Measurement of Diffractive Scattering of Photons with Large Momentum Transfer at HERA

results recently published in
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On behalf of the H1 Collaboration

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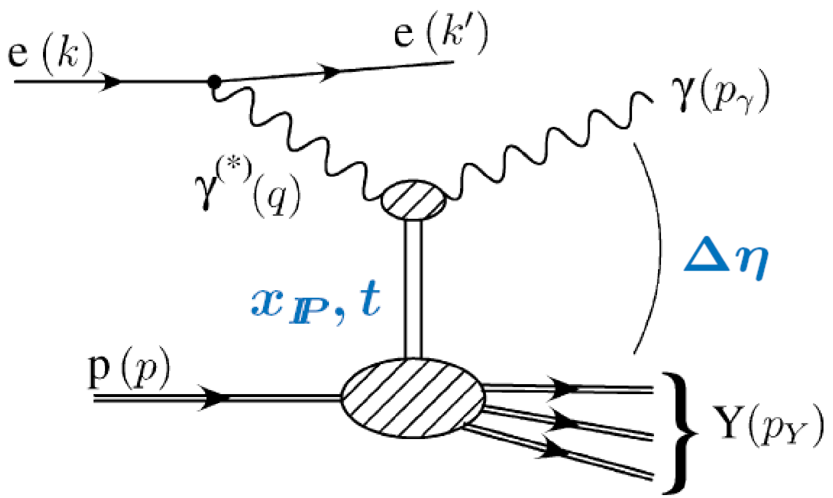
Introduction $e^+p \to e^+\gamma Y$

$$E_e = 27.6 \text{ GeV} \rightarrow\leftarrow E_p = 920 \text{ GeV}$$
$$\sqrt{s} \simeq 319 \text{ GeV}$$



scattering process is described by the usual DIS kinematic variables:

$$Q^2 = -q^2 = -(k' - k)^2$$

$$W^2 = (q + p)^2$$

in addition the diffractive kinematics:

$$x_{I\!P} = \frac{q\cdot(p - p_Y)}{q\cdot p} \qquad t = (q - p_X)^2$$

$$y_{I\!P} = \frac{p\cdot(q - p_X)}{p\cdot q} \approx e^{-\Delta\eta}$$

Kinematic domain:

	Q^2	$< 0.01 \text{ GeV}^2$
$175 <$	W	$< 247 \text{ GeV}$
$4 <$	$\lvert t\rvert$	$< 36 \text{ GeV}^2$
	$y_{I\!P}$	< 0.05

- process is an extension of Deeply Virtual Compton Scattering at large $|t|$ and small Q^2
- complements measurements of vector mesons at large $|t|$ $\rho,\ \phi,\ J/\psi$

Introduction $\gamma p \rightarrow \gamma Y$

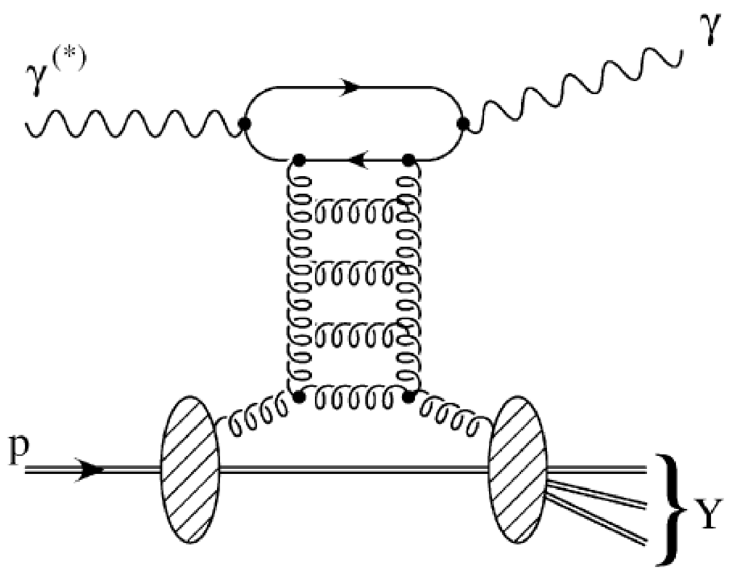
- hard scale *t* is present at photon and proton vertices

- γp interaction: via the photon fluctuation into $q\bar{q}$ pair

- the p_T of the scattered photon is balanced by the struck parton in the proton

$$\Delta\eta \simeq \log(\hat{s}/p_T^2)$$

- no strong ordering in k_T, but strong ordering in 1/x: process expected to be described by the BFKL approach



