ZEUS results : a preview

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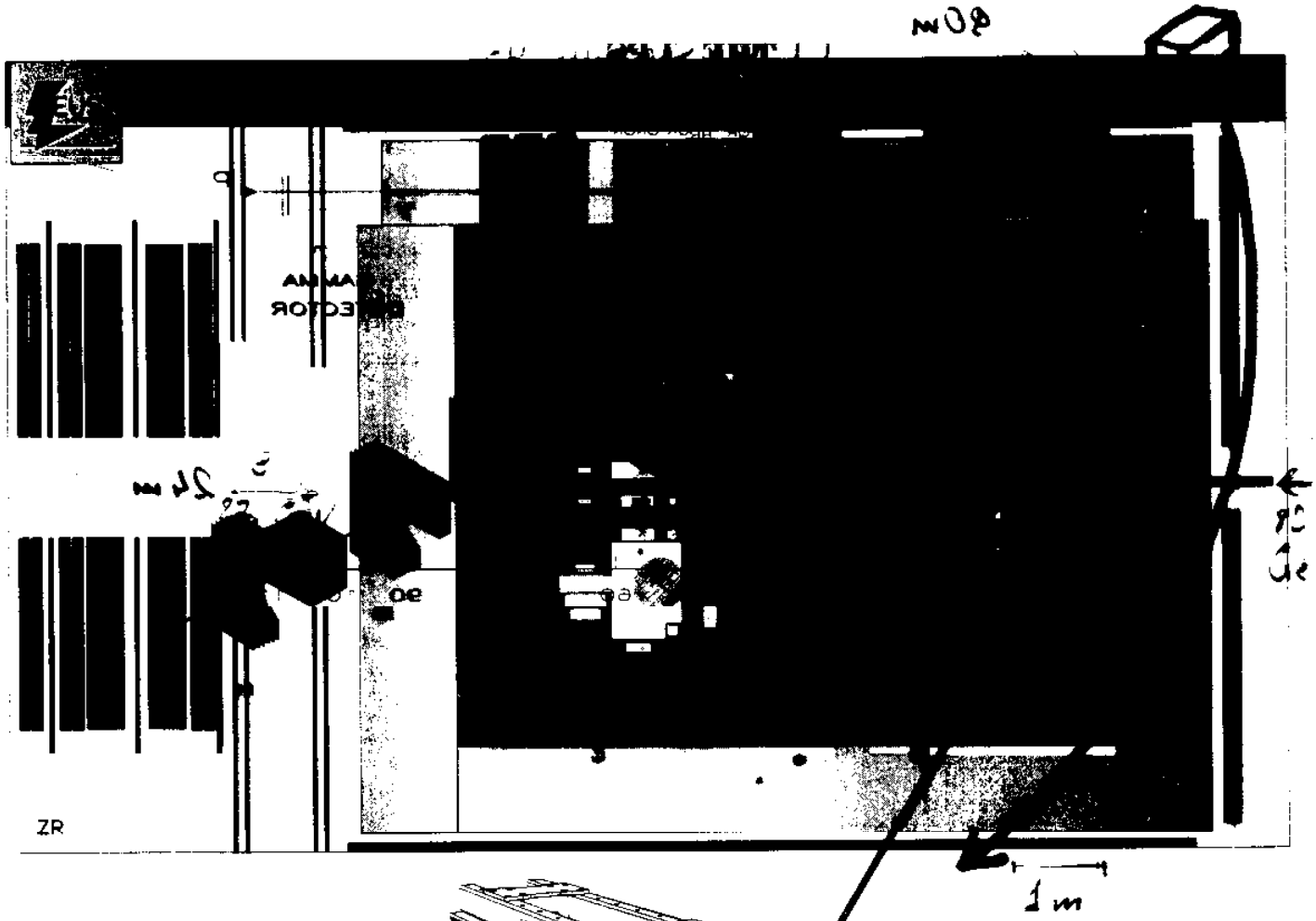
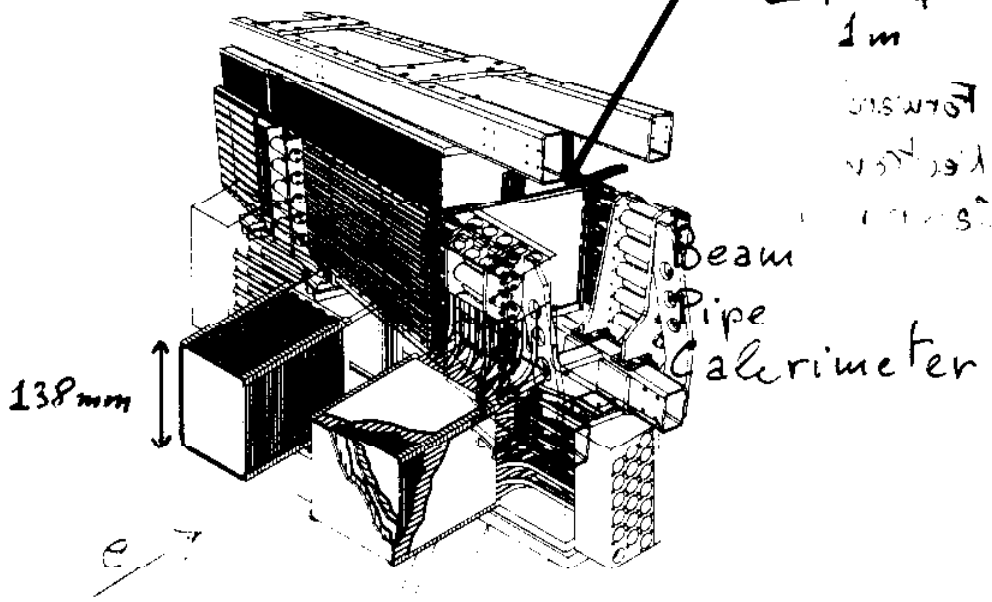
on behalf of the ZEUS collaboration

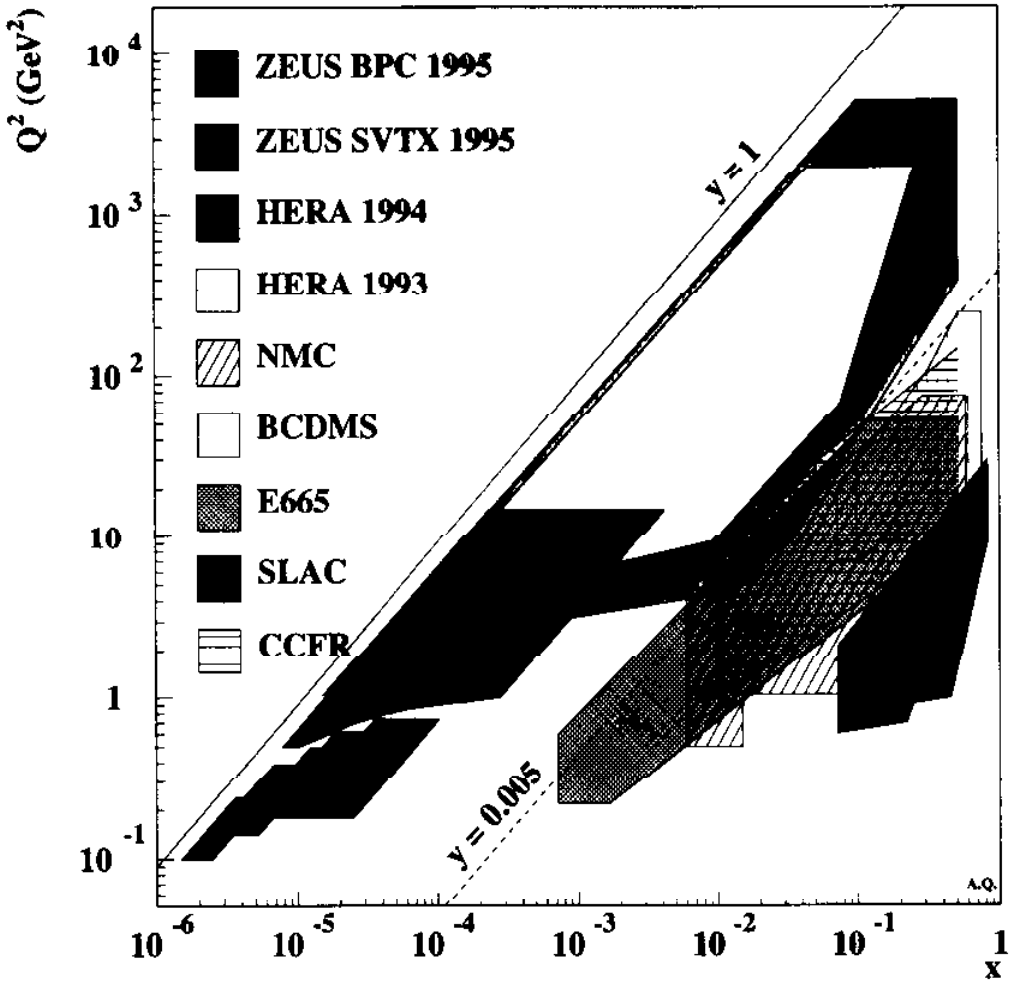
— Is QCD a consistent theory ? —

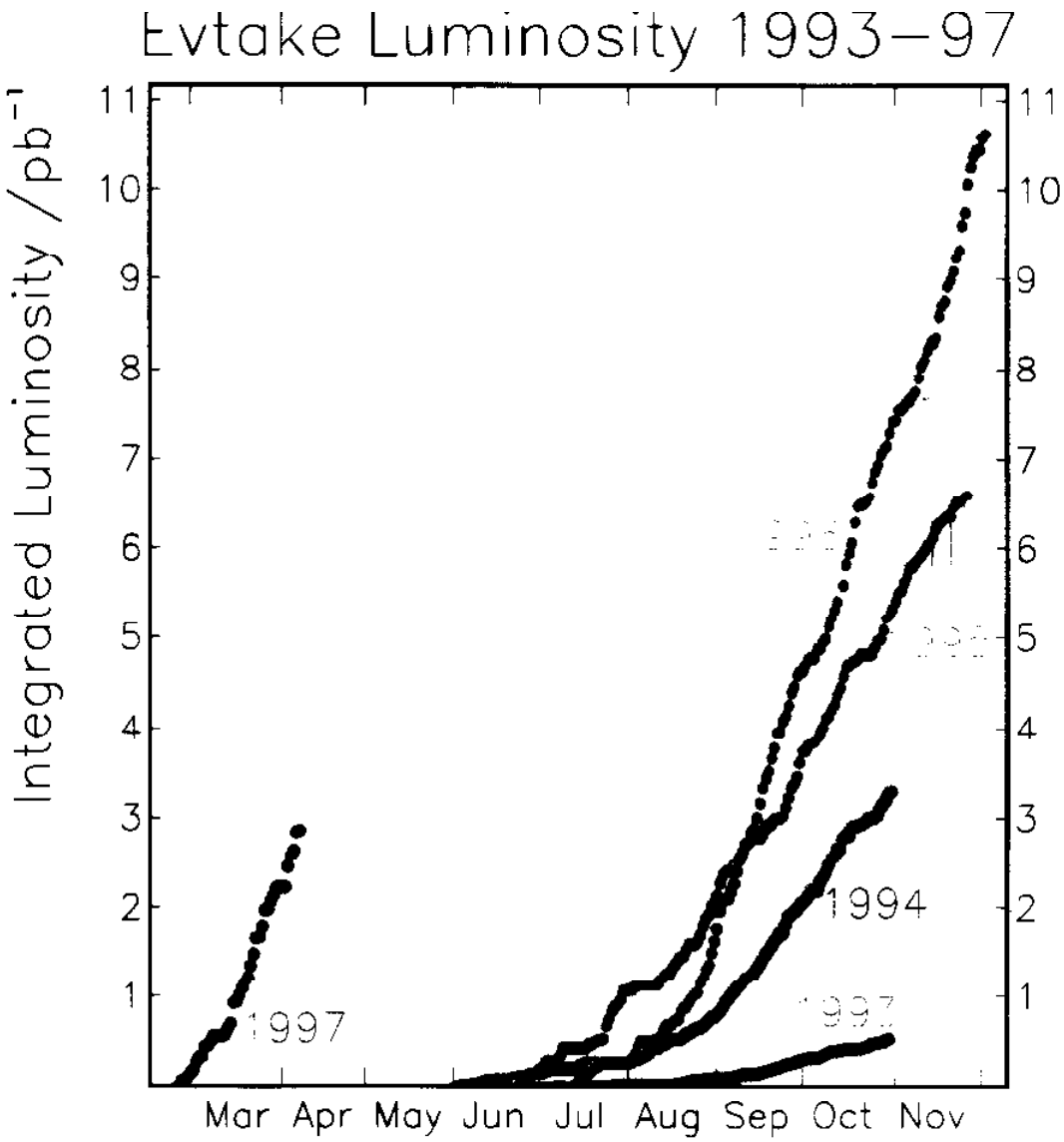
- QCD tests with jets and particles
- Diffractive physics
- Structure Functions at low Q^2 and High x events
- Open questions for DIS 97

THE ZEUS DETECTOR






ZEUS BPC 1995
ZEUS SVTX 1995
HERA 1994
HERA 1993
NMC
BCDMS
E665
SLAC
CCFR
y = 1
y = 0.005
A.Q.
Q^2 (GeV^2)
10^4
10^3
10^2
10
1
10^{-1}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
1
x


Evtake Luminosity 1993–97
Integrated Luminosity /pb^{-1}
1997
1994
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov

QCD tests final state

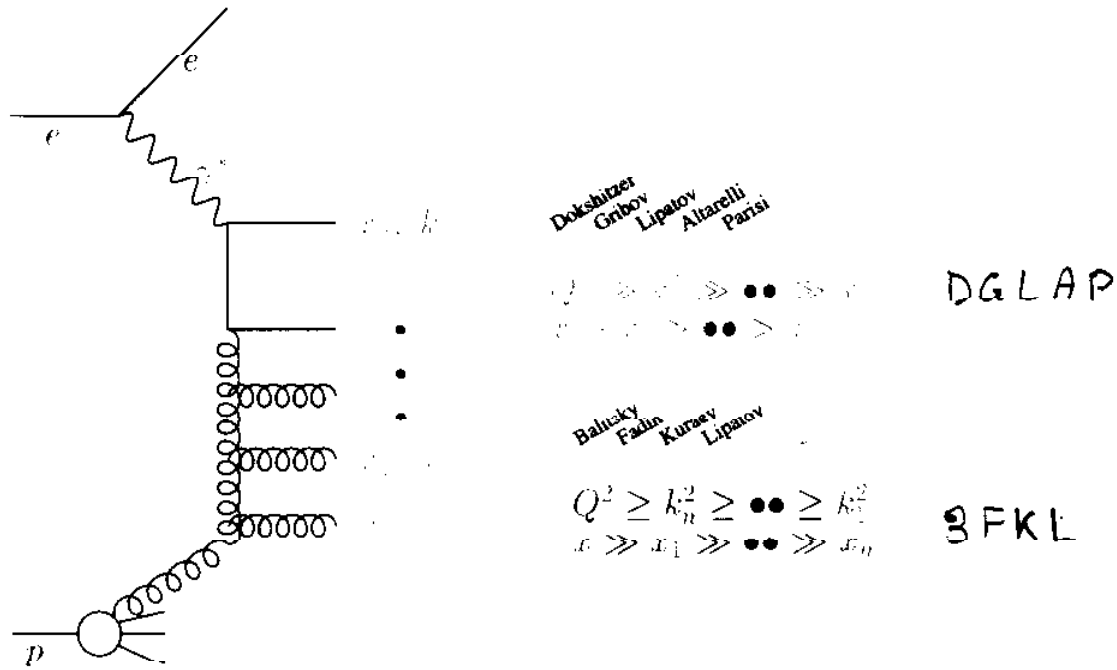
Observation of jets in γp (direct/resolved) and DIS and general tests of QCD comparing with LO MC

Jets

[redacted]

Particles
[redacted] and
Charm

Inclusive jets measurements in DIS



Comparison with NLO DGLAP calculations

- Dijets and gluon density determination
- After a careful evaluation of the p-remnant contribution a disagreement at very low x_{BJ} is observed for jets in the forward region

How reliable is the gluon extraction form jets ?
Are higher order contributions important ?
Any sign for BFKL ?

