Measurement of F_2 and $R=\sigma_L/\sigma_T$ in Nuclei at Low Q^2 - Phase 1

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Outline

- Description and Physical Motivation of Experiments E02-109/E04-001 (“Jan05”)
- Analysis Status
- Results
- Future Plans

Experiment Description

- E02-109: Meas. of F_2 and R on Deuterium.
- E04-001: Meas. of F_2 and R on Carbon, Iron, and Aluminum. Also, Hydrogen for crosschecks. (Data from this will also be used by neutrino scattering community).
- Experiments ran for ~2 weeks in Hall C of January 2005 to cover $0.3 < Q^2 < 2$ and $W^2 < 4.25$.
- Beam Energies used were: 4.6, 3.5, 2.3, and 1.2 GeV.

Kinematic Coverage

Rosenbluth Separation Data

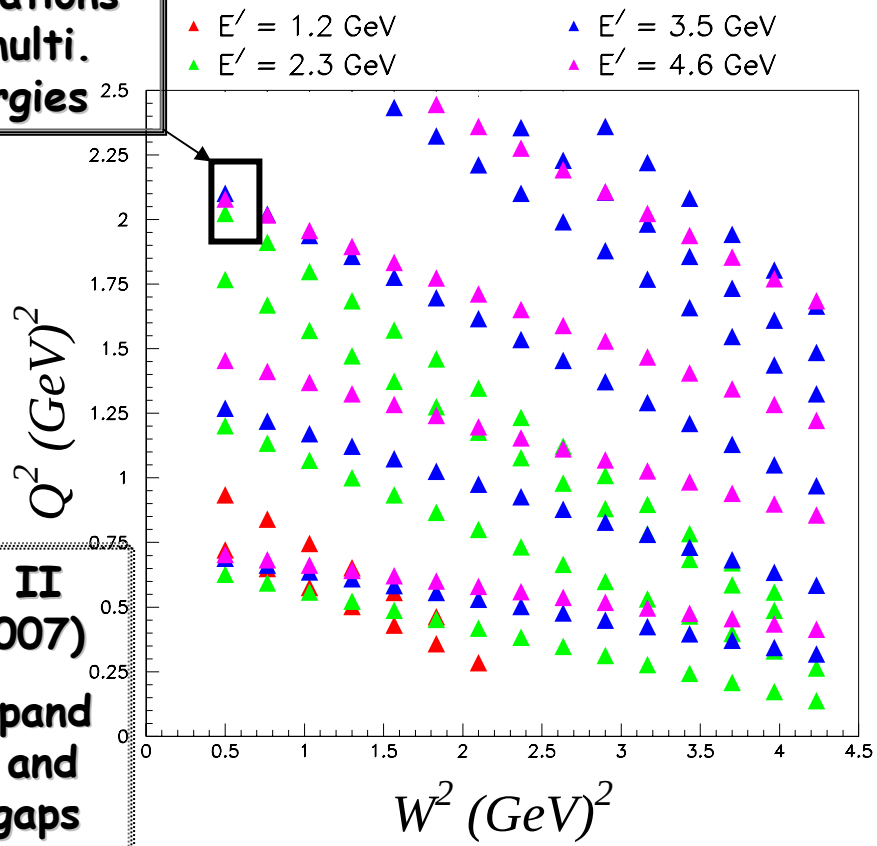
- Targets: D, C, Al, Fe , and some H
- Uncertainties in preliminary data estimated at 1.6 % pt-pt in ε (2% normalization).

