Factorisation in diffraction at HERA

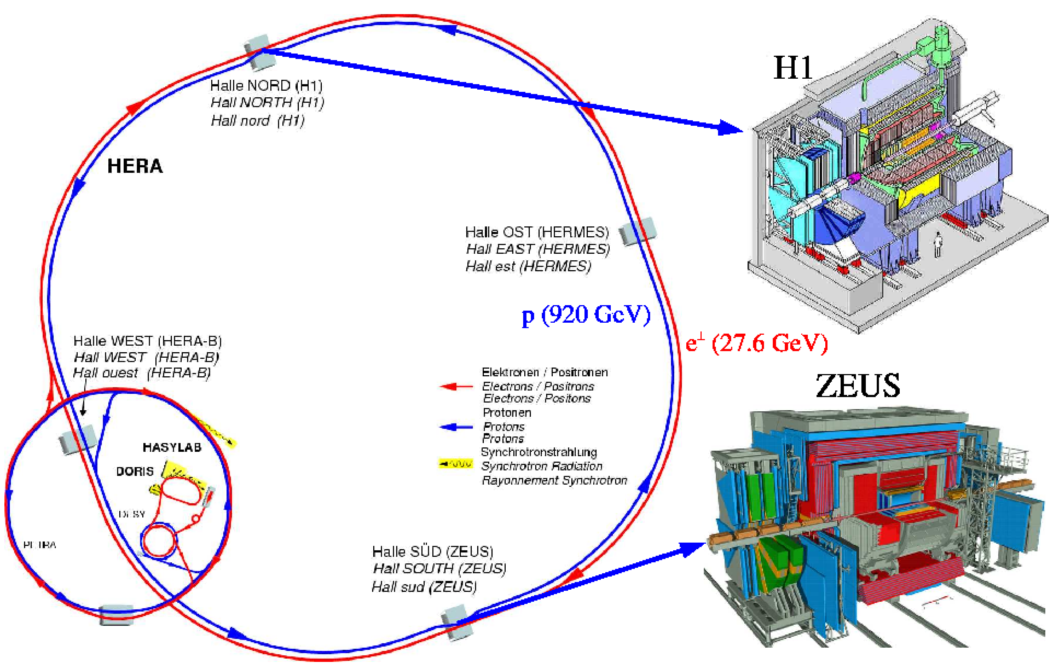
Alice Valkárová
Charles University, Prague

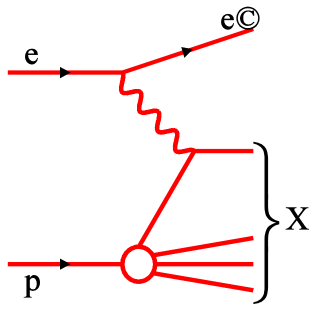
Representing H1 and ZEUS collaborations

Low x workshop, Kavala 2010

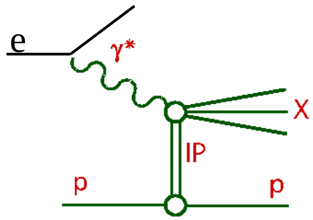
HERA collider experiments

- 27.5 GeV electrons/positrons on 920 GeV protons →$\sqrt{s}$=318 GeV
- two experiments: H1 and ZEUS
- HERA I,II: about 500 pb^{-1}
- closed July 2007, still lot of excellent data to analyse……



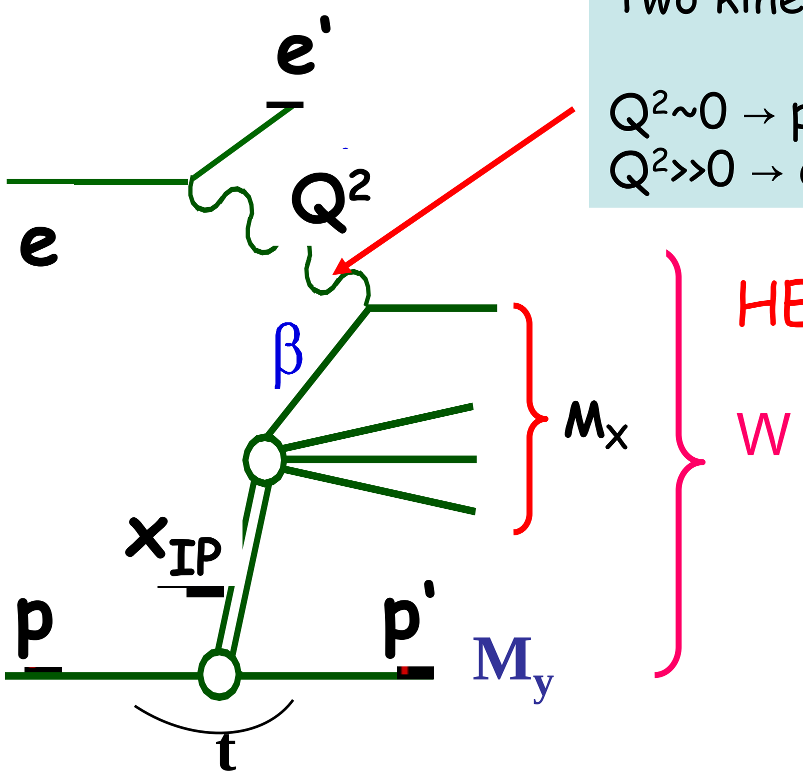


DIS: Probe structure of proton → F_2



Diffractive DIS: Probe structure of difraction → F_2^D

Diffraction and diffraction kinematics



Two kinematic regions 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 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