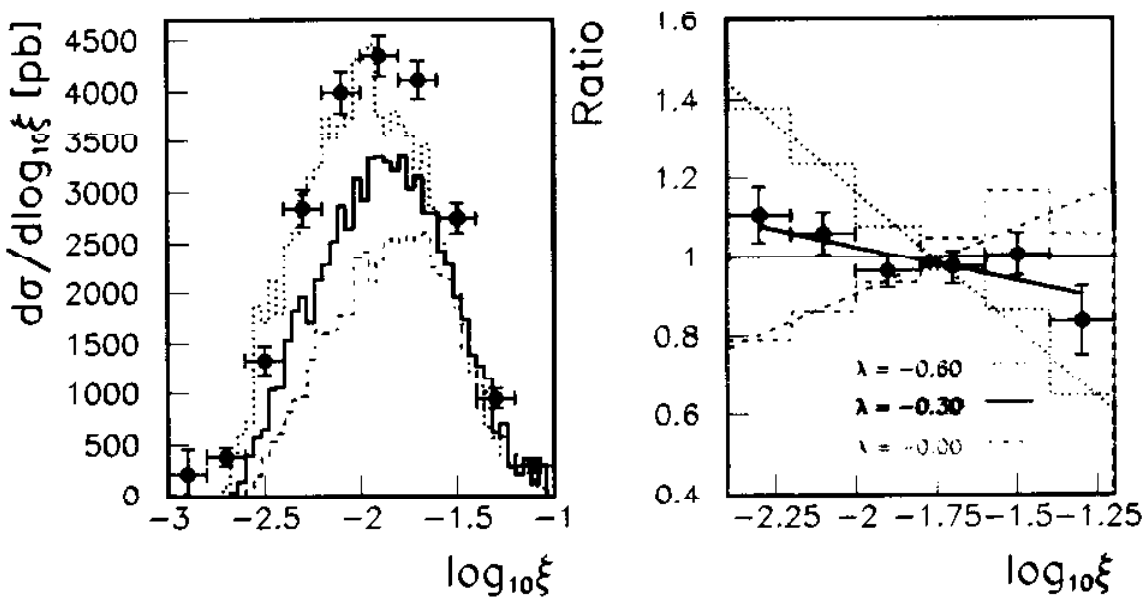
[illegible] analysis

- $7 < Q^2 < 100$ GeV^2 $\quad y > 0.04$
- Cone algorithm $R = 1$, $\eta_{jet}^{LAB} < 2$

  $p_{jet}^{T\,LAB} > 2.5$ GeV, $p_{jet}^{T\,HCM} > 4$ GeV
- MEPJET (Mirkes + Zeppenfeld)

  $g(x, Q_0^2) = A_g x^{+\lambda} (1-x)^{\beta} (1 + \eta x)$ at $Q_0^2 = 4$ GeV
- $\xi = x_{BJ} + \frac{m_{jj}^2}{s\,y}$ momentum fraction of gluon

ZEUS 1994 – Preliminary



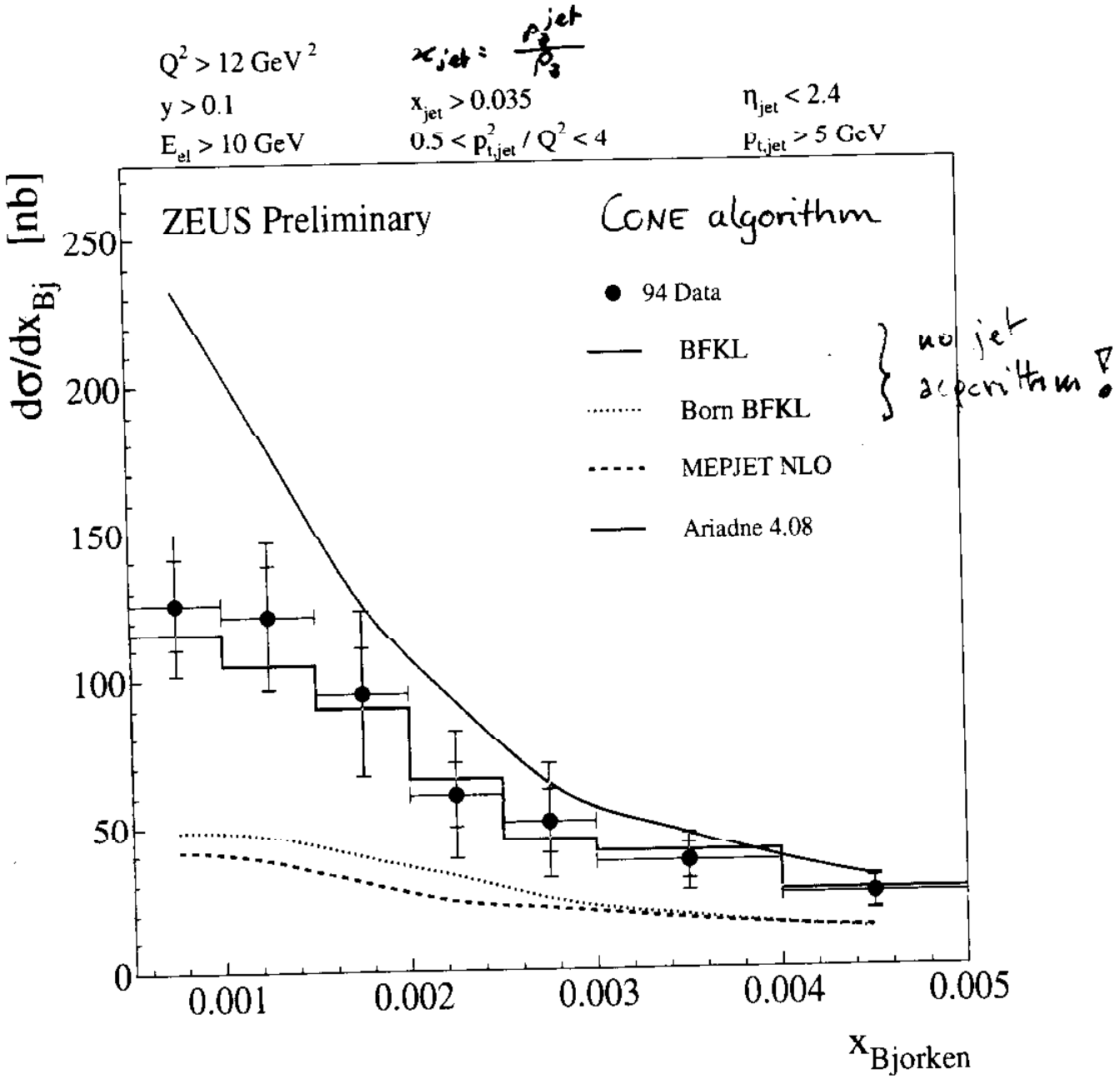
Discrepancy of ~34% in normalization w.r.t. $\lambda = 0.30$

Is shape independent from normalization

$\lambda = -0.5 \pm 0.04 \pm 0.18$

at $\mu_0^2 = 4$ GeV^2

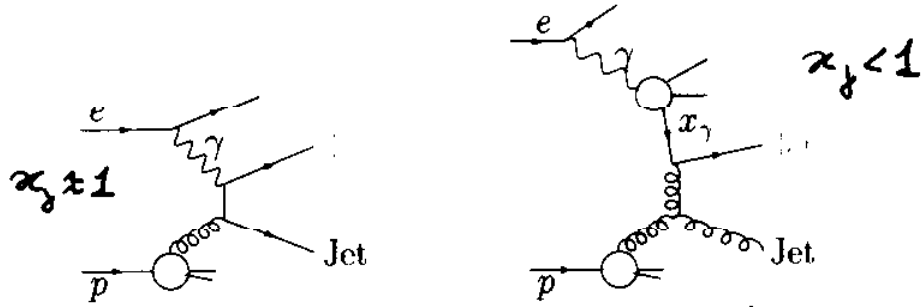
Differential cross section for forward jets (parton level)



BFKL : Bartels + Wüsthoff

MEPJET: Mirkes + Zeppenfeld

Inclusive jets in γp



Direct Photoproduction Resolved Photoproduction

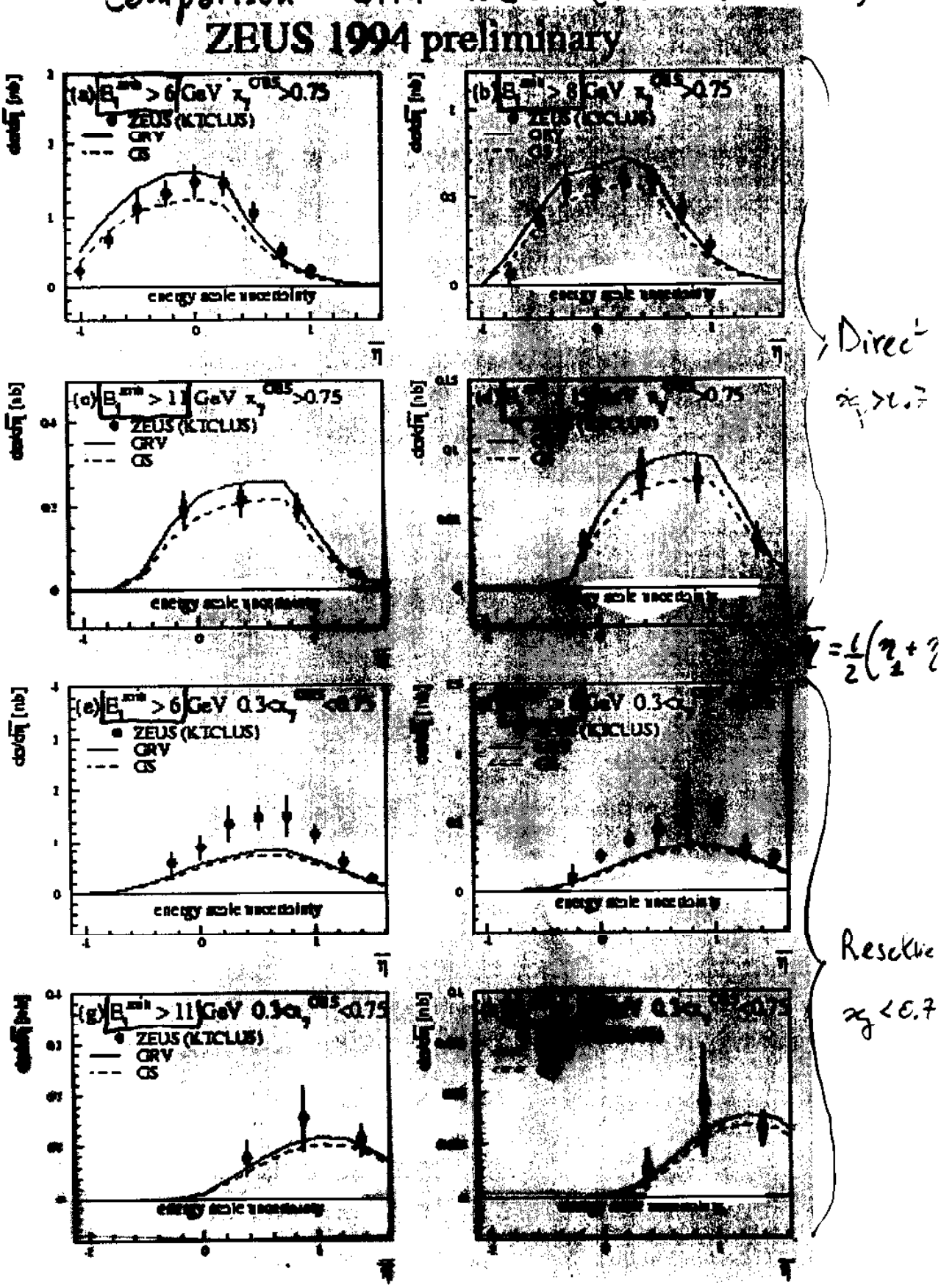
Comparison with NLO pQCD calculations

- Agreement at higher E_T^{jet} both for direct and resolved
- At lower E_T^{jet} in resolved interaction we get disagreement with pQCD prediction.

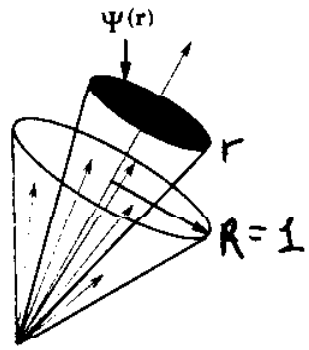
In resolved interactions strong interplay with multiple interactions. Can we still obtain measurements capable to distinguish different photon SF's ? Can we think at any topological cuts ?

Dijet cross section - k_T algorithm

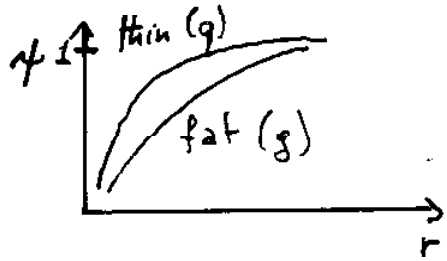
Comparison with NLO (Klasen, Kramer)



Jets shapes in γp and DIS



$$\psi(r) = \frac{1}{N_{jet}} \sum_{jet} \frac{E_T^{<r}}{E_T^{<R}}$$



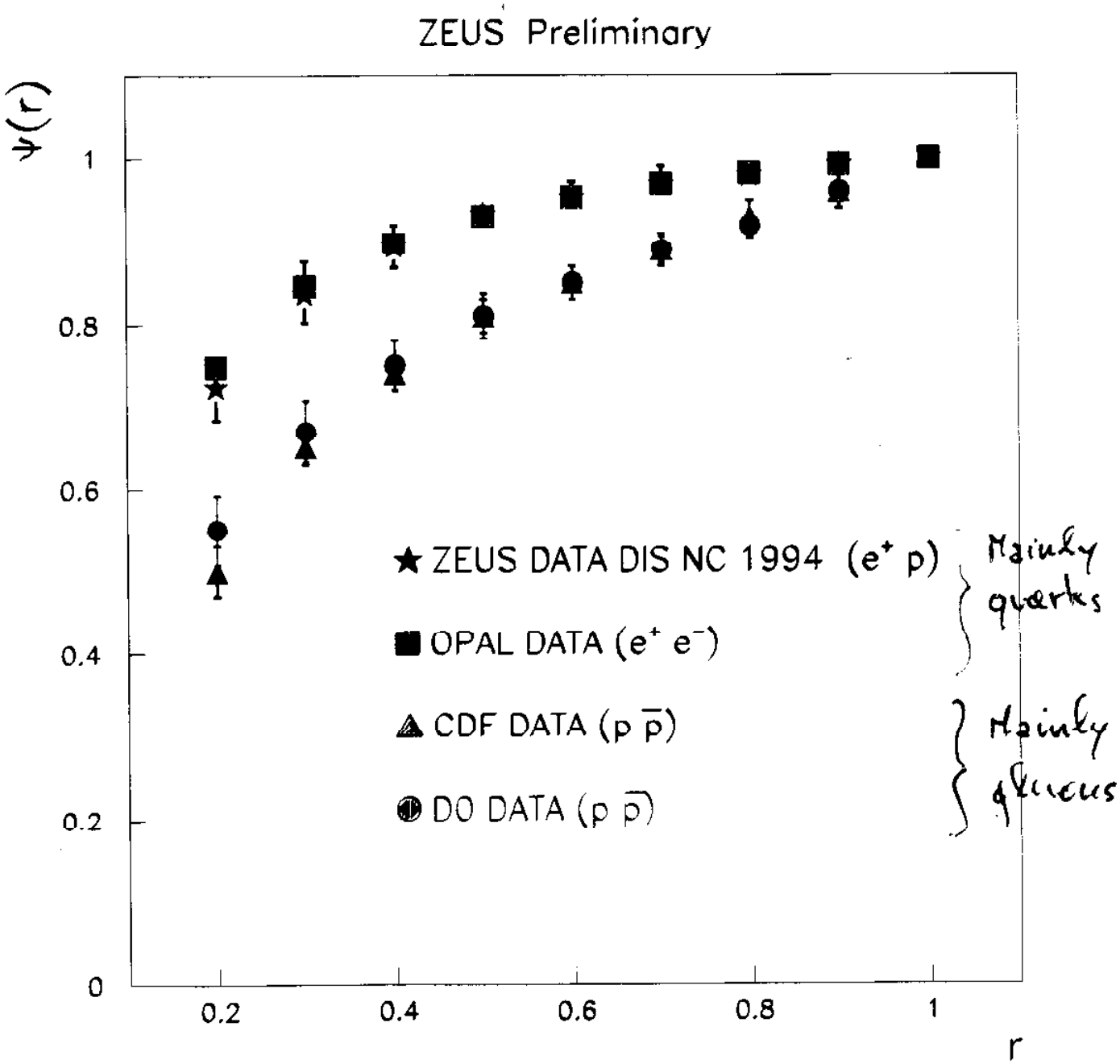
Are current quark jets in NC as wide as in e^+e^- or pp ?

- Data indicate the same universal quark fragmentation process

Do we see more gluon jets in resolved γp ?

