Inclusive and jet cross sections in diffraction at HERA

W. Schmidke
MPI München
On behalf of the H1 and ZEUS collaborations
ISMD 2007 Berkeley, CA

Outline:

- Diffractive processes:
  - colorless exchange
  - experimental measurement
- Structure of colorless exchange:
  - Diffractive Parton Density Functions (DPDFs)
  - measurement in inclusive DIS: quarks
  - measurement in dijets in DIS: gluons
- DPDFs $\rightarrow$ photoproduction at HERA $\sim$ hadron-hadron
  - test of factorization

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

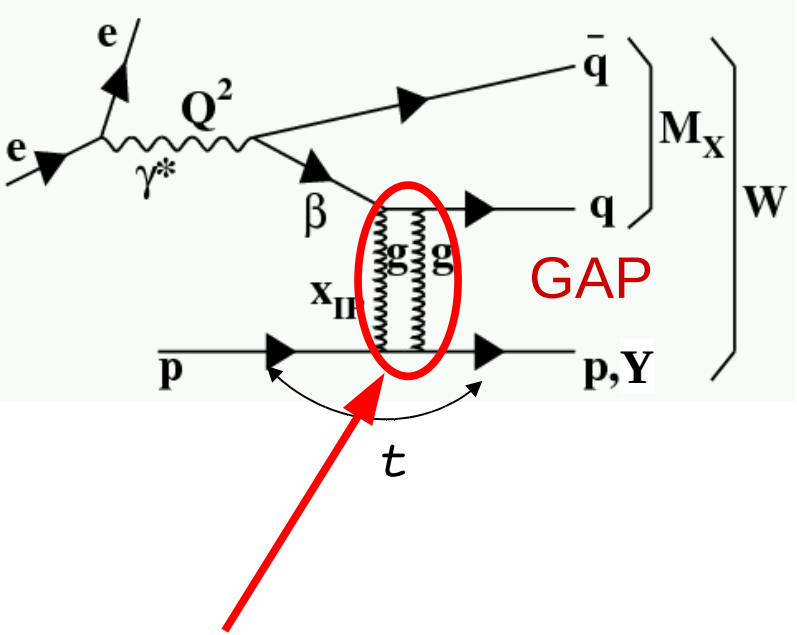
W = invariant mass of γ-p system

M_X = invariant mass of γ-IP system

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

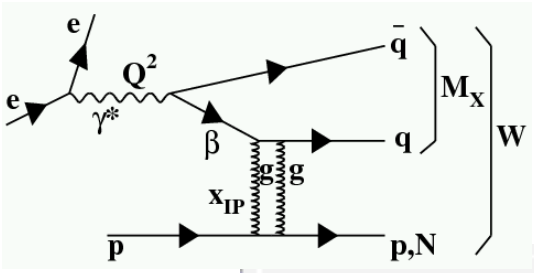
ß(= z_{IP}) = Bjorken's variable for the IP
= fraction of IP momentum carried by struck quark
= x/x_{IP}

Diffractive DIS



- Probe structure of color singlet exchange (IP) → F_2^D
- A non-perturbative feature of proton structure

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: e.g. dijets

p'

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

LRG

no color flow

e'

scattered electron

LPS, FPS:

+ clean, no proton dissociation background
- low statistics

LRG, M_x:

+ high statistics
- proton dissoc. bkg.
- non-diffractive bkg.

QCD factorization in hard diffraction

- Diffractive DIS, like inclusive DIS, is factorizable:

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

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

$\sigma_{\gamma^* p}(z,Q^2)$: universal partonic cross section

$f_{i/p}(z,Q^2,x_{IP},t)$: 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:

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

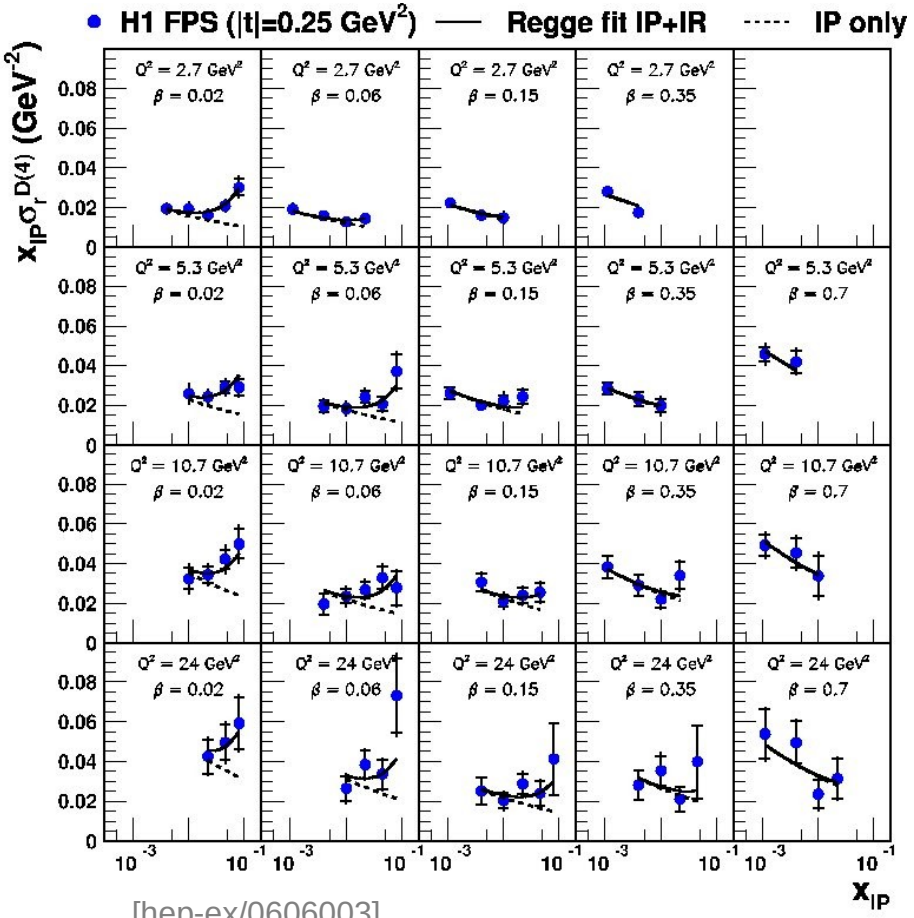
$f_{IP/p}(x_{IP},t)$: Regge motivated IP flux

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

H1 inclusive diffractive measurements

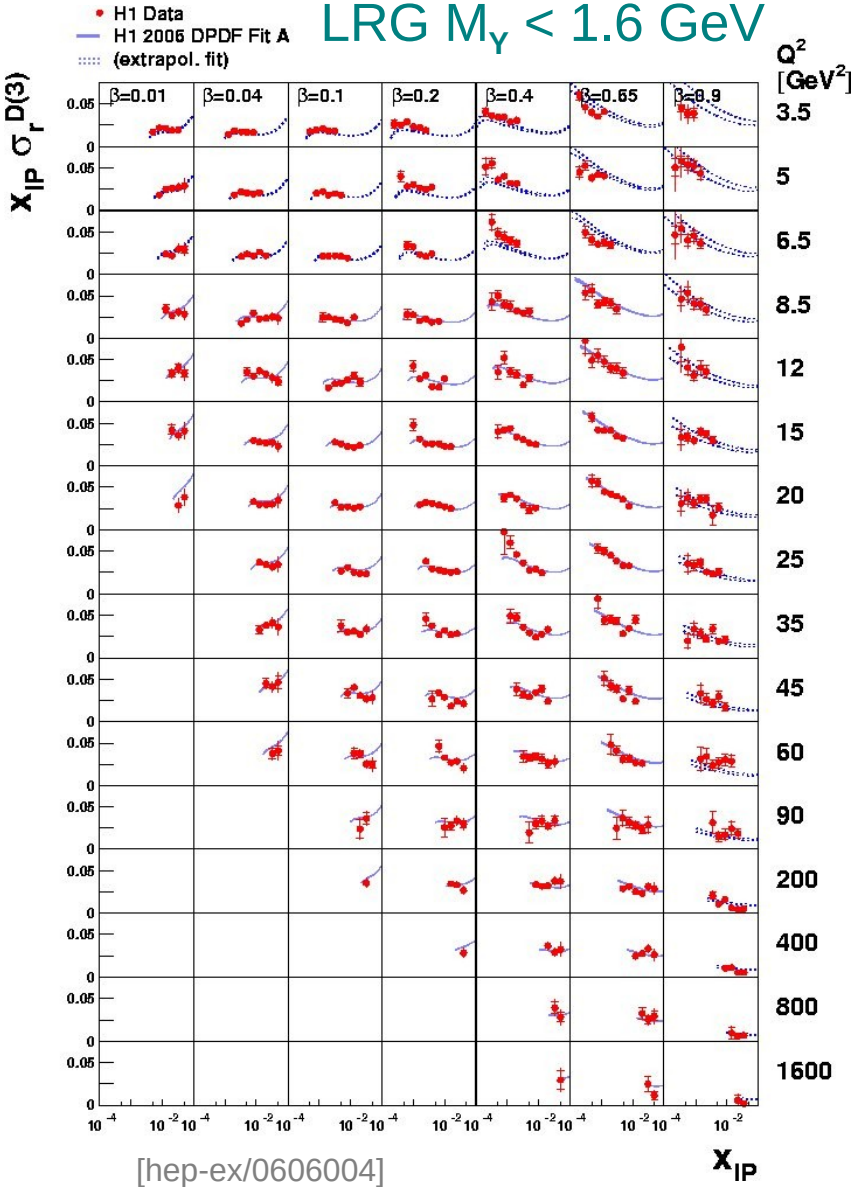
$\sigma_r^{D(3)} \sim F_2^{D(3)} - y^2/(1-(1-y)^2)\, F_L^{D(3)}$

