Neutral Pion Electroproduction in the Δ Resonance Region

A Study of the $6.36 \leq Q^2 \leq 7.7$ *Region*

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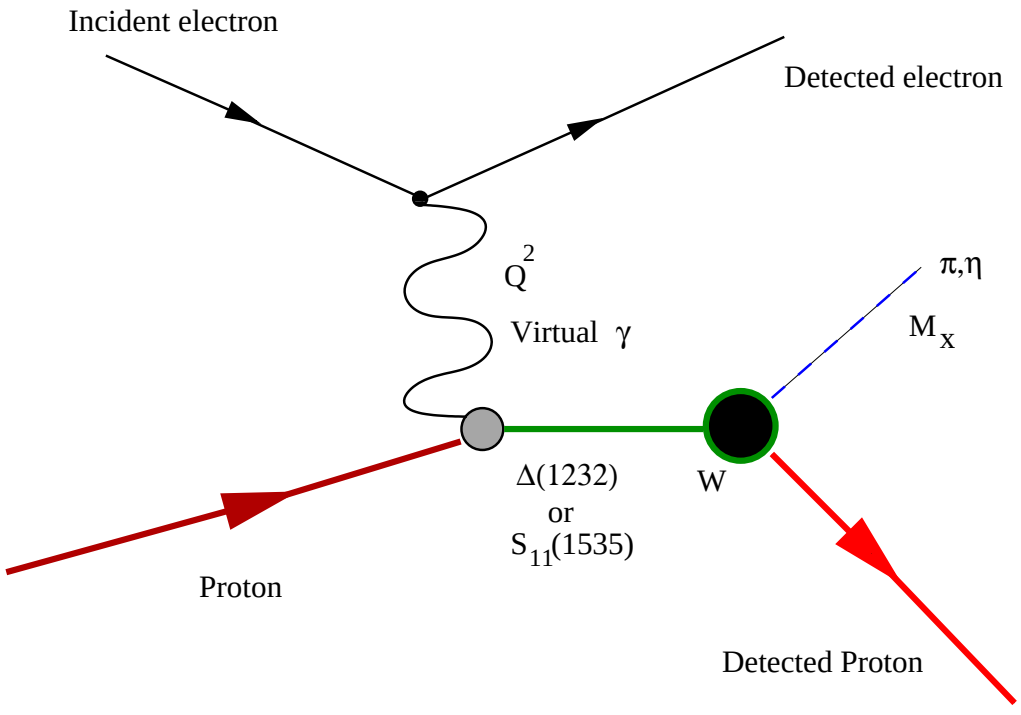
Institutions (Full Listing)

