Diffraction in ep collisions

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on behalf of

- **Introduction**
- **Diffractive structure functions**
- **t - distribution**
- **Φ – distribution**
- **Summary**

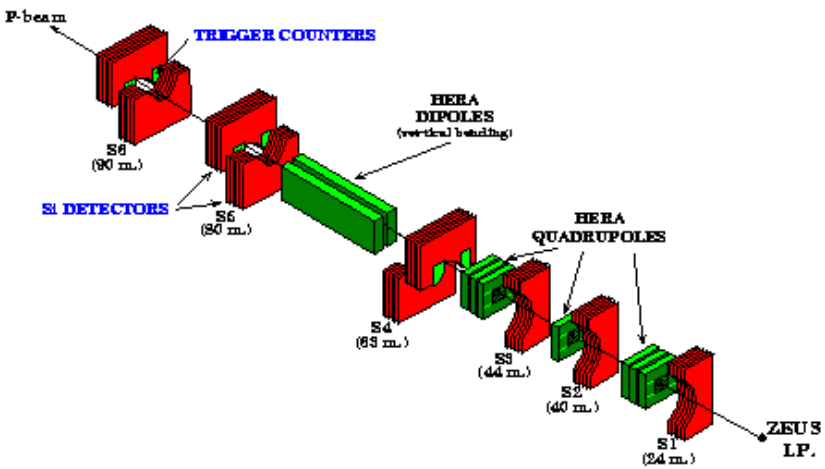
Diffraction at HERA

At HERA about 10% of the events are diffractive: photon dissociates into hadrons via colourless exchange, leading to a Large Rapidity Gap

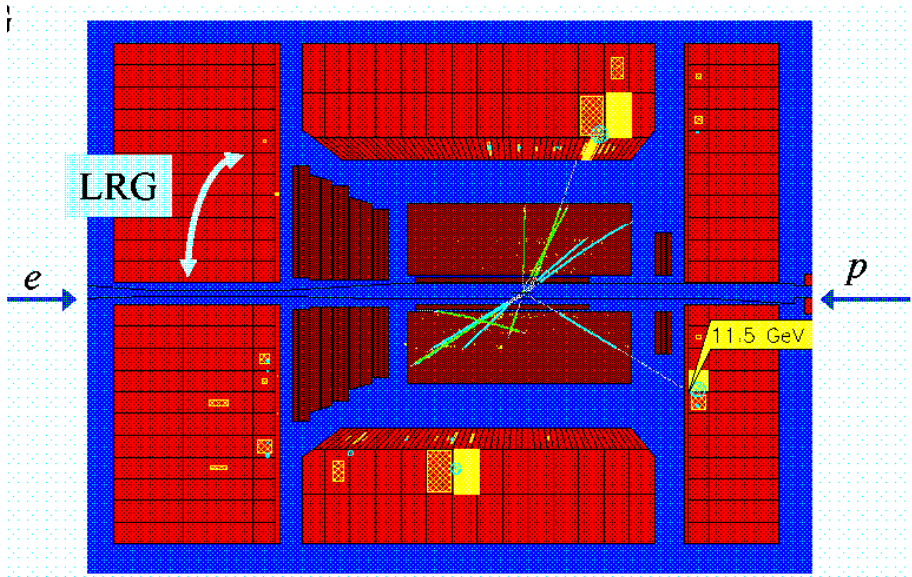
Traditionally such events described in terms of "Pomeron" exchange in hadron-hadron interactions (Regge Theory)

Diffraction is a sizeable fraction of total hadron-hadron cross section

Can we understand in terms of pQCD?



