Prompt photon plus jet photoproduction with the ZEUS detector

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On Behalf of the ZEUS Collaboration

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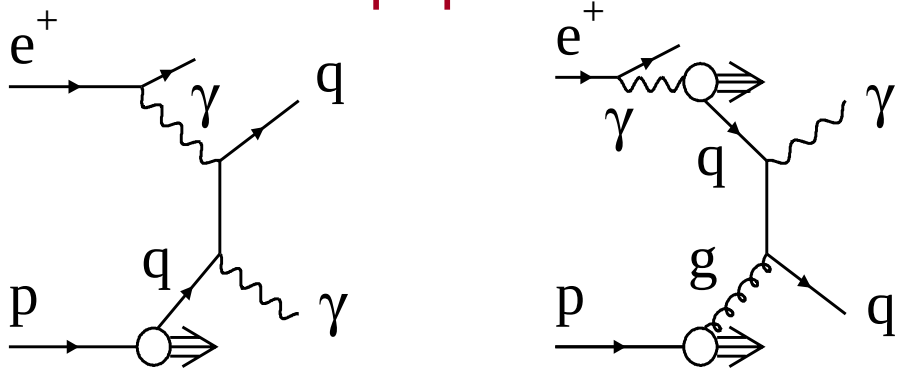
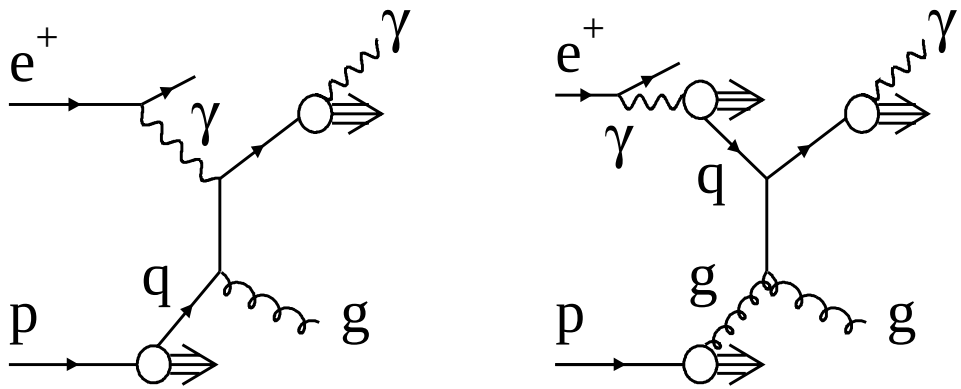
Prompt Photons

Prompt photon:



(a) Direct (b) Resolved

Radiative photon:



(c) Direct (d) Resolved

Prompt Photon

- γ is produced in the hard scatter
  - → Carries information about the struck parton
  - → No Hadronisation correction
  - → Sensitive to both quark and gluon densities
- Radiative events: Photon is radiated after the interaction

Non-Prompt Background

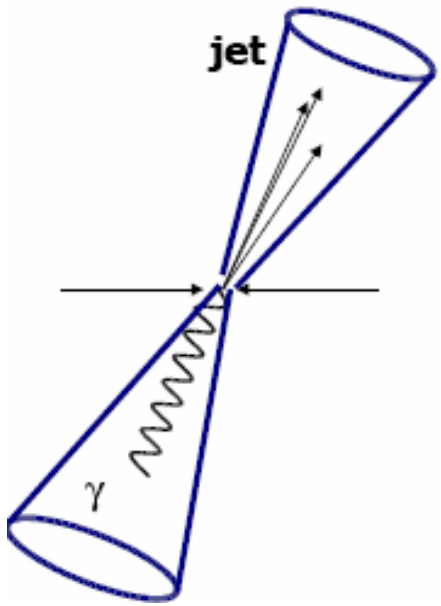
- Neutral mesons: Photon originates from a decay of a hadron

$$\pi^0 \rightarrow 2\gamma$$

Prompt Photons + Jet in Photoproduction

Presence of a jet:

- More sensitivity to underlying partonic processes
- Introduces some hadronisation
  - Smaller hadronisation correction than dijets
- Theoretical predictions for γ+jet more reliable than low-E_t dijet studies



