Recent HERA results on hard diffraction

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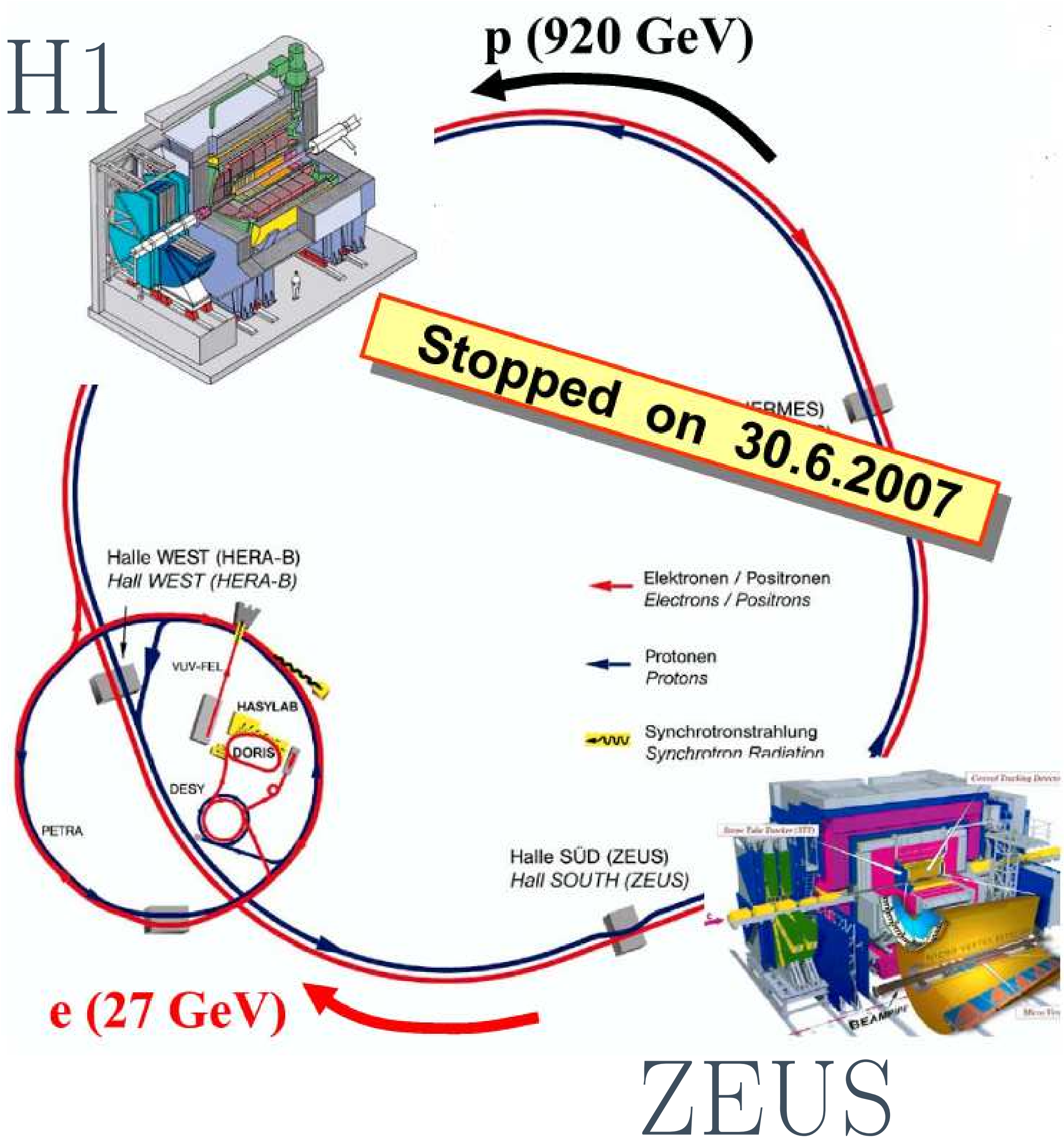
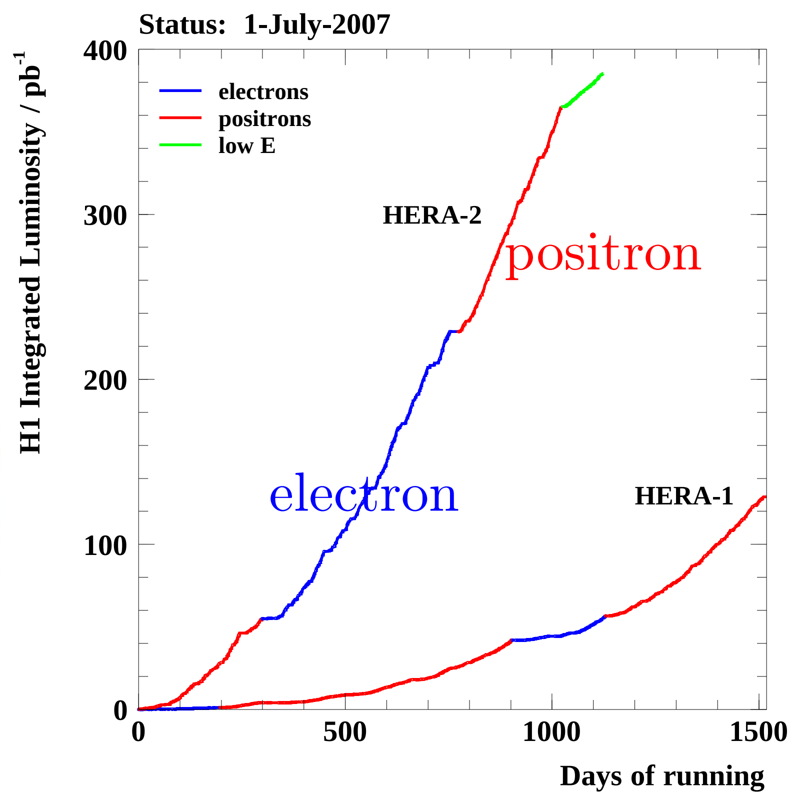
On behalf of the H1 and ZEUS collaborations

