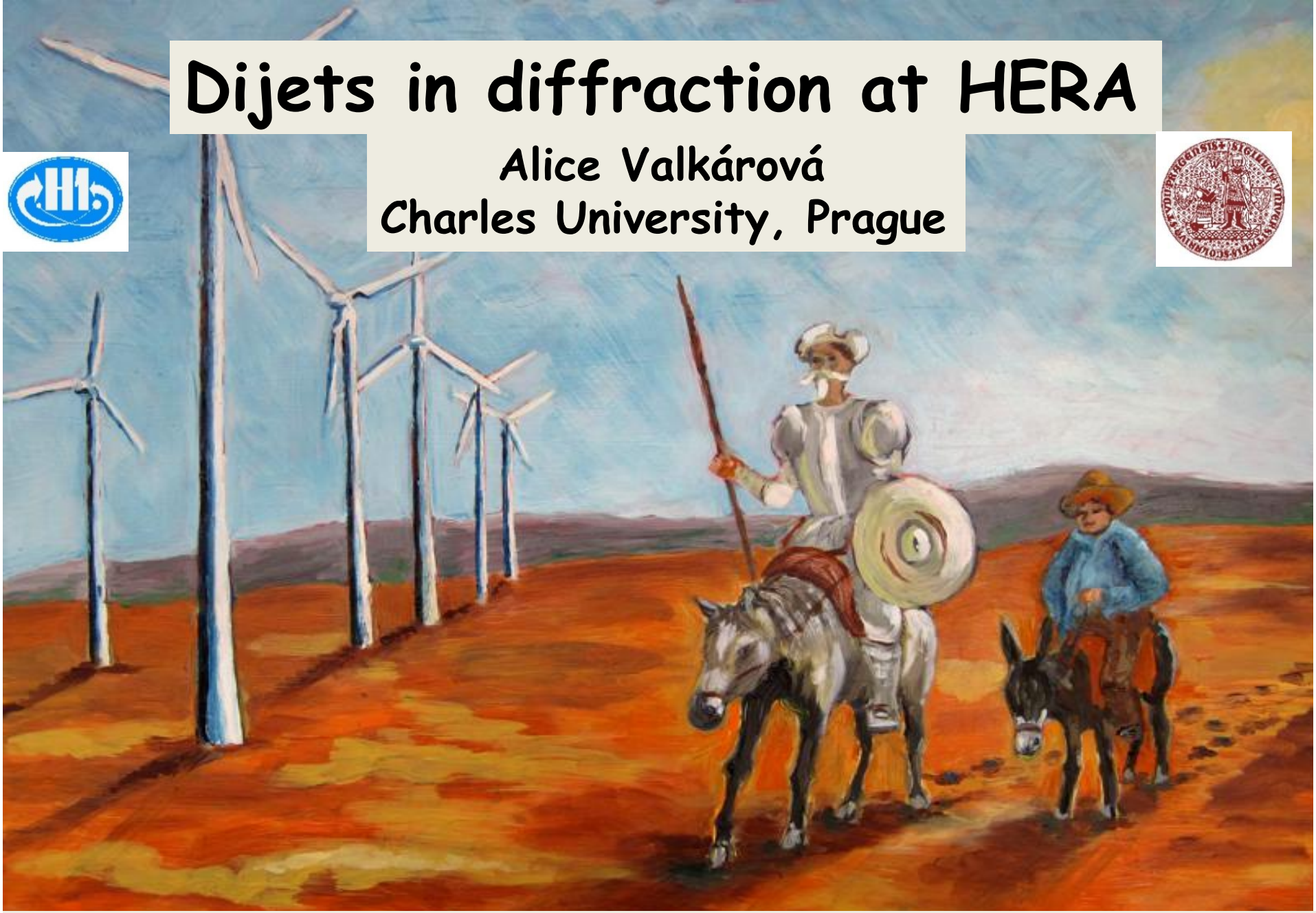
Dijets in diffraction at HERA

Alice Valkárová
Charles University, Prague



on behalf of H1 Collaboration

HERA collider experiments

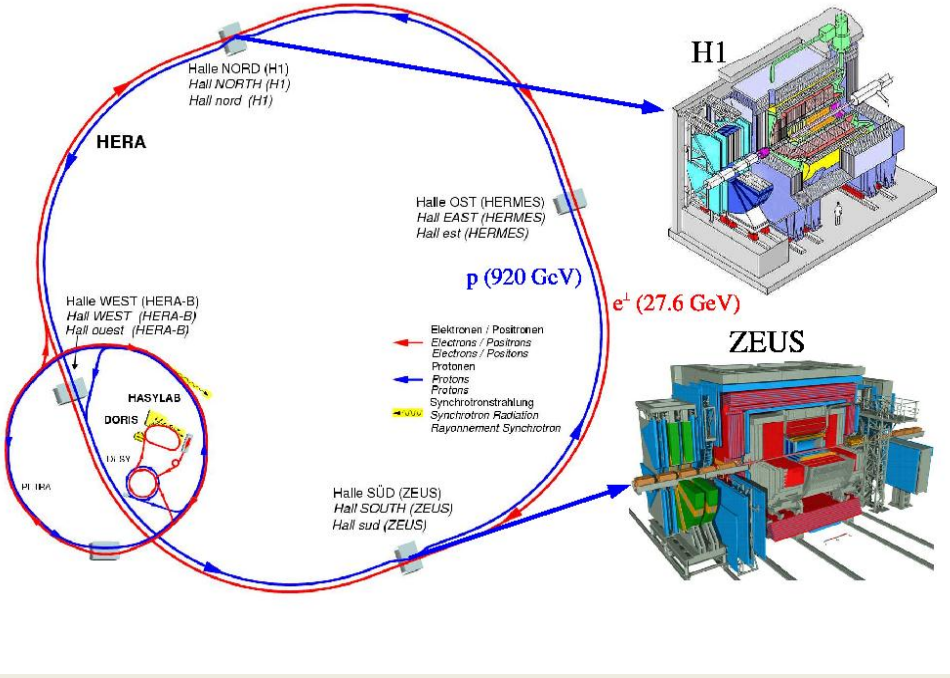
- 27.5 GeV electrons/positrons on 920 GeV protons →√s=318 GeV
- data taken in 1992-2007
- HERA I,II: ~ 500 pb^{-1} per experiment
- H 1 & ZEUS - 4π detectors

Why to study diffraction?

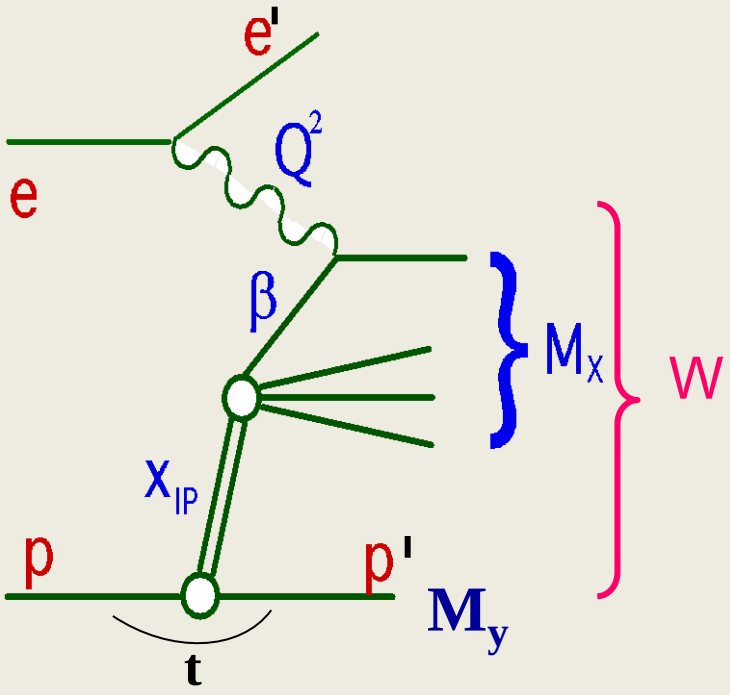
Fundamental aim:
understand high energy limit of QCD

Novelty:
probe partonic structure of diffractive exchange

Applications: study factorisation properties, transport PDFs to hadron-hadron scattering (Tevatron, LHC).



