Inclusive hard diffraction at HERA

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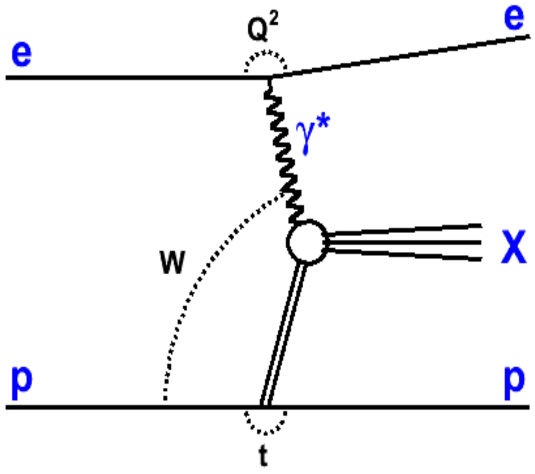
on behalf of the H1 and ZEUS collaboratons

- Comparison of different diffractive data
- QCD fits
- Diffractive F_L
- Diffractive dijet production

Kinematics

- $-Q^2 = (p_e - p_{e'})^2$ - photon virtuality
- $M_X = (p_\gamma + p_{IP})^2$ - mass of system X
- $t = (p_p - p_{p'})^2$ - 4-momentum squared at proton vertex
- $W^2 = (p_\gamma + p_p)^2$ - gamma-p mass squared

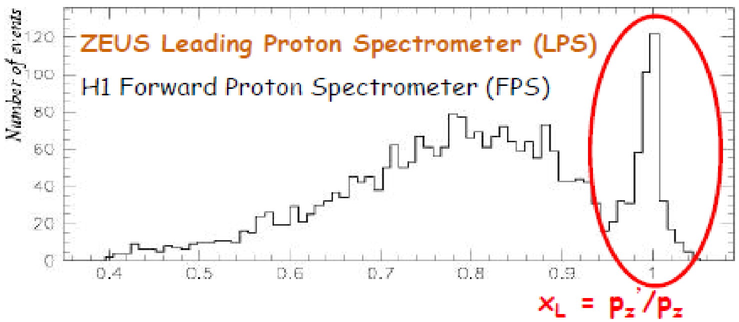


$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} = \frac{Q^2 + M_X^2 - t}{Q^2 + W^2 - M_p^2}$$ - *proton momentum fraction carried by t − channel exchange*

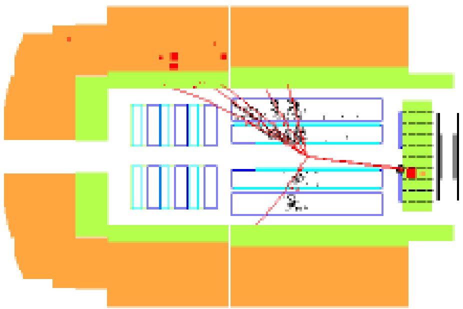
$$\beta = \frac{Q^2}{2(p - p') \cdot q} = \frac{Q^2}{Q^2 + M_X^2 - t}$$ - *Bjorken variable wrt t − channel exchange*

Diffractive event selection

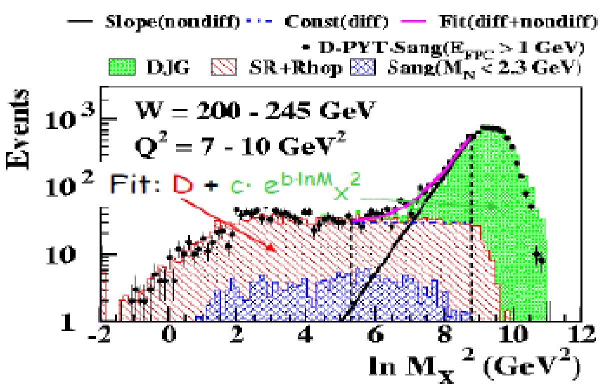
- Direct proton detection (LPS, FPS)
  - ✓ measure proton momentum $x_{IP}<0.1$
  - ✓ no p-diss background
  - ✓ low statistics



- Rapidity gap selection (LRG)
  - ✓ proton not detected $x_{IP}<0.02$-0.03
  - ✓ p-diss background (~20-30%)
  - ✓ high statistics



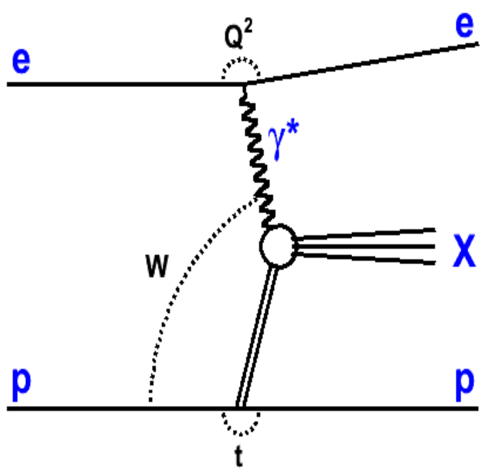
- Mass decomposition (MX)
  - ✓based on difference in M_X distributions in diffraction and non-diffractions
  - ✓p-diss background



Diffractive structure functions

- Reduced cross sections $\sigma_r^{D(4)}$

$$\frac{d^4\sigma^{ep}}{dQ^2\, d\beta\, dx_{IP}\, dt} = \frac{4\pi\alpha^2}{\beta Q^4}\left(1 - y + \frac{y^2}{2}\right)\sigma_r^{D(4)}$$



related to diffractive structure functions $F_2^{D(4)}$ and $F_L^{D(4)}$

$$\sigma_r^{D(4)} = F_2^{D(4)} - \frac{y^2}{2(1 - y + y^2/2)} F_L^{D(4)}$$

reduced cross section integrated over t

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

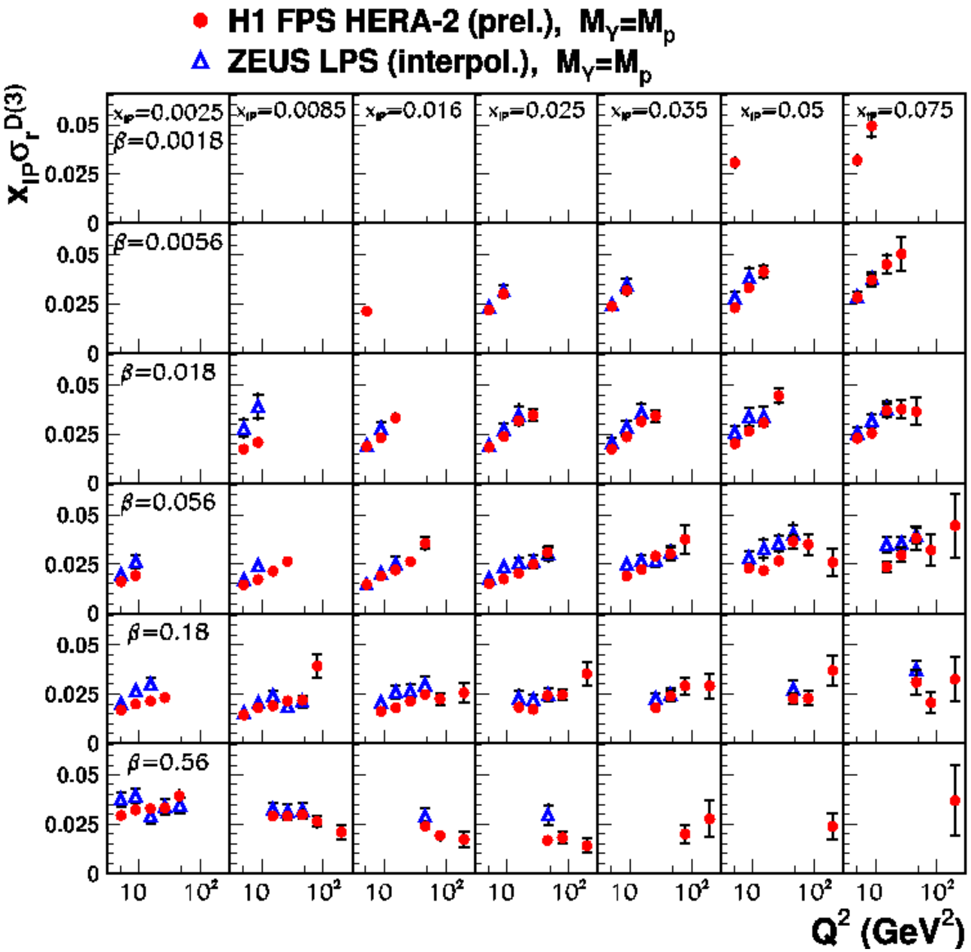
Proton tagged data

New H1 FPS HERA-2 data 156 pb-1
20 times more events than at HERA-1
Extend phase space to higher Q^2

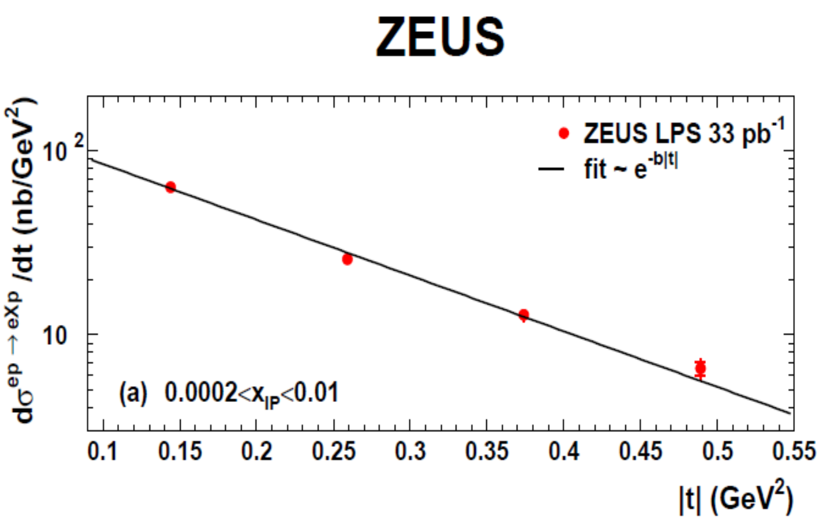
Reasonable agreement between ZEUS LPS and H1 FPS.

