Diffractive Dijet Production in ep Collisions at HERA

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on behalf of H1 collaboration

Low X 2014 – Kyoto, Japan

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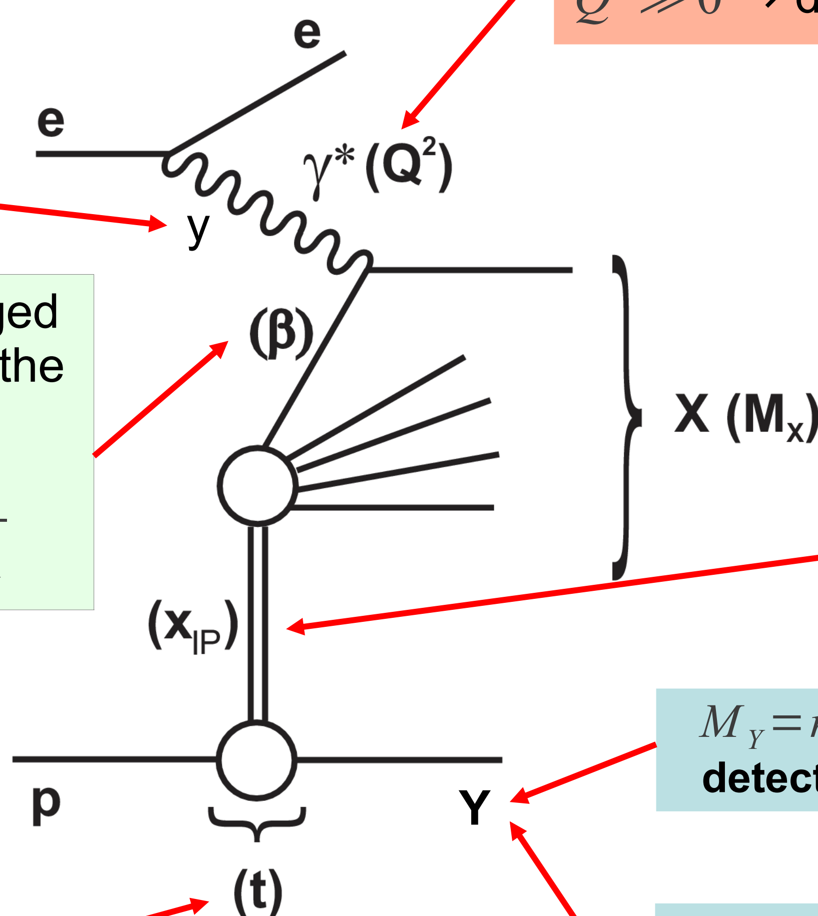
Diffractive Kinematics

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

Q^2 Virtuality of the photon
$Q^2 \approx 0$ → photoproduction
$Q^2 \gg 0$ → deep inelastic scattering (DIS)

Inelasticity $y = \frac{p \cdot q}{p \cdot k}$



The fraction of exchanged momentum entering to the hard subprocess

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

Momentum fraction of the diffractive exchange

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

$M_Y = m_p$ proton stays intact, needs **detector to detect forward protons**

$M_Y > m_p$ proton dissociates, approx. 20 % in **H1 large rapidity gap (LRG) measurement**

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

Factorization in Diffraction

QCD factorization holds for inclusive and exclusive processes if:
- photon is point-like (Q^2 is high enough)
- higher twist corrections are negligible (problems around $\beta = 1$)

  QCD factorization theoretically proven for DIS (Collins 1998)

$$d\sigma^D(\gamma p \to Xp) = \sum_{parton_i} f_i^D(\beta, Q^2, x_{IP}, t) * d\hat{\sigma}^{\gamma i}(x, Q^2)$$

f_i^D — DPDFs, obeys DGLAP evolution, process independent

$d\hat{\sigma}^{\gamma i}$ — Process dependent partonic x-section, calculable within P-QCD

Assuming validity of DGLAP evolution and Regge vertex factorization the DPDFs are obtained by fitting of the inclusive (+ dijets) DIS data

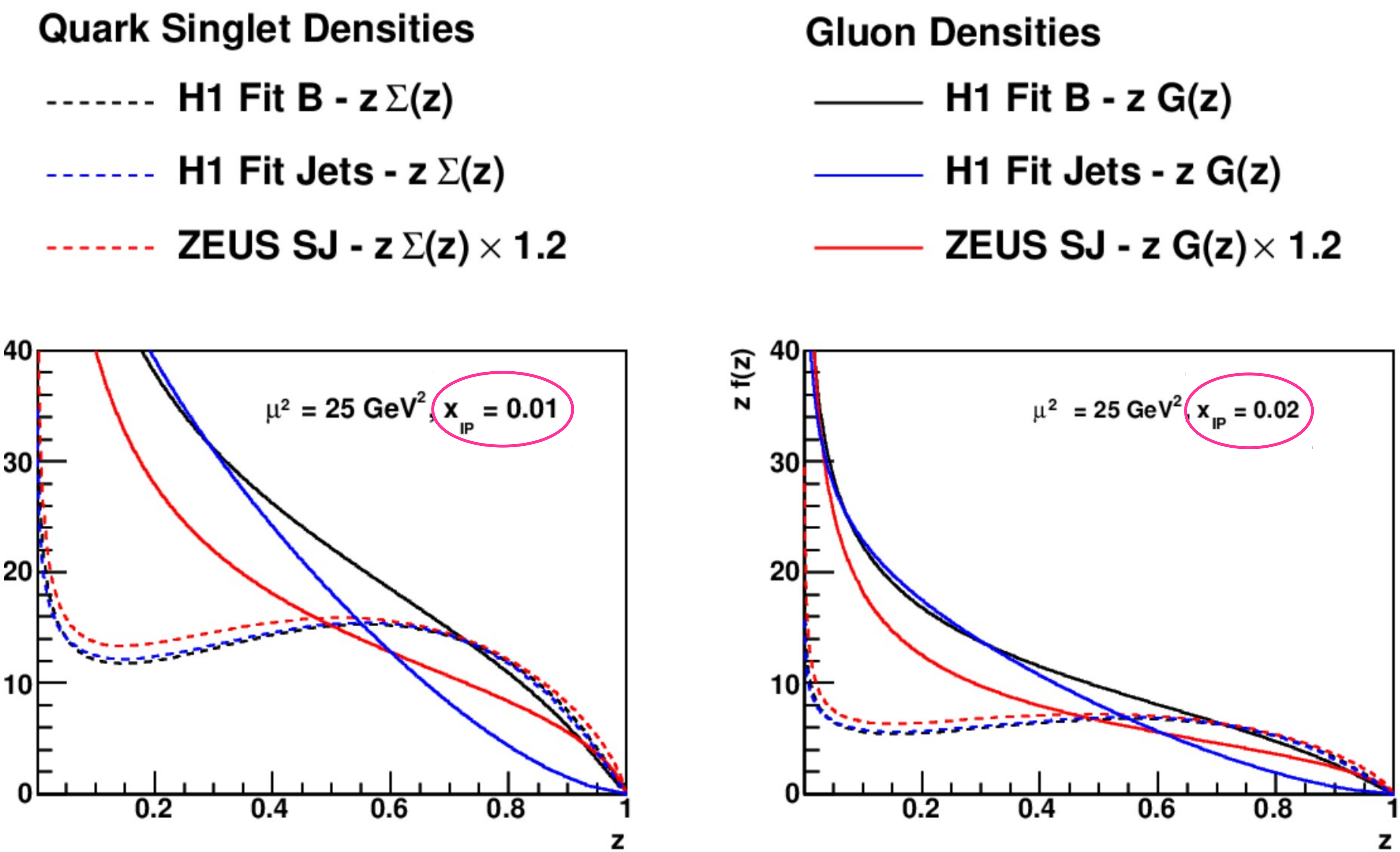
Regge vertex factorization for DPDF:

$$f_i^D(\beta, Q^2, x_{IP}, t) = \underbrace{f_{IP/p}(x_{IP}, t)}_{\text{pomeron flux factor}} \cdot \underbrace{f_i^{IP}(\beta, Q^2)}_{\text{pomeron PDF}}$$

DPDFs

Differ mainly in gluon contribution

Measurement directly sensitive to the gluon contribution crucial to achieve higher precision



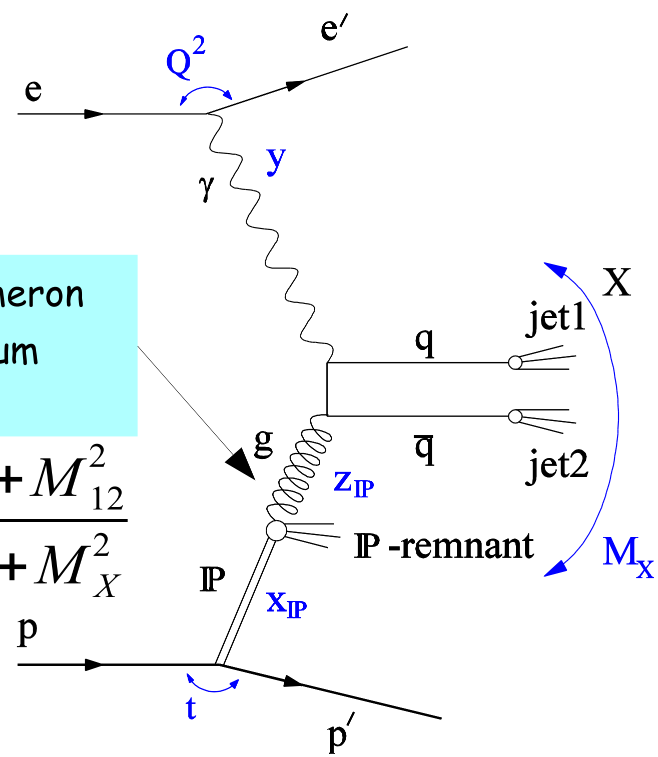
Diffractive Dijet Production - DIS

- Photon enters directly into the hard subprocess
- One remnant
- Boson-gluon fusion dominates
- Factorization theoretically proven

Could be used to improve gluon contribution of DPDF

z_{IP} - pomeron momentum fraction

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

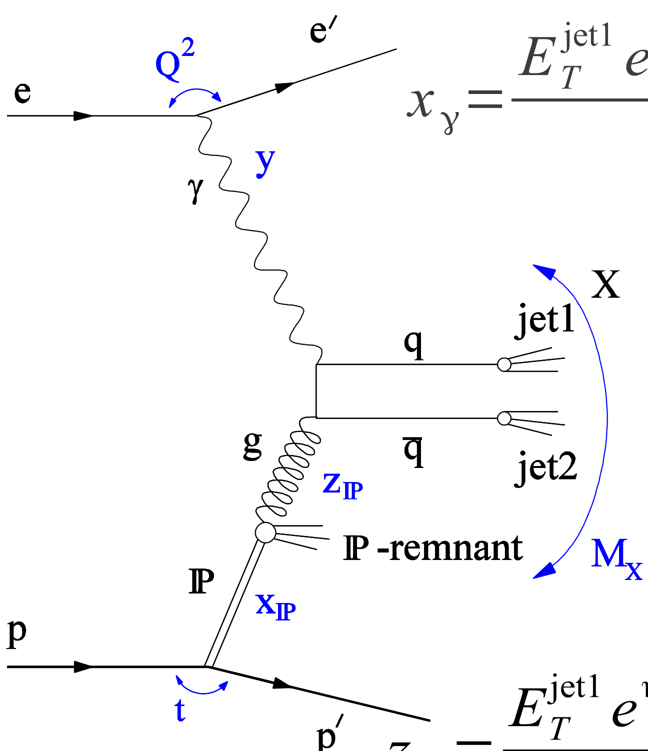


LO diagram!

Diffractive Dijet Production - Photoproduction

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

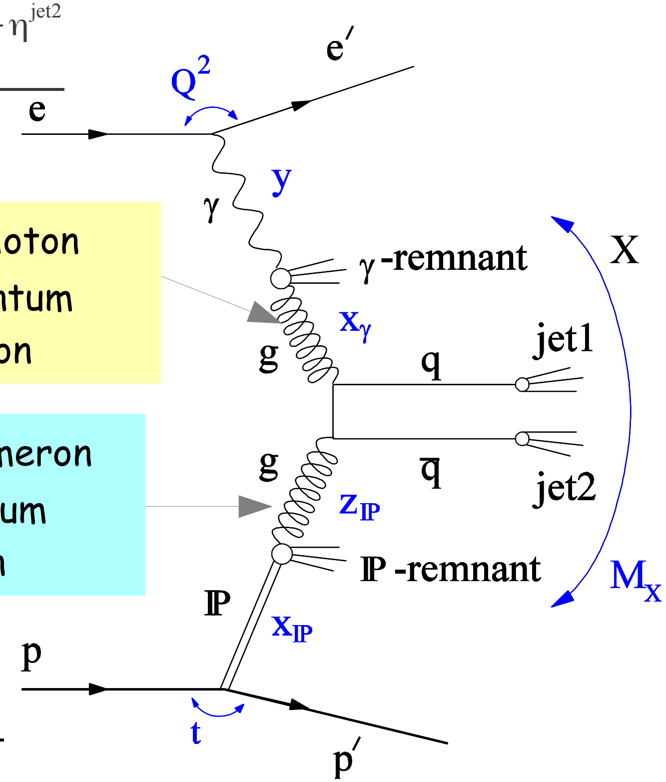
Resolved
- Photon remnant
- $x_\gamma < 1$
- Dominant for low Q^2, γ-PDF introduced



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

x_γ - photon momentum fraction

z_{IP} - pomeron momentum fraction



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

Resembles hadron-hadron interactions (two-remnants) where the factorization breaking was observed (**suppression** of data with respect to theoretical predictions by **factor ~10**)

LO diagrams!

