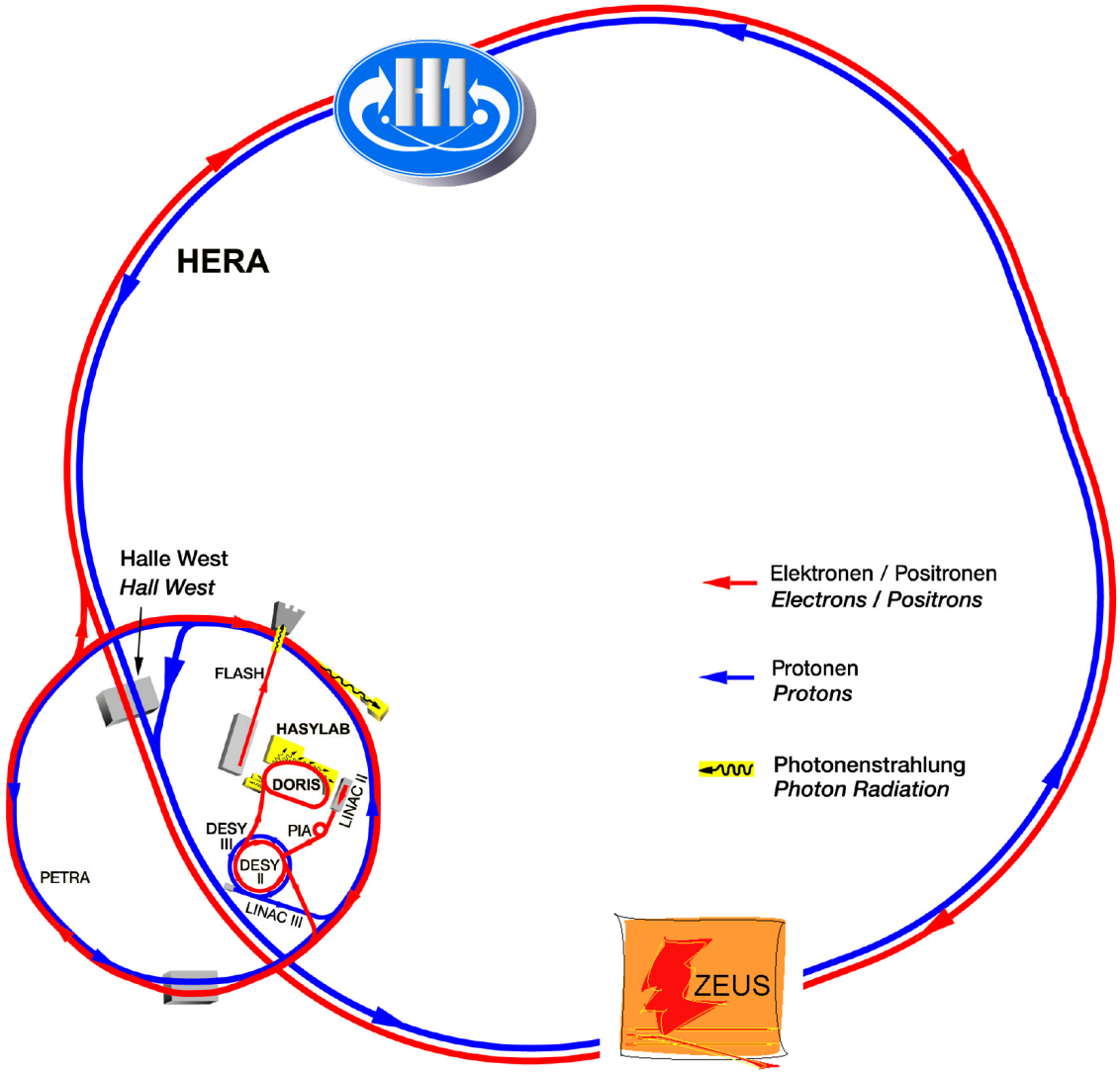
Selected Results on Diffraction at HERA

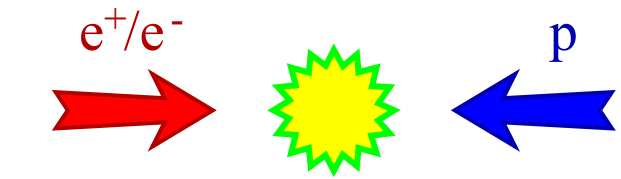
Grzegorz Gach

Various Faces of QCD
10 May 2014

HERA

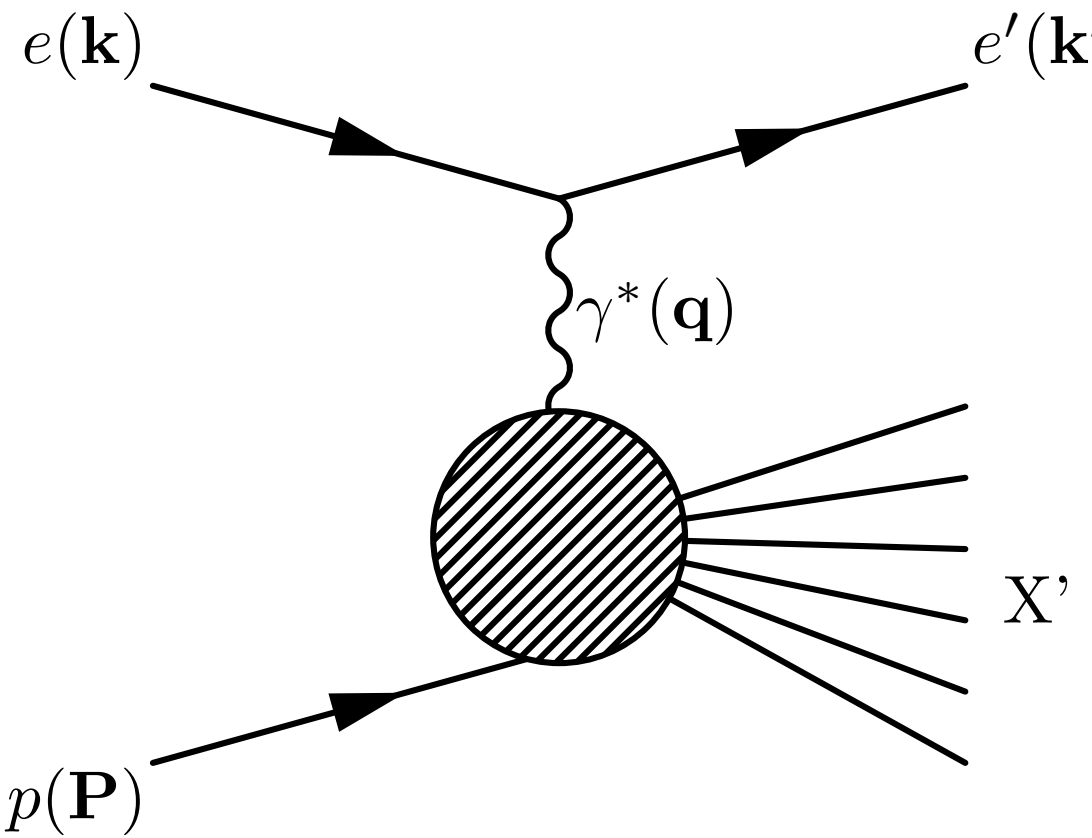


DESY, Hamburg
1992-2007



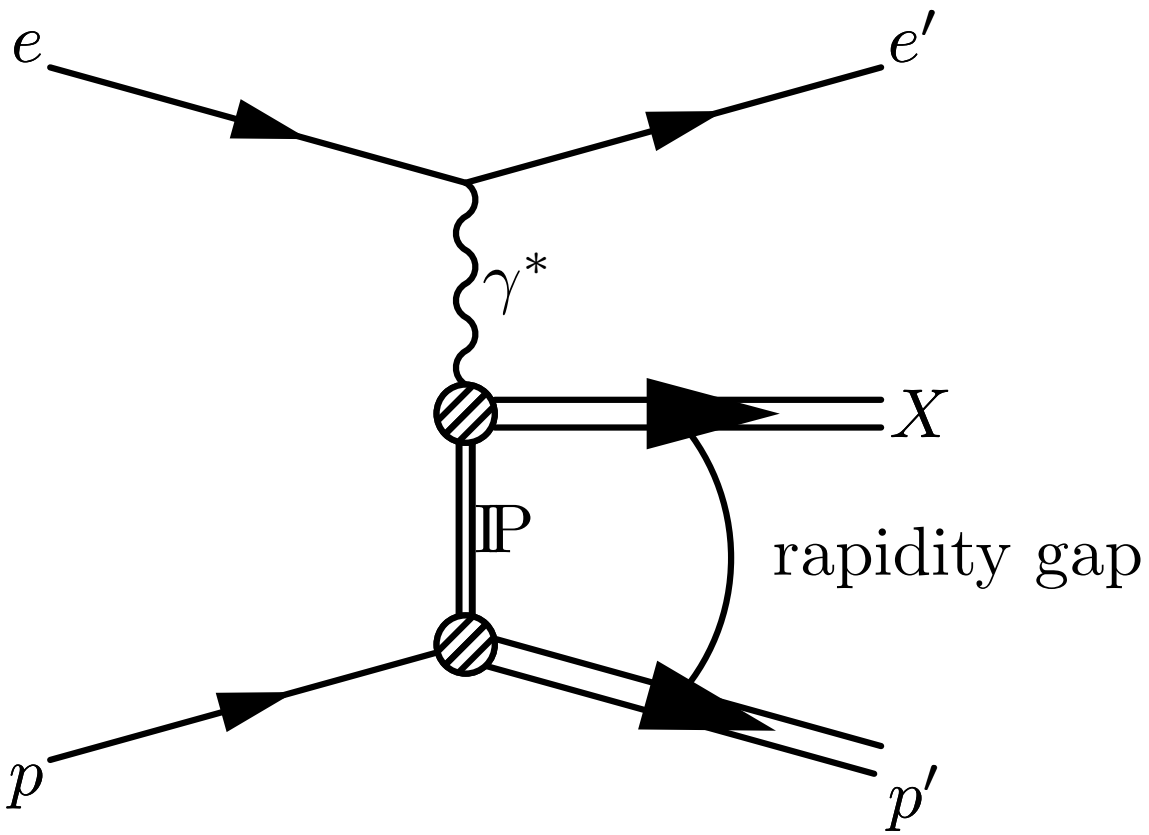
$$\int L dt = 0.5 \text{ fb}^{-1}$$
per experiment

