Diffractive dijet and D* production at ZEUS

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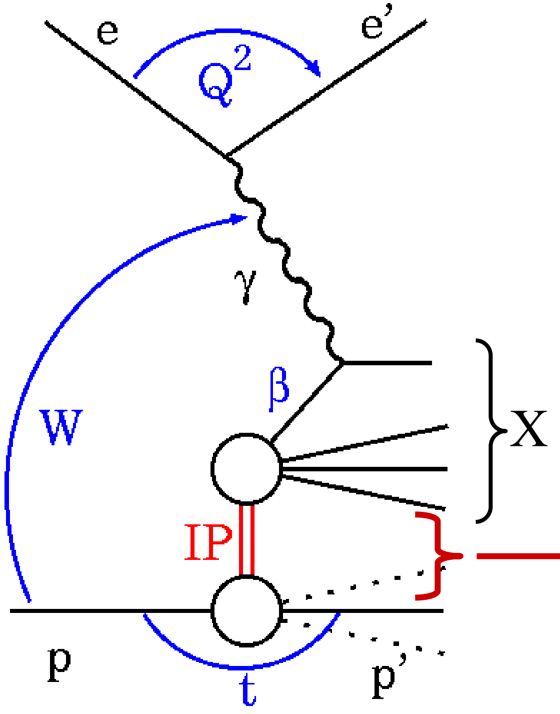
Outline

- Introduction
- Diffractive structure functions
- Diffractive dijet production in DIS
  (result from EPS2005)
- Diffractive D* in photoproduction ($Q^2 \approx 0$)
  (new result - will be sent to Directorate in the next days)
- Summary and Outlook

Inclusive diffraction and factorisation theorem



Diffractive structure function:

$$F_2^{D(3)}(\beta, Q^2, x_{IP}) = \frac{\beta Q^4}{4\pi\alpha^2(1-y+y^2/2)} \cdot \frac{d\sigma^D_{ep\to e'Xp'}}{d\beta dQ^2 dx_{IP}}$$

QCD Factorisation:

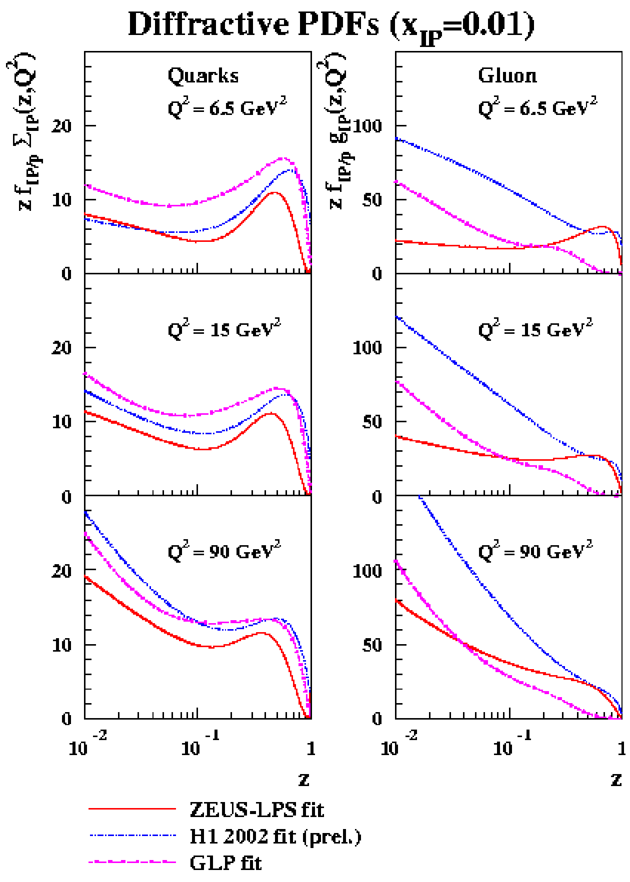
$\sigma_{measure}$ = universal diffractive PDF ⊗ hard ME

Factorisation proven for DDIS and exclusive hard diffraction by Collins.

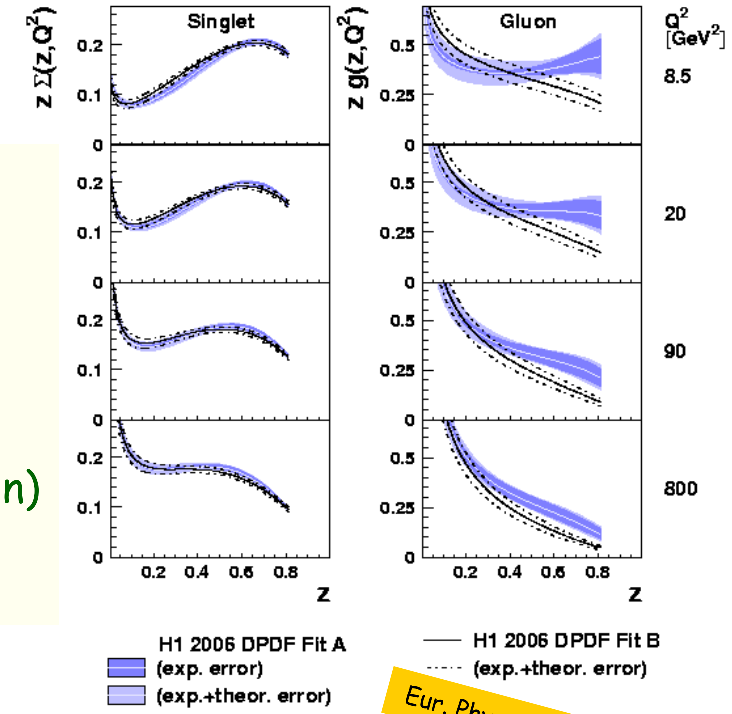
Rapidity gap due to exchange of colorless object with vacuum quantum numbers

