Diffractive Dijet Production with Leading Proton in ep Collisions at HERA

JHEP [arXiv:1502.01683]

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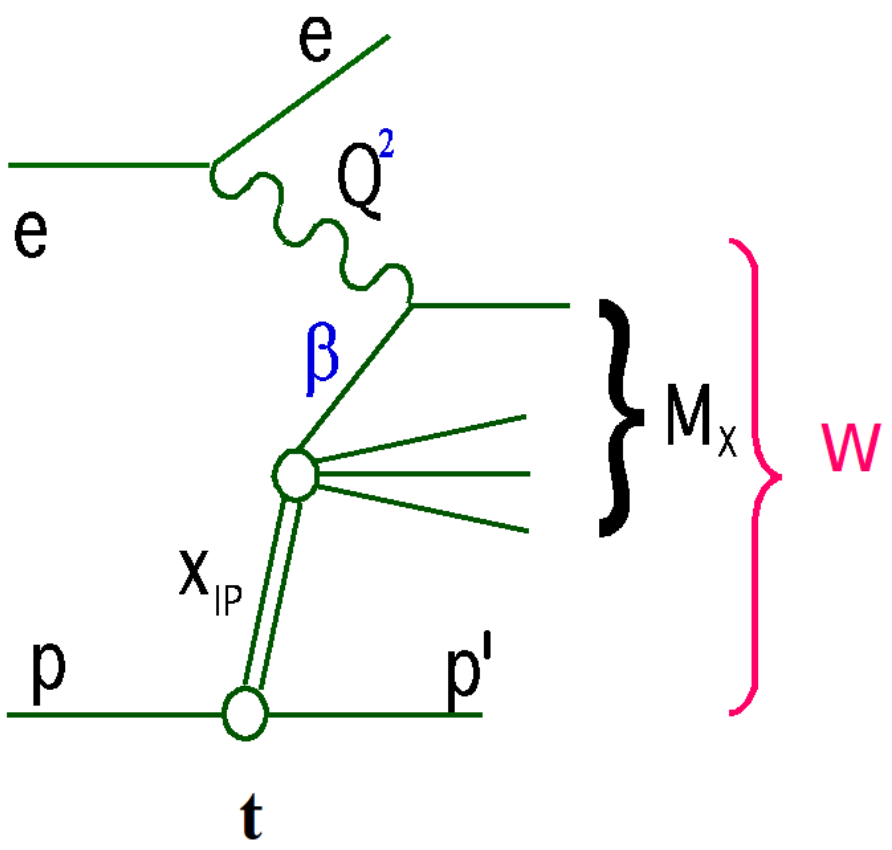
Erice 2015

Diffraction

- The scattered proton stays intact
- Exchange with vacuum quantum numbers – Pomeron (from Regge theory)

Q^2	Photon virtuality
$Q^2 \gg 0$	DIS
$Q^2 \approx 0$	photoproduction



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

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} = 1 - \frac{E_p'}{E_p^{beam}}$$

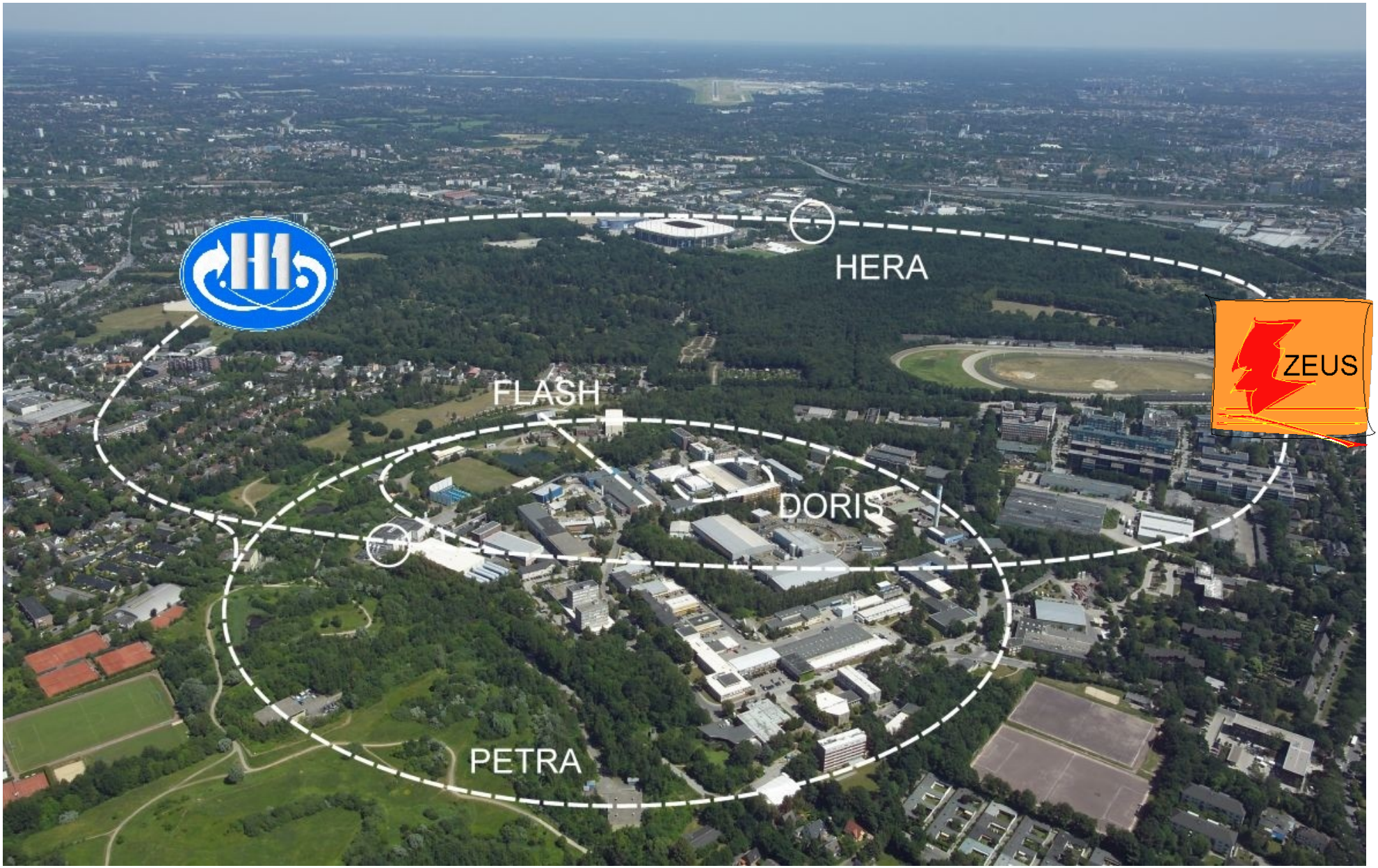
Fractional momentum loss of the scattered proton

$$t = (p - p')^2 \approx -p_T^2$$

Four-momentum transfer at the proton vertex

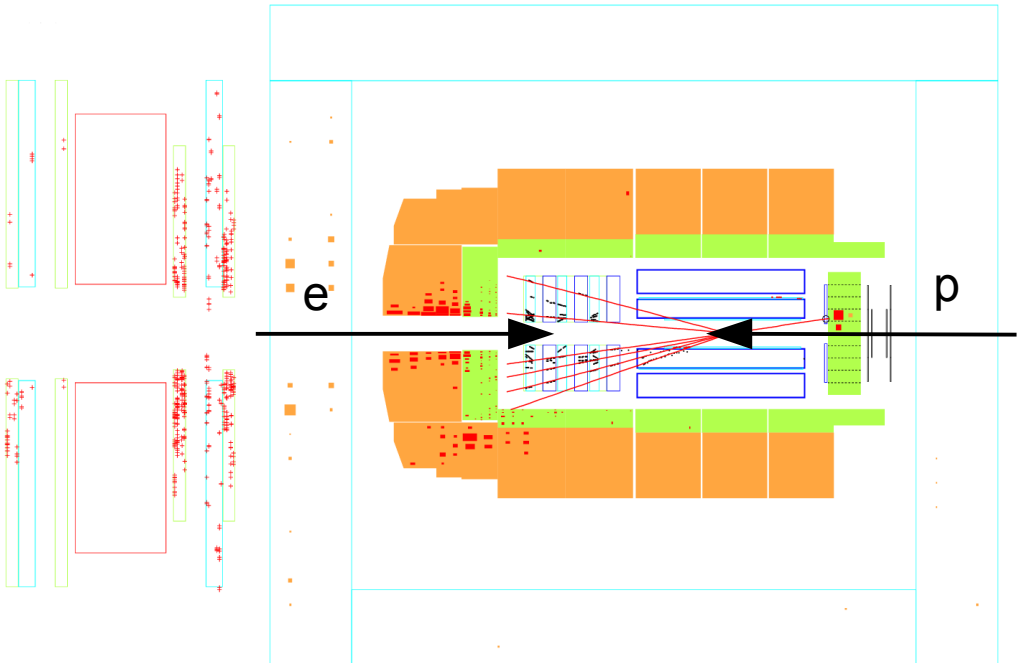
HERA

p (920 GeV) + $e^{\pm}$ (27.6 GeV)



