DIS97-Workshop
April 14-18 1997
Chicago

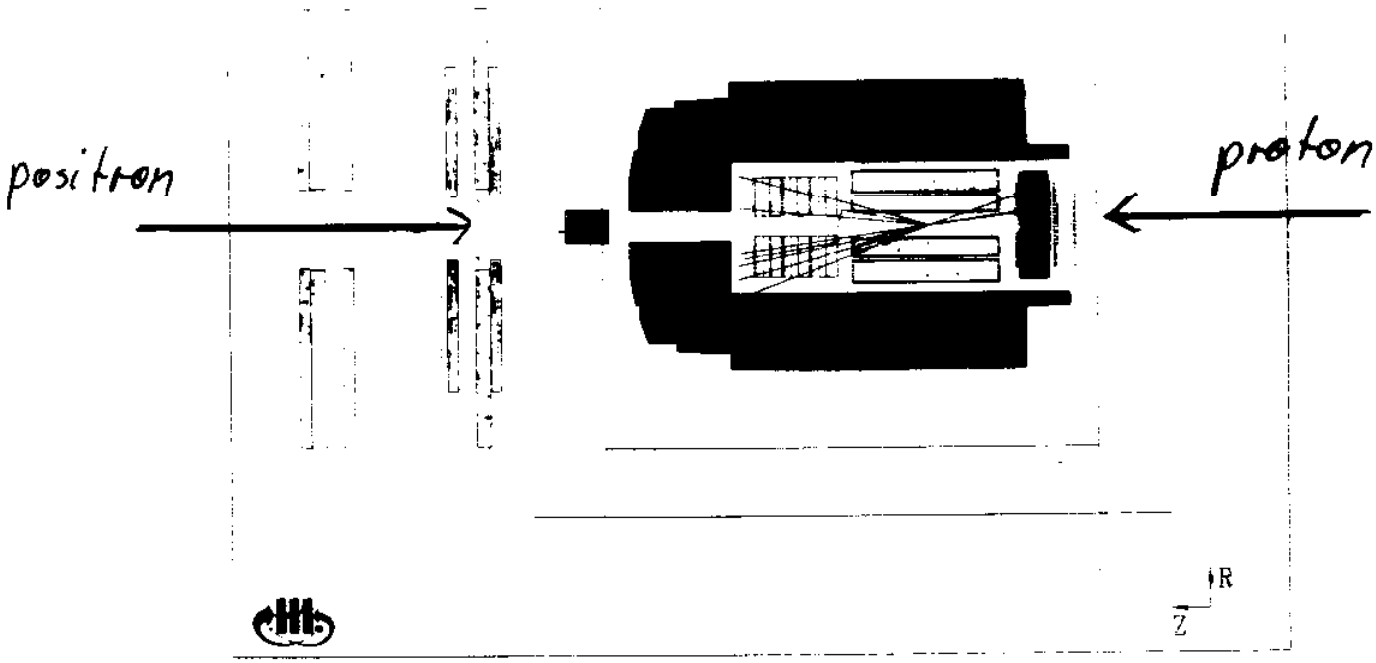
Measurement and Interpretation of $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$

M. Dirkmann; Universität Dortmund
for the H1 Collaboration

- Brief description of the H1-detector
- Kinematics of diffraction
- Measurement of $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$
- Factorisation breaking
- Measurement of $\tilde{F}_2^D(\beta, Q^2)$
- QCD-analysis of $\tilde{F}_2^D(\beta, Q^2)$
- Summary and Conclusions

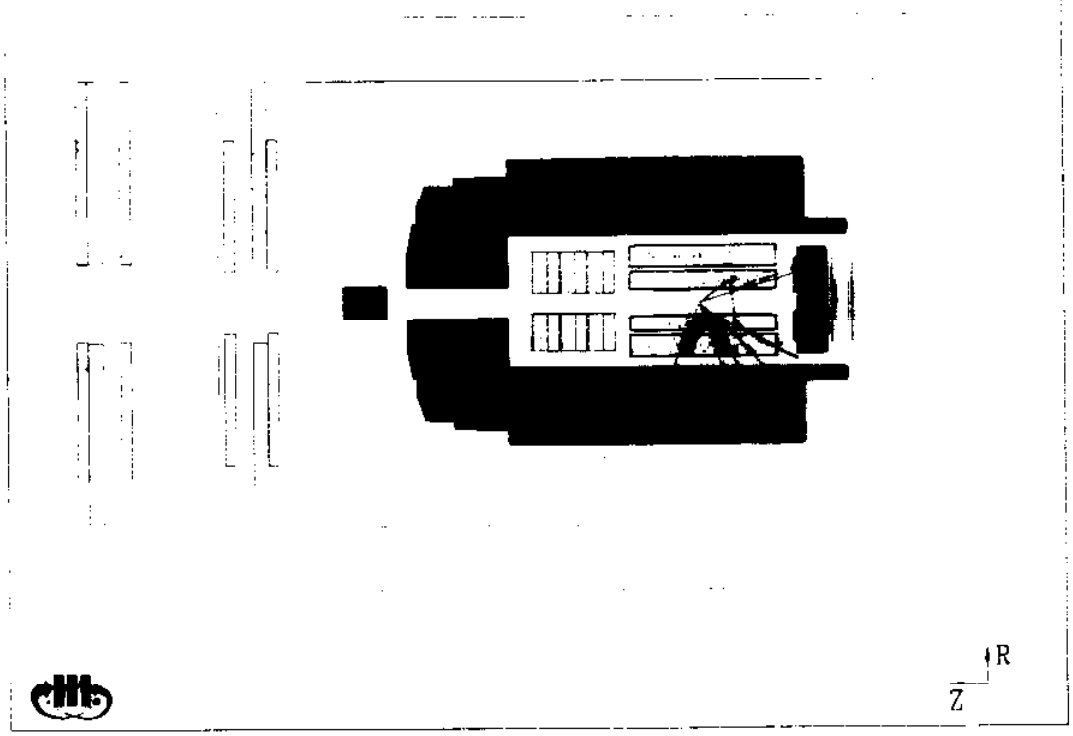
Run 64901 Event 33275 Class 3 10 11 26 28 Date 13/07/1994

"standard"-DIS



Run 63718 Event 44072 Class 3 10 11 16 17 26 Date 13/07/1994

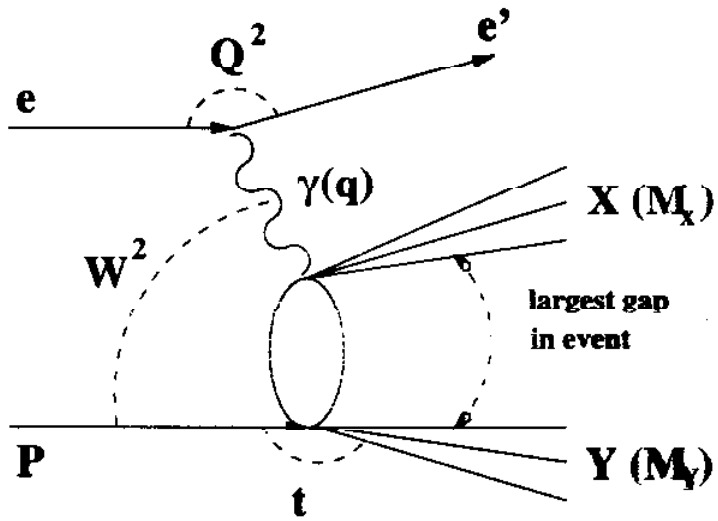
diffractive



Diffraction at HERA

"standard" kinematic variables for DIS:

$$Q^2 = -q^2 \;\; ; \;\; x_{Bj} = \frac{Q^2}{2 P \cdot q} \;\; ; \;\; y = \frac{q \cdot P}{e \cdot P} \;\; ; \;\; W^2 = (q+P)^2$$



additional variables in terms of systems X and Y:

$$\beta = \frac{Q^2}{2q\cdot(P-Y)} \approx \frac{Q^2}{Q^2+M_X^2}$$

$$x_{I\!P} = \frac{q\cdot(P-Y)}{q\cdot P} \approx \frac{Q^2+W^2}{Q^2+M_X^2}$$

$$\Rightarrow x_{Bj} = \beta \cdot x_{I\!P}$$

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definitions are applicable to ANY type of process

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interpretation in terms of exchange :

$x_{I\!P}$ momentum fraction of exchange particle

β momentum fraction of parton

Definition of Cross Section

diffractive events are selected by requiring:

a gap in pseudorapidity ($\eta = -\ln\tan(\frac{\Theta}{2})$)
between 7.5 and 3.4 ($< 3.5°$)