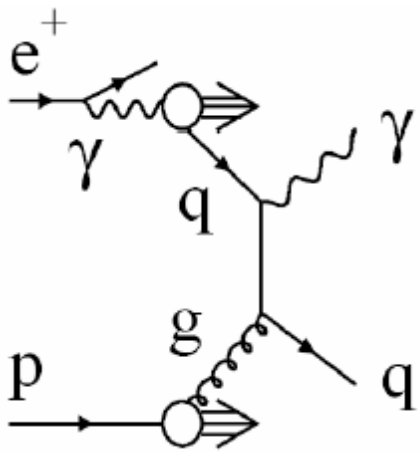
Photoproduction (Q^2 <1):

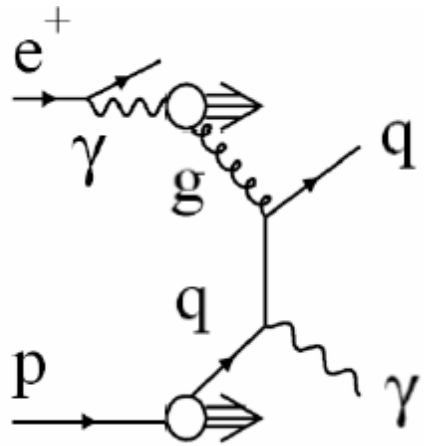
- No additional P_t given to the γ+jet system by $e^{\pm}$
- The γ+jet will be back to back → Well separated

Resolved contribution:

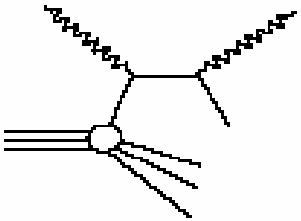
- γ hadronic structure
- Constrain gluon distribution

NLO calculation available:

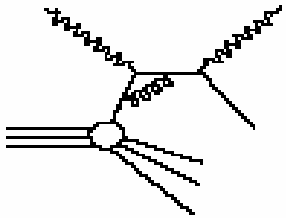




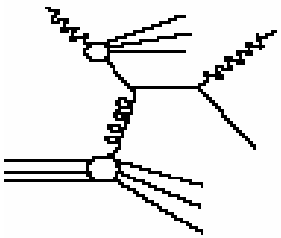
Theoretical Predictions



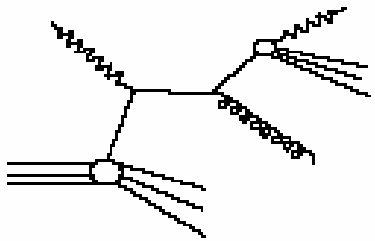
Compton Process α_{em}^2



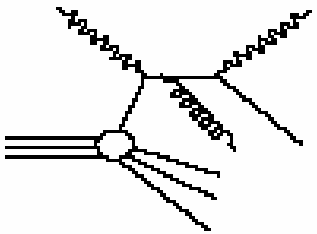
$\alpha_s\alpha_{em}^2$



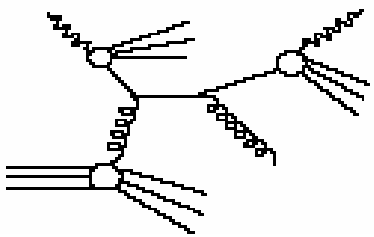
Resolved initial photon
$\alpha_s\alpha_{em}$



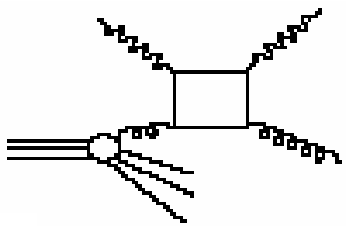
Resolved final photon
$\alpha_s\alpha_{em}$



$\alpha_s\alpha_{em}^2$



Double resolved $\alpha_s^2\alpha_{em}^2$



Box diagram $\alpha_s^2\alpha_{em}^2$

K.Krawczyk & A.Zembrzuski (KZ):

