Factorisation in diffractive photoproduction at HERA

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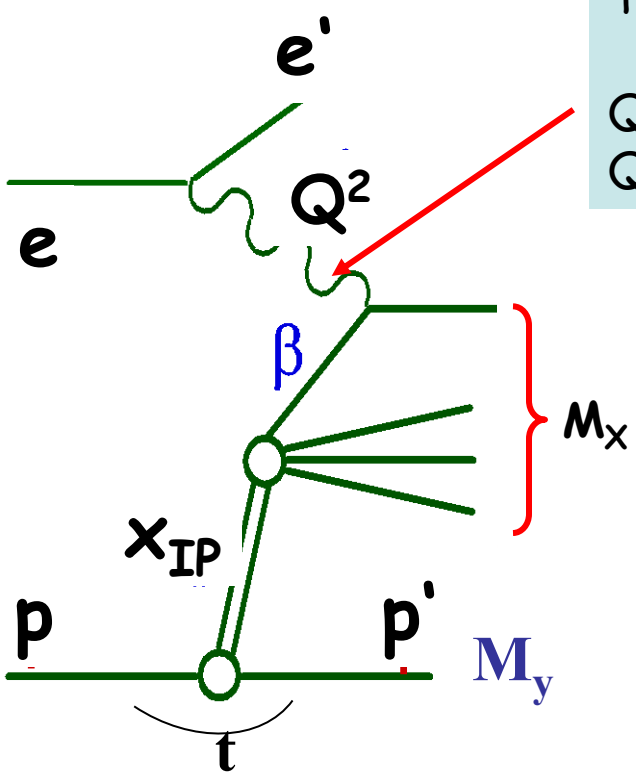
Diffraction and diffraction kinematics



Two kinematic regions of diffractive events:

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

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

W

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

momentum fraction of color singlet exchange

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

fraction of exchange momentum, coupling to γ

$$t = (p - p')^2$$ → 4-momentum transfer squared

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

$M_y > m_p$ proton dissociates, → contribution should be understood

Two types of factorisation

QCD factorisation holds for inclusive and non-inclusive processes if:

- photon is point-like (Q^2 is high enough)
- higher twist corrections are negligible (M_x is high enough)

QCD factorisation theoretically proven for DIS (Collins 1998)

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

f_i^D → DPDFs – obey DGLAP, universal for diff. ep DIS (inclusive,dijet,charm)

$\sigma^{\gamma^* i}$ → hard scattering QCD matrix element, perturbatively calculated, process dependent

It allows the extraction of DPDFs from the (DIS) data

H1 and ZEUS –QCD fits assuming Regge factorisation for DPDF

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

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

pomeron flux factor

pomeron PDF

Tests of QCD factorisation

What kind of final states?

- processes with a hard scale
- sensitive to gluons (gluons contribute by up to 80% to the DPDFs).

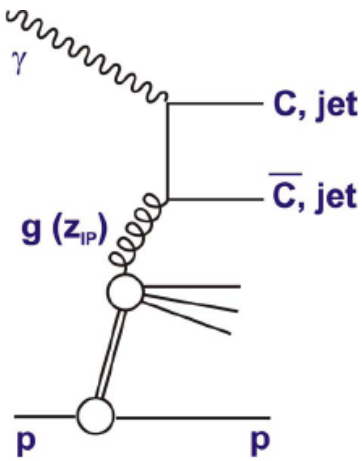
Dijets and D* in DIS, D* in photoproduction – factorisation holds (tested by H1 and ZEUS).

What about dijets in photoproduction?
Similarity with hadron-hadron interactions..

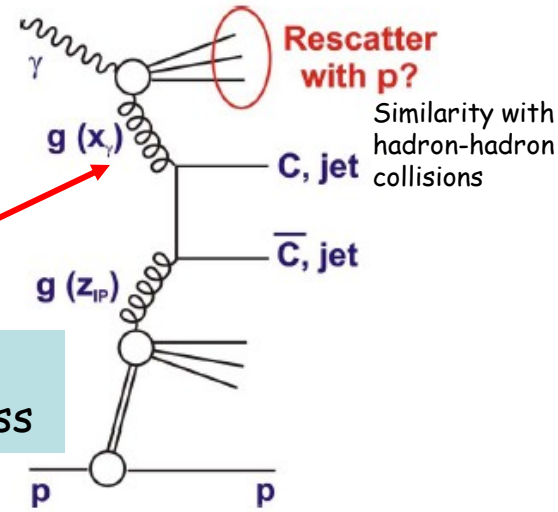
Photoproduction, γp, $Q^2 \to 0$

In LO!

