Factorization in diffraction

On behalf of H1 and ZEUS collaborations

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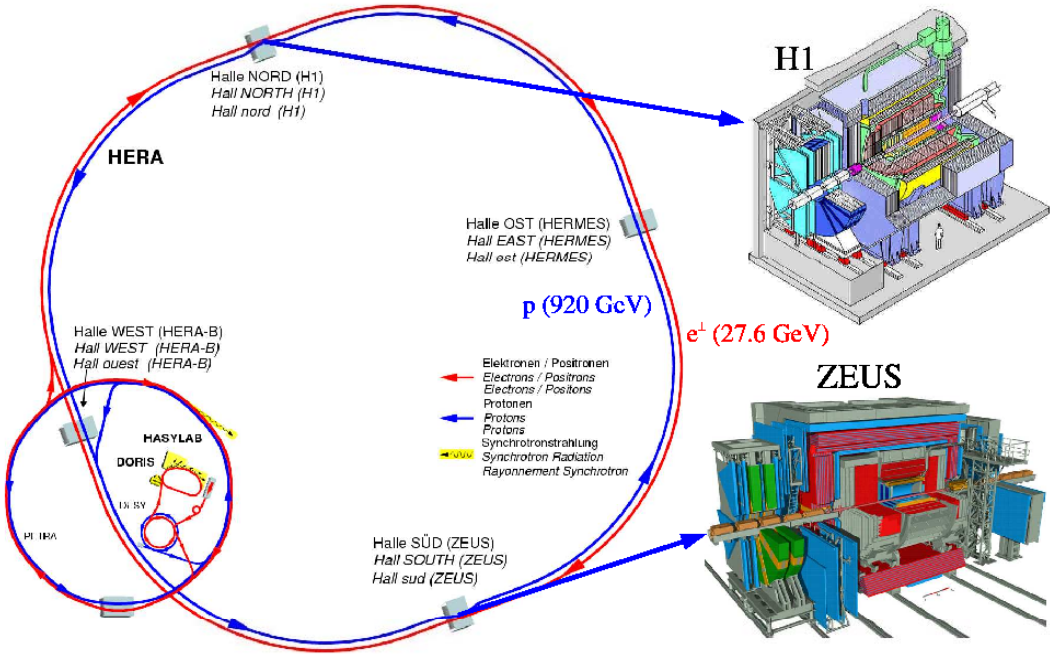
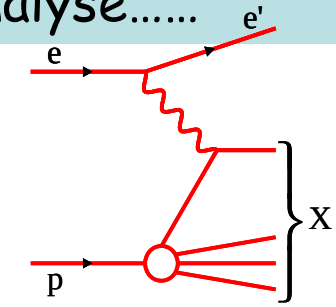
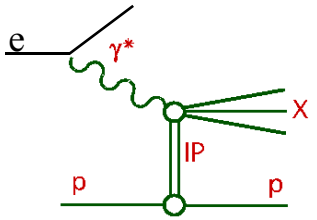
HERA collider experiments

- 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: ~ 500 pb^{-1}, ~ 40% polarisation of e+,e-
- closed July 2007, still lot of excellent data to analyse……





DIS: Probe structure of proton → F_2

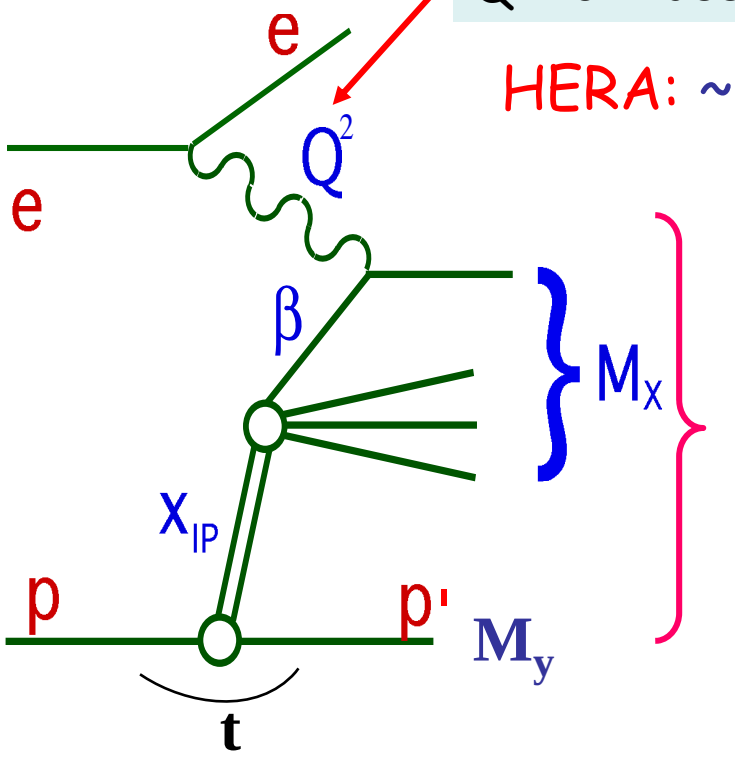


Diffractive DIS: Probe structure of color singlet exchange → F_2^D

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

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

momentum fraction of color singlet exchange

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

fraction of exchange momentum, coupling to γ*

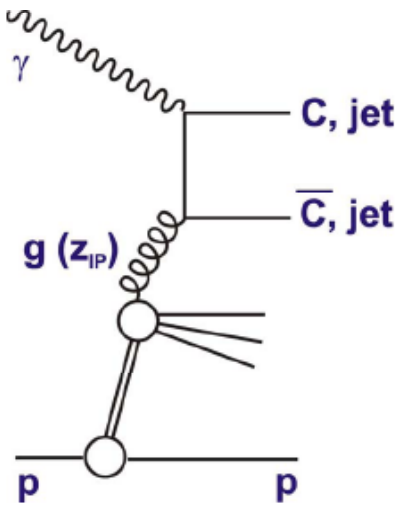
$$t = (p - p')^2$$ ⟶ 4-momentum transfer squared

Dijets in diffractive ep scattering

Pointlike photon

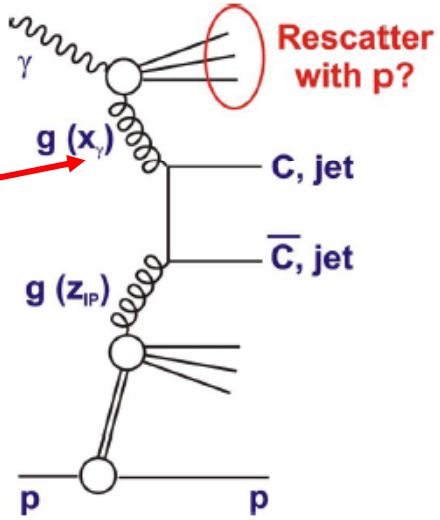
LO QCD

Resolved photon



x_γ - fraction of photon's momentum in hard subprocess

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



DIS, direct PHP

photon directly involved in hard scattering

$x_\gamma = 1$ (at parton level),

due to hadronization and resolution not exactly true for measured x_γ

resolved PHP

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

$x_\gamma < 1$

(at parton level)

What is QCD factorization?

