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

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Outline

- Description and Physical Motivation of Experiments E02-109/E04-001
- Analysis Status
- Preliminary Results
- Future Plans

Experiment Description

- E02-109: Meas. of F_2 and R on Deuterium.
- E04-001: Meas. of F_2 and R on Hydrogen, Carbon, Iron, and Aluminum.
- Proposed kinematics: $0.3 < Q^2 < 4$ and $W^2 < 4$
- Dedicated (Very) Low Q^2 data for neutrino modeling
- Experiments ran for ~2 weeks in Hall C in Jan. 2005 and obtained subset of data in the range $0.3 < Q^2 < 2$.
- Beam Energies used were: 4.6, 3.5, 2.3, and 1.2 GeV.

Kinematic Coverage

Rosenbluth Separation Data

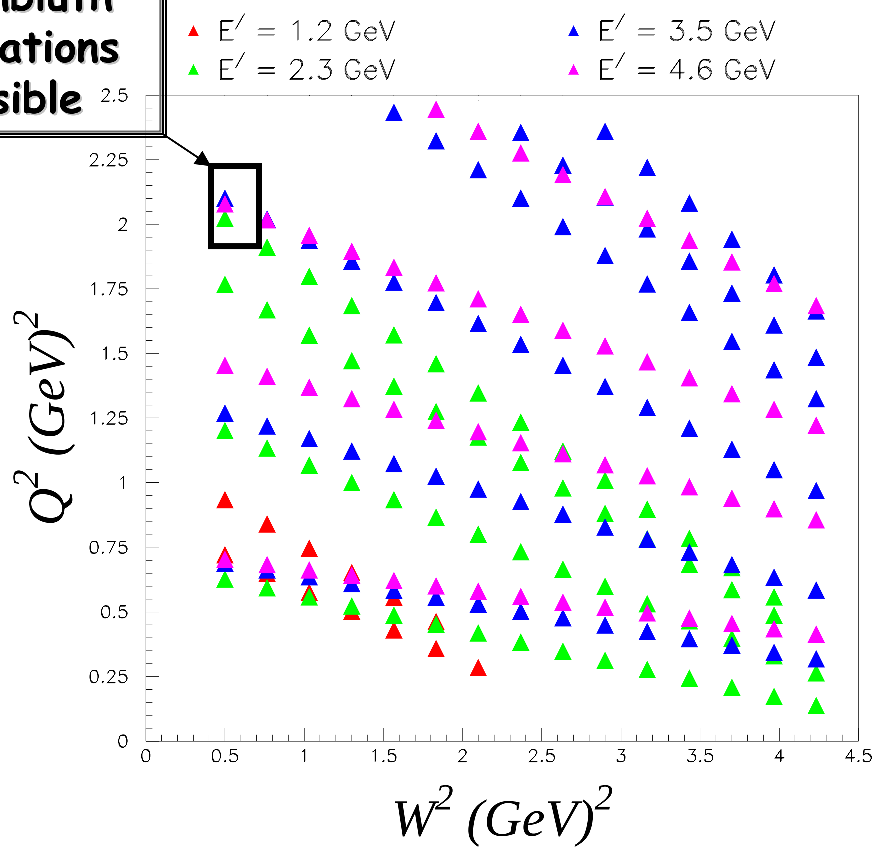
- Targets: D, C, Al, Fe , and some H for crosschecks
- Projected final Uncertainties estimated at 1.6 % pt-pt.

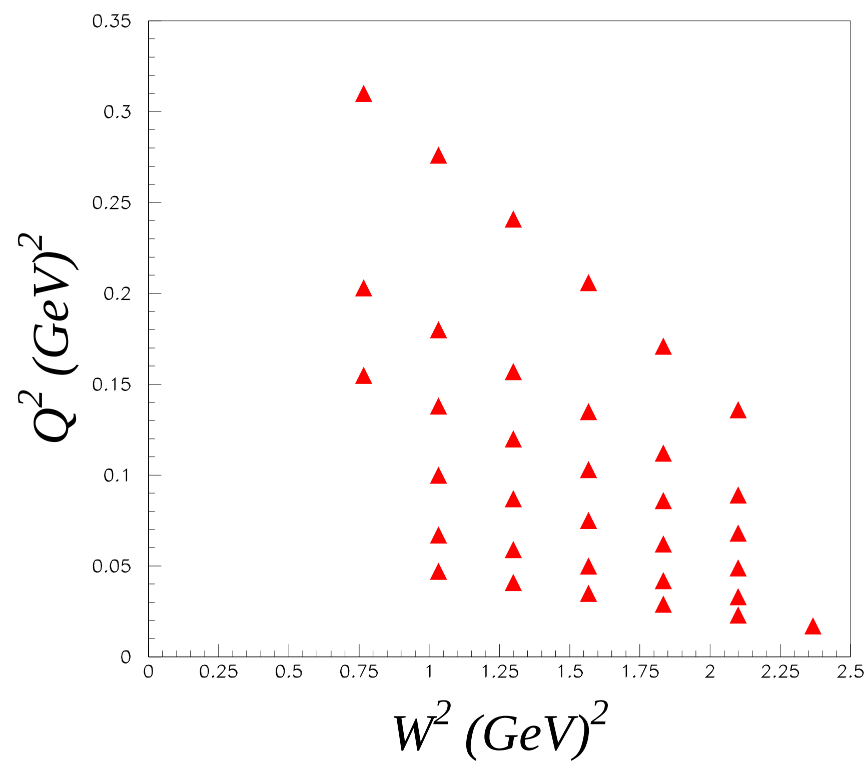
Low Q^2 data for ν modeling

- Targets: H,D, C, Al
- Projected final Uncertainties estimated at ~3 - 8%

(Much larger RCs and rates)

Rosenbluth separations possible





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…

Neutrinos at JLab?

- Upcoming neutrino oscillation experiments require good models of cross sections and nuclear corrections.
- Not many good neutrino cross sections
- Reliable global models linking electron and neutrino scattering data need to be developed.
- Nuclear data necessary for neutrino measurements.
- In the resonance region, nuclear effects may be large, different from the DIS region, and Q^2 dependent.

e - N scattering

Born Approximation

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

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

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

Transverse virtual photon flux

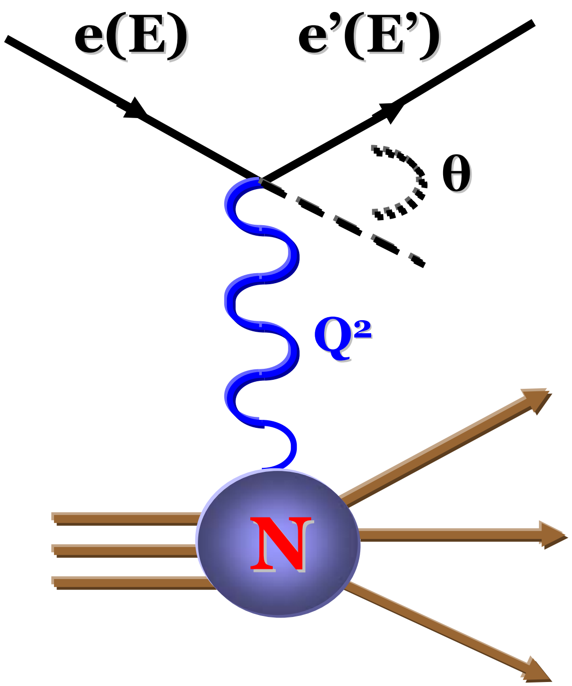
Q^2 - Negative squared mass of the virtual photon

