Diffraction and Diffractive Final States at HERA

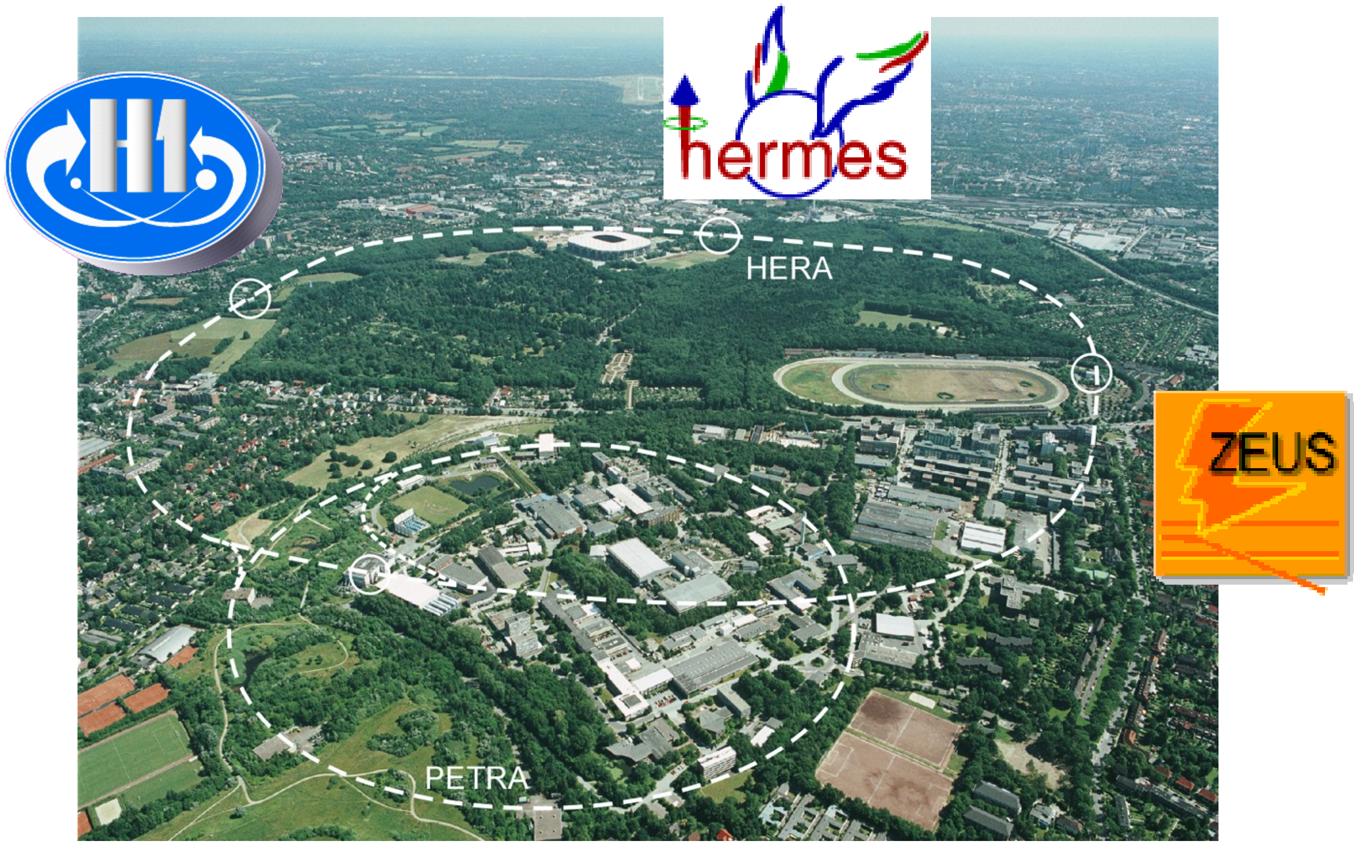
A.Bonato (DESY / Universität Hamburg)
on the behalf of the ZEUS and H1 Collaborations

Lake Louise Winter Institute, 24/02/2007

Outline

- Introduction: motivations, features and kinematics
- Inclusive diffraction measurements
- Diffractive final states: jets and open charm
- Conclusion

HERA



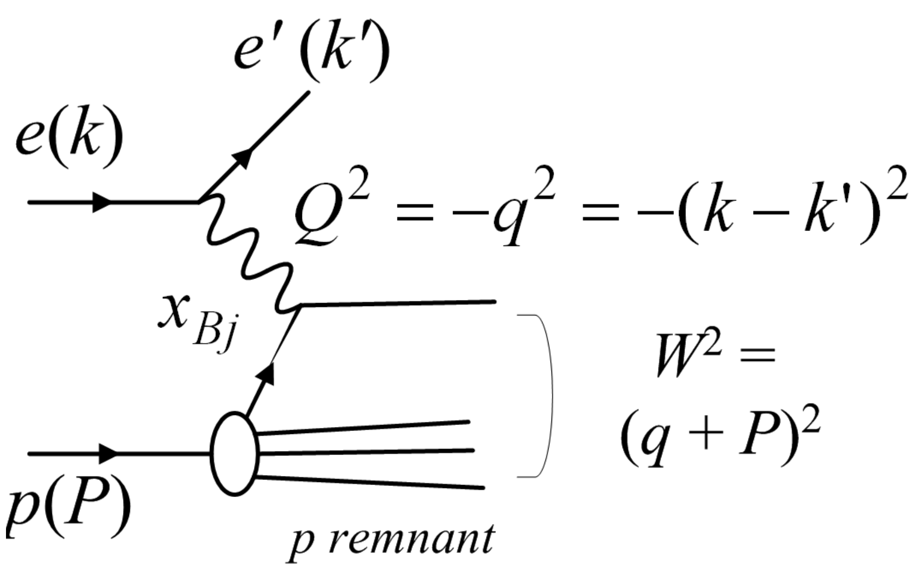
- R_{HERA} ~ 1 Km
- 27.5 GeV e^- (e^+)
- 920 GeV p
- 200 pb^{-1} delivered by HERA I
- 500 pb^{-1} delivered by HERA II

H1 and ZEUS general purpose detectors:

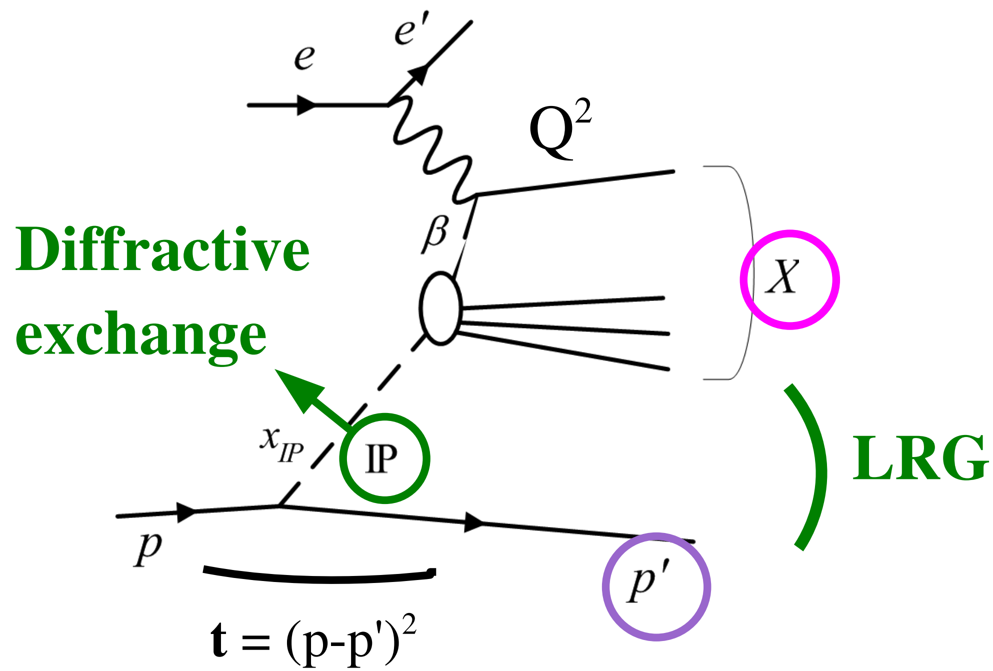
- EW studies and Proton PDF measurement
- Jet physics
- Search for new physics (leptoquarks, CI, SUSY…)
- Heavy flavour physics
- **Diffraction**

Diffraction at HERA

Deep Inelastic Scattering (DIS)



Diffractive DIS (dDIS)

