Diffractive Dijets Production HERA vs LHeC

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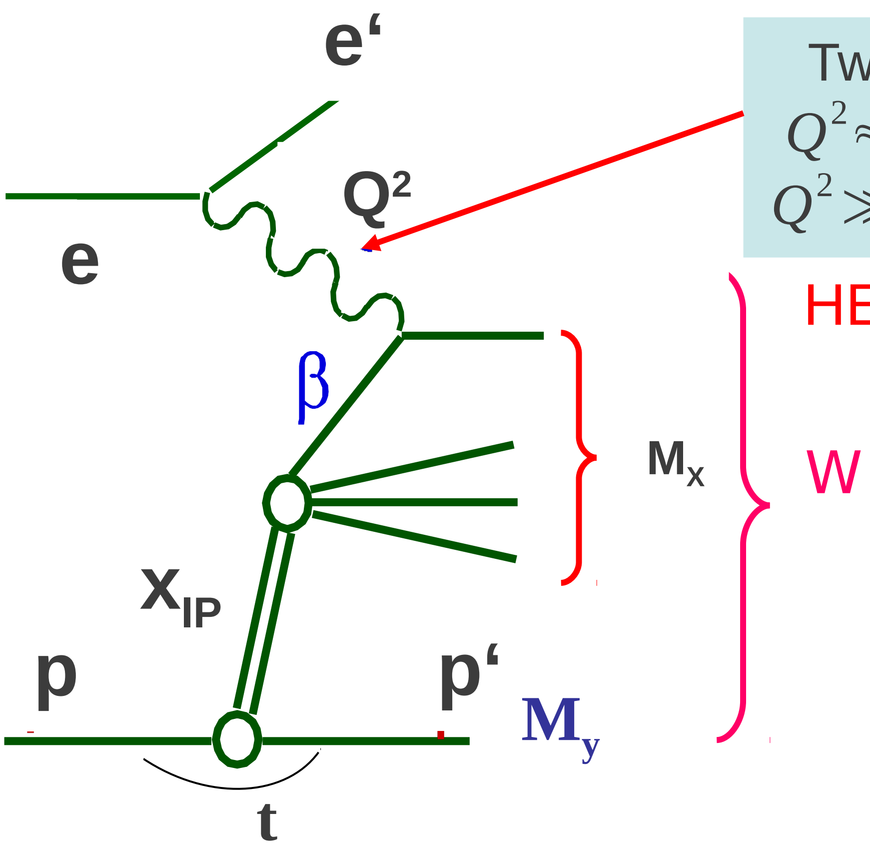
Kinematics of Inclusive Diffraction



Two kinematic regions of diffractive events:

$Q^2 \approx 0 \;\rightarrow\;$ photoproduction (PHO)

$Q^2 \gg 0 \;\rightarrow\;$ deep inelastic scattering (DIS)

HERA: ~10% of low-x DIS events diffractive

Momentum fraction of the diffractive exchange

$$x_{IP} = \frac{q \cdot (p - p')}{q \cdot p} \approx \frac{Q^2 + M_X^2}{Q^2 + W^2} \approx 1 - \frac{E_p'}{E_p}$$

Fraction of exchange momentum entering hard subprocess

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

$M_Y = m_p$ proton stays intact, needs detector setup to detect protons

$M_Y > m_p$ proton dissociates, approx. 20 % in H1 LRG measurement

4-momentum transfer squared $\quad t = (p - p')^2 \approx -p_T'^2$

Zero-order process $\gamma^* q \rightarrow q'$ dominates

Usually $\quad x_{IP} \approx 0.01 \qquad |t| \ll 1\,\mathrm{GeV}^2$

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 for small Q^2 around $\beta \simeq 1$)

QCD factorization theoretically proven for DIS (Collins 1998)

$$d\sigma^D(\gamma p \rightarrow Xp) = \sum_{parton_i} f_i^D(\beta, Q^2, x_{IP}, t) * d\hat{\sigma}^{\gamma i}(x, Q^2)$$

f_i^D — DPDFs, obeys DGLAP evolution, process independent

$d\hat{\sigma}^{\gamma i}$ — Process dependent partonic x-section, calculable within pQCD

In addition to DGLAP evolution, Regge vertex factorization is assumed:

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

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

$$\alpha(t) = \alpha_0 + \alpha' t$$

Pomeron flux factor
Parametrization inspired by „old“ Regge theory

Pomeron PDF
Obey DGLAP evolution

DIS Dijets and DPDFs

$$f_i^D(\beta, Q^2, x_{IP}, t) \rightarrow f_i^D(z_{IP}, \mu_f^2, x_{IP}, t)$$

Various choices of hard scale exist

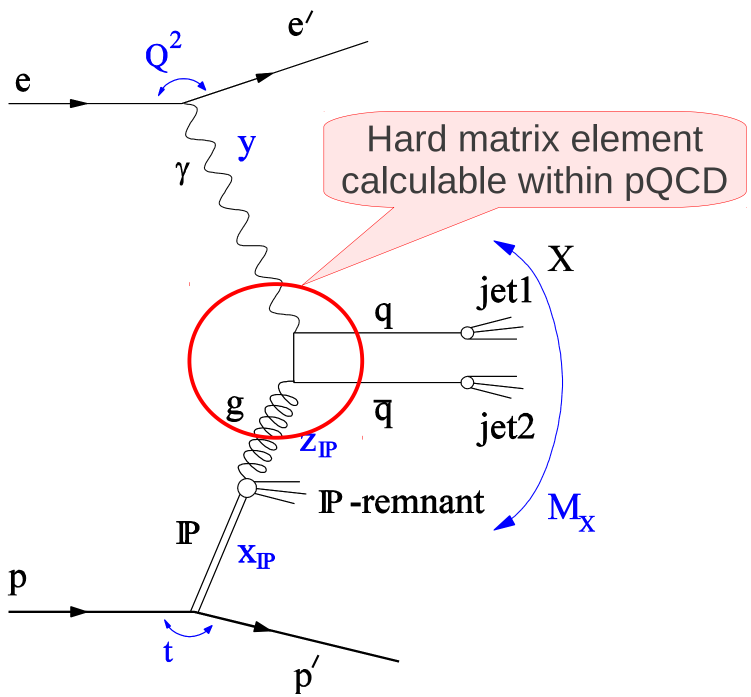
$$\mu_f^2 = (E_T^{\text{jet1}})^2$$

$$\mu_f^2 = Q^2 + (E_T^{\text{jet1}})^2$$

$$\mu_f^2 = (E_T^{\text{jet1}})^2 + 4m_q^2$$

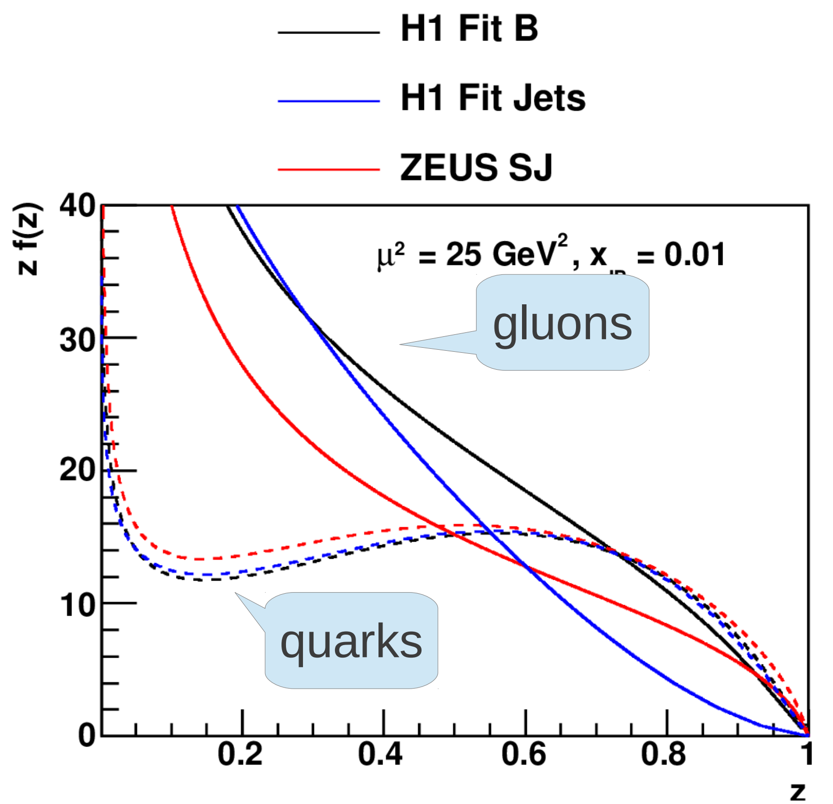
Pomeron four-momentum fraction entering hard matrix element

$$z_{IP} = \frac{Q^2 + M_{12}^2}{Q^2 + M_X^2}$$



First-order process $\gamma^* g \rightarrow q\bar{q}$ dominates

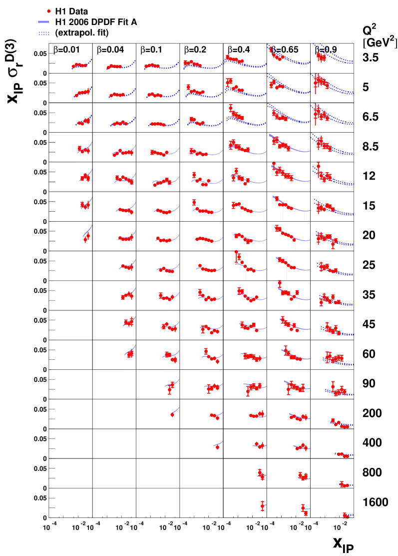
Large discrepancies between recent fits for gluon contribution



Dijets Are Useful

- For diffraction identified by LRG t is not measured, known only upper limit

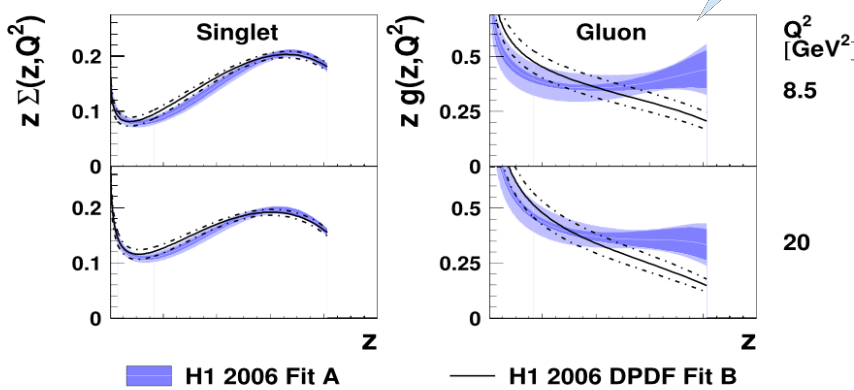
Inclusive measurement $\sigma_r(\beta, Q^2, x_{IP})$



QCD fit

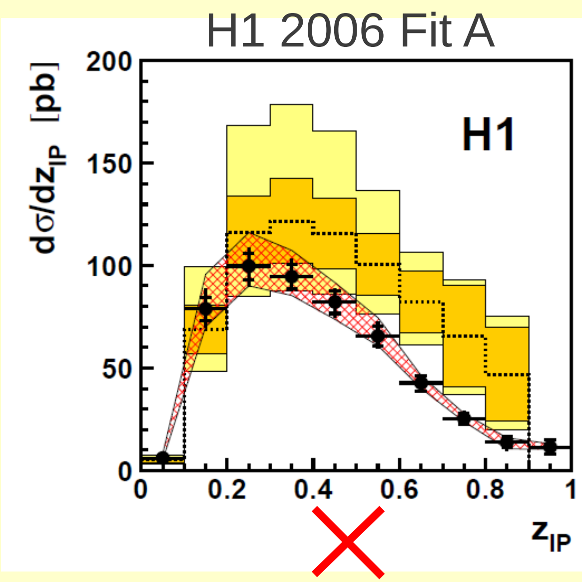
Two fits with different parametrization but **equal Chi²**

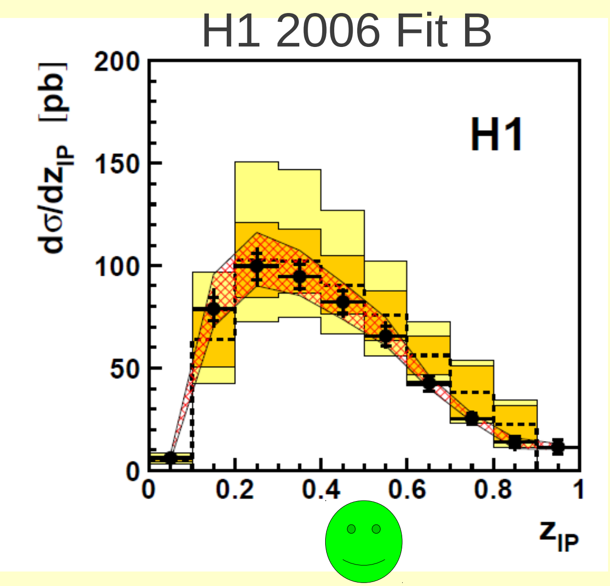
Gluon contribution weakly constrains



Let's see the predictions for DIS dijets data

Dijet measurement determines, due to high fraction of BGF processes, gluon-PDF much better !