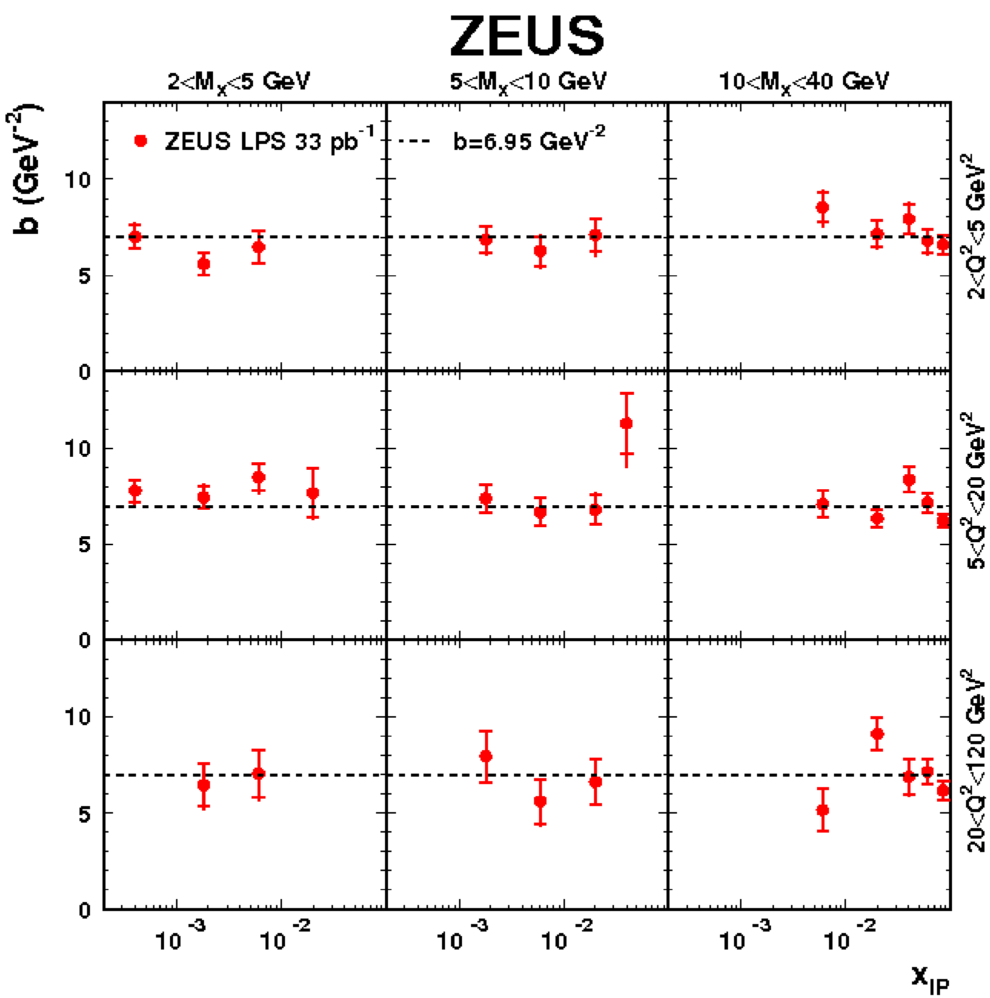
Norm uncertainties:
FPS ~ 6%
LPS ~ 10%

$\sigma_r^{D(3)}$ vs Q^2



Proton tagged data (t dependence)





- Exponential shape, e^{bt} , with

  b=6-7 GeV^{-2}

- No dependence on Q^2 and β

Proton tagged data (x_{IP} dependence)

$\sigma_r^{D(4)}$ at two t values

- Regge fit (Pomeron+Reggeon)