Diffractive kinematics



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

HERA: ~10% of events diffractive

$$x_{I\!P} = \xi = \frac{Q^2 + M_X^2}{Q^2 + W^2}$$

momentum fraction of color singlet exchange

$$\beta = \frac{Q^2}{Q^2 + M_X^2} = x_{q/I\!P} = \frac{x}{x_{I\!P}}$$

fraction of exchange momentum, coupling to γ

$M_y = m_p$ proton stays intact, needs detector setup to detect protons
$M_y > m_p$ proton dissociates, contribution should be understood

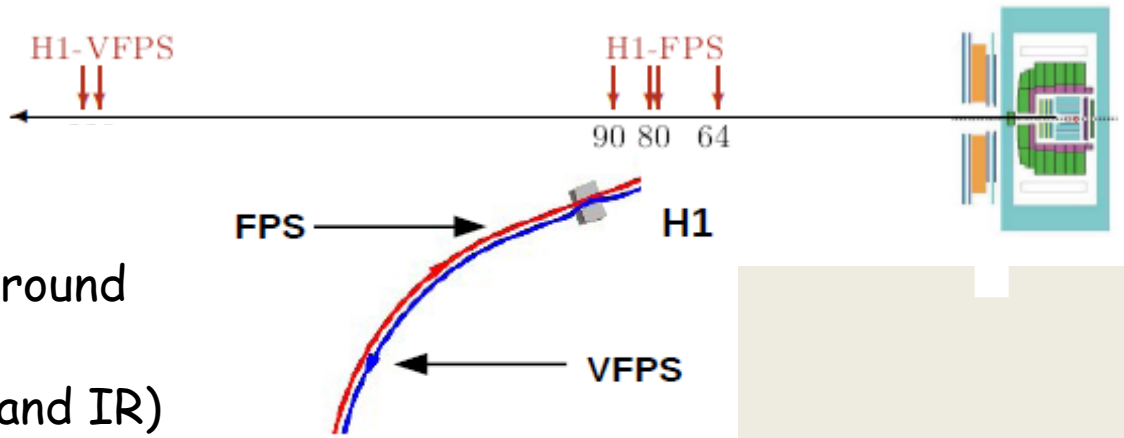
$$t = (p - p')^2 \longrightarrow$$ 4-momentum transfer squared

Methods of diffraction selection

Proton spectrometers

H1: VFPS (2005-2007)
FPS (1997-2007)

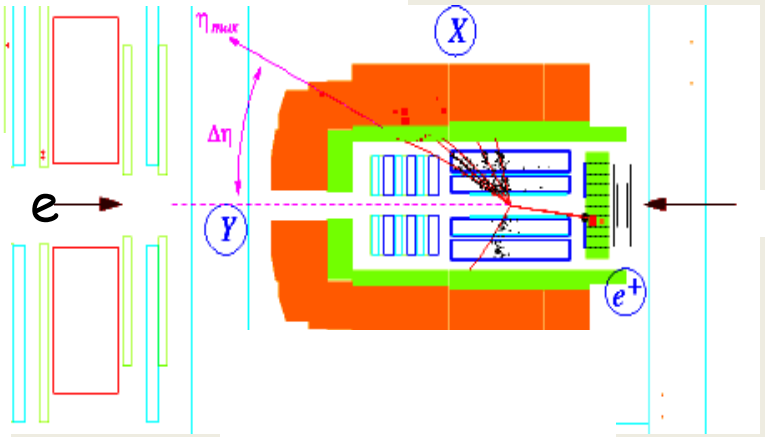
☺ free of p-dissociation background
☺ x_{IP} and t measurements
☺ access to high x_{IP} range (IP and IR)
☹ small acceptance, small statistics



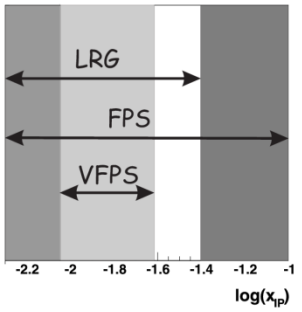
Large Rapidity Gap

require no activity beyond η_{max}

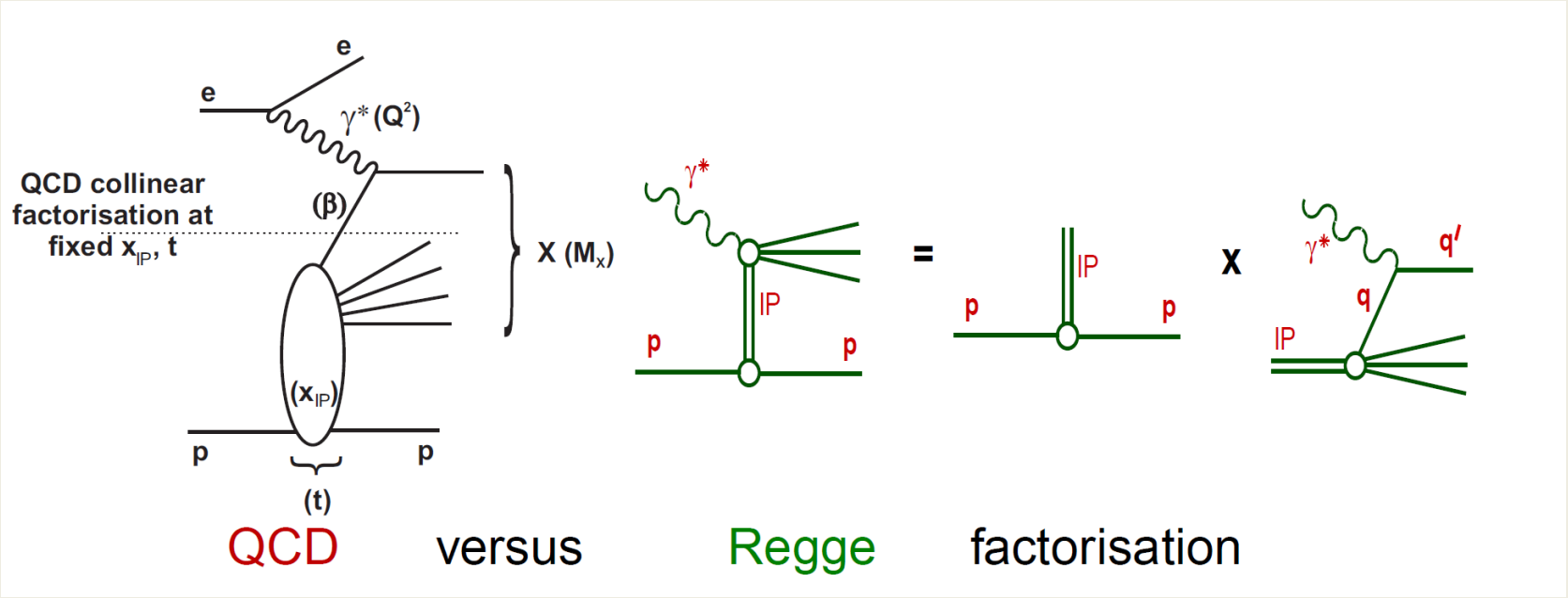
☹ t not measured, integrated over $|t|<1GeV^2$
☺ very good acceptance at low x_{IP}
☹ p-diss background about 20% ☠



Different phase space and systematics – non-trivial to compare!



Factorisation properties of diffraction



QCD factorisation
(rigorously proven for DDIS by Collins et al.)

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

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

$\sigma^{\gamma^* i}$ - hard scattering cross section (same as in non-diffractive DIS)

Regge factorisation
(conjecture, e.g. Resolved Pomeron Model by Ingelman&Schlein)

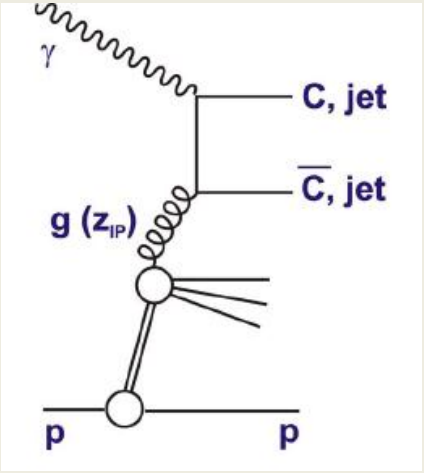
$$f_i^{\,D}(x, Q^2, x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{\,IP}(\beta = x/x_{IP}, Q^2)$$