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

Measured Process



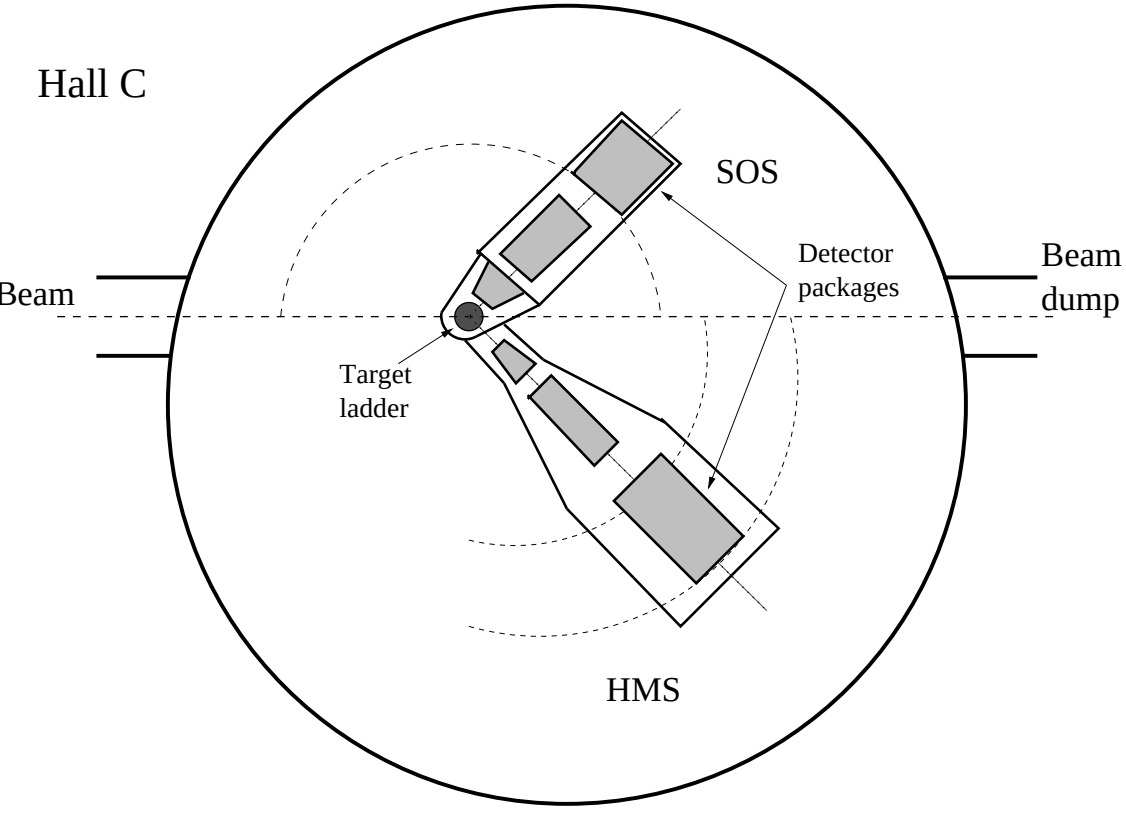
- Observed process

  $e + p \rightarrow e' + p' + \pi^0$

- Resonance process

  $\gamma^* + p \rightarrow \Delta \rightarrow p' + \pi^0$

Jefferson Lab Hall C

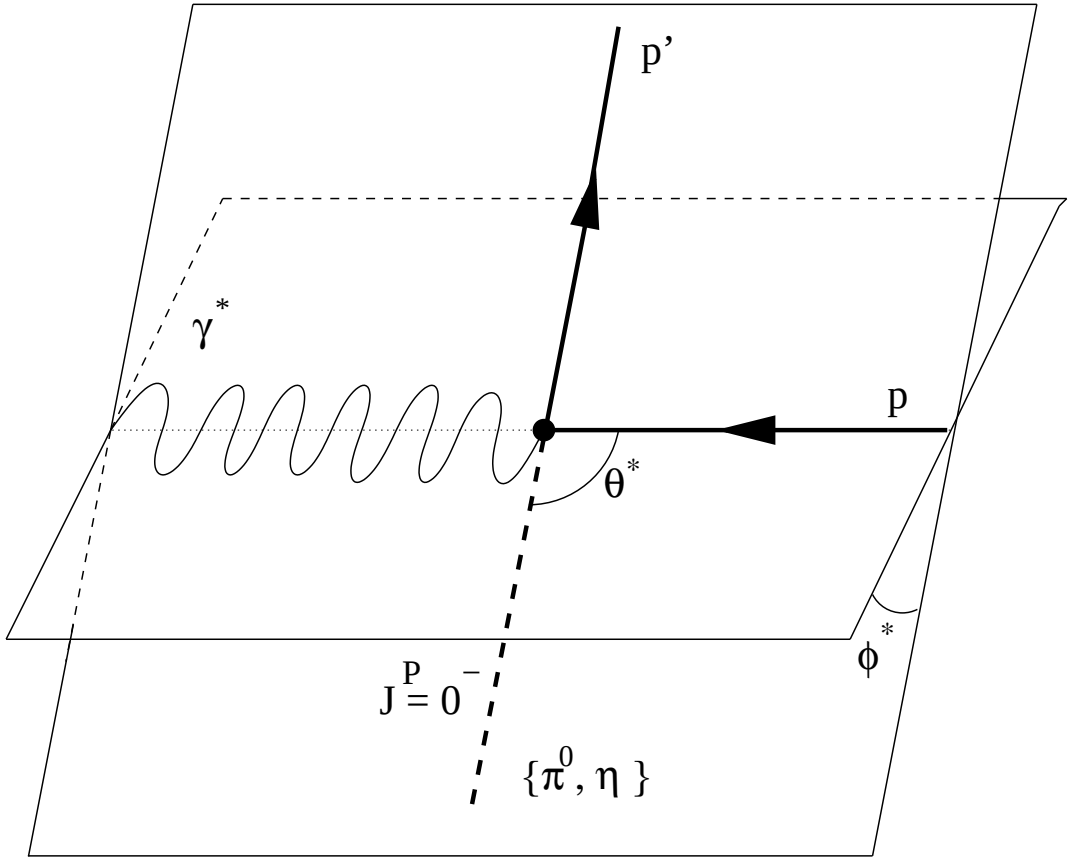


- SOS detect electrons
  - $Q^2 \sim 6.36$ GeV^2
  - $Q^2 \sim 7.7$ GeV^2
- HMS detect protons
  - $10^o \leq \theta \leq 23^o$
  - $2.2 \leq P \leq 4.5$ GeV
- Experiment E01-002
  Hall C collaboration
  Spring 03'

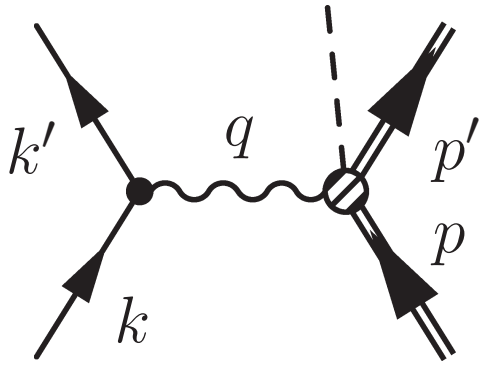
Overview

- Physical Motivation
  - Reduction of 5-fold cross section to $\gamma^* p \rightarrow p' \pi^0$
  - Multipoles $M_{l\pm}, E_{l\pm}, S_{l\pm}$ and transition form factor G_M^*
  - Perturbative QCD
- Data Manipulation
  - Backgrounds and particle ID
  - Radiative corrections
- Observable Extraction
  - Center of mass cross section $d\sigma^{\gamma^*}/d\Omega_\pi$
  - Multipole extraction
- Summary

Center of Mass Kinematics



Cross Section



- $Q^2 \equiv -q^2$
- $W \equiv \sqrt{(q+p)^2}$
- Differential cross section

$$\frac{d\sigma}{dE' d\Omega_e d\Omega_\pi^*} = \frac{\alpha}{2\pi^2} \frac{E'}{E} \frac{(W^2 - m_p^2)}{2 m_p Q^2} \frac{1}{1-\epsilon} \left(\frac{d\sigma^{\gamma^*}}{d\Omega_\pi^*} \right)$$

CGLN Multipoles

$$\frac{d\sigma^{\gamma^*}}{d\Omega_\pi^*} = \frac{|\mathbf{k}_\pi^*|}{|\mathbf{q}^*|}|\epsilon_\mu \mathcal{F}^\mu|^2$$

$$\epsilon_\mu \mathcal{F}^\mu = \sum_{i=1,6} F_i(W, Q^2, \cos\theta^*)\bar{u}(\mathbf{p}'^*)O_i u(\mathbf{p}^*)$$

$$F_1 = \sum_l \Big[P'_{l+1}(x)E_{l+} + P'_{l-1}(x)E_{l-} + P'_{l+1}(x)M_{l+} + (l+1)P'_{l-1}(x)M_{l-} \Big]$$

