Factorisation in diffraction

Representing H1 and ZEUS experiments

Hadron structure ´09

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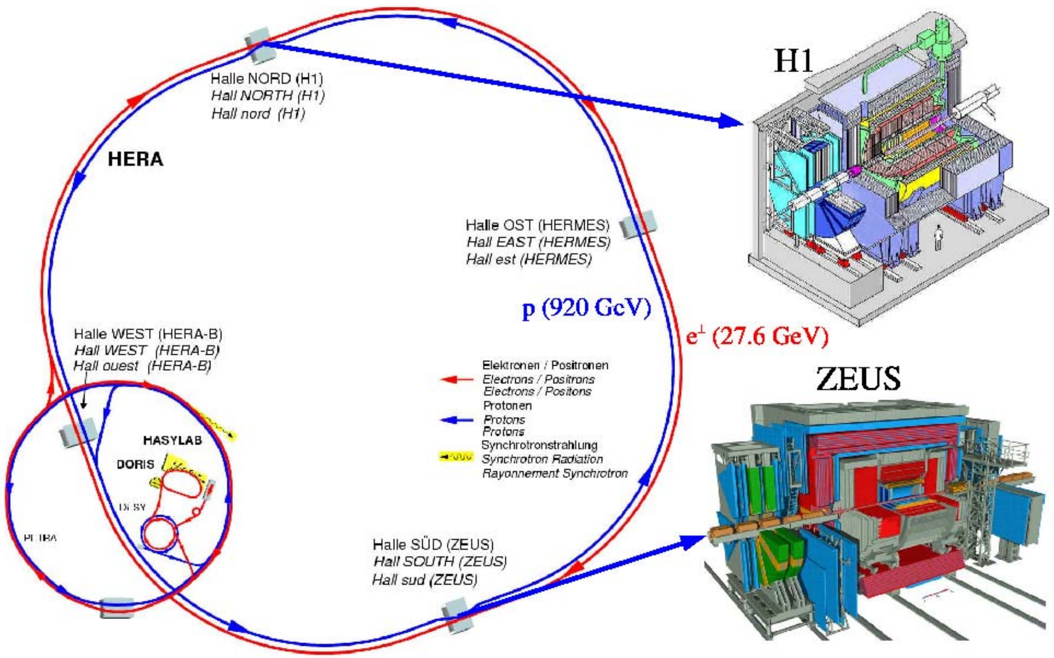
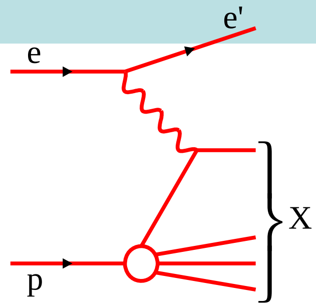
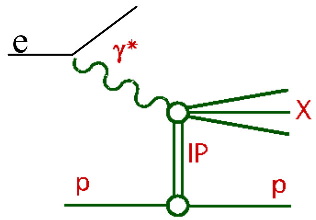
HERA collider experiments

- 27.5 GeV electrons/positrons on 920 GeV protons →$\sqrt{s}$=318 GeV
- two experiments: H1 and ZEUS
- HERA I: 16 pb^{-1} e-p, 120 pb^{-1} e+p
- HERA II: ~ 550 pb^{-1}, ~ 40% polarisation of e+,e-
- closed July 2007, still lot of excellent data to analyse……





DIS: Probe structure of proton → F_2

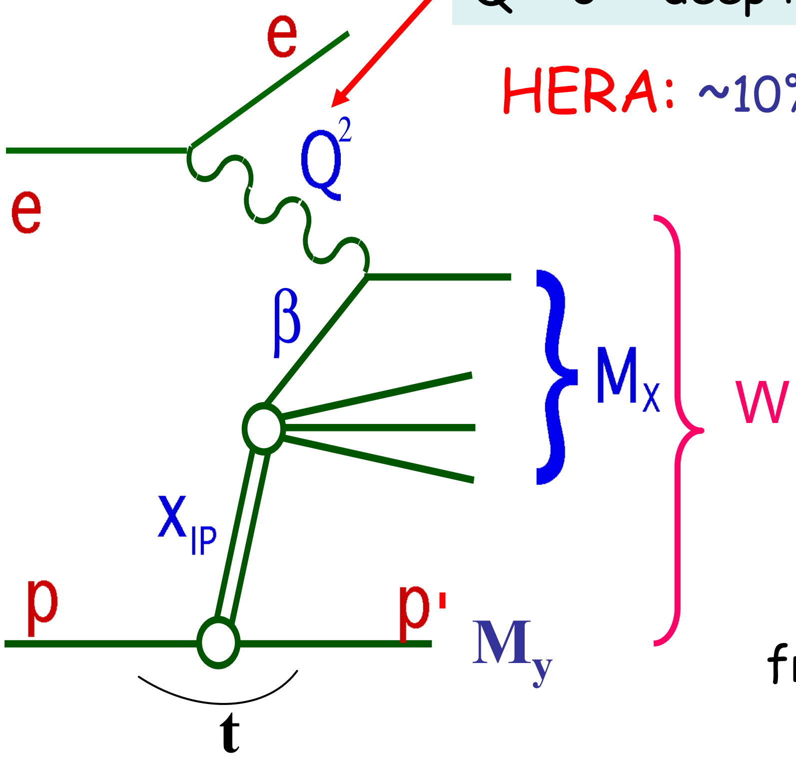


Diffractive DIS: Probe structure of color singlet exchange → F_2^D

Diffraction and diffraction kinematics

Two classes of diffractive events:

$Q^2 \sim 0 \rightarrow$ photoproduction
$Q^2 \gg 0 \rightarrow$ deep inelastic scattering (DIS)



HERA: ~10% of low-x DIS events are diffractive

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

momentum fraction of color singlet exchange

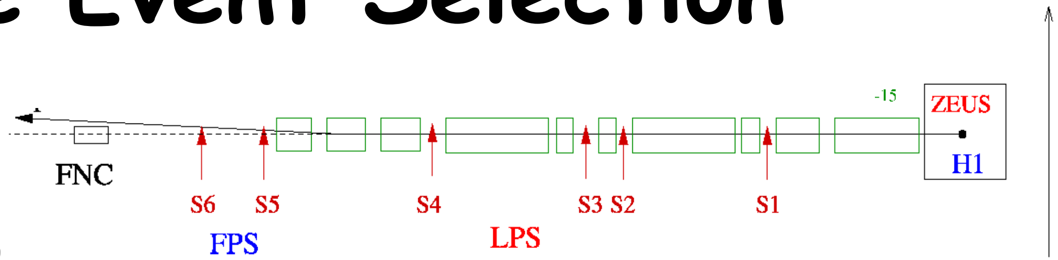
$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^2} \longrightarrow$$

