The Low x Workshop 2003 - Nafplion, Greece

THE UNIVERSITY of LIVERPOOL

INCLUSIVE DIFFRACTION AT H1

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Overview:

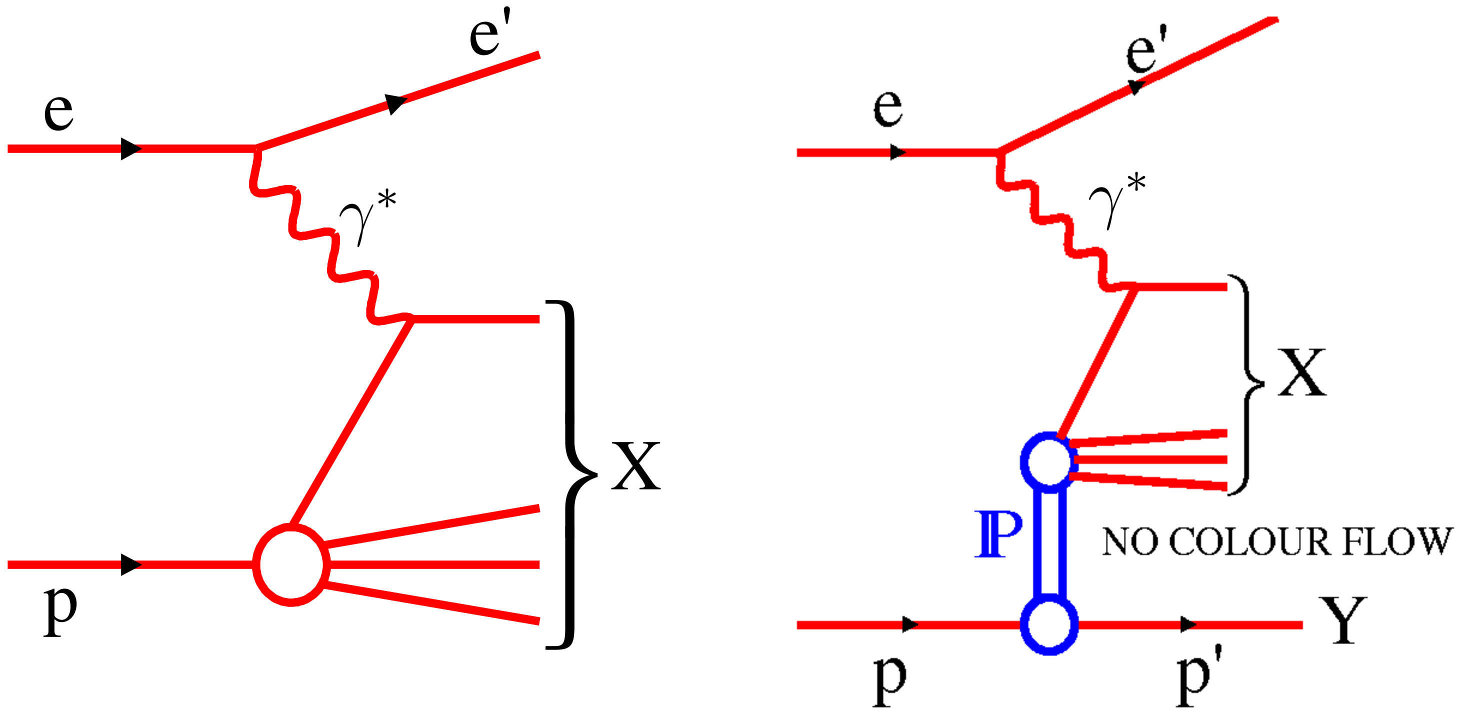
- DIFFRACTION AT HERA
- MEASUREMENT TECHNIQUES
- LATEST MEASUREMENTS
- QCD ANALYSIS
- INCLUSIVE VS DIFFRACTIVE
- SUMMARY

Inclusive Diffractive DIS at HERA

A large fraction of hadronic interactions at high energy are diffractive

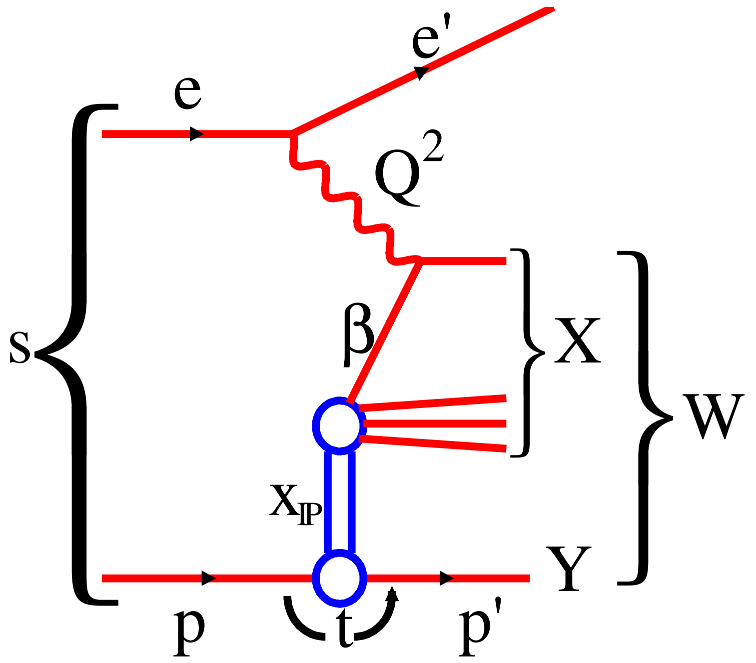
Study the QCD Structure of these interactions using :

$$\gamma^* p \longrightarrow Xp$$



Probe the proton $\longrightarrow F_2^{Proton}$ Probe Diffractive dynamics $\longrightarrow F_2^D$

Inclusive Diffractive DIS $\gamma^* p \longrightarrow Xp$



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

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

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

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

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

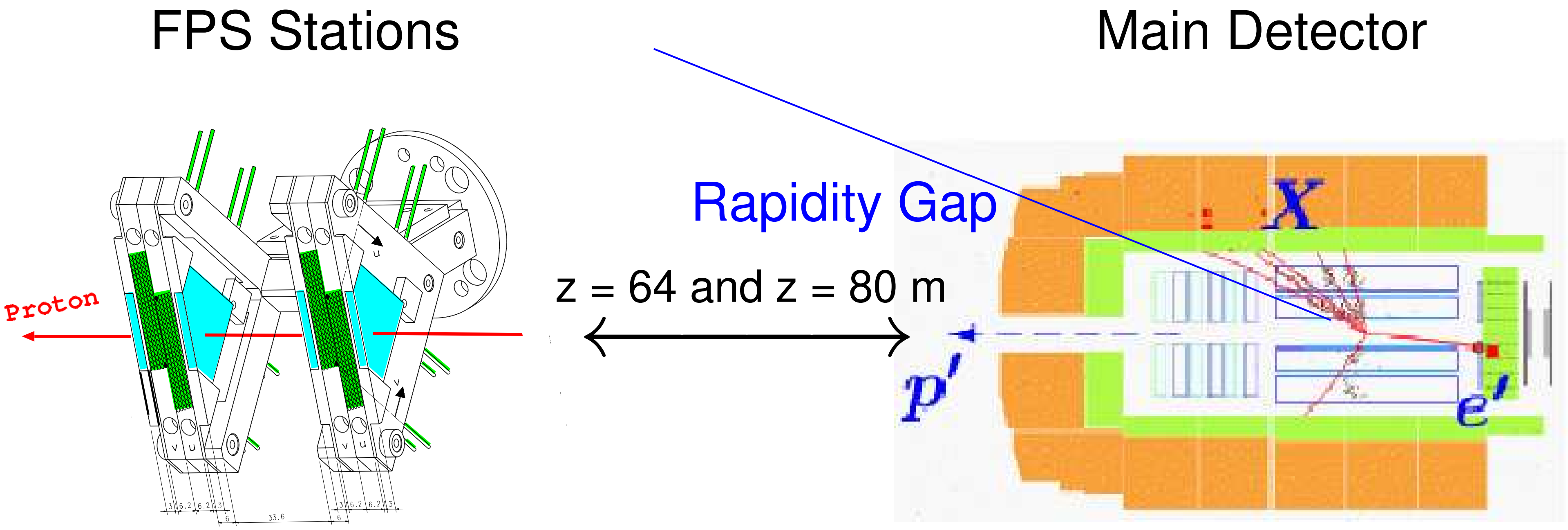
Cross Section :

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

Reduced Cross Section :