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

$$\nu = E - E'$$



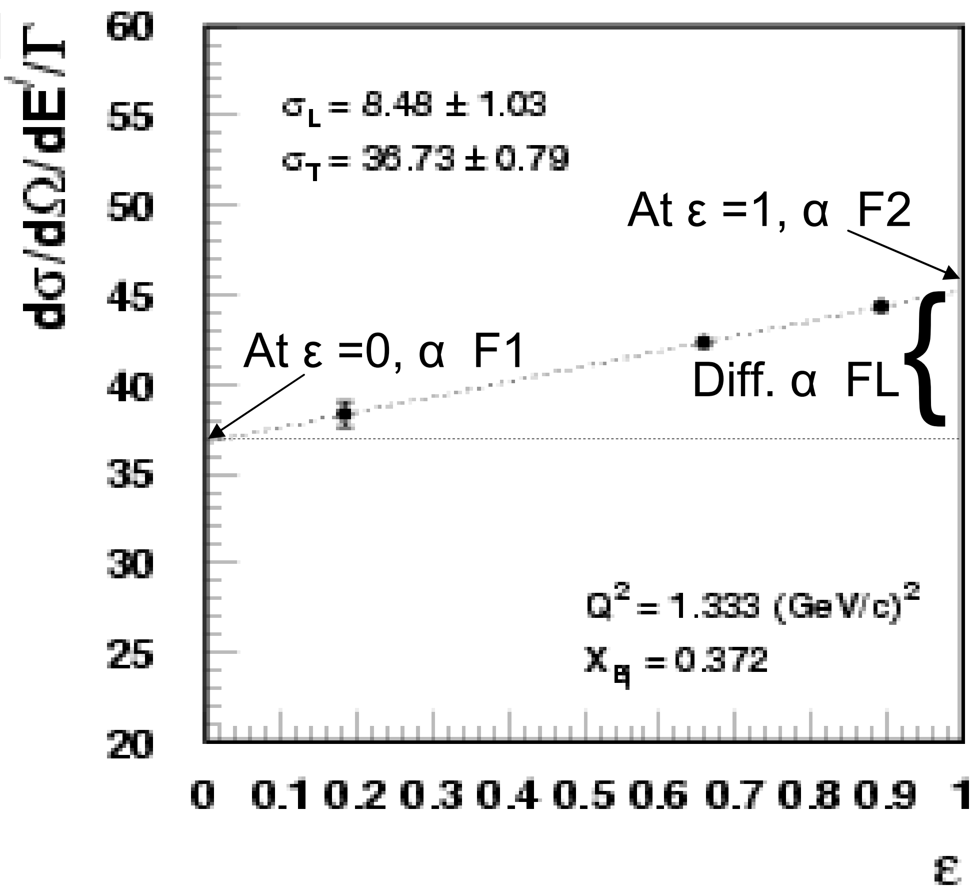
V. Tvaskis

Rosenbluth Separation

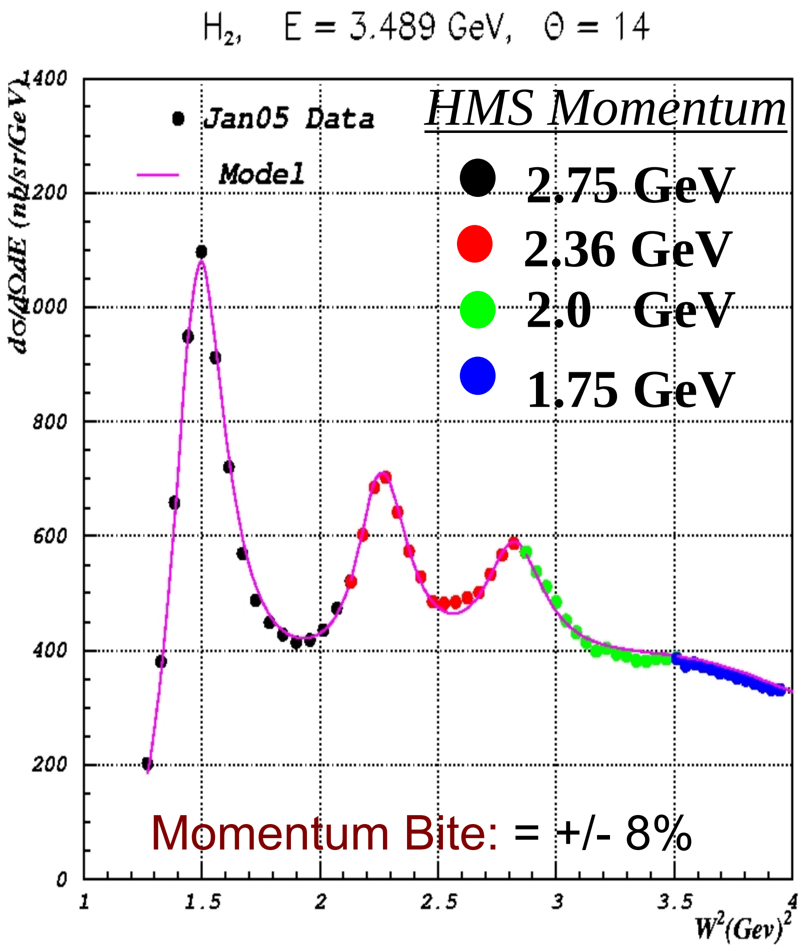
Reduced cross-section

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

- 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



Analysis Methodology



- Bin efficiency corrected e^- yield in $\delta p/p$ - θ.
- Subtract scaled dummy yield bin-by-bin to remove e^- Al and charge symmetric e^+ background.
- Apply acceptance correction for each δ-θ bin.
- Apply radiative corrections bin-by-bin.
- Apply θ bin-centering correction and average over θ => for each δ bin.

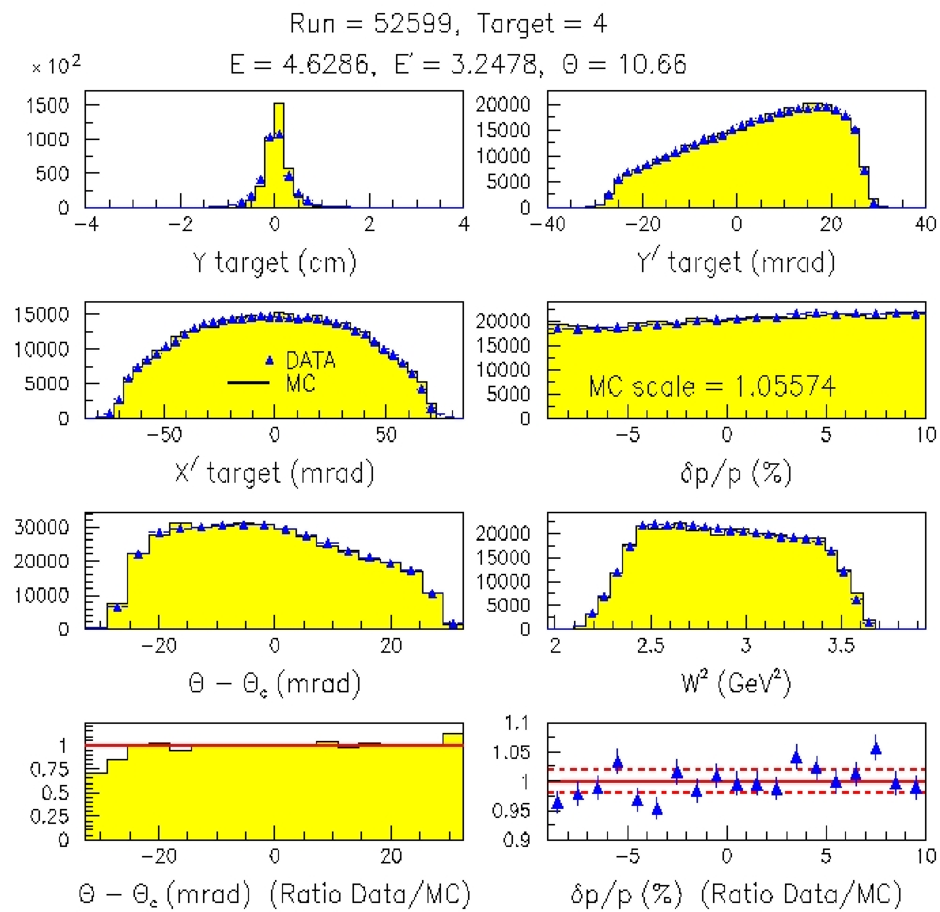
Analysis Status

Detector Calibrations	Completed
Calorimeter Eff.	Completed
Cerenkov Eff.	Nearly Completed
Tracking Eff.	Nearly Completed
Trigger Eff.	Nearly 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
■ Charge Symmetric Background	Completed for 2.3 GeV
■ Cross-Sections	Preliminary inelastic ~5%