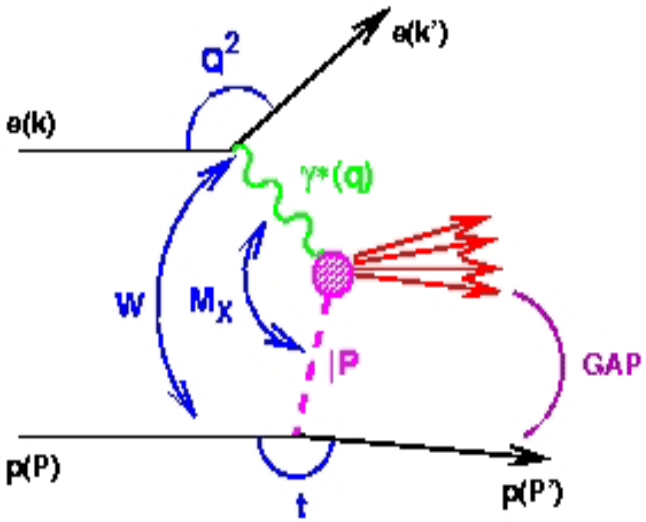
Fast forward (leading) proton



Large rapidity gap (LRG)

The partonic pomeron

Diffractive DIS viewed as γIP* inelastic scattering**



the pomeron carries fraction x_{IP} of the initial proton momentum

the struck parton carries fraction β of the Pomeron momentum

HERA is an ideal laboratory to study diffraction

ep interaction ⇒ γ*p interaction

γ* probes QCD structure of Pomeron with varying resolution

- **determine diffractive parton densities (dPDFs)**
- **investigate universality of dPDFs**

Regge theory

Pomeron as a "trajectory"

$$\alpha_{IP}(t) = \alpha_{IP}(0) + \alpha'_{IP} \cdot t \qquad \alpha_{IP}(0) \simeq 1.086$$

pomeron intercept $\alpha_{\mathrm{IP}}(0)$ **controls energy dependence of total cross sections** $\rightarrow \sigma_{\mathrm{tot}} \sim s^{\alpha_{IP}(0)-1}$

but no known hadronic bound states lying on this trajectory

DDIS allows to probe the partonic structure of pomeron

Hard Diffraction in QCD

- **Diffractive structure function** $F_2^{D(4)}$

$$\frac{d^4\sigma_{ep}^{diff}}{d\beta dQ^2 dx_{IP} dt} = \frac{2\pi\alpha^2}{\beta Q^2}\left[1+(1-y)^2\right] F_2^{D(4)}(\beta, Q^2, x_{IP}, t)$$

- **QCD factorization proven in ep (Collins 1997)**

$$F_2^D \sim f_{i/p}^D \otimes \hat{\sigma}_i$$

universal partonic cross section (inclusive DIS)

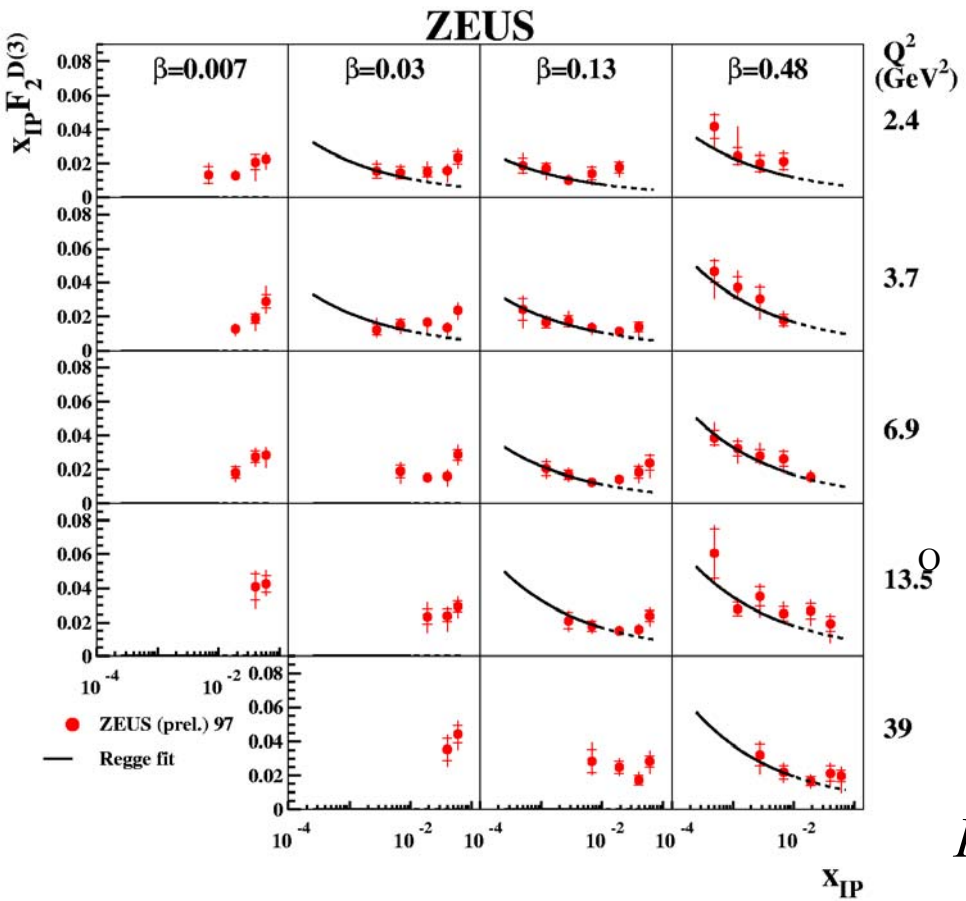
diffractive parton distribution functions – evolve according to DGLAP equations