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

Diffraction in H1 $ep \longrightarrow e'Xp'$



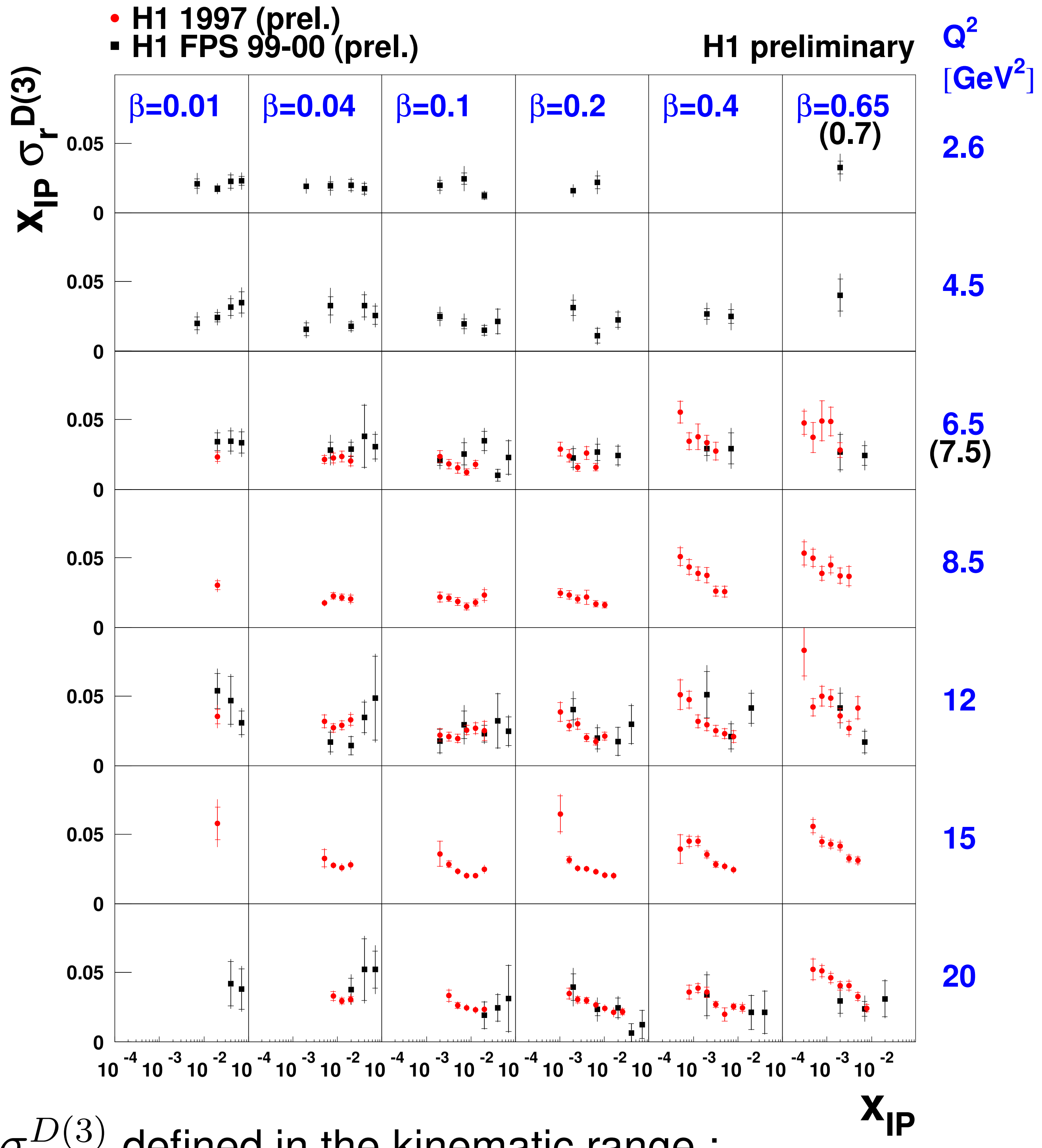
Measure Leading Proton

- Free of p dissociation background
- Measure t distribution
- Lower statistics due to acceptance

Require Large Rapidity Gap

- Kinematics measured from X system
- Integrate over t and M_Y
- Higher statistics

Tagged Proton Vs Rapidity Gap Selection



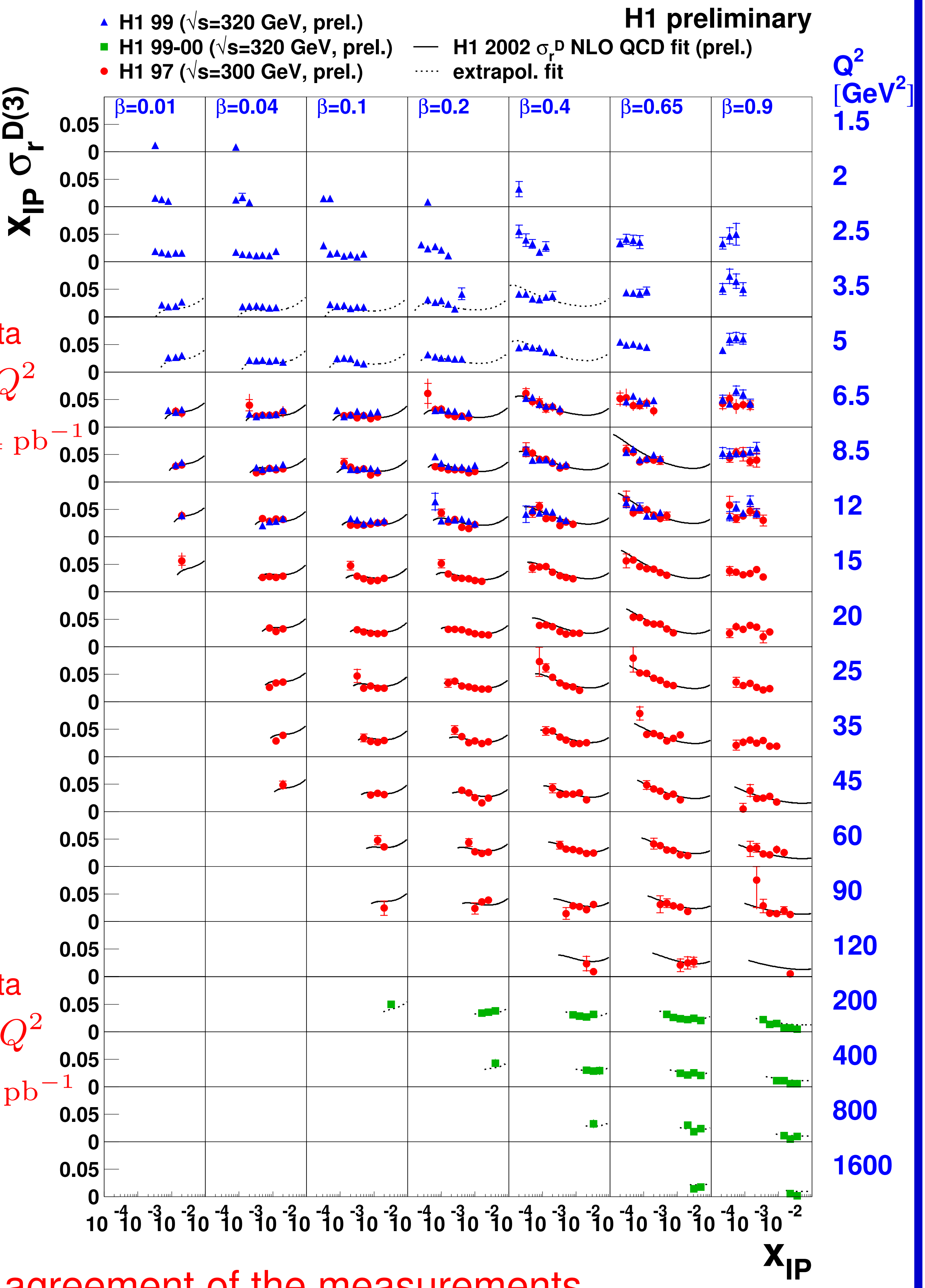
$\sigma_r^{D(3)}$ defined in the kinematic range :

$M_Y < 1.6$ GeV and $|t| < 1.0$ GeV^2

Compare to $\sigma_2^{D(4)}$ integrated over measured t slope

$\longrightarrow$ Good agreement between the two techniques

New H1 Measurements at Low and High Q^2



New data at Low Q^2

$\mathcal{L} = 3.4\ \mathrm{pb}^{-1}$

New data at High Q^2

$\mathcal{L} = 65\ \mathrm{pb}^{-1}$

Good agreement of the measurements

All data well-described by the fit, more later ...

Factorisation Properties of σ_r^D

1. QCD Hard Scattering Factorisation for Diffractive DIS

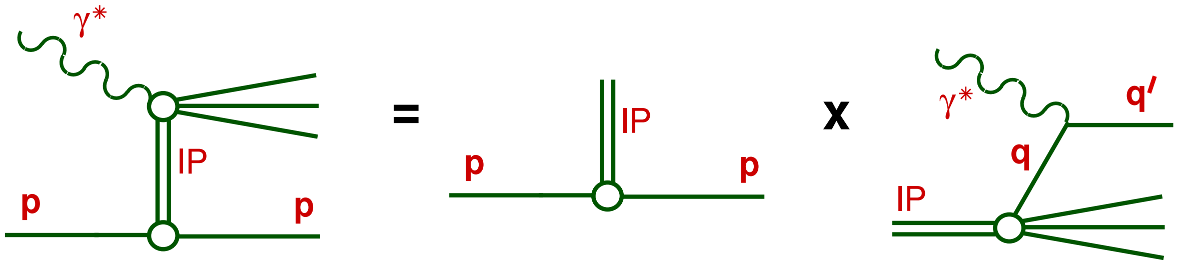
QCD Proof by Collins

$$\sigma(\gamma^* p \to Xp) \quad \sim \quad p_{q/p}(x_{IP}, t, x, Q^2) \quad \otimes \quad \hat{\sigma}_{\gamma^\star q}(x, Q^2)$$

At fixed x_{IP}, t, Diffractive Parton Densities evolve with x, Q^2 according to DGLAP

2. 'Regge' Factorisation

Additional assumption - Shape of Diffractive pdfs are independent of x_{IP} and t

