

Recent HERA results on hard diffraction

L. Favart (IIHE - Université Libre de Bruxelles)

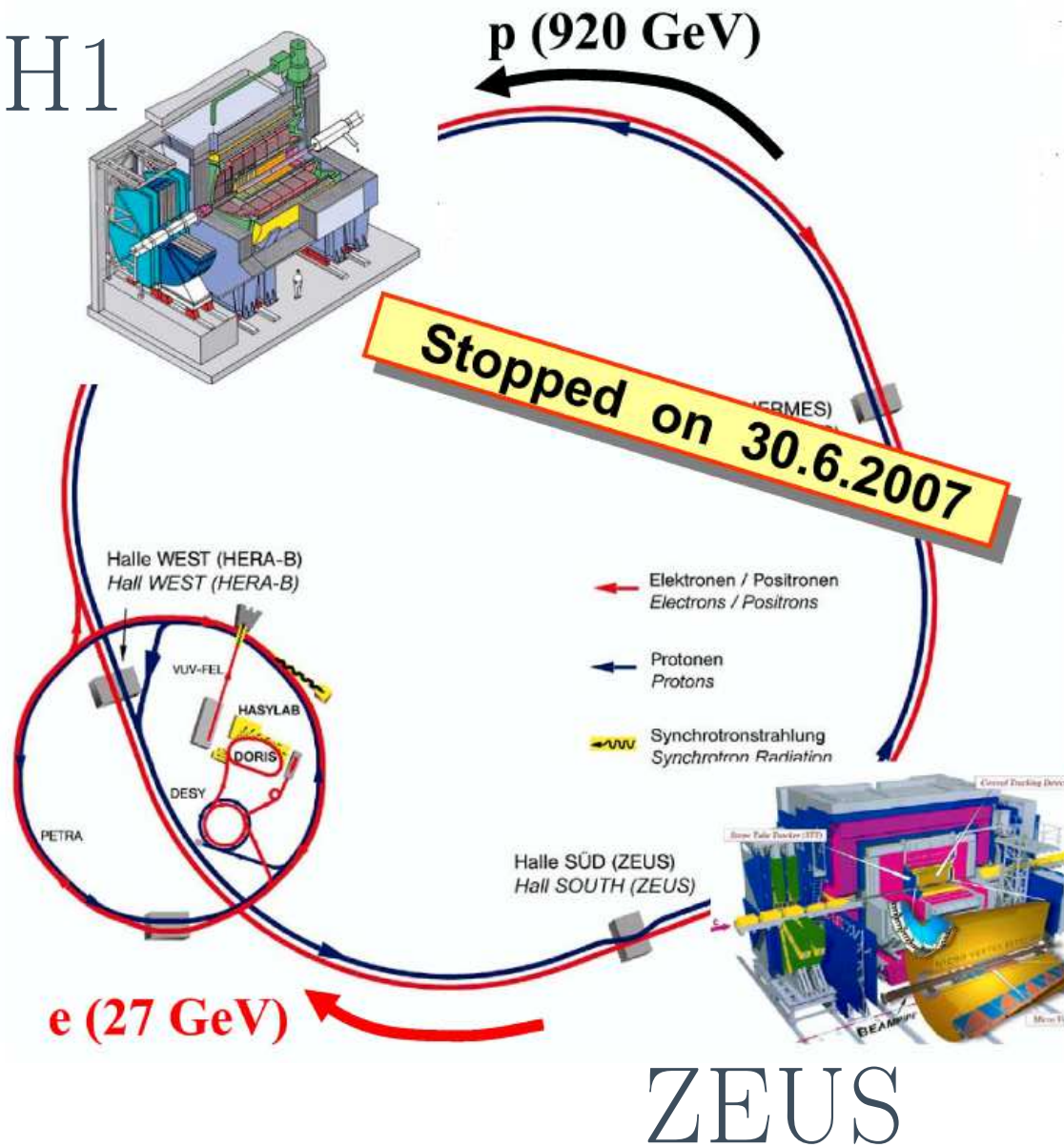


On behalf of the  and  collaborations

LISHEP 2015 conference, 2-9 August 2015, Manaus - Brazil

HERA - $e - p$ collider at DESY

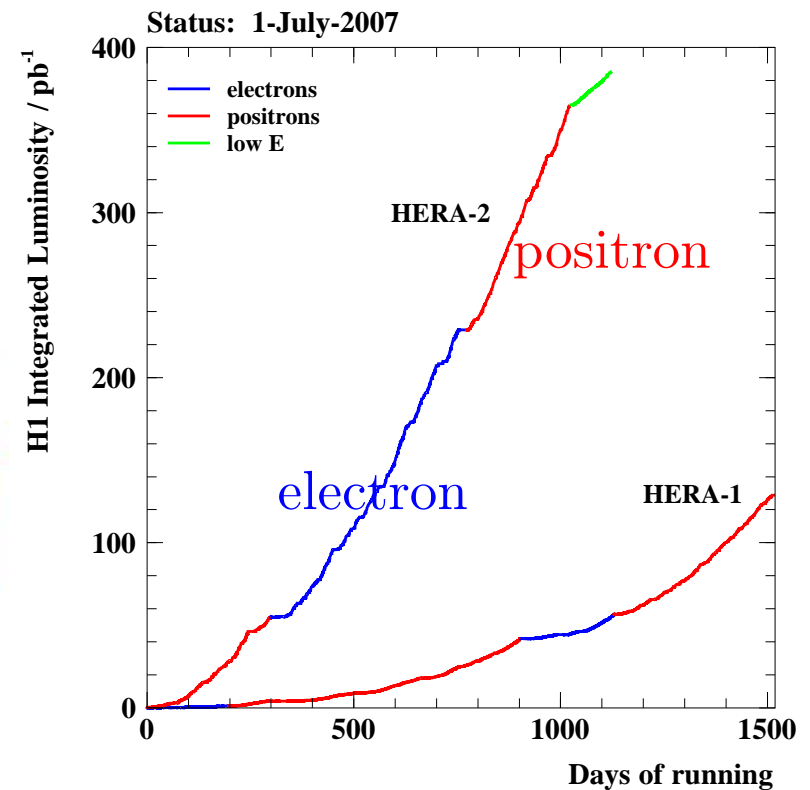
H1



Integrated luminosity
96-00 + 03-07 (high energy)