Is it possible to factorize hard diffractive processes into two parts?

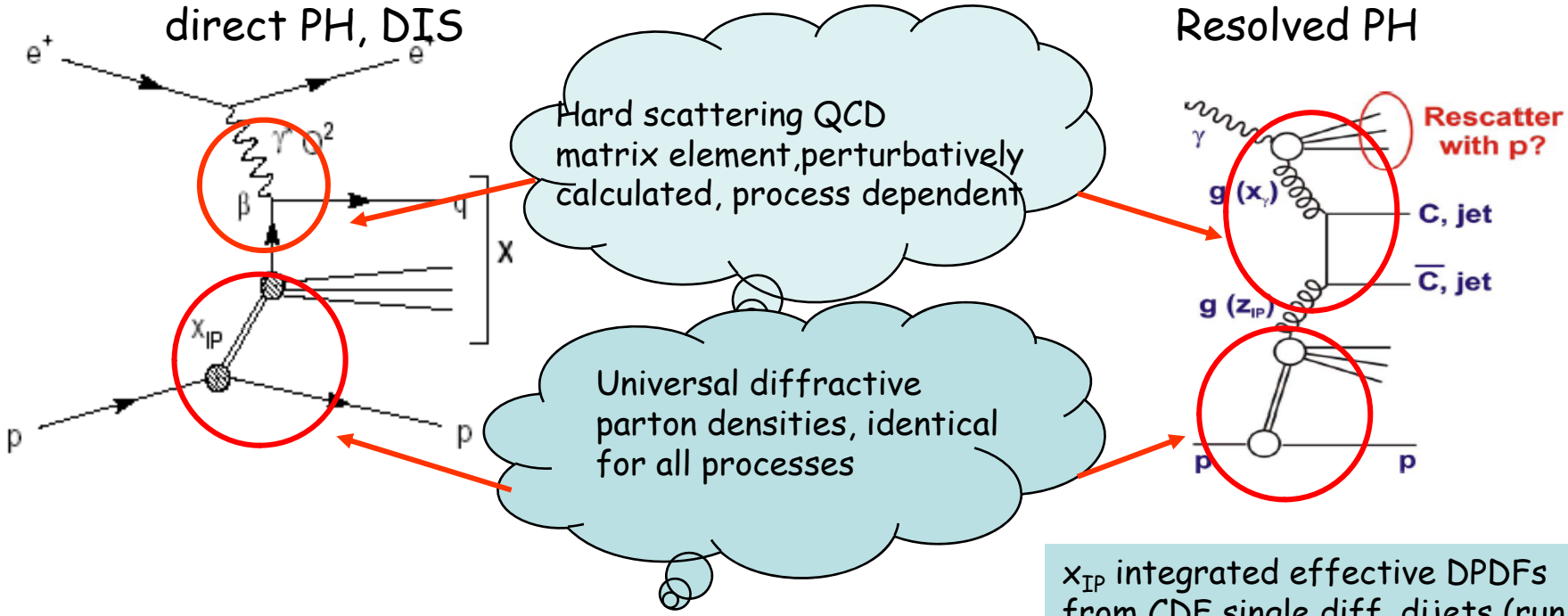
- non-perturbative Diffractive Parton Density Functions (DPDFs) of an colorless object
- perturbatively calculable partonic cross section

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

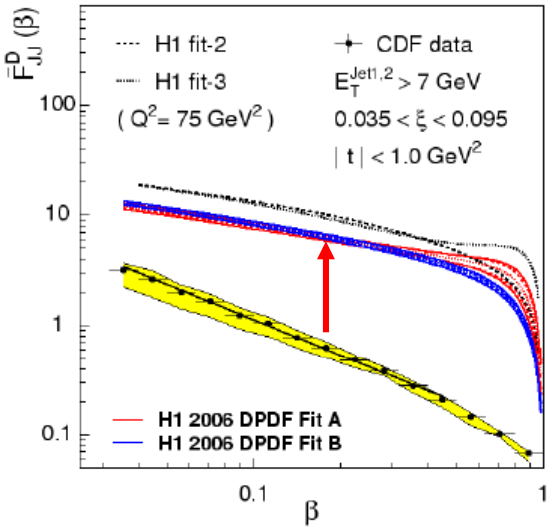
?

- proven for DIS (J.Collins (1998)), $Q^2 \gg 0$
- not proven for photoproduction, $Q^2 \sim 0$

QCD factorization



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



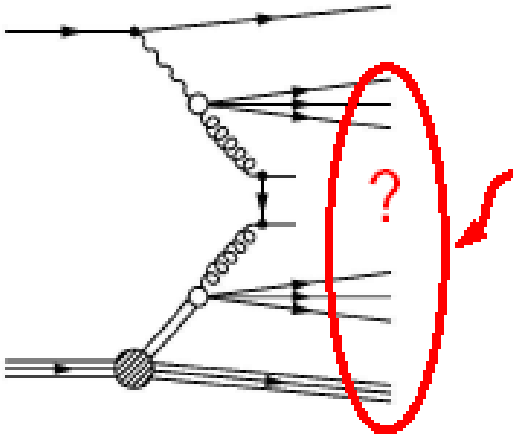
Factorization ensures:
Get DPDFs from inclusive measurement and predict the cross sections for exclusive processes
(dijet production, D* production)

It is not fulfilled in the case of Tevatron dijet production!
Multi-pomeron exchange, remnant interactions, screening?

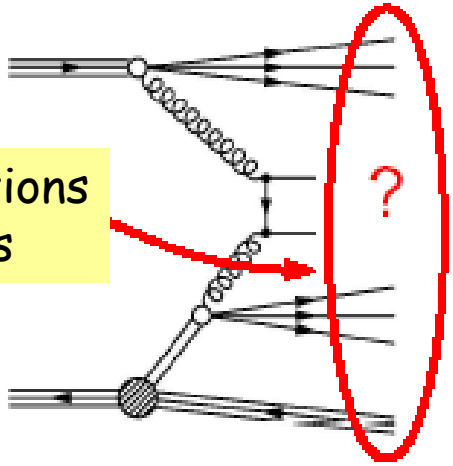
Photoproduction as hadronic process

Factorization broken by β dependent factor ~ 10

HERA resolved photoproduction



Tevatron



Secondary interactions between spectators

Rescattering leads to factorization breaking and rapidity gap fill up
suppression of cross section ~ 1 – (rapidity gap survival probability)

resolved contribution expected to be suppressed by factor 0.34
(Kaidalov,Khoze,Martin,Ryskin:Phys.Lett.B567 (2003),61)

Questions…

- Is factorization valid for diffractive dijets and D* production in DIS and photoproduction?
- How large is the suppression in comparison to no breaking ?
- Does breaking of factorization occur in both PH direct and resolved dijet production?
- Comparison of the value of suppression to theory and hadron-hadron collisions at Tevatron and LHC.

