Nucleon and Nuclear Structure Function Measurements in the resonance region at low Q^2

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Workshop on Intersections of Nuclear Physics with Neutrinos and Electrons

JLab – May 4, 2006

- **JLab has a large program of structure function measurements in the resonance region at low Q^2.**

- **This talk will focus on unpolarized structure function measurements in Hall C and specifically ...**

Longitudinal and Transverse (L/T) separated structure functions, F_1, F_L *, and*

$$F_2 = (2xF_1 + F_L)/(1+M^2x^2/Q^2),$$

for nucleons and in nuclei

=> learn about medium modifications / nuclear effects

(ie. distinguish various models of EMC)

Rosenbluth Separation

Reduced cross-section:

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

- **Fit reduced cross section linearly with ε at fixed W^2 and Q^2 (or x, Q^2).**

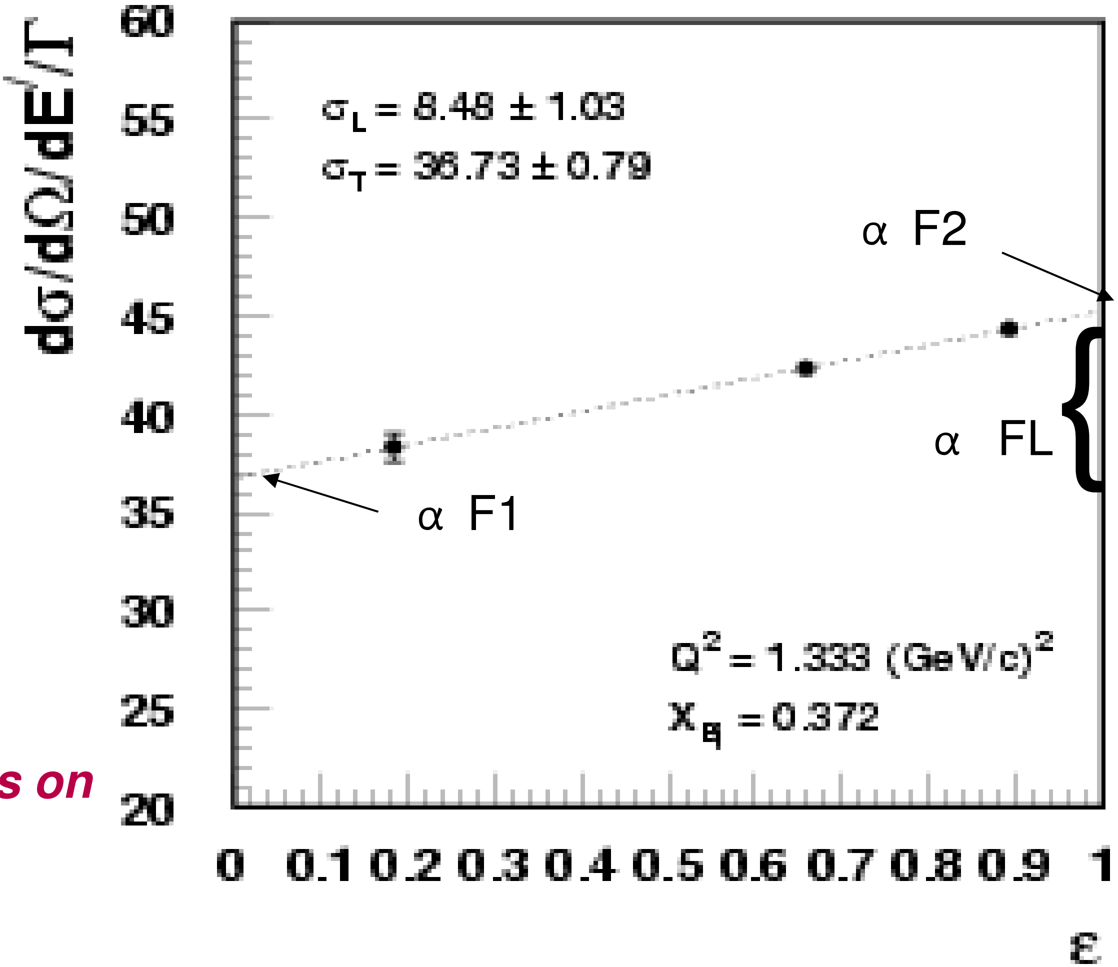
- **Linear fit yields:**

  σ_L = Slope

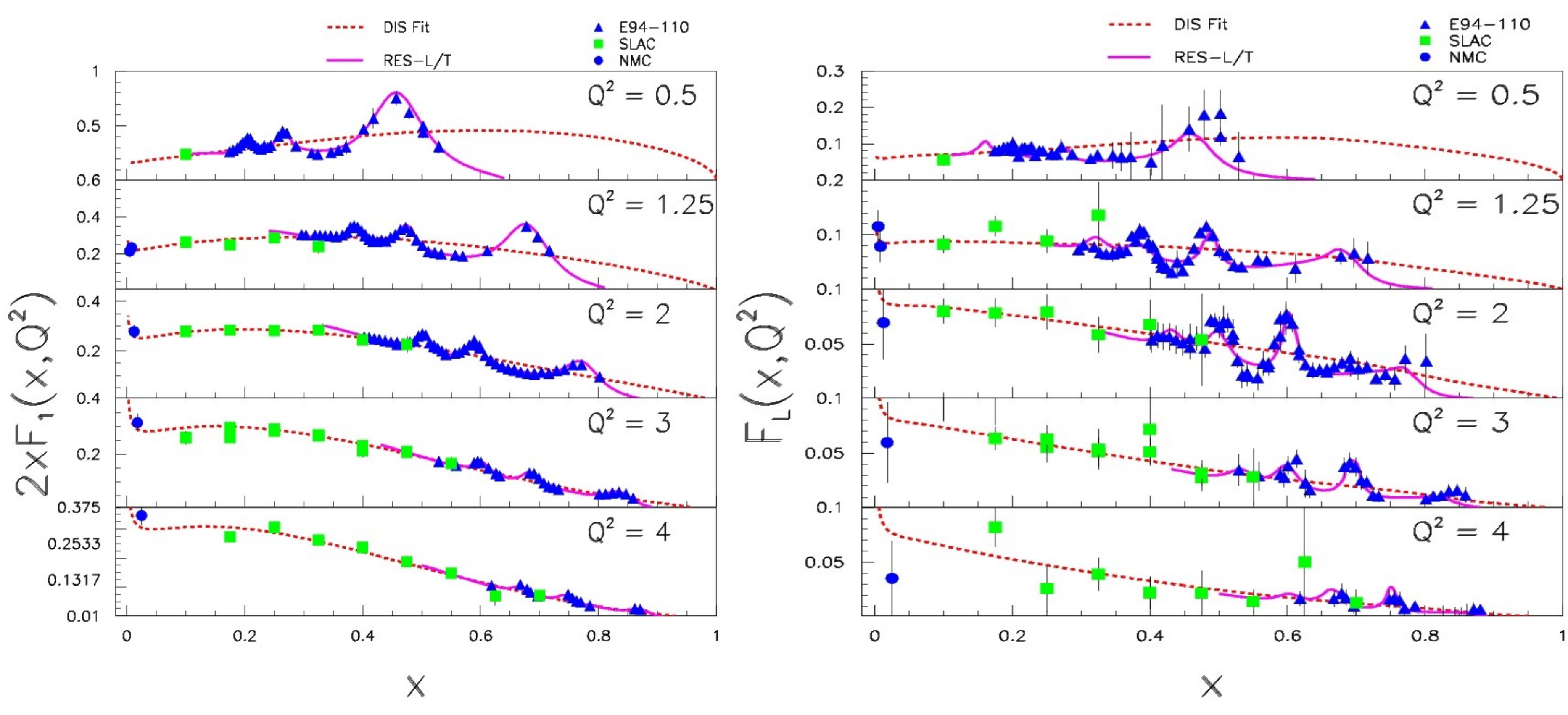