NLO DGLAP FIT
⇒ PDF

Diffractive PDFs:
- assume Regge factorisation
- parametrise flavour singlet and gluons at Q^2 = 2 or 3 GeV^2
- evolve with NLO DGLAP and fit

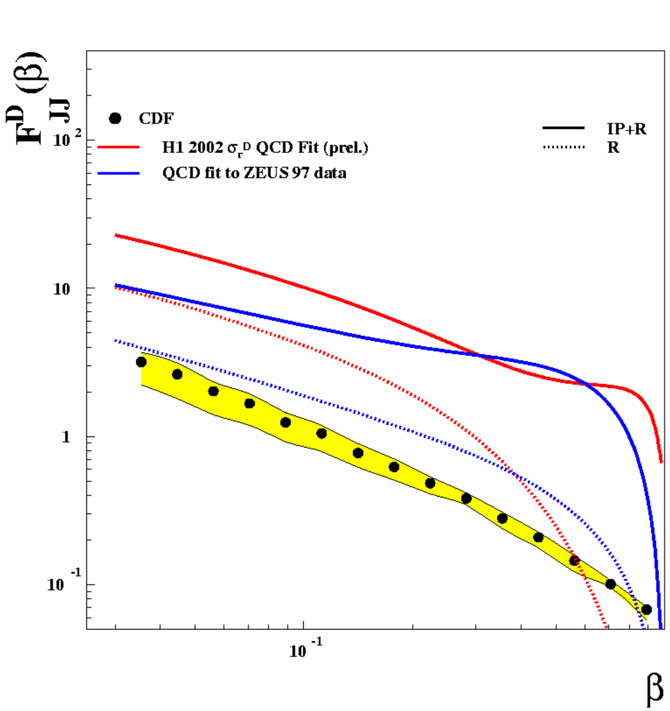


- Gluon dominated
- quark density well constrained
- larger gluon uncertainty at high z (fractional momentum of parton)
- check with dijets and charm (D*)



Eur. Phys. J. C48 (2006) 715-748

Comparison to Tevatron



Dijet cross section factor **3-10 lower** than expected using different HERA PDFs

TEVATRON and LHC:
interaction of two hadronic systems

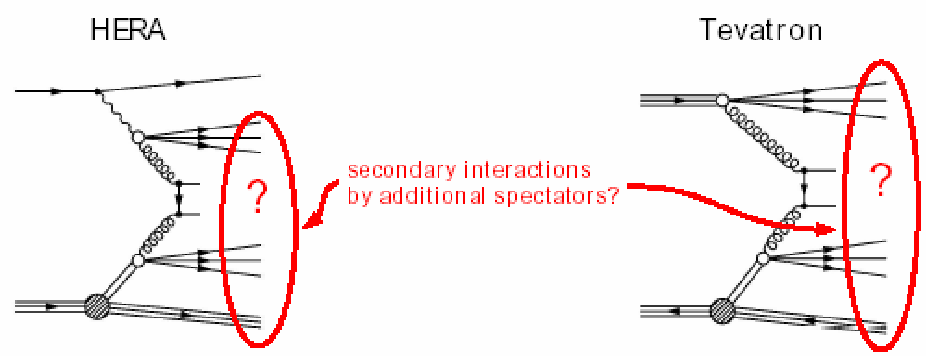
⇔

HERA:
DIS (Q^2>5GeV^2) and direct photoproduction (Q^2≈0):
- photon directly involved in hard scattering

Resolved photoproduction:
- photon fluctuates into hadronic system, which takes part in hadronic scattering

Comparison to Tevatron

Why is the TEVATRON cross section lower?
Idea: suppression due to secondary interactions by add. spectators



Test at HERA with resolved part of photoproduction
Kaidalov et al.: rescaling of resolved part by 0.34 (for dijets,
less for charm due to enhancement of direct part)

Phys.Lett.B567 (2003),61

Use of dijet and charm data:
Hard scale: E_T of jet or charm mass
- tests of universality of PDF's (=QCD factorisation)
- test of DGLAP evolution

Diffractive Dijets: DIS (EPS2005)

