Baryon Spectroscopy with CLAS

Volker Credé

Florida State University
Tallahassee, FL

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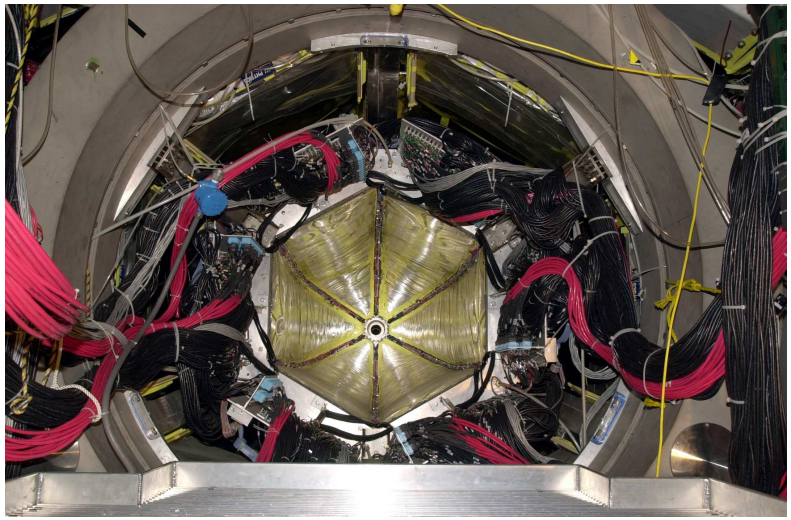
Outline



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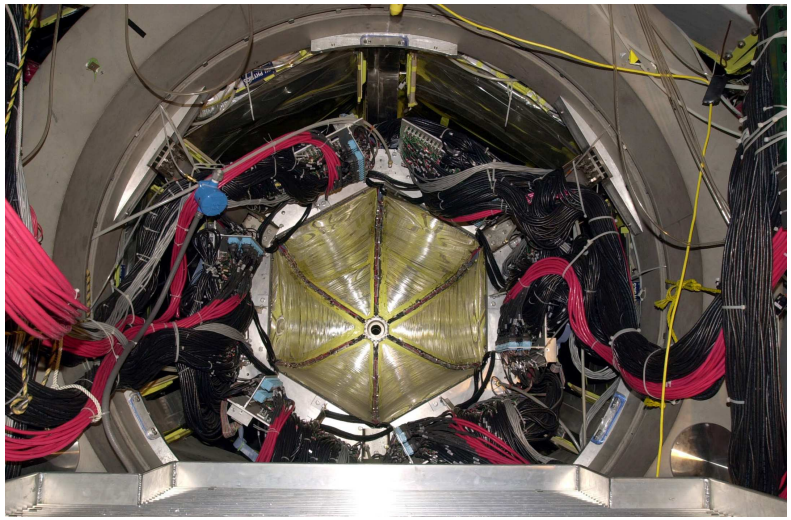


General Physical Motivation

Search for *missing* resonances

Quark models predict many more baryons than have been observed

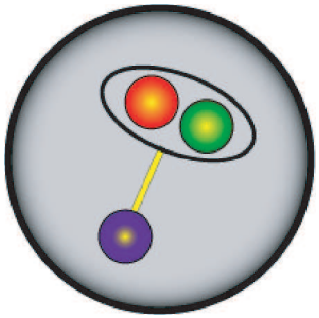
	****	***	**	*
N Spectrum	11	3	6	2
Δ Spectrum	7	3	6	6

$\Rightarrow$ according to PDG
(Phys. Rev. **D66** (2002) 010001)

$\Rightarrow$ little known
(many open questions left)

Possible solutions:

1. Quark-diquark structure



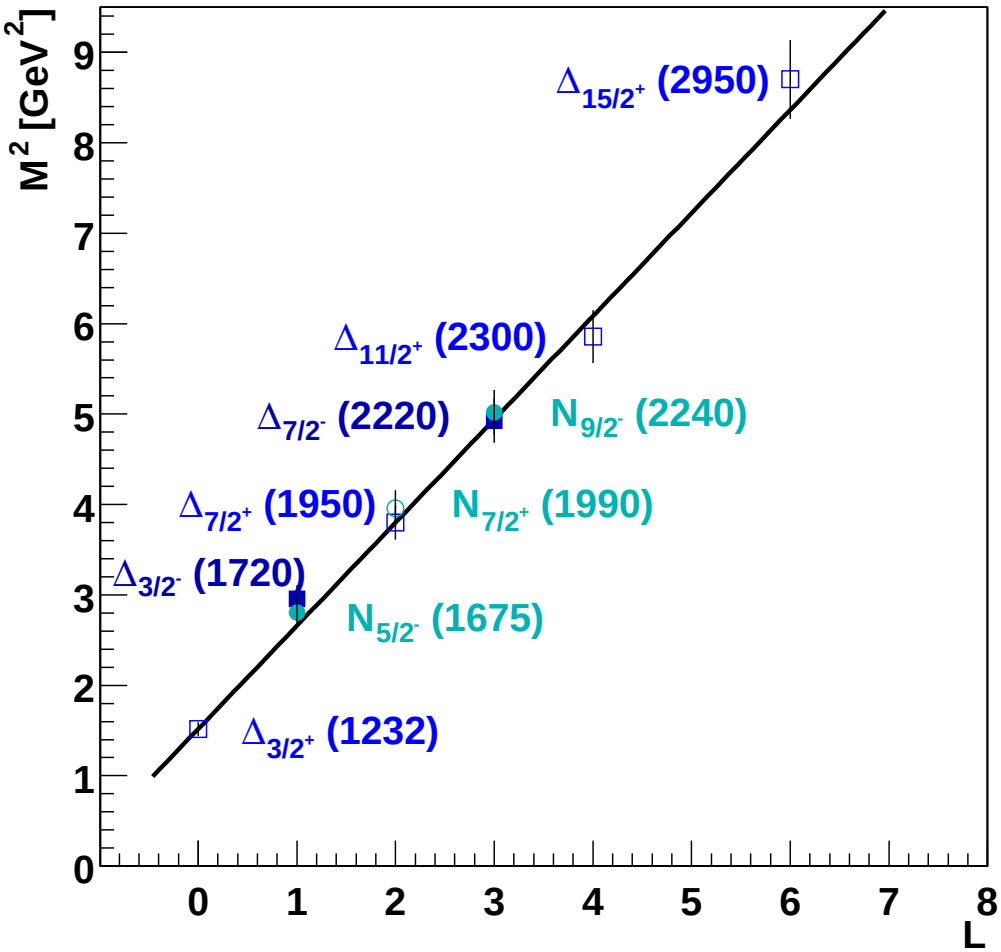
one of the
internal degrees
of freedom
is frozen

2. Have not been observed, yet

Nearly all existing data result from
πN scattering experiments

➜ If the missing resonances did not couple to Nπ, they would not have been discovered!!

Possible Quark-Diquark Structure?



