Lowx06, 28th June - 1st July 2006, Lisbon, Portugal

Particle Momentum Distributions and Prompt Photon Production at HERA

Joerg Gayler, DESY

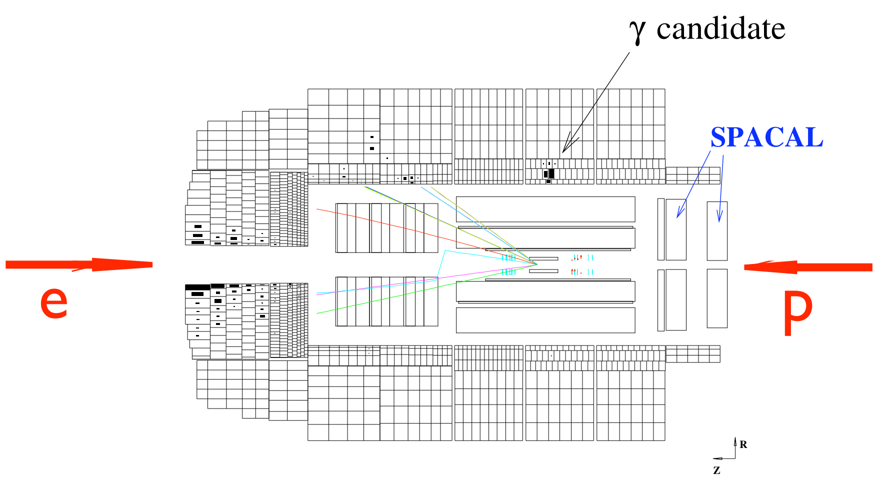
Inclusive Hadron Distributions

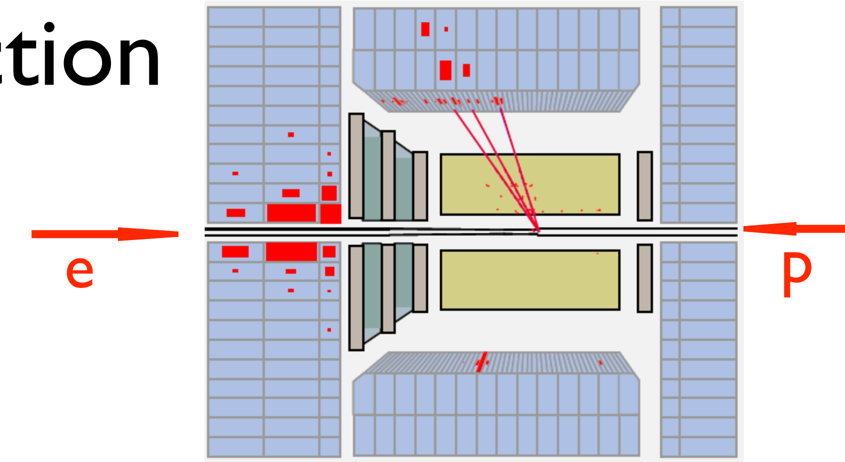
Prompt Photons :

inclusive and γ + jet in ep DIS

γ + jet in photoproduction

Conclusions





Scaled Energy Distributions

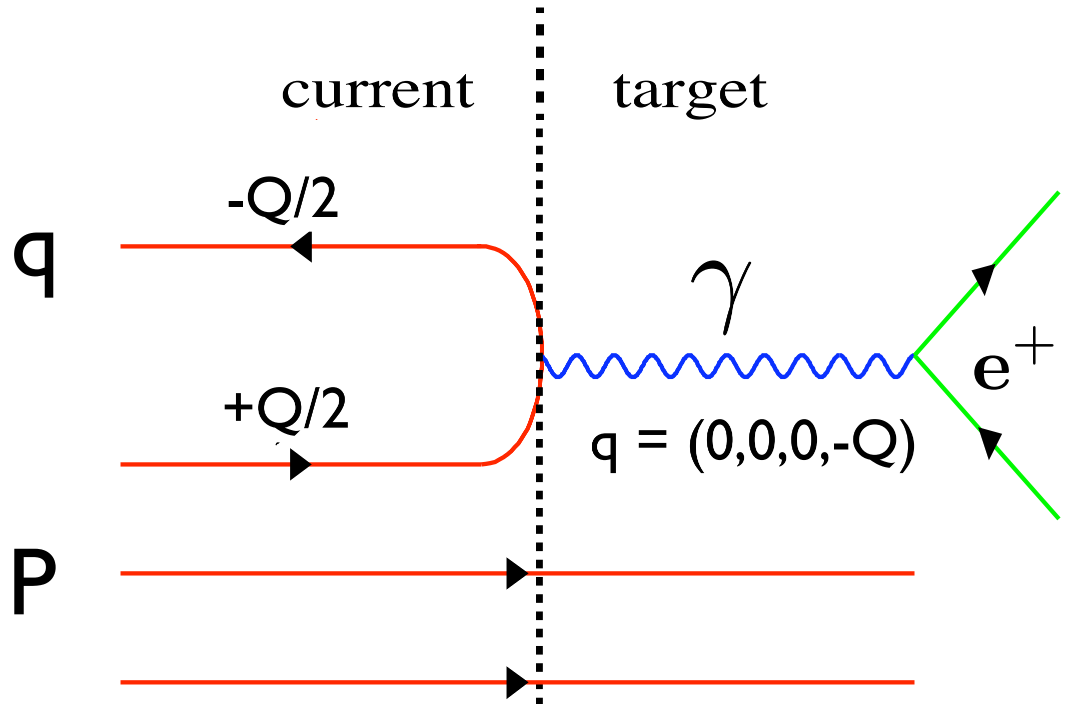
Motivation

- Test quark fragmentation universality and factorisation by comparison with e^+e^-
- pQCD : Study scaling violations due to parton splitting like in structure functions
- Test fragmentation and hadronisation models (colour dipole model, parton showers, strings and clusters)

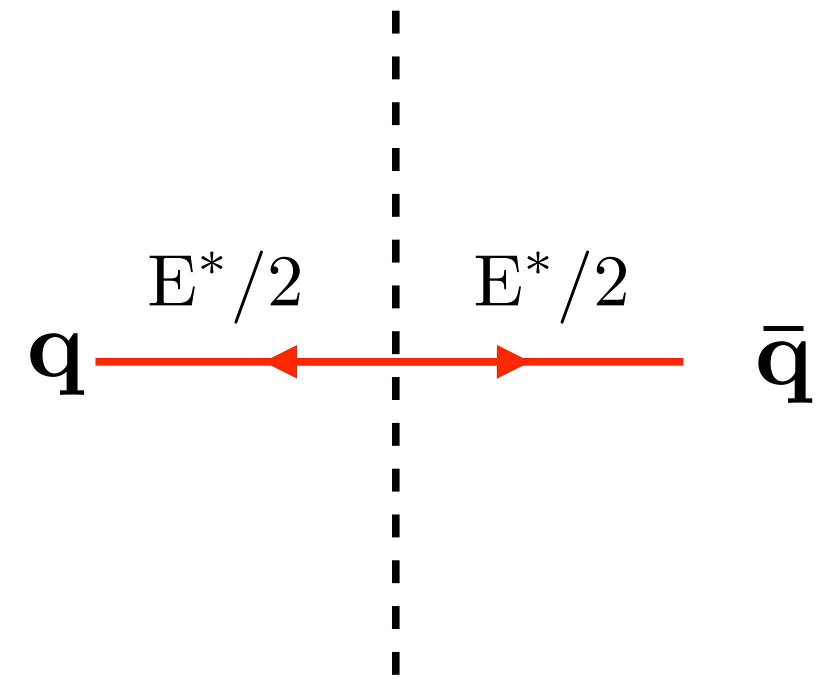
Compare ep with e^+e^-

current hemisphere in Breit frame

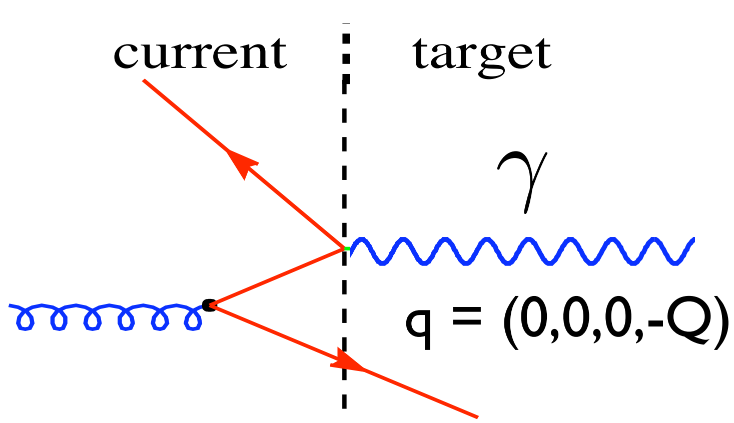
QPM



half sphere



~~QPM~~ e.g. Boson Gluon Fusion (BGF)



less clear separation !

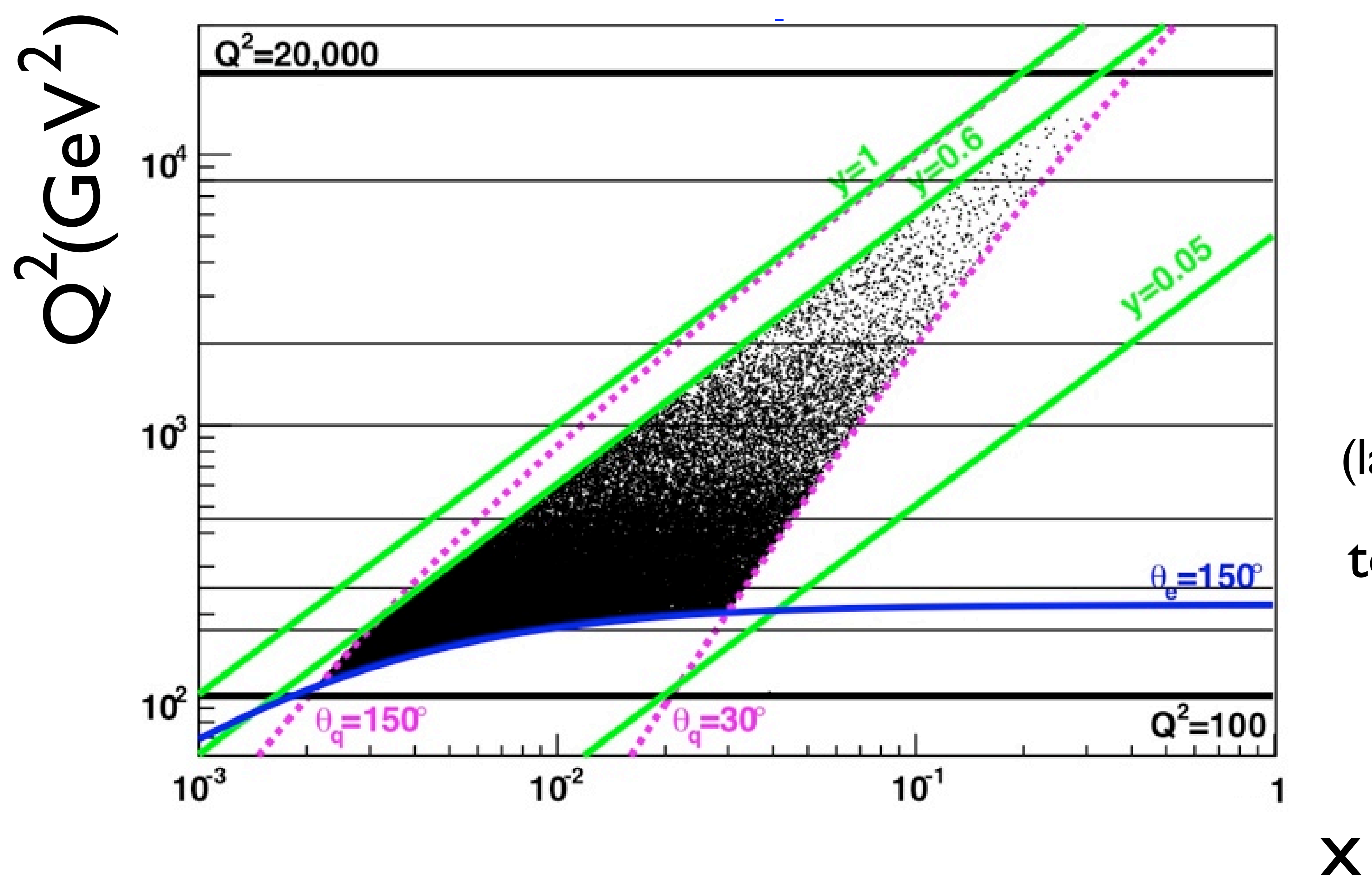
identify :

$$Q \leftrightarrow E^*$$

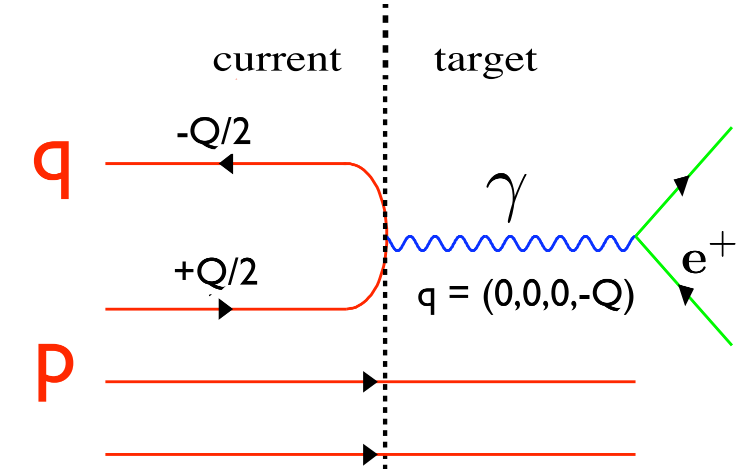
scaled hadron momenta x_p :

$$p_h/(Q/2) \leftrightarrow p_h/(E^*/2)$$

Cuts and Bins in x, Q^2 plane



QPM, Breit frame



require θ_{quark}

(lab angle between p and q)