Data sample:
98-00 ep data with
$\mathcal{L}$ = 65 pb^{-1}

Event selection:
- diffractive cuts:
  - $\eta_{max} < 2.8$
  - $x_{IP} < 0.030$
- dijet cuts:
  - ≥ 2 jets
  - $E_T^{*\,jet1(2)} > 5(4)$ GeV in γ^*p frame
  - $|\eta^{jet1(2)}| < 2$
- Kinematic range:
  - $5 < Q^2 < 100$ GeV^2
  - $100 < W < 250$ GeV

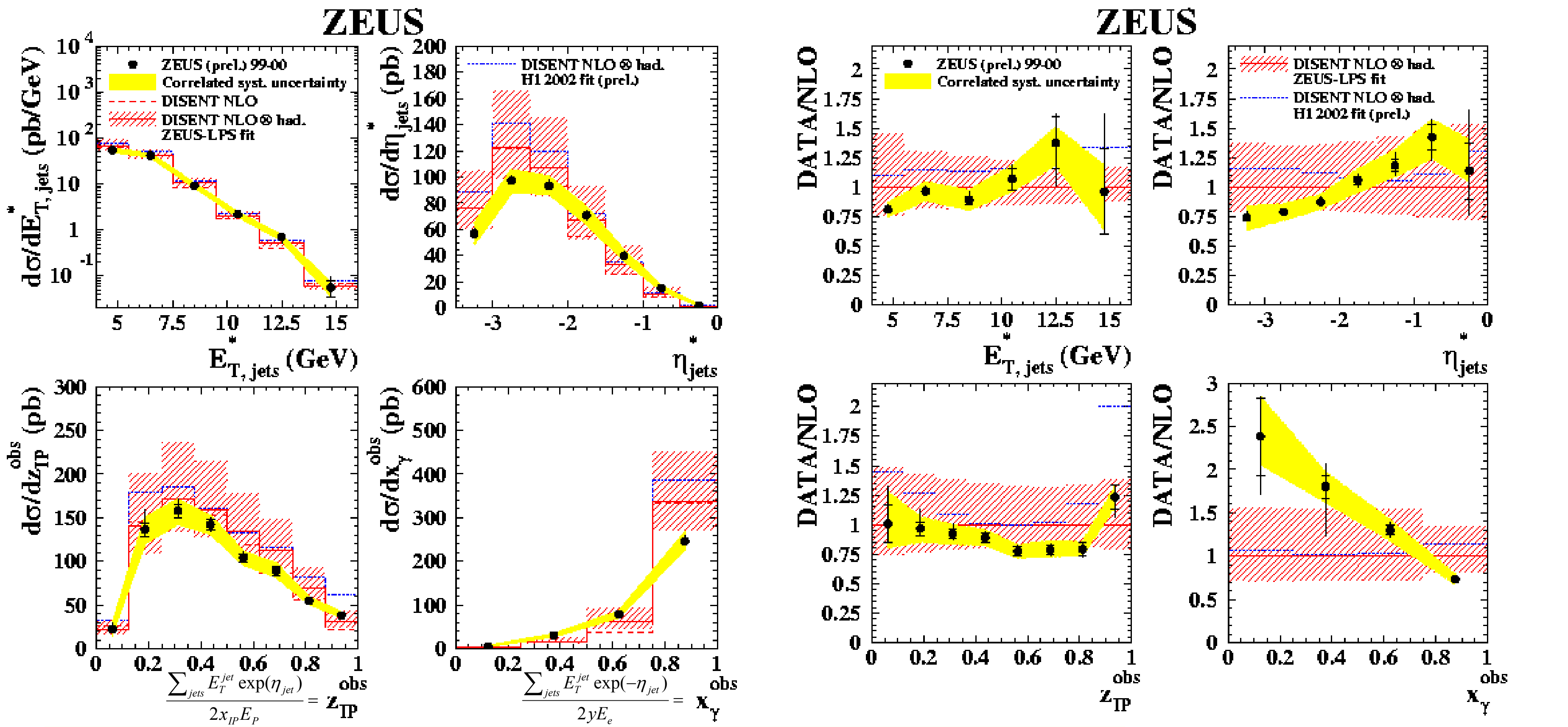
3711 events after all cuts

NLO calculation:
DISENT with the following PDFs:
- H1 2002 fit prel.
- ZEUS-LPS fit

Photon PDF: GRV-G-HO

Note:
Final ZEUS analysis expected in few months

Diffractive Dijets: DIS (EPS2005)



Agreement with NLO for both H1 fit 2002 (prel.) and LPS fit
☛ **factorisation holds as expected (proven by Collins)**

Result of final analysis will confirm this result

Diffractive D*(2010): γP (new!)