$$F_6 = \sum_l \left[(l+1)P'_{l+1}(x)S_{l+} - lP'_{l-1}(x)S_{l-} \right]$$

Multipoles Form Factors and Predictions

- Multipole ratios for Δ resonance, $I = \frac{3}{2}$

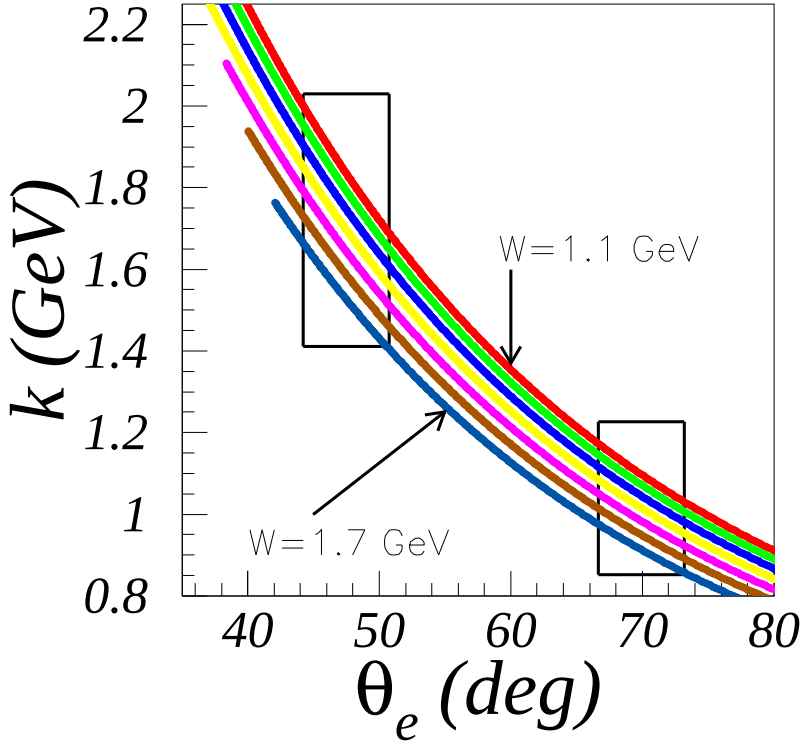
$$R_{EM} = \frac{\Im\left(E_{1+}^{(3/2)}\right)}{\Im\left(M_{1+}^{(3/2)}\right)} \quad ; \quad R_{SM} = \frac{\Im\left(S_{1+}^{(3/2)}\right)}{\Im\left(M_{1+}^{(3/2)}\right)}$$

- Transition form factor

$$M_{1+} = \eta\sqrt{\frac{2}{3}}G_M^*$$

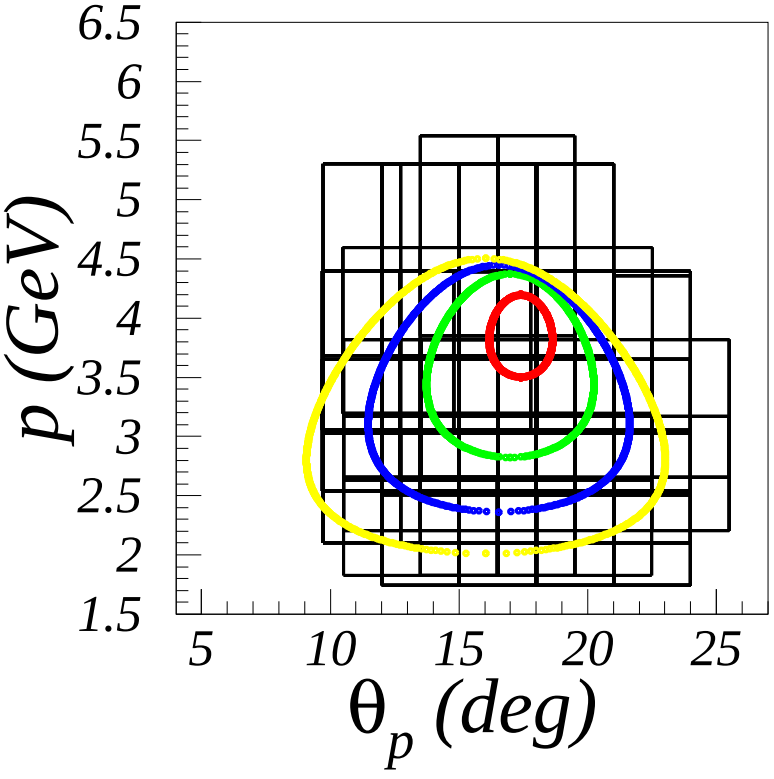
- The constituent quark model predicts R_{EM}=0, or very nearly so
- Perturbative QCD predicts R_{EM}=1 and G_M^* falling like $\frac{1}{Q^4}$

SOS Kinematics



- Curves represent constant W in steps of .1 GeV
- Q^2 from 5.0 to 9.0 GeV^2
- Boxes in the background are experimental settings