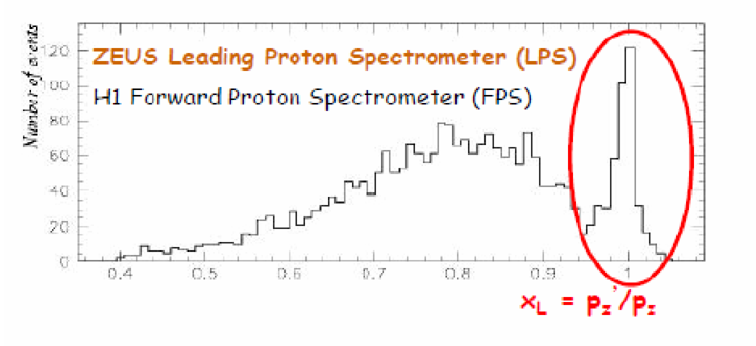
fraction of exchange momentum, coupling to γ^*

$$t = (p - p')^2 \longrightarrow$$ 4-momentum transfer squared

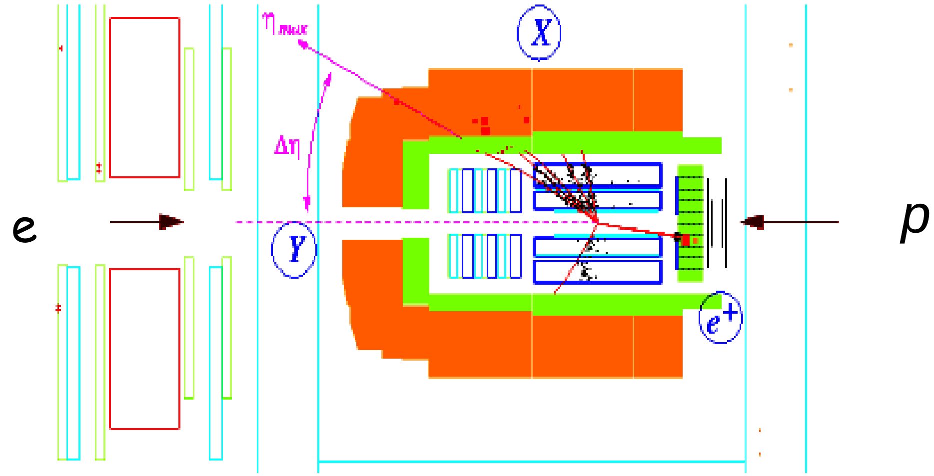
Diffractive Event Selection

1) Proton Spectrometers:
ZEUS: LPS (1993-2000)
H1: FPS (1995-2007),VFPS (2004-07)
t measurement
access to high x_{IP} range
free of p-dissociation background at low x_{IP}
small acceptance → low statistics ☠





2) Large Rapidity Gap, H1, ZEUS:
Require no activity beyond η_{max}
t not measured,
very good acceptance at low x_{IP}
p-diss background ~ 20% ☠



What is QCD factorisation?

Factorisation holds for inclusive and non-inclusive processes when:

- photon is point-like (Q^2 is high enough)
- higher twist corrections are negligible

$$\sigma^D(\gamma^* p \to Xp) = \sum_{parton\_i} f_i^D(x, Q^2, x_{IP}, t) \cdot \sigma^{\gamma^* i}(x, Q^2)$$

$f_i^D \to$ DPDFs – obey DGLAP, universal for diff. ep DIS (inclusive,dijet,charm)

$\sigma^{\gamma^* i} \to$ universal hard scattering cross section (same as in inclusive DIS)

It allows to extract DPDFs from the (DIS) data

H1 and ZEUS –QCD fits assuming Regge factorisation for DPDF

$$f_i^D(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{IP}(\beta = x / x_{IP}, Q^2)$$

$$f_{IP/p}(x_{IP}, t) = \frac{e^{Bt}}{x_{IP}^{2\alpha(t)-1}}$$

pomeron flux factor

pomeron PDF

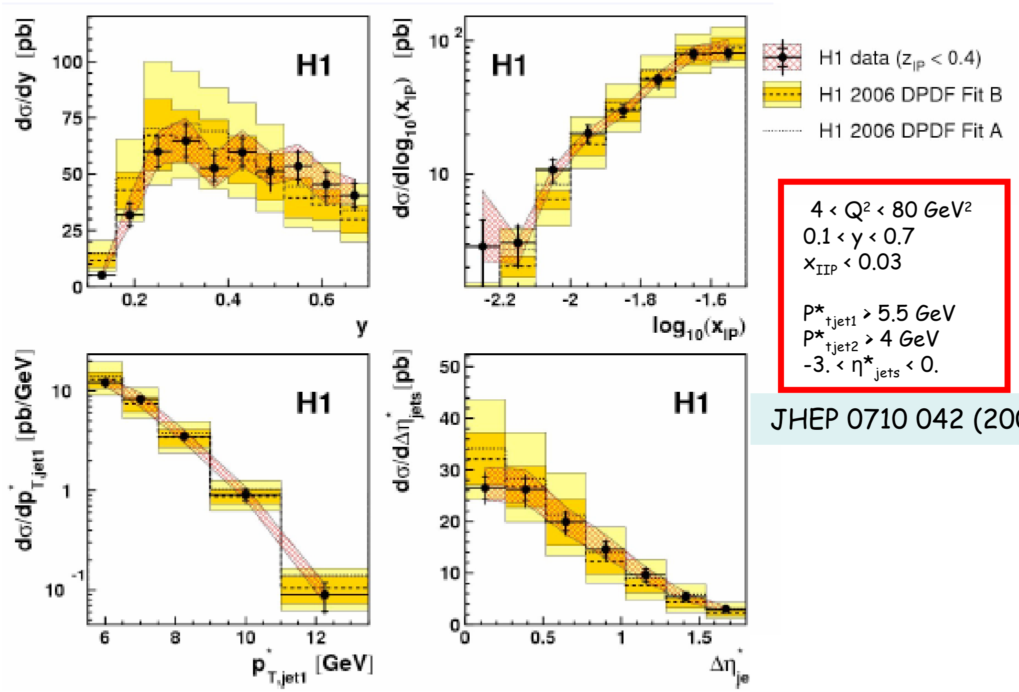
How to profit from factorisation?

- to extract DPDFs from inclusive DIS and to estimate cross sections for dijet and D* production – then compare with data ➡ **tests of factorisation**

- to extract DPDFs from inclusive and semi-inclusive DIS (dijets,D*) – only semi-inclusive data are sensitive to gluon contribution, mainly at large z_{IP}

Used by H1 and ZEUS

semi-inclusive data ⟶ dijets in DIS

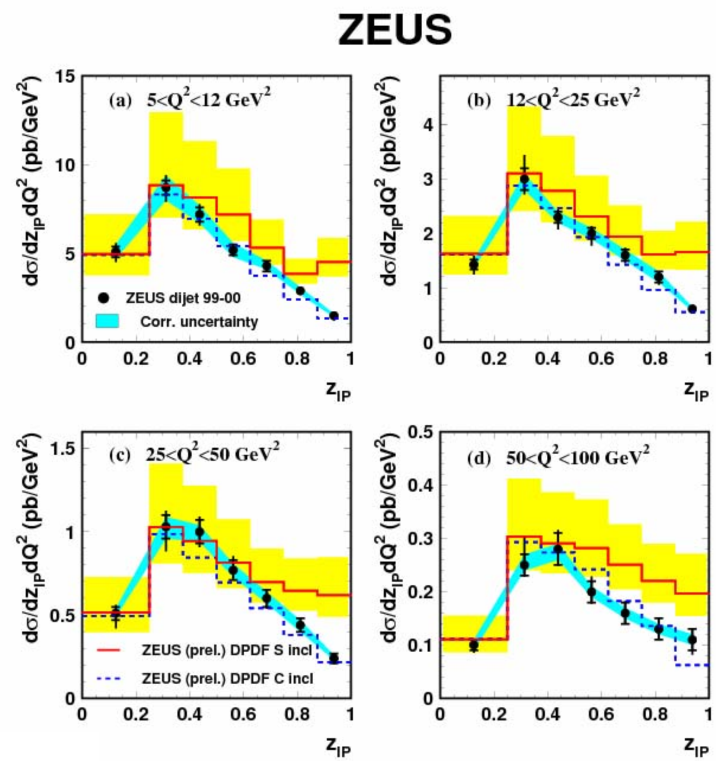


$4 < Q^2 < 80$ GeV²
$0.1 < y < 0.7$
$x_{IP} < 0.03$

$P^*_{tjet1} > 5.5$ GeV
$P^*_{tjet2} > 4$ GeV
$-3. < \eta^*_{jets} < 0.$

JHEP 0710 042 (2007)

