The Determination of Beam Asymmetry from Double Pion Photoproduction

Charles Hanretty
Florida State University
On behalf of the CLAS Collaboration
Funding provided by DOE
APS DNP Conference
May 2, 2009
Denver, Colorado

Outline

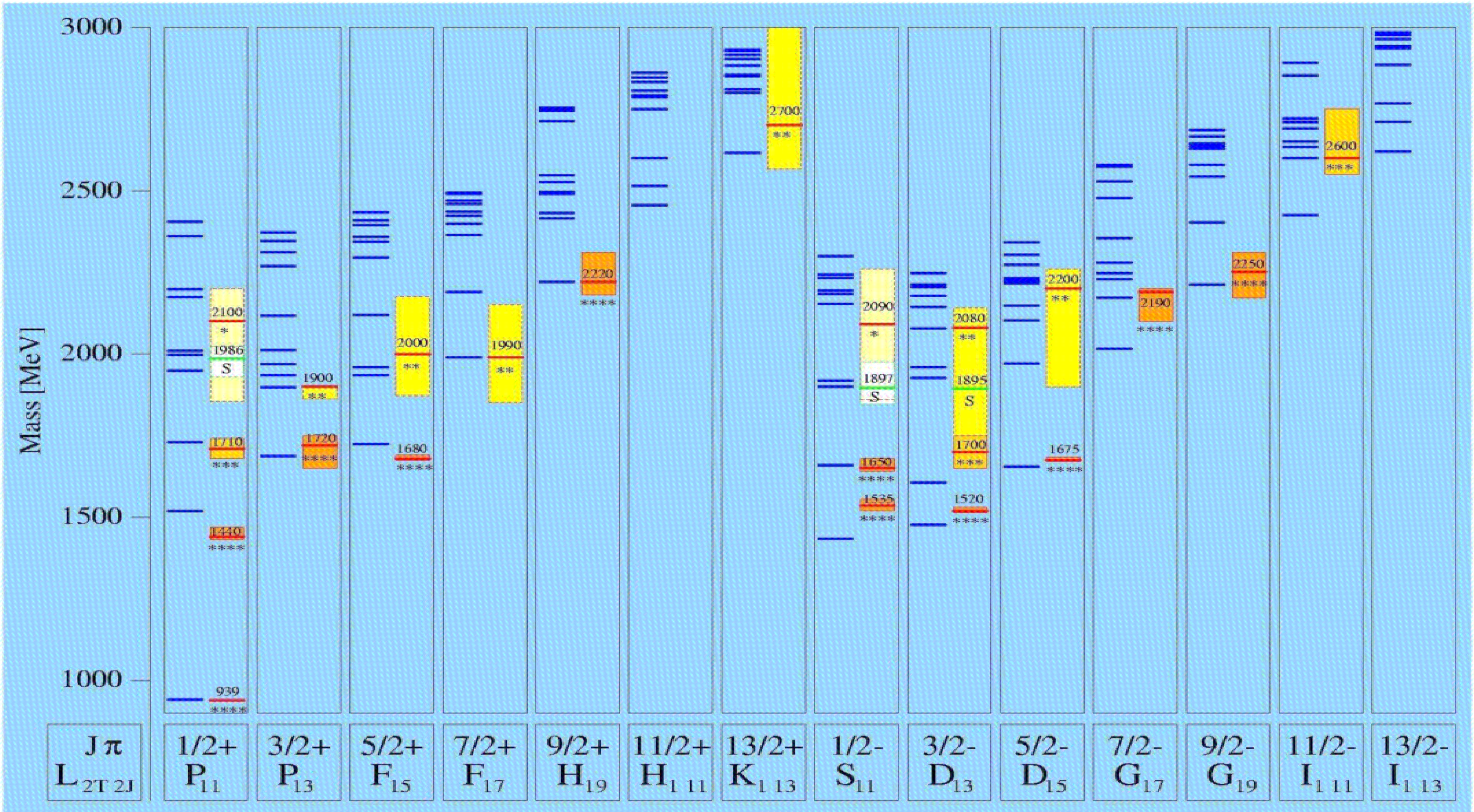
- Introduction:
  - Problems in Hadron Spectroscopy
- Experimental Facility
- Analysis
  - Coordinate system
  - Final State Equations ($\gamma p \rightarrow p\, \pi^{+}\pi^{-}$)
  - Preliminary Results from g8b

Problems in Hadron Spectroscopy

- Interactions occur between quarks ⇒ described by Quantum Chromodynamics (QCD).
- But...
  - QCD Lagrangian is not solvable in the low energy range of bound states.
  - Lattice-QCD calculations cannot presently provide us with a complete solution.
- We do have Constituent Quark Models.

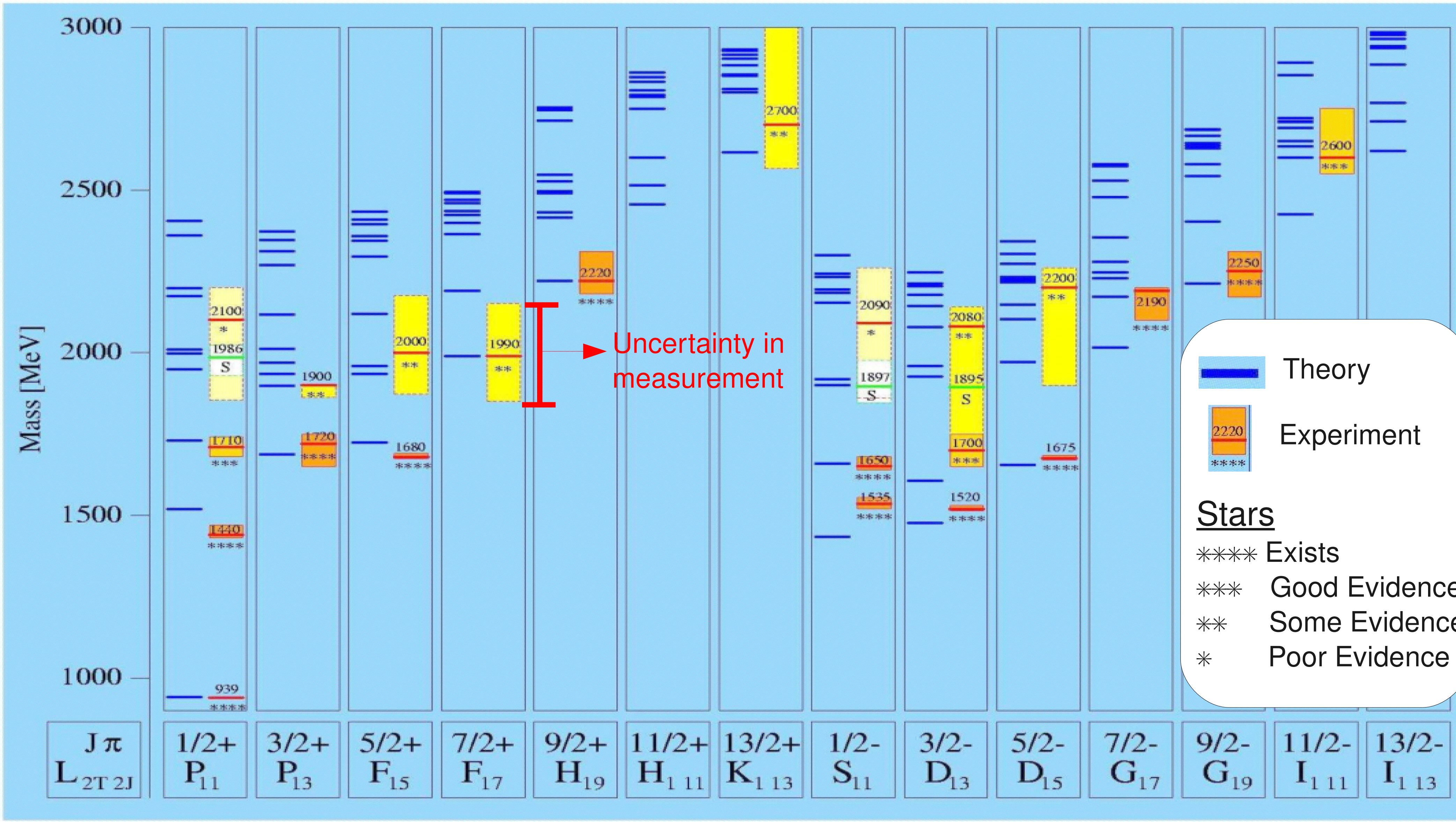
Problems in Hadron Spectroscopy

N* Resonances (Isospin = ½ states)