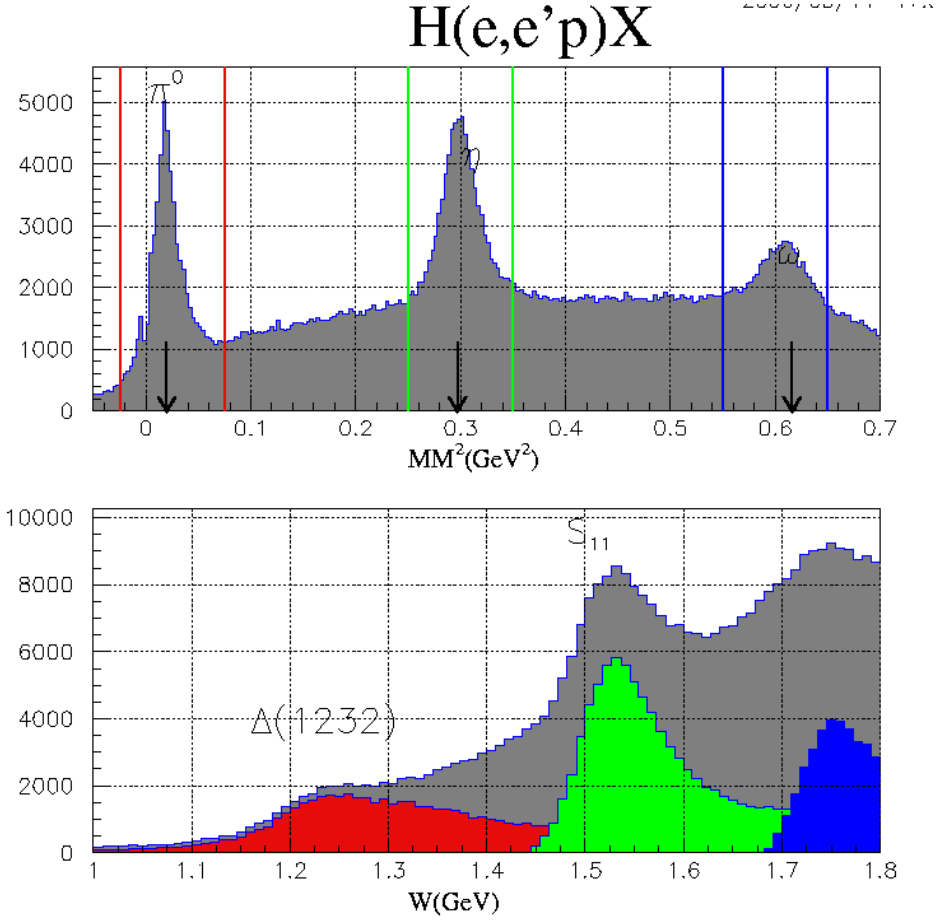
Exclusive π^0 in HMS



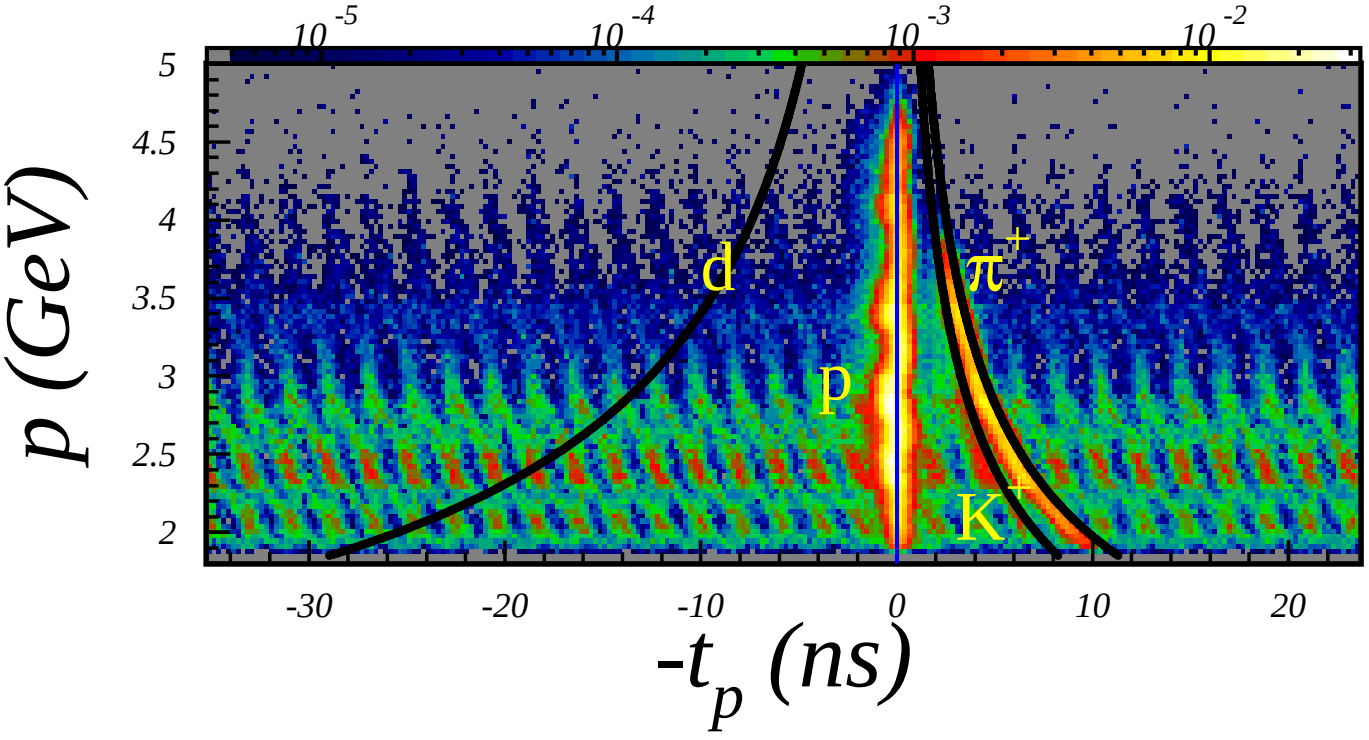
- Curves represent constant W in steps of .1 GeV
- Q^2 taken close to middle of SOS acceptance
- Boxes in the background are experimental settings

