

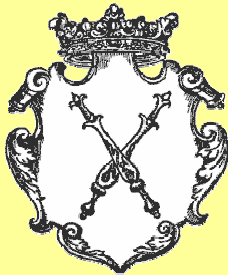
Dijets in Diffractive Deep Inelastic Scattering and Photoproduction

DIS 2008

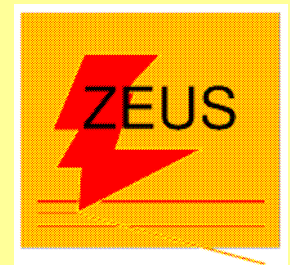
Diffractive and Vector Mesons parallel session

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 $\sqrt{s} = 318$ GeV

$$e^\pm p \rightarrow e^\pm p j_1 j_2 \dots$$

or

$$\gamma p \rightarrow p j_1 j_2 \dots$$

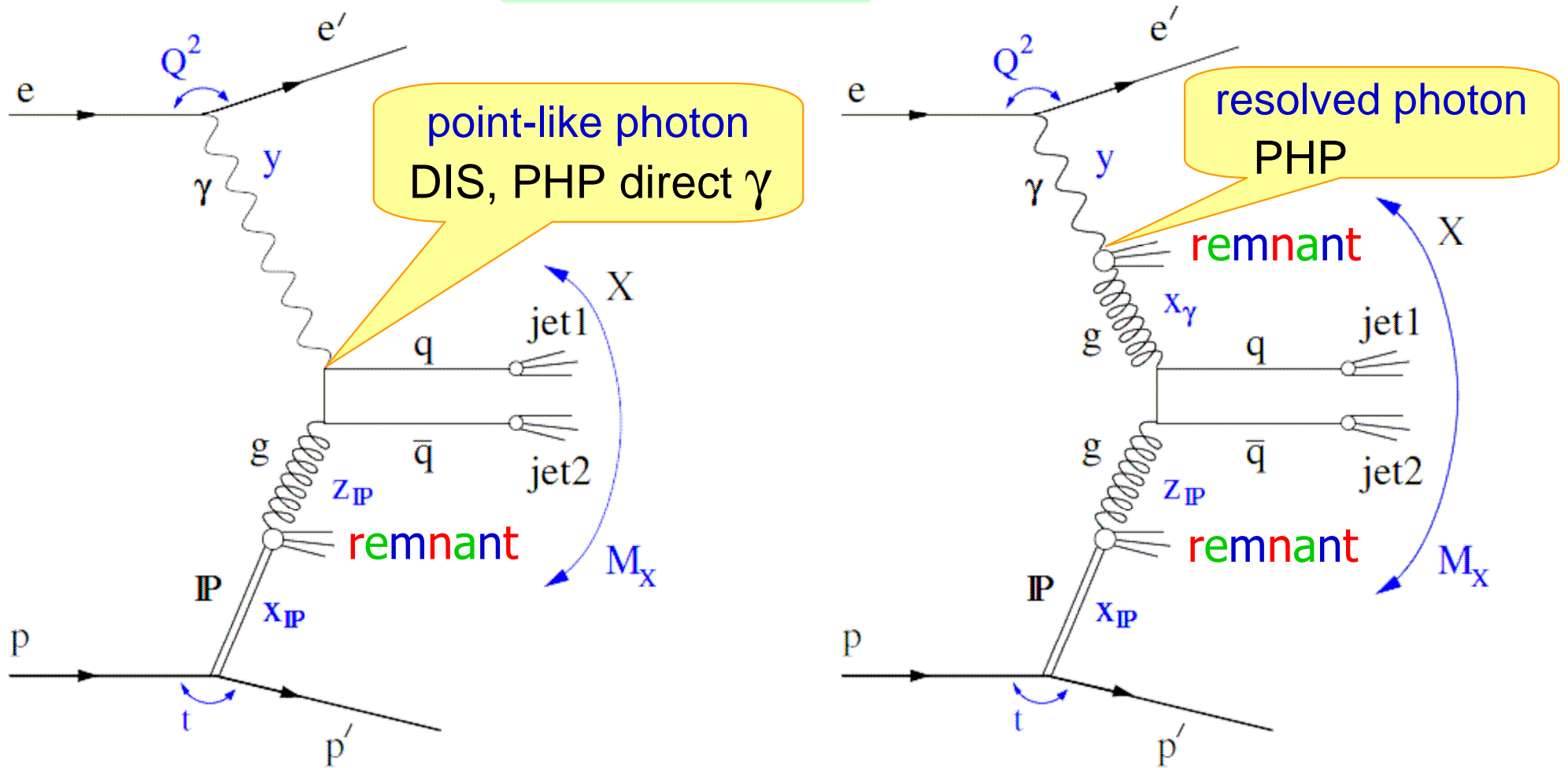
photon diffractive dissociation
into a state containing two
large p_T (E_T) jets, j_1, j_2