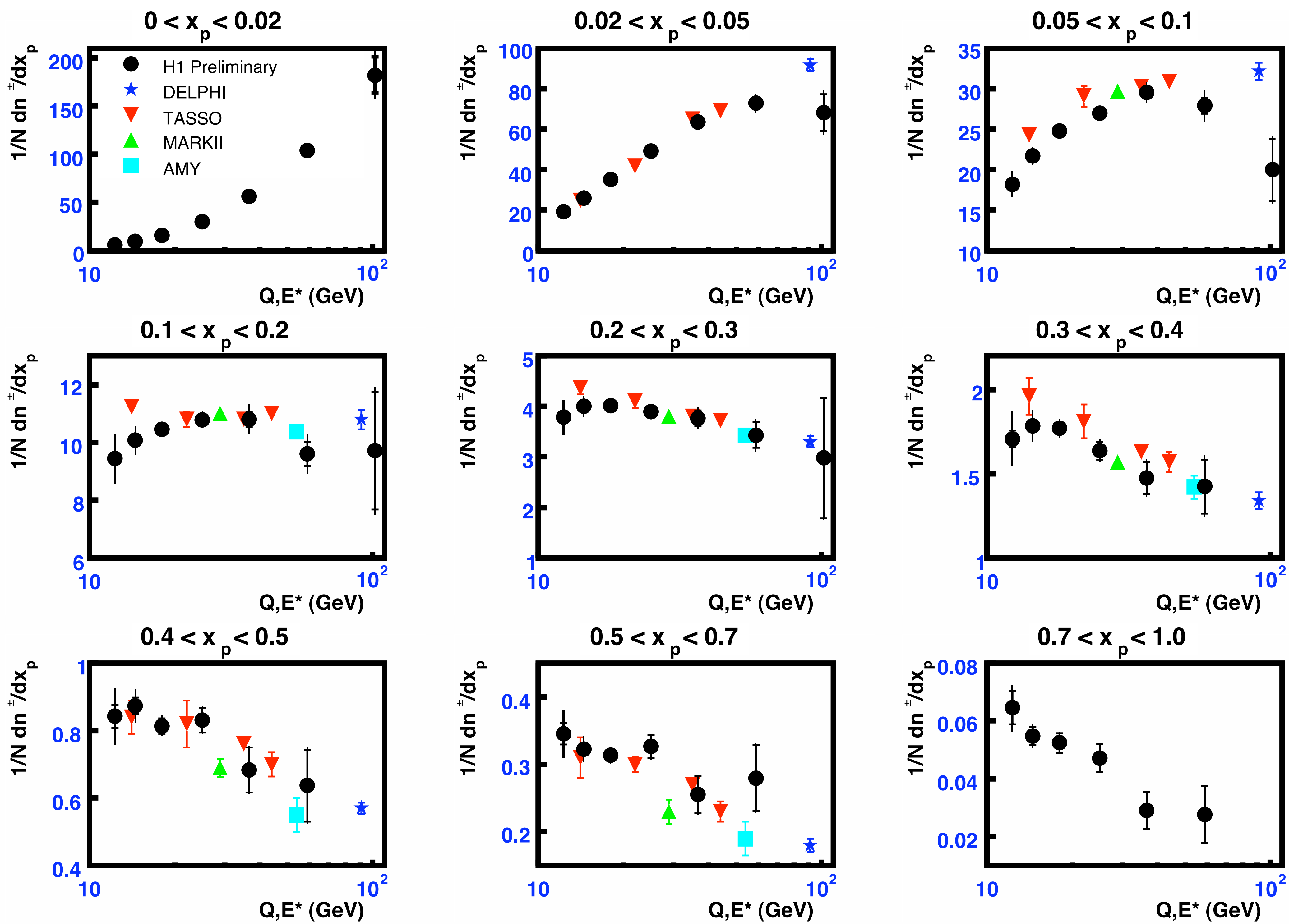
to be well in detector :

$30^\circ < \theta_{quark} < 150^\circ$

$100 < Q^2 < 20{,}000$ GeV^2 $\quad y < 0.6$

$\theta_{electron} < 150^\circ$ $\quad p_{t,lab} > 120$ MeV

$1/N\, \mathrm{d}n^{\pm}/\mathrm{d}x_p$ vs. $\mathbf{Q}, \mathbf{E}^*$ in comparison to $\mathrm{e}^+\mathrm{e}^-$



small $\mathbf{x_p}$:
rise with $\mathbf{Q}, \mathbf{E}^*$

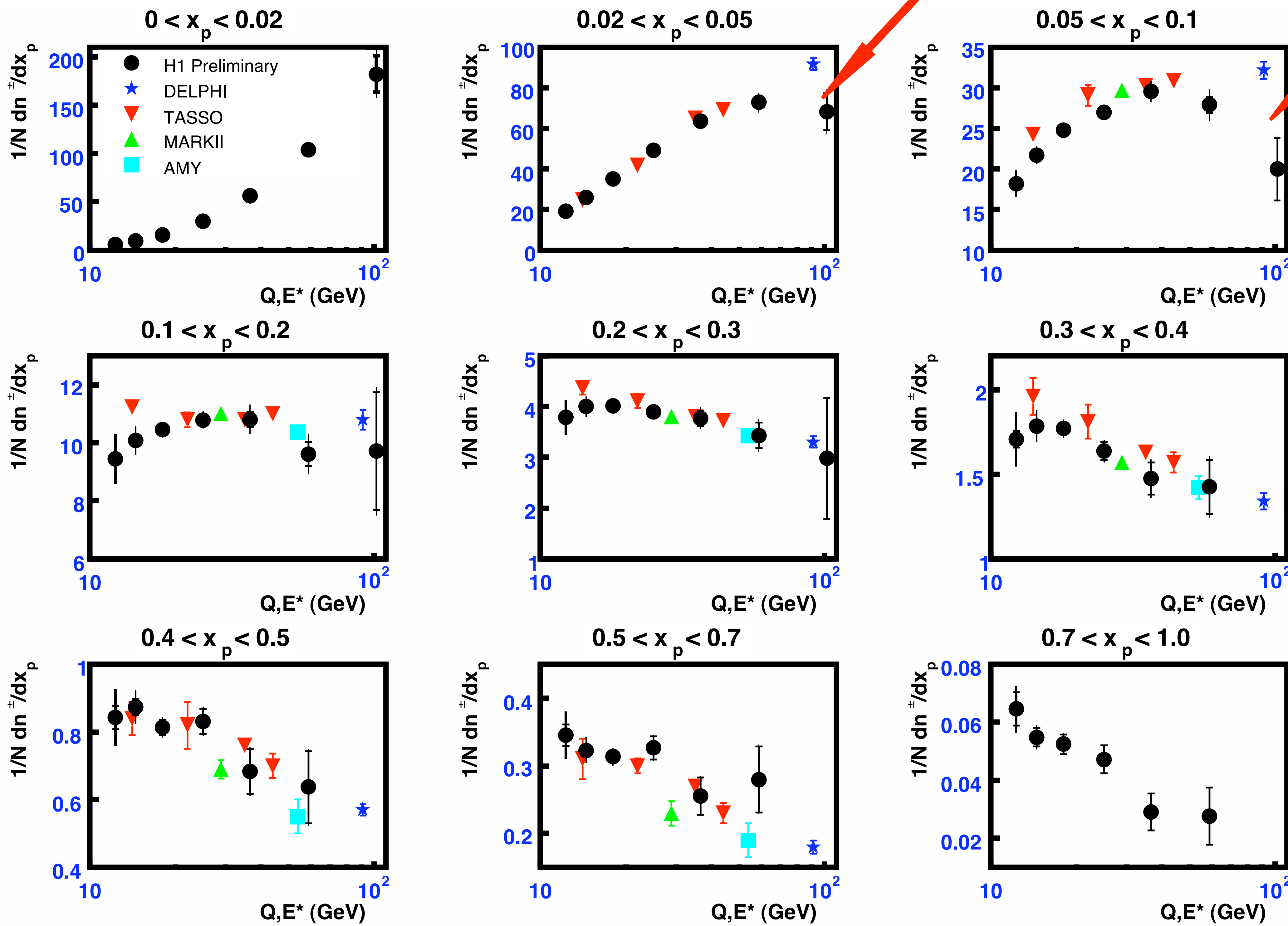
large $\mathbf{x_p}$:
fall with $\mathbf{Q}, \mathbf{E}^*$

remarkable agreement !

supports fragmentation universality

$1/N \, \mathrm{d}n^{\pm}/\mathrm{d}x_p$ vs. $\mathbf{Q}, \mathbf{E^*}$ in comparison to $\mathrm{e^+e^-}$

more detailed look



discrepancy at large Q, small x_p (not understood)

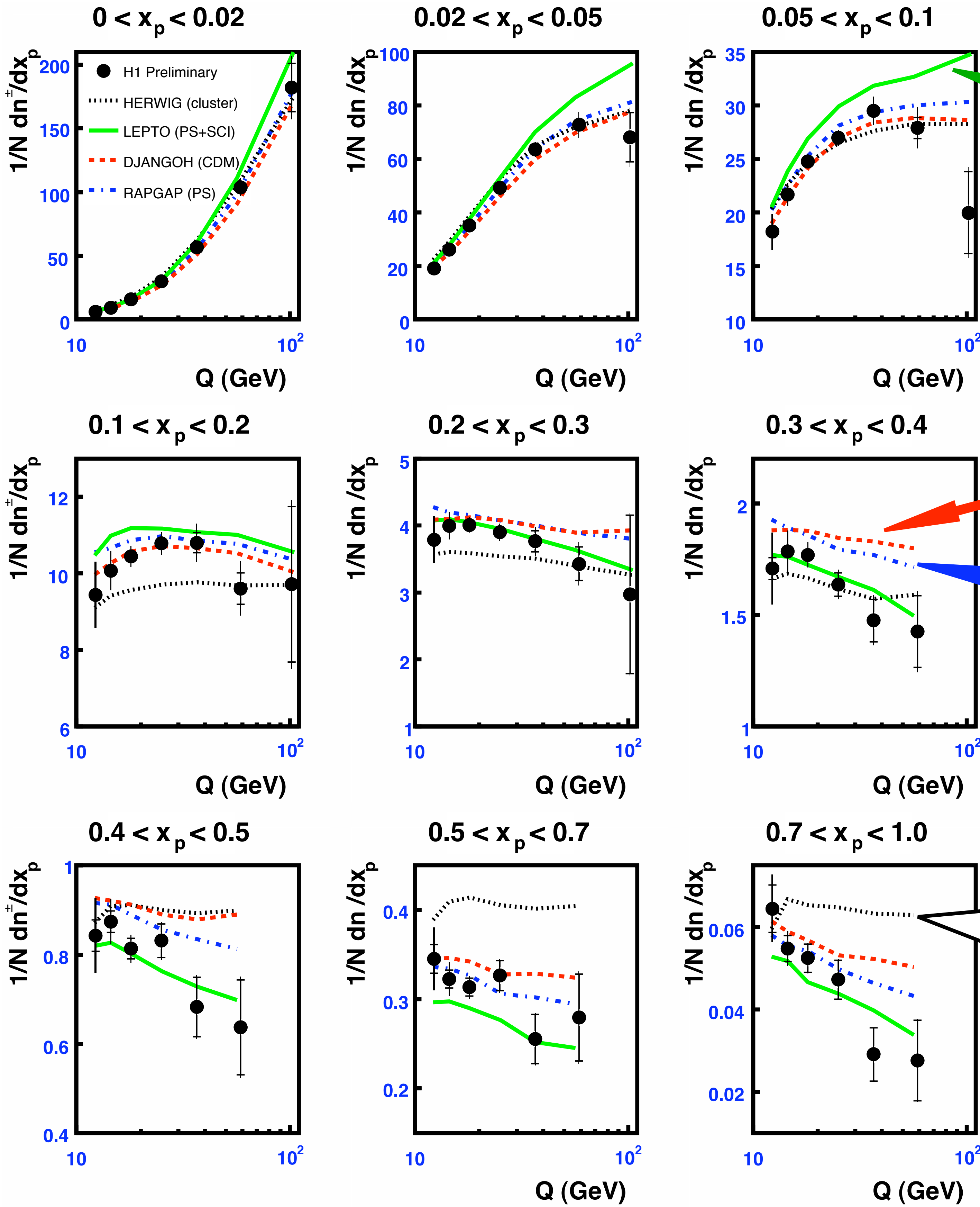
but what level of agreement to expect ?

$\mathrm{e^+e^-}$ $\quad$ ep

CMS <-> Breit ?

E* <-> Q ?

Comparison with Models



LEPTO (parton showers, soft colour interactions)

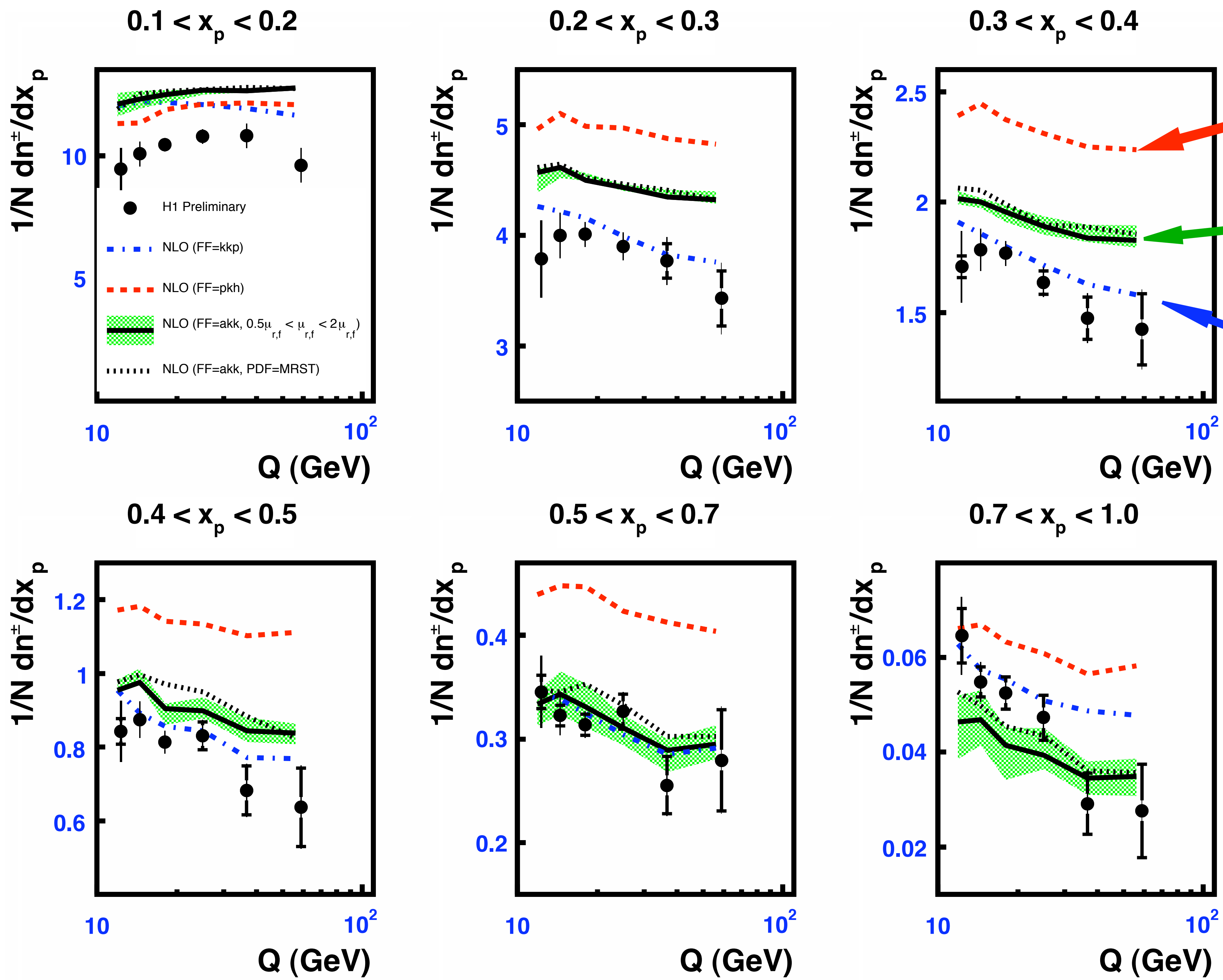
DJANGOH (Colour Dipole Model)

