Update: Results on σ_L/σ_T

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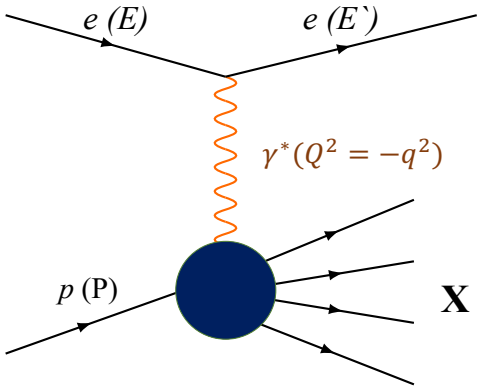
(but presented by Thia Keppel)

Inclusive $e + p \rightarrow e + X$ Scattering

The Cross section:

$$\frac{d^2\sigma}{dE'd\Omega}(E, E', \theta) = \frac{4\alpha^2(E')^2}{Q^4}\cos^2(\frac{\theta}{2})\left[\frac{F_2(x)}{\nu} + \frac{2F_1(x)}{M}\tan^2(\frac{\theta}{2})\right] \quad (1)$$



Alternatively:

$$\left(\frac{d^2\sigma}{dE'd\Omega}\right) = \Gamma(\sigma_T + \epsilon\sigma_L) \quad (2)$$

where:

Γ : Flux of transversely polarized virtual photons

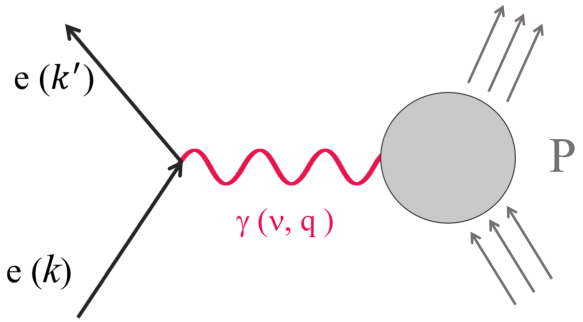
ϵ : relative longitudinal polarization

$$F_L = \left(1 + \frac{Q^2}{\nu^2}\right)F_2 - 2xF_1 \qquad R = \frac{\sigma_L}{\sigma_T} = \frac{F_L}{2xF_1}$$

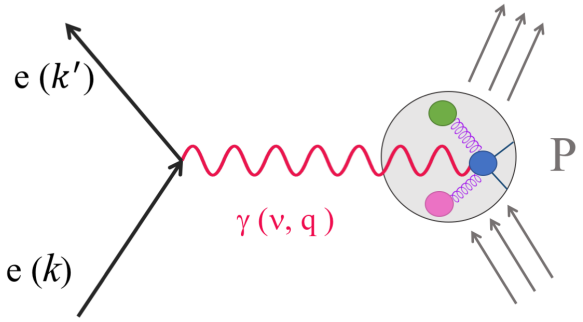
Inclusive $e + p \rightarrow e + X$ Scattering

Single photon exchange:

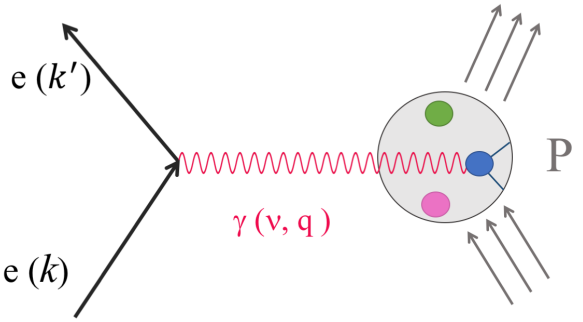
Elastic

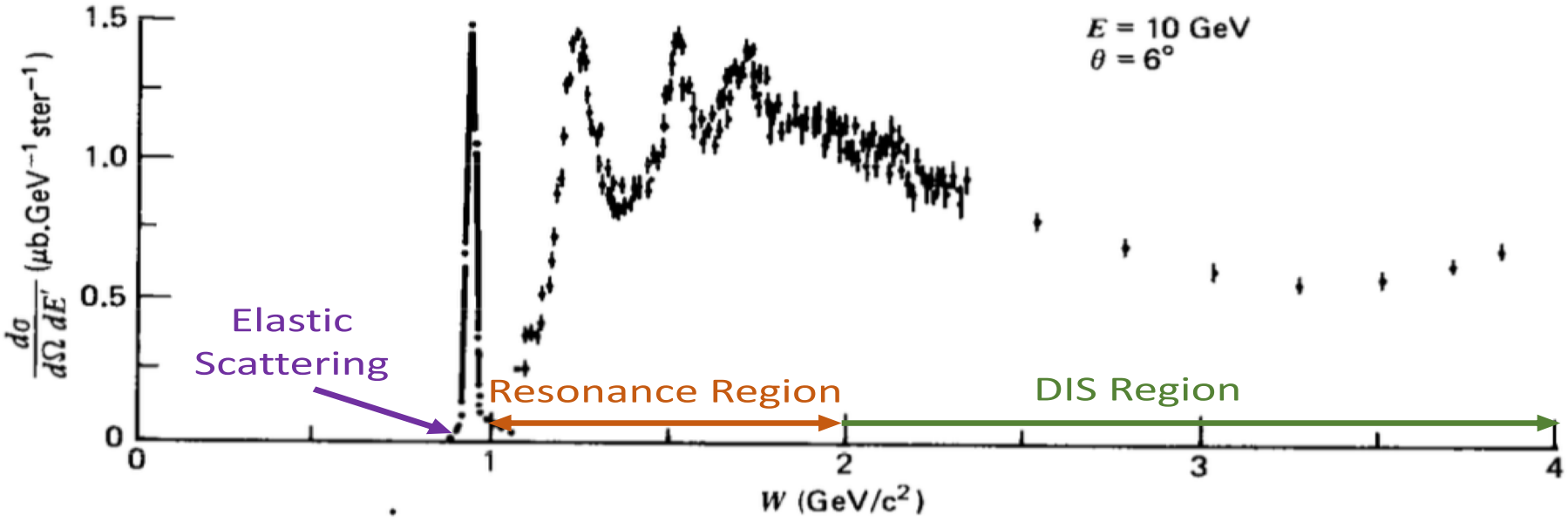


Resonance



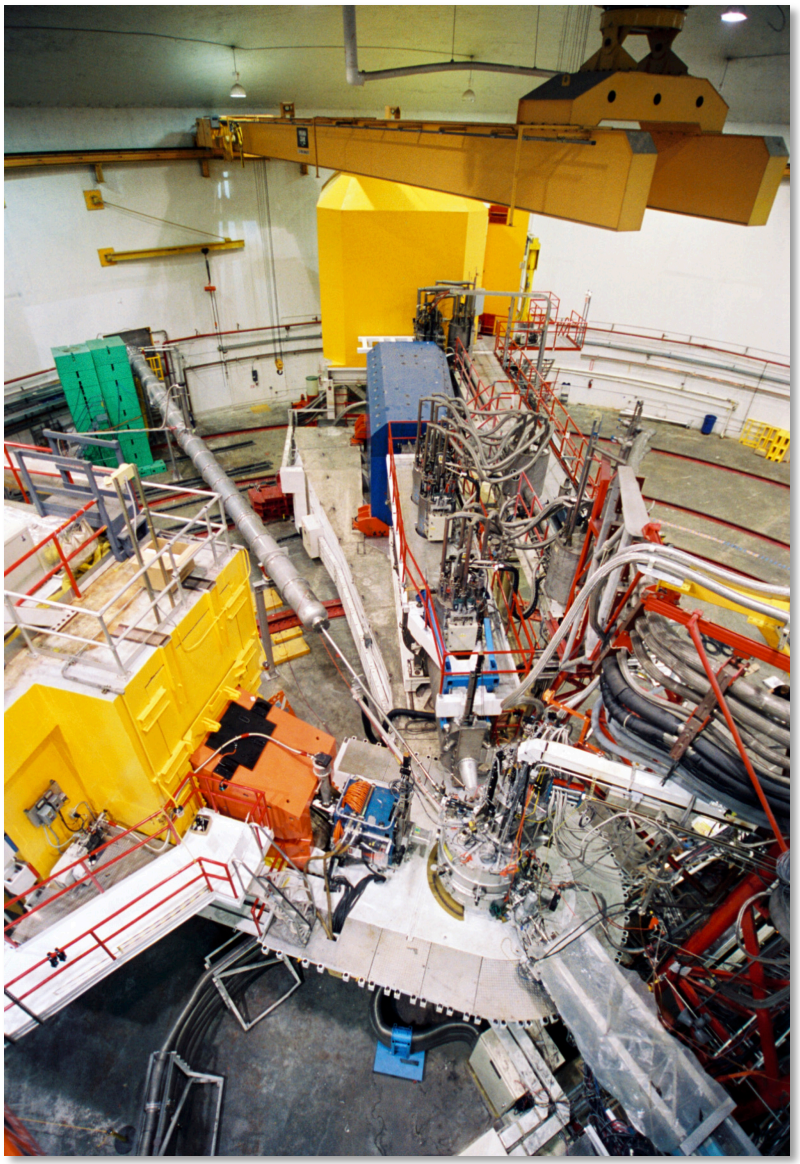
DIS





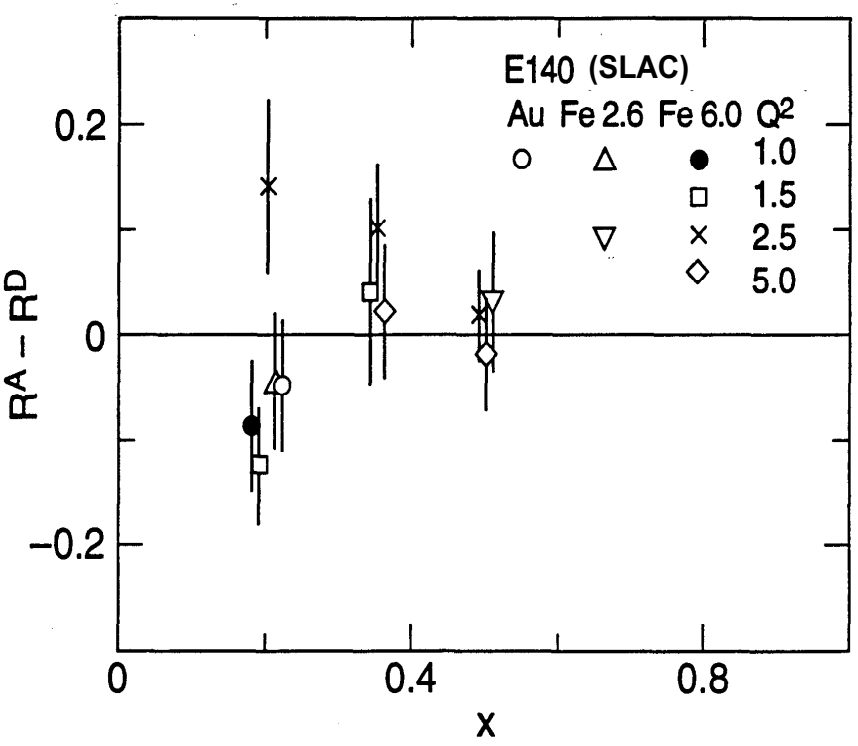
6 GeV Era Program of Inclusive Structure Function Measurements in Hall C (High Precision Cross Sections and L/T Separations)

Experiment	target(s)	W range	Q^2 range
E94-110	p	RR	0.3 - 4.5
E99-118	p, d	DIS+RR	0.1 - 1.7
E00-002	p, d	DIS+RR	0.25 - 1.5
E02-109	d	RR+QE	0.2 - 2.5
E06-009	d	RR+QE	2.0 - 4.0
E04-001 - I	C, Al, Fe	RR+QE	0.2 - 2.5
E04-001 - II	C, Al, Fe	RR+QE	2.0 - 4.0

