H1 Results on Inclusive Diffraction

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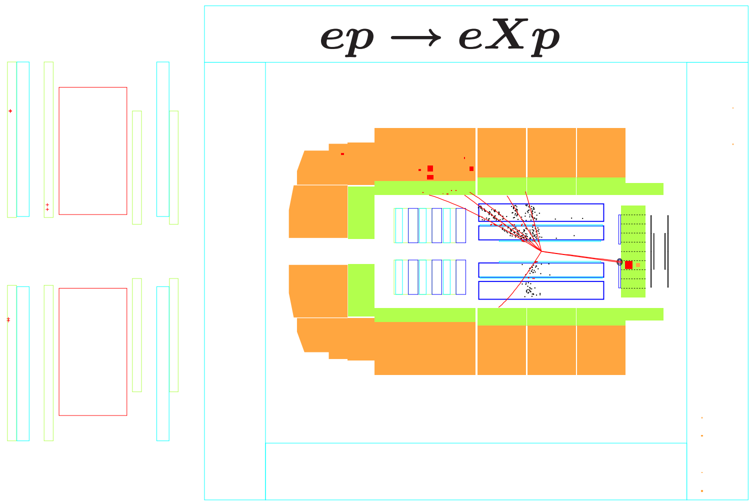
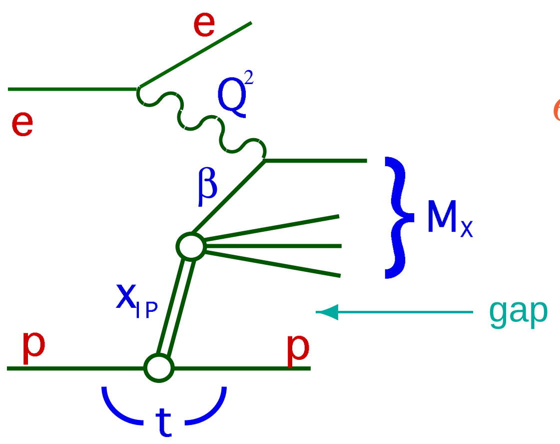
- New Datasets
- $x_{I\!P}$ and t dependences
- β and Q^2 dependences - QCD analysis
- Diffractive v Inclusive Data



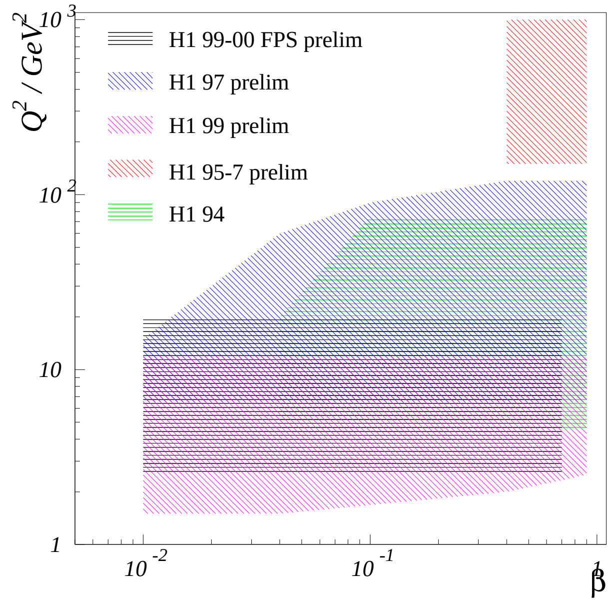
Diffractive Deep Inelastic Scattering



$ep \to eXp$

Several recent measurements:

- 99-00 FPS: $30\,\mathrm{pb}^{-1}$ p-tagged
- 97 rapgap: $11\,\mathrm{pb}^{-1}$ bulk phase space
- 99 rapgap: $3.5\,\mathrm{pb}^{-1}$ low Q^2 run



Typically $10 - 15\%$ uncertainties

Presented as diffractive reduced cross section

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

$$Y_+ = (1 - y + y^2/2)$$

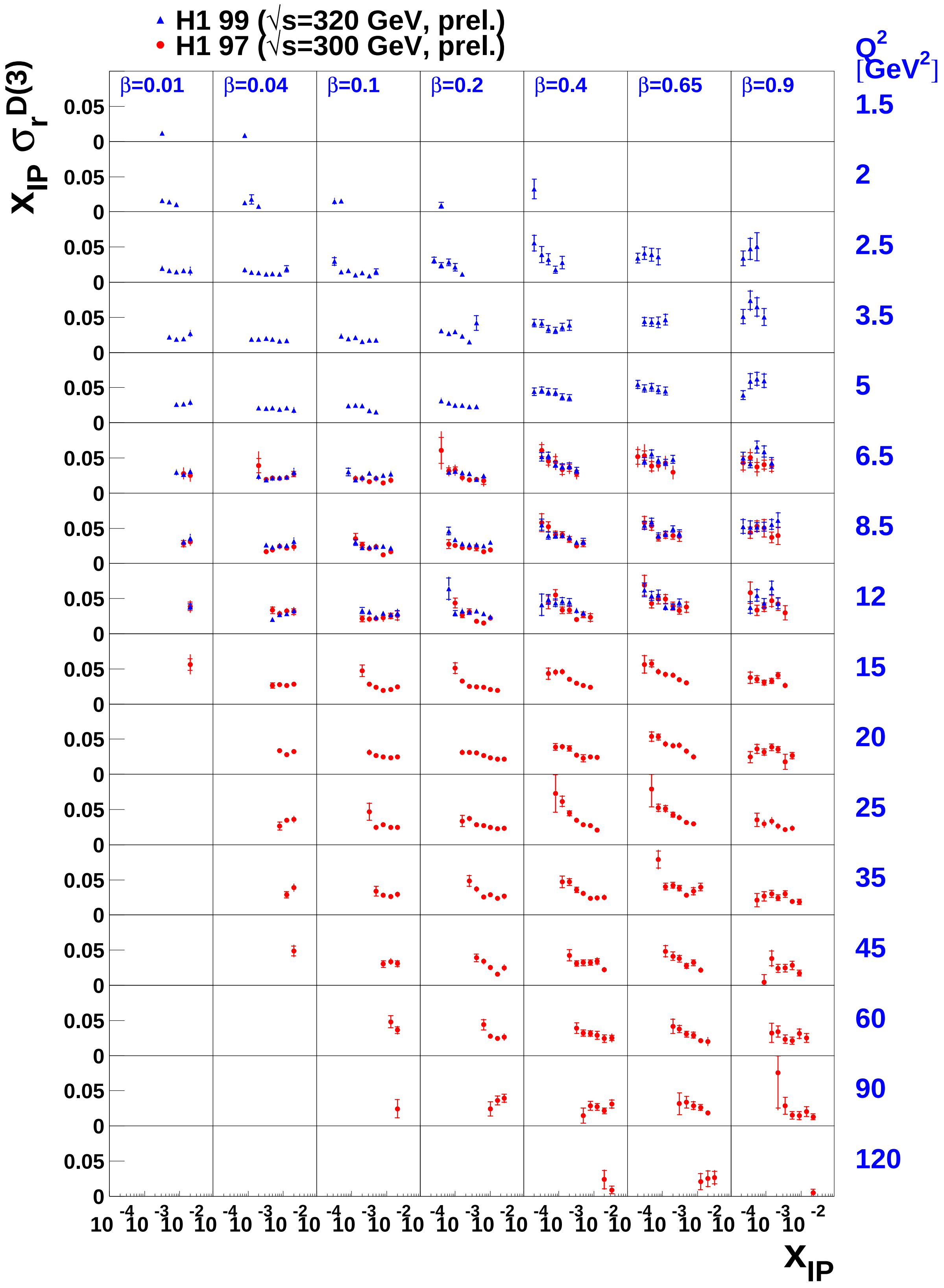
FPS (proton tagged) method:

Measure all 4 variables.

