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for the
ZEUS and H1
collaborations

Prompt Photon Production at ZEUS and H1

Workshop on Low-x Physics,
Prague, 2004

Outline

- Overview of prompt photons and the QCD processes
- Outline of ZEUS method
- ZEUS results: photoproduction
- ZEUS results in DIS
- Outline of the H1 method
- H1 results
- Comparison between ZEUS and H1 Inclusive photoproduction results
- Conclusion

Prompt photon overview

- A ‘prompt’ photon is a high-E_T, isolated photon.
- These arise as part of the pQCD process, rather than fragmentation or decay.
- Prompt photon processes are a clean probe of QCD:
    - ▷ Emerge from the interaction without intermediate hadronisation.

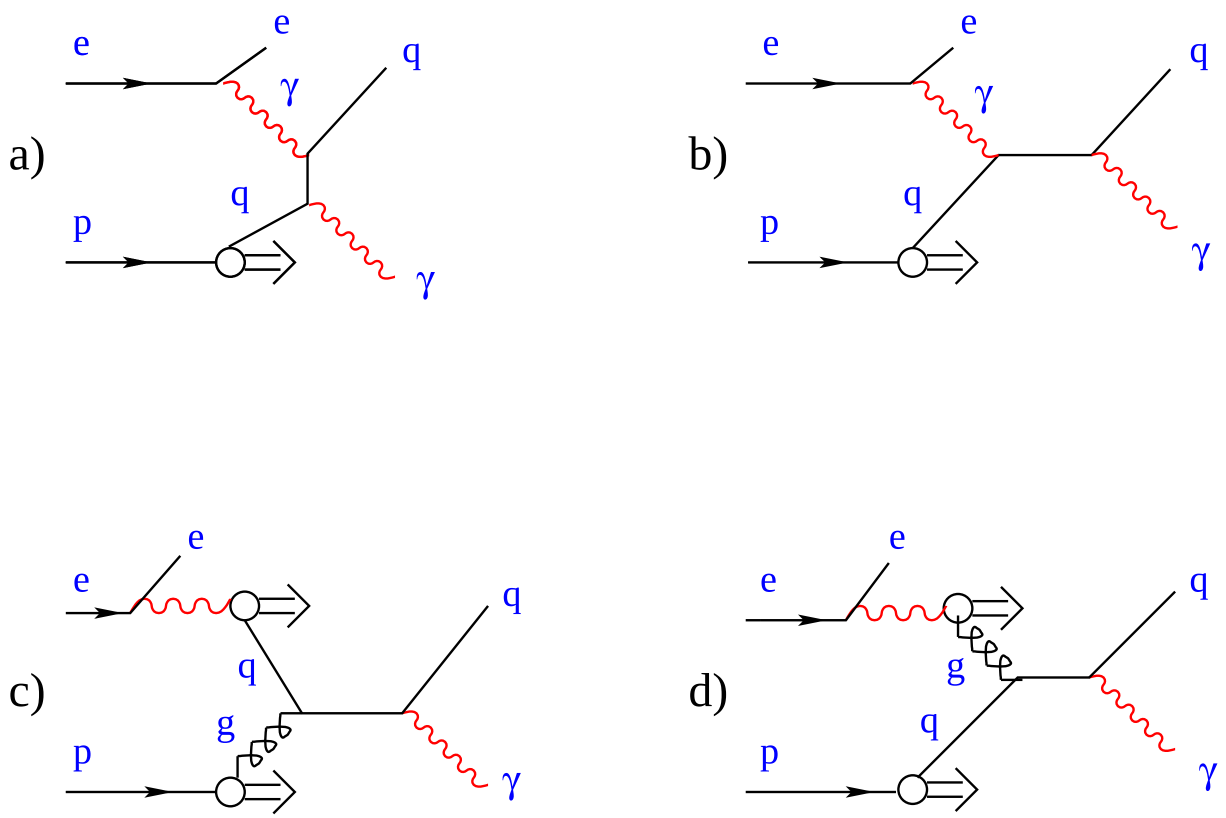
- At HERA, two neutral current processes have been studied:

  $\mathbf{e^{\pm}p} \rightarrow \gamma + \mathrm{X}$: the *inclusive* process

  $\mathbf{e^{\pm}p} \rightarrow \gamma + \mathrm{jet} + \mathrm{X}$: the *photon plus jet* process.
- The jet requirement constrains the measurement, however it also introduces hadronic corrections.

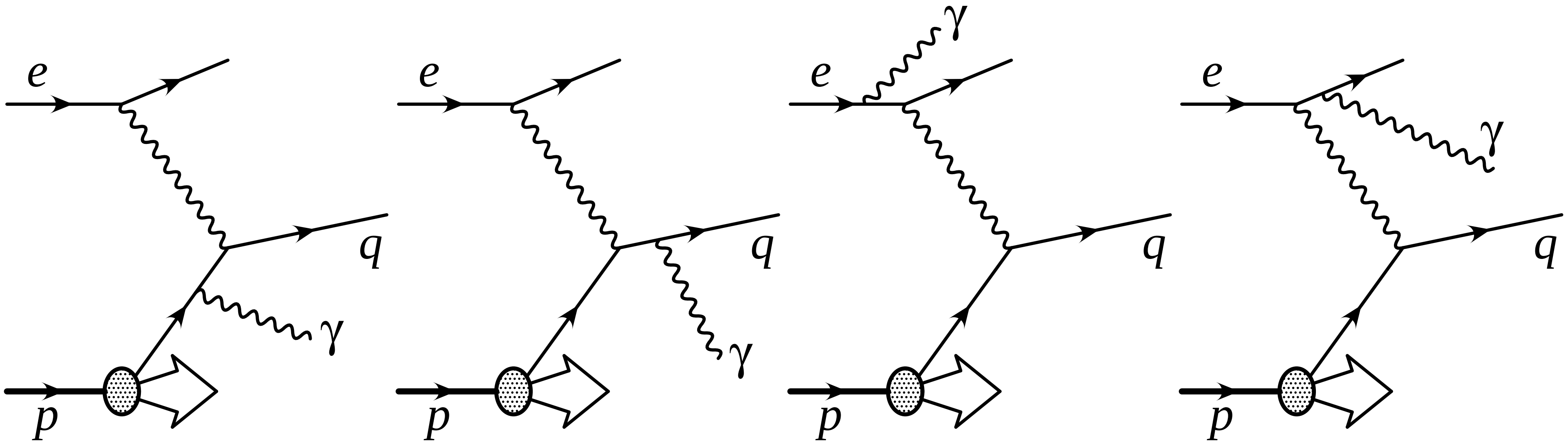
- ZEUS has studied prompt photons in both the photoproduction and the DIS regimes.
- H1 has recently published results in the photoproduction regime.