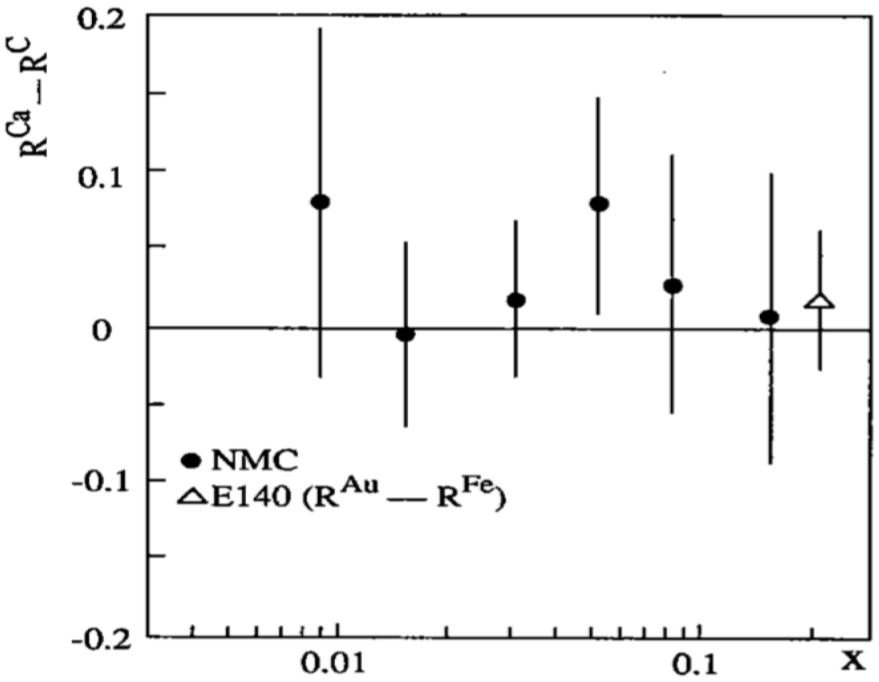


Nuclear Dependence of R : Previous Studies

SLAC



NMC



$R_A - R_D = -0.035 \pm 0.042$

$R_{Ca} - R_C = 0.027 \pm 0.026\,(stat) \pm 0.02(sys)$

ΔR consistent with zero

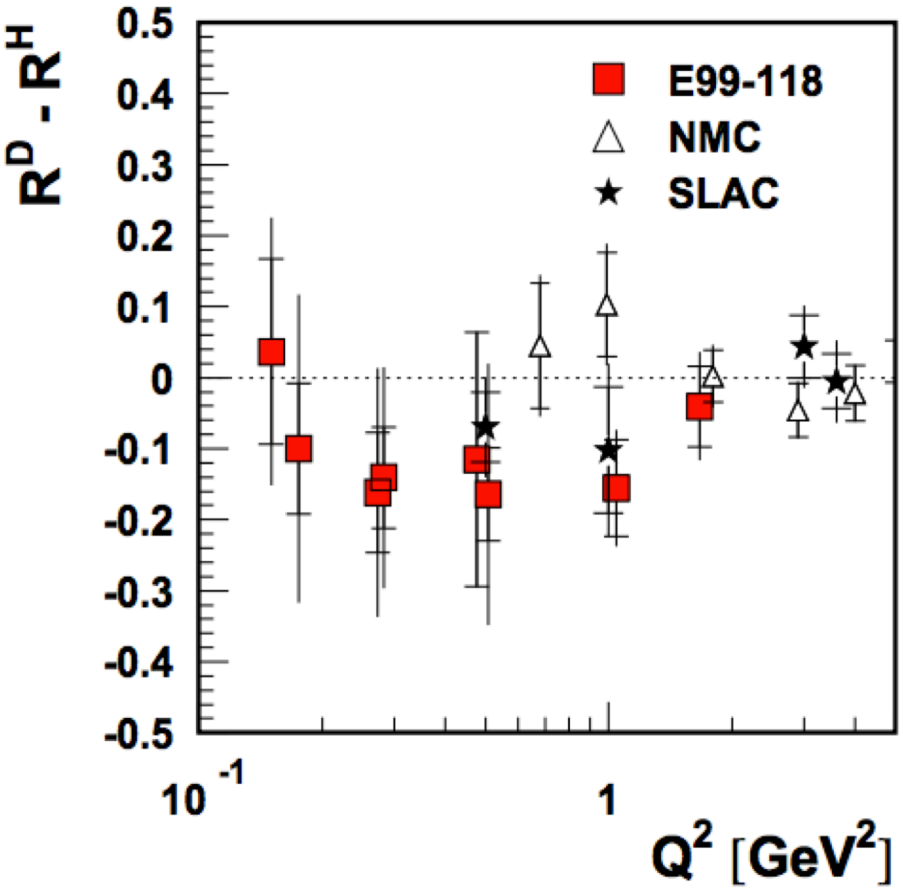
Similar results from HERMES

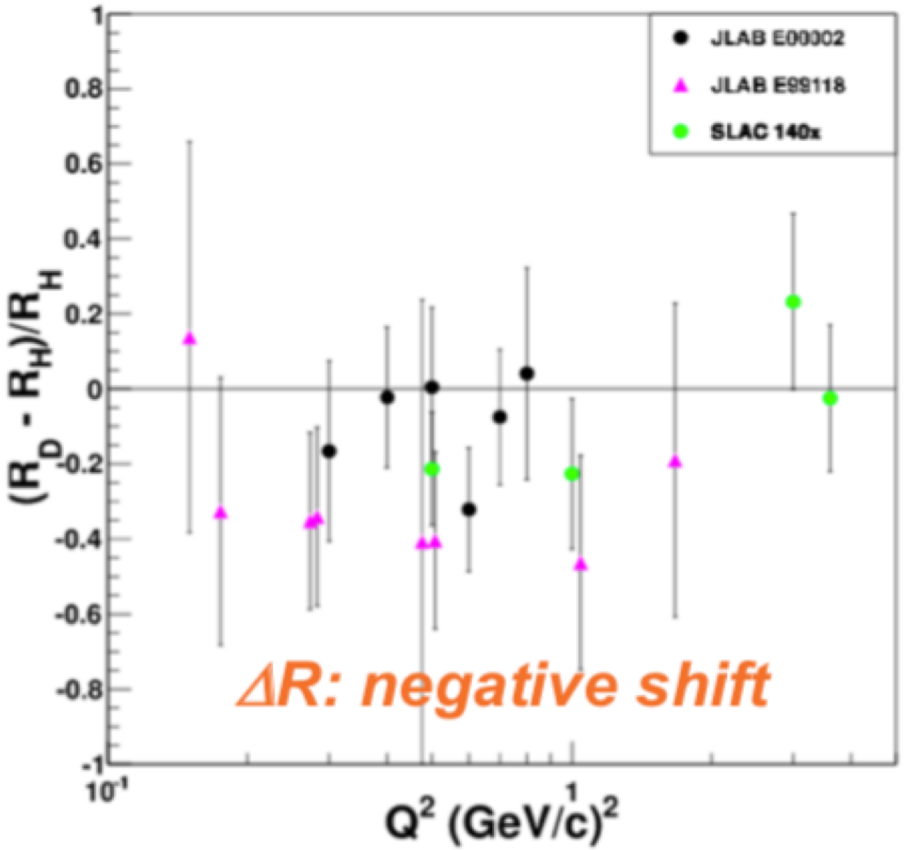
But… in all, large uncertainties and measured where R is small

Nuclear Dependence of R : Previous Studies

E99-118 (Hall C – Jefferson Lab) – low Q^2

Phys. Rev. C97 (2018) no.4, 045204





$$R_D - R_H = -0.054 \pm 0.029$$

First Hint of nuclear dependence of R in Deuterium at low Q^2

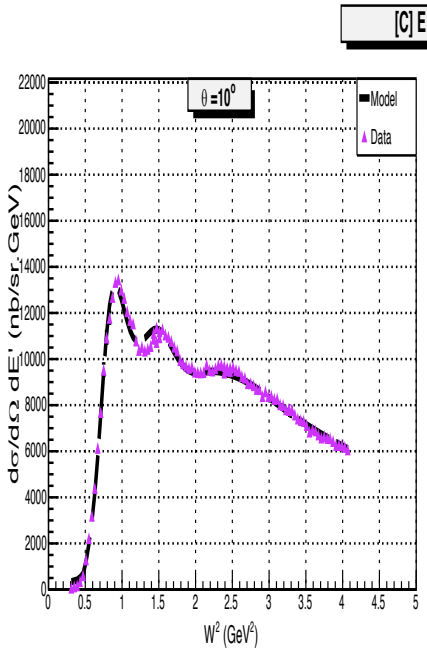
Nuclear Dependence of R : So far …

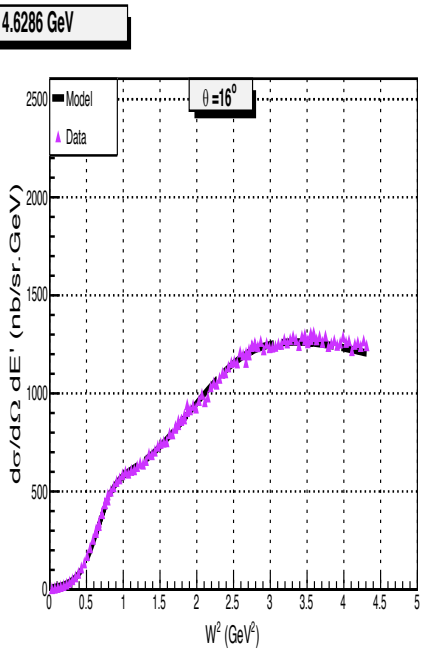
- **Several experiments found that ΔR to be consistent with zero at high Q^2 and with large uncertainty**
- **Only hints of nuclear dependence of R, (Deuterium, low Q^2)**
- **No available data to confirm that $\Delta R \neq 0$ for nuclear targets (low and moderate Q^2)**

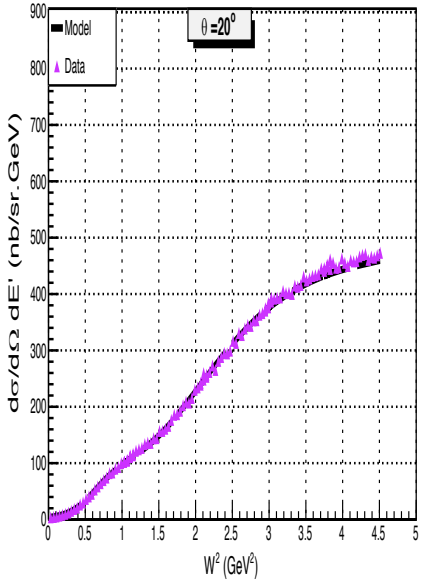
E04-001 (Hall C – Jefferson Lab)

