Diffractive Dijet Production with Leading Proton in ep Collisions at HERA

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on behalf of H1 collaboration

DIS 2014

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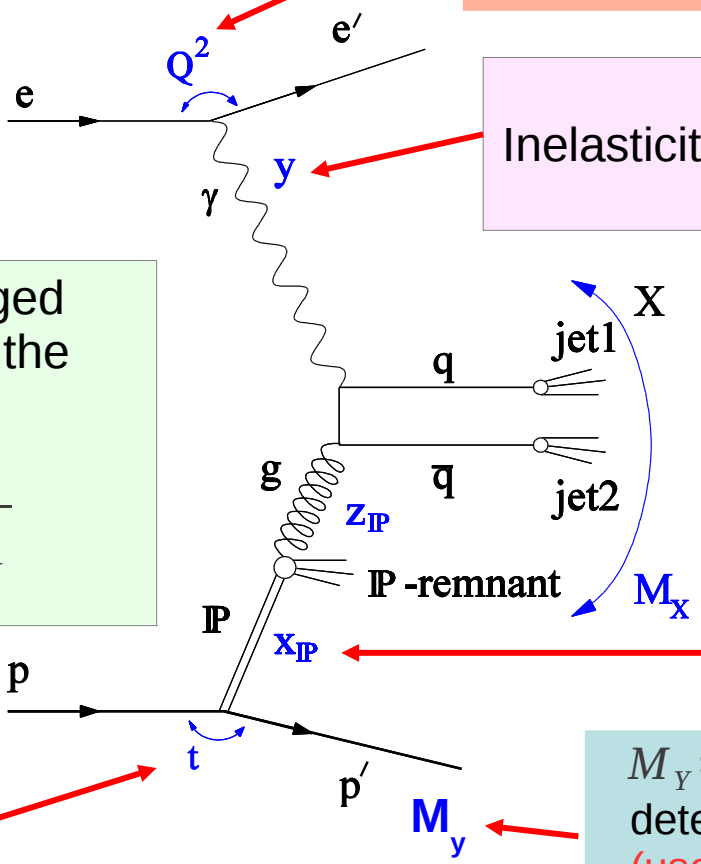
Diffractive Kinematics

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

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

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

$M_Y = m_p$ proton stays intact, needs detector setup to detect protons (used in this analysis)

$M_Y > m_p$ proton dissociates, approx. 20 % in H1 LRG measurement

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)

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

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

$\mathrm{d}\hat{\sigma}^{\gamma i}$ — 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:

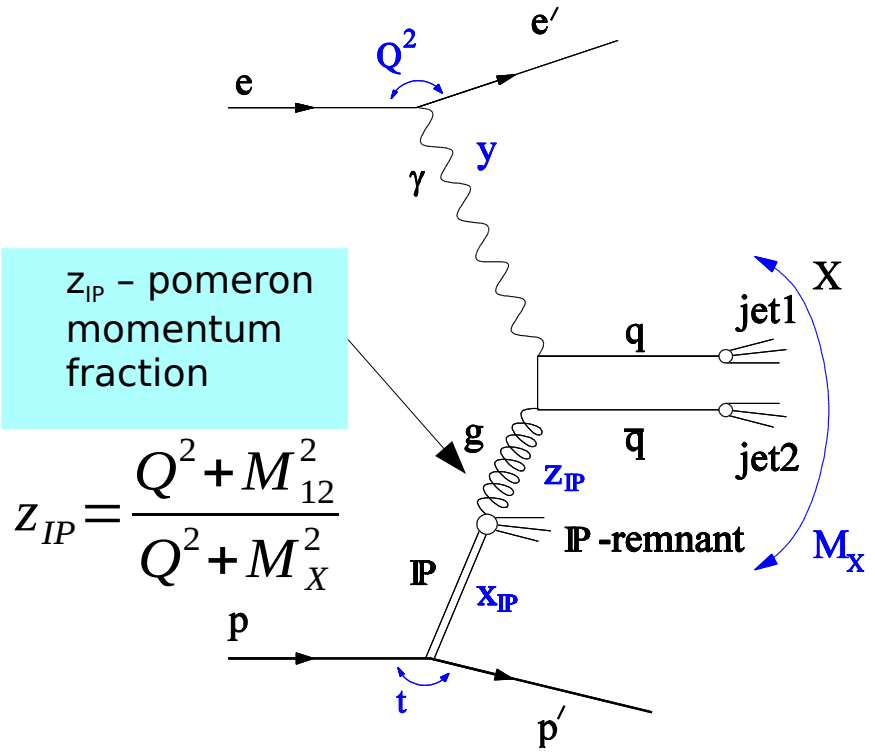
$$f_i^D(\beta, Q^{2,} x_{IP}, t) = f_{IP/p}(x_{IP}, t) \cdot f_i^{IP}(\beta, Q^2)$$