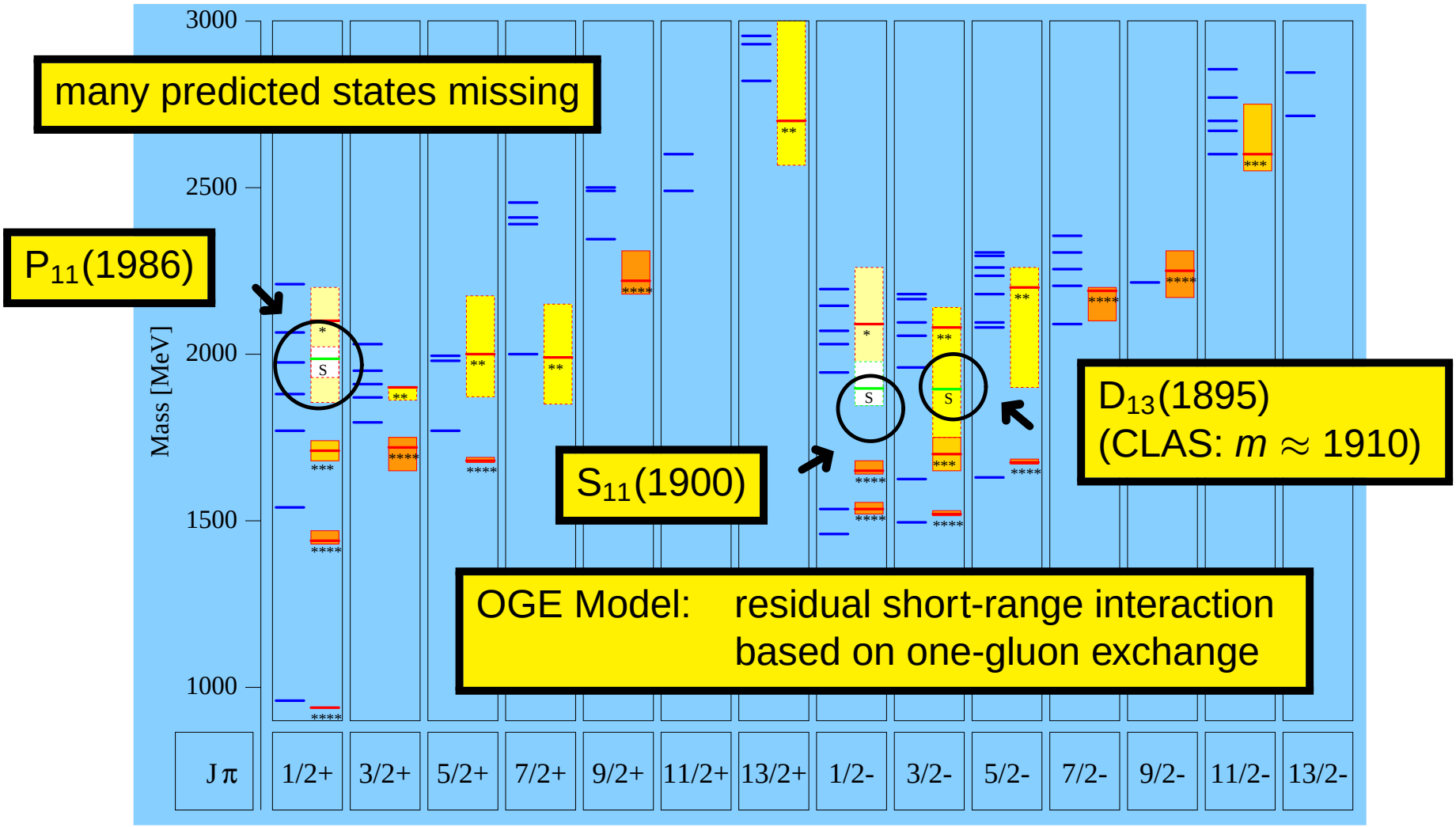
Regge trajectory for Δ^* states with intrinsic spin $S = 1/2$ and $S = 3/2$, and for N^* states with spin $S = 3/2$ (M^2 versus L, not J)

1. Common Regge trajectory for N/Δ states with $S = 3/2$
2. Not shown, but slope of the Regge trajectory for meson and Δ excitations is identical

➜ Are baryons quark-diquark excitations?

Nucleon Resonances: Status

S. Capstick and N. Isgur, Phys. Rev. **D34** (1986) 2809



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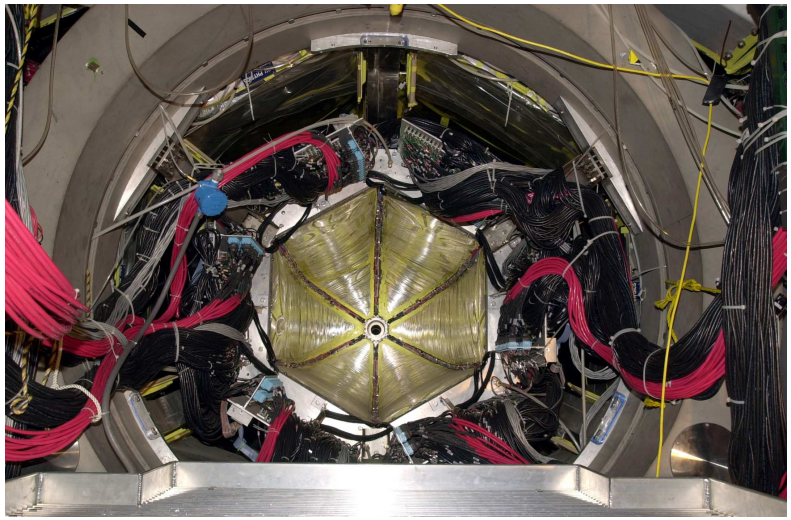


The CLAS Polarization Program

The Double-Polarization Program (FROST) at JLab:

- E 02-112 $\Rightarrow$ *Photoproduction of Hyperons* ($K^+\Lambda$ (Σ^0), $K^0\Sigma^+$)
- E 03-105 $\Rightarrow$ $\pi^0 p$, $\pi^+ n$ *Photoproduction*
  E 04-102
- E 05-012 $\Rightarrow$ η *Photoproduction*
- E 06-013 $\Rightarrow$ $\pi^+\pi^-$ *Photoproduction*

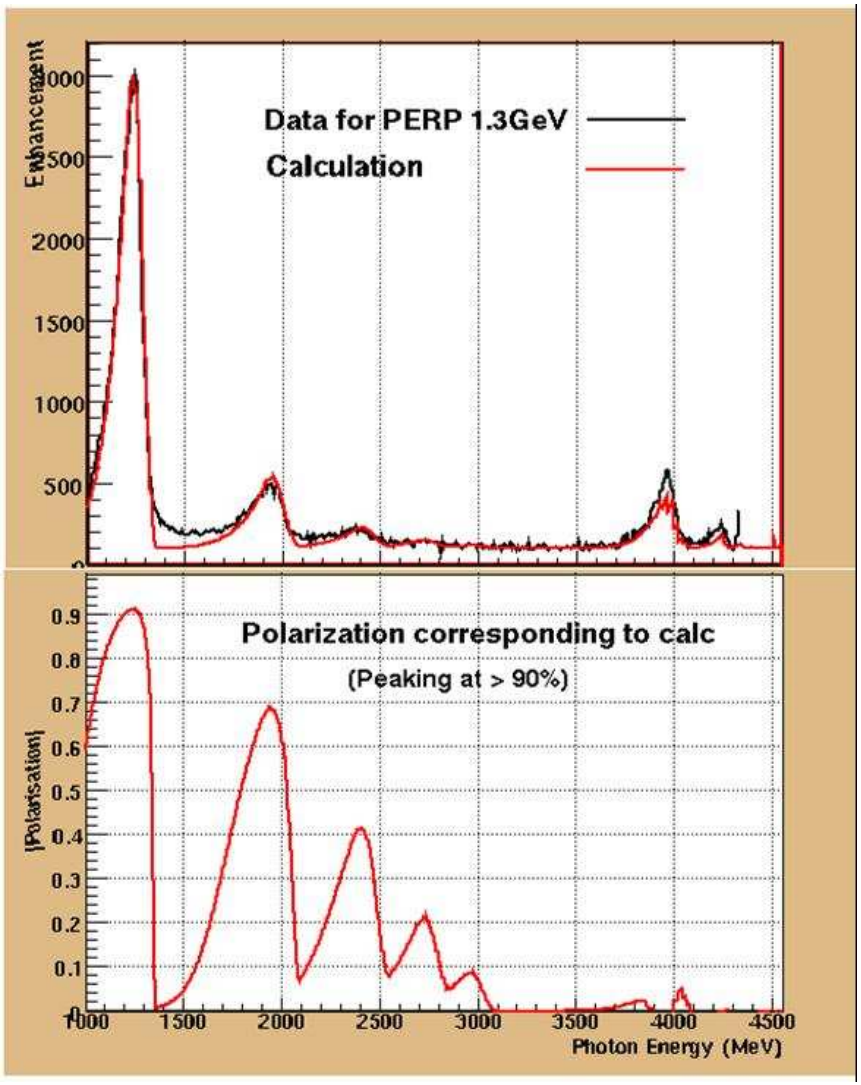
The Polarized Deuterium-Target Program (HD-Ice target from BNL):