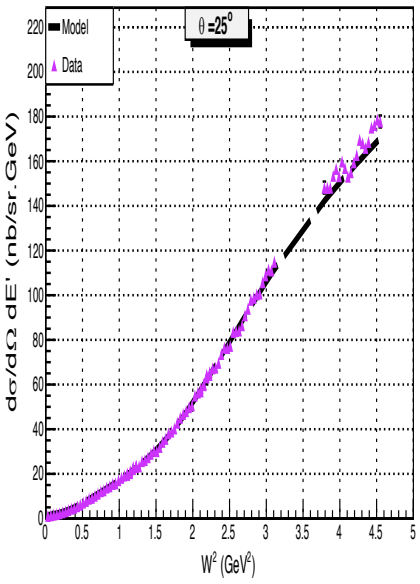
Cross Section Results

C Cross Sections

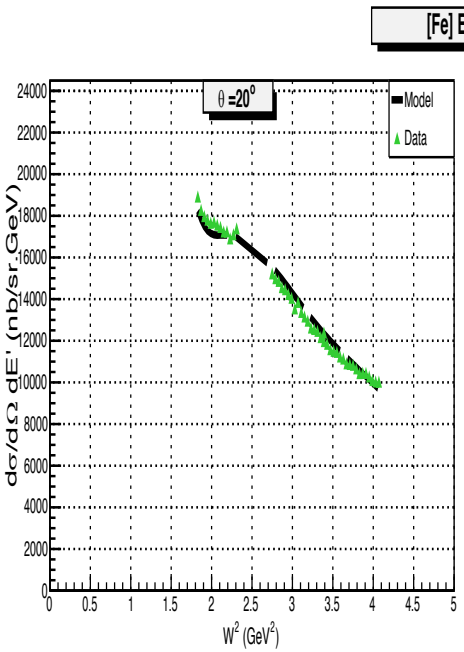


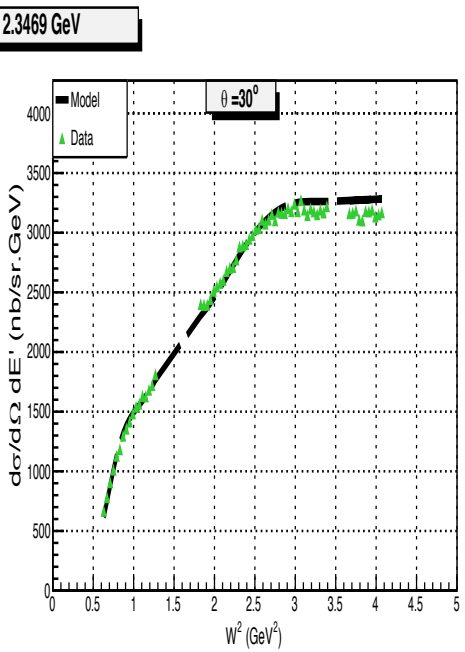


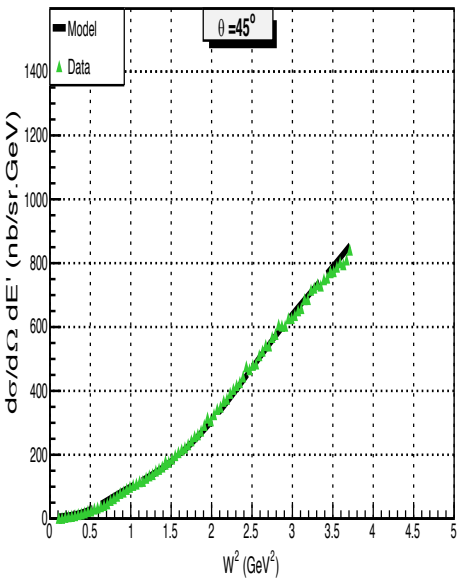


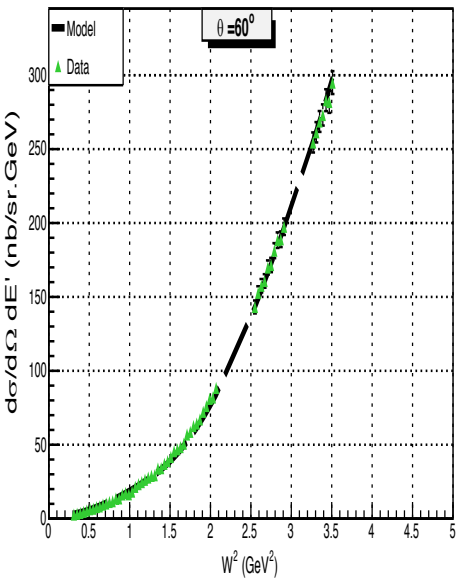


Fe Cross Sections









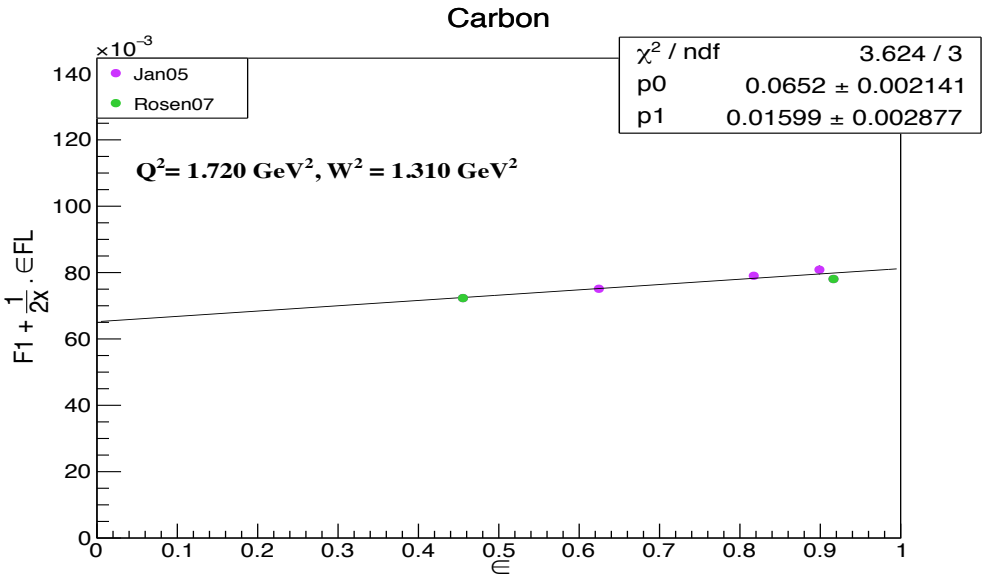
Point-to-Point Uncertainties

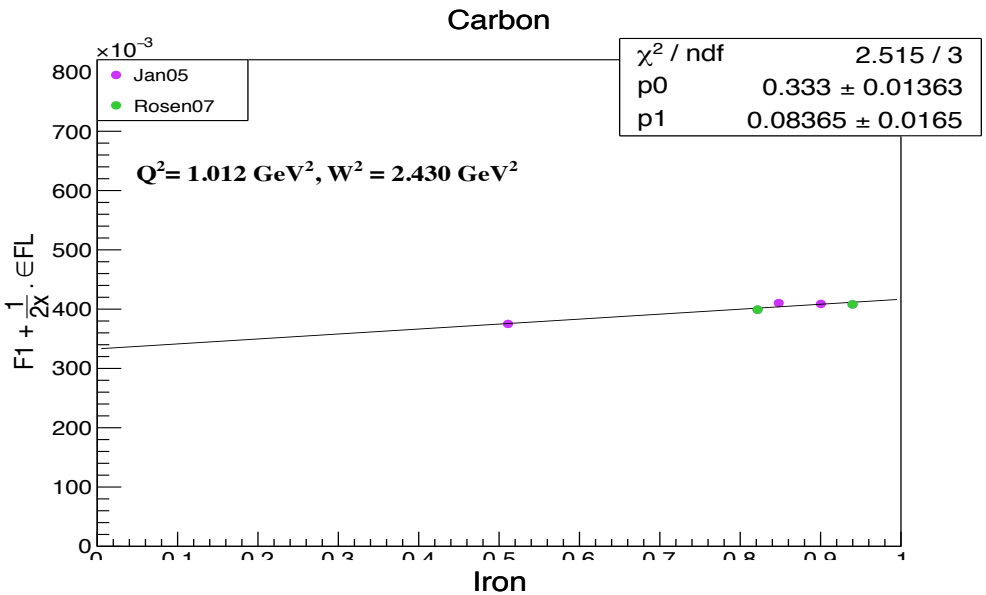
Quantity	Uncertainty
Beam Energy E	4×10^{-4} GeV
Scattering Energy E'	4×10^{-4} GeV
Scattering Angle θ	0.35 mrad
Beam Charge	0.23 μA
Trigger Efficiency	0.46 %
Calorimeter Efficiency	0.1%
Cerenkov Efficiency	0.04 %
Computer Deadtime	0.2 %
Electronic Deadtime	20 %
Charge Symmetric Background	0.05 - 2 %
Optics	0 - 1%
Acceptance	0.6 %
Radiative Corrections	1 %
TOTAL	**1.6% typical**

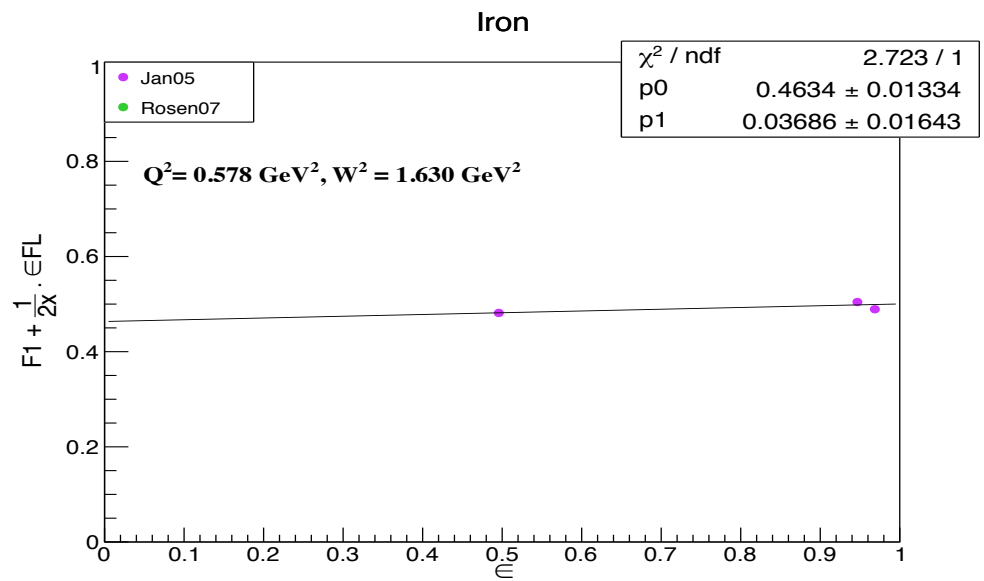
0-.5%, <.1% typical

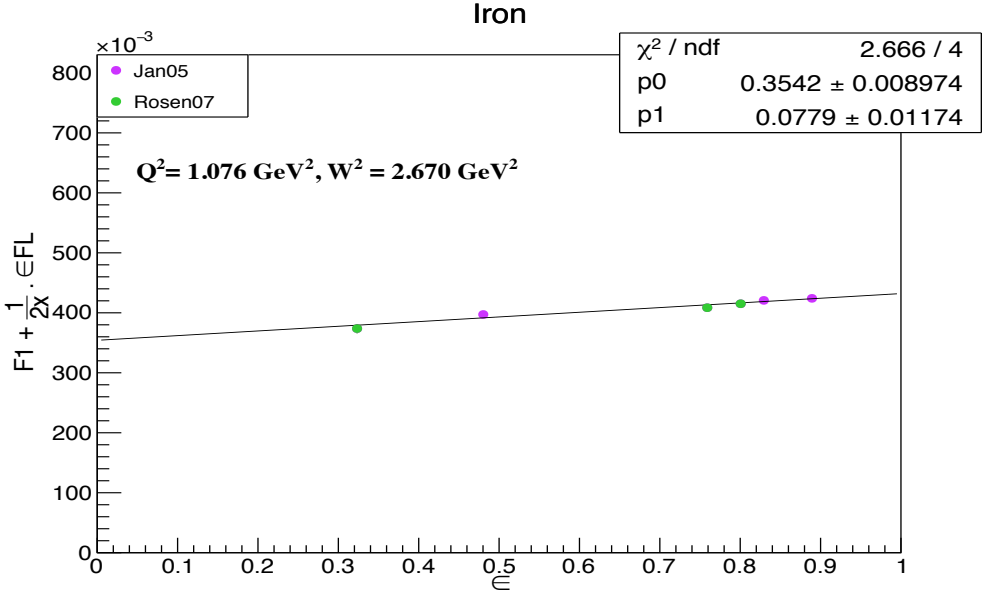
The Point-point Systematic Uncertainties in the Differential Cross Section