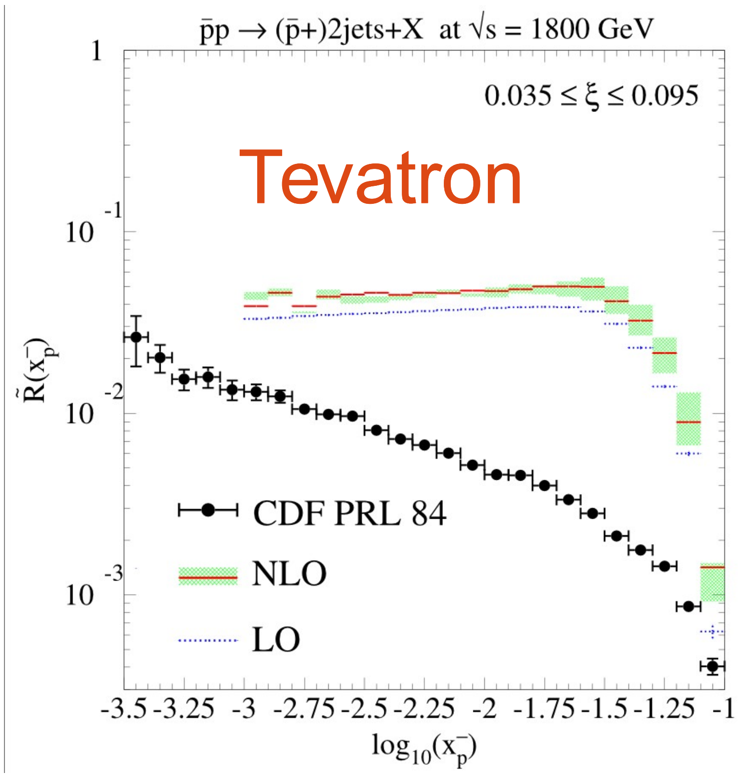
Diffractive Factorization

HERA DPDF fails to predict hadron-hadron cross section

Suppression factor introduced: $S^2 = \frac{\sigma^{Data}}{\sigma^{Theor.}}$

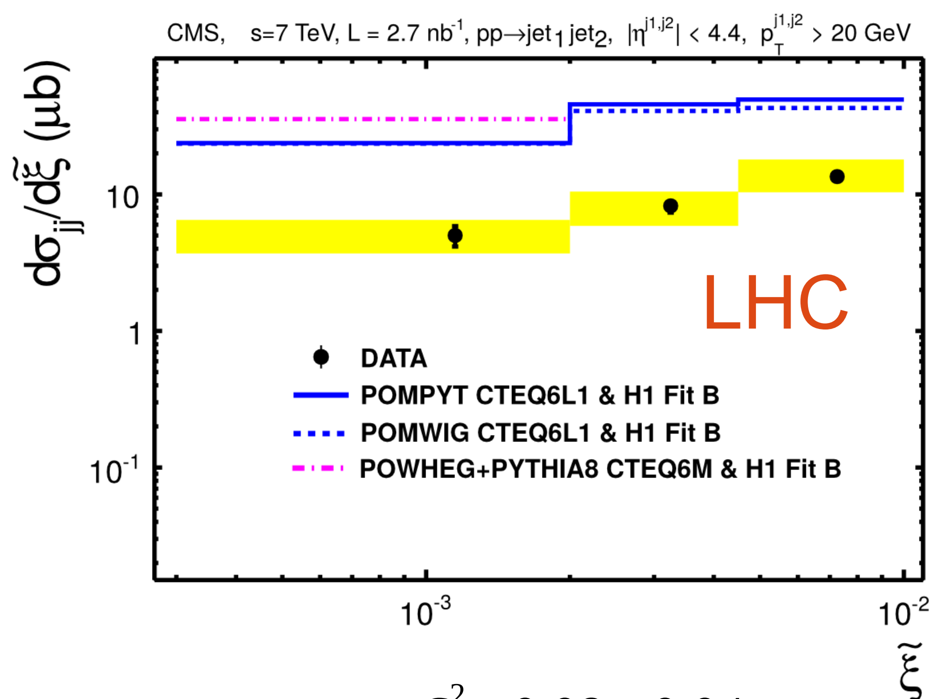
Based on diffractive collinear factorisation

PoS DIS2010 (2010) 073



$S^2 = 0.1 - 0.2$

Phys. Rev. D 87 (2013) 012006



$S^2 = 0.08 \pm 0.04$

What about diffractive photoproduction in ep?

History of Diffractive ep Photoproduction

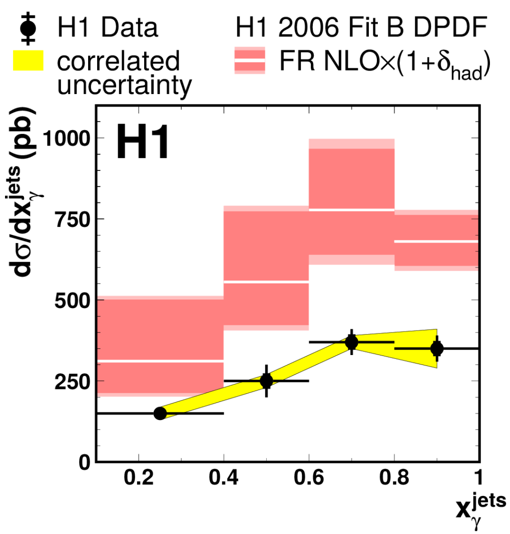
- Two **H1** measurement and one **ZEUS** LRG measurements

820 GeV

Eur. Phys. J. C 51 (2007) 549

H1:

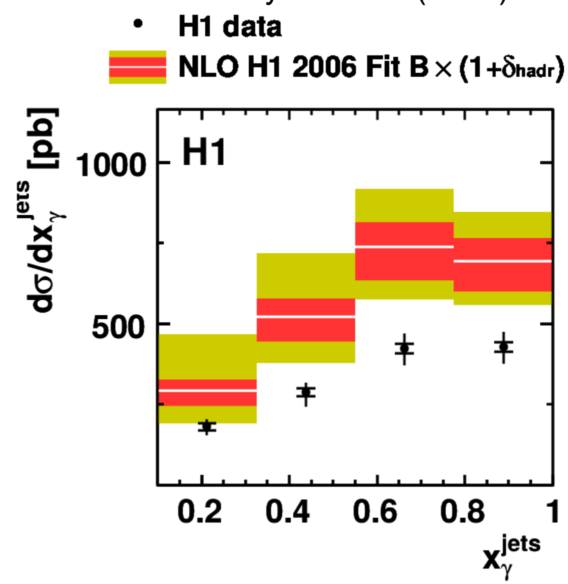
$S^2 \sim 0.5$



Eur. Phys. J. C 55 (2008) 177-191

920 GeV

Eur. Phys. J. C70 (2010) 15

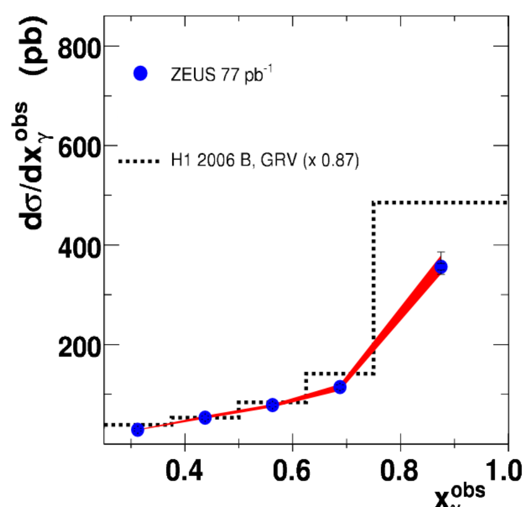


$S^2 \sim 0.6$

Eur.Phys.J. C66 (2010) 373-376
KKMR model:

H1:	$S_g^2 = 0.5$	$S_q^2 = 0.7$
ZEUS:	$S_g^2 = 0.6$	$S_q^2 = 0.8$

ZEUS:



$S^2 \sim 0.9$

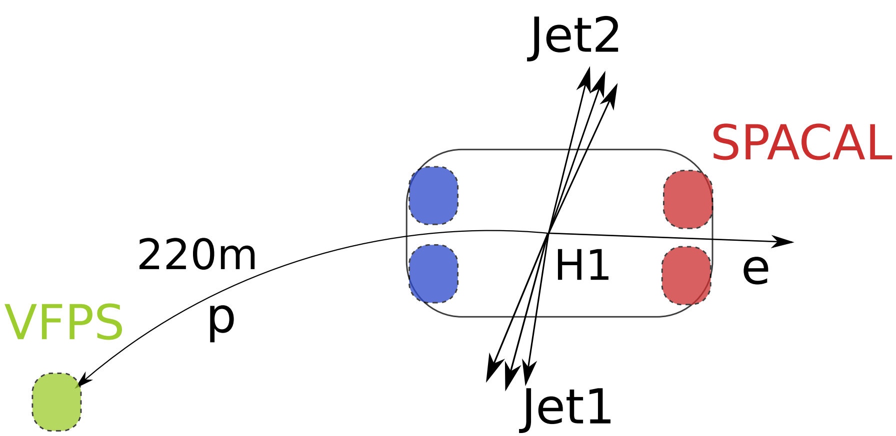
Measurement Setup

- Analysis based on 2006/07 e^+p HERA data, integrated lumi ~30 pb^{-1}
- Leading proton measured by proton spectrometer VFPS → $M_Y = M_P$