$f_{IP/p}$ — pomeron flux factor

f_i^{IP} — pomeron PDF

Diffractive Dijet Production - DIS

- Photon enters directly into the hard subprocess
- One remnant
- Factorization theoretically proven

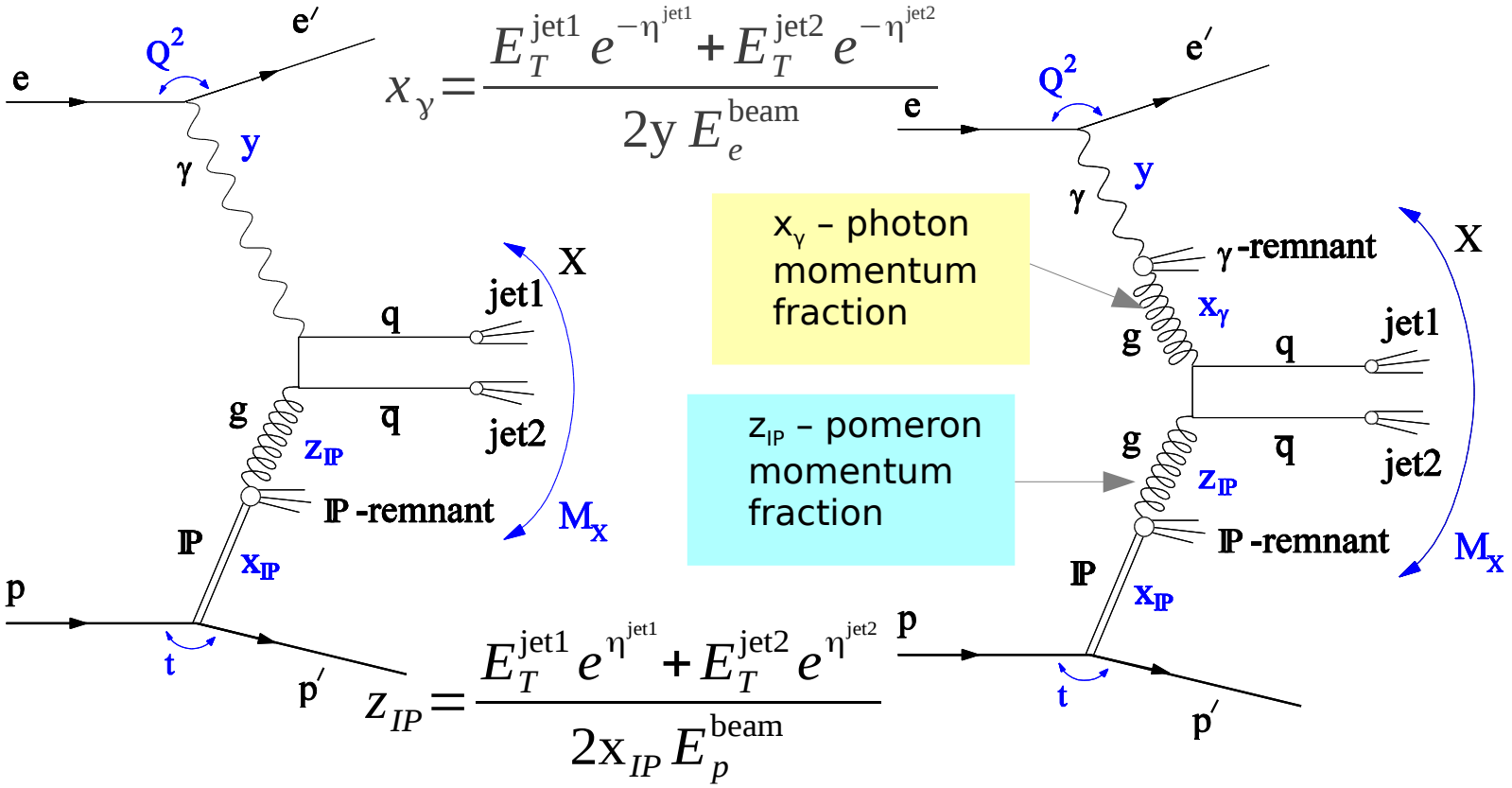


LO diagram!

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

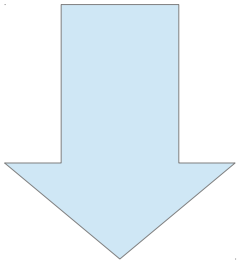


LO diagrams!

