Small X and Diffraction Workshop
FERMILAB, March 28th-31th 2007

Diffractive parton densities and factorization tests at HERA

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- H1 inclusive diffractive measurements
- H1 diffractive PDFs
- ZEUS and H1 diffractive final states: jets and open charm

Diffractive DIS at HERA

HERA: 10% of low-x Deep Inelastic Scattering (DIS) events are diffractive

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

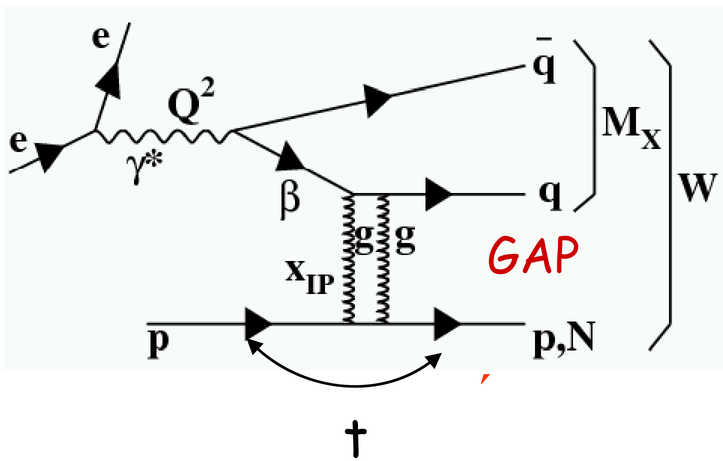
W = invariant mass of γ-p system

M_X = invariant mass of γ-IP system

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

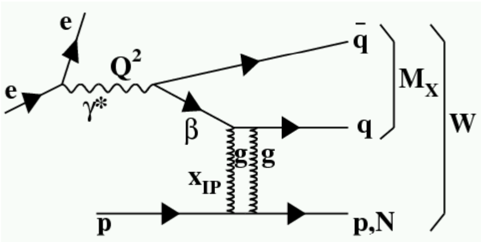
ß = Bjorken's variable for the IP
= fraction of IP momentum carried by struck quark
= x/x_{IP}

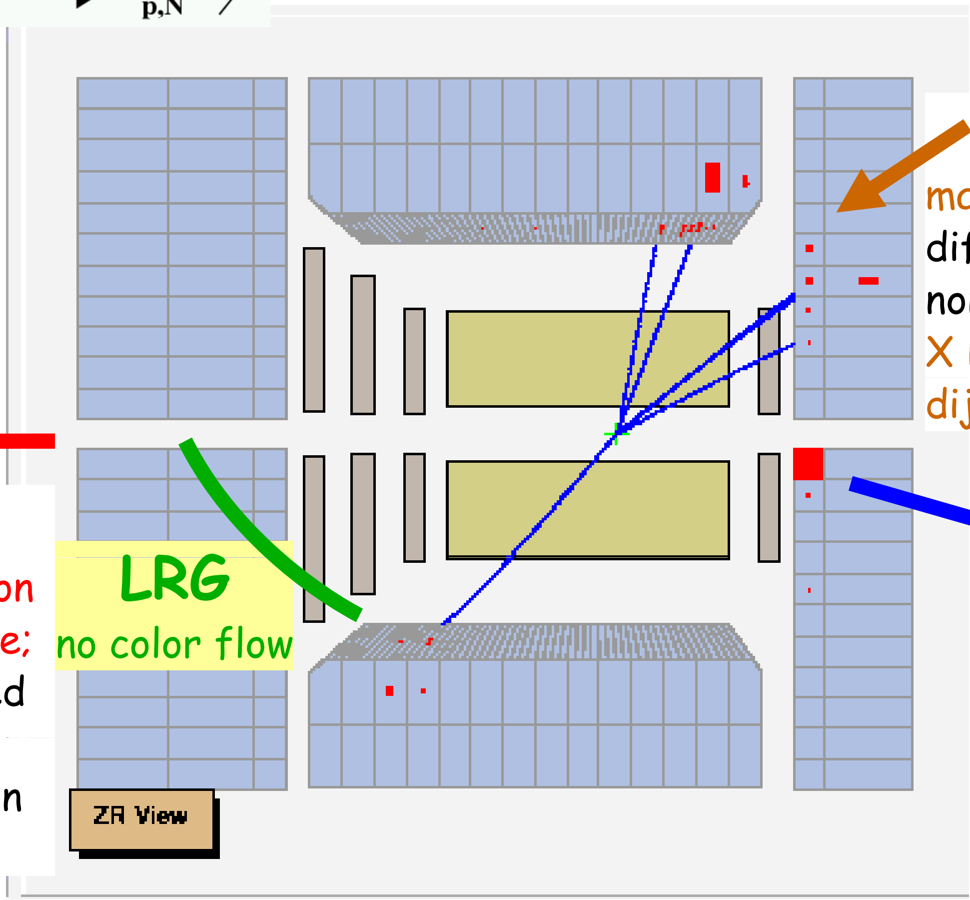
Diffractive DIS



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 fwd 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)...]

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

universal partonic cross section

Diffractive Parton Distribution Function (DPDF)

$f_{i/p}(z,Q^2,x_{IP},t)$ expresses 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 – the DPDFs are a feature of the proton and evolve according do DGLAP

- Assumption → proton vertex factorization:

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

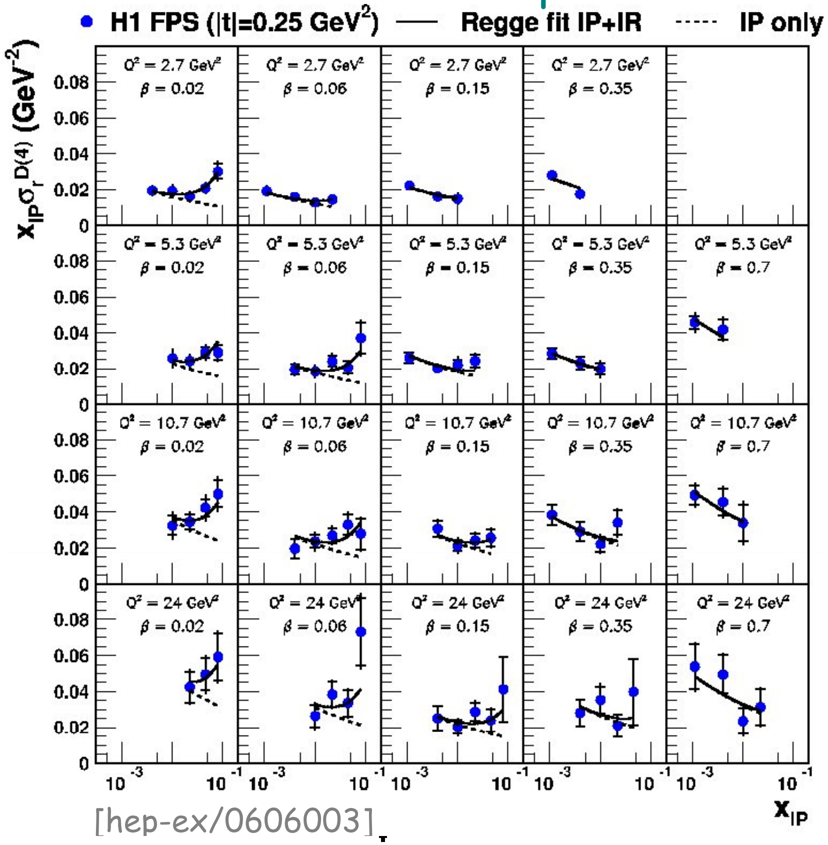
Regge motivated IP flux

At large x_{IP}, a separately factorizable sub-leading exchange (IR), with different x_{IP} dependence and partonic composition

H1 inclusive diffractive measurements

$\sigma_r^{D(3)} \sim F_2^{D(3)} - y^2/(1-(1-y)^2)\, F_L^{D(3)}$

FPS: N = p

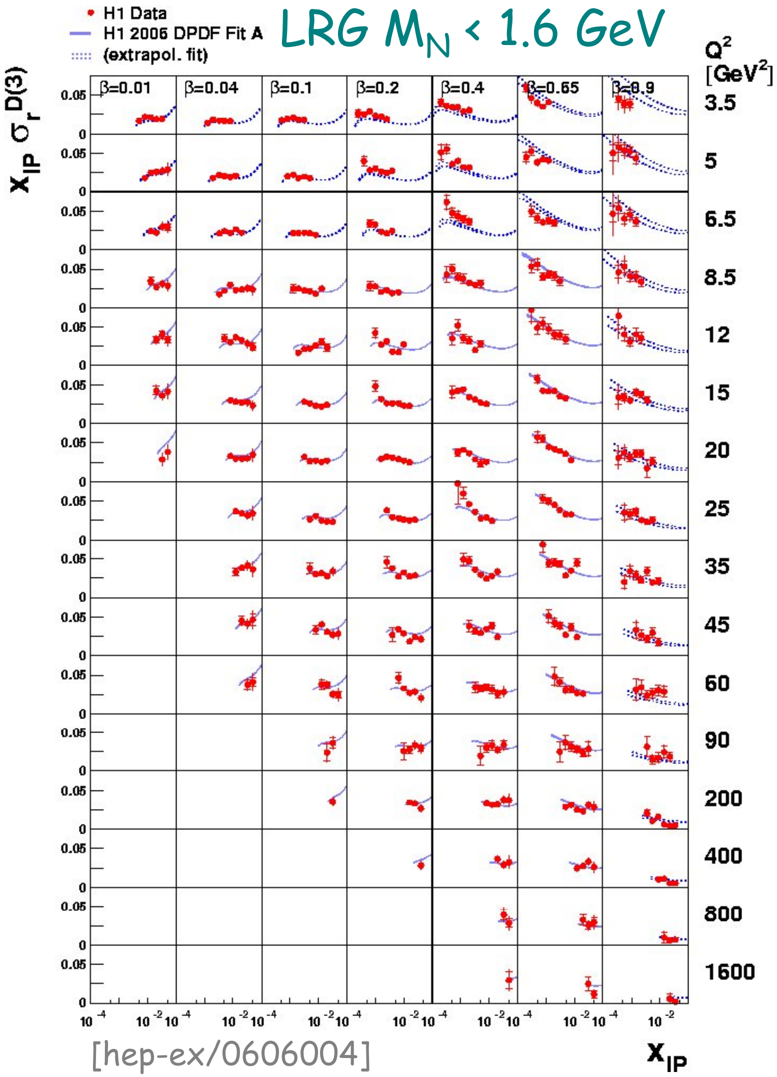


[hep-ex/0606003]

