Diffractive ep photoproduction with leading proton at HERA

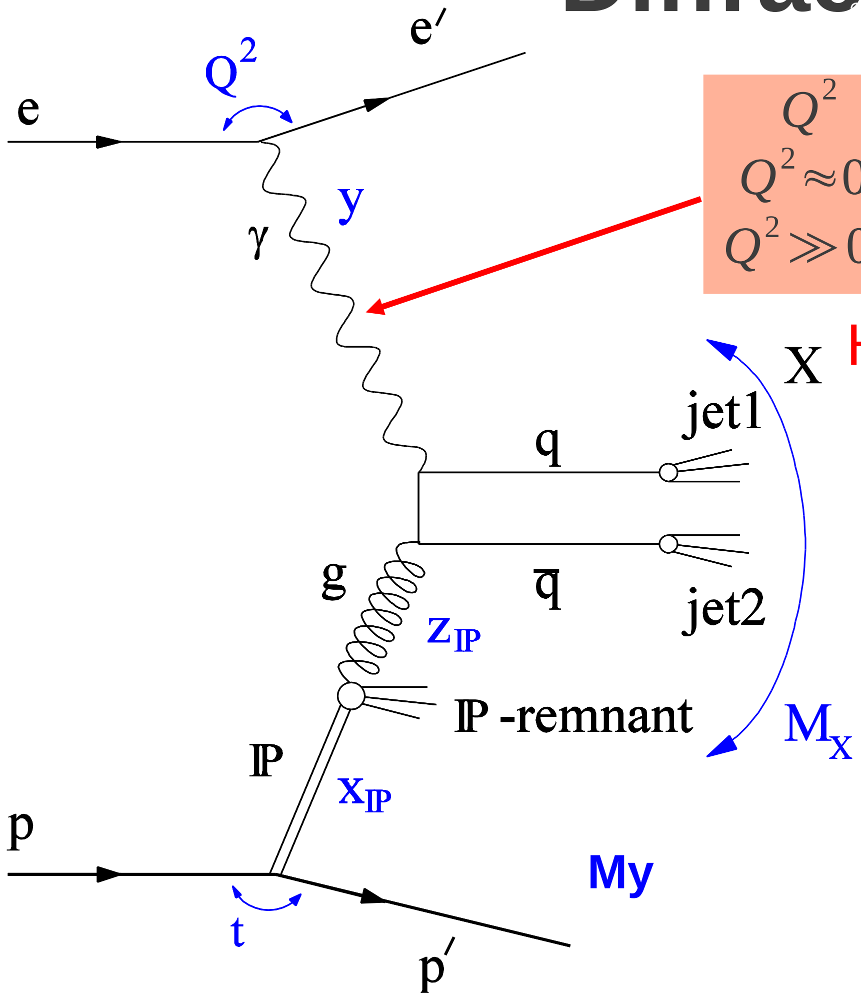
Radek Žlebčík

on behalf of H1 collaboration

DIS 2013

25th April 2013

Diffractive Kinematics



Q^2 Virtuality of the photon

$Q^2 \approx 0$ → photoproduction

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

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

Momentum fraction of the diffractive exchange

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2} \approx 1 - \frac{E_p'}{E_p}$$

The fraction of exchanged momentum entering to the hard subprocess

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

4-momentum transfer squared $t = (p - p')^2 = \frac{-p_T^2}{1 - x_{IP}}$

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

$M_Y = m_p$ 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)

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

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:

