Les Rencontres de Physique de la Vallee d'Aoste
La Thuile, Aosta Valley - Italy, March 4th-10th 2007

Diffractive parton densities and factorization tests at HERA

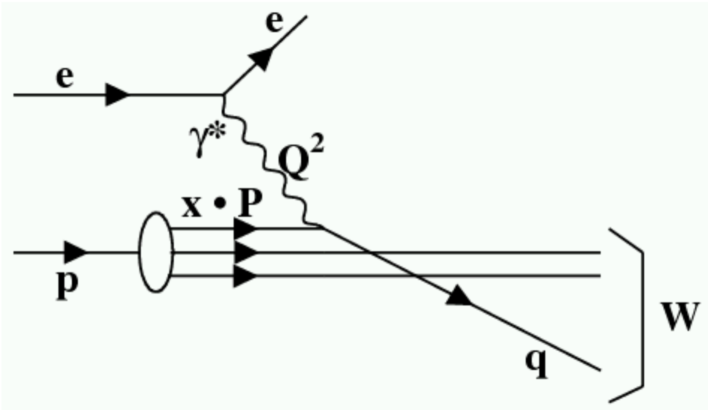
Marta Ruspa, Univ. Piemonte Orientale, Novara (ITALY)

- Diffraction at HERA
- Inclusive diffractive measurements and diffractive PDFs
- Diffractive final states: jets and open charm

Diffractive DIS at HERA

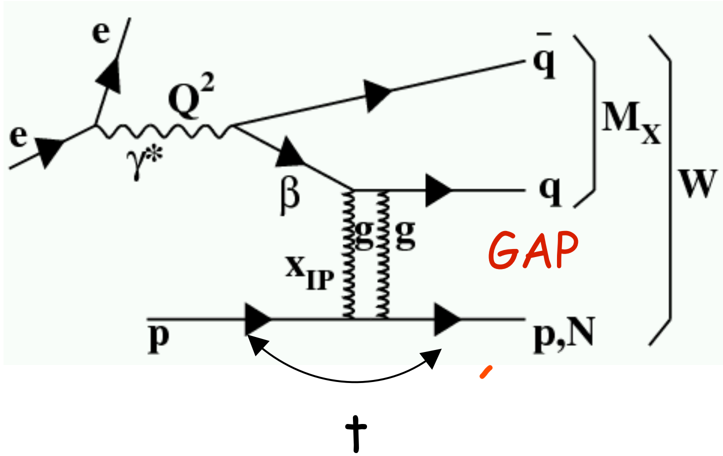
HERA: ~ 10% of low-x DIS events are diffractive

Standard DIS



Probe structure of proton → F_2

Diffractive DIS



Probe structure of color singlet exchange (IP) → F_2^D

Diffractive DIS at HERA

Q^2 = virtuality of photon =
= (4-momentum exchanged at e vertex)^2

t = (4-momentum exchanged at p vertex)^2
typically: $|t|<1$ GeV^2

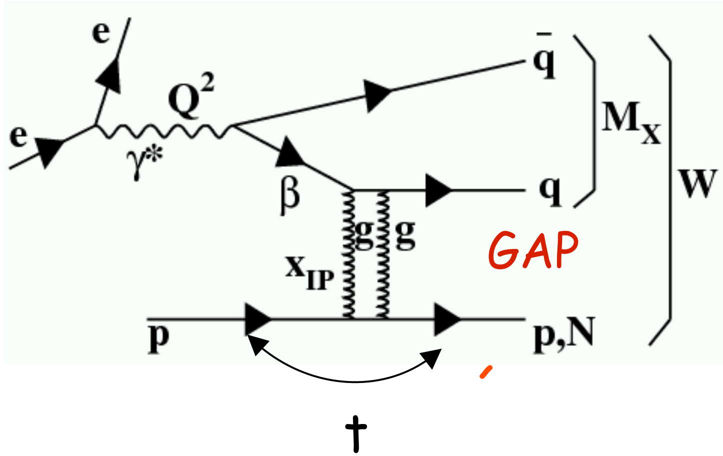
W = invariant mass of γ-p system

M_X = invariant mass of γ-IP system

x_{IP} = fraction of proton's momentum taken by IP

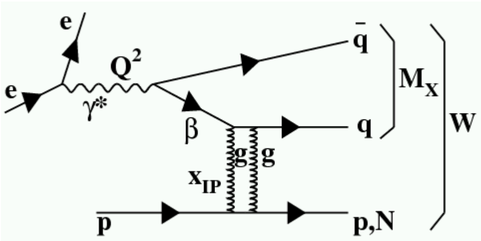
ß = Bjorken's variable for the IP
= fraction of IP momentum carried by struck quark
= x/x_{IP}

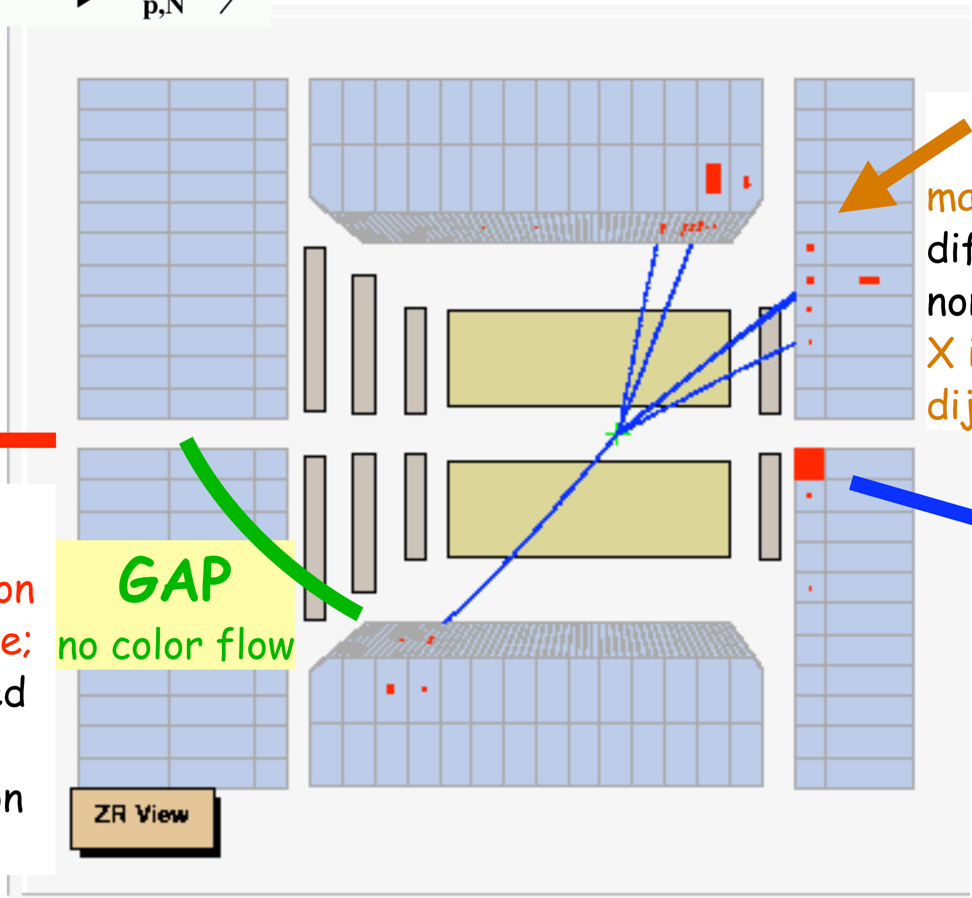
Diffractive DIS



Probe structure of color singlet exchange (IP) → F_2^D

Diffractive event selection





M_x

mass of the diffractive system;
different M_x shape between non-diffr DIS and diffr DIS
X includes diffractive final states: dijets, charm, …

p'

scattered proton in the beam pipe;
can be detected by forward instrumentation (LPS, FPS)

e'

scattered electron

QCD factorization in hard diffraction

- Diffractive DIS, like inclusive DIS, is factorizable:

[Collins (1998); Trentadue, Veneziano (1994); Berera, Soper (1996)…]

universal partonic cross section

$$\sigma\,(\gamma^{*}p \rightarrow Xp) \approx f_{i/p}(z,Q^2,x_{IP},t) \times \sigma_{\gamma^{*}p}\,(z,Q^2)$$

Diffractive Parton Distribution Function (dPDF), evolve according to DGLAP

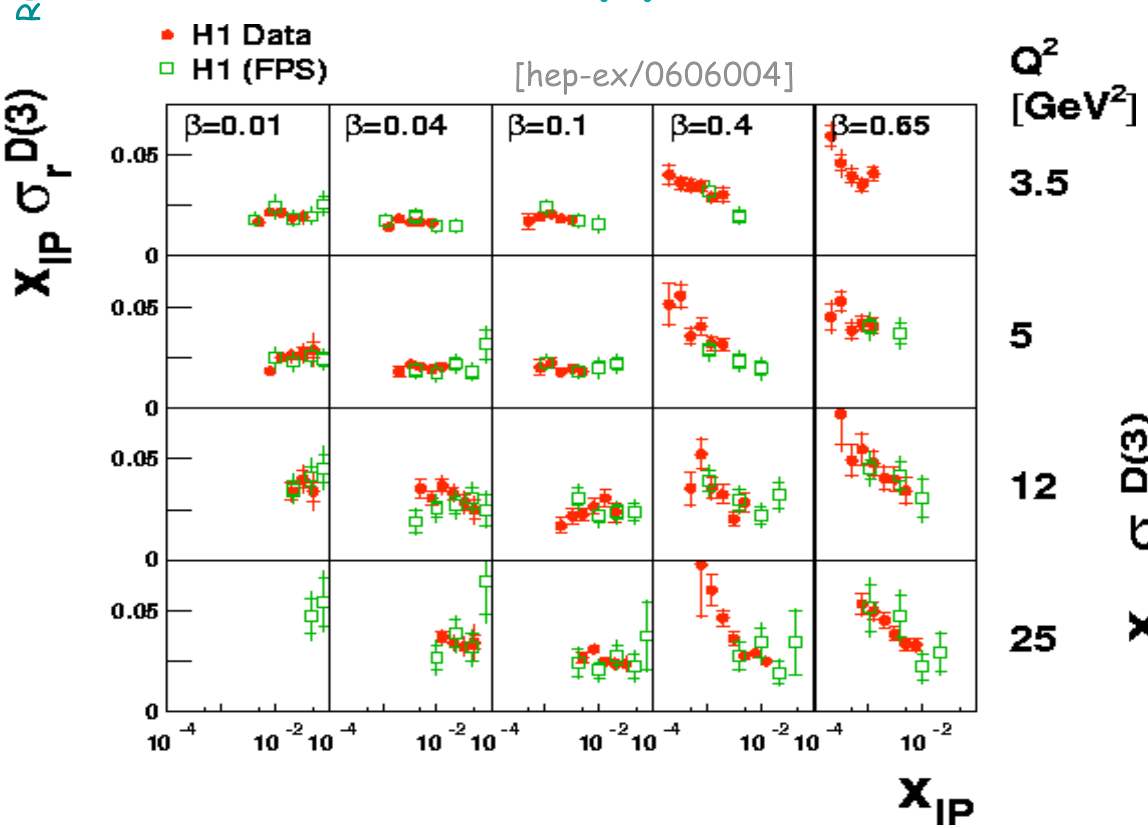
$f_{i/p}\,(z,Q^2,x_{IP},\,t)$ express the probability to find, with a probe of resolution Q^2, in a proton, parton i with momentum fraction z, under the condition that the proton remains intact, and emerges with small energy loss, x_{IP}, and momentum transfer t – diffractive PDFs are a feature of the proton

- *Assumption → proton vertex factorization:*

$$\sigma\,(\gamma^{*}p \rightarrow Xp) \approx f_{IP/p}(x_{IP},t) \times f_{i/p}(z,Q^2) \times \sigma_{\gamma^{*}p}\,(z,Q^2)$$

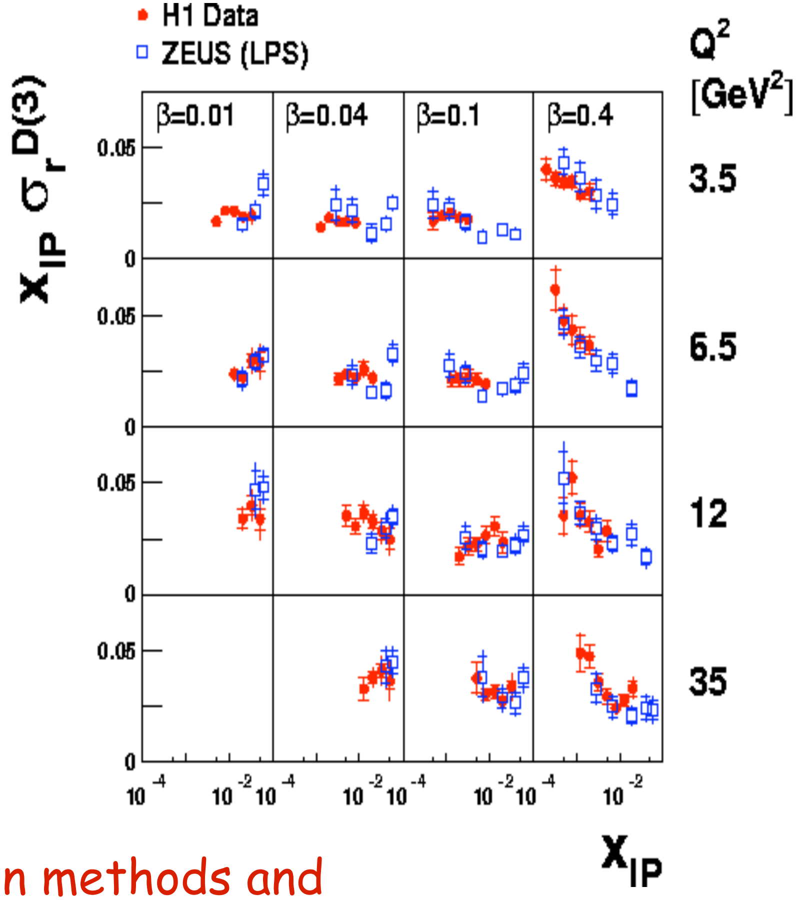
IP flux

Inclusive diffractive DIS



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

$$F_2^{D(3)}(\beta, Q^2, x_{IP}, t) = \frac{\beta Q^4}{4\pi\alpha^2(1 - y + y^2/2)} \cdot \frac{d\sigma^D_{ep\to e'Xp'}}{d\beta dQ^2 dx_{IP}}$$