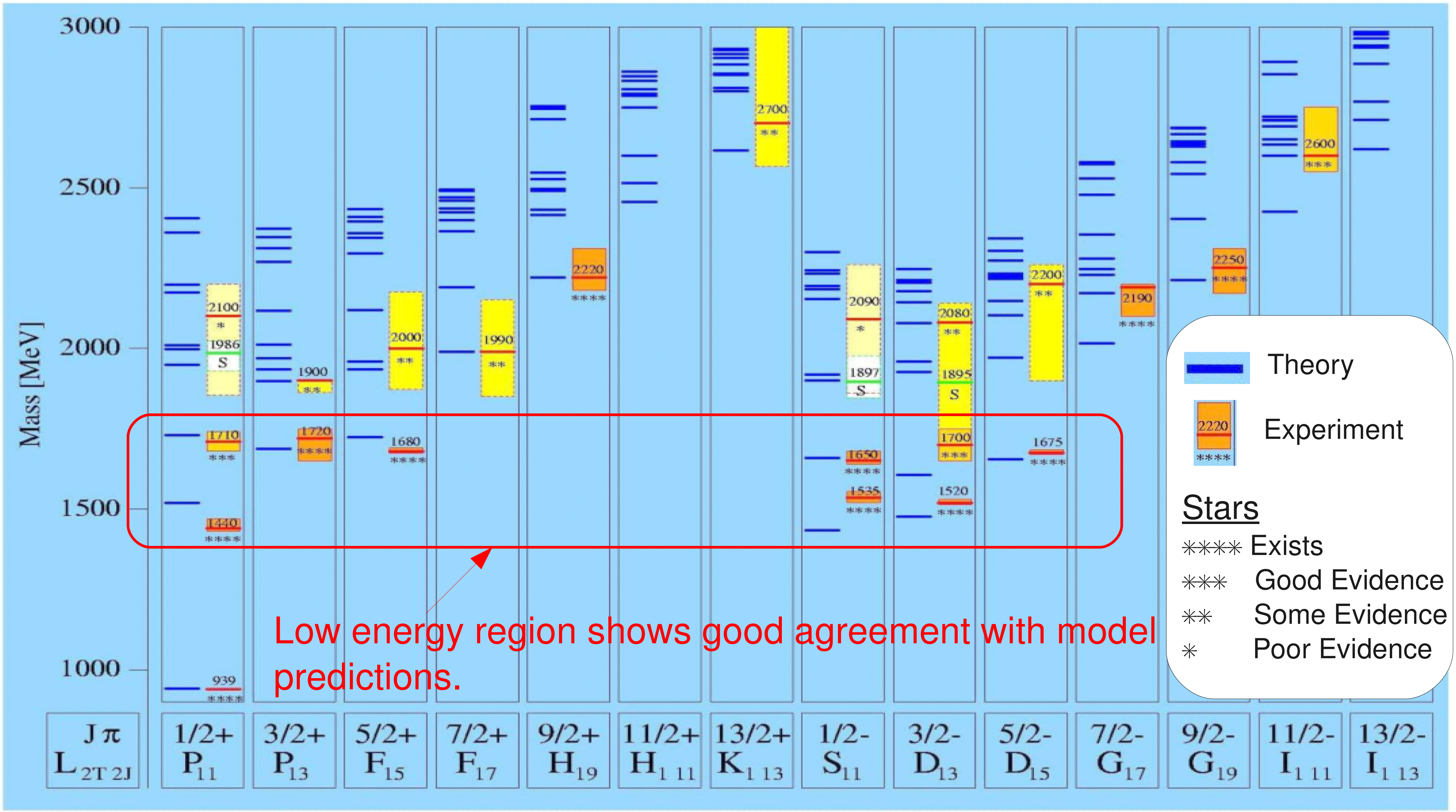
Problems in Hadron Spectroscopy

N* Resonances (Isospin = ½ states)



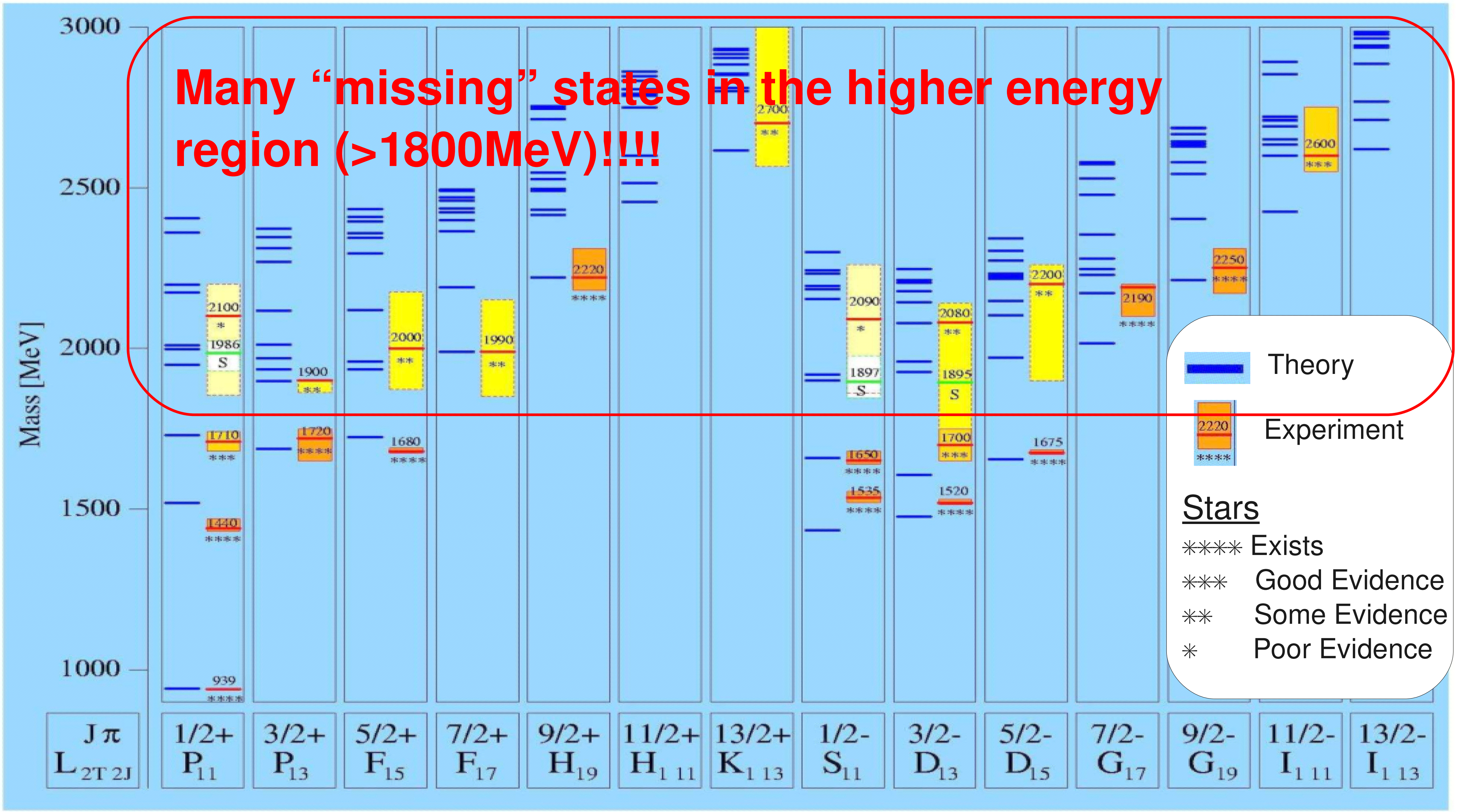
Problems in Hadron Spectroscopy

N* Resonances (Isospin = ½ states)

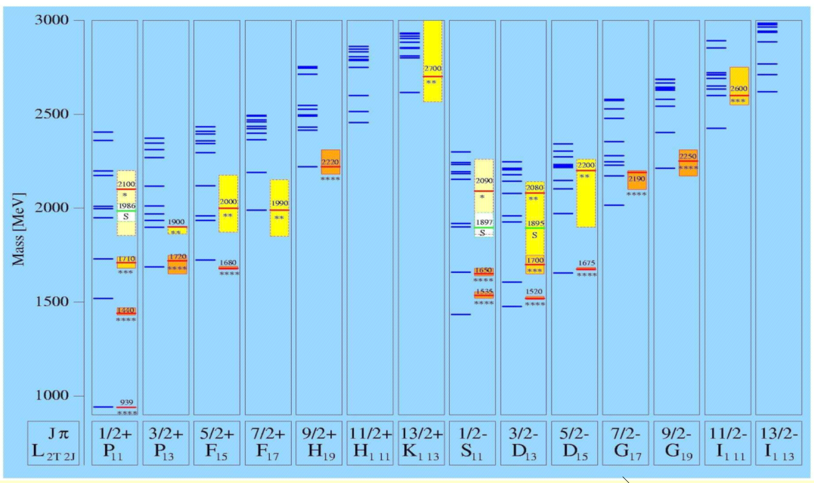


Problems in Hadron Spectroscopy

N* Resonances (Isospin = ½ states)

