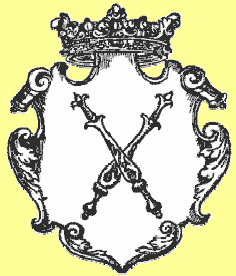
Dijets in Diffractive Deep Inelastic Scattering and Photoproduction

DIS 2008

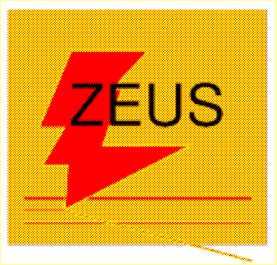
Diffraction and Vector Mesons parallel session

April 8, 2008, London

Wojciech Słomiński (Jagellonian University, ZEUS)



On behalf of the ZEUS collaboration



What is measured

27.5 GeV $e^{\pm}$ + 920 GeV p at HERA collider $\sqrt{s} = 318\ \mathrm{GeV}$

$$e^{\pm}\ p \to e^{\pm}\ p\ j_1\ j_2 \cdots$$

or

$$\gamma\, p \to p\ j_1\ j_2 \cdots$$

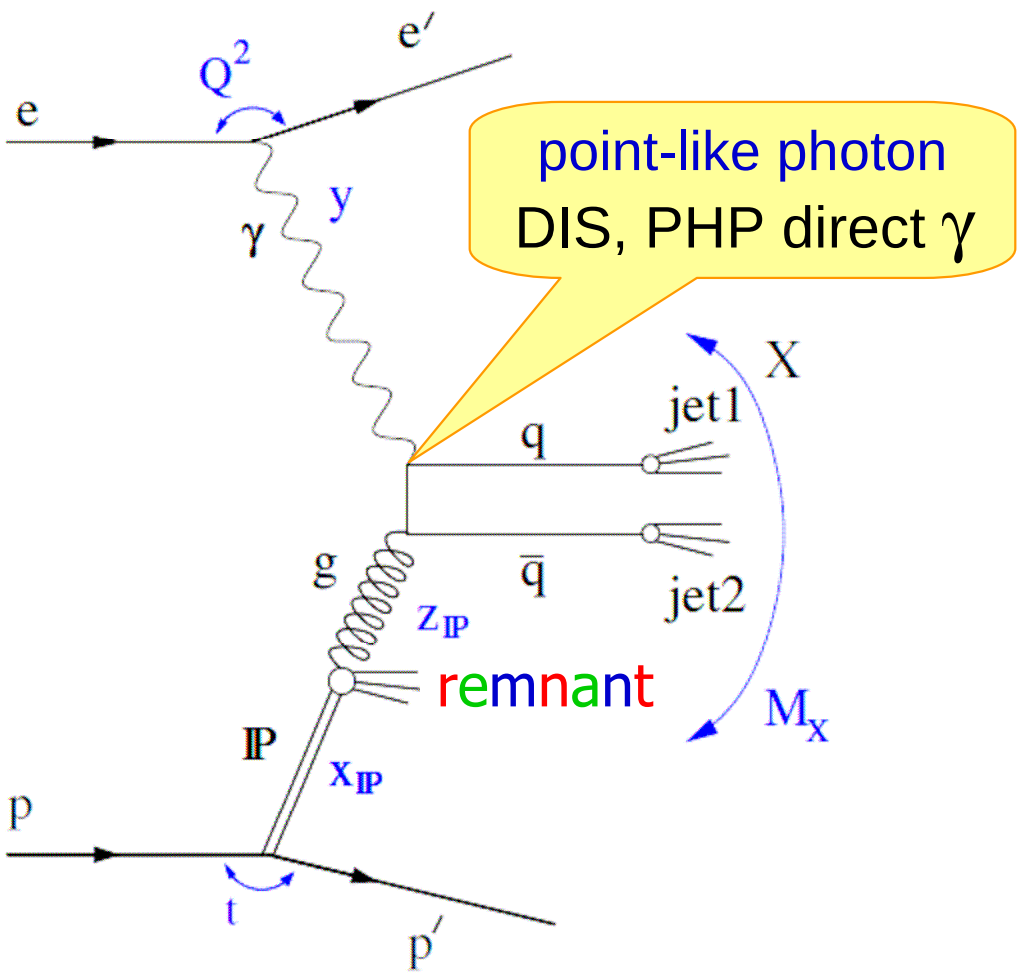
photon diffractive dissociation into a state containing two large p_T (E_T) jets, j_1, j_2

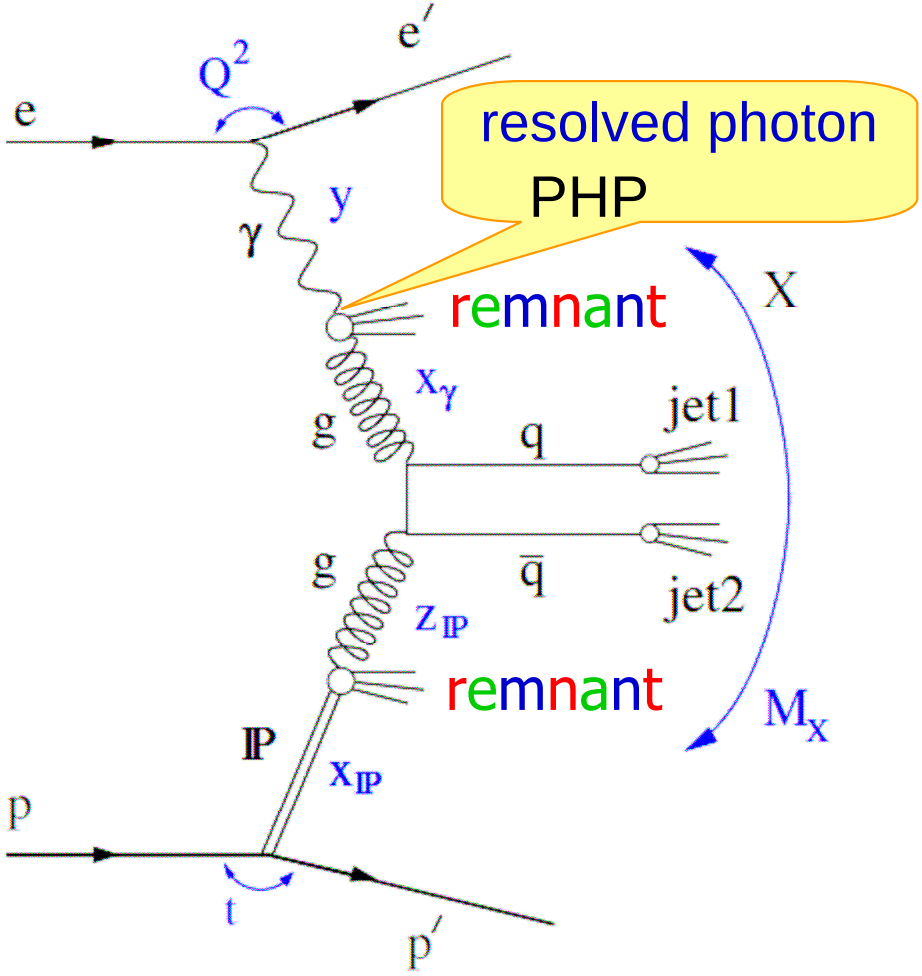
Two important kinematic regions

- **DIS** – Deep Inelastic Scattering
  - γ^* = a photon of high virtuality $Q^2 > 5\ \mathrm{GeV}^2$
- **PHP** – Photoproduction
  - γ = nearly real photon $Q^2 < 1\ \mathrm{GeV}^2$, Q^2 median = $0.001\ \mathrm{GeV}^2$

Dijets in diffractive ep scattering

LO intuitive view





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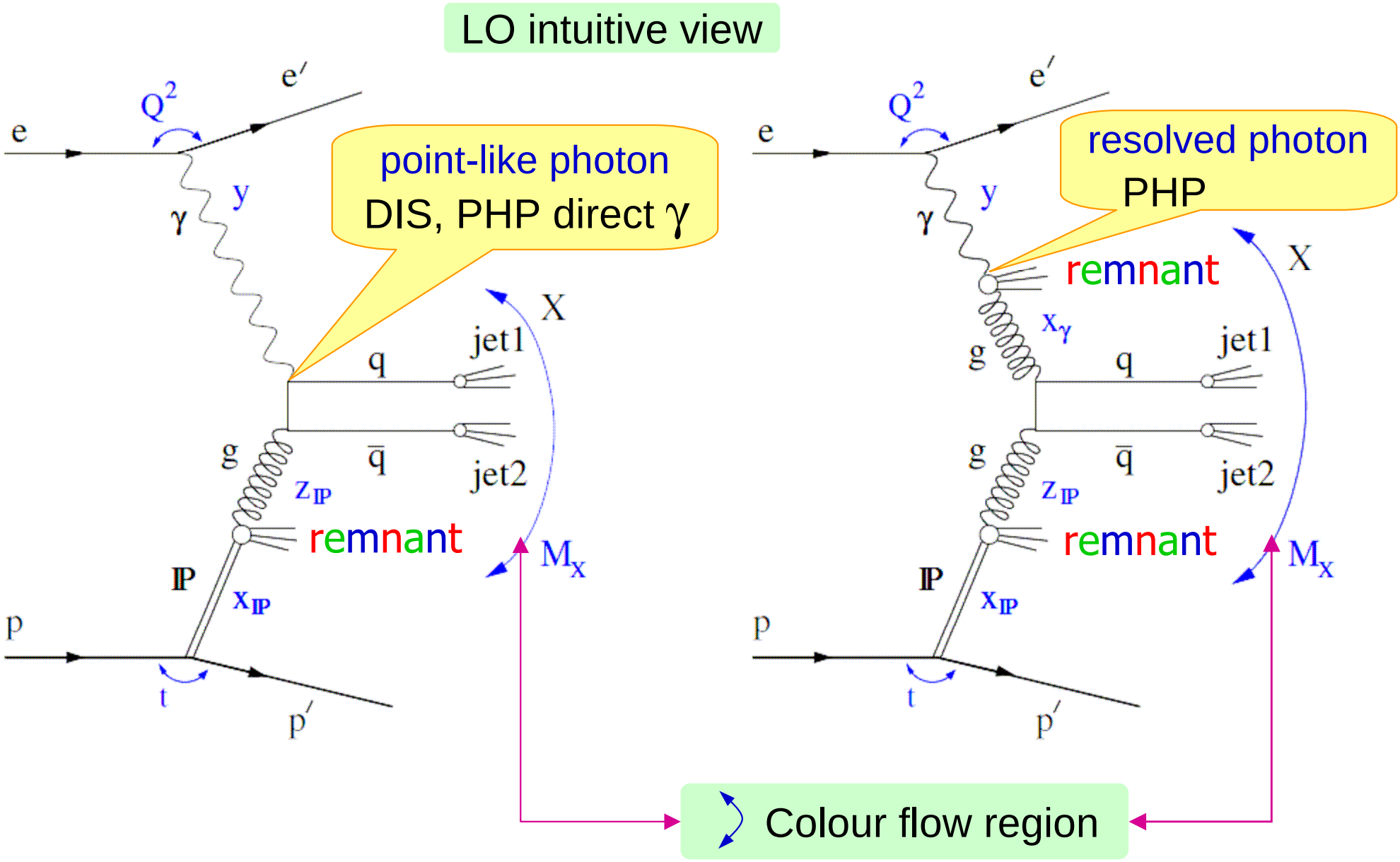