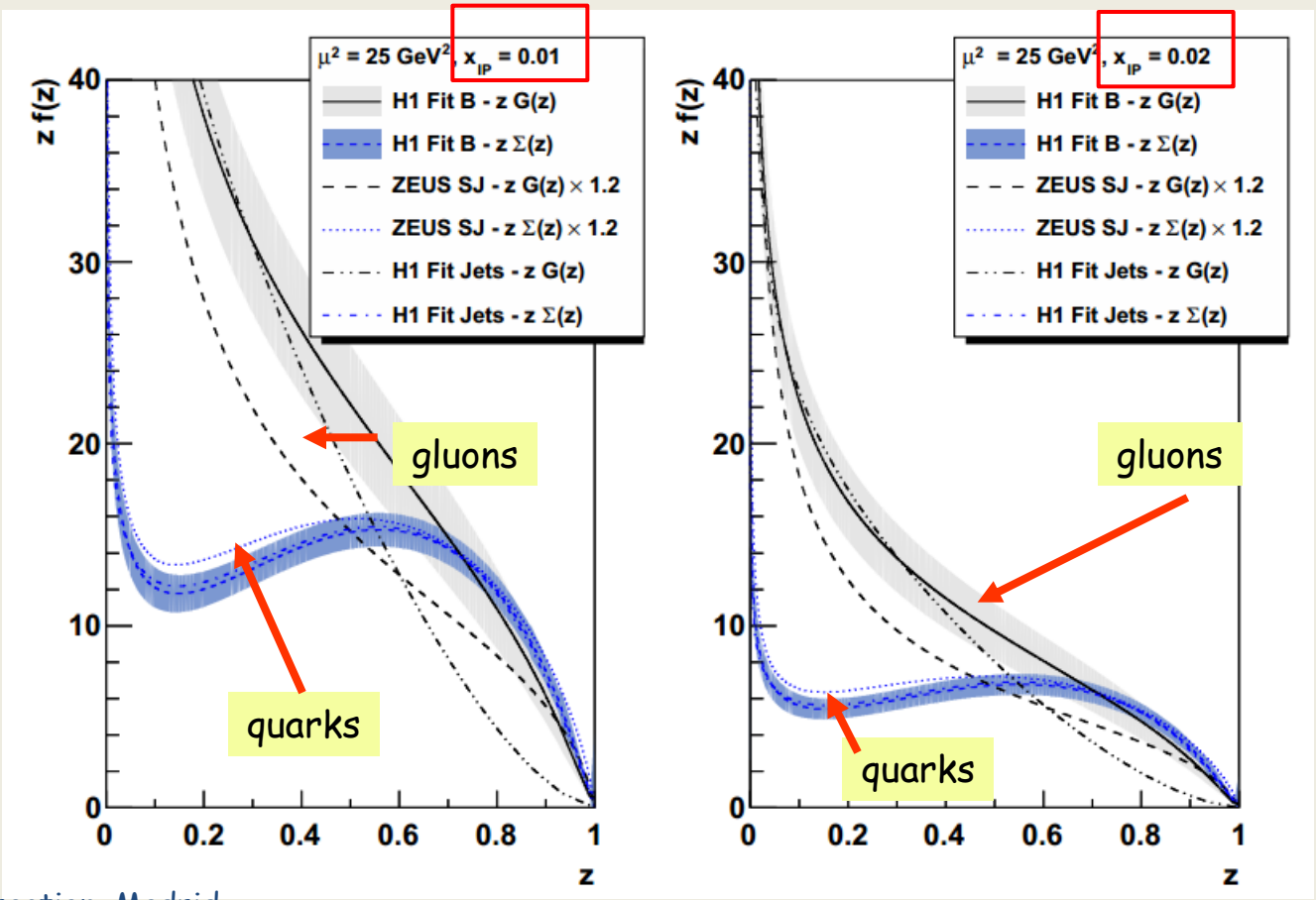
pomeron flux factor — pomeron PDF

DPDFs in DIS

DPDFs obtained by H1 and ZEUS from inclusive, dijet (and D* measurements….)
DPDFs used in HERA analyses - **H1 fit B, H1 fit Jets, ZEUS fit SJ**
Main differences are in gluonic part.

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





Factorisation tests in diffractive dijet production

Measurements compared to NLO QCD predictions, (using HERA DPDFs).

suppression factor

$$S^2 = \frac{\sigma\,(\text{data})}{\sigma\,(\text{theory}_{(\text{NLO QCD})})}$$

Motivation:
Factorisation was found to be broken in hadron-hadron collissions at Tevatron and LHC (CMS and ATLAS), suppression factors $S^2 \sim 0.1$

DIS - several measurements

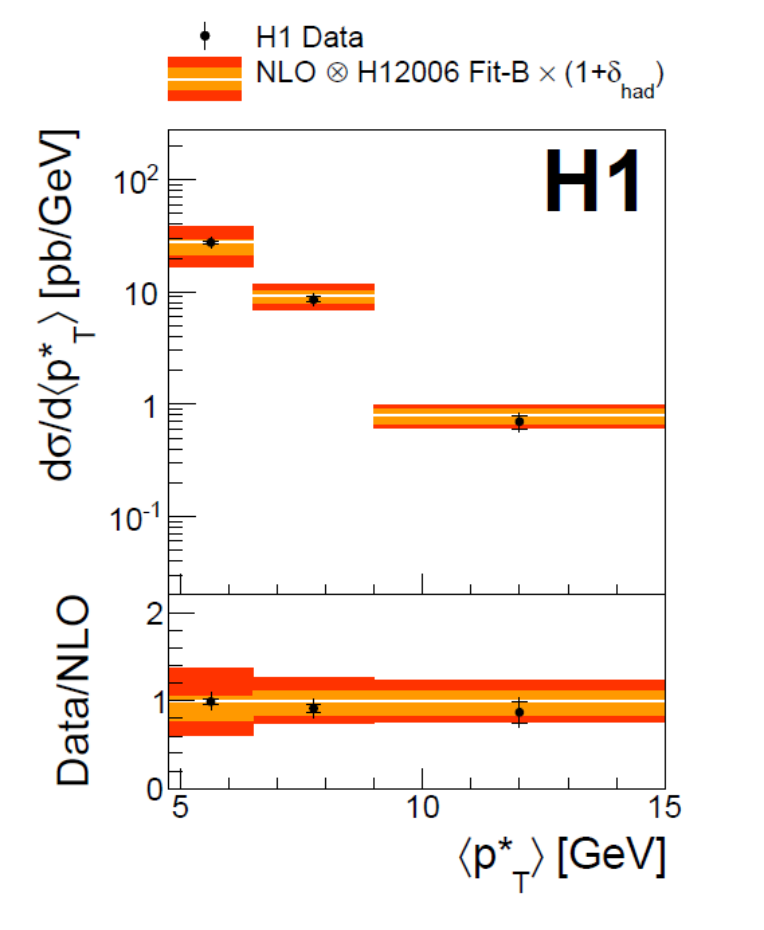
Factorisation **confirmed** by H1 and ZEUS measurements for dijets in DIS using **both** methods for diffraction selection
→ LRG and forward proton detection (H1 -> FPS)

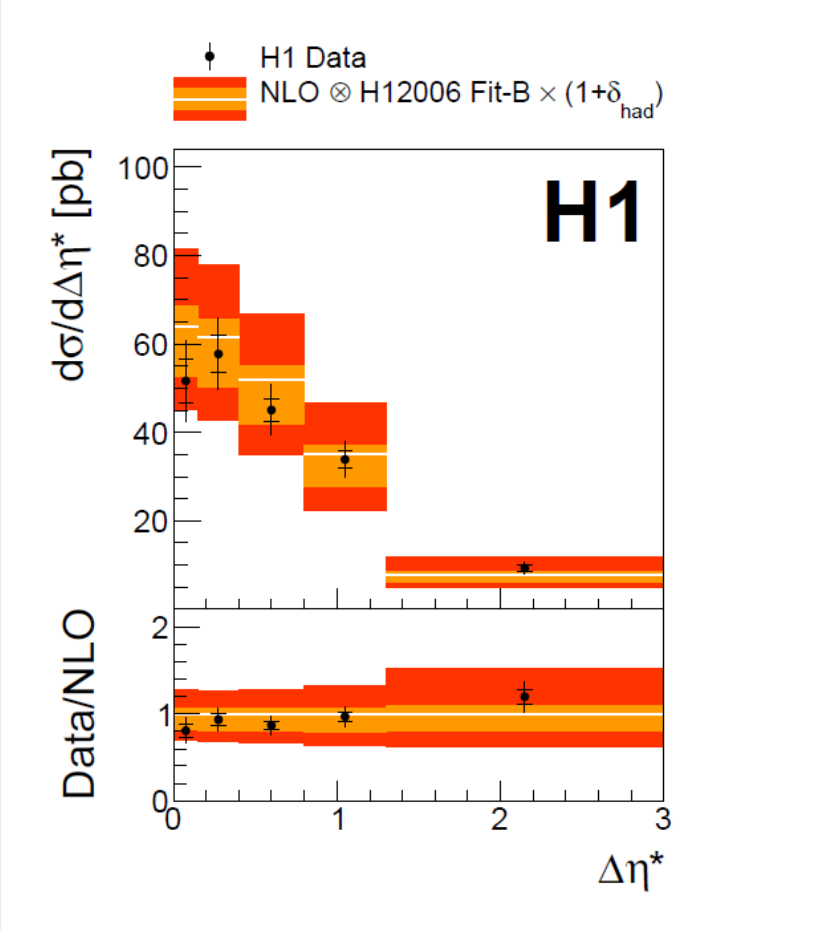
New measurement with 6x larger statistics than previous measurements, LRG method, $E_T^*{}_{\text{jet1(2)}} > 5.5(4)$ GeV, sophisticated unfolding procedure

