High Precision Measurements of $R = \sigma_L / \sigma_T$ in the Nucleon Resonance Region

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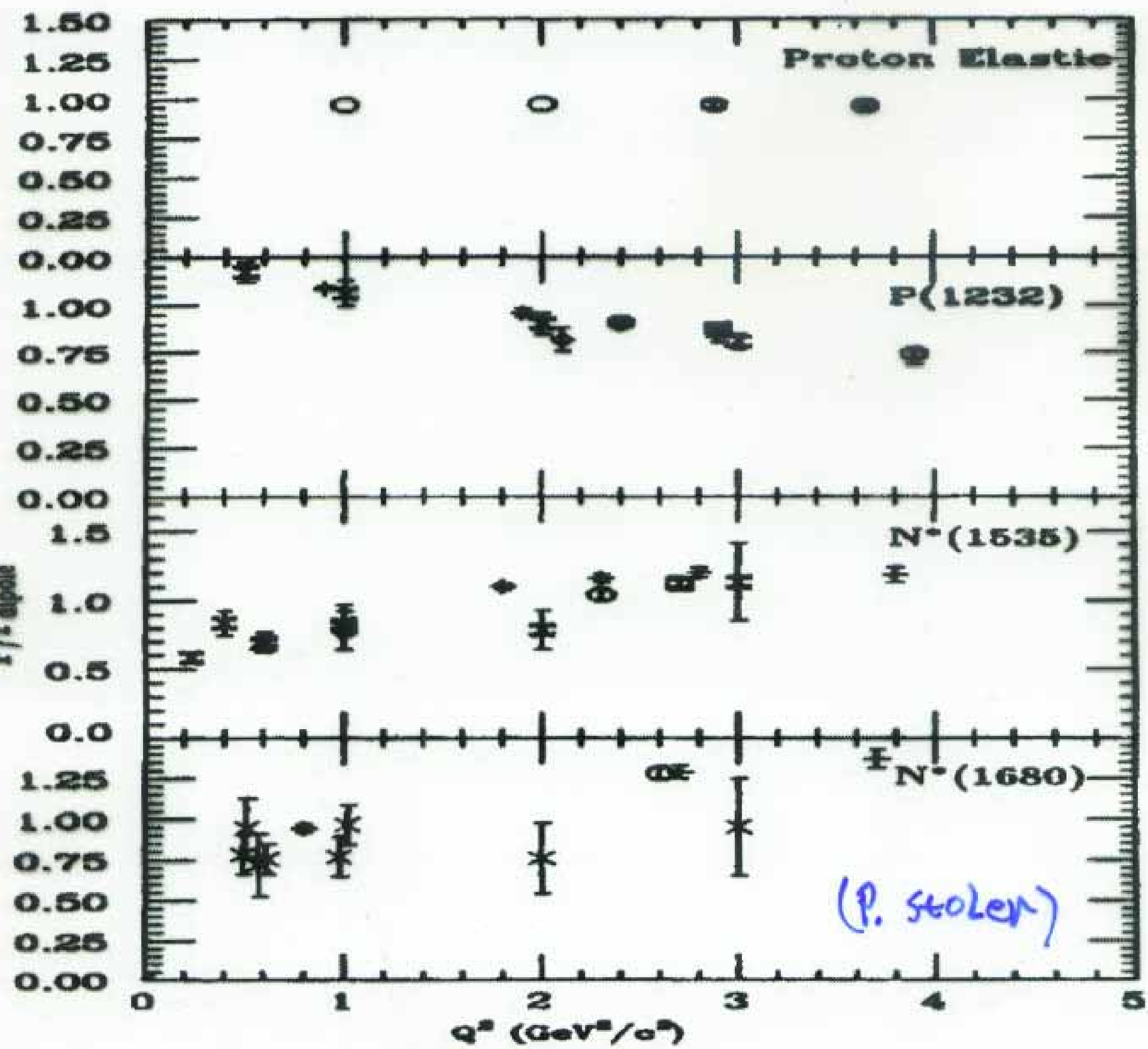
JLAB HALL C
E94-110

Resonant Transition Form Factors

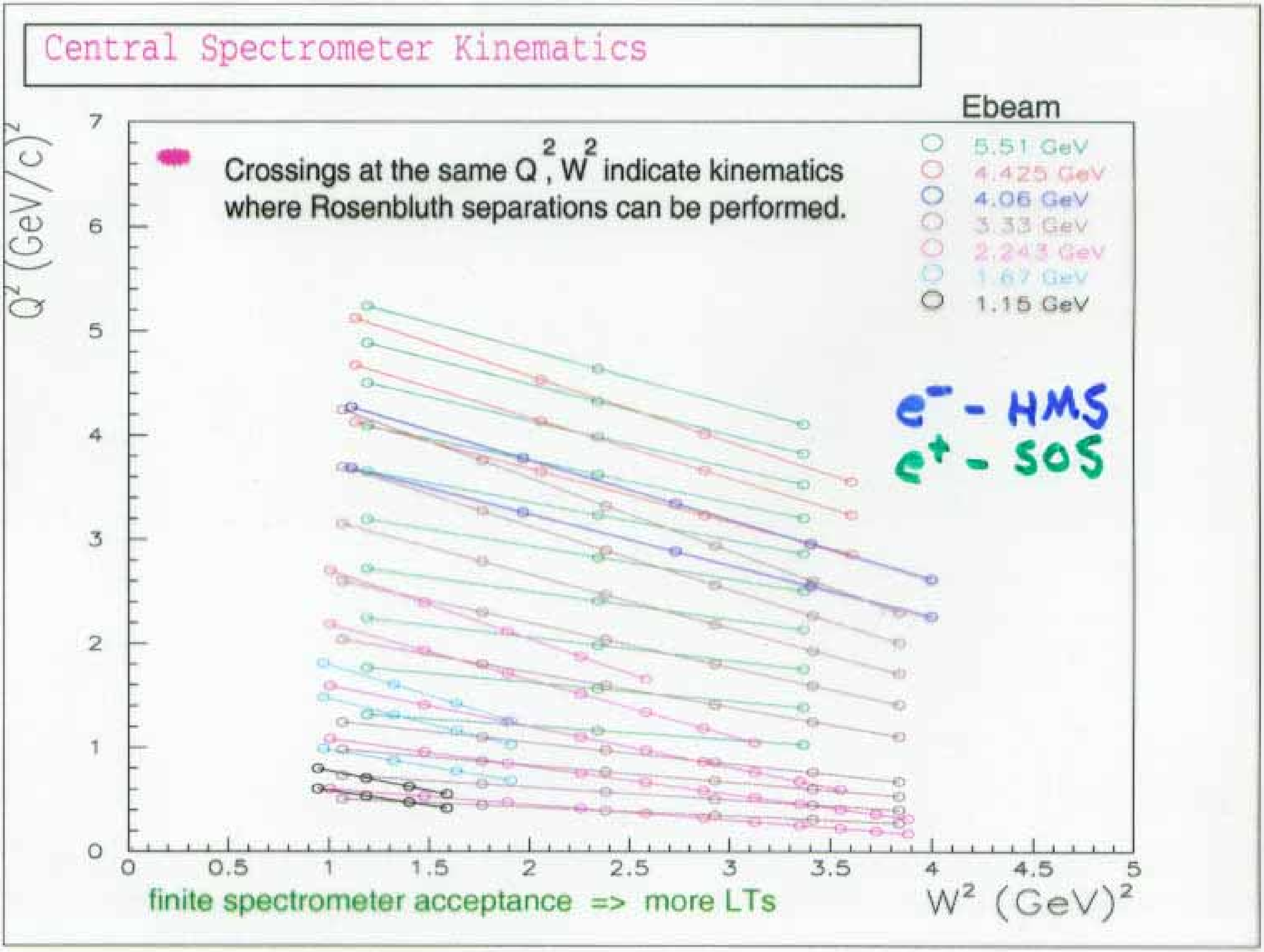
$$\left| F_\Delta(Q^2) \right|^2 = \frac{2\Gamma_R \pi M_\Delta}{} \frac{F_1}{Q^2} \propto \frac{A_{1/2}^2 + A_{3/2}^2}{Q^2}$$