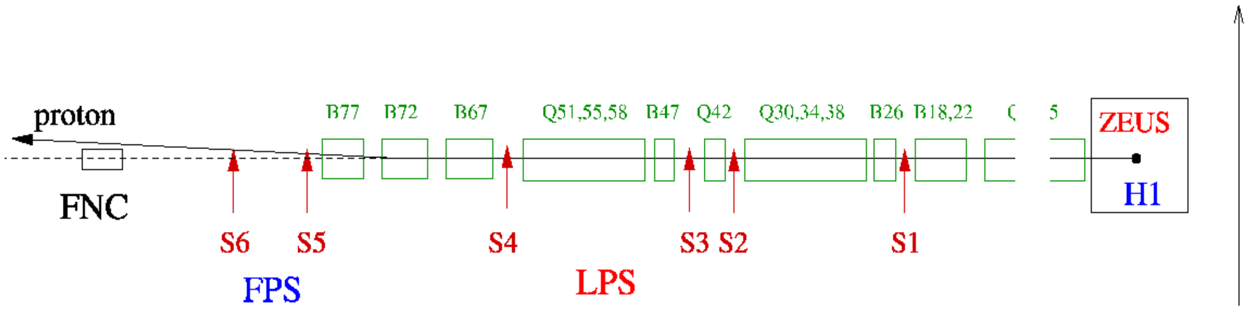
$M_y = m_p$ proton stays intact, needs detector setup to detect protons

$M_y > m_p$ proton dissociates, $\longrightarrow$ contribution should be understood

Methods of diffractive ev.selection

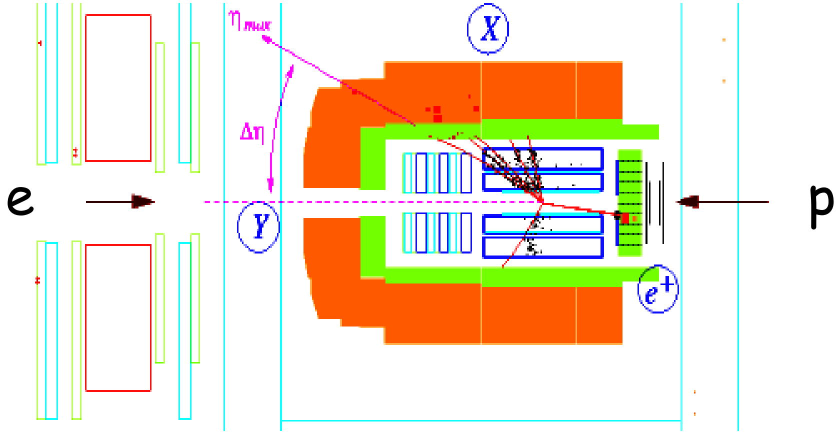
Proton spectrometers

ZEUS: LPS (1993-2000)
H1: FPS (1995-2007)
VFPS (2002-2007)



M_x method, ZEUS:
Diffractive vs non-diffractive: exponential fall off vs constant distribution in $\ln M_x^2$

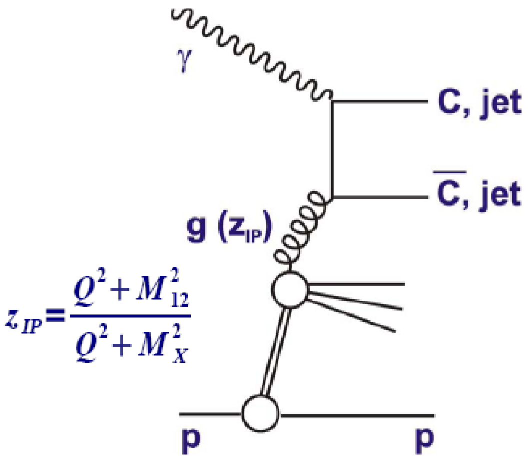
Large Rapidity Gap, H1, ZEUS:
require no activity beyond η_{max}
t is not measured
very good acceptance at low x_{IP}
p-diss background about 20% ☠



Different systematics – non-trivial to compare!

Next results -> LRG method was used!

Photoproduction, γp, $Q^2 \to 0$

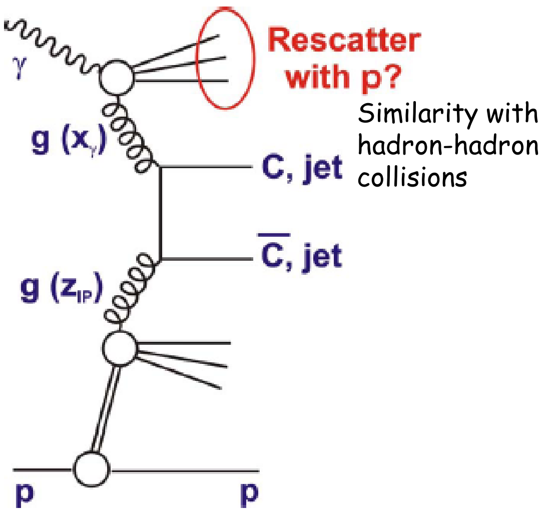


direct

In LO!

x_γ - fraction of photon's momentum in hard subprocess

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



resolved

direct photoproduction

photon directly involved in hard scattering

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

hadron -like component

photon fluctuates into hadronic system, which takes part in hadronic scattering

$x_\gamma < 0.2$ (at parton level)

point -like component of resolved photon

dominates in the region of $0.2 < x_\gamma < 1$

Two types of factorisation

QCD factorisation holds for inclusive and non-inclusive processes:
- photon is point-like (Q^2 is high enough)
- higher twist corrections are negligible (M_X is high enough)

QCD factorisation theoretically proven for DIS (Collins 1998)

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

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

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

It allows the extraction of 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

Tests of QCD factorisation

Basic strategy:

- measure a particular diffractive final state
- compare the measurement with NLO calculation using DPDFs previously extracted

What kind of final states?

- processes with a hard scale
- sensitive to gluons (gluons contribute by up to 80% to the DPDFs, mainly for high z_{IP})

Dijets and D* in DIS/photoproduction are the best candidates!