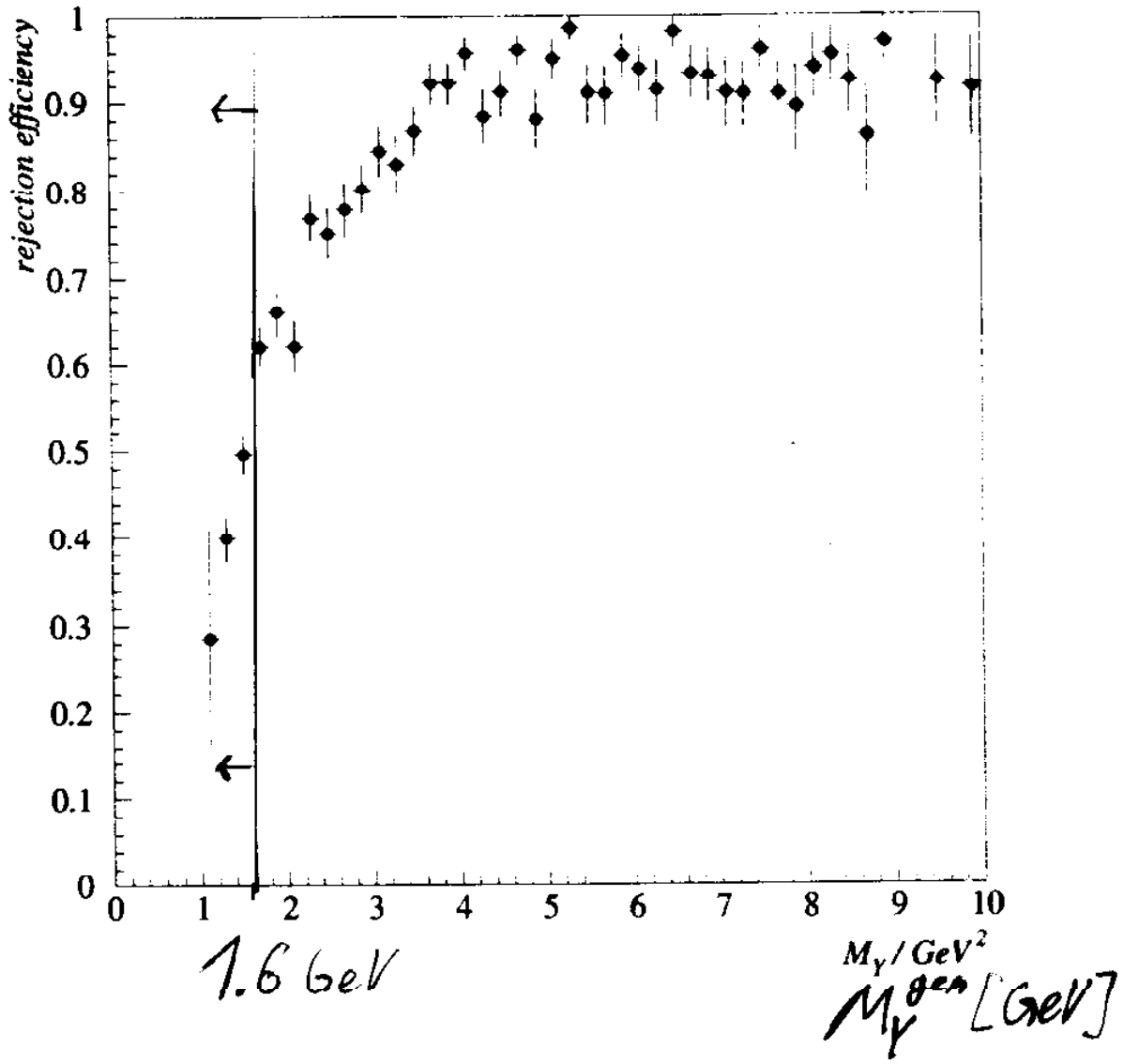
$\Rightarrow$ insures that system X is completely contained

$\Rightarrow$ measured cross section with

- $x_{I\!P} < 0.05$ (Y carries >95% of the proton momentum)
- $M_Y < 1.6\,\mathrm{GeV}$ ($\rightarrow$ see plot)

$\Rightarrow$ guided by data
$\Rightarrow$ well defined on hadron level
$\Rightarrow$ applicable to ANY kind of process

Rejection Efficiency for Proton Dissociation



cross checked with various proton dissociation MCs

Data and MC

selection of data:

- selection of events with positrons ($E > 8\,\mathrm{GeV}$) and no signals in forward detectors
- additional cuts for rejection of background and to secure good resolution

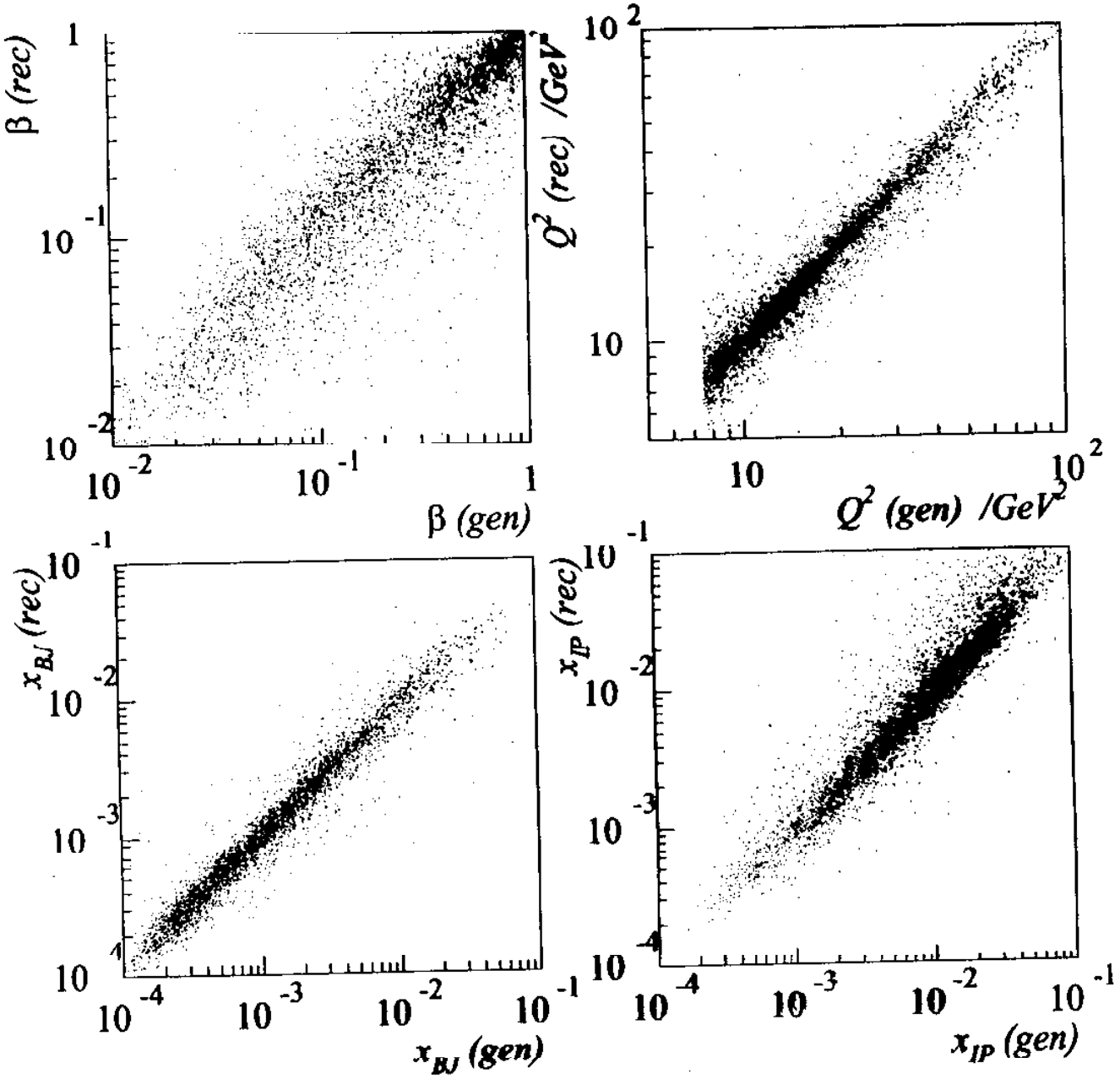
correcting data for losses and smearing with MC mixture

- diffractive process : RapGap $I\!P$
- "standard"-DIS : DJANGO
- charge exchange : RapGap π^+
- vector mesons : DIFFVM

(DJANGO and RapGap π^+ are modelling the high $x_{I\!P}$ region
the measurement is insensitive to whether
DJANGO or RapGap π^+ is used)

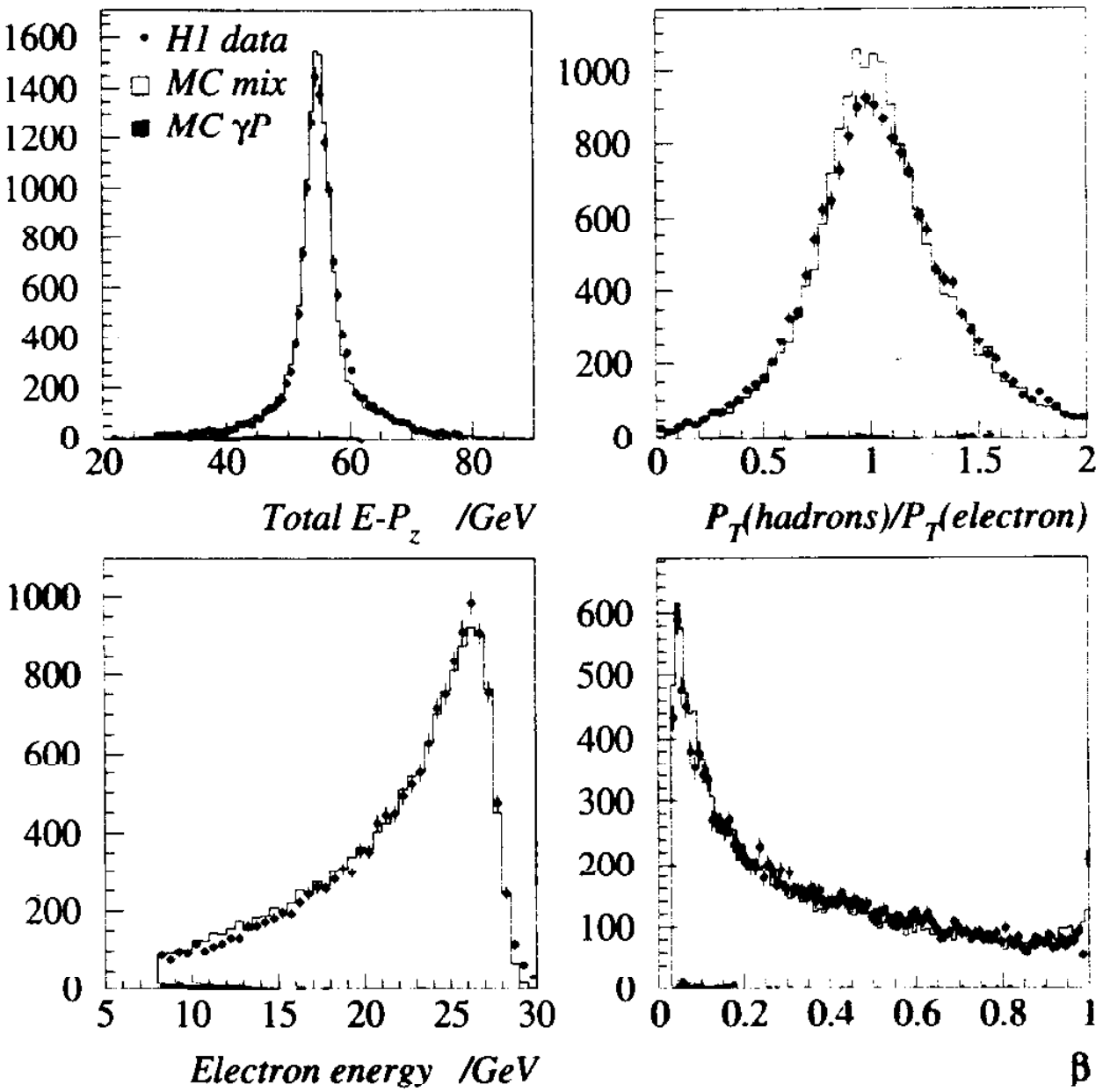
$\rightarrow$ controlplots

Reconstruction of Kinematic Quatities (from RAPGAP MC)



vrew

Control Plots



Diffractive Structurefunction $F_2^{D(3)}(x_{\mathbb{P}}, \beta, Q^2)$

following Ingelman and Schlein

$$\frac{d^4\sigma^D_{ep\to e'XY}}{d\beta dQ^2 dx_{\mathbb{P}} dt} = \frac{4\pi\alpha^2}{\beta Q^4}(1 - y + \frac{y^2}{2(1+R)}) \cdot F_2^{D(4)}(Q^2, \beta, x_{\mathbb{P}}, t)$$