HMS Monte Carlo

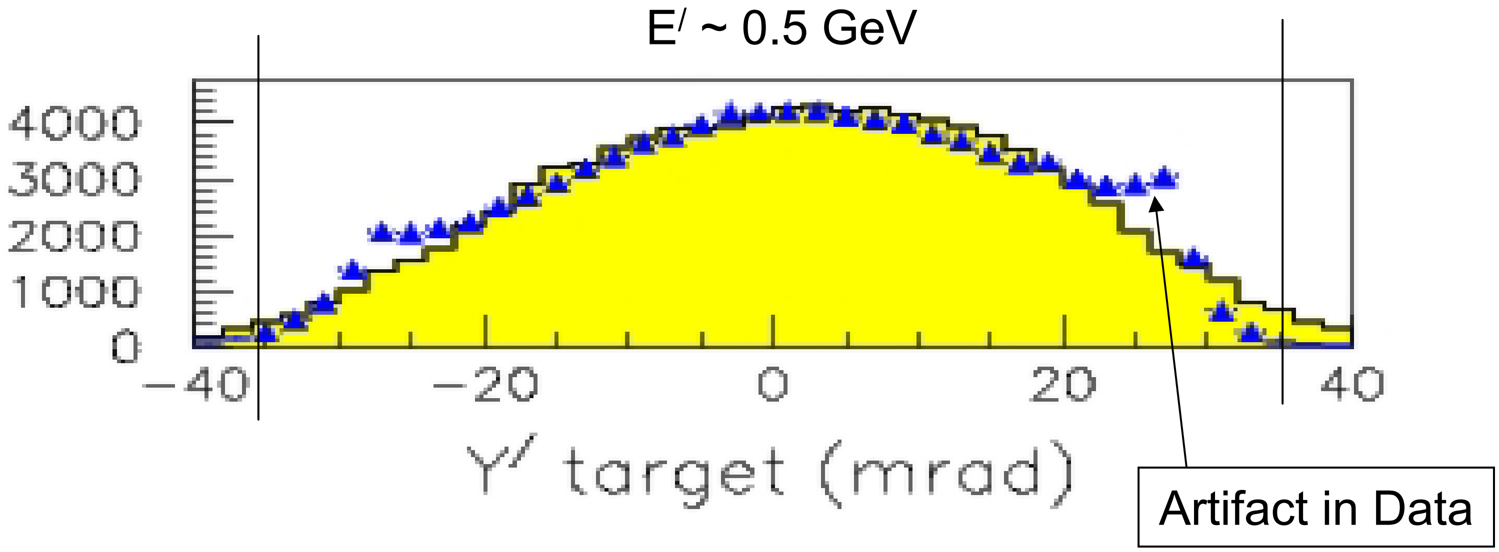
- Use Uniform Illumination MC to generate Acceptance Corrections

- For comparisons to data we include weighting factors for cross section model, backgrounds, and radiative effects.
- Comparisons to data look good for large scattering momenta.



But at low momenta…

Reconstruction Problem at Low $E^/$

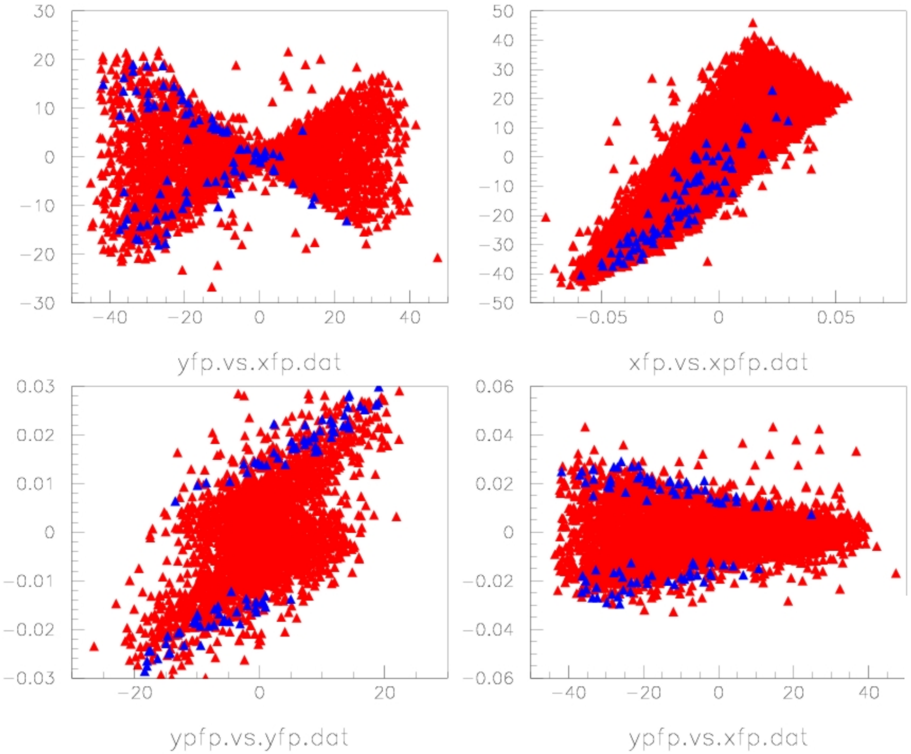


What has changed?

- Found large additional multiple scattering caused by the new HMS exit window (now 20mil Titanium!)
- Supposition: Due to additional MS, the focal plane is being populated in an area which it was not during the optics runs used to fit the matrix elements

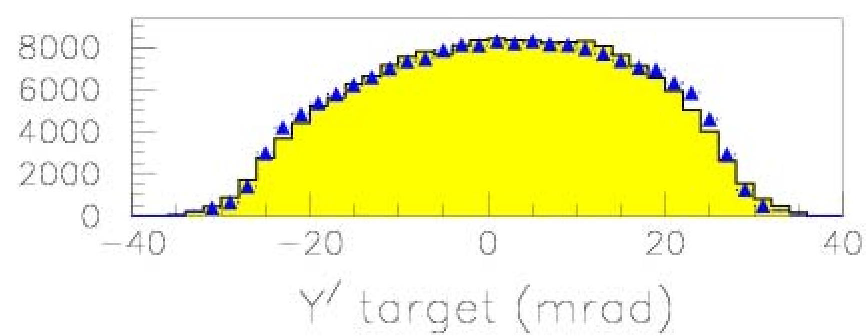
Multiple Scattering

Red – Data Blue – MC abs(Y/tar)>35mrad



- This plot of the focal plane indicates how these events on the fringes of the MC are being reconstructed improperly