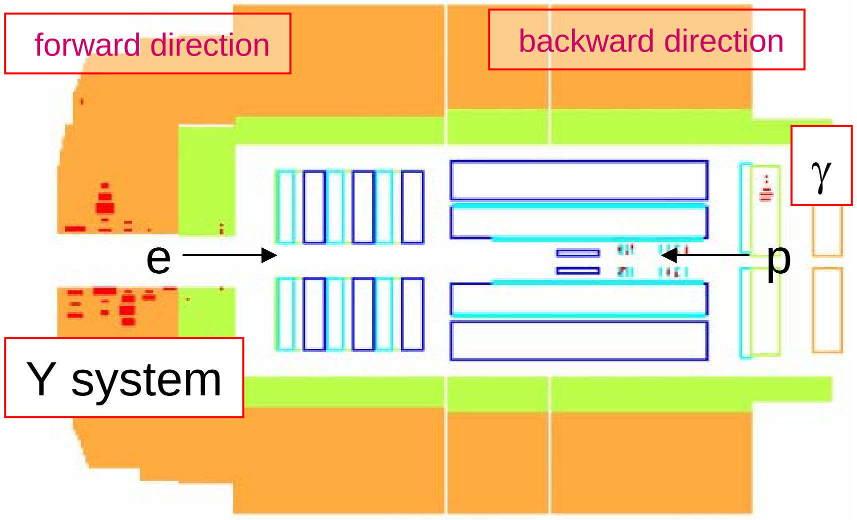
- the only non-perturbative part of the calculation: PDFs

- in the LLA approx., the exchanged colour singlet is modelled by the effective exchange of a gluon ladder

- this BFKL approach is implemented into MC

Data Selection

-analysed is 1999/2000 (HERA I) data period (integrated luminosity of 46.2pb^{-1})



$$e^+p \rightarrow e^+\gamma Y$$

$p_T^\gamma > 2$ GeV

e$^+$ in e-tagger limits Q^2, W to

$$Q^2 < 0.01 \text{ GeV}^2$$
$$175 < W < 247 \text{ GeV}$$

240 selected events

Kinematic Reconstruction

$$|t| = (p_T^\gamma)^2 \qquad W \simeq (1 - E_{e'}/E_e)s$$

$$x_{I\!P} \simeq \frac{(E+P_z)_\gamma}{2E_p} \qquad y_{I\!P} \simeq \frac{\Sigma_Y(E-P_z)}{2(E_e - E_{e'})}$$

Signal Simulation

HERWIG 6.4 using LLA BFKL *Cox and Forshaw, J.Phys.G26 (2000) 702*

- 2 free parameters: strong coupling α_s and scale c which defines the leading logarithms in the expansion of the BFKL amplitude

  for vector meson production $c = m_{VM}/2$
  in $\gamma p \to \gamma Y$ the scale is unknown – absence of normalisation prediction for σ

  $\alpha_s^{BFKL} = 0.17$ (running with scale is ignored at LLA)

- in the asymptotic approximation of the calculations:

$$\sigma(W) \sim W^{\delta} \qquad \delta = 4(3\alpha_s^{BFKL}/\pi)4\ln 2$$

$$d\sigma/d|t| \sim |t|^{-n}$$

- M_Y dependence given by the dynamics

Background Estimate

contribution to σ

Inclusive diffractive γp $ep \rightarrow eXY$
- PHOJET MC
- single em particle (π^0) mimicking the final state photon

3%

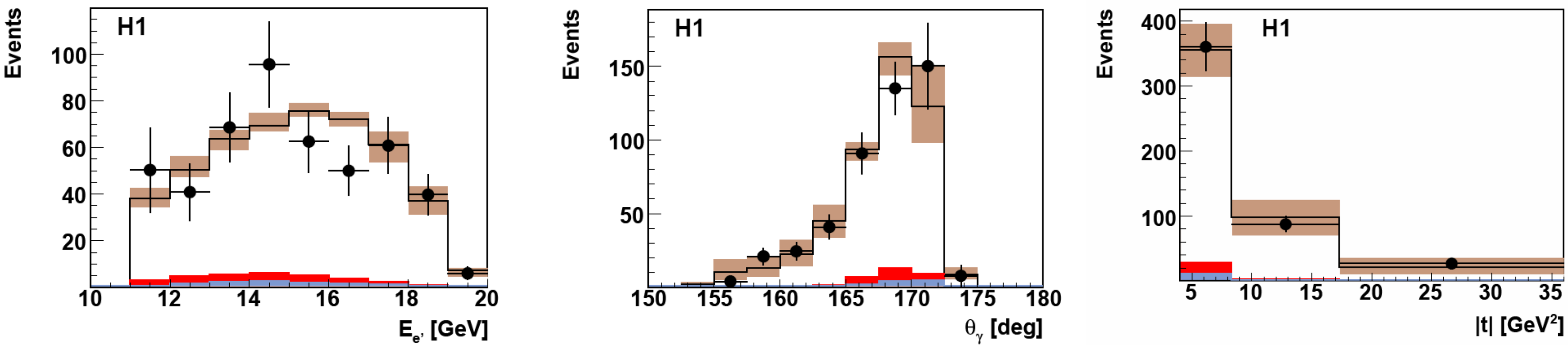
Dileptons $ep \rightarrow ee^+e^-X$
- elastic+inelastic channels (GRAPE MC)
- topology:
  1 lepton in electron tagger (mimic the scattered electron)
  1 lepton in backward calo (mimic the final state photon)
  1 lepton lost in the beam pipe