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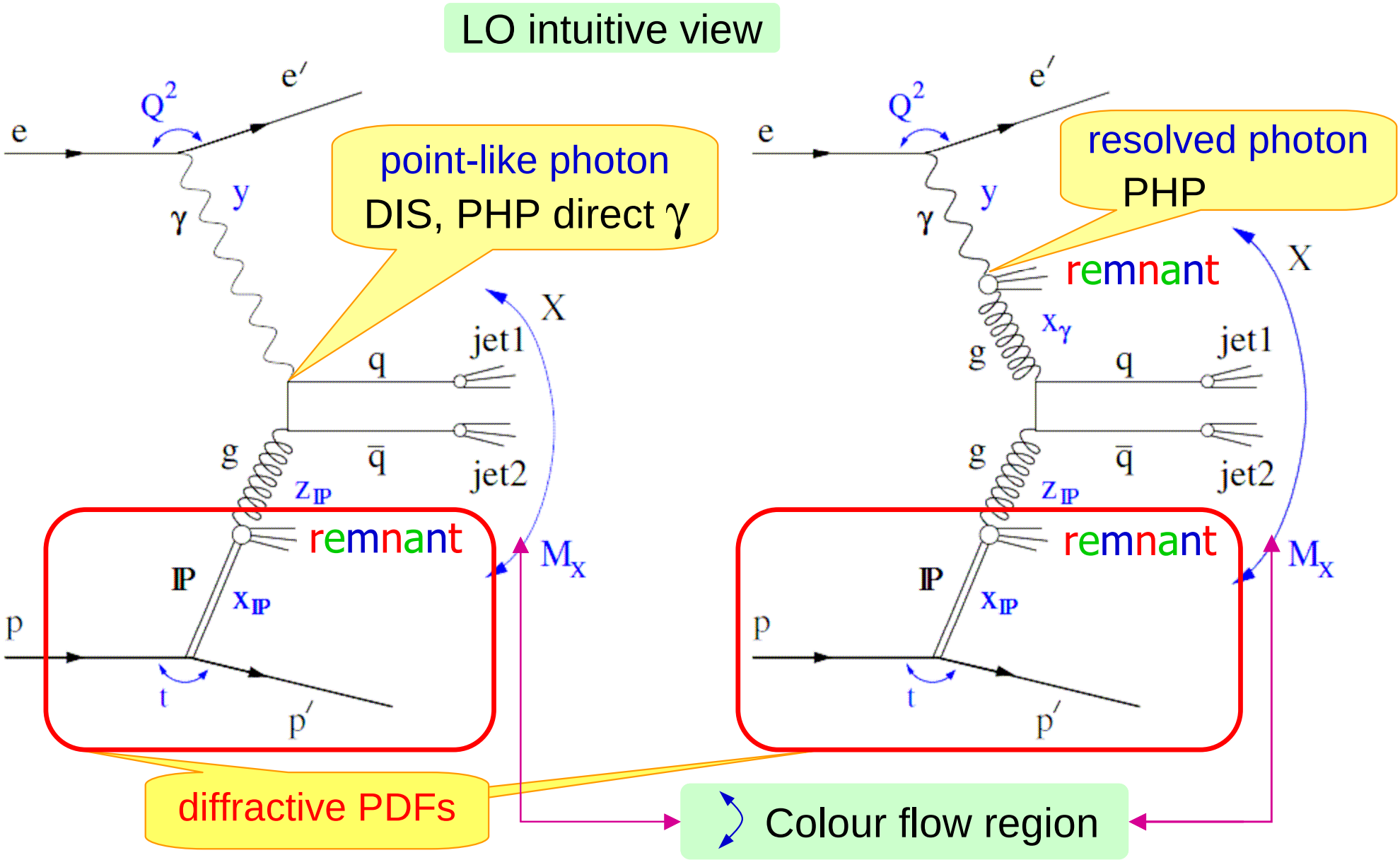


DIS vs. PHP cross-sections

Point-like photon

$$d\sigma = \sum_{j=g,q,\bar{q}} f_j^{\mathrm{D}}\left(x_{\mathbb{P}}, z_{\mathbb{P}}, \mu^2\right)\, \hat{\sigma}^{\gamma j}\left(z_{\mathbb{P}}, \mu^2\right)\, dx_{\mathbb{P}}\, dz_{\mathbb{P}}$$

diffractive PDFs same as in inclusive DDIS

Factorisation proven *J.C. Collins 1998*

If NLO fails ➔ we need: higher QCD orders, better DPDFs ...

Hadron-like photon

$$d\sigma = \sum_{i,j=g,q,\bar{q}} f_i^{\gamma}\left(x_{\gamma}, \mu^2\right) f_j^{\mathrm{D}}\left(x_{\mathbb{P}}, z_{\mathbb{P}}, \mu^2\right)\, \hat{\sigma}^{ij}\left(z_{\mathbb{P}}, \mu^2\right)\, dx_{\gamma}\, dx_{\mathbb{P}}\, dz_{\mathbb{P}}$$

Factorisation assumed ➔ we want to test it experimentally

Nb. Regge factorisation: $f_i^{D}\left(x_{IP}, t, z, Q^2\right) = f_i^{IP}\left(z, Q^2\right) f_{IP}^{p}\left(x_{IP}, t\right)$

What we want to learn

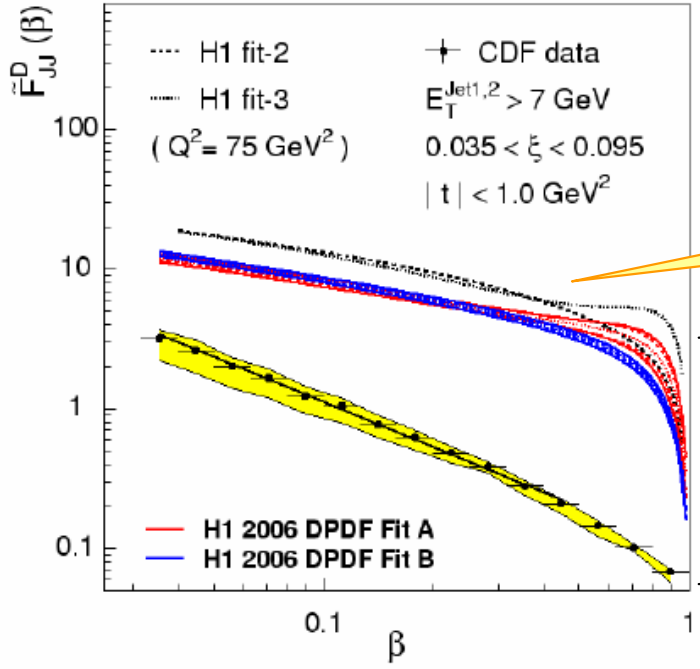
- Diffractive gluon content of the proton
  - DPDFs are extracted from inclusive diffractive DIS
  - DDIS is mainly sensitive to quarks, while gluons contribute at higher orders and via DGLAP evolution
  - dijet production is directly sensitive to f_g^D
- Does factorisation hold for the diffractive dijet photoproduction where ...?
  - known to be strongly broken in *pp* diffraction

Pros & Cons of factorisation in PHP

Message from CDF

PRL 84 (2000) 5043 + Paul Newman/H1

Dijet production
in diffractive *pp* scattering



$\xi = x_P$

NLO predictions
with DPDFs from HERA

~ order of magnitude suppression

$$\beta = \frac{Q^2}{2(p-p')q} \approx \text{parton in IP fract. momentum} = z_P$$

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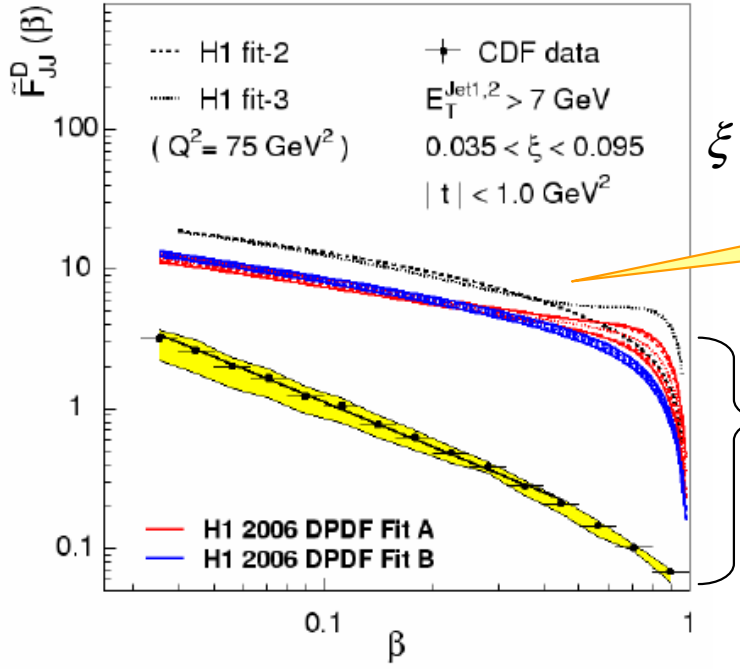

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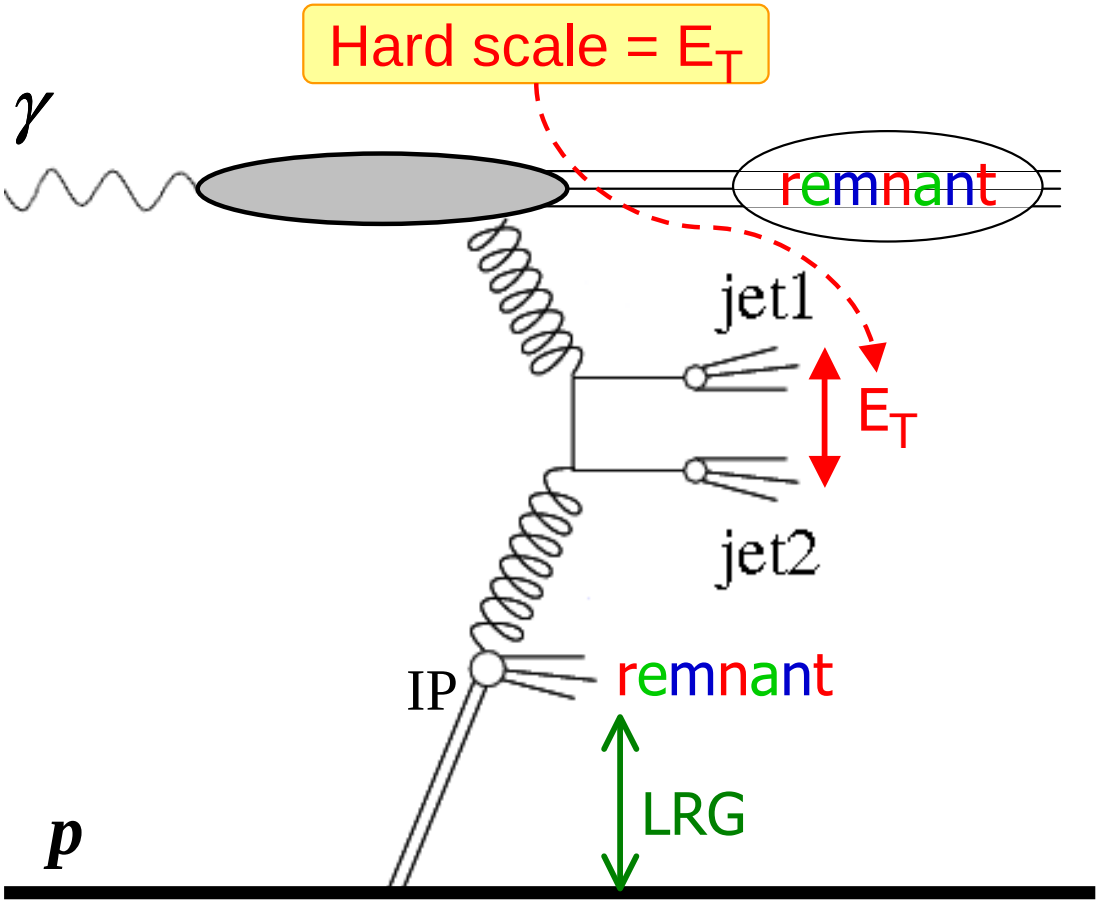
TEVATRON: projectile = proton, HERA: projectile = photon

