The Structure Function $R(x, Q^2) = \sigma_L/\sigma_T$: Experimental Status and Future Prospects

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What is R and why is it interesting?

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

$$= \Gamma \frac{4\pi^2\alpha}{2xM(Q^2+\nu^2)^{1/2}} \left[2xF_1(x,Q^2) + \epsilon F_L(x,Q^2)\right]$$

$$R(x,Q^2) \equiv \sigma_L(x,Q^2)/\sigma_T(x,Q^2) = \frac{F_L(x,Q^2)}{2xF_1(x,Q^2)}$$

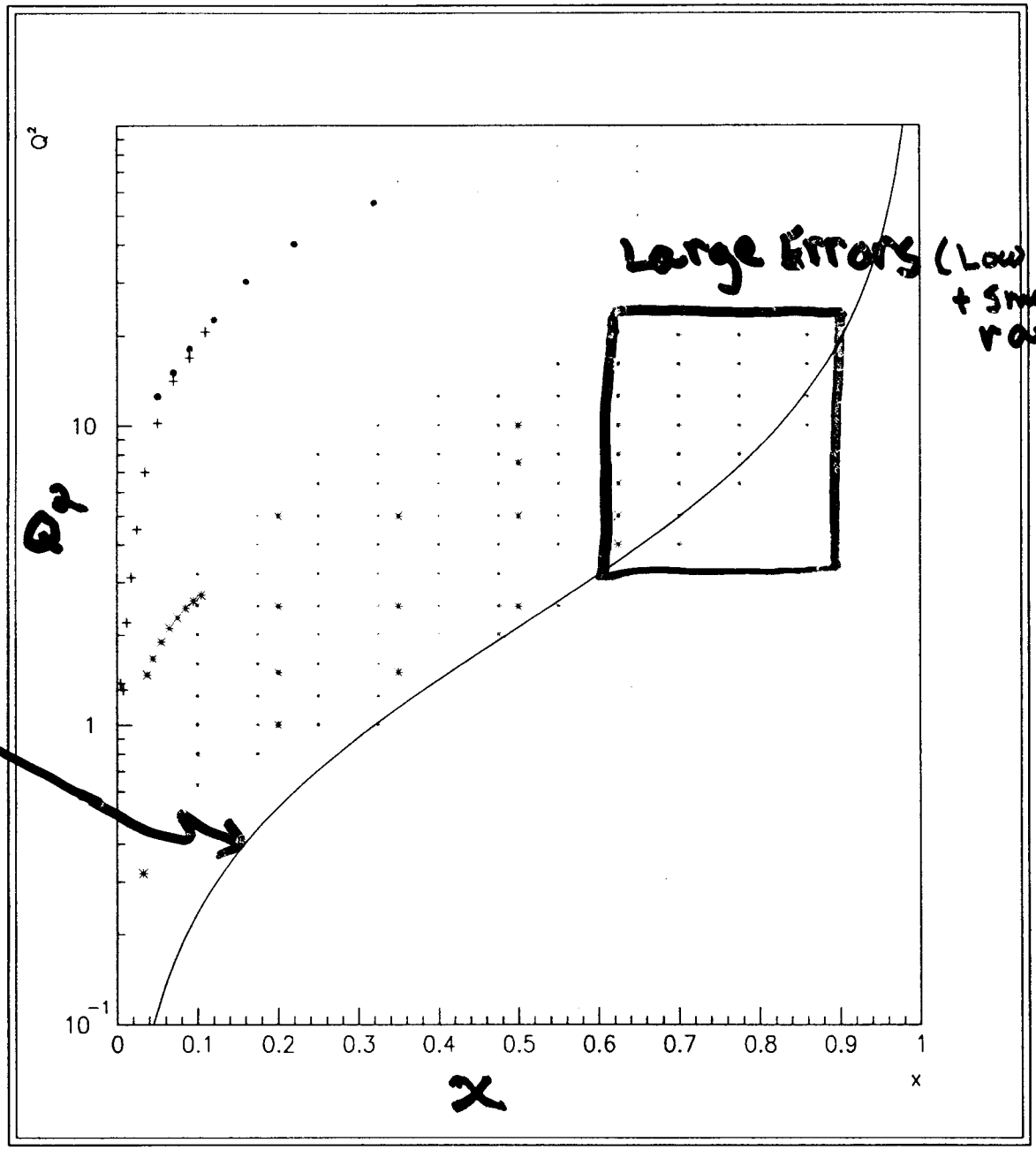
- $R \to 4\frac{(m^2+k_T^2)}{Q^2}$ for Large Q^2 in Naive Parton Model (for $Q^2 \to \infty$ value of R is predicted by PQCD)

- $\frac{d\sigma}{d\Omega dE'} \to F_2,\ g_1,\ g_2$ need R

- R might exhibit duality (Carlson-Mukhopadhyay)

[⇒ R_A/R_D @ small x, Q^2 ('Hermes' effect)
⇒ $\lim_{Q^2 \to 0}$ (fixed x) R_H = ?]

World F. Data

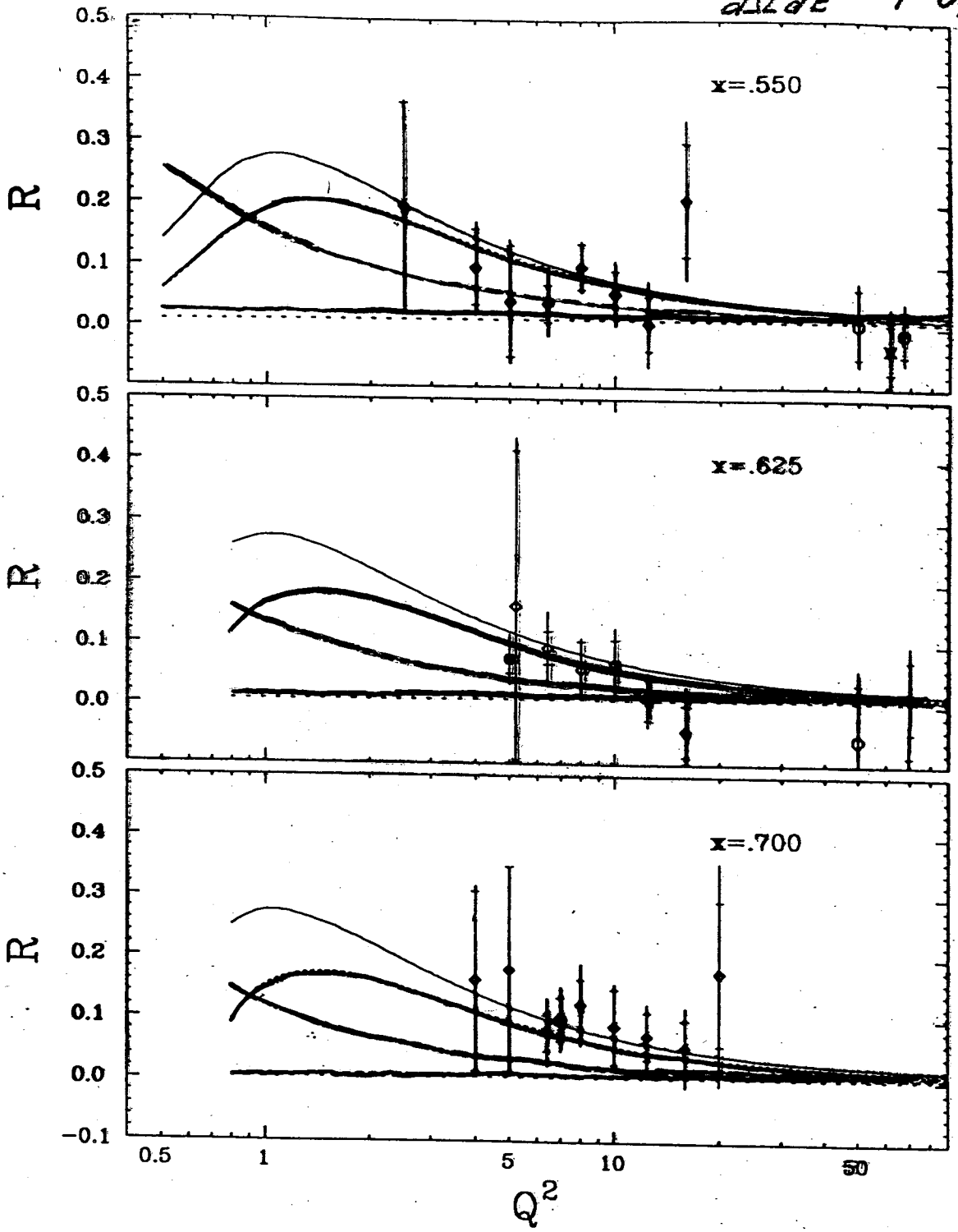


→ No Resonance Data

→ No Quality high-x Data

→ No very small x, Q^2 Data

$R = \sigma_L / \sigma_T$ $\quad \frac{d^2\sigma}{d\Omega\, dE'} = \Gamma \sigma_T (1 + \epsilon R)$



— GLOBAL FIT (Whitlow)

— R^{QCD} (NL+NNL) + TM + HT (W.L. van Neerven)

— R^{QCD} (NL+NNL) + TM

— R^{QCD} (NL + NNL)

L.H. Tao et al, E140X, Z. Phys. C70 (1996) 387

- No Data at very high x

* (Needed for measurable H-T effects)

- No Data at very low x, Q^2

* (lim R = ? $Q^2 \to 0$, fixed x?)