- E 06-101 $\Rightarrow$ $\gamma n \rightarrow \pi^- p$, $\pi^+\pi^- n$, $K\ Y$ ($K^0\Lambda$, $K^0\Sigma^0$, $K^+\Sigma^-$)

Polarized photon beams on unpolarized targets:

- g1, g8 $\Rightarrow$ Reactions on Hydrogen ($\checkmark$)
- g13 $\Rightarrow$ Reactions on Deuterium ($\checkmark$)

The Coherent Bremsstrahlung Facility at CLAS

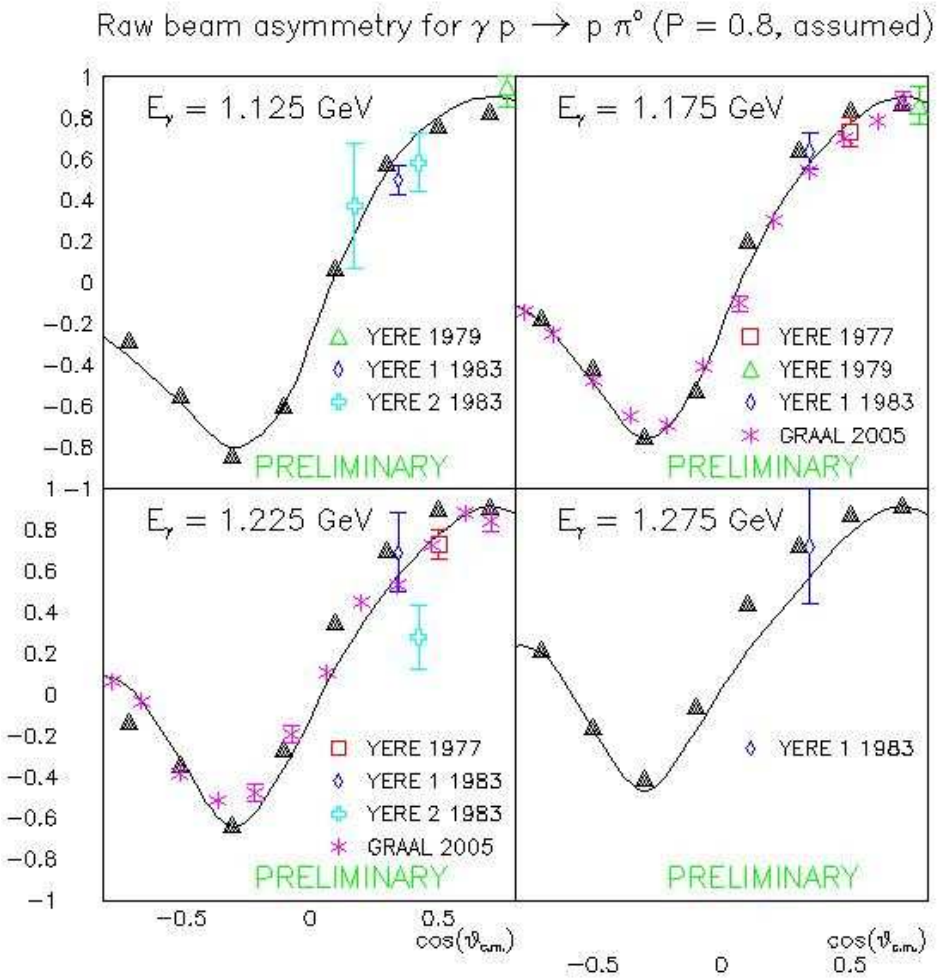


g8b Run Group (data from 2005)

Bremsstrahlung in 50 μ diamond:

- 40 cm liquid hydrogen target located 20 cm upstream
- Two linear polarization states (vertical & horizontal)
- Incident electron energy from CEBAF of 4.55 GeV
  ➜ 1.0 GeV < E_γ < 2.1 GeV
- Single-charged particle trigger

Linearly-Polarized Beam at JLab: g8b Run Group

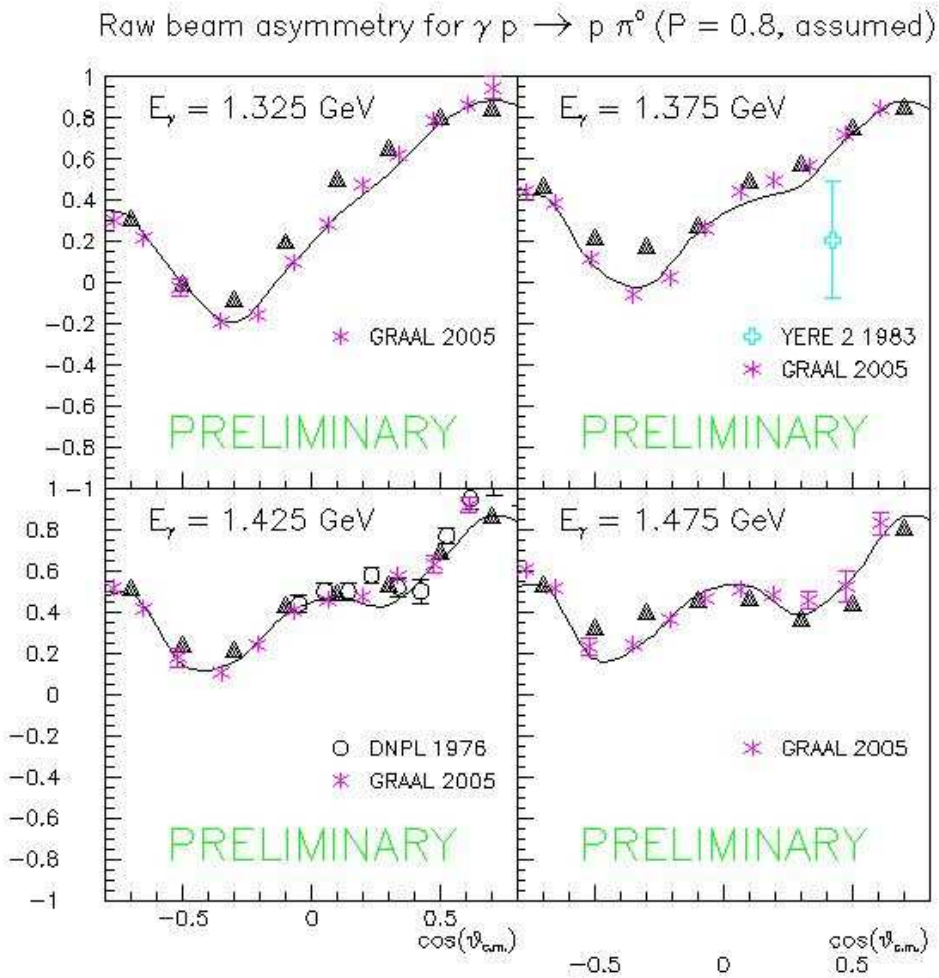


- Many channels being analyzed:
- High statistics > 10 billion events
- High photon polarization from 1.3 – 2.1 GeV

