Prompt photon production in deep inelastic scattering at HERA

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(For the ZEUS collaboration)

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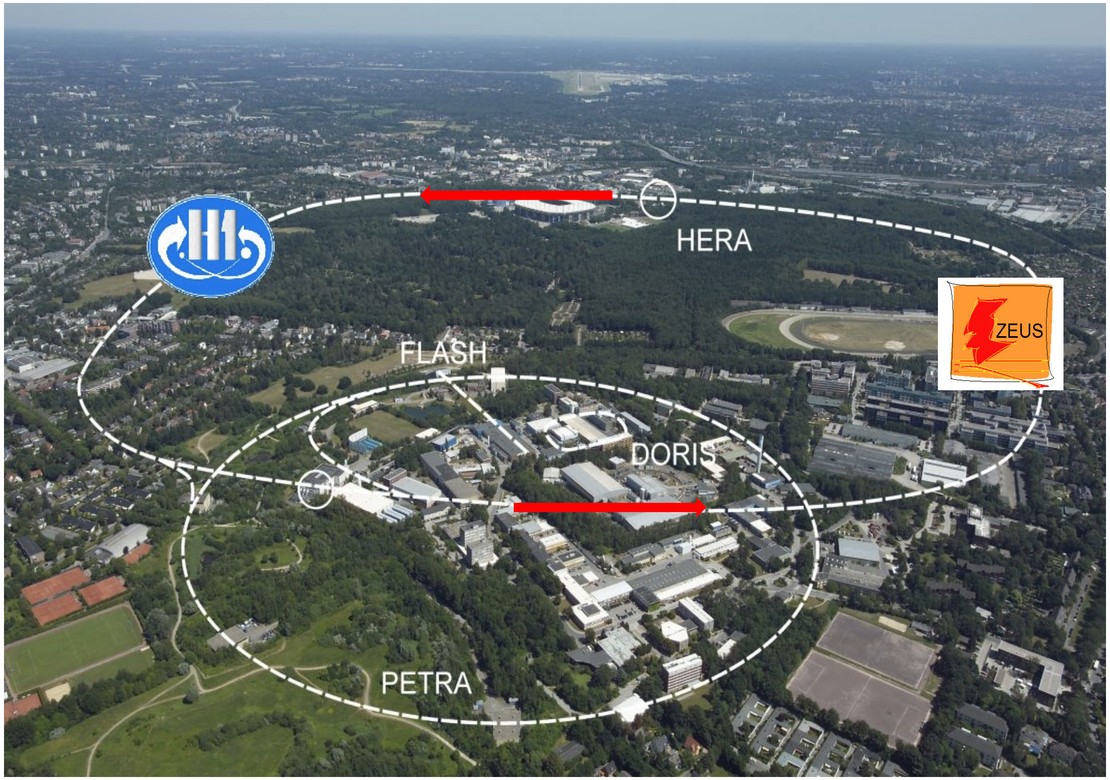
The ZEUS Detector at HERA

Protons: 920 GeV

Electron/Positrons: 27.5 GeV



Data

- HERA II period (2004-2007)
- Integrated Luminosity: 326 pb^{-1}

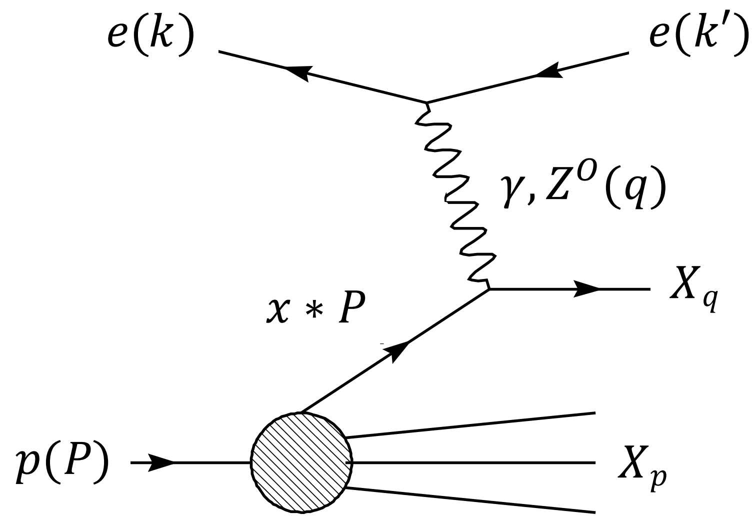
MC

- PYTHIA (signal)
- ARIADNE (background)