- GRV parametrisation:
  - photon structure function
  - proton structure function
  - fragmentation function

Fontanaz, Guillet & Heinrich (FGH):

- MRST01 proton structure function
- AFG02 photon structure function

A.Lipatov & N.Zotov (LZ):

- K_t-factorization approach
  - Unintegrated quark/gluon densities using Kimber-Martin-Ryskin prescription

ZEUS Isolated γ Identification

Previous analyses used shower-shape variables (e.g. D0, H1, ZEUS)

Now we use preshower detector (e.g. CDF)

- Particle decay before the preshower detector

Use the K_t jet finder on both the photon and hadron jet

- Keeps the hadron and the 'photon' jet on equal footing
- Require isolation for NLO & MC (E_t^{γ} / $E_t^{\gamma\text{-total}}$) > 0.9

ZEUS Barrel Preshower detector (BPRE)

- Scintillator tiles in front of Barrel Calorimeter

Photons

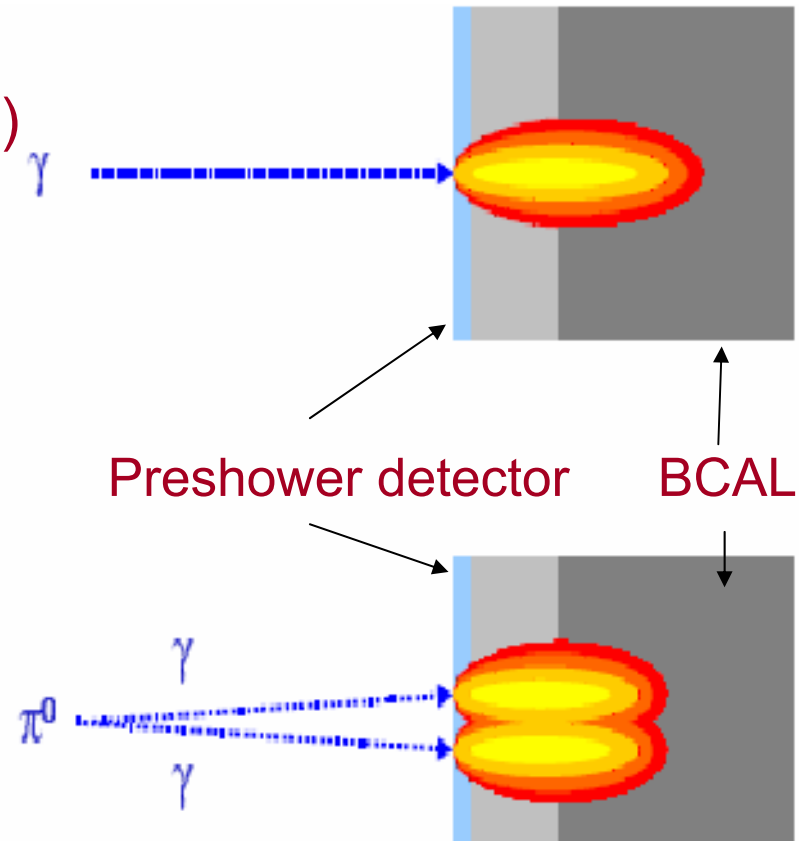
- Isolated e.m. CAL shower
- No associated track
- Low signal in BPRE

Background

- Neutral mesons (η, π^0)
- Higher BPRE signal than γ's

Modeling the BPRE

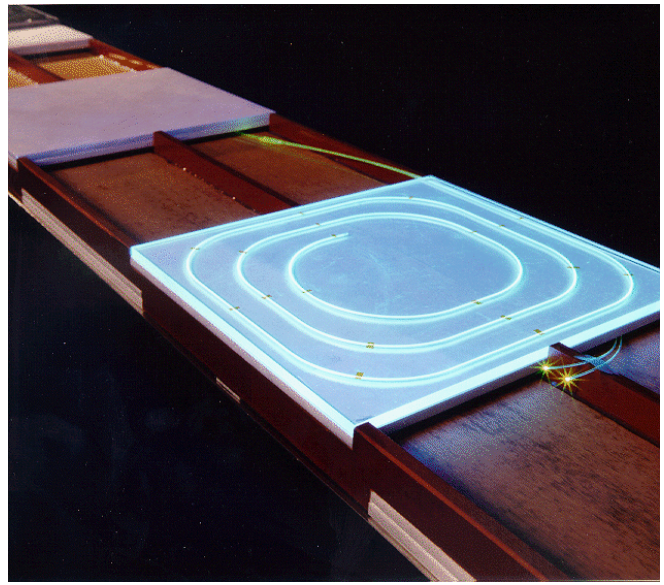
- ZEUS Deeply Virtual Compton Scattering (DVCS)
  - Provides a clean photon sample