Much smaller suppression of the photon dissociation expected from phenomenology:
Bialas (2002), Kaidalov, Khoze, Martin, Ryskin (2003)

Rescattering effects for hadron-like photon



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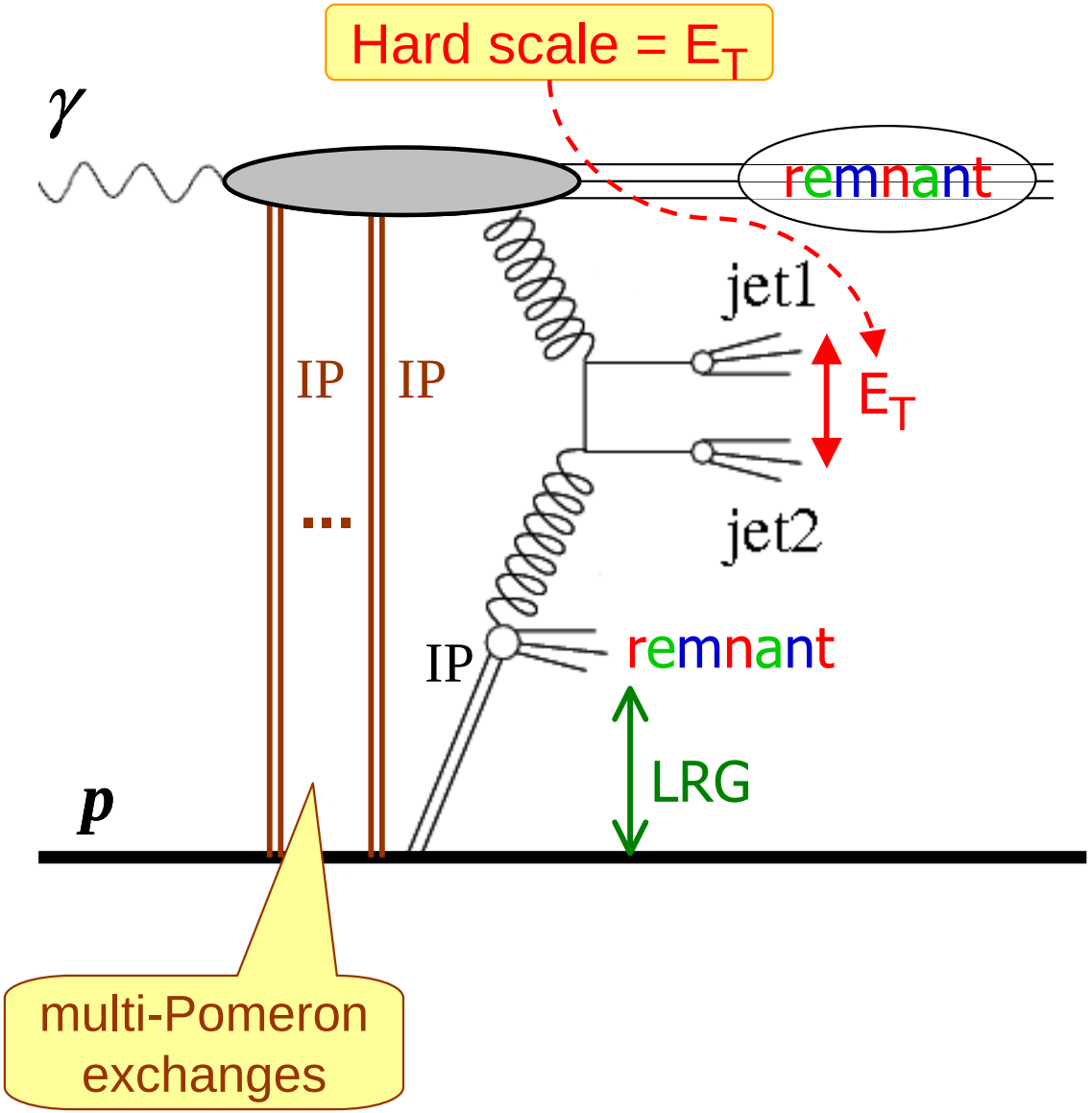

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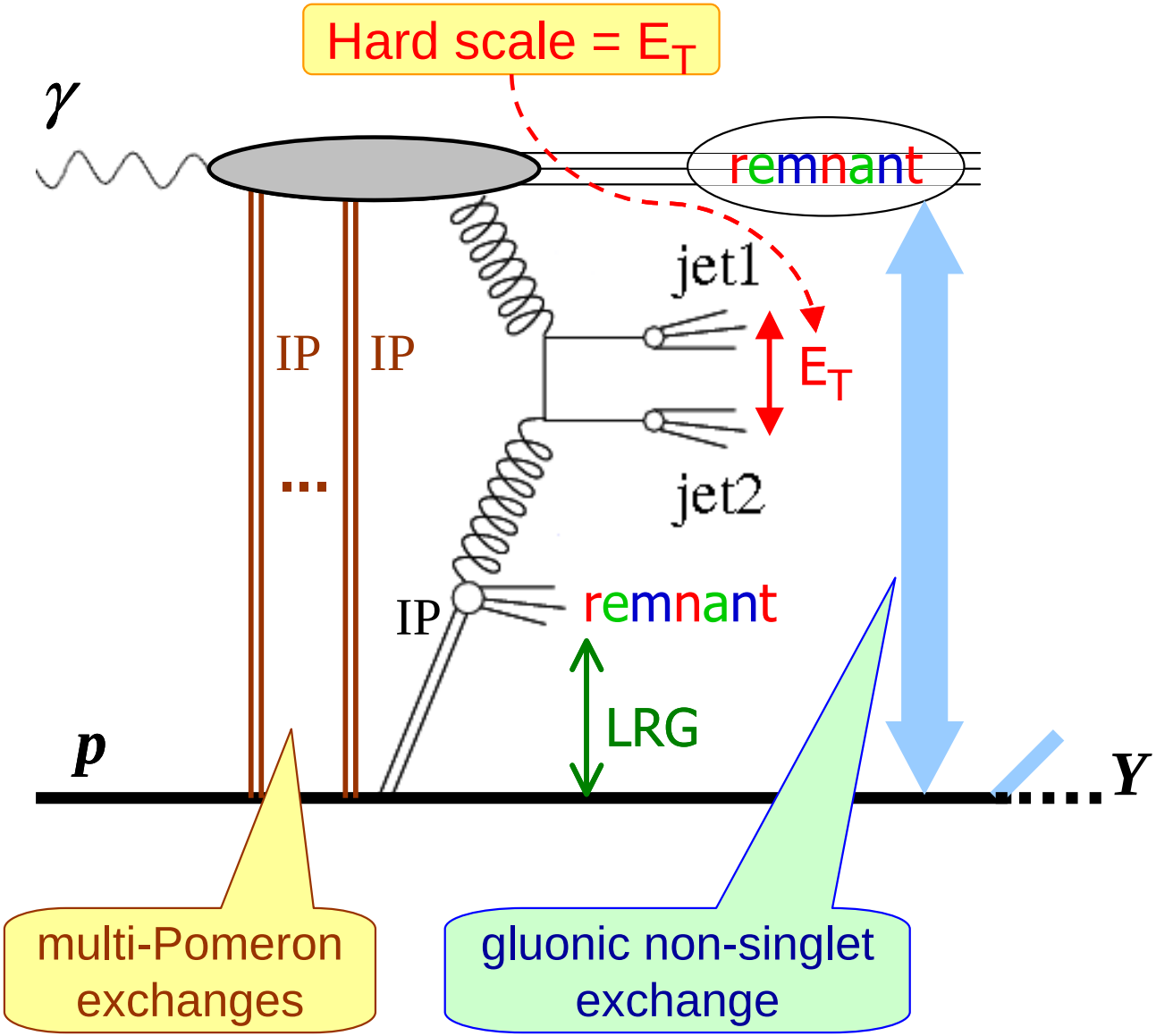

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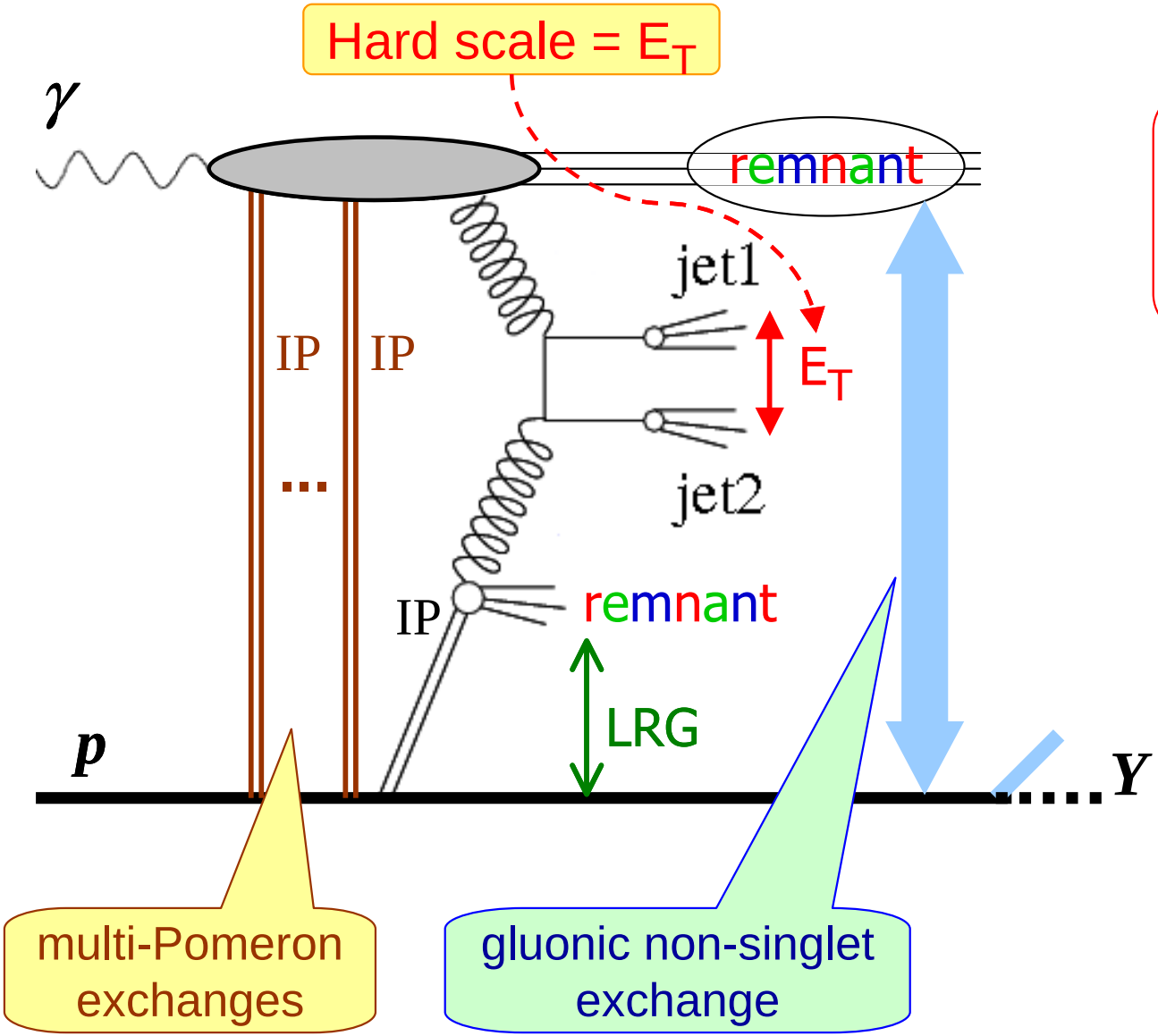