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



x_γ - fraction of photon's momentum in hard subprocess



resolved

direct

direct photoproduction

photon directly involved in hard scattering

$x_\gamma = 1$ (at parton level)

hadron –like component

photon fluctuates into hadronic system, which takes part in hadronic scattering

$x_\gamma < 0.2$ (at parton level)

point –like component of resolved photon

dominates in the region of $0.2 < x_\gamma < 1$

Factorisation in hadron-hadron collisions

Exporting DPDFs from HERA to Tevatron does not work

$$S^2 = \frac{\sigma\,(\text{data})}{\sigma\,(\text{theory})}$$

suppression factor

Factorisation broken by β-dependent factor ~ 10, S^2 ~ 0.1.

Dijets in diffractive photoproduction

In 2010 new theoretical prediction by KKMR:
(European Journal of Physics 66,373 (2010))
Suppression 0.34 present only for hadronic part of photon PDF (x_γ<**0.2**),
for dominant point-like component

suppression: quarks GRV **0.71(0.75)** E_T^{jet1} >5 (7.5) GeV
gluons GRV **0.53(0.58)** E_T^{jet1} >5 (7.5) GeV

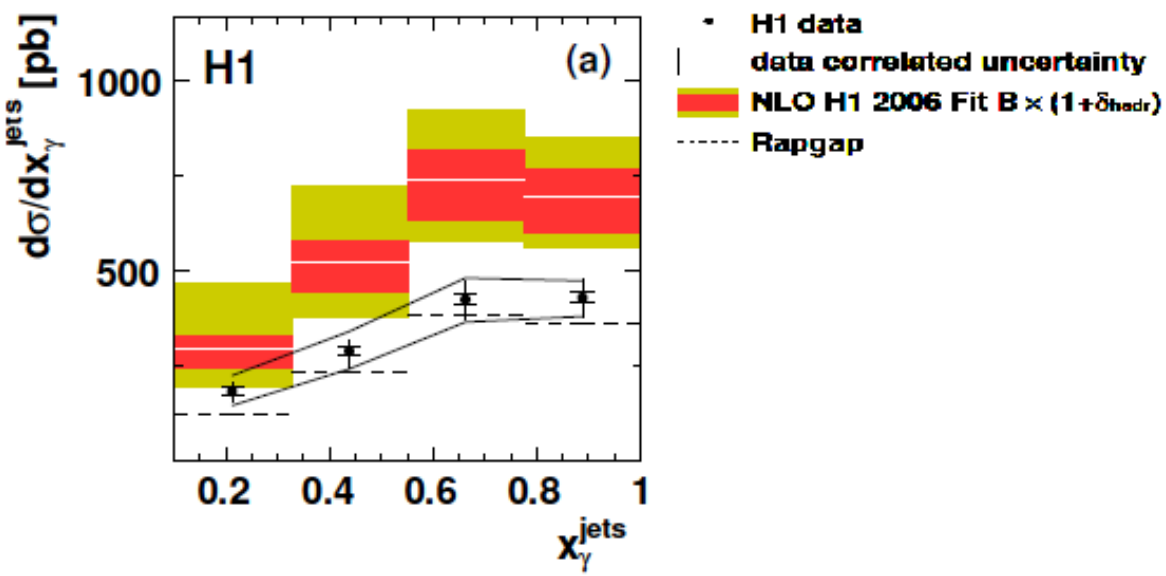
According to theoretical predictions still some suppression around 0.5-0.8 should exist!

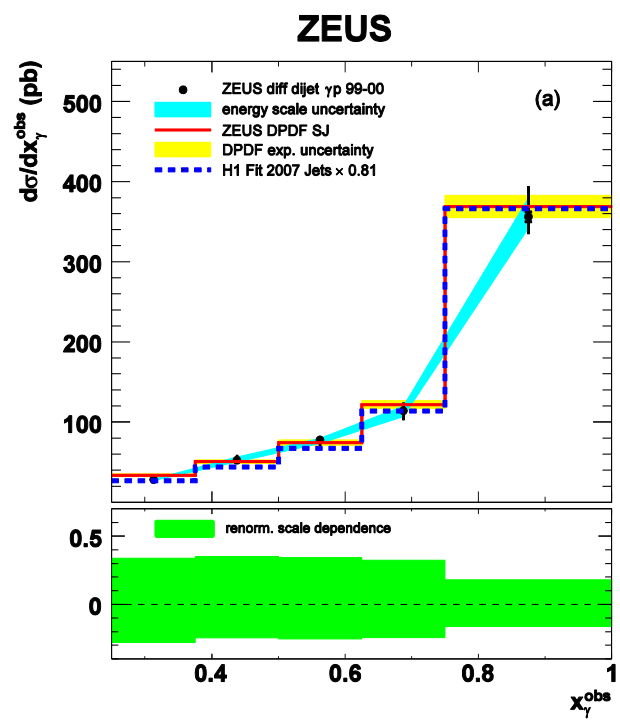
Dijets in photoproduction

Factorisation breaking observed by H1, two analyses,
EPJC C51 (2007),549, – suppression ~ **0.5**
EPJ C68 (2010),381 – suppression ~ **0.6**

not observed by ZEUS, Nucl.Phys. B381 (2010),1 – no suppression

Do we understand this difference?





