Charm production in diffractive DIS and PHP at ZEUS

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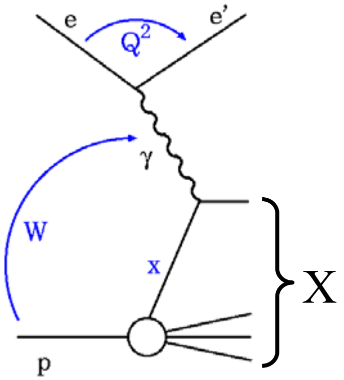
Outline

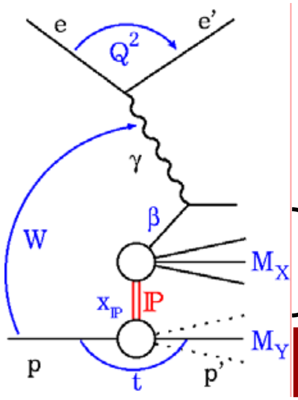
- Introduction
- Selection of diffractive events
- Reconstruction of D*
- Diffractive D* in photoproduction ($Q^2 \approx 0$) (new result)
- Comparison to inclusive D*
- Summary and Outlook

Diffractive DIS at HERA

Deep Inelastic Scattering at HERA:
diffraction contributes substantially to the cross section
(~ 10% of visible 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

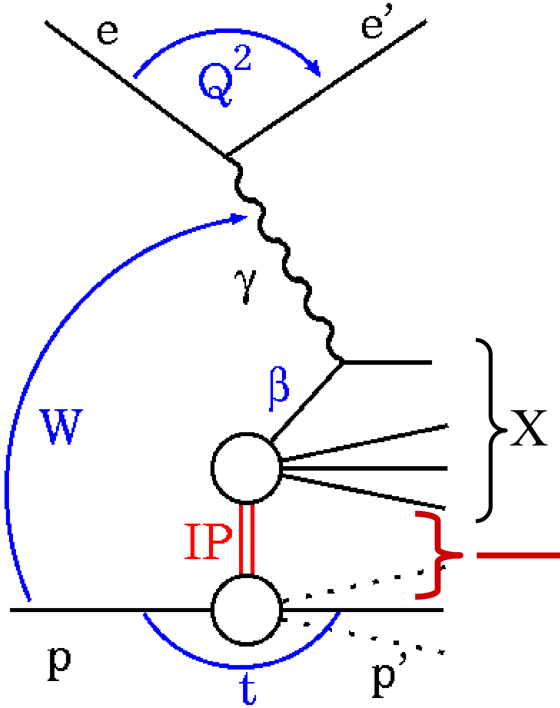
x_{IP}: fraction of p momentum carried by the Pomeron (IP)

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

β: fraction of IP momentum carried by struck quark

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

Inclusive diffraction and factorisation theorem



Diffractive structure function:

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

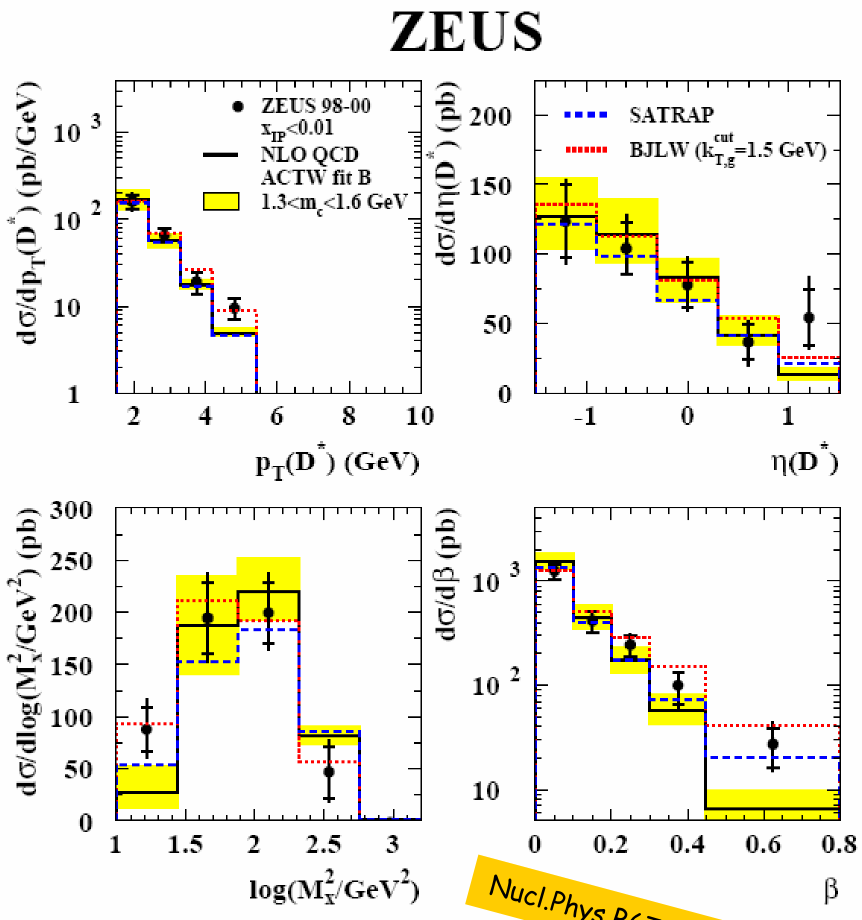
QCD Factorisation:

σ^D = universal diffractive PDF ⊗ hard ME

Factorisation proven for DDIS by Collins.

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

Reminder: Diffractive D* in DIS



Nucl.Phys.B672 (2003),3

Kinematic range:
- $1.5 < Q^2 < 200$ GeV^2
- $0.02 < y < 0.7$
- $\beta < 0.8$

D* cuts:
- $p_T(D^*) > 1.5$ GeV
- $|\eta(D^*)| < 1.5$

NLO calculation:
HVQDIS with:
- ACTW fit B (gluon dominated fit to H1 and ZEUS incl. diffr. DIS and ZEUS diffr. γP data)

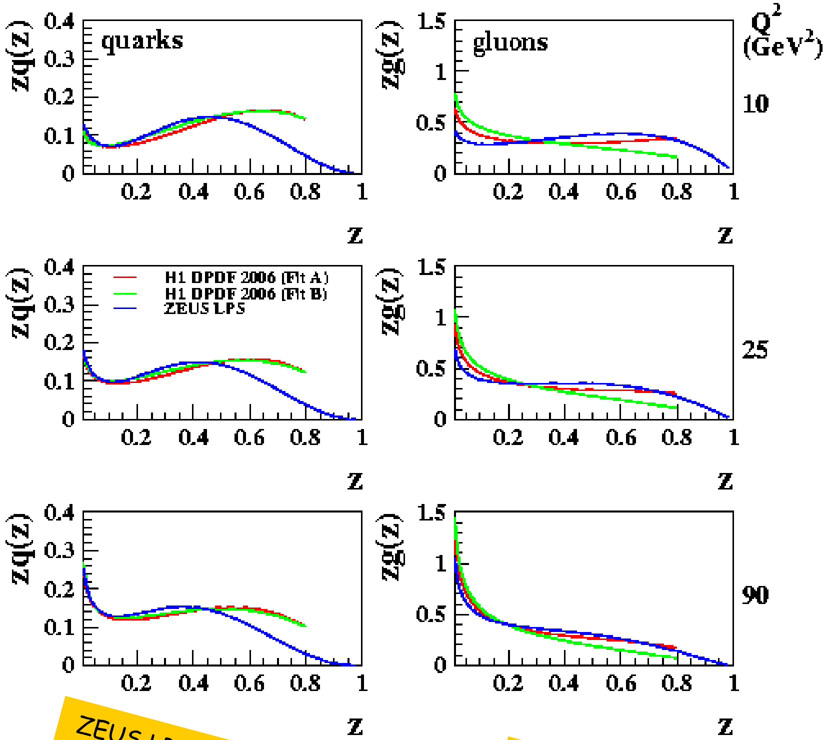
Phys.Rev.D59 074022(1999)

- good agreement of NLO calculations with data
- **confirms QCD factorisation in DDIS**
- **data used to constrain gluons in ZEUS LPS fit**

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

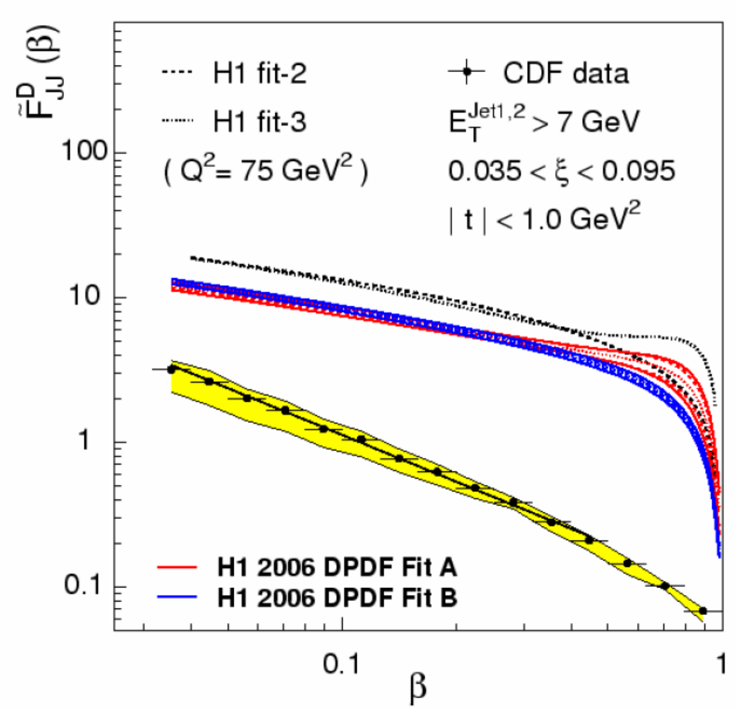
- Gluon dominated
- quark density well constrained
- larger gluon uncertainty at high z (fractional momentum of parton)