- No Data on R in Resonance Region

    1. Study Duality in L-T channels

    2. High precision extraction of other structure fns.

** (R even Less well measured for A > 1)

JLAB E94110 (ran summer 1999)

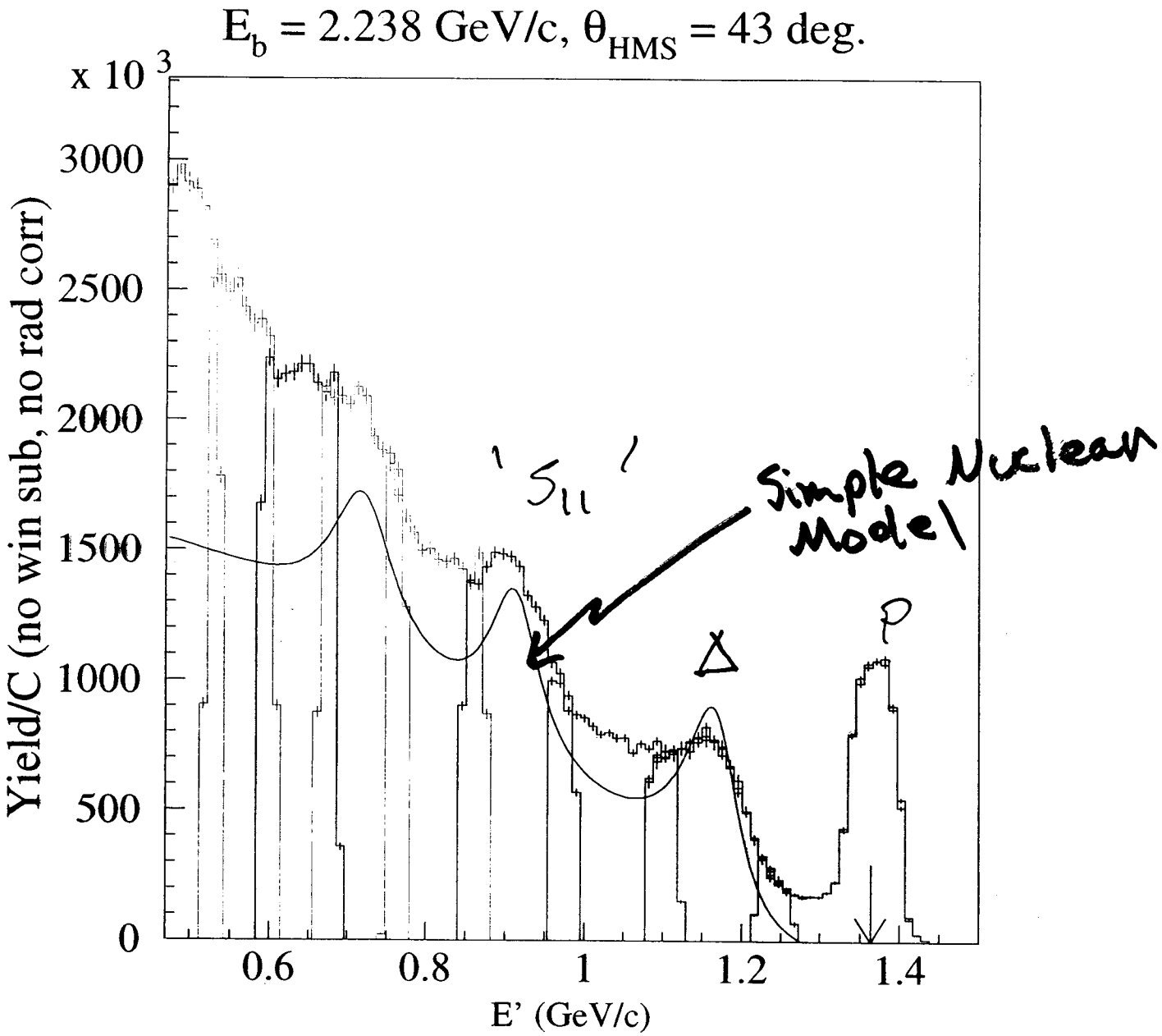
- $Q^2 < 4\ (GeV/s)^2$

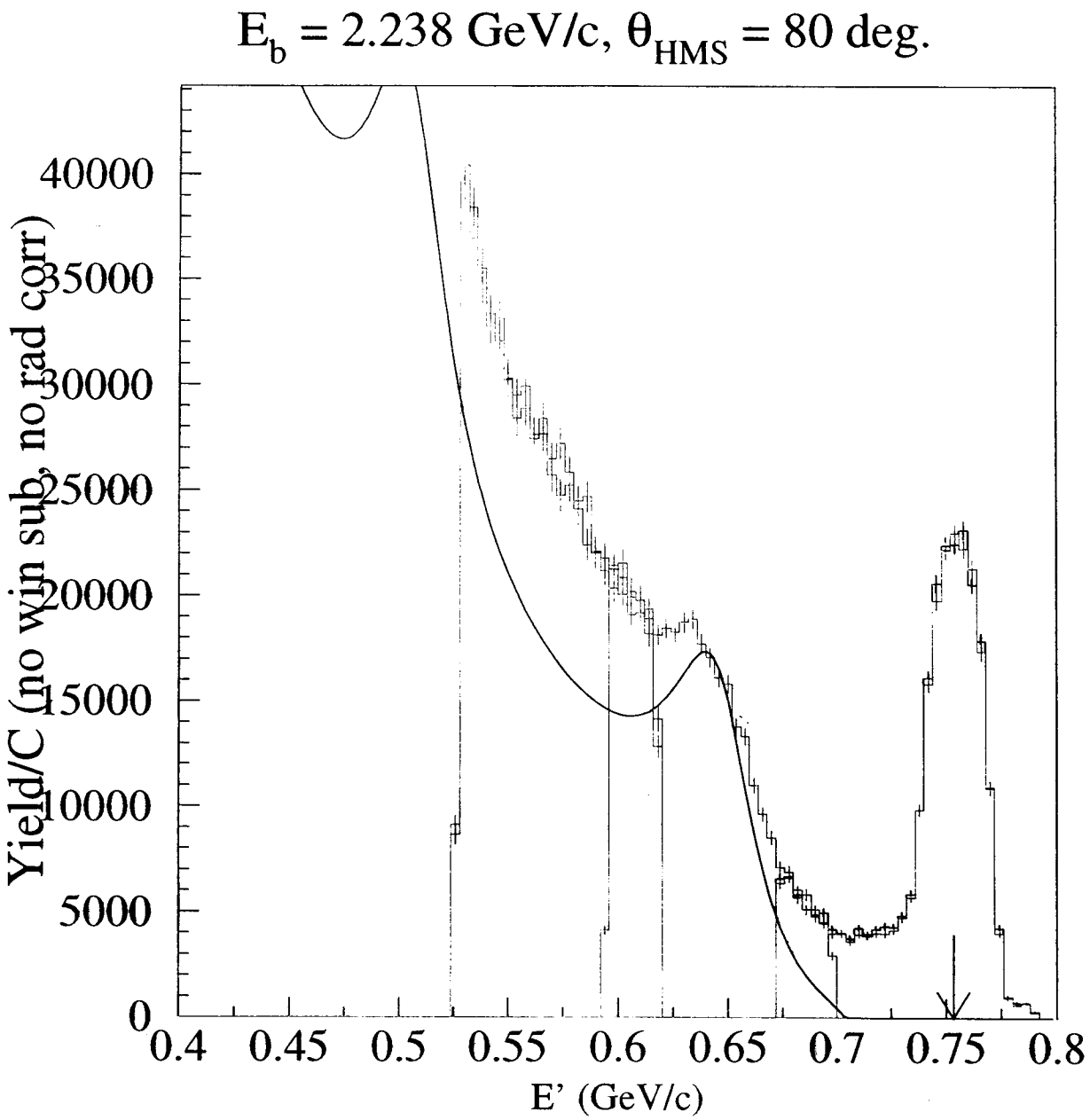
- Very high statistics, large # of kin.