Two important kinematic regions

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

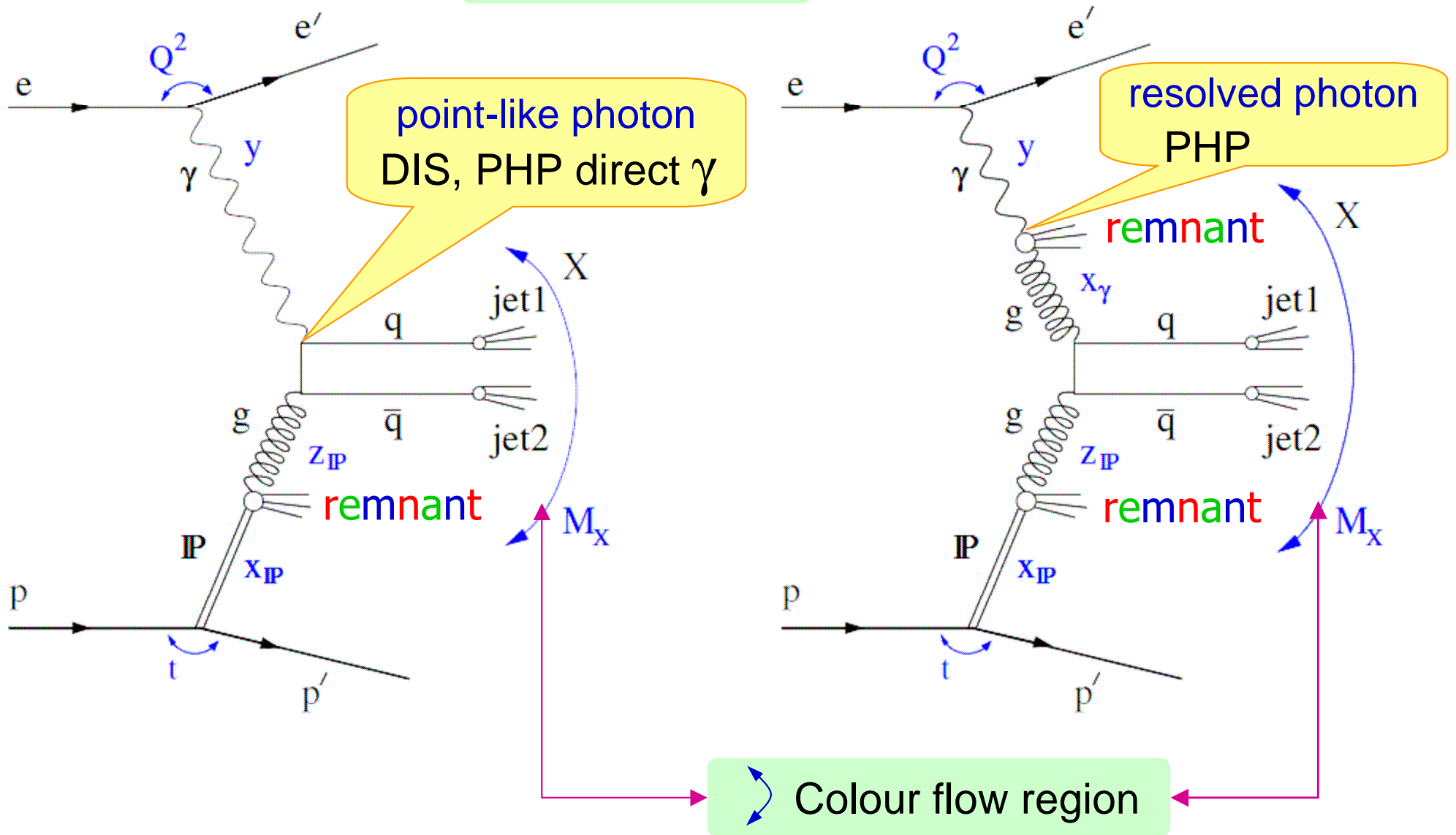
Dijets in diffractive ep scattering

LO intuitive view



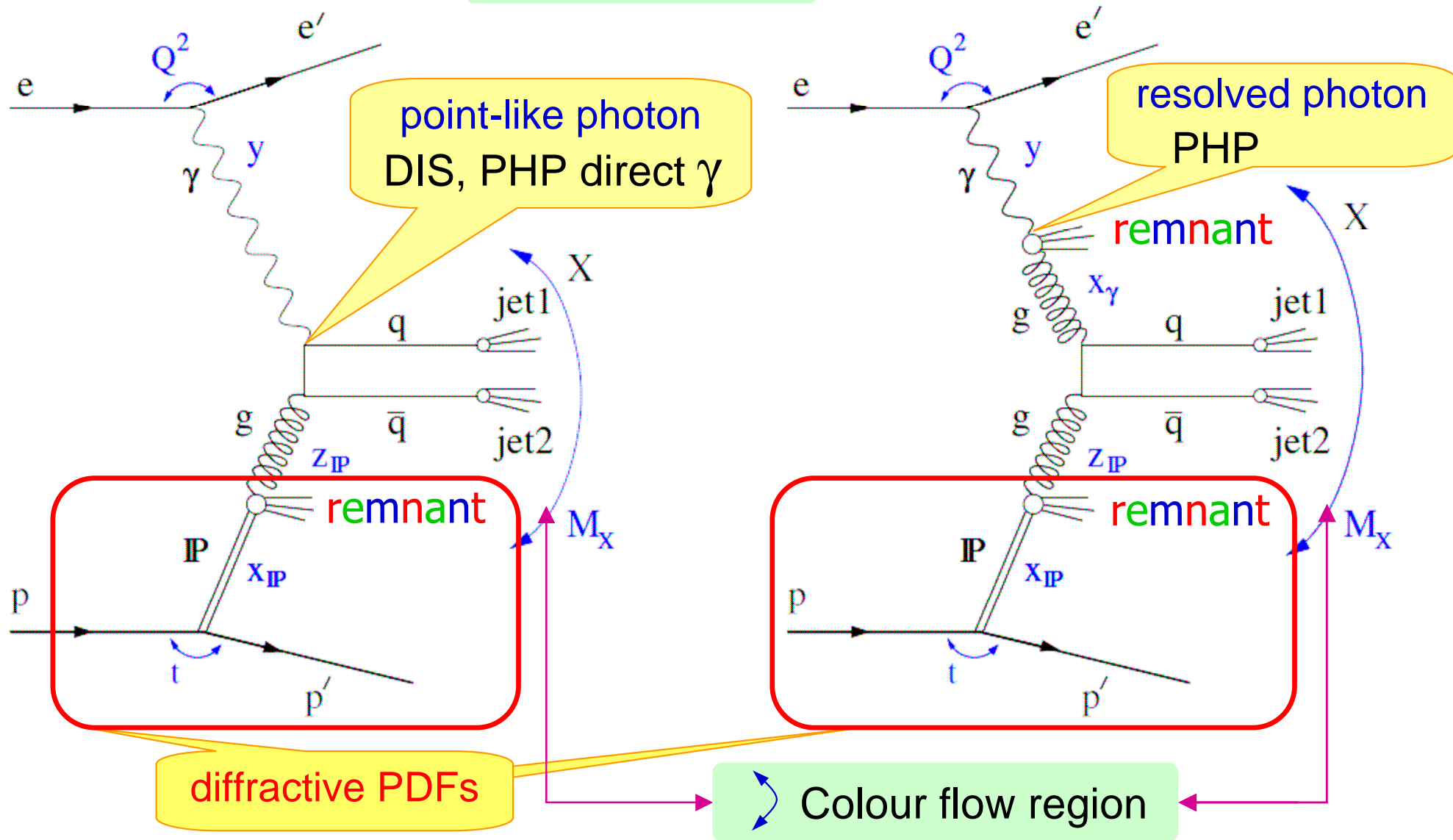
Dijets in diffractive ep scattering

LO intuitive view



Dijets in diffractive ep scattering

LO intuitive view



DIS vs. PHP cross-sections

Point-like photon

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

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

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

Factorisation assumed → we want to test it experimentally

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

What we want to learn

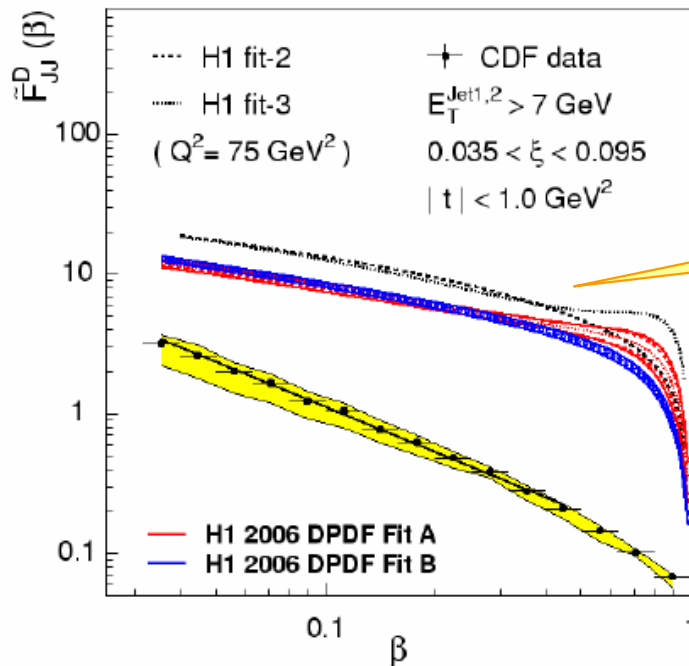
- Diffractive gluon content of the proton
 - DPDFs are extracted from inclusive diffractive DIS
 - DDIS is mainly sensitive to quarks, while gluons contribute at higher orders and via DGLAP evolution
 - dijet production is directly sensitive to f_g^D
- Does factorisation hold for the diffractive dijet 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



NLO predictions
with DPDFs from HERA

~ order of magnitude suppression

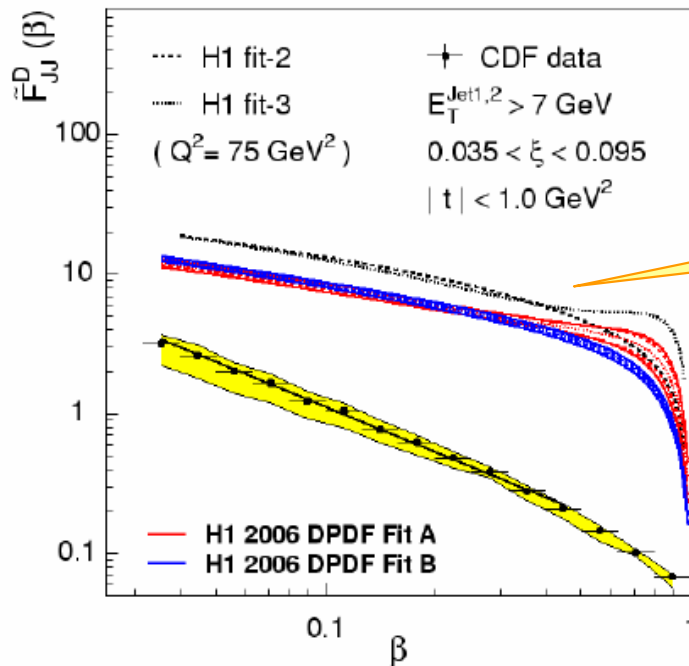
$$\beta = \frac{Q^2}{2(p - p')q} \approx \text{parton in IP fract. momentum} = z_P$$

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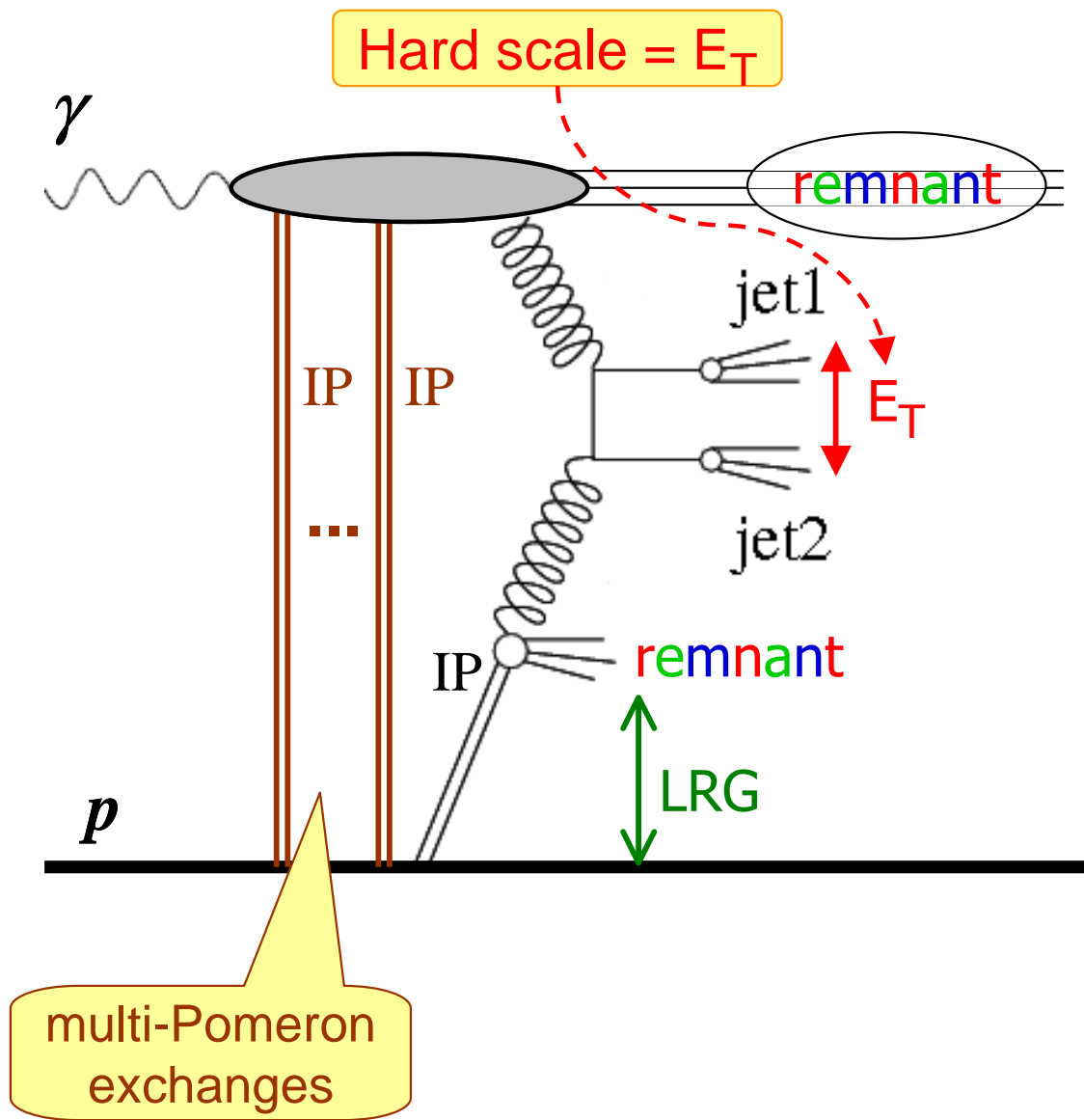
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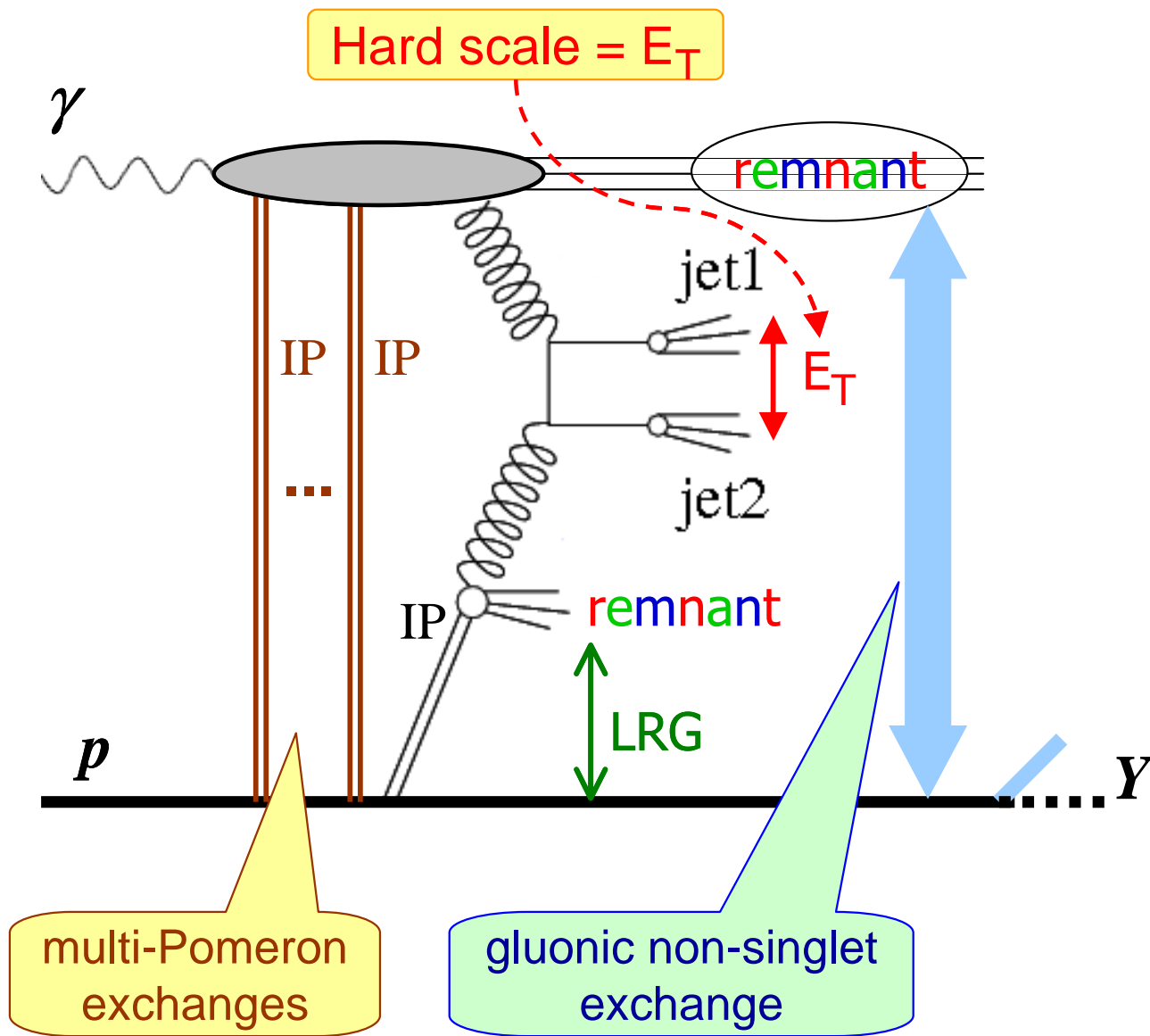
TEVATRON: projectile = proton, HERA: projectile = photon