ZEUS LPS+charm fit:
From incl. diffr. data in
Eur. Phys. J. C38 (2004) 43-67
and DIS charm data in
Nucl.Phys.B672 (2003),3

H1 2006 fits:
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

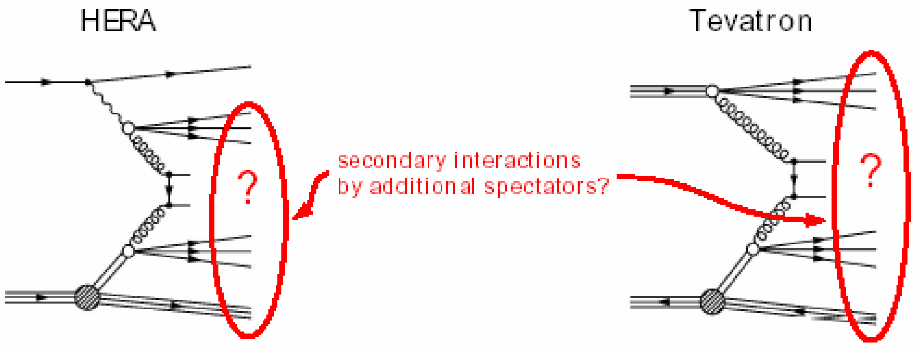
⇔

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

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

Dijet and charm data:

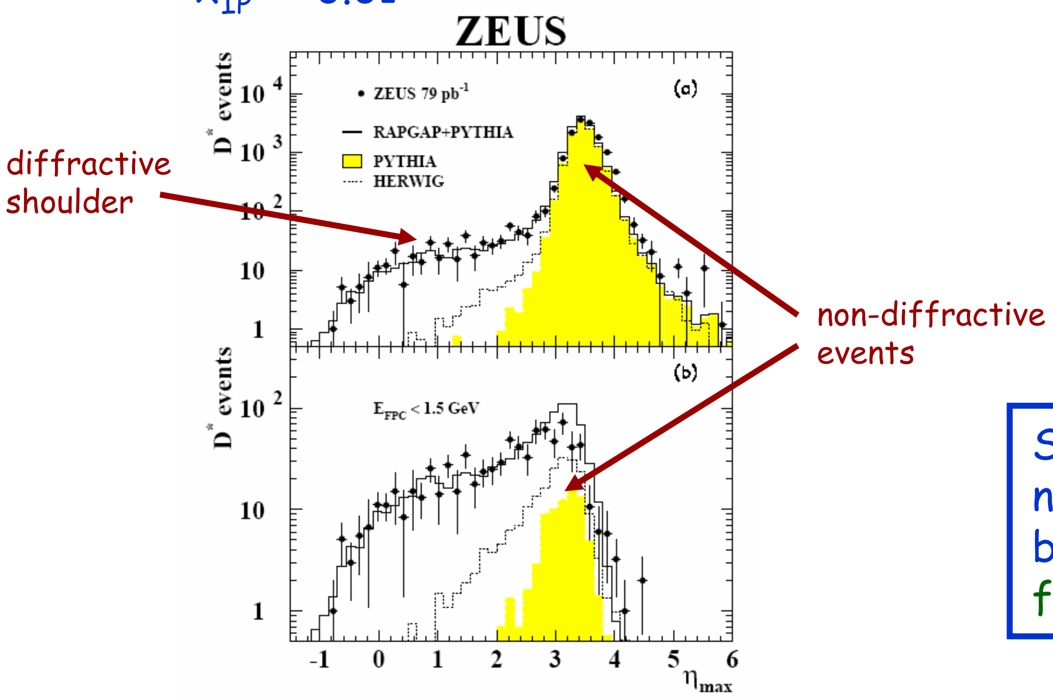
Hard scale: E_T of jet or charm mass

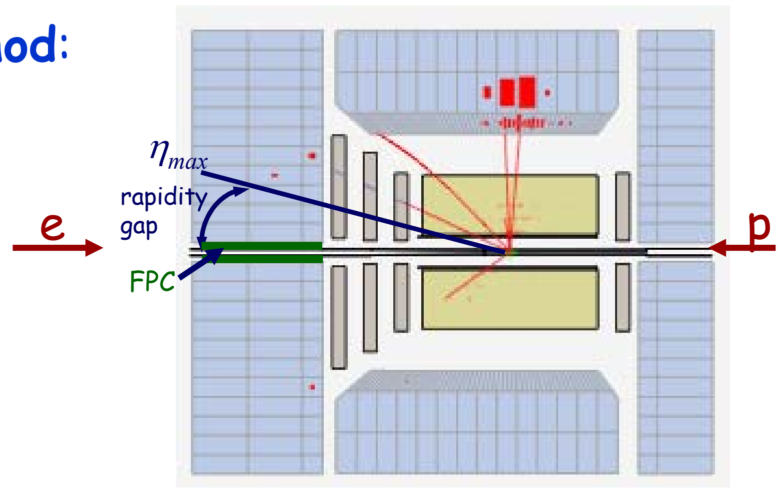
- tests of universality of PDF's (=QCD factorisation)
- test of DGLAP evolution

Diffractive D*(2010) in γP: diffractive selection

Diffractive selection with **rapidity gap method**:

- $\eta_{max} < 3.0$
- $x_{IP} < 0.035$
- subset for cleaner diffr. events:
  $x_{IP} < 0.01$





Strong reduction of non-diffractive background by cut on forward plug calorimeter (FPC).

Diffractive D*(2010) in γP: D* selection

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

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

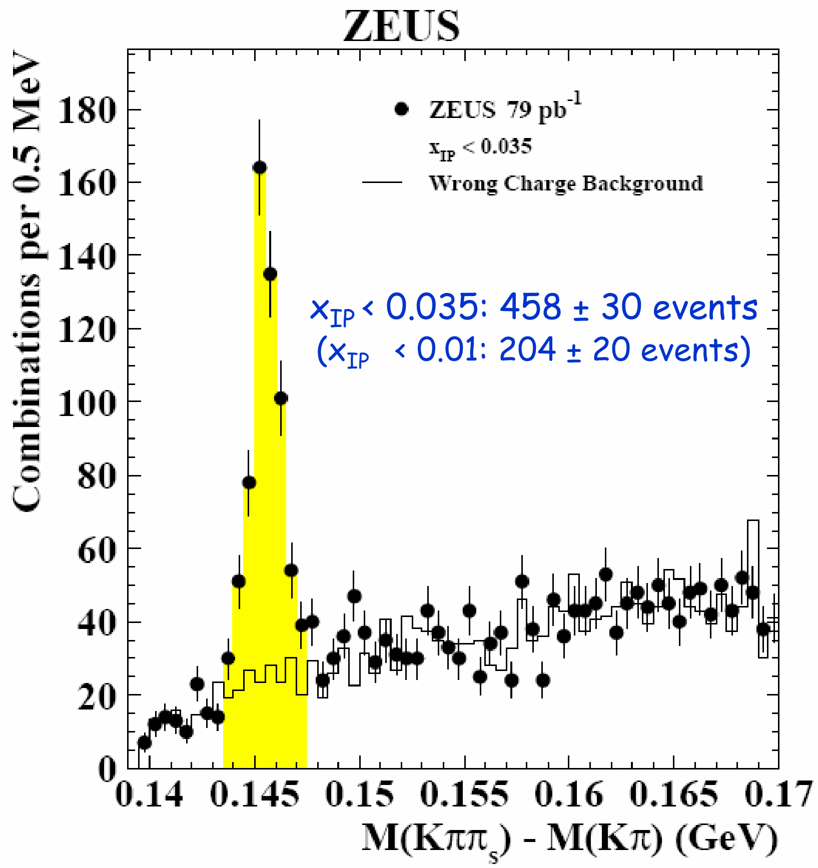
$D^0 \Rightarrow K^- \pi^+$

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

Event selection:

➢ Kinematic range:
- $Q^2 < 1$ GeV^2
- $130 < W < 300$ GeV

➢ D* cuts:
- $p_T(D^*) > 1.9$ GeV
- $|\eta(D^*)| < 1.6$



Diffractive D*(2010) in γP

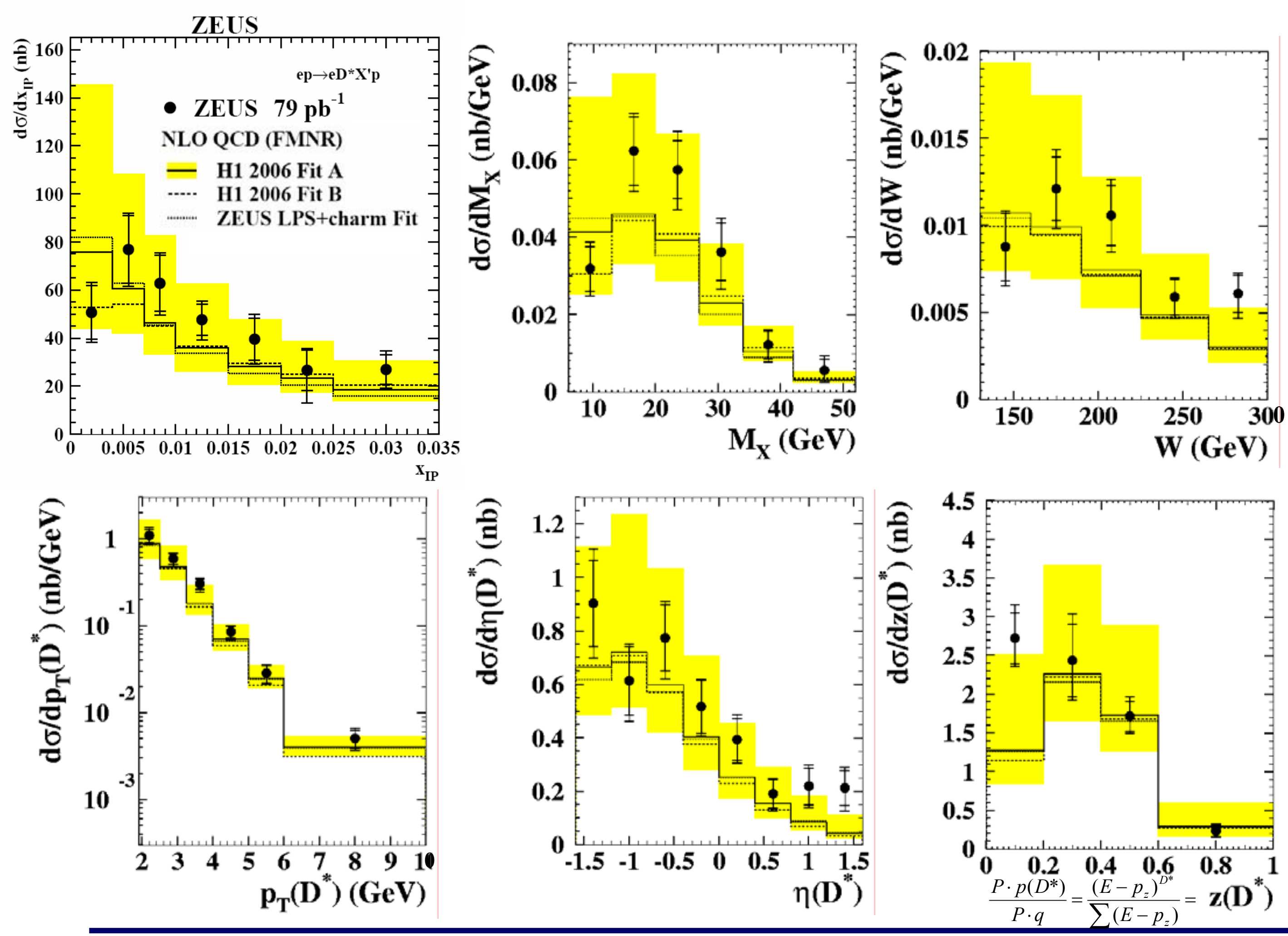
90% of events produced in **direct process**
(due to color enhancement),
only **10% resolved** (including flavor excitation).
☛ good statistics to check factorisation in direct γP
☛ too poor statistics to check factorisation for resolved γP