ZEUS $\alpha_{IP}(0)=1.11\pm0.02\pm0.02$

H1 $\alpha_{IP}(0)=1.12\pm0.01\pm0.02$

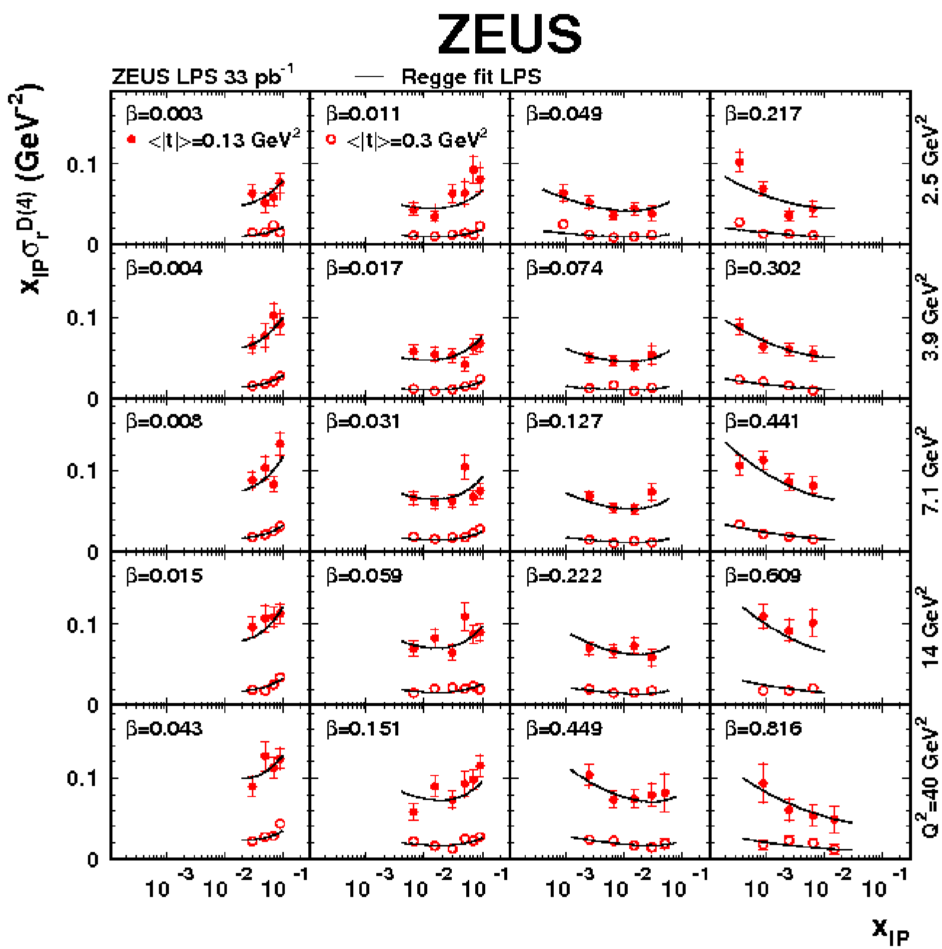
$\alpha_{IP}(0)$ close to soft 1.08

ZEUS $\alpha'_{IP}=-0.01\pm0.06\pm0.05\ \mathrm{GeV}^{-2}$

H1 $\alpha'_{IP}=0.06\pm0.13\ \mathrm{GeV}^{-2}$

α'_{IP} is not consistent with 0.25 GeV^{-2}

- Consistent with Regge factorization assumption

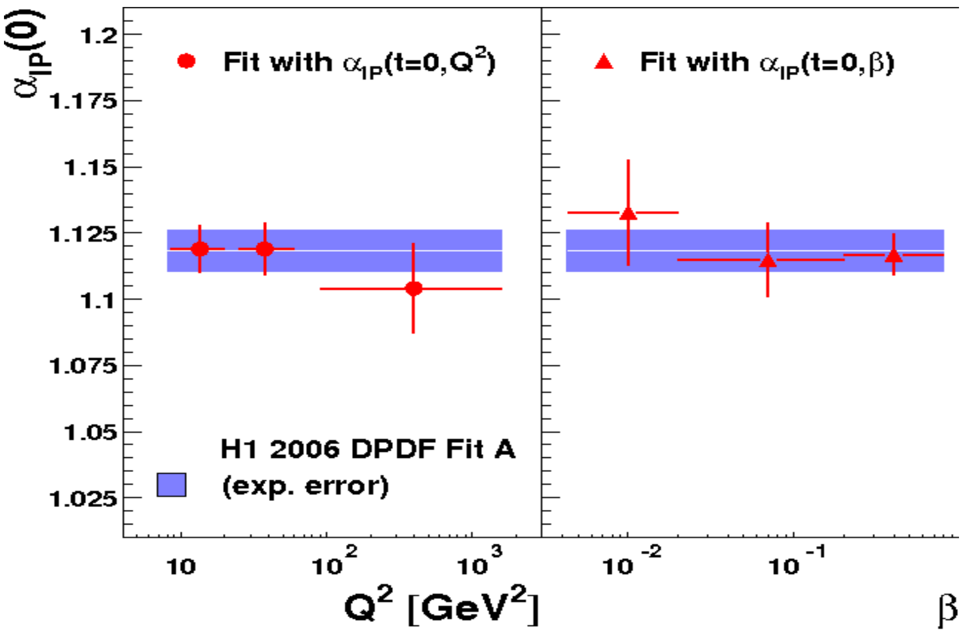


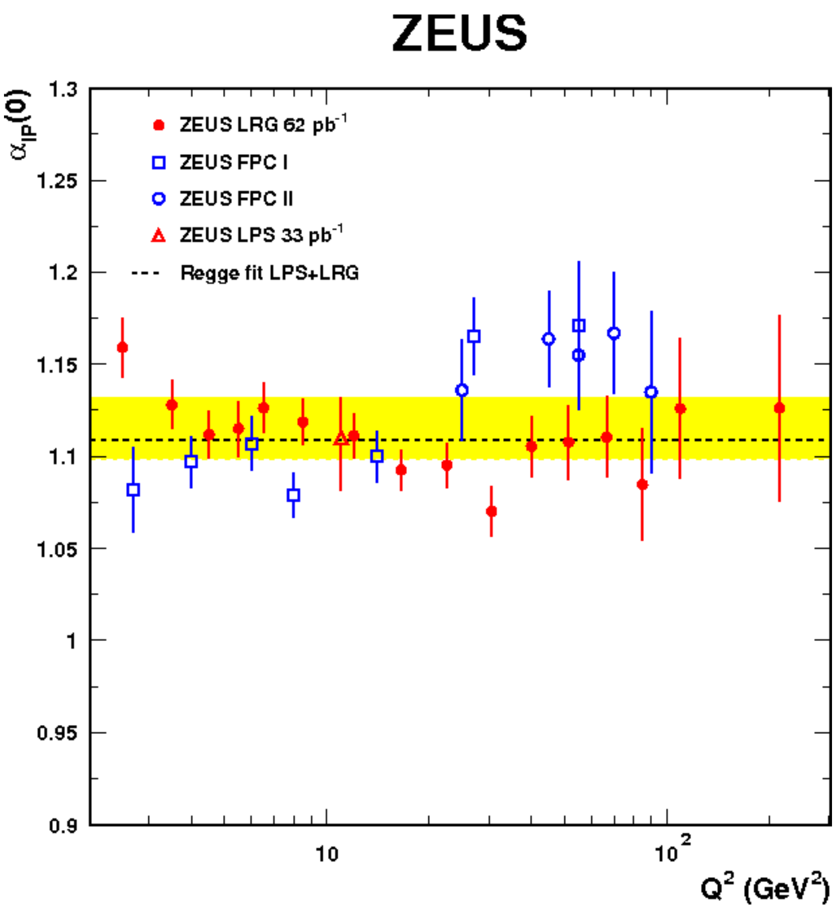
Pomeron intercept

- Regge fit in different Q^2 bins

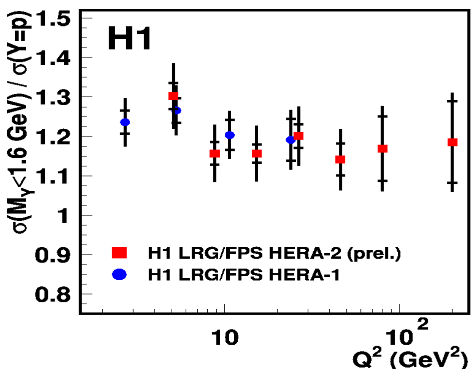
No strong evidence for $\alpha_{IP}(0)$ variation

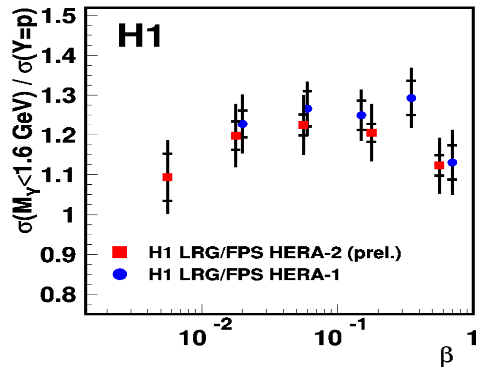
Regge factorization is a good approximation

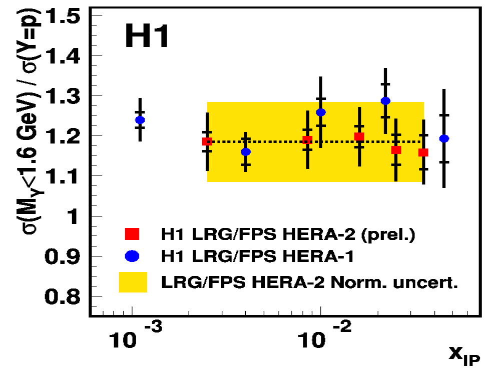


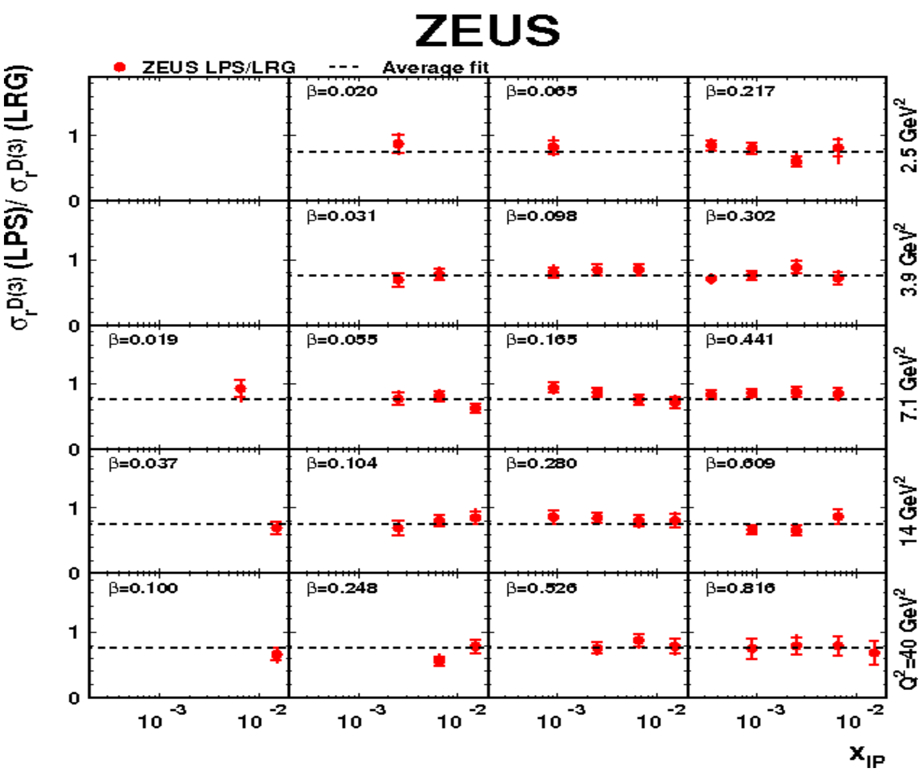


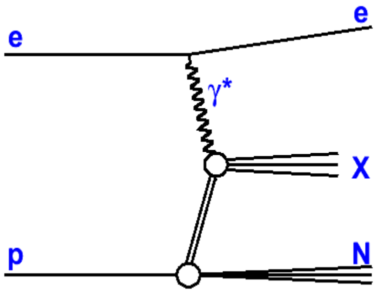
Proton tagged vs LRG data











LRG/FPS (LPS/LRG) does no depend on Q^2, β, x_{IP}

Proton dissociative background in LRG data is ~20-30%

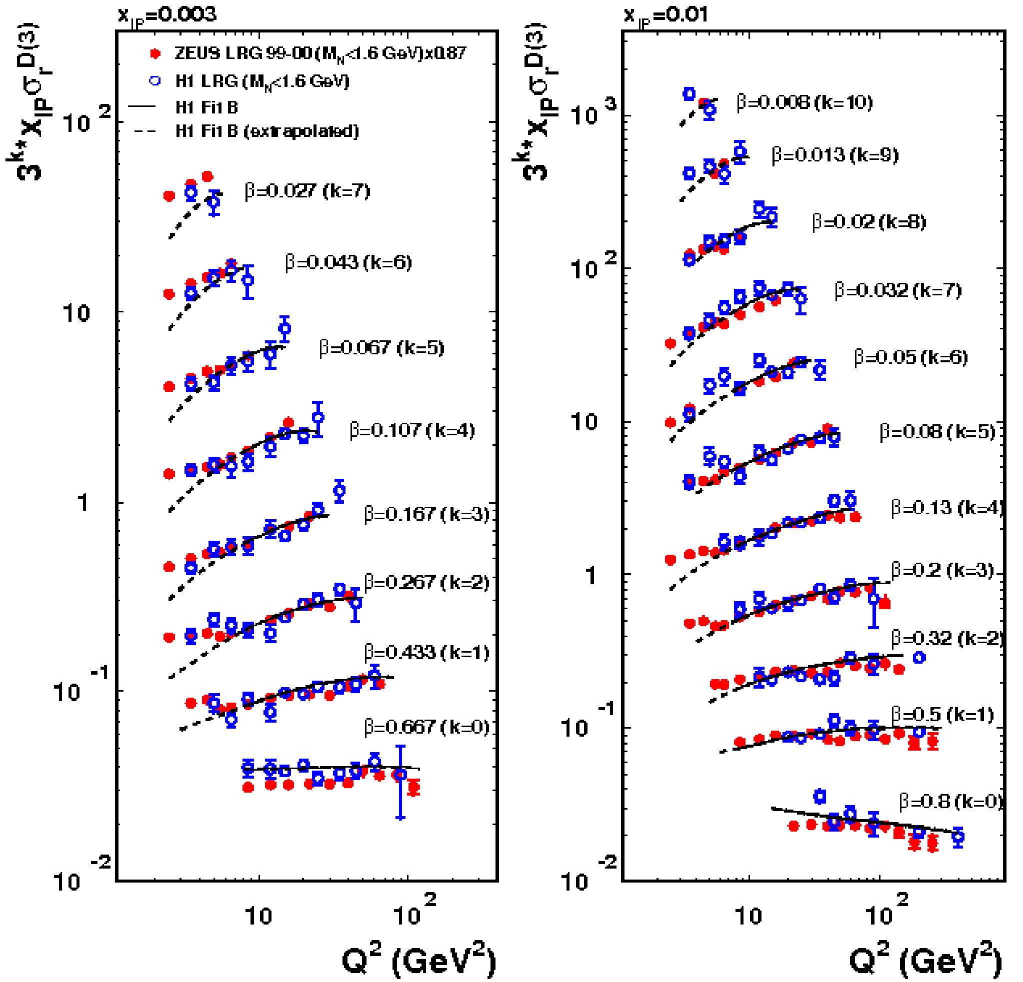
LRG data (H1 vs ZEUS)