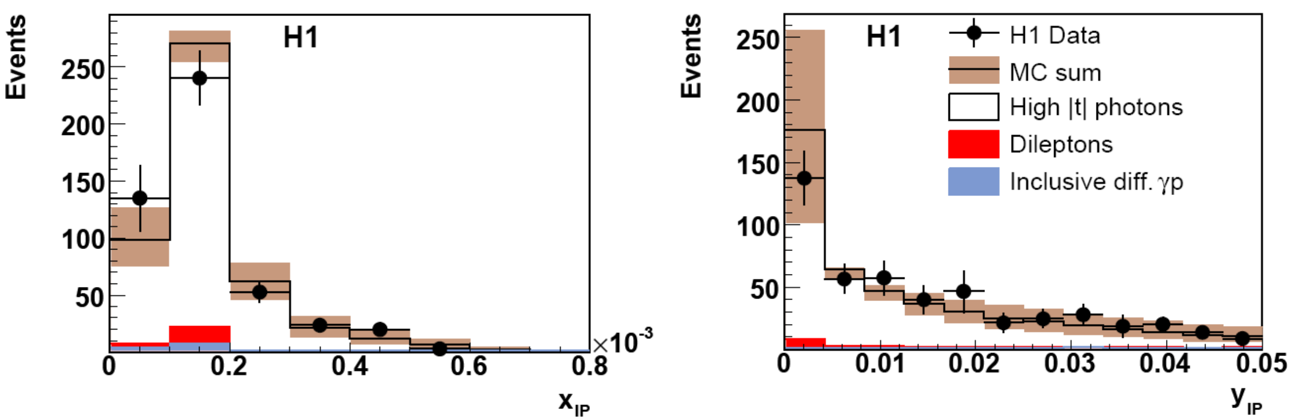
4%

ω^0 production
- elastic/proton-dissociation high |t| ω^0 production
($\pi^+ \pi^- \pi^0$ and $\pi^0 \gamma$ decays) found to be negligible (DIFFVM MC)

negligible

Control Plots





background is normalised to luminosity

signal MC normalised to number of events corrected for background

in order to describe data distribution for the acceptance correction:
t-slope reweighted by $t^{0.73}$

distributions are reasonably described by the sum of MC
(after the |t| reweight of HERWIG)