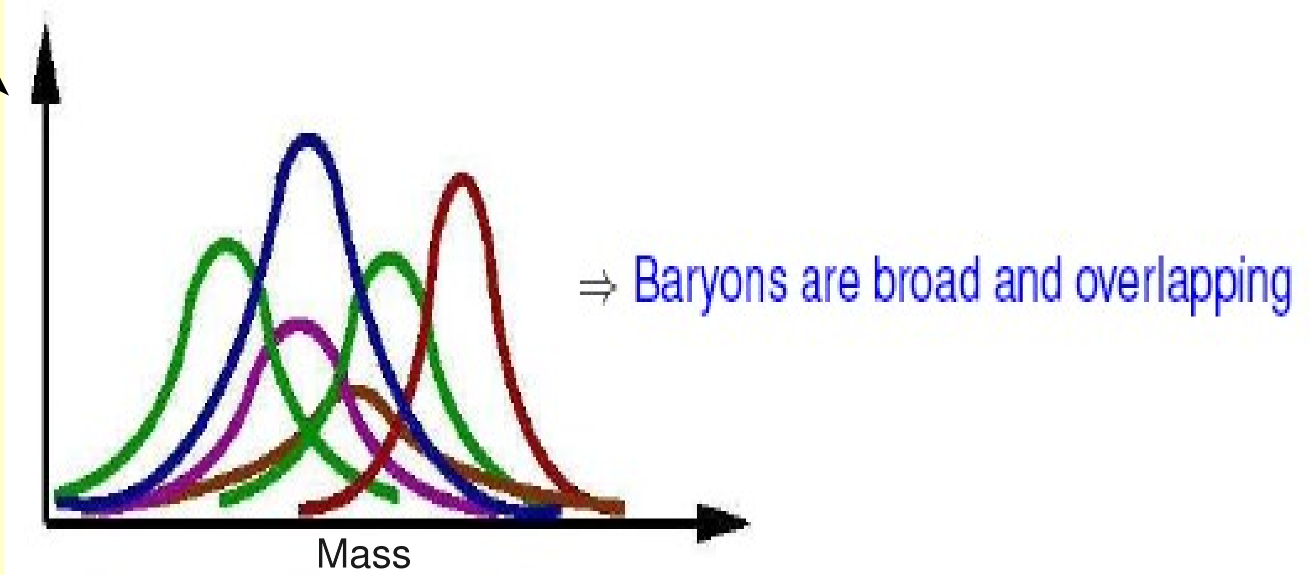


Entangled Resonances



Need to find a way to isolate singular resonance contributions!!

Projection onto mass axis ⇒

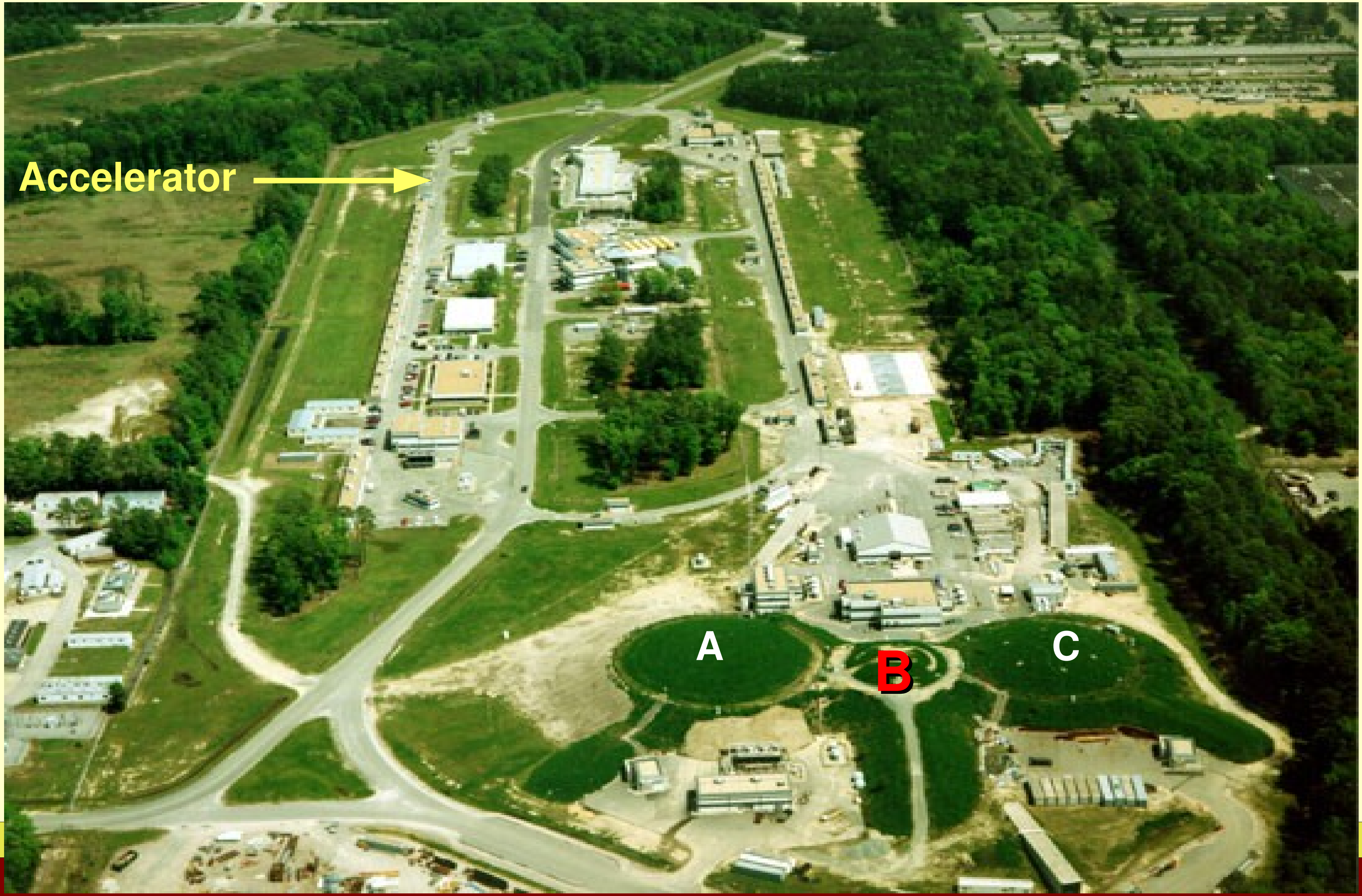


Why the lack of evidence? What can we do?

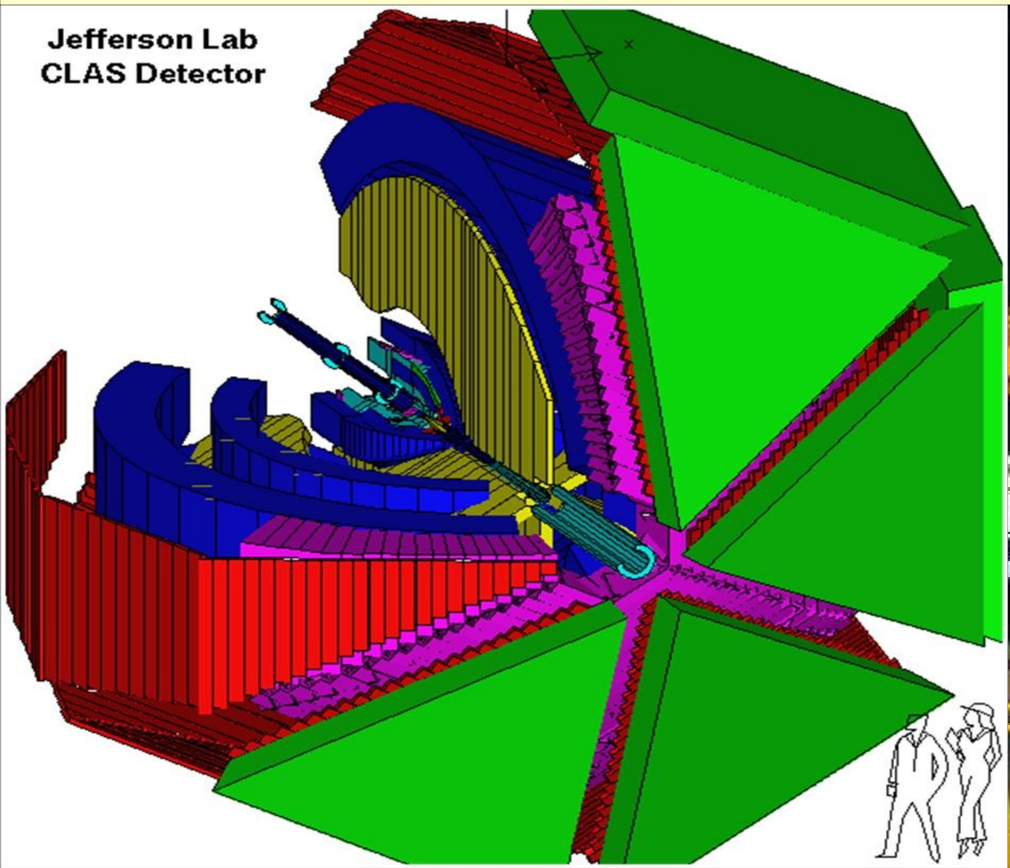
- Most of the existing data regarding N* resonances involves πN elastic scattering.
  - Photoproduction (γp) is predicted to be a promising method for producing these states.
- Existing polarized photoproduction data mainly covers a mass range up to about 1800 MeV with analyses involving a single meson.
  - 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.