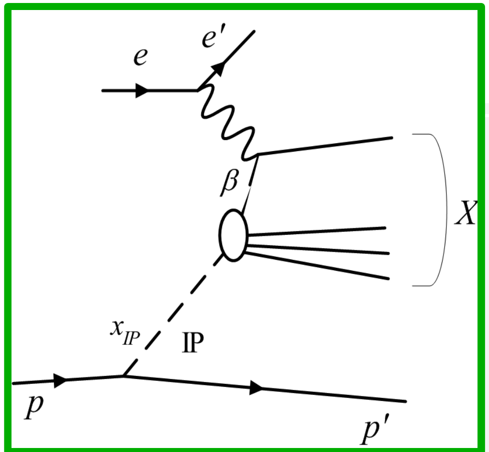


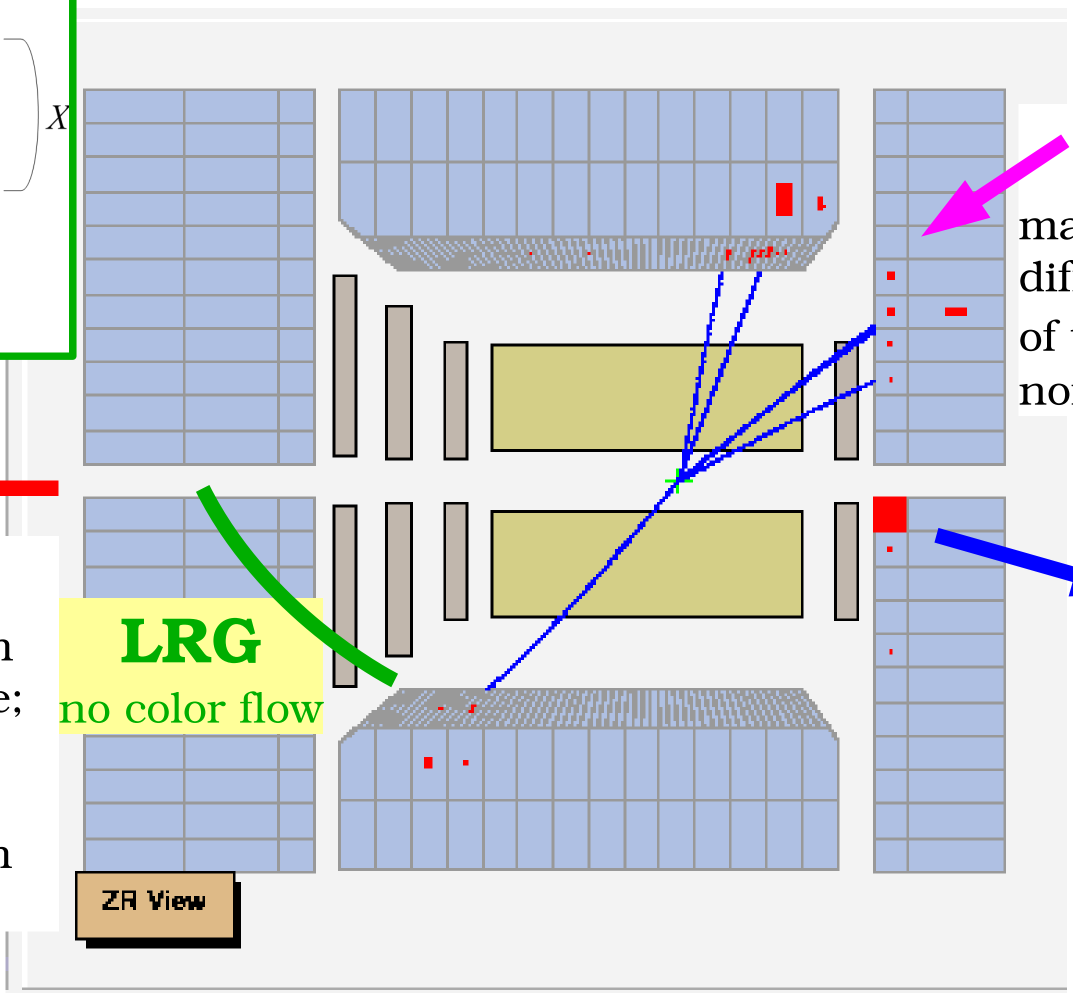
- γ^* probes p internal structure with resolution given by **Q^2**
- **x_{Bj}** = fraction of p momentum taken by parton
- **p breaks up**

- **p stays intact** and escapes in the beam pipe
- no quantum numbers exchanged btw γ^* and p
  - no colour flow ⟶ **Large Rapidity Gap**
- Hadronic system with **low masses** compared to the total available energy

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

Experimental features





LRG

no color flow

M_x

mass of the diffractive system; different M_x dependence of the σ between non-diffr DIS and diffr DIS

p'

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

e'

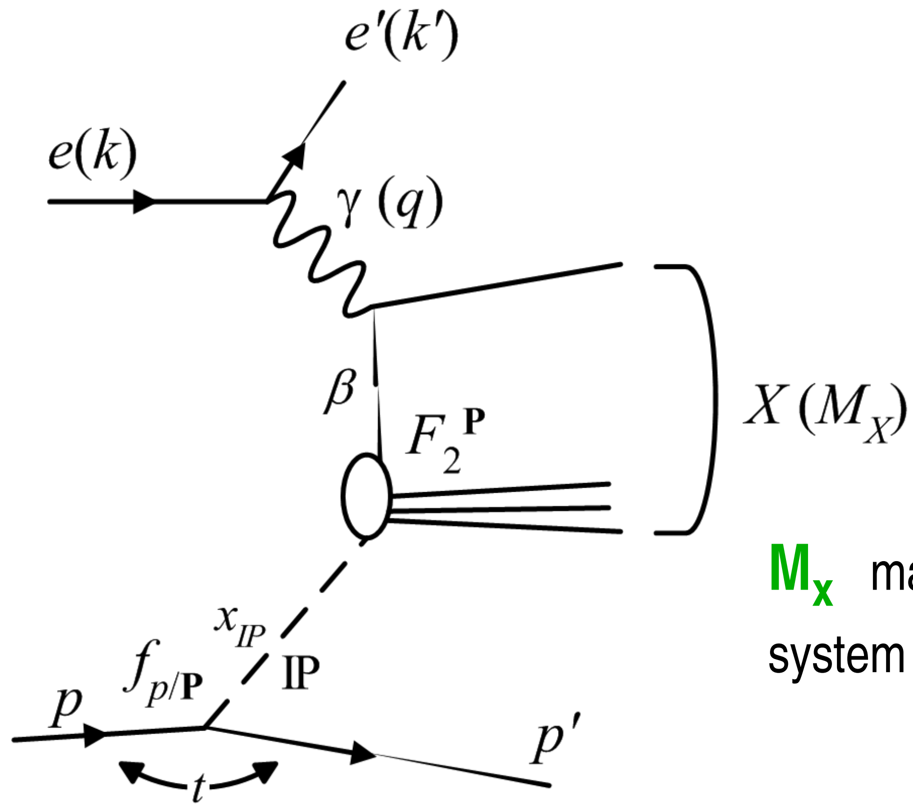
scattered electron

Kinematic variables

$x_{Bj} = x_{IP} \cdot \beta$

β fraction of IP momentum taken by parton in hard subpr

x_{IP} fraction of p momentum taken by IP



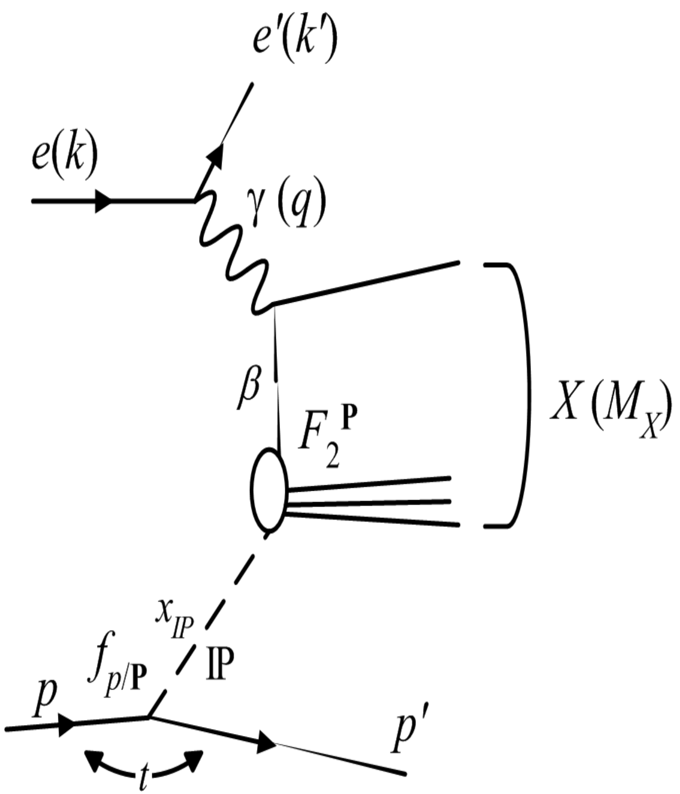
M_x mass of the diffractive final system

t 4-mom squared transferred at p vtx

$$\frac{d\sigma^D}{dt\, dx_{IP}\, d\beta\, dQ^2} = \frac{4\pi\alpha^2}{\beta\, Q^2}\left[\left(1-y+\frac{y^2}{2}\right) F_2^{D(4)}(t, x_{IP}, \beta, Q^2)\right]$$