Photoproduction

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

VFPS + jets+ SPACAL VETO

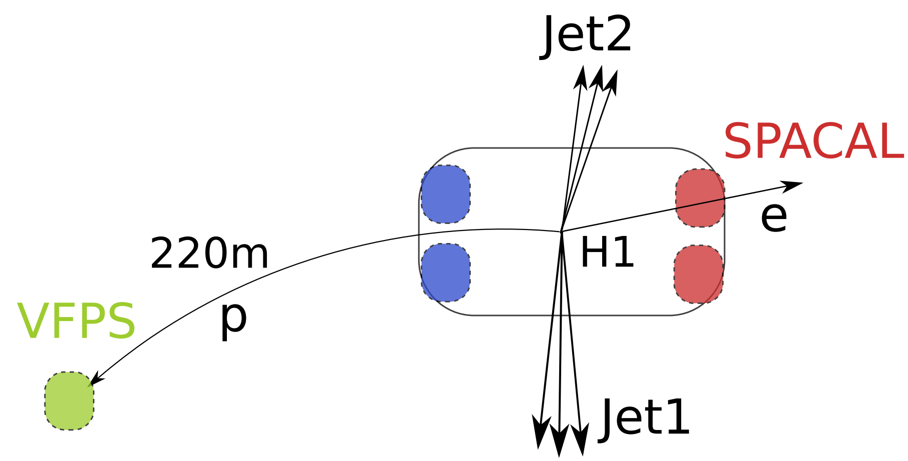


~ 3600 events

DIS

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

VFPS + jets + SPACAL positron

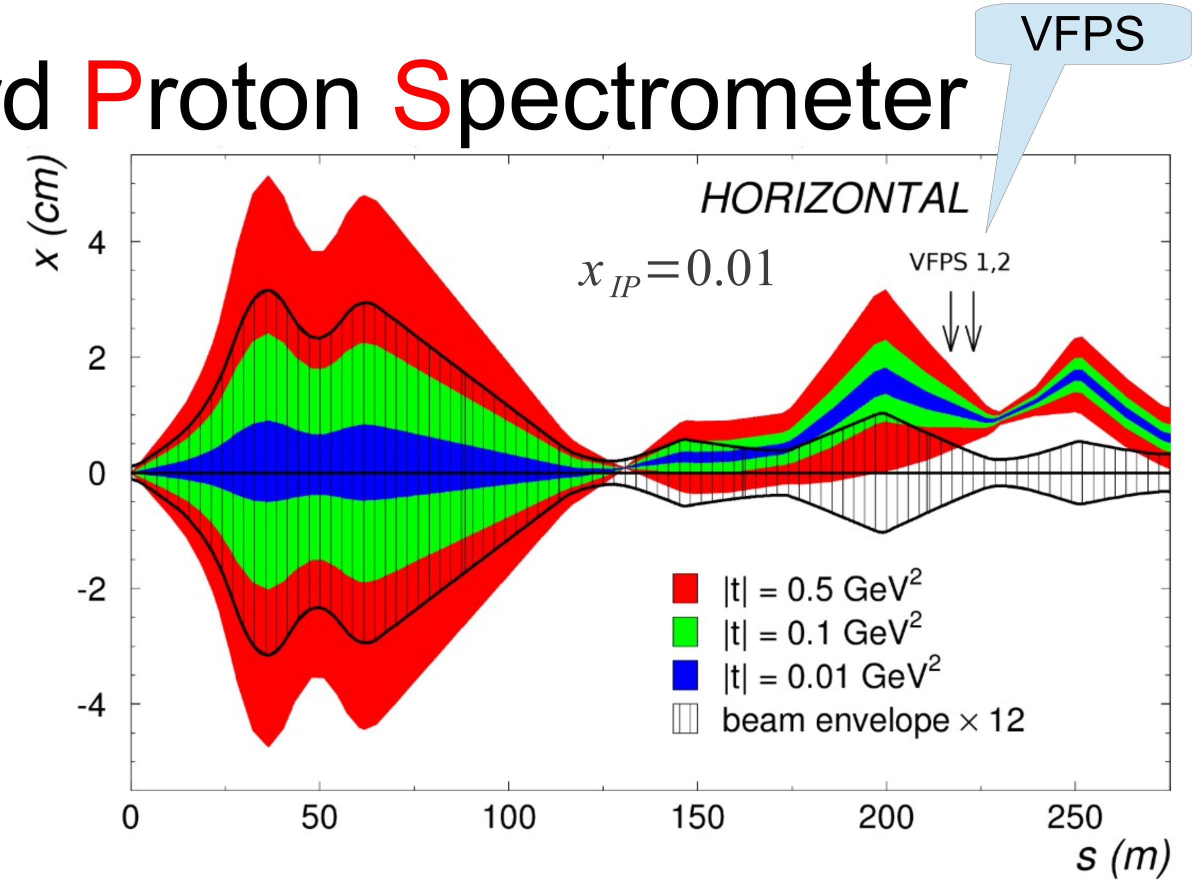


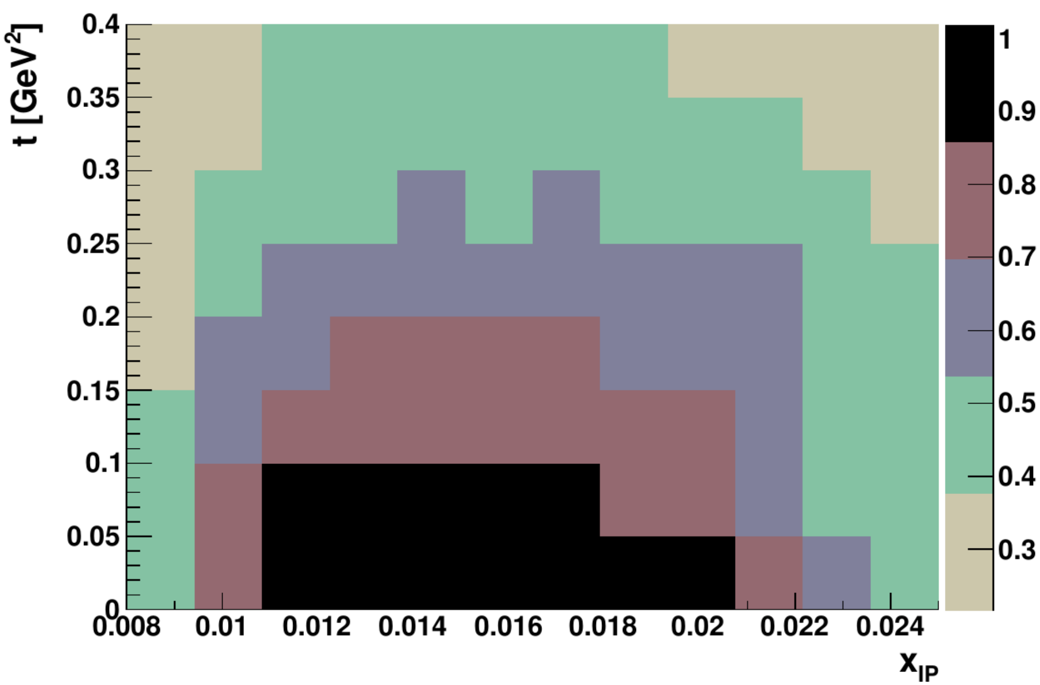
~ 300 events

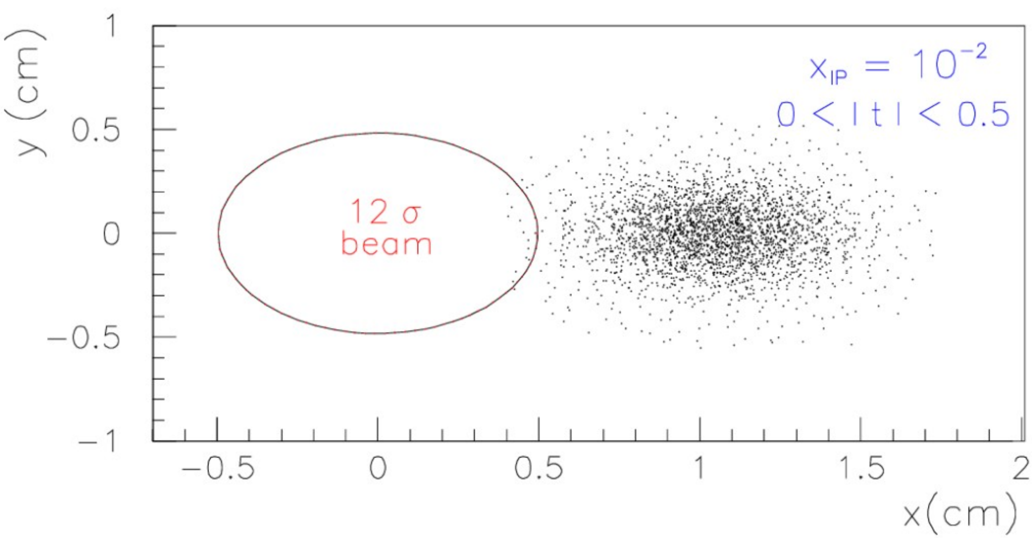
Data unfolded to the level of stable hadrons using Tikhonov method (program TUnfold)