$$\alpha_{IP}(0) = 1.114 \pm 0.018(stat.) \pm 0.012(syst.)^{+0.040}_{-0.020}(theory)$$

$$\alpha'_{IP} = 0.06 \pm^{0.19}_{0.06}\ GeV^{-2}$$

LRG M_N < 1.6 GeV



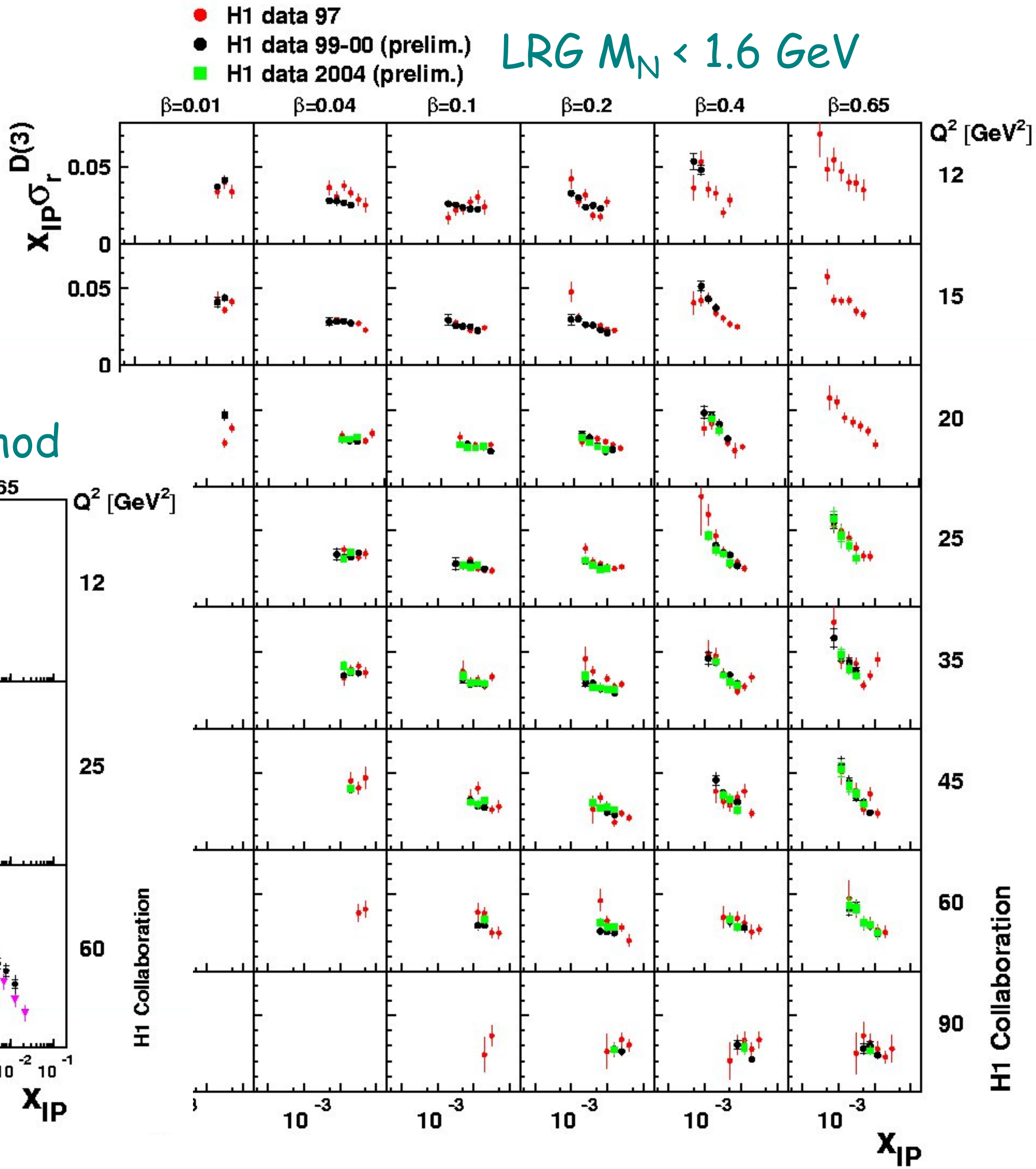
[hep-ex/0606004]

$$\frac{\sigma(M_Y < 1.6\ \mathrm{GeV})}{\sigma(Y = p)} = 1.23 \pm 0.03\ (\mathrm{stat.}) \pm 0.16\ (\mathrm{syst.})$$