- integration over $|t_{min}| < |t| < 1\,\text{GeV}^2$
- set $R = 0$

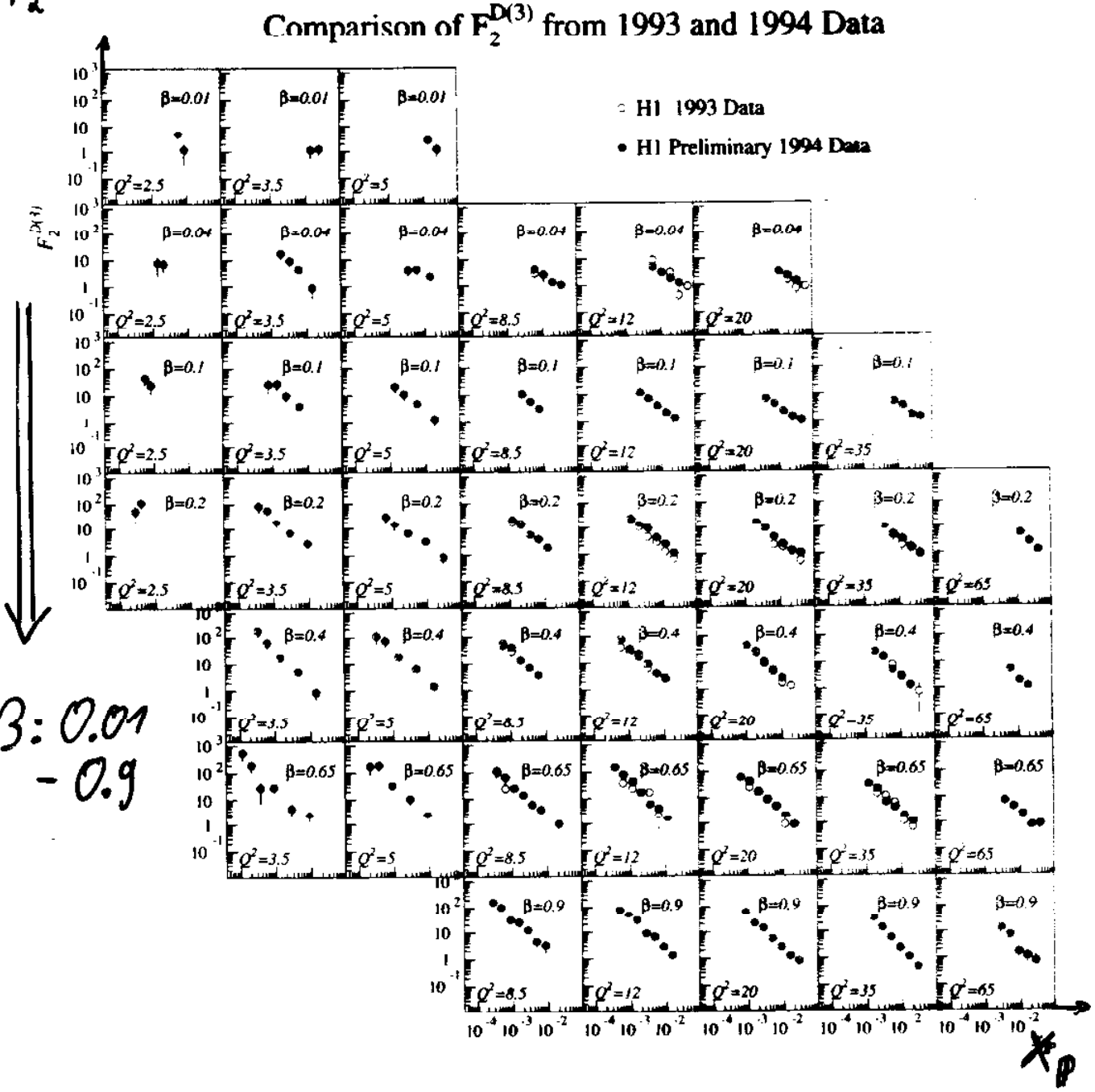
$$\frac{d^3\sigma^D_{ep\to e'XY}}{d\beta dQ^2 dx_{\mathbb{P}}} = \frac{4\pi\alpha^2}{\beta Q^4}(1 - y + \frac{y^2}{2}) \cdot F_2^{D(3)}(Q^2, \beta, x_{\mathbb{P}})$$

kinematic range:

$2.5 <$	Q^2	$< 65\,\text{GeV}^2$
$0.01 <$	β	< 0.9
$0.0001 <$	$x_{\mathbb{P}}$	< 0.05

Measurement of $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$

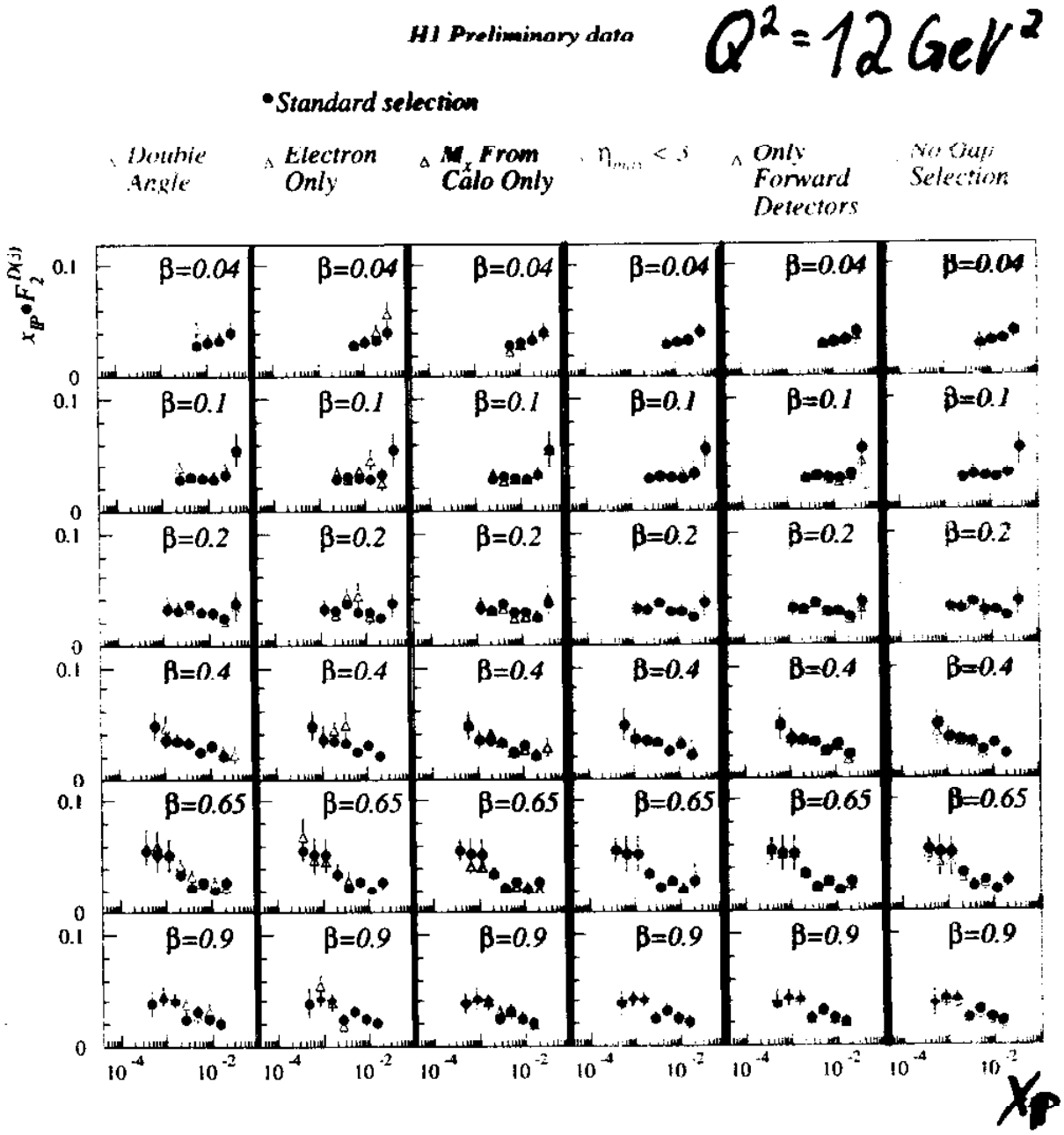
$F_2^{D(3)}$



β: 0.01 - 0.9

Q^2: 2.5 - 65 GeV^2

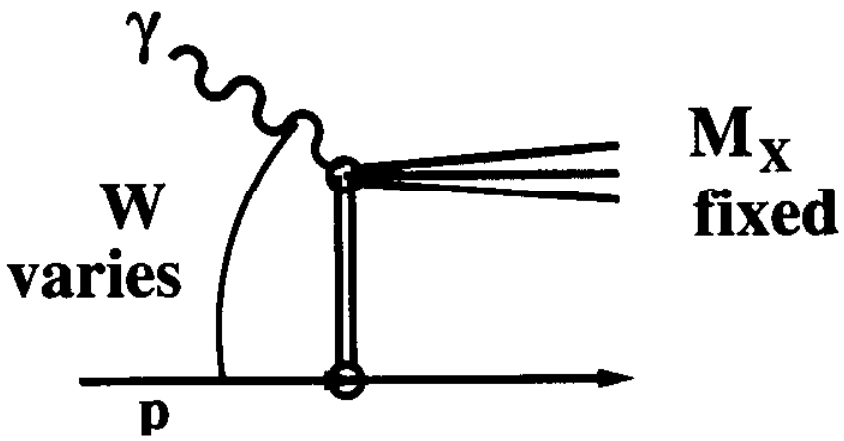
Cross Check



- different selection and reconstruction methods
- correction to defined cross section