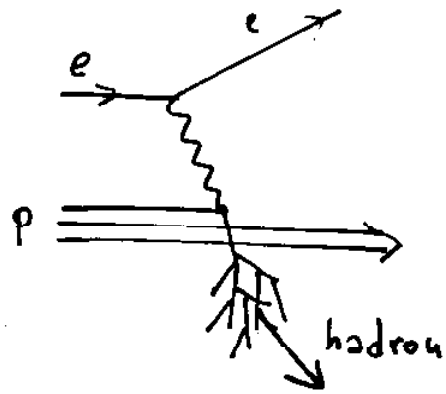
- Data show wider (gluon) jets in resolved enriched sample as expected from pQCD calculation.

Can the study of the jet structure help to isolate multiple interactions ?


ZEUS Preliminary
ψ(r)
1
0.8
0.6
0.4
0.2
0
0.2
0.4
0.6
0.8
1
r
ZEUS DATA DIS NC 1994 (e⁺ p)
OPAL DATA (e⁺ e⁻)
CDF DATA (p p̄)
D0 DATA (p p̄)
Mainly quarks
Mainly gluons

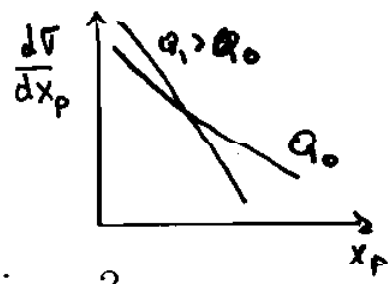
QCD tests with particles - J. Bromley

Fragmentation functions in DIS



$$x_p = \frac{p^{hadron}}{p_{max}} = \frac{2\,p^{hadron}}{Q}$$

in Breit frame $\left(p_{max} = \frac{Q}{2}\right)$

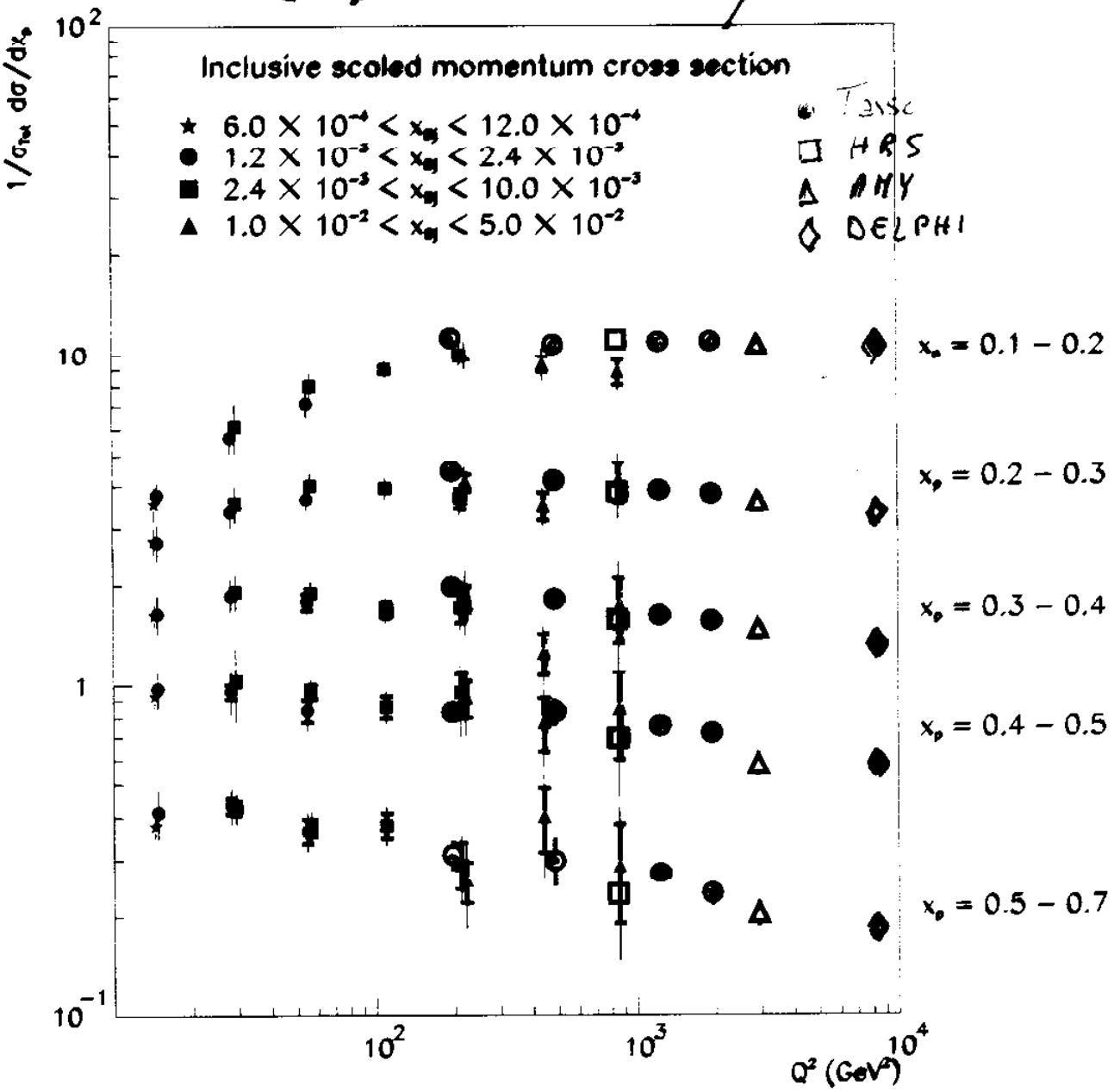


Universal behavior in different interactions ?

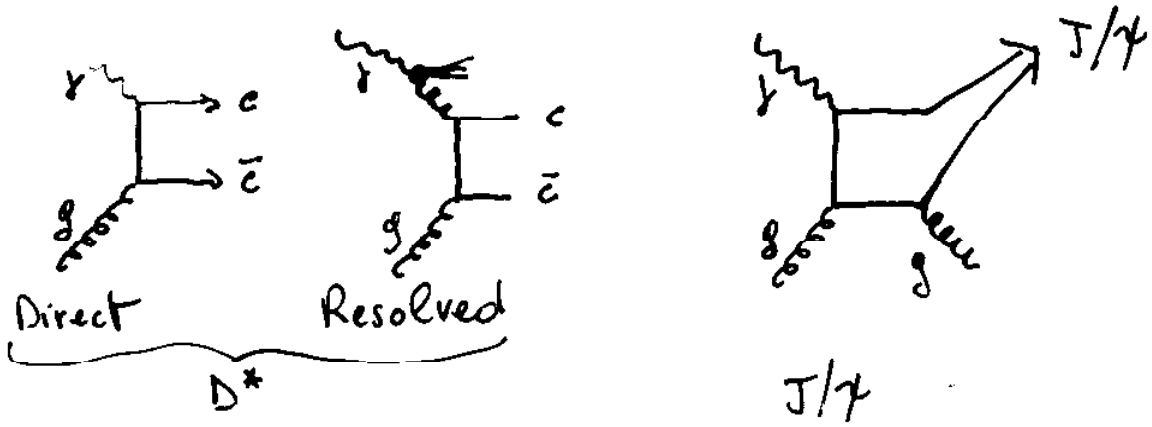
- Remarkable overlap with e^+e^- results : the quarks fragments in the same way
- Nice agreement with NLO pQCD preliminary calculation

How reliable is the α_s measurement ?

ZEUS Preliminary



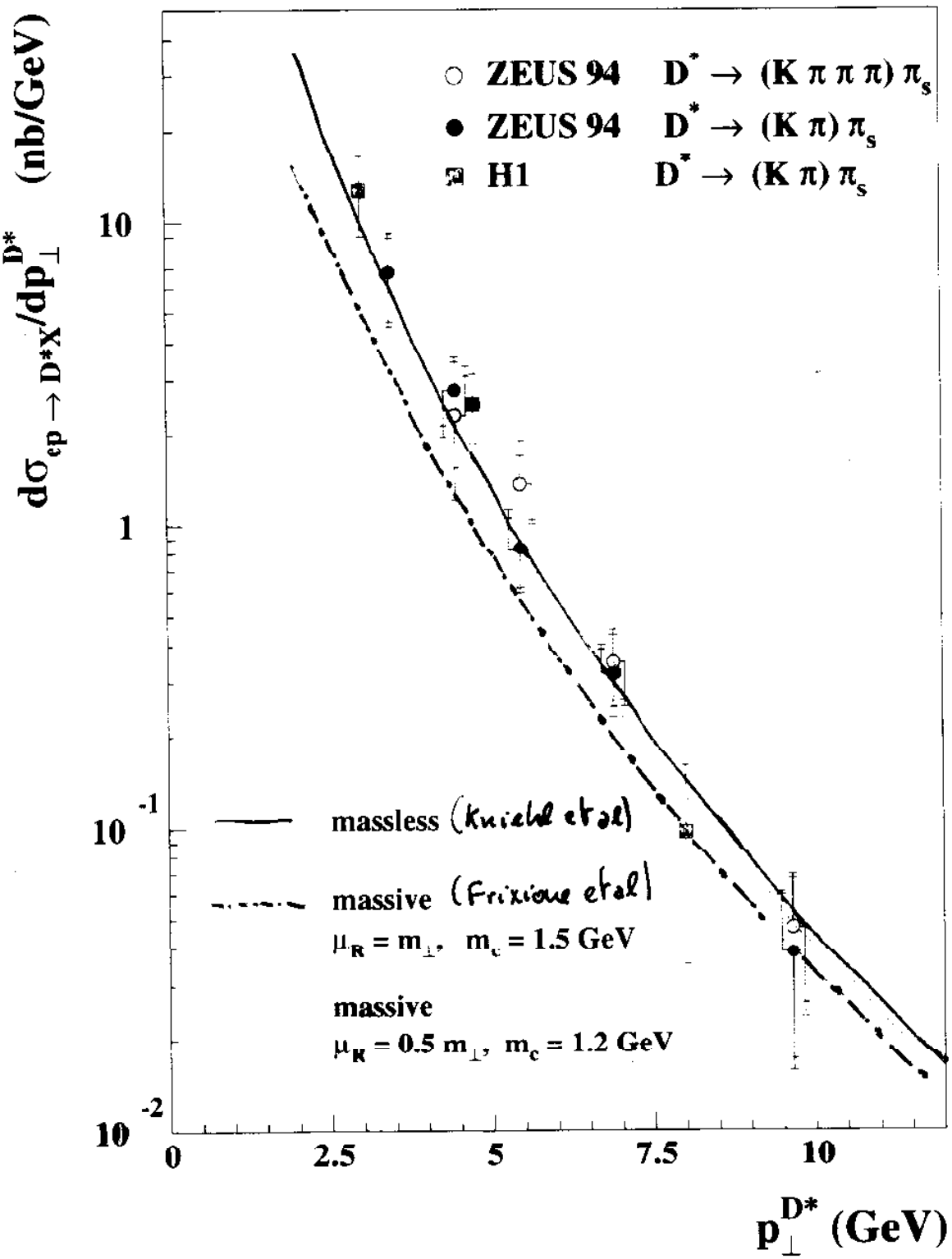
D^* and inelastic J/ψ in γp



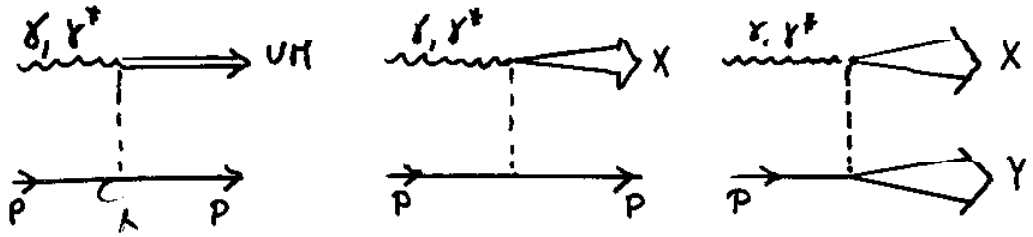
How does it compare with pQCD calculation ?

- Good agreement with massless approach with gluons á la F_2 but many refinements in theory are still possible !
- First reasonable agreement of theory with J/psi measurements

Can we reliably extract the gluon density ?
How important is the resolved photon contribution ?
Isolation of *charm component* in photon and/or proton ?
Can theory be extended into lower p_t region for J/ψ ?
What about the octet contribution for the J/ψ ?


ZEUS 94 D* → (K π π π) π_s
ZEUS 94 D* → (K π) π_s
H1 D* → (K π) π_s
massless (Kniehl et al)
massive (Frixione et al)
μ_R = m_⊥, m_c = 1.5 GeV
massive
μ_R = 0.5 m_⊥, m_c = 1.2 GeV
dσ_ep → D*X/dp_⊥^D* (nb/GeV)
p_⊥^D* (GeV)
10
1
10^-1
10^-2
0
2.5
5
7.5
10

DIFFRACTION AT HERA



Diffractive events are observed at HERA in DIS and γ p

Large scale
Q^2, M^2_{VM}, t

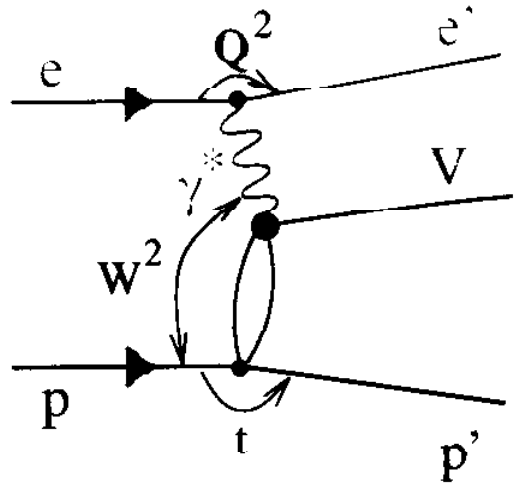
Small scale

NEW

NEW

NEW

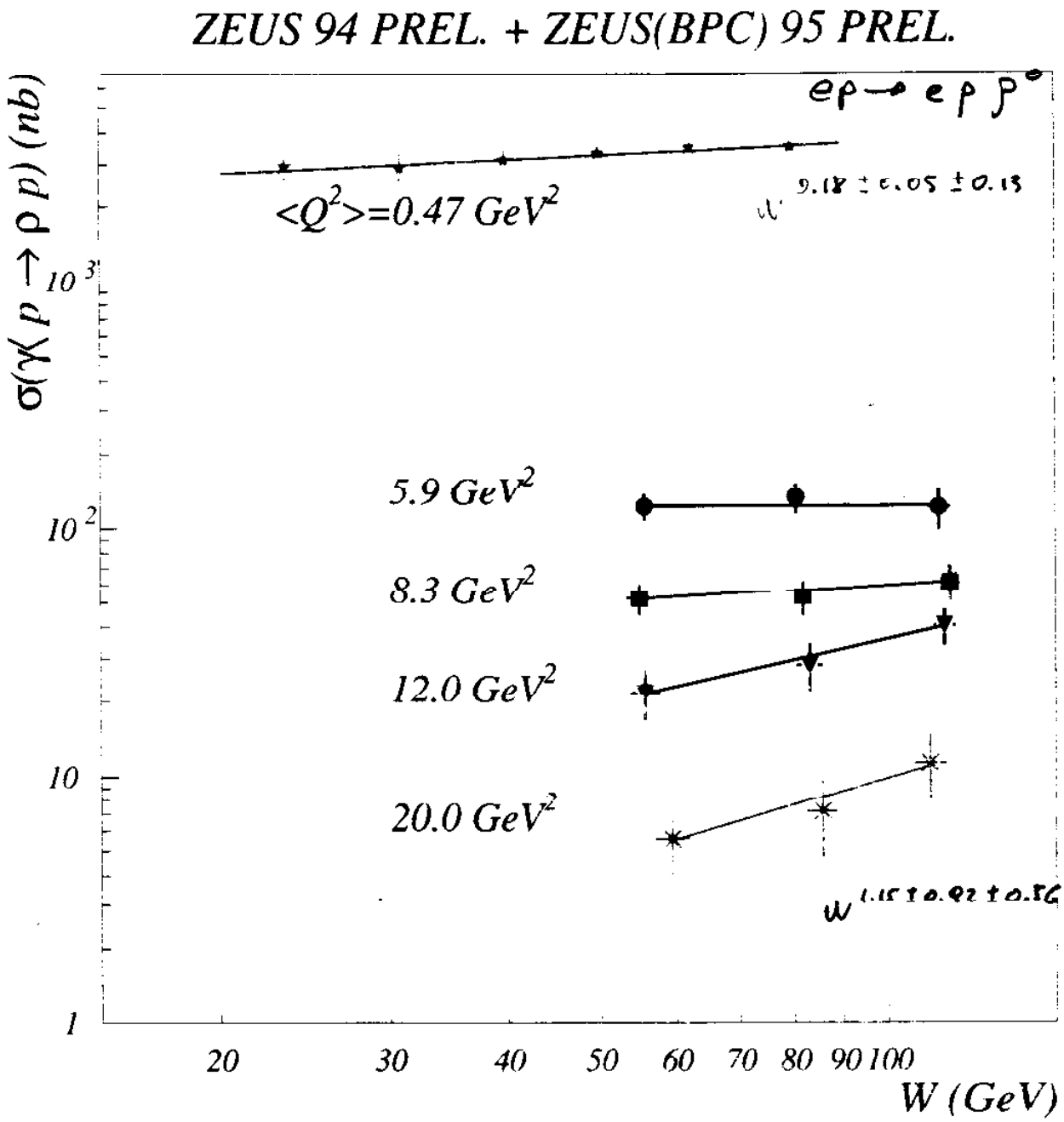
Vector mesons production from γp to DIS



Check the hadronic properties of the photon at HERA γp energies. Provide measurements as a function of different scales (Q^2, t, M^2_{VM}).