Prompt photon processes: PHP



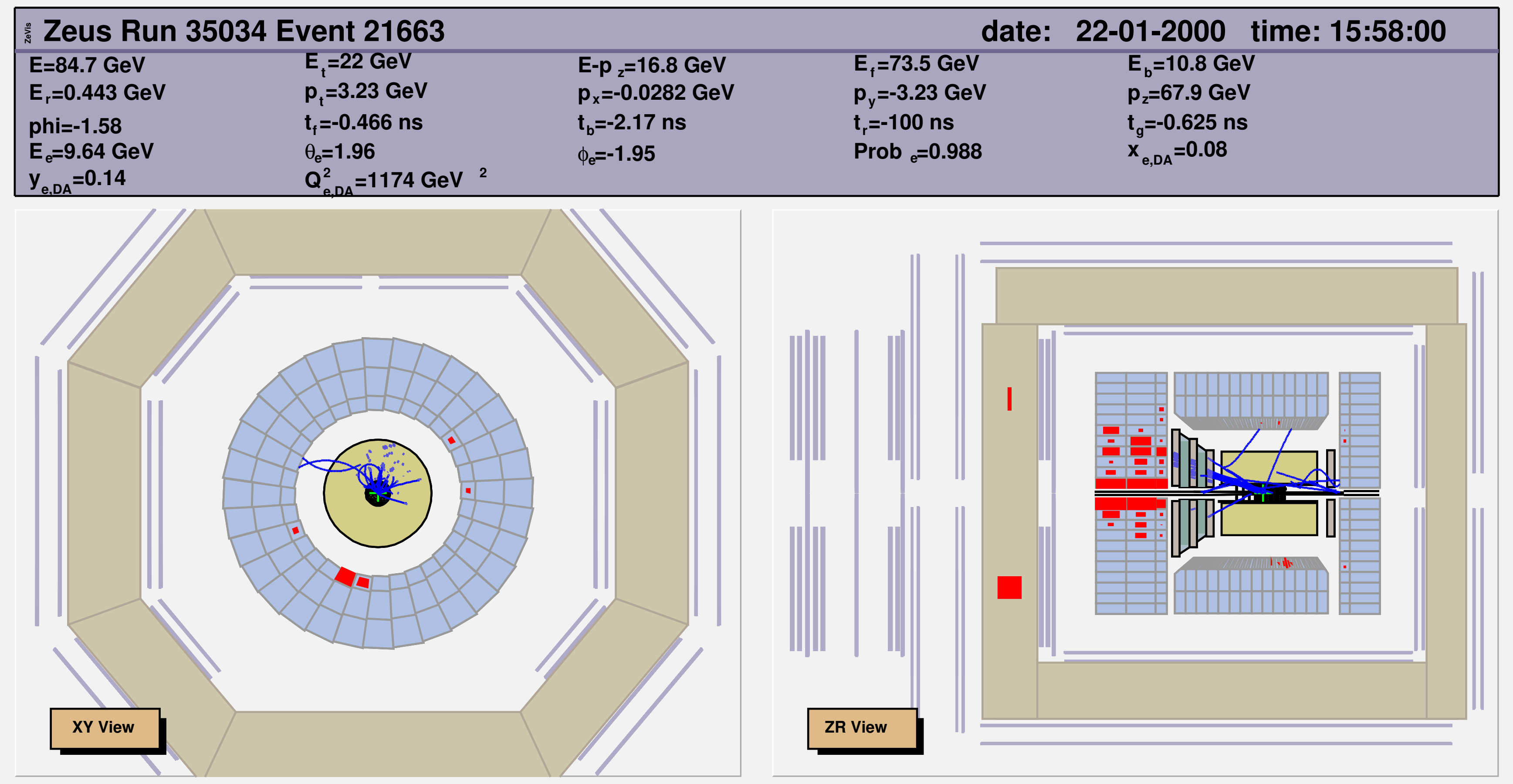
- **The LO processes contributing to cross-section in PHP.**
- **'Radiative' events occur when a high-E_T γ is radiated from a final state quark.**
  - ▷ **These form an irreducible background and must also be modelled.**

Prompt photon processes: DIS



- The LO processes contributing to cross-section in DIS are 0th order in α_s
- The right hand diagrams show final-state photon emission from the lepton line.
- In DIS the interplay between the diagrams is rather more complex.

Sample ZEUS prompt photon event



- A sample ZEUS prompt photon event with balancing jet

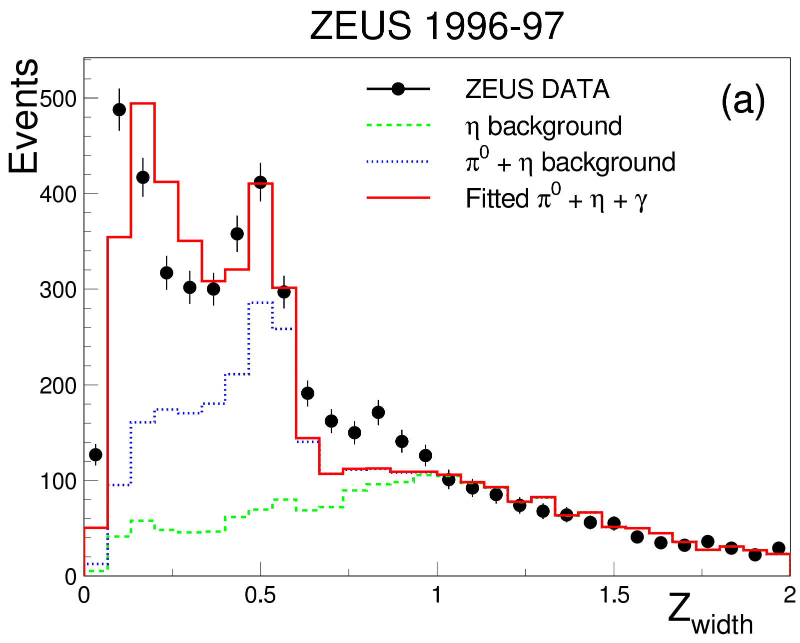
ZEUS Selection

- **Outline of method**
  - ▷ **Locate a cluster of electromagnetic energy in the BCAL**
  - ▷ **Remove clusters with nearby tracks**
  - ▷ **Apply isolation criterion:**

    In unit cone around photon: $\sum \mathbf{E_T} < \mathbf{0.1E_T^\gamma}$
- **Photoproduction Selection:**
  - ▷ $\mathbf{0.2 < y < 0.9}$
  - ▷ $\mathbf{-0.7 < \eta^\gamma < 0.9}$
  - ▷ $\mathbf{5 < E_T^\gamma < 15}$ GeV **for the** E_T^γ **distributions.**

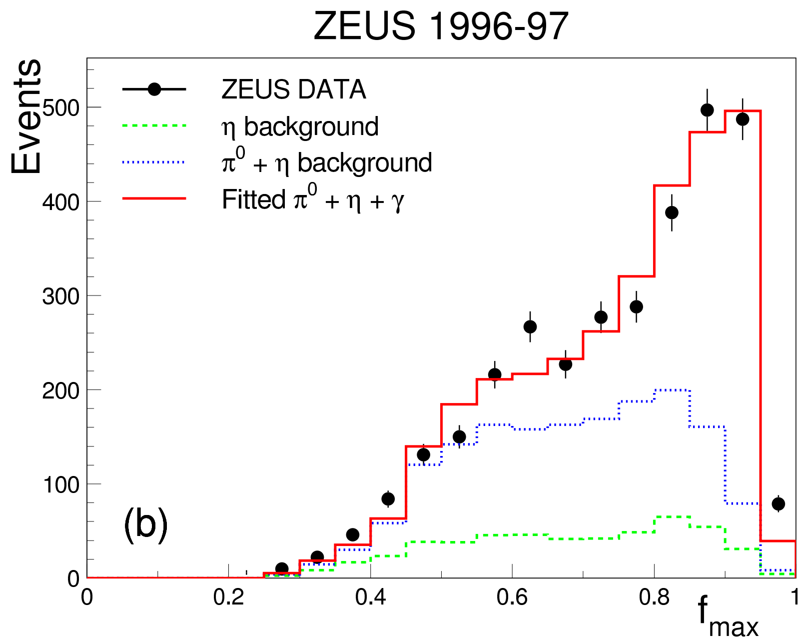
    Distribution is restricted to < 10 GeV in η^γ**.**
- **DIS Selection:**
  - ▷ $\mathbf{Q^2 > 35}$ $\mathrm{GeV}^\mathbf{2}$, $\mathbf{E_e > 10}$ GeV, $\mathbf{139.8^\circ < \theta_e < 171.8^\circ}$
  - ▷ $\mathbf{-0.7 < \eta^\gamma < 0.9}$ **and** $\mathbf{5 < E_T^\gamma < 10}$ GeV
  - ▷ **Where jets are required:** $\mathbf{E_T^{jet} > 6}$ GeV **and** $\mathbf{-1.5 < \eta^{jet} < 1.8}$.
- **Still contribution from neutral mesons, which mimic photon signal in the CAL.**
  - ▷ **These decay to multiple photons, providing a different cluster shape.**
  - ▷ **Use this to perform a statistics-based background subtraction.**