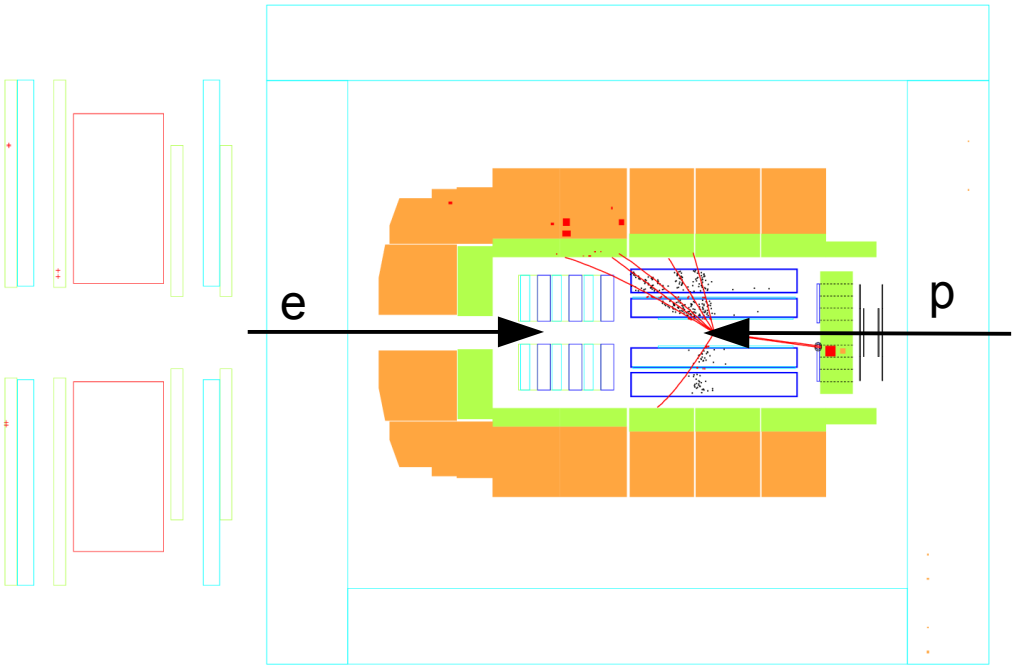
Large Rapidity Gap

Hadronic activity in forward part of detector



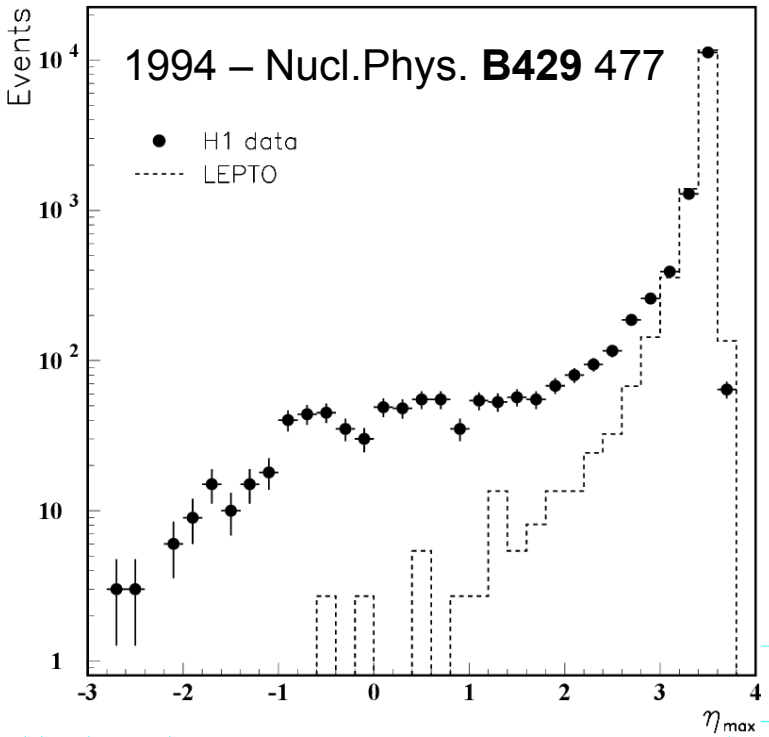
Non-diffractive event

Without hadronic activity in forward part of detector

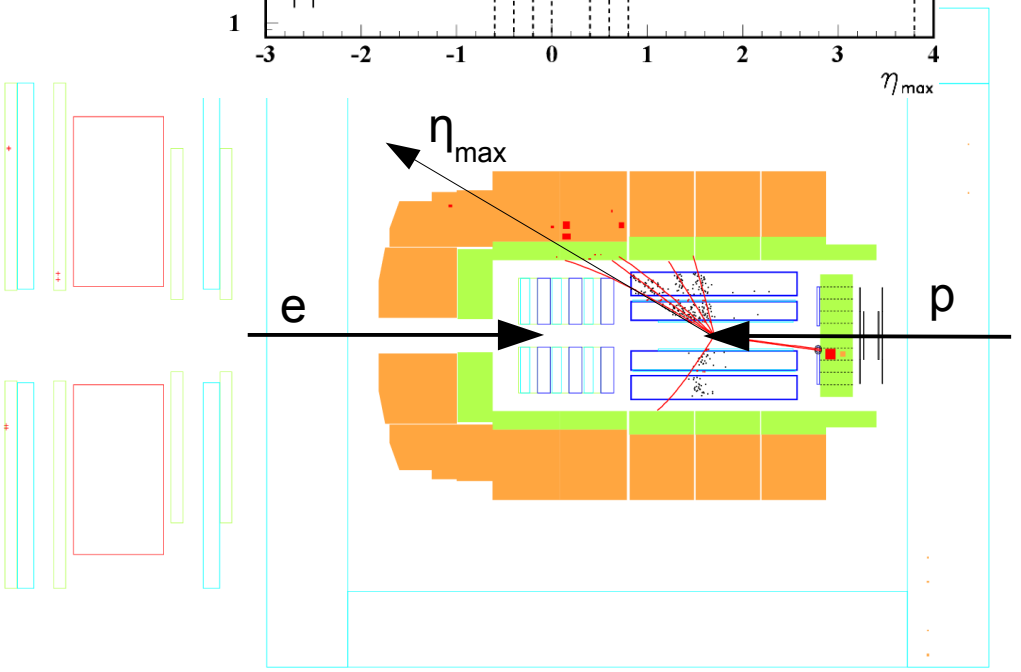


Diffractive event

Large Rapidity Gap



Without hadronic activity in forward part of detector

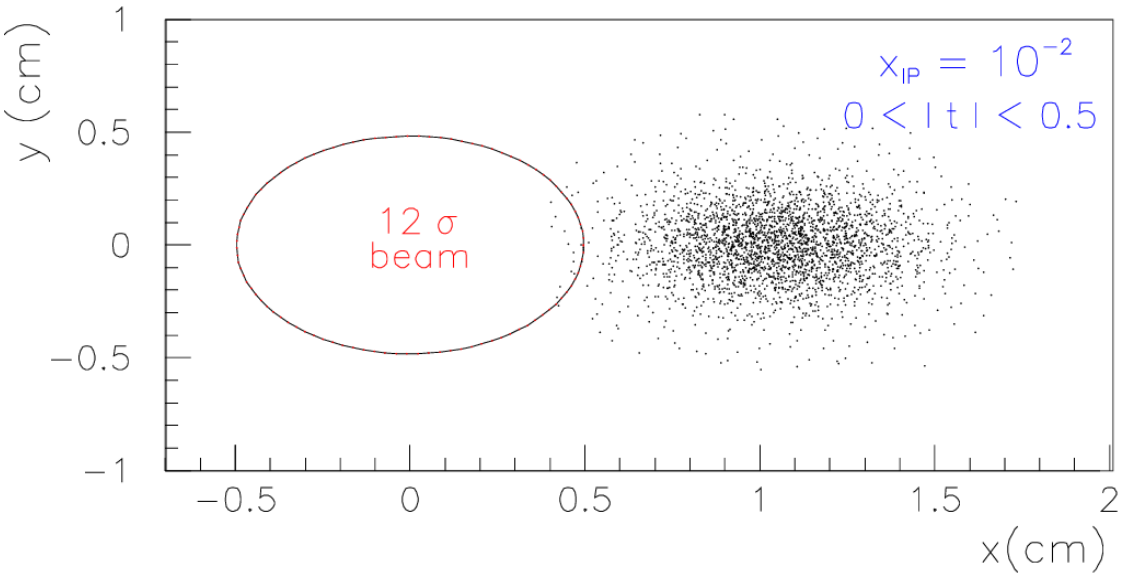


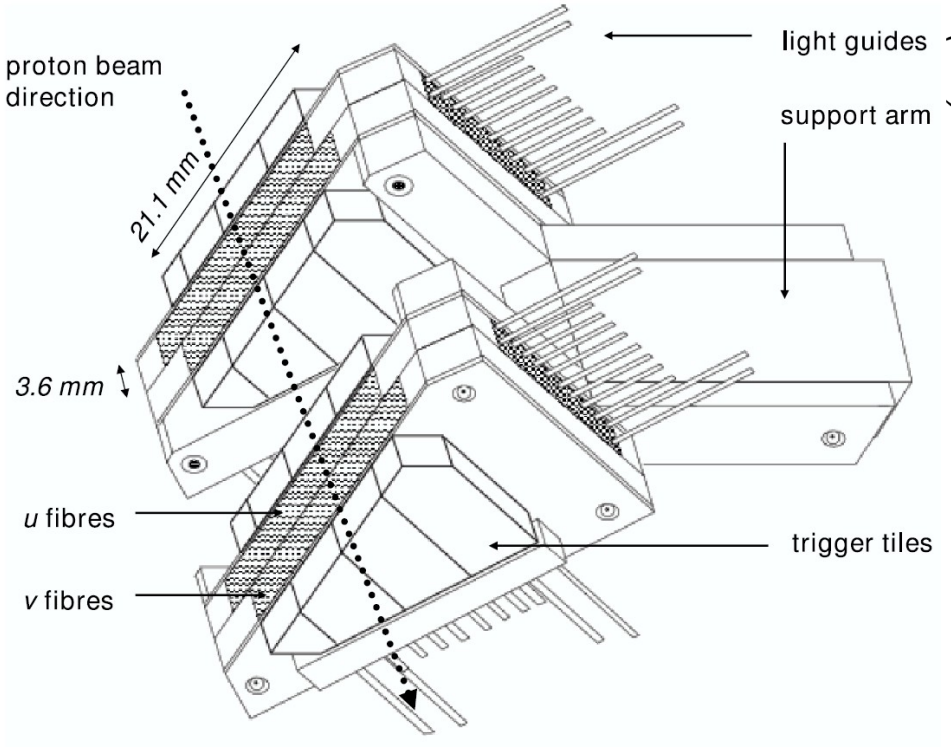
Diffractive event