NC Lepton-Proton Interaction



- $Q^2 = -(\mathbf{k} - \mathbf{k}')^2$
  virtuality of exchanged boson
  - $Q^2 \approx 0 \Rightarrow$ PHP
  - $Q^2 > 1$ GeV$^2 \Rightarrow$ DIS
- $y = \frac{\mathbf{P} \cdot \mathbf{q}}{\mathbf{P} \cdot \mathbf{k}}$
  inelasticity
- $W^2 = (\mathbf{P} + \mathbf{q})^2$
  photon-proton CME
- $s = (\mathbf{P} + \mathbf{k})^2$
  lepton-proton CME

Diffraction

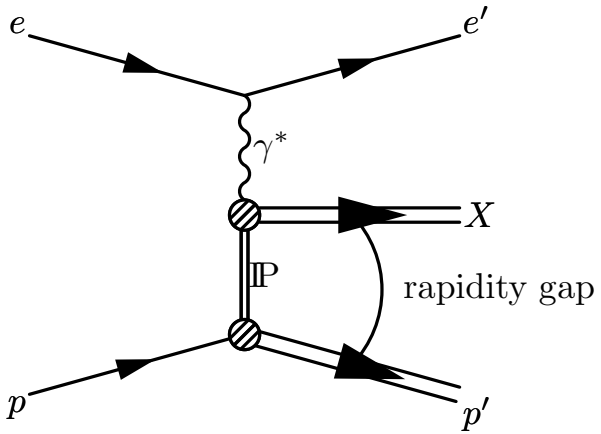


quantum numbers of:

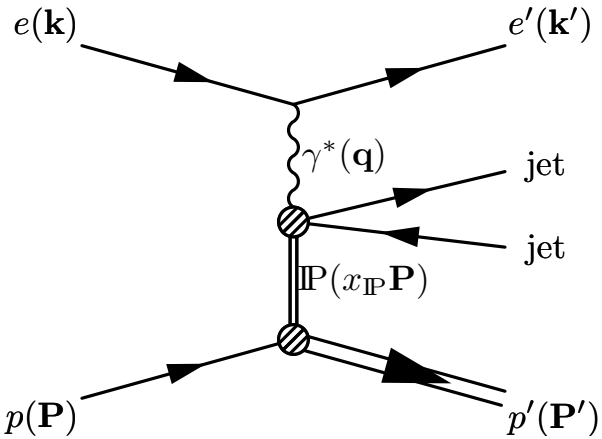
- γ^* and X are equal
- p and p' are equal

- $x_{\mathbb{P}}$ fraction of proton momentum carried by Pomeron
- $\beta = x/x_{\mathbb{P}}$ variable equivalent to the Bjorken x, but relative to the pomeron momentum

