Prompt Photons at HERA

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HERA and the LHC – CERN 6.-9. June 06

Inclusive prompt photon production in DIS

- signal-background separation with shower shape analysis
- significantly extend phasespace of former measurement by ZEUS
- comparison to new LO calculation
  (hep-ph/0601073, hep-ph/0604030)

Photon plus jet cross section in Photoproduction

- new method of signal-background separation
- access to high photon energies
- comparison to NLO and k_t factorisation approach

Prompt Photons: Motivation

Crucial to understand the production of photons in association with hadrons

- possible signature for new physics
- important background for the search for Higgs: $H \rightarrow \gamma\gamma$
  LHC: $m_H < 130\ GeV$ most promising channel $H \rightarrow \gamma\gamma X$

  - Prompt photon cross section
  - Quark-to-photon fragmentation function $D_{q \rightarrow \gamma}$ so far only measured at ALEPH
    is it possible to measure it at HERA?

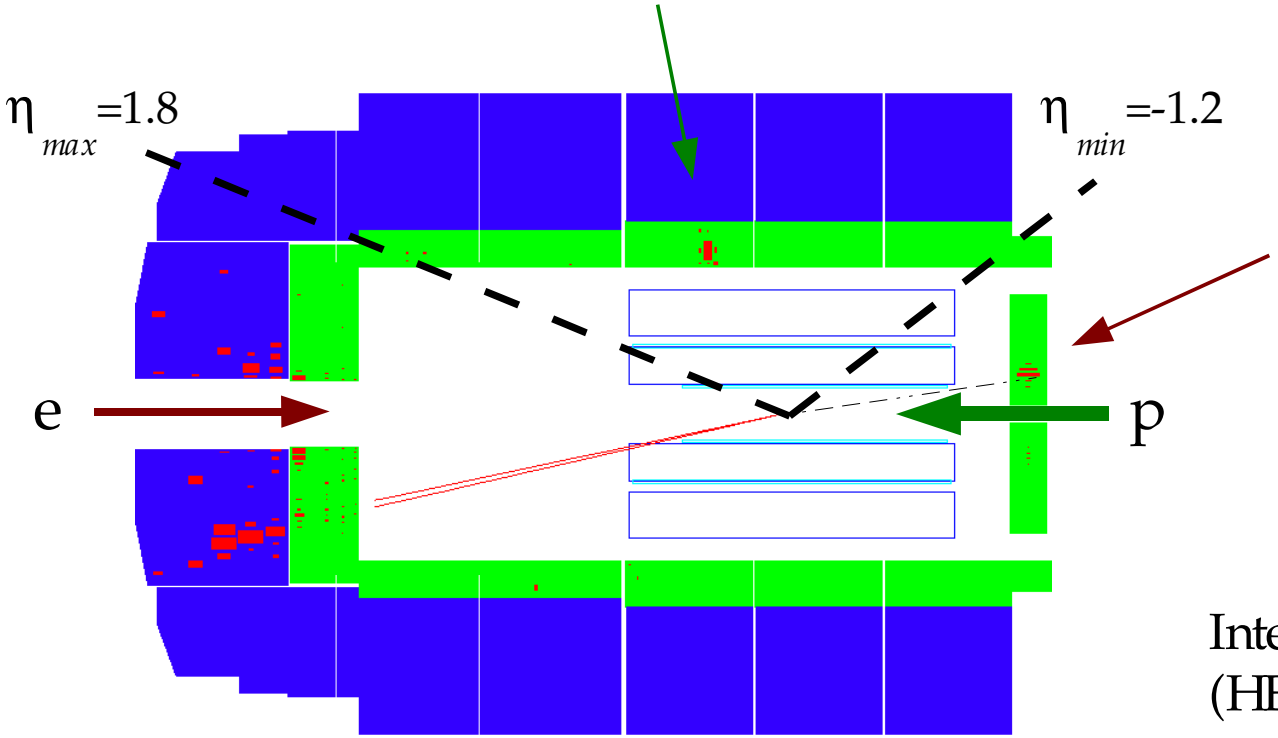
Prompt Photons in DIS: Selection

Photon: cluster in electromagnetic calorimeter $3 < E_t^{\gamma} < 10$ GeV

no track $-1.2 < \eta^{\gamma} < 1.8$

Isolation: $z = E^{\gamma}/E^{PhotonJet} > 0.9$

(democratic clustering approach)



MC event

Kinematics

$E^{Elec} > 10$ GeV

$151^{o} < \Theta^{Elec} < 177^{o}$

$Q^2 > 4$ GeV^2

$y > 0.05$

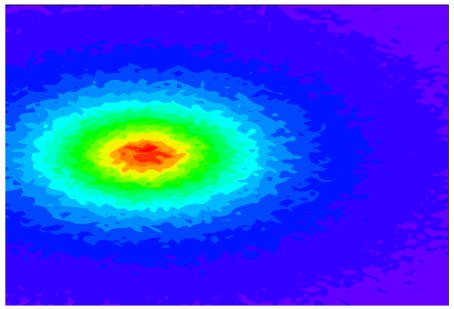
$\exists$ track in: $30^{o} < \theta < 150^{o}$

Integrated luminosity = 70.6 pb^{-1}
(HERA I)

Background: neutral mesons

Photon signal

γ



Compact electromagnetic cluster
no track pointing to it

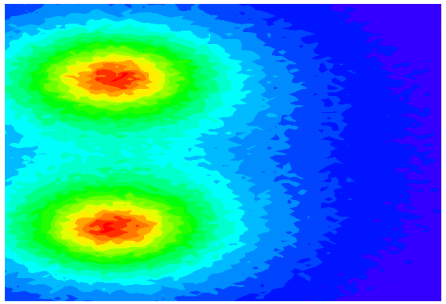
Background: neutral mesons decaying into multiple photons
π^0, η, η', ρ, ω, K^0, K^*, K_L, K_S, n

decay photons form a single cluster at high energies

γ

π^0

γ



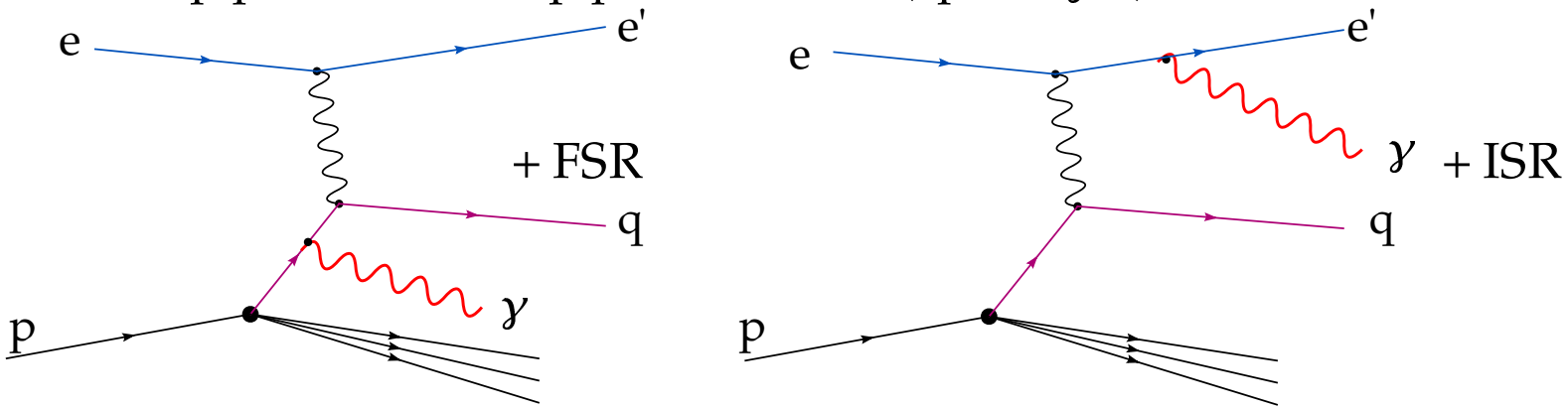
Identify multi photon clusters by analysis of shower shapes:
- transverse radius
- compactness
- symmetry
- energyfraction in first layer
- energy fraction of hottest cell
- transverse kurtosis

MC Generators and LO calculation

MC Generators

1) PYTHIA 6.2, HERWIG 6.5 γ+q → γ+q
   Flux of incoming photons is approximated in DIS mode
2) ISR and FSR radiation off the electron RAPGAP 3.1