Neglecting longitudinal momenta in the proton

QCD factorisation and diffractive parton densities



QCD Factorisation theorem

(proven for diffr DIS, J.Collins, 1998)

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

Hard subprocess

equal to non diffr. ,
calculated with pQCD

Diffractive PDFs

defined as the std PDFs +
diffractive requirement

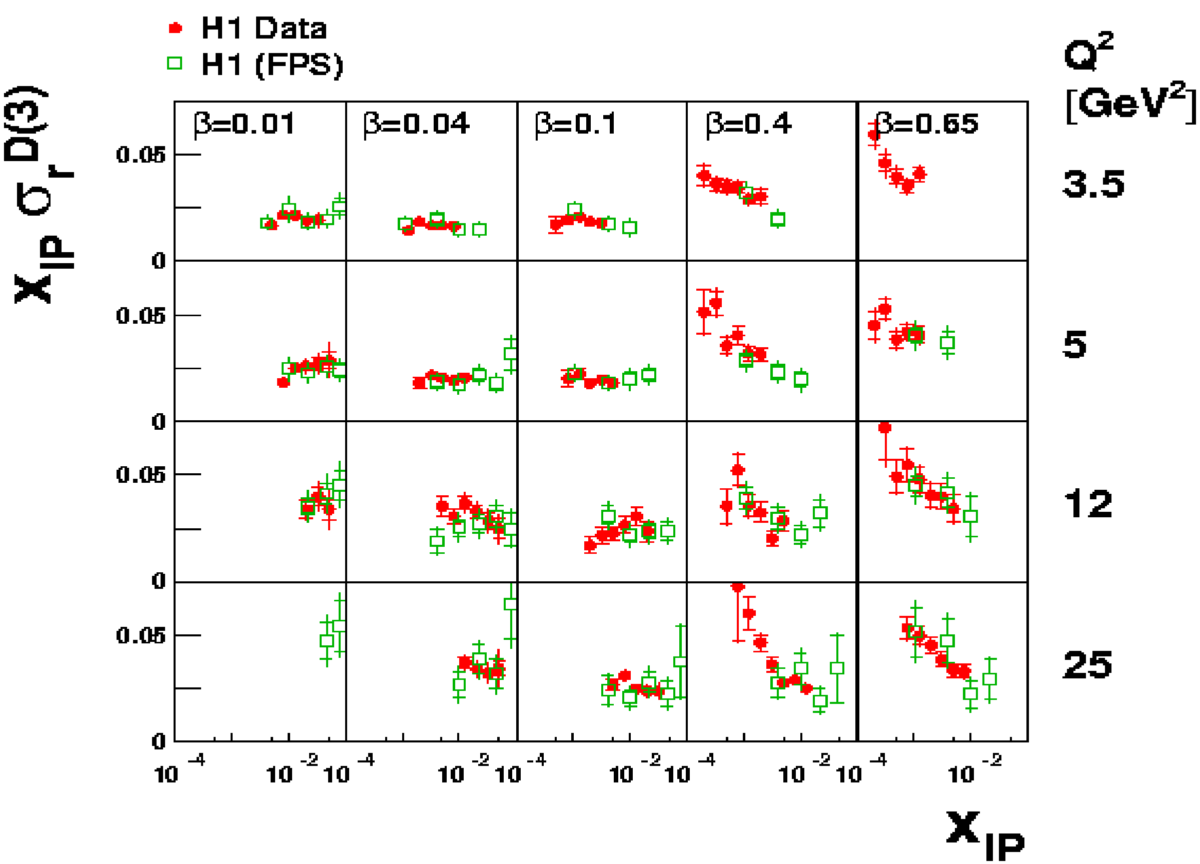
Universal

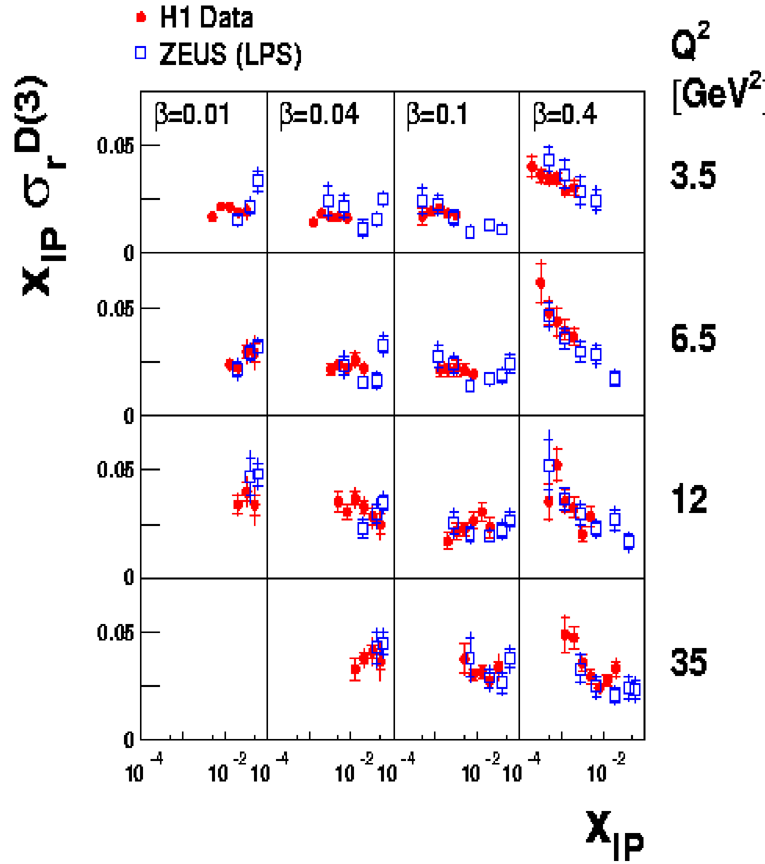
At HERA we can extract the dPDFs via NLO-QCD fits to inclusive diffractive measurements. They can be used later in calculations for other diffractive processes (dijets, charm...).

