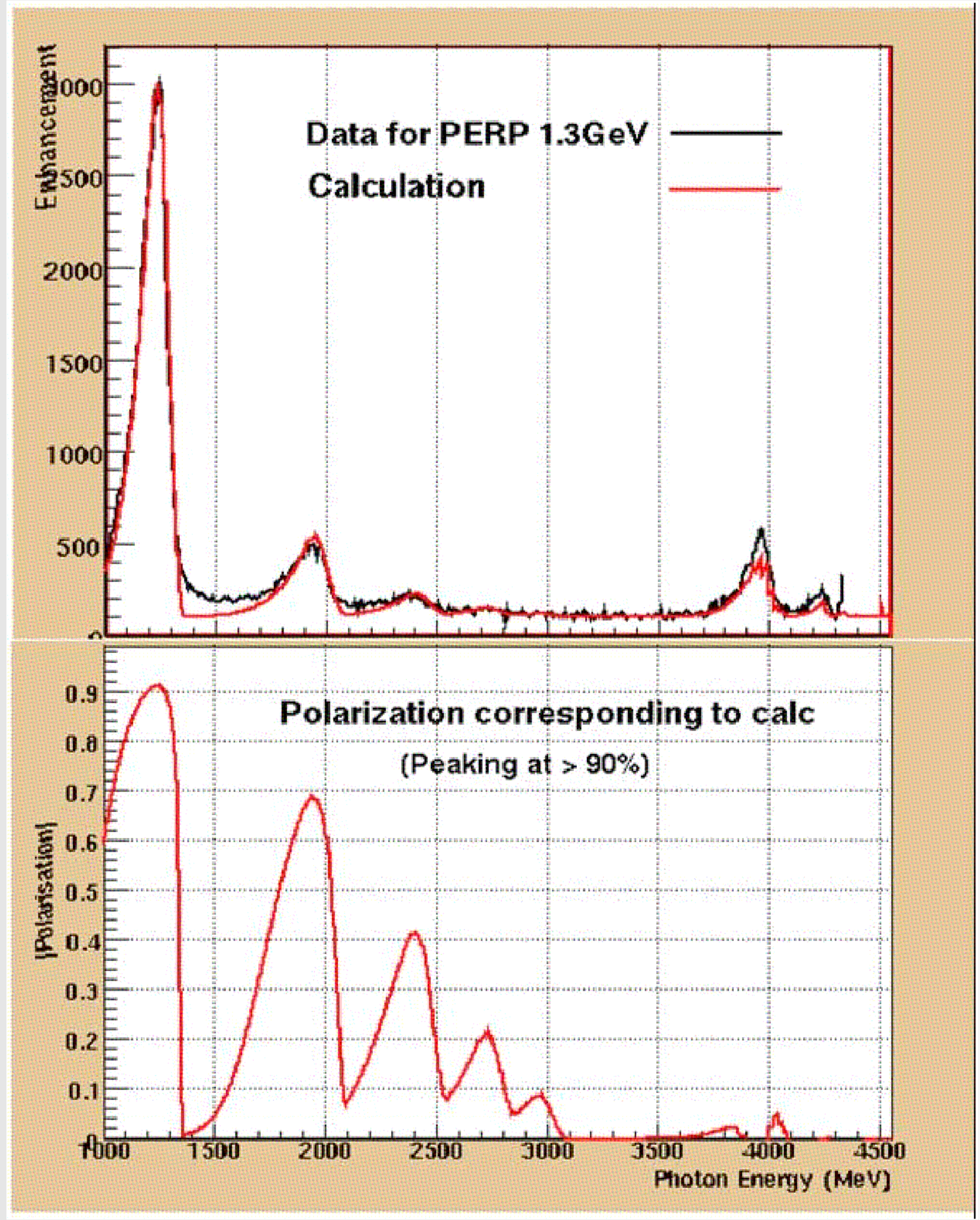




- Yellow : Torus Magnet
- Blue : Drift Chambers
- Purple : Cerenkov Counters
- Red : Time of Flight Scintillators
- Green : Electromagnetic Calorimeters

Polarized and Tagged Photon Beam

- Hall B has the ability of producing a beam of tagged photons.
- Using coherent bremsstrahlung radiation, these tagged photons can also be polarized.
- linearly polarized photon beam = unpolarized electron beam + oriented diamond radiator
- Can obtain 90% polarization



Final State Equation

- To isolate resonance contributions we aim to measure polarization observables.

- The final state equation for two mesons in the final state has a total of 15 observables.

$$I = I_0 \{(1 + \Lambda_i \bullet \mathbf{P}) + \delta_{\odot}(\mathbf{I}^{\odot} + \Lambda_i \bullet \mathbf{P}^{\odot}) + \delta_l [\sin 2\beta(\mathbf{I}^{s} + \Lambda_i \bullet \mathbf{P}^{s}) + \cos 2\beta(\mathbf{I}^{c} + \Lambda_i \bullet \mathbf{P}^{c})]\}$$

I_0 = unpolarized reaction rate
Λ_i = degree of polarization of target
$\delta_{\odot, l}$ = degree of polarization of photon beam
$\mathbf{P}$ = observables arising from target polarization
$\mathbf{I}^{\odot, s, c}$ = observables arising from use of polarized photons
β = orientation of polarization w.r.t. a final state particle

- Through the use of experimental conditions/setup, we can reduce the number of observables making a measurement possible.

Experimental Setup : g8b

- The g8b experiment ran from July - Sep 1st, 2005.
- Produced polarized photons at 5 coherent edge energies: 1.3, 1.5, 1.7, 1.9, 2.1 GeV
- Used linearly polarized photons incident on an unpolarized LH_2 target.

$$I = I_0 \{(1 + \Lambda_i \cdot \mathbf{P}) + \delta_\odot(\mathbf{I}^\odot + \Lambda_i \cdot \mathbf{P}^\odot) + \delta_l [\sin 2\beta(\mathbf{I}^s + \Lambda_i \cdot \mathbf{P}^s) + \cos 2\beta(\mathbf{I}^c + \Lambda_i \cdot \mathbf{P}^c)]\}$$

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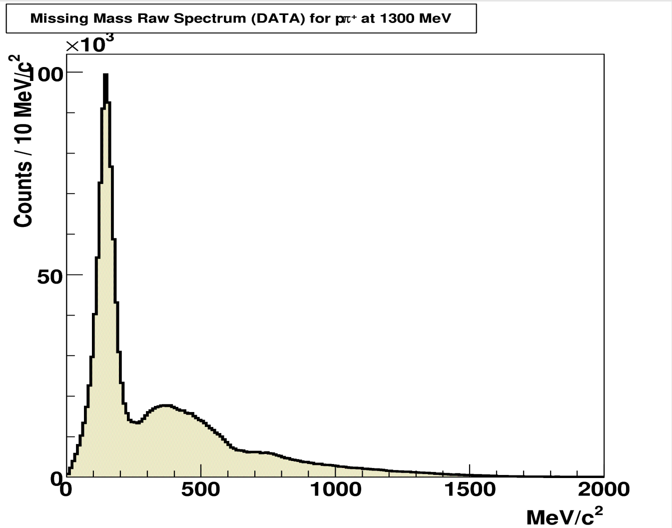
⇩

$$I = I_0 \{1 + \delta_l [\mathbf{I}^s \sin 2\beta + \mathbf{I}^c \cos 2\beta]\}$$

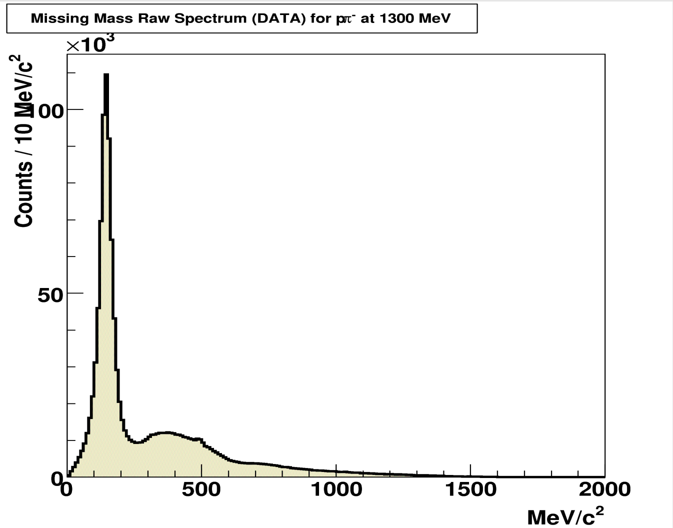
- I^c (also known as Σ in the single meson equation)
- I^s
- Measuring both for $\gamma p \rightarrow p\, \pi^+ \pi^-$

