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Diffractive dijet production at HERA

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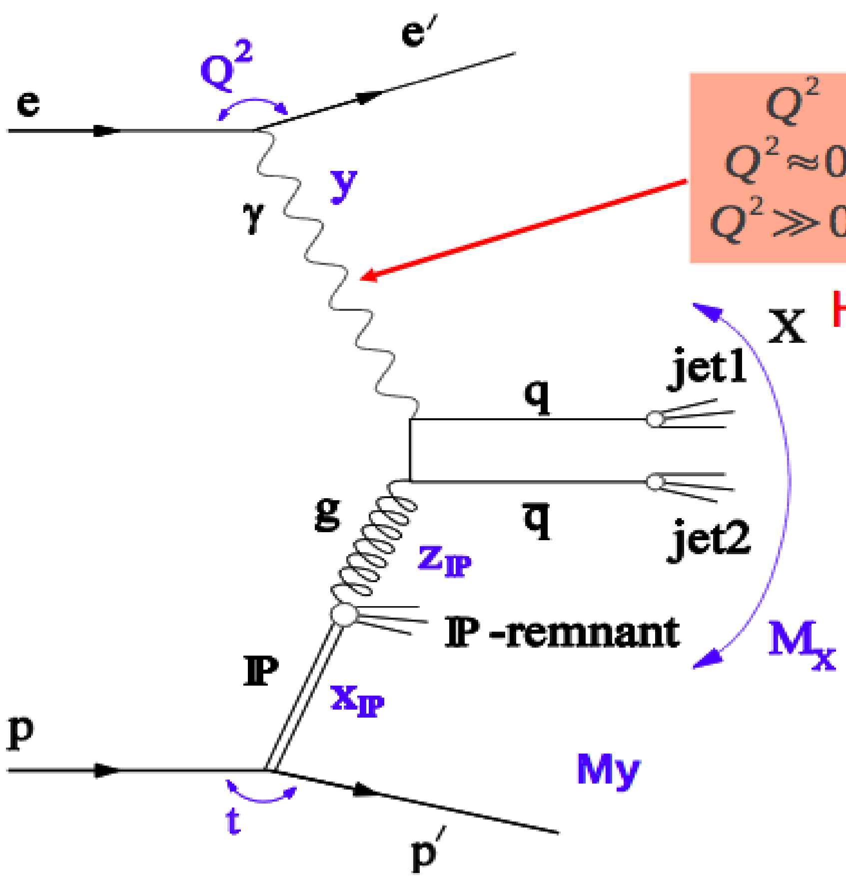
DESY

On behalf of the H1 Collaboration

Outline:

- **Dijet production in diffractive deep-inelastic scattering using FPS**
  [Eur.Phys.J C72 (2012) 1970]
- **Dijet production in diffractive deep-inelastic scattering using VFPS**
  [H1prelim-11-013]
- **Diffractive dijet photoproduction using VFPS for proton tagging**
  [H1prelim-13-011]

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

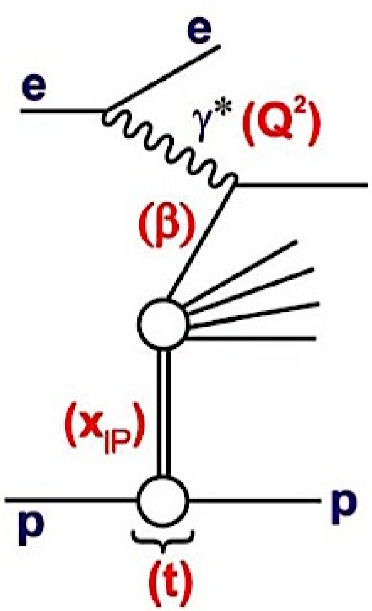
$$\beta = \frac{x}{x_{IP}} \approx \frac{Q^2}{Q^2 + M_X^2}$$

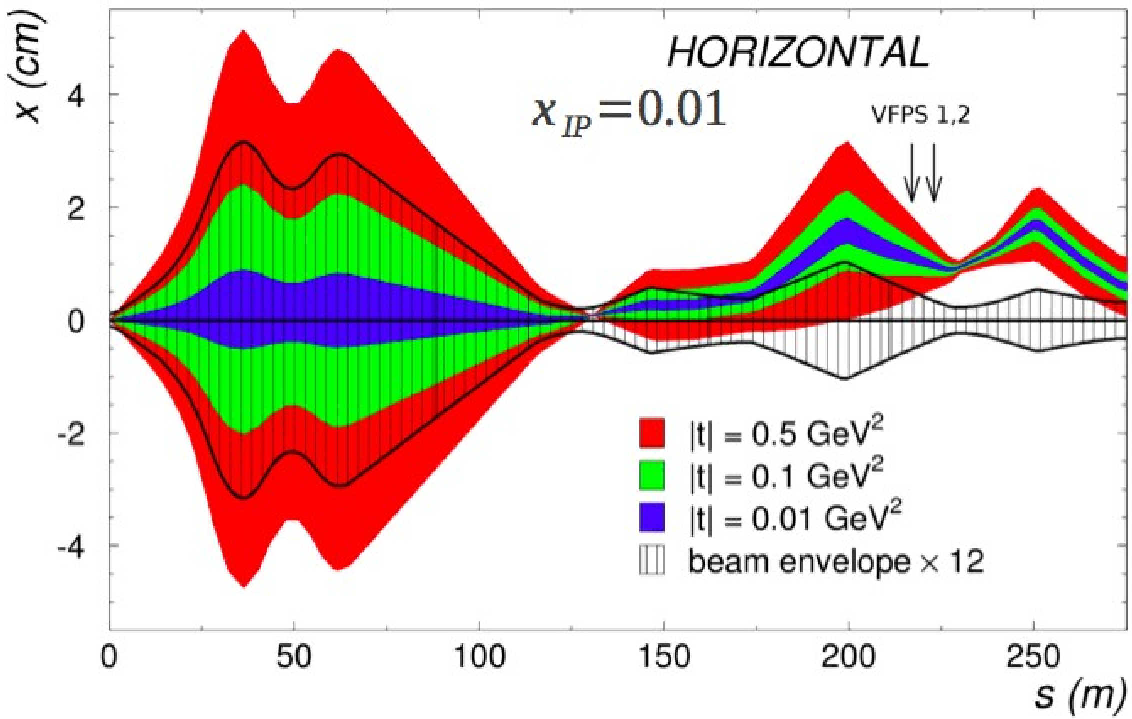
4-momentum transfer squared $t = (p - p')^2 = \frac{-p_T^2}{1 - x_{IP}}$

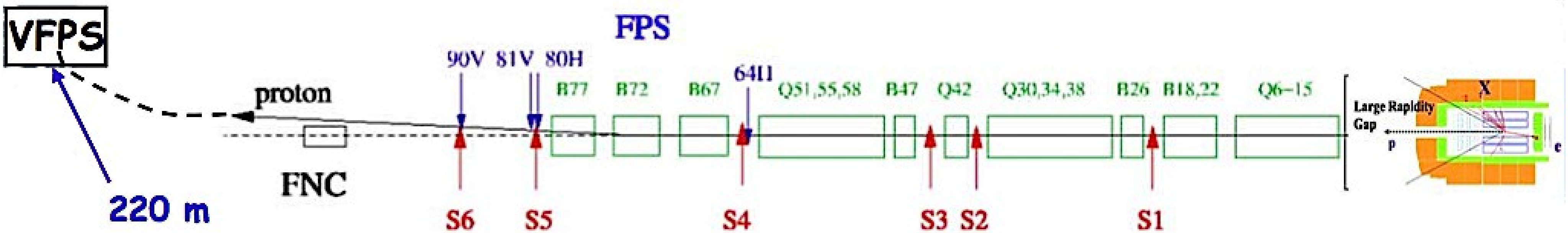
Inelasticity $y = \frac{p \cdot q}{p \cdot k}$

