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F_2^D MEASUREMENTS at ZEUS

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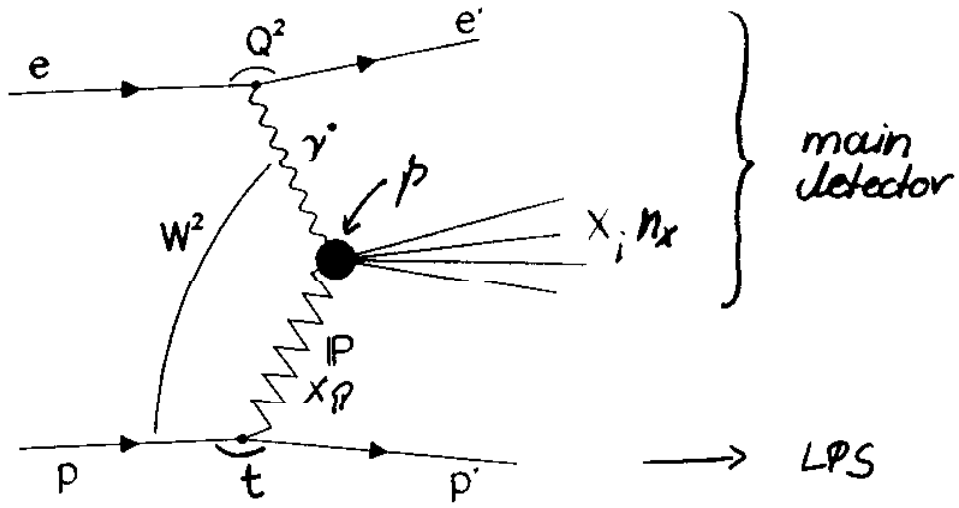
1) Reminder of $\frac{d\sigma}{dM_x}$ with the M_x method

2) Update of $F_2^{D(3)}$ with the
ZEUS LEADING PROTON SPECTROMETER (LPS)

3) Comparison of $F_2^{D(3)}$ from M_x method and LPS

4) Summary



in addition to "standard DIS" variables

$$\begin{cases} M_X^2 = (q+P)^2 \\ t = (P-P')^2 \\ x_{\mathbb{P}} = (P-P')\cdot q/(Pq) \approx (M_X^2+Q^2)/(W^2+\ldots \\ \beta = Q^2/(2(P-P')q) \approx Q^2/(M_X^2+Q^2) \end{cases}$$

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

$\Downarrow$ integrate over t

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

Experimental definitions of DIFFRACTION at ZEUS

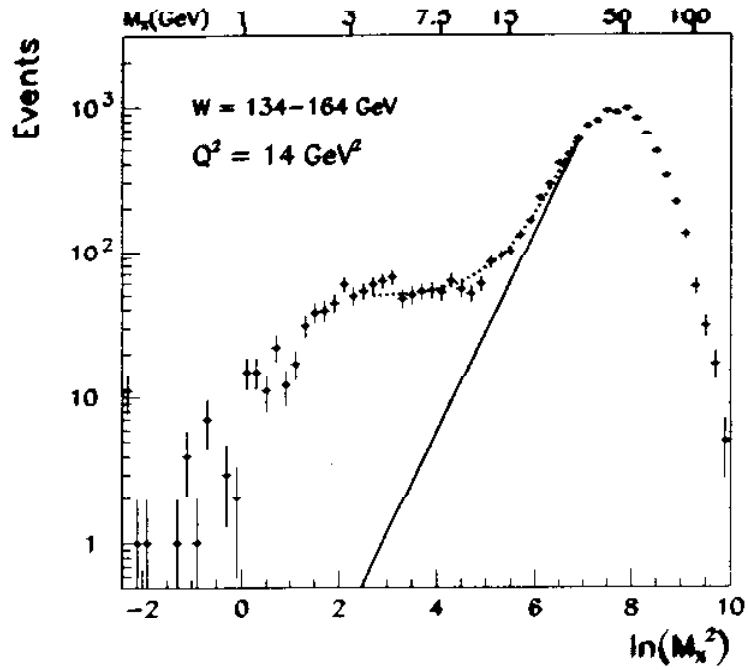
M_X analysis: Diffractive events form the excess over the exponential fall-off in the $\ln(M_X^2)$ distribution.

LPS analysis: Diffractive events have a leading proton that carries more than 97% of the initial longitudinal momentum of the beam proton.