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

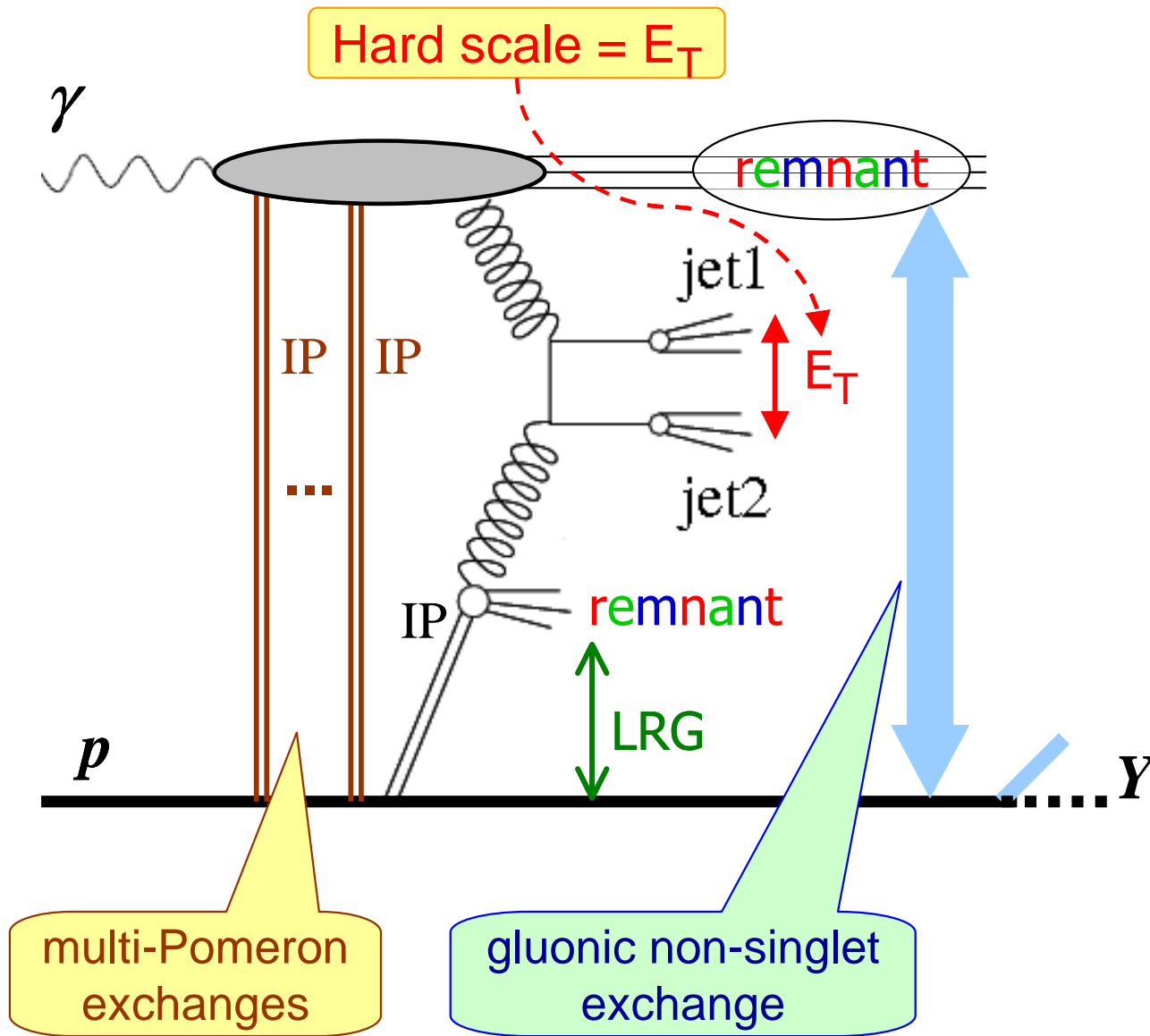
Rescattering effects for hadron-like photon



Rescattering effects for hadron-like photon



Rescattering effects for hadron-like photon



Rescattering leads to:

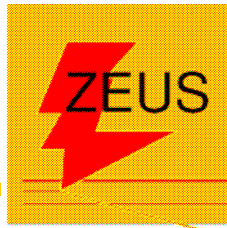
- Factorisation breaking
- Screening
- Rapidity gap fill-up

Suppression
of the cross-section
 $\approx 1 - (\text{rapidity gap survival probability})$

By general arguments
we would expect it
to decrease with E_T

Quantitative predictions
require a model,
e.g. KKMR

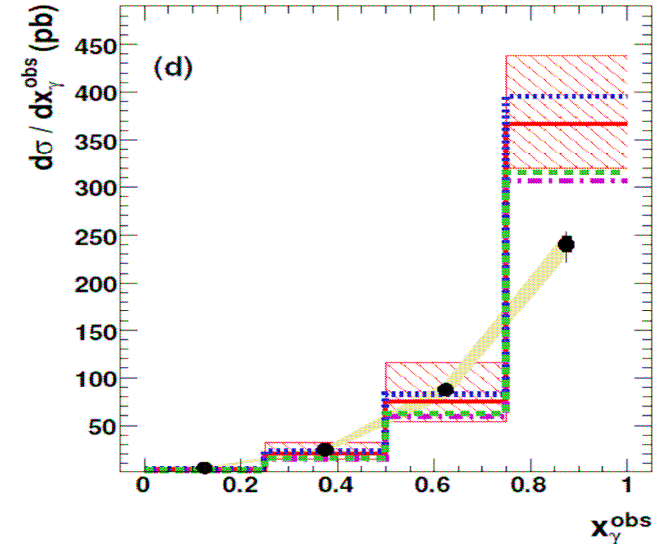
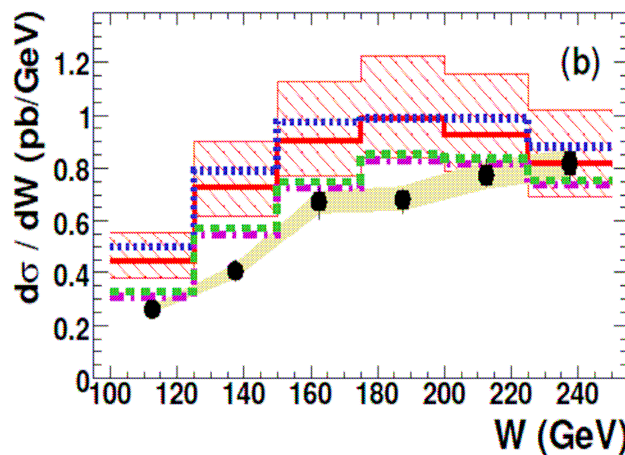
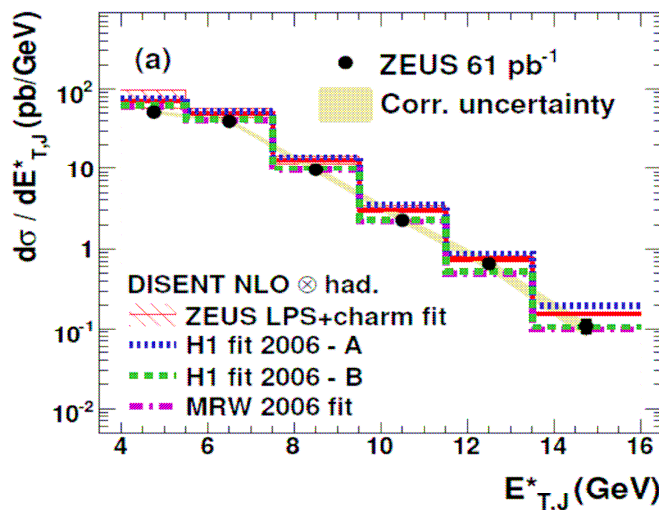
Diffractive *DIS* data vs. NLO QCD