D*(2010)±: reconstructed using decay chain:

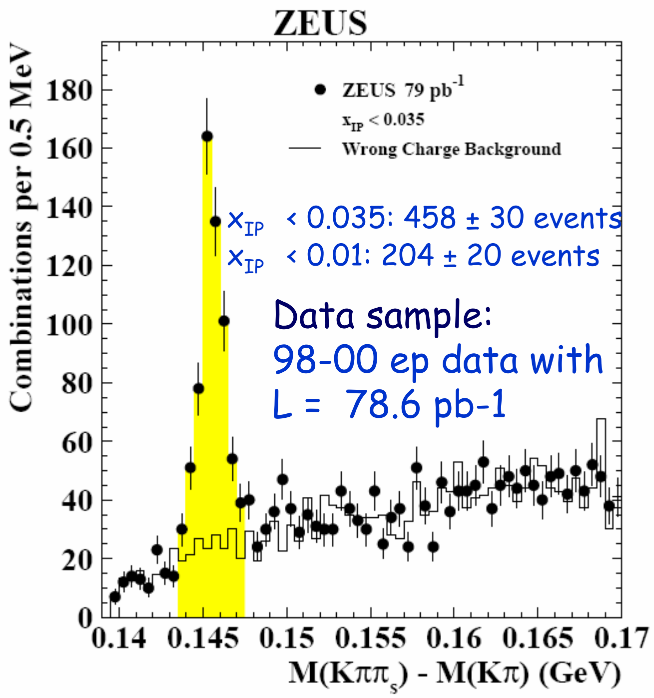
$D^*(2010)^+ \Rightarrow D^0 \pi^+$ (soft pion)

$D^0 \Rightarrow K^- \pi^+$

- Identification of D* with mass difference method.
- Background estimated using wrong charge combinations.

Event selection:

- diffractive cuts:
  - $\eta_{max} < 3.0$
  - $x_{IP} < 0.035$
  - subset for cleaner diffr. events: $x_{IP} < 0.01$
- D* cuts:
  - $p_T(D^*) > 1.9$ GeV
  - $|\eta(D^*)| < 1.6$
- Kinematic range:
  - $Q^2 < 1$ GeV^2
  - $130 < W < 300$ GeV



Diffractive D*(2010): γP (new!)

90% of events produced in **direct process** (due to color enhancement), only **10% resolved** (hadron-like).

NLO calculation:
FMNR with the following diffractive PDFs:
- H1 fit 2006 A and B
- ZEUS-LPS fit