Reasonable agreement in shape

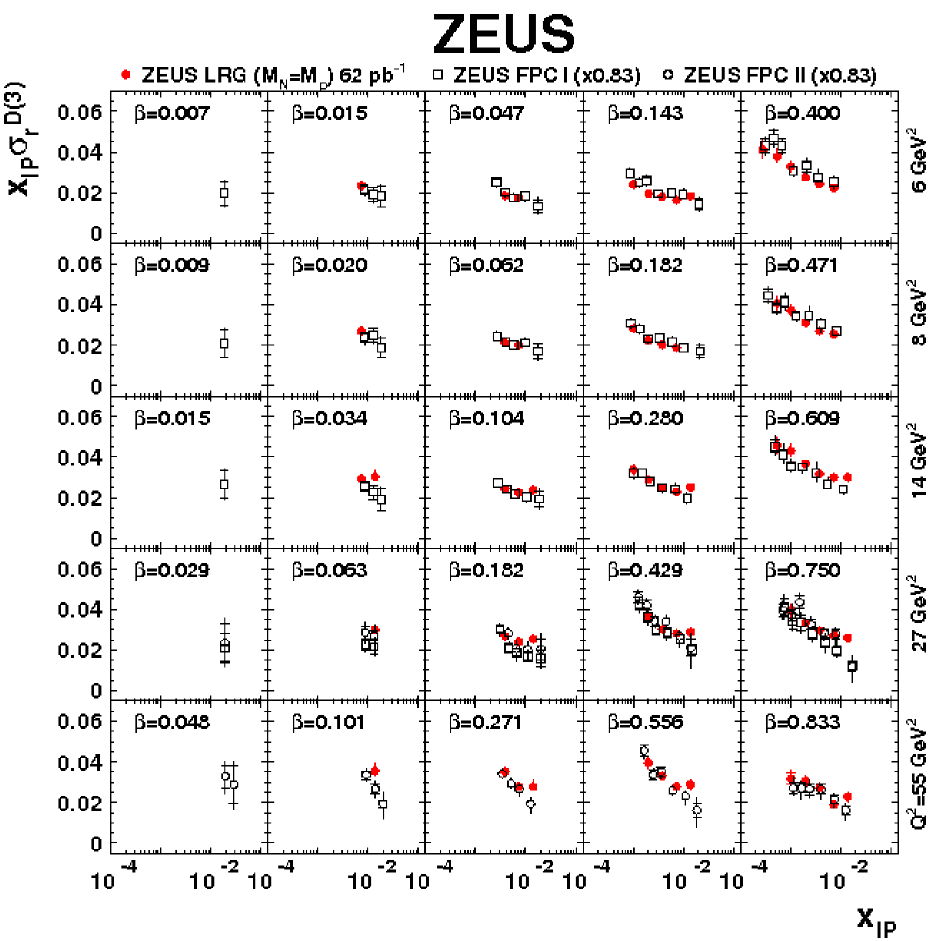
~13% normalization difference

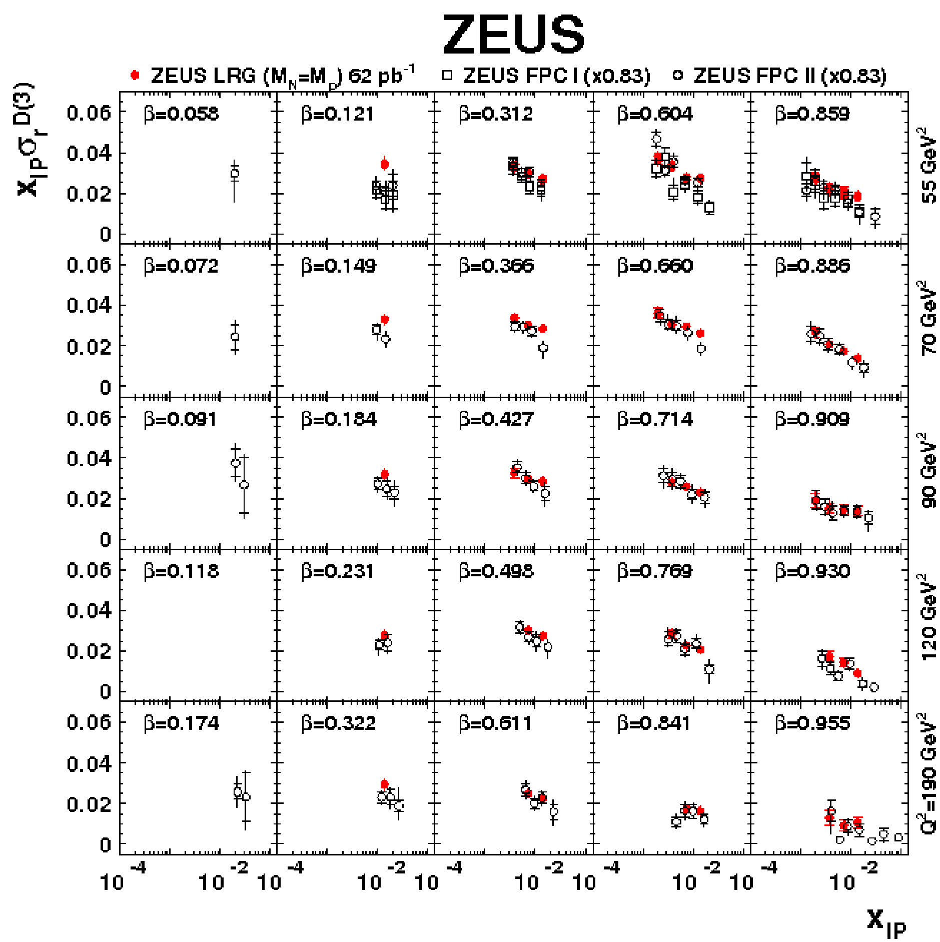
Both measurements have norm uncertainties (dominant contribution from p-diss background)

$\sigma_r^{D(3)}$ at x_{IP}=0.003 and 0.01



LRG (ZEUS) vs MX





Agreement in shape (some difference at high x_{IP} can be expected)

~17% difference in normalization (p-dissociation)

ZEUS diffractive QCD fits

- Regge factorization assumption

$$F_{2/L}^{D(4)}(x_{IP},t,Q^2,\beta)=f(x_{IP},t)\,F_{2/L}^{IP}(Q^2,\beta)+f(x_R,t)\,F_{2/L}^{R}(Q^2,\beta)$$

$$f(x_{IP},t)=A\frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}},\quad \alpha(t)=\alpha(0)+\alpha' t$$

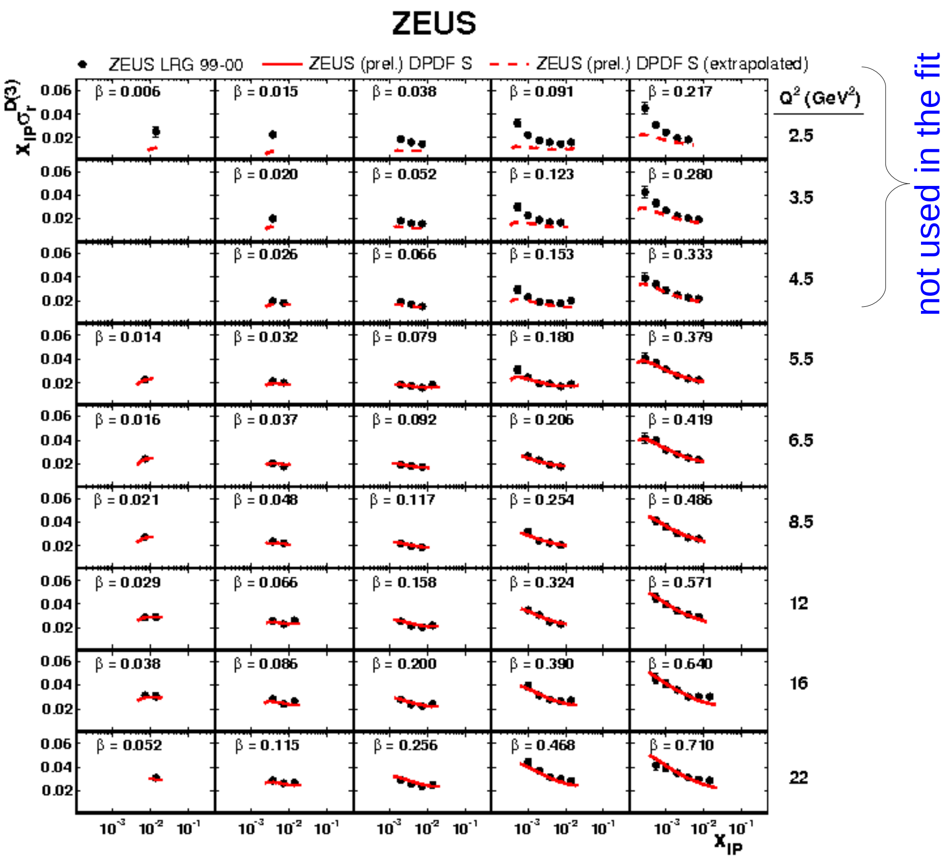
- Quarks, gluons parameterized at initial Q^2_0

