Diffraction in *ep* collisions

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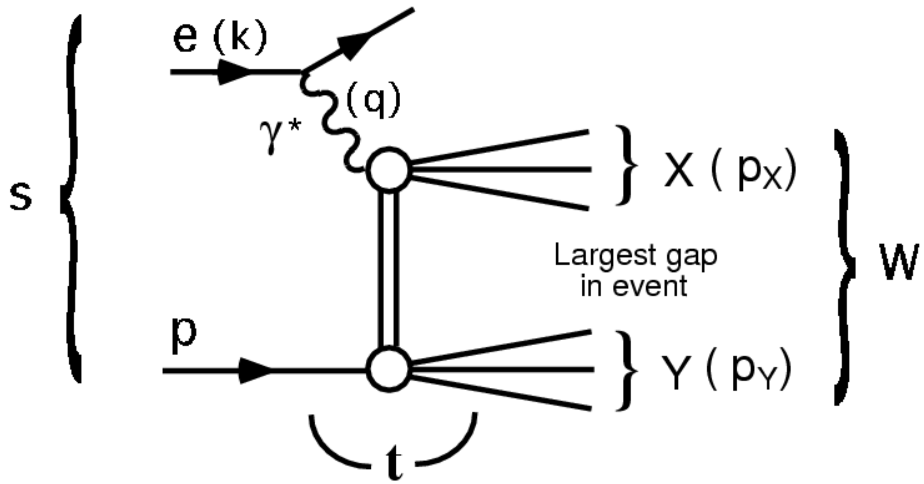
Outline:

- Introduction
- Inclusive diffractive DIS cross section
- Diffractive photoproduction of jets
- Open charm production in diffractive DIS

The process $e\,p \to e\,X\,Y$



Kinematics:

- longitudinal momentum fraction of the proton carried by the colourless exchange:

$$x_{IP} = \frac{q \cdot (P - p_Y)}{q \cdot P} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

- longitudinal momentum fraction of the colourless exchange carried by the struck quark:

$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^2}$$

Cross section:

- reduced cross section defined through:

$$\frac{\mathrm{d}^3 \sigma^D}{\mathrm{d}\,x_{IP}\,\mathrm{d}\,x\,\mathrm{d}\,Q^2} = \frac{4\pi\alpha^2}{x Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_r^{D(3)}(x_{IP}, x, Q^2)$$

- relation to $F_2^{D(3)}$ and $F_L^{D(3)}$:

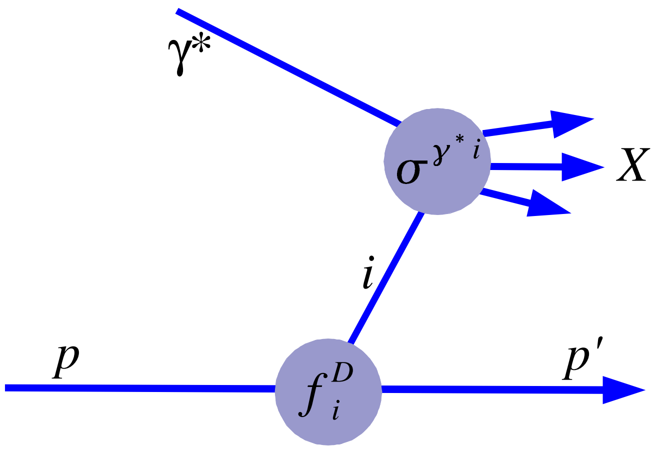
$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{1 + (1-y)^2} F_L^{D(3)}$$

QCD and Regge factorisation

QCD hard scattering factorisation:

$$\sigma^{\gamma^* p \to p'X} = \sigma^{\gamma^* i} \otimes f_i^D$$

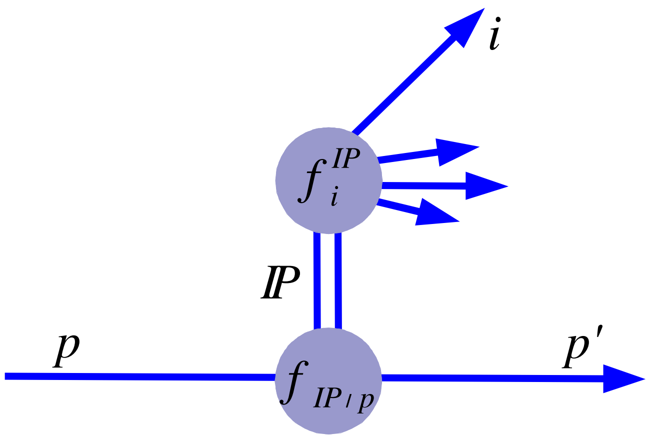
- $\sigma^{\gamma^* i}$ the universal partonic cross section (same as in inclusive DIS)
- f_i^D the parton distribution function for a parton i under the constraint that the proton survives the diffractive scattering (f_i^D should obey the DGLAP evolution equations)