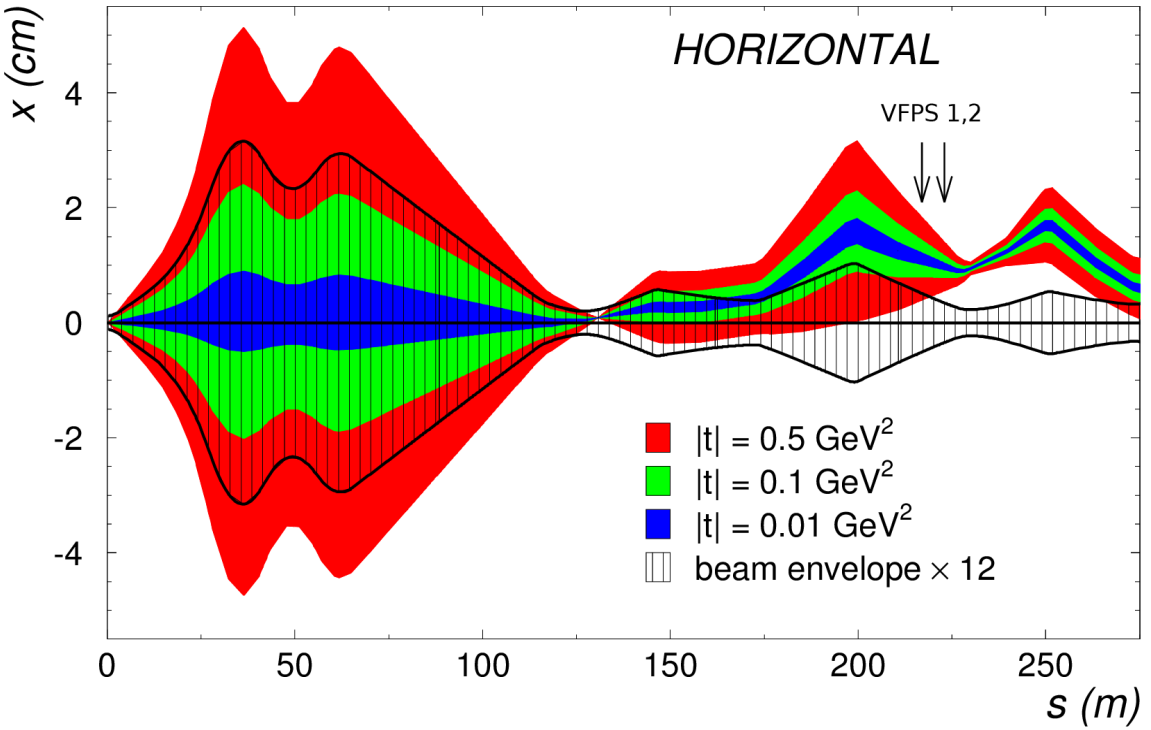
Direct Proton Detection

Very Forward Proton Spectrometer

- 2 stations - 218 a 222 m from interaction point
- 120 scintillating fibers in one layer



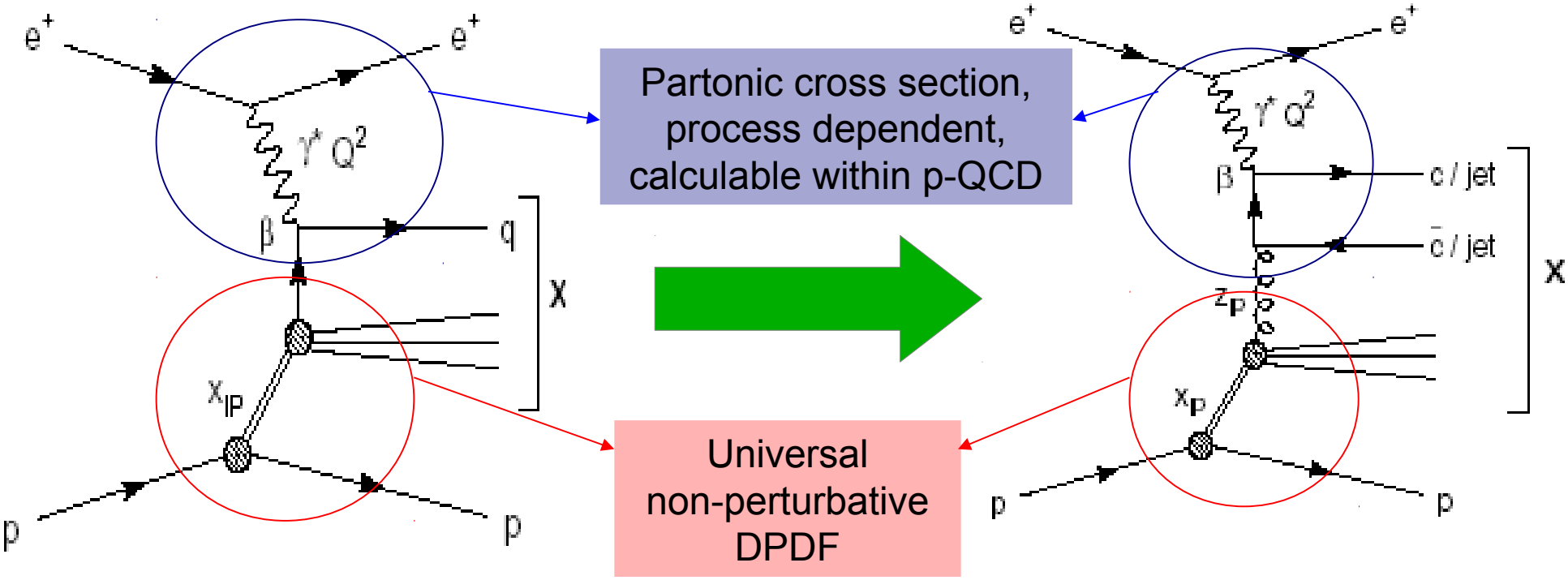




Factorization in Diffraction

- DPDFs determined from inclusive measurement are capable to predict results for other, more exclusive processes (dijets, D*), Collins 1997

$$\sigma^D(ep \to Xp) = \sum_{parton_i} f_i^D(\beta, Q^2, x_{IP}, t)\, \sigma^{ei}(\beta, Q^2)$$