Possible explanation….?

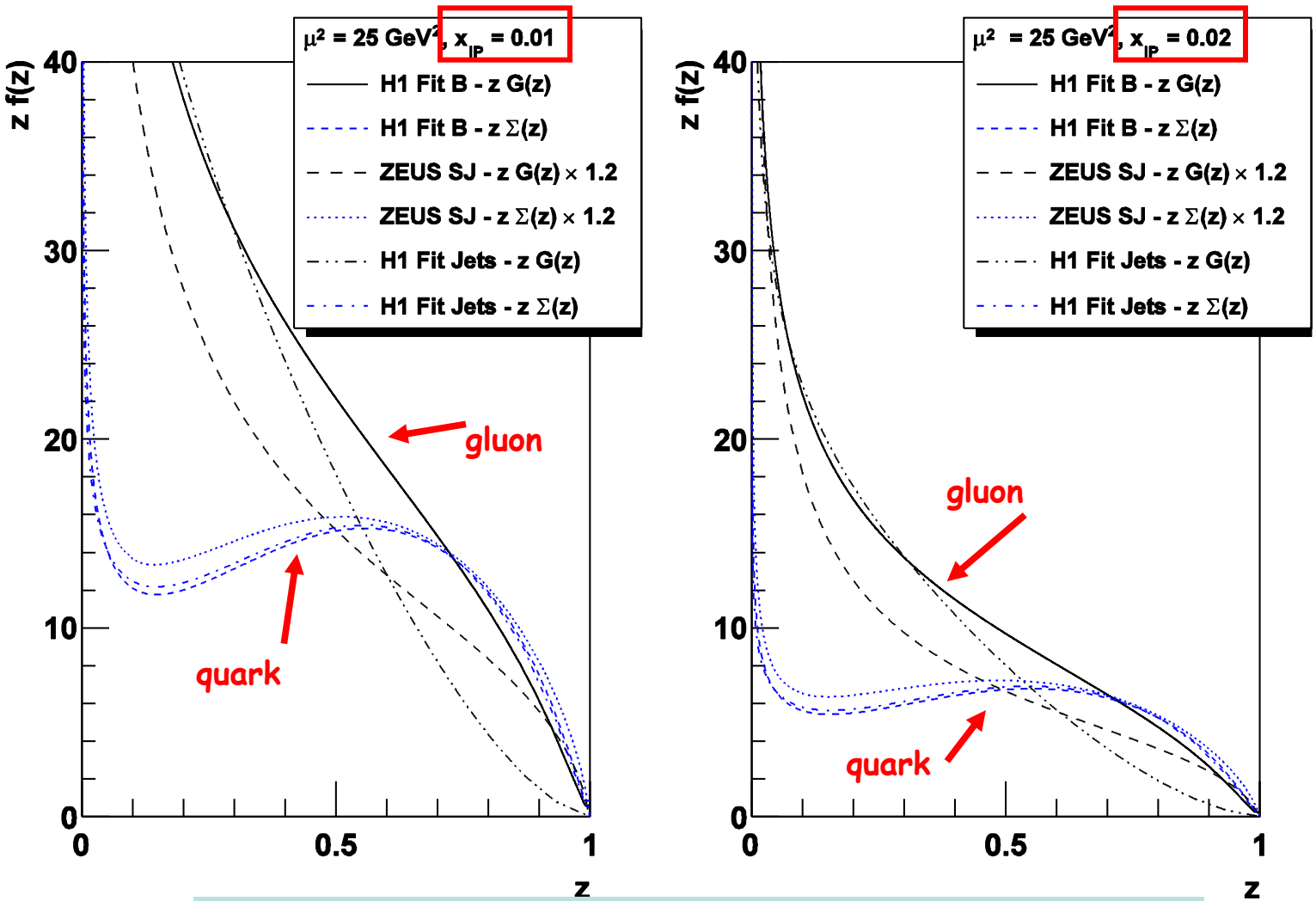
- the different phase space of both analyses – larger E_t of jets in ZEUS analysis etc. (the influence of larger E_t cut was however not fully confirmed – see EPJ C68 (2010),381)