  σ_T = Intercept

Extraction of F_2 depends on

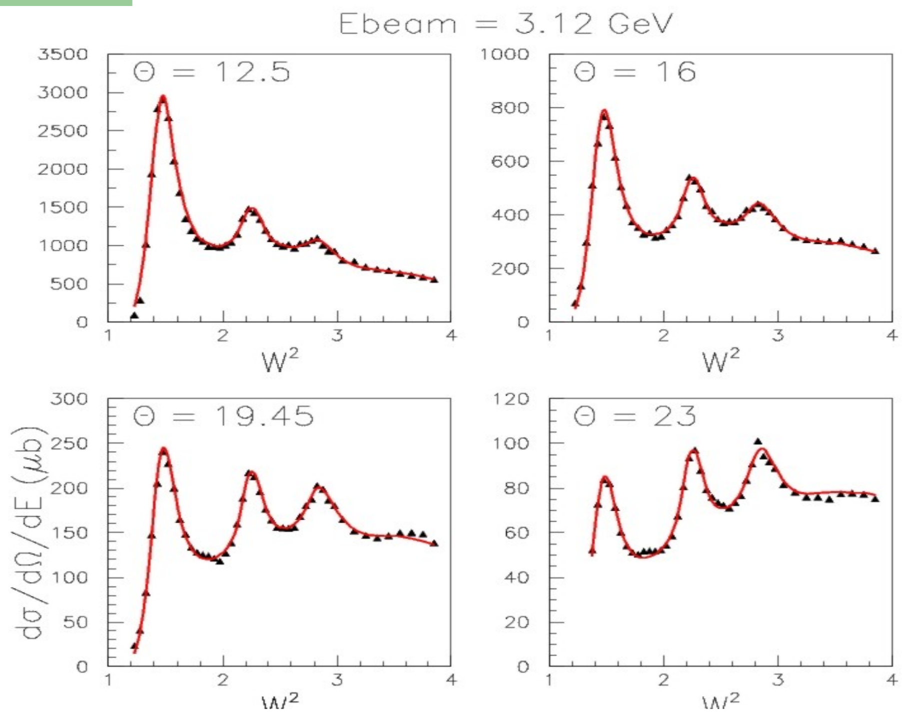
$R = \sigma_L / \sigma_T$ and ε !

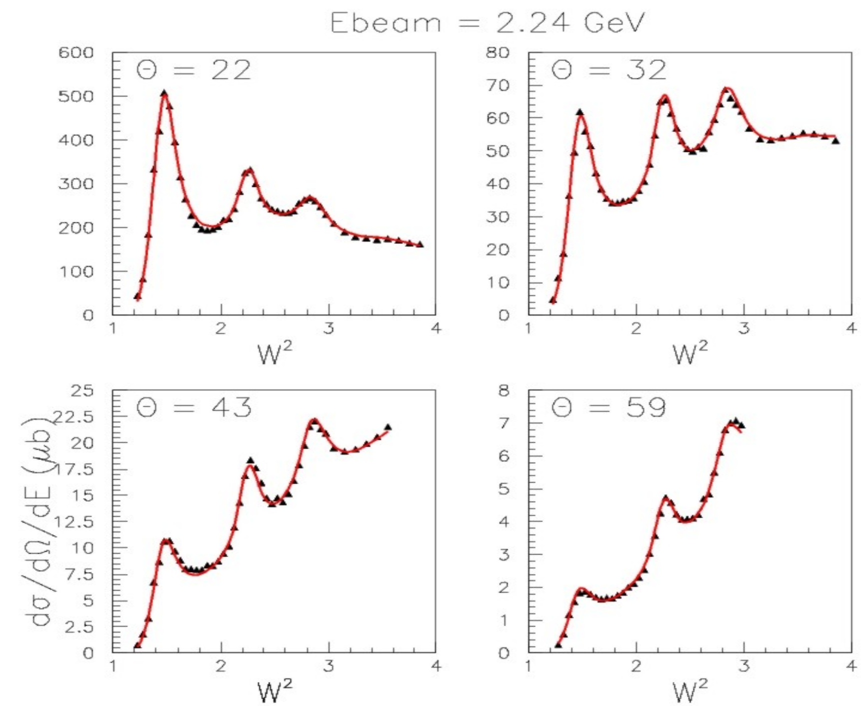


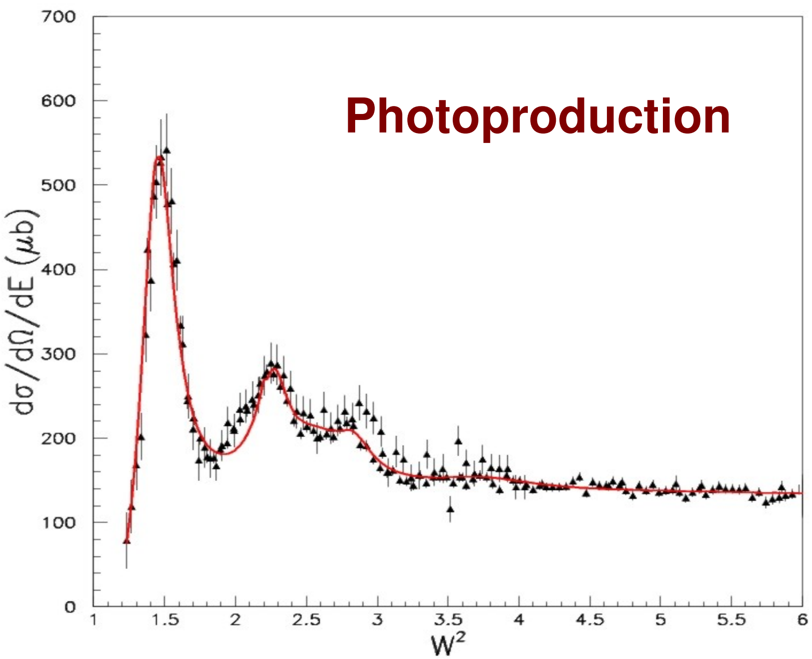
Proton L/T Separated SFs (E94-110)



- Large body of high precision resonance data ($0.3 < Q^2 < 4.5$) - links smoothly to DIS data set.
- Duality observed in both transverse and longitudinal structure functions.
- Hardly any L/T for nuclear targets at the JLab kinematics.
- Resonance region fit to σ_T ***AND*** σ_L available ....

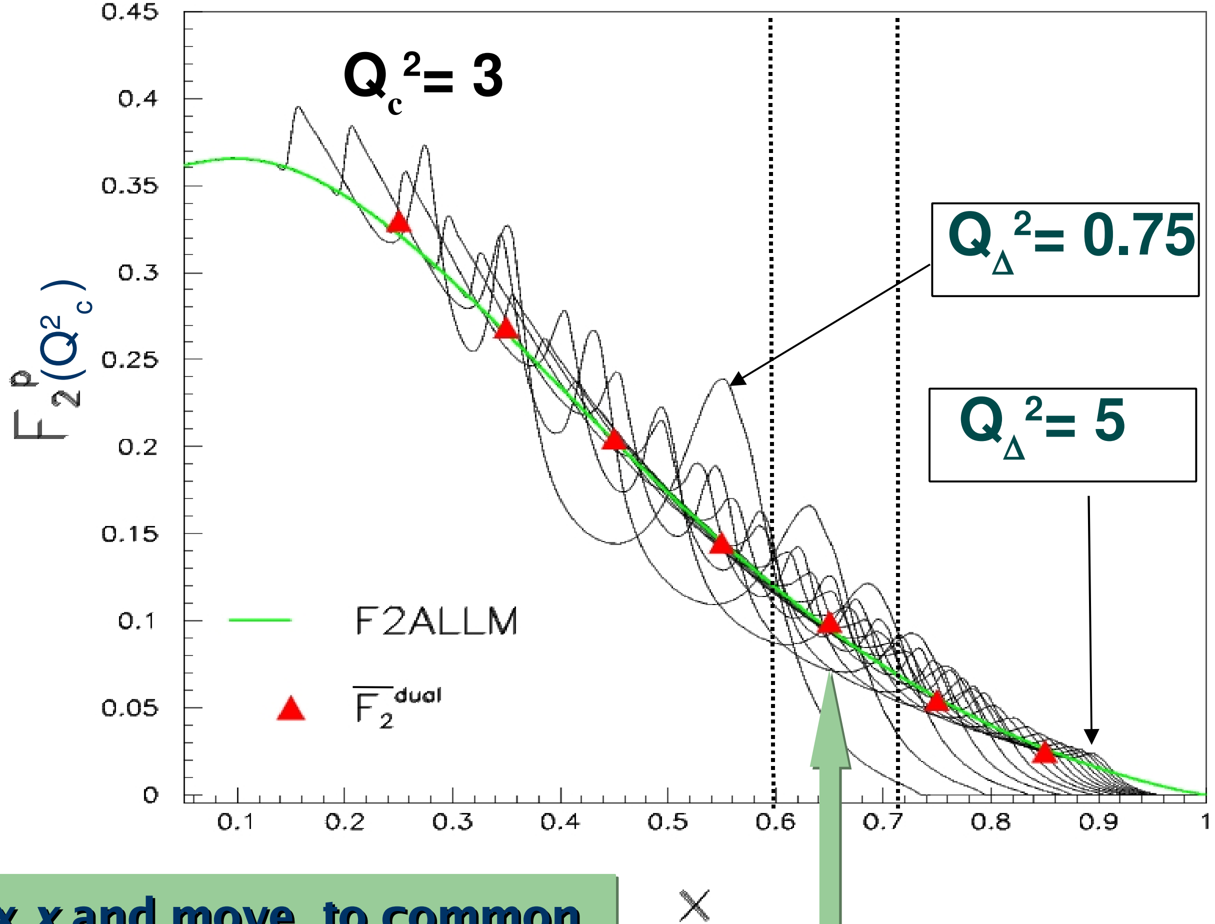






- Energy dependent Breit-Wigners with current best guess of dominant resonances, including decay modes and branching fractions.
- σ_T constrained by photoproduction.
- Fit typically good to better than 3%.
- Fit available at www.jlab.org/~christy/cs_fits/cs_fits.html

Duality Averaged Proton Data



Fix *x* and move to common Q^2 at using Q^2 dependence of DIS fits.