Detecting leading proton

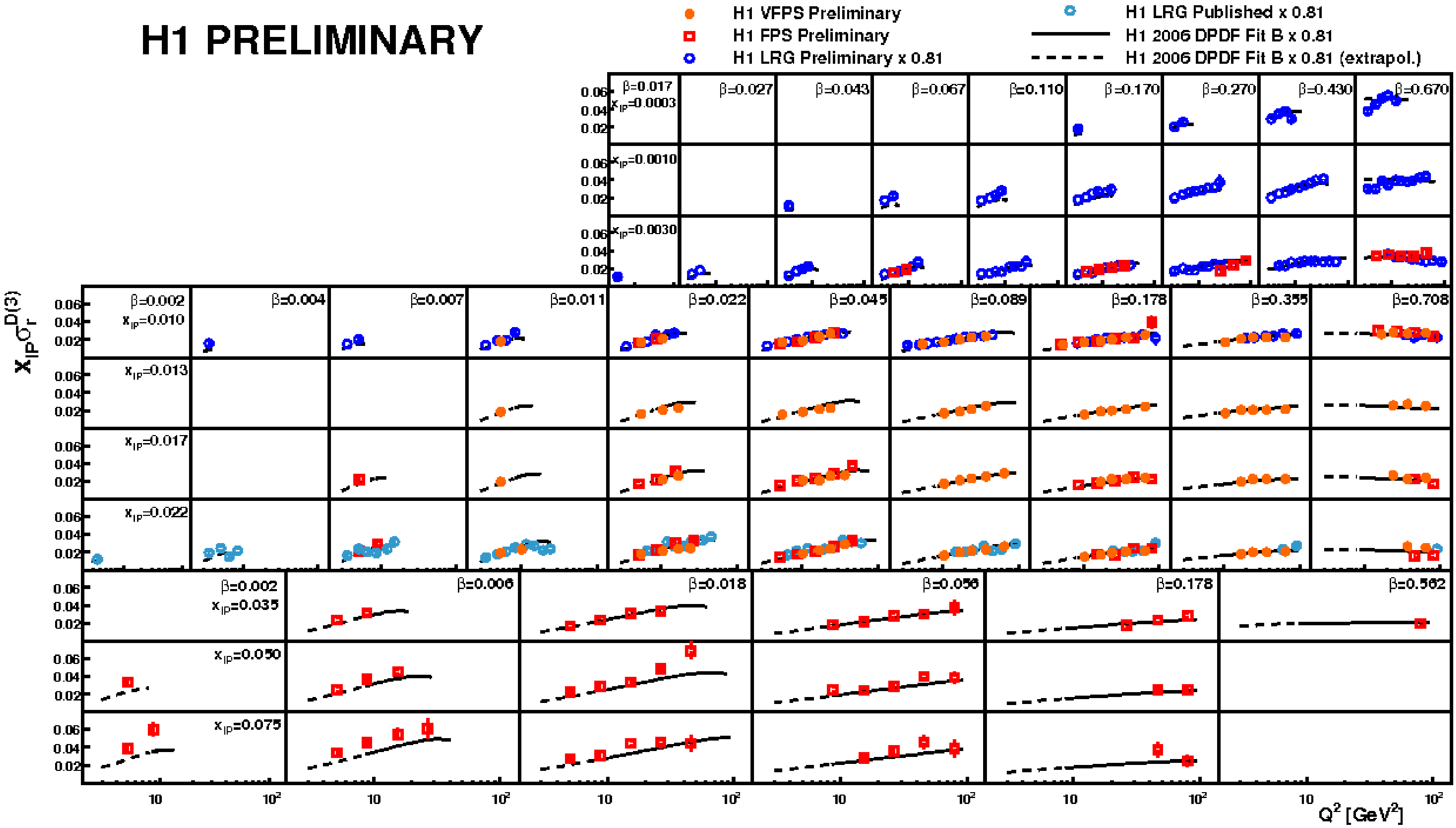
Analyses discussed here use proton spectrometers installed in the HERA tunnel. Forward Proton Spectrometer (FPS) is installed at 61 and 81m downstream the proton beam, Very Forward Spectrometer (VFPS) has stations at 218 and 222m. Analyses uses either FPS or VFPS data – different kinematic regions.







Inclusive measurements comparison (LRG,FPS,VFPS)

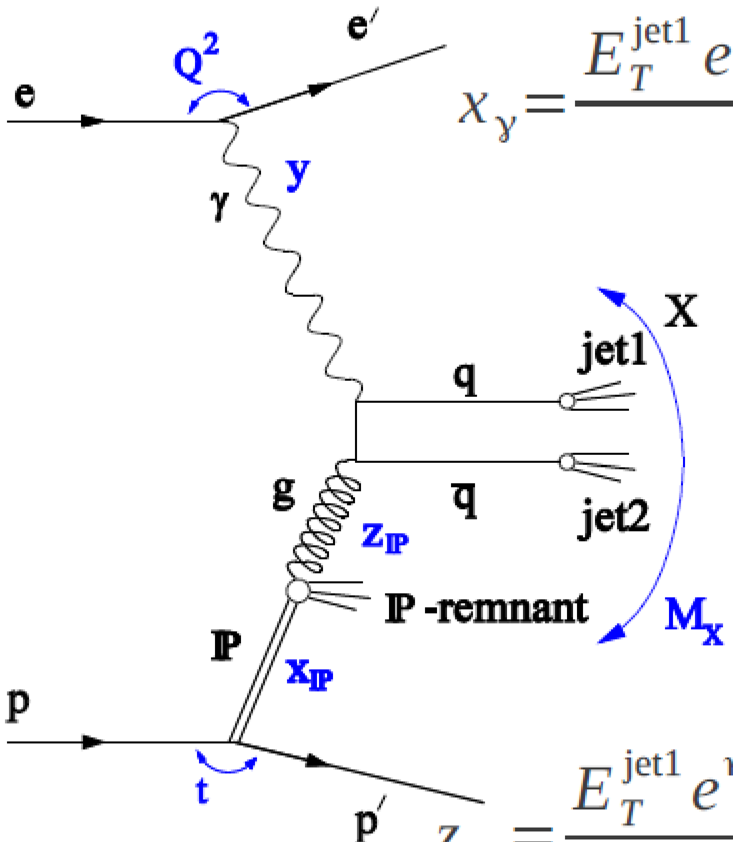


Jet kinematics

Direct:
No photon remnant
$x_\gamma = 1$ (at parton level)
Dominant for high Q2 (DIS)

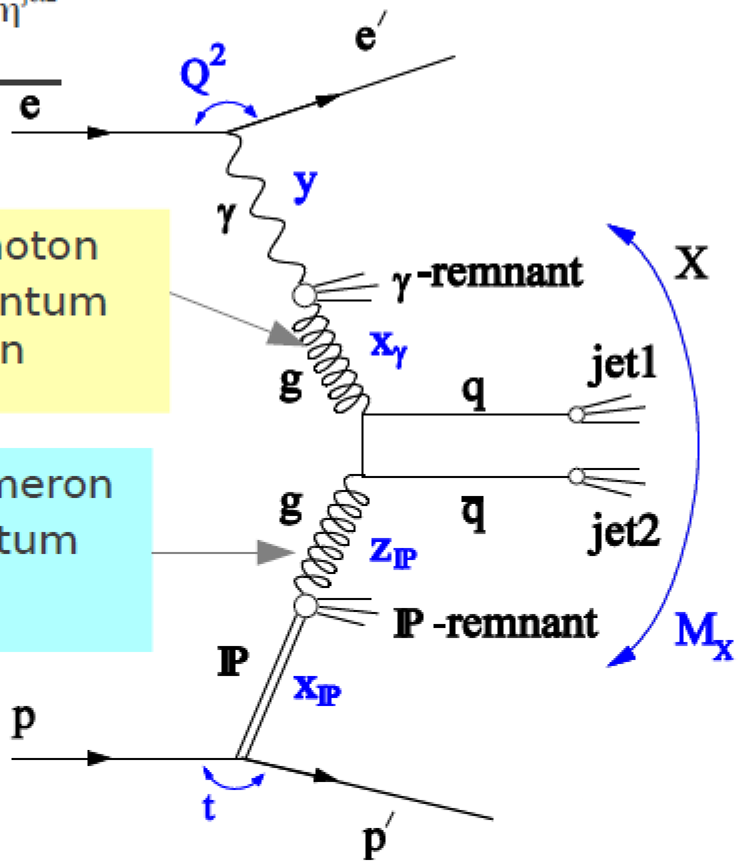
Resolved:
Photon remnant $x_\gamma < 1$
Dominant for low Q2 (PHP)

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



x_γ – photon momentum fraction

z_{IP} – pomeron momentum fraction



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

LO diagrams!

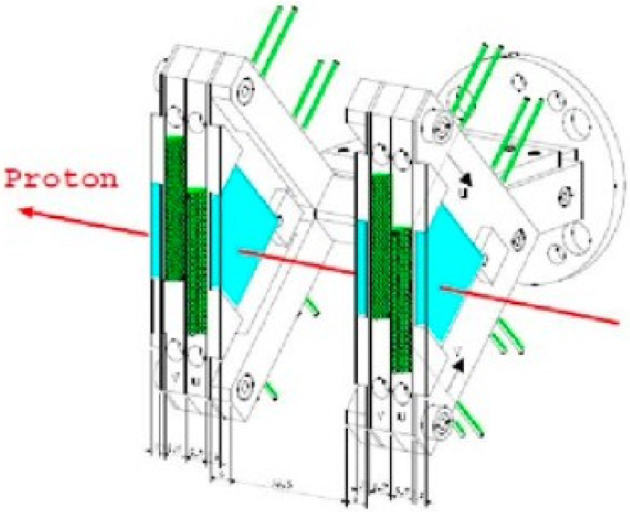
DIFFRACTIVE DIJET PRODUCTION IN DIS

Measurement of Dijet Production in Diffractive Deep-Inelastic Scattering with a leading proton

