

Exclusive Production of Baryon Resonances Using $^1H(e, e'p)X$ Update

Experiment 01-002 at Jefferson Lab in Hall C

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Institutions (Full Listing)

Spring 03 Collaboration

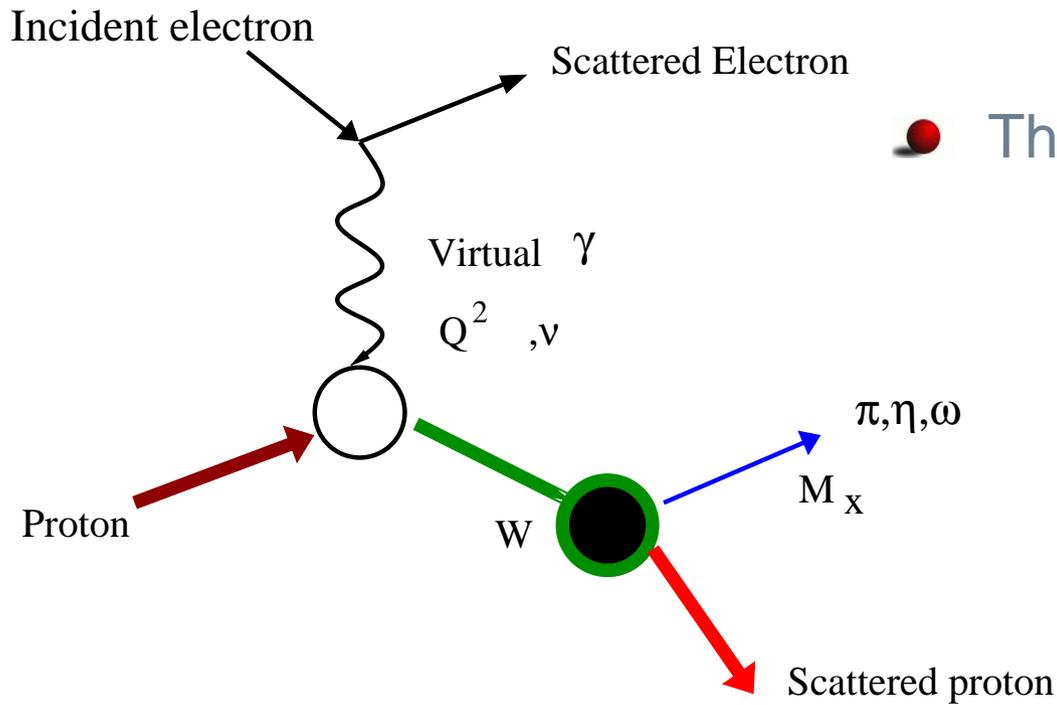
Argonne Nat. Lab., Bucharest, Univ. of Colorado, Duke Univ., Florida Int. Univ., George Washington Univ., Hampton Univ., Jefferson Lab, Mississippi State Univ., Univ. North Carolina A & T, NIKHEF, Rensselaer Polytechnic Institute, Univ. of Regina, Univ. of Massachusetts, Univ. North Carolina at Wilmington, Univ. of Virginia, Yerevan Physics Institute, Ohio Univ., Univ. of the Witwatersrand, Univ. of Houston

Goals of the Experiment

- Baryon resonances $\Delta(1232)$ and S_{11} studied to extract **transition amplitudes** for exclusive π^0, η, ω production
- Differential cross sections extracted and used to determine **multipole** transition amplitudes at larger value of Q^2 than previously achieved
- **Transition to pQCD** will be studied through the Q^2 dependence of the quantity $E2/M1$ on the Δ (should approach unity in pQCD)
- W range of the experiment is expanded since the last installment in 1997 (experiment 97-101)
- Transition **form factors** extracted for $\Delta(1232)$ and S_{11} at the highest Q^2 thus far



Electro-production Process



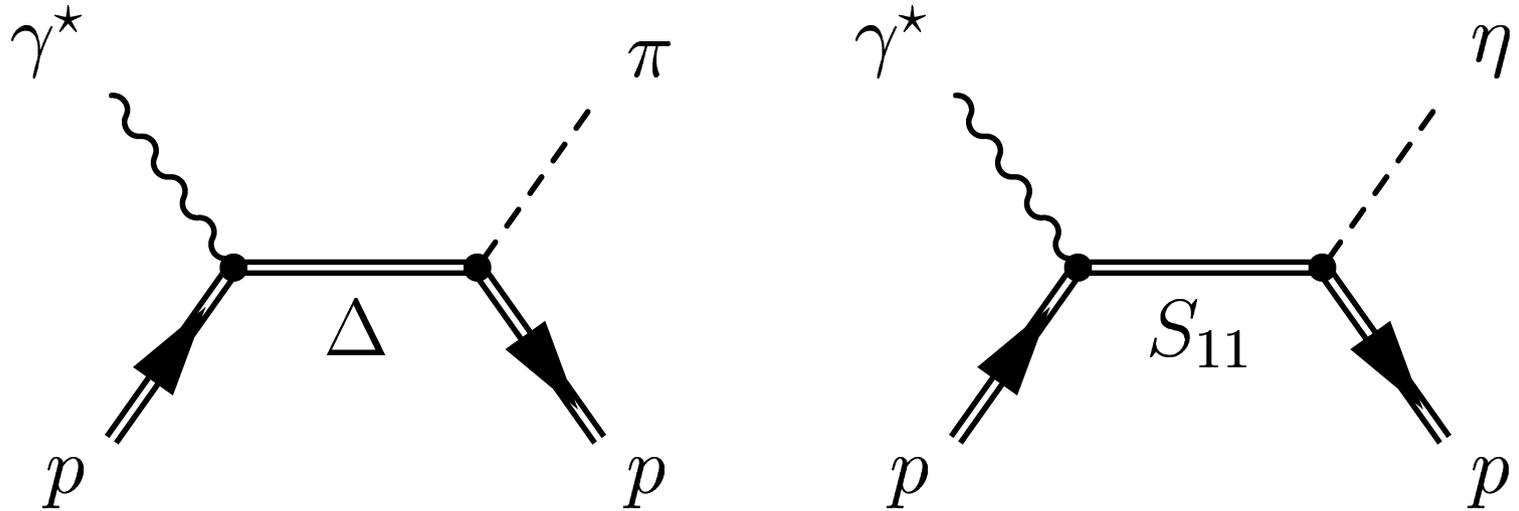
● The reactions for this analysis are:

$$\gamma^* + p \rightarrow (N^*, \Delta) \rightarrow p + \pi^0$$

$$p + \eta$$

$$p + \omega$$

Resonance Production (Δ, S_{11})



- Restriction to Δ, S_{11} decreases the number of independent functions to three
- Functions can be represented:

$$G^{\pm,0} = \frac{1}{2M} \langle (\Delta, S_{11}), \lambda_{res} | \epsilon_{\mu}^{\pm,0} J_{had}^{\mu} | P, \lambda_p = \pm \frac{1}{2} \rangle$$

Multipole Definition

- For strictly pseudoscalar meson production one can expand matrix element according to total angular momentum, i.e. :

$$\langle N\pi | \vec{J}_{had} | N \rangle = (\chi^\dagger \vec{\sigma} \chi) \sum_{l \geq 0} \left[\left(l M_{l+} + E_{l+} \right) P'_{l+1} + \left((l+1) M_{l-} + E_{l-} \right) P'_{l-1} \right] \dots$$

- Considering only Δ production reduces the number of multipoles

$$A_{\frac{1}{2}} \propto G^+$$

$$A_{\frac{3}{2}} \propto G^-$$

$$C_{\frac{1}{2}} \propto G^0$$

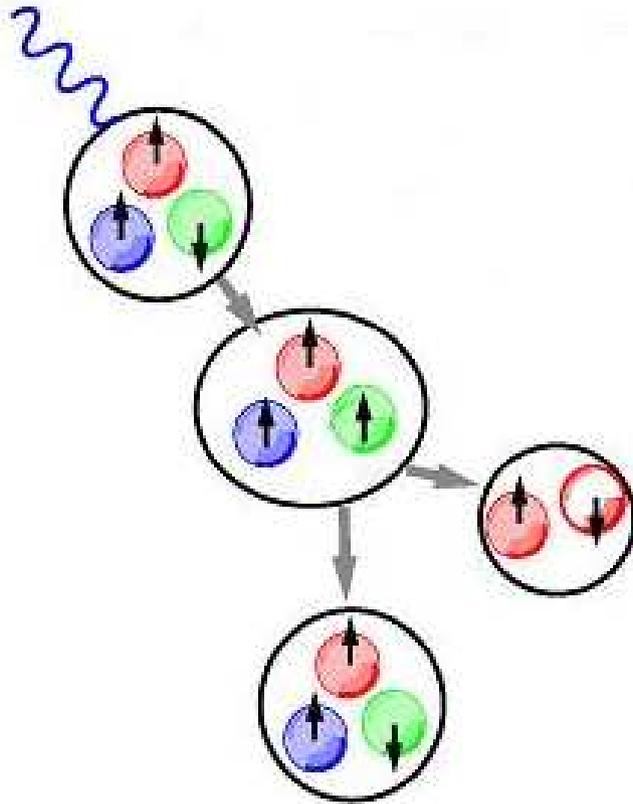
- Also These can be related (through $E_{l\pm}$ and $M_{l\pm}$) to E2 and M1:

$$A_{\frac{1}{2}} = -\frac{1}{2}(M1 + 3E2)$$

$$A_{\frac{3}{2}} = \frac{\sqrt{3}}{2}(E2 - M1)$$

$$C_{\frac{1}{2}} = -S2$$

CQM Predictions



- Process described by a single quark spin flip
- Predicts M1 dominance as is seen at low energy