*Eur.Phys.J.C*52:813-832,2007

1999-2000 data, 61 pb⁻¹

$$Q^2 \in [5, 100] \text{ GeV}^2 \quad E_{\perp 1}^* > E_{\perp 2}^*, \quad E_{\perp 1}^* > 5 \text{ GeV}, \quad E_{\perp 2}^* > 4 \text{ GeV} \quad \text{in CM}(\gamma^*p)$$



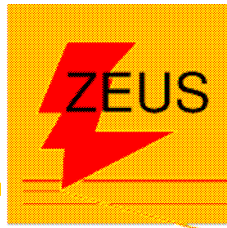
NLO QCD predictions from DISENT
(Catani, Seymour)

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

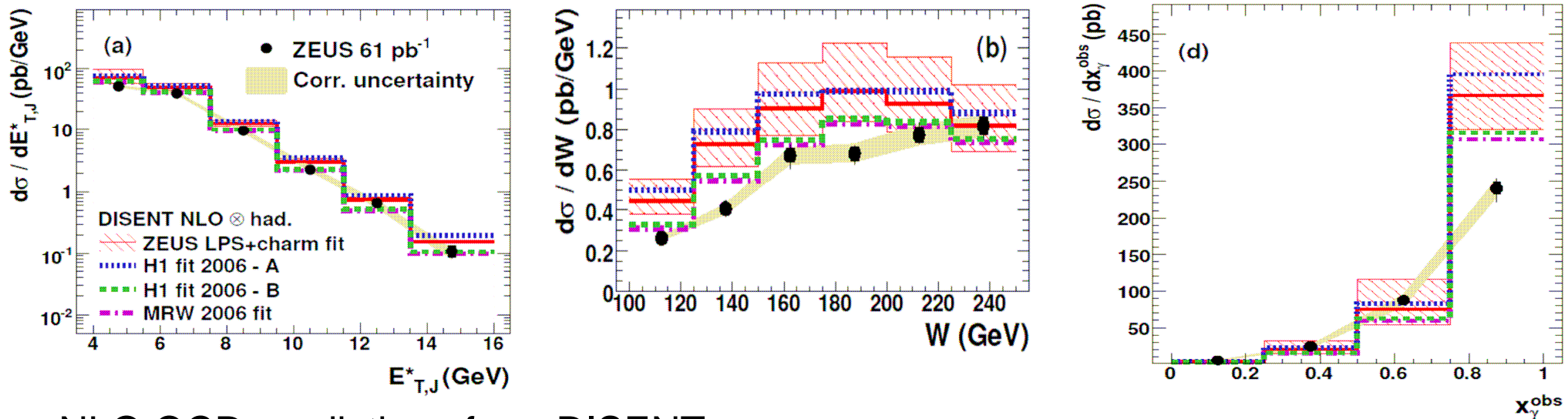
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NLO vs. data

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

Known uncertainties for D-*DIS* JJ predictions

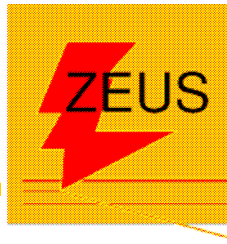
- Large scale dependence
 - higher orders of QCD important
 - e.g. $\mu_F = Q$ used in DISENT
changing μ_F to E_{T1} could significantly decrease σ
- Flavour Scheme dependence
 - DPDFs fitted using 3-flavour FFNS + massive c, b
 - dijets calculated with all flavours massless – ZM-VFNS
 - another $\sim 10\%$ 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

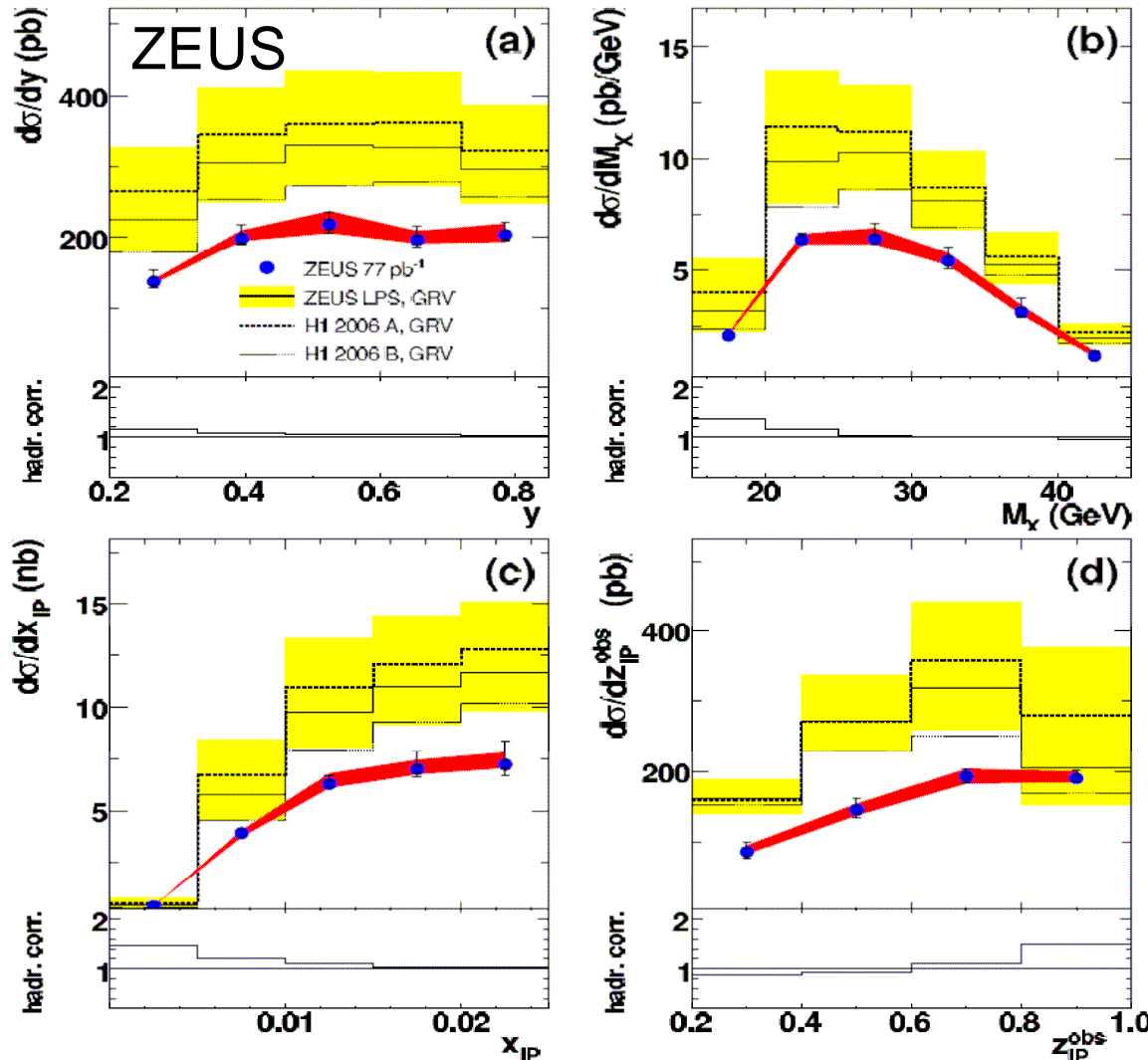
Diffractive *PHP* data vs. NLO QCD (1)



Accepted by EPJC, arXiv:0710.1498

1999-2000 data, 77.2 pb⁻¹

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



NLO predictions obtained
assuming factorisation

Computer codes:

1. Klasen & Kramer
 2. Frixione & Ridolfi
- } *Same results*

PDFs used:

GRV-HO γ \otimes

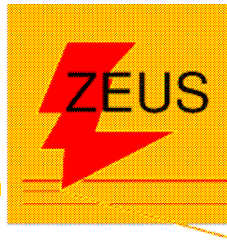
ZEUS LPS

H1 2006-A

H1 2006-B

Closest to
the data

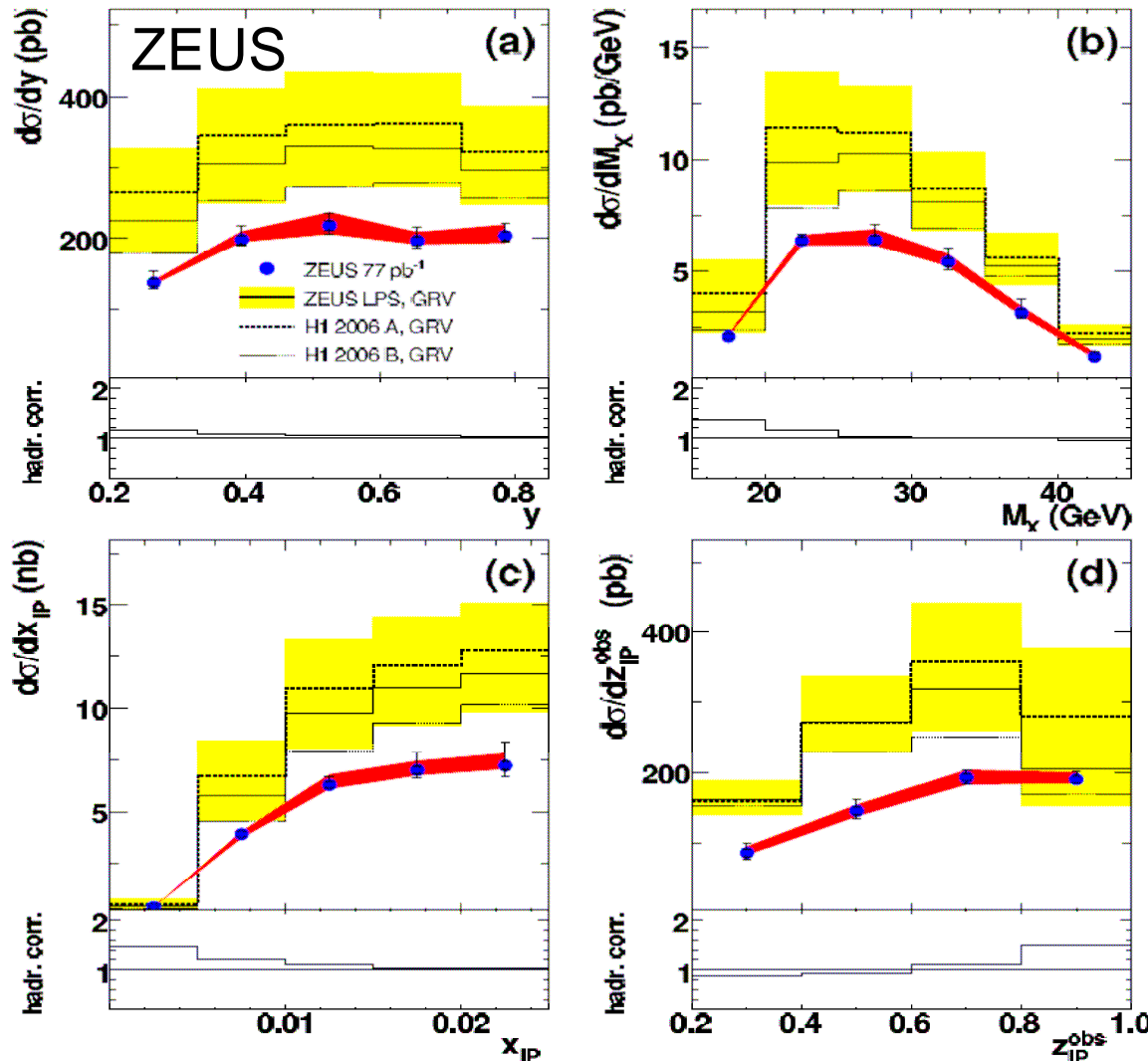
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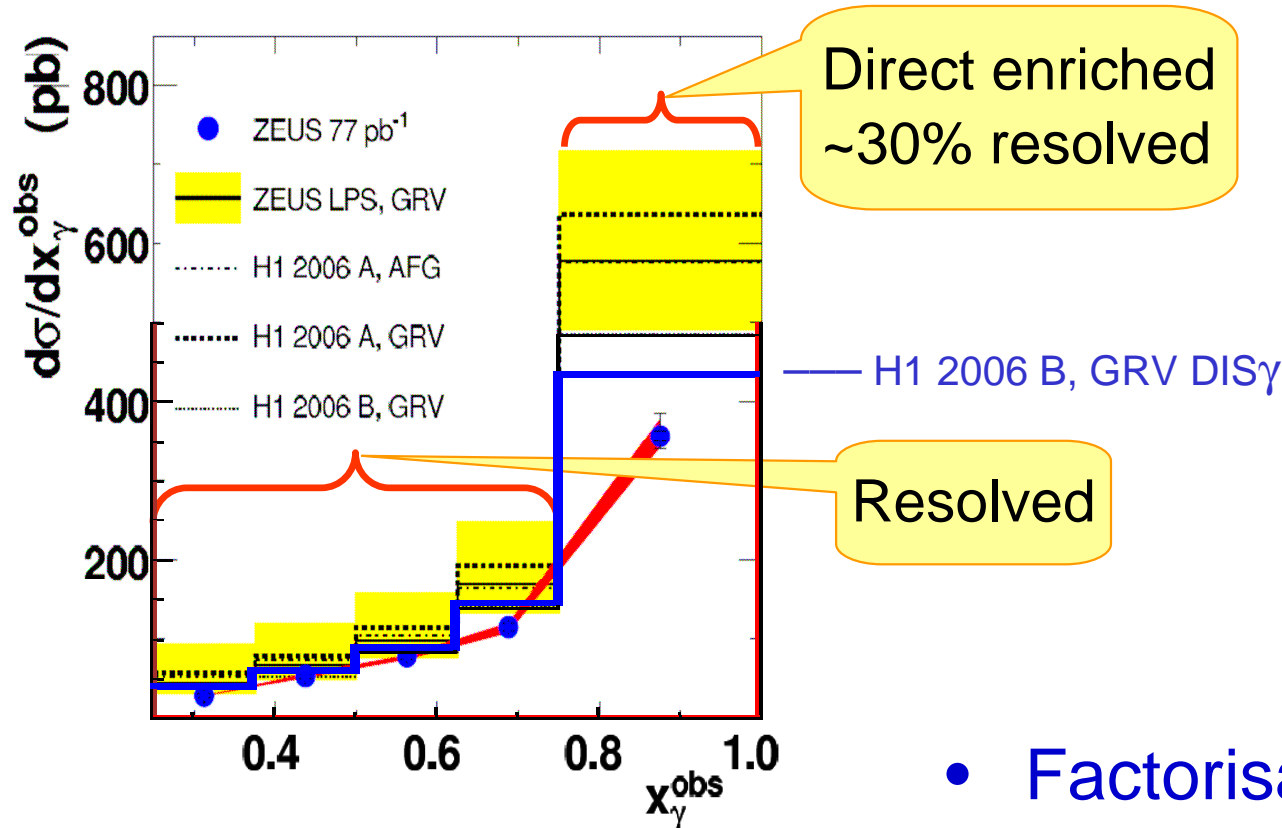
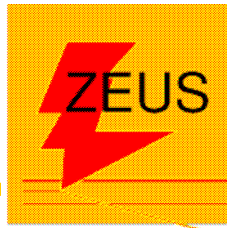
H1 2006-A

H1 2006-B

Closest to
the data

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

Diffractive dijet *PHP* vs. x_γ



Nb. kinematics

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

$$x_P < 0.025$$

$$yx_\gamma z_P > 0.1$$

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

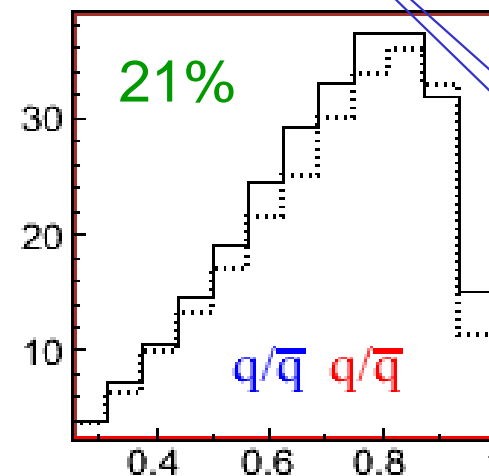
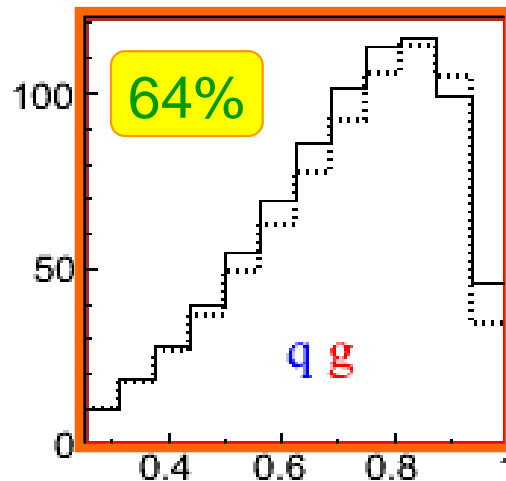
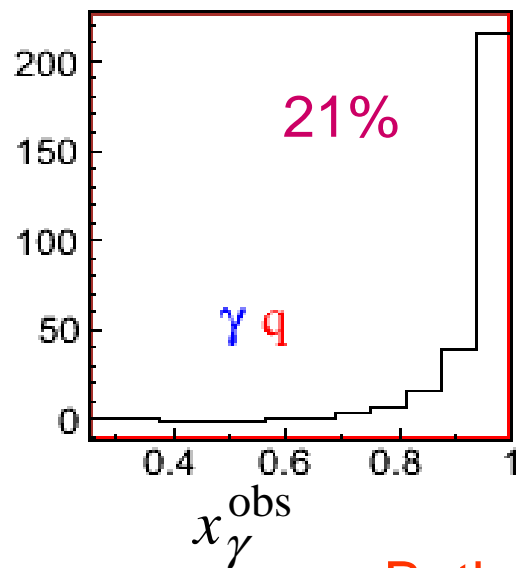
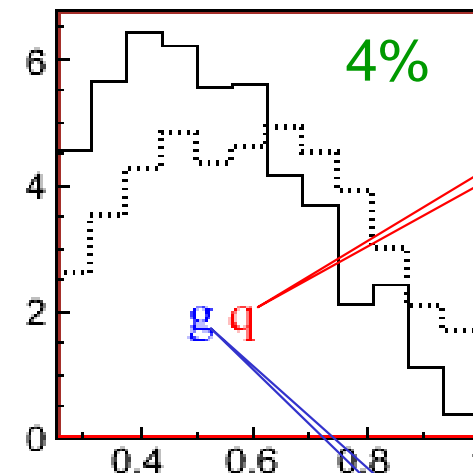
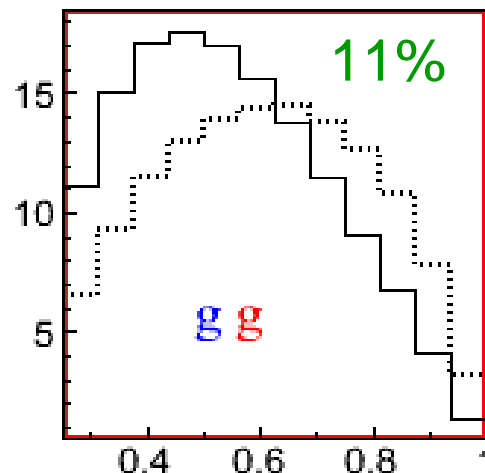
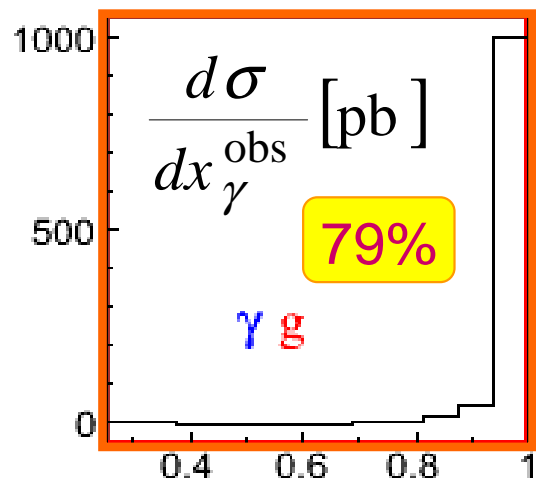
= estimator of x_γ – parton from the photon fractional momentum