⇐ Preliminary analysis of $\gamma p \rightarrow p\pi^0$ (Mike Dugger, ASU)

- P_γ estimated at 0.8
- — SAID prediction
- Data with statistical errors (no systematic)

Linearly-Polarized Beam at JLab: g8b Run Group

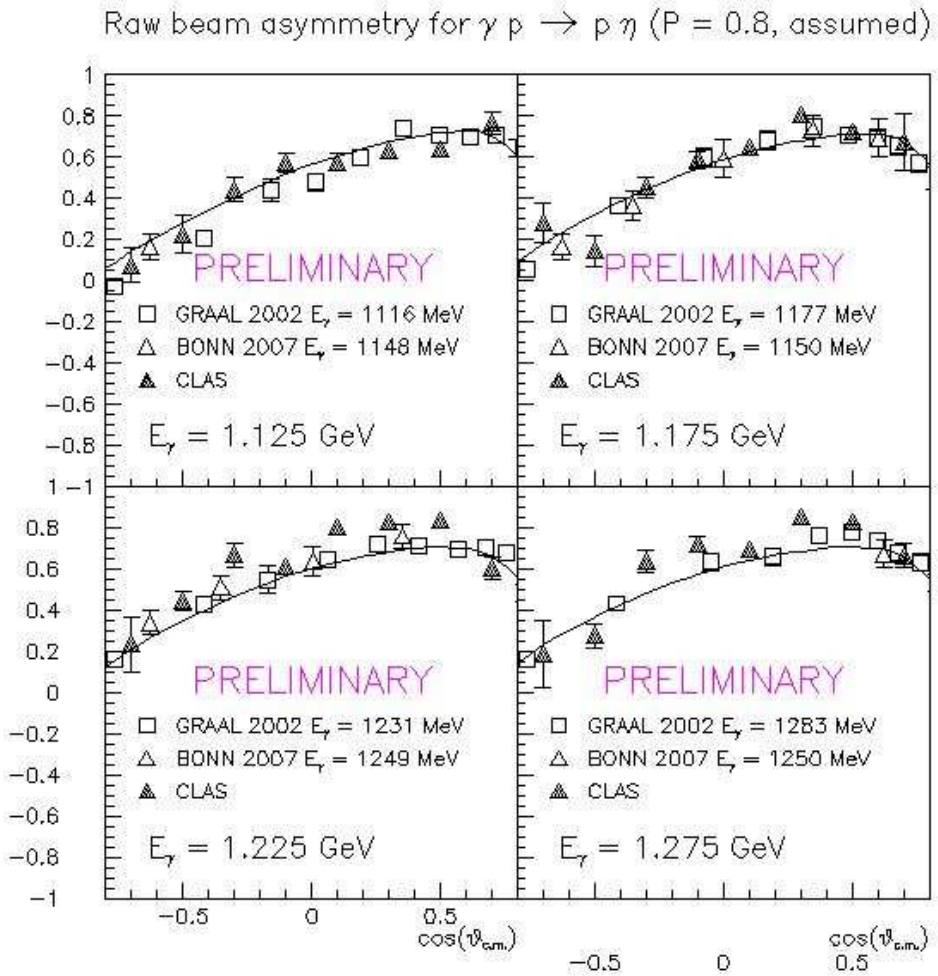


- Many channels being analyzed:
- High statistics > 10 billion events
- High photon polarization from 1.3 – 2.1 GeV

⇐ Preliminary analysis of $\gamma p \to p\pi^0$ (Mike Dugger, ASU)

- P_γ estimated at 0.8
- — SAID prediction
- Data with statistical errors (no systematic)

Linearly-Polarized Beam at JLab: g8b Run Group



Good agreement with other data

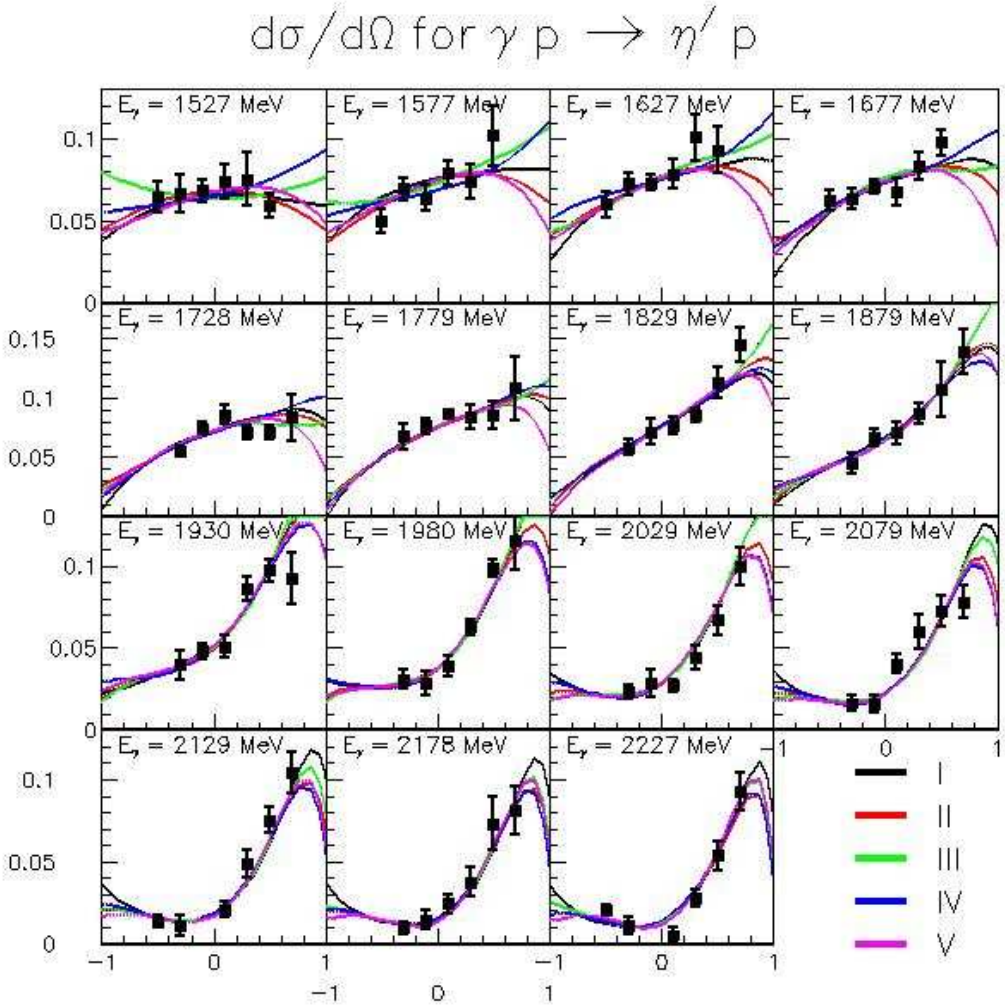
- Interpretation of Bonn (PWA) and CLAS data (SAID) different:
  $P_{13}(1720) \Leftrightarrow P_{11}(1710)$

Preliminary analysis of $\gamma p \rightarrow p\eta$

(Mike Dugger, ASU)

- P_γ estimated at 0.8
- — SAID prediction
- Data with statistical errors (no systematic)