$\Rightarrow$ results unchanged

simple Regge picture



$$F_2^{D(3)}(x_{I\!P}, \beta, Q^2) \;-\; f_{I\!P/P}(x_{I\!P}) \cdot \tilde{F}_2^D(\beta, Q^2)$$

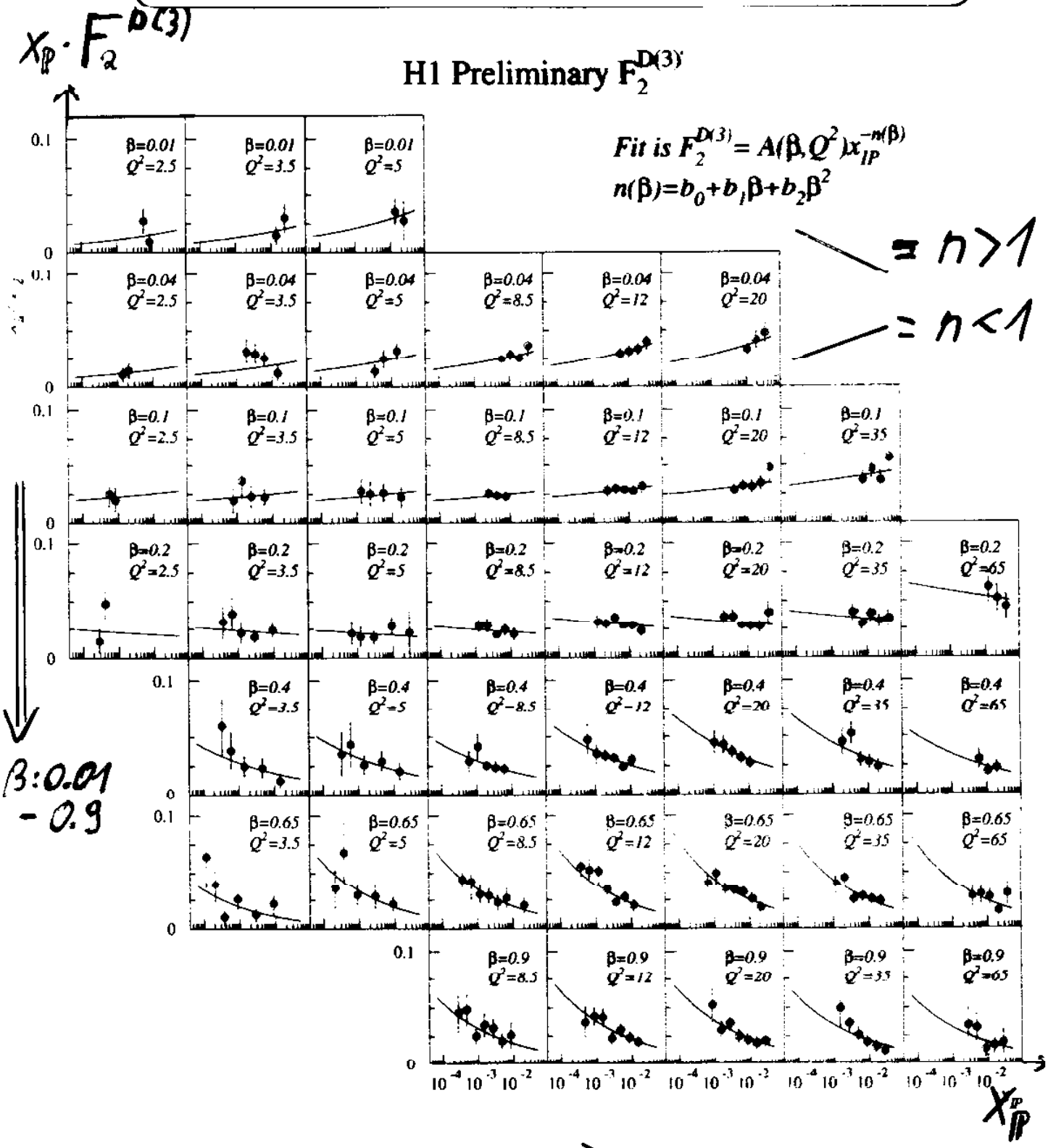
with $\quad f_{I\!P/P} \propto \dfrac{1}{x_{I\!P}^n} = \dfrac{1}{x_{I\!P}^{2\alpha(t)-1}}$

to test factorisation

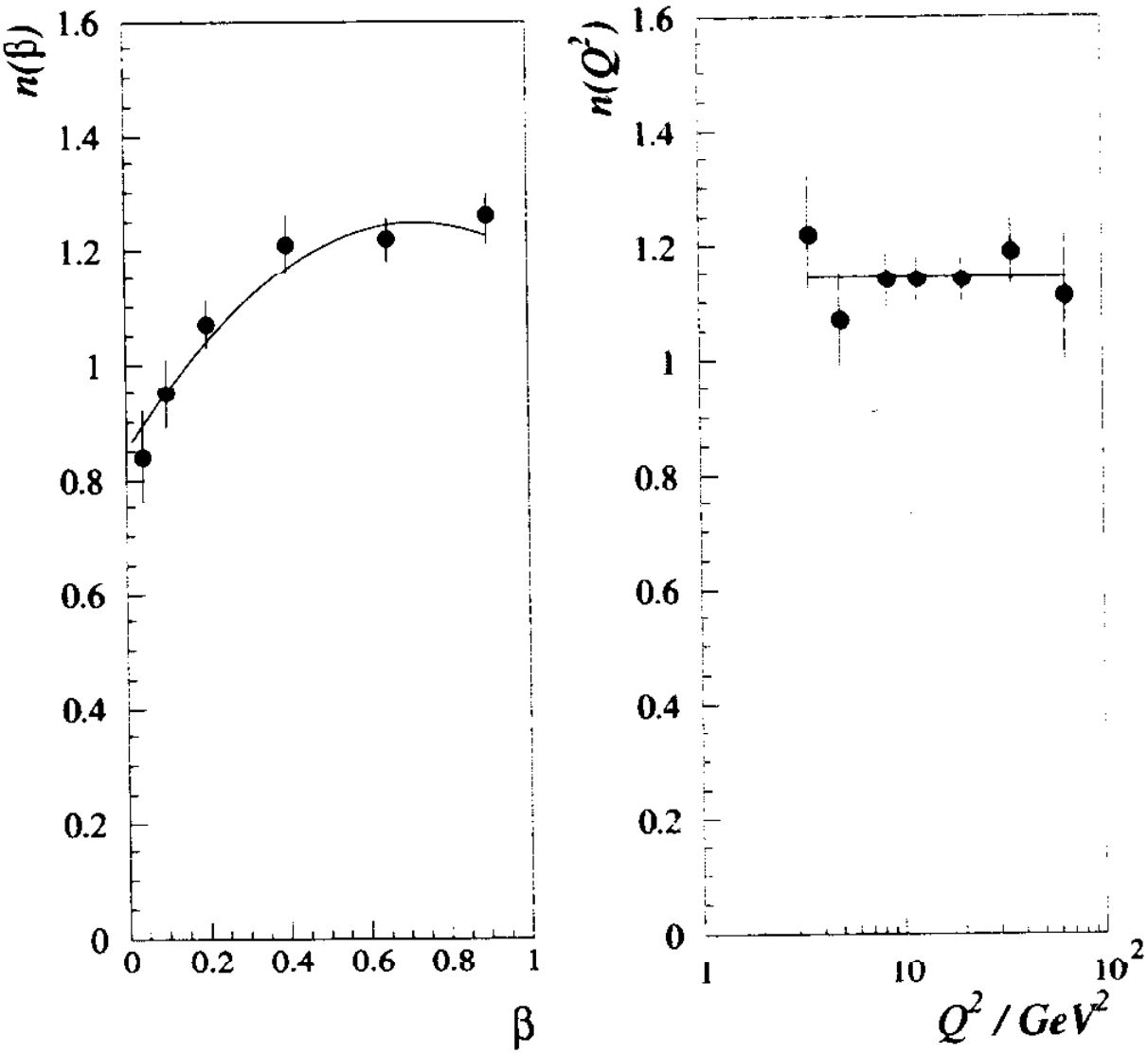
$$F_2^{D(3)}(x_{I\!P}, \beta, Q^2) \;=\; A(\beta, Q^2) \cdot \frac{1}{x_{I\!P}^n}$$

fit data with $n = n(\beta)$ or $n = n(Q^2)$

Measurement of $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$



Factorisation Breaking

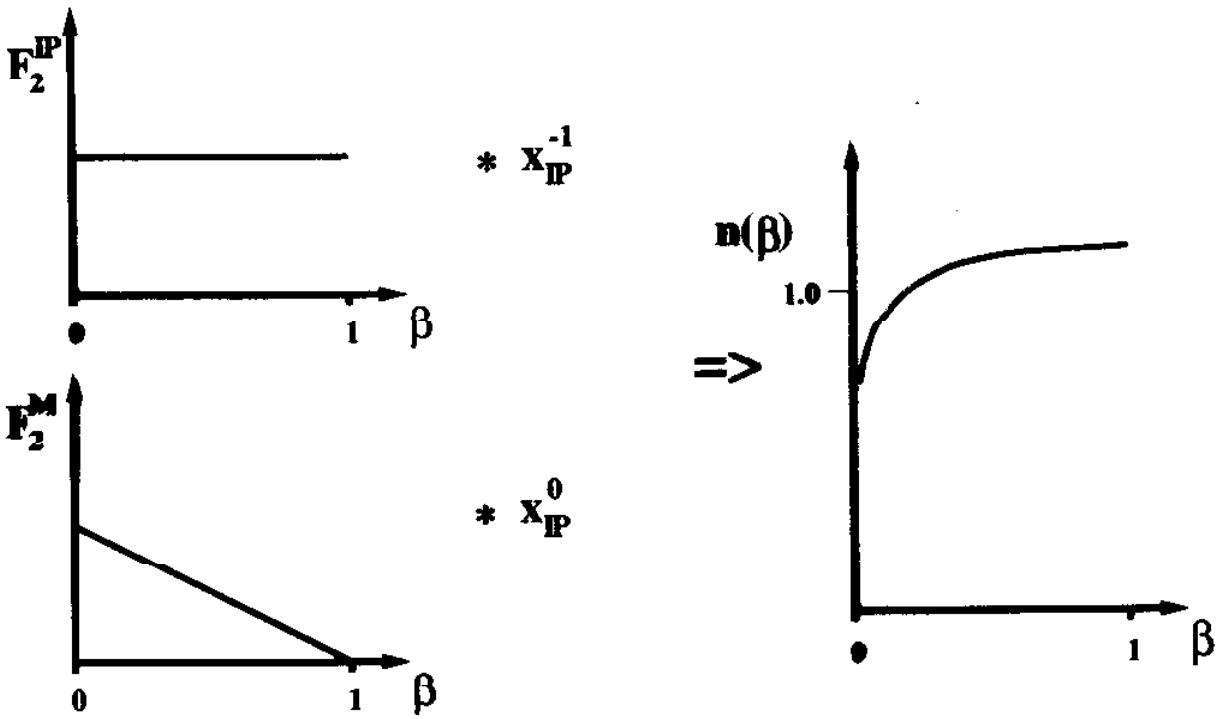


- clear evidence for change of n with β
- no dependencd on Q^2 visible

Possible Explanation for Non-Factorisation

- subleading trajectory $F_2^{D(3)}(x_{I\!P}, \beta, Q^2) \propto \frac{1}{x_{I\!P}^{2\alpha-1}} = \frac{1}{x_{I\!P}^n}$

