Inclusive Diffraction in DIS at HERA

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on behalf of the **H1** and **ZEUS** collaborations

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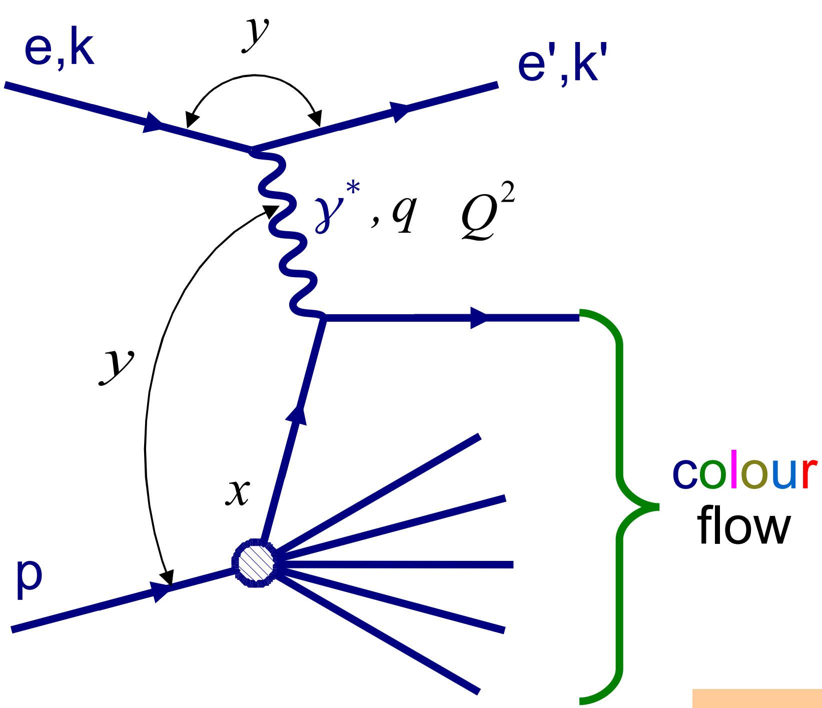
Outline

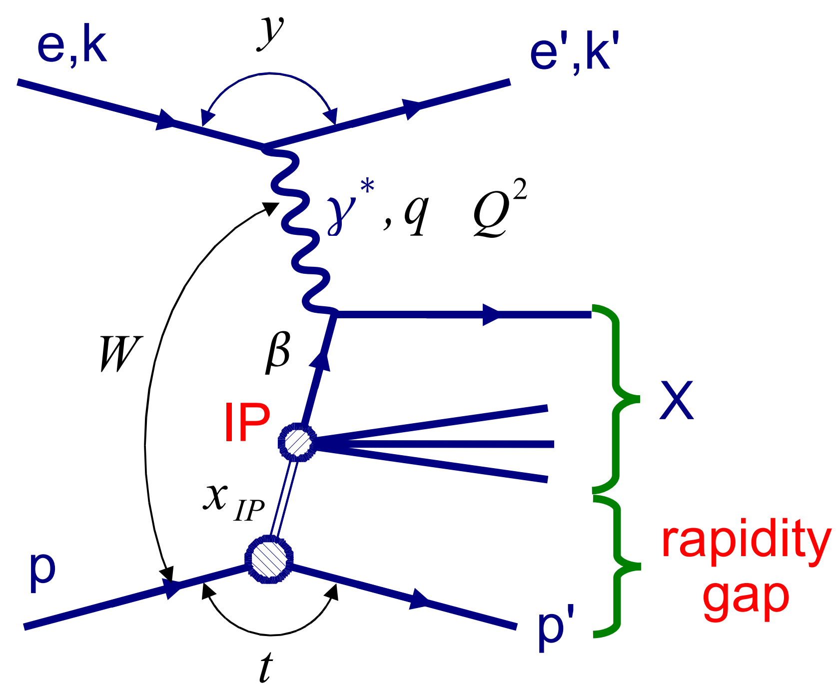
- Introduction – description of NC diffractive DIS, event topologies, structure functions
- Methods of diffractive sample selection: Scattered proton tagging, LRG, M_X
- H1 and ZEUS results, Regge fit, H1 2006 DPDF fits, Q^2 dependence, comparisons
- Summary

NC Deep Inelastic *ep* Scattering

Standard



Diffractive



Q^2, x, y

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

$x = \beta\, x_{IP}$

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

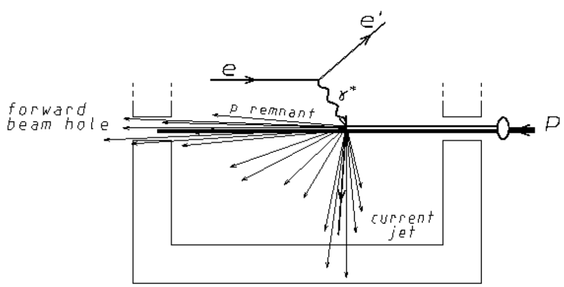
M_X – diffractive mass

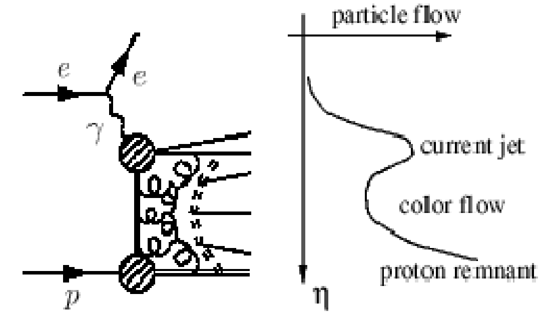
$x_{IP} = \dfrac{(p-p')\cdot q}{p\cdot q}$ – fraction of the proton momentum carried by the *IP*

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

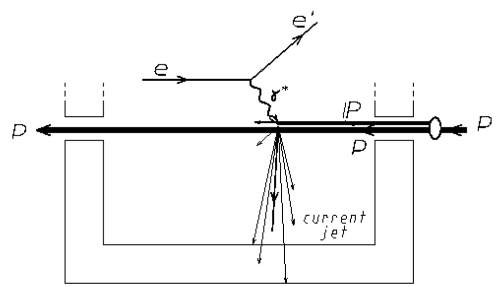
Event topologies

non-diffractive DIS

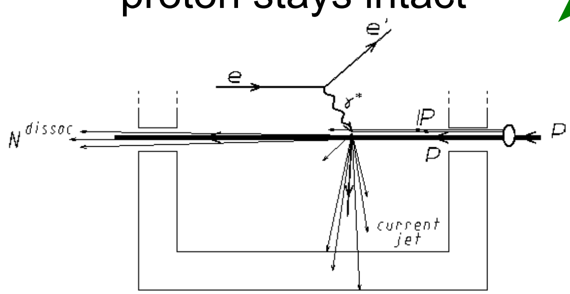




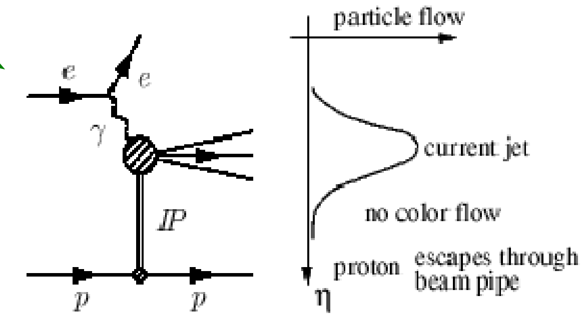
diffractive DIS



proton stays intact



proton dissociation



Diffractive structure functions

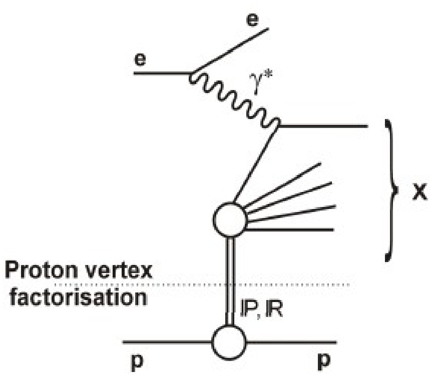
$$\frac{d^4\sigma^D_{\gamma^* p}}{dQ^2\, d\beta\, dx_{IP}\, dt} = \frac{2\pi\alpha^2_{em}}{\beta Q^4}\left(1+(1-y)^2\right) F_2^{D(4)}\left(Q^2,\beta,x_{IP},t\right)$$

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:

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

Reduced cross section:

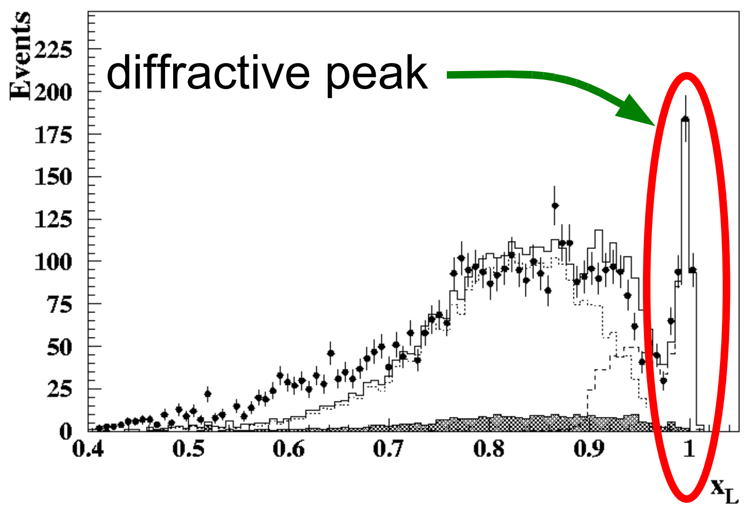
$$\frac{d^4\sigma^D}{d\beta\, dQ^2\, dx_{IP}\, dt} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1-y+\frac{y^2}{2}\right)\cdot\sigma_r^{D(4)}(\beta, Q^2, x_{IP}, t)$$

$$\sigma_r^D = F_2^D - \frac{y^2}{1+(1-y)^2} F_L^D$$

σ_r^D contain the F_L^D contribution

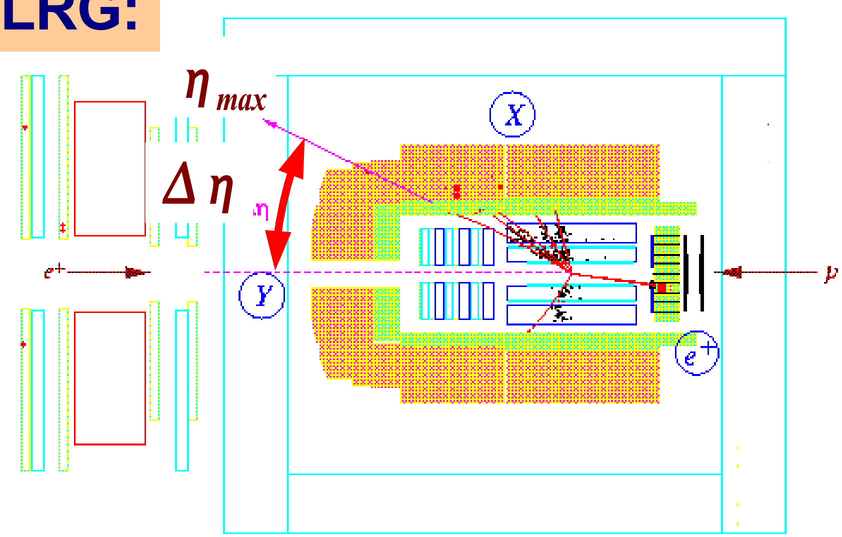
Diffractive event selection

p tagging:

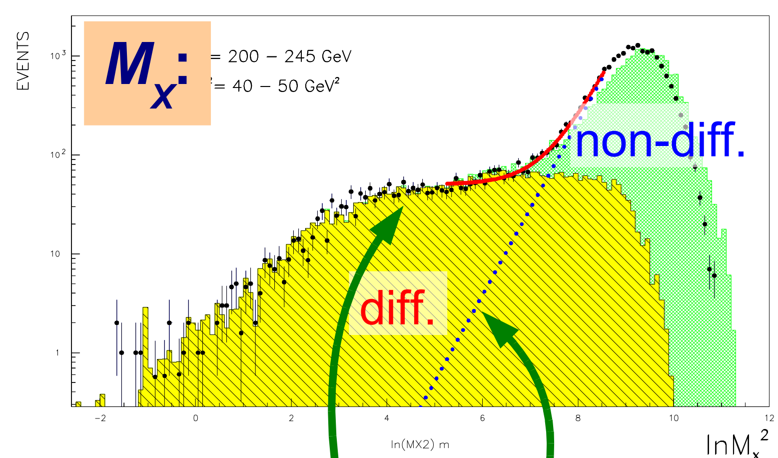


- outgoing p tagging
  - FPS (H1), LPS (ZEUS)
  - clean signature, measurement of t
  - low acceptance
- LRG, M_X
  - high statistics methods
  - different p dissociation background, need to be subtracted

LRG:



M_X:



$$\frac{dN}{d\ln(M_X^2)} = D + c\exp(b\ln(M_X^2))$$

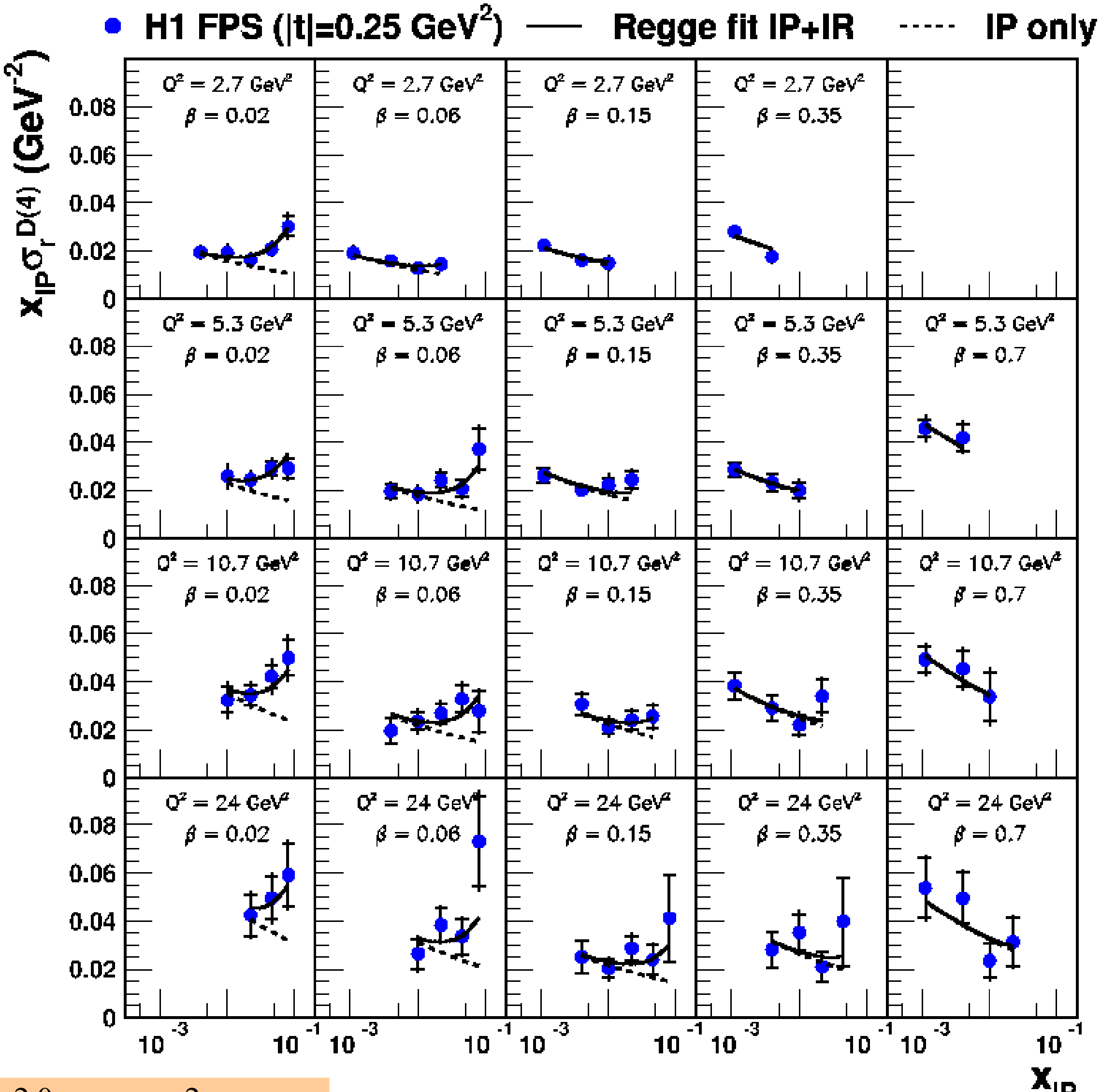
H1 FPS results

Results published:
Eur. Phys. J. C48 (2006) 749-766
hep-ex/0606003

- 99-00 data, 28.4 pb^{-1}
- $x_{IP} < 0.1$, $2 < Q^2 < 50$ GeV^2

Regge fit:

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



$$\alpha_{IP}' = 0.06^{+0.19}_{-0.06}\,\mathrm{GeV}^{-2} \qquad B_{IP} = 5.5^{-2.0}_{+0.7}\,\mathrm{GeV}^{-2}$$

