Factorisation breaking in diffraction

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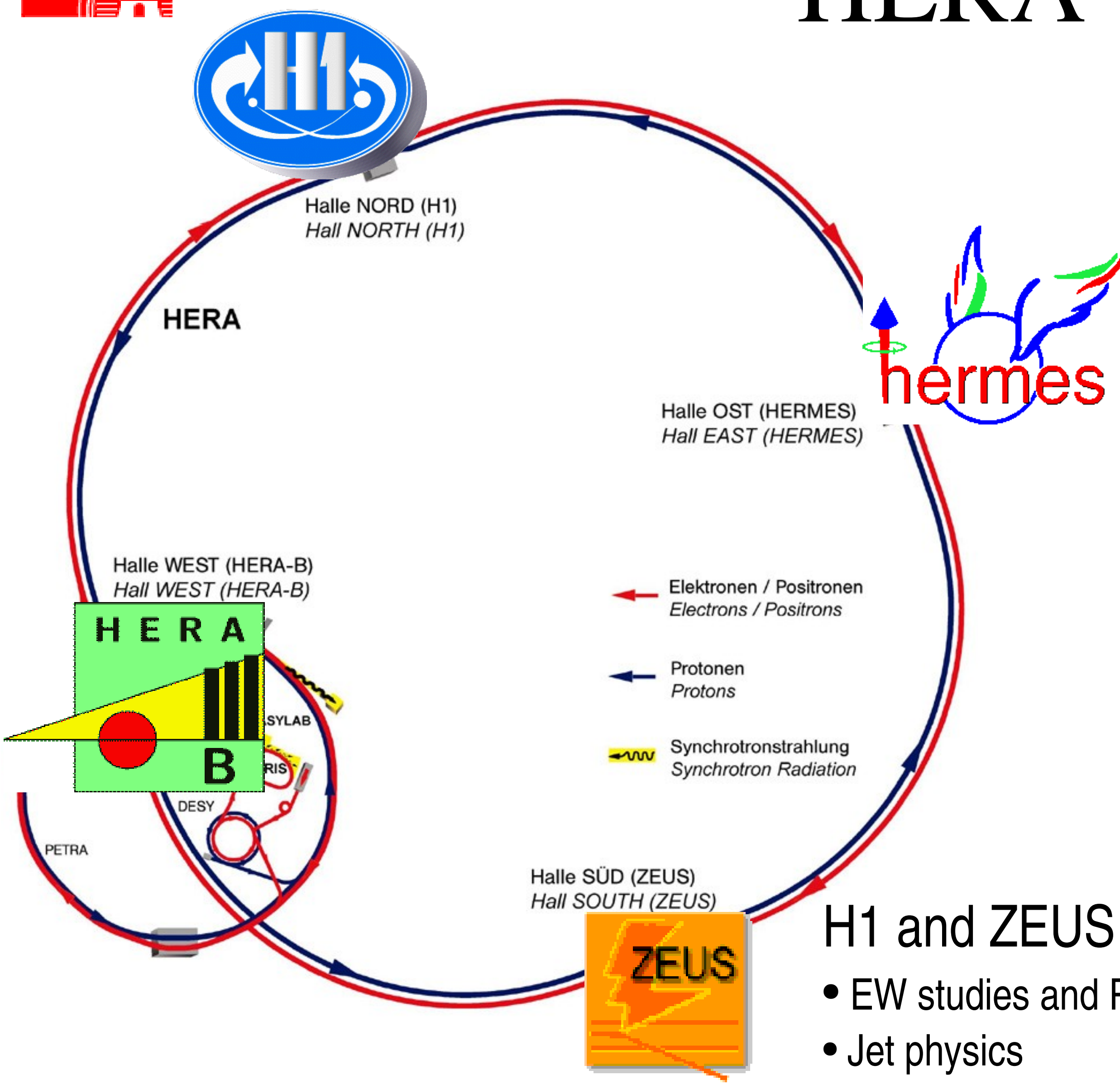
12th International Conference on
Elastic and Diffractive Scattering,

Hamburg, 24/05/2007

Outline

- Introduction: diffraction at HERA and dPDFs
- QCD Factorisation in diffraction
- Test of QCD factorisation at HERA:
  - Dijets
  - D*(2010)
- Vertex factorisation breaking for Leading Neutrons

HERA



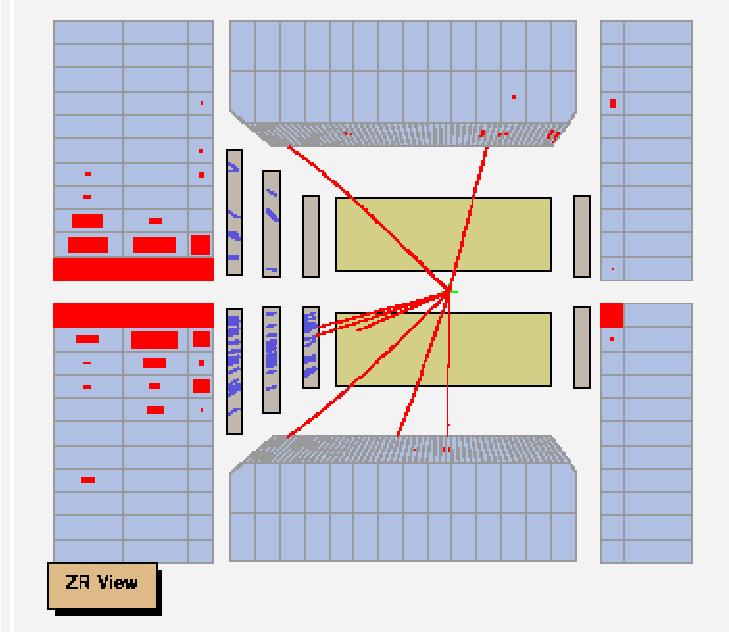
- R_{HERA} ~ 1 Km
- 27.5 GeV e^- (e^+)
- 920 GeV p
- 200 pb^{-1} delivered by HERA I
- 500 pb^{-1} delivered by HERA II

H1 and ZEUS general purpose detectors:

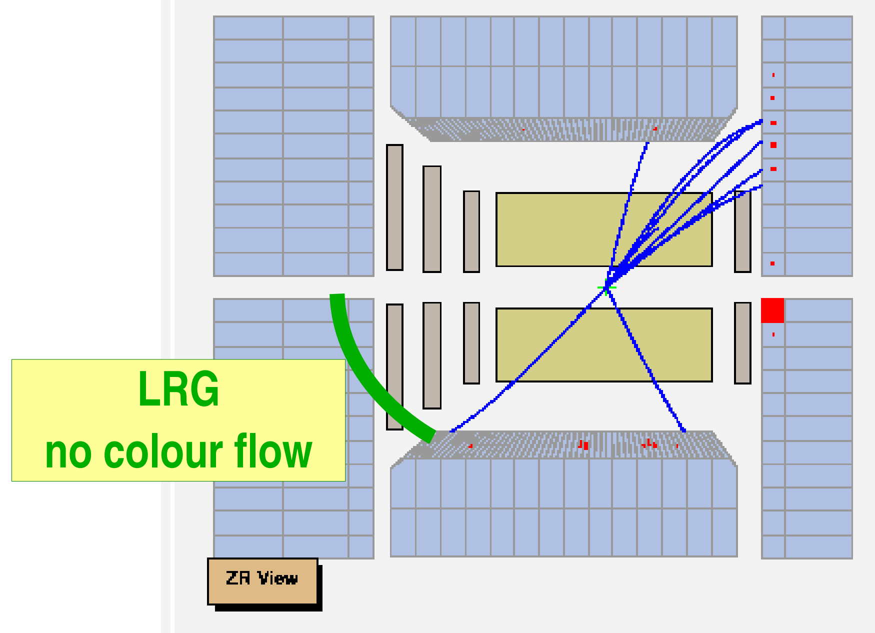
- EW studies and Proton PDF measurement
- Jet physics
- Search for new physics (leptoquarks, CI, SUSY...)
- Heavy flavour physics
- **Diffraction**

Diffraction in *ep* scattering

NON-DIFFRACTIVE DIS



DIFFRACTIVE DIS



Diffractive ep scattering: p stays intact, only slightly deflected

Presence of a Large Rapidity Gap used for tagging.

Large fraction (~ 10%) of DIS events is diffractive.

Providing a QCD motivated description of diffraction is important for having a comprehensive understanding of the strong interaction.