$f_i^D(\beta, Q^2, x_{IP}, t)$ DPDFs which obey DGLAP evolution

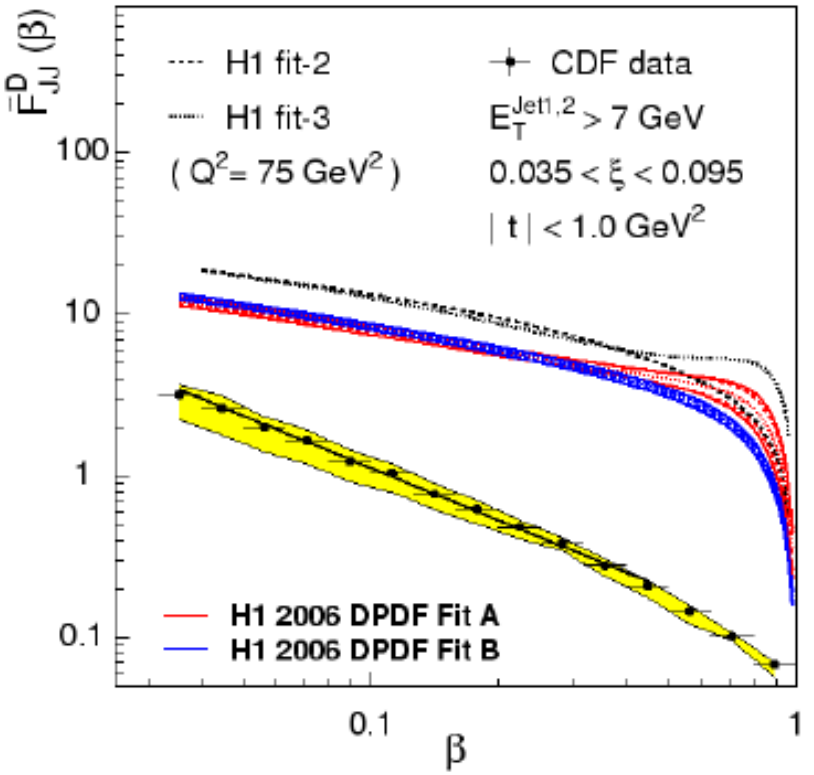
$\sigma^{ei}(\beta, Q^2)$ Partonic cross section

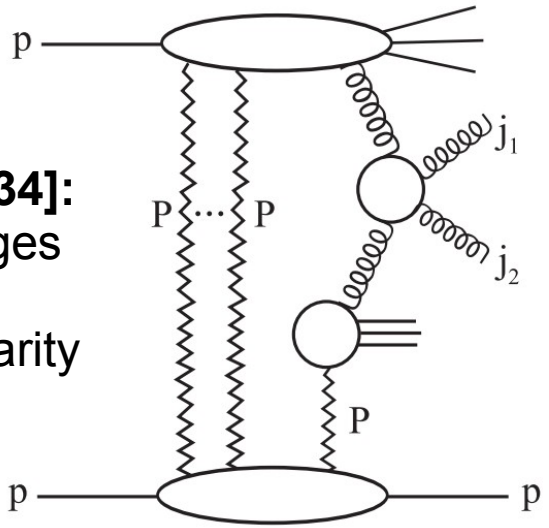
Hadron-Hadron Interactions

Export of DPDFs from HERA to Tevatron…..

Phys.Rev.Lett. **84** (2000) 5043-5048

Single-diffractive / non-diffractive Dijet cross section





KKMR [hep-ph/0306134]:
Multi-pomeron exchanges introduced to take into account s-channel unitarity

Suppression factor is introduced:

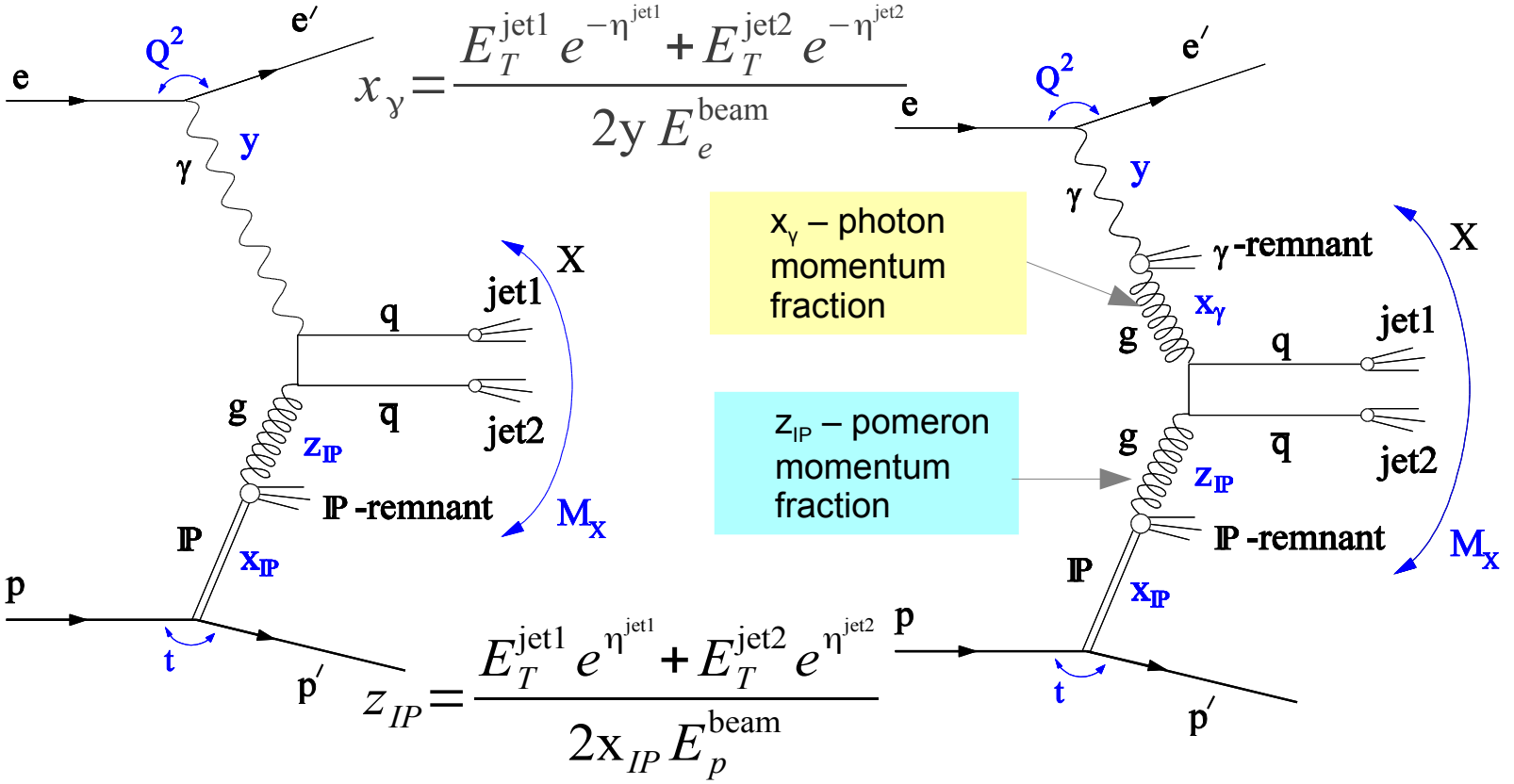
- HERA DIS 1
- Tevatron ~0.1

Factorization broken by factor around 10 !