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

HERA - $e - p$ collider at DESY

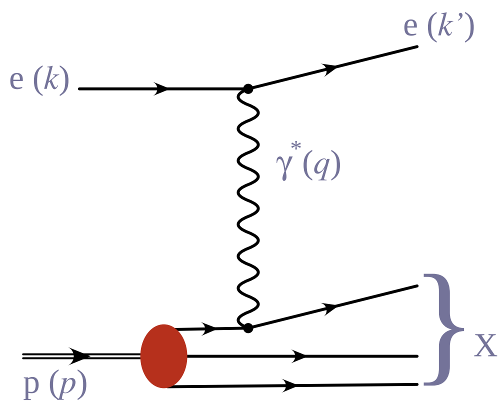


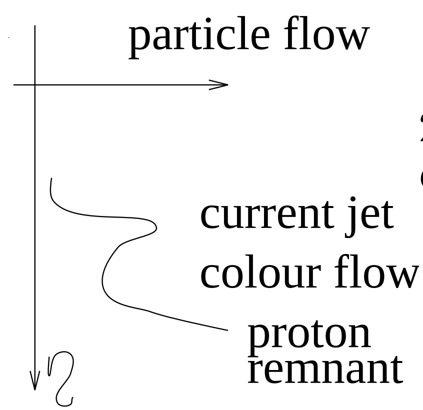
Integrated luminosity
96-00 + 03-07 (high energy)
$e^+p :\sim 300 \text{pb}^{-1}$
$e^-p :\sim 185 \text{pb}^{-1}$

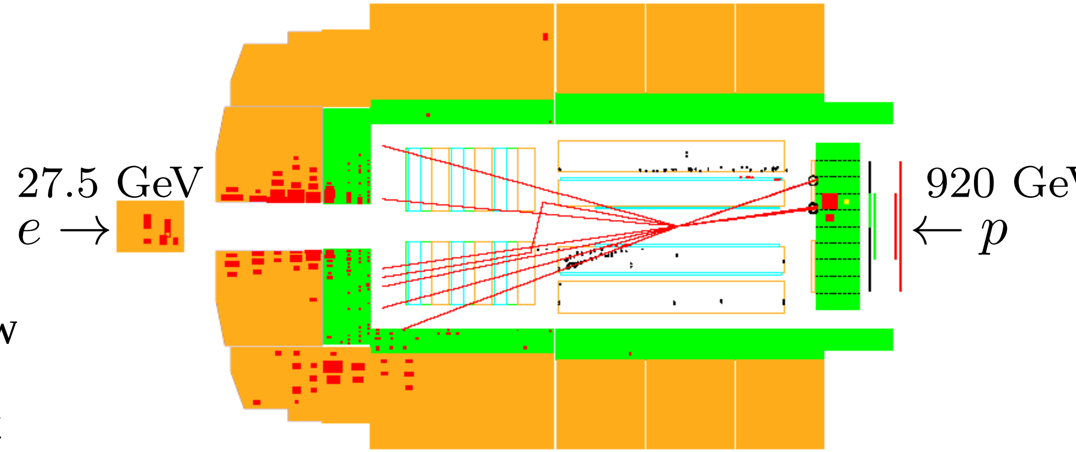


Diffractive Scattering

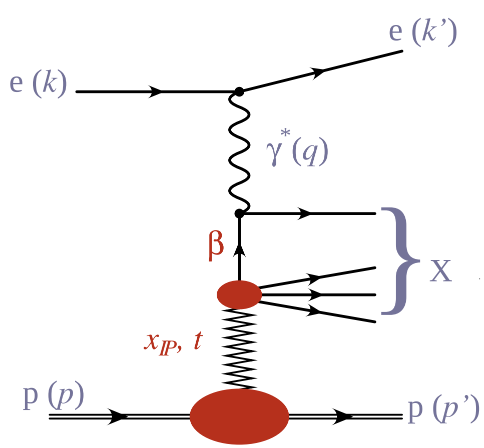
Deep Inelastic Scattering (DIS)

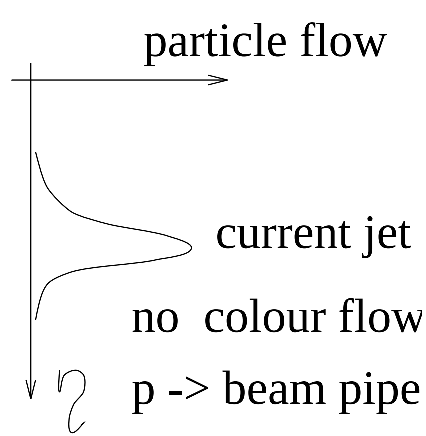


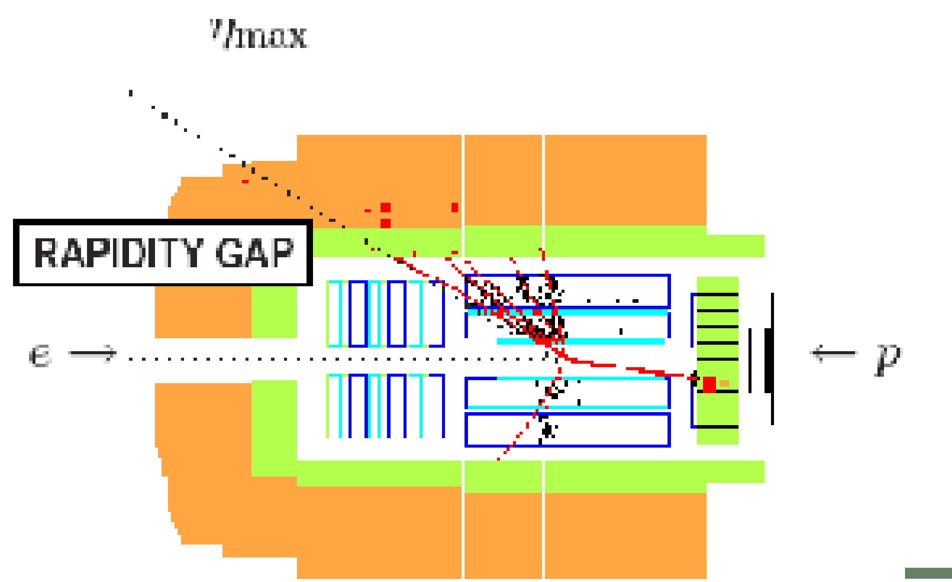




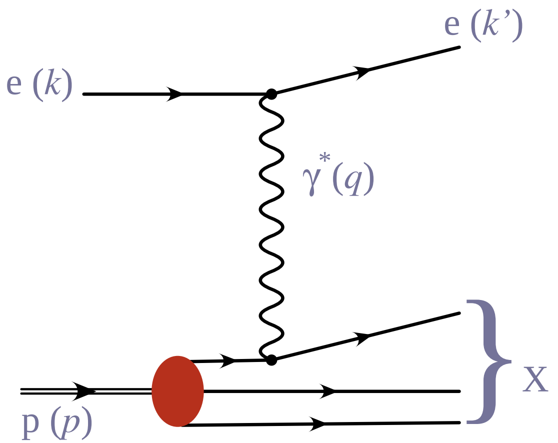
Diffractive Scattering (DDIS)