Linearly-Polarized Beam at JLab: g8b Run Group



Set IV

$N(1535)S_{11}$, $N(2090)S_{11}$

$N(1710)P_{11}$, $N(2100)P_{11}$

$N(1700)D_{13}$, $N(2080)D_{13}$

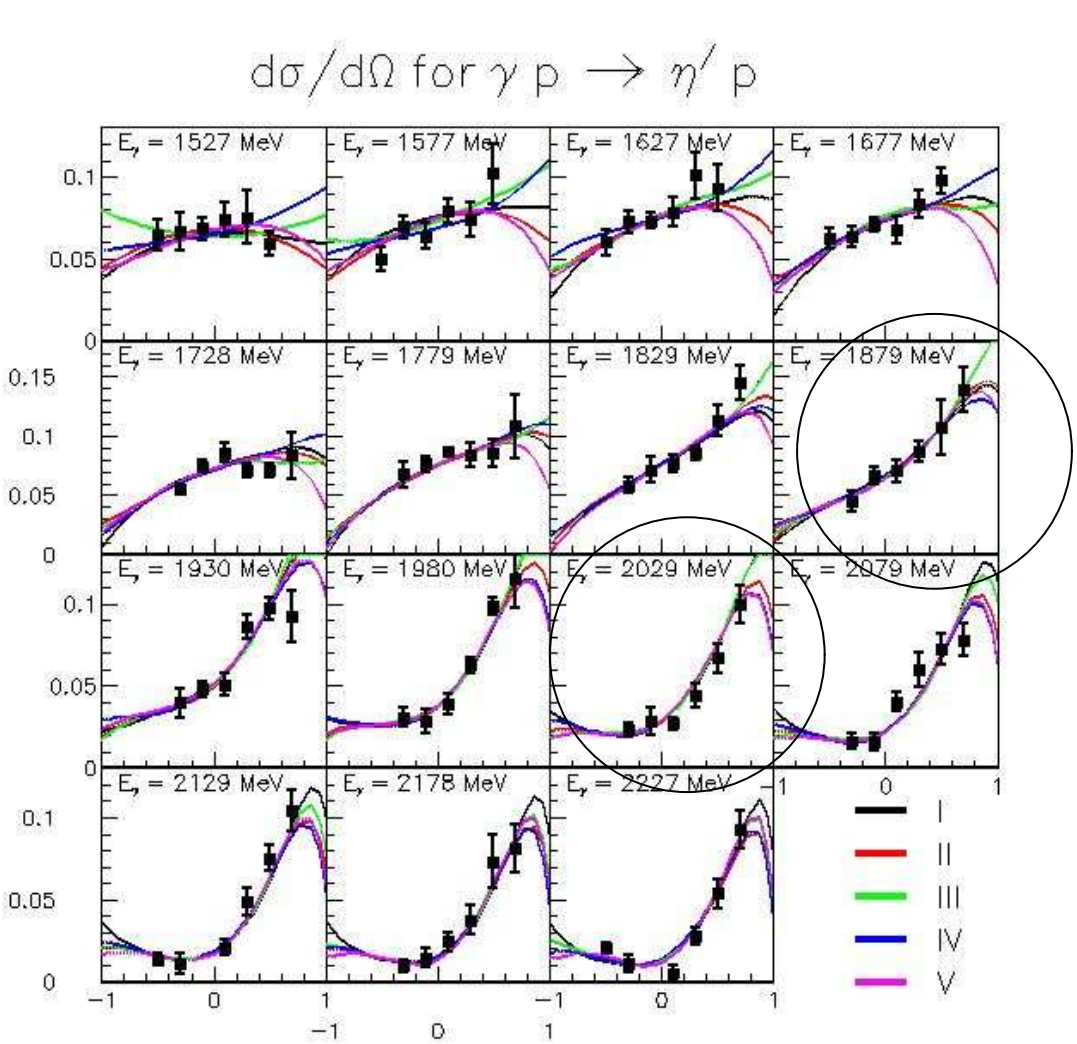
Similar to η analysis:

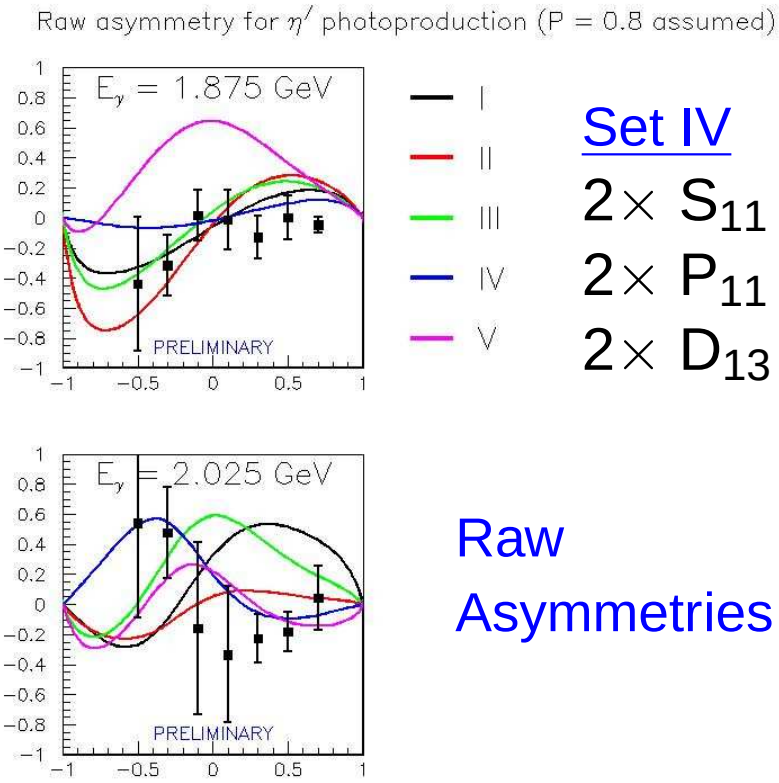
$N(1535)S_{11}$ and $N(1710)P_{11}$ dominant (SAID, MAID)!

Analysis of $\gamma p \rightarrow p\eta\prime$

Phys. Rev. Lett. **96**, 062001 (2006)

Linearly-Polarized Beam at JLab: g8b Run Group





Set IV
$2\times S_{11}$
$2\times P_{11}$
$2\times D_{13}$

Raw Asymmetries

Analysis of $\gamma p \rightarrow p\eta\prime$
Phys. Rev. Lett. **96**, 062001 (2006)

Beam-Target Polarization Observables

$$\frac{d\sigma}{d\Omega} = \sigma_0 \{ 1 - \delta_l \, \Sigma \cos 2\phi + \Lambda_x (-\delta_l \, \mathbf{H} \sin 2\phi + \delta_\odot \, \mathbf{F}) - \Lambda_y (-\mathbf{T} + \delta_l \, \mathbf{P} \cos 2\phi) - \Lambda_z (-\delta_l \, \mathbf{G} \sin 2\phi + \delta_\odot \, \mathbf{E}) \}$$

$\Leftarrow$ Single-Meson Final States (7 Observables)

