Measurements of diffractive structure functions with the LRG method and using the leading proton spectrometer at ZEUS

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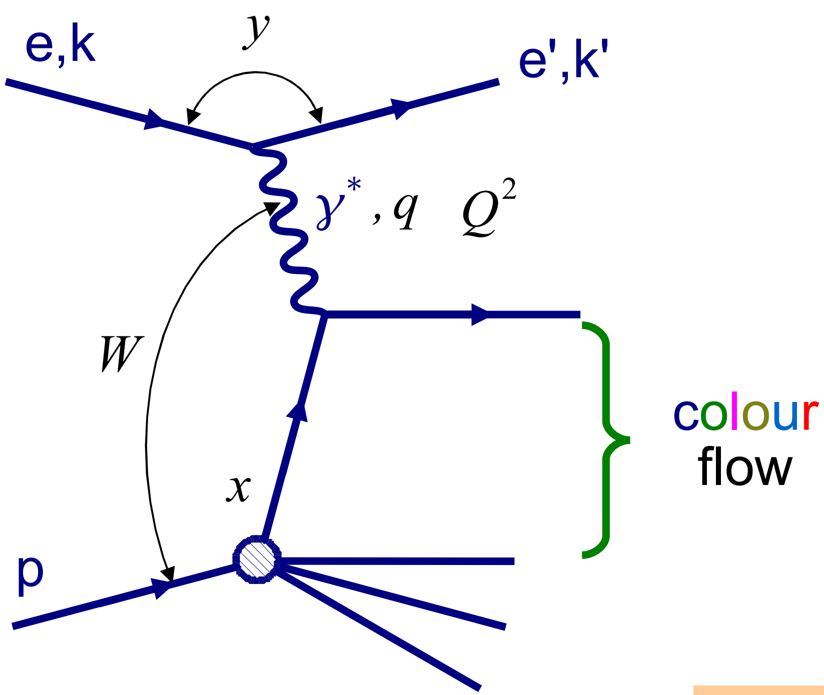
Outline

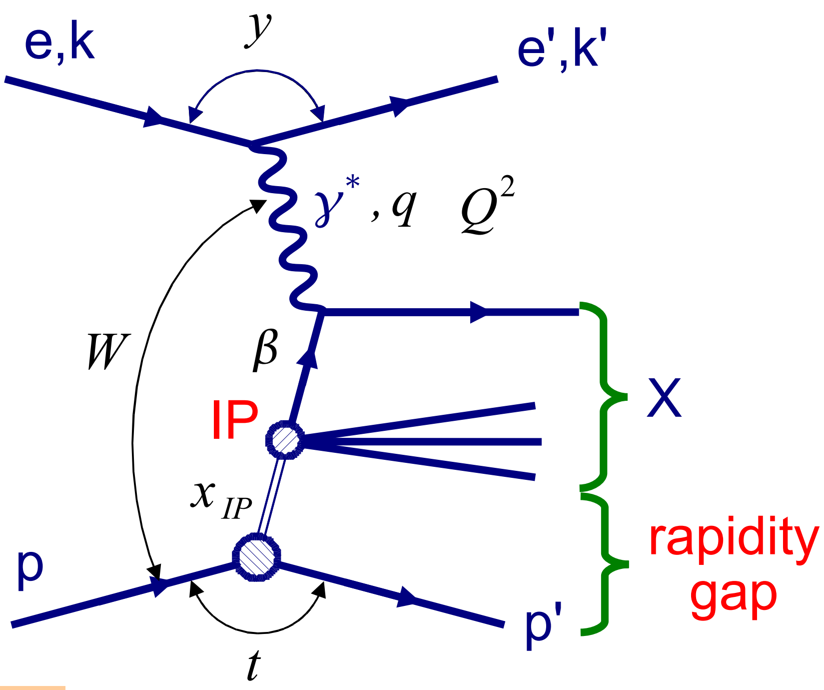
- Introduction – description of NC diffractive DIS, event topologies, structure functions
- Methods of diffractive sample selection: LPS, LRG
- Preliminary results, comparisons
- Summary

NC Deep Inelastic *ep* Scattering

Standard



Diffractive



Q^2, x, y

$$x \equiv \frac{Q^2}{2p \cdot q}$$

$x = \beta x_{IP}$

$t = (p - p')^2$ – (four momentum transfer at proton vertex$)^2$

M_X – diffractive mass

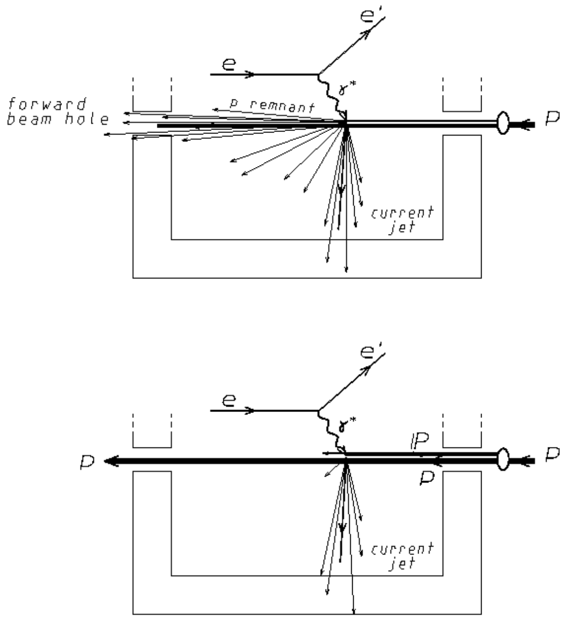
$x_{IP} = \frac{(p - p') \cdot q}{p \cdot q}$ – fraction of the proton momentum carried by the *IP*

$\beta = \frac{Q^2}{2(p - p') \cdot q}$ – fraction of the *IP* momentum carried by the struck quark

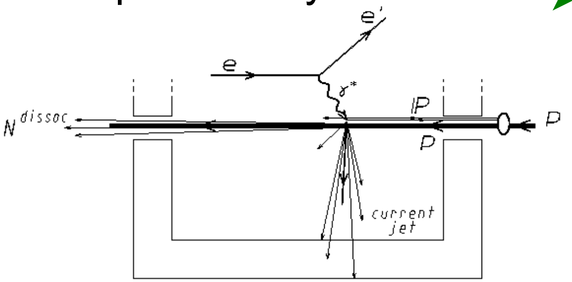
Event topologies

non-diffractive DIS

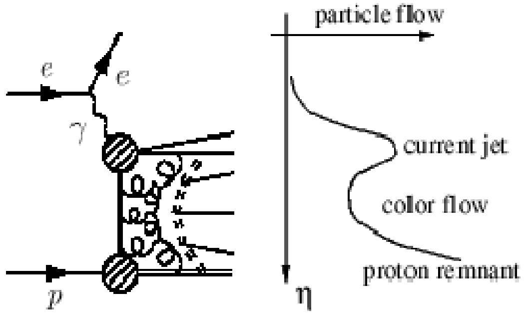
diffractive DIS

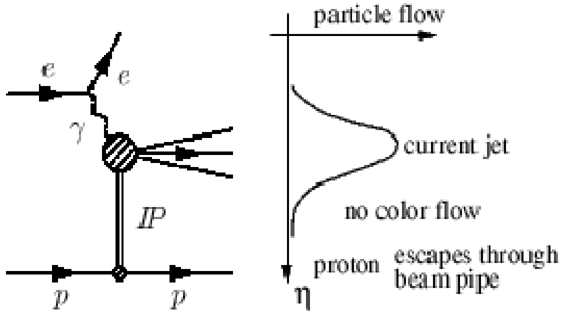


proton stays intact



proton dissociation





Diffractive structure functions

$$\frac{d^4\sigma^D_{\gamma*p}}{dQ^2\,d\,\beta\,dx_{IP}\,dt}=\frac{2\,\pi\,\alpha^2_{em}}{\beta\,Q^4}\left(1+\left(1-y\right)^2\right)F_2^{D(4)}\left(Q^2,\beta,x_{IP},t\right)$$