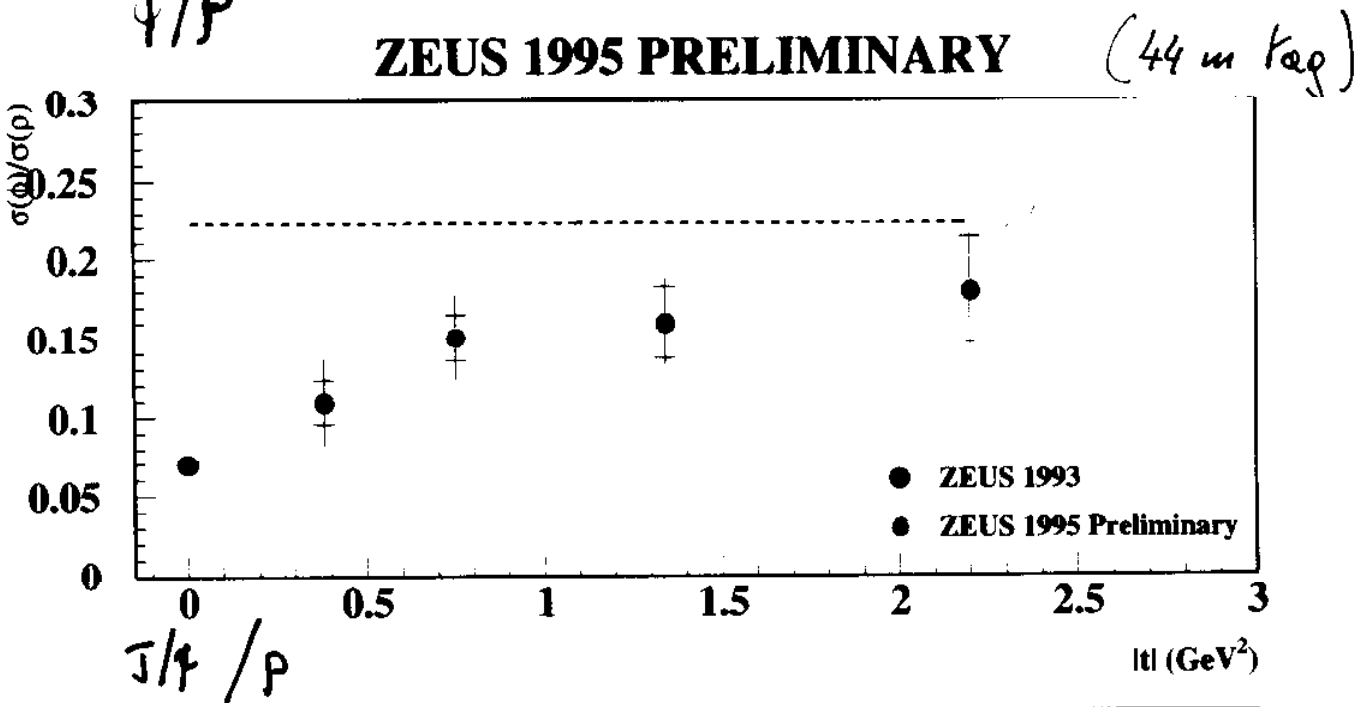
- Improved measurements of ρ at $.25 < Q^2 < .85$ which show agreement with soft Pomeron models
- Detailed studies of the spin density matrix elements
- New measurement of J/ψ in DIS

Which ~~What~~ is the correct scale for the process ?
Where does the transition soft - pQCD happens ?
Is the transition region for inclusive (F_2) and exclusive (VM) processes the same ?
Can measurements allow a reliable extraction of the gluon ?

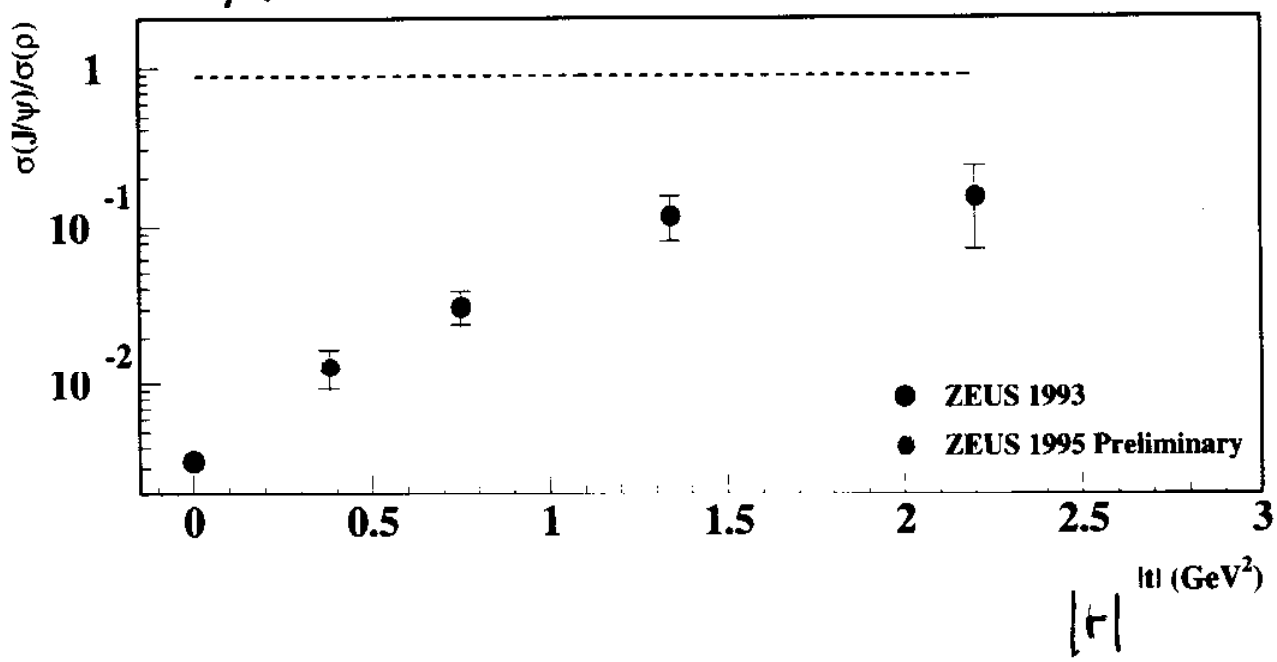

ZEUS 94 PREL. + ZEUS(BPC) 95 PREL.
σ(γ* p → ρ p) (nb)
<Q²>=0.47 GeV²
5.9 GeV²
8.3 GeV²
12.0 GeV²
20.0 GeV²
10³
10²
10
1
20
30
40
50
60
70
80
90
100
W (GeV)

SU(4) Symmetry

ϕ/ρ



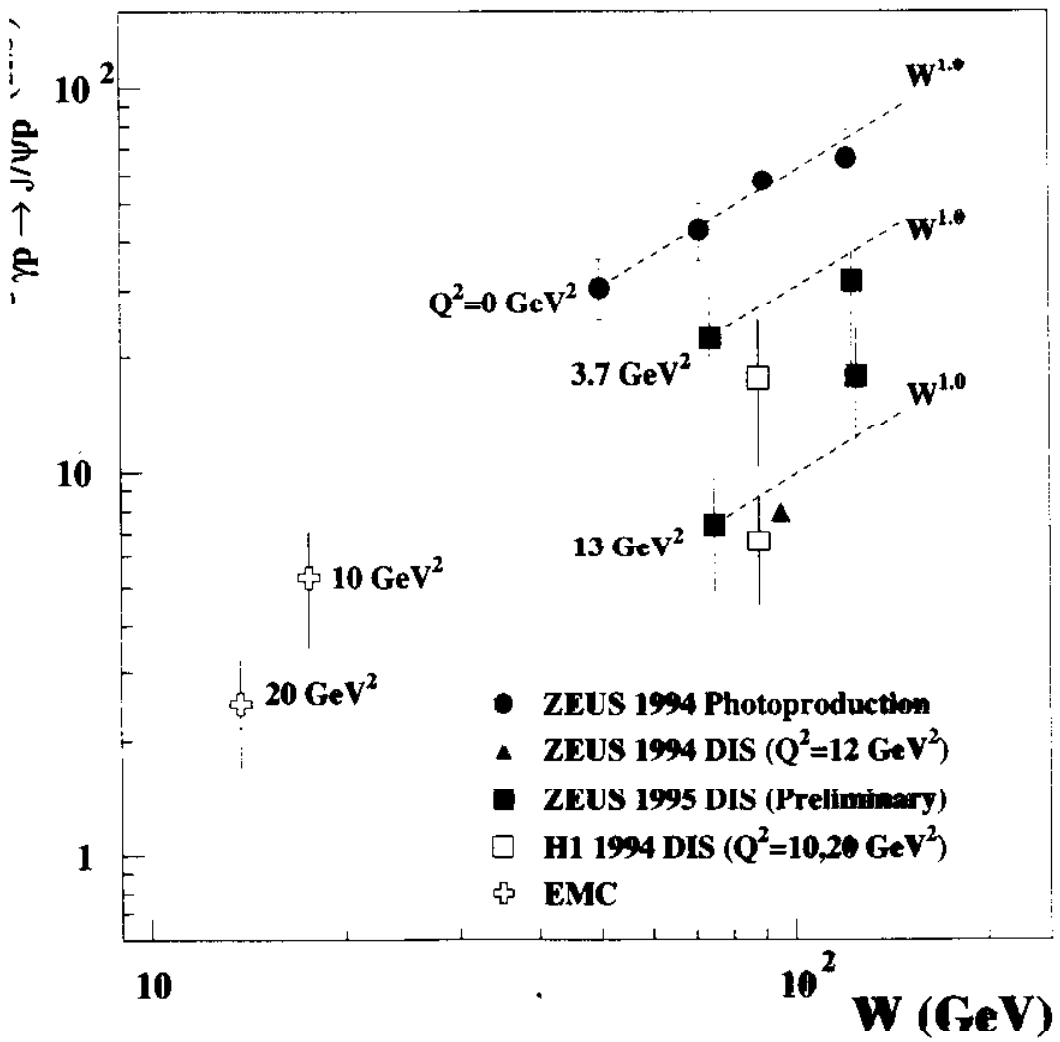
$J/\psi/\rho$



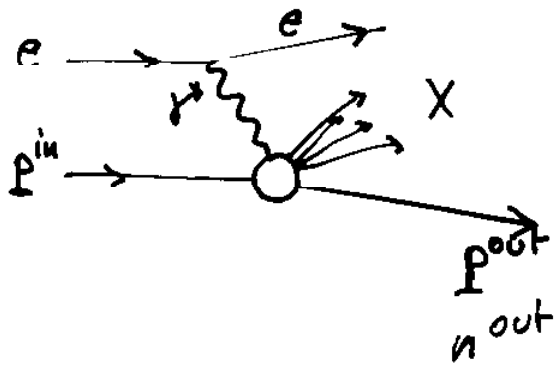
$|t|$

$\gamma^* p \to J/\psi\, p$

σ(nb) $2 < Q^2 < 40$ GeV^2



Leading baryons in γp and DIS



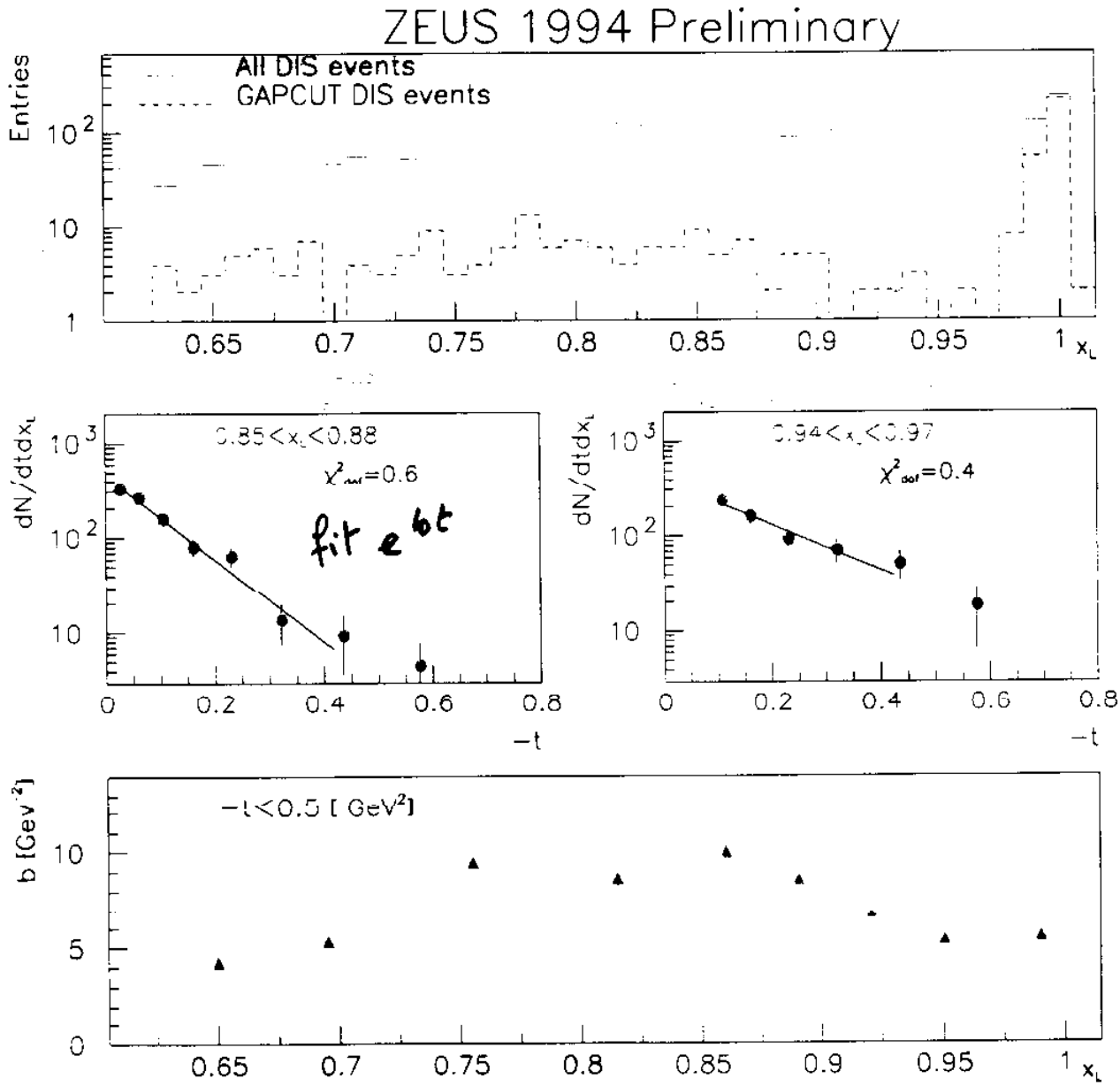
$$x_L = \frac{p_z^{out}}{p_z^{in}}$$

First look at the low x_L region for leading proton/neutron production

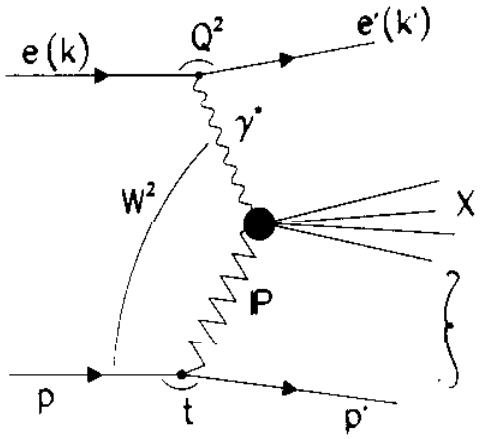
- Small fraction of events with rapidity gaps $\longrightarrow$ mainly π or Reggeon exchange processes
- b slope change with x_L .

Does data give an indication of several concurring processes ?
Can we disantangle the various contributions ?