Reminder of $\frac{d\sigma}{dM_X}$ with the M_X method

→ talk G. Briskin this morning

ZEUS 1994 Preliminary



Assumption inspired by Regge-Theory

$$\frac{dN}{d\ln M_X^2} = \underset{\text{diffractive}}{D} + \underbrace{a\exp(b\ln M_X^2)}_{\text{non-diffractive non-}\mathbb{P}\text{ exchange}}$$

⟹ By subtracting exponential fall-off:
Non $\mathbb{P}$-exchange is being subtracted

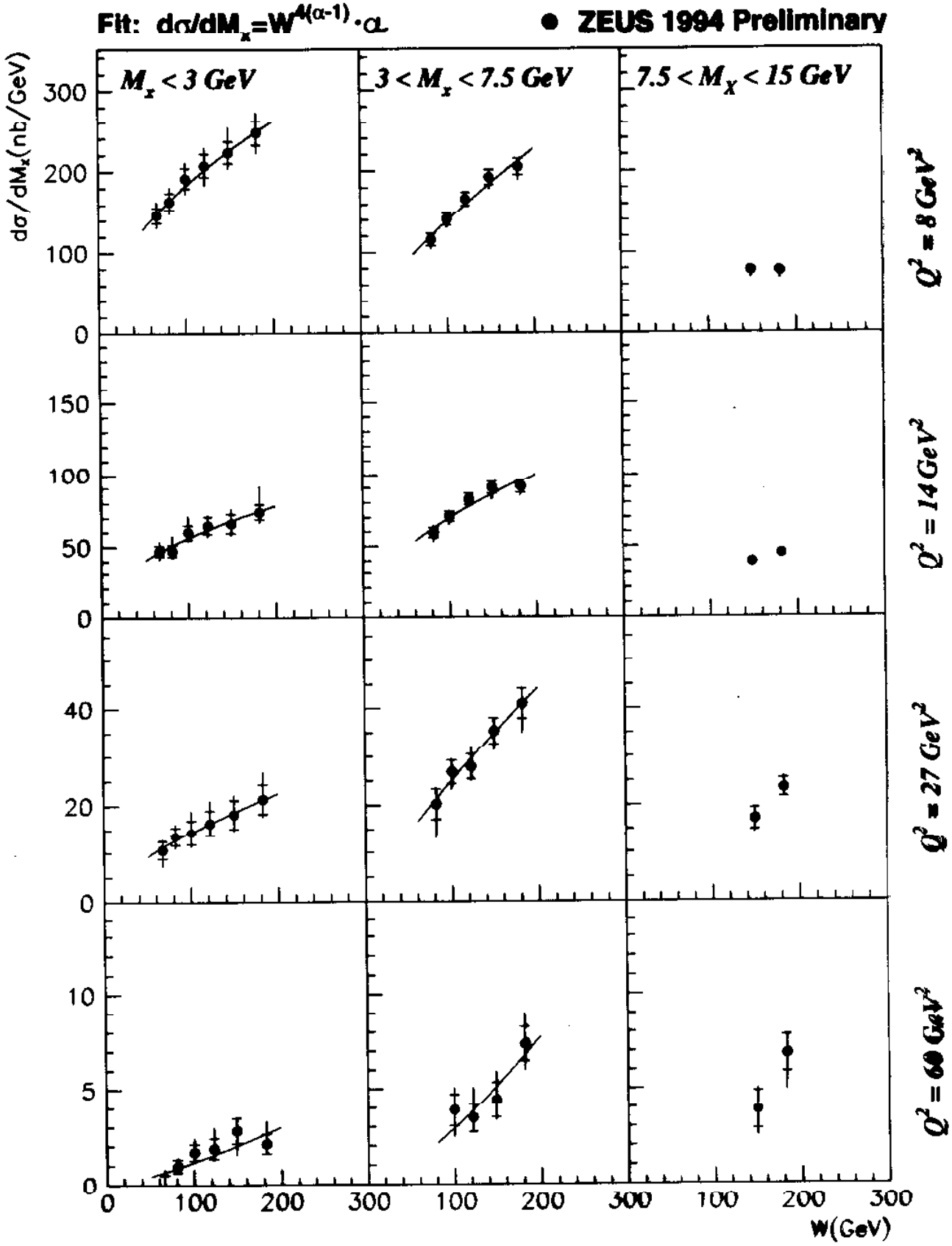
⟶ Method measures:

