Diffractive final states at ZEUS

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Outlook

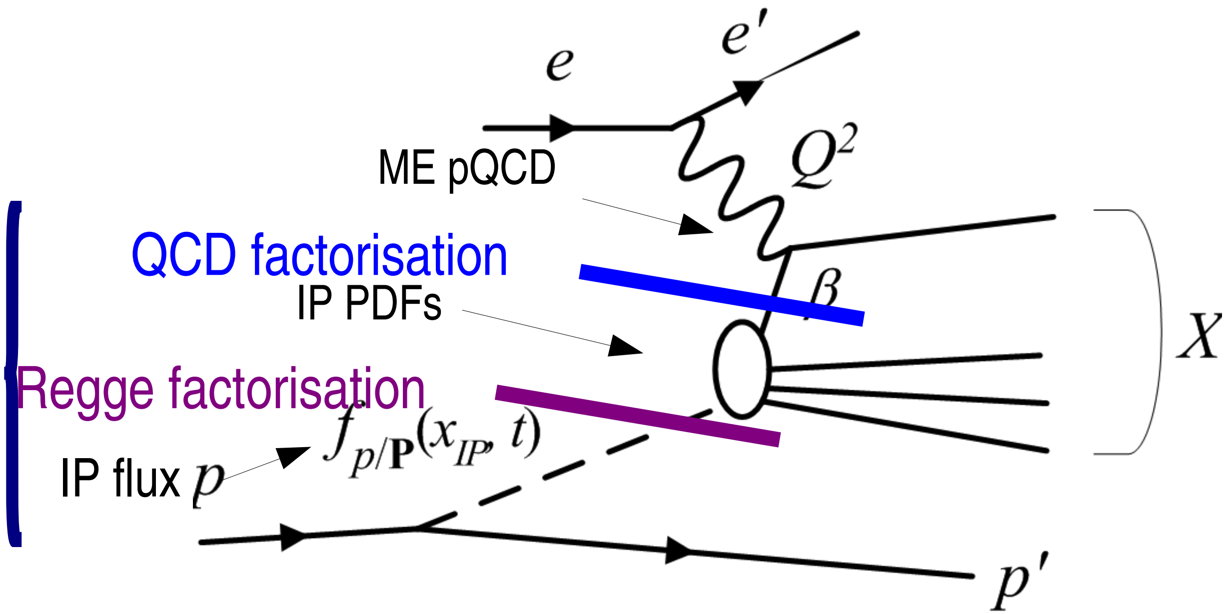
- Introduction
- Diffractive final states at ZEUS
  - Dijets in diffractive DIS
  - Dijets in diffractive γp
  - D* in diffractive γp
- Conclusions and plans

QCD factorisation in diffraction

$$d\sigma = \sum_i \int d\xi \, f_i^D(x_{IP}, t, M_{P'}; \xi, \mu) \cdot d\hat{\sigma}$$

+ higher-twist terms (non-leading powers of 1/Q)

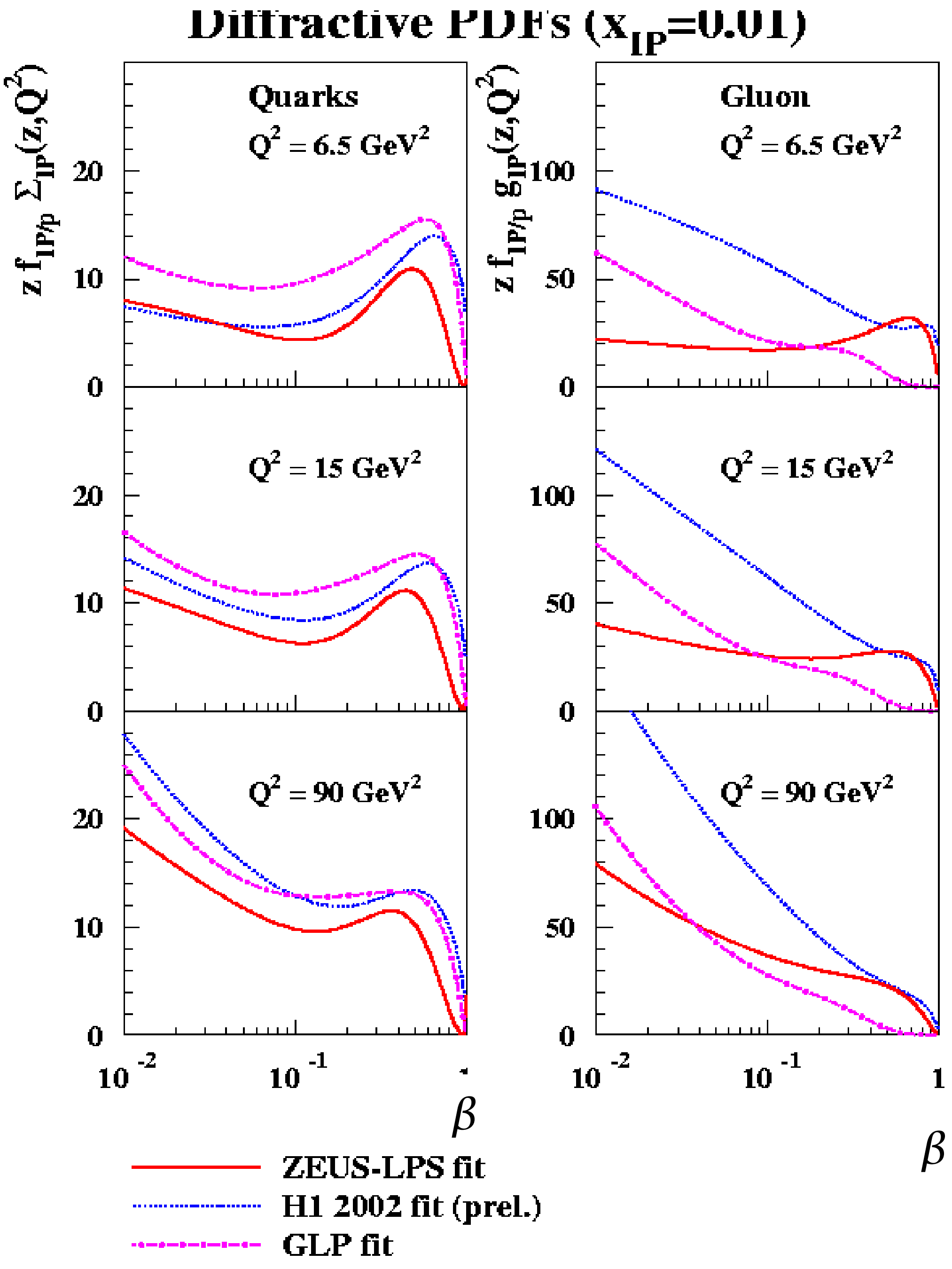
$f_i^D(x_{IP}, t, M_{P'}; \xi, \mu)$



The cross section can be calculated as convolution of a process-dependent scattering amplitude and some process-independent parton densities (dPDFs) *(Phys.Rev. D57, 3051(1998); erratum-ibid. D61, 019902 (2000))*.