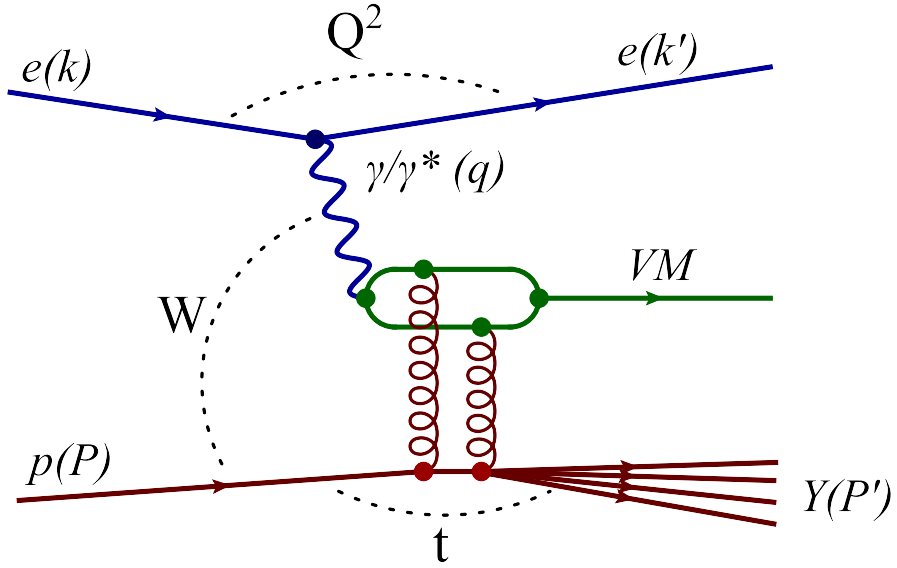
Outline



Inclusive Diffraction in DIS

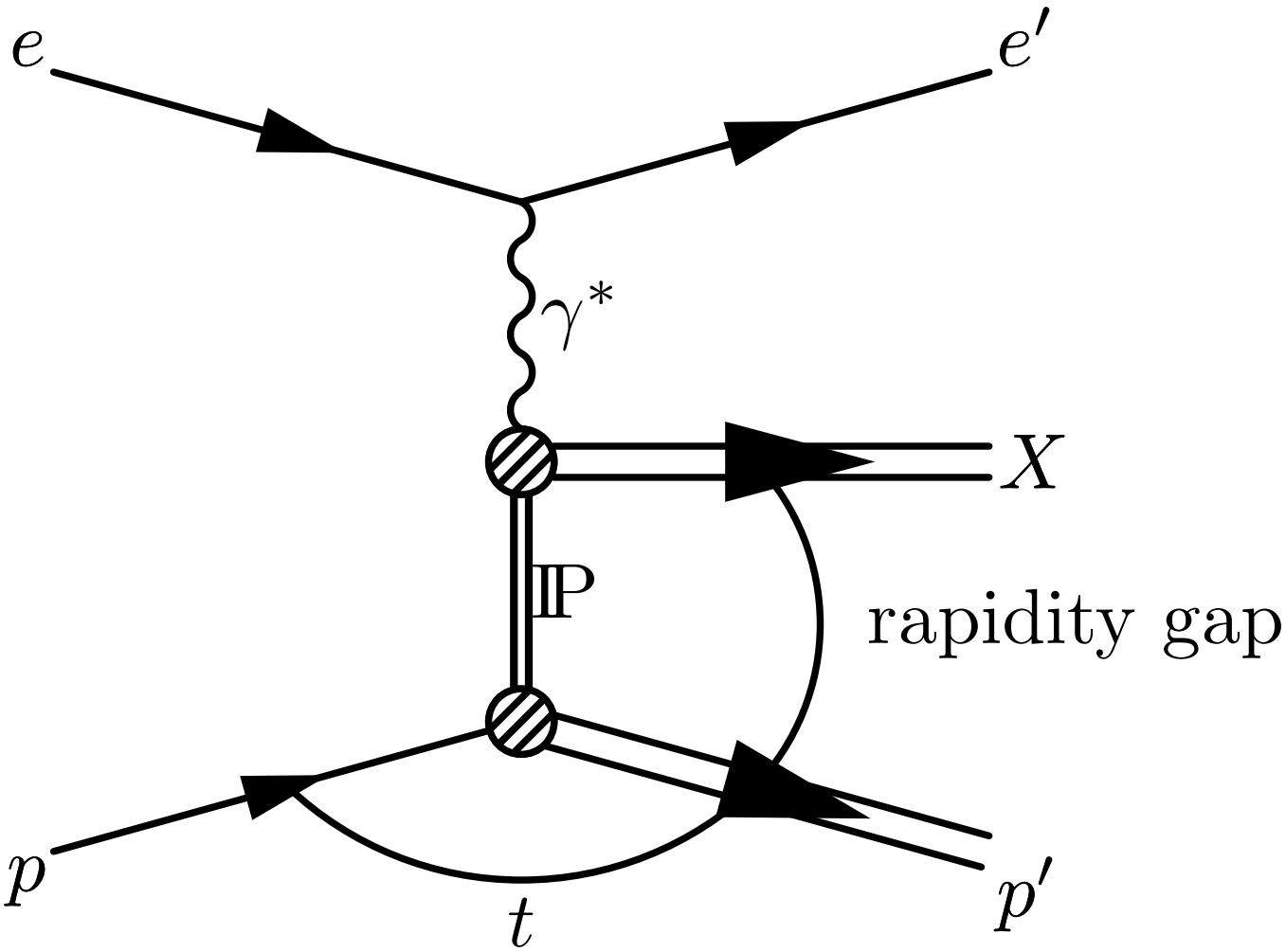


Exclusive Diffractive Dijet Production in DIS



Diffractive Vector Meson Production in PHP

Inclusive Diffraction



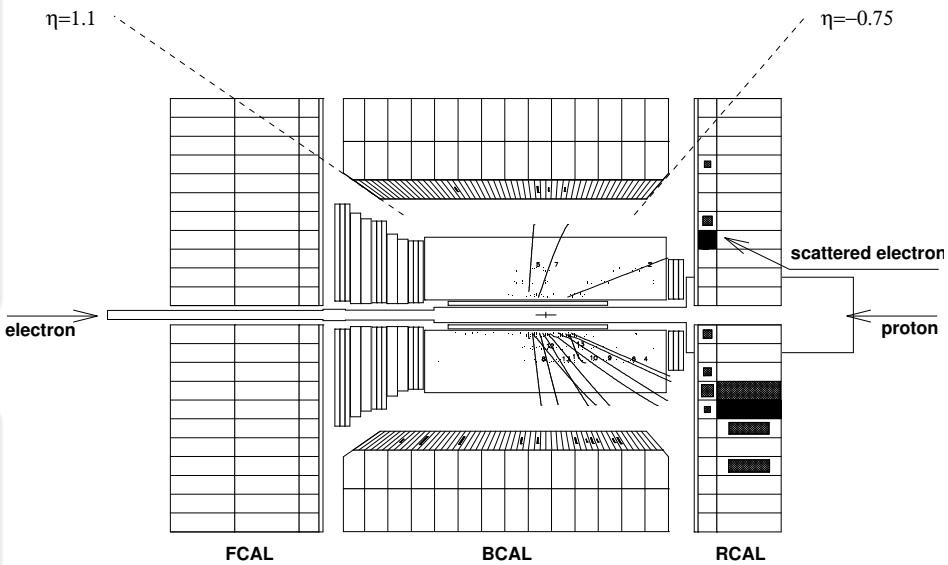
Diffractive Selection

Proton Spectrometer

- clean measurement - no double dissociative background
- low statistics

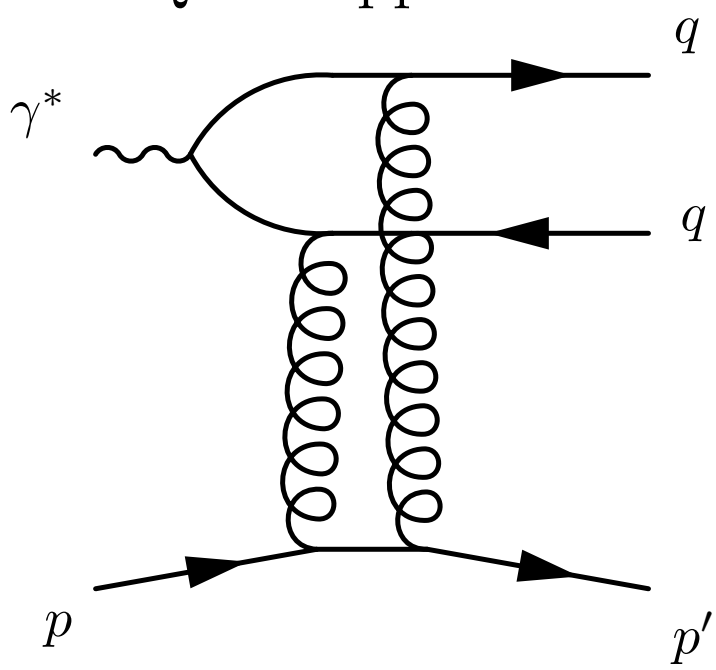
Large Rapidity Gap

- high statistics
- contains double dissociative background



Factorisation

QCD Approach



colour singlet gluon system is exchanged

QCD Factorisation

$$\sigma^D(\gamma^* p \to Xp) \sim$$
$$f_i^D(x, Q^2, x_{\mathbb{P}}, t) \times \sigma_{\gamma^* i}(x, Q^2)$$
$$\Downarrow$$

universal diffractive parton densities

Proton Vertex Factorisation

$$f_i^D(x, Q^2, x_{\mathbb{P}}, t) \sim$$
$$f_{\mathbb{P}/p}(x_{\mathbb{P}}, t) \times \quad f_{i/\mathbb{P}}^D(x/x_{\mathbb{P}}, Q^2)$$
$$\| \qquad\qquad\qquad \|$$

pomeron flux — pomeron parton densities

$$\frac{d^4\sigma^{ep\to e'Xp'}}{d\beta dQ^2 dx_{\mathbb{P}} dt} = \frac{2\pi\alpha^2}{\beta Q^4} y_+ \left[F_2^{D(4)}(\beta, Q^2, x_{\mathbb{P}}, t) - \frac{y^2}{y_+} F_L^{D(4)}(\beta, Q^2, x_{\mathbb{P}}, t) \right]$$
$$\|$$
$$\sigma_r^{D(4)}(\beta, Q^2, x_{\mathbb{P}}, t)$$

HERA Combined Cross Sections

Eur. Phys. J. C72 (2012) 2175

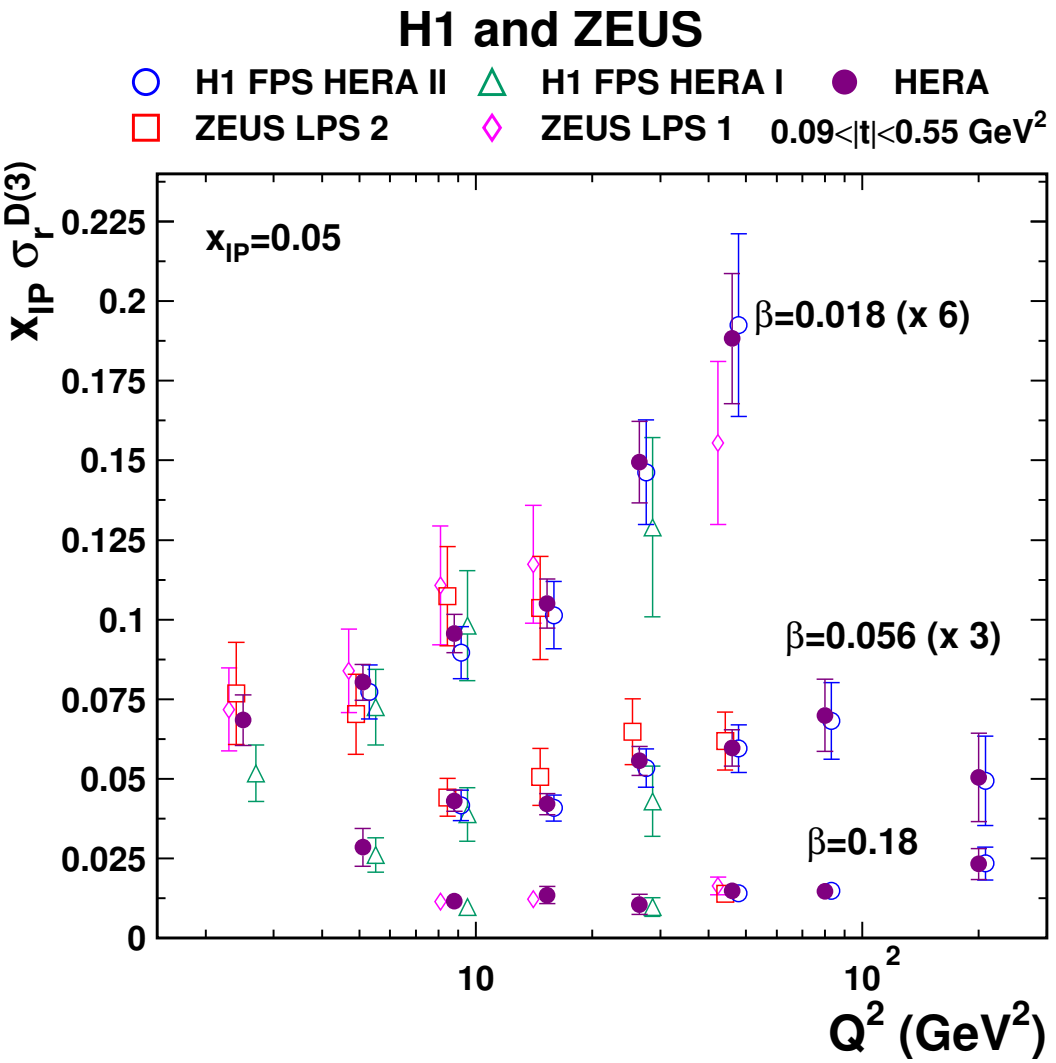
$$
\begin{aligned}
2.5 \leq \quad & Q^2 \quad \leq 200\ \mathrm{GeV}^2, \\
0.0018 \leq \quad & \beta \quad \leq 0.816, \\
0.00035 \leq \quad & x_{\mathbb{P}} \quad \leq 0.09, \\
0.09 < \quad & |t| \quad < 0.55\ \mathrm{GeV}^2
\end{aligned}
$$

ZEUS

- EPJ C38, 43 (2004)
- Nucl. Phys. B816, 1 (2009)