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

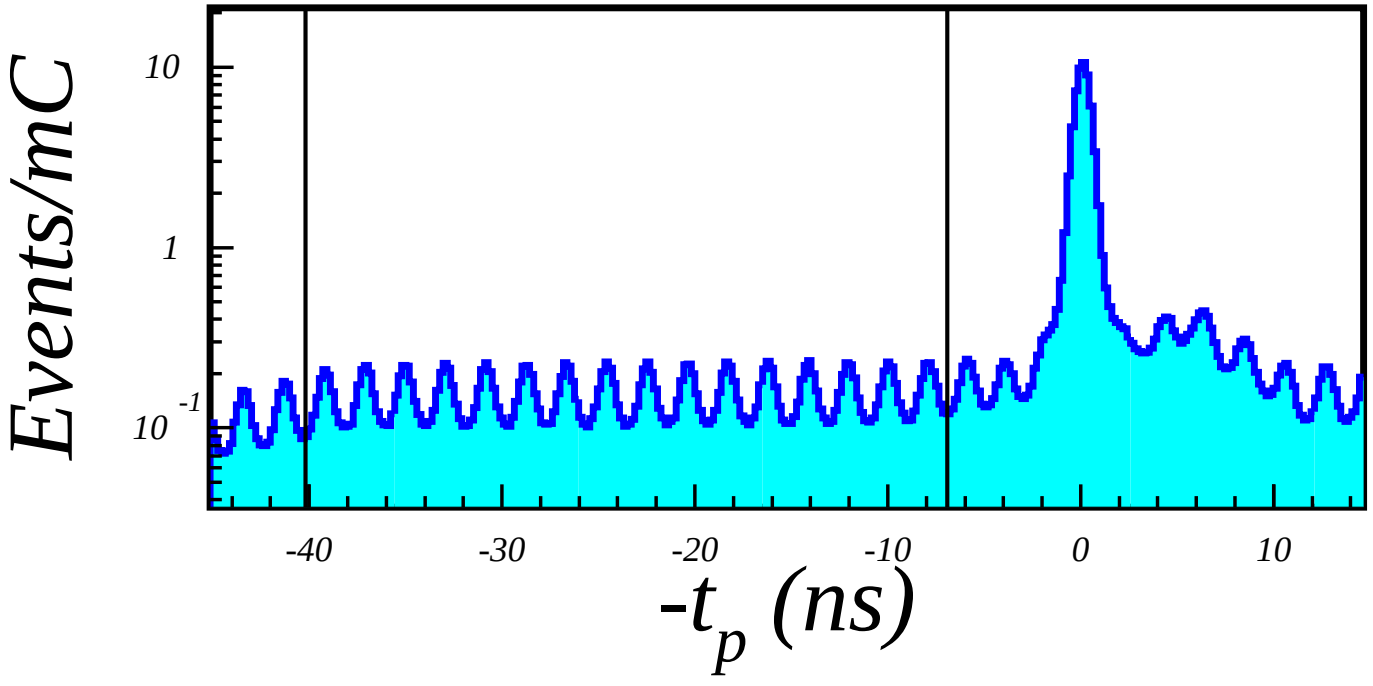


Particle Selection



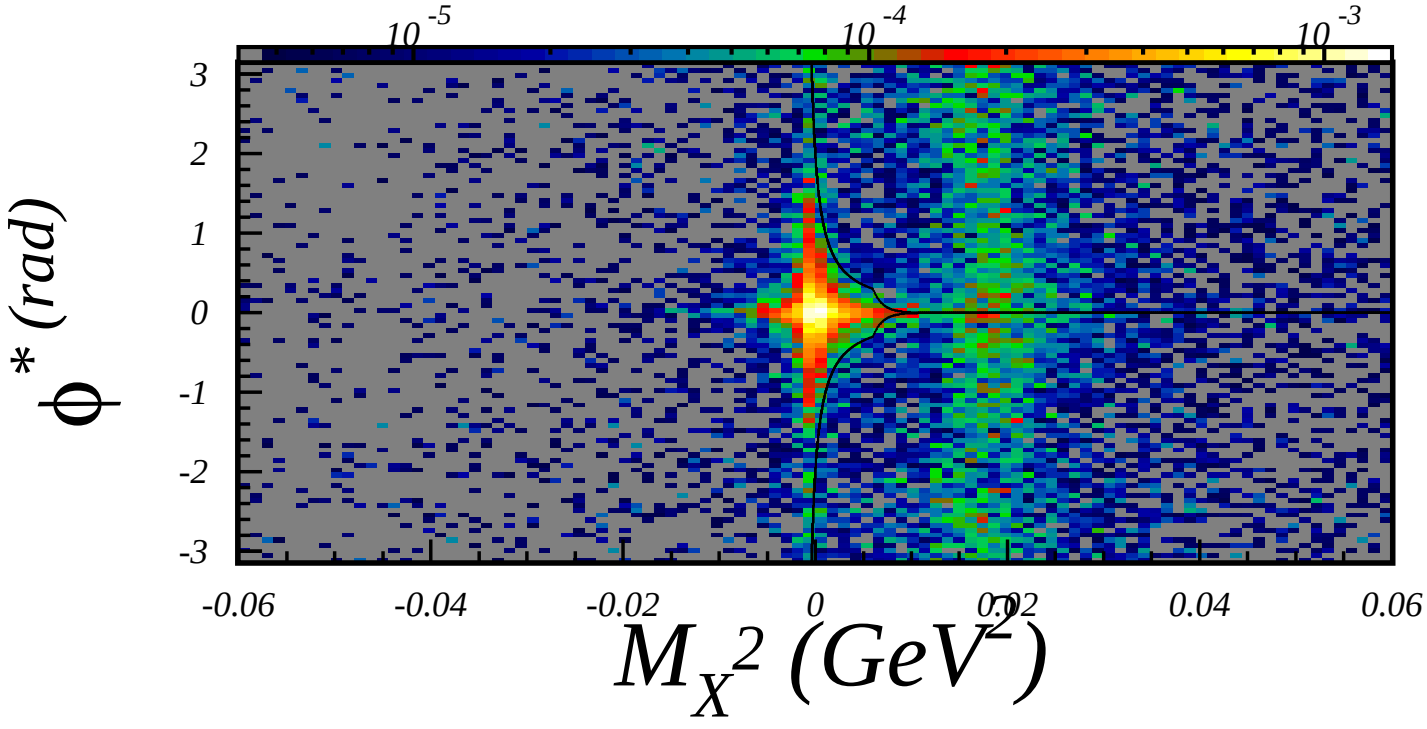
- Clean separation of p and π^+ events
- Enough π^+ events for $\gamma^* p \rightarrow n\pi^+$

Accidental Corrections



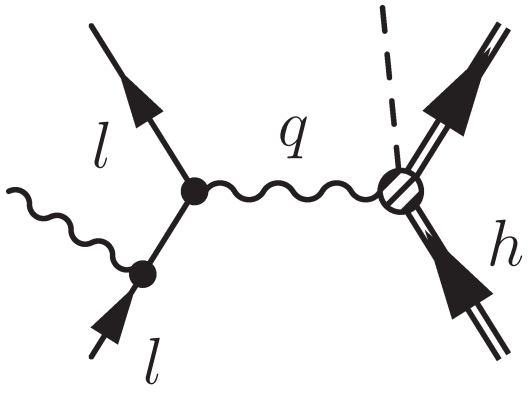
- Use the beam structure away from coincidence proton peak
- Extract angular distribution by above cut and subtract
- Low momentum hadrons dominate beam structure