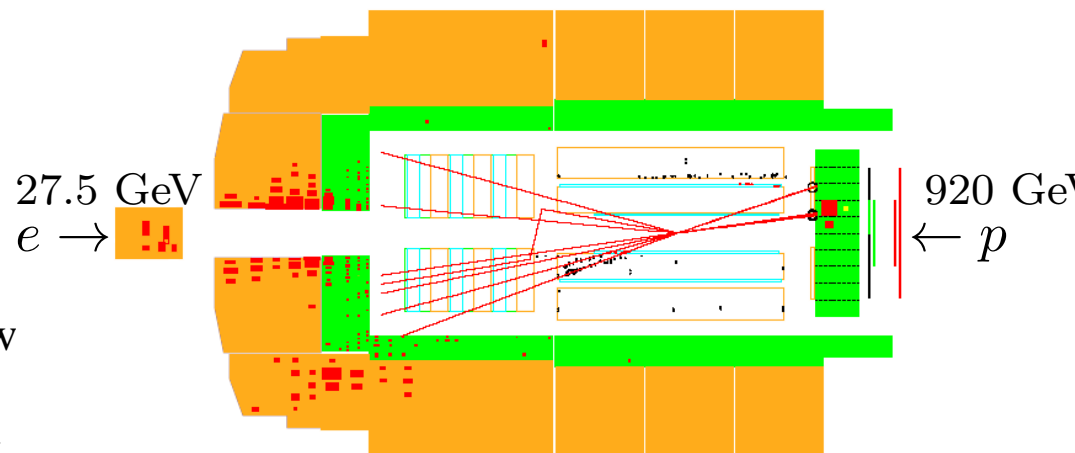
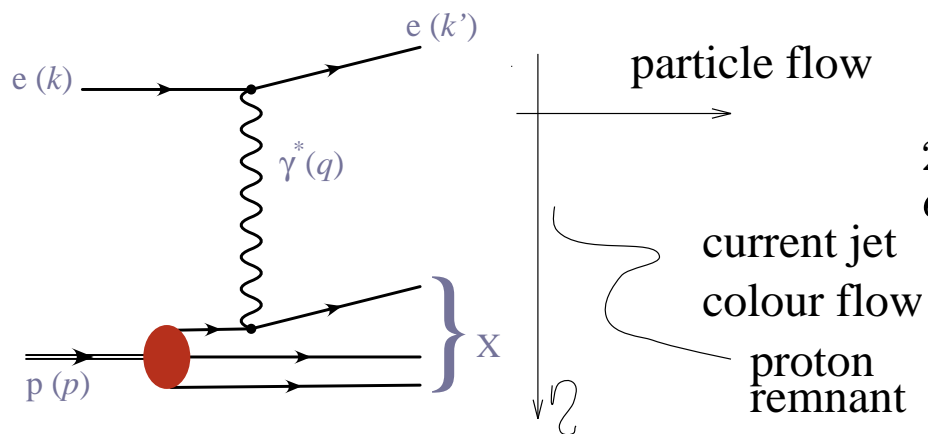
$$e^+p : \sim 300 \text{ pb}^{-1}$$

$$e^-p : \sim 185 \text{ pb}^{-1}$$

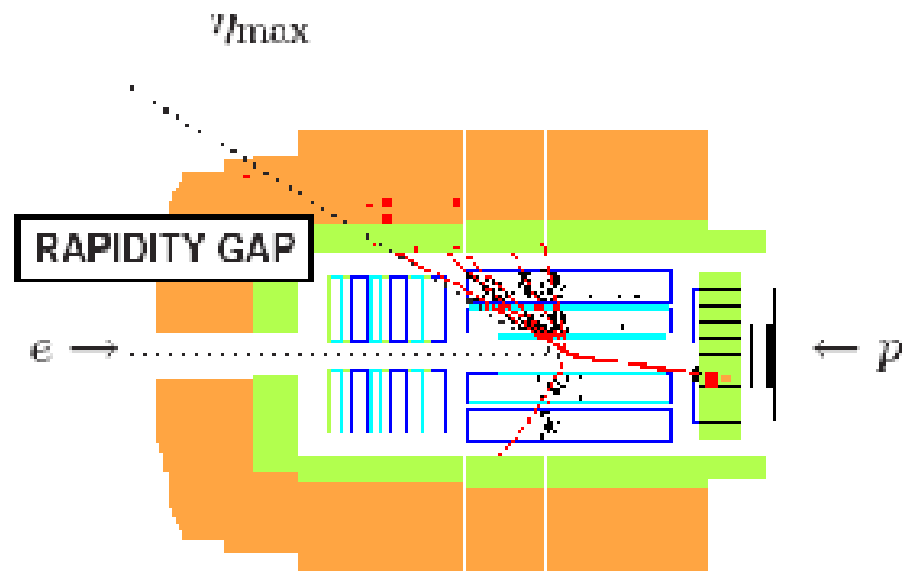
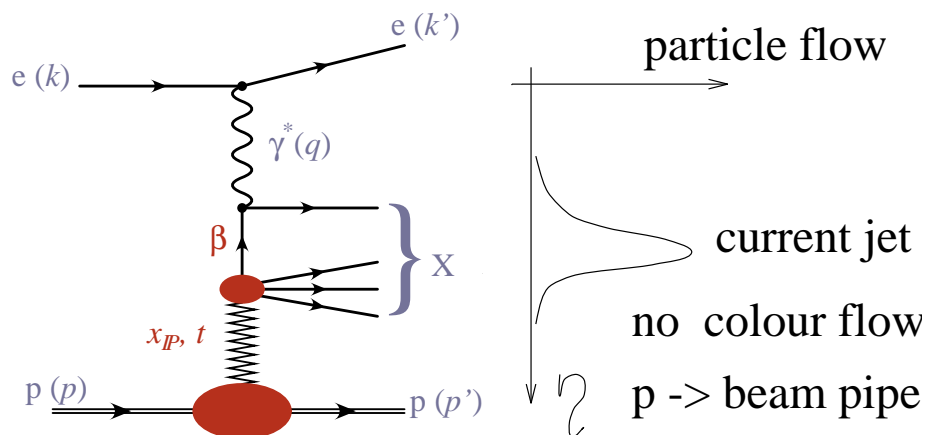


Diffractive Scattering

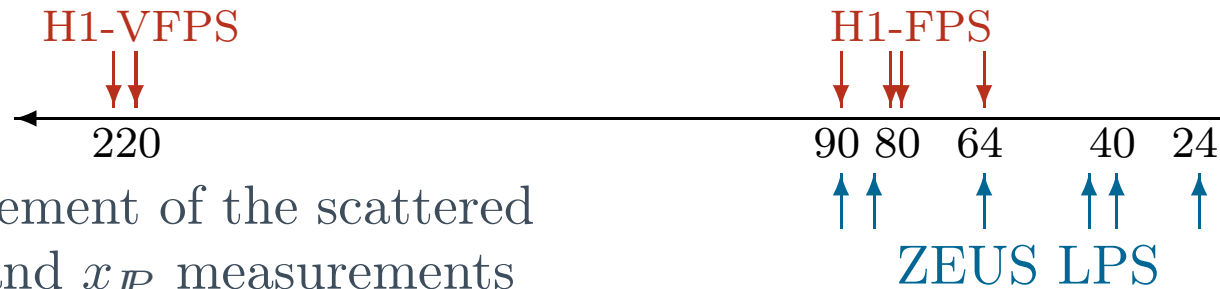
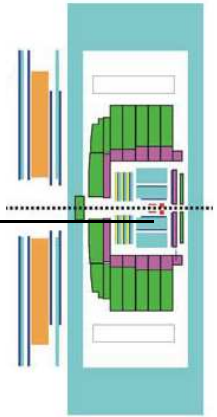
Deep Inelastic Scattering (DIS)



Diffractive Scattering (DDIS)