Factorisation in hadron-hadron collisions

Exporting DPDFs from HERA to Tevatron does not work

$$S^2 = \frac{\sigma\,(\text{data})}{\sigma\,(\text{theory})}$$ → suppression factor

Factorisation broken by β-dependent factor ~ 10, $S^2 \sim 0.1$.

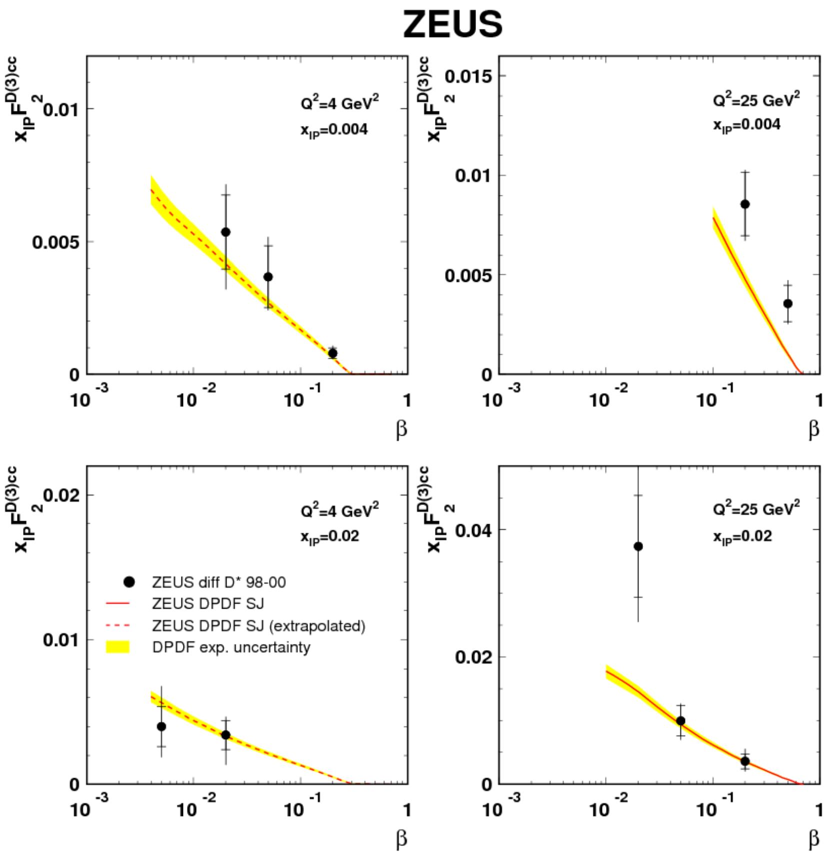
Succesfully explained in terms of rescattering and absorption
(see Kaidalov,Khoze,Martin,Ryskin:Phys.Lett.B567 (2003),61)
KKMR predicted suppression factor for HERA resolved photoproduction

$S^2 \sim 0.34$

In 2010 new theoretical prediction by KKMR:
(European Journal of Physics 66,373 (2010))
Suppression 0.34 present only for hadronic part of photon PDF (**x_γ<0.2**),
for dominant point-like component →
suppression: quarks GRV **0.71(0.75)** E_T^{jet1} >5 (7.5) GeV
gluons GRV **0.53(0.58)** E_T^{jet1} >5 (7.5) GeV

What we learned from HERA data?

DIS dijets – factorisation theoretically predicted.
Both H1 and ZEUS confirmed experimentally and used for QCD fits („H1 fit jets“, „ZEUS fit SJ“).



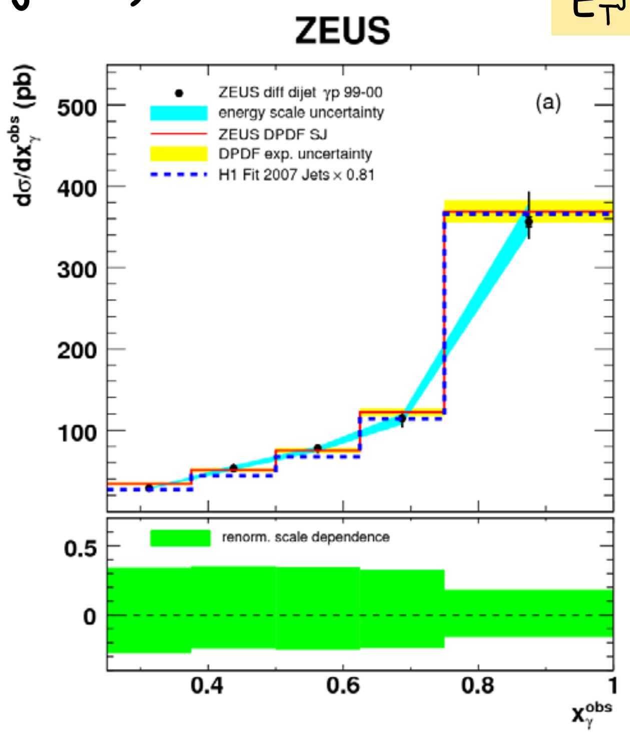
D* in DIS & photoproduction–
data within large errors not in contradiction with factorisation

New ZEUS fits compared to published DIS D* data.
(Nucl.Phys. B672 (2003),3.)
(Nucl.Phys. B831 (2010), 1)

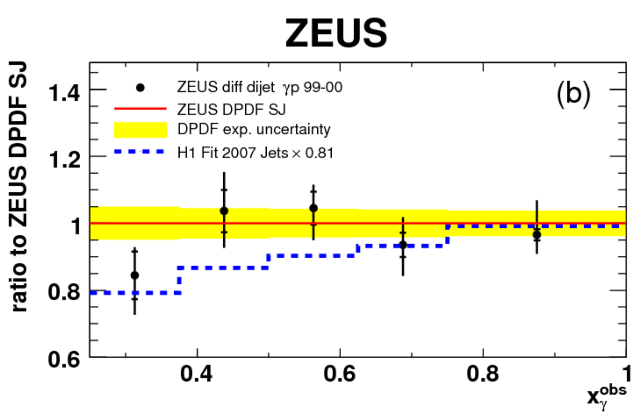
What we learned from HERA data?