- Assumes $\sigma_L^{res} = 0$ for inclusive extraction

E94-110 Central Spectrometer Kinematics

Essentially the same as PR02-009



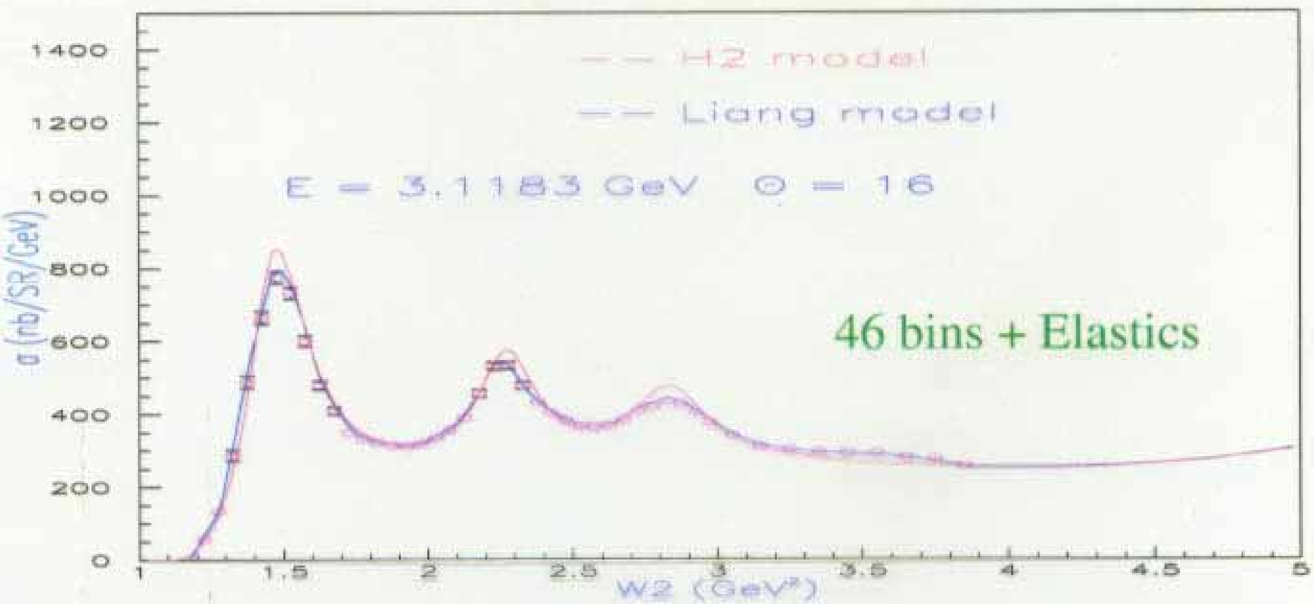
2 Methods are employed for extracting the complete unpolarized structure functions:

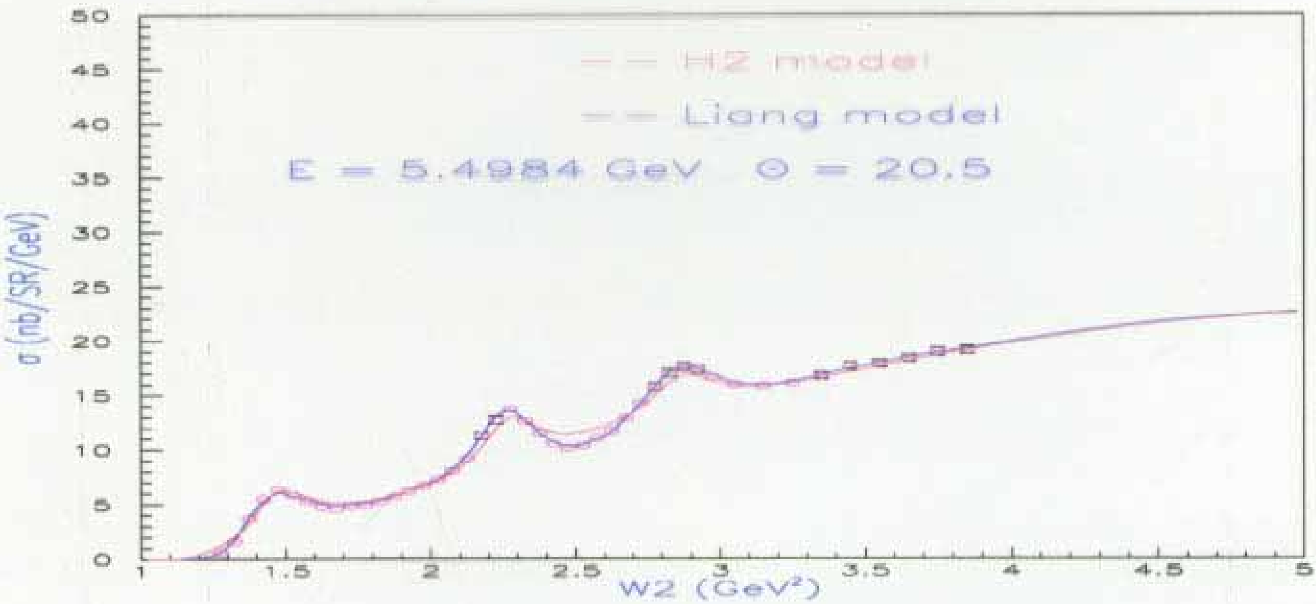
1. Rosenbluth separations where possible. (Some kinematic evolution is needed)