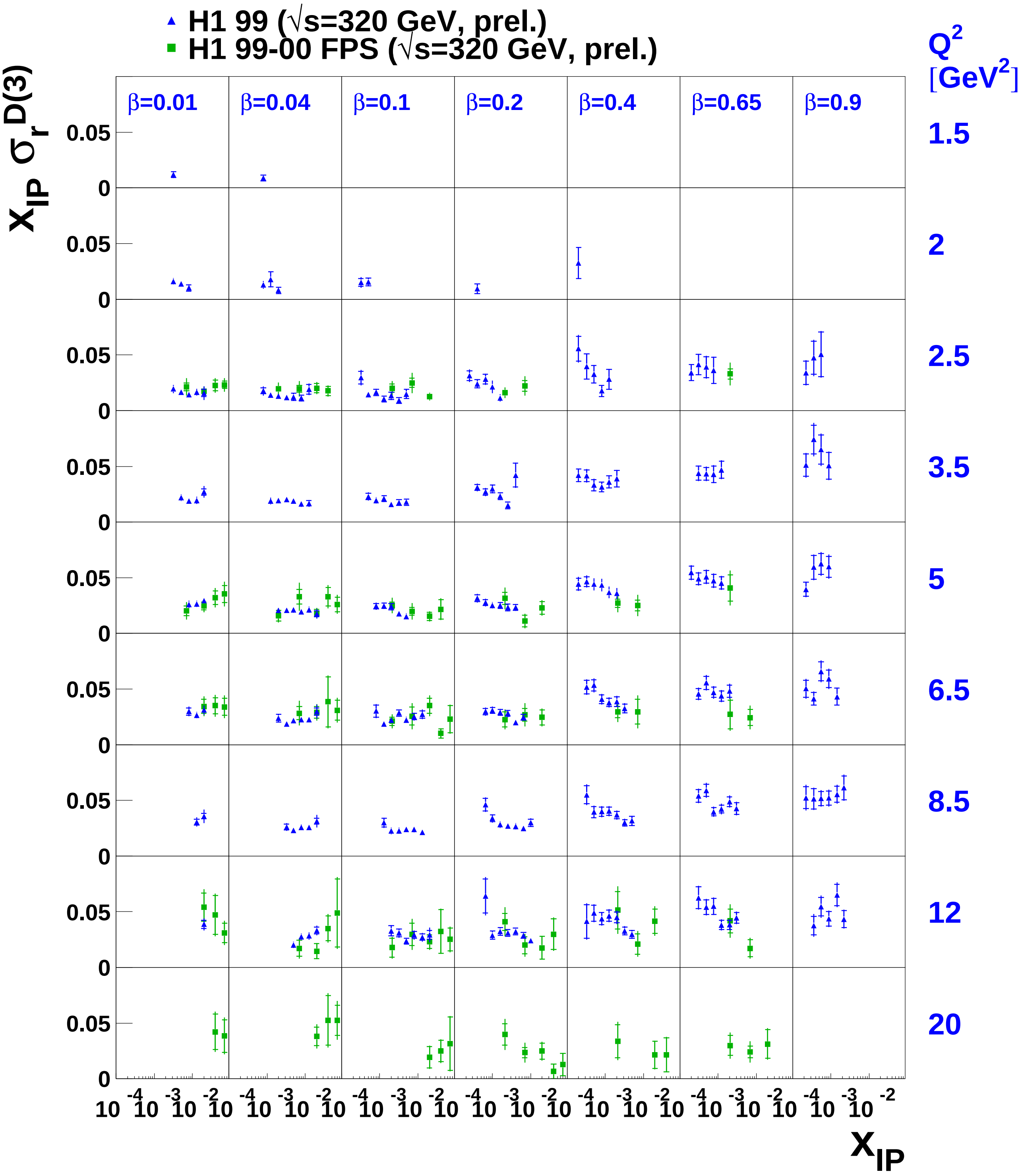
Rapidity gap method: $\to \sigma_r^{D(3)}(\beta, Q^2, x_{I\!P})$

Integrated over $|t| < 1\,\mathrm{GeV}^2$, $M_Y < 1.6\,\mathrm{GeV}$

New Data from Rapidity Gap Method



Comparison of Rapidity Gap with FPS Data



Rapgap data scaled $\times 0.9$ to correct $M_Y < 1.6\,\mathrm{GeV}$ to $Y = p$

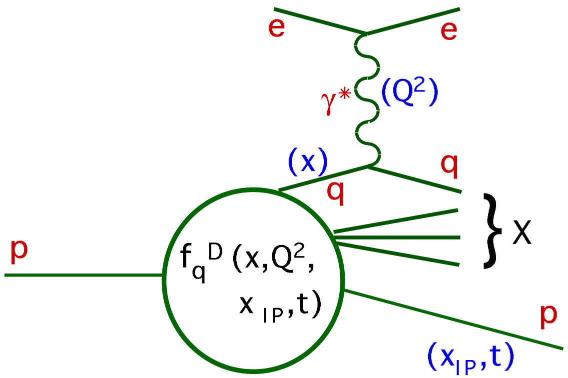
Factorisation Properties of F_2^D

QCD Hard Scattering Factorisation

$$\sigma_{\rm DIS}^{\rm Dif} \sim f_q^D(x_{I\!P}, t, x, Q^2) \otimes \hat{\sigma}_{\rm pQCD}$$

Diffractive parton densities $f_q^D(x_{I\!P}, t, x, Q^2)$ $\longrightarrow$ *conditional* proton parton probability distributions for particular $x_{I\!P}, t$.

DGLAP applicable for Q^2 evolution.

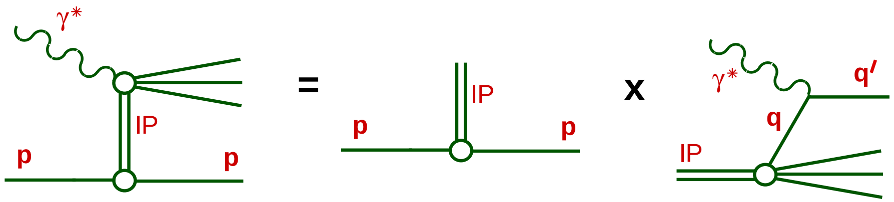


Rigorous for leading Q^2 dependence

Regge Factorisation

$$f_q^D(x_{I\!P}, t, x, Q^2) = f_{\rm I\!P/p}(x_{I\!P}, t) \cdot q_{\rm I\!P}(\beta, Q^2)$$

Diffractive parton densities factorise into "pomeron flux factor" and "pomeron parton densities"



$I\!P$ flux factor from Regge theory . . .

$$f_{\rm I\!P/p}(x_{I\!P}, t) \quad = \quad \frac{e^{Bt}}{x_{I\!P}^{2\alpha(t)-1}}$$ where . . .