EPJ C52 (2007) 813



H1 QCD inclusive+dijet fit

$$z\Sigma(z,Q_0^2) = A_q z^{B_q}(1-z)^{C_q}$$

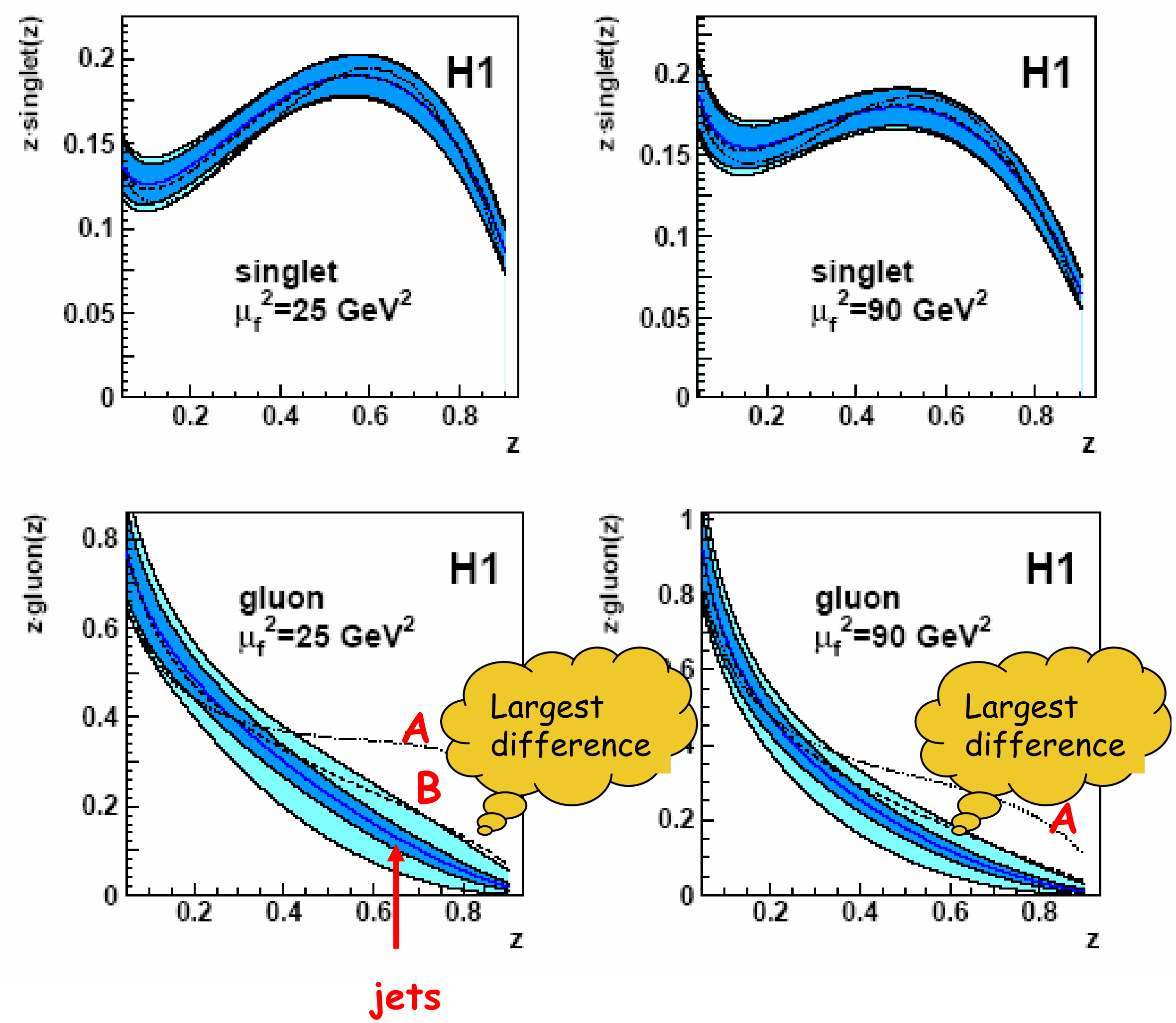
Inclusive fits A and B

Fit jets uses dijets in DIS

No difference for quarks, large difference for gluons at large z_{IP}.

JHEP 0710:042,2007

- H1 2007 Jets DPDF
- exp. uncertainty
- exp. + theo. uncertainty
- H1 2006 DPDF fit A
- H1 2006 DPDF fit B