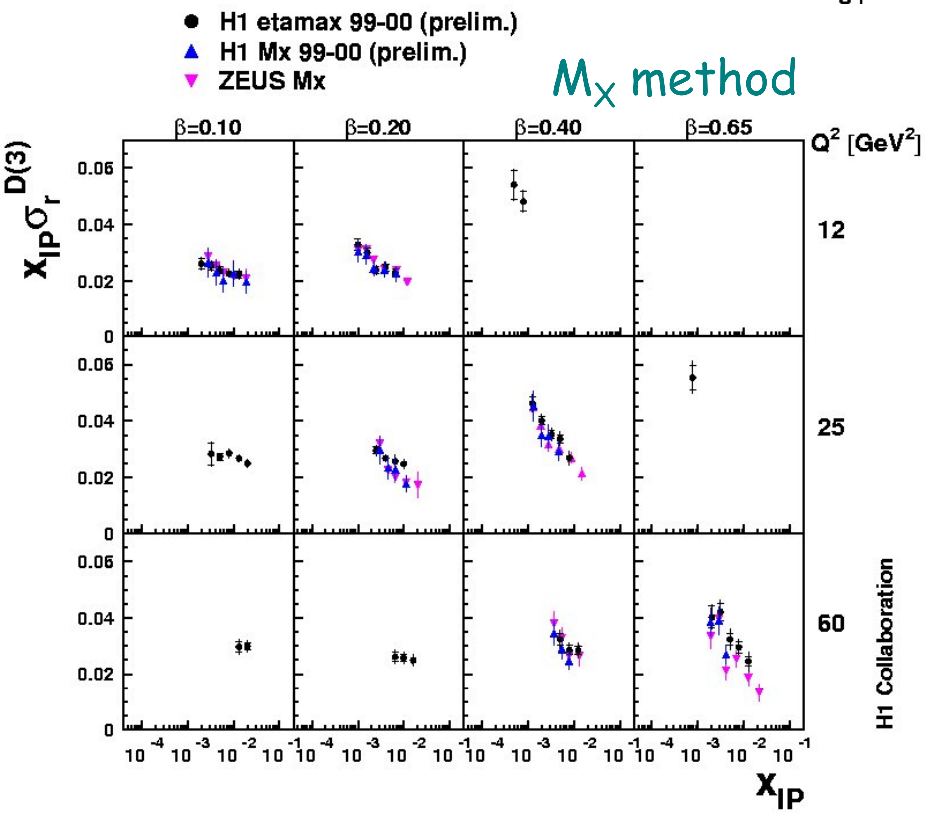
H1 inclusive diffractive measurements

- Also
  - recent HERA II LRG
  - recent M_X method

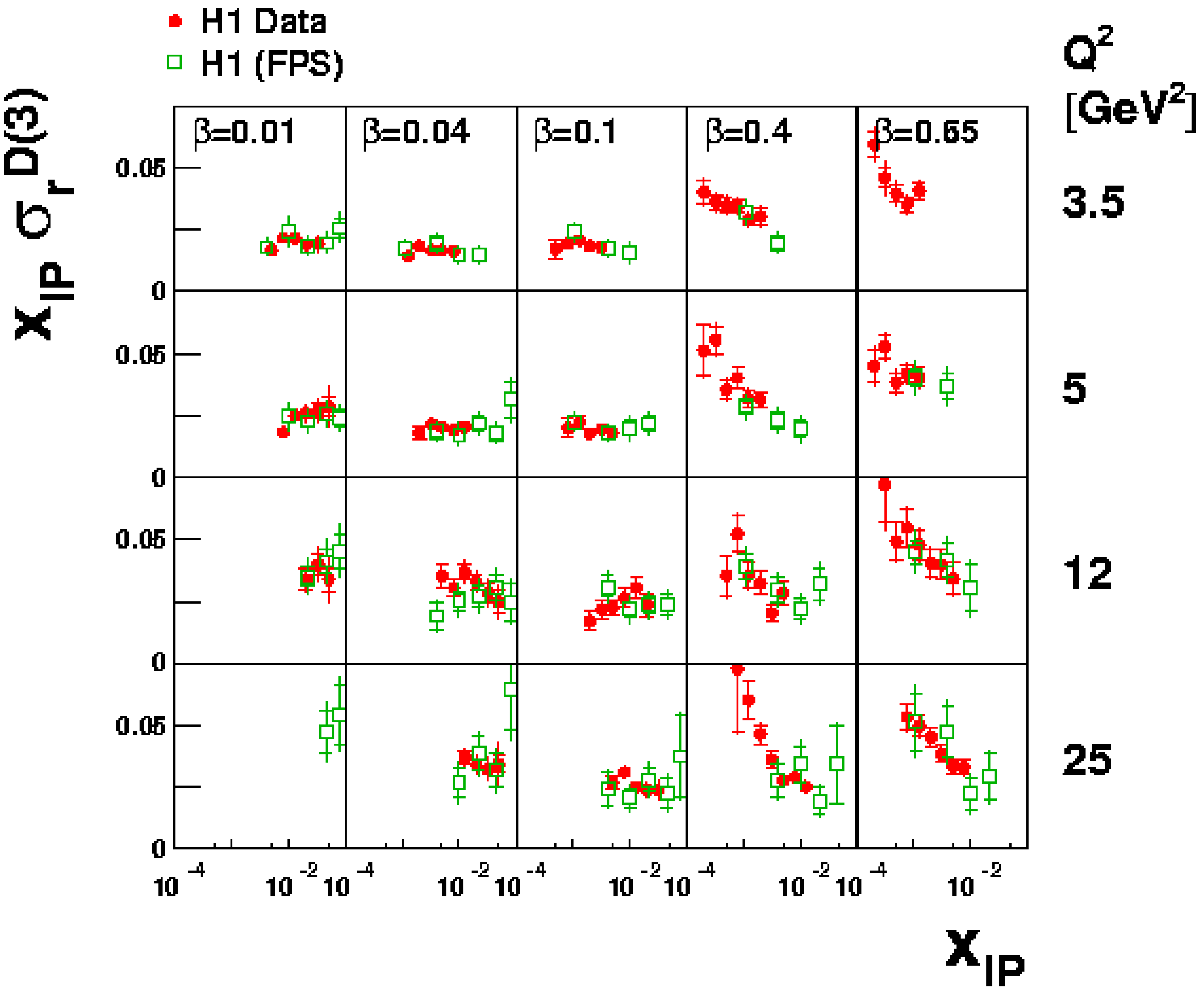
LRG M_N < 1.6 GeV



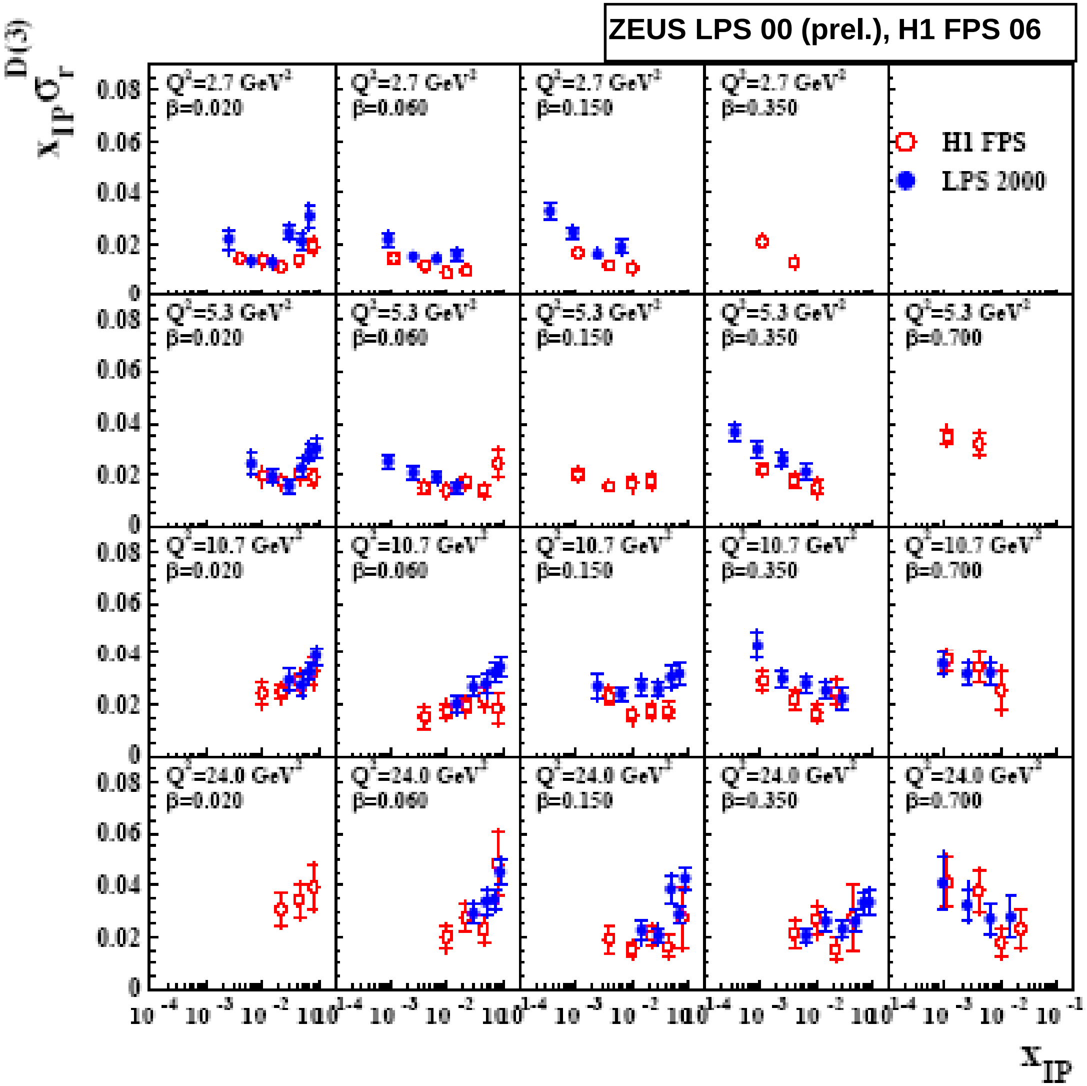
M_X method



Comparison H1 LRG - H1 FPS



Comparison ZEUS LPS - H1 FPS



- Normalization uncertainties not shown:

+12% / -10% for ZEUS LPS

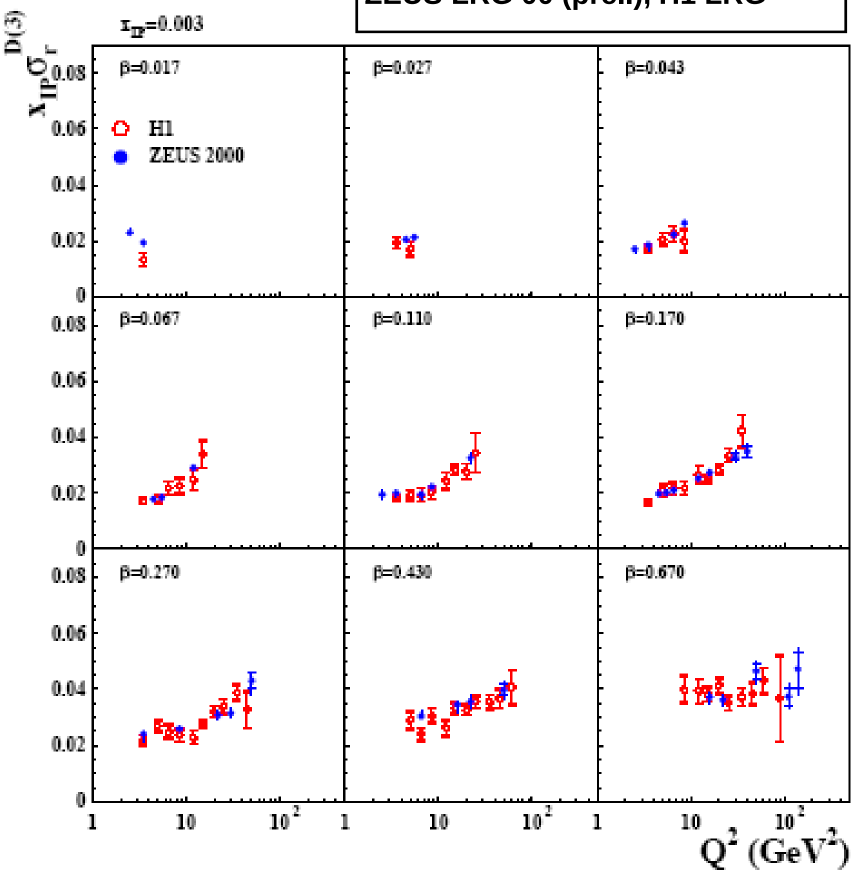
+/-10% for the H1 FPS data

→ Fair agreement

Comparison ZEUS LRG - H1 LRG

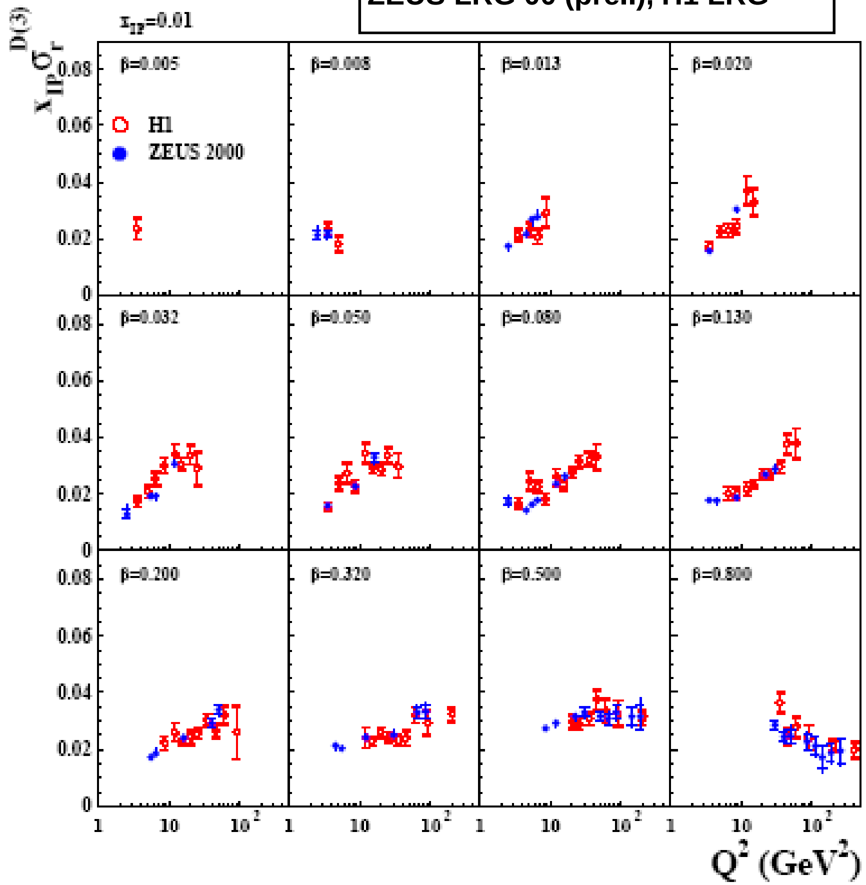
x_{IP} = 0.003

ZEUS LRG 00 (prel.), H1 LRG



x_{IP} = 0.01

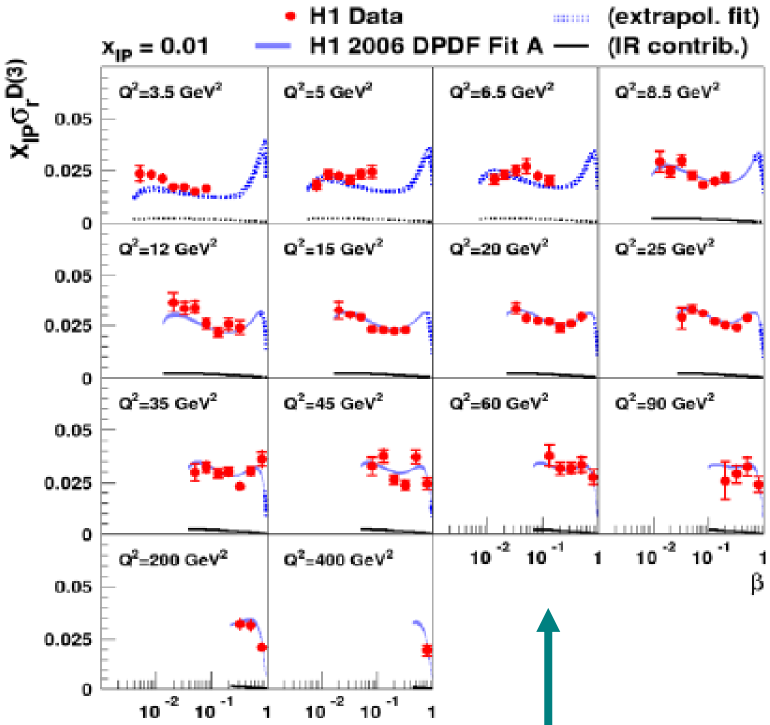
ZEUS LRG 00 (prel.), H1 LRG

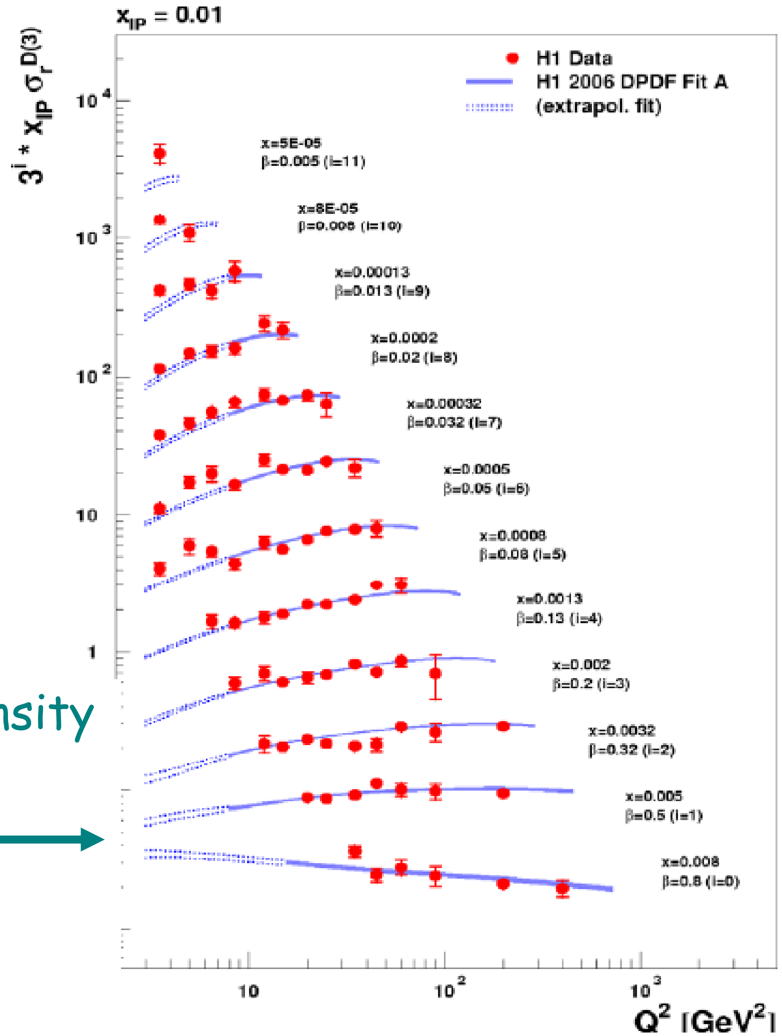


→ Fair agreement

- Fraction of proton dissociation events different for ZEUS and H1 detectors
- ZEUS LRG data normalized to H1 LRG data

DPDFs extraction





Reduced cross section constrains quark density

lnQ^2 dependence constrains gluon density →

- Positive scaling violations up to high β

→ lot of gluons in the diffractive exchange

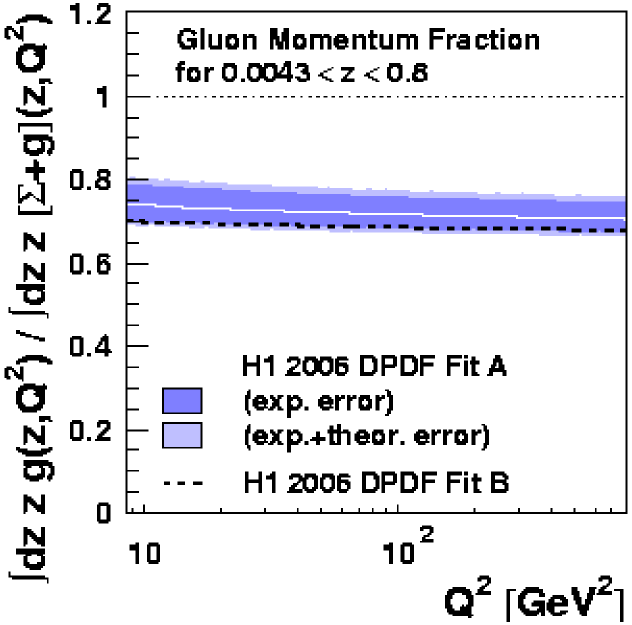
> Fit LRG data with fixed x_{IP} binning
> Use proton vertex factorization with $\alpha_{IP}(t)$ from FPS and LRG data to relate data from different x_{IP} values with complementary β, Q^2 coverage
> Exclude data with M_X < 2 GeV or β > 0.8 and with Q^2 < 8.5 GeV²