Rescattering leads to:

- Factorisation breaking
- Screening
- Rapidity gap fill-up

⇓

Suppression of the cross-section ≈ 1 – (rapidity gap survival probability)

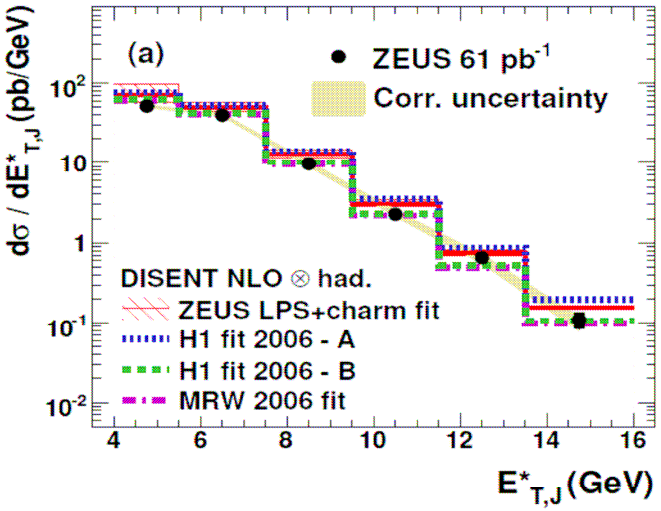
By general arguments we would expect it to decrease with E_T

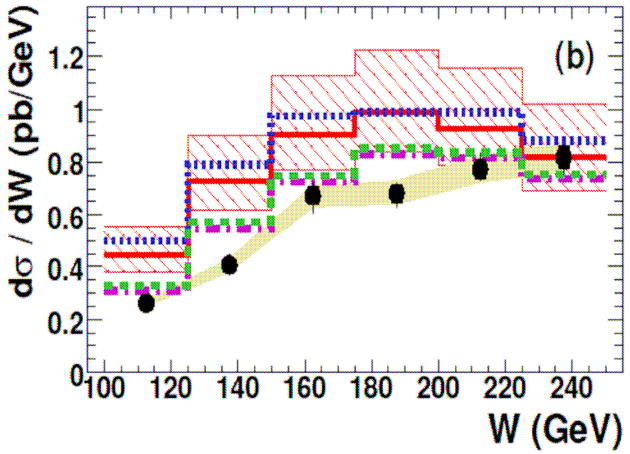
Quantitative predictions require a model, *e.g.* KKMR

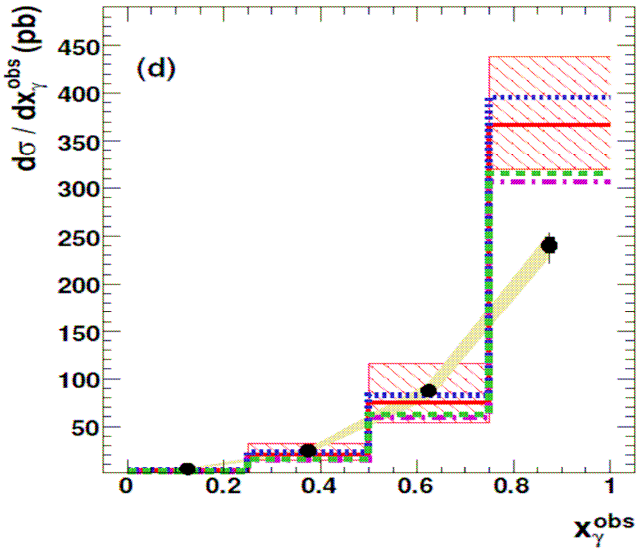
Diffractive DIS data vs. NLO QCD

Eur.Phys.J.C52:813-832,2007 1999-2000 data, 61 pb^{-1}

$Q^2 \in [5,100]\,\mathrm{GeV}^2 \quad E^*_{\perp 1} > E^*_{\perp 2},\ E^*_{\perp 1} > 5\,\mathrm{GeV},\ E^*_{\perp 2} > 4\,\mathrm{GeV}$ in CM(γ*p)







NLO QCD predictions from DISENT
(Catani, Seymour)

DPDFs used:
- ZEUS LPS+charm fit
- H1 fit 2006 - A
- H1 fit 2006 - B
- MRW 2006 fit

Best agreement for **H1 2006-B** and **Martin-Ryskin-Watt**

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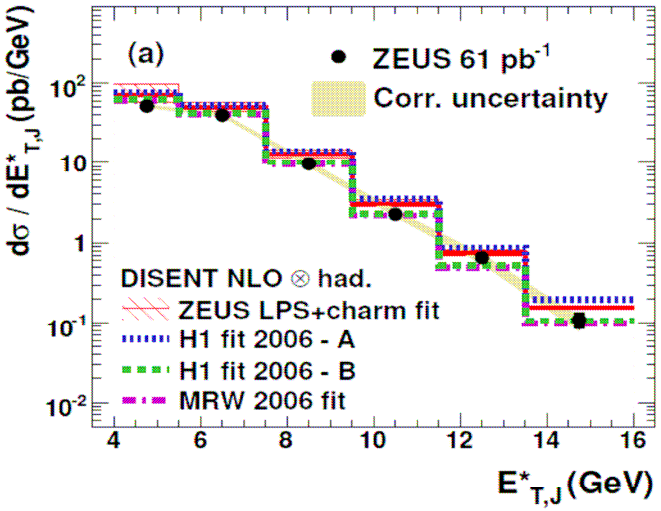

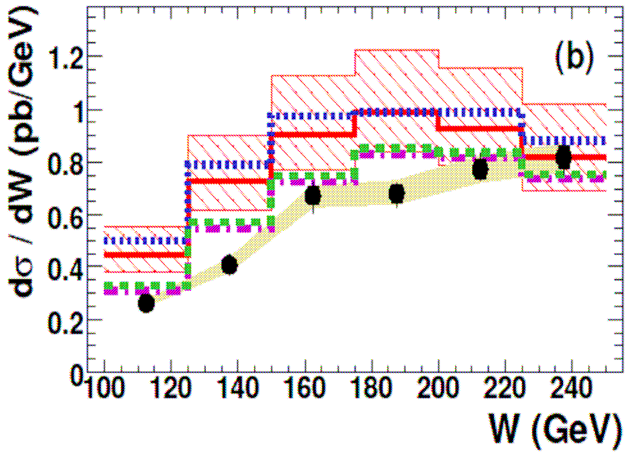

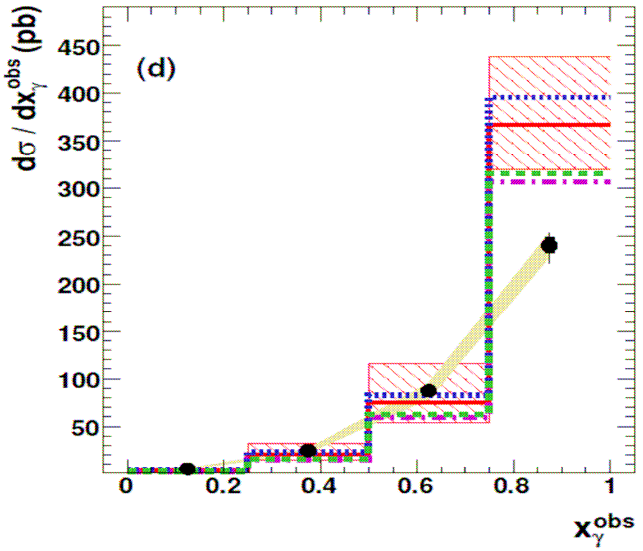

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NLO vs. data
- Agreement depends on kinematic region
- Varies from very good to ~25% above the data

Known uncertainties for D-DIS JJ predictions

- Large scale dependence
  - ➢ higher orders of QCD important
  - – *e.g.* $\mu_F = Q$ used in DISENT
    changing μ_F to E_{T1} could significantly decrease σ
- Flavour Scheme dependence
  - – DPDFs fitted using 3-flavour FFNS + massive *c, b*
  - – dijets calculated with all flavours massless – ZM-VFNS
  - ➢ another ~10% effect expected
- Gluon content of the Pomeron
  - – poorly constrained by the fit to the inclusive D-DIS data
  - – H1 estimate: 15% at low z_P, grows at higher z_P
- Proton dissociation correction factor
  - – H1 estimate (DIFFVM): $0.87^{+0.07}_{-0.10}$
  - ➢ next 10% uncertainty

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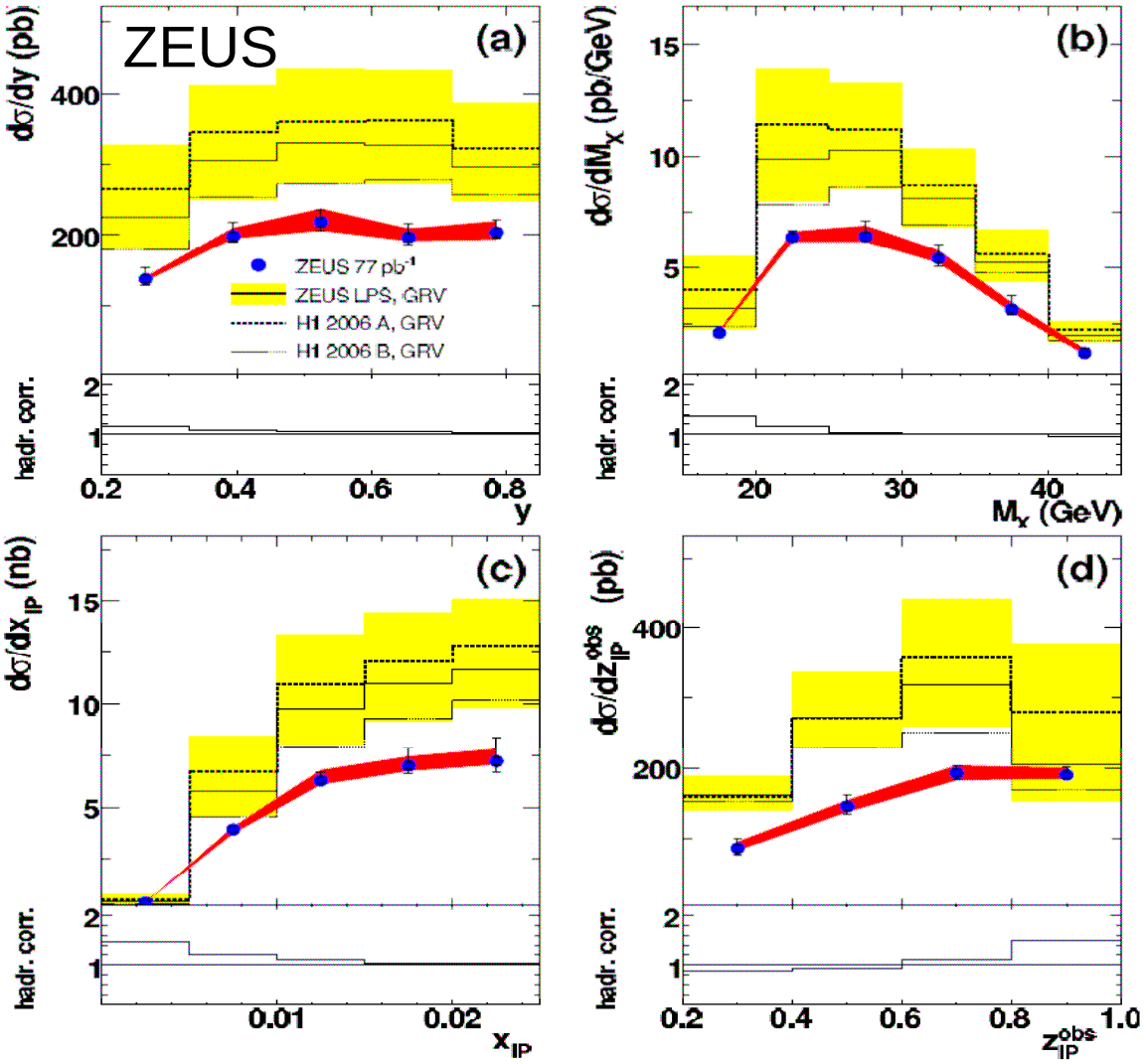
20% – 30% DIS vs. NLO discrepancy is within known uncertainties