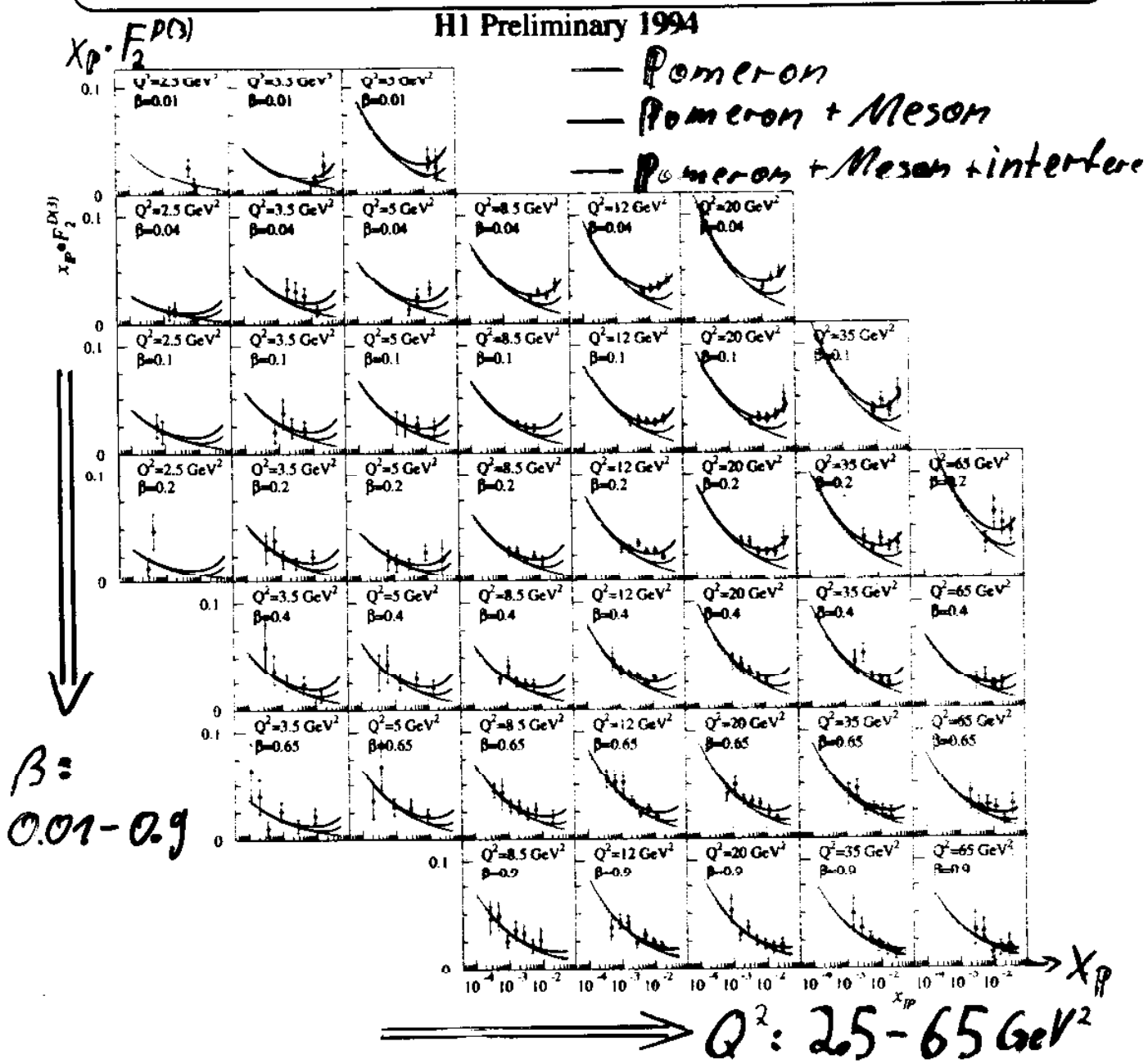
$I\!P$	$\alpha(0) \approx 1.1$	$F_2^{D(3)} \propto x_{I\!P}^{-1.2}$	$n \approx 1.2$
$f_2, \cdots$	$\alpha(0) \approx 0.5$	$F_2^{D(3)} \propto x_{I\!P}^{0}$	$n \approx 0$
$\pi, \cdots$	$\alpha(0) \approx 0.0$	$F_2^{D(3)} \propto x_{I\!P}^{1}$	$n \approx -1$



- non factorising Pomeron like in some pertubative models
  $\rightarrow$ some models predict rising n for low β

- ?

Pomeron + Meson: Phenomenological Fit



$$F_2^{D(3)}(x_{\mathbb{P}}, \beta, Q^2) = \underline{F_2^{\mathbb{P}}(\beta, Q^2) \cdot x_{\mathbb{P}}^{-n_1}} + C_M \cdot F_2^M \cdot x_{\mathbb{P}}^{-n_2} + \underline{int_{45^\circ}}$$

fit of $F_2^{\mathbb{P}}(\beta, Q^2)$, n_1 , C_M , n_2

Result: $n_1 = 1.29 \pm 0.03$ $\quad \chi^2/ndf = 170/156$

$n_2 = 0.3 \pm 0.3$

Pomeron + Meson

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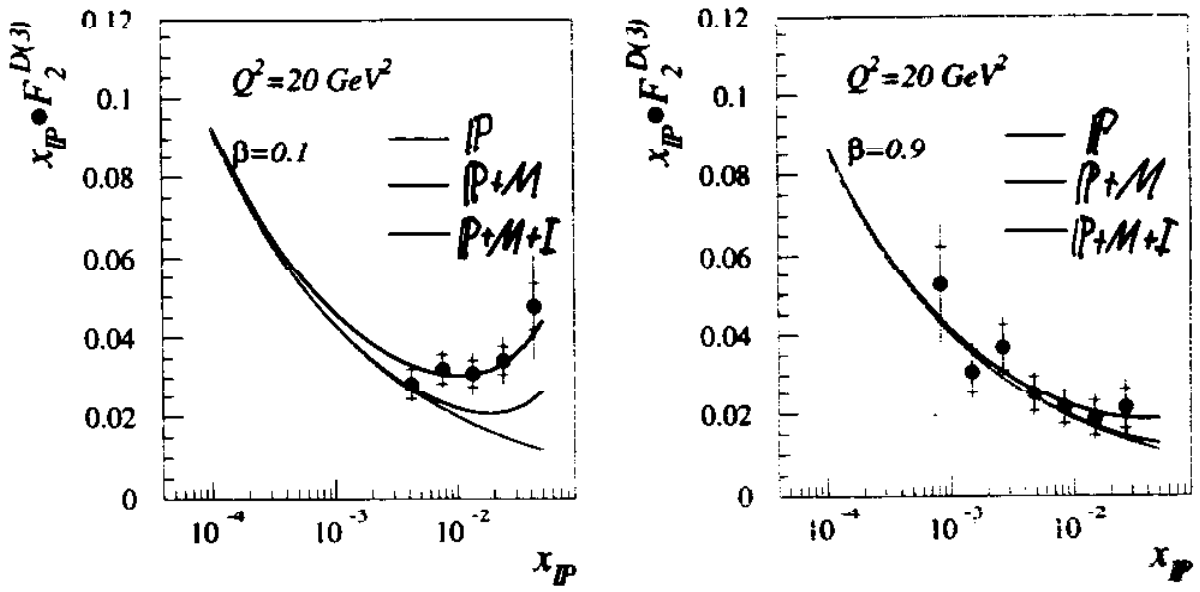


- large meson contribution at small β and high $x_{\mathbb{P}}$
- 50% meson intensity at low β and $x_{\mathbb{P}} = 0.05$
- few % meson intensity for $x_{\mathbb{P}} < 0.01$ or high β
- large contribution of interference

here it becomes clear that it is important to measure a model independent cross section; we cannot make ad hoc assumptions on how the subleading contribution and the interference behave

systematic error on $\alpha_{I\!P}(0)$ and $\alpha_M(0)$

- covariance matrix for systematic errors on $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$

- allow any phase between $0°$ and $90°$

- meson structure: $(1-\beta)^{0.5}$ to $(1-\beta)^4$

- additional trajectory with $n_3 = 0(\pi)$
  normalisation is consistent with zero

			stat	syst	model
result:	$n1$	$= 1.29$	± 0.03	± 0.06	± 0.03
	$n2$	$= 0.3$	± 0.3	± 0.6	± 0.2

