On behalf of H1 and ZEUS Collaborations

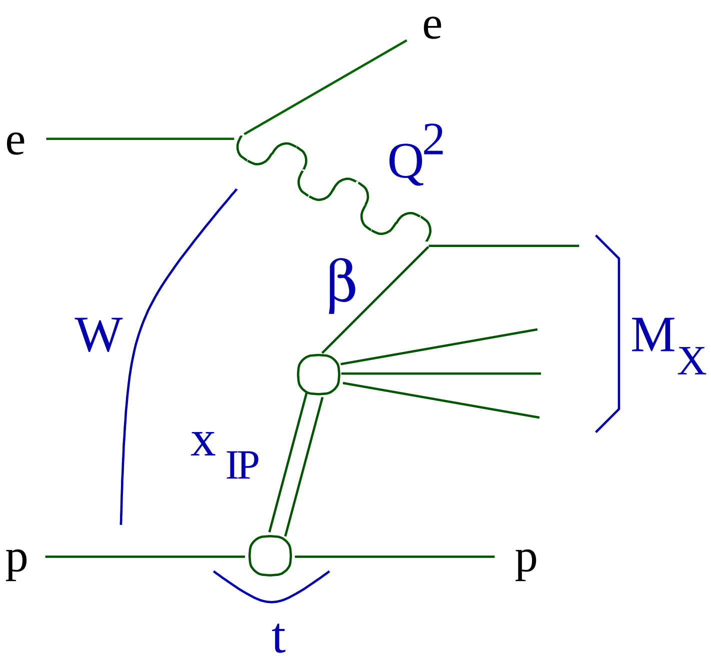
Inclusive measurements on diffractive procecesses in ep collisions

XXXVI International Symposium on Multiparticle Dynamics

Paraty, Brazil, 2nd-8th Sept., 2006

Inlusive diffraction at HERA

$$e + p \longrightarrow e + X + p$$



Proton stays intact and loses small momentum fraction

Q^2 Photon virtuality

x Bjorken-x

$x_{I\!P}$ Momemtum fraction of colour singlet exchange

β Fraction of exchange momemtum of struck q

t 4-momemtum transfer squared

W Photon-proton cms energy

$$x = x_{I\!P}\,\beta\,;\, W = Q^2\left(\frac{1}{x} - 1\right)$$

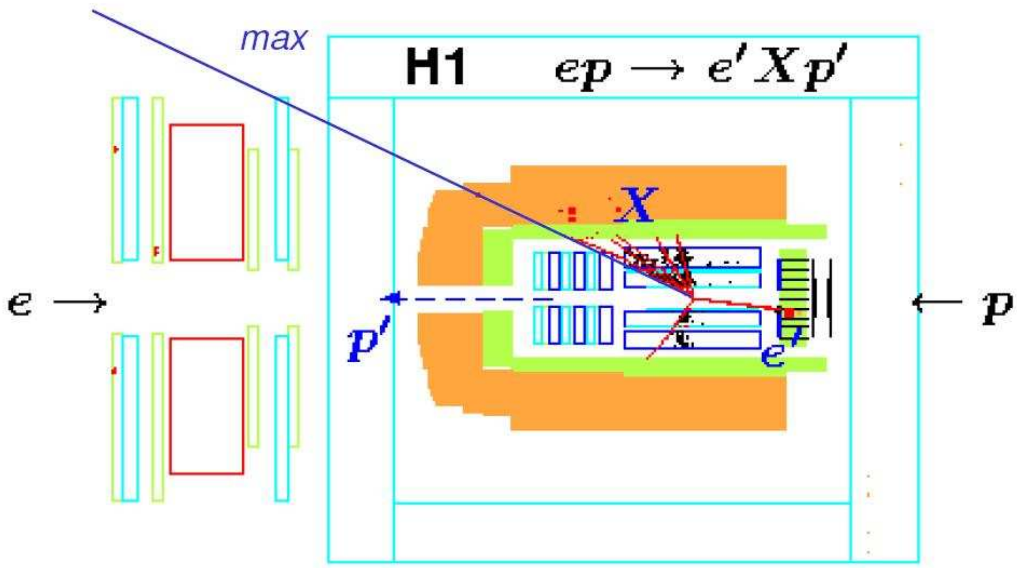
Main observable: Reduced cross section σ_r^D

$$\frac{d^4\sigma^{ep\rightarrow eXp}}{dx\,dQ^2\,dx_{I\!P}\,dt} = \frac{4\pi\alpha^2}{xQ^4}\, Y_+\, \sigma_r^{D(4)}(x, Q^2, x_{I\!P}, t)$$

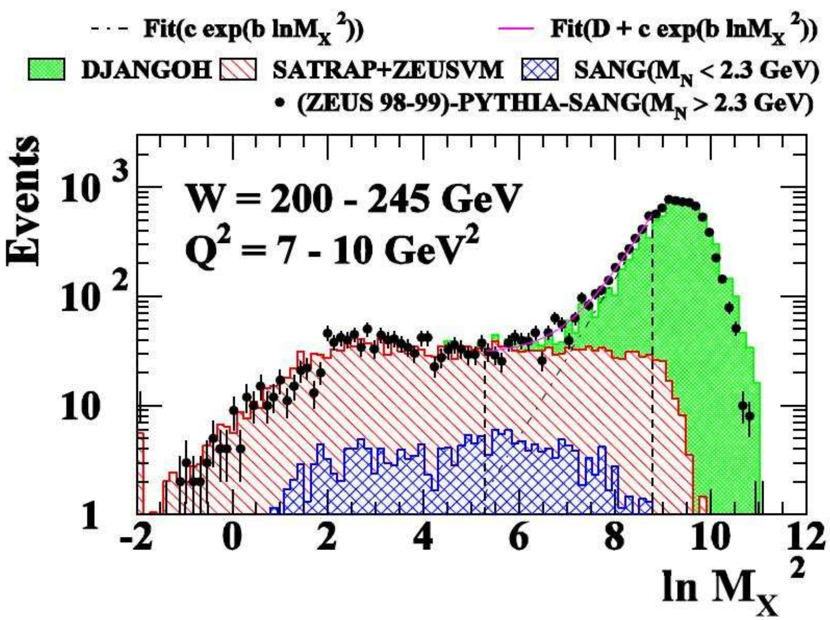
$$\sigma_r^{D(4)}(x, Q^2, x_{I\!P}, t) = F_2^{D(4)} - \frac{y^2}{Y_+} F_L^{D(4)} \approx F_2^{D(4)}$$

Selection Methods

H1: Large Rapidity Gap Method



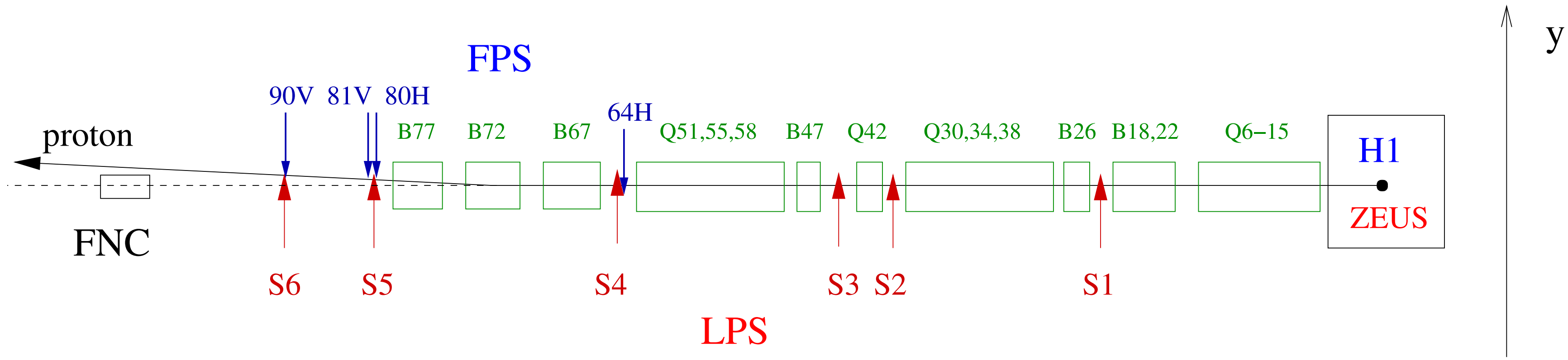
ZEUS: M_X Method



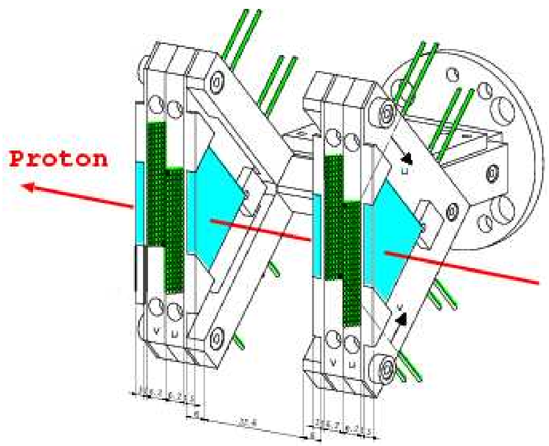
- Gap spanning $3.3 < \eta < 7.5$
- Measure kinematic from hadrons in central detector
- Some proton dissociation $\to$ Correct to $M_Y < 1.6$ GeV

- Flat vs ln M_X^2 for diffractive events
- non-diffracive events substracted from fit
- Proton dissociation $ep \to eXY$ corrected to $M_Y < 2.3$ GeV

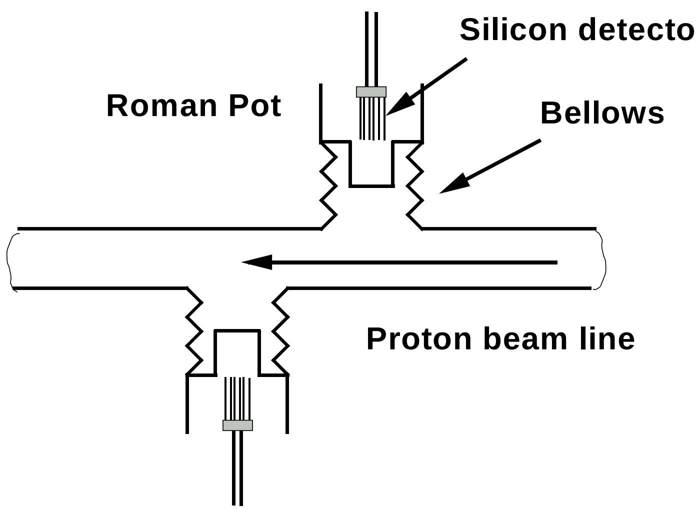
Selection Methods



Forward Proton Spectrometer | **Leading Proton Spectrometer**



Scintillating fibre detector



Silicon Micro-Strip Detector

- Free of proton dissociation bkgd
- p 4-momemtum measurment $\rightarrow t$
- Low statistic (acceptance)

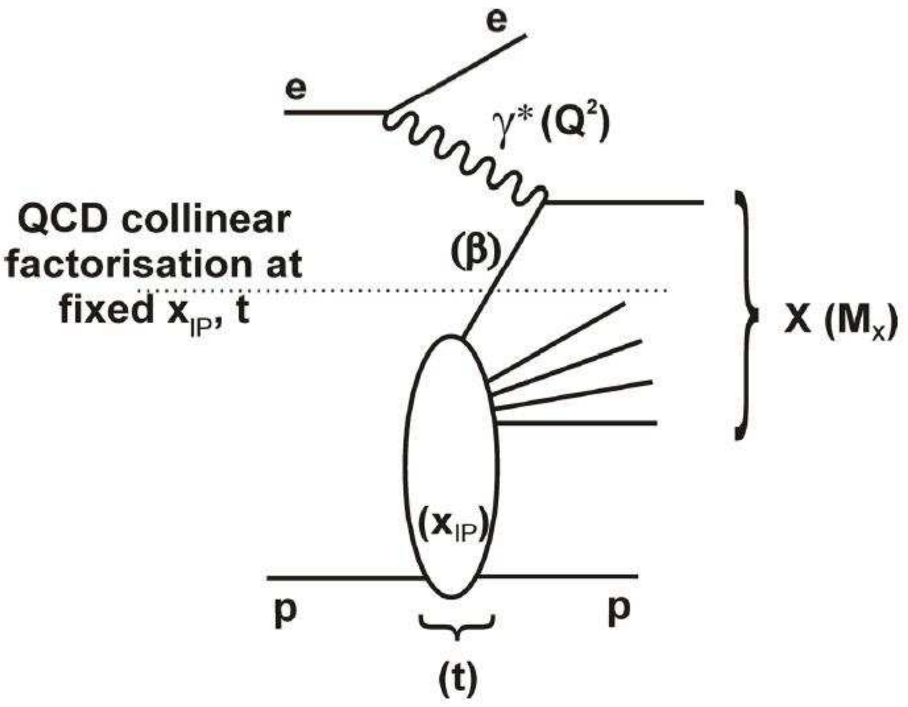
Factorization Properties

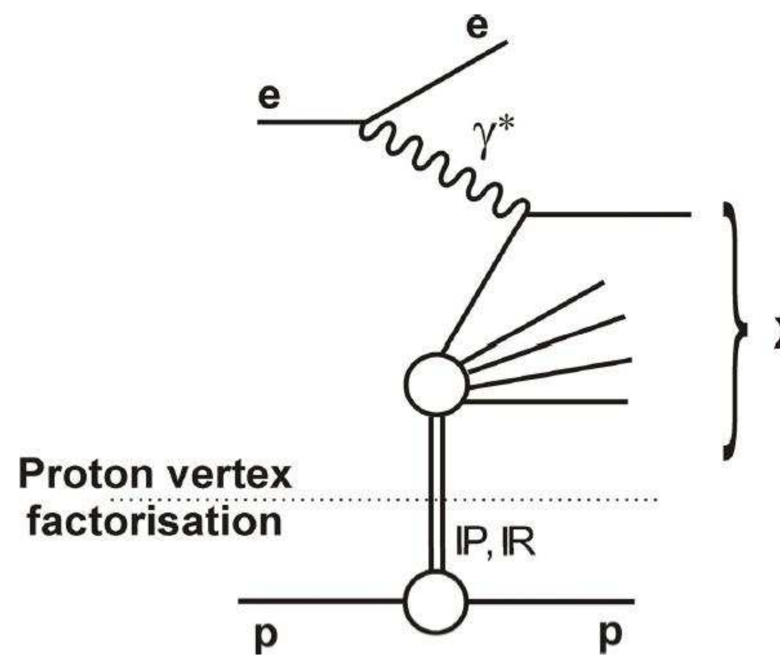
- QCD hard scattering collinear factorization (Collins) at fixed $x_{I\!P}$ and t

  $\rightarrow$ DGLAP applicable for Q^2 evolution.