Diffractive PHP data vs. NLO QCD (1)

Accepted by EPJC, arXiv:0710.1498 1999-2000 data, 77.2 pb^{-1}

$Q^2 < 1\,\mathrm{GeV}^2$ $E_{\perp 1} > E_{\perp 2}$, $E_{\perp 1} > 7.5\,\mathrm{GeV}$, $E_{\perp 2} > 6.5\,\mathrm{GeV}$ in LAB



NLO predictions obtained *assuming factorisation*

Computer codes:

1. Klasen & Kramer
2. Frixione & Ridolfi

} *Same results*

PDFs used:

GRV-HOγ ⊗

ZEUS LPS

H1 2006-A

H1 2006-B

Closest to the data

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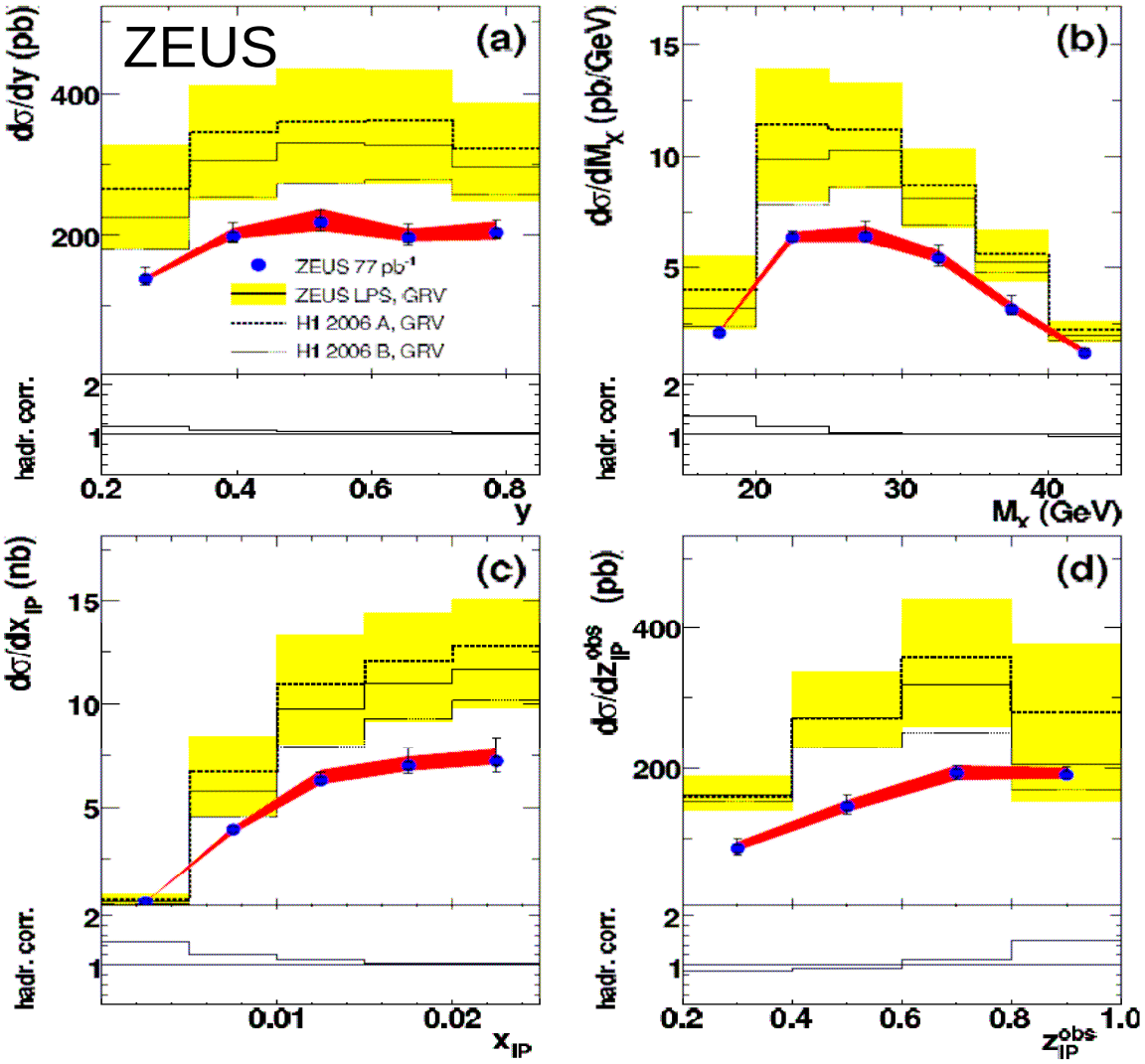

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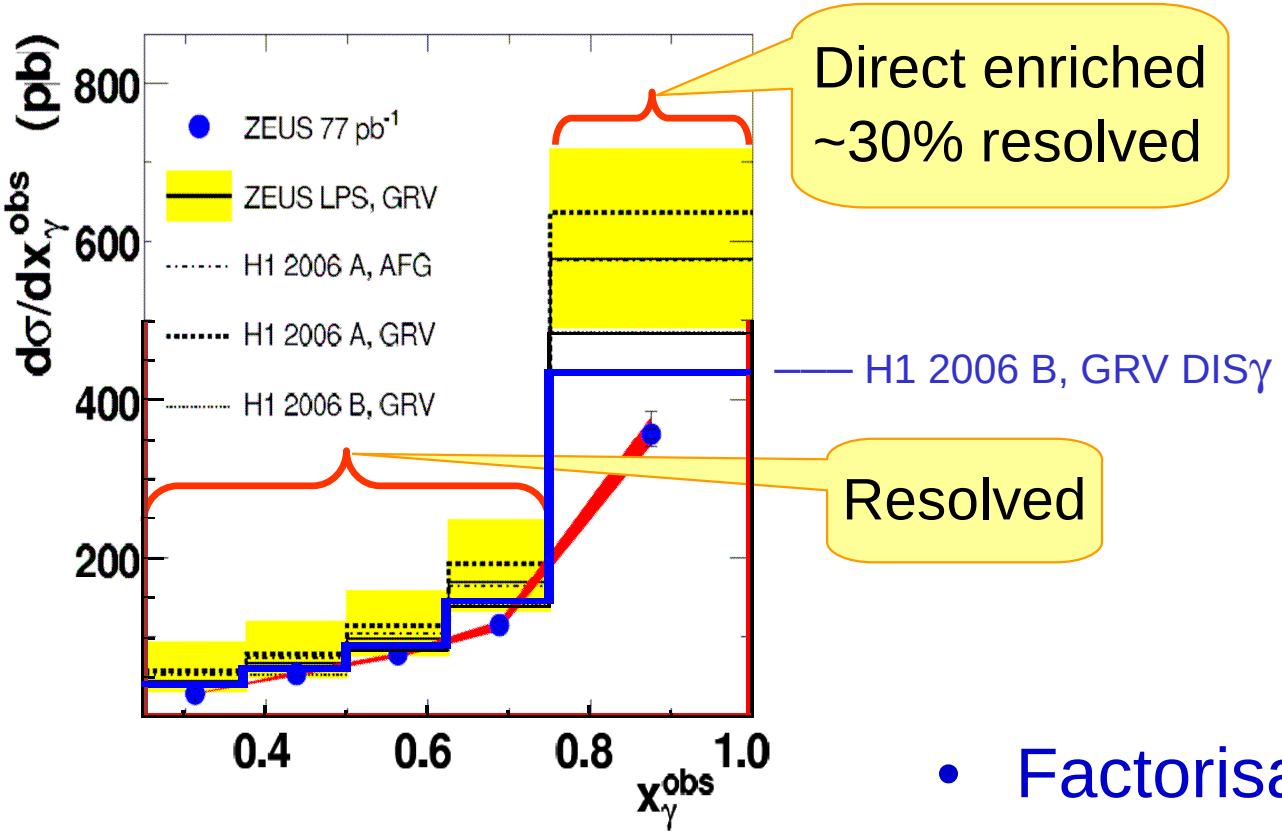
Closest to the data

NLO vs. data
the level of
(dis)agreement ~ DIS

Diffractive dijet PHP vs. x_γ



Direct enriched
~30% resolved

H1 2006 B, GRV DISγ

Resolved

Nb. kinematics

$$yx_\gamma x_P z_P > \frac{4E_\perp^2}{s}$$

$$x_P < 0.025$$

$$yx_\gamma z_P > 0.1$$

$$x_\gamma^{\text{obs}} = \frac{E_{\perp 1} e^{-\eta_1} + E_{\perp 2} e^{-\eta_2}}{2yE_e}$$