- Valid under certain assumptions (e.g., sufficiently large Q^2 at fixed x_{IP}, β, t)
- Additional factorisation (Regge factorisation) not needed (either justified) by theory but useful for the calculation.

The diffractive PDFs



H1 fit 2002 (prelim.) -> H1 1997 data, LRG

ZEUS LPS -> ZEUS 1997 data, LPS (+diffr. charm)

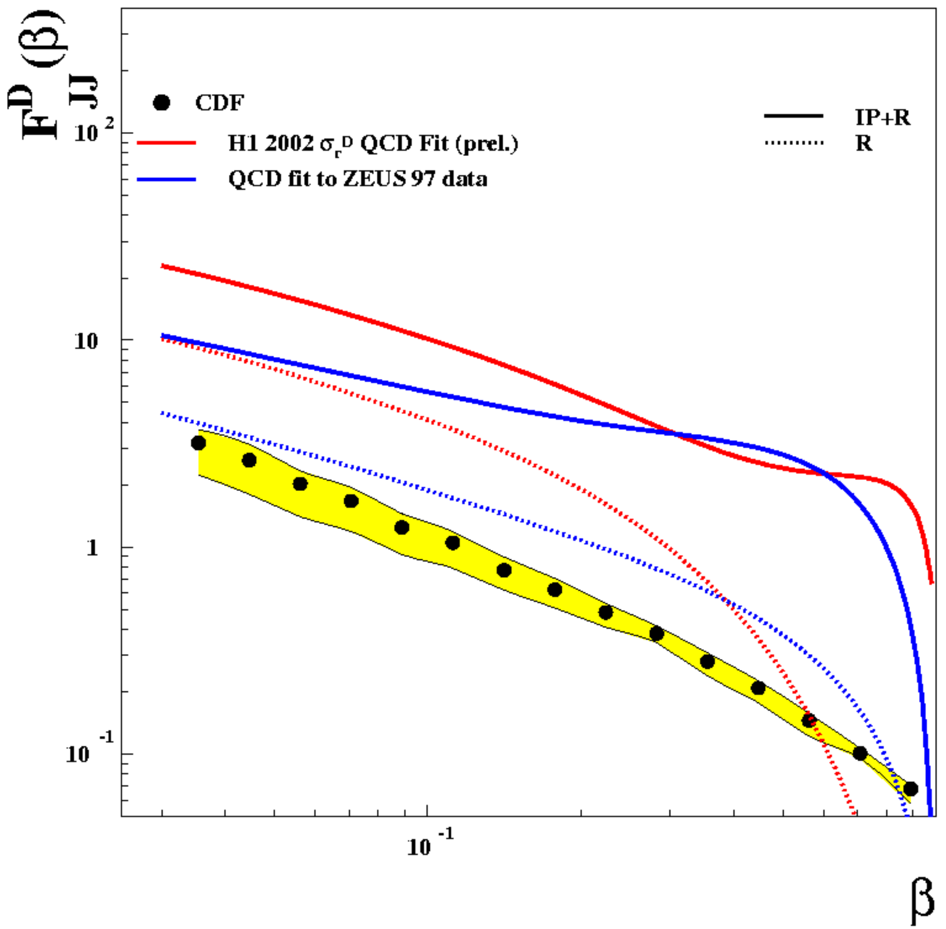
GLP fit -> ZEUS 1998-99 data, Mx

Differences in the dPDFs associated to:

- Differences in the data sets
- Poor constraint of the inclusive data sets on the gluon density (especially at high β)

QCD factorisation breaking

Diffractive dijet production at CDF



Trying to use these dPDF for diffractive final states at TeVatron. NLO calculation using the HERA-dPDFs

QCD factorisation theorem is violated.

Data compared to the predictions are suppressed of a factor 7÷10

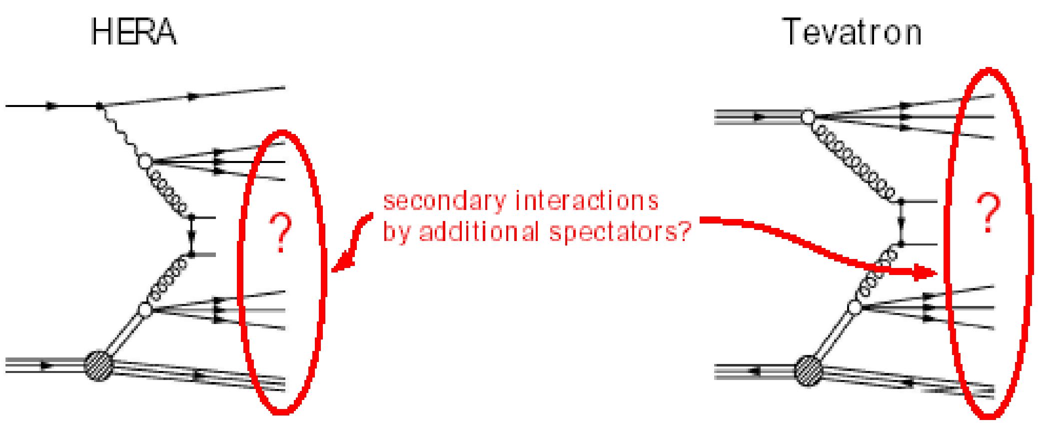
Same effect for inclusive diffraction or other diffr. final states at $p\,\bar{p}$ collider.