- "Proton vertex" factorisation of x, Q^2 from $x_{I\!P}$, t (and M_Y) dependences

  No fi rm basis in QCD !

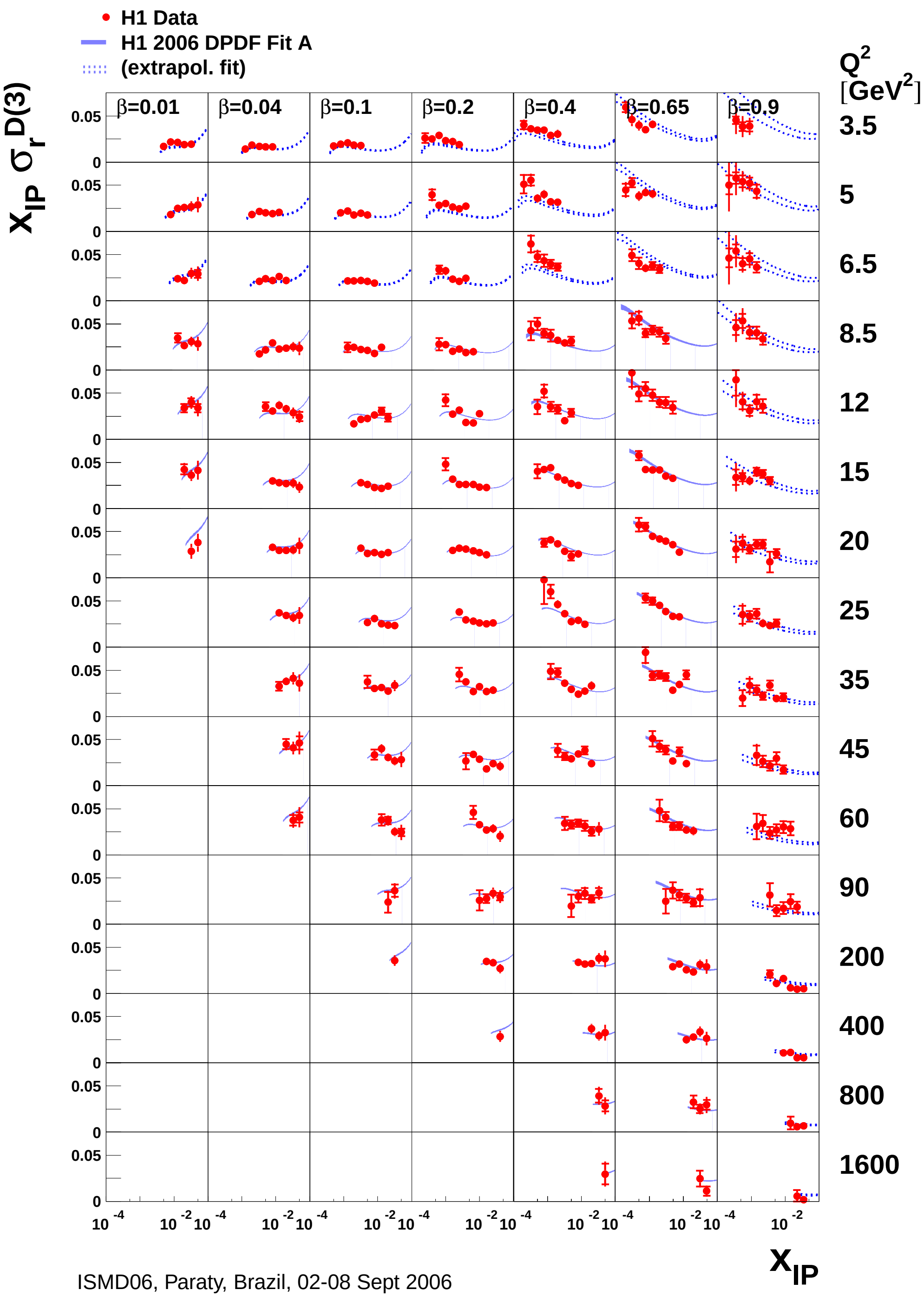




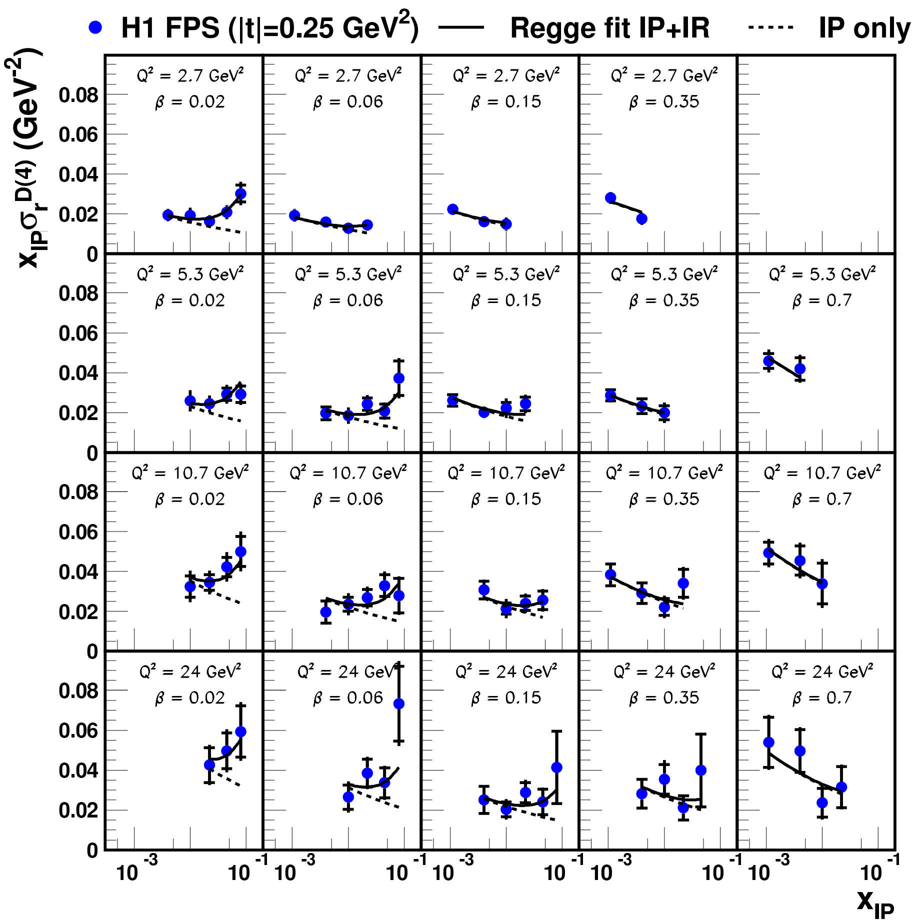
$$\mathrm{d}\sigma_\mathrm{i}(\mathrm{ep} \rightarrow \mathrm{eXp}) =$$
$$f_i^D(x, Q^2, x_{I\!P}, t) \otimes \mathrm{d}\hat{\sigma}^\mathrm{i}(\mathrm{x}, \mathrm{Q}^2)$$

$$f_i^D(x, Q^2, x_{I\!P}, t) =$$
$$f_{I\!P/p}(x_{I\!P}, t) \times f_i^{I\!P}(\beta = x/x_{I\!P}, Q^2)$$

H1 Published Data Overview

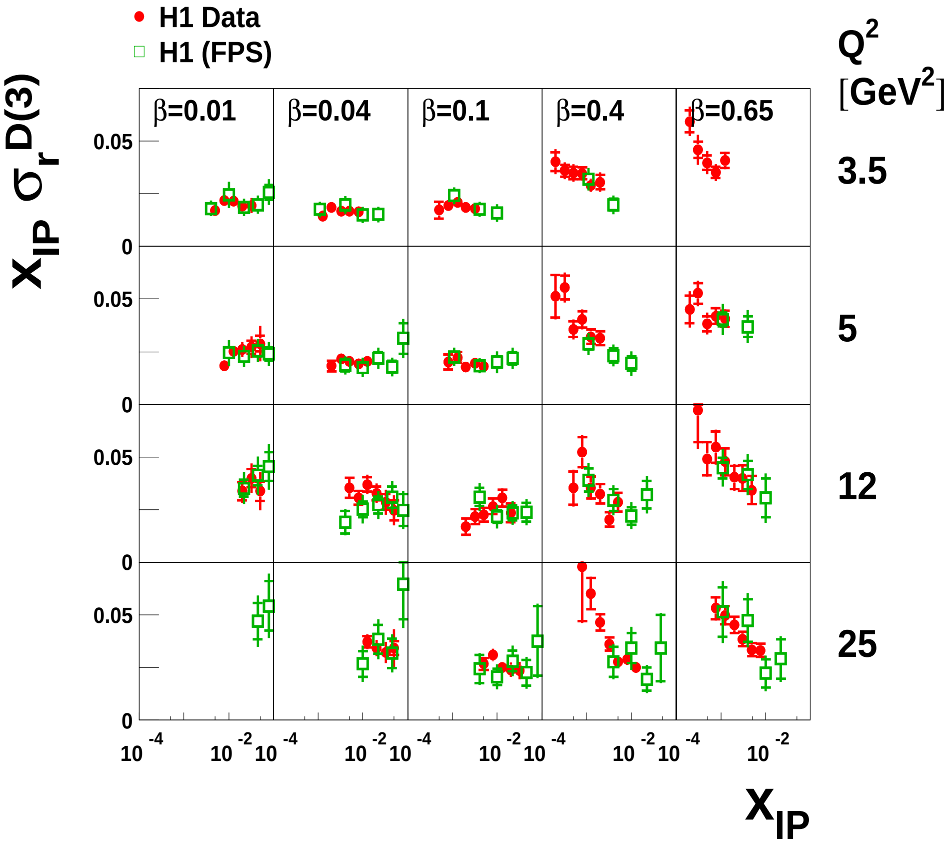


- LRG: $M_Y < 1.6$ GeV
  $3.5 < Q^2 < 1600\ \mathrm{GeV}^2$
- FPS: $Y = p$
  $2.7 < Q^2 < 24\ \mathrm{GeV}^2$