Fit A

$$z_g(z,Q_0^2) = A_g(1-z)^{C_g}$$

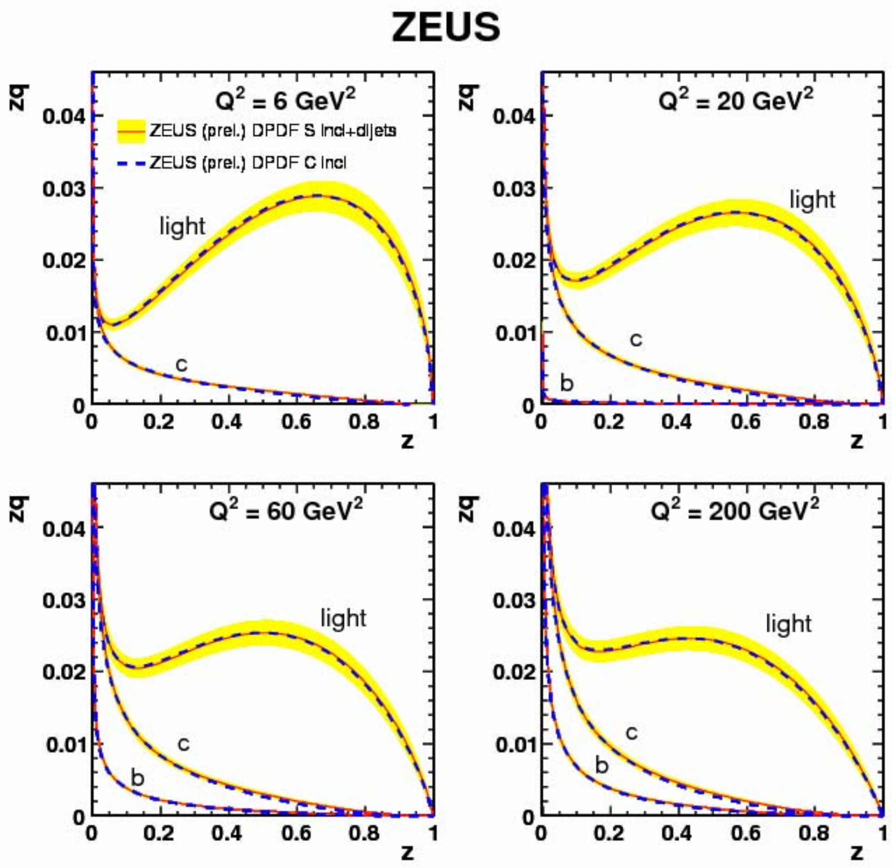
Fit B

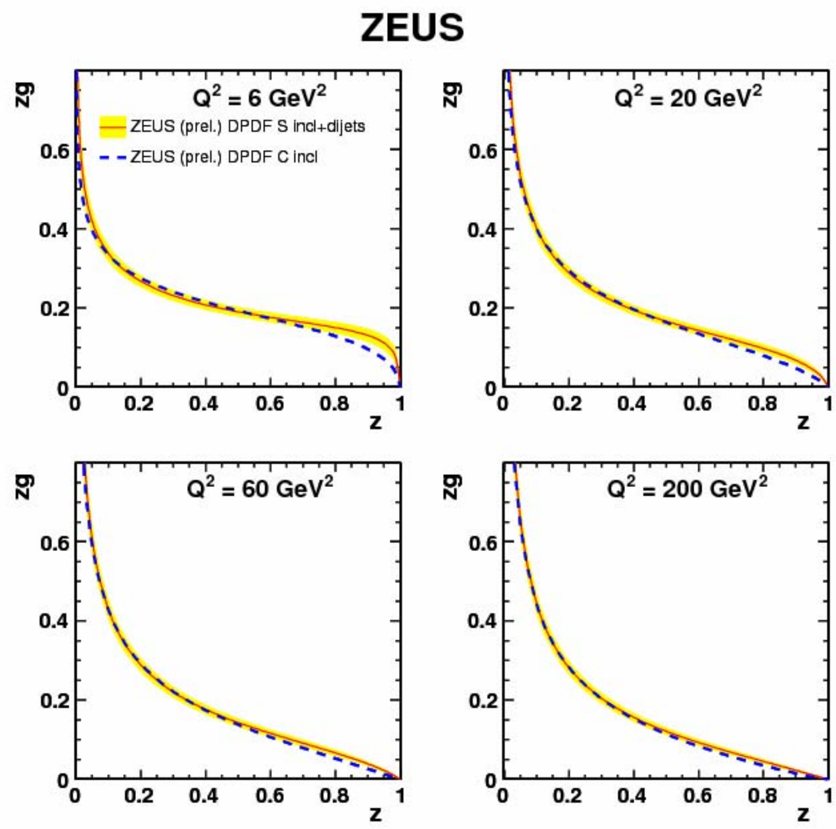
$$z_g(z,Q_0^2) = A_g$$

ZEUS QCD inclusive+dijet fit

ZEUS fit C is the fit with same conditions as H1 fit B

The results of fits of both experiments are similar.

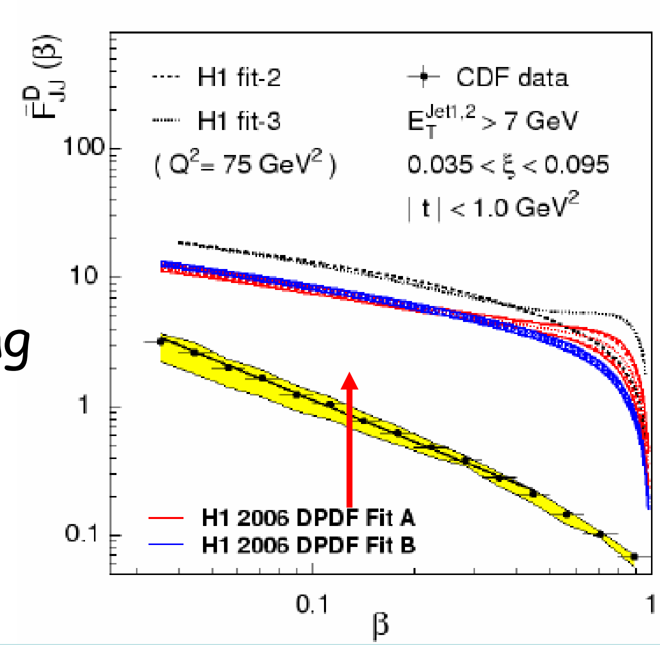




Factorisation in hadron-hadron collisions

Factorisation broken by β-dependent factor ~ 10, S ~ 0.1

Exporting DPDFs from HERA to Tevatron.....



x_{IP} integrated effective DPDFs from CDF single diff. dijets (run I)

Succesfully explained by terms of rescattering and absorption
(see Kaidalov,Khoze,Martin,Ryskin:Phys.Lett.B567 (2003),61)

Must be understood for LHC...e.g. CEP Higgs, (S=1-3%), related to underlying event.....

Tests of factorisation - HERA

- dijets in DIS – factorisation holds – H1 → JHEP 0710 042 (2007)
  ZEUS → EPJ C52 (2007) 813
- D* in DIS and photoproduction - H1 Coll. EPJ C50 (2007) 1
  ZEUS Coll. EPJ C51 (2007) 301

H1 double ratio $R^{\gamma p}_{DIS}$= (data/theory)$^{\gamma p}$/(data/theory)$_{DIS}$

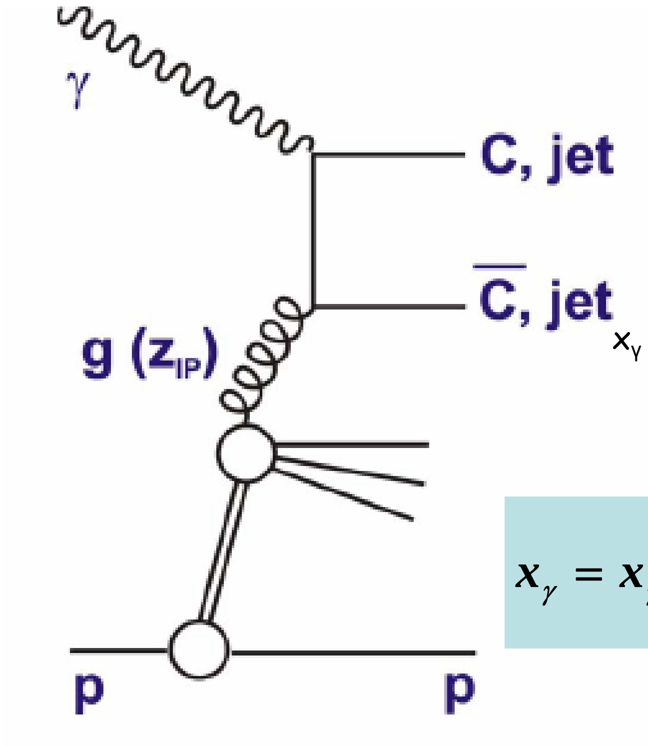
$R^{\gamma p}_{DIS}$=1.15 ± 0.40 (stat.) ± 0.09 (syst.)

↓

within large errors no evidence for suppression,
factorisation holds

- what about dijets in photoproduction????

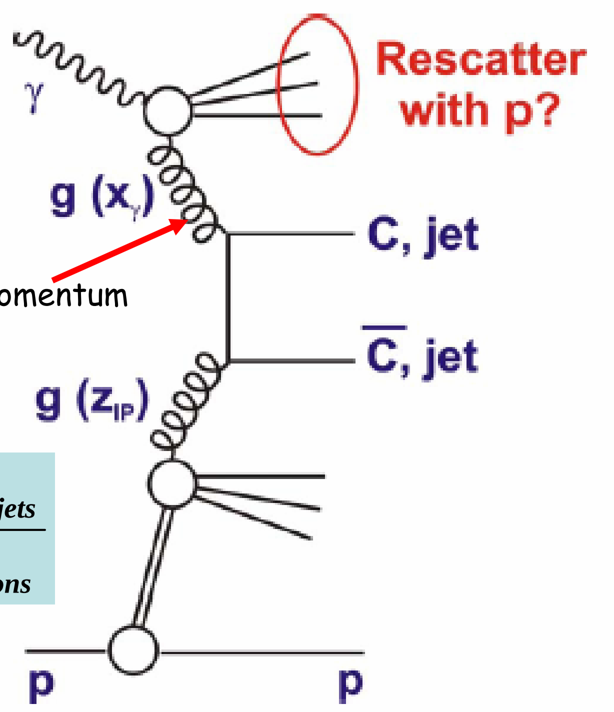
Photoproduction, $\gamma^{*}p$, $Q^2 \to 0$