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

Motivation for the measurement

- Diffractive dijet photoproduction measured extensively by HERA, so far only by **large rapidity gap** method
- DIS 2013: First dijet photoproduction measurement with **leading proton** detection. Theoretical uncertainties too large to make definite conclusion about factorization breaking



- New measurement with leading proton in diffractive DIS. Similar kinematic region as in photoproduction
- The double ratios of data to NLO QCD prediction for photoproduction and DIS introduced to reduce experimental and **theoretical** errors

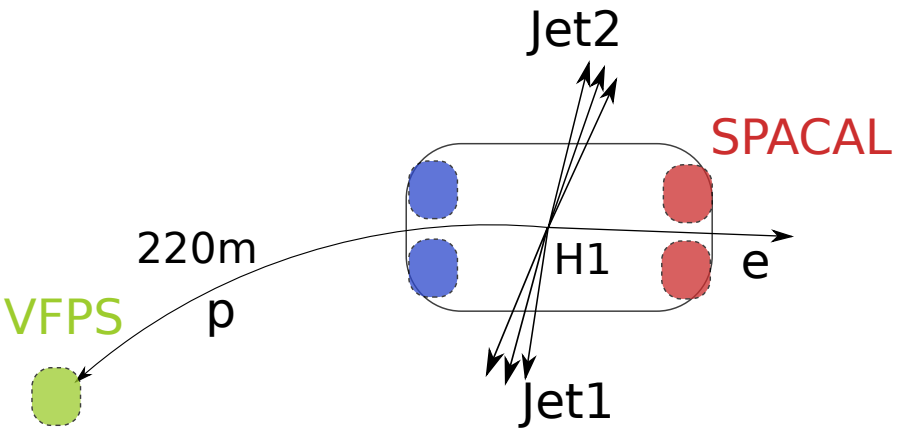
Measurement Setup

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

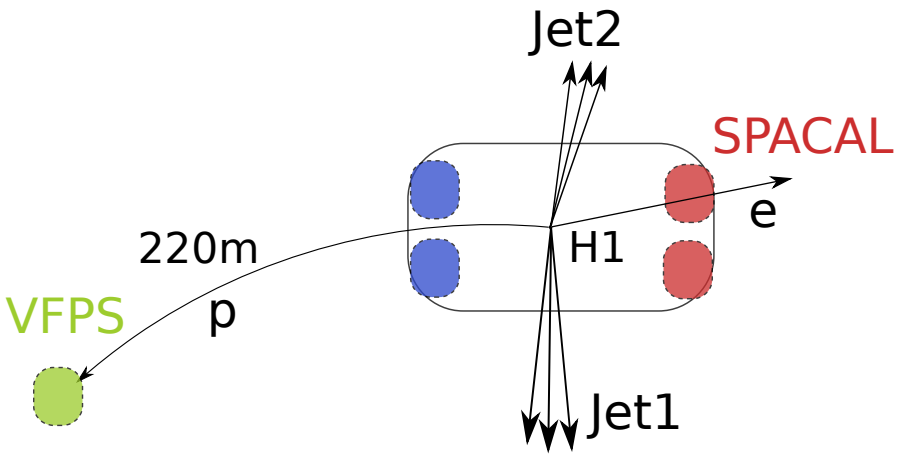


~ 3600 events

DIS

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

VFPS + jets + SPACAL positron