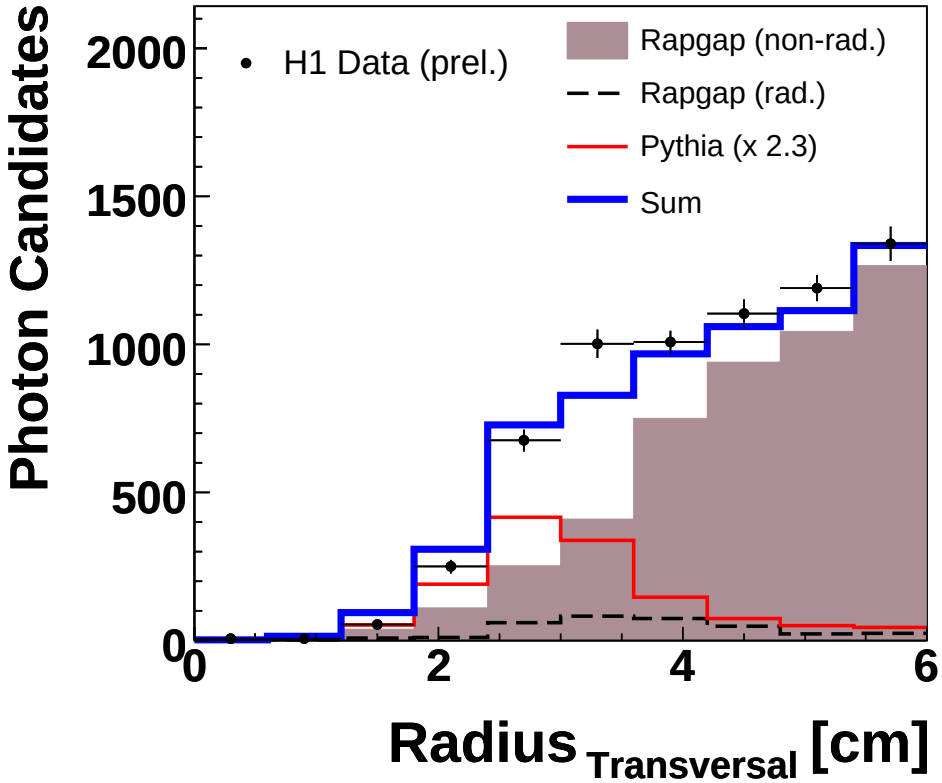
LO(α^3) calculation by Gehrmann et al. for prompt photon crosssection in DIS
hep-ph/0601073, hep-ph/0604030 $\sigma(ep \rightarrow e\gamma X)$



Contributions: QQ radiation off the quark
(including large angle radiation and photon fragmentation)
LL radiation off the electron
QL interference (negligible)

Signal-Background separation

Transverse radius of the cluster



Background:

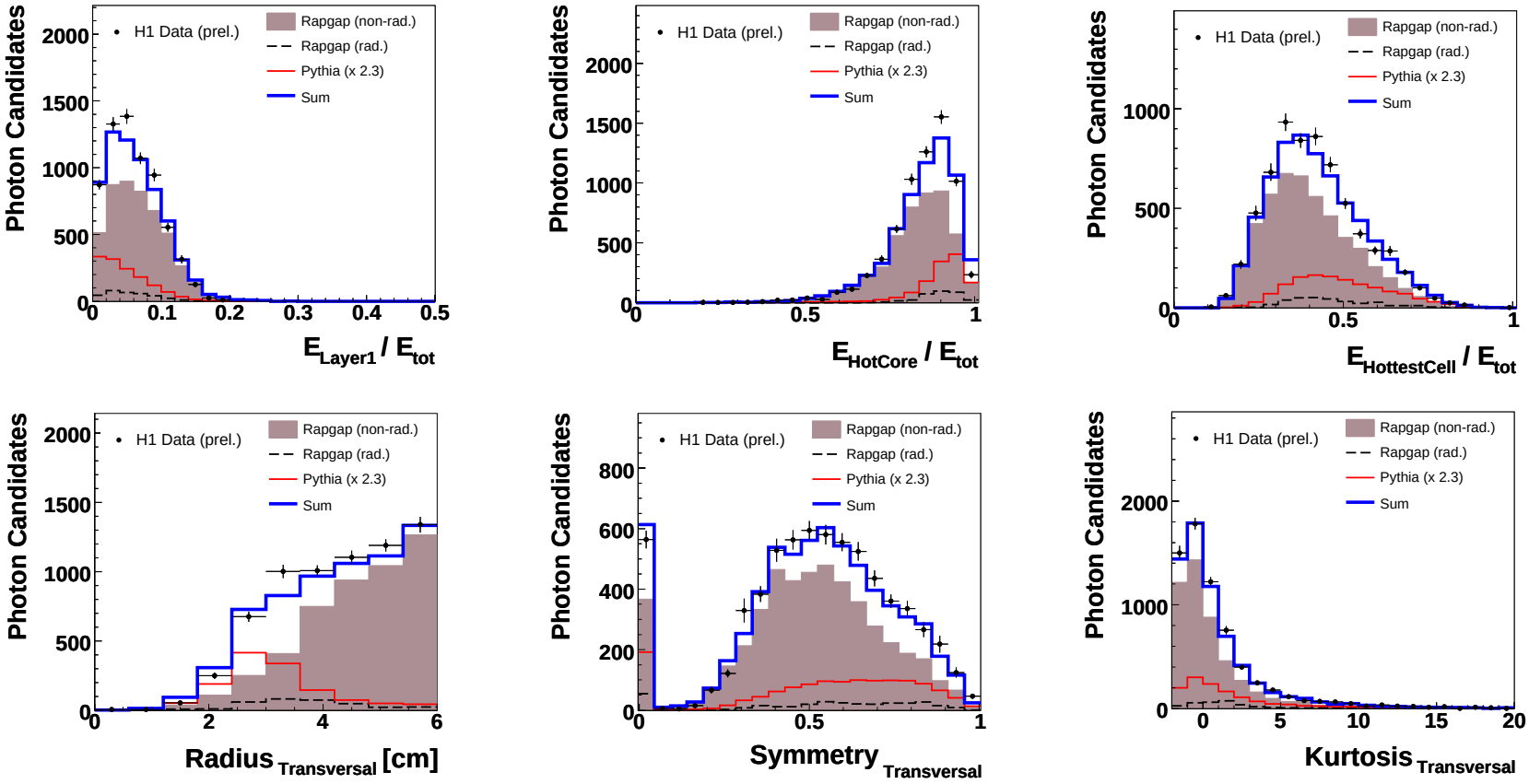
neutral mesons RAPGAP(non rad) without radiated photons

Signal:

1) Photons from quark line PYTHIA (scaled by 2.3)

2) Photons from electron line RAPGAP (rad)

Discrimination by shower shapes



All six Cluster shapes well described by sum of MC

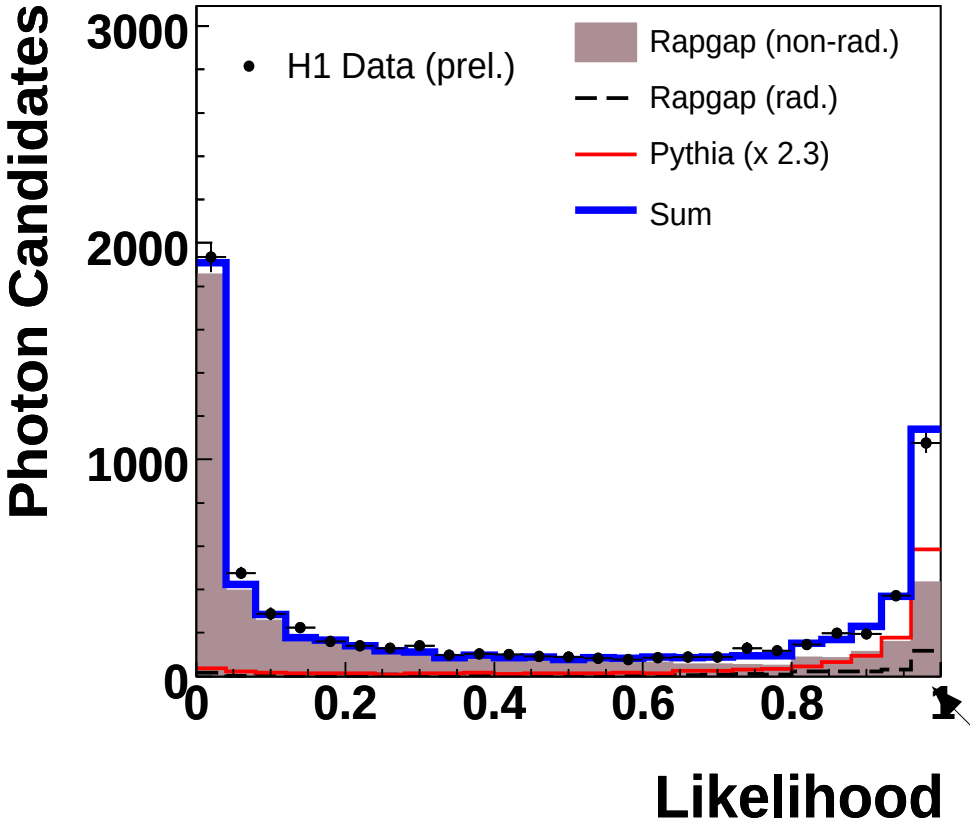
Extraction of the signal with single particles, ratio of neutral mesons from RAPGAP

Extraction of photon signal

All six variables combined in a Likelihood method (naive Bayes)