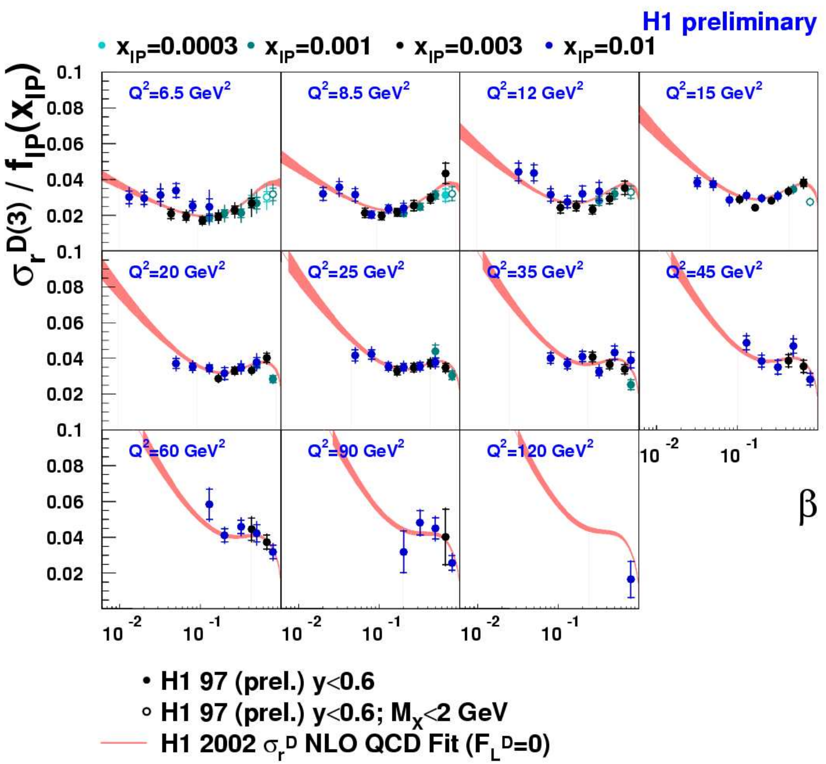
Regge factorisation:

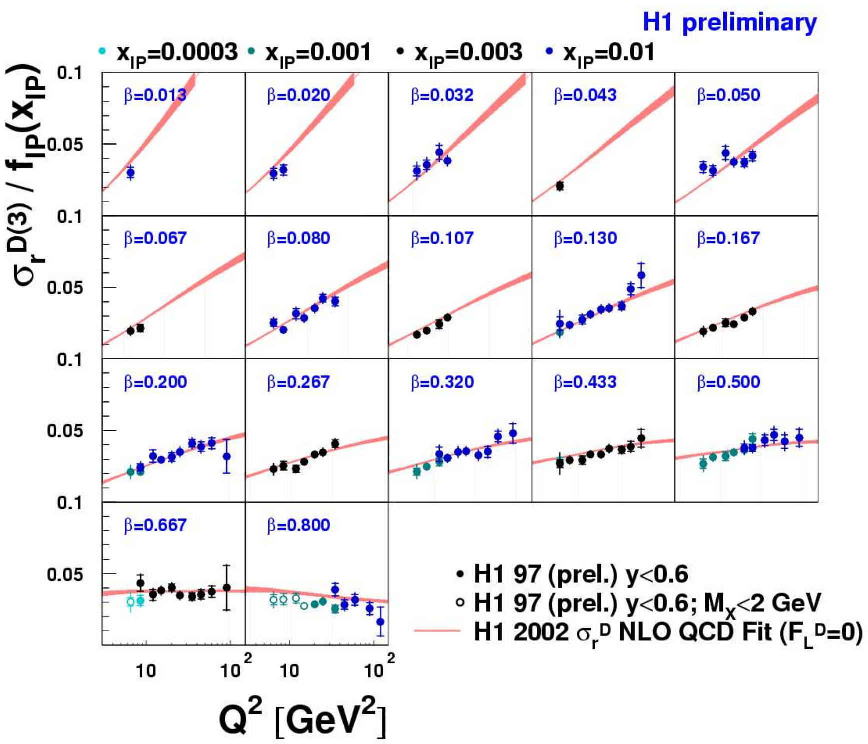
$$f_i^D(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \, . \, f_i^{IP}(\beta = x/x_{IP}, Q^2)$$

- $f_{IP/p}$ "pomeron flux factor" (can be parameterized according to Regge theory)
- f_i^{IP} "pomeron parton distribution"



Diffractive reduced cross section





Regge fit: parameters: $\alpha_{IP}(0)$, $A_{IP}(\beta,Q^2)$, $A_{IR}(\beta,Q^2)$