Low Q^2 data for ν modeling

- Targets: H,D, C, Al
- Uncertainties in preliminary data estimated at ~3 - 8%

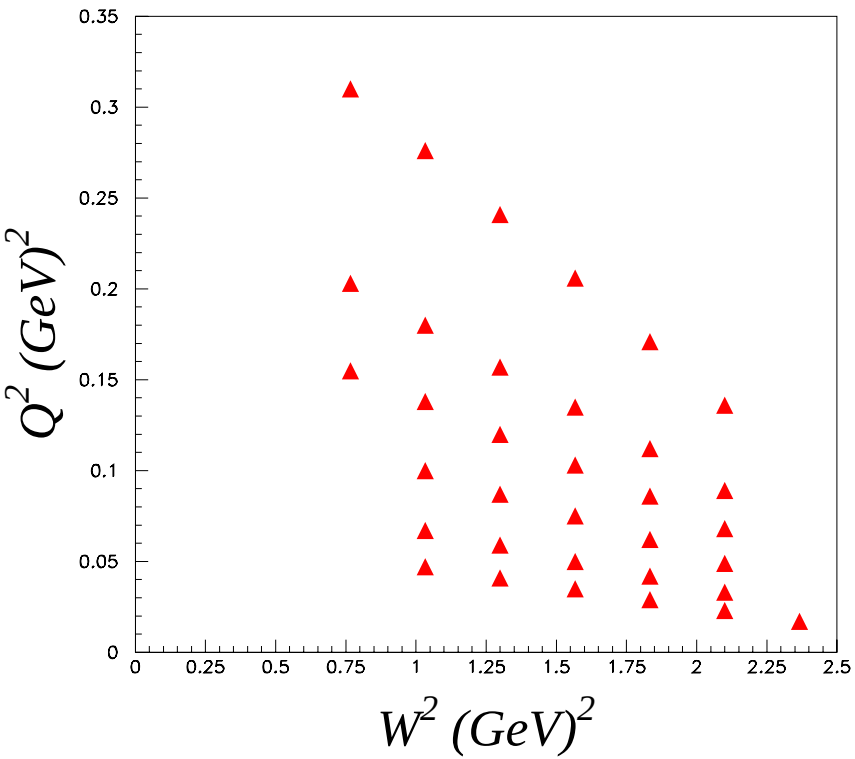
(Much larger RCs and rates)

Rosenbluth separations at multi. energies



Phase II (Fall 2007)

Will expand region and fill in gaps



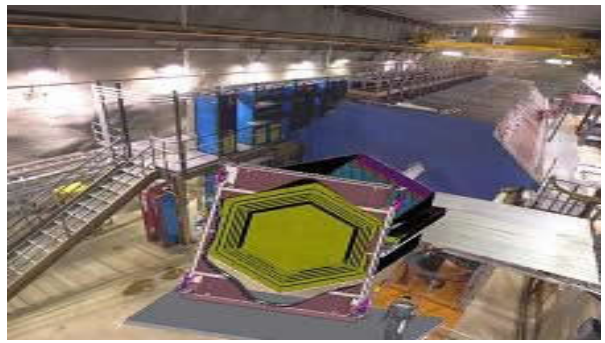
Physical Motivation

- Sparse data available in Resonance Region on Fundamental Separated Structure Functions in Nuclei (F_1,F_2,F_L, R)
- Low Q^2 L/T Structure Function Moments
- Study Quark-Hadron Duality in Deuteron, Neutron, and Nuclei.
- Also, important input for Spin Structure Function extraction from asymmetry measurements, RCs, etc…

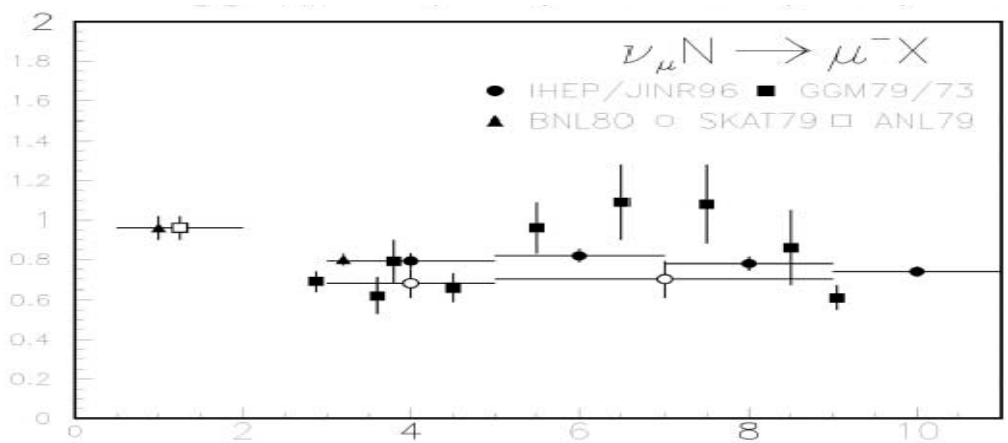
Motivation from Neutrino Experiments

- New generation of neutrino expt. are being built to investigate neutrino oscillations and interactions