$ep \longrightarrow epX$

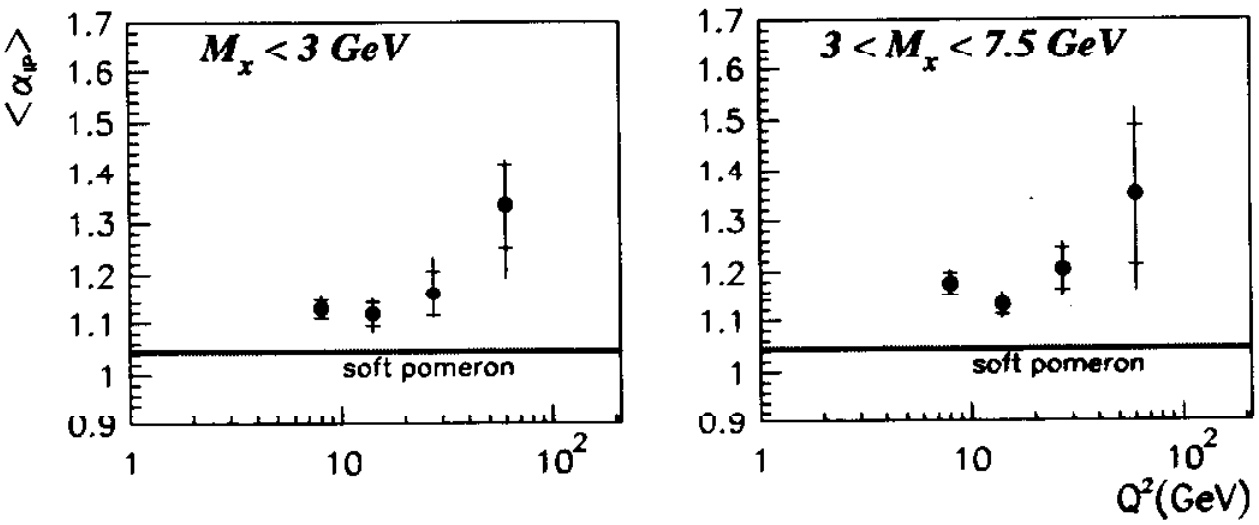
$ep \longrightarrow eNX$; $M_N < 4$ GeV ~25%

estimate from other processes

Diffractive $\gamma^* p$ cross-section



- **ZEUS 94 (preliminary)**



ZEUS diffractive cross sections are not compatible with the Donnachie-Landshoff Soft Pomeron

there is a tendency for α_{IP} to grow with Q^2(GeV) (more data needed)

Note: $\langle \alpha_{\mathbb{P}} \rangle \approx \alpha_{\mathbb{P}}(0) - 0.03$
We measure $\alpha_{\mathbb{P}}$ averaged over a certain t range.

Measurement with the ZEUS Leading Proton Spectrometer (LPS)

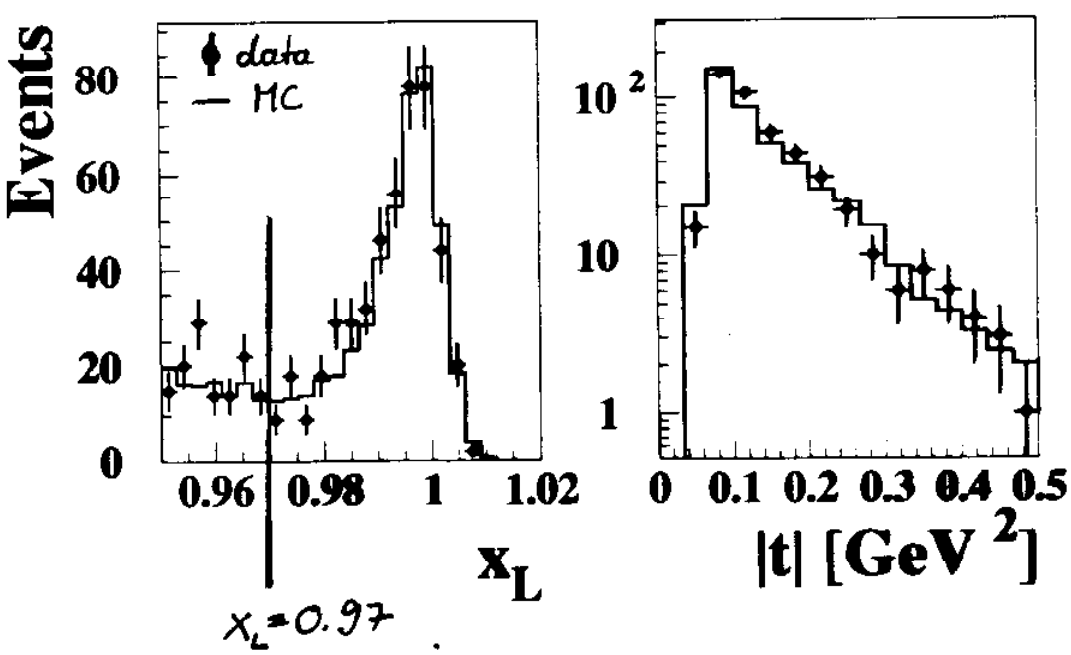
Direct measurement of the momentum (P_x', P_y', P_z') of the leading proton