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

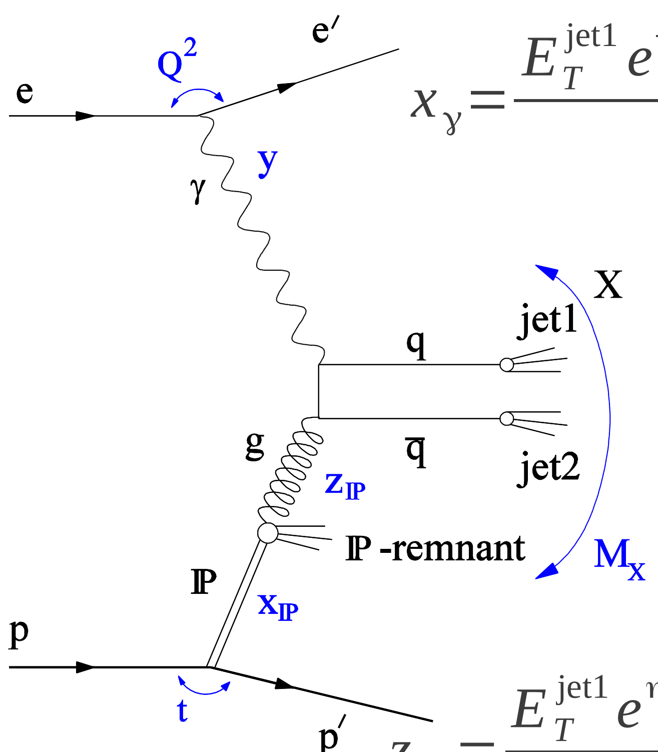
$f_{IP/p}$: pomeron flux factor

f_i^{IP}: pomeron PDF

Diffractive Dijet Photoproduction

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

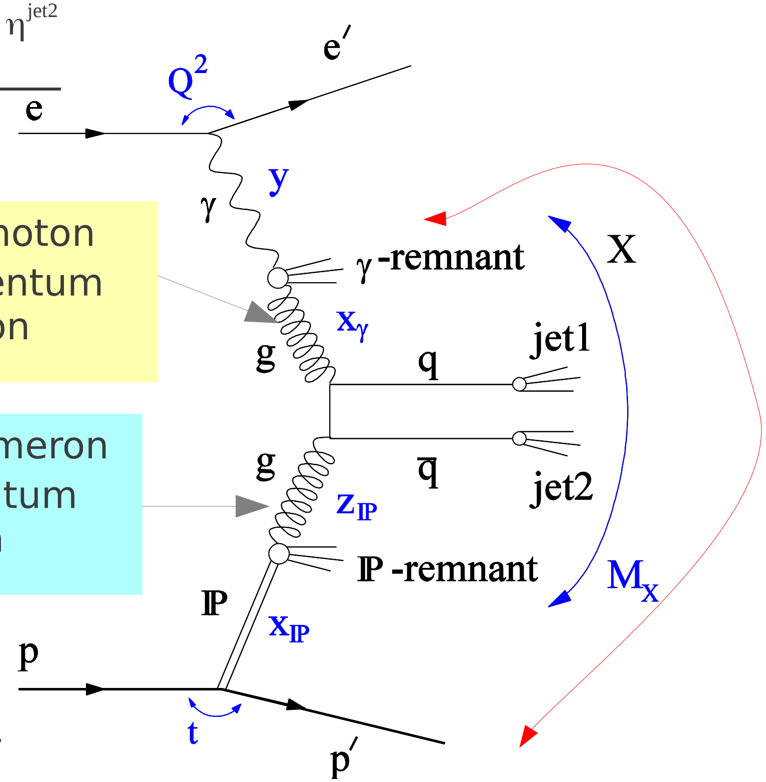
Resolved
photon remnant
$x_\gamma < 1$
Dominant for low Q^2, γ-PDF introduced
Resembles hadron-hadron interactions (two-remnants)



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

x_γ – photon momentum fraction

z_{IP} – pomeron momentum fraction



Additional interactions which spoil rap. Gap? (like in pp)

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

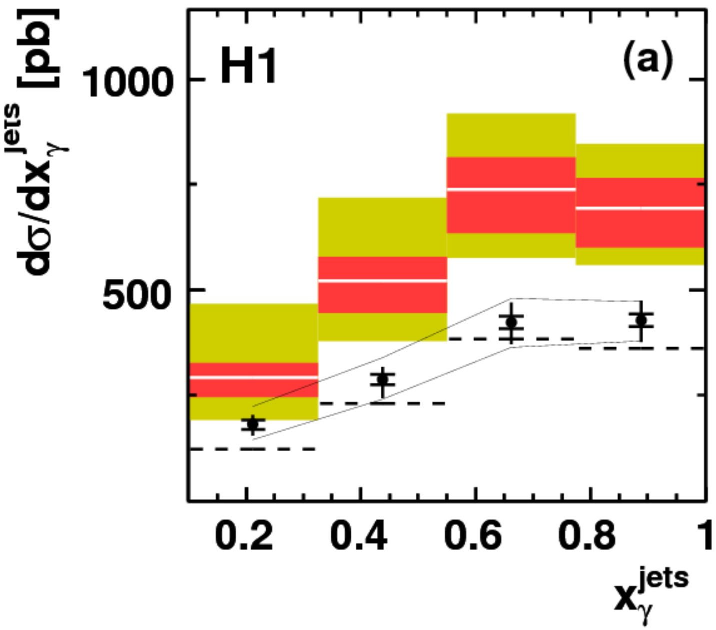
LO diagrams!

History – H1 and ZEUS Measurements

- The suppression is supposed to be stronger at low scales and low x_γ

Eur. Phys. J. C68 (2010) 381

$E_T^{\text{jet1}(2)} > 5(4)\,\text{GeV}$

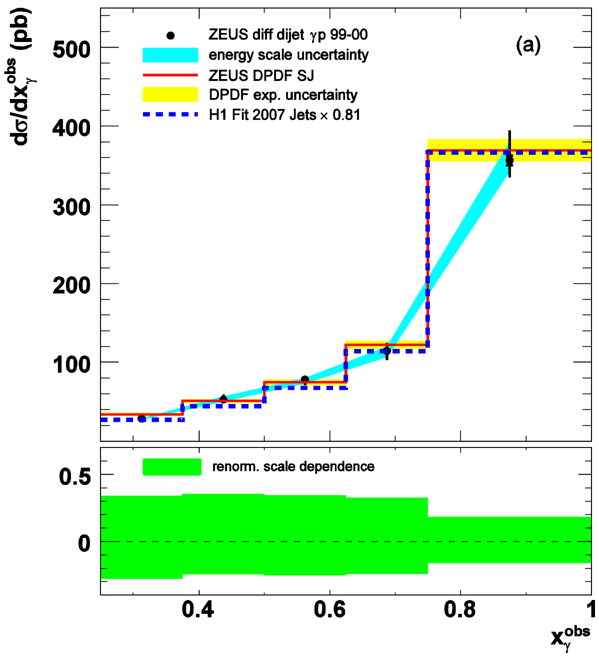


$\sigma_{data}^{H1} / \sigma_{NLO}^{H1} \approx 0.6$

LRG + electron tagger

Nucl. Phys. B381 (2010)