FPS: Y = p



[hep-ex/0606003]

LRG M_Y < 1.6 GeV



[hep-ex/0606004]

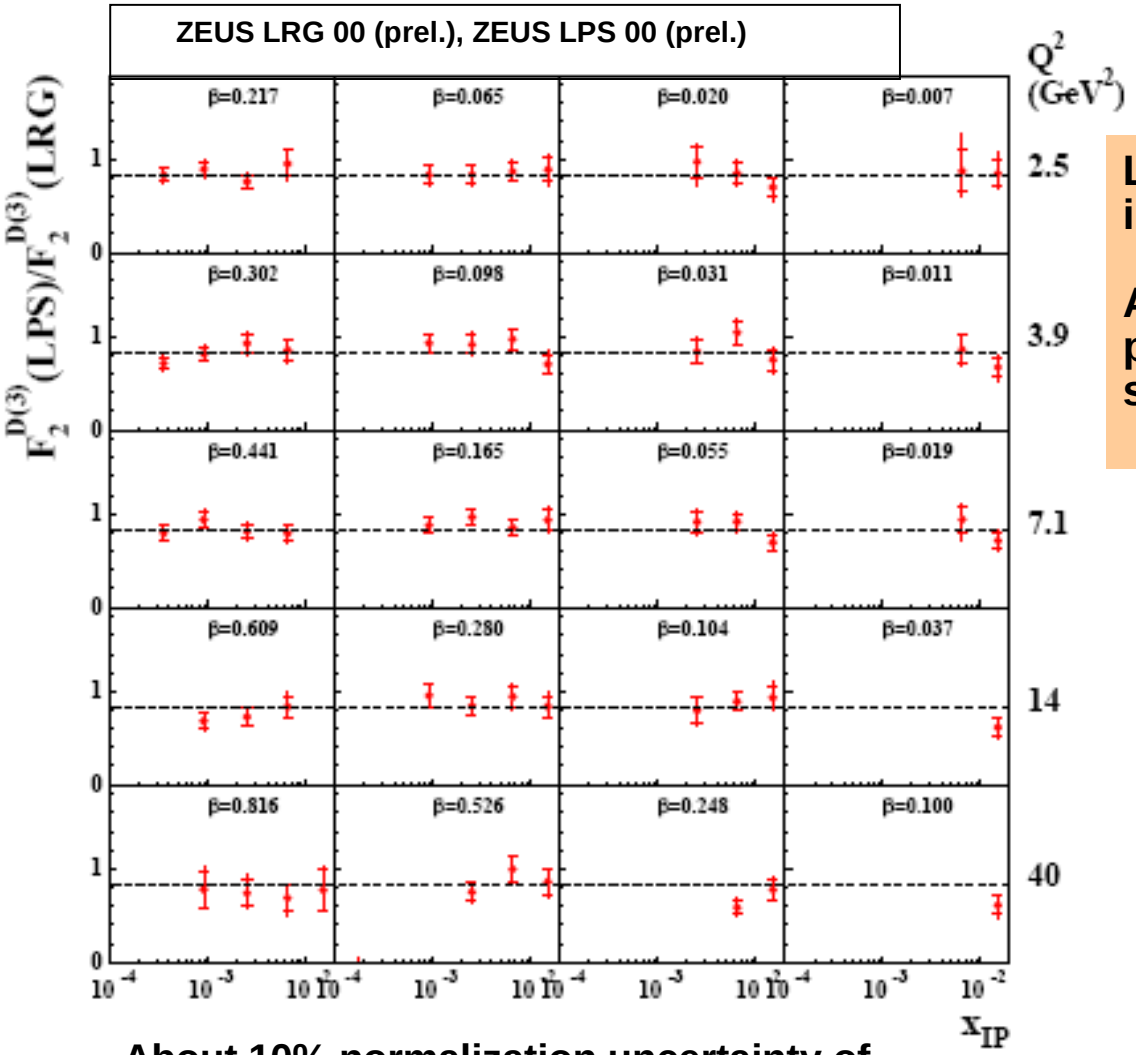
$$\alpha_{IP}(0) = 1.114 \pm 0.018(stat.) \pm 0.012(syst.)^{+0.040}_{-0.020}(theory)$$

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

Regge flux params.

