KEPPEL

Workshop on Physics Opportunities with 12-GeV Electrons

Jefferson Lab, Newport News, Virginia
January 13-15, 2000

[Second Circular | Agenda | About the Workshop | Time Line | Transportations/Accomodations | Charge To the Plenary Speakers | Charge To the Parallel Session Chairs | Parallel Session Program | Talks]

CHARGE TO THE PARALLEL SESSION CHAIRS

Parallel Session Chairs are requested to organize and chair their sessions, lead the discussion, and initiate the process of drafting a report that identifies potential experiments that could lead to physics pre-proposals which drive the 12 GeV energy upgrade. A Board of Directors? Representative is assigned to each Parallel Session to assist in this procedure.

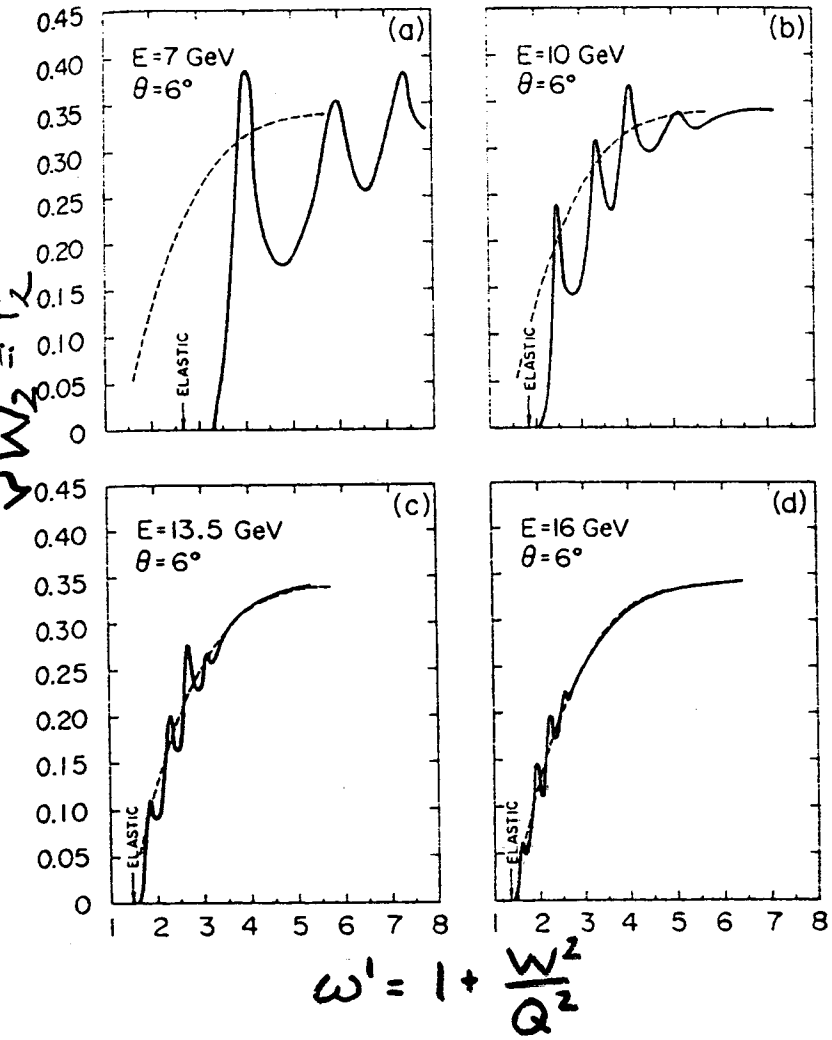
The emphasis of the parallel sessions should be on discussions and development of physics cases for the 12 GeV upgrade. The emphasis should be less on formal presentations. A model for the parallel sessions could be two or three presentations of 30 minutes to initiate the discussions, and additional short presentations at the discretion of the Chairs. The Chairs are urged to request the assistance of Users in the preparation of an initial draft of a report (computers will be made available).

The Chairs are requested to lead a discussion on the compatibility of the present plans for beam, target, and detectors, and their physics subject. Do the present plans limit a full investigation of the best physics subjects to be studied at this energy? Are there viable alternatives?

The Chairs are asked to choose a representative user (this could be one of the Chairs) to present a Summary talk at the last afternoon Workshop. A strong endorsement of the JLab User Community for the Physics cases supporting the 12 GeV upgrade, developed in the Chairs? parallel session, will result in request to the Chairs to initiate mini-workshops on these subjects, with the intent of developing these cases into more complete proposals. The final proposals are expected to be concrete, with projected uncertainties based upon design characteristics of planned accelerator and equipment. Such proposals will be presented at the June 2000 JLab Users Meeting, and are intended to be part of the Conceptual Design Report for JLab?s 12 GeV Energy Upgrade program.

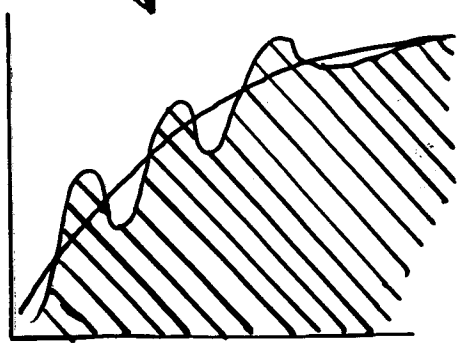
SCALING, DUALITY, AND THE BEHAVIOR OF RESONANCES IN INELASTIC ELECTRON-PROTON SCATTERING*

E. D. Bloom and F. J. Gilman
Stanford Linear Accelerator Center, Stanford University, Stanford, California 94305
(Received 25 June 1970)



$$\frac{2M}{q^2}\int_0^{\nu_m} d\nu\, \nu W_2(\nu, q^2)$$

$$= \int_1^{(2M\nu_m + m^2)/q^2} d\omega'\, \nu W_2(\omega')$$



We therefore propose that the resonances are not a separate entity but are an intrinsic part of the scaling behavior of νW_2, and that a substantial part of the observed scaling behavior of inelastic electron-proton scattering is nondiffractive in nature.