H1 Coll., JHEP 1503 (2015) 092

Diffractive dijet production in DIS

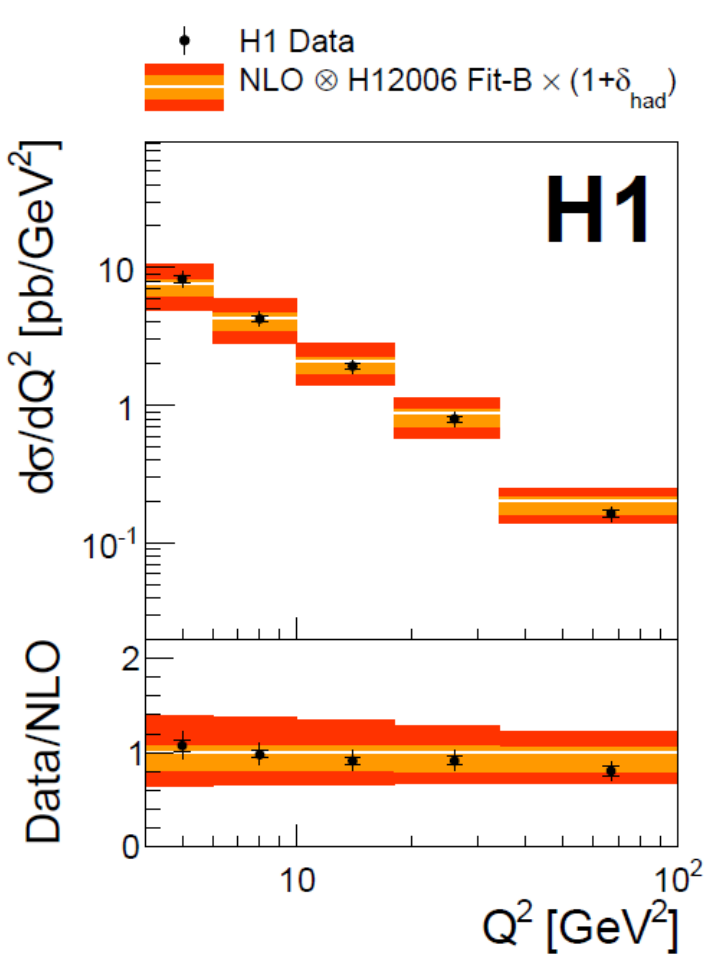
$4 < Q^2 < 100\ GeV^2$, $E_T^*{}_{jet1(2)} > 5.5(4)\ GeV$

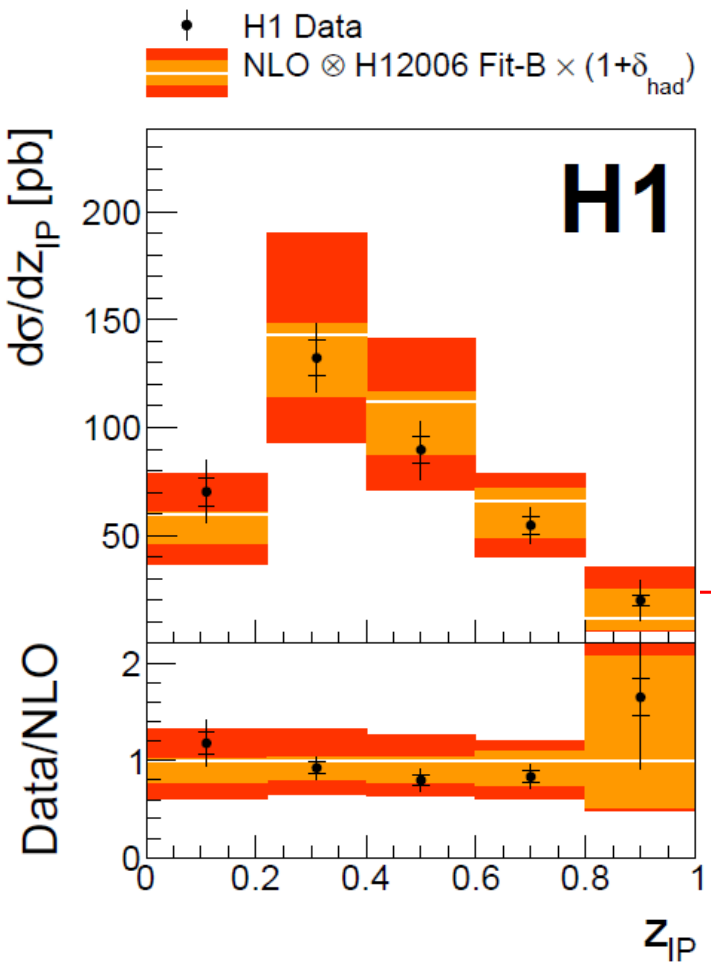


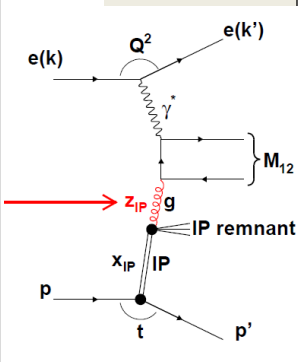


Measurements in agreement with NLO QCD calculations, factorisation confirmed.

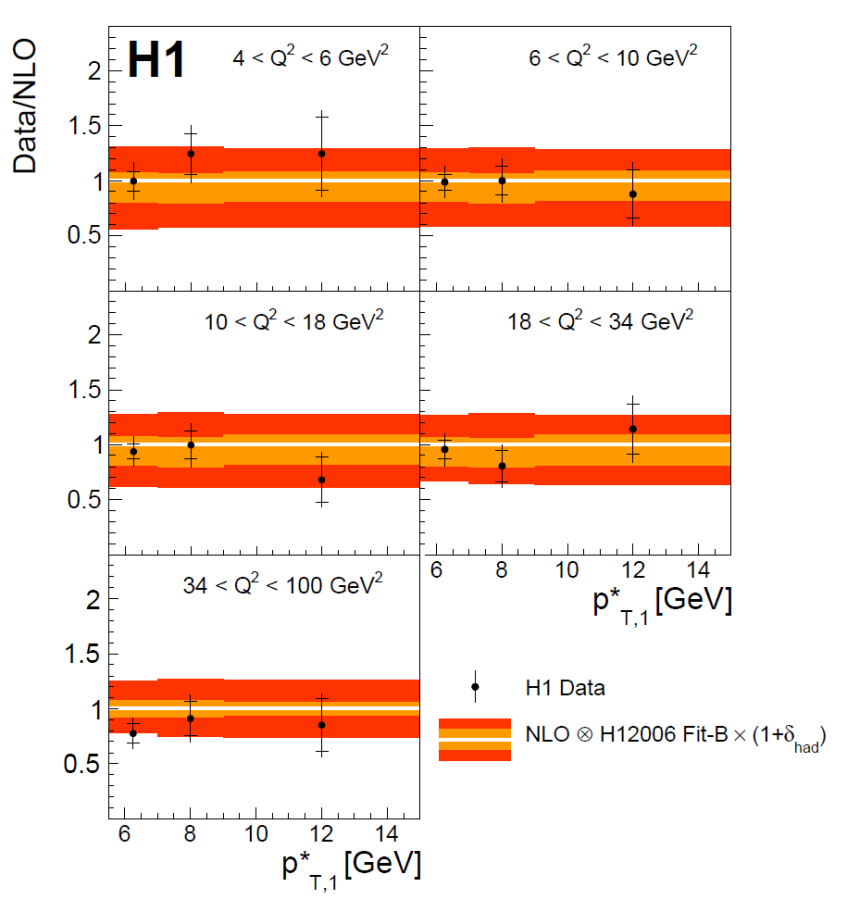
Diffractive dijet production in DIS

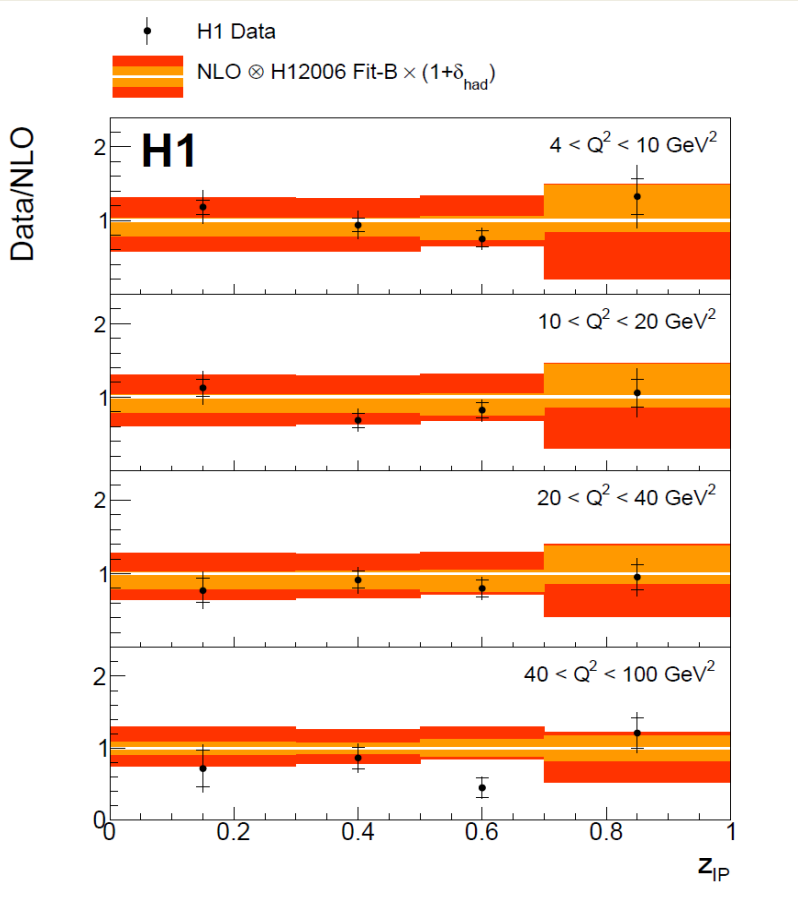






Diffractive dijet production in DIS





$$\alpha_s(M_Z) = 0.119 \pm 0.004\,(\mathrm{exp}) \pm 0.012\,(\mathrm{DPDF, theo})$$