Barrel Preshower Detector

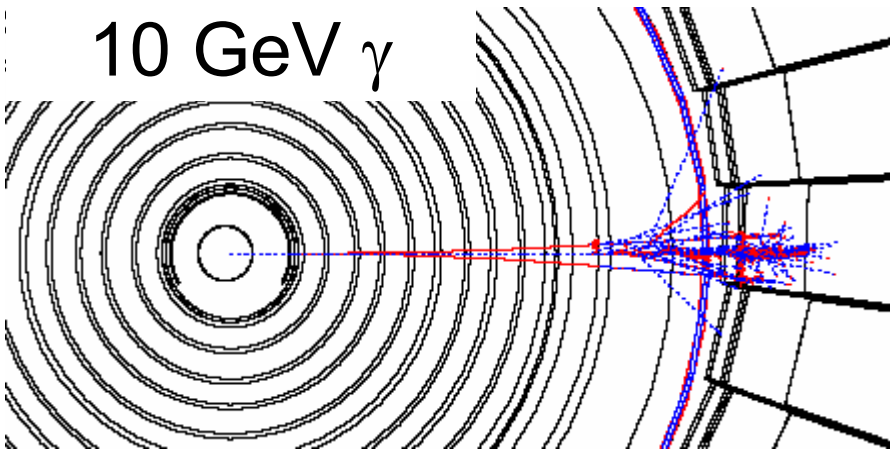
As a particle moves from the interaction point it passes through dead material in front of the BCAL

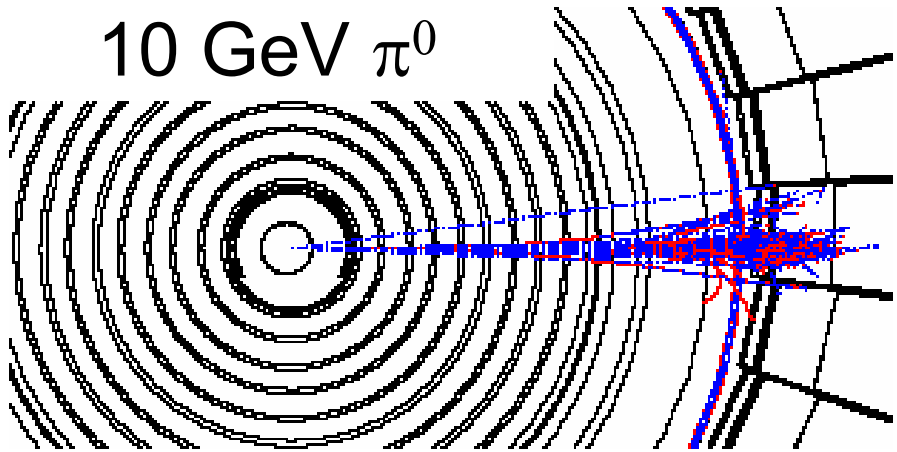
- This leads to energy loss before measurement



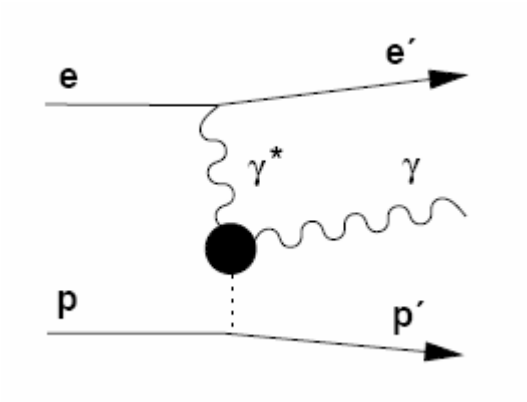
BCAL Presampler measurement

- Measured energy is proportional to the number of photons, not the energy of the individual photons → Neutral meson separation