  -i.e. MinervA, NOvA, T2K



- However…Neutrino Cross Sections still poorly understood



- Global models needed linking electron and neutrino scattering data

Accurate and precise knowledge of the v cross section… plays an important role for the next gen. of experiments.
-Flavio Cavanna

e - N scattering

Born Approximation

$$\frac{d\sigma}{d\Omega dE'} = \Gamma\left[\sigma_T\left(x, Q^2\right) + \varepsilon\sigma_L\left(x, Q^2\right)\right]$$

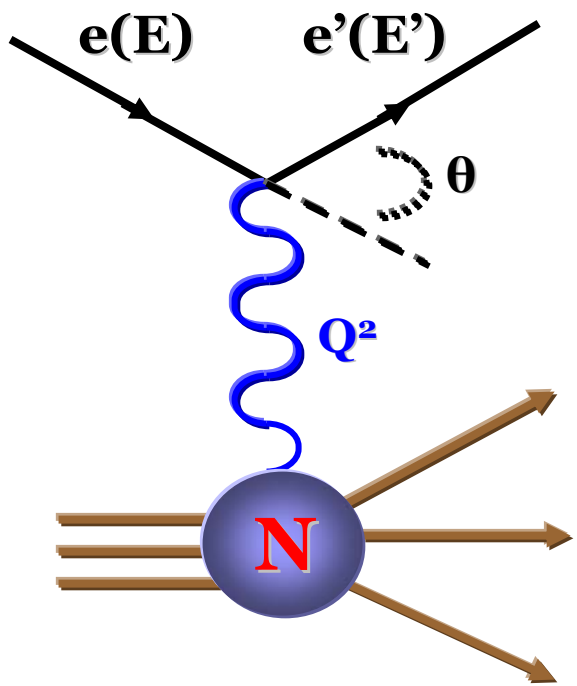
σ_T (σ_L) is the Transverse (Longitudinal) virtual photon Cross Section

$$\Gamma = \frac{\alpha E'\left(W^2 - M_p^{\,2}\right)}{2\pi Q^2 M_p E\left(1-\varepsilon\right)}$$

Transverse virtual photon flux

Q^2 - Negative squared mass of the virtual photon

M_p - mass of the Proton



$$\varepsilon = \left[1 + 2\left(1 + \frac{\nu^2}{Q^2}\right)\tan^2\frac{\theta}{2}\right]^{-1}$$