The Neutral Meson Background Subtraction

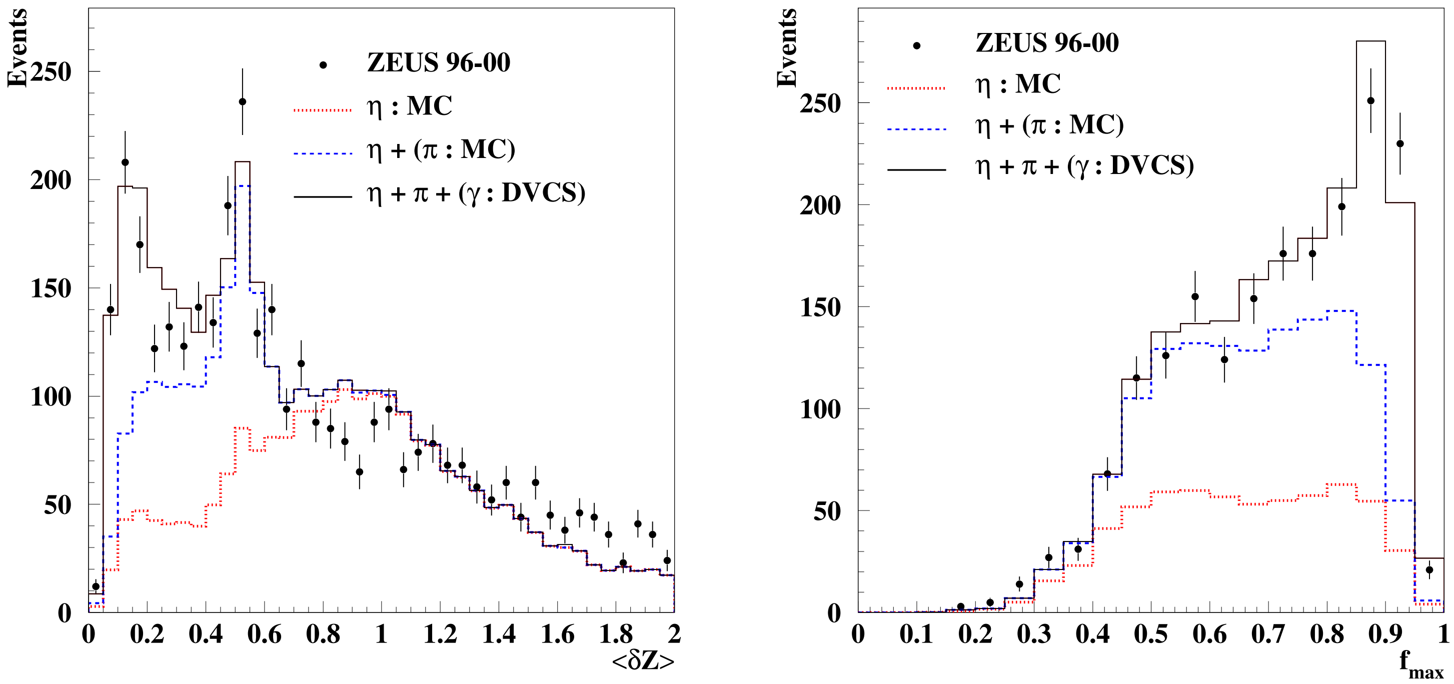


- $\langle \delta Z \rangle = \dfrac{\Sigma(E_{cell}|z_{cell} - \bar{z}|)}{\Sigma E_{cell}}$
- **Measures the cluster width in z**
- **A cut at 0.65 removes the η-meson tail**

- $f_{max} = \dfrac{\textbf{Energy in most energetic cell}}{\textbf{Total energy in cluster}}$
- **We define two regions:**
  - ▷ **'good': f_{max} > 0.75 and**
  - ▷ **'poor': f_{max} < 0.75.**
- **Use a statistical signal extraction.**



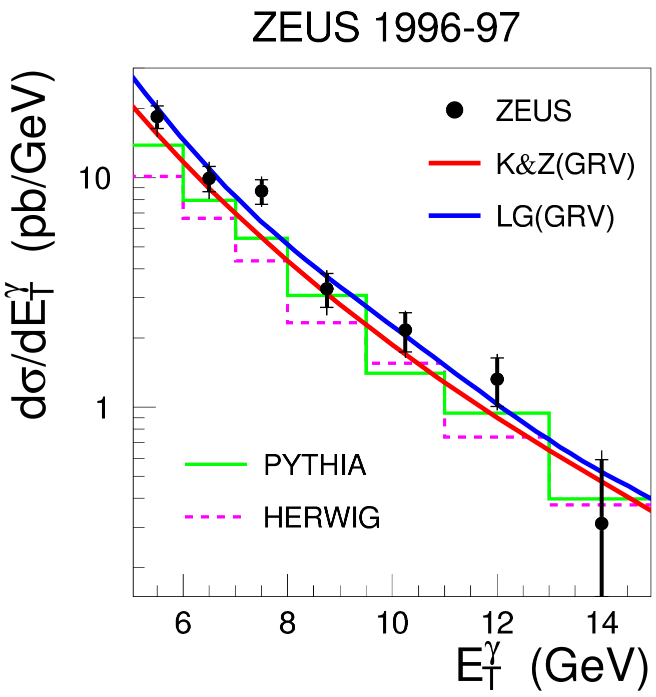
Prompt photons in DIS at ZEUS: DVCS background subtraction

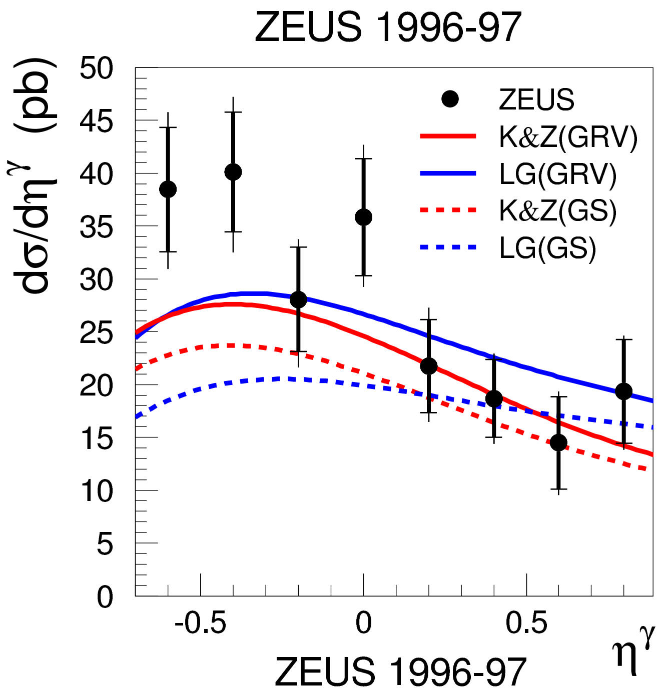


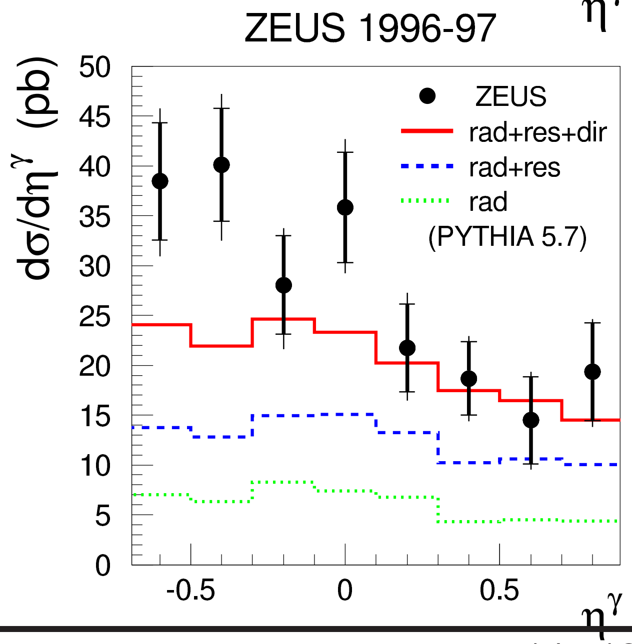
- **Single particle Monte Carlo does not well model the data**
- **For the DIS analysis: use DVCS photons instead of simulated single photons.**
  - ▷ **DVCS: Deeply Virtual Compton Scattering**
  - ▷ ***Diffractive* process: no hadronic activity in the detector**