Photoproduction dijets – factorisation not predicted theoretically, experimentally not fully understood…. different conclusions made by H1 and ZEUS, H1 observed suppression about 0.5-0.6, ZEUS negligible suppression (in different phase space, e.g.larger E_T of jets.)

$E_T^{jet1} > 7.5$ GeV, $E_T^{jet2} > 5$ GeV



Published ZEUS dijet photoproduction data (Eur.Phys.J.C 55 (2008),177) compared to NLO with „H1 fit Jets" and „ZEUS fit SJ"



Dijet photoproduction

$E_T^{jet1} > 5$ GeV

$E_T^{jet2} > 4$ GeV

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

$x_{IP} < 0.03$

$0.3 < y_e < 0.65$

$Q^2 < 0.01\ GeV^2$

$|t| < 1\ GeV^2$

$M_Y < 1.6$ GeV

$z_{IP} < 0.8$

H1 data 1999-2000

DESY10-043 (2010)

Data compared to RAPGAP MC and NLO
GRV photon structure function

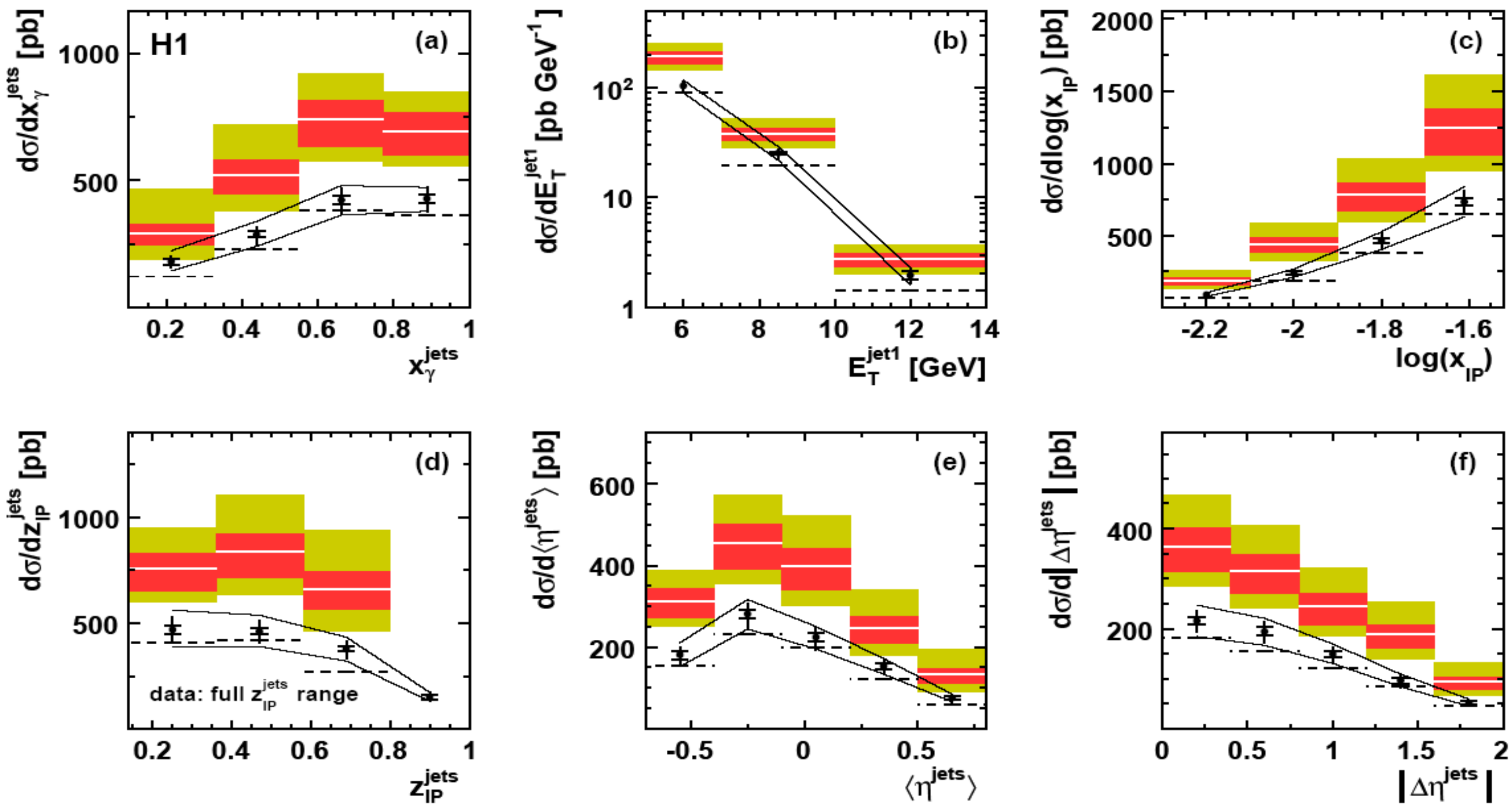
NLO calculations – Frixione/Ridolfi

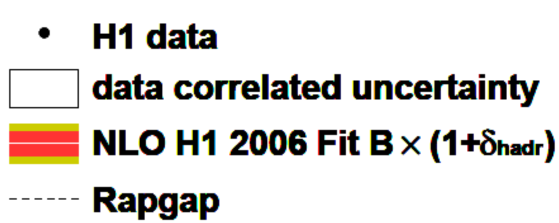
3 sets of DPDFs

- H1 2006 fit B – using inclusive data
- H1 2007 fit jets
- ZEUS SJ fit

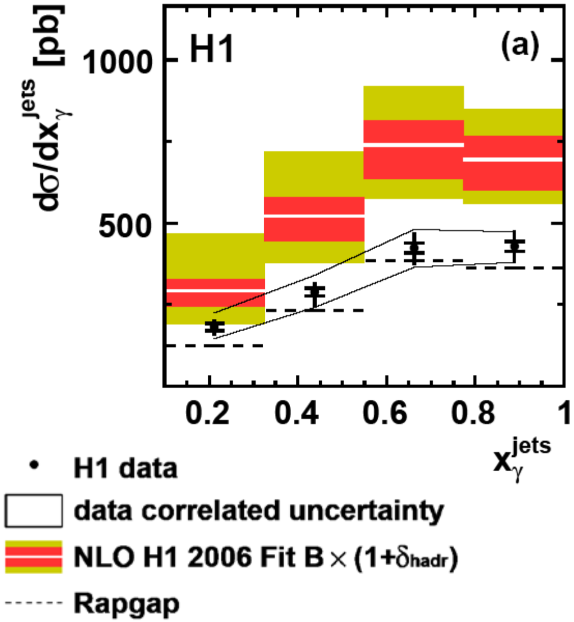
} using DIS dijets

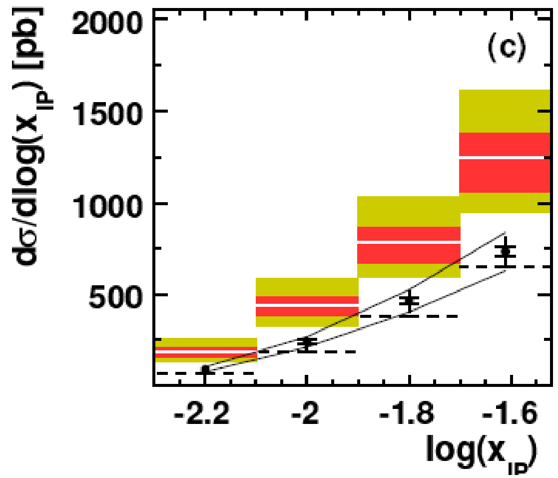
Dijets in photoproduction

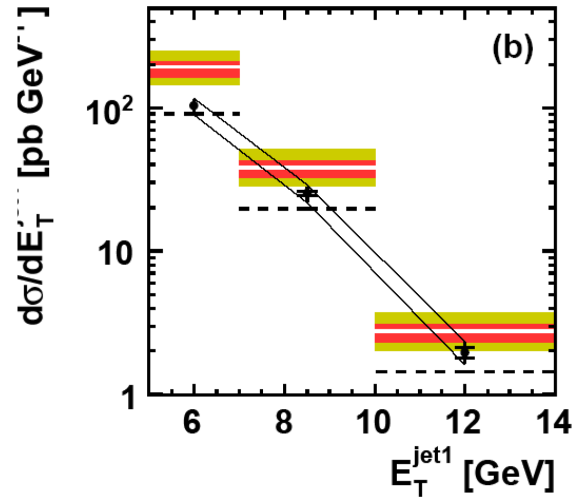




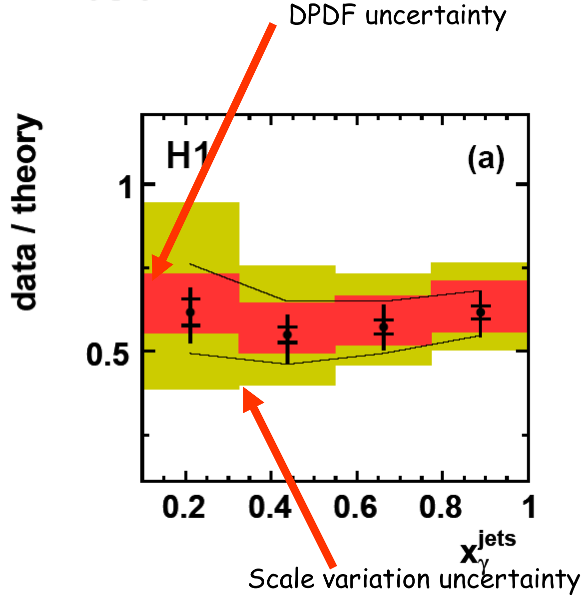
NLO with „H1 fit B“ → larger cross section than data. Shapes of distributions are described. RAPGAP describes data satisfactorily.

