KENT STATE UNIVERSITY

Jefferson Lab
Exploring the Nature of Matter

Medium Modification of Separated Longitudinal and Transverse Structure Functions in the Resonance Region

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JLab Users Group Meeting

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Talk Structure

- Experiment Motivation (E02-109 & E04-001)
- HallC LT Program at JLab
- Physics Overview
- Experimental Setup
- Analysis Steps and Preliminary Results
- Future work

Experiment Motivation
(E02-109 , E04-001)

- Measure the separated longitudinal and transverse structure functions F_L and F_1 from nuclei in the resonance region.

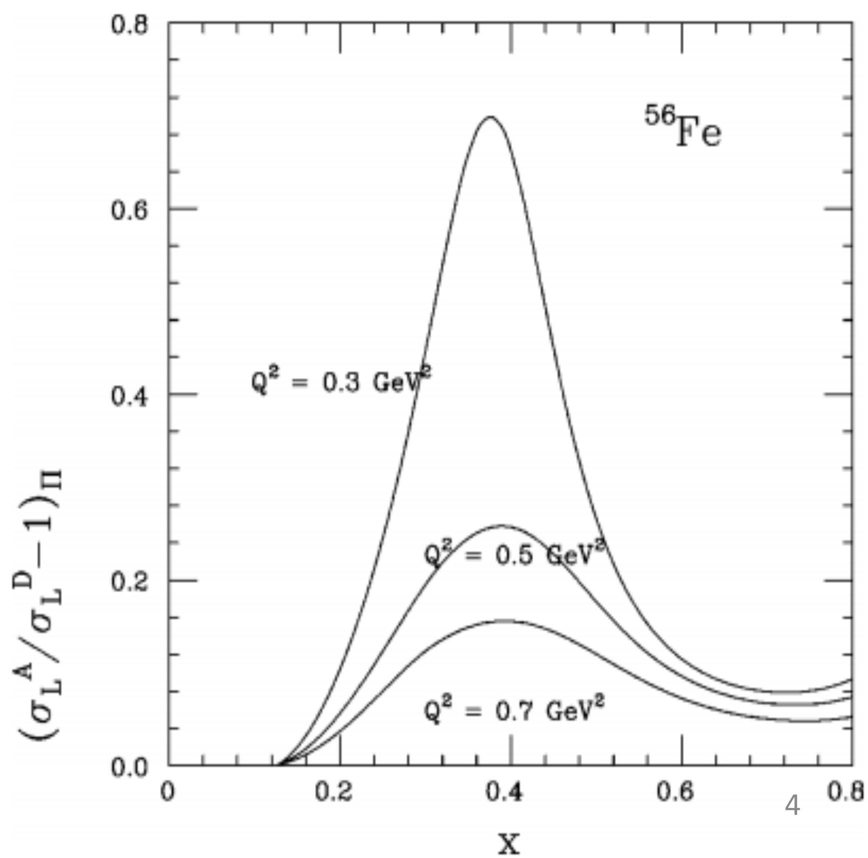
- Investigate quark-hadron duality in nuclei

- Neutrino cross section model development in collaboration with the neutrino community . Measurement of neutrino oscillation parameters require precise knowledge of structure functions. The vector part of F1 and F2 in neutrino scattering can be modeled using electron scattering data.

Experiment Motivation
(E02-109 , E04-001)

- Provide information of medium modifications of separated F_1 and F_L. Non-zero R_D- R_A requires that the medium modifications are different for F_1, F_L, and F_2.

- look for nuclear pions (G. A Miller, Phys. ReV. C 64, 022201 (2001))
- look at EMC effect ratios for FL, F1 (L/T) separately
- check observed SRC correlation for L/T components separately



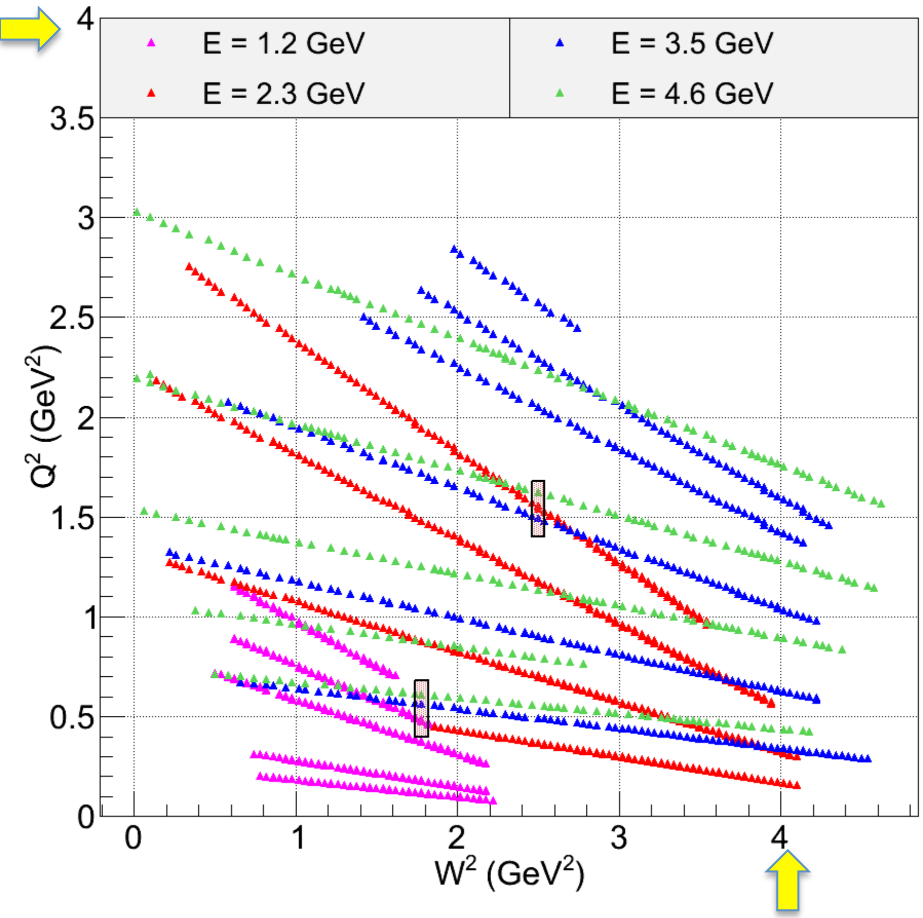
6 GeV L/T Separation Program in HallC

Experiment	target(s)	W range	Q^2 range	Status
E94-110	p	RR	0.3 - 4.5	nucl-ex/041002
E99-118	p,d	DIS+RR	0.1 - 1.7	PRL98:14301
E00-002	p,d	DIS+RR	0.25 - 1.5	Analysis finalized/Published **Phys.Rev. C97 (2018) no.4, 045204**
E02-109	d	RR+QE	0.2 - 2.5	Finalizing dσ analysis
E06-009	d	RR+QE	2.0 - 4.0	Cross section, F_L finalized Non-singlet moments paper in collaboration review
E04-001 - I	C,Al,Fe	RR+QE	0.2 - 2.5	Finalizing dσ analysis
E04-001 - II	C,Al,Fe	RR+QE	2.0 - 4.0	Cross section, RA-Rd finalized for most targets