Inclusive diffractive DIS

ep→epX

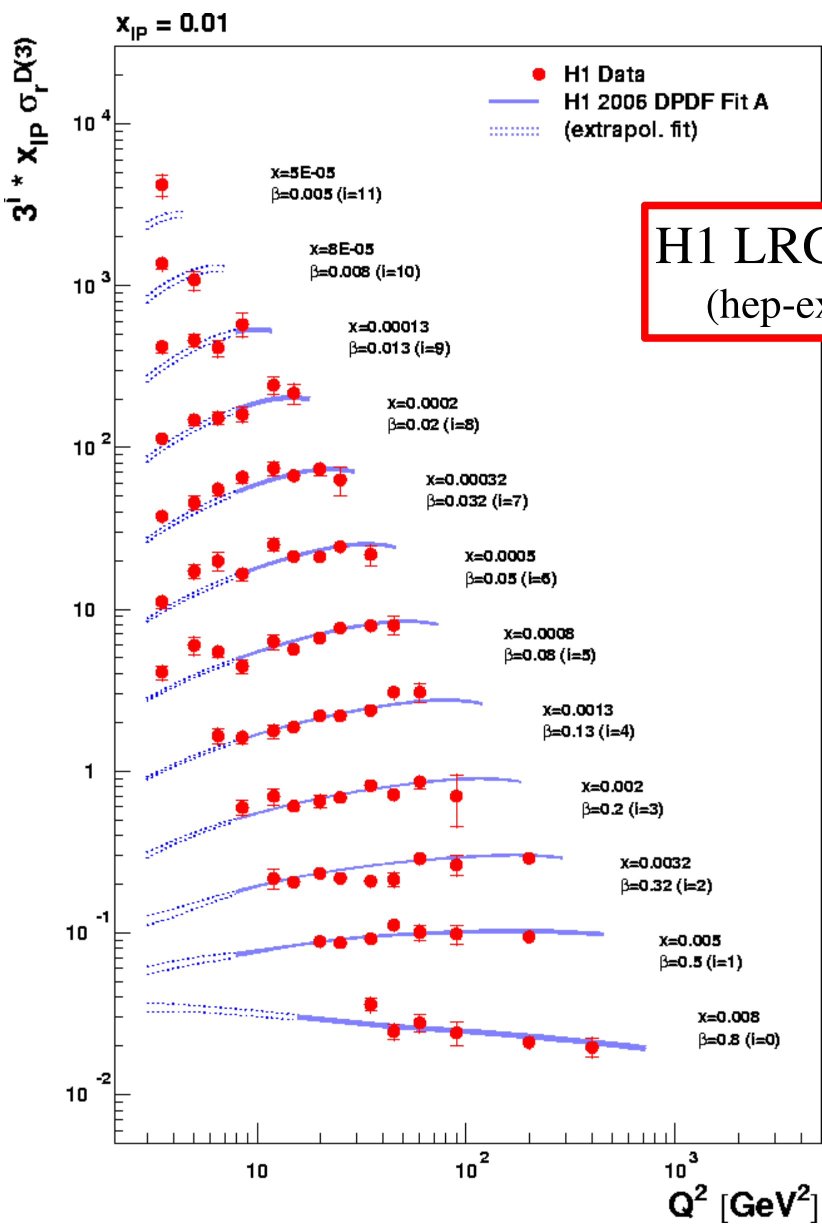
H1 LRG published
(hep-ex/0606004)





Good agreement between different selection methods and different experiments

Diffractive PDFs



H1 LRG published
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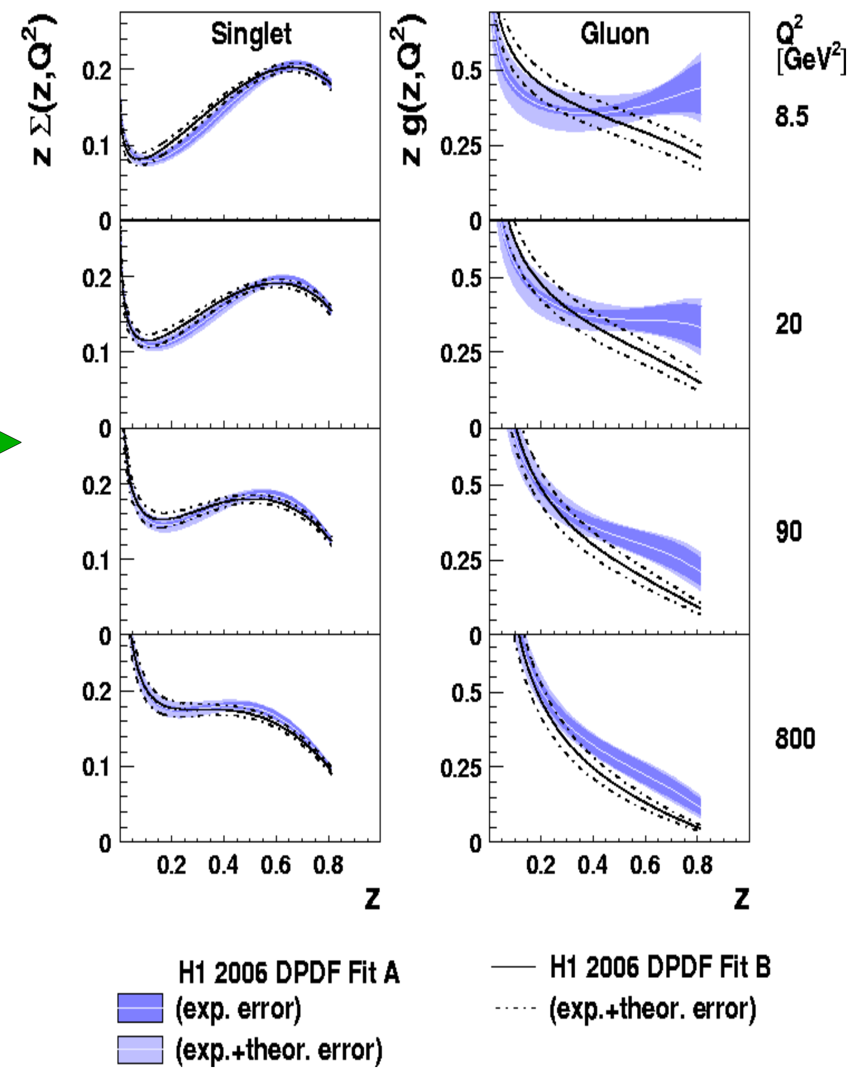
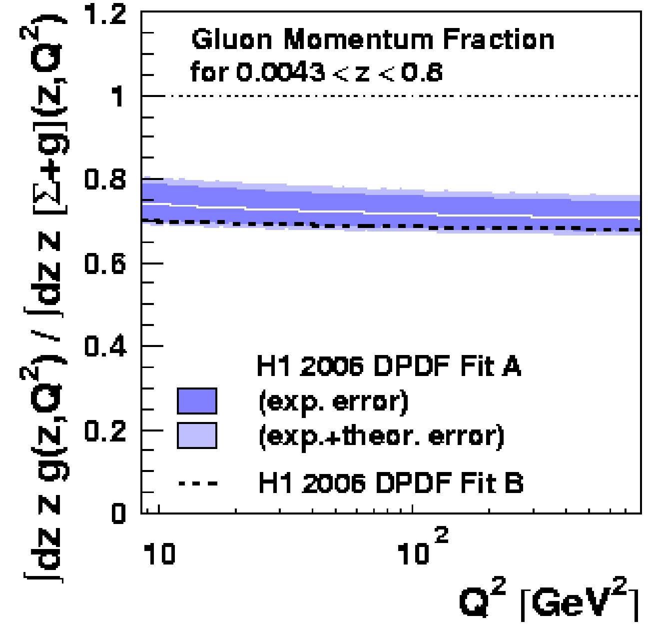
Extract the dPDFs