Virtual photon polarization parameter

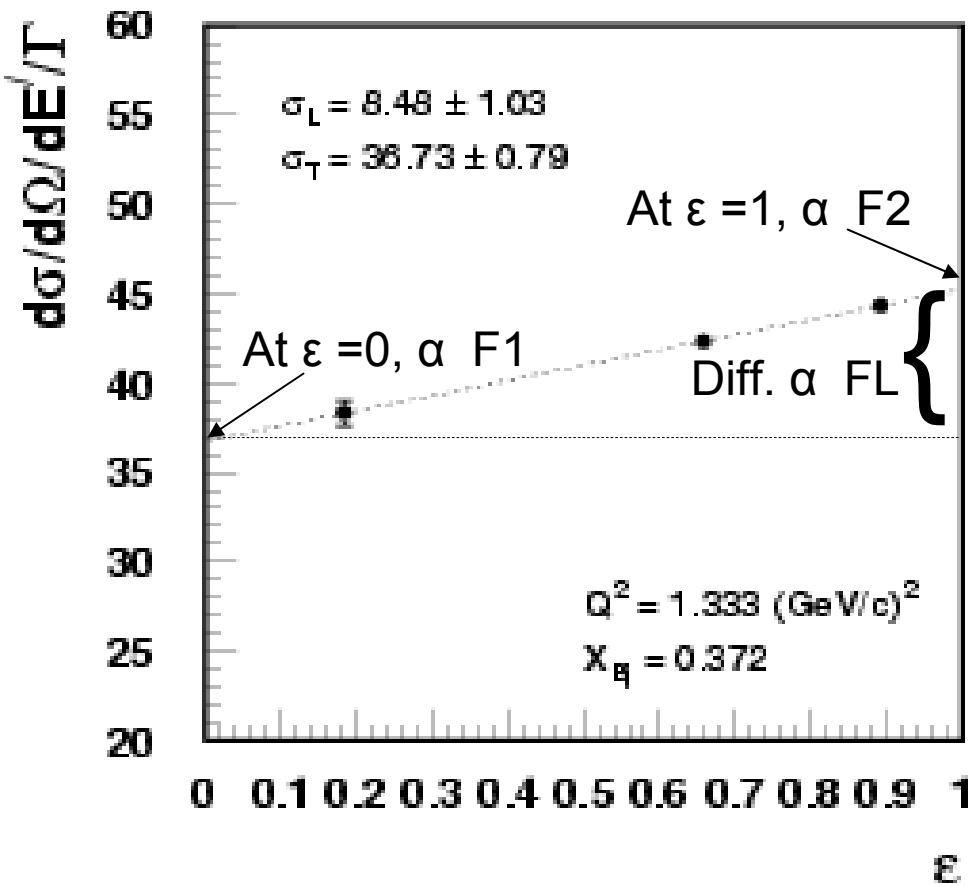
$$\nu = E - E'$$

Rosenbluth Separation

Reduced cross-section

$$\frac{1}{\Gamma}\frac{d\sigma}{d\Omega dE'} = \sigma_T\left(x, Q^2\right) + \varepsilon\sigma_L\left(x, Q^2\right)$$

- While keeping W^2 and Q^2 fixed, we plot the reduced cross-section vs ε
  - Linear fit yields:
    σ_L = Slope
    σ_T = Intercept



Extracting F_2 and R

- F_2 – Momentum distribution of the nucleon

$$F_2\left(x,Q^2\right)=\frac{\nu K(\sigma_T+\sigma_L)}{4\pi^2\alpha(1+Q^2/4M^2x^2)}$$

Where

$$K=\frac{2M\nu-Q^2}{M}$$

- R – L/T ratio of virtual photon cross-sections

$$R\left(x,Q^2\right)=\frac{\sigma_L}{\sigma_T}$$

Obtain σ_T and σ_L from Rosenbluth Separation

Analysis Status

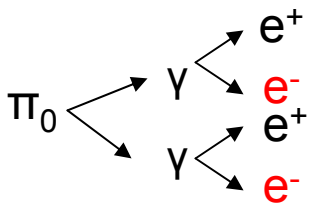
Detector Calibrations	Completed
Calorimeter Eff.	Completed
Cerenkov Eff.	Completed
Tracking Eff.	Completed
Trigger Eff.	Completed
Computer Dead Time	Completed
Acceptance Corrections	Completed for $E^{/} > 1.5$ GeV
Beam Position Offsets	Completed for C and Fe
Beam Position Stability	Completed
Kinematic Offsets	Completed
Beam Energy Stability Study	Completed
Target Density Corrections	Completed
Optics Checks	Preliminary Sieve Slit
Rad. Corrections	In progress (iterating)
Charge Symmetric Background	Nearly completed (completed for 2.3 GeV)
Cross-Sections	inelastic ~5% and Preliminary QE

Analysis Highlights

- Charge Symmetric Background (Positron Cross-Sections)
- Inelastic Cross-Sections
- Preliminary Quasi-Elastic Cross-Sections

Charge Symmetric Backgrounds

- Subtract off Charge Symmetric electrons by subtracting off positron Cross-Sections.