In LO!

x_γ - fraction of photon's momentum in hard subprocess

$$x_\gamma = x_\gamma^{OBS} = \frac{\sum (E - p_z)_{jets}}{(E - p_z)_{hadrons}}$$



direct photoproduction ($Q^2 \simeq 0$):

photon directly involved in hard scattering

$x_\gamma = 1$

(at parton level)

resolved photoproduction ($Q^2 \simeq 0$):

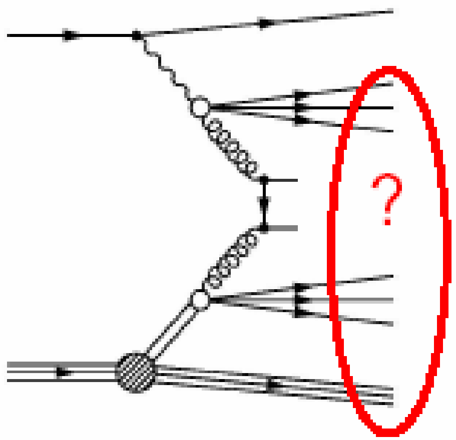
photon fluctuates into hadronic system, which takes part in hadronic scattering, dominant at $Q^2 \simeq 0$

$x_\gamma < 1$

(at parton level)

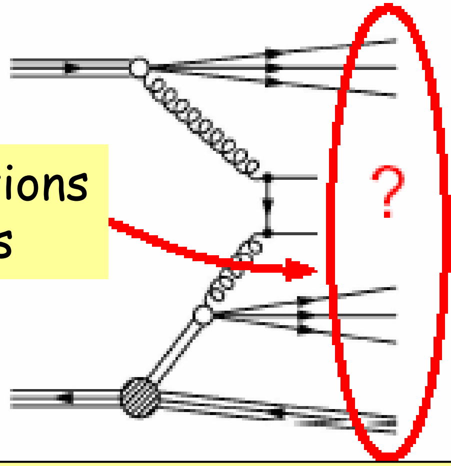
Photoproduction as hadronic process

HERA resolved photoproduction



Secondary interactions between spectators

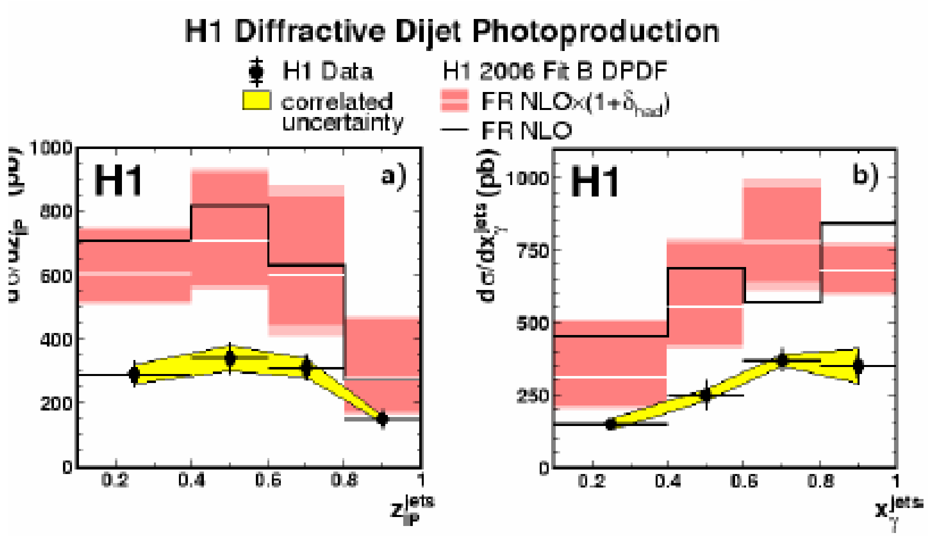
Tevatron

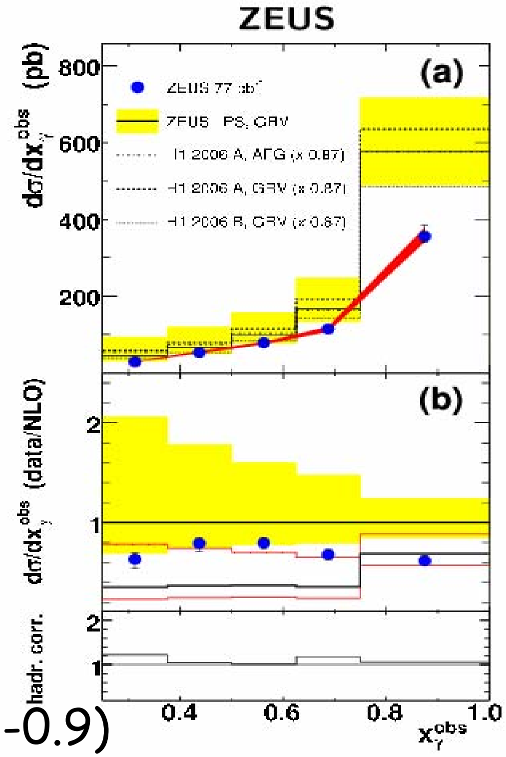


Typical models that describe suppression at Tevatron assume secondary interactions of spectators as the cause:

resolved contribution expected to be suppressed by factor 0.34
see Kaidalov et al.

2007 - DIS 07….





H1: E_{tjet1} > 5 GeV suppression of factor ~0.5

ZEUS: E_{tjet1} > 7.5 GeV weak (if any) suppression (0.6-0.9)

Neither collaboration sees difference between the resolved and direct regions, in contrast to theory!

Possible explanation of differences between H1 and ZEUS (DIS 2007)

Different phase space of both analyses ……..?

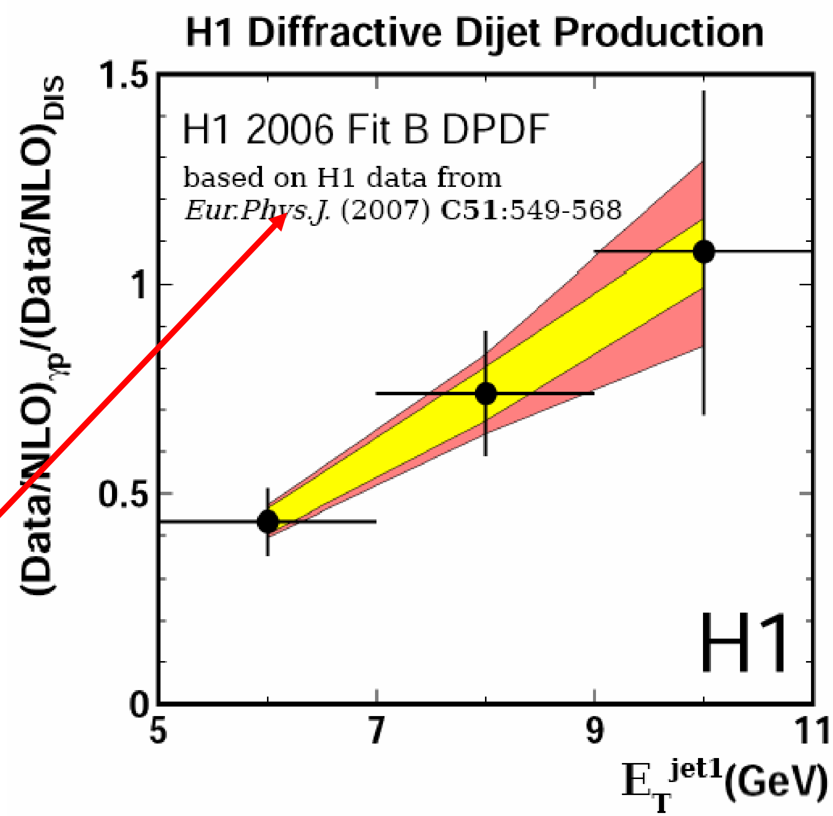
H1 – double ratio, E_t dependence?