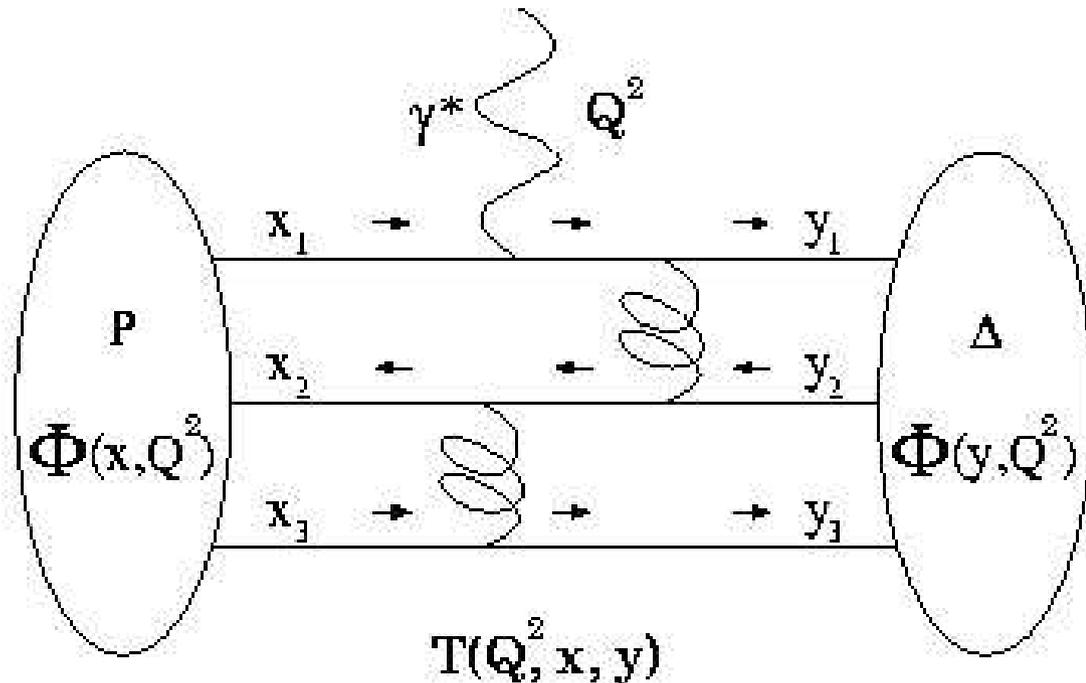
pQCD Limit

- QCD Factorization Theorem

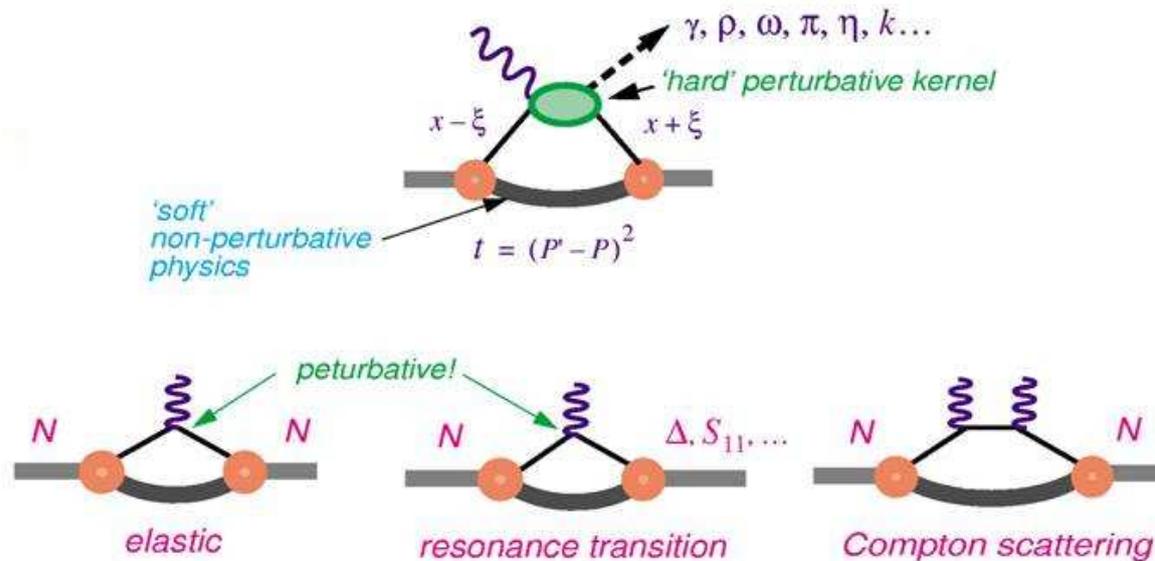
$$\mathcal{A}(Q^2) = \int dx dy \Phi_p(Q^2, x) T(Q^2, x, y) \Phi_\Delta(Q^2, y)$$

- Indications of pQCD

- $G_M^* \sim \frac{1}{Q^4}$
- $A_{\frac{1}{2}} \sim \frac{1}{Q^3}$
- $\frac{A_{\frac{3}{2}}}{A_{\frac{1}{2}}} \rightarrow 0$
- $\left(\frac{E2}{M1}\right)_\Delta \rightarrow 1$