WHY IS DUALITY INTERESTING?

- DUALITY PROBES THE RELATIONSHIP BETWEEN CONFINEMENT AND ASYMPTOTIC FREEDOM

  RESONANCES $\Leftrightarrow$ SCALING STRUCTURE FUNCTIONS

  HADRONIC $\Leftrightarrow$ PARTONIC DEGREES OF FREEDOM

- INTIMATELY RELATED TO THE NATURE OF THE TRANSITION BETWEEN NON-PERTURBATIVE + PERTURBATIVE QCD

- QUARK-HADRON DUALITY IS QUITE GENERAL, AND MANIFESTS ITSELF IN MANY PROCESSES

  - $e^+, e^- \to X$, heavy quark decays, ...
  - arises in simplest of models / theories which display confinement

- INDICATES IMPORTANCE OF POWER CORRECTIONS TO PERTURBATIVE EXPANSIONS

  e.g. n-th moment of structure function:

$$M_n(Q^2) = A_n^{(0)} + \frac{A_n^{(2)}}{Q^2} + \frac{A_n^{(4)}}{Q^4} + \cdots\cdots$$

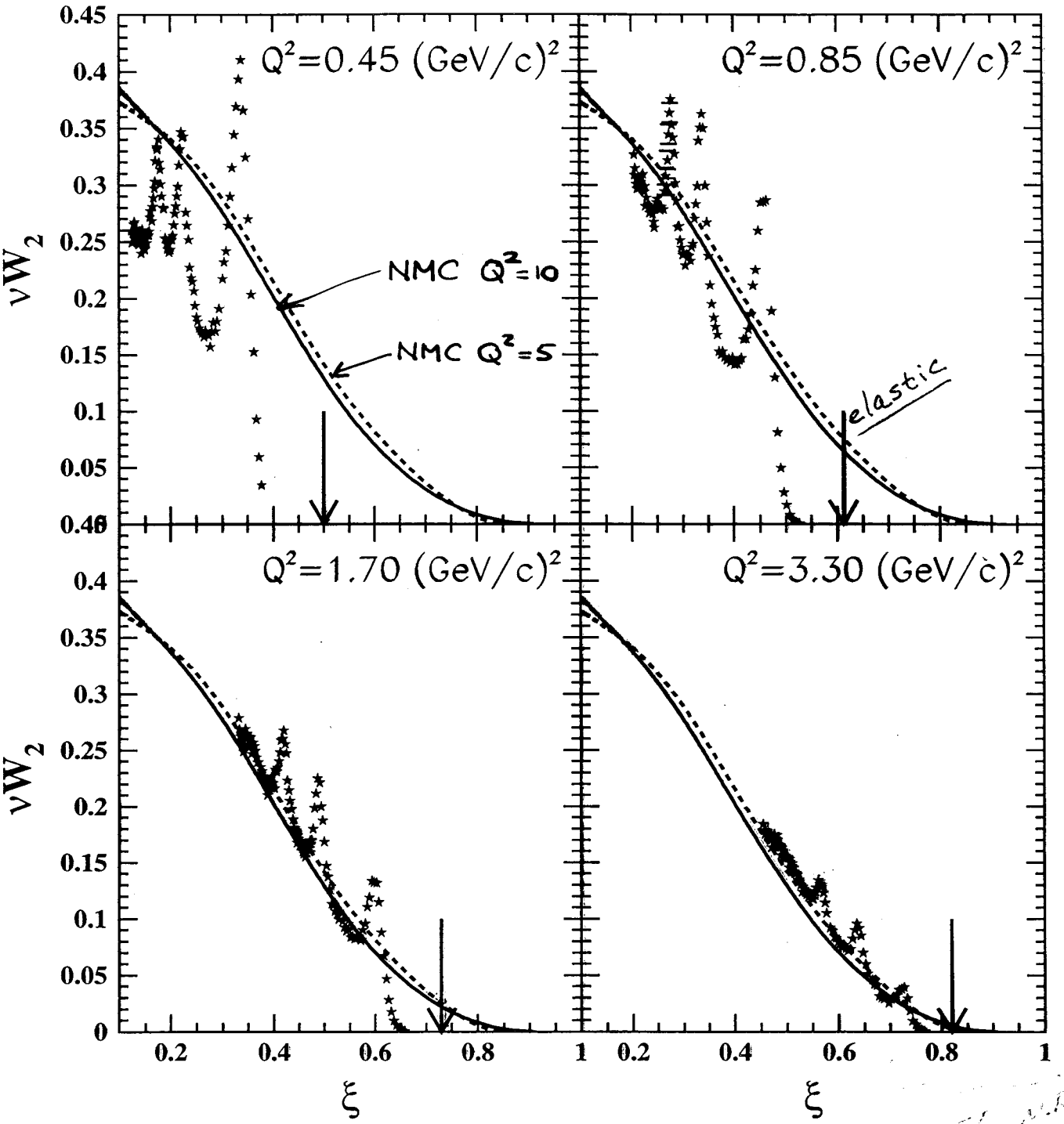
leading twist, single quark scattering

higher twist, quark-gluon correlations

- UNDERSTANDING DUALITY $\Leftrightarrow$ HIGHER TWIST

  - backgrounds for leading twist vs. signal for non-perturbative QCD

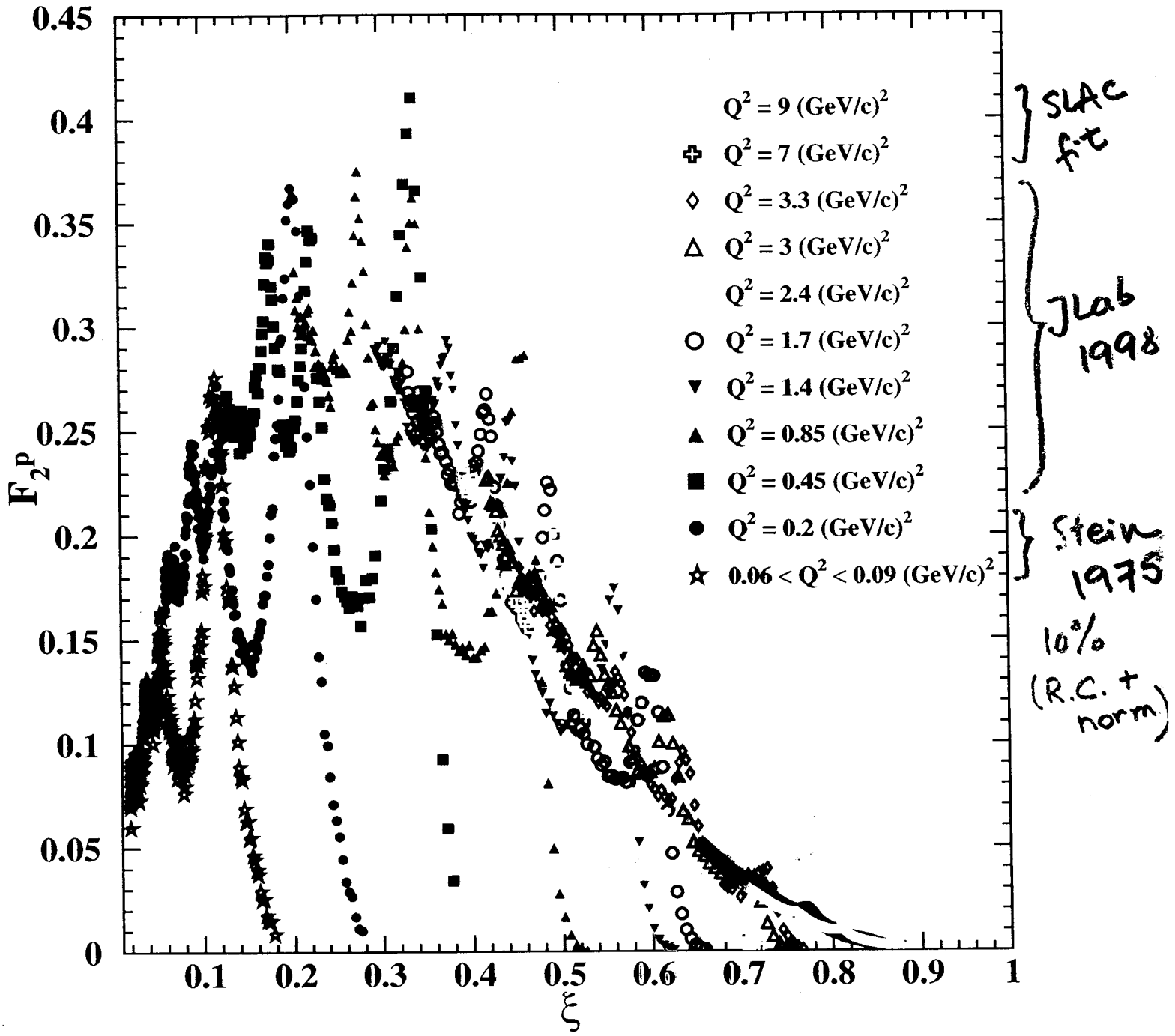
ABOVE $Q^2 \sim 1\,(\frac{GeV}{c})^2$, DUALITY WORKS WITHIN ~ 5%.



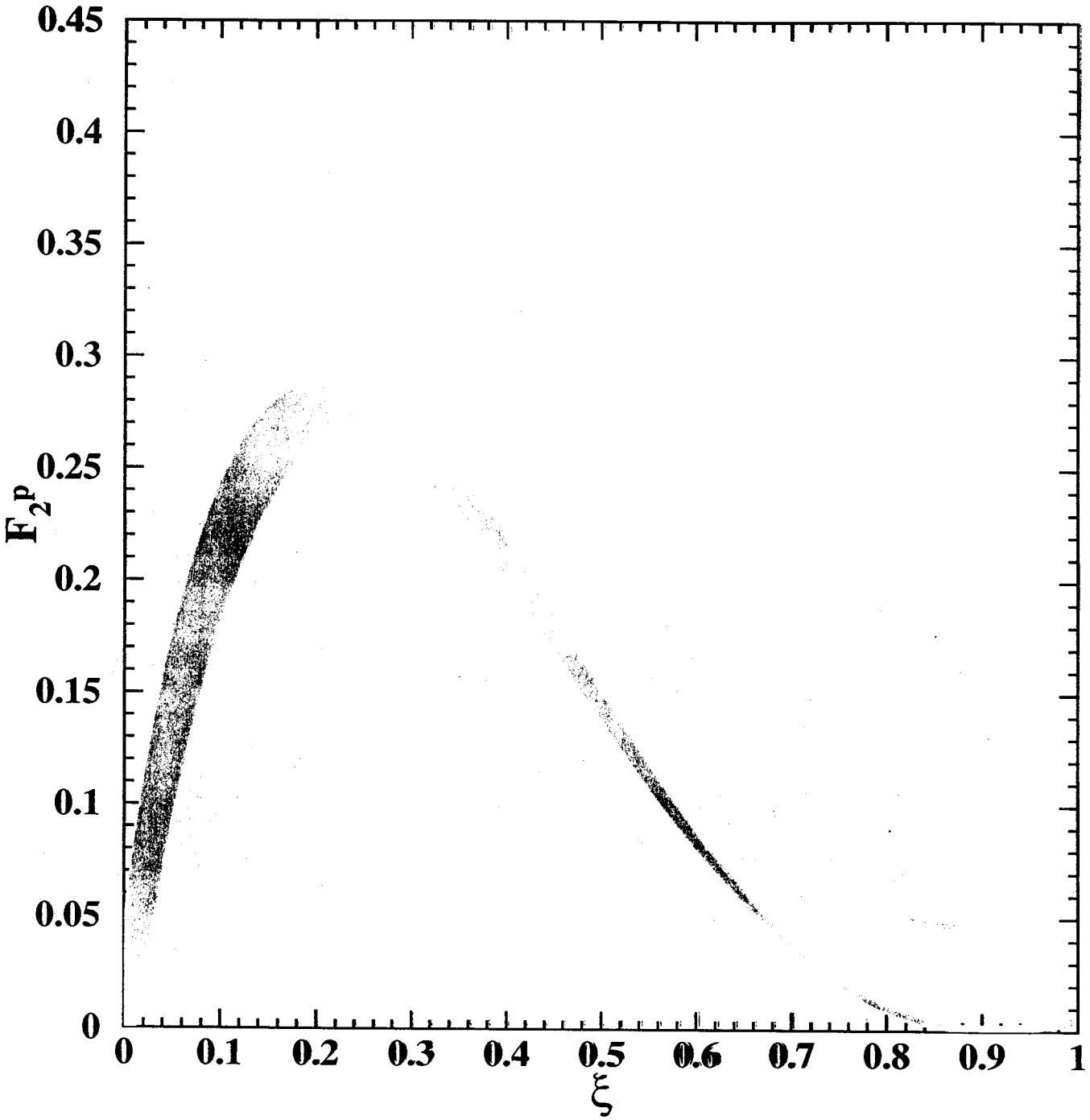
STEEP SLOPES underneath!