Systematic Errors

calculated using HERWIG signal MC

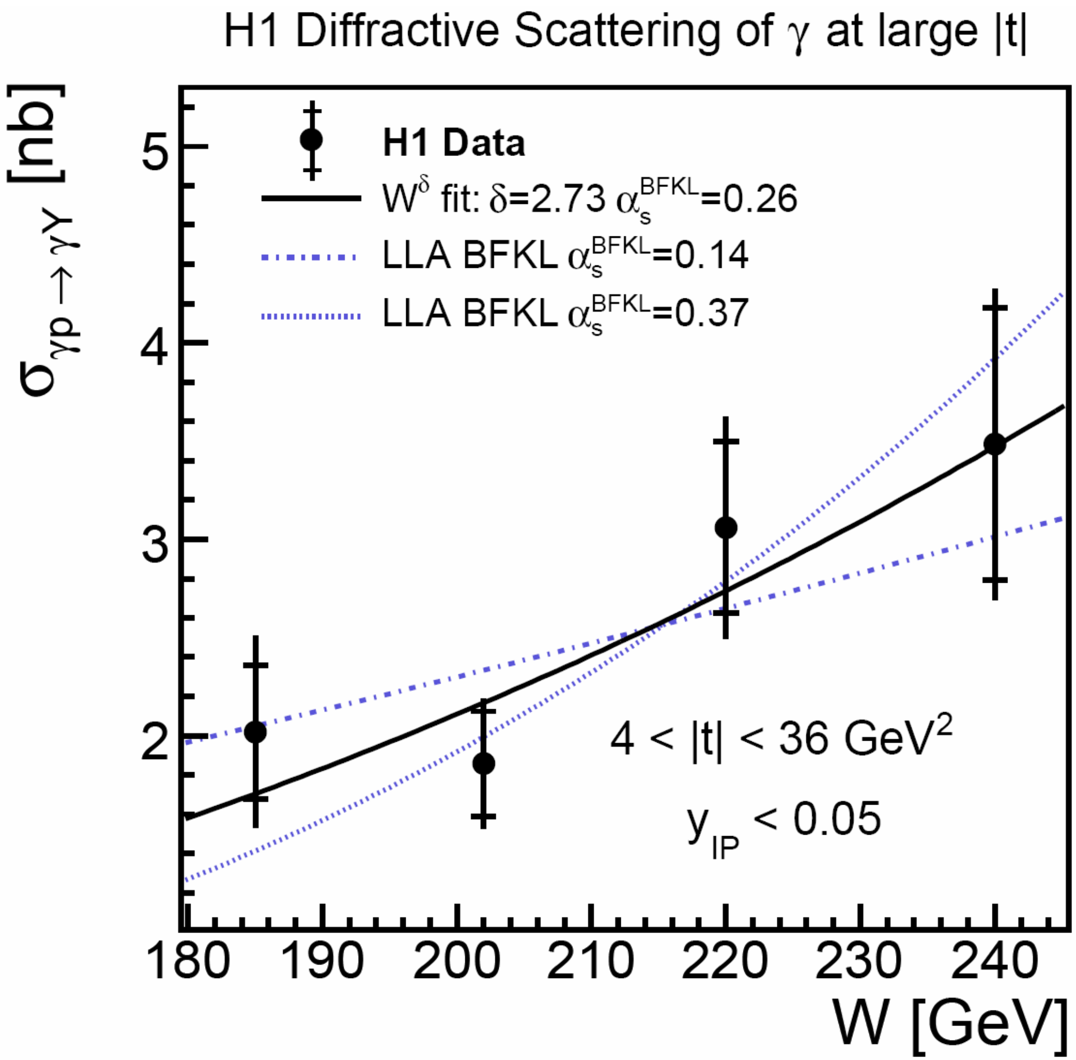
Experimental	Variation	Model Parameters	Variation
photon energy scale	$\pm 1\%$	$x_{I\!P}$ dependence	$(1/x_{I\!P})^{\pm 0.4}$
photon polar angle	± 2.5 mrad	$\|t\|$ dependence	$(1/\|t\|)^{\pm 0.2}$
HFS energy scale	$\pm 4\%$	M_Y dependence	$(1/M_Y^2)^{\pm 0.3}$
e-tagger energy scale	$\pm 1.5\%$	incl. diffr. γp contribution	100%
calo noise thresh.	$\pm 25\%$		
luminosity uncertainty	$\pm 1.5\%$		

Largest contributions: $x_{I\!P}$ slope / e-tagger energy (~10% for the *W* cross-section)

Other contributions < 5%

Systematic errors are smaller / comparable to statistical errors

γp Cross Section in W



LLA BFKL is normalised to integrated measured cross section

Fit: $\sigma \sim W^\delta$

$\boldsymbol{\delta = 2.73 \pm 1.02(\mathrm{stat})^{+0.56}_{-0.78}(\mathrm{syst})}$