Diffractive Dijet Production - Photoproduction

Direct
- No photon remnat
- $x_\gamma = 1$ (at parton-level)
- Dominant for high Q^2

Resolved
- Photon remnat
- $x_\gamma < 1$
- Dominant for low Q^2
- γ-PDF introduced



$$x_\gamma = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2y E_e^{beam}}$$

$$z_{IP} = \frac{E_T^{jet1} e^{\eta^{jet1}} + E_T^{jet2} e^{\eta^{jet2}}}{2x_{IP} E_p^{beam}}$$

x_γ – photon momentum fraction

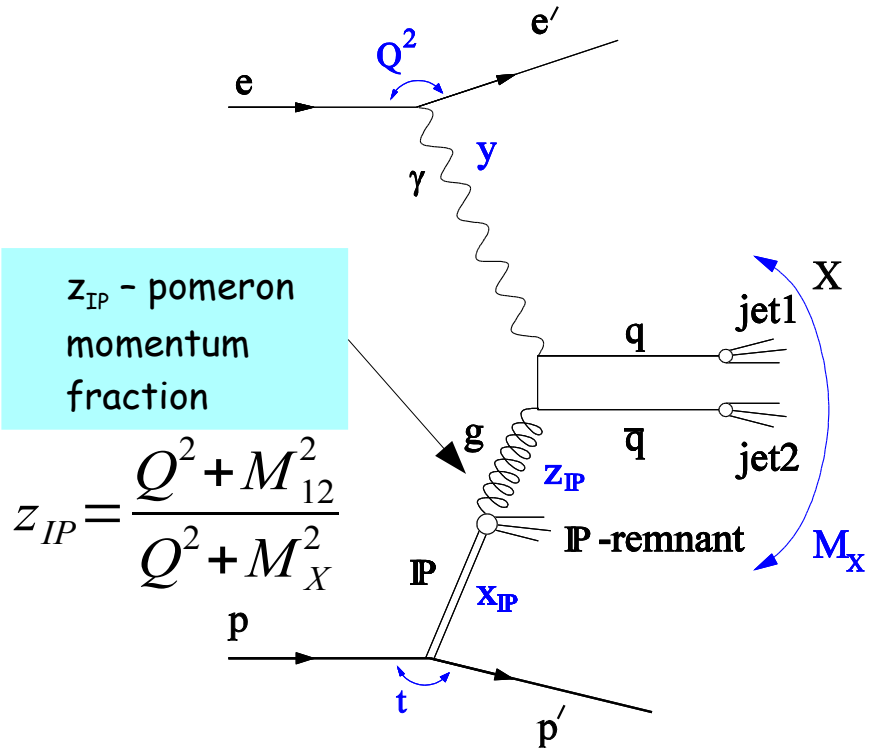
z_{IP} – pomeron momentum fraction

Resembles hadron-hadron interactions (two-remnants) where the factorization breaking was observed

LO diagrams!

Diffractive Dijet Production - DIS

- Photon enters directly into the hard subprocess
- One remnant
- Factorization theoretically proven (Collins 1997)



LO diagram!

Motivation for the measurement

- Diffractive dijet photoproduction measured so far only by **large rapidity gap** method

H1 (2010)
[arXiv:1006.0946]

$$\frac{\sigma_{DATA}}{\sigma_{NLO}} = 0.58 \pm 0.12\,(\text{data}) \pm 0.17\,(\text{theory})$$

ZEUS (2008)
[arXiv:0710.1498]

$$\frac{\sigma_{DATA}}{\sigma_{NLO}} = 0.77 \pm 0.06\,(\text{data}) \pm 0.19\,(\text{theory})$$

KKMR [arXiv:0911.3716]

$$S^2 \sim 0.5$$

KKMR [arXiv:0911.3716]

$$S^2 \sim 0.6$$

- New measurement with leading proton for diffractive photoproduction and DIS as a reference
- The double ratios of data to NLO QCD prediction for photoproduction and DIS introduced to better control experimental and **theoretical** errors

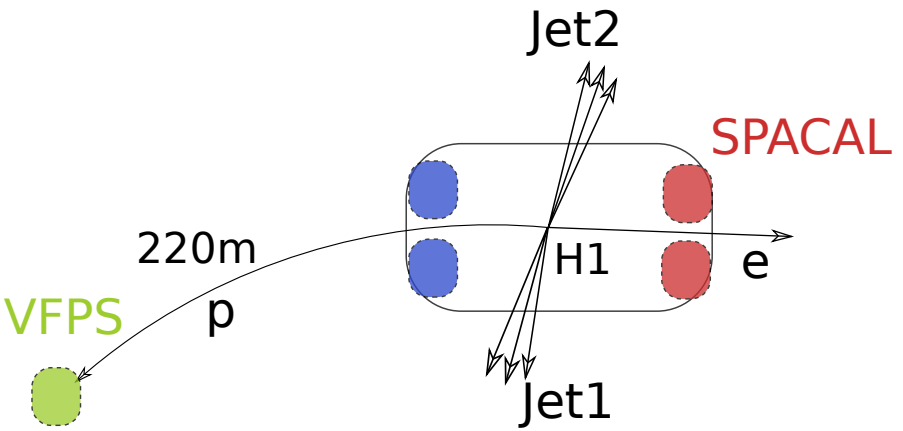
Measurement Setup

- Analysis based on 2006/07 e^+p HERA data, integrated lumi ~30 pb^{-1}
- Leading proton measured by proton spectrometer VFPS
- Photoproduction and DIS phase spaces identical up to Q^2 range
- Jets defined by k_T-algorithm