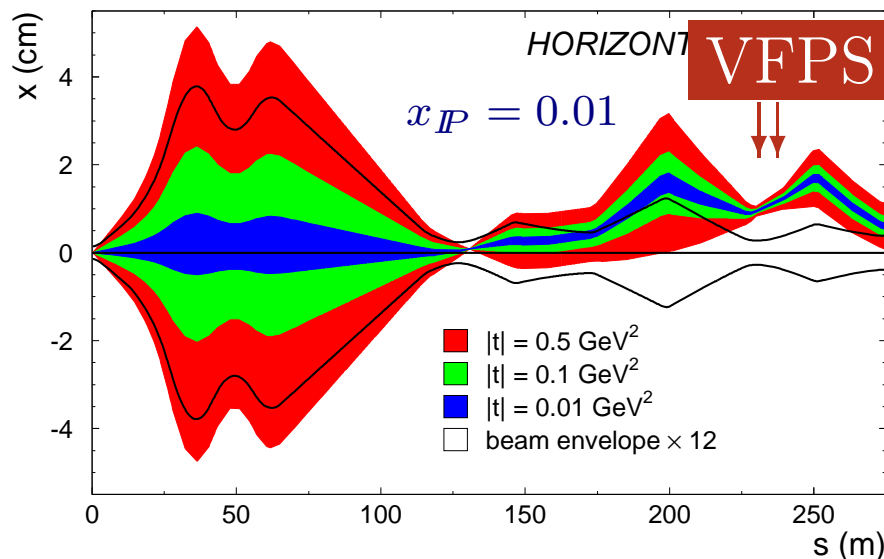
Roman Pot



→ direct measurement of the scattered proton: giving t and $x_{\mathcal{P}}$ measurements

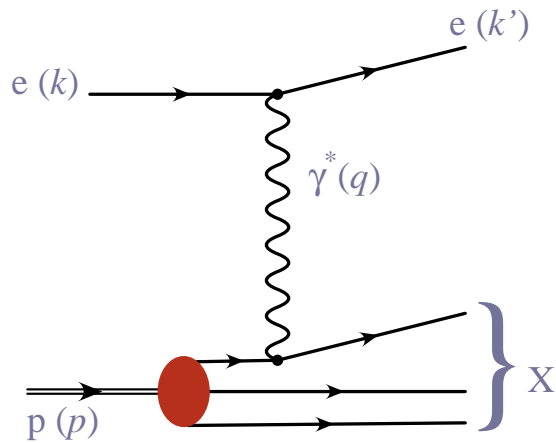
→ but lower statistics due to Roman Pot detector acceptance

H1 FPS	$x_{\mathcal{P}} < 0.1$	156 pb ⁻¹	HERA I+II
ZEUS LPS	$x_{\mathcal{P}} < 0.1$	33 pb ⁻¹	HERA I
H1 VFPS	$0.009 < x_{\mathcal{P}} < 0.03$	87 pb ⁻¹	HERA II (e^+p)



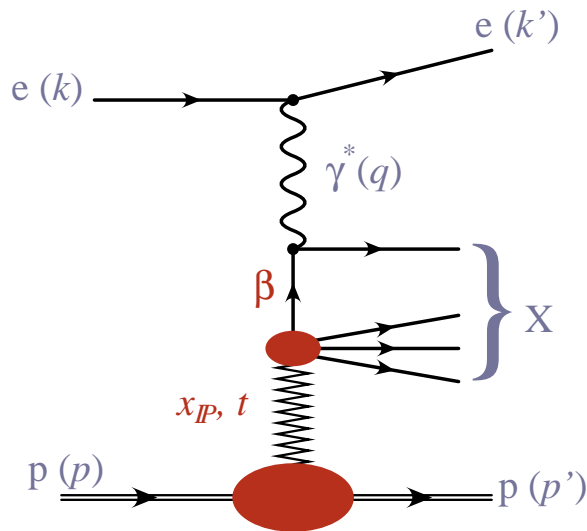
- 2 stations at 218 and 222 m
- high acceptance (90 %)
- high rec. efficiency (96%)
- low Bg (1%)

Kinematics



Deep Inelastic Scattering $ep \rightarrow eX$

- $Q^2 = -q^2$ - virtuality of the exchanged photon
- W γ^* - p system energy
- x Bjorken- x : fraction of proton's momentum carried by the struck quark
- y γ^* inelasticity : $y = Q^2 / s x$



Diffractive Scattering $ep \rightarrow eXp$

- x_P fraction of proton's momentum of the colour singlet exchange
- $x_P \simeq \frac{Q^2 + M_X^2}{Q^2 + W^2}$
- β fraction of P carried by the quark "seen" by the γ^* $\beta = x/x_P$
- $t = (p - p')^2$, 4-momentum squared at the p vertex

Factorisation Properties

QCD Hard Scattering Fact.

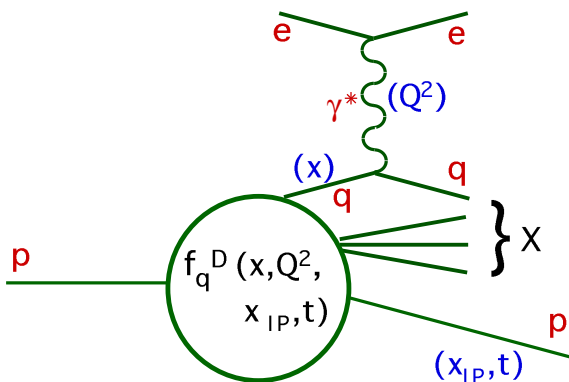
$$\sigma_{\text{DIS}}^{\text{Dif}} \sim f_q^D(x_{\mathbb{P}}, t, x, Q^2) \otimes \hat{\sigma}_{\text{pQCD}}$$

Diffractive parton densities

$$f_q^D(x_{\mathbb{P}}, t, x, Q^2)$$

→ *conditional* proton parton probability distributions for particular $x_{\mathbb{P}}, t$.

DGLAP applicable for Q^2 evolution.

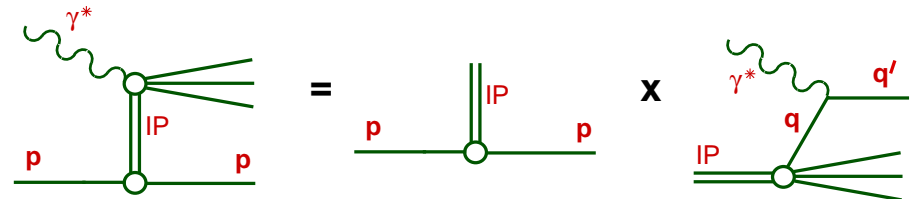


Rigorous for leading Q^2 dependence
but not in hadron-hadron collisions

Regge Factorisation

$$f_q^D(x_{\mathbb{P}}, t, x, Q^2) = f_{\mathbb{P}/p}(x_{\mathbb{P}}, t) \cdot q_{\mathbb{P}}(\beta, Q^2)$$

Diffractive parton densities factorise into “pomeron flux factor” and “pomeron parton densities”



\mathbb{P} flux factor from Regge theory ...