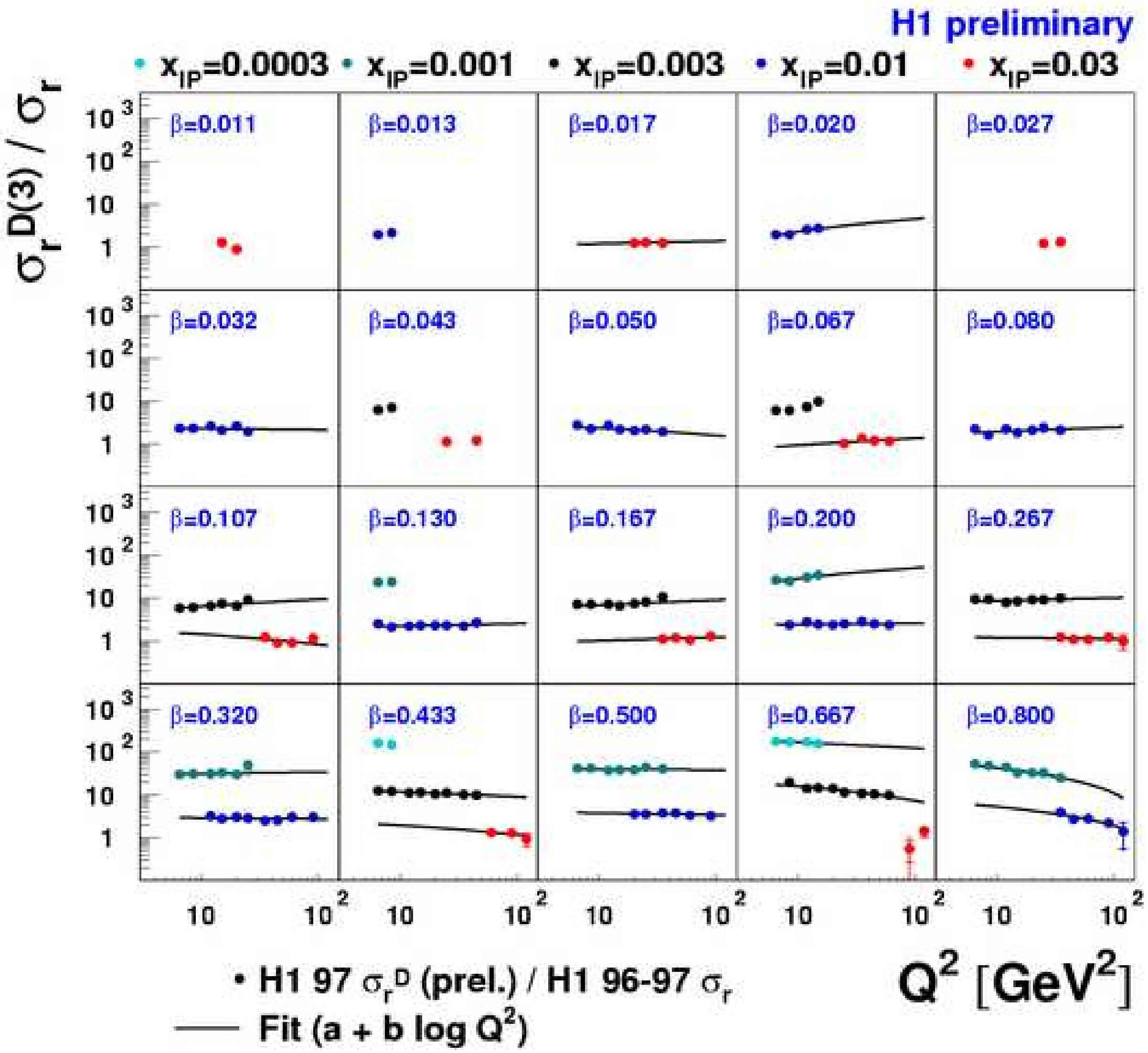
$$\sigma_r^{D(3)}(x_{IP},\beta,Q^2)=f_{IP}(x_{IP})\cdot A_{IP}(\beta,Q^2)(+IR)$$

$$f_{IP}(x_{IP})=\int_{t_{cut}}^{t_{min}} e^{B_{IP}t}/(x_{IP}^{2\alpha_{IP}(t)-1})\,\mathrm{d}t$$

- σ_r from different x_{IP} regions overlap nicely
- positive scaling violations in most of the phase space

$$\alpha_{IP}(0)=1.173\pm0.018\,(\mathrm{stat.})\pm0.017\,(\mathrm{syst.})^{+0.063}_{-0.035}(\mathrm{model})$$