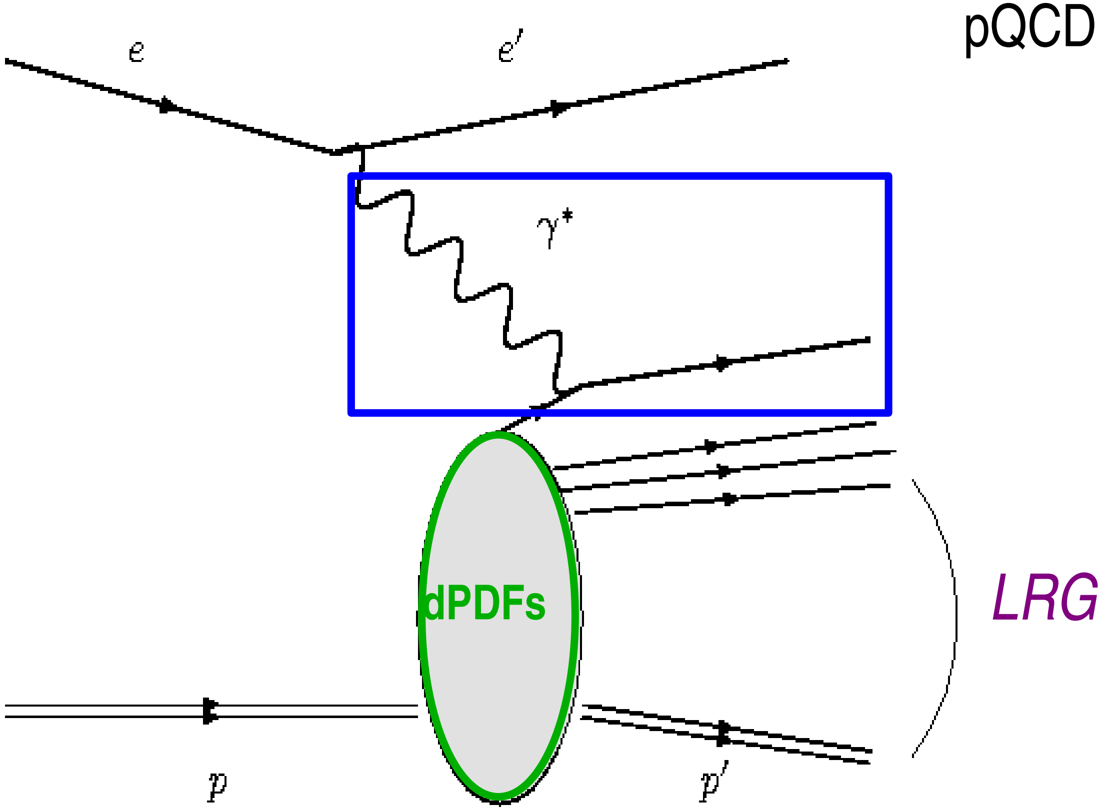
Diffractive Parton Distribution Functions

QCD Factorisation theorem

$$\sigma^{D}(\gamma * p \rightarrow Xp) \simeq \sum_{i=q,g} \hat{\sigma} \otimes f_i^{D}(t, x_{IP}, \beta, Q^2)$$

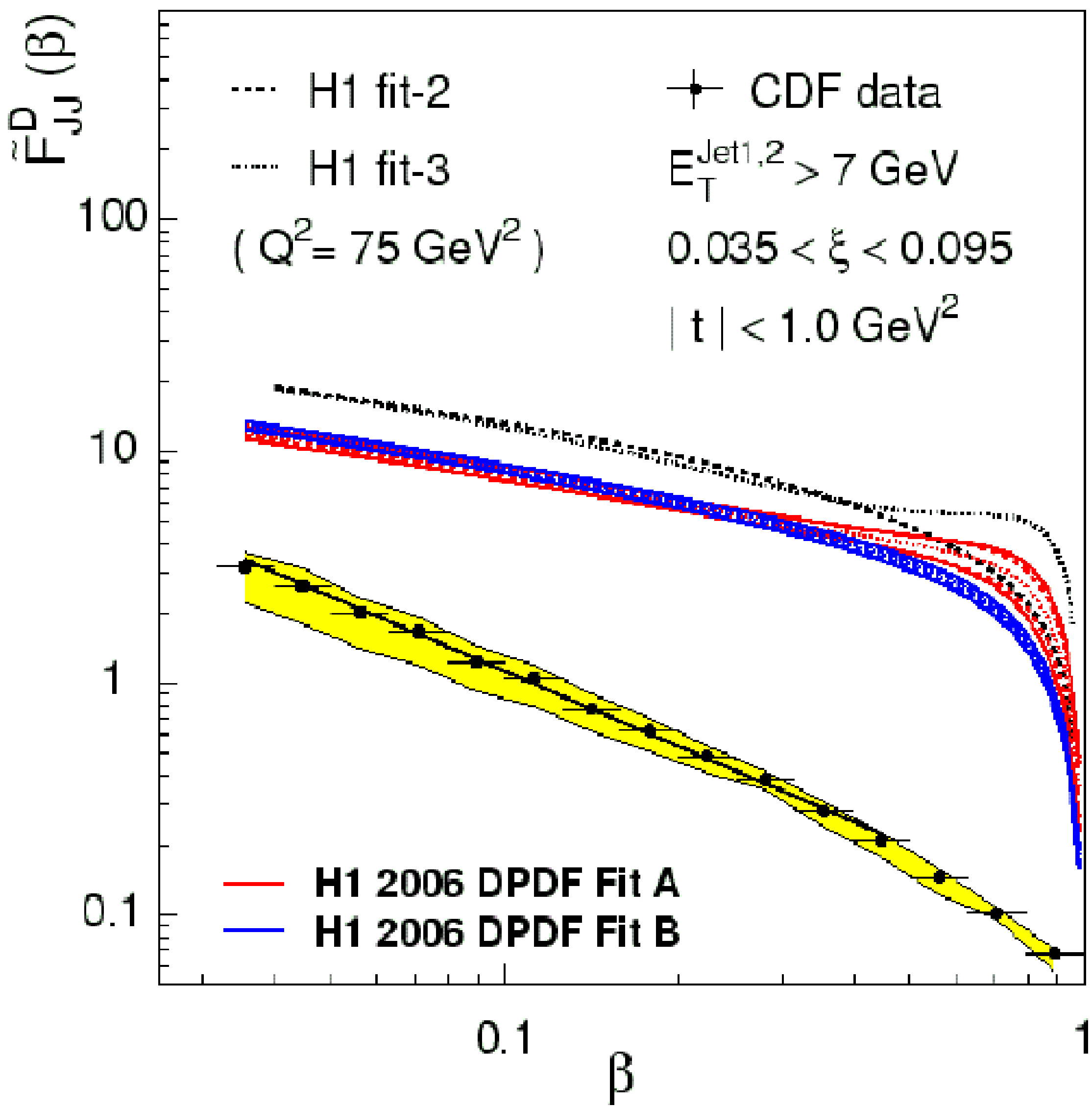
Hard subprocess ME
pQCD calculable

Diffractive PDFs
defined as the std PDFs + diffractive requirement
Universal



dPDFs can be used in calculations for different diffractive final states and different experiments.
This ansatz has to be validated experimentally.

Factorisation breaking in $p\bar{p}$ collisions



Diffractive dijet measurement by CDF. Comparison with NLO prediction using as input H1-2006 fitA and fitB extracted at HERA (see P.Laycock's talk).

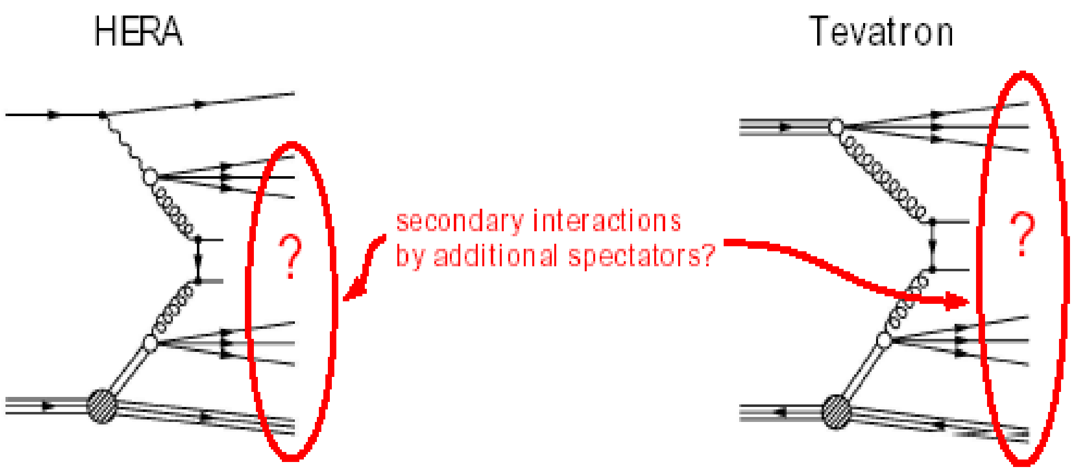
Significant overestimation by NLO of the data.