2. Iteratively Fit to F_2 and R over the entire kinematic range.

Global extraction

E94-110 Cross Sections

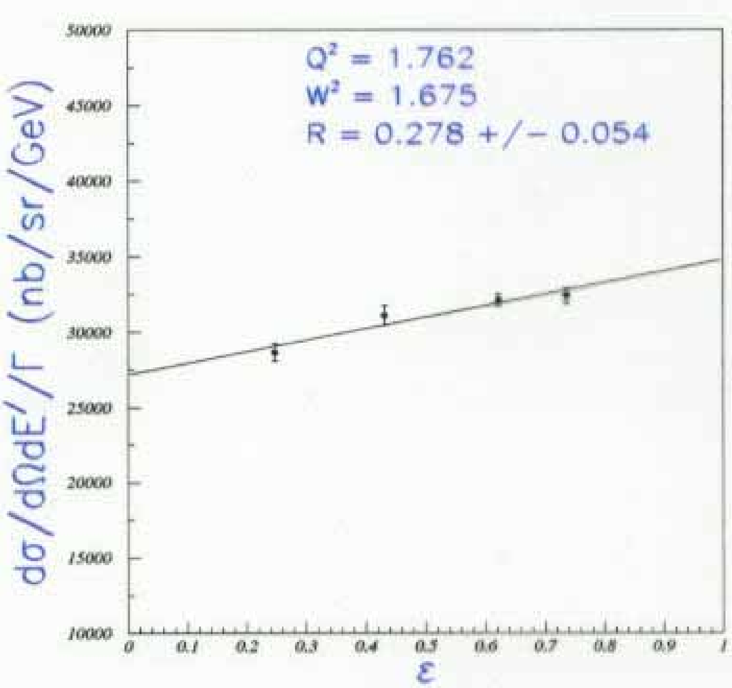


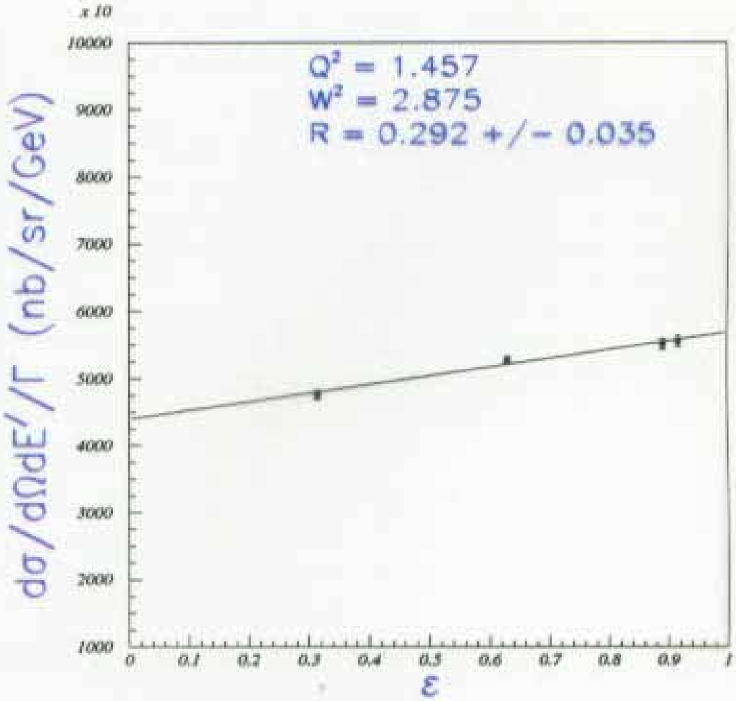


- Statistical uncertainties are included (typically < 1 %) (overlapping points are averaged).
- Current fit (Liang) reproduces data cross section well.

L/T Separations

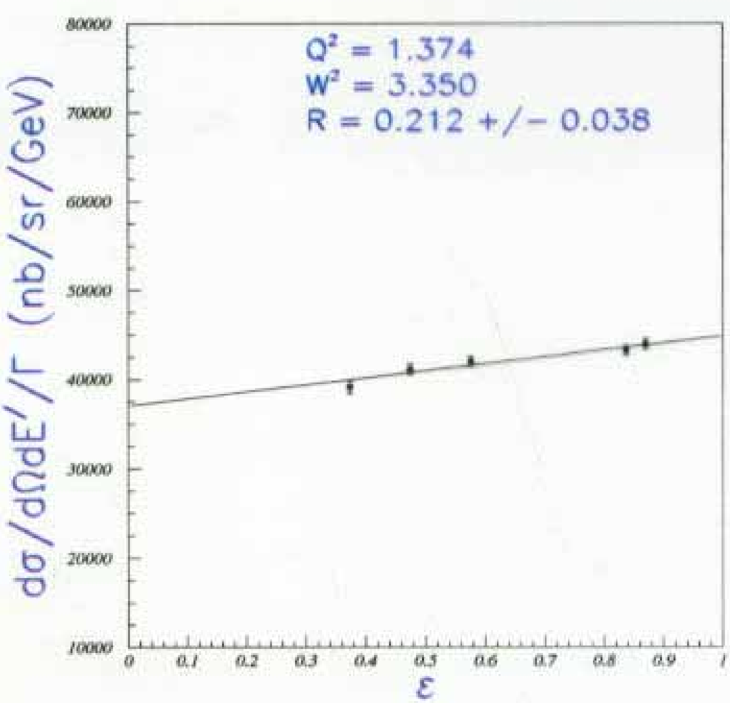
180+ Direct L/T Separations Performed

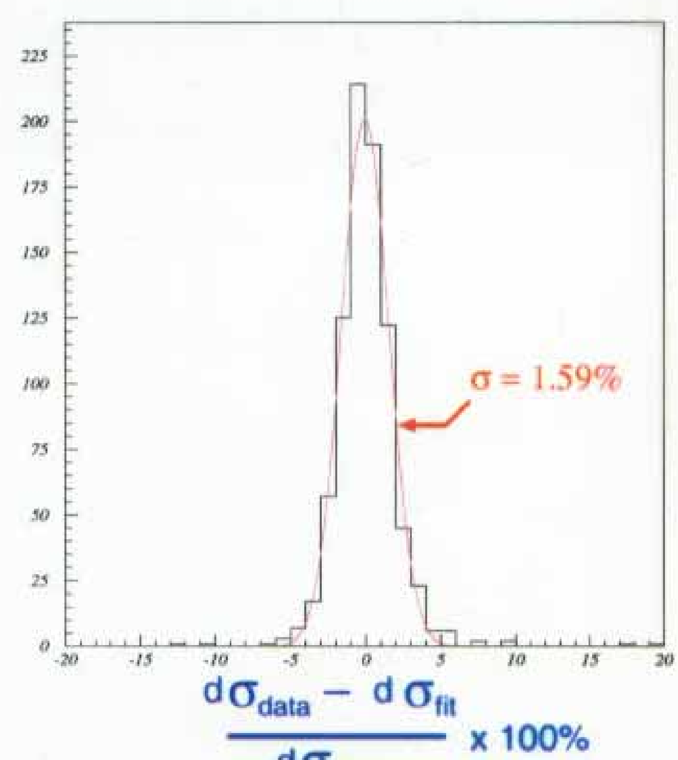




$$\frac{1}{\Gamma}\frac{d\sigma}{d\Omega dE'} = [\sigma_T(W^2,Q^2) + \varepsilon\sigma_L(W^2,Q^2)]$$

1.0 - 1.5% pt-to-pt systematics





Model Iteration Procedure

Model is used for radiative corrections and bin-centering the data in θ. ←

↓ ↑

Extract σ^{exp} from data.

↓ ↑

Use model to decompose σ^{exp} into F_2^{exp} and R^{exp}.