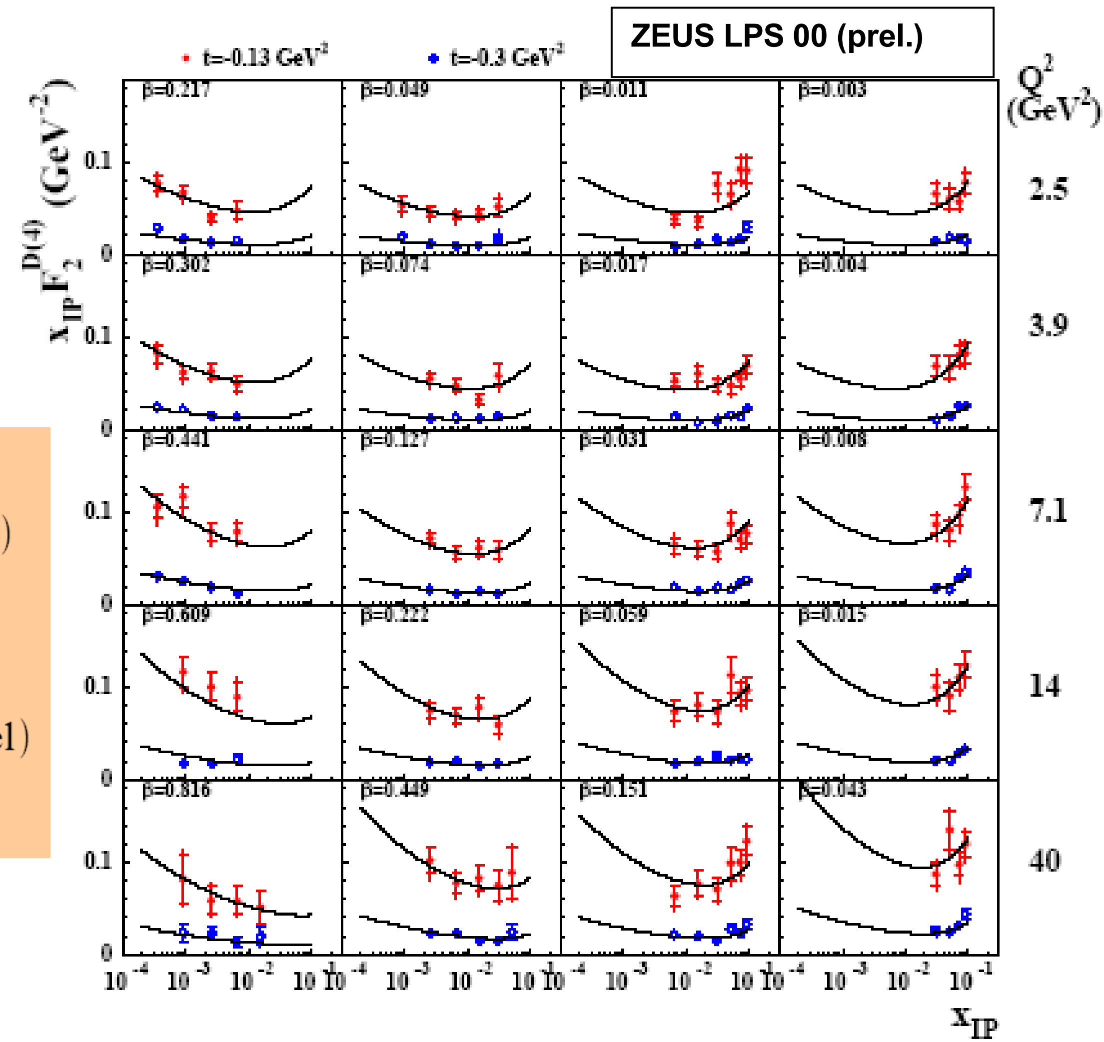
$$\alpha_{IP}(0) = 1.114 \pm 0.018\,(\mathrm{stat.}) \pm 0.012\,(\mathrm{syst.})^{+0.040}_{-0.020}\,(\mathrm{model.})$$

ZEUS LPS results

Preliminary results:

- 2000e⁺ data, 32.6 pb⁻¹
- $x_{IP} < 0.1$, $2 < Q^2 < 120$ GeV²

● t = -0.13 GeV²   ● t = -0.3 GeV²



— Regge fit

Fit results:

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

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

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

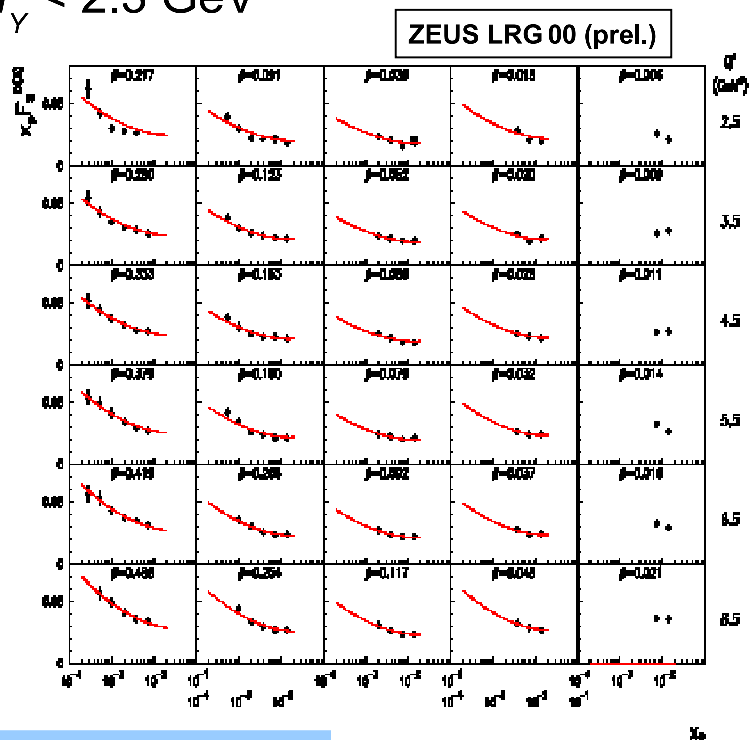
$$\alpha_{IR}(0) = 0.75 \pm 0.07(\text{stat.})^{+0.02}_{-0.04}(\text{syst.}) \pm 0.05(\text{model})$$

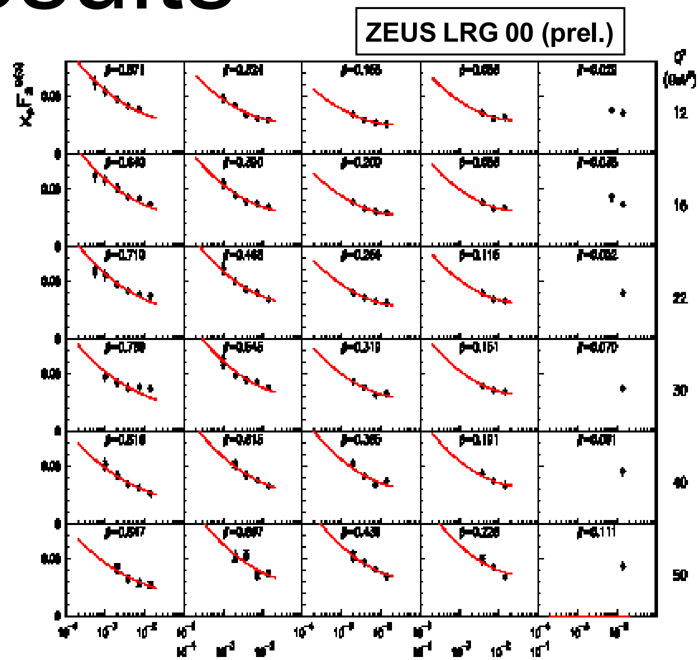
$$\chi^2/\text{ndf} = 172.5/153 = 1.13$$

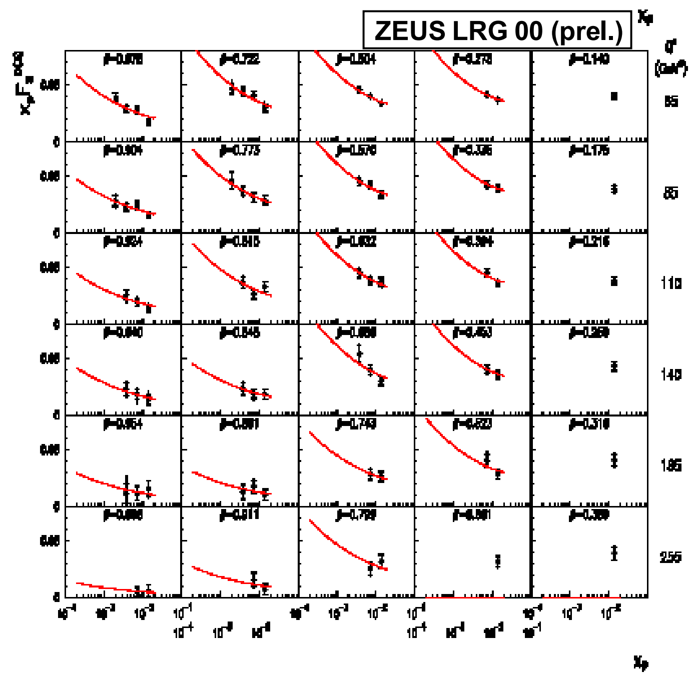
ZEUS LRG results

Preliminary results:

- 2000e+, 45.4 pb^{-1}
- corrected to $M_Y < 2.3$ GeV







— Regge fit

Fit results:

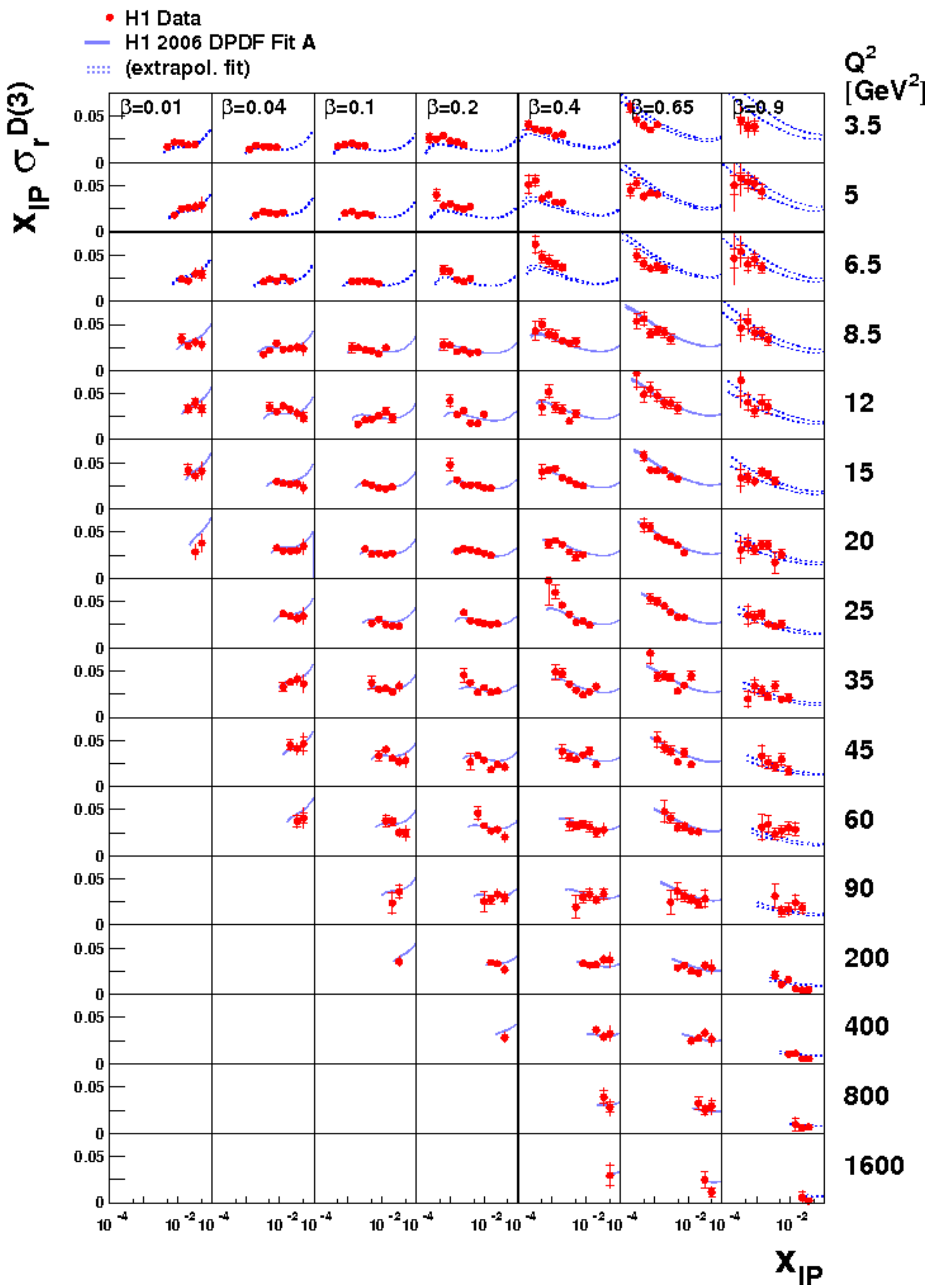
$$\alpha_{IP}(0)=1.117\pm0.005(\text{stat.})^{+0.024}_{-0.007}(\text{model})$$

- The Regge-fit gives a good description of the ZEUS LRG data
- χ^2/ndf = 159/185 (=0.86)

H1 LRG results

Results published:
Eur. Phys. J. C48 (2006) 715-748
hep-ex/0606004

- Data samples:
  - 1997 MB, 2 pb^{-1},
    $3 < Q^2 < 13.5$ GeV^2
  - 1997 all, 10.6 pb^{-1},
    $13.5 < Q^2 < 105$ GeV^2
  - 99-00, 61.6 pb^{-1},
    $133\ GeV^2 > Q^2$
- $x_{IP} < 0.05$, $3.5 < Q^2 < 1600$ $GeV^{2,}$
- $M_Y < 1.6$ GeV



H1 2006 DPDF fits (1)

- QCD hard scale scattering collinear factorisation at fixed x_{IP} and t
  - present data: $ep \rightarrow eXY$, $M_Y < 1.6$ GeV, $|t| < 1$ GeV^2
- Proton vertex factorisation
  - DPDFs are factorised into two terms depending only on (x_{IP},t) and (x,Q^2)
- Fitted region: $\beta \leq 0.8$, $M_X > 2$ GeV, $Q^2 \geq 8.5$ GeV^2, 190 data points
- Parametrisation of quark singlet and gluon distributions:

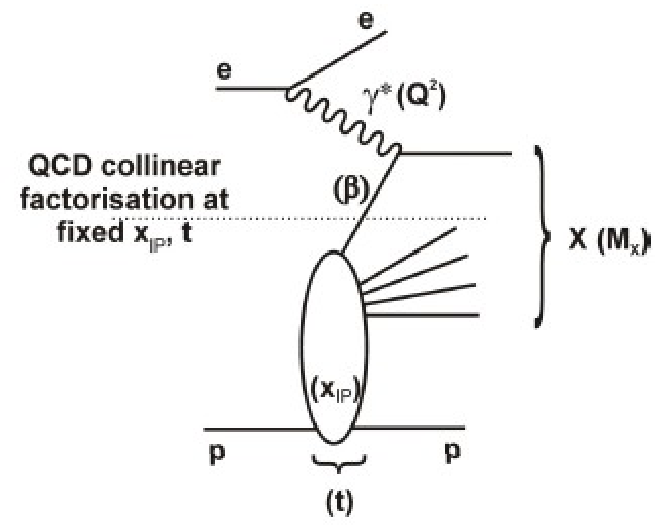
$$z\Sigma(z,Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$$
$$zg(z,Q_0^2) = A_g(1-z)^{C_g}$$

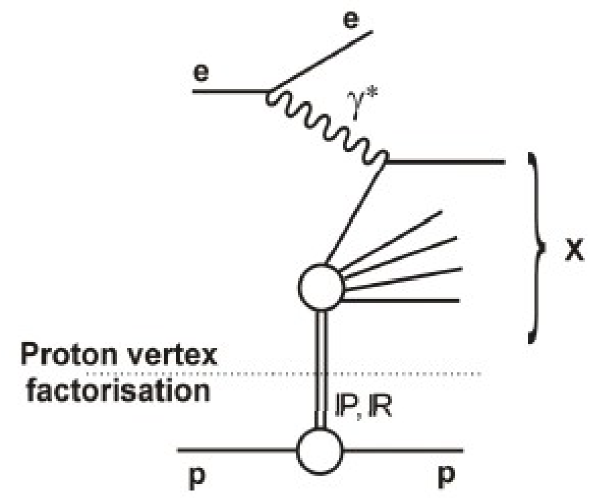
  gluon density insensitive to the B_g

- The x_{IP} dependence parametrisation:

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

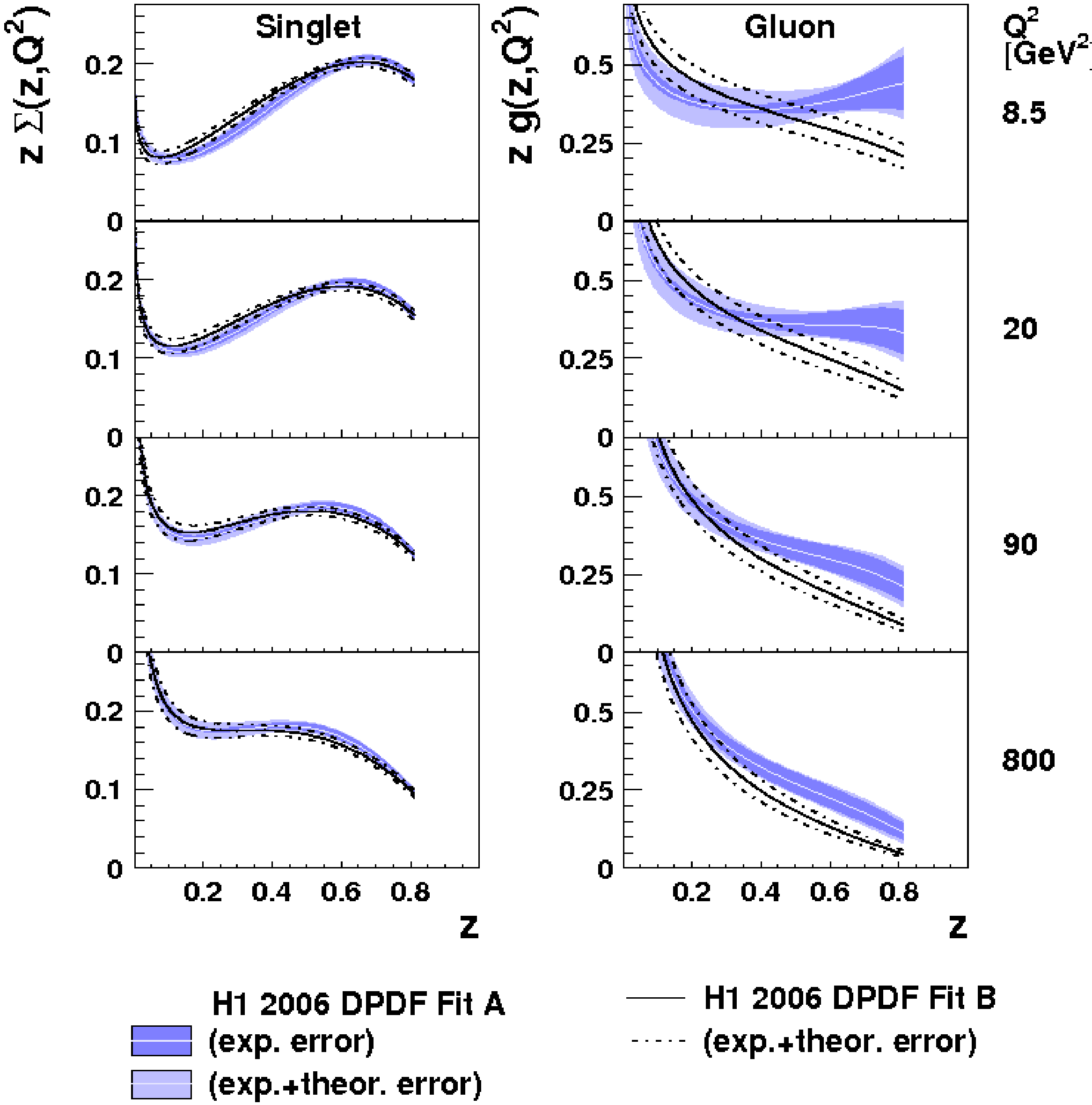
- Sub-leading exchange (IR) is included
  - contributes significantly at low β and large x_{IP}
  - PDFs – from π structure function data (Owens)