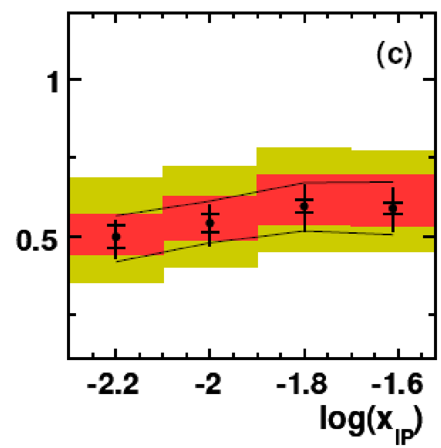


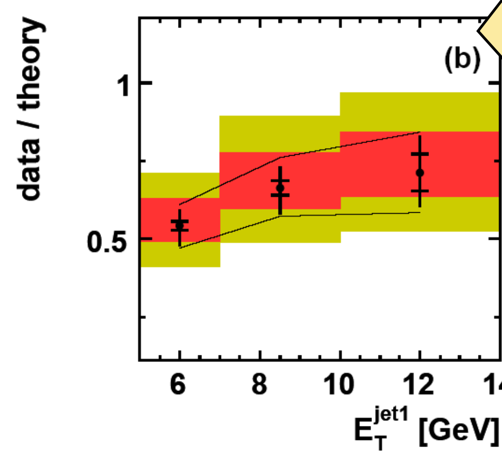




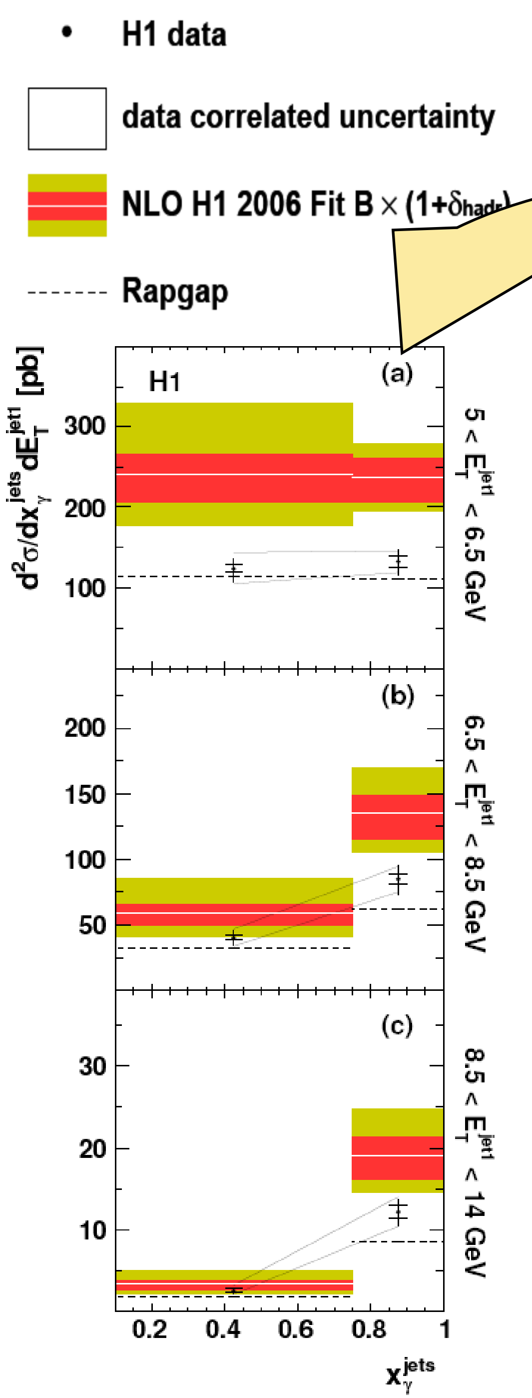
Shapes of distributions are described succesfully, (with the exception of E_t^{jet1}), global suppression of about 0.6 observed….