$$\xi = \frac{2x}{1+\sqrt{1+\frac{4M^2x^2}{Q^2}}}$$

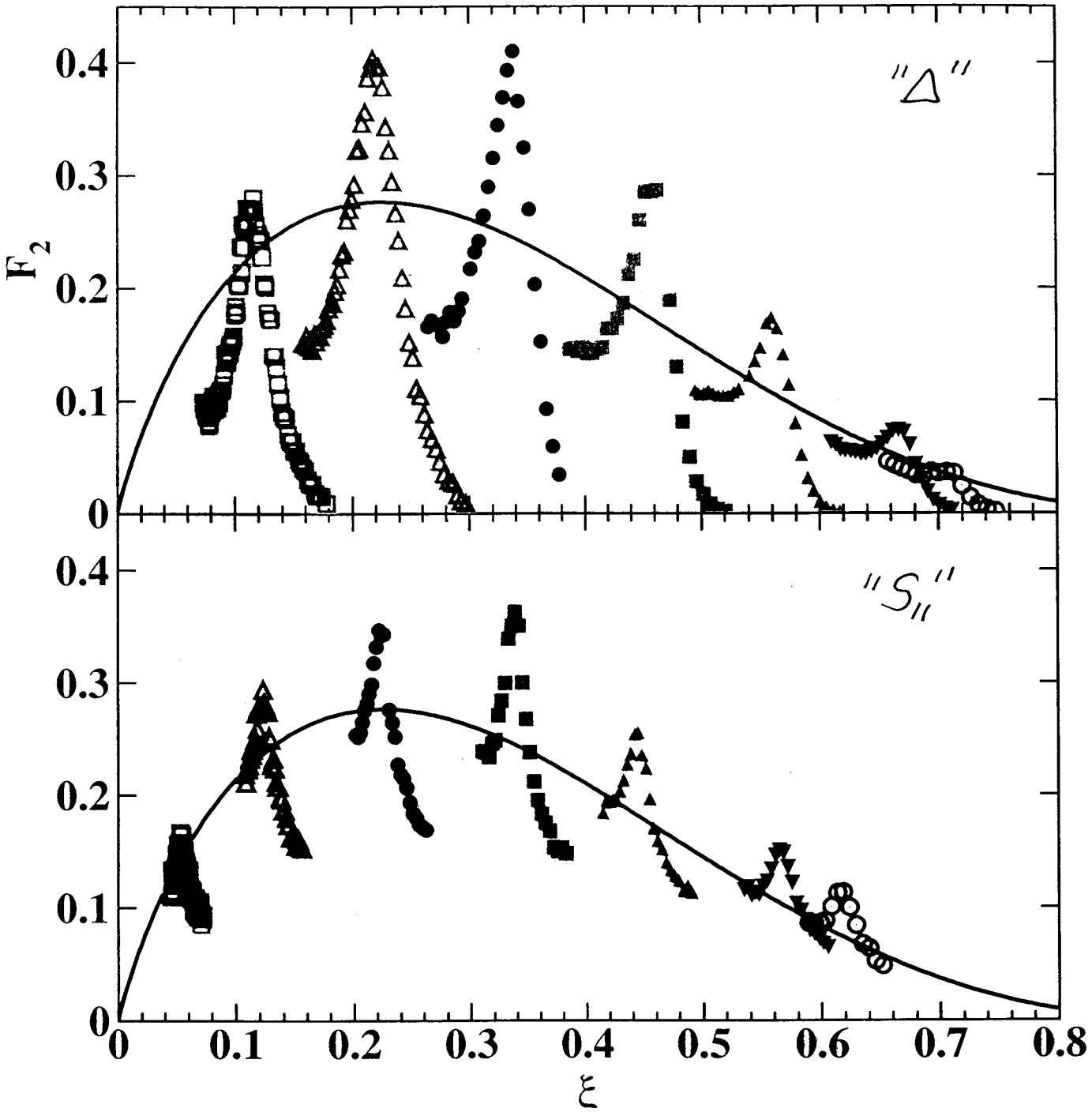
HIGHER ξ $\Longleftrightarrow$ HIGHER Q^2
(x)