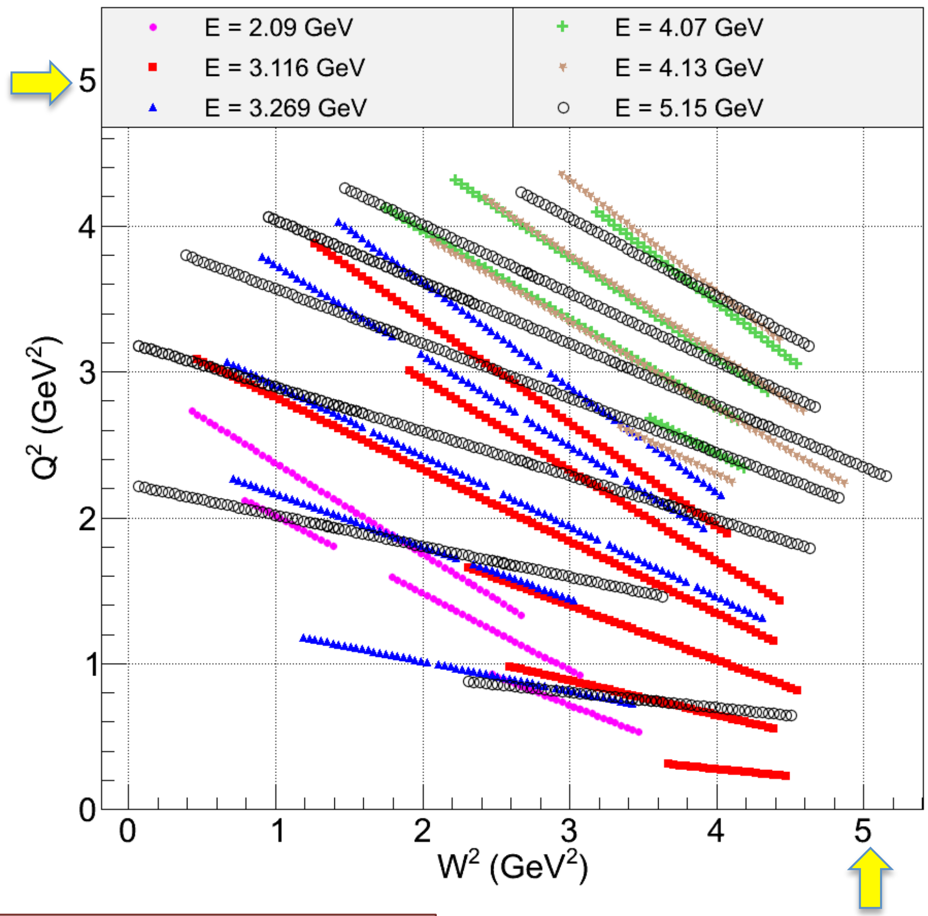
First to see some nuclear dependence

6 GeV L/T Separation Program in HallC

Phase I



Phase II



Greatly expanding of W^2 and Q^2

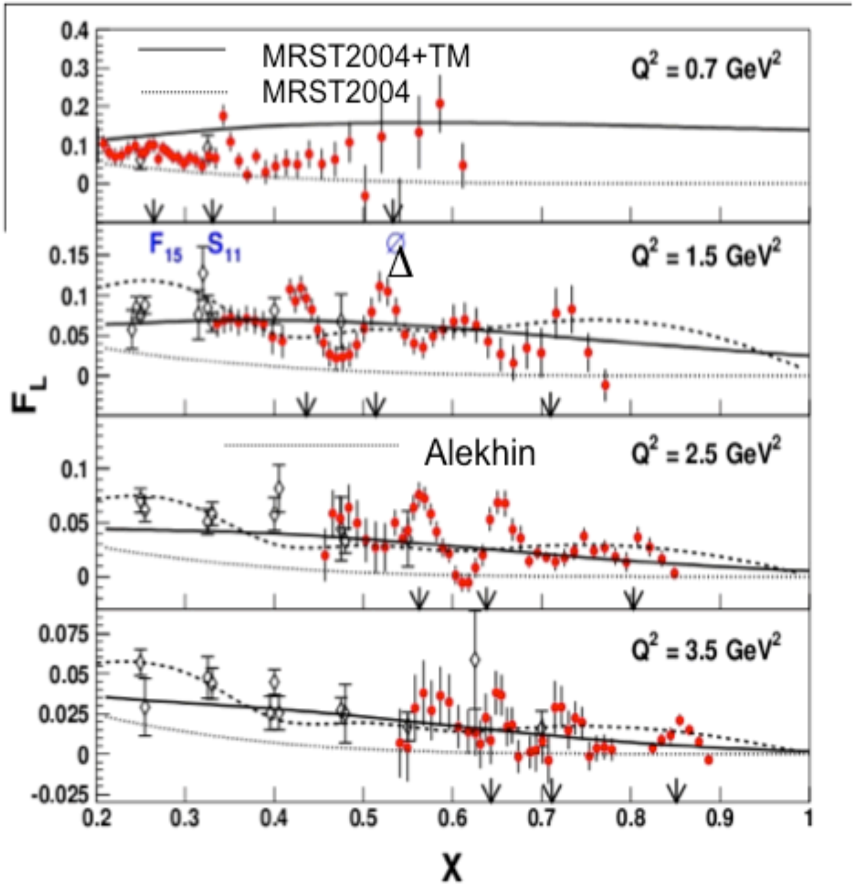
Phase II achieved uncertainties

Total < 2.% point-to-point

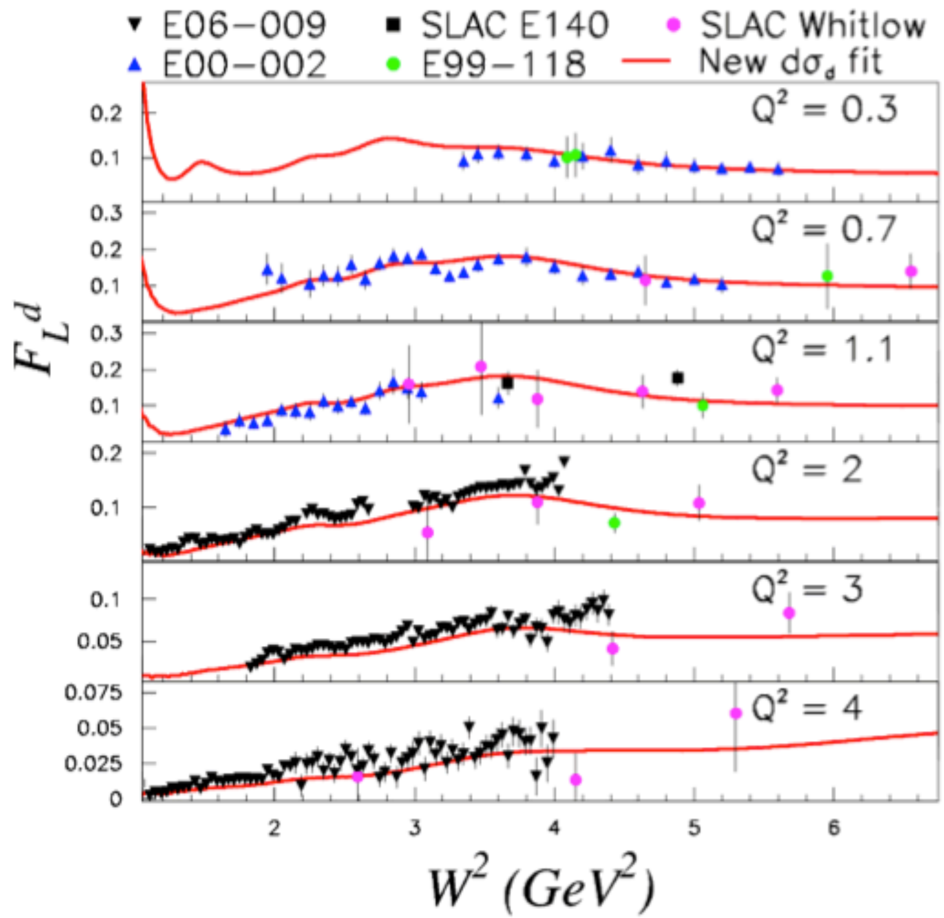
Quantity	Uncertainty	$\delta\sigma\%$
Beam Energy, E	0.05%	0.25 %
Scattered electron energy, E'	0.06%	0.025 %
Scattered electron angle, θ	0.2 mrad	0.3 %
Beam Current	0.3 μA	0.3 %
Electronic Live Time	0.008%	0.008 %
Computer Live Time	0.2%	0.2 %
Trigger Efficiency	0.007%	0.007 %
Tracking Efficiency	0.15%	0.15 %
Cerenkov Efficiency	0.15%	0.15 %
Calorimeter Efficiency	0.05-0.2%	0.05-0.2 %
Charge Symmetric Background Correction	0.1-0.4%	0.1-0.4 %
Acceptance	0.7%	0.7 %
Radiative Corrections		$\leq$1.0 %

Previous results from HallC LT program

Proton: E94-110 + SLAC



Deuteron



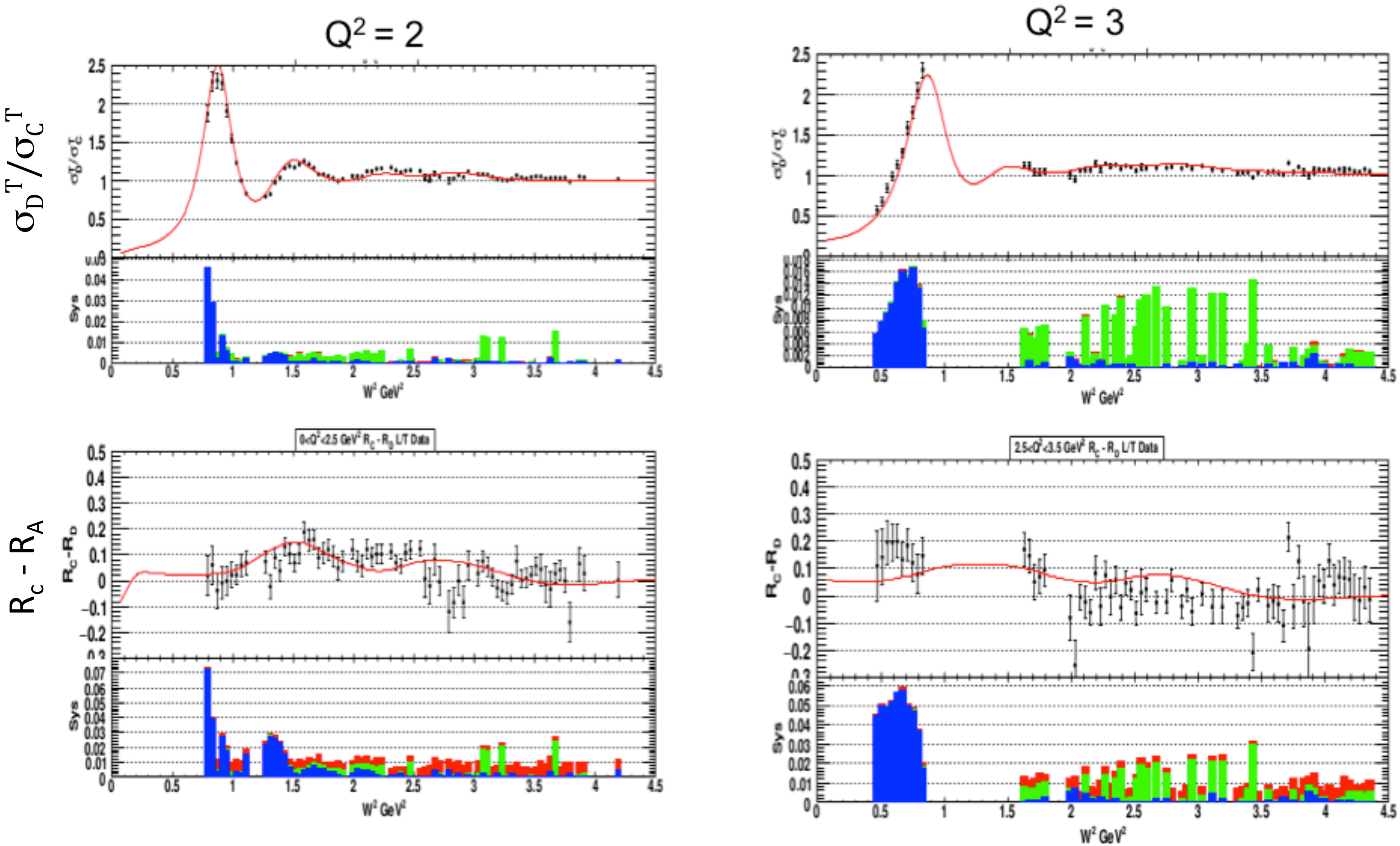
Phase I (E02-109) **deuteron** will:

→ add more precision points at low Q^2 and W^2

→ improve precision at intermediate Q^2 when combined with Phase II (E06-009)

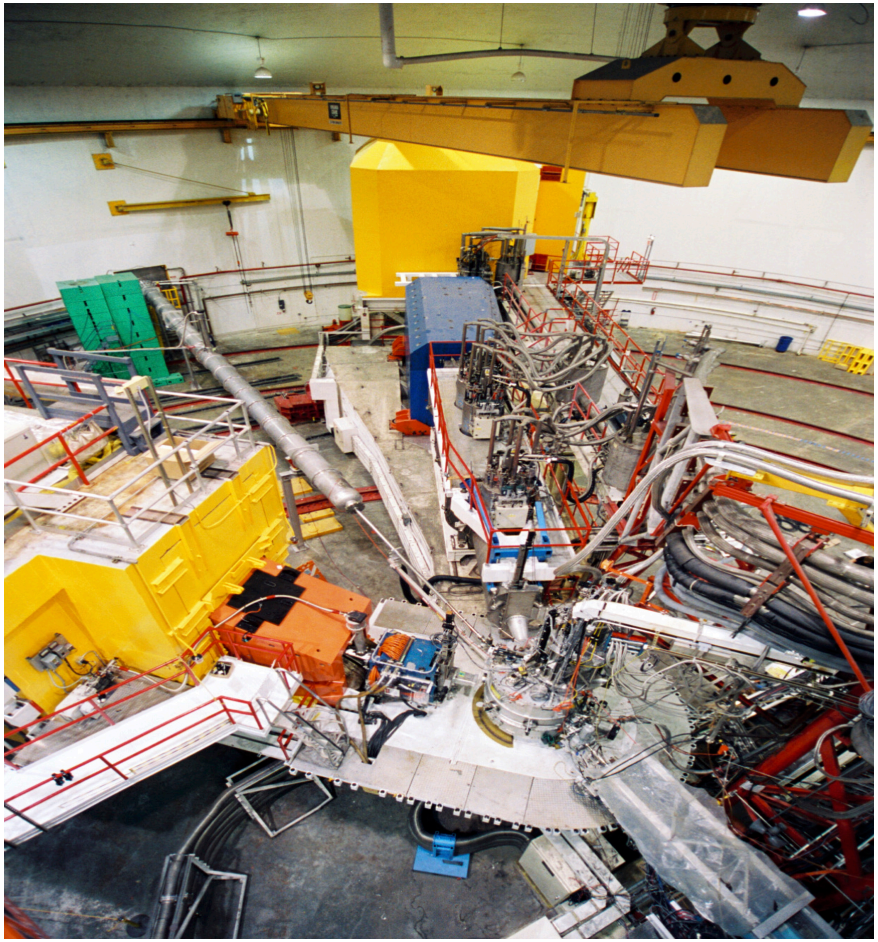
Nuclear study dependence study at larger Q2

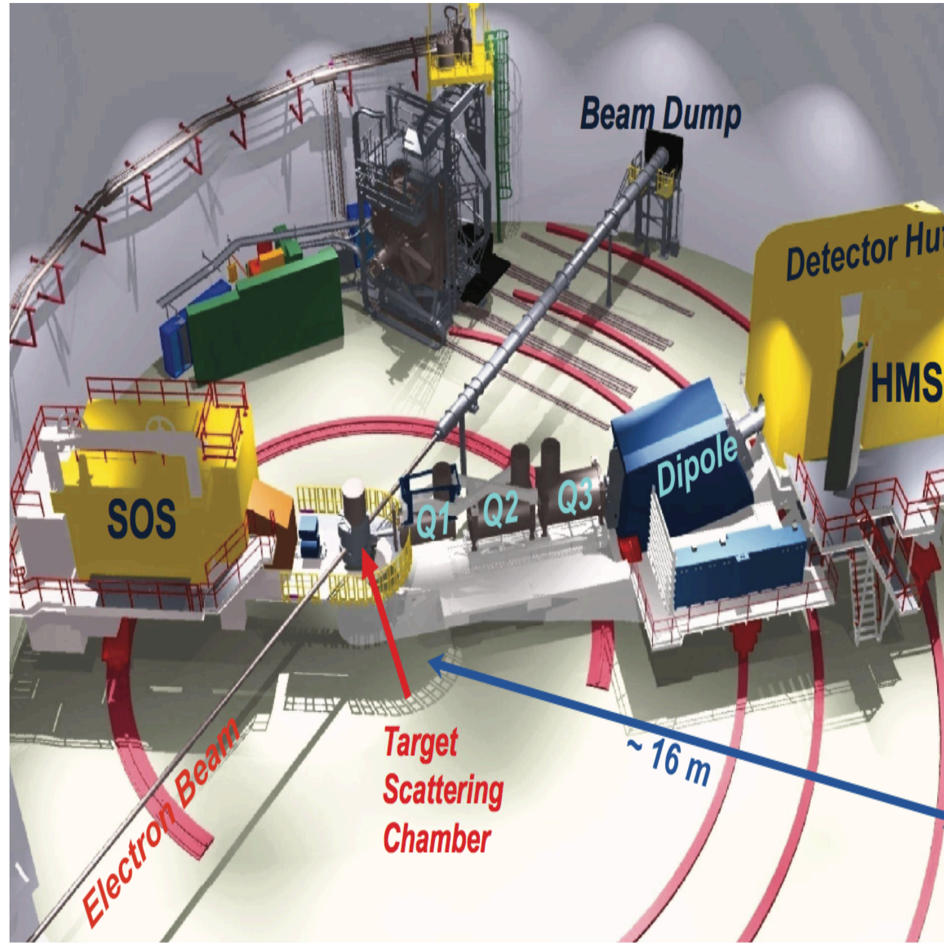
^{12}C: Phase-II



Modeling suggests that the enhancement is due to different Fermi smearing for different nuclei

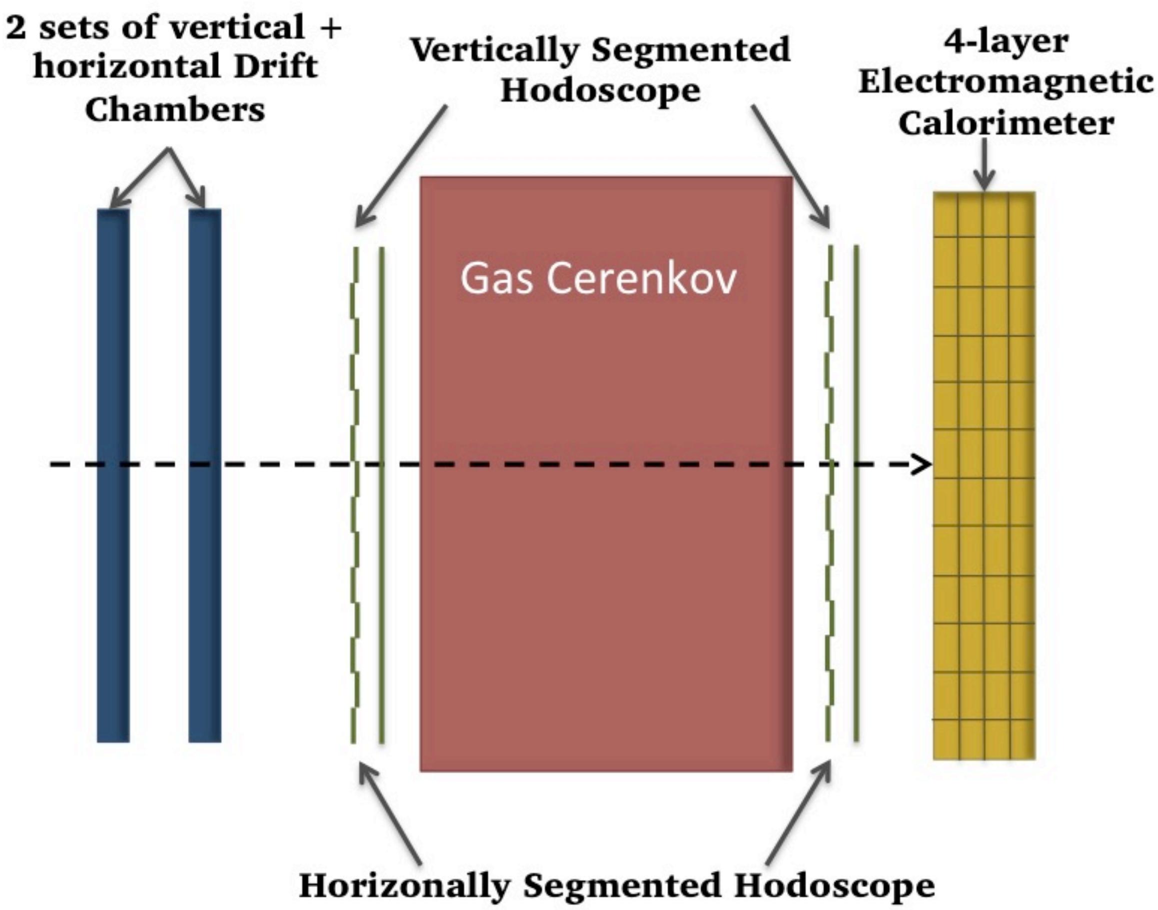
Experimental Setup





Hall C top view (6 GeV era). High Momentum Spectrometer (HMS) was used to detect scattered electrons, whereas the Short Orbit Spectrometer (SOS) was used largely for charge symmetric background rejection.