RAPGAP (Parton Showers, string fragmentation)

reasonable descriptions

HERWIG (cluster fragmentation) too hard

Comparison with NLO QCD, CYCLOPS (D. Graudenz)



+ fragmentation functions

(Kretzer)
hep-ph/0003177

(Albino, Kniehl, Kramer)
hep-ph/0502188, 0510173

(Kniehl, Kramer, Pötter)
hep-ph/0010289

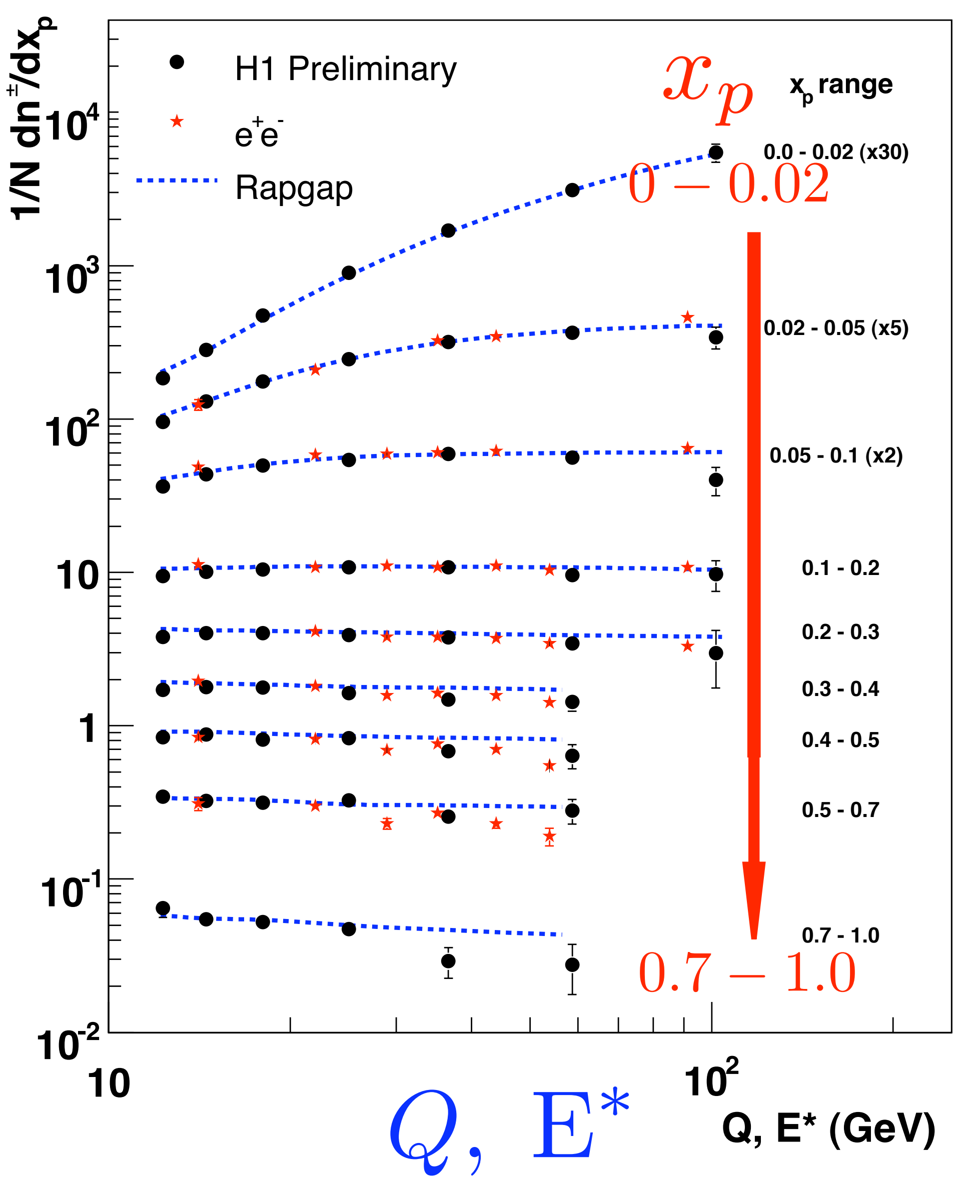
leads to best description

large uncertainty related to fragmentation functions

Scaling Violation

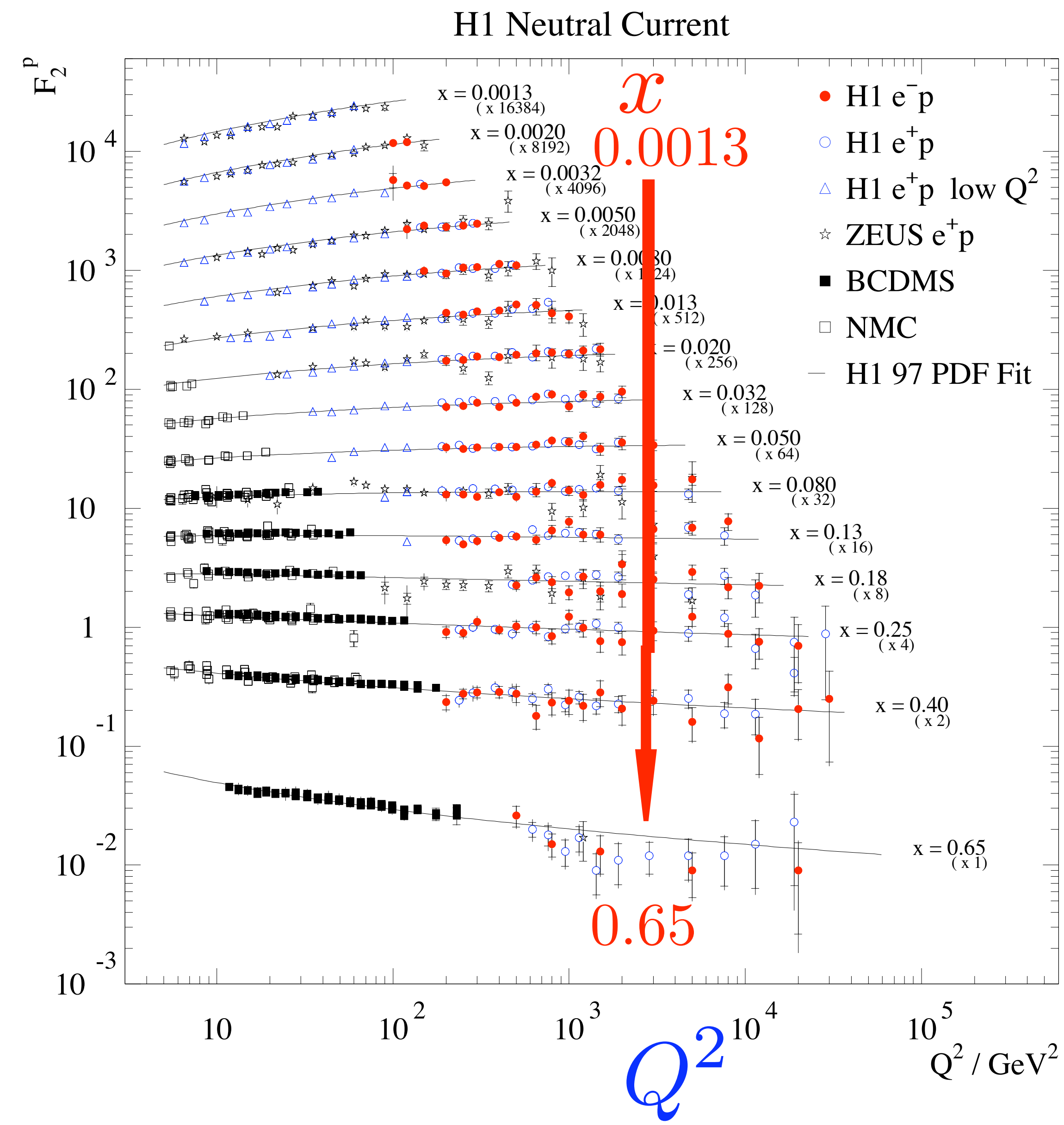
hadron production

in ep and e^+e^-



$$x_p = P_h/(Q/2)$$

inclusive NC

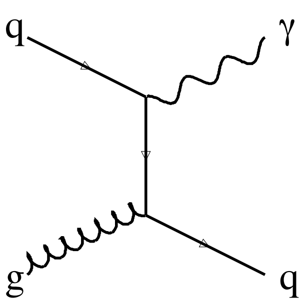


$$x = Q^2/(2pq)$$

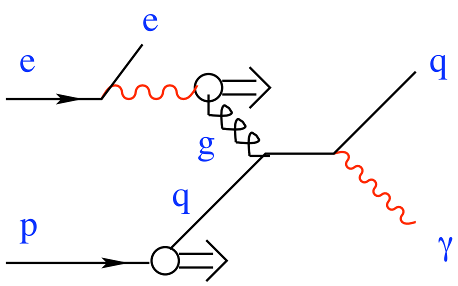
Prompt Photons

of general interest, because

hh



γp



- more directly related to partonic interactions than jets
- sensitive to gluon content of proton (and resolved photon)
- important background for searches at LHC (e.g. Higgs $\rightarrow \gamma\gamma$)
- they help in nuclear interactions to disentangle different effect (initial/final states, QGP, hadron gas, ...), as not strongly interacting

→ important to understand hopefully clean cases γp , ep

drawbacks :

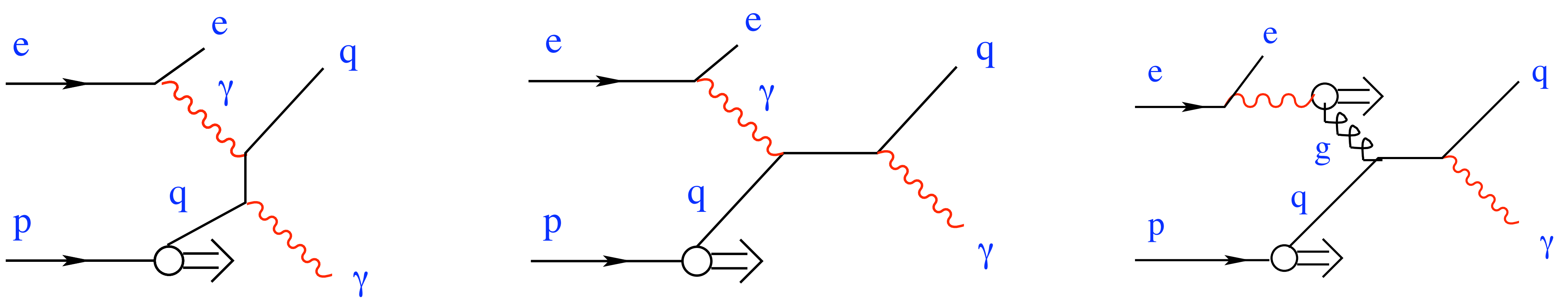
- small cross sections
- background from neutral hadrons ($\pi^0, \eta \ldots$)

→ needs careful subtraction of $\pi^0, \eta \ldots$

and/or sophisticated shower shape analyses

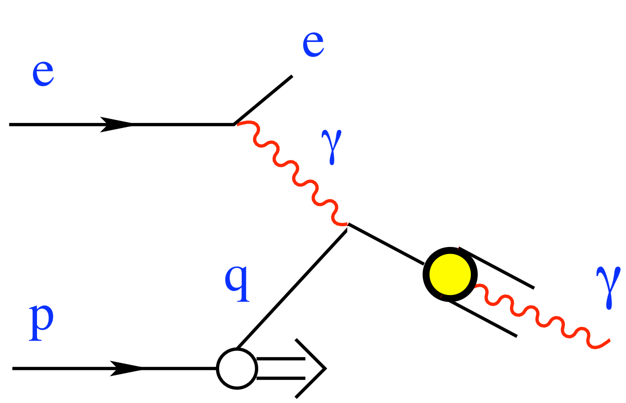
Prompt photon production in γp and ep DIS

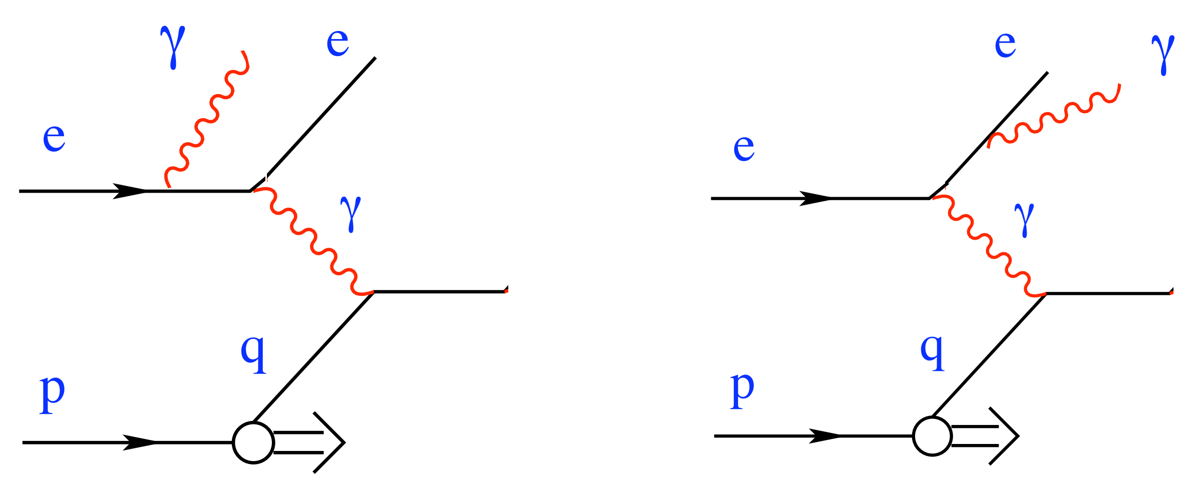
γp : high pt prompt photon implies jet activity (no electron recoil)