$$\alpha(t) = \alpha(0) + \alpha' t$$

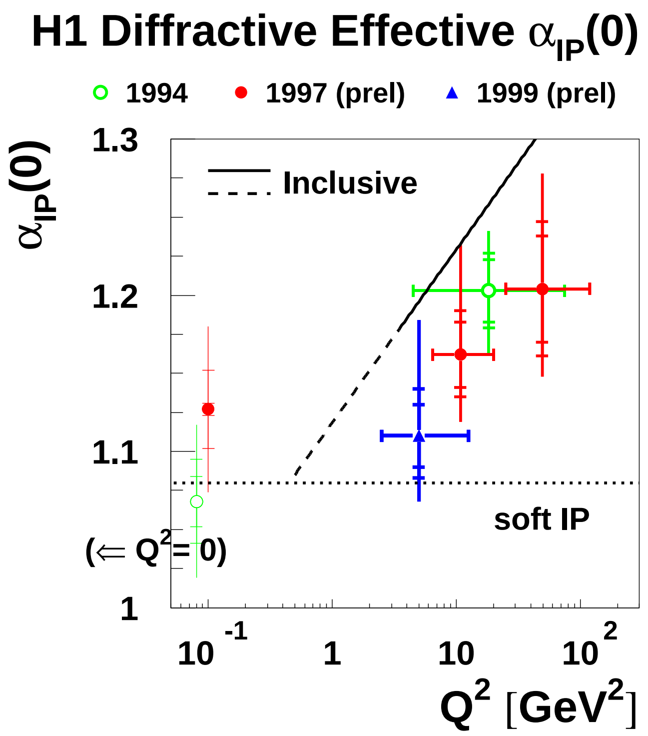
No firm basis in QCD

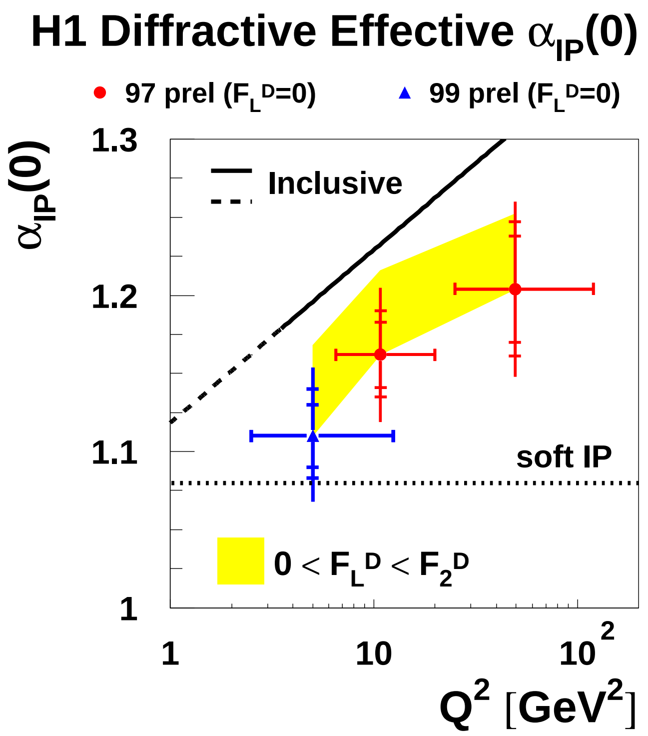
Regge Factorisation and Effective Pomeron Intercept

No evidence for breaking of Regge factorisation within any single dataset

Suggestion of Regge factorisation breaking when different datasets compared.

Firm conclusions difficult due to uncertainty from F_L^D

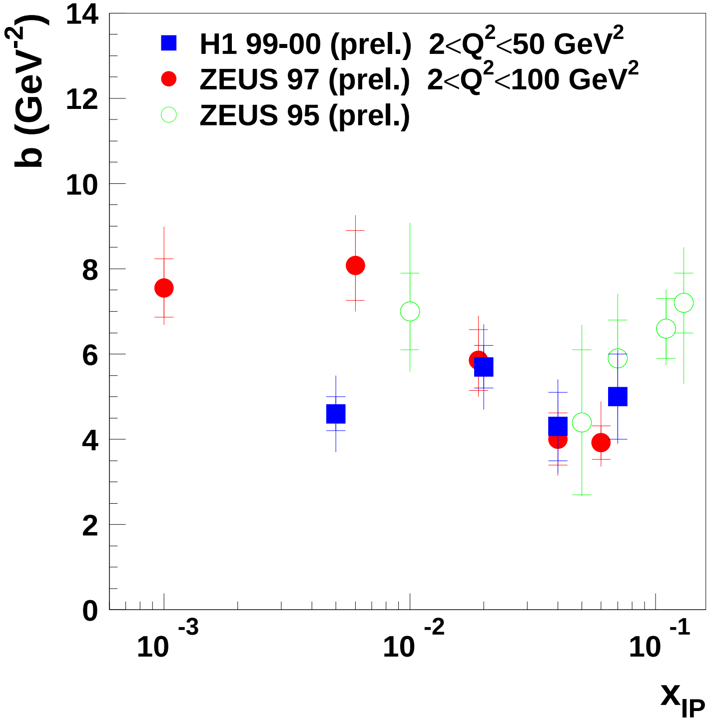




Different $\alpha_{\mathrm{IP}}(0)$ for inclusive and diffractive DIS?

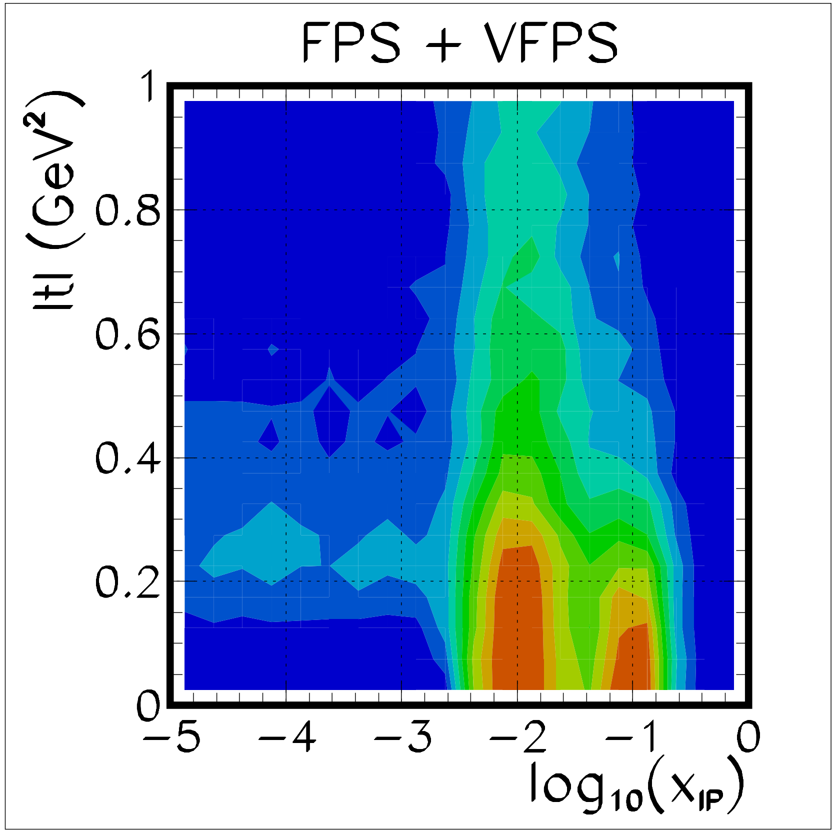
t Dependence from FPS data

Fits to $\frac{d\sigma}{dt} \propto e^{(b\,t)}$: Does b vary with $x_{I\!P}$?
Shrinkage expected for soft processes, but not hard $(b = b_0 + 2\alpha' \ln 1/x_{I\!P})$