$$f_{\mathbb{P}/p}(x_{\mathbb{P}}, t) = \frac{e^{Bt}}{x_{\mathbb{P}}^{2\alpha(t)-1}} \quad \text{where ...}$$

$$\alpha(t) = \alpha(0) + \alpha' t$$

No firm basis in QCD

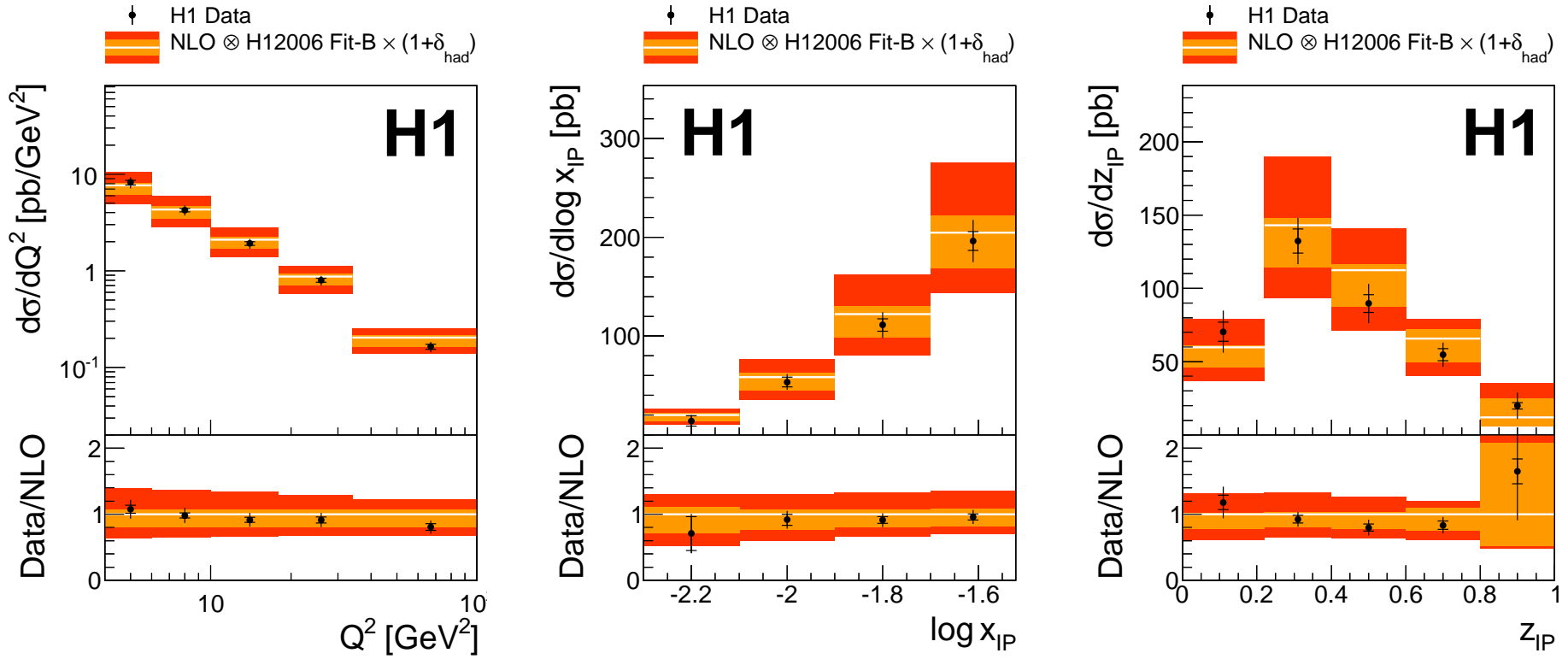
In this talk: recent results from H1 and ZEUS

Jet production in Diffraction

- LRG measurement in DIS H1 [arxiv:1412.0928]
- p measured in Roman Pots (VFPS) H1 [arxiv:1502.01683]
in DIS and photoproduction regimes
- photon + jet in photoproduction ZEUS-prel-15-001
- exclusive dijet production in DIS ZEUS [arxiv:1505.05783]

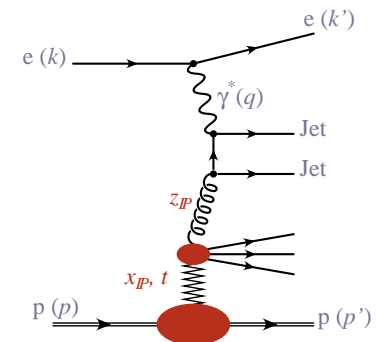
Test of QCD factorisation: H1 Dijet in DIS

LRG: $Q^2 > 4 \text{ GeV}^2$, $P_T^{jet1} > 5.5 \text{ GeV}$, $P_T^{jet2} > 4 \text{ GeV}$

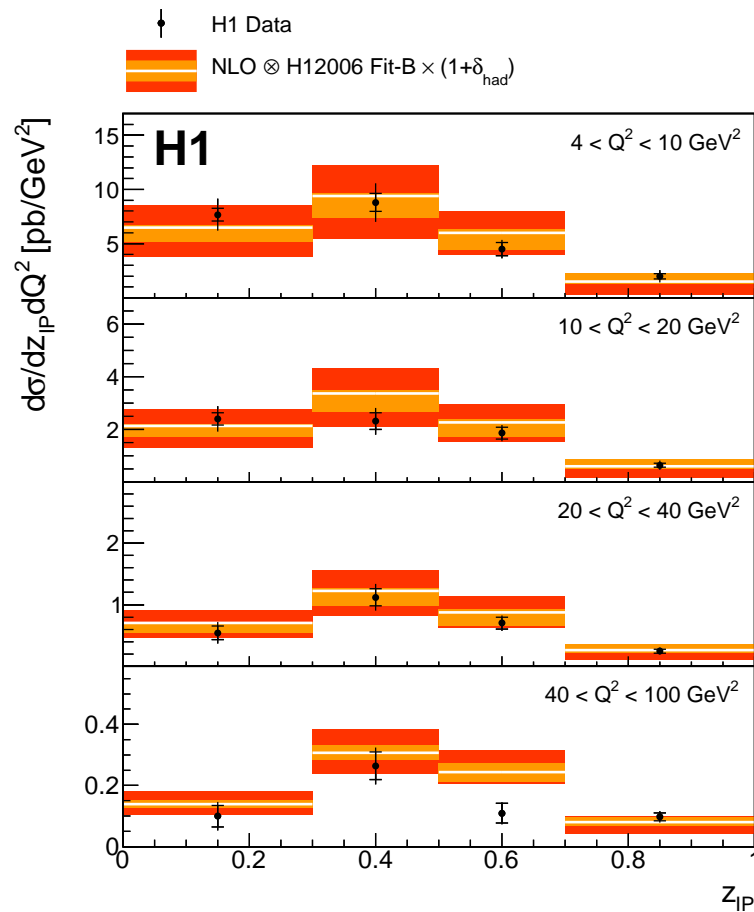
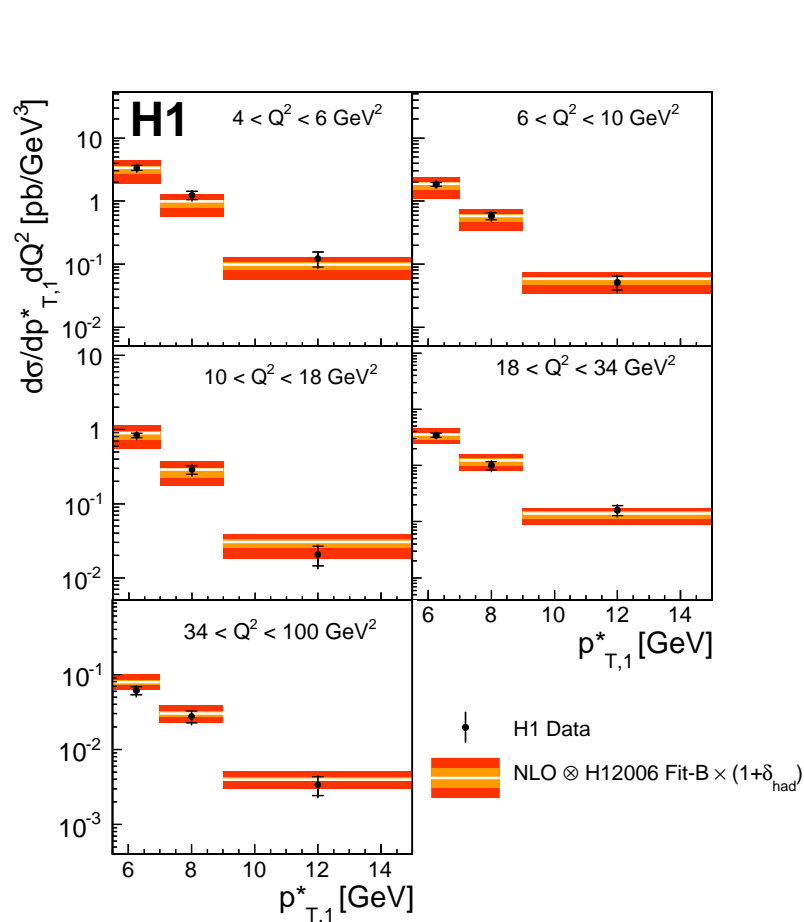