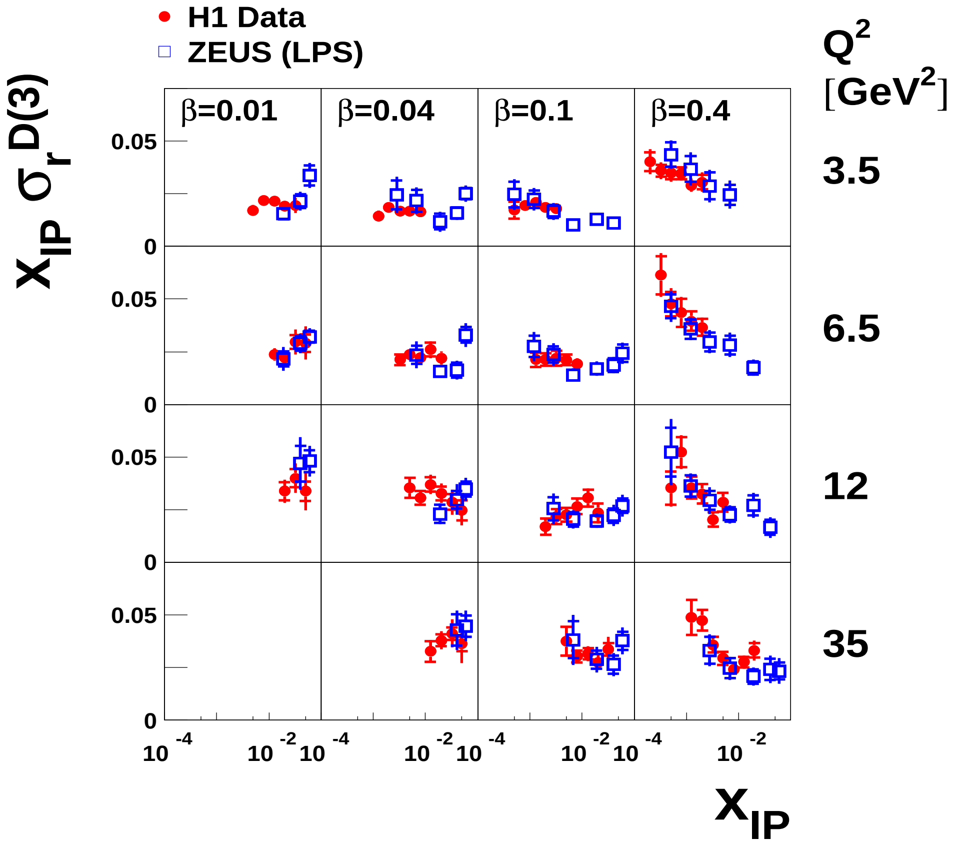


H1 Rapidity Gap vs Leading Proton data

H1 LRG vs H1 FPS

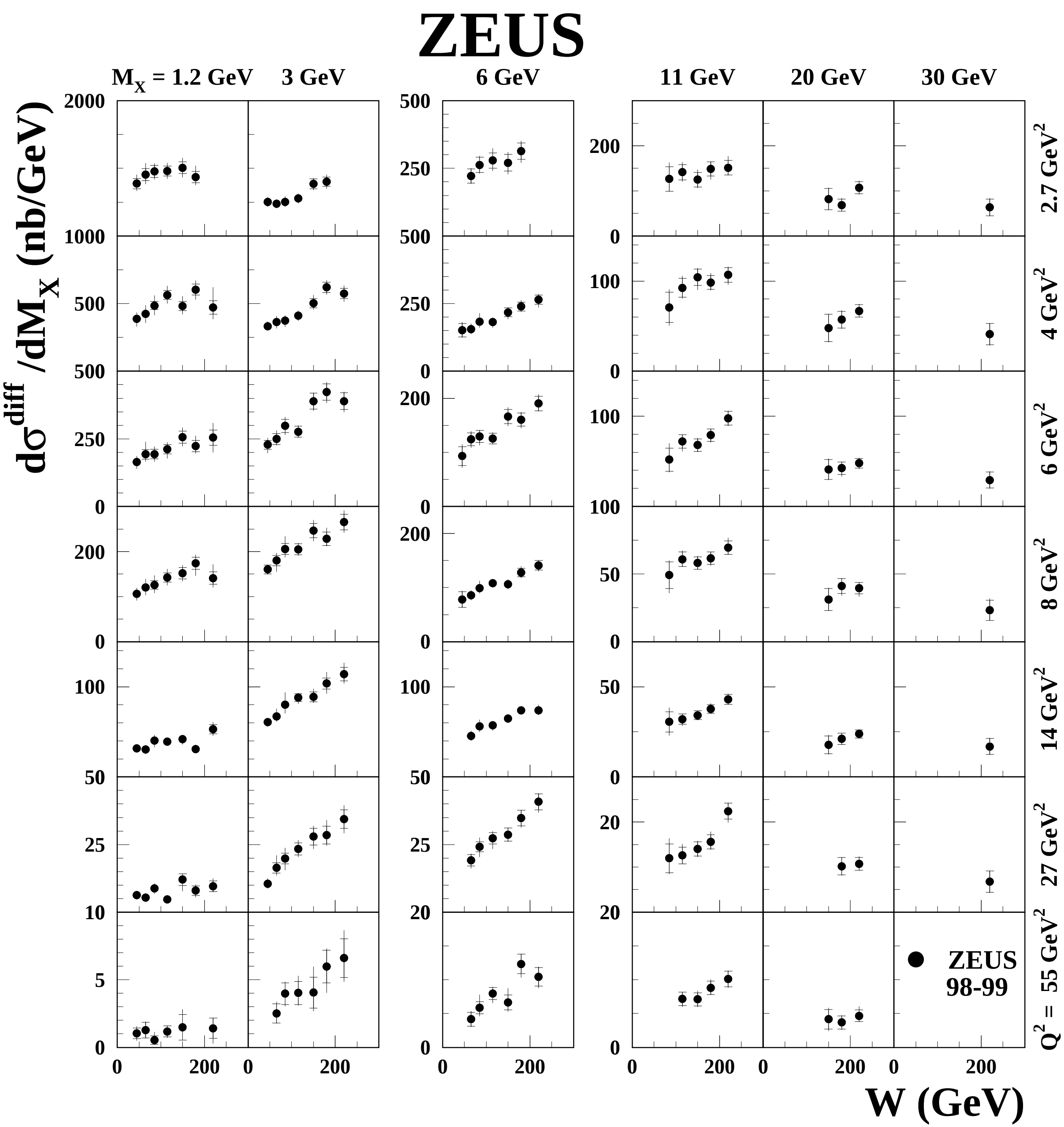


H1 LRG vs ZEUS LPS



- Agreement between LRG ans FPS methods taking into account the ratio $\sigma(M_y < 1.6\ \mathrm{GeV})/\sigma(\mathrm{Y} = \mathrm{p}) = 1.23 \pm 0.03$(stat.) ± 0.16(syst.) to correct for proton dissociation
- ZEUS-LPS and H1-FPS normalizations agree to 8 %

ZEUS Diffractive Cross Section (M_X Method)



$$\frac{d\sigma^{diff}_{\gamma p \to XY}}{dM_X}, \; M_Y < 2.3 \text{ GeV}$$

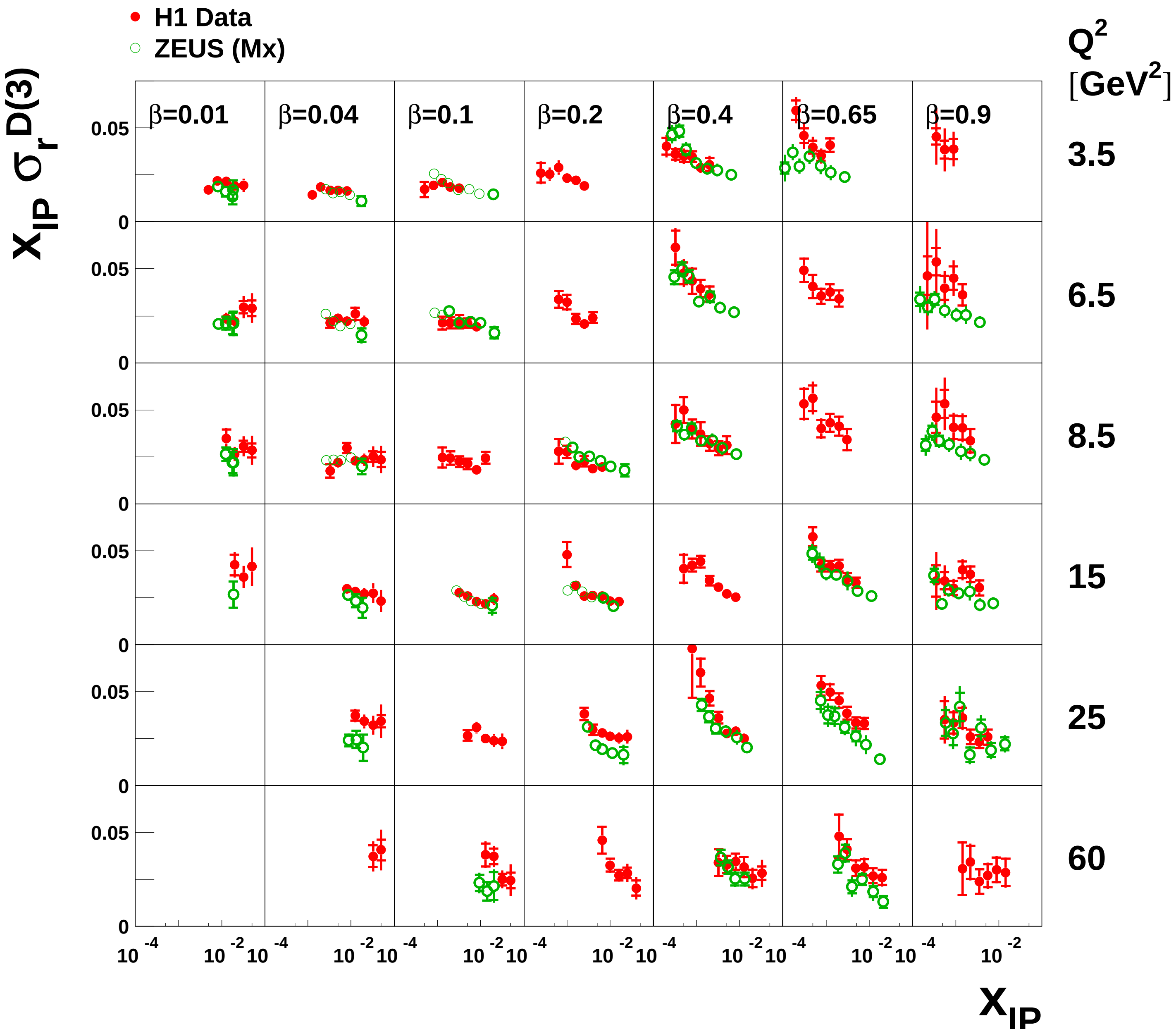
For $M_X < 2$ GeV

$\frac{d\sigma^{diff}}{dM_X}$ depends weakly on W

For $M_X > 2$ GeV

$\frac{d\sigma^{diff}}{dM_X}$ rises rapidly with W

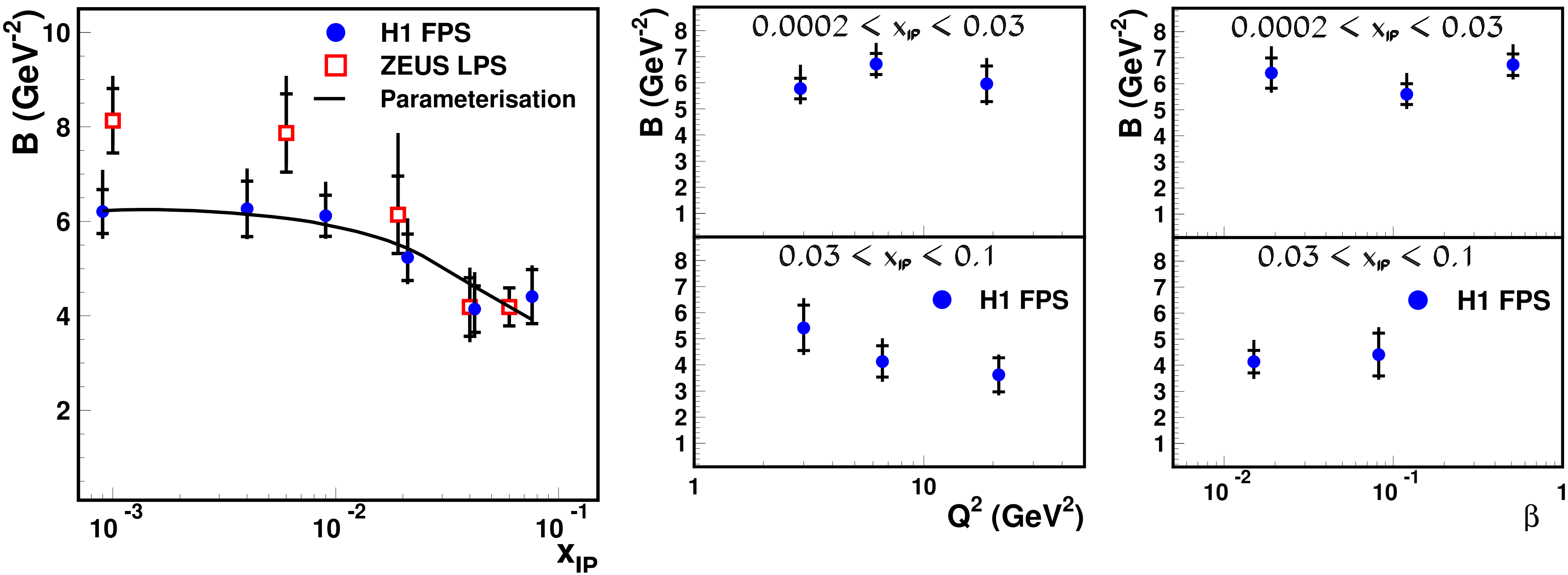
ZEUS M_X Method vs H1 Rapidity Gap Data



Globally consistent data sets, stronger Q^2 dependence in H1

t dependence from FPS and LPS data

- $B(x_{I\!P})$ from fit $\mathrm{d}\sigma/\mathrm{dt} \propto \exp(\mathrm{B}|\mathrm{t}|)$
- Independent of β, Q^2 within errors

