Factorisation in charm and jet processes in diffractive DIS and γp

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on the behalf of the H1 and ZEUS Collaborations

Diffraction 2008

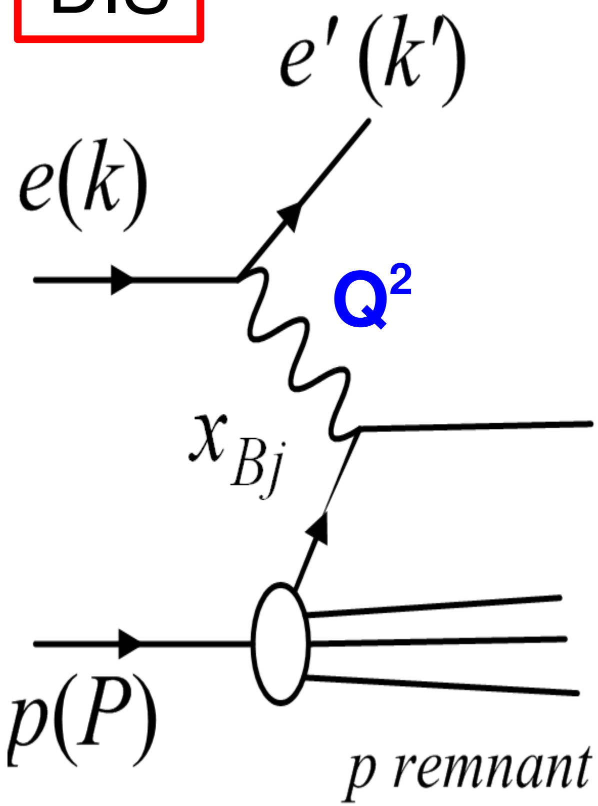
La Londe-les-Maures , 13/09/2008

Outline

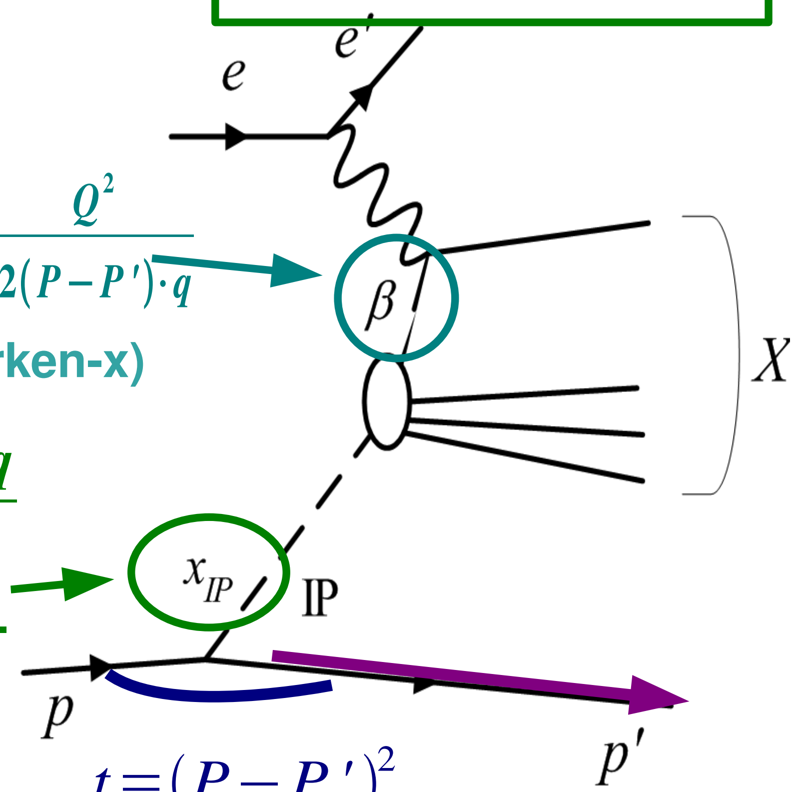
- Introduction
- Testing QCD factorisation in diffraction at HERA:
  - Open charm
  - Dijets
    - studies on the E_T dependence of the Gap Survival Probability (**GSP**)
- Conclusions

$ep \rightarrow epX$ kinematics

DIS



Diffractive DIS



$$z_{IP} \cong \beta = \frac{Q^2}{2(P-P')\cdot q}$$

(~ Bjorken-x)

$$x_{IP} = \frac{(P-P')\cdot q}{P\cdot q}$$

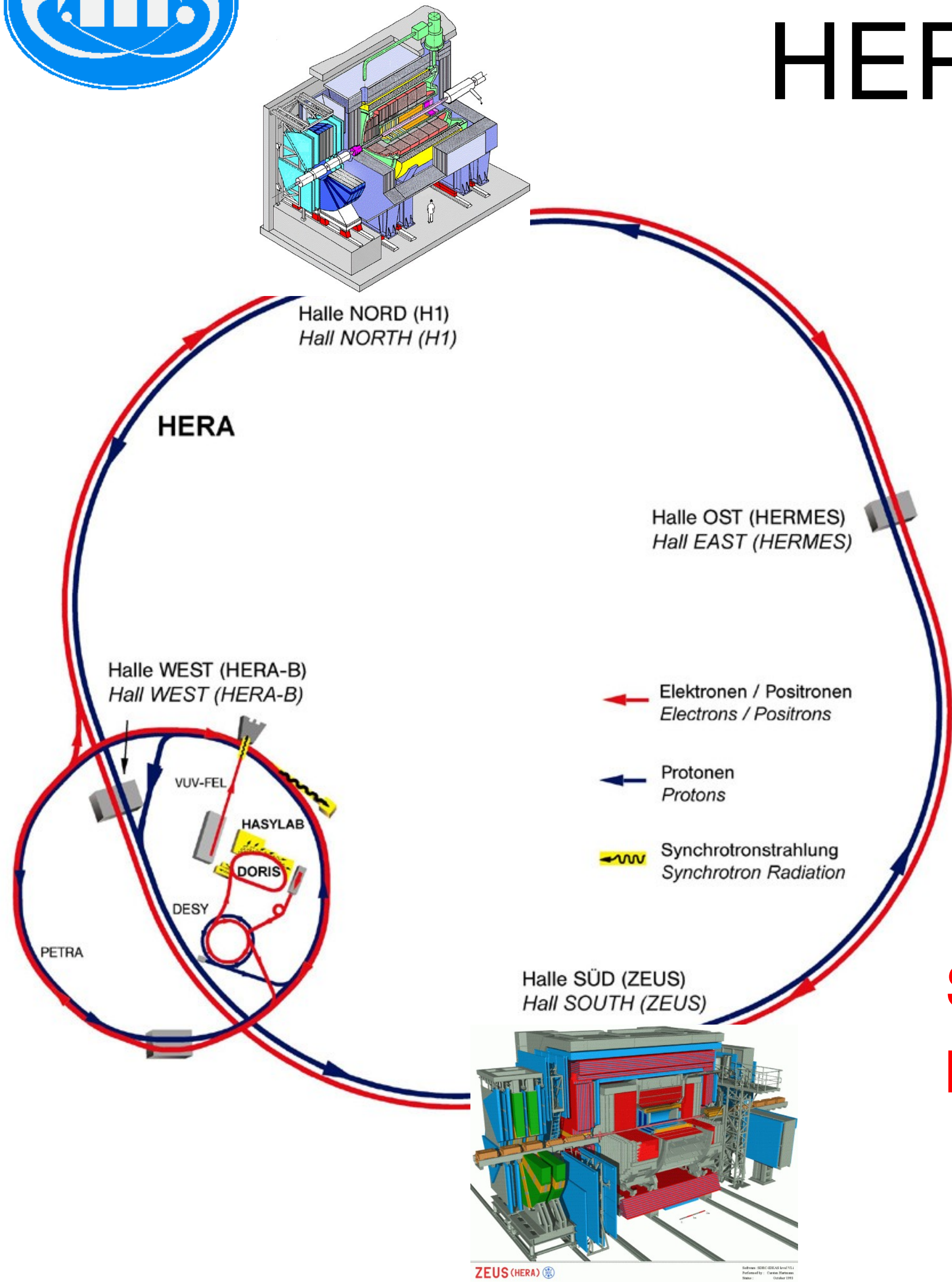
x_{IP} = fraction 4-mom lost by P

$$t = (P-P')^2$$

$$M^2_{P'} \simeq M^2_P$$

$$\frac{d\sigma^D}{d\beta\, dQ^2\, dx_{IP}\, dM_{P'}\, dt} = \frac{2\pi\alpha}{xQ^4}\left[y_+ F_2^D(x_{IP}, M_{P'}, t; \beta, Q^2) + y^2 F_L^D(x_{IP}, M_{P'}, t; \beta, Q^2)\right]$$

HERA



27.5 GeV $e^{+/-}$

820 / 920 GeV p

$\sqrt{s}$ = 308 / 318 GeV

~ 0.75 fb^{-1} delivered !

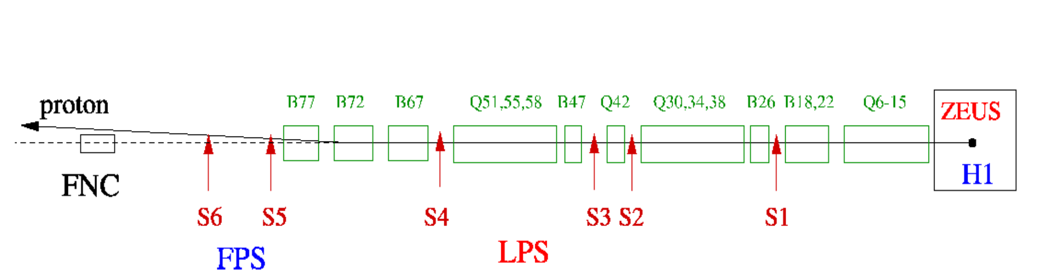
~ 15 pb^{-1} with p @ 460 GeV

~ 10 pb^{-1} with p @ 575 GeV

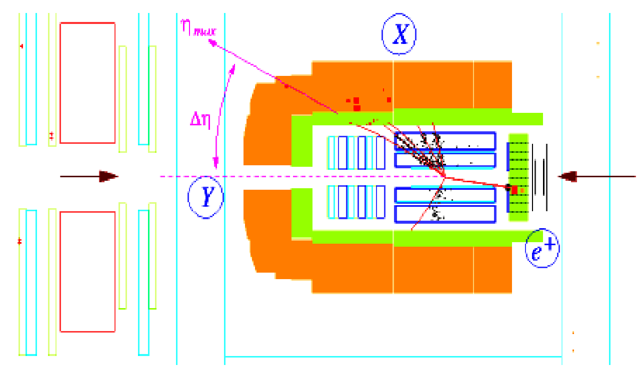
Significant improvement of our knowledge of QCD ! (α_S, F_2, F_L...)