Leading Proton Sprectrometer



Inclusive diffraction in $\gamma^* p$ and DIS



$$t = (P - P')^2$$

$$M_X^2 = (q + IP)^2$$

rapidity gap

In DIS you can define also

$$x_{I\!P} = \frac{(P-P')\cdot q}{P\cdot q} = \frac{M_X^2+Q^2-t}{W^2+Q^2-M_p^2} \qquad = 1 - x_L$$

$$\beta = \frac{Q^2}{2(P-P')\cdot q} = \frac{x}{x_{I\!P}} = \frac{Q^2}{M_X^2+Q^2-t}$$

$$\frac{d^4\sigma_{diff}}{dQ^2 d\beta dx_{I\!P} dt} = \frac{2\pi\alpha^2}{\beta Q^4}\left(1 + (1-y)^2\right) F_2^{D(4)}(Q^2, \beta, x_{I\!P}, t)$$

$$F_2^{D(3)} = \int dt\, F_2^{D(4)}$$

In ZEUS we measure inclusive diffraction using three methods:

- measure with the LPS the scattered proton.
- rapidity gaps
- the exponential lnM_X^2 distribution of non-diffractive events

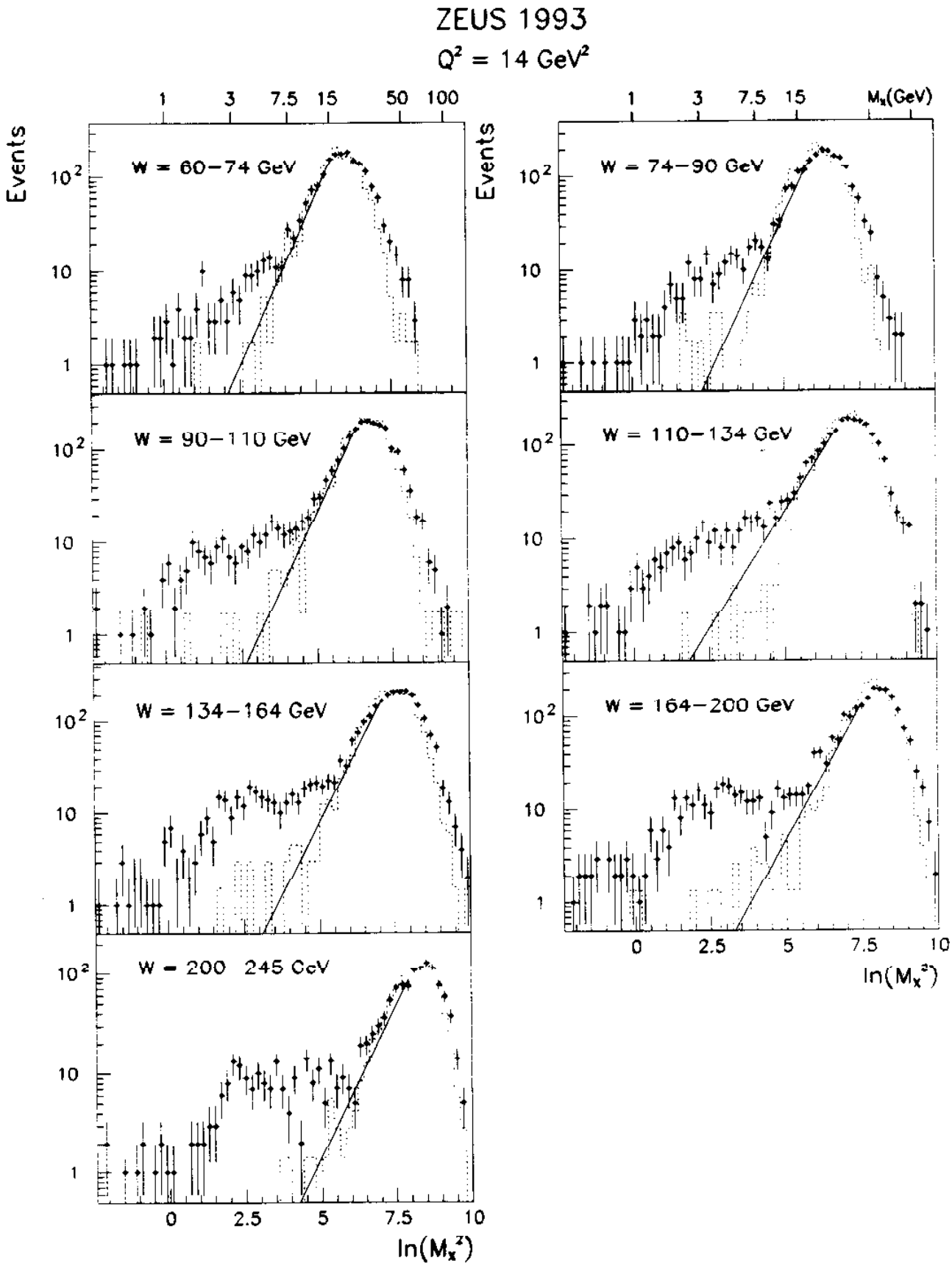
Test the soft pomeron description at HERA γp energies ?

- Data show a soft pomeron behavior in γp, but requires $I\!P I\!P I\!P$ + $I\!P I\!P I\!R$ terms for $3 < M_X < 24$ GeV

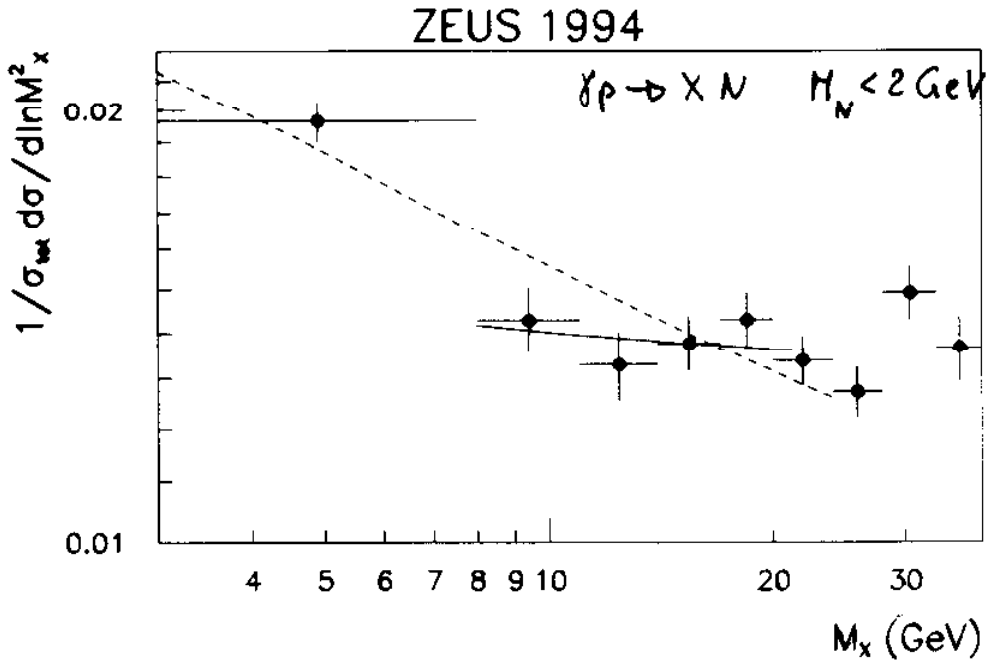
Test the soft pomeron description at higher Q^2

- The use two different methods (LPS and $ln M_X^2$) which are sensitive to slightly different processes, allow a comparative measurement
  $ln M_X^2$: $ep \to eXN$ $M_X < 4GeV$
  LPS : $ep \to eXp$ with possible π or Reggeon contribution
- Consistent values of F_2^D in the overlapping region

Is factorization a correct assumption ?
Does $\alpha_{I\!P}$ have a Q^2 dependence (transition soft $\leftrightarrow$ pQCD) ?
Can we improve our understanding of the competitive contributions to F_2^D ?
What is the best approach to the study of the Pomeron structure functions ?


ZEUS 1993
Q² = 14 GeV²
Events
W = 60−74 GeV
W = 74−90 GeV
W = 90−110 GeV
W = 110−134 GeV
W = 134−164 GeV
W = 164−200 GeV
W = 200 245 GeV
1 3 7.5 15 50 100
1 3 7.5 15 Mx(GeV)
10²
10
1
0 2.5 5 7.5 10
ln(Mx²)

Photon dissociation in γp



Analysis:

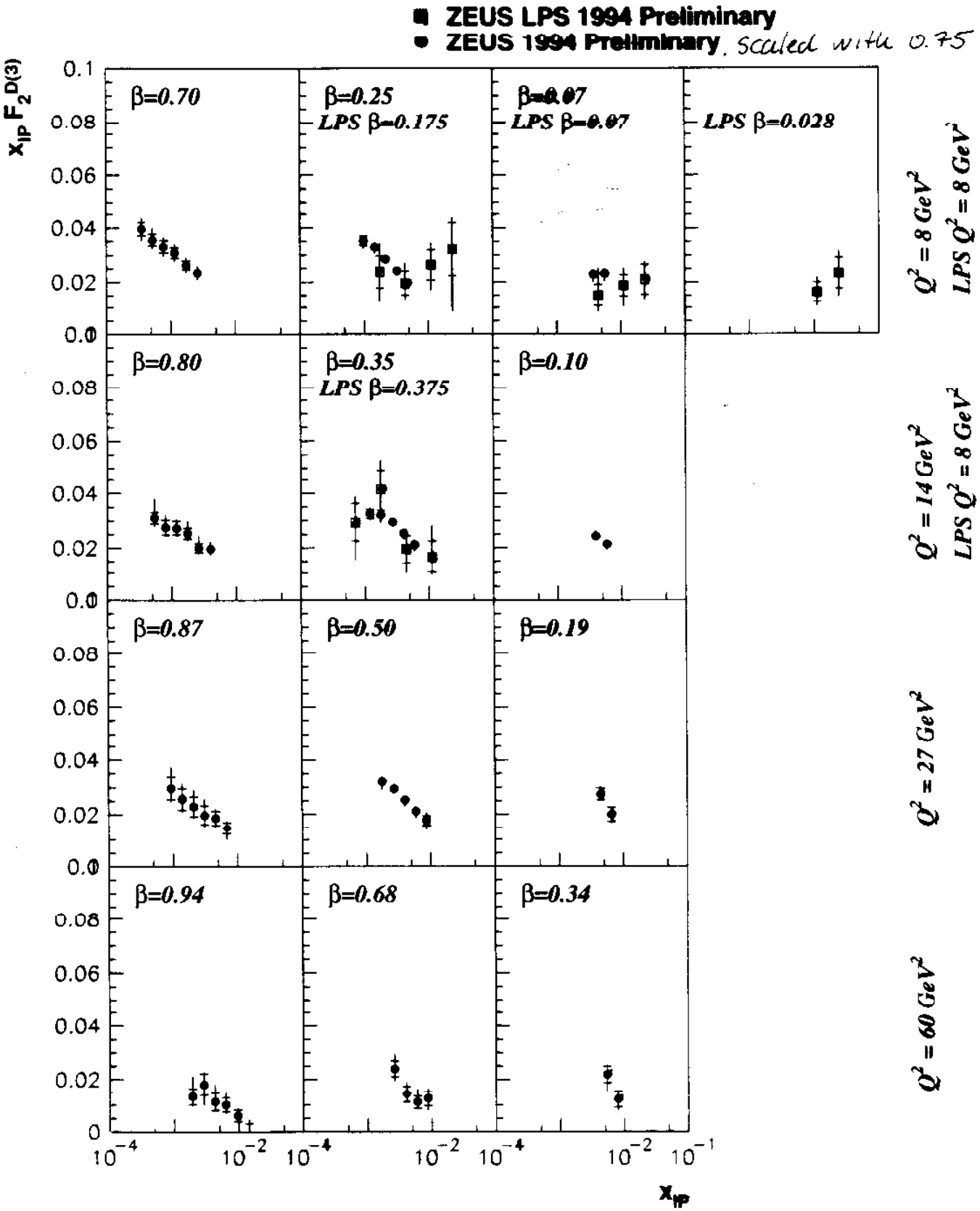
- Selection based on a rapidity gap $4.3 < \eta < 5.8$
- MC subtraction of non diffractive contribution

Results:

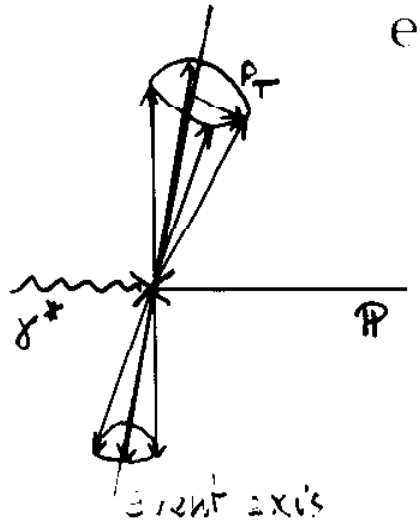
- fit $\mathbb{P}\mathbb{P}\mathbb{P}$ for $8 < M_X < 24$ GeV

$$\bar{\alpha}_{\mathbb{P}}(0) = 1.12 \pm 0.04 \pm 0.08$$

- need for $\mathbb{P}\mathbb{P}\mathbb{P} + \mathbb{P}\mathbb{P}\mathbb{R}$ terms for $3 < M_X < 24$ GeV


ZEUS LPS 1994 Preliminary
ZEUS 1994 Preliminary, scaled with 0.75
$x_{IP} F_2^{D(3)}$
β=0.70
β=0.25
LPS β=0.175
β=0.07
LPS β=0.07
LPS β=0.028
β=0.80
β=0.35
LPS β=0.375
β=0.10
β=0.87
β=0.50
β=0.19
β=0.94
β=0.68
β=0.34
$Q^2 = 8\ GeV^2$
LPS $Q^2 = 8\ GeV^2$
$Q^2 = 14\ GeV^2$
LPS $Q^2 = 8\ GeV^2$
$Q^2 = 27\ GeV^2$
$Q^2 = 60\ GeV^2$
x_{IP}

Event shape properties of diffractive events



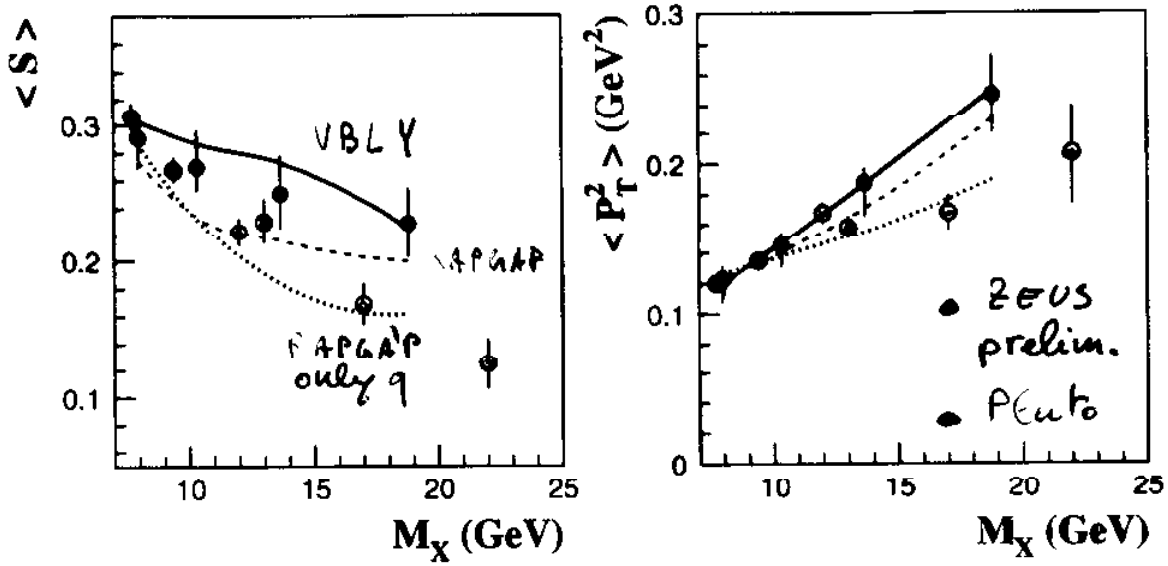
$$S = \frac{3}{2} \min_{\vec{n}} \frac{\sum_i p_{T_i}^2}{\sum_i p_i}$$