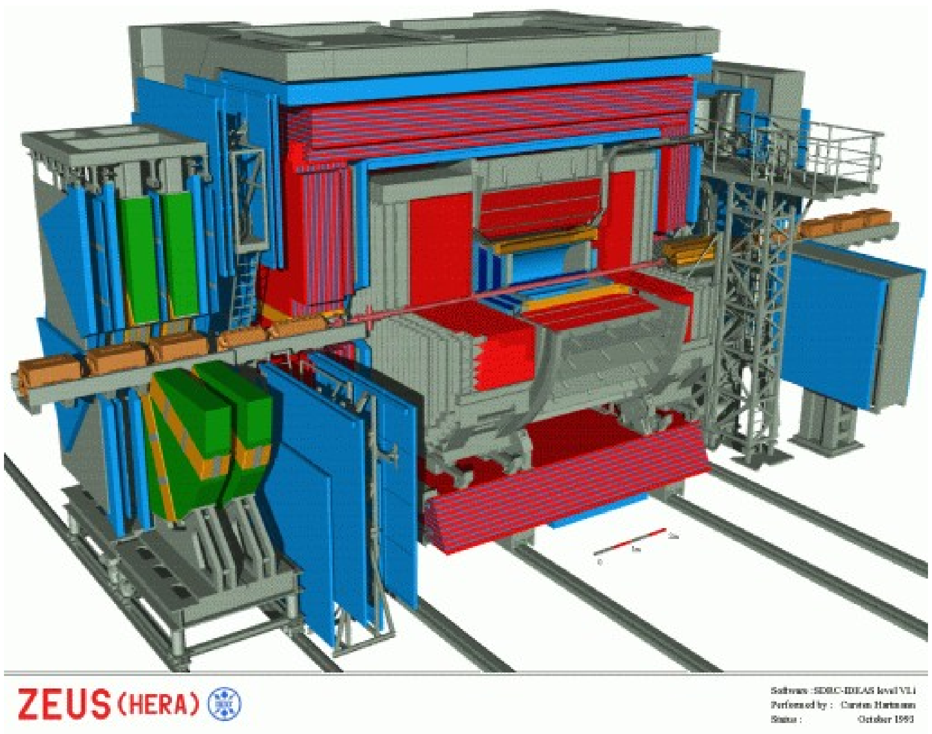
Secondary Interactions spoil the LRG

Understanding them and defining a precise framework in which QCD factorisation theorem is valid is fundamental for diffractive studies at TeVatron and LHC

Same effect should be visible at HERA in γP

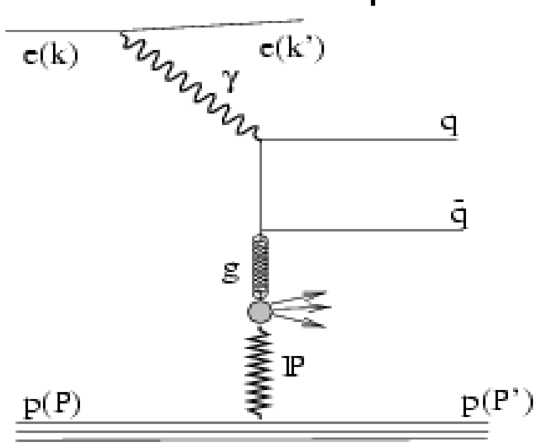
(large size γ^* ~ hadron)





Direct γ^* (small γ^*) couples directly to parton

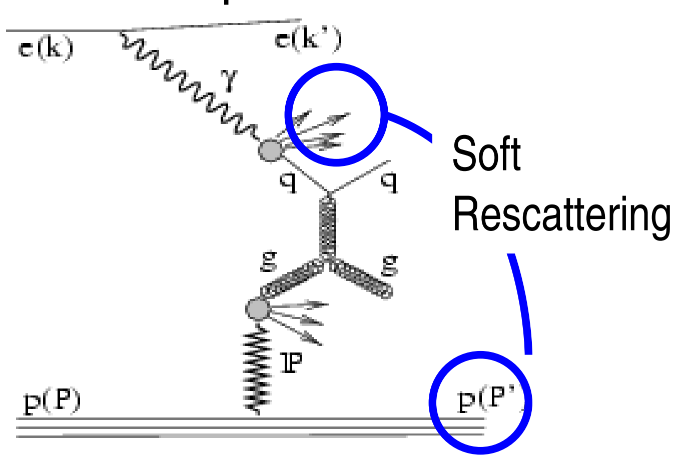
QCD factorisation is expected to hold



(a)

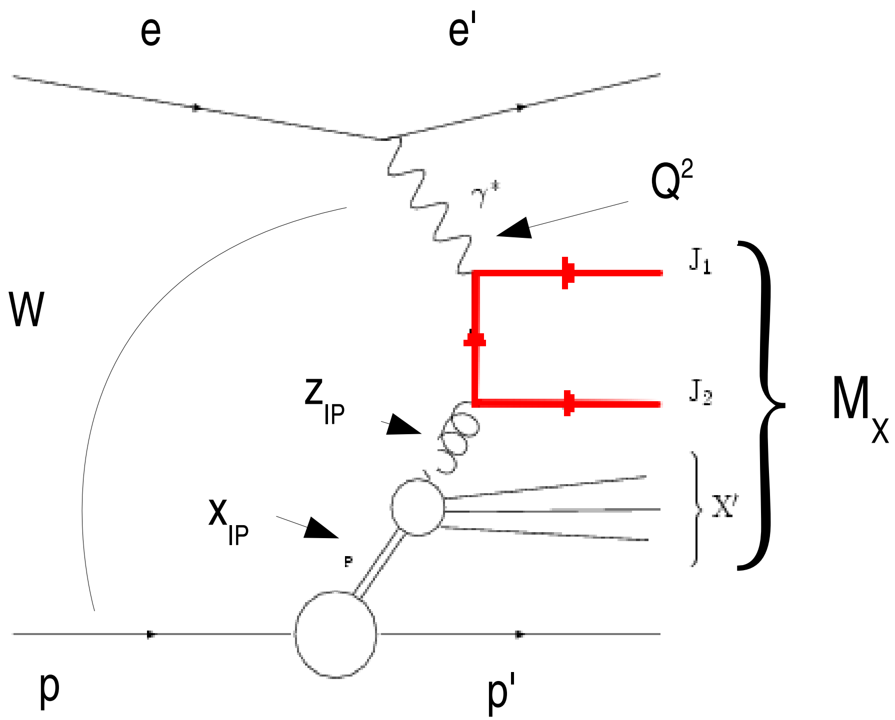
Resolved γ^* (large γ^*) behaves like a hadron

QCD factorisation is expected to break



(b)

Dijets in dDIS



$Q^2 = -q^2 = -(e-e')^2$, $W^2 = (p+q)^2$

$$x_{IP} = \frac{Q^2 + M_X^2}{Q^2 + W^2} \quad , \quad \beta = \frac{x}{x_{IP}} = \frac{Q^2}{Q^2 + M_X^2}$$

$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2} \quad , \quad x_\gamma = \frac{\sum_{dijets} E - p_z}{\sum_X E - p_z}$$