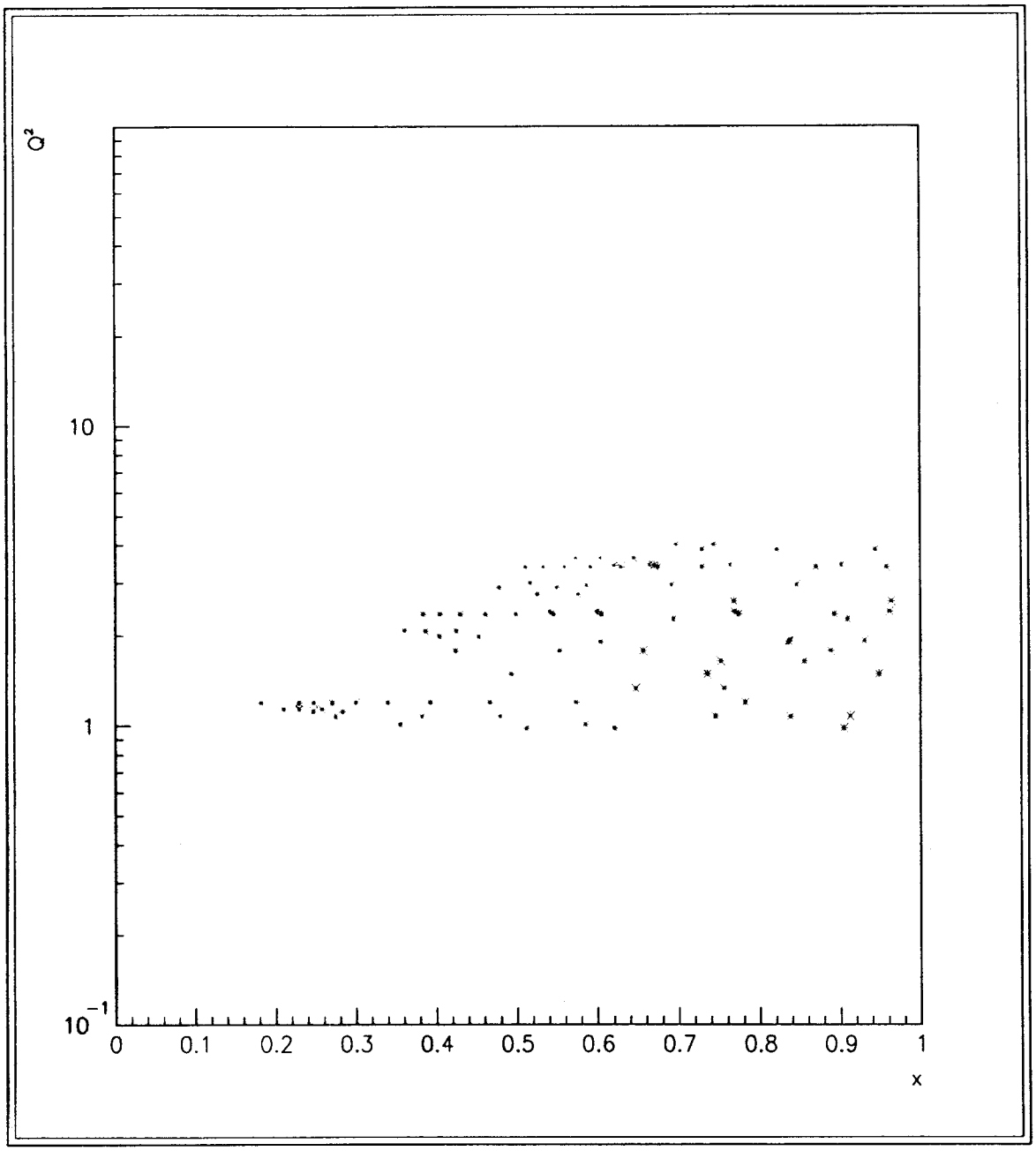
- Extract R to high precision in Resonance Region

- Systematics still being studied

** Work in progress **


E_b = 2.238 GeV/c, θ_{HMS} = 43 deg.
x 10 3
3000
2500
2000
1500
1000
500
0
Yield/C (no win sub, no rad corr)
0.6
0.8
1
1.2
1.4
E' (GeV/c)
'S11'
Simple Nuclear Model
Δ
P


E_b = 2.238 GeV/c, θ_{HMS} = 80 deg.
Yield/C (no win sub, no rad corr)
40000
35000
30000
25000
20000
15000
10000
5000
0
0.4
0.45
0.5
0.55
0.6
0.65
0.7
0.75
0.8
E' (GeV/c)



~ 10 Days running (High statistics per point)

Does R exhibit quark-hadron duality?

• Recent Jlab Study extracting G_E^P from DIS data by assuming duality suggests that it might. (R. Ent, T. Keppel, I. Niculescu)

Extract (IS Duality Works) (Georgi - Politzer)

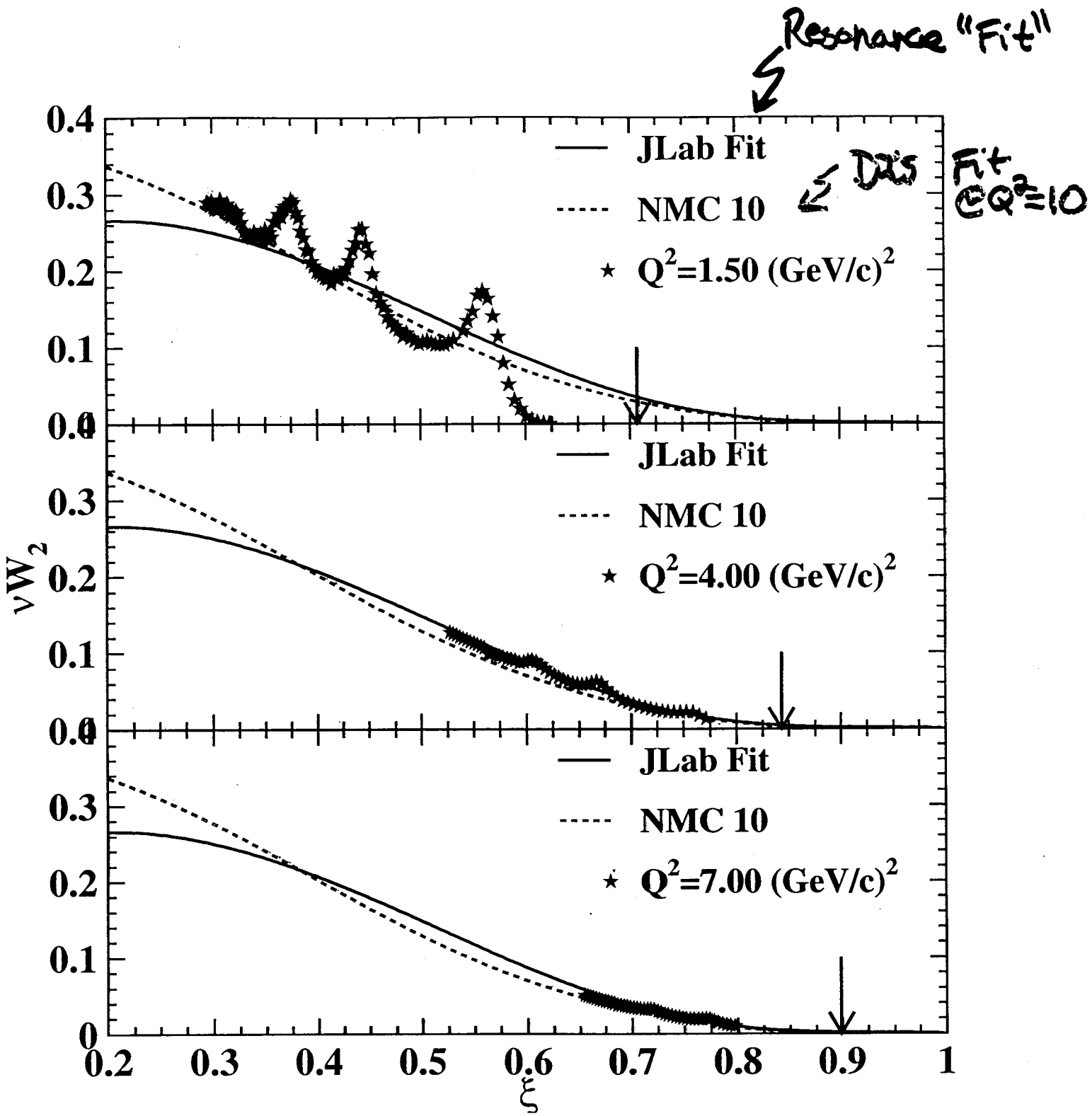
$$G_M^2 = \frac{1+4M^2/\mu^2Q^2}{1+4M^2/Q^2}\frac{2-\xi_p}{\xi_p^2}\int_{\xi_{thr}}^1 F_2 d\xi \quad \text{and} \leftarrow \text{DIS + Res.}$$