Monte Carlo (for corrections):
RAPGAP 2.08/18 with H1 FIT2 LO

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

Photon PDF: GRV-G-HO

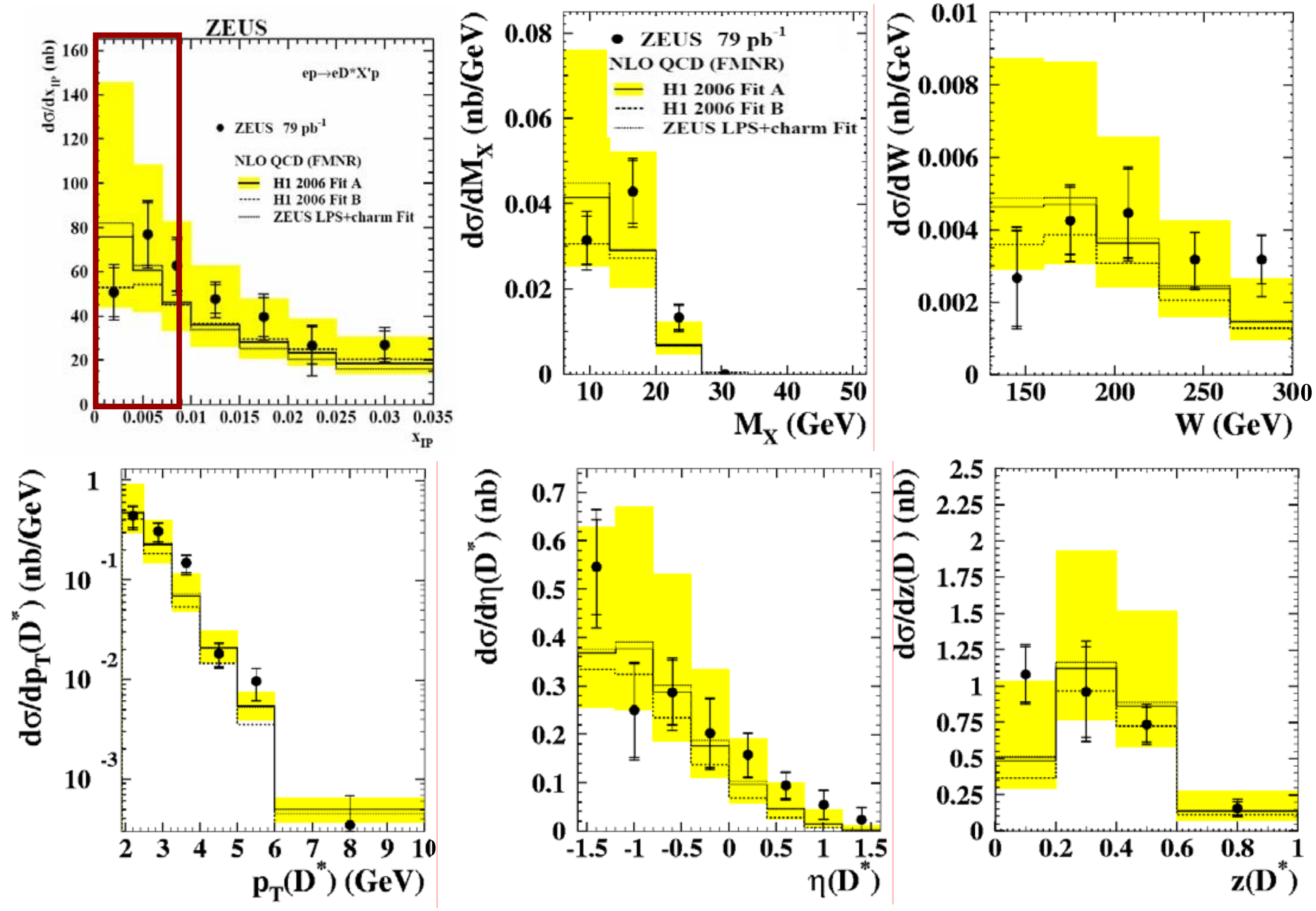
Diffractive D*: γP
$x_{IP} < 0.035$ (new)



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

- **supports QCD 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 QCD factorisation in direct γP**

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

Calculation of **ratio diffractive** (x_{IP}<0.035) **/inclusive**:

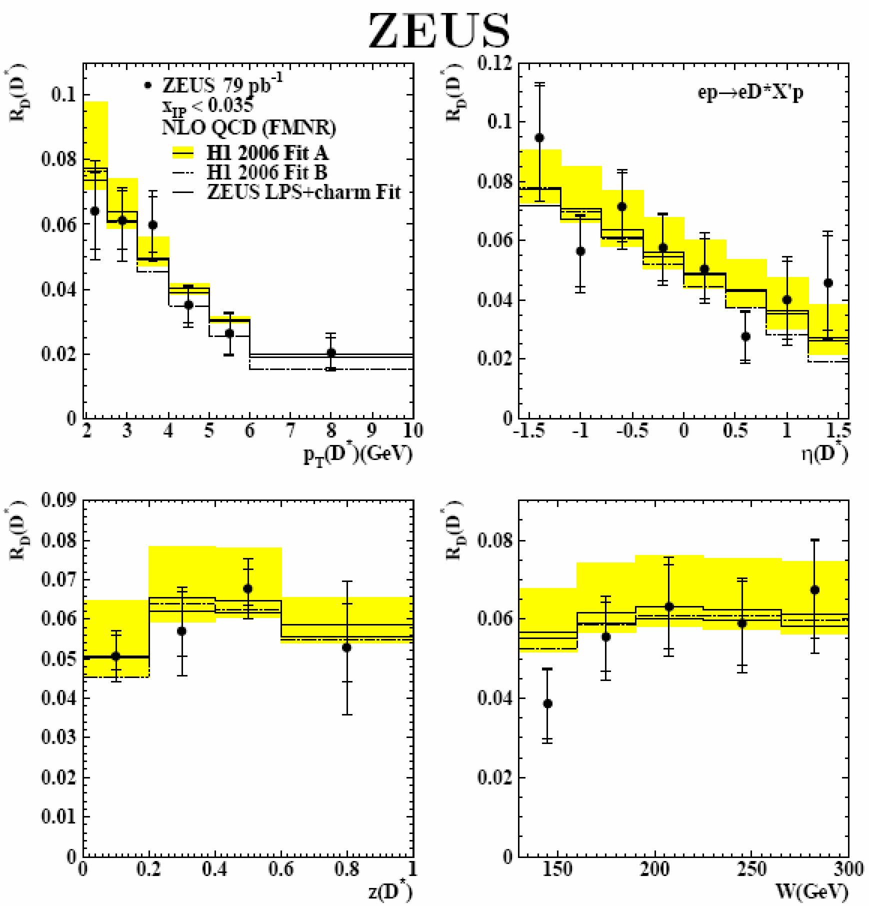
- ➢ Perform exactly the same analysis with/without diffractive cuts
- ➢ Use exactly the same program (FMNR) only with different PDFs