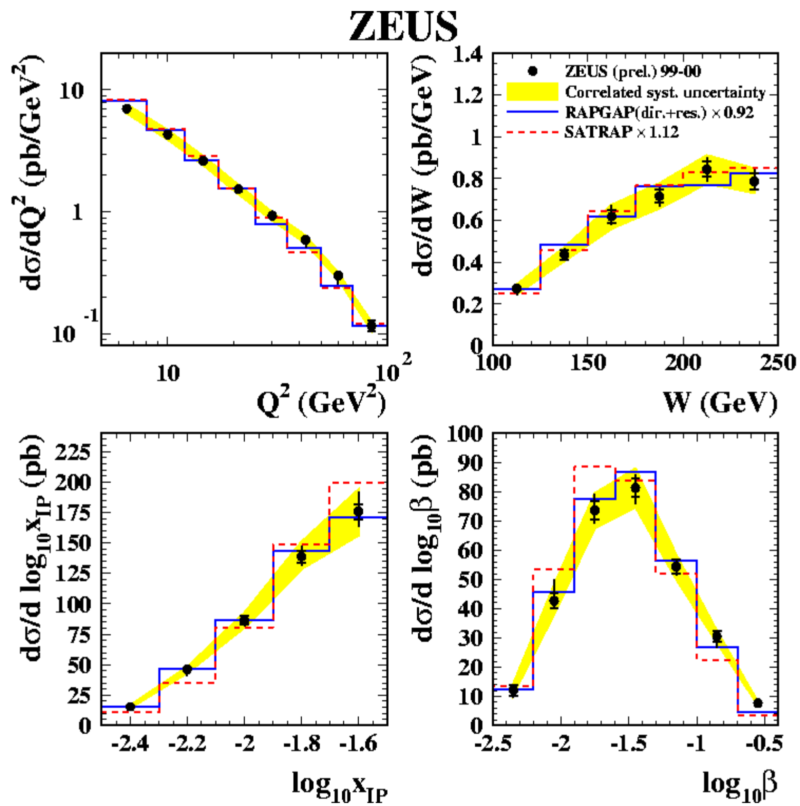
This process provides:

- ✔ Hard scale (Q^2 & E_T) → perturbative QCD, Q^2 evolution of PDF
- ✔ Strong sensitivity to gluon content of dPDFs

From this analysis we can obtain

Test of QCD factorisation

Constraints on dPDFs



Kinematic region of definition of the cross section

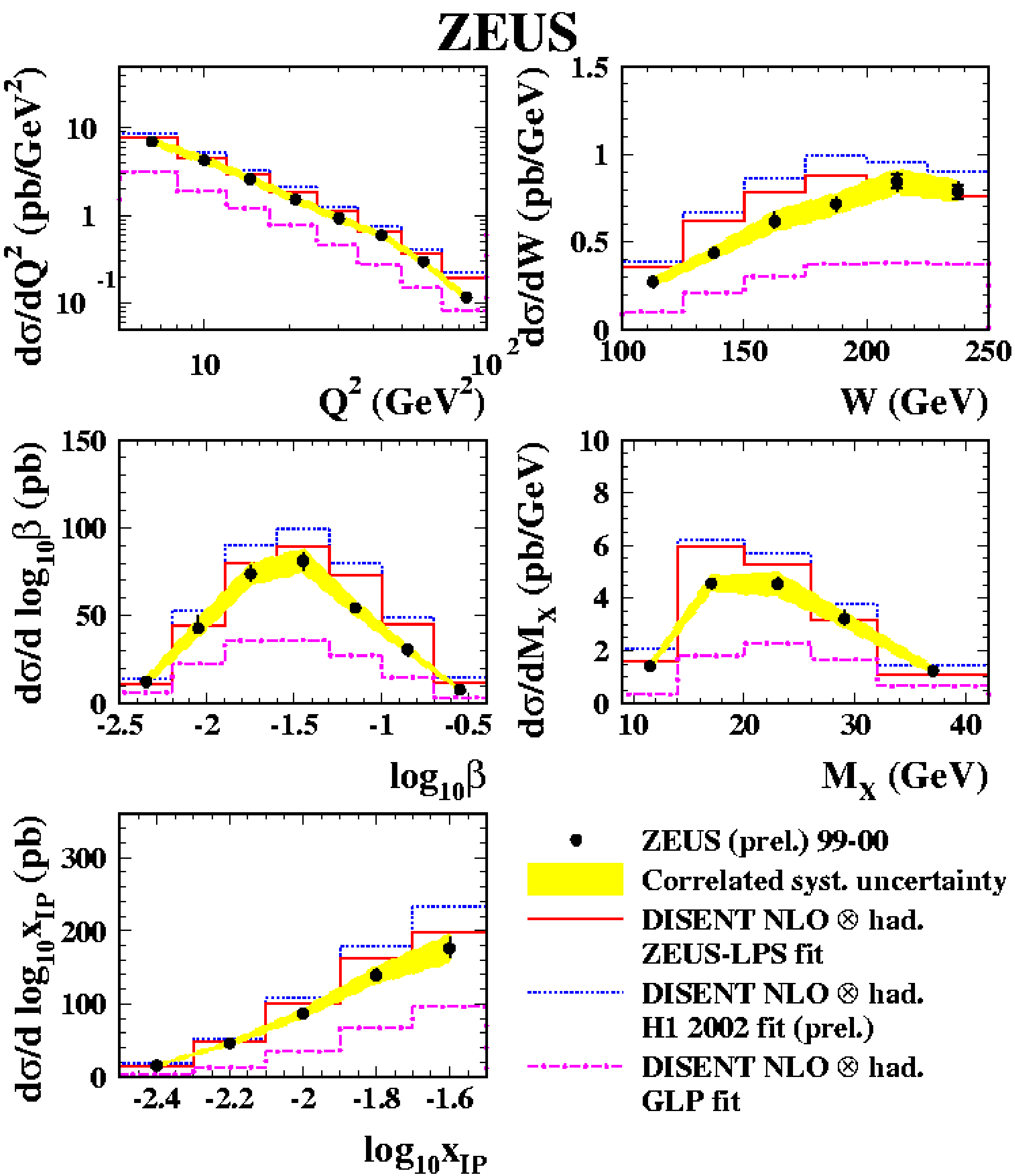
- $5 < Q^2 < 100$ GeV^2
- $100 < W < 250$ GeV
- Njets ≥ 2 (K_T algorithm run on Tracks+Clusters Objects ($* \equiv \gamma$ -proton c.m.s))
- $E^*_{T,jet1} > 5$ GeV, $E^*_{T,jet2} > 4$ GeV
- $-3.5 < \eta^*_{jets} < 0.0$
- $x_{IP} < 0.03$