- 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)

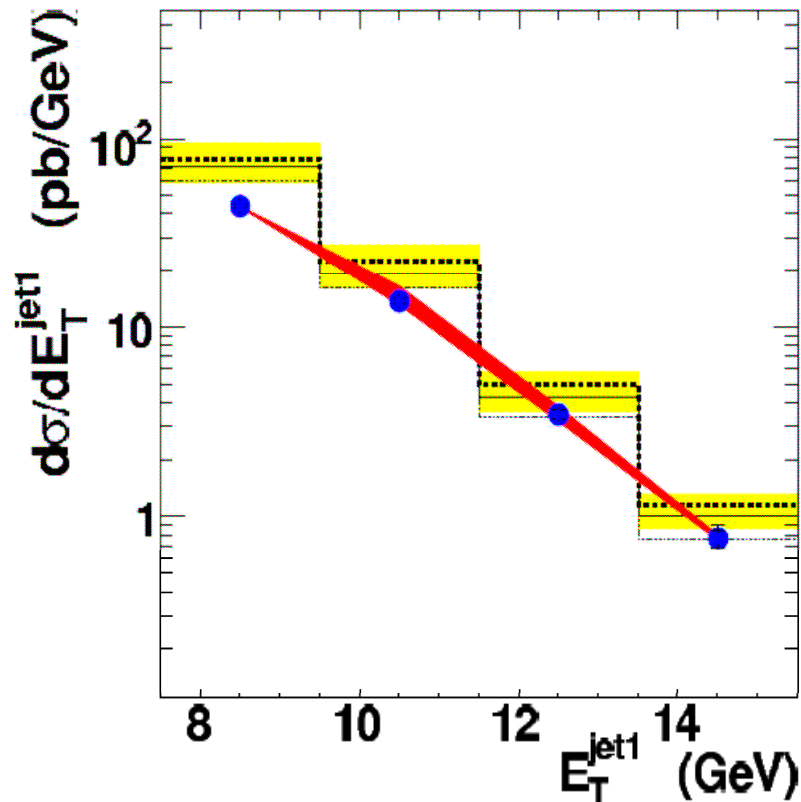


in P
H1-2006-B
⊗
Photon:
— GRV
..... SAL

in γ

Both direct and resolved contributions mostly sensitive to f_g^D

Diffractive dijet *PHP* vs. E_T



ZEUS

$$E_{\perp 1} > 7.5 \text{ GeV},$$

$$E_{\perp 2} > 6.5 \text{ GeV}$$

Hardly any
suppression
except in
lowest E_T bin

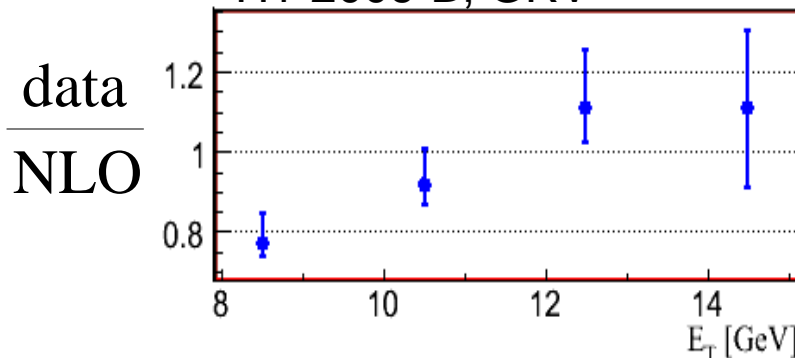
H1

$$E_{\perp 1} > 5 \text{ GeV},$$

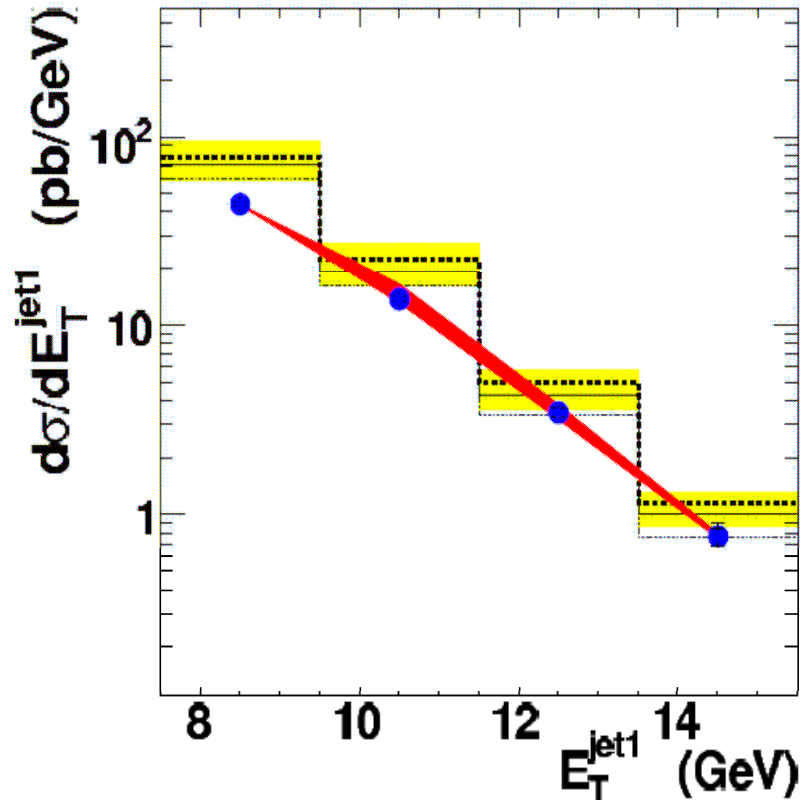
$$E_{\perp 2} > 4 \text{ GeV}$$

~50%
suppression
observed

H1-2006-B, GRV



Diffractive dijet *PHP* vs. E_T



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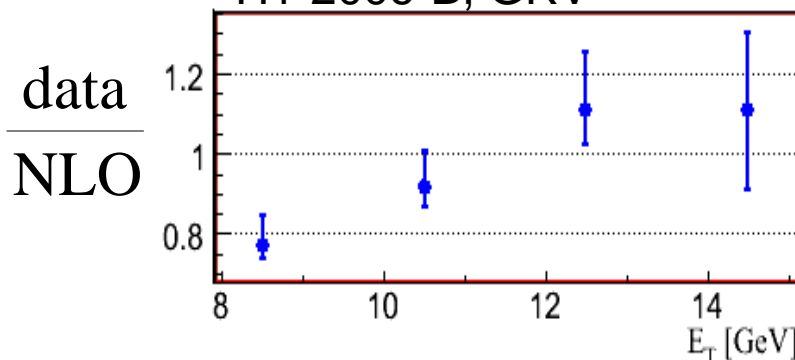
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H1-2006-B, GRV



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*

Known uncertainties for *D-PHP* JJ predictions

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- Factorisation scheme dependence for the photon
 - $\overline{\text{MS}}$ $\sim 10\%$ higher than $\text{DIS}\gamma$
- Quark/Gluon content of the photon?
 - quite safe for $x_\gamma > 0.2$

Known uncertainties for D-*PHP* JJ predictions

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Again up to $\sim 30\%$ uncertainty

Conclusions & Outlook

- Diffractive dijet production at HERA measured by ZEUS in wide range of photon virtualities – from 0 to 100 GeV²
- Experimental errors much smaller than theoretical uncertainties
- Within these uncertainties data compatible with the factorisation assumption
 - suppression of 0 – 20% compatible with the data
 - suppression tends to be larger at smaller E_T

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- Cross-sections' ratios can be useful
 - like PHP/DIS or dijets/inclusive
 - the ratio $\langle \text{PHP/DIS} \rangle_{\text{data}} / \langle \text{PHP/DIS} \rangle_{\text{NLO}}$ under study