Photoproduction

$(Q^2 < 2\,\mathrm{GeV}^2)$

VFPS + jets+ SPACAL VETO

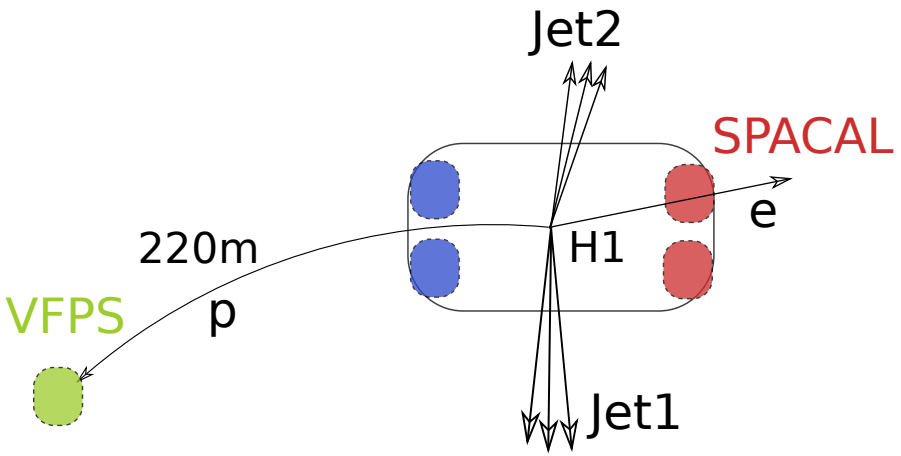


~ 3600 events

DIS

$(4\,\mathrm{GeV}^2 < Q^2 < 80\,\mathrm{GeV}^2)$

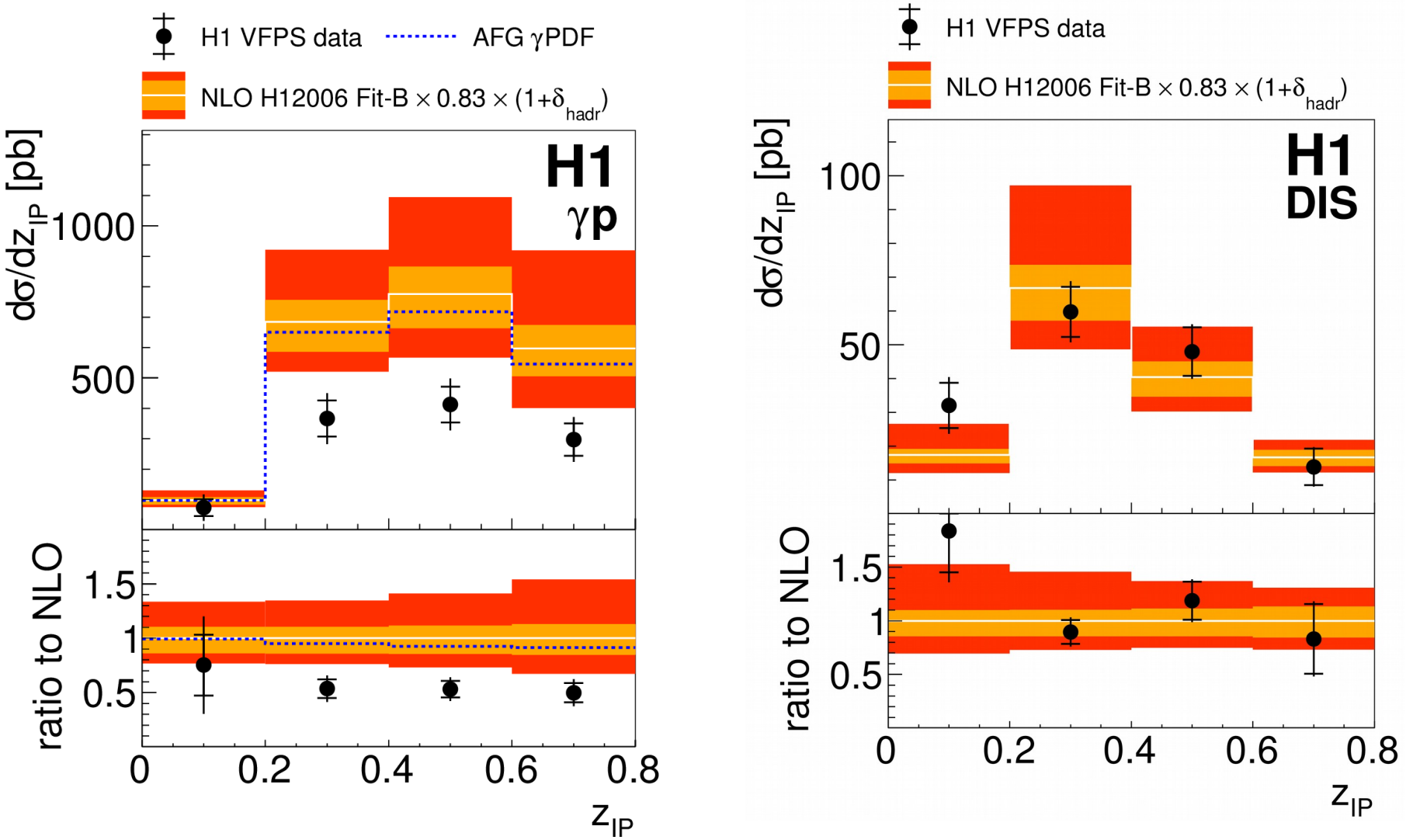
VFPS + jets + SPACAL positron



~ 500 events

Data unfolded to the level of stable hadrons using Tikhonov method

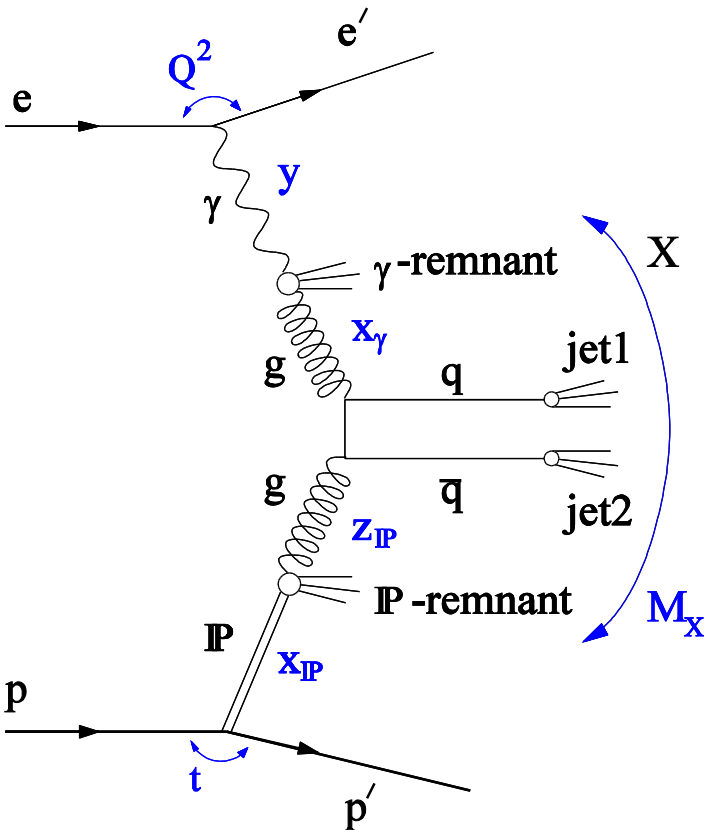
Differential Cross Section in z_{IP}

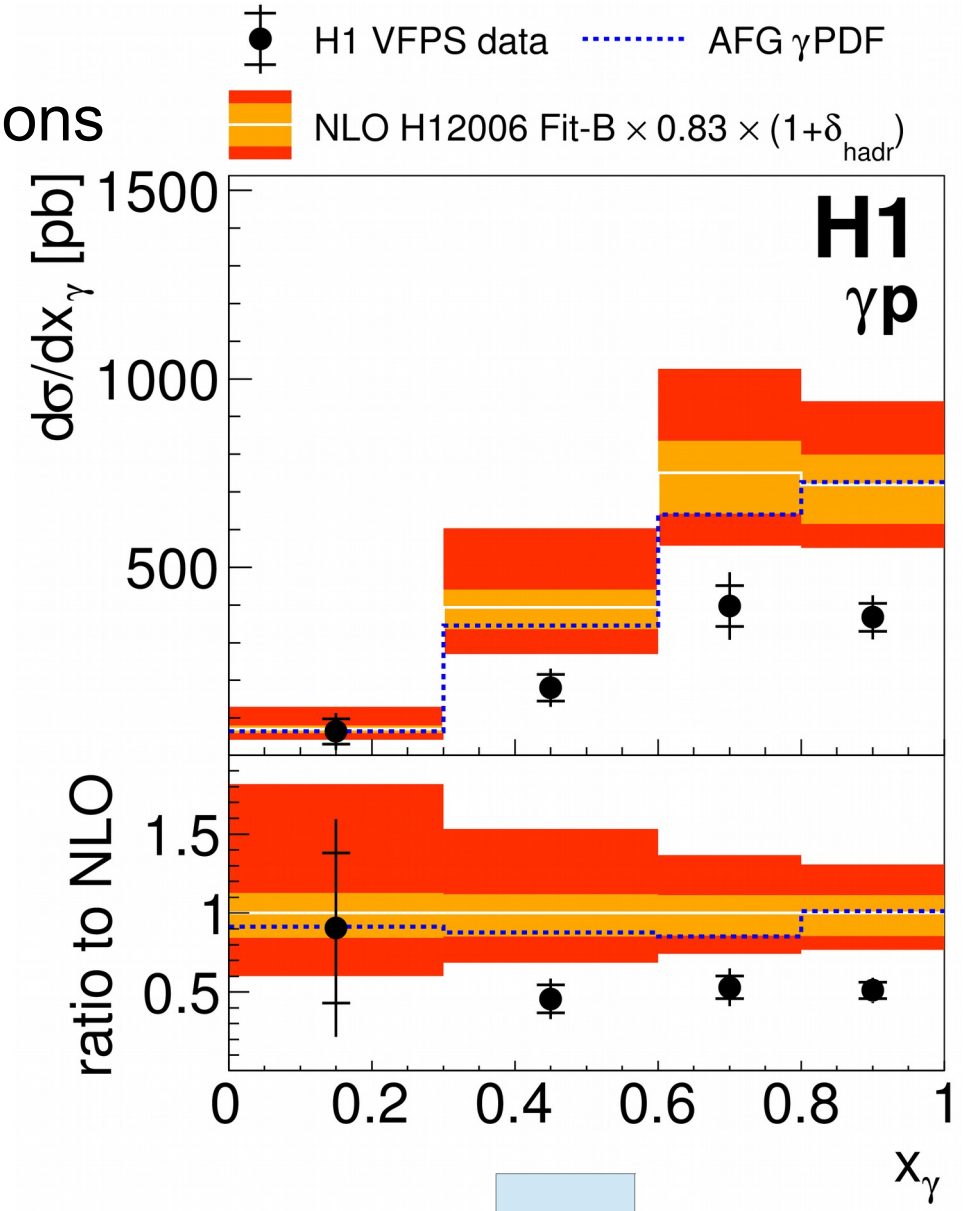


- In **photoproduction** data suppressed by factor ~0.6 in comparison to NLO
- In **DIS** data satisfactorily described by NLO

Differential Cross Section in x_γ

Q: Resolved photoproduction ($x_\gamma < 1$) resembles hadron-hadron interactions Higher suppression?