The HERA dPDFs cannot be used directly at TeVatron.

Secondary interactions between spectator partons spoil the LRG, no diffractive tag anymore.

Models are able to describe the suppression observed at TeVatron (Kaidalov, Khoze, Martin, Ryskin).

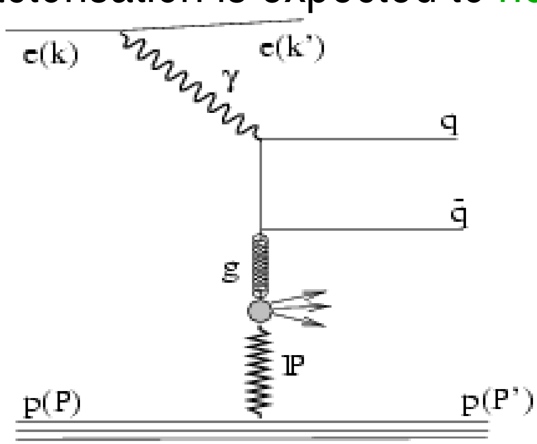
Factorisation breaking at HERA



Same effect should be visible at HERA in γp

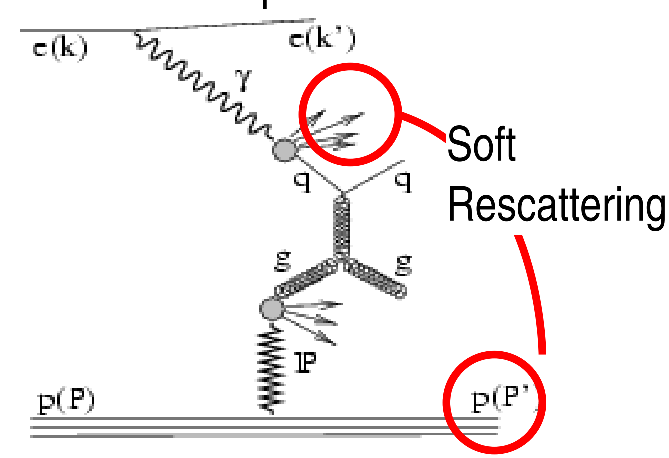
(i.e. $Q^2 \approx 0$ → large sized γ^* ~ hadron)

Direct γ^* (small γ^*) couples directly to parton (DIS and part of γp). QCD factorisation is expected to hold.



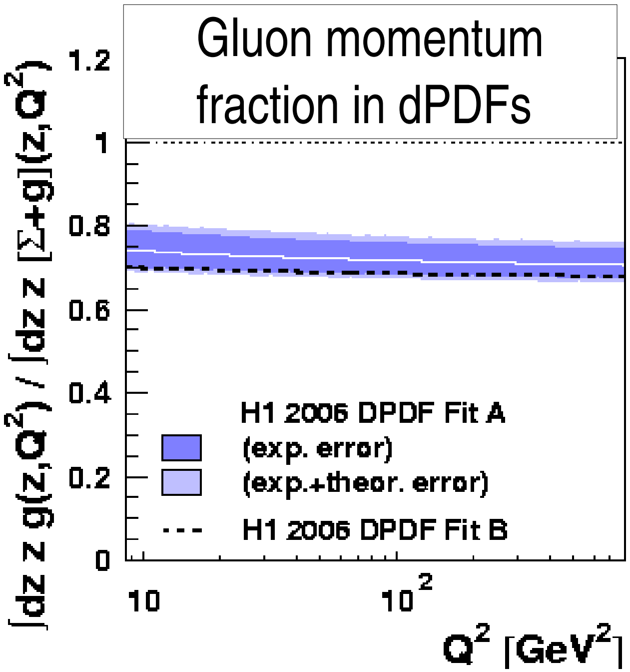
(a)

Resolved γ^* (large γ^*) behaves like a hadron (other part of γp). QCD factorisation is expected to break



(b)

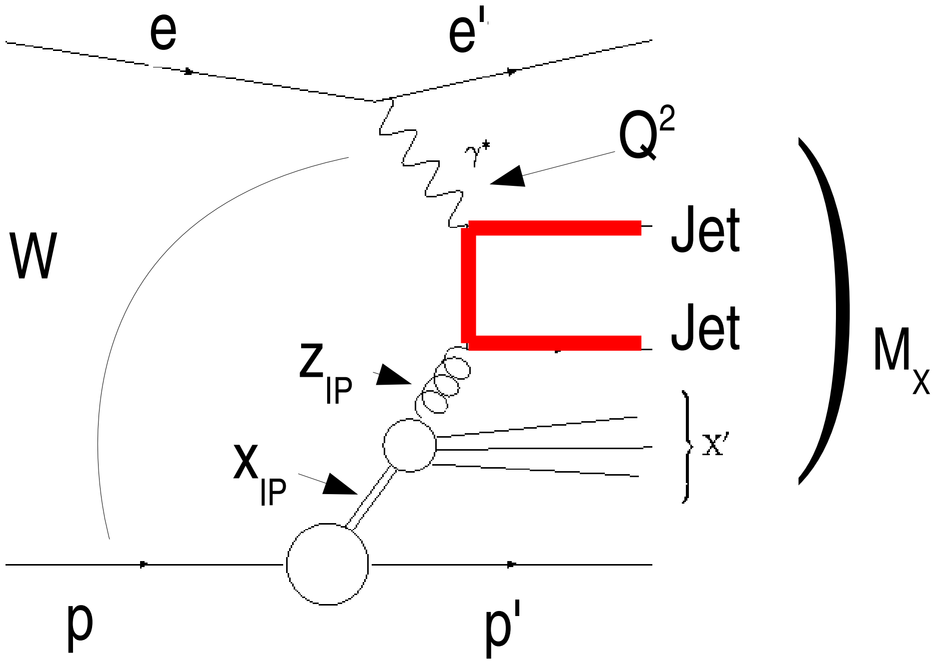
Test of QCD Factorisation



- Basic strategy:
  - Measure a particular diffractive final state.
  - Compare the measurement to NLO calculations using dPDFs previously extracted.
- What kind of final states?
  - Processes with a **hard scale** (pQCD, DGLAP)
  - **Sensitive to gluons** (gluons contribute to the main part of dPDFs)

Dijets and D* meson
are the best suited final states for this task !!!