Experimental Setup



HMS Detector Stack (view from above)

HMS Properties	
Kinematic Range	
Momentum:	0.5-7.5 GeV/c
Angular:	10.5°-80°
Acceptance	
$\Delta\Omega$	~6.5 msr
$\Delta p/p$	+/-10 %
Resolution	
$\Delta p/p$	<0.1 %
θ	~ 1 mrad

Cross Section Extraction

1. For each kinematic, generate MC events with σ "model" weighting including the radiative contributions. The "model" is a global fit including preliminary data from this experiment **Model: Global fit to existing data by M.E. Christy, A Bodek, T. Gautam (in preparation), based on Bosted-Mamyan**

2. The efficiency corrected electron yield after subtraction of BG events is:

$$Y_{Data} = L_{Data} .\, \sigma_{Data} .(\Delta E' . \Delta\Omega).A$$

$$Y_{MC} = L_{MC} .\, \sigma_{MC.} (\Delta E' . \Delta\Omega).A_{MC}$$

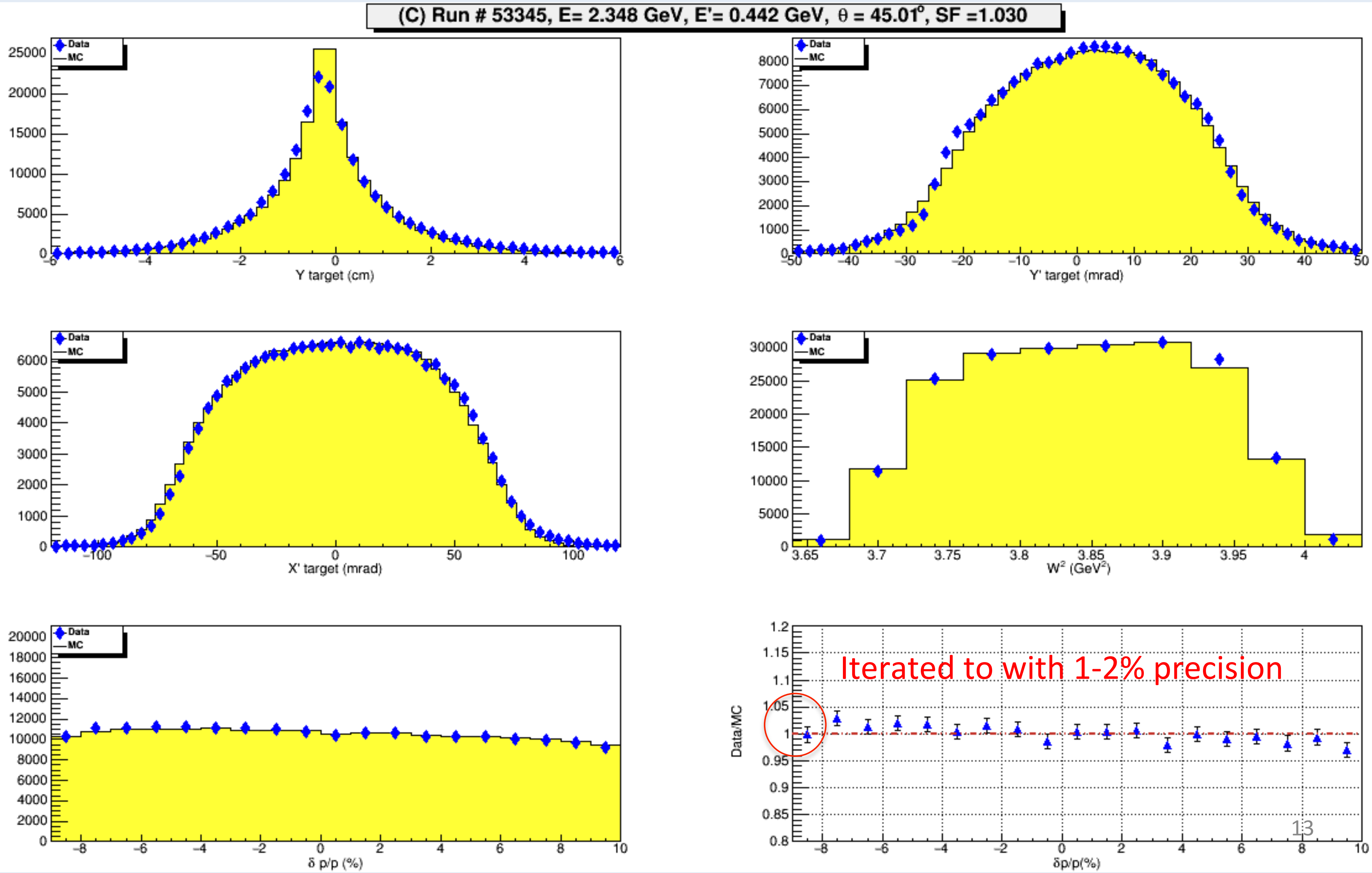
3. Assuming that the acceptance $A = A_{MC}$, the ratio of the Data to the model Yield leads to:

$$\frac{Y_{Data}}{Y_{MC}} = \frac{L_{Data} . \sigma_{Data} . A}{L_{MC} . \sigma_{MC} . A}$$

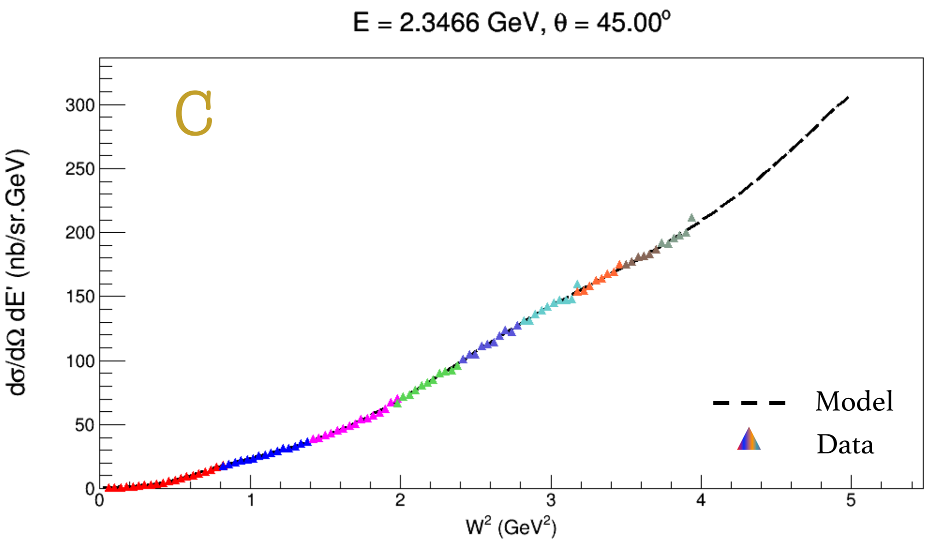
4. After Scaling the MC luminosity by a factor of L_{Data}/L_{MC} so that $L_{Data} = L_{MC}$, the cross section is calculated for each W^2 bin and integrated over θ using:

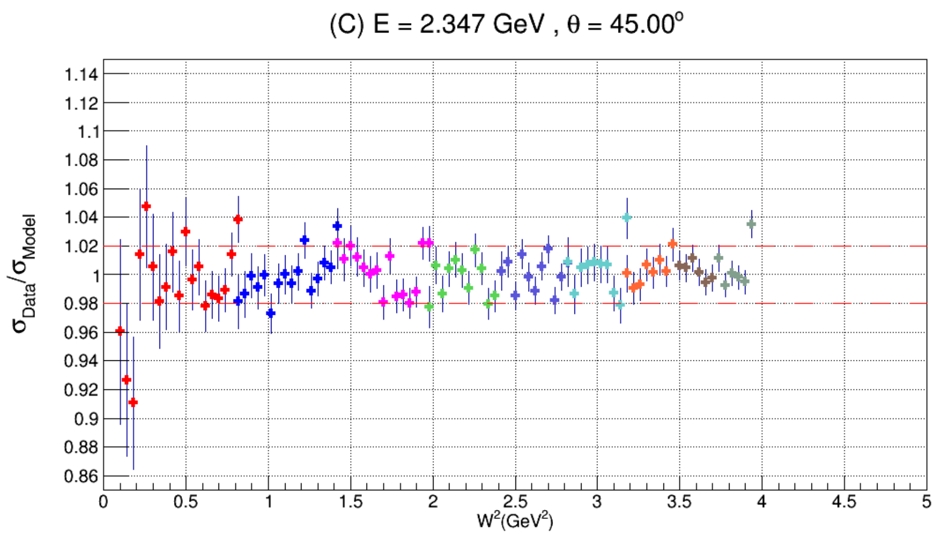
$$\sigma_{Data} = \sigma_{MC} \times \frac{Y_{Data}}{Y_{MC}}$$

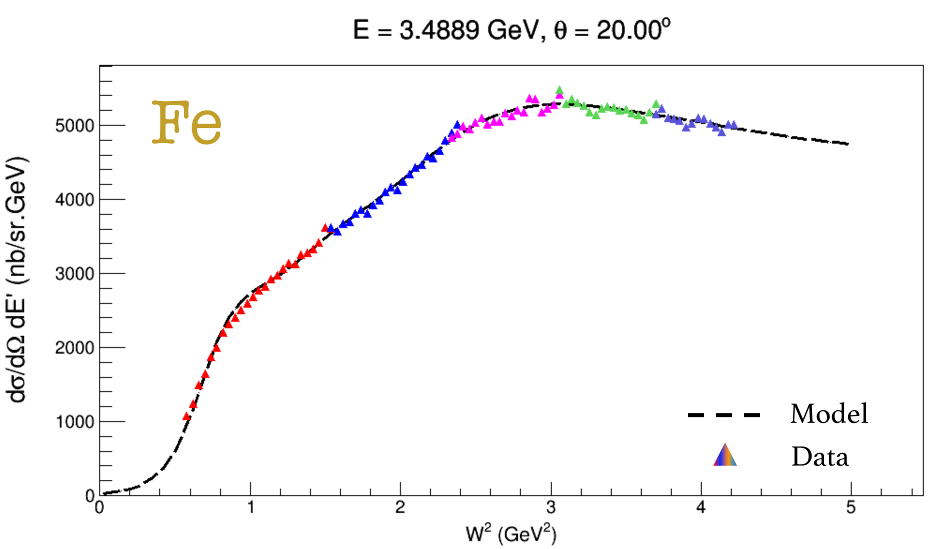
MC includes all the physics, and well modeled spectrometer-> allows precision in extracting cross section