- in H1 and ZEUS different hadronisation corrections (estimated by MC RAPGAP and applied to NLO QCD calculations)

- old photon structure GRV – used however by both H1 and ZEUS

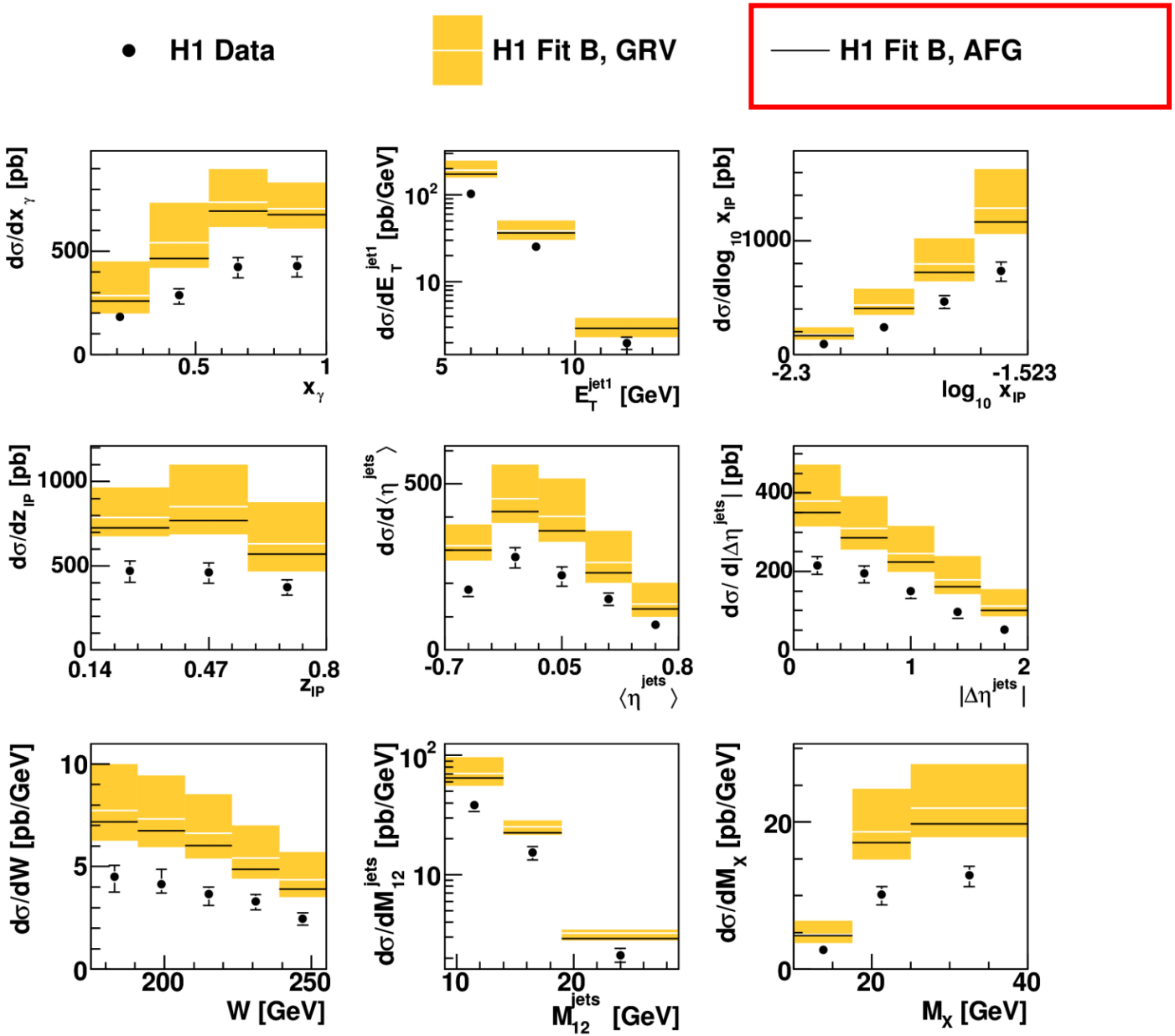
Here an attempt to crosscheck critical points….