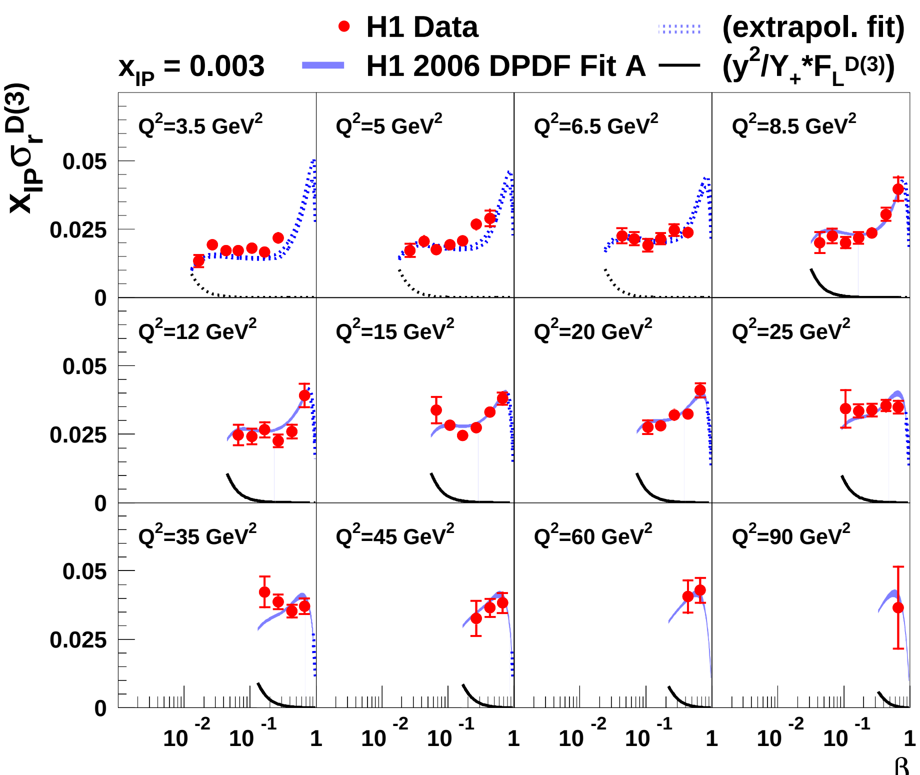


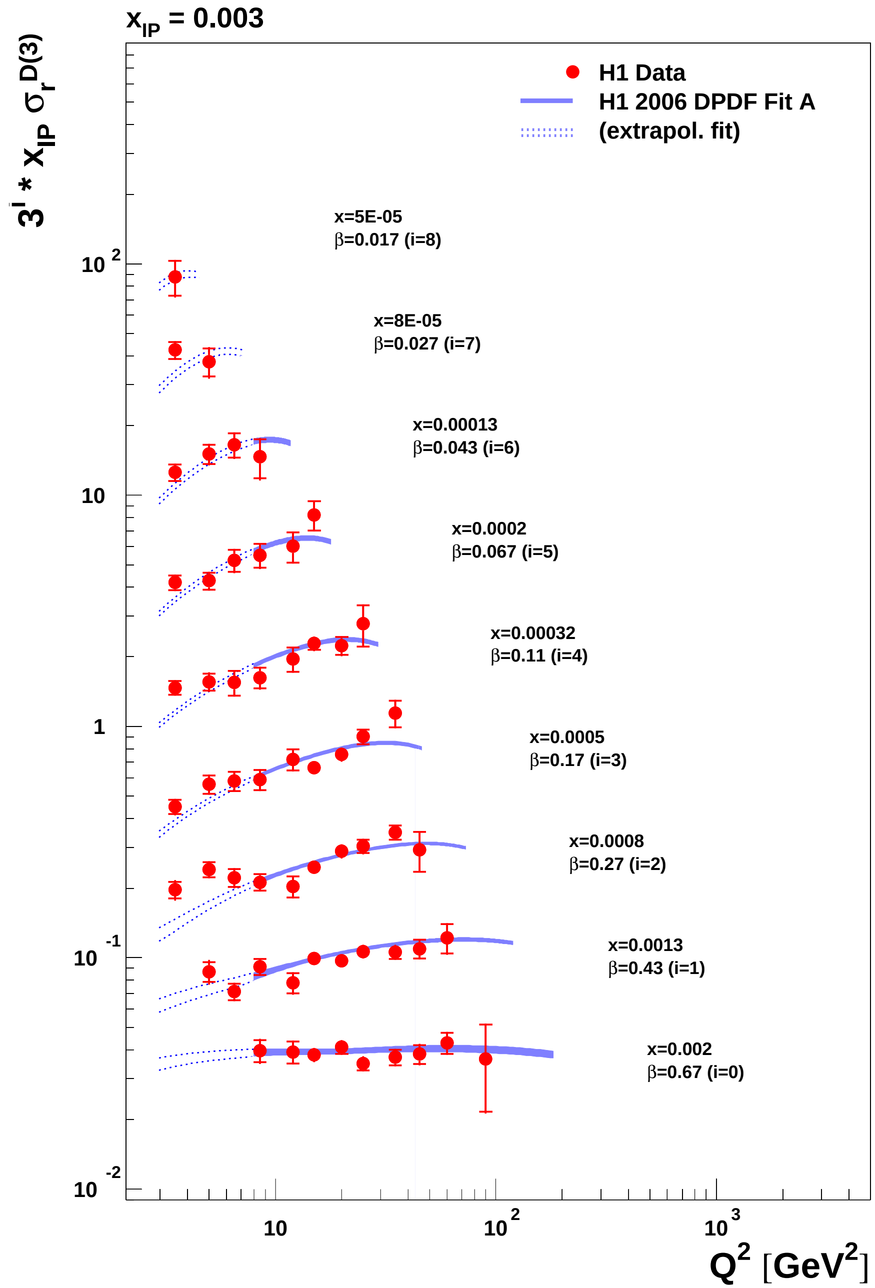
- $B(x_{I\!P})$ data constrain $I\!P$, $I\!R$ flux in proton vertex factorization model
- Regge motivated form: $f_{I\!P/p}(x_{I\!P}, t) = \frac{e^{B_{I\!P} t}}{x_{I\!P}^{2\alpha_{I\!P}(t)-1}}; \alpha_{I\!P}(t) = \alpha_{I\!P}(0) + \alpha'_{I\!P} t$
- Fitting H1 data to $B = B_{x_{I\!P}} + 2\alpha'_{I\!P} \ln(1/x_{I\!P})$ gives:

$$B_{x_{I\!P}} = 5.5^{-2.0}_{+0.7}\mathrm{GeV}^{-2} \qquad \alpha'_{I\!P} = 0.06^{+0.19}_{-0.06}\mathrm{GeV}^{-2}$$

H1: $\sigma_r^{D(3)}(\beta, Q^2, x_{\mathbb{P}})$ at fixed $x_{\mathbb{P}}$ $(x_{\mathbb{P}} = 0.003)$

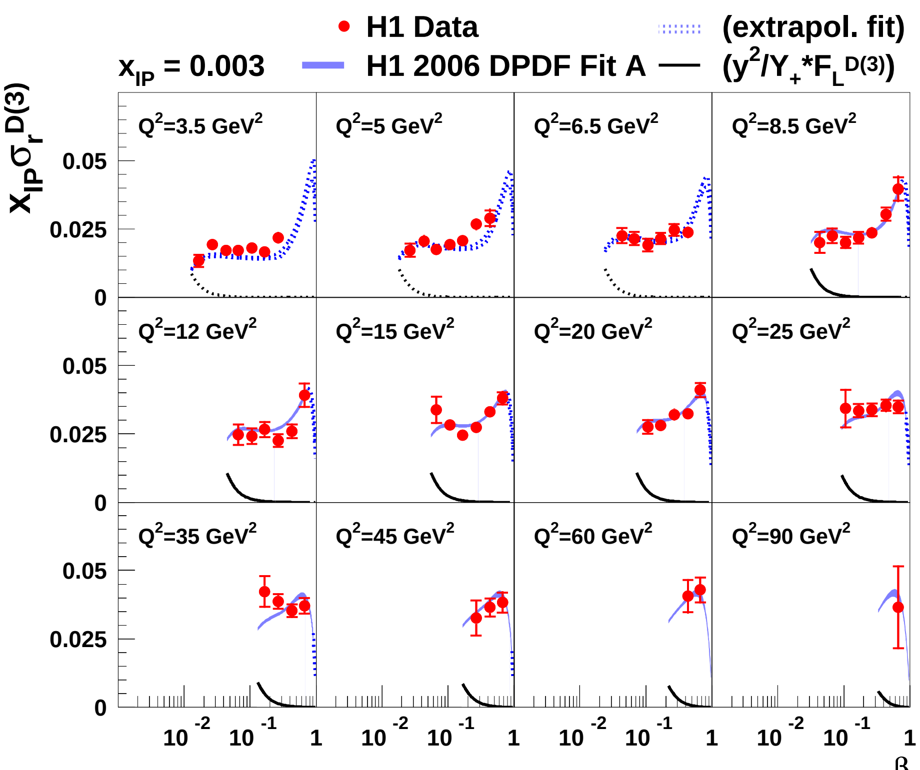
- Study x ($= \beta . x_{\mathbb{P}}$) and Q^2 depend. at few fixed $x_{\mathbb{P}}$ values
- Good precision (in best region)
  - Stat. error: $\sim 5\%$
  - Syst error: $\sim 5\%$
  - Norm. error: $\sim 6\%$

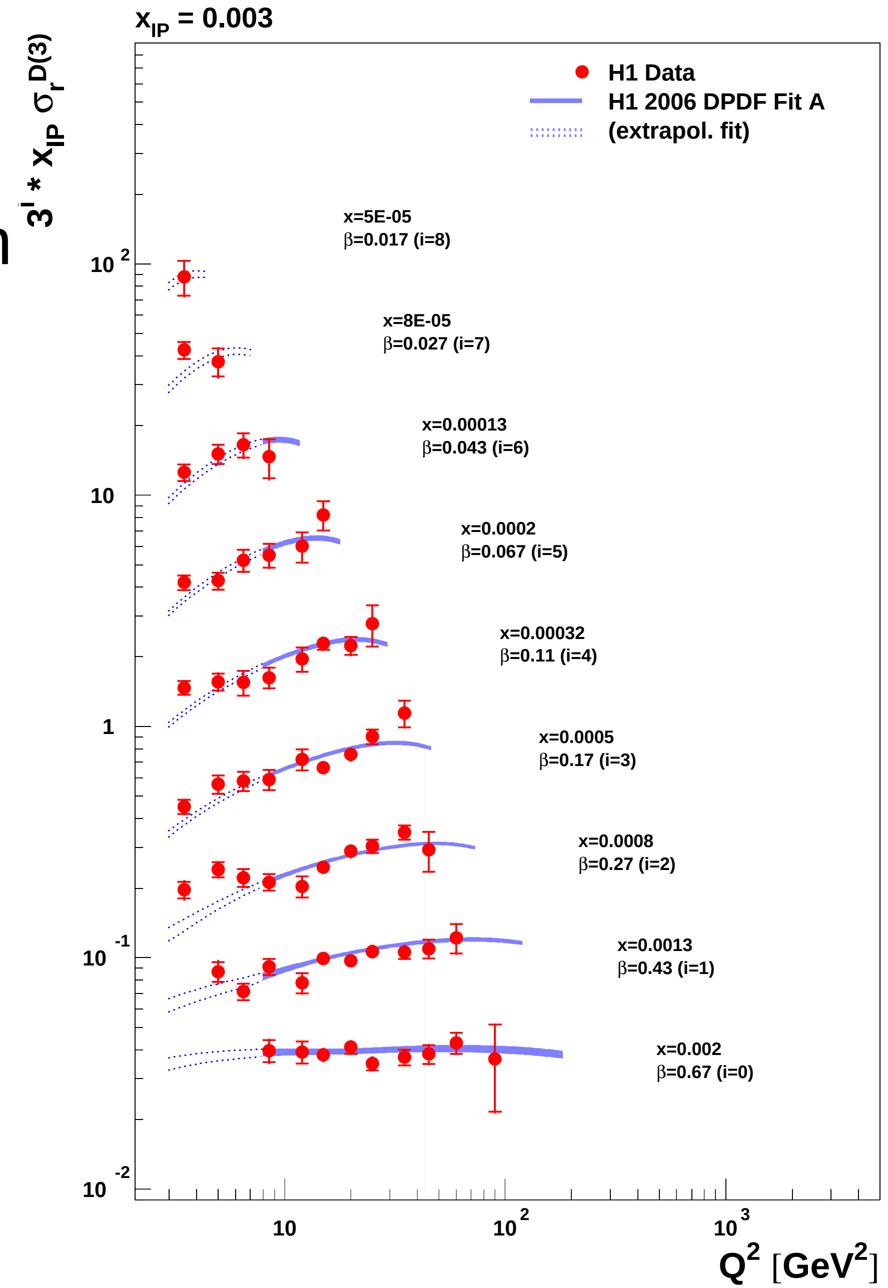




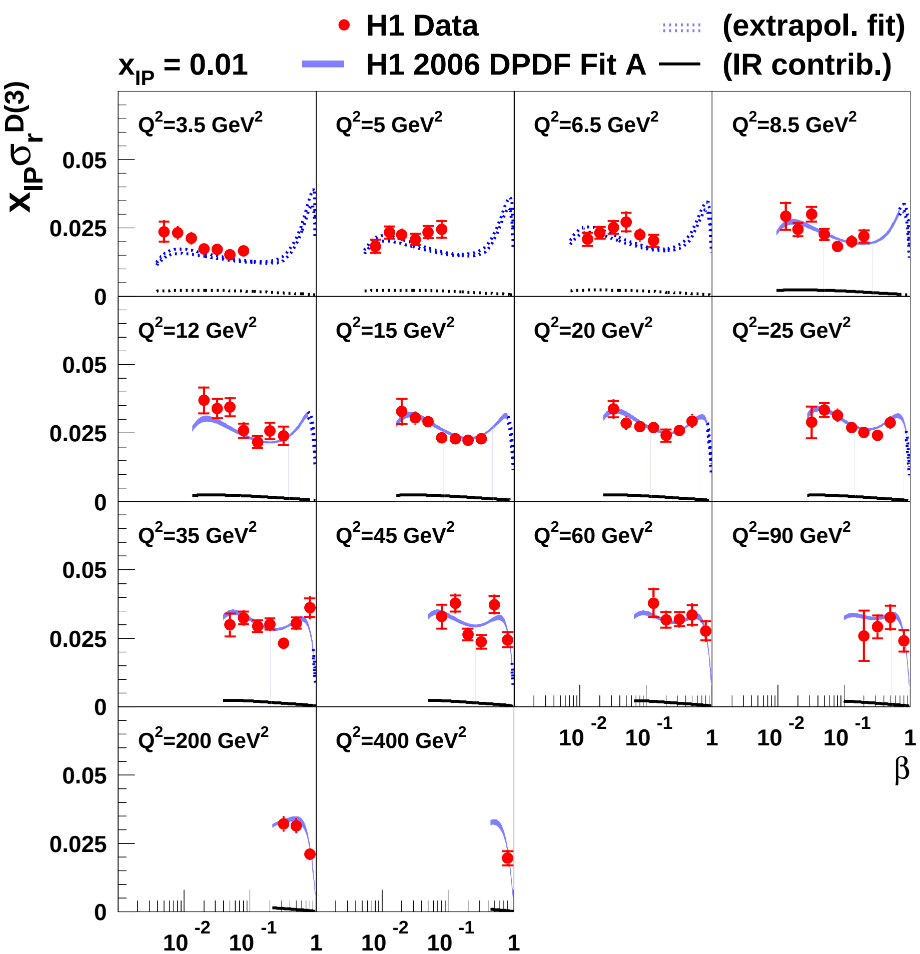
H1: $\sigma_r^{D(3)}(\beta, Q^2, x_{I\!P})$ at fixed $x_{I\!P}$ $(x_{I\!P} = 0.003)$