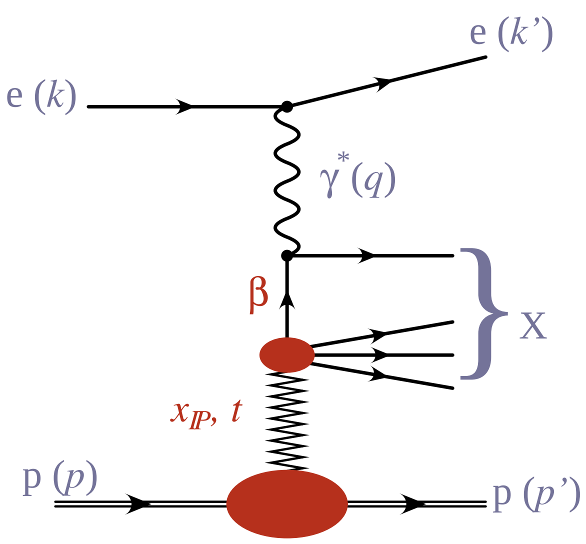


Kinematics



Deep Inelastic Scattering $ep \to eX$

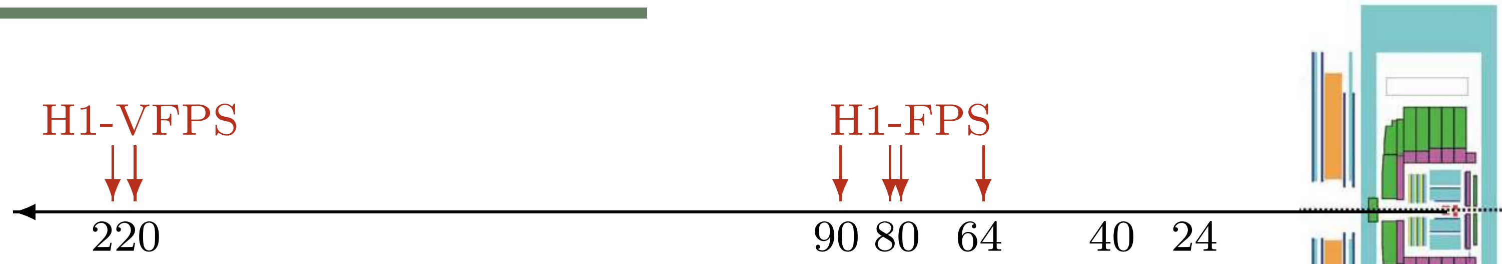
Q^2	$= -q^2$ - virtuality of the exchanged photon
W	$\gamma^* - p$ system energy
x	Bjorken-x: fraction of proton's momentum carried by the struck quark
y	γ^* inelasticity : $y = Q^2/s\, x$

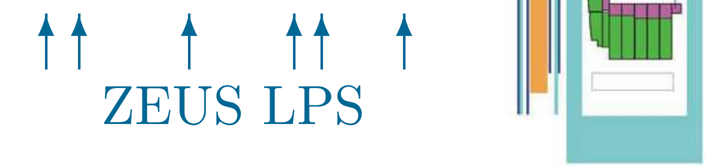


Diffractive Scattering $ep \to eXp$

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

Roman Pot

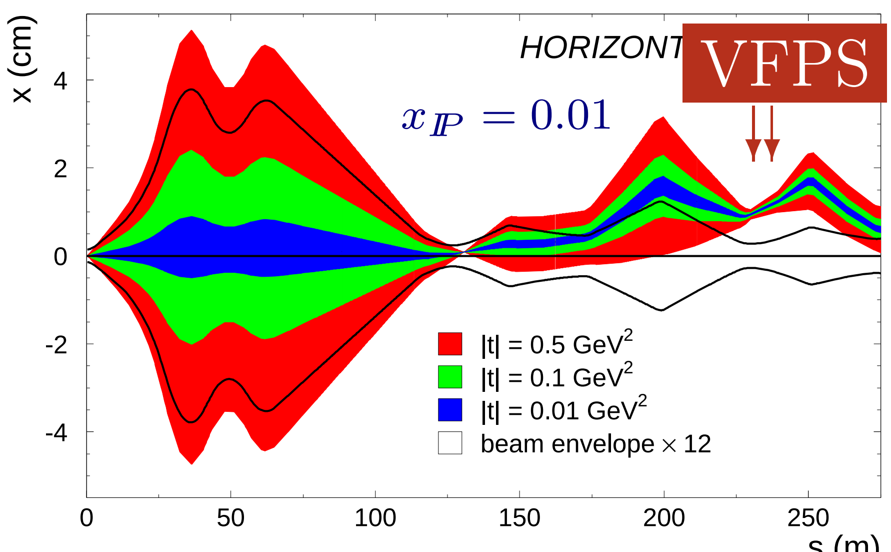




→ direct measurement of the scattered proton: giving t and $x_{I\!P}$ measurements

→ but lower statistics due to Roman Pot detector acceptance

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



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

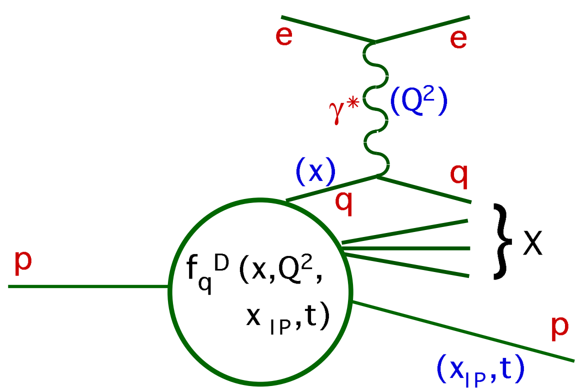
Factorisation Properties

QCD Hard Scattering Fact.

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

Diffractive parton densities $f_q^D(x_{I\!P}, t, x, Q^2)$
$\rightarrow$ *conditional* proton parton probability distributions for particular $x_{I\!P}, t$.

DGLAP applicable for Q^2 evolution.

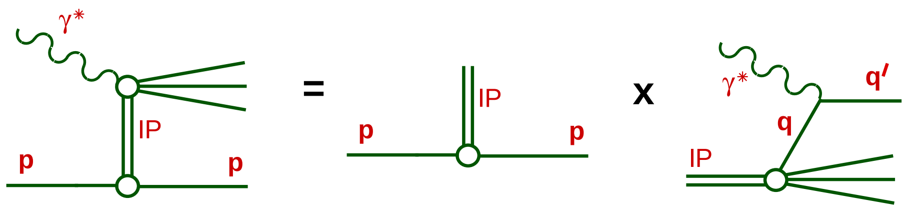


Rigorous for leading Q^2 dependence
but not in hadron-hadron collisions

Regge Factorisation

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

Diffractive parton densities factorise into "pomeron flux factor" and "pomeron parton densities"



$I\!P$ flux factor from Regge theory ...