H1 vs ZEUS for DIS Dijets

- Factorization within theoretical scale uncertainties holds for both collaboration for H1 2006 Fit B (used in rest of presentation)
- H1 and ZEUS data compatible

Large theoretical scale uncertainties not plotted (see previous slide)

$$\frac{\sigma_{data}^{H1}/\sigma_{NLO}^{H1}}{\sigma_{data}^{ZEUS}/\sigma_{NLO}^{ZEUS}}=1.06$$

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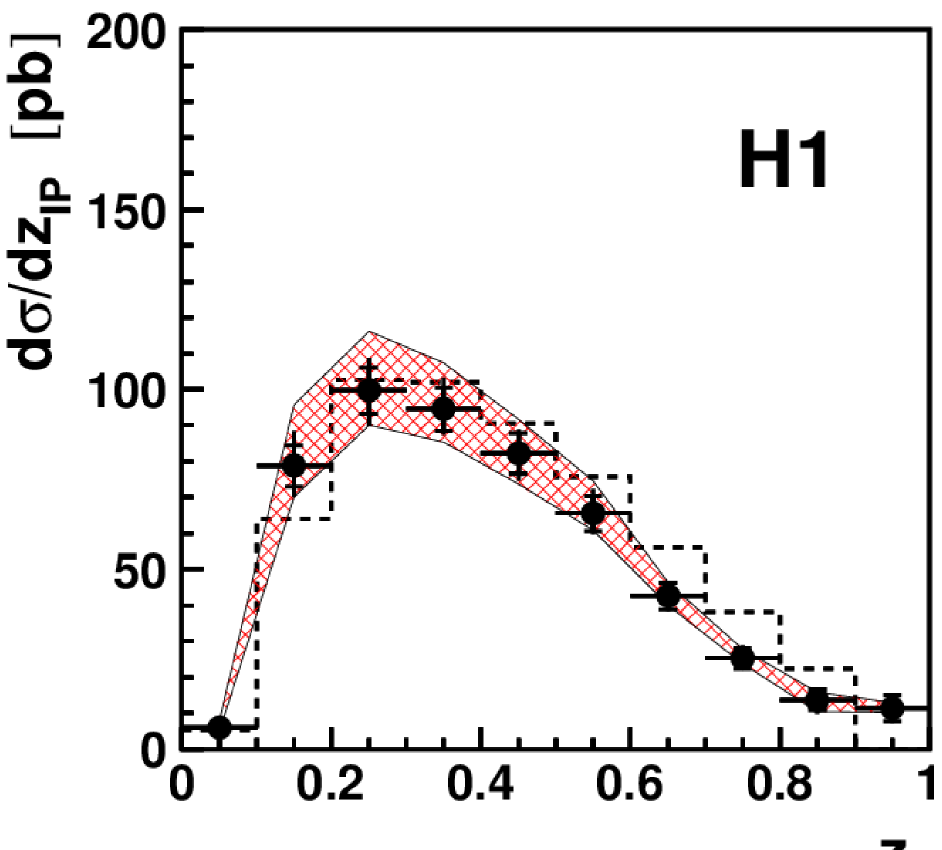

$$\sigma_{data}^{H1}/\sigma_{NLO}^{H1}=0.91$$

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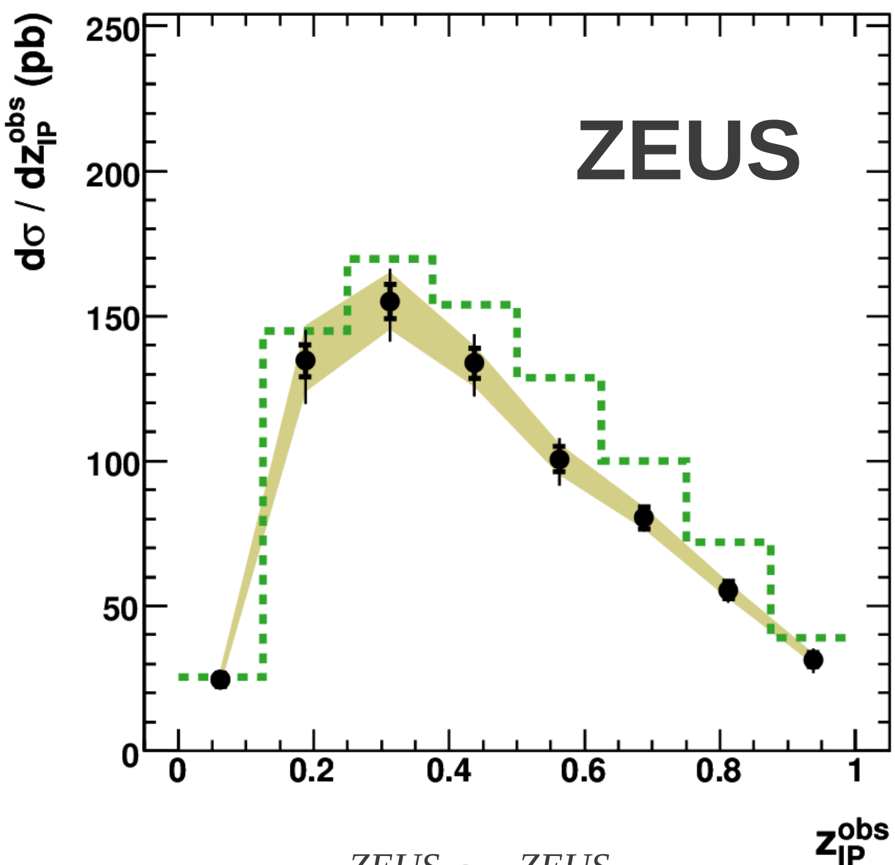


