Inclusive Diffraction at H1

Paul Thompson

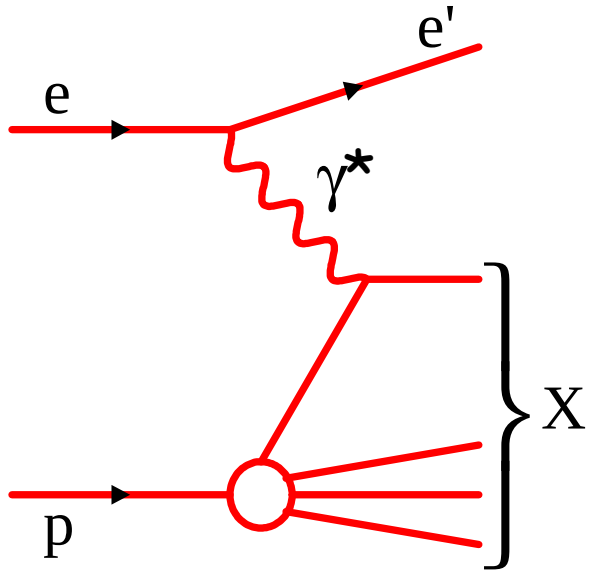
Birmingham University

- Diffraction at HERA
- Measurement technique
- Latest measurements
- Effective $\alpha_{IP}(0)$
- Q^2 and β dependences
- QCD analysis
- Summary

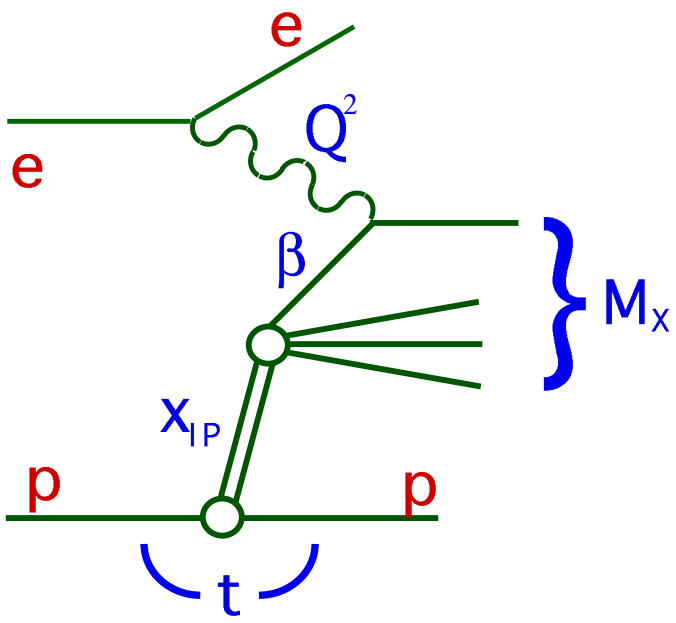
Diffractive DIS at HERA

Study QCD Structure of high energy diffraction using $\gamma^* p \rightarrow X p$

Standard DIS



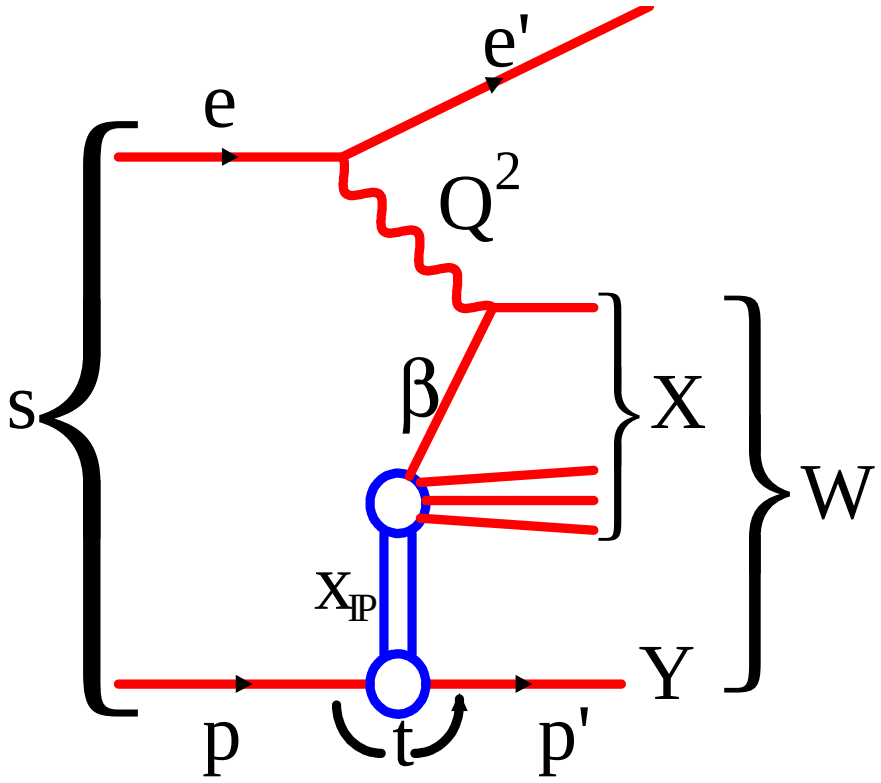
Diffractive DIS



Probe proton $\rightarrow$ F_2 Proton

Probe the Pomeron $\rightarrow$ F_2^D

Diffractive Kinematics



$$Q^2 = -(e - e') = -q^2$$

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

$$\beta = x_{\text{quark/IP}}$$

$$x_{IP} = x_{IP/\text{proton}}$$

$$x_{Bjorken} = \beta \cdot x_{IP}$$

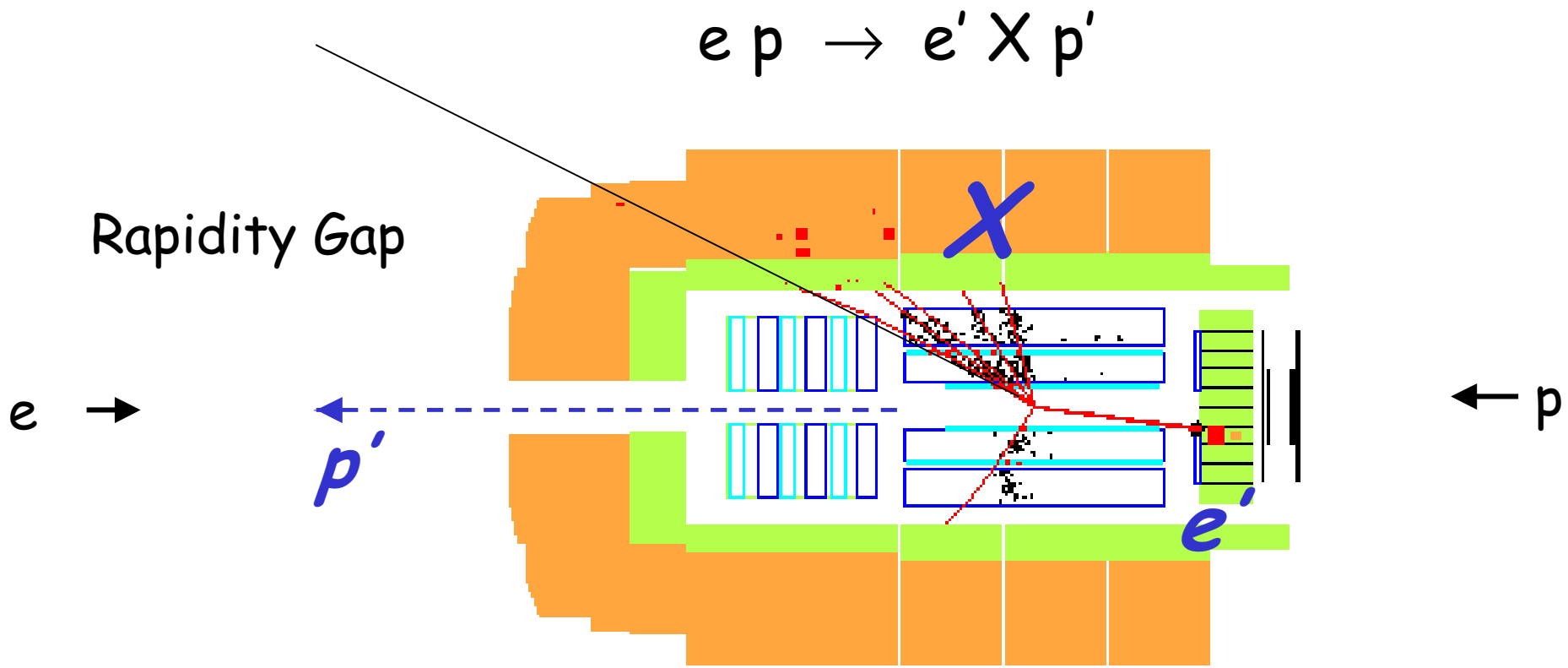
Cross section:

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

Reduced Cross Section:

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{1+(1-y)^2} F_L^{D(4)} \quad (\sigma_r^{D(4)} = F_2^{D(4)} \text{ if } F_L^{D(4)} = 0)$$

Measurement at H1



Require Large Rapidity Gap

Kinematics measured from X system and e′

Integrate over t and $M_Y < 1.6$ GeV

Overview of $\sigma_r^{D(3)}$ measurements at H1

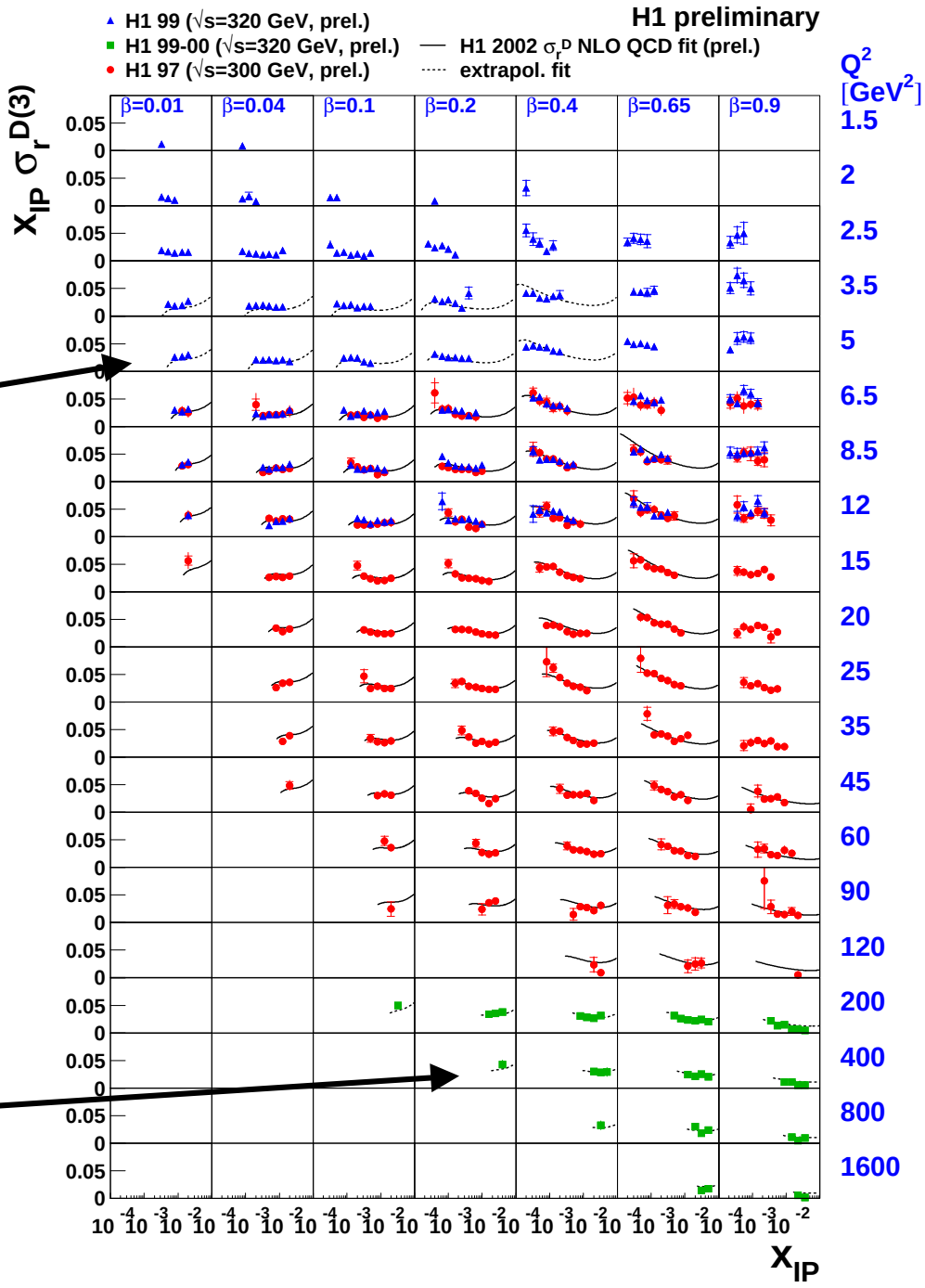
New data at Low Q^2, $\ell = 3.4\ \mathrm{pb}^{-1}$

New H1 Measurements at Low and High Q^2

Good agreement between measurements.

Data well described by QCD Fit (more later)

New data at High Q^2, $\ell = 65\ \mathrm{pb}^{-1}$



Factorisation of $\sigma_r^{D(3)}$

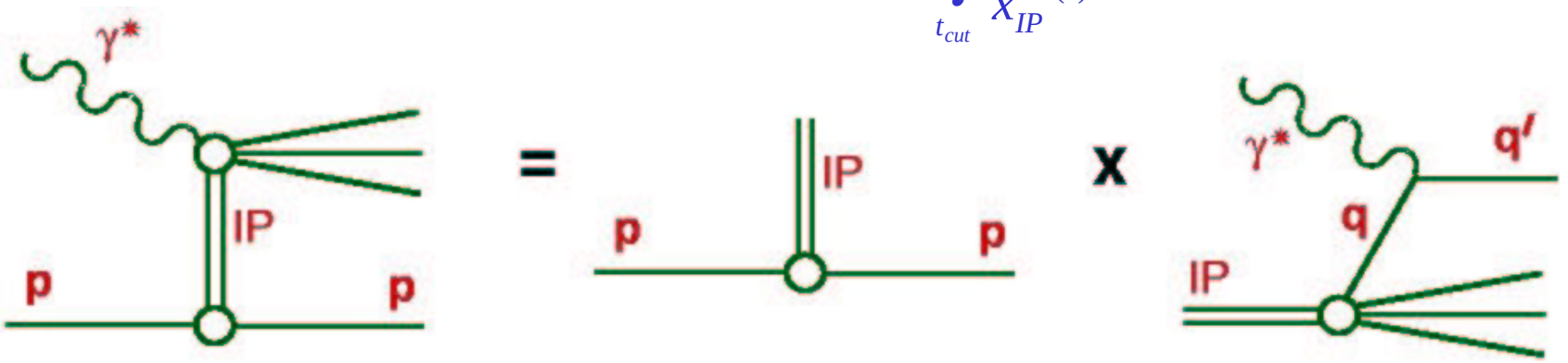
QCD Hard Scattering Factorisation for Diffractive DIS (Collins)

- At fixed x_{IP},t, Diffractive Parton Densities p(x,Q^2) evolve with x and Q^2 via DGLAP equations

Regge Factorisation

- shape of diffractive PDFs independent of x_{IP} and t
- Regge motivated flux factor

$$f_{IP/p}(x_{IP}) = \int_{t_{cut}}^{t_{min}} \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}} dt$$