Elastic Radiative



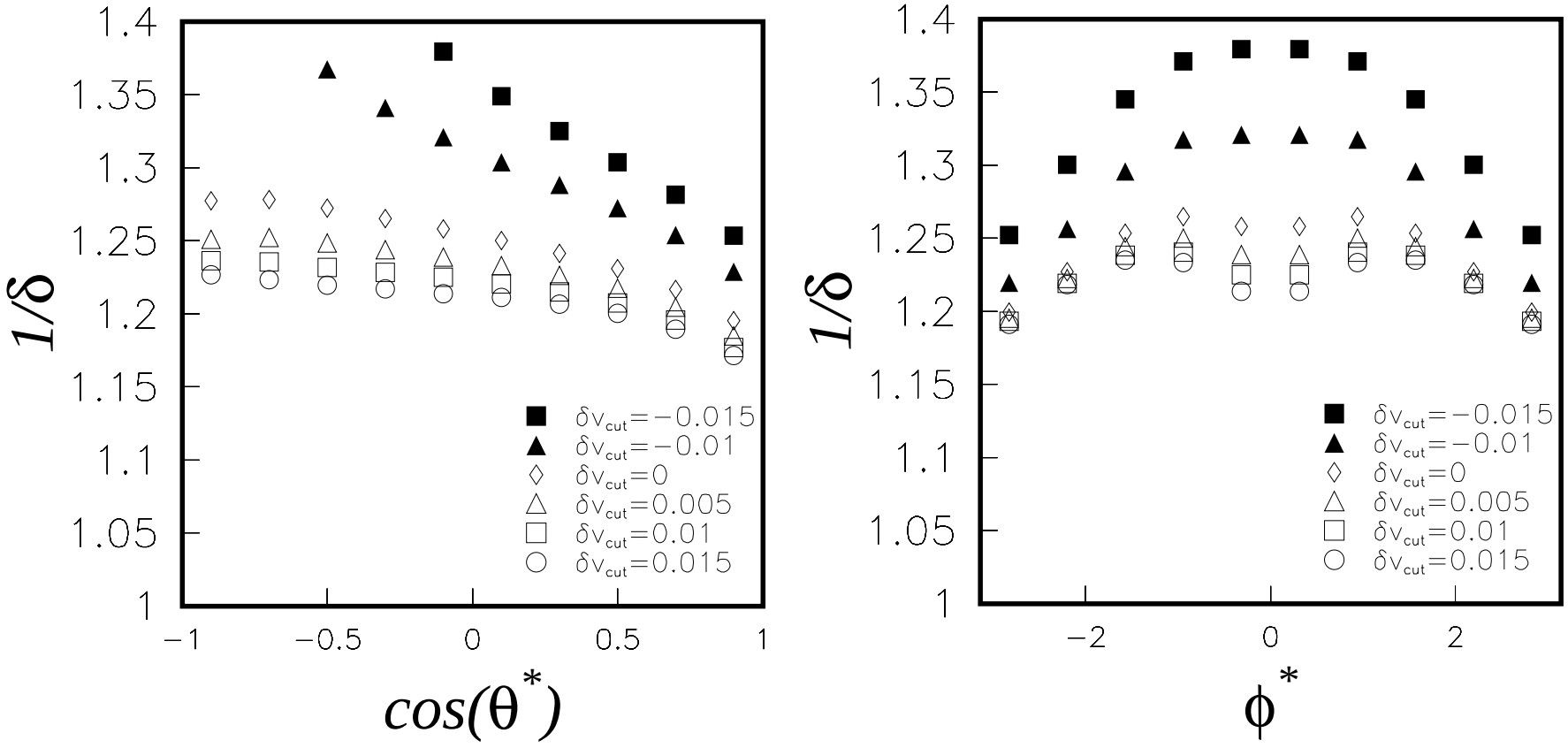
- Above example for $-1.0 \leq \cos\theta^* < -.4$
- For lowest $\cos\theta^*$ elastic radiative concentrated
- Use same form for other $\cos\theta^*$ bins but different parameters

Radiative Corrections



- Diagrams like above must be computed
- Process has low energy (IR) divergence
- Correction model dependent

Radiative Corrections



- Parameter δv_{cut} difference M_X^2 cut from nominal
- Reference: A. Afanasev, et al. Phys. Rev. **D**66 074007 (2002)