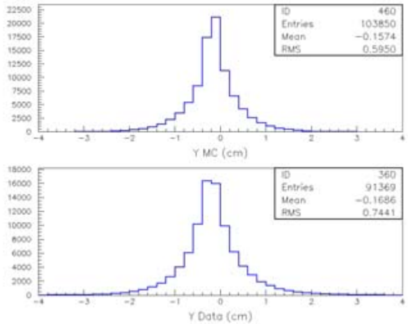
- Applying cuts to remove this problem at the focal plane. (study by E. Christy)



Additional ongoing studies to correct this problem

Beam Position Offsets

- Comparing the beam position of the Data to the Monte Carlo we've arrived at these offsets for C and Fe

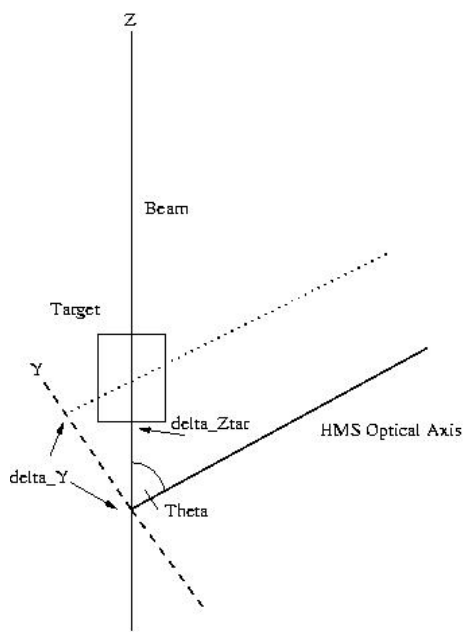


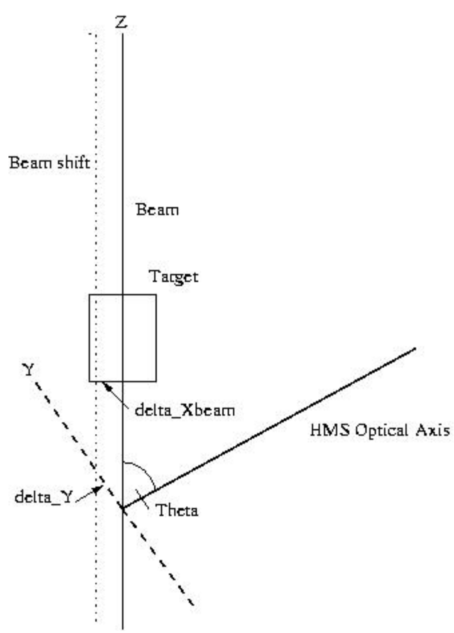
$$\Delta Y = Y_{Data} - Y_{MC}$$

From geometry, we can express this as:

$$\Delta Y / \cos\theta = \Delta X + \Delta Z * \tan\theta$$

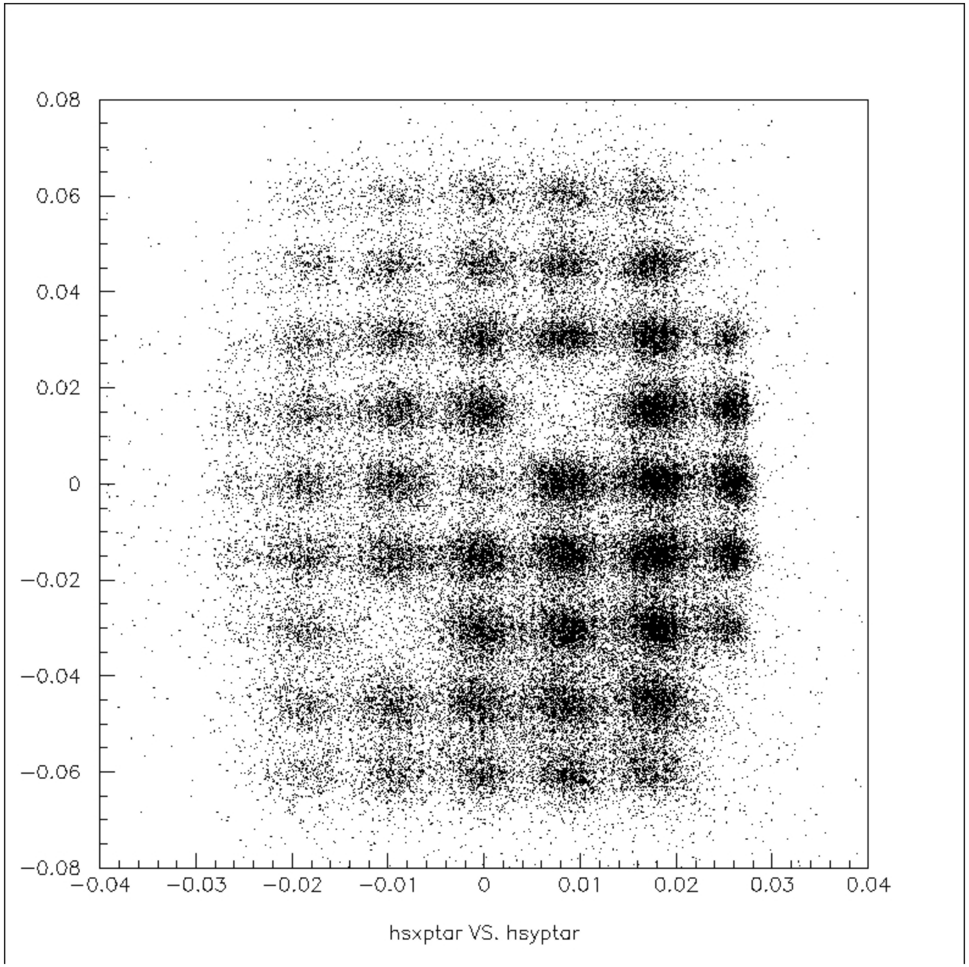
Where ΔX is the offset of the beam, ΔZ is the offset of the target relative to the pivot, and θ is the HMS angle.