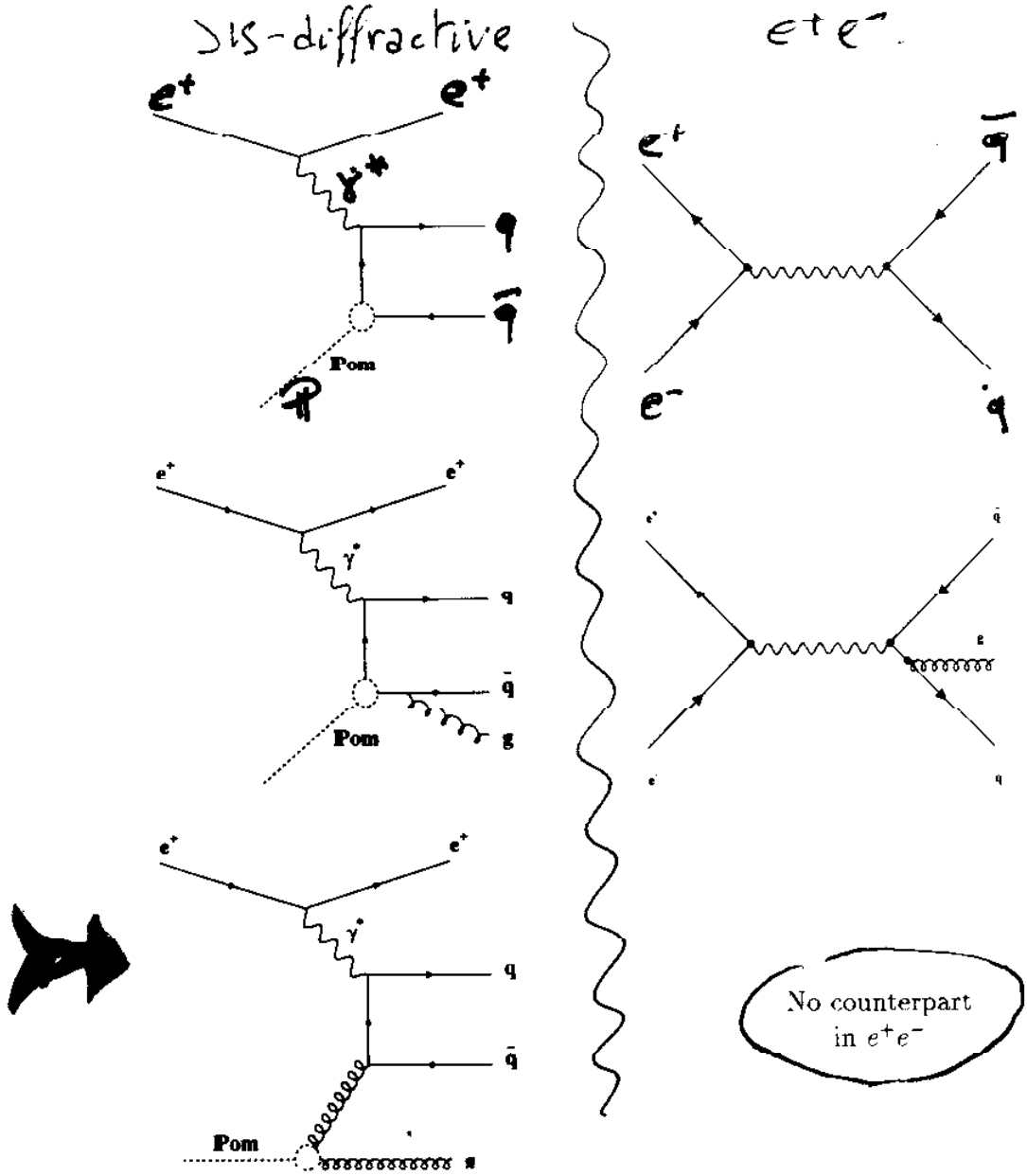
$$\begin{cases} S = 0 & \text{2 jets event} \\ S = 1 & \text{spherical event} \end{cases}$$

How do diffractive events compare with e^+e^- processes ?

- At high masses higher values of Sphericity are observed w.r.t. e^+e^-
- Evidence for an extra diagram in the diffractive processes

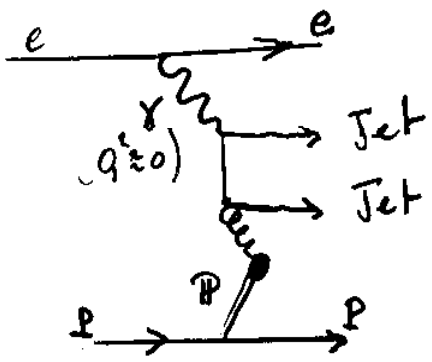
Can we distinguish the different models ?
Are there specific distributions sensitive to the nature of the Pomeron ?

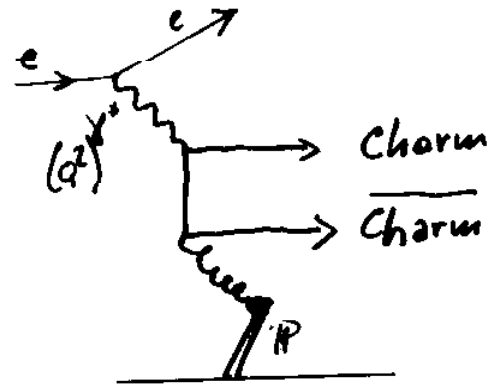

< S >
0.3
0.2
0.1
VBLY
RAPGAP
RAPGAP only q
10
15
20
25
M_X (GeV)
< P_T^2 > (GeV^2)
0.3
0.2
0.1
0
ZEUS prelim.
PLUTO
10
15
20
25
M_X (GeV)


DIS-diffractive
e+ e-
e+
e+
γ*
q
q̄
Pom
e+
e-
q̄
q
e+
e+
γ*
q
q̄
g
Pom
e+
e+
γ*
q
q̄
Pom
No counterpart in e+e-

Diffraction - J. Terron

Jets and HF in diffractive events





Which is the Pomeron structure?

- QCD fits to $\sigma^{diff}_{2\text{-jet}}$ and $F_2^{D(3)}$ → large gluon contrib.
- New results on diffractive D^* production in DIS

Can we distinguish **the different models** ?
Are there specific distributions **sensitive to the nature** of the Pomeron ?

Comparison of the Fits with ZEUS Dijet Cross Sections in Diffractive Photoproduction

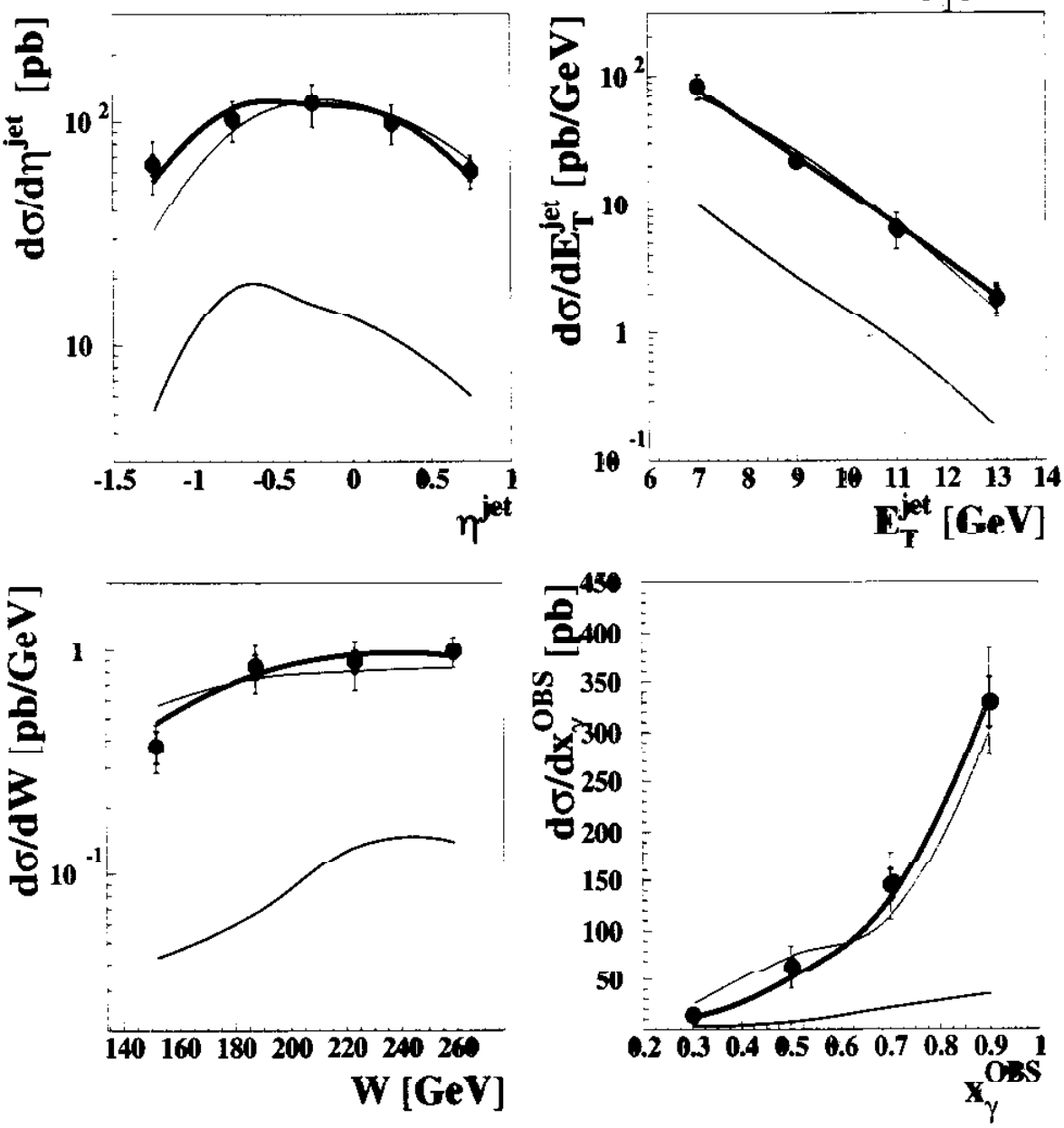
Cone algorithm

$\eta_{max} < 1.8$

$-1.5 < \eta^{jet} < 1.8$

$E_T^{jet} > 6$ GeV

ZEUS 1994 Preliminary



	$\beta f_{i/I\!P}(\beta, Q_0^2)$	$\beta f_{g/I\!P}(\beta, Q_0^2)$	C_g	Zeus Data
	$a\beta(1-\beta)+c(1-\beta)^2$			
	$a\beta(1-\beta)+c(1-\beta)^2$	$b\beta(1-\beta)$	0.87	E. Scale 3%
	$a\beta(1-\beta)$	$b\beta(1-\beta)$	0.87	Stat. errors
	$a\beta(1-\beta)$	$b\beta^8(1-\beta)^{0.3}$	0.69	Syst. errors

Precise F_2 measurements at HERA

F_2 and g(x) rises at low x

Low Q^2

Study Transition from γp to DIS: where does pQCD begin to dominate ?

High Q^2

Where does the standard model break down ?

Structure functions at low Q^2

$$\frac{d^2\sigma}{dx\, dQ^2} = \frac{2\pi\alpha^2}{xQ^4}\left\{Y_+ F_2(x,Q^2) - y^2 F_L((x,Q^2)\right\}$$

where

$$Y_\pm = 1 \pm (1-y)^2$$

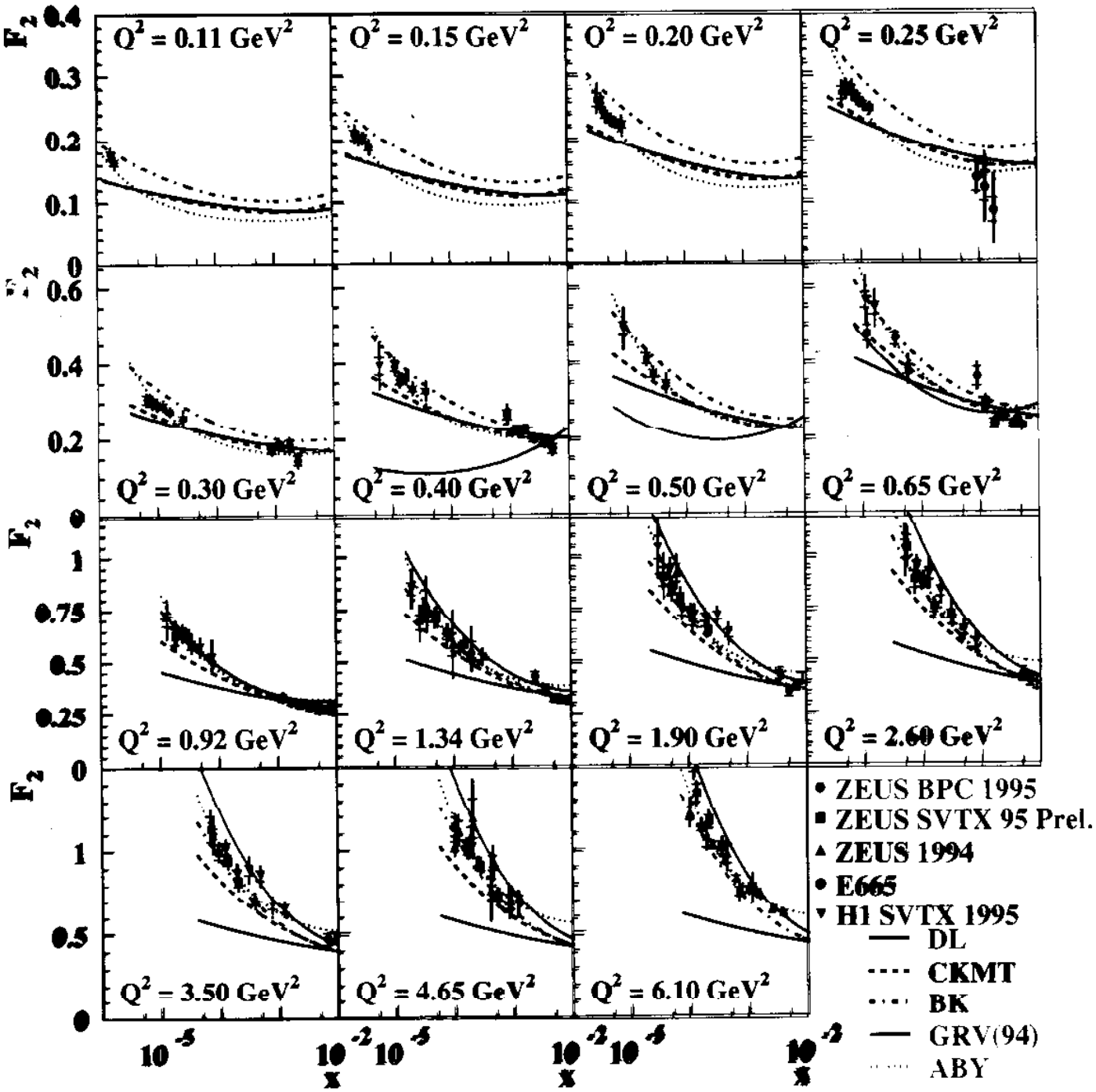
Measure F_2 and $\sigma_{tot}^{\gamma^* p} = (4\pi^2\alpha/Q^2)F_2$ making use of Shifted Vertex and Beam Pipe Calorimeter (BPC) data

Down to which Q^2 pQCD works ?

- A very careful analysis is performed around the transition region from soft to DIS interactions.

Which variables are relevant for the transition from γp to pQCD (Q^2, W , x ..) ?
Where have higher twists disappeared ?