Diffractive Dijets



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

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

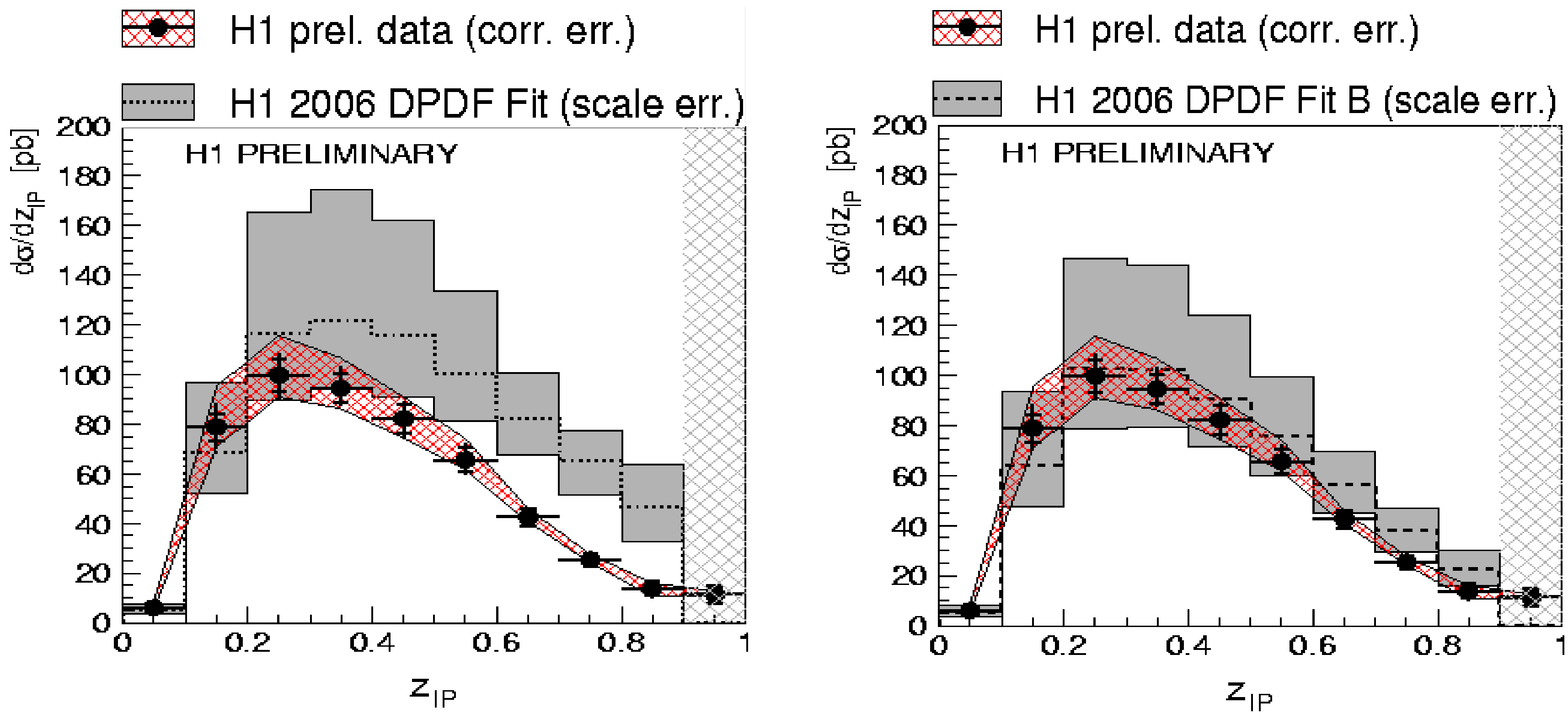
This process provides:

- ✔ Hard scale: E_T & (only in DIS) Q^2
  → pQCD, Q^2 evolution of PDF
- ✔ Strong sensitivity to gluon content of dPDFs

Test of QCD factorisation
Constraint on dPDFs

Recent publication from H1 (hep-ex/0703022)

Diffractive Dijets in DIS



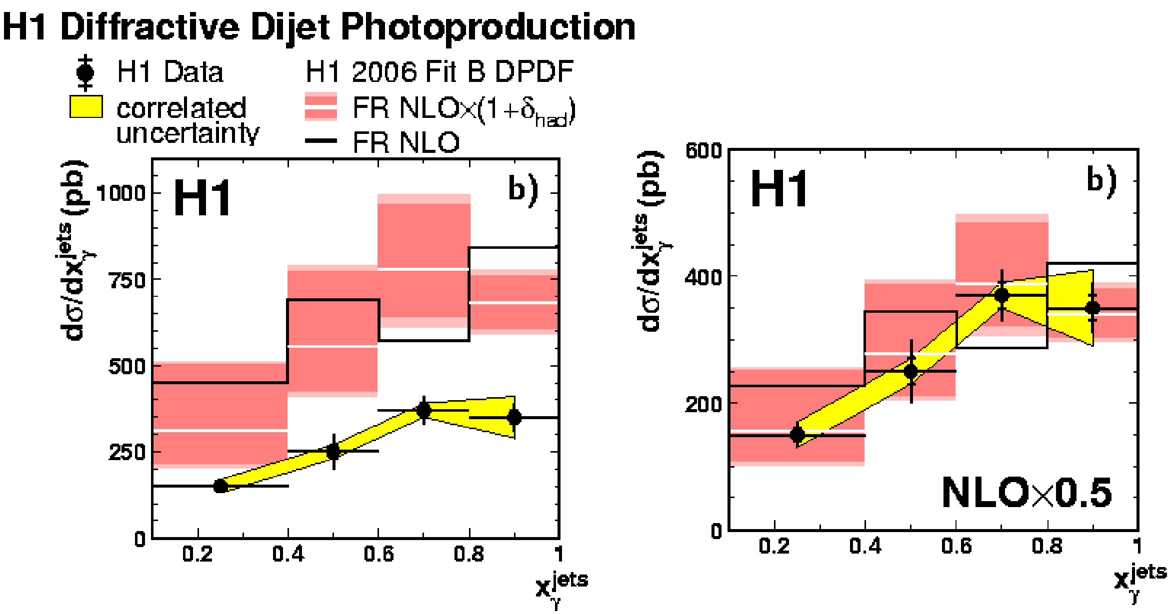
Preliminary results from H1.

Good agreement between data and central values of the NLO using the H1 2006 fitB dPDFs.

Within large theoretical uncertainties, QCD factorisation seems to hold.

Data are able to discriminate better performing dPDFs.