- ☛ systematic errors in analysis cancel out
- ☛ NLO uncertainties cancel out
- ☛ more precise test of PDFs

inclusive Monte Carlo (for corrections):
HERWIG 6.301

inclusive NLO calculation:
- ➢ FMNR with CTEQ5M

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



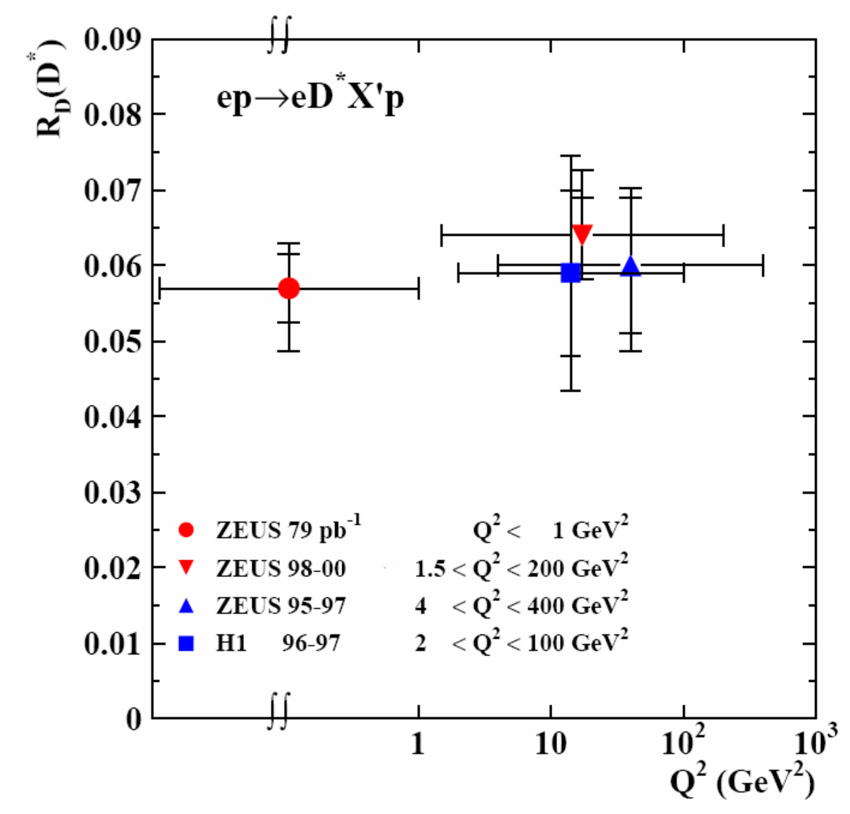
Ratio diffractive/inclusive D* (R_D) for x_{IP}<0.035 :

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

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

Very good agreement: strongly supports QCD factorisation for direct γP

Diffractive D*: γP and DIS



Ratio R_D for $x_{IP} < 0.035$

- visible cross section: 6% of D* are produced diffractively
- no Q^2 dependence observed

Conclusions and Outlook

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

Data very well described by NLO

- ☛ about 6% of D* are produced diffractively for DIS and γP.

- **DIS:**
  - NLO QCD calculations with **diffr. PDFs describe data**
    - ☛ **QCD factorisation confirmed**
- γ**P:**
  - NLO QCD calculations with **diffr. PDFs describe D* data**
    - ☛ **strongly supports QCD factorisation for direct γP**
    - ☛ too large uncertainties to draw conclusion for resolved γP (contribution only about 10 %)