$$t \approx -p_t^2 / x_L = -(P_x'^2 + P_y'^2)/x_L$$
$$x_{I\!P} \approx 1 - x_L = 1 - P_z' / E_{beam}$$

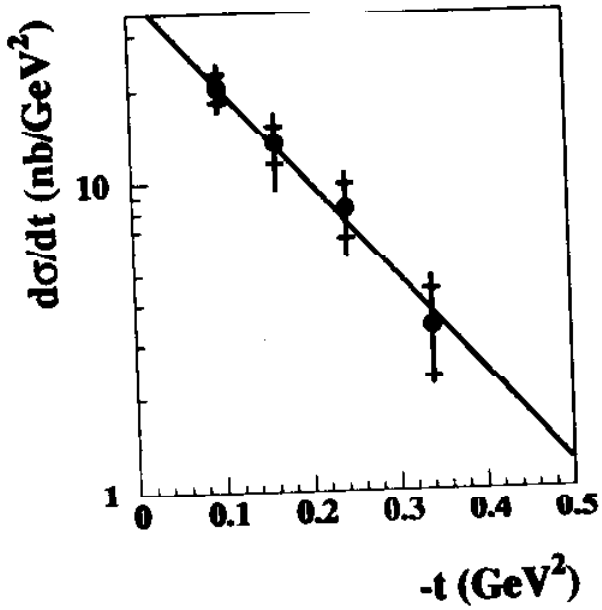
with $\frac{\Delta x_L}{x_L} = 0.4\%$ and $\Delta p_t = 100$ MeV
(due to beam characteristics; intrinsic resolution of LPS $\Delta p_t = 5$ MeV)

select diffractive events with requirement: $x_L > 0.97$

t range of LPS limited to: $0.07\ GeV^2 < |t| < 0.5\ GeV^2$
For $F_2^{D(3)}$ extrapolate down to $|t| = 0\ GeV^2$ with MC and integrate over full t range.



Measurement of the t slope in diffractive DIS



t measured as

$$t = \frac{-p_t^2}{x_L}$$

Resolution $\Delta p_t \approx 100\,\mathrm{MeV}$
limited by beam characteristics

Kinematic range:
(changed with respect to Warsaw to make compatible to kin. range for F_2^D)

$0.97 < x_L < 1.02$

$5\,\mathrm{GeV}^2 < Q^2 < 20\,\mathrm{GeV}^2$

$0.03 < y < 0.8$

$0.015 < \beta < 0.5$

Fit to: $\frac{d\sigma}{dt} = A \exp(bt)$

$$b = \left(7.1 \pm 1.1 \,{}^{+0.7}_{-1.0}\right) \mathrm{GeV}^{-2}$$

Compatible to $b = b_0 + 2\alpha' \ln \frac{1}{x_{\mathbb{P}}}$ with $\alpha' = 0.25\,\mathrm{GeV}^{-2}$
and $b_0 = 4.5\,\mathrm{GeV}^{-2}$

Update on the $F_2^{D(3)}$ with the ZEUS LPS

Select DIS event by requiring the scattered positron to be detected in the main detector.