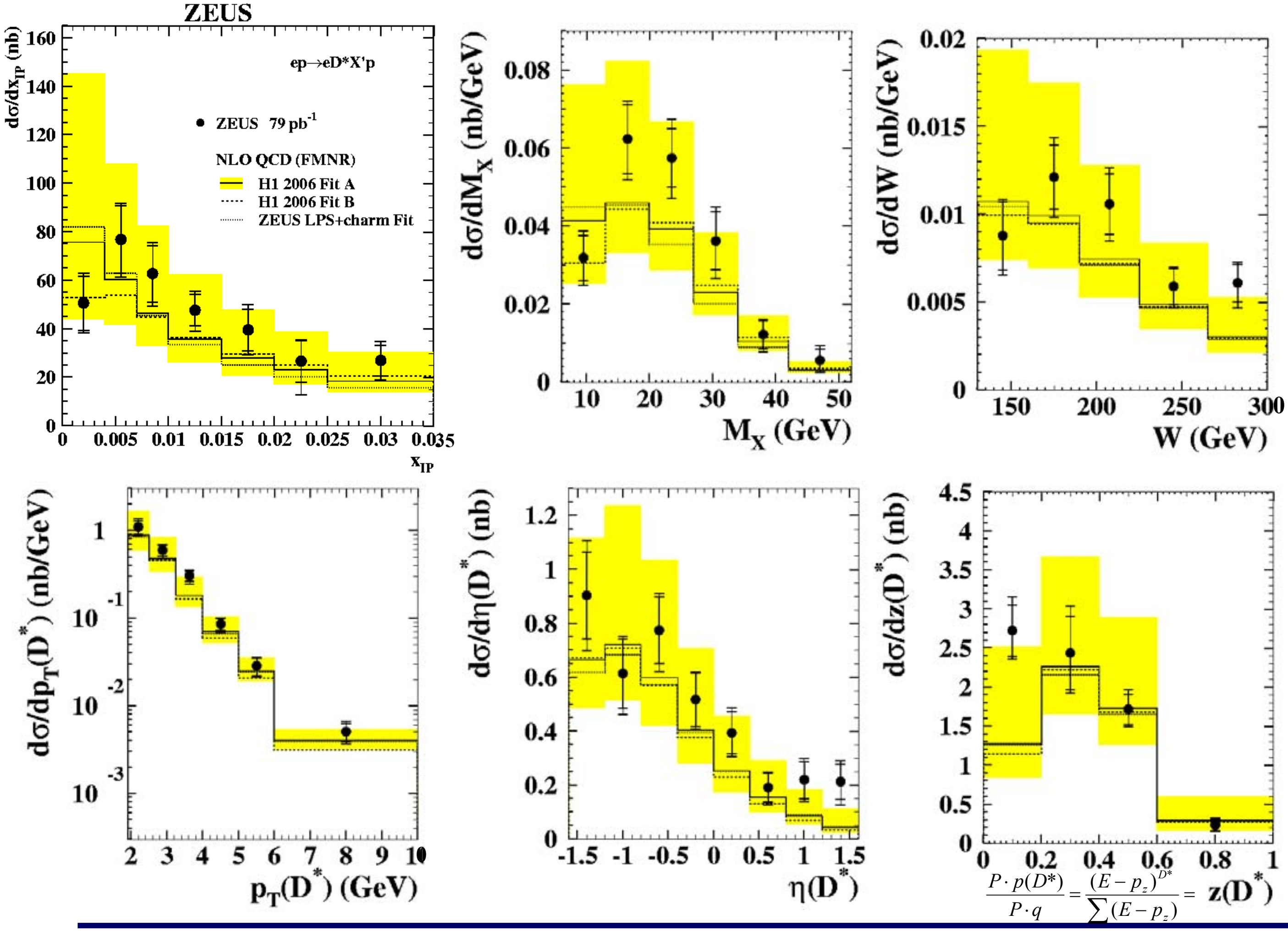
Photon PDF: GRV-G-HO

Changes with respect to preliminary result:
- H1 2002 fit (prel) was not multiplied by factor 0.81 to account for proton-dissociative contribution (now done for H1 fit 2006).
- Improved analysis
- GLP fit (describing shape but not normalisation): taken out because new fit done in slightly different kinematic range on new M_x data behaves different

In addition: calculation of **ratio diffractive/inclusive**:
- NLO uncertainties cancel out
- more precise test of PDFs

inclusive NLO calculation:
- FMNR with CTEQ5M

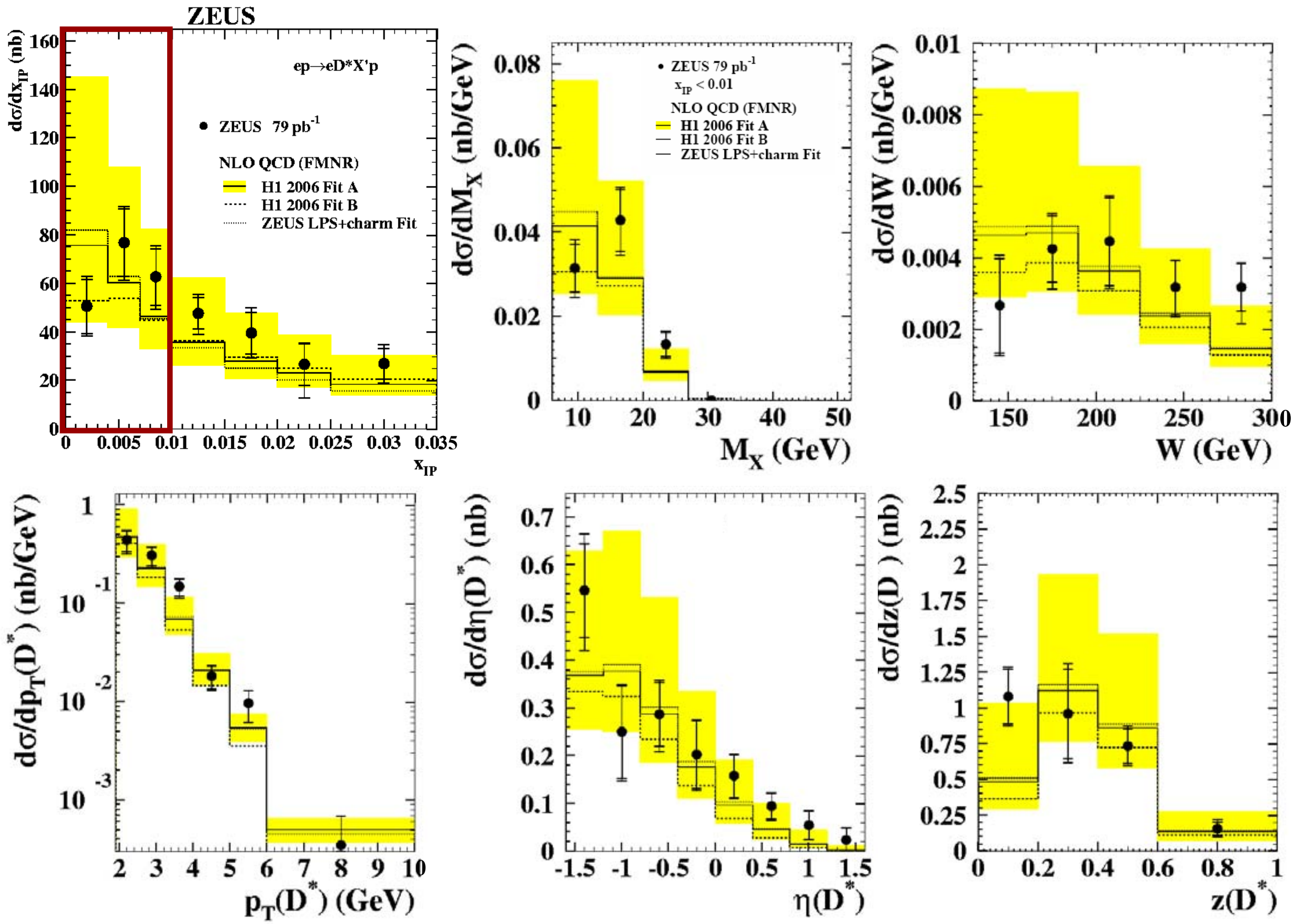
Diffractive D*: γP
$x_{IP} < 0.035$ (new!)