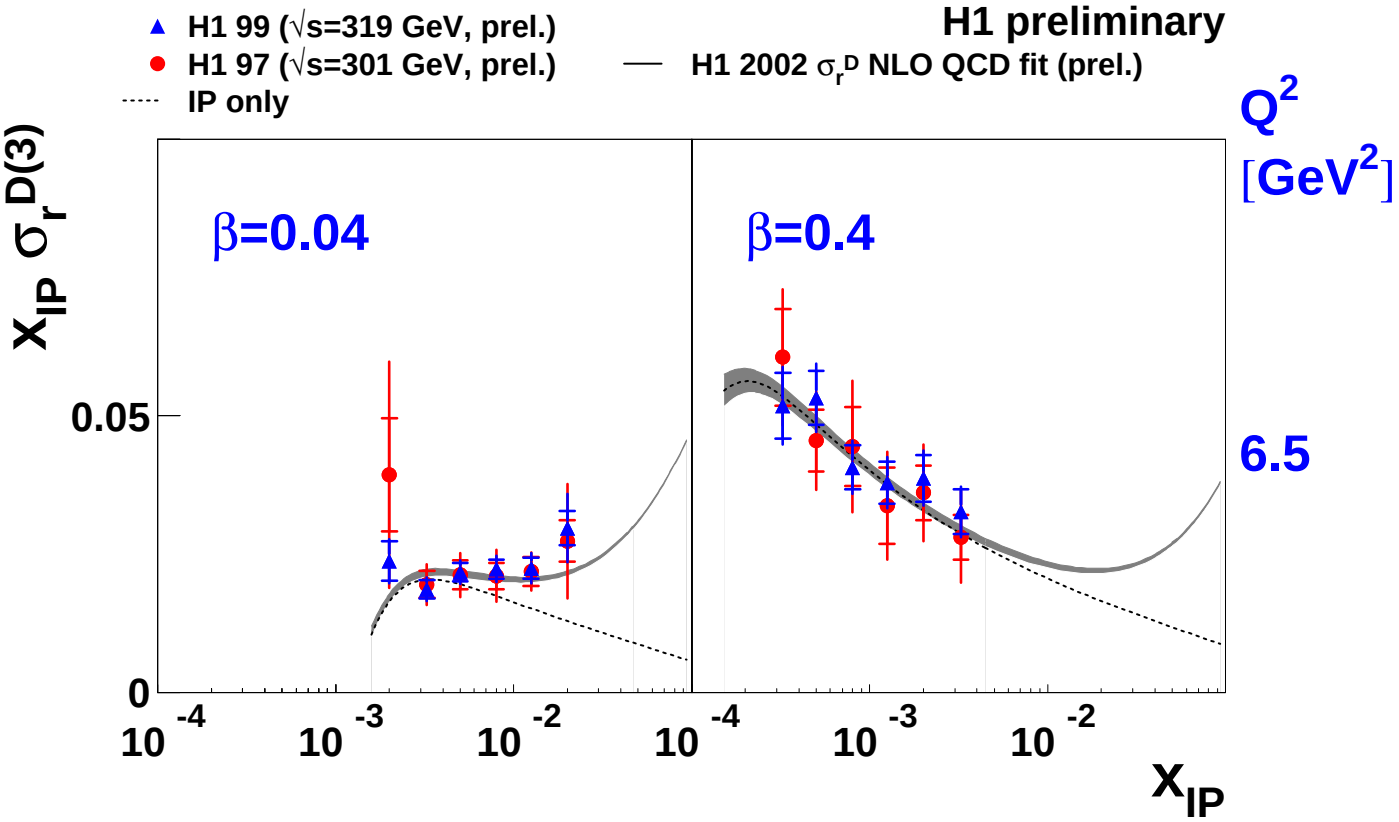
$$\sigma(\gamma^* p \to Xp) \approx f(x_{IP},t) \otimes p(\beta,Q^2) \otimes \hat{\sigma}(\beta,Q^2)$$

Test of Regge Factorisation

$$x_{IP} F_2^D \approx A(\beta, Q^2) x_{IP}^{-2(\alpha(t)-1)}$$

Fit x_{IP} dependence at fixed β and Q^2

Avoid F_L $y < 0.45$



Data well described by exchange of Pomeron and Reggeon

$\chi^2 / \mathrm{ndf} = 0.95$

$$\alpha_{IP}(0) = 1.173 \pm 0.018\,(\mathrm{stat.}) \pm 0.017\,(\mathrm{syst.})^{+0.063}_{-0.035}\,(\mathrm{model})$$

Effective $\alpha_{IP}(0)$

Possible increase with Q^2?