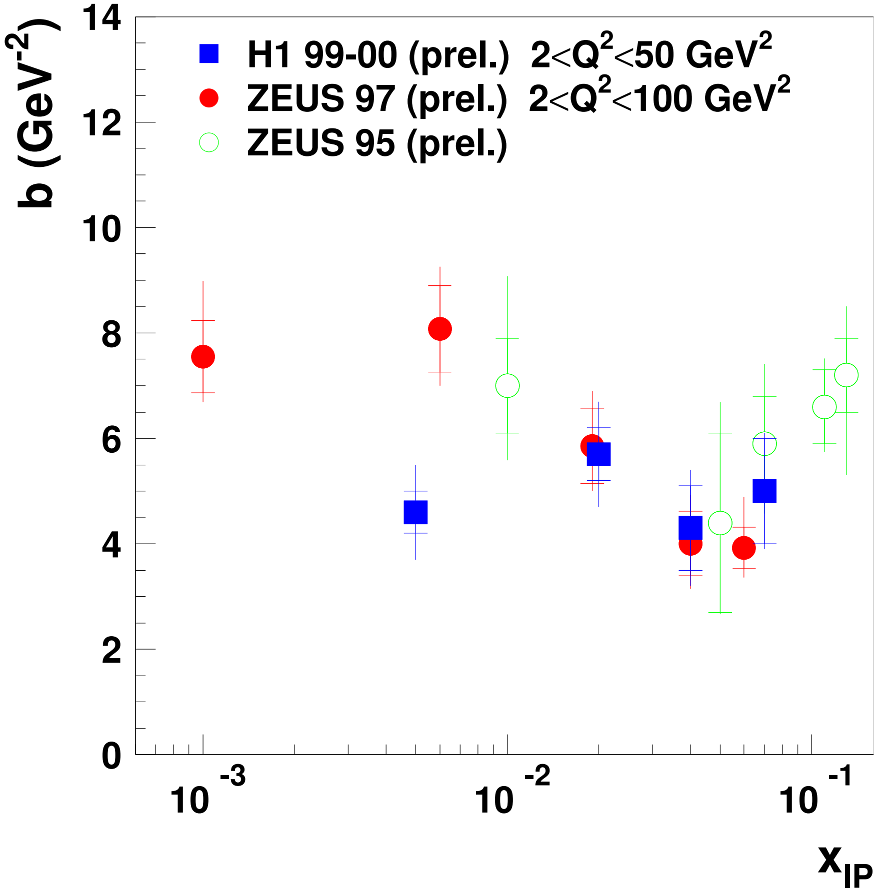


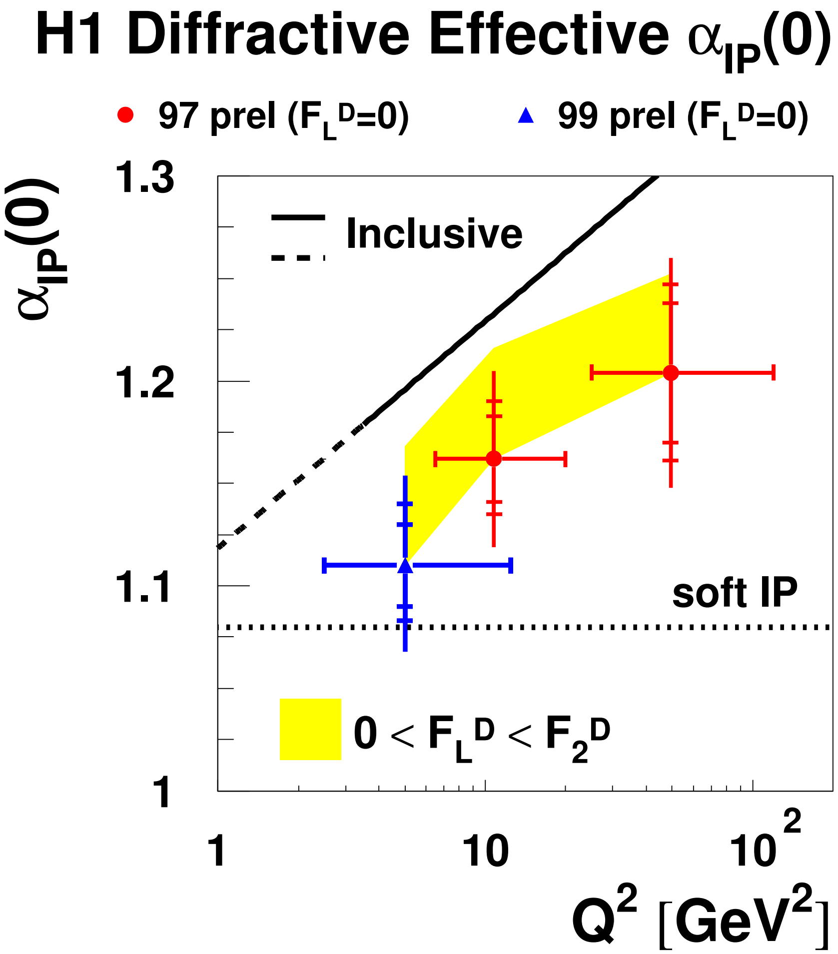
$$\sigma(\gamma^* p \to Xp) \quad \sim \quad f_{IP/p}(x_{IP}, t) \quad \otimes \quad p_{q/IP}(\beta, Q^2) \quad \otimes \quad \hat{\sigma}_{\gamma^\star q}(\beta, Q^2)$$

Diffractive flux — Pomeron pdfs — Hard Scatter

Flux parameterised as $$f_{IP/p}(x_{IP}) \ = \int_{t_{cut}}^{t_{min}} \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}} \, \mathrm{d}t$$

t-dependence and $\alpha_{IP}(0)$





In Regge theory expect shrinkage :

$$B = B_0 + 2\alpha' \ln \frac{1}{x_{IP}}$$

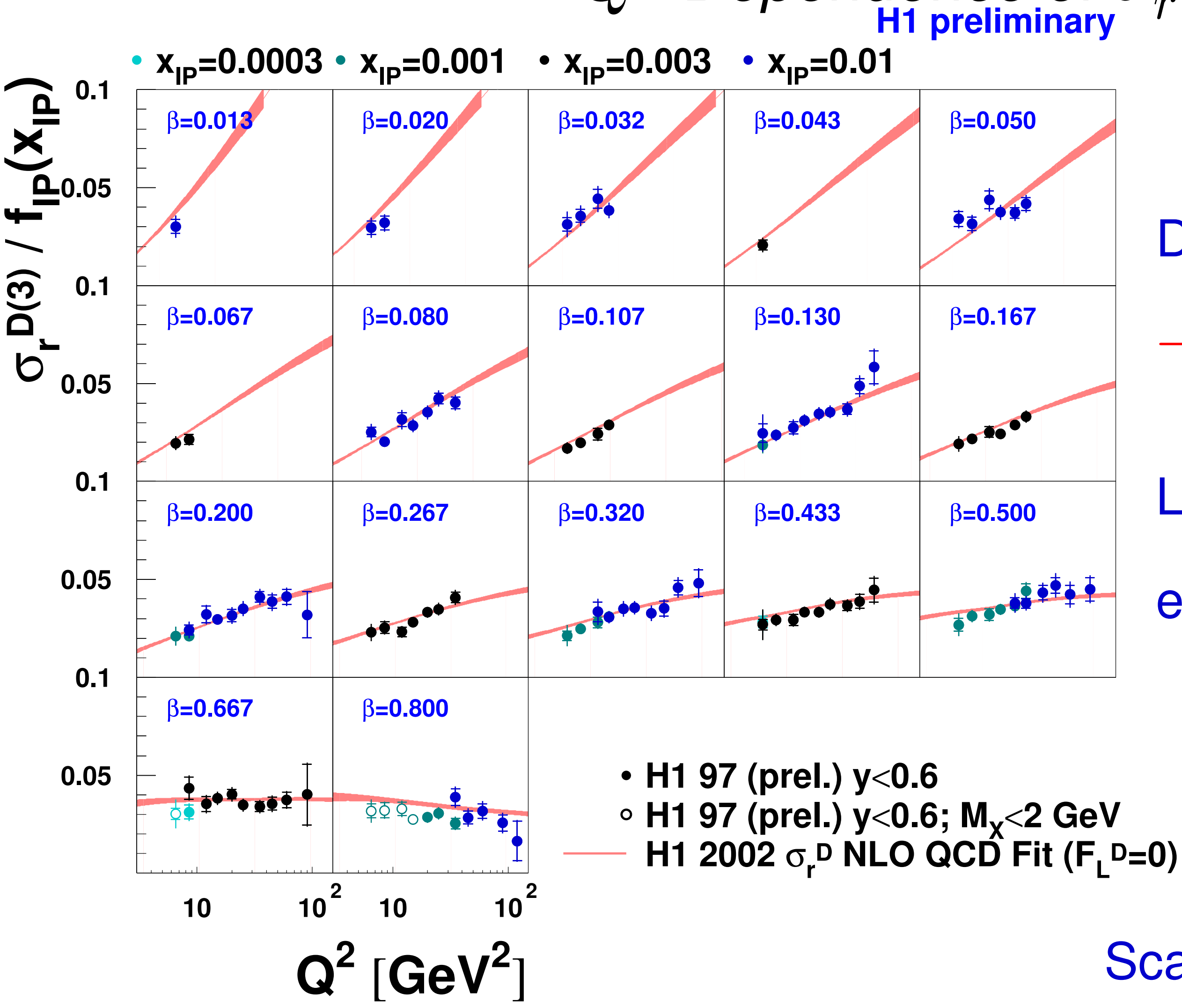
For $x_{IP} < 10^{-2}$ data inconclusive

Possible increase with Q^2 ?