- good agreement of all NLO calculations with data
- large error in theory mainly due to scale variations

- **supports factorisation in direct γP**

Diffractive D*: γP
x_{IP} < 0.01 (new!)

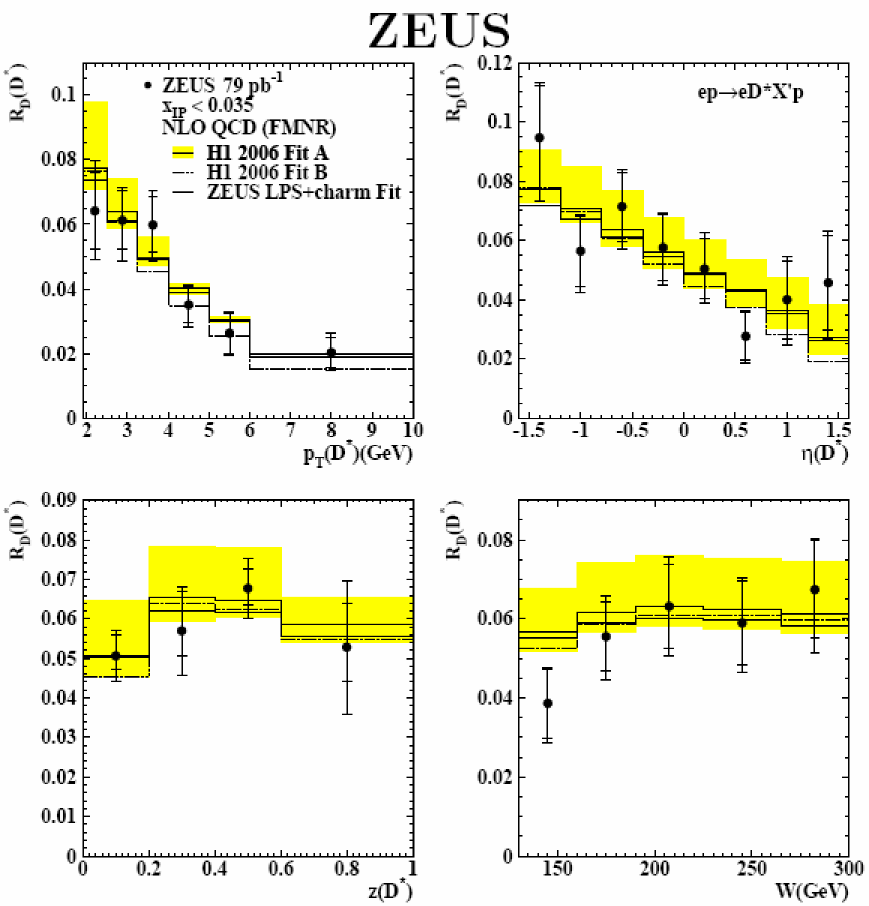


x_{IP} < 0.01: cleaner events:
- Reggeon contribution negligible,
- non-diffr. background reduced

- ☛ *good agreement of all NLO calculations with data*
- ☛ *large error in theory mainly due to scale variations*

- ☛ ***supports factorisation in direct γP***

Diffractive D*: γP comparison to inclusive D* (new!)



Ratio diffractive/inclusive D* (R_D):

$R_D(D^*) = 5.7 \pm 0.5_{(stat)}\,{}^{+0.7}_{-0.4}\,{}_{(syst)} \pm 0.3_{(p.d.)}$ %

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

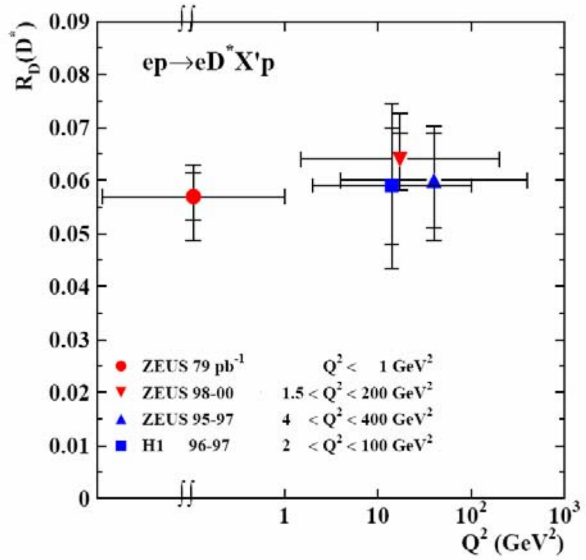
Very good agreement: strongly supporting diffractive factorisation works for direct γP

Diffractive D*: γP (new!)