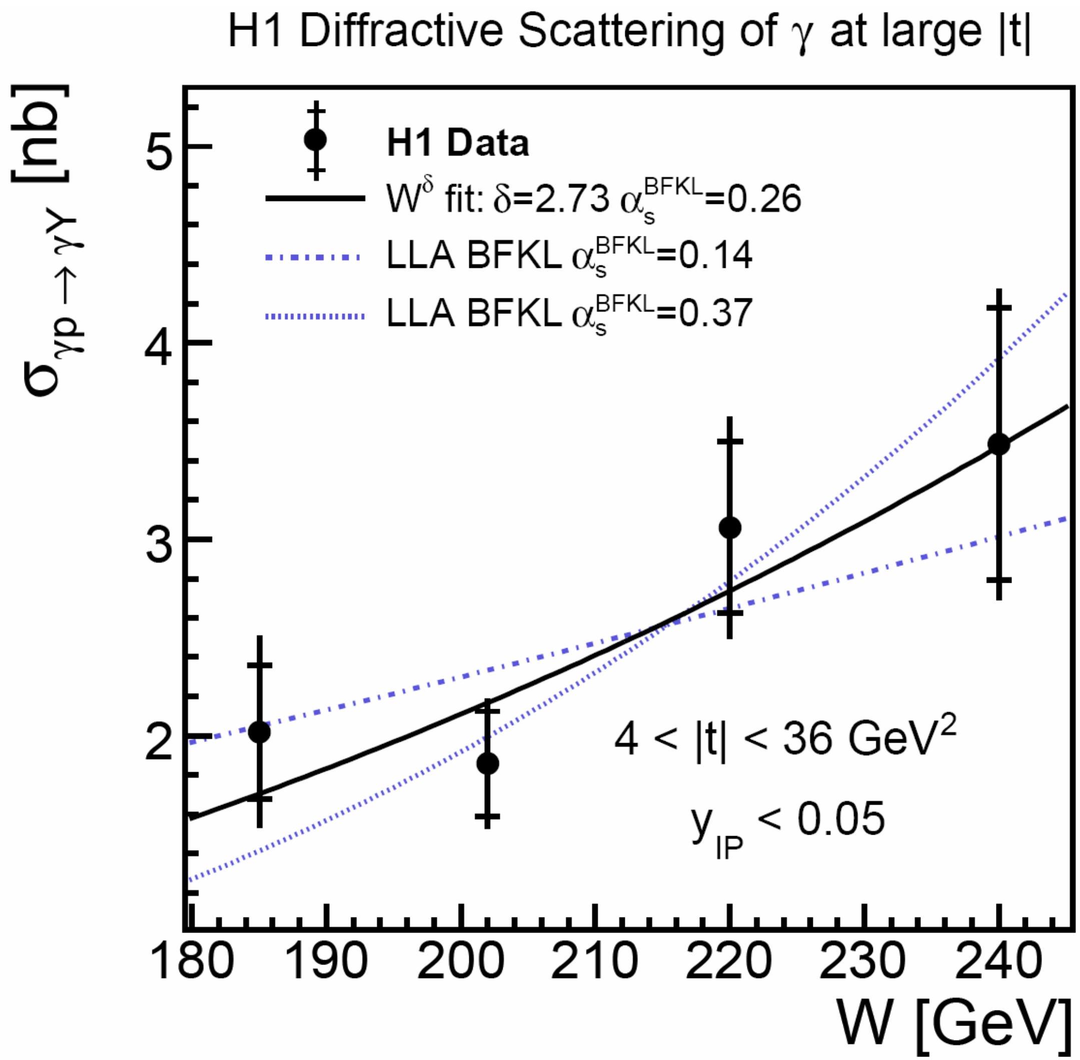
at $\langle |t| \rangle = \mathbf{6.1}\ \mathrm{GeV}^2$

- steep rise of σ with W:
hard subprocess in interaction

- δ compatible with J/ψ in photopr. at $\langle |t| \rangle = \mathbf{6.93}\ \mathrm{GeV}^2$

$\boldsymbol{\delta_{J/\psi} = 1.29 \pm 0.23(\mathrm{stat}) \pm 0.16(\mathrm{syst})}$

γp Cross Section in W



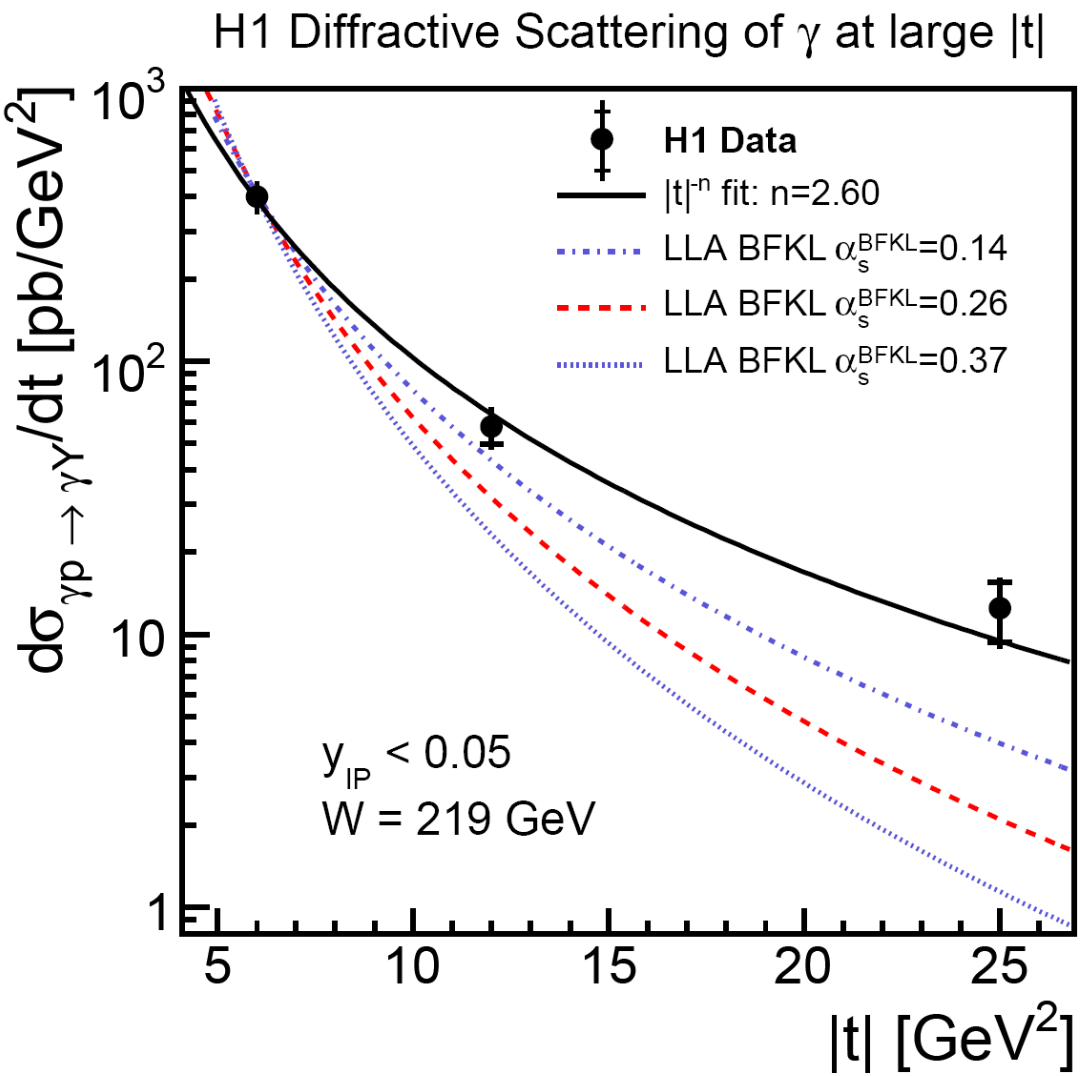
$$\delta = 4(3\alpha_s^{Fit}/\pi)4\ln 2$$