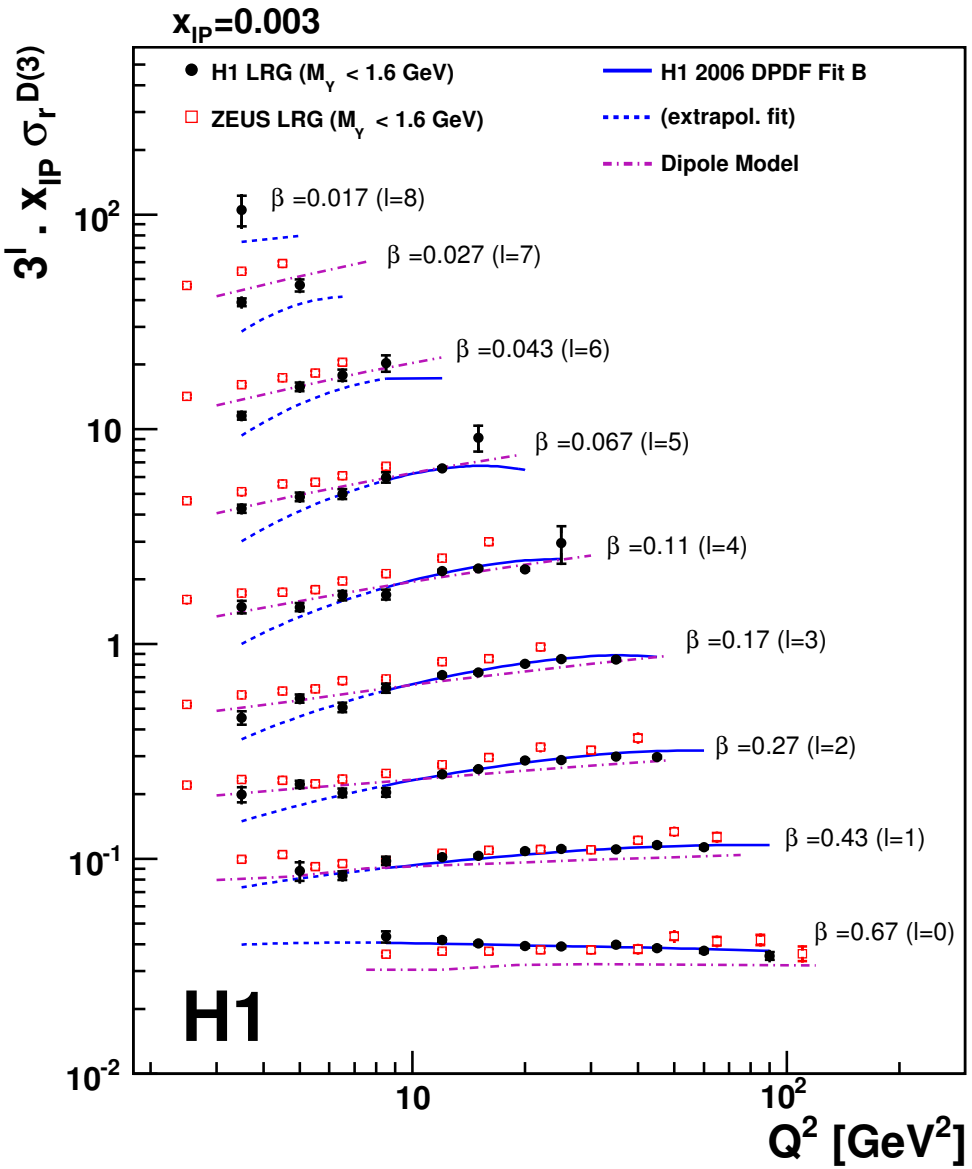
H1

- EPJ C48, 749 (2006)
- EPJ C71, 1578 (2011)

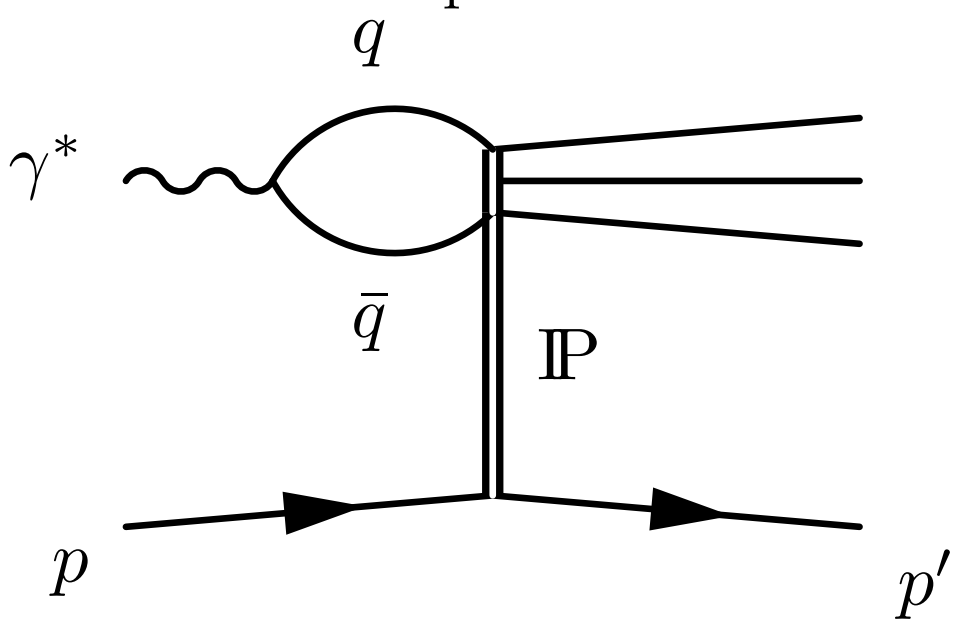


Inclusive Diffractive DIS at HERA

EPJ C72 (2012) 2074



Color Dipole Model



- DPDF calculations describe data at $Q^2 > 10$ GeV^2
- the dipole model is better at low Q^2

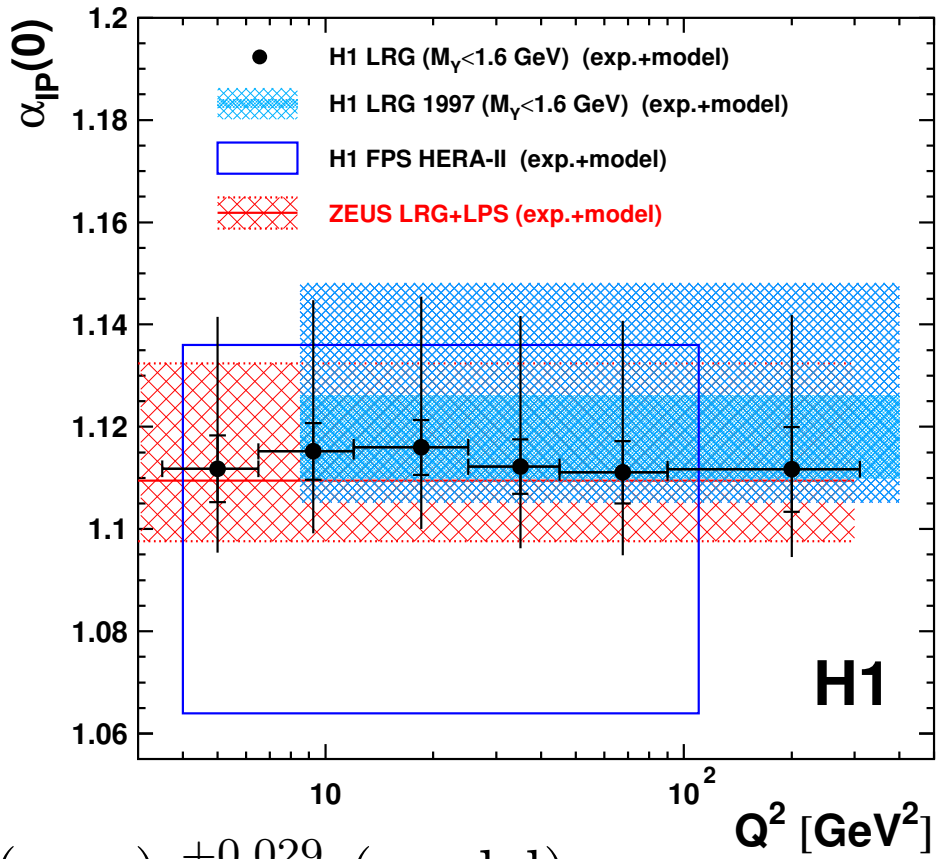
Inclusive Diffractive DIS at HERA

EPJ C72 (2012) 2074

$$F_2^{D(3)}(Q^2,\beta,x_{I\!P}) = f_{I\!P/p}(x_{I\!P})\ F_2^{I\!P}(Q^2,\beta) + n_{I\!R}\ f_{I\!R/p}(x_{I\!P})F_2^{I\!R}(Q^2,\beta)$$