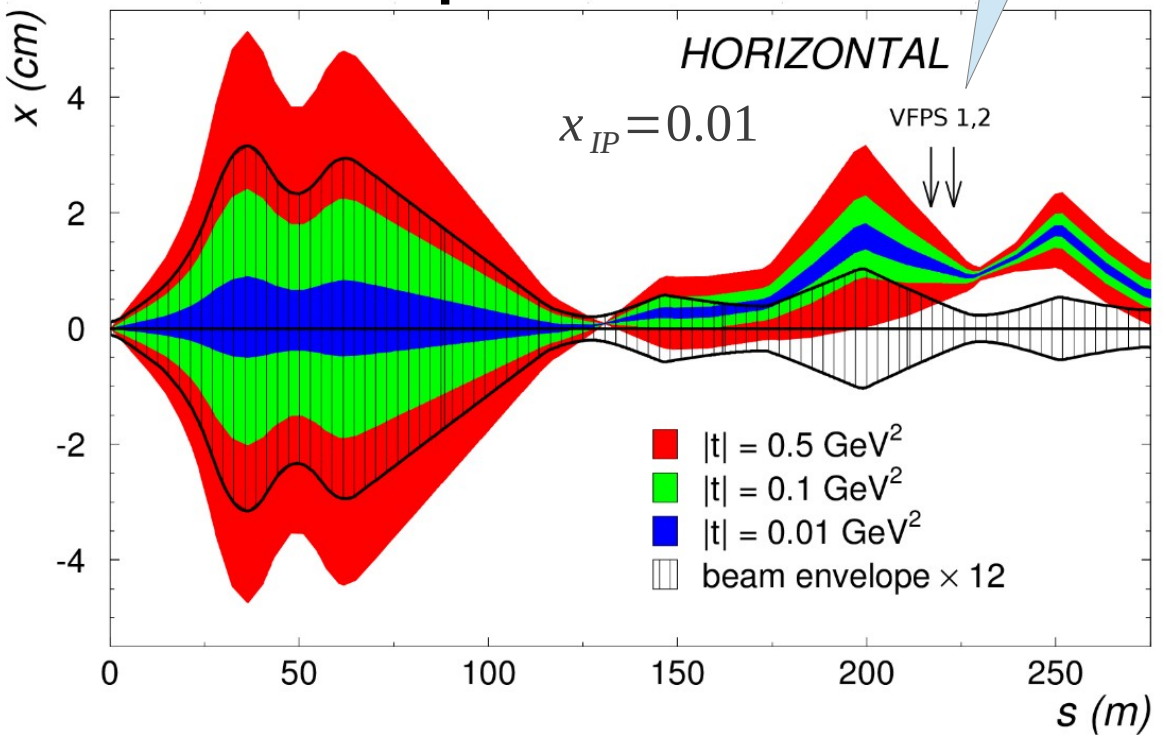
~ 300 events

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

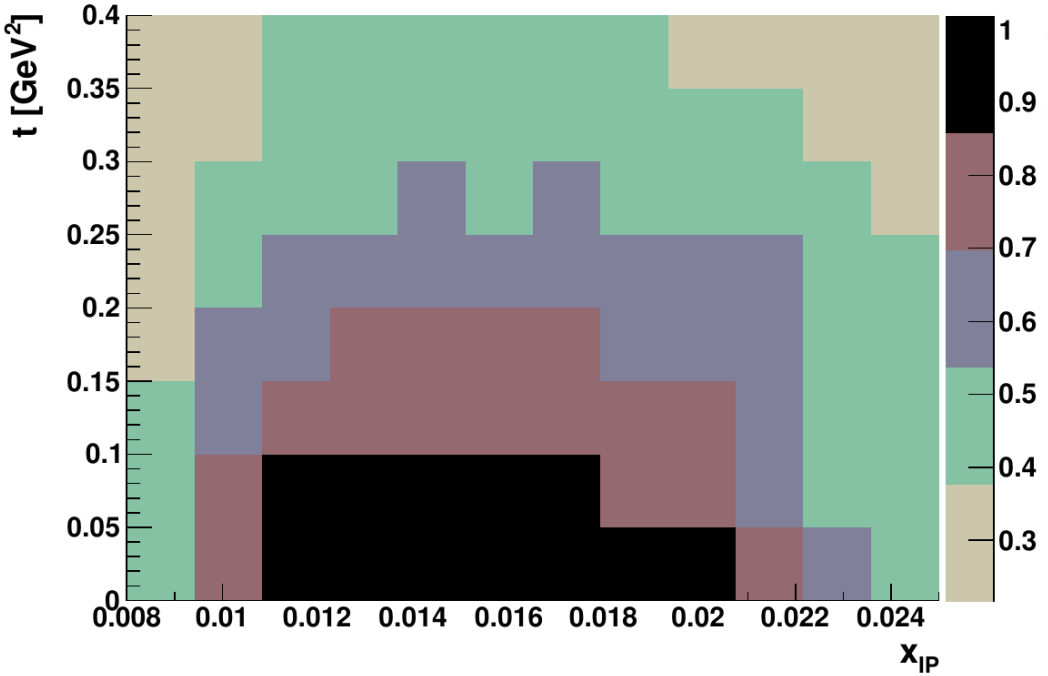
H1 Very Forward Proton Spectrometer

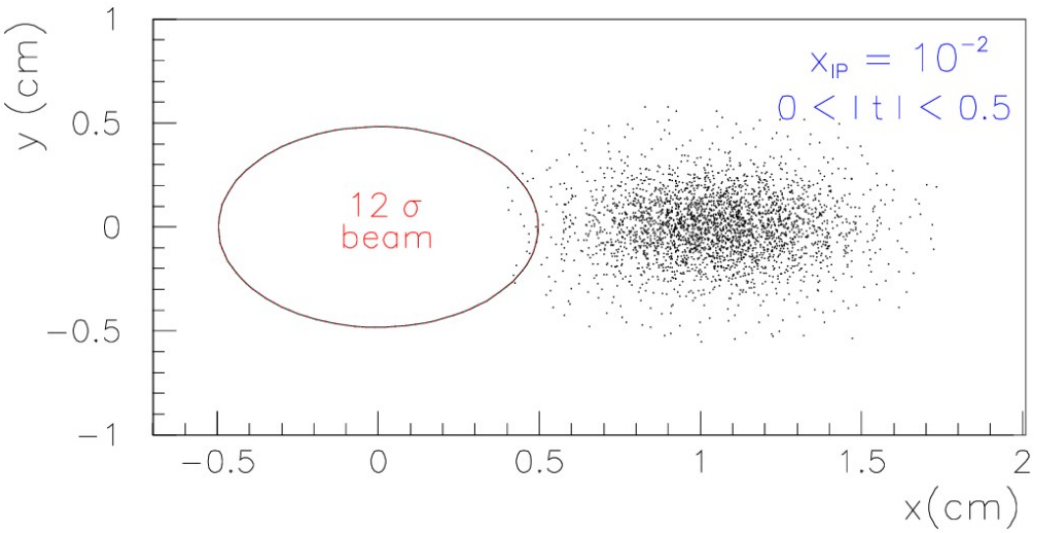
VFPS

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



VFPS Acceptance





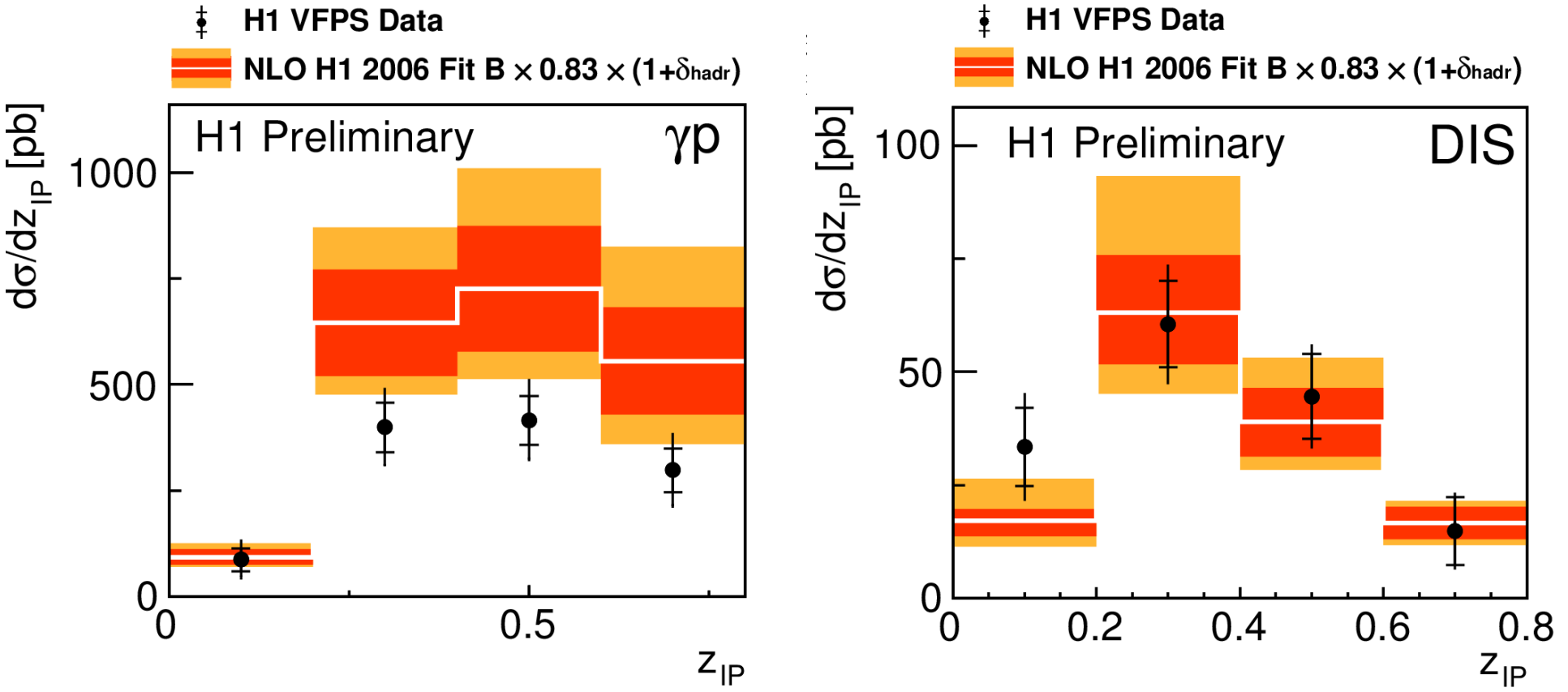
Theoretical Predictions

- 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%)