Limited by ignorance of F_L

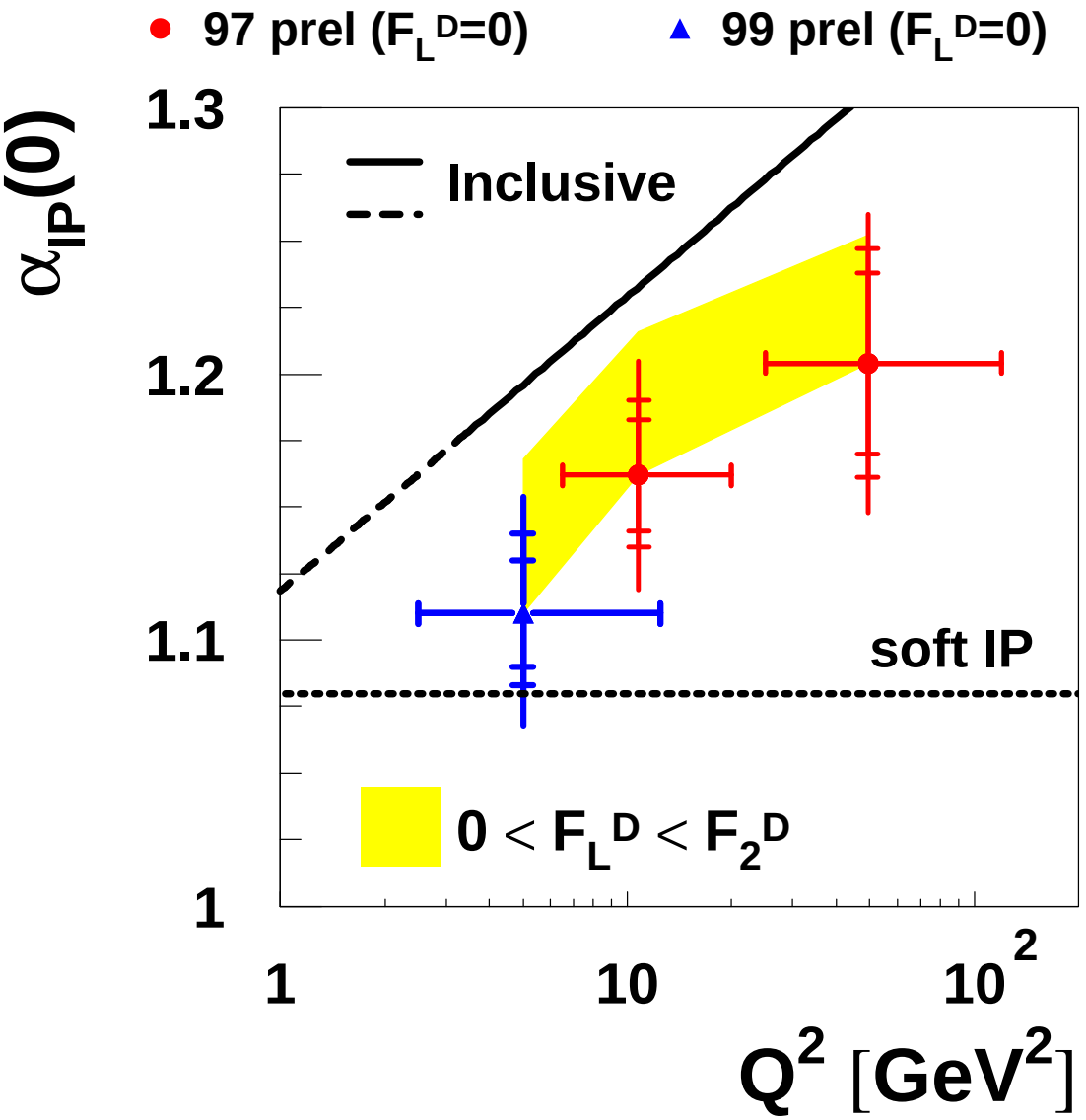
Data inconclusive

Effective $\alpha_{IP}(0)$ at large Q^2 greater than for soft IP

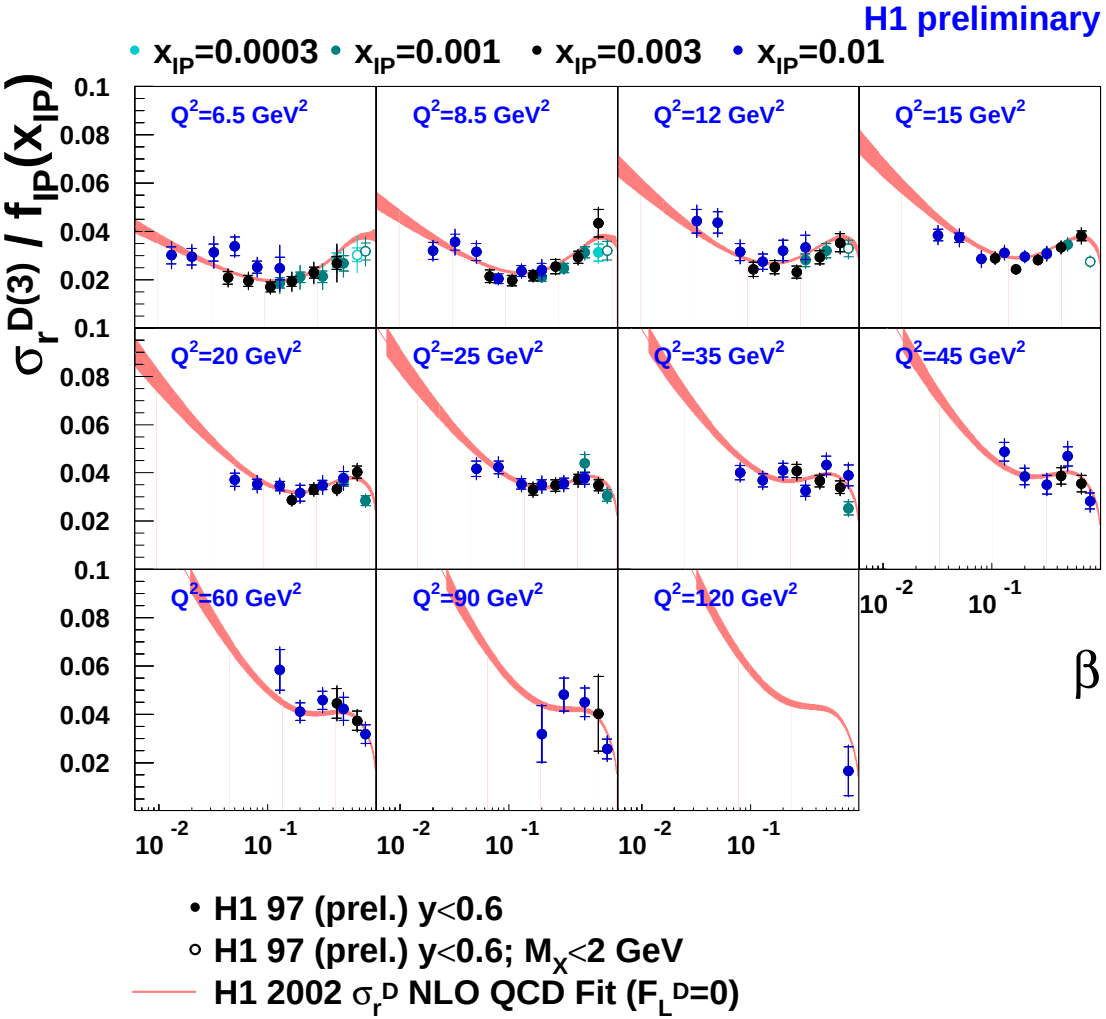
$\alpha_{IP}(0)$ lower than for inclusive cross section