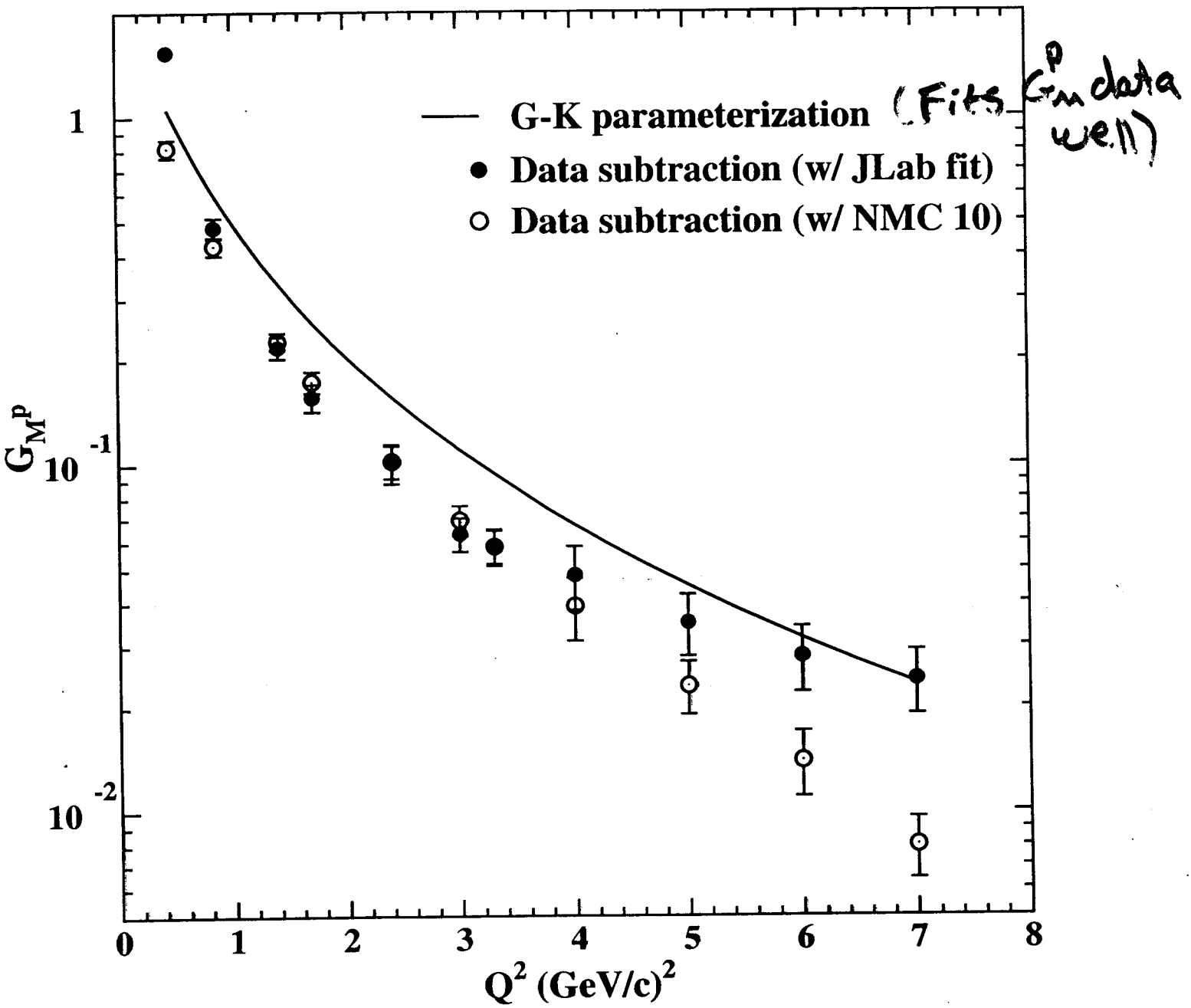
$$\frac{\mu G_E}{G_M} = \frac{\mu Q^2}{2M}\sqrt{\frac{\int d\xi \sigma_L}{\int d\xi \sigma_T}} \leftarrow \text{DIS only}$$ suggested by E-P no data.

with $\sigma_T = F_2\left[\frac{r\pi^2\alpha}{\nu}\frac{2M}{W^2-M^2}\frac{1+\nu^2/Q^2}{1+R}\right]$,

$\sigma_L = R\sigma_T$

$\xi = \frac{2x}{(1+\sqrt{1+4M^2x^2/Q^2})} \rightarrow x$ for small x Large Q^2


Resonance "Fit"
DIS Fit @ Q^2=10
JLab Fit
NMC 10
Q^2=1.50 (GeV/c)^2
Q^2=4.00 (GeV/c)^2
Q^2=7.00 (GeV/c)^2
νW_2
ξ
0.4
0.3
0.2
0.1
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1



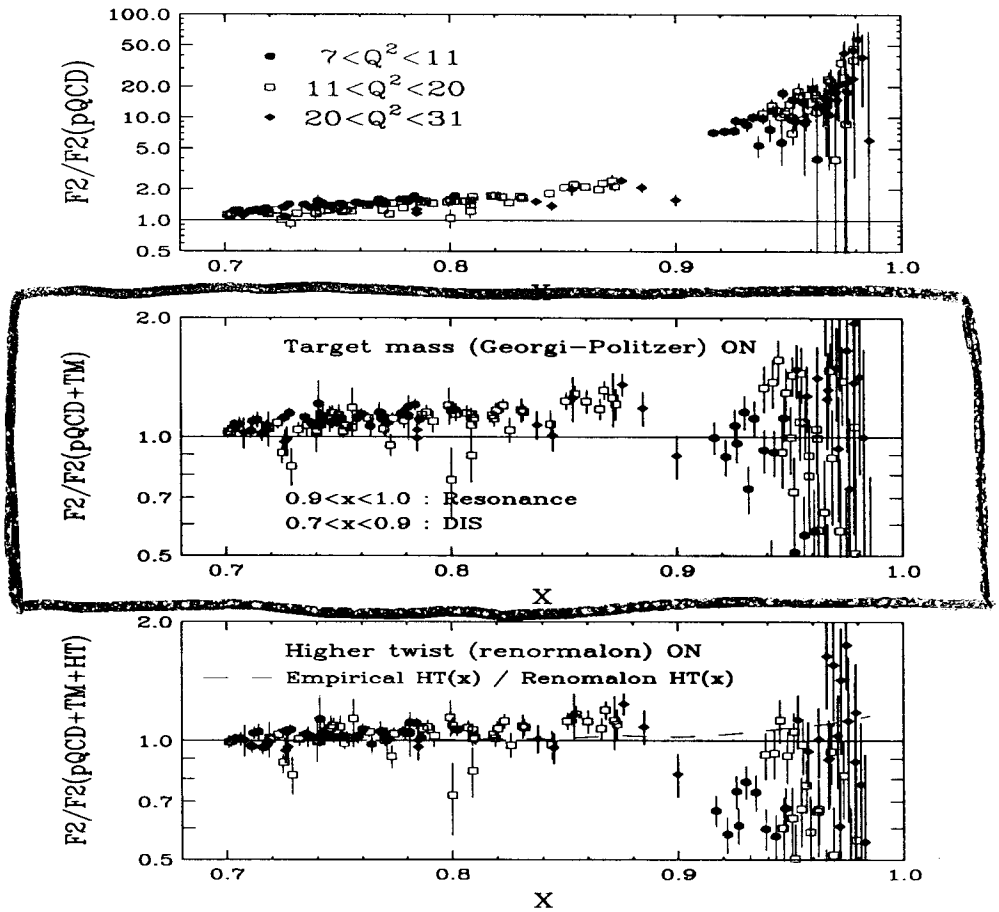
(Fits G_M^p data well)

Bodek

Very high x F_2^p SLAC data

DIS($0.7 < x < 0.9$) + Resonance($0.9 < x < 1$)

- Good agreement between data and theory only with additional non-perturbative effects.
  (Georgi Politzer target mass + Renormalon higher twist)
- The higher twist was estimated from fits to the $x < 0.75$ region.