- Proton dissociation background subtracted (16 ± 4%)
- Good description provided by LO MC

Diffractive selections:

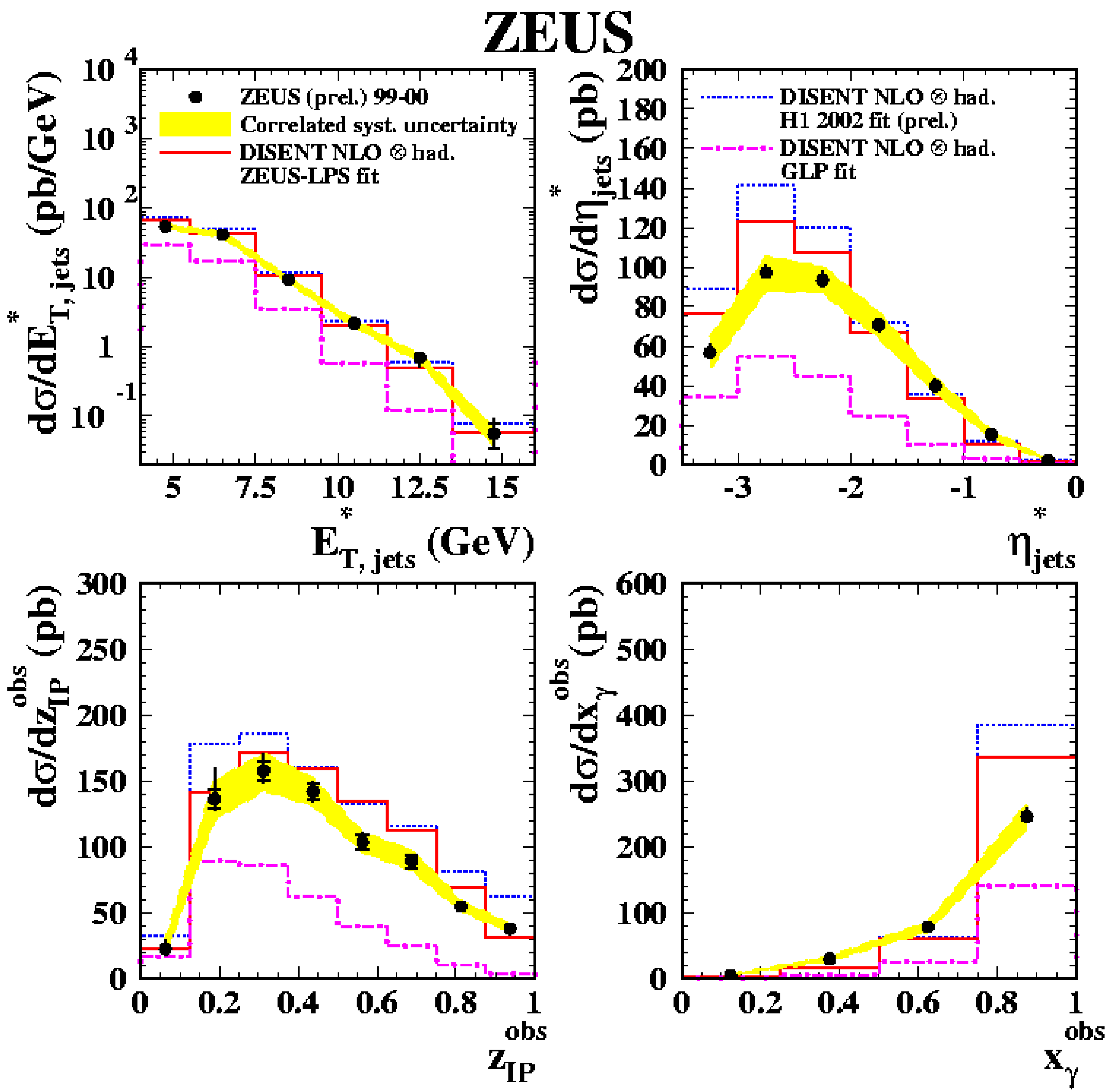
- $E_{FPC} < 1$ GeV
- η of most forward track/cluster with E> 400 MeV $\eta_{MAX} < 2.8$
- $x_{IP} < 0.03$

DATA vs NLO



- Three different dPDFs used in the NLO calculations (DISENT program)
- $\alpha_S(M_z^2) = 0.1085$ for H1fit2002
  $\alpha_S(M_z^2) = 0.1180$ for ZEUS-LPS and GLP
- $\mu_R^2 = (E_{T,jet1}^*)^2$
  $\mu_F^2 = 40\ GeV^2$ (aver. jet p_T)
- IP-flux integrated up to $|t| = 10\ GeV^2$

Scale uncertainties not displayed but large (~20%).
Uncertainty due to dPDFs not evaluated



Reasonable description of data (slightly overestimating) by H1fit2002 and ZEUS-LPS calculations

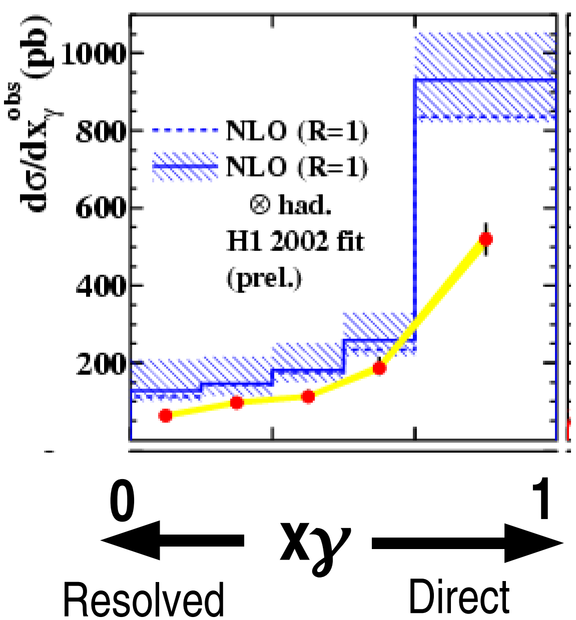
Significant underestimation by GLP fit

Scale uncertainties not displayed but large (~20%). Uncertainty due to dPDFs not evaluated

Dijets in diffractive PhP

- Same motivations as for DIS case: hard scale (E_T), gluon sensitivity.
- Factorisation breaking expected due to soft interactions between resolved photon and proton.
- Event with quasi-real γ which couples directly to the parton should not be suppressed.
- Not a clear way to separate direct from resolved processes. Direct processes concentrate at high x_γ (~1).