Rosenbluth Separation

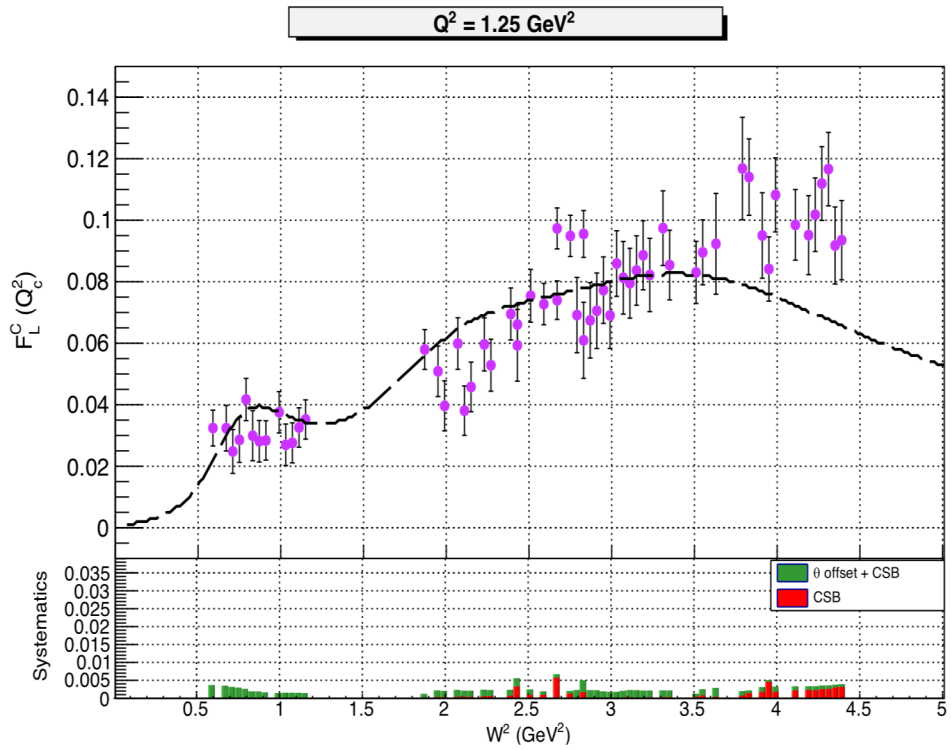


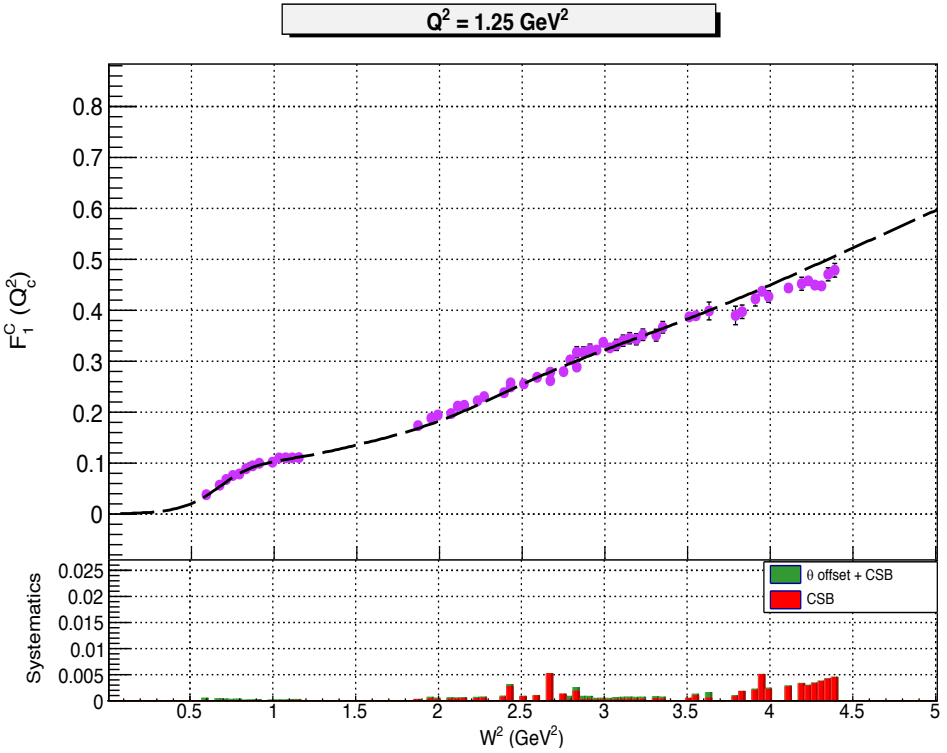




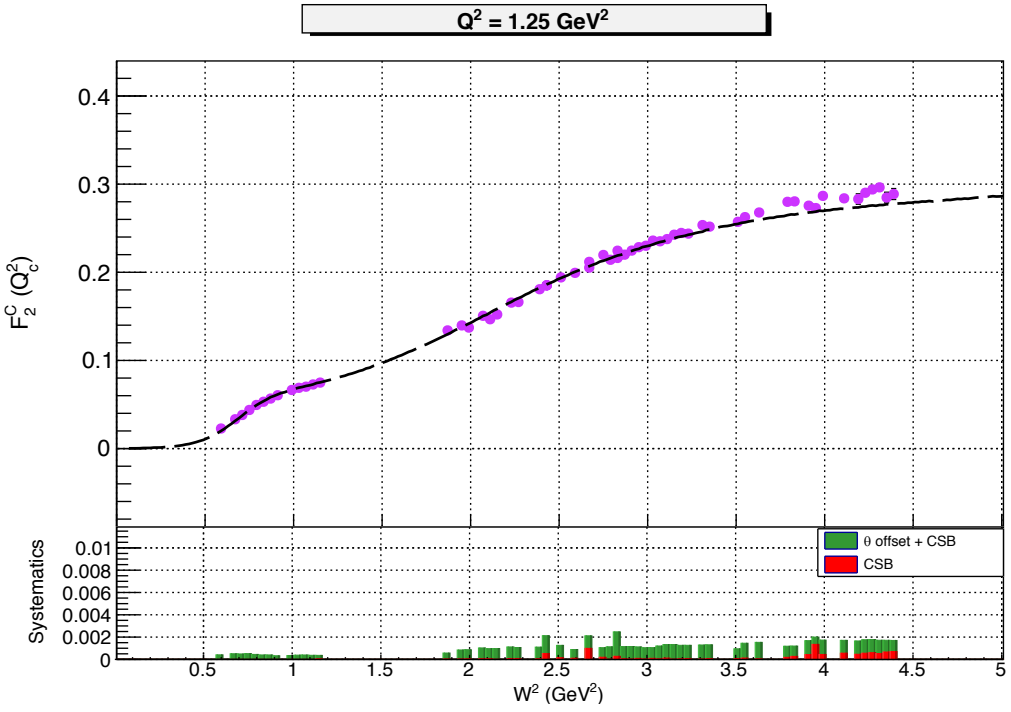


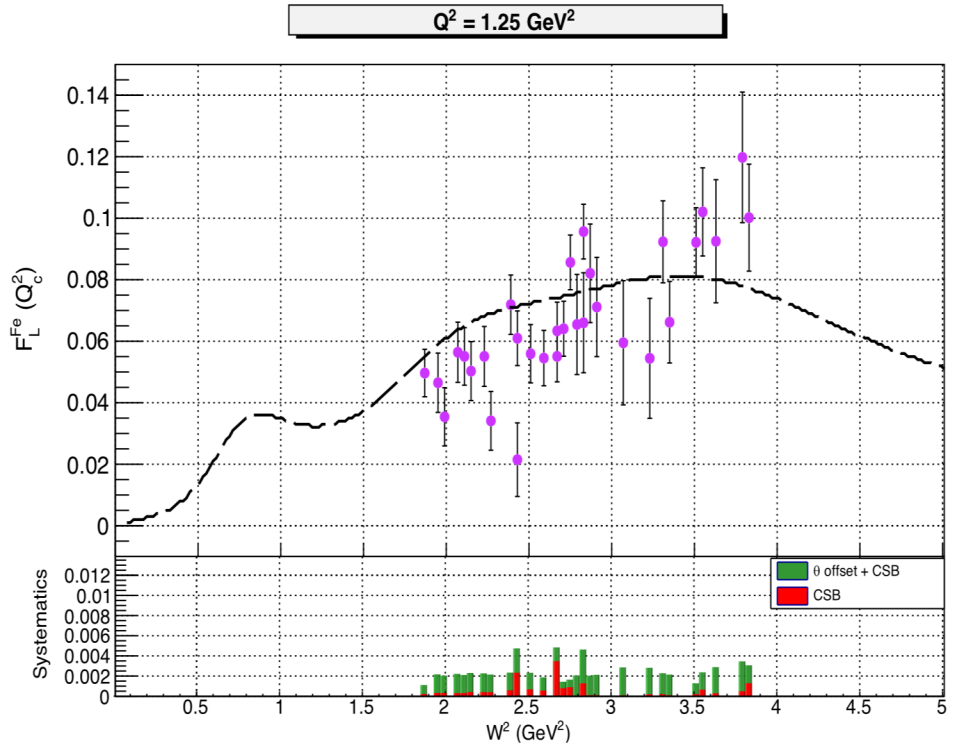
Over 500 individual L/T Separations – no repeated cross sections