Select DIFF event by requiring track in LPS with $x_L > 0.97$

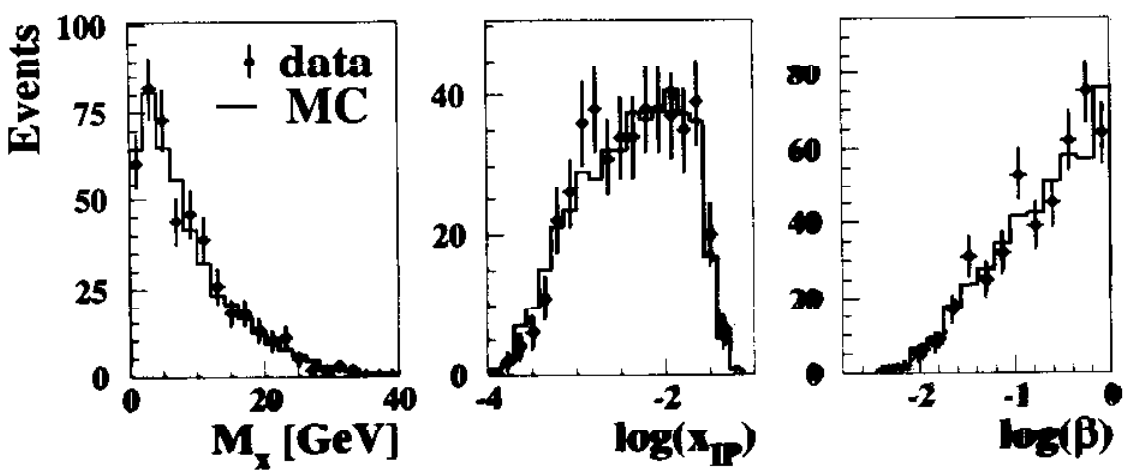
Reconstruct "standard" DIS variables from angle of scattered positron and angle of hadronic system (2α metho

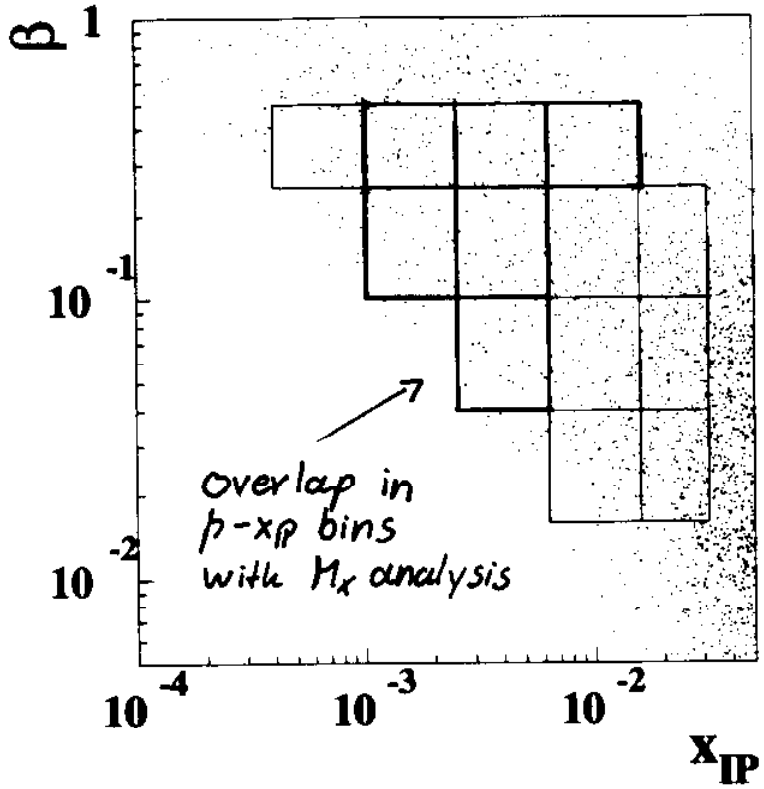
Improved M_X reconstruction by combining UCAL and tracking information. ($\Delta M_X = 22\%$)

$$\beta = Q^2/(Q^2+M_X^2) \quad ; \quad \Delta\beta = 24\%$$
$$x_{I\!P} = x_{Bj}/\beta \quad ; \quad \Delta x_{I\!P} = 28\%$$

Improved MC description (RAPGAP with factorizable $I\!P$ model) in particular for the low mass region.

Slightly modified bins.