    $\rightarrow$ No contamination from neutral mesons
- **These photons make for a much improved fit to the prompt photon data.**

Inclusive photon results in PHP: ZEUS



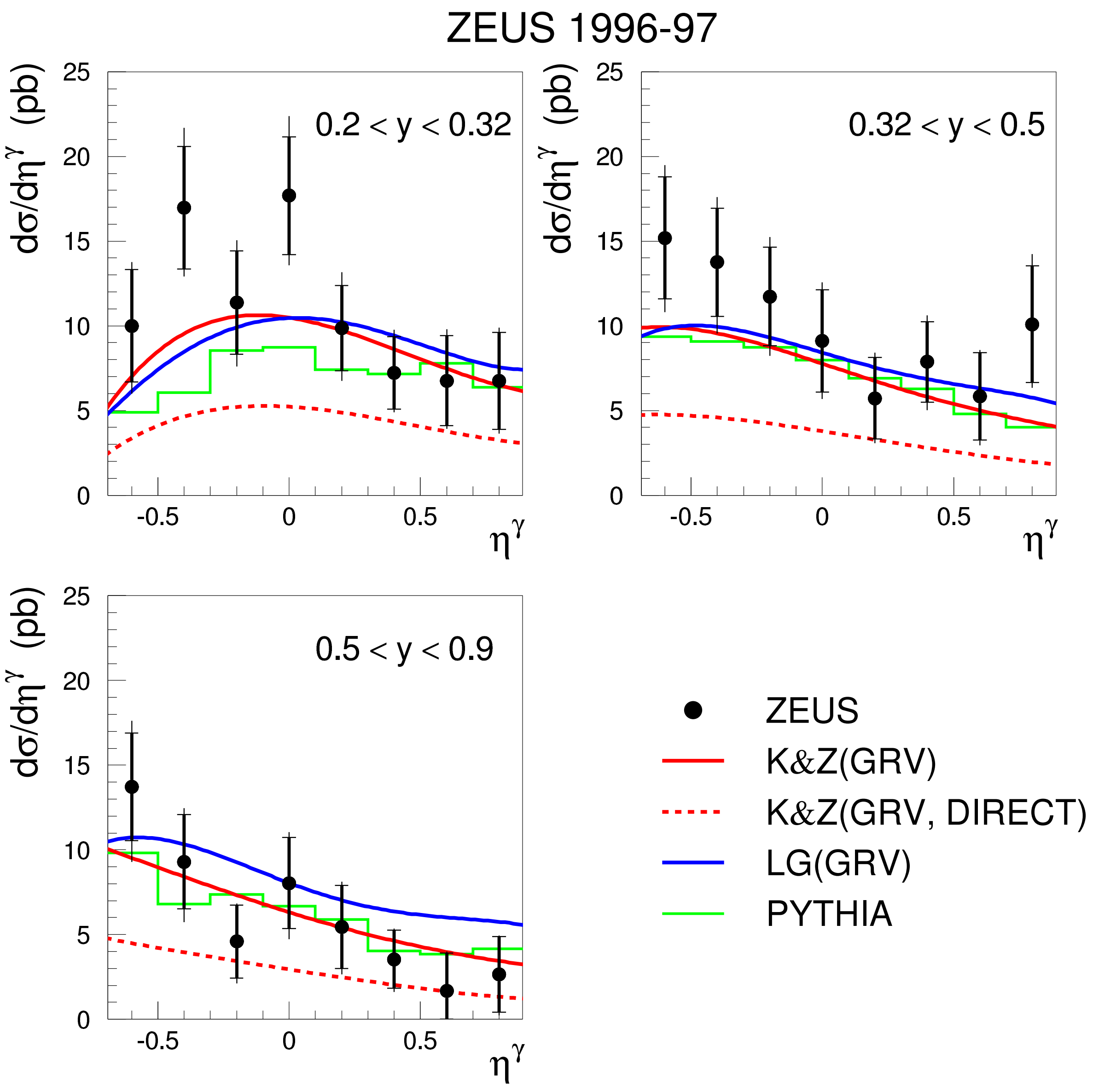




- **96-97 ZEUS data**
- **Measured cross section**
  - ▷ **Compared to Pythia 5.7**
  - ▷ **NLO from Gordon (LG) and Krawczyk and Zembrzuski(K&Z)**

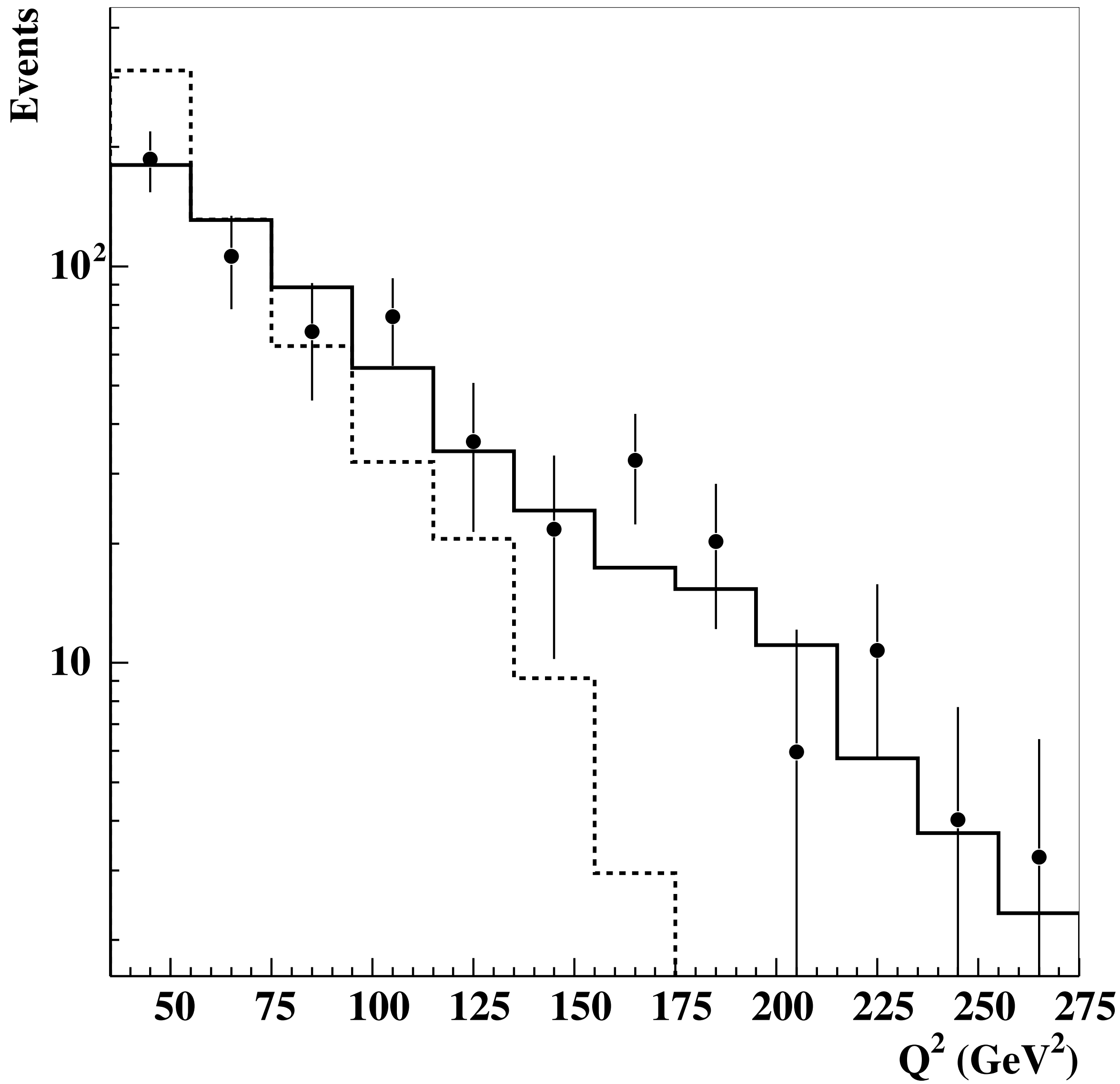
The η cross section in y sections

- **Examining the excess in η^γ in slices of y**
- **Most notable for $y < 0.5$**
- **The peak is seen in simulations**
  - ▷ **More prominent for data**