H1 2006 DPDF fits (2)

- Free parameters:
  - *A*, *B*, *C* parameters for quark singlet and gluon distributions
  - $\alpha_{IP}(0) - x_{IP}$ dependence
  - n_{IR} – normalisation of the *IR* part



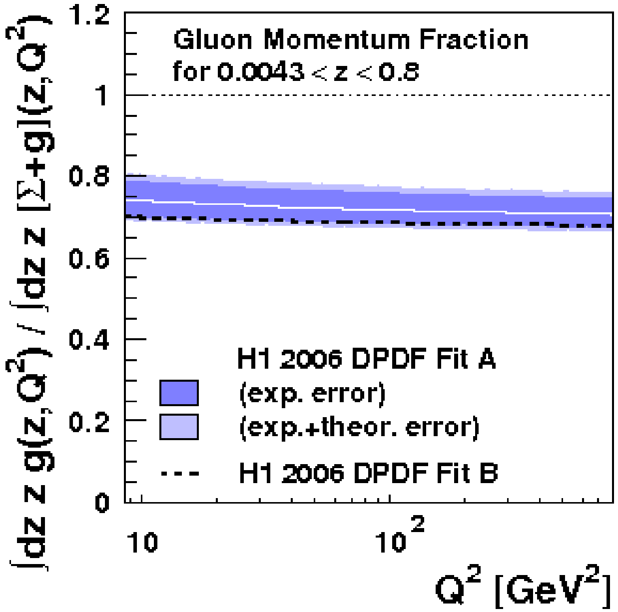
Fit A:
- Q_0^2=1.75 GeV^2
- χ^2/ndf = 158 / 183

Fit B:
- C_g = 0 (gluon parametrised as a constant)
- Q_0^2=2.5 GeV^2
- χ^2/ndf = 164 / 184

- Quark singlet constrained to ~5%, very stable
- Gluon constrained to ~15% at low *z*
- Substantial change to gluon at high *z*

H1 2006 DPDF fits (3)

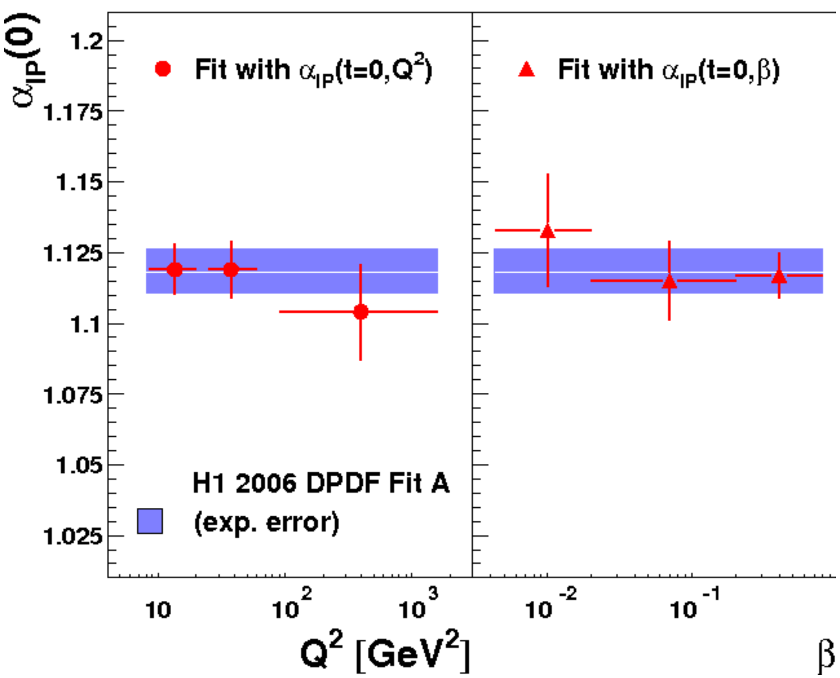
- ~70% of the exchanged momentum carried by gluons
- Fits A & B are consistent within the uncertainties



Effective Pomeron trajectory (Fit A):

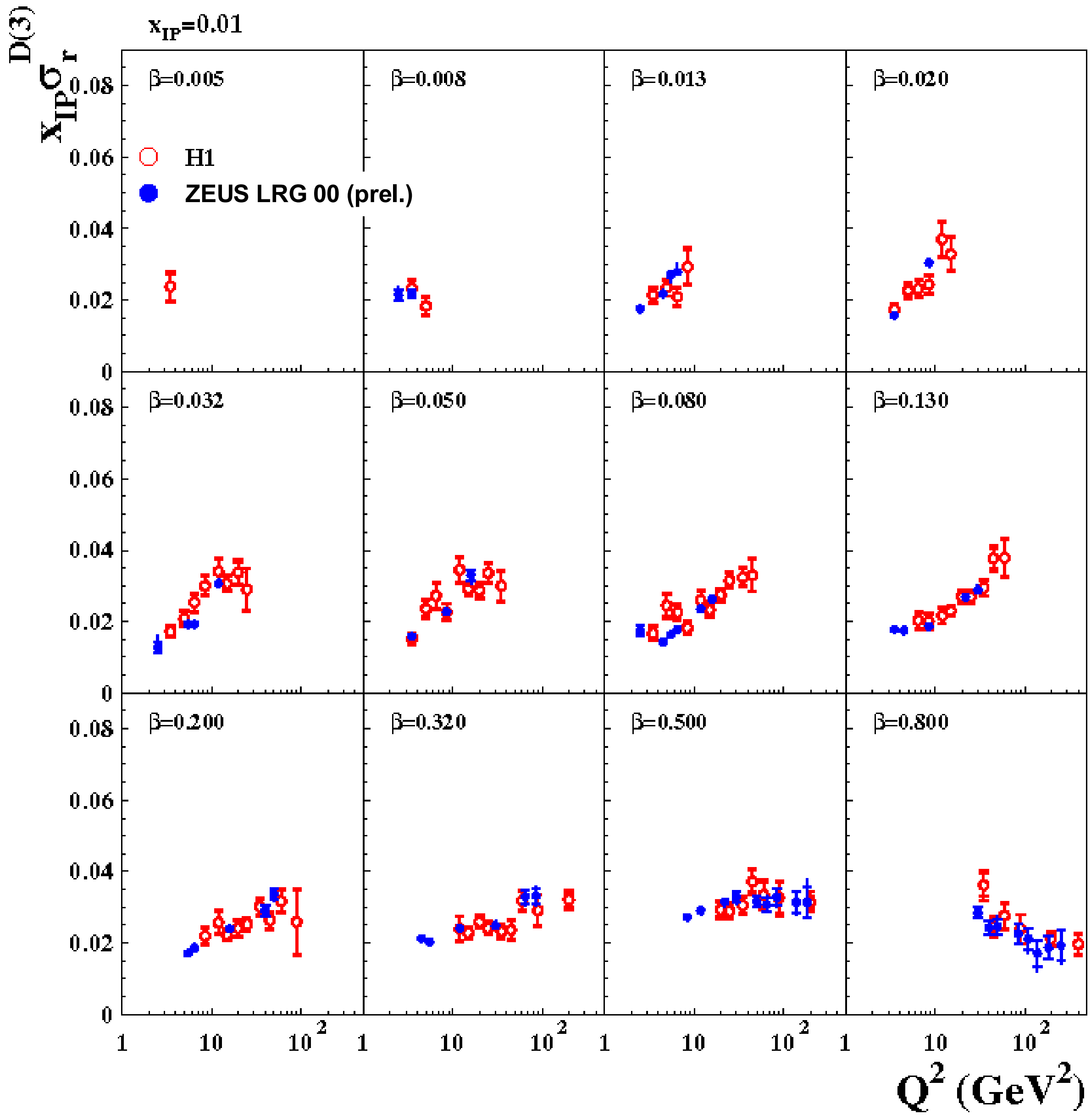
$$\alpha_{IP}(0)=1.118\pm0.008(\text{exp.})^{+0.029}_{-0.010}(\text{model})$$