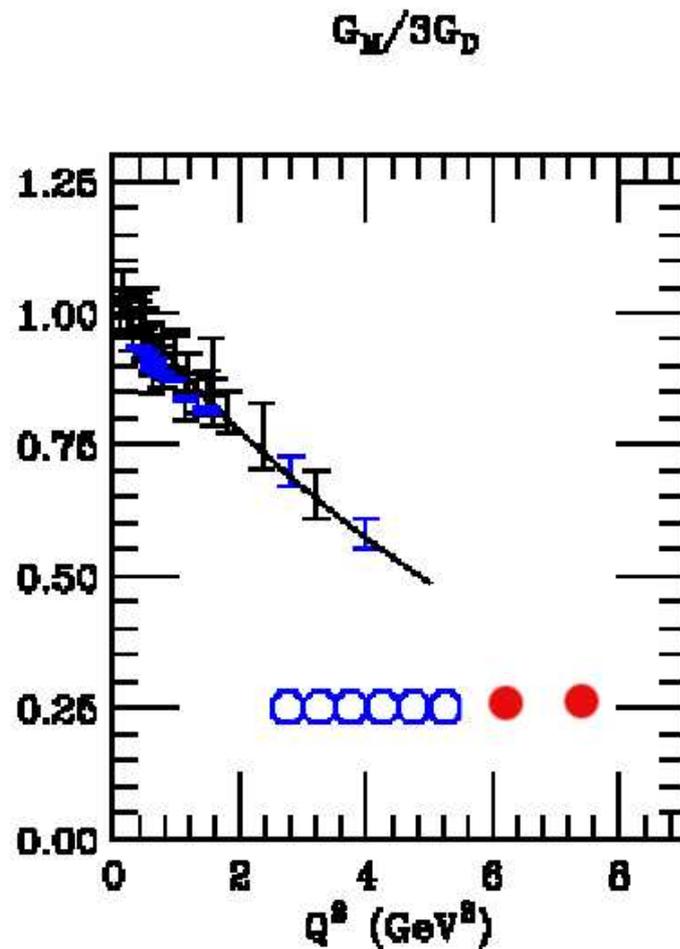


GPD Description



- Parameterize soft non-perturbative physics into a Generalized Parton Distribution
- Full specification of GPD's relates several interactions

Form Factor Data



- Form factor is falling faster than dipole

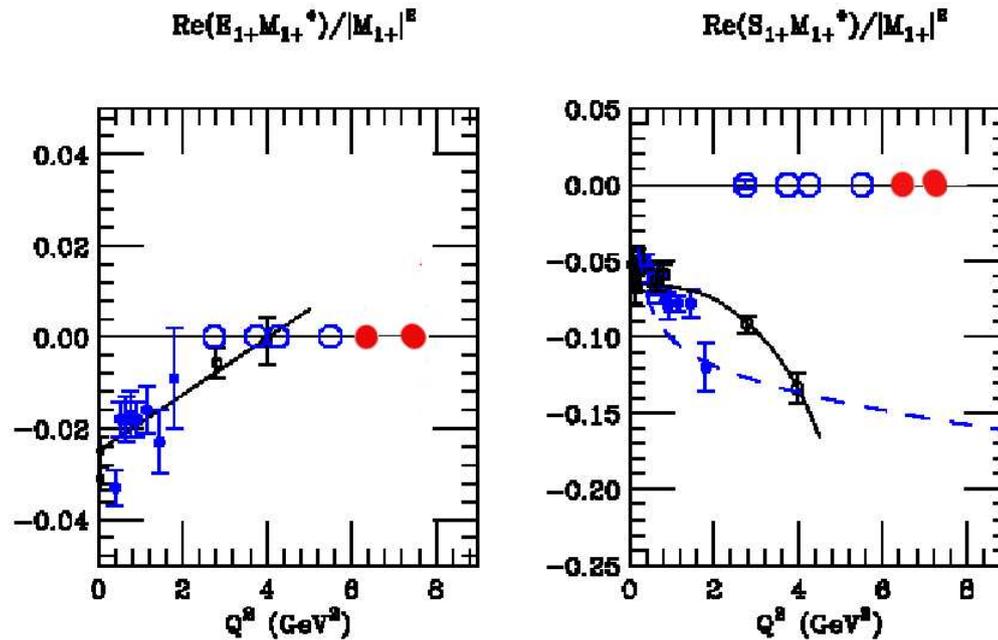
- $G_D = \frac{1}{(1 + \frac{Q^2}{.71})^2}$

- Recall pQCD predicts $\frac{1}{Q^4}$ dependence

- Expected Hall B points shown in blue

- GPD descriptions imply that G_M is directly related to G_{Ep} in the large N_c limit

Multipole Amplitudes



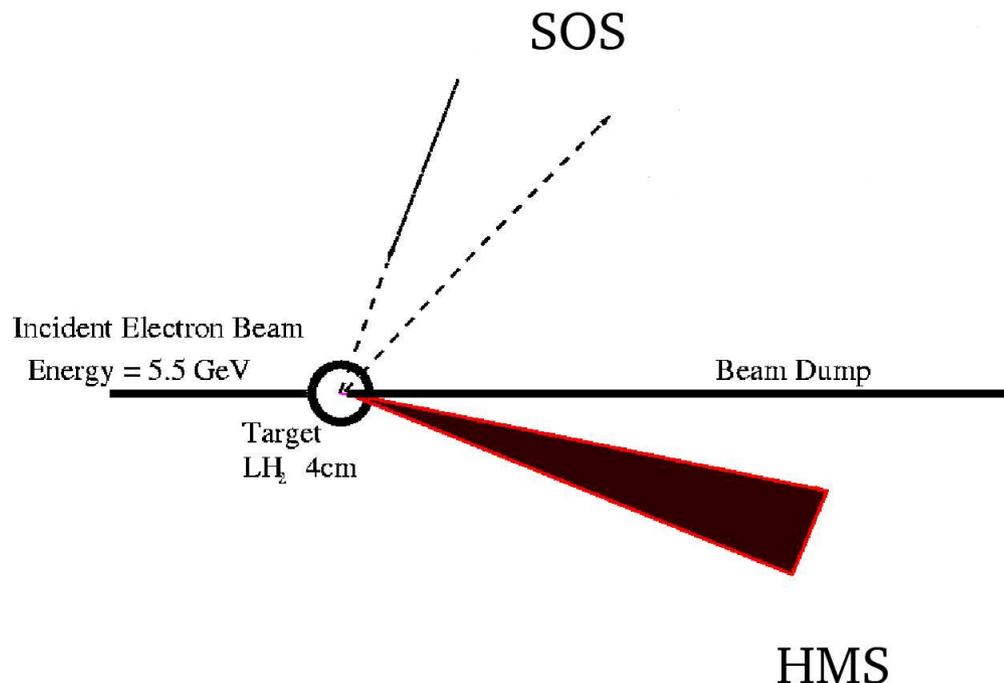
● pQCD limits are not realized in previous measurements