DPDFs used



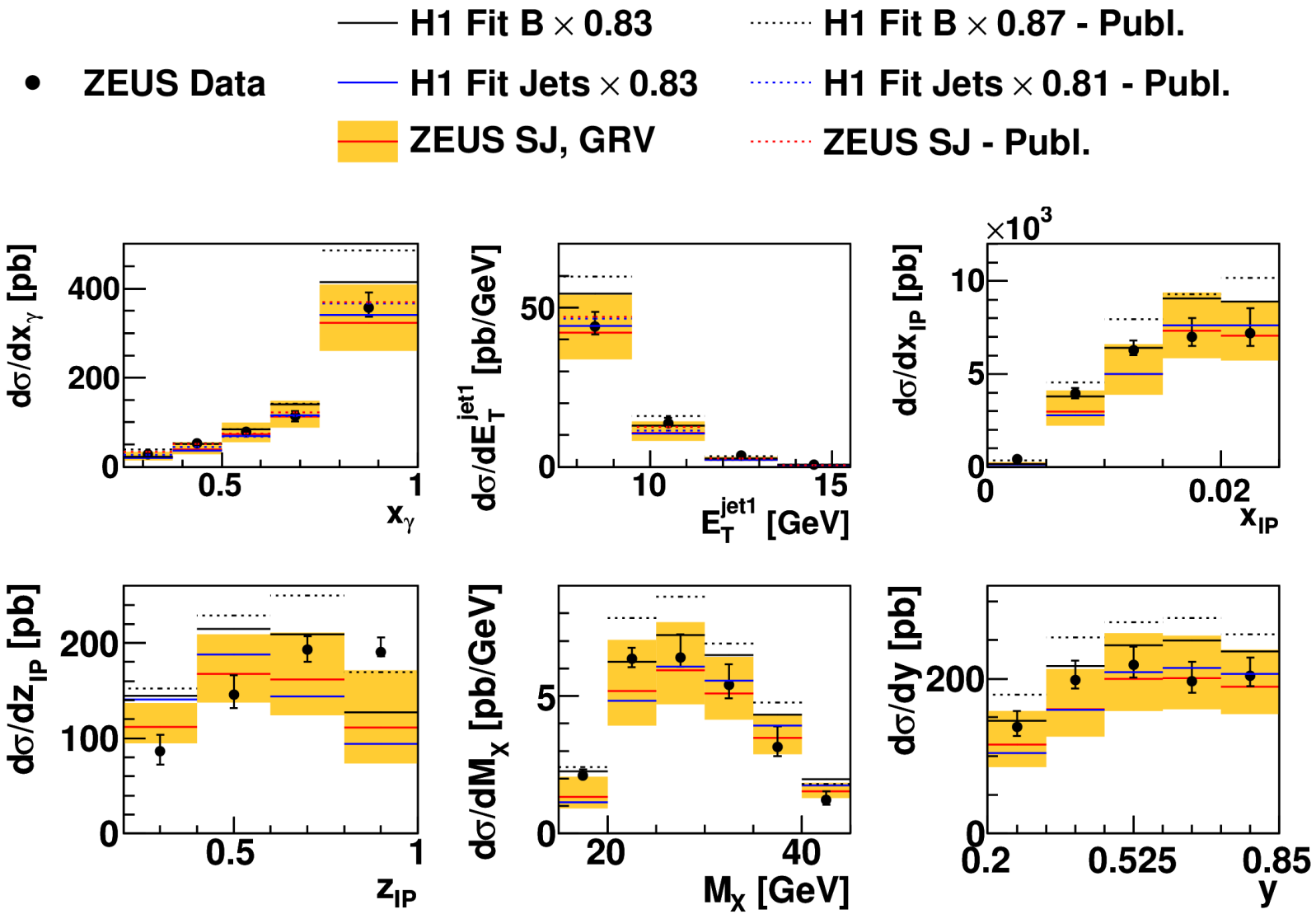
H1 fit B, H1 fit Jets, ZEUS fit SJ

H1 diff. cross sections and NLO



ZEUS diff. cross sections and NLO

- Our calculations (ZEUS fit SJ), suppression ~ 1.1
- ZEUS published (ZEUS fit SJ), suppression ~ 1.