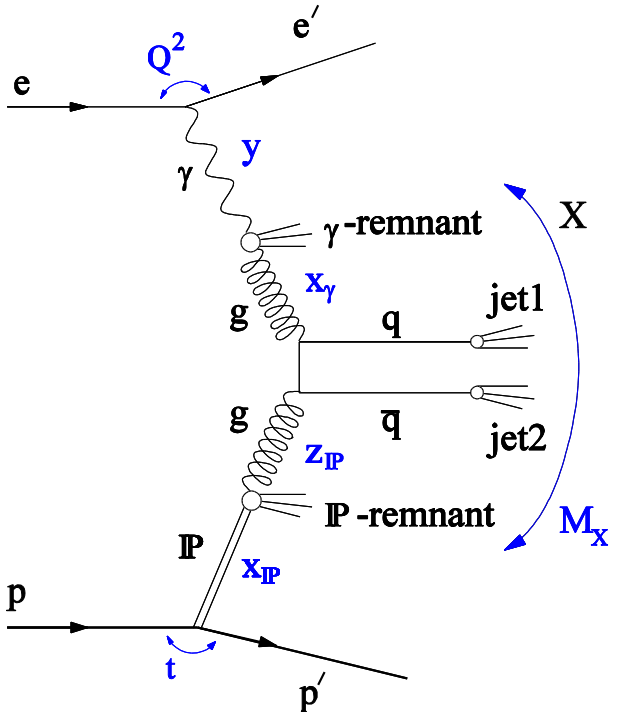
Differential Cross Section in z_{IP}

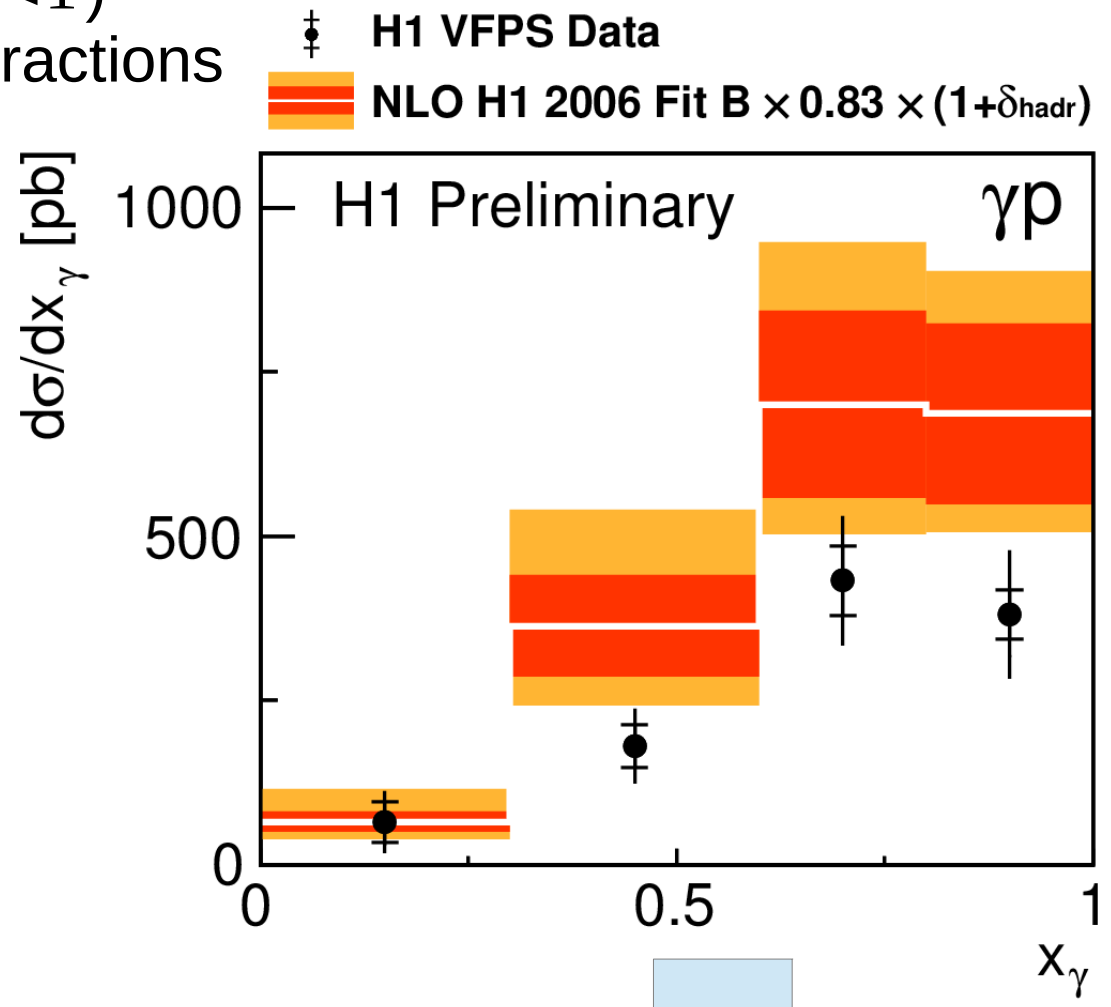


- In **photoproduction** data suppressed by factor ~0.6 in comparison to NLO
- In **DIS** data satisfactorily described by NLO

Differential Cross Section in x_γ

Q: Resolved photoproduction (x_γ<1)
resembles hadron-hadron interactions
Higher suppression?