● $\frac{E_{1+}}{M_{1+}} \neq 1$

● $\frac{S_{1+}}{M_{1+}}$ not constant

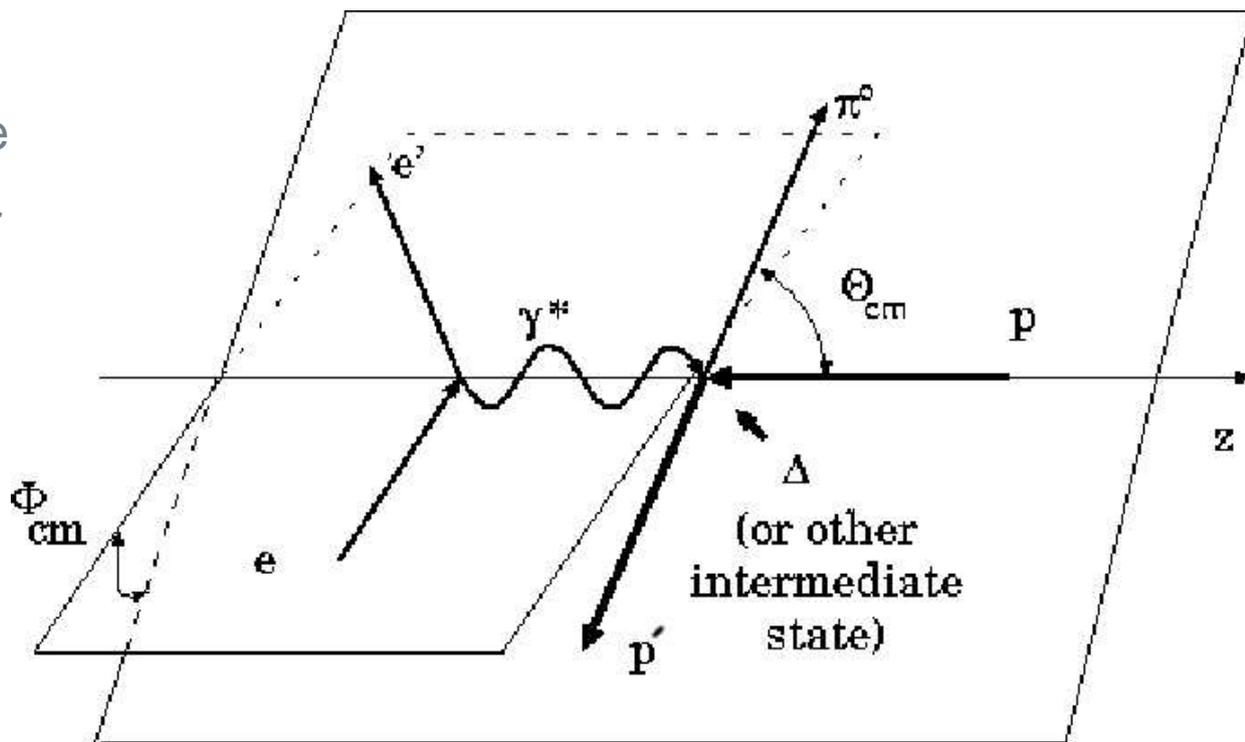
Hall C E01-002 Settings

- $Q^2 = 6.3 \text{ GeV}^2$ setting
 - $2.13 \text{ GeV} \leq P_p \leq 4.7 \text{ GeV}$
 - $11.22^\circ \leq \Theta_p \leq 24.0^\circ$
- $Q^2 = 7.7 \text{ GeV}^2$ setting
 - $3.24 \text{ GeV} \leq P_p \leq 4.7 \text{ GeV}$
 - $\Theta_p = 11.22^\circ, 14.2^\circ$