$$x_{IP}F_2^D \approx A(\beta, Q^2)x^{-2(\alpha(t)-1)}$$

$$F_2 \approx Bx^{-(\alpha(t)-1)}$$



β Dependence of σ_r^D



Divide by $f_{IP}(x_{IP})$

Compare different x_{IP} bins

β dependence relatively flat

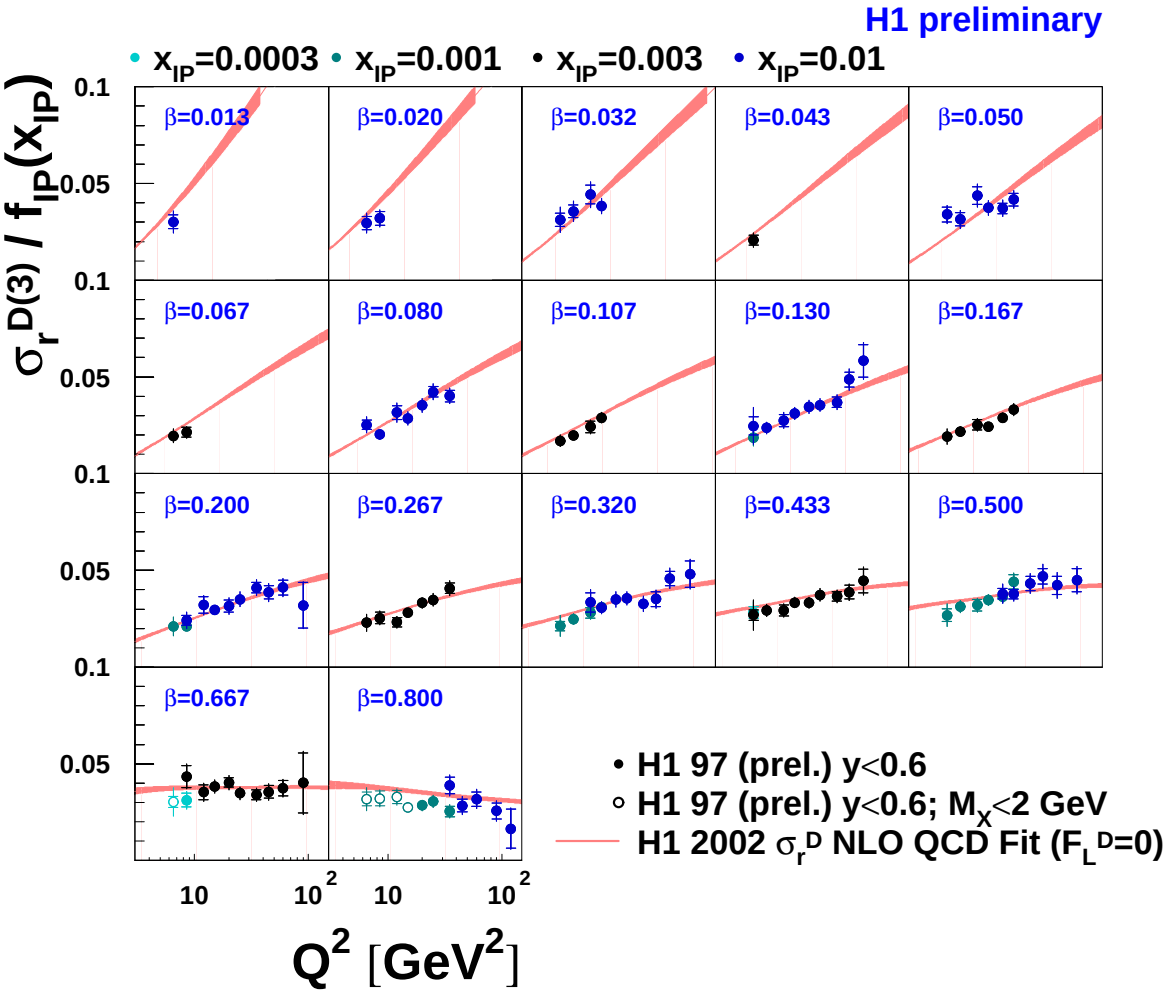
-> Gluon dominated

Structure similar at all values of x_{IP}

-> supports Regge factorisation

$$F_2^{IP}(\beta, Q^2) = \beta \sum_i e_i^2 p_i(x, Q^2)$$

Q^2 Dependence of σ_r^D



Divide by $f_{IP}(x_{IP})$

Compare different x_{IP} bins

Large +'ve scaling violations except at highest β

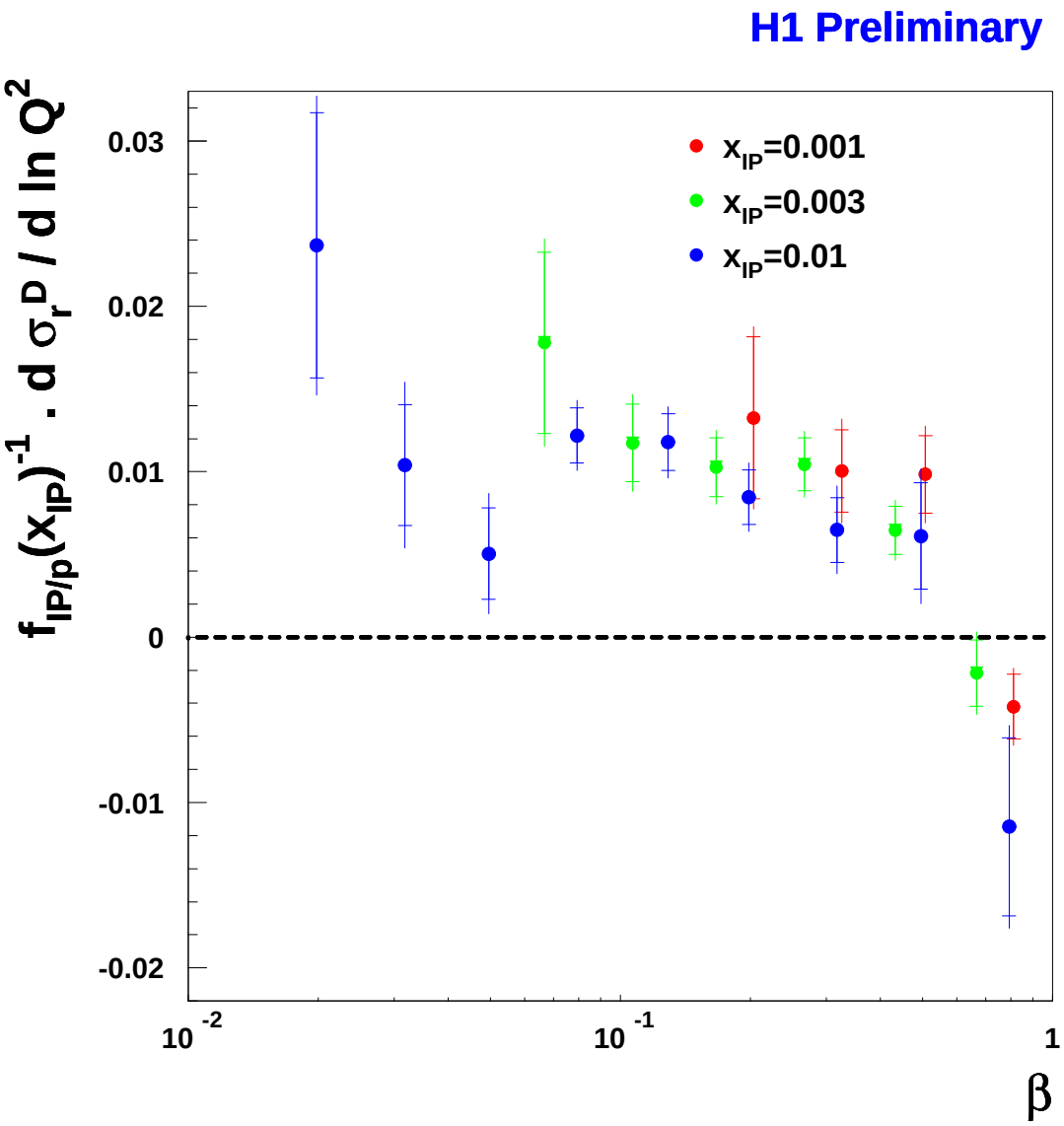
-> Gluon dominated

$$F_2^{IP}(\beta, Q^2) = \beta \sum_i e_i^2 p_i(x, Q^2)$$

Scaling violations similar at all values of x_{IP}

-> supports Regge factorisation

Scaling Violations



Quantify Scaling violations…

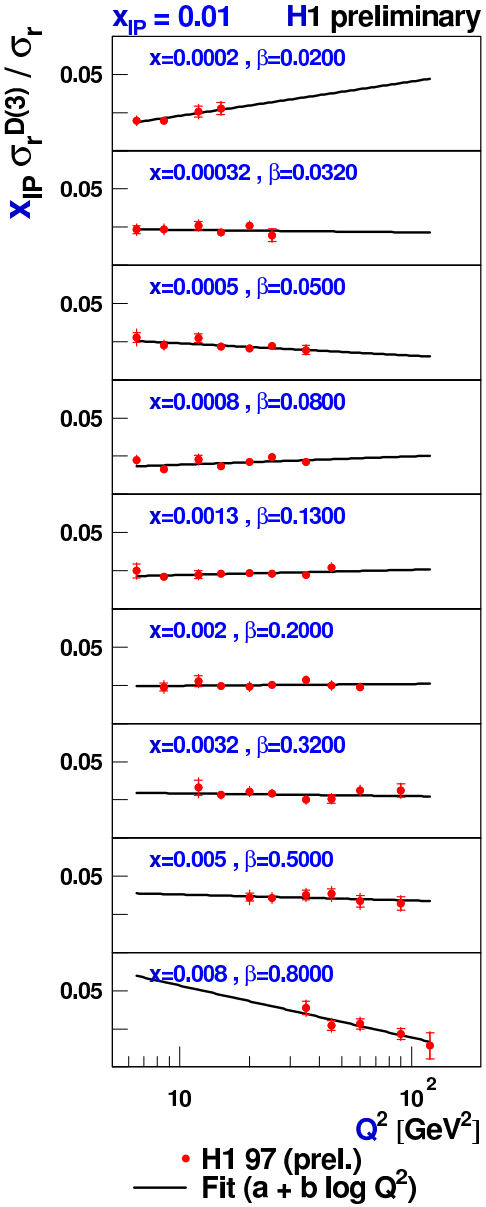
Divide by $f_{IP}(x_{IP})$

$$\sigma_r^D = A + B \ln Q^2$$

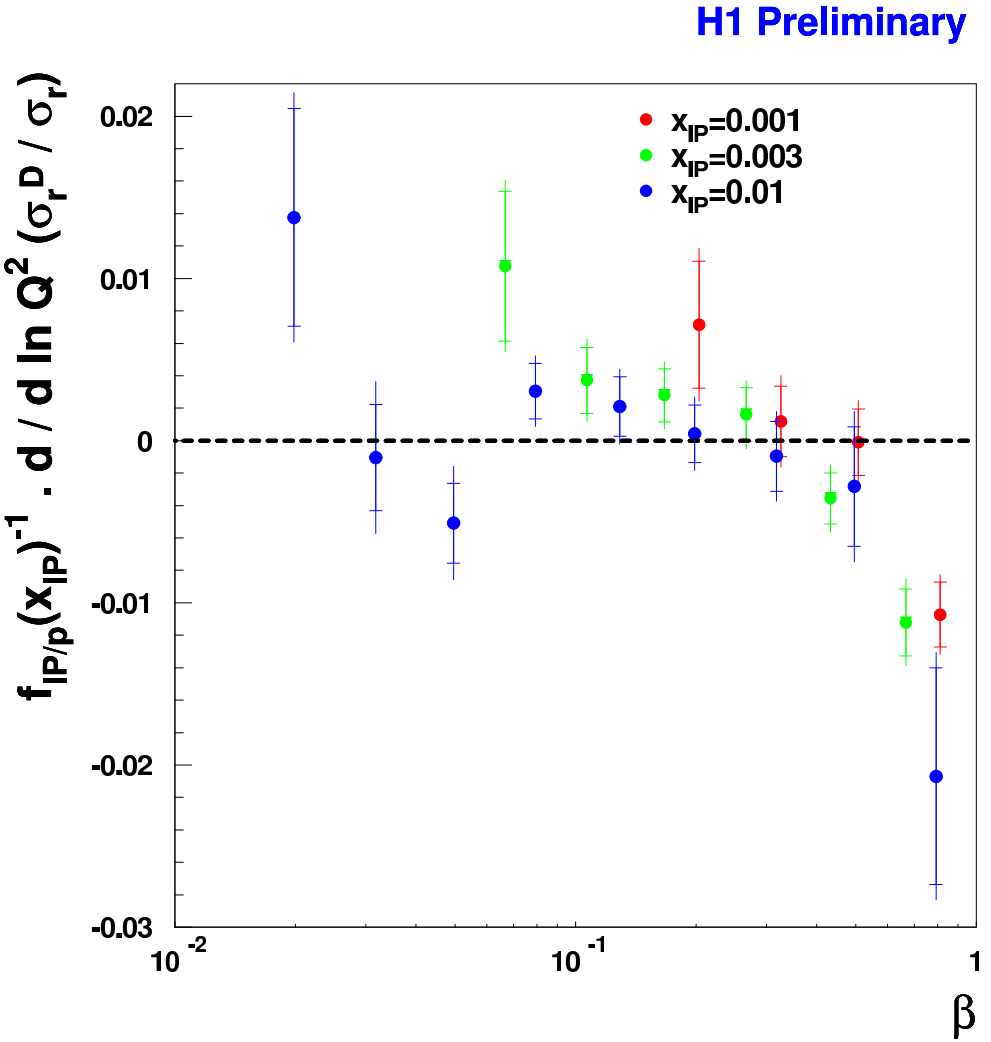
$$B = \frac{d\sigma_r^D}{d \ln Q^2 (\sigma_r^D)}$$