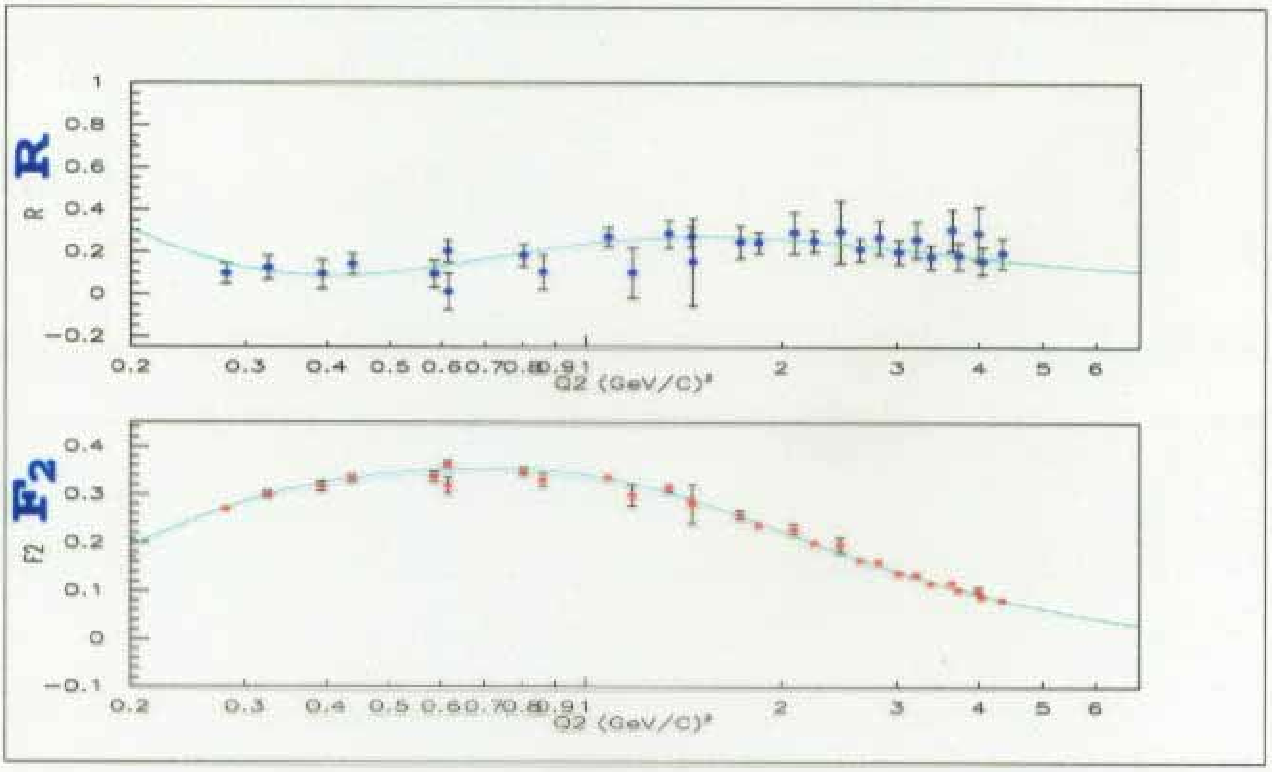
↓ ↑

For each W^2 bin, fit F_2^{exp} and R^{exp} vs Q^2 to get new model. →

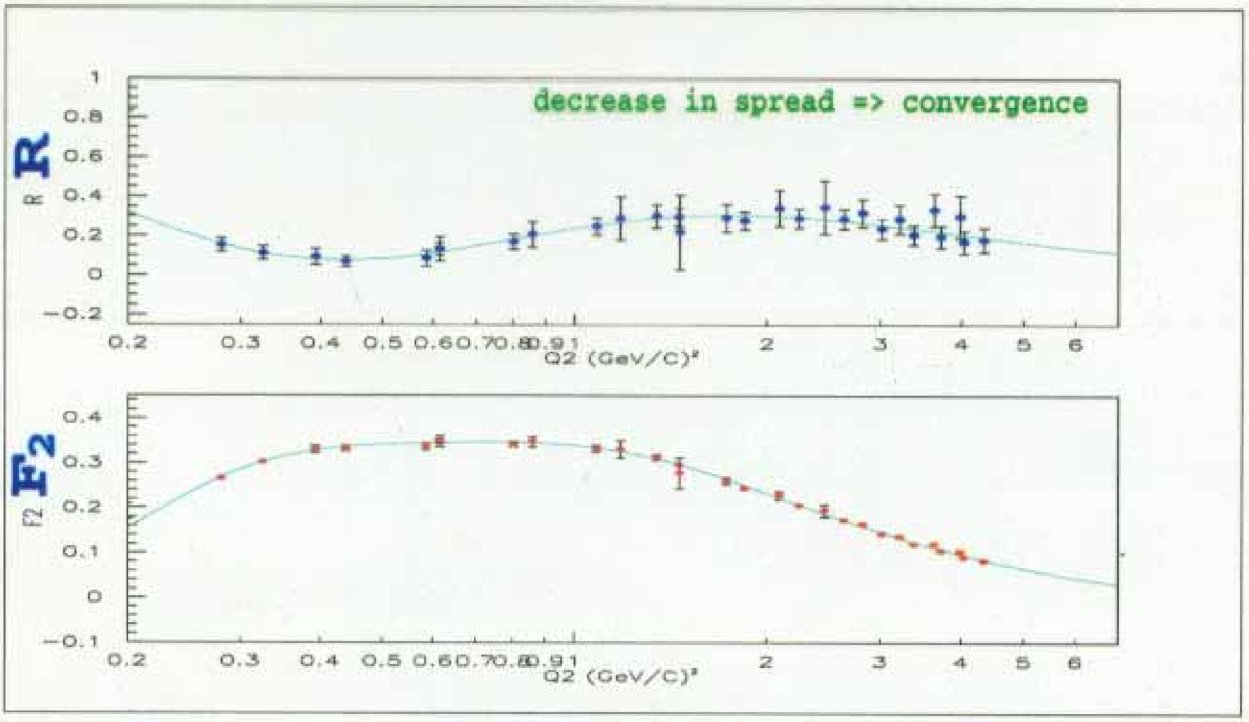
- *Strength gets shuffled between* F_2 *and* R *until convergence is reached.*
- *When calling model, interpolate in* W^2

Structure Function Extraction via Model Iteration

3rd Resonance Peak, Iteration 0:



3rd Resonance Peak, Iteration 2:



→ First precision Separation of σ_L / σ_T in nucleon Resonance Region.

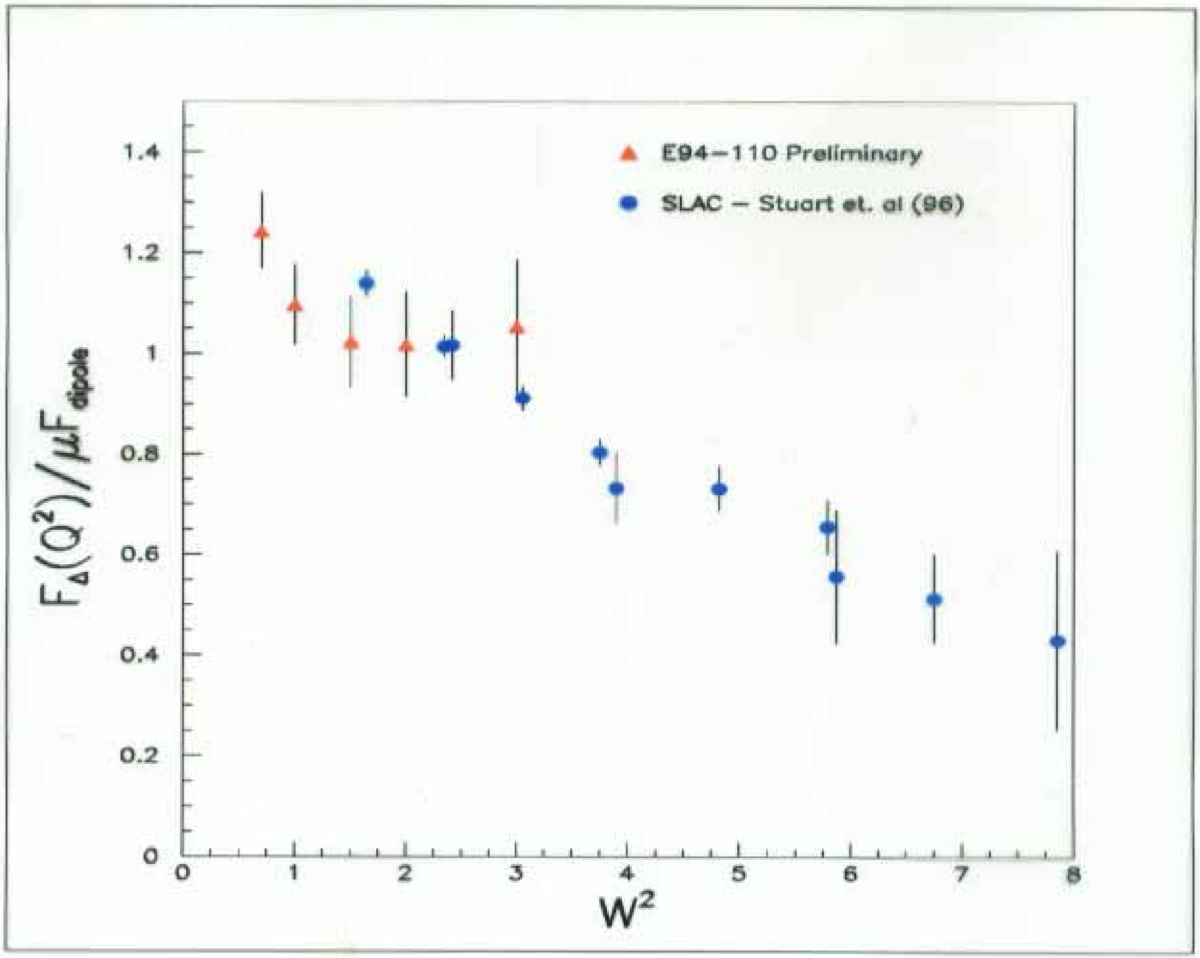
→ Both $\sigma_T + \sigma_L$ show Resonant Structure ($\sigma_L^{res} \neq 0$)

→ Lots of good physics

* F_1, F_2 Moments at Low Q^2
* Transition FFs
* Quark–Hadron duality in 2π channels

Resonant Transition Form Factors

$$\left| F_{\Delta}(Q^2) \right|^2 = \frac{2\Gamma_R \pi M_{\Delta}}{} \frac{F_1}{Q^2}$$



Expect that Δ T.F.F. will be consistent with earlier results.