Prob. density functions defined by single particles samples – high statistics

Signal: Photons, Background 10 types of neutral mesons



Number of Photons

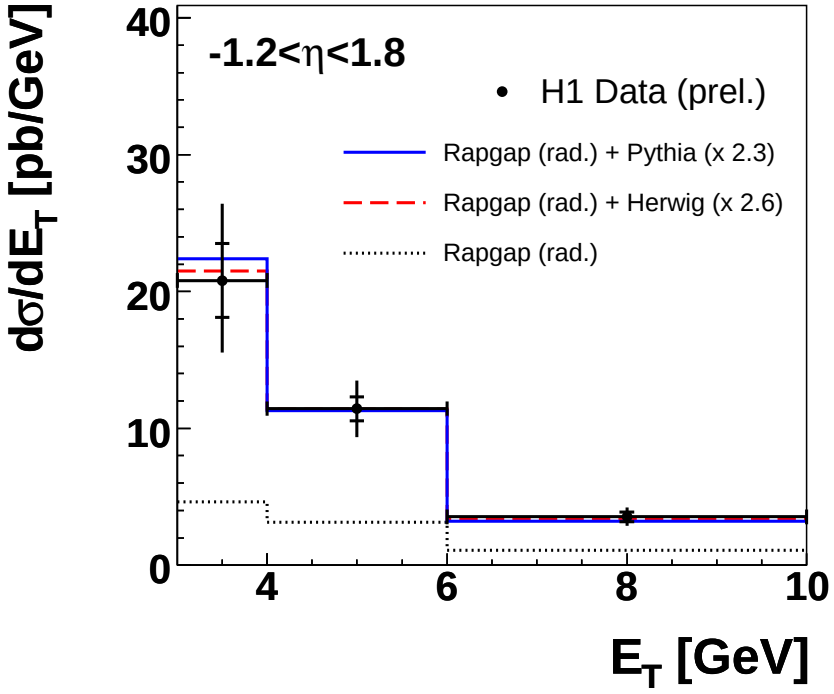
χ^2 fit to Likelihood

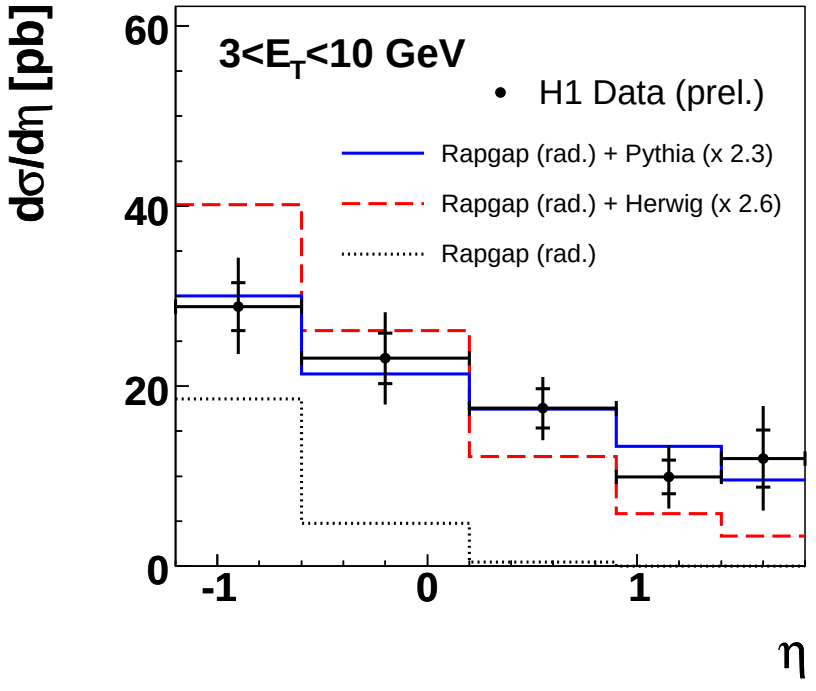
in bins in E_T^{γ} and η^{γ}

MC describes the fraction of neutral mesons very well

Inseparable background

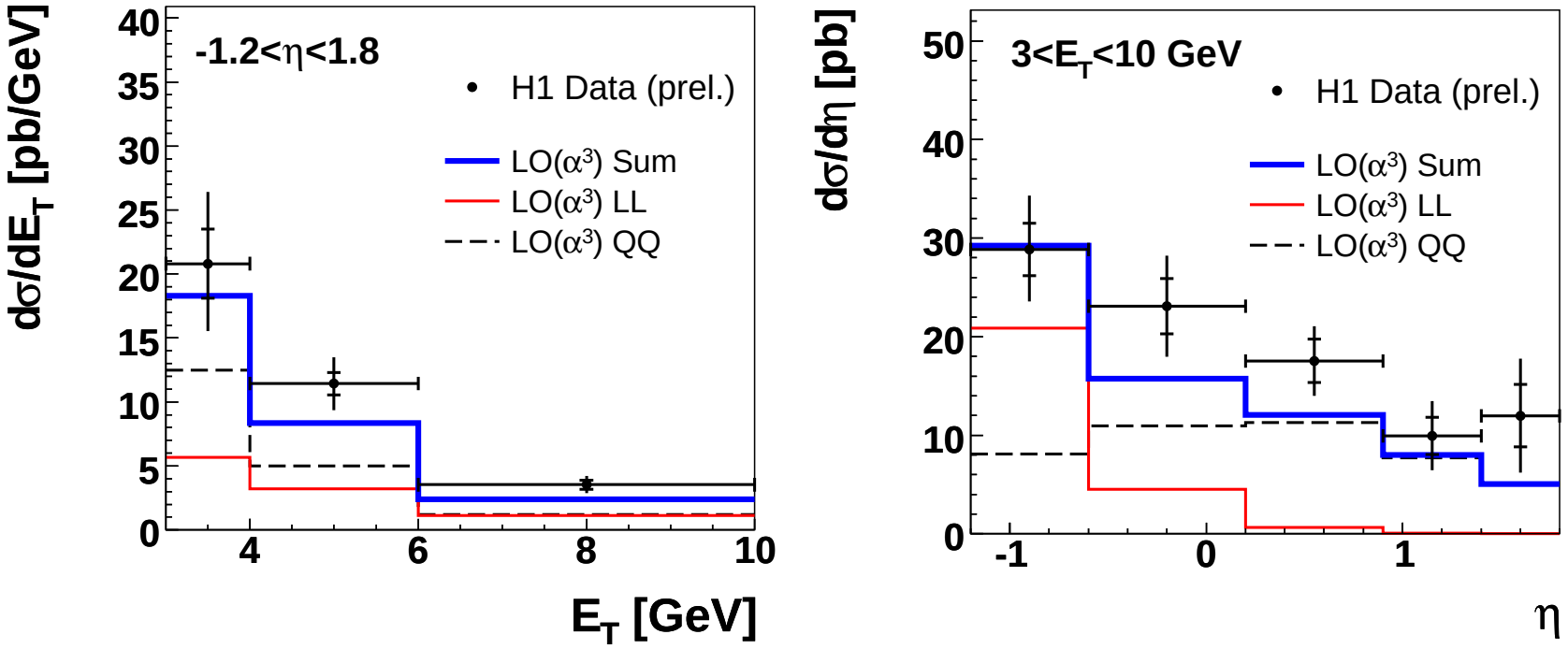
Cross Sections and Generators





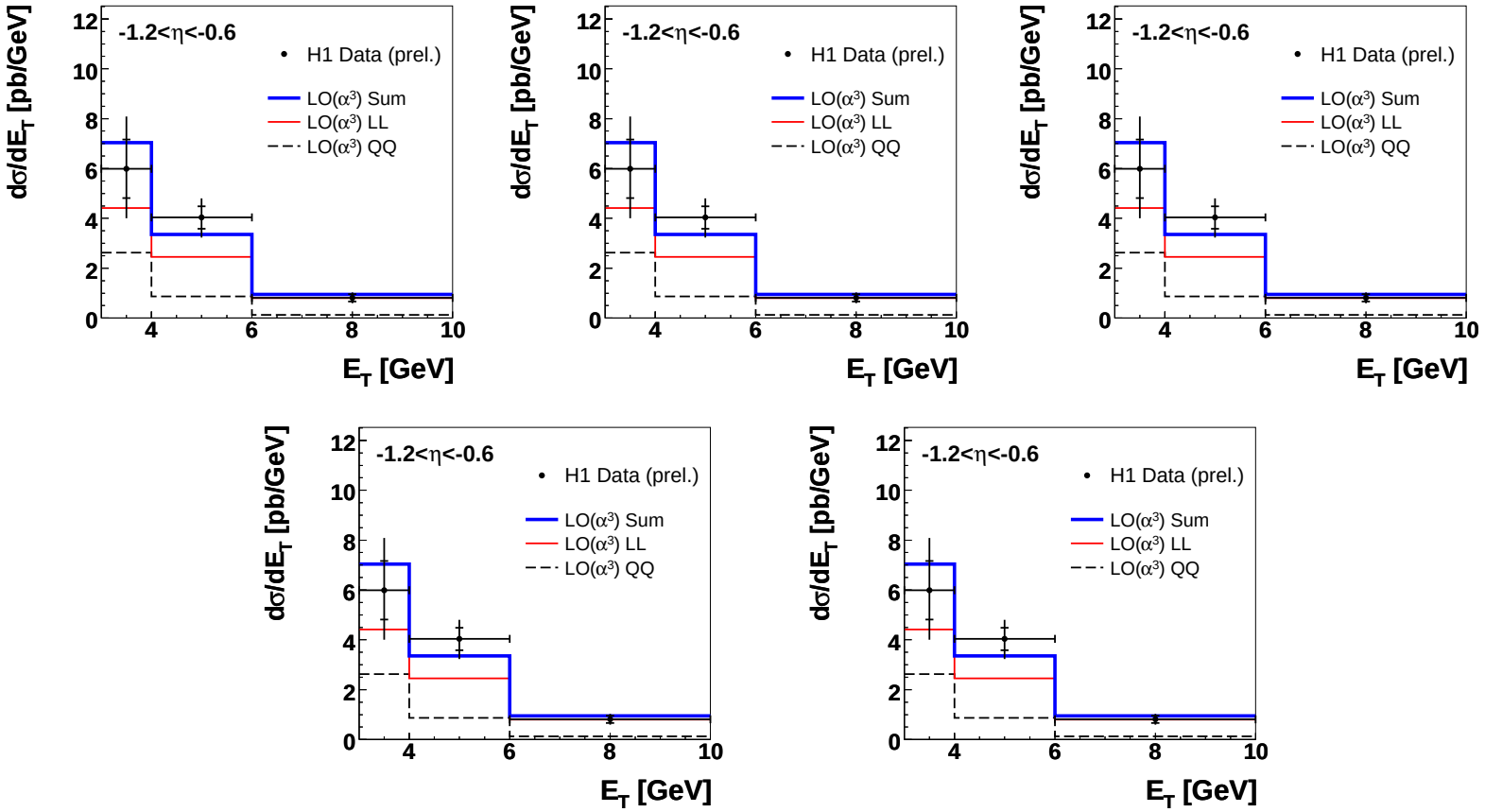
- Both generators need scaling to match total cross section
  PYTHIA: factor 2.3, HERWIG 2.6
- Backward region: radiation off the electron line dominates
- PYTHIA gives a better description of the η distribution

Cross Sections and LO calculation



- LO calculation by Gehrmann et al. (hep-ph/0601073, hep-ph/0604030)
- Good description of data, normalization and shapes reproduced
- Data slightly higher
- Large η: QQ term dominates

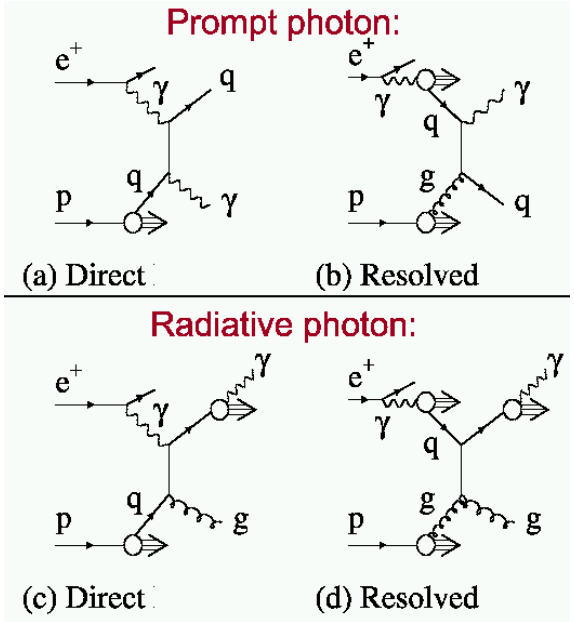
Cross Sections in η-bins