Diffraction at HERA

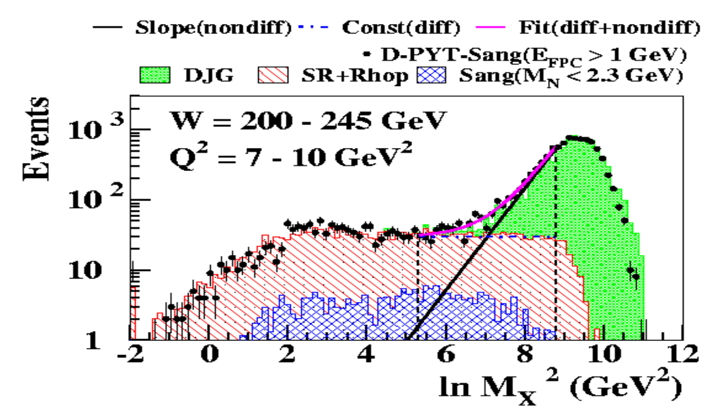
- **Proton Spectrometer**:
  - ZEUS: LPS ; H1: FPS, VFPS
  - Direct tag of scattered p
  - Rich of informations (e.g., t)
  - Low acceptance: statistically limited



- **Large Rapidity Gap**:
  - Exchange of colourless IP: lack of particle flow in p direction
  - High statistics
  - Loss of information about scattered p
  - Contribution from p dissociation



- **M_X method**:
  - Different dependence on Mx of the DDIS and DIS cross section Diffraction at low M_X
  - High statistics
  - No info on p, p dissociation still a problem



QCD factorisation in diffraction

QCD Factorisation theorem

proven for DIS by J.Collins, *Phys.Rev. D57, 3051(1998)*

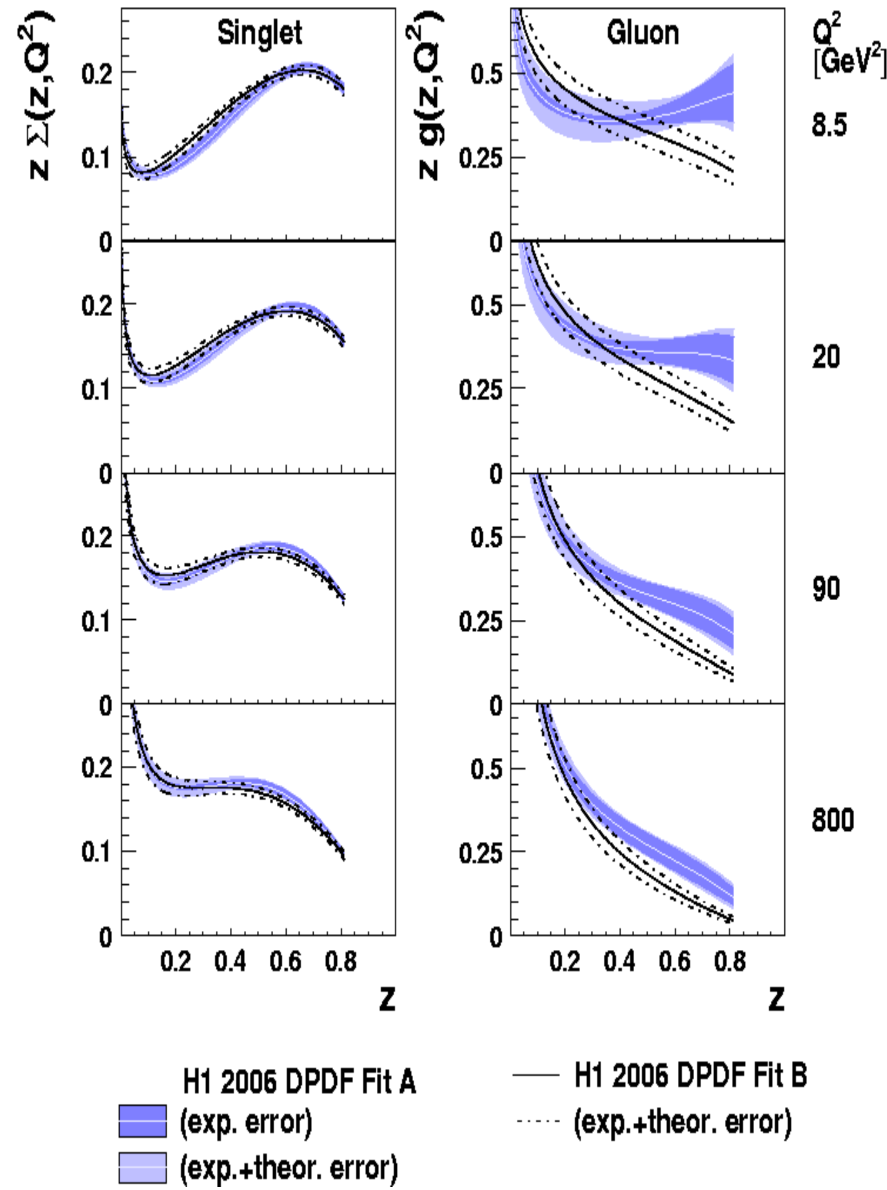
$$\sigma^D(\gamma* p\rightarrow Xp)\simeq \sum_{i=q,g} \hat{\sigma}\otimes f_i^D(t, x_{IP}, \beta, Q^2)$$

Hard subprocess ME

pQCD calculable

Diffractive PDFs

defined as the std PDFs + diffractive requirement



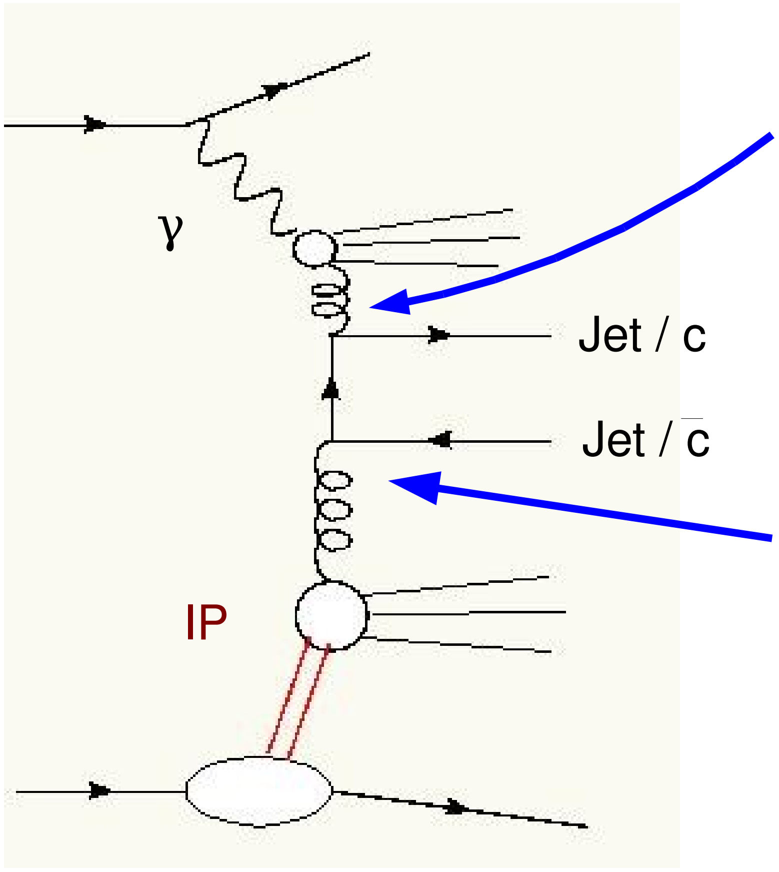
DPDFs extracted via DGLAP fit from inclusive DDIS

Direct sensitivity (good precision) to quark singlet, fits generally in agreement.
Larger uncertainties on the gluon density, especially at high β. Predictions guaranteed only up to β~0.8

Use DPDFs extracted from inclusive DDIS for calculating NLO predictions to semi-inclusive final states.

Using open charm and dijets:

- Direct sensitivity to gluons (main content of diffractive exchange)
- Hard scale in the process (use of pQCD, QCD-factorisation theorem)



x_γ = fraction of momentum of γ in the hard process.

Direct γ: all momentum contributes , i.e. $x_\gamma \simeq 1$

Resolved γ: parton carrying a fraction of momentum of γ interacts with the IP, i.e. $x_\gamma < 1$