$E_T^{\text{jet1}(2)} > 7.5(6.5)\,\text{GeV}$



$\sigma_{data}^{ZEUS} / \sigma_{NLO}^{ZEUS} \approx 1.0$

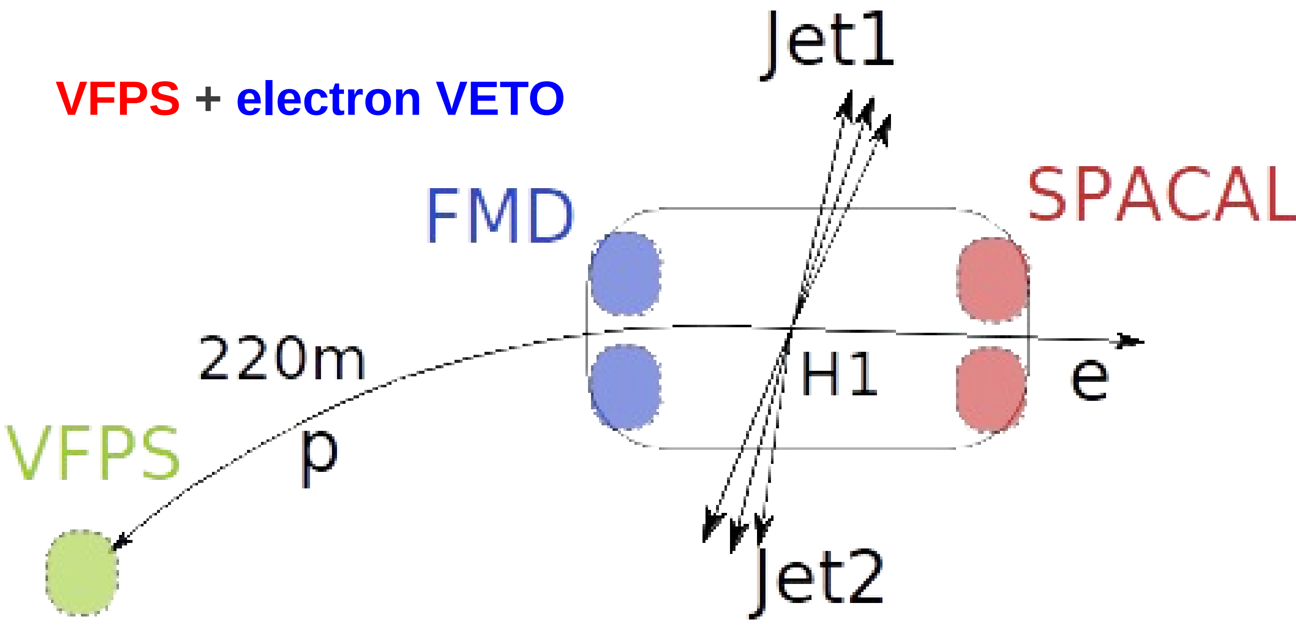
LRG + electron VETO

- Factorization breaking **observed by H1** but **not observed by ZEUS**
- No x_γ dependence of suppression-factor visible

Analysis cuts

- Analysis based on 2006/07 e^+p HERA data, integrated lumi ~30 pb^{-1}
- Leading proton measured by proton spectrometer → $M_Y = M_P$
- Untagged photoproduction (=events selected by electron VETO)