Deep inelastic scattering

- Kinematics:
  - $Q^2 = -q^2$ – virtuality 4-momentum transfer
  - $y = \frac{P \cdot q}{P \cdot k}$ – inelasticity measure fraction of the lepton energy lost in the interaction
  - $x = \frac{Q^2}{2P \cdot q}$ – Bjorken scaling momentum fraction carried by the incoming parton
- DIS:
  - $Q^2 > 1$ GeV²
  - Found electron

Neutral current scattering



$$Q^2 = sxy$$

$$\sqrt{s} = 318 \text{ GeV}$$

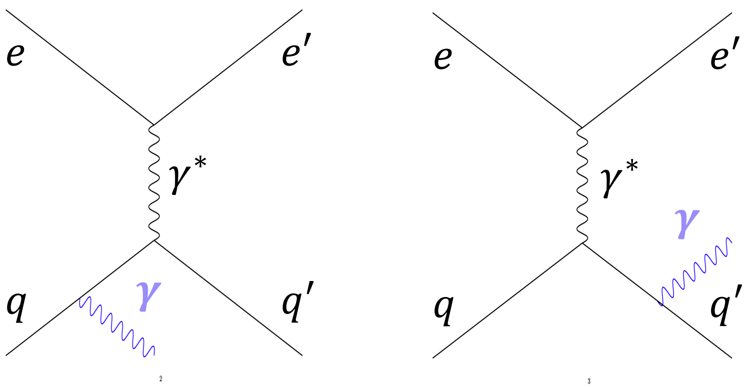
Motivation

- A study of prompt photons can give a check of the proton's parton distribution functions.
- Photons are a possible background to new physics processes
- A study of the dynamics of prompt photon emission can be used to probe different theoretical models such as the k_t-factorisation model and pQCD approaches
- It is interesting to know how dynamics changes with virtuality scale

Prompt photons

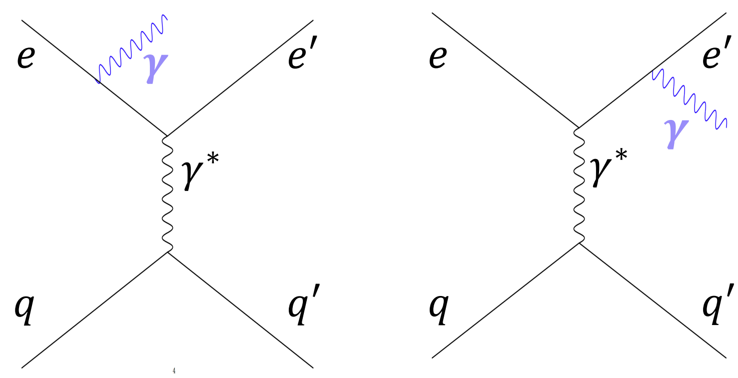
- Photons which are produced promptly in the collision - **before quarks and gluons form hadrons**

QQ - photons



prompt photons are emitted from a quark as part of hard process

LL - photons



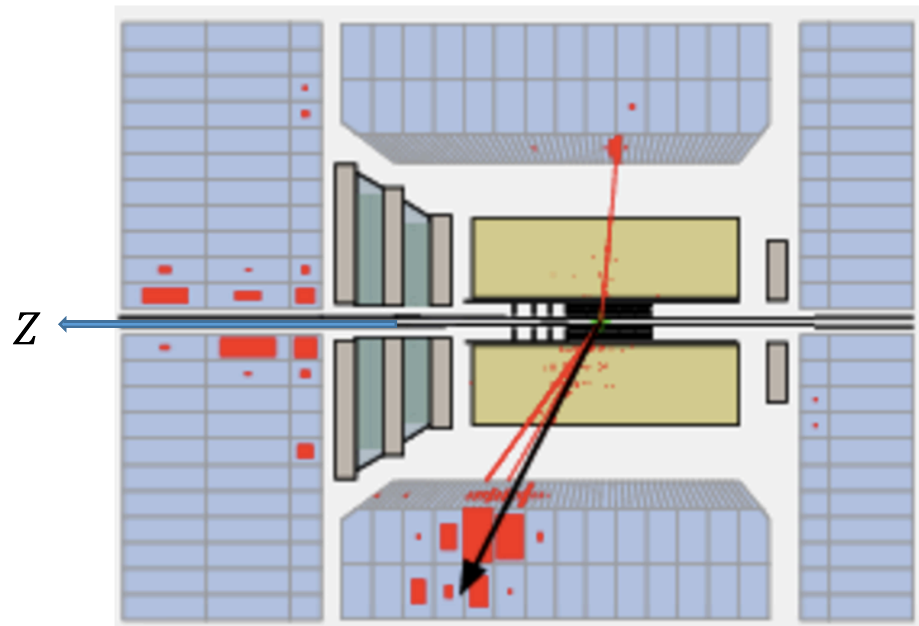
photon is radiated from an incoming or outgoing lepton