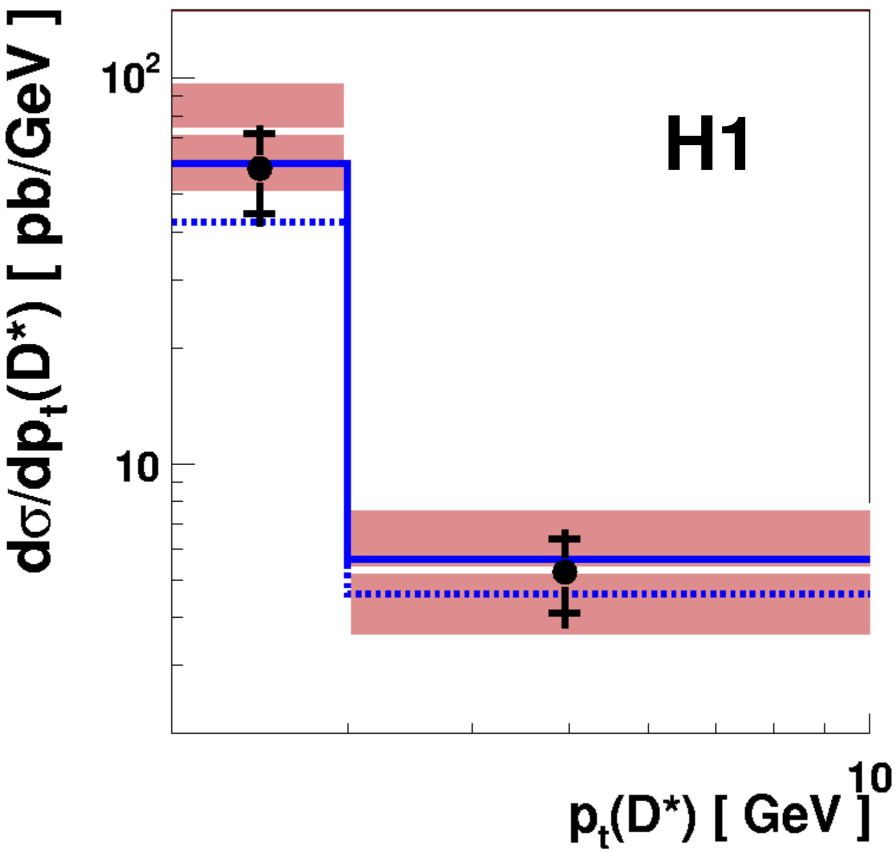
DIS dominated by direct γ

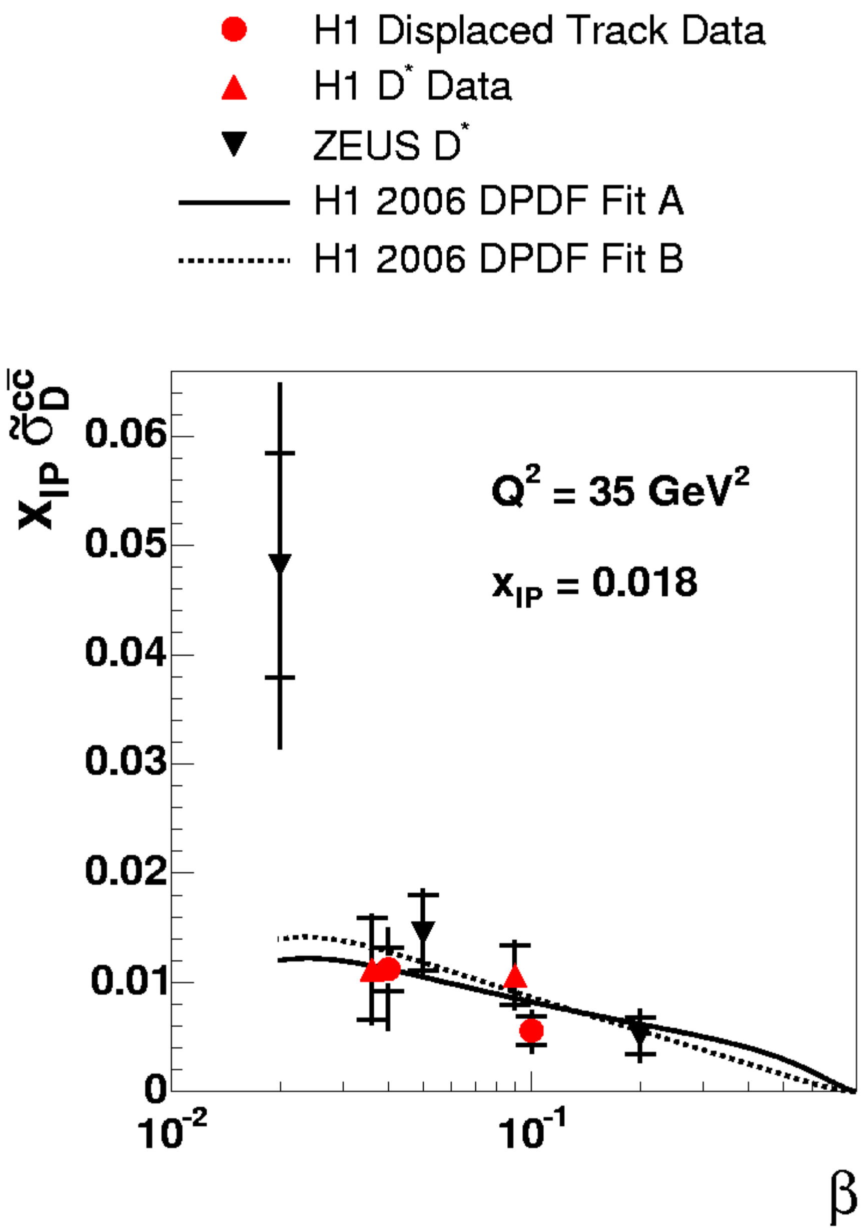
z_{IP} = fraction of momentum of IP in the hard process.

Replaces β in dijets/open charm case.

Variable sensitive to the DPDFs !

D* in DDIS



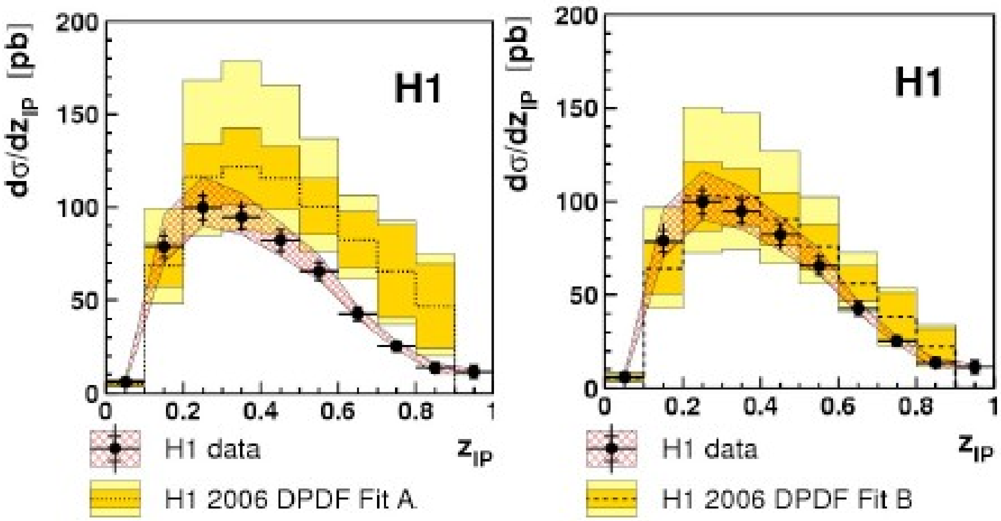


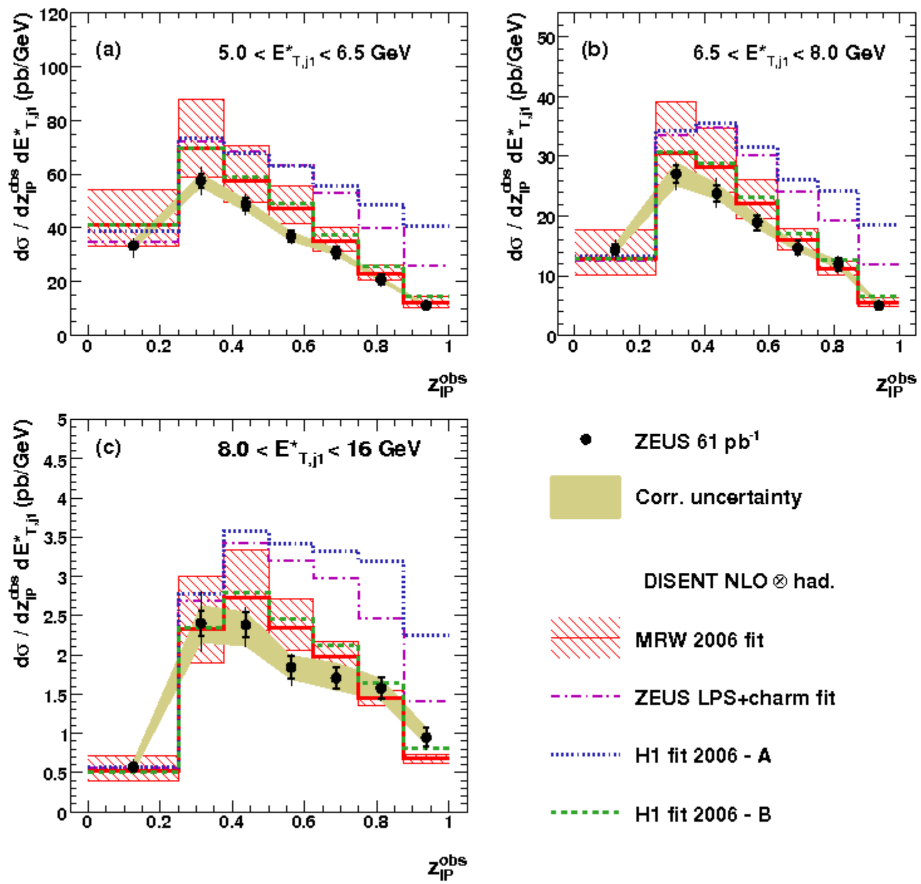
NLO describes data.

Very large theoretical uncertainties.

Different measurements in good agreement.

Dijets in DDIS





z_{IP} is the most sensitive variable to the DPDFs.

Both H1 and ZEUS in agreement with NLO calculations. Best agreement obtained with H1-fitB and MRW2006 fit.

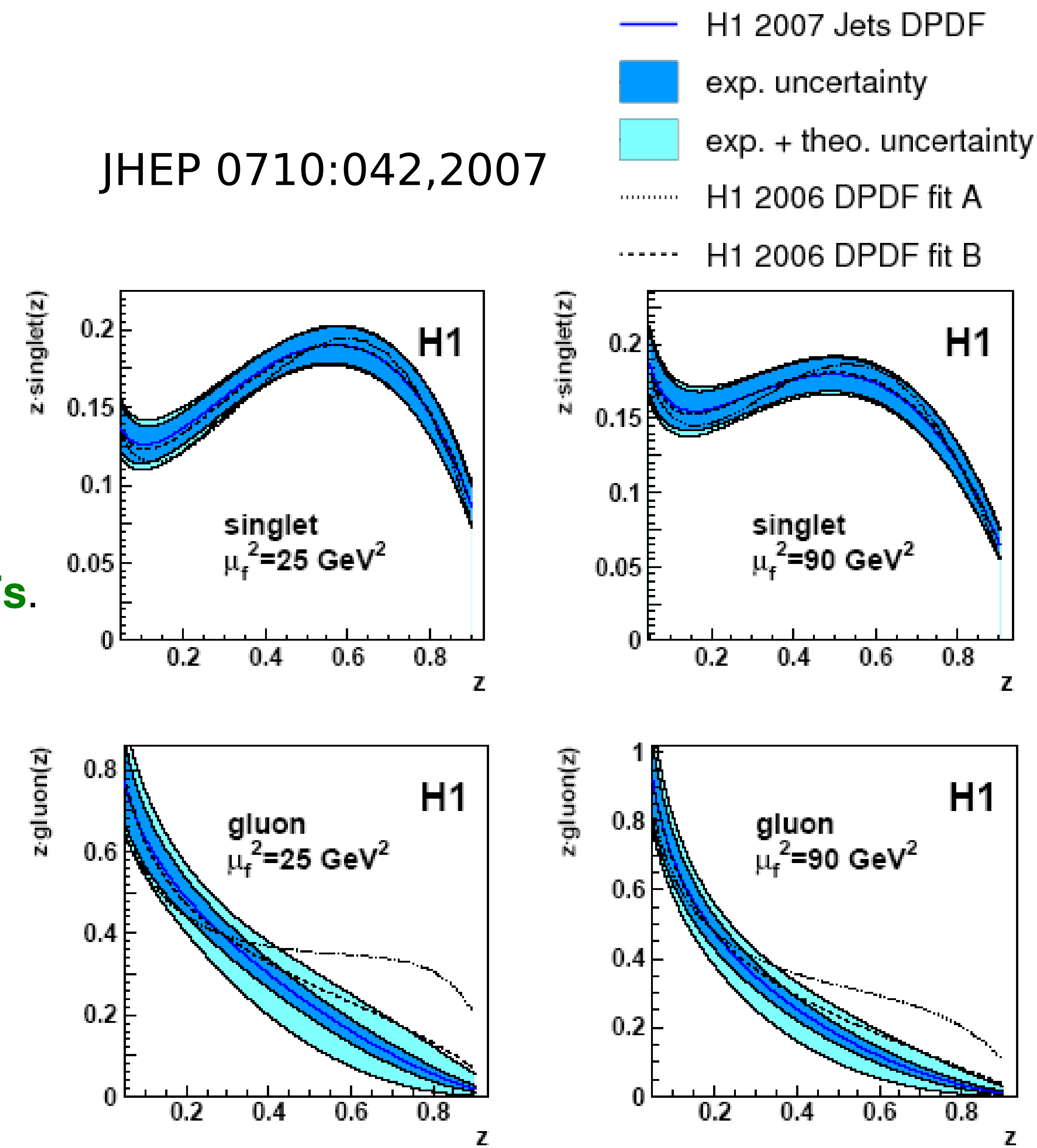
Message from H1 and ZEUS: Factorisation holds in DDIS !