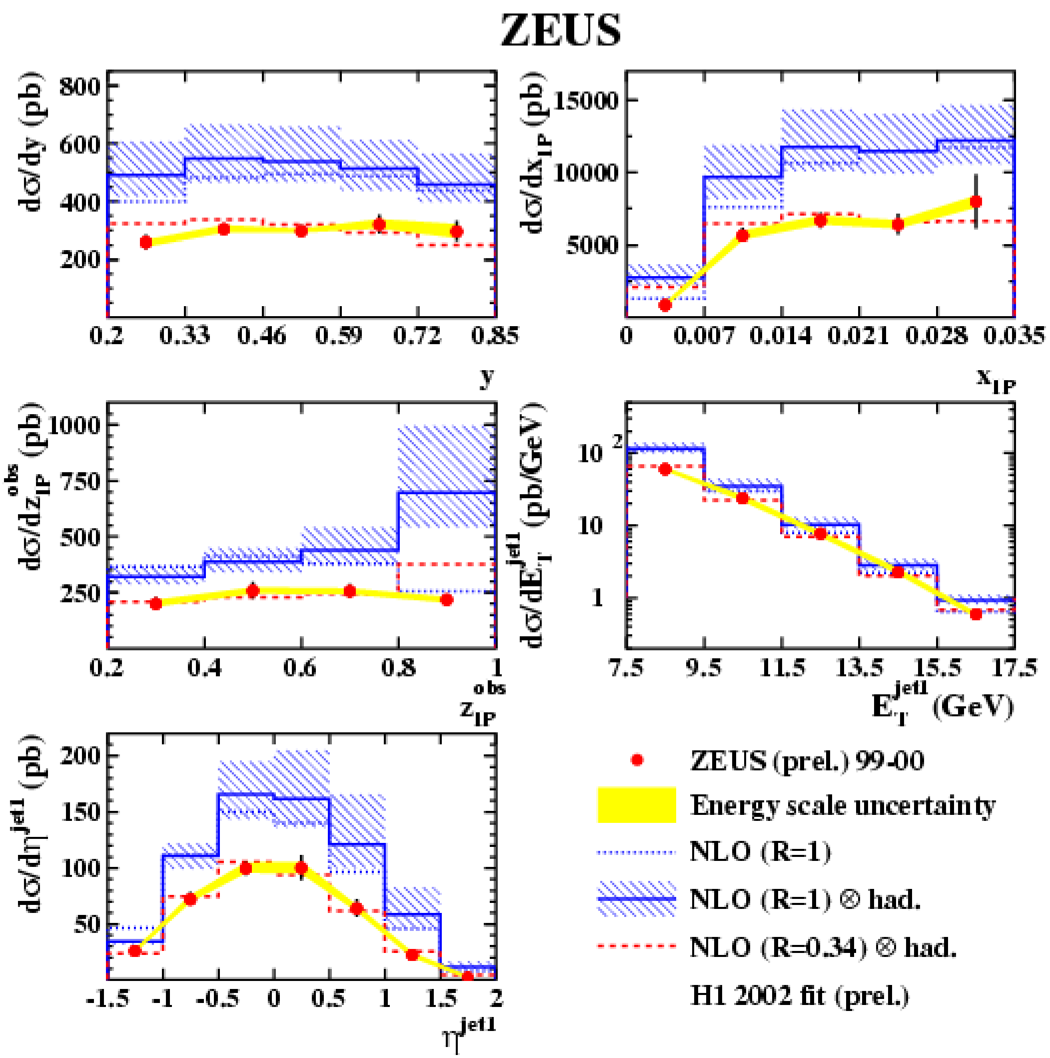
$$x_\gamma = \frac{\sum_{\mathrm{dijets}} E - p_z}{\sum_{\mathrm{X}} E - p_z}$$

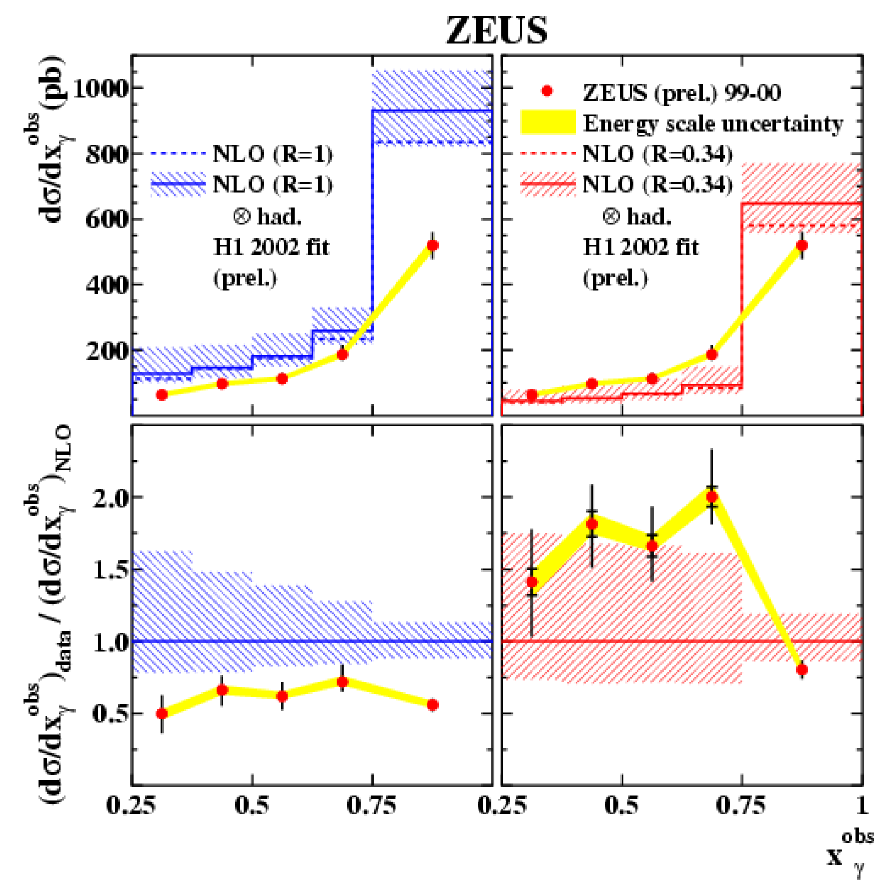


- $Q^2 < 1$ GeV^2
- $0.2 < y < 0.85$
- Njets $\geq$ 2 (KT algorithm in LAB frame)
- $E_{T,jet1}^{LAB} > 7.5$ GeV, $E_{T,jet2}^{LAB} > 6.5$ GeV
- $-1.5 < \eta_{jet}^{LAB} < 2.0$
- $x_{IP} < 0.035$