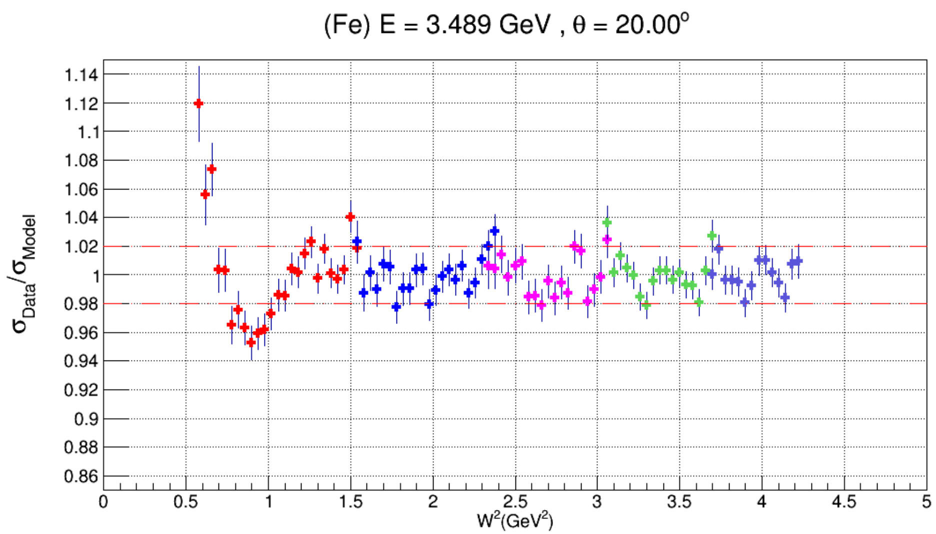


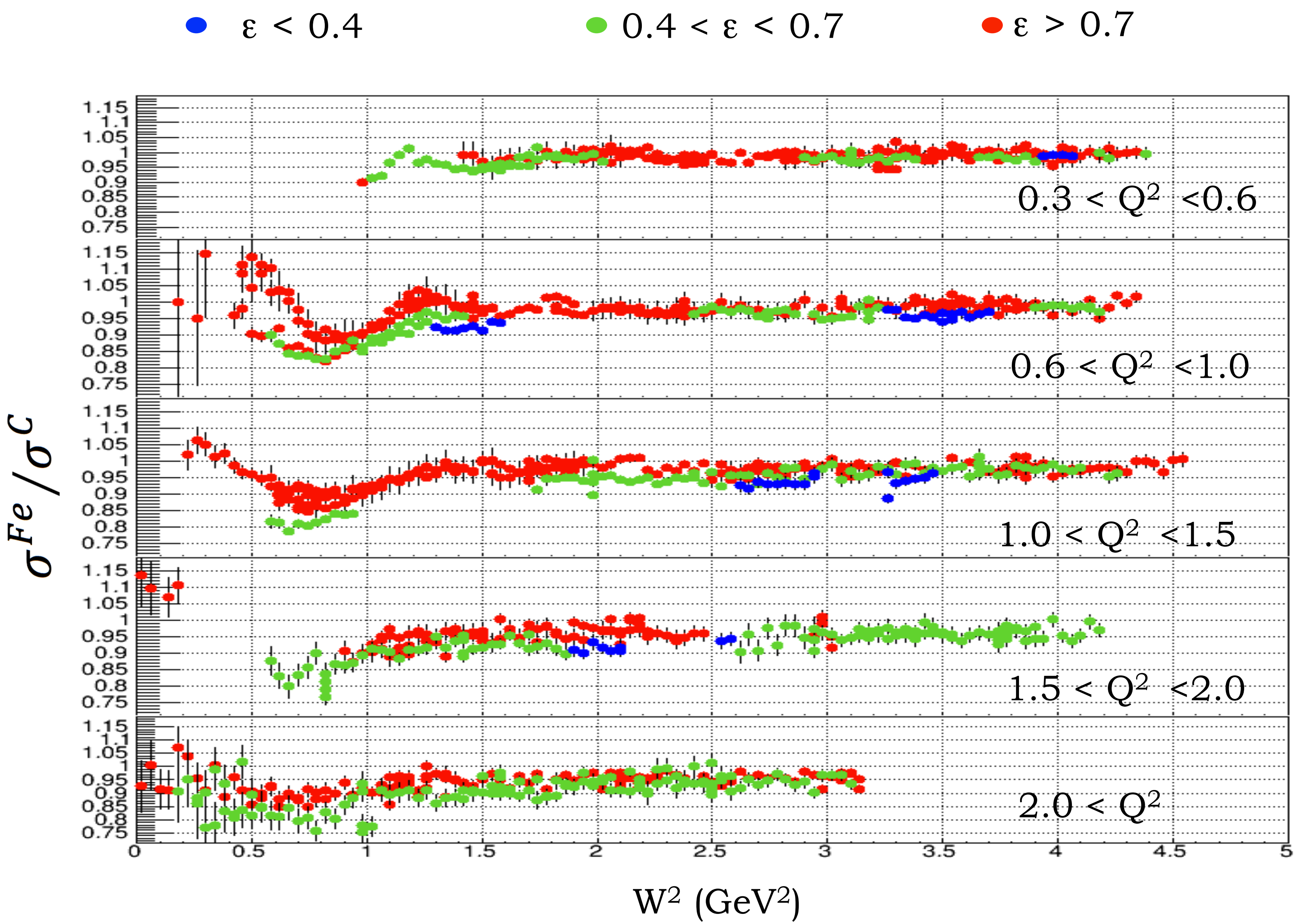
Cross Section Extraction











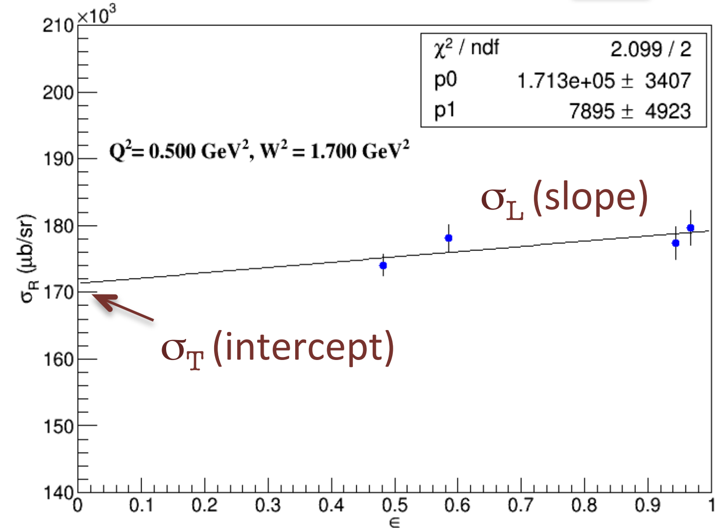
Evedence some ε dependence , and nuclear longitudinal dependence.
Validation requires final evaluation of full systematics

Rosenbluth Separation

- The reduced cross section σ_R is linear in ε:

$$\sigma_R = \sigma_T + \varepsilon\sigma_L$$

Hence, one can plot σ_R versus ε for fixed W^2 and Q^2 and extract σ_L (slope) and σ_T (intercept). This method is called ***Rosenbluth separation technique***.



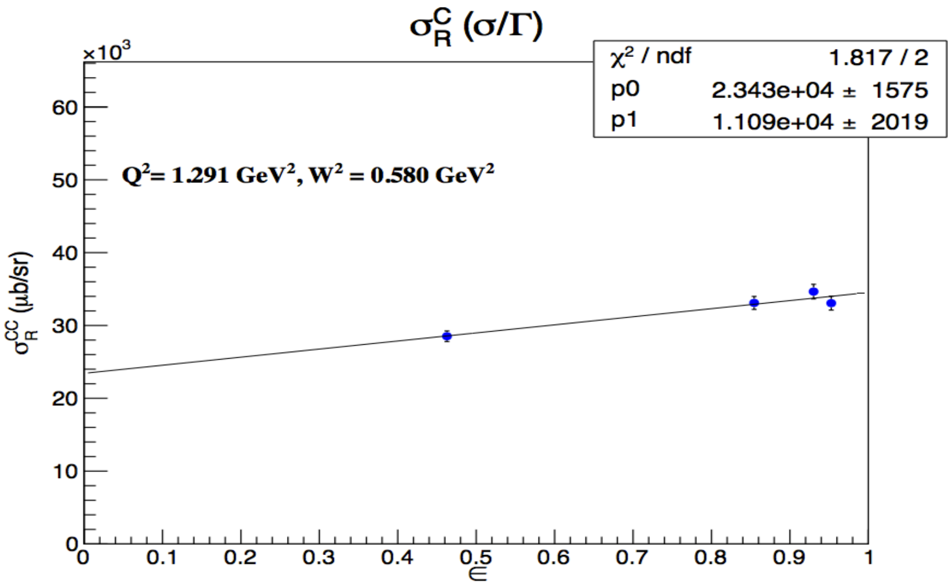
- The Rosenbluth separation points are chosen for each target, where the points have the same W^2 and in a Q^2 range of 15% about a central Q^2_c (got almost 188 LT sets, will be increaded when combined with phase II data).
- The difference R_D-R_A and F_{2D}/F_{2A} are extracted from the linear fits to the ratio of differential cross section