Bins in η correspond to wheels in calorimeter

LO calculation by Gehrmann et al. (hep-ph/0601073, hep-ph/0604030)

Prompt photons plus jet in γp



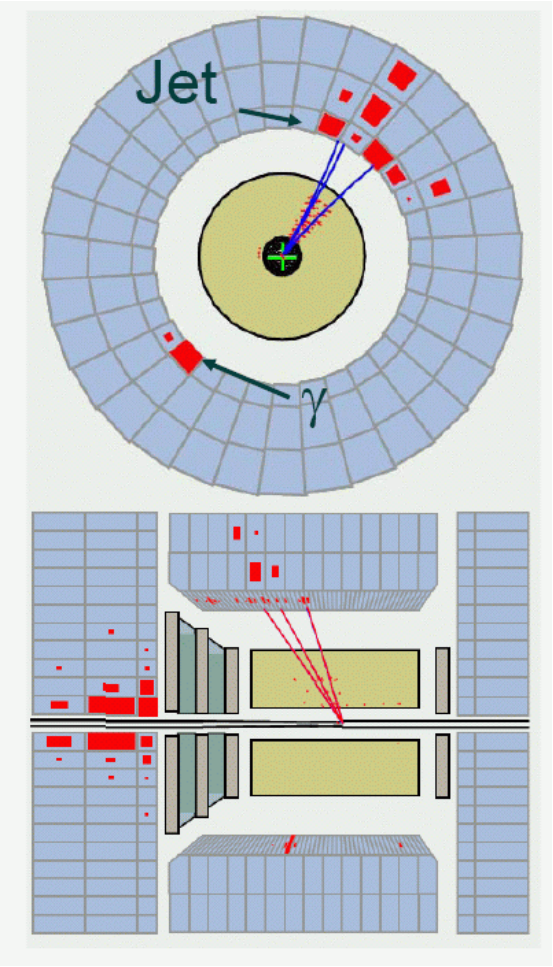
- Sensitivity to quark und gluon densities in proton and photon
- less corrections for hadronisation and fragmentation than with di-jets

- Photon plus jet → x_γ
- theoretical predictions more reliable NLO calculation available
- Photoproduction: photon and jet well separated

Theoretical Predictions

- KZ: M. Krawczyk and A. Zembrzuski (NLO with GRV)
- FGH: Fontanaz, Guillet and Heinrich (NLO with MRST01, AFG02)
- LZ: A. Lipatov and N. Zotov (k_t factorization approach)
  unintegrated quark gluon densities using Kimber-Martin-Ryskin prescription

Event selection



Integrated luminosity: 77.1 pb^{-1}

Kinematics: $Q^2 < 1\ GeV^2$, $0.2 \leqslant y_{jb} \leqslant 0.8$

Jets: 2 or more jets (K_t algorithm)

Photoncandidate $E_{EMC}/E \geqslant 0.9$

$E_T/E_T^{Photonjet} > 0.9$ (Isolation)