ZEUS 1995


F_2
Q^2 = 0.11 GeV^2
Q^2 = 0.15 GeV^2
Q^2 = 0.20 GeV^2
Q^2 = 0.25 GeV^2
Q^2 = 0.30 GeV^2
Q^2 = 0.40 GeV^2
Q^2 = 0.50 GeV^2
Q^2 = 0.65 GeV^2
Q^2 = 0.92 GeV^2
Q^2 = 1.34 GeV^2
Q^2 = 1.90 GeV^2
Q^2 = 2.60 GeV^2
Q^2 = 3.50 GeV^2
Q^2 = 4.65 GeV^2
Q^2 = 6.10 GeV^2
x
ZEUS BPC 1995
ZEUS SVTX 95 Prel.
ZEUS 1994
E665
H1 SVTX 1995
DL
CKMT
BK
GRV(94)
ABY

Structure of the proton - M. Botje

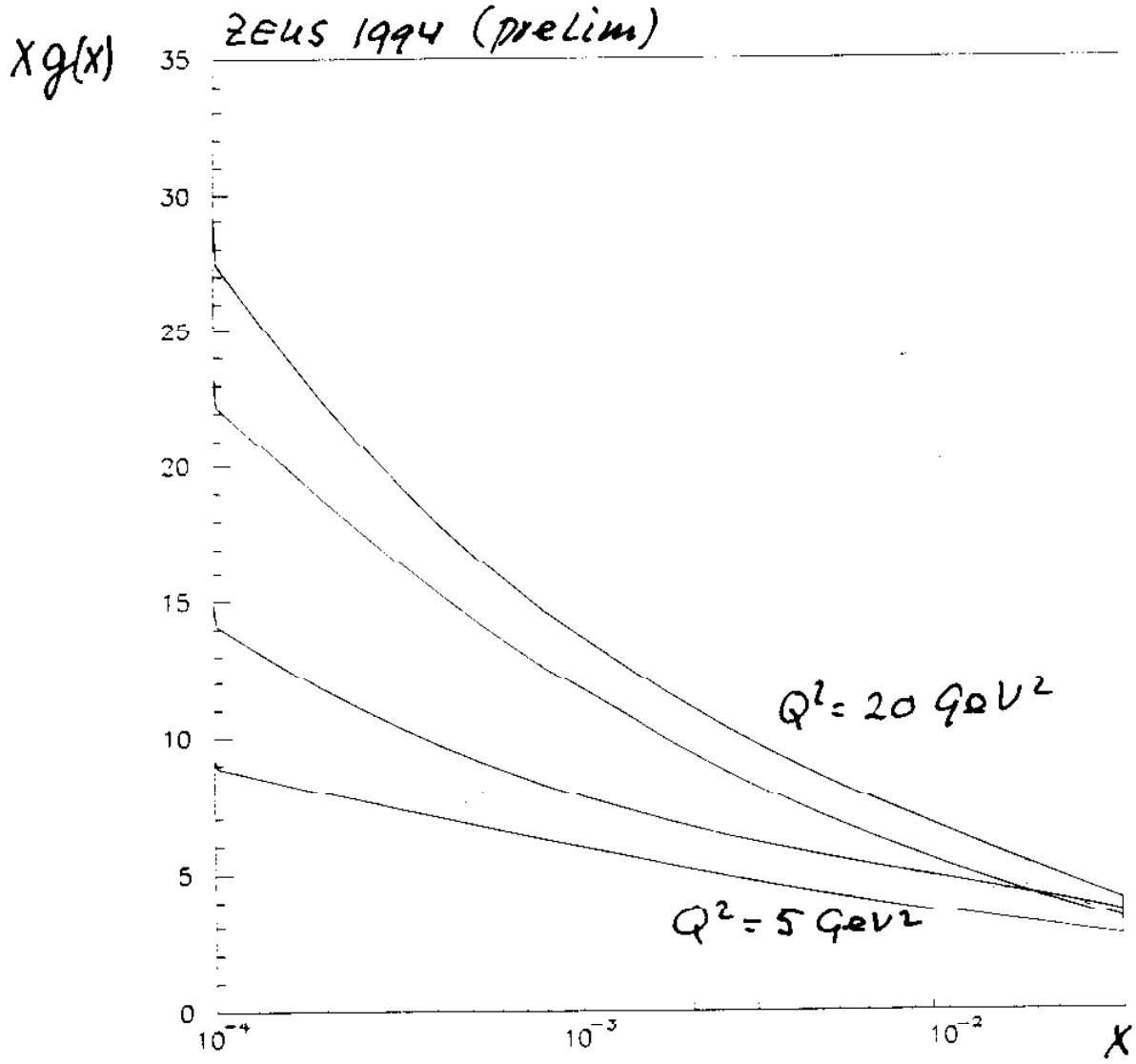
QCD fits and gluon determination

- Improved analysis and error treatment.
- Good agreement with F_2^{charm} measurements using the measured gluon density

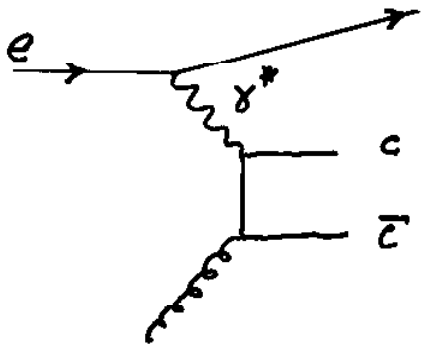
How reliable are the extrapolation to high x high Q^2 region ?

□ $xg(x)$ at $Q^2 = 5$ and $20\ GeV^2$

▭ } total error band (incl. $\Delta\alpha_s$).



F_2^{charm} measurements

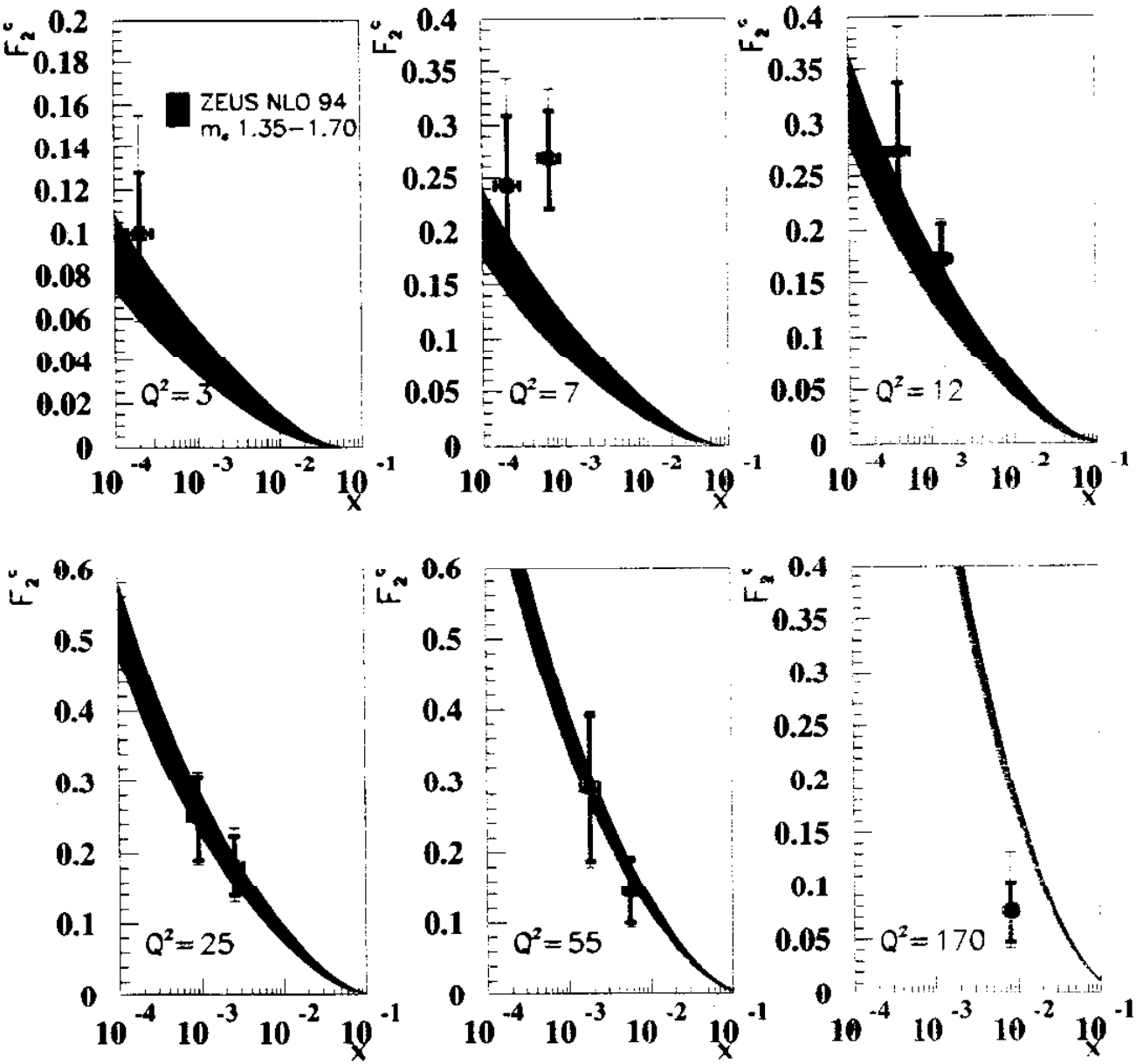


Comparison with NLO pQCD calculations

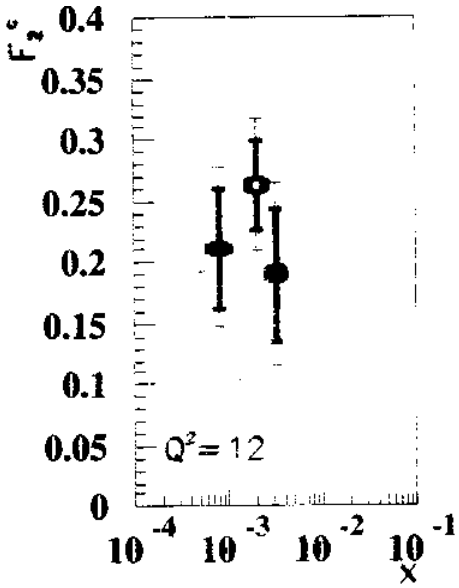
- Agreement of NLO pQCD (3 flavour) when using gluon structure function compatible with HERA F_2 measurements

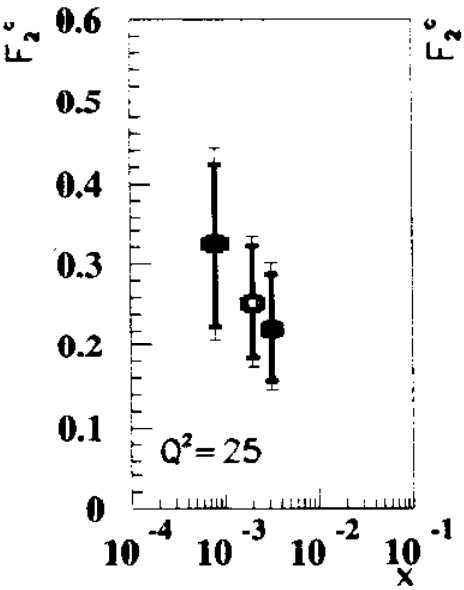
Is there a *charm component* in the proton ?
Can we isolate it ?

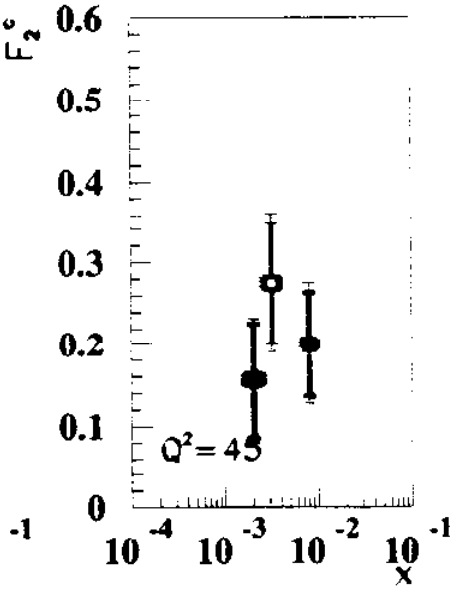
PRELIMINARY ZEUS 95



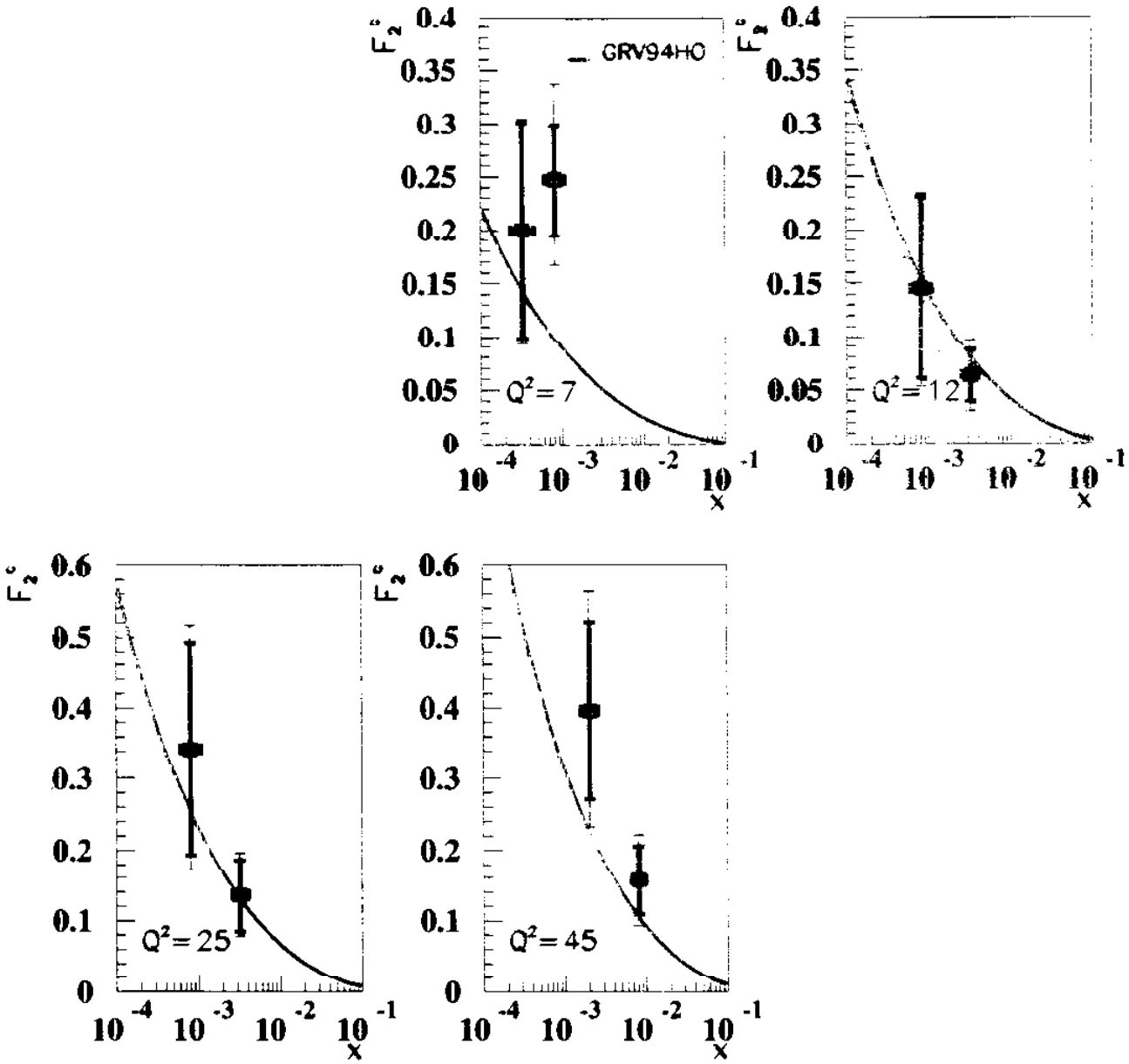
H1 94


F_2^c
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
$Q^2 = 12$
10^{-4} 10^{-3} 10^{-2} 10^{-1}
x


F_2^c
0.6
0.5
0.4
0.3
0.2
0.1
0
$Q^2 = 25$
10^{-4} 10^{-3} 10^{-2} 10^{-1}
x

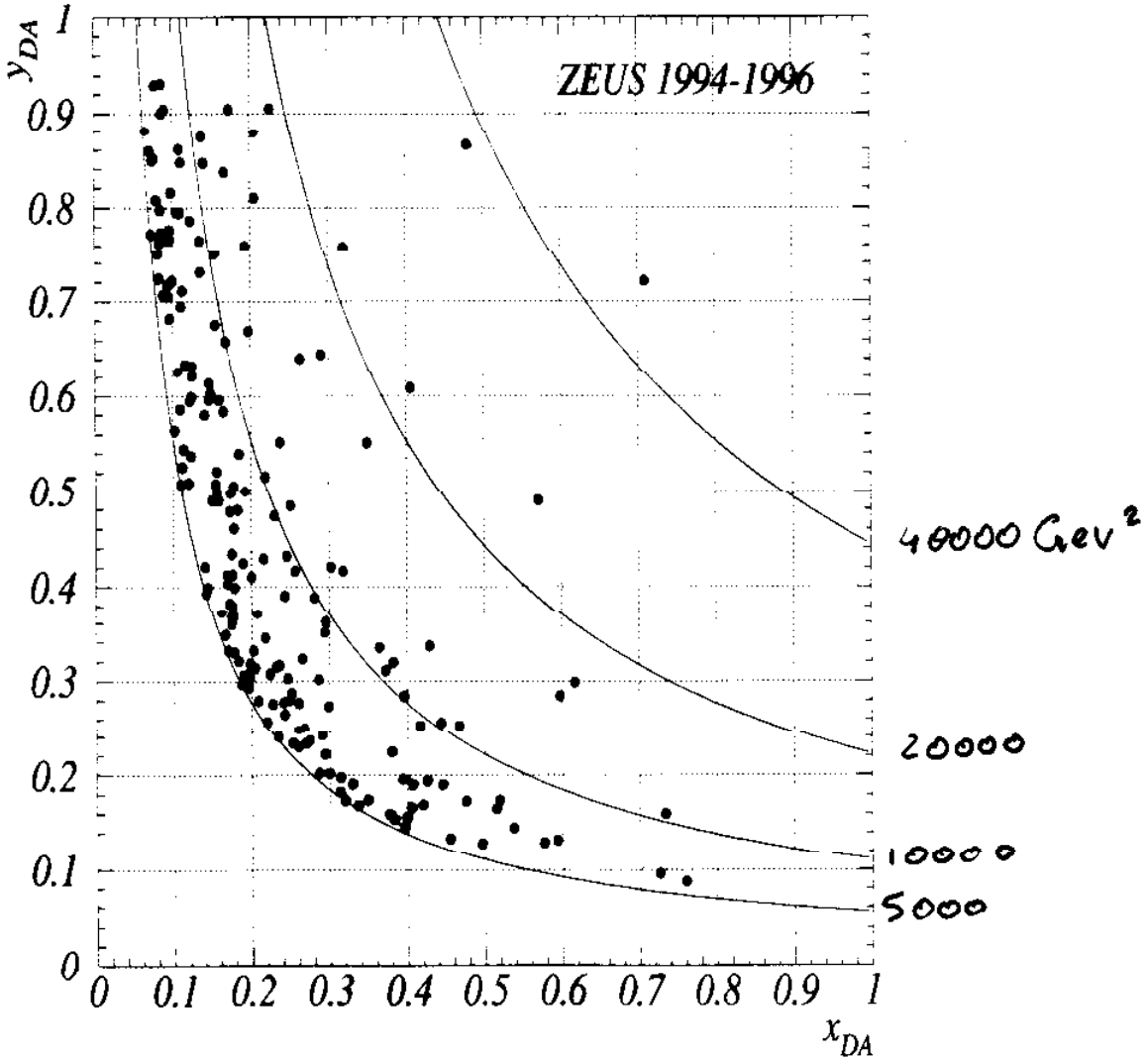

F_2^c
0.6
0.5
0.4
0.3
0.2
0.1
0
$Q^2 = 45$
10^{-4} 10^{-3} 10^{-2} 10^{-1}
x

ZEUS 94 Preliminary



High x events

Final sample of 191 events. Curves indicate $Q^2_{\mathrm{DA}} = 5000$, 10000, 20000, 40000 GeV^2.