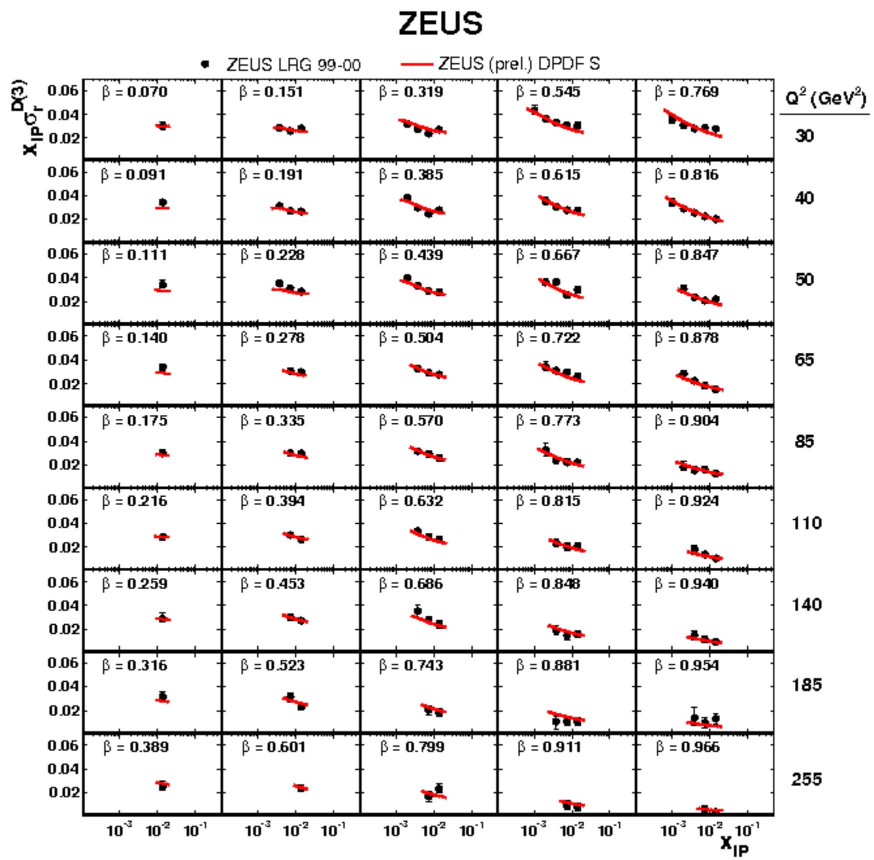
$$zq(z)=A_q z^{B_q}(1-z)^{C_q}\qquad zg(z)=A_g z^{B_g}(1-z)^{C_g}$$

Fit C gluons with B_g=C_g=0 (as H1 Fit B) LRG+LPS data
Fit S gluons with B_g and C_g fitted LRG+LPS data
Fit SJ gluons with B_g and C_g fitted LRG+LPS+dijet data

- NLO DGLAP (QCDNUM, QCDC)
- Heavy quarks treatment – Thorn-Roberts VFNS (H1 - FFNS)
- Reggeon is treated as pion, GRV-pdfs (H1 - Owens)
- Q^2_{min}> 5 GeV^2 (H1 - Q^2_{min}> 8.5 GeV^2)

QCD fits to ZEUS diffractive data

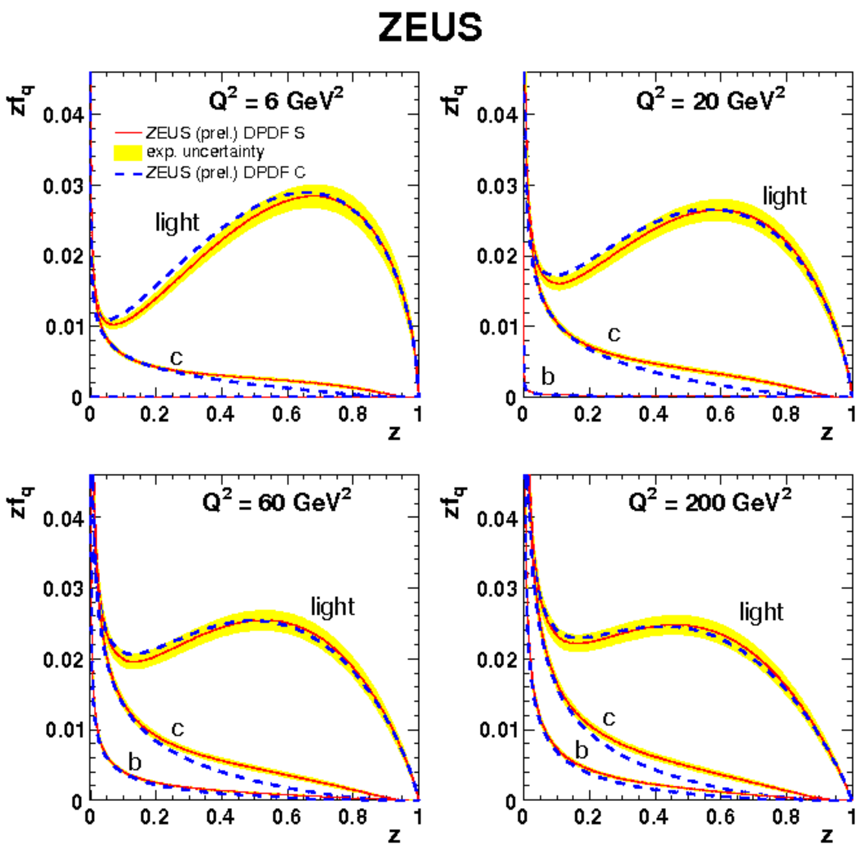




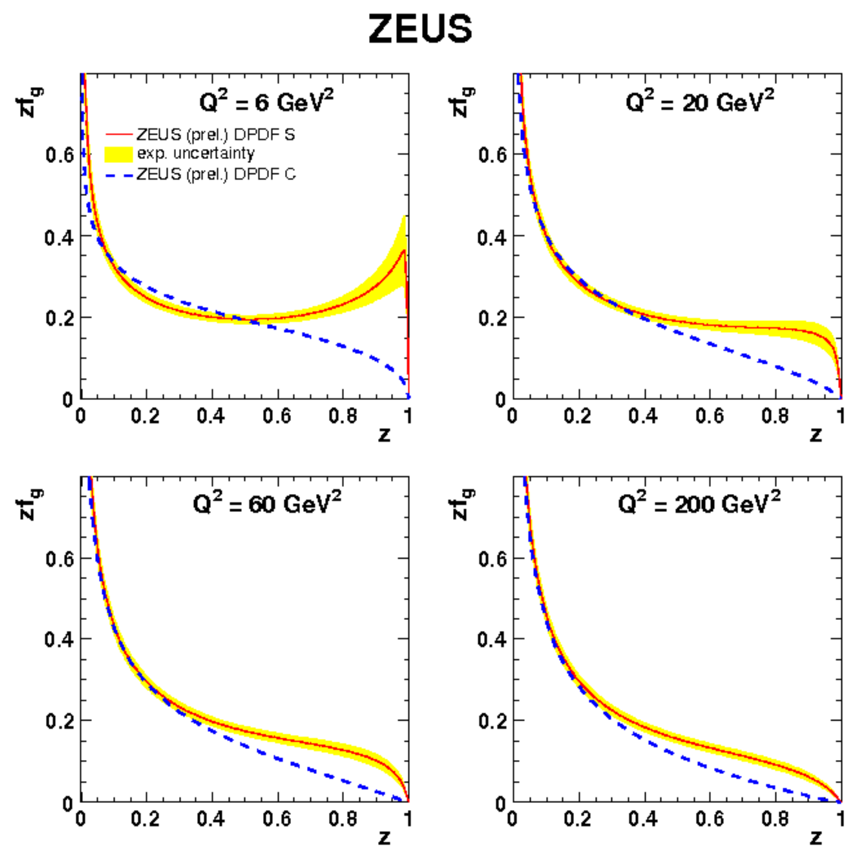
Both fits C and S describe data (Q^2>5 GeV^2)

ZEUS dpdfs

Quarks in Fit C and S are almost the same,
gluons are very different

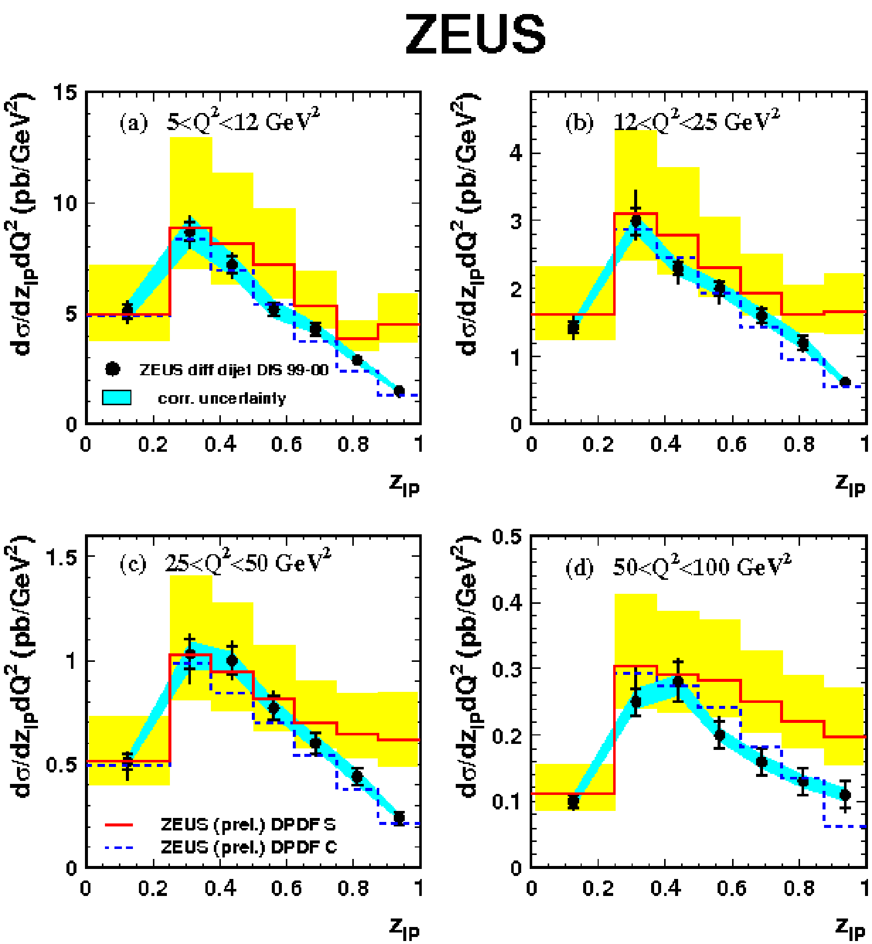


quarks at different values of Q^2

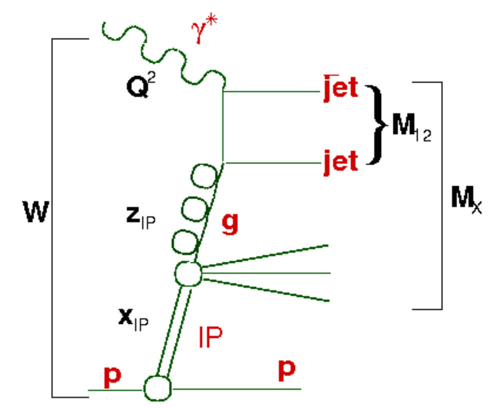


gluons at different values of Q^2

Dijets cross sections (DIS)