$$\alpha_s^{Fit} = 0.26 \pm 0.10(\text{stat})^{+0.05}_{-0.07}(\text{syst})$$

comparable with other measurements:

		$\langle\alpha_s^{BFKL}\rangle$
H1:2003	J/ψ at high $\|t\|$	0.18
H1:2006	ρ at high $\|t\|$	0.20
ZEUS:2003	ϕ at high $\|t\|$	0.20
ZEUS:2007	gaps between jets	0.11

γp Cross Section differential in |t|



LLA BFKL is normalised to the integrated measured cross section

Fit: $d\sigma/dt \sim |t|^{-n}$

$$n = 2.60 \pm 0.19(\text{stat})^{+0.03}_{-0.08}(\text{syst})$$

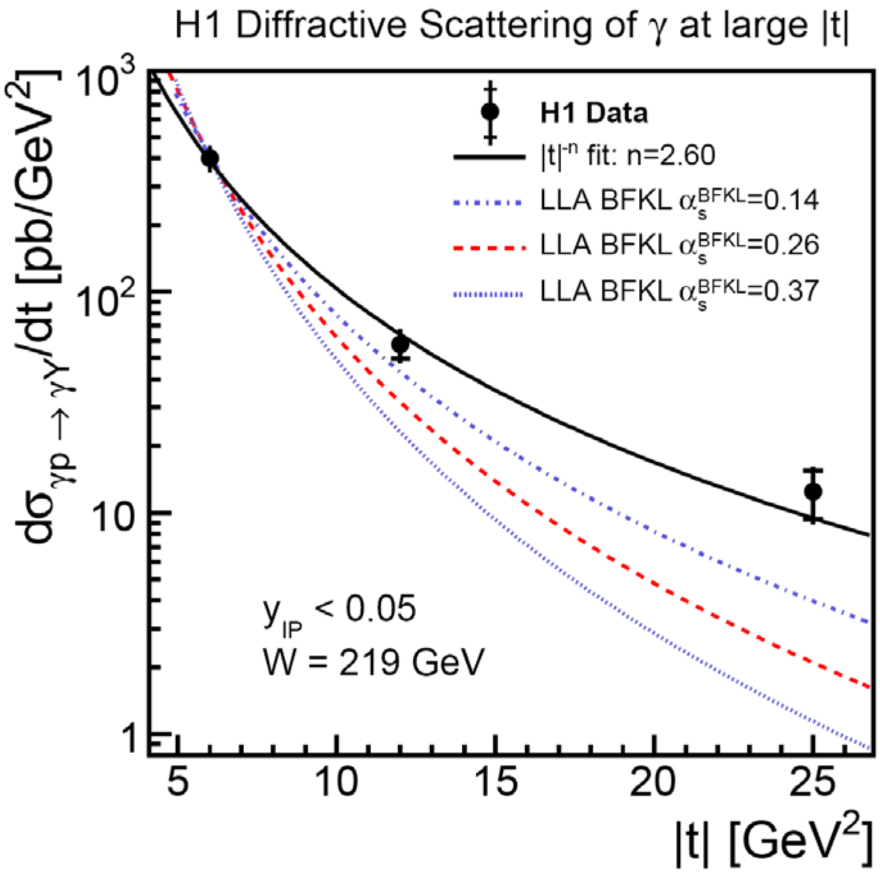
- harder |*t*| distribution than predicted by LLA BFKL