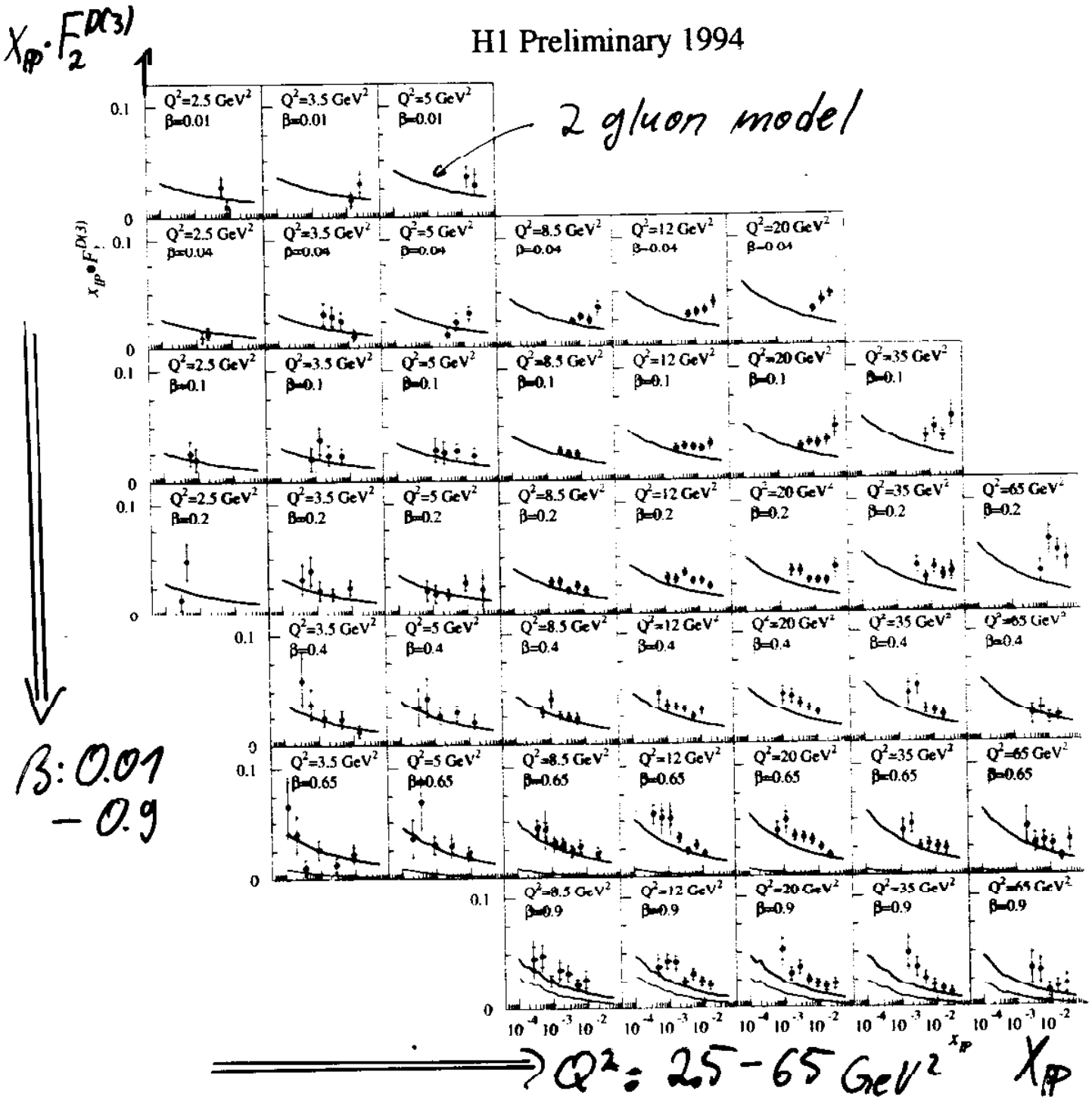
calculation of $\alpha_{I\!P}(0)$ and $\alpha_M(0)$:
assuming peripheral t-dependence ($\propto e^{bt}$)
and linear trajectories $\alpha(t) = \alpha(0) + \alpha' \cdot t$

assumptions	result
$\alpha'_M = 1, b_M = 5$	$\alpha_M(0) = 0.6 \pm 0.1 \pm 0.3$
$\alpha'_{I\!P} = 0$	$\alpha_{I\!P}(0) = 1.15 \pm 0.02 \pm 0.04$
$\alpha'_{I\!P} = 0.3, b_{I\!P} = 6$	$\alpha_{I\!P}(0) = 1.18 \pm 0.02 \pm 0.04$

2-Gluon Exchange Model

Hard pomeron model in which energy dependence and normalisation are determined by gluon distribution in proton (M. Wüsthoff, J. Bartels)

Other models give similar result → overview in paper by M.C. McDermont and G. Briskin (HEP-PH 9610245)



Determination of $\tilde{F}_2^D(\beta, Q^2)$

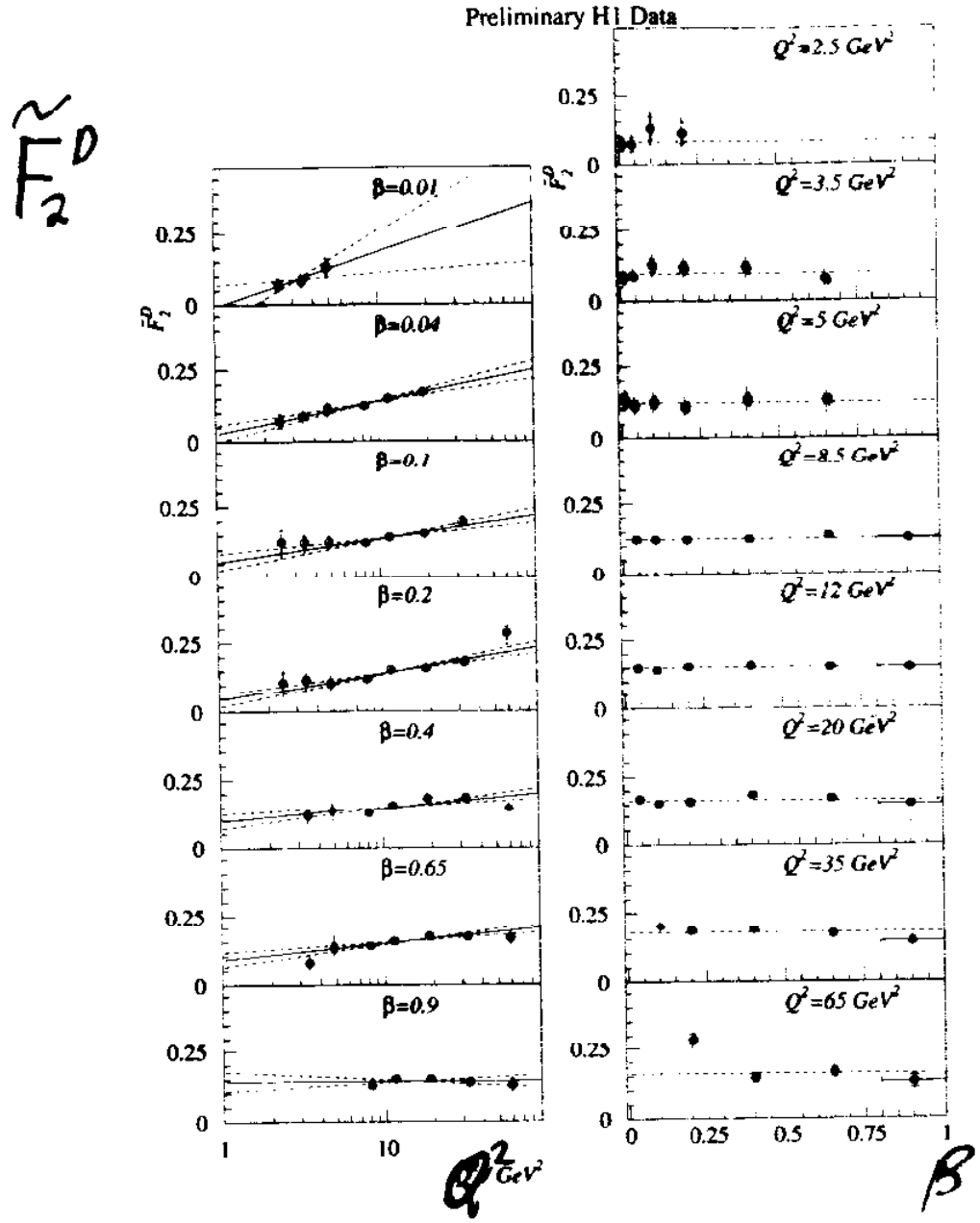
$$\tilde{F}_2^D(\beta, Q^2) = \int_{x_{\mathbb{P}L}}^{x_{\mathbb{P}H}} F_2^{D(3)}(x_{\mathbb{P}}, \beta, Q^2) \mathrm{d}x_{\mathbb{P}}$$

- $x_{\mathbb{P}L} = 0.0003$ and $x_{\mathbb{P}H} = 0.05$: near experimental limits
- $F_2^{D(3)}(x_{\mathbb{P}}, \beta, Q^2)$-parameterisation is used to extrapolate into non-measured region

in factorisation models:

$$\tilde{F}_2^D(\beta, Q^2) \propto F_2^{\mathbb{P}}(\beta, Q^2)$$

$\Rightarrow \tilde{F}_2^D(\beta, Q^2)$ can be used to study scaling properties



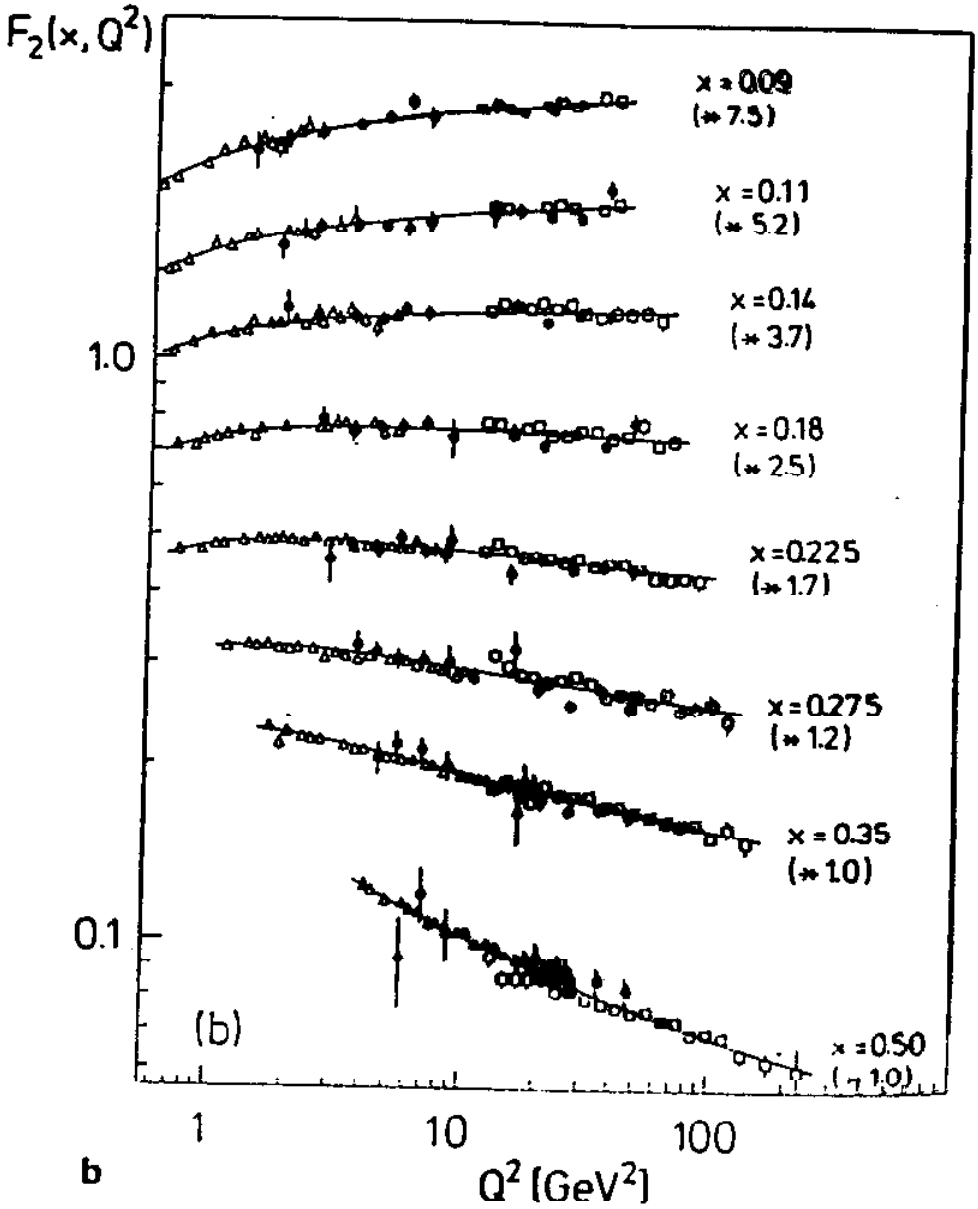
- rise in $\log(Q^2)$ even to high β ;
  not seen in F_2^{Proton} $\rightarrow$ evidence for gluons at high β?

- approximately flat in β

- calculation with $\tilde{F}_2^D(\beta, Q^2)_{x_{\mathbb{P}}<0.01}$ and $F_2^{\mathbb{P}}(\beta, Q^2$ (Pomeron part of fit) give consistent result

β

$F_2^{Proton}(x, Q^2)$.



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Influence of Meson Exchange

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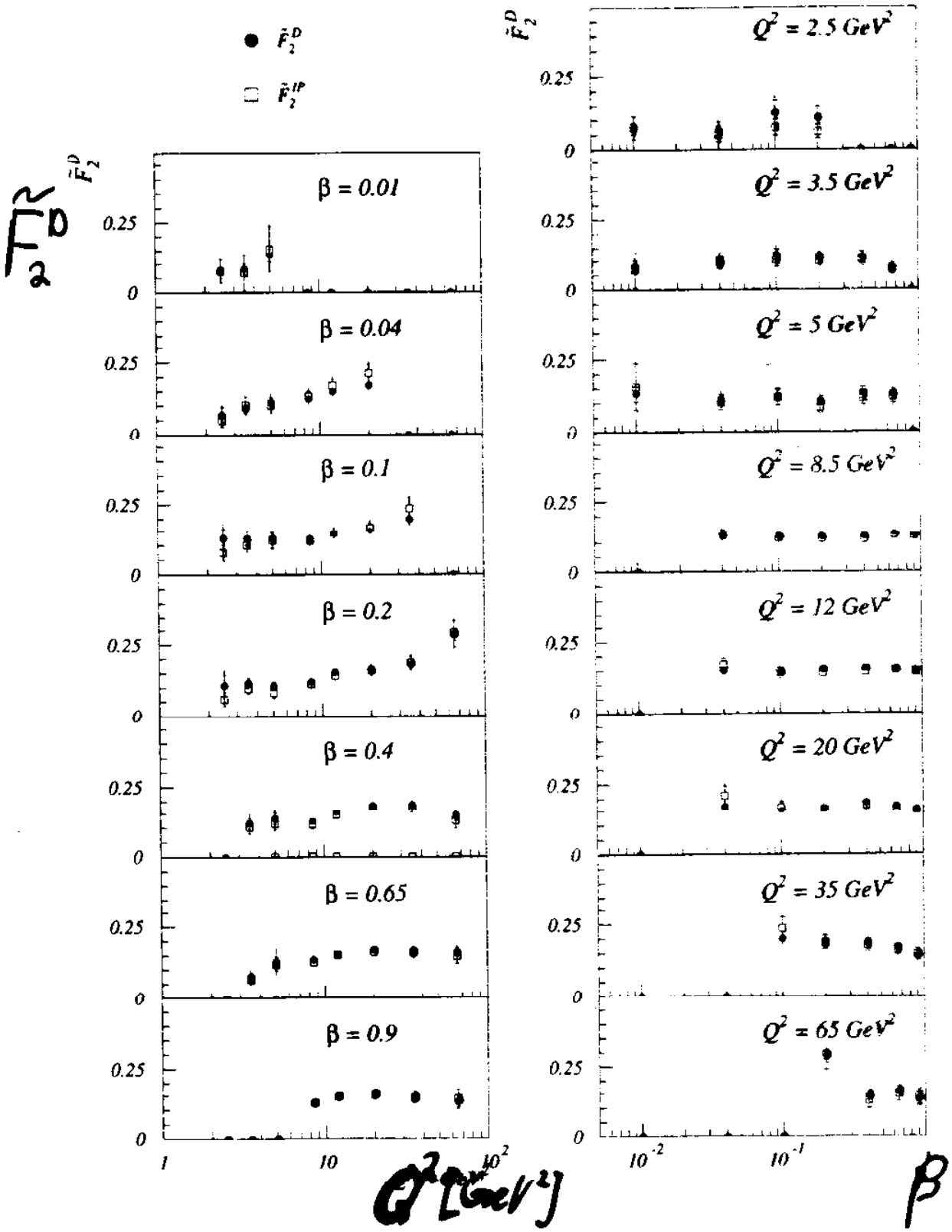


QCD-Analysis

Q: Can DGLAP describe $\tilde{F}_2^D(\beta, Q^2)$ and quantify the qualitative conclusion from the scaling violations?

various theoretical predictions:

- DGLAP should not work at all
- DGLAP should be OK, but fail at $\beta \to 1$

$\Rightarrow$ no consensus

Experimentally look for failure of DGLAP!

Results:

- DGLAP seems to be ok, but does that mean anything?
  Do we really see consequences of 'leading gluon' in final state?
  Or is DGLAP just a good parameterisation?
- look at charm, topology, . . .

QCD-Analysis of $\tilde{F}_2^D(\beta, Q^2)$ in LO

- consider light flavour singlet and gluon

- parametrise parton density at $Q_0^2 = 2.5\,\mathrm{GeV}^2$:
  $\beta f_i(\beta) \;=\; A_i \beta^{B_i}(1-\beta)^{C_i}$

- solve DGLAP evolution to evolve parton densities

- fit A_i, B_i and C_i to data (i=singlet,gluon)
  - charm included via photon-gluon fusion
    no momentum sum rule imposed

two scenarios:

- only quarks at $Q_0^2 \;\Rightarrow\; A_{gluon} = 0$

- quarks and gluons present at Q_0^2

cross checks:

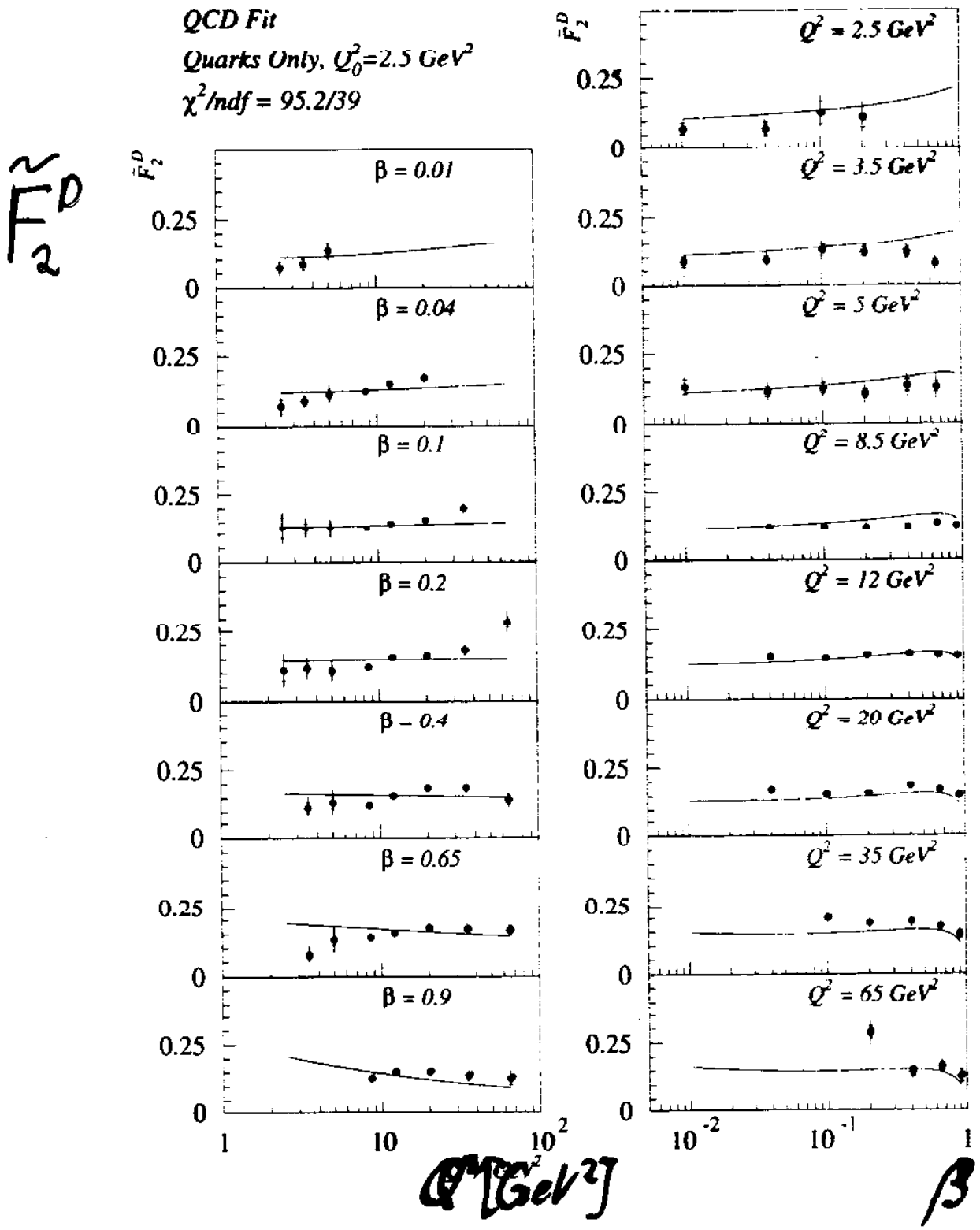
- analysis done with $\tilde{F}_2^D(\beta, Q^2)_{x_{\mathbb{P}}<0.05/0.01}, \tilde{F}_2^{\mathbb{P}}$