$5 \leqslant E_t^{\gamma} \leqslant 16$ GeV

$-0.7 \leqslant \eta^{\gamma} \leqslant 1.1$

no track

Asssociated jet: $E_{EMC}/E \leqslant 0.9$

$6 \leqslant E_t^{Jet} \leqslant 17$ GeV

$-1.6 \leqslant \eta^{Jet} \leqslant 2.4$

Separation photon-neutral mesons with preshower detector

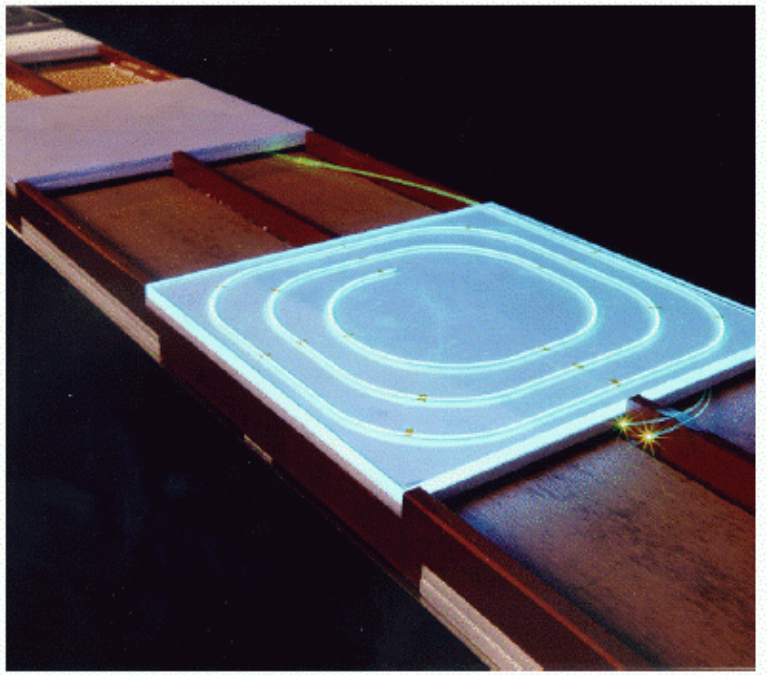
Monte Carlo: PYTHIA6.3, HERWIG 6.5

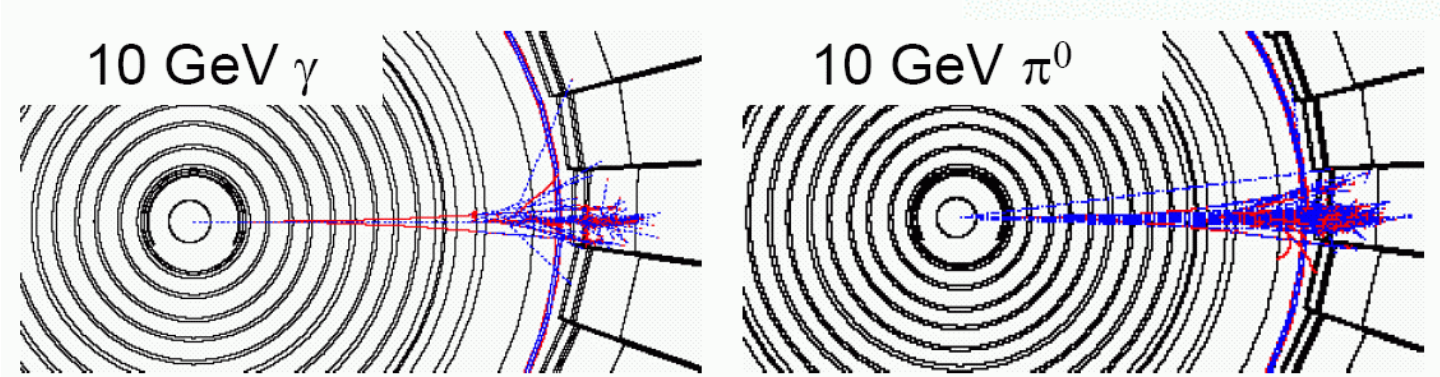
Barrel Preshower detector

Scintillator tiles in front of calorimeter

Energy in BCAL presampler is proportional to number of photons

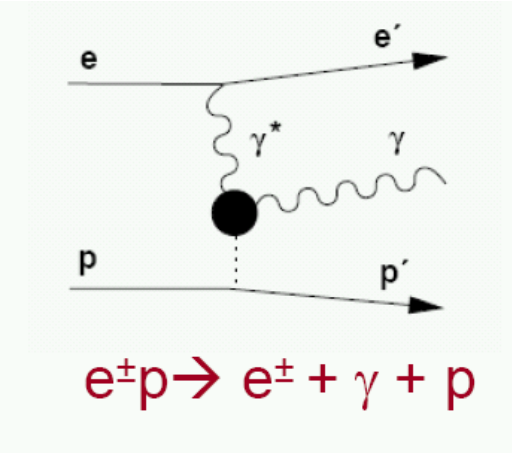
→ Allows separation also for high energies



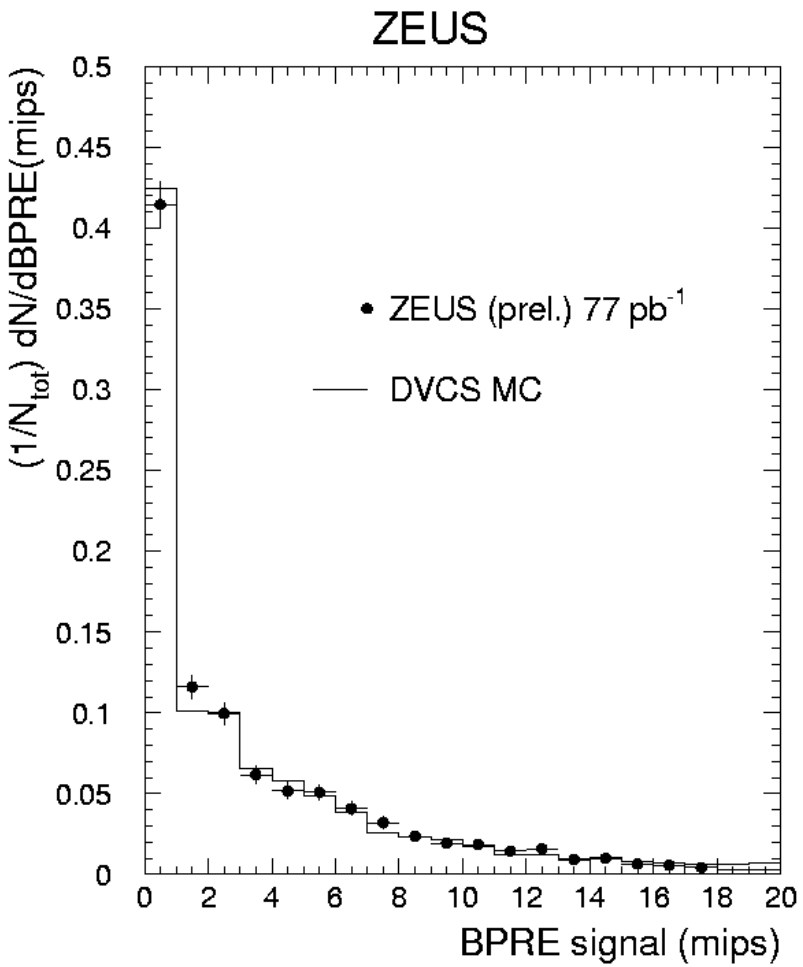


Preshower signal: DVCS sample

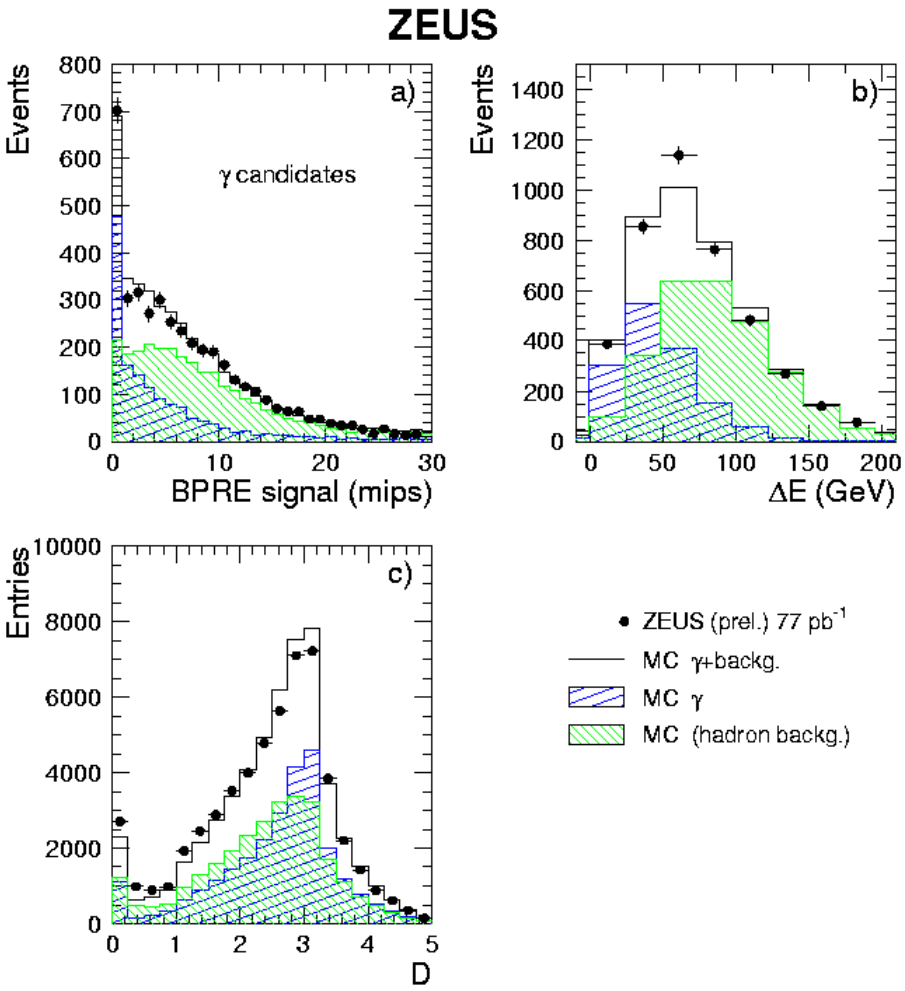
Study with DVCS sample:
events with one track
two isolated elmgn. clusters