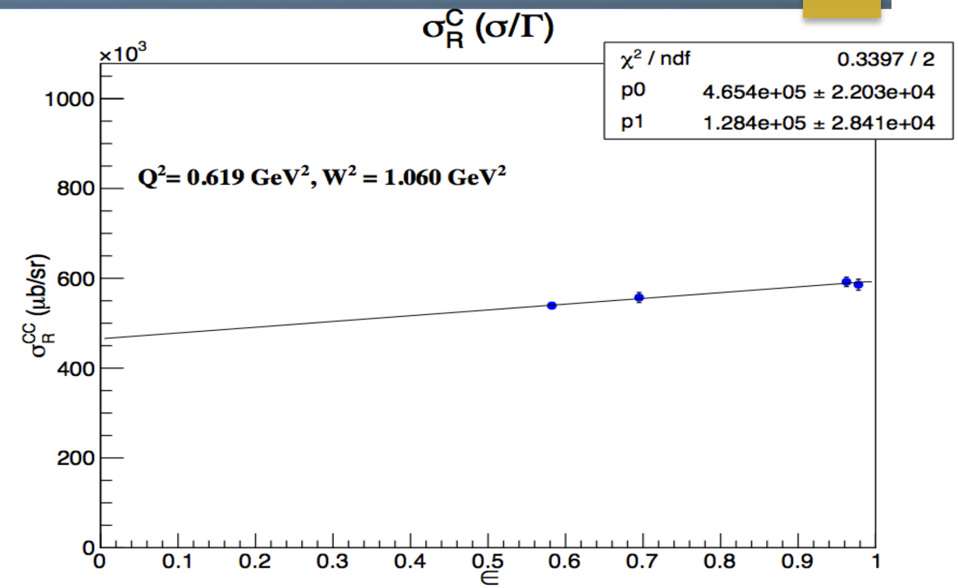
$$\frac{\sigma_D}{\sigma_A} = \frac{\sigma_D^T}{\sigma_A^T}[1 + \epsilon'(R_D - R_A)]$$

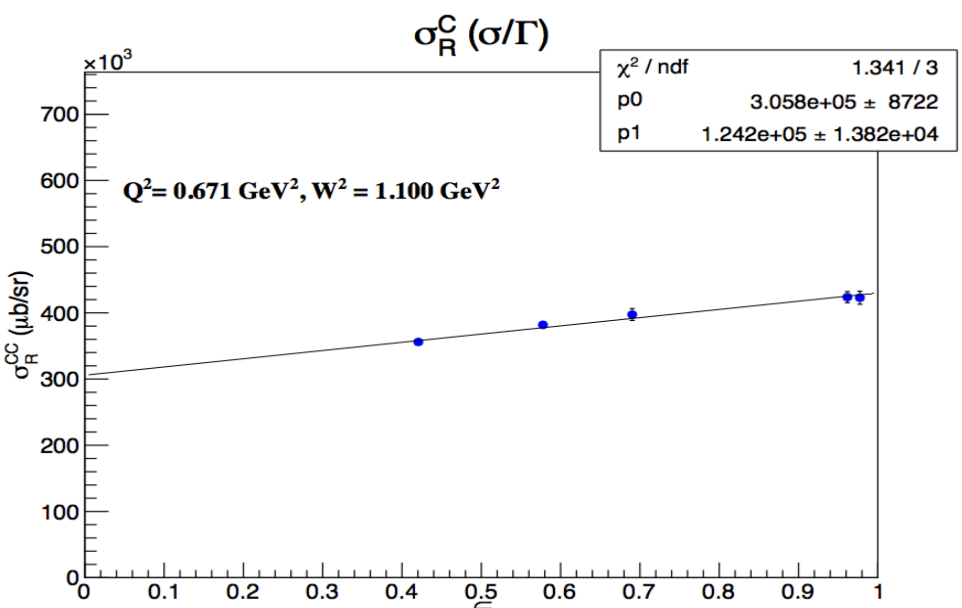
where:

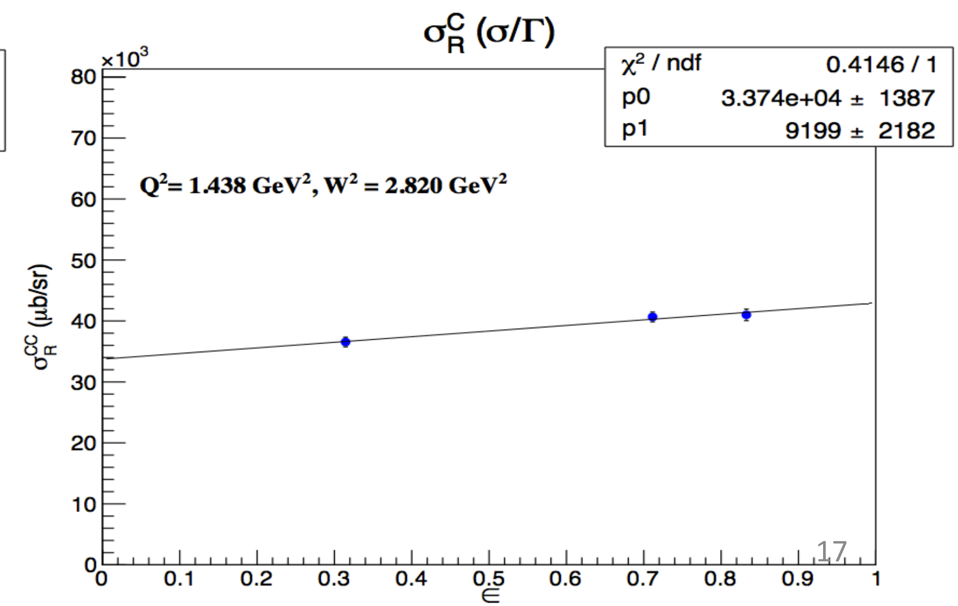
$$\epsilon' = \epsilon/(1 + \epsilon R_A)$$