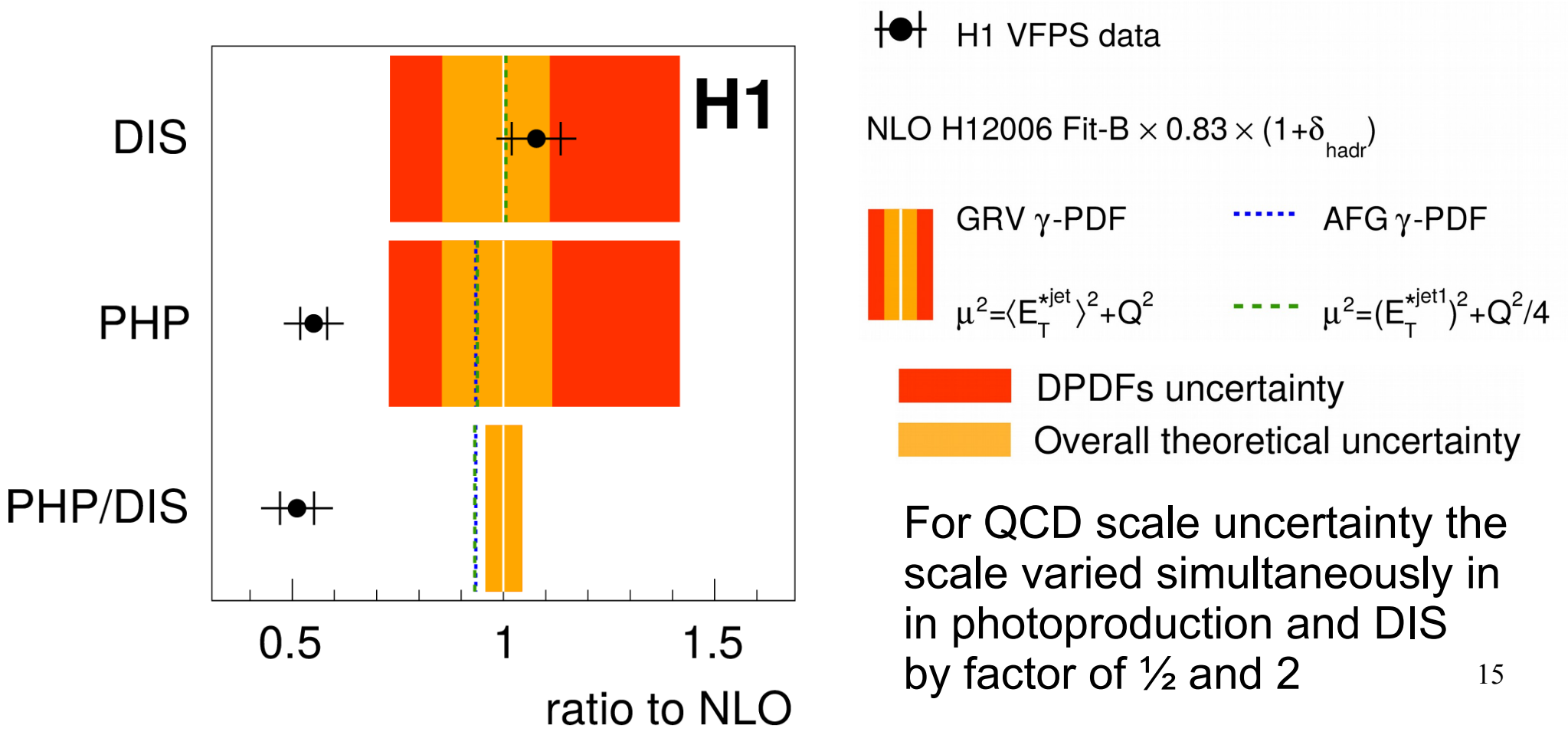


A: No hint for higher suppression for $x_\gamma < 1$

Double Ratio

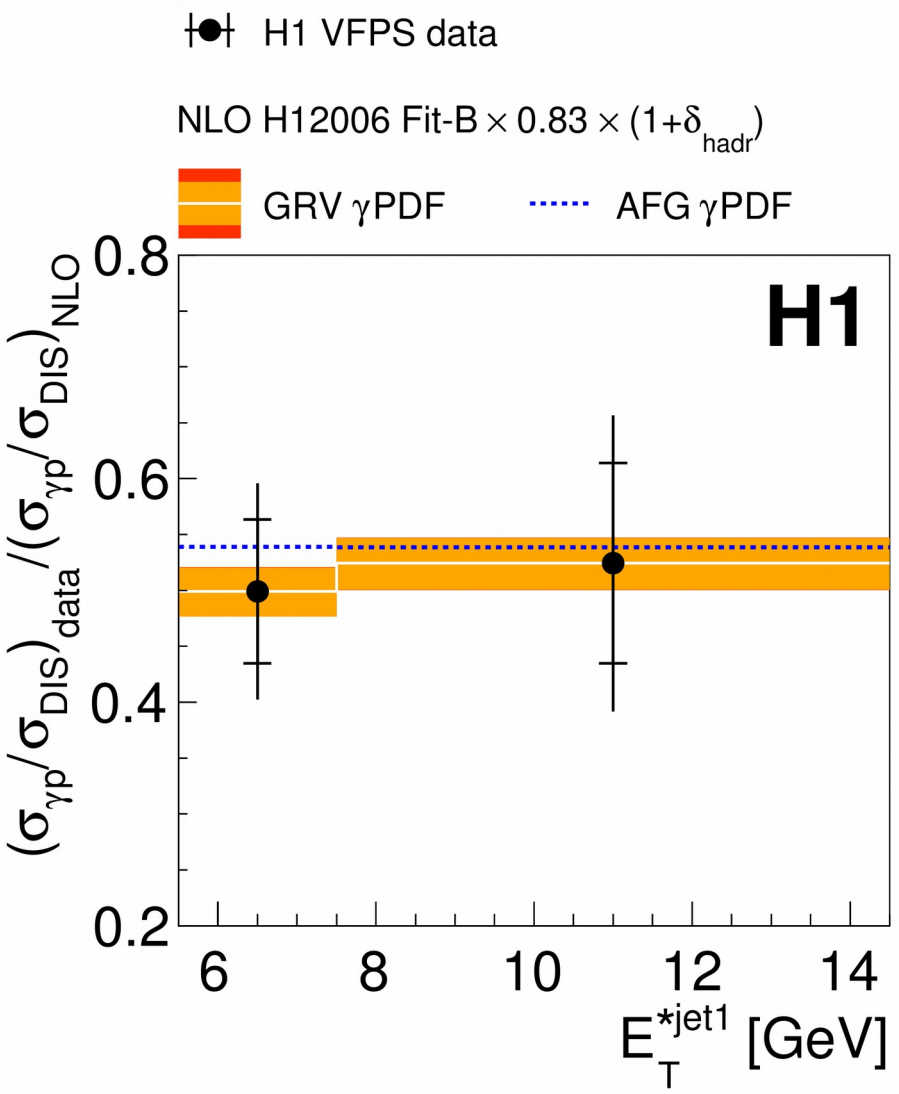
- Double ratio of data to NLO QCD predictions for photoproduction and DIS reduce data systematic and **theoretical** uncertainties