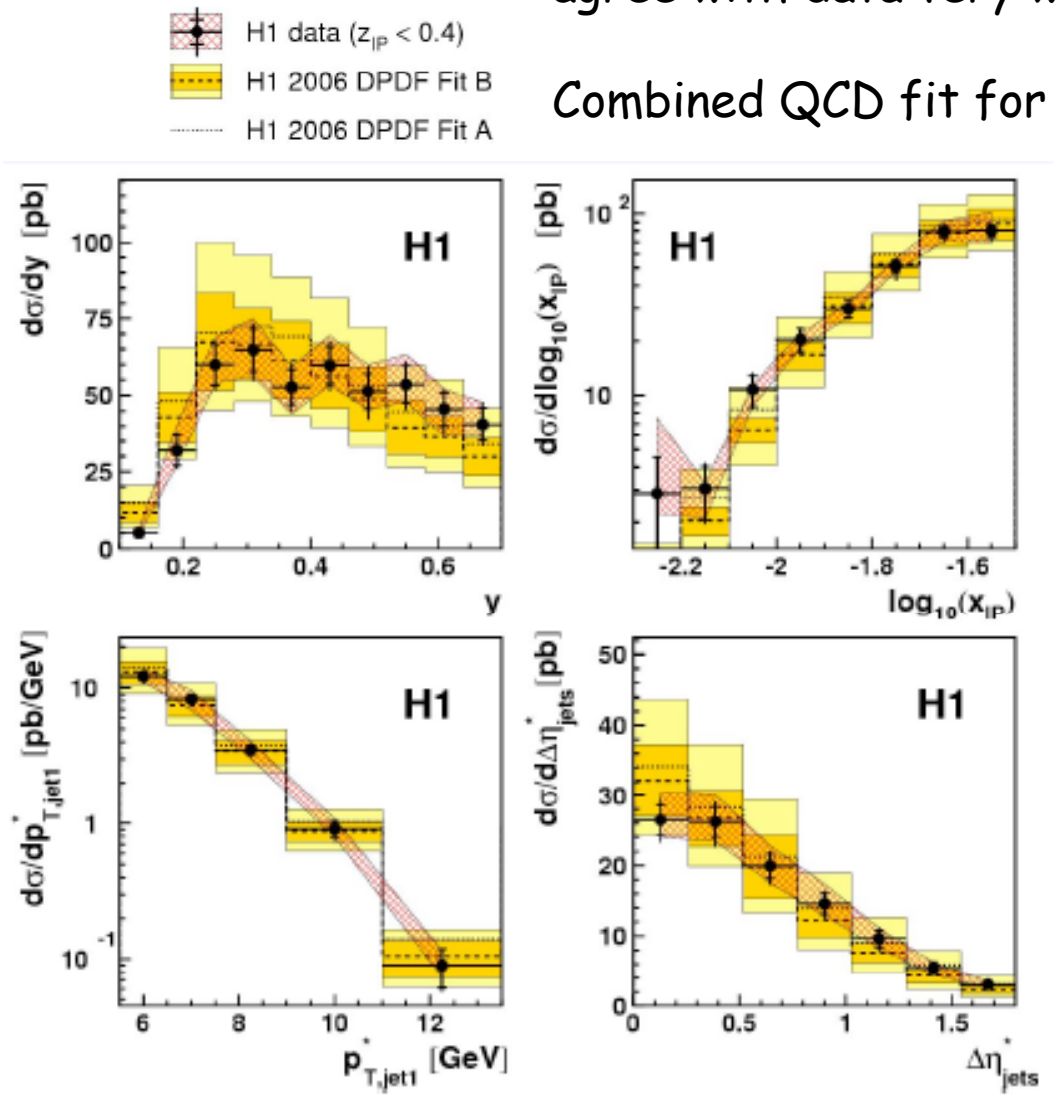
Dijets in diffractive DIS, H1

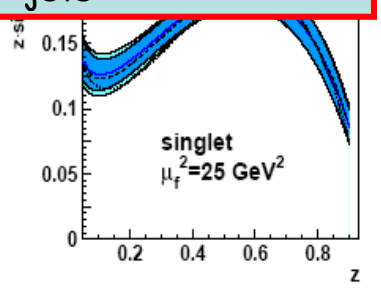
For $z_{IP} < 0.4$ NLO predictions using fits 2006 A and B agree with data very well

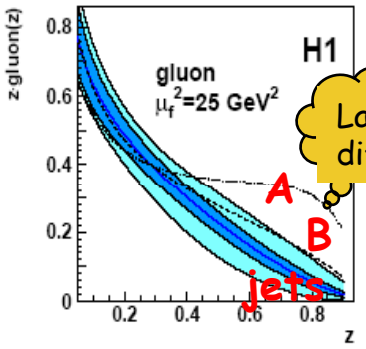
Combined QCD fit for ir ta.....