Ratio of diffractive to inclusive σ_r



$$R = \frac{\sigma_r^D(x_{IP}, x, Q^2)}{\sigma_r(x, Q^2)}$$

ratio is reasonably flat as function of Q^2

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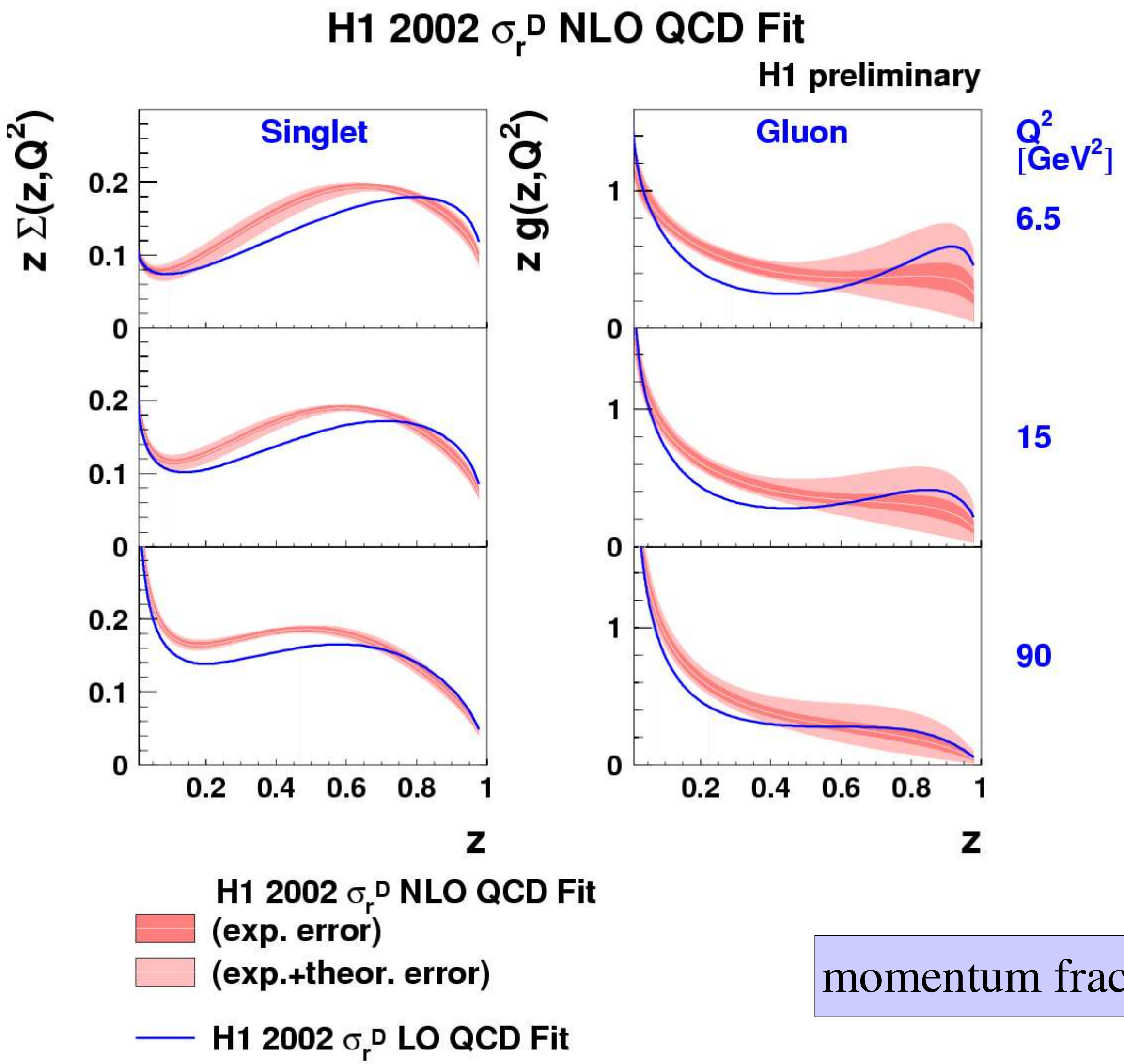
same scaling violations are observed in diffractive and inclusive DIS