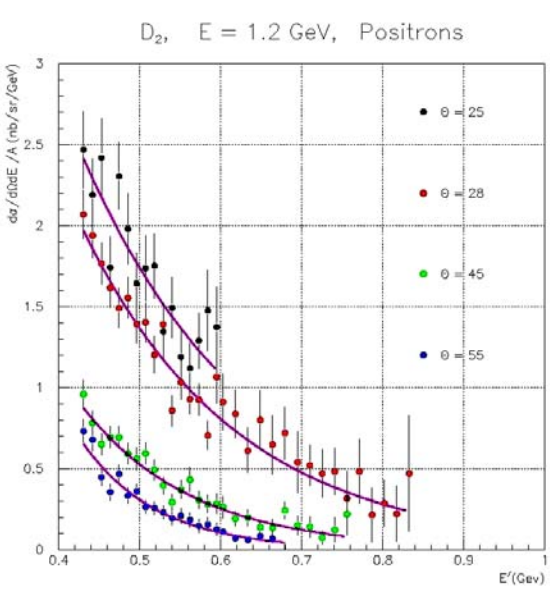
Parameterized e+ CS

$$\sigma_{e+}(E') = e^{p1}(e^{p2(E-E')} - 1)$$

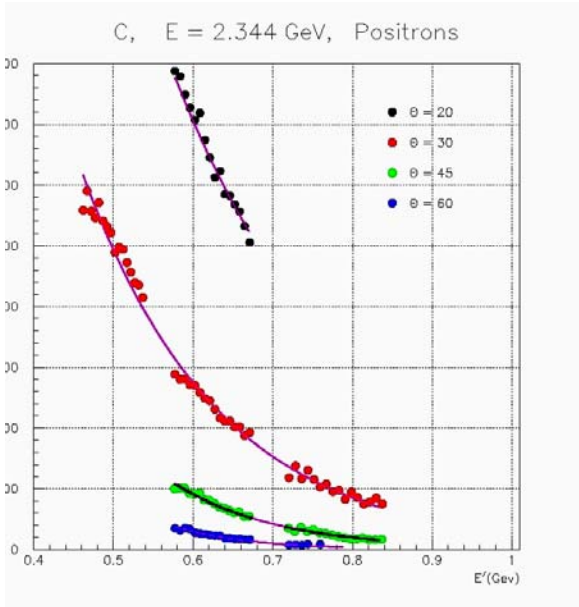
↓

Polynomial Fit across Theta

$$\sigma_{Corrected} = \sigma_{Total} - \sigma_{e+}$$



SOS e+ Cross-section

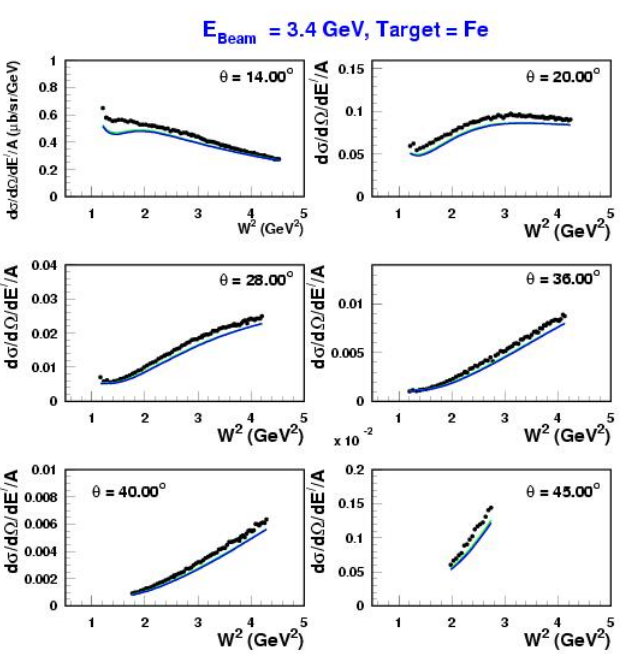


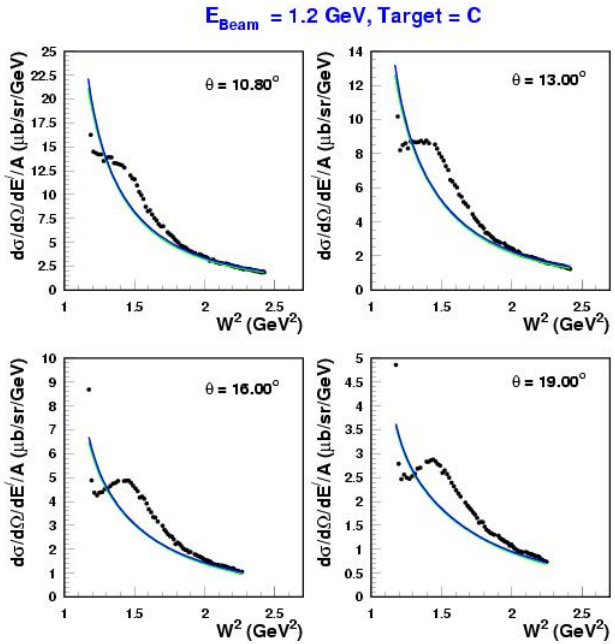