$\Longleftarrow$ Note at $Q^2 = 7$ the elastic peak contribution needs to be accounted for

Based on the NLO MRS(R2) with the d/u correction

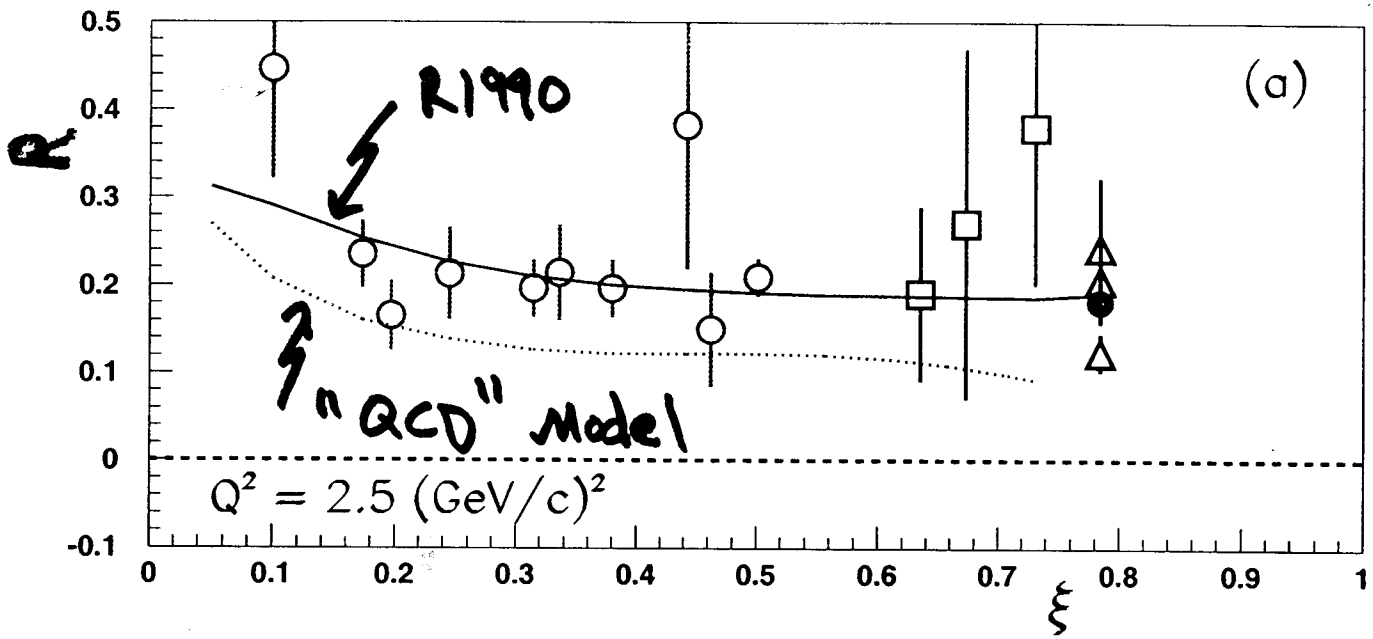
- Duality: The average behaviour of resonance and elastic peak follows the DIS scaling limit.

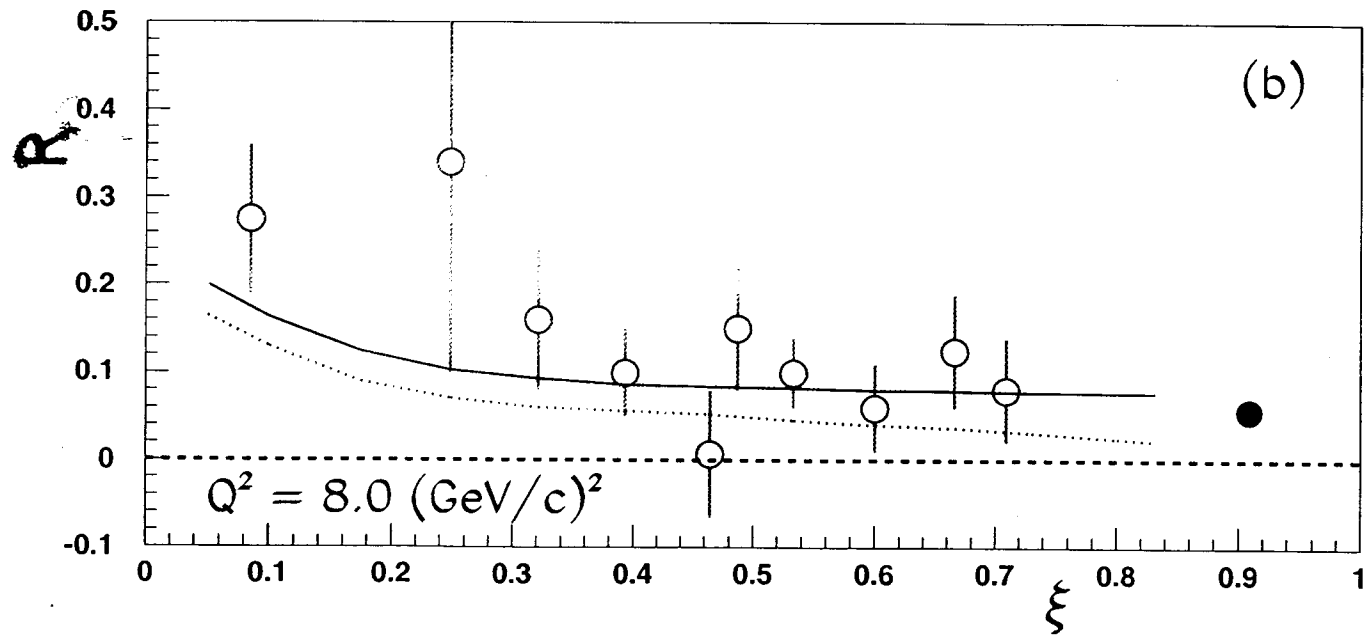
use R.

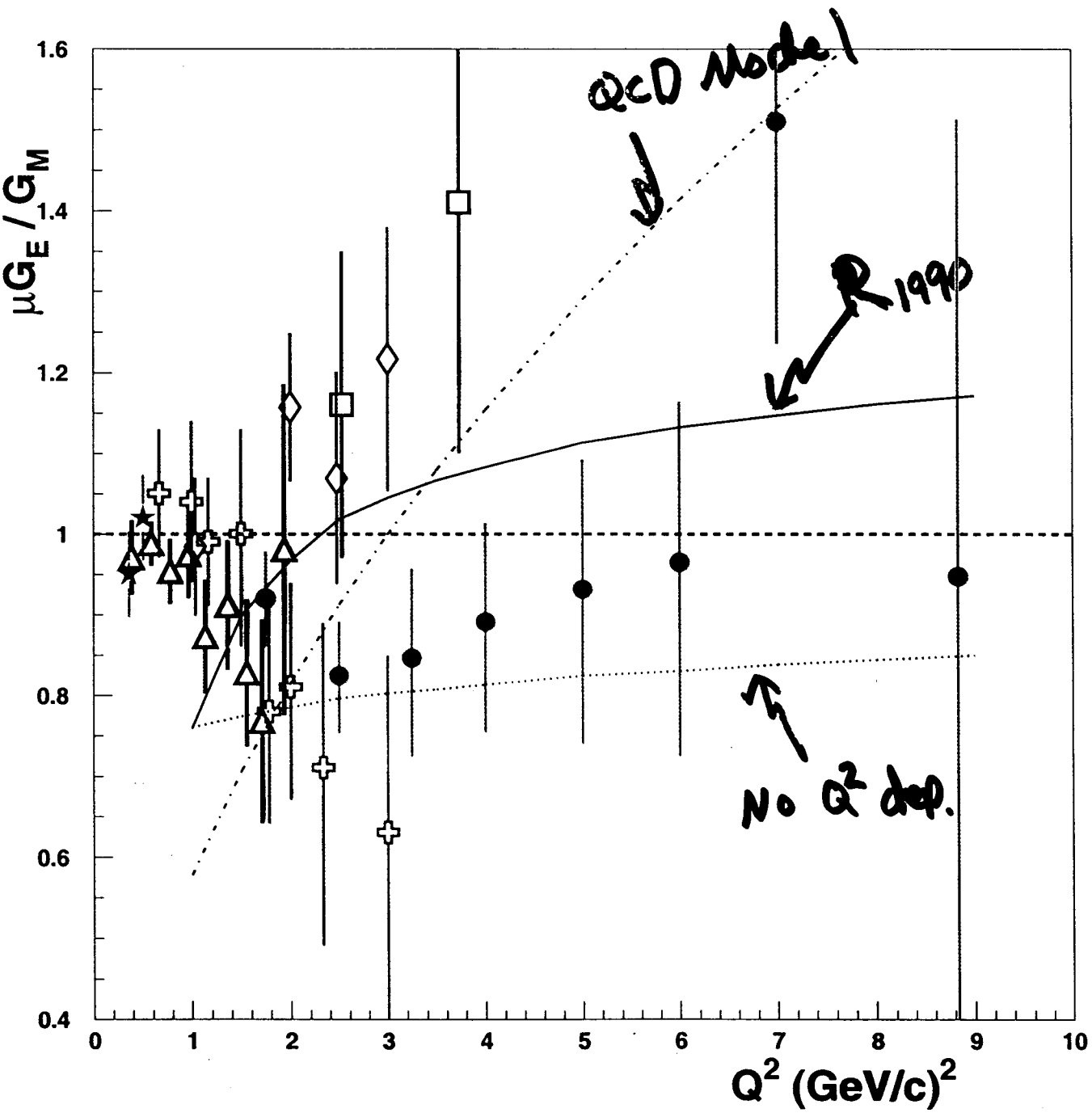
$$\frac{\mu G_E}{G_M} = \frac{\varepsilon Q^2}{2M} \sqrt{\frac{\int d\xi\, \sigma_L}{\int d\xi\, \sigma_T}}$$