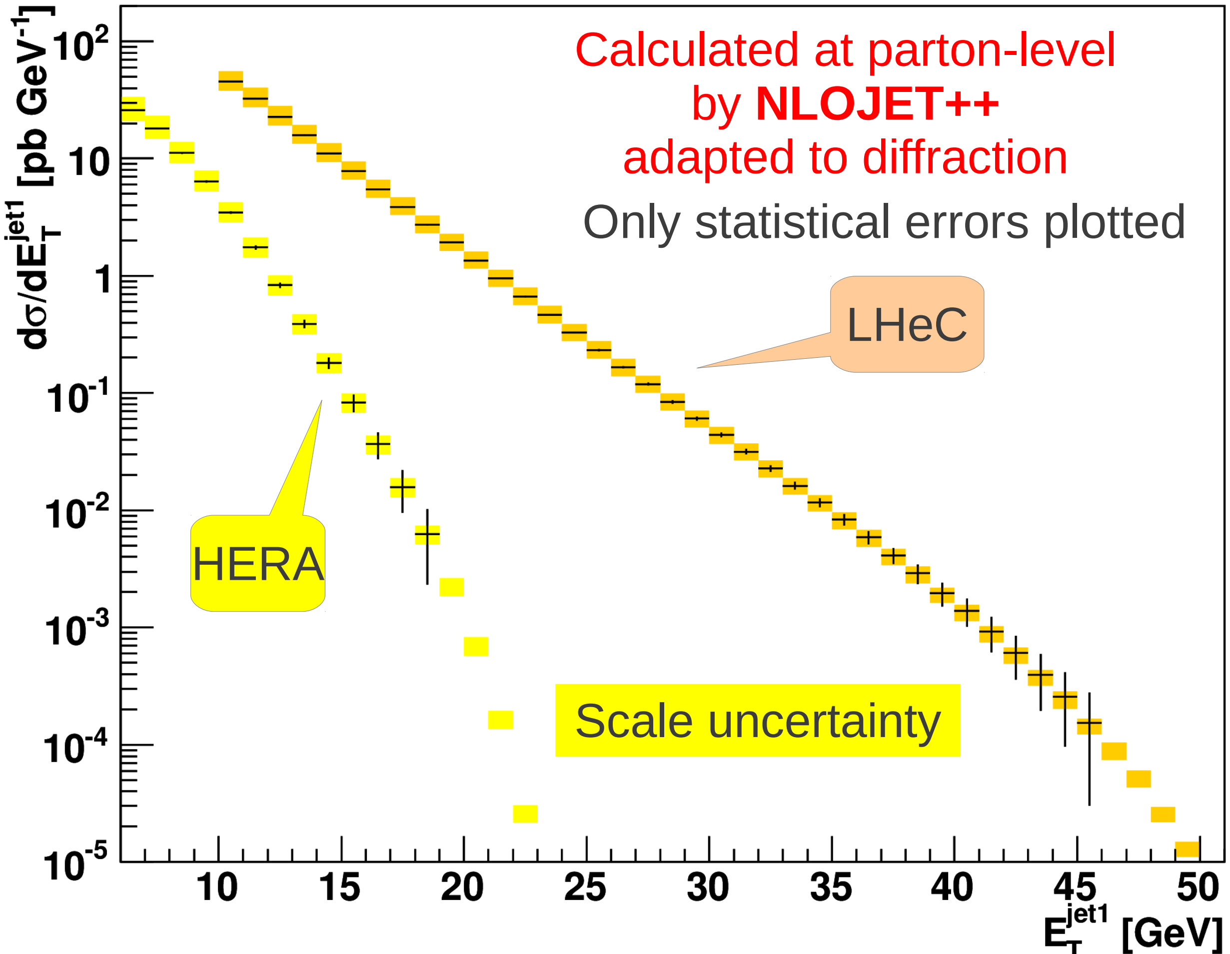
$$\sigma_{data}^{ZEUS}/\sigma_{NLO}^{ZEUS}=0.85$$

Plotted correlated (color band) and uncorrelated data errors

DIS Dijets HERA vs LHeC
Comparison of Synthetic Data

- Higher CMS energy makes higher scales accessible

HERA	LHeC
$E_T^{jet1} \sim 15\,\text{GeV}$	$E_T^{jet1} \sim 40\,\text{GeV}$



$Q^2 > 4$ for LHeC reduced σ by ~20 %

920 + 27.5 HERA ($400\,\text{pb}^{-1}$)

$$Q^2 > 4\,\text{GeV}^2 \wedge 0.1 < y < 0.7$$
$$x_{IP} < 0.03 \wedge |t| < 1\,\text{GeV}^2$$
$$M_Y < 1.6\,\text{GeV}$$
$$E_T^{jet1} > 6\,\text{GeV}$$
$$E_T^{jet2} > 4\,\text{GeV}$$
$$-1 < \eta^{jets} < 2$$

7000 + 60 LHeC ($10\,\text{fb}^{-1}$)

$$Q^2 > 2\,\text{GeV}^2 \wedge 0.1 < y < 0.7$$
$$x_{IP} < 0.01 \wedge |t| < 1\,\text{GeV}^2$$
$$M_Y < 1.6\,\text{GeV}$$
$$E_T^{jet1} > 10\,\text{GeV}$$
$$E_T^{jet2} > 6.5\,\text{GeV}$$
$$-3 < \eta^{jets} < 3$$

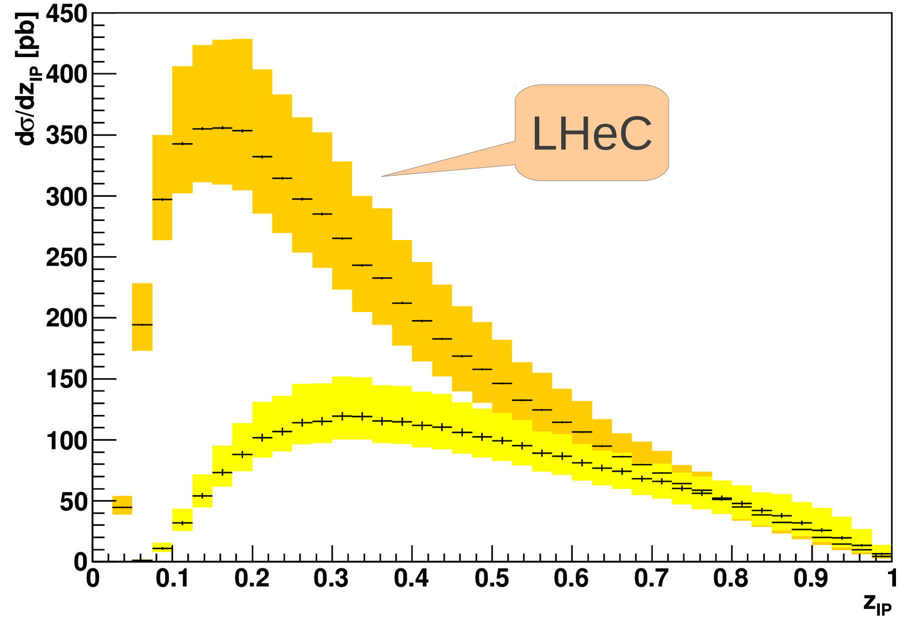
$$Q^2 > 2\,\text{GeV}^2 \rightarrow \theta_{el} < 178.5°$$
$$Q^2 > 4\,\text{GeV}^2 \rightarrow \theta_{el} < 176.5°$$