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

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

No firm basis in QCD

In this talk: recent results from H1 and ZEUS

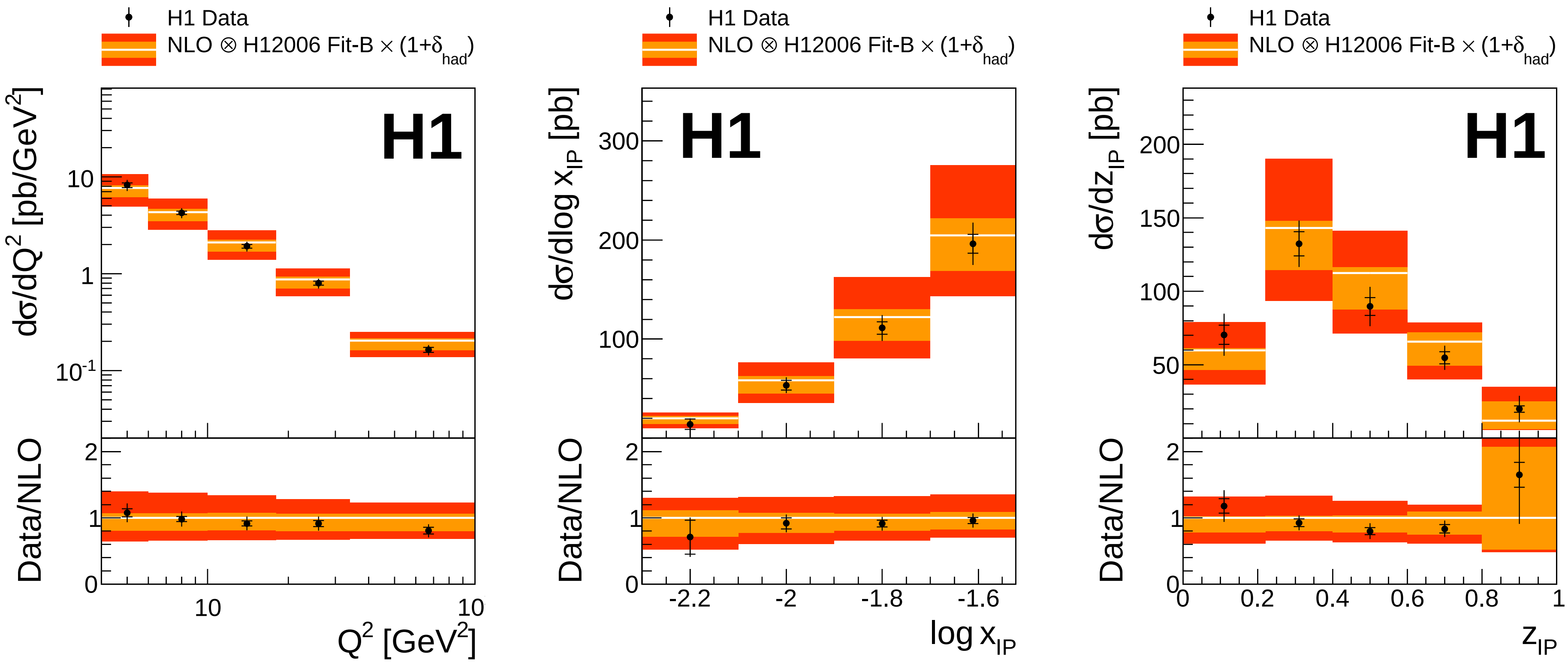
Jet production in Diffraction

- 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

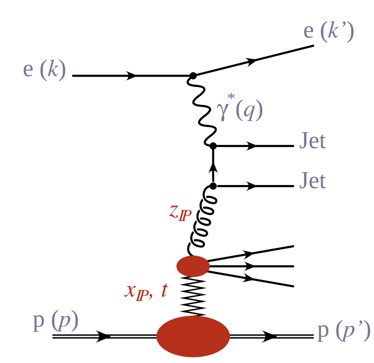
LRG: $Q^2 > 4\ \text{GeV}^2$, $P_T^{jet1} > 5.5$ GeV ,$P_T^{jet2} > 4$ GeV