VFPS + electron VETO



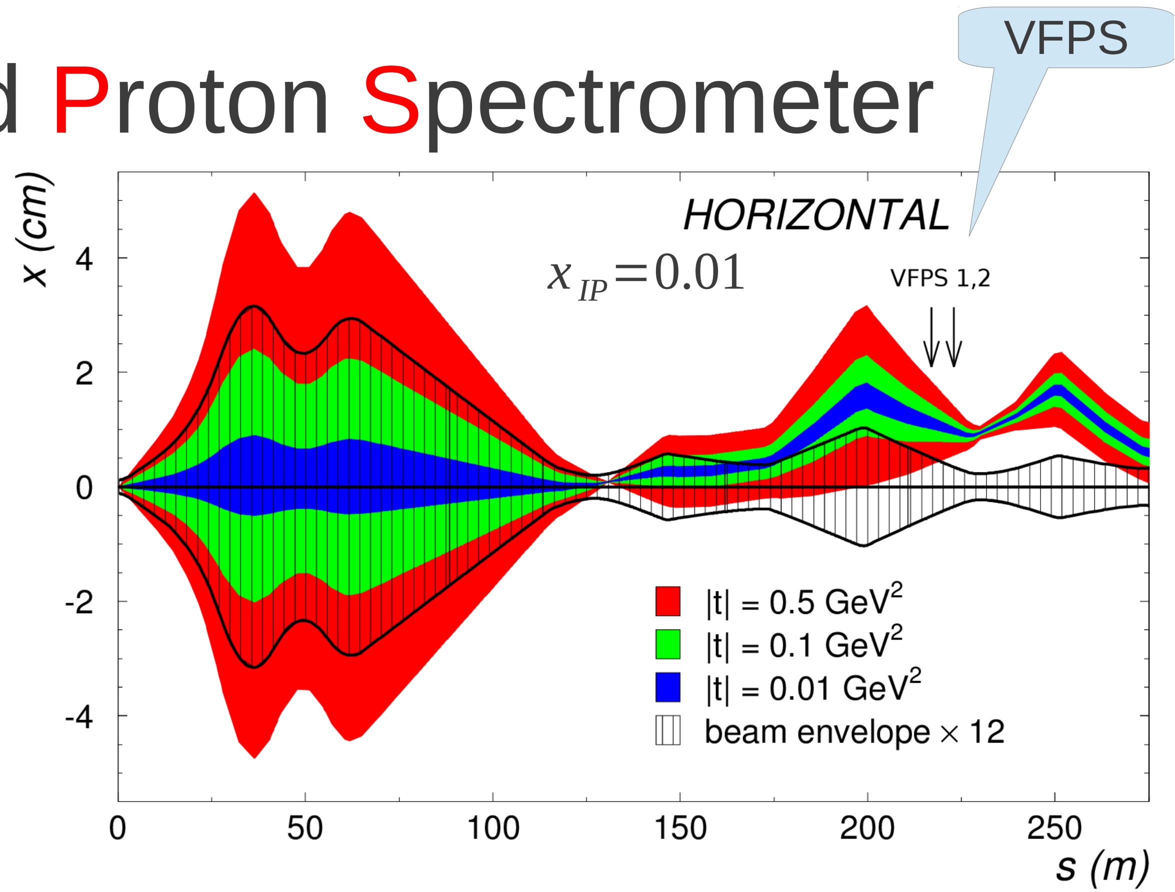
~ 4800 events which fulfill all cuts

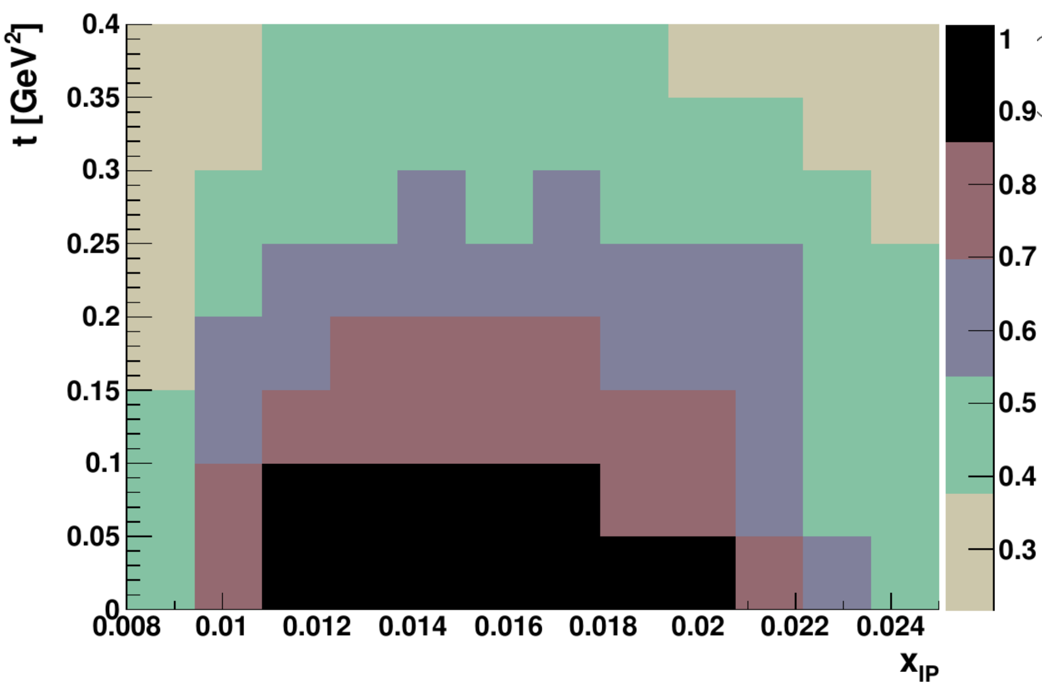
Data unfolded to the level of stable hadrons using method of Singular Value Decomposition of the response matrix (program TUnfold)

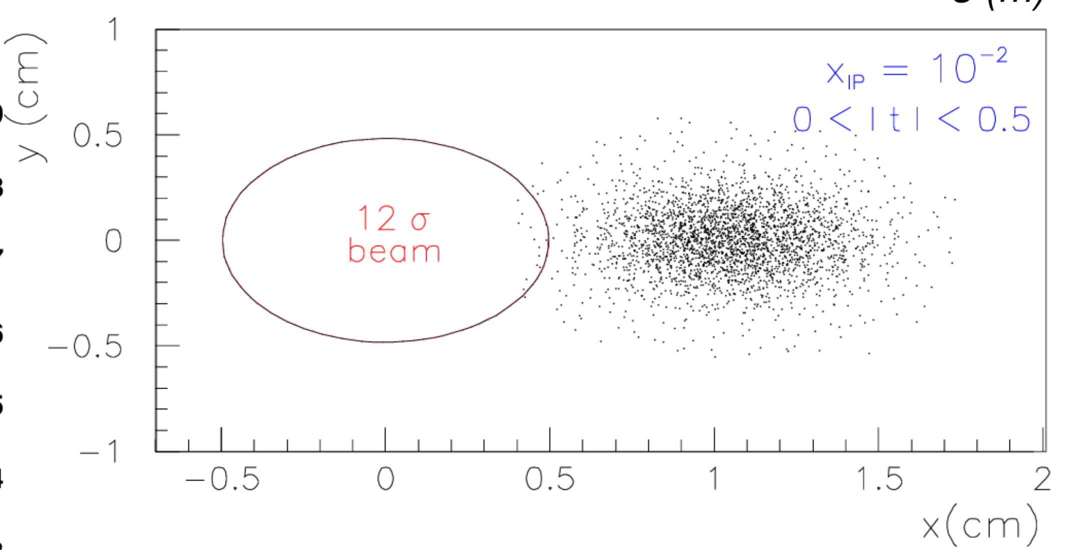
Phase-space definition
$Q^2 < 2\,\mathrm{GeV}^2$
$0.2 < y < 0.8$
k_T jet algorithm:
$E_T^{jet1(2)} > 5.5(4)\,\mathrm{GeV}$
$-1 < \eta^{jet1,2} < 2.5$
Diffractive:
$0.010 < x_{IP} < 0.024$
$\lvert t \rvert < 0.6\,\mathrm{GeV}^2$
$M_Y = M_p$