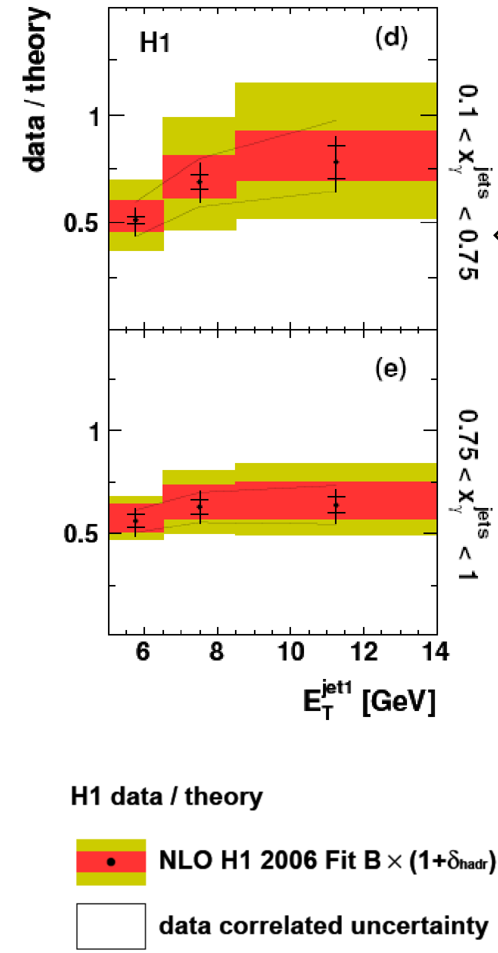






Double differential cross sections

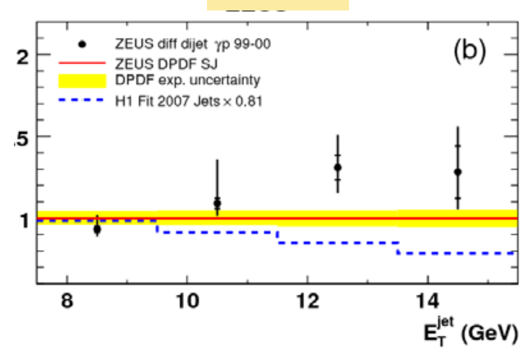




Clear evidence for decrease of resolved component with increasing E_t

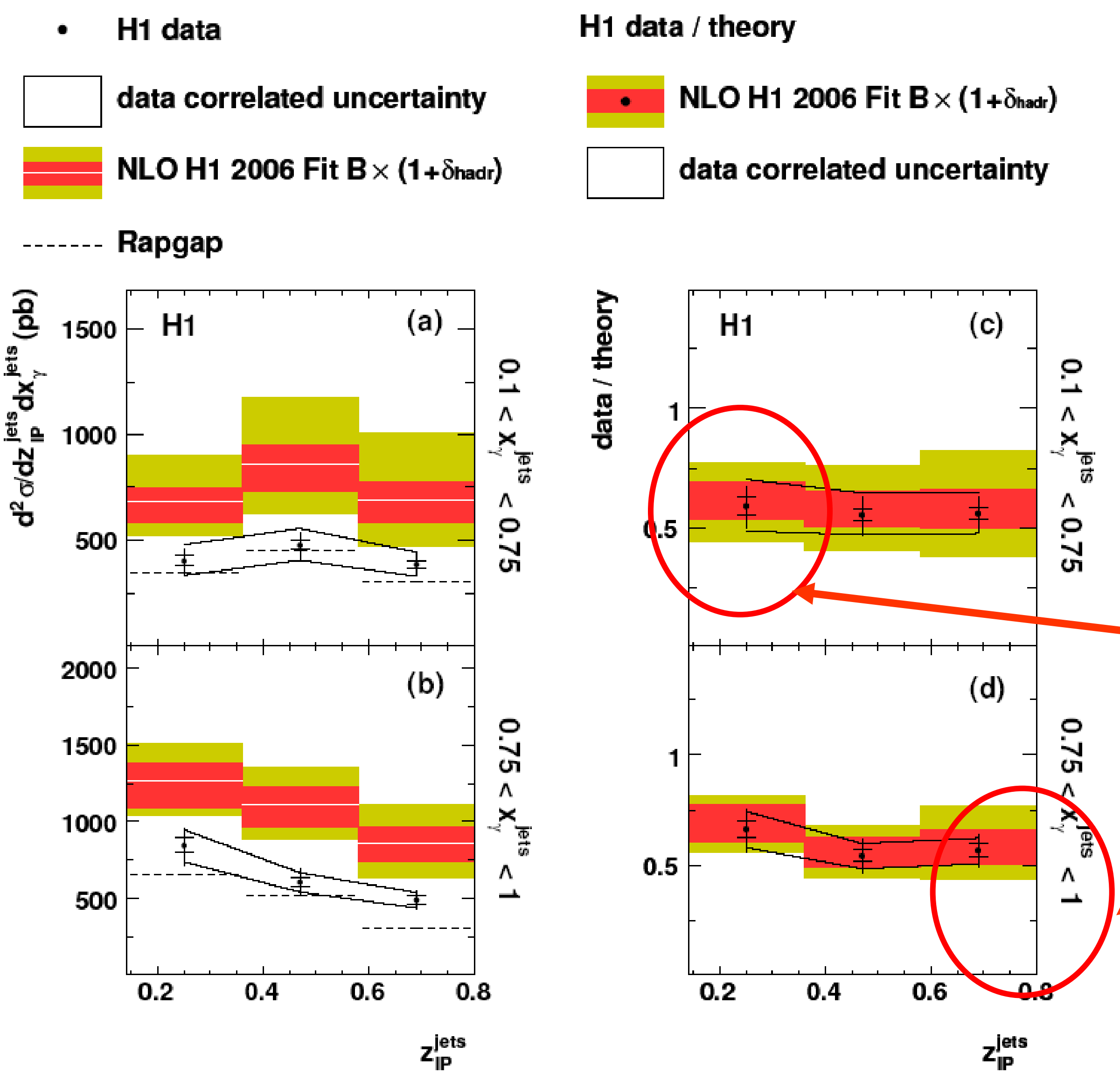
The suppression in resolved enriched region of x_γ may be