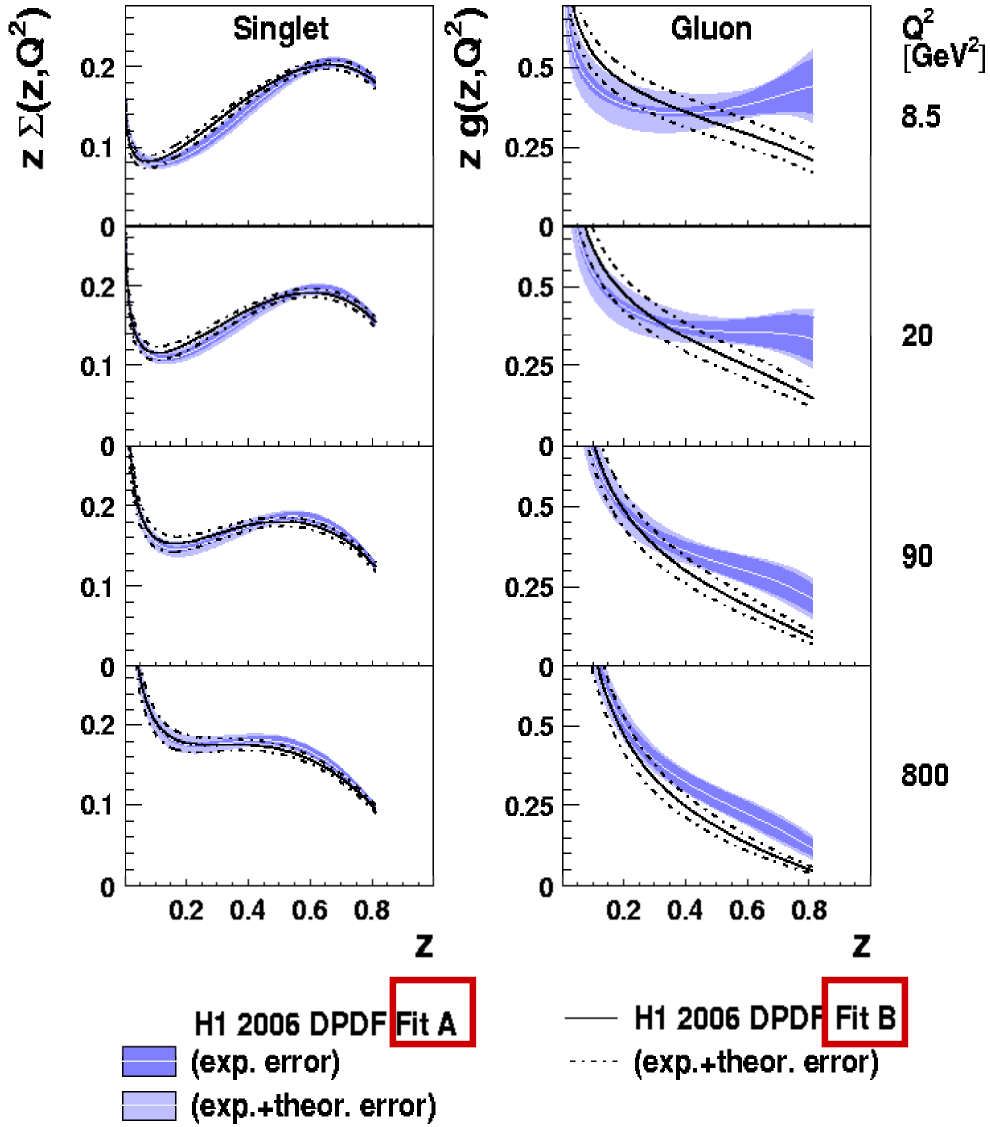
DPDFs

- H1 DPDFs Fit A & B

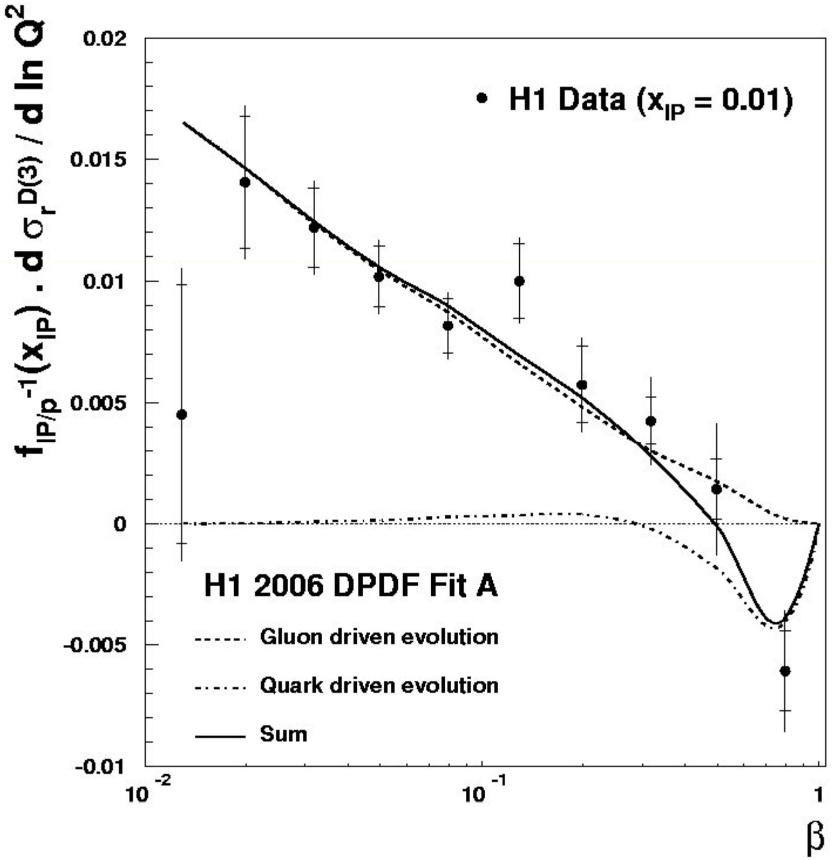
  (error analysis performed)
- Well constrained singlet
- Weakly constrained gluons

  (exp. at high values of z)





Why is the high z gluon so poorly known?



- Low β :
  evolution driven by **g → qqbar,**
  strong sensitivity to gluons

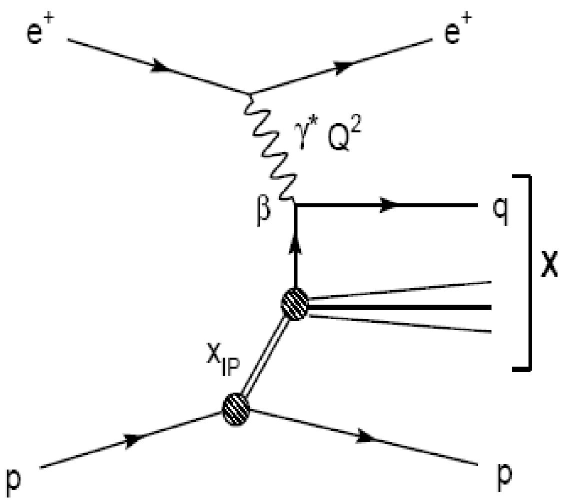
- High β:
  relative error on derivative grows,
  q→ qg contribution to evolution dominant

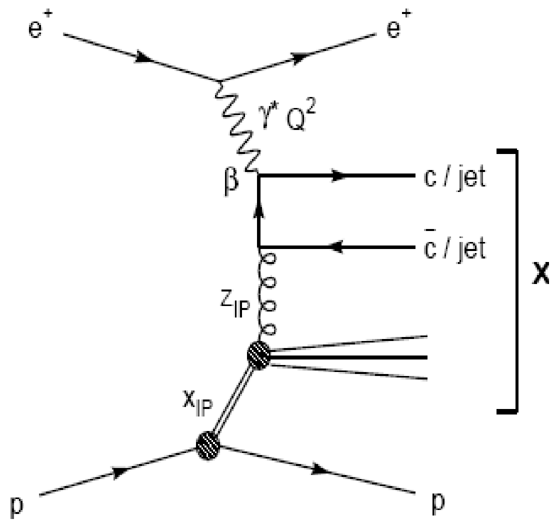
- Fit A: $zg(z, Q_0^2) = A(1-z)^B$
  Fit B: $B = 0$
  gluon constant at Q_0^2

Hard factorization tests in diffraction

Get PDFs from inclusive Diffraction

Predict Cross Sections from exclusive Final States in Diffraction



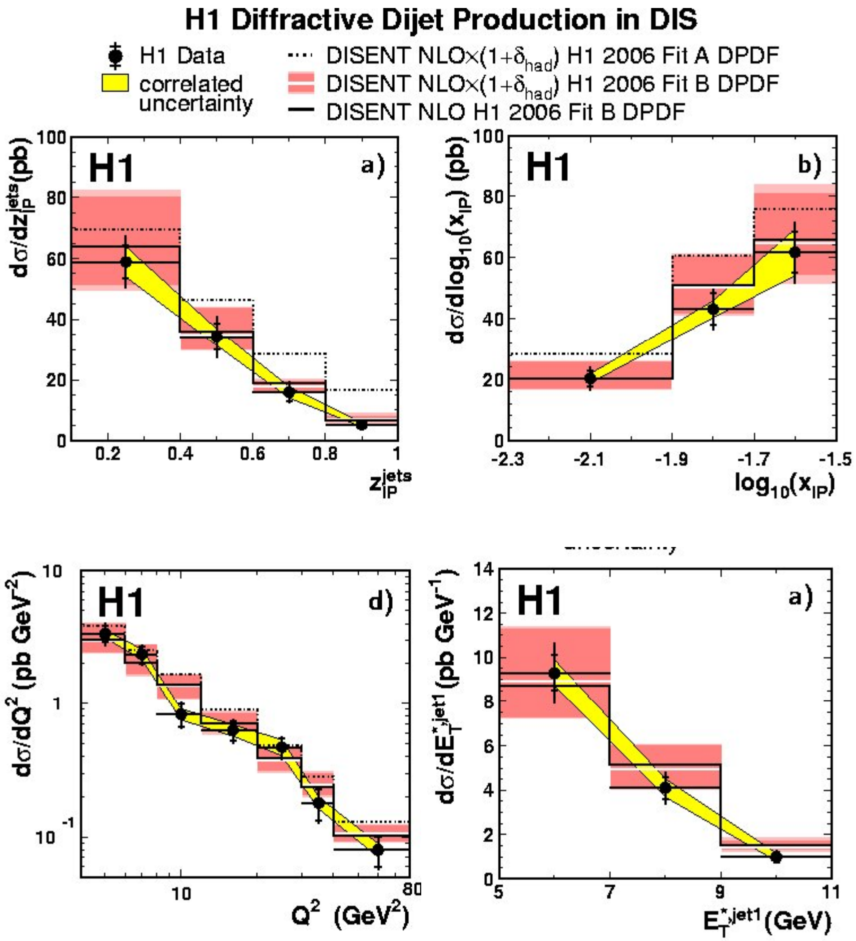


Gluon density only indirectely from scaling violations

Direct access to gluon density

(boson gluon fusion)

Diffractive dijet production in DIS



[hep-ex/0703022]

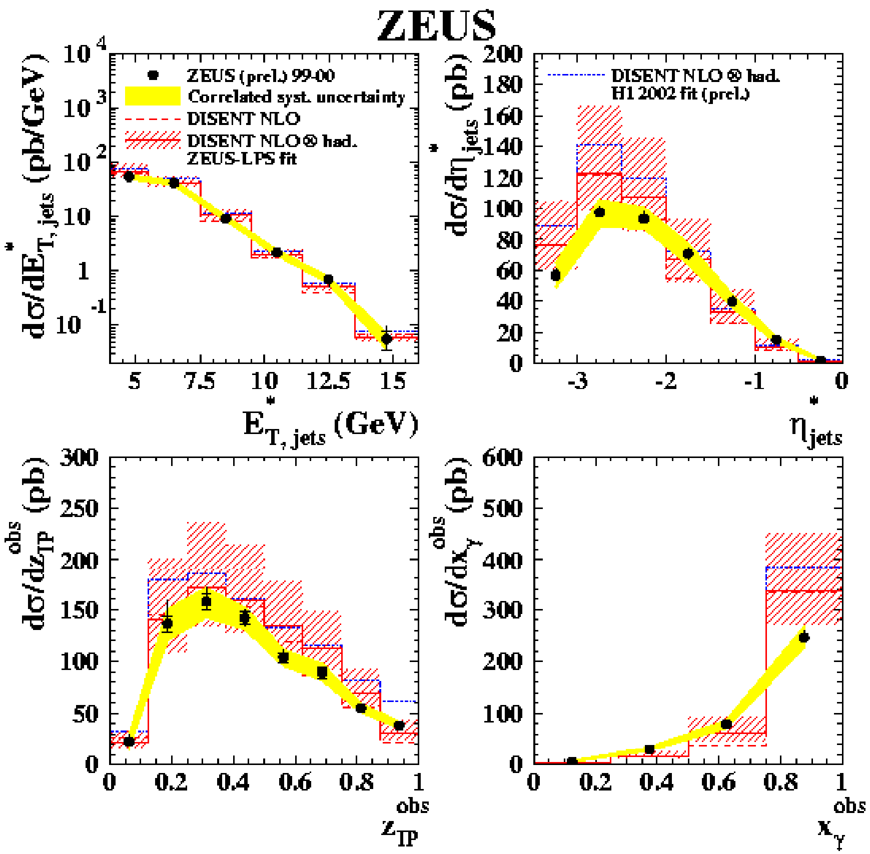
z_{IP} = fractional momentum of the diffractive exchange participating in the hard scattering