H1-Jets fit to DPDFs

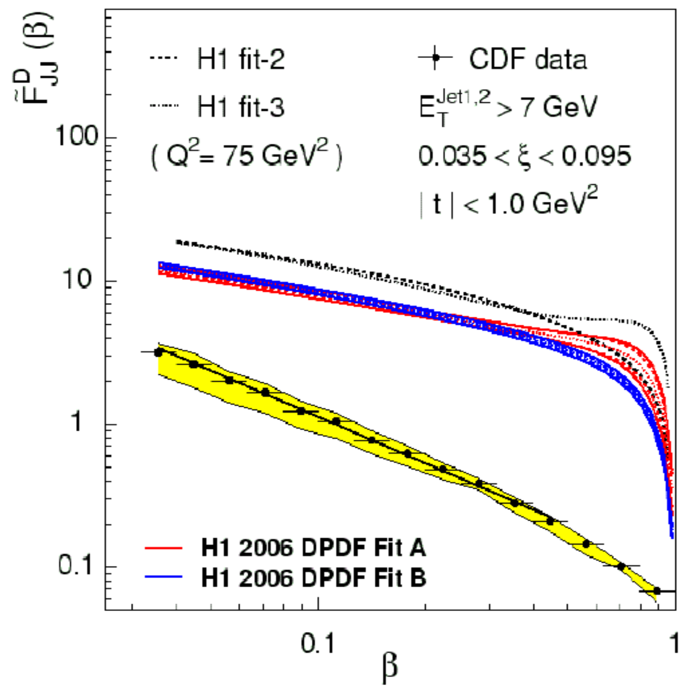
Inclusive diffractive DIS has not direct sensitivity to gluon content of diffractive exchange.
Jet production mechanism has it:
extending precision and range of validity of gluonic densities by including DDIS jets in the fit to DPDFs.

As expected, large differences in gluon densities at high β.

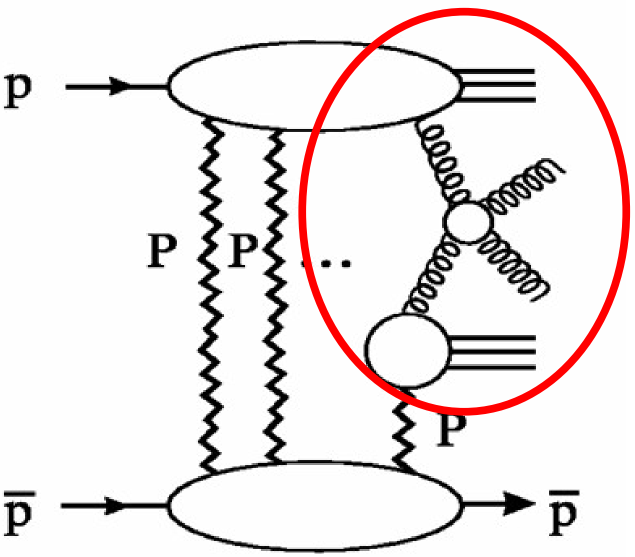
JHEP 0710:042,2007



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



Diffractive dijet measurement by CDF.
Comparison with NLO prediction using as input dPDFs extracted at HERA .
Significant overestimation by NLO of the data.
The HERA DPDFs cannot be used directly at TeVatron.



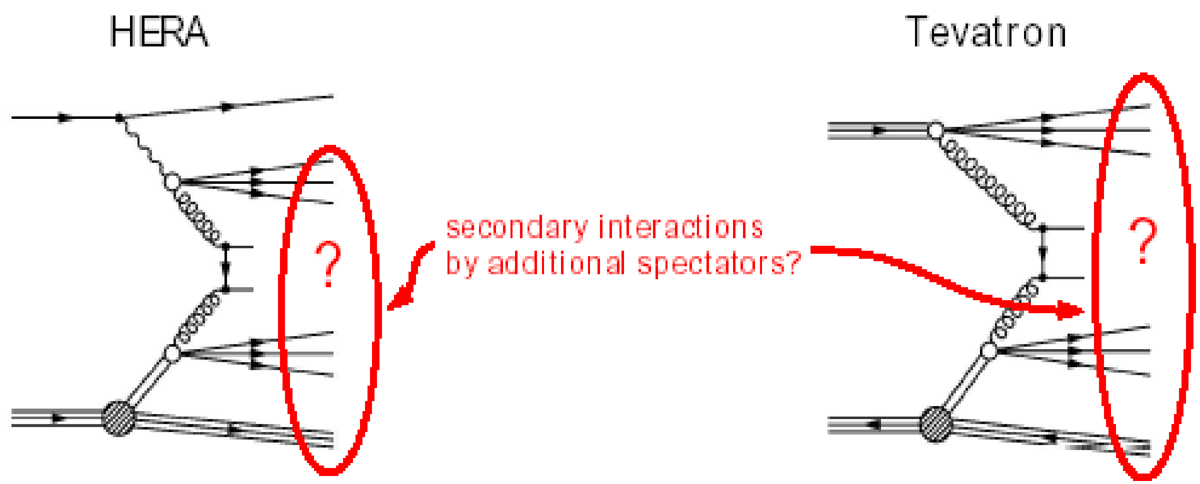
Secondary interactions between spectator partons spoil the LRG, no diffractive tag anymore.
Models are able to describe the suppression observed at TeVatron (Kaidalov, Khoze, Martin, Ryskin...).

Test of factorisation in diffractive γp

At HERA we have something similar to a hadron:

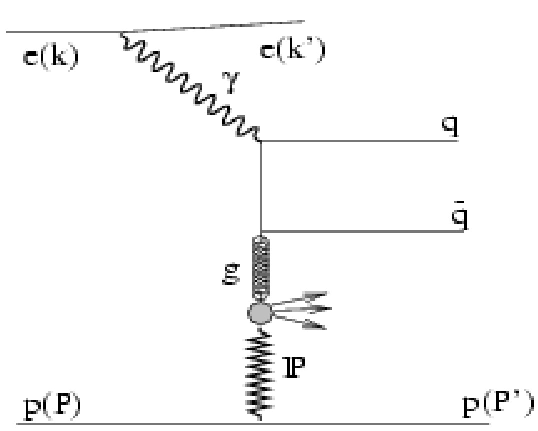
photoproduction (γ**P**) photon ($Q^2 \sim 0$).

Low Q^2 γ fluctuates in $q\,\bar{q}$ pairs and behave ~ vector meson

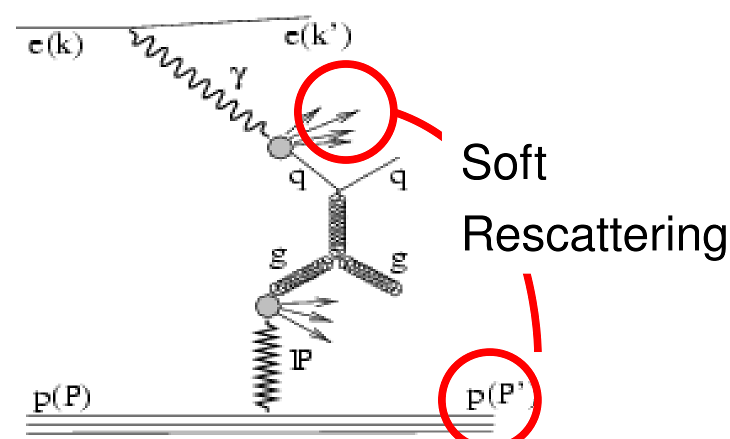


Direct γ^* (small y^*) couples directly to parton (DIS and part of γp). QCD factorisation is expected to hold.

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

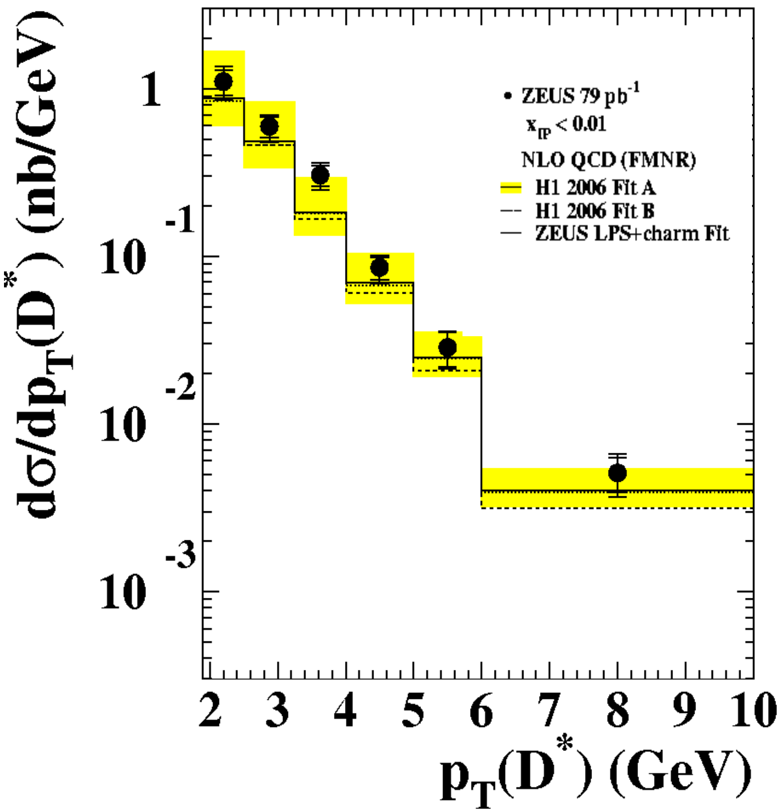


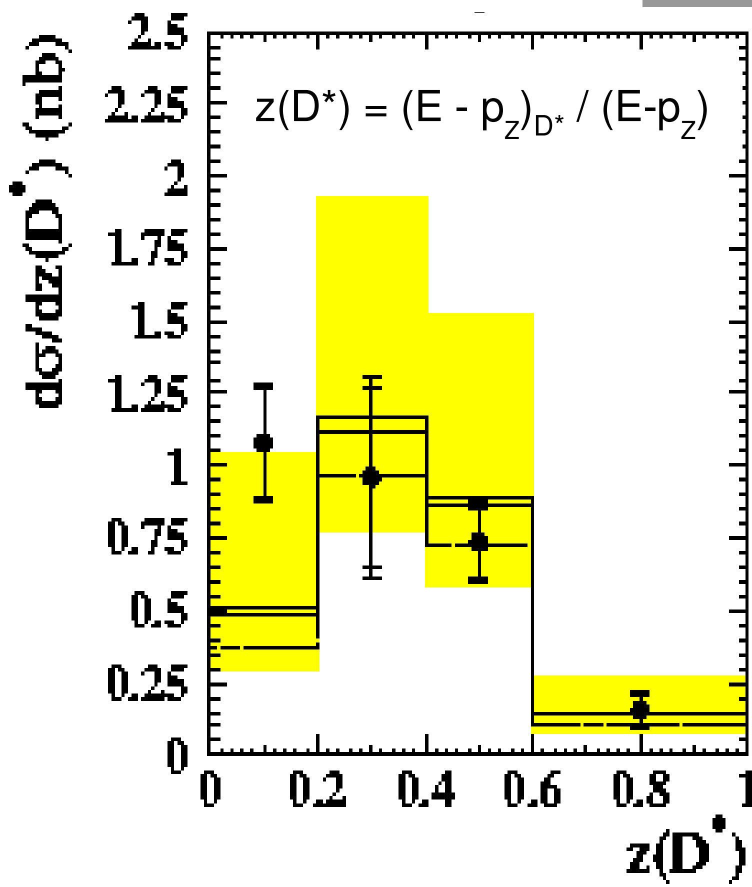
(a)



(b)

D* in Diffractive γp





Satisfactory agreement DATA vs NLO.