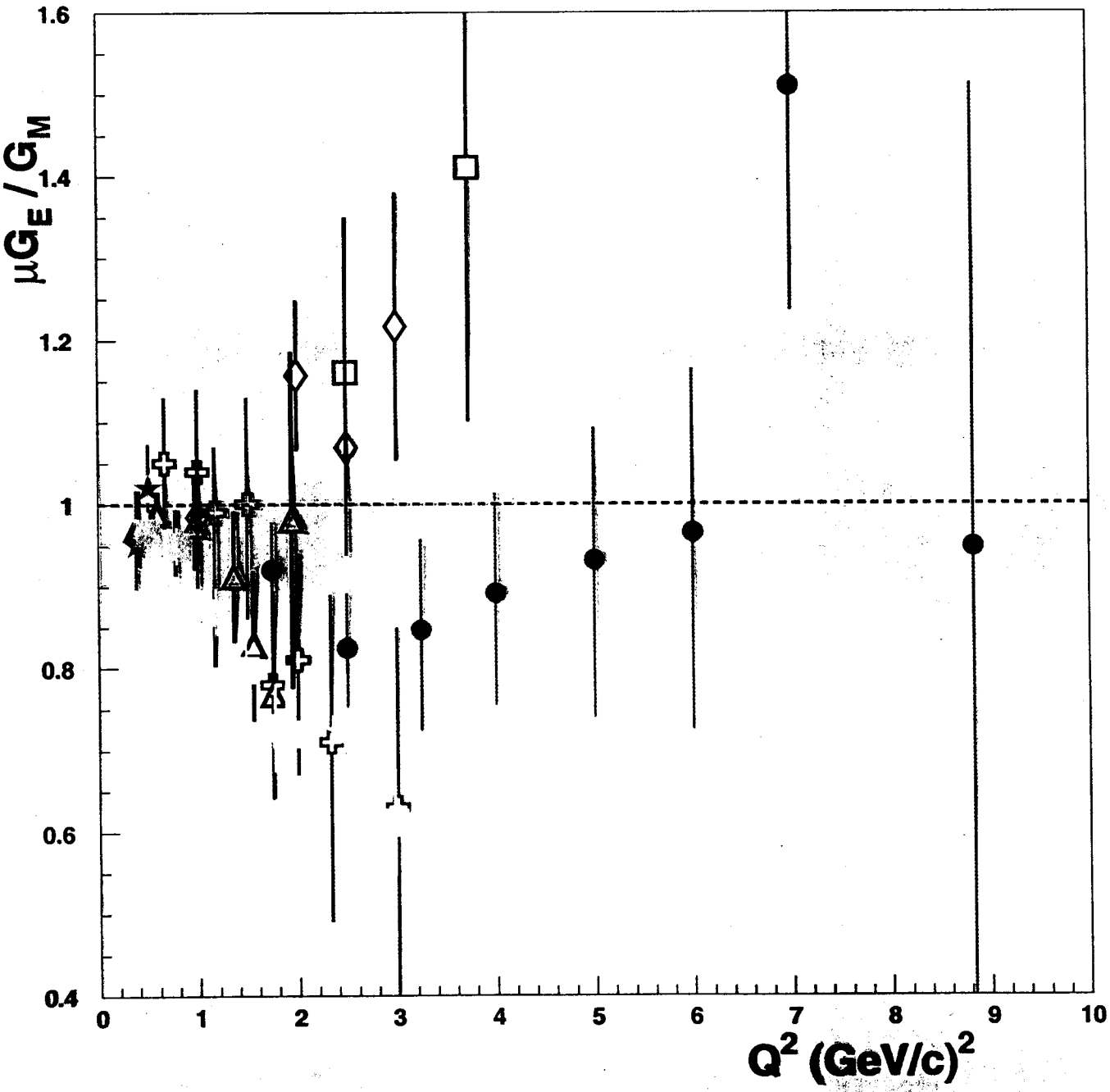
↓ – DIS ↓ – Resonance ↓ Elastic

↓ $G_M = \mu G_E$



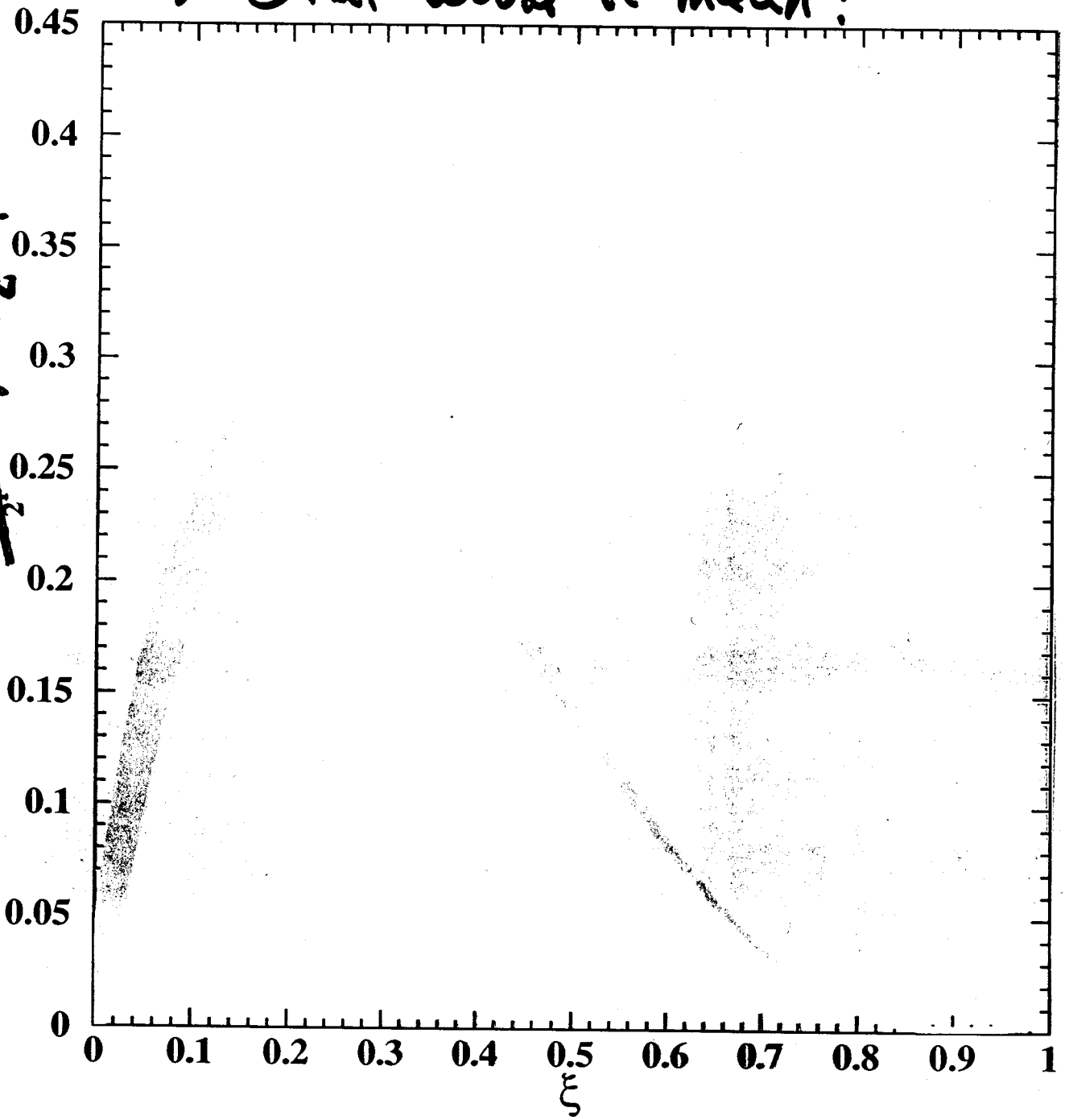



QCD Model
R1990
No Q² dep.
μG_E / G_M
Q² (GeV/c)²
1.6
1.4
1.2
1
0.8
0.6
0.4
0
1
2
3
4
5
6
7
8
9
10