Event selection

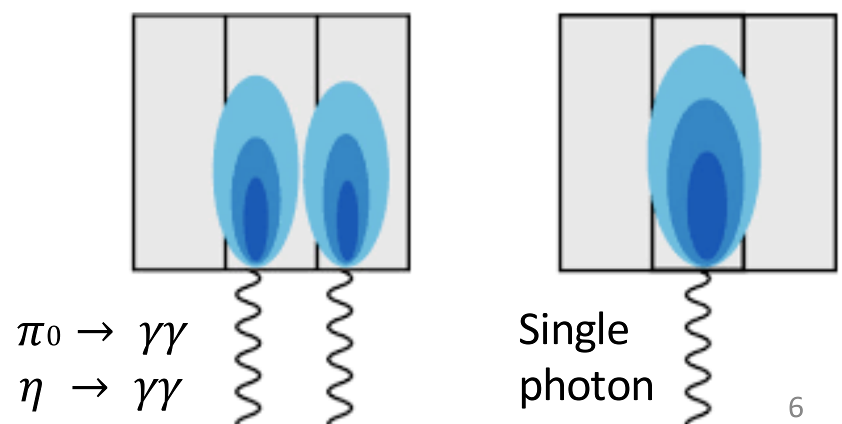
- Prompt photon selection
  - $4 < E_T^{\gamma} < 15\ GeV$
  - $-0.7 < \eta_{\gamma} < 0.9$ – in BCAL
  - $E_{EMC} \,/\, (E_{EMC} + E_{HAD}) > 0.9$
  - $\Delta R(\eta, \varphi) < 0.2$
  - $E_{\gamma} \,/\, E_{jet\ with\ \gamma} > 0.9$