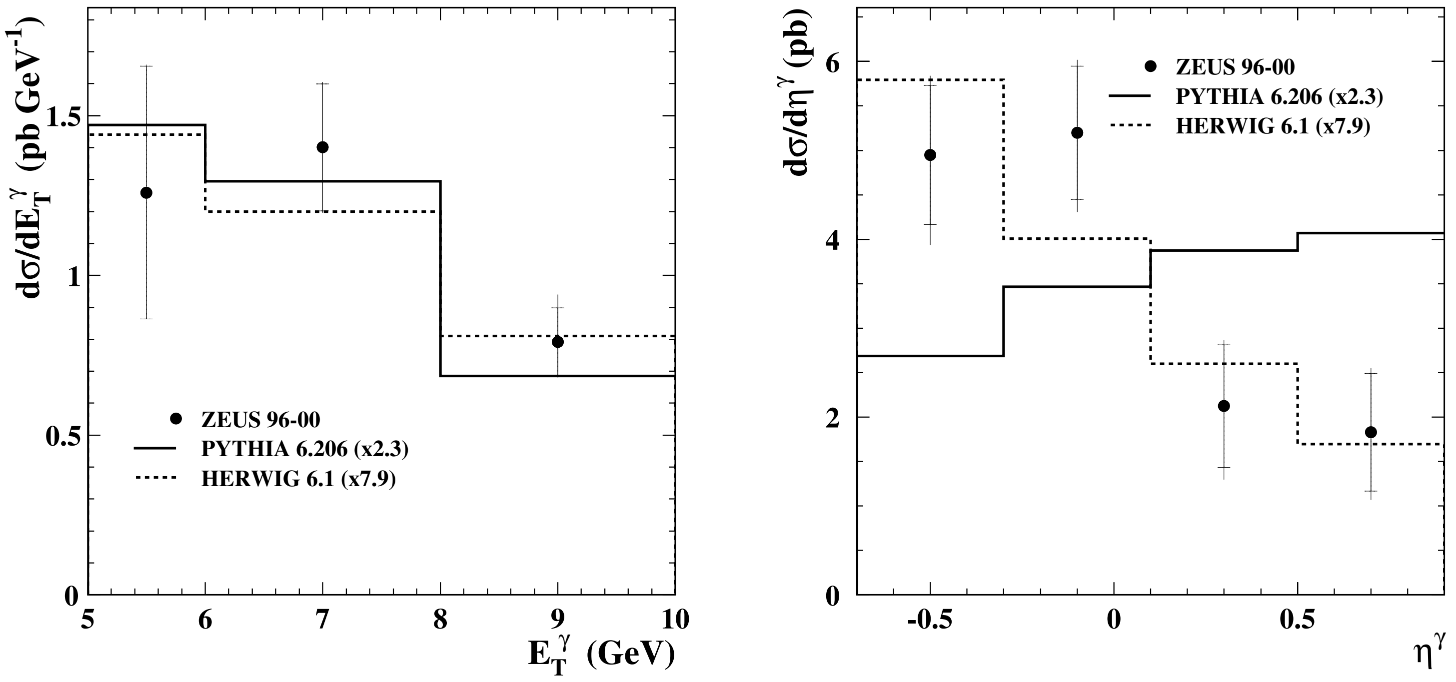


The ZEUS DIS measurement

- Q^2 **distribution in DIS**
- **ZEUS data 96-00**
- **Histograms: PYTHIA (solid) and HERWIG (dashed)**
- **PYTHIA models the data reasonably well**



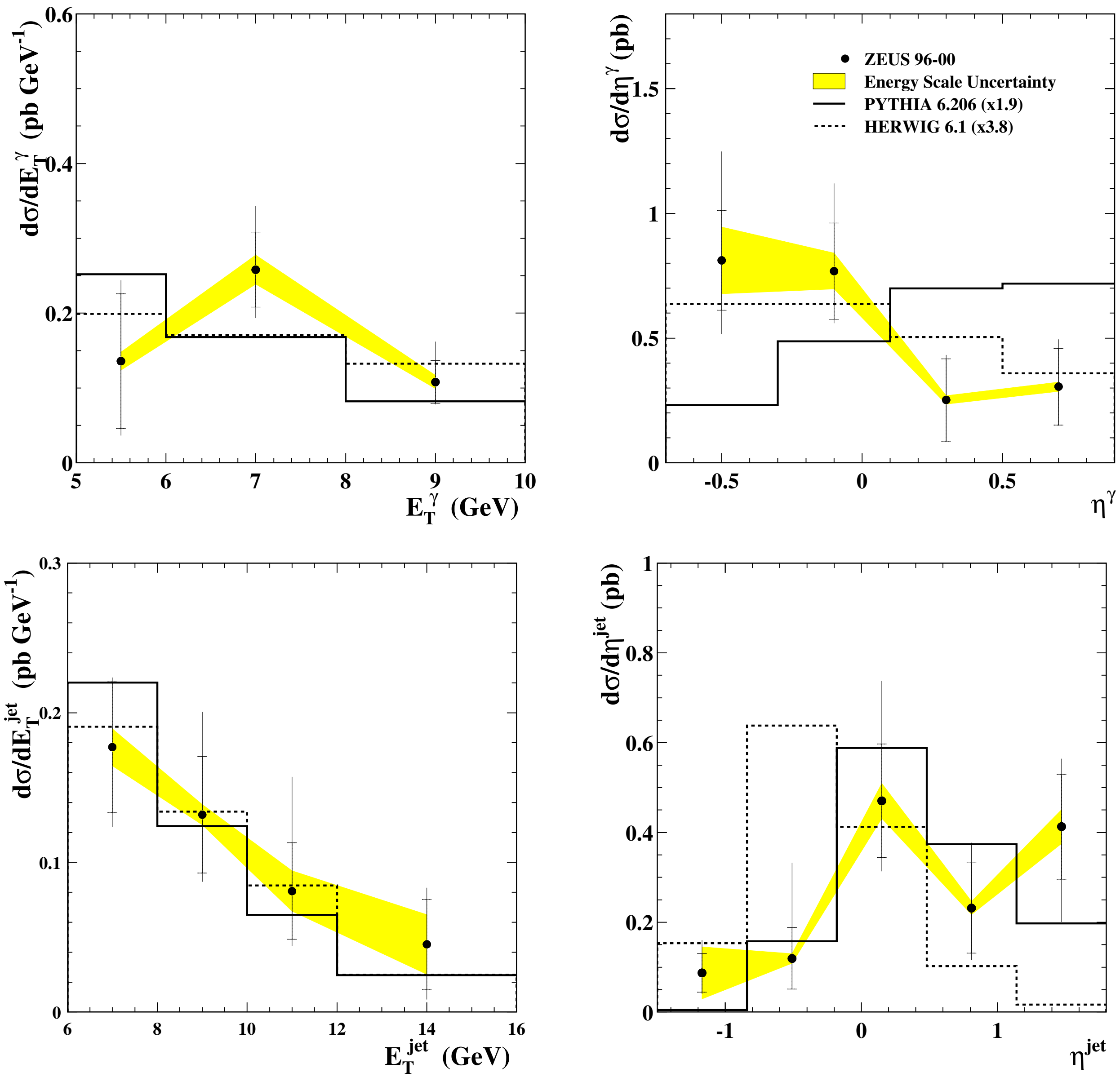
Inclusive prompt photons in DIS at ZEUS



- Cross Sections shown for the inclusive process in DIS
- Comparisons to PYTHIA and HERWIG shown
  - ▷ Neither MC fits the data well
  - ▷ Both require normalisation
- $\mathbf{Q^2} > \mathbf{35}\ \mathrm{GeV}^{\mathbf{2}}$