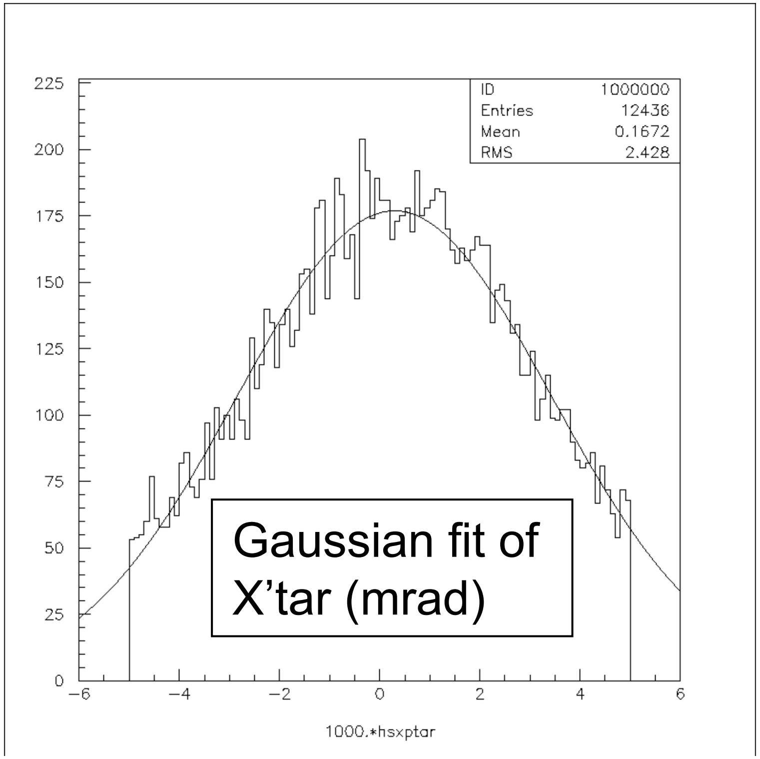


	Fe	C
ΔX =	0.8627	1.1837
Err =	0.2811	0.4530

Vertical beam position

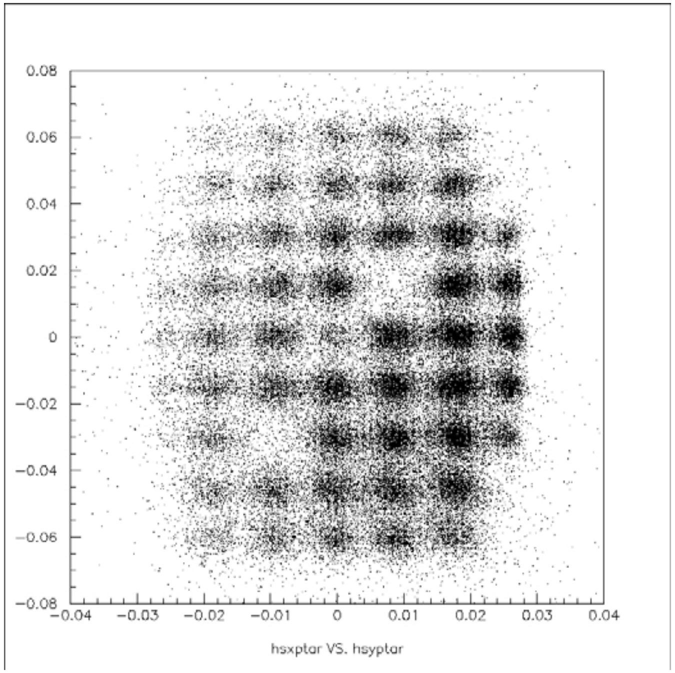


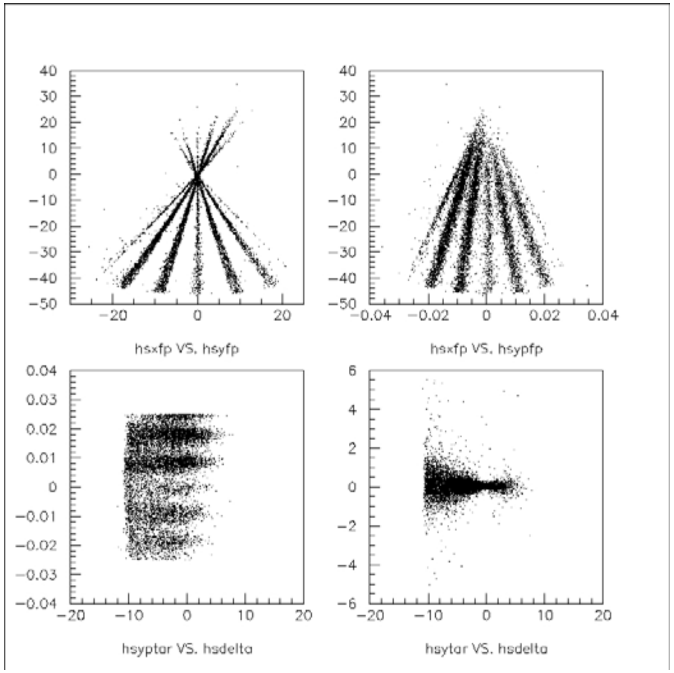
From HMS optics:
$\Delta X'tar$ (mrad) = $1.73 * \Delta y_{beam}$ (mm)



HMS Optics

- Preliminary Sieve Slit studies (just started).

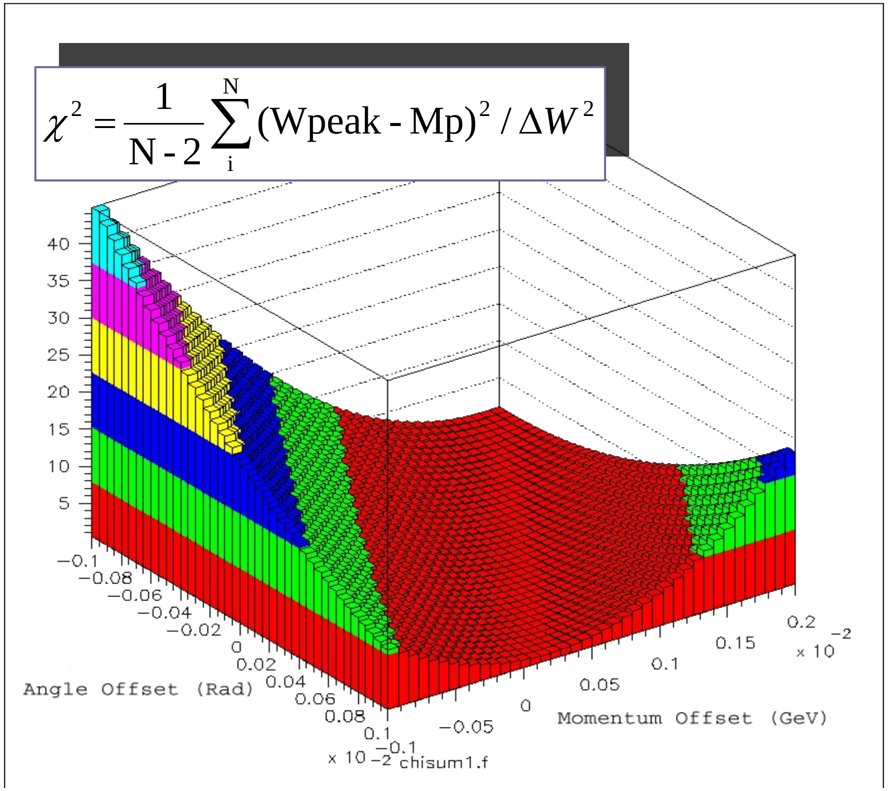




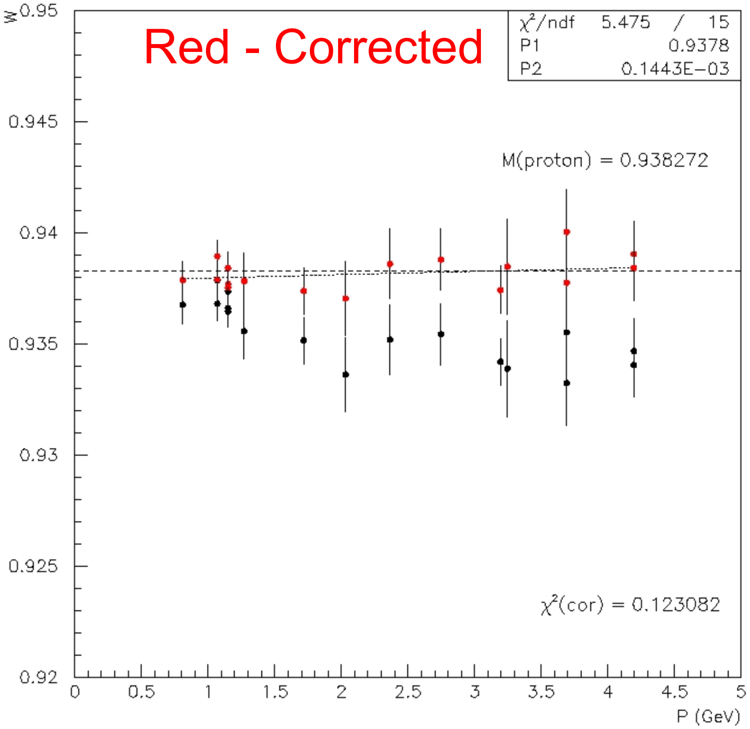
Kinematic Offsets

- Assuming Arc Beam energy measurements are correct.
- Created fitting program that found optimal offsets by finding minimal χ^2 to the proton mass .