Dijet cross section is sensitive to gluons



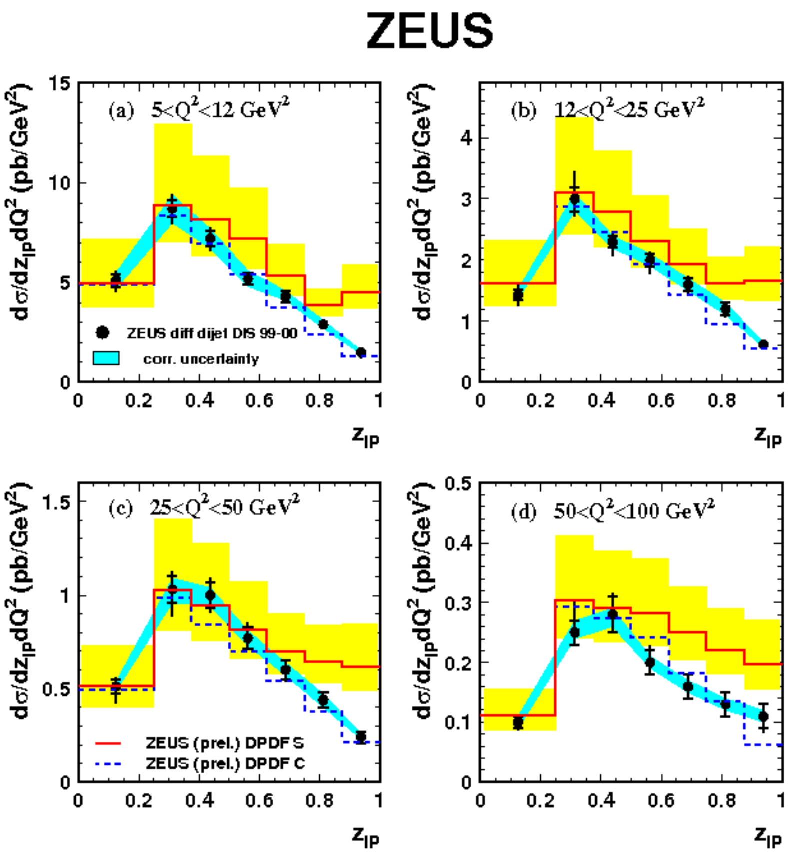
Fit S fails at high z_{IP}

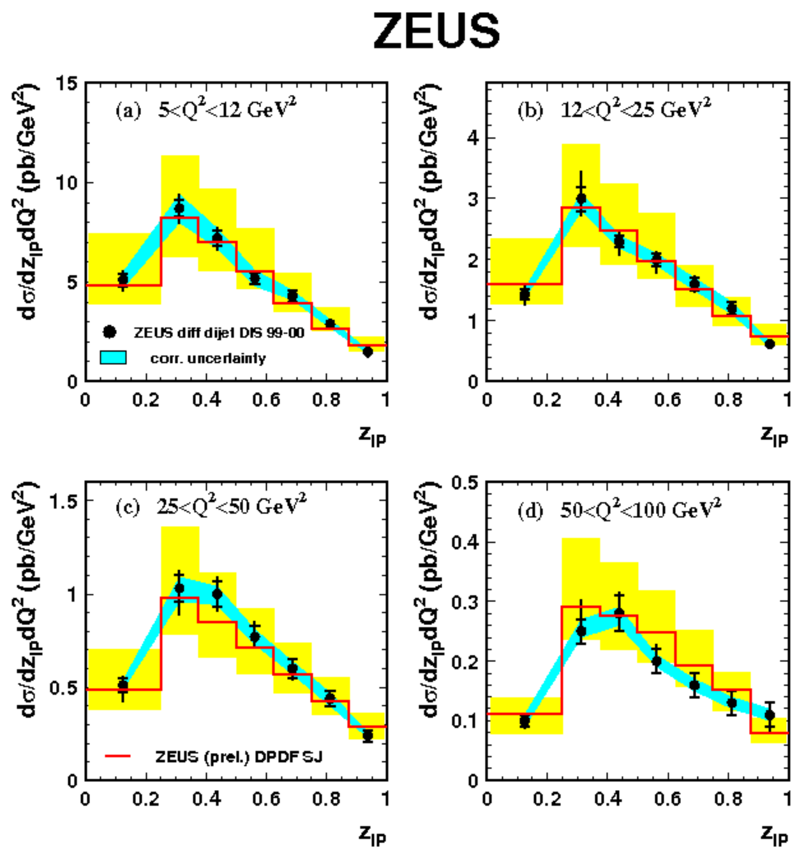
Fit C describes dijet data

$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

QCD dijet fit

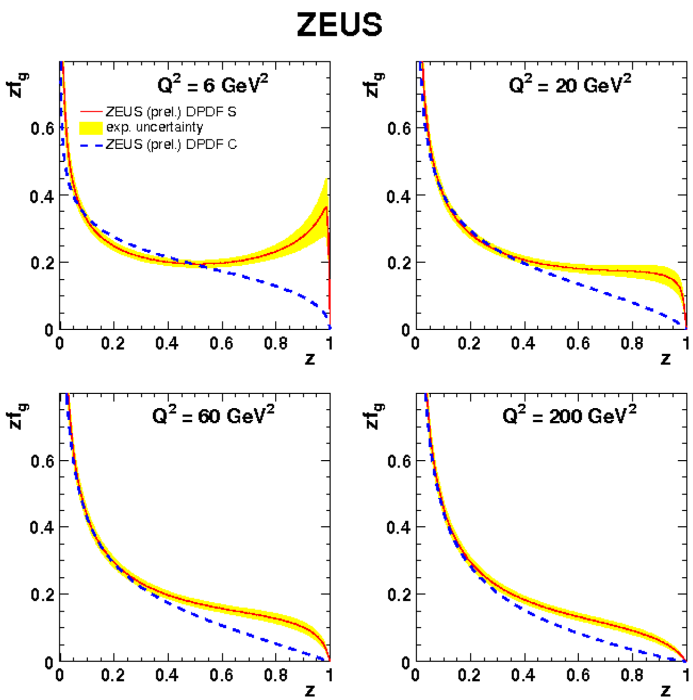
Dijet cross sections constrain gluons at high z

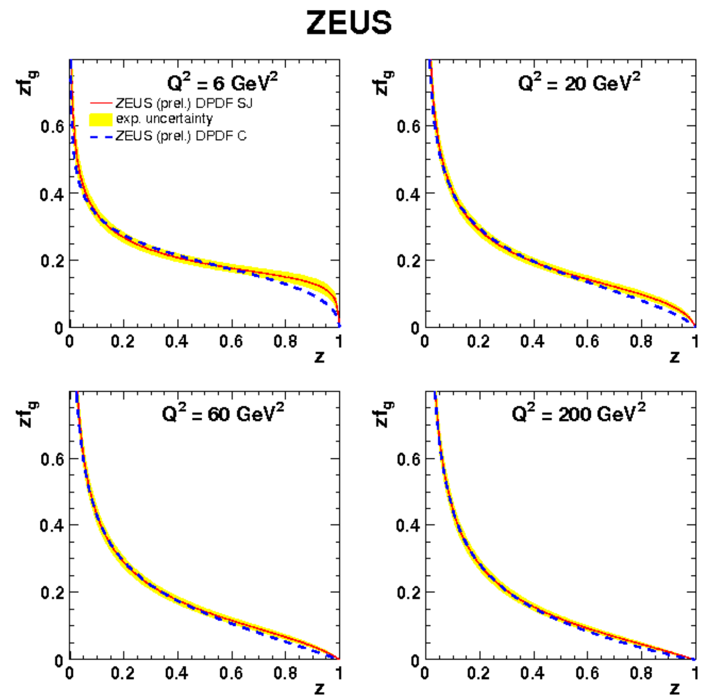




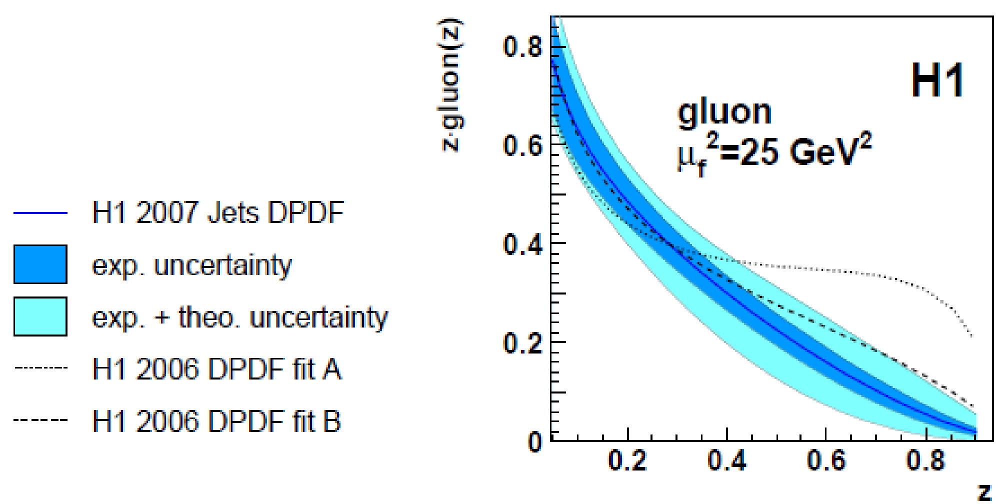
$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