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

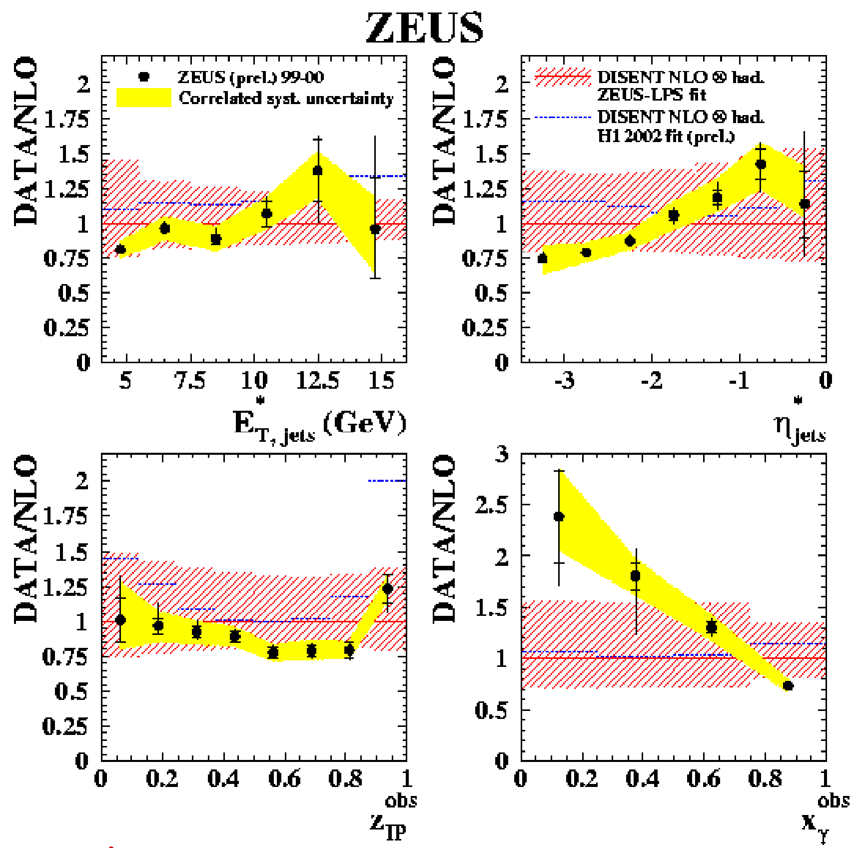
  → data agree with NLO predictions and support factorization

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

Diffractive dijet production in DIS



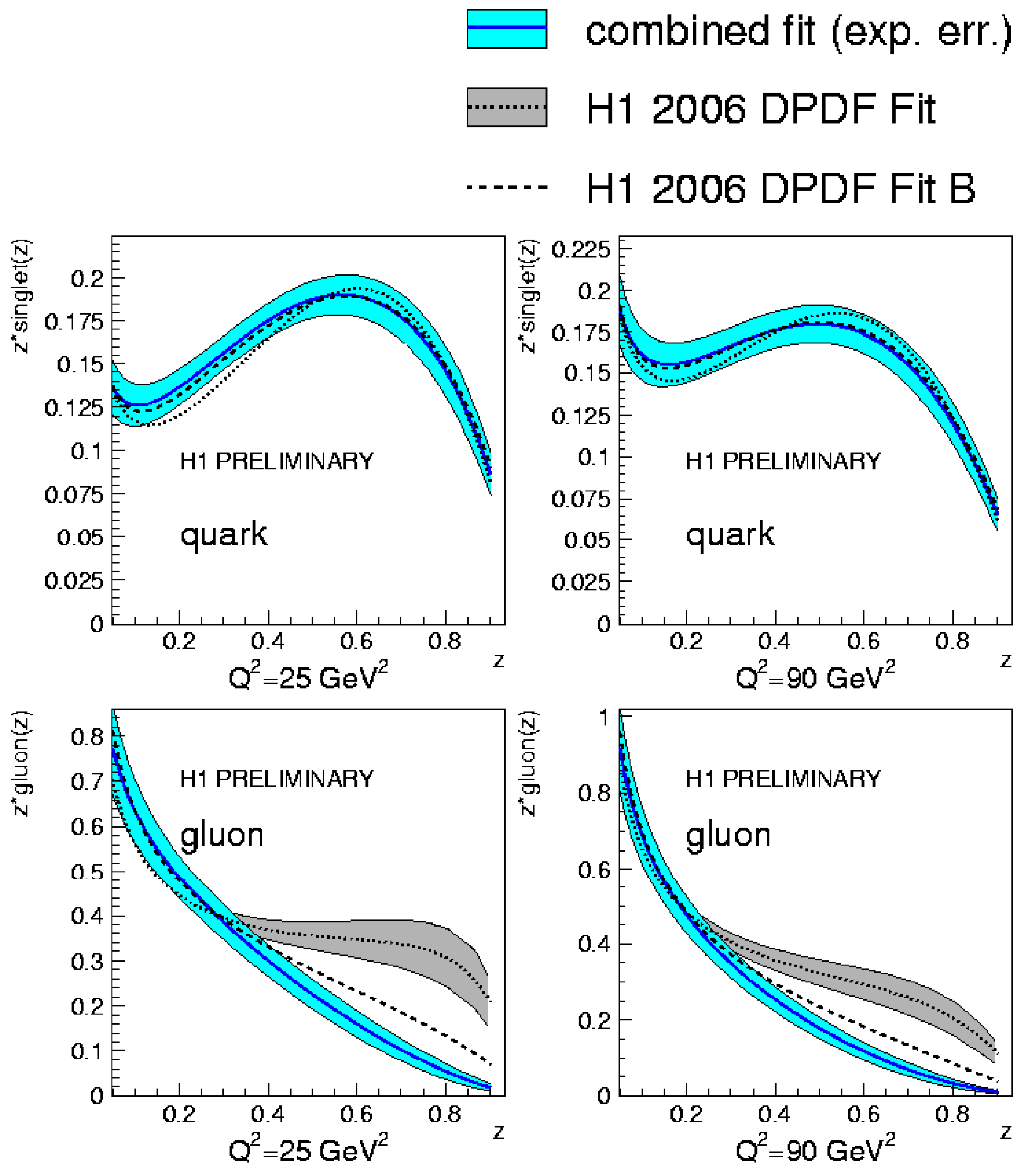
x_γ = fractional momentum of the photon participating in the hard scattering



- ZEUS LPS-fit: LPS data fitted together with open charm data [EPJ C 38 (2004)]

→ Similar conclusion from ZEUS prel results

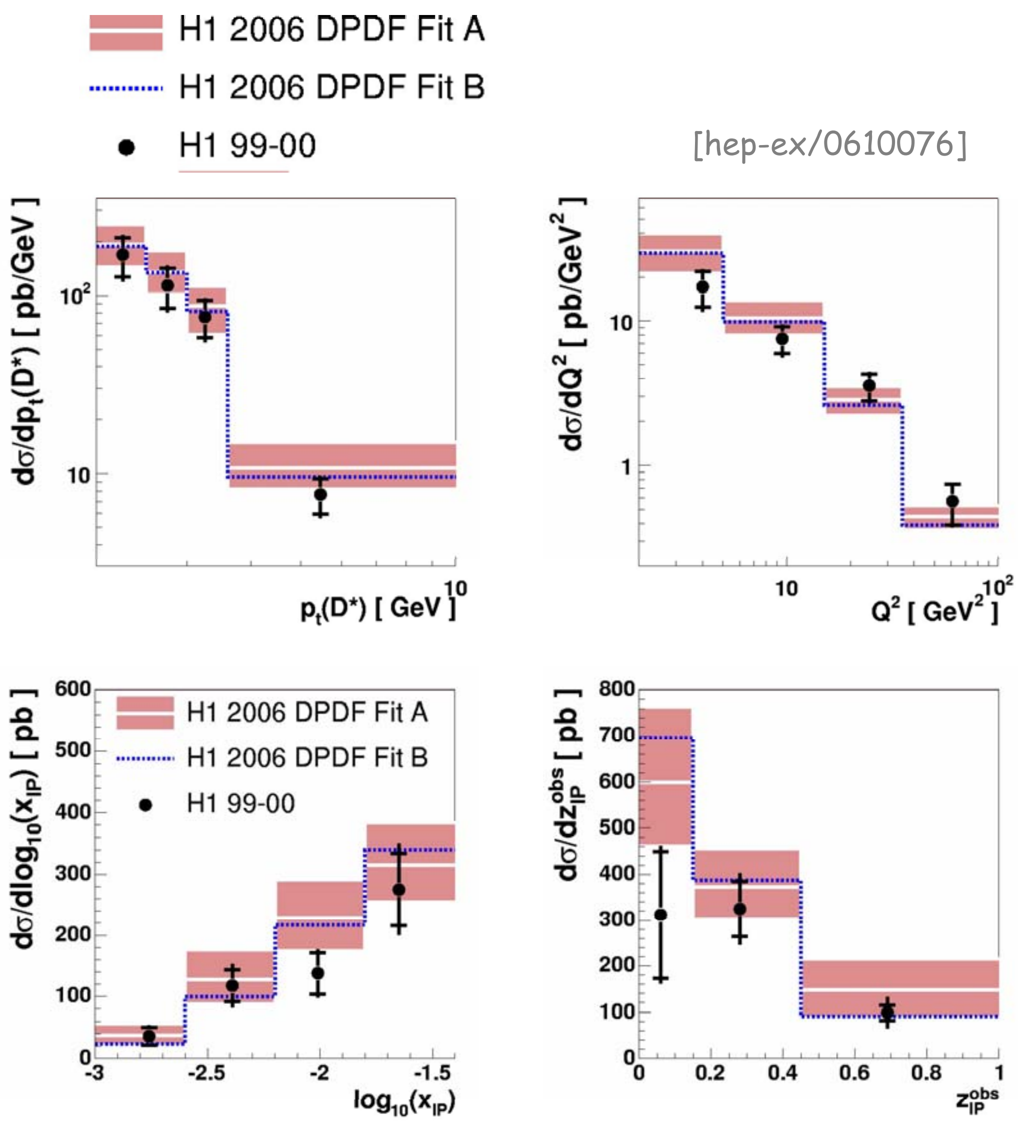
Combined fit to inclusive and dijet data



→ Combined fit constrains quark and gluon densities over a wide range ($0.05 < z_{IP} < 0.9$)