$$\chi^2 = \frac{1}{N-2}\sum_{i}^{N}(\text{Wpeak} - \text{Mp})^2 / \Delta W^2$$



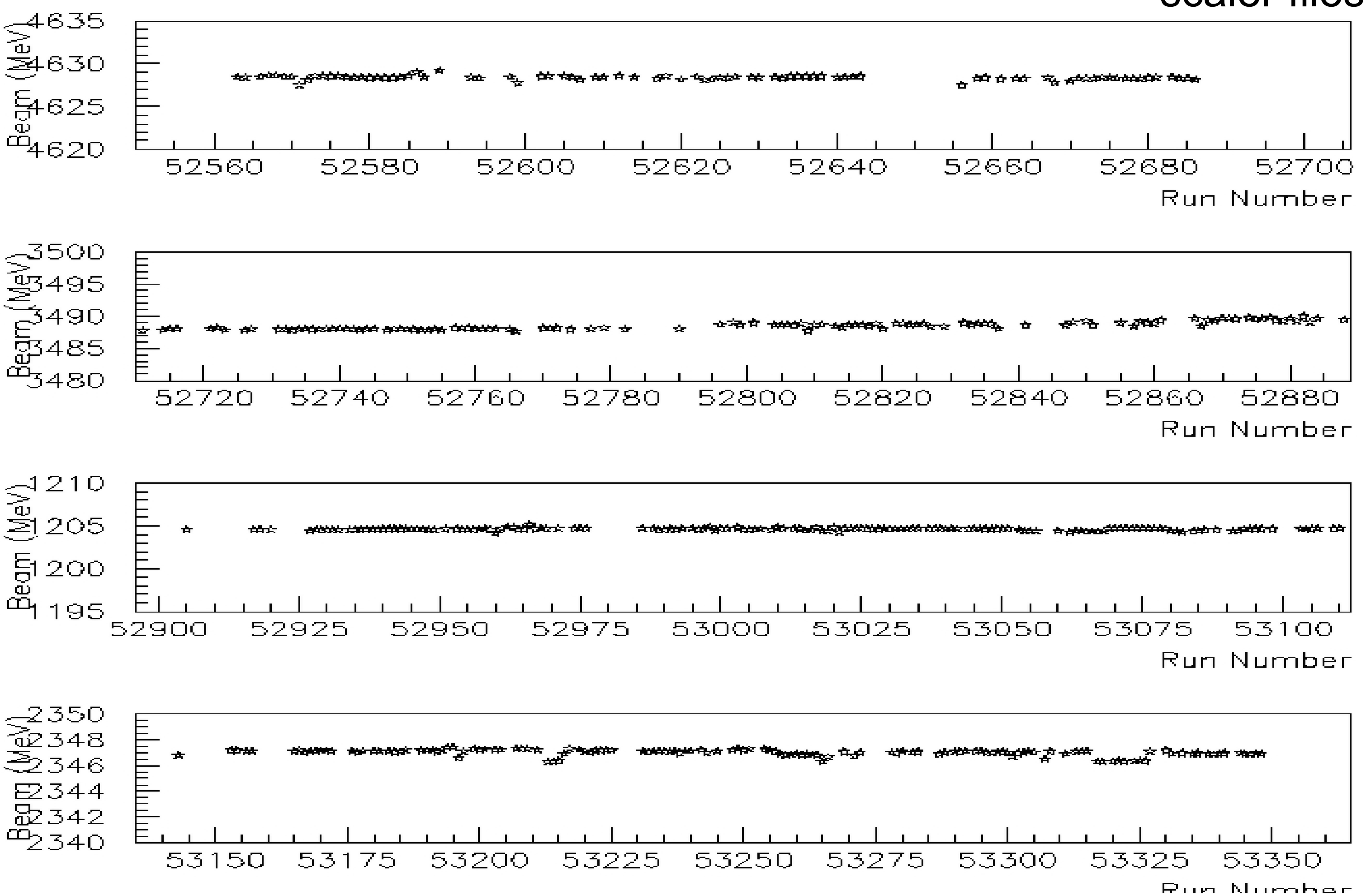
Plot of W vs. $E^{/}$ for H elastic runs



Momentum Offset relative to Field03 program: -0.00249 (dp/p)
Angle Offset: 0.1 mRad

Beam Energy Stability

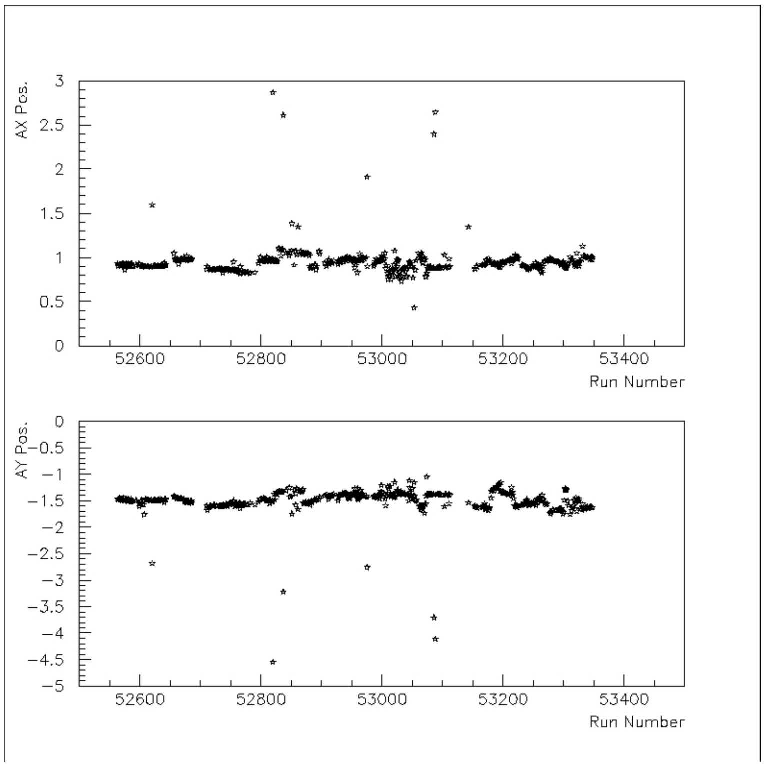
Determined by Arc BPM as read from scaler files

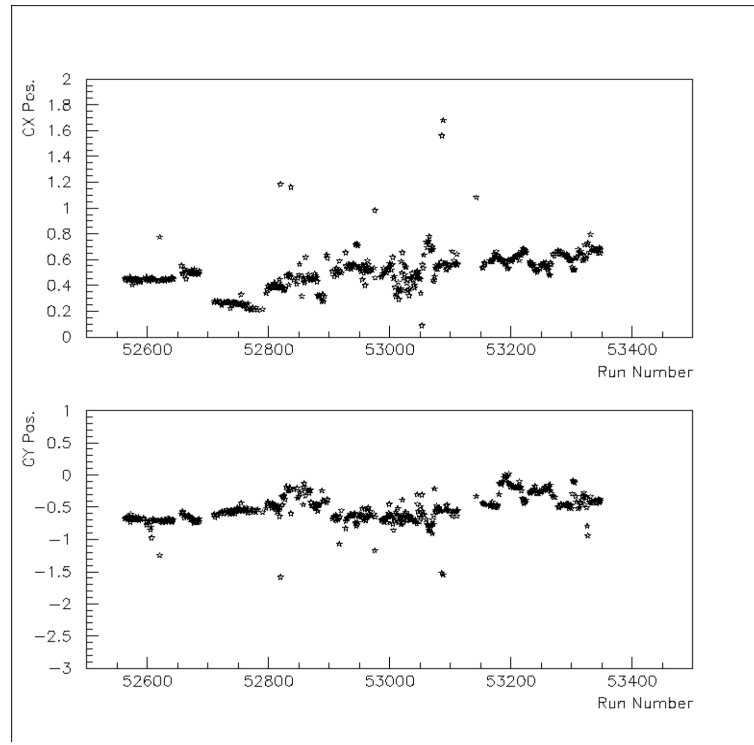


- Plots of BE stability vs. Run # found Beam Energy is stable to ~0.03%.
- Corrections are being made to account for run-to-run variations