- Dominant uncertainty from strong correlation with α'_{IP}: $\alpha_{IP}(0)$ increases to ~1.15 if α'_{IP}= 0.25 (instead of 0.06 GeV^{-2})
- No evidence for variation of $\alpha_{IP}(0)$ with Q^2 or β (consistent with *p* vertex factorization)
- Consistent with fits to FPS data



H1 vs ZEUS – LRG results

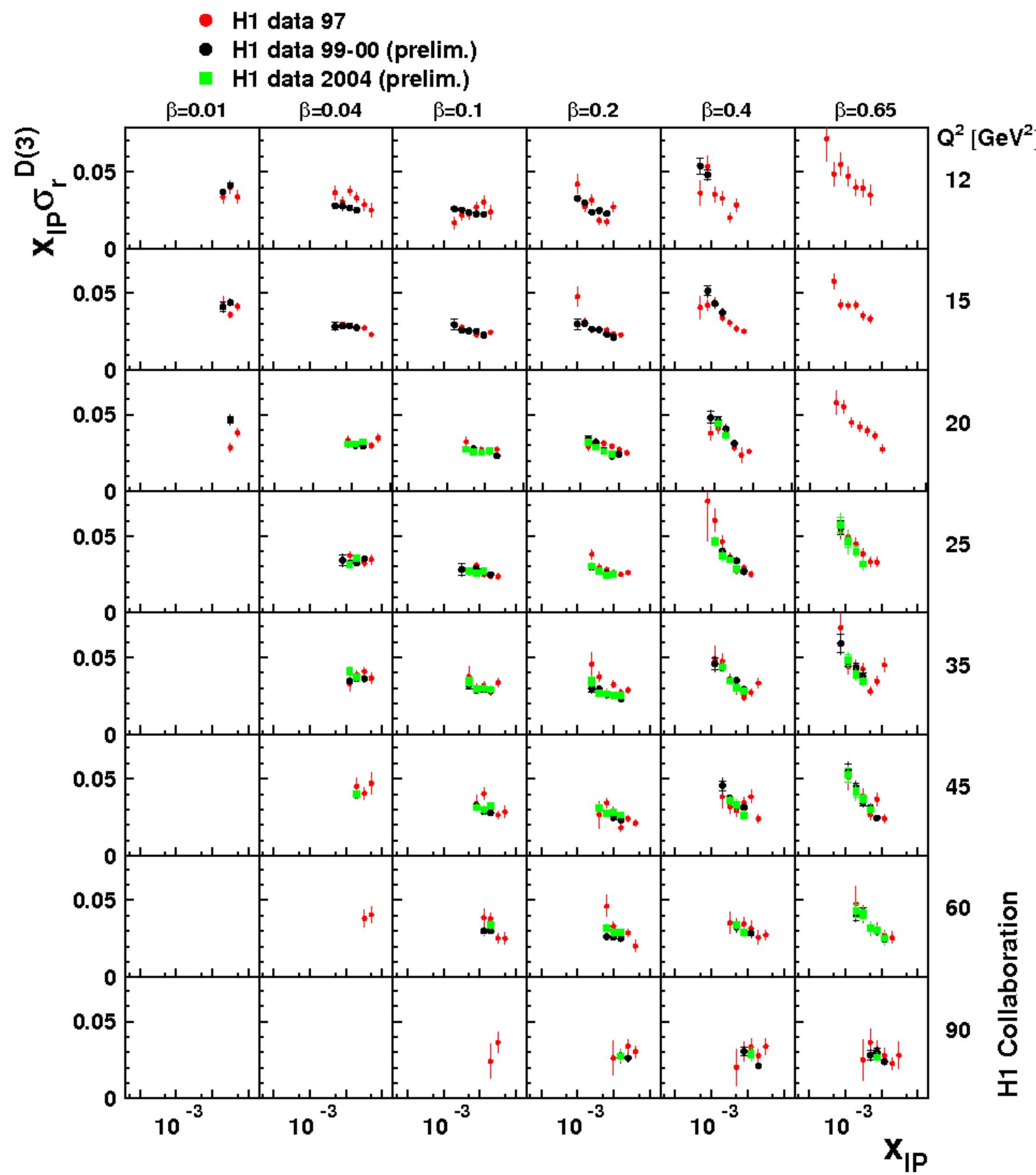
- Q^2 dependence of $x_{IP}\sigma_r^{D(3)}$
- Positive scaling violations, up to high β values – large gluon component
- ZEUS results normalised to H1 (different p-dissociation contribution)
- Good agreement in shapes



H1 new results – LRG method

Preliminary results:

- Data samples:
  - 99-00 data, 34 pb^{-1}
    $10 < Q^2 < 105$ GeV^2
  - 2004 data, 34 pb^{-1}
    $17.5 < Q^2 < 105$ GeV^2
- results corrected to $M_Y < 1.6$ GeV, $|t| < 1$ GeV^2
- 6 times larger statistics

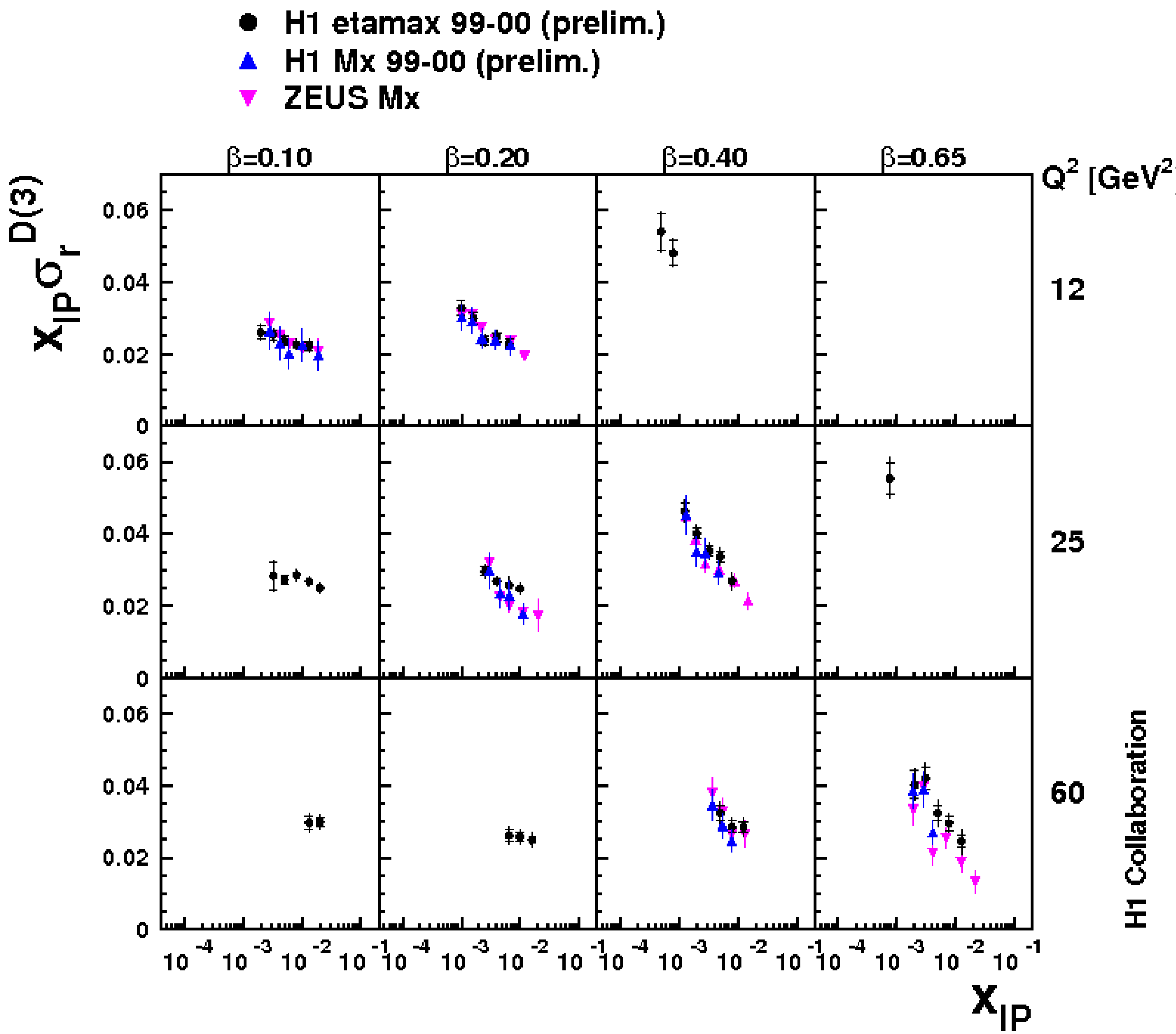


Good agreement between data sets

H1 new results – M_X method

Preliminary results:

- 99-00 data analysed with M_X method
- M_X points moved to Q^2, β, x_{IP} bins and normalised to the same M_Y range (M_Y< 1.6 GeV)
- ZEUS measurement (M_Y< 2.3 GeV) normalised by a factor 0.85



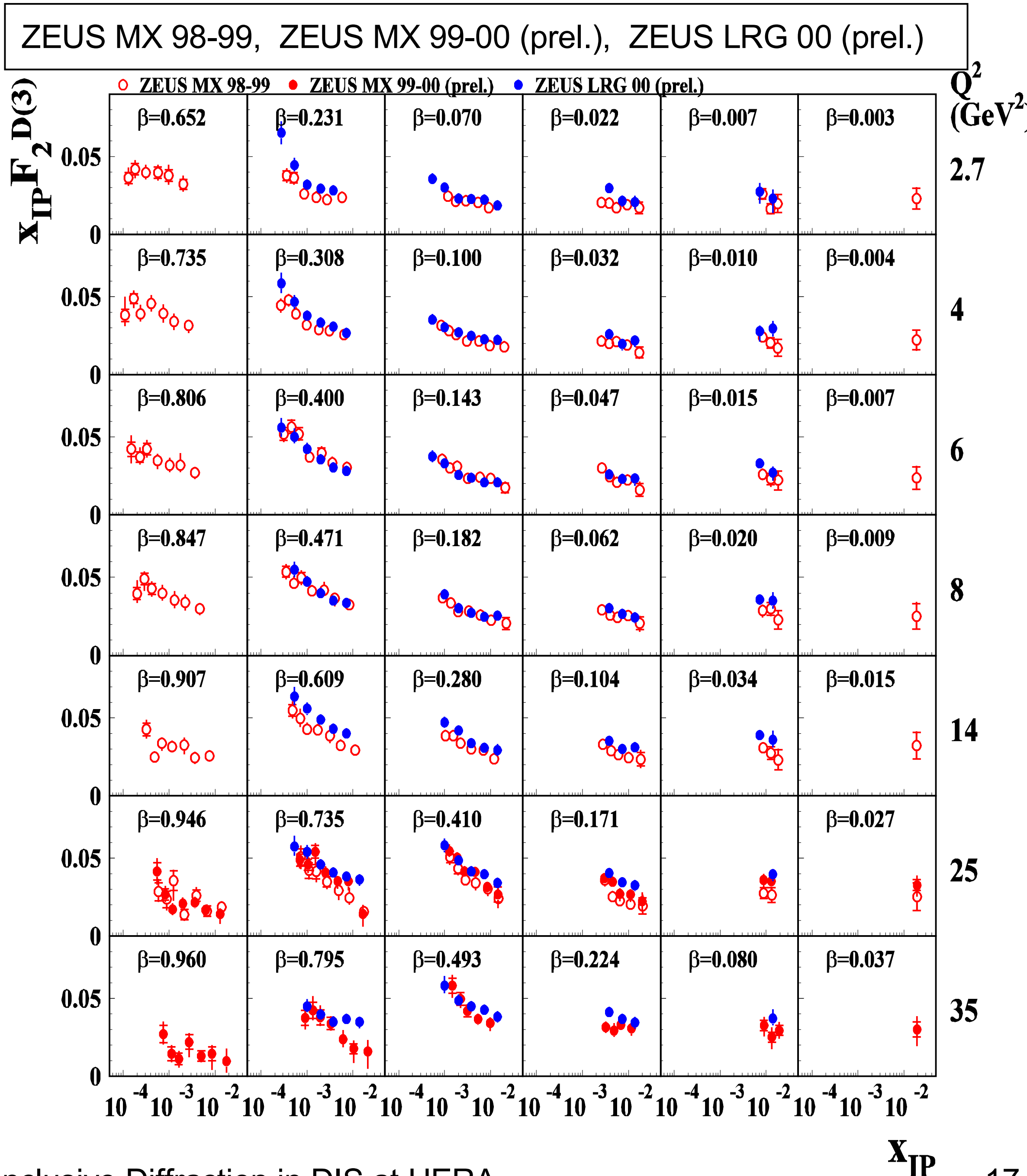
ZEUS: comparison of M_X and LRG results (1)

Published data:
ZEUS Coll., S. Chekanov et al., Nucl. Phys. B 713, 3 (2005)

- M_X 98-99, 4.2 pb^{-1}
- $2.7 < Q^2 < 55$ GeV^2

Preliminary results:

- M_X 99-00, 52.4 pb^{-1}
- $25 < Q^2 < 320$ GeV^2, $1.2 < M_X < 30$ GeV
- Extension of M_X 98-99 analysis to higher Q^2

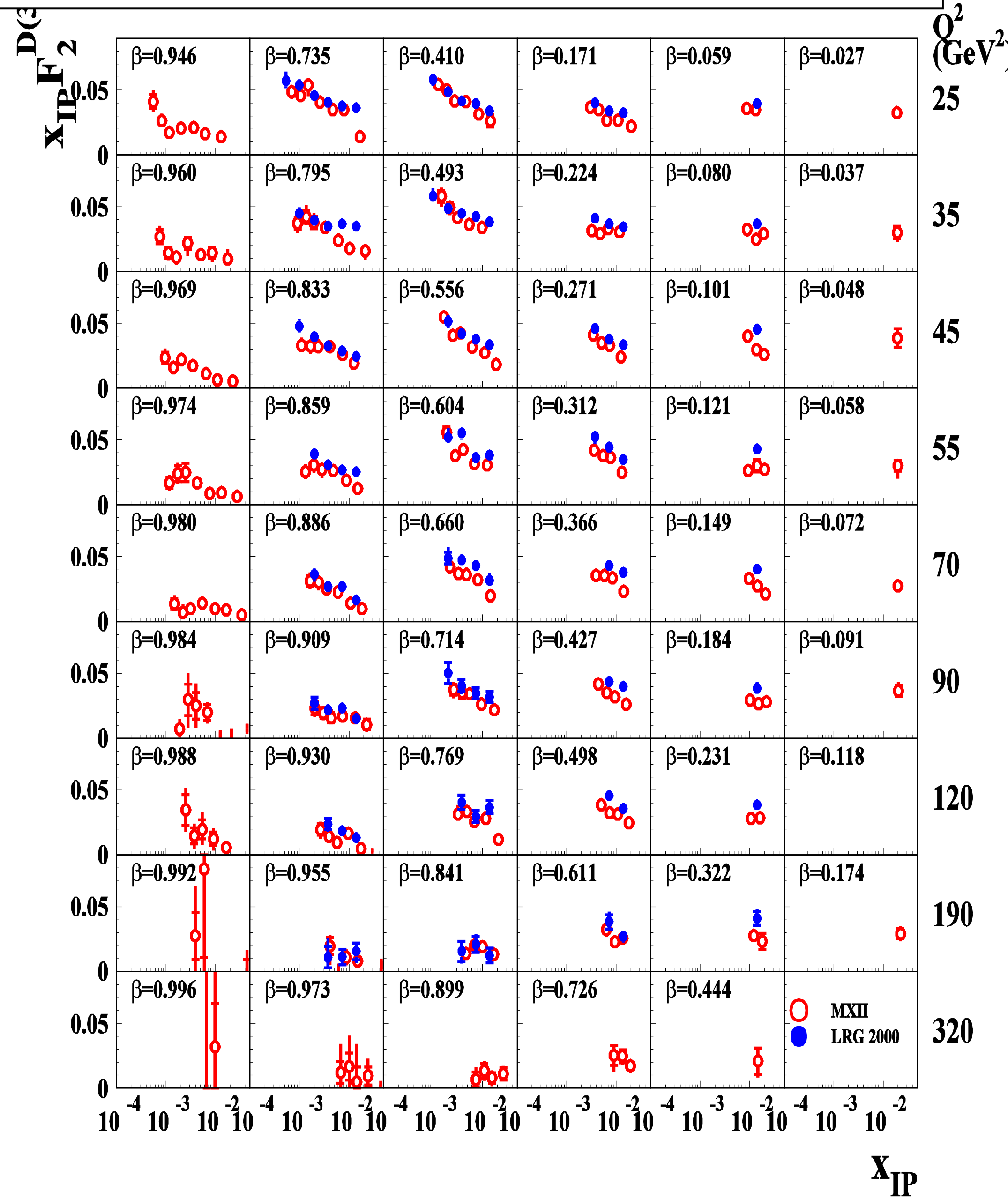


results corrected to $M_Y < 2.3$ GeV

M_X 98-99 and M_X 99-00 analyses have common bin at $Q^2 = 25$ GeV^2

ZEUS: comparison of M_X and LRG results (2)