Limited by ignorance of F_L^D

Data inconclusive

Q^2 Dependence of $\sigma_r^{D(3)}$



At fixed x_{IP} and β

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

$\longrightarrow$ compare different x_{IP} bins

Large +ve Scaling violations

except at highest β

$\longrightarrow$ gluon dominated

Scaling violations similar at

all values of x_{IP}

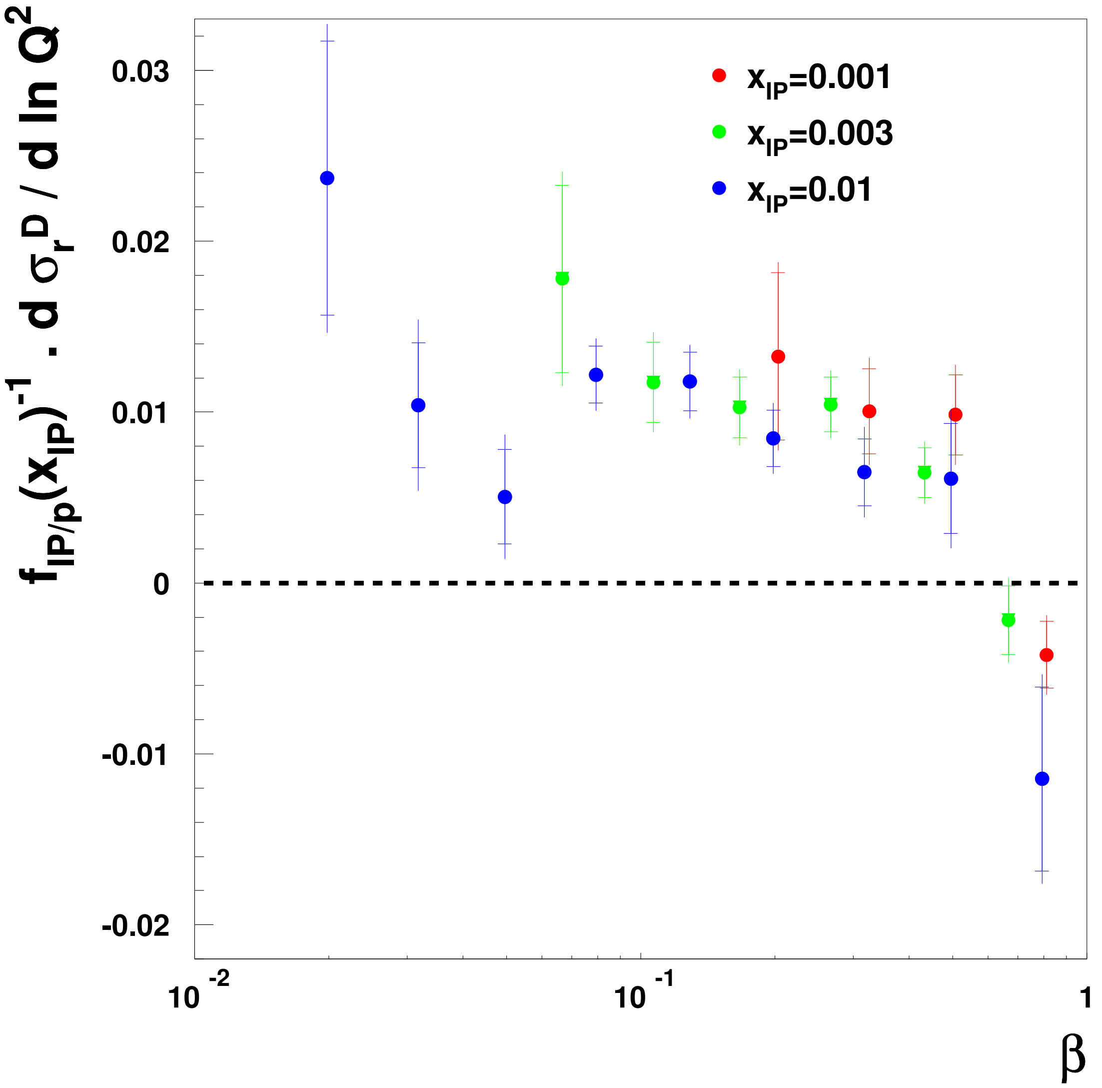
QCD fit describes the data

Details to follow

$\longrightarrow$ Support for Regge factorisation

Logarithmic Q^2 derivative of $\sigma_r^{D(3)}$

H1 Preliminary



Quantify Scaling violations ...

At fixed x_{IP} and β

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

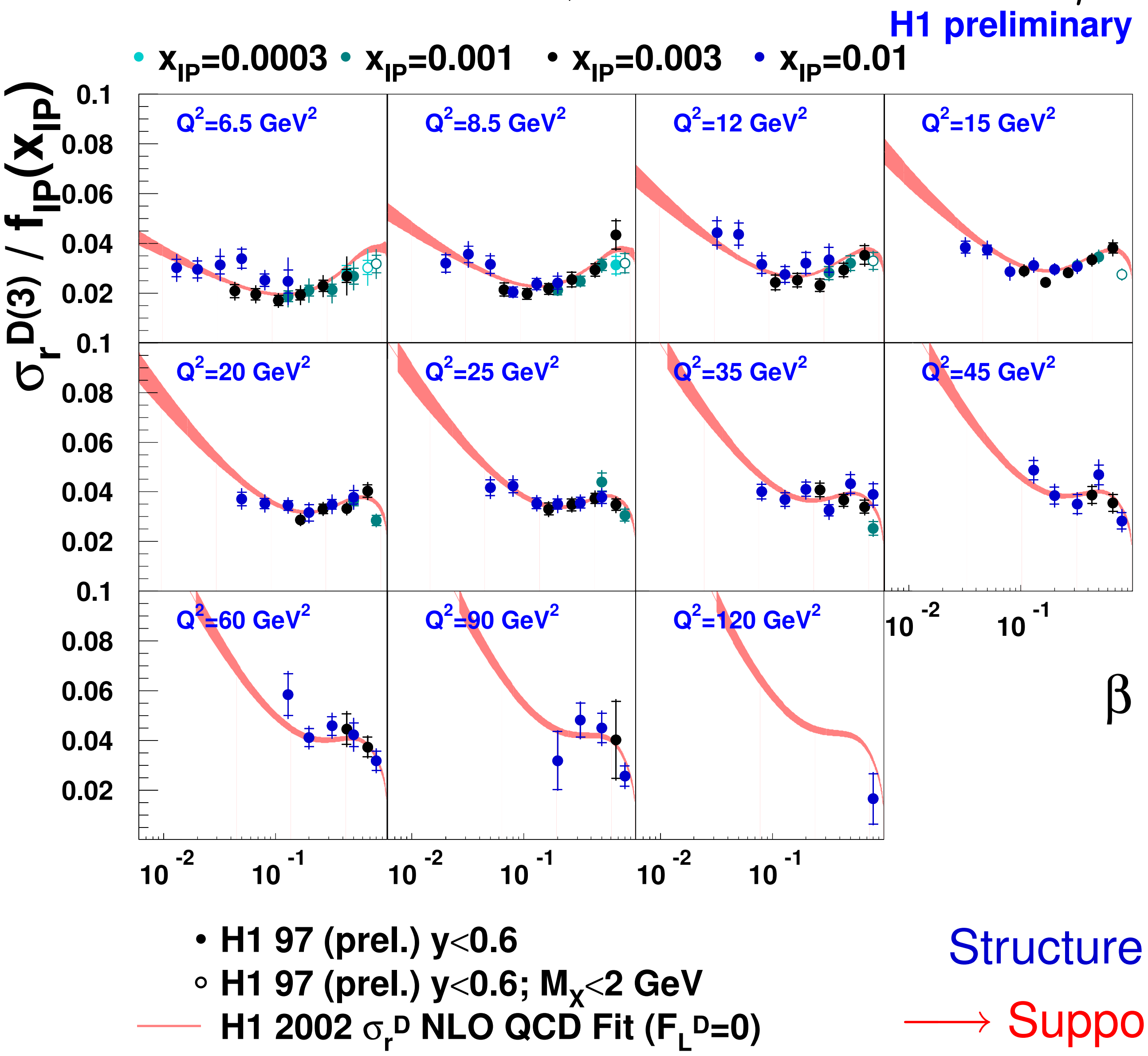
$\longrightarrow B = \frac{d}{d \ln Q^2}(\sigma_r^D)$

Large +ve Scaling violations

Flat at $\beta \simeq 0.6$

$\longrightarrow$ gluon dominated

β Dependence of $\sigma_r^{D(3)}$



At fixed x_{IP} and Q^2

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

compare different x_{IP} bins

$\longrightarrow$ See full β structure

Structure similar at all values of x_{IP}

$\longrightarrow$ Support for Regge factorisation

New NLO DGLAP Fit $\longrightarrow$ PDF's

QCD Fit technique :

Fit medium Q^2 data

Singlet Σ and gluon g

components with $Q_0^2 = 3\ \mathrm{GeV}^2$

x_{IP} / Regge factorisation

Include sub-leading trajectory

NLO DGLAP evolution

Full propagation of errors

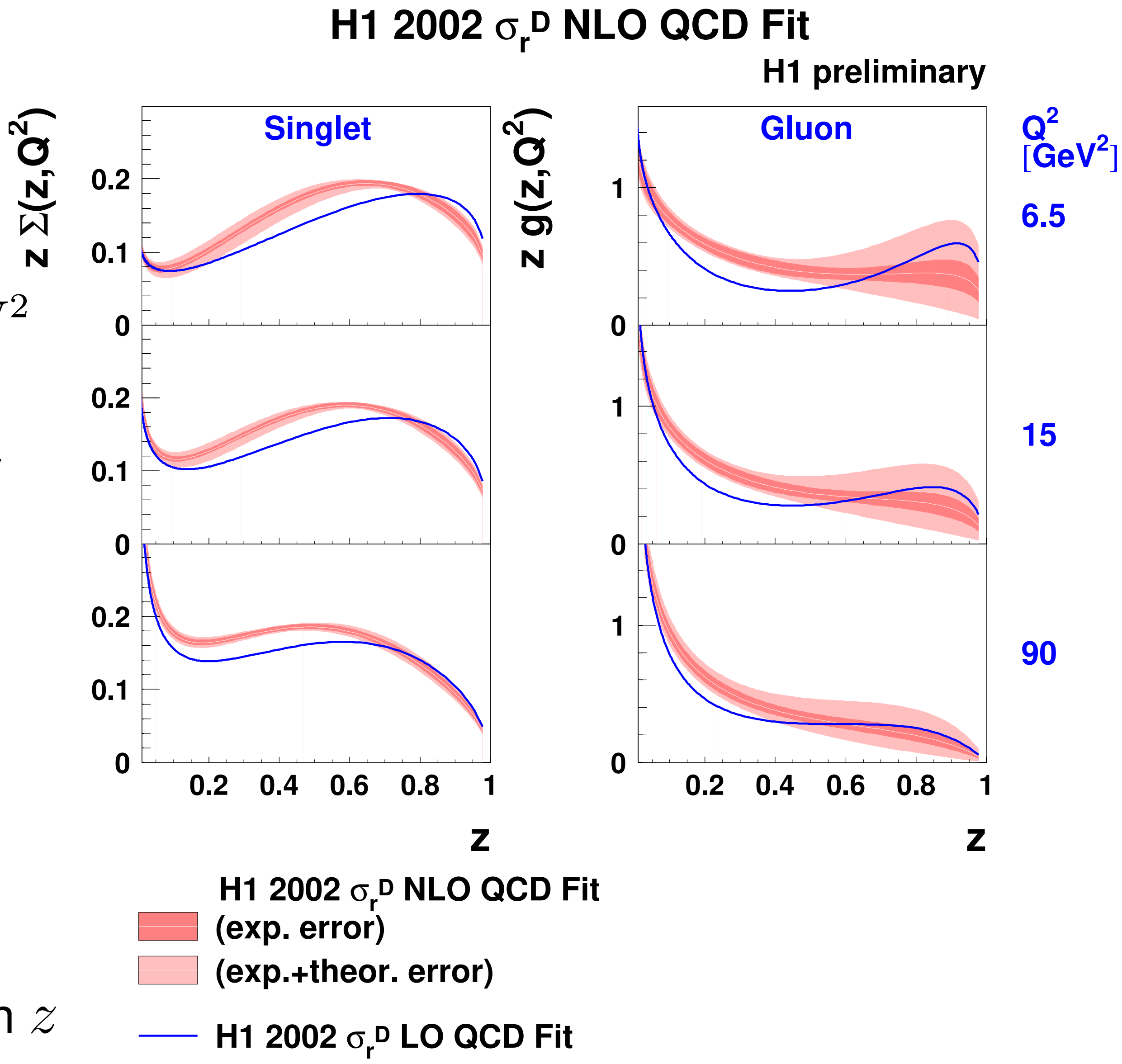
PDF's of diffraction :