If Regge factorization:

$$F_2^{D(4)}\left(\beta,Q^{2,}x_{IP},t\right)=f_{IP}(x_{IP},t)\,F_2^{IP}\left(\beta,Q^2\right)$$

IP flux

IP structure function

When *t* is not measured:

$$\frac{d^3\sigma^D_{\gamma*p}}{dQ^2\,d\,\beta\,dx_{IP}}=\frac{2\,\pi\,\alpha^2_{em}}{\beta\,Q^4}\left(1+\left(1-y\right)^2\right)F_2^{D(3)}\left(Q^2,\beta,x_{IP}\right)$$

Reduced cross section:

$$\frac{d^3\sigma^D}{dx_{IP}\,dx\,dQ^2}=\frac{4\,\pi\,\alpha^2}{xQ^4}\left(1-y+\frac{y^2}{2}\right)\cdot\sigma_r^{D(3)}(x_{IP},x,Q^2)$$

we neglect F_L^D contribution

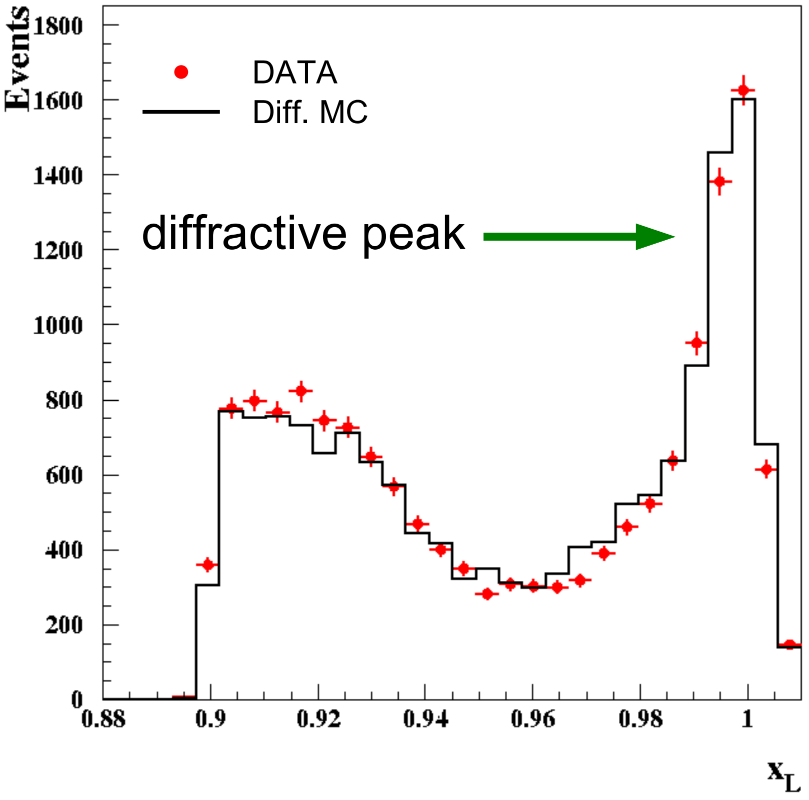
Scattered proton tagging

- Clean experimental signature
- Outgoing proton escapes through the forward beam hole
- A fraction of these events can be detected by the Leading Proton Spectrometer (LPS)
- LPS measures the momentum of the scattered proton – *t* information available

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

- Practically free of p-dissociation background
- **Drawback**: limited acceptance of the LPS (few %), dependent on x_L and p_T of outgoing proton

$x_L = \frac{p_z'}{p_z}$ spectrum:

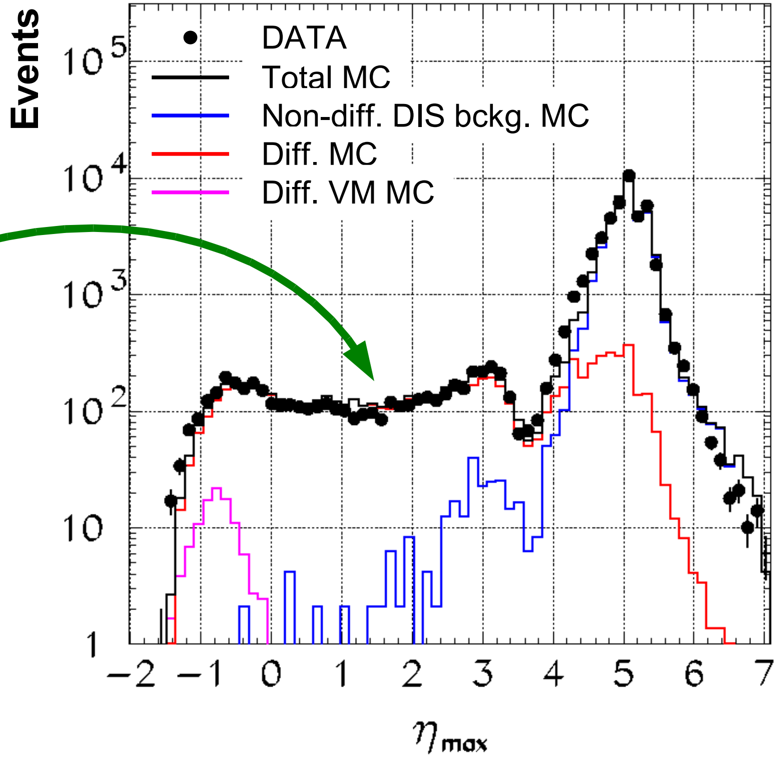


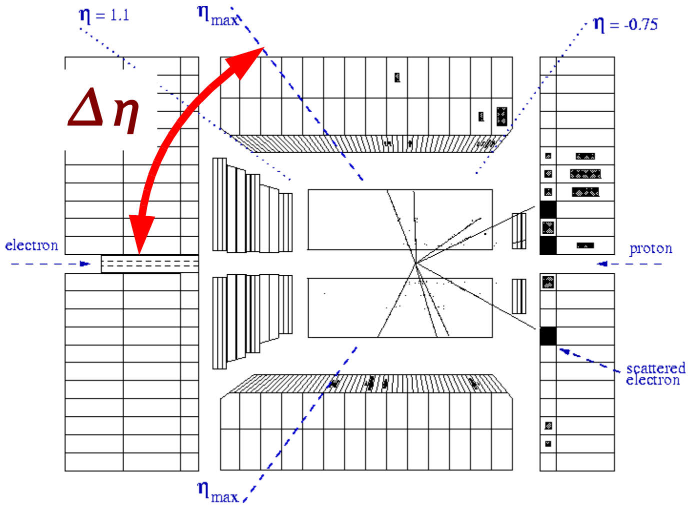
x_L>0.97 – a clean sample of diffractive events

Selection methods – LRG

- A large rapidity gap between the system *X* and outgoing proton (or proton remnant system *N*)
- Pseudorapidity of the most forward going particle: η_{max} distribution
- Plateau-like structure, due to diffractive events mainly, extends to low η_{max} values – diffractive tail
- **Drawback:** background from proton dissociation

η_{max} spectrum:





η_{max}< 3 – a small non-diffractive background

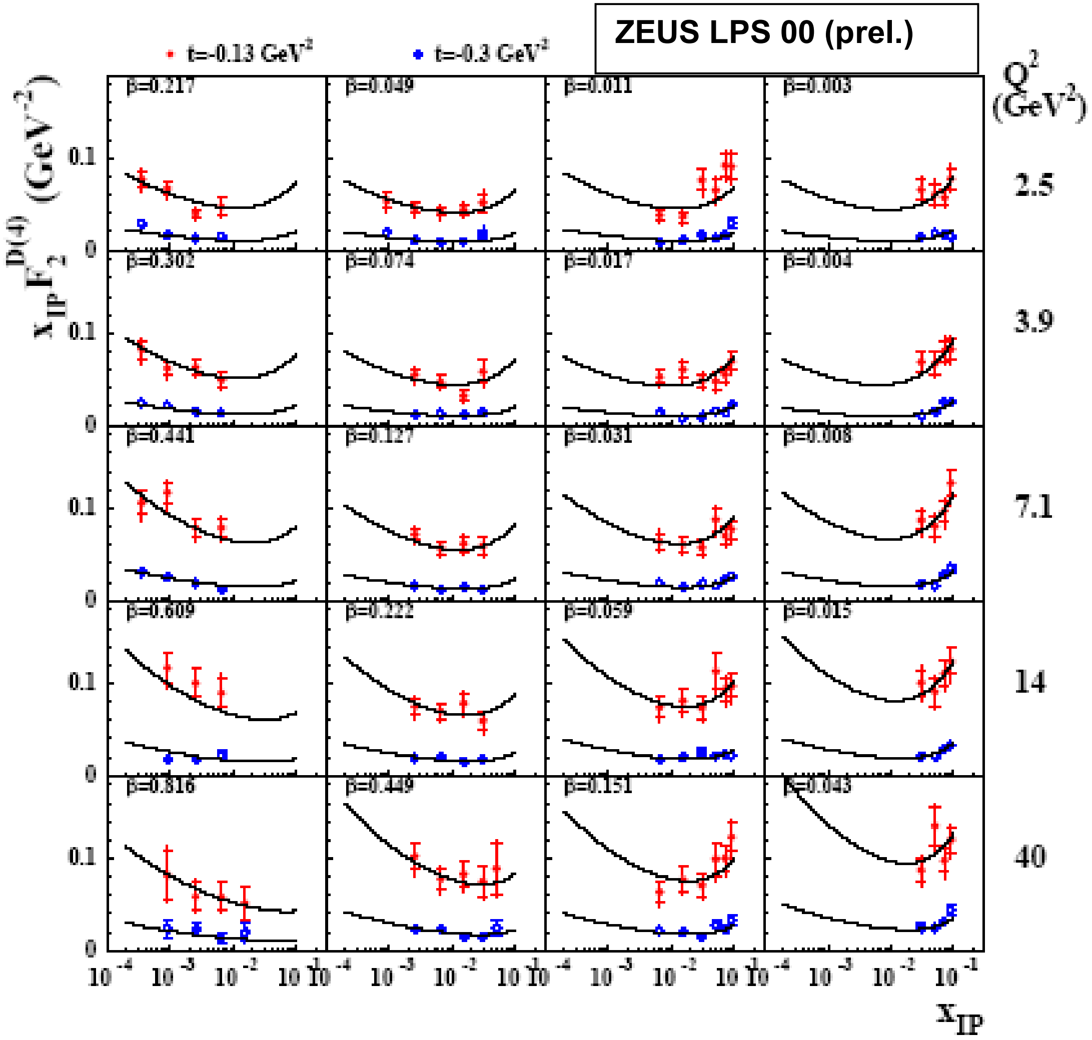
Details of the analyses

- DATA
  - 2000e+, LPS (32.6 pb^{-1}), LRG (45.4 pb^{-1})
  - Three analysis methods applied for the same data taking period (for M_X analysis – see Bernd's presentation)
- Kinematic coverage
  - LPS: $2 < Q^2 < 120$ GeV^2, $40 < W < 240$ GeV, $2 < M_X < 40$ GeV
  - LRG: $2 < Q^2 < 305$ GeV^2, $40 < W < 240$ GeV, $2 < M_X < 25$ GeV
- Event selection
  - Scattered electron in the calorimeter
  - LPS: detection of scattered proton
  - LRG: energy in the Forward Plug Calorimeter (FPC) < 1 GeV, $\eta_{max} < 3$

ZEUS LPS results (1)

— Regge fit: $F_2^{D(4)} = f_{IP}(x_{IP},t)\cdot F_2^{IP}(\beta,Q^2) + n_{IR}\cdot f_{IR}(x_{IP},t)\cdot F_2^{IR}(\beta,Q^2)$

● t = -0.13 GeV² ● t = -0.3 GeV²



$$f_{IP}(x_{IP},t) = \frac{e^{B_{IP}t}}{x_{IP}^{2\alpha_{IP}(t)-1}}$$

$$f_{IR}(x_{IP},t) = \frac{e^{B_{IR}t}}{x_{IP}^{2\alpha_{IR}(t)-1}}$$

$F_2^{IR}(\beta,Q^2)$ − pion structure function (GRV)

Fit results:

$$\alpha_{IP}(0) = 1.1 \pm 0.02(\text{stat.})^{+0.01}_{-0.02}(\text{syst.}) + 0.02(\text{model})$$

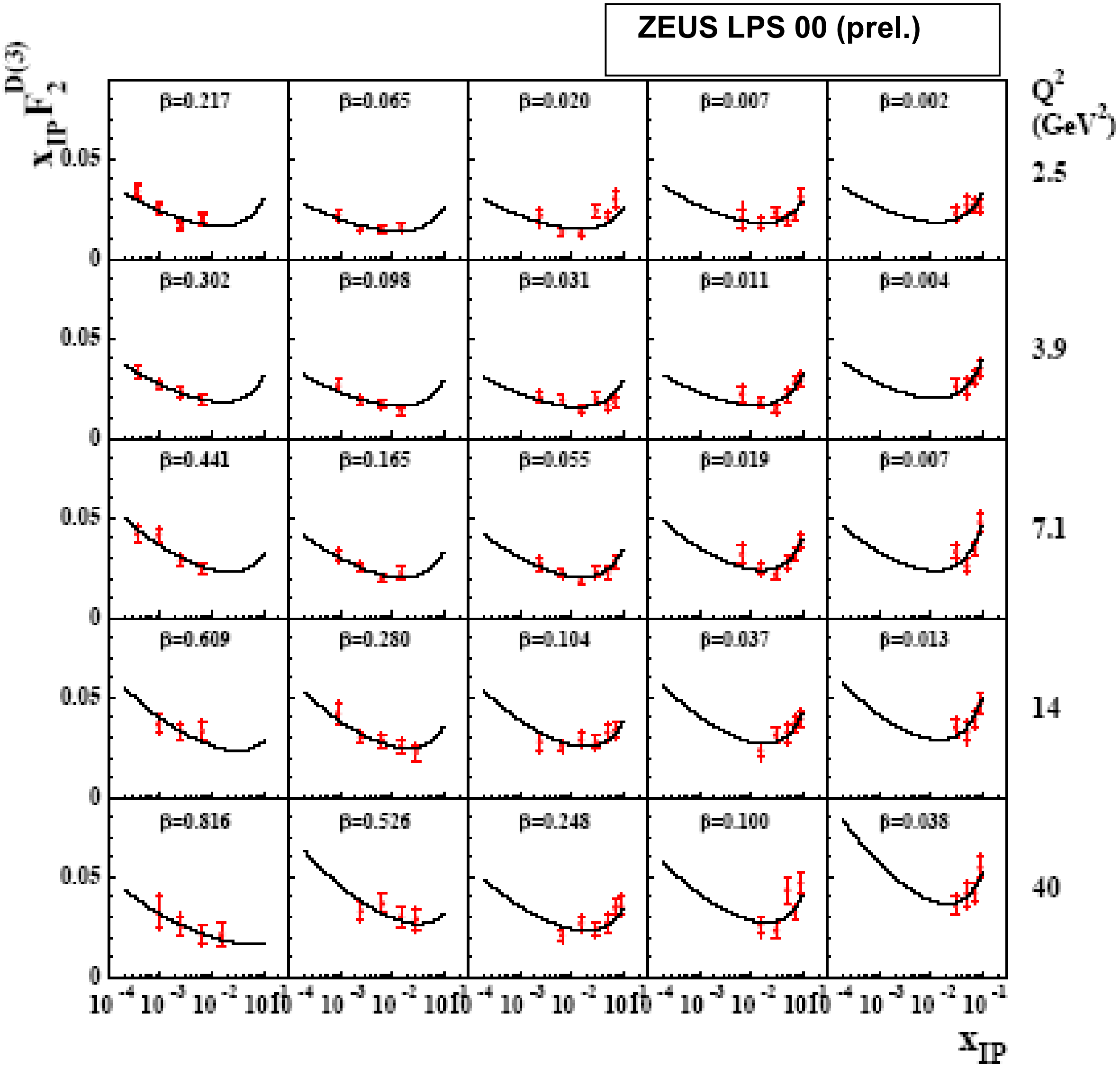
$$\alpha_{IP}{}' = -0.03 \pm 0.07(\text{stat.})^{+0.04}_{-0.08}(\text{syst.})\ \text{GeV}^{-2}$$

$$B_{IP} = 7.2 \pm 0.7(\text{stat.})^{+1.4}_{-0.7}(\text{syst.})\ \text{GeV}^{-2}$$

$$\alpha_{IR}(0) = 0.75 \pm 0.07(\text{stat.})^{+0.02}_{-0.04}(\text{syst.}) \pm 0.05(\text{model})$$