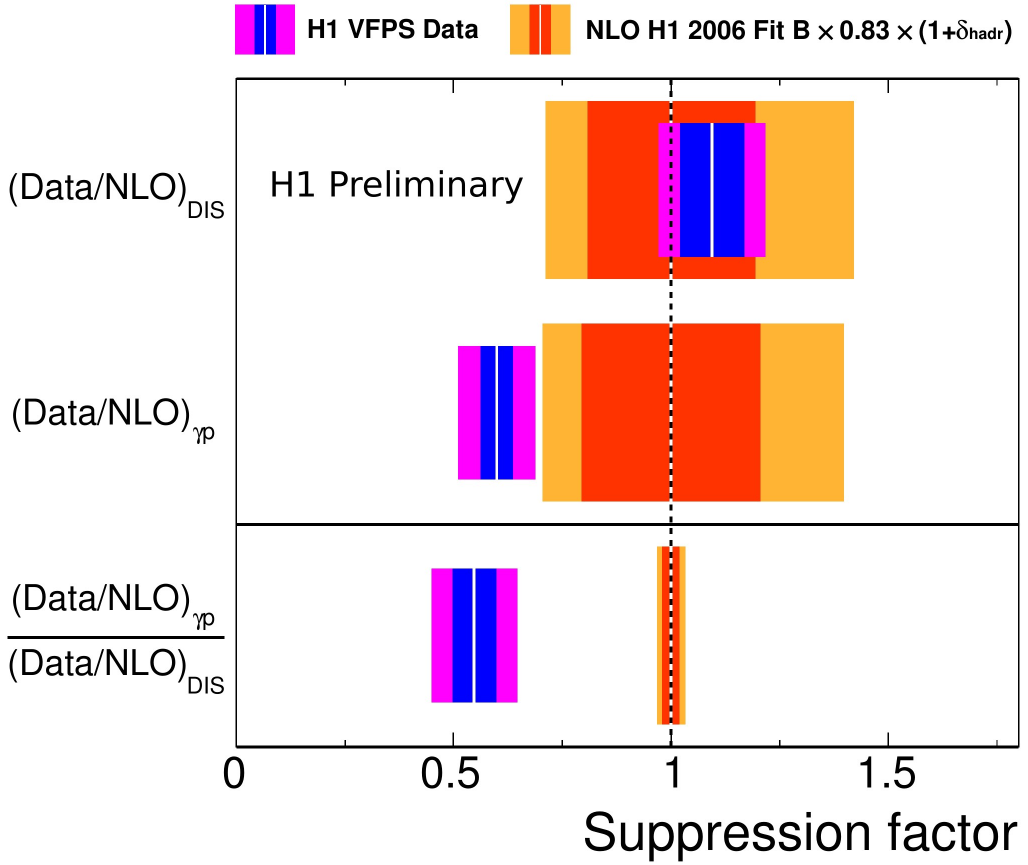


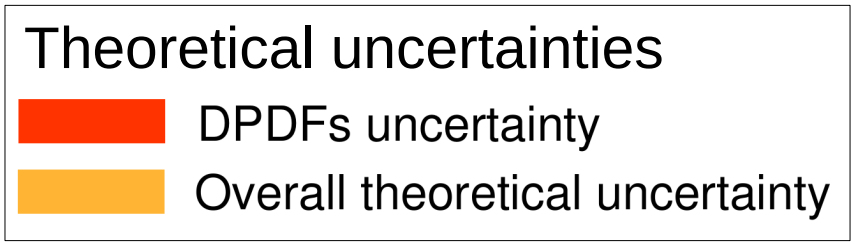
A: No hint for higher suppression for x_γ<1

Double Ratio

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

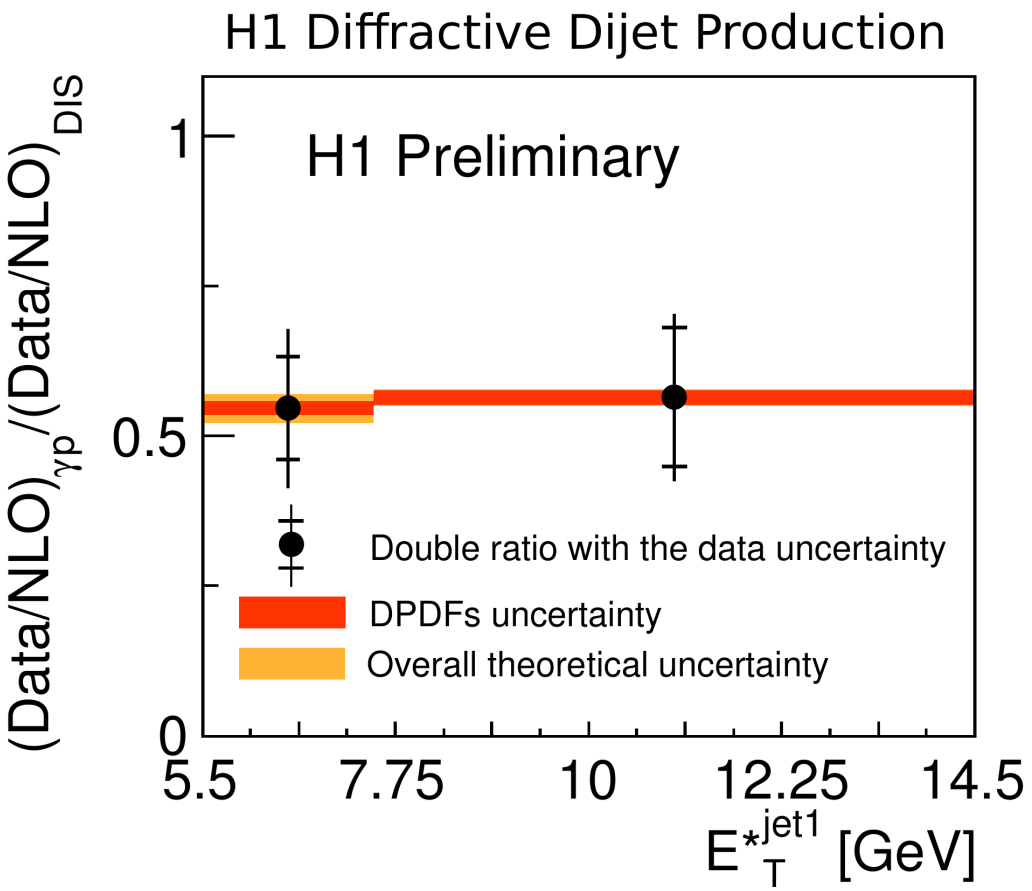
$$\frac{(\mathrm{DATA/NLO})_{\gamma p}}{(\mathrm{DATA/NLO})_{\mathrm{DIS}}} = 0.55 \pm 0.10\,(\mathrm{data}) \pm 0.02\,(\mathrm{theor.})$$