Isolation In CAL

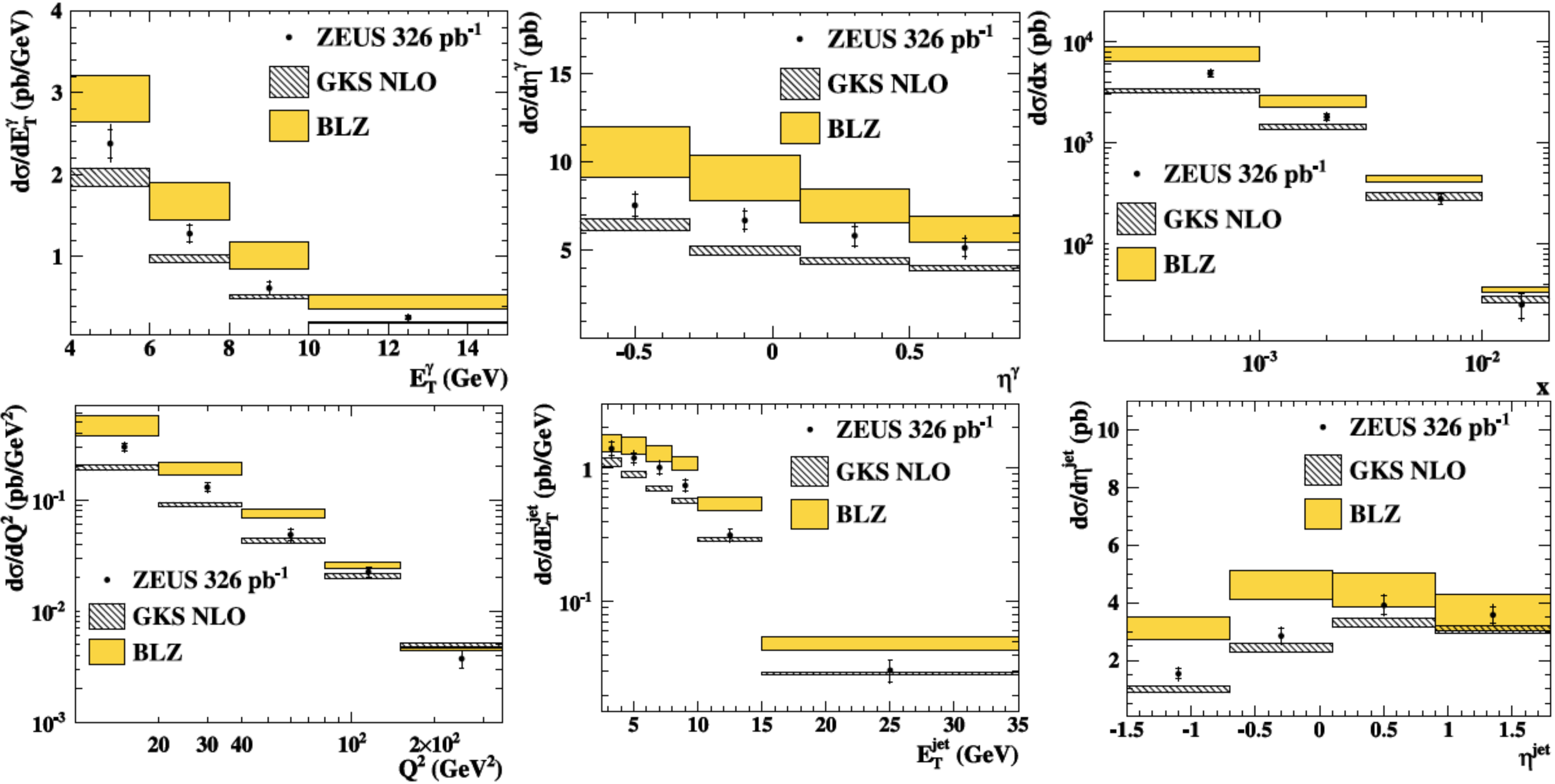
- Jet selection
  - $E_T^{jet} > 2.5\ GeV$
  - $-1.5 < \eta_{jet} < 1.8$
  - Jet with $E_{T,max}^{jet}$
- Some Kinematics:
  - $10 < Q_{el}^2 < 350\ GeV^2$
  - $E_{e,corr} > 10\ GeV$
  - $140^o < \theta_{el} < 180^o$
  - $35 < E - p_z < 65, GeV$