(resolved photon)

ep : pt provided already by electron recoil





non-p. $q \to \gamma$ fragmetation

contributes at LO

lepton radiation

contributes substantially

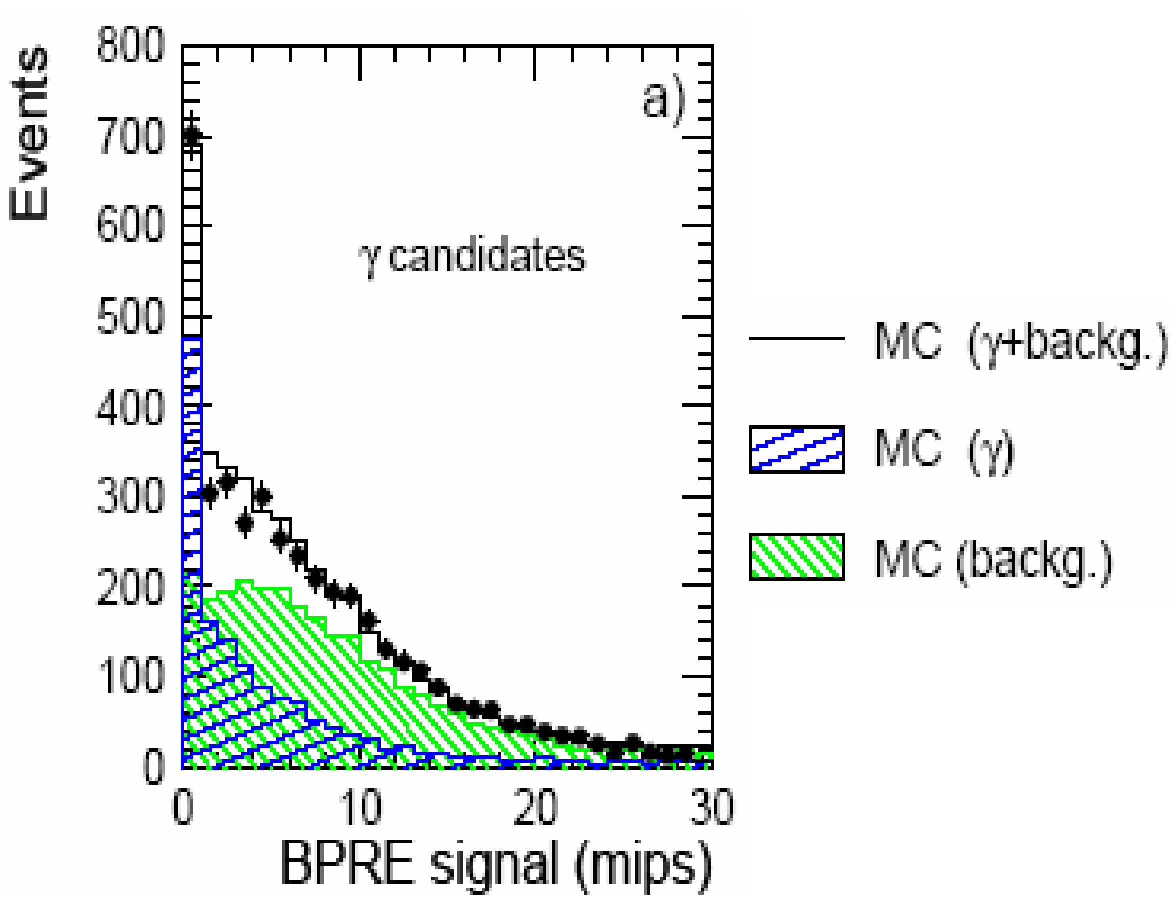
Photon Identification

main challenge : background from neutral hadrons (π^0, η ...)

most recent preliminary analyses :

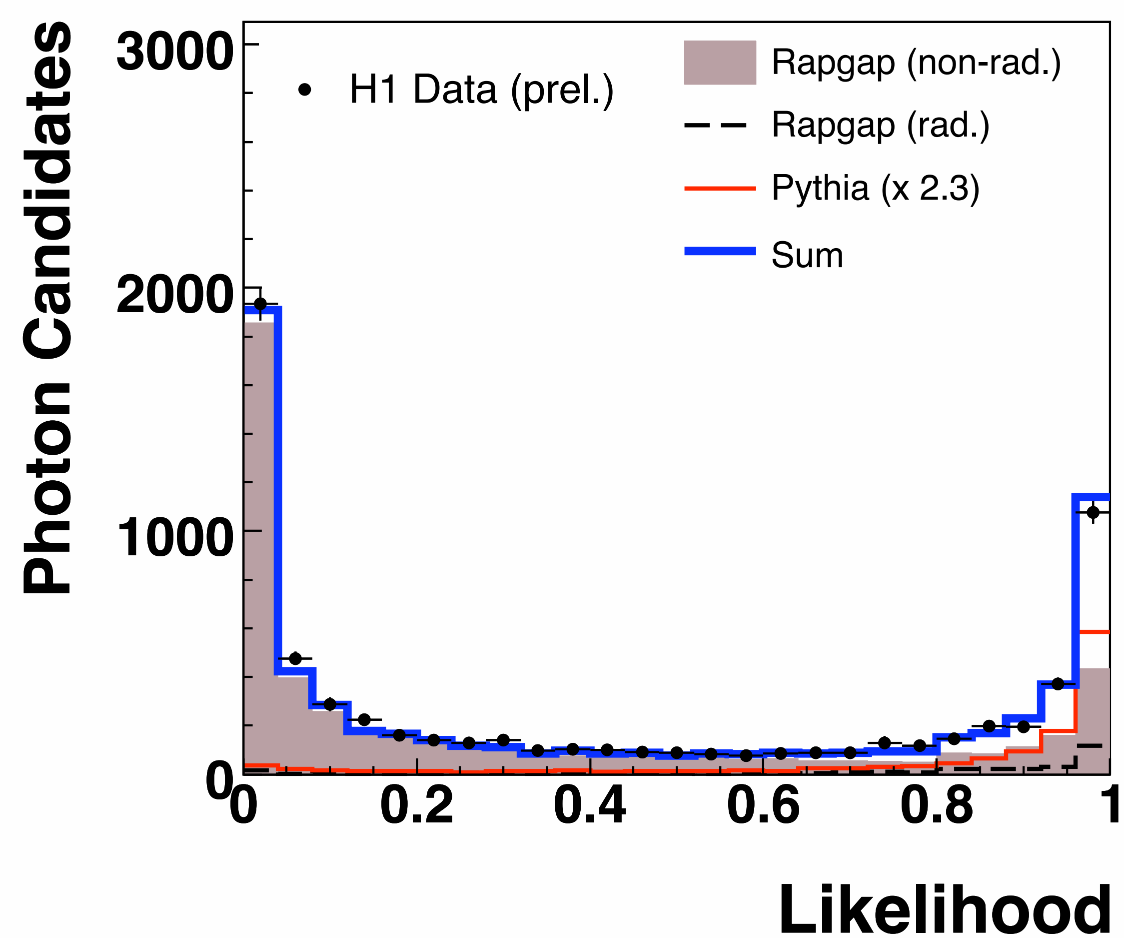
ZEUS $\gamma p \to \gamma + \text{jet}$

after preselection, fit of MC to spectrum in preshower scintillator



H1 DIS inclusive γ

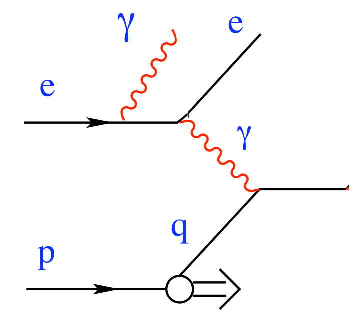
various LAr shower shape variables combined and fit by MC

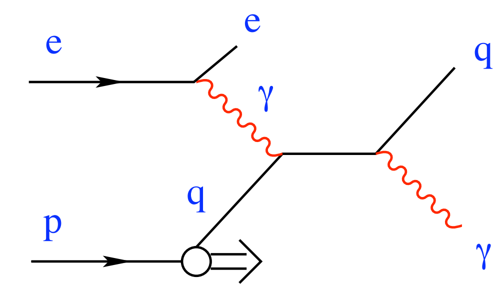


Predictions for prompt photons in ep DIS

γ + (0 + 1) jet , γ + (1+1) jet and γ inclusive

p remnant jet





Gehrmann-De Ridder, Gehrmann, Poulsen (hep-ph/0601073, /0604030)

$\mathcal{O}(\alpha^3)$ calculation with lepton radiation (LL), quark radiation (QQ) and interference (QL).

QQ includes non perturbative fragmentation function D($q \rightarrow \gamma$) (based on ALEPH data)

NLO correction for γ + (1+1) jet $\mathcal{O}(\alpha^3 \alpha_s)$

Gehrmann-De Ridder, Kramer, Spiesberger (hep-ph/9903377, /0003082)

DIS cross sections and Generators

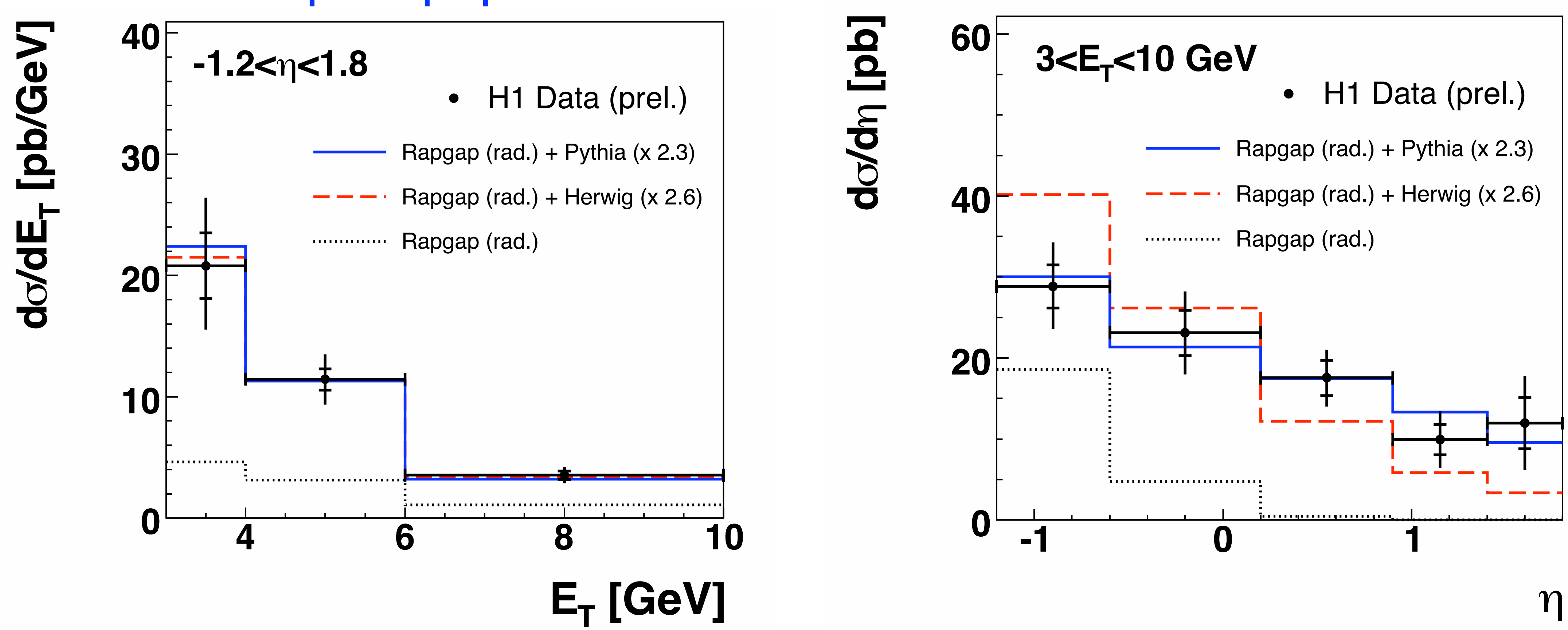
data not described by HERWIG or PYTHIA

match taking

$q \rightarrow \gamma\, q$ from PYTHIA (HERWIG) scaled by factor 2.3 (2.6) and

$e \rightarrow \gamma\, e$ from RAPGAP generator

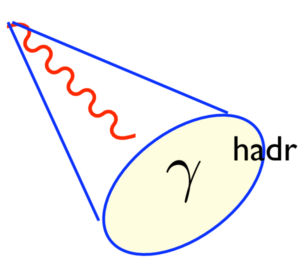
inclusive prompt photons



further comparisons with $\mathcal{O}(\alpha^3)$ calculations

Prompt photons in ep DIS

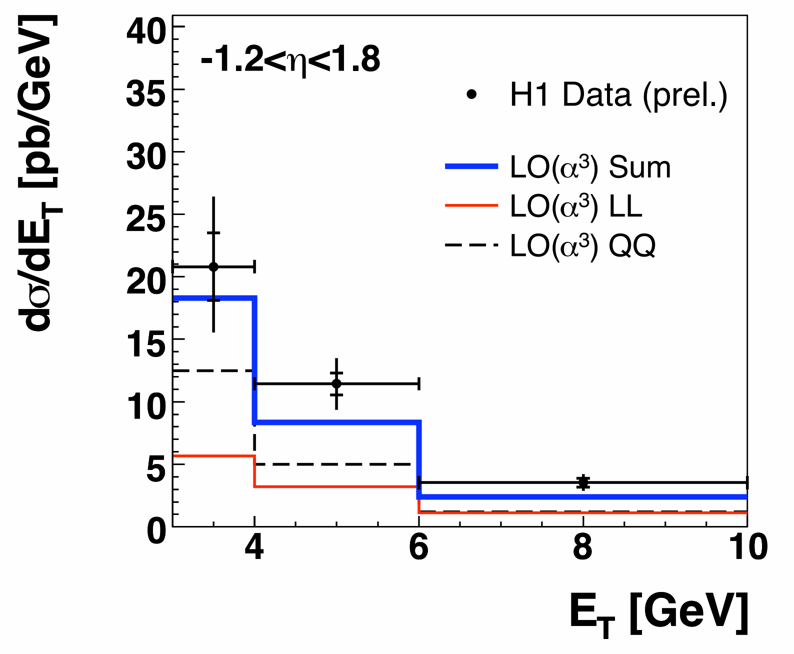
ZEUS hep-ex/0402019		H1 , preliminary
$121\ \mathrm{pb}^{-}1$	$\mathcal{L}$	$70.6\ \mathrm{pb}^{-}1$
$> 35\ \mathrm{GeV}^2$	Q^2	$> 4\ \mathrm{GeV}^2$
$> 10\ \mathrm{GeV}$	$\mathrm{E}^{\mathrm{electron}}$	$> 10\ \mathrm{GeV}$
shower shape	γ	shower shape
$5 < \mathrm{E}_\mathrm{t}^\gamma < 10\ \mathrm{GeV}$	$\mathrm{E}_\mathrm{t}^\gamma$	$3 < \mathrm{E}_\mathrm{t}^\gamma < 10\ \mathrm{GeV}$
$-0.7 < \eta^\gamma < 0.9$	η^γ	$-1.2 < \eta^\gamma < 1.8$
$\mathrm{E}_\gamma > 0.9\ \mathrm{E}_{\mathrm{cone}}$	isolation	$\mathrm{E}_\gamma > 0.9\ \mathrm{E}_{\gamma-\mathrm{jet}}$ ($\mathrm{k_t}$ algo)
cone algo, $\mathrm{R} = 0.7$	jet	
$\mathrm{E}_\mathrm{t}^{\mathrm{jet}} > 6\ \mathrm{GeV}$	$\mathrm{E}_\mathrm{t}^{\mathrm{jet}}$	
$-1.5 < \eta^{\mathrm{jet}} < 1.8$	η^{jet}	