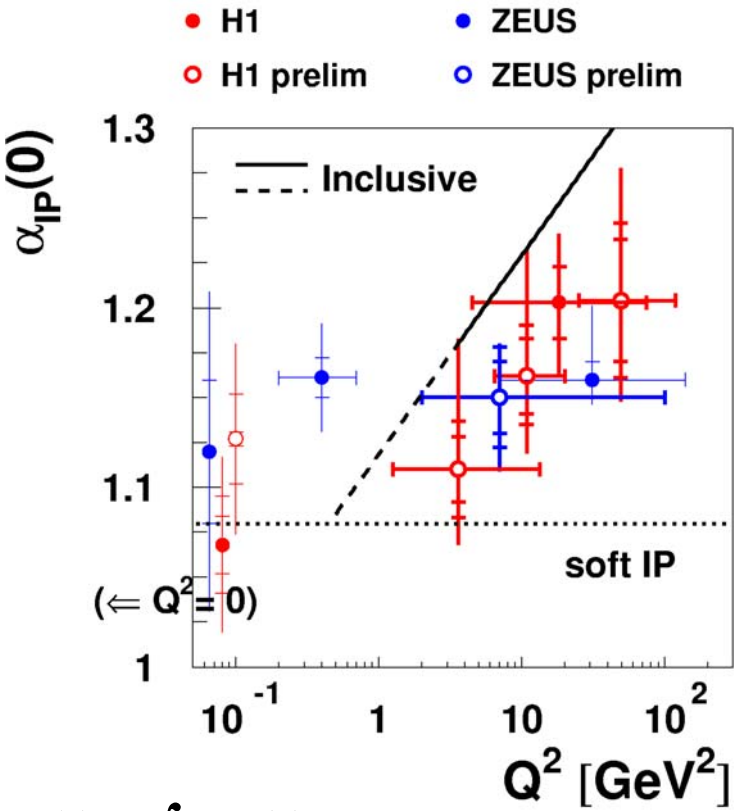
- **Regge factorization (IP with partonic structure)**

$$F_2^{D(4)} = f_{IP/p}(x_{IP}, t) \cdot F_2^{IP}(Q^2, \beta)$$

$F_2^{IP}(\beta, Q^2)$ evolves following DGLAP equations

Diffractive structure function and the "universal" IP





$$F_2^{D(3)} = \int F_2^{D(4)} dt$$

Fit all data with one value of flux factor

Regge factorization supported

$$x_{I\!P} F_2^{D(3)}(x_{I\!P}, \beta, Q^2) \sim \frac{1}{x_{I\!P}^{2\alpha_{I\!P}-2}} F_2^{I\!P}(\beta, Q^2)$$