HMS e+ Cross-section

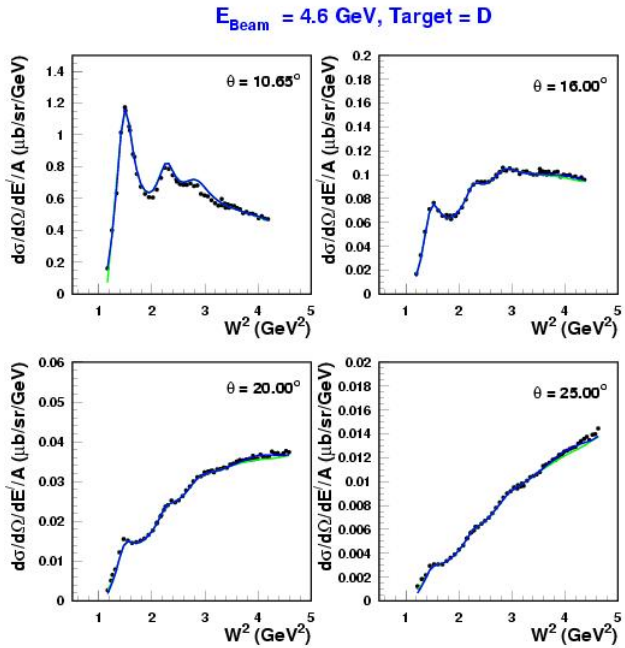
Inelastic Cross-Sections

- For all beam energies.

Green – RC Model from P. Bosted
Blue – Model from V. Tvaskis

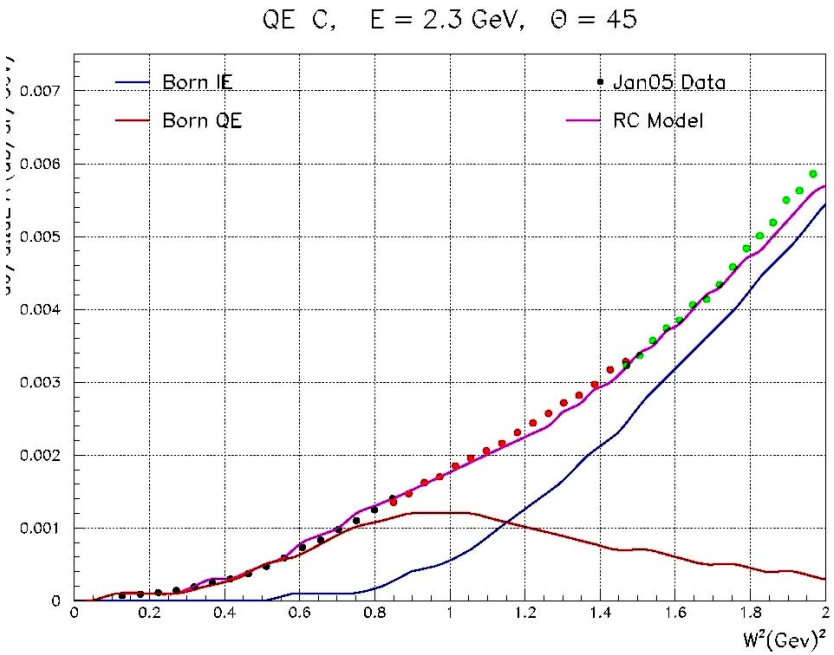




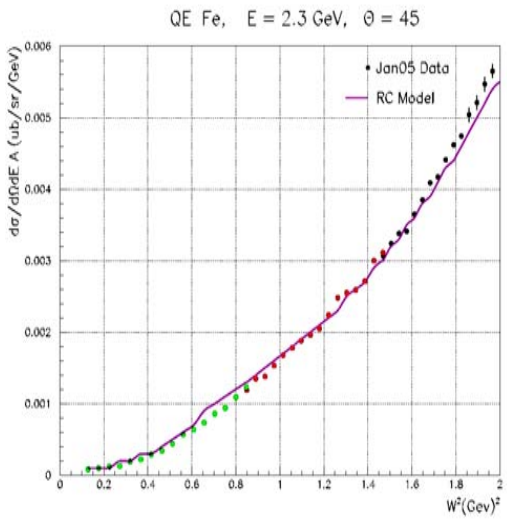


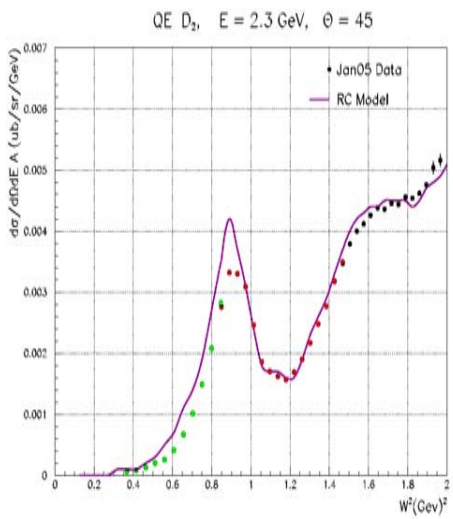
- Results do not account for Quasi-Elastic contribution