Data so far inconclusive

Improved precision expected with new H1 VFPS / FPS at HERA-II



β Dependence of F_2^D (97 rapgap data)

Regge factorisation works $\rightarrow$

Can be used to parameterise $x_{I\!P}$ dependence

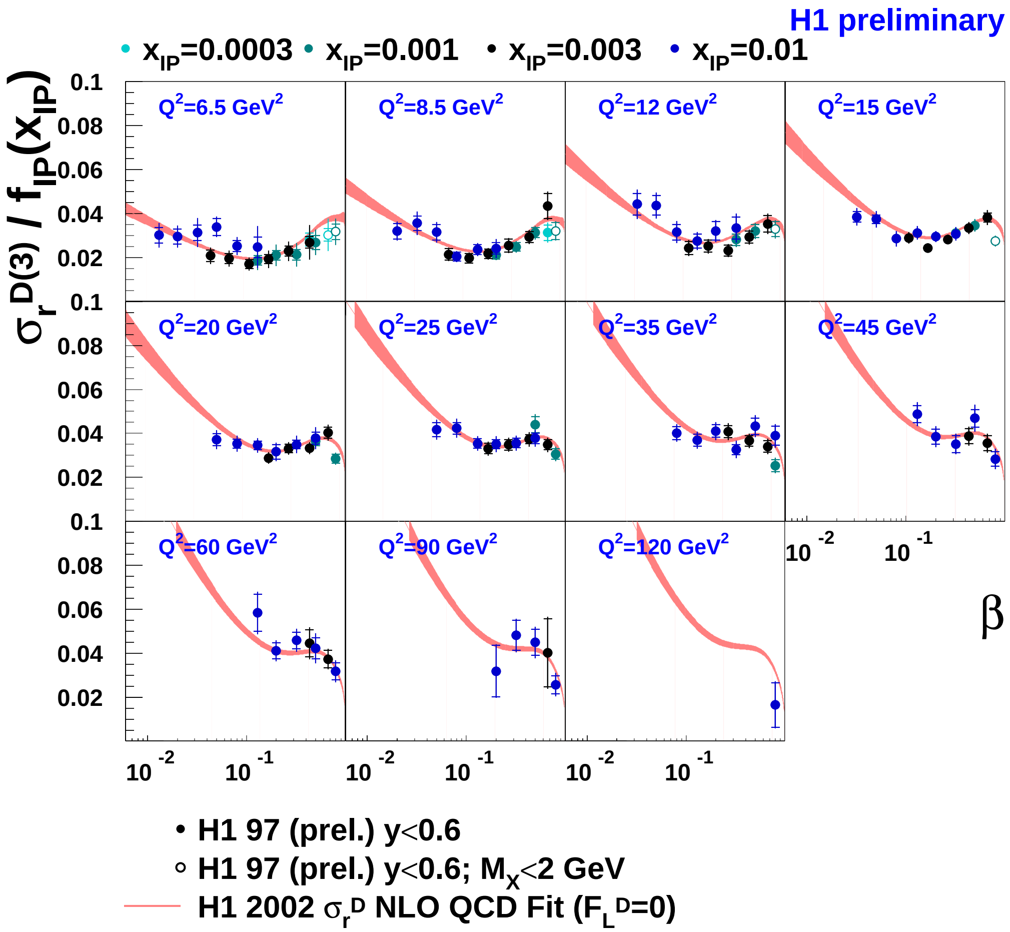
Study (β, Q^2) dependence combining different $x_{I\!P}$ after factoring out $x_{I\!P}$ dependence

$$f_{\mathrm{I\!P}/\mathrm{p}}(x_{I\!P}, t) = \frac{e^{Bt}}{x_{I\!P}^{2\alpha(t)-1}}$$

Take experimentally measured B, $\alpha(0)$

Use $\alpha' = 0.25\ \mathrm{GeV}^2$

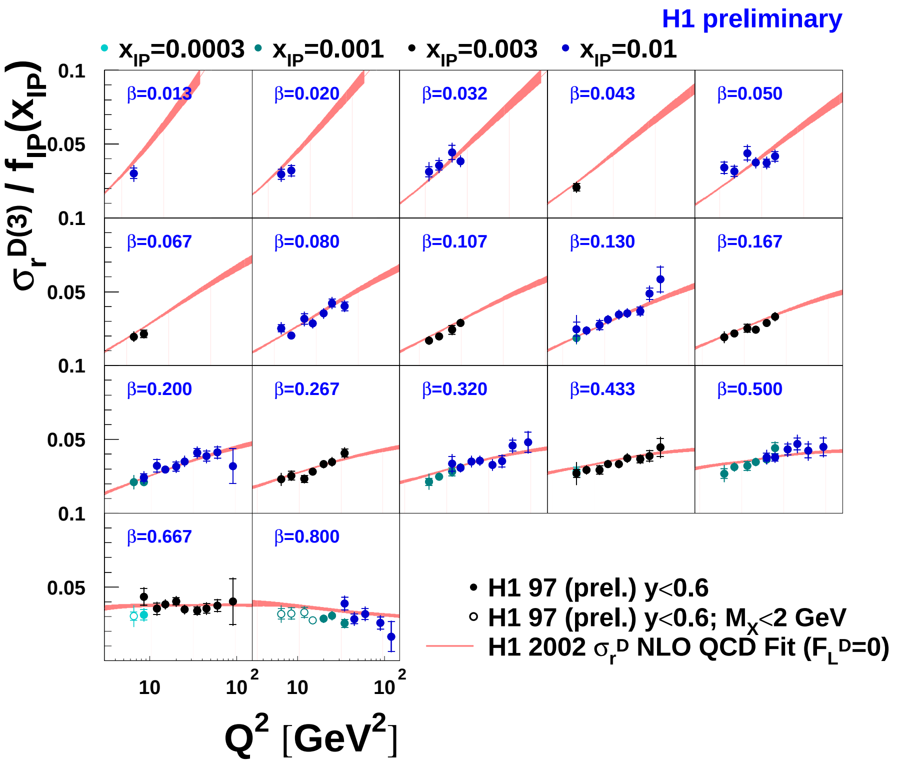
$$\sigma_r^D / f_{\mathrm{I\!P}/\mathrm{p}} \sim \sum_q e_q^2\, \beta\, q(\beta)$$