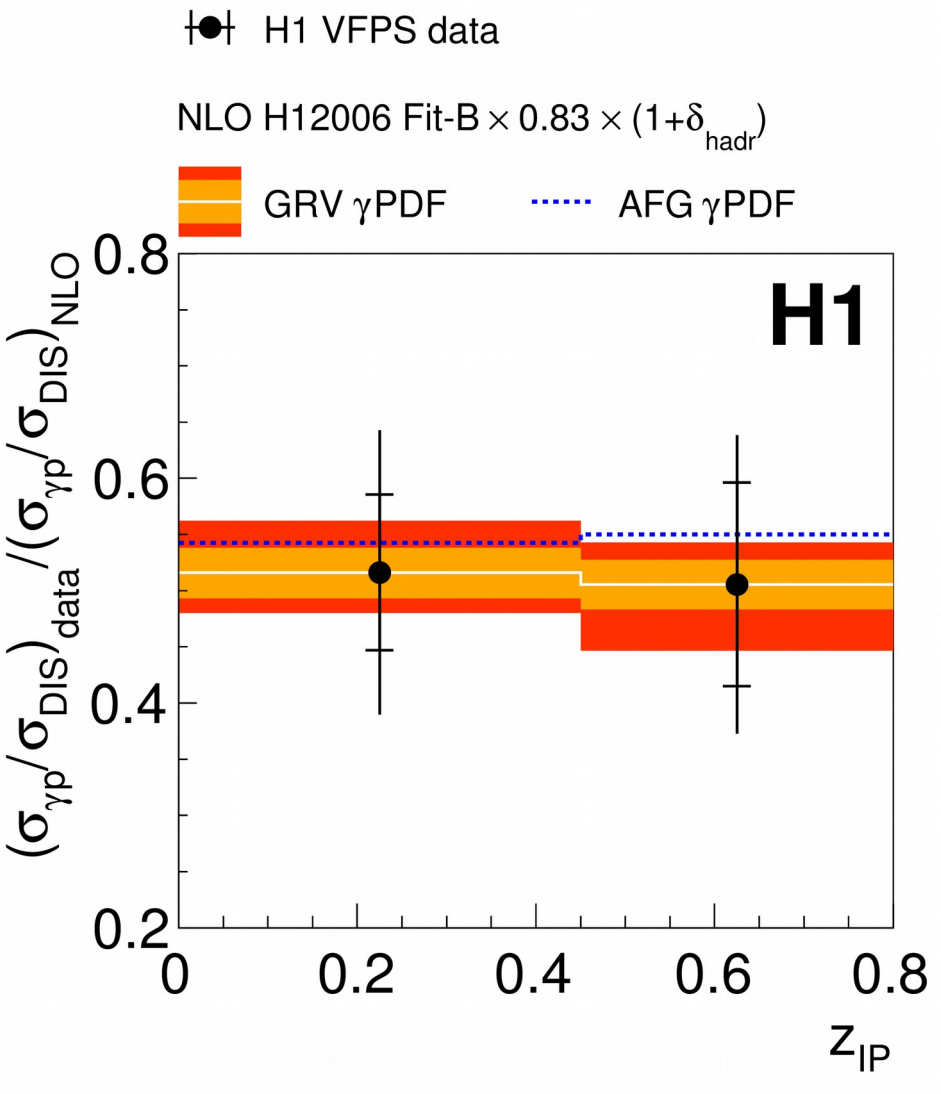
$$\frac{(DATA/NLO)_{PHP}}{(DATA/NLO)_{DIS}} = 0.51 \pm 0.08(\text{data}) \pm 0.03(\text{theory})$$



For QCD scale uncertainty the scale varied simultaneously in in photoproduction and DIS by factor of ½ and 2

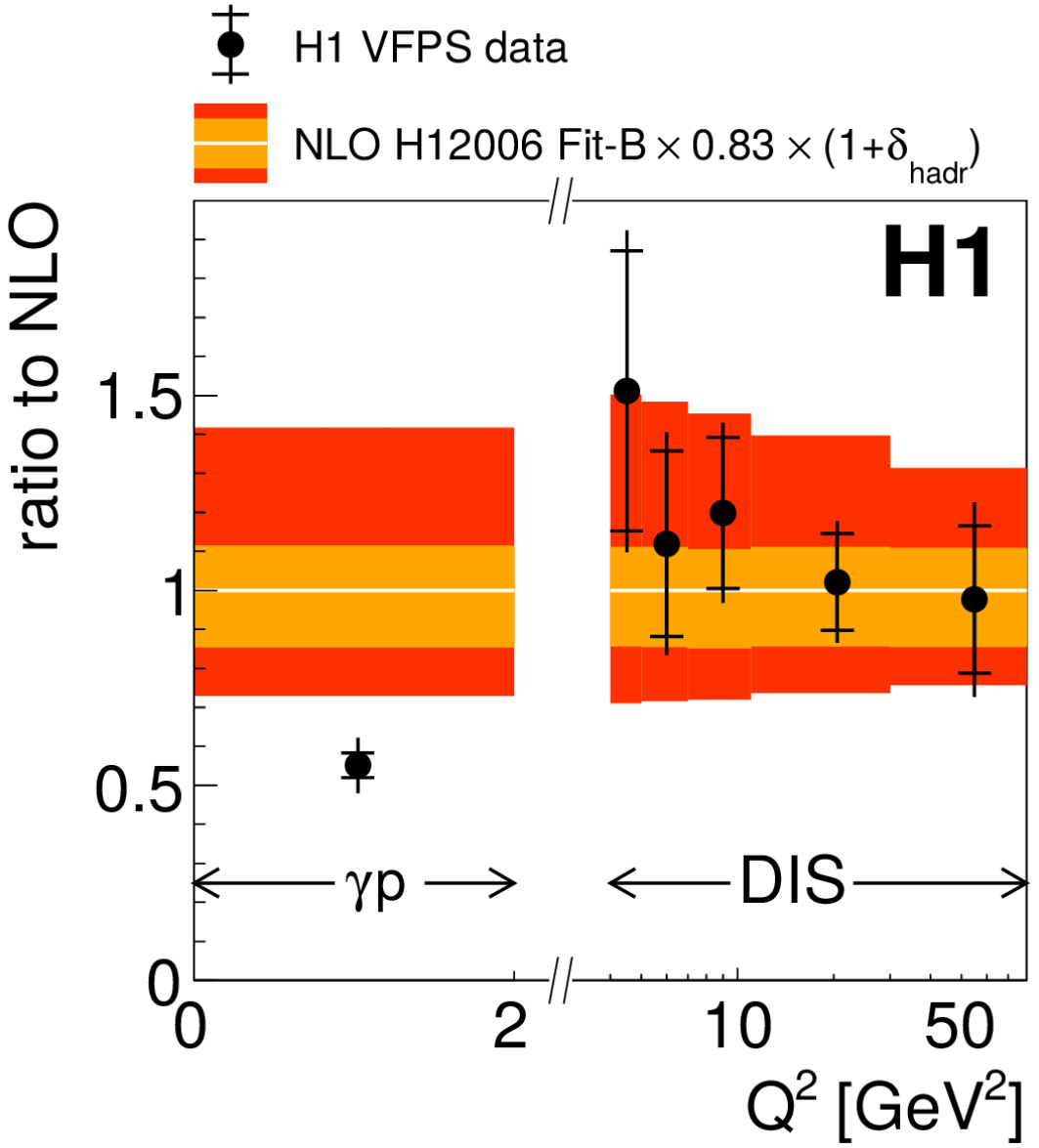
Differential Double Ratios





- Double ratios are within errors constant
- Dependence of the suppression on E_T of the leading jet not observed

Dependence on Q^2



Summary

- Dijet diffractive cross sections measured in two distinct Q^2 regions, photoproduction and DIS
- Suppression factor in photoproduction about 0.5 established
- Previous H1 measurement confirmed by complementary experimental method (detection of leading proton)
- No hint of a dependence of the suppression on x_γ and E_T of the leading jet

Backup

Kinematic Quantities

$0.2 < y < 0.7$	
Photoproduction	Deep-inelastic scattering
$Q^2 < 2\,\mathrm{GeV}^2$	$4\,\mathrm{GeV}^2 < Q^2 < 80\,\mathrm{GeV}^2$

Diffractive selection

$$0.010 < x_{IP} < 0.024$$
$$|t| < 0.6\,\mathrm{GeV}^2$$
$$z_{IP} < 0.8$$

Jet Definition

$$E_T^{*\mathrm{jet1}} > 5.5\,\mathrm{GeV}$$
$$E_T^{*\mathrm{jet2}} > 4.0\,\mathrm{GeV}$$
$$-1 < \eta^{\mathrm{jet1,2}} < 2.5$$