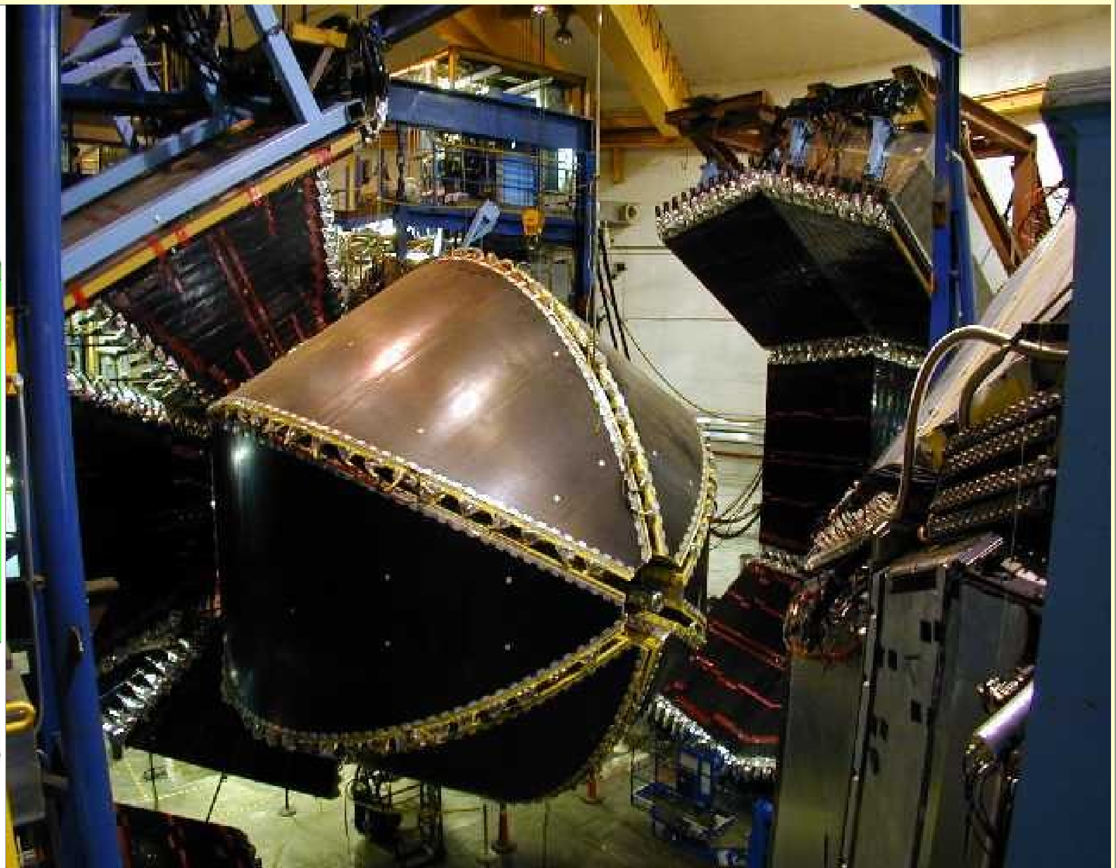
The Facility: Jefferson Lab in Newport News, VA

The Facility: Jefferson Lab in Newport News, VA



The Hall B Detector : CLAS





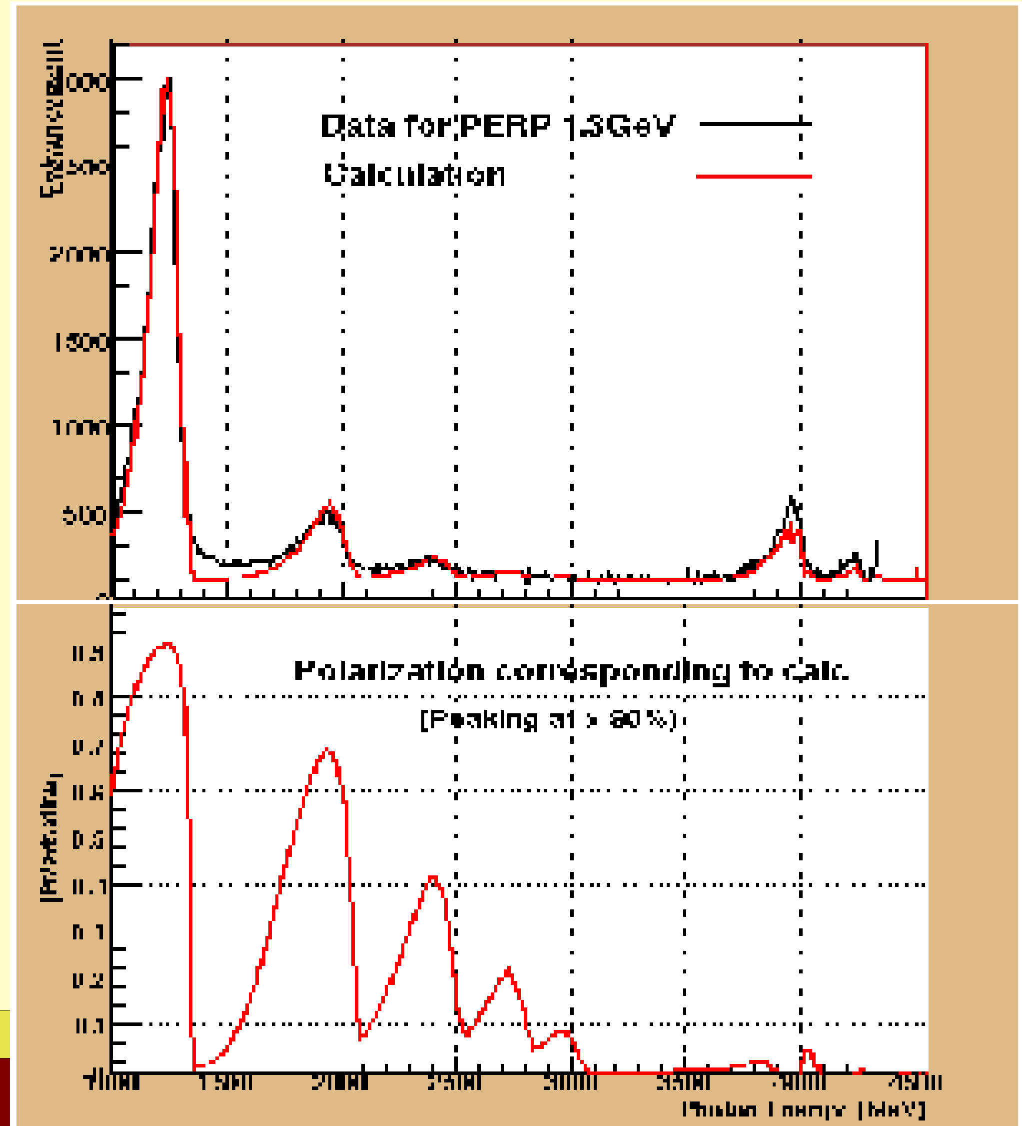
- Yellow : Torus Magnet
- Blue : Drift Chambers
- Purple : Cerenkov Counters