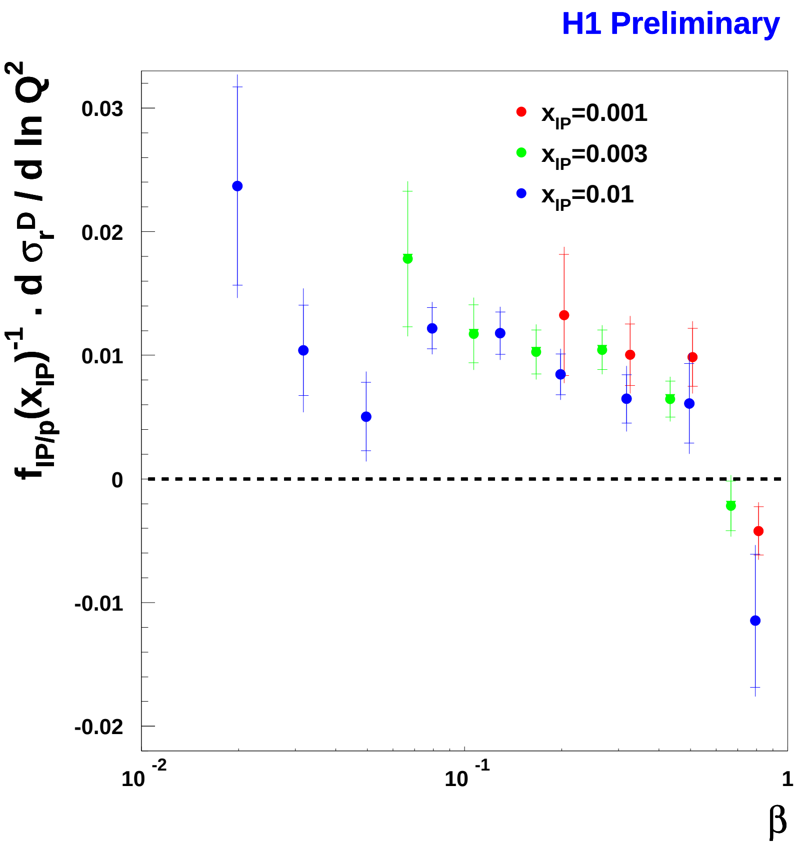


Measures quark density over wide β range.

Q^2 Dependence of F_2^D (97 rapgap data)

Q^2 dependence displays strong scaling violations with positive $\partial\sigma_r^D/\partial\ln Q^2$ up to high β





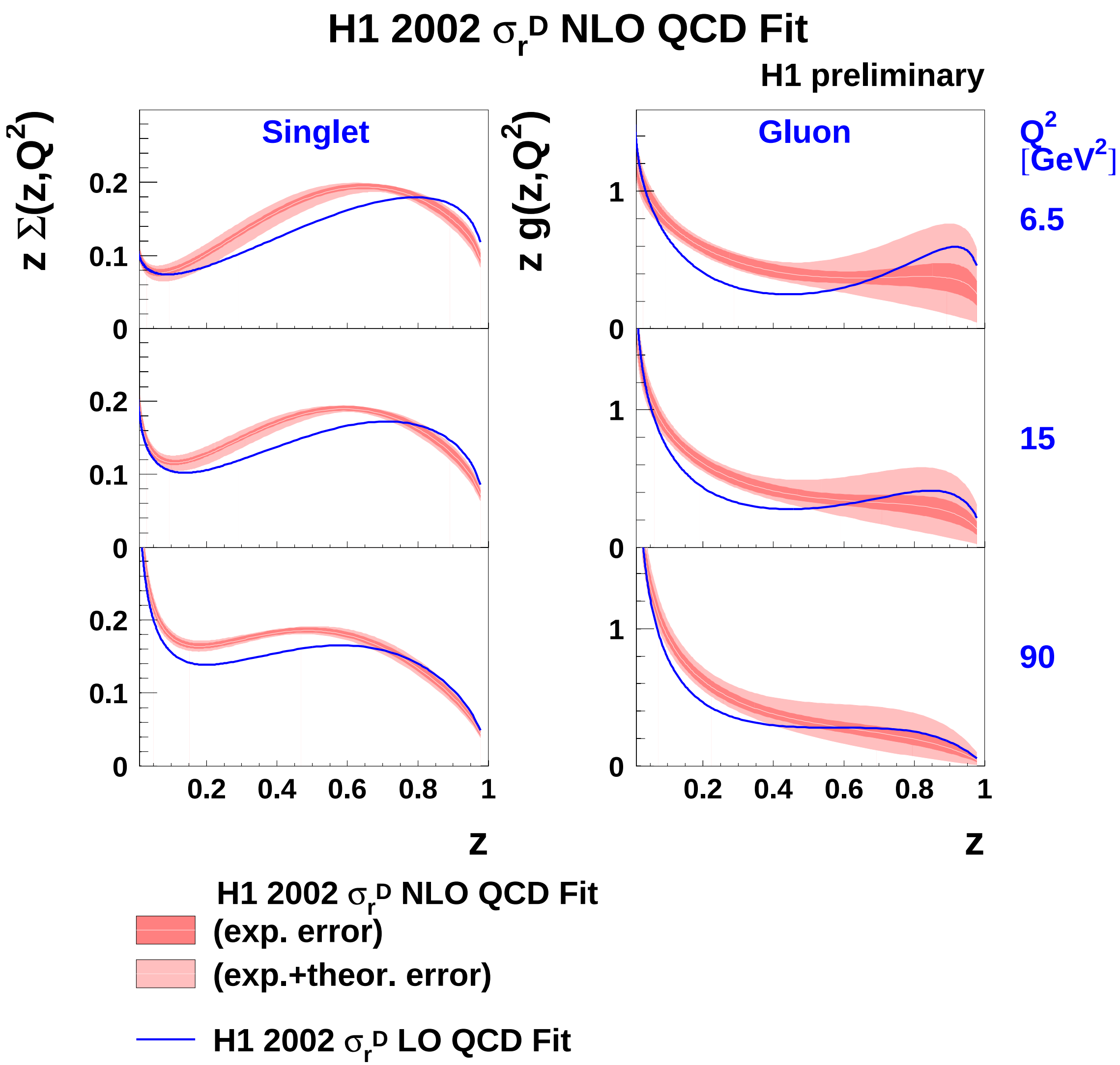
Log Q^2 derivative from fits at fixed $(\beta, x_{I\!P})$

$$\frac{\partial\sigma_r^D/\partial\ln Q^2}{f_{I\!P/p}} \sim xG(x) \otimes \alpha_s \otimes P_{qg}$$

NLO DGLAP QCD Fits (95-7 medium and high Q^2 rapgap data)