Agreement between data and MC
with additional dead material



Extraction of photon signal



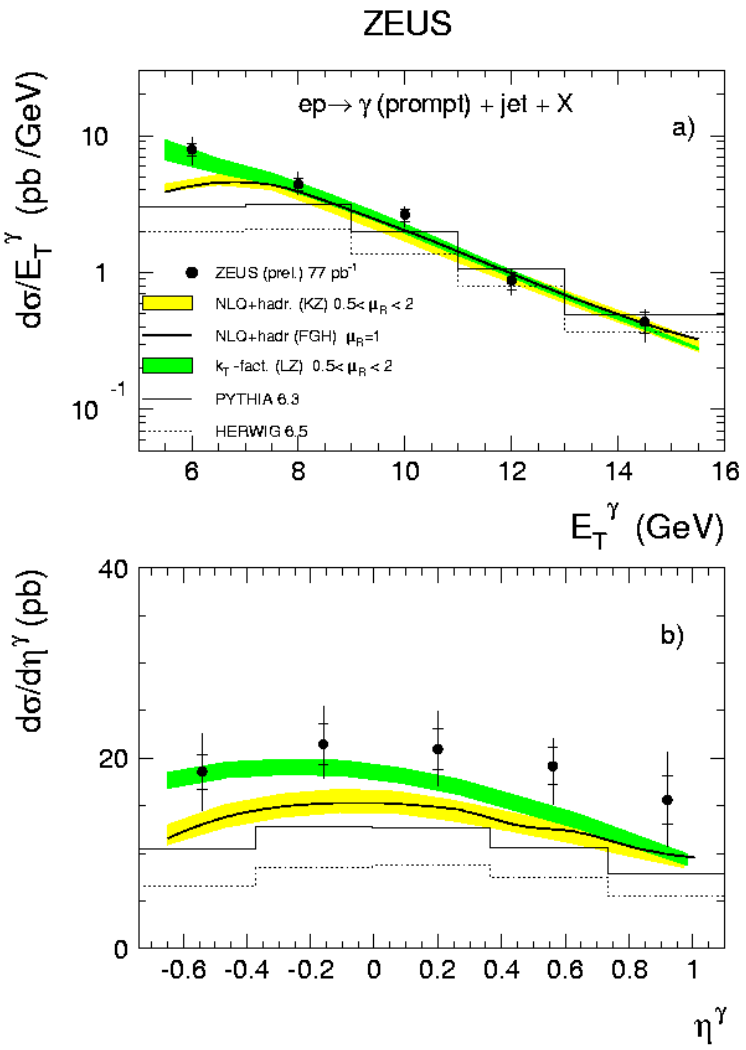
Fit sum of prompt γ and background MC to BPRE signal in bins of E_t , η of photon and jet and x_γ

Control distributions

- $\Delta E = E_{Total} - E_{(\gamma+Jet)}$
- D: Distance in $\eta\varphi$ from Photon to energy flow objects

well described by signal+background MC

Cross sections: Photon E_t^γ , η^γ



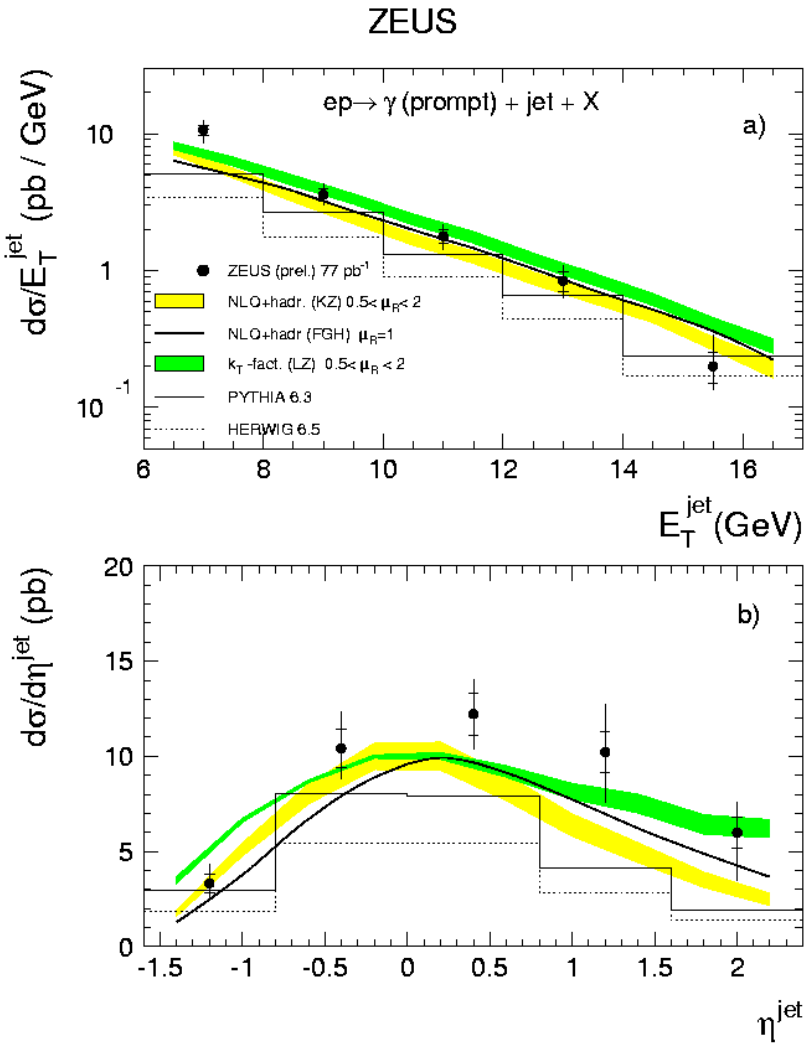
HERWIG and PYTHIA :
significantly lower at low E_t^γ

KZ and FGH:
low in lowest E_t^γ bin

LZ describes shapes and normalization

E_T>10 GeV: new measurement at HERA
not accessible with shower shape analysis!
H1 measurement $E_T \leqslant 10$ GeV (hep-ex/0407018)

Cross sections: Jets E_t^{Jet} , η^{Jet}



HERWIG and PYTHIA :

forward jets not well described

measured cross section underestimated

Theoretical predictions describe the data

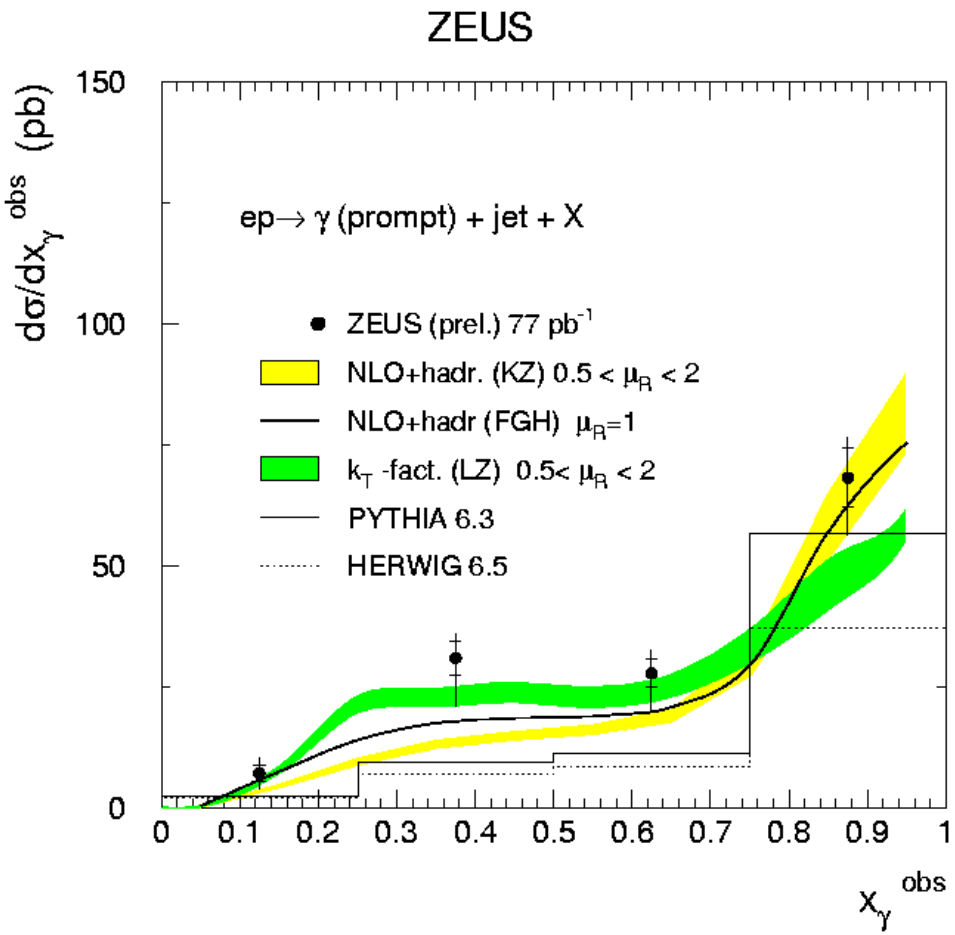
forward region best described by LZ

Cross sections: x_γ

NLO calculations (KZ FGH)
describe direct component

LZ describe resolved component

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



Summary: prompt photons in γp

Prompt Photon plus Jet cross section in photoproduction

- new technique for photon-neutral meson separation, based on the signal in the preshower detector
- PYTHIA and HERWIG have problems describing the data in shape and are low in normalization
- Theoretical calculations describe the data reasonably

Summary: prompt photons in DIS

Inclusive Prompt Photons in DIS

- new analysis, extending the phasespace of the previous measurement by ZEUS (he-ex/0402019) significantly (E_t^γ , η^γ, Q^2)
  10x higher cross section

- Data well described by new LO(α^3) calculation (Gehrmann et al)

- PYTHIA and HERWIG plus radiation off the electron line describe the shape but are low in normalization

Outlook: more statistics with HERA II (expected: 220 pb^{-1})
Photon plus jet(s)
Quark-to-photon fragmentation function at lower z