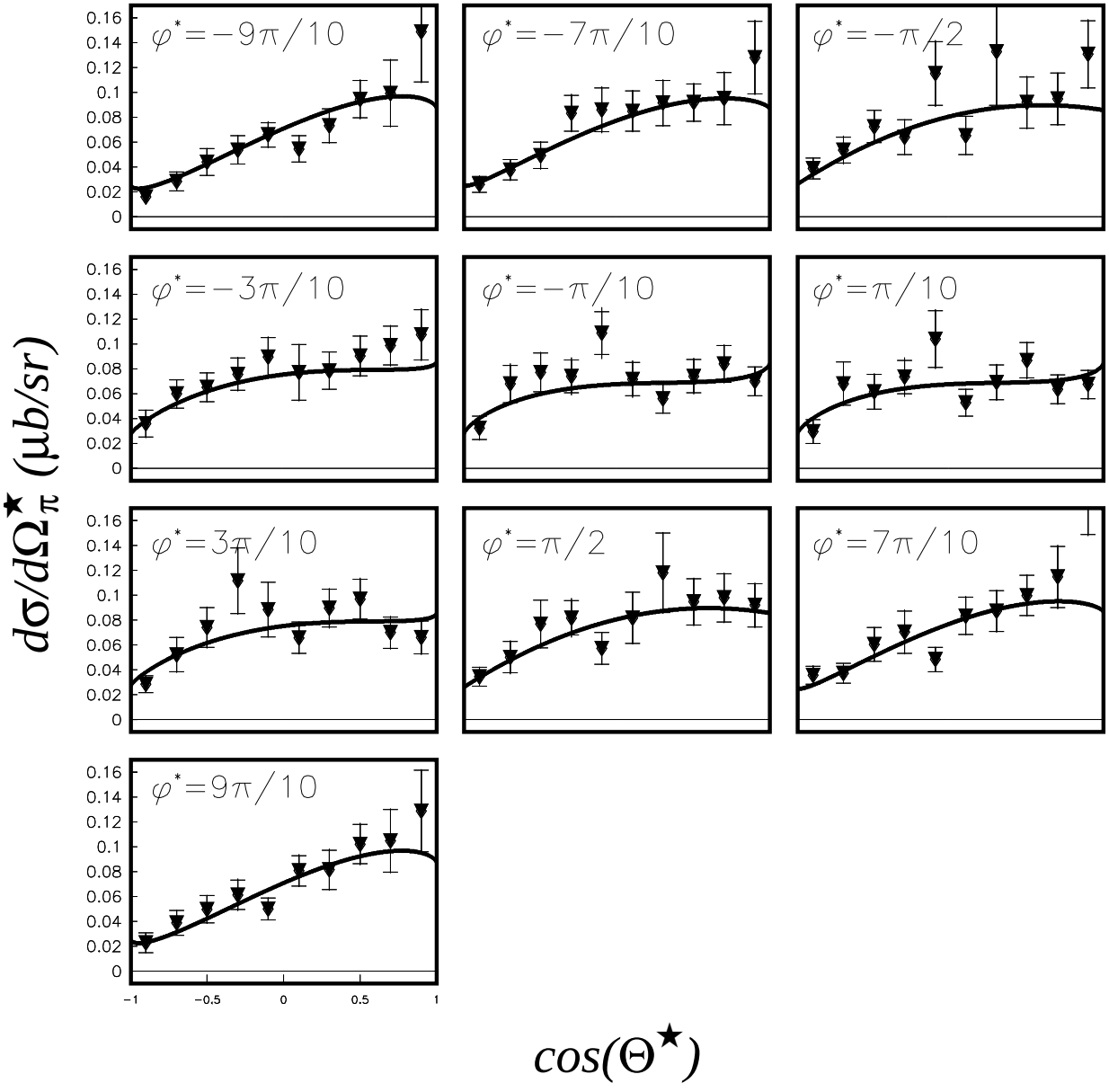
Fit Measured Cross Sections

- Differential cross section takes form

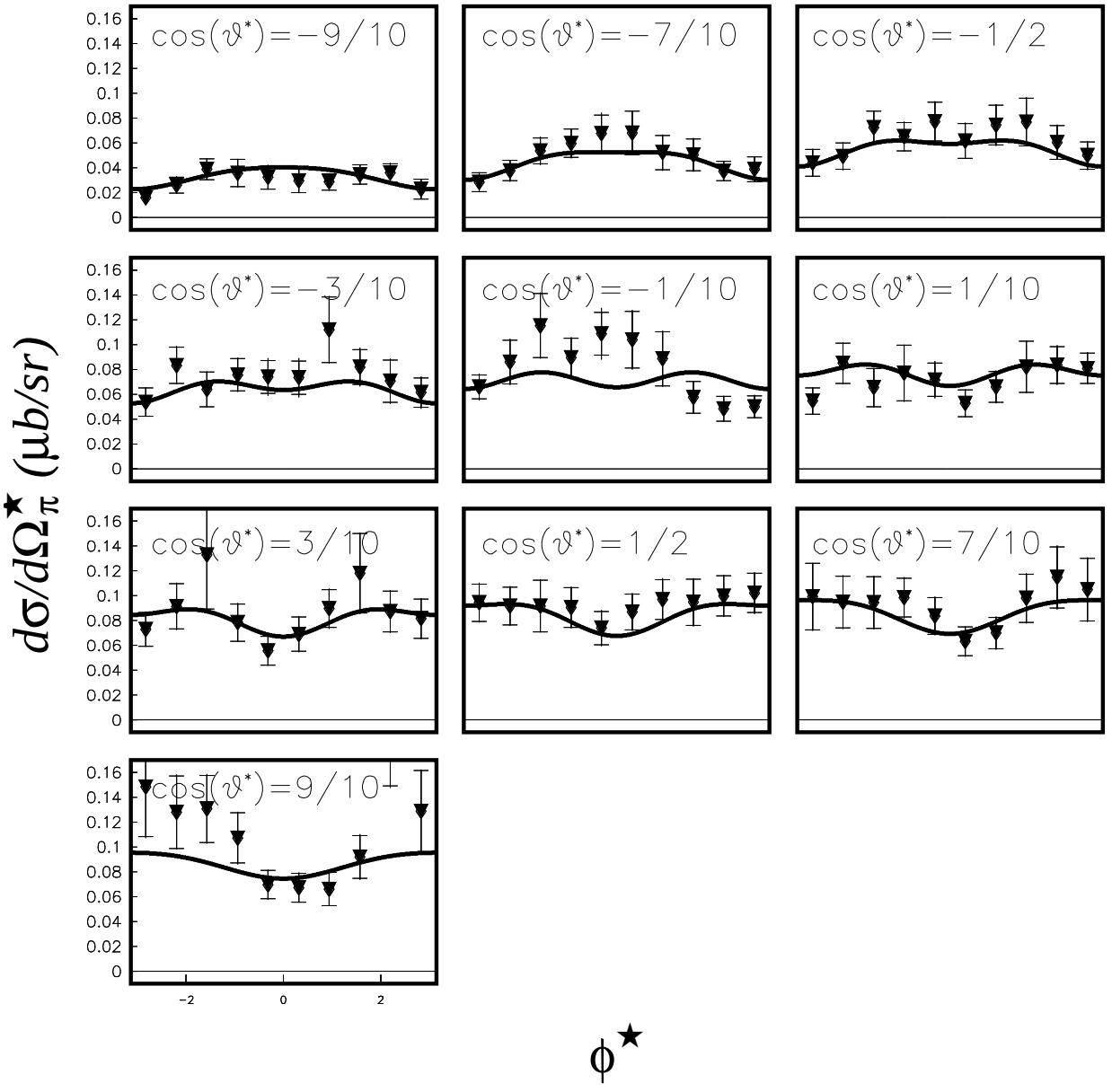
$$\frac{d\sigma^{\gamma^*}}{d\Omega_\pi^*} = A(\cos\theta^*) + \epsilon B(\cos\theta^*)\cos 2\phi^* + \sqrt{2\epsilon(1+\epsilon)}C(\cos\theta^*)\cos\phi^*$$