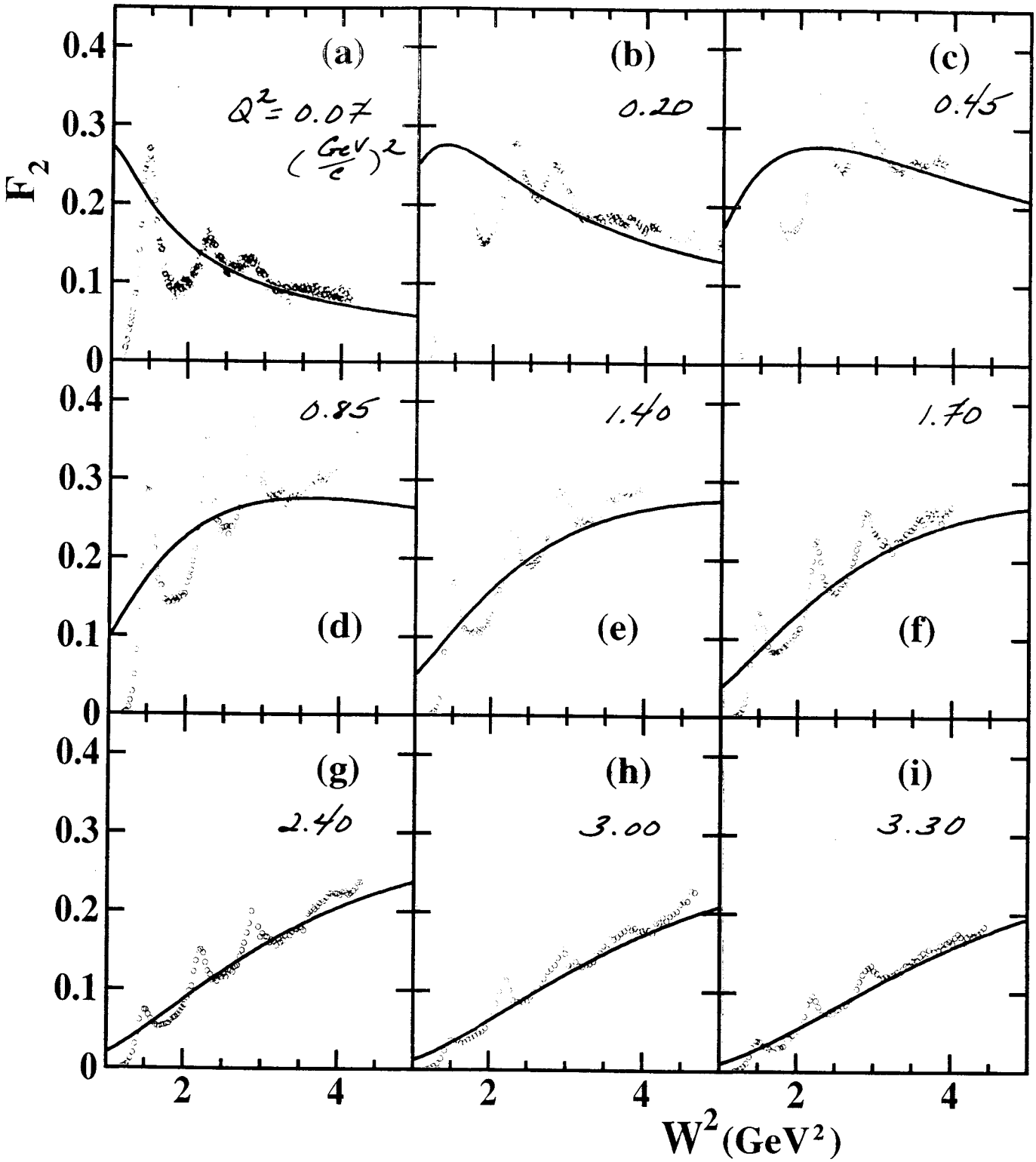

0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
F_2^p
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
ξ
$Q^2 = 9$ (GeV/c)^2
$Q^2 = 7$ (GeV/c)^2
$Q^2 = 3.3$ (GeV/c)^2
$Q^2 = 3$ (GeV/c)^2
$Q^2 = 2.4$ (GeV/c)^2
$Q^2 = 1.7$ (GeV/c)^2
$Q^2 = 1.4$ (GeV/c)^2
$Q^2 = 0.85$ (GeV/c)^2
$Q^2 = 0.45$ (GeV/c)^2
$Q^2 = 0.2$ (GeV/c)^2
$0.06 < Q^2 < 0.09$ (GeV/c)^2
SLAC fit
JLab 1998
Stein 1975
10%
(R.C. + norm)

Scaling curve



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


"Δ"
"S11"
F2
ξ
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8


(a)
$Q^2 = 0.07$
$(\frac{GeV}{c})^2$
(b)
0.20
(c)
0.45
(d)
0.85
(e)
1.40
(f)
1.70
(g)
2.40
(h)
3.00
(i)
3.30
F_2
$W^2(GeV^2)$
0
0.1
0.2
0.3
0.4
2
4

from model:

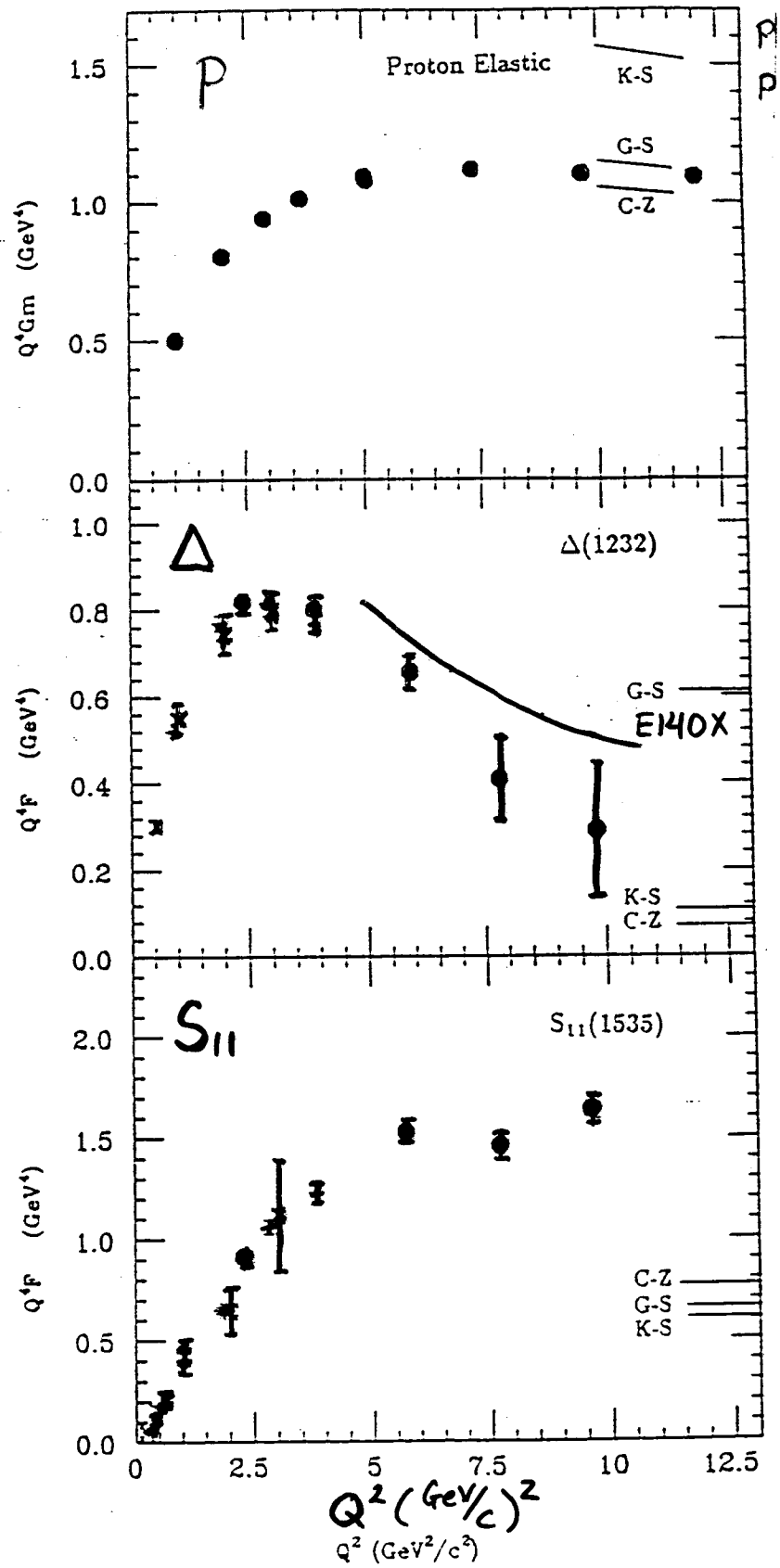
RESONANCE FORM FACTOR EXTRACTION

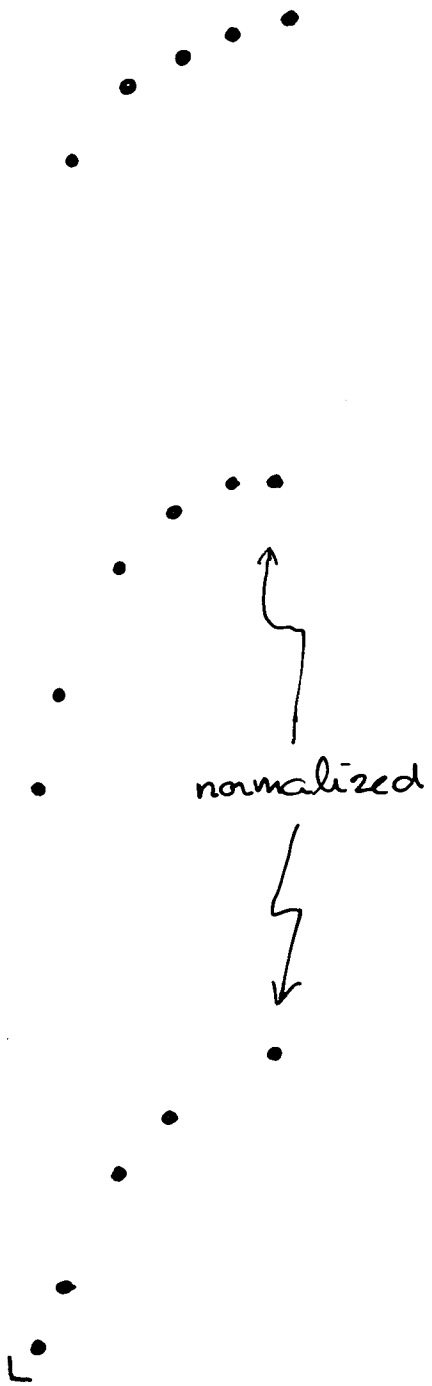
P. Stoler
PRL 66, 1003 (1991)