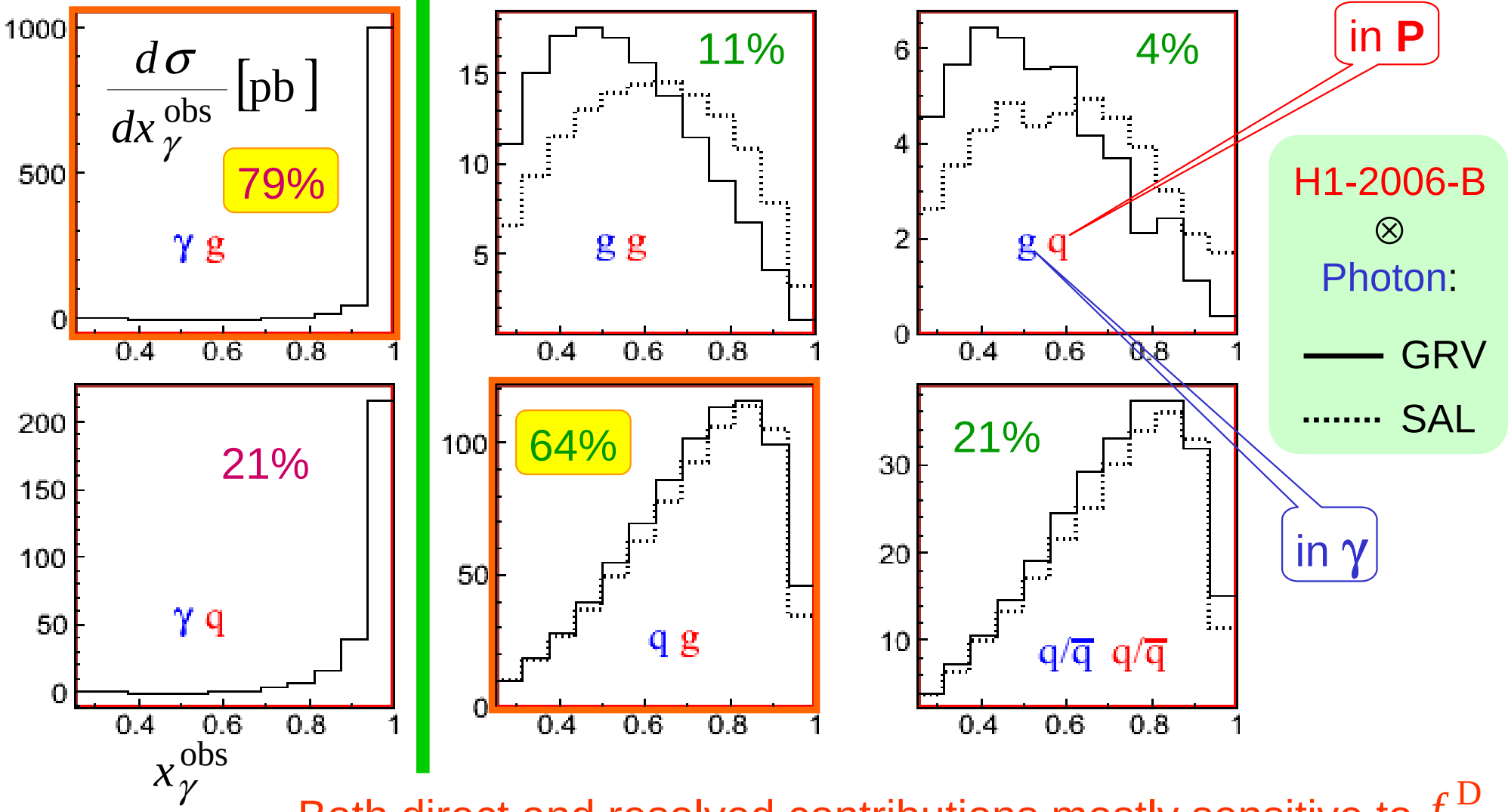
= estimator of x_γ – parton from the photon fractional momentum

- Factorisation should hold for direct photon – $x_\gamma = 1$
- Suppression – if any – expected for resolved photon – $x_\gamma < 1$

PHP sensitivity to PDFs f_k^{γ} and f_k^{D}

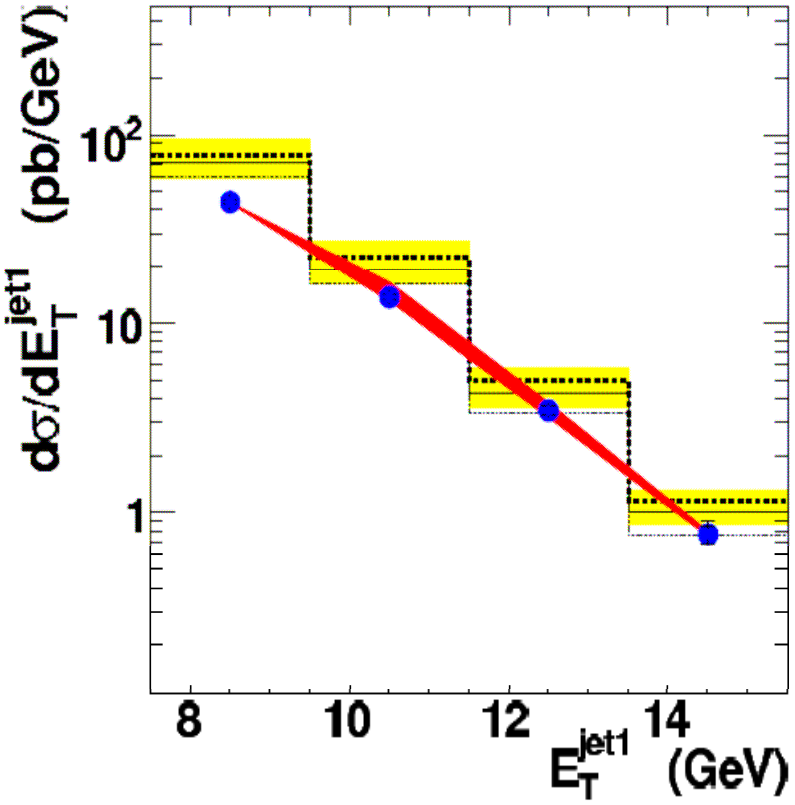
σ direct = 83.5 pb

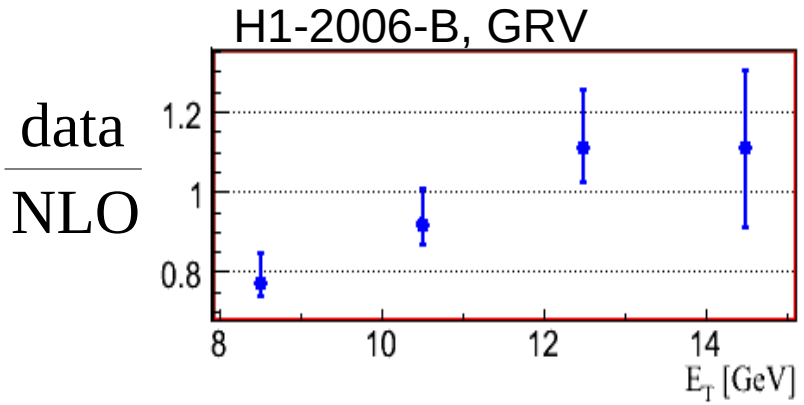
σ resolved = 77.2 pb (GRV), 71.5 pb (SAL)



Both direct and resolved contributions mostly sensitive to f_g^{D}

Diffractive dijet PHP vs. E_T





ZEUS	H1
$E_{\perp 1} > 7.5\,\text{GeV},$	$E_{\perp 1} > 5\,\text{GeV},$
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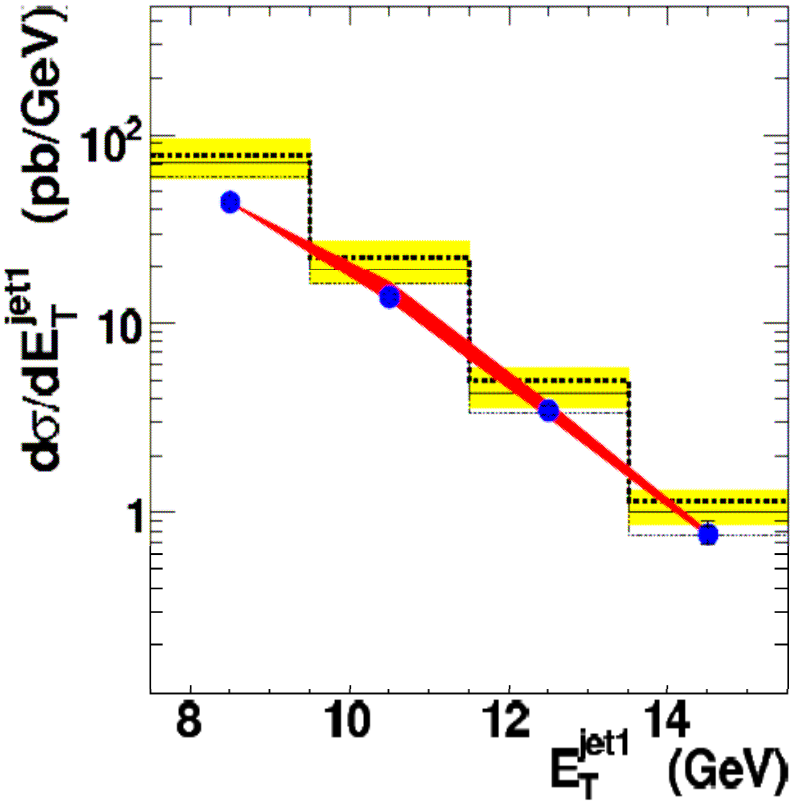
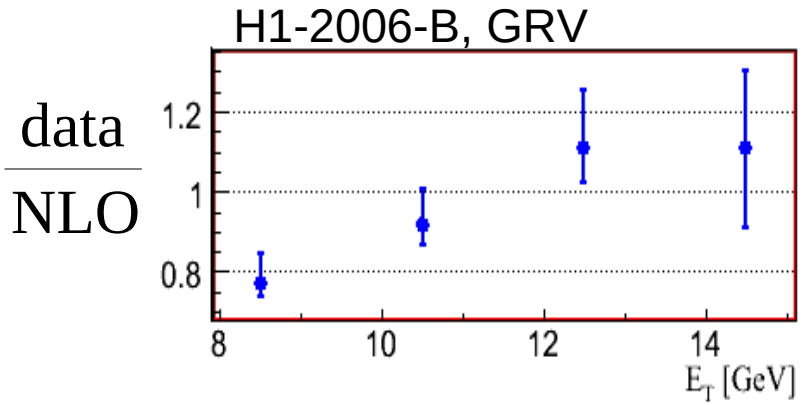
Hardly any suppression except in lowest E_T bin	~50% suppression observed

Diffractive dijet PHP vs. E_T





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A signal of possible suppression increase at small E_T

Known uncertainties for D-PHP JJ predictions

- Large scale dependence
  - still higher for resolved photon
- Flavour Scheme dependence
- Gluon content of the Pomeron
- Proton dissociation correction

} *as in DIS*

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  - quite safe for $x_\gamma > 0.2$

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Again up to ~30% uncertainty