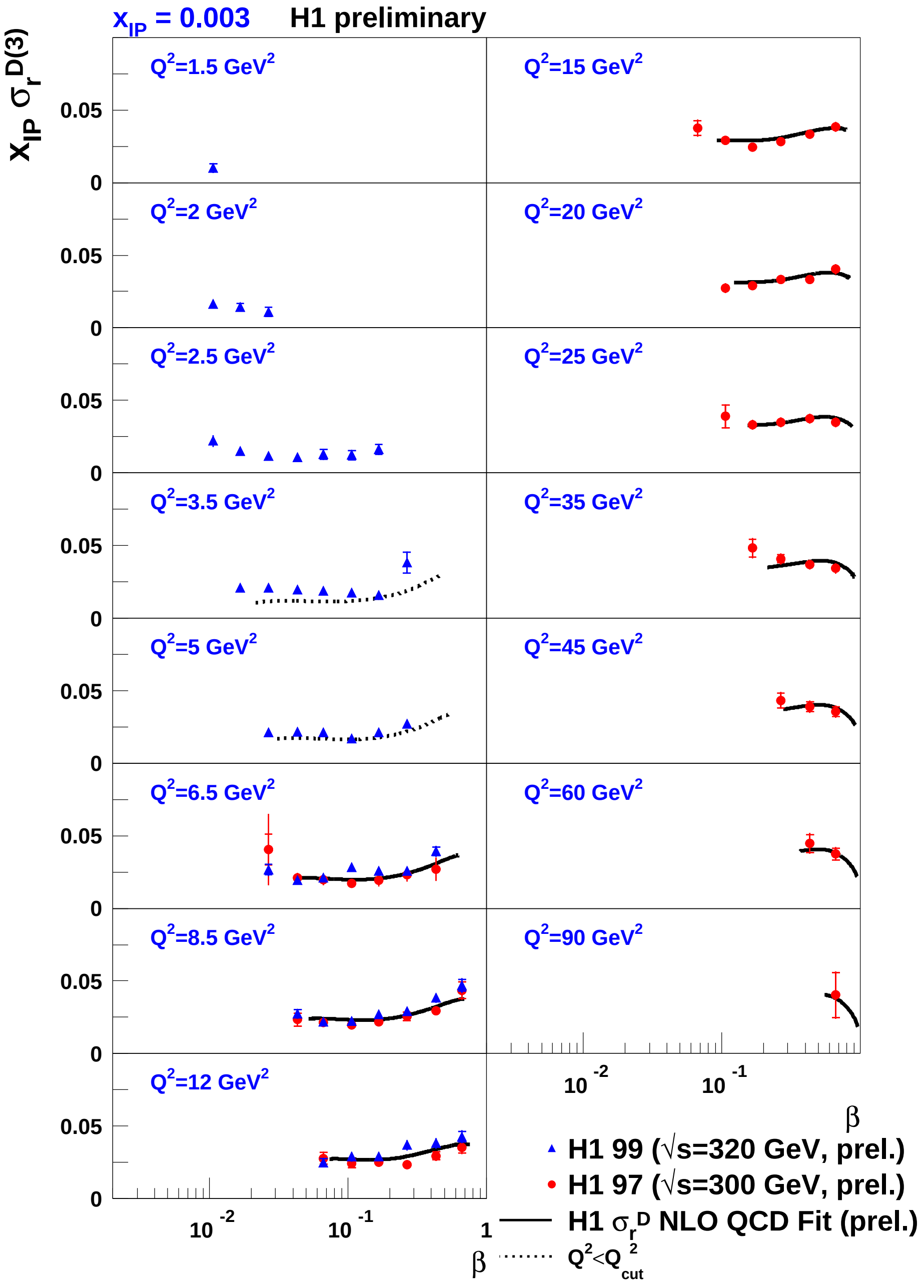
- Singlet quark Σ and gluon g parameterised at $Q_0^2 = 3\,\mathrm{GeV}^2$
- DGLAP evolution to fit to $Q^2 \geq Q^2_{min} = 6.5\,\mathrm{GeV}^2$
- Exclude $M_X < 2\,\mathrm{GeV}$ (HT / F_L^D)
- Regge factorisation assumed
- Full propagation of experimental and theoretical uncertainties

- Similar to previous fits
- High β gluon poorly constrained
- Integrated gluon fraction $75 \pm 15\%$
- See talk of Sebastian Schaetzel for final state comparisons



Comparison of Fit with low Q^2 Data

Example data at $x_{I\!P} = 0.003$



Breakdown at or below $Q^2 = 3.5\ \mathrm{GeV}^2$

Improved fit with lower Q^2_{min} possible using both datasets

What is Q^2 limit of validity of DGLAP? c.f. Inclusive?

Relationsip between Diffractive and Inclusive DIS

Diffractive pdfs → Diffractive exchange is gluon dominated (as is proton at low x)

Effective $\alpha_{I\!P}(0)$ → Energy dependences of diffractive and inclusive DIS not related as expected in Regge models or naively from 1 / 2 gluon exchange

Direct study of Diffractive / Inclusive ratio leads to interesting observations . . .

. . . but what should be kept fixed?

1) Fix $Q^2, M_X\ (\beta)$, vary $W\ (x)$

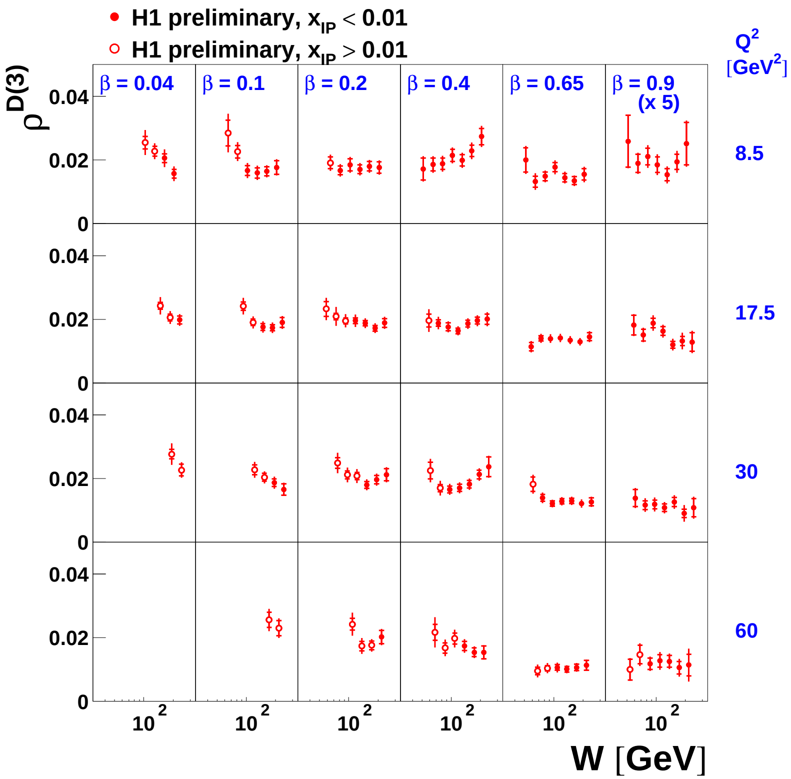
$x_{I\!P} = x/\beta$ changes

$$\rho^{D(3)} = M_X^2 \, \frac{\mathrm{d}\sigma(\gamma^* p \to X p)}{\mathrm{dM_X^2}} \, / \, \sigma_{\mathrm{tot}}(\gamma^* p \to X)$$

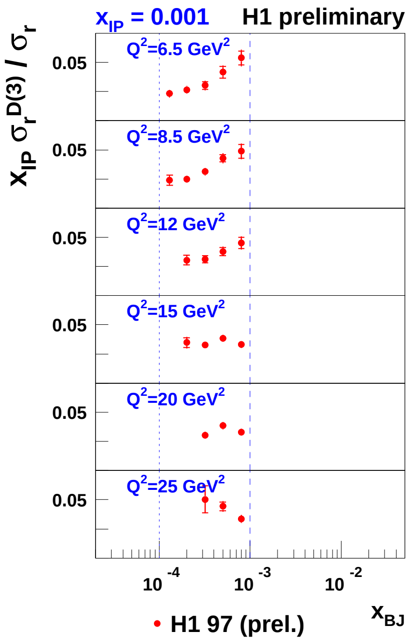
Ratio ∼ flat! (c.f. ZEUS 94)