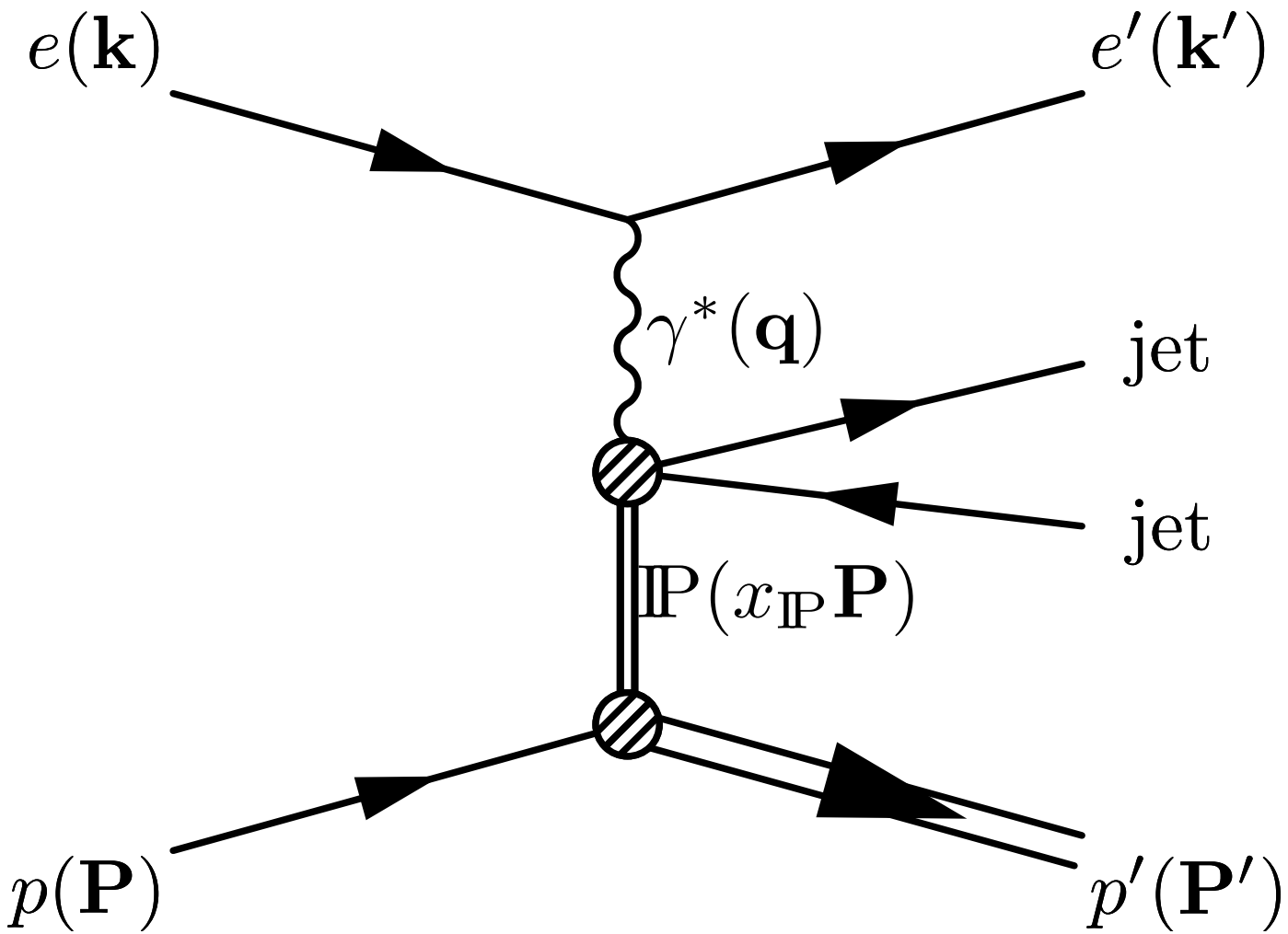
$$f_{I\!P/p}(x_{I\!P}) = \int_{t_{cut}}^{t_{min}} \frac{e^{B_{I\!P}t}}{x_{I\!P}^{2\alpha_{I\!P}(t)-1}}\,dt$$

- no Q^2 dependence supports the proton vertex factorisation hypothesis



$$\alpha_{I\!P}(0) = 1.113\ \pm 0.002\ (\text{exp.})\ ^{+0.029}_{-0.015}\ (\text{model})$$