- from F_2^D measurements DPDFs are extracted and used to predict dijet production in DIS regime

→ QCD factorisation OK (in DIS)



LRG: H1 Dijet in DIS - con't



- Double diff. x-sect. shown for the first time

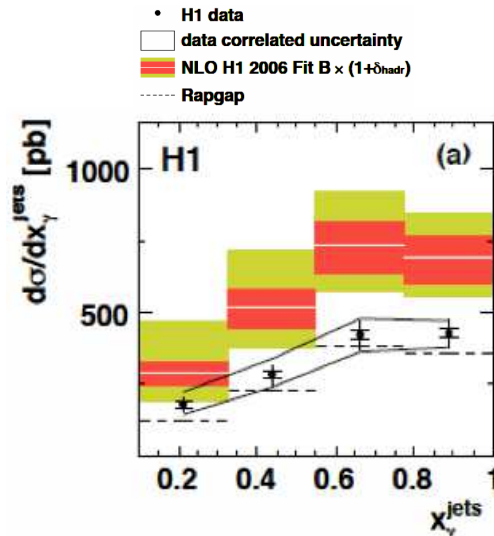
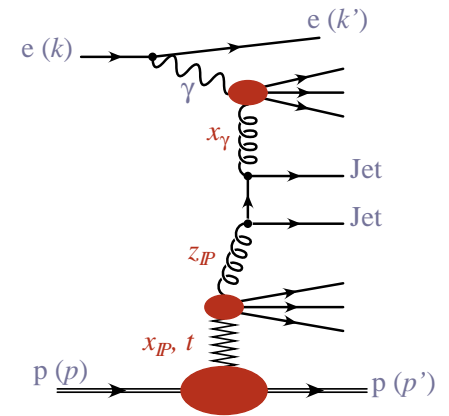
→ in agreement with QCD factorisation

- precision of data allowed extraction of :

$$\alpha_S(M_Z) = 0.119 \pm 0.004(\text{exp}) \pm 0.012(\text{PDF, theo})$$

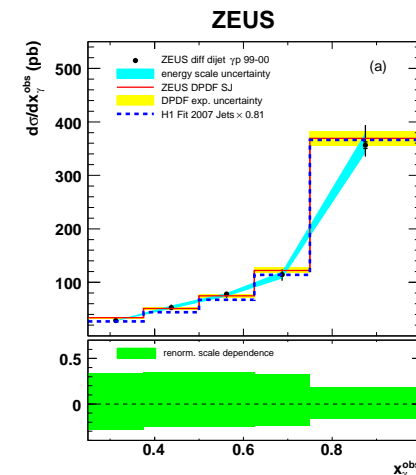
Dijet in Photoproduction: history

- For dijet in DIS: the factorisation holds.
- in $p - p$ collisions (TeVatron) the factorisation is broken.
- Look at **dijet in Photoproduction**
- Real photon ($Q^2 \simeq 0$) can develop a hadronic structure



Eur.Phys.J. C70 (2010) 15

$$\sigma_{data}/\sigma_{NLO} = 0.58 \pm 0.21$$



Nucl. Physics B 831 (2010) 1

$$\sigma_{data}/\sigma_{NLO} \simeq 1$$

Why ?

- Suppression observed in H1.
- Suppression has no x_γ dependence.

Dijet in Photoproduction: history

Why is the QCD factorisation broken ? / Why is there a difference H1/ZEUS ?

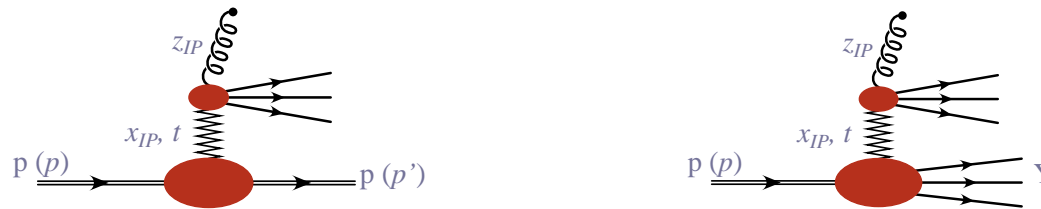
- Different space phase in H1/ZEUS analyses.

H1: $Et > 5(4)$ GeV

ZEUS: $Et > 7.5(6.5)$ GeV

- studies show is not the reason [EPJC(2011) 71:1741]
the measurements are different in an identical phase space.