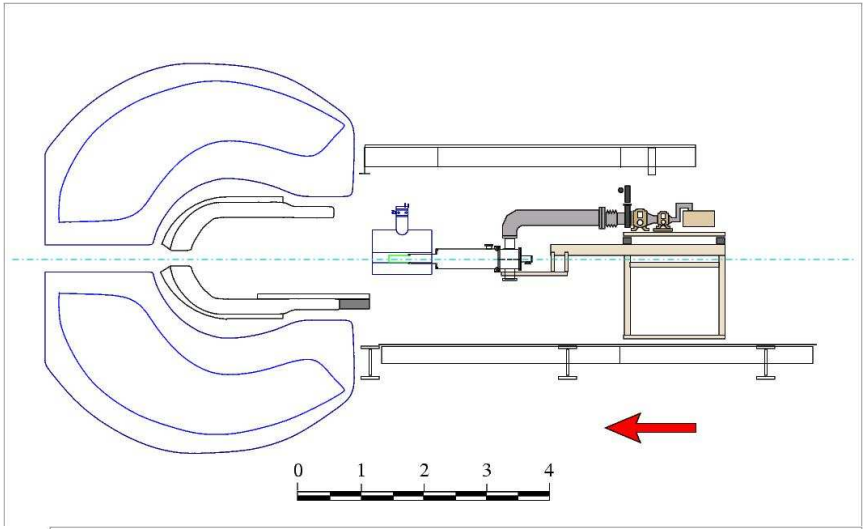
Two-Meson Final States $\Rightarrow$ (15 Observables)

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

Double-Polarization Experiments

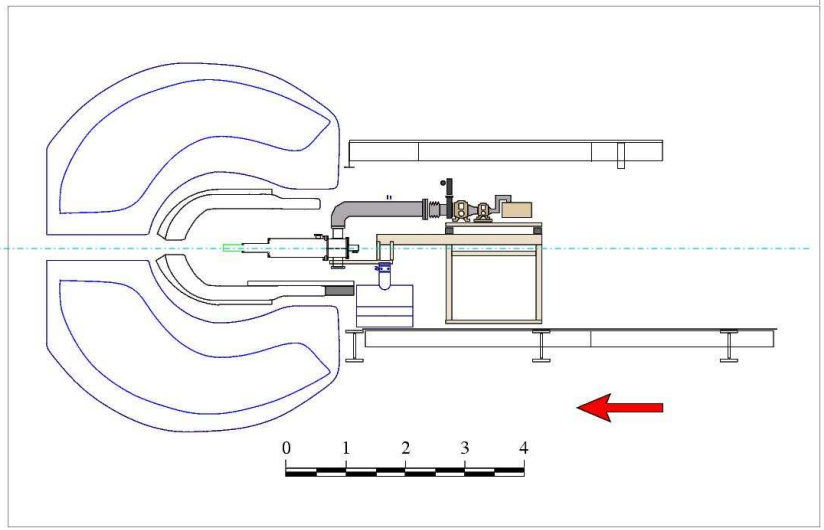
Polarizing Mode

- Microwaves, 5 T magnet ON
- Temperature 0.5 K
- Photon Beam OFF

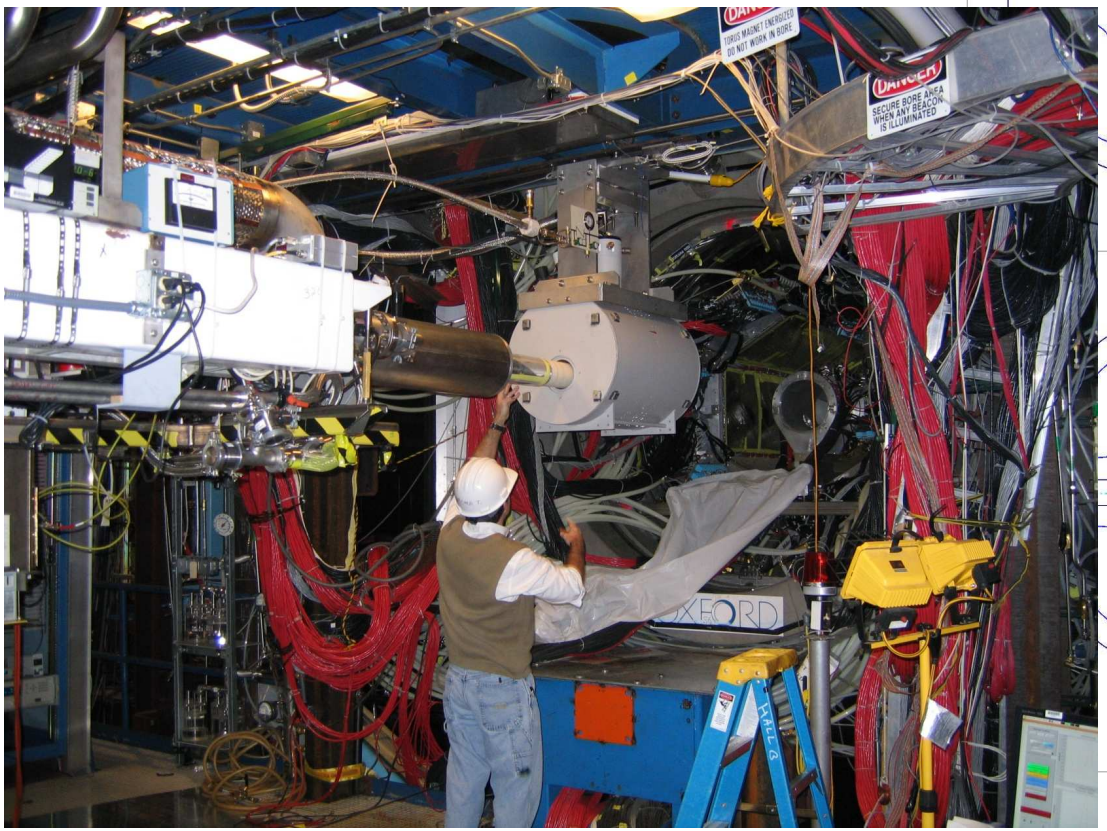


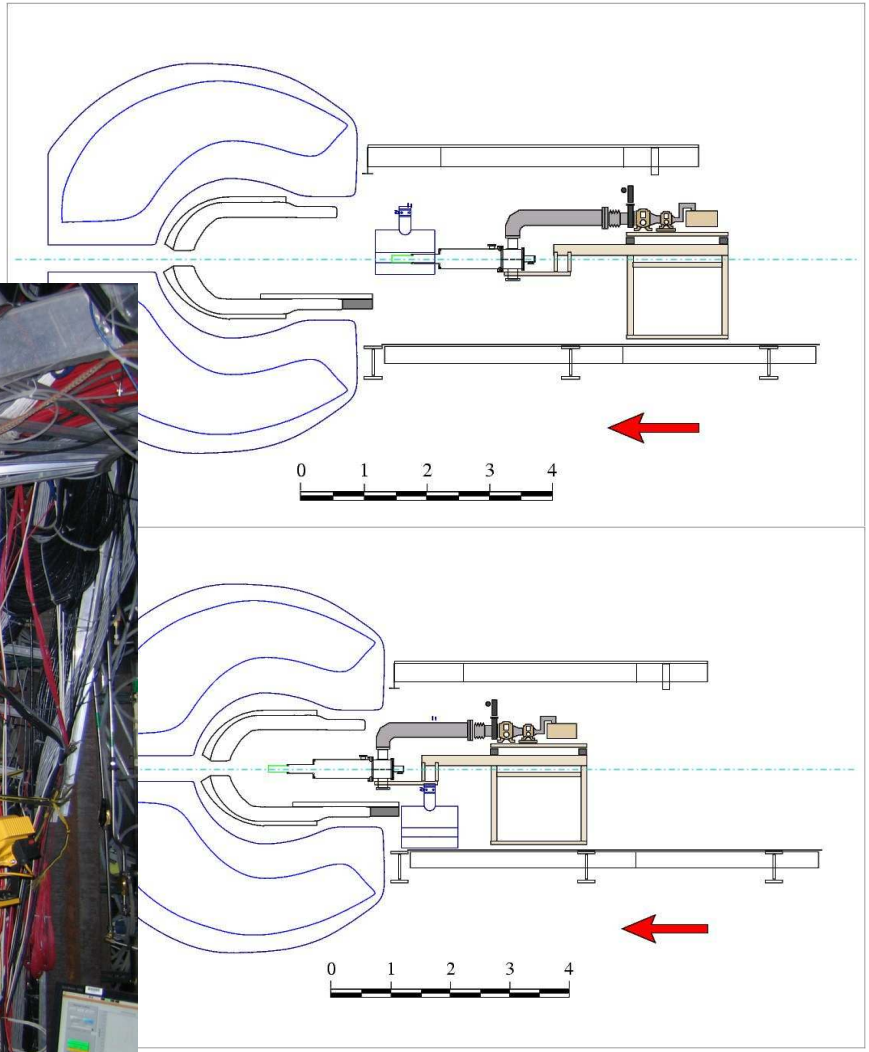
Frozen-Spin Mode

- Microwaves, 5 T magnet OFF
- 0.5 T holding magnet ON
- Temperature $\sim$ 0.05 K
- Photon Beam ON