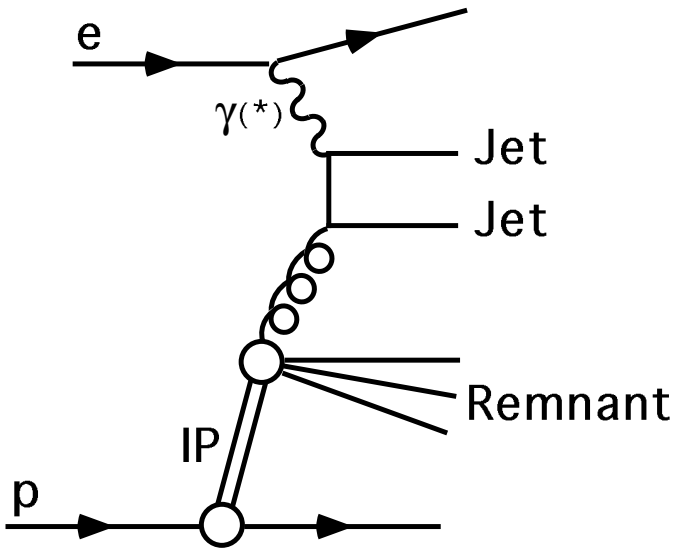
Exclusive Diffractive Dijets in DIS



Exclusive Diffractive Dijets in DIS

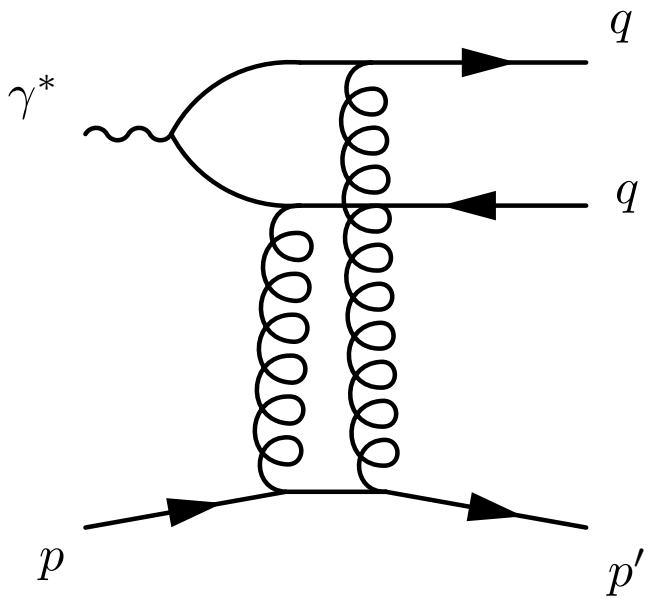
ZEUS-prel-14-004

BGF



- requires diffractive parton density functions

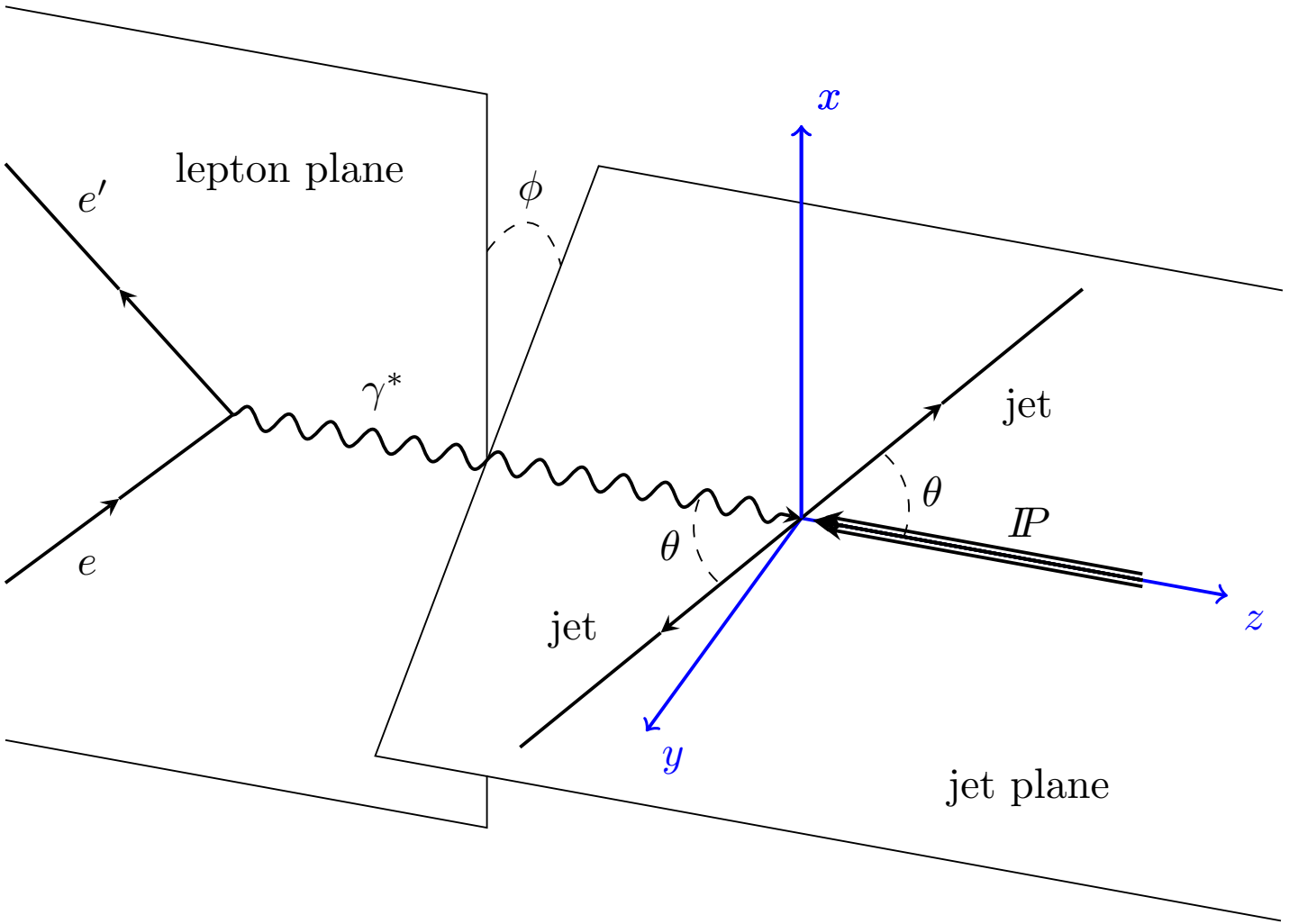
2-gluon exchange



- pure QCD calculations

Exclusive Diffractive Dijets in DIS

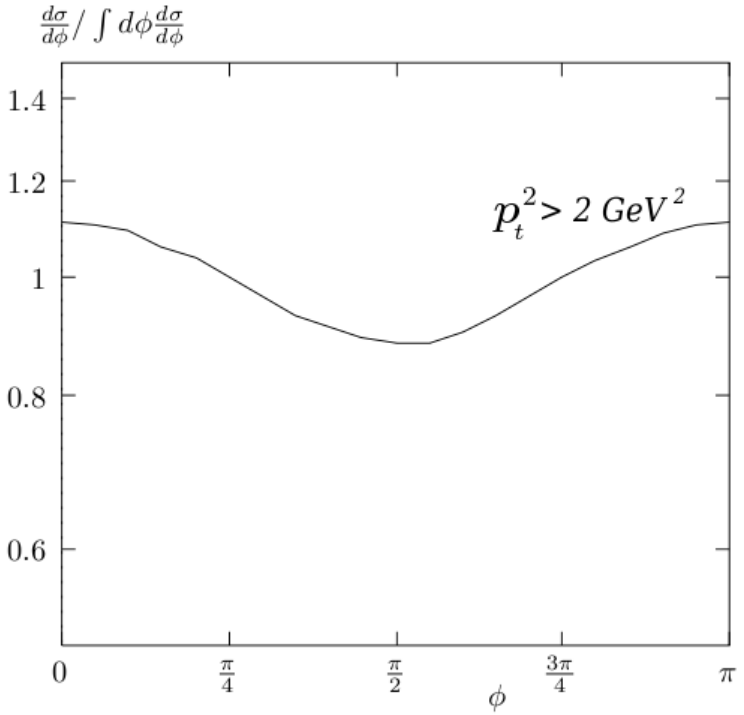
ZEUS-prel-14-004



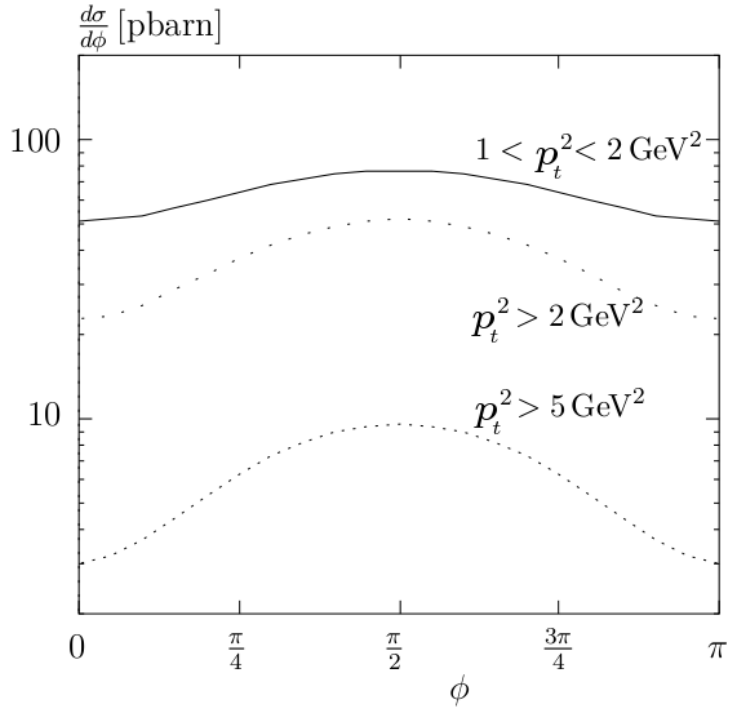
Exclusive Diffractive Dijets in DIS

ZEUS-prel-14-004

BGF



2-gluon exchange

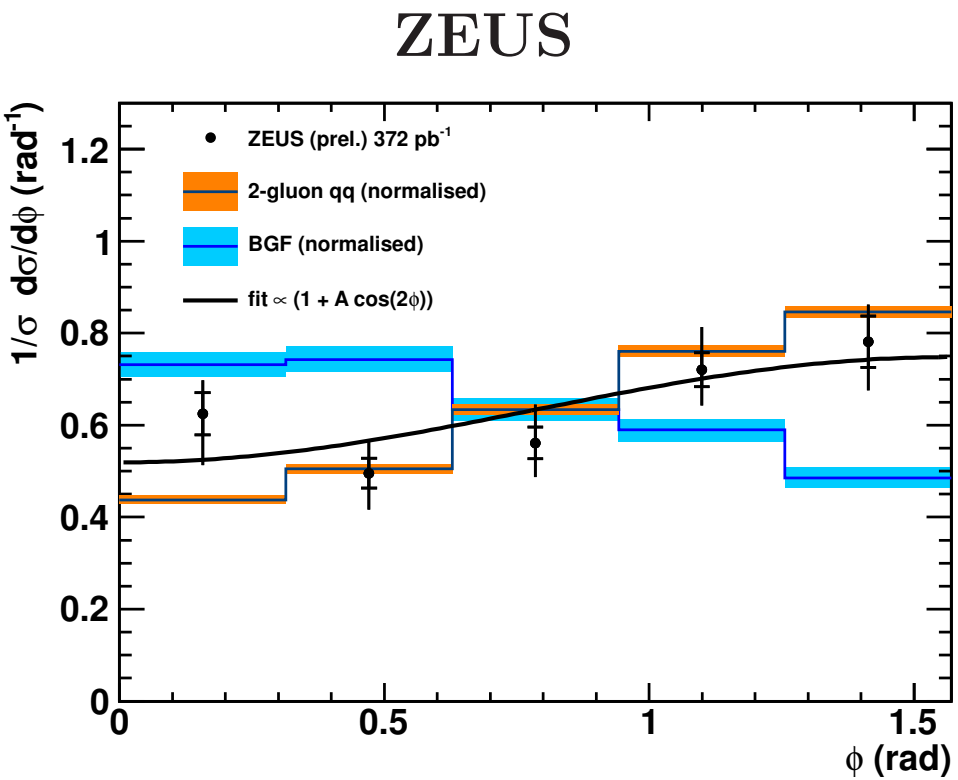


$$d\sigma/d\phi \propto 1 + A\cos(2\phi)$$

- $d\sigma/d\phi$ described by the same function in both mechanisms
- two-gluon exchange mechanism predicts negative A
- boson-gluon fusion mechanism predicts positive A