Gluon dominated

Extend to large z

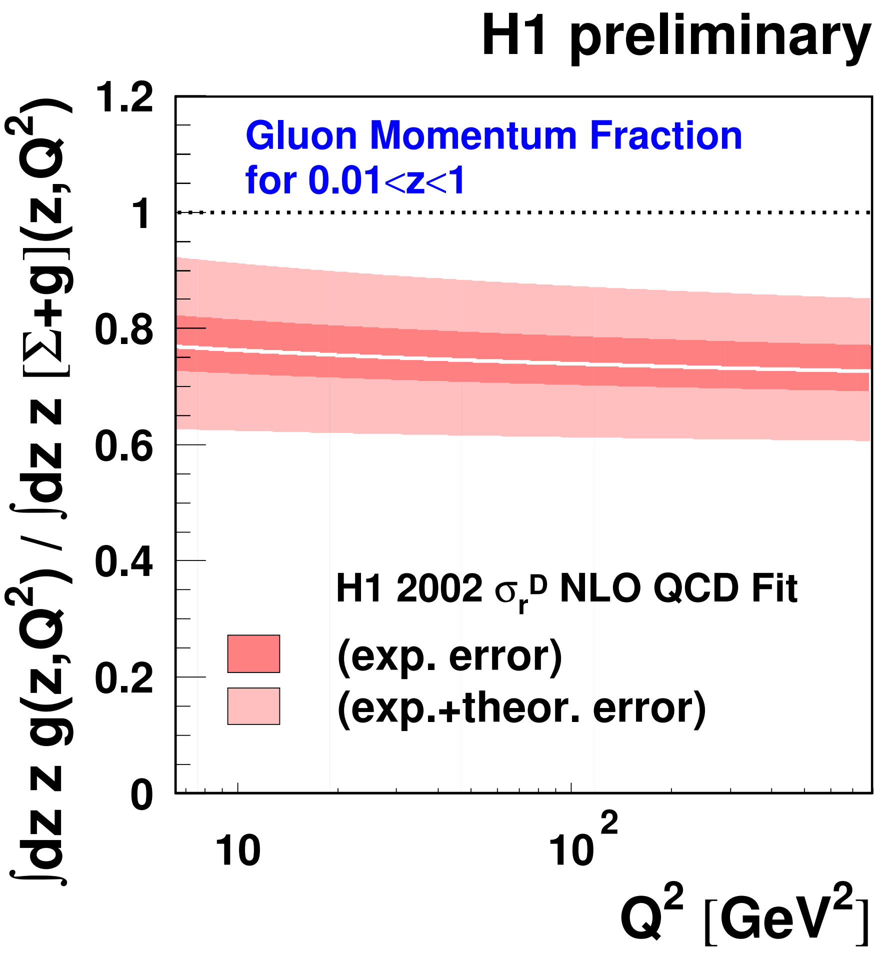
Σ well constrained

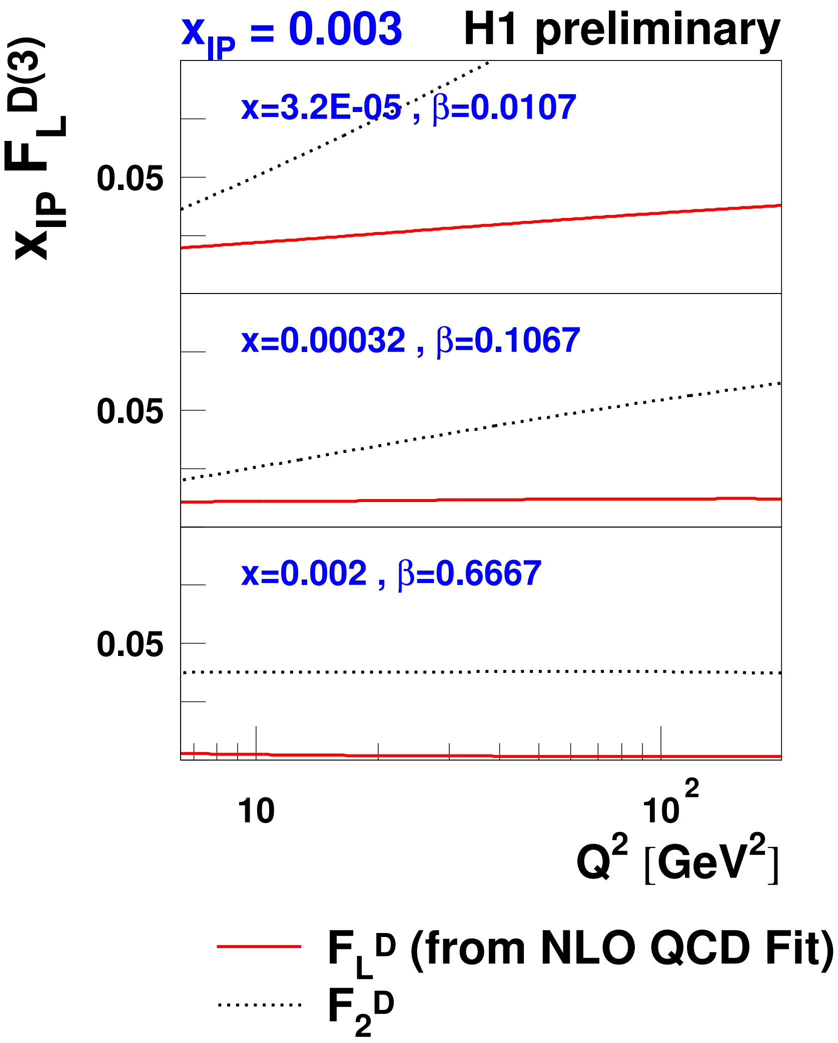
Large uncertainty on g at high z



$\longrightarrow$ Final State Comparisons See Talk of Tinne Anthonis

The gluon momentum fraction and F_L





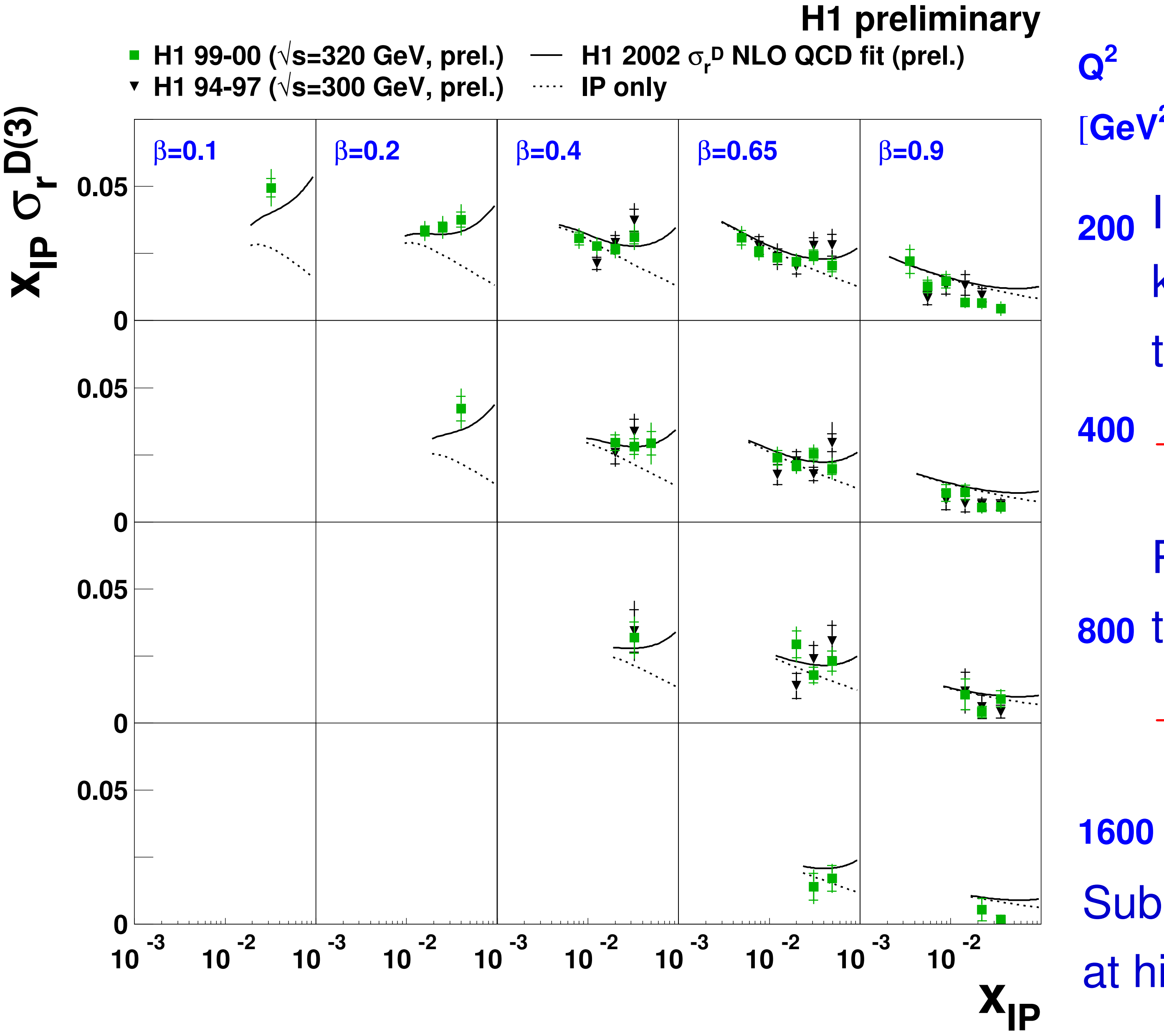
Momentum fraction of diffractive exchange carried by gluons