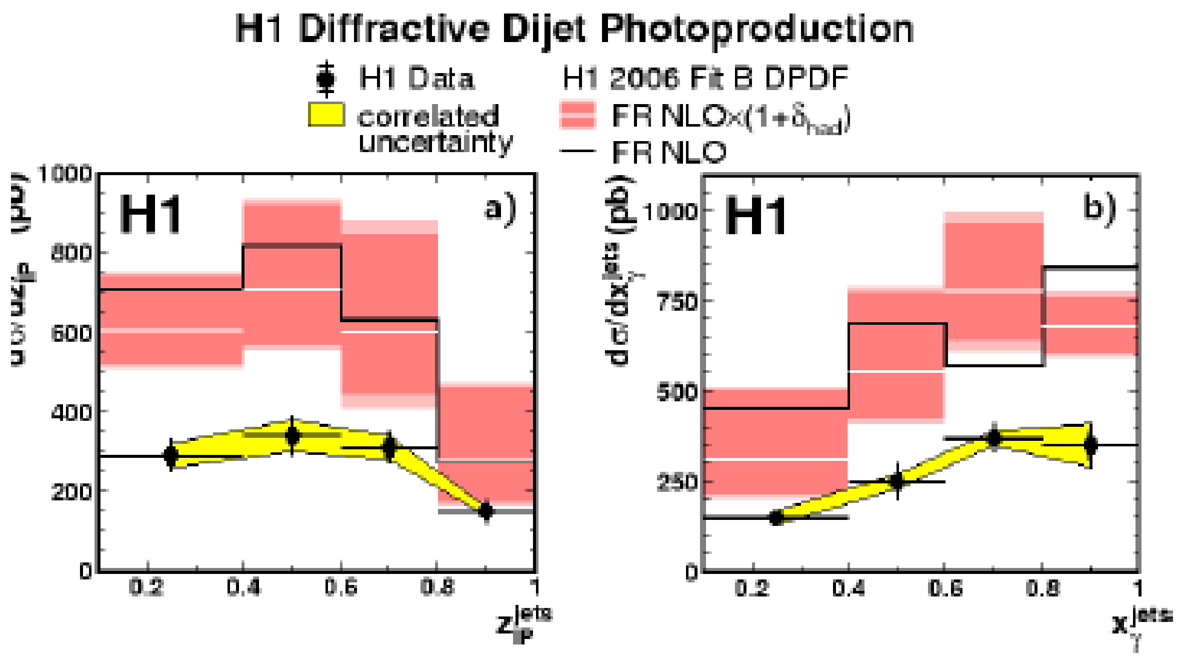
Data compatible with factorisation within uncertainties.

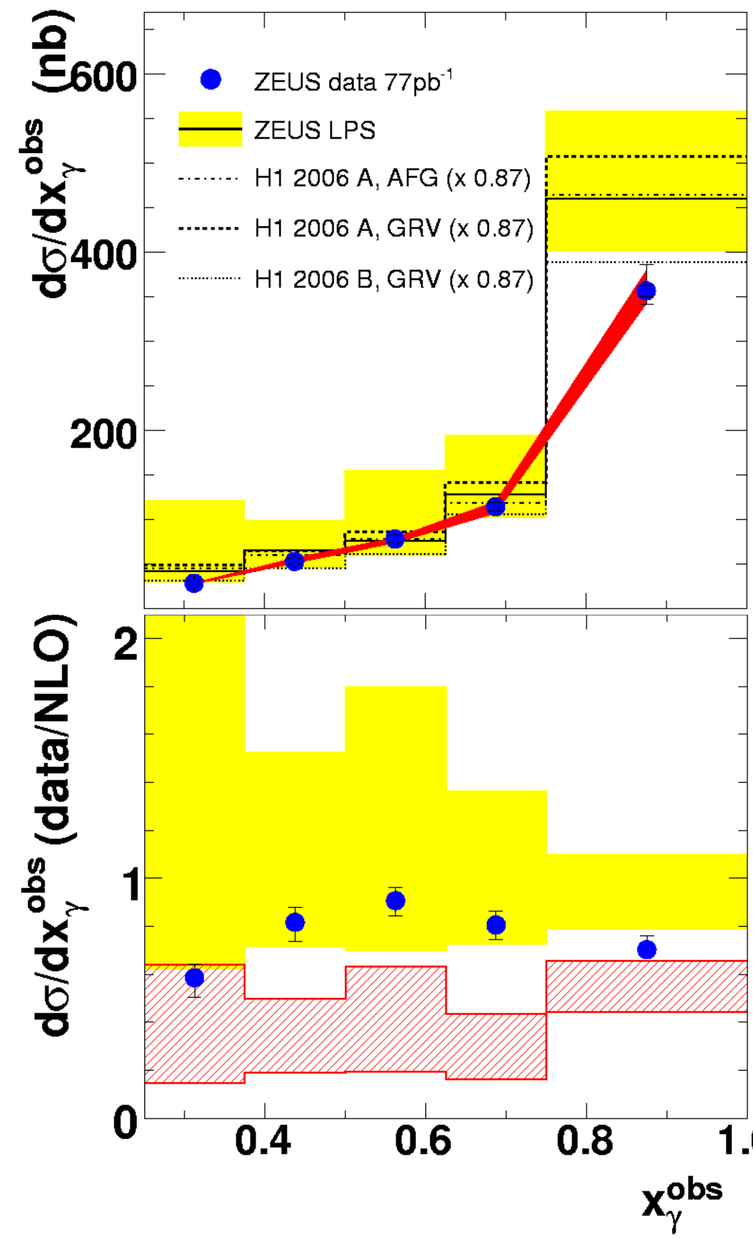
But:

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

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

Dijets in Diffractive γp





$\mathbf{x_\gamma}$ = fraction of initial γ mom taken by the dijets

$x_\gamma \sim 1$ direct enhanced

$x_\gamma << 1$ resolved enhanced

H1: suppression ~ 0.5

ZEUS: weak (if any) suppression

Both : no dependence of GSP on x_γ

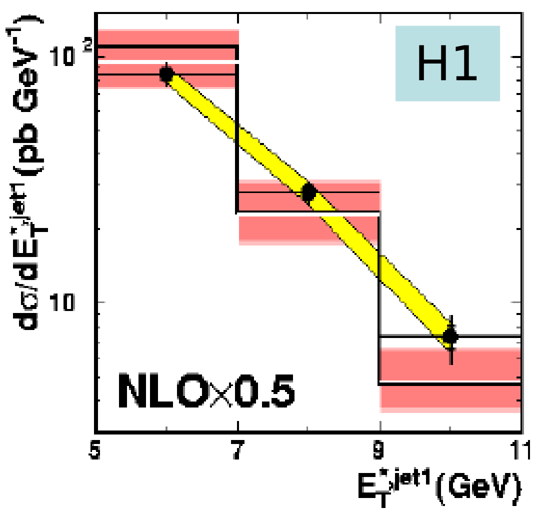
E_T dependence ?

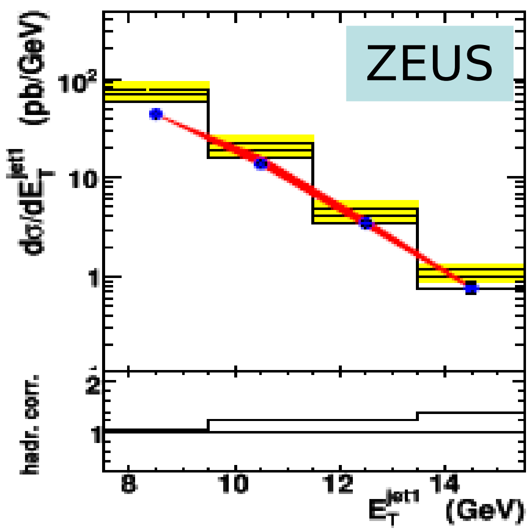
Investigating the differences between H1 and ZEUS results.

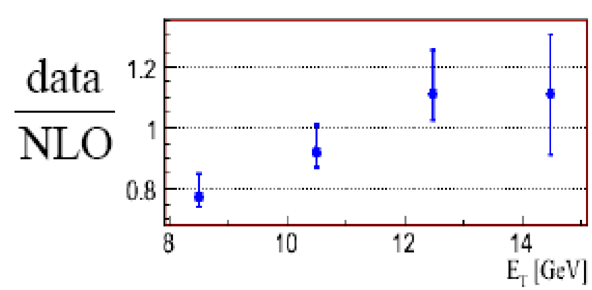
H1: $E_{T,j1} > 5$ GeV, $E_{T,j2} > 4$ GeV, $0.3 < y < 0.65$

ZEUS: $E_{T,j1} > 7.5$ GeV, $E_{T,j2} > 6.5$ GeV, $0.2 < y < 0.85$

Can it be due to different kinematic regions ?





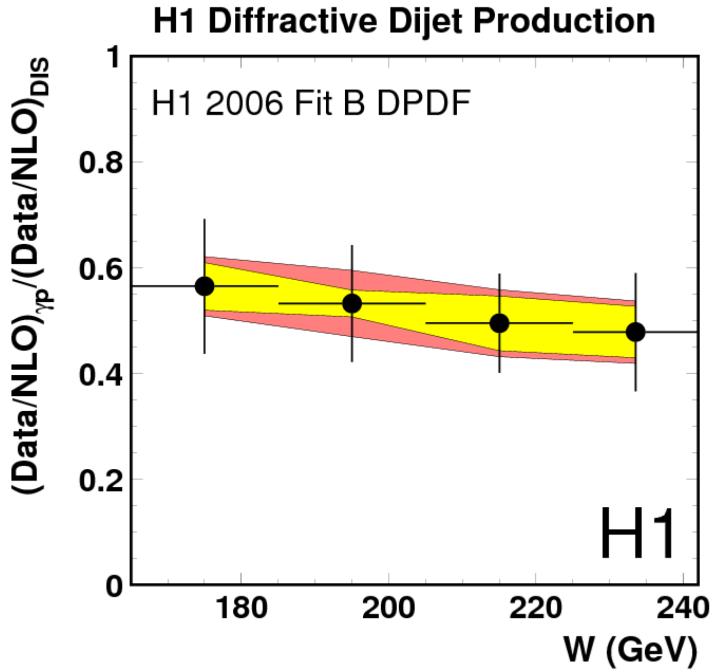


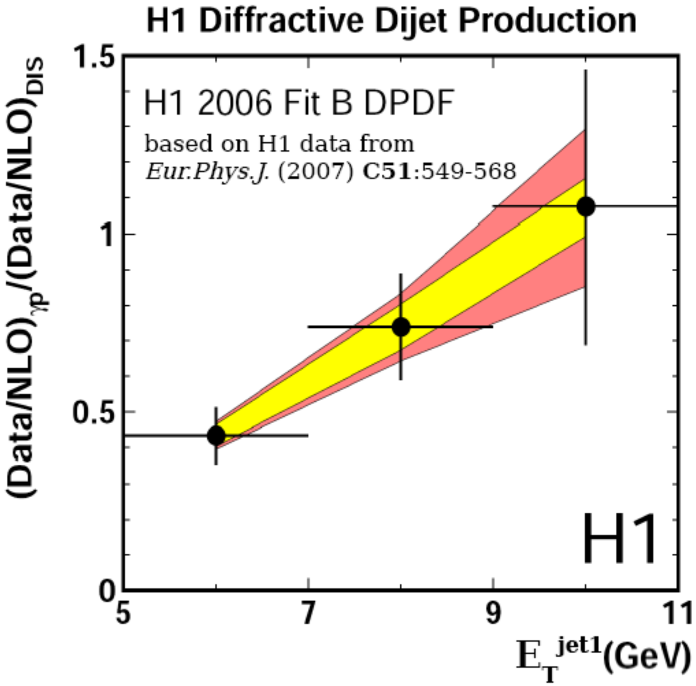
H1 and ZEUS observe that the data have a harder E_T slope than NLO

Double Ratio = $\frac{(\text{DATA / NLO})_{\gamma P}}{(\text{DATA / NLO})_{DIS}}$

Several uncertainties cancel out!