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

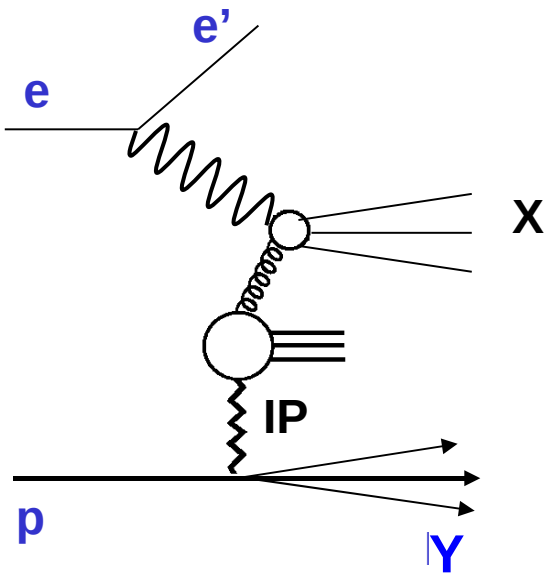
ZEUS LRG vs LPS results



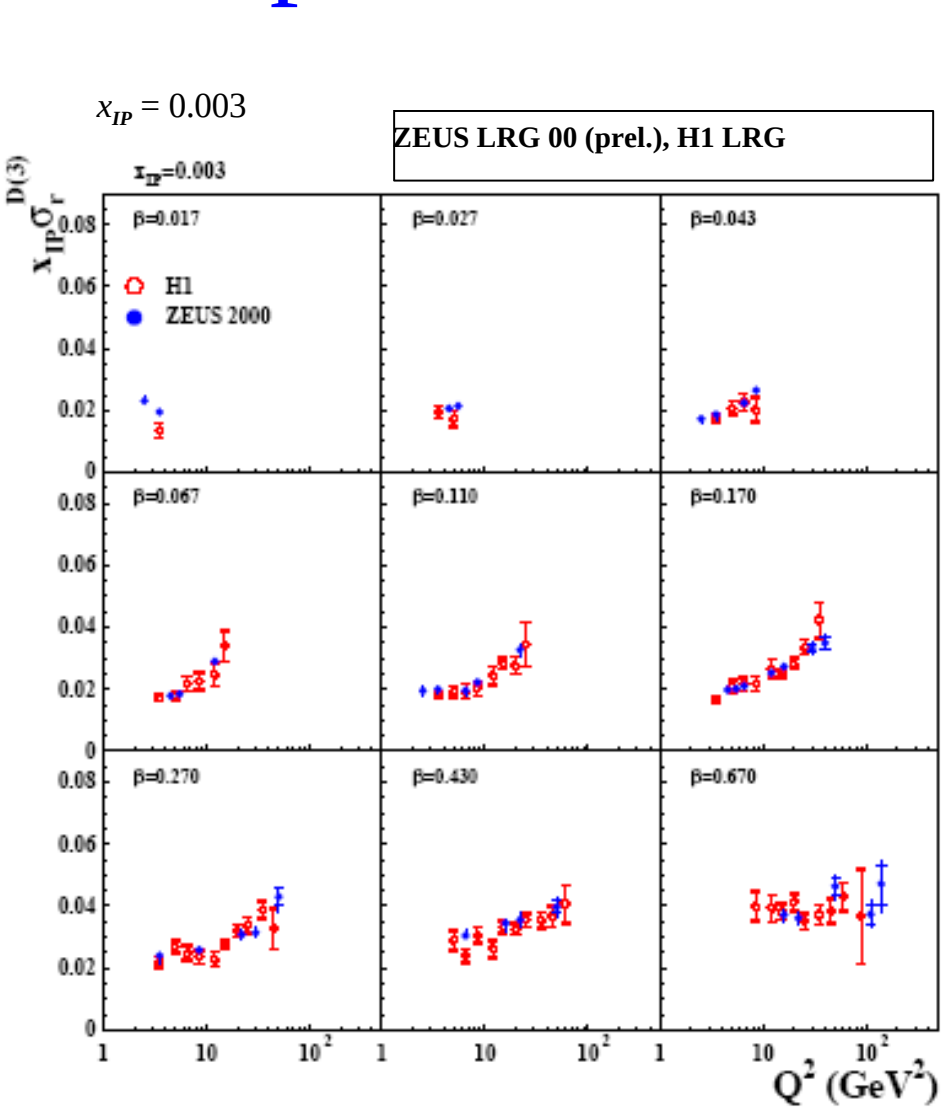
About 10% normalization uncertainty of the LPS measurement not shown

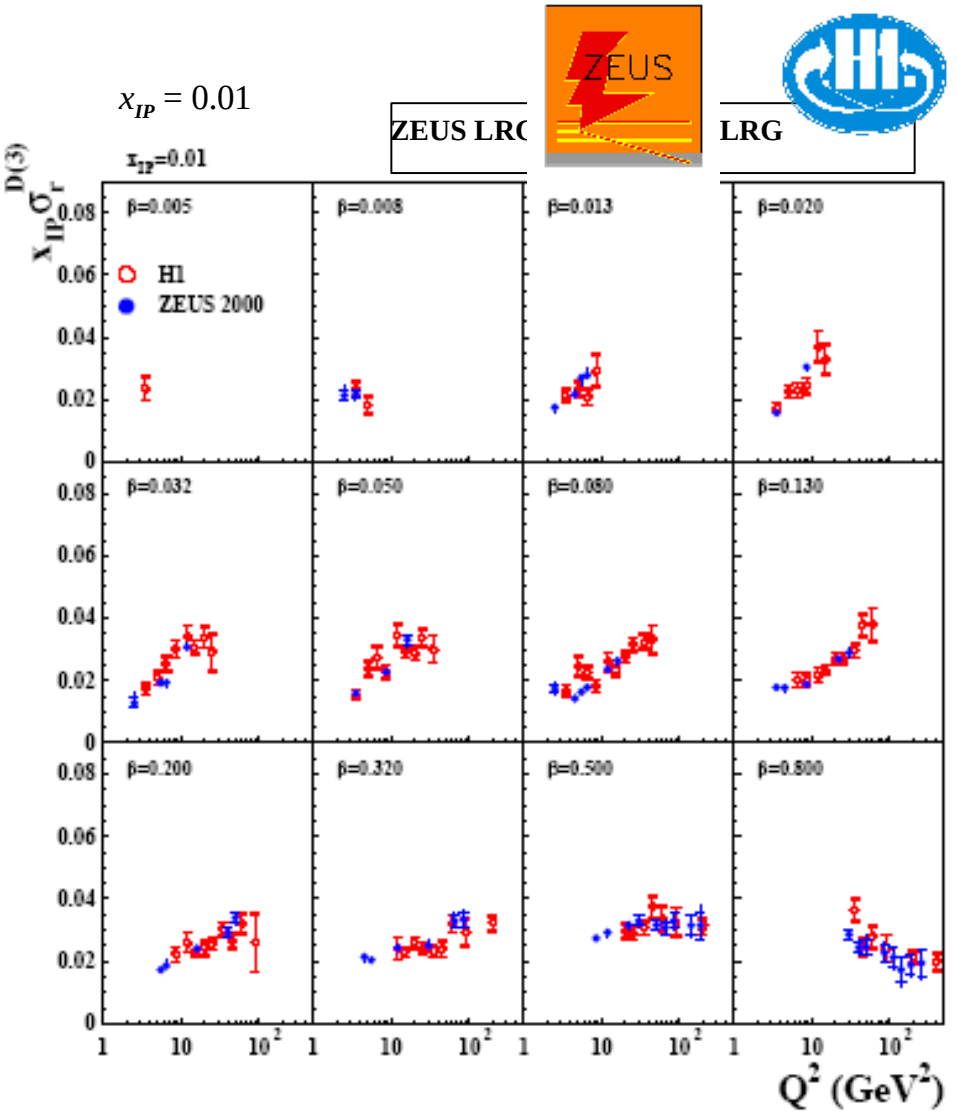
LPS/LRG=0.82±0.01(stat.)±0.03(sys.) independent of Q^2 and β