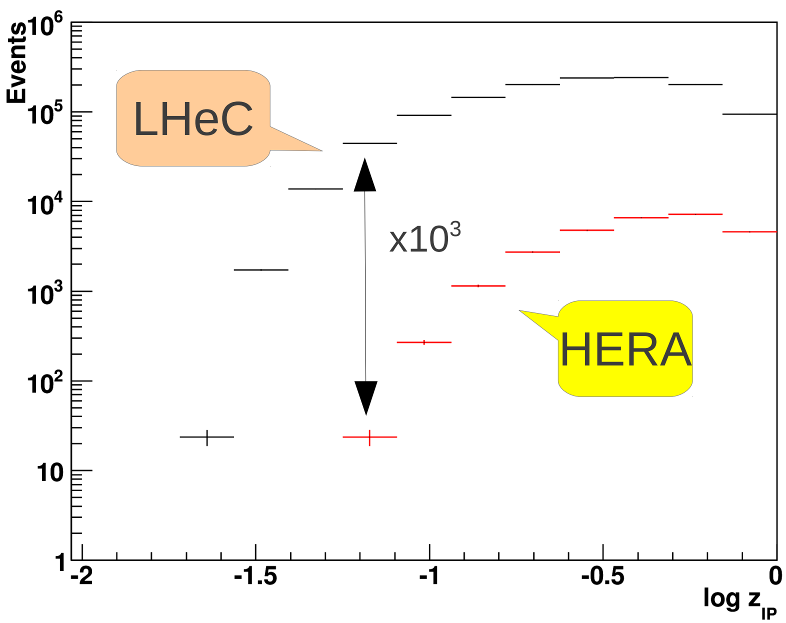
DIS Dijets HERA vs LHeC

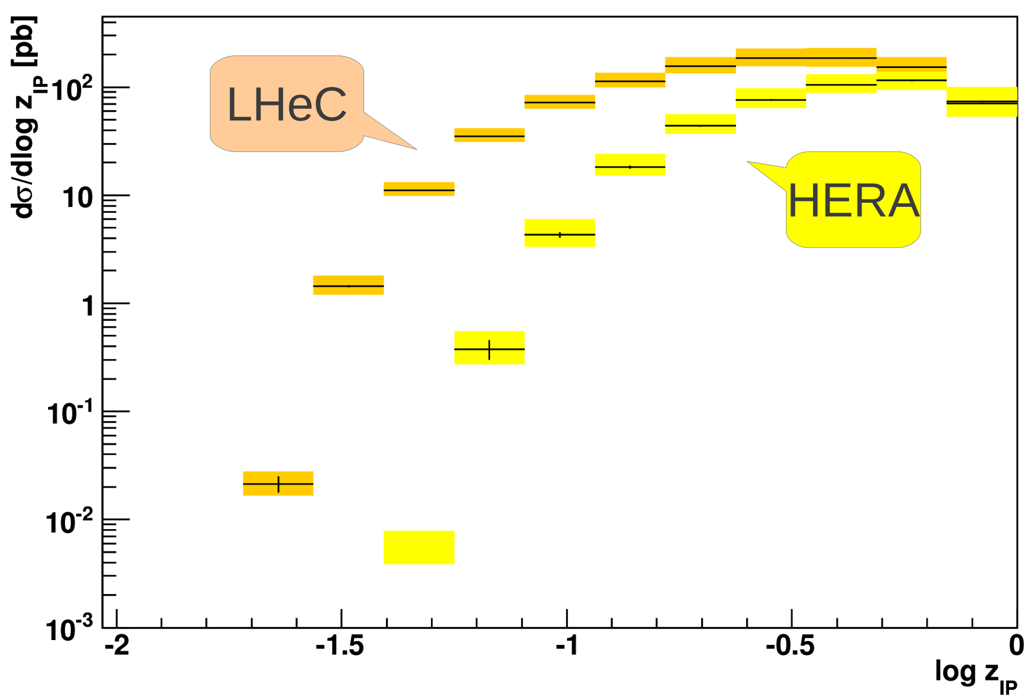
- At LHeC much higher statistics for small z_{IP} , where gluon-PDF weakly constrained from inclusive measurement, dominates
- High z_{IP} and low Q^2 region sensitive to the possible higher twist effect
- Access to small z_{IP} depends on ability of measurement of small E_T jets

$$z_{IP}^{\min} \simeq \frac{\left(E_T^{\text{jet1}(\min)} + E_T^{\text{jet1}(\min)}\right)^2}{x_{IP}^{\max}\, y^{\max}\, s}$$

HERA	→	LHeC
$z_{IP} \sim 0.07$		$z_{IP} \sim 0.02$







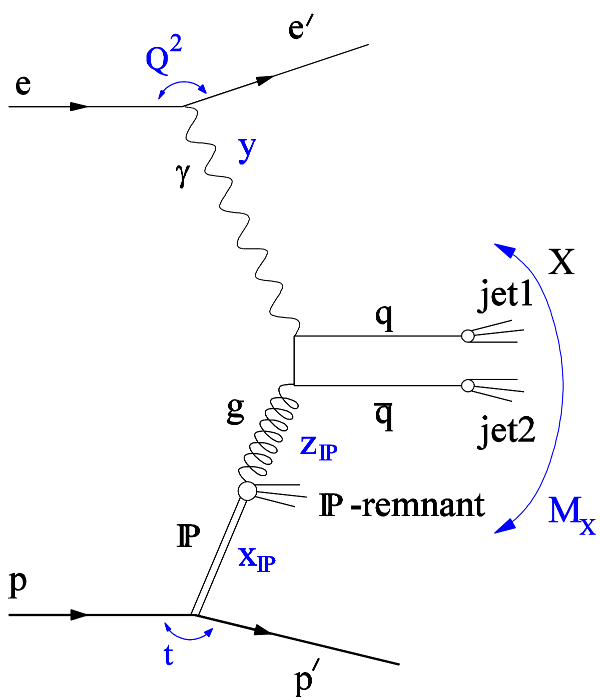
Diffractive Dijet Photoproduction

Direct
No photon remnant
$x_\gamma = 1$ (at parton-level)
Dominant for high Q^2
(near DIS region)

- Division of γ-PDF to point- and hadron-like part depends on starting scale in DGLAP evol. of the fit

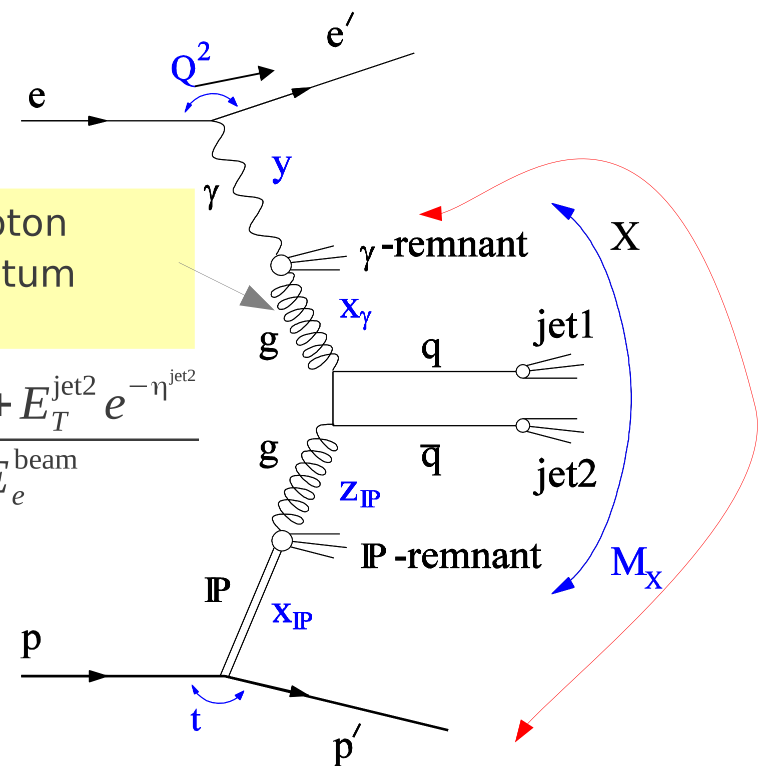
Resolved
photon remnant
$x_\gamma < 1$
Dominant for low Q^2, γ-PDF introduced:

Point like-part	Hadron-like part
Generated by inhomogeneous term in DGLAP for photon, dom.: $0.2 < x_\gamma < 1$	Photon fluctuated into hadronic bounded state, dominates for: $x_\gamma < 0.2$
Suppression of ~0.6	Suppression of 0.34



x_γ – photon momentum fraction

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



Additional interactions which spoil rap. Gap? (like in pp)

H1 vs ZEUS for PHO Dijets

- Factorization breaking **observed by H1** but do **not observed by ZEUS**
- Data of both collaborations seem to be incompatible

The newest theoretical prediction of suppression by KKMR for γ-PDF
Quarks – 0.71 (0.75) , for $E_T^{jet1} > 5\,\text{GeV}$ H1 $\left(E_T^{jet1} > 7.5\,\text{GeV}\right)$ (ZEUS)
Gluons – 0.53 (0.55)

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

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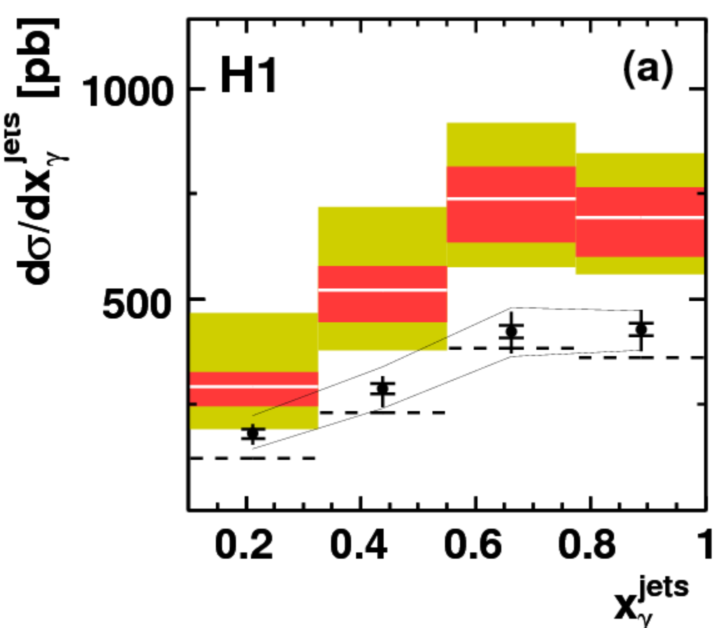
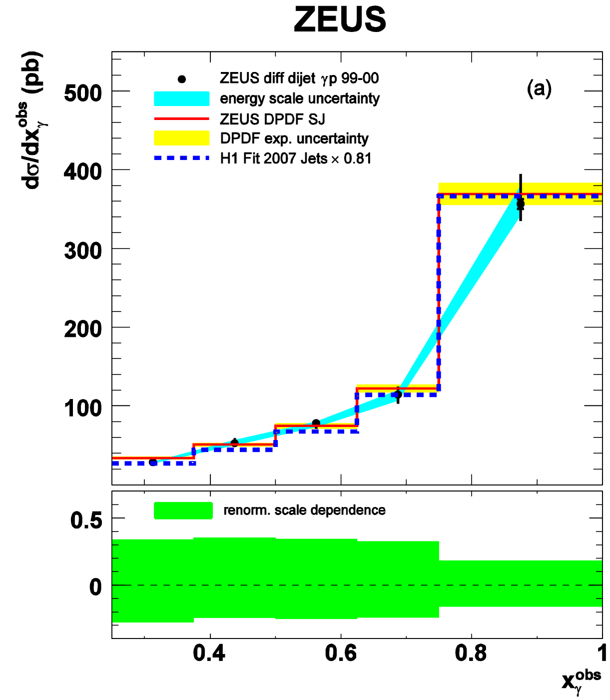
Nucl. Phys. B381 (2010)



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

$$\frac{\sigma_{data}^{H1}/\sigma_{NLO}^{H1}}{\sigma_{data}^{ZEUS}/\sigma_{NLO}^{ZEUS}} = 0.6$$



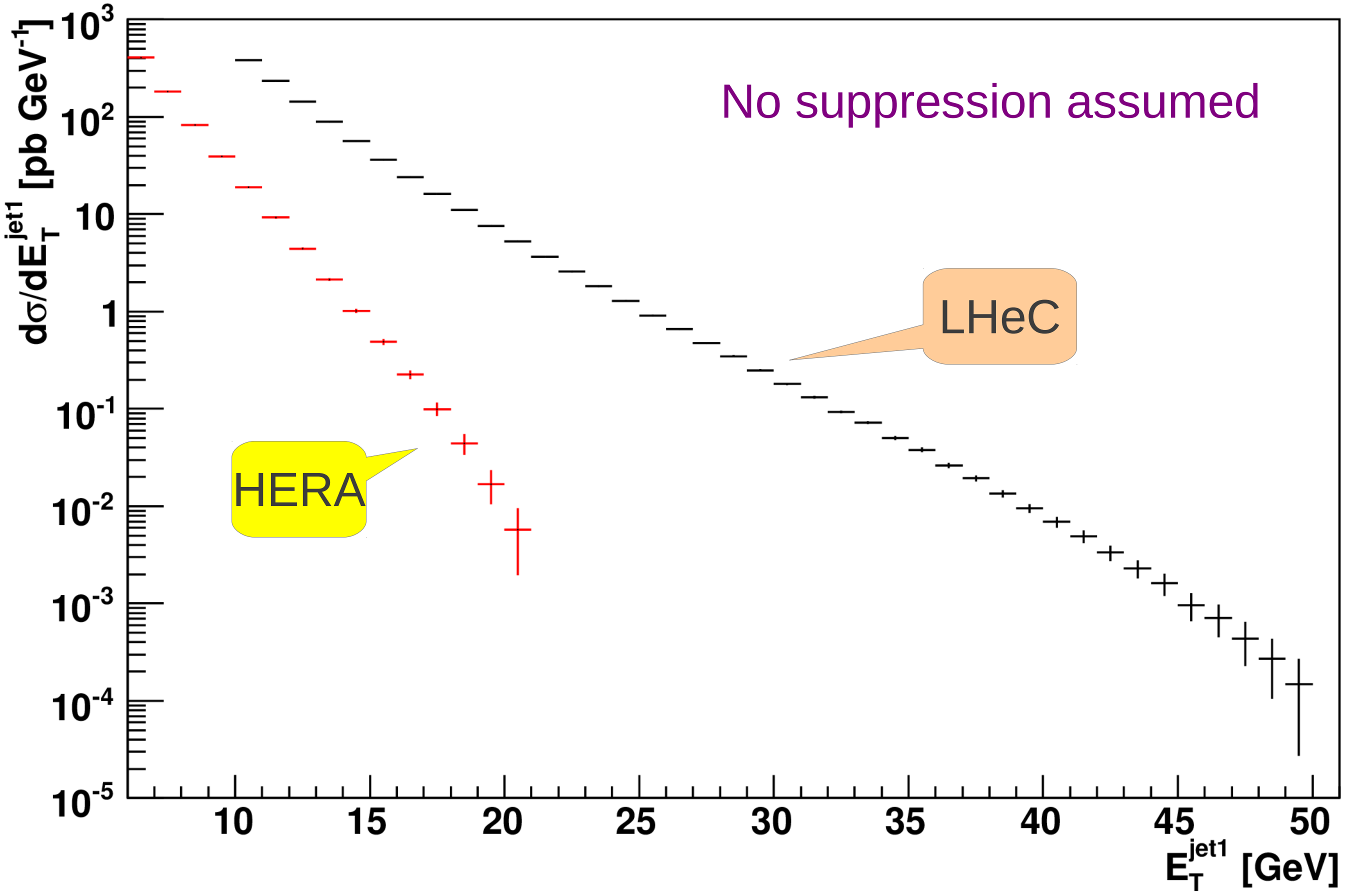
$$\sigma_{data}^{ZEUS}/\sigma_{NLO}^{ZEUS} = 1.0$$