- two DGLAP evolution programs: working in x_{Bj}-space and using Mellin tranformation method

- result of H1 QCD analysis of 1993 data has been reproduced by several independent theoretical groups

ONLY Quarks at $Q_0^2 = 2.5\,\mathrm{GeV}^2$

H1 Preliminary 1994



Quarks and Gluons at $Q_0^2 = 2.5\,\mathrm{GeV}^2$

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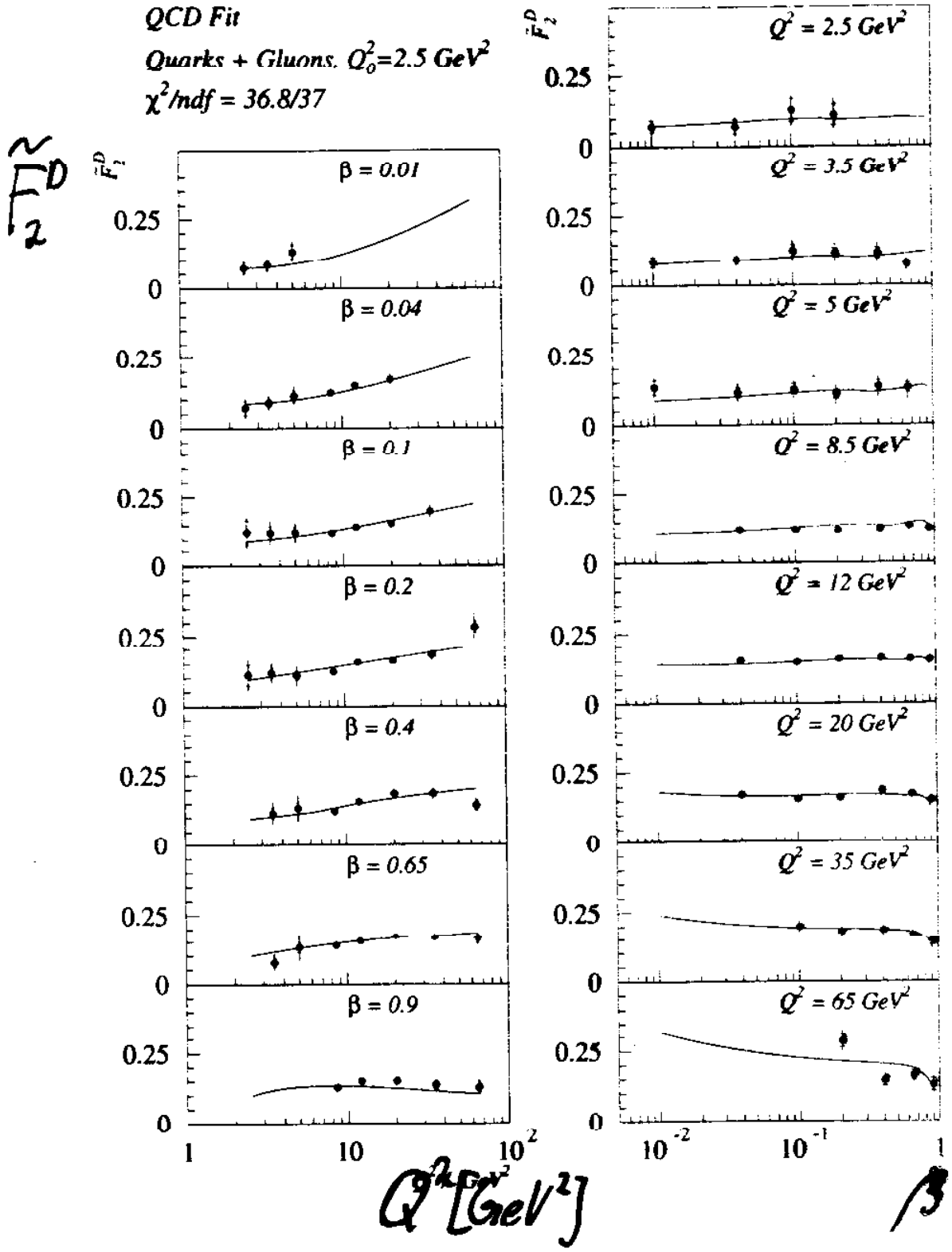

Parton Distribution Functions

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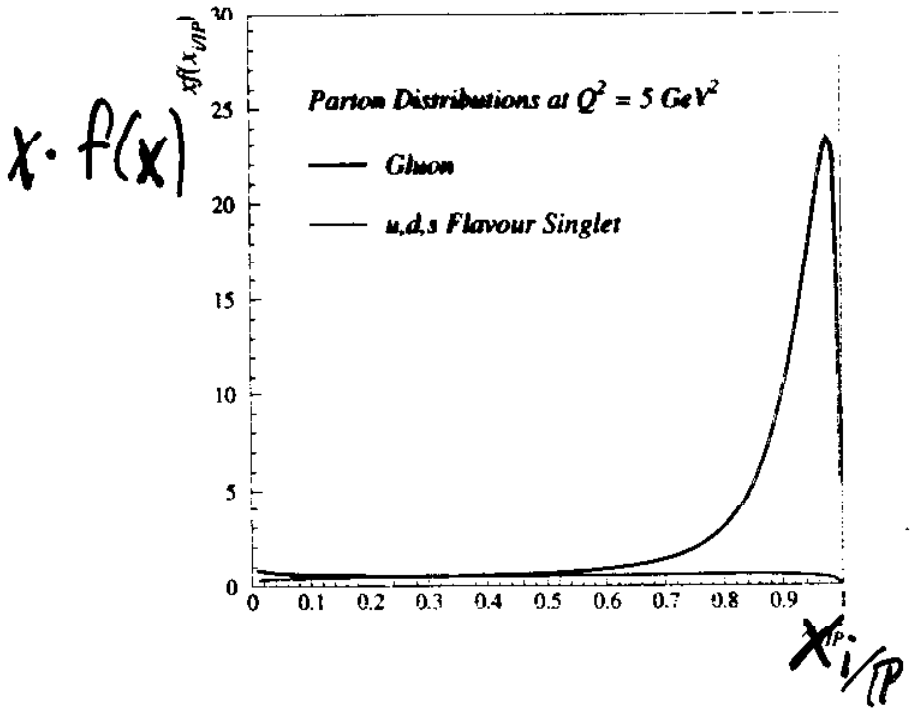

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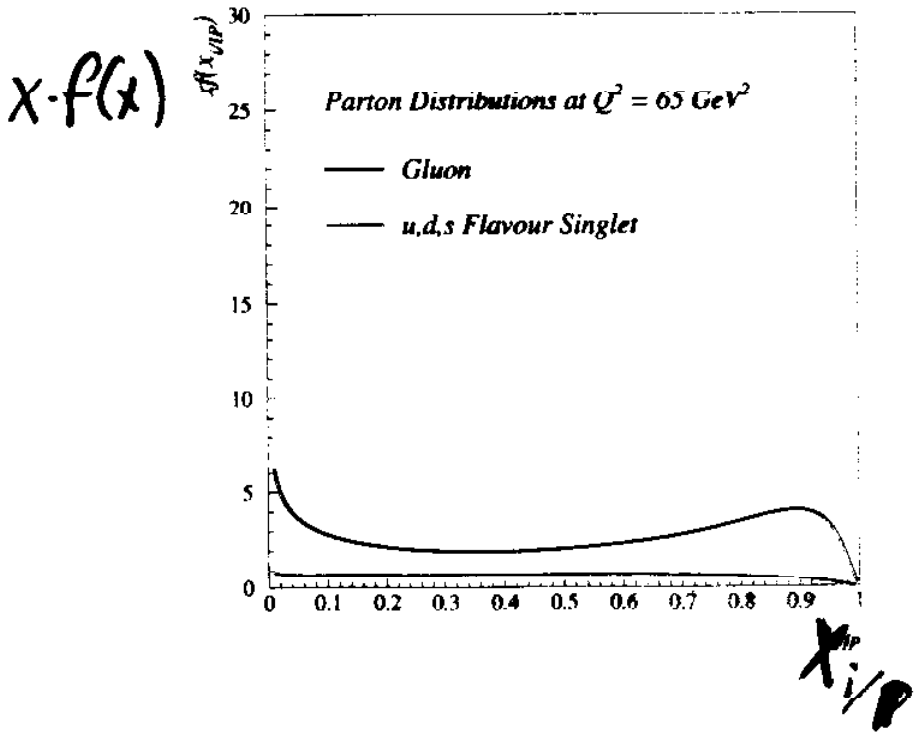

Summary/Conclusions/Outlook

- $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$ has been measured over a wider kinematic range and to better precision

- evidence for factorisation breaking in β
  $\Rightarrow$ possible explaination of breaking: subleading trajectory

- $\tilde{F}_2^D(\beta, Q^2)$ is flat in β

- scaling violations observed which hint for gluon dominance

- QCD-fit results in 'leading' gluon structure

- more insight into hadronic structure by looking into hadronic final state: talk on Wednesday

- soon measurement of $F_2^{D(3)}(x_{I\!P}, \beta, Q^2)$ for lower Q^2