The g8b Data Set

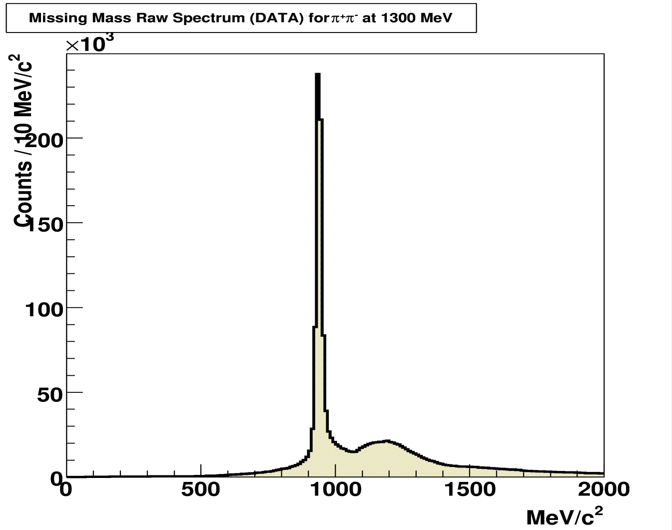
- $\gamma p \rightarrow p\, \pi^+ \pi^-$ from the g8b data set
- Kinematically fitting four topologies:



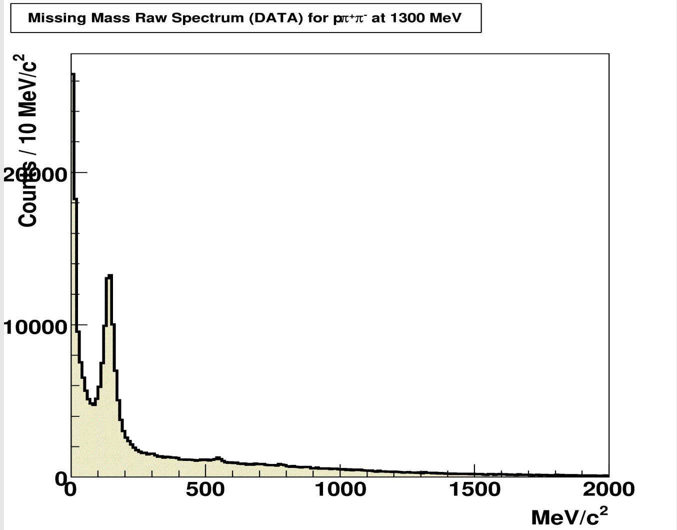
$p\, \pi^+ (\pi^-)$



$p\, \pi^- (\pi^+)$



$\pi^+ \pi^- (p)$



$p\, \pi^+ \pi^- (\ )$

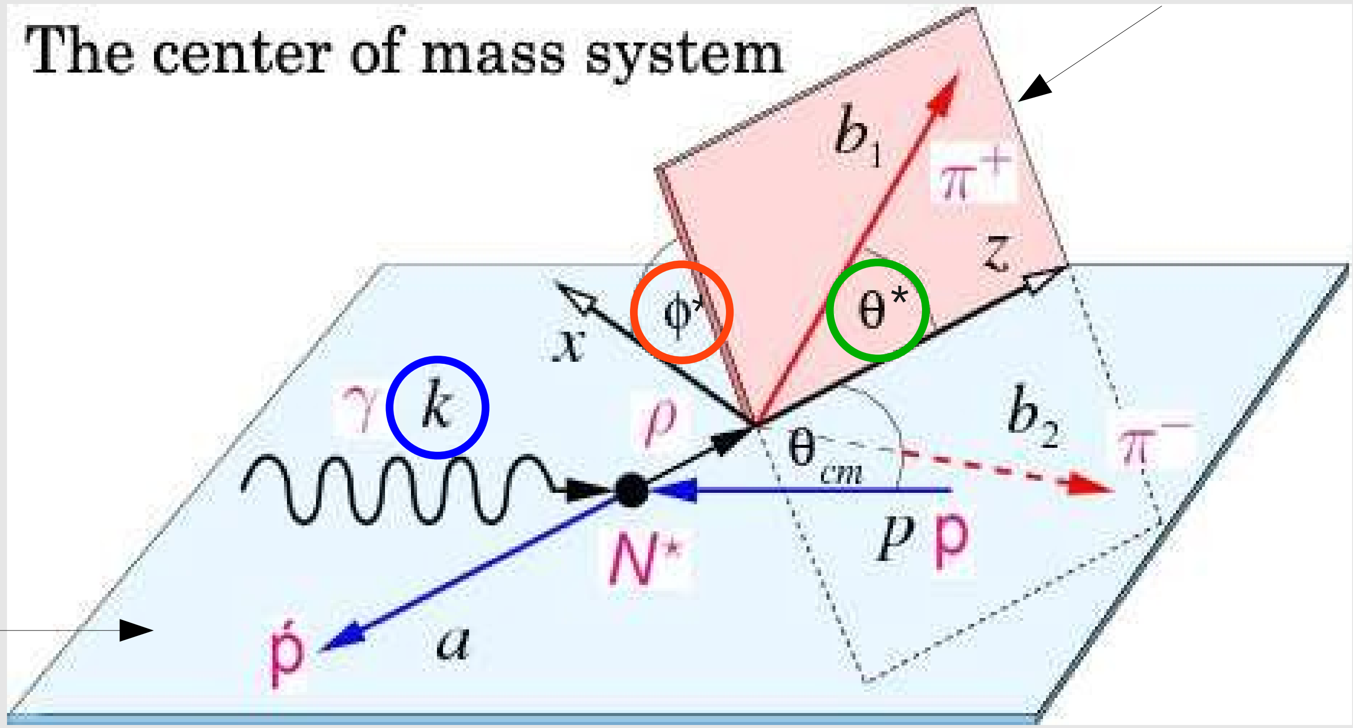
Correcting the g8b data set

- Momentum corrections were determined using the pulls generated from fitting to a p $\pi^{+}\pi^{-}$() final state.
- The errors applied to the covariance matrix (used for kin fitting) were determined by starting with the g11a errors. Errors were altered to obtain pull widths of one.
- A study into the sag of the tagger E-counters produced an energy dependent photon correction.
- Momentum corrections were refined after the application of the photon corrections.
- Covariance matrix errors were also refined/finalized.

CM Coordinate System for $\gamma p \rightarrow p\,\pi^+\pi^-$

- Analysis of the $\gamma p \rightarrow p\,\pi^+\pi^-$ channel requires the employ of 5 independent variables, for example : $\cos\theta_{cm}$, m, k, ϕ^*, θ^*
- $\gamma p \rightarrow N^* \rightarrow N\rho \rightarrow p\,\pi^+\pi^-$

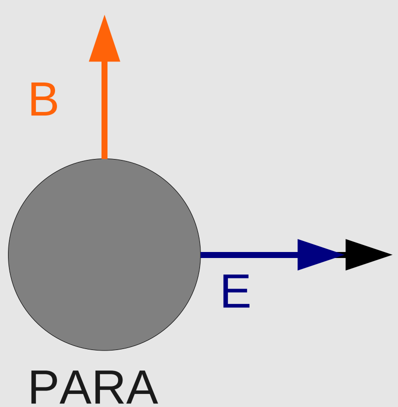
Event plane formed by 2 final state particles

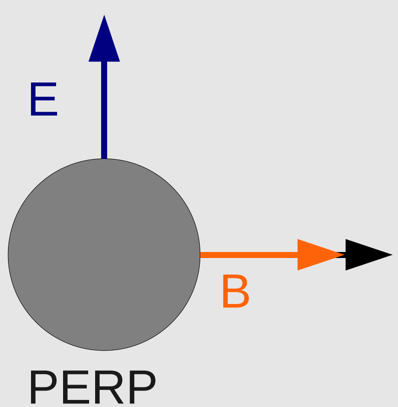


Production plane

Preliminary Results: Phi Distributions

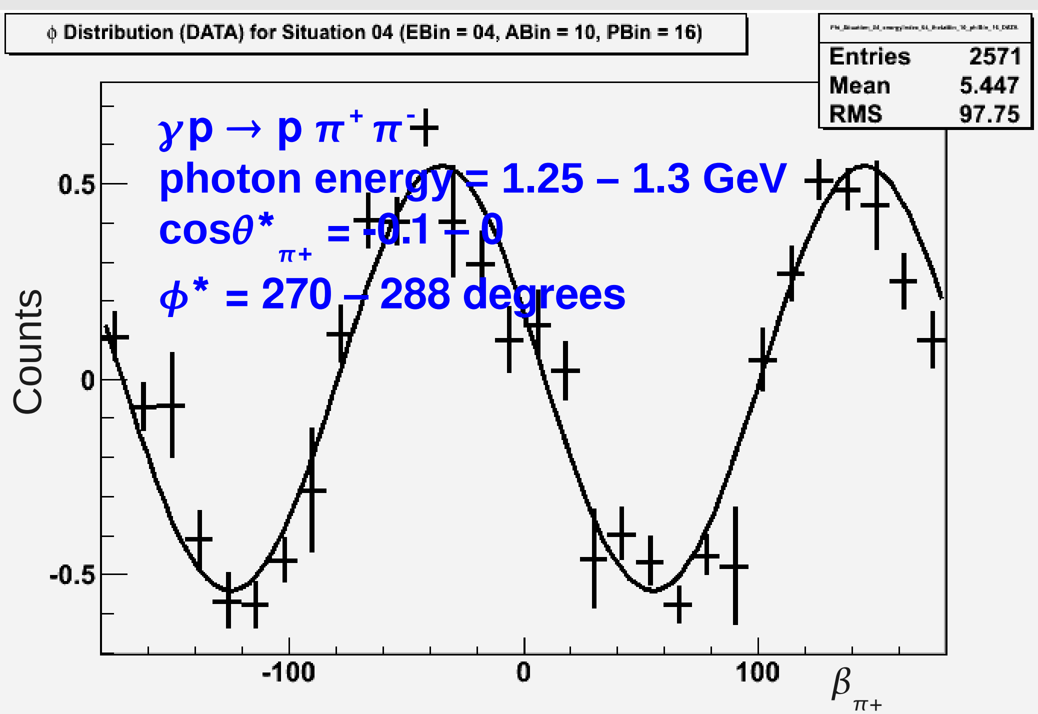
- Distribution of p $\pi^+\pi^-$ events is normally independent of the lab angle ϕ but the polarized photons break that symmetry.
- CLAS Language: Linear Polarization
  - PARA = E field parallel to the floor
  - PERP = E field perpendicular to the floor
  - AMO = no polarization