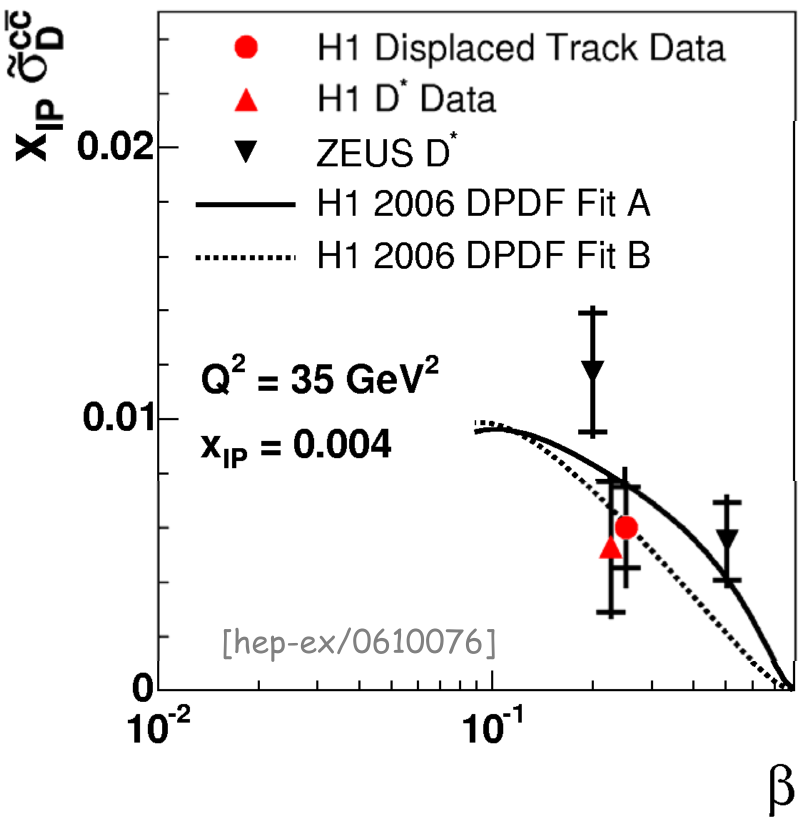
→ Uncertainty on gluon density reduced

Diffractive charm production in DIS

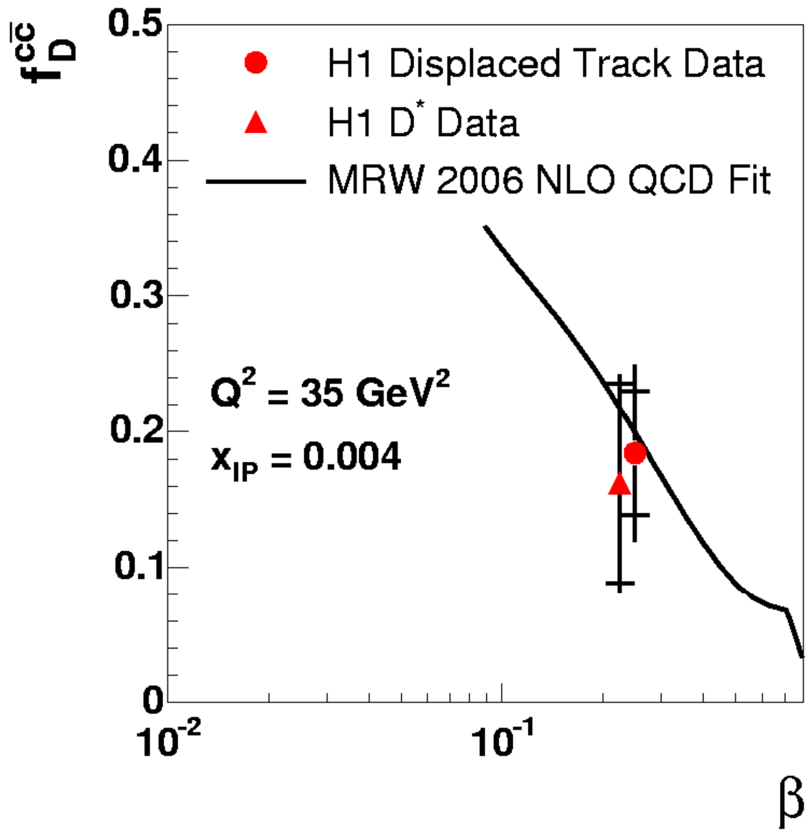


→ Within the present experimental errors and theoretical uncertainties data agree with NLO predictions and support factorization

Diffractive charm production in DIS



charm contribution to F_2^D



- Statistically limited
- Charm contribution to F_2^D ~20% → comparable with charm fraction in inclusive DIS

→ Data support factorization

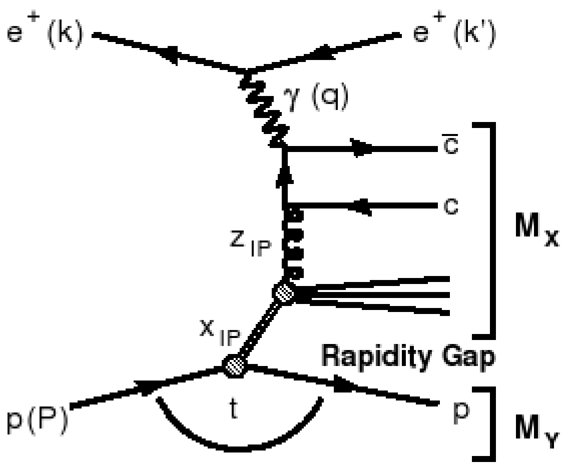
Transition from ep to hadron-hadron

- Factorisation not expected to hold in pp, $p\bar{p}$ scattering
[Kaidalov, Khoze, Martin, Ryskin, Goulianos, Levin., Gotsman, Maor, ..]

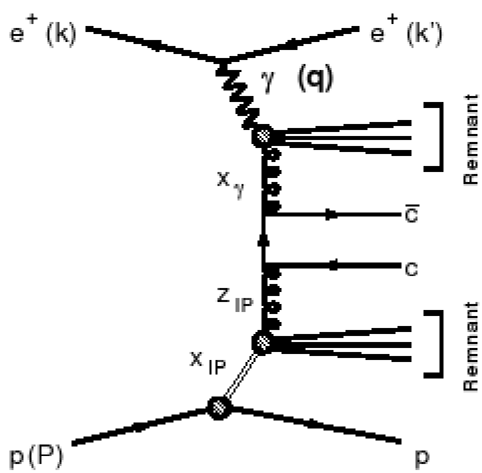
Indeed it does not: factor 10 normalization discrepancy when HERA dPDFs are extrapolated to Tevatron