- Can expand and fit simply assuming S-wave and P-wave only

Example Fit W=1.232 GeV Low Q^2

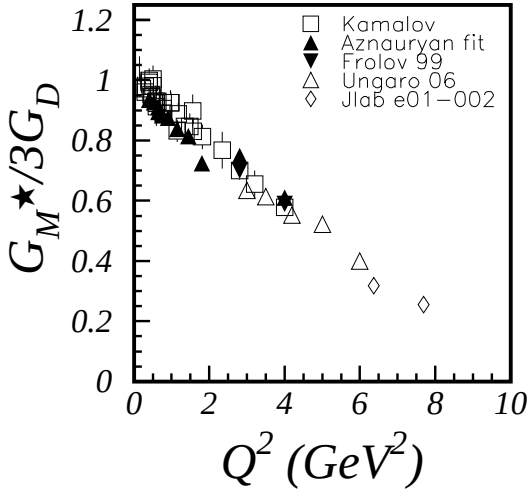


Example Fit W=1.232 GeV Low Q^2

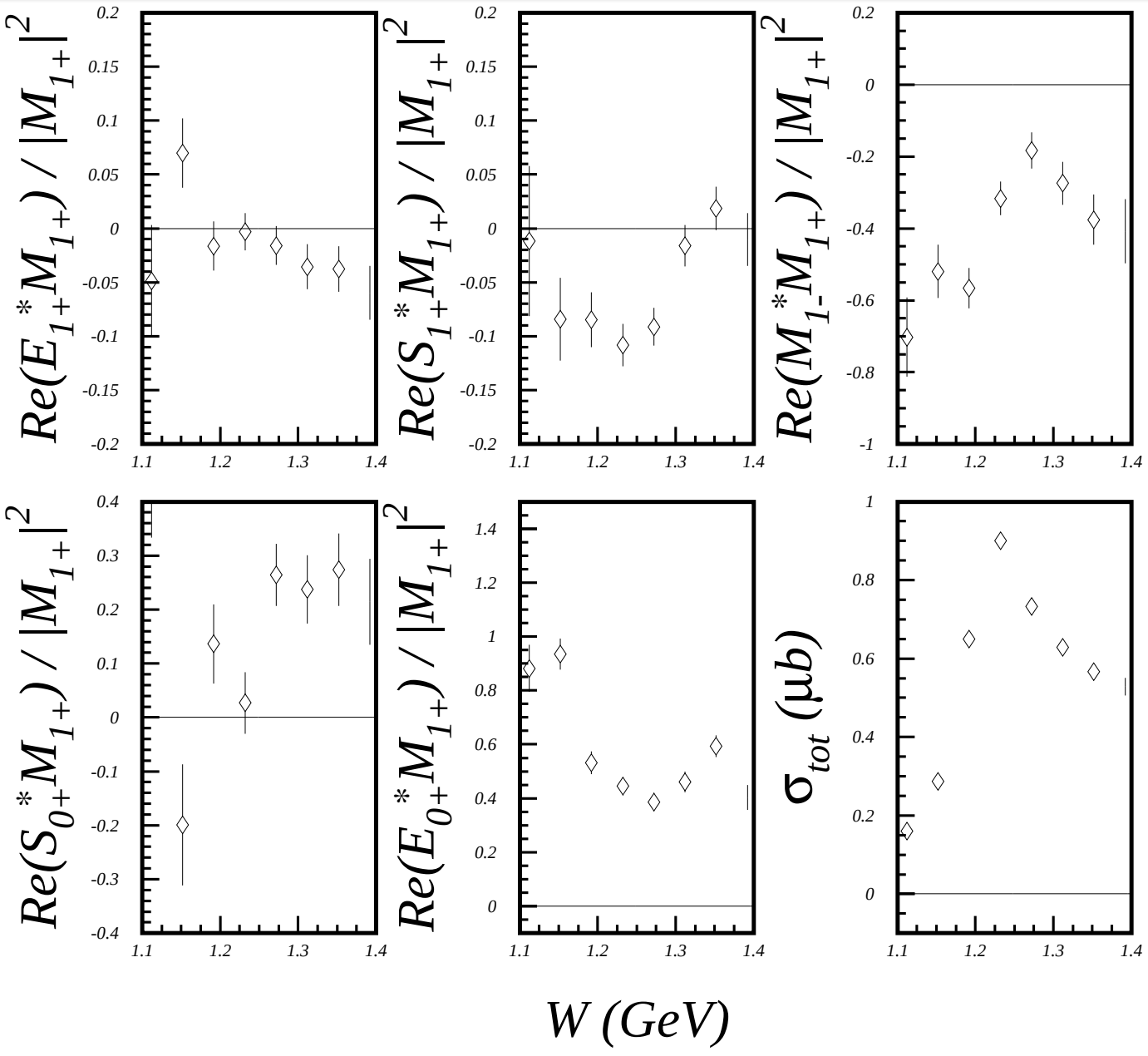


Extracted Physics

- **Assume** that **the resonance is dominant** and **the** M_{1+} **amplitude is dominant**
- With this assumption Q^2=6.36 GeV^2 extract value of R_{EM}=-0.3$\pm$2.0% and R_{SM}=-11.0$\pm$2.0%
- Have cross section data at higher Q^2 setting but canno constrain the ratios on its own



Multipole Amplitudes in M_{1+} Dominance



What Does it Mean?

- The world has brand new pion electroproduction data at both $Q^2 \simeq$6.36 GeV^2 and $Q^2 \simeq$7.7 GeV^2
- In a fit where one includes only S-wave and P-wave contributions and assumes that the Δ dominates and that the magnetic dipole dominates then obtain R_{EM} consistent with zero
- Since G_M^* seems to still fall faster than the dipole form, $\frac{1}{Q^4}$ the physics is not totally in realm of pQCD
- If the R_{EM} zero holds up in a more detailed fit, we may b seeing a turn toward positive! Expectation is that sophist cated fit will bring R_{EM} down.