Beam Position Stability

- Generally stable except for certain runs



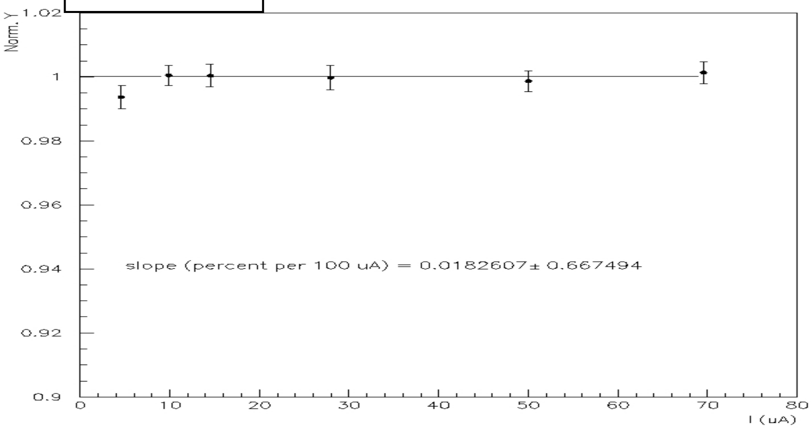


Target Density Corrections

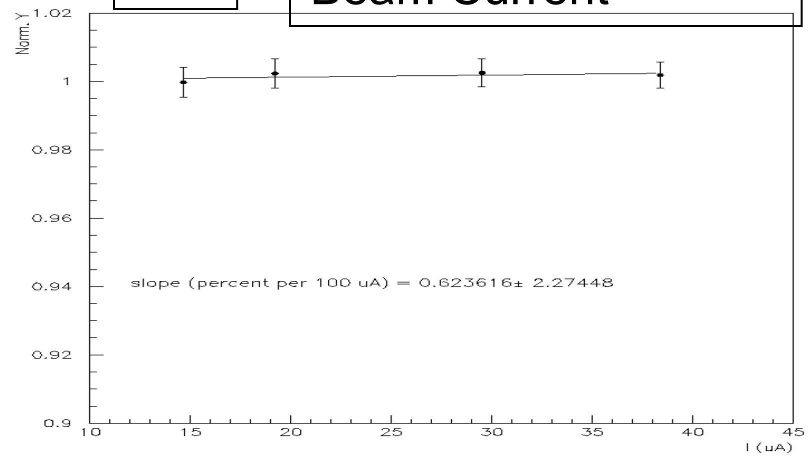
- Solid targets consistent w/ no boiling – good
- Cryo targets ~-1%/100uA

Luminosity Normalized Yield vs. Beam Current

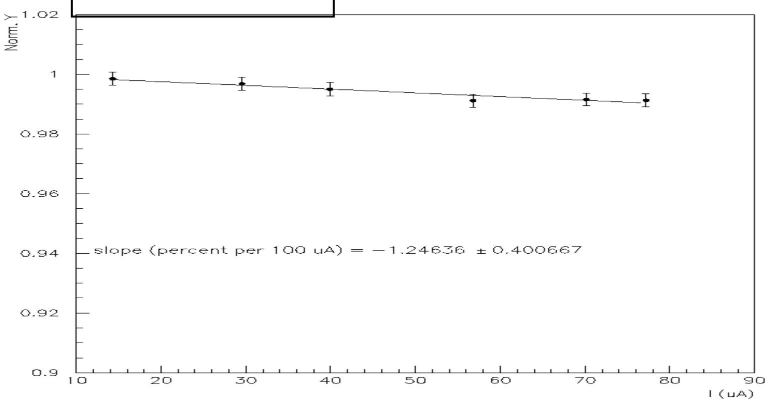
Carbon



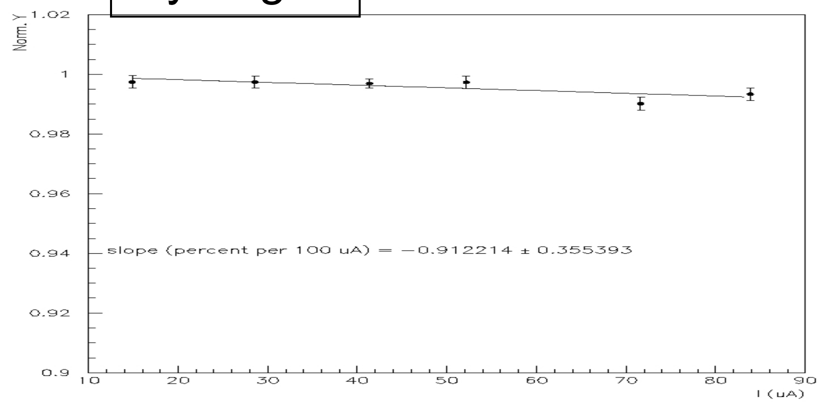
Iron



Deuterium



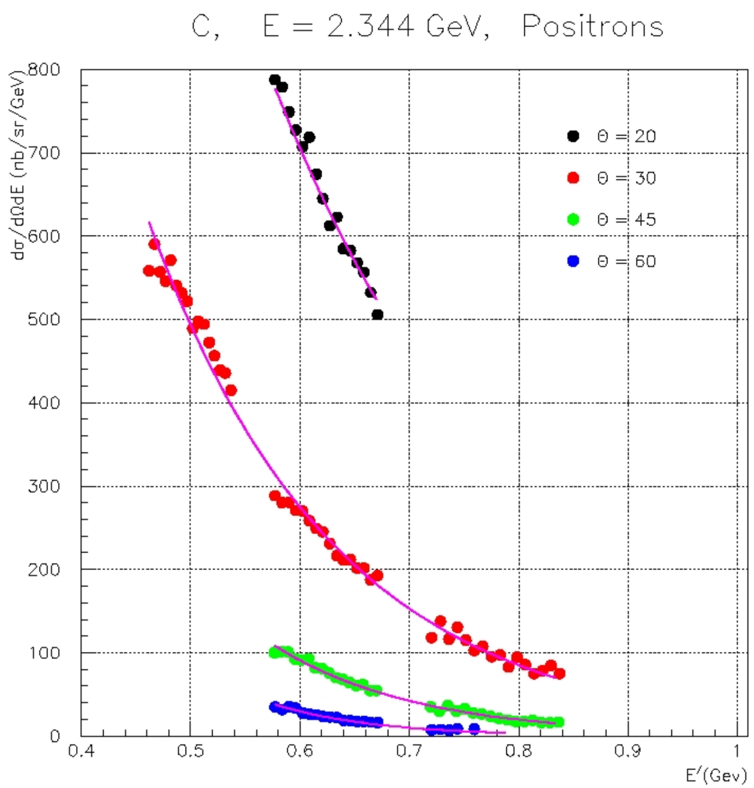
Hydrogen



Charge Symmetric Backgrounds

- Determined CSB by measuring the positron cross section.