Average over this x-bin

=> 'DIS-like' data

Global Fitting of DIS + Ave. Resonance data

Finite mass nucleon => modification of scaling limit structure functions.

Prescription due to Geogi & Politzer '76

$$F_2(x,Q^2)=\frac{x^2}{\kappa^3}F_2^{bg}(\xi)+6\frac{M^2}{Q^2}\frac{x^3}{\kappa^4}\int_\xi^1 dx'\,F_2^{bg}(x')+12\frac{M^4}{Q^4}\frac{x^4}{\kappa^5}\int_\xi^1 dx'\int_{x'}^1 dx''\,F_2^{bg}(x'')$$

With the M=0 structure function given

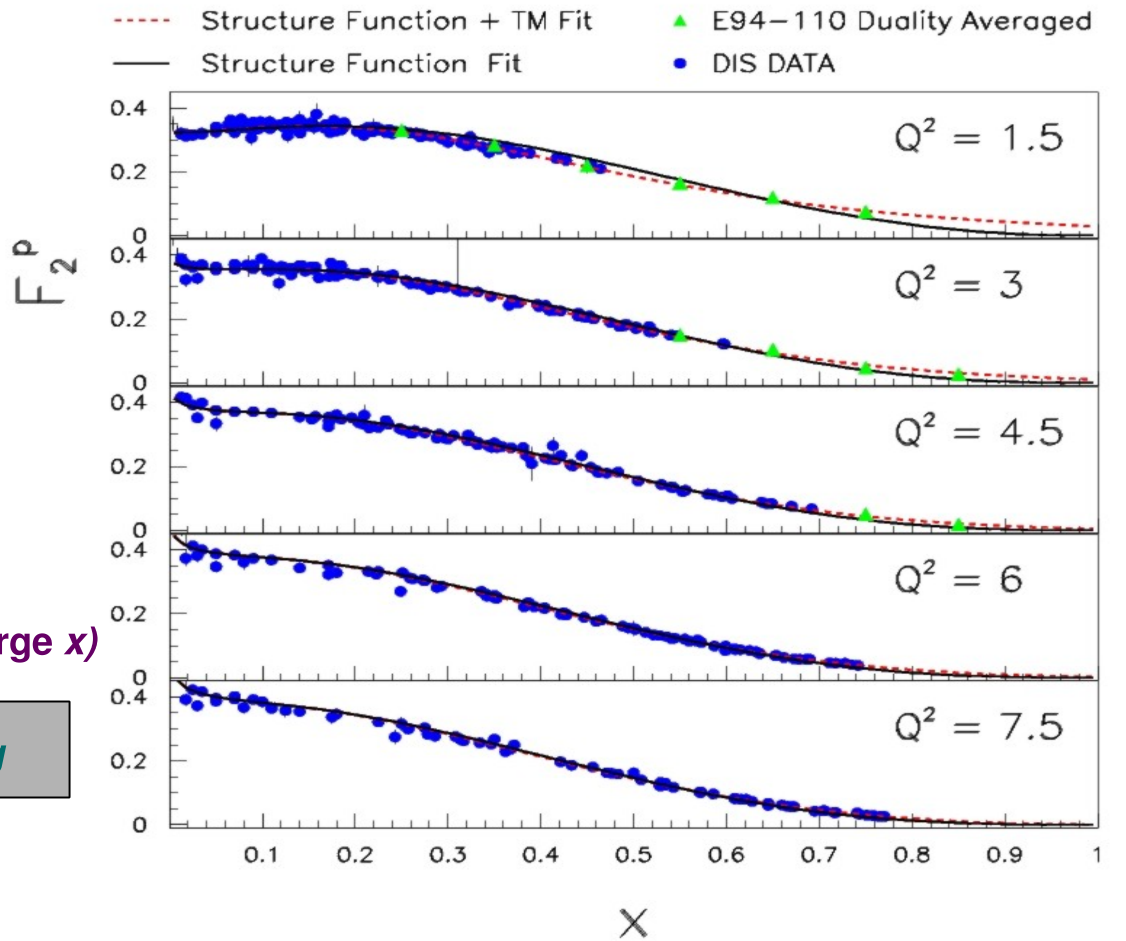
by $F_2^{M=0} = x^2 F_2^{bg}$

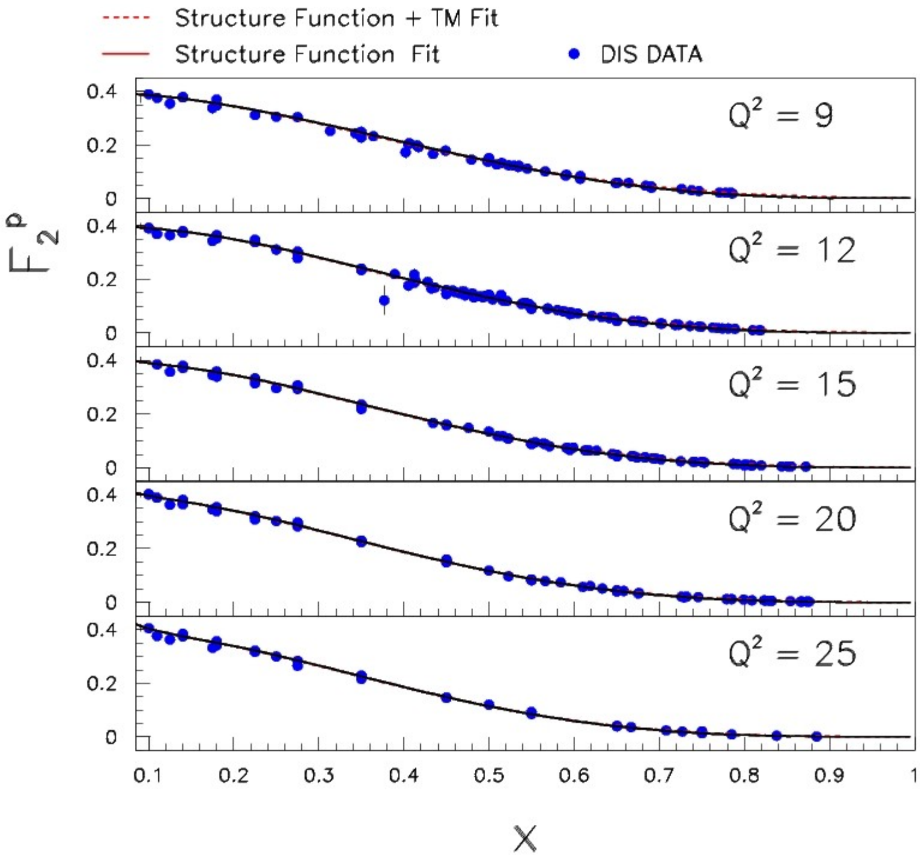
Parameterize $F_2^{M=0}$ (x,Q^2) and fit $F_2(x,Q^2)$ to

world data set

(duality averaged data used to constrain large *x*)