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%)





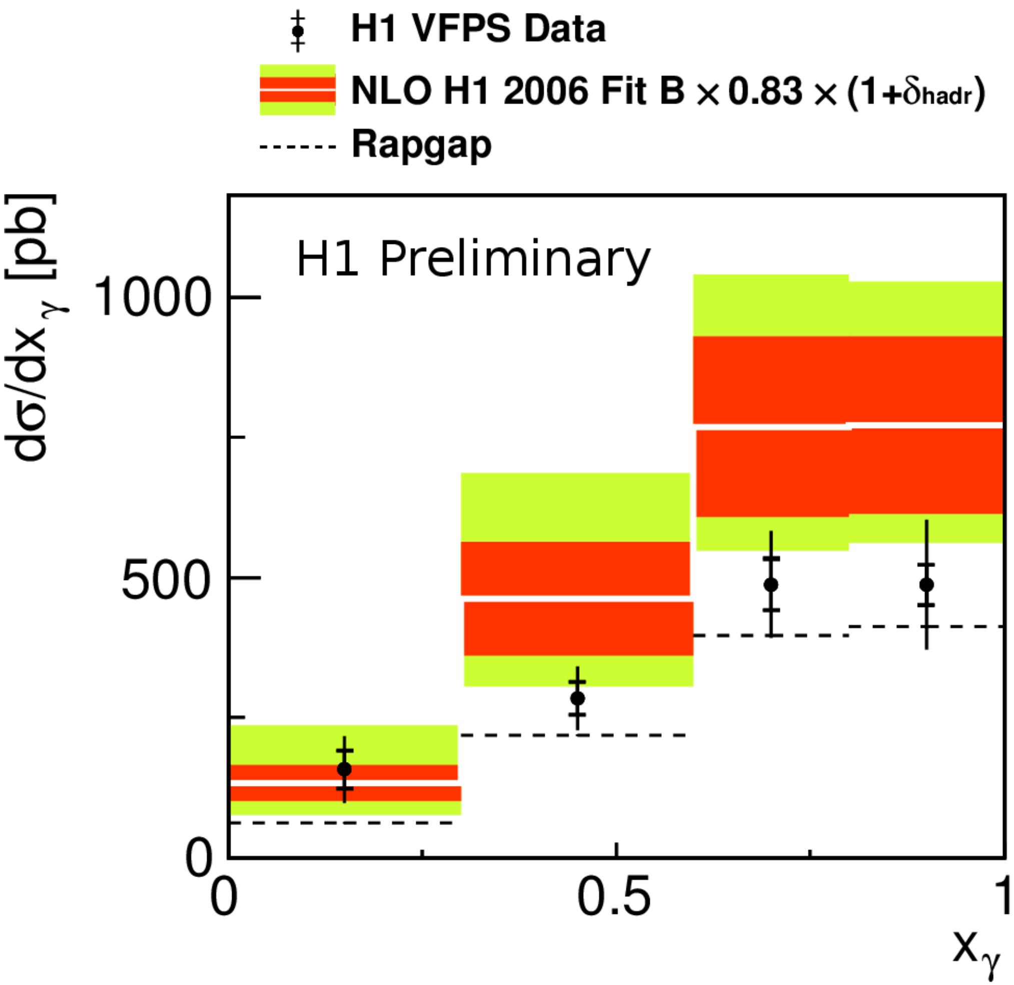


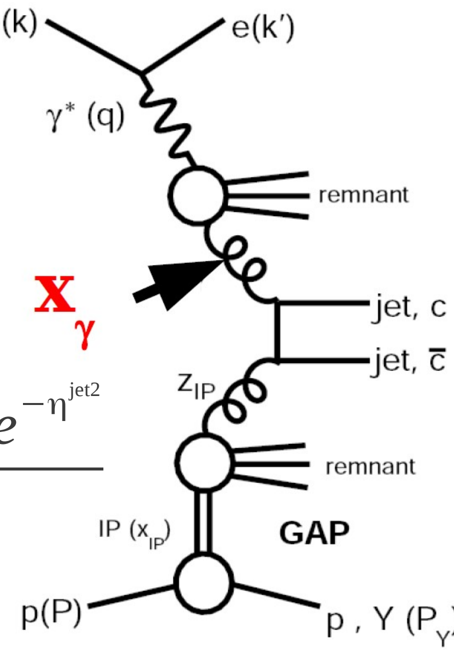
Theoretical Predictions

The NLO QCD calculations (Frixione-Ridolfi) are compared to H1 VFPS Data

- $\mu_r = \mu_f = E_T^{\text{jet1}}$
- DPDF H1 2006 Fit B and GRV-HO γ-PDF used
- NLO QCD predictions are corrected for hadronization effects by means of hadronization corrections calculated by Monte Carlo model Rapgap