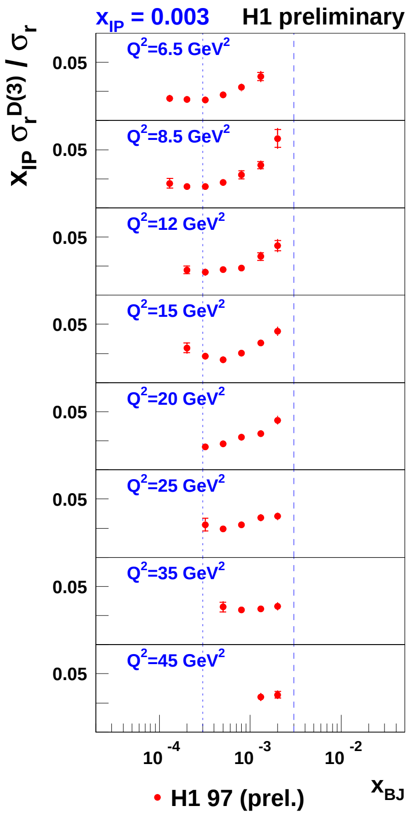
2) Fix $Q^2, x_{I\!P}$, vary $W\ (x)$

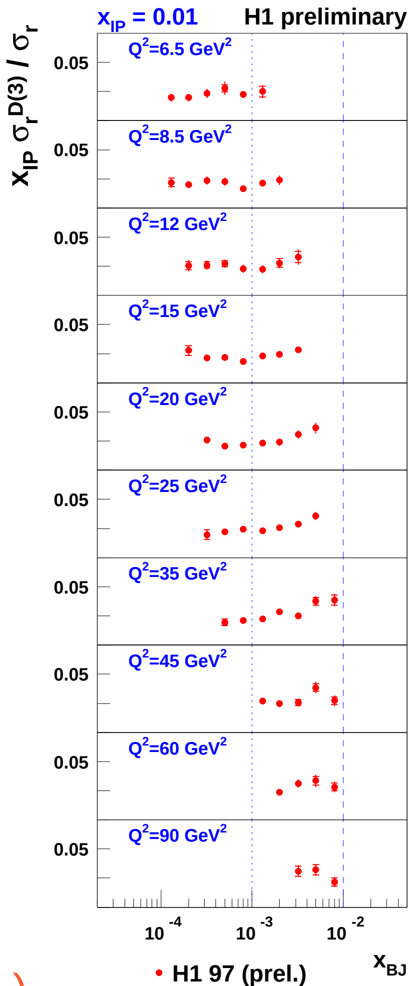
β and $M_X^2 = Q^2(x_{I\!P}/x - 1)$ change . . .

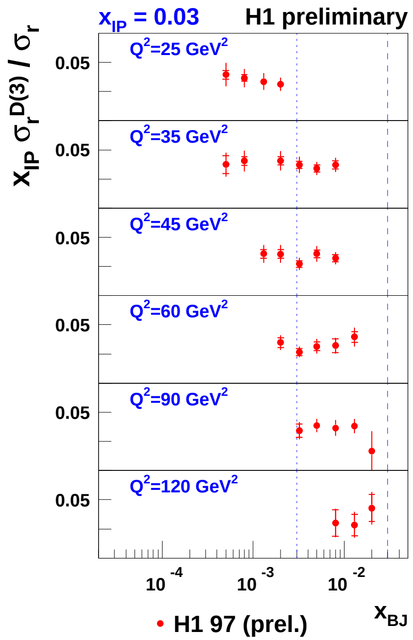


x Dependence of Ratio at fixed $x_{I\!P}$









$0.1 < \beta < 1$

Complicated structure

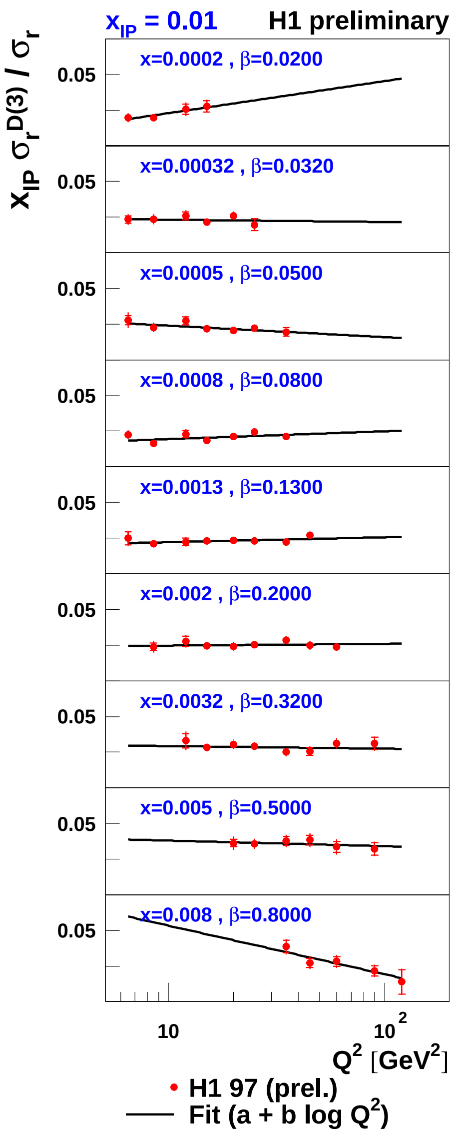
when studied at fixed $x_{I\!P}$

(p' 4 vector fixed, M_X varying.)

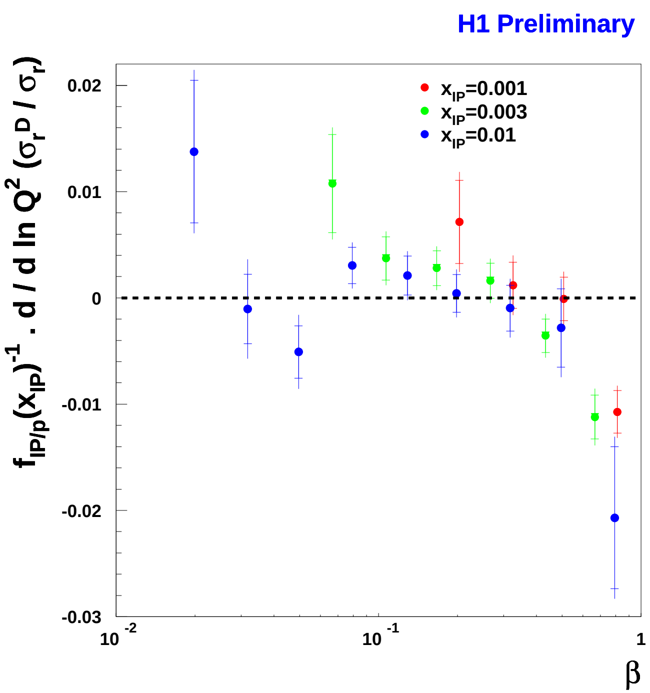
As $x \to x_{I\!P}$ ($\beta \to 1$) ratio depends on β, (not x)

$\sim$ flat for $\beta \lesssim 0.1$? (limited data)

Q^2 Dependence of Diffractive to Inclusive Ratio (97 data)



F_2^D/F_2 $\sim$ flat at large Q^2, $\beta \lesssim 0.7$ …deep connection between diffractive and inclusive gluon?



Fix $x, x_{I\!P}$ …

(β fixed, Q^2, W, M_X vary.)

$$\frac{1}{f_{I\!P/p}(x_{I\!P})} \frac{\partial}{\partial \ln Q^2} \left(\frac{\sigma_r^D}{\sigma_r} \right)$$

- Soft (probabilistic) gap production at low β?
- pQCD 2 gluon exchange (higher twist) at high β?

Why is diffractive : inclusive ratio so flat?

Flatness can be generated in various models . . .