$4 < Q^2 < 80\ GeV^2$
$0.1 < y < 0.7$
$x_{IIP} < 0.03$

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



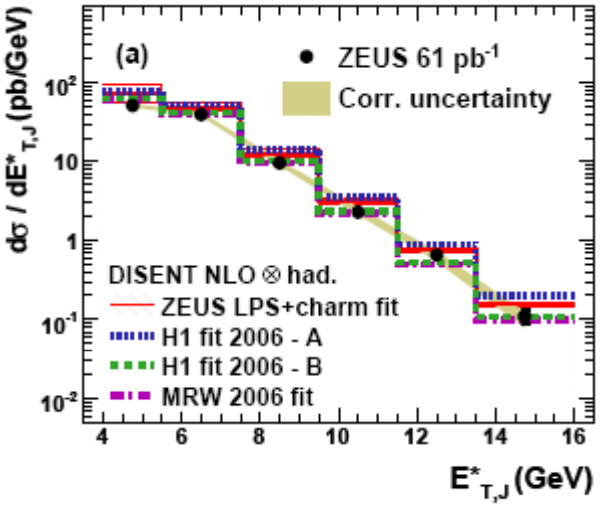


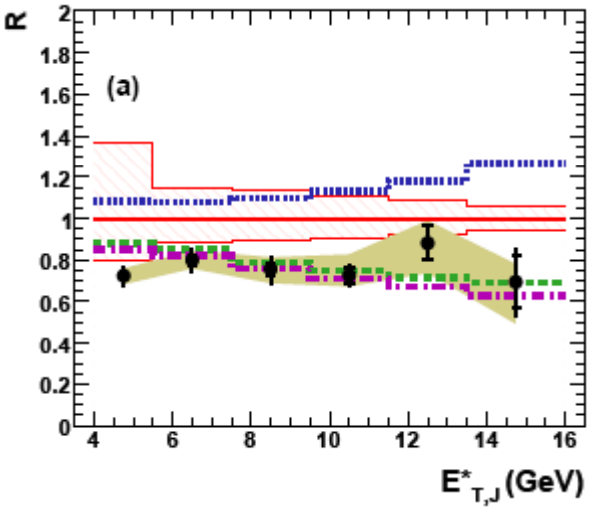


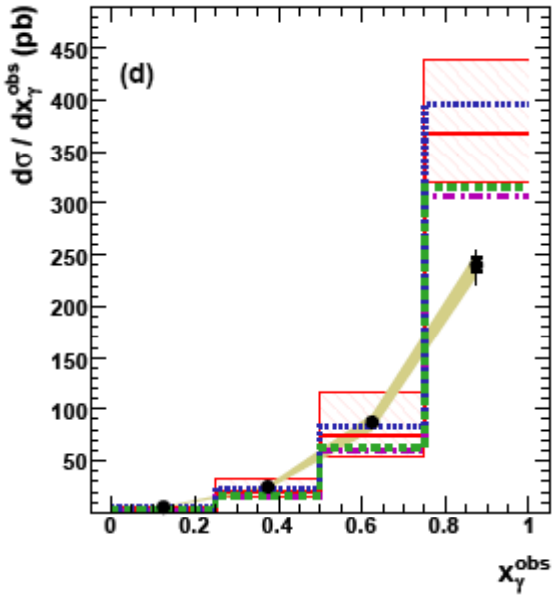
Largest difference

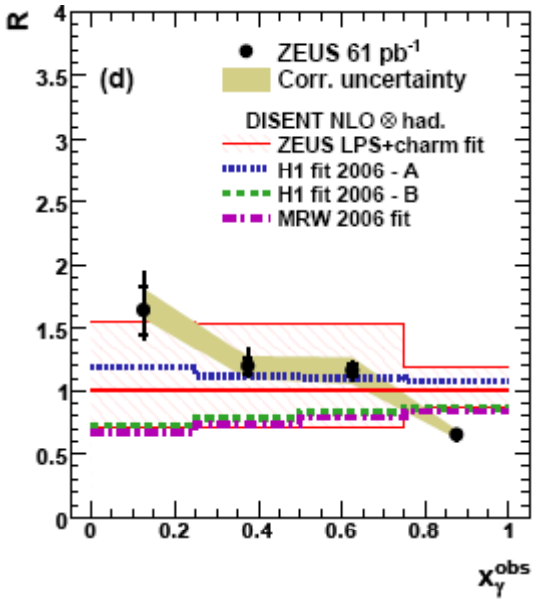
published, JHEP,0710:042

Dijets in diffractive DIS, ZEUS









Eur.Phys.J.C52: 83 (2007)

$E^*_{tjet1} > 5$ GeV
$5 < Q^2 < 100$ GeV^2

Data 99/00

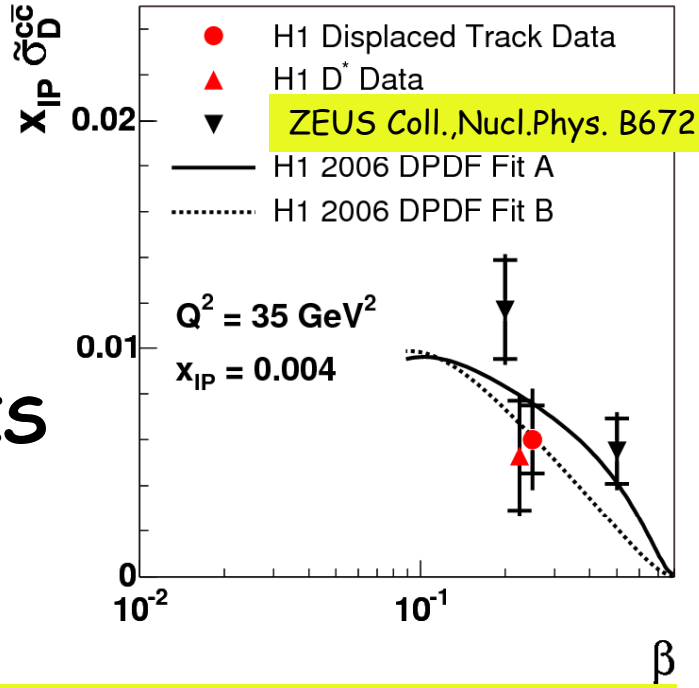
R=data/NLO(ZEUS LPS)

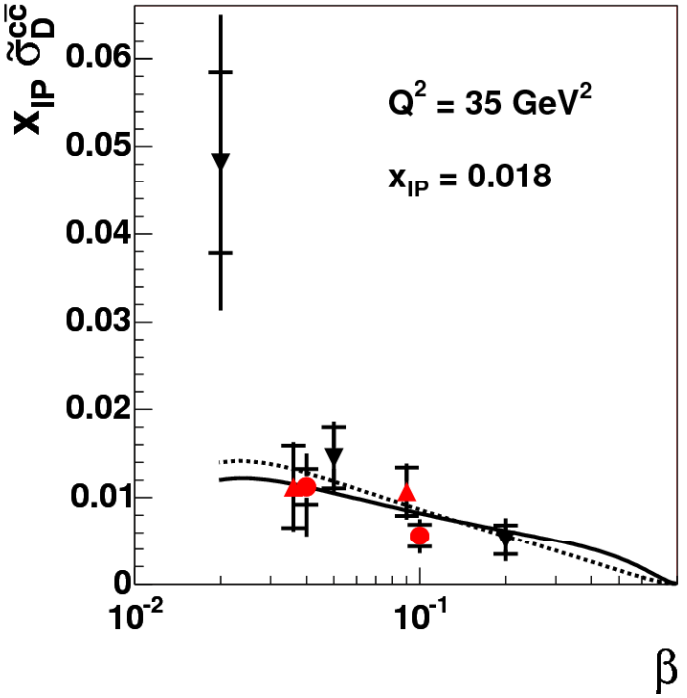
Conclusions:
the best agreement of data and NLO
for H1 2006 fit B and MRW 2006

H1, ZEUS: for DIS dijets factorization holds…..

D* production-DIS, photoproduction

DIS





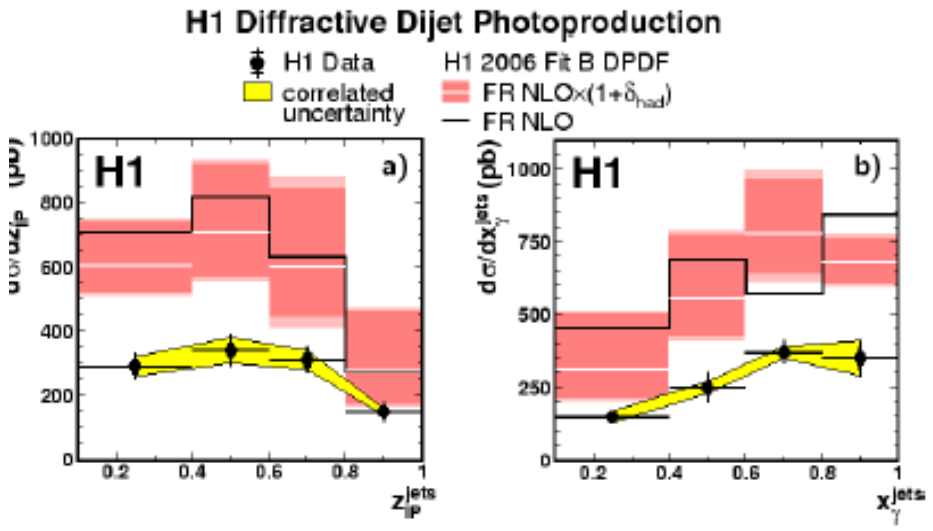
H1 Coll. Eur.Phys. J C50,1,(2007)