BCAL is finely segmented in the Z direction



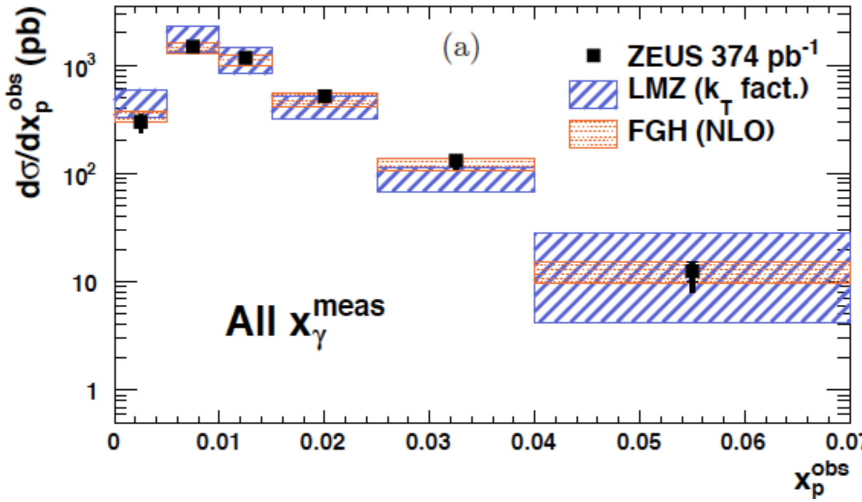
Previous study



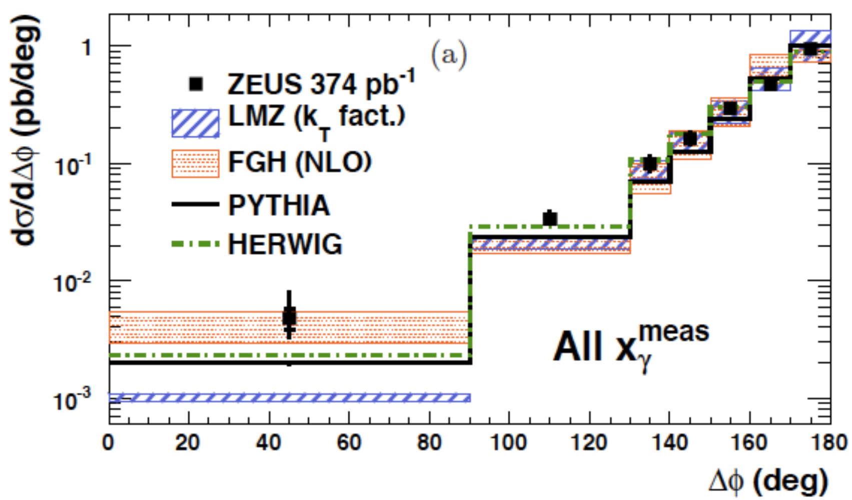
- A previous publication (Physics Letters B 715 (2012) 88-97) has covered x, Q^2, E_T^γ, η_γ, E_T^{jet} and η_{jet}.

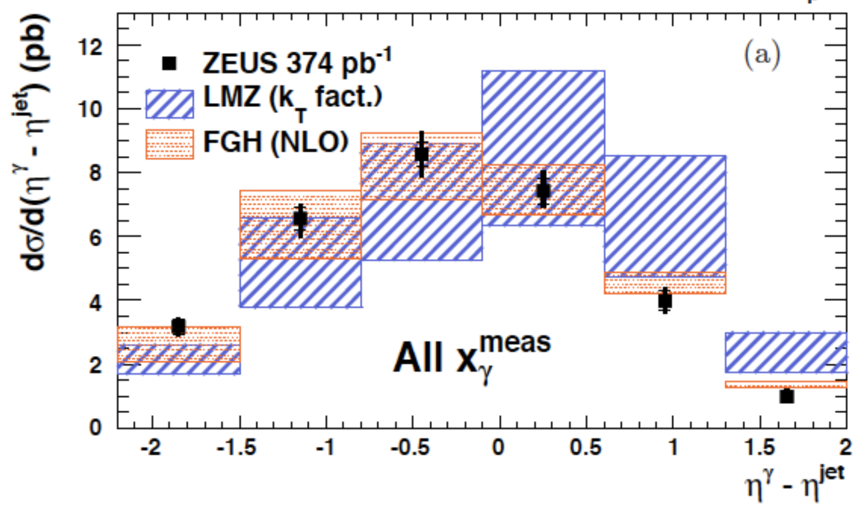
Study of photon-jet and photon-electron variables

- $x_\gamma = \frac{\sum_{jet,\gamma}(E-p_z)}{2y_{JB}E_e}$
- $x_p = \frac{\sum_{jet,\gamma}(E+p_z)}{2E_p}$
- $\Delta\eta = \eta_{jet} - \eta_\gamma$
- $\Delta\varphi = \varphi_{jet} - \varphi_\gamma$
- $\Delta\varphi_{e,\gamma} = \varphi_e - \varphi_\gamma$
- $\Delta\eta_{e,\gamma} = \eta_e - \eta_\gamma$