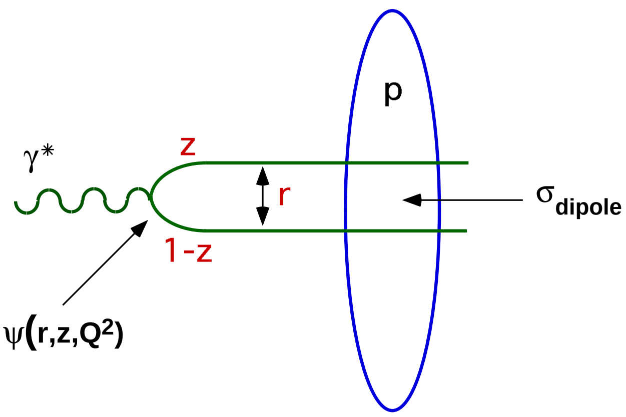
- Natural in soft colour interaction models
- Can be obtained from separate DGLAP fits to σ_r, σ_r^D
- Appears in dipole models due to different weights of dipole cross section . . .

F_2: $\sigma_{T,L}(x, Q^2) = \int d^2r\, dz\ \left|\psi_{T,L}(r, z, Q^2)\right|^2\ \sigma_{\rm dipole}(x, r)$

F_2^D: $\sigma_{T,L}(x, Q^2) = \int d^2r\, dz\ \left|\psi_{T,L}(r, z, Q^2)\right|^2\ \sigma^2_{\rm dipole}(x, r)$

Dipole cross section . . .

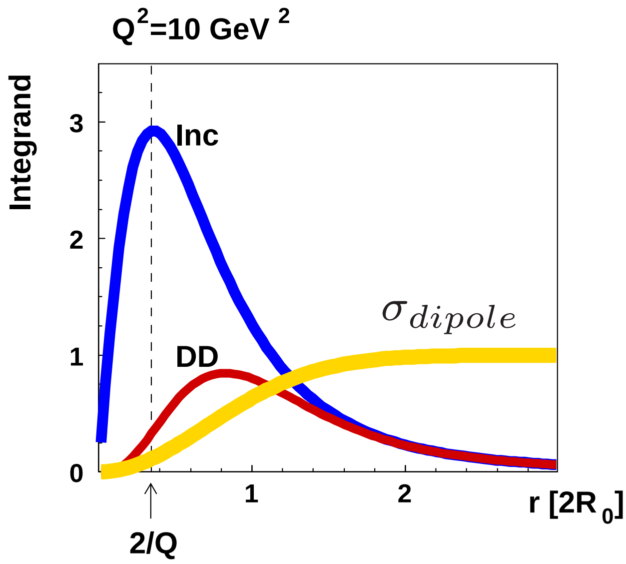
- $\sim r^2$ as $r \to 0$ (pQCD)
- $\to$ flatter. as $r \to \infty$



Extra factor of $\sigma_{\rm dipole}$ in diffractive case gives increased weight to large dipole sizes.

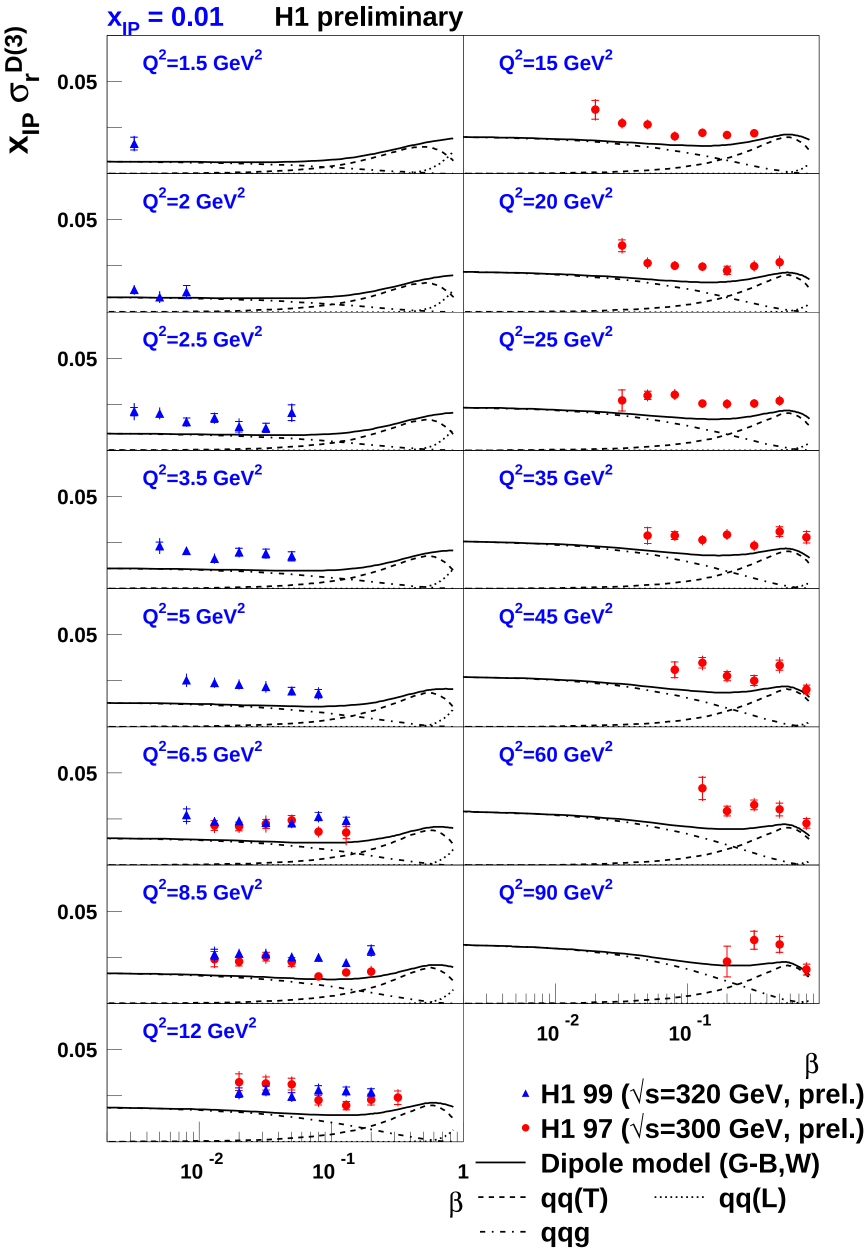
Large $r \to$ small $k_{\rm T}$

Bigger ‘soft’ contribution (weaker energy dependence) in diffractive case



Golec-Biernat & Wüsthoff Comparison

Extra colour factor $(4/9)^2$ included for $q\bar{q}g$ dipoles relative to $q\bar{q}$ since original version



$q\bar{q}g$ fluctuations of γ_T^* insufficient to describe low β, high Q^2

Further refinements (higher multiplicity fluctuations?) needed

Summary and Open Questions

Precise data for diffractive cross section at low-medium Q^2

Regge factorisation holds within any single dataset. Suggestions that it may break when all datasets considered together?

Uncertainty in F_L^D limits precision on $\alpha_{I\!P}(0)$

Still no strong evidence for variation of t slope with $x_{I\!P}$, β or Q^2

Diffractive parton densities extracted with errors - still not possible without Regge factorisation assumption

Remarkable flatness of diffractive : inclusive ratio over wide β, $x_{I\!P}$ range, but what should be kept fixed?

More work needed on dipole models, especially for low β region