Double-Polarization Experiments

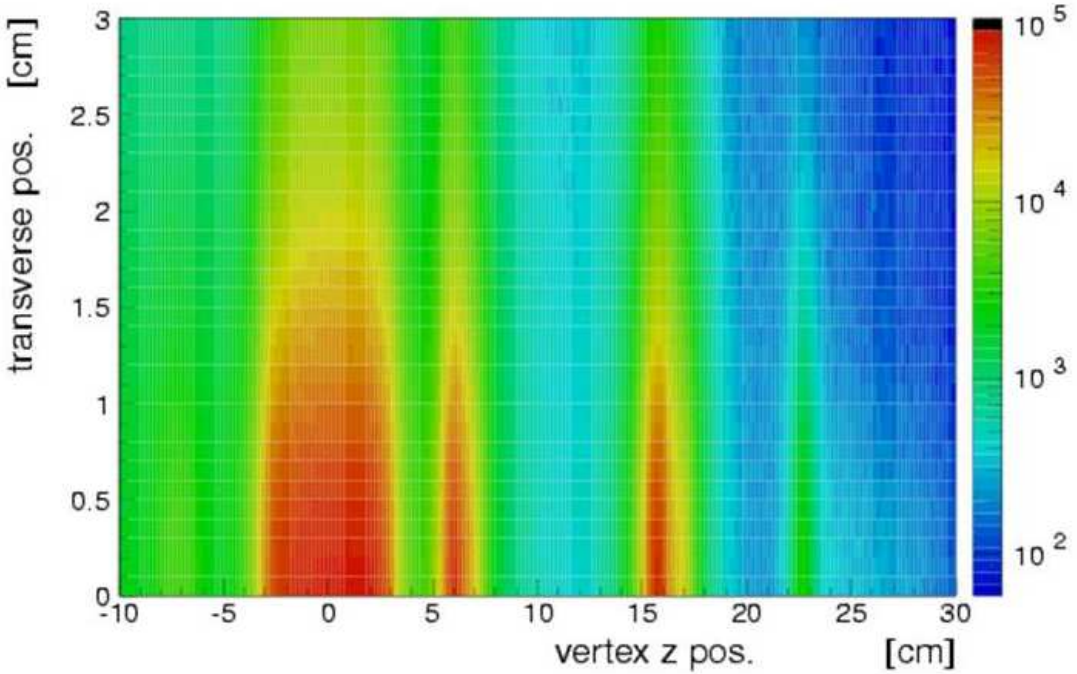




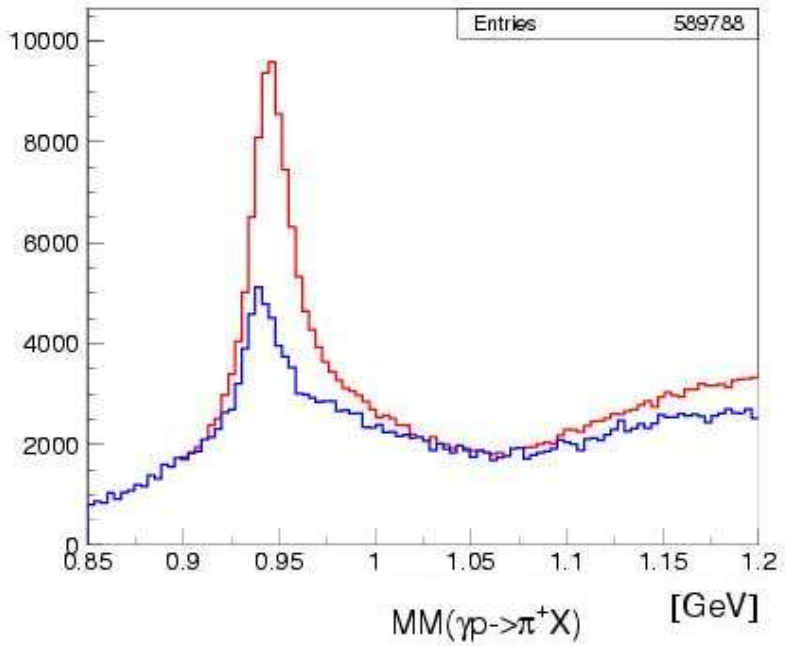
Observation of the Reaction $\gamma p \rightarrow n \pi^+$

Vertex cuts for 3 targets

1. Polarized Butanol
2. Carbon
3. Polyethylene



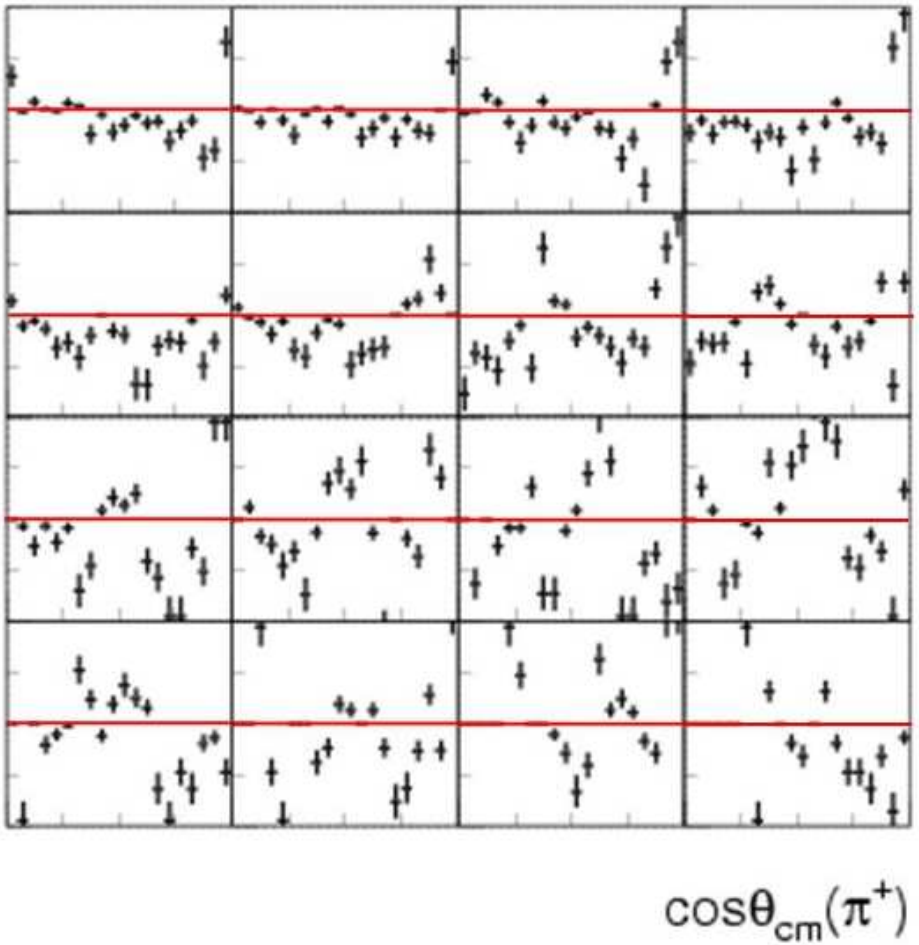
Identification of missing neutron



butanol target

C, CH_2 targets $\times 3.1$

Extremely Preliminary E for $\gamma p \rightarrow n \pi^+$



Experimental Conditions

- Circularly-polarized tagged-photon beam
- Longitudinally-polarized target
- Energy range: 0.6 - 2.4 GeV