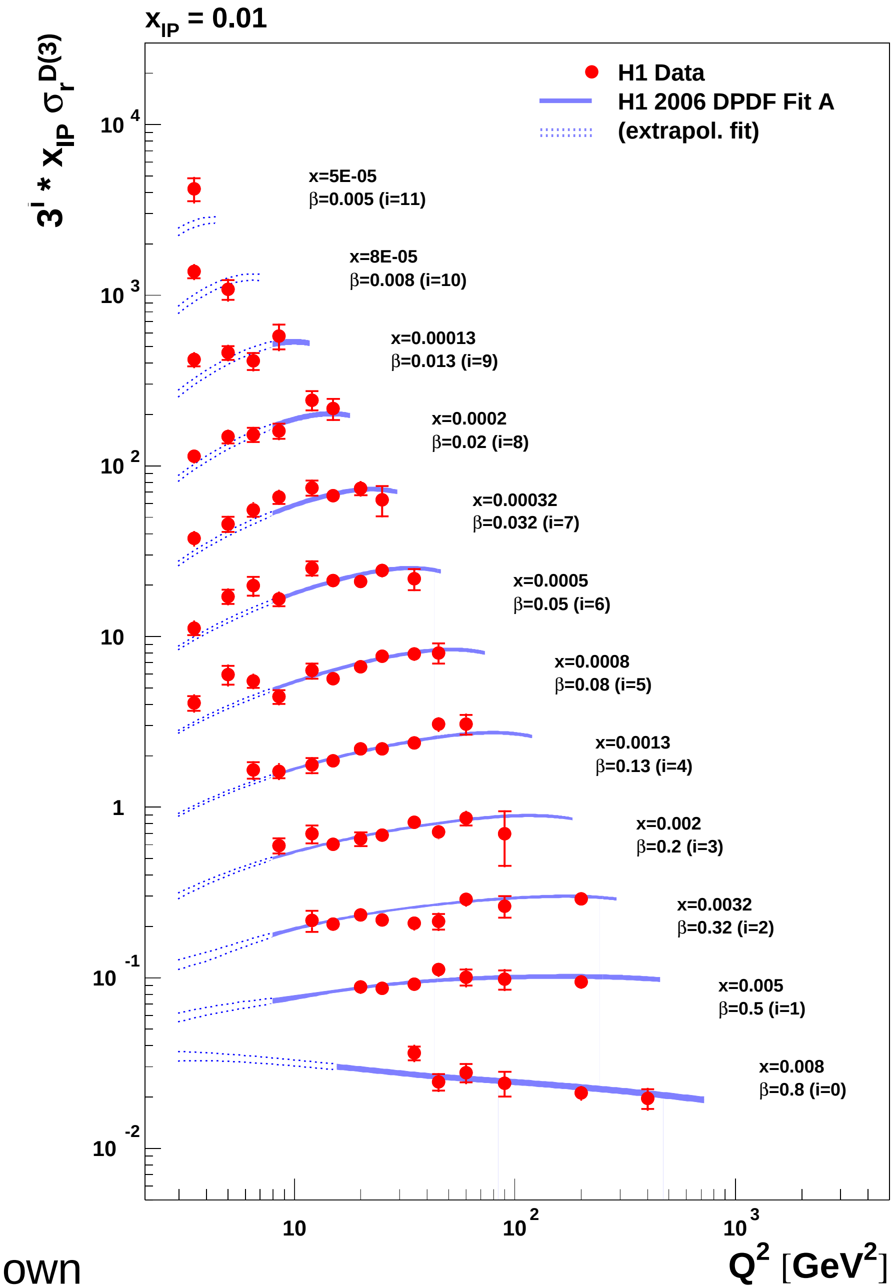
- Data compared with "H1 2006 DPF fit" + error band
- Large positive Q^2 scaling violation up to high β values
- Small F_L^D contribution at low β





H1: $\sigma_r^{D(3)}(\beta, Q^2, x_{I\!P})$ at fixed $x_{I\!P}$ ($x_{I\!P} = 0.01$)



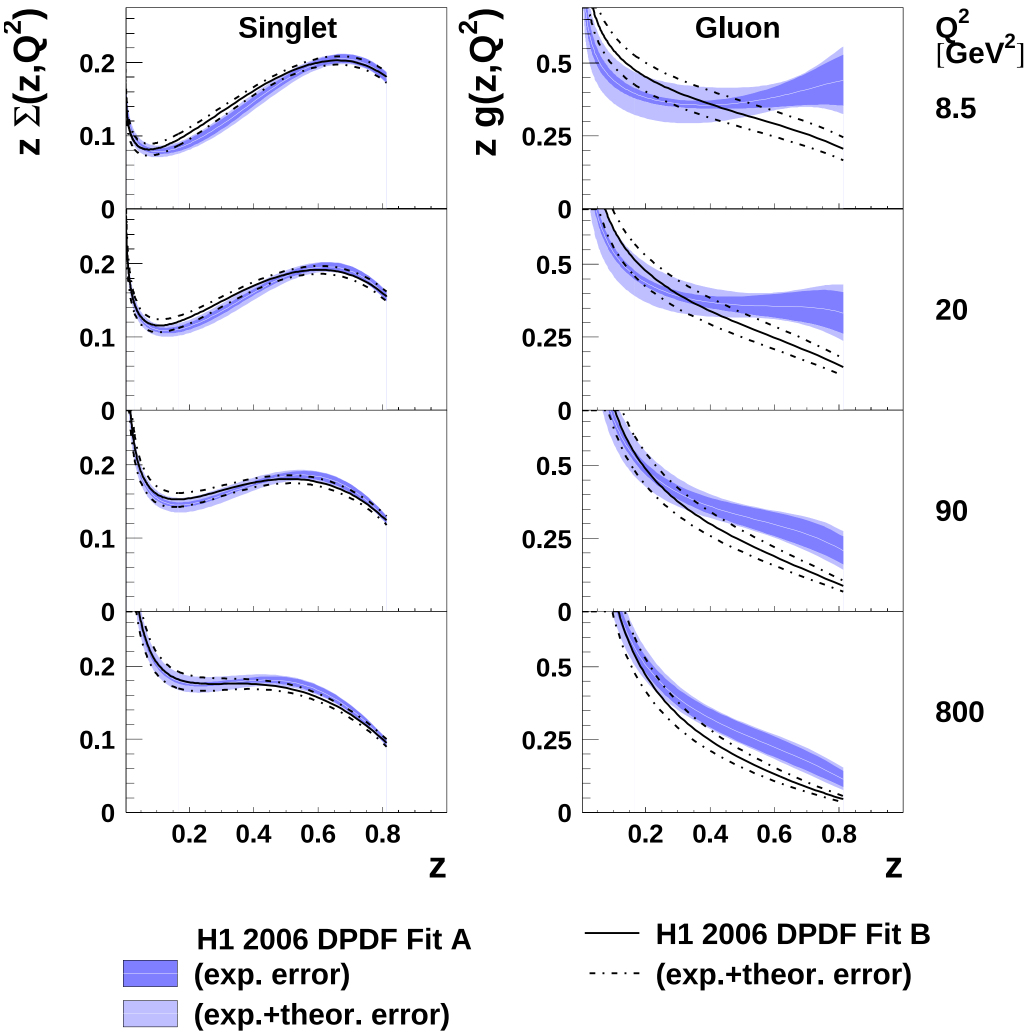


+ Other $x_{I\!P}$ bins at 0.0003, 0.001 and 0.03 not shown

QCD Analysis of H1 Data

- Fit H1 LRG data in fixed $x_{I\!P}$ binning using NLO DGLAP evolution of DPDFs (massive scheme) to describe x, Q^2 dependences
- Proton vertex factorization framework assumed
- Fit all H1 LRG data with $Q^2 \geq 8.5\ \mathrm{GeV}^2, \mathrm{M_X} > 2\ \mathrm{GeV}, \beta \leq 0.8$
  $\longrightarrow$ Ensure stability of fit with variations of kinematic boundaries
- Parametrize:
  - quark singlet: $z\Sigma(z, Q_0^2) = A_q\ z^{B_q}\ (1-z)^{C_q}$
  - gluon density: $zg(z, Q_0^2) = A_g\ (1-z)^{C_g}$
    gluon insensitive to B_g
  - $\alpha_{I\!P}(0)$ (describes $x_{I\!P}$ dependence)
- Fix:
  - use world average for $\alpha_s(M_Z) = 0.118$
  - sub-leading $I\!R$ flux parameters taken from previous data
  - sub-leading $I\!R$ PDFs from Owens-π but free normalization
- Small number of parameters in DPDFs
  $\longrightarrow$ Need to optimize Q_0^2 wrt χ^2

H1 2006 DPDF fit results



- **Fit A:** $Q_0^2 = 1.45\ \mathrm{GeV}^2$
  $\chi^2 \sim 158/183$ dof
  - Singlet constrained to $\sim 5\%$
  - Gluon to $\sim 15\%$ at low z
  - Gluon error band blowing up at highest z

- **Fit B:** $zg(z, Q_0^2) = A_g$
  $\chi^2 \sim 164/184$ dof
  - Singlet very stable
  - Gluon similar at low z
  - Gluon change at high z

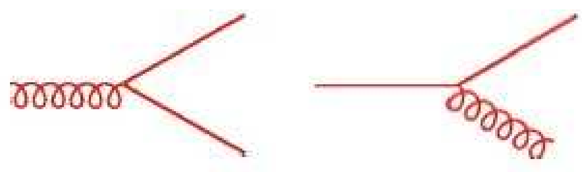
$\longrightarrow$ New Diffractive PDFs available

$\longrightarrow$ Lack of sensitivity to gluon at high z

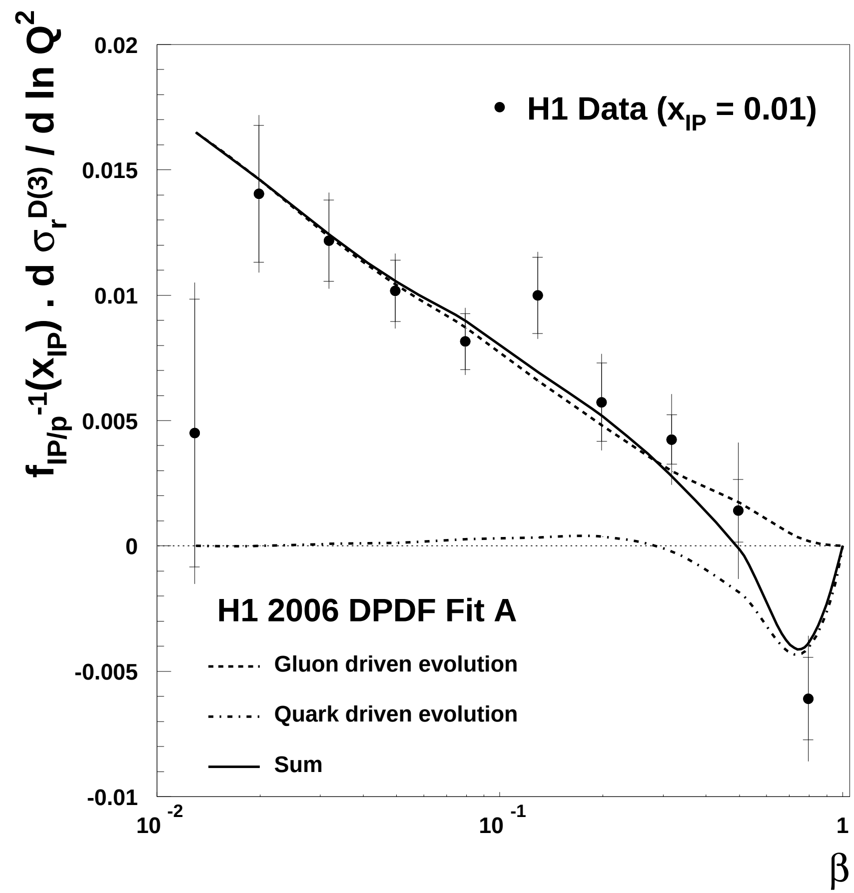
H1 Fit: High z sensitivity to gluon

- As there are only singlet quarks, the evolution eq. for F_2^D is

$$\frac{\mathrm{d}F_2^D}{\mathrm{dln}Q^2} \sim \frac{\alpha_s}{2\pi}\left[P_{qg} \otimes g + P_{qq} \otimes \Sigma \right]$$