procedure similar to radiative unfolding

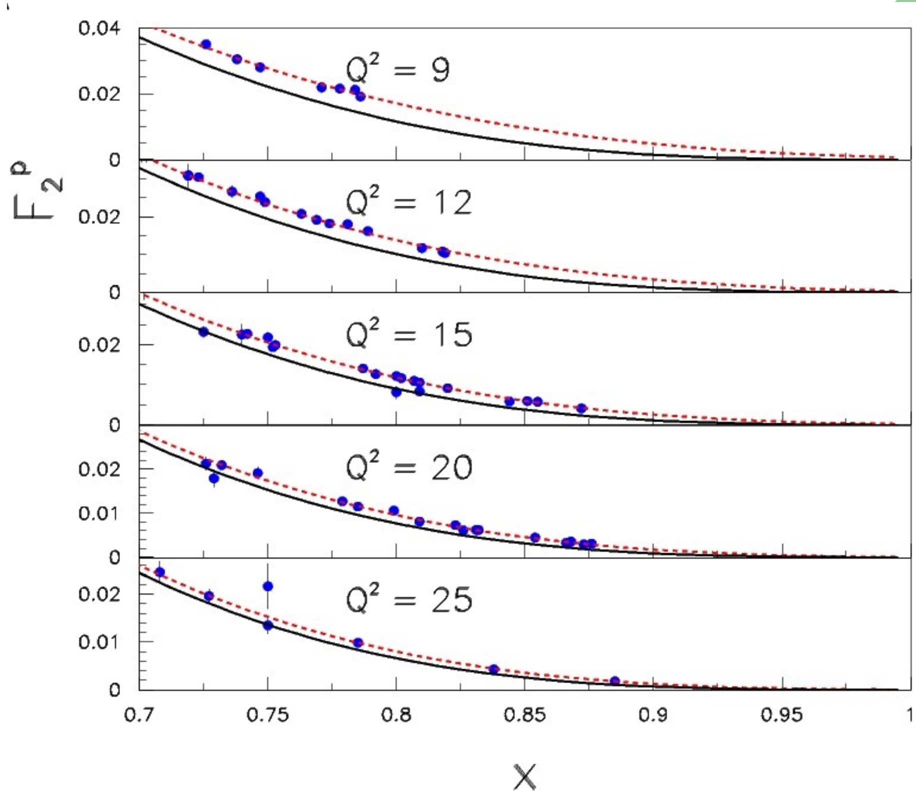




- Full data set fit covers

  $0.3 < Q^2 < 250$ GeV

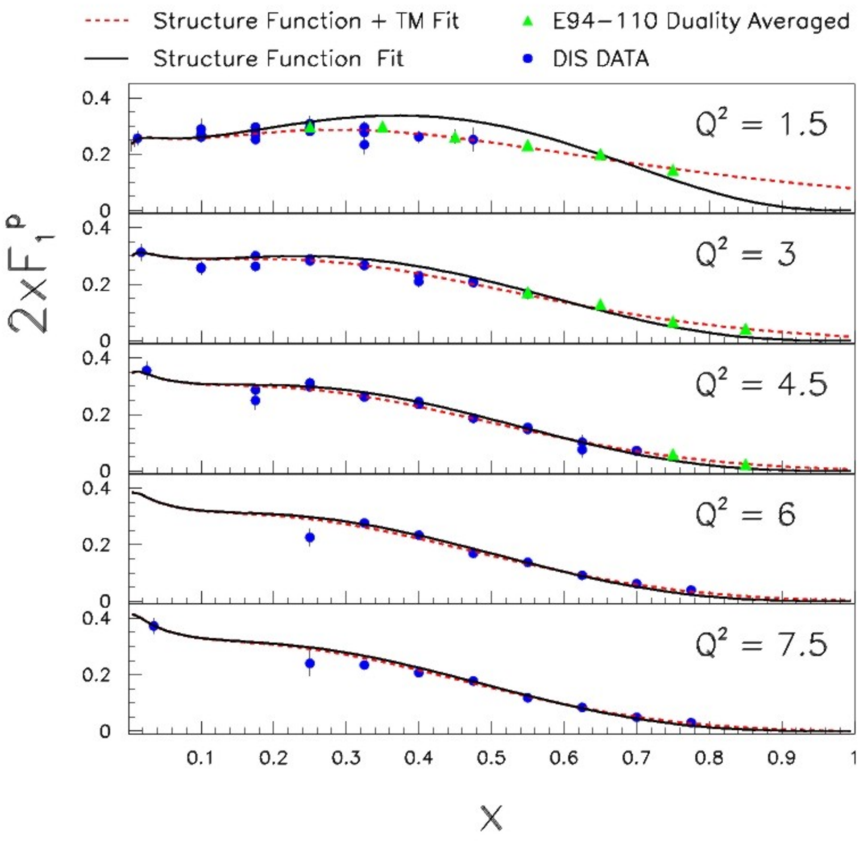
- x^2/dof = 0.98

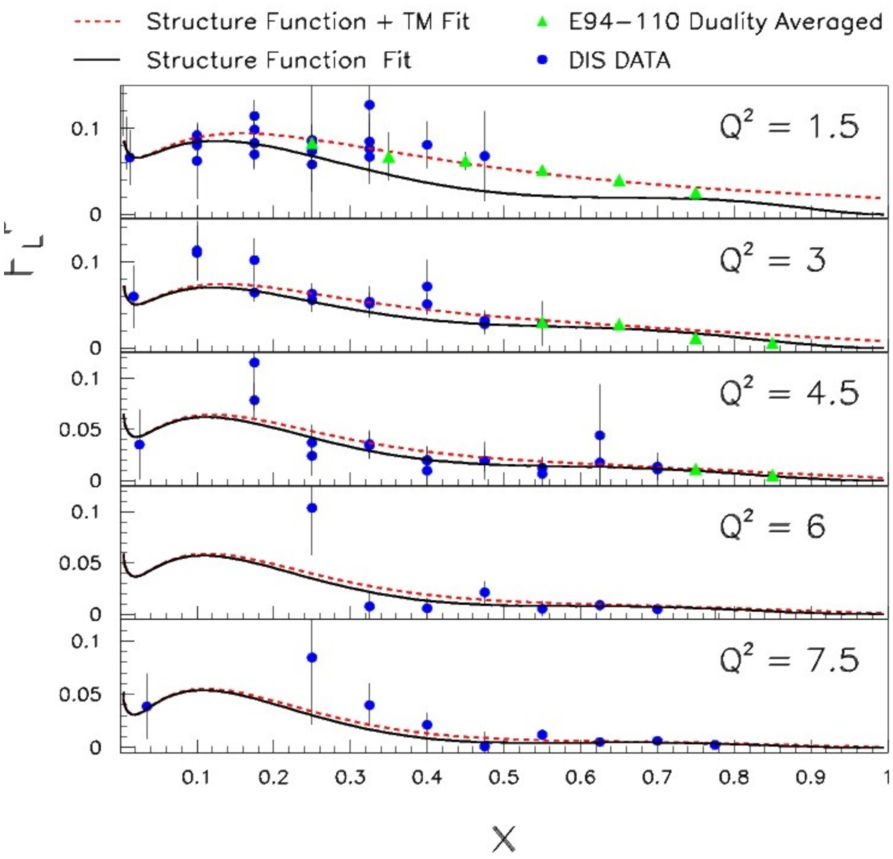


- Even at $Q^2 = 9$ TM is ~7% effect at x = 0.7!
- Fit results provide both $F_2^{M=0}$ and full F_2.

F_1 and F_L ...

- For F_1 only L/T separated data are fit (much more limit data set).
- Need L/T separated data for $x < 0.2$ and $Q^2 > 3$!
- F_L is determined from F_2 & F_1 fits.