E_t dependent. (suppression less for higher E_t.)

ZEUS



ZEUS photoproduction dijets
Nucl.Phys. B831 (2010), 1

Double differential cross sections

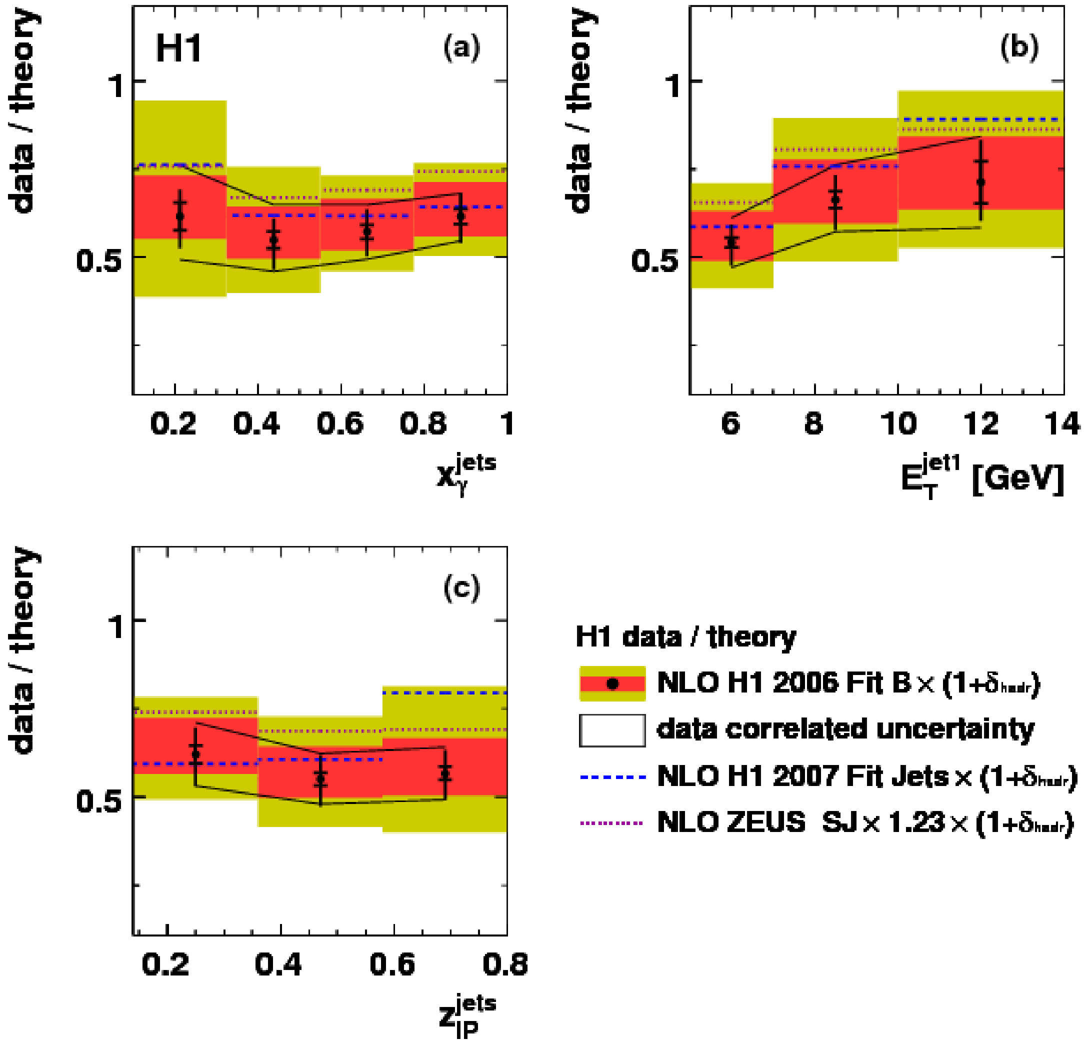


$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$

Shapes of distributions described by NLO well.