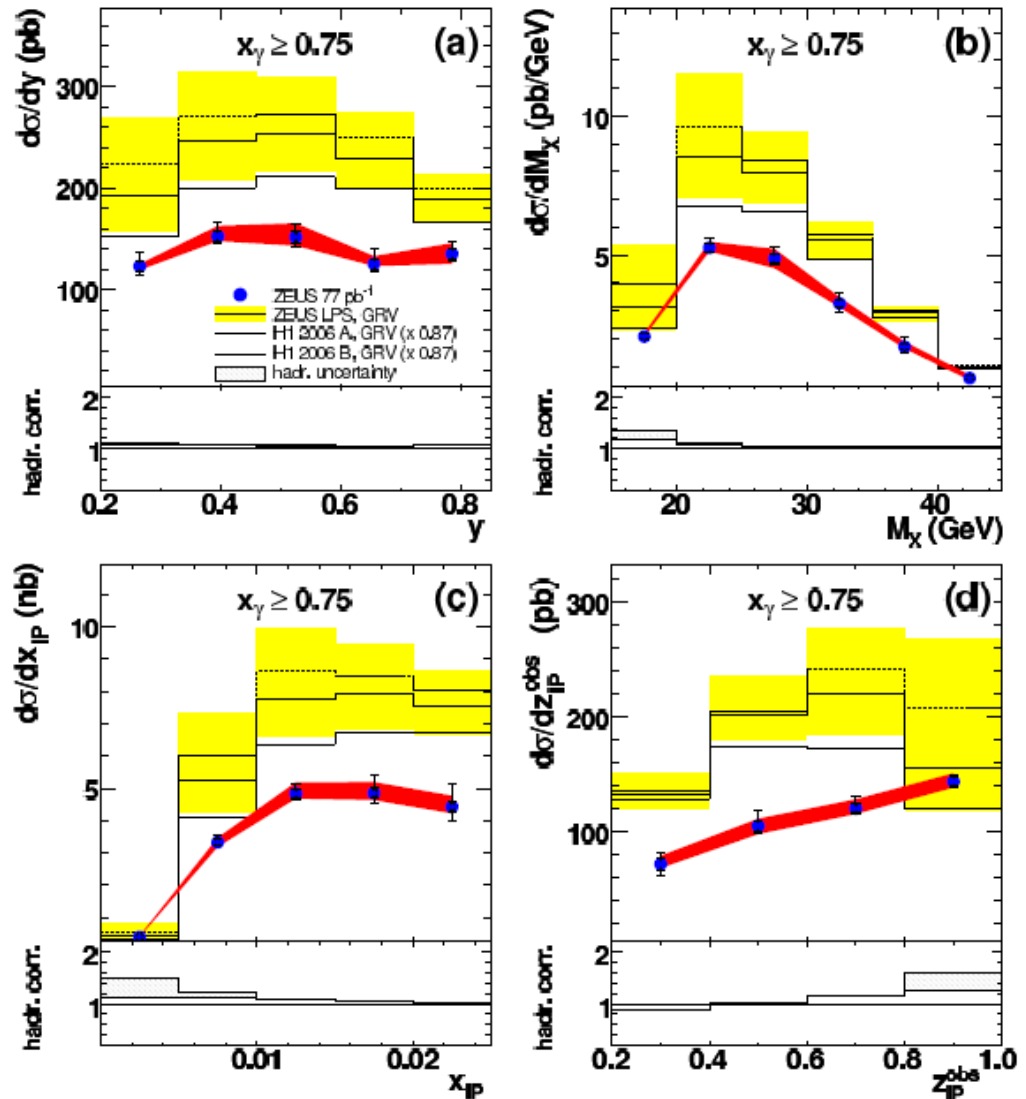
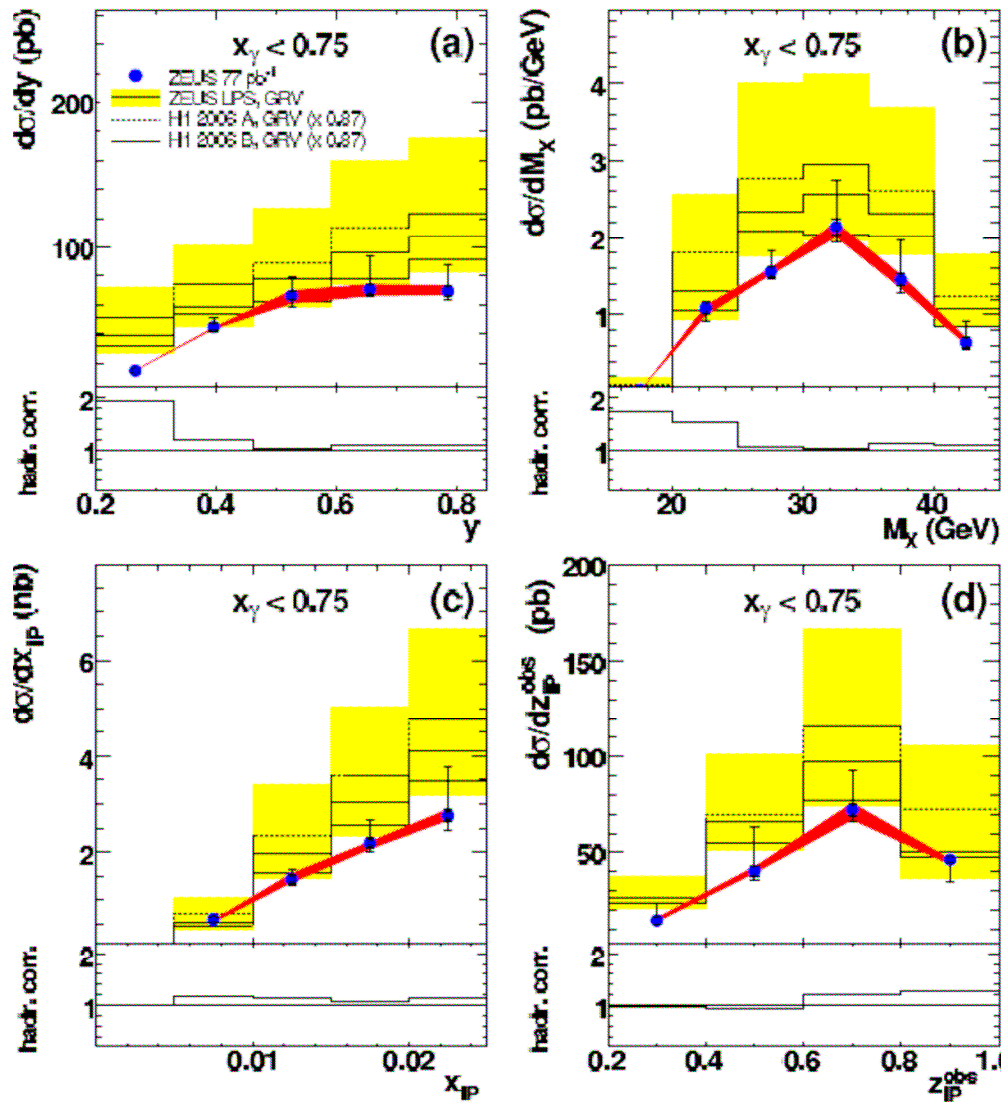
EXTRAS