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

t-distribution from leading proton data

Exponential fit to t distribution

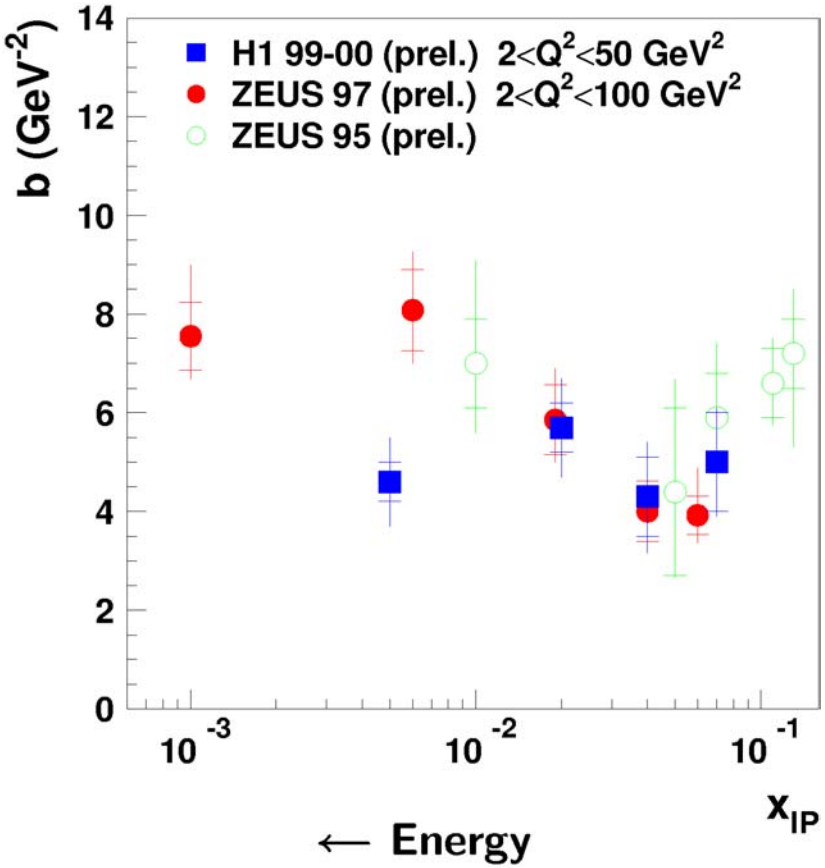
$$\frac{d\sigma}{d|t|} \sim e^{-b|t|}$$

b is related to interaction radius:

$$b = R^2/4$$

According to Regge phenomenology proton size "grows" with energy

$$b = b_0 + 2\alpha' \ln \frac{W^2}{M_X^2} \approx b_0 + 2\alpha' \ln \frac{1}{x_{IP}}$$