Conclusion:

Data very well described by NLO

- **strongly supports factorisation in direct γP**
- no conclusion for resolved γP (contribution only about 10 %): experimental and theoretical uncertainties too large to test significant suppression of hadron-like process
- Ratio diffractive/inclusive D* (R_D) about 6% for DIS and γP.



Conclusions and Outlook

Test of diffractive PDFs with ep dijets and charm (D*) data:

- **DIS (dijets and D*):**
  - NLO QCD calculations with **diffr. PDFs describe data**
    - ☛ **factorisation confirmed**
- **γP:**
  - NLO QCD calculations with **diffr. PDFs describe D* data**
    - ☛ **factorisation holds for direct γP**
    - ☛ too large uncertainties to draw conclusion for resolved γP
  - **only dijet data contains large resolved contribution**
    - ☛ no suppression of resolved component with respect to direct

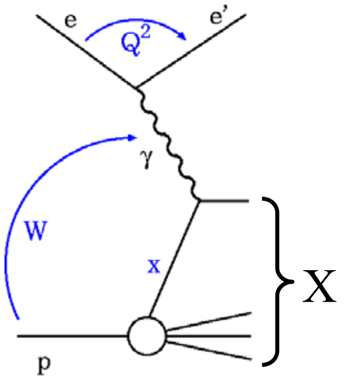
    wait for new results for final conclusion on factorisation

Outlook: final dijet data to come soon…

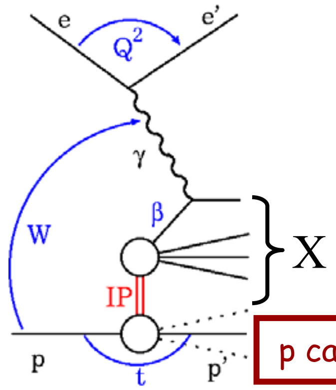
BACKUP

Diffrative DIS at HERA

Deep Inelastic Scattering at HERA:
diffraction contributes substantially to the cross section
(~ 10% of low-x events)



Inclusive DIS:
Probe partonic structure of the proton → F_2



Diffractive DIS:
Probe structure of the exchanged color singlet → F_2^D

p can stay intact or dissociate

Q^2: 4-momentum exchange
W: γ p centre of mass energy
x: fraction of p momentum carried by struck quark

x_{IP}: fraction of p momentum carried by the Pomeron (IP)

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

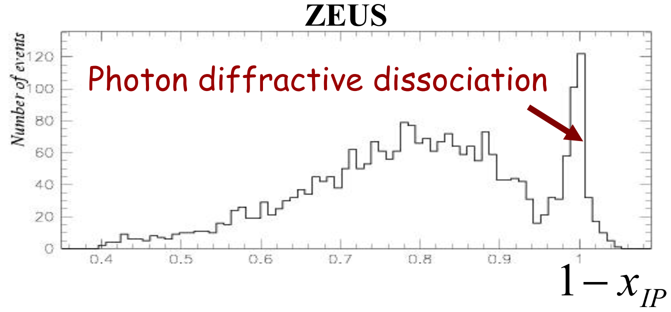
β: fraction of IP momentum carried by struck quark

$$\beta = \frac{Q^2}{2q \cdot (p - p')} \approx \frac{Q^2}{Q^2 + M_X^2} = \frac{x}{x_{IP}}$$

Event selection: LPS, M_x and LRG method

LPS

Use of leading proton spectrometer (LPS):
- t-measurement
- access to high x_{IP} range
- free of p-dissociation background
- small acceptance → low statistics



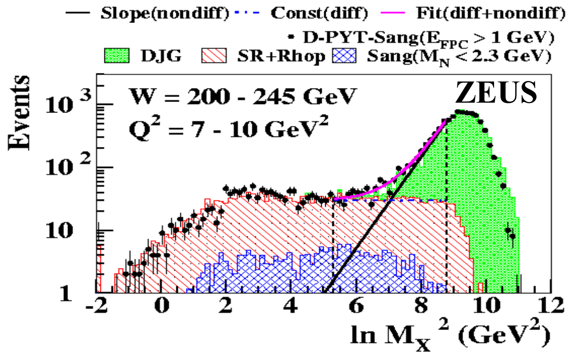
M_x

Diffr. Non-diffr.

$$\frac{dN}{d\ln M_X^2} = D + c \cdot exp(b \cdot \ln M_X^2)$$

(D, c, b from a fit to data)

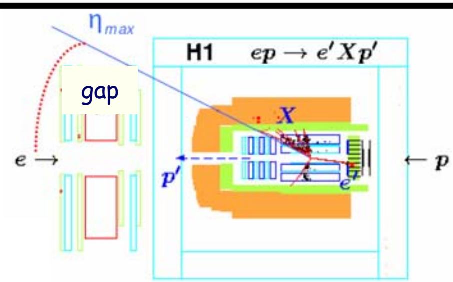
- **flat** vs $\ln M_x^2$ for **diffractive** events
- **exponentially falling** for decreasing M_x for **non-diffractive** events