$\int \mathcal{L} = 290\ pb^{-1}$

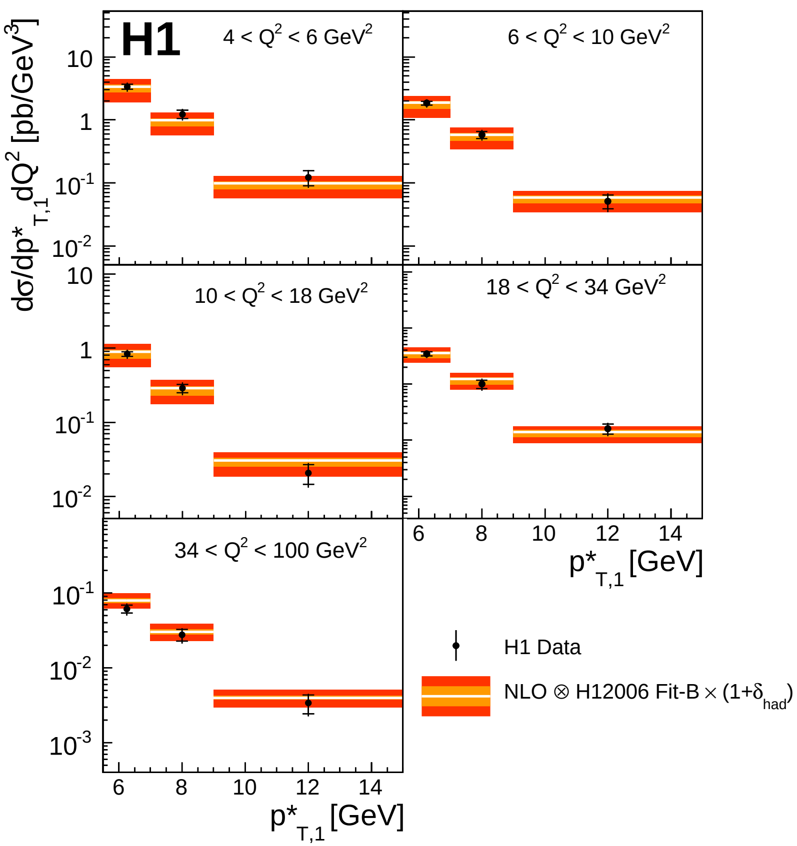


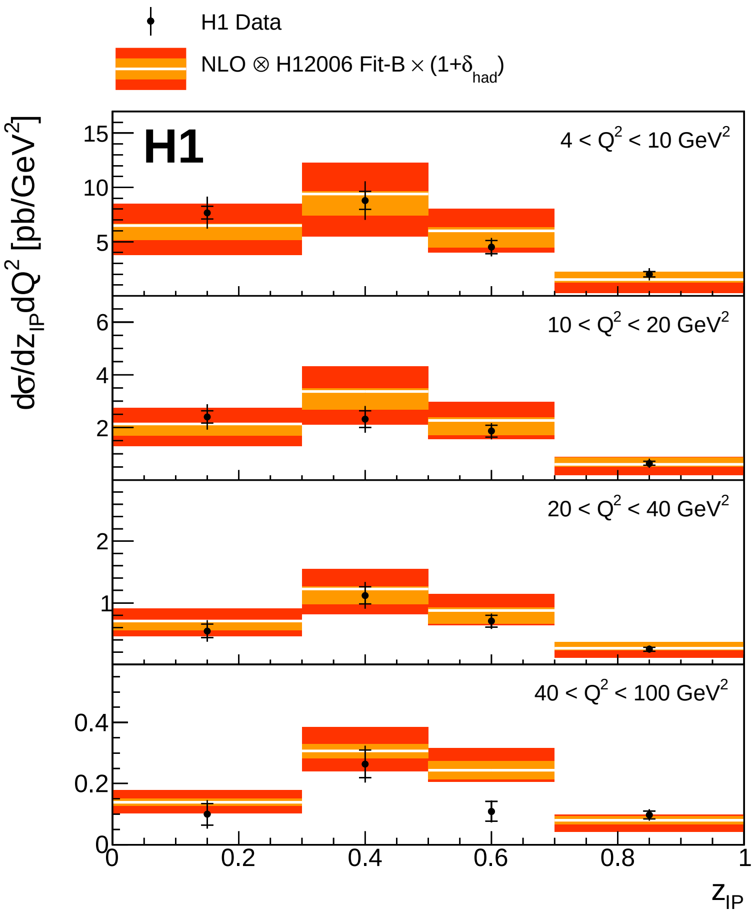
- from F_2^D measurements DPDFs are extracted and used to predict dijet production in DIS regime

→ 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

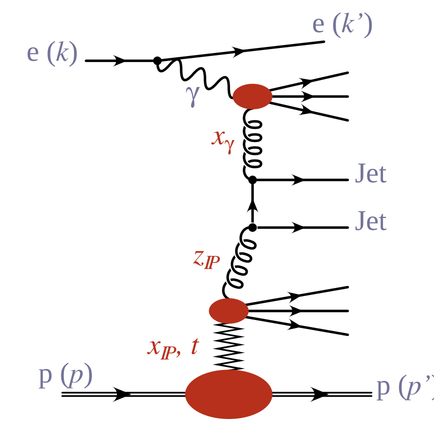
- precision of data allowed extraction of :
$\alpha_S(M_Z) = 0.119 \pm 0.004(\text{exp}) \pm 0.012(\text{PDF, theo})$

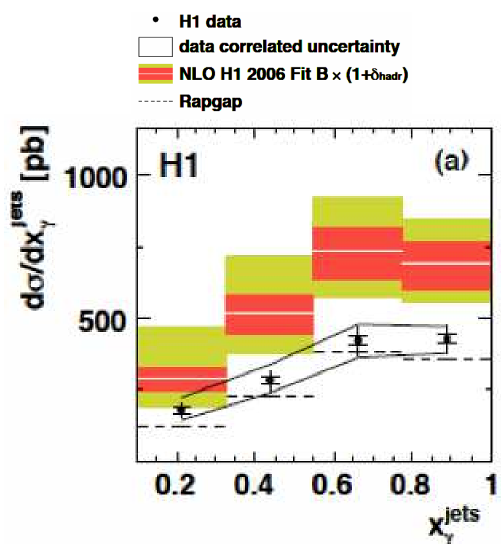
Dijet in Photoproduction: history

- 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





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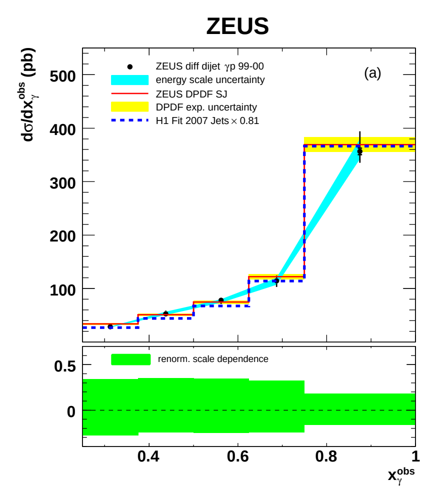
$\sigma_{data}/\sigma_{NLO} = 0.58 \pm 0.21$



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

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 ?

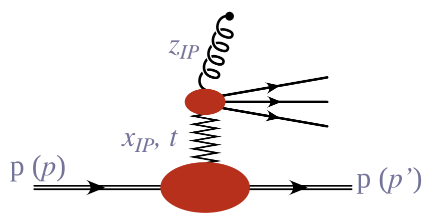
- Different space phase in H1/ZEUS analyses.

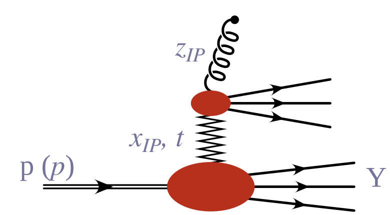
  H1: $Et > 5(4)$ GeV
  ZEUS: $Et > 7.5(6.5)$ GeV

  → 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	$\gamma - p$
$4 < Q^2 < 80$ GeV^2	$Q^2 < 2$ GeV^2