Exclusive Diffractive Dijets in DIS

ZEUS-prel-14-004

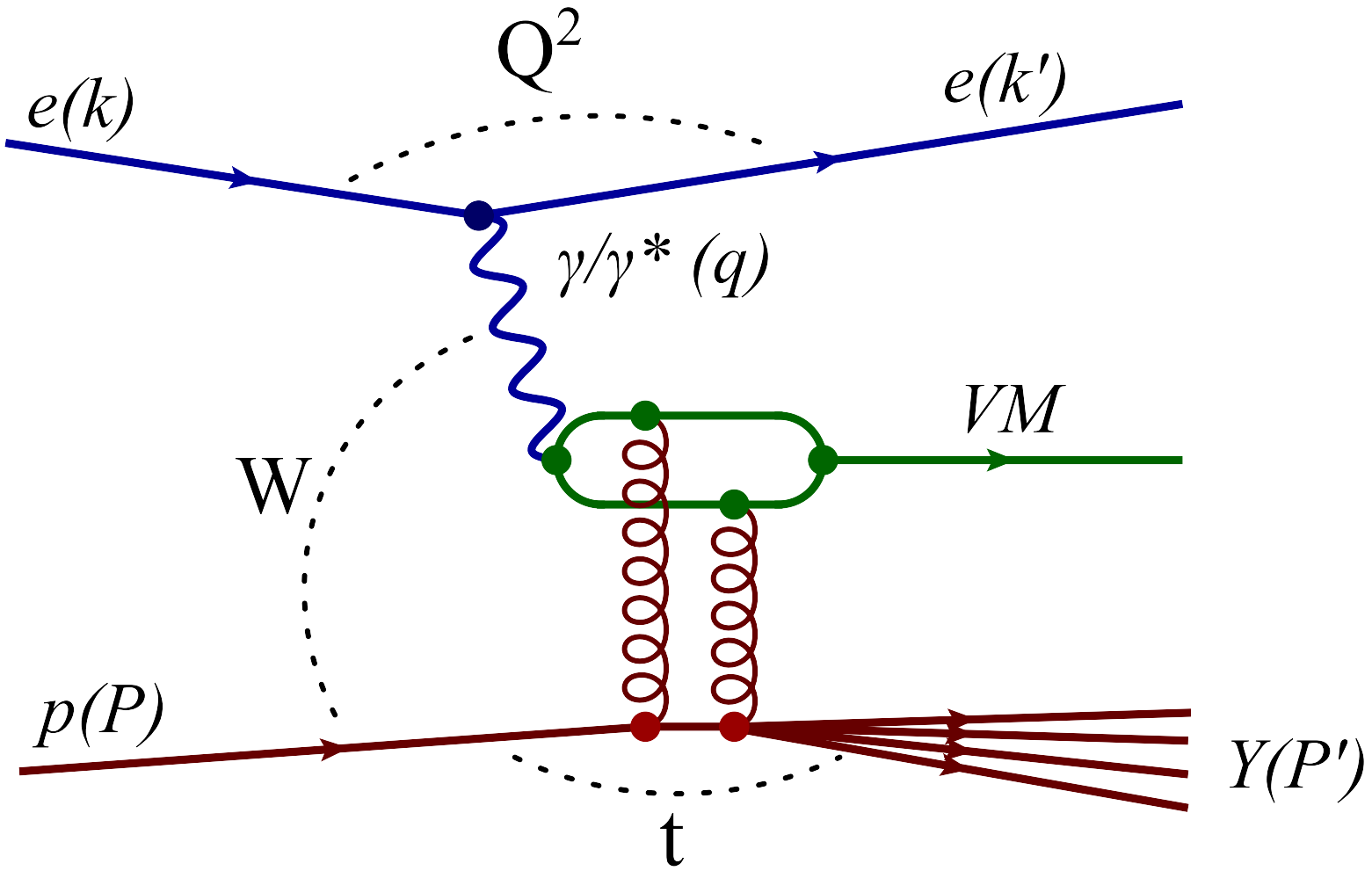


A	χ^2/NDF
$-0.18 \pm 0.06(\text{stat.})^{+0.06}_{-0.09}(\text{sys.})$	4.11/3

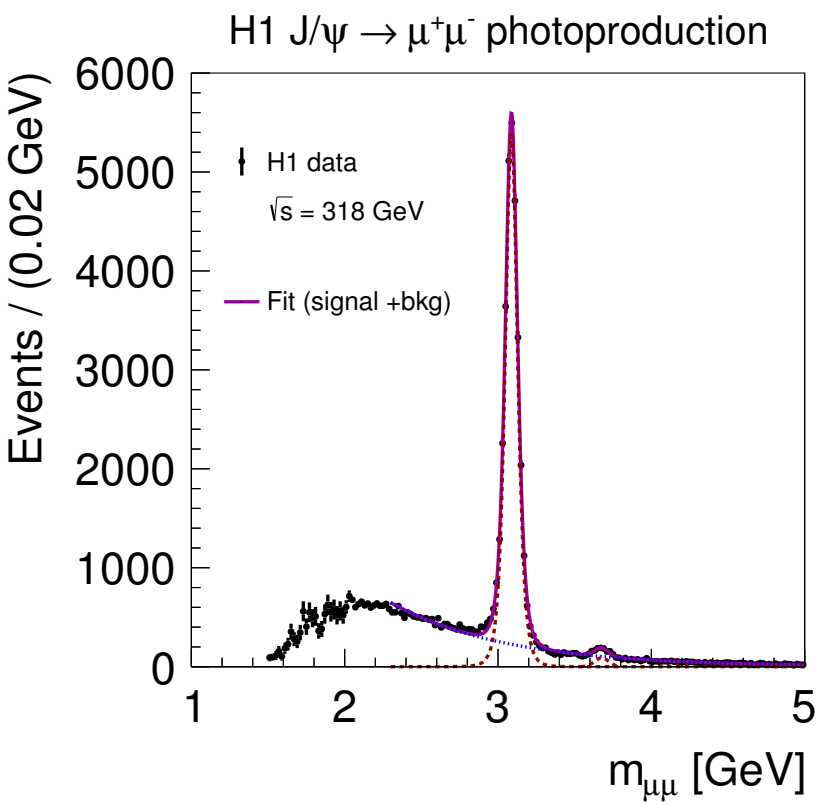
$$d\sigma \propto 1 + A\cos(2\phi)$$

negative A factor

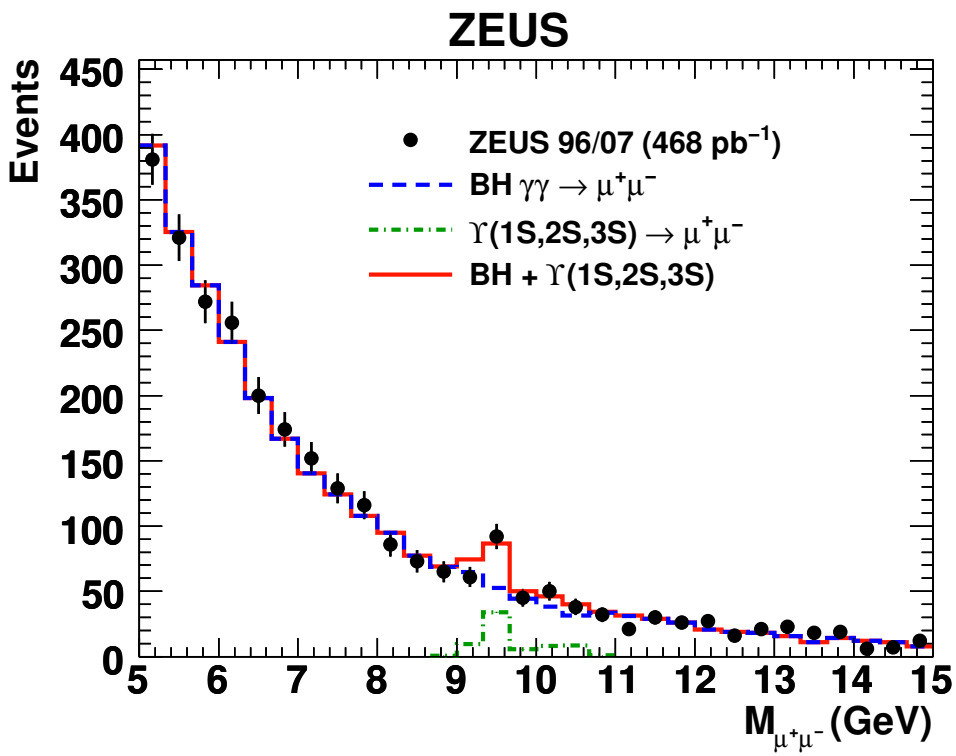
Diffractive Vector Meson Production



Diffractive Vector Meson Production



Eur. Phys. J. C73 (2013) 2466



Phys. Lett. B 708 (2012) 14

J/ψ Photoproduction

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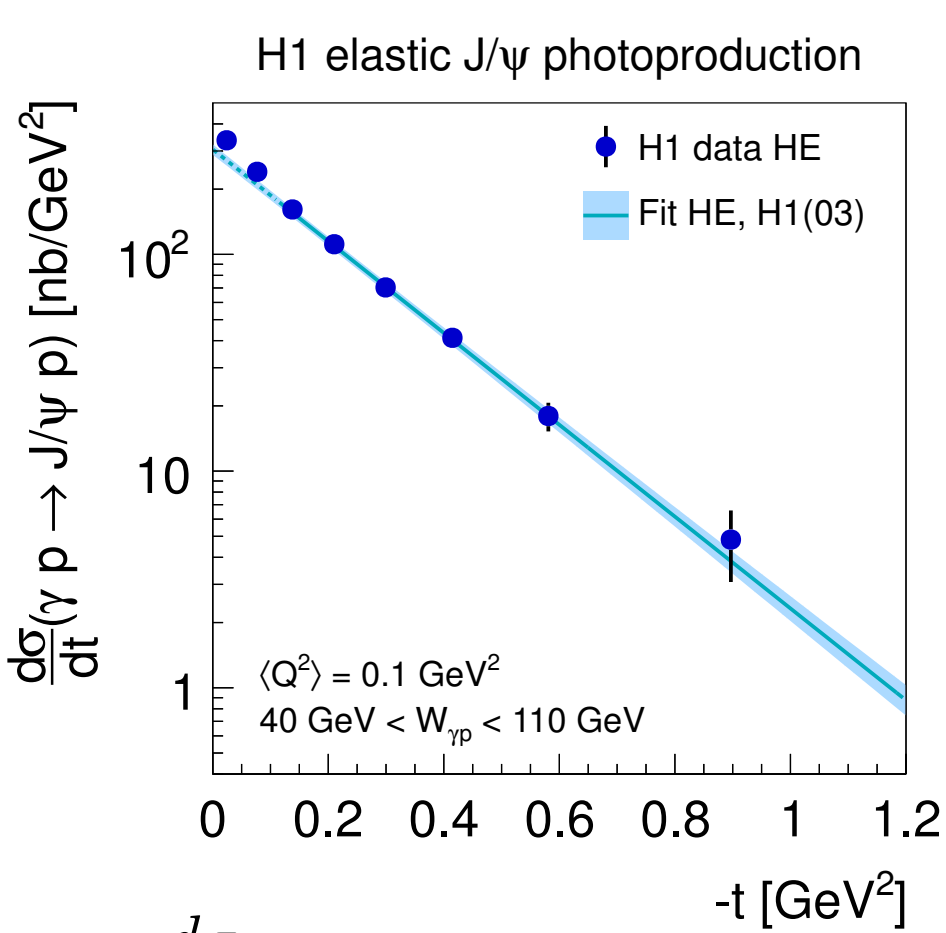
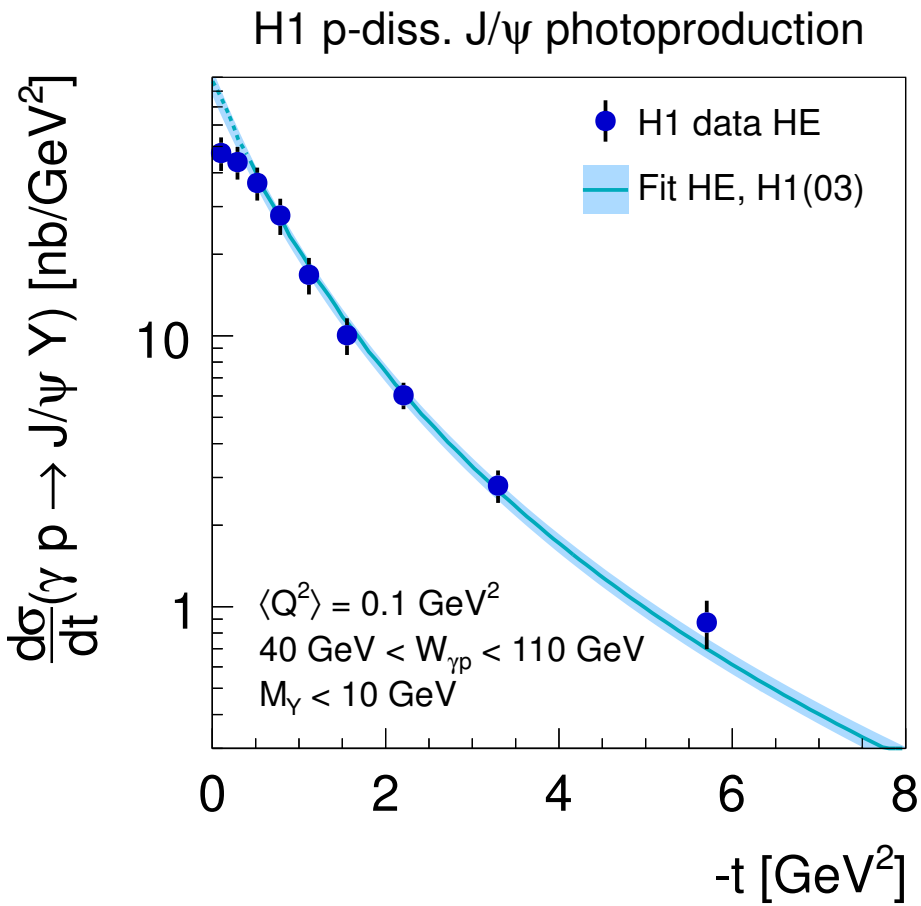