Large +'ve Scaling violations until β ~ 0.6

Comparison with inclusive DIS



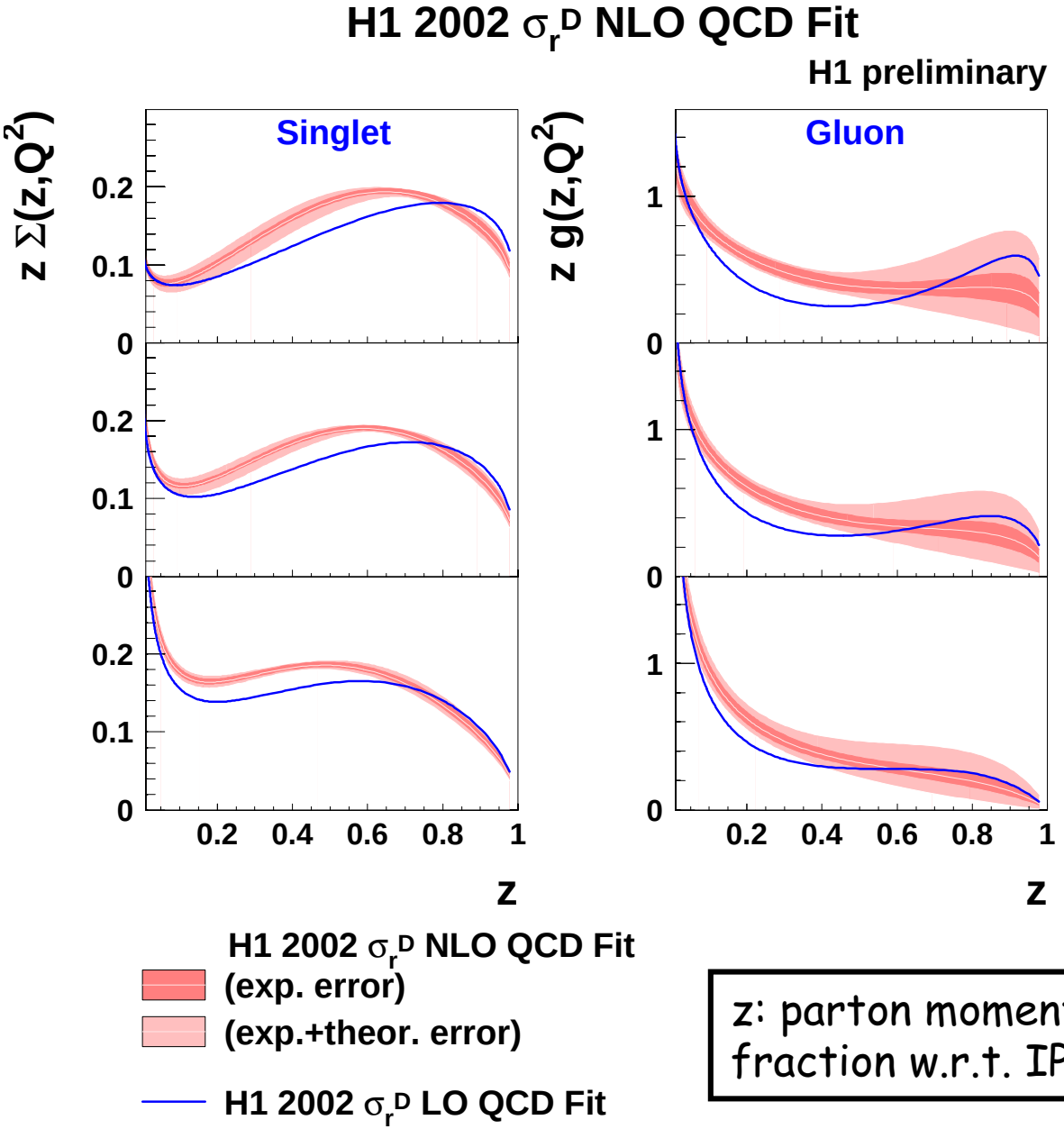
$$x = x_{IP} \cdot \beta$$



Fit R = a + b ln Q^2, σ_r^D/σ_r ~ flat vs Q^2

Similar Q^2 dynamics?

Diffractive Parton Densities

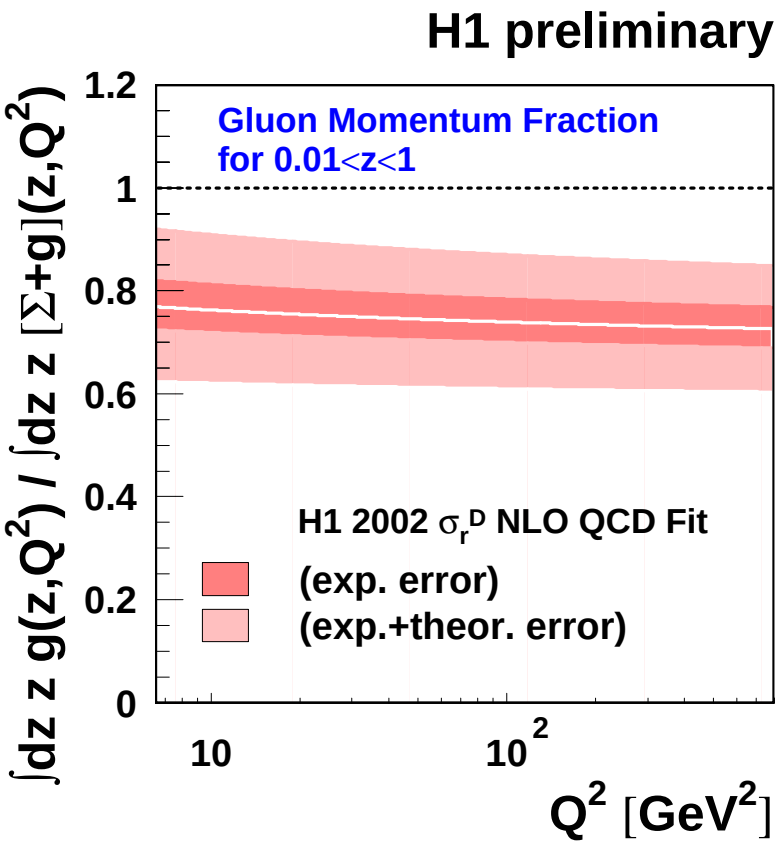


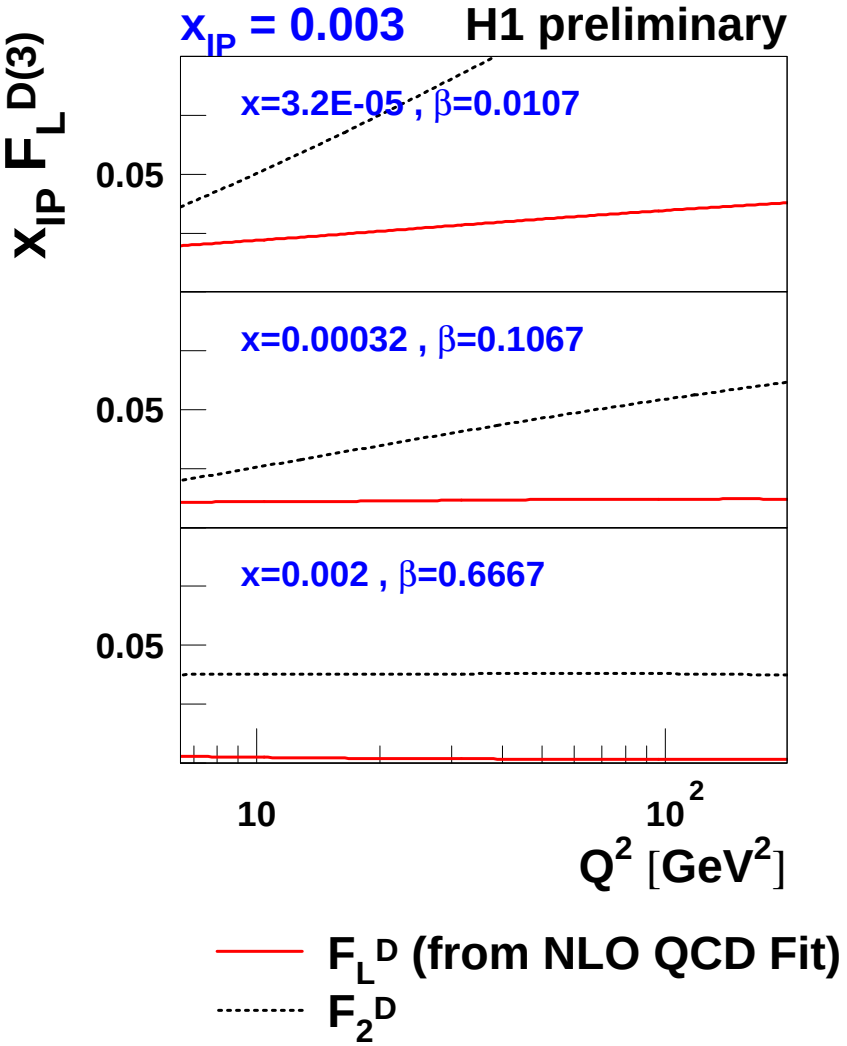
- Fit data: $Q^2 > 6.5$ GeV^2
- $M_x > 2$ GeV (leading twist)
- x_{IP}/Regge factorisation
- DGLAP evolution
- LO fit: $y < 0.45$
- NLO fit: F_L^D and full propagation of errors

z: parton momentum fraction w.r.t. IP

- Diffractive PDF Gluon dominated
- Extend to large z
- Large uncertainty on gluon at high z