$0.2 < y < 0.8$

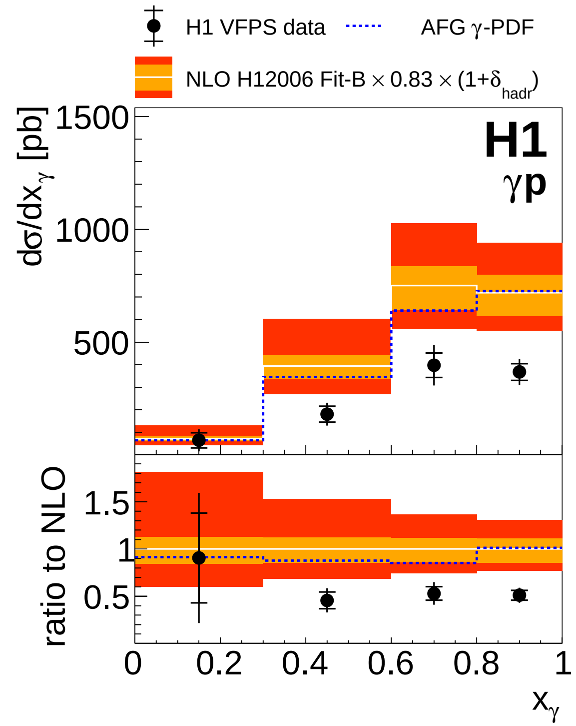
$E_T^{jet1(2)} > 5.5(4)$ GeV

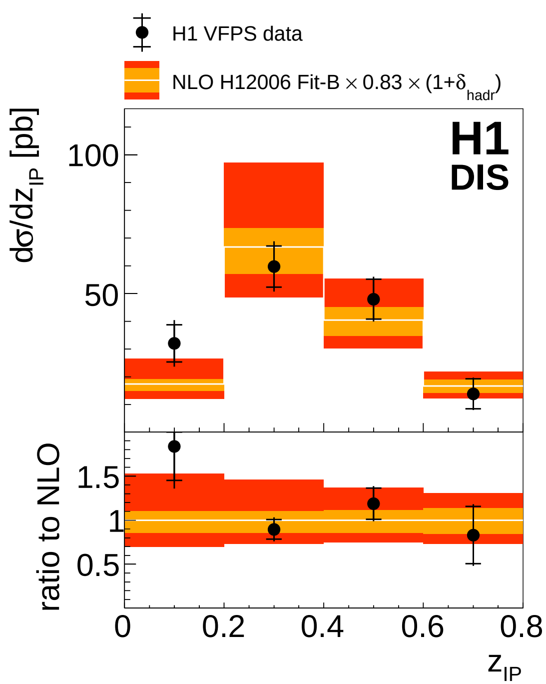
$-1 < \eta_{jet1,2} < 2.5$

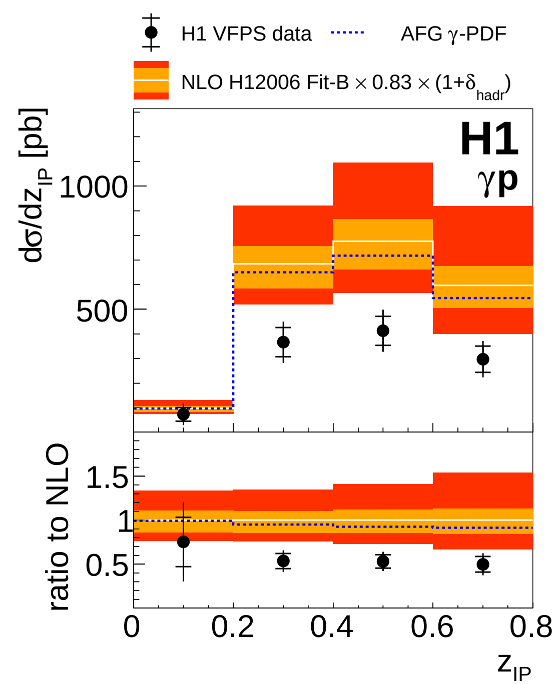
$0.010 < x_{I\!P} < 0.024$

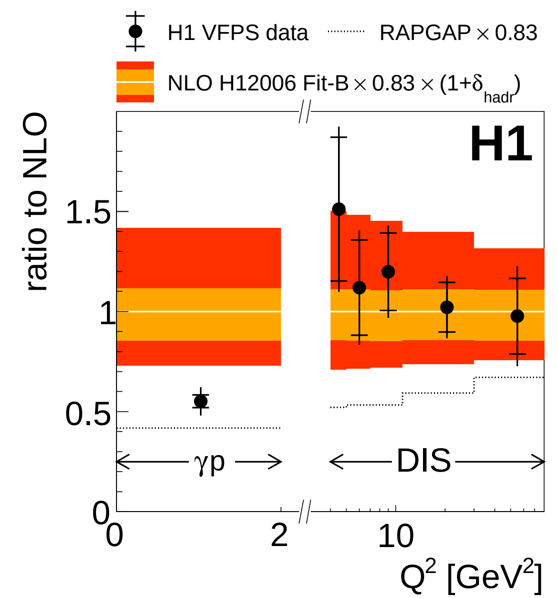
$|t| < 0.6$ GeV^2

$M_Y = M_p$



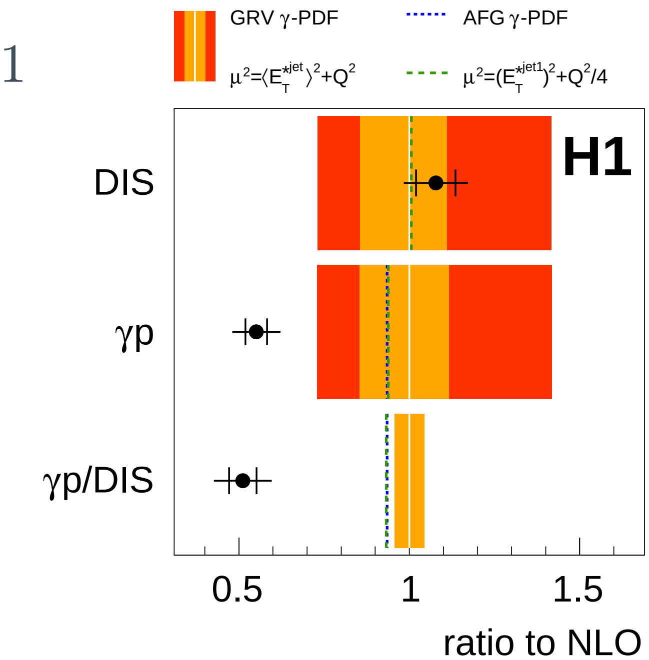


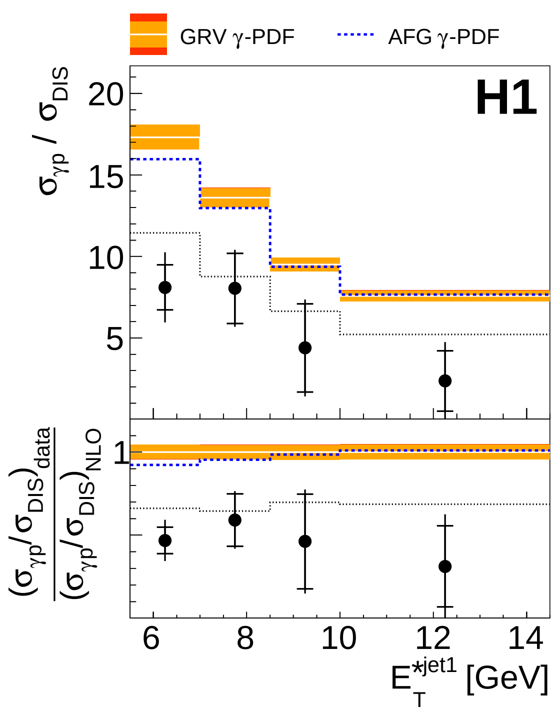


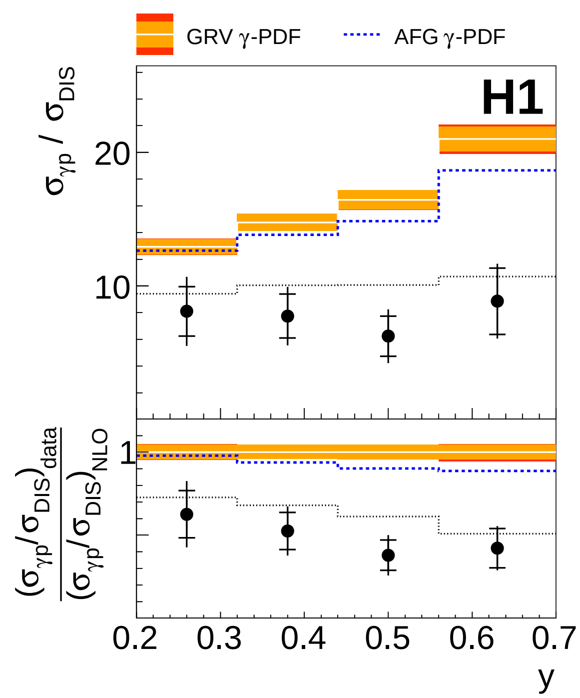