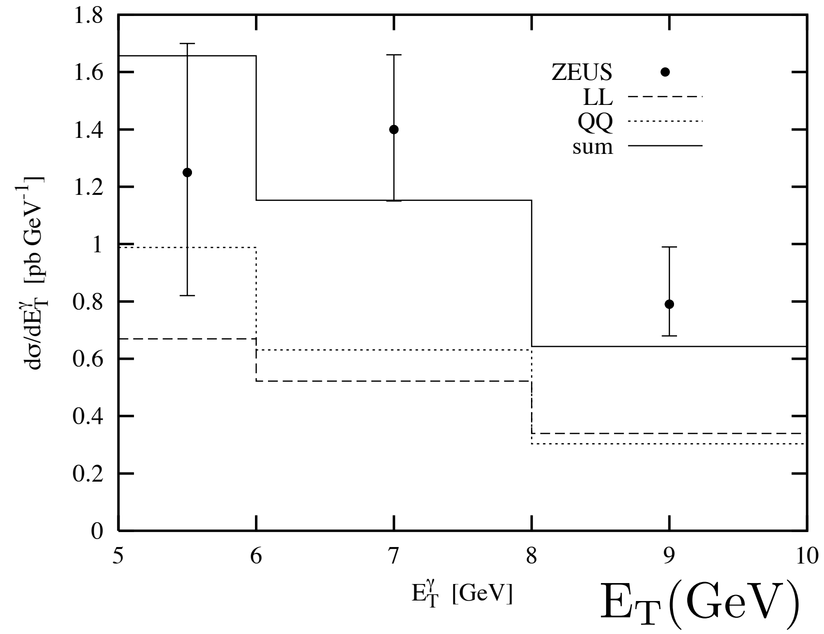


Inclusive promt photons and LO(α^3) calculation

H1 — $Q^2 > 4\ \mathrm{GeV}^2$

ZEUS — $Q^2 > 35\ \mathrm{GeV}^2$

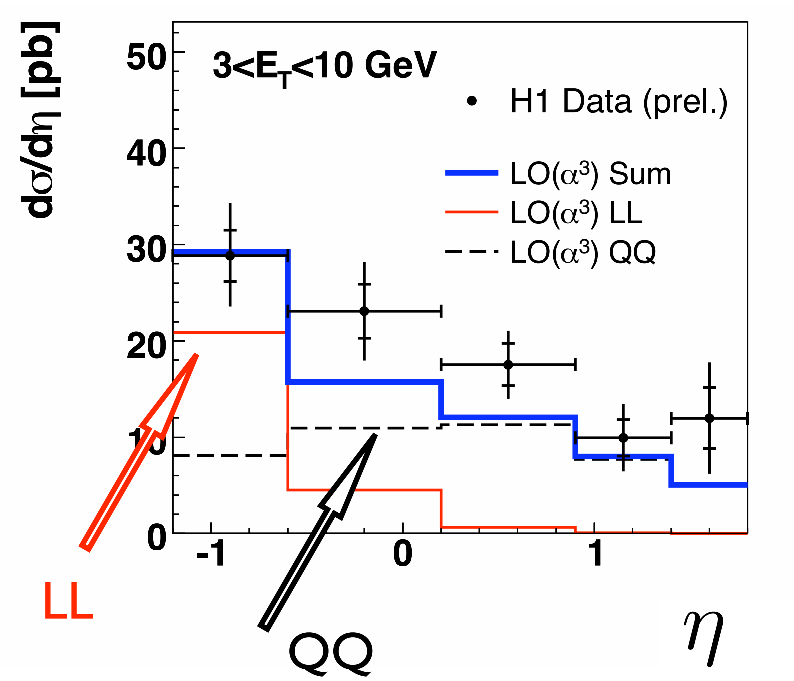


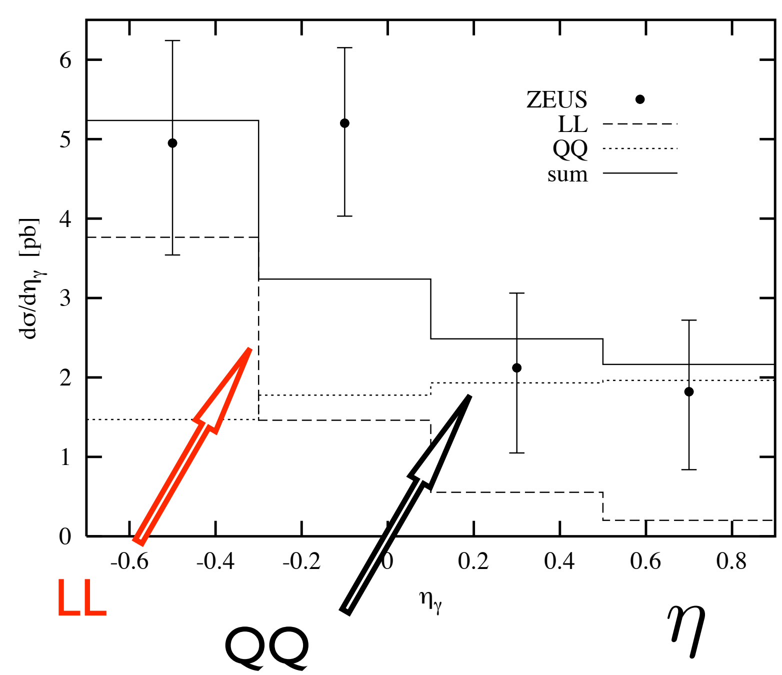


quark radiation (QQ)

dominates at large η

(vs. p beam direction)

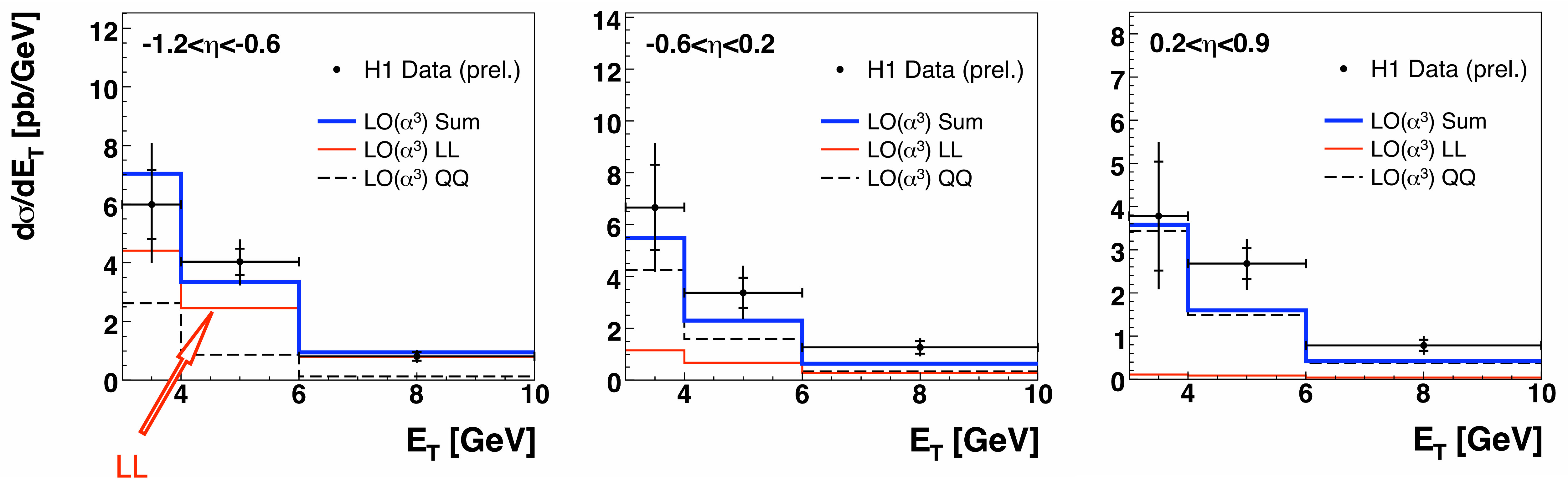


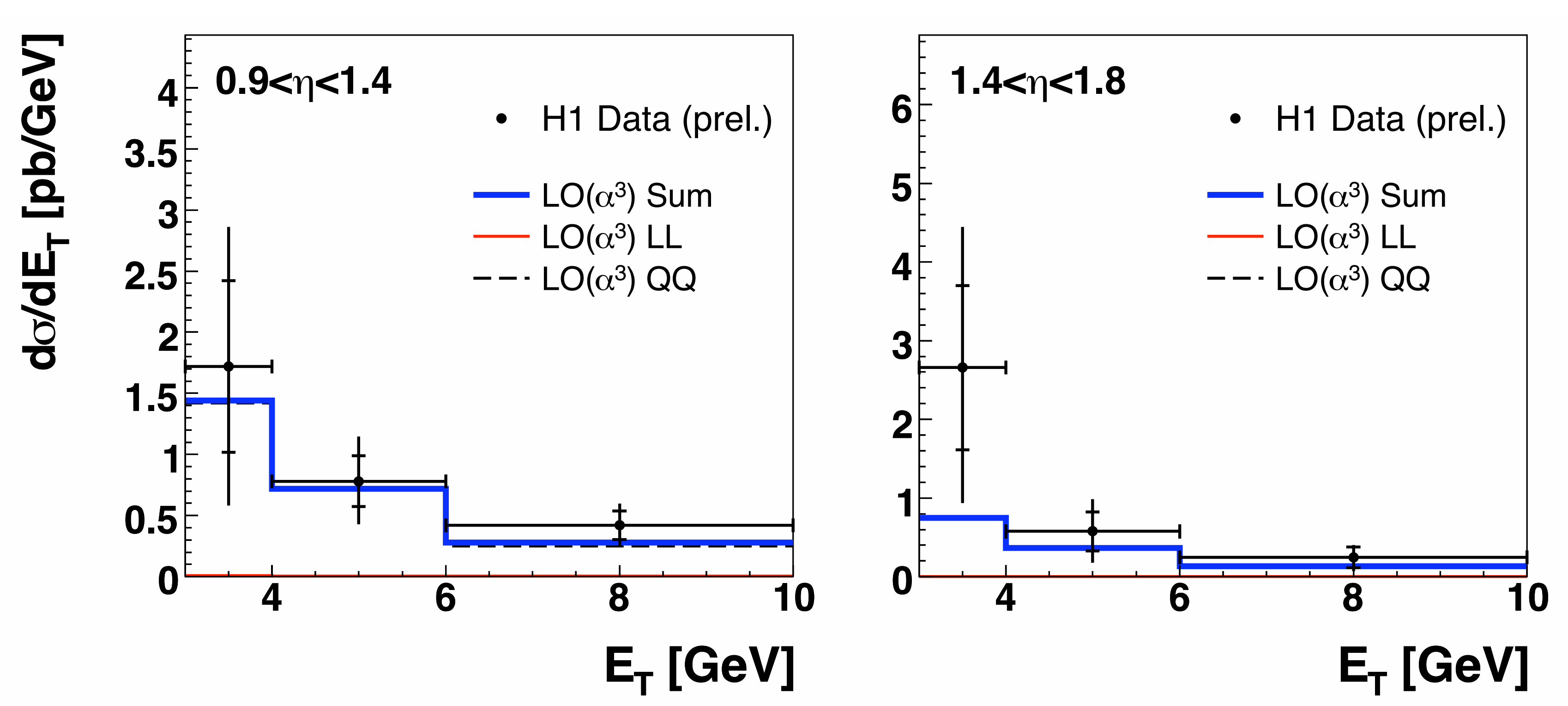


reasonable description of all results

$\eta - \mathrm{E_T}$ bins

$p \rightarrow\leftarrow e$





e-radiation (LL)

at $\eta > 0.2$

small for all $\mathrm{E_T}$

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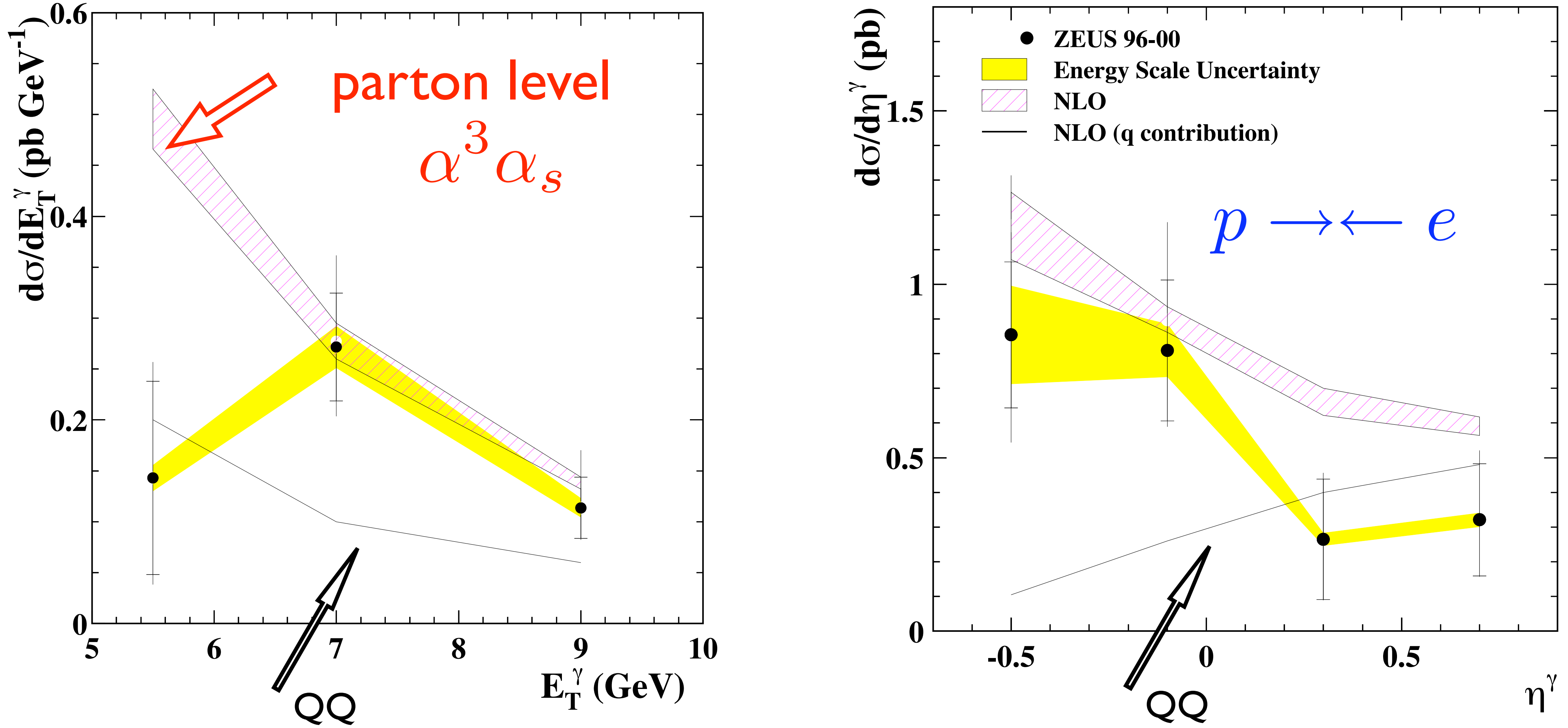
data well described

photon + jet $(\gamma$ + (1+1) jet)