Diffractive Dijets in γp



x_γ =fraction of initial γ mom taken by the dijet system

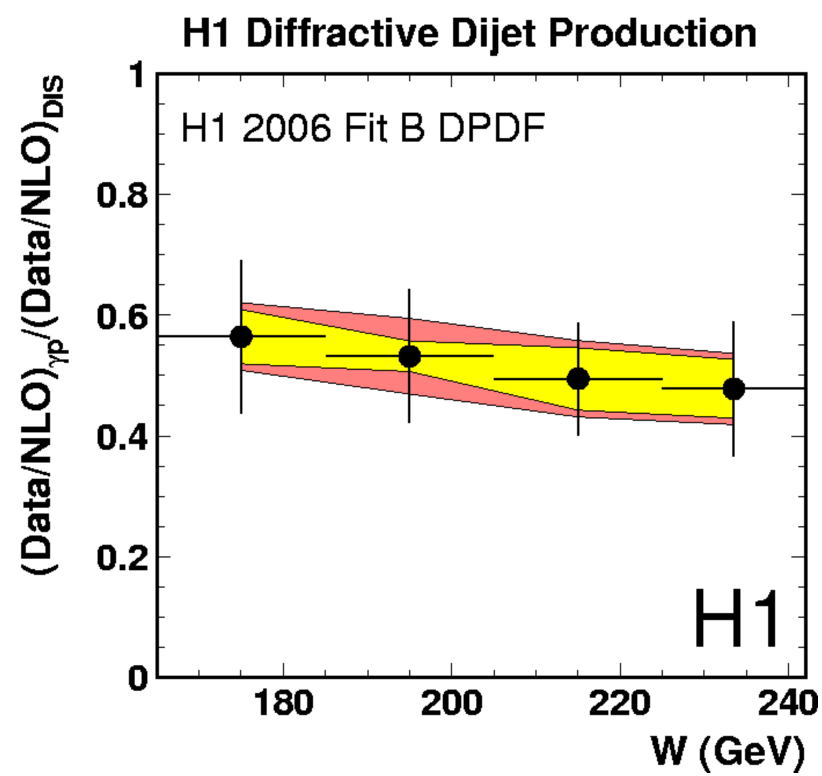
x_γ ~ 1 direct enhanced

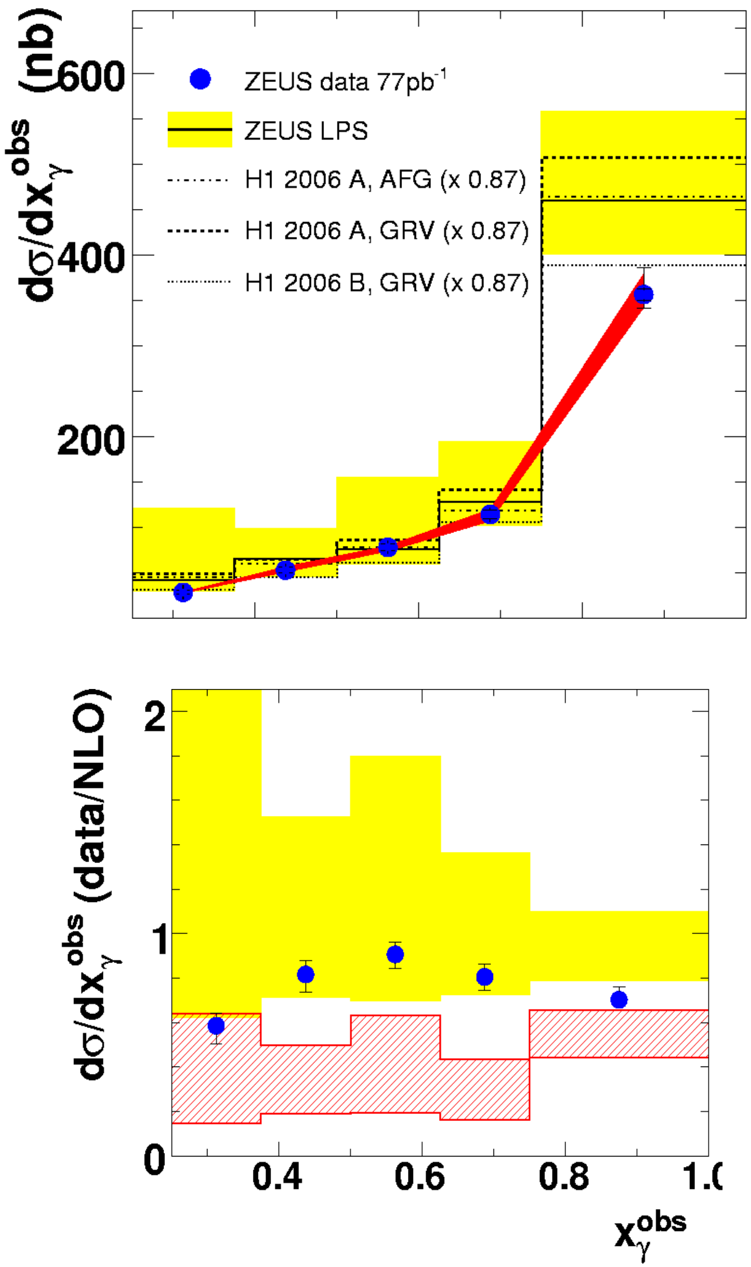
x_γ<< 1 resolved enhanced

Expectation (based on CDF results):

suppression at low x_γ

H1 observes a **suppression** (~ factor 2) of the measured σ compared to NLO over the entire kinematic range.





Same measurement, ZEUS results.
NLO calculation still under check.
Disagreement DATA vs NLO compatible within uncertainties.

No evidence for a factorisation breaking.

ZEUS and H1 measurements cover **different kinematic ranges**

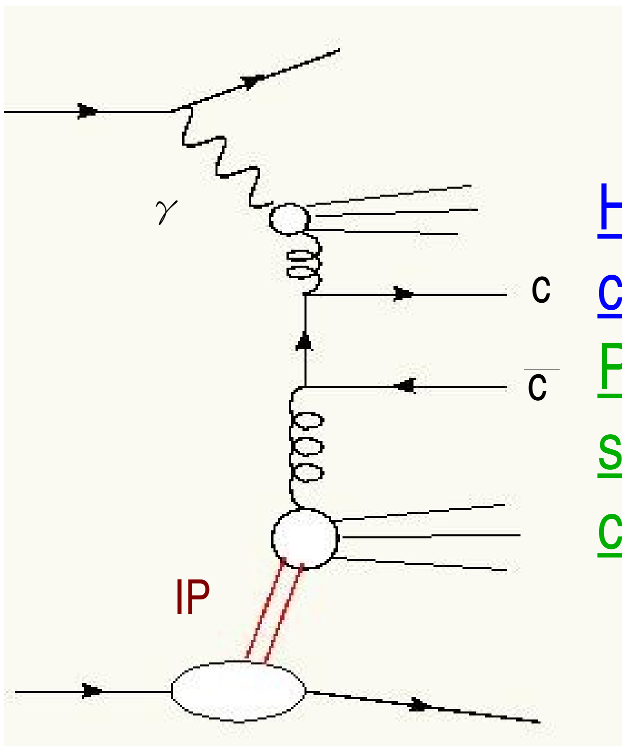
H1: $E_T > 5$ GeV , $x_{IP} < 0.030$

ZEUS: $E_T > 7.5$ GeV, $x_{IP} < 0.025$

Not necessarily a contradiction between H1 and ZEUS. Different kinematic range can explain it.

The issue is intriguing and under study...

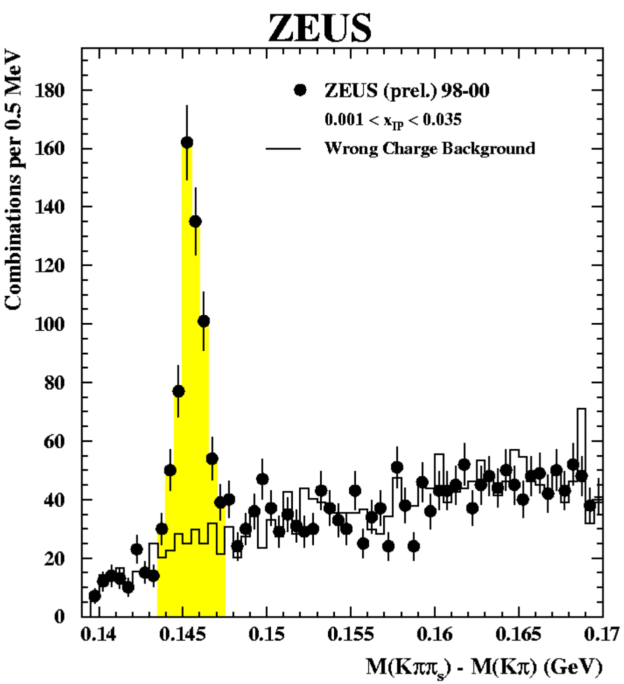
Diffractive Production of D*(2010) mesons



Hard scale from charm mass.

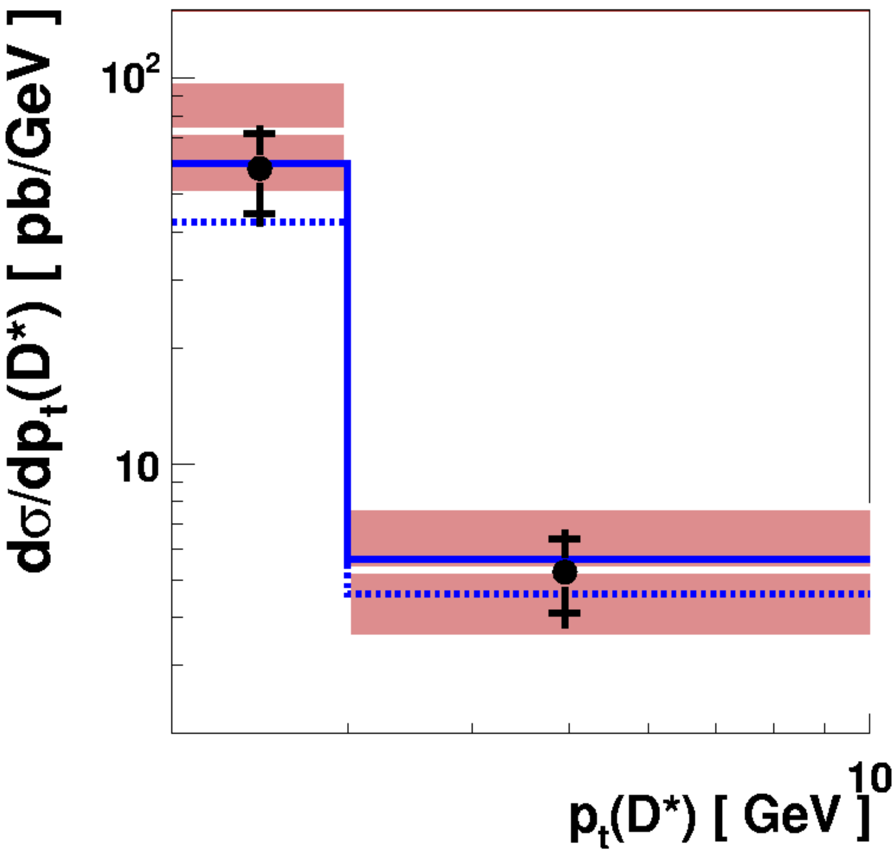
Production mechanism sensitive to gluon content of the dPDFs