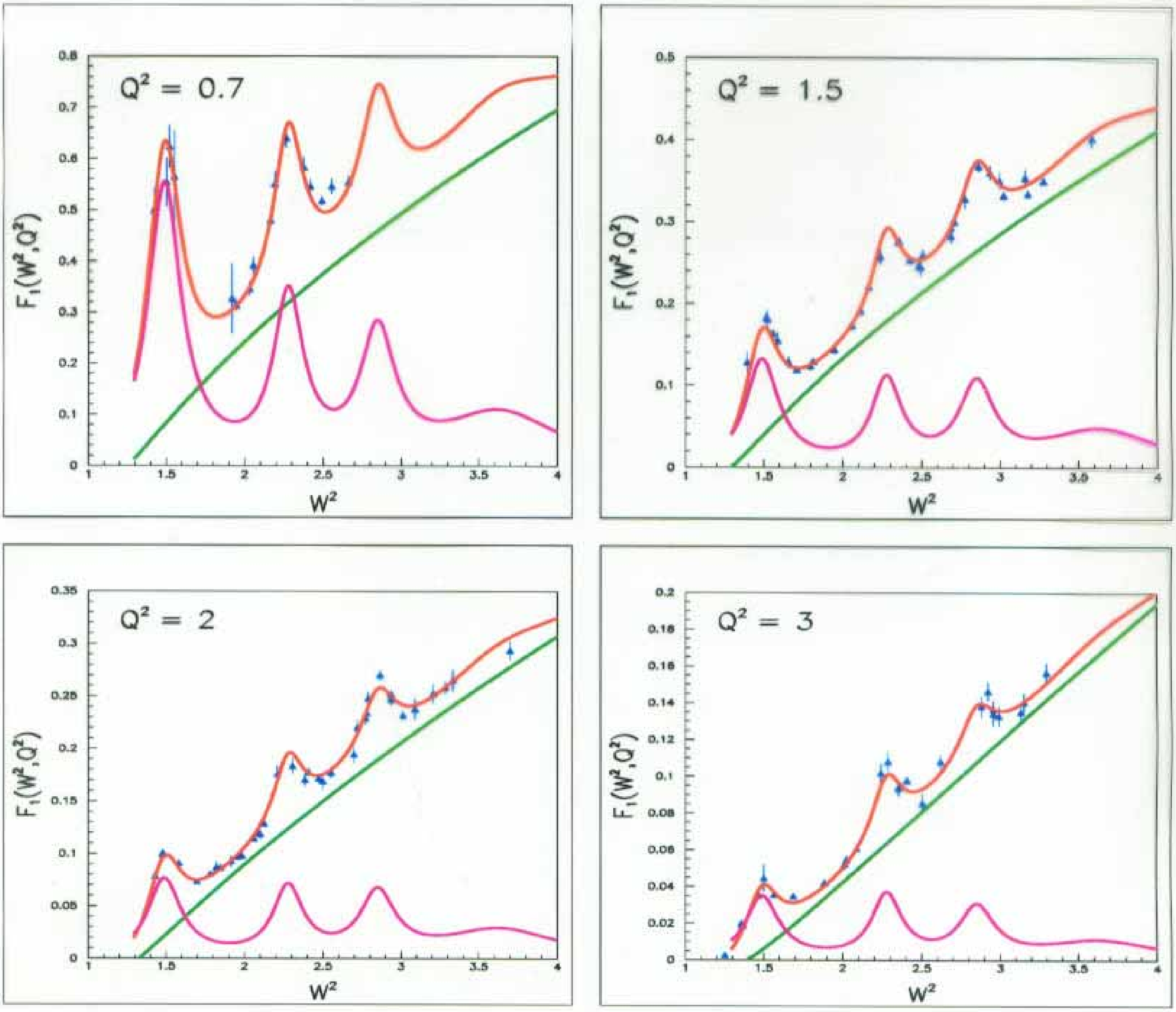
since σ_L^{RES} is small.

But for 2nd and 3rd Resonance region σ_L^{RES} is not small!

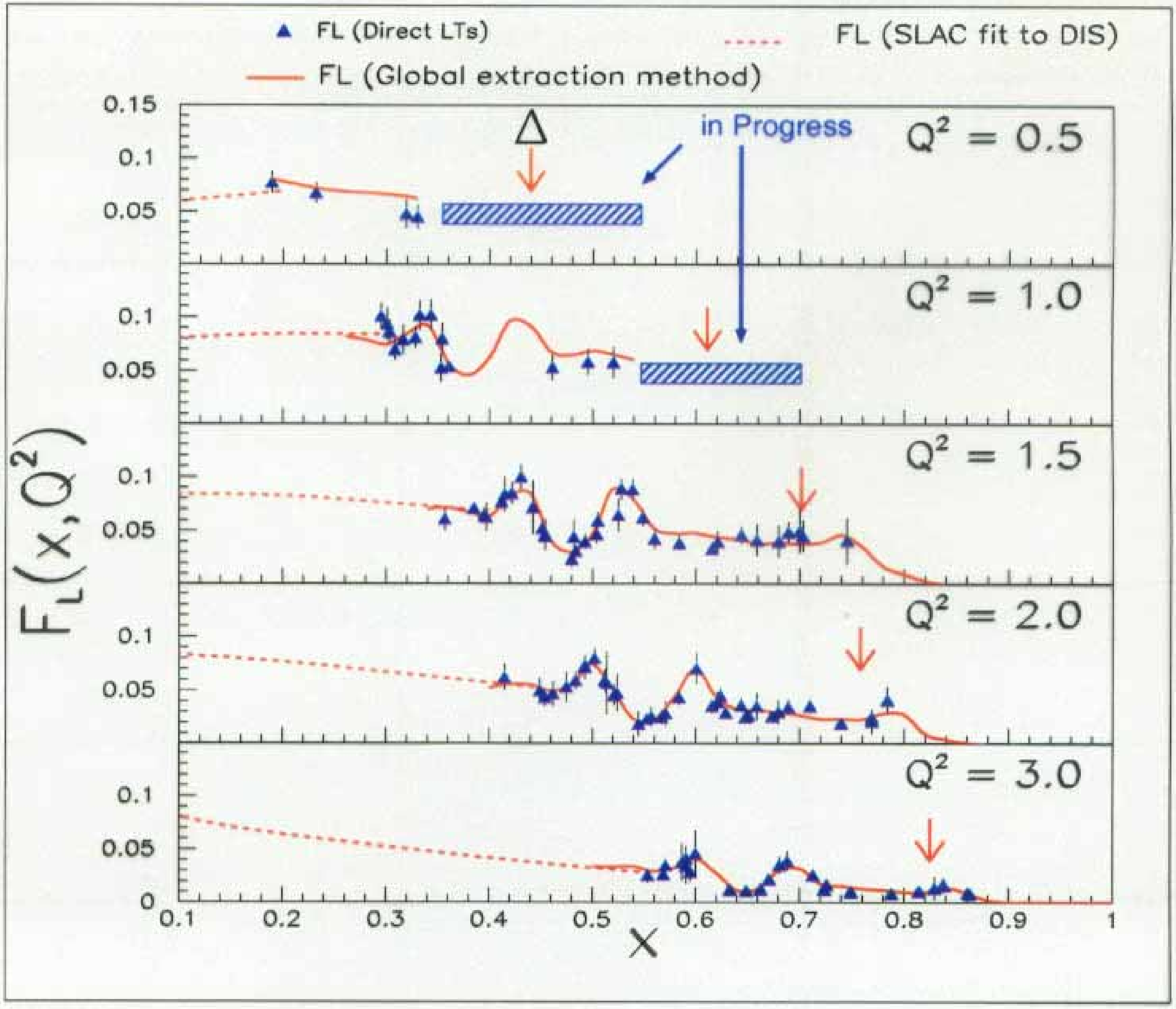
Resonant Transverse Structure Function

$$\sigma_T = \frac{4\pi^2}{\kappa M_n}\alpha F_1 \qquad \kappa = \frac{W^2 - M_n}{2M_n}$$

- Only 60% of Rosenbluth Separated data shown.
  10x as much cross section data to be included!