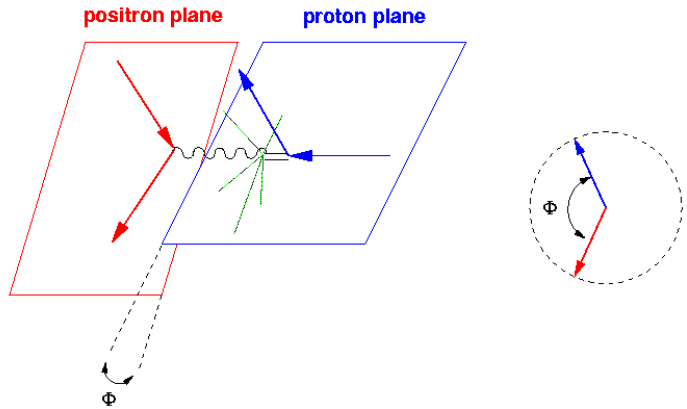


For $x_{IP} < 10^{-2}$ data prevent any firm conclusion

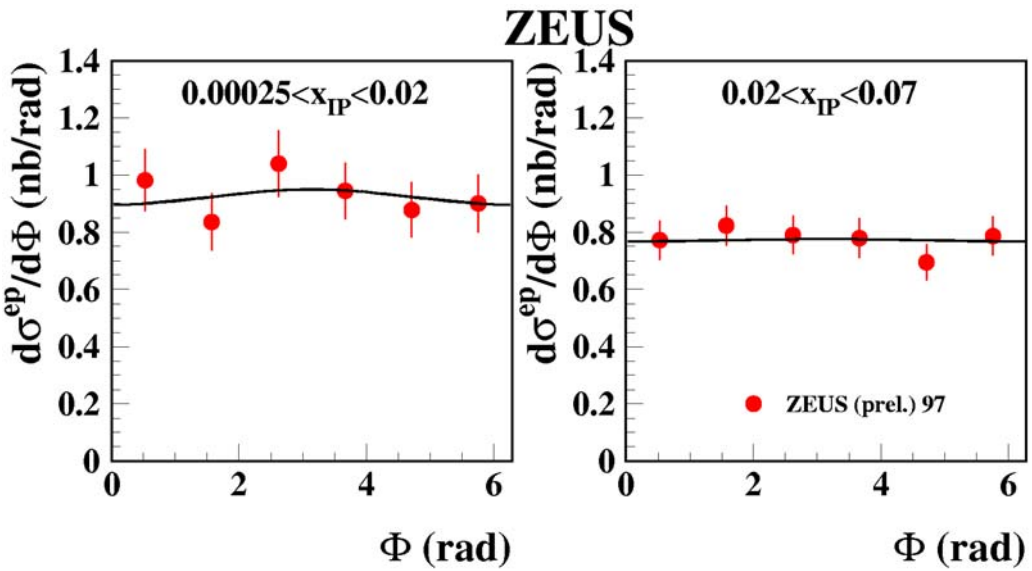
Azimuthal asymmetry from leading proton data

For unpolarized positrons: $\frac{d\sigma^D}{d\Phi} \sim \sigma_T^D + \epsilon\sigma_L^D - 2\sqrt{\epsilon(1+\epsilon)}\sigma_{LT}^D \cos\Phi - \epsilon\sigma_{TT}^D \cos 2\Phi$

Φ – angle between positron and proton scattering planes in γ^* p rest frame



Non-uniform Φ distribution reflects non-zero value of $R^D = \sigma_L^D/\sigma_T^D$



■ **Fit:** $\frac{d\sigma}{d\Phi} \propto 1 + A_{LT}\cos\Phi$

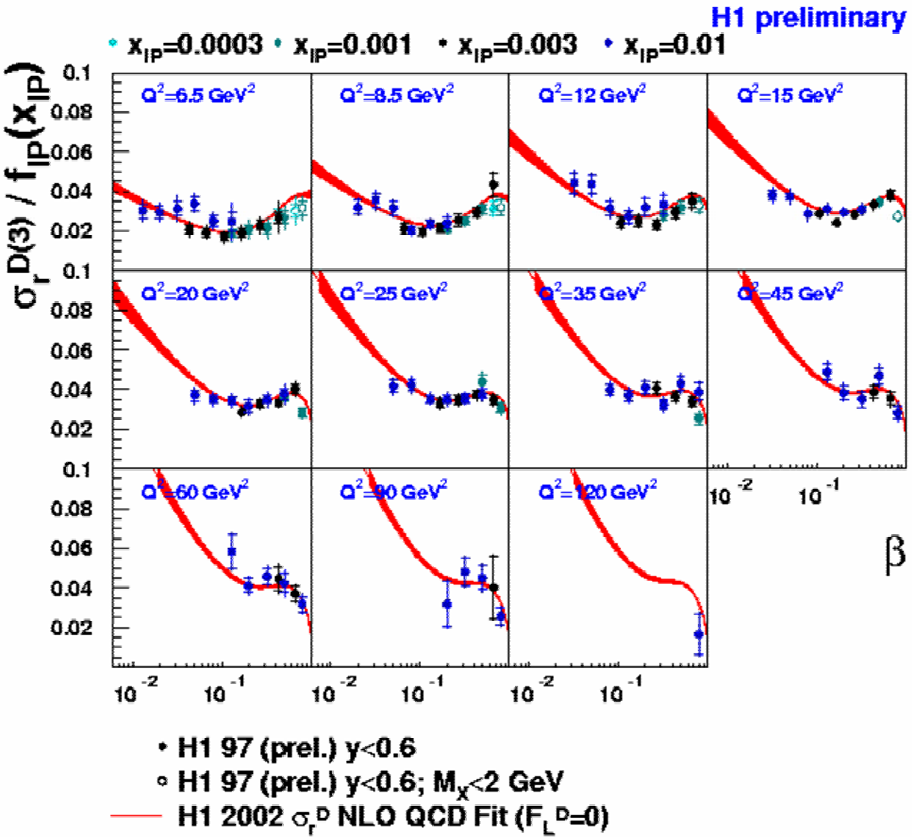
$A_{LT} = -0.029 \pm 0.066^{+0.026}_{-0.047}$
$(0 \lesssim x_{I\!P} < 0.02\ ;\ \beta \approx 0.32)$