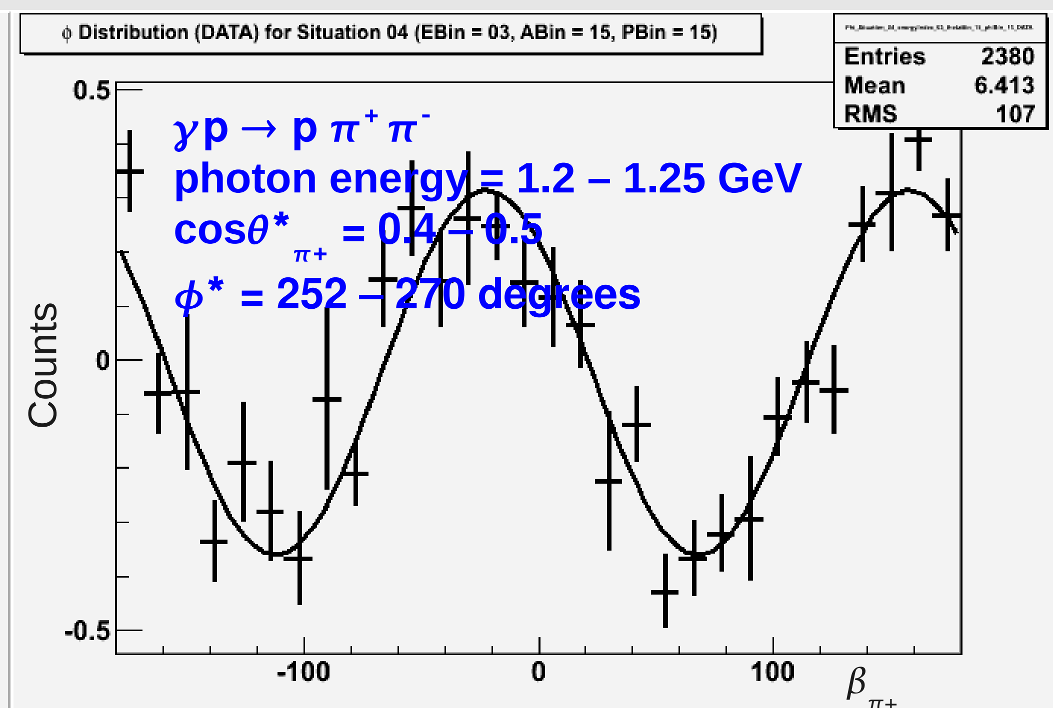




Preliminary Results: Phi Distributions

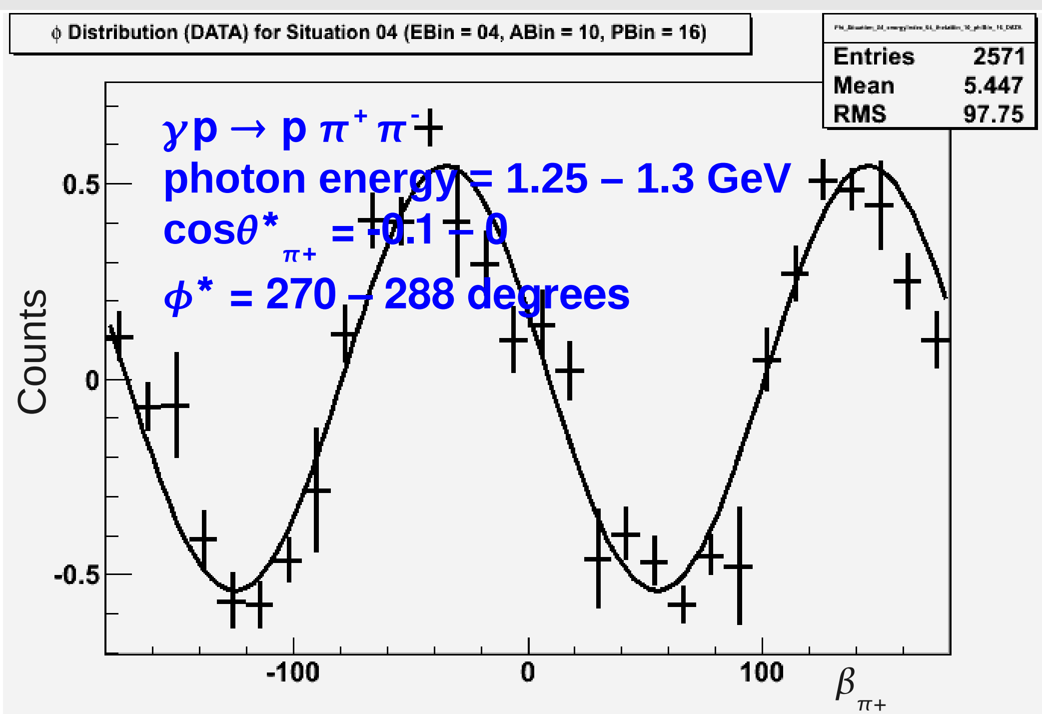
- To remove systematics while maintaining statistics, the phi distributions for PARA are normalized to the PERP phi distributions.
- Fit to : $\dfrac{PARA - PERP}{PARA + PERP} = \dfrac{I_{PARA} - I_{PERP}}{I_{PARA} + I_{PERP}}$

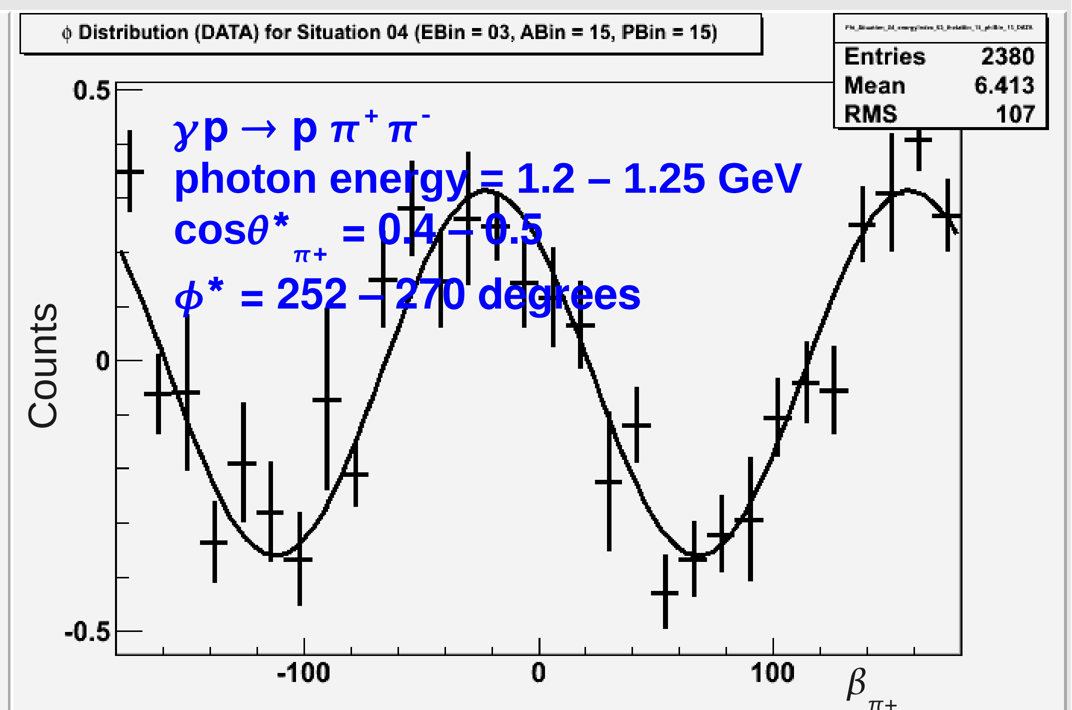




Preliminary Results: Phi Distributions

- To remove systematics while maintaining statistics, the phi distributions for PARA are normalized to the PERP phi distributions.
- Fit to : $\dfrac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$ $\quad \beta=\phi_{lab}+\phi_{polarization}$