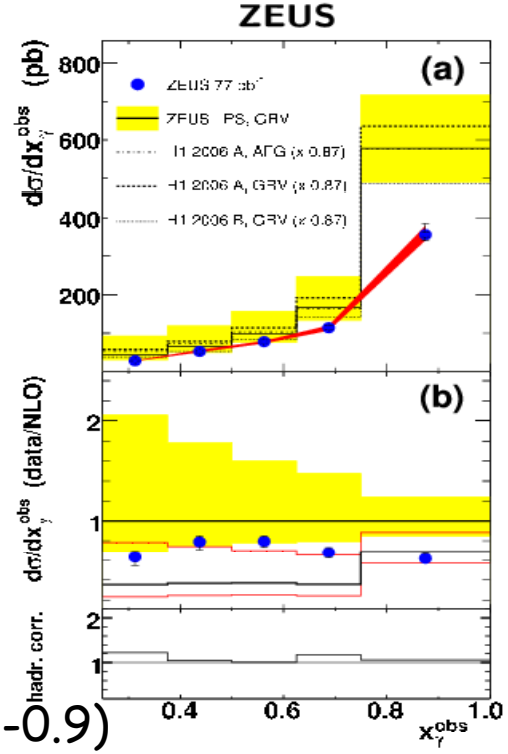
$R^{\gamma p}_{DIS}$= (data/theory)$^{\gamma p}$/(data/theory)$_{DIS}$

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

Within large errors no evidence for a suppression of the photoproduction component……

Dijet factorization tests in 2007





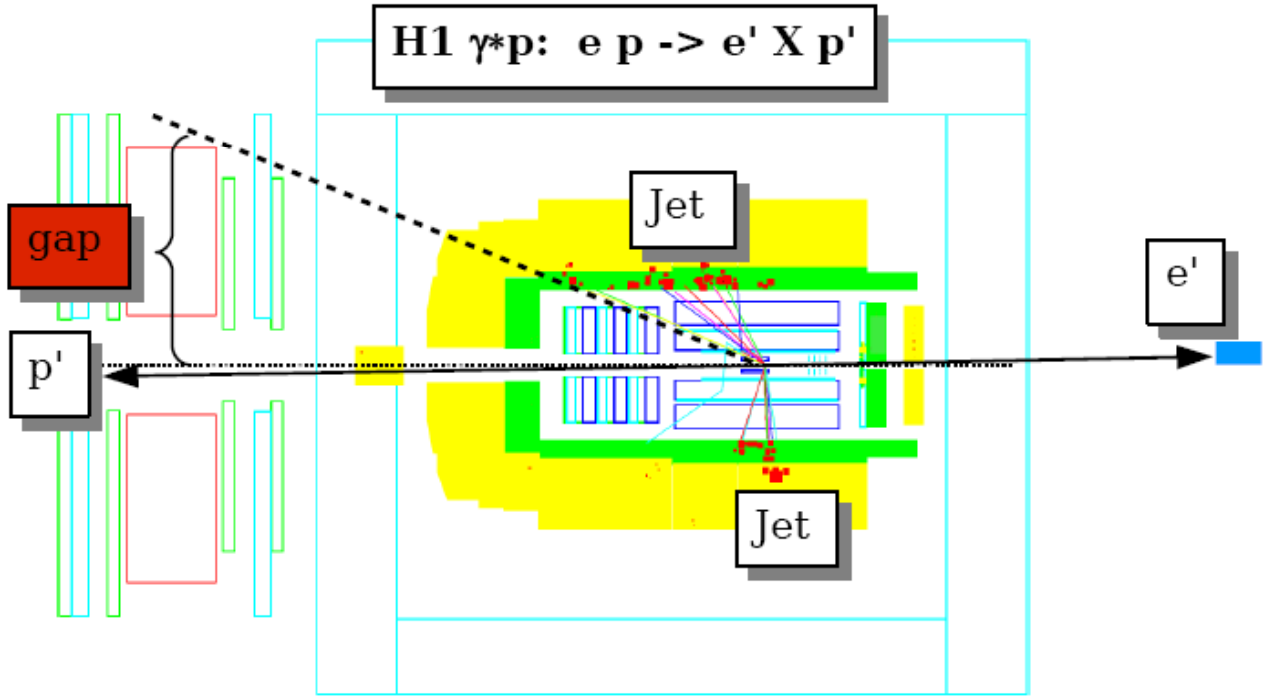
H1: $E_{tjet1} > 5$ GeV suppression of factor ~0.5
ZEUS: $E_{tjet1} > 7.5$ GeV weak (if any) suppression (0.6-0.9)

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 analysis – data 99/00

Tagged photoproduction, luminosity 3x larger than for 97 diffractive events found by Large Rapidity Gap method (LRG)



Two cut scenarios

To crosscheck previous H1 results

$E_T^{jet1} > 5$ GeV

$E_T^{jet2} > 4$ GeV

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

$x_{IP} < 0.03$

$0.3 < y_e < 0.65$

$Q^2 < 0.01$ GeV^2

$|t| < 1$ GeV^2

$M_Y < 1.6$ GeV

To approach closest to ZEUS cuts

$E_T^{jet1} > 7.5$ GeV

$E_T^{jet2} > 6.5$ GeV

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

$x_{IP} < 0.025$

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

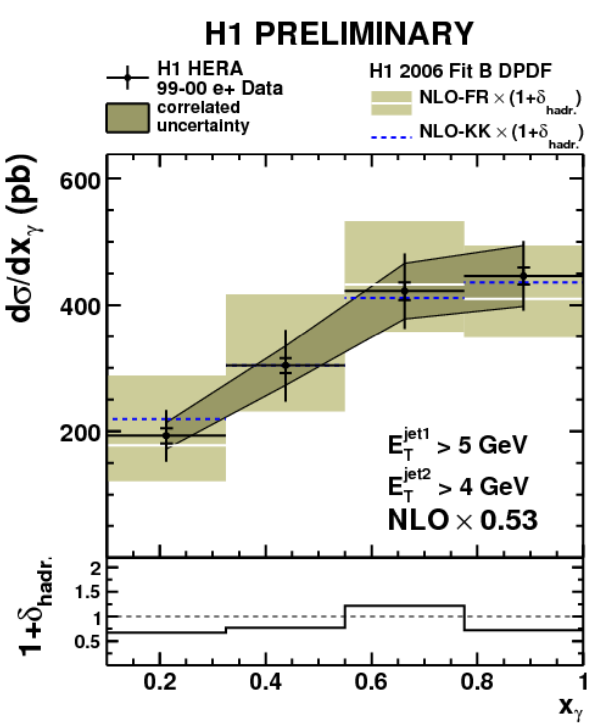
$|t| < 1$ GeV^2

$M_Y < 1.6$ GeV

2 programs for NLO calculations, 3 sets of DPDFs:

Frixione/Ridolfi → H1 2006 Fit A
H1 2006 Fit B
H1 2006 Fit Jets

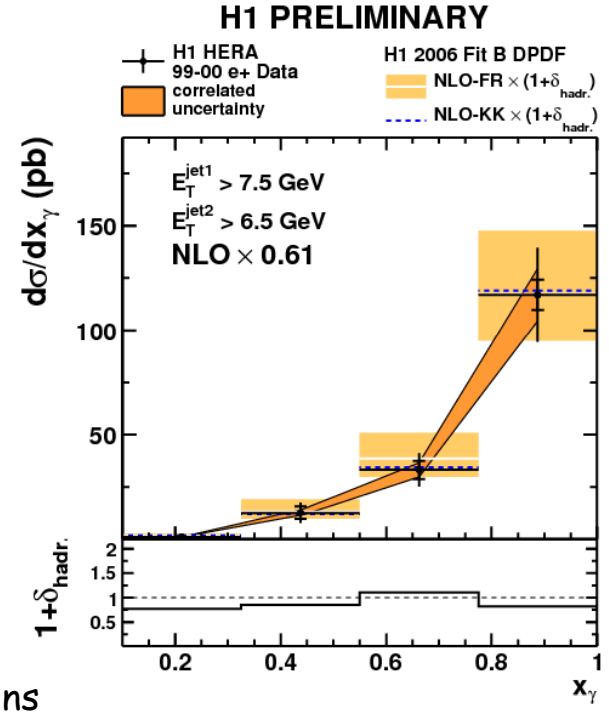
Kramer/Klasen → H1 2006 Fit B (thanks to Michael K.)



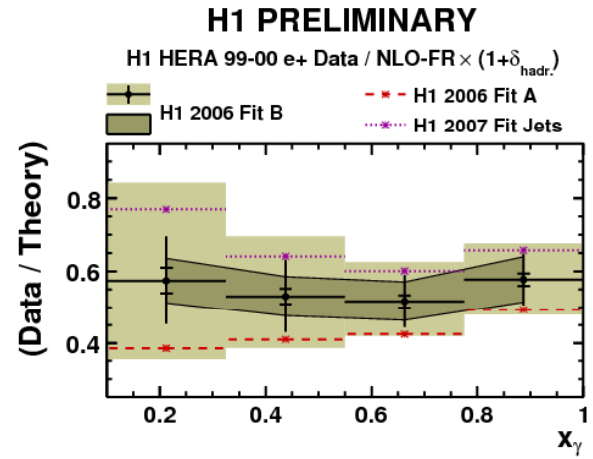
x_γ

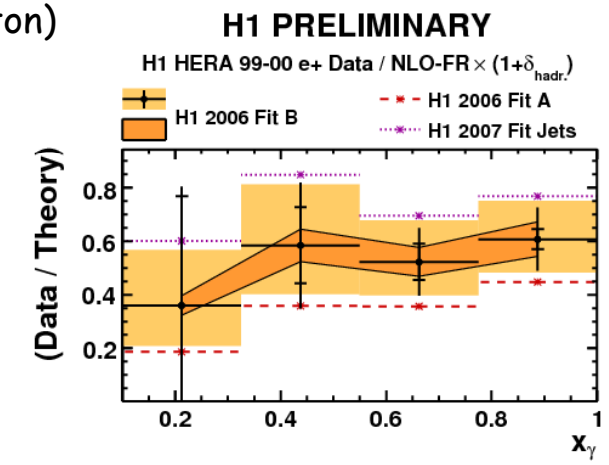
Lower E_t cut

Higher E_t cut



Hadronization corrections
δ_{hadr}=MC(hadr)/MC(parton)





No difference in survival probabilities for resolved and direct regions of x_γ , previous H1 and ZEUS analyses confirmed!

Integrated survival probabilities

Lower E_t scenario

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

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

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

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

$$S = \frac{\sigma\,(\text{data})}{\sigma\,(\text{theory})}$$

Compared to:

0.47 ± 0.16 for $x_\gamma < 0.9$
0.53 ± 0.14 for $x_\gamma > 0.9$
H1 Coll., Eur.Phys.J C51,549(2007)

Higher E_t scenario

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

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

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

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

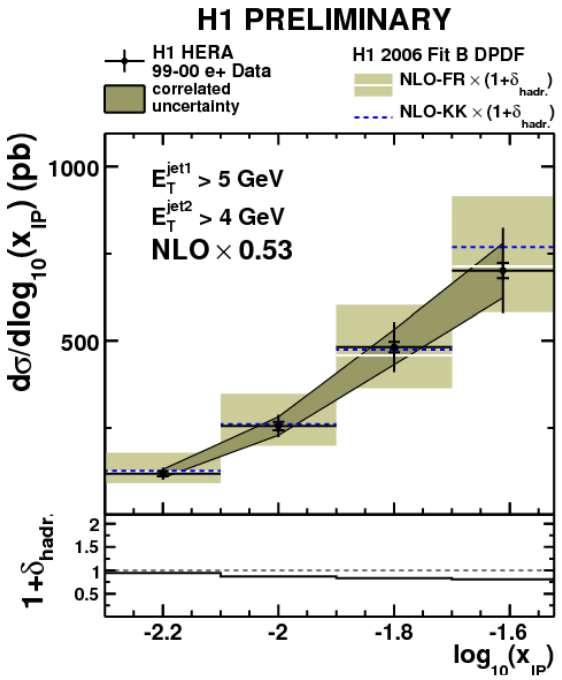
Compared to:

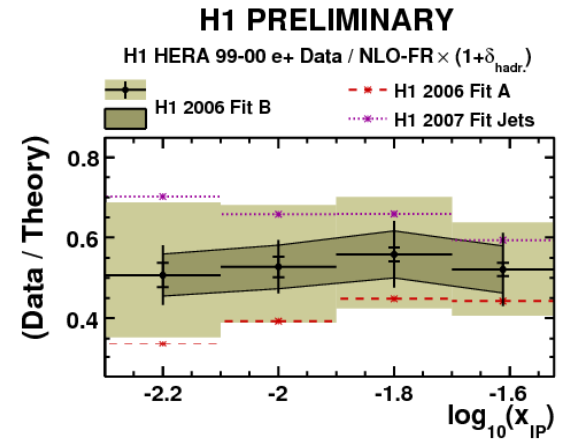
0.6 – 0.9, depending on dPDF
ZEUS coll.,Eur.Phys.J C55,177 (2008)