$Q^4 G_M$

$Q^4 F_\Delta$

$Q^4 F_{S11}$



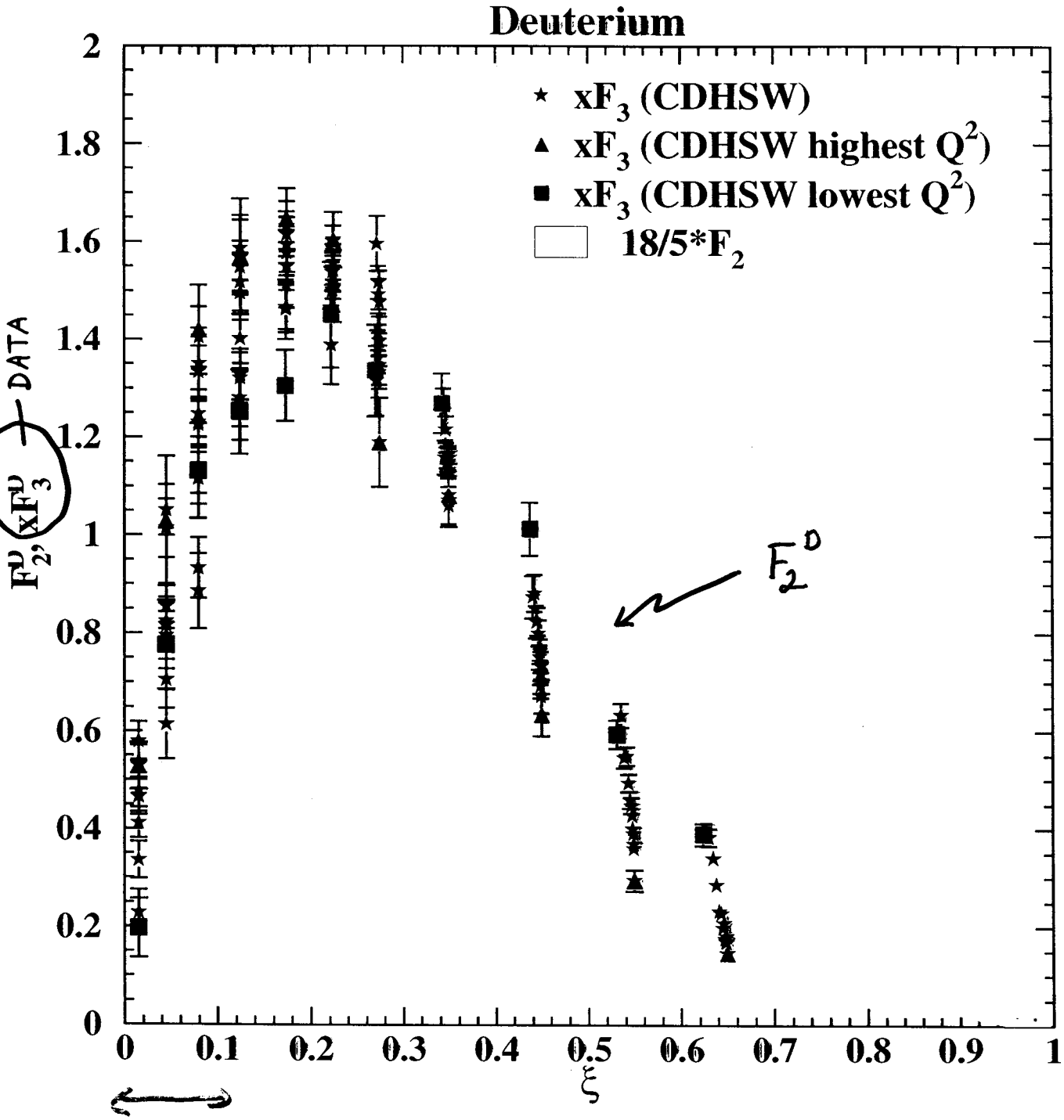


$$Q^4 F \sim Q^4 \sqrt{F_2 / Q_2} \qquad F_2 = \int_{\xi^{(-)}}^{\xi^{(+)}} F_2(\xi)\, d\xi$$

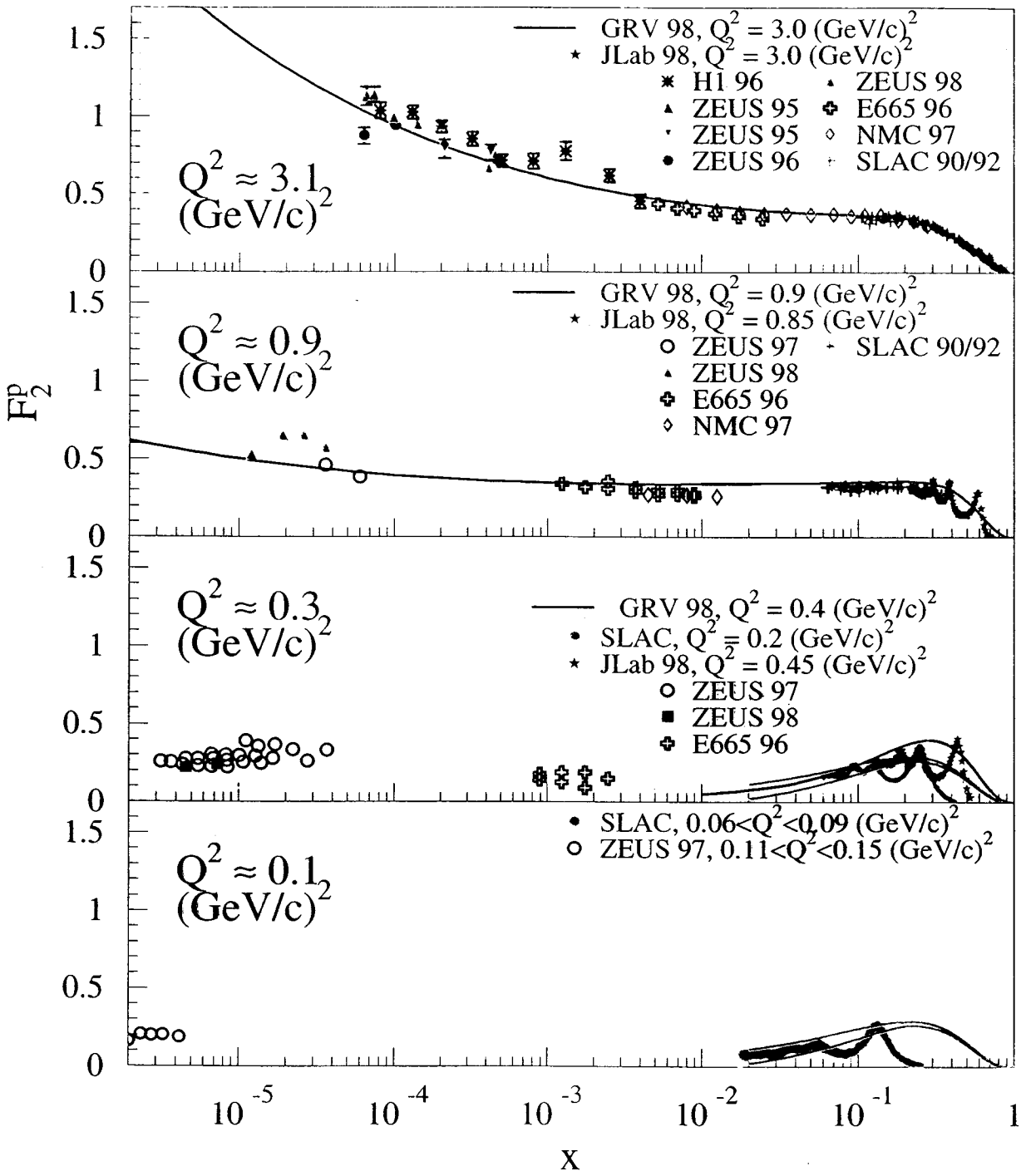
WHY DOES DUALITY WORK AT ALL?