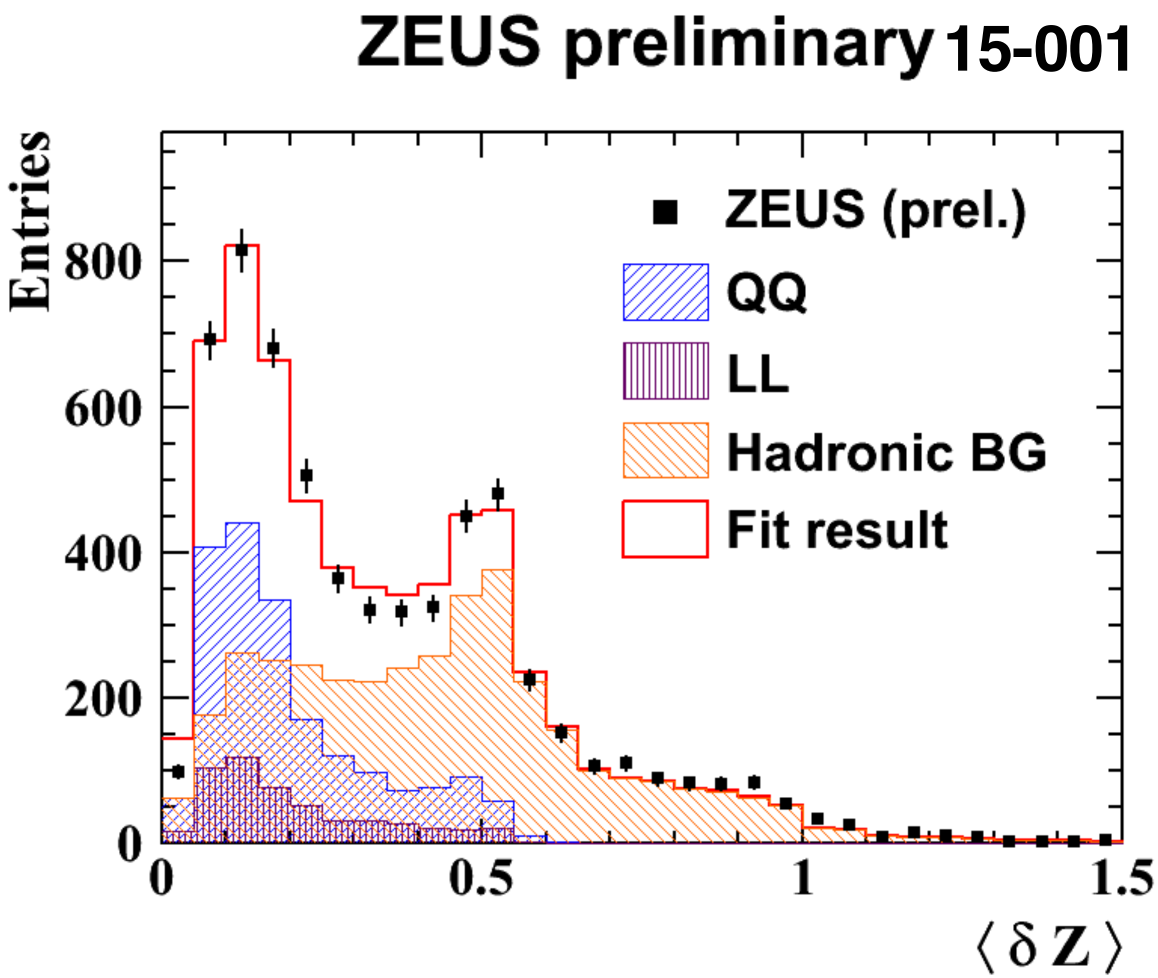
A similar kind of analysis was previously done for photoproduction ($Q^2 < 1$ GeV²)





arXiv:1405.7127v2 [hep-ex] “Further studies of the photoproduction of isolated photons with a jet at HERA”, DESY-14-086 September 15, 2014

Signal extraction



Energy-weighted mean width of the electromagnetic shower(cluster) in calorimeter relative to its centroid:

$$\langle \delta Z \rangle = \frac{\sum_i |z_i - z_{cluster}| \cdot E_i}{l_{cell} \sum E_i}$$

- Improved the fit
- Corrected signal shape

Summary of uncertainties

- Uncertainties sources:
  - $\Delta\mathcal{L}$ – not included
  - ΔN – statistical errors on QQ and LL MC samples
  - ΔAcc – acceptance uncertainty,~3-4%effect (max 22% in high x_p)
  - Δa – uncertainty of fit parameter, ~1% effect
- Typical mean statistical uncertainty is 13% with maximum 26% for first bin of x_γ and last bin of x_p
- Typical mean systematic uncertainty is 10% with maximum 50% in last bin of x_p

Cross Sections

- For a given observable Y , the production cross section:

$$\frac{d\sigma}{dY} = \frac{N(\gamma_{QQ})}{A_{QQ} \cdot \mathcal{L} \cdot \Delta Y} + \frac{d\sigma_{LL}^{MC}}{dY}$$