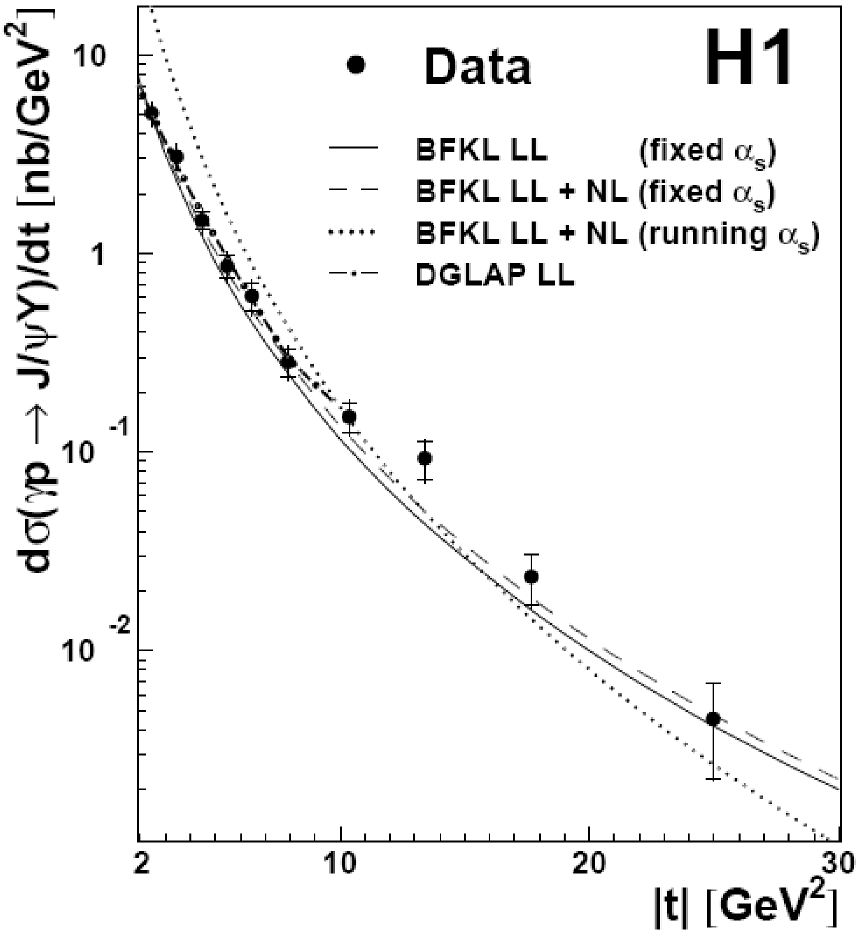
J/ψ measurement at high |*t*|

$$n_{J/\psi} = 3.78 \pm 0.17(\text{stat}) \pm 0.06(\text{syst})$$

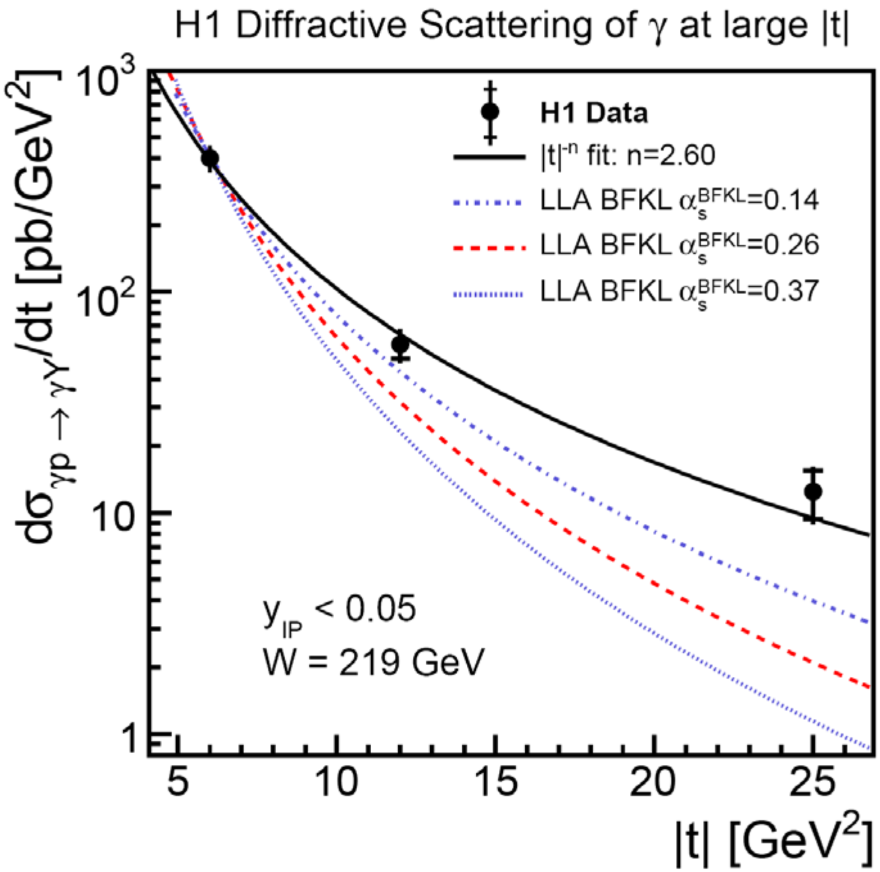
in the range $2 < |t| < 30\ \text{GeV}^2$