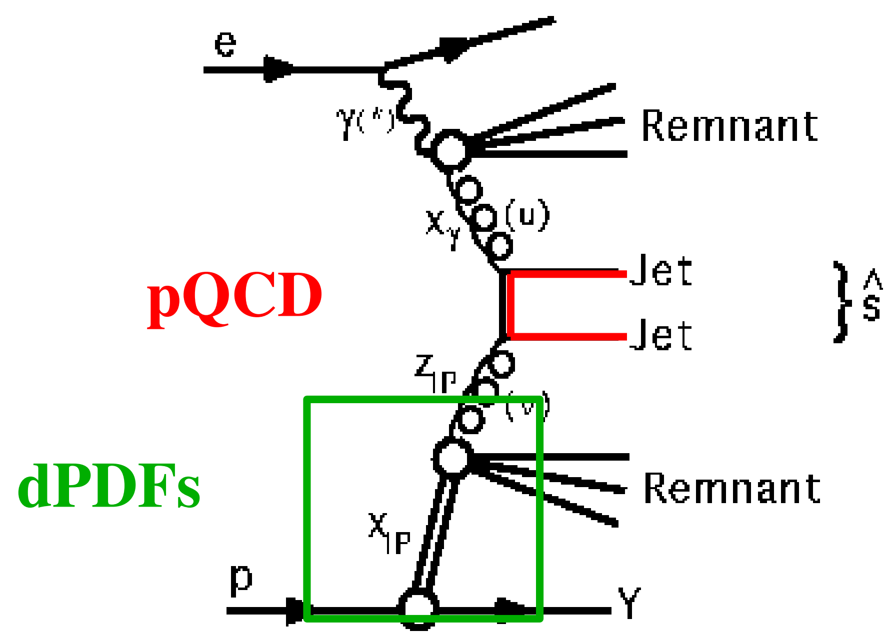
Diffractive semi-inclusive processes



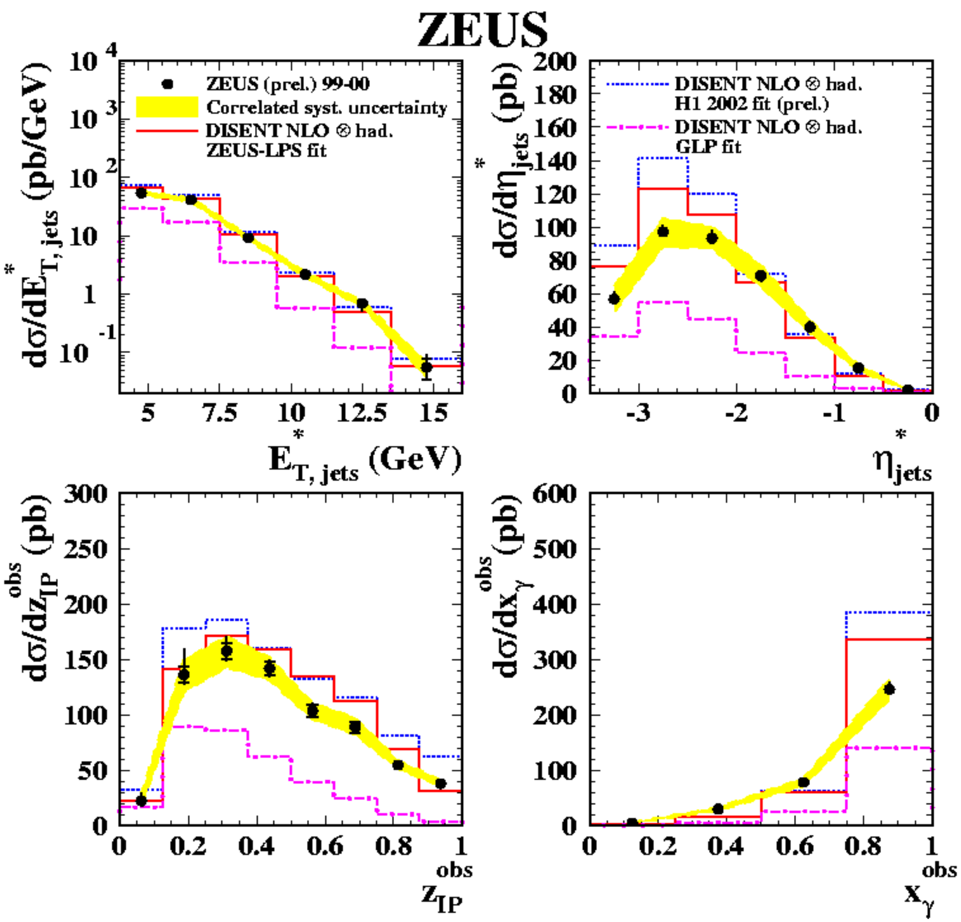
- Choose processes with a hard scale (be sure to be in a pQCD framework)
- A lot of gluons in the dPDFs ! Processes sensitive to gluon content are preferred.

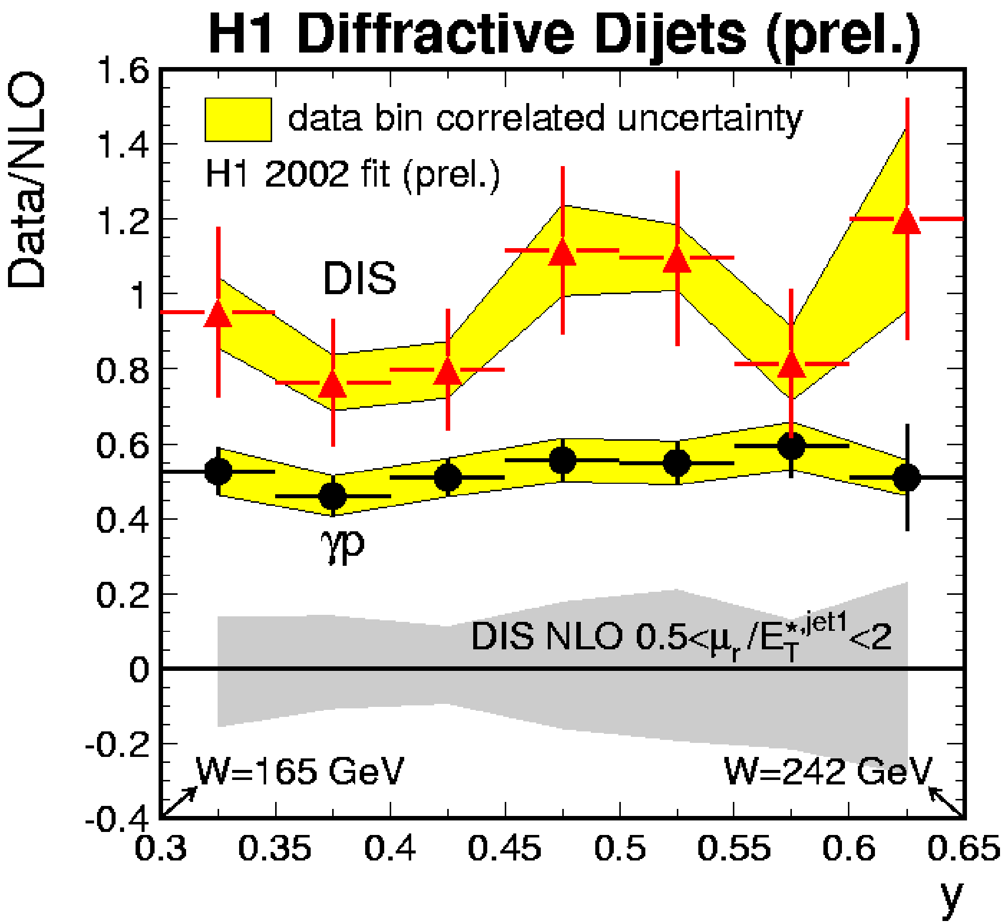
→ **Dijets and open charm**

- Check QCD factorisation comparison DATA vs NLO theoretical prediction: not only DIS, also γp (i.e. $Q^2 \approx 0$)
- Eventually add these data to the inclusive ones for a more constrained fit to the dPDFs.



Diffractive dijets





Diffr DIS dijets vs NLO:

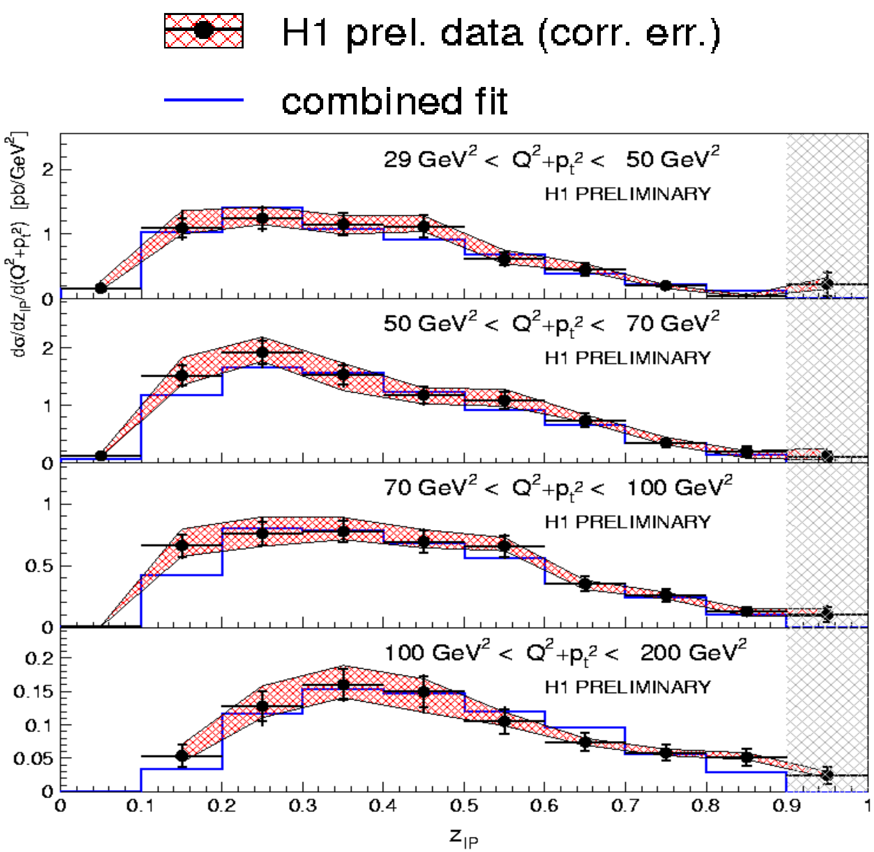
- Different dPDFs used for the NLO predictions
- General good agreement with data
- Large theoretical uncertainties (~40%, not shown)

Ratio Diffr dijets over NLO:

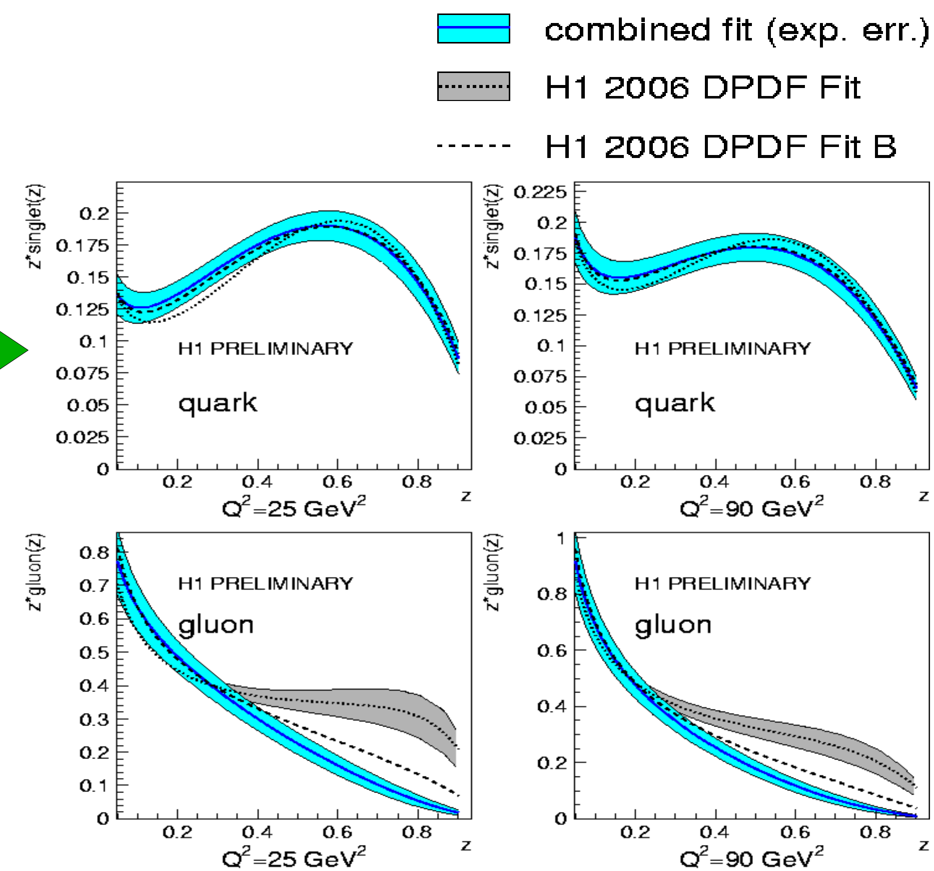
- Good agreement in DIS
- Suppression for γp

Combined fit dijets+ inclusive

Diffr dijets in DIS (double differential)

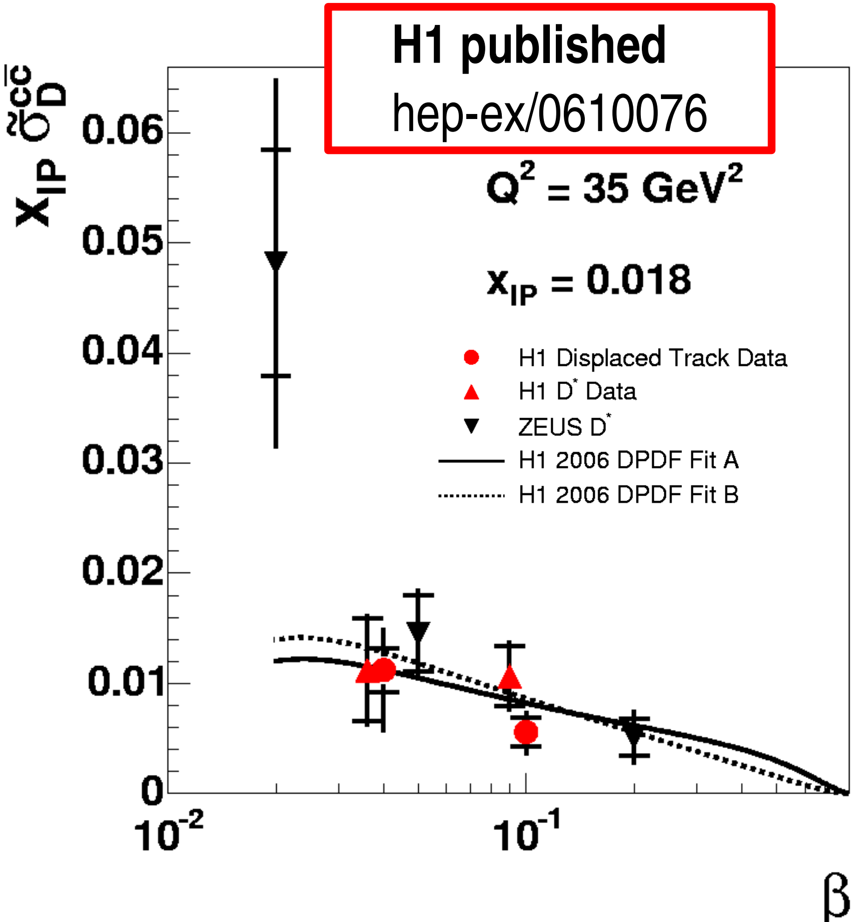


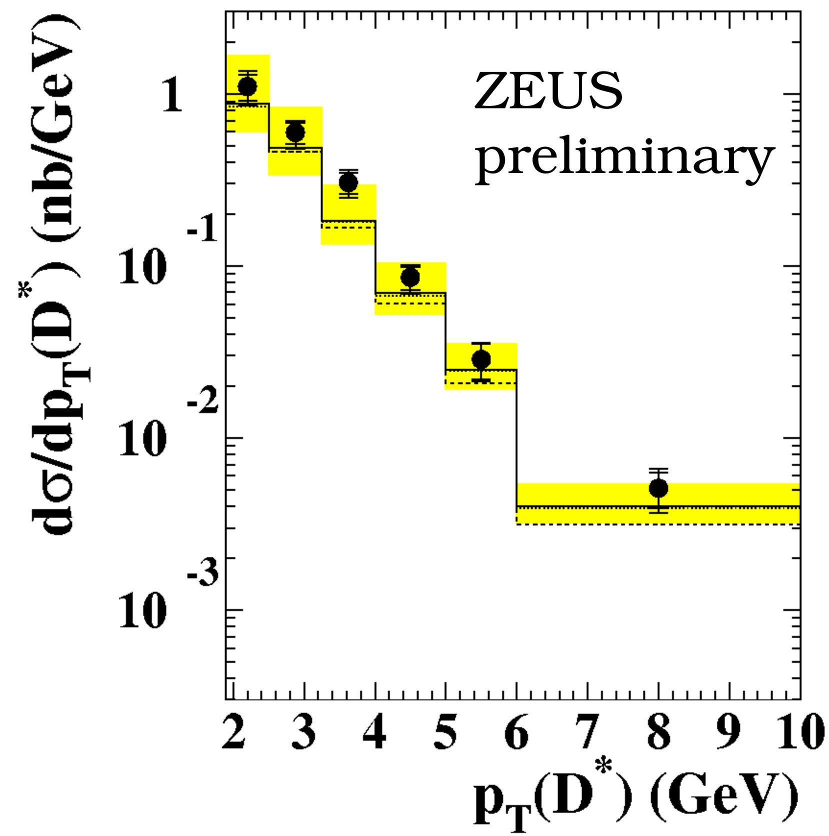
Combined fit (dijets + F_2^D)



- Extended kinematic coverage
- Uncertainty on gluon dPDF reduced
- NLO fit describes well both dijets and inclusive
- Validation of QCD factorisation theorem in diffr DIS

Diffractive D*





DIS measurement:

- Statistically limited
- Good agreement btw experiments and theory

γp measurement:

- Comparison to many NLO predictions
- Statistically limited
- Huge theoretical uncertainty
- NO evidence of factorisation breaking