Diffractive selection carried out through LRG

$\eta_{MAX} < 3.0$





Resolved suppression factor estimated = 0.34 in
Kaidalov et al., Phys.Lett. B567 (2003),61

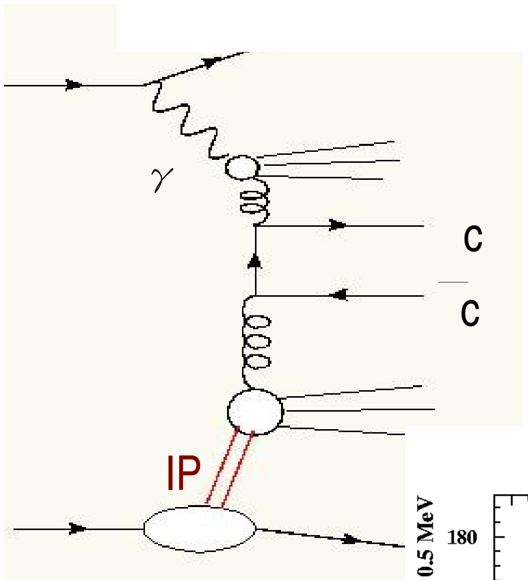
NLO calculation performed with procedure similar to dijets in diffractive DIS

H1 fit 2002 (prel.) used as input dPDFs

Apparent need for a global suppression of NLO prediction (both low and high x_γ)

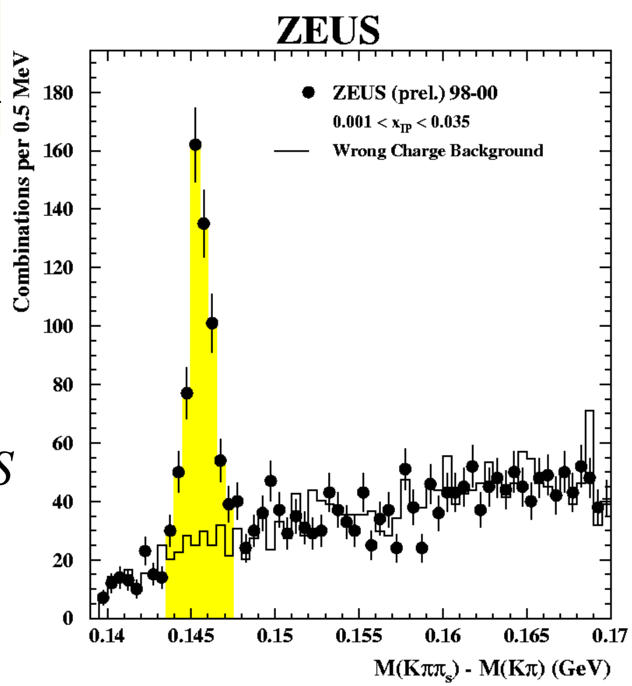
Large uncertainties again

D*(2010) in diffractive PhP



Hard scale from charm mass

$$D^{*} \rightarrow K\pi\pi_S$$



454 +/- 30 diffr.D* cand.

Kinematic region of cross section definition:

- $Q^2 < 1$ GeV^2
- $130 < W < 300$ GeV
- $p_\perp(D^*) > 1.9$ GeV
- $|\eta(D^*)| < 1.6$
- $x_{IP} < 0.035$

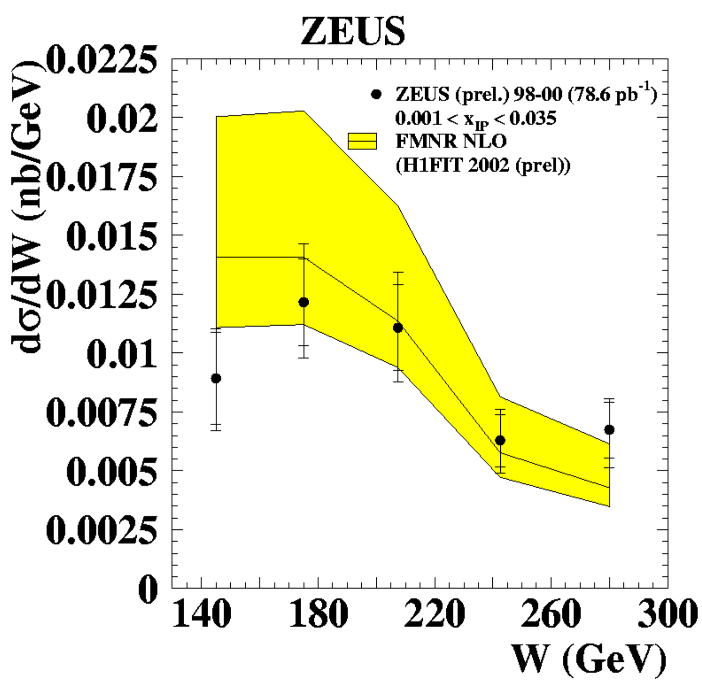
Diffraction selection

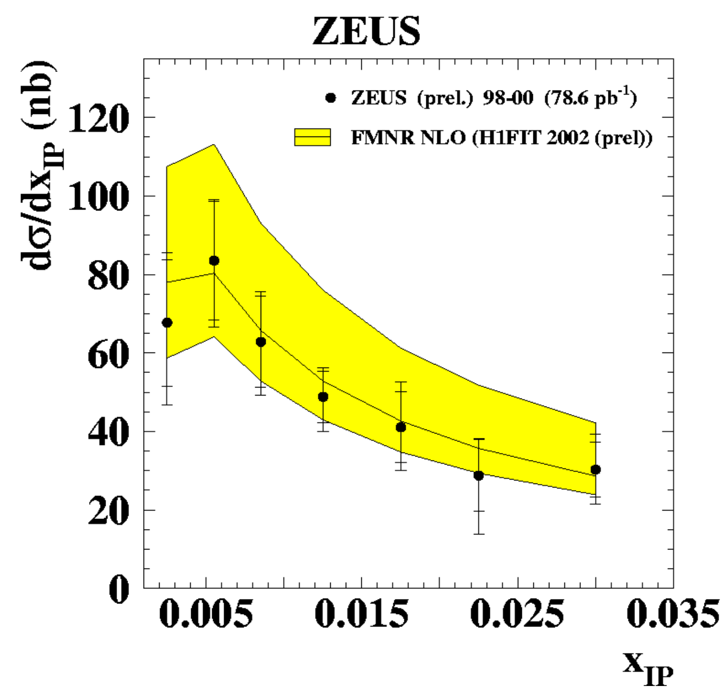
- $E_{FPC} < 1.5$ GeV
- $\eta_{max} < 3.0$
- $x_{IP} < 0.035$