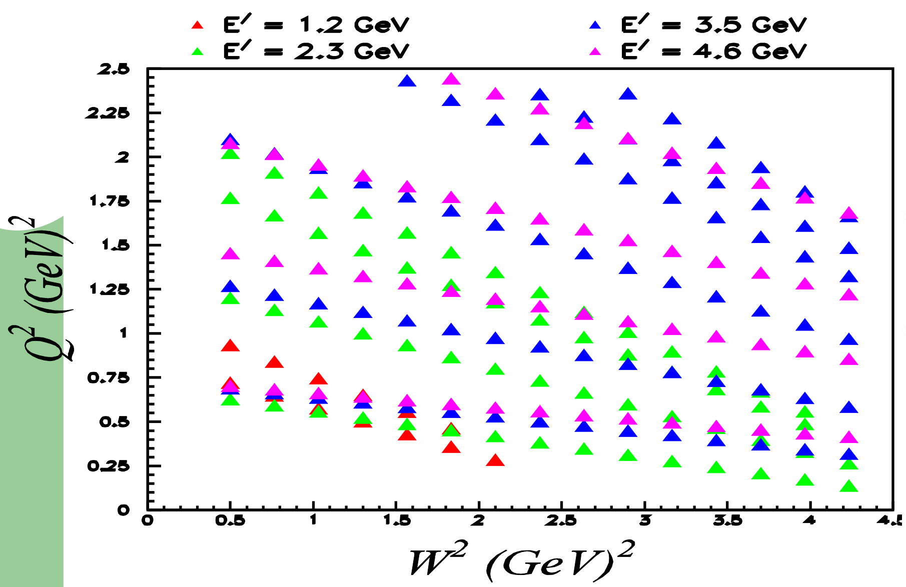




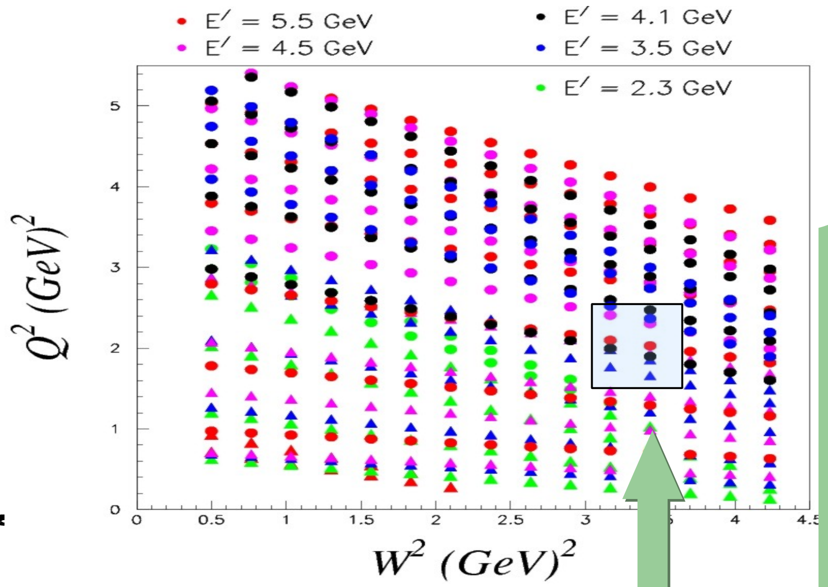
L/T Separated Structure Functions on Nuclei (JLab E02-109, E04-001 and E06-009)

•**L/T Separation Data:** Targets: D, C, Al, Fe - Final uncertainties 1.6 % pt-pt in ε (2% normalization) - essentially, duplicate proton data.

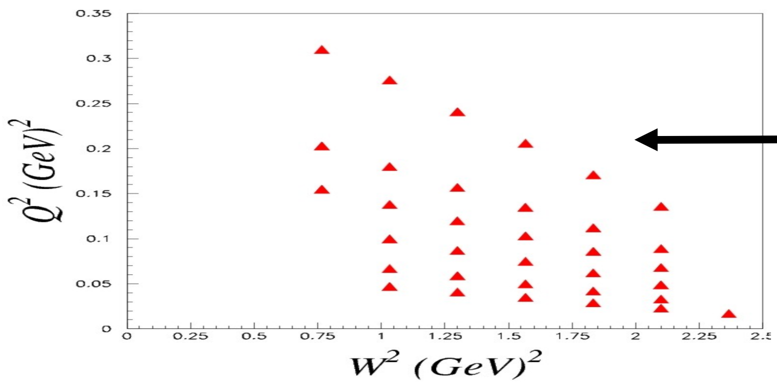
Data from Jan '05



Approved future running



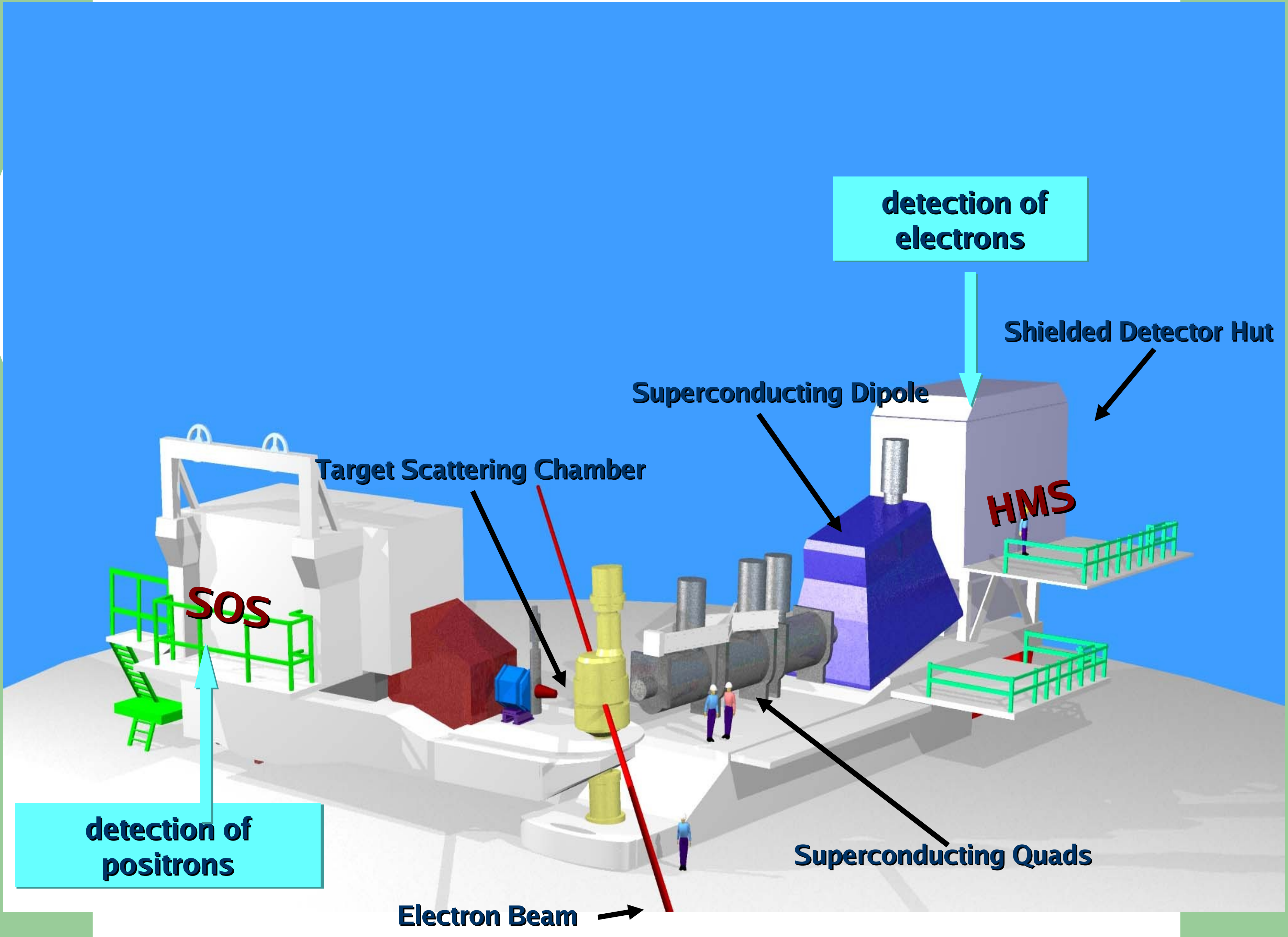
L/T separations where multiple energies.