Extrapolation

H1

Inclusive

$Q^2 < 0.01\text{GeV}^2$

$0.3 < y < 0.65$

$E_T^{\text{jet1(2)}} < 5(4)\text{GeV}$

$-1 < \eta^{\text{jet1(2)}} < 2$

Diffractive

$x_{IP} < 0.03$

$|t| < 1\text{GeV}^2$

$M_Y < 1.6\text{GeV}$

$z_{IP} < 0.8$

expansion $Q^2, y, \eta^{\text{jets}}, z_{IP}$

contraction $E_T^{\text{jets}}, x_{IP}, \eta^{\text{jets}}, M_Y$

expansion $\eta^{\text{jets}}, z_{IP}$

contraction $\eta^{\text{jets}}, E_T^{\text{jets}}, x_{IP}$

ZEUS

Inclusive

$Q^2 < 1\text{GeV}^2$

$0.2 < y < 0.85$

$E_T^{\text{jet1(2)}} < 7.5(6.5)\text{GeV}$

$-1.5 < \eta^{\text{jet1(2)}} < 1.5$

Diffractive

$x_{IP} < 0.025$

$|t| < 1\text{GeV}^2$

$M_Y = M_P$

H1 – high Pt

Preliminary

Inclusive

$Q^2 < 0.01\text{GeV}^2$

$0.3 < y < 0.65$

$E_T^{\text{jet1(2)}} < 7.5(6.5)\text{GeV}$

$-1.5 < \eta^{\text{jet1(2)}} < 1.5$

Diffractive

$x_{IP} < 0.025$

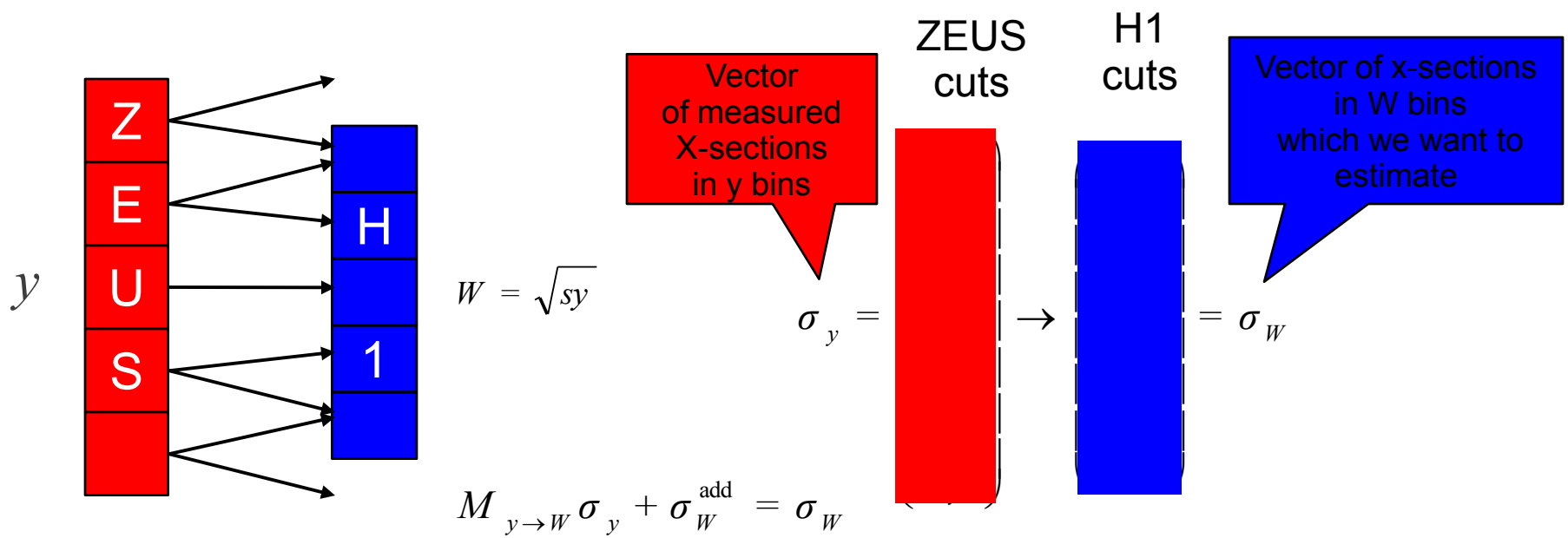
$|t| < 1\text{GeV}^2$

$M_Y < 1.6\text{GeV}$

expansion M_Y

contraction Q^2, y

Method of Extrapolation



$(M_{y \rightarrow W})_{ij} = p_{yj \rightarrow Wi}$	Transition matrix
$p_{yj \rightarrow Wi}$	Probability that event in yj bin will be registered in Wi (from MC fitted to the data)
$\sum p_{yj \rightarrow Wi} \leq 1$	Some events missing
σ_W^{add}	Vector of x-sections of events which don't fulfill H1 cuts but agree with ZEUS (from MC RAPGAP)