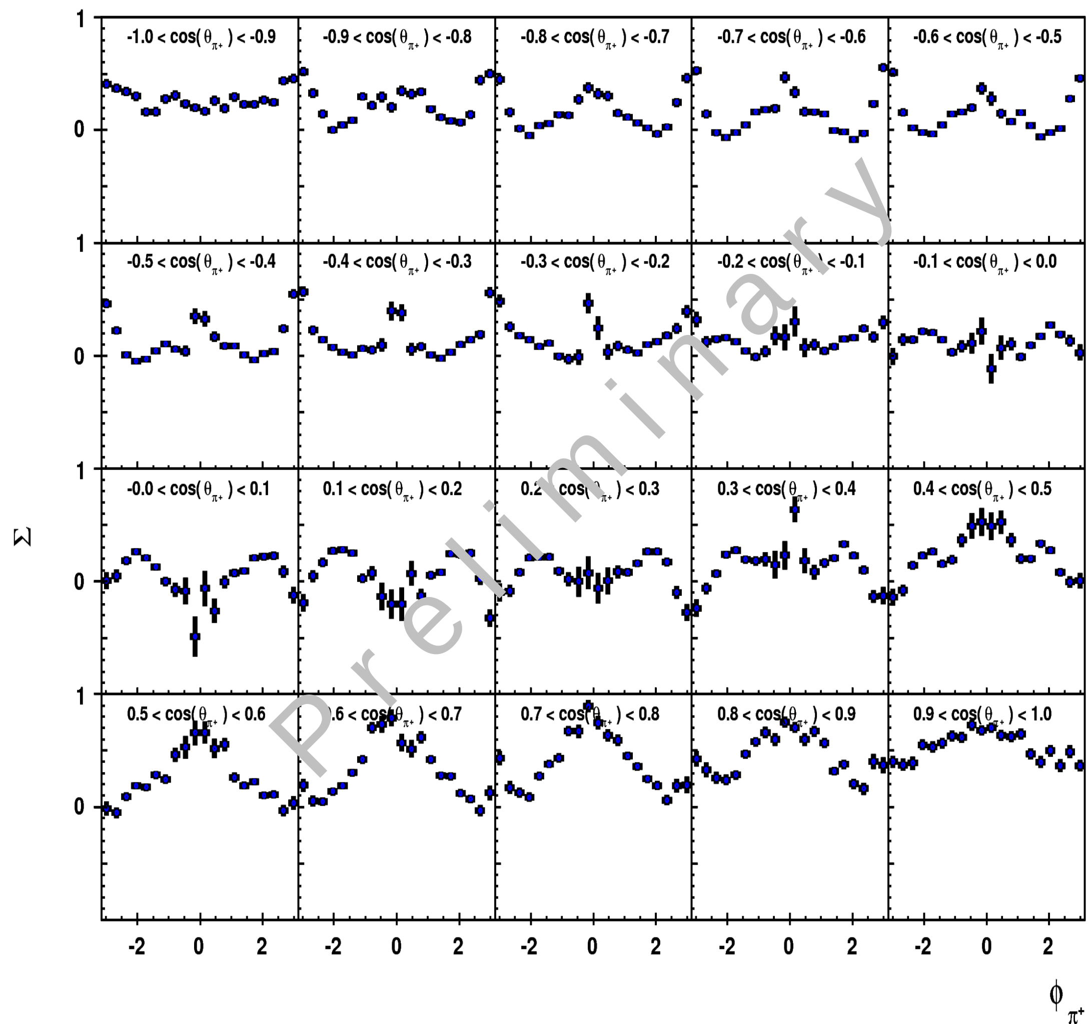


Preliminary Results : I^c

$$\frac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(\text{۲}\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$$

- Photon energy of 1100 – 1150 MeV
- Each square is an bin in $\cos\theta^*$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- We see a non-zero value for I^c (Σ).
- I^c is symmetric around the origin.

$\gamma p \rightarrow p\, \pi^+\pi^-$ ()

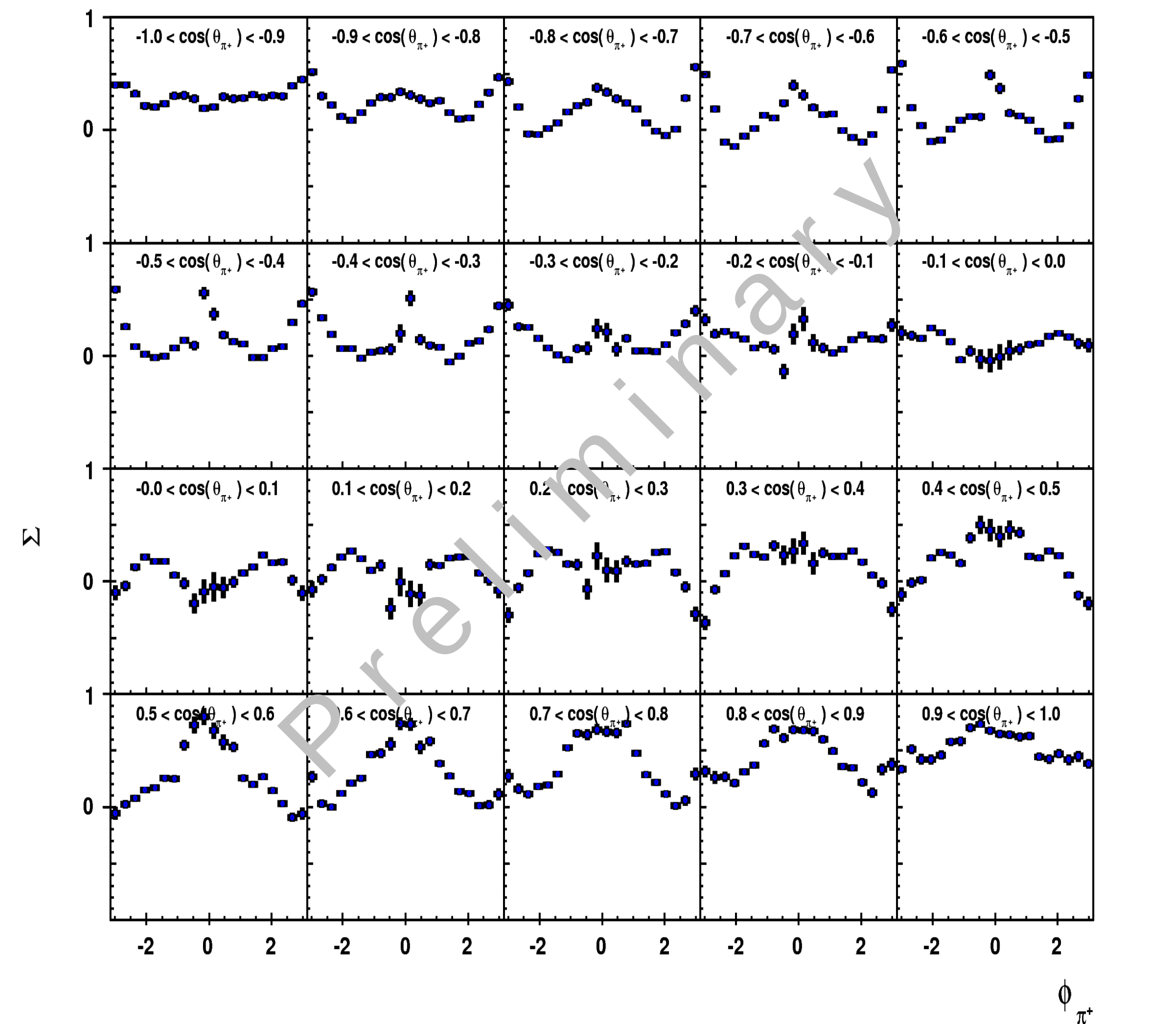


Preliminary Results : I^c

$$\frac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$$

- Photon energy of 1150 – 1200 MeV
- Each square is an bin in $\cos\theta^*$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- We see a non-zero value for I^c (Σ).
- I^c is symmetric around the origin.

$\gamma p \rightarrow p\,\pi^+\pi^-$ ()