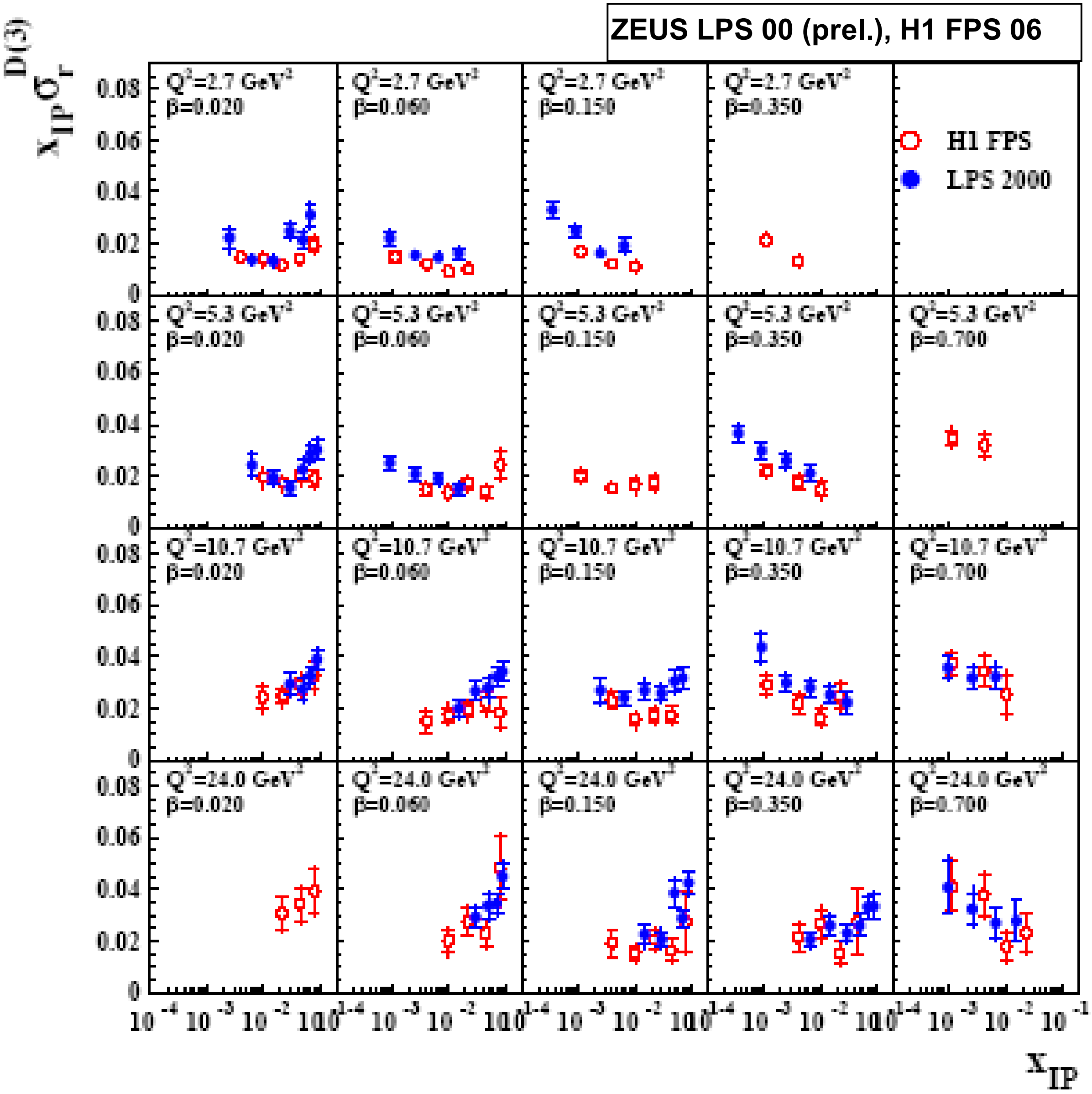
$$\chi^2/\text{ndf} = 172.5/153 = 1.13$$

ZEUS LPS results (2)



ZEUS LPS results (3)

Comparison of recent LPS and H1 FPS results:



$$R^D = \sigma_L^{\gamma^* p \to pX} / \sigma_T^{\gamma^* p \to pX}$$

$$R^D = 0 \longrightarrow x_{IP} F_2^{D(3)} = x_{IP} \sigma_r^{D(3)}$$

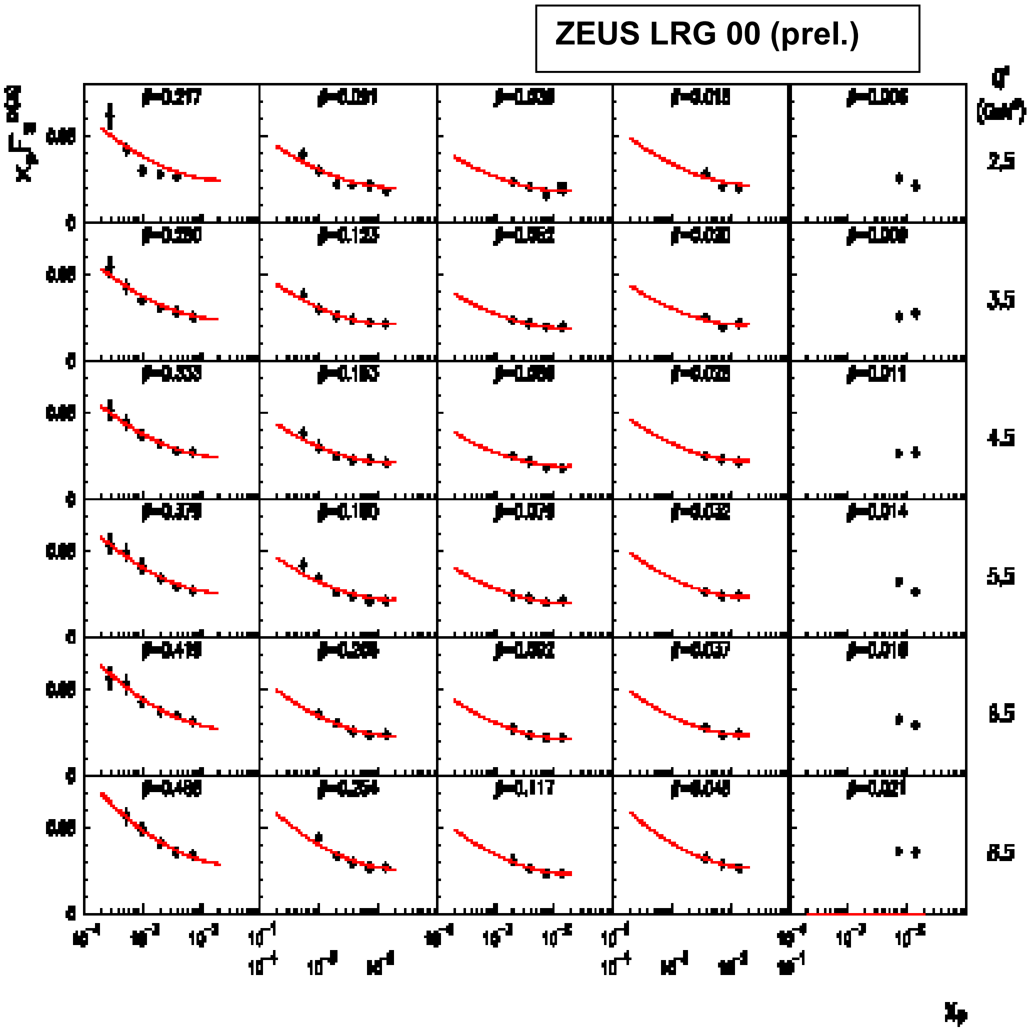
Normalization uncertainties are not shown:

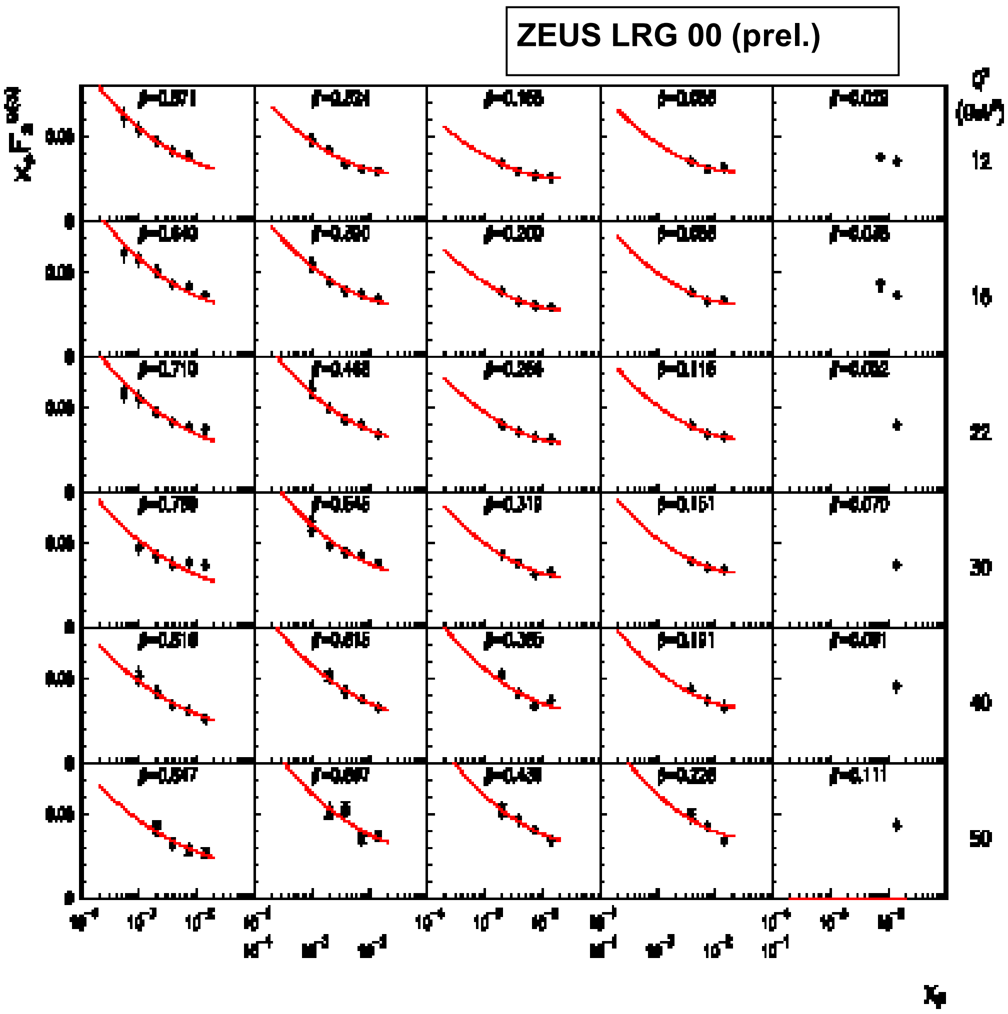
+12% / -10% for ZEUS LPS

+/-10% for the H1 FPS data

The agreement is fair

ZEUS LRG results (1)





Input parameters to the Regge-fit:

$\alpha'_{IP} = 0.0$ GeV^{-2}, $B_{IP} = 7.2$ GeV^{-2}

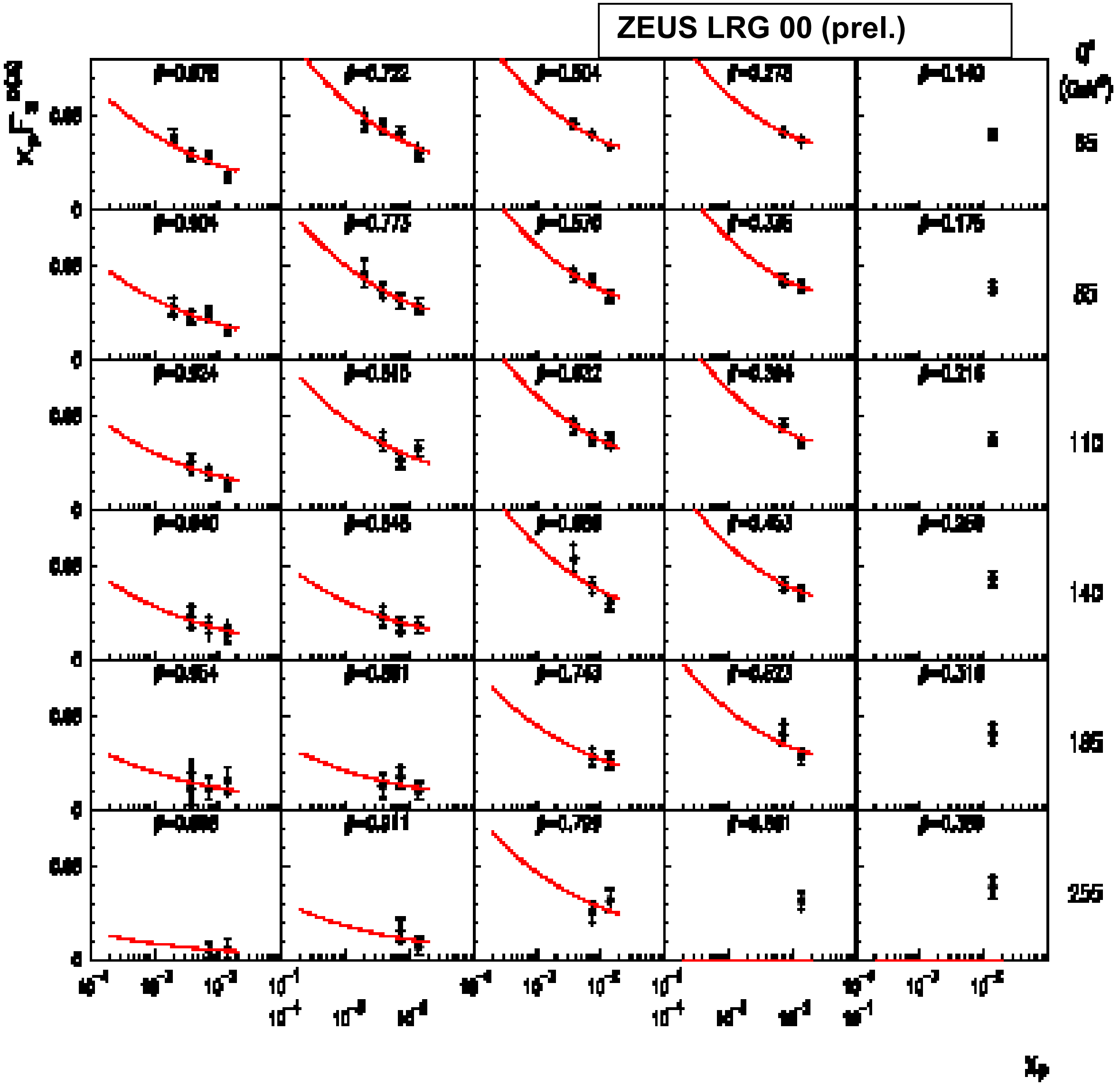
$\alpha_{IR}(0) = 0.75$, $B_{IR} = 2.0$ GeV^{-2}