$Q^2 > 35\ \mathrm{GeV}^2$



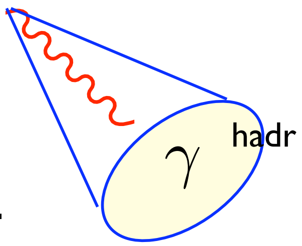
substantial contribution of LL (electron radiation)

uncertainties still large

data consistent with NLO

Photoproduction of prompt photons with accompanying jet

ZEUS preliminary		H1 , hep-ex/0407018
$77.1\ \mathrm{pb}^{-1}$	$\mathcal{L}$	$105\ \mathrm{pb}^{-1}$
$< 1\ \mathrm{GeV}^2$	Q^2	$< 1\ \mathrm{GeV}^2$
$0.2 < y < 0.8$	y	$0.2 < y < 0.7$
preshower + shower shape	γ	shower shape
$5 < \mathrm{E}_t^\gamma < 17\ \mathrm{GeV}$	E_t^γ	$5 < \mathrm{E}_t^\gamma < 10\ \mathrm{GeV}$
$-0.7 < \eta^\gamma < 1.1$	η^γ	$-1.0 < \eta^\gamma < 0.9$
$\mathrm{E}_\gamma > 0.9\ \mathrm{E}_{\gamma-\mathrm{jet}}$	isolation	$\mathrm{E}_\gamma > 0.9\ \mathrm{E}_{\mathrm{cone}}$
$\mathrm{k_t}$ algo	jet	$\mathrm{k_t}$ algo
$6 < \mathrm{E}_t^{\mathrm{jet}} < 17\ \mathrm{GeV}$	$\mathrm{E}_t^{\mathrm{jet}}$	$4.5\ \mathrm{GeV} < \mathrm{E}_t^{\mathrm{jet}}$
$-1.6 < \eta^{\mathrm{jet}} < 2.4$	η^{jet}	$-1.0 < \eta^{\mathrm{jet}} < 2.3$



prompt photon + jet data are compared with

NLO pQCD , Fontannaz, Guillet, Heinrich (FGH)

p : MRST01 (ZEUS), MRST02 (H1), γ AFG02, frag. BFG

Krawczyk, Zembrzuski (K&Z)

(equivalent, but no higher order for resolved photon graph)

p , γ , frag. : as for FGH (H1), GRV (ZEUS)

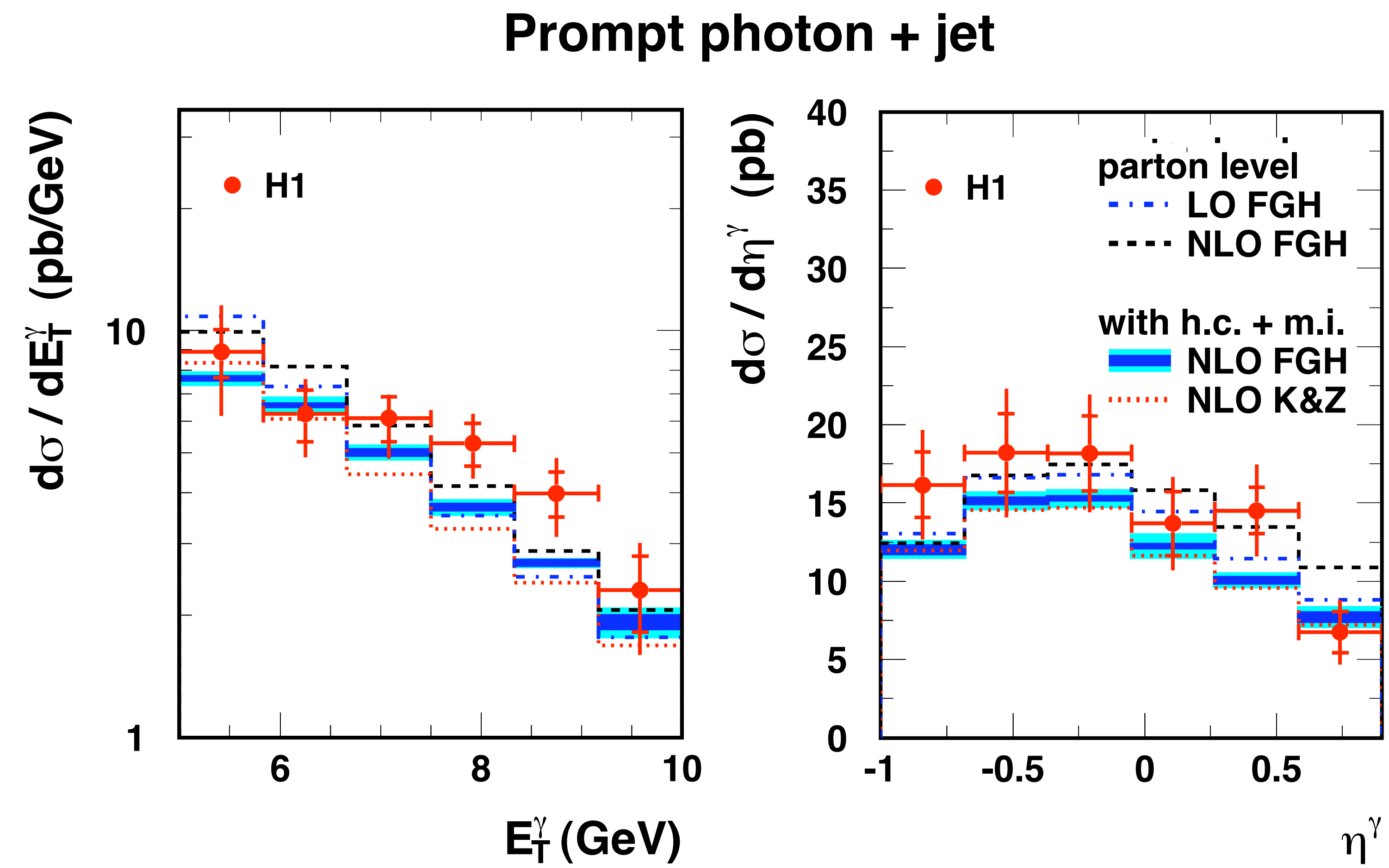
kt -factorisation, LO, A. Lipatov, N. Zotov (LZ)

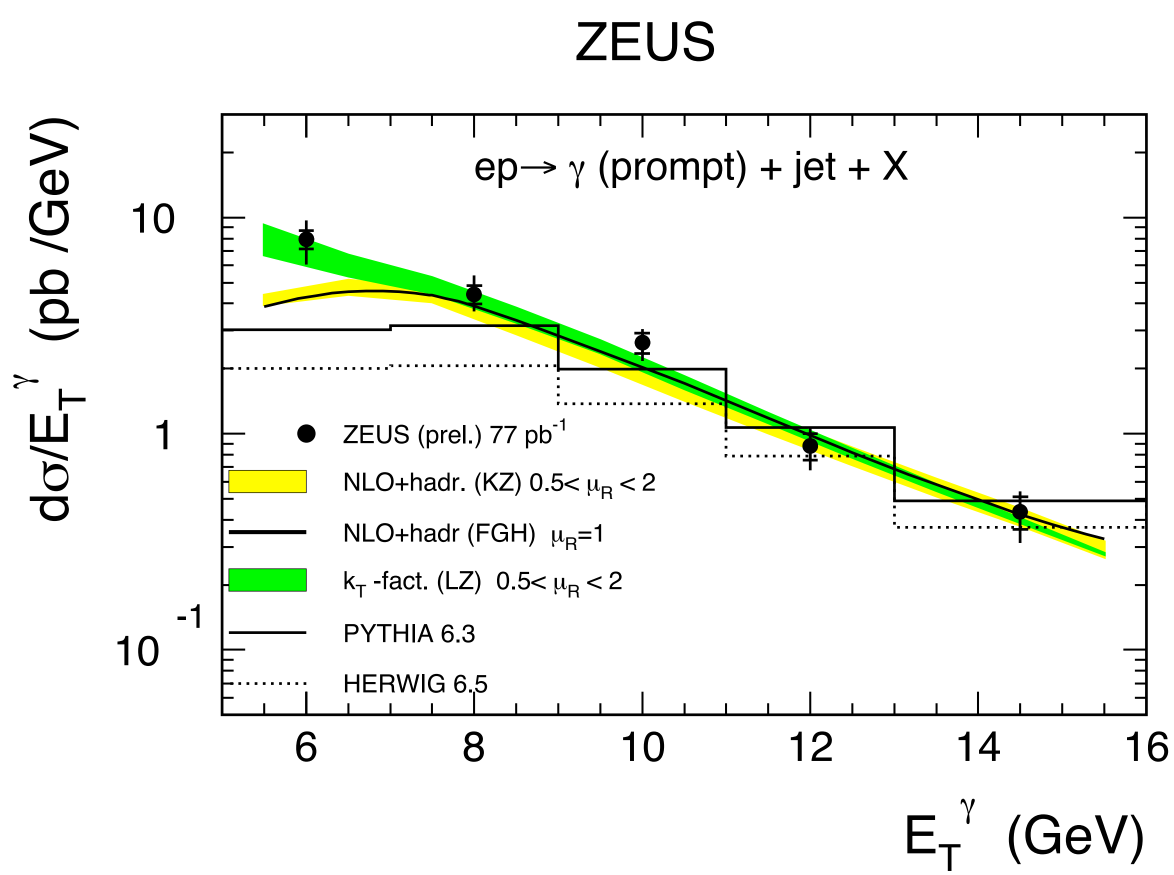
unintegrated quark/gluon densities
following Kimber-Martin-Ryskin prescription

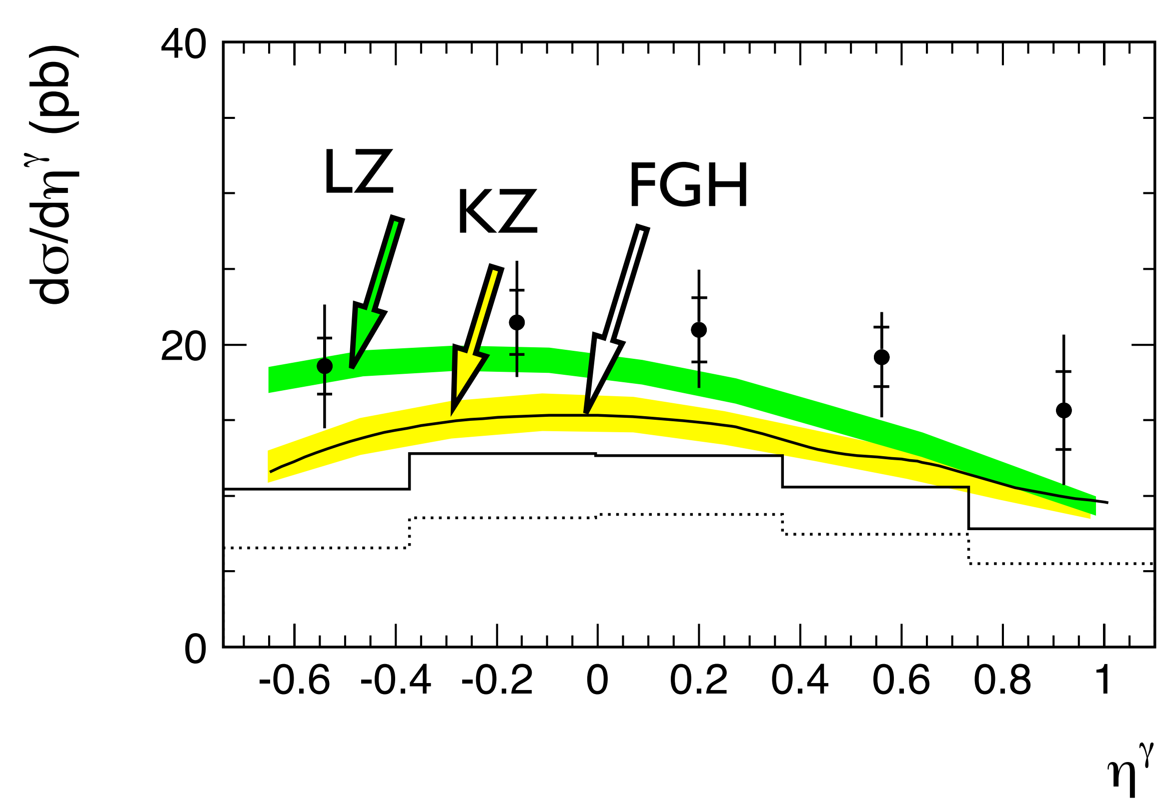
Generators PYTHIA 6.3 HERWIG 6.5

photon variables :