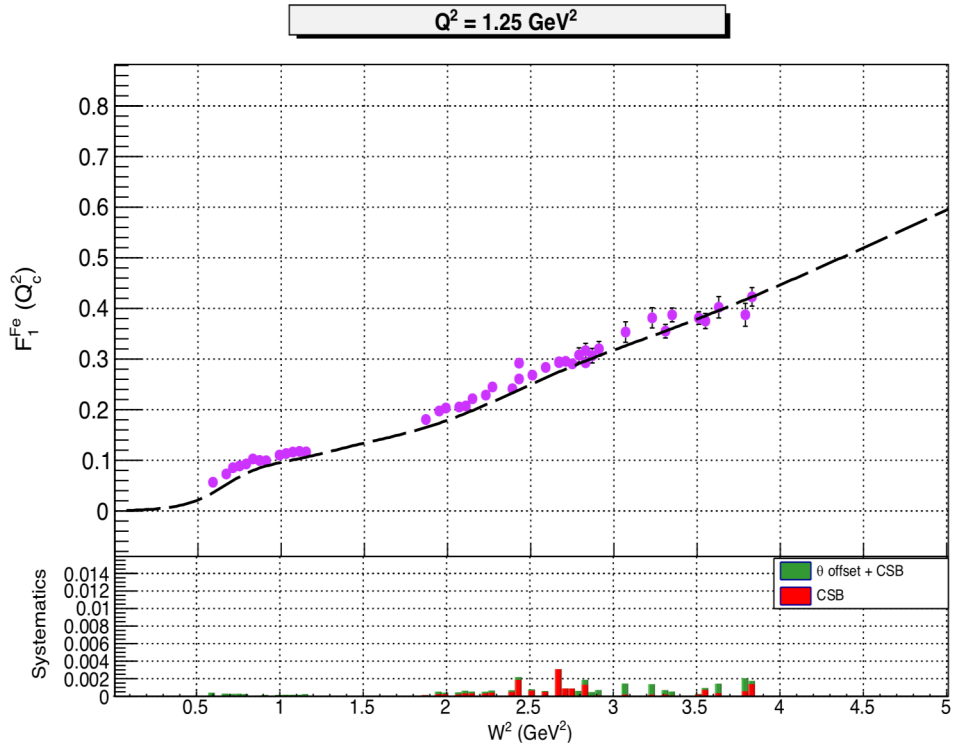

Q^2 = 1.25 GeV^2
F_L^C (Q_c^2)
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)


Q^2 = 1.25 GeV^2
F_1^C (Q_c^2)
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)

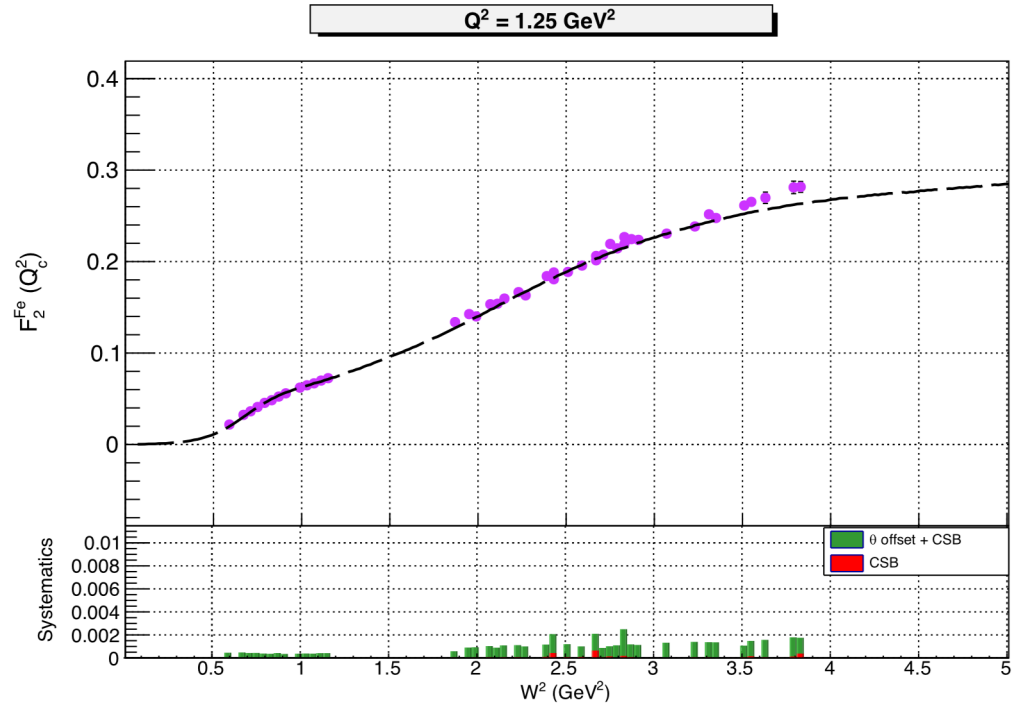
Carbon


Q^2 = 1.25 GeV^2
F_2^C (Q_c^2)
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)

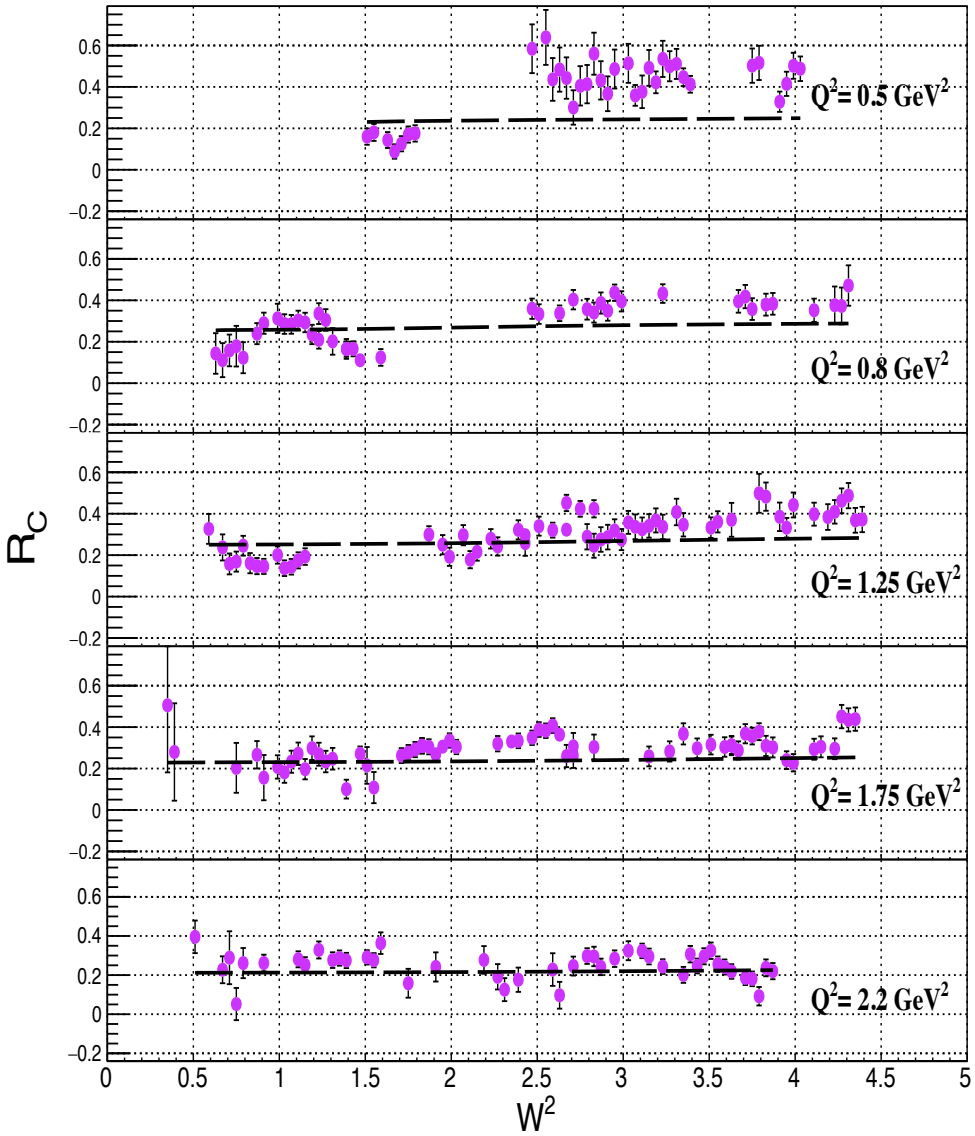

Q^2 = 1.25 GeV^2
$F_L^{Fe}(Q_c^2)$
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)