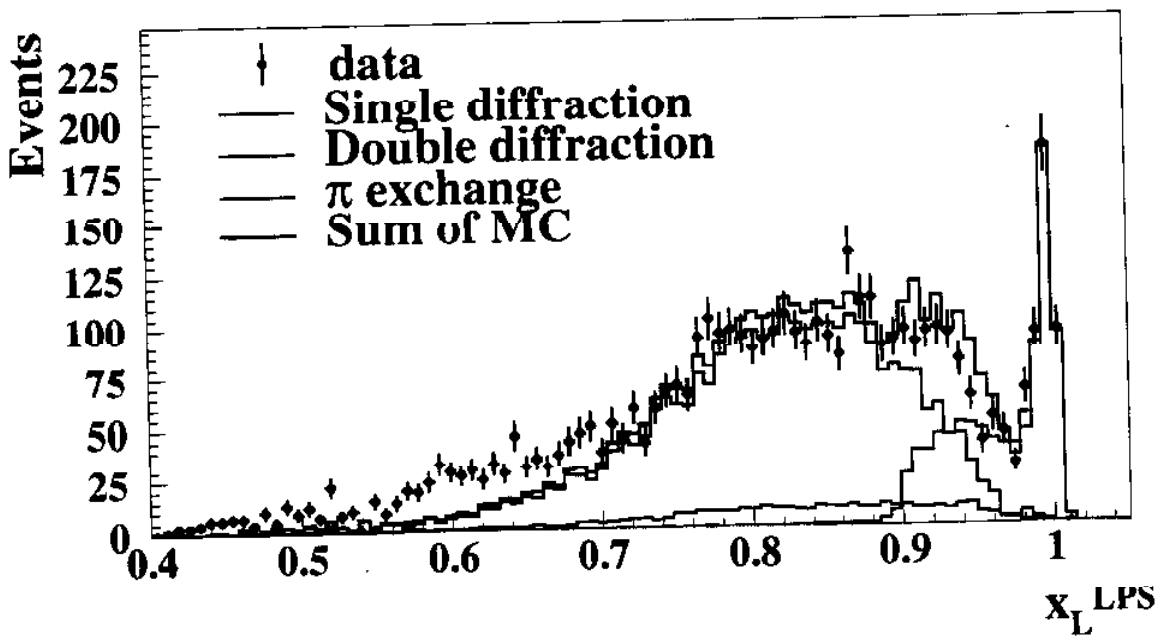
Luminosity taken with LPS in 1994: $\mathcal{L} \sim 900\,nb^{-1}$

After all cuts left with ~470 with $Q^2 > 5\,GeV^2$

⇒ Bin size chosen with respect to statistics rather than resolution.

⇒ Only one Q^2 bin: $5\,GeV^2 < Q^2 < 20\,GeV^2$

Purity in bins typically better than 40%


Events
225
200
175
150
125
100
75
50
25
0
0.4
0.5
0.6
0.7
0.8
0.9
1
x_L^{LPS}
data
Single diffraction
Double diffraction
π exchange
Sum of MC

Background estimate by fit to LPS x_L spectrum

1) normalize DD MC to # events in data with
$\eta_{max} < 1.5 \wedge x_L < 0.95$

2) normalize SD to # events in data with $x_L > 0.97$
2*) leave normalization of SD MC free

3) fit x_L^{LPS} spectrum with π exchange MC normalization free

no non-diffr.
DIS MC used
in fit

Background estimate: no background subtraction

constant in all bins: beam-halo events $3 \div 4\,\%$

in selected bins for $F_2^{D(3)}$:

with $x_L > 0.97$ overall less than 3.5%

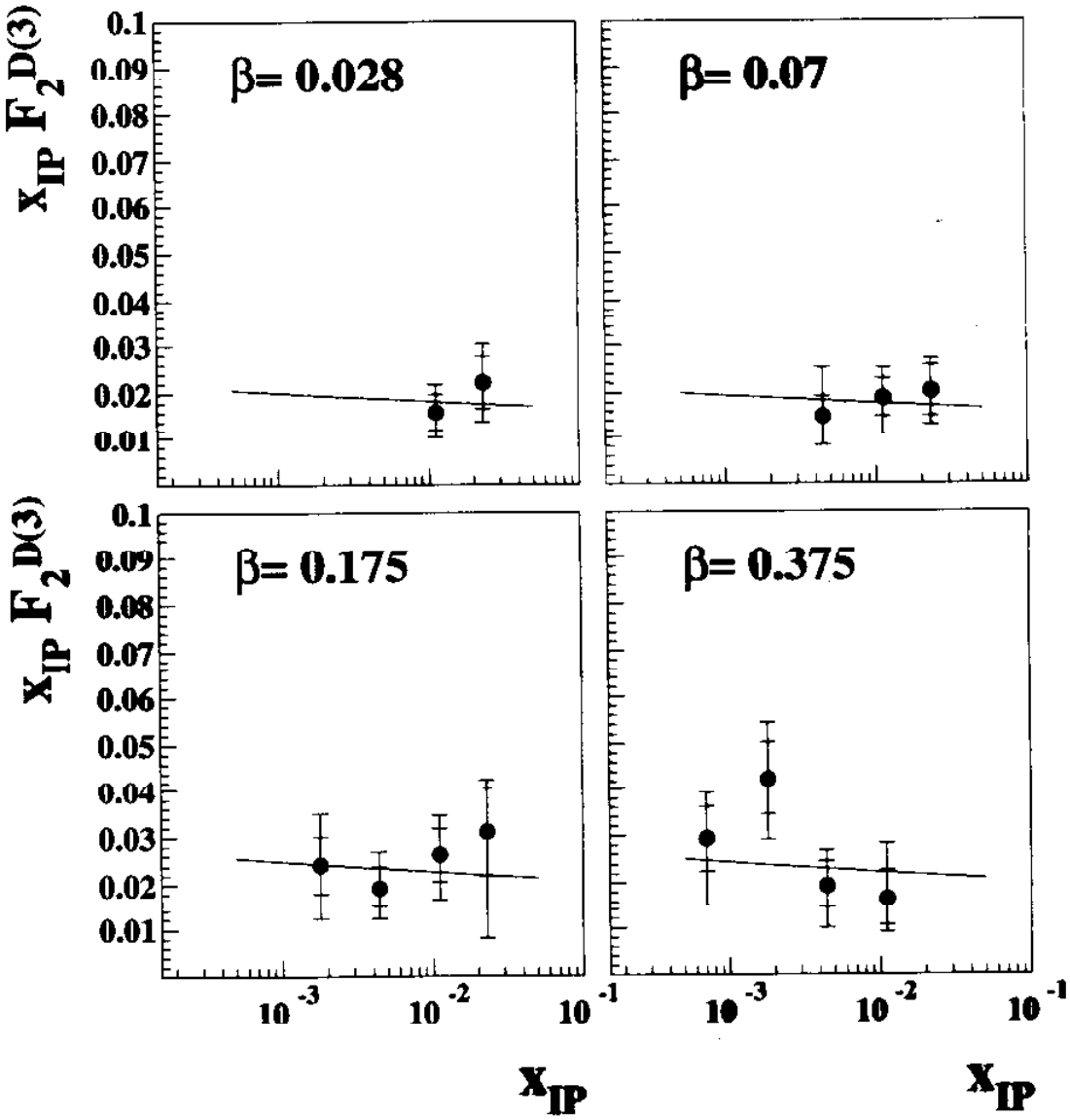
maximum contribution per single bin by

π exchange $< 5\%$

double diffraction $< 10\%$

$\longrightarrow$ contribution by non-$\mathbb{P}$ exchange other than π ?