dpdfs from dijet fit



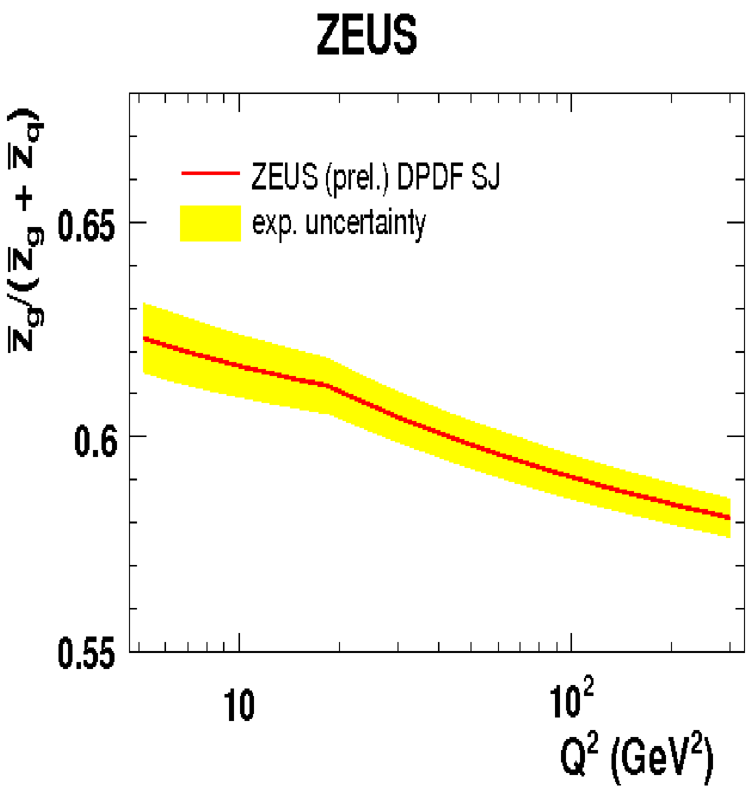


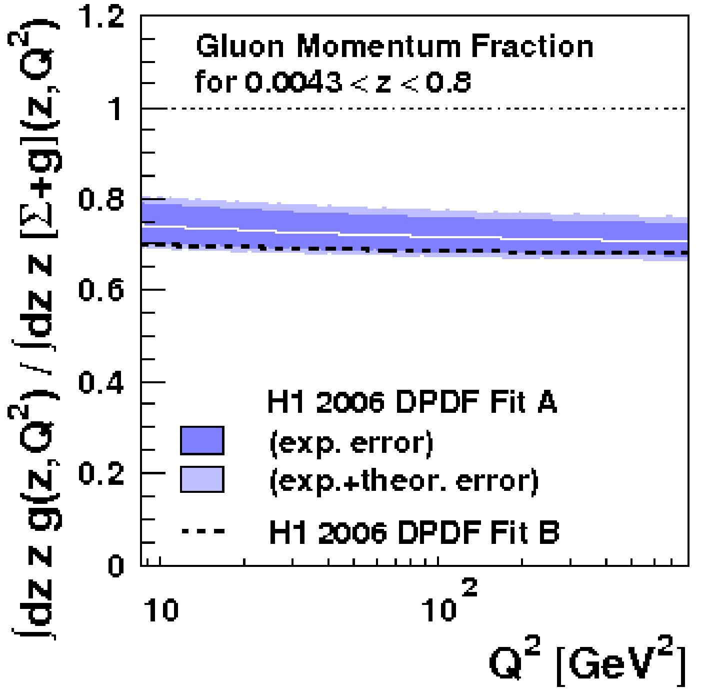
Dijets constrain gluons
at hight z_{IP}



Gluon momentum fraction

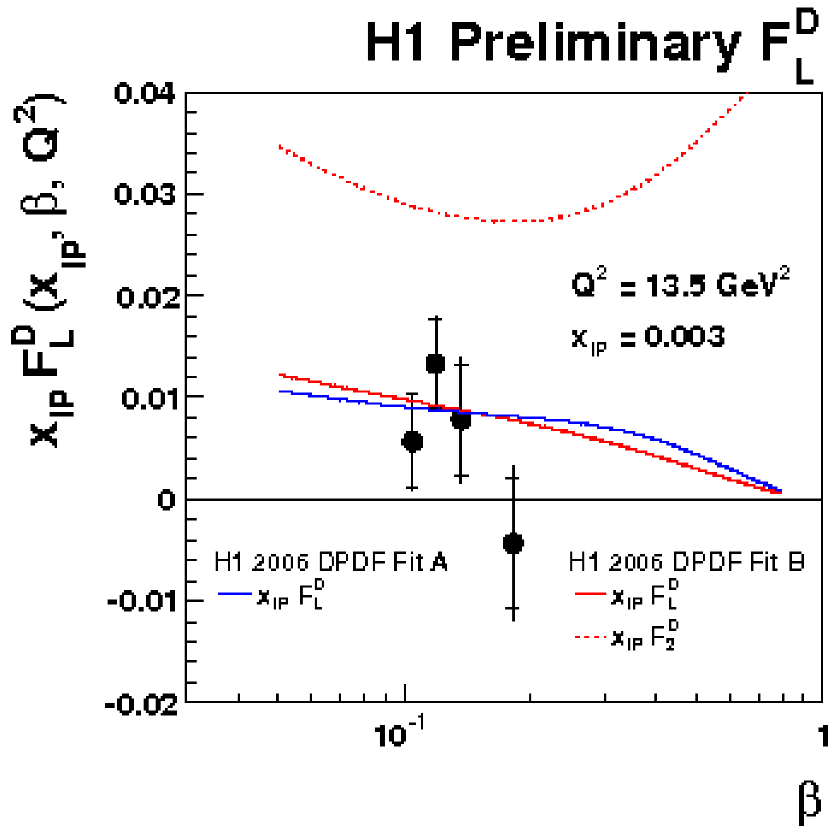
Gluon momentum fraction ~ 60-70%





First F_L^D measurement

$$\sigma_r^{D(3)}(Q^2,\beta,x_{IP}) = F_2^{D(3)} - \frac{y^2}{2(1-y+y^2/2)} F_L^{D(3)}$$



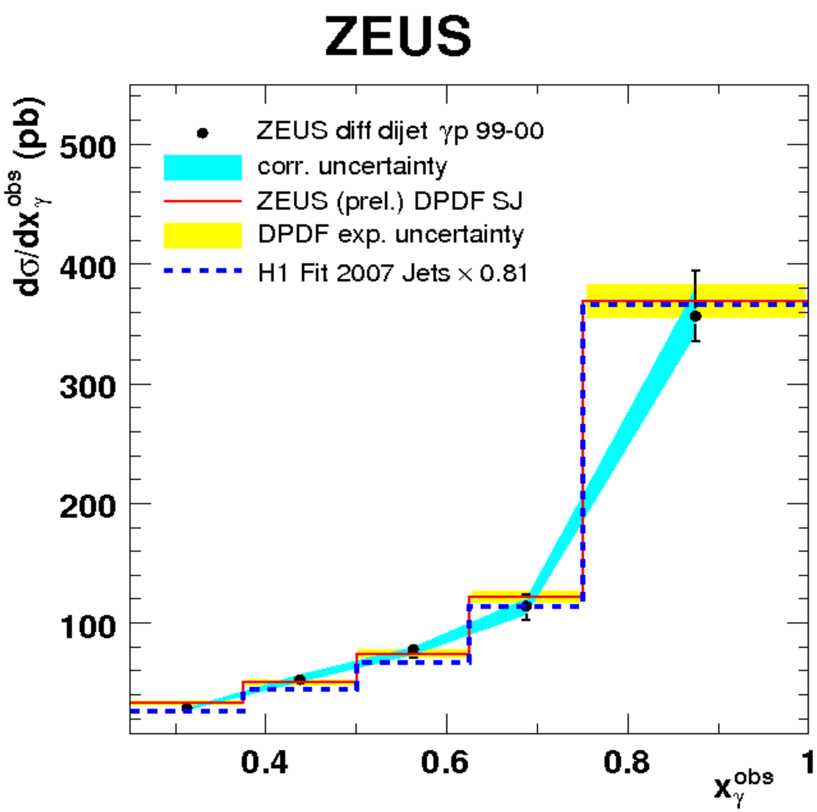
Three proton beam energy:
920 GeV (21 pb^{-1})
575 GeV (11 pb^{-1})
460 GeV (6 pb^{-1})

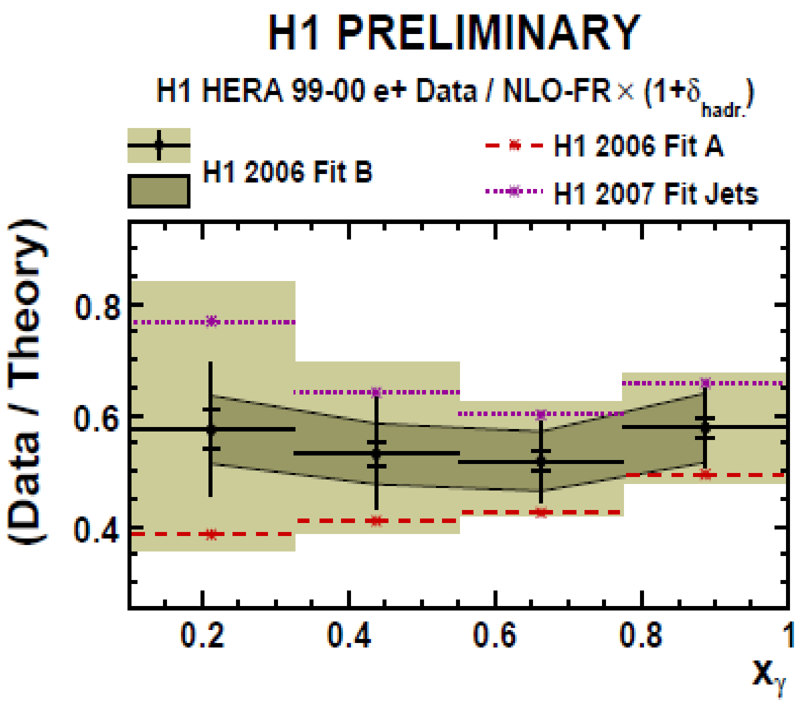
Measure $\sigma_r^{D(3)}$ at fixed Q^2, β, x_{IP} and different y