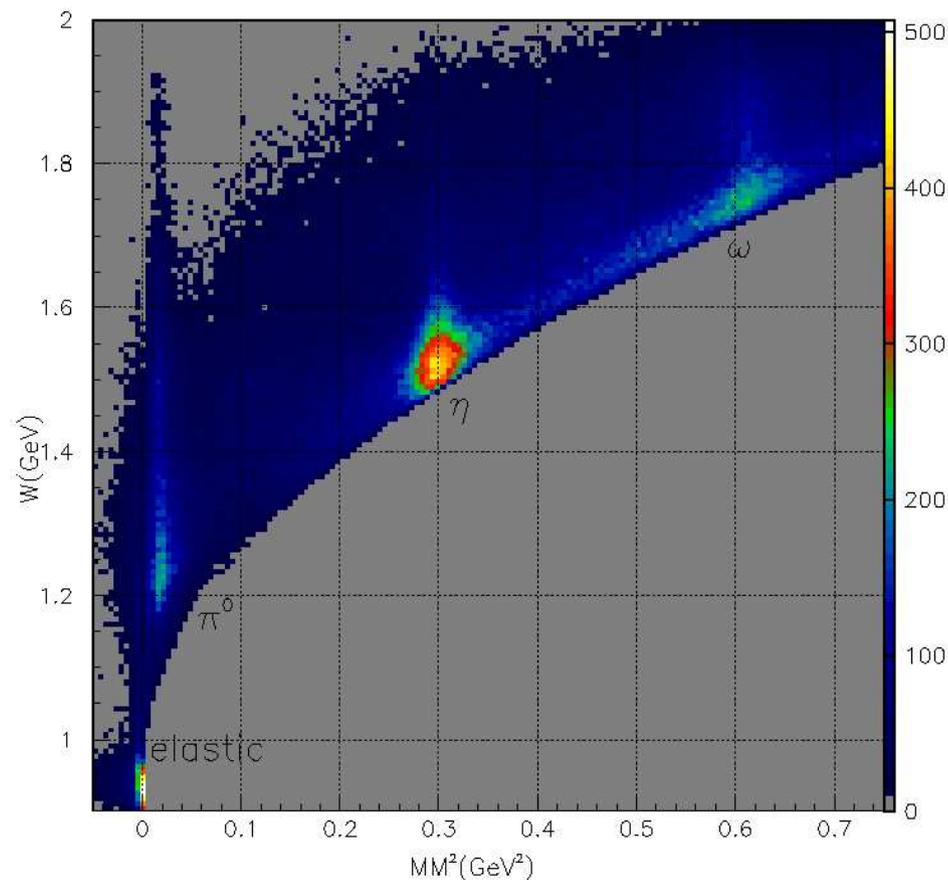
The Reaction Planes

- The center of mass frame is shown where γ^* and p are colinear with equal and opposite momentum

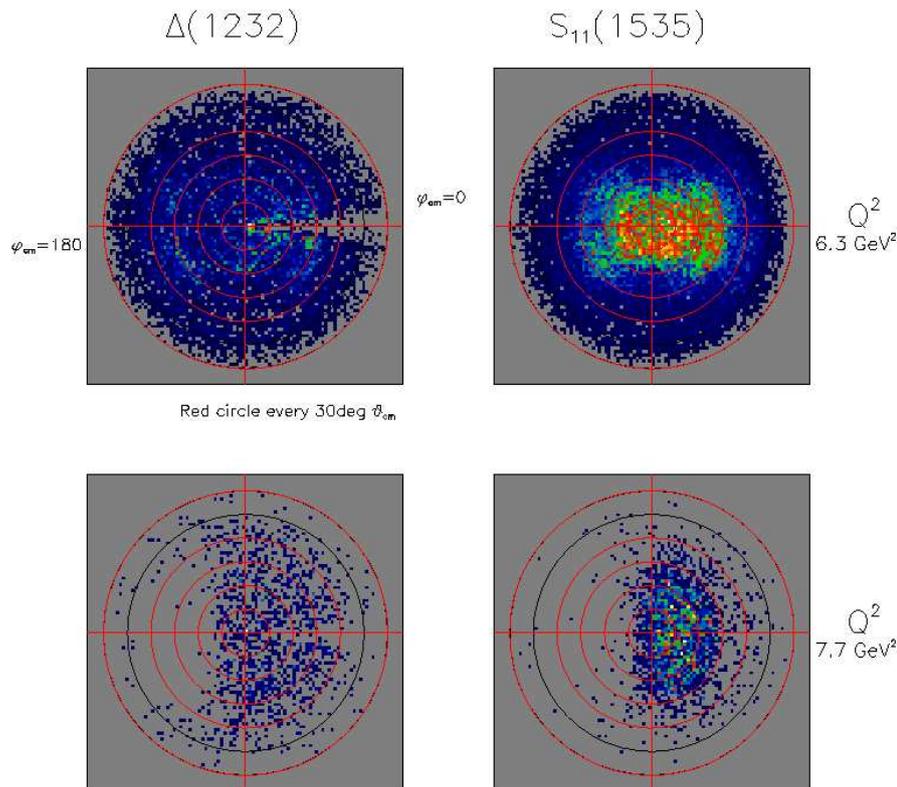


Baryon Resonances

- The $\Delta(1232)$ and S_{11} resonances are clearly correlated with the π^0 and η M_x^2 peaks
- The elastic events clearly come from lower W with some overlap into a higher W region due to pre or post radiation
- The ω meson comes from the largest W region for the experiment



Angular Coverage in CM



● Events on plot are mapped by:

● $x = \theta_{cm} \cos(\phi_{cm})$

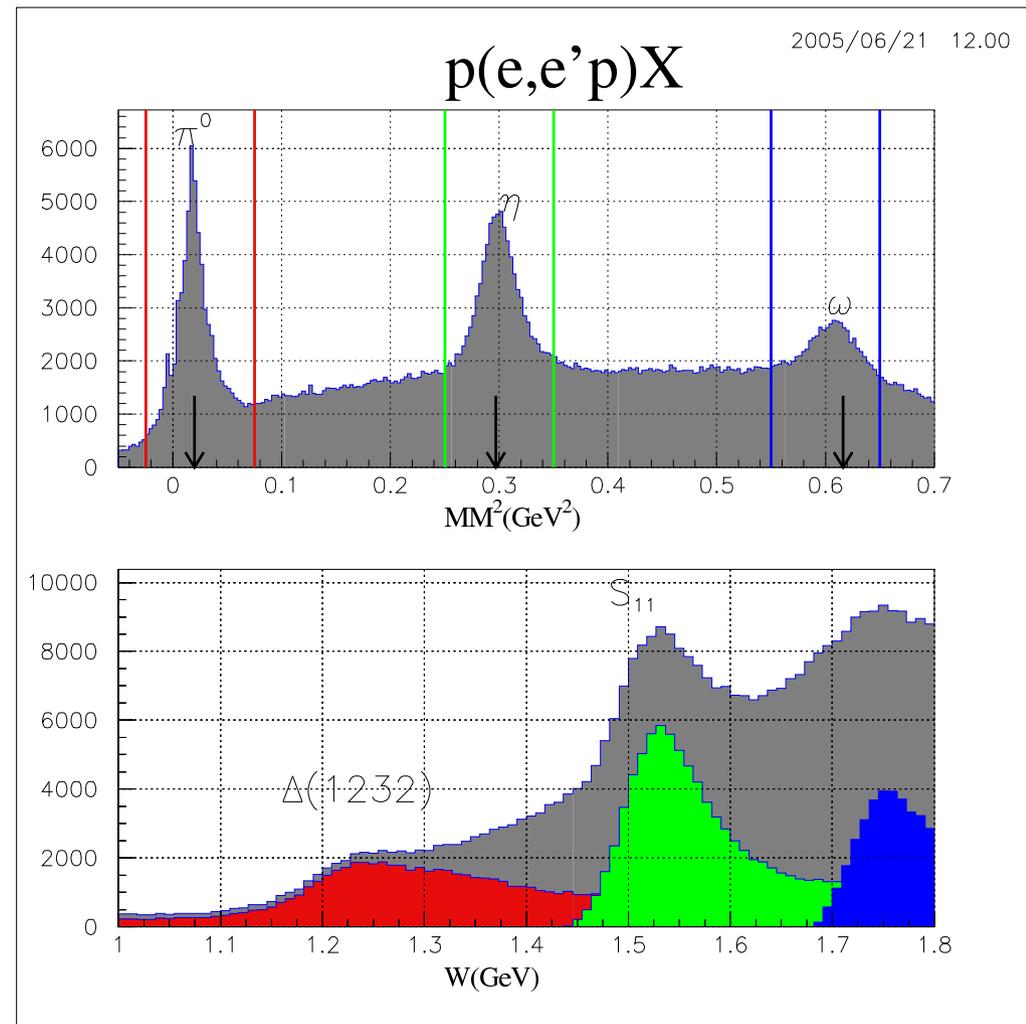
● $y = \theta_{cm} \sin(\phi_{cm})$

● Each concentric circle represents 30 degrees in θ_{cm}

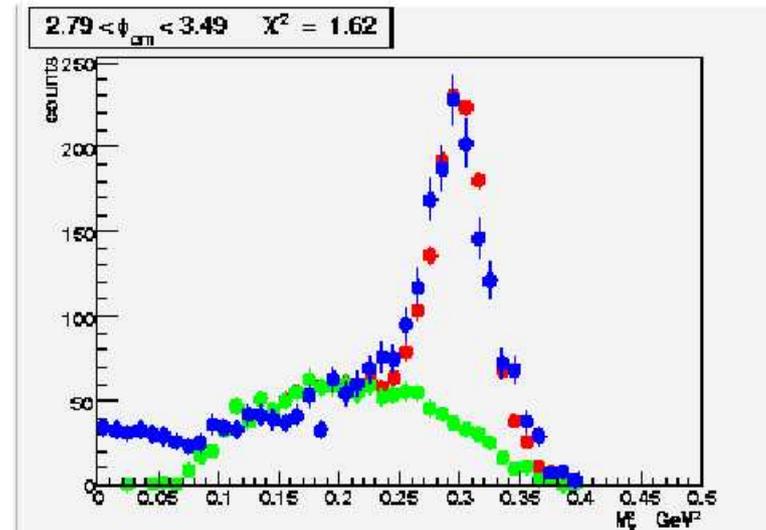
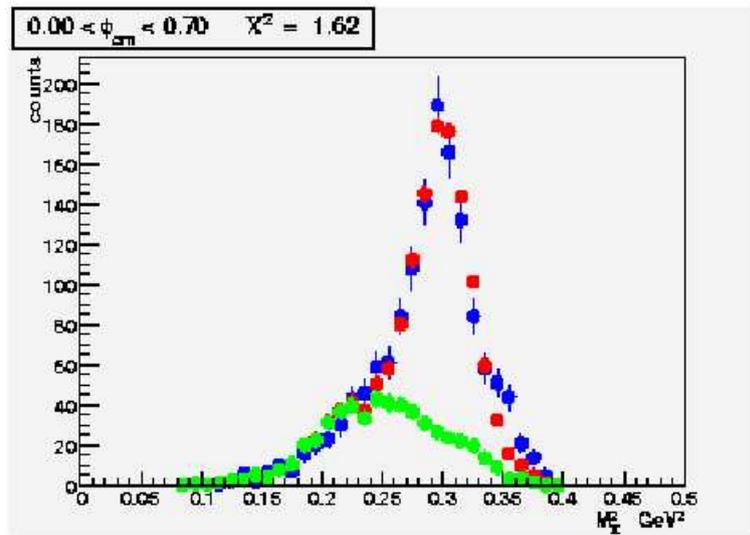
● Shows good coverage of center of mass variables