Test of method

H1

Inclusive

$Q^2 < 0.01\text{GeV}^2$

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$|t| < 1\text{GeV}^2$

$M_Y < 1.6\text{GeV}$

$z_{IP} < 0.8$

expansion $\eta^{\text{jets}}, z_{IP}$

contraction $\eta^{\text{jets}}, E_T^{\text{jets}}, x_{IP}$

H1 – high Pt

Preliminary

Inclusive

$Q^2 < 0.01\text{GeV}^2$

$0.3 < y < 0.65$

$E_T^{\text{jet1(2)}} < 7.5(6.5)\text{GeV}$

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$x_{IP} < 0.025$

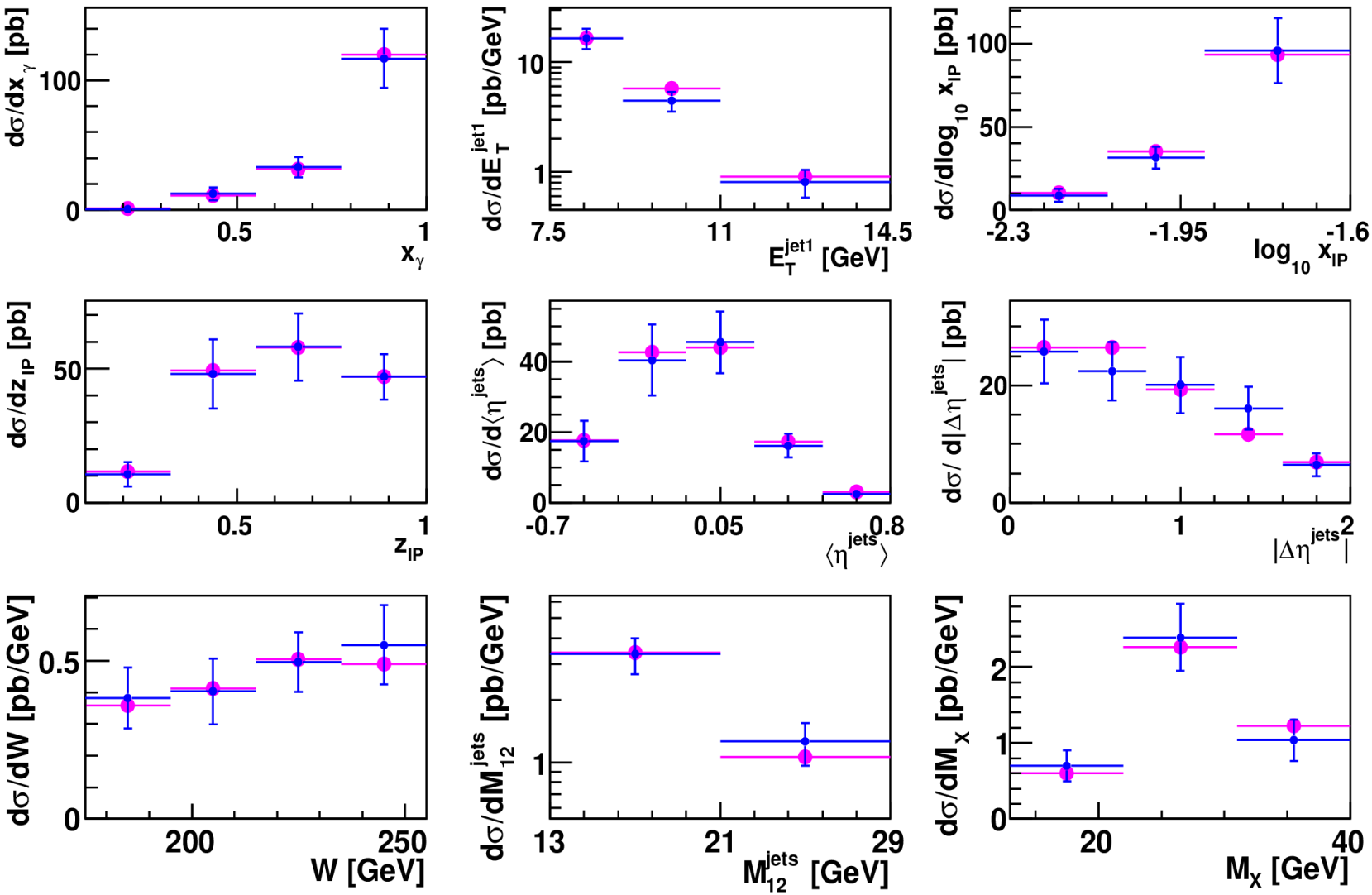
$|t| < 1\text{GeV}^2$

$M_Y < 1.6\text{GeV}$

See: K.Černý, talk in DIS08, London 2008

Results, H1 → H1 High P_t

- H1 High Pt Data - Preliminary
- H1 Low Pt - Extrapolated



Extrapolation

H1

Inclusive

$Q^2 < 0.01\text{GeV}^2$

$0.3 < y < 0.65$