E_T^γ η^γ



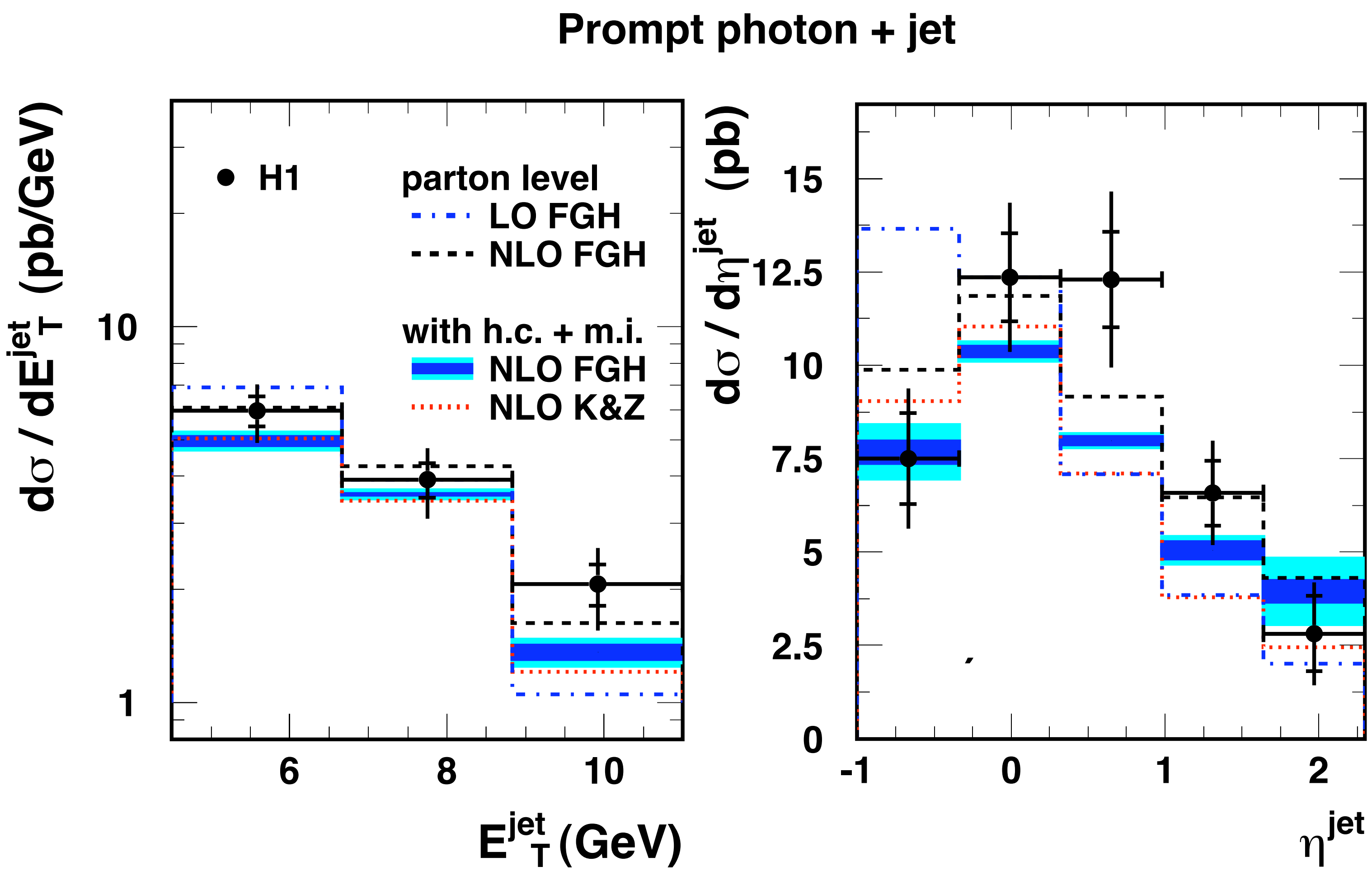


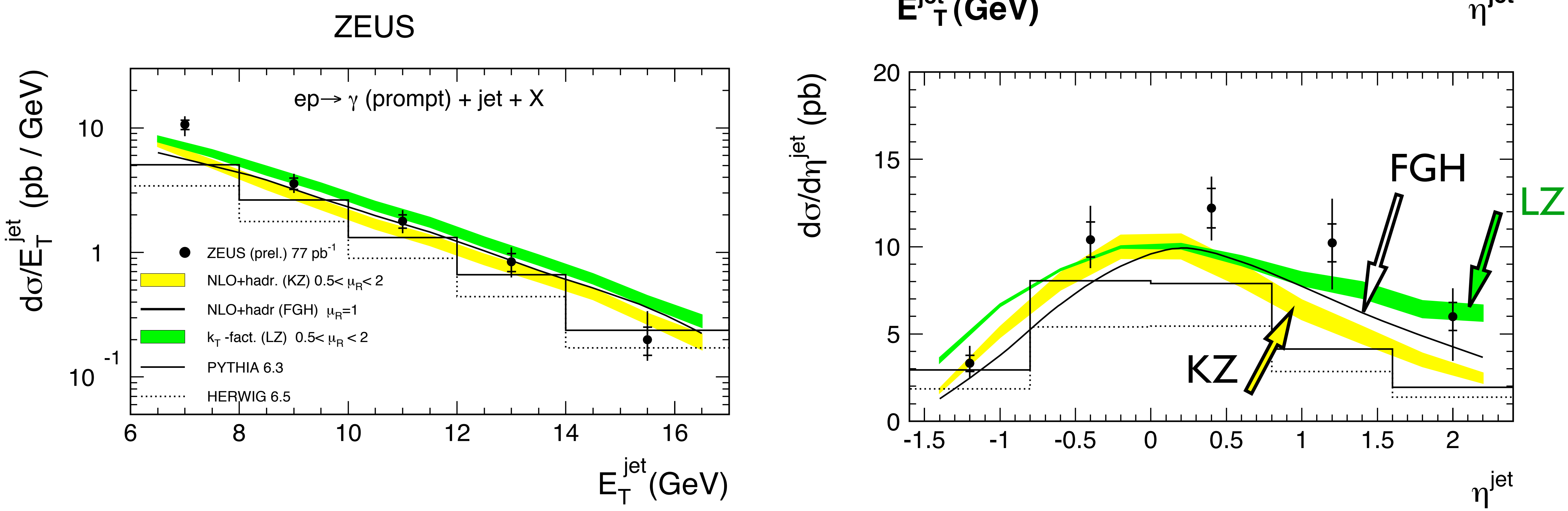


- in general good description by calculations
- kt fact. (LZ) approach best at low E_T^γ η^γ
- PYTHIA, HERWIG low

jet variables

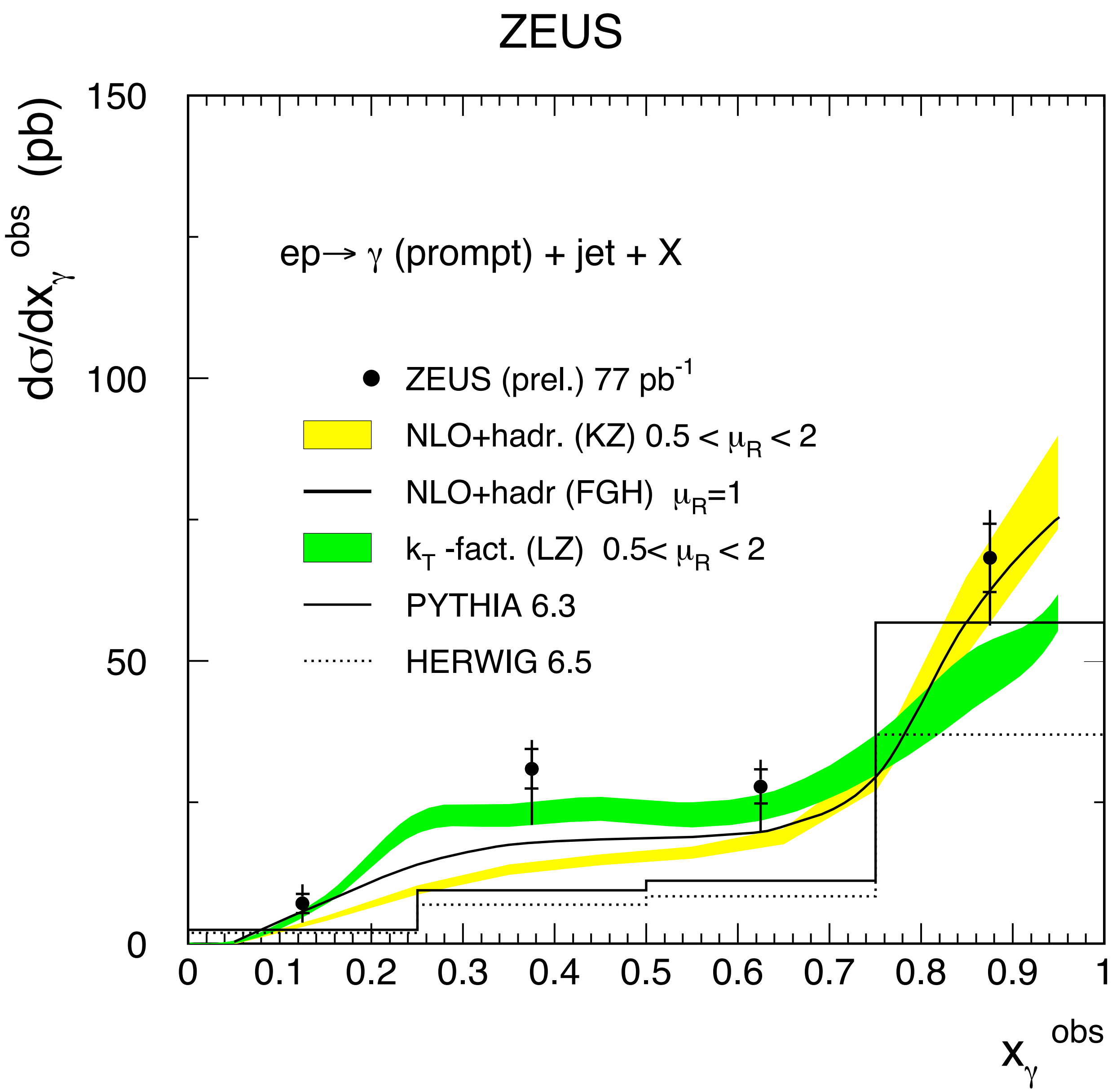
E_T^{jet} η^{jet}

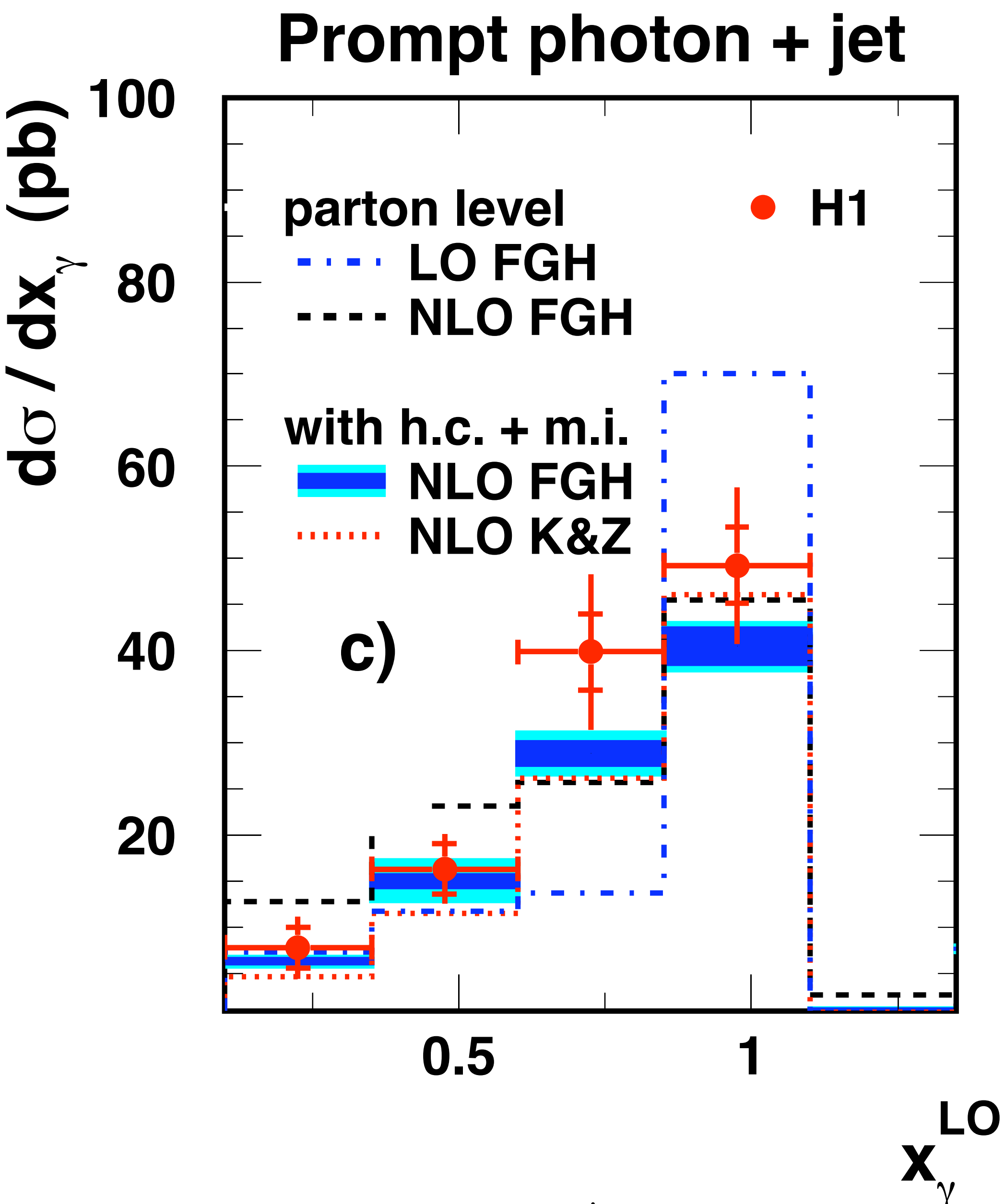




- again good description by calculations
- differences small in view of exp. uncertainties
- PYTHIA, HERWIG low

γ and jet combined





$$x_\gamma^{obs} = \sum_{\gamma,jet} \frac{E - P_z}{2E_e y}$$

$$x_\gamma^{LO} = \mathrm{E_T^\gamma}(\mathrm{e}^{-\eta^{\mathrm{jet}}} + \mathrm{e}^{-\eta^\gamma})/2\mathrm{E_e y}$$

FHG, KZ, LZ within errors consistent with the data

Conclusions

Inclusive Hadron Distributions

x_p distributions very similar in ep DIS and e^+e^-

reasonable description by MC models (HERWIG too hard)

NLO calculation consistent with data,
but strong sensitivity to fragmentation functions