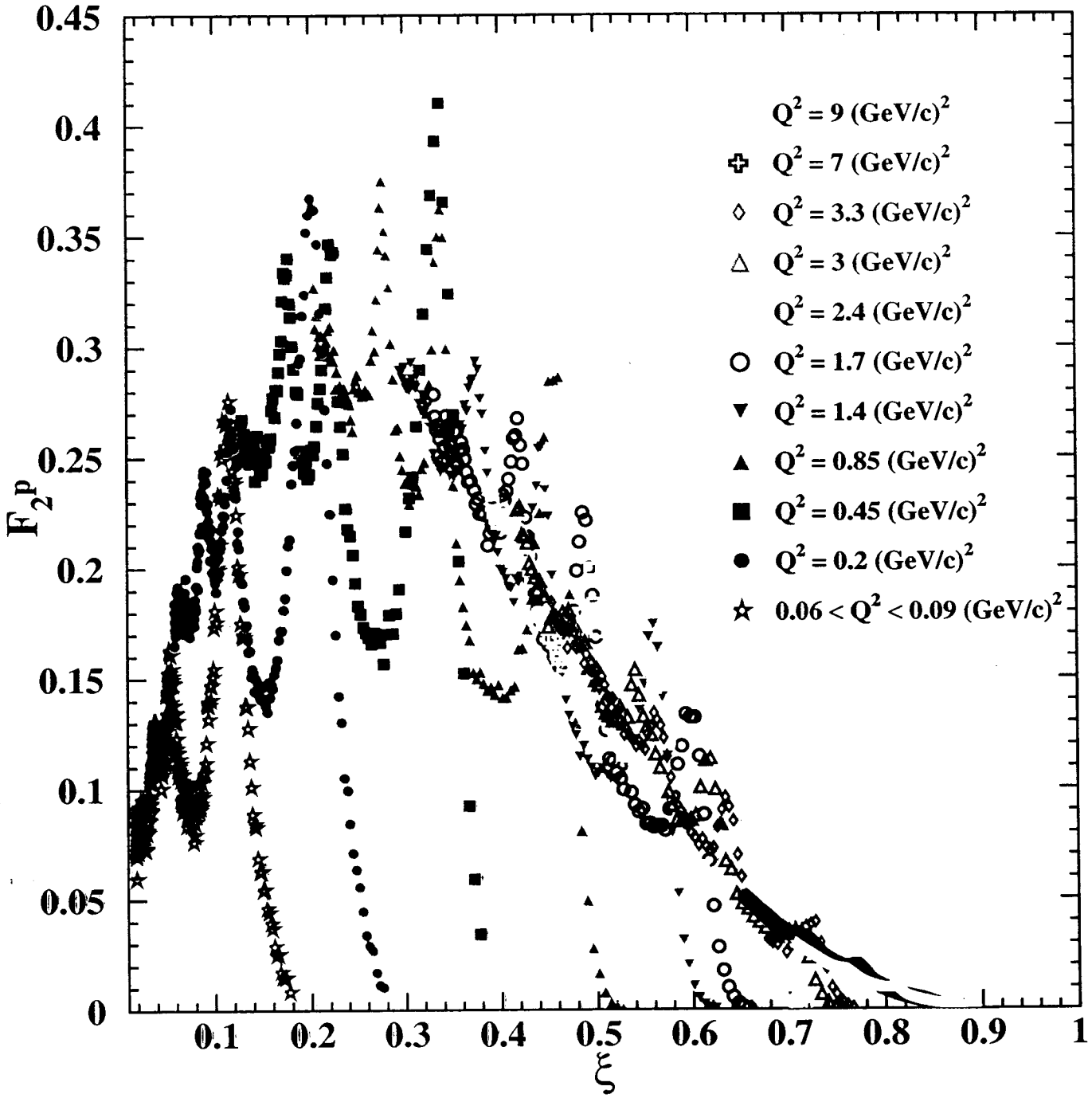

1.6
1.4
1.2
1
0.8
0.6
0.4
$\mu G_E / G_M$
0
1
2
3
4
5
6
7
8
9
10
Q^2 (GeV/c)^2

→ Scaling curve for $F_2(R)$?

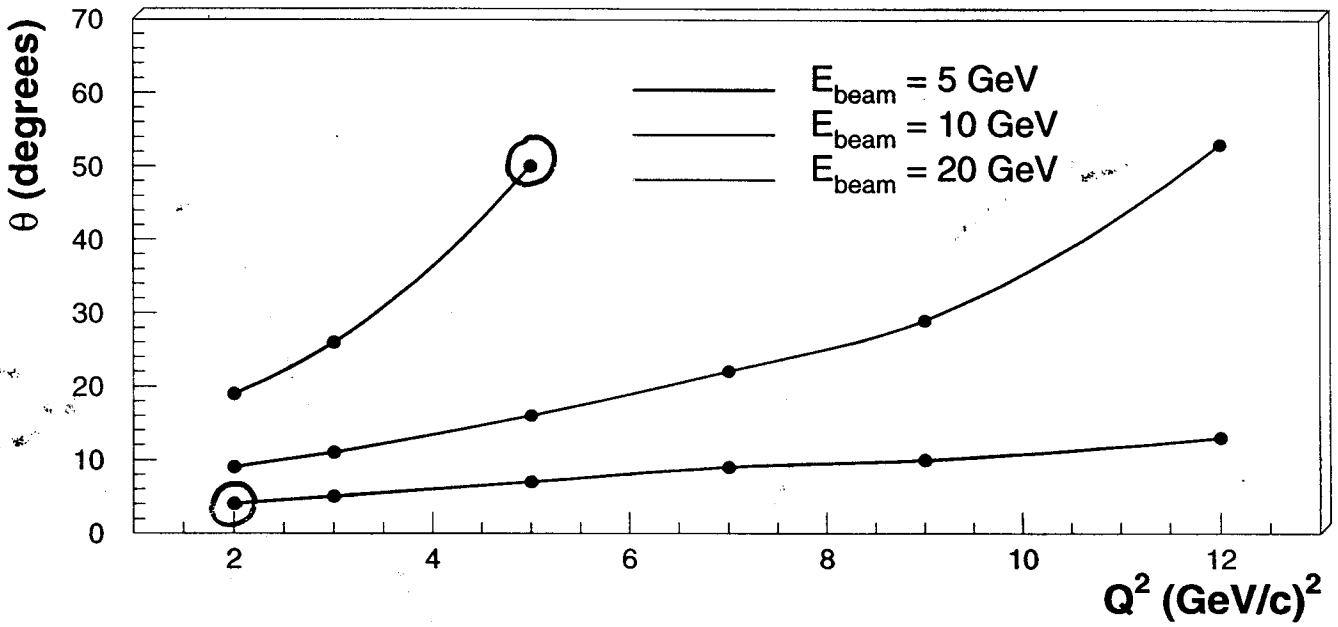
→ What would it mean?

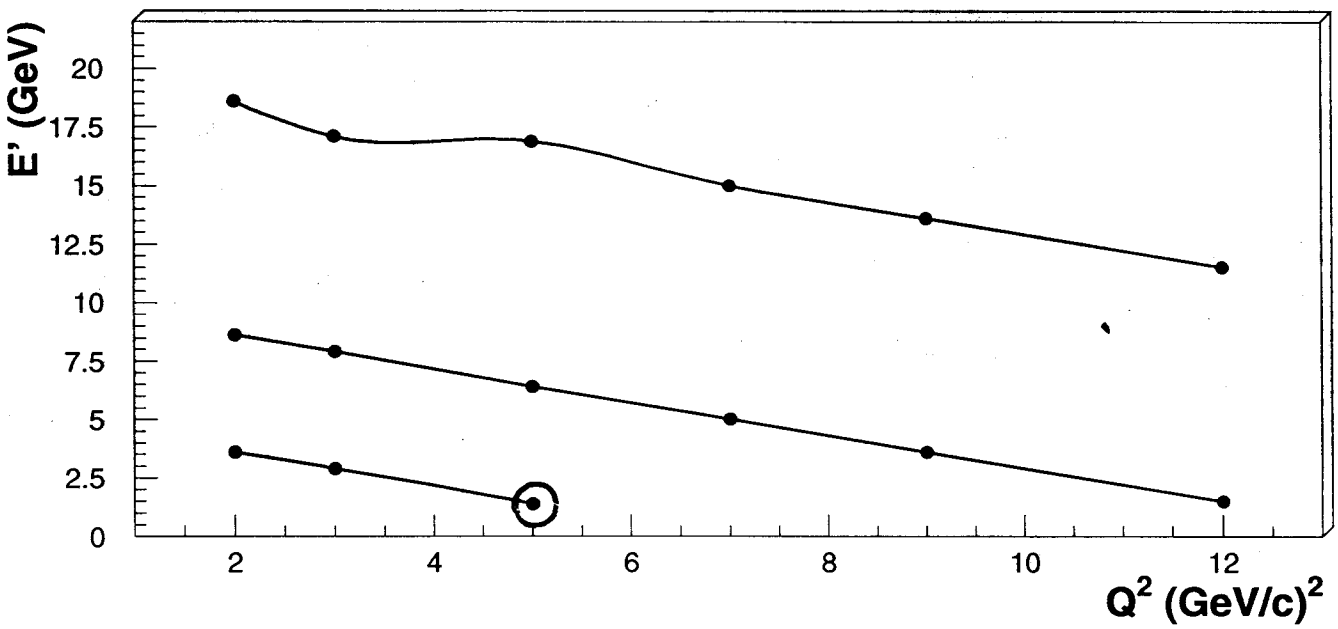


$F_2 = \xi^{0.870}(1-\xi)^{0.006}\left[0.005 - 0.058(1-\xi) - 0.017(1-\xi)^2 + 2.469(1-\xi)^3 - 0.240(1-\xi)^4\right]$