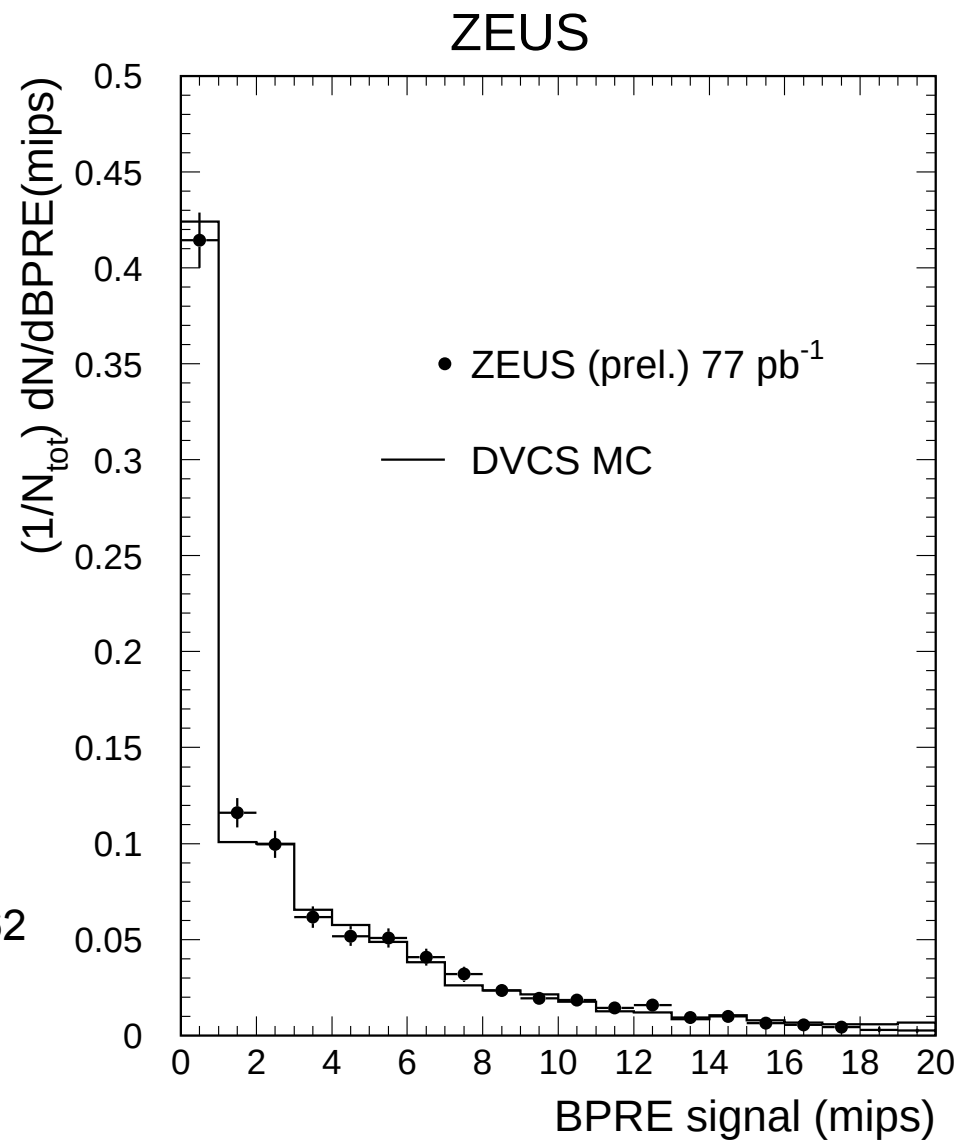




ZEUS BPRE DVCS Sample



$e^{\pm}p \rightarrow e^{\pm} + \gamma + p$

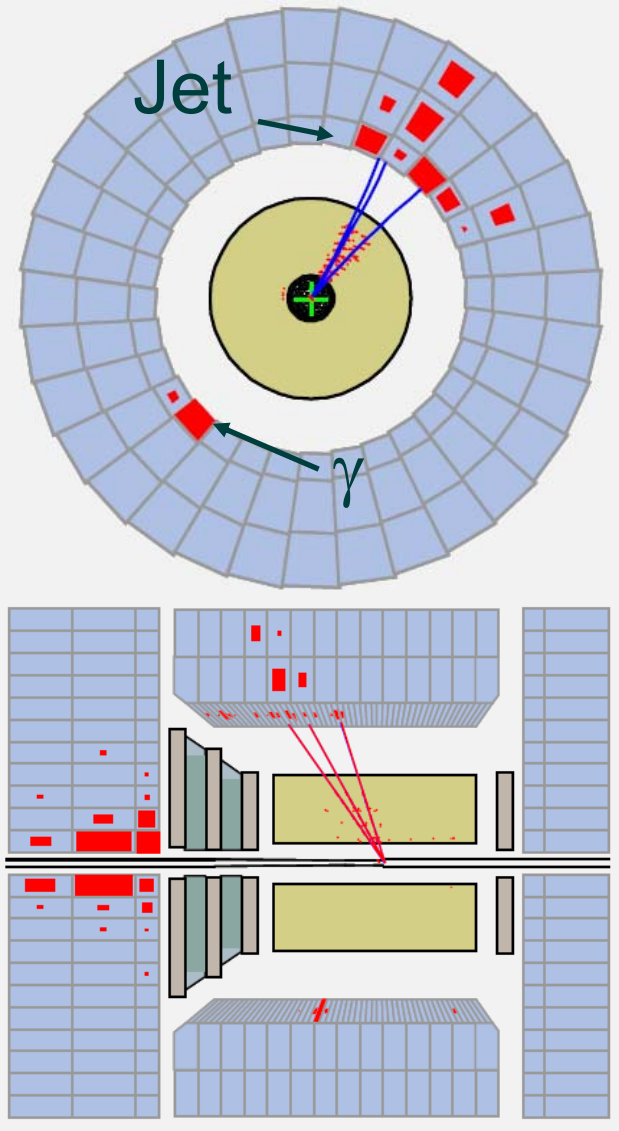


DVCS Sample:

- Only one track per event ($e^{\pm}$)
- Two isolated EM deposits (γ,$e^{\pm}$)
- Other cuts as in the paper:
  - *"Measurement of deeply virtual Compton scattering at HERA"* Physics Letters B 573 (2003) 46-62

Improved agreement with additional dead material

Event Selection



99-00 Data, 77.1 pb^{-1}

Photoproduction Sample:

$0.2 \leq Y_{JB} \leq 0.8$

$Q^2 < 1\ GeV^2$

2 or more jets from the K_t algorithm:

Photon candidate:

$E_{EMC}/E_{Total} \geq 0.9$

$-0.7 \leq \eta^{\gamma} \leq 1.1$ (BCAL region)

$5.0 \leq E_t^{\gamma} \leq 16.0$ GeV

No associated track

Low multiplicity: # of energy flow objects

Associated jet:

$E_{EMC}/E_{Total} \leq 0.9$

$-1.6 \leq \eta^{jet} \leq 2.4$

$6.0 \leq E_t^{jet} \leq 17.0$ GeV

(Note the asymmetric E_t cuts)

Prompt γ & Photoproduction Background MCs

Prompt γ PYTHIA 6.3 & HERWIG 6.5 Monte Carlo models

- Only prompt photon subprocesses
- Generated with default parameters
- CTEQ5L proton structure function & SaS-2D parameterization for photon structure
- Both direct and resolved events were generated
- Full detector simulation
  - Improved dead material map
- Also used for hadronisation correction of KZ, FGH and LZ

Fully inclusive photoproduction sample

- w/o Prompt photon subprocesses
- Used to model hadronic background
  - i.e. Photons originating from the parton shower & resonance decays
- Combine with prompt photon MC according to BPRE distribution