- Accomplished for 2.3 GeV runs all taken in HMS
- Other Beam Energies positrons taken w/ SOS – in progress

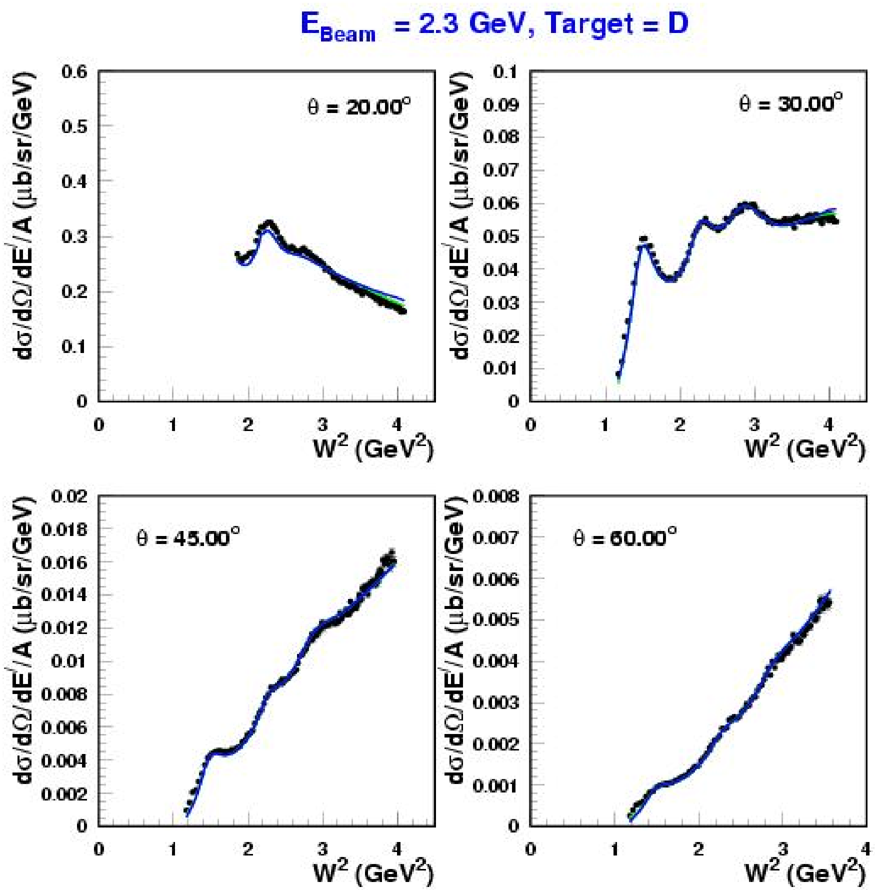


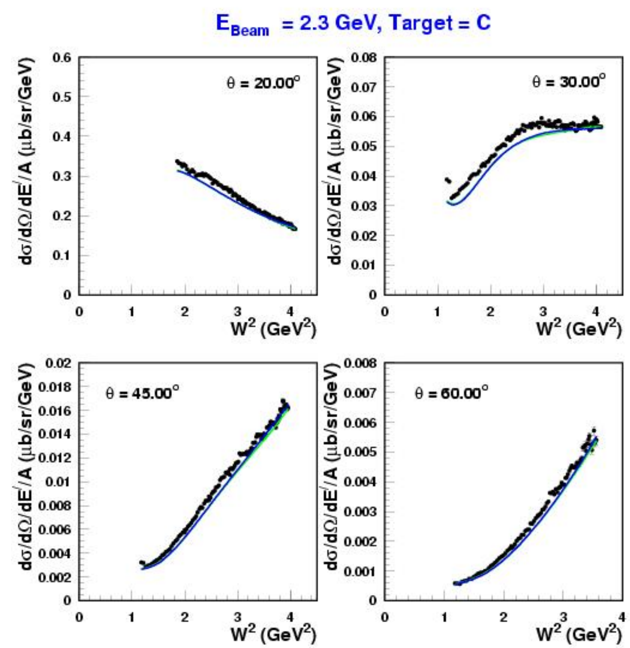
HMS e+ Cross-section

Cross- Sections – Inelastic only

- CS for Beam 2.3 GeV completed

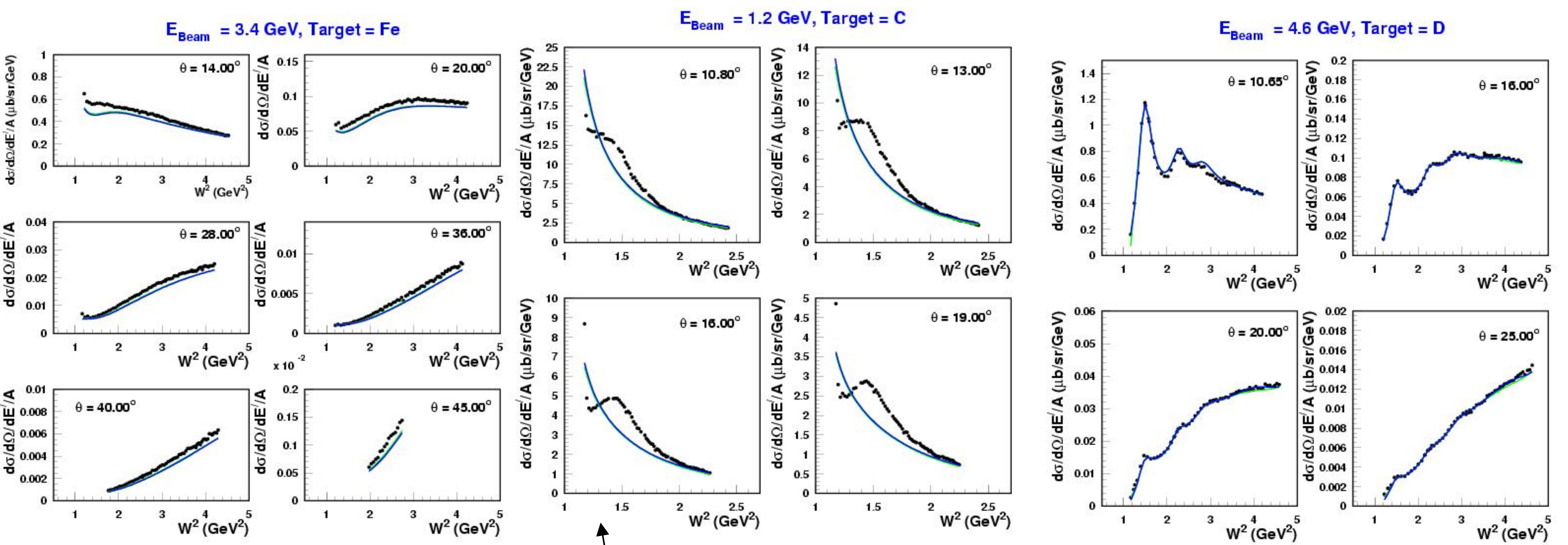
Green – CS input model to RC
Blue – Prev. Data Fit





Cross-Sections – Inelastic only

- For other beam energies, don’t have CSB or Rad. Corrections finalized yet.



Model does not accurately account for resonances at low Q2

Plans in the Future

- Software not set up for Quasi-elastic region yet
- Extract QE and Inelastic cross sections
- Develop Global Fits of Data
- Complete Final Cross Sections
- Rosenbluth Separations

Extracting F_2 and R

- F_2 – Momentum distribution of the nucleon

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

Where

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

- 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