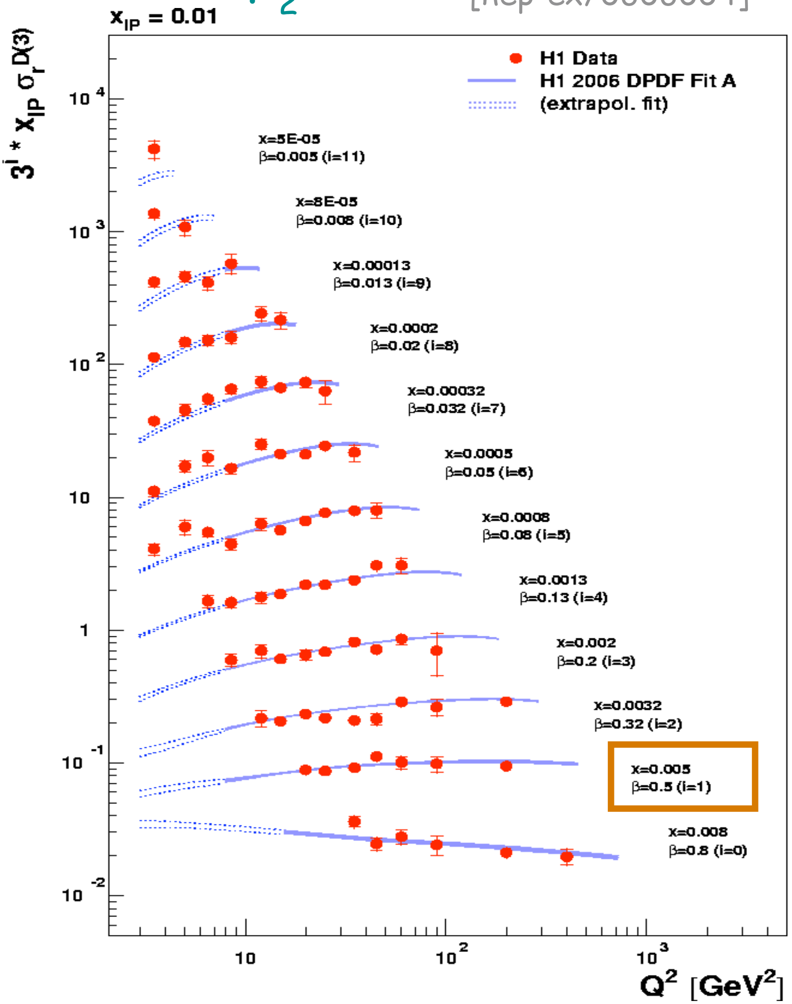


→ Good agreement between different selection methods and different experiments

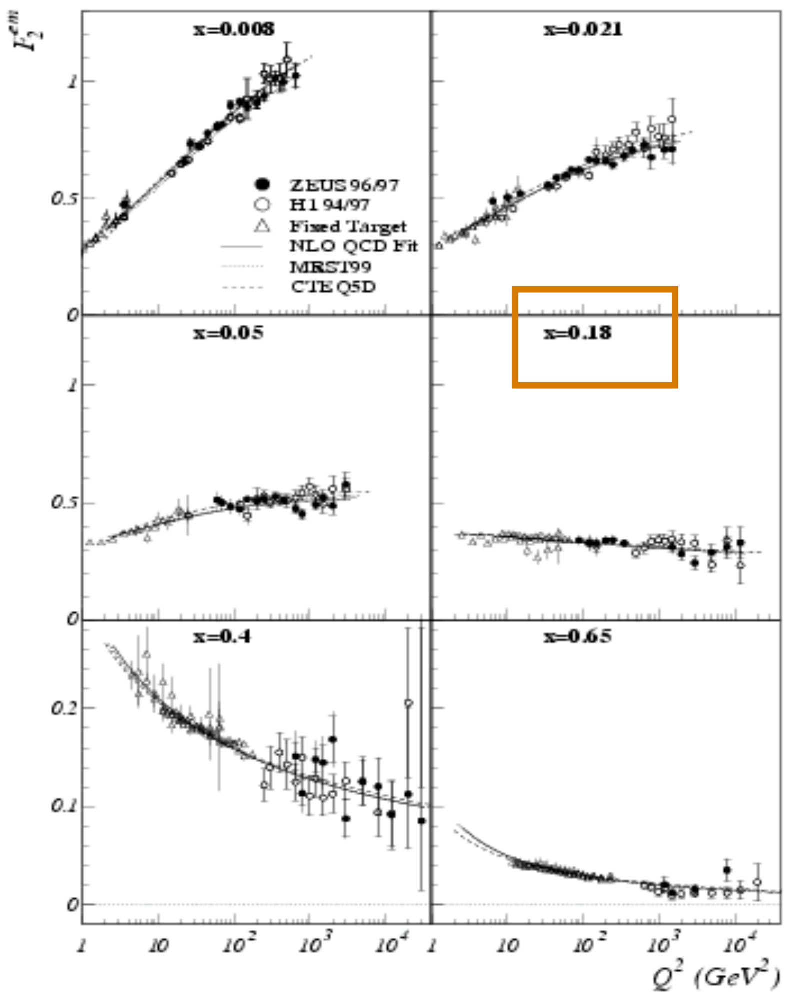
Inclusive diffractive DIS

F_2^D

[hep-ex/0606004]