Exclusive Studies

- The M_x^2 peaks can be used to constrain the reaction and/or baryon resonance
- The M_x^2 resolution for the π^0 allows detailed study of the reaction ${}^1H(e, e'p)\pi^0$
- Exclusive cross sections and amplitudes will be compared to models and previous data



Two π Background

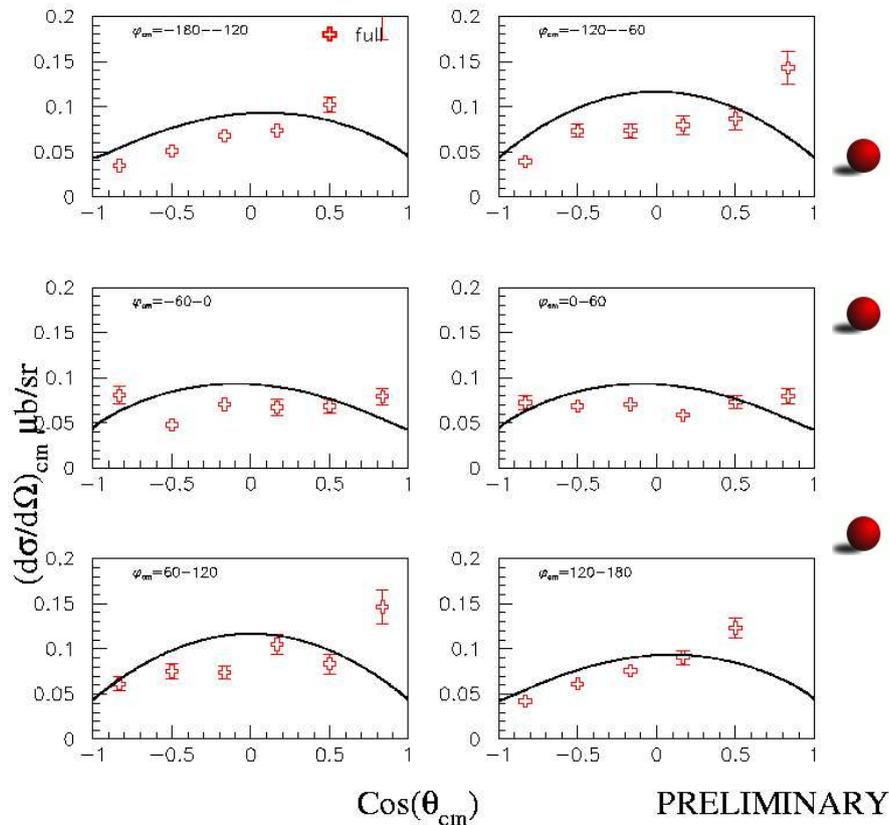


- Two π background model does fairly well but cannot get overall absolute normalization
- Fit the simulated distributions to the overall data spectrum
- Fit is occasionally misled by large tail at low MM^2 (right plot)

Plots courtesy of M. Dalton

$\Delta(1232)$ Differential Cross Section

$W=1.235$ GeV $Q^2=6.3$ GeV²



● Radiative cut utilized, not a full correction

● Seem to see some flattening and forward enhancement this may change as analysis progresses

● 30 MeV W bin on top of the $\Delta(1232)$

Timetable Estimate

- Fully corrected differential cross sections (Projected: March 06)
- Form factors (Projected: April 06)
- Extracted multipoles (Projected: June 06)
- Interpretation and comparison

Summary

- Beam energy of 5.5GeV with two Q^2 settings
 - Measure the cross sections for $^1H(e, e'p)X$, $X = \{\pi^0, \eta, \omega\}$
 - X identified by missing mass, M_x
 - Q^2 of 6.3 and 7.7GeV for Δ resonance
 - Varied proton arm angle and momentum to cover wide range of θ_{cm} and ϕ_{cm} bins for W up to 2GeV
- Physics to extract
 - Plan to extract the G_M^* , E_{1+}/M_{1+} , S_{1+}/M_{1+} for the Δ
 - Plan to extract $Q^3 A_{\frac{1}{2}}$ for the S_{11}
 - Study the transition from *soft* to *hard* physics as a function of Q^2
 - Constrain the t and x dependence of the **GPD** with elastic and transition form factors and wide angle Compton form factors