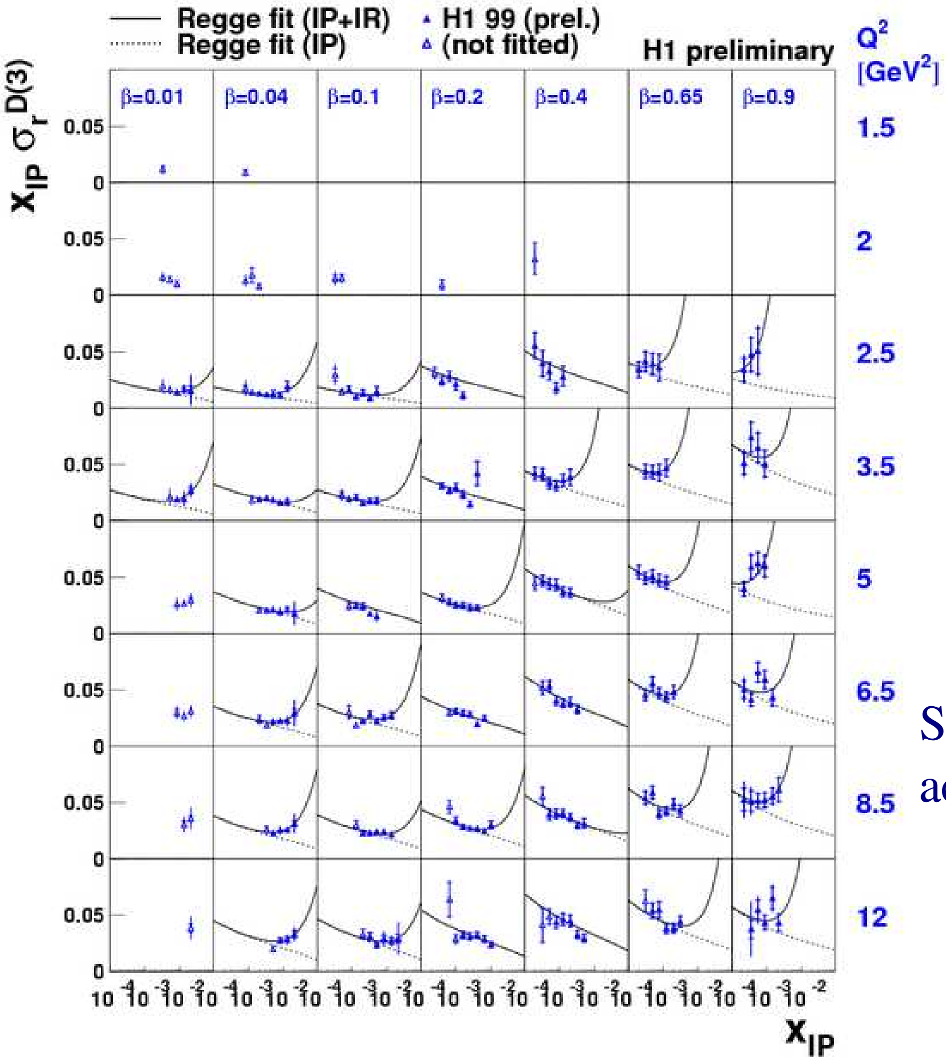
NLO DGLAP QCD fit

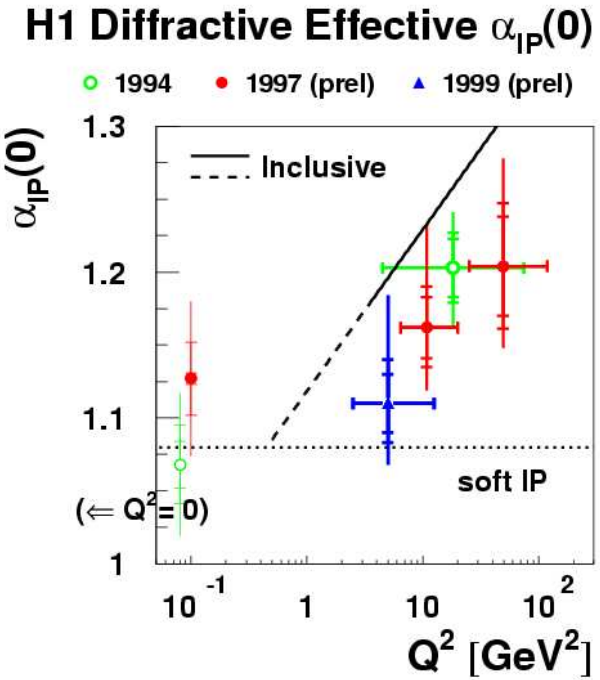


- quark and gluon densities are parameterized as Chebychev polynomials at starting scale $Q_0^2 = 3$ GeV^2
- fit also includes high Q^2 data ($200 < Q^2 < 800$ GeV^2)
- subleading reggeon exchange is included using the pion structure function
- χ^2/ndf = 308.7/306
- propagation of statistical, systematic experimental and theoretical errors