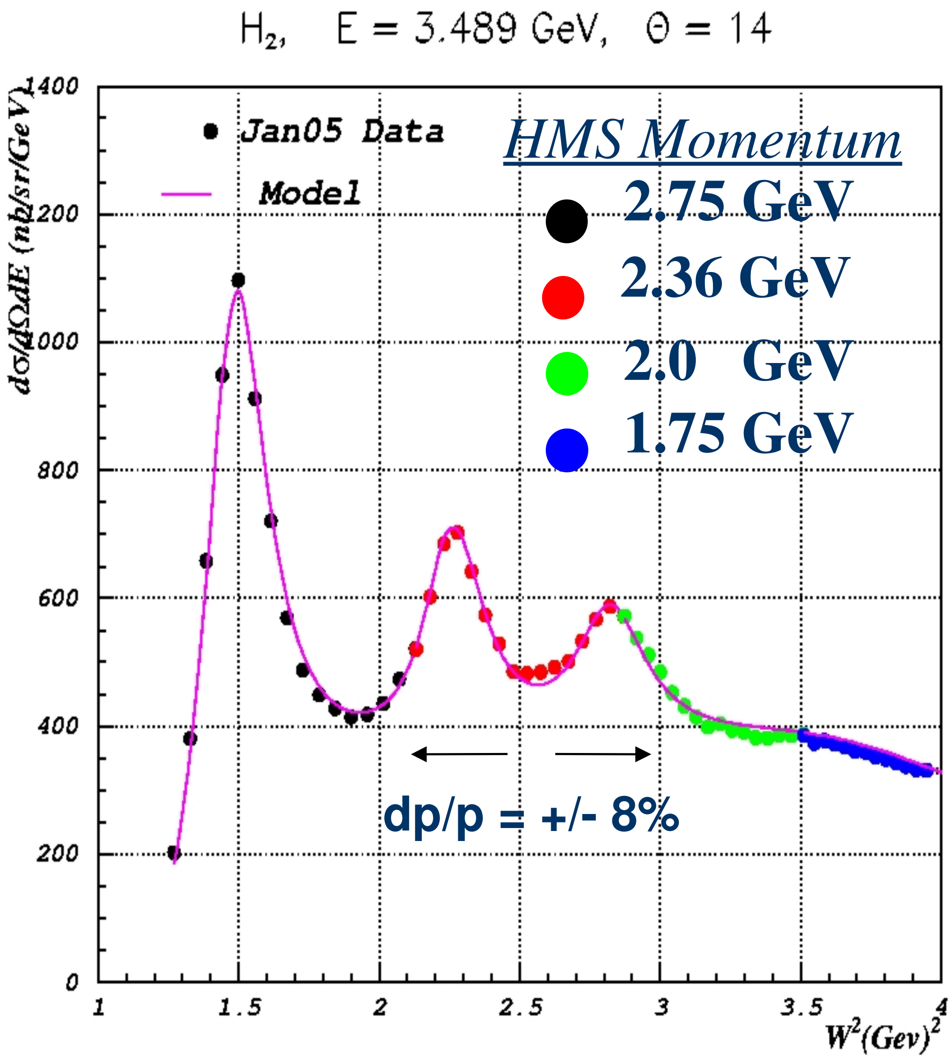
Low Q^2 mod

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

(Much larger RCs and rates)

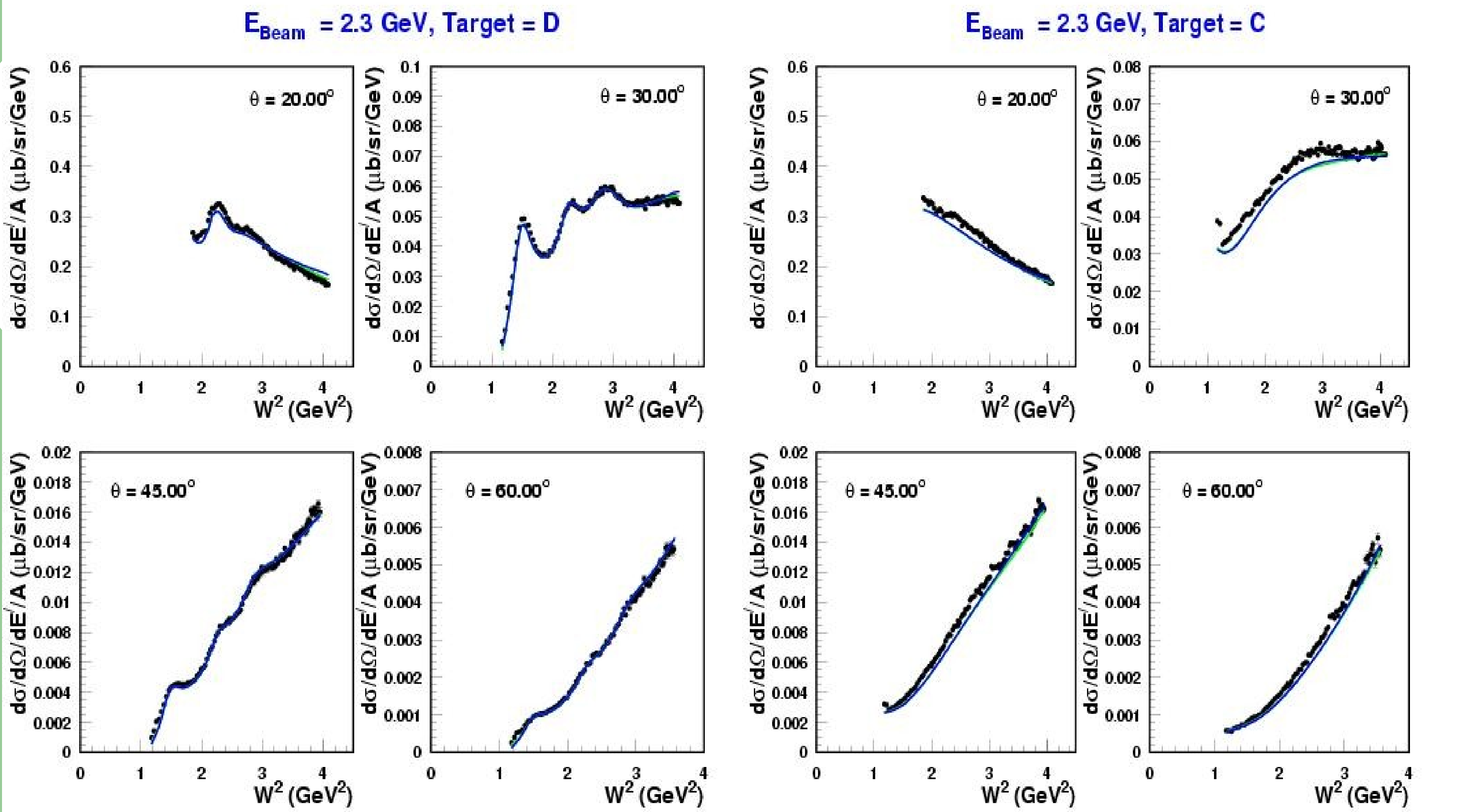

detection of electrons
Shielded Detector Hut
Superconducting Dipole
Target Scattering Chamber
HMS
SOS
detection of positrons
Superconducting Quads
Electron Beam

Inclusive cross sections in Hall C



- **Efficiency corrected e- yield HMS**
- **** For cryo targets, subtract empty target background**
- **Subtract charge symmetric e- yield (e+ yields measured in SOS)**
- **Apply acceptance corrections.**
- **Apply radiative corrections.**