Eur.Phys.J C72 (2012) 1970

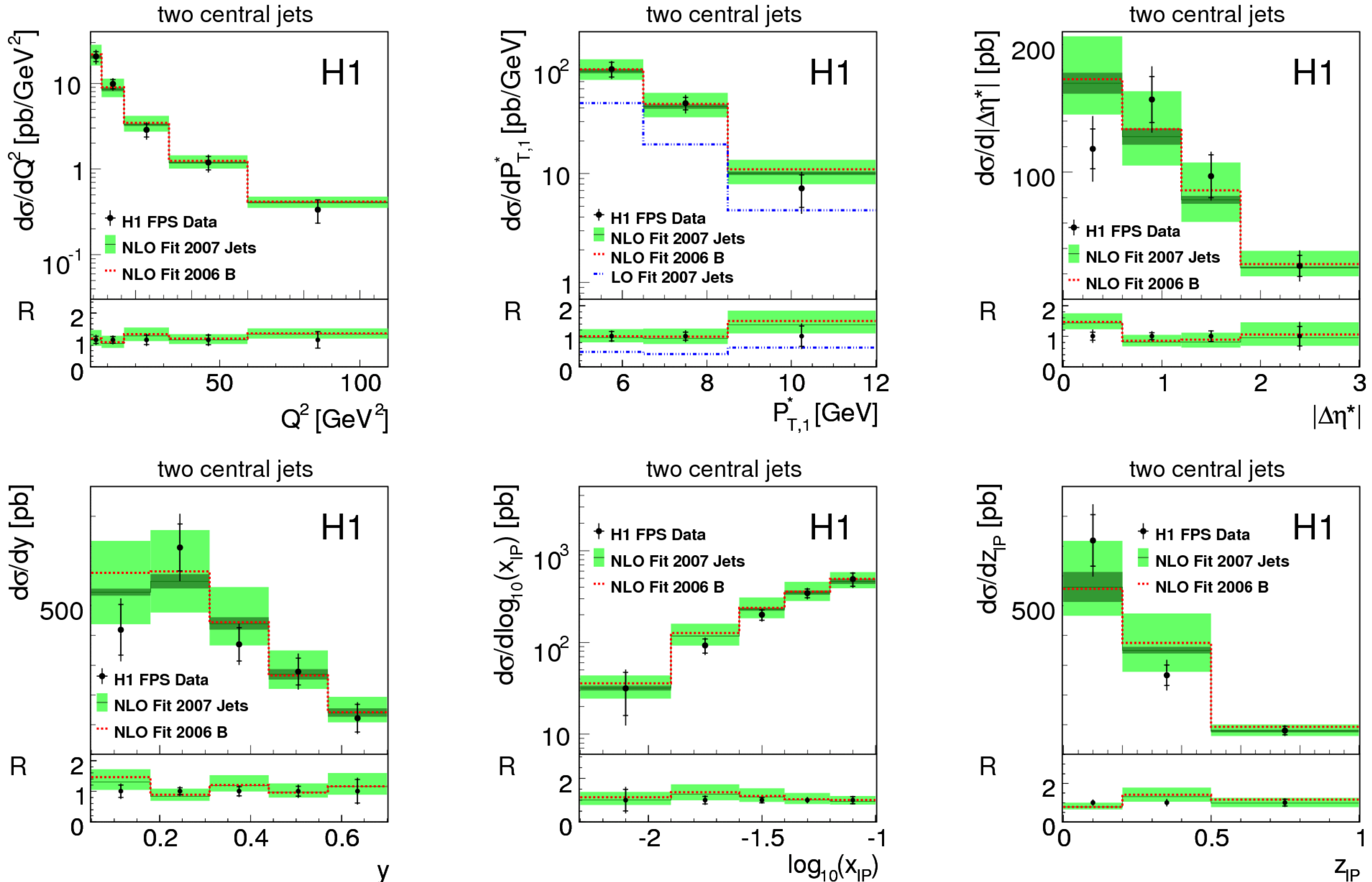
In this analysis H1 Forward Proton Spectrometer (FPS horizontal stations at 61m and 81m) was used to tag a leading proton

Selection	two central jets	one central + one forward jet
DIS	$4 < Q^2 < 110$ GeV^2 $0.05 < y < 0.7$	
Leading Proton	$x_{IP} < 0.1$ $\|t\| < 1$ GeV^2	
Jets	$P^*_{T,1} > 5$ GeV $P^*_{T,2} > 4$ GeV $-1 < \eta_{1,2} < 2.5$	$P^*_{T,c}, P^*_{T,f} > 3.5$ GeV $M_{jj} > 12$ GeV $-1 < \eta_c < 2.5$ $1 < \eta_f < 2.8, \eta_f > \eta_c$



Dijets in DIS

Two central jets, comparison with NLO

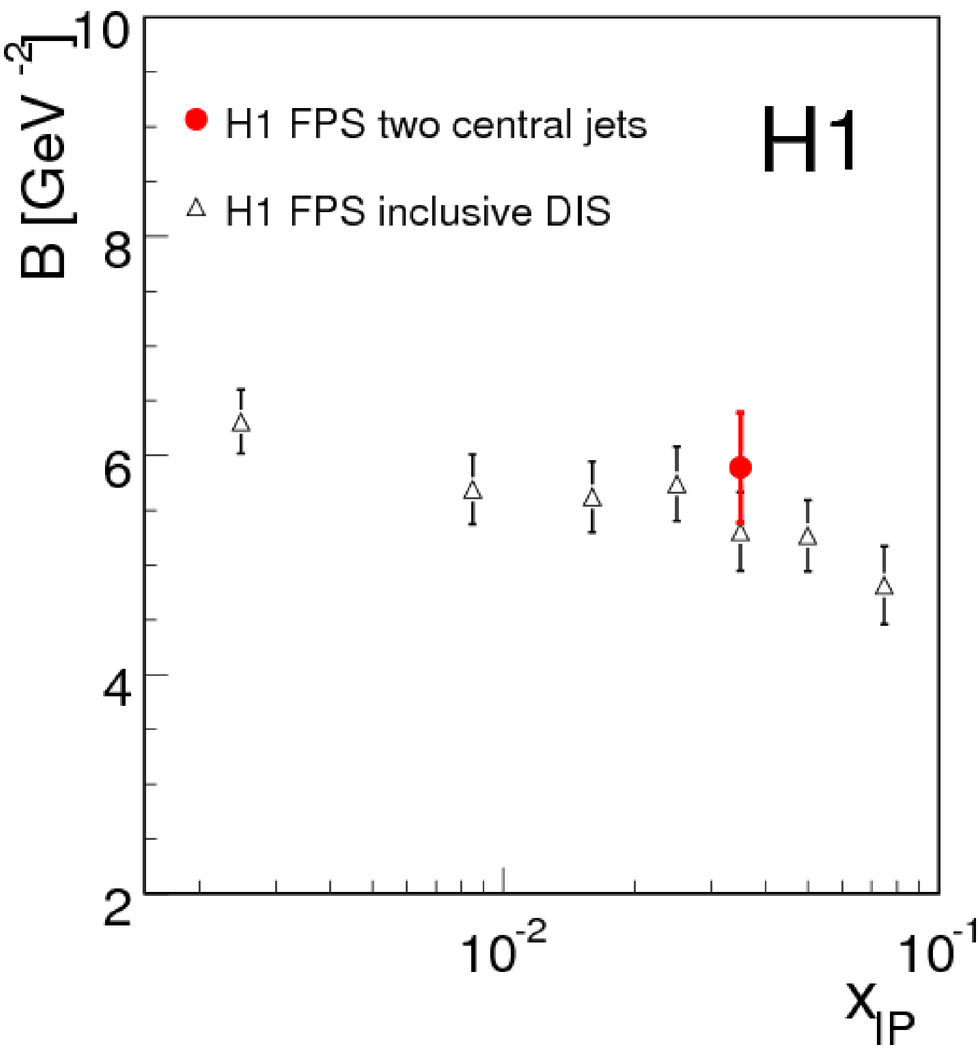


Data are well described by the NLO predictions

Proton vertex factorisation

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

$$f_{IP/p}(x_{IP}, t) = A_{IP} \frac{e^{B_{IP} t}}{x_{IP}^{2\alpha(t)-1}}$$



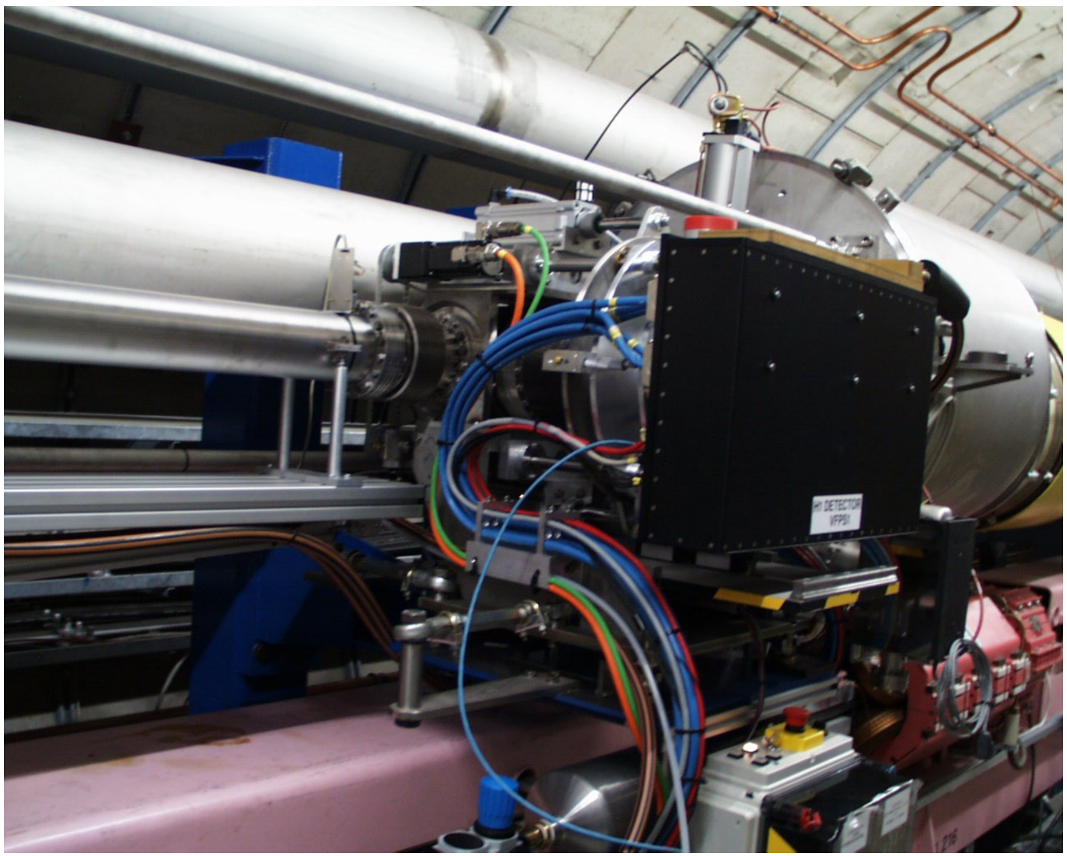
B = 5.89 ± 0.50 GeV^{-2}

Consistent with inclusive measurements

Measurement of Dijet Production in Diffractive Deep-Inelastic Scattering with a leading proton

H1prelim-11-013

In this analysis H1 Very Forward Proton Spectrometer (VFPS stations at 218m and 222m) was used to tag a leading proton. Different from FPS kinematic region.