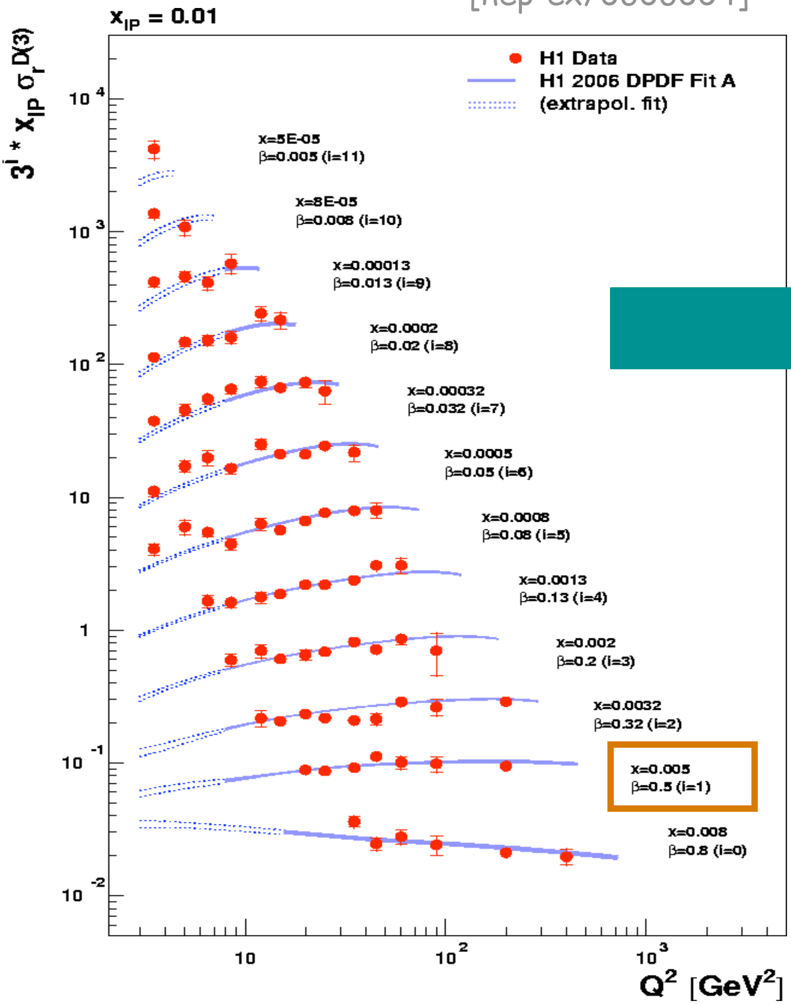
F_2



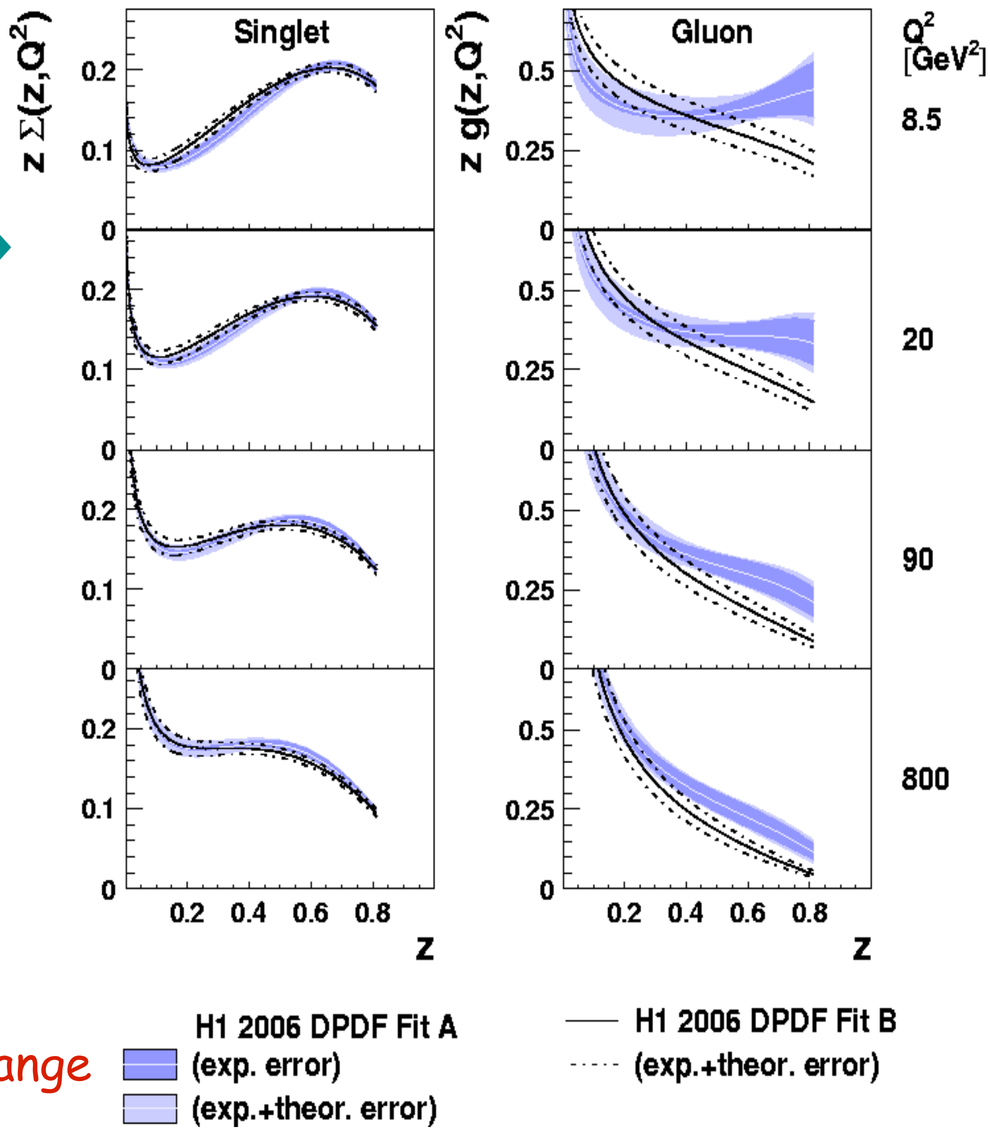
Positive scaling violations up to high β
→ lots of gluons in the diffractive exchange

Diffractive Parton Density Functions

[hep-ex/0606004]



z = fractional momentum of the diffractive exchange participating to the hard scattering

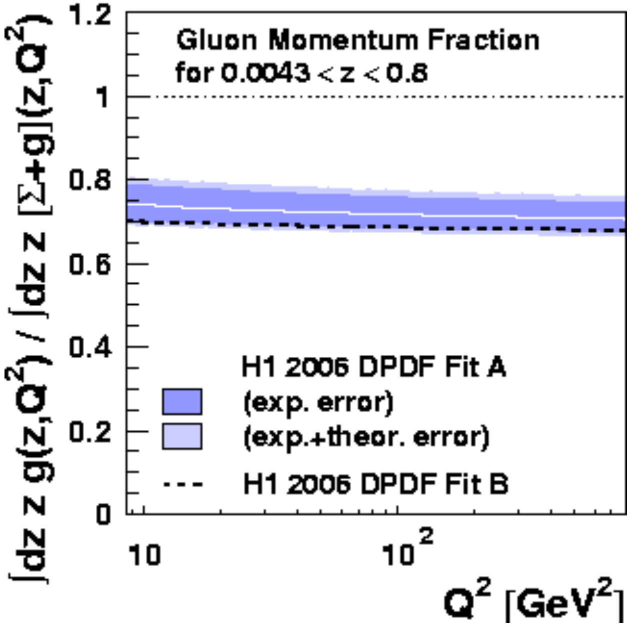


Positive scaling violations up to high β
→ lots of gluons in the diffractive exchange

Diffractive Parton Density Functions

- H1 DPDFs Fit A & B
- Well constrained singlet
- Weakly constrained gluons

(especially at high values of z)