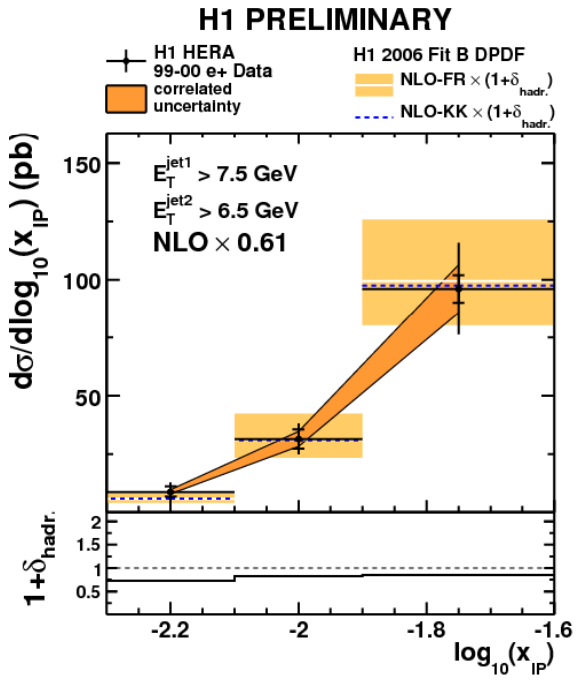
Lower E_t scenario

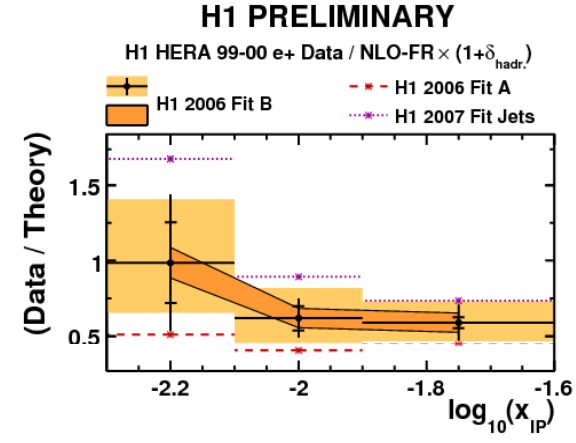
x_{IP}

Higher E_t scenario

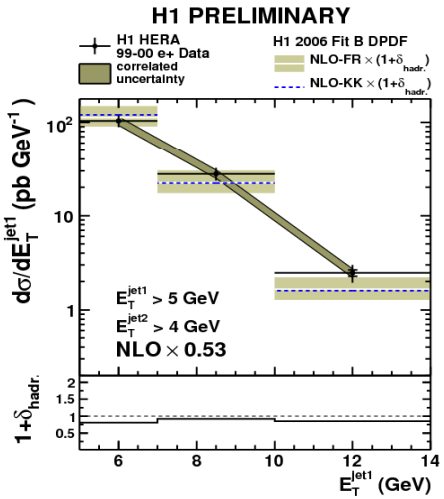


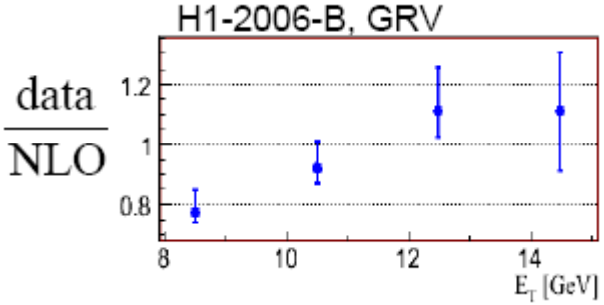




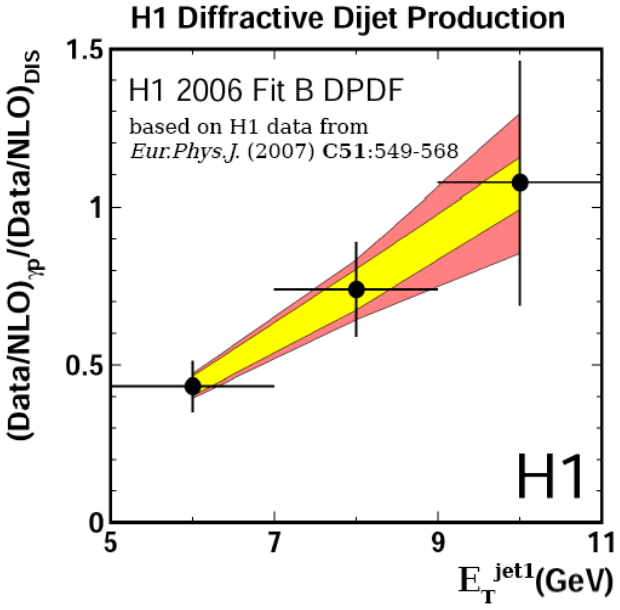


E_t dependence of suppression?





W.Slomiński, ZEUS, DIS 2008

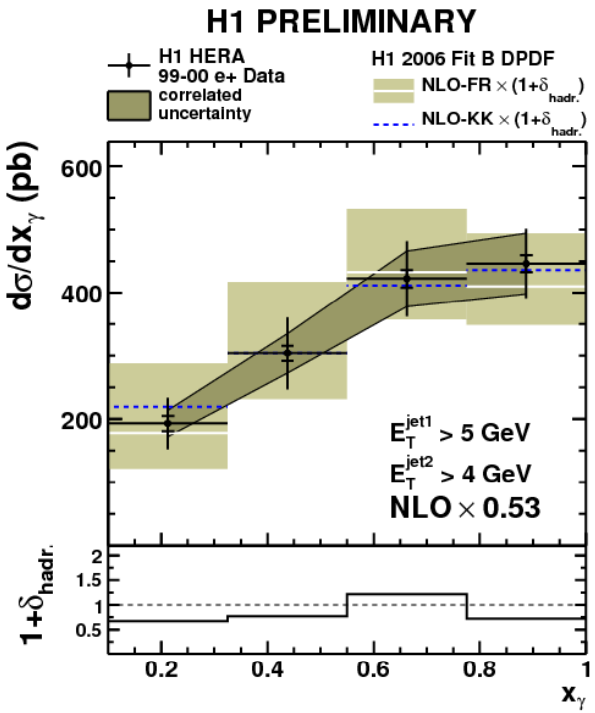


The suggestion of E_t dependence is even stronger when looking at the double ratio NLO/data for photoproduction and DIS – some systematic uncertainties cancelled…..