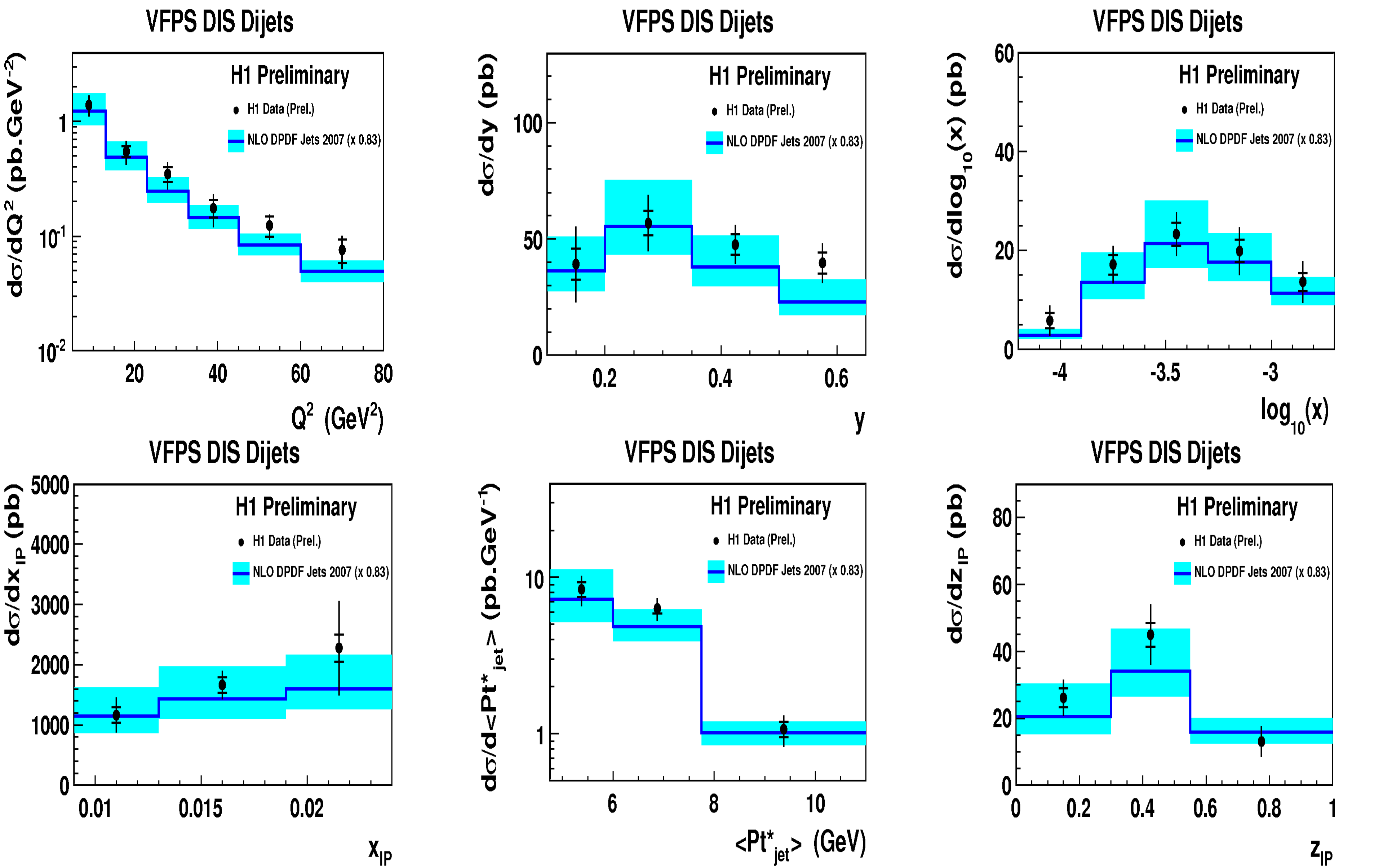


$5 < Q^2 < 80$ GeV^2
$0.1 < y < 0.65$

$0.009 < x_{IP} < 0.025$
$-t < 1$ GeV^2

$E_T^{jet1(2)} > 5.5(4)$ GeV
$-2 < \eta^{jets} < 2$
k_T jets algorithm

Comparison with NLO



NLO predictions using DPDF Jets 2007 well describe data

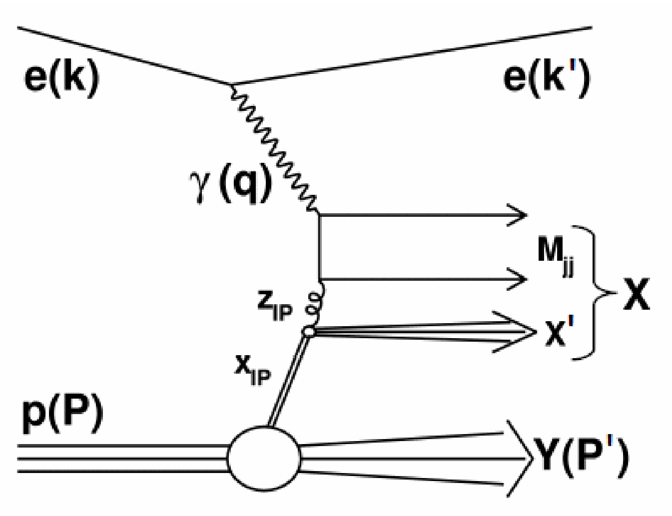
DIFFRACTIVE DIJETS IN PHOTOPRODUCTION

Measurement of Diffractive Dijet Photoproduction with a leading proton at HERA

H1prelim-13-011

In this analysis H1 Very Forward Proton Spectrometer (VFPS stations at 220m downstream proton beam) was used to tag a leading proton

e + p → e + p + jj + X



Phase-space definition

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

$0.2 < y < 0.8$

k_T jet algorithm:

$E_T^{\mathrm{jet1(2)}} > 5.5(4)\,\mathrm{GeV}$

$-1 < \eta^{\mathrm{jet1,2}} < 2.5$

Diffractive:

$0.010 < x_{IP} < 0.024$

$|t| < 0.6\,\mathrm{GeV}^2$

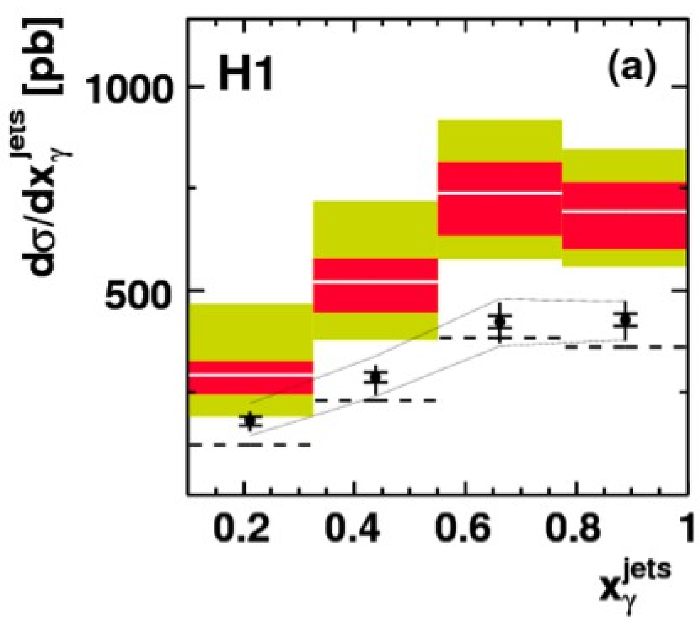
$M_Y = M_p$

H1 old results

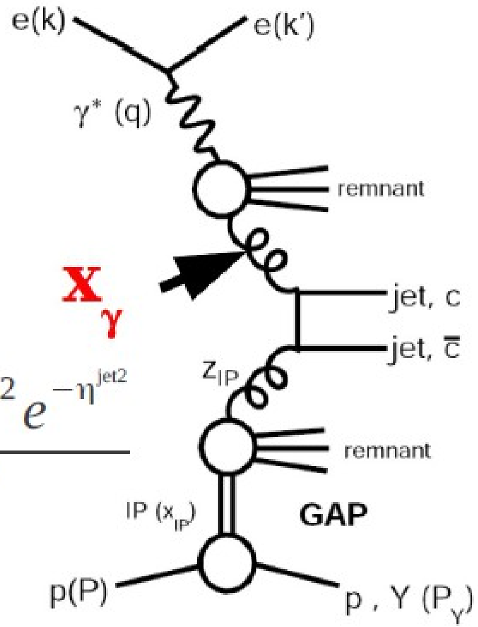
The suppression is supposed to be stronger at low scales and low x_γ