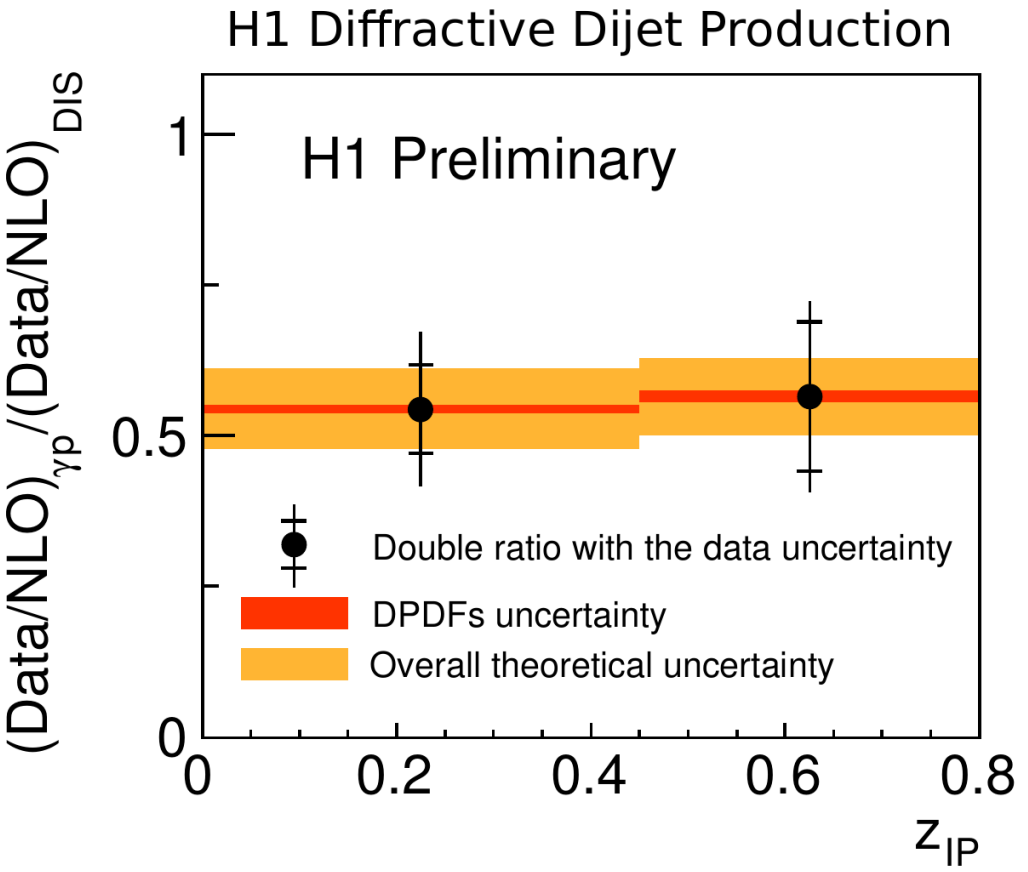




For QCD scale uncertainty the scale varied simultaneously in in photoproduction and DIS by factor of ½ and 2

Differential Double Ratios





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

Summary

- Dijet diffractive cross sections measured in two Q^2 regions, photoproduction and DIS using **proton spectrometer**
- Previous H1 measurements based on large rapidity gap method confirmed
- **Suppression** factor in photoproduction about **0.55** established
- No hint of a dependence of the suppression on x_γ and E_T of the leading jet

Backup

Analysis cuts

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