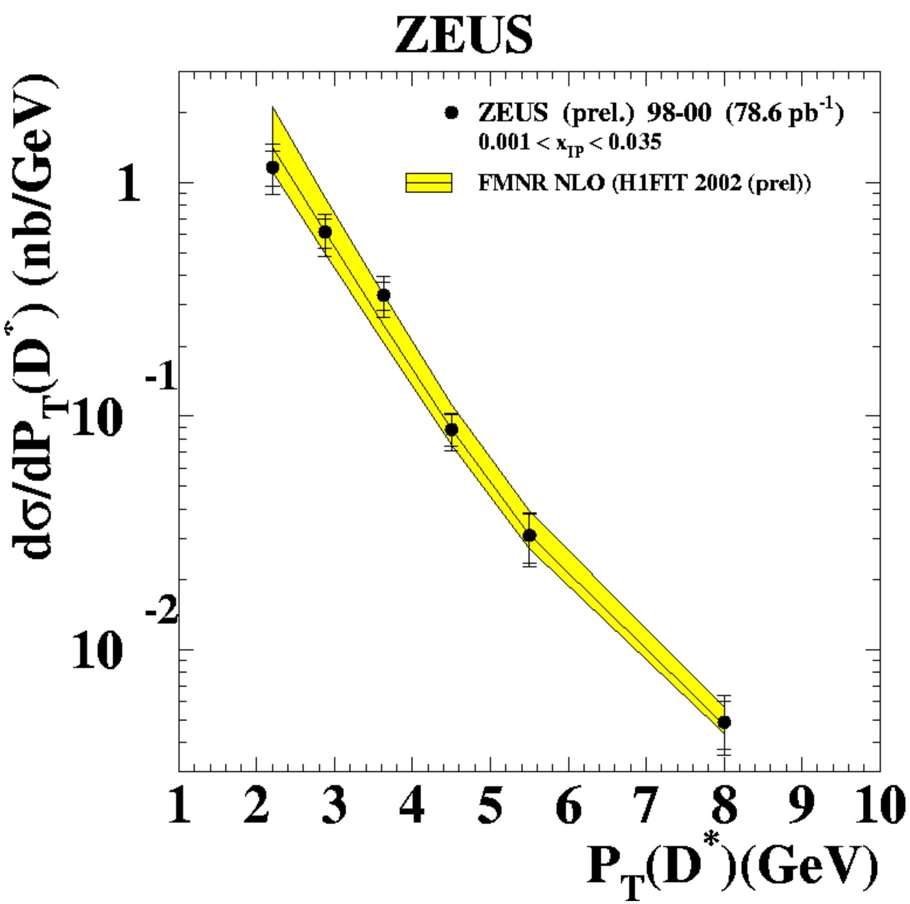
NLO calculation performed with the program FMNR using H1fit2002 (prel.) dPDFs :

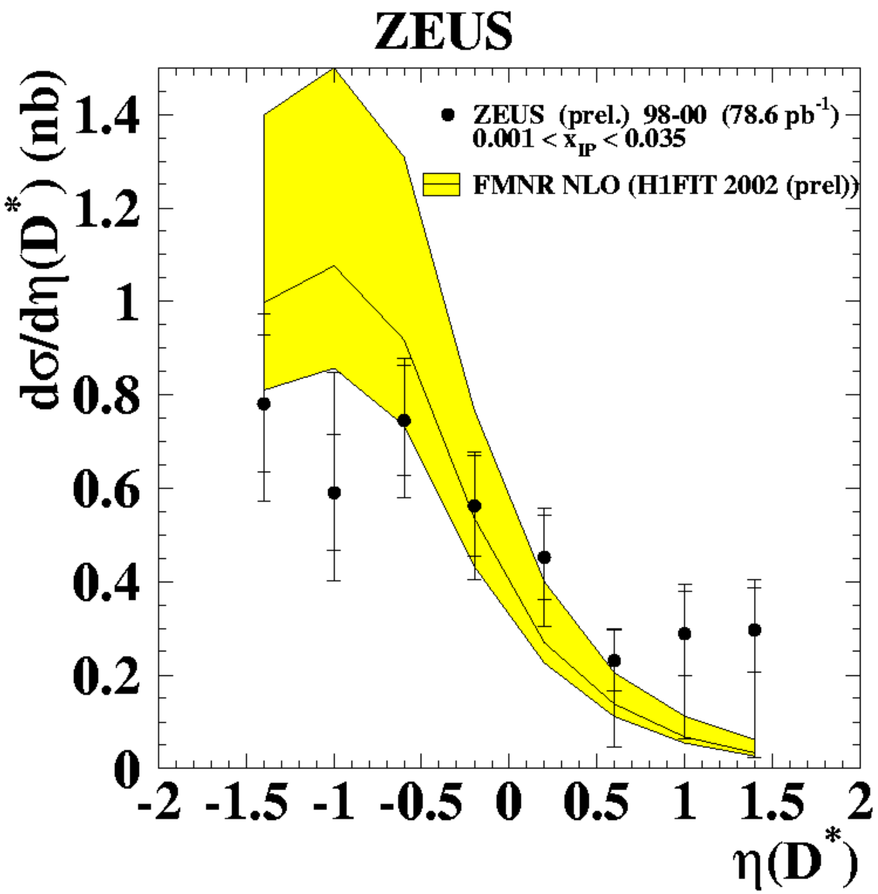
Settings:

- m_c = 1.5 GeV (±0.2 GeV)
- Λ_5 = 0.2 GeV
- dPDFs: H1fit2002 (prel.)
- γ PDFs: AFG
- Renormalisation and factorisation scale: $\mu_r = \mu_f = \sqrt{(m_C^2 + p_T^2)}$
- Petersen fragmentation function with ε = 0.035
- Fragmentation fraction: 0.235









- Data and NLO are consistent within the errors
- Uncertainties are too large for strong any strong statement

Summary

- Understanding diffractive PDFs and soft rescattering are necessary steps for any diffractive study at LHC.
- Big steps forward in the last years: dPDFs extracted and NLO predictions performed.
- Big differences in data sets and large uncertainties in theoretical calculations affect these predictions.
- Need for a better understanding of data sets and for more precise calculations before clearing definitely the issue of QCD factorisation in diffraction.

Plans

- Efforts on understanding the differences between the data sets extracted with different experimental methods are ongoing at ZEUS.
- Brand new dPDFs from H1 available, they will be tested on ZEUS data in the near future.