━ Regge fit

Fit results:

$$\alpha_{IP}(0) = 1.117 \pm 0.005(\text{stat.})^{+0.024}_{-0.007}(\text{model})$$

ZEUS LRG results (2)

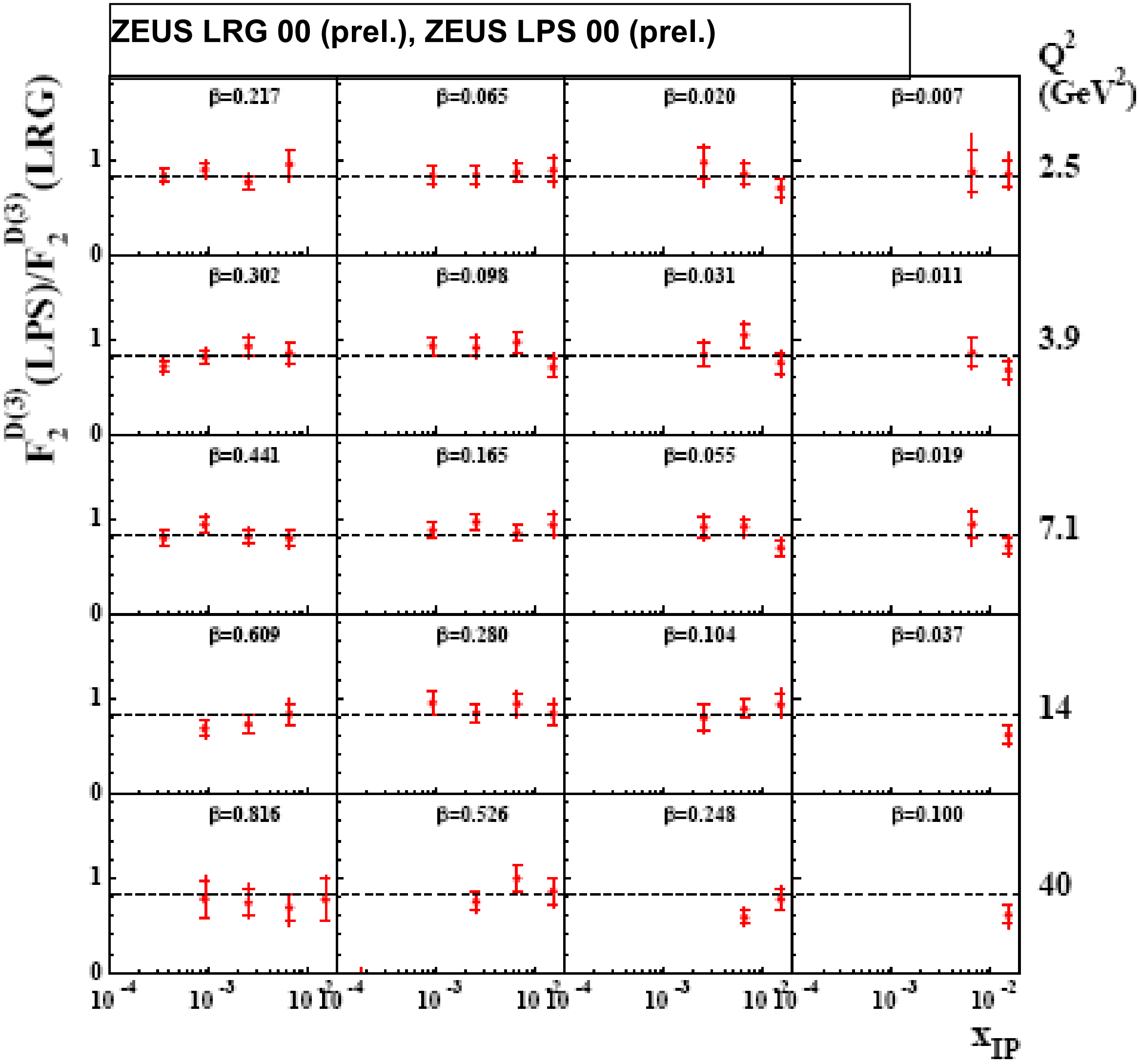


The Regge-fit gives a good description of the ZEUS LRG data

χ^2/ndf = 159/185 (=0.86)

ZEUS LRG results (3)

Comparison of the ZEUS LRG with LPS data:



LPS/LRG = 0.82 ±0.01(stat.) ±0.03(syst.)

independent of Q^2 and β

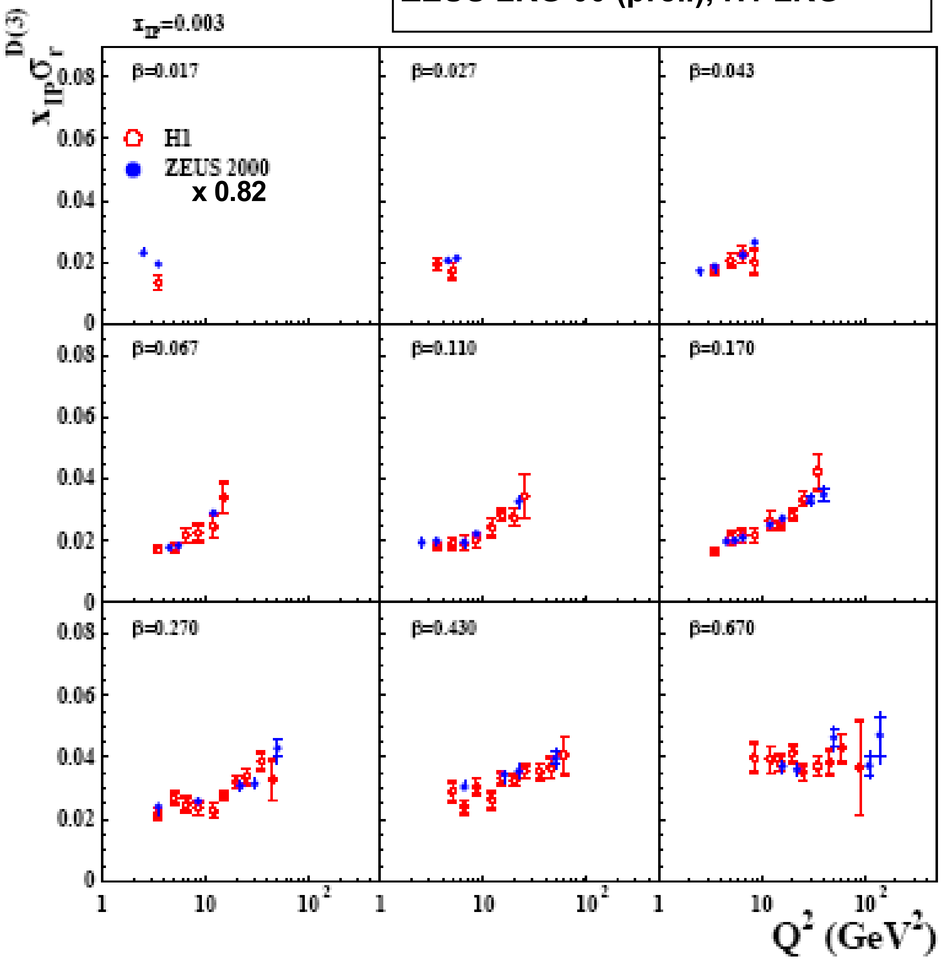
- rough *p*-dissociation background estimation