Conclusions & Outlook

- Diffractive dijet production at HERA measured by ZEUS in wide range of photon virtualities – from 0 to 100 GeV^2
- Experimental errors much smaller than theoretical uncertainties
- Within these uncertainties data compatible with the factorisation assumption
  - suppression of 0 – 20% compatible with the data
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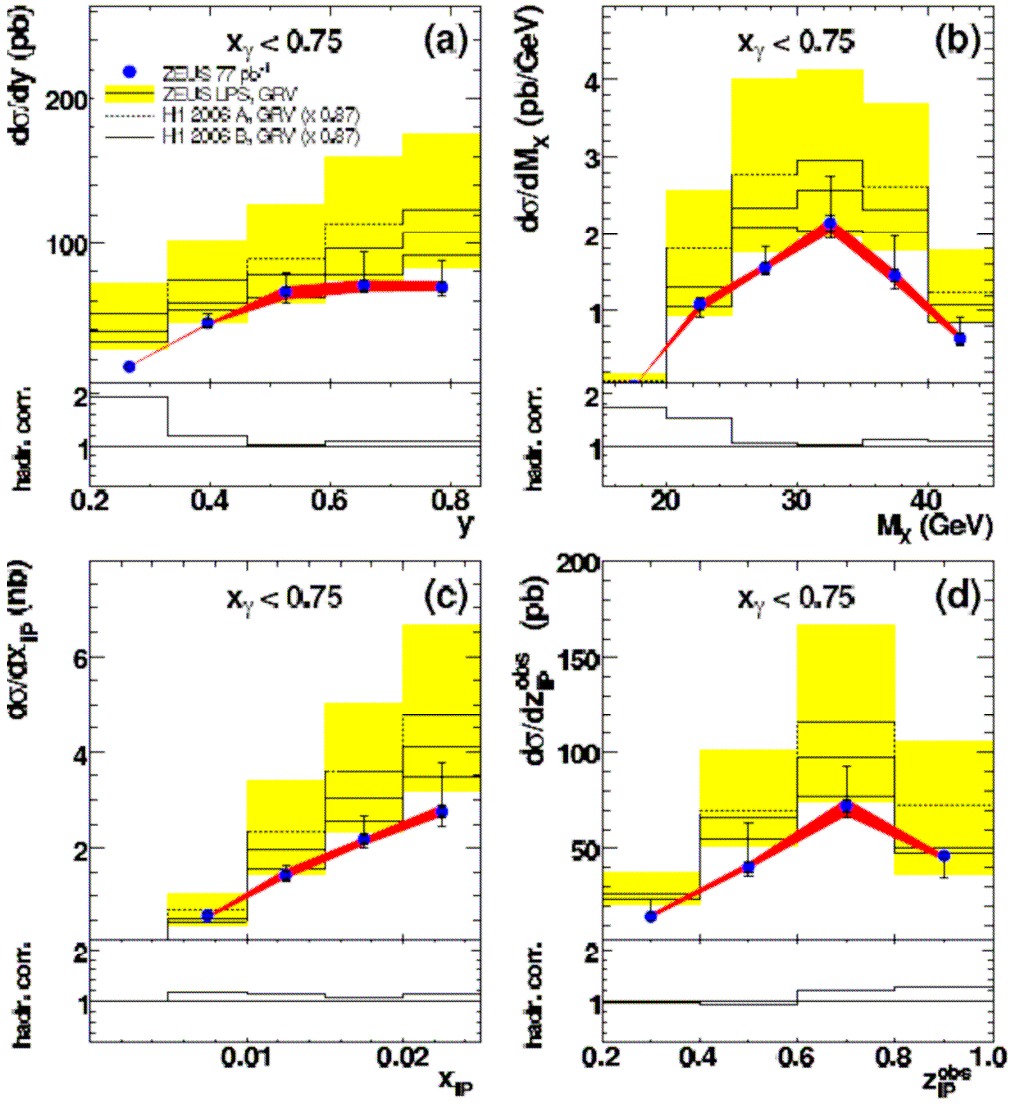
- Cross-sections' ratios can be useful
  - like PHP/DIS or dijets/inclusive
  - the ratio $\langle PHP/DIS \rangle_{data} / \langle PHP/DIS \rangle_{NLO}$ under study