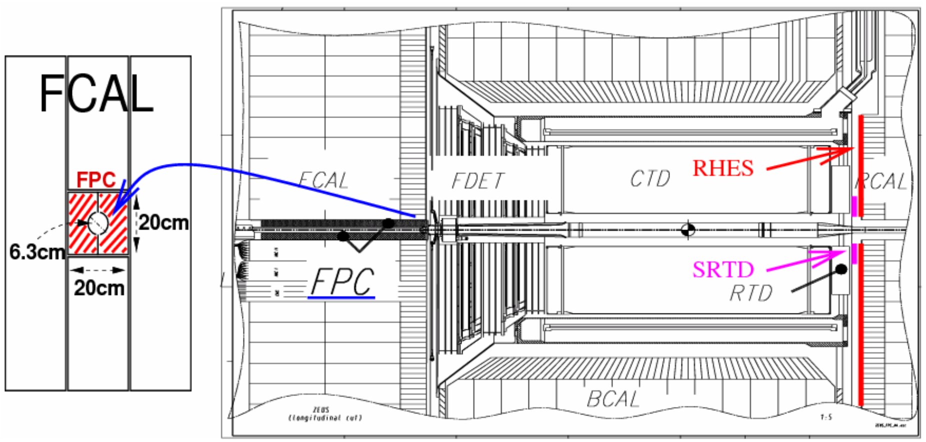
p-dissociation background subtracted for mass of diss. p M_N > 2.3 GeV

LRG

events with large rapidity gap (LRG):
p-dissociation background for
M_N < 1.6 GeV, |t|<1 GeV^2



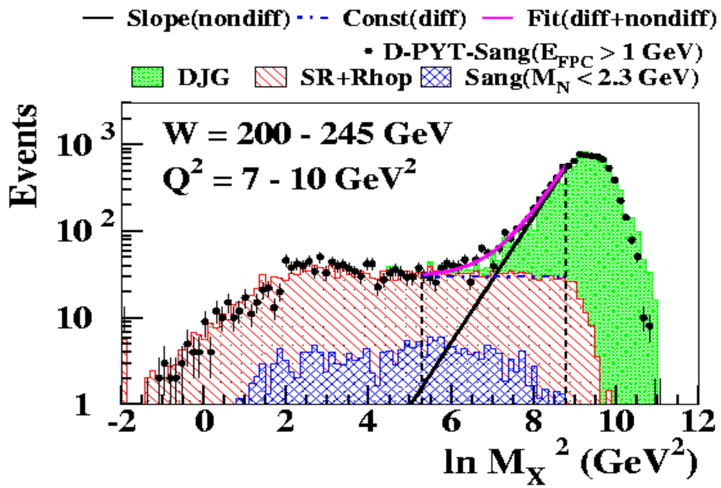
Event selection with M_x method



Forward Plug Calorimeter (FPC):

CAL acceptance extended in pseudorapidity from η=4 to η=5

- higher M_x (a factor 1.7) and lower W
- p-dissociation events: for M_N > 2.3 GeV energy in FPC > 1GeV recognized and rejected



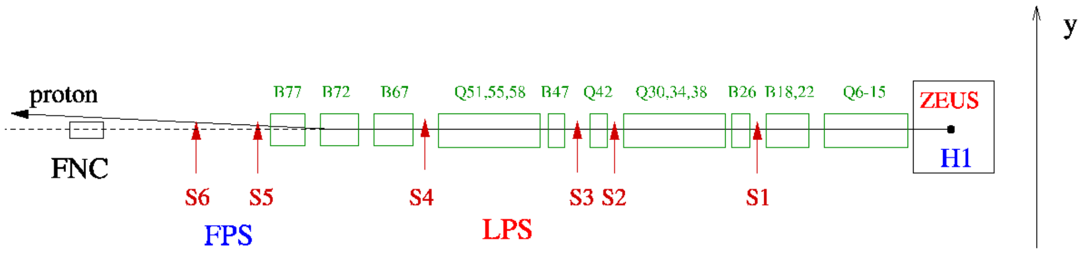
Diffr. Non-diffr.

$$\frac{dN}{d\ln M_X^2} = D + c \cdot exp(b \cdot \ln M_X^2)$$

(D, c, b from a fit to data)

- **flat** vs ln $M_x{}^2$ for **diffractive** events
- **exponentially falling** for decreasing M_x for **non-diffractive** events

Event selection with LPS



- t-measurement
- x_{IP} - measurement (access to high x_{IP} range)
- free of p-dissociation background
- small acceptance → low statistics

$$x_{IP} = 1 - \frac{E'_p}{E_p}$$

$$x_L = \frac{p'_z}{p_z} \approx 1 - x_{IP}$$