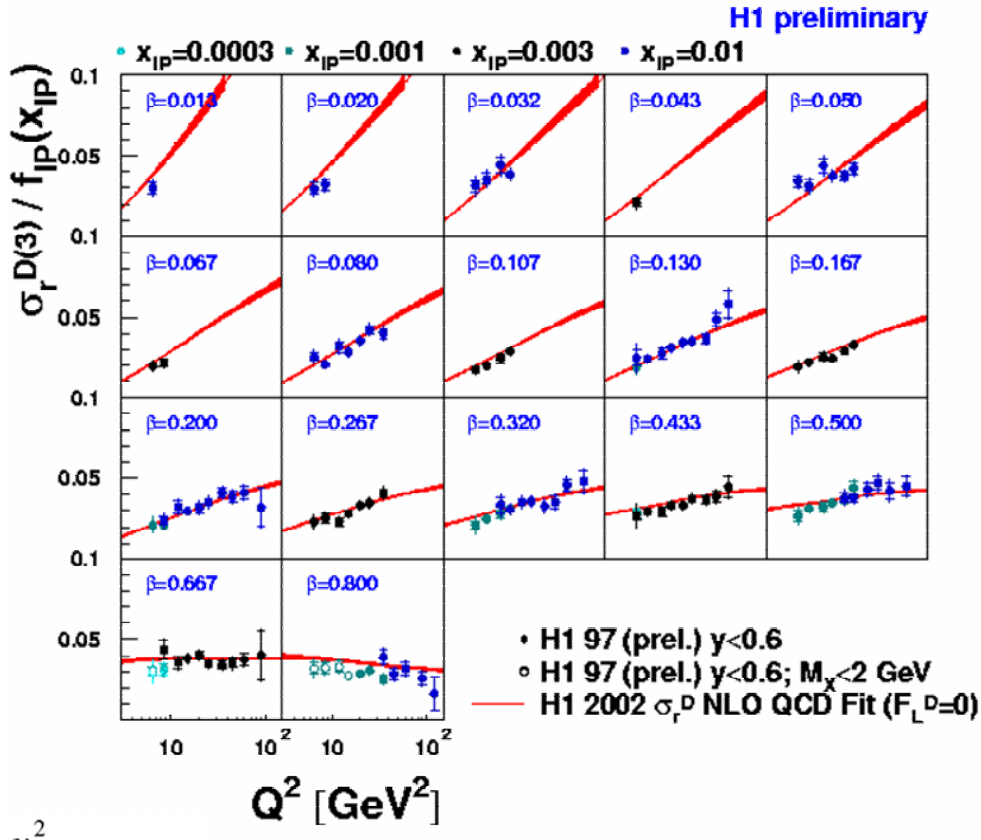
$A_{LT} = -0.005 \pm 0.052^{+0.048}_{-0.047}$
$(0.02 < x_{I\!P} < 0.07\ ;\ \beta \approx 0.1)$

Interference term small at low β

More statistics needed to explore the high β region (large asymmetry expected)