Double ratio of Data/NLO for photoproduction and DIS

→

Very useful – full or partial cancellation of many uncertainties (energy scales for data, DPDFs used…etc).

Figure extracted from published results



Double ratio is within errors E_t dependent!

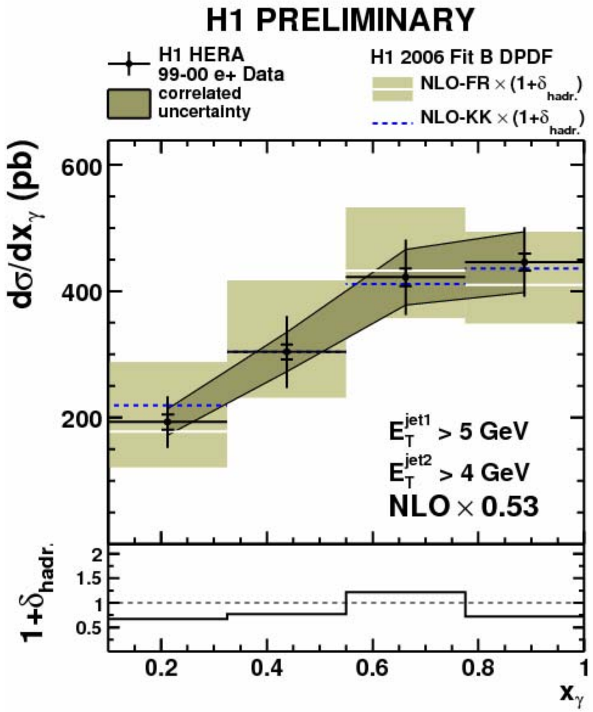
New H1 analysis -two cut scenarios

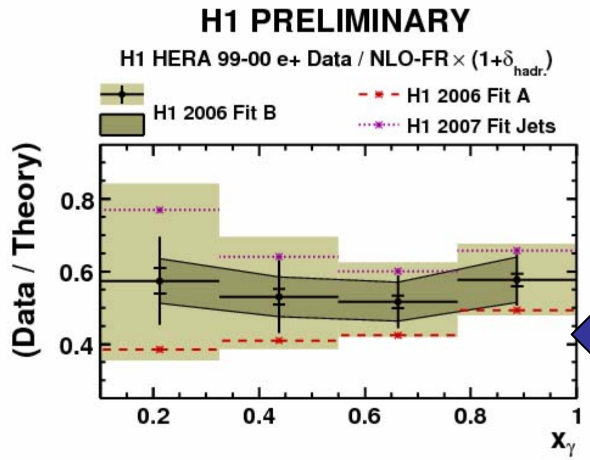
Tagged dijet photoproduction, data 99/00, three times larger statistics, LRG

To crosscheck previous H1 results	To approach closest to ZEUS cuts
$E_T^{jet1} > 5$ GeV	$E_T^{jet1} > 7.5$ GeV
$E_T^{jet2} > 4$ GeV	$E_T^{jet2} > 6.5$ GeV
$-1 < \eta^{(jet\ 1\ and\ 2)} < 2$	$-1.5 < \eta^{(jet\ 1\ and\ 2)} < 1.5$
$x_{IP} < 0.03$	$x_{IP} < 0.025$
$0.3 < y_e < 0.65$	$0.3 < y_e < 0.65$ ... $0.2 < y_{JB} < 0.85$ ZEUS
$Q^2 < 0.01$ GeV^2	$Q^2 < 0.01$ GeV^2... $Q^2 < 1$ GeV^2
$\|t\| < 1$ GeV^2	$\|t\| < 1$ GeV^2
$M_Y < 1.6$ GeV	$M_Y < 1.6$ GeV

different from ZEUS (applies to the y_e, Q^2, $|t|$ and M_Y cuts of the right column)

Lower E_t cut scenario





Integrated survival probabilities (ISP)

$$S^{FR}_{fit\,B} = \underline{0.54} \pm 0.01\,(stat.) \pm 0.10\,(syst.)\,^{+0.14}_{-0.13}\,(scale)$$

$$S^{KK}_{fit\,B} = 0.51 \pm 0.01\,(stat.) \pm 0.10\,(syst.)$$

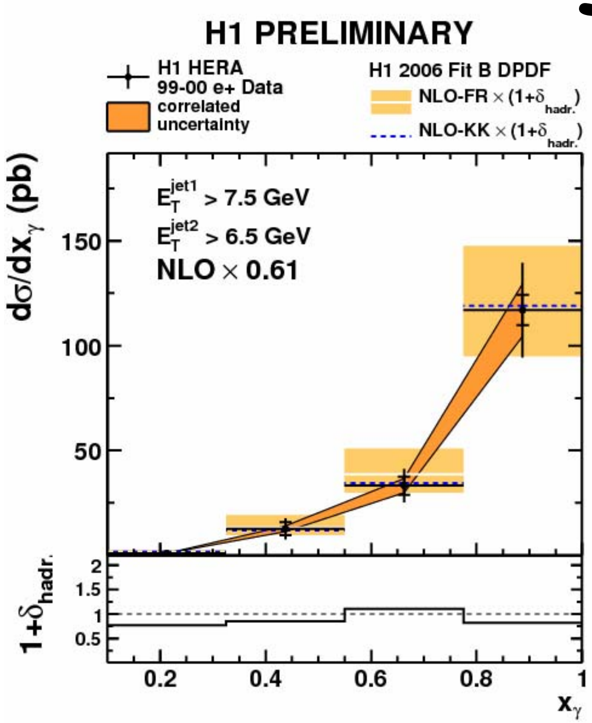
$$S^{FR}_{fit\,Jets} = 0.65 \pm 0.01\,(stat.) \pm 0.11\,(syst.)$$

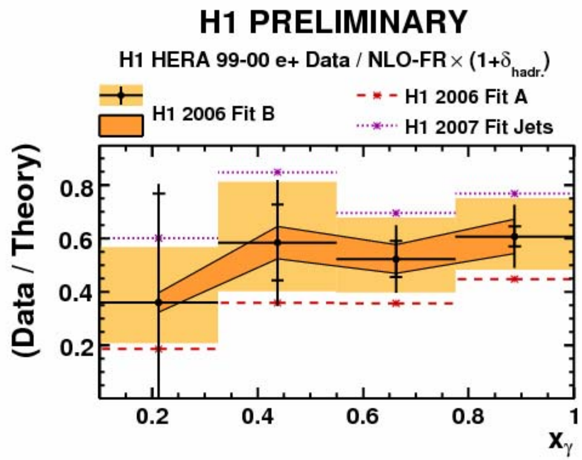
$$S^{FR}_{fit\,A} = 0.43 \pm 0.01\,(stat.) \pm 0.10\,(syst.) \quad 11$$

Within errors no difference in ISP using different DPDFs

No difference in survival probabilities for resolved and direct regions of x_{γ}, like in previous H1 and ZEUS analyses