Preliminary Cross Section Results

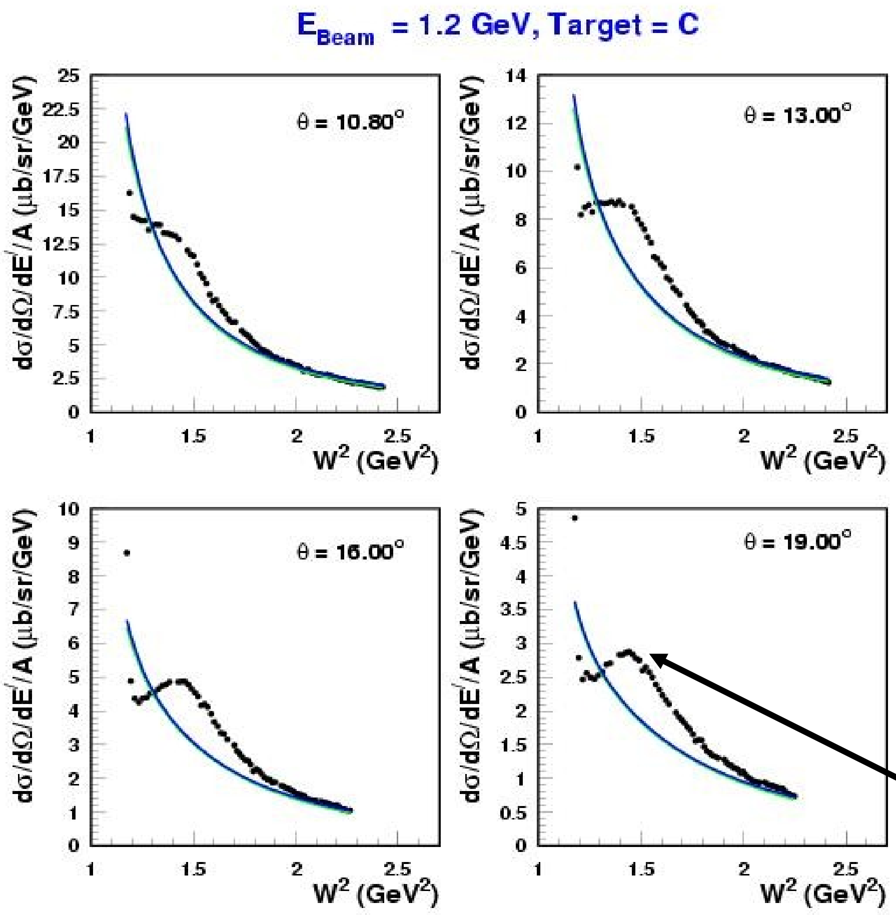


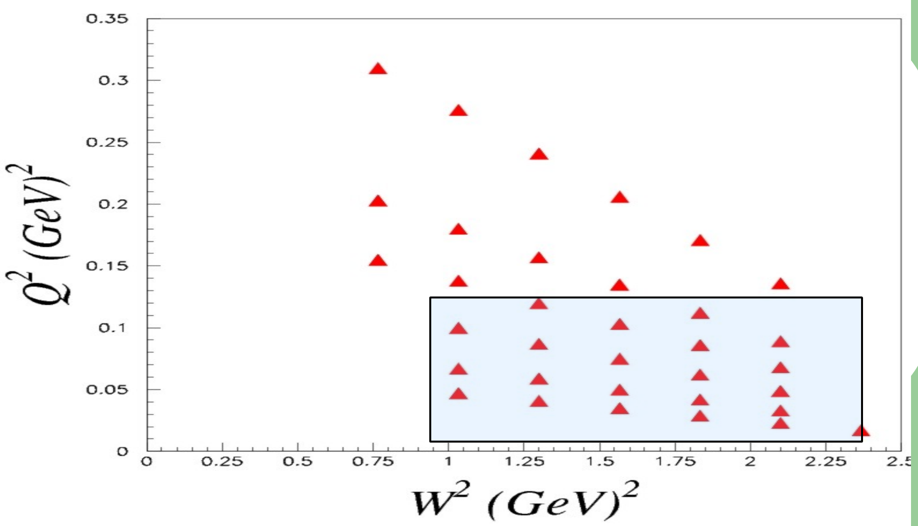
- Error bars are statistical only.
- Only inelastic data shown.

Deuterium: Fits to previous JLab & SLAC resonance region data.

Heavy targets: fits to DIS data (F_2 & R) + y-scaling QE model.

Low Q^2 Cross Sections





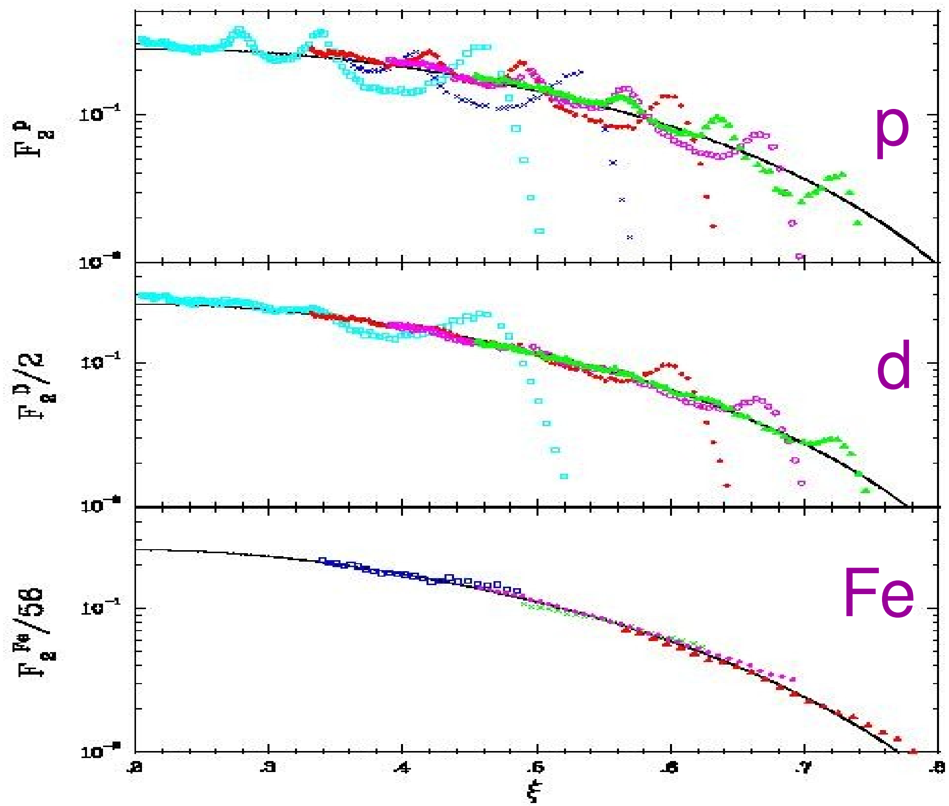
- Low Q^2 data (< 0.15 GeV^2) will provide ~5-7% cross sections.
- Δ resonance is quite strong in nuclei at low Q^2.
- Quasi-elastic data still to be analyzed.

Even for deuterium, we need better models at low Q2 – P. Bosted talk.

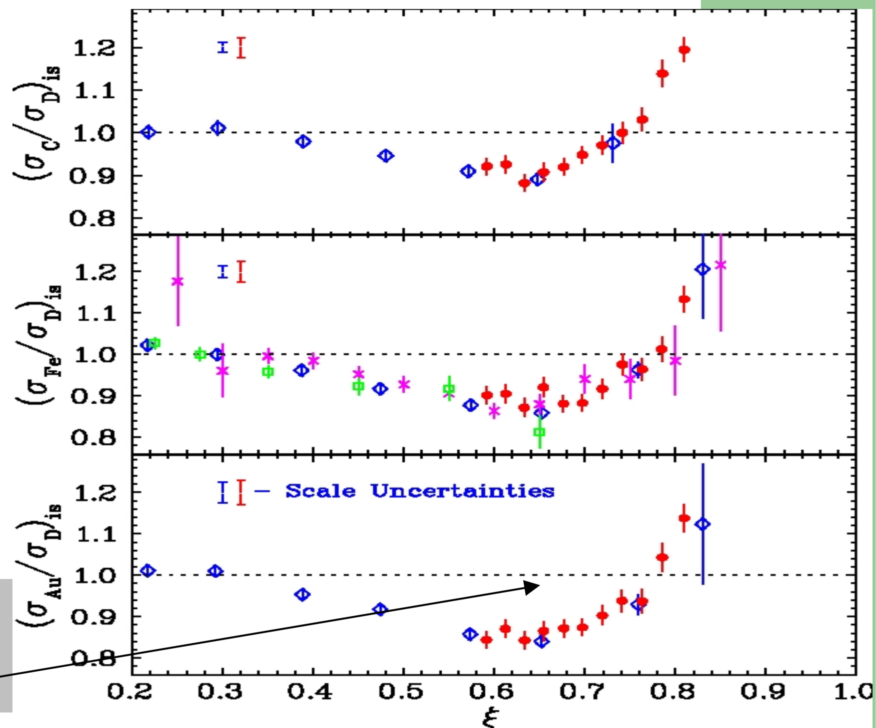
Nuclear Structure Functions

Arrington, Keppel, Ent, Niculescu PRC73:045206 (2006)

Arrington, Keppel, Ent, Mammei, Niculescu PRC73: 035205, 2006



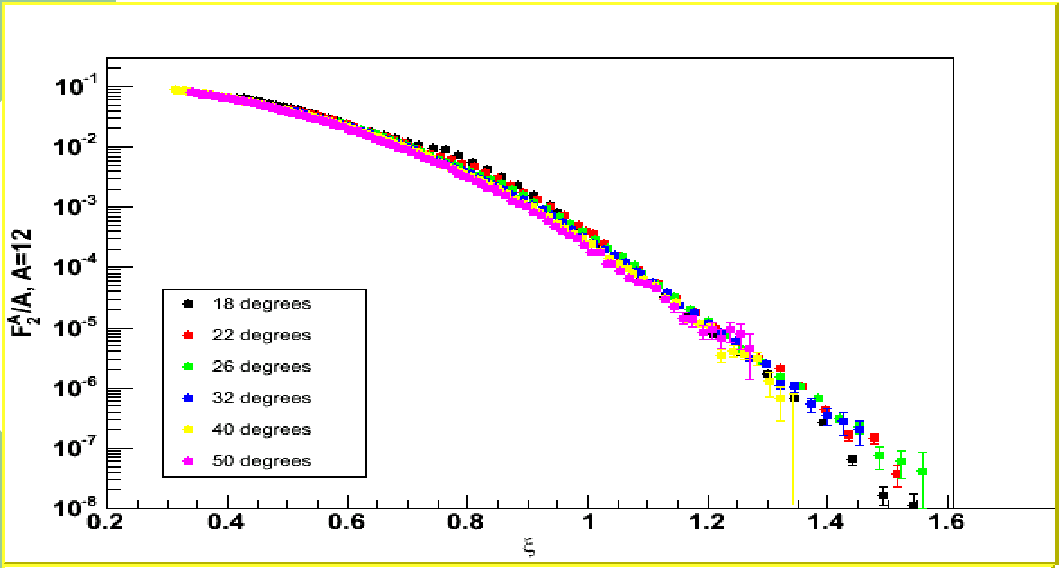
- Nuclear structure functions follow a single curve – *shallow Q^2 dependence, ξ-scaling*.
- In nuclei the averaging is nearly accomplished by Fermi motion.
- No low Q^2 or L/T data.