H1 Very Forward Proton Spectrometer

- 2 stations - 218 and 222 m away from the interaction point
- High track reconstruction efficiency (~96%) and low background (<1%)







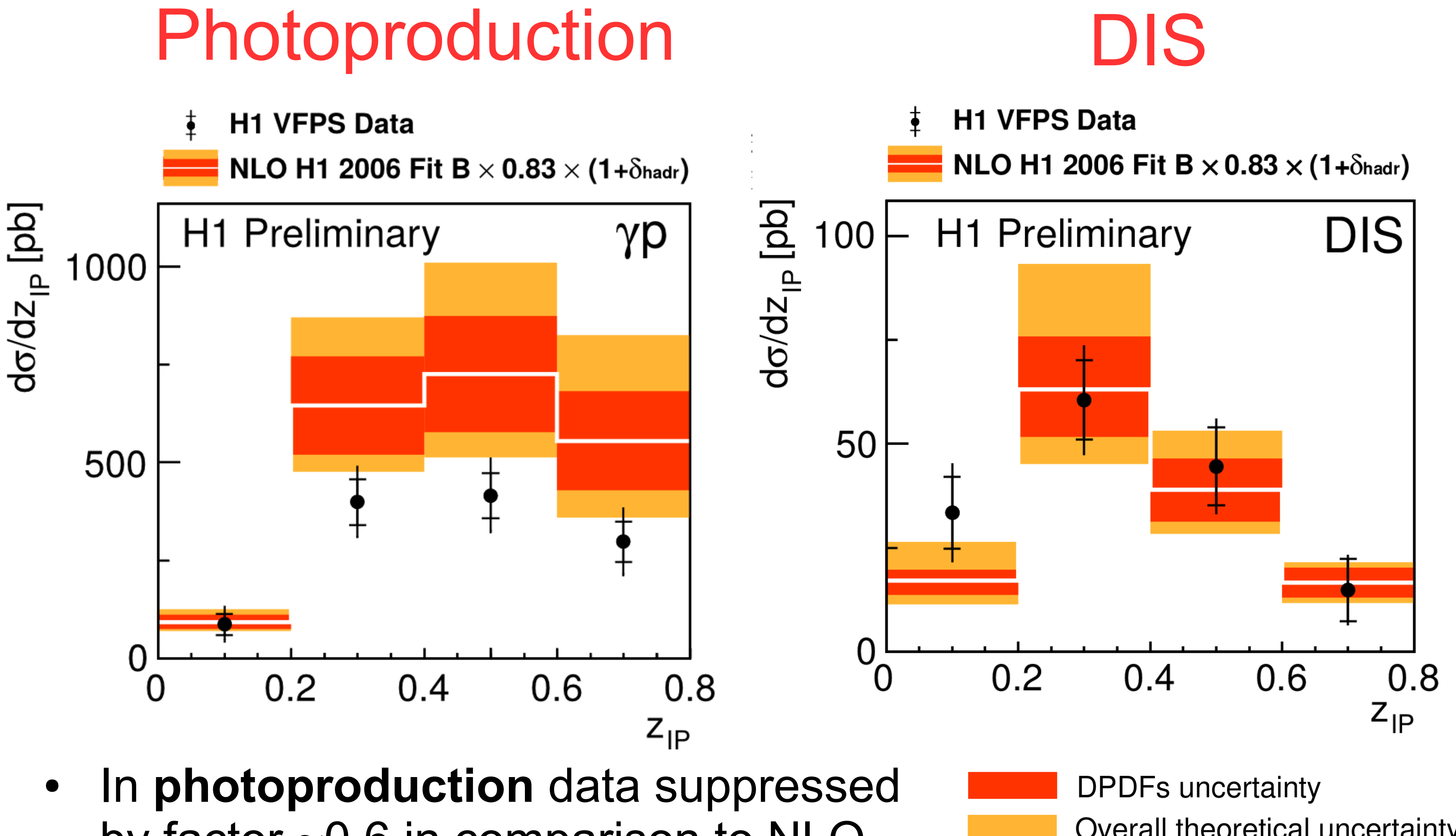
Analysis Phase Space

- Photoproduction and DIS phase spaces differ only in Q^2 range
- Jets defined by k_T-algorithm
- Cut $z_{IP}<0.8$ used because H1 Fit B fitted only to 0.8

γp	DIS
$Q^2 < 2\,\mathrm{GeV}^2$	$4\,\mathrm{GeV}^2 < Q^2 < 80\,\mathrm{GeV}^2$
Common Cuts	
$0.2 < y < 0.7$ $E_T^{*\mathrm{jet1}} > 5.5\,\mathrm{GeV}$ $\quad$ $E_T^{*\mathrm{jet2}} > 4.0\,\mathrm{GeV}$ $-1 < \eta^{\mathrm{jet1,2}} < 2.5$	
$0.010 < x_{I\!P} < 0.024$ $\lvert t\rvert < 0.6\,\mathrm{GeV}^2$ $z_{I\!P} < 0.8$	

- Results compared with NLO QCD predictions (H1 2006 Fit B, $\mu^2=(E_T^{*\,\mathrm{jet}\,1})^2+Q^2/4$) corrected for hadronisation effects