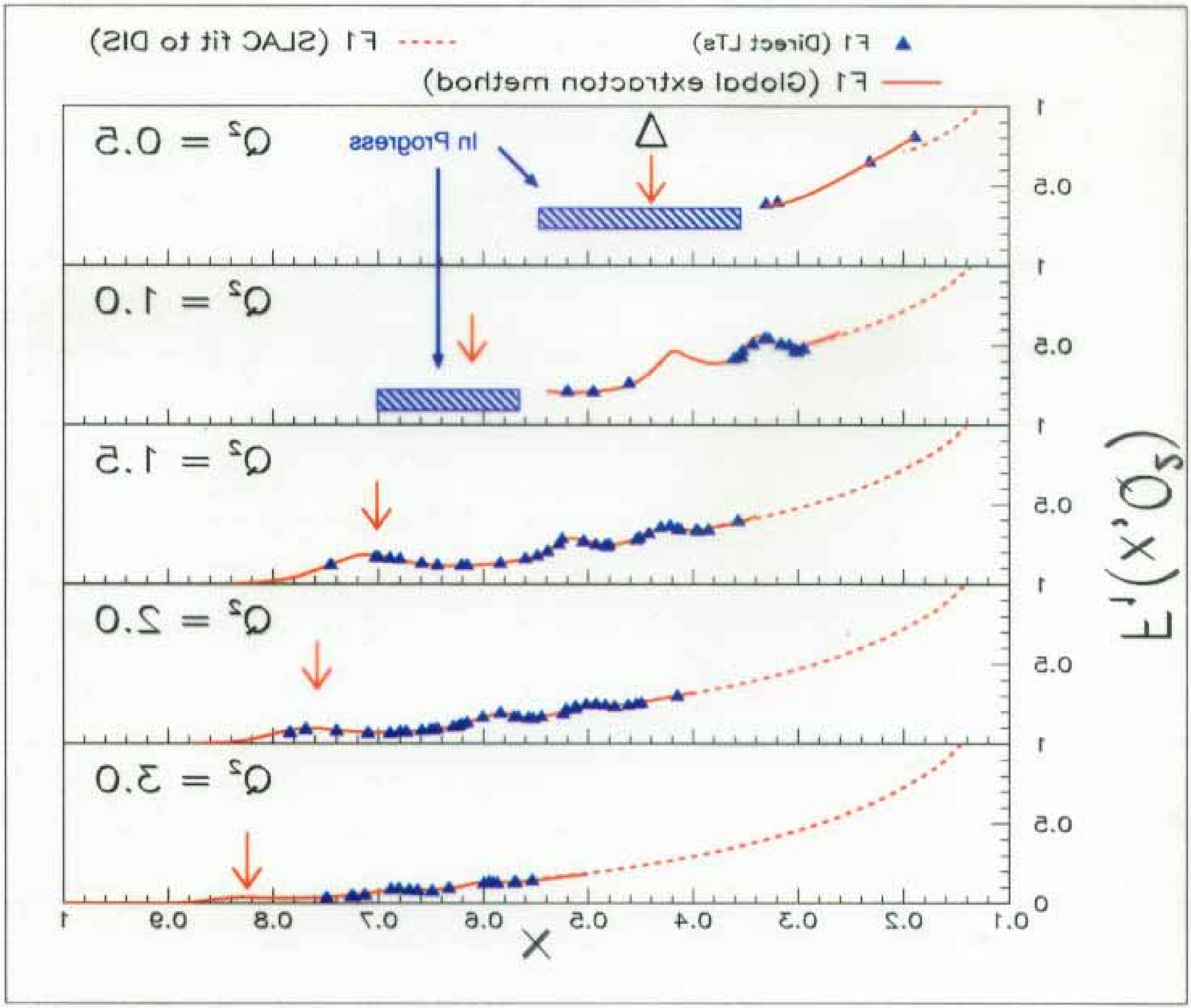
Results for F_L^p



- ➡ Both longitudinal and transverse structure functions exhibit resonant behaviour

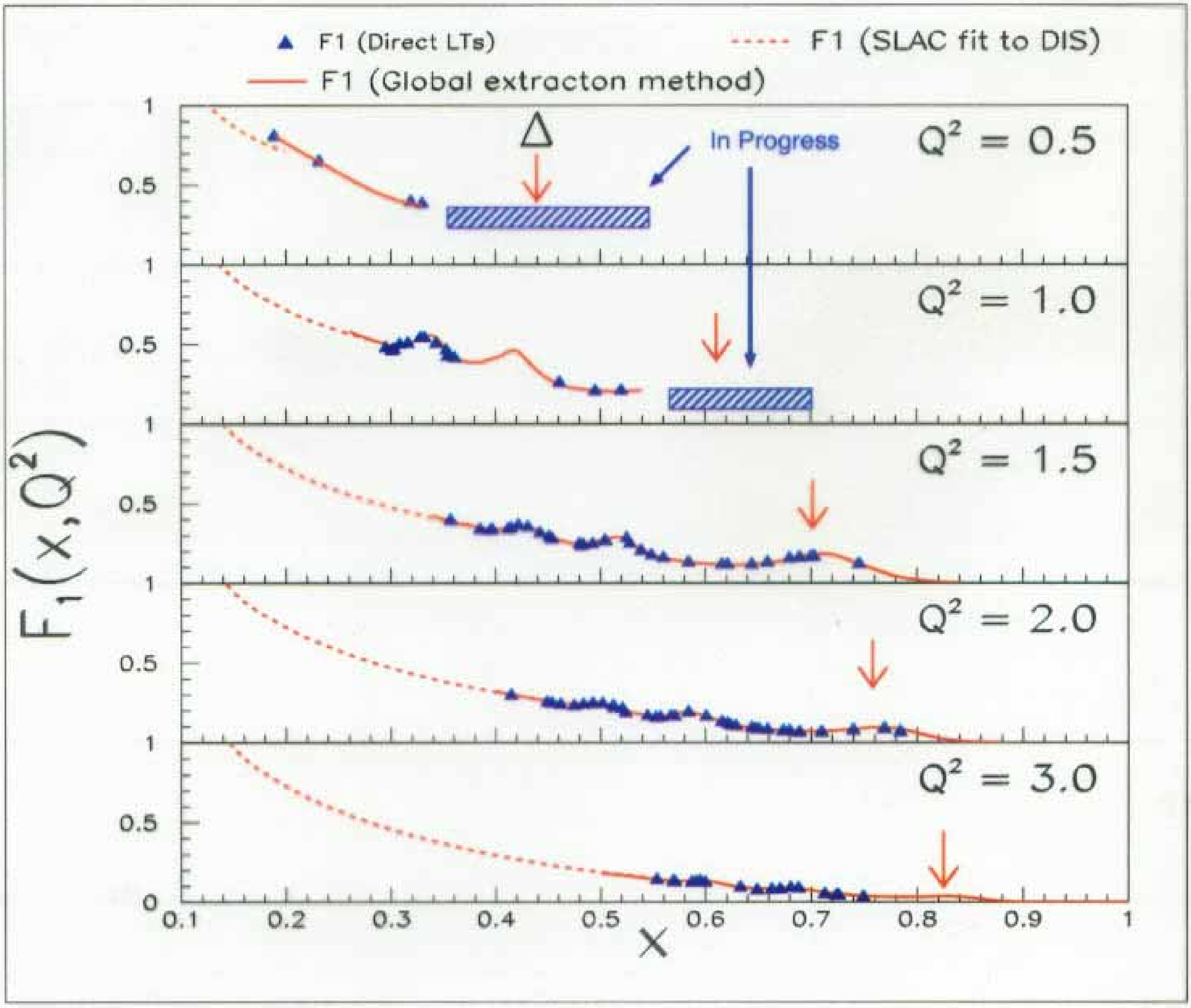
- ➡ Can easily extract moments, as all that is currently missing is resonance (large x) data.