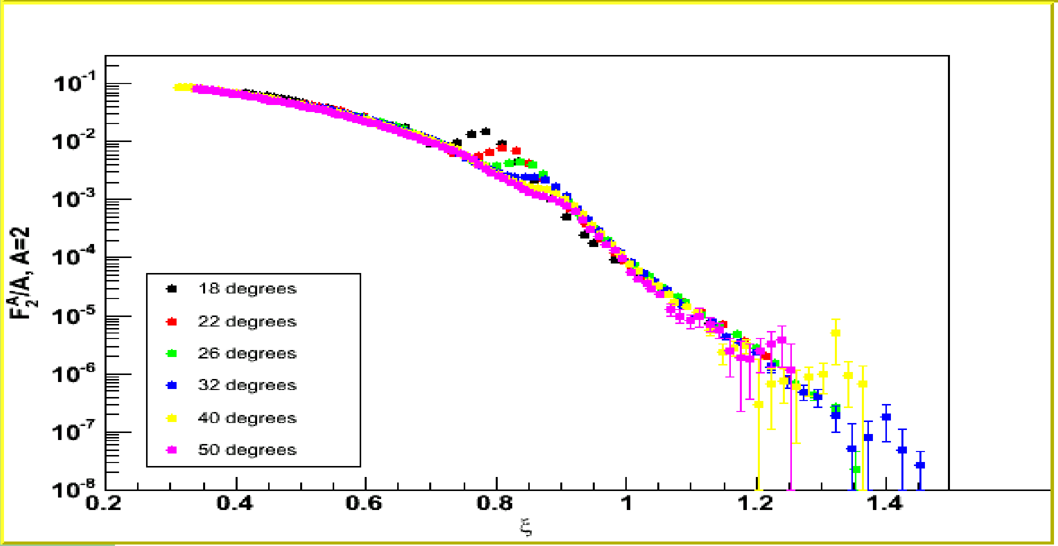


$\xi = 2x[1 + (1 + 4M^2x^2/Q^2)^{1/2}]$

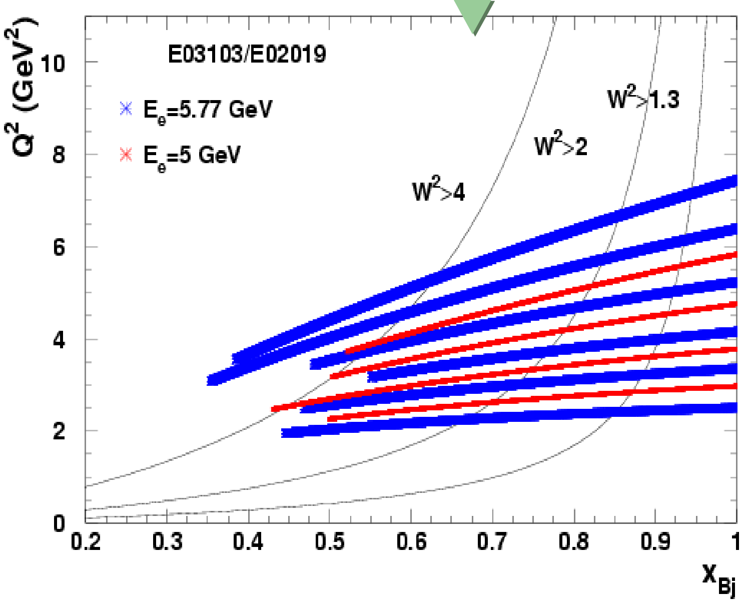
- EMC effect is the same whether in DIS or resonance region.

New data: Jlab E03-103 – *EMC in light nuclei*

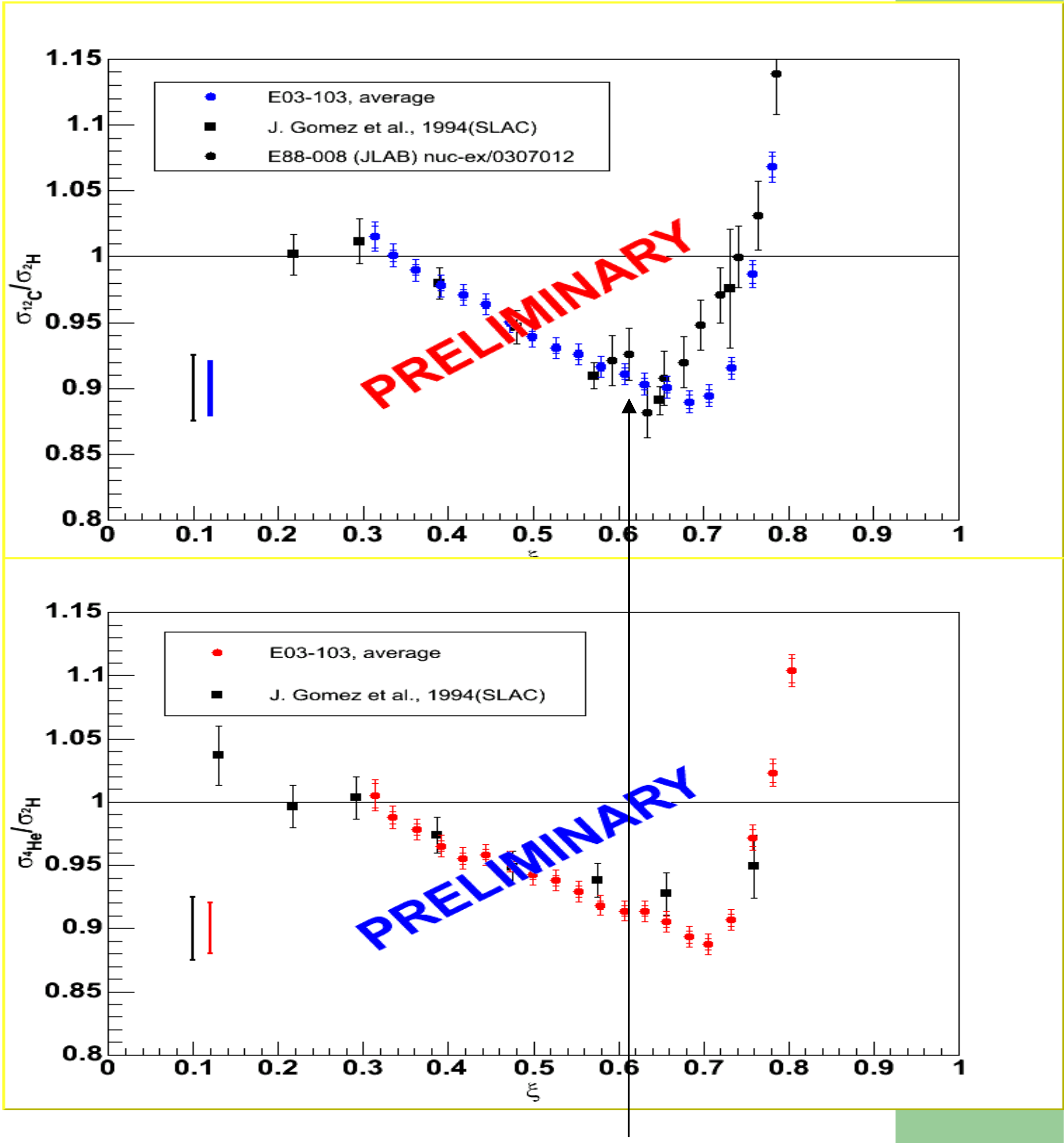




- Ran Fall 2004 in Hall C.
- Provides precision data on nuclear SFs/ nuclear modifications in light nuclei.
- Large kinematic coverage to study x and Q^2 dependences.



- EMC effect is the same in resonance region as in DIS.
- Data will provide precision data on A-dependence of EMC effect => help distinguish models of EMC
- Can determine Q^2 at which duality in EMC breaks down.



$W^2 \sim 4\ GeV^2$

Summary

- Proton L/T separated SFs measured in RR for $0.3 < Q^2 < 4.5$.
- RR cross section fit available for proton data constrained to $Q^2 = 0$.
- SF fit performed to world DIS + RR duality data including TM.
- Preliminary low Q^2 data for RR L/T SFs in nuclei (larger Q^2 to come)
- Preliminary EMC data for light nuclei shown
  => duality in EMC observed.
- Will help discriminate between various models for EMC .