Powerful tool for spotting trends and features.





No evident W dependence.

Evidence for a dependence on E_T !!!

New H1 study of dijets in γp

Based on 1999/2000 data, **luminosity x3** respect to old analysis with 1997 data

Photoproduction tagged directly, diffraction tagged with the **LRG method**.

Two different kinematic regions:

Low E_T scenario

(cross check to old H1 analysis)

$E_T^{jet1} > 5$ GeV

$E_T^{jet2} > 4$ GeV

$-1 < \eta^{(jet\ 1\ and\ 2)} < 2$

$x_{IP} < 0.03$

as previous H1 analysis:

$0.3 < y_e < 0.65$

$Q^2 < 0.01$ GeV^2

$|t| < 1$ GeV^2

$M_Y < 1.6$ GeV

High E_T scenario

(similar to ZEUS kinematic region)

$E_T^{jet1} > 7.5$ GeV

$E_T^{jet2} > 6.5$ GeV

$-1.5 < \eta^{(jet\ 1\ and\ 2)} < 1.5$

$x_{IP} < 0.025$

different from ZEUS:

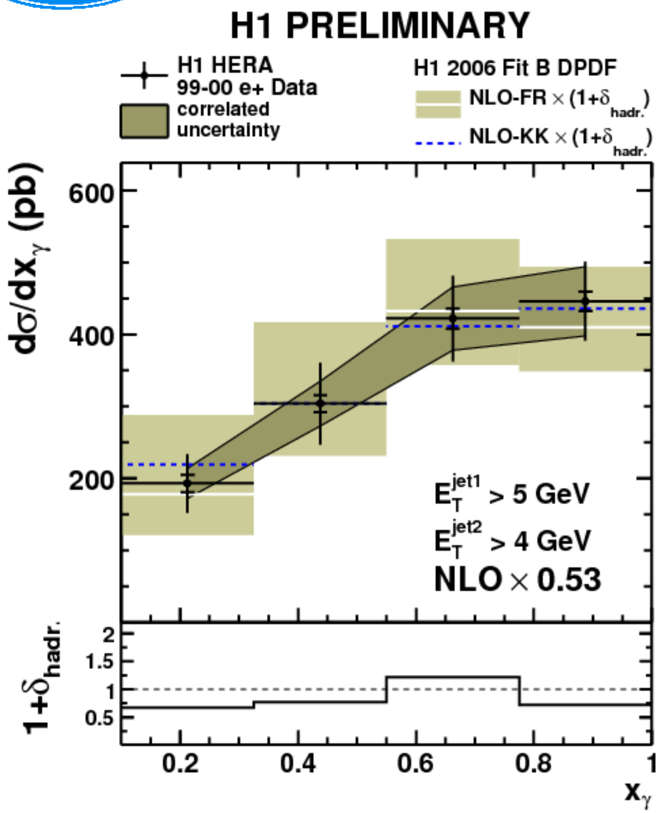
$0.3 < y_e < 0.65$ … $0.2 < y_{JB} < 0.85$ ZEUS

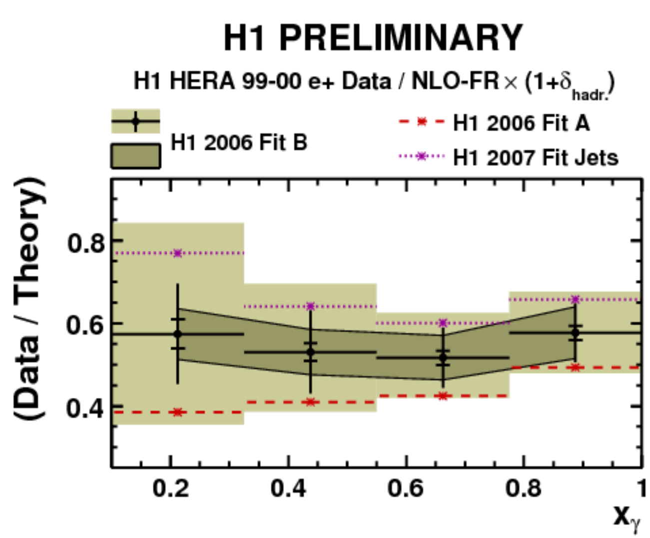
$Q^2 < 0.01$ GeV^2… $Q^2 < 1$ GeV^2

$|t| < 1$ GeV^2

$M_Y < 1.6$ GeV

Low E_T scenario





$E_{T,j1}$ > 5 GeV, $E_{T,j2}$>4 GeV

Measurement compared to two independent NLO calculations: Frixione-Ridolfi and Klasen-Kramer.

No x_γ dependence of Gap Survival Probability.

$E_{T,j1}$ > 5 GeV, $E_{T,j2}$> 4 GeV

Another hint of an E_T spectrum harder in data than in MC.

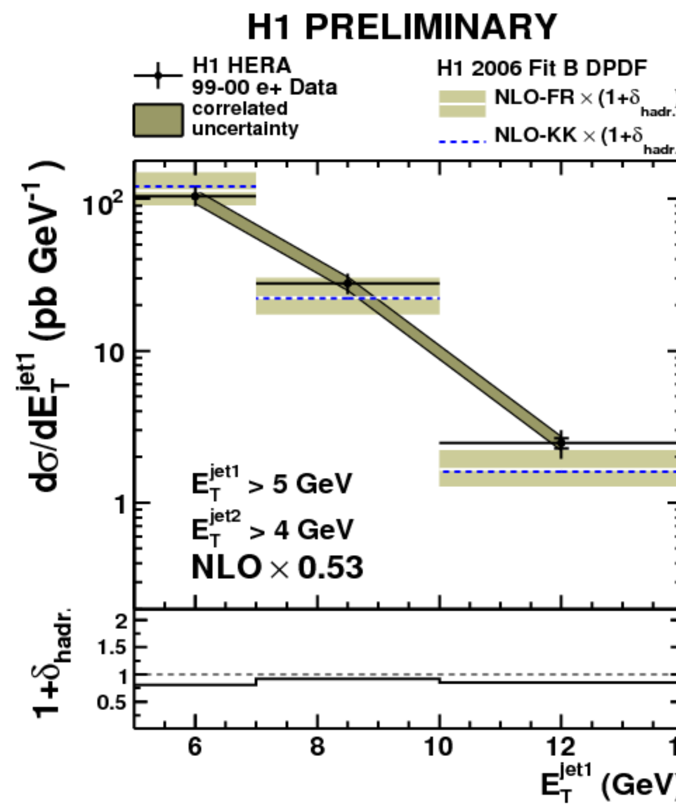
Integrated Survival Probabilities
0.43 – 0.65 (depending on the DPDFs used, always compatible one with each other within unc.)

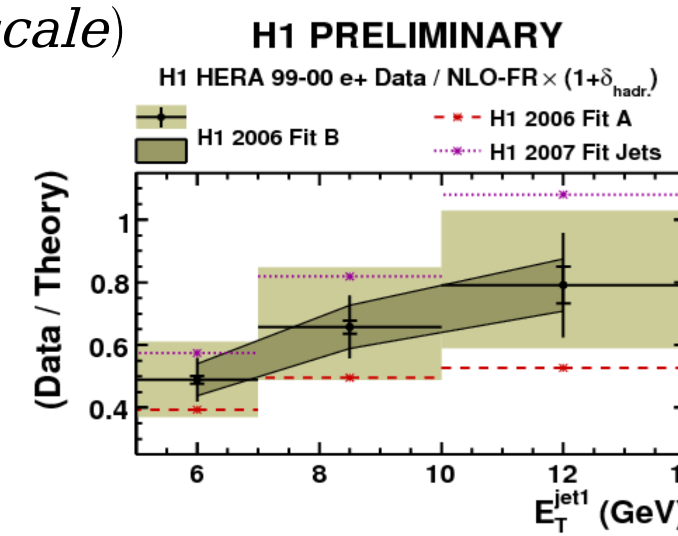
$$ISP^{FR}_{fitB} = 0.54 \pm 0.01(stat.) \pm 0.10(syst.)\,^{+0.14}_{-0.13}(scale)$$

$$ISP^{KK}_{fitB} = 0.51 \pm 0.01(stat.) \pm 0.10(syst.)$$

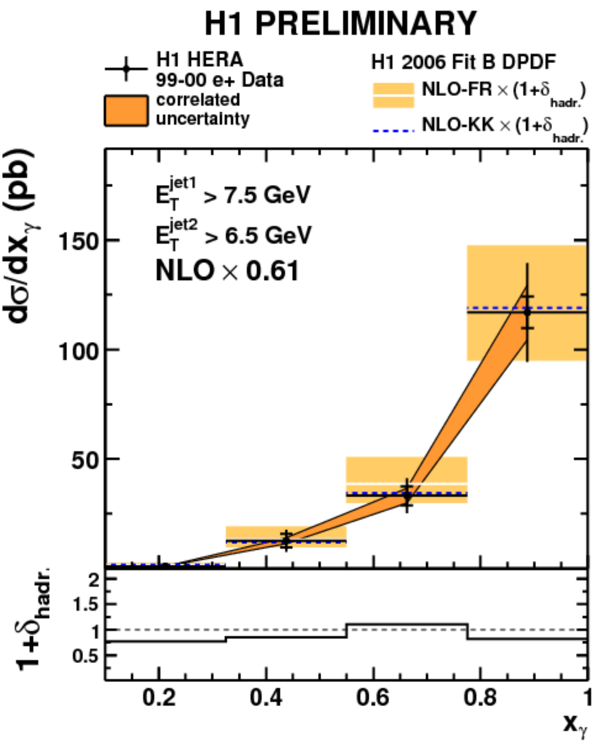
$$ISP^{FR}_{fitA} = 0.43 \pm 0.01(stat.) \pm 0.10(syst.)$$