A measure of the contamination by proton dissociative events in the LRG sample



Comparison ZEUS LRG ↔ H1 LRG

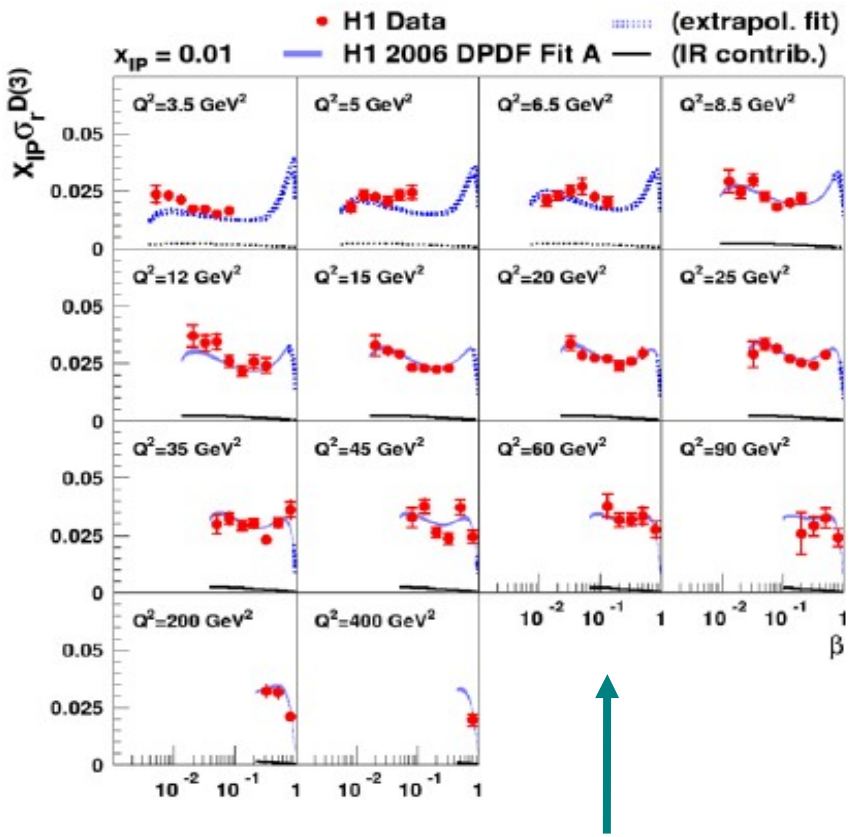


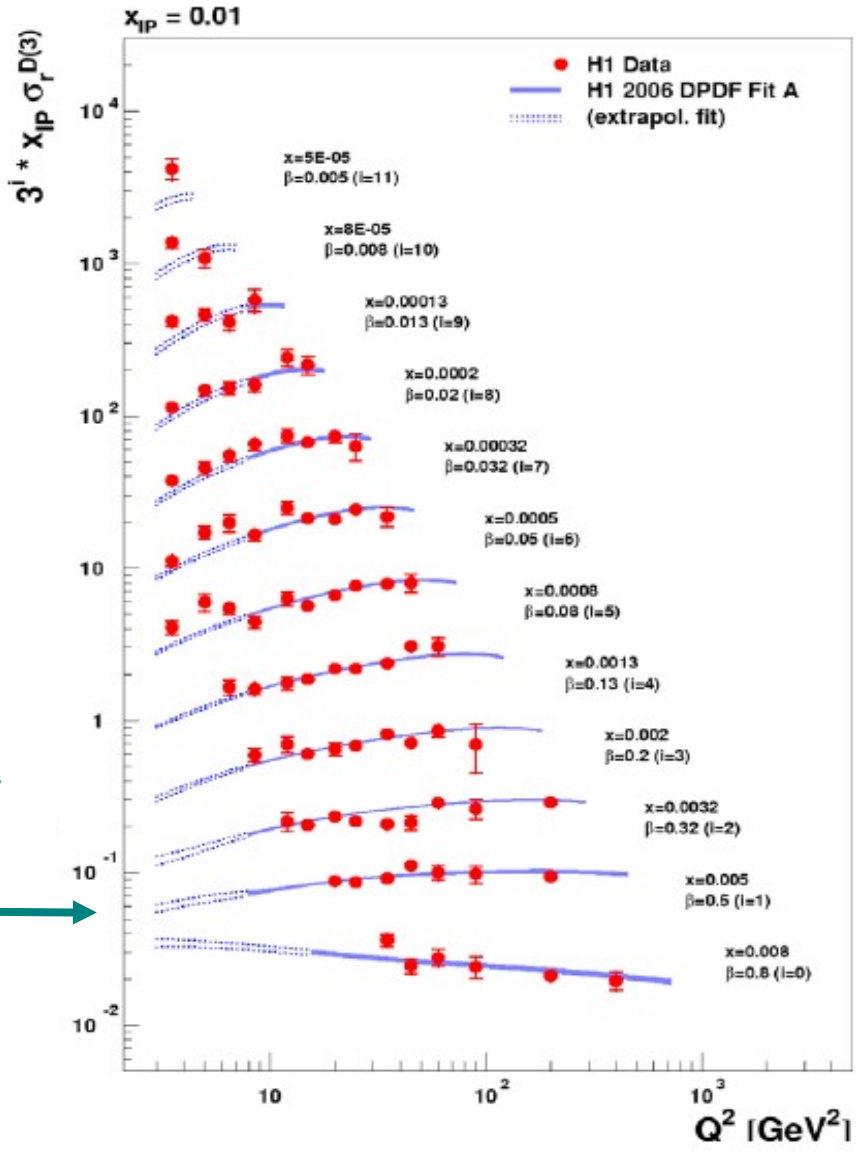


→ Fair agreement H1&ZEUS

- 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

$\ln Q^2$ dependence constrains gluon density

- Positive scaling violations up to high β

→ a lot of gluons in the diffractive exchange

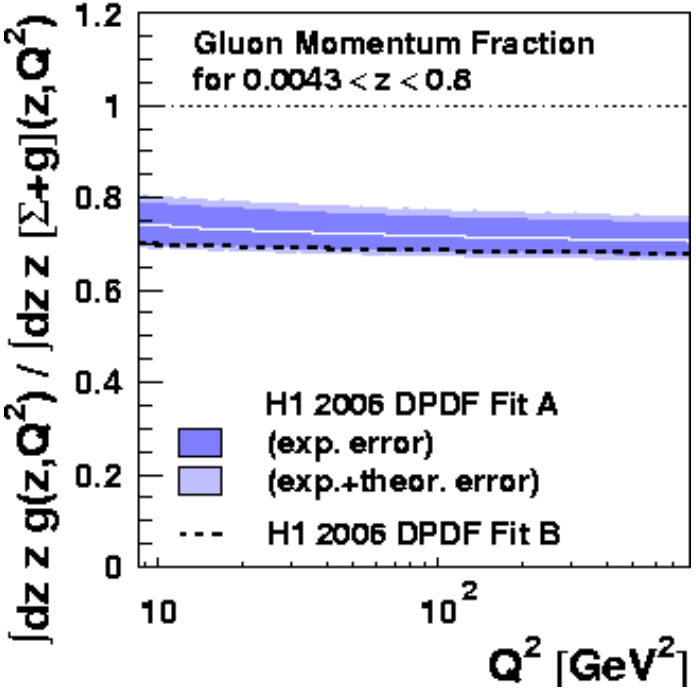
> Fit LRG data with fixed x_{IP} binning
> Use proton vertex factorization with $\alpha_{IP}(t)$ from FPS and LRG data to relate data from different x_{IP} values with complementary β, Q^2 coverage
> Exclude data with M_X < 2 GeV or β > 0.8 and with Q^2 < 8.5 GeV^2 (poor measurement, theory)

DPDFs

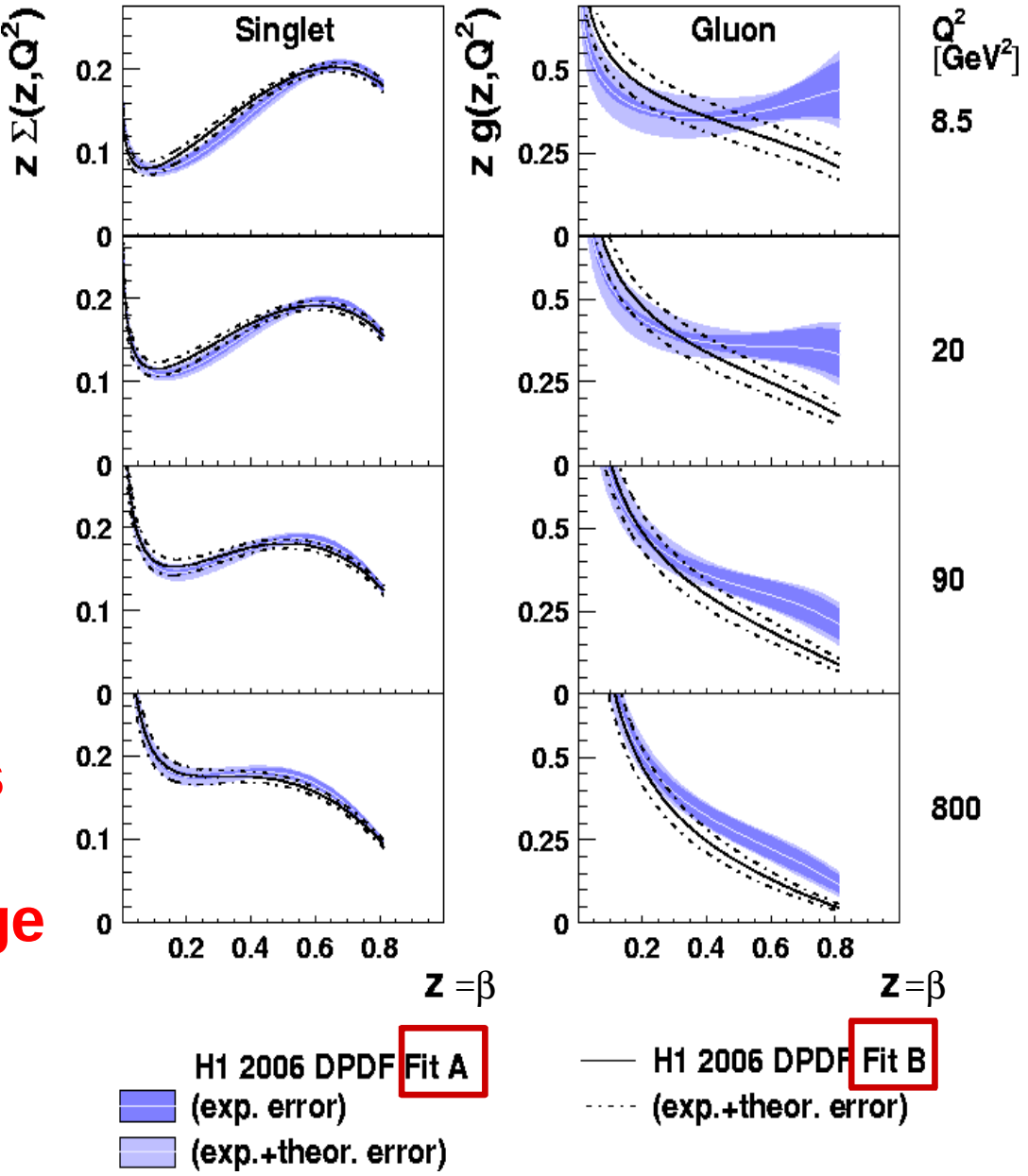
- H1 DPDFs Fit A & B

  different starting parameterizations
- Well constrained singlet
- Weakly constrained gluons