Higher E_t cut scenario





Now much more „direct-like" events than in low E_t analysis, peak at higher x_γ

Integrated survival probabilities (ISP)

$$S^{FR}_{fit\,B} = \underline{0.61} \pm 0.03\,(stat.) \pm 0.13\,(syst.)\,^{+0.16}_{-0.14}\,(scale)$$

$$S^{KK}_{fit\,B} = 0.62 \pm 0.03\,(stat.) \pm 0.14\,(syst.)$$

$$\boxed{S^{FR}_{fit\,Jets} = 0.79 \pm 0.04\,(stat.) \pm 0.16\,(syst.)}$$

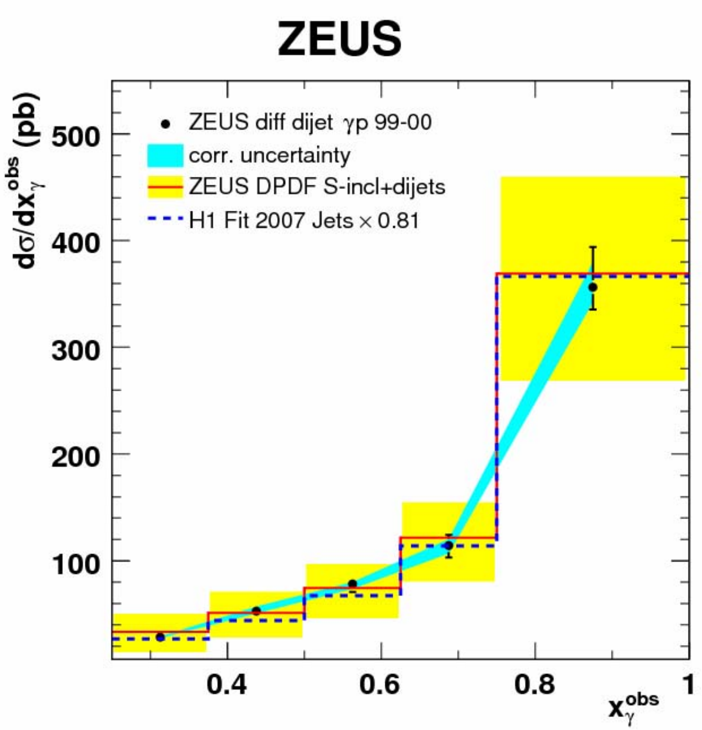
$$S^{FR}_{fit\,A} = 0.44 \pm 0.02\,(stat.) \pm 0.09\,(syst.)$$

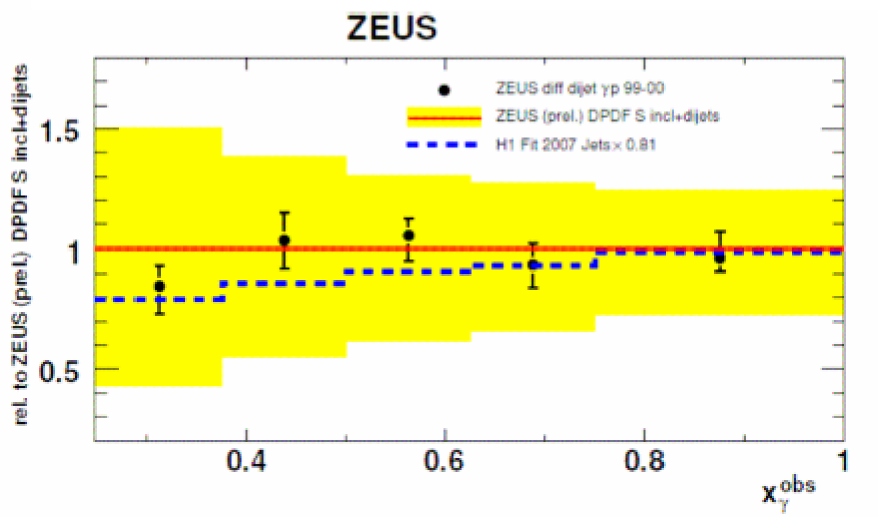
Larger ISP than for lower E_t cut scenario
→ more close to ZEUS results!!!

New ZEUS fit-comparison with old data

Published data: EPJ C55 (2008) 177

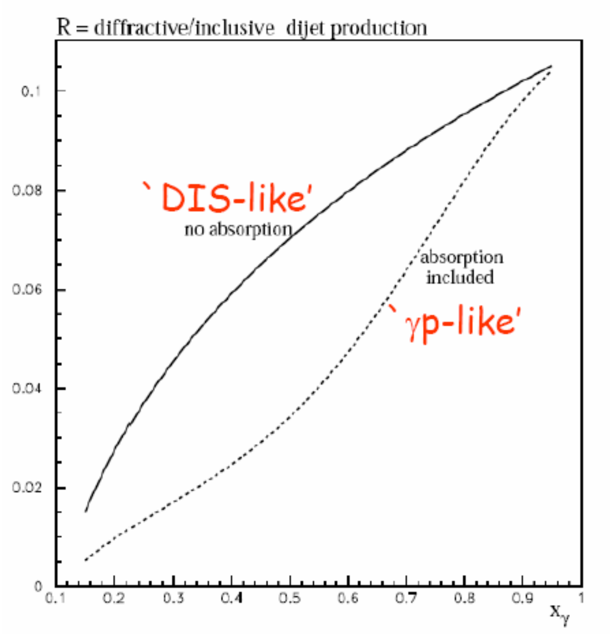
Very good description → no evidence for suppression for ZEUS combined fit and H1 fit jets.





Ratio diffractive to inclusive

Proposed by Kaidalov et al. Phys.Lett B567 (2003) 61



Full or partial cancellation of PDF uncertainties, scales…..

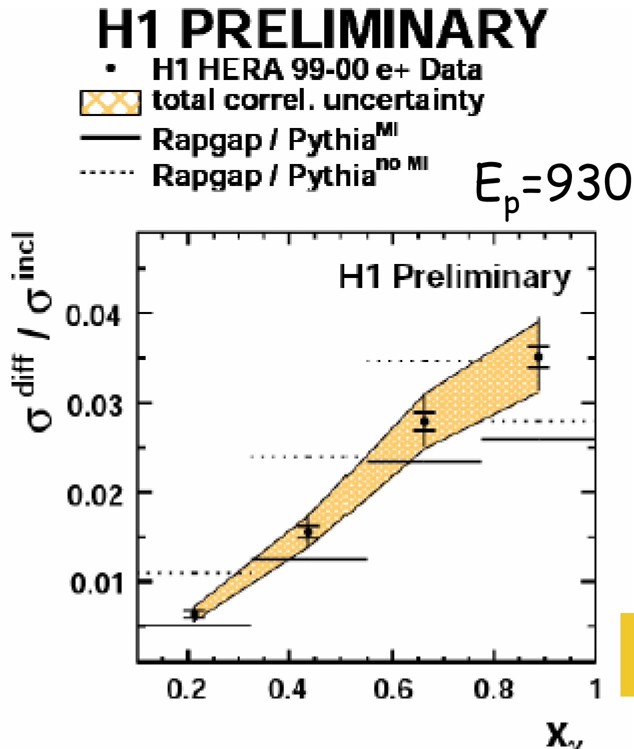
Distribution of x_γ sensitive to gap survival.

H1 - measured in same kinematic range with same method as diffractive cross sections
Acceptance corrections – PYTHIA

Problem → describes low E_t inclusive data with inclusion of multiple interactions only, large hadronisation corrections!