$\rightarrow 75 \pm 15\%$

F_L^D predicted at leading twist

$\rightarrow$ F_L^D is large at low Q^2 and low β

New Measurement at High Q^2



Improved statistics and kinematic range compared to previous measurement

$\longrightarrow$ Good agreement

Prediction of NLO Fit to medium Q^2 data

$\longrightarrow$ Good agreement

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

β Dependence at Low x_{IP}

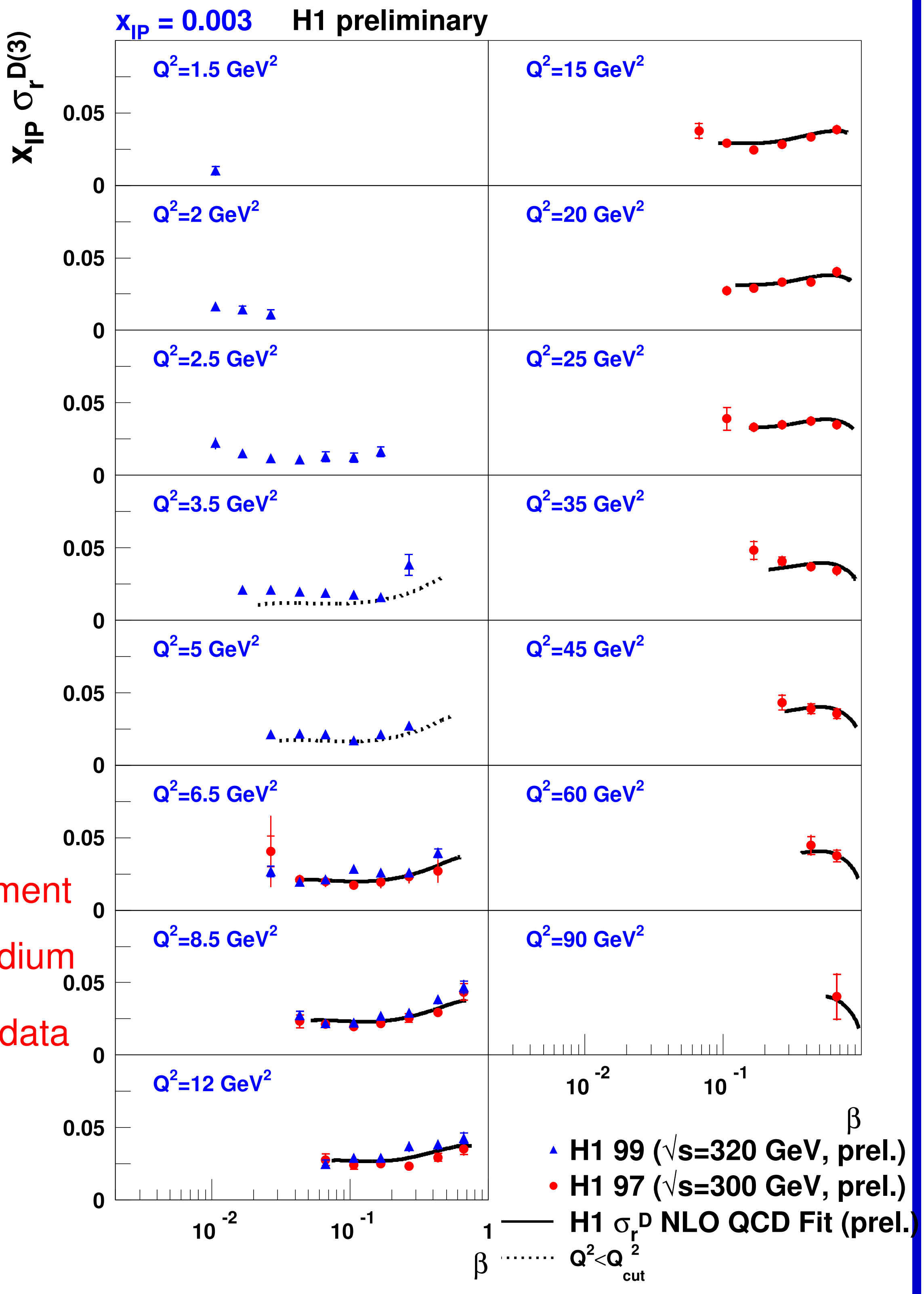
New data at

low $Q^2 \longrightarrow$

Good agreement

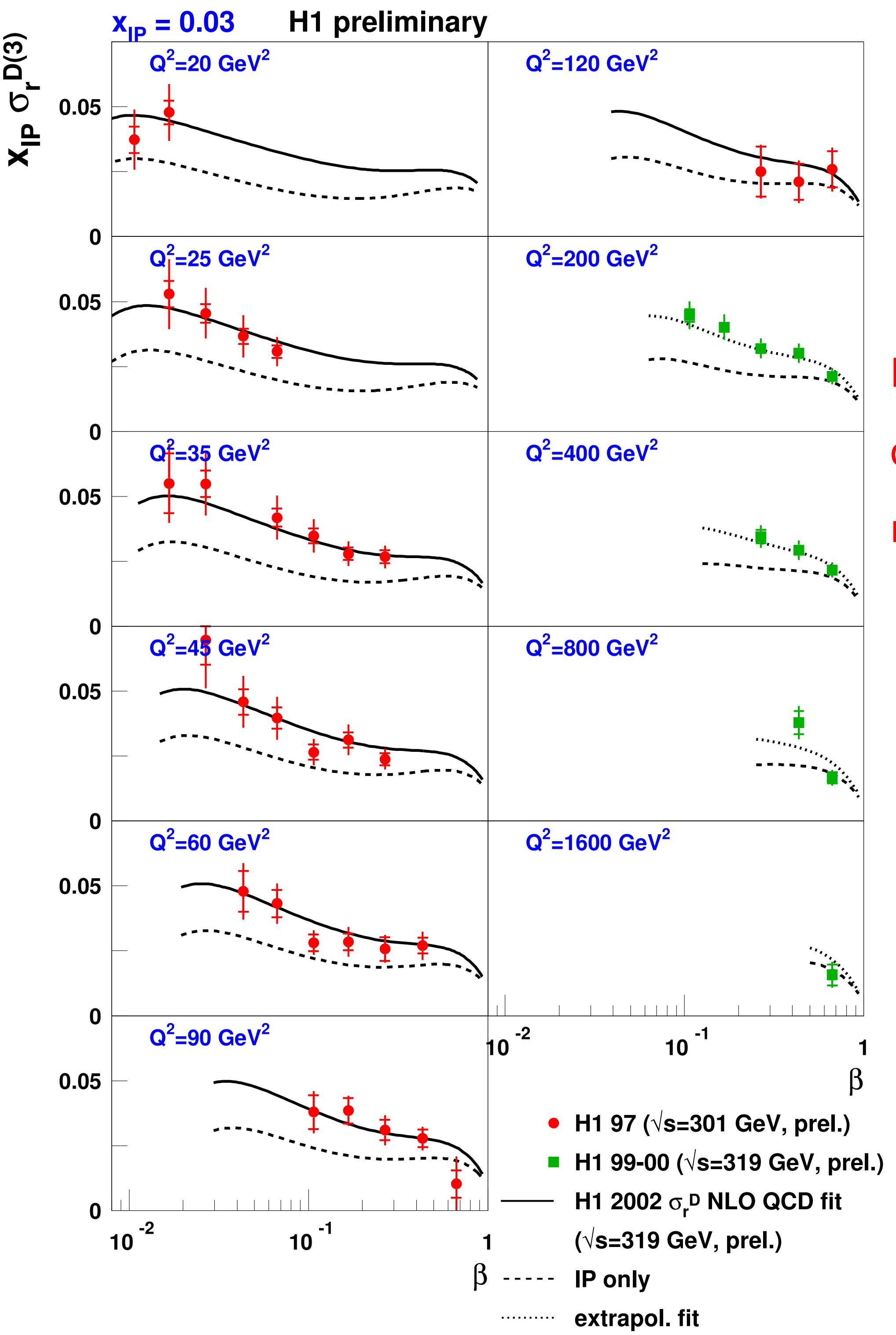
between medium

and low Q^2 data



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

β Dependence at High x_{IP}

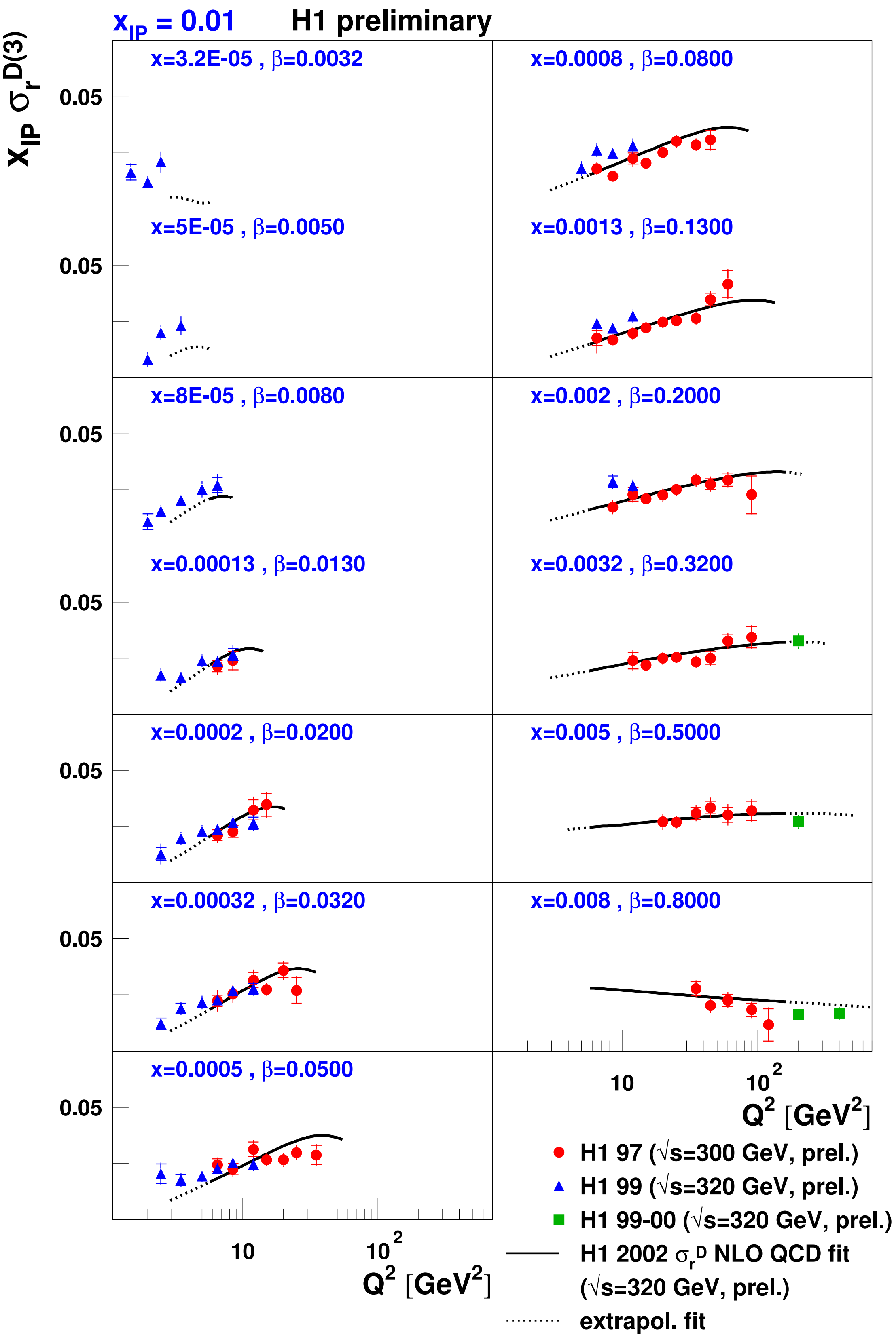


Negative slope due to influence of meson exchange

New data at $\leftarrow$ high Q^2

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

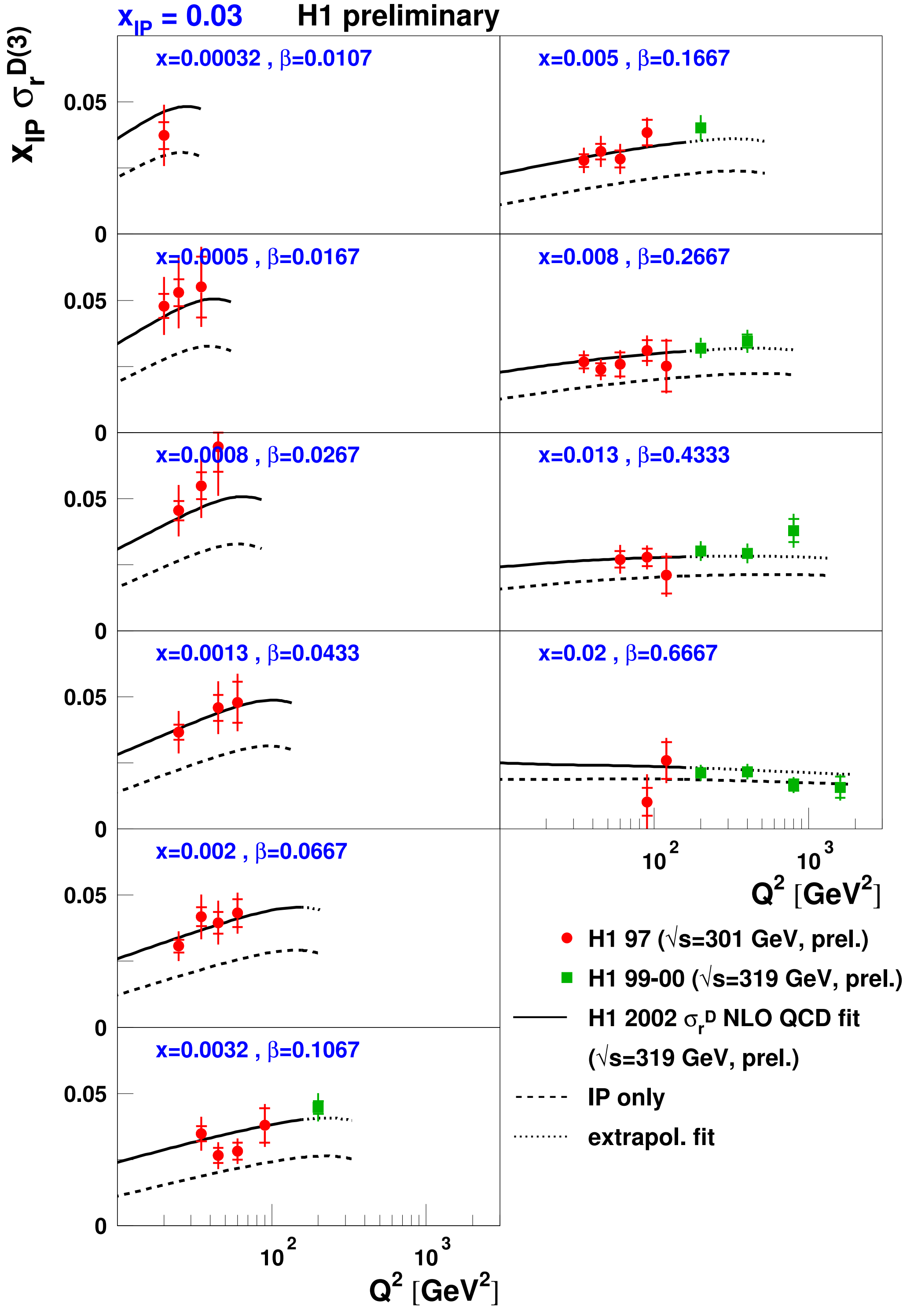
Q^2 Dependence at Low x_{IP}