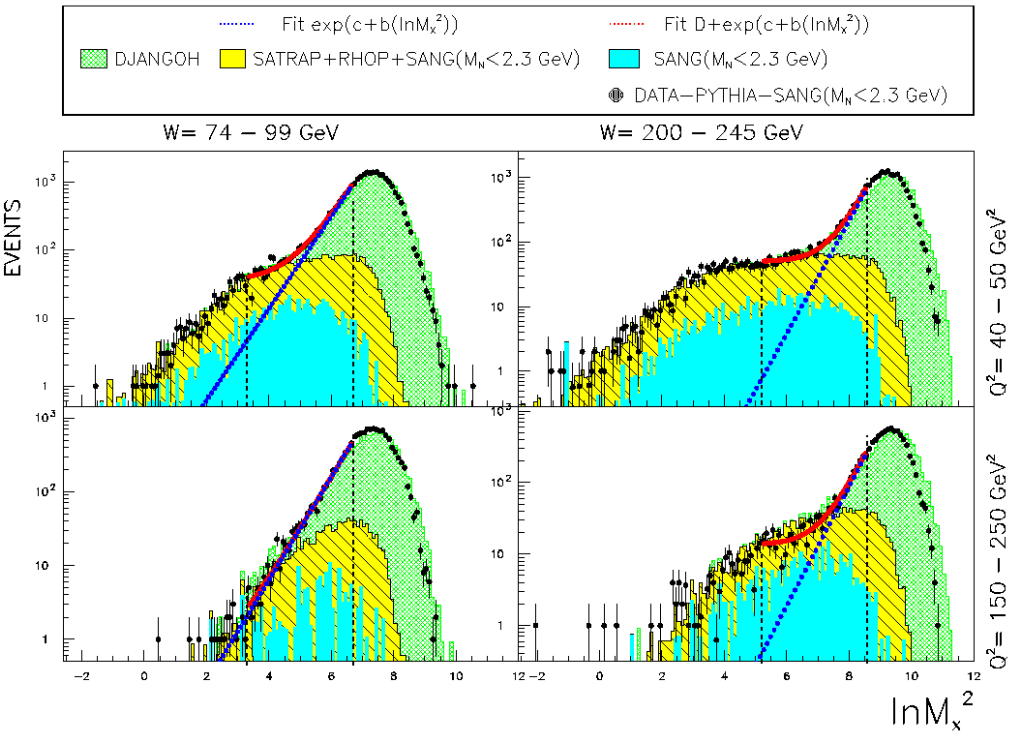
Summary

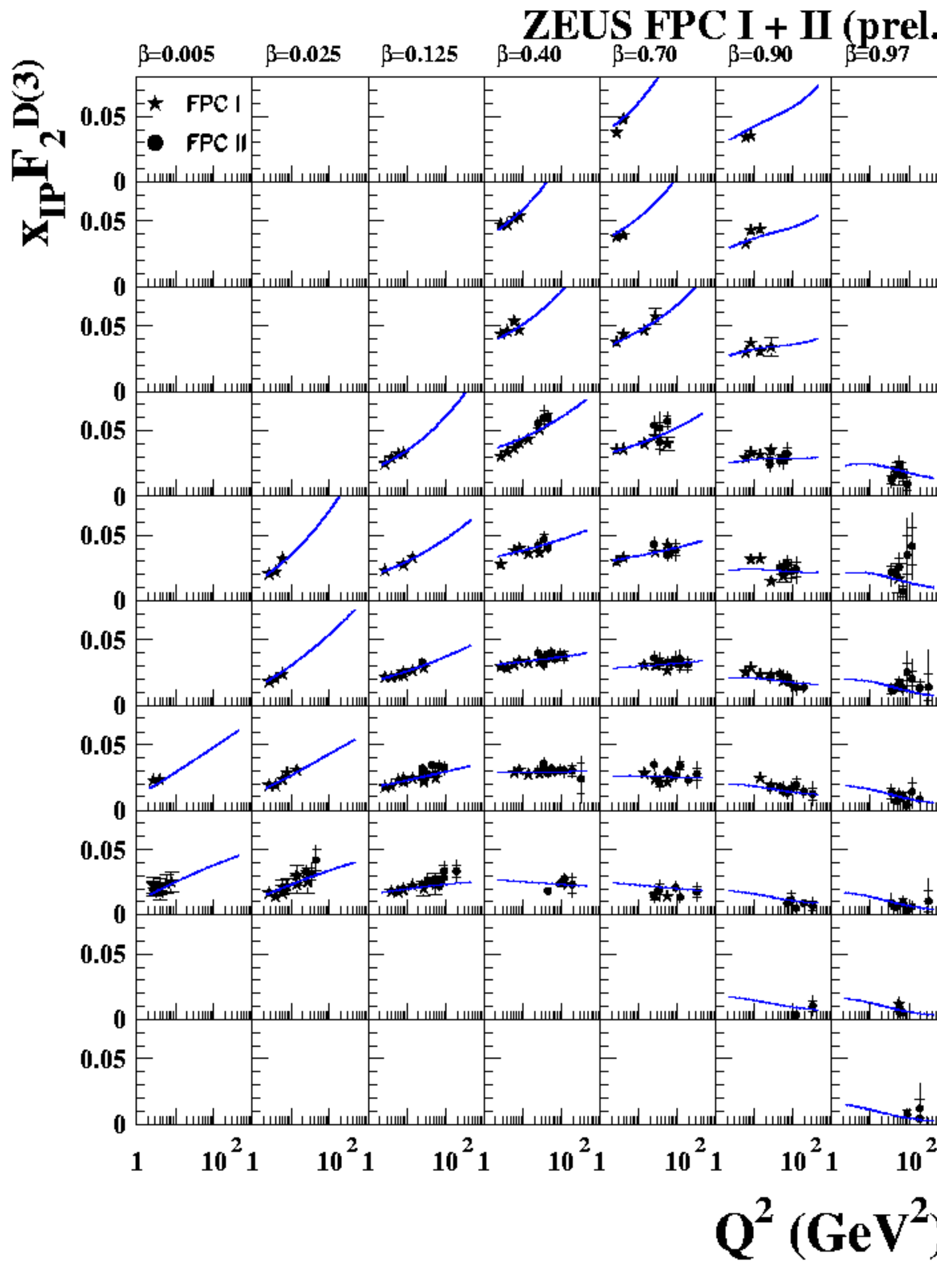
- At HERA diffraction is studied within the QCD framework
  - Many final states under examination
  - Several experimental techniques
  - Diffractive PDFs are extracted
  - Diffractive PDFs can be used for many theoretical predictions (QCD factorisation for diffraction).
- Diffractive final states are a powerful benchmark for the theory
  - D* in DIS confirms QCD factorisation
  - Dijets in DIS can put an important constrain on the dPDF
  - Dijets in γp show factorisation breaking
  - D* in γp studies are statistically limited but no clear hint of factorisation breaking is observed.

Backup slides

Inclusive diffractive DIS

ep→epX (M_x method)