QCD Fit



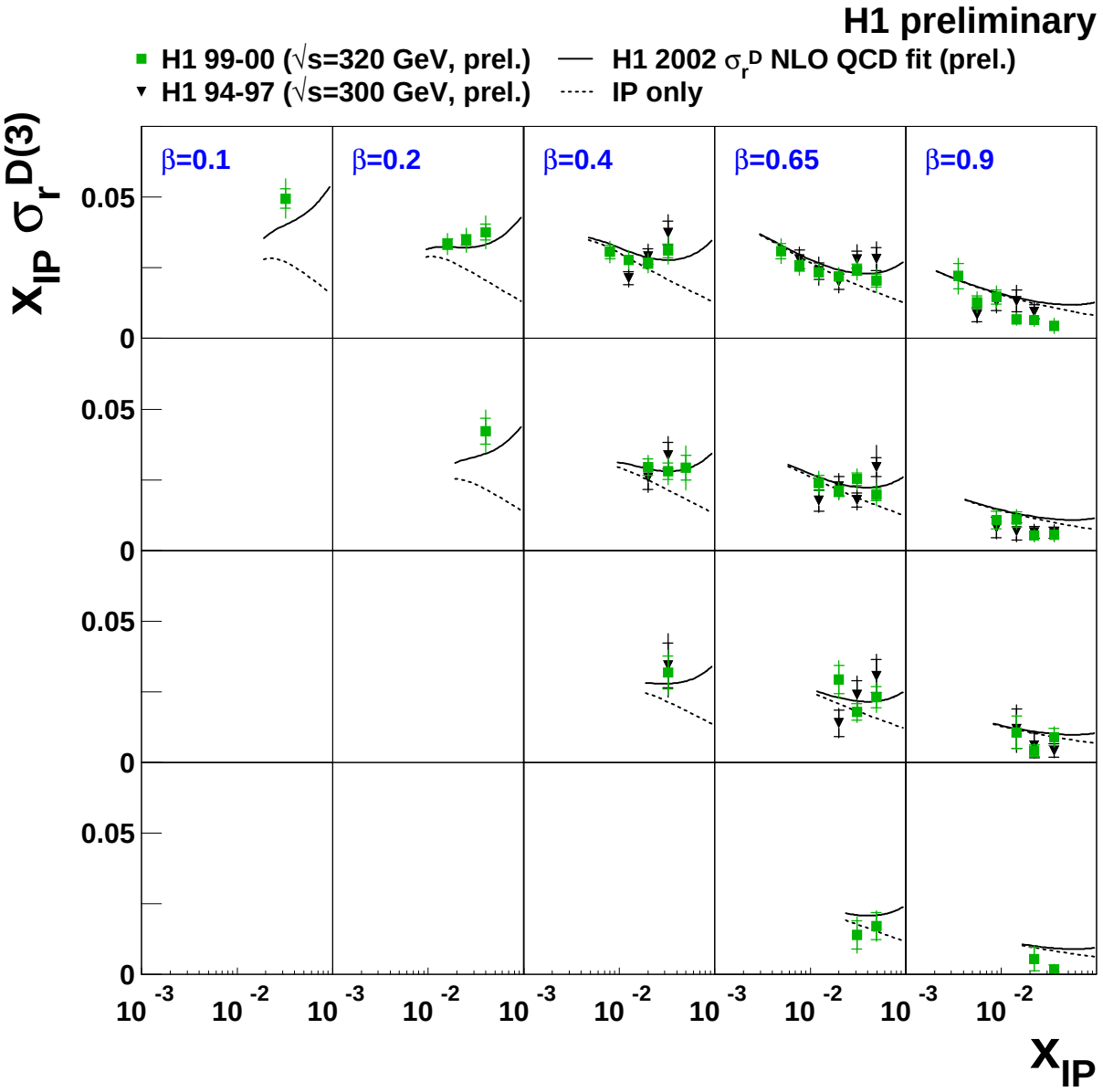


75 ± 15% diffractive exchange carried by gluons

F_L^D predicted at leading twist

-> large at low Q^2 and low β

New Measurement at High Q^2



Q^2 [GeV^2]

200

400

800

1600

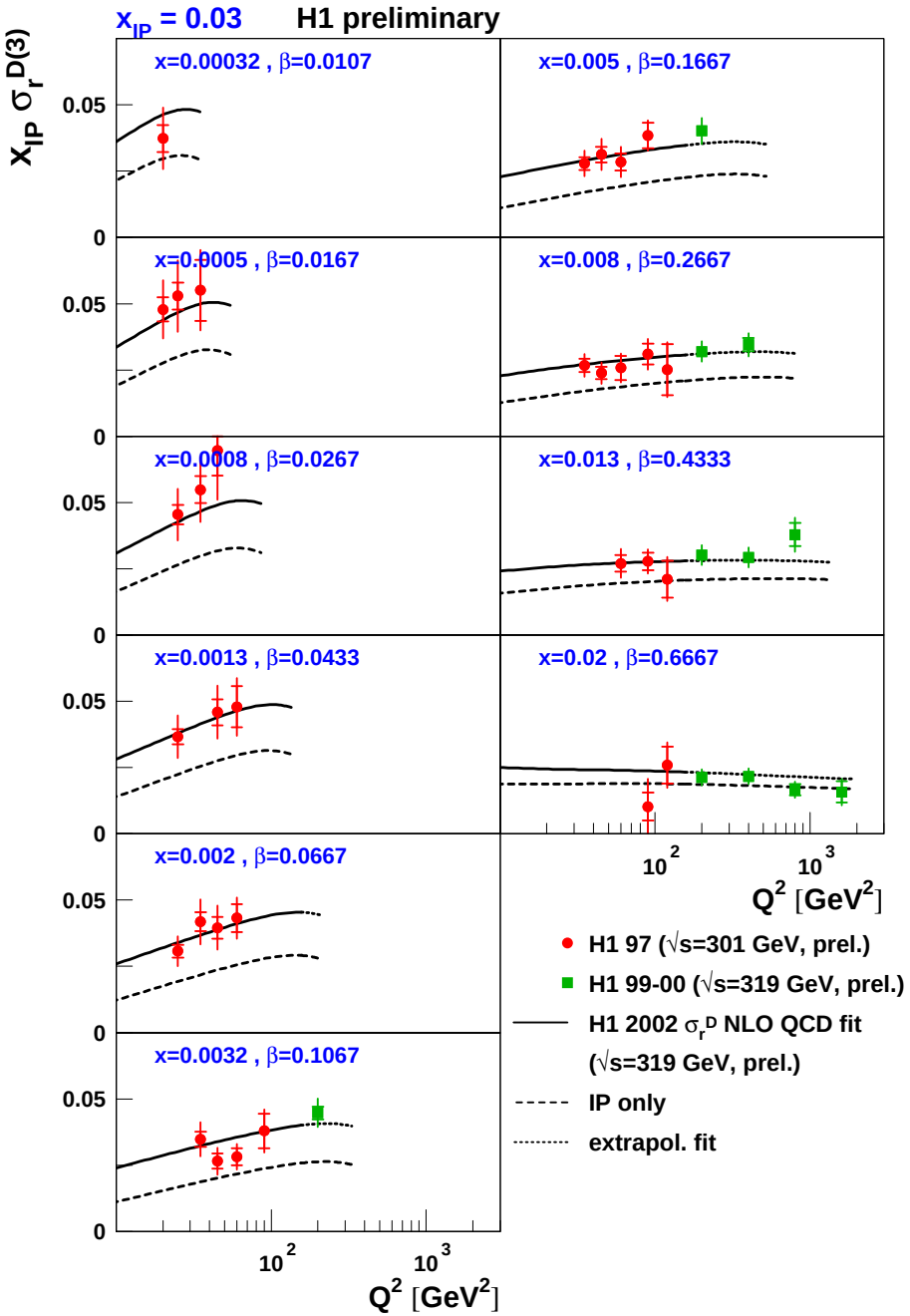
Improved statistics and kinematic range of 99-00 measurement compared with 94-97