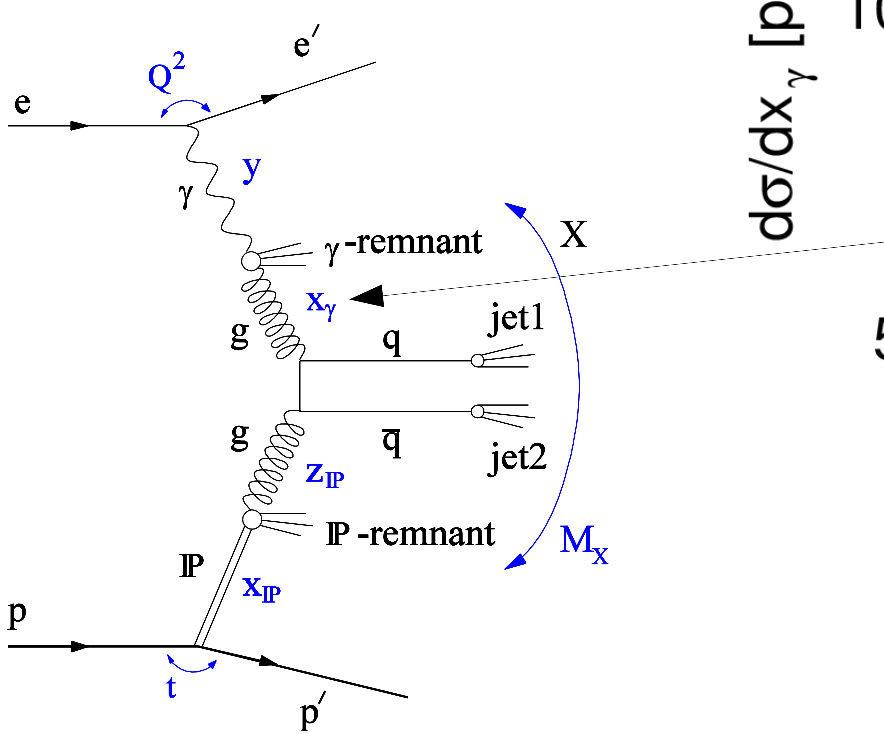
Differential Cross Section in z_{IP}

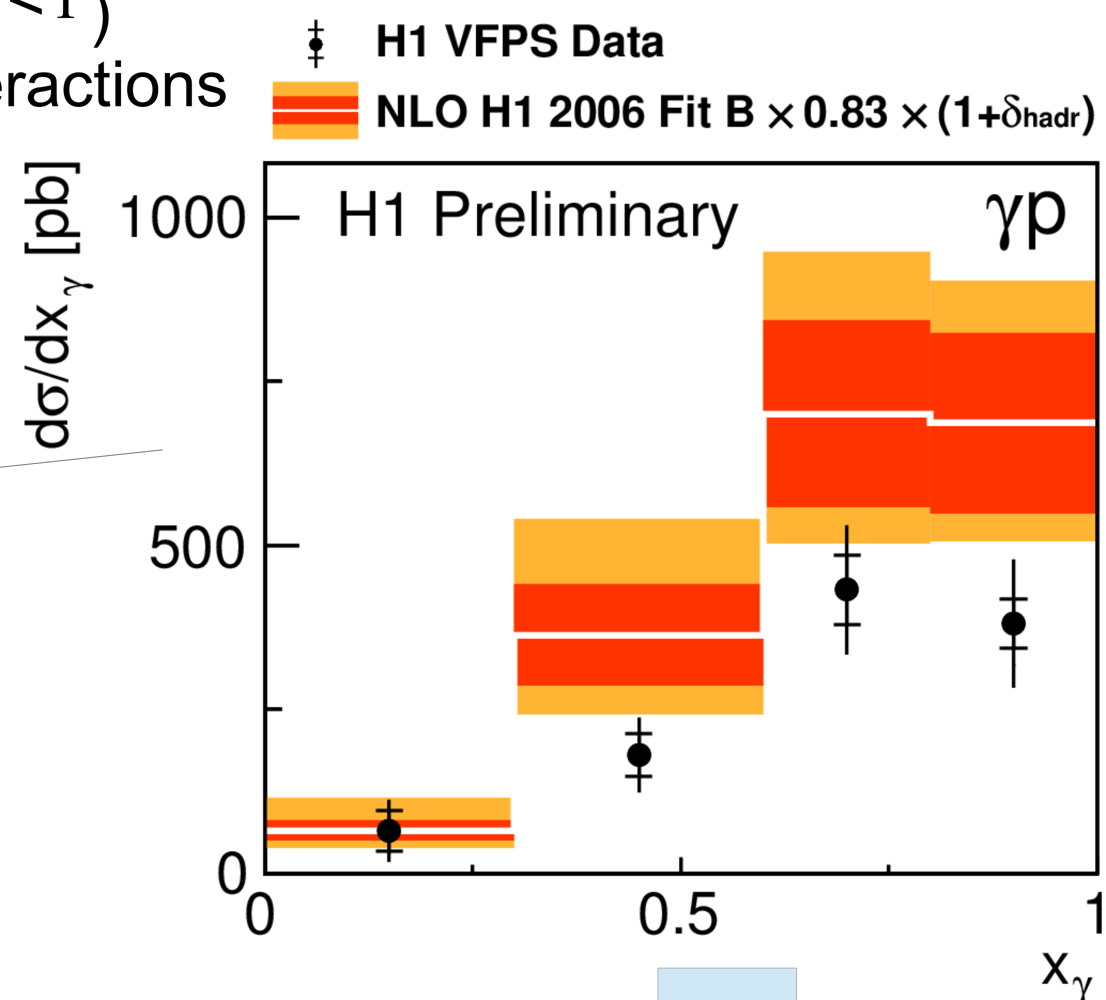


- In **photoproduction** data suppressed by factor ~0.6 in comparison to NLO
- In **DIS** data satisfactorily described by NLO

Differential Cross Section in x_γ for Photoproduction

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





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

How to reduce uncertainties?

- To test factorisation $R_{DIS}^{\gamma p}$ introduced, which is less sensitive to the input DPDF and QCD scale uncertainties

$$R_{DIS}^{\gamma p} = \frac{\left(\sigma^{Data} / \sigma^{Theor.}\right)_{\gamma p}}{\left(\sigma^{Data} / \sigma^{Theor.}\right)_{DIS}}$$

- Previously measured by H1 for:

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Dijets selected by LRG

$$R_{DIS}^{\gamma p} = 0.5 \pm 0.1$$

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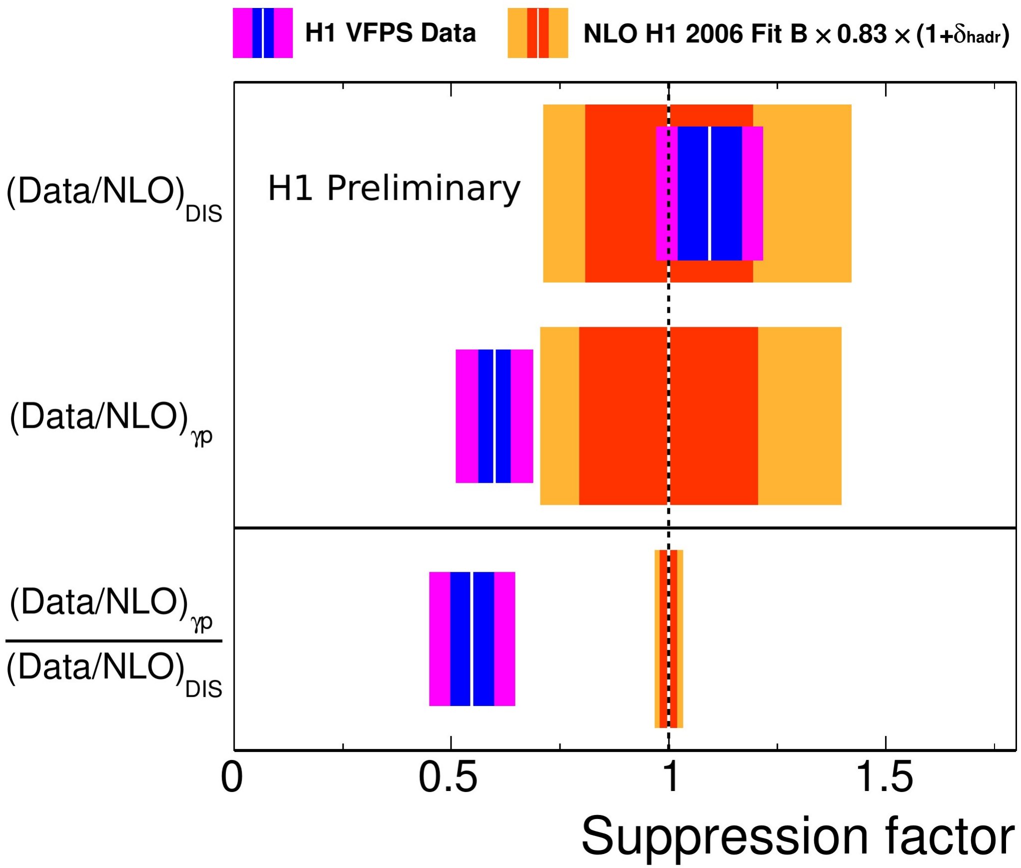
D* selected by LRG

$$R_{DIS}^{\gamma p} = 1.1 \pm 0.4$$

Double ratio $R_{DIS}^{\gamma p}$ measured for the first time by proton spectrometer → New way of testing diffractive factorisation

Double Ratio



DPDFs uncertainty

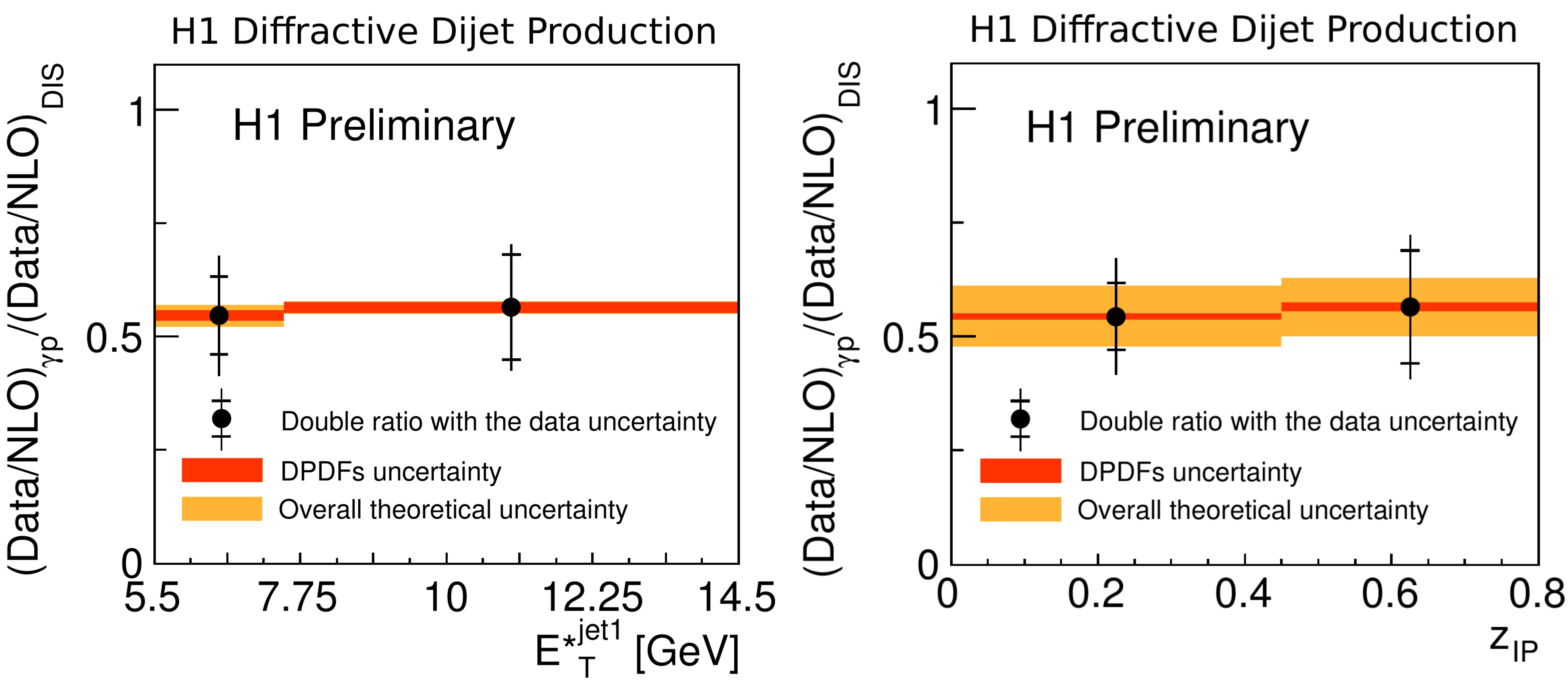
Overall theoretical uncertainty

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

- Previous H1 measurements confirmed
- The QCD factorisation breaking in diffractive dijet photoproduction confirmed

$$R^{\gamma p}_{DIS} = \frac{(\mathrm{DATA/NLO})_{\gamma p}}{(\mathrm{DATA/NLO})_{\mathrm{DIS}}} = 0.55 \pm 0.10\,(\mathrm{data}) \pm 0.02\,(\mathrm{theor.})$$

Differential Double Ratios



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

Summary

- Dijet diffractive cross sections measured in two Q^2 regions, photoproduction and DIS
- Factorisation in DIS confirmed
- In photoproduction the suppression factor about 0.55 observed
- Previous H1 measurements 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

Theoretical Predictions

- NLO QCD predictions were compared with measured H1 VFPS data

Process	Photoproduction	DIS
Program for NLO	Frixione-Ridolfi NLO	NLOJET++
Proton DPDF	H1 2006 Fit B	H1 2006 Fit B
γ-PDF	GRV-HO	-
Hard scale	$\left(E_T^{*\,\mathrm{jet1}}\right)^2$	$\left(E_T^{*\,\mathrm{jet1}}\right)^2 + Q^2/4$

- NLO QCD predictions are corrected for hadronization effects by means of hadronization corrections calculated by Monte Carlo model Rapgap (typically less than 10%)