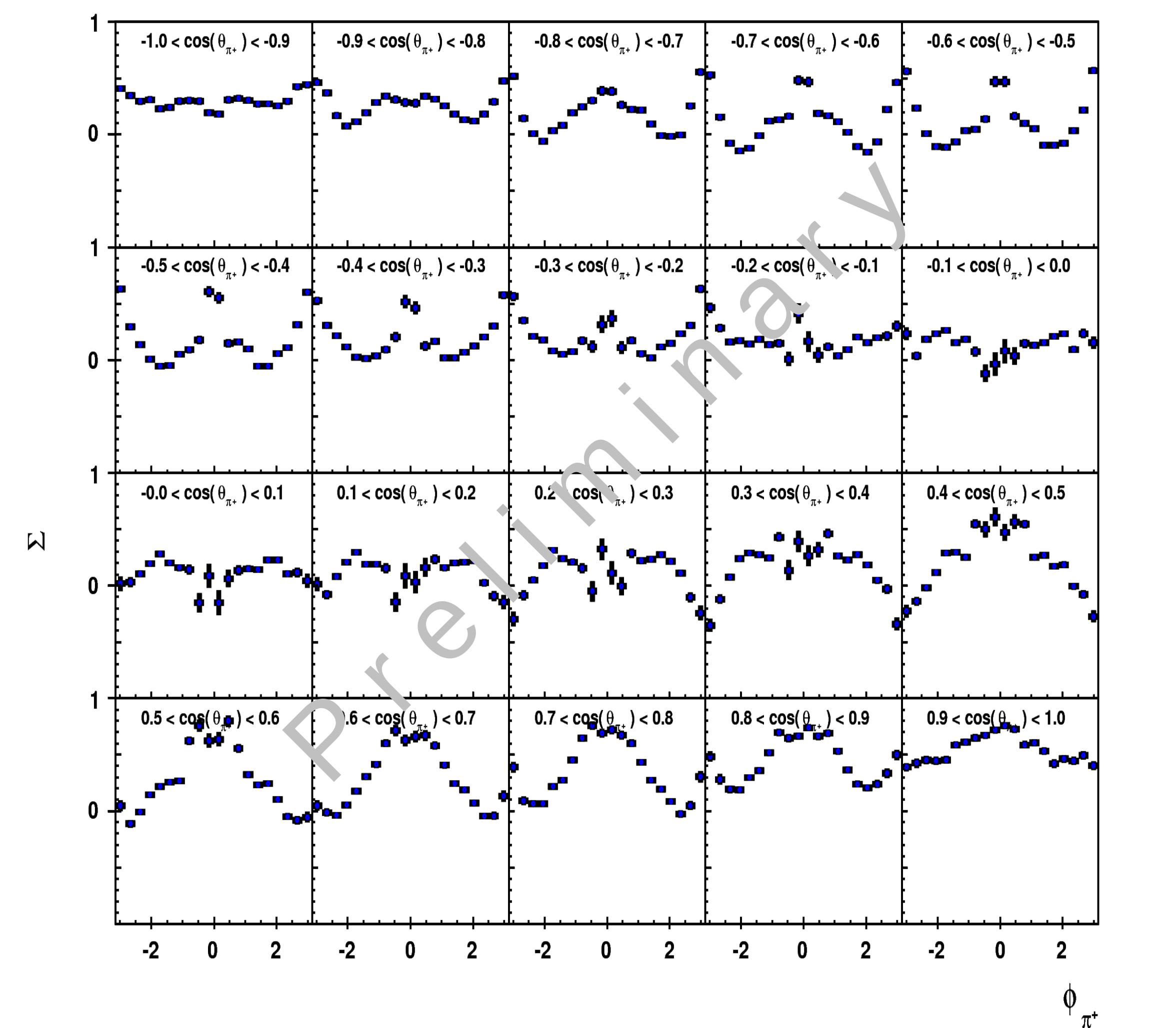


Preliminary Results : I^c

$$\frac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$$

- Photon energy of 1200 – 1250 MeV
- Each square is an bin in cosθ* of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- We see a non-zero value for I^c (Σ).
- I^c is symmetric around the origin.

$\gamma p \to p\,\pi^+\pi^-$ ()

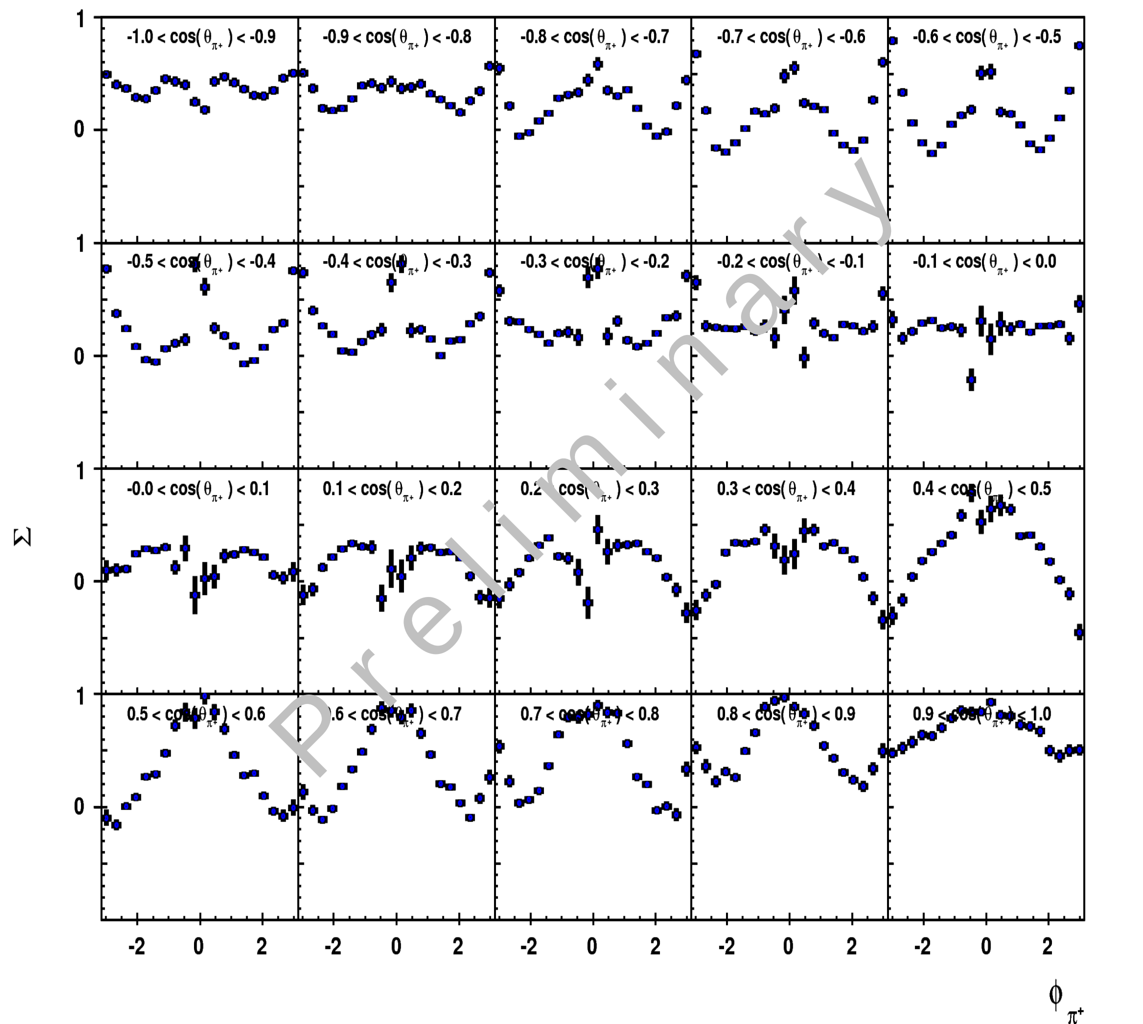


Preliminary Results : I^c

$$\frac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$$

- Photon energy of 1250 – 1300 MeV
- Each square is an bin in $\cos\theta^*$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- We see a non-zero value for I^c (Σ).
- I^c is symmetric around the origin.

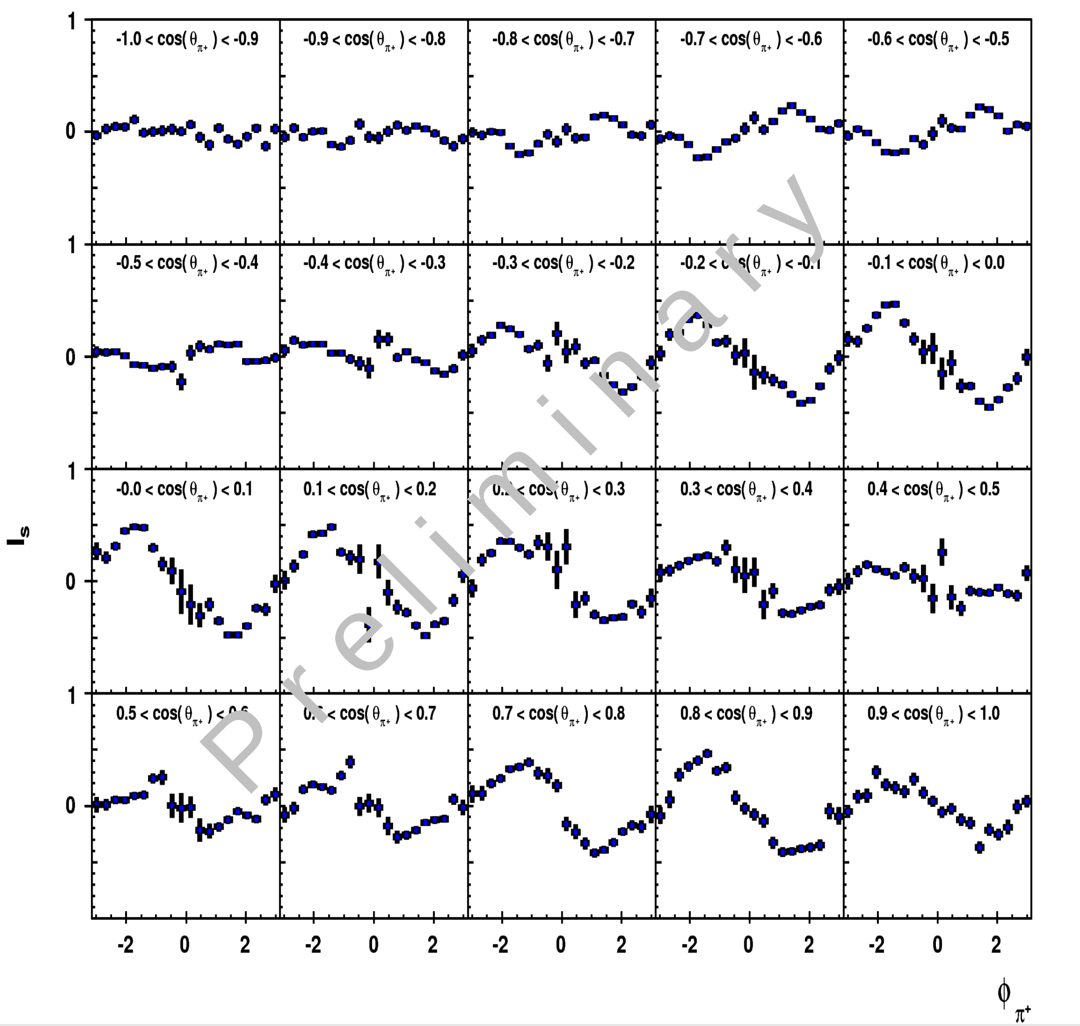
$\gamma p \to p\,\pi^+\pi^-$ ()