Red : Time of Flight Scintillators

Green : Electromagnetic Calorimeters

Polarized and Tagged Photon Beam

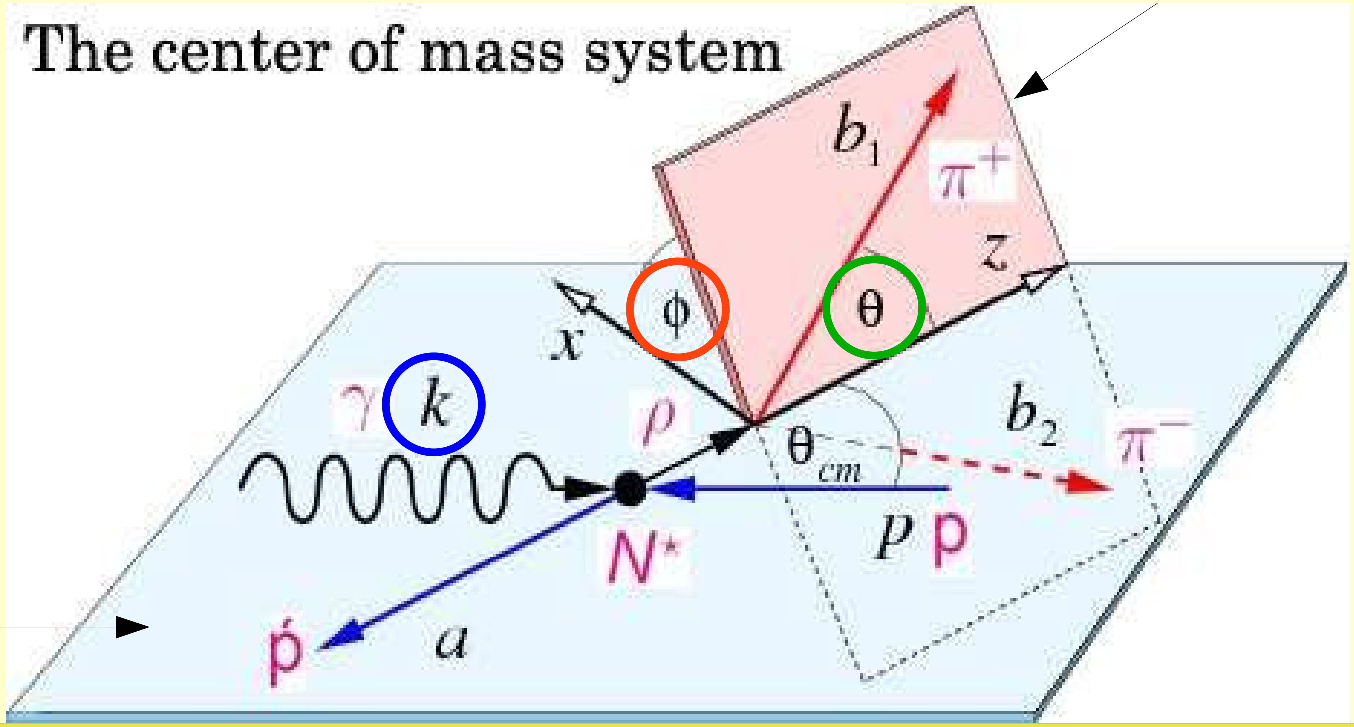
- Hall B has the ability to produce a beam of polarized, tagged photons.
- linearly polarized photon beam = unpolarized electron beam + oriented diamond radiator
- Can obtain 90% polarization



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 : $\cos\theta_p^{cm}$, $m_{p\pi}$, W, ϕ, θ
- $\gamma p \rightarrow N^* \rightarrow N\rho \rightarrow p\,\pi^+\pi^-$

Event plane formed by 2 final state particles



Production plane

Analysis : Final State Equation

- 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.
- Used linearly polarized photons incident on an unpolarized LH_2 target.

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

Experimental Setup : g8b

- The g8b experiment ran from July - Sep 1st, 2005.
- Used linearly polarized photons incident on an unpolarized LH_2 target.

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

⇩

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

Experimental Setup : g8b

- The g8b experiment ran from July - Sep 1st, 2005.
- Used linearly polarized photons incident on an unpolarized LH_2 target.

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

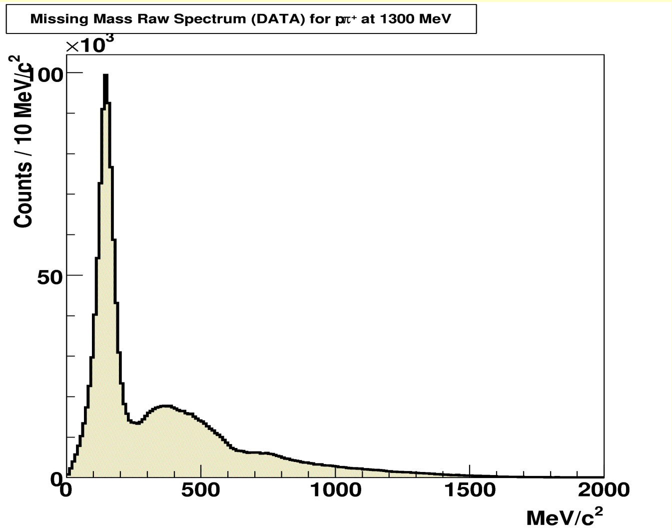
$$\Downarrow$$

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

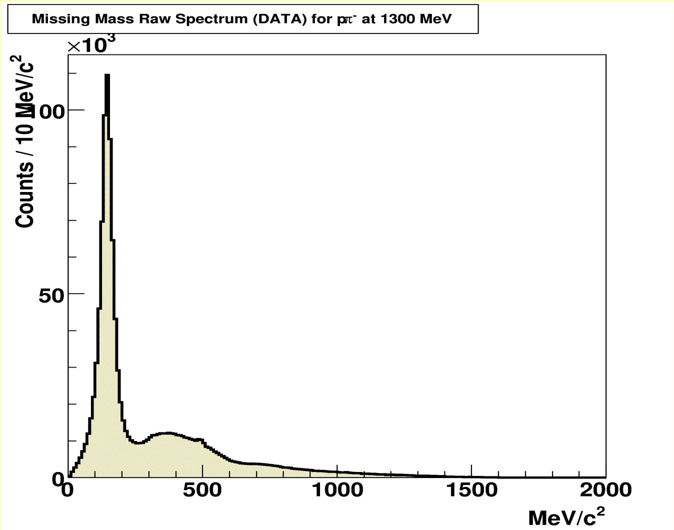
- I^c (also known as Σ in the single-meson equation)
- I^s

The g8b Data Set

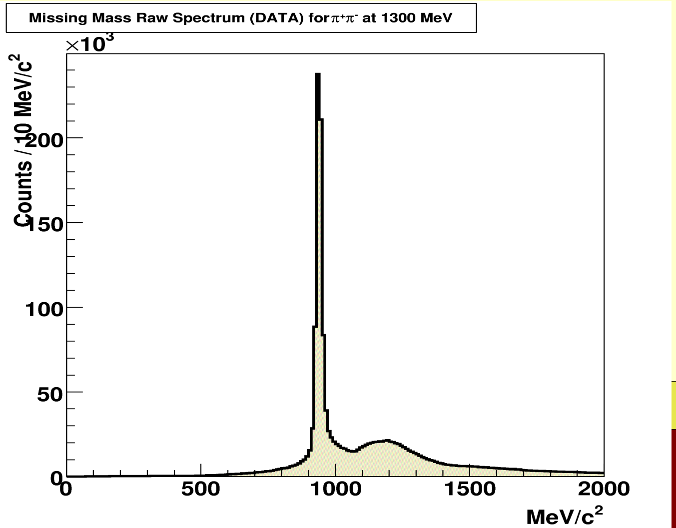
- $\gamma p \rightarrow p\ \pi^{+}\pi^{-}$ from the g8b data set
- Kinematically fitting four topologies



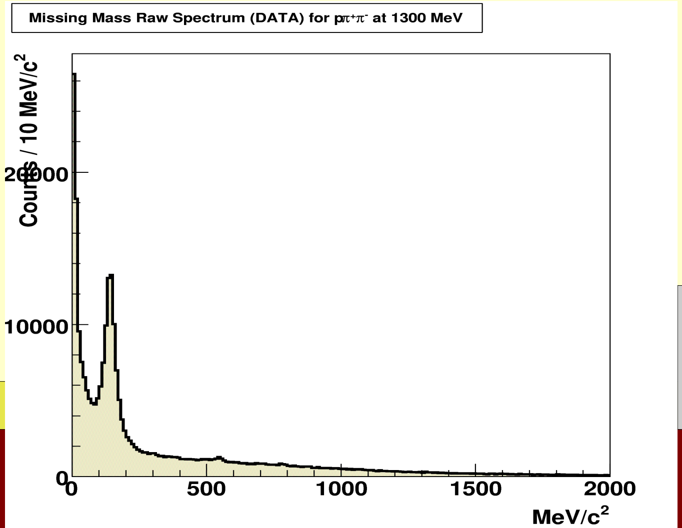
$p\ \pi^{+}(\pi^{-})$



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



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

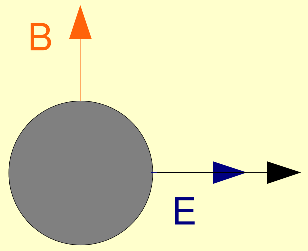


$p\ \pi^{+}\pi()$

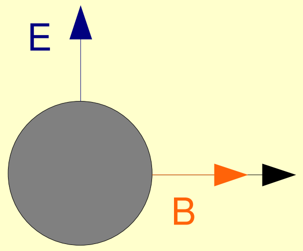
51.32 M events!!