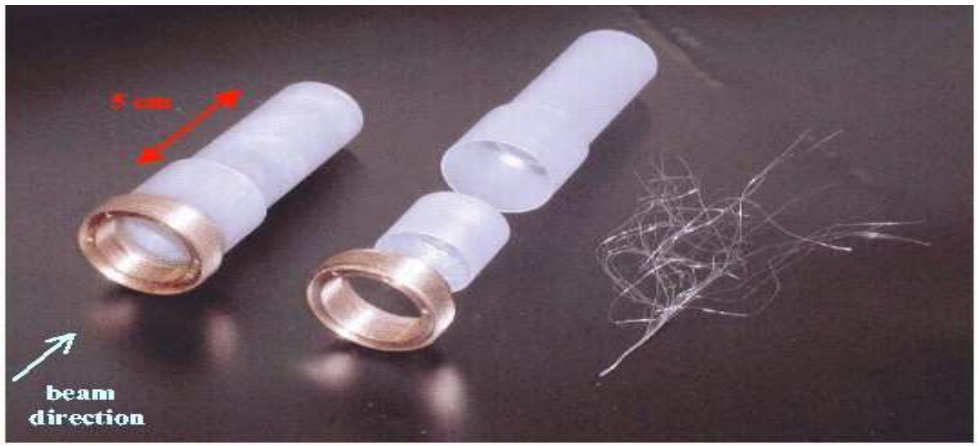
Helicity Asymmetry E

$$\frac{d\sigma}{d\Omega} = \sigma_0 \left[1 - \Lambda_z \, \delta_\odot \, E\right]$$

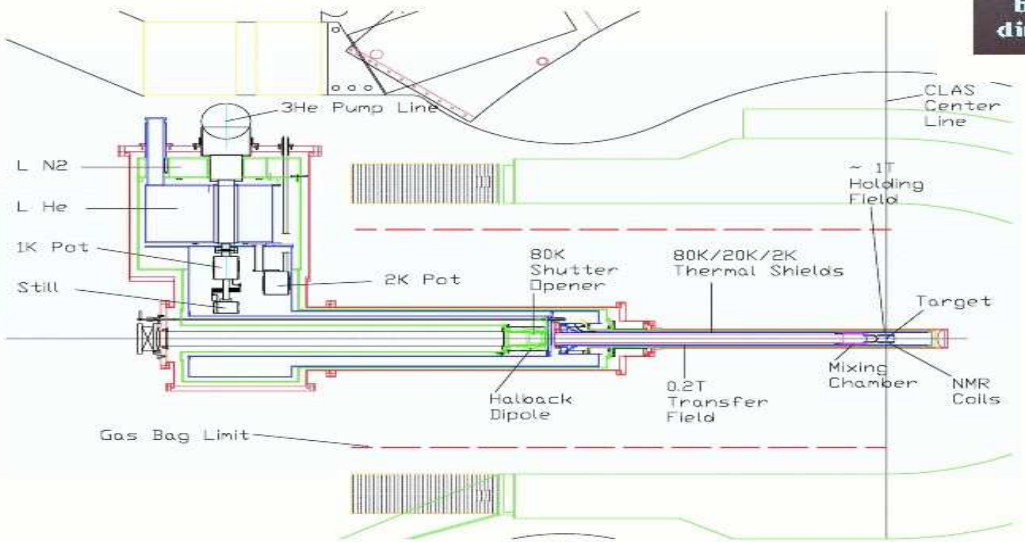
Raw Asymmetry $A = \frac{N^{\leftarrow\Leftarrow} - N^{\leftarrow\Rightarrow}}{N^{\leftarrow\Leftarrow} + N^{\leftarrow\Rightarrow}}$

Polarized Deuterium Target Program (HD Target)

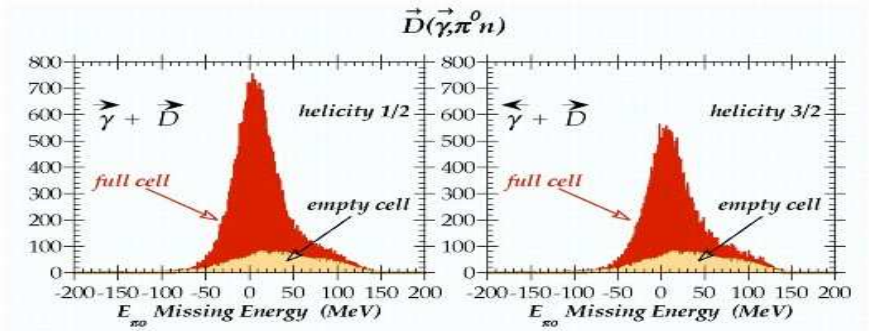
target: Ø25mm x 50mm
3g of solid H-D composite
density: 0.147 g/cm³
2050 cooling wires (Al) Ø50μm
$P_V(D) \sim 40\%$, $P(H) \sim 40\%$ or
$P_V(D) \sim 0\%$, $P(H) \sim 80\%$



In-Beam-Cryostat for CLAS



additional empty cell downstream:
subtraction of Al background



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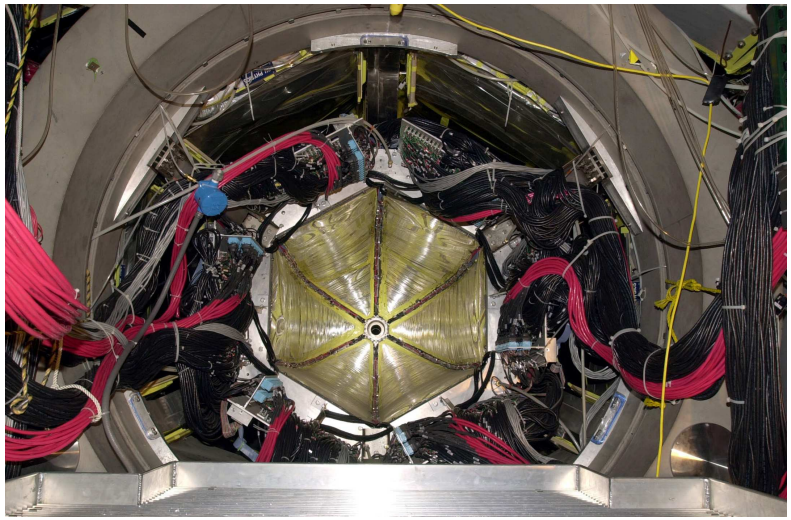

Summary and Outlook

Successful Excited-Baryon Program at JLab using CLAS

- Improved statistics and new data

  World database greatly enhanced during last years!

- Beam asymmetries agree faily well with and improve previous measurements

Double-Polarization Program

- Complete determination of KΛ amplitude
- Almost complete sets for Nπ, Nη, N$\pi\pi$, ...

  FROST-(a) program completed in Spring 2008

  HD program scheduled to run in 2010