Differential Cross Section in x_γ



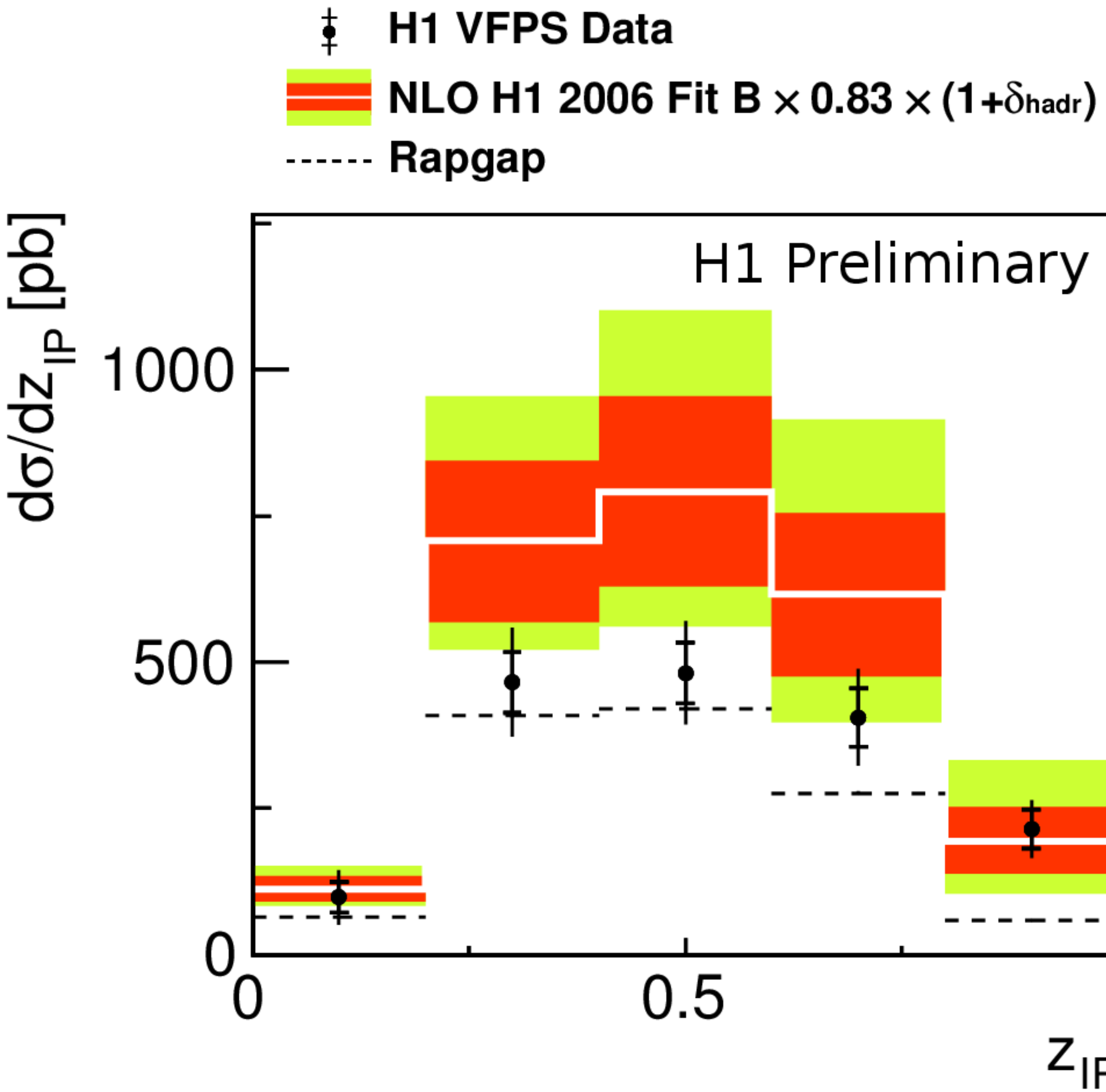


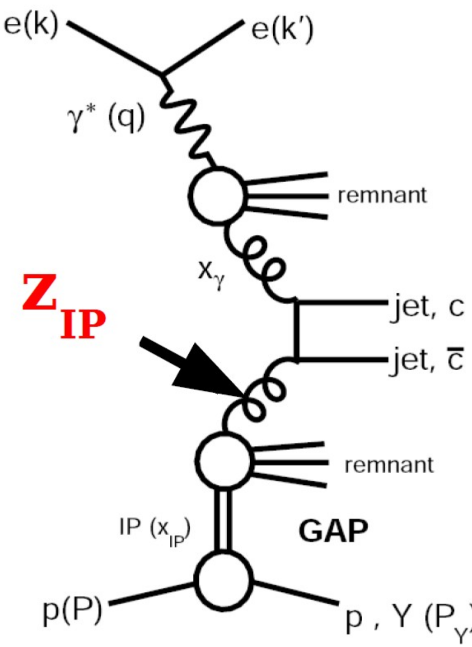
$$x_\gamma = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2y\, E_e^{beam}}$$

- Data are suppressed by factor ~0.67
- Experimental errors are small, theoretical uncertainties dominate
- Suppression is not larger for small x_γ - in contrast to theoretical predictions

$$\sigma_{DATA}/\sigma_{NLO} = 0.67 \pm 0.04(\text{stat.}) \pm 0.09(\text{syst.}) \pm 0.20(\text{scale}) \pm 0.14(\text{DPDF})$$