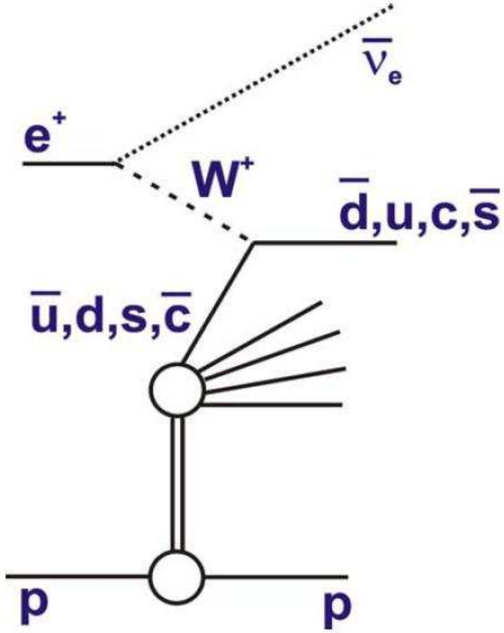
Log. Derivative wrt Q^2

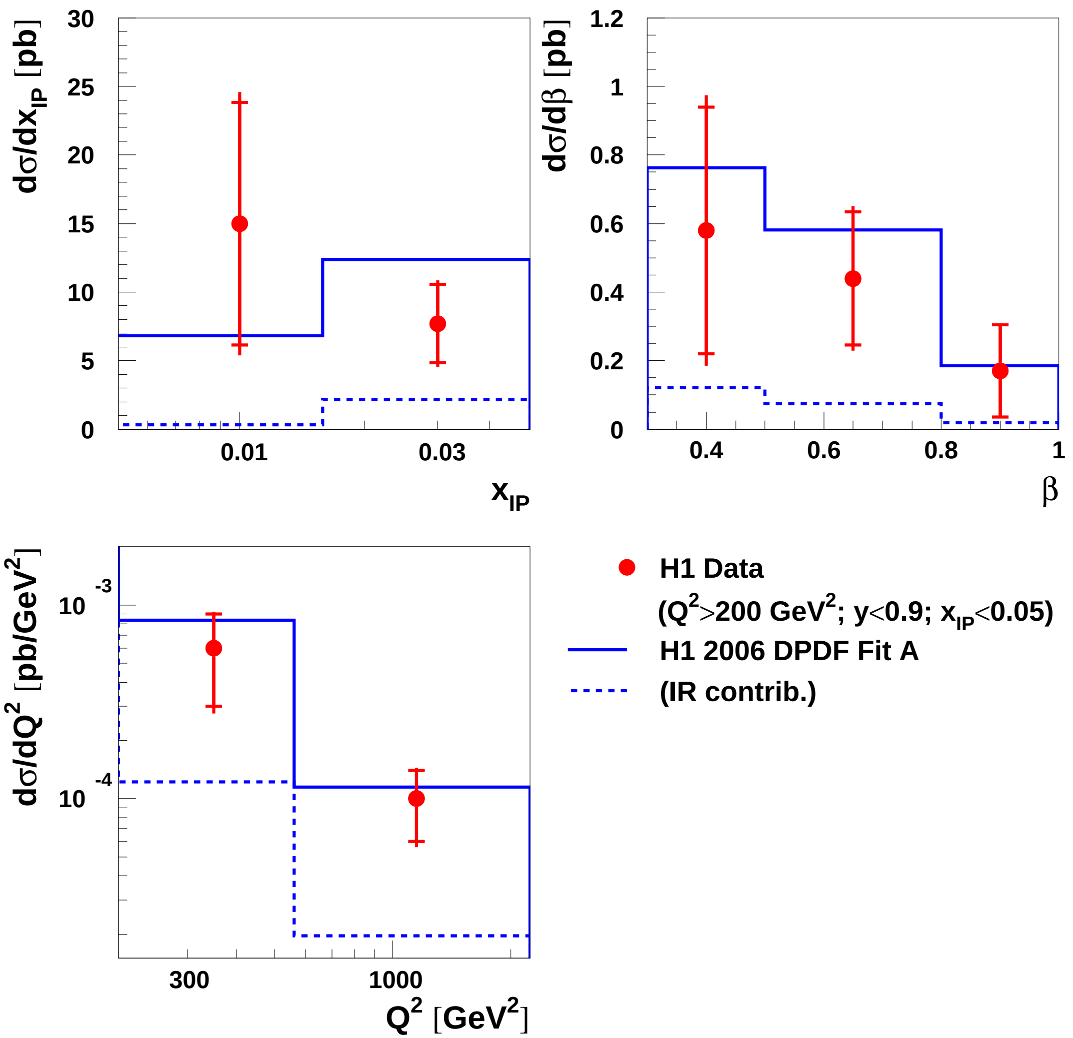


- At low β, evolution driven by $g \longrightarrow qq$
  $\longrightarrow$ strong sensitivity to gluon

- At high β, relative error on derivative grows, $q \longrightarrow qg$ contribution becomes important
  $\longrightarrow$ sensitivity to gluon is lost

Diffractive Charged Current Cross Section

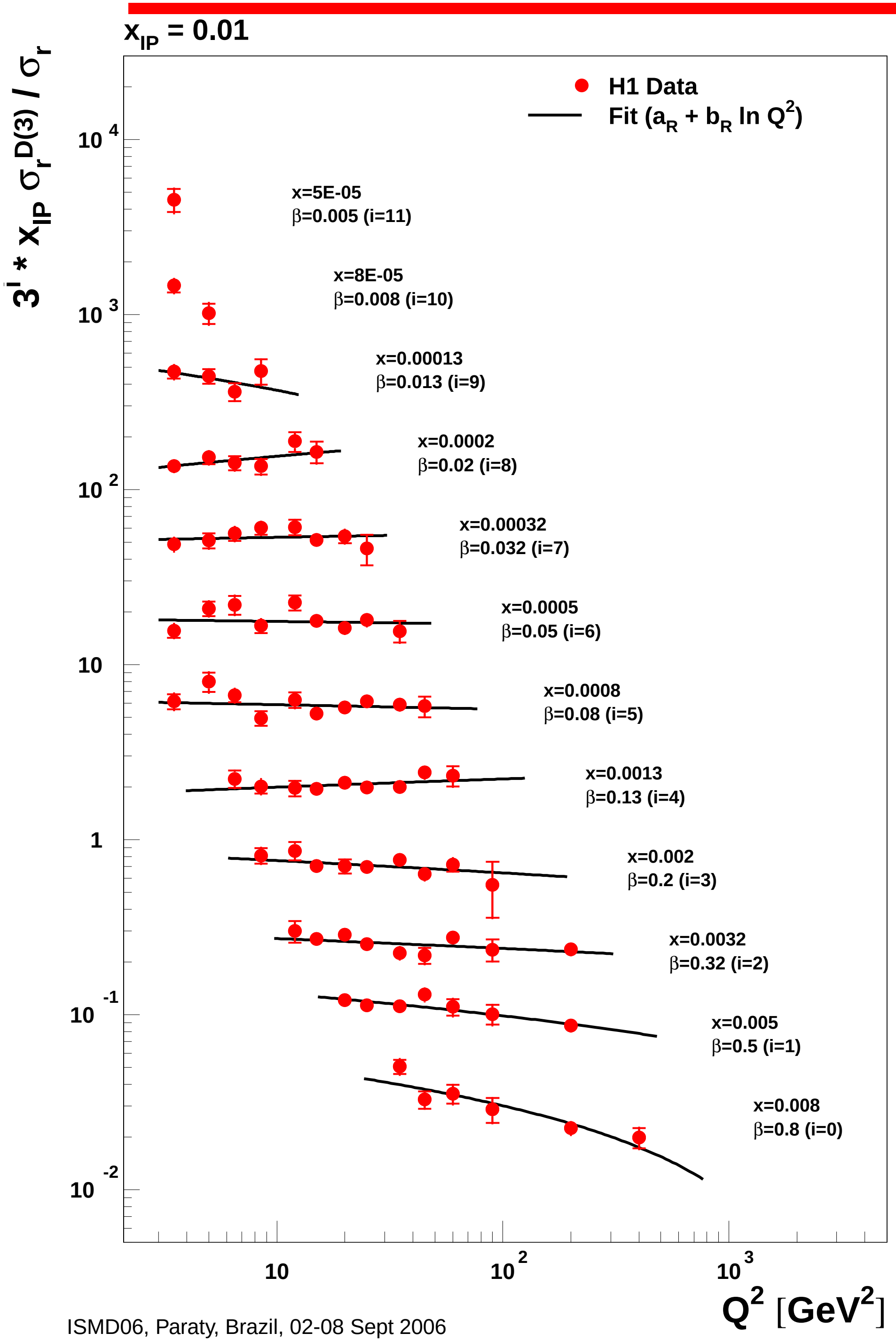




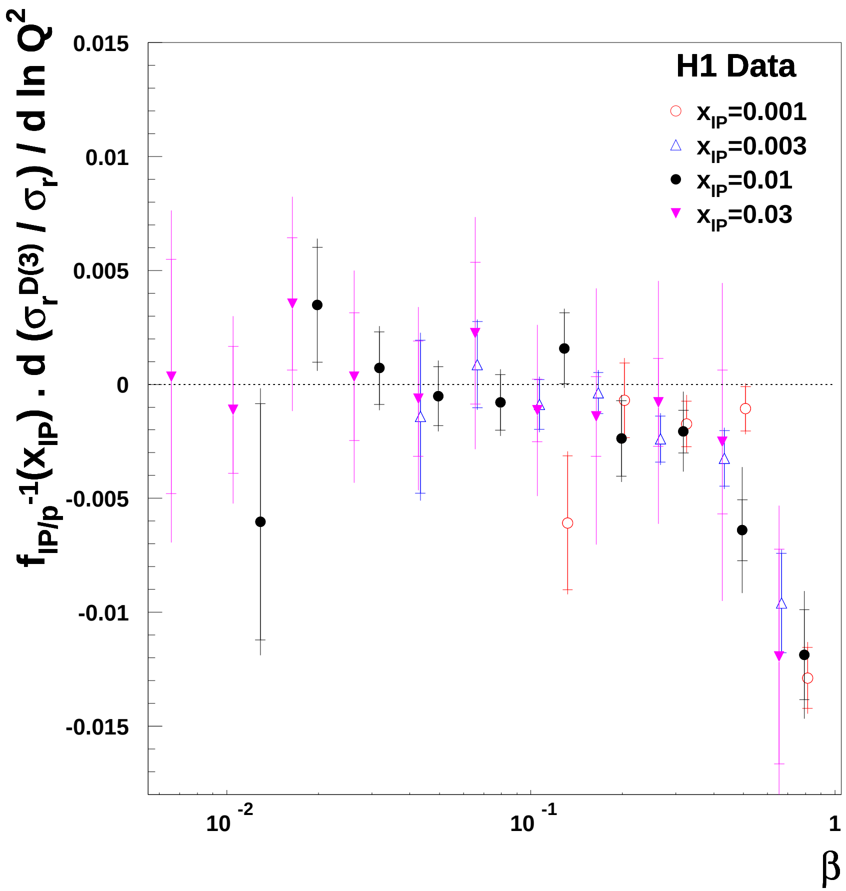
Sensitive to flavour decomposition of quark singlet (unconstrained by Neutral Currents)

Agreement with H1 2006 DPDFs (assumes $u = d = s = \bar{u} = \bar{d} = \bar{s}$)
but statistical precision very limited so far