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



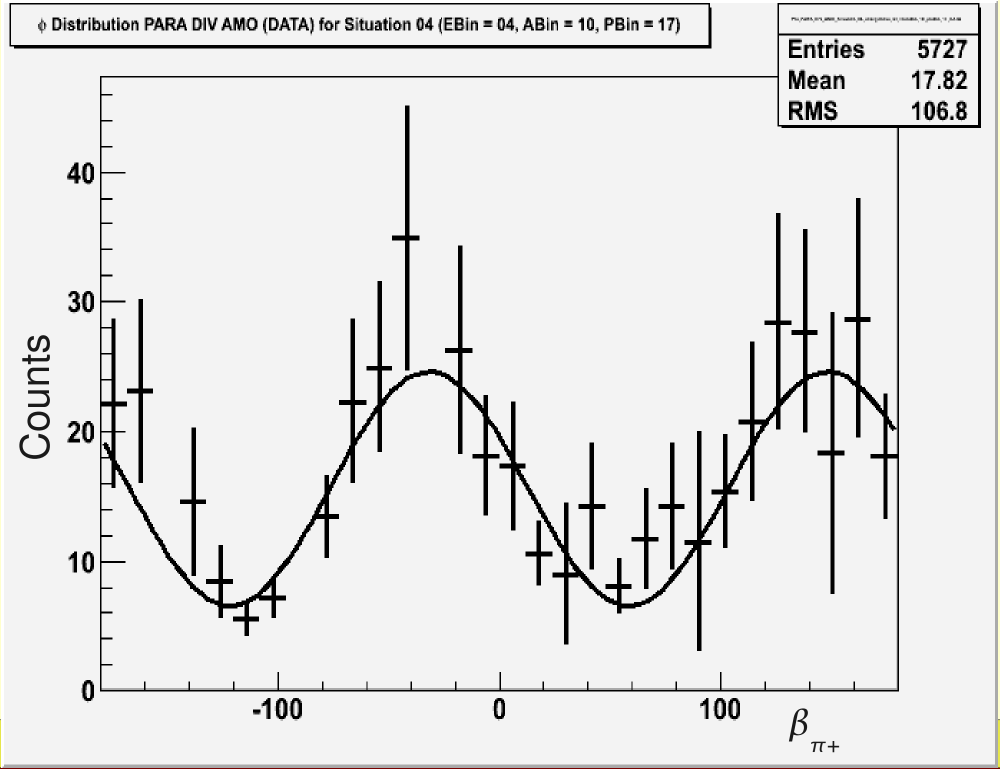
PARA

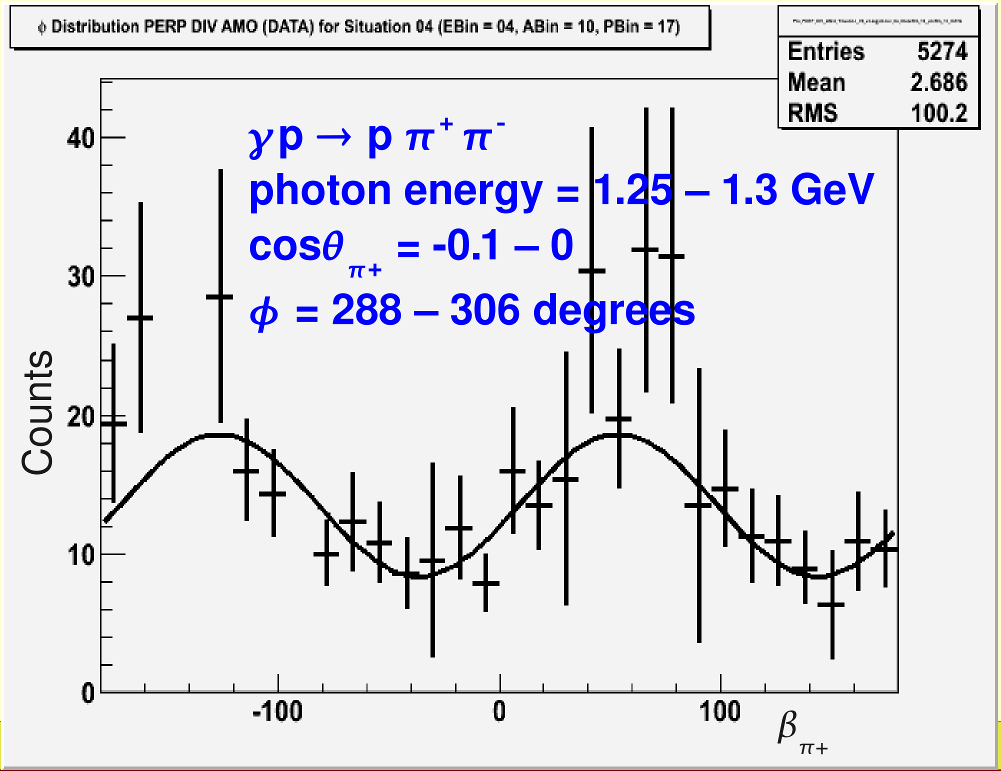


PERP

Preliminary Results: Phi Distributions

- To remove effects of the experimental setup and to be able to garner physics from the data, the phi distributions for PARA and PERP are divided by the AMO phi distributions.
- Fit to : $x + \delta_l[\mathbf{I}^s\sin 2\beta + \mathbf{I}^c\cos 2\beta]\}$





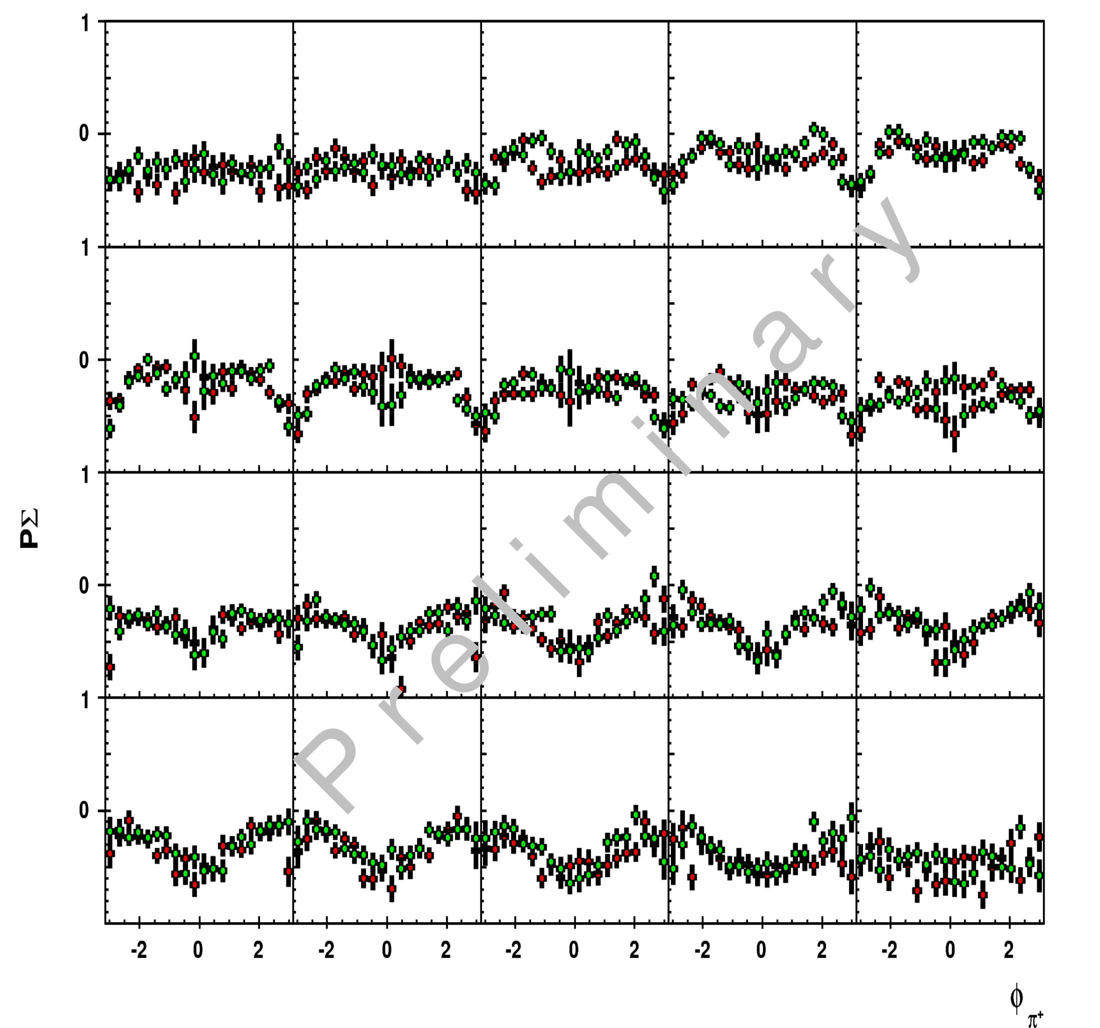
90 degree shift between PARA and PERP distributions!!