H1-ZEUS: Photon + jet in γp

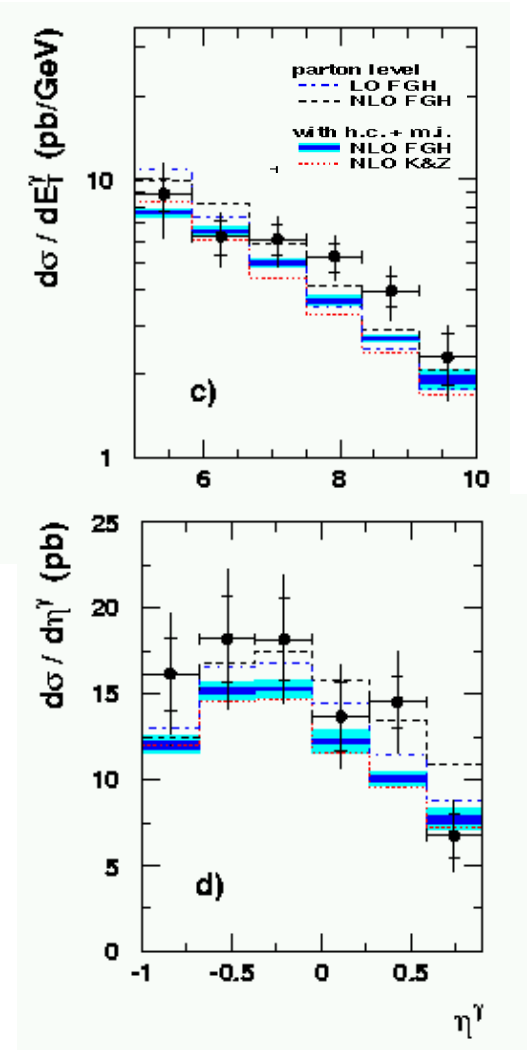
Published in 04:

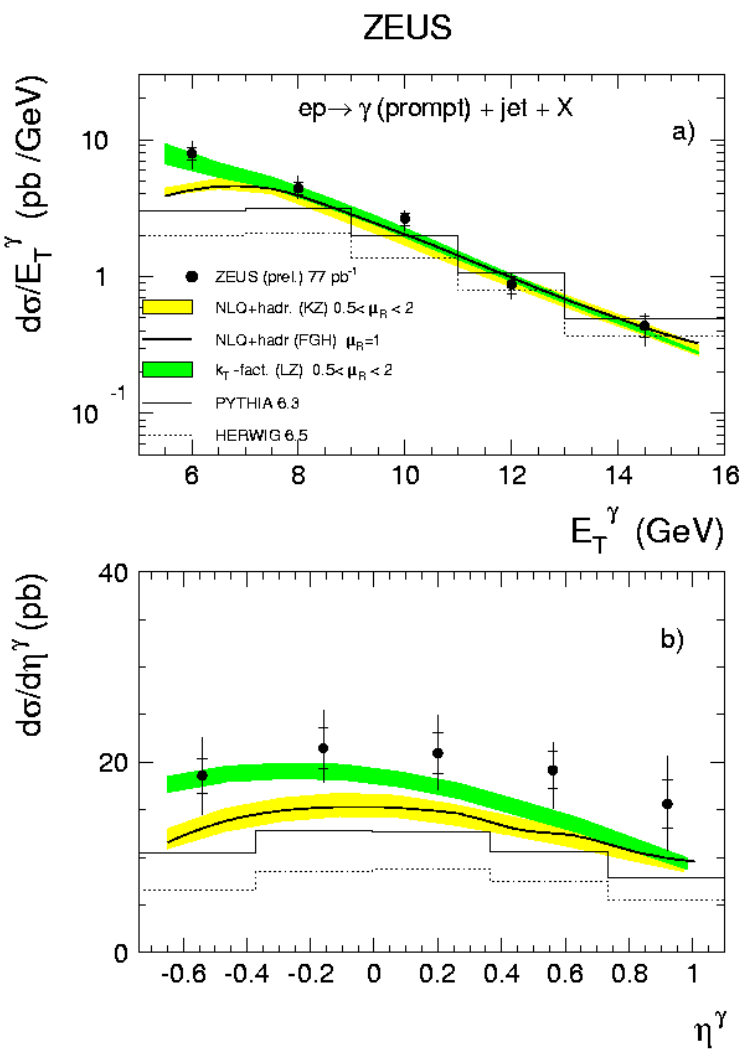
hep-ex/0407018

note:

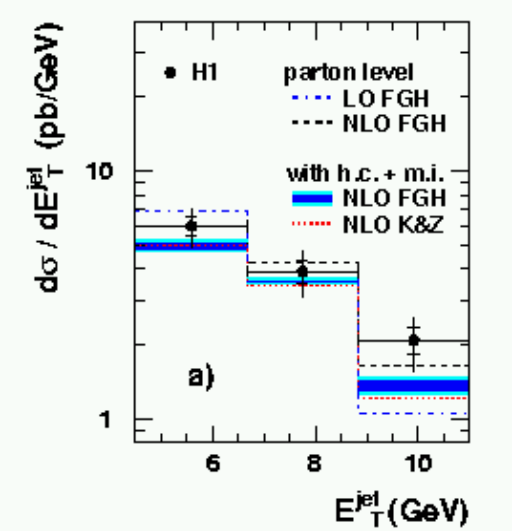
different range

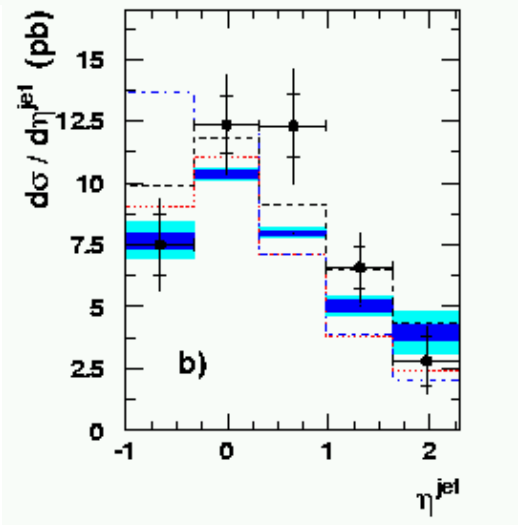
E_t^γ η^γ and y!