PHP Dijets HERA vs LHeC

- Due to much higher E_T^{jet} jets at LHeC is LHeC better tool to investigate possible factorisation breaking

Calculated at parton-level by **Frixione NLO** adapted to diffraction

HERA	LHeC
$E_T^{jet1} \sim 17\,\mathrm{GeV}$	$E_T^{jet1} \sim 42\,\mathrm{GeV}$



920 + 27.5 HERA (400 pb^{-1})

$$Q^2 < 2\,\mathrm{GeV}^2 \wedge 0.2 < y < 0.8$$
$$x_{IP} < 0.03 \wedge |t| < 1\,\mathrm{GeV}^2$$
$$M_Y < 1.6\,\mathrm{GeV}$$
$$E_T^{jet1} > 6\,\mathrm{GeV}$$
$$E_T^{jet2} > 4\,\mathrm{GeV}$$
$$-1 < \eta^{jets} < 2$$

7000 + 60 LHeC (10 fb^{-1})

$$Q^2 < 2\,\mathrm{GeV}^2 \wedge 0.2 < y < 0.8$$
$$x_{IP} < 0.01 \wedge |t| < 1\,\mathrm{GeV}^2$$
$$M_Y < 1.6\,\mathrm{GeV}$$
$$E_T^{jet1} > 10\,\mathrm{GeV}$$
$$E_T^{jet2} > 6.5\,\mathrm{GeV}$$
$$-3 < \eta^{jets} < 3$$

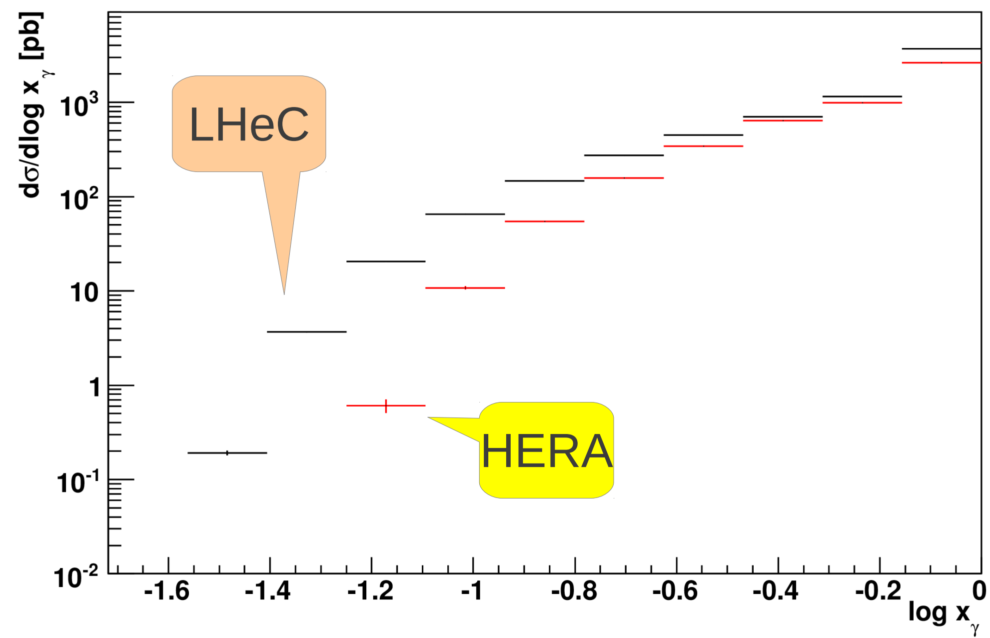
Only statistical errors of synthetic data depicted
No acceptance and detector smearing effects take into account

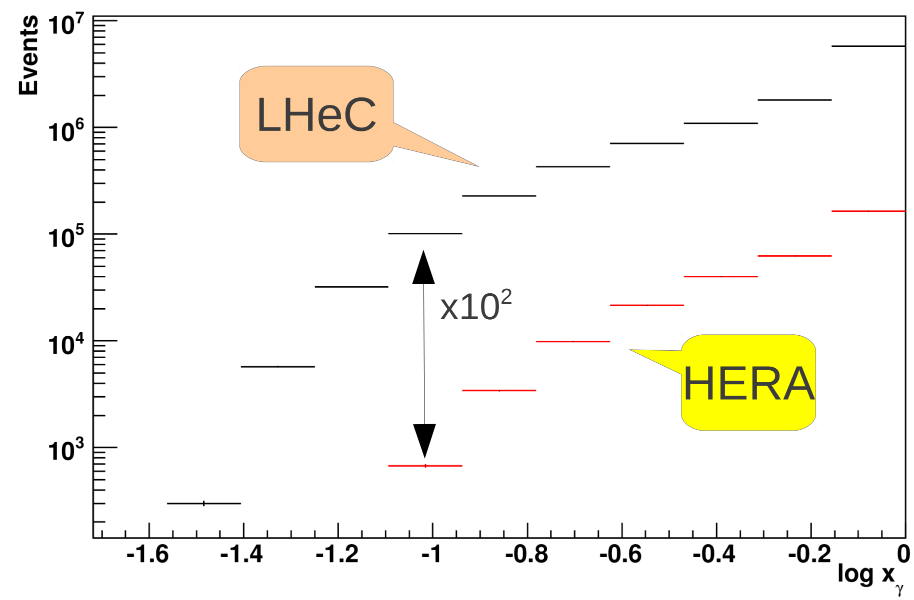
PHP Dijets HERA vs LHeC

- From theory is expected the suppression factor should be x_γ - dependent
- **Neither** HERA experiment has seen such dependence (due to resolution and smearing?)
- At small scales and small x_γ the resolved part of γ-PDF is not negligible and it is supposed to be suppressed by pp-like rapidity gap survival probability factor (0.34 for ep at HERA, see KKMR)