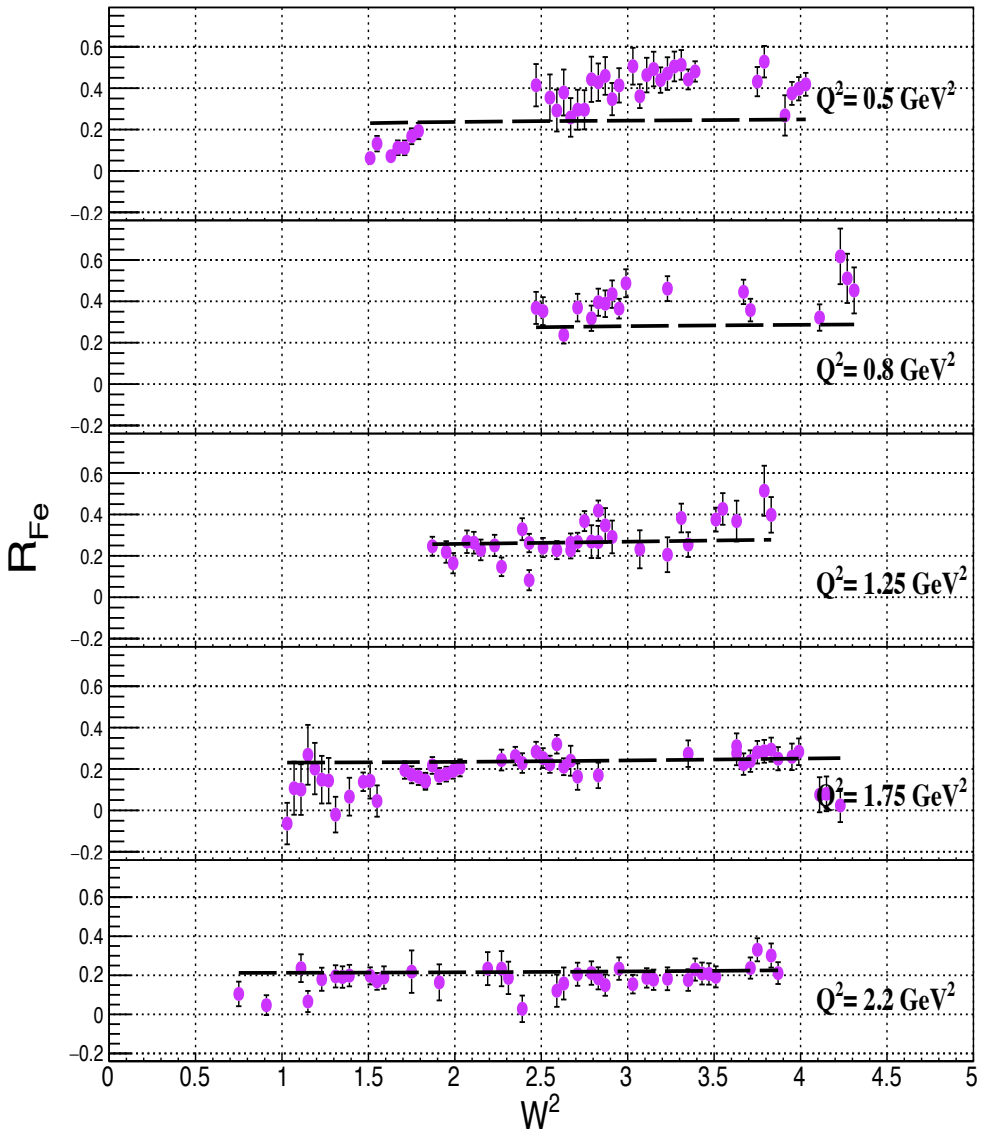

Q^2 = 1.25 GeV^2
$F_1^{Fe}(Q_c^2)$
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)

Iron


Q^2 = 1.25 GeV^2
$F_2^{Fe}(Q_c^2)$
Systematics
θ offset + CSB
CSB
W^2 (GeV^2)