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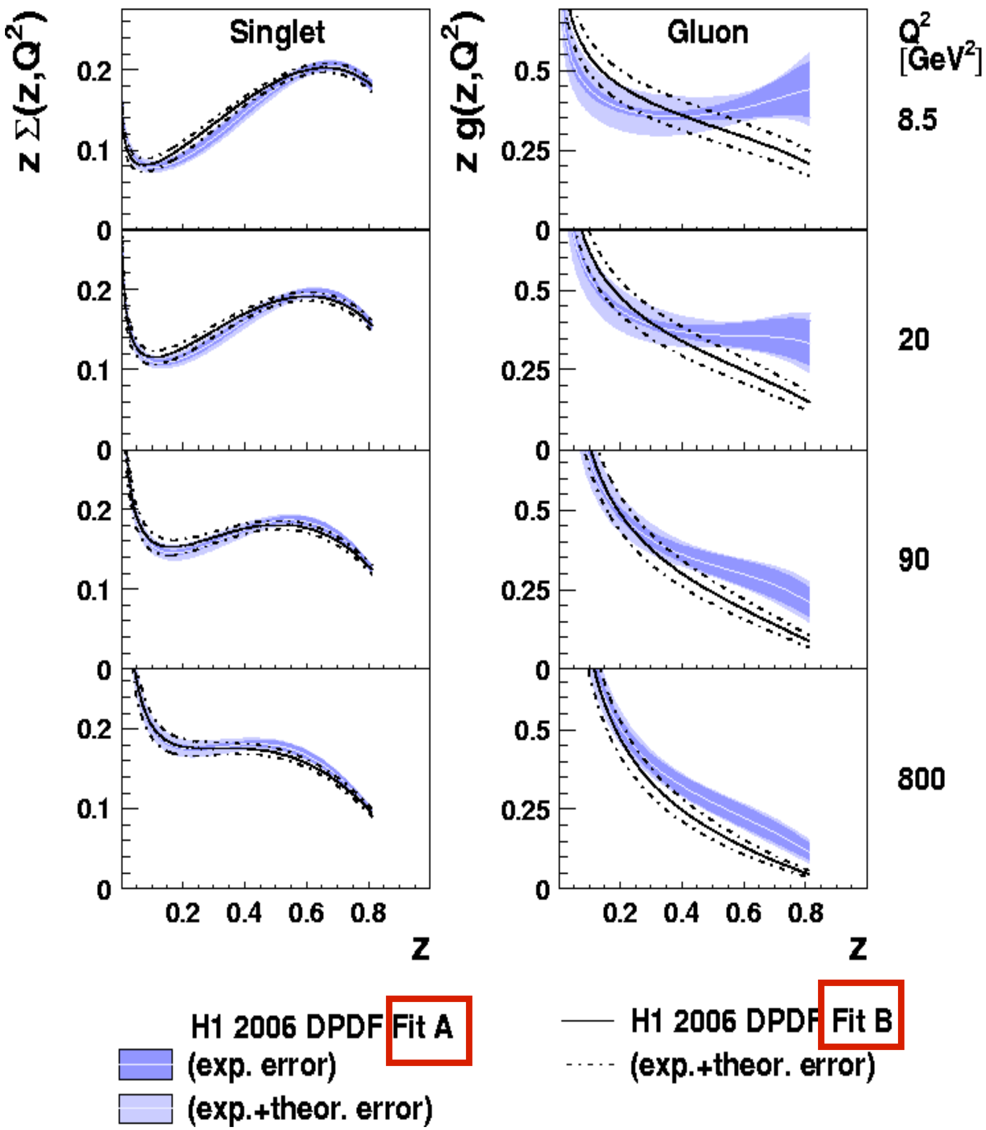
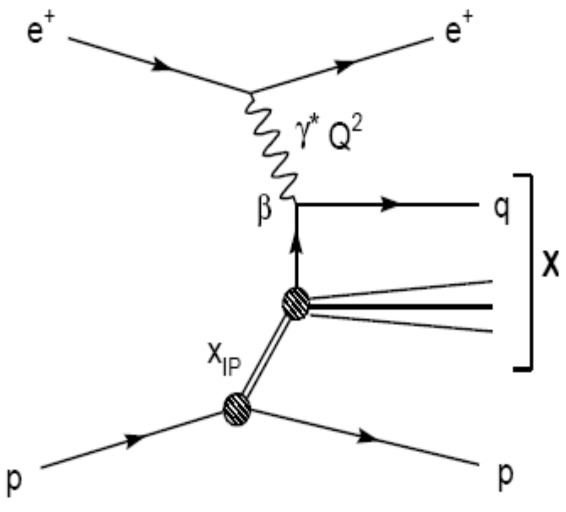
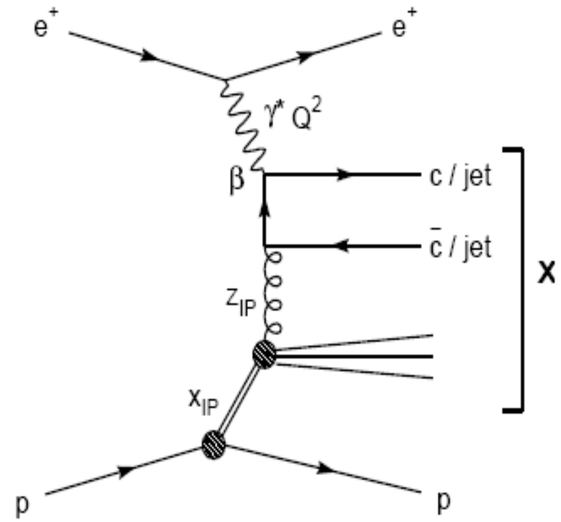