Eur. Phys. J. C68 (2010) 381

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



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



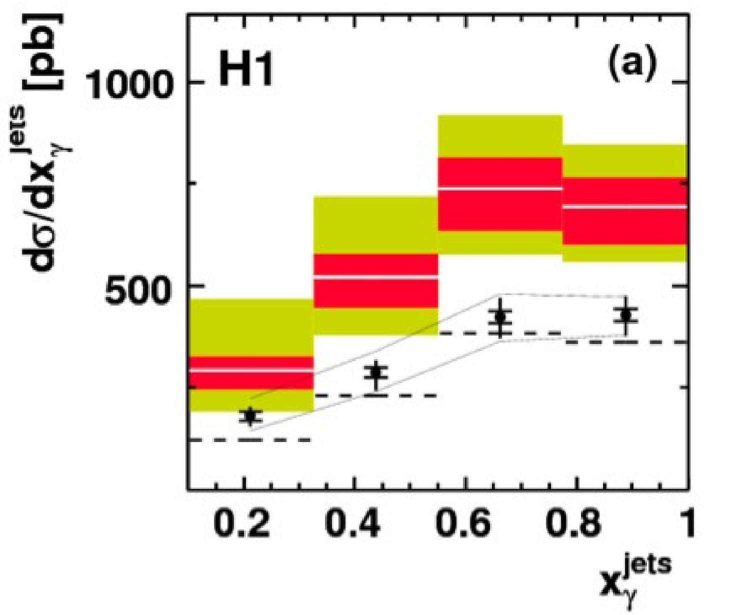
- Factorisation breaking observed by H1
- No x_γ dependence of suppression factor visible

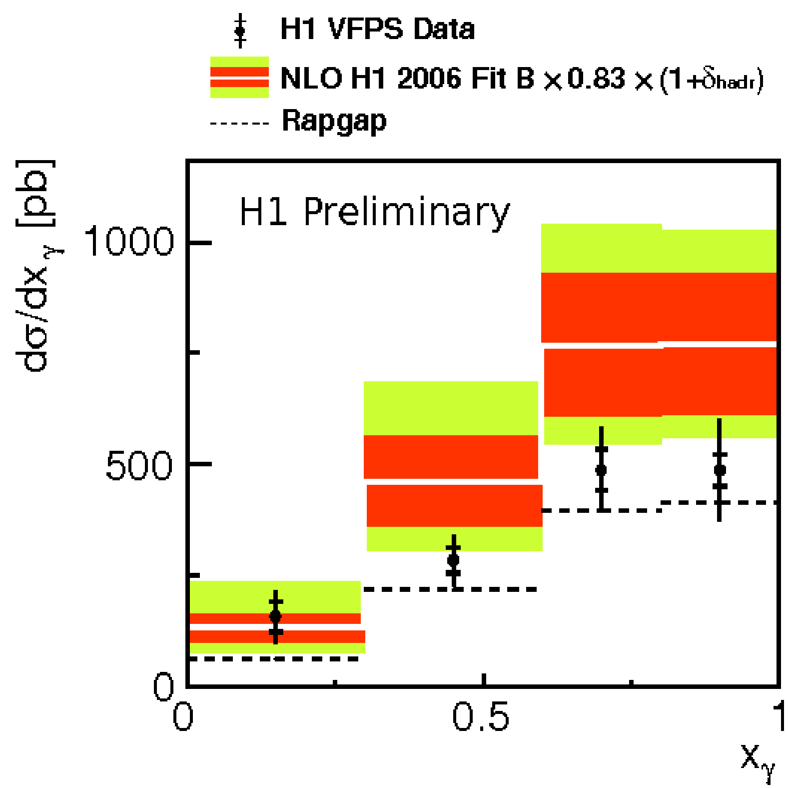
H1 old and new results

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

Eur. Phys. J. C68 (2010) 381

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





- Factorisation breaking also observed in new measurement
- Theory predictions assume factorization

History – H1 and ZEUS measurements

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

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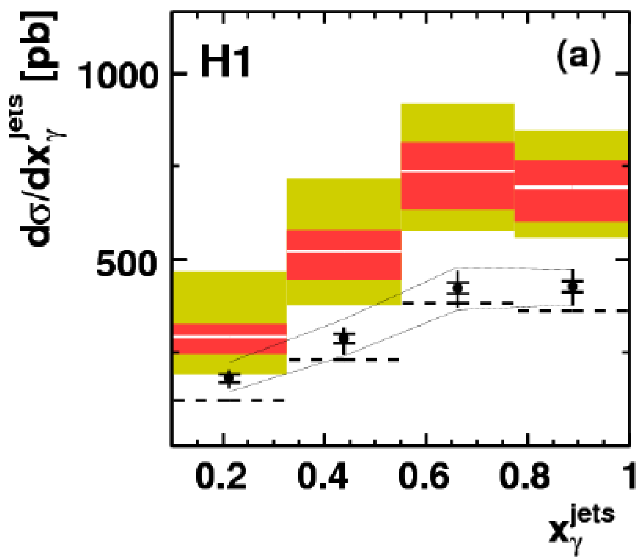
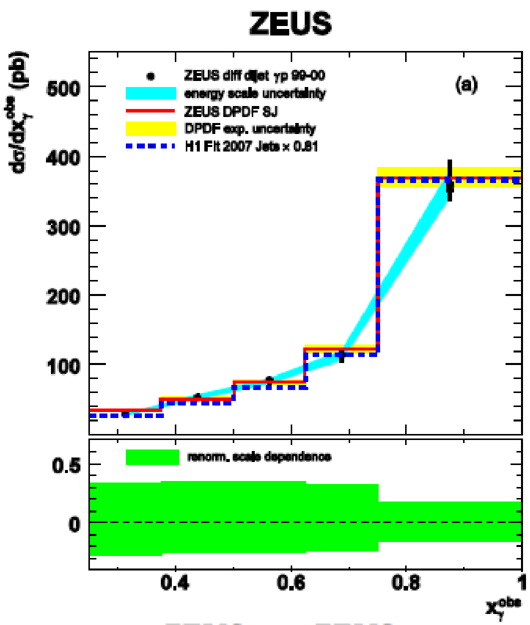
$E_T^{\mathrm{jet}1(2)} > 5(4)\,\mathrm{GeV}$



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

Nucl. Phys. B381 (2010)

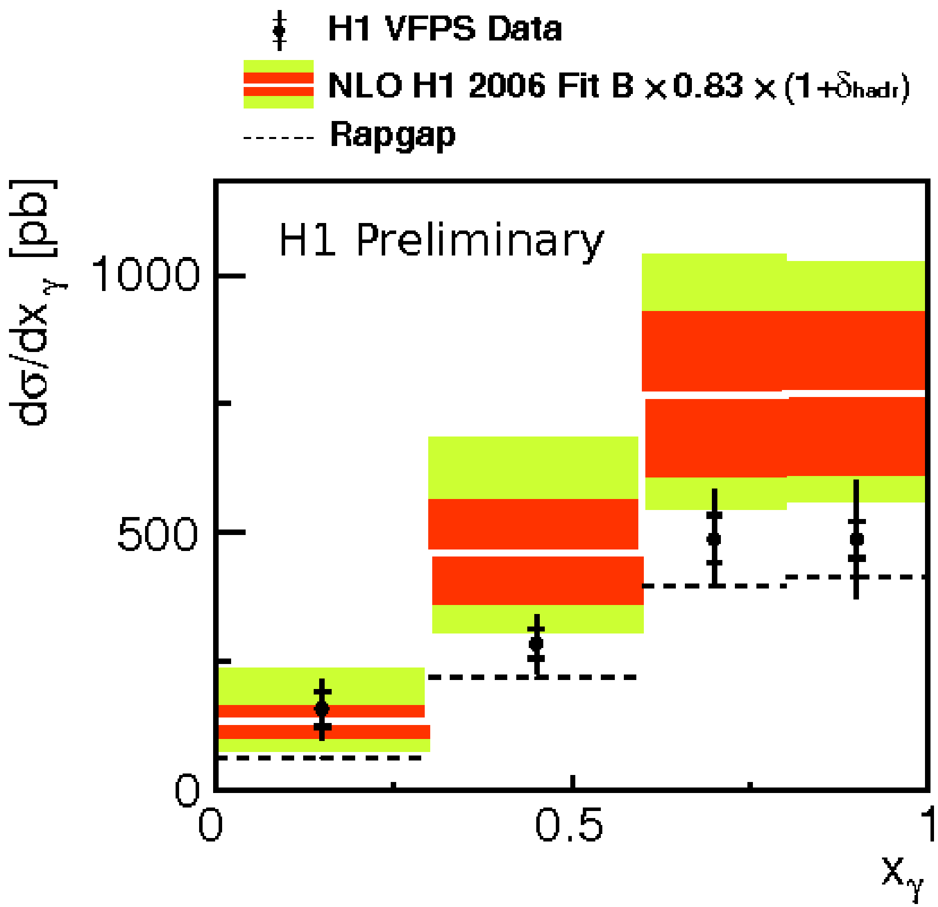
$E_T^{\mathrm{jet}1(2)} > 7.5(6.5)\,\mathrm{GeV}$