H1 and ZEUS observe the data have harder E_t slope than NLO

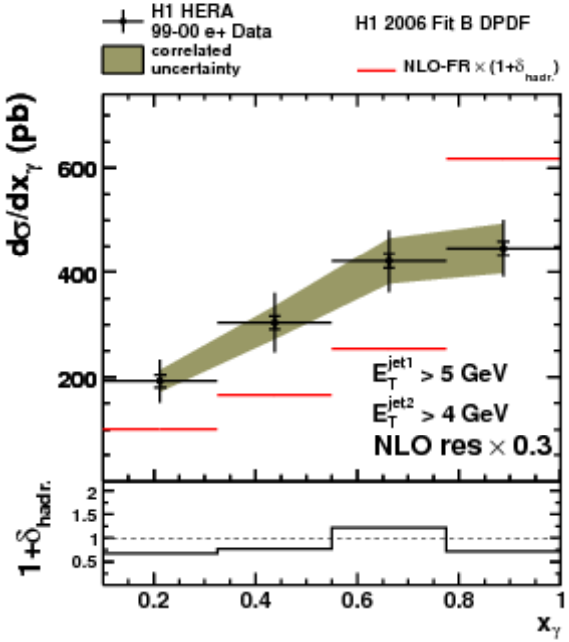
Global and resolved only suppression…

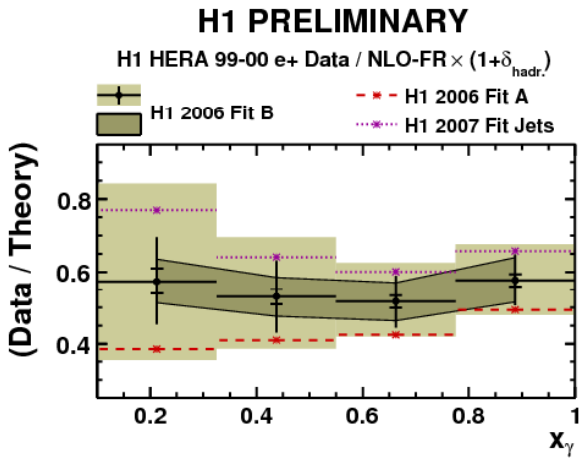
H1 lower E_t cut scenario



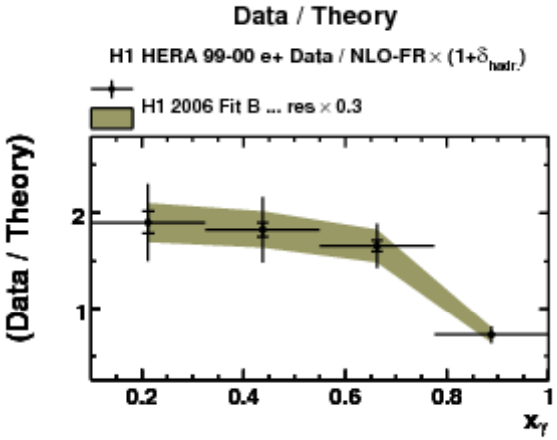
Global suppression 0.53

Data H1 preliminary, suppression of NLO resolved component by 0.3



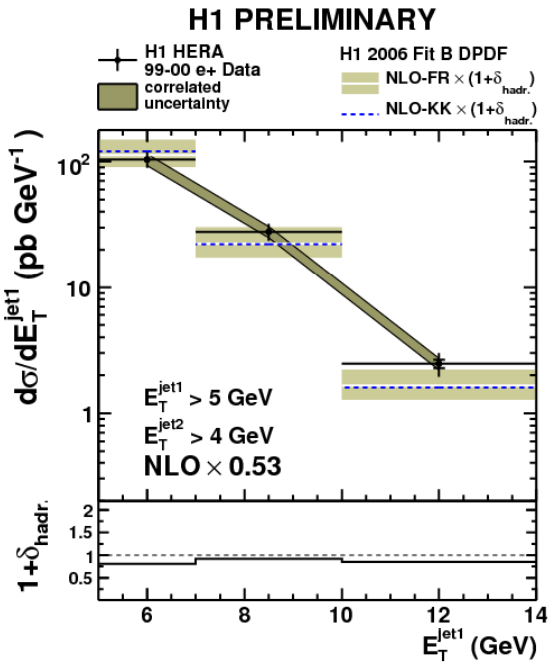


Much worse agreement than for global suppression



Global and resolved only suppression…

H1 lower E_t cut scenario



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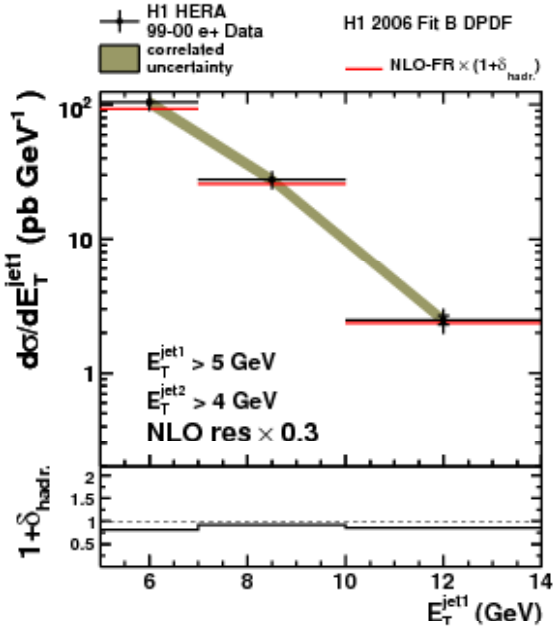
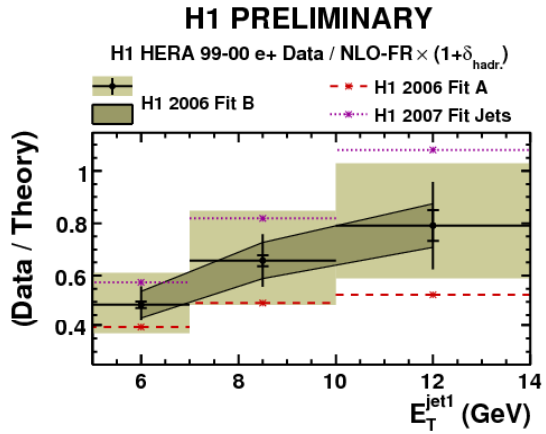
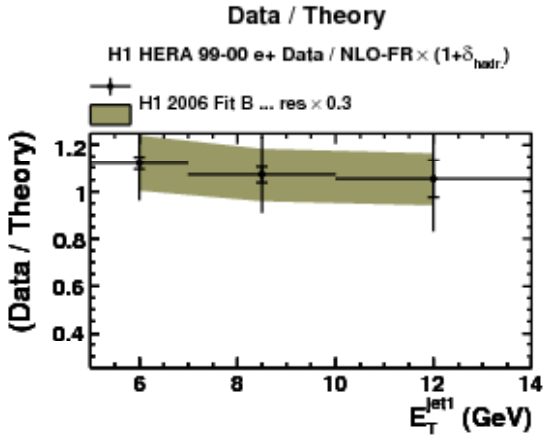




No E_t dependence but prize is worse agreement data & NLO for x_γ **and also for other distributions!!!**



(Some) answers…

- Is factorization valid for diffractive dijets and D* production in DIS and photoproduction?

Factorization seems to be valid for difractive DIS dijets and D* DIS and photoproduction.
Factorization is broken for dijets in photoproduction.

- How large is the suppression in comparison to no breaking ?

Suppression seems to be dependent on the E_t cut of the leading jet, it is about 0.5 for lower E_t cut of jets and is weaker for higher E_t cut

- Does breaking of factorization occur in both PH direct and resolved dijet production?

Yes, it was obtained by both H1 and ZEUS by three independent measurements.
The global suppression gives better agreement data & NLO than resolved only suppression

Weak points….

The most weak points:

- data & NLO → without hadronization corrections (taken from LO Monte Carlo!) direct comparison with NLO not possible
- theory – huge scale uncertainties → NNLO?

Outlook

Very important for LHC predictions, measuring of Higgs in diffraction etc.