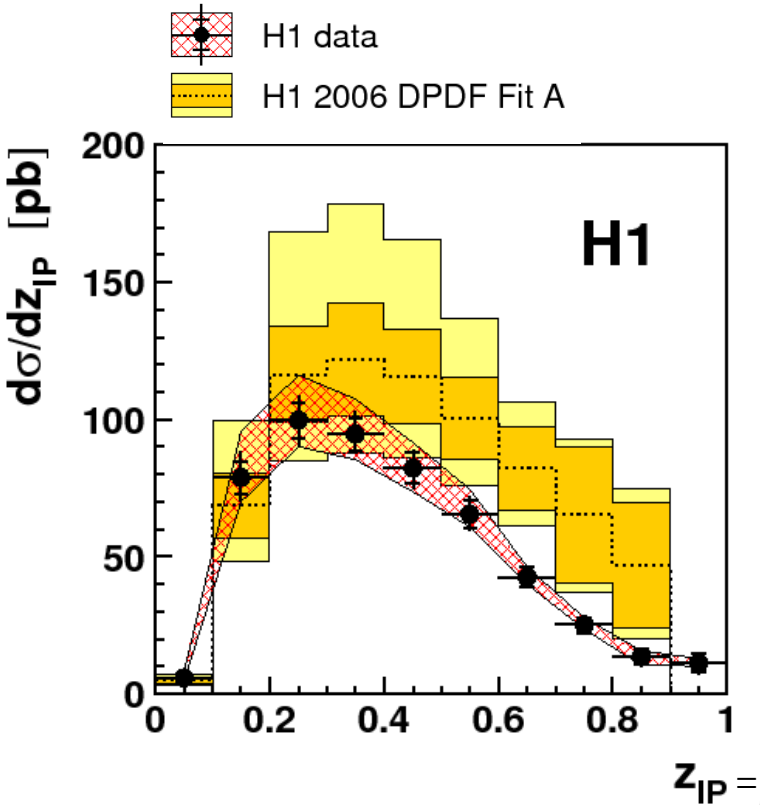
  (esp. at high values of β)