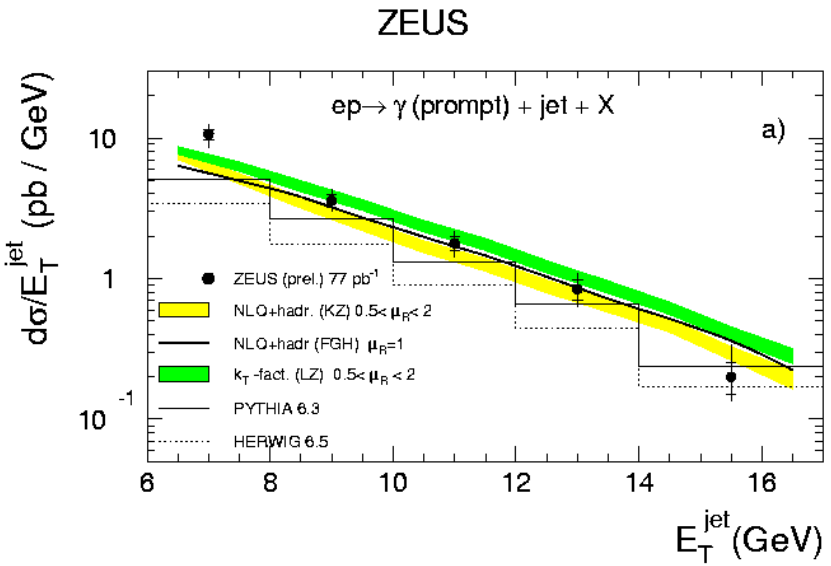


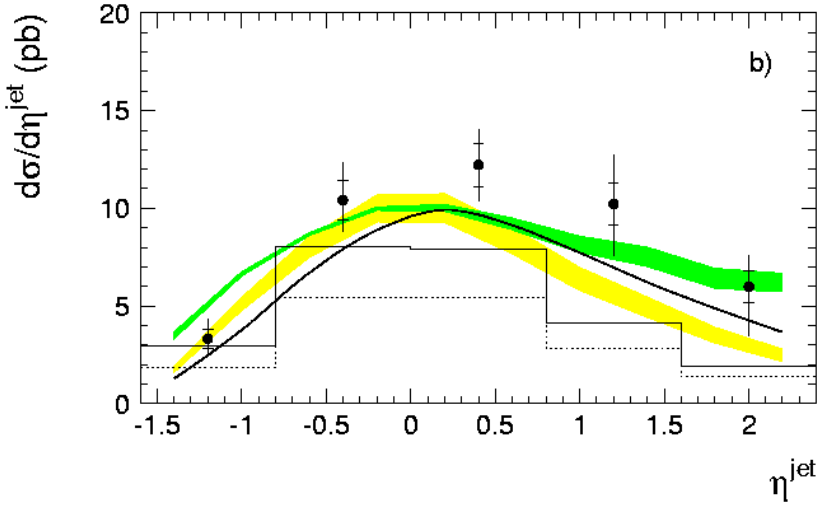


H1-ZEUS :Photon + jet in γp





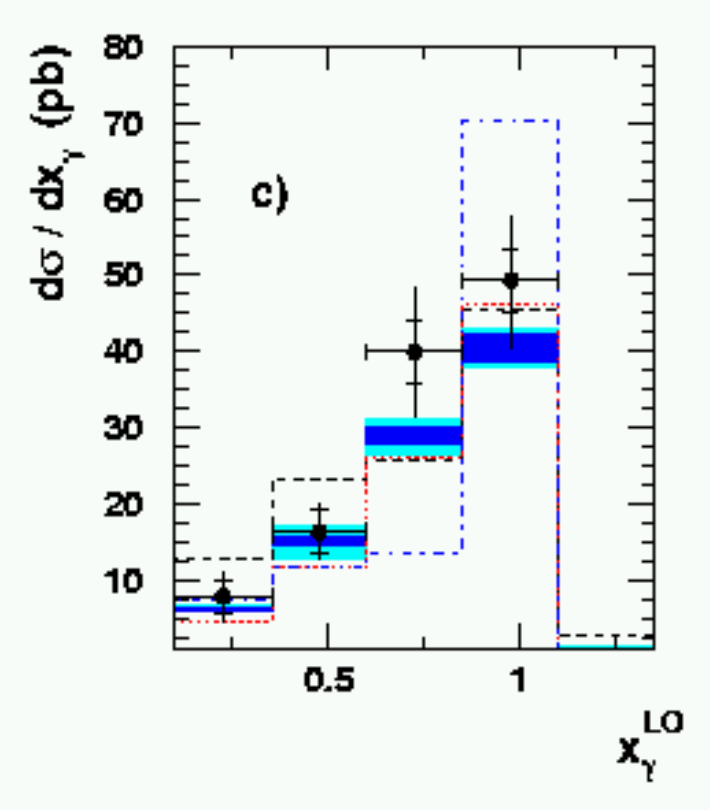


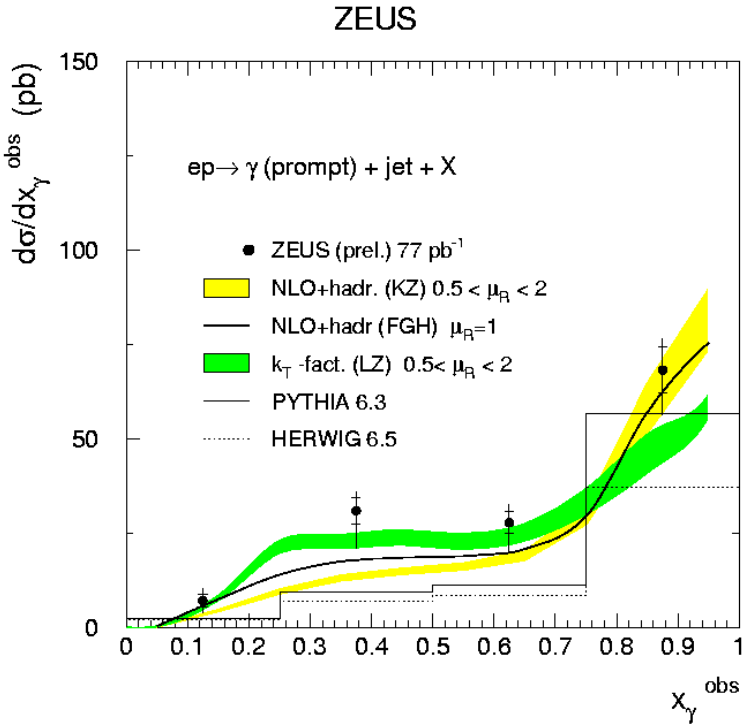


H1-ZEUS: Photon + jet in γp

H1 Published in 04: hep-ex/0407018

Note different kinematical regions





H1 and ZEUS: prompt γ in DIS

ZEUS published in 04:

hep-ex/0402019

E_t^{γ}

ZEUS: 5-10 GeV

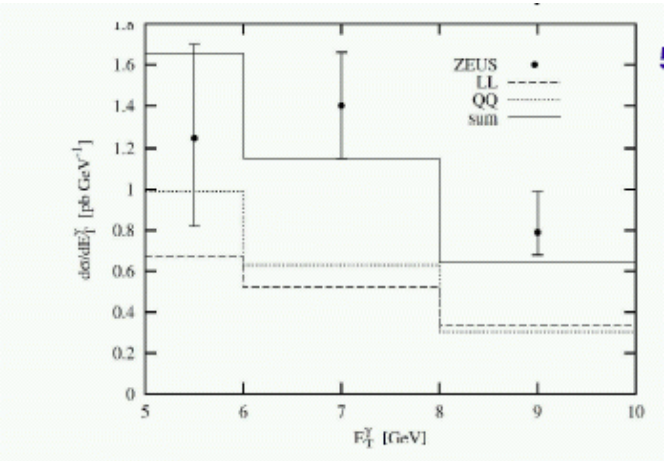
H1: 3-10 GeV

η^{γ}

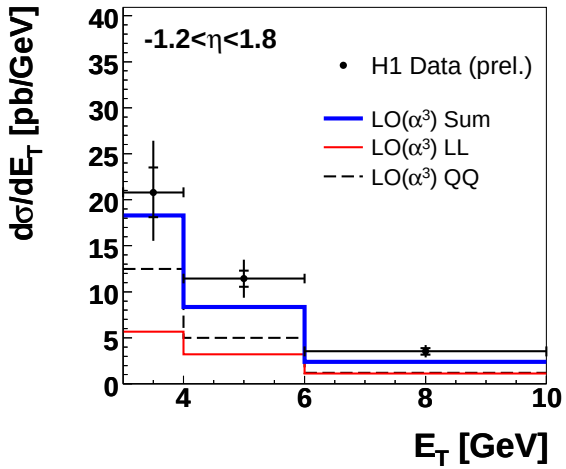
ZEUS -0.7-0.9

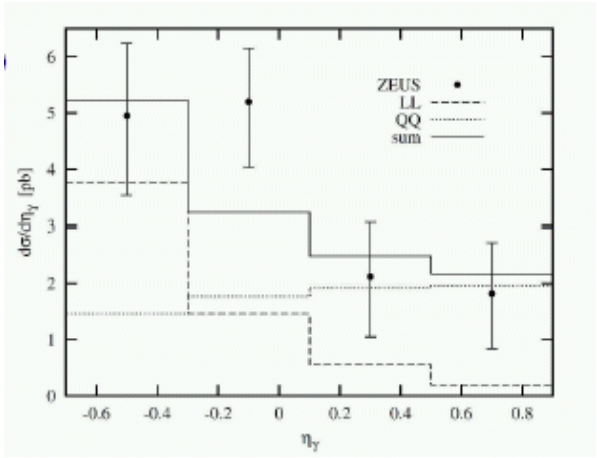
H1 -1.2-1.8

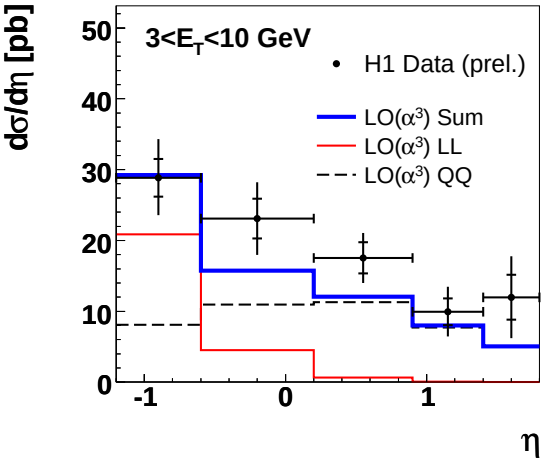
ZEUS: $Q^2 > 35$ GeV^2



H1: $Q^2 > 4$ GeV^2







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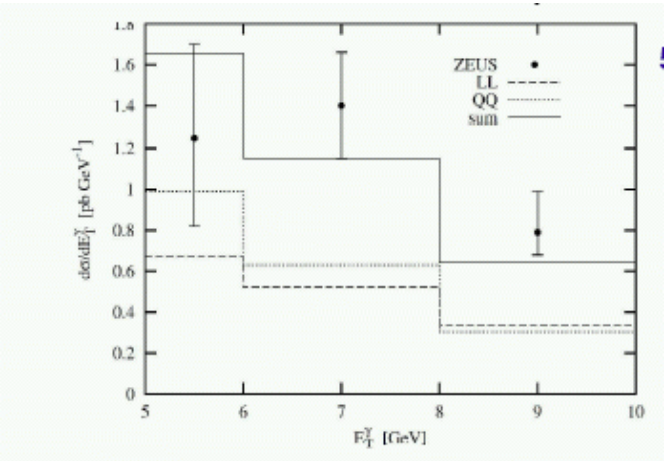

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