$$\frac{d\sigma_{el}}{dt} = N_{el}\exp(-b_{el}|t|)$$

$$b_{el} = (4.88 \pm 0.15)\mathrm{GeV}^{-2}$$



$$\frac{d\sigma_{pd}}{dt} = N_{pd}(1 + b_{pd}|t|/n)^{-n}$$

$$b_{pd} = (1.79 \pm 0.12)\mathrm{GeV}^{-2}$$

J/ψ Photoproduction

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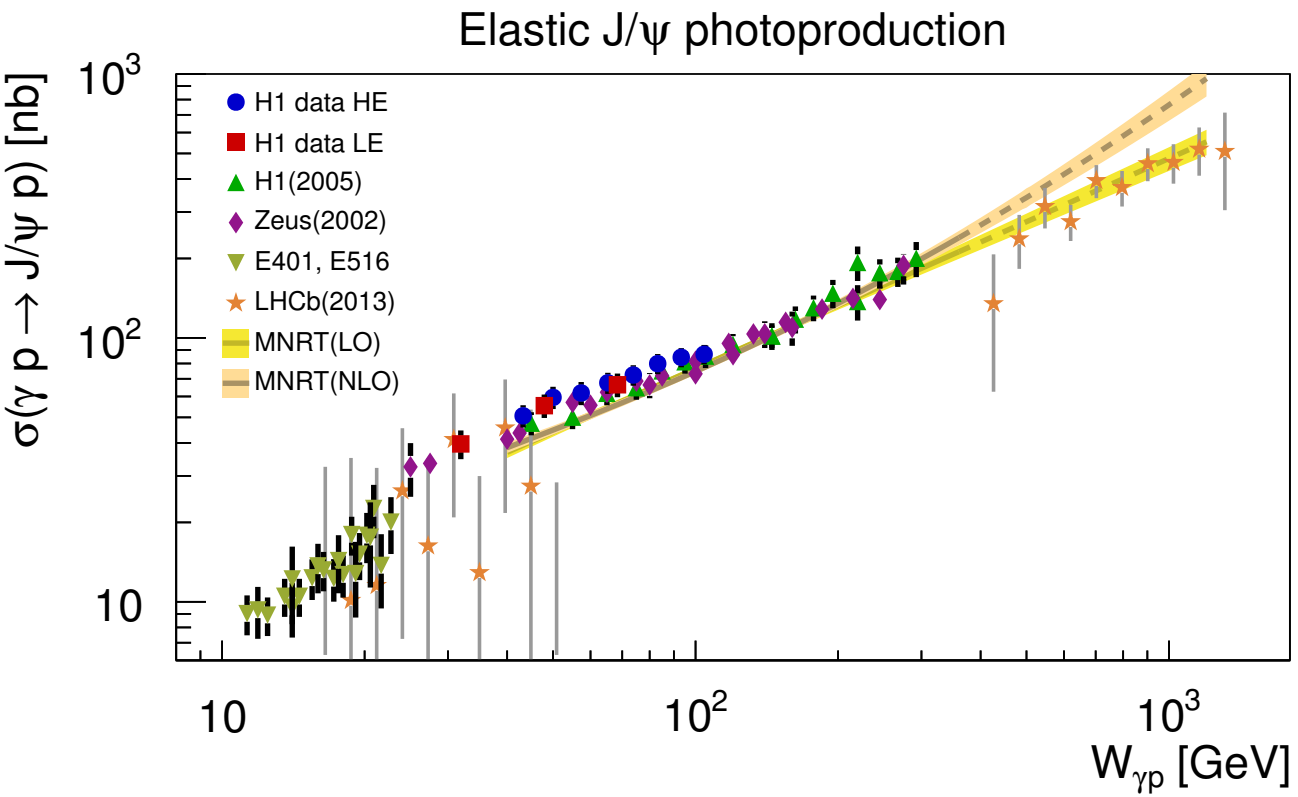
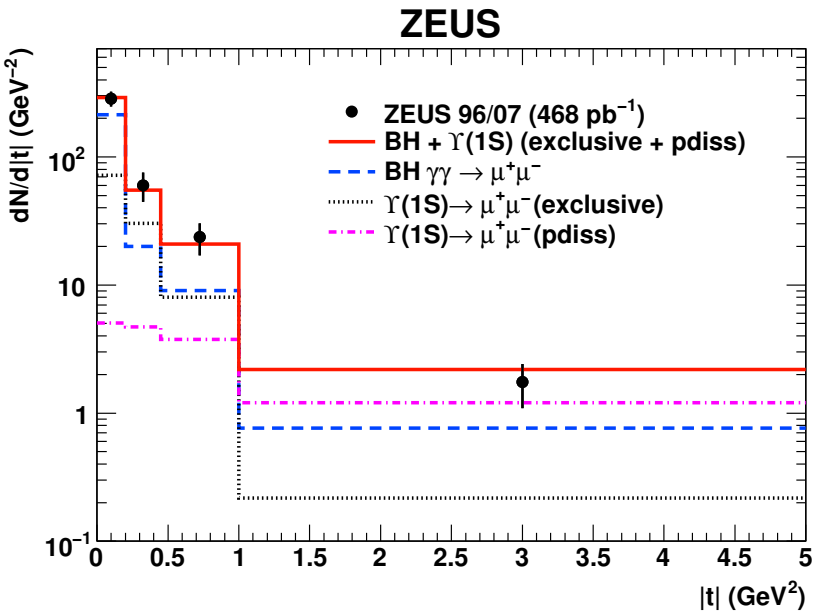
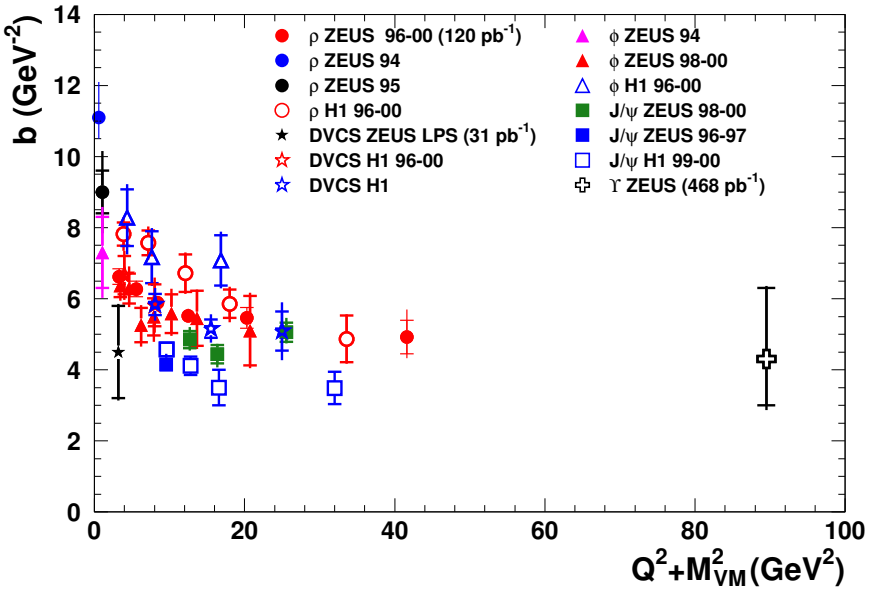


- LO fits describe all (including LHCb) data well
- NLO fits overestimate LHCb data

Upsilon (1S) Exclusive Photoproduction

Phys. Lett. B 708 (2012) 14





$$b = 4.3^{+2.0}_{-1.3}(stat.)^{+0.5}_{-0.6}(syst.)\mathrm{GeV}^{-2}$$

- first determination of $\Upsilon(1S)$ $|t|$ slope
- $|t|$ slope measurement extended to $Q^2 + M^2_{VM} \approx 90$ GeV^2

Summary

- Inclusive Diffraction in DIS
  - H1 and ZEUS result combination provide unprecedented precision
  - measurements support proton vertex factorisation
- Exclusive Diffractive Dijet Production in DIS
  - the first measurement of the jet azimuthal angular distribution in $e^{\pm}p$ interactions
  - data favour 2-gluon exchange model
- Vector Meson Production
  - elastic and proton dissociative t slopes measured in J/Ψ production
  - the first measurement of Υ (1S) t slope

Thank You for Your Attention!