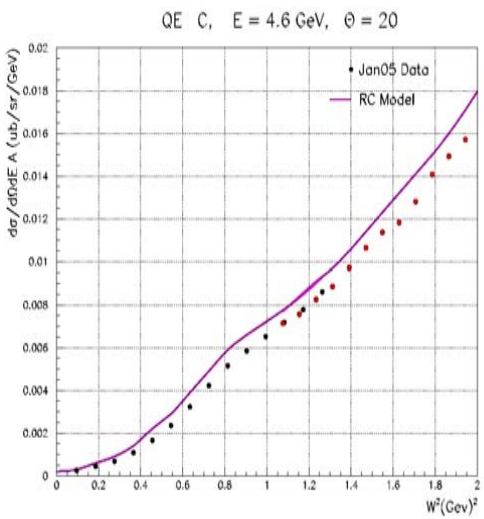
Quasi-Elastic Cross Sections



- All Beam Energies – Preliminary
- Sample Cross Section w/ overlaps from Born CS from Inelastic and Quasi-Elastic contributions







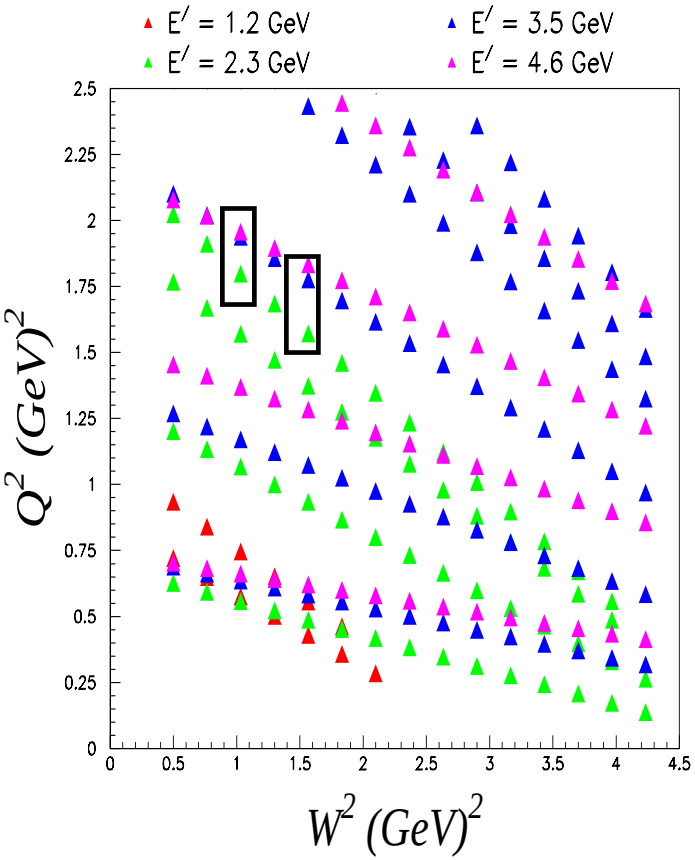
LT Separations

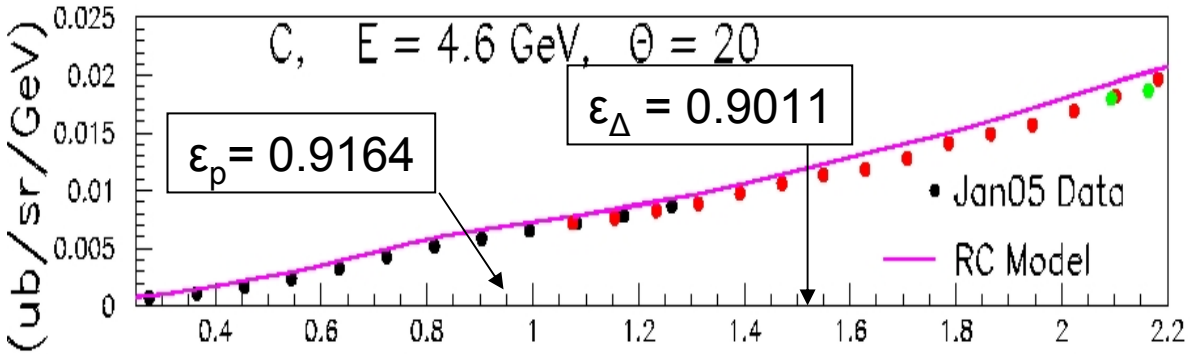
- Besides obtaining High Quality data for Fundamental Structure Functions (F_1,F_2,F_L, R) and Moments, LT Separations can be used to investigate additional physics..
- In QE region (W^2~mp^2), obtain info on Coulomb Sum Rule
- Search for Nuclear Pions* on heavy nuclei in region (W^2~$m\Delta^2$)