Preliminary Results : I^s

$$\frac{[(\delta_l^{para}+\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})I^c\cos(2\beta)}$$

$\gamma p \rightarrow p\,\pi^+\pi^-$ ()

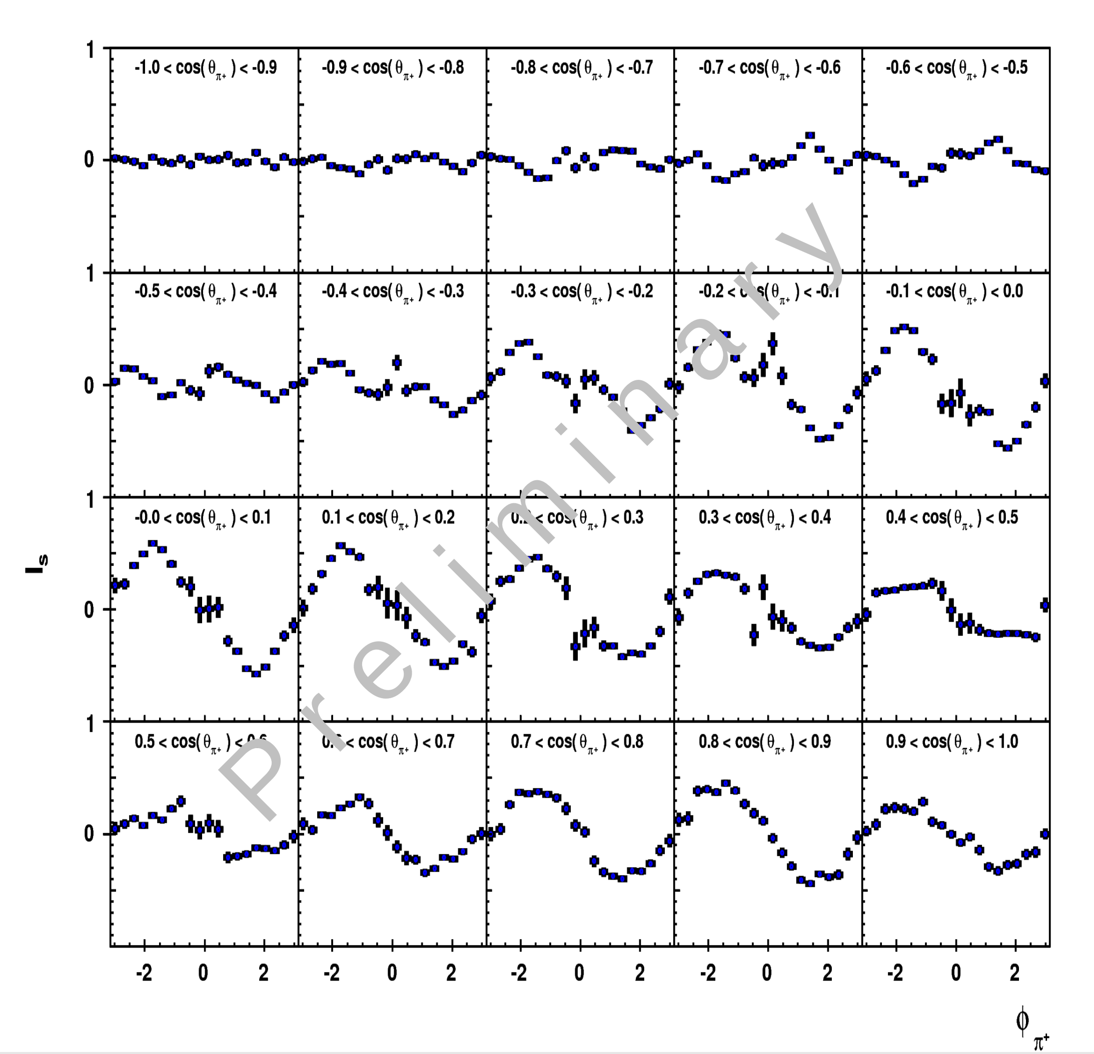


- Photon energy of 1100 – 1150 MeV
- Each square is an bin in $\cos\theta^*$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- I^s is antisymmetric around the origin.

Preliminary Results : I^s

$$\frac{[(\delta_l^{para}+\delta_l^{perp})\, I^s \sin(2\beta) + (\delta_l^{para}+\delta_l^{perp})\, I^c \cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})\, I^s \sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})\, I^c \cos(2\beta)}$$

$\gamma p \rightarrow p\, \pi^+ \pi^-$ ()

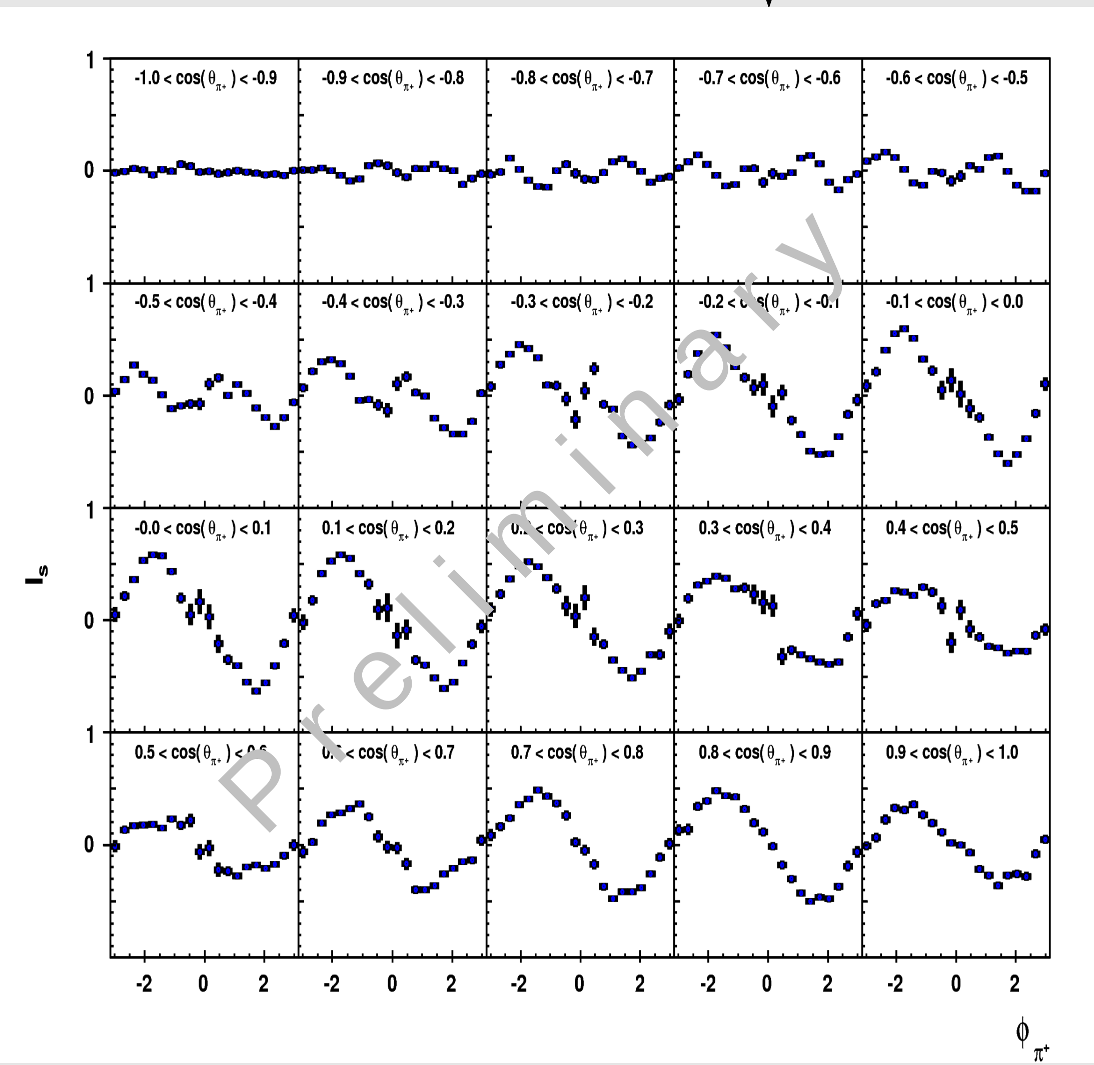


- Photon energy of 1150 – 1200 MeV
- Each square is an bin in cosθ* of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- I^s is antisymmetric around the origin.