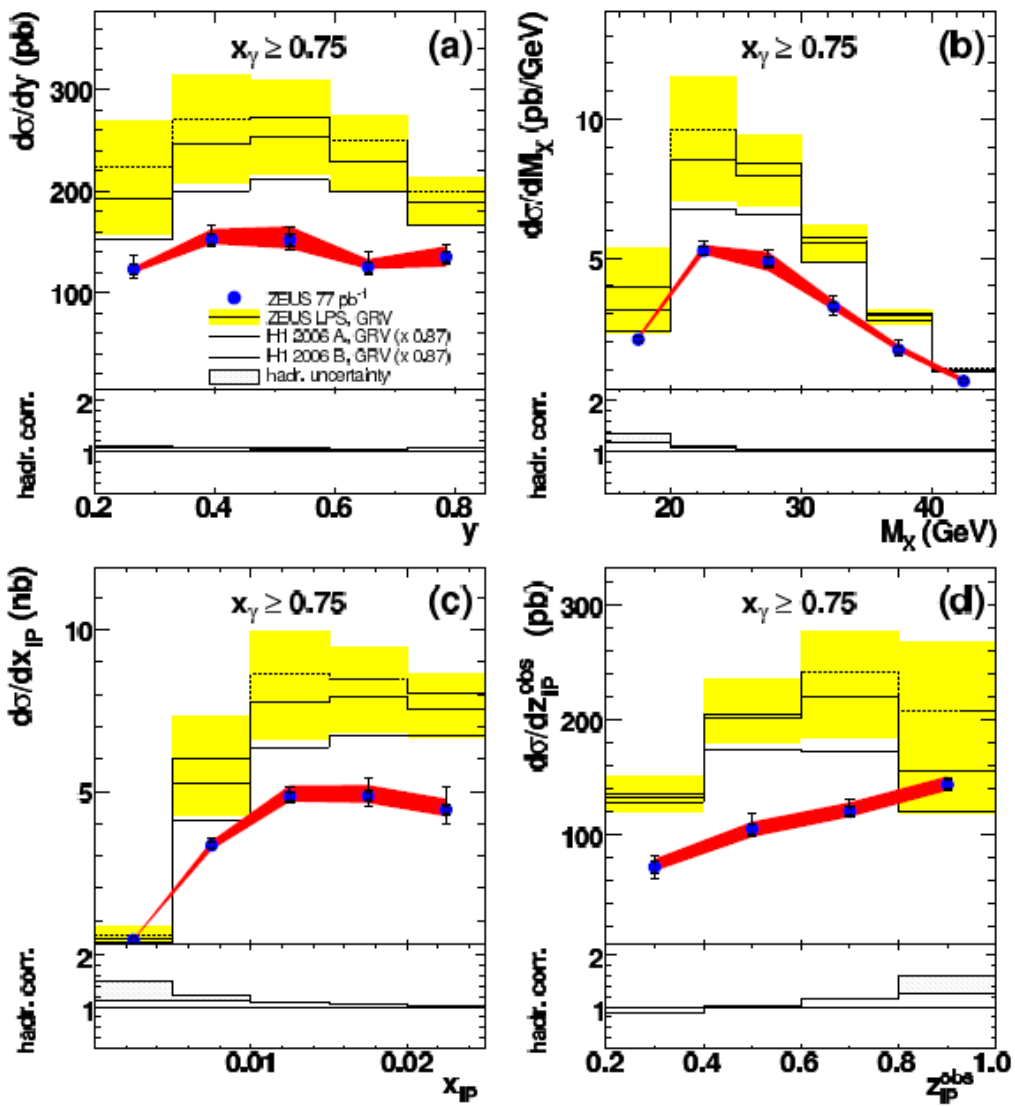
EXTRAS

Resolved- vs. Direct-enriched PHP

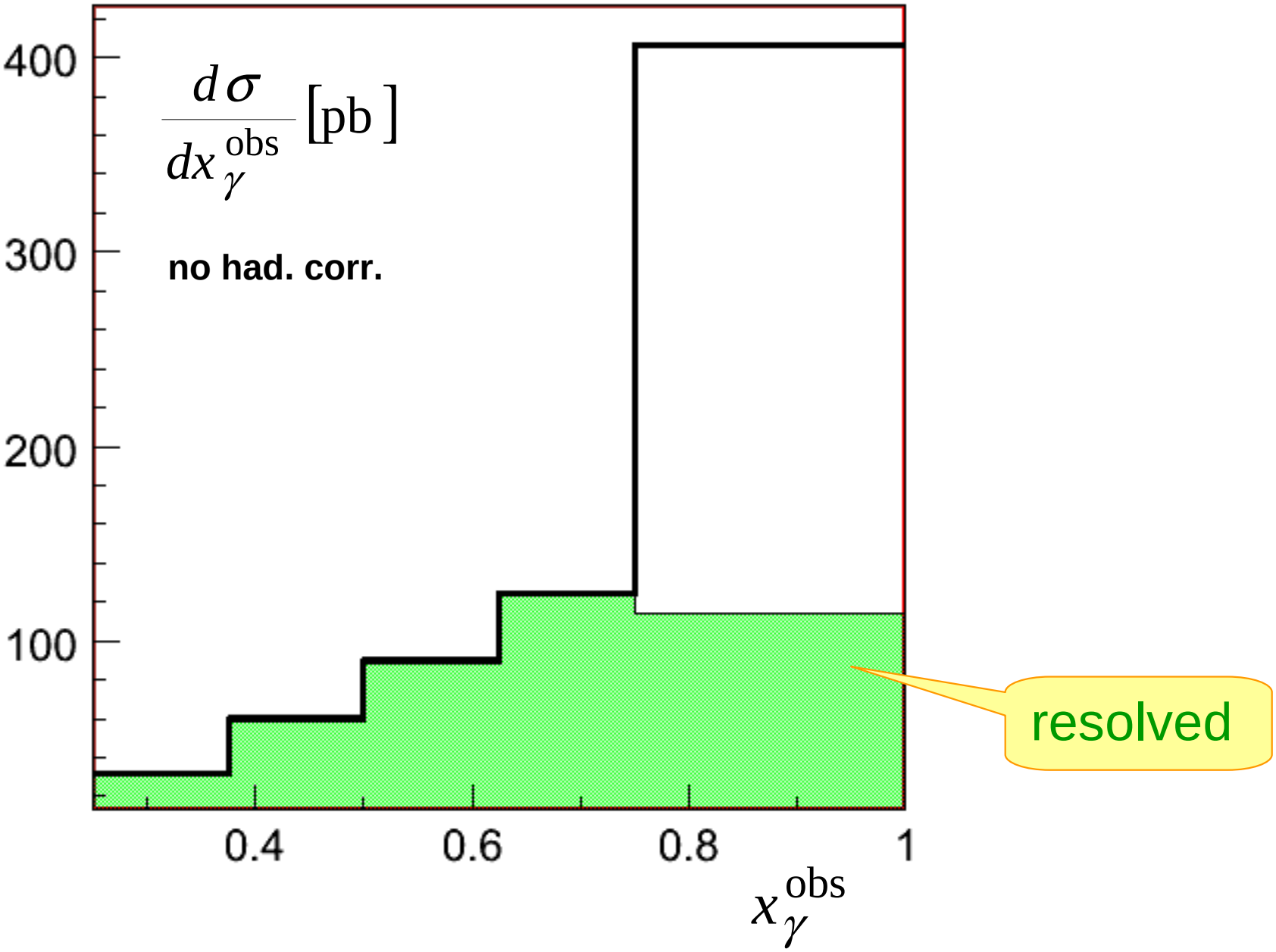
$x_\gamma^{\mathrm{obs}} < 0.75$



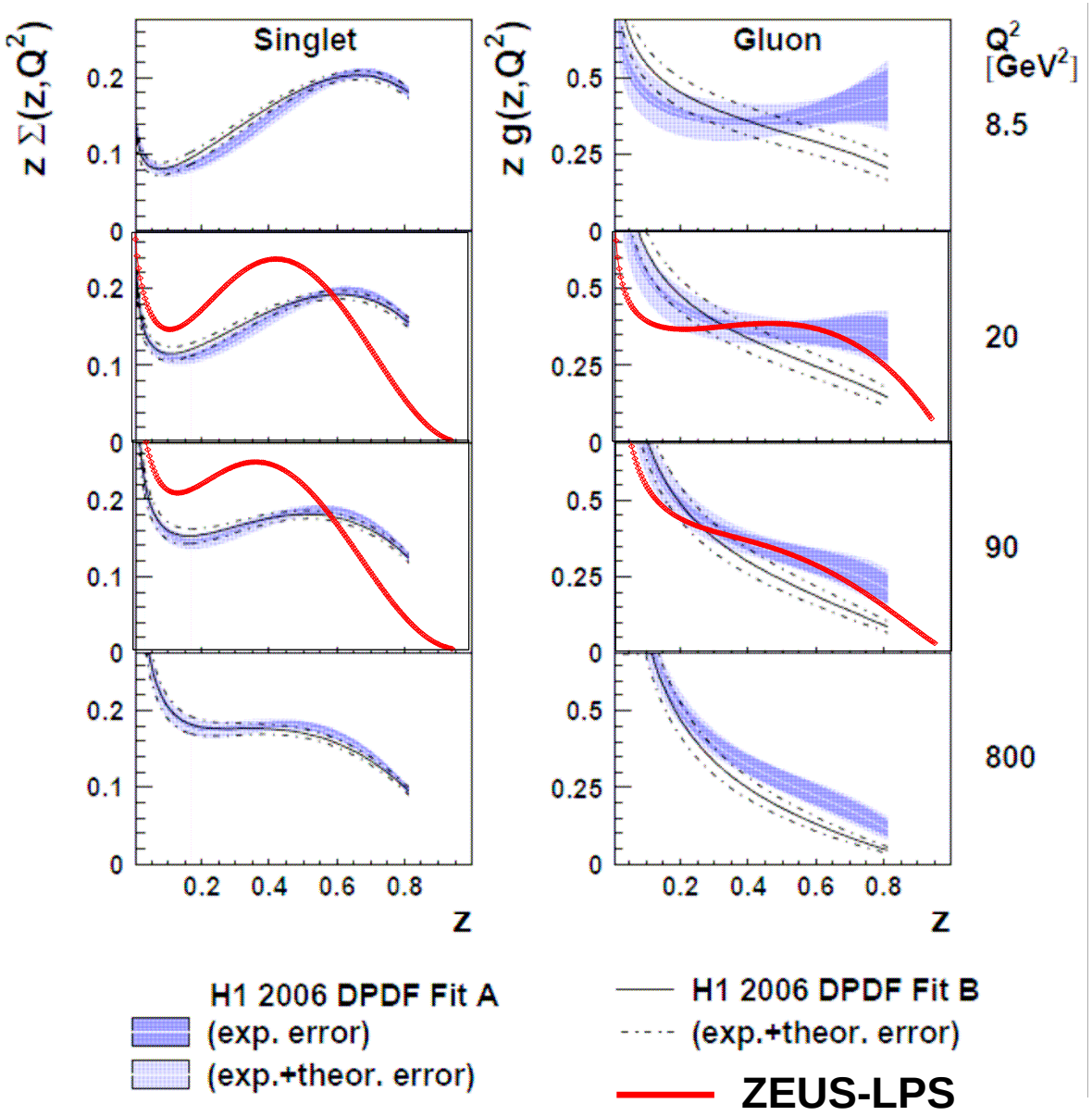
$x_\gamma^{\mathrm{obs}} \geq 0.75$



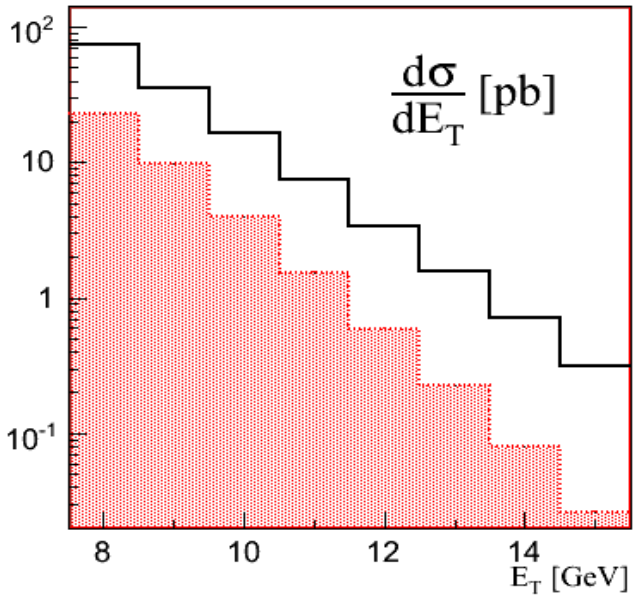
Resolved contribution



DPDFs – H1-2006 and ZEUS-LPS



E_T dependence



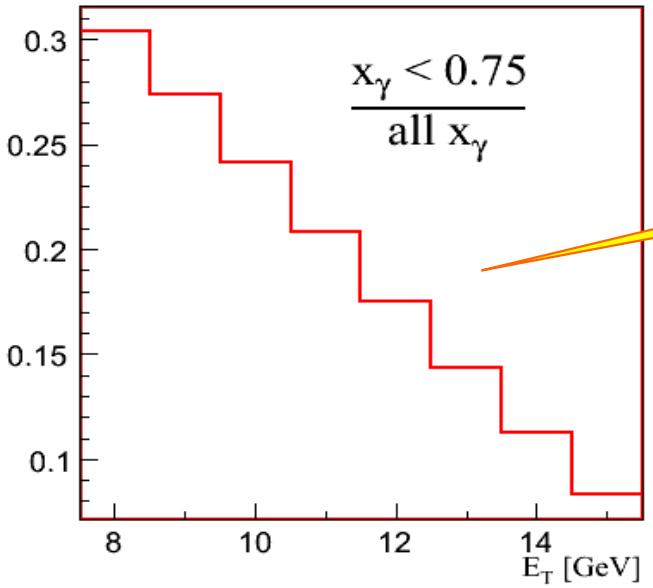
FR ZEUS

DPDF = H1-2006B * 0.87

Nf = 4, Λ = 330 MeV, α(10 GeV) = 0.175

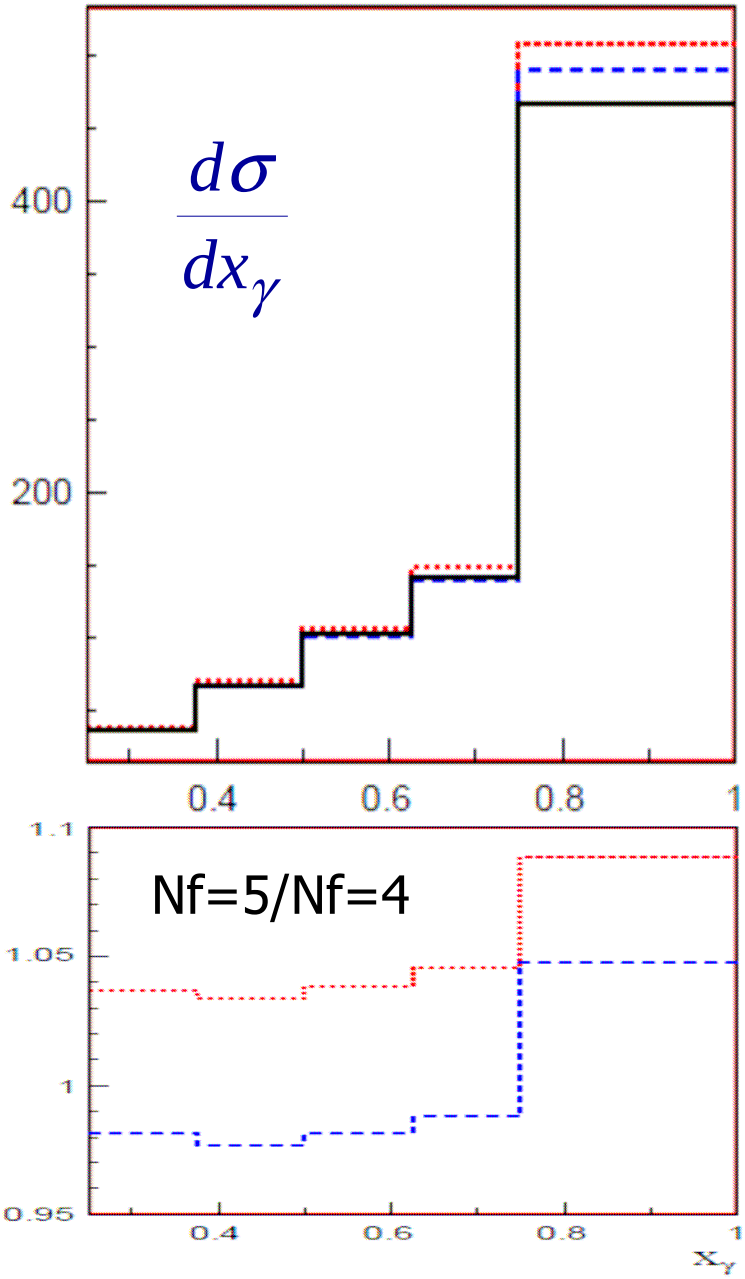
all x_γ, σ = 140 pb

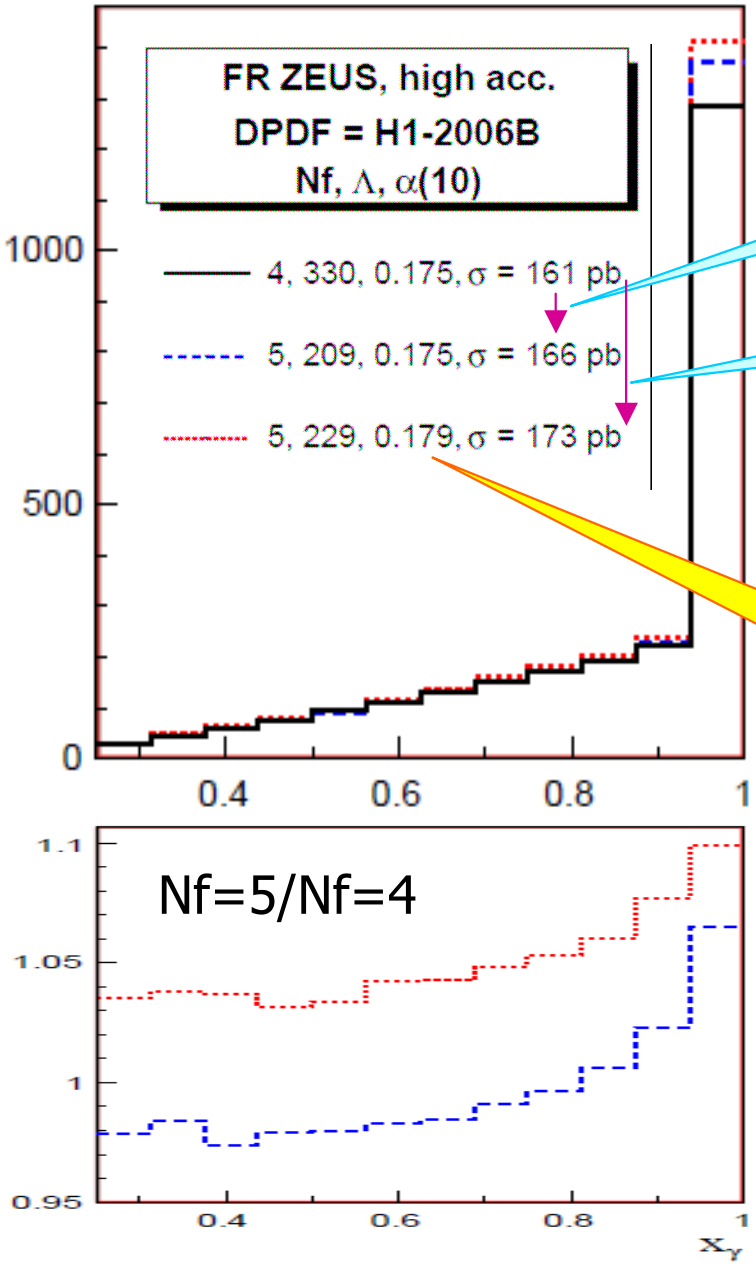
$x_\gamma < 0.75$, σ = 39 pb



Resolved γ decreases with E_T

N_f dependence





3%

7%

$\alpha_s(\mu, N_f)$ grows with N_f