Prompt Photons

ep DIS

γ inclusive : good description by LO α^3 calculation

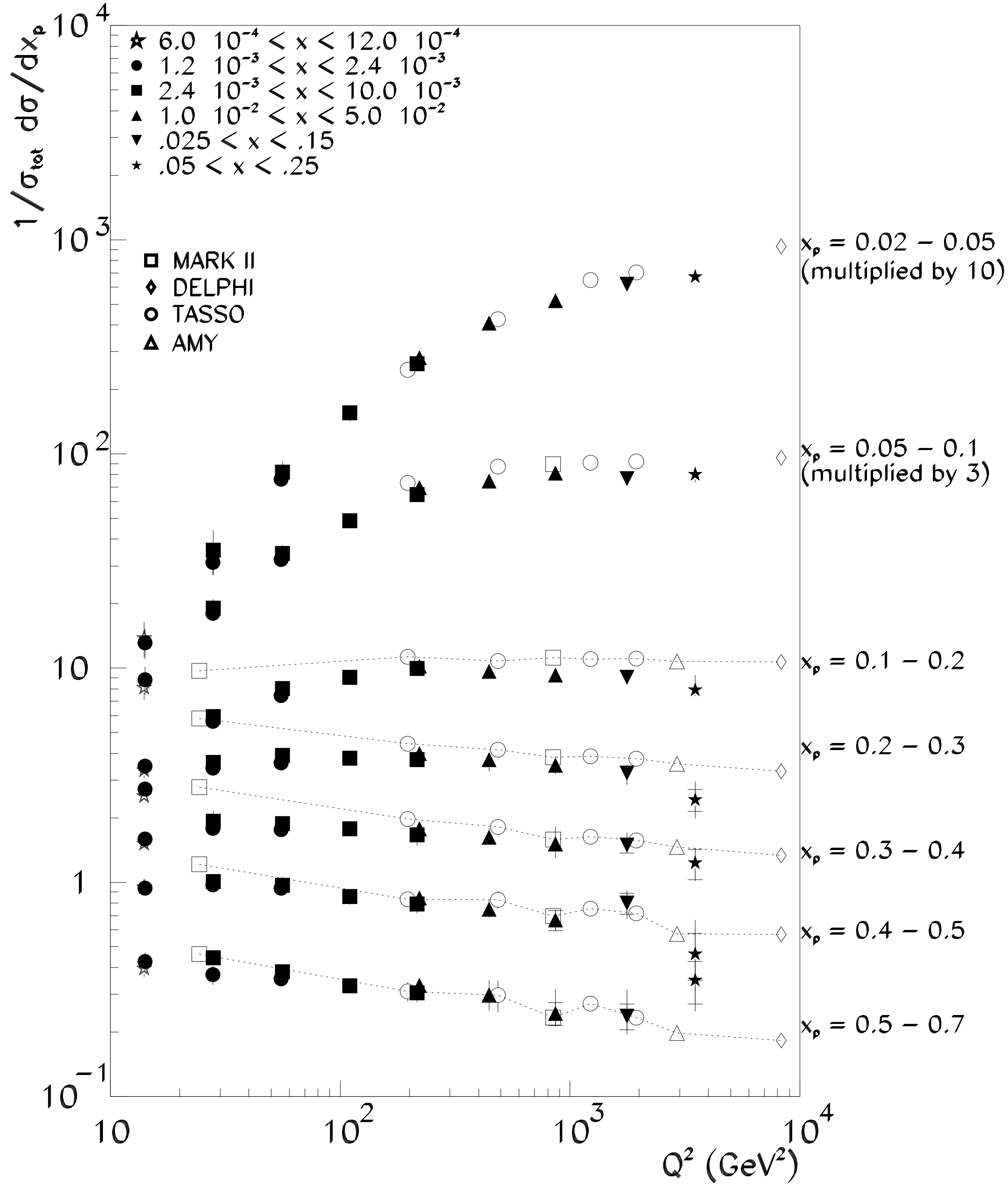
γ + jet : still large uncertainties

Photoproduction

γ + jet : good description by fixed order NLO and by kt factorised LO approach

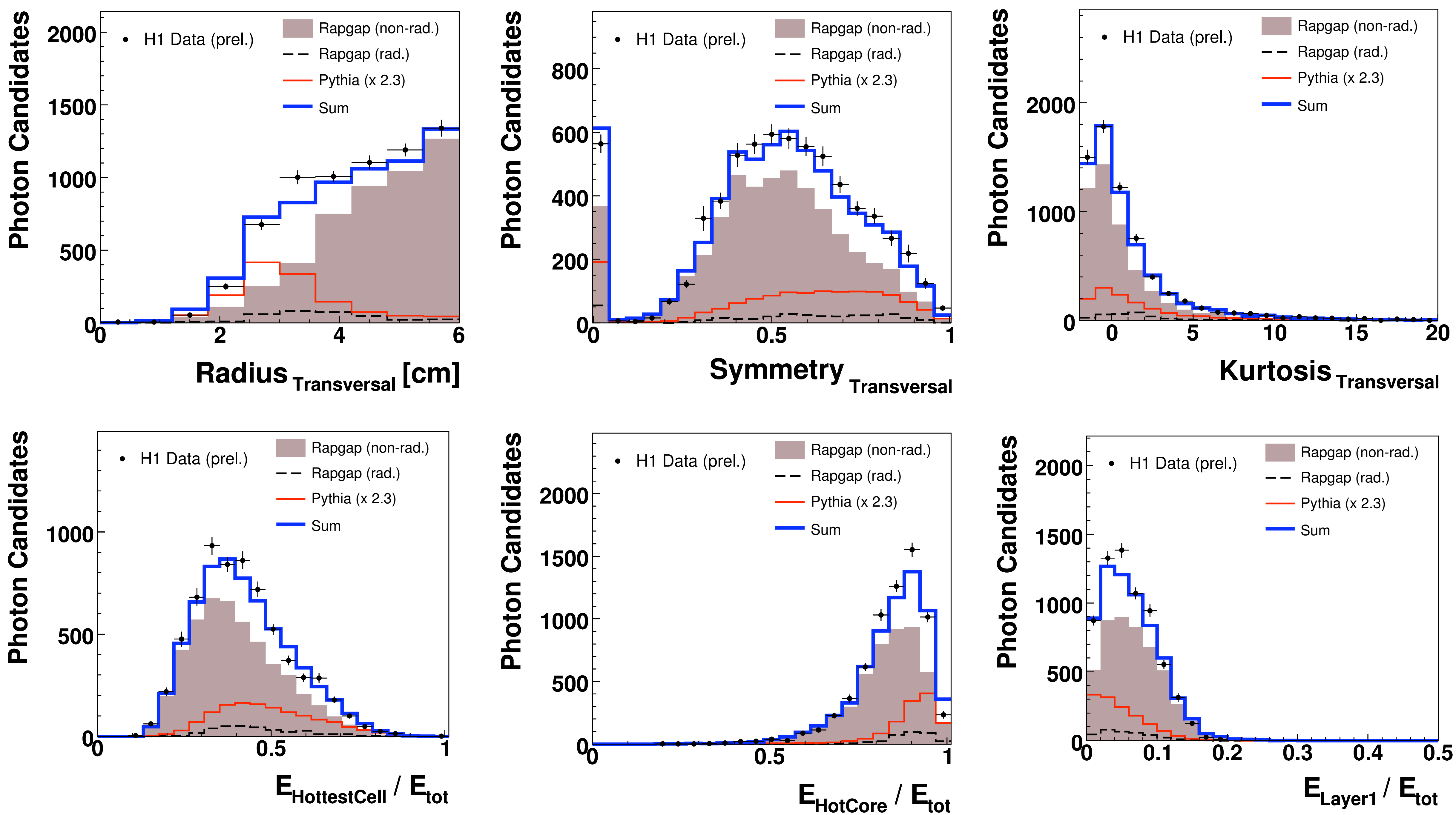
Backup

ZEUS 1994−97 (hep-ex/9903056)



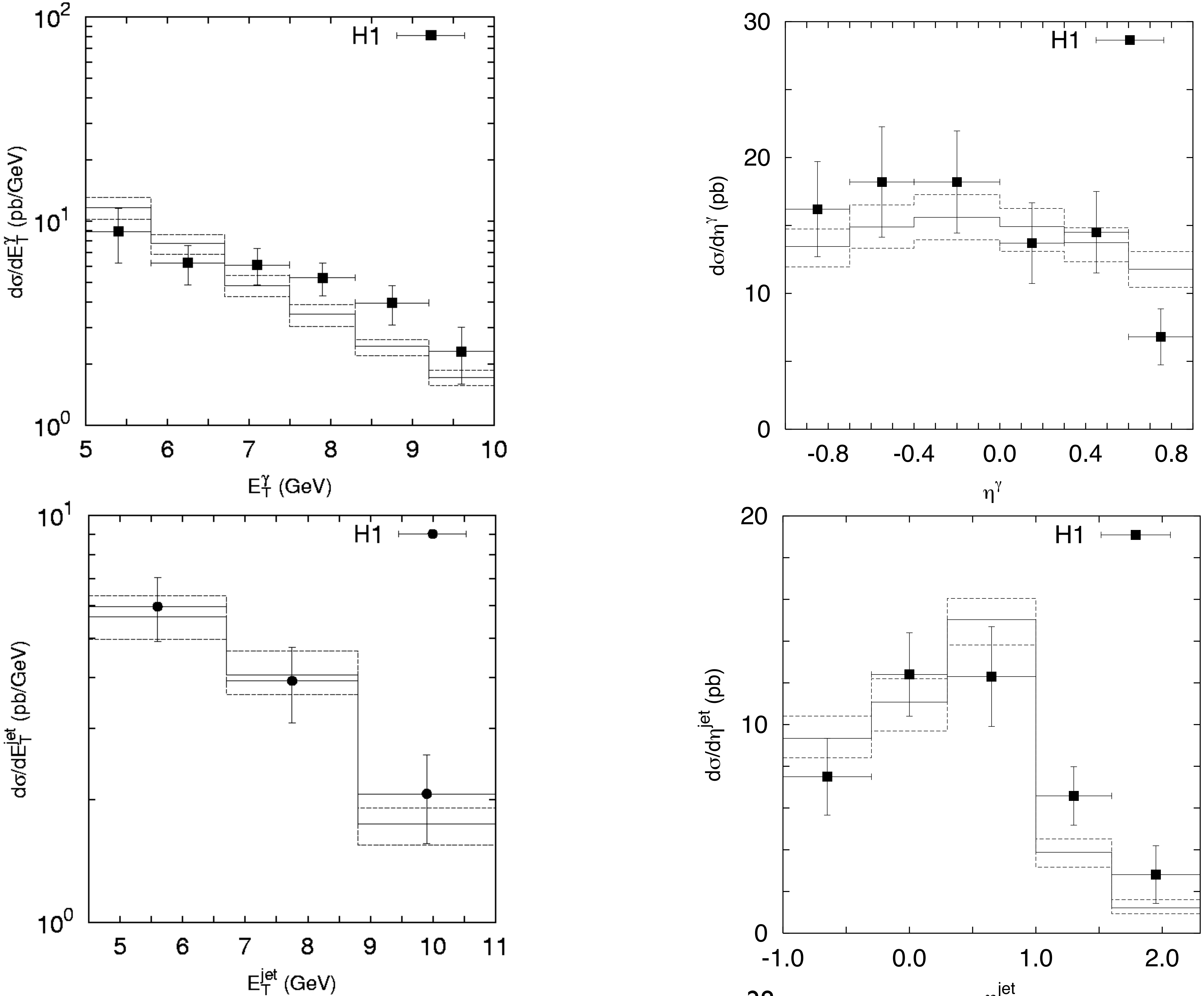
earlier ZEUS data show similar differences at large Q

Discriminating cluster variables



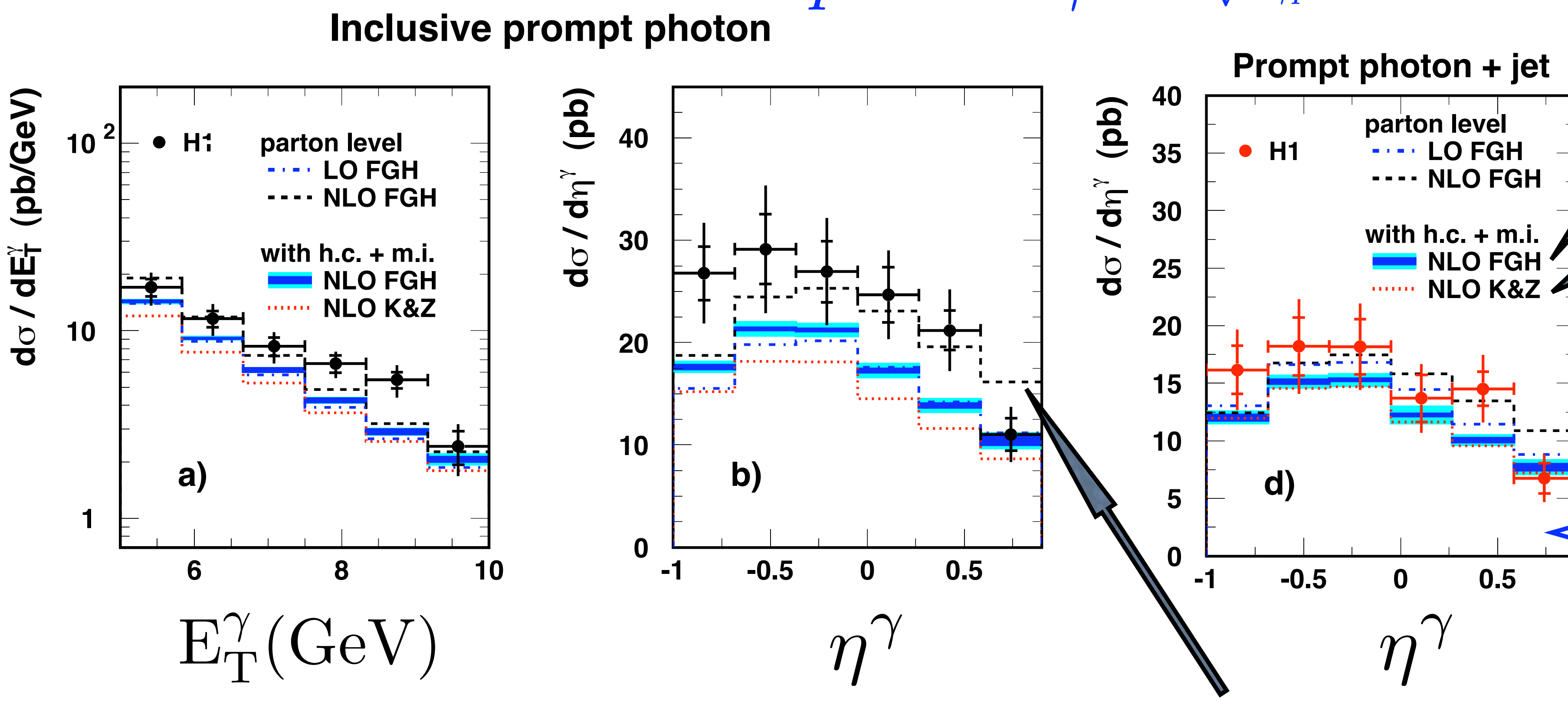
All shapes well described by MC

Prompt photon and jet compared with kt fact. approch (A. Lipatov, N. Zotov)



E_T and pseudorapidity distributions in $\gamma\, p$, HERA

$p \longrightarrow \longleftarrow \gamma \qquad \sqrt{s_{\gamma p}} \sim 200$ GeV



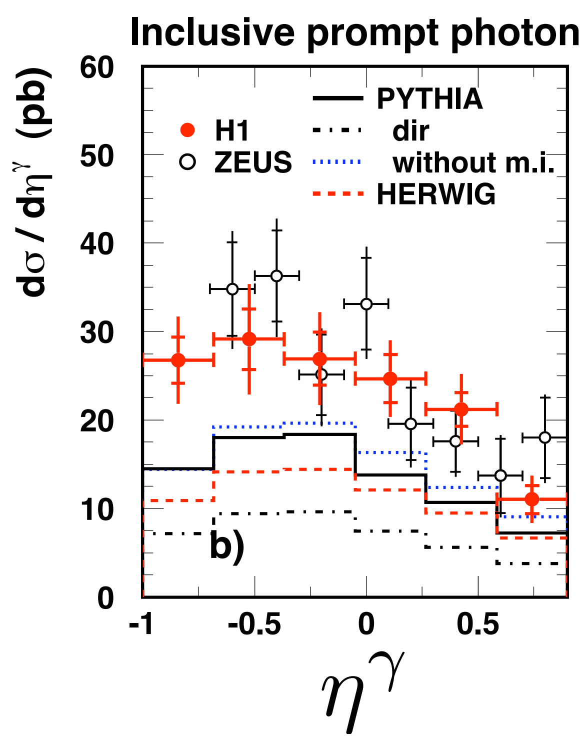
NLO pQCD

Fontanaz, Guillet, Heinrich

Krawczyk,Zembrzuski

description improved, if jet required

NLO and models PYTHIA, HERWIG describe shapes, but low in normalisation ~30...40%



note :

NLO before corrections for hadronisation is closer to the data

(H1 corrects with PYTHIA and HERWIG)

PYTHIA similarly low in $\gamma\gamma$ (OPAL)