TRIVIAL ANSWER: IF QCD IS THE CORRECT THEORY OF HADRONS, THEN A QUARK DESCRIPTION OF ANY PROCESS MUST COINCIDE WITH A HADRONIC DESCRIPTION — UNITARITY, COMPLETENESS

QUESTION IS NOT WHETHER DUALITY WORKS, BUT WHY DOES IT WORK AND WHERE DOES IT?



THE DUALITY-OBTAINED SCALING CURVE IS SENSITIVE TO THE VALENCE-LIKE DISTRIBUTION ONLY!


GRV 98, Q^2 = 3.0 (GeV/c)^2
JLab 98, Q^2 = 3.0 (GeV/c)^2
H1 96
ZEUS 98
ZEUS 95
E665 96
ZEUS 95
NMC 97
ZEUS 96
SLAC 90/92
$Q^2 \approx 3.1$ (GeV/c)^2
GRV 98, Q^2 = 0.9 (GeV/c)^2
JLab 98, Q^2 = 0.85 (GeV/c)^2
ZEUS 97
SLAC 90/92
ZEUS 98
E665 96
NMC 97
$Q^2 \approx 0.9$ (GeV/c)^2
GRV 98, Q^2 = 0.4 (GeV/c)^2
SLAC, Q^2 = 0.2 (GeV/c)^2
JLab 98, Q^2 = 0.45 (GeV/c)^2
ZEUS 97
ZEUS 98
E665 96
$Q^2 \approx 0.3$ (GeV/c)^2
SLAC, 0.06<Q^2<0.09 (GeV/c)^2
ZEUS 97, 0.11<Q^2<0.15 (GeV/c)^2
$Q^2 \approx 0.1$ (GeV/c)^2
F_2^p
0
0.5
1
1.5
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x

SPIN DEPENDENCE

- TO WHAT EXTENT IS DUALITY SPIN-DEPENDENT?
- ARE HIGHER TWIST CORRECTIONS LARGER FOR g_1 THAN FOR F_2?
- HOW DO g_1, g_2 AT LOW Q^2 APPROACH THE SCALING CURVE?
- COMPLETE ABSENCE OF DATA IN RESONANCE REGION, LARGE x!
- IS g_1 AS VALENCE-LIKE AS F_2?

How Local is Duality?

"Global Duality"

$$\frac{d\sigma}{dQ^2} \sim \int dx\, F(x, Q^2) \sim M_2(Q^2)$$

⇓

"Local Duality"

$$\frac{d^2\sigma}{dQ^2 dx} \sim F(x, Q^2)$$

⇓

"Fragmentation Duality"

$$\frac{d^3\sigma}{dQ^2 dx\, dz} \sim F(x, Q^2)\, D(z, Q^2)$$

Duality in Semi-Inclusive Scattering

- Flavor dependence
  - u, d separation

- Factorization
  - Semi-inclusive cross section

$$\frac{d^3\sigma}{dQ^2 dx dz} \sim \sum_q e_q^2 \, xq(x,Q^2) \, D_q(z,Q^2)$$

  - Can we expect it to work at JLab ν? ⇒ test!!

- Duality for fragmentation function?
  - Confirmation of factorization and duality would open the way to an enormously rich semi-inclusive program allowing unprecedented quark spin + flavor decomposition (c.f. HERMES)

EXPERIMENTS AT 12 GEV

- INCLUSIVE STRUCTURE FUNCTIONS

  PLANNED HALL C HMS (SHMS) OPTIMIZED FOR INCLUSIVE STUDIES OVER WIDE RANGE OF Q^2 ($0 \lesssim Q^2 \lesssim 15\ GeV^2$) UP TO LARGE x

  - F_2: $0 \lesssim Q^2 \lesssim 20\ GeV^2$, $x \lesssim 0.95$
    F_L: $0 \lesssim Q^2 \lesssim 12\ GeV^2$, $x \lesssim 0.9$
    g_1, g_2: $0 \lesssim Q^2 \lesssim 10\ GeV^2$, $x \lesssim 0.85$

- SEMI-INCLUSIVE SCATTERING

  - FLAVOR DEPENDENCE OF DUALITY
  - TEST FACTORIZATION AT LOW ν

- A-DEPENDENCE

"KILLER" APPLICATION

IF DUALITY CAN BE UNDERSTOOD WELL ENOUGH TO BE USED AS A TOOL

ACCESS MORE KINEMATIC REGIONS, PREVIOUSLY BELIEVED UNACCESSIBLE TO QUARK DESCRIPTIONS, VIA RESONANCES + DUALITY

- LARGE x DIS SPIN STRUCTURE FUNCTIONS
- F_2^n / F_2^p AT LARGE x