Results compatible with QCD fit predictions
$\sigma_L/\sigma_T \sim 0.5$

Diffractive dijets in photoproduction

- Cross section vs x_γ



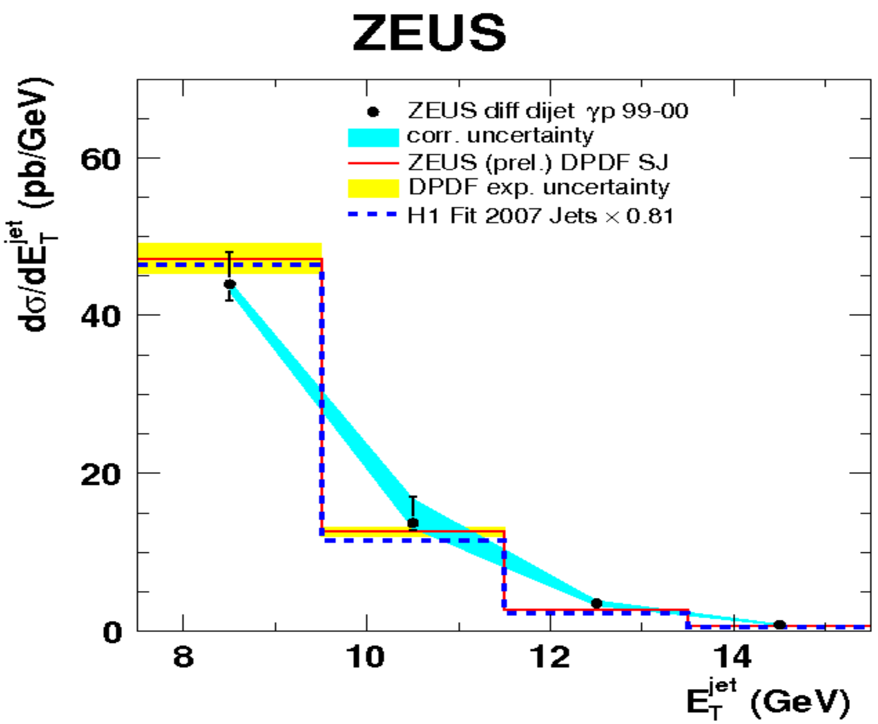


Suppression by factor of ~ 2
No x_γ dependence

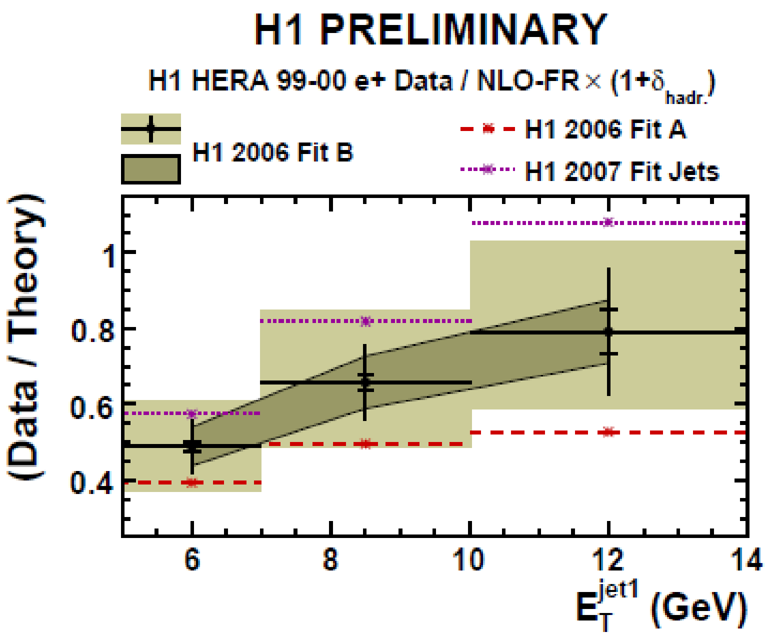
Good data description
No visible x_γ dependence

Diffractive dijets in photoproduction

- Cross section vs E_T^{jet1}



Good description of the data



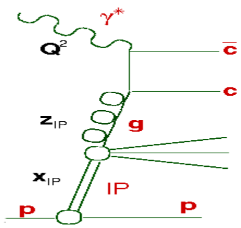
Suppression depends on E_T ?

Different E_T cuts:

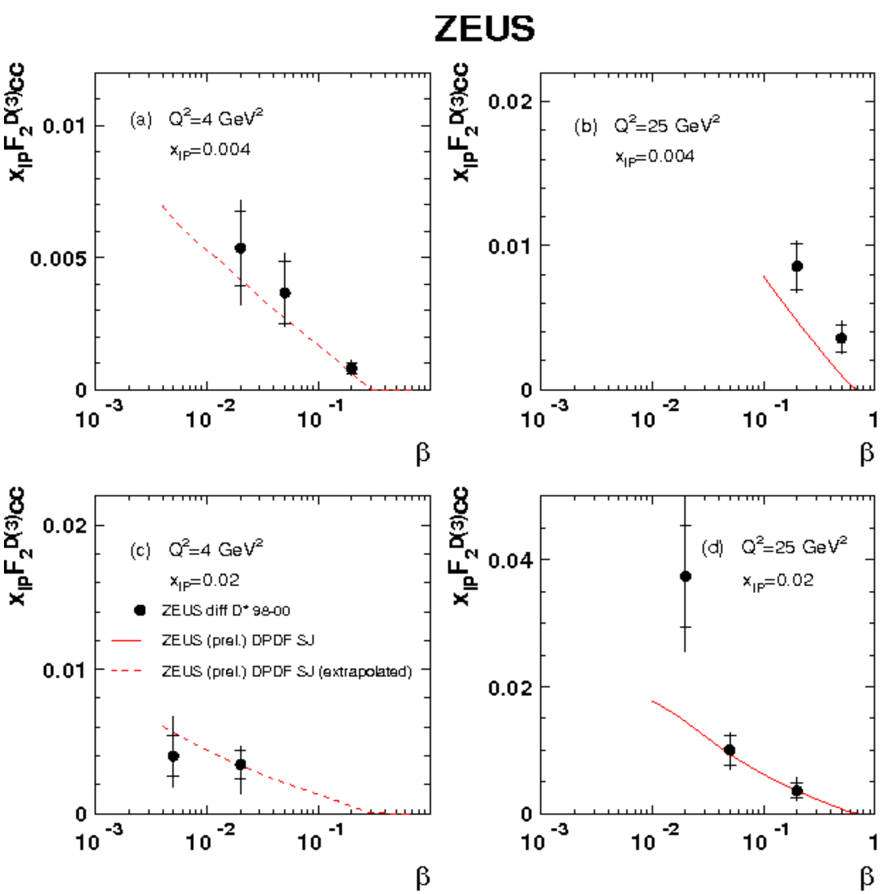
H1 $E_t^{jet1} > 5$ GeV

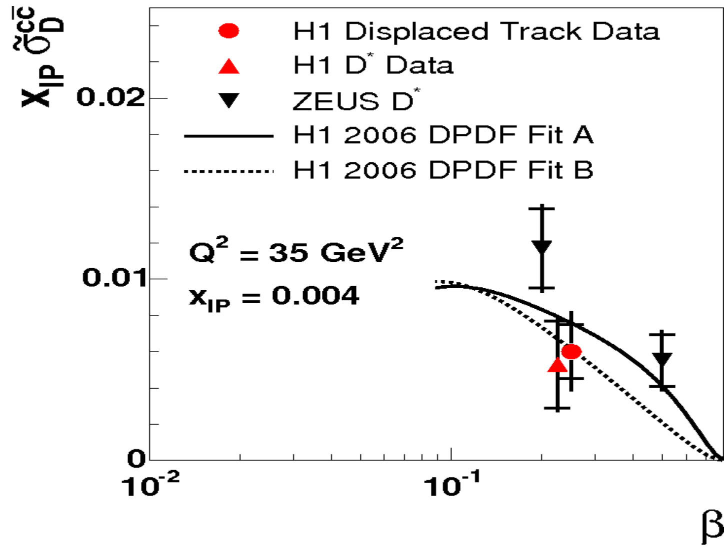
ZEUS $E_t^{jet1} > 7.5$ GeV

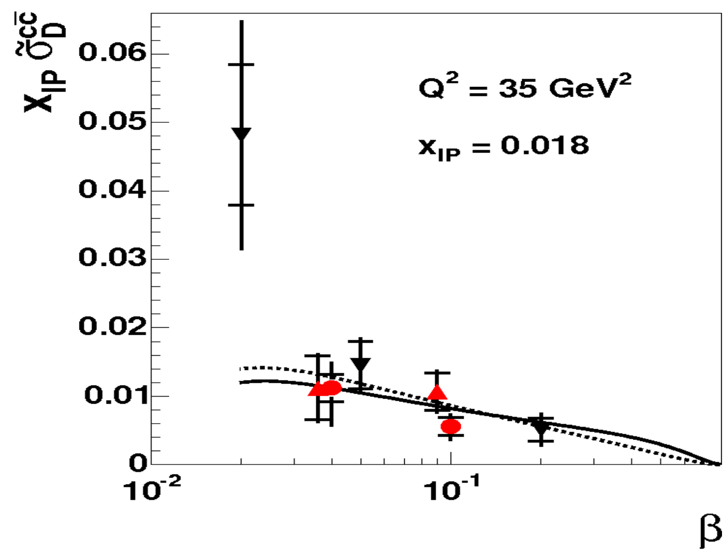
Diffractive charm production



Charm cross section is also described by dpdfs







Conclusions

- HERA produced a lot of results on diffraction, more results are coming.
- Agreement between H1 and ZEUS and between different methods used to extract diffraction. Better understanding of proton dissociative background.
- Regge factorization assumption is a good approximation to describe diffractive data at HERA.
- Diffractive QCD fits describe inclusive, dijet and charm cross sections.
- More studies are needed to understand the difference in dijet photoproduction.

Diffractive and inclusive dijet ratio