Preliminary Results : I^s

$$\frac{[(\delta_l^{para}+\delta_l^{perp})\,I^s\sin(2\beta)+(\delta_l^{para}+\delta_l^{perp})\,I^c\cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp})\,I^s\sin(2\beta)+(\delta_l^{para}-\delta_l^{perp})\,I^c\cos(2\beta)}$$

$\gamma p \rightarrow p\,\pi^+\pi^-$ ()

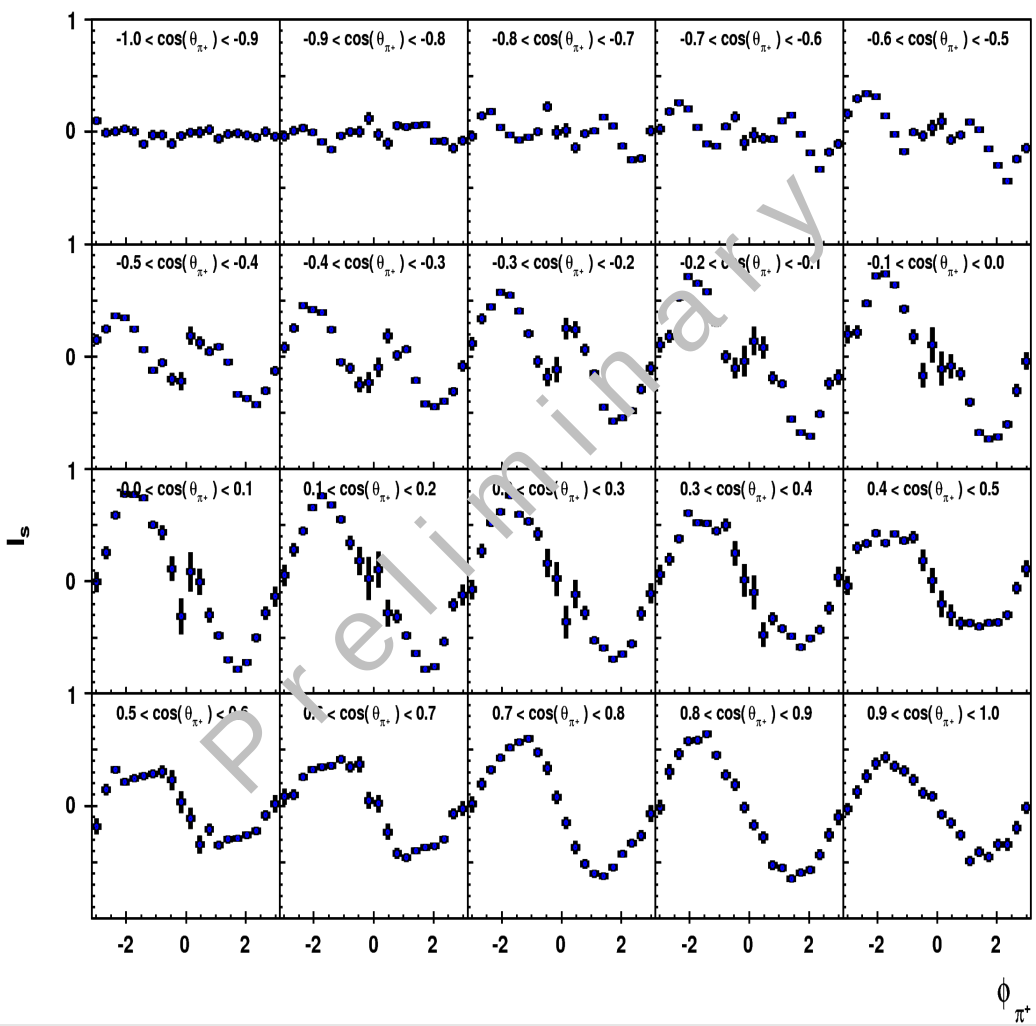


- Photon energy of 1200 – 1250 MeV
- Each square is an bin in cosθ* of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- I^s is antisymmetric around the origin.

Preliminary Results : I^s

$$\frac{[(\delta_l^{para}+\delta_l^{perp}) I^s \sin(2\beta)+(\delta_l^{para}+\delta_l^{perp}) I^c \cos(2\beta)]}{2+(\delta_l^{para}-\delta_l^{perp}) I^s \sin(2\beta)+(\delta_l^{para}-\delta_l^{perp}) I^c \cos(2\beta)}$$

$\gamma p \rightarrow p\, \pi^+ \pi^-$ ()

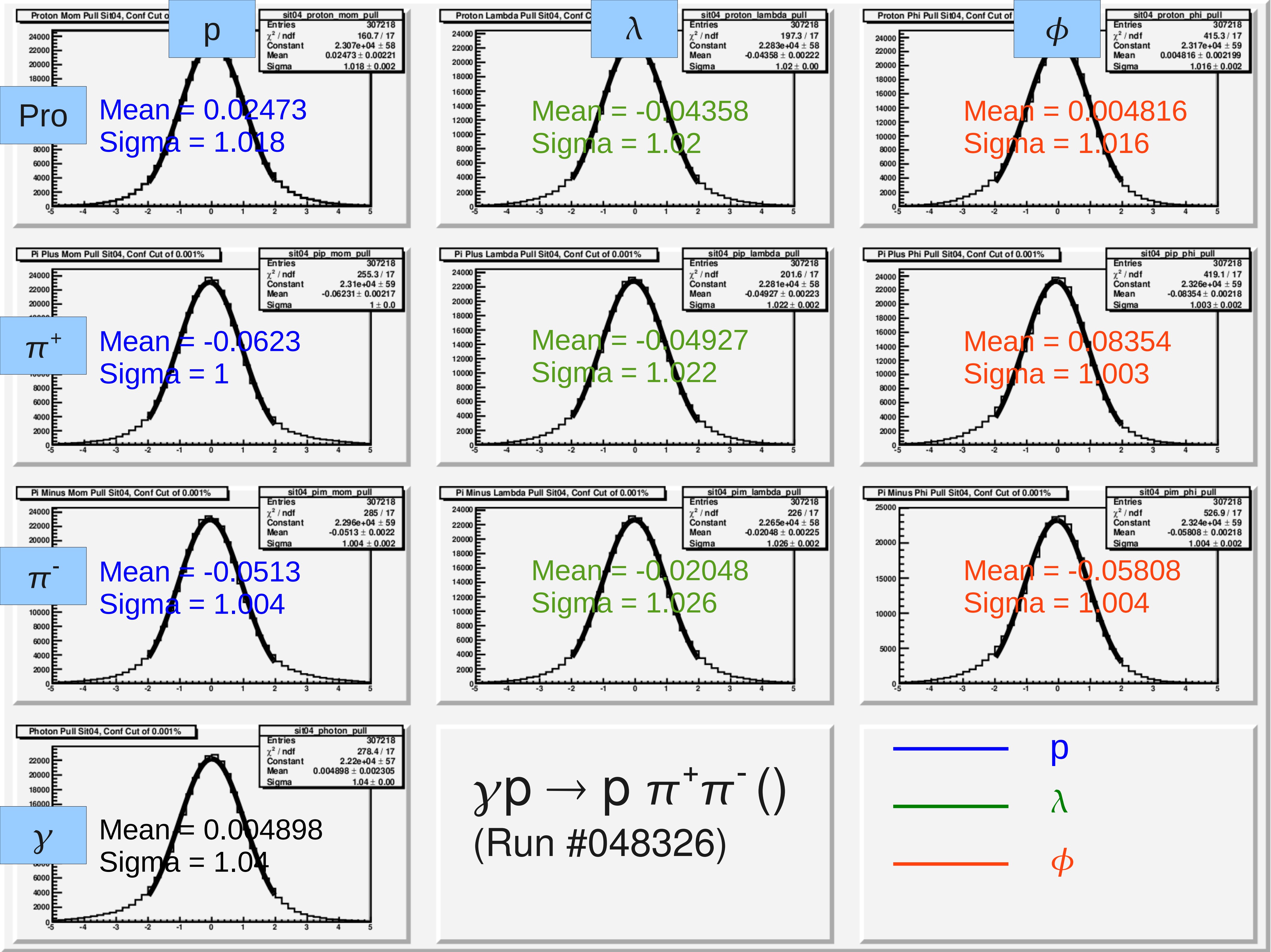


- Photon energy of 1250 – 1300 MeV
- Each square is an bin in cosθ* of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- I^s is antisymmetric around the origin.