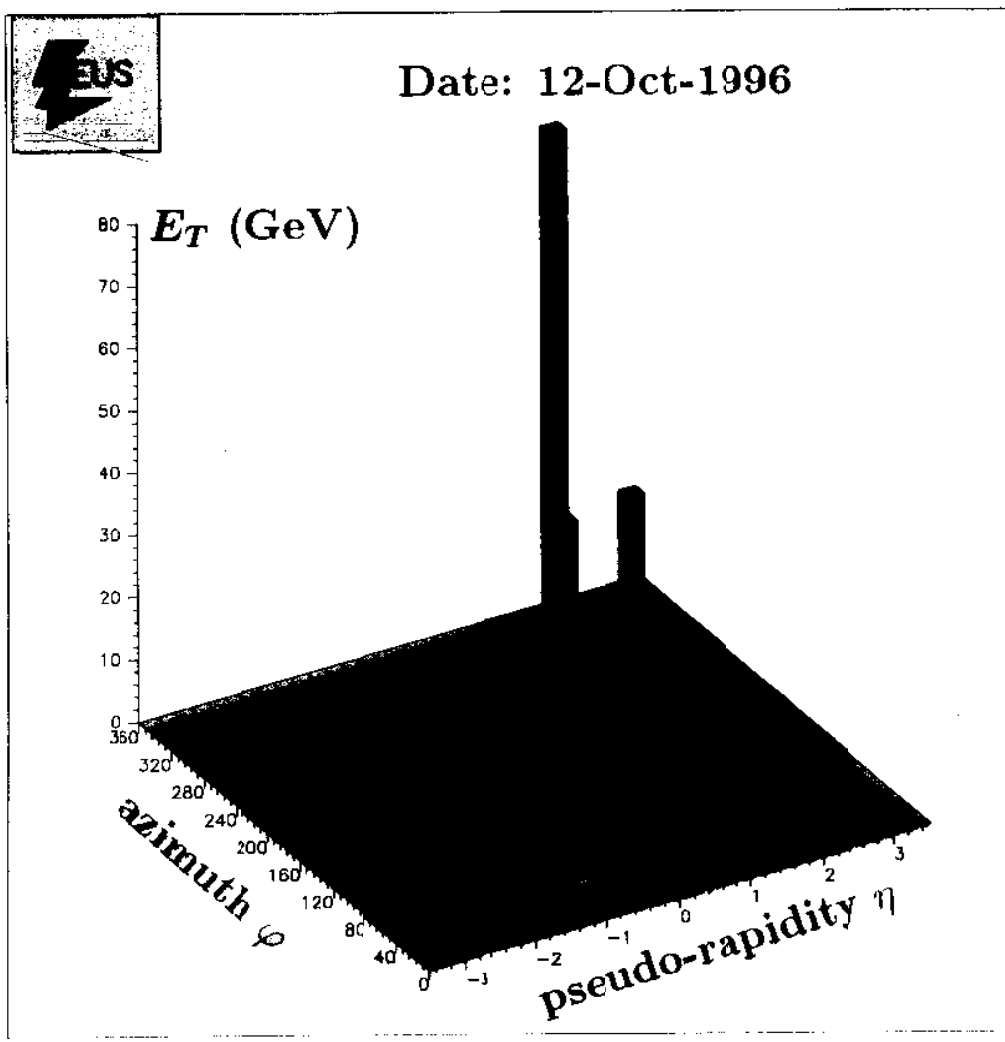
$E_t = 204\ GeV \quad E - p_Z = 50.2\ GeV \quad \gamma = 38.6^\circ$

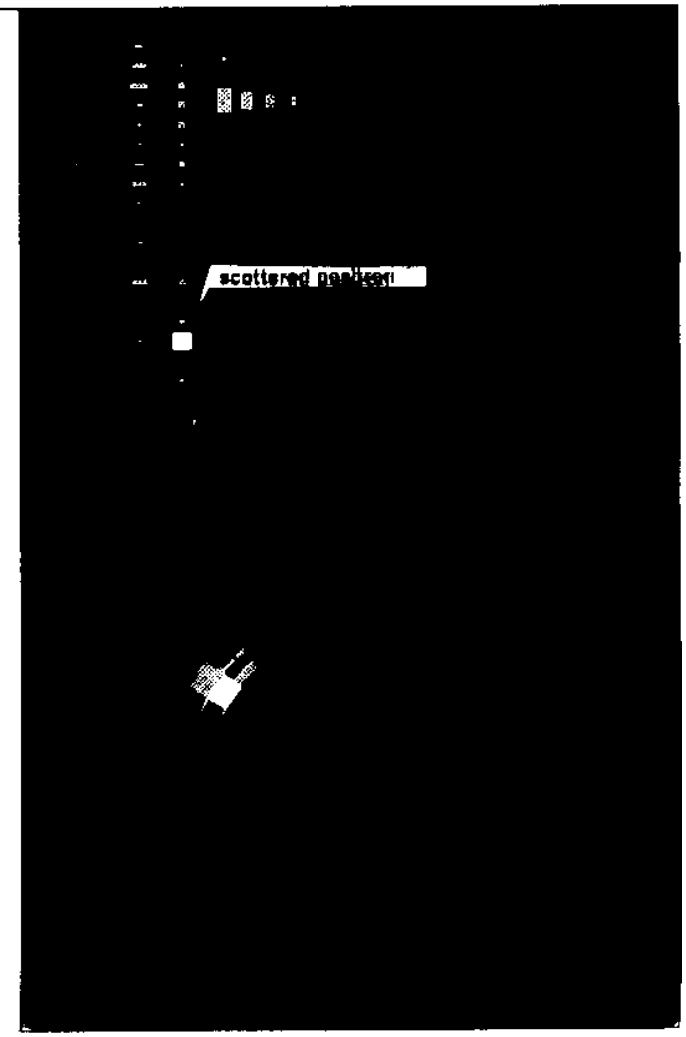
$p_t = 2.2\ GeV \quad E'_e = 380\ GeV \quad \theta_e = 15.4^\circ$

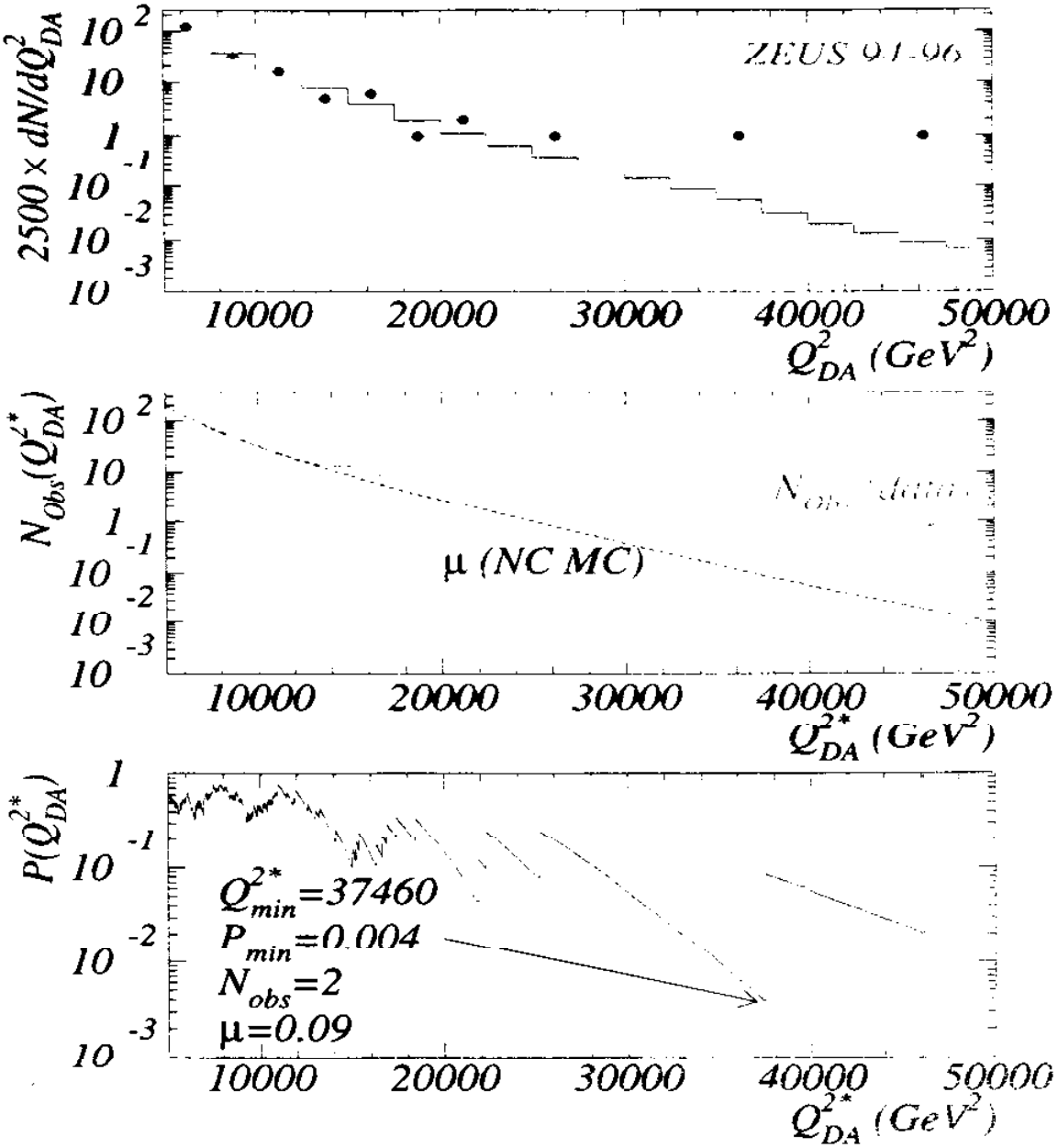
$x_{DA} = 0.709 \pm 0.034 \qquad x_e = 0.605 \pm 0.060$

$y_{DA} = 0.721 \pm 0.008 \qquad y_e = 0.752 \pm 0.021$

$Q^2_{DA} = 46100 \pm 1600\ GeV^2 \qquad Q^2_e = 41000 \pm 3000\ GeV^2$

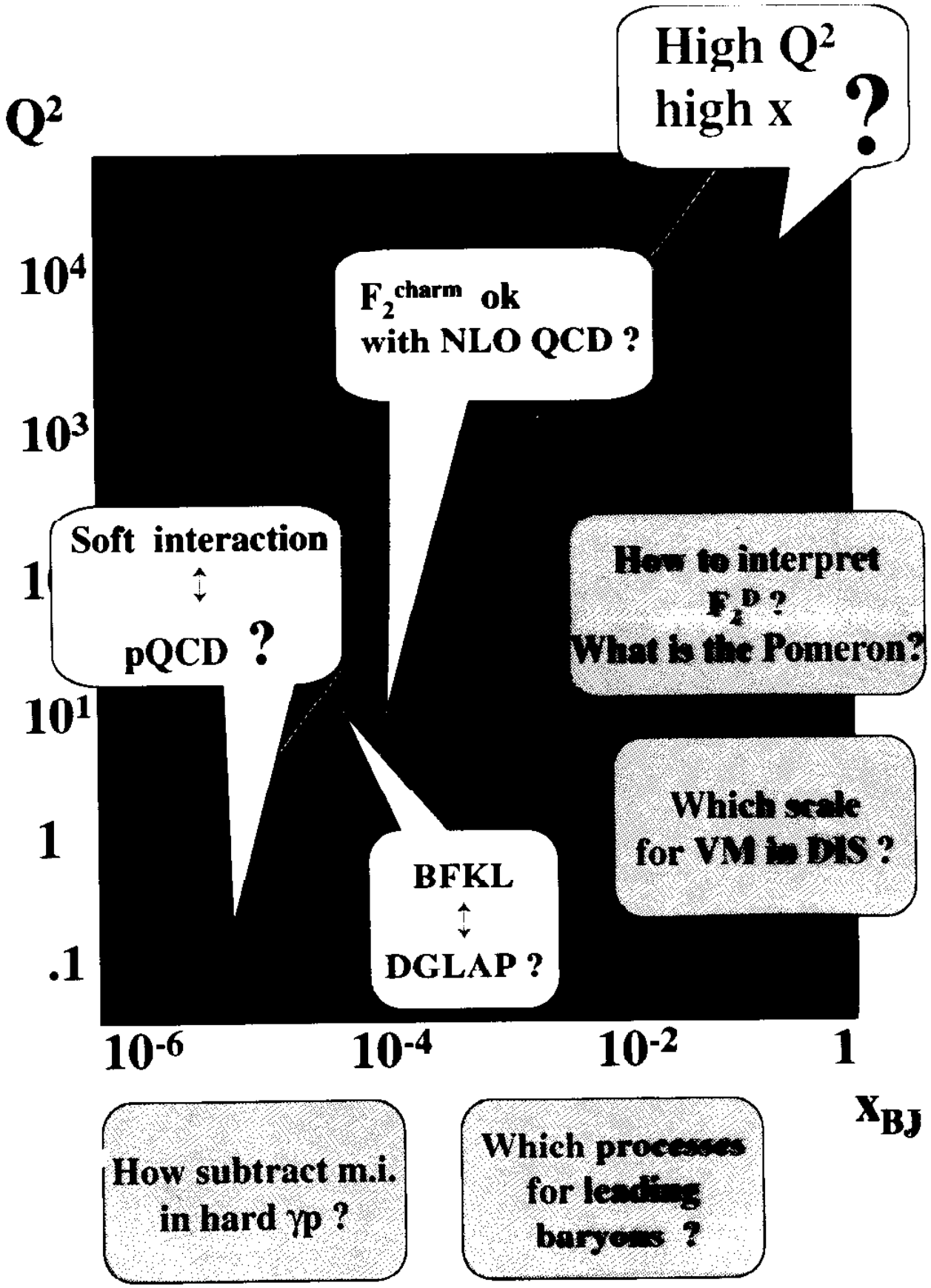






$$N_{obs} = \int_{Q^{2*}_{\mathrm{DA}}}^{s} dQ^2_{\mathrm{DA}} dN/dQ^2_{\mathrm{DA}}$$

$$\mathcal{P}(Q^{2*}_{\mathrm{DA}}) = \sum_{n=N_{obs}}^{\infty} e^{-\mu} \frac{\mu^n}{n!}$$


High Q^2 high x ?
Q^2
10^4
10^3
10^1
1
.1
F_2^{charm} ok with NLO QCD ?
Soft interaction ↕ pQCD ?
How to interpret F_2^D ? What is the Pomeron?
Which scale for VM in DIS ?
BFKL ↕ DGLAP ?
10^{-6}
10^{-4}
10^{-2}
1
x_{BJ}
How subtract m.i. in hard γp ?
Which processes for leading baryons ?