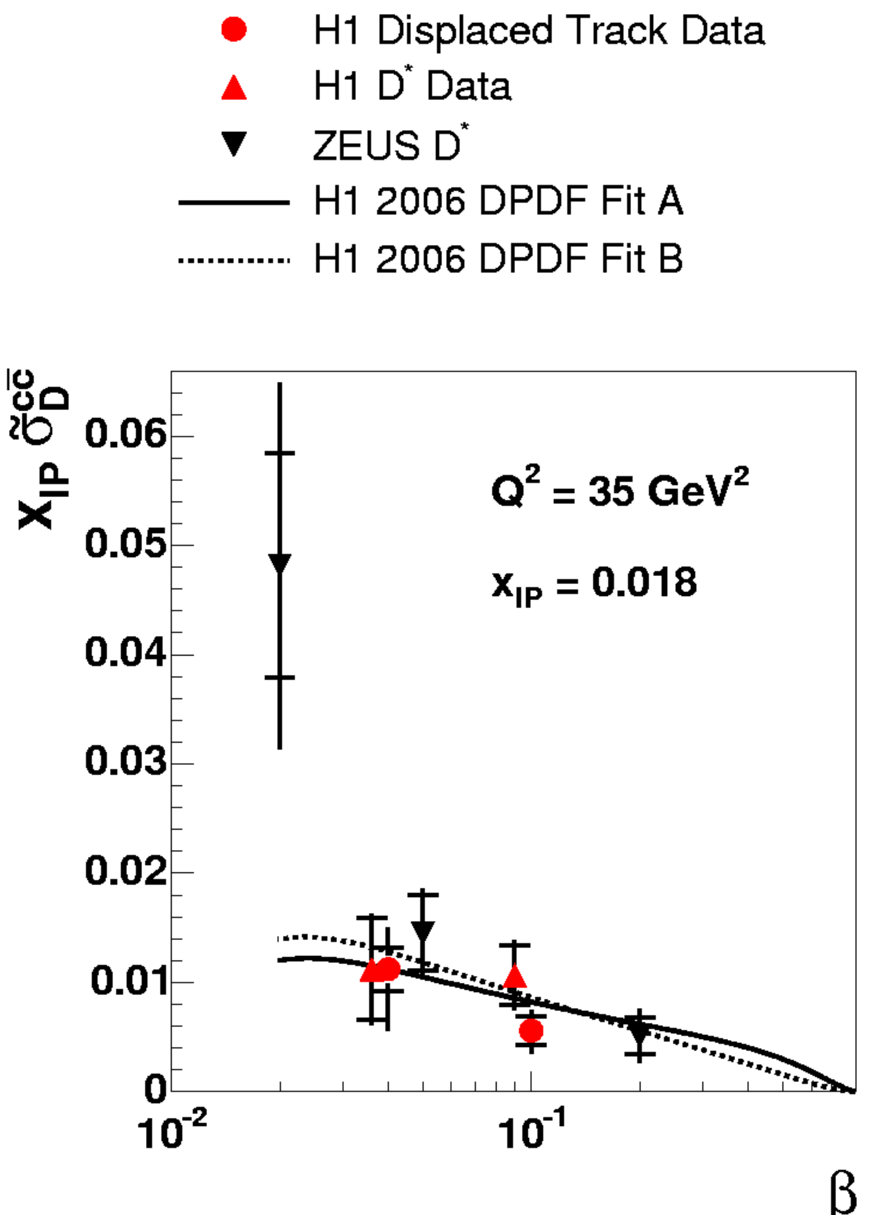
$$D^* \to K\pi\pi_S$$



Recent publications from both H1 (DIS and γp) and ZEUS (γp).
As before, factorisation breaking expected in γp but not in DIS.

Diffractive D* in DIS





NLO describes data.

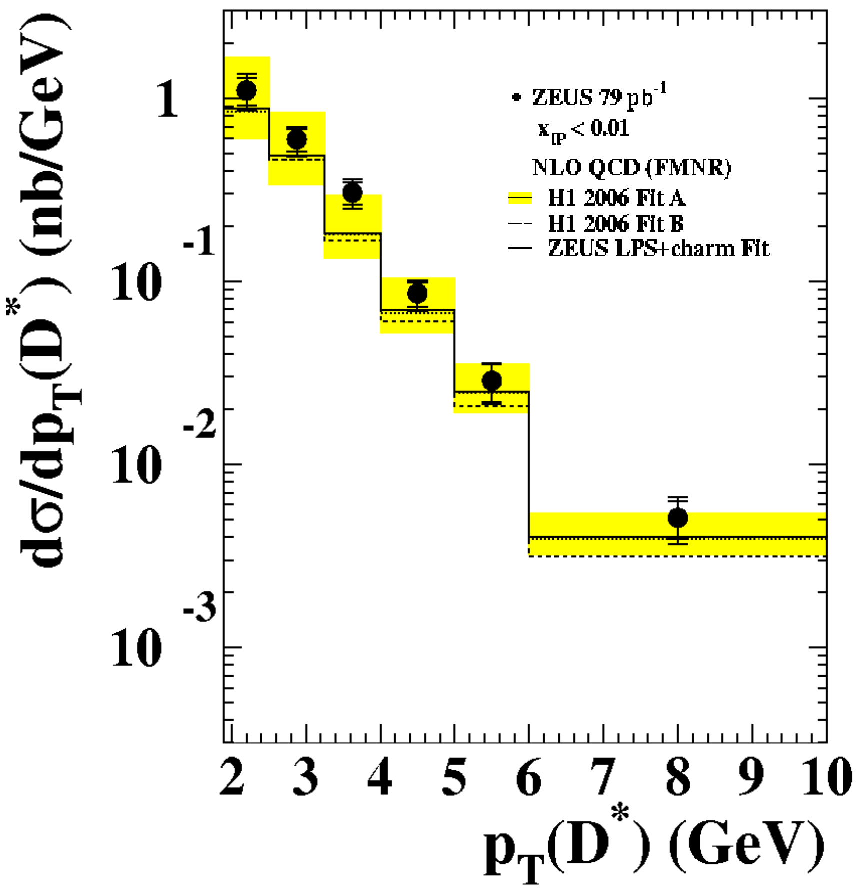
Very large theoretical uncertainties.

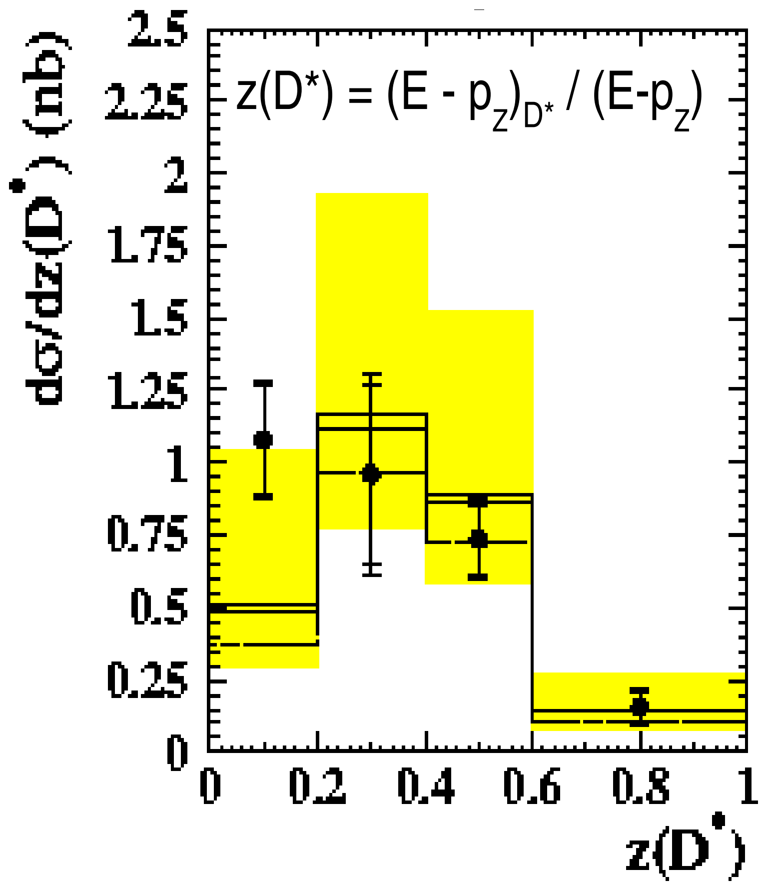
Different measurements in good agreement.

hep-ex/0610076

Diffractive D* in γp

hep-ex/0703046





Satisfactory agreement DATA vs NLO.

No evidence for factorisation breaking.