Reduced diffractive cross section

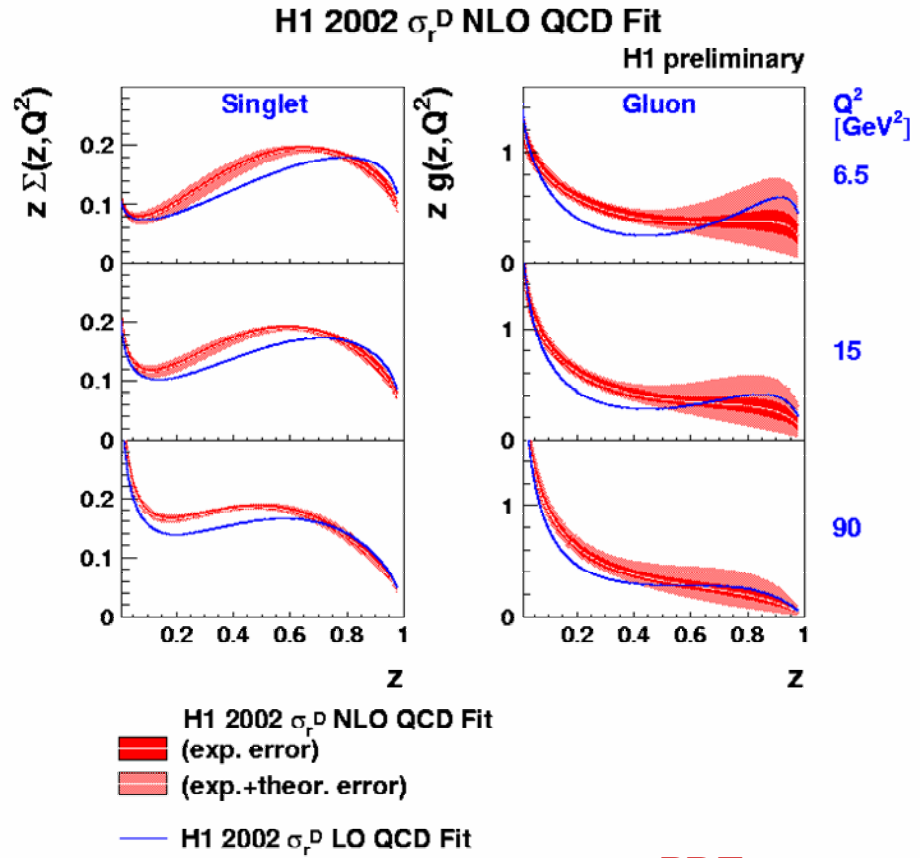


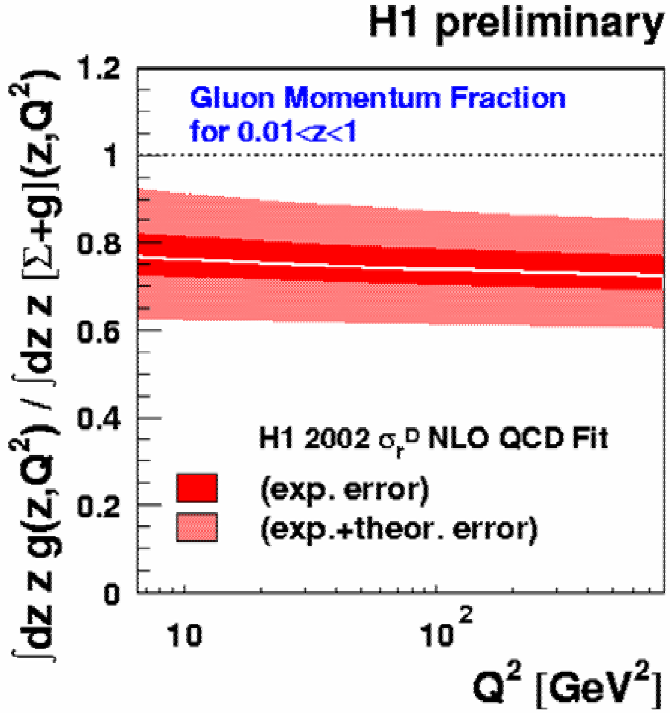


$$\sigma_r^{D(3)} = F_2^{D(3)} - \frac{y^2}{1+(1-y)^2} F_L^{D(3)}$$

- Weak dep. on β: high momentum partons → looks like a photon more than a proton
- Scaling violations positive up to large ß
- DGLAP evolution based fit describes the data → large gluon contribution