~10% normalization uncertainty of the LPS measurement is not shown

LRG results – ZEUS vs. H1

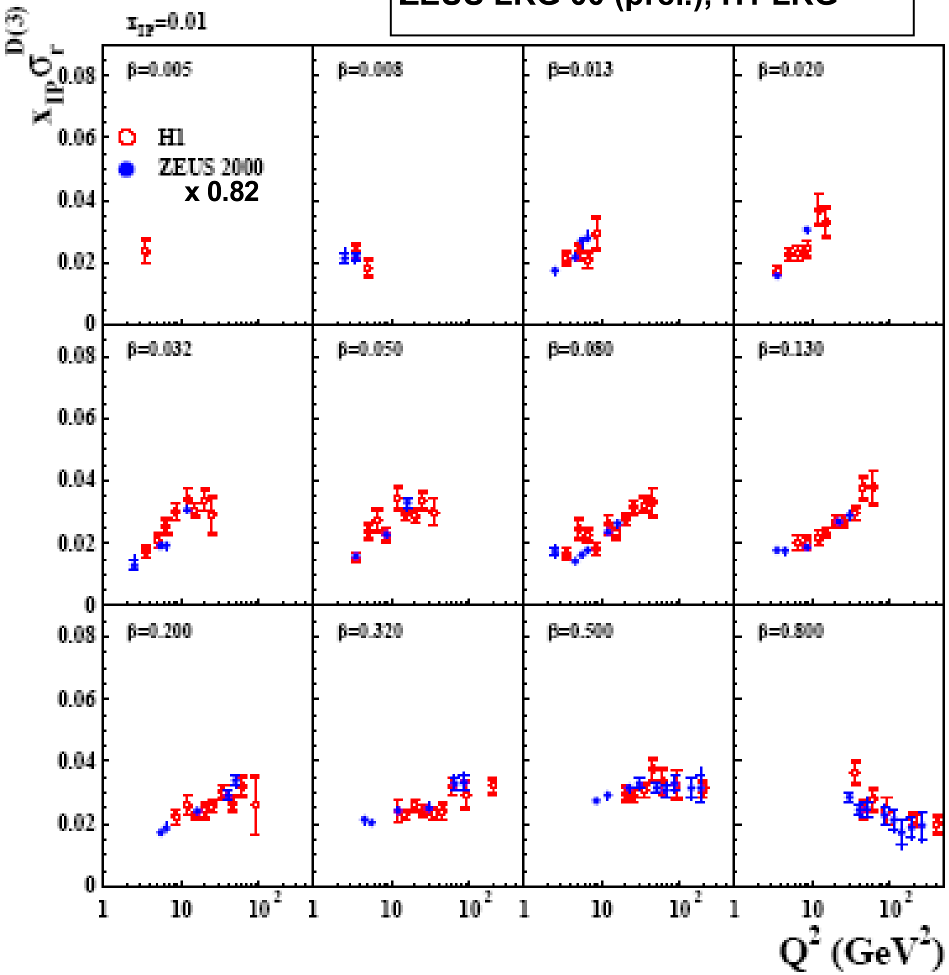
x_{IP} = 0.003

ZEUS LRG 00 (prel.), H1 LRG



x_{IP} = 0.01

ZEUS LRG 00 (prel.), H1 LRG

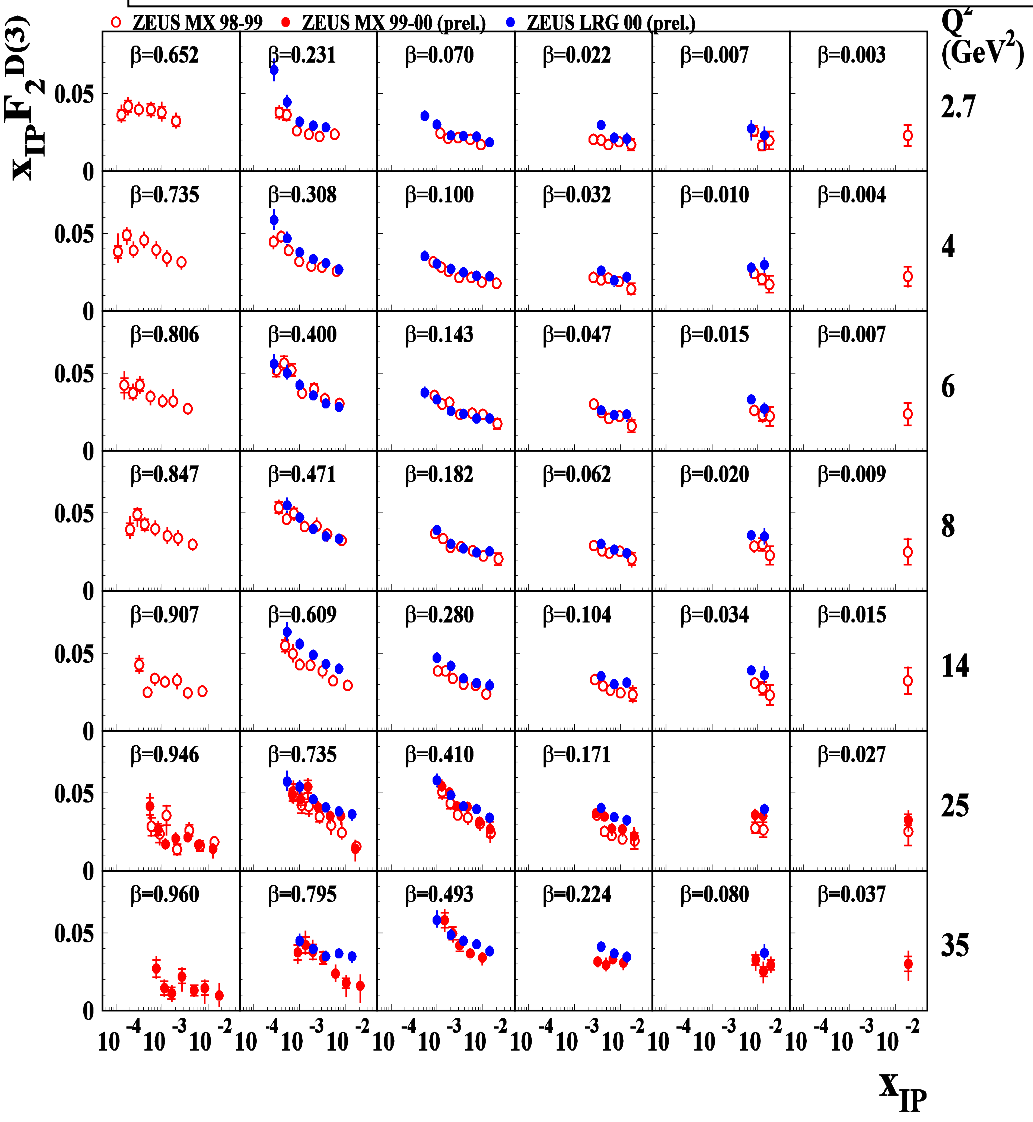


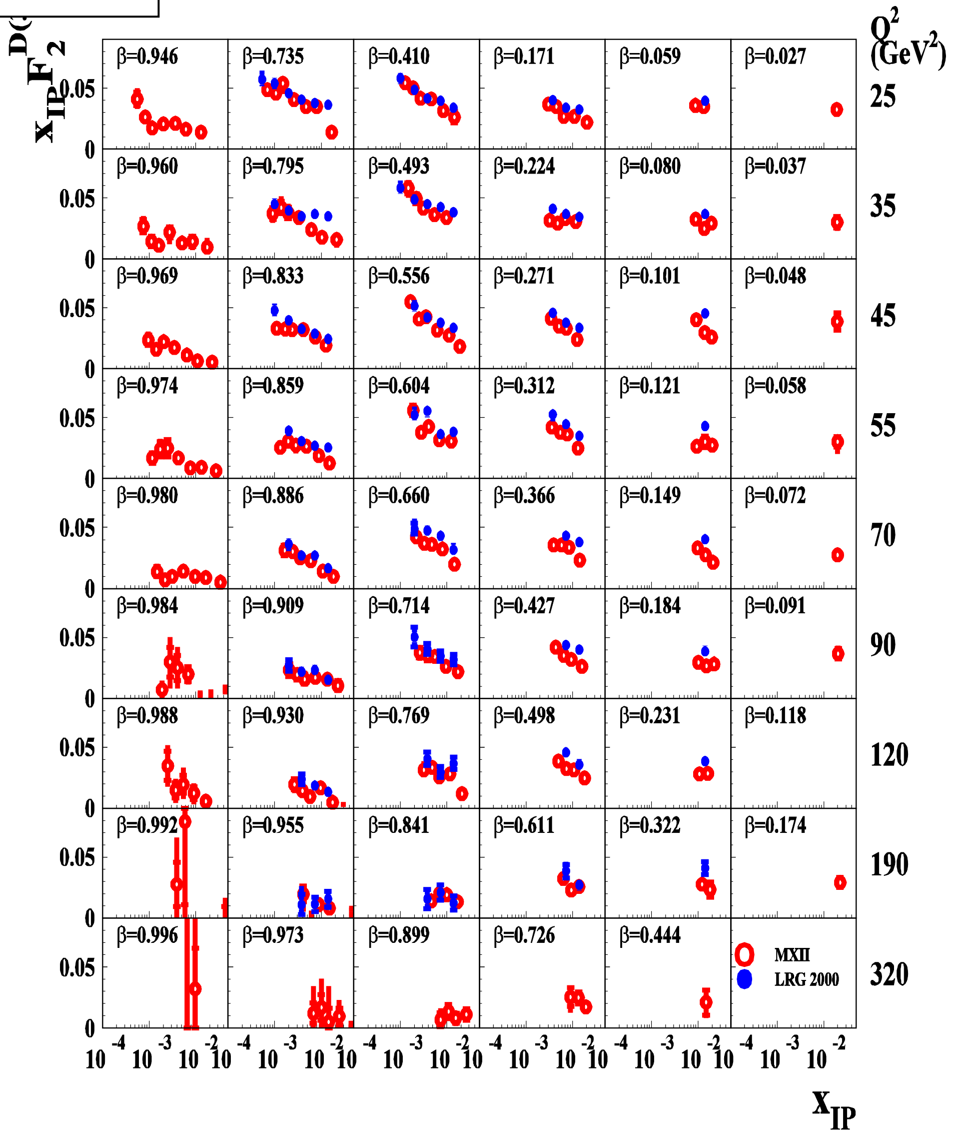
- Fraction of proton dissociation events for ZEUS and H1 detectors is different
- The ZEUS LRG data are rescaled to the H1 LRG data

Good agreement in shapes is observed

ZEUS: comparison of M_X and LRG results (1)

ZEUS MX 98-99, ZEUS MX 99-00 (prel.), ZEUS LRG 00 (prel.)

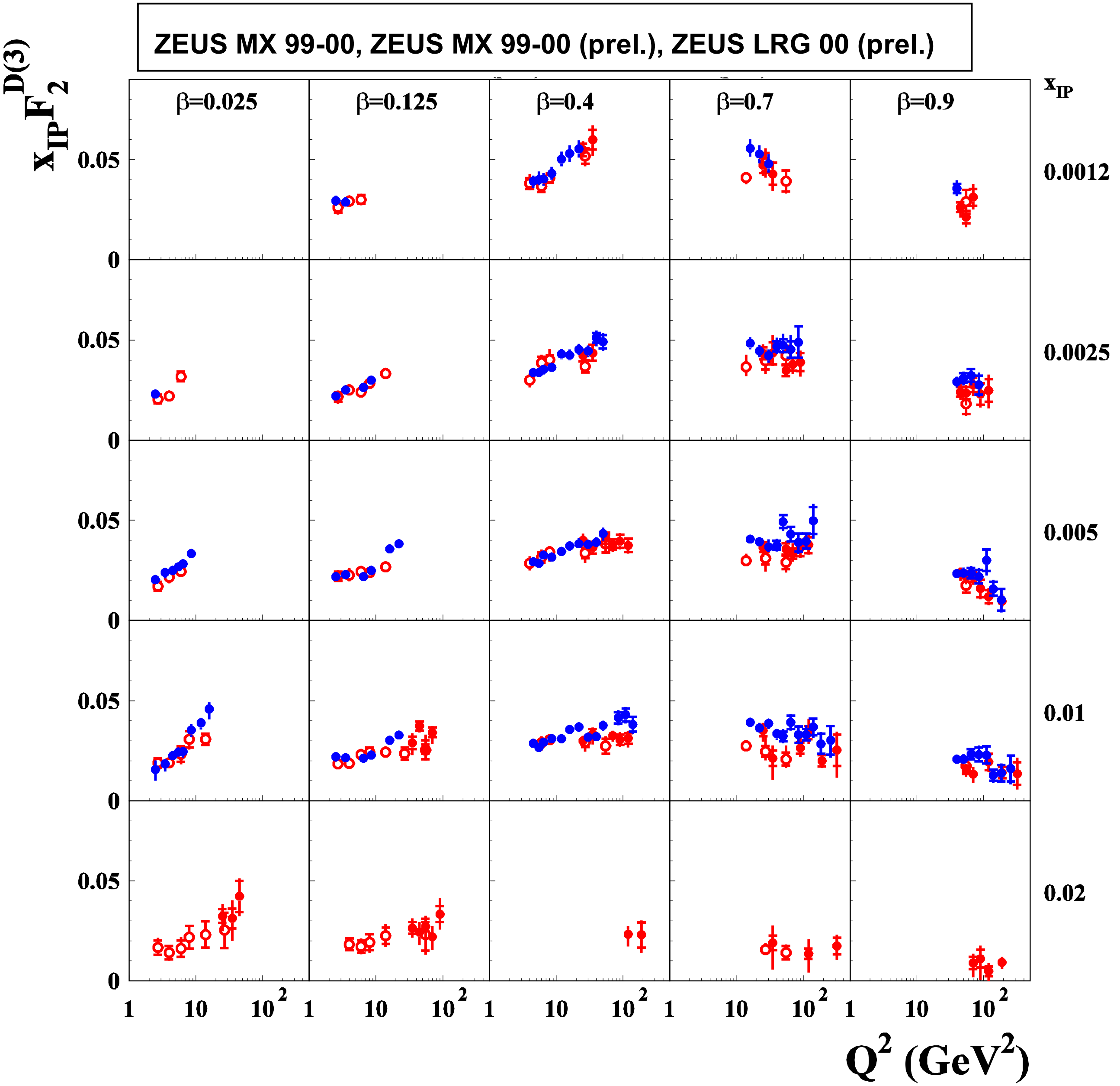




In general reasonable agreement for $x_{IP} < 0.01$

For $x_{IP} > 0.01$ one can expect some differences from Reggeon contributions to the LRG data

ZEUS: comparison of M_X and LRG results (2)



$x_{IP}F_2^{D(3)}$ vs. Q^2

- ○ ZEUS M_X 98-99
- ● ZEUS M_X 99-00 (prel.)
- ● ZEUS LRG 00 (prel.)

- reasonable agreement
- work on understanding remaining differences is continuing

Summary

- ZEUS presented preliminary results on inclusive diffraction obtained with three different methods
- Results for all three methods are derived from data taken during the same time
- The results span a wide kinematic range, up to high Q^2
- There is a good to reasonable agreement for the results from all three methods
- There is also a good agreement compared to H1 results for the LRG and FPS methods
- Work on understanding some remaining differences, in particular with respect to the relative normalisation, continues
- We try to get a consistent picture of the inclusive diffractive DIS