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

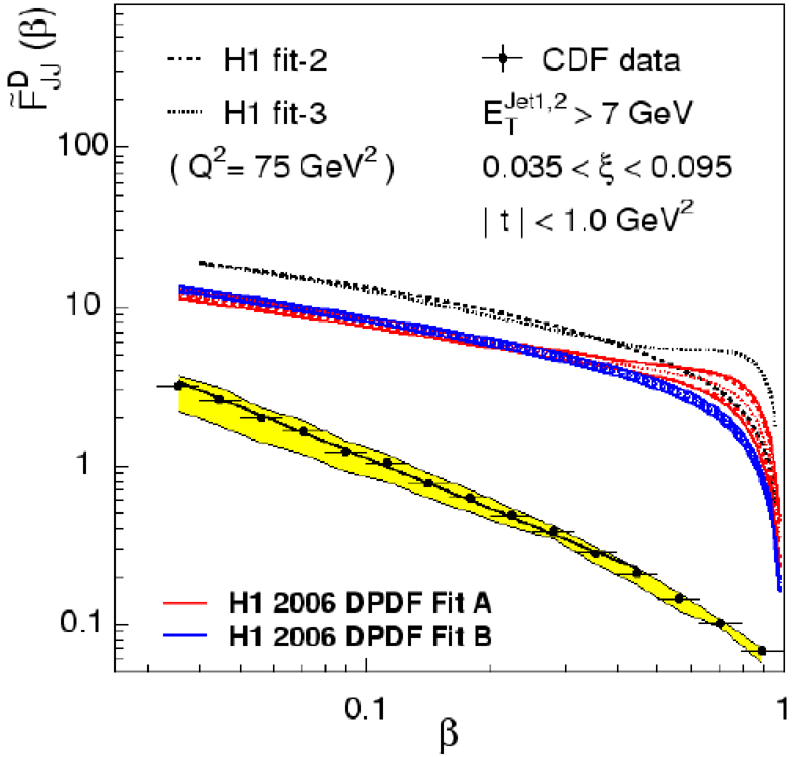
DIS and direct PhP



resolved PhP



Example Comparison with Tevatron: CDF Jets

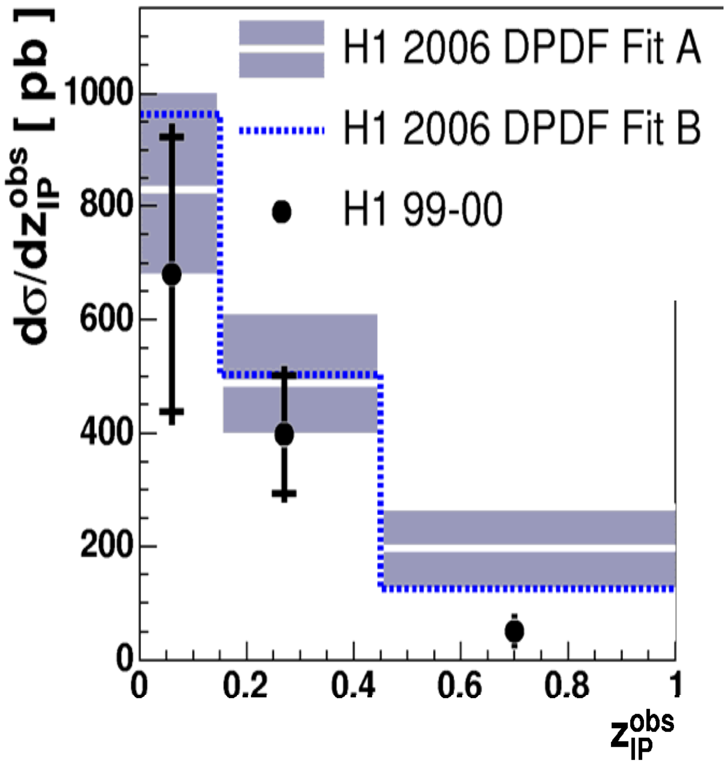


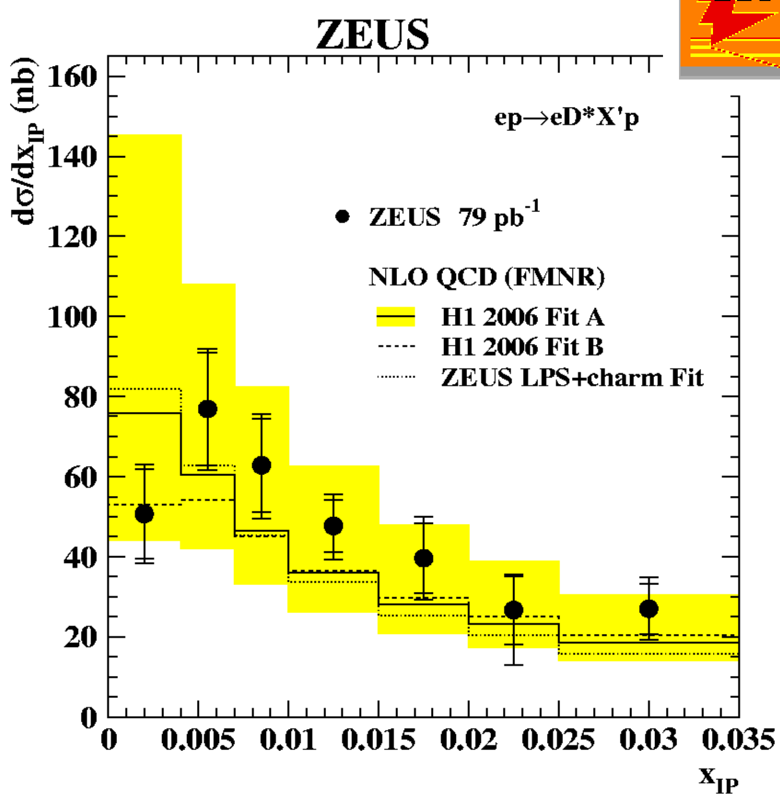
- Fit A and fit B predictions in good agreement at low β.
- ~30% lower than earlier predictions, because gluon smaller and meson smaller.
- Basic conclusion of large factorisation breaking holds
- Reassess gap survival factors?
- High β still problematic

slide: Paul Newman, HERALHC worshop, March 07

Diffractive charm production in PhP

[hep-ex/0610076]

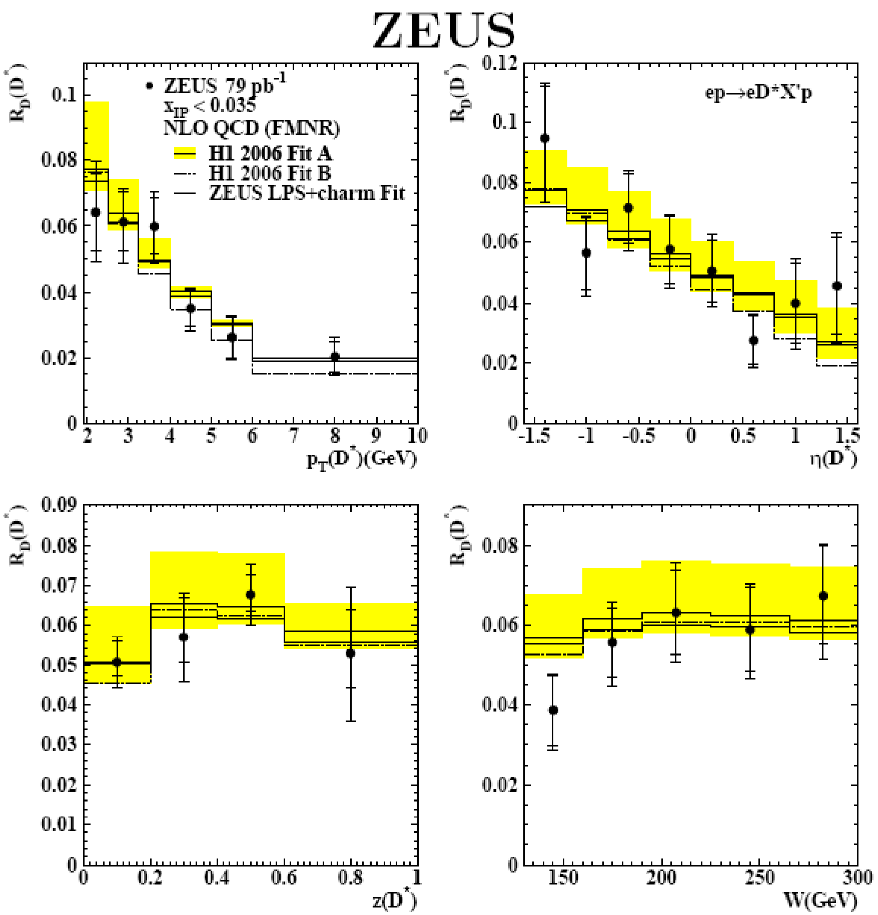




→ No evidence of factorization breaking but large NLO uncertainties and limited statistics

Diffractive charm production in PhP

Ratio diffractive/inclusive

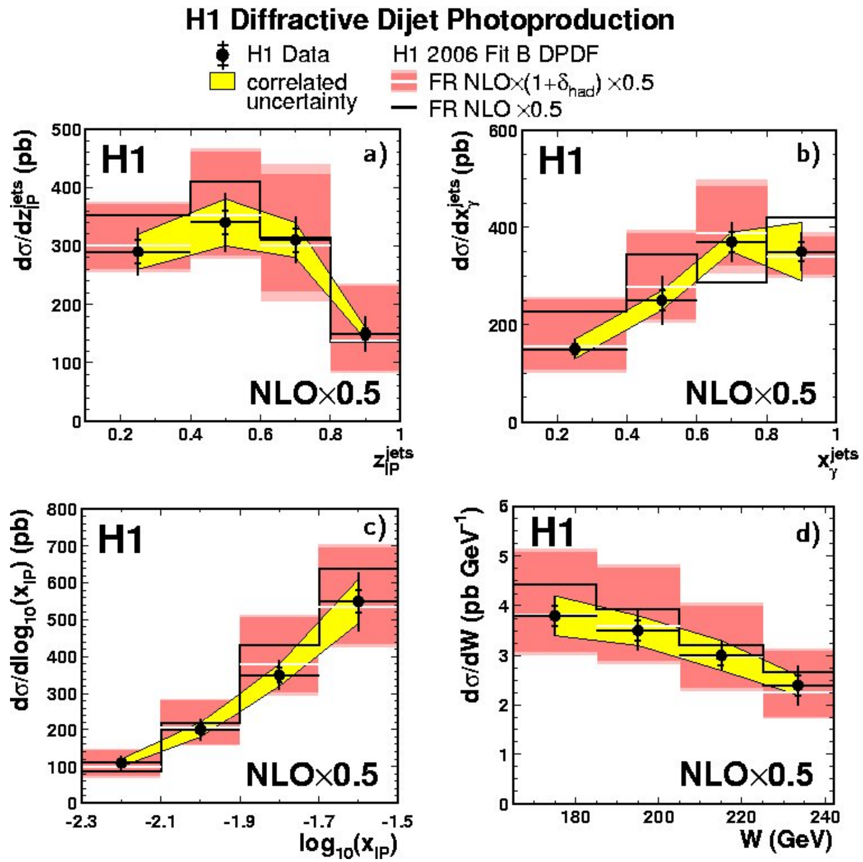


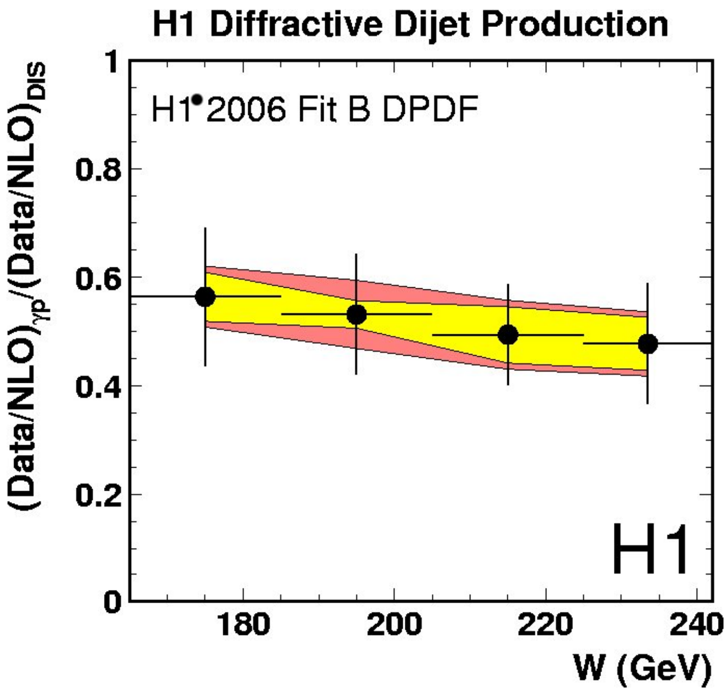
$R_D(D^*) = 5.7 \pm 0.5_{(stat)}\ {}_{-0.4\,(syst)} \pm 0.3_{(p.d.)}\ \%$

Ratio from NLO calculations:
H1 2006 Fit A: 6.0%
H1 2006 Fit B: 5.7%
LPS Fit: 5.8%

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

Diffractive dijet production in PhP





→ Data described in shape by NLO QCD predictions,

→ Suppression factor ~ 0.5 common for both direct and resolved photon

→ Factorization breaking for dijets in PhP

Summary

- At HERA diffraction is studied within the QCD framework
  - 2 experiments, different selection methods
  - many final states under examination

- New DPDFs available to test hard scattering factorization
  - H1 fit A, B: different parameterizations at initial scale
  - 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 (ZEUS and H1) consistent with NLO predictions based on DPDFs from inclusive data → support factorization

- Diffractive dijet PhP data (H1) suppressed by a factor 2 relative to NLO predictions based on DPDFs from inclusive data, both for direct and resolved processes → seem to indicate breakdown of factorization

- Diffractive charm PhP data (ZEUS and H1): within low statistics and large NLO uncertainties no clear hint of factorization breaking observed