momentum fraction carried by gluons: 75 ± 15%

Diffraction at low Q^2



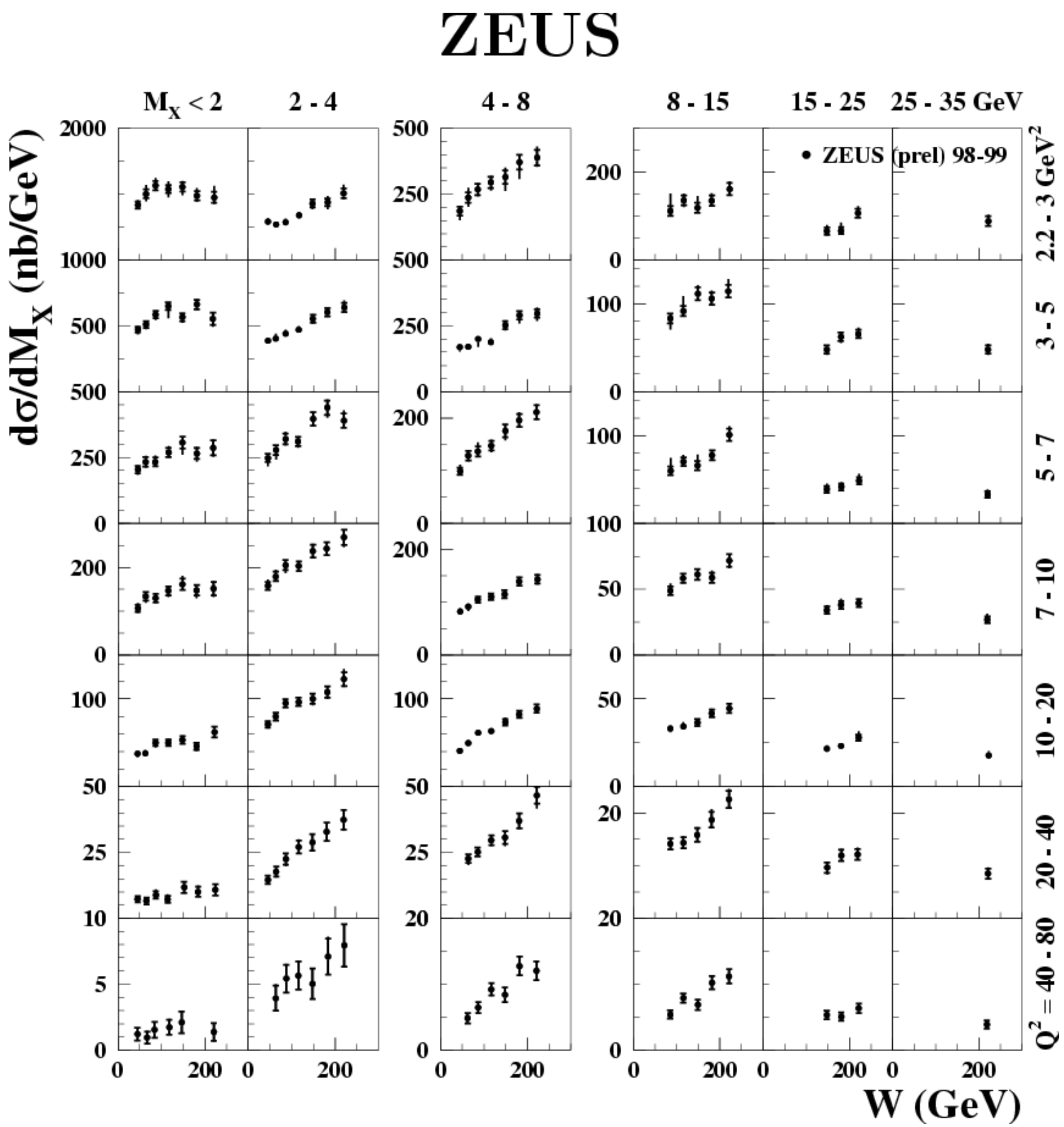


Special run with minimally biased triggers to access low Q^2:

- at low Q^2, $\alpha_{I\!P}(0)$ is consistent with the soft pomeron intercept of 1.08
- H1 data suggest a rise of $\alpha_{I\!P}(0)$ with Q^2

$$\alpha_{IP}(0) = 1.110 \pm 0.020\,(\text{stat.}) \pm 0.024\,(\text{syst.})^{+0.068}_{-0.033}\,(\text{model})$$

Differential cross section $d\sigma/dM_X$



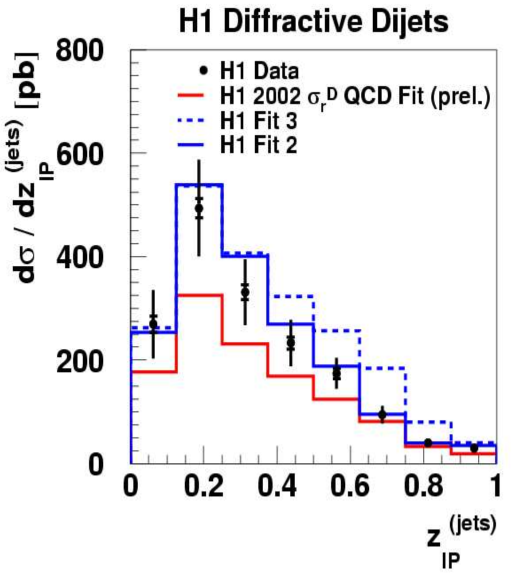
New Forward Plug Calorimeter :

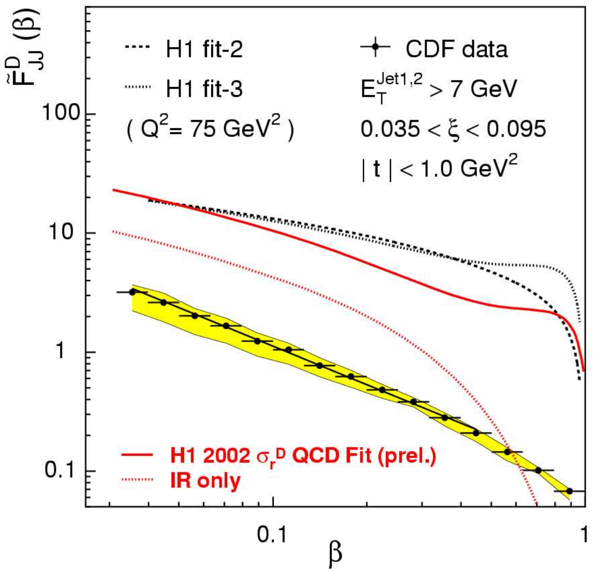
- covers pseudorapidities $4 < \eta < 5$
- increases measurable range in M_X ($M_X < 35$ GeV)
- reduces the mass of the dissociation system Y ($M_Y < 2.3$ GeV)