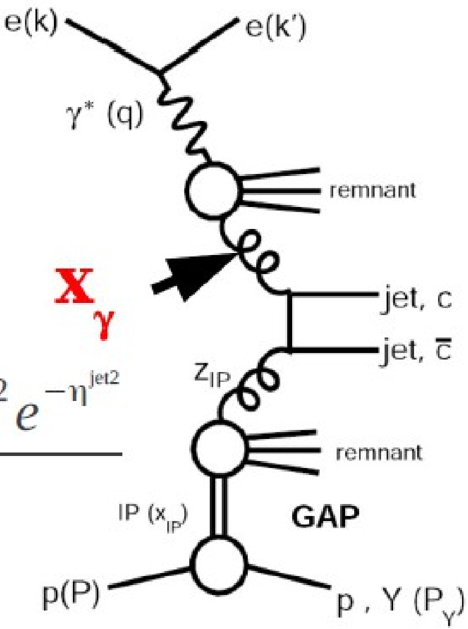


$\sigma_{data}^{ZEUS} / \sigma_{NLO}^{ZEUS} \approx 1.0$

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

Differential cross section in x_γ



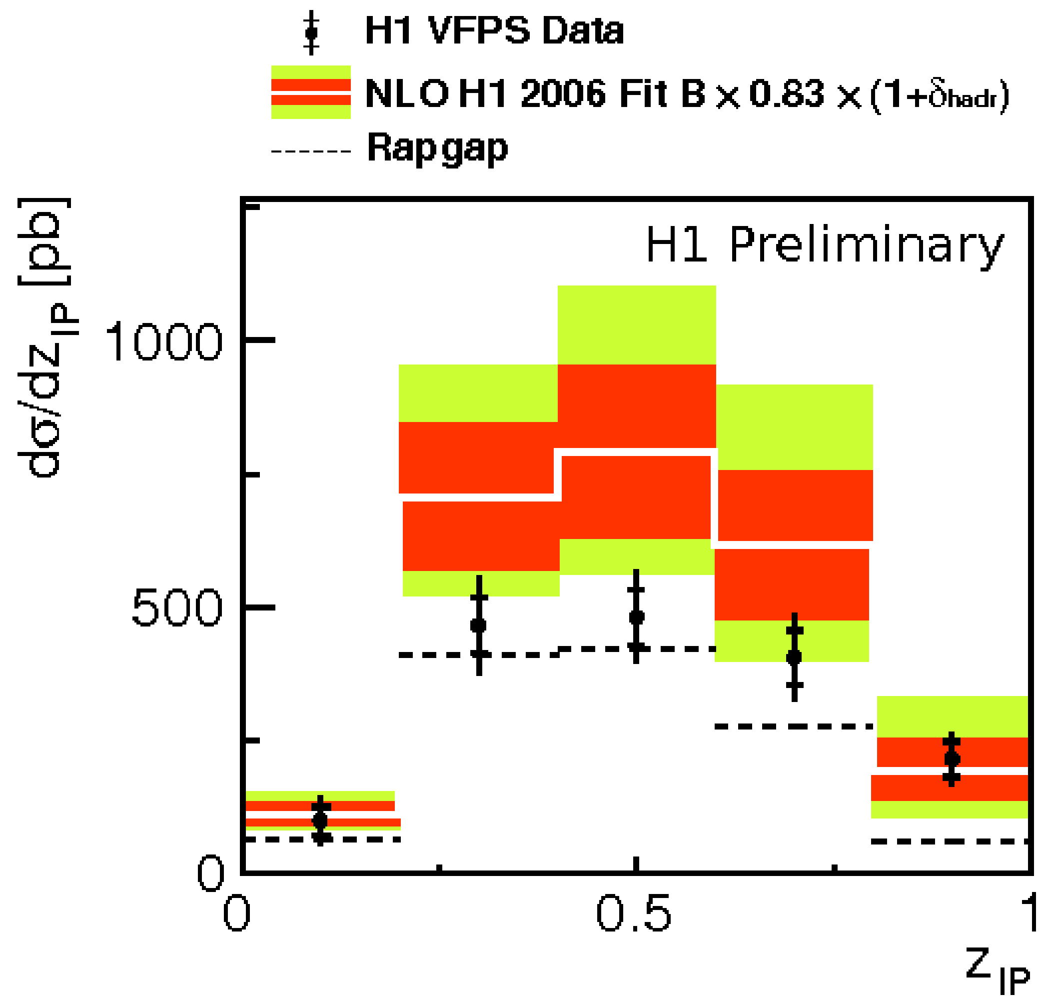


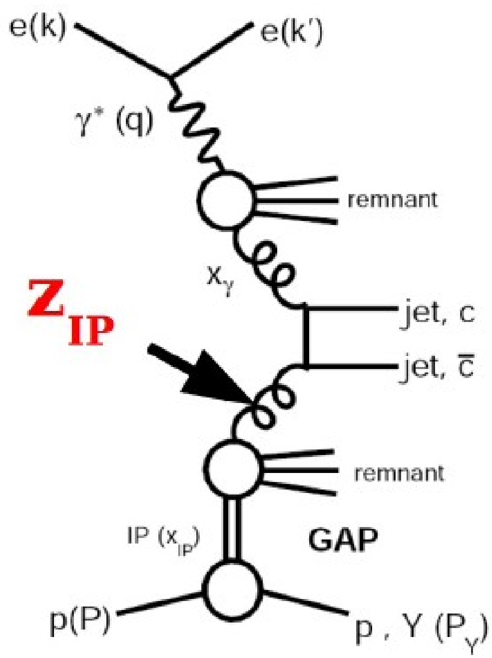
$$x_\gamma = \frac{E_T^{jet1} e^{-\eta^{jet1}} + E_T^{jet2} e^{-\eta^{jet2}}}{2y\, E_e^{beam}}$$

- Data are suppresses 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 ± 0.04 (stat.) ± 0.09 (syst.) ± 0.20 (scale) ± 0.14 (DPDF)