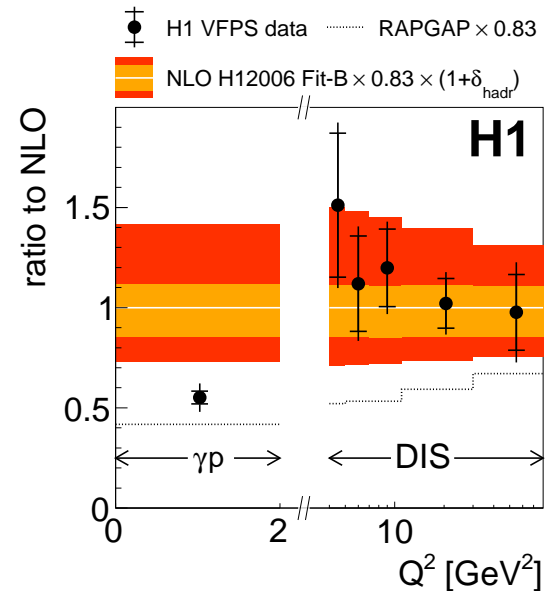
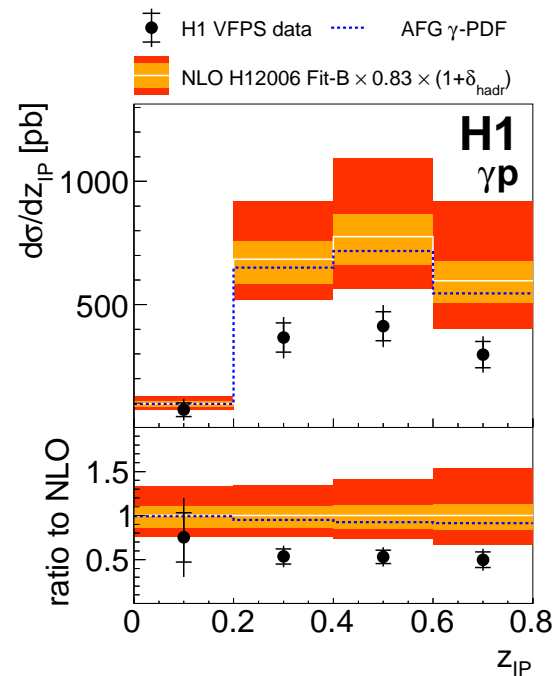
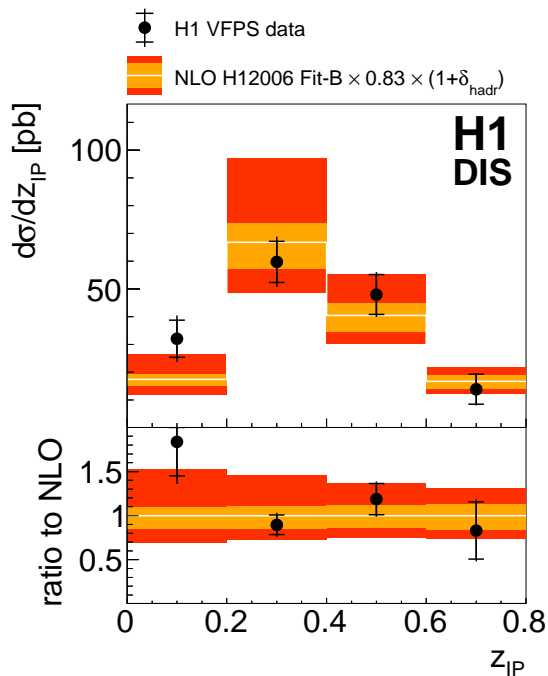
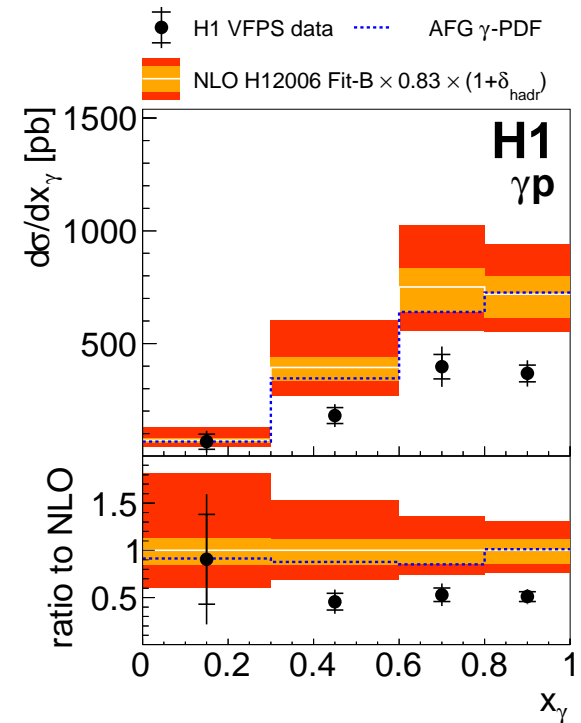
- Could the contribution of p dissociation be the reason?



- new analysis, with measured final state proton.

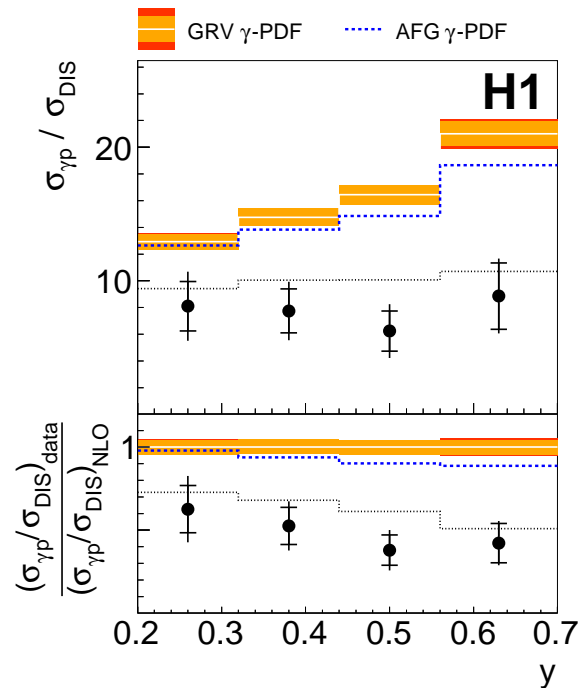
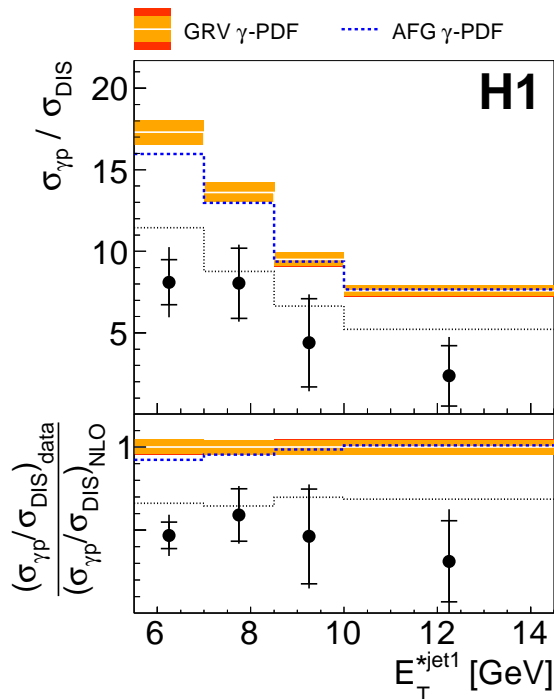
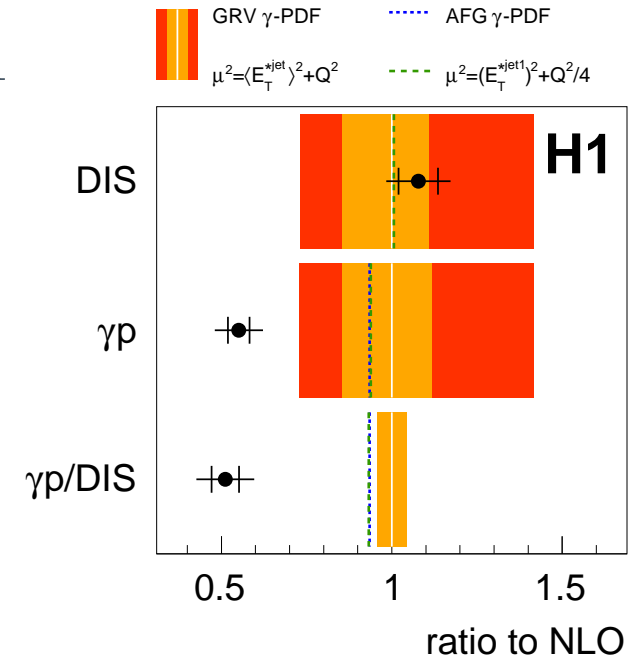
VFPS: Dijet in DIS and in Photoproduction