VFPS Dijet - conclusion

- 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.

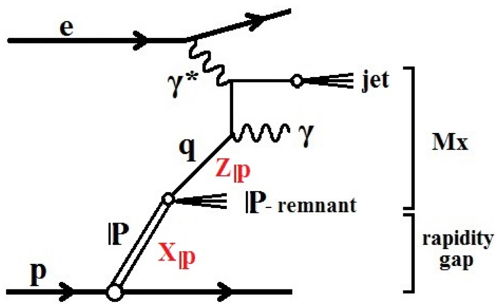


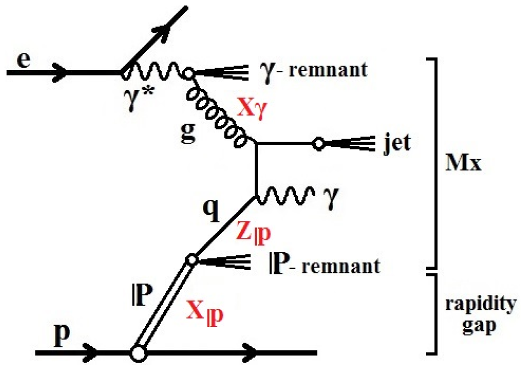


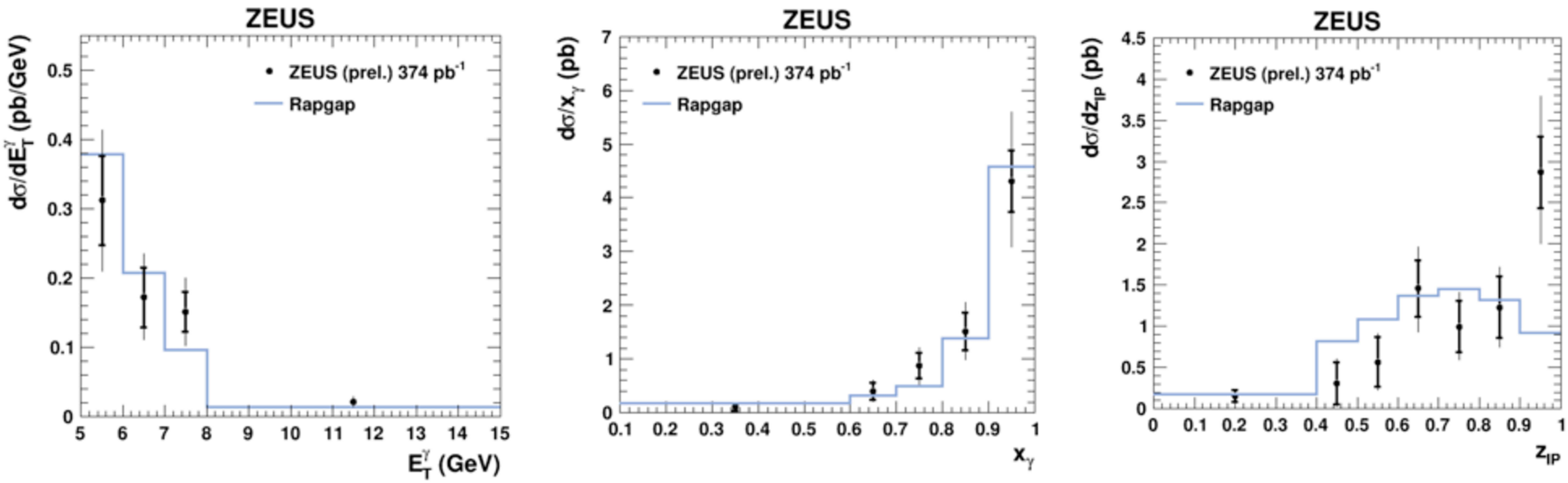


Photon + jet in photoproduction

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





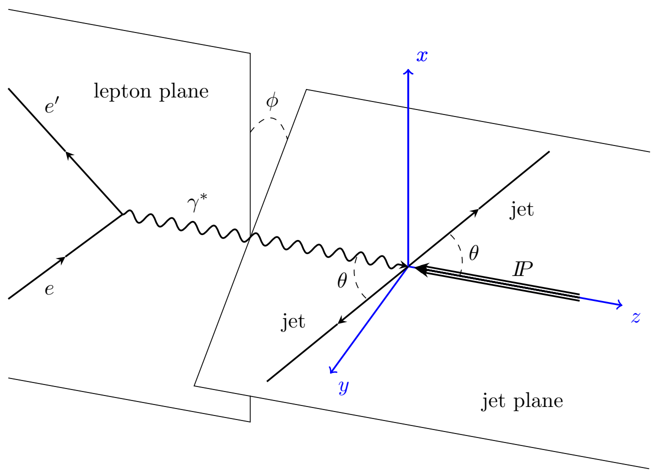


- Fair description by RAPGAP (Fit B)
- Except at $z_{I\!P} \approx 1$ (where Fit B not fitted)