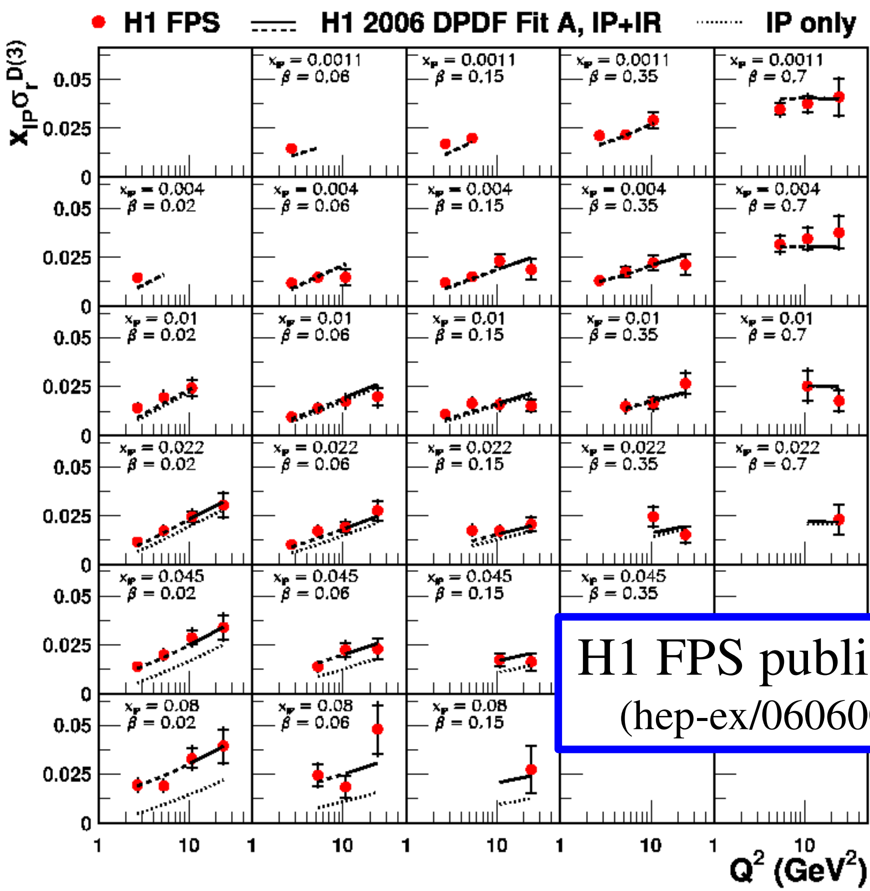




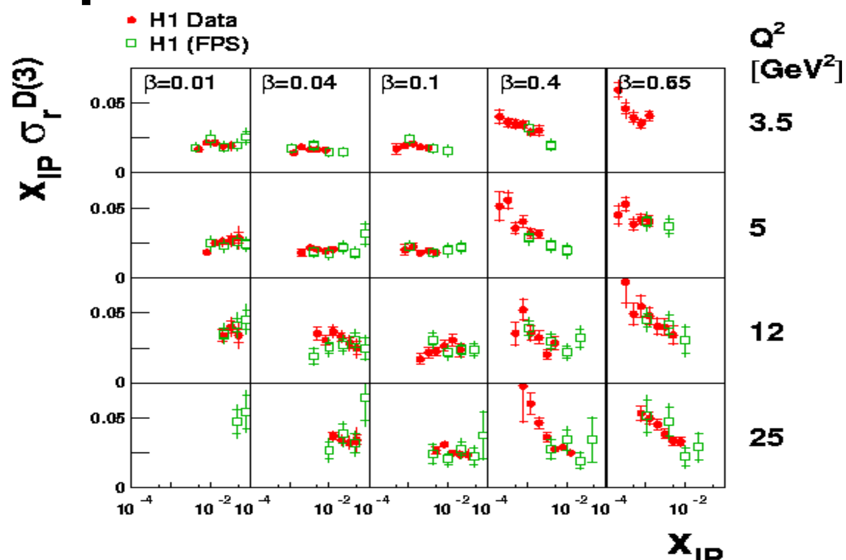
- ZEUS preliminary results
- Diffractive tail at low M_x^2
- Diffractive sample extracted statistically from the total (nondiffr+diffr) DIS sample
- Diffractive sample used for extracting F_2^D

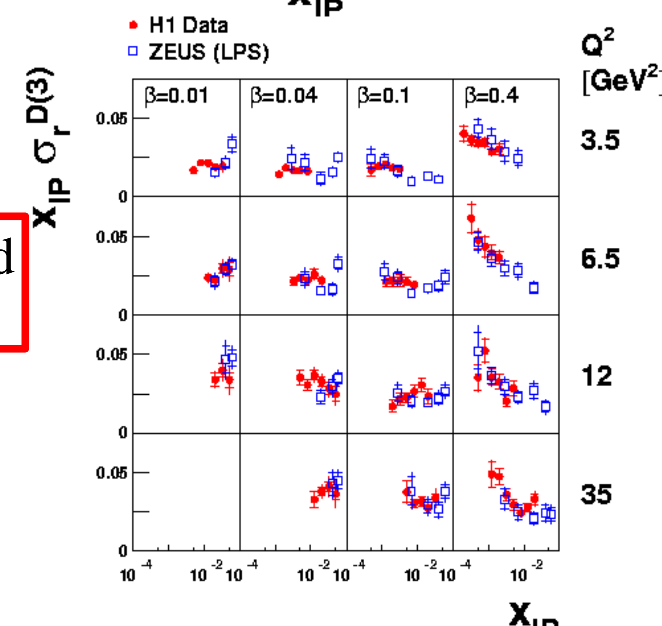
Inclusive diffractive DIS

ep→epX



H1 FPS published
(hep-ex/0606003)





H1 LRG published
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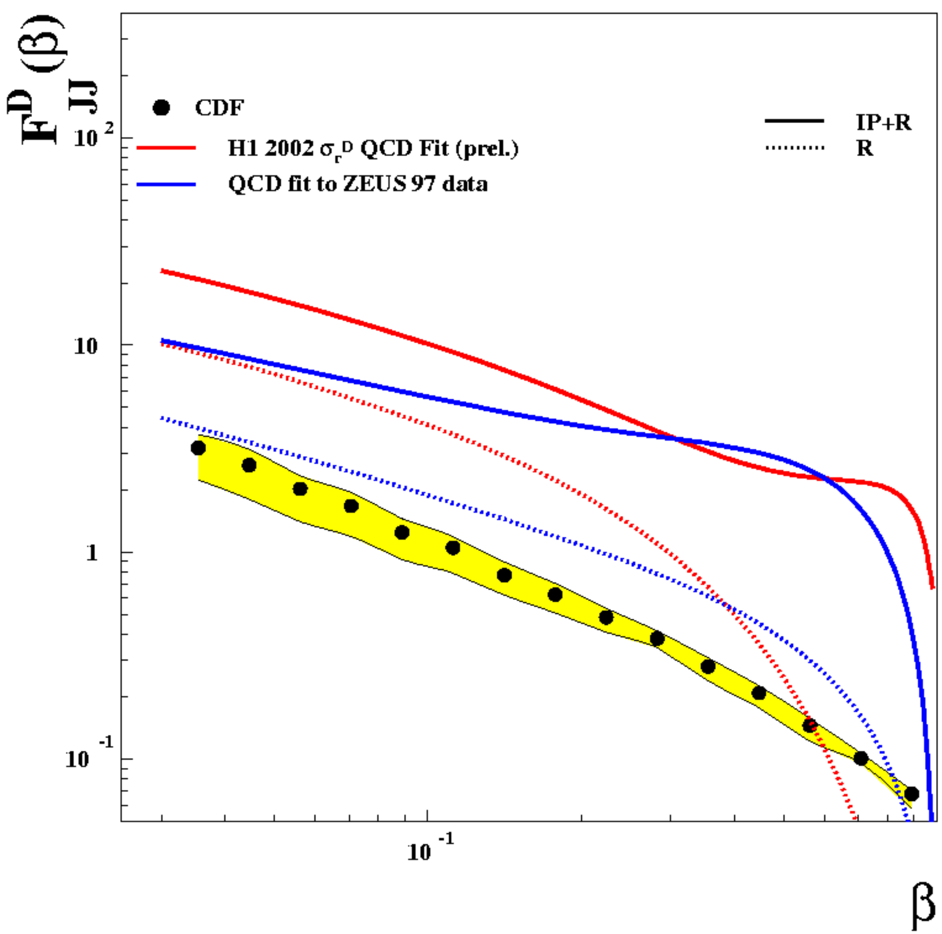
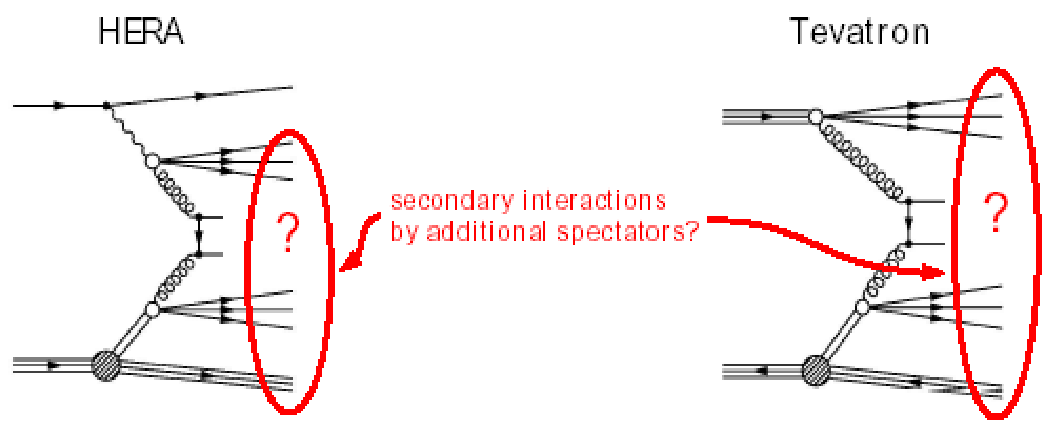
Good agreement btw different selection methods and different experiments

QCD factorisation breaking

Diffractive dijet production at CDF



HERA dPDFs don't work at TeVatron !
Predictions overestimate data.
Most accepted interpretation: secondary interactions.
One can correct for that and restore the agreement theory/data.



At HERA the same thing should be visible in PHP ($Q^2 \approx 0$) when the photon behaves like a hadron (resolved photon).