DIS	$\gamma - p$
$4 < Q^2 < 80 \text{ GeV}^2$	$Q^2 < 2 \text{ GeV}^2$
$0.2 < y < 0.8$	
$E_T^{jet1(2)} > 5.5(4) \text{ GeV}$	
$-1 < \eta_{jet1,2} < 2.5$	
$0.010 < x_P < 0.024$	
$ t < 0.6 \text{ GeV}^2$	
$M_Y = M_p$	



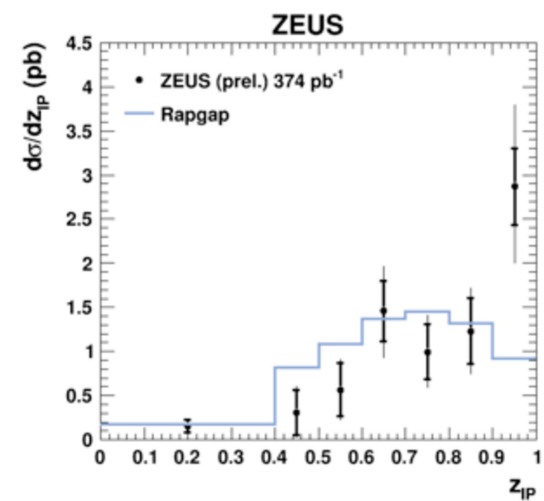
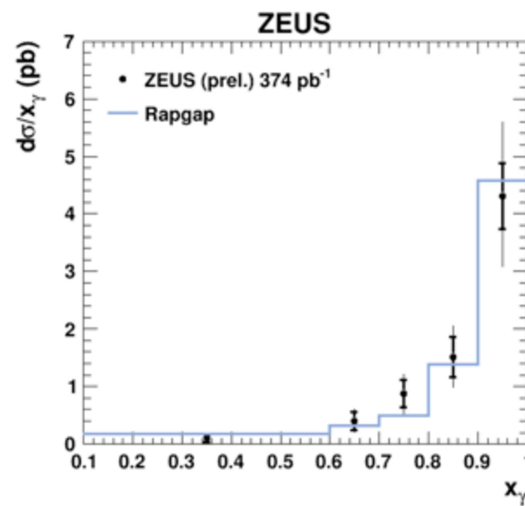
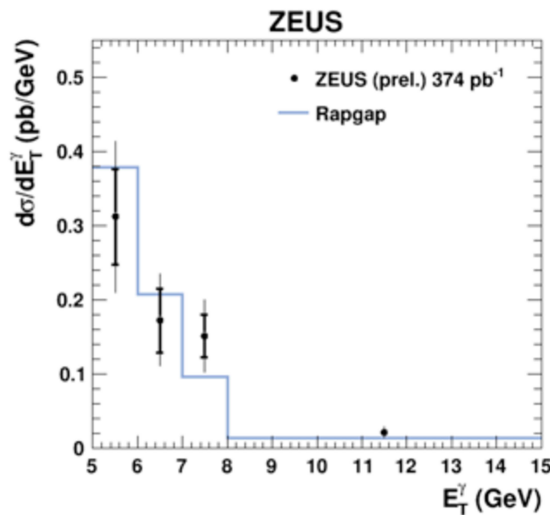
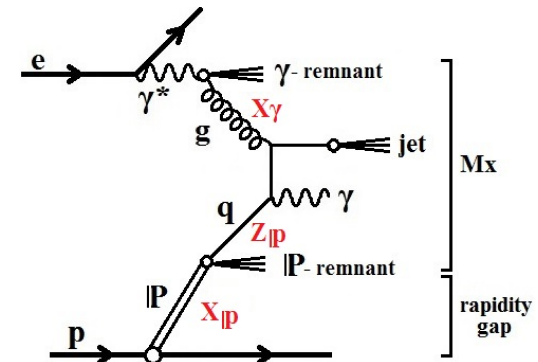
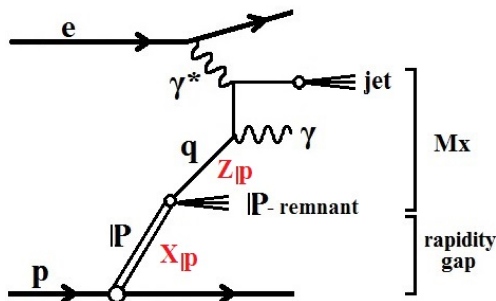
VFPS Dijet - conclusion

- DIS in agreement with QCD factorisation
- Factorisation broken in $\gamma - p$ (confirming previous H1 measurements)
- VFPS (i.e. p tagging): **not related to p dissociation**
- confirms **not related to x_γ** value (i.e. direct/resolved)
- Double ratio shows **no jet E_T dependence**
- Double ratio **y dependence not described by NLO.**



Photon + jet in photoproduction

LRG: $Q^2 < 1 \text{ GeV}^2$, $x_{IP} < 0.03$, $E_T^\gamma > 5 \text{ GeV}$, $-0.7 < \eta^\gamma < 0.9$, $E_T^{\text{jet}} > 4 \text{ GeV}$

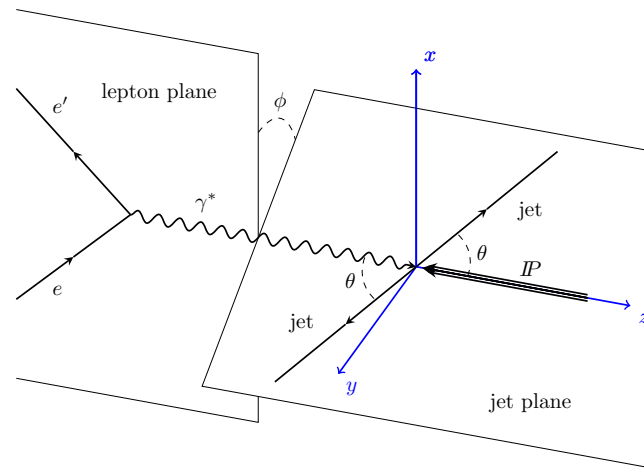


- Fair description by RAPGAP (Fit B)
- Except at $z_{IP} \approx 1$ (where Fit B not fitted)