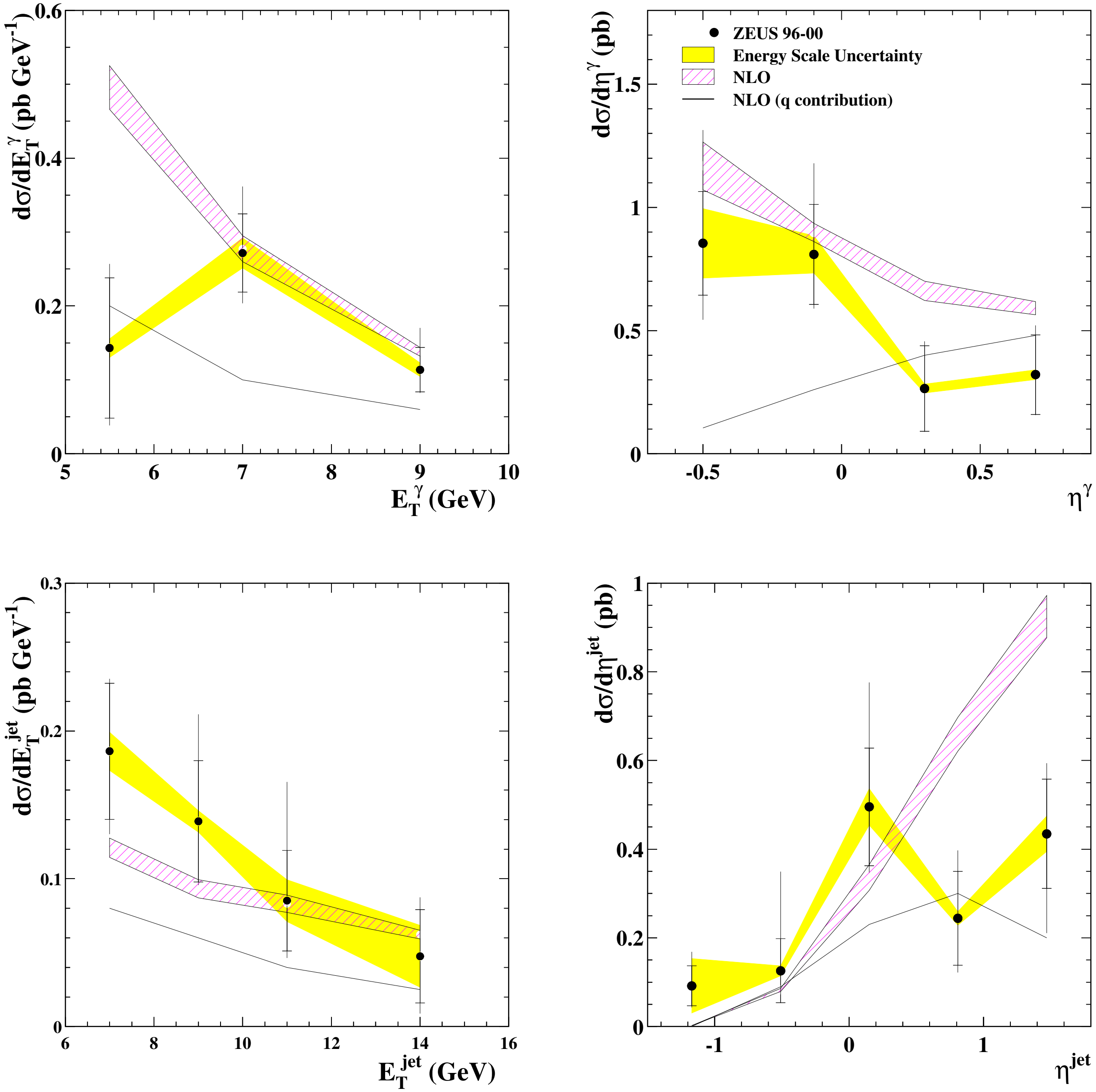
Prompt photons with jet in DIS at ZEUS

- 96-00 ZEUS DIS data
- The histograms show PYTHIA and HERWIG predictions
  - ▷ Scaling required in both cases.
- $Q^2 > 35\ \mathrm{GeV}^2$



Prompt photons with jet in DIS at ZEUS: NLO

- **96-00 ZEUS DIS data**
- **Compared to NLO predictions from Kramer and Spiesberger**
- **Black line shows the quark-line contribution.**
- $\mathbf{Q^2 > 35}$ GeV^2



The H1 measurement

- **The H1 method is similar to the ZEUS method**
  - ▷ **An electromagnetic shower in the LAr Calorimeter is required where:**
    - ◇ $-1 < \eta^{\gamma} < 0.9$ **and** $E_T^{\gamma} > 5$ **GeV**
  - ▷ **Candidates with tracks within 25cm are removed**
  - ▷ **The isolation criterion is enforced as in the ZEUS analysis**
  - ▷ **Jets, for the photon plus jet process, must fulfill**
    - ◇ $E_T^{\mathrm{jet}} > 4.5$ **GeV**
    - ◇ $-1 < \eta^{\mathrm{jet}} < 2.3$
- **The cross sections are presented for the kinematic region:**

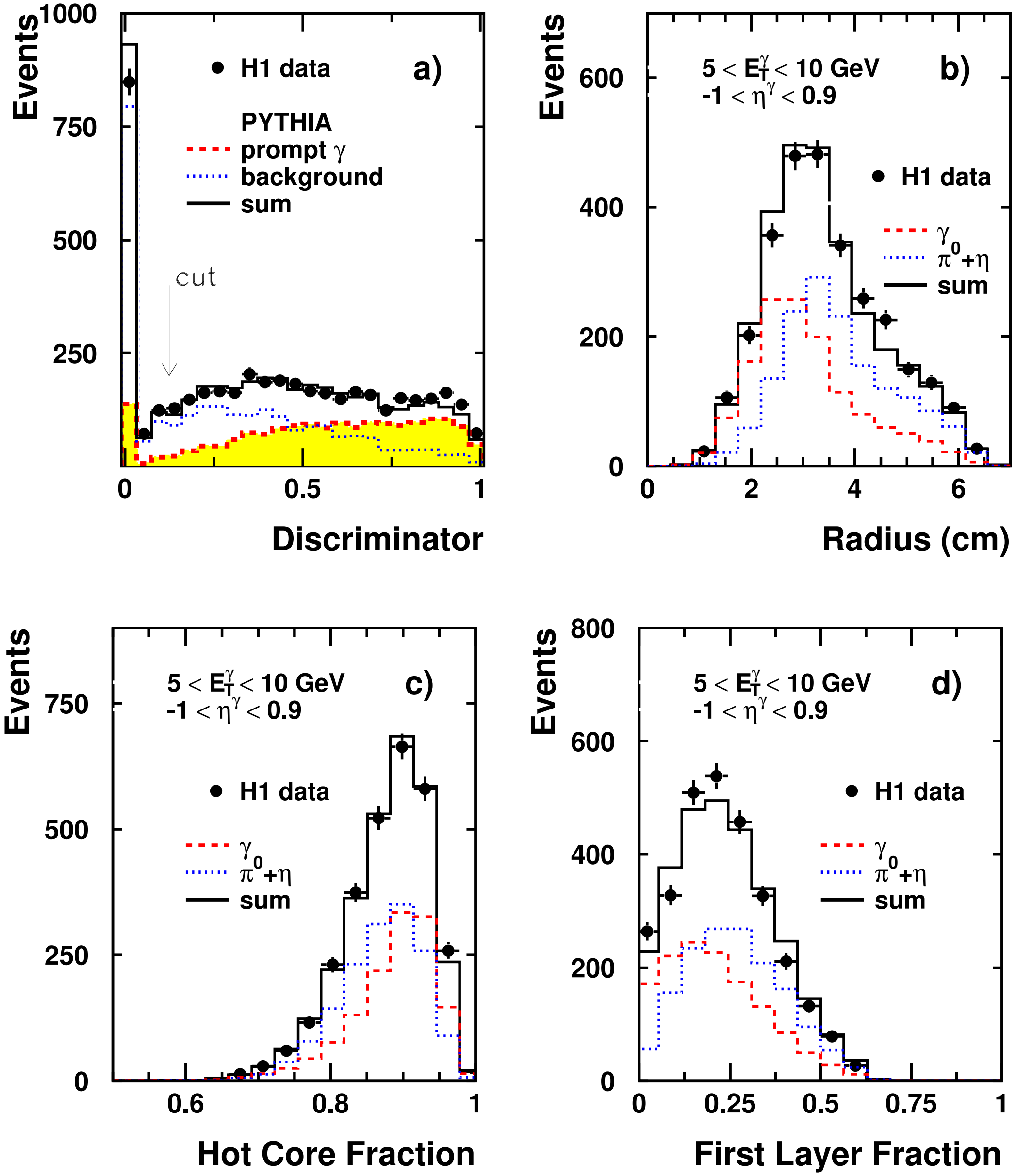
$$\sqrt{s} = 319\ \mathrm{GeV},\ 0.2 < y < 0.7,\ Q^2 < 1\ \mathrm{GeV}^2$$