HERA	LHeC
$x_\gamma \sim 0.09$	$x_\gamma \sim 0.03$

With electron tagger much smaller <Q^2>
Higher fraction of theoretically interesting **resolved part**

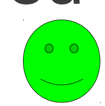




Conclusions

- DIS dijet measurement at LHeC can improve gluon-DPDF precision, mainly for very small z_{IP} (not accessible by HERA)

- High-energy high-luminosity LHeC data can allow more precise studies of diffractive factorization breaking specially in “problematic” photoproduction region

- Inconsistencies between HERA collaborations concerning of factorization can be definitely solved because only one experiment at LHeC will exist  .

D* in Diffractive Photoproduction

Low statistics in measurement of both collaborations

Does the factorization hold here?

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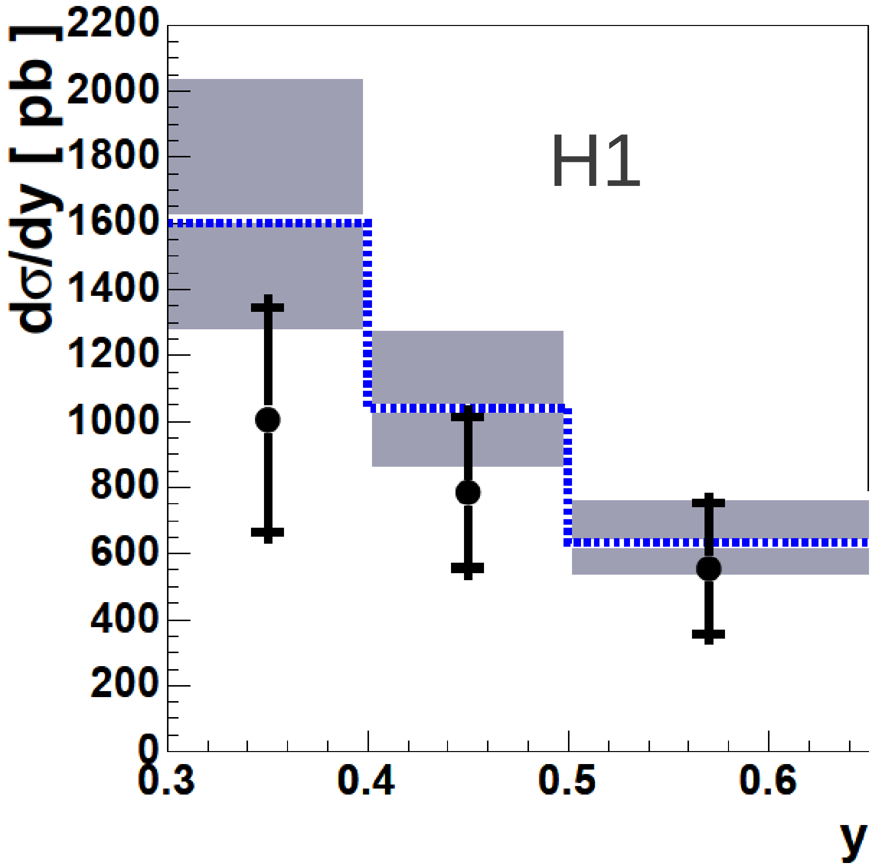

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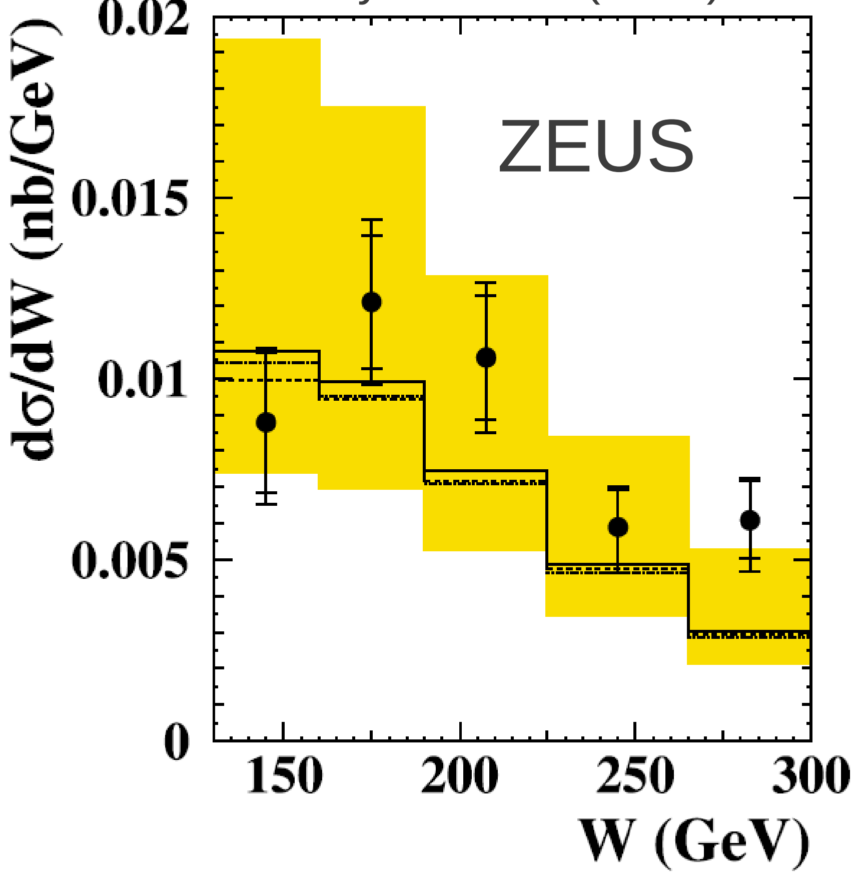

$$\frac{\sigma_{data}^{H1}/\sigma_{NLO}^{H1}}{\sigma_{data}^{ZEUS}/\sigma_{NLO}^{ZEUS}} = 0.55 \pm 0.21$$

Hopefully LHeC measurement could answer