ZEUS 1994 Preliminary

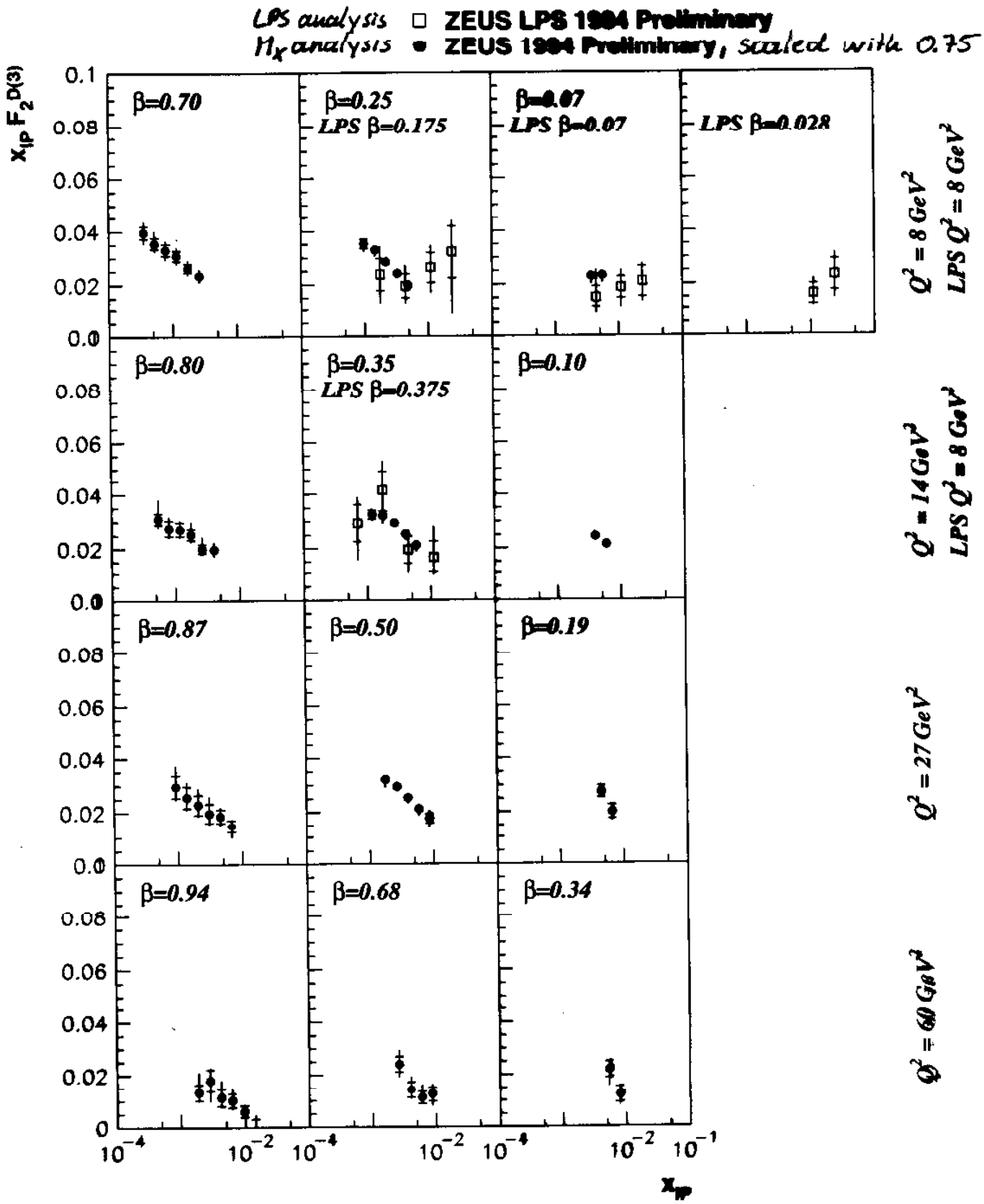


Fit with one fixed $x_{\mathbb{P}}$ slope "α" in all β bins yields:

$$\alpha = 1.04 \pm 0.09\,(\text{stat.})\ ^{+0.14}_{-0.13}\,(\text{sys.}) \quad ; \chi^2/\text{ndof} = 12/8$$

$$\bar{\alpha}_{\mathbb{P}} = 1.02 \pm 0.05\,(\text{stat.})\ ^{+0.07}_{-0.07}\,(\text{sys.})$$

Comparison of ZEUS $F_2^{D(3)}$ results



Comparison of ZEUS $F_2^{D(3)}$ results

Possible sources of differences between M_X and LPS analysis

1) Contribution of double diffraction

M_X analysis: $ep \longrightarrow epX$

$ep \longrightarrow eNX$ with $M_N < 4\,GeV$

contribution of double diffraction assumed to be constant per bin and of the order of 25%

LPS analysis:

maximum contribution of double diffraction per bin of the order of 10%, overall less than 3.5%

$\longrightarrow$ for comparison: $F_2^{D(3)}$ from M_X analysis scaled down by factor of 0.75

2) Contribution of non-$\mathbb{P}$ exchange

M_X analysis: non-$\mathbb{P}$ exchange is being subtracted

LPS analysis: non-$\mathbb{P}$ exchange is not being subtracted

LPS has bins at higher $x_{\mathbb{P}}$ where exchange might become important

3) Different regions of phase space

LPS analysis: only one Q^2 bin between $5\,GeV^2$ and $20\,GeV^2$

restricted t range: $0.07\,GeV^{-2} < |t| < 0.5\,GeV^{-2}$

bins at higher $x_{\mathbb{P}}$ and lower β

Summary

Two different approaches for measuring F_2^D at ZEUS:

M_X analysis: Events above the exponential fall-off in the $\ln(M_X^2)$ distribution

LPS analysis: Events with a fast leading proton

LPS analysis

+ well defined final state
o higher $x_{\mathbb{P}}$, lower β
  ↳ contribution from non-$\mathbb{P}$ trajectories ?
+ possibility of measuring t
  $\Rightarrow F_2^{D(4)}$
− small acceptance
  ↳ small statistics

M_X analysis

+ large statistics
+ small (if any) contribution from non-$\mathbb{P}$ trajectories
− ρ dissociative background

In the region of overlap both methods give consistent results.