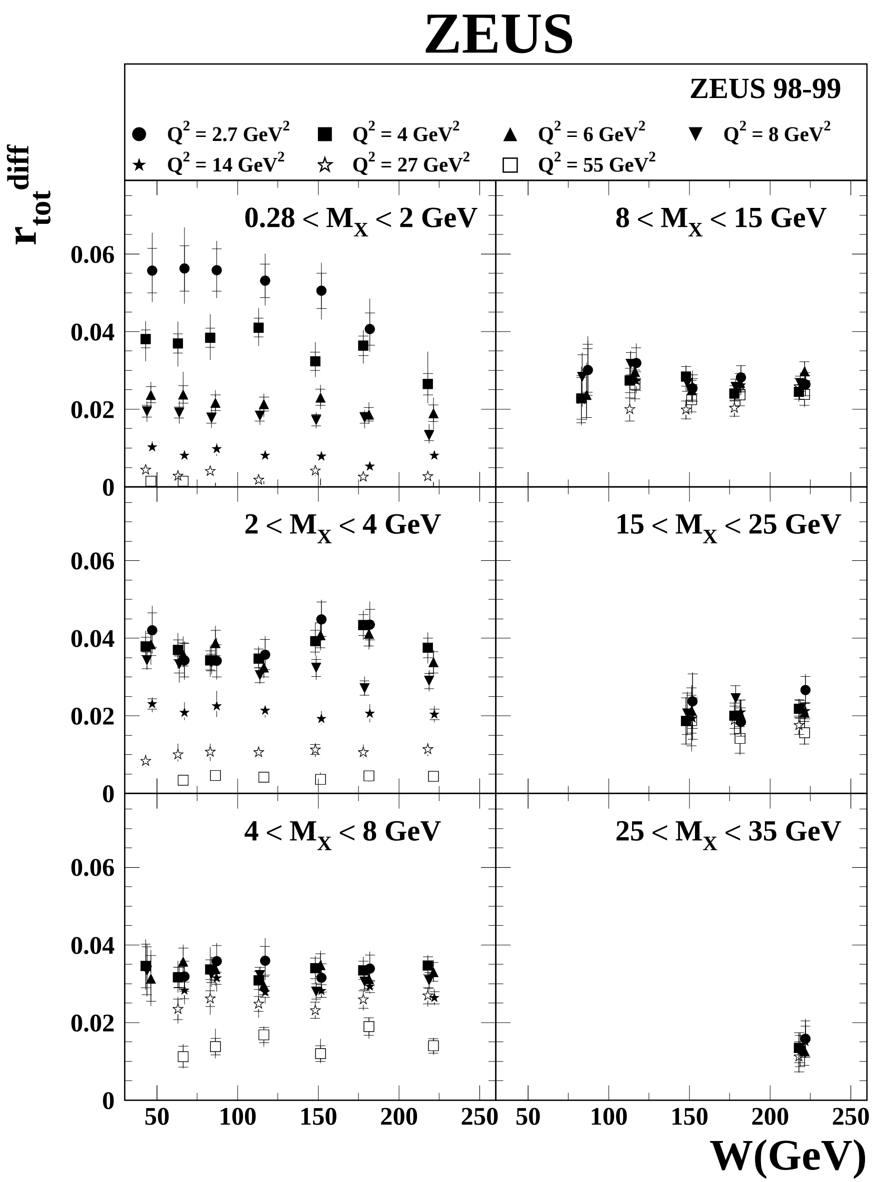
Diffractive / Inclusive DIS Ratio



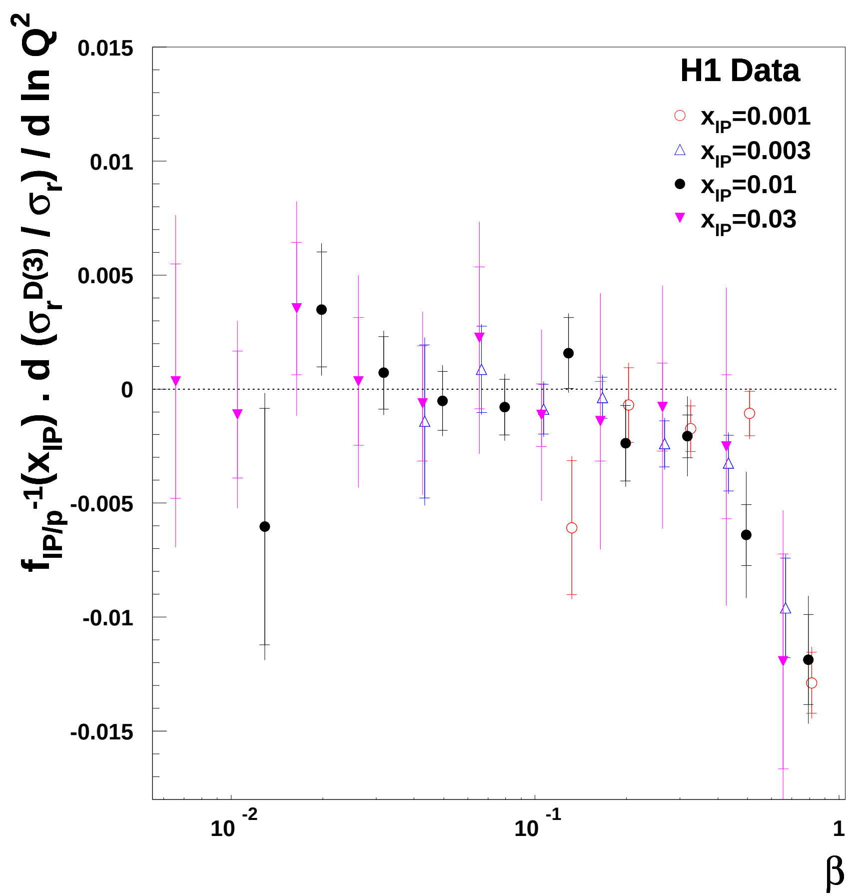
- Ratio is flat (fit $A + B \ln Q^2$) except at high β (low M_X) $\leftrightarrow$ derivative ~ 0



Diffractive / Inclusive DIS Ratio

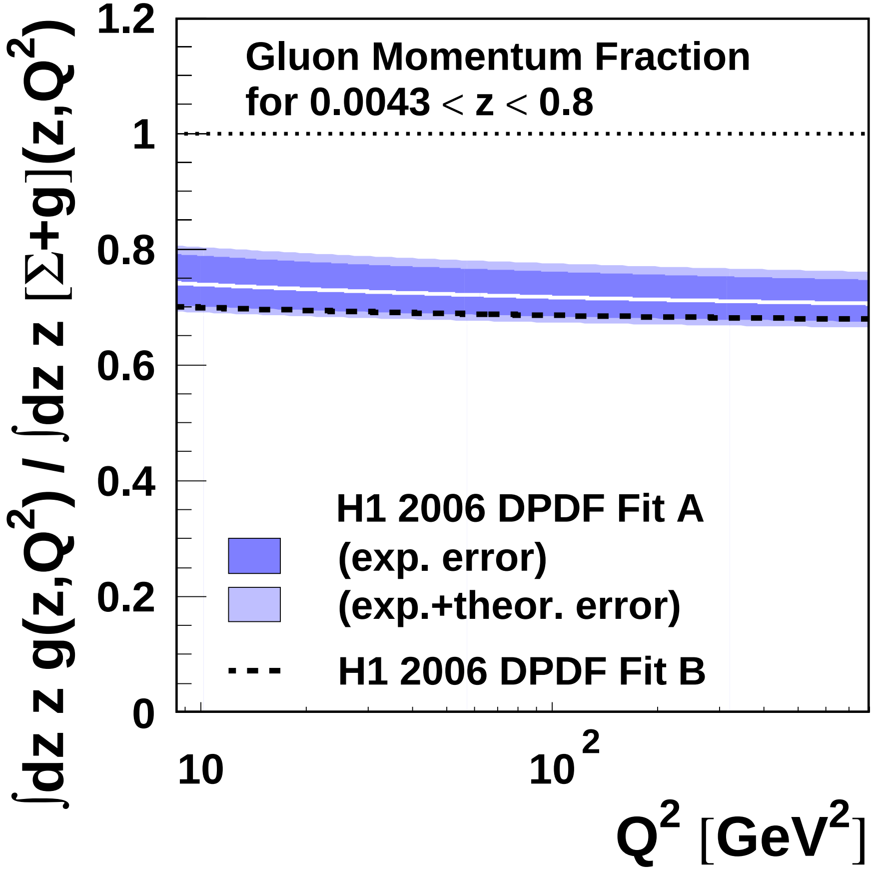


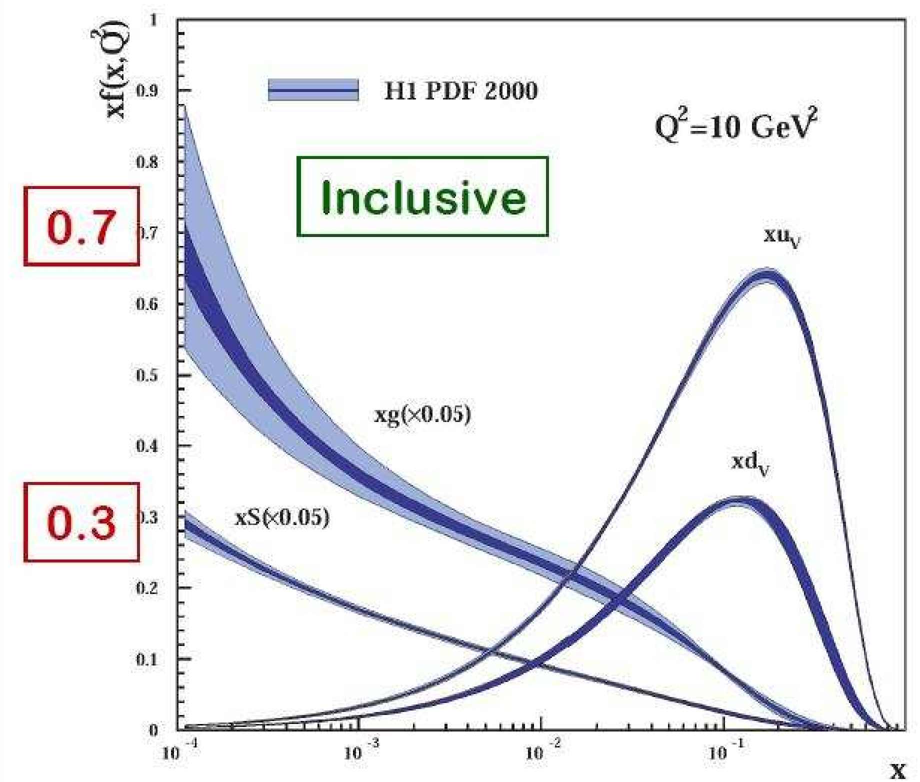
- Ratio is flat (fit $A + B \ln Q^2$) except at high β (low M_X) $\leftrightarrow$ derivative ~ 0
- Similar results from ZEUS



H1: Gluon Momentum Fraction

If $\frac{d(\sigma_r^D/\sigma_r)}{d\ln Q^2} \sim 0 \Longrightarrow \frac{1}{\sigma_r^D}\frac{d\sigma_r^D}{d\ln Q^2} \simeq \frac{1}{\sigma_r}\frac{d\sigma_r}{d\ln Q^2} \Longrightarrow \frac{g^D}{q^D} \simeq \frac{g}{q}$



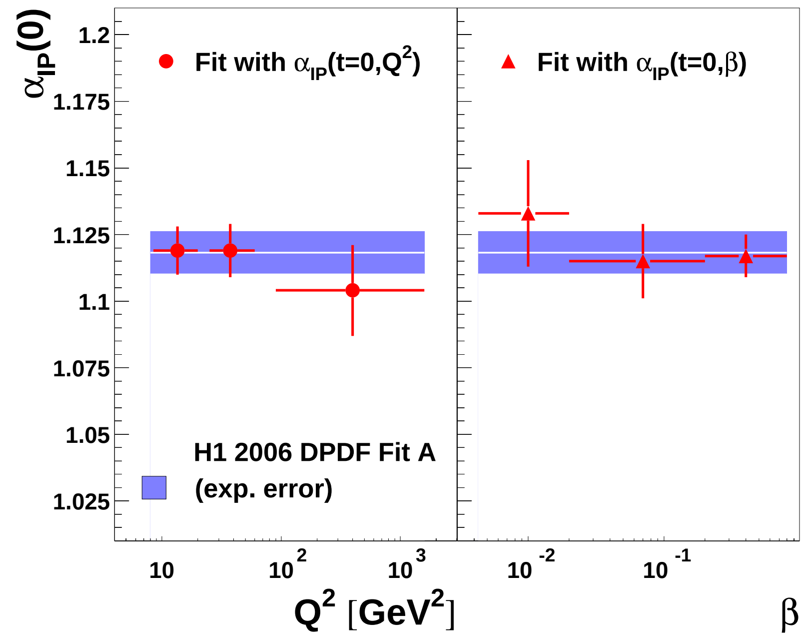


At low x, quark:gluon ratio $\sim 70\%/30\%$, as in inclusive case

Effective Pomeron Trajectory Intercept

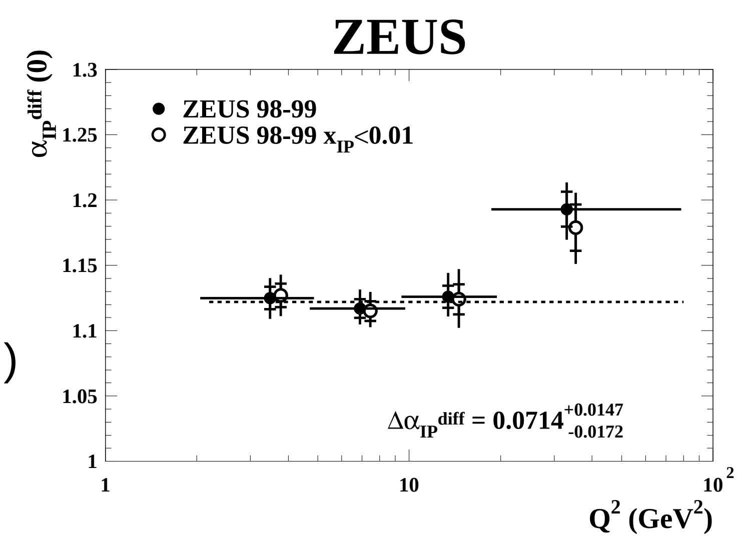
H1 Pomeron Intercept from QCD fit:

- $\alpha_{I\!P}(0) = 1.118 \pm 0.008(\text{exp.})^{+0.029}_{-0.10}(\text{th.})$
- Dominant uncertainty from strong correlation with $\alpha'_{I\!P}$
- No variation in Q^2 or β
  $\rightarrow$ support p vertex factorization
- Consistent with FPS result:
  $\alpha_{I\!P}(0) = 1.114 \pm 0.018(\text{stat.}) \pm 0.012(\text{syst.})^{+0.040}_{-0.020}(\text{th.})$

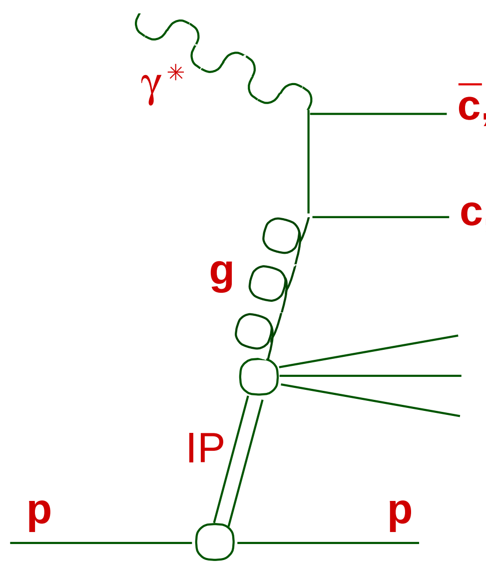


ZEUS results:

- Variation with Q^2 observed
- $\alpha_{I\!P}(0) = 1.1220 \pm 0.0140(\text{stat.})^{+0.0.0132}_{-0.0.0114}$ (syst.)