Observations:

- for $M_X < 2$ GeV (resonance production) there is little dependence on W
- at higher M_X, a strong rise with W is observed at all Q^2, compatible with the energy dependence of inclusive data

Factorisation tests





take diffractive pdf's from cross section measurement

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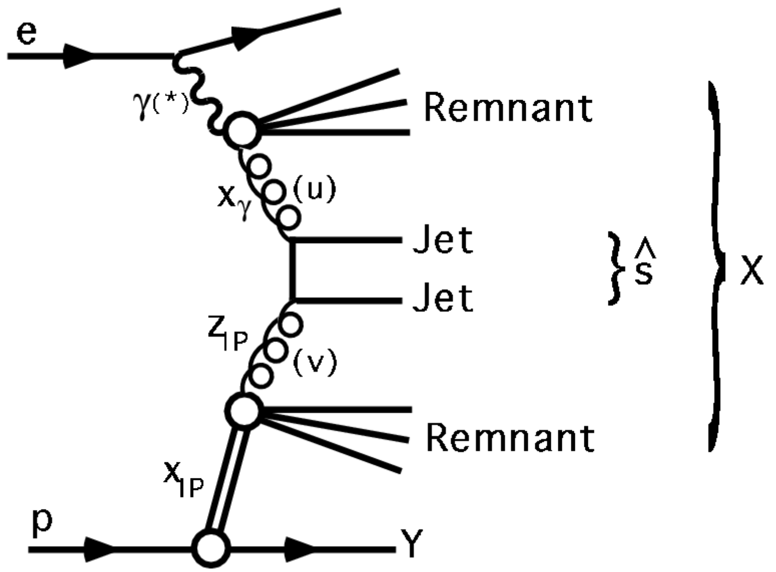
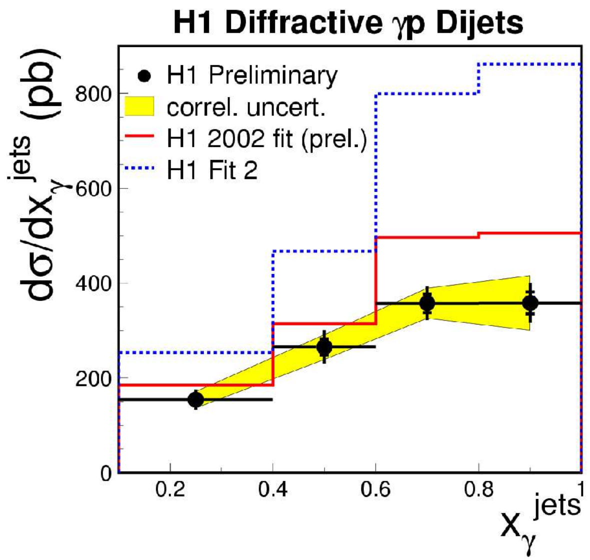
predict diffractive final state observables

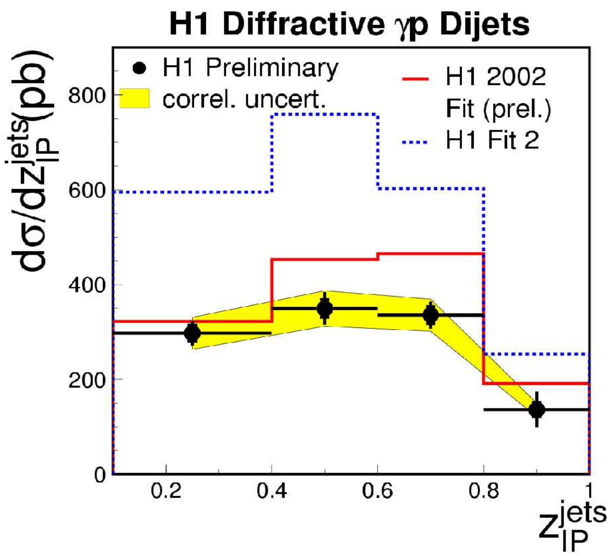
- At HERA:
  compare with diffractive dijet and open charm production (both driven by the gluon content of the pomeron through boson-gluon-fusion)
  ➔ no evidence for breakdown of QCD hard scattering factorisation in diffraction DIS (within errors)
- At the Tevatron:
  compare to diffractive dijet production in the process $p\,\overline{p} \rightarrow p\,X$
  ➔ breakdown of factorisation between *ep* and *pp* data due to secondary interactions between remnants in *pp* collisions (➔ rapidity gap survival probability)

What about diffractive dijet photoproduction?