Outlook: need dijet analysis for conclusion on resolved γP

☛ new ZEUS results presented by Y. Yamazaki

BACKUP

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

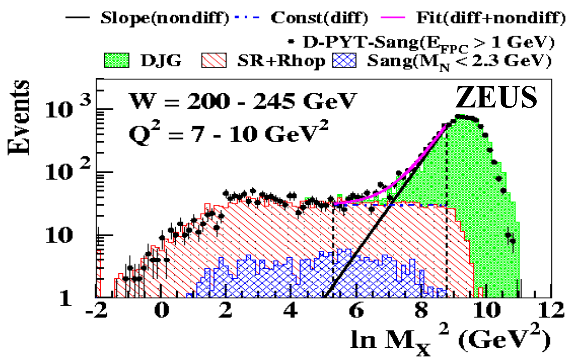
M_x

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

Diffr.: D; Non-diffr.: c, b

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

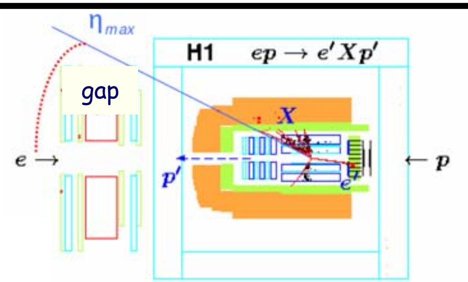
- **flat** vs ln M_x^2 for **diffractive** events
- **exponentially falling** for decreasing M_x for **non-diffractive** events



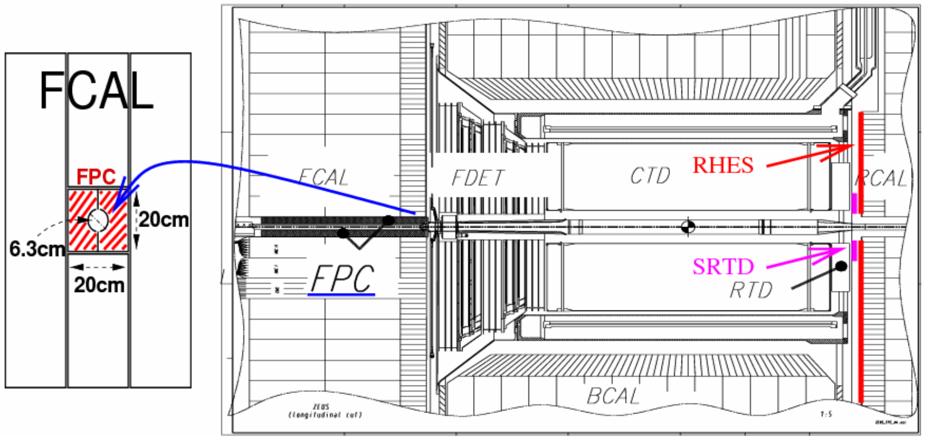
p-dissociation background subtracted for mass of diss. p M_N > 2.3 GeV

LRG

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



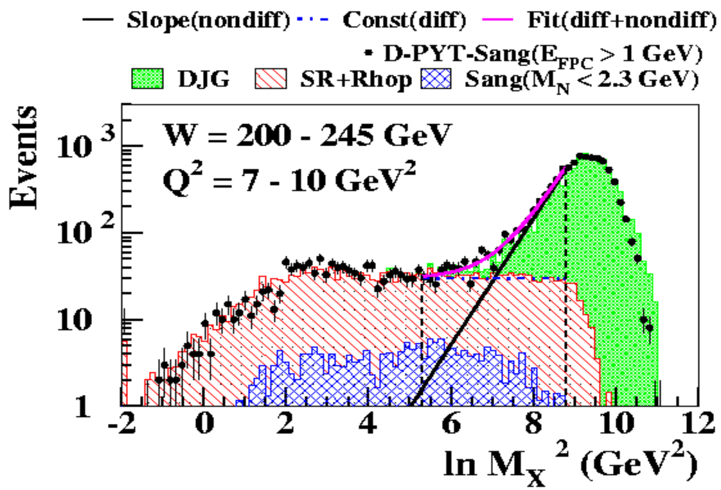
Event selection with M_x method



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



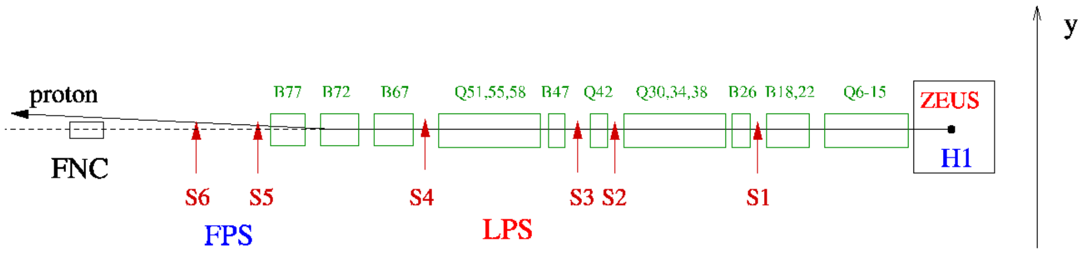
Diffr. Non-diffr.

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

(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

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

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