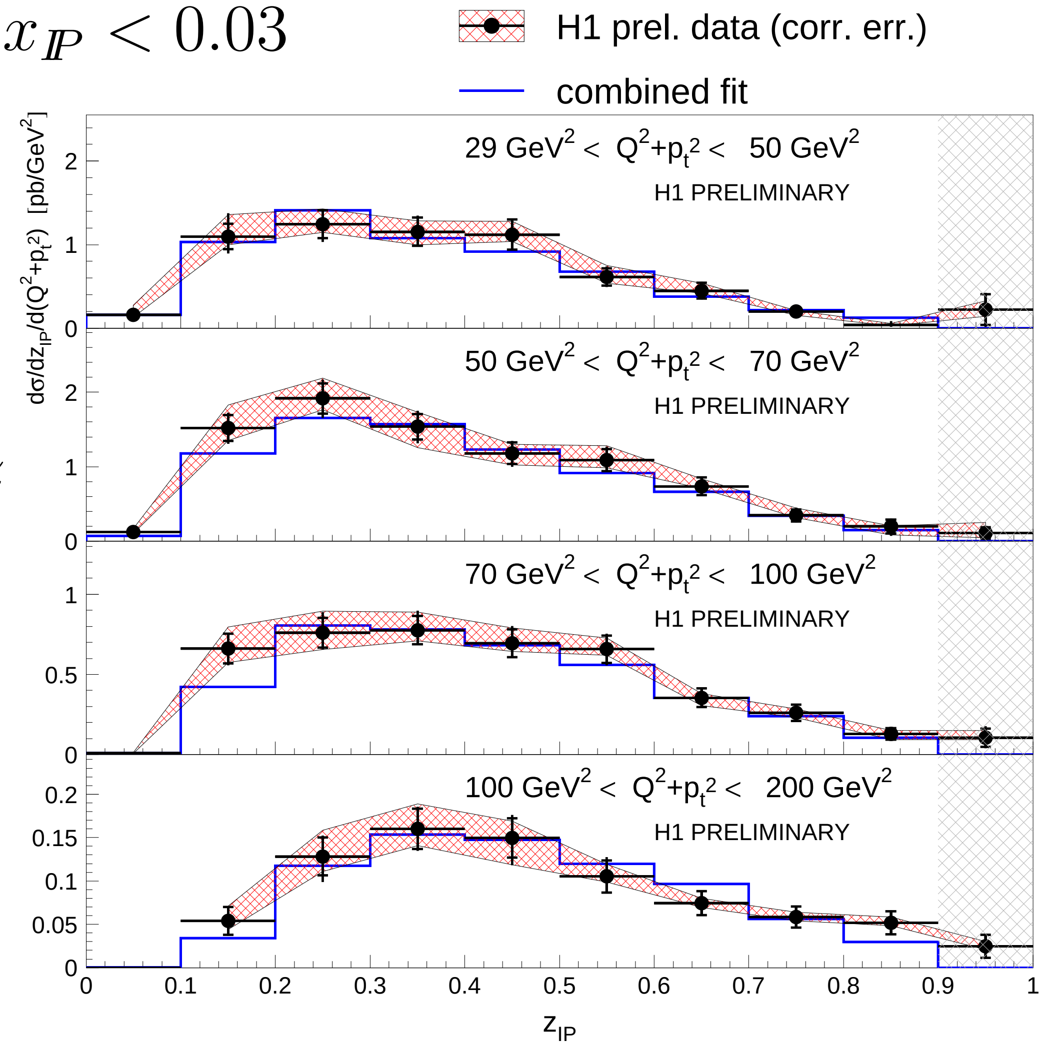


H1: Combined fit with diffractive dijets



Diffractive dijets H1 Preliminary results

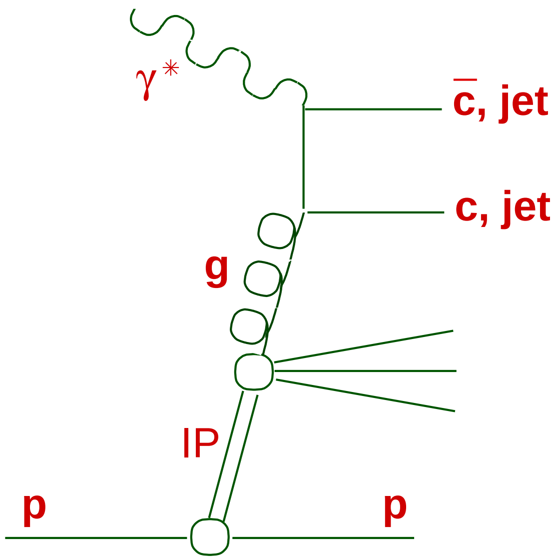
- 99-2000 data (50 pb^{-1})
- $4 < Q^2 < 80\ \mathrm{GeV}^2, 0.1 < y < 0.7$
- $x_{I\!P} < 0.03$



- Sensitivity to gluon at high z

  $\rightarrow$ Combined QCD fit to dijets and inclusive data to constrain gluon at high z

H1: Combined fit with diffractive dijets



Diffractive dijets H1 Preliminary results

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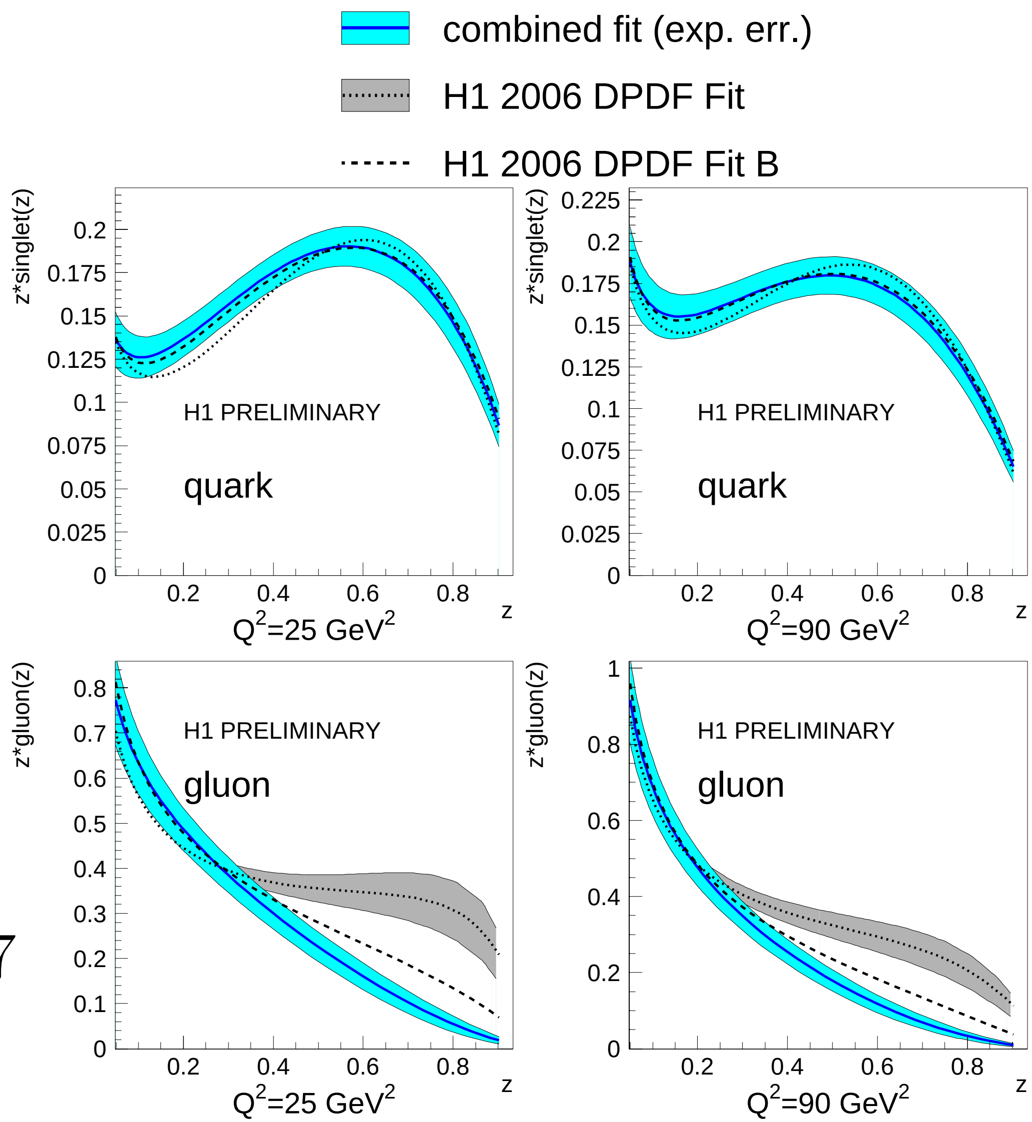


- Sensitivity to gluon at high z

  $\rightarrow$ Combined QCD fit to dijets and inclusive data to constrain gluon at high z

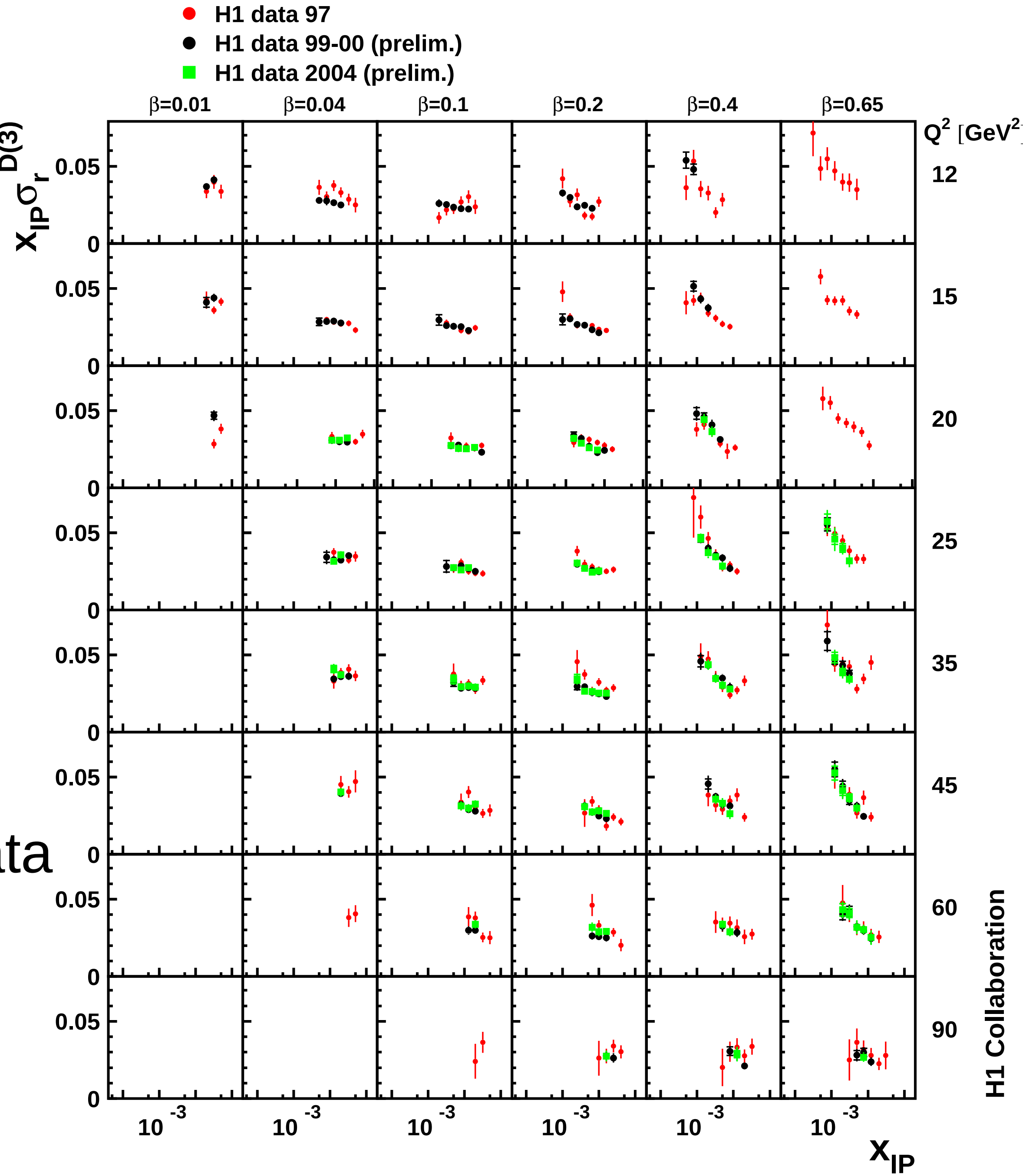
- Fit successfull: $\chi^2 = 196/217$ and stable at high z

New H1 Data with Rapidity Gap Method

- H1 published data
- H1 Prelim. 99-00, 34 pb^{-1}

  $10 < Q^2 < 105\ \mathrm{GeV}^2$
- H1 Prelim. 2004, 34 pb^{-1}

  $17.5 < Q^2 < 105\ \mathrm{GeV}^2$
- Large increase in statistics
- Consistent with publised data



CONCLUSION

- H1 diffractive measurements (FPS and LRG methods) published
  - hep-ex/0606003 and hep-ex/0606004 (accept. by EPJC)
  - Data from both methods agree in detail
  - Good agreement with ZEUS-LPS data
- New preliminary H1 data with large statistics
- Proton vertex factorization provides a good approximation for the $x_{\mathbb{P}}$ dependence (except maybe at high Q^2, cf ZEUS data)
- Ratio diffractive/inclusive DIS measured
  - Flat with Q^2 and W except at high β (i.e. low M_X)
- Diffractive PDFs extracted from NLO QCD fits to H1 data
  - Quark singlet very well constrained ($\sim 5\%$)
  - Gluon constrained to $\sim 15\%$, but poorly known at high z
  - Combined fits with diffractive dijets helps to constrain the gluon at high z