Rosenbluth Separation

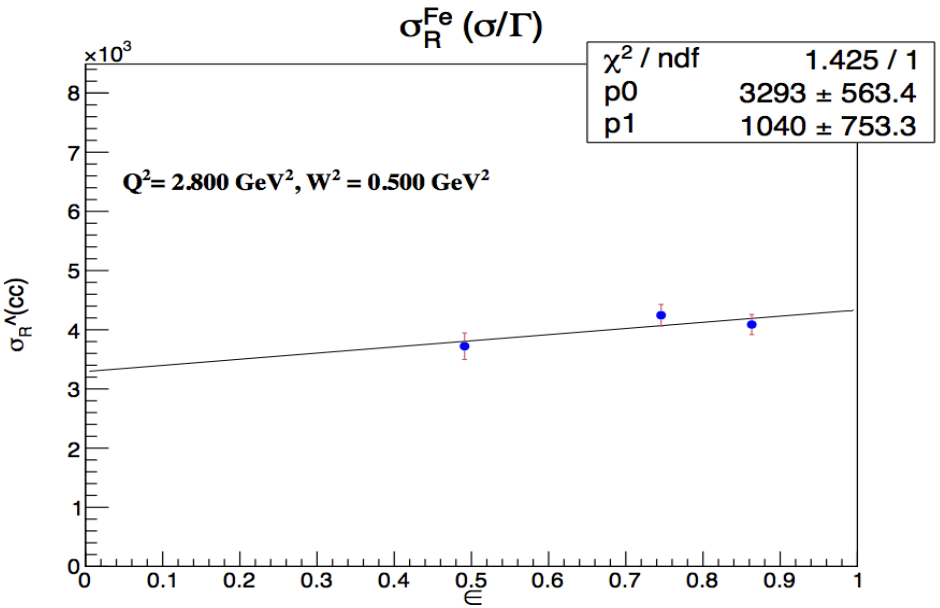


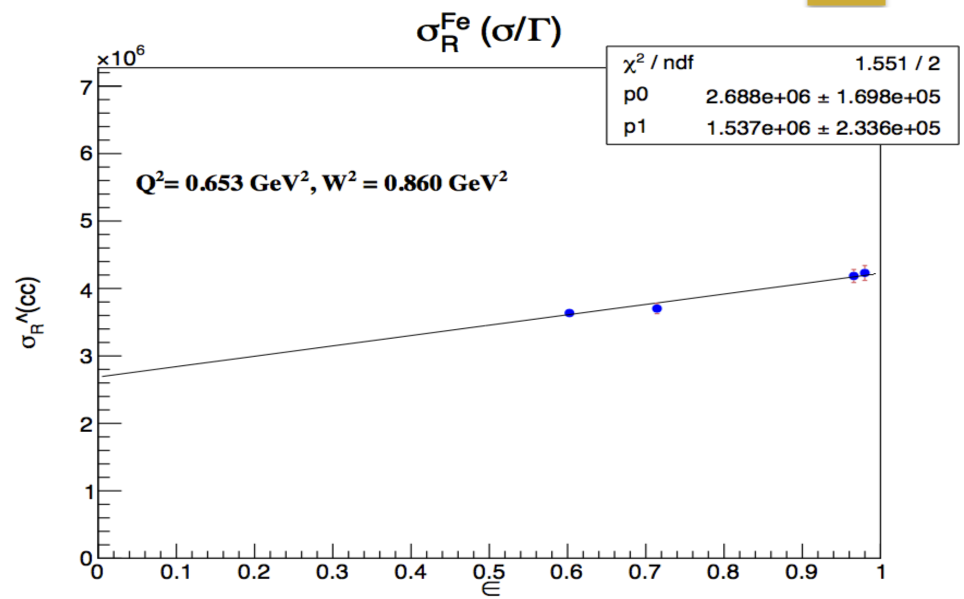


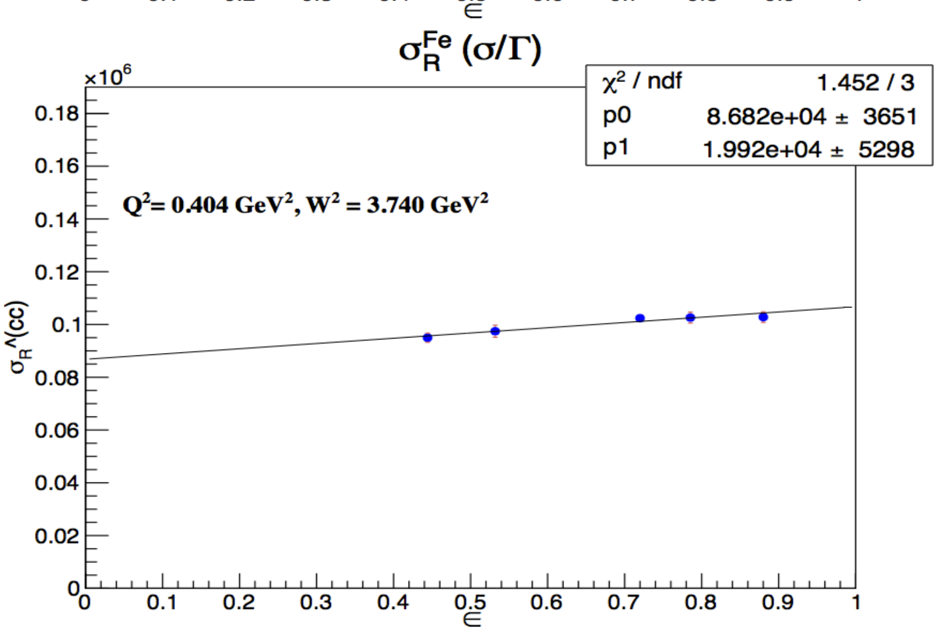


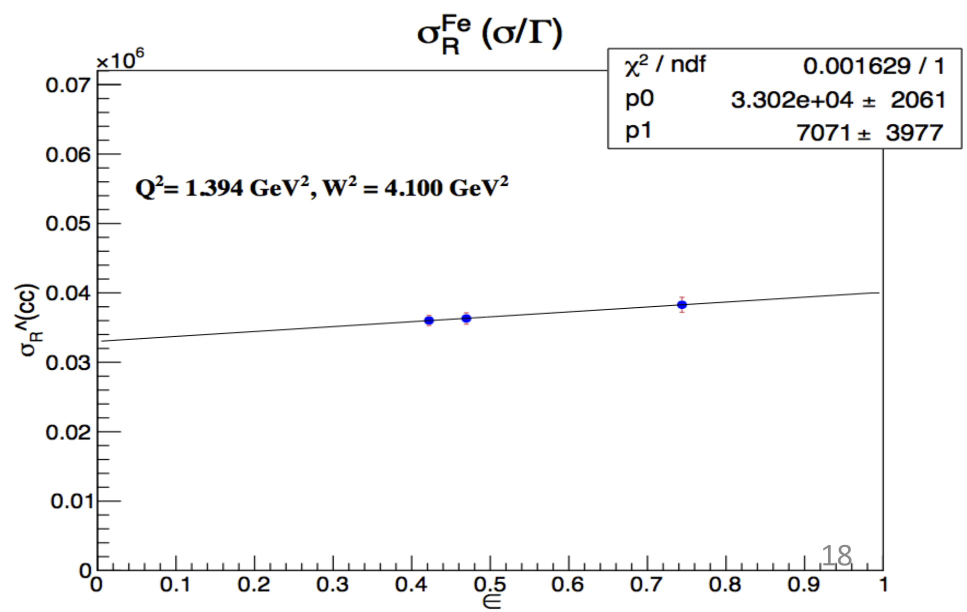


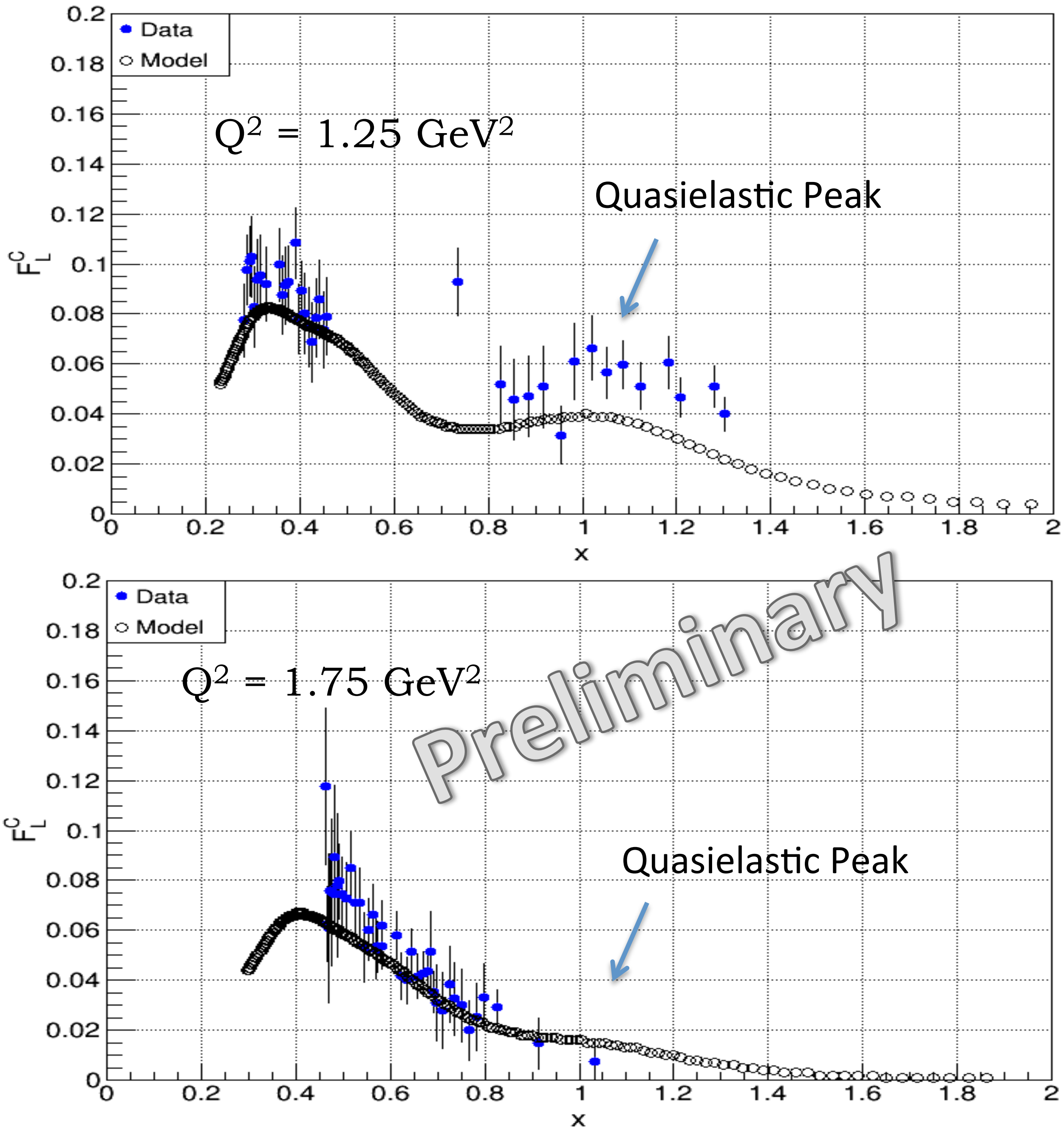
Rosenbluth Separation





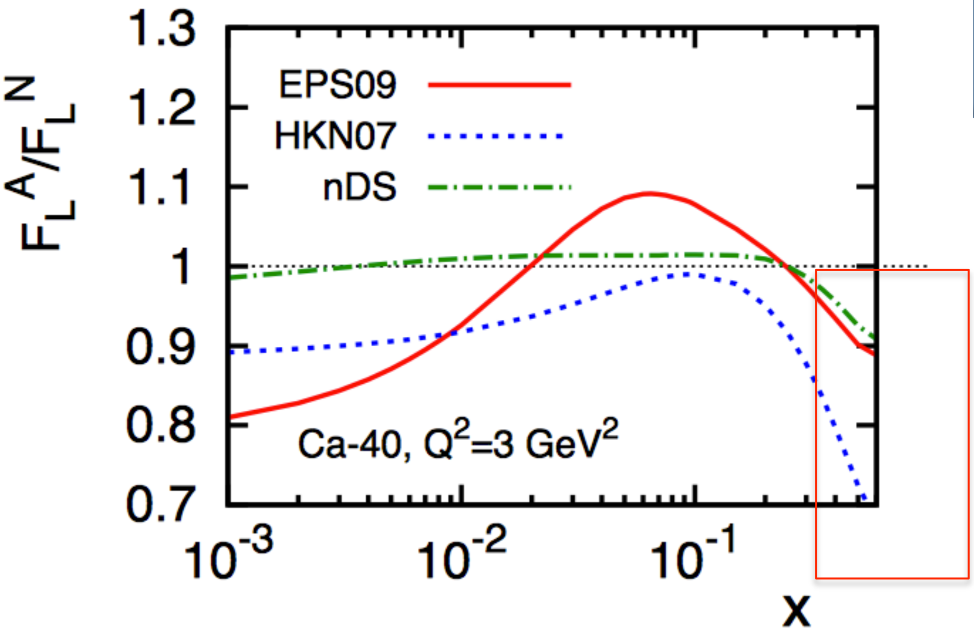




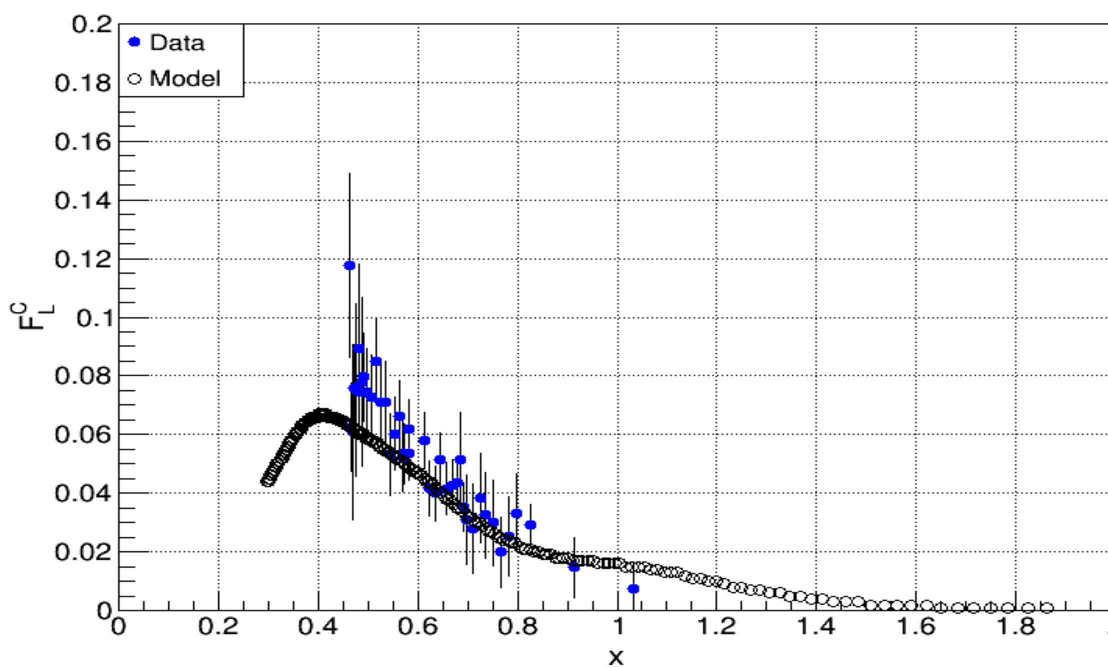


Study of the inelastic Q2 dependence requires subtraction of the QE contribution

Fit : M.E. Christy, A Bodek, T. Gautam (in preparation)