Exclusive Dijets in DIS

LRG: $Q^2 > 25 \text{ GeV}^2$, $x_{IP} < 0.01$, $N_{\text{jet}} = 2$, $P_T^{\text{jets}} > 2 \text{ GeV}$

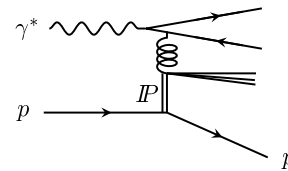
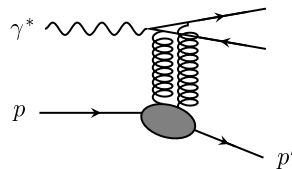
- using Durham jet algorithm in $\gamma^* - IP$ rest frame in exclusive mode (all objects are in jets), $y_{\text{cut}} = 0.15$.
- test the **nature of the exchanged object** in diffractive interactions
- reconstruct **ϕ angle** between lepton and jet planes



→ $d\sigma/d\phi \sim 1 + A(P_T^{\text{jet}}) \cos 2\phi$ [J.Bartels et al., PLB386,(1996)389]

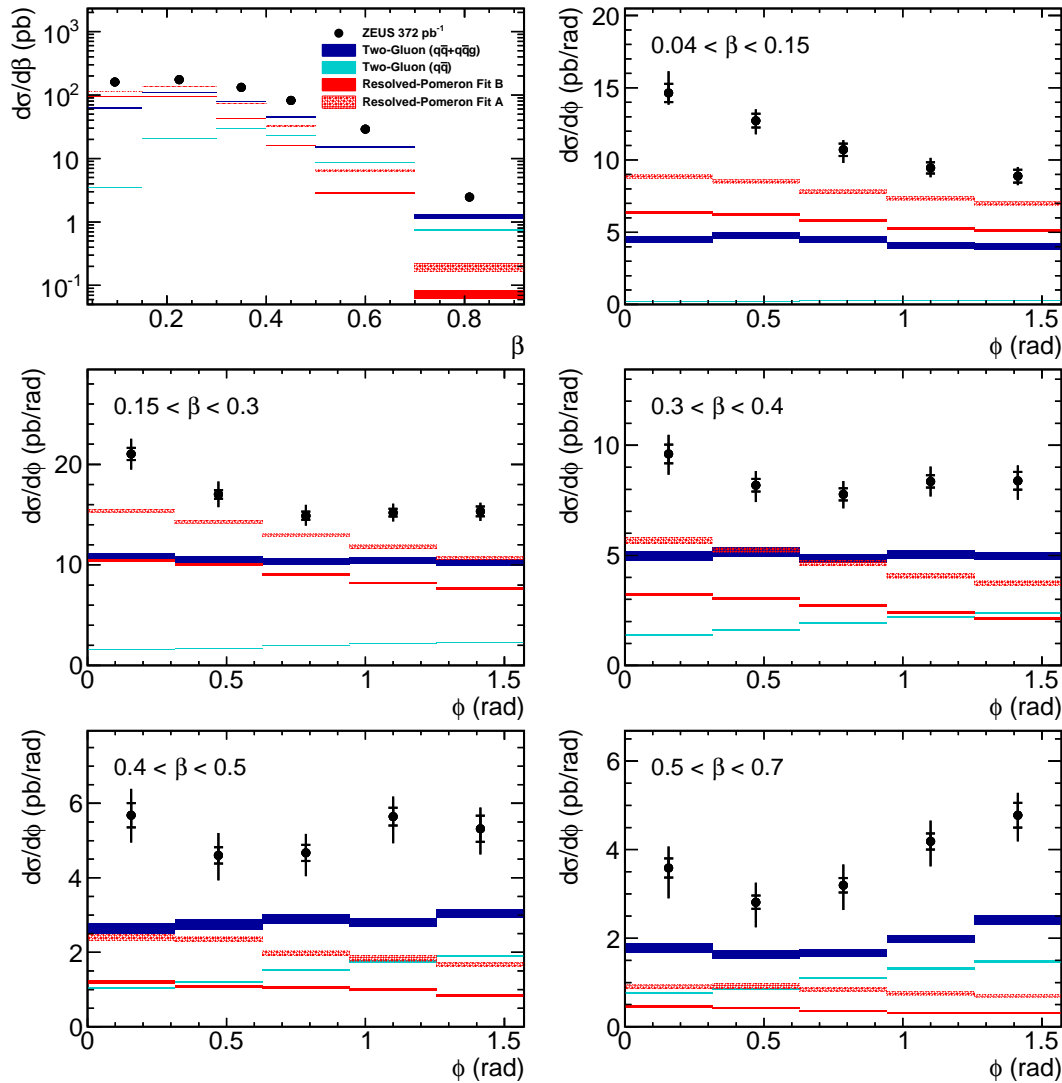
$A > 0$ for $q\bar{q}$ produced from single gluon

$A < 0$ two gluons exchange.



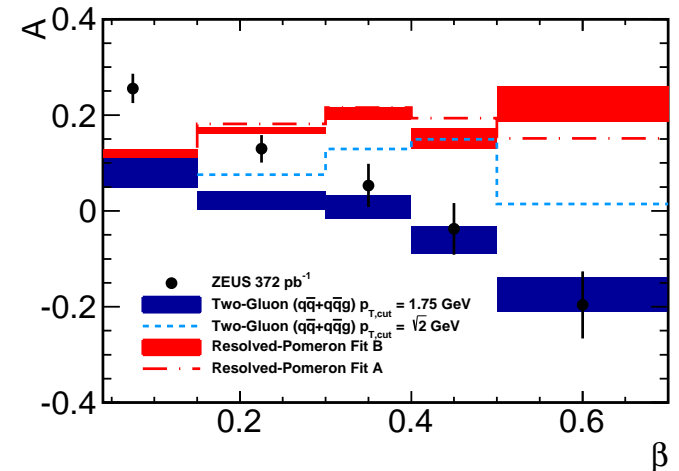
Exclusive Dijets in DIS

ZEUS



- $d\sigma/d\phi$ fitted in each β bin

ZEUS



- normalisation discrepancy of factor two (NLO large ?)
- A vs ϕ : good description by the two gluon model for $\beta > 0.3$ (i.e. towards exclusive dijets).

Conclusion

Studies based on jet production in Diffraction

- the QCD factorisation is confirmed with higher precision in DIS regime
- the factorisation suppression that takes place for the dijet diffractive photoproduction has been investigated further
- the new results confirm the suppression factor and
 - its independence w.r.t. p-dissociation
 - its independence w.r.t. x_γ
 - its independence w.r.t. E_T^{jet} .
- First photon+jet diffractive measurement - shapes agree with RAPGAP except in $z_{\mathcal{P}}$.
- study of nature of exclusive dijets: two-gluon exchange dominated (NLO needed).