Result is consistent within uncertanties with the world average

Factorisation tests in diffractive dijet production

Not evident that factorisation should be valid also for **photoproduction**, in LO photoproduction contributions of resolved photon process

History -three independent measurements

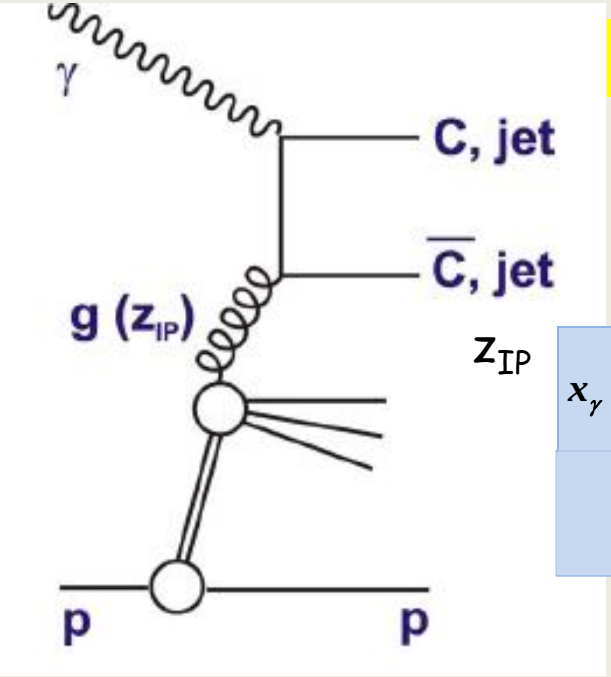
- **H1** – LRG method, tagged photoproduction, $E_T^{jet1(2)}>5(4)$ GeV,
  $S^2 = 0.5 \pm 0.1$ EPJC C51 (2007),549

- **H1** – LRG method, tagged photoproduction , $E_T^{jet1(2)}>5(4)$ GeV,
  $S^2 = 0.58 \pm 0.01 \pm 0.12(exp) \pm 0.14 \pm 0.09(th)$ EPJ C68 (2010),381

- **ZEUS** – LRG method, untagged photoproduction $E_T^{jet1(2)}>7.5(6.5)$ GeV
  $S^2 \sim 1$ Nucl.Phys. B381 (2010)

A new H1 measurement with different diffractive method selection – proton measured in forward proton spectrometer VFPS

Factorisation tests in diffractive dijet photoproduction



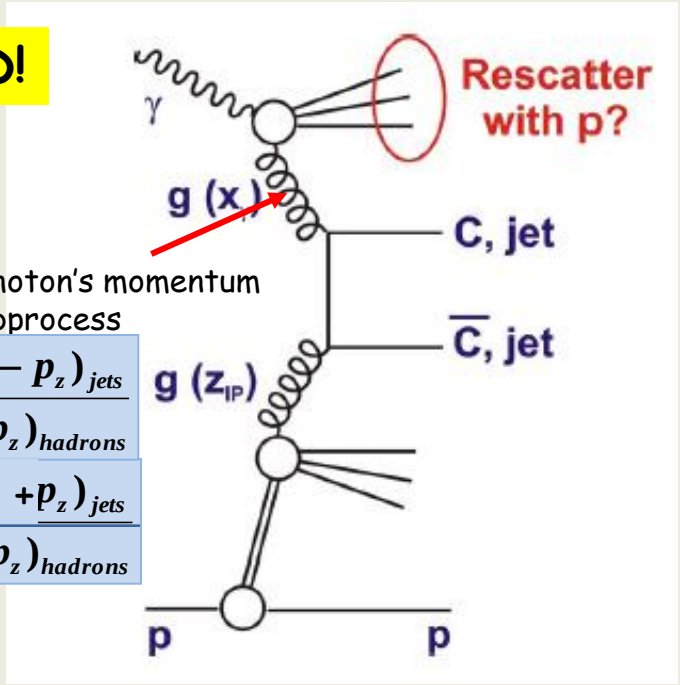
In LO QCD!

x_γ - fraction of photon's momentum in hard subprocess

z_{IP}

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

$$z_{IP} = \frac{\sum (E + p_z)_{jets}}{(E + p_z)_{hadrons}}$$



direct photoproduction:
photon directly involved in hard scattering -> $x_\gamma = 1$

resolved photoproduction:
photon fluctuates into hadronic system, which takes part in hadronic scattering dominant at $Q^2 \simeq 0$ -> $x_\gamma < 1$

Theor.prediction of Kaidalov,Khoze,Martin,Ryskin
(European Journal of Physics 66,373 (2010))

no suppression

suppression: quarks 0.71(0.75) E_T^{jet1} >5 (7.5) GeV
gluons 0.53(0.58) E_T^{jet1} >5 (7.5) GeV

Diffractive dijet photoproduction & DIS - measurement in Very Forward Proton Detector

H1, DESY-14-242, accepted by JHEP

DIS & photoproduction

$4 < Q^2 < 80\ GeV^2$ $Q^2 < 2\ GeV^2$

other cuts identical:

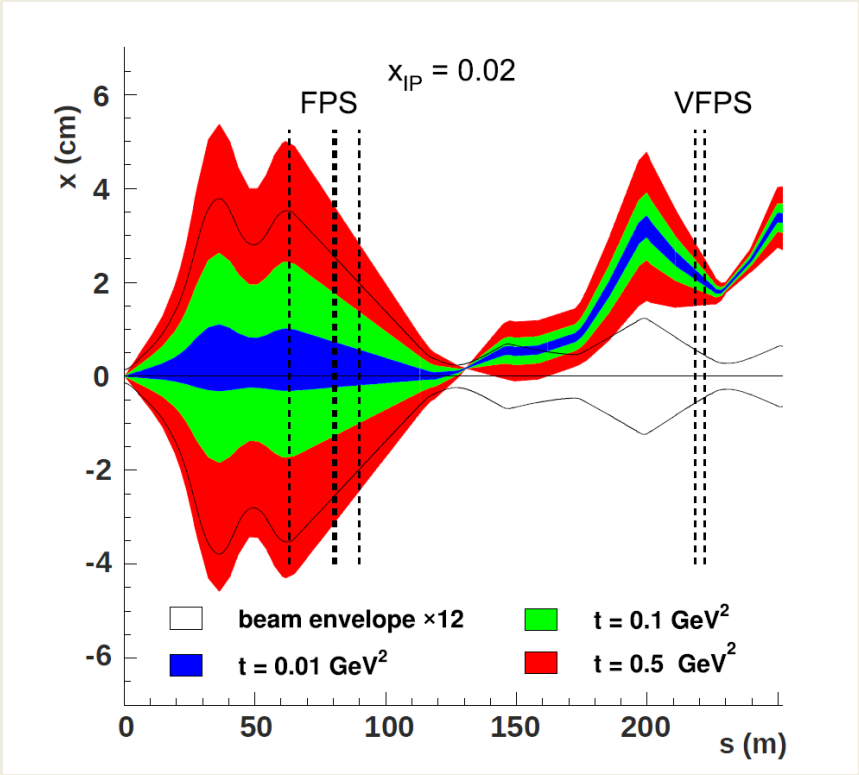
$0.01 < x_{IP} < 0.024$

$|t| < 0.6\ GeV^2$

$z_{IP} < 0.8$

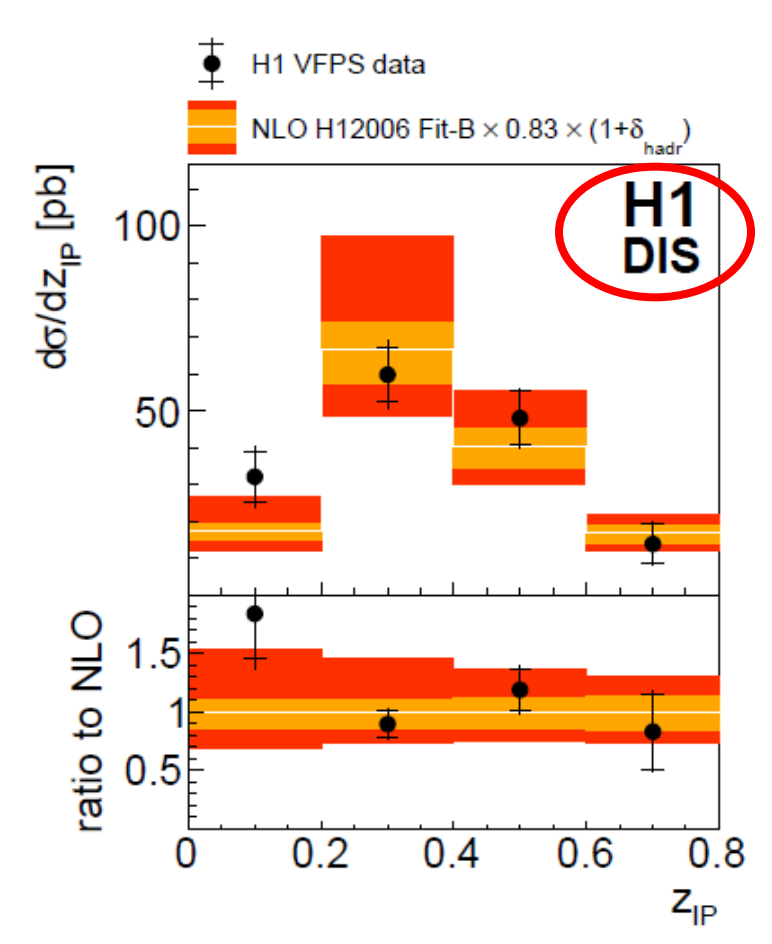
$E_T^*{}_{jet1(2)} > 5.5(4)\ GeV$

$-1 < \eta_{jet1(2)} < 2.5$

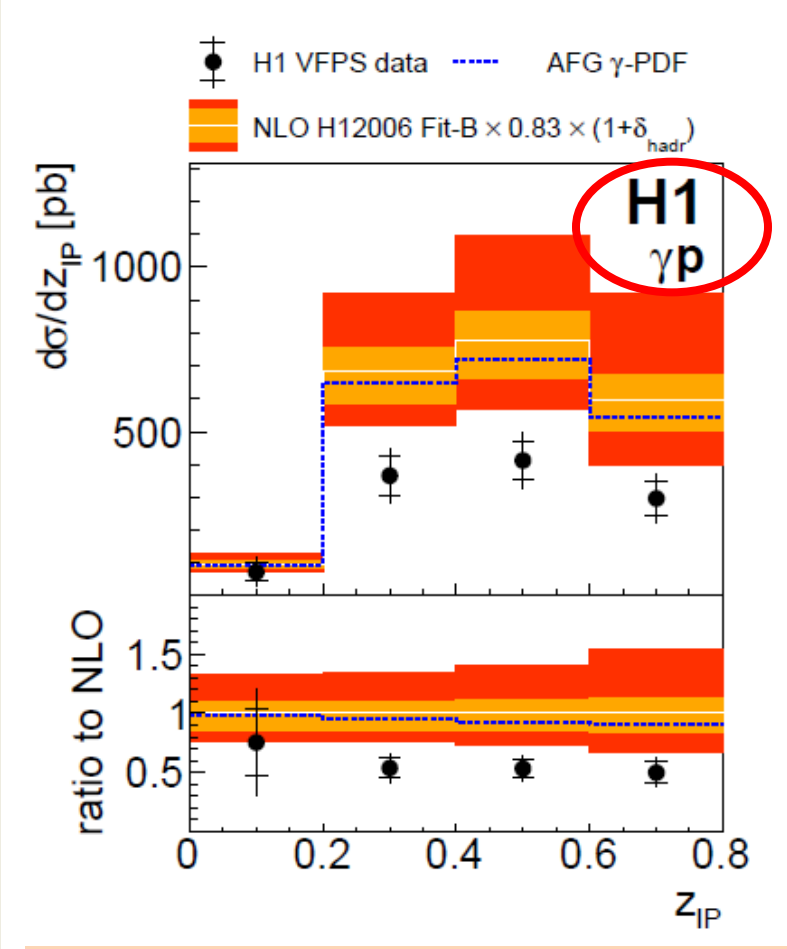


Data unfolded to the level of stable hadrons using Tikhonov method (program TUnfold)

Diffractive dijet photoproduction & DIS

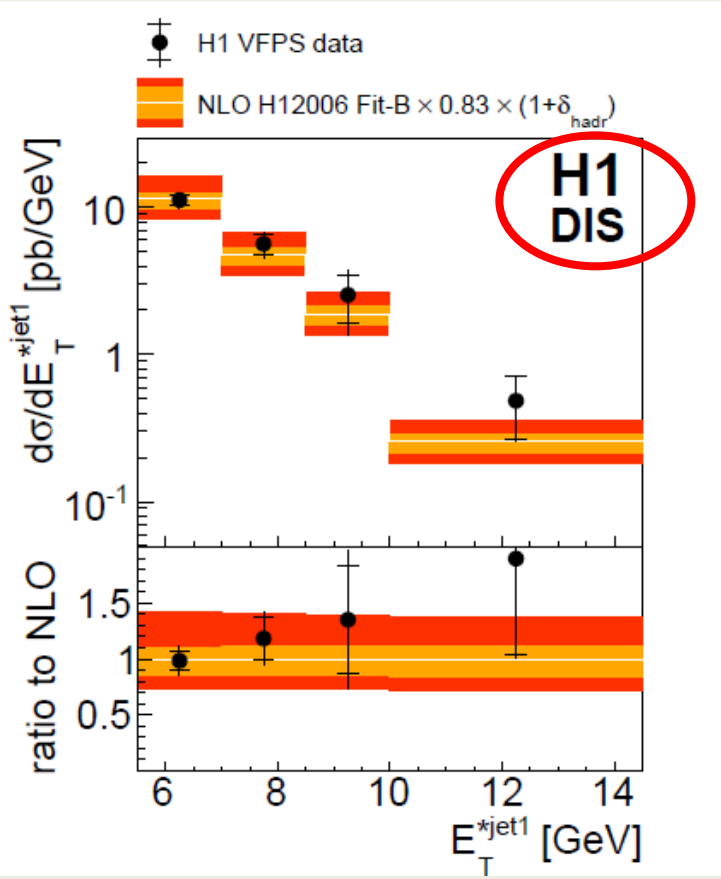


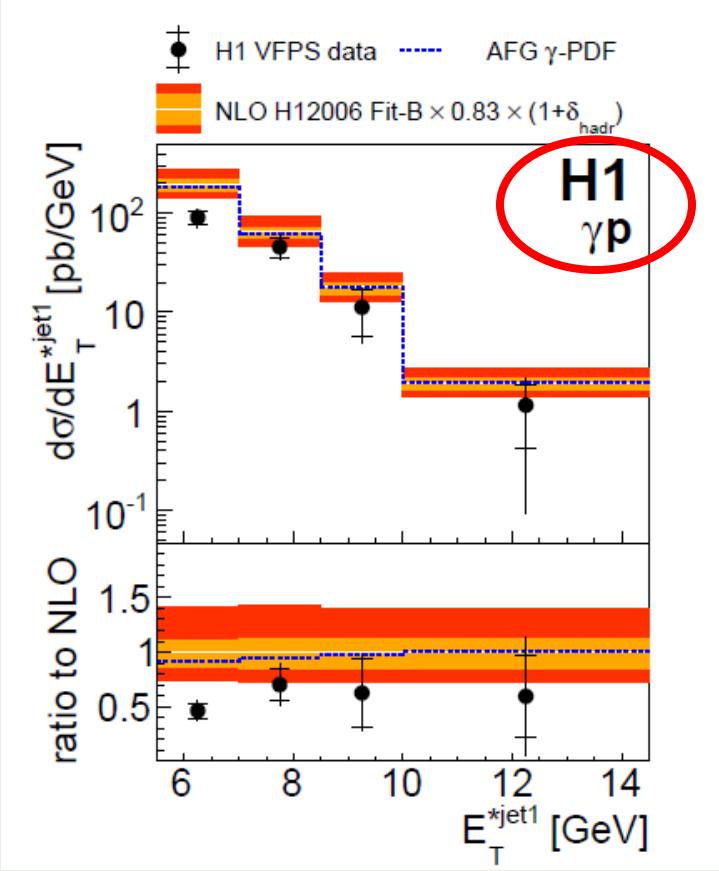
Data in agreement with NLO in DIS, within uncertainites