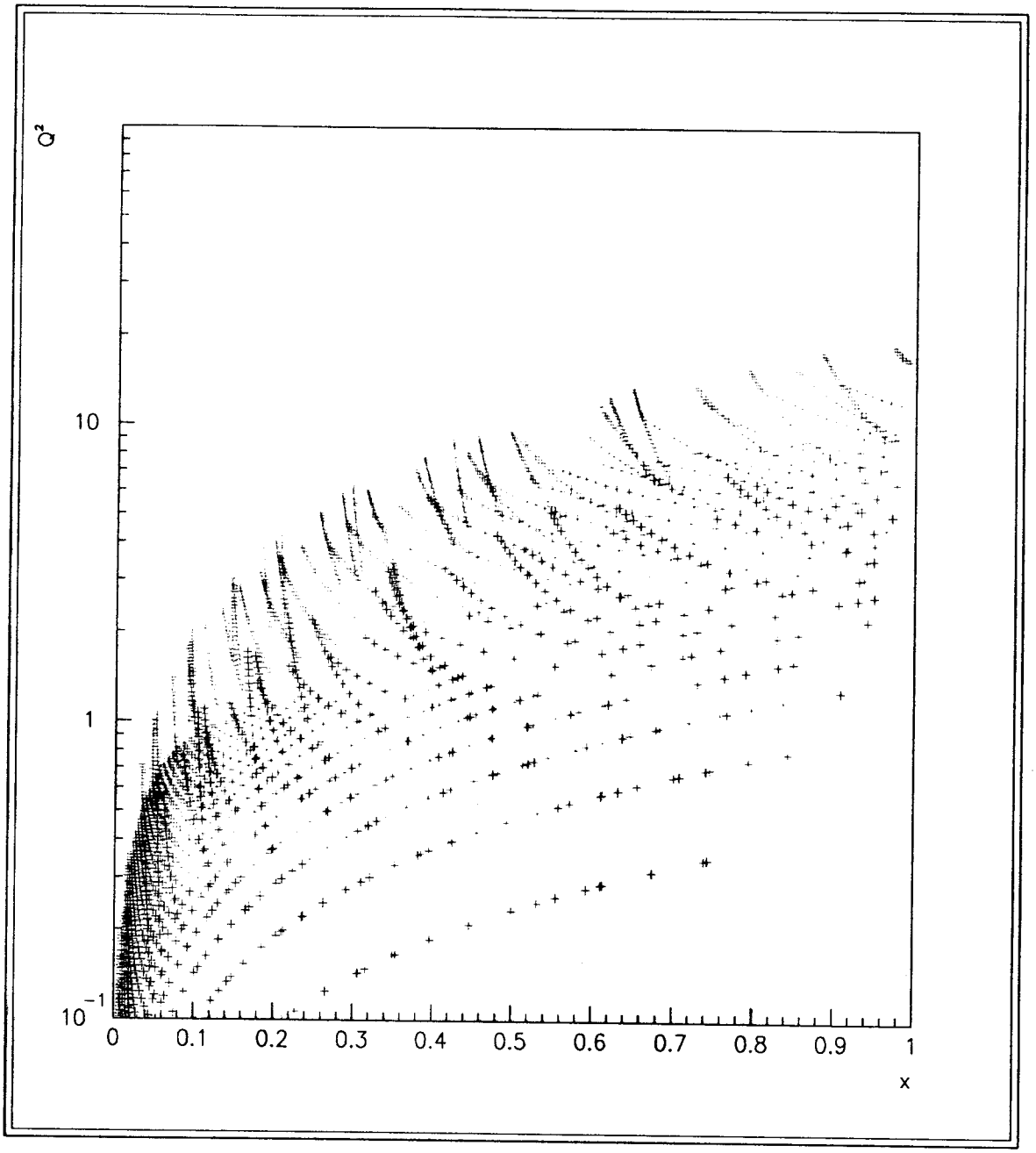

0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
F_2^p
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ξ
Q^2 = 9 (GeV/c)^2
Q^2 = 7 (GeV/c)^2
Q^2 = 3.3 (GeV/c)^2
Q^2 = 3 (GeV/c)^2
Q^2 = 2.4 (GeV/c)^2
Q^2 = 1.7 (GeV/c)^2
Q^2 = 1.4 (GeV/c)^2
Q^2 = 0.85 (GeV/c)^2
Q^2 = 0.45 (GeV/c)^2
Q^2 = 0.2 (GeV/c)^2
0.06 < Q^2 < 0.09 (GeV/c)^2

Deep Inelastic Kinematics at x = 0.75





The high x and intermediate Q^2 region is optimally accessed by a ~10 GeV JLab.

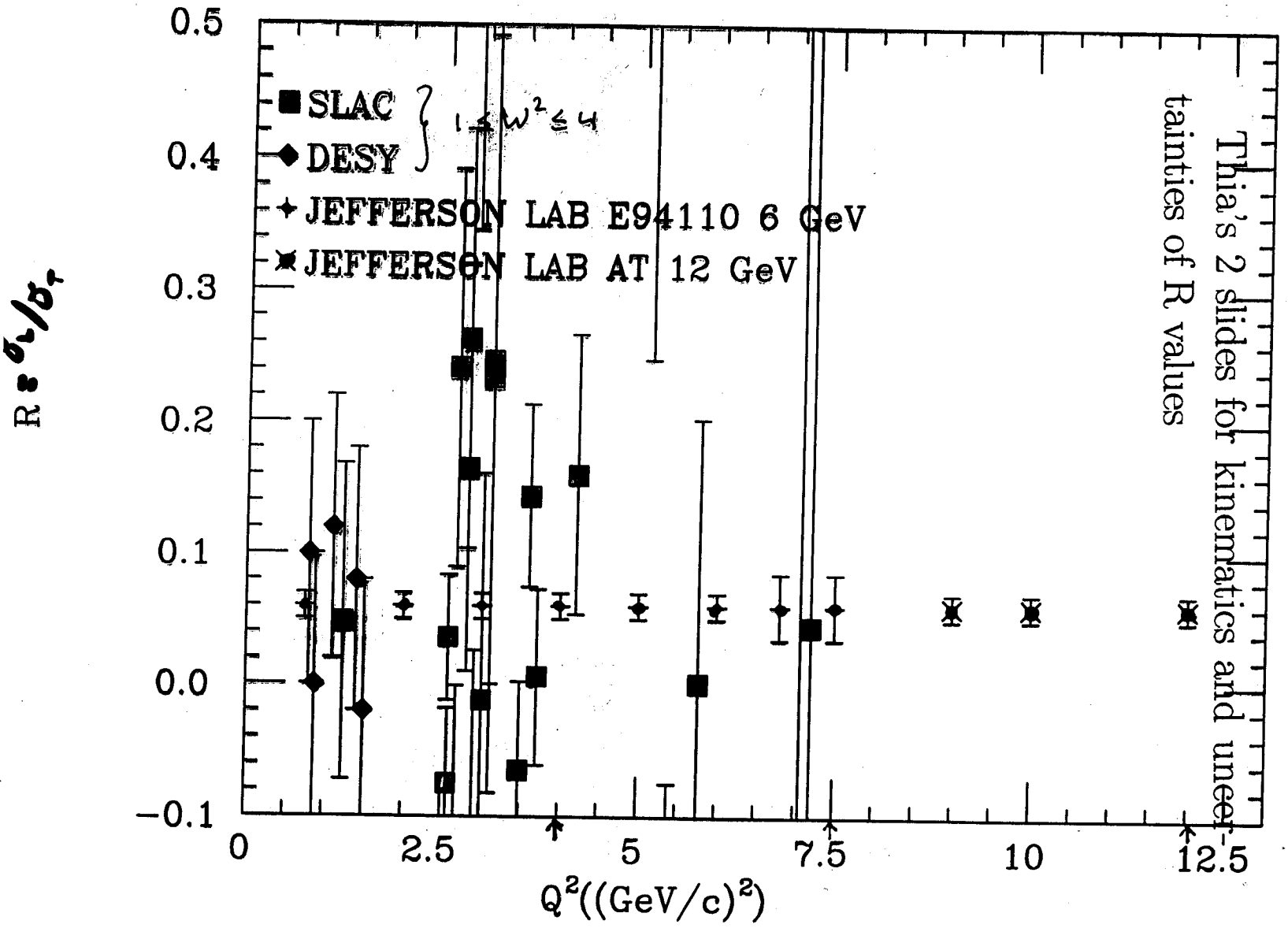


→ High statistics Data in Resonance but also DIS Large x

↓↓↓

→ More forward Angles ⇒ higher rates
→ Larger Range in ϵ.

$R_\Delta = \sigma_L/\sigma_T$



~ SAME FOR OTHER RESONANCES, DIS

Conclusions

1. Very little existing data at large x and moderate-high Q^2, and at low x, low Q^2

- Need broad kinematic coverage in x, Q^2 to investigate Duality

- This range is measurable with 12 GeV JLAB

2. 12 GeV JLab is optimal for studying R

- Duality tests (Resonance vs. DIS)

- Potential HT extractions used to extract other Structure Functions

3. Study the onset of duality in R(F_L)

(What would R scaling curve mean?)