$$5 < E_T^{\gamma} < 10\ \mathrm{GeV},\ -1 < \eta^{\gamma} < 0.9,\ E_T^{\mathrm{cone}} < 0.1E_T^{\gamma}$$

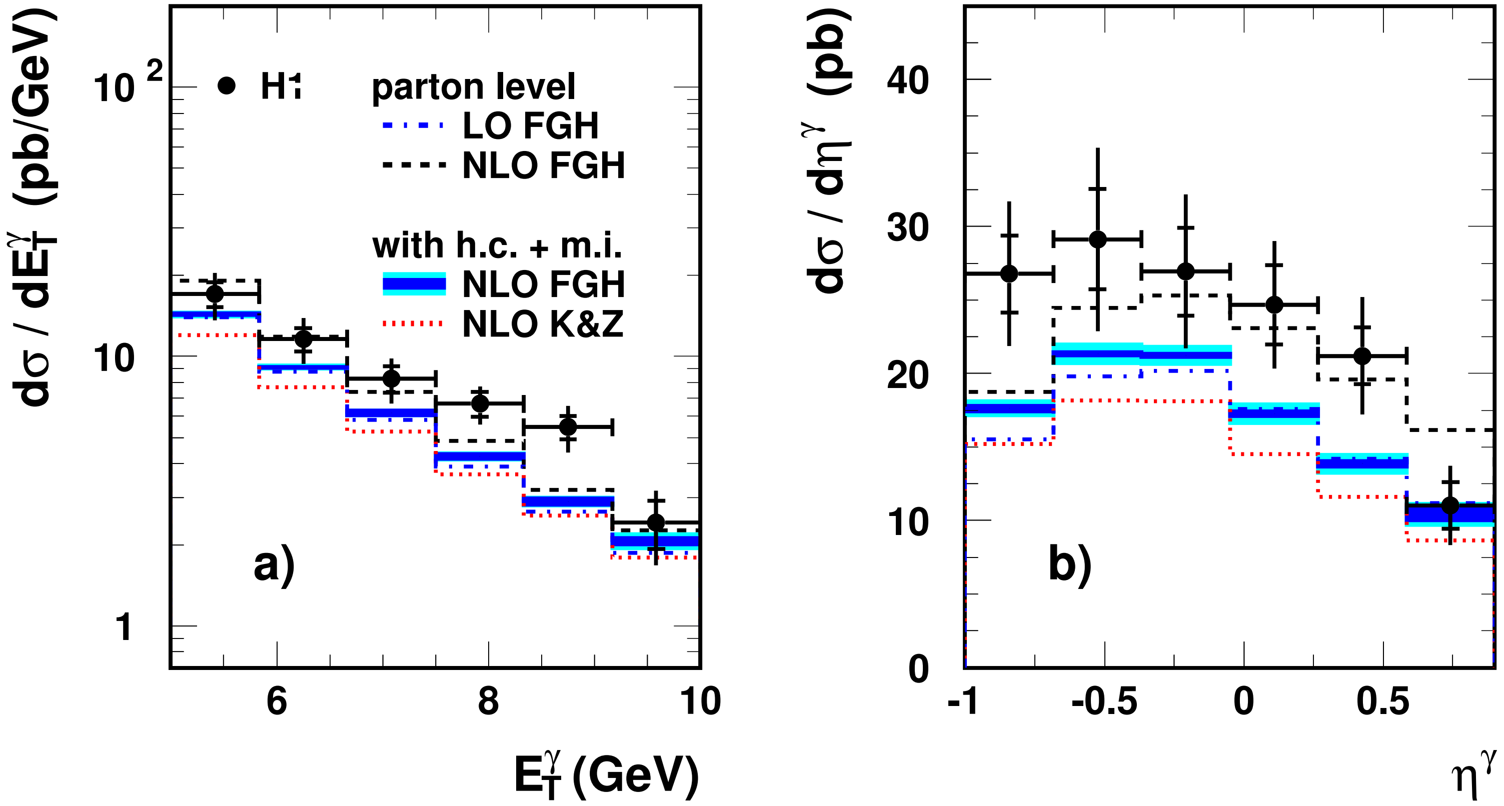
- **As in the ZEUS case, background from neutral mesons of the order of the prompt photon signal still exists.**
  - ▷ **These are removed by a discriminator function.**

The H1 background subtraction

- **The discriminator depends on**
  - ▷ **radius of the shower** (R).
  - ▷ **fraction in the highest energy cell** (HCF),
  - ▷ **depth the photon penetrates** (FLF),
- **Use** R, HCF **and** FLF **to generate a likelihood function based on photon,** π^0 **and** η**-meson simulation.**
- **Discriminator** d **is formed by likelihood**(γ)**/likelihood**$(\gamma + \pi^0)$
- **Place a cut:** $\mathrm{d} > 0.125$