Data suppressed in comparison with NLO in photoproduction

Diffractive dijet photoproduction & DIS

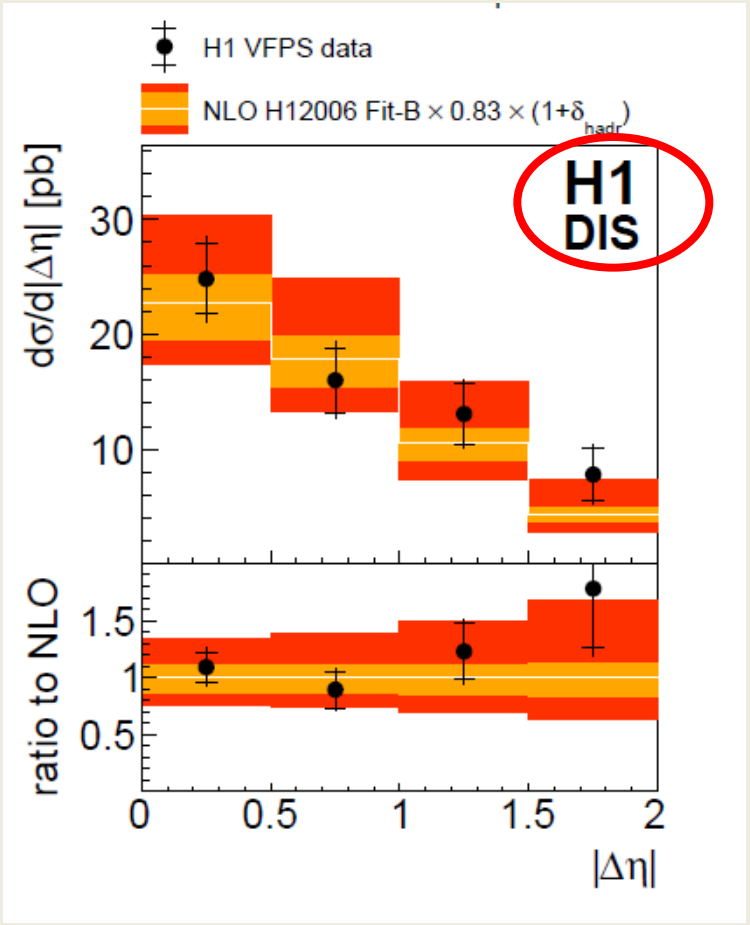


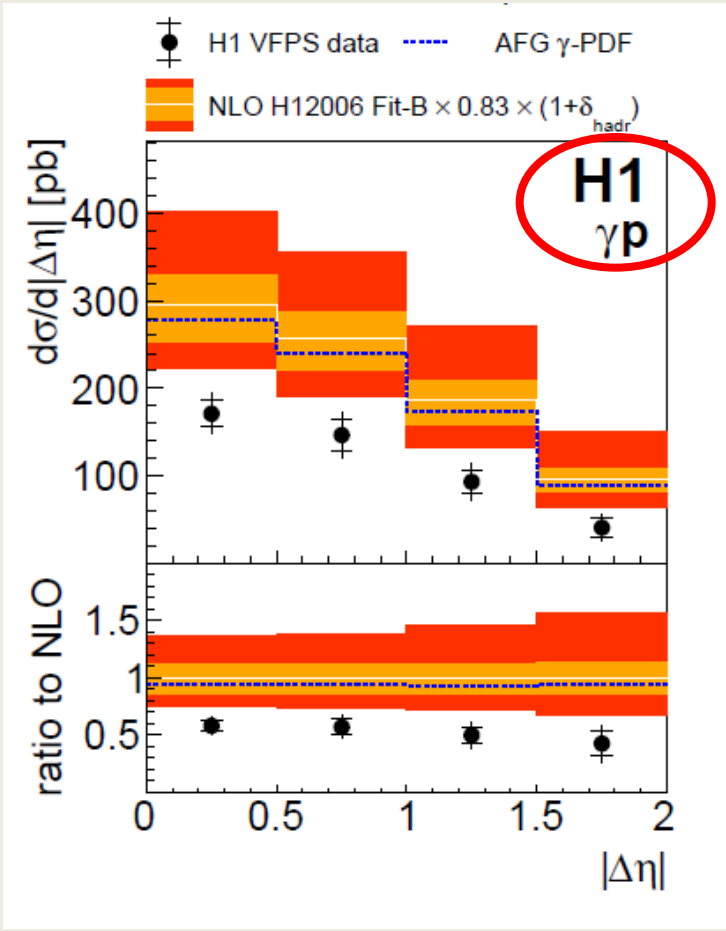


Data in agreement with NLO in DIS, within uncertainites

Data suppressed in comparison with NLO in photoproduction

Diffractive dijet photoproduction & DIS

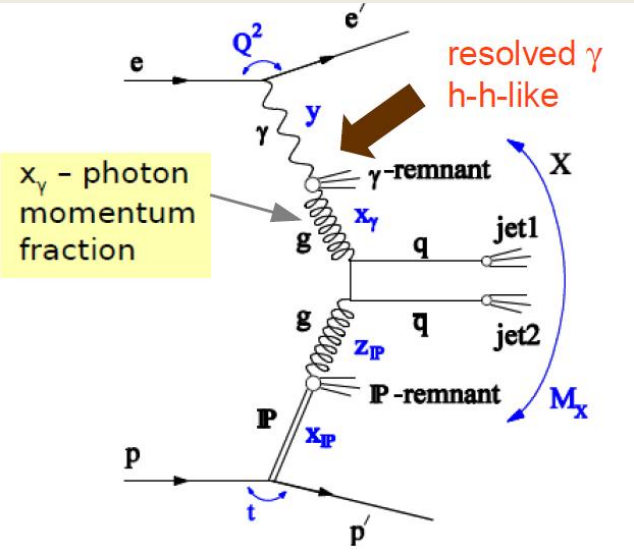




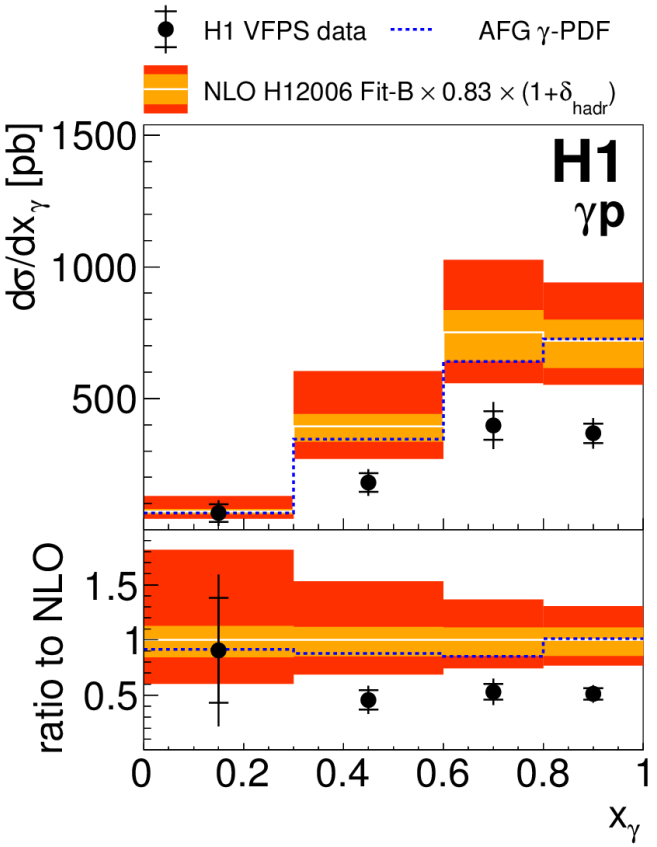
Data in agreement with NLO in DIS, within uncertainites

Data suppressed in comparison with NLO in photoproduction

Diffractive dijet photoproduction

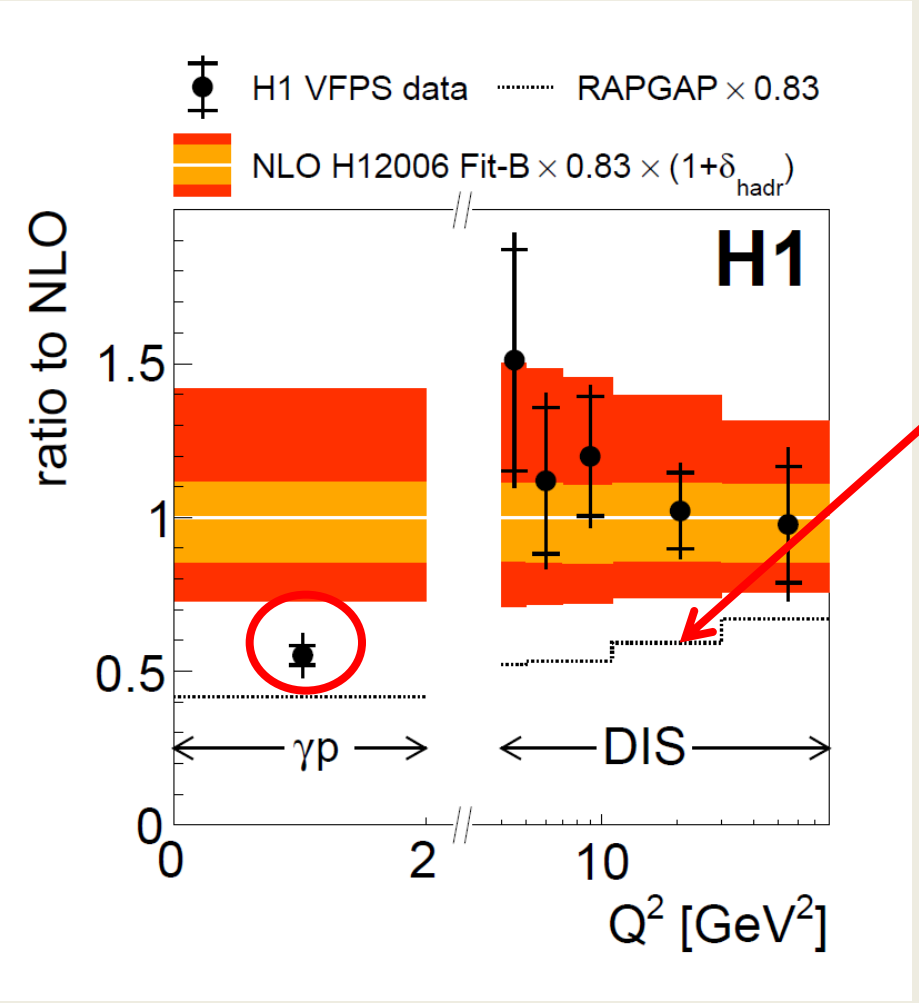


$$x_\gamma = x_\gamma^{OBS} = \frac{\sum (E - p_z)_{jets}}{(E - p_z)_{hadrons}}$$



The suppression seems to be not dependent on x_γ .
It is in agreement with previous H1 and ZEUS observations!