Differential Cross Section in z_{IP}

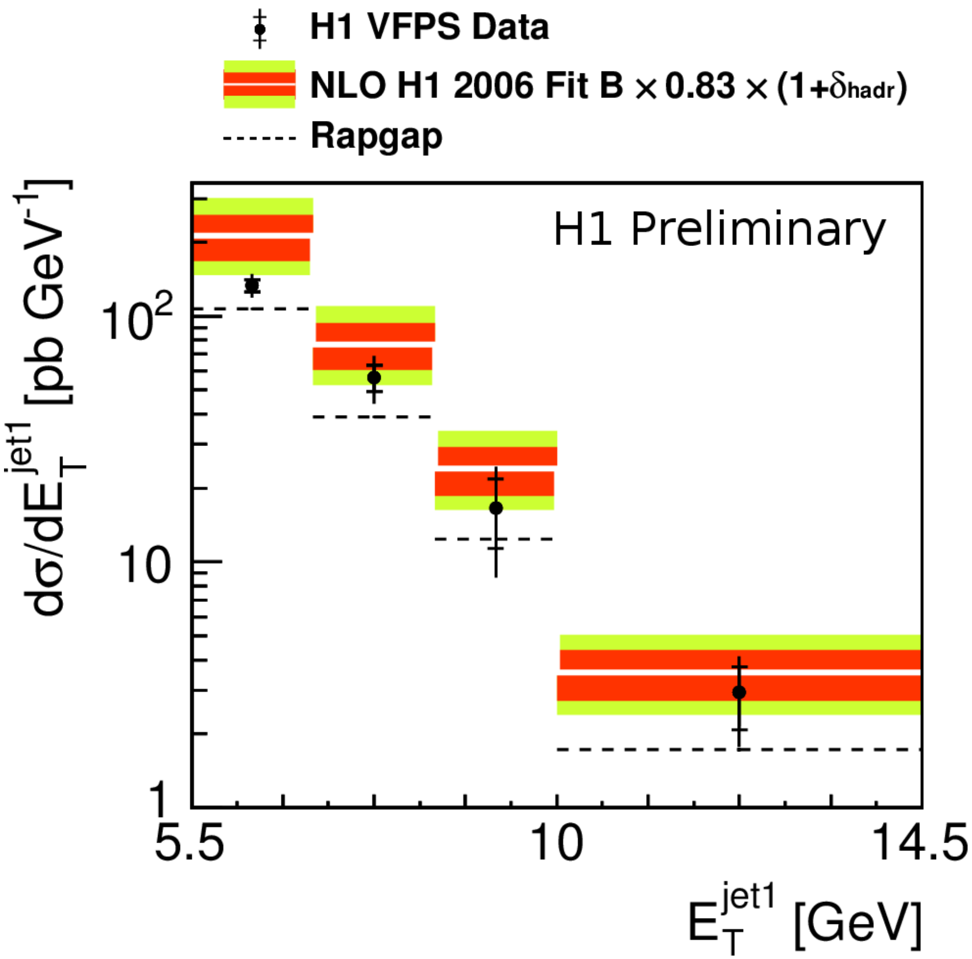


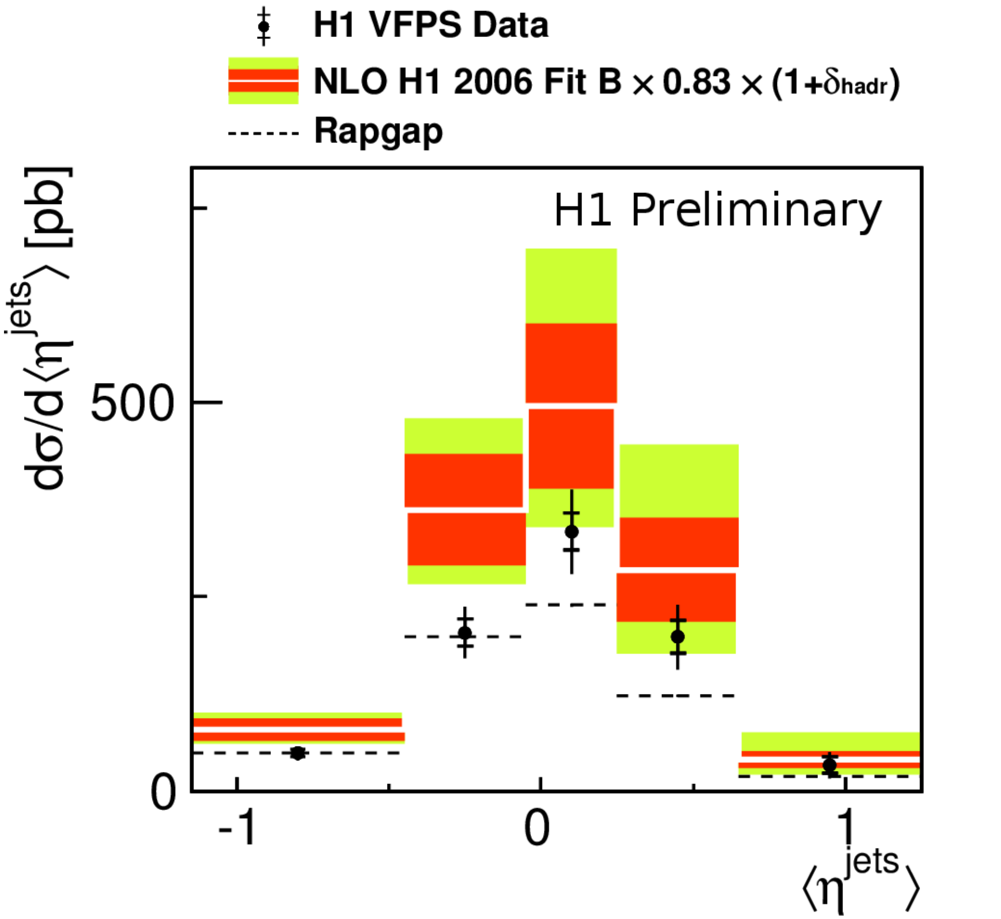


$$z_{IP} = \frac{E_T^{\text{jet1}} e^{\eta^{\text{jet1}}} + E_T^{\text{jet2}} e^{\eta^{\text{jet2}}}}{2x_{IP} E_p^{\text{beam}}}$$

For $z_{IP} > 0.8$ the extrapolated DPDF Fit B is used

Differential Cross Sections in E_T^{jet1} and $\langle \eta^{\text{jets}} \rangle$





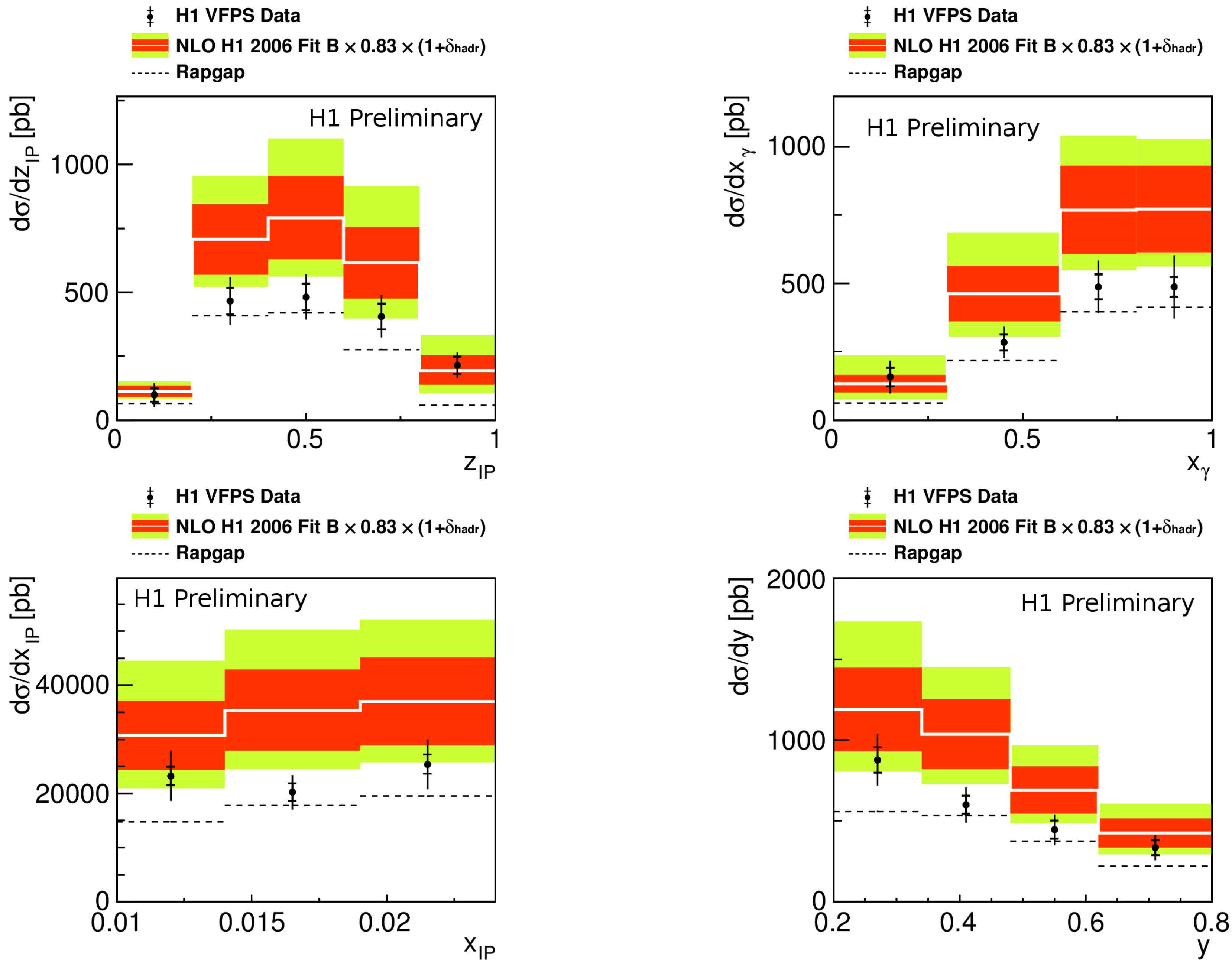
- E_T dependence of the suppression cannot be excluded within large uncertainties
- Rapgap MC cross sections too low as compared to the measurement

Summary

- Dijet diffractive photoproduction cross section with proton tagged in VFPS measured
- Consistency with previous analyses proven
- Gap survival probability $0.67 \pm 0.10(\text{exp.}) \pm 0.24(\text{theor.})$
- No evidence for any difference between the survival probability for the resolved and direct processes

Backup

Cross Sections



Cross Sections