$$ISP^{FR}_{fitJets} = 0.65 \pm 0.01(stat.) \pm 0.11(syst.)$$



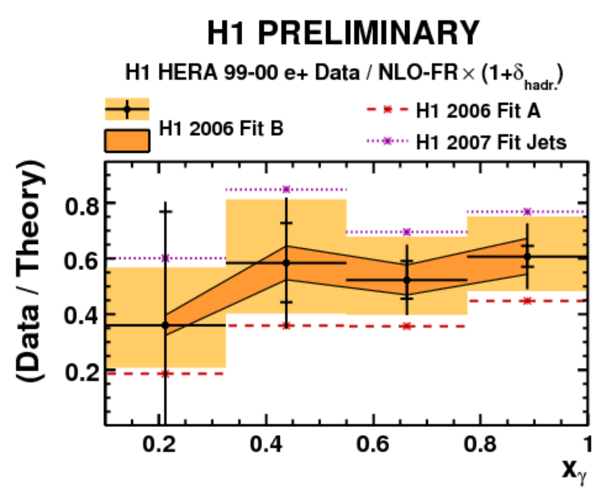


High E_T Scenario



$E_{T,j1}$ > 7.5 GeV, $E_{T,j2}$> 6.5 GeV

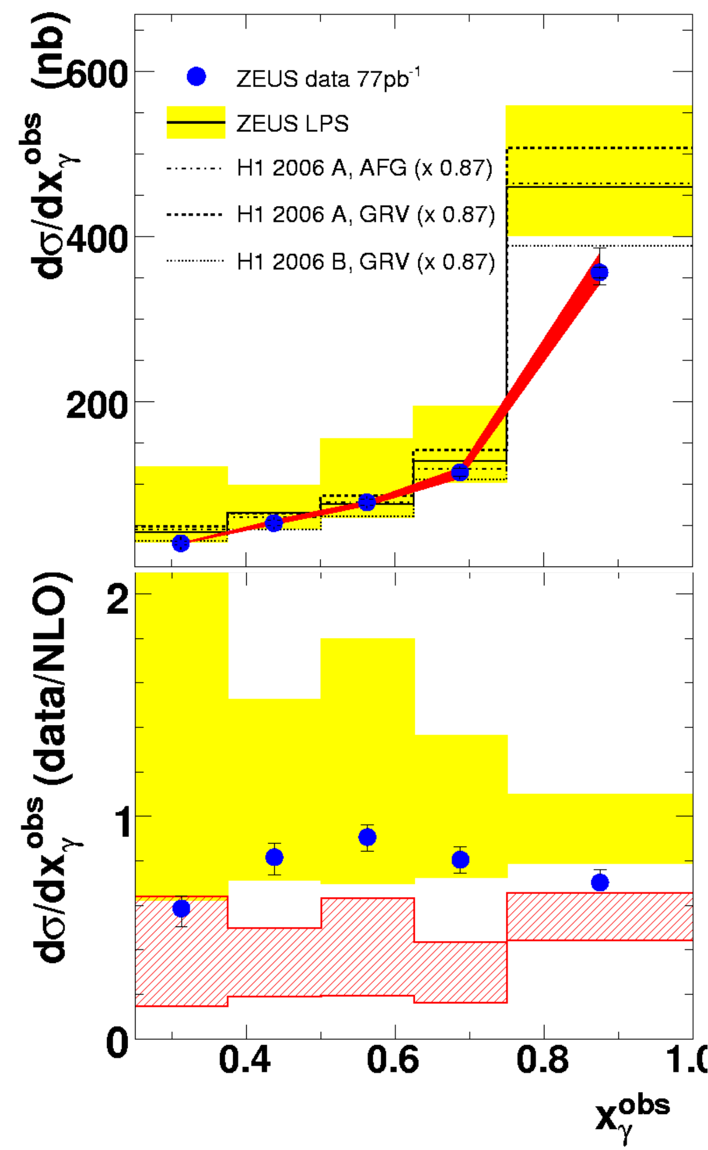
Higher E_T cut selects more direct-like events (appearance of a peak at high x_γ).



No x_γ dependence of the suppression.

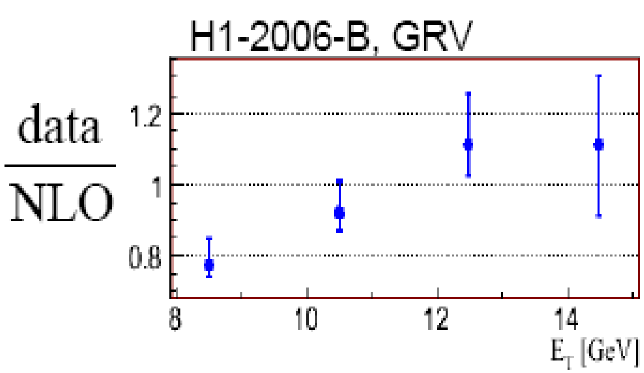
ISP slightly higher than in low E_T .

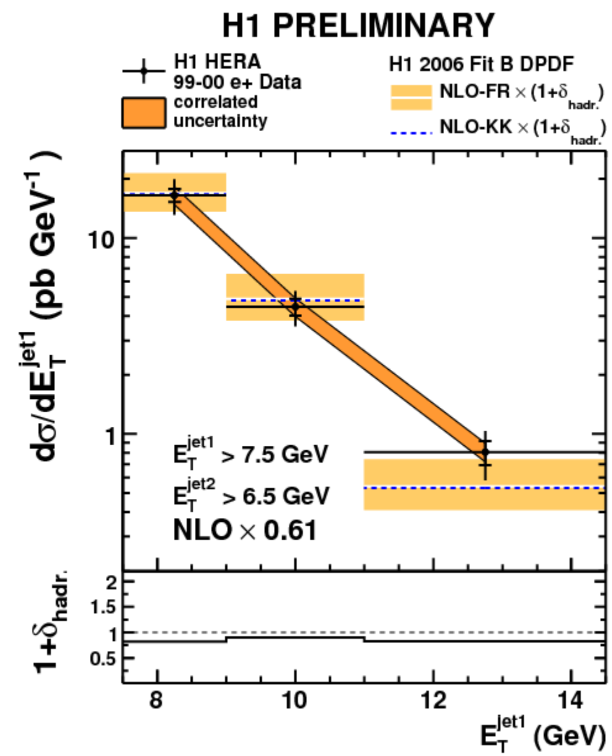
$$ISP^{FR}_{fitB} = 0.61 \pm 0.03(stat.) \pm 0.13(syst.)\,^{+0.16}_{-0.14}$$
$$ISP^{KK}_{fitB} = 0.62 \pm 0.03(stat.) \pm 0.14(syst.)$$
$$ISP^{FR}_{fitA} = 0.44 \pm 0.02(stat.) \pm 0.16(syst.)$$
$$ISP^{FR}_{fitJets} = 0.79 \pm 0.04(stat.) \pm 0.09(syst.)$$

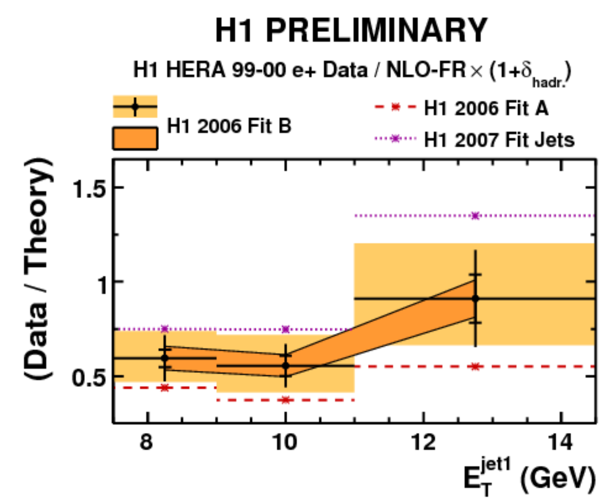


$E_{T,j1}$ > 7.5 GeV, $E_{T,j2}$> 6.5 GeV

No independent test of an E_T dependence, but values move in the direction of ZEUS results.





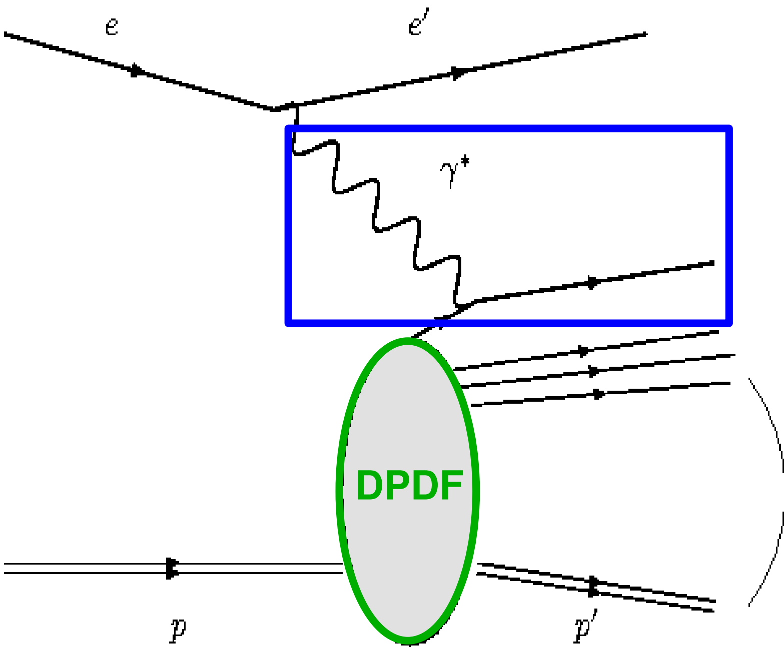


Summary

- **DDIS data from HERA confirm validity of QCD factorisation in diffraction.** Dijets in γp: results from H1 and ZEUS in tension?
- New H1 analysis on dijets in diffractive γp. Confirms previous H1 results, Gap Survival Probability ~ 0.5
- If kinematical range similar to ZEUS: increased compatibility between the two (GSP~0.6).
  - Hints of a dependence on E_T of the GSP.
  - Confirmation that no x_γ dependence of the GSP is observed.
  - Main limitation: systematics, theoretical predictions in particular.
- **Important for LHC predictions**: CEP of SM-Higgs, SUSY, dijets...