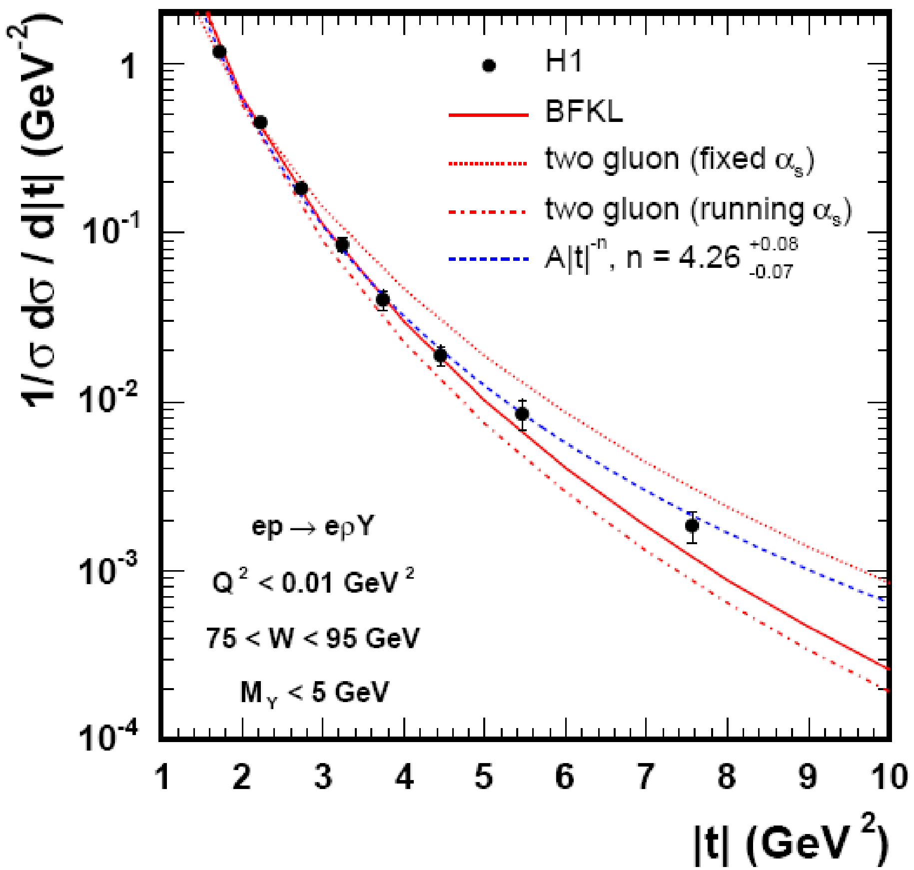
Comparison with J/ψ at high $|t|$





Comparison with ρ at high $|t|$





Conclusion

- diffractive photon scattering $\gamma p \to \gamma Y$ at high |*t*| has been measured for the first time

- important test of the BFKL dynamics

- measured *W* power $\delta = 2.73 \pm 1.02(\text{stat})^{+0.56}_{-0.78}(\text{syst})$
  corresponds to $\alpha_s^{\text{Fit}} = 0.26 \pm 0.10(\text{stat})^{+0.05}_{-0.07}(\text{syst})$

  is compatible with the LLA BFKL and with the J/ψ production at high |*t*| and is one of the strongest energy dependences measured in diffractive processes

- measured |*t*| power $n = 2.60 \pm 0.19(\text{stat})^{+0.03}_{-0.08}(\text{syst})$
is harder than that predicted by the LLA BFKL and that measured for diffractive production of J/ψ

Backup

Cross Sections

ep cross sections are calculated as

$$\frac{d^2\sigma_{ep\to e\gamma Y}}{dW\,dt} = \frac{N_{\rm data} - N_{\rm bgr}}{\mathcal{L} A \Delta W \Delta t}$$

γp single-differential cross sections are then extracted using photon flux Γ

$$\frac{d^2\sigma_{ep\to e\gamma Y}}{dW\,dt} = \Gamma(W)\frac{d\sigma_{\gamma p\to\gamma Y}}{dt}(W)$$