QCD factorization tests in hard diffraction

Get PDFs from inclusive Diffraction

Predict Cross Sections from exclusive Final States in Diffraction



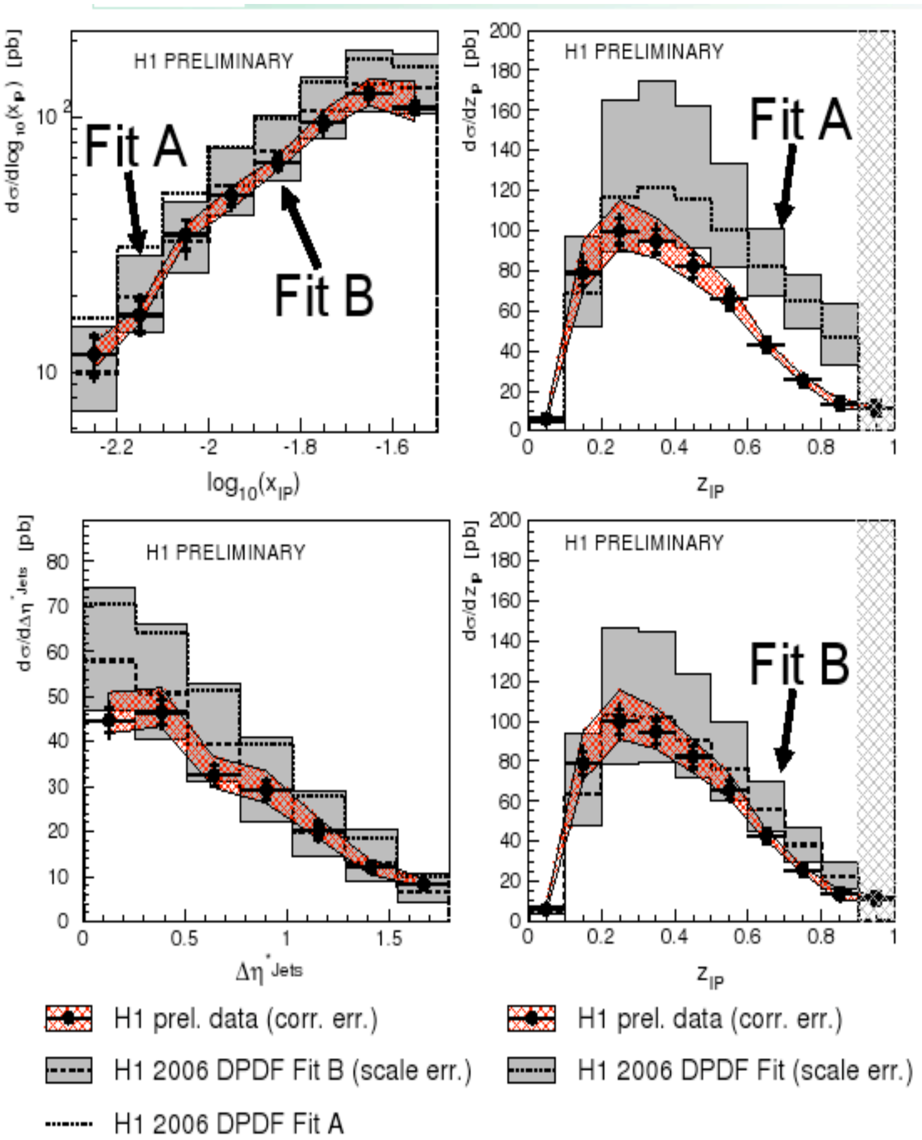


Gluon density only indirectely from scaling violations

Direct access to gluon density

(boson gluon fusion)

Diffractive dijet production in DIS



→ Fit A uncertainty not shown

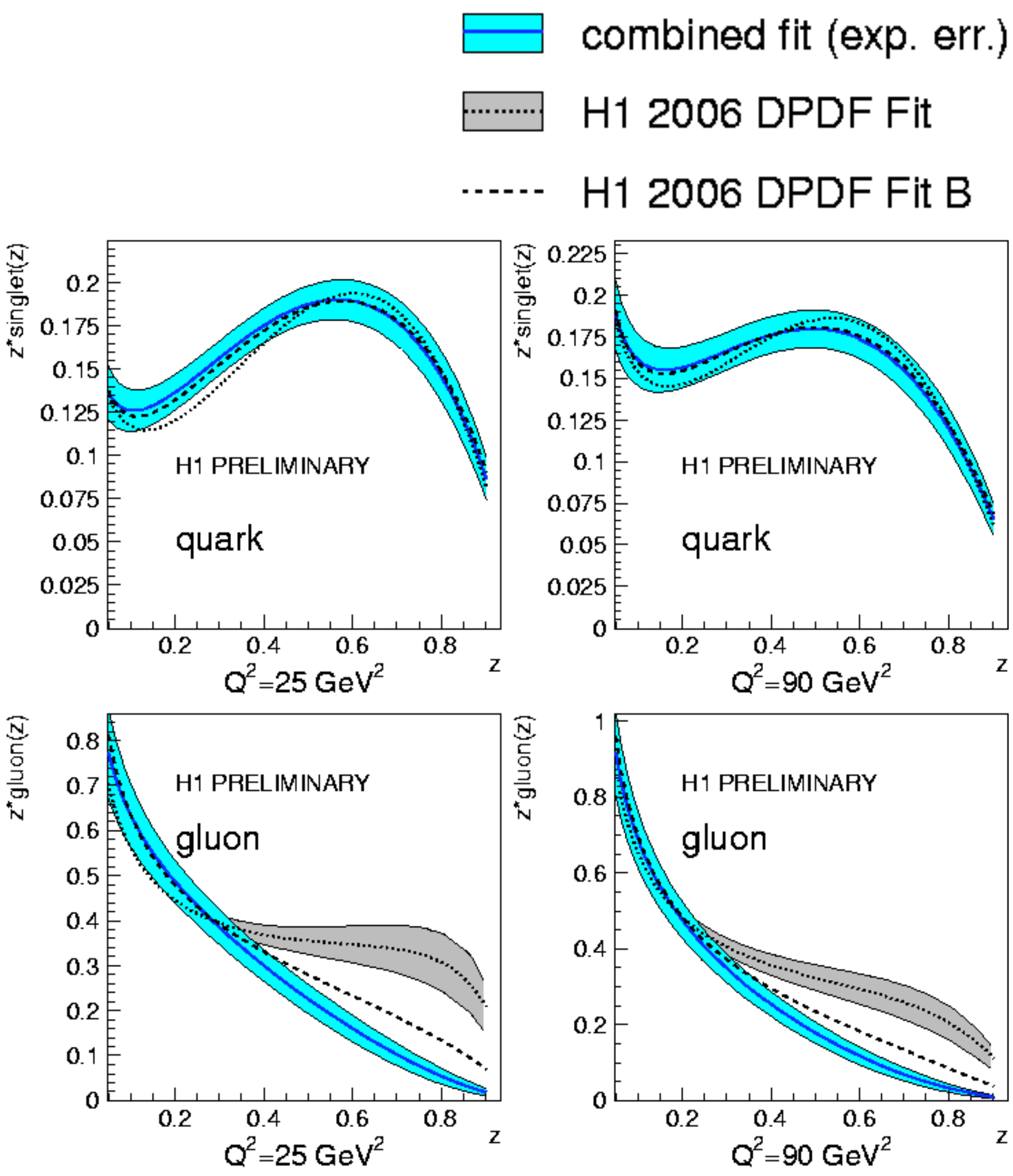
z_{IP} = fractional momentum of the diffractive exchange participating to the hard scattering

- z_{IP} distribution is the most sensitive to gluon dPDFs
→ difference between fit A and B at high z_{IP}

→ Data agree with NLO predictions and support factorization

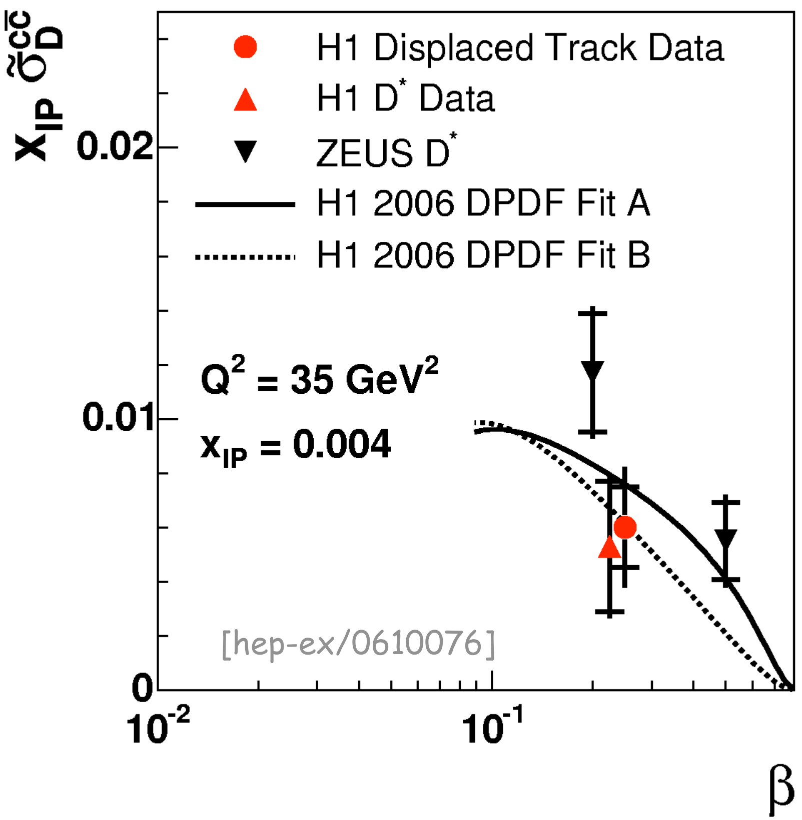
- statistics sufficient to make combined QCD fit to inclusive and dijets data