$E_T^{\text{jet1(2)}} < 5(4)\text{GeV}$

$-1 < \eta^{\text{jet1(2)}} < 2$

Diffractive

$x_{IP} < 0.03$

$|t| < 1\text{GeV}^2$

$M_Y < 1.6\text{GeV}$

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ZEUS

Inclusive

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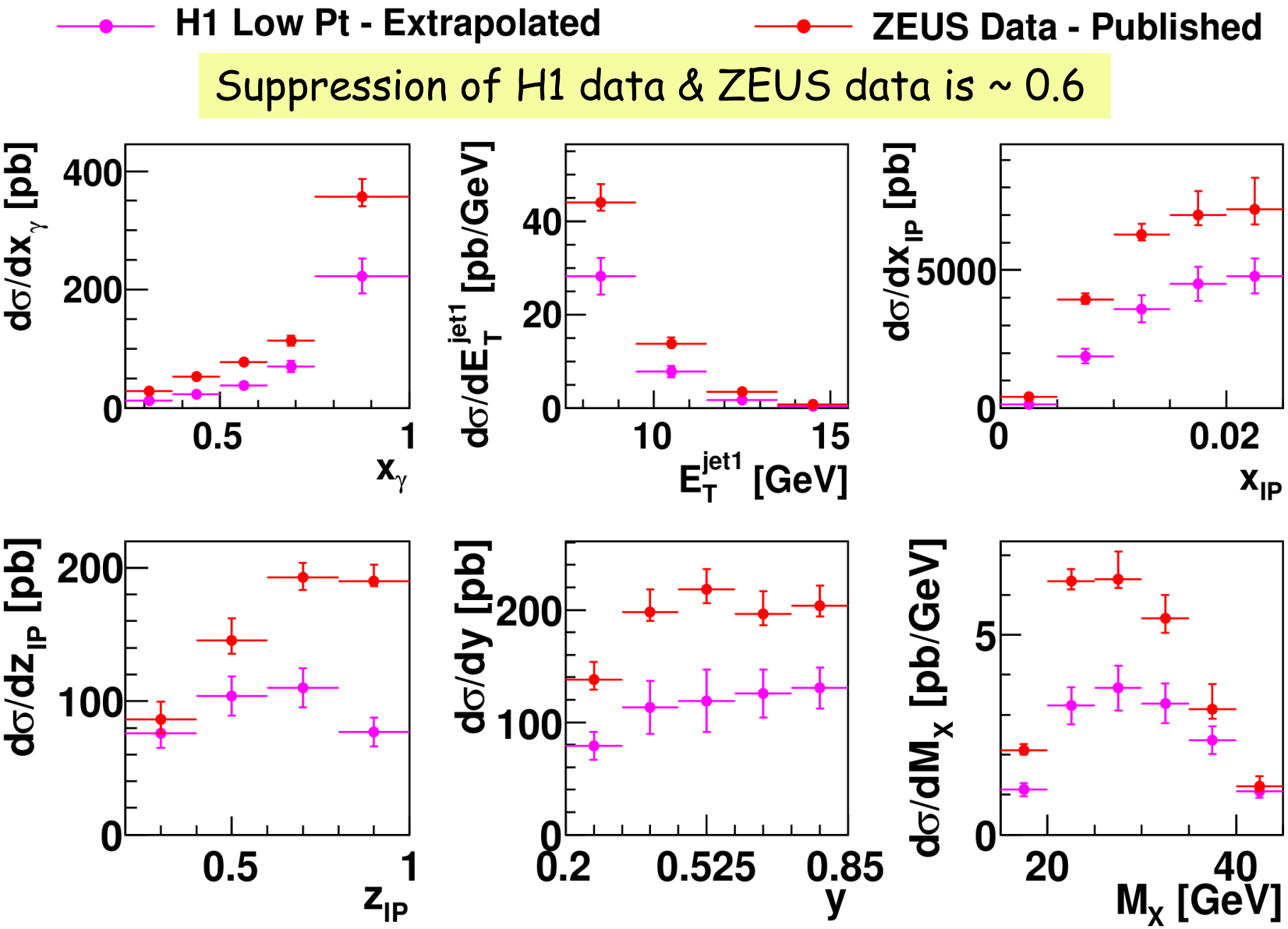
$M_Y = M_P$

expansion $Q^2, y, \eta^{\text{jets}}, z_{IP}$

contraction $E_T^{\text{jets}}, x_{IP}, \eta^{\text{jets}}, M_Y$

Results, H1 → ZEUS



Suppression of H1 data & ZEUS data is ~ 0.6

Conclusions

- NLO calculations (with 3 DPDFs) and hadronisation corrections checked for H1 and ZEUS
- Sensitivity to photon structure function checked
- H1 data extrapolated with the help of MC RAPGAP to ZEUS phase space

Data of H1 and ZEUS are different in the identical (ZEUS) phase space….