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

Summary

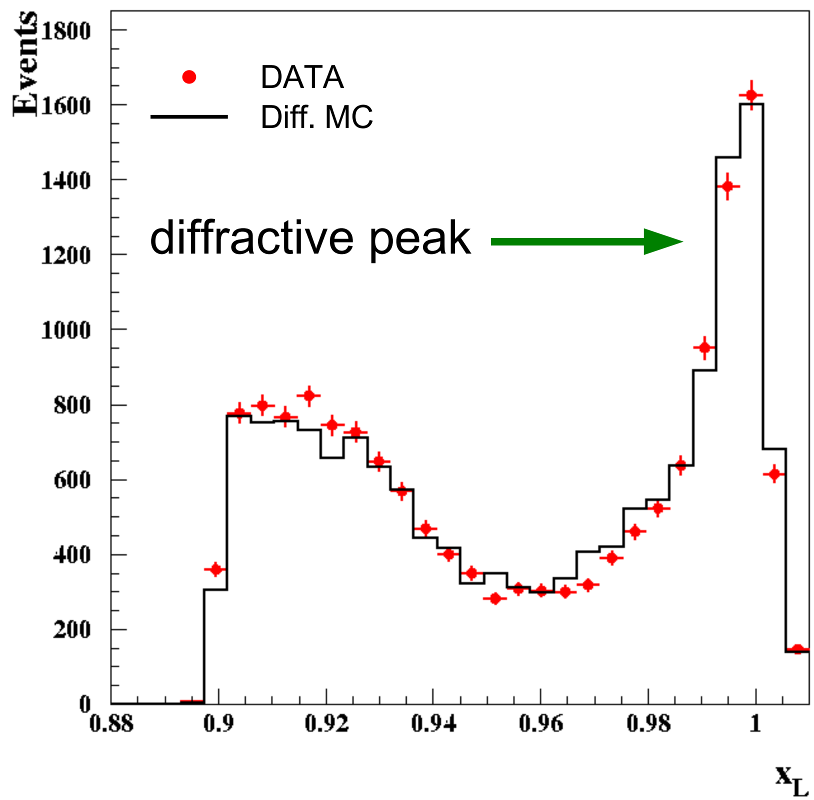
- Results on inclusive diffraction obtained by H1 and ZEUS collaborations with three different methods are presented
- The results span a wide kinematic range, up to high Q^2
- DPDFs obtained, have large gluonic component
- There is a good to reasonable agreement for the results from all methods
- Work on understanding some remaining differences, in particular with respect to the relative normalisation, continues
- We are arriving to a consistent picture of the inclusive diffractive DIS

Backup slides

Scattered proton tagging

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

- Clean experimental signature
- Outgoing proton escapes through the forward beam hole
- A fraction of these events can be detected by the detectors located close to the outgoing proton beam line – FPS (H1), LPS (ZEUS)
- They measure the momentum of the scattered proton – t information available $t = (p - p')^2$
- Practically free of p-dissociation background
- **Drawback**: limited acceptance (few %), dependent on x_L and p_T of outgoing proton

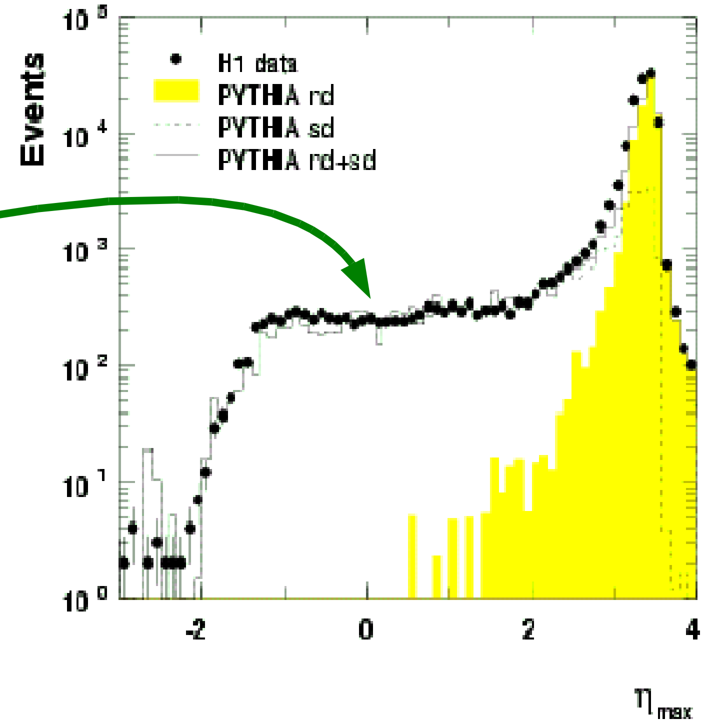


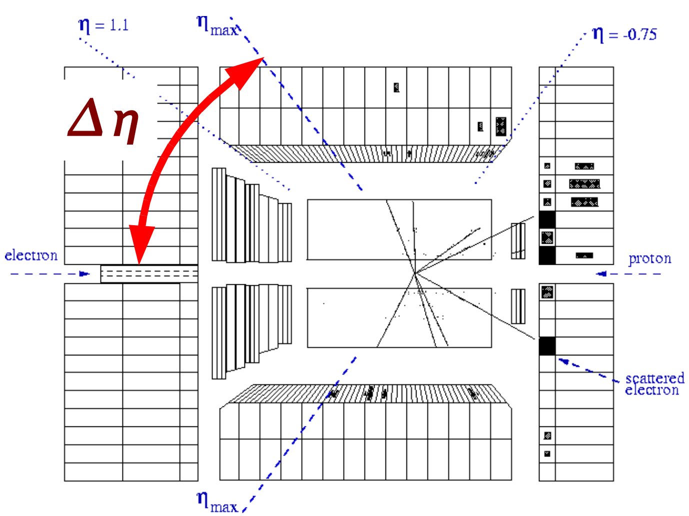
$x_L > 0.97$ – a clean sample of diffractive events

Selection methods – LRG

- A large rapidity gap between the system X and outgoing proton (or proton remnant system Y)
- 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:





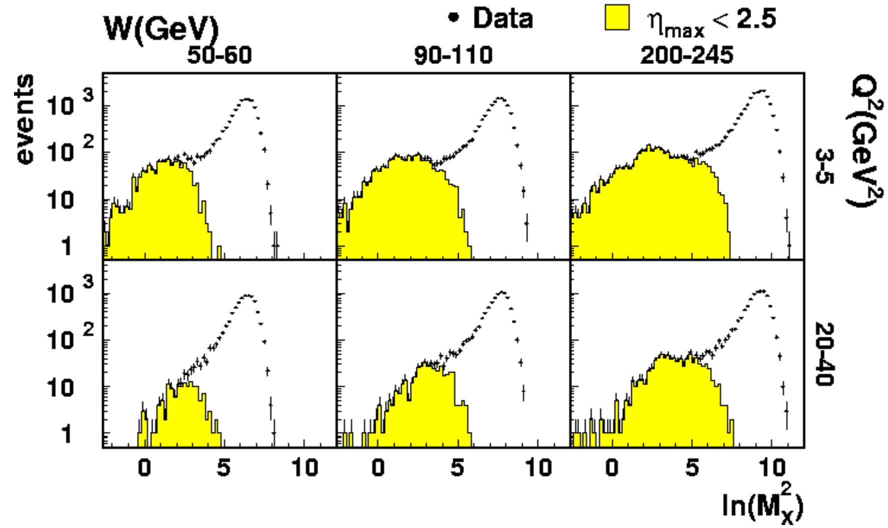
$\eta_{max} < 3$ – a small non-diffractive background

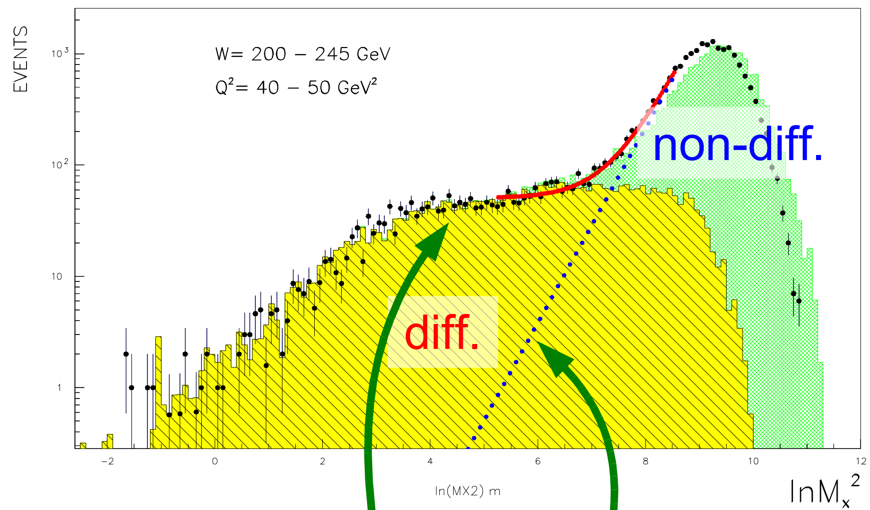
Selection methods – M_X

- Properties of $\ln(M_X^2)$ distribution:
  - flat for diffractive events
  - for non-diffractive events – exponential fall-off towards low masses
  - position of the non-diffractive peak changes with W

- Identifies the diffractive contribution as the excess of events over the exponential fall-off of the non-diffractive part

Drawback:
- Sensitivity to the proton dissociation background





$$\frac{dN}{d\ln(M_X^2)} = D + c\exp(b\ln(M_X^2))$$