Preliminary Results : I^c

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

- Red = PARA/AMO
  Green = PERP/AMO
- 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.

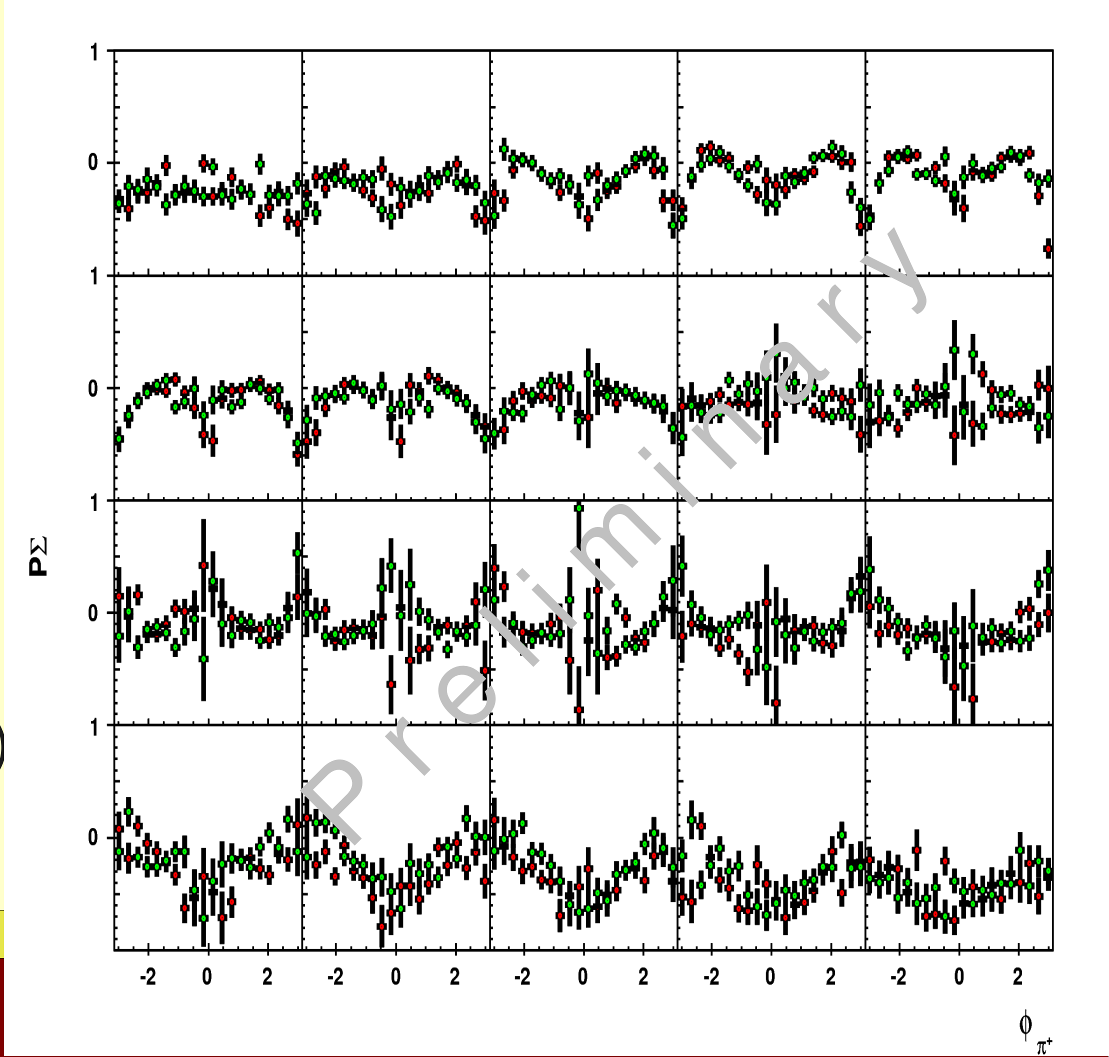
$\gamma p \rightarrow \pi^+ \pi^-$ (p)



Preliminary Results : I^c

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

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

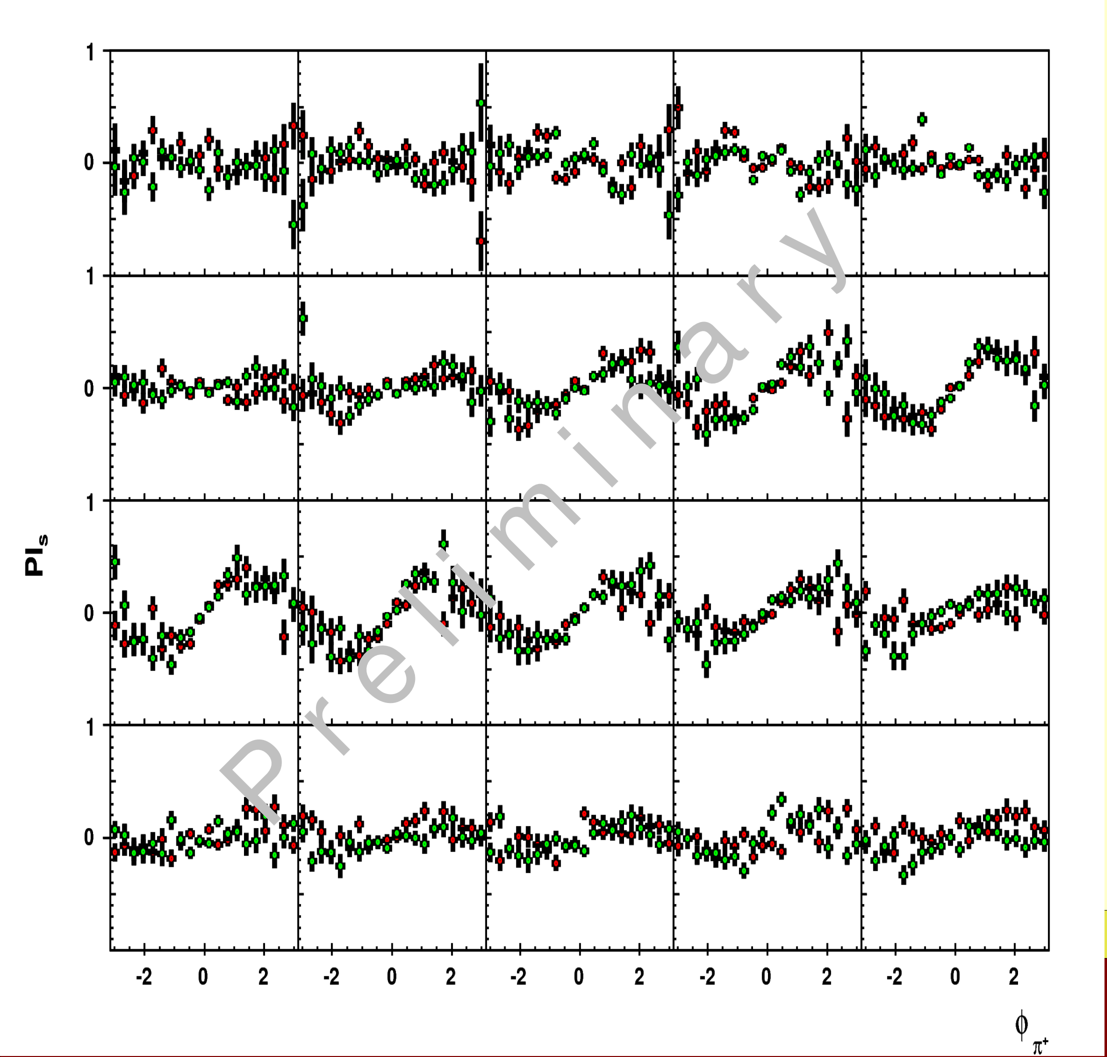


- Red = PARA/AMO
  Green = PERP/AMO
- Photon energy of 1150 – 1200 MeV
- Each square is an bin in cosθ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- We see a non-zero value for I^c (Σ)
- I^c is symmetric around the origin.