Large positive scaling violations

$\longrightarrow$ Large gluon content

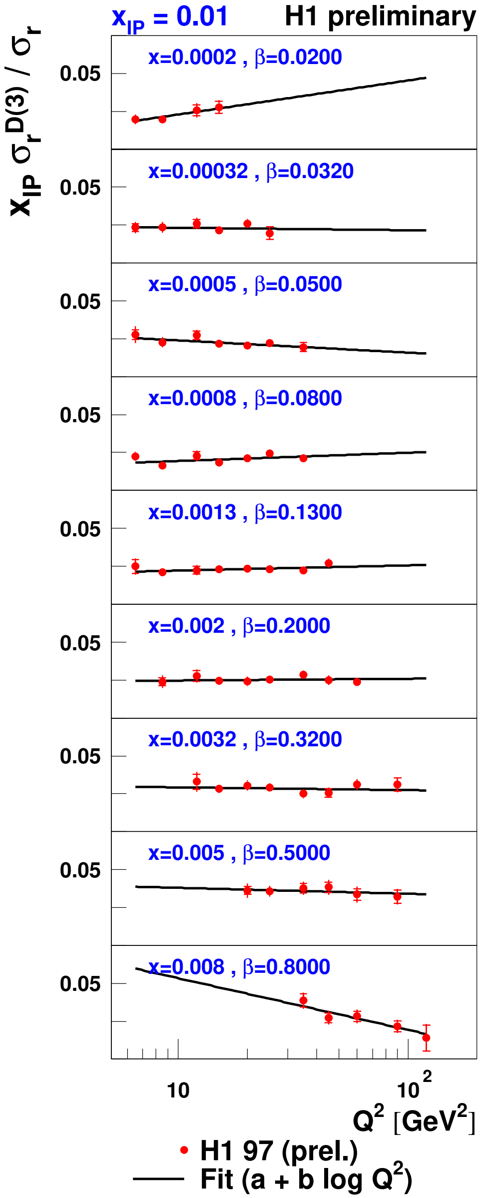
Q^2 *Dependence at High* x_{IP}

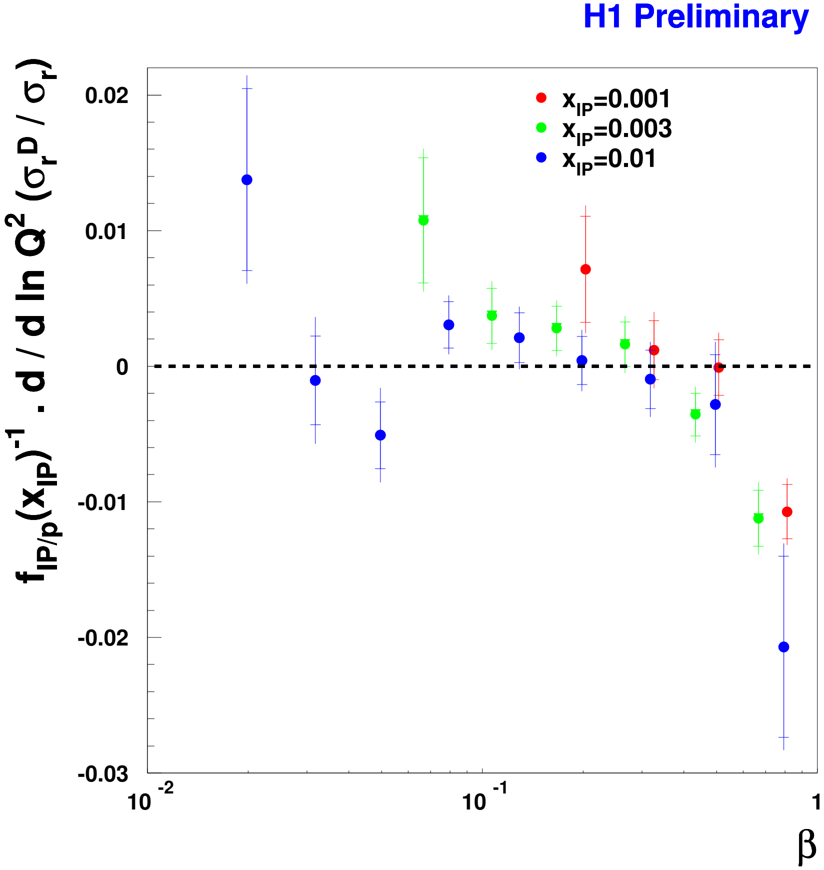


Extrapolation of the fit over an order of magnitude in Q^2

$\longrightarrow$ Good description of the data

Logarithmic Q^2 *derivative of ratio* $\frac{\sigma_r^{D(3)}}{\sigma_r}$





Fit $R = A + B \ln Q^2$

Divided by $f_{IP/p}(x_{IP})$

$\longrightarrow$ No remaining

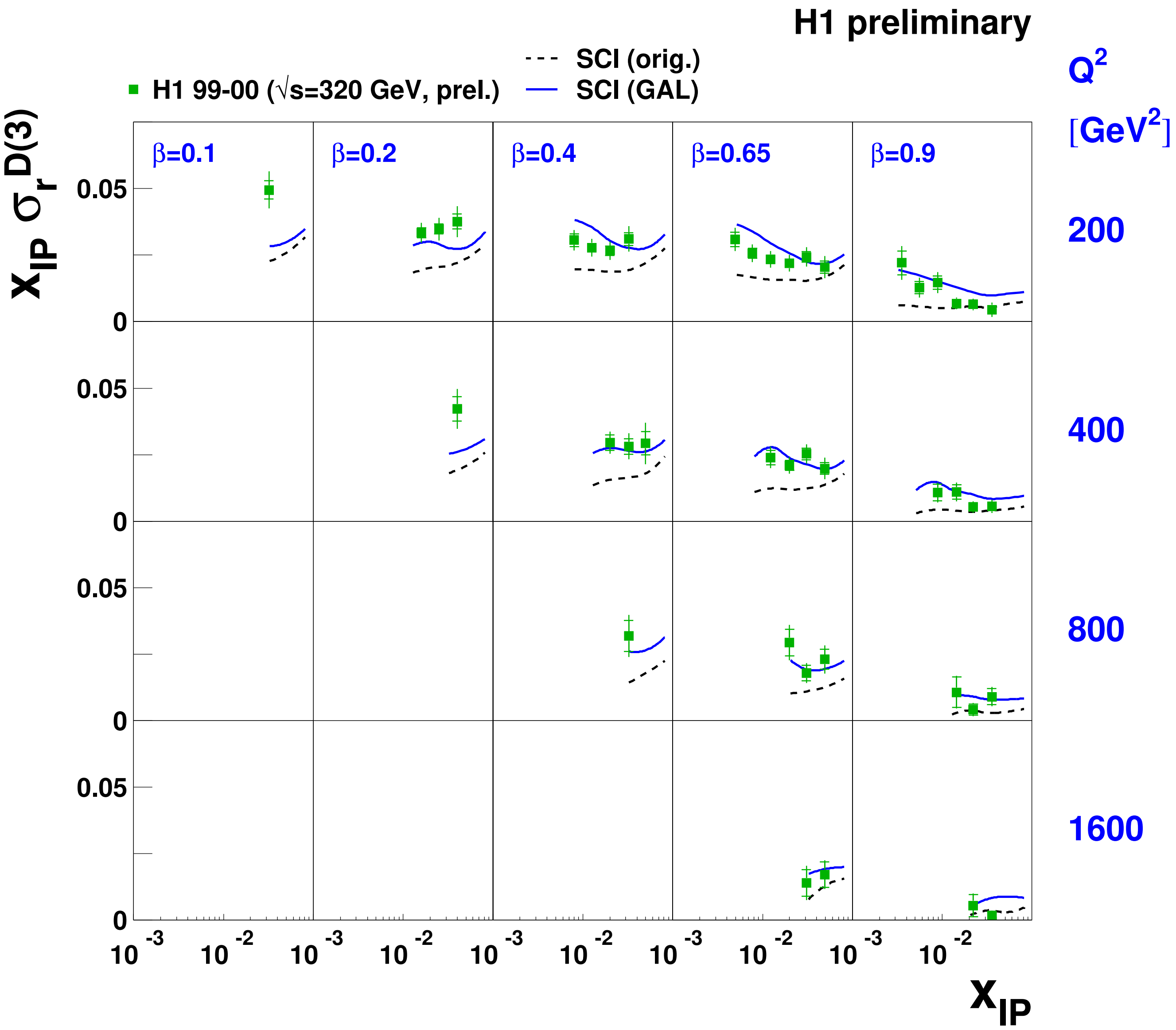
x_{IP} dependence

Look at ratio in the DIS regime

$\frac{\sigma_r^D}{\sigma r} \sim$ flat vs Q^2 Except at highest β

Similar Q^2 dynamics ?

Comparison of SCI Model with the High Q^2 Data



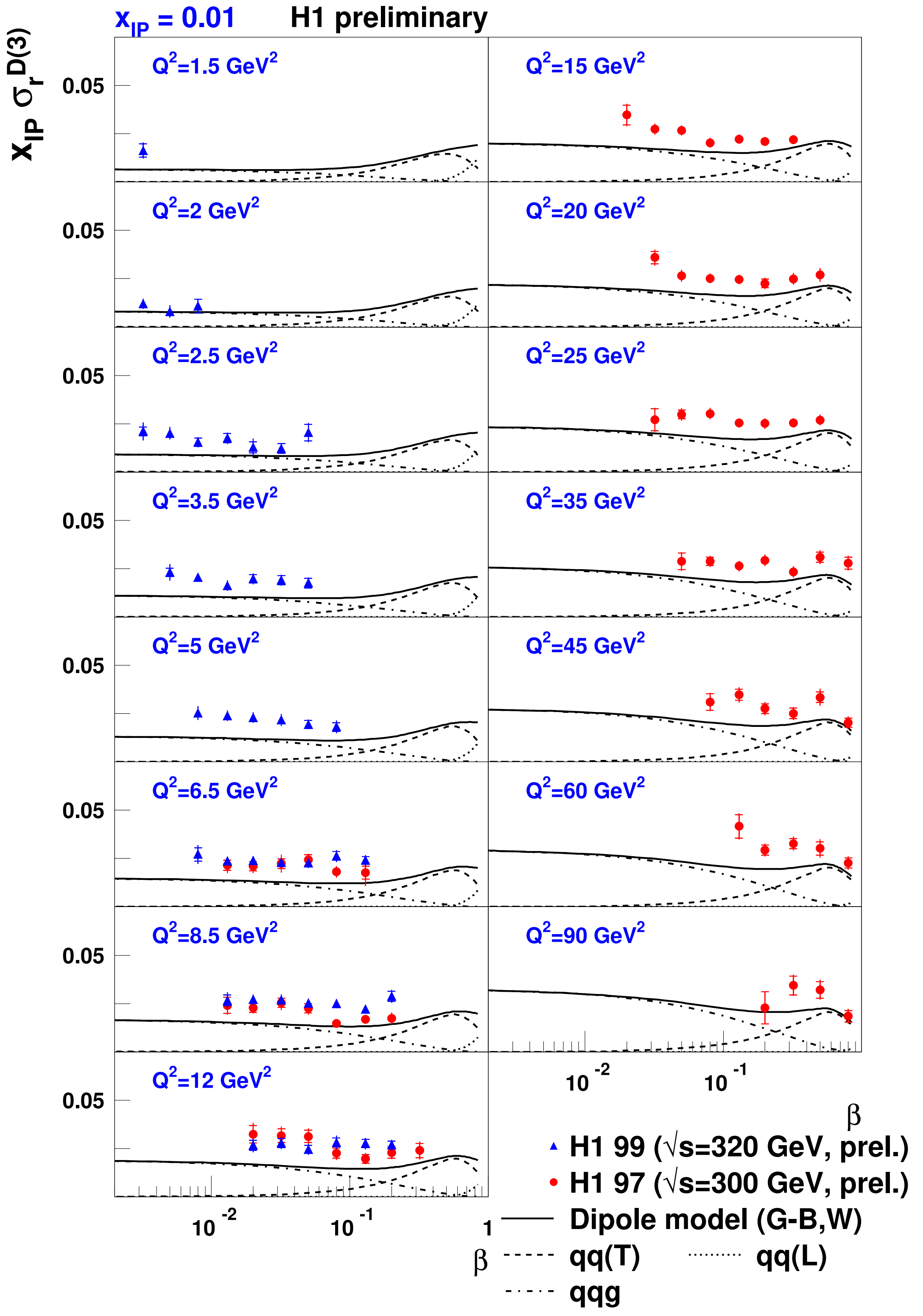
Constrained by lower Q^2 data

$\longrightarrow$ Good description

Model incorporating a Generalised Area Law better than original

Failing at low β ?

Comparison of the Saturation Model with the Low Q^2 Data



Model consistently undershoots the data

$\longrightarrow q\bar{q}g$ was better without 4/9 factor !

Summary

The Data describing the QCD Structure of Diffractive Interactions has reached high precision. QCD Hard Scattering Factorisation for Diffractive DIS is at the same level of theoretical prescription as for inclusive DIS

$\longrightarrow$ Precision measurements testing precision theory

- $\alpha_{IP}(0)$ **larger in DIS than in photoproduction and soft pomeron**
- **NLO QCD fit yields PDF's dominated by gluon**
- **Large gluon density persists out to very high** β
- **Suggestion of similar (x, Q^2) dynamics to inclusive DIS at medium** β
- **SCI model describes the high** Q^2 **data well except at low** β
- **Saturation model consistently undershoots the data at low** β
- **New measurements from H1 at low and high** Q^2

$\longrightarrow$ Further constraints for fits and models