With such a low E_t jets problems also with NLO description of data – see for example H1 inclusive jet paper (EPJ C 129 (2003) 497)

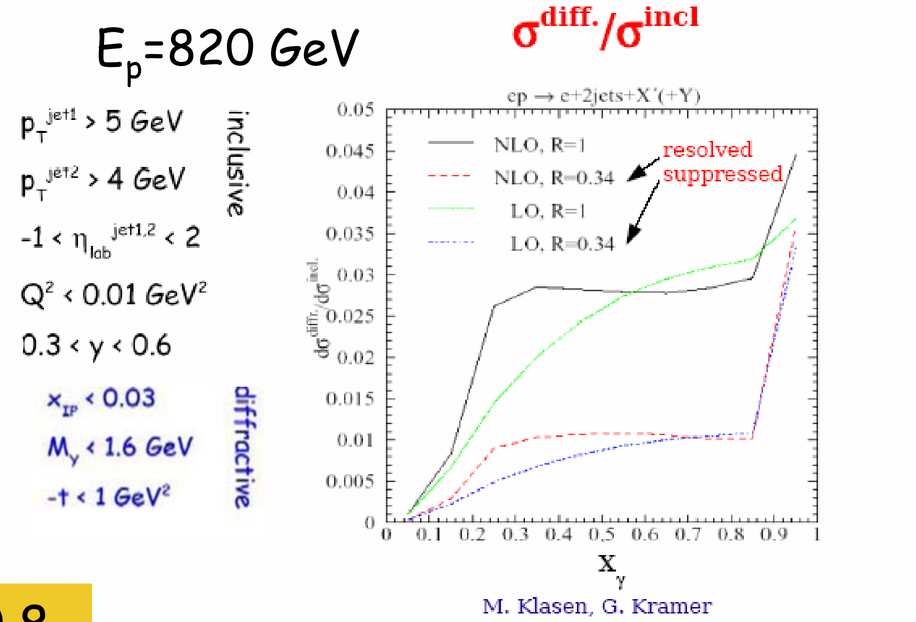
Ratio diffractive to inclusive



E_p=930 GeV

z_{IP} < 0.8

E_p=820 GeV



- comparison to MC models - RAPGAP/PYTHIA
- very different phase space for incl.& diffr.
- large sensitivity to multiple interactions (MI) for inclusive dijets
- better agreement of data ratio with PYTHIA MI

Summary

- for dijets in photoproduction gap survival probability: significantily less than 1. for events with low E_t leading jets, for higher E_t (DPDF H1 fit jets 2007) ~ 0.8, consistent with ZEUS results (ZEUS combined fit 2009) ~ 1.

- hint that suppression is dependent on E_t of the leading jet, → evidence that gap destruction becomes less likely as E_t increases

- the evidence that suppression is not different for direct and resolved events remains (from theory not expected)

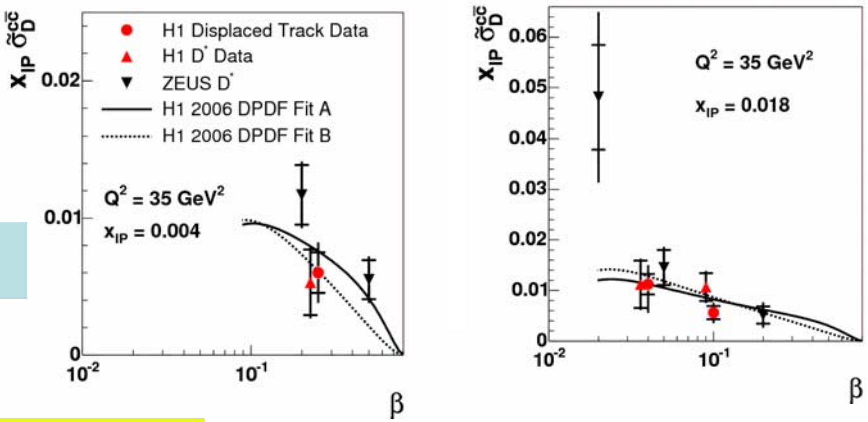
- ratio diffractive dijets/inclusive dijets measured for the first time – the multiple interactions play important role for inclusive dijets → interpretation difficult

Backup

Tests of factorisation - HERA

- dijets in DIS – factorisation holds – H1 → JHEP 0710 042 (2007)
  ZEUS → EPJ C52 (2007) 813
- D* in DIS and photoproduction - H1 Coll. Eur.Phys. J C50,1,(2007)

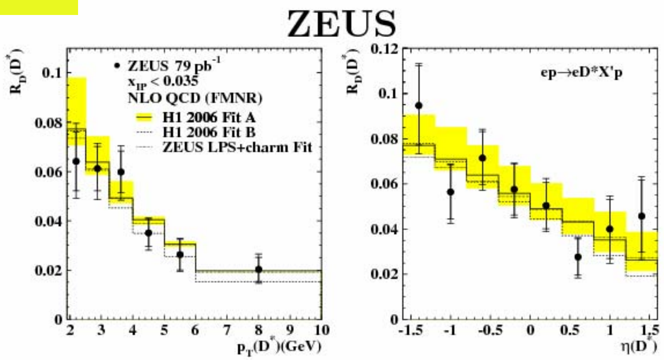
DIS



$R^{\gamma p}_{DIS}$= (data/theory)$^{\gamma p}$/(data/theory)$_{DIS}$

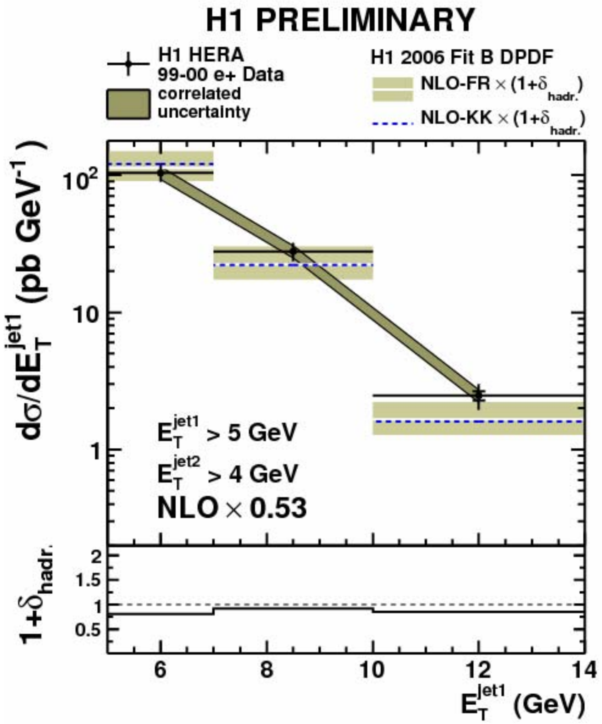
$R^{\gamma p}_{DIS}$=1.15 ± 0.40 (stat.) ± 0.09 (syst.)

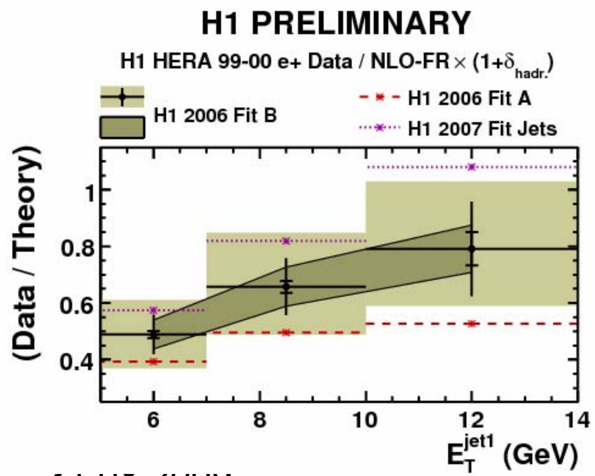
ZEUS coll. EPJ C51 (2007) 301



within large errors
no evidence for suppression,
factorisation holds

Lower E_t cut scenario





Another hint of E_t harder slope for data than NLO

Hadronization corrections

δ_{hadr}=MC(hadr)/MC(parton)