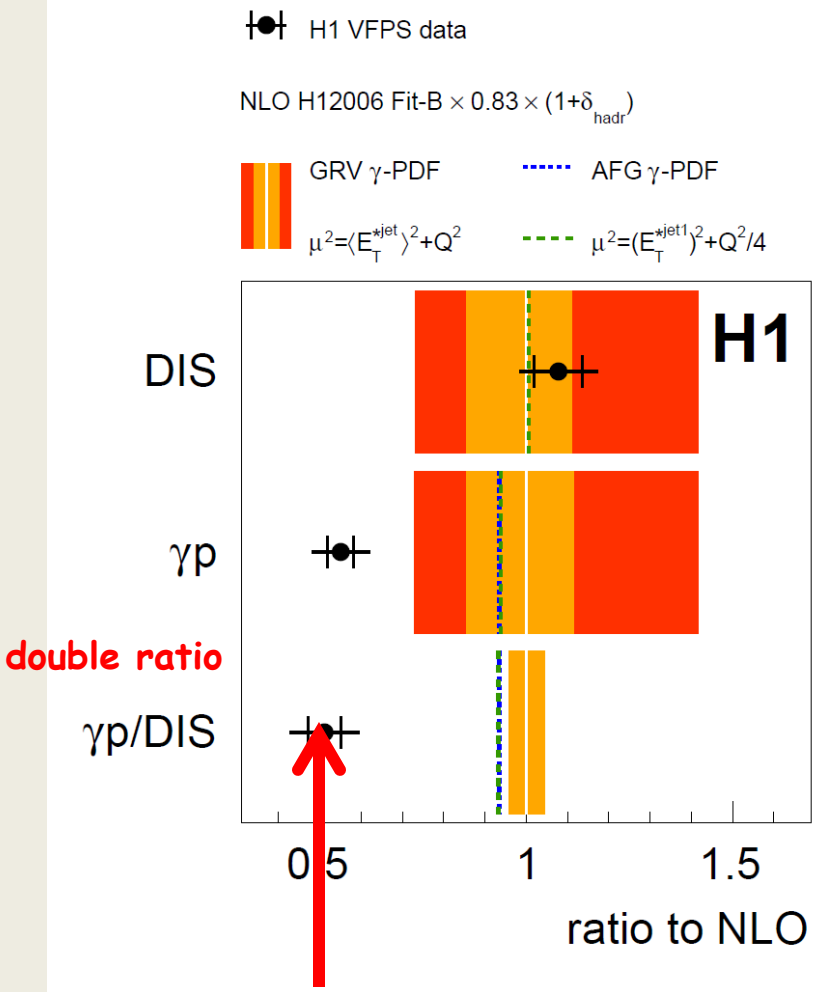
Diffractive dijet photoproduction & DIS



Data in agreement with NLO in DIS, data suppressed for photoproduction.

MC RAPGAP is not able to describe shape and absolute value of the cross sections neither for DIS nor for photoproduction.

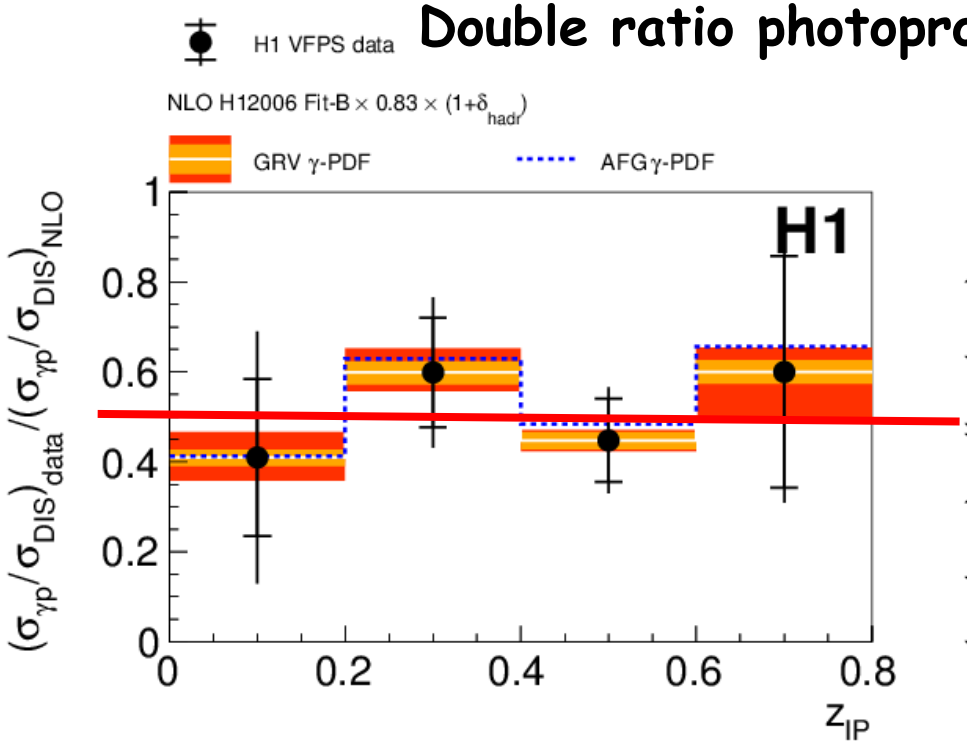
Diffractive dijet photoproduction & DIS

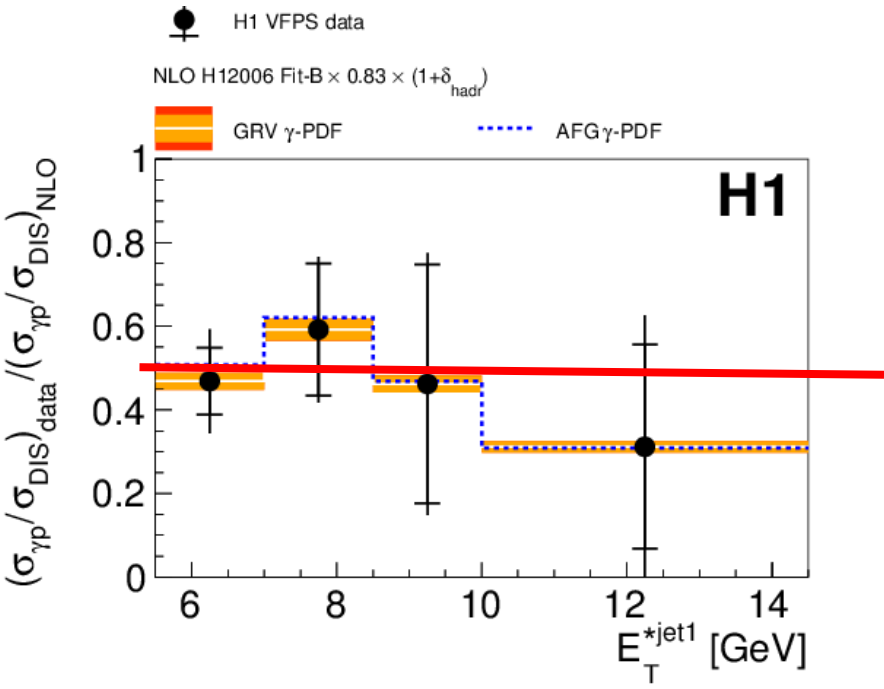


Previous H1 measurements confirmed, factorisation breaking in diffractive dijet photoproduction by factor ~ 0.5 observed

Diffractive dijet photoproduction & DIS

Double ratio photoproduction/DIS





Dependence of the suppression on E_T of the leading jet and z_{IP} not observed!
The reason of the difference of suppression for H1 and ZEUS is not connected with different phase space in E_T of jets

Conclusions

- New H1 measurement of diffractive dijet production in DIS → **measurements described by NLO QCD predictions using H1 DPDF, value of $\alpha_s(M_Z)$ obtained from this measurement is in agreement with world average.**

- New H1 measurement of diffractive photoproduction & DIS dijets using VFPS proton spectrometer →
  DIS dijets in agreement with NLO QCD prediction,
  suppression factor 0.5 ± 0.1 in photoproduction dijets observed, consistent with factorisation breaking!

- **Third H1 measurement with the same result as previously - this measurement uses complementary experimental methods as compared with previous measurements.**