EPS09
HKN07
nDS
Ca-40, Q²=3 GeV²
F_L^A/F_L^N
x



Data
Model
F_L^C
x

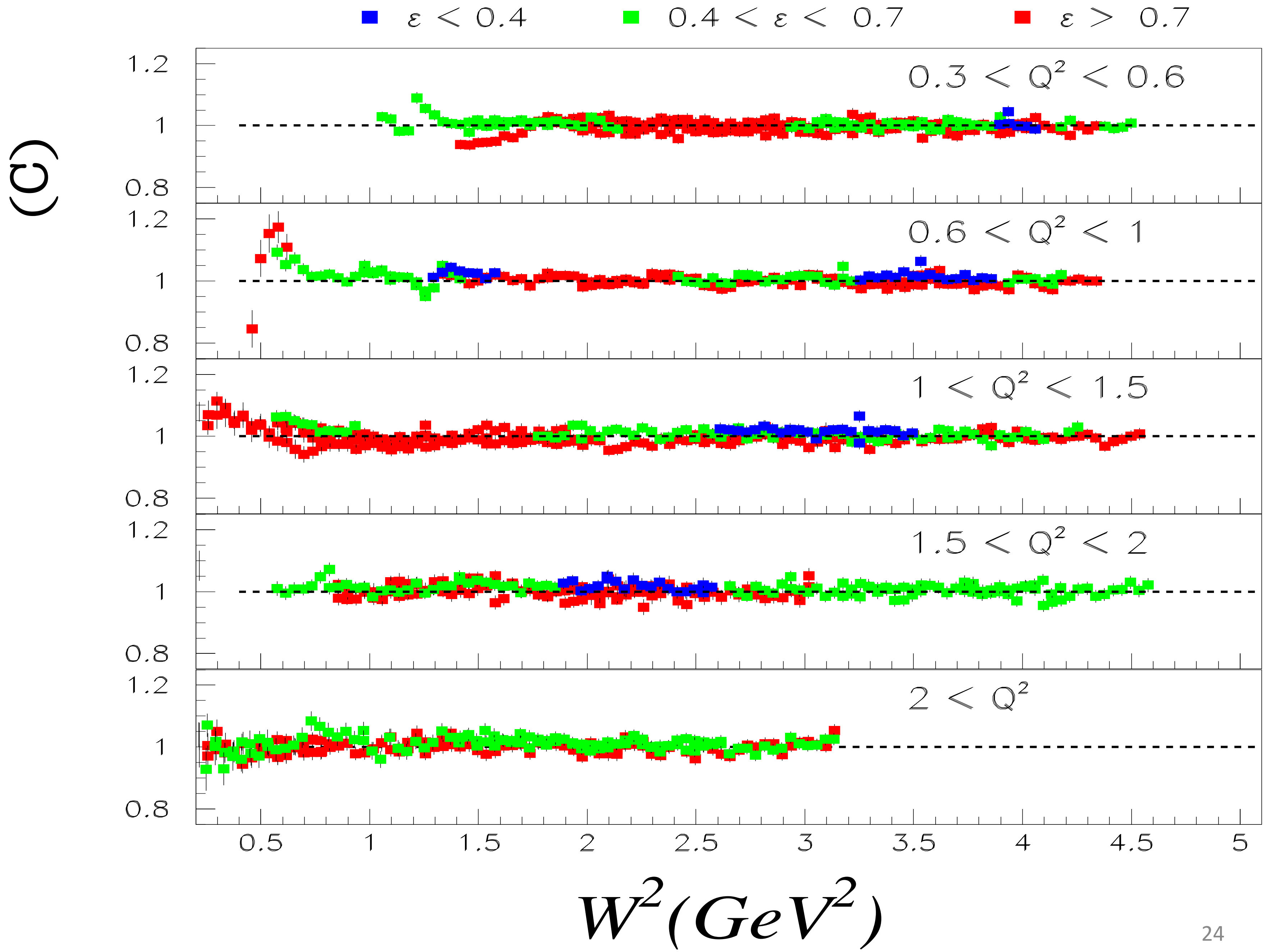
What's Next?

- Finalize extracting FL, F1, F2 for all targets (d, Al, C and Fe) (Check EMC)
- Check the pion enhancement at low Q^2 region.
- Final results -> by end of summer 2018

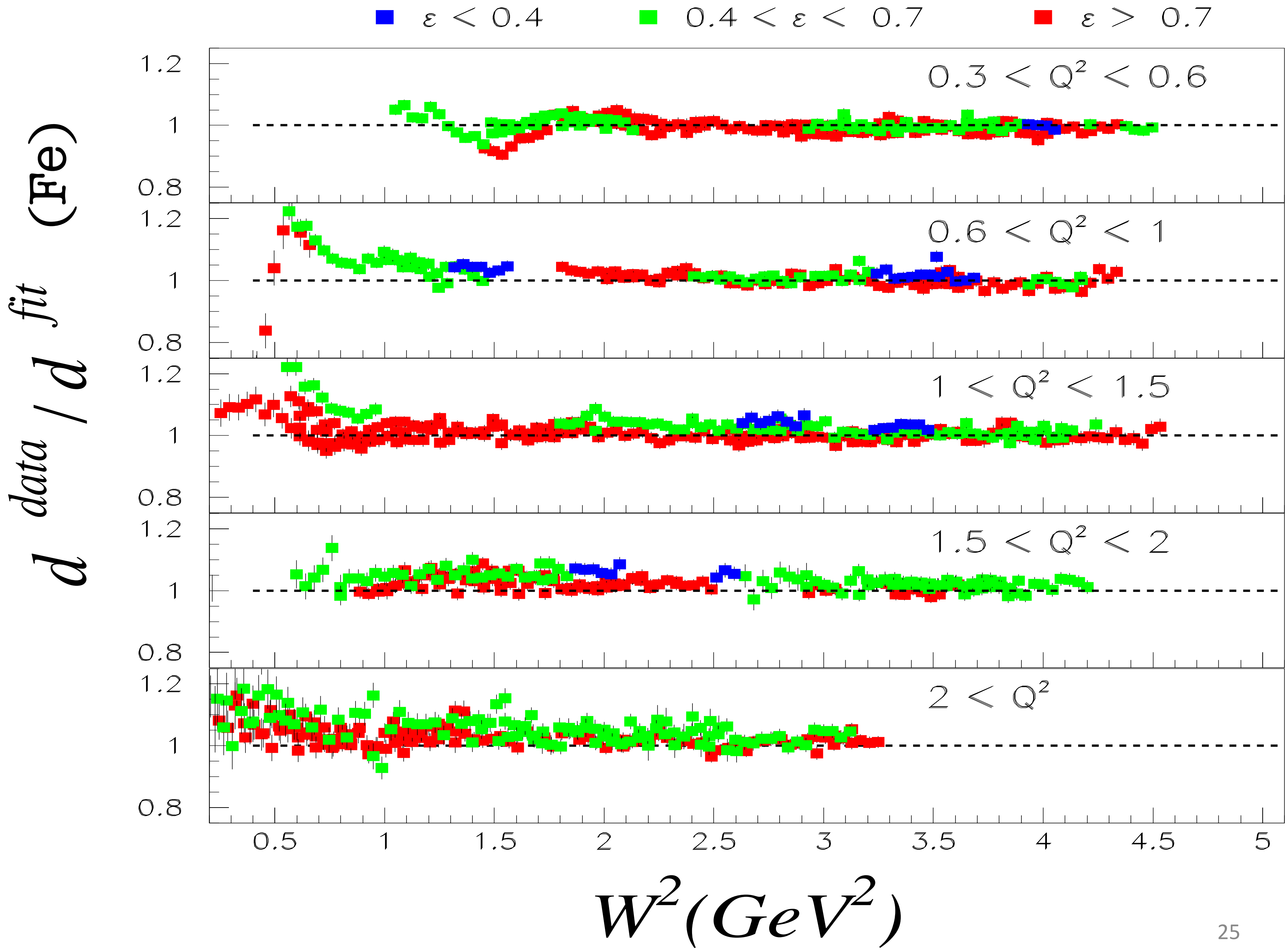
Great thanks to all the spokespeople of E02-109/ E04-001.

Special Thanks for Eric Christy

Thanks!



ε < 0.4
0.4 < ε < 0.7
ε > 0.7
(C)
0.3 < Q² < 0.6
0.6 < Q² < 1
1 < Q² < 1.5
1.5 < Q² < 2
2 < Q²
1.2
1
0.8
0.5
1
1.5
2
2.5
3
3.5
4
4.5
5
W²(GeV²)



ε < 0.4
0.4 < ε < 0.7
ε > 0.7
0.3 < Q² < 0.6
0.6 < Q² < 1
1 < Q² < 1.5
1.5 < Q² < 2
2 < Q²
σ data / σ fit (Fe)
W²(GeV²)