But:

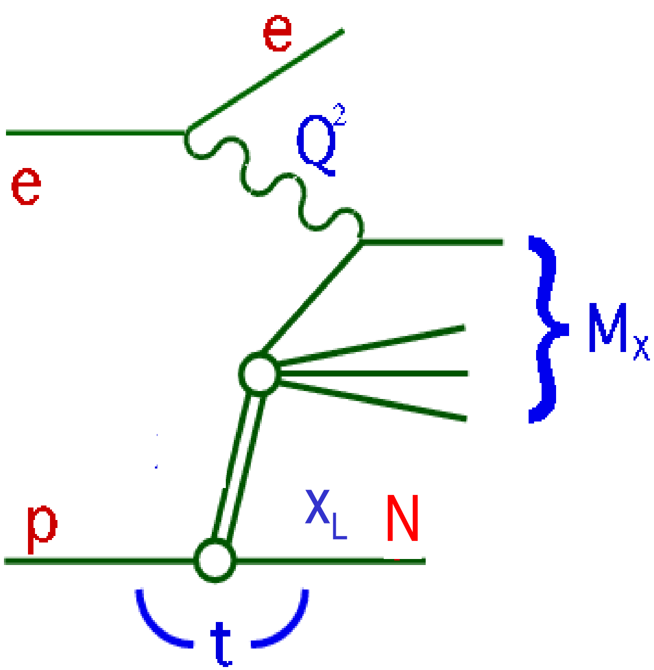
- Small hadron-like contribution in NLO.
- Large theoretical uncertainties.

Testing factorisation breaking for the resolved γ from these data is difficult.

Summary (1)

- QCD factorisation breaking in diffraction is observed in $p\bar{p}$ collisions.
- The same effect is expected to be seen in a fraction of *ep* collisions.
- QCD factorisation holds for production of dijets and D* in DIS (as expected). Large theoretical uncertainties in the NLO calculations. Data can be used to constrain the dPDFs.
- Production of D* mesons in γp doesn't exhibit any hint of QCD factorisation breaking.
- Situation in dijets in γp is still unclear. Experimental results show differences probably due to different kinematic ranges.

Leading Neutrons

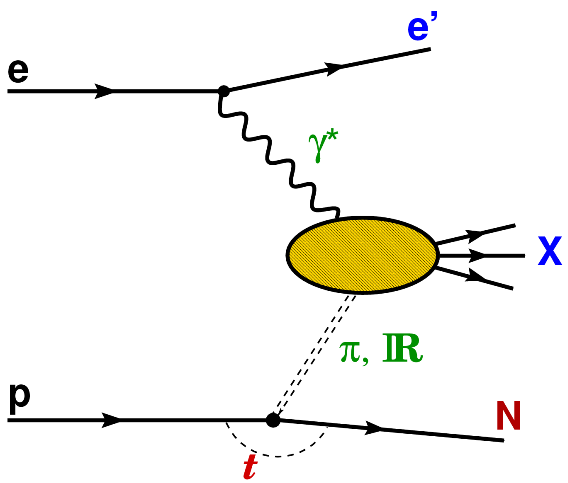


Standard lepton variables:
Q^2, W, x, y

Leading baryon variables:

$x_L = E_n / E_p$

$t = (p - N)^2 \sim p_T^2 / x_L$



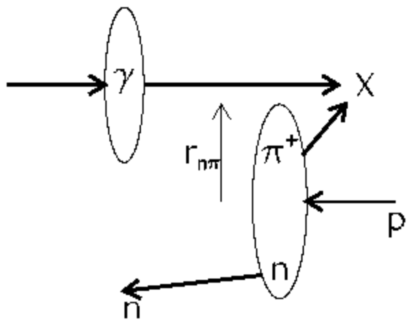
Production mechanism not yet completely understood. Significant contribution from
One Pion Exchange (OPE):

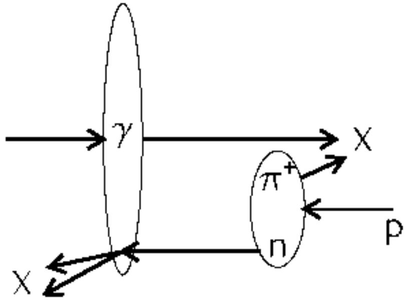
Limiting fragmentation hypothesis: leading neutron production independent of the lepton variables (i.e. the two vertexes factorise).

Factorisation breaking in leading neutrons

Basic idea:
re-scattering can lead to absorption and migrations of the outgoing neutron

- Theoretical model I (D'Alesio & Pirner (EPJ A7 (2000), 109)):

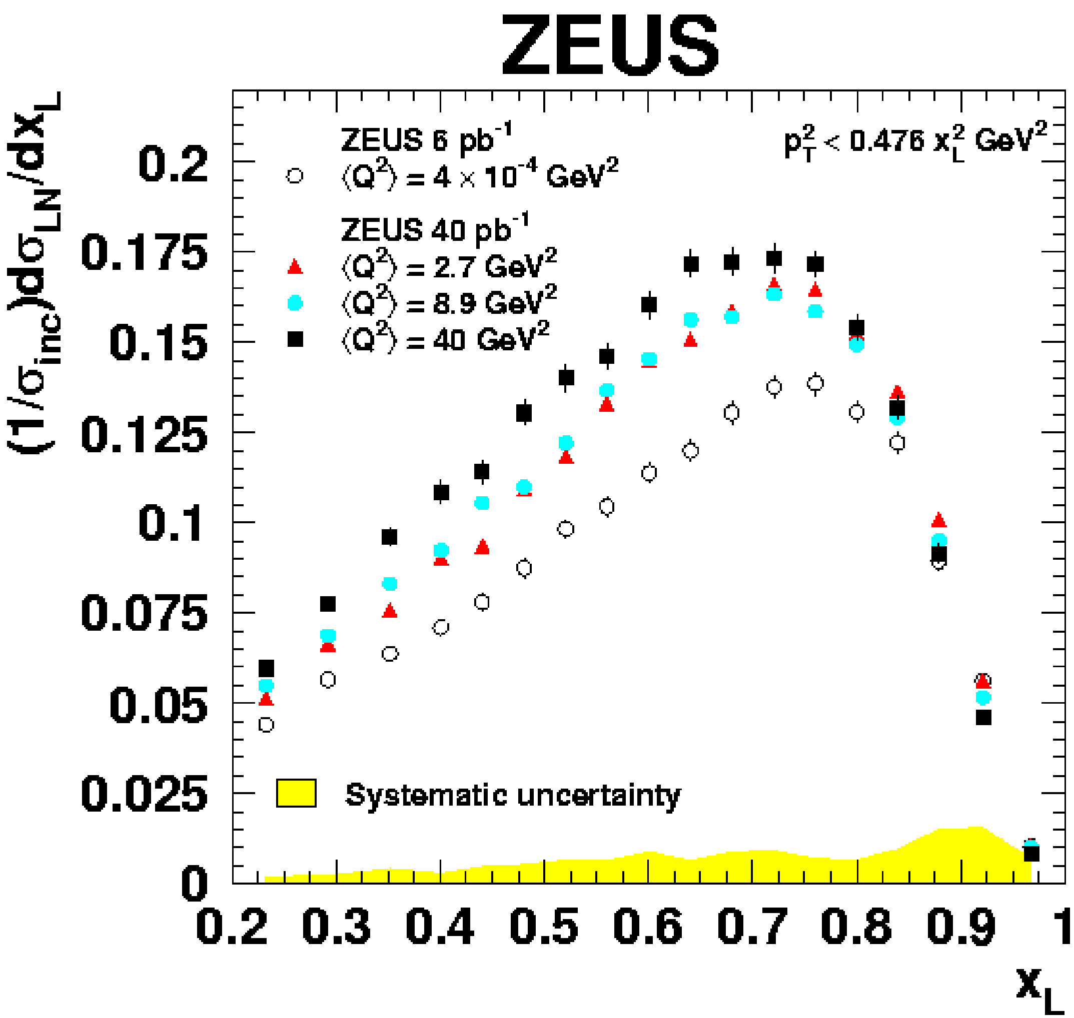




Re-scattering enhanced for large γ and large π-n transverse sizes.
LN escapes detection.

- Theoretical model II (NikholaevSpethZakharov (hep-ph/9708290), KaidalovKhozeMartinRyskin (hep-ph/0602215, hep-ph/0606213)):
  additional multi-pomeron terms cause rescattering

Q^2 dependence of the σ



Size of the γ inversely related to Q^2.

Cross section decreases with Q^2.

Clear suppression for γp ($Q^2 \sim 0$) events.