$N(\gamma_{QQ})$ - number of QQ photons extracted from the fit,

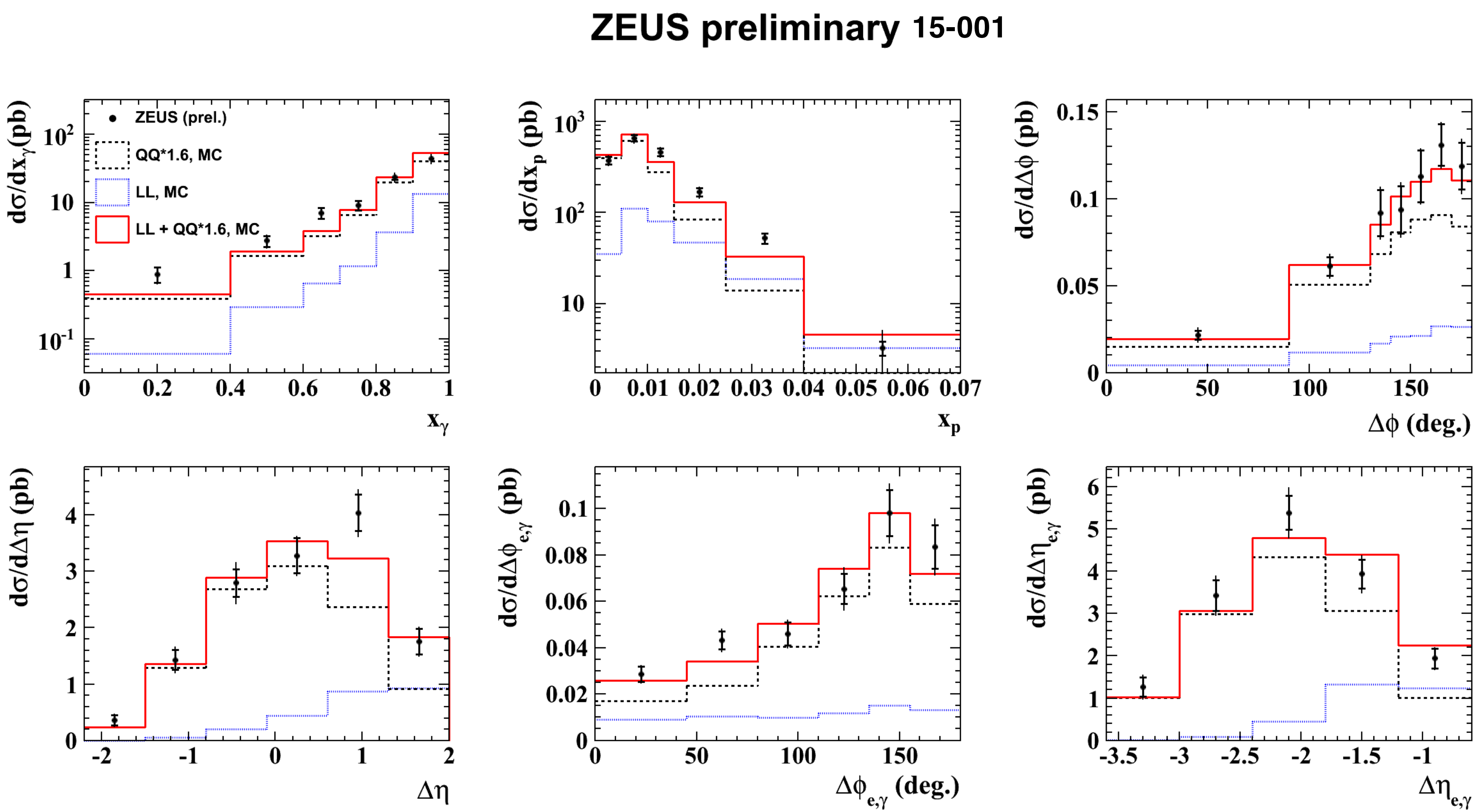
ΔY - bin width,

$\mathcal{L}$ - total integrated luminosity,

$\frac{d\sigma_{LL}^{MC}}{dY}$- cross section for LL photons

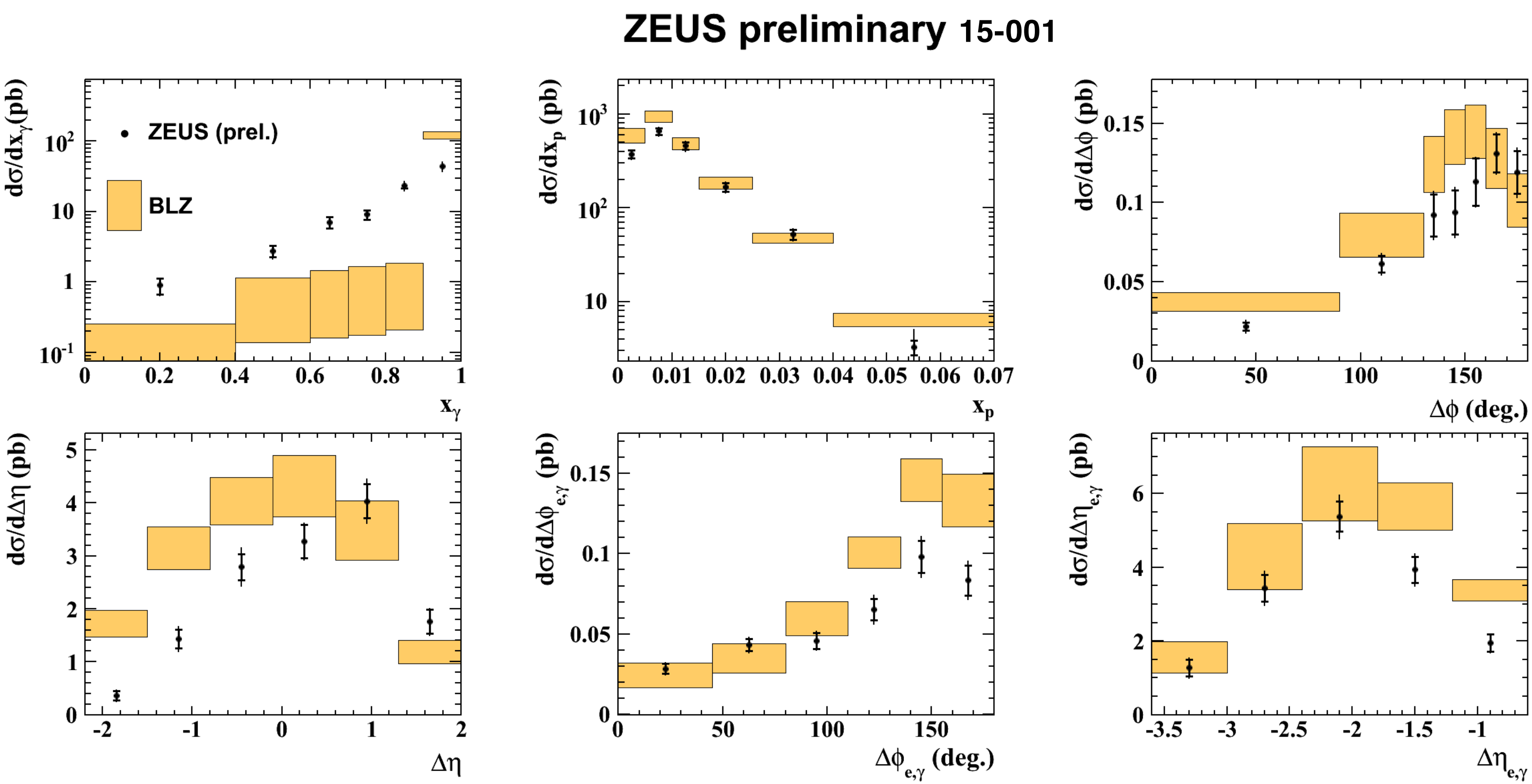
A_{QQ} - ratio of the number of events reconstructed to those generated in a given bin

Cross Sections compared to weighted LO MC



Comparison with Baranov-Lipatov-Zotov(BLZ) theory

(PHYSICAL REVIEW D 81, 094034 (2010))



Conclusion

- Prompt photons in DIS have been measured
- The fitting procedure was improved to estimate the CS
- Experimental differential cross sections have been obtained for x_γ, x_p, $\Delta\eta$, $\Delta\varphi$, $\Delta\eta_{e,\gamma}$, $\Delta\varphi_{e,\gamma}$ observables
- Pythia describes the shape of the data reasonably well when rescaled by a factor 1.6, as in the previous ZEUS DIS publication.
- We compared results with k_t-factorisation model that show a fair agreement of the kinematic distributions of the data with exception of x_γ and $\Delta\eta$. Further investigations needed to understand the results