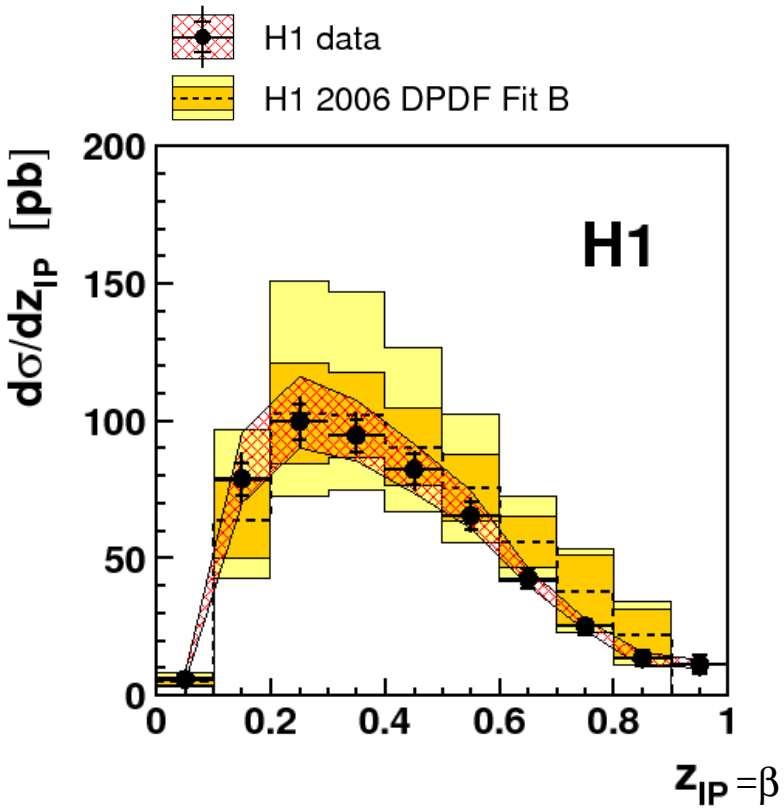


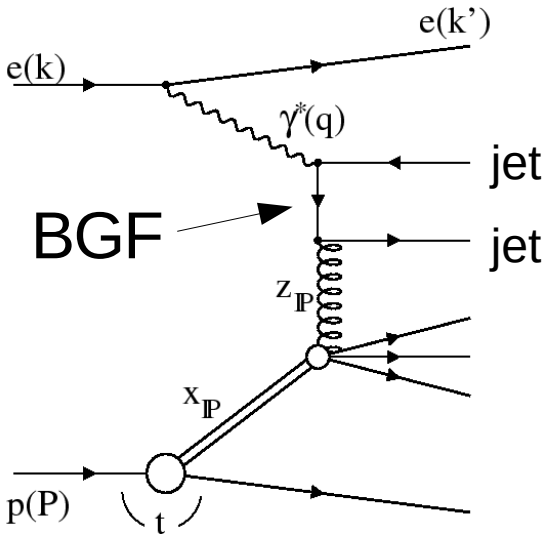
~75% gluons in diff. exchange



These fit DPDFs: compare to diffractive dijets in DIS



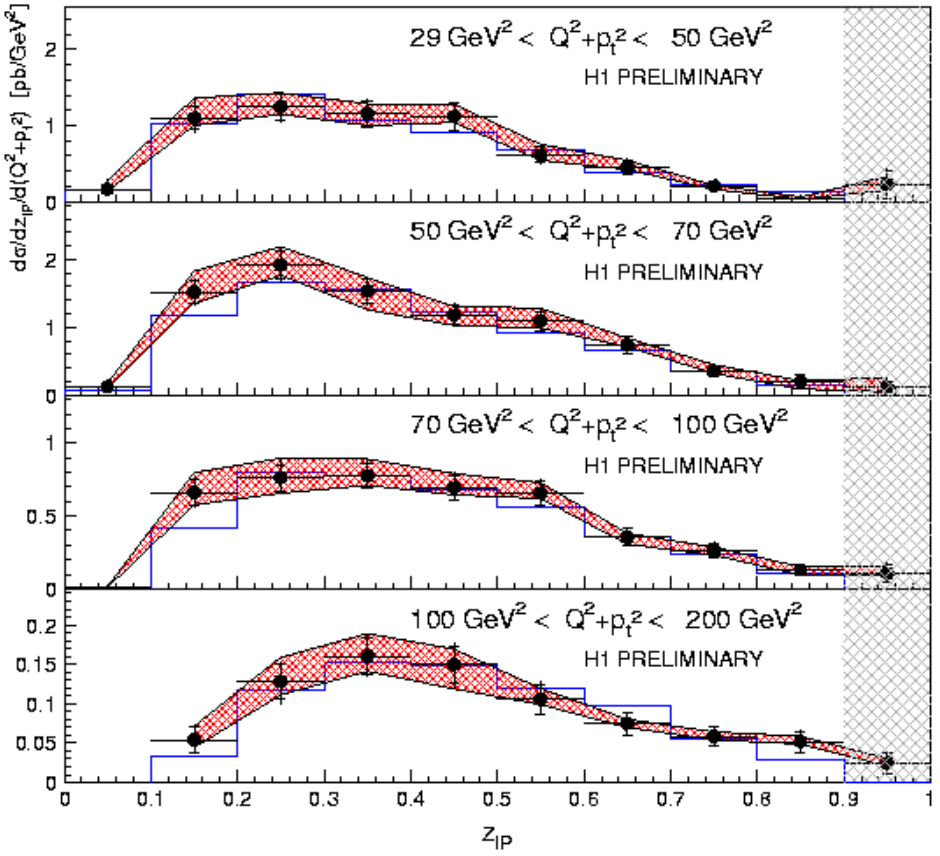




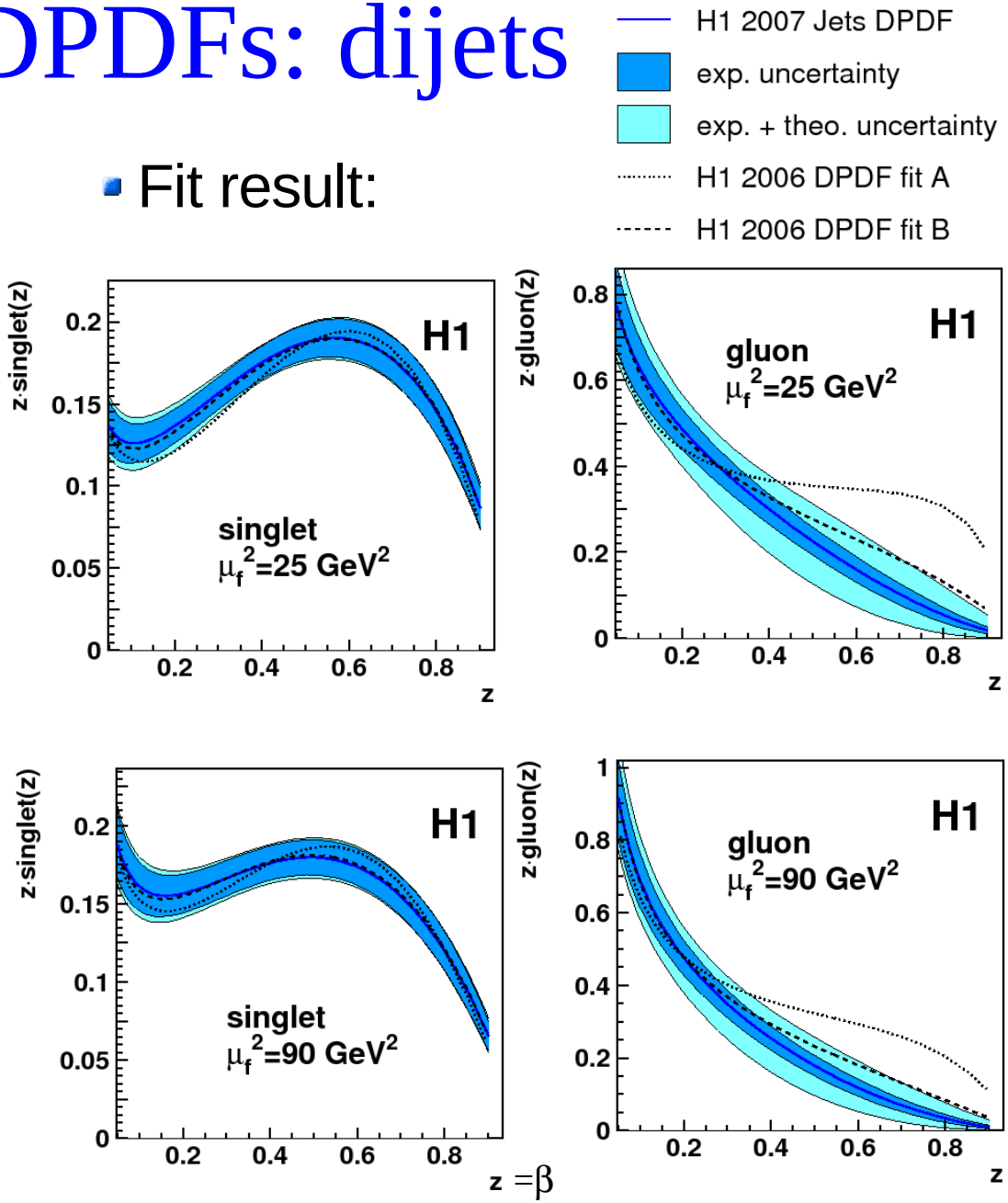
- At low β (< 0.3) Fit A and Fit B are similar, agree with predictions from fit DPDFs
- Consistent with factorization
- At high β the diffractive dijet data clearly prefer FitB
- Sensitive to g(β,Q^2) via *boson-gluon fusion* (BGF)
- Include DIS diffractive dijets in DPDF fit ↘

Improved DPDFs: dijets

Include in QCD fit:



- Fit result:



- **Include dijets ⇒ much improved g(b,Q²) at high β**

Transition ep → hadron-hadron

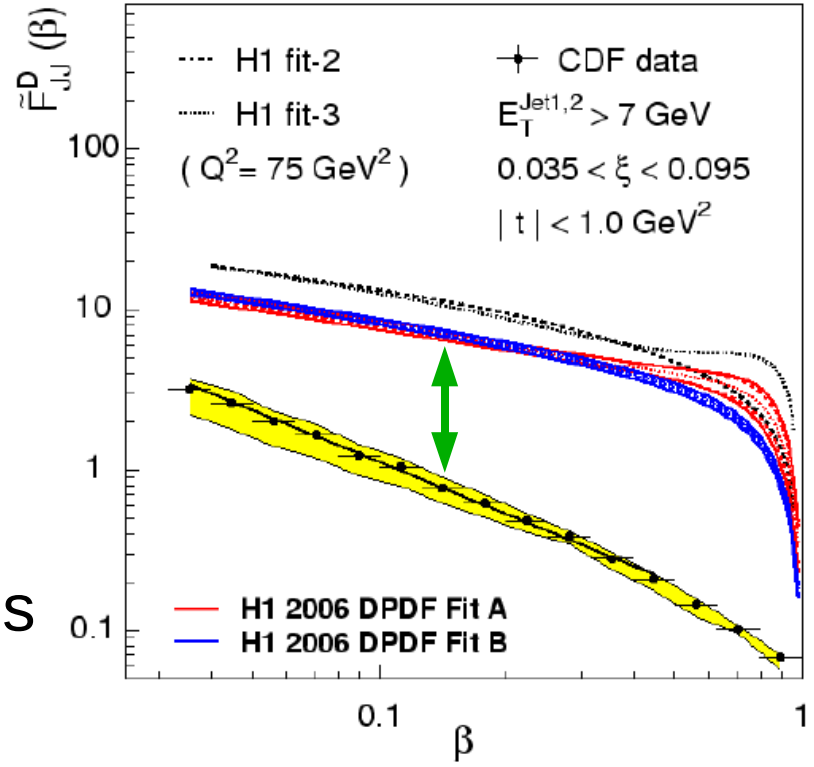
- Factorisation not expected to hold in pp, pp scattering

[Kaidalov, Khoze, Martin, Ryskin, Goulianos, Levin., Gotsman, Maor, ..]

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

- The picture for this: rescattering
- Additional interactions between pp in initial, final state; can simultaneously:
  - drop final state p to lower energy, not detected in forward spectrometer
  - products from interaction can destroy the rapidity gap

⇒ loss of diff. events all selection methods

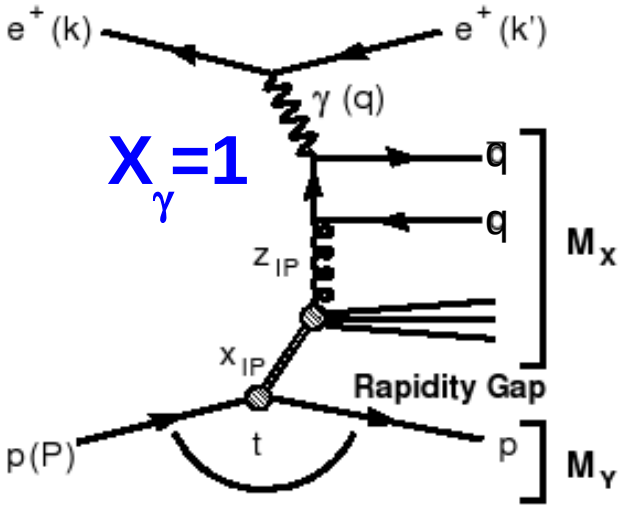


- Investigate at HERA: transition high Q^2 DIS → Q^2~0 photoproduction

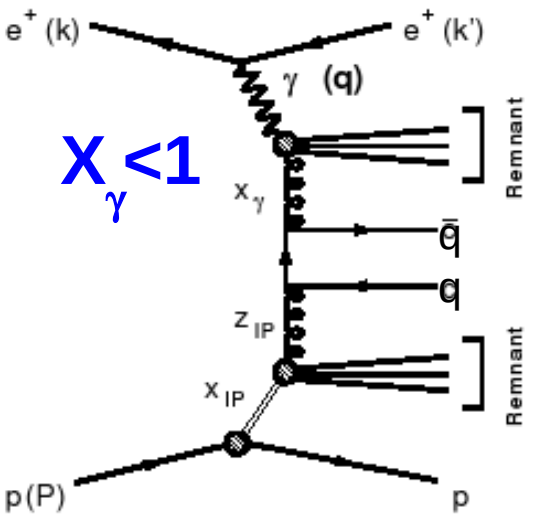
Diff.-dijets: DIS → photoproduction

- With dijets have additional observable: x_γ^-
  X_γ = fraction of photon momentum in hard scattering
- 'Direct' photon w/ X_γ=1 behaves pointlike
- 'Resolved' photon w/ X_γ<1in photoproduction (PhP)
  can behave like a hadron:

DIS and direct PhP



resolved PhP



interactions destroy gap for resolved PhP

Diffractive-dijets in PhP: ZEUS&H1 measurements & theory comparison

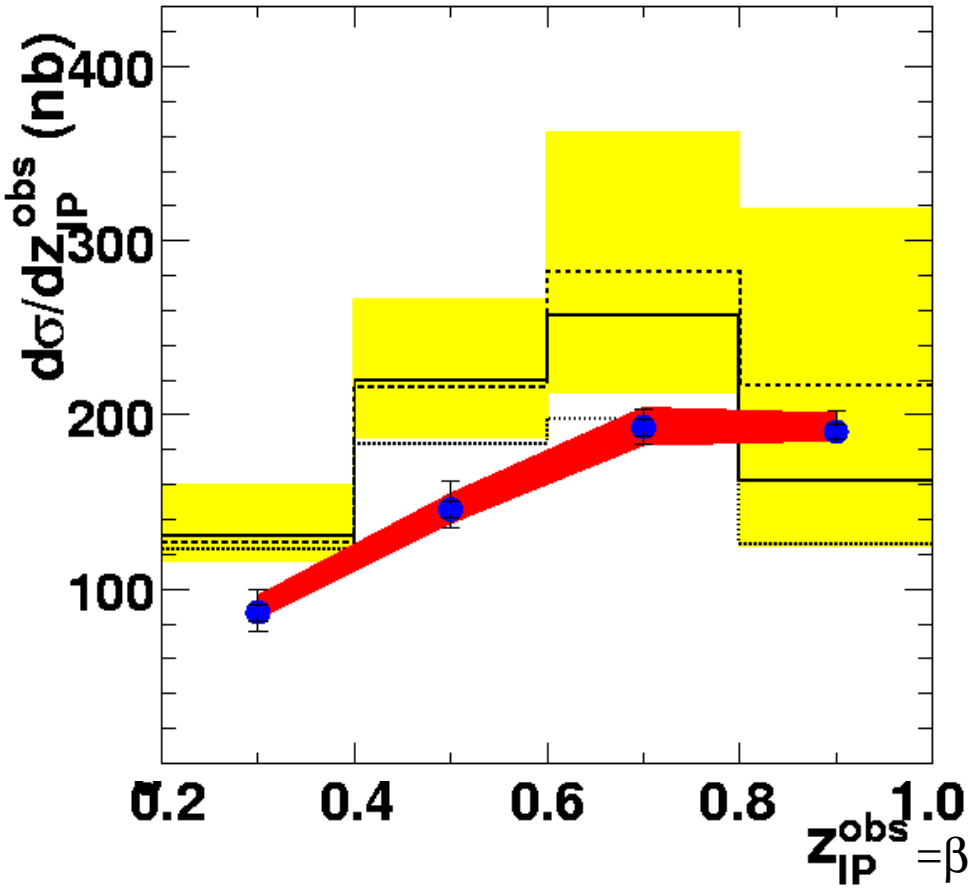
- ZEUS measurement
  - k_T algorithm in LAB frame, R=1
  - E_T^{jet1} (E_T^{jet2}) > 7.5 (6.5) GeV
  - $\langle Q^2 \rangle$ = 0.02 GeV^2
  - -142 < W < 293 GeV
  - X_{IP} < 0.025

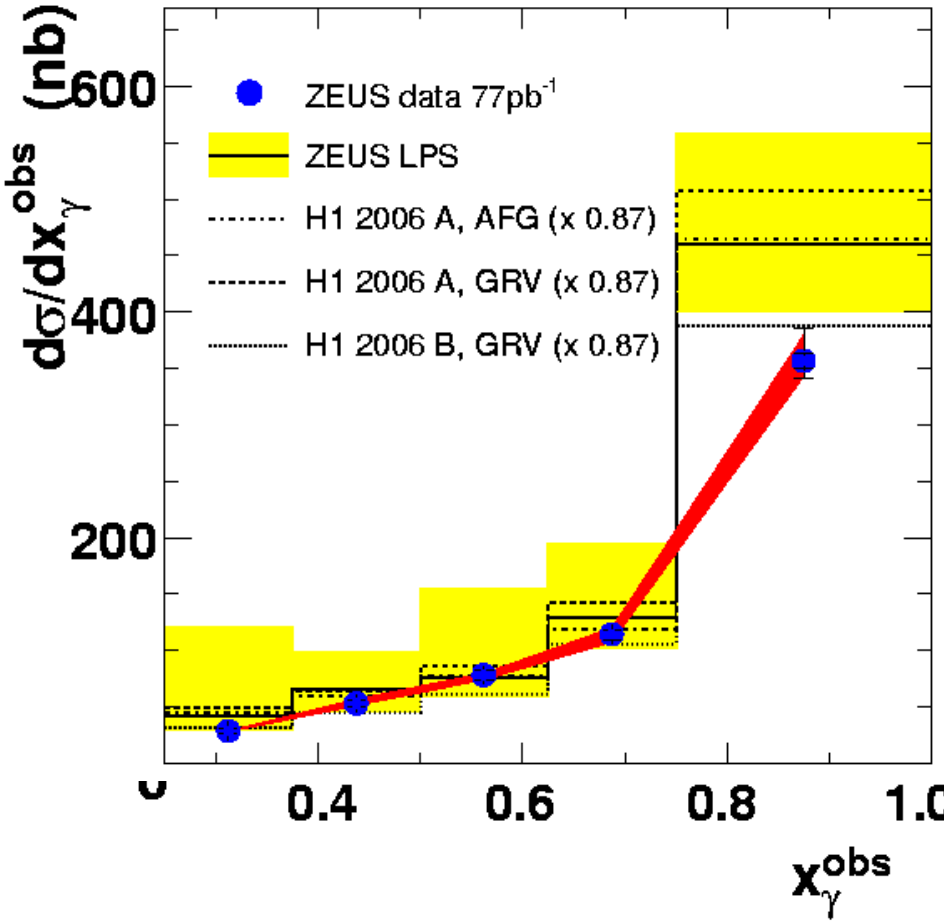
- H1 measurement
  - k_T algorithm in LAB frame, R=1
  - E_T^{jet1} (E_T^{jet2}) > 5 (4) GeV
  - Q^2 < 0.01 GeV^2
  - -165 < W < 242 GeV
  - X_{IP} < 0.03

- ZEUS comparison:
  - -NLO calculation Klasen&Kramer
  - input recent fit DPDFs

- H1 theory comparison:
  - -NLO calculation Frixione&Ridolfi
  - input recent fit DPDFs