-> Good agreement

Prediction of NLO fit to medium Q^2 data

-> Good agreement

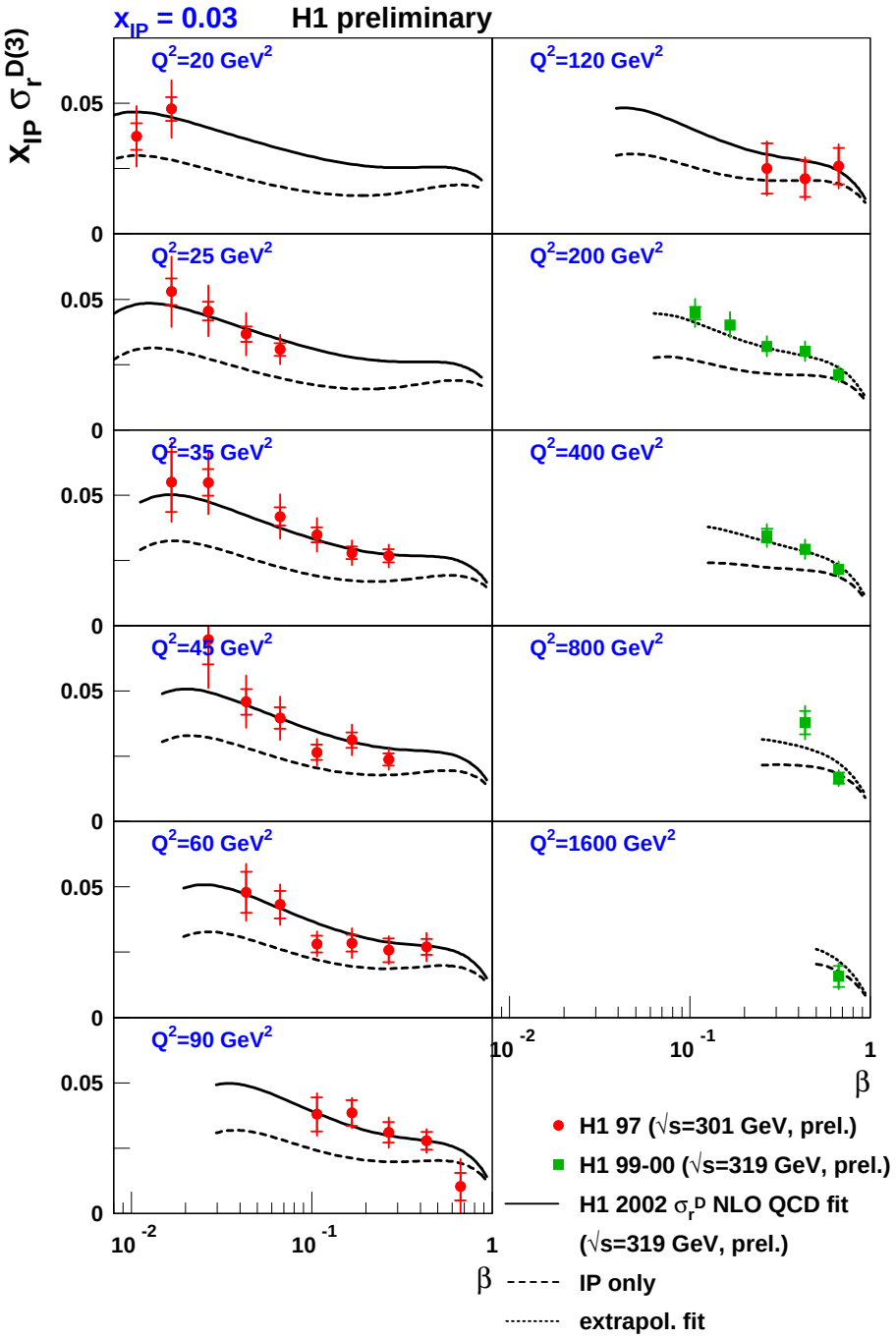
Subleading trajectory needed at high x_{IP} and low β



Q^2 Dependence at high x_{IP}

Extrapolation of the fit over an order of magnitude in Q^2 !!!

->Good description of the data



β Dependence at high x_{IP}

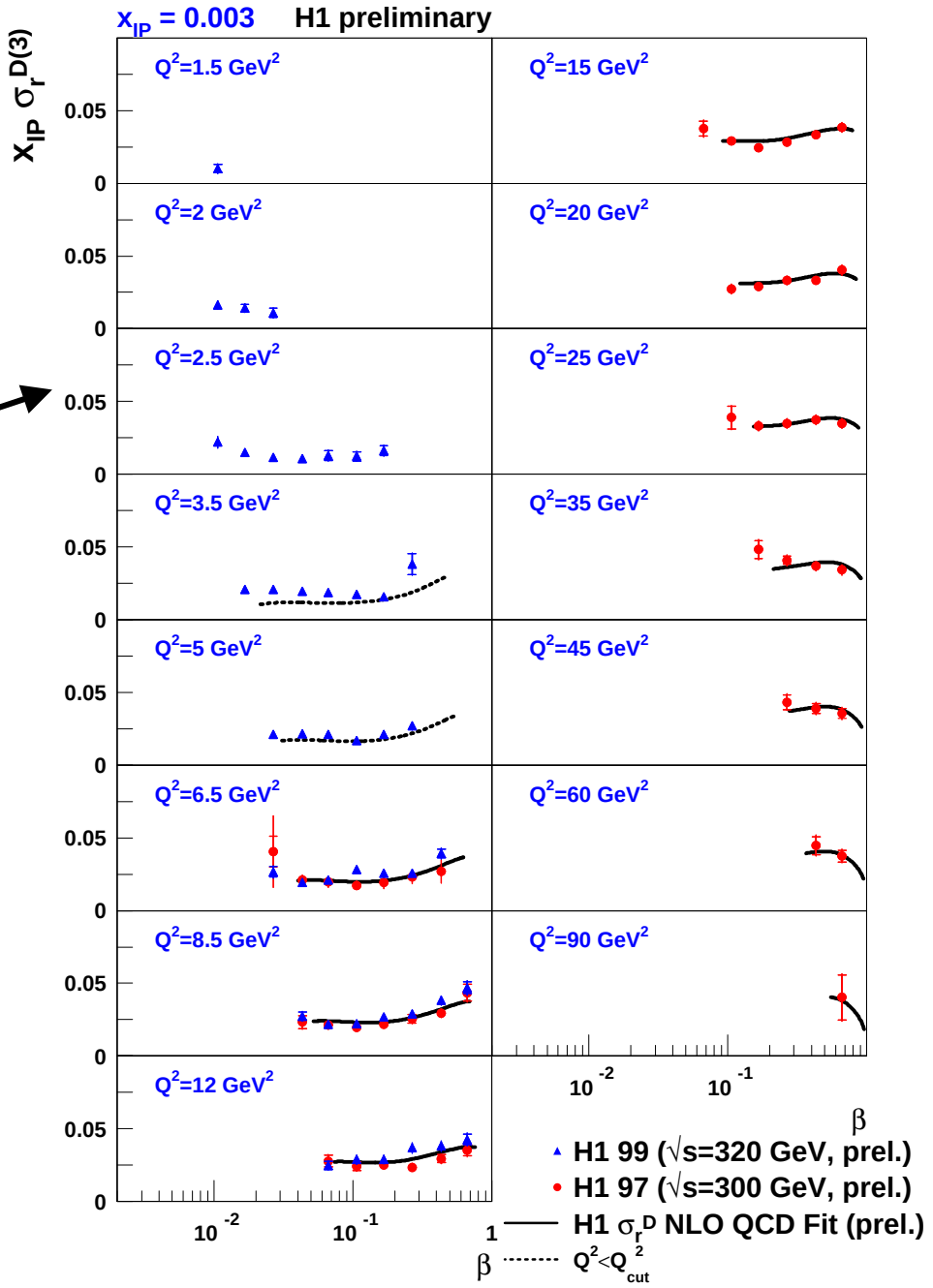
Meson exchange has negative slope

← New data at high Q^2 will provide constraint to future fits

β Dependence at low x_{IP}

New data at low Q^2 will provide important constraint to future fits

Good agreement between medium and low Q^2 data



Summary

- New measurements from H1 at low and high Q^2
- Data will provide further constraints for fits and models
- $\alpha_{IP}(0)$ in diffractive DIS larger than soft Pomeron
- NLO QCD fit yields PDFs dominated by gluon to large β
- Similar Q^2 dynamics to inclusive DIS at medium β

High Precision measurement of $F_2^{D(3)}$ combined with QCD factorisation theorem:

tools for pQCD to provide complete description of diffractive final state as for inclusive DIS?