Differential cross section in z_{IP}

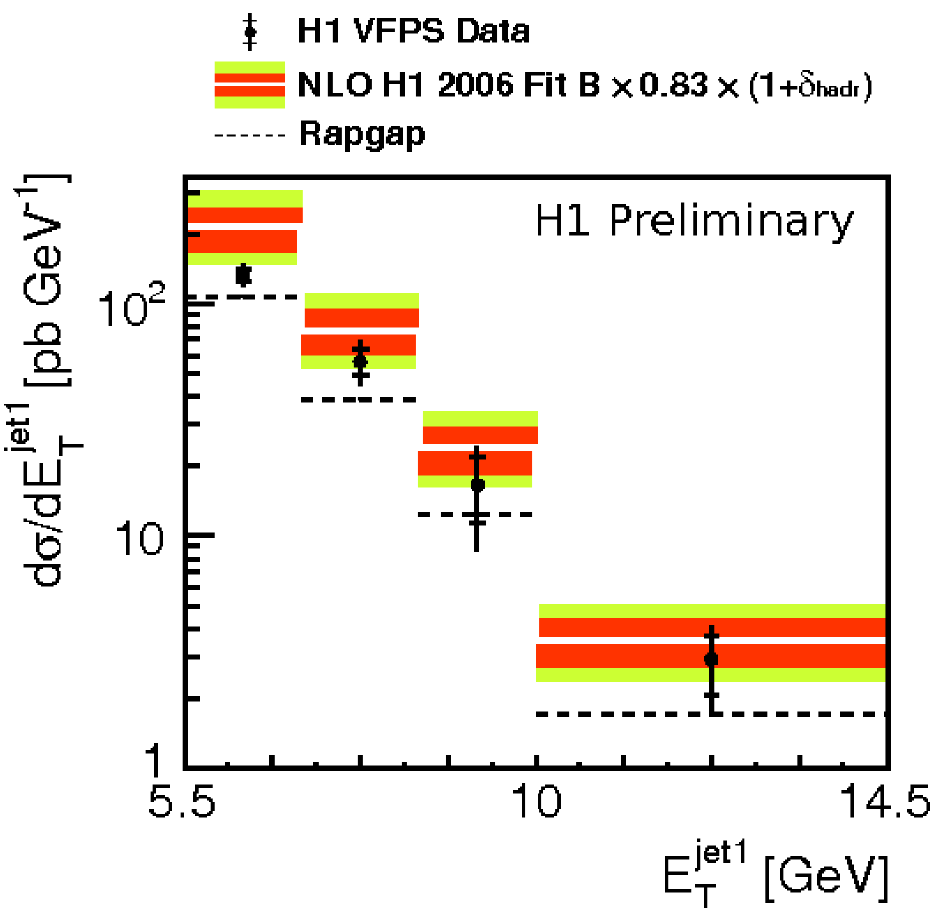


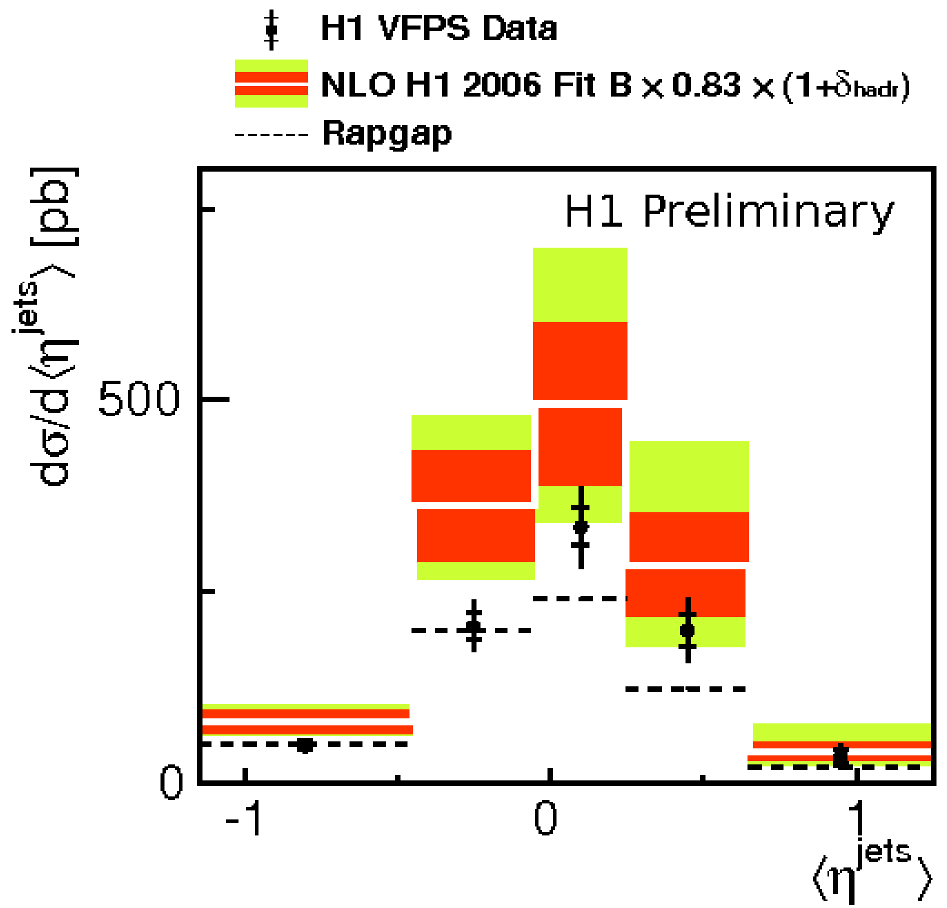


$$z_{IP} = \frac{E_T^{jet1} e^{\eta^{jet1}} + E_T^{jet2} e^{\eta^{jet2}}}{2 x_{IP} E_p^{beam}}$$

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

Differential cross section in E_T^{jet1} and η^{jets}





E_T dependence of the suppression cannot be excluded within large uncertainties

Rapgap MC cross sections too low as compared to the measurement

Summary

- **Diffractive dijet in deep-inelastic scattering measurement with leading proton tagged in H1 FPS detector performed for the first time**
- **New measurement of dijet production in DIS using H1 VFPS detector**
- **Proton vertex factorization holds in DIS**
- **Amount of the proton dissociation in dijet events is same as in inclusive events**
- **NLO predictions based on DPDF H1 2007 Jets describe the data within errors**

- **New measurement of dijet diffractive photoproduction with proton tagged in VFPS**
- **Consistency with previous H1 analyses proven**
- **Difference between data and NLO is the same, independent of studied variables**

BACKUP SLIDES

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

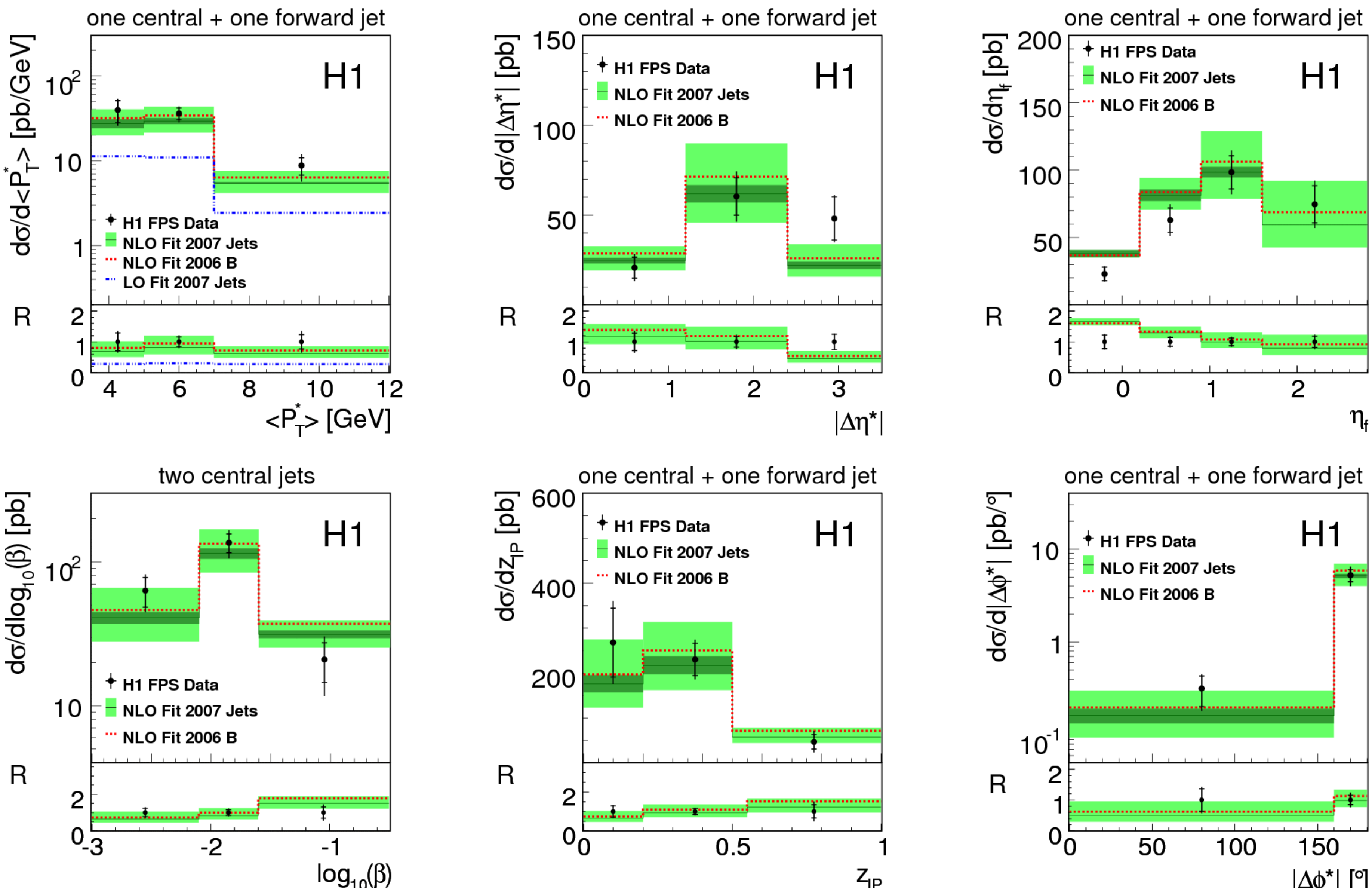
Regge vertex factorization for DPDF:

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

$f_{IP/p}(x_{IP}, t)$ — pomeron flux factor

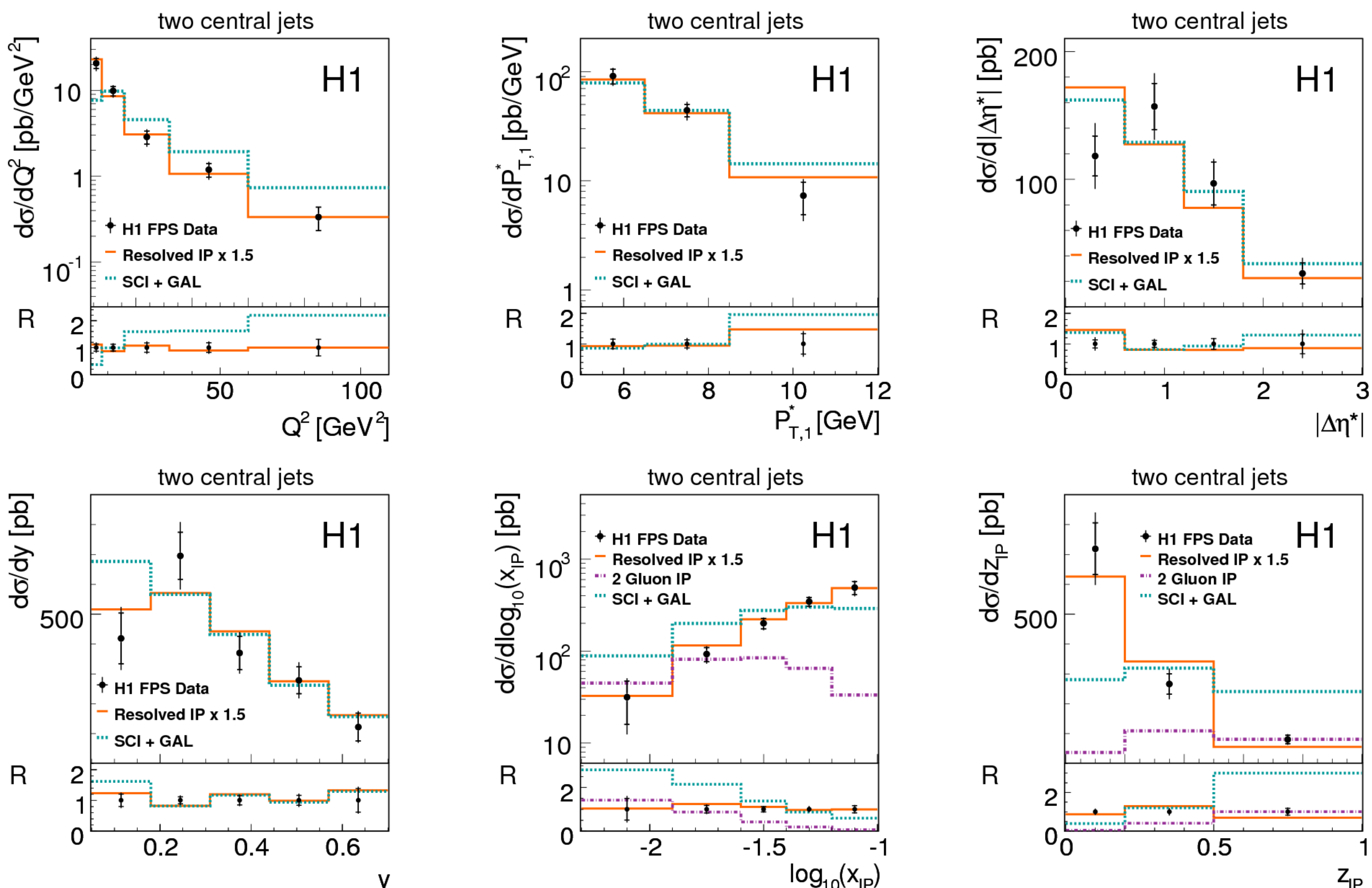
$f_i^{IP}(\beta, Q^2)$ — pomeron PDF

One central + one forward jet, comparison with NLO



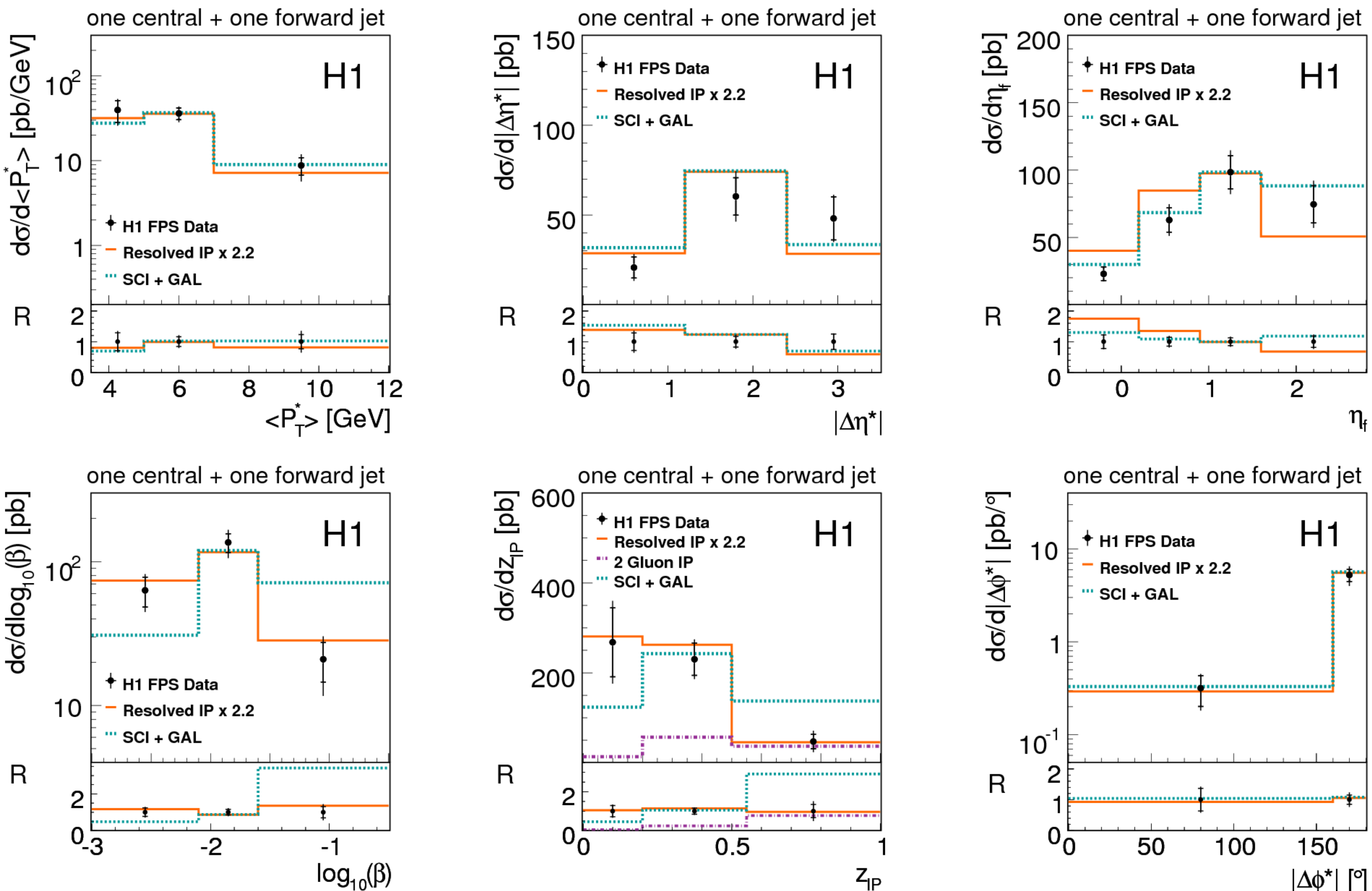
No significant deviations from DGLAP NLO QCD

Two central jets, comparison with LO MC



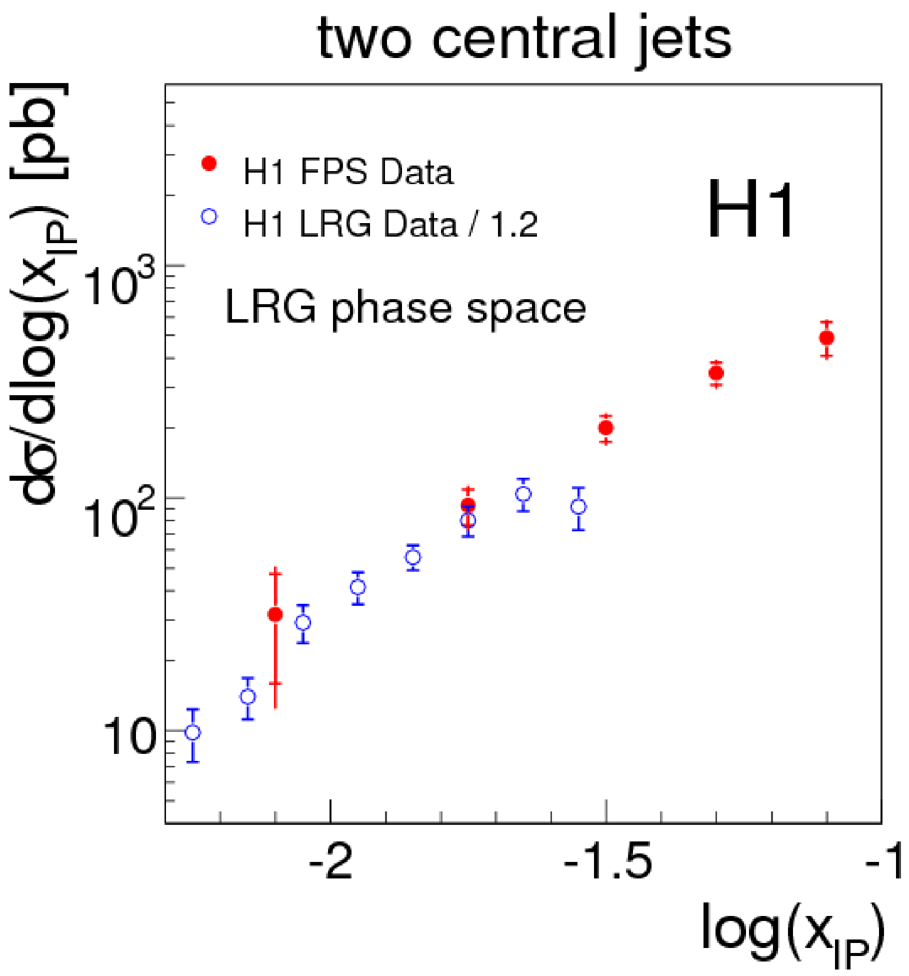
None of MC models describes the data in all aspects

One central + one forward jet, comparison with LO MC



None of MC models describes the data in all aspects

Comparison of LRG and FPS



Theoretical predictions

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

$\mu_r = \mu_f = E_T^{jet1}$

DPDF H1 2006 Fit B and GRV-HO γ-PDF used

NLO QCD predictions are corrected for hadronisation effect by means of hadronisation corections calculated by Monte Carlo model Rapgap