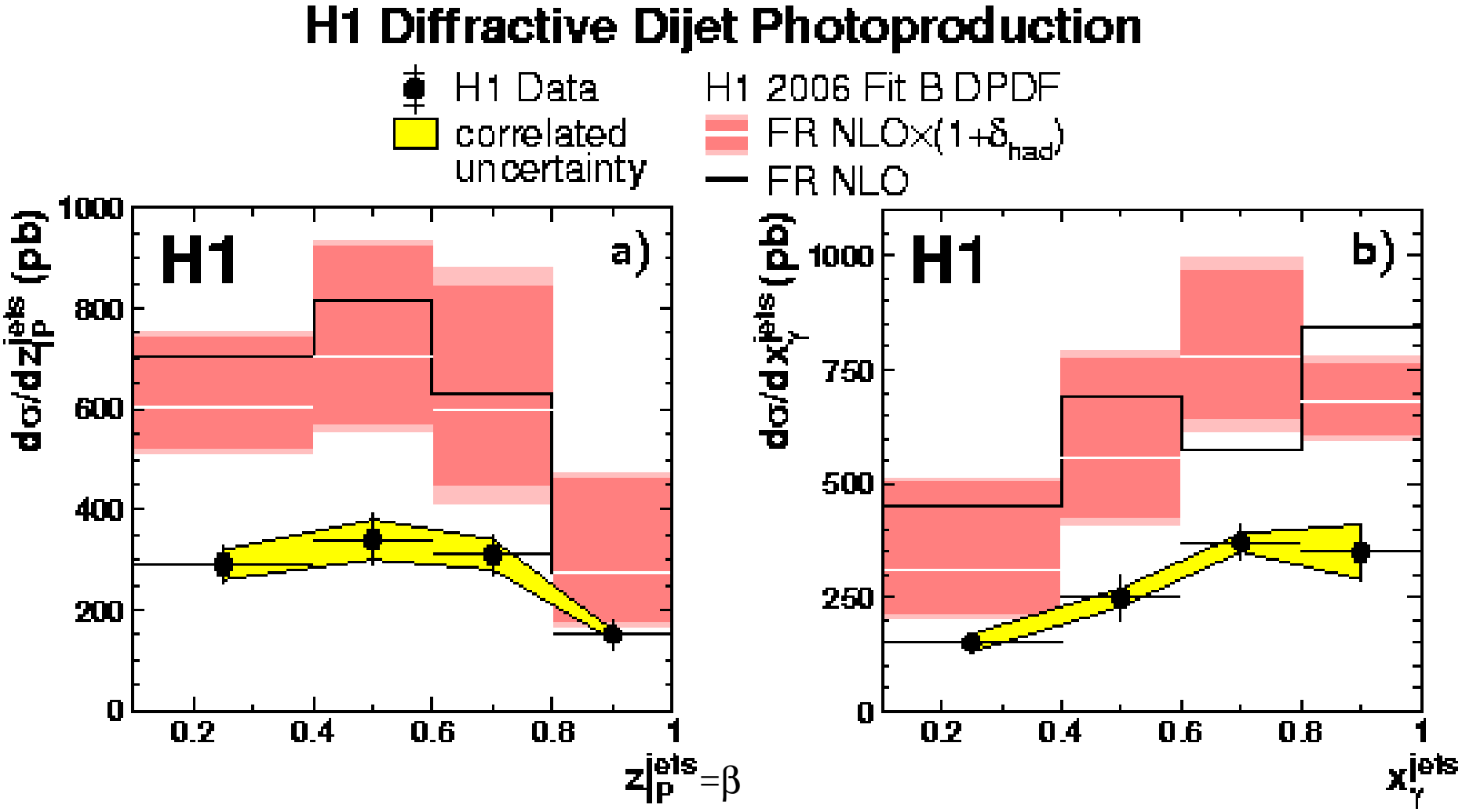
Diffractive-dijets in PhP: ZEUS





- Reasonable agreement with Klasen&Kramer NLO
- **No strong evidence of cross section suppression w.r.t. K&K**
- No preferential suppression of resolved contribution

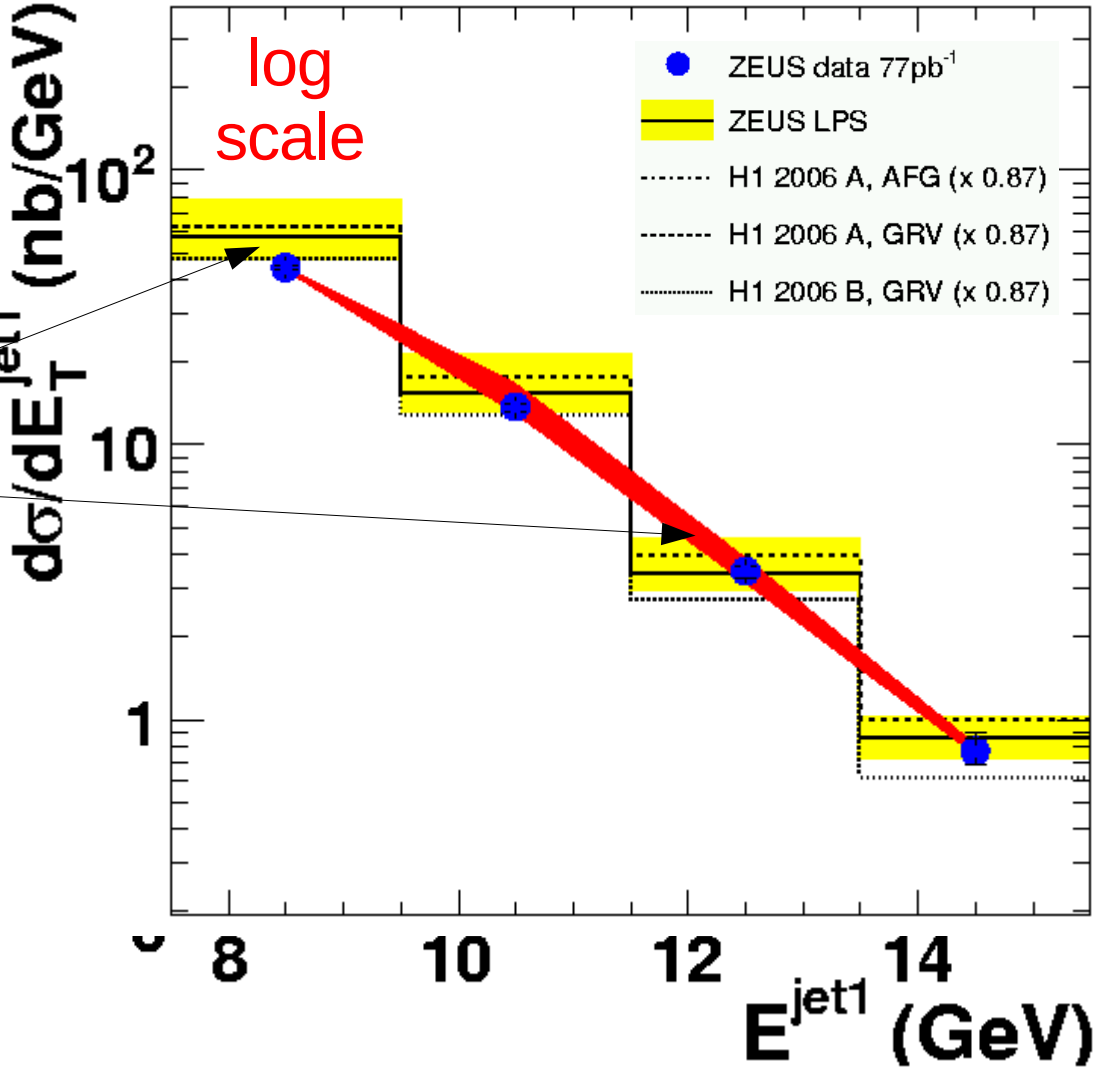
Diffractive-dijets in PhP: H1



- Data ~½ of Frixione&Ridolfi NLO calculation
- **Evidence of cross section suppression w.r.t. F&R**
- No preferential suppression of resolved contribution

ZEUS↔H1 inconsistent?Not clearly...

- H1 starts at lower E_T^{jet}
  - H1: $E_T^{jet1(jet2)}$ > 5 (4) GeV
  - ZEUS :$E_T^{jet1(jet2)}$> 7.5 (6.5) GeV
- x_P range slight difference:
  - H1: < 0.03, ZEUS < 0.025
- E_T^{jet1} in the data seems harder than the NLO
  - Both in H1 and ZEUS
  - Seems the reason to have more suppression at low E_T^{jet} i.e. the H1 result
- Problem in the NLO?
  Or, suppression only at low-E_T^{jet} events?
- **Data is ~final**
- **Implementation of DPDFs to NLO calculations still work in progress...**



Summary

- Diffraction (color singlet exchange) measured in DIS and photoproduction at HERA

- Structure of exchange: DPDFs
  - Inclusive DIS $\rightarrow$ quark structure
  - DPDFs $\leftrightarrow$ dijets in DIS: factorization holds
  - Dijets in DIS $\rightarrow$ improved gluon structure

    $\Rightarrow$ Gluon dominated: ~75%

- Transport DPDFs $\rightarrow$ hadron-hadron
  - Seen to fail badly ($\times$10) at Tevatron
  - Photoproduction at HERA: may apply in some kinematic regions, not others (?)

    $\Rightarrow$ work in progress...