NLO QCD fit: the gluon density





Assume:

Regge factorization (c.f. data)

Singlet Σ and gluon g parameterized at $Q_0^2 = 3\ \mathrm{GeV}^2$

NLO DGLAP evolution

get PDFs:

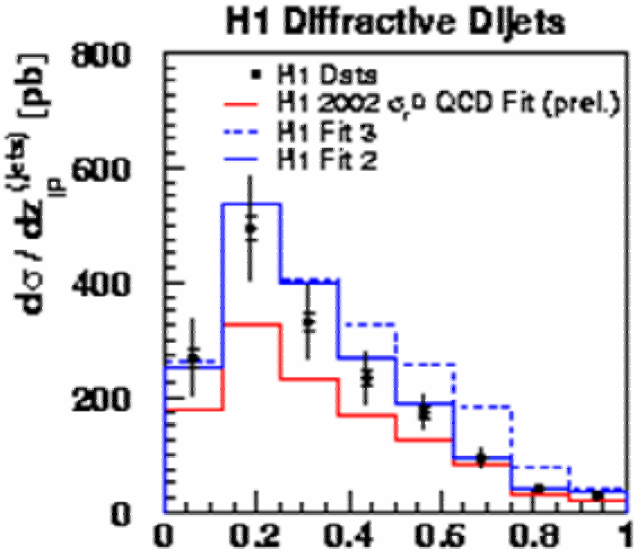
Extending to large fractional momenta z

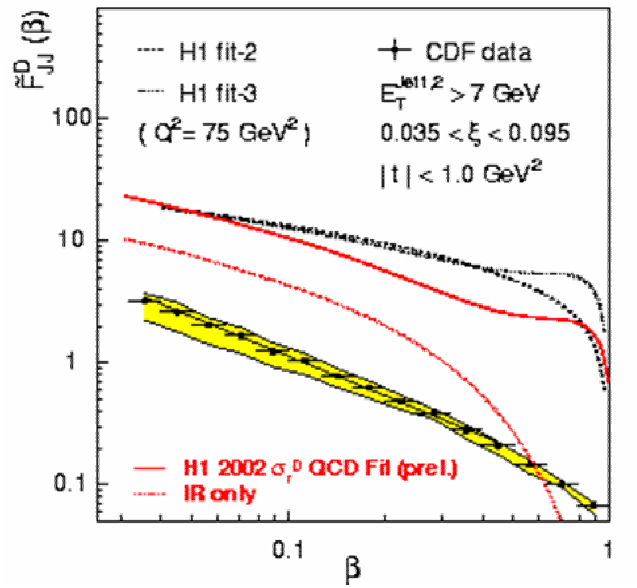
Gluon dominated

Momentum fraction of diffractive exchange carried by gluons:

$75 \pm 15\ \%$

Diffractive final states: a test of QCD factorization





Use diffractive PDFs to predict cross sections for diffractive production of charm and dijet

At HERA: **Shapes of distributions well reproduced by dPDFs description**

Normalization ~ ok within uncertainties

Consistent with QCD factorization

At the Tevatron: **Serious breakdown of factorization between ep and pp data due to additional spectator interactions**

Summary

Measurements of inclusive diffraction at HERA

- **used to test QCD factorization**
  - **dijet and charm cross sections at HERA are found to be approx. consistent**
  - **a discrepancy ~ one order of magnitude observed in the predictions of dijet cross sections from the Tevatron**

- **support Regge factorization**
- **can be described within a consistent picture using**
  - **NLO DGLAP evolution**
  - **gluon dominated diffractive PDFs**

- **analyzed for the first time in terms of azimuthal asymmetry indicate interference between L and T photons small at low β**

Dynamics of diffractive exchange understandable in the frame of pQCD