Combined fit to inclusive and dijet data

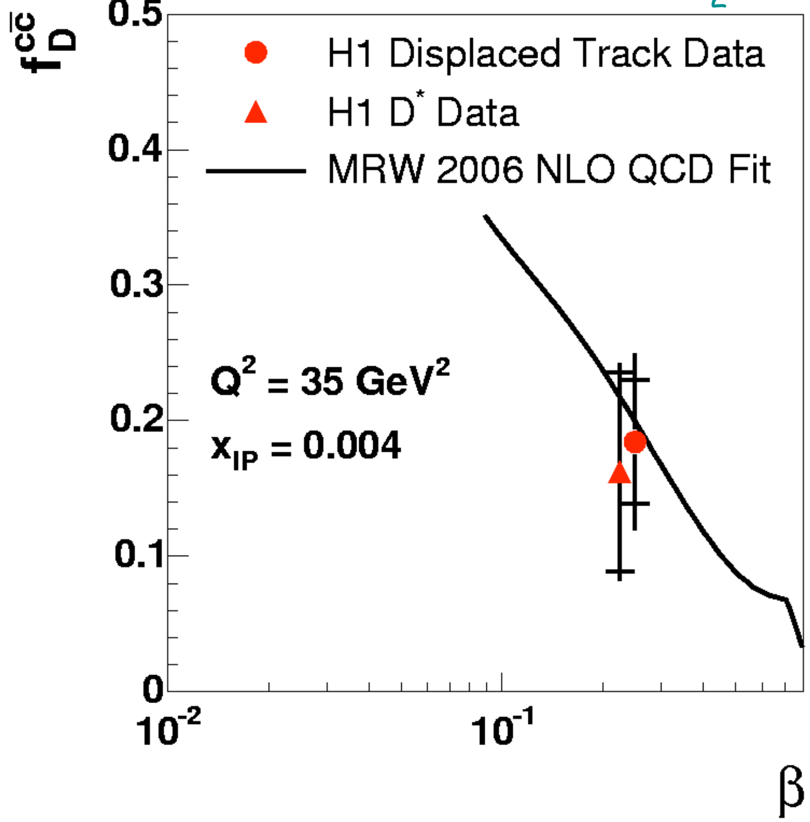


- combined fit constrains quark and gluon densities over a wide range ($0.05 < z_{IP} < 0.9$)
- uncertainty on gluon dPDFs reduced

Diffractive charm production in DIS



charm contribution to F_2^D



- statistically limited
- charm contribution to F_2^D comparable with charm fraction in inclusive DIS

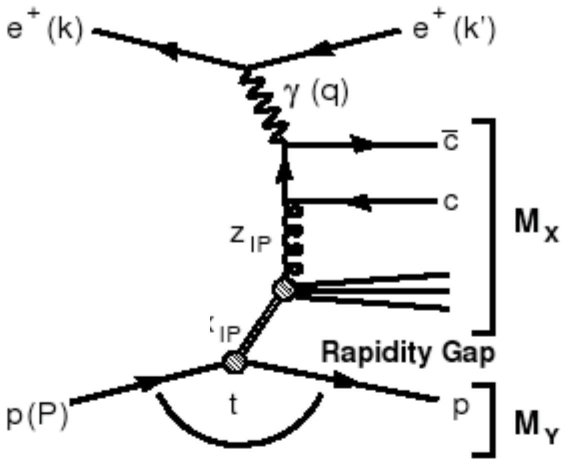
→ Data support factorization

Transition from ep to hadron-hadron

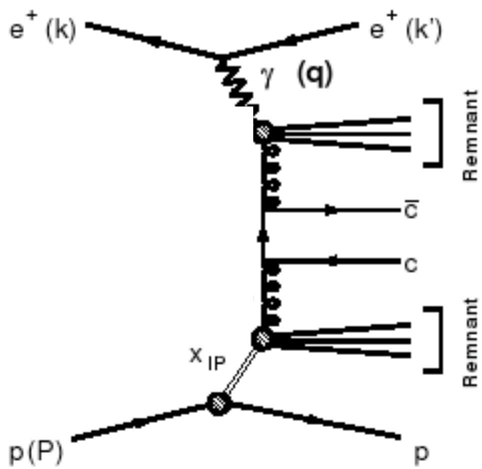
- Factorisation not expected to hold in pp, p$\bar{\text{p}}$ scattering – indeed it does not: factor 10 normalization discrepancy when HERA dPDFs are extrapolated to Tevatron → understood in terms of (soft) rescattering corrections of the spectator partons [e.g. Kaidalov, Khoze, Martin, Ryskin]

- At HERA the resolved photon in photoproduction (PhP) behaves like a hadron:

DIS and direct PhP



resolved PhP

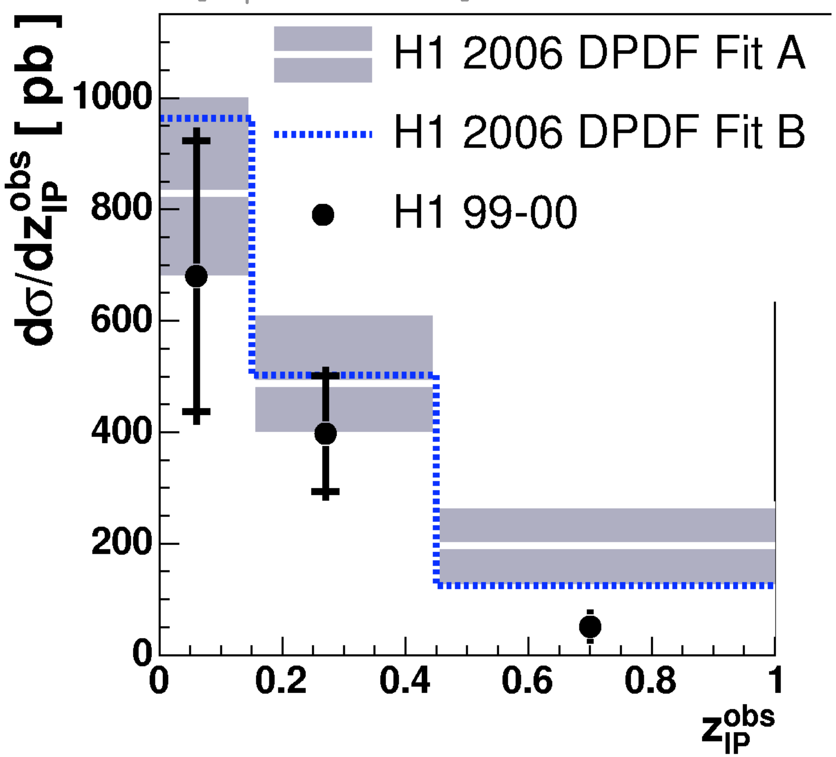


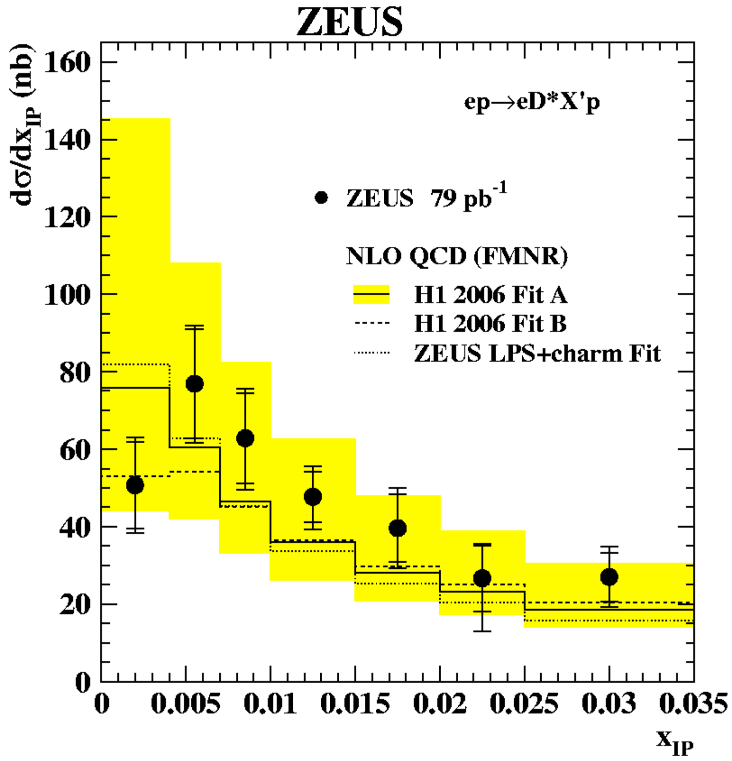
- Suppression factor 0.34 predicted for resolved PhP

[A. Kaidalov et al., Eur. Phys. J. C21, 521 (2001)]

Diffractive charm production in PhP

[hep-ex/0610076]

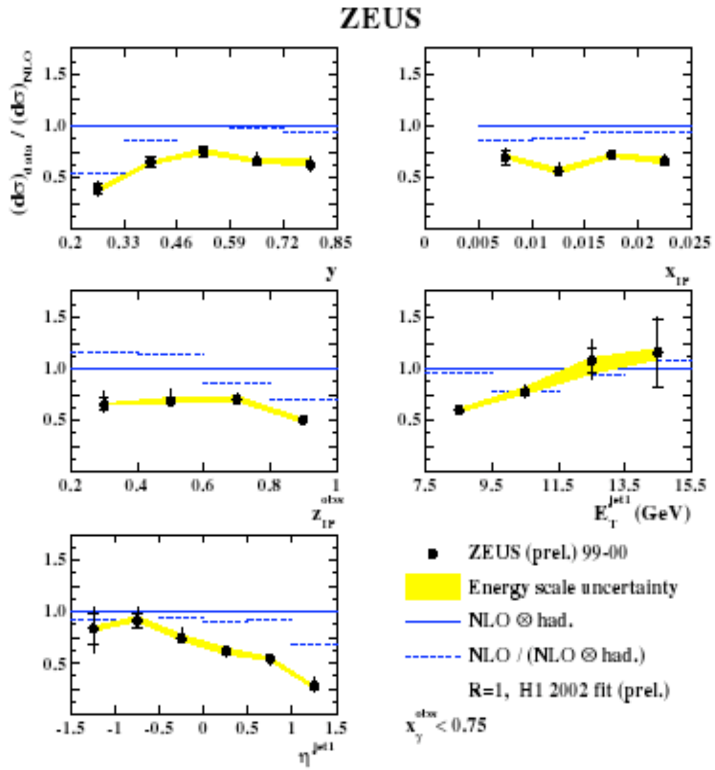


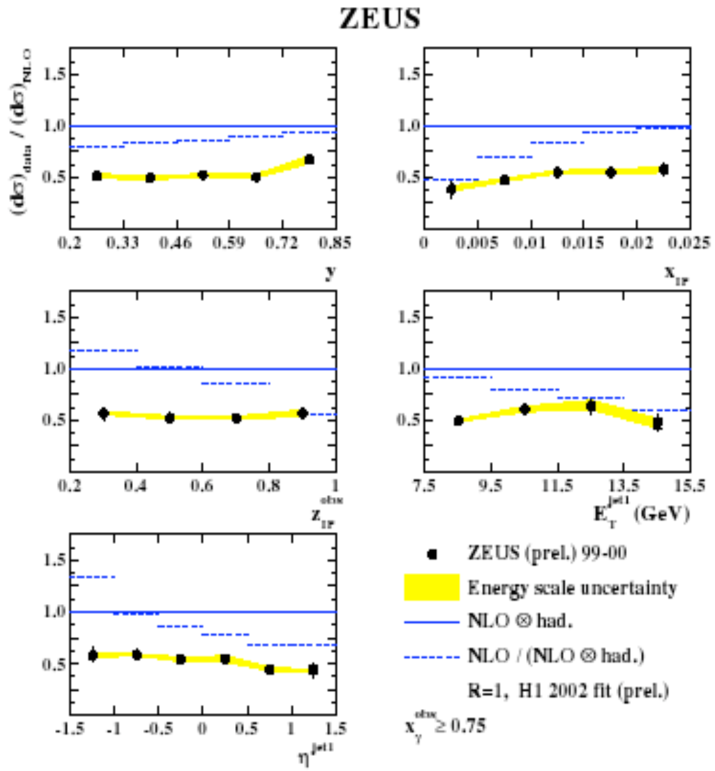


→ No evidence of factorization breaking but large NLO uncertainties and limited statistics

Diffractive dijet production in PhP

Resolved enriched $x_\gamma < 0.75$ | Direct enriched $x_\gamma > 0.75$





→ Data described in shape by NLO QCD predictions, but suppression factor common for both direct and resolved components

Summary

- Hard diffraction well understood in terms of QCD
- At HERA 2 experiments, different selection methods, many final states
- New dPDFs extracted from inclusive data available to test hard scattering factorization
  - inclusion of dijet data in the fits provides a much better constraint of the gluon density at high z
- Diffractive charm and dijet DIS data consistent with NLO predictions based on dPDFs from inclusive data → support factorization
- Diffractive dijet PhP data: no evidence of a suppression for the resolved component
- Diffractive charm PhP data: QCD factorization holds (but large NLO uncertainties)