Results for F_1^p



- Publication in progress
- Excellent agreement between global extraction and direct L-Ts

Results for F_1^p



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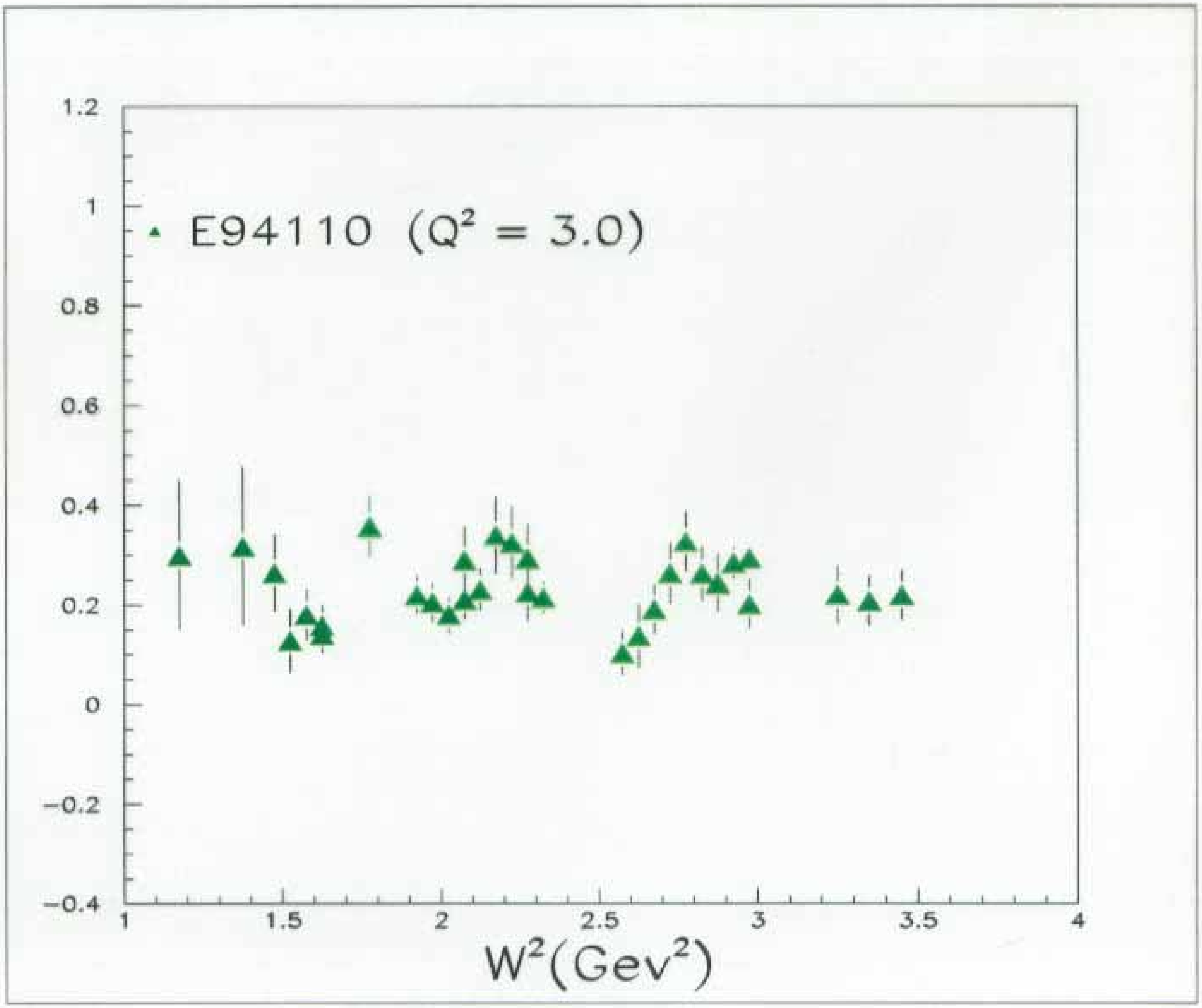
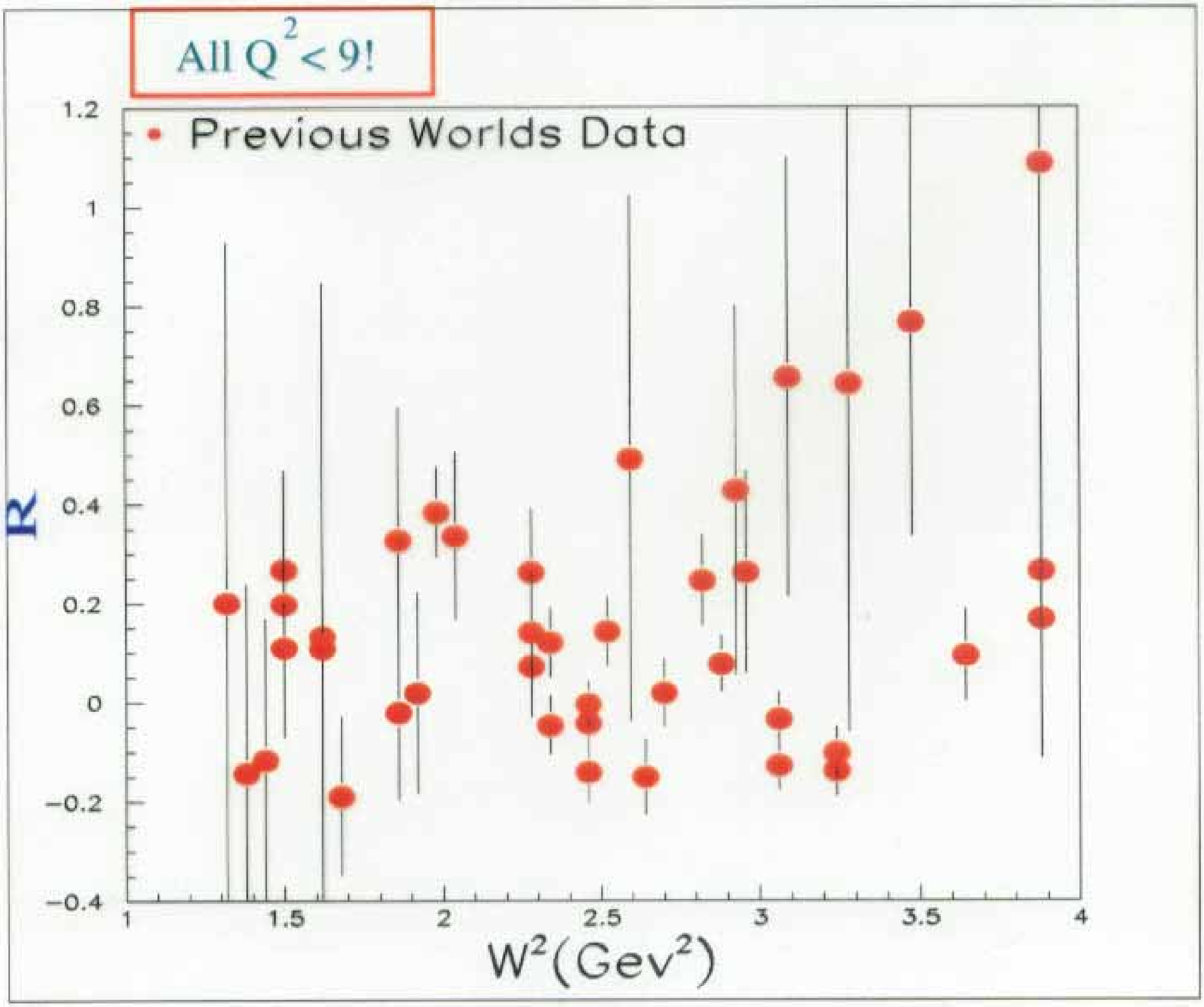


Comparable data will be obtained for the deuteron, where the L/T structure is even less well measured!