Violation of vertex factorisation

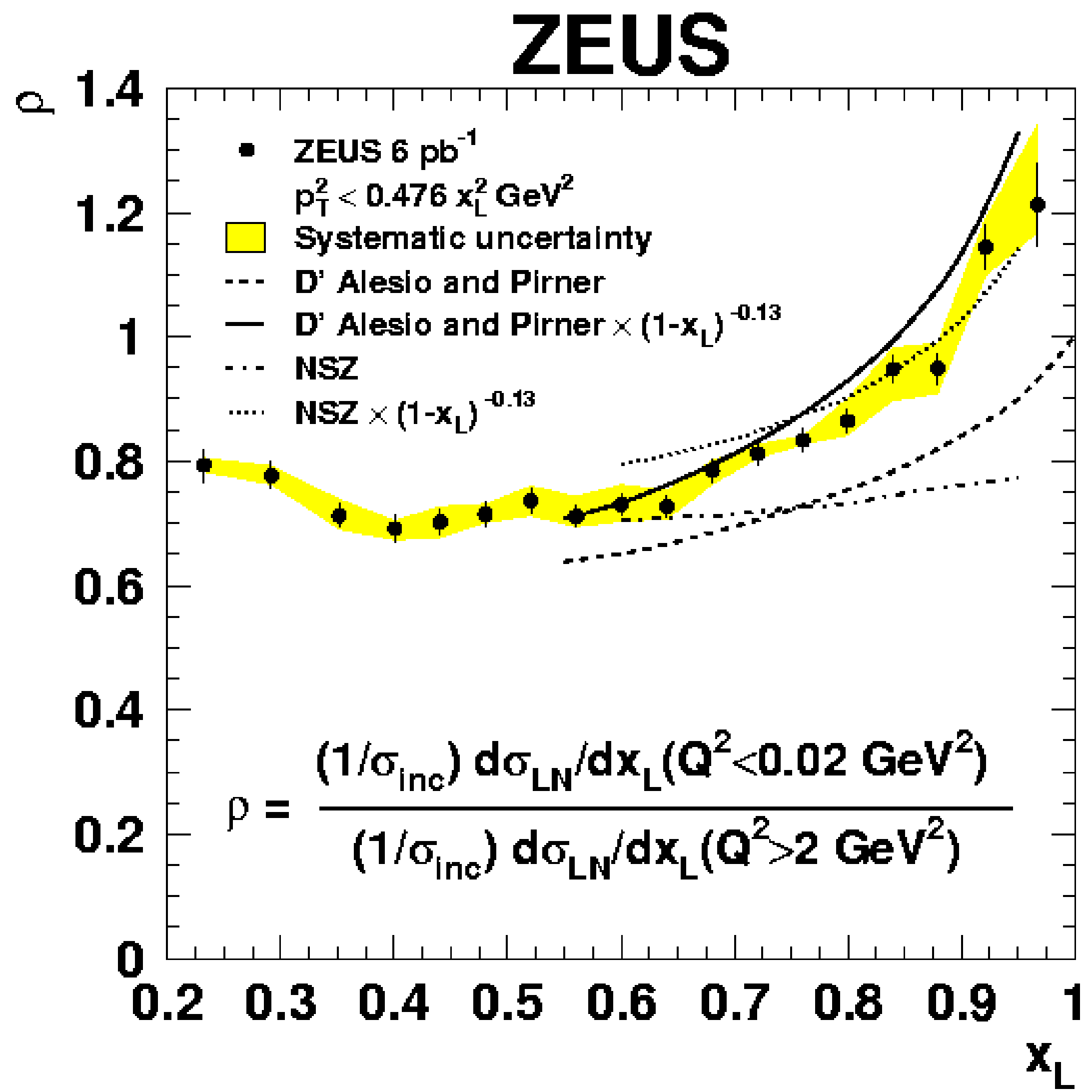
Ratio γp / DIS

Deviation from unity of the ratio is a sign of vertex factorisation breaking.

γp suppressed in the low x_L range.

OPE model with neutron absorption describes both normalisation and trend of the measurement.

Multi-pomeron exchange is close in magnitude but x_L dependence is not enough steep.



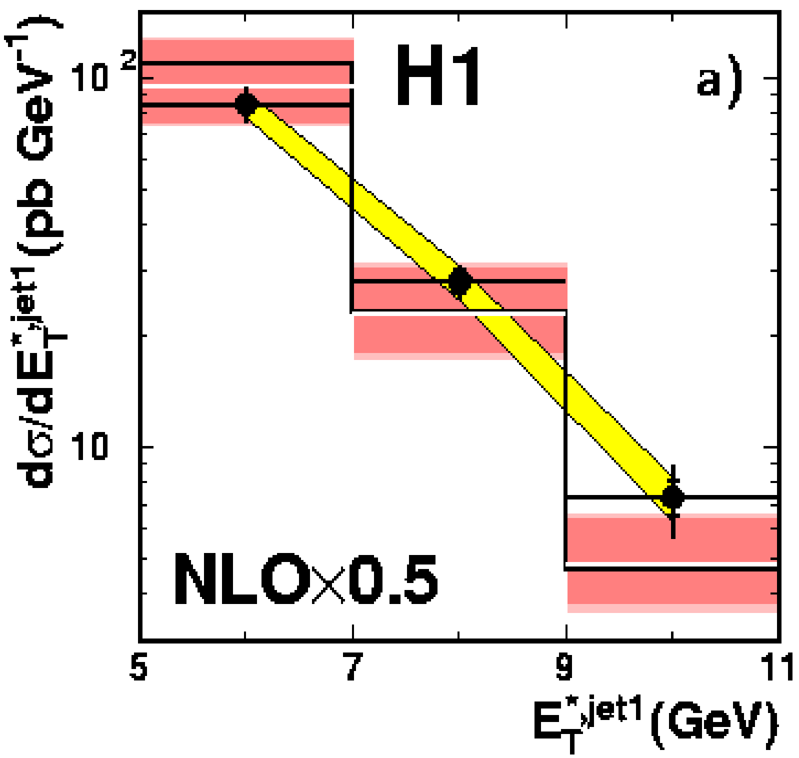
Summary (LN)

- Naive model expects a factorisation of the lepton and proton vertexes variables.
- This factorisation is broken.
- Different models try to address this effect with satisfactory results.
- Calculations of absorption can be transported to LHC (e.g. rapidity gap survival probability for exclusive Higgs production).

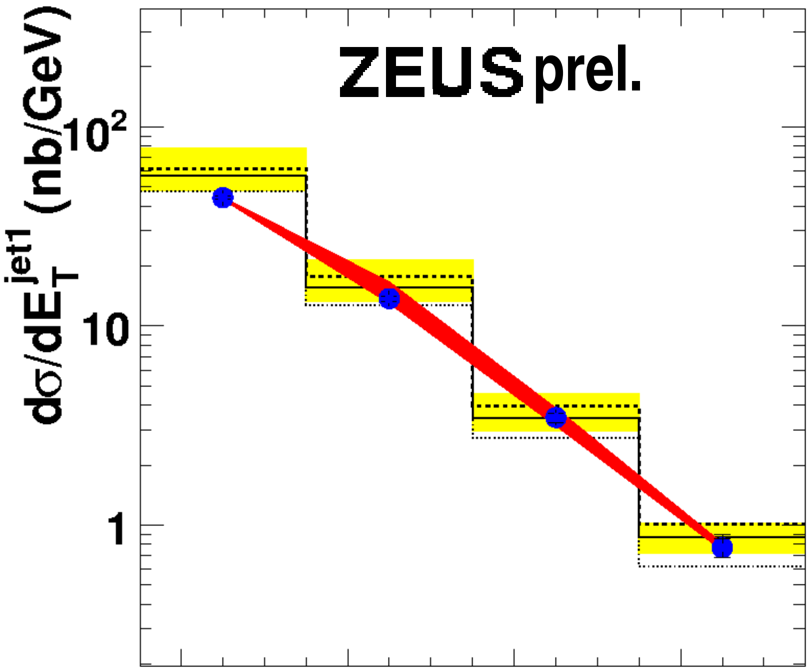
Conclusions

- QCD factorisation breaking is observed in diffractive processes.
- Vertex factorisation breaking is observed in leading-neutron production processes.
- Many experimental activities in this field at HERA.
- QCD factorisation breaking (rapidity gap survival probability) and vertex factorisation breaking can be interpreted as a result of re-scattering effects.
- The experience and the results obtained at HERA are a fundamental ingredient for diffractive studies at LHC.

Additional slides



H1 cut: E_T>5 GeV



ZEUS cut: E_T>7.5 GeV

The data suppression seems to be enhanced at low E_T.

The tighter E_T cut made by ZEUS could hide it.