Preliminary Results : I^s

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

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

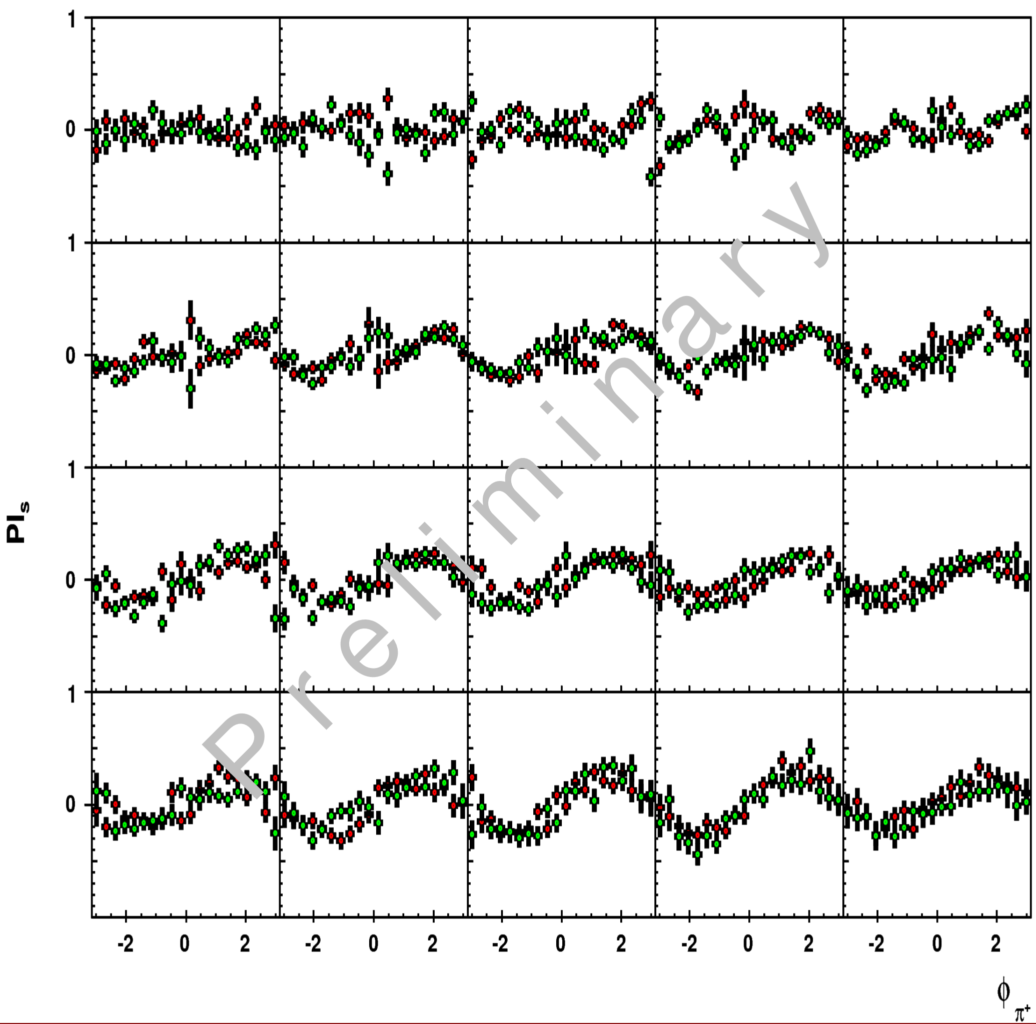


- Red = PARA/AMO
  Green = PERP/AMO
- Photon energy of 1150 – 1200 MeV
- Each square is an bin in $\cos\theta$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- Once we bin in the second angle (ϕ of the π^+) we see a non-zero value for I^s.
- I^s is antisymmetric around the origin.

Preliminary Results : I^s

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

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

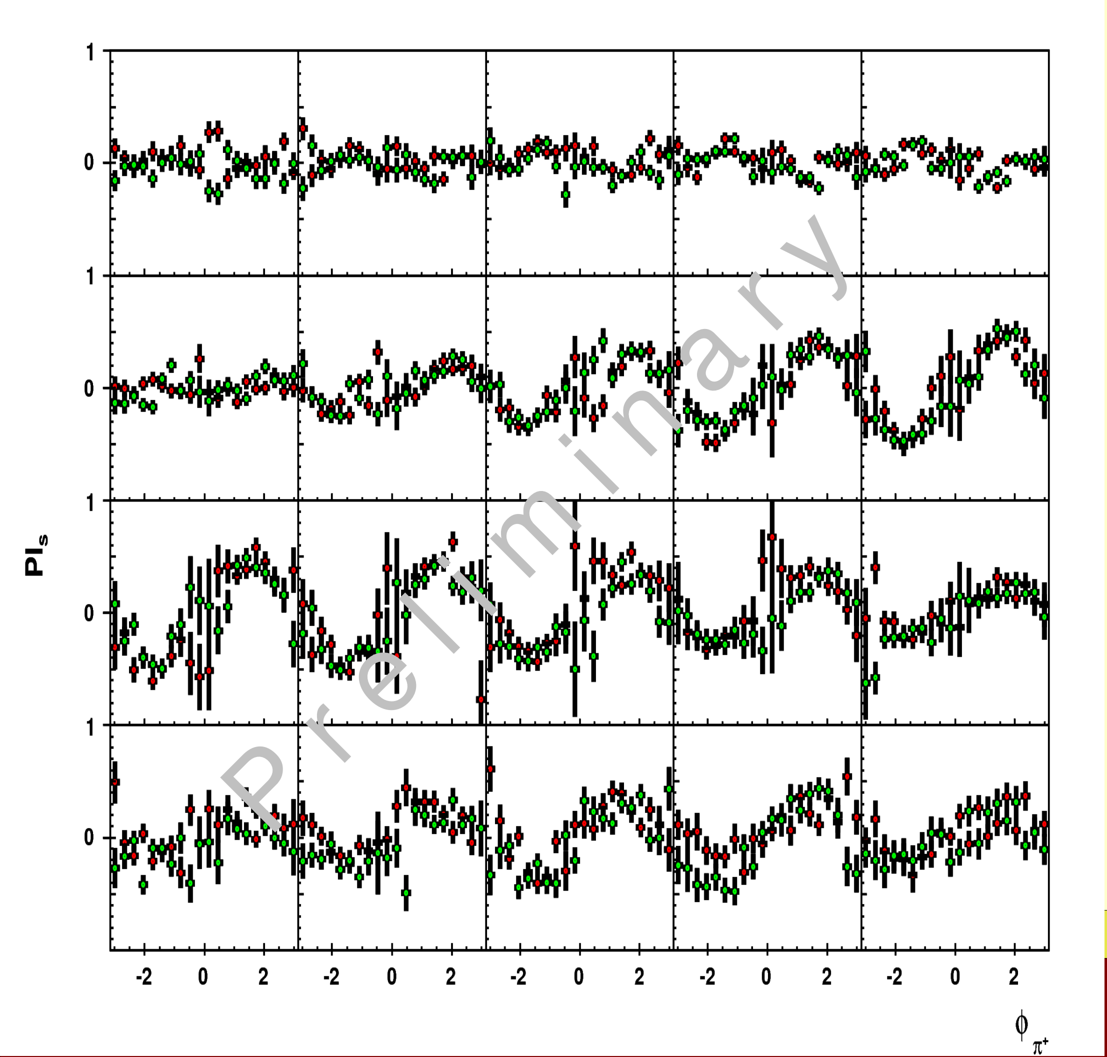


- Red = PARA/AMO
  Green = PERP/AMO
- Photon energy of 1150 – 1200 MeV
- Each square is an bin in $\cos\theta$ of the π^+.
- Y-axis is the value of the observable.
- X-axis is the ϕ of the π^+.
- Once we bin in the second angle (ϕ of the π^+) we see a non-zero value for I^s.
- I^s is antisymmetric around the origin.

Preliminary Results : I^s

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

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



- Red = PARA/AMO
  Green = PERP/AMO
- 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^+.
- Once we bin in the second angle (ϕ of the π^+) we see a non-zero value for I^s.
- I^s is antisymmetric around the origin.

Summary

- There is a high amount of statistics available in the g8b data set for the study of the $\gamma p \rightarrow p\, \pi^{+}\pi^{-}$ channel.
- The first (preliminary) measurements of I^{s} and I^{c} for $\gamma p \rightarrow p\, \pi^{+}\pi^{-}$ have been made.
- The measurement of these polarization observables as well as others are key to understanding the issue of “missing” resonances seen in CQMs.
- Polarized photoproduction experiments will provide insight into these elusive states.

END