Resolved- vs. Direct-enriched PHP

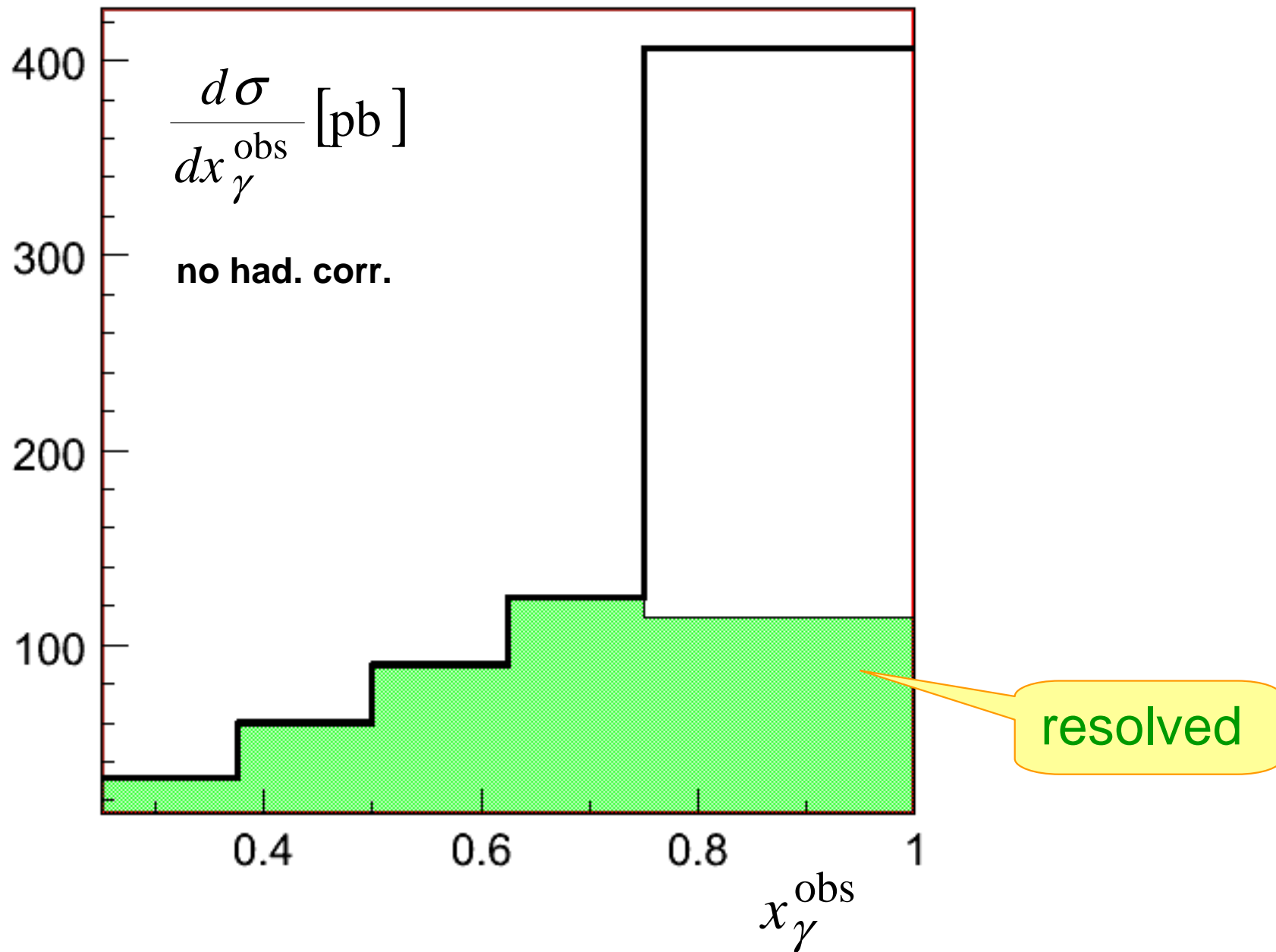


$$x_\gamma^{\text{obs}} < 0.75$$

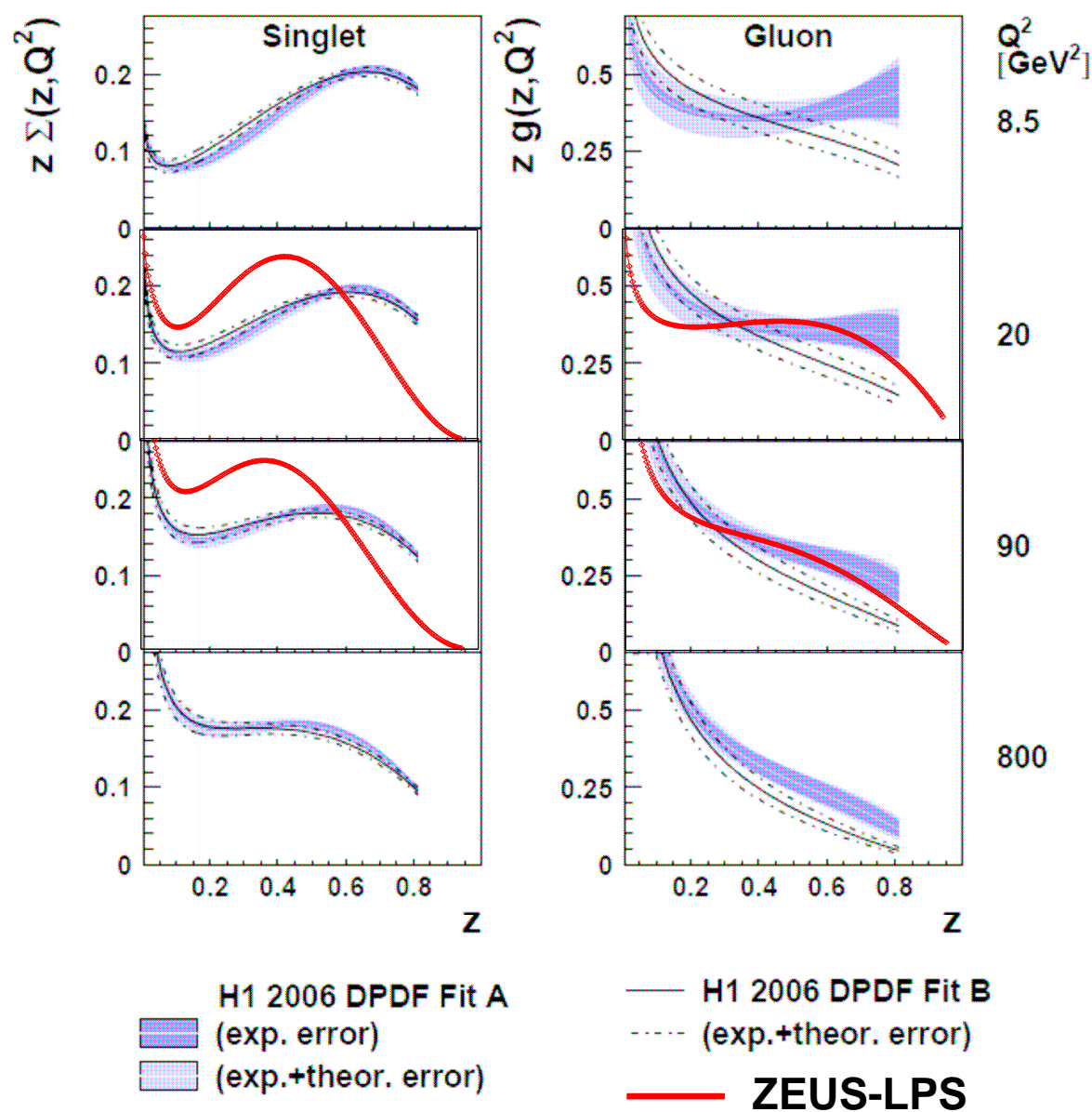
$$x_\gamma^{\text{obs}} \geq 0.75$$



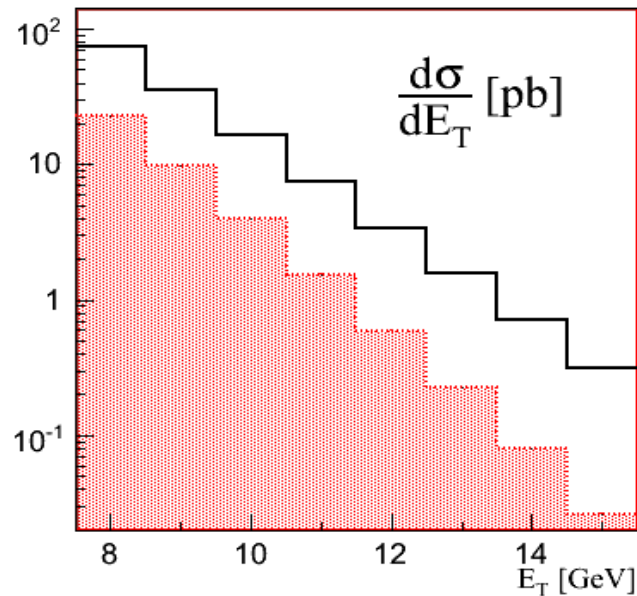
Resolved contribution



DPDFs – H1-2006 and ZEUS-LPS




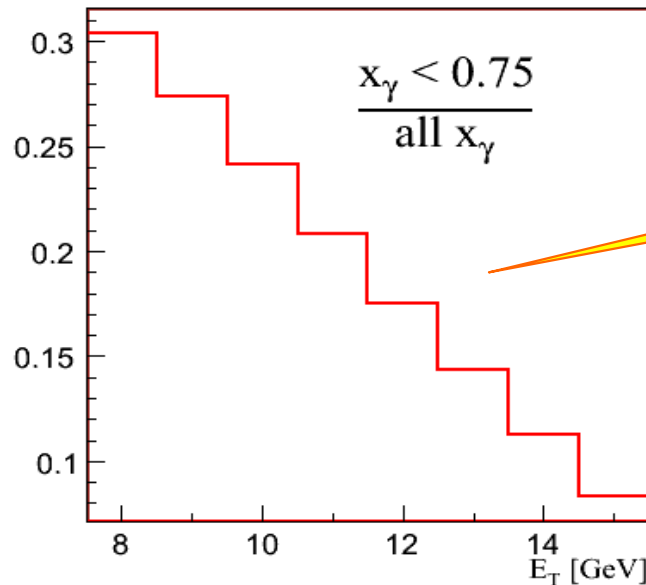
E_T dependence



FR ZEUS
DPDF = H1-2006B * 0.87
Nf = 4, $\Lambda = 330$ MeV, $\alpha(10 \text{ GeV}) = 0.175$

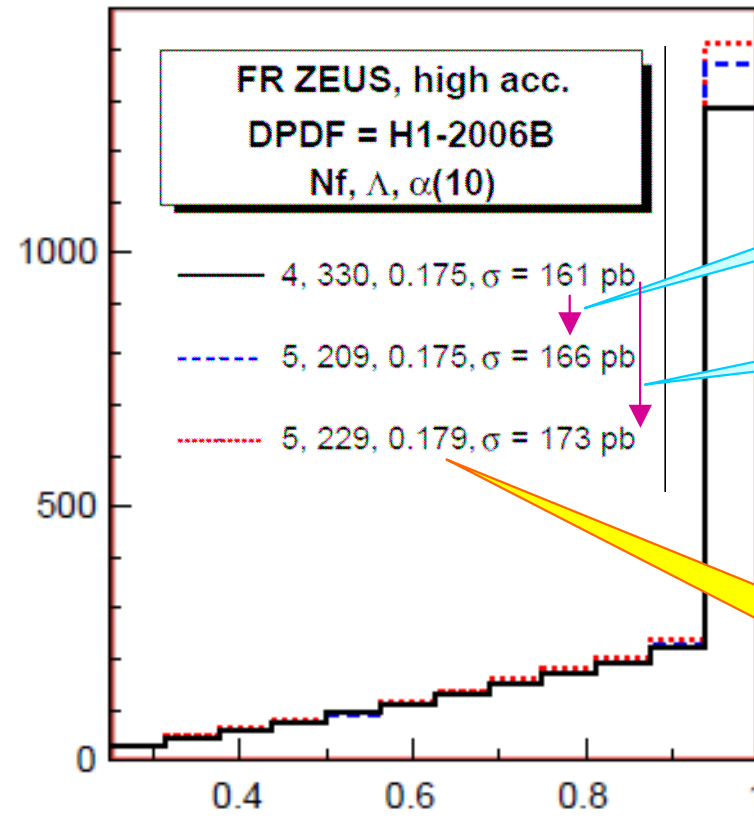
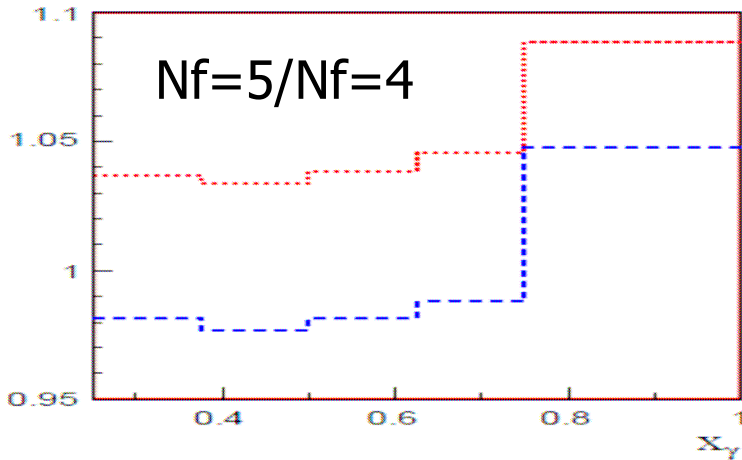
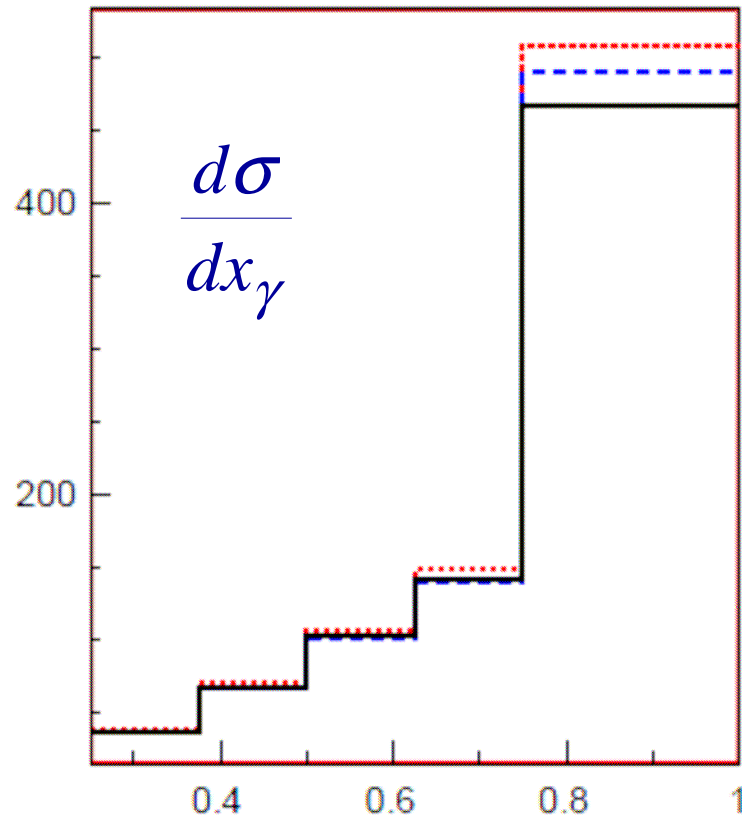
— all x_γ , $\sigma = 140$ pb

 $x_\gamma < 0.75$, $\sigma = 39$ pb



Resolved γ decreases with E_T

N_f dependence



3%

7%

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