Gap survival probabability is insensitive to the presence or nature of remnant (either the photon or diffractive exchange)

Ratio data/theory – 3 DPDFs



„H1 fit jets" and „ZEUS fit SJ" give similar agreement in shape. „ZEUS fit SJ" gives larger prediction by about 15-20 % than „H1 fit B". Differences are covered by theor. uncertainties.

Global suppression:
0.58 for „H1 fit B"
0.64 for „H1 fit jets"
0.70 for „ZEUS fit SJ"

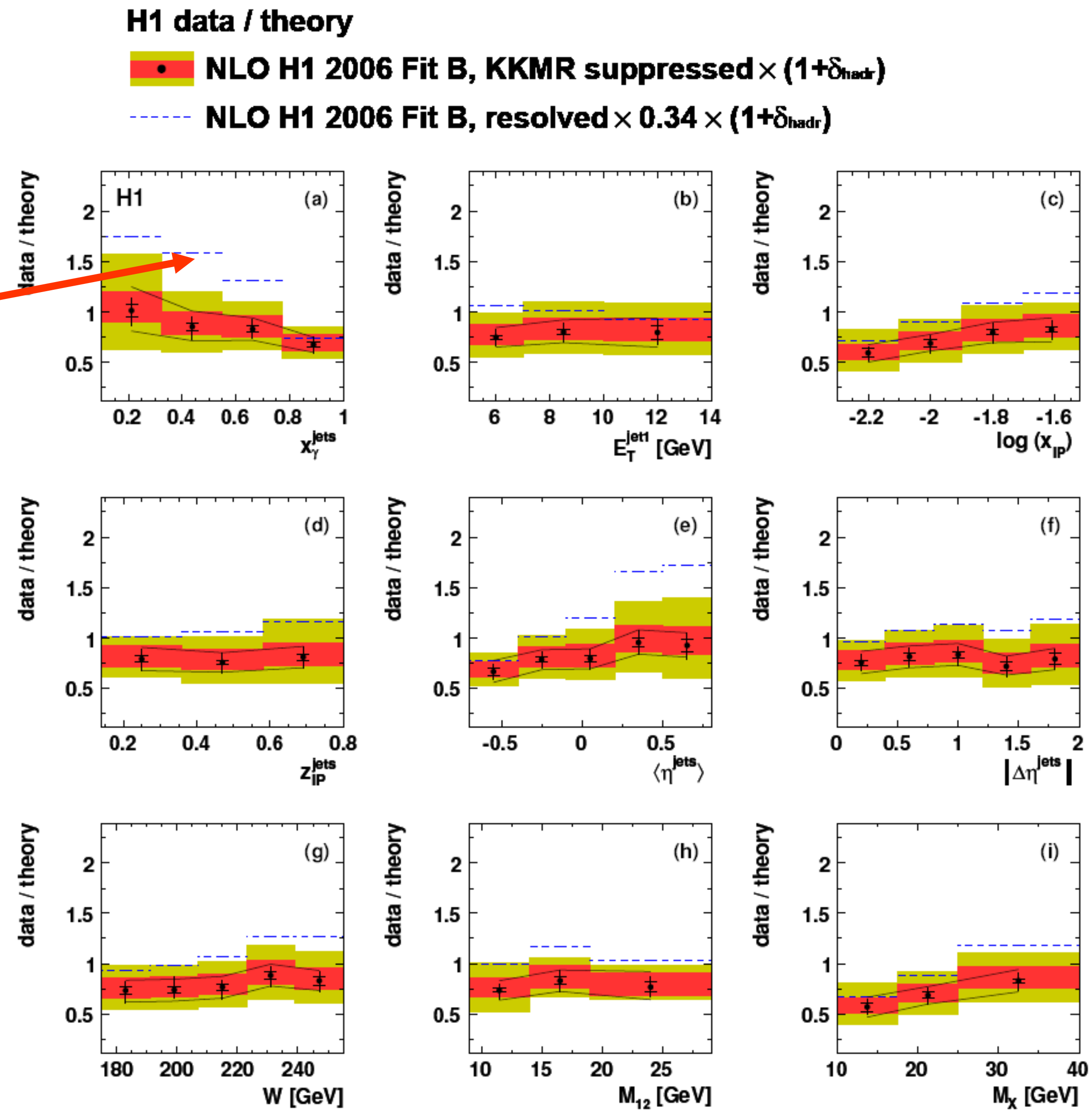
Comparison with KKMR models

NLO calculations

Model KKMR 2003:
resolved part suppressed by 0.34.

Model KKMR 2010:
quarks suppressed by 0.71
gluons suppressed by 0.53

Model KKMR 2010 agrees with H1 data better than model 2003 but shape description is still better with global suppression.



Conclusions

- **DIS dijets, D* in DIS & photoproduction** – factorisation holds.

- **Dijets in photoproduction**:
  conclusions about factorisation using H1 and ZEUS data (with the identical DPDFs) are different….
  H1 – data suppressed by global factor 0.57-0.7 (depending on DPDF).
  ZEUS – compatible with no suppression
  possible explanation →
  suppression is decreasing with increasing E_T of the jets.

- Shapes of distributions described better by NLO using „H1 fit B" and global suppression than using the suppression from KKMR 2010 model.
- Suppression is insensitive to the presence or nature of remnant (either the photon or diffractive exchange).