Dijets in diffractive photoproduction







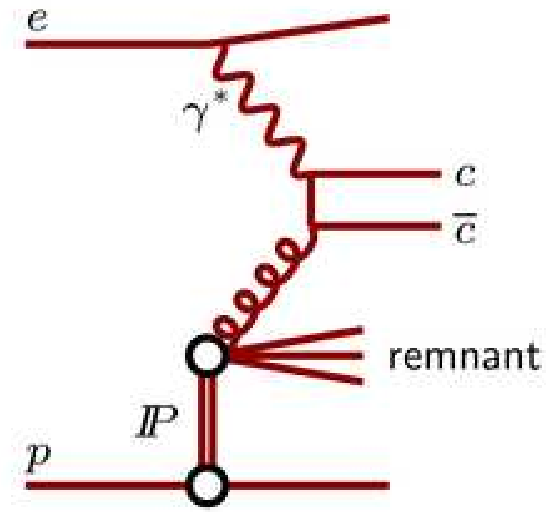
x_γ: fraction of photon momentum entering dijet system

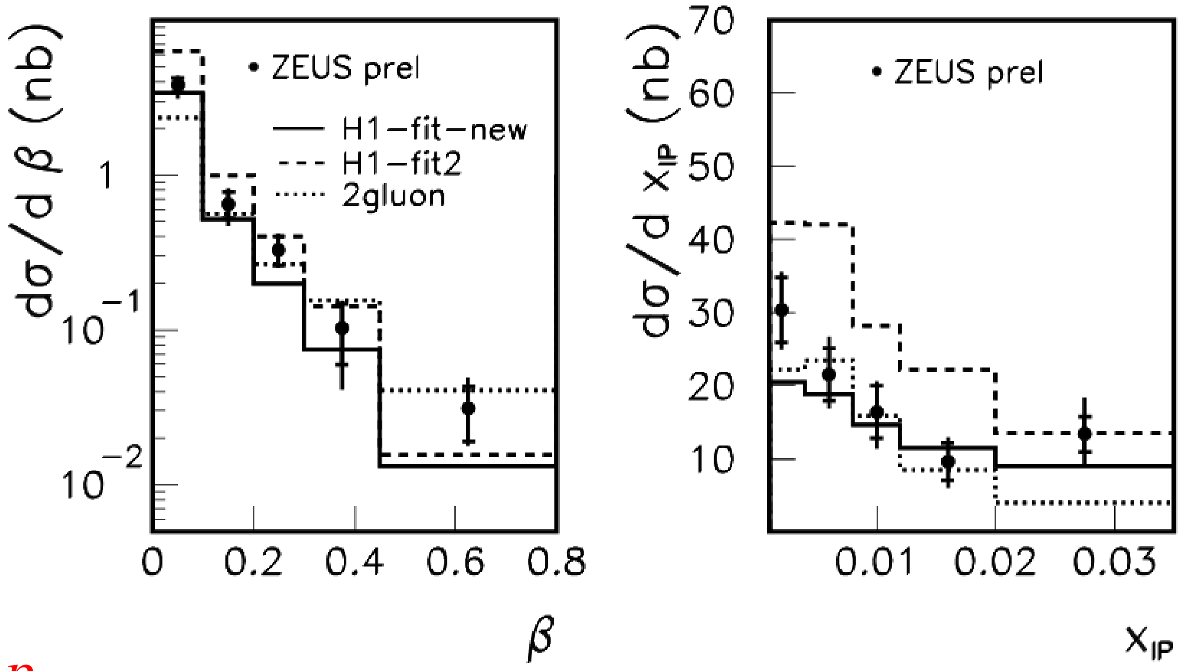
z_{IP}: fraction of pomeron momentum entering dijet system

→ suppression factor for dijet photoproduction relative to DIS dijets: 1.80 ± 0.45

suppression found to be the same (within errors) for direct and resolved processes!

Open charm production in diffractive DIS





Measurement of

$$e^+ p \rightarrow e^+ D^{*\pm} X p$$

(through D → K π π_s)
in the kinematic range:

$1.5 < Q^2 < 200$ GeV^2, $0.02 < y < 0.7$
$x_{IP} < 0.035$, $\beta < 0.8$
$p_T(D^*) > 1.5$ GeV, $|\eta(D^*)| < 1.5$

$$\sigma = 505 \pm 43\,(\text{stat.})^{+30}_{-61}(\text{syst.})^{+21}_{-21}(\text{p. diss.})\ \text{pb}$$

prediction from the resolved pomeron model:
$\sigma = 530$ pb

Summary

- High precision measurements of the diffractive reduced cross section in DIS have been performed by H1 and ZEUS in an increased region of phase space
- The data supports Regge factorisation (provided subleading trajectories can contribute) with a value for the pomeron intercept which is larger than for the soft pomeron
- New NLO QCD fits are available of the diffractive parton densities and can be used to test QCD hard scattering factorisation
- At HERA, data on the inclusive cross section and diffractive final states observables (charm and dijet production) are in agreement with QCD factorisation
- Breaking of QCD factorisation is observed when using HERA diffractive parton density functions to describe Tevatron data on diffractive dijets
- A study of diffractive photoproduction of jets finds a suppression factor wrt. DIS dijets of 1.8 ± 0.45, but cannot confirm different suppression factors for resolved and direct processes