Exclusive Dijets in DIS

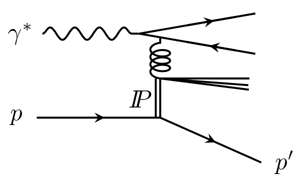
LRG: $Q^2 > 25$ GeV^2, $x_{I\!P} < 0.01$, $N_{\rm jet} = 2$, $P_T^{\rm jets} > 2$ GeV

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

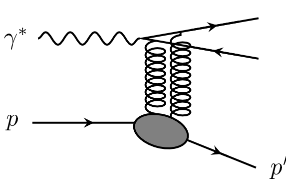


→ $d\sigma/d\phi \sim 1 + A(P_T^{\rm jet})\cos 2\phi$ [J.Bartels et al.,PLB386,(1996)389]

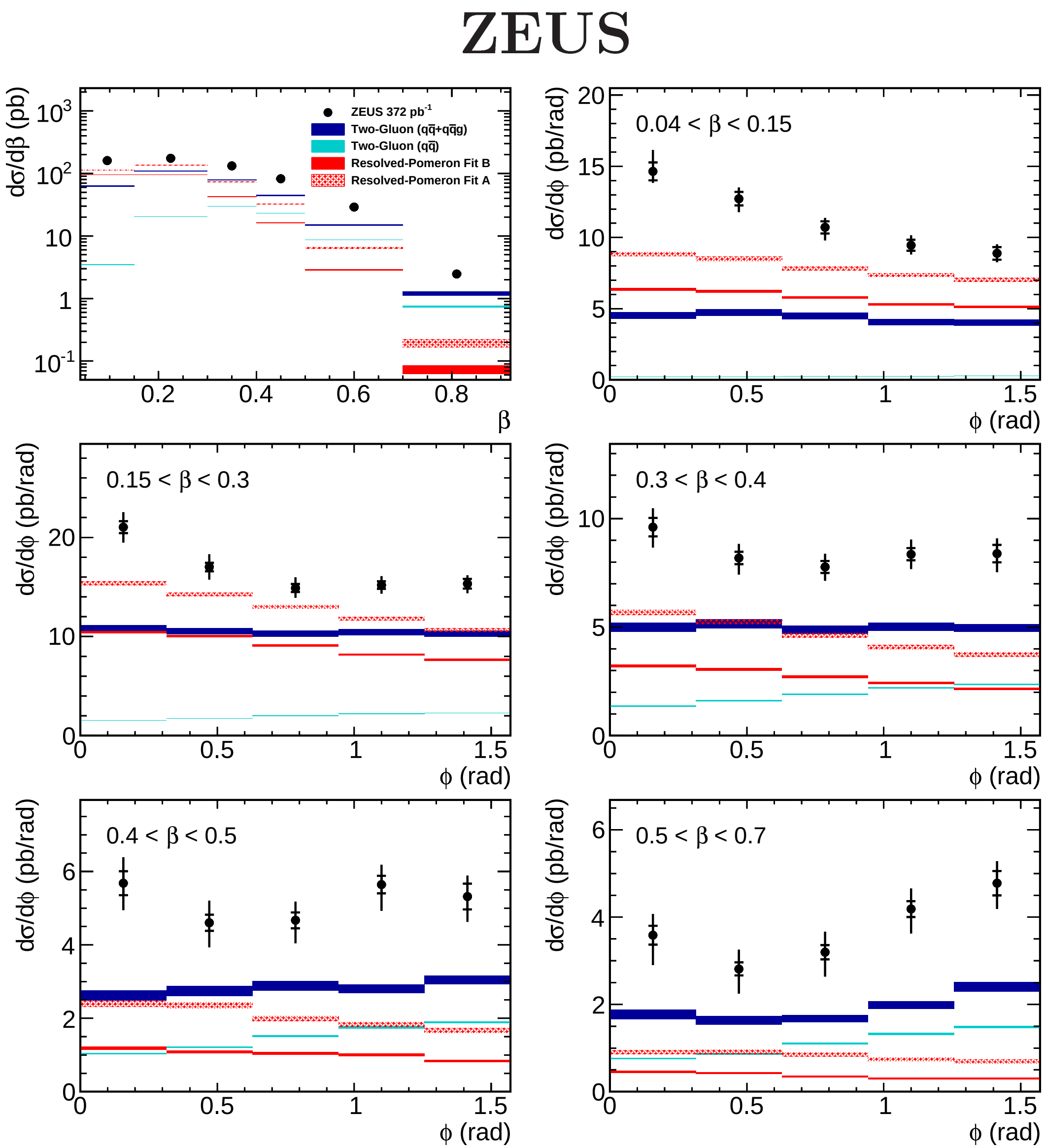
$A > 0$ for $q\bar{q}$ produced from single gluon



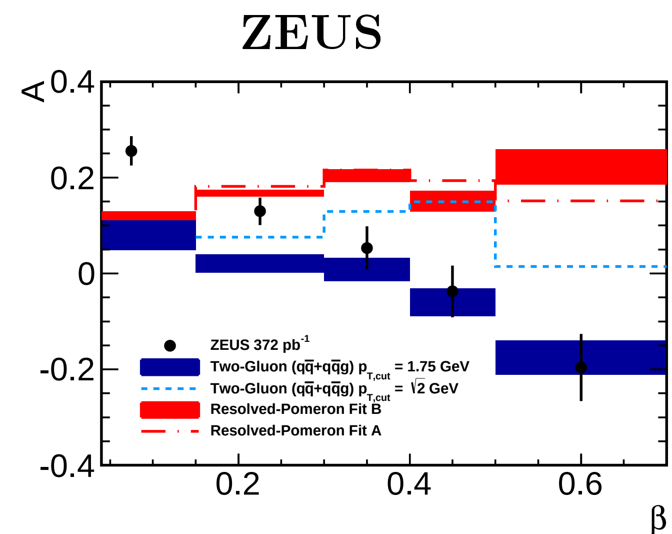
$A < 0$ two gluons exchange.



Exclusive Dijets in DIS



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



- 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 $z_{I\!P}$.
- study of nature of exclusive dijets: two-gluon exchange dominated (NLO needed).