Summary

- The first (preliminary) measurements of the polarization observables I^s and I^c for $\gamma p \rightarrow p\, \pi^+ \pi^-$ have been made using the high amount of statistics available in the g8b data set (possible binning in third angle).
- The measurements of polarization observables are key to understanding the missing resonances in the CQM.
- Other polarized photoproduction experiments (such as FROST) will allow access to more polarization observable measurements.
- To Do: Background subtraction (via Q-value method)

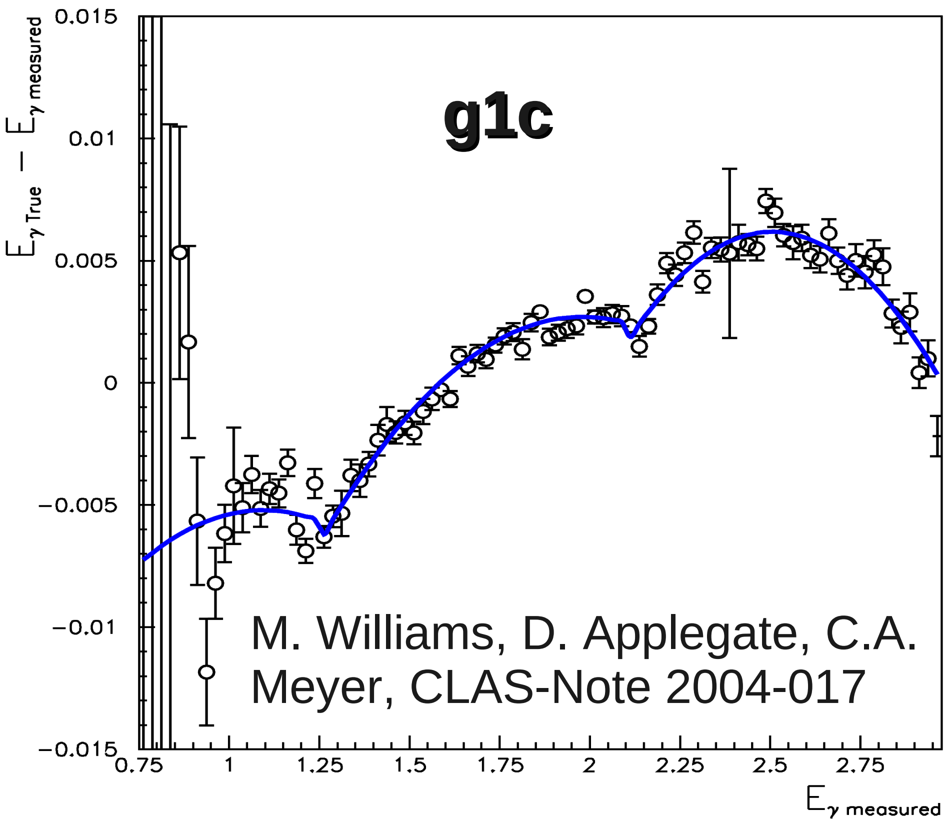
END

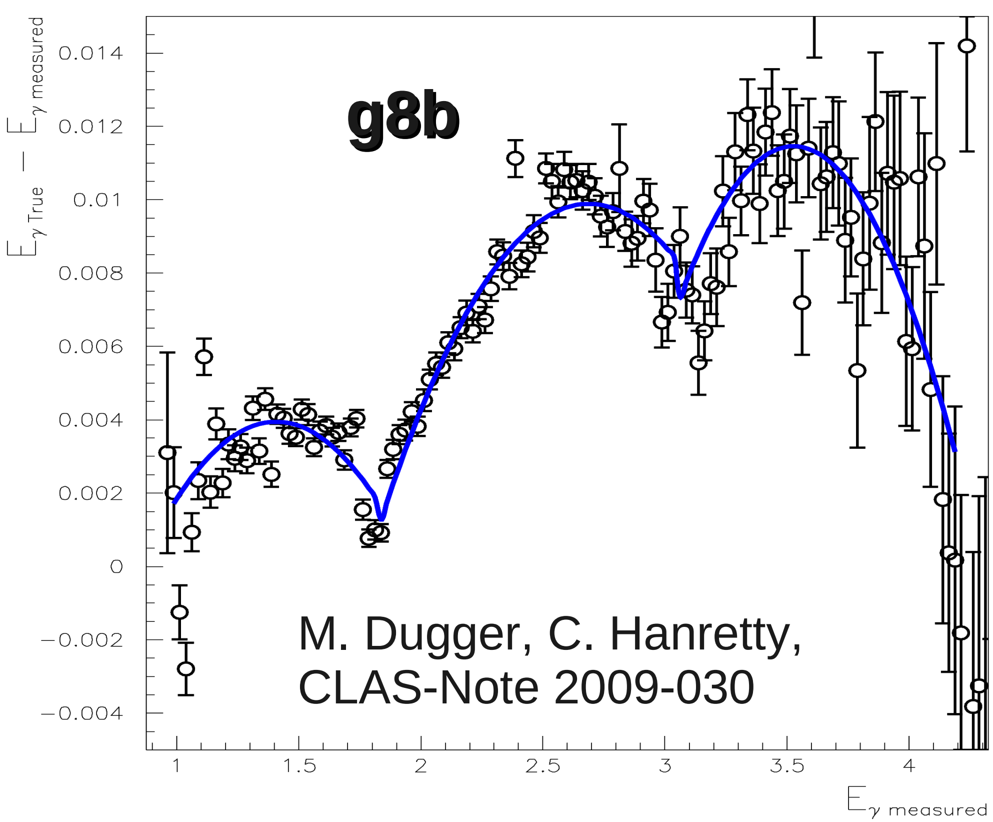


p
λ
φ
Pro
π+
π-
γ
Proton Mom Pull Sit04, Conf Cut o
sit04_proton_mom_pull
Entries 307218
χ2 / ndf 160.7 / 17
Constant 2.307e+04 ± 58
Mean 0.02473 ± 0.00221
Sigma 1.018 ± 0.002
Mean = 0.02473
Sigma = 1.018
Proton Lambda Pull Sit04, Conf C
sit04_proton_lambda_pull
Entries 307218
χ2 / ndf 197.3 / 17
Constant 2.283e+04 ± 58
Mean -0.04358 ± 0.00222
Sigma 1.02 ± 0.00
Mean = -0.04358
Sigma = 1.02
Proton Phi Pull Sit04, Conf Cut of
sit04_proton_phi_pull
Entries 307218
χ2 / ndf 415.3 / 17
Constant 2.317e+04 ± 59
Mean 0.004816 ± 0.002199
Sigma 1.016 ± 0.002
Mean = 0.004816
Sigma = 1.016
Pi Plus Mom Pull Sit04, Conf Cut of 0.001%
sit04_pip_mom_pull
Entries 307218
χ2 / ndf 255.3 / 17
Constant 2.31e+04 ± 59
Mean -0.06231 ± 0.00217
Sigma 1 ± 0.0
Mean = -0.0623
Sigma = 1
Pi Plus Lambda Pull Sit04, Conf Cut of 0.001%
sit04_pip_lambda_pull
Entries 307218
χ2 / ndf 201.6 / 17
Constant 2.281e+04 ± 58
Mean -0.04927 ± 0.00223
Sigma 1.022 ± 0.002
Mean = -0.04927
Sigma = 1.022
Pi Plus Phi Pull Sit04, Conf Cut of 0.001%
sit04_pip_phi_pull
Entries 307218
χ2 / ndf 419.1 / 17
Constant 2.326e+04 ± 59
Mean -0.08354 ± 0.00218
Sigma 1.003 ± 0.002
Mean = 0.08354
Sigma = 1.003
Pi Minus Mom Pull Sit04, Conf Cut of 0.001%
sit04_pim_mom_pull
Entries 307218
χ2 / ndf 285 / 17
Constant 2.296e+04 ± 59
Mean -0.0513 ± 0.0022
Sigma 1.004 ± 0.002
Mean = -0.0513
Sigma = 1.004
Pi Minus Lambda Pull Sit04, Conf Cut of 0.001%
sit04_pim_lambda_pull
Entries 307218
χ2 / ndf 226 / 17
Constant 2.265e+04 ± 58
Mean -0.02048 ± 0.00225
Sigma 1.026 ± 0.002
Mean = -0.02048
Sigma = 1.026
Pi Minus Phi Pull Sit04, Conf Cut of 0.001%
sit04_pim_phi_pull
Entries 307218
χ2 / ndf 526.9 / 17
Constant 2.324e+04 ± 59
Mean -0.05808 ± 0.00218
Sigma 1.004 ± 0.002
Mean = -0.05808
Sigma = 1.004
Photon Pull Sit04, Conf Cut of 0.001%
sit04_photon_pull
Entries 307218
χ2 / ndf 278.4 / 17
Constant 2.22e+04 ± 57
Mean 0.004898 ± 0.002305
Sigma 1.04 ± 0.00
Mean = 0.004898
Sigma = 1.04
γp → p π+π- ()
(Run #048326)
p
λ
φ

Tagger Sag

- Results from a physical “sagging” of the E-counter scintillator bars.
- Has been seen in several runs.





Tagger Sag

- Results from a physical “sagging” of the E-counter scintillator bars.
- Has been seen in several runs.
- Requires and energy-dependent photon energy correction.