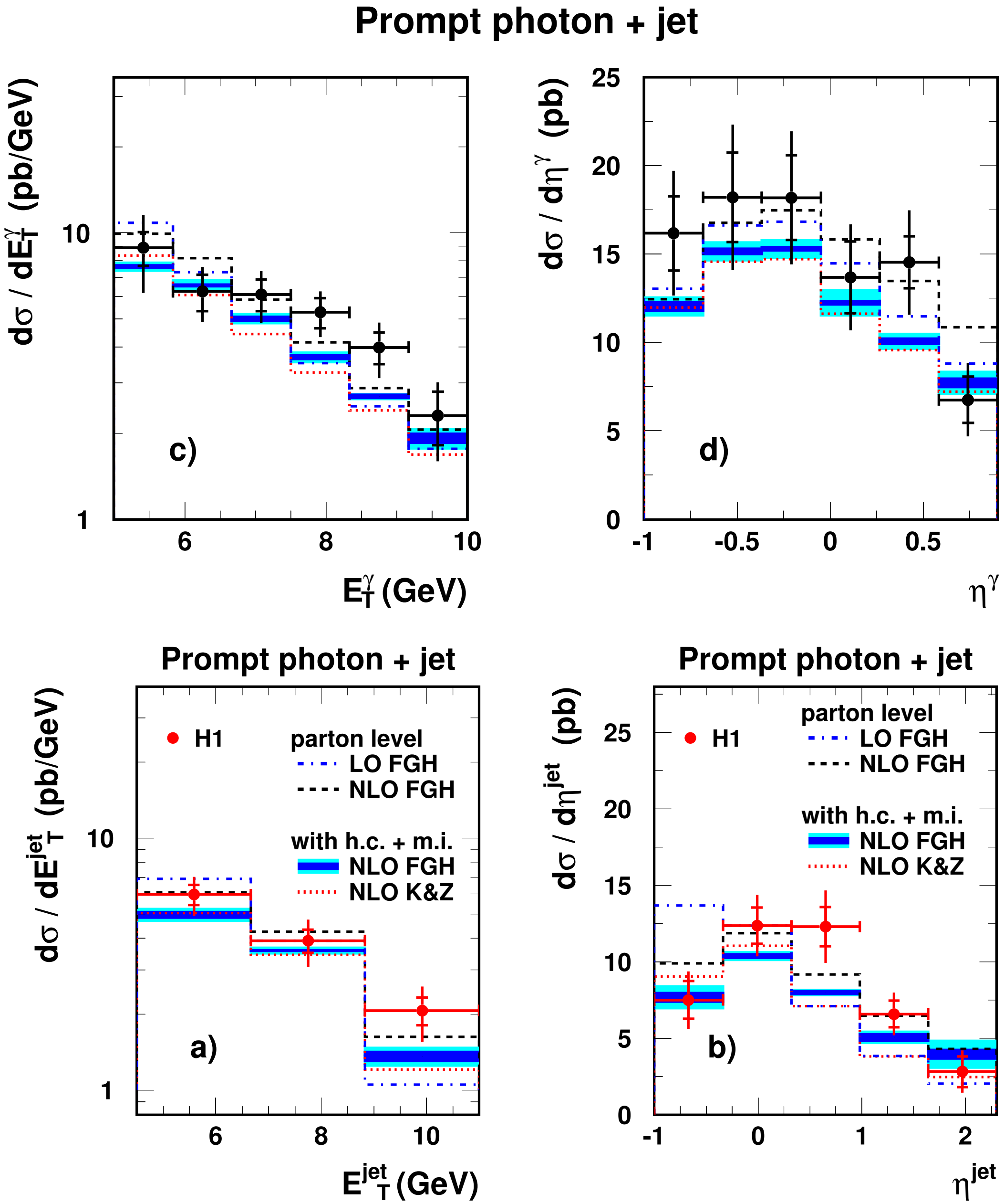
H1 results: Inclusive prompt photon production



- **Cross Sections shown for the inclusive process in photoproduction**
- **Compared to LO and NLO predictions:**
  - ▷ **Calculations by Fontannaz, Guillet and Heinrich (FGH)**
  - ▷ **Also by Krawczyk and Zembrzuski (red)**

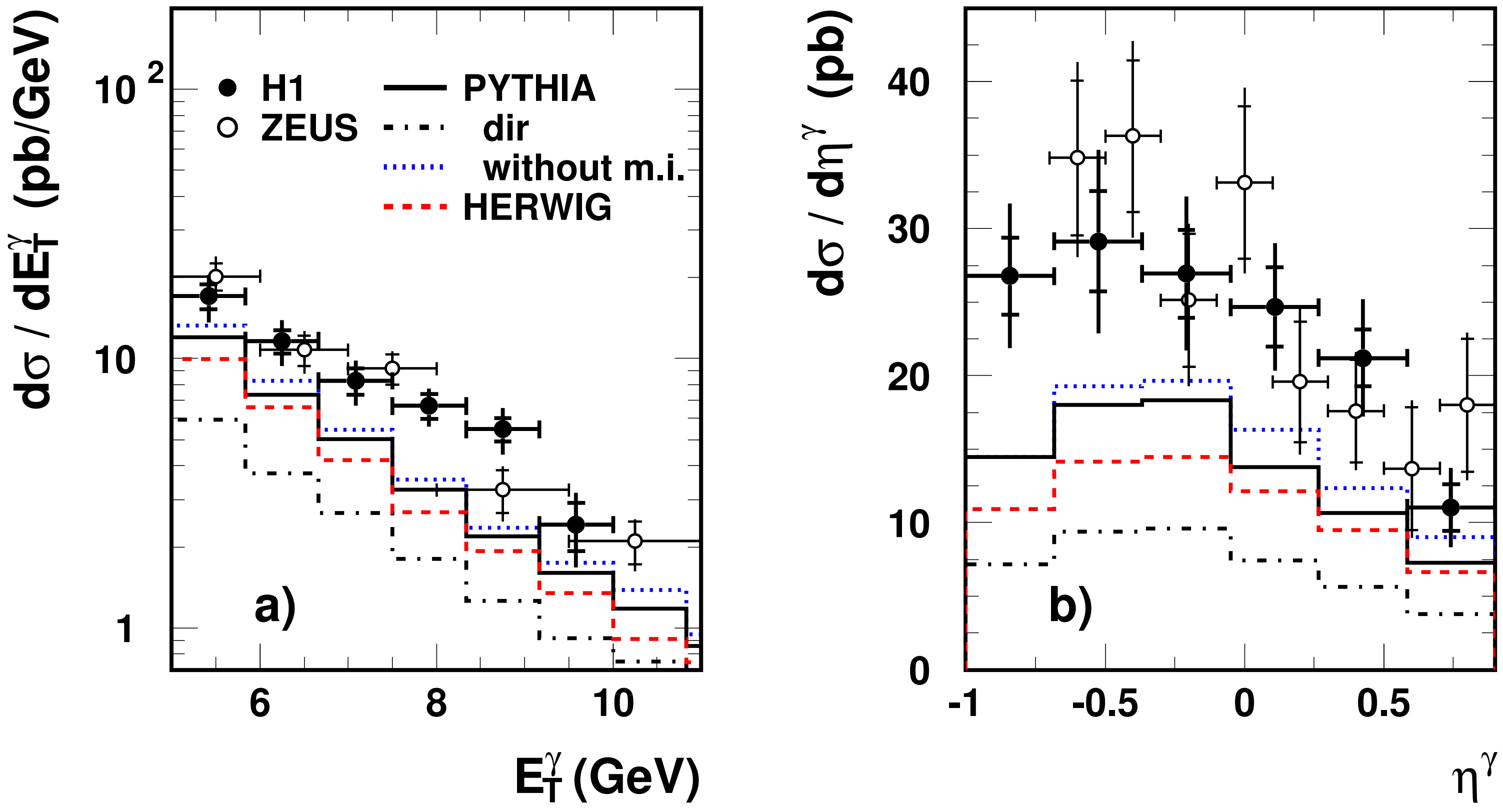
H1 results: Prompt photon with jet

- Cross Sections shown for the γ + jet process
- Compared to LO and NLO predictions:
- Calculations by
  - ▷ Fontannaz, Guillet and Heinrich
  - ▷ Krawczyk and Zembrzuski (red)



Comparing ZEUS and H1

Inclusive prompt photon



- Open circles - ZEUS 96-97 data
- Closed circles - H1 96-2000 data
- Compared to PYTHIA, HERWIG (histograms)
  - ▷ Red dashed histogram is HERWIG, black solid histogram is PYTHIA

Summary

- Prompt photon results have been presented from ZEUS and H1.
- From ZEUS:
  - ▷ Inclusive results from the photoproduction regime
  - ▷ Inclusive results in DIS
  - ▷ Photon + jet results in DIS
- From H1:
  - ▷ Inclusive results in photoproduction
  - ▷ Photon + jet results from photoproduction
- Comparisons between H1 and ZEUS show reasonable agreement
- NLO calculations describe the data rather better than PYTHIA or HERWIG
- Progress in understanding the background:
  - ▷ Use of discriminator by H1
  - ▷ Use of DVCS data photons by ZEUS
- The topic continues to be a fruitful one.