Backup slides

QCD factorisation in diffraction



Hard subprocess

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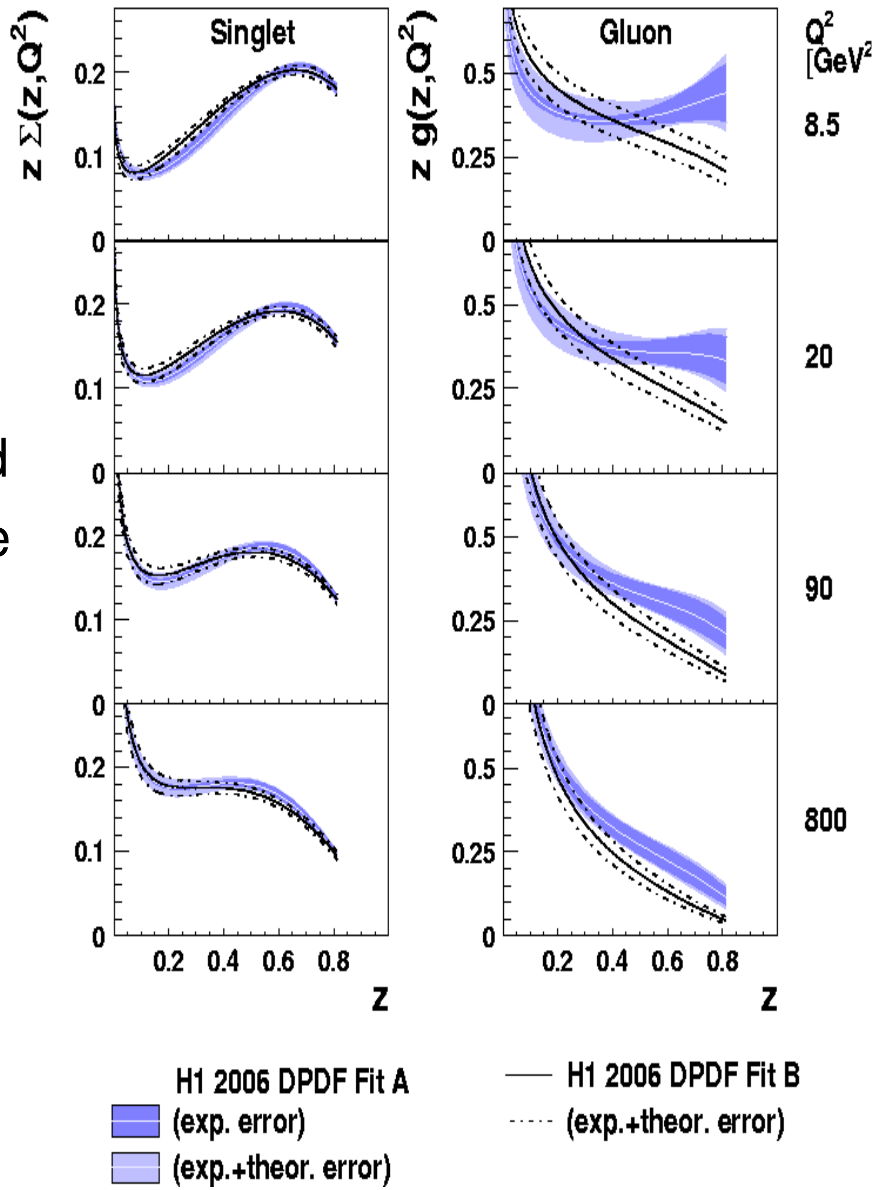

DPDFs extracted via DGLAP fit from inclusive DDIS

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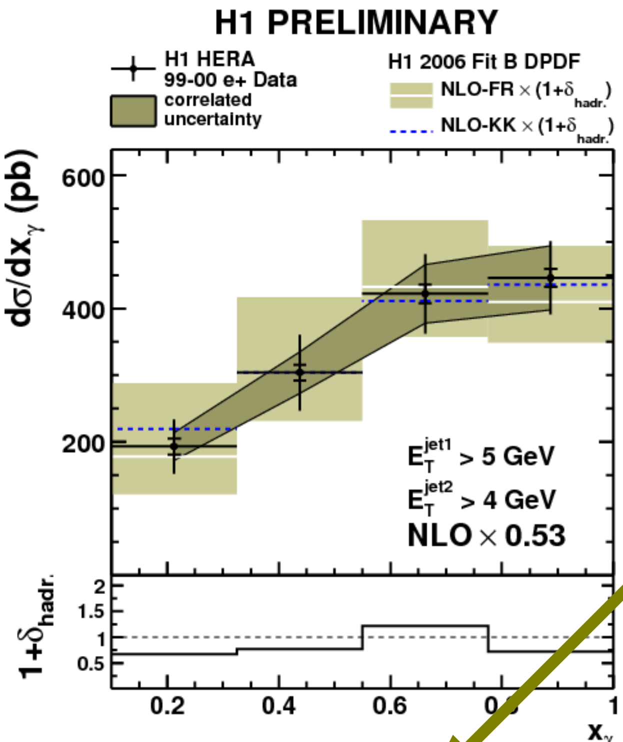
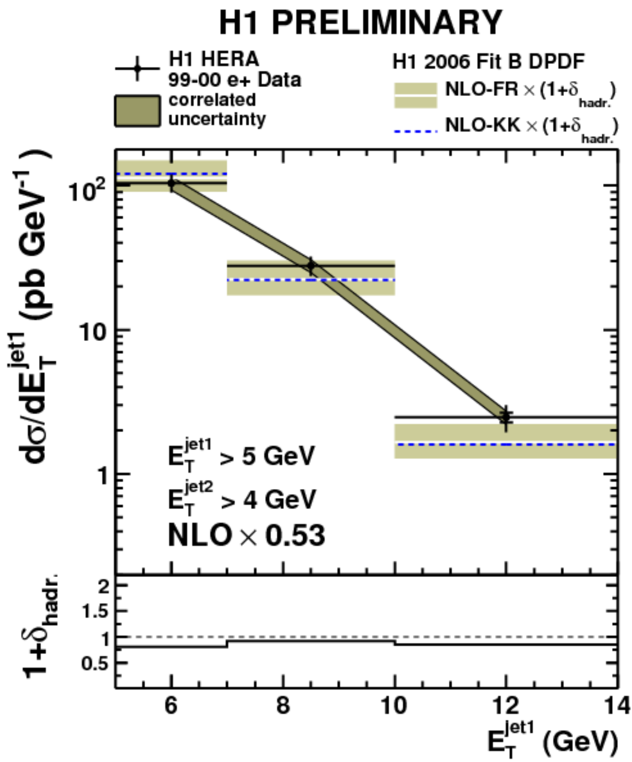
Larger uncertainties on the gluon density, especially at high β. Predictions guaranteed only up to β~0.8

Low E_T scenario



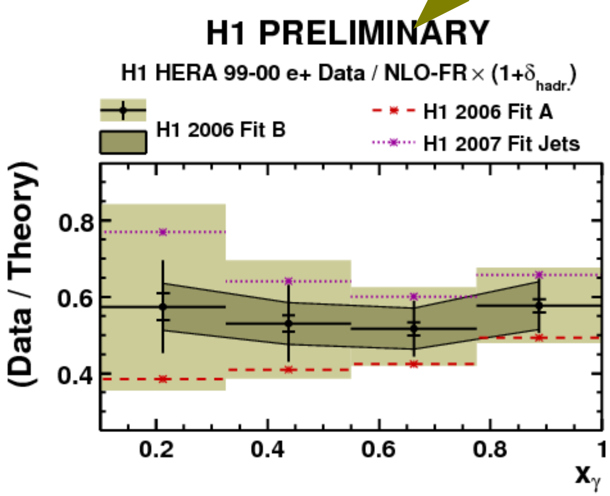


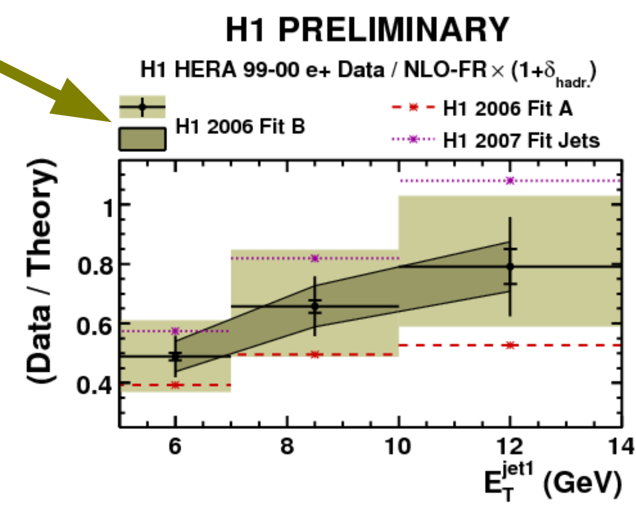
Measurement compared to two independent NLO calculations: Frixione-Ridolfi and Klasen-Kramer.

No x_γ dependence of rapidity gap survival probability.

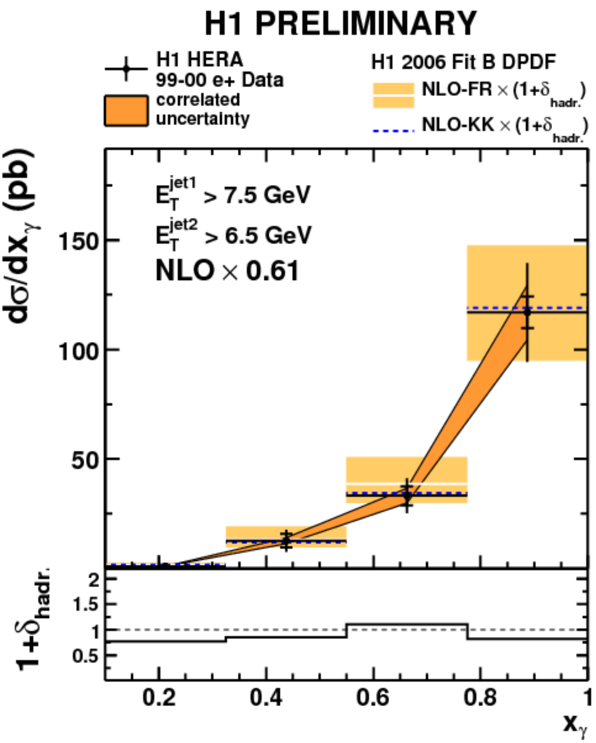
Another hint of an E_T spectrum harder in data than in MC.

Integrated Survival Probabilities 0.43 – 0.65 (depending on the DPDFs used, always compatible one with each other within theor. unc.)





High E_T Scenario



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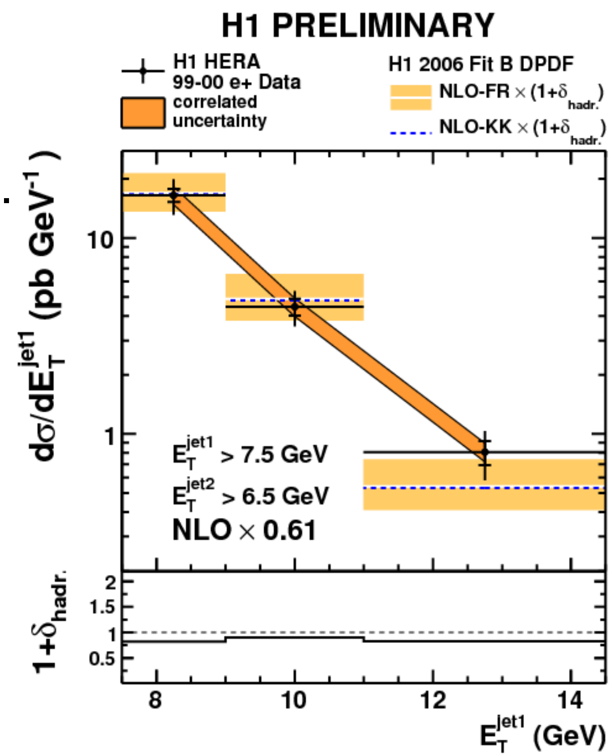

No independent test of an E_T dependence, but values more similar to ZEUS respect previous cases