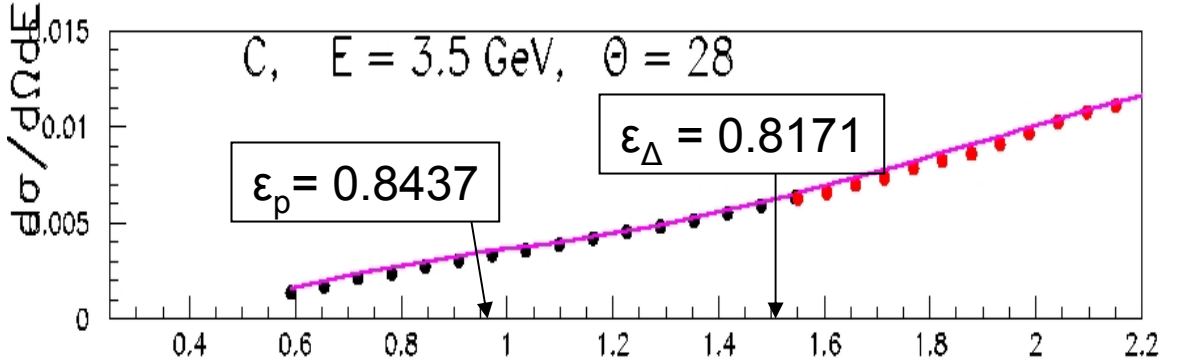
*G.Miller, Phys. Rev.C 64 (2001) 22201

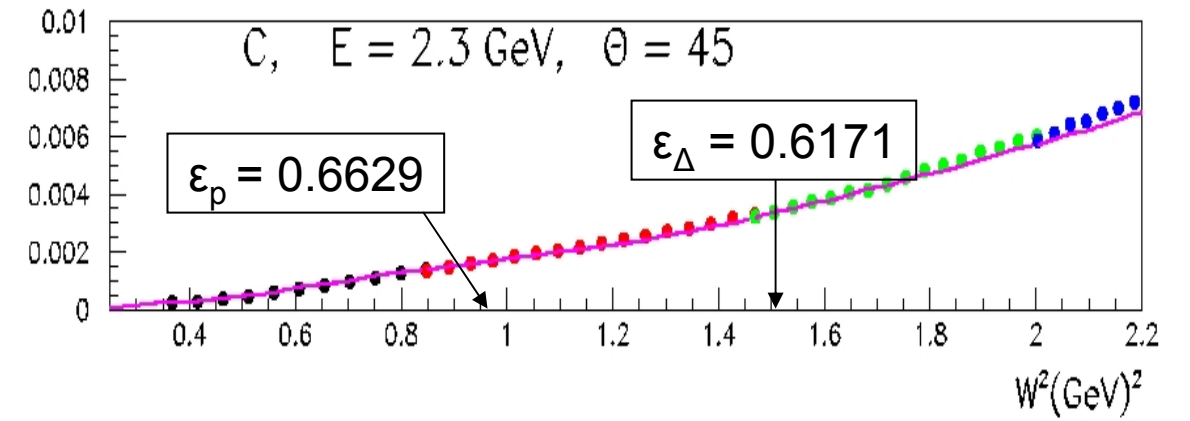
Sample C Cross Sections for L/T Separations

- $Q^2 \sim 2.0$









Plans in the Future

- Extract QE and Inelastic cross sections
- Improve on Global Fits of Data
- Complete Final Cross Sections
- Rosenbluth Separations
- Extract Structure Functions