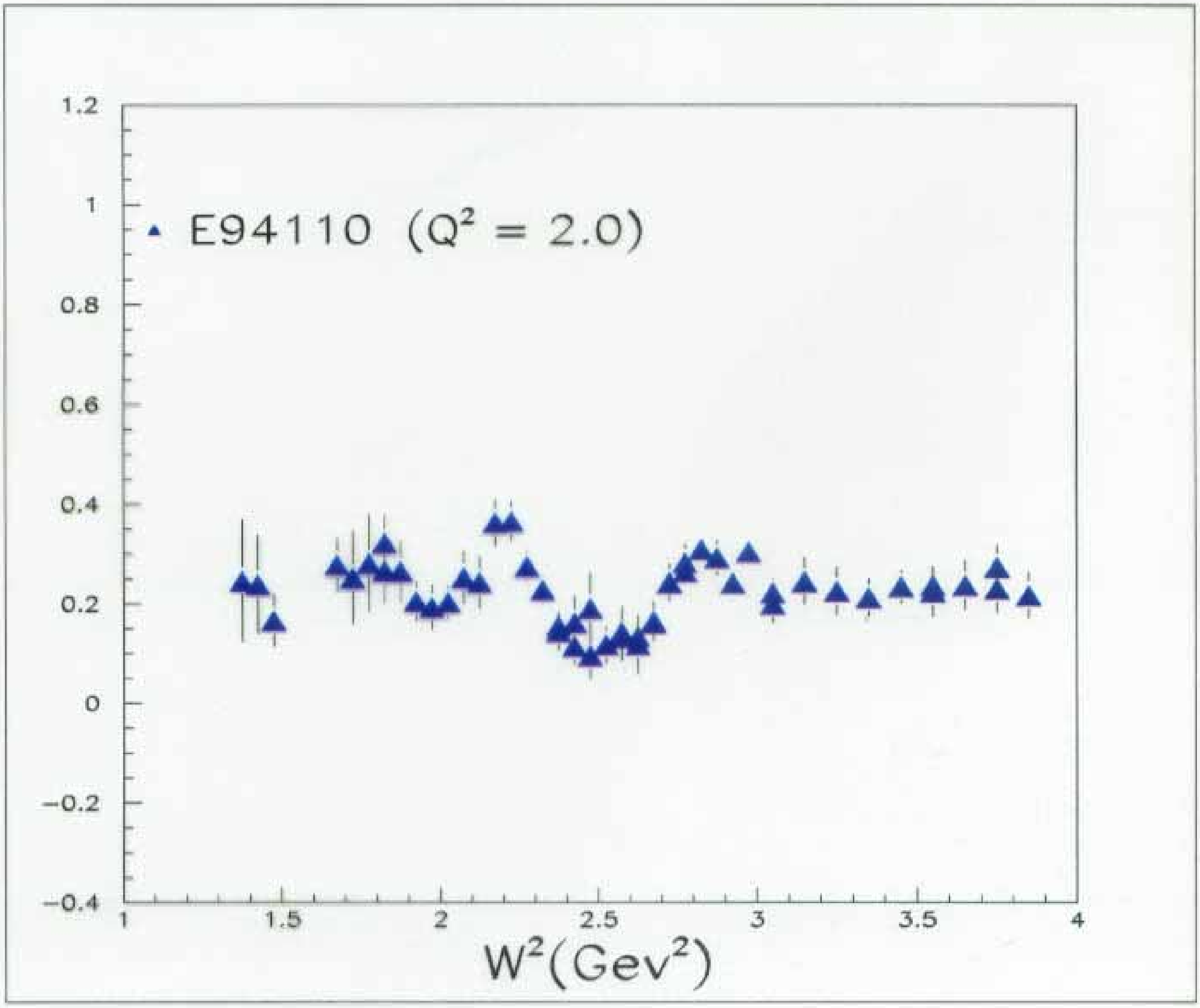
Both the W^2 structure and the Q^2 dependence can be studied!

World's Data on Proton R in the Resonance Region

Prior to E94-110:



Prior: Could not explore Resonant Structure!
(experiments optimized for DIS)



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Current Data on $R = \sigma_L / \sigma_T$ ($F_L = 2xF_1 R$)

Elastic	Resonance	DIS
$Q^2 < 8.83\ GeV^2/c^2$		$Q^2 < 50\ GeV^2/c^2$

In NPM

for parton with intrinsic transverse momenta p_T:

$$R = \frac{2M}{Q}\frac{G_E(Q^2)}{G_M(Q^2)} \qquad R = ? \qquad R = \frac{4(M^2x^2 + \langle p_T\rangle^2)}{Q^2 + \langle p_T\rangle^2}$$

Charge - Current Structure of the Nucleon

(Higher twist effects from both kinematic (TM) and dynamic origins can significantly modify R.)

(At low x, F_L is sensitive to the gluon distribution function.)

Lacking data on R (F_L) in Resonance Region

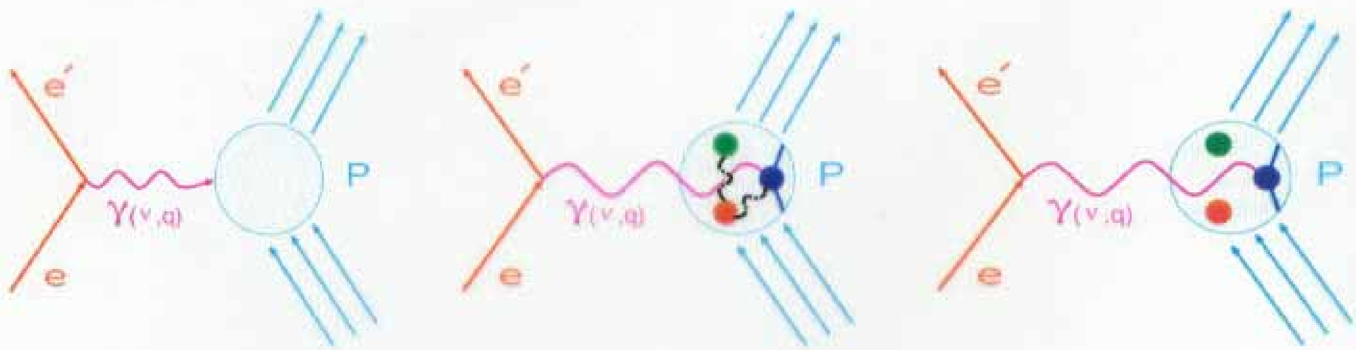
Precise measurement of *complete* unpolarized structure functions in RR is needed for:

- Gain futher information about fundamental nucleon structure
  - R might be small (duality)
  - R might be large (higher twist effects)
- Extraction of polarized structure functions from asymmetry measurements.

Unpolarized Electron - Nucleon Scattering

Single Photon Exchange

Elastic — **Resonance** — **DIS**



In terms of γ coupling:

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

Γ : virtual γ flux

ε : virtual γ longitudinal polarization

Alternatively:

$$\frac{d\sigma}{d\Omega\, dE'} = \Gamma \frac{4\pi^2\alpha}{x\,(W^2 - M_N^2)} \, [\, 2x F_1(x,Q^2) + \varepsilon F_L(x,Q^2)\,]$$

$$\left(F_L = F_2 \left(1 + \frac{4M_N^2 x^2}{Q^2}\right) - 2xF_1 \right)$$

Experimentally, F_2 Requires a separation of L/T strengths!