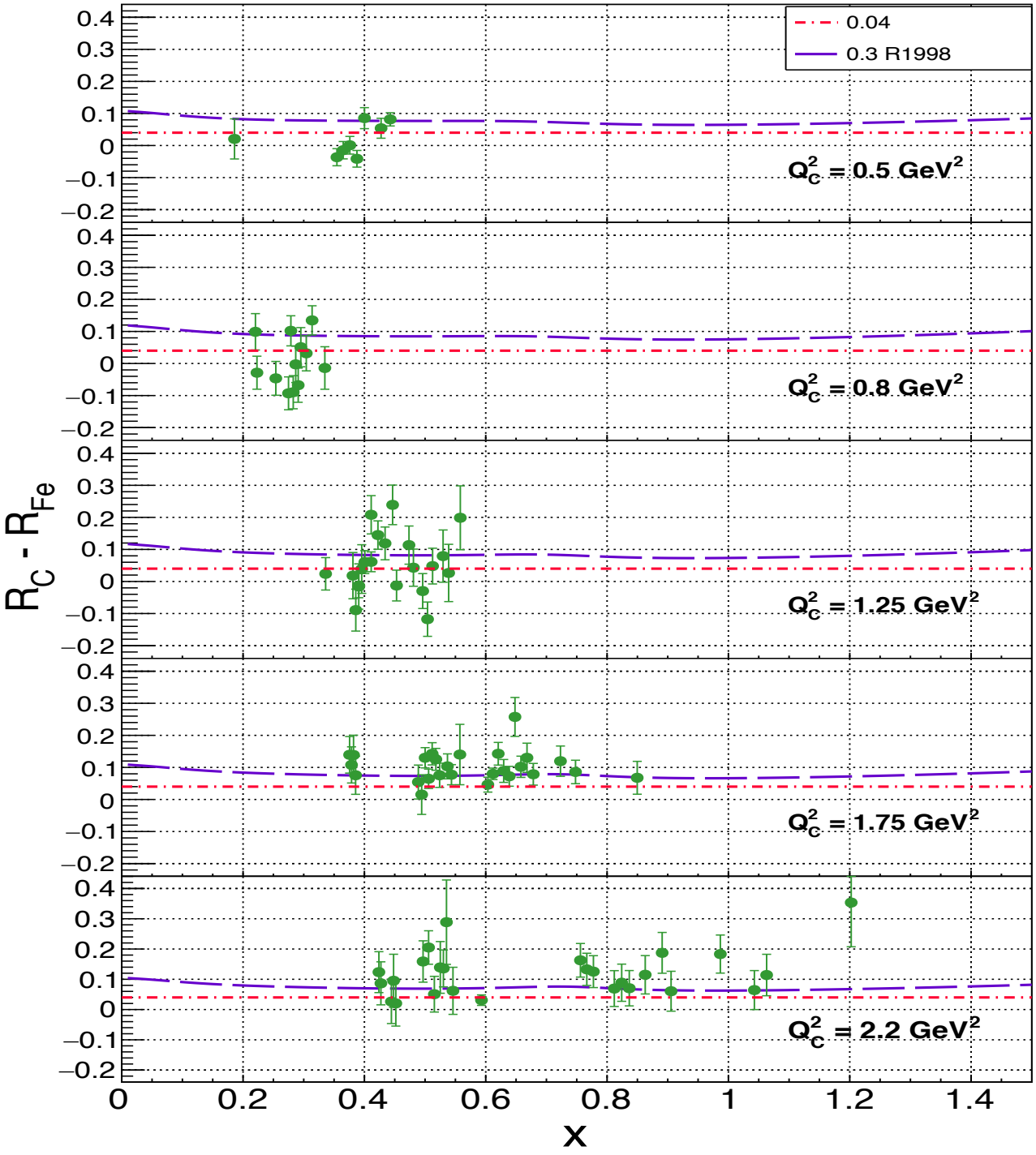
R Results

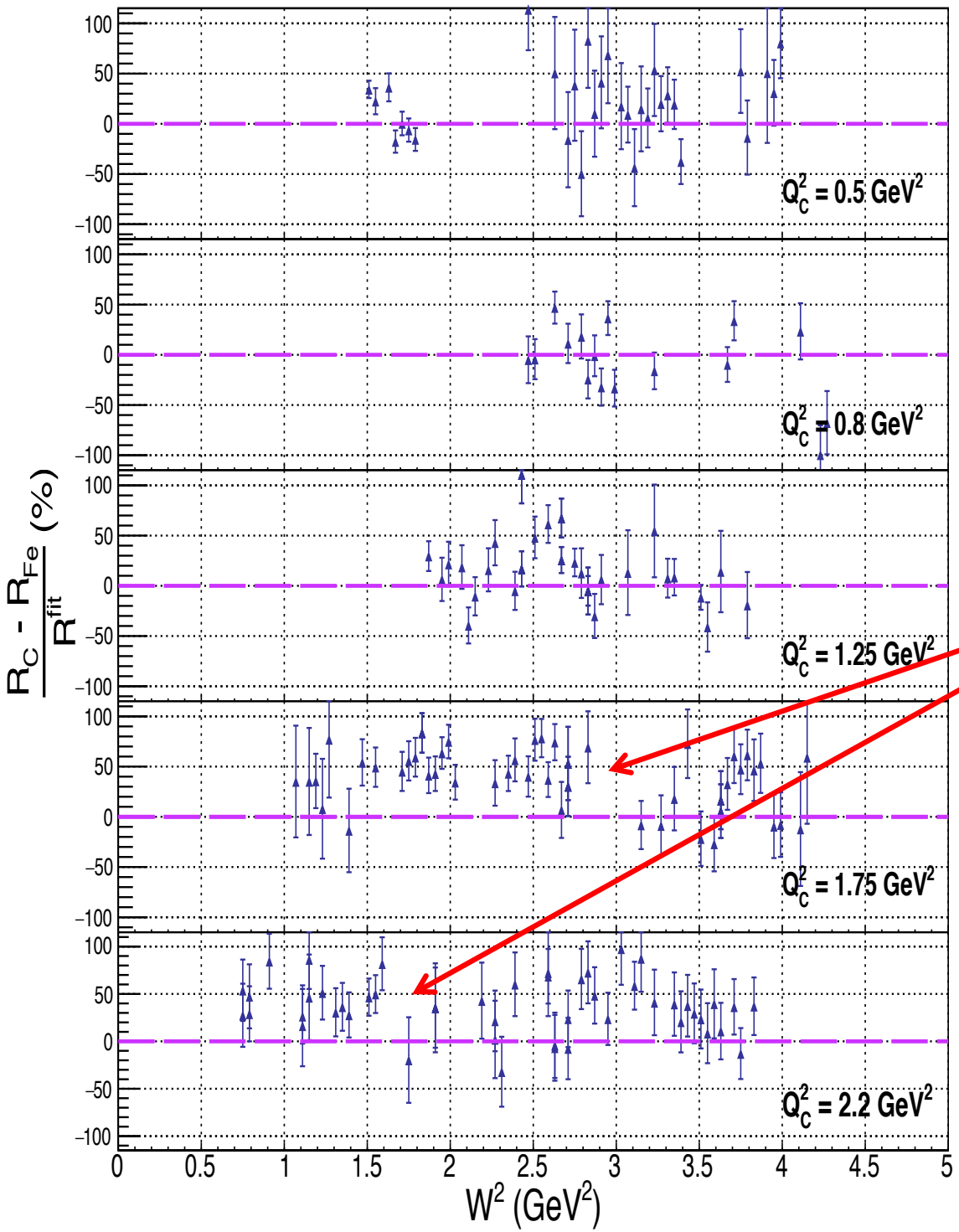




- Data differ from the fit with assumption $R_A = R_D = R_p$ (nuclear dependence)
- Q^2 dependent effect
- Decreases with Q^2 (expected)

ΔR Results


0.04
0.3 R1998
Q_c^2 = 0.5 GeV²
Q_c^2 = 0.8 GeV²
Q_c^2 = 1.25 GeV²
Q_c^2 = 1.75 GeV²
Q_c^2 = 2.2 GeV²
$R_C - R_{Fe}$
x



50 %

For the first time, we can state that there IS with no doubt a nuclear dependence to R (F_L) .. and it is BIG!

Conclusions and to do's

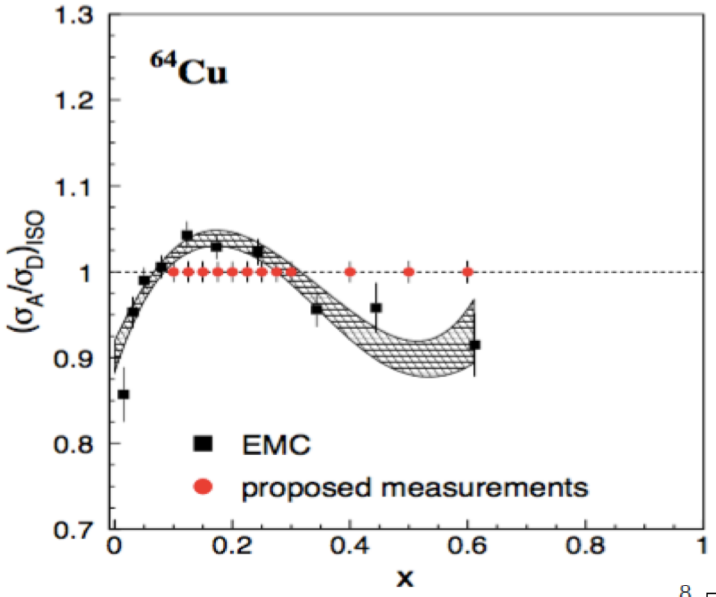
- The Inclusive electron-nucleon cross sections for both Carbon and Iron were extracted in the nucleon resonance region with high precision (stat + sys better than 2%).
- The Rosenbluth separation was performed on both Carbon and Iron cross sections to extract the structure functions F_L , F_1 , F_2 and the Ratio R (more than 500 L/T's in total).
- Our results confirm that $\Delta R \neq 0 \Longrightarrow$There is a nuclear dependence on R and F_L

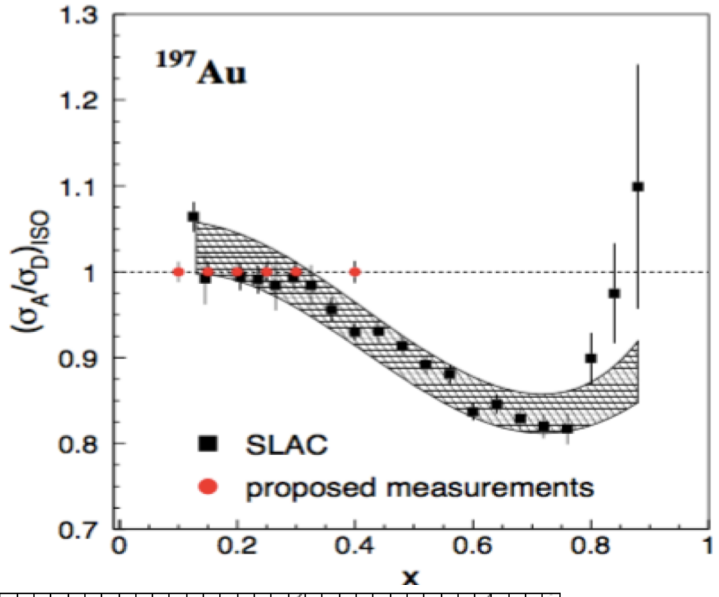
Conclusions and to do's

- Host Sheren here this summer
- Ratios to deuterium
- Extract F_L separately
- Assess impact on EMC effect measurements
- Incorporate into models
- Obtain more data!>>>>

Continue into 12 GeV Era:

Hall C Experiment E12-14-002 (S. Malace, E. Christy, D. Gaskell, CK, P. Solvignon, H. Szumilla-Vance





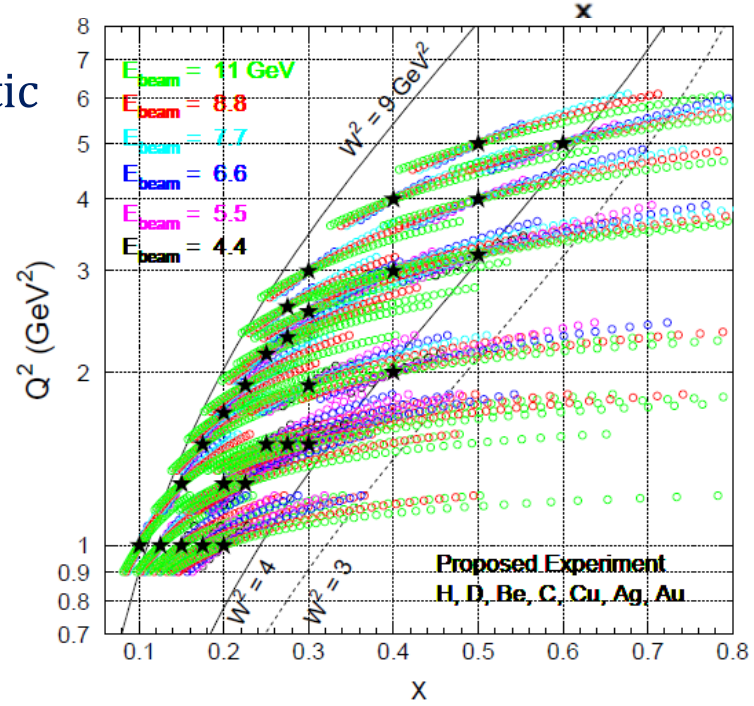
~1.6% point-to-point systematic uncertainty cross sections

H,D,Be,C,Cu,Ag,Au targets

$0.1 < x < 0.8$, DIS

$0.9 < Q^2 < 6$ GeV^2

300+ L/Ts



Study both anti-shadowing and EMC regimes