MC samples were re-weighted in E_t and η for hadronisation and acceptance corrections

Photoproduction background

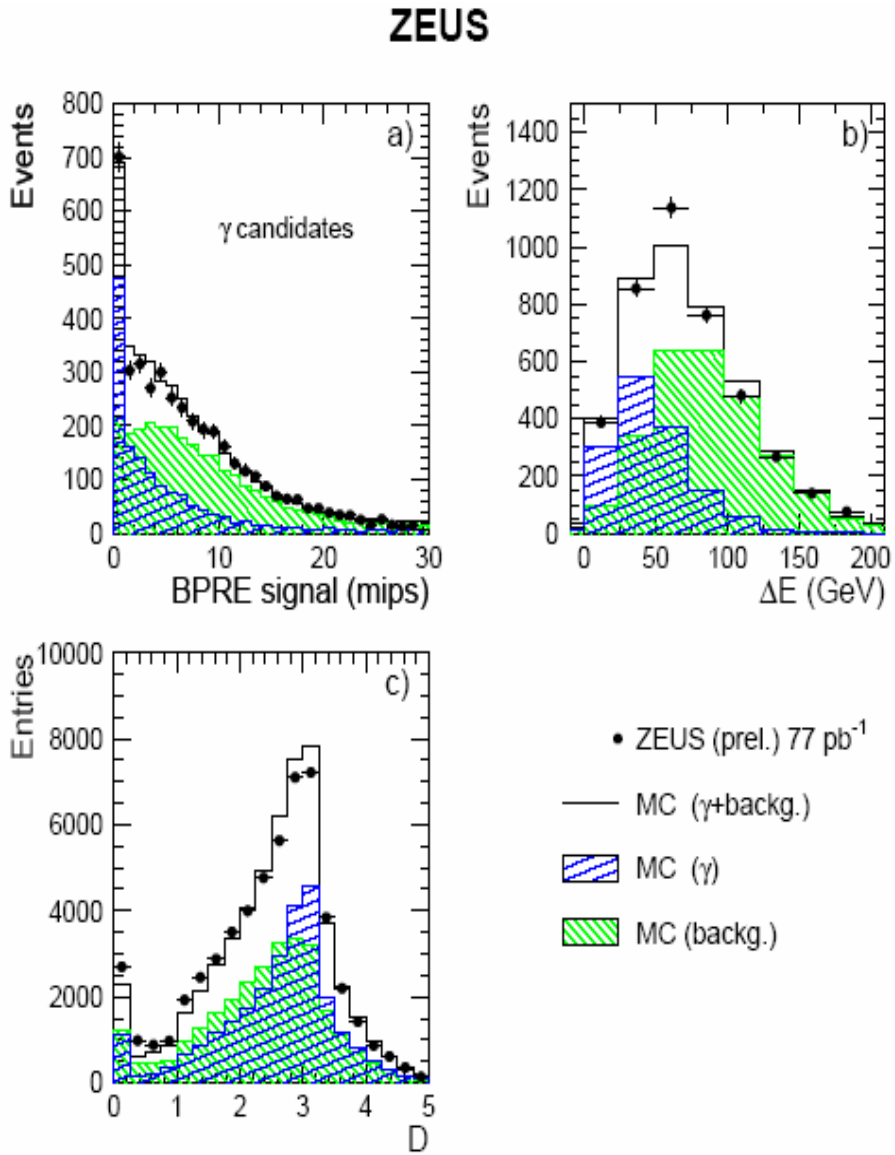
Fit sum of prompt γ MC & background MC to BPRE signal

- Determine relative amounts
- Done bin-by-bin for E_t's, η's and $X\gamma$ distributions

Large fraction of events with <1 MIP (Similar to the DVCS sample) → high purity

Examine calorimeter based variables

- $\Delta E = E_{Total} - E_{(\gamma + jet)}$
- D = Distance (in $\eta\phi$) from γ to energy flow objects
- Both are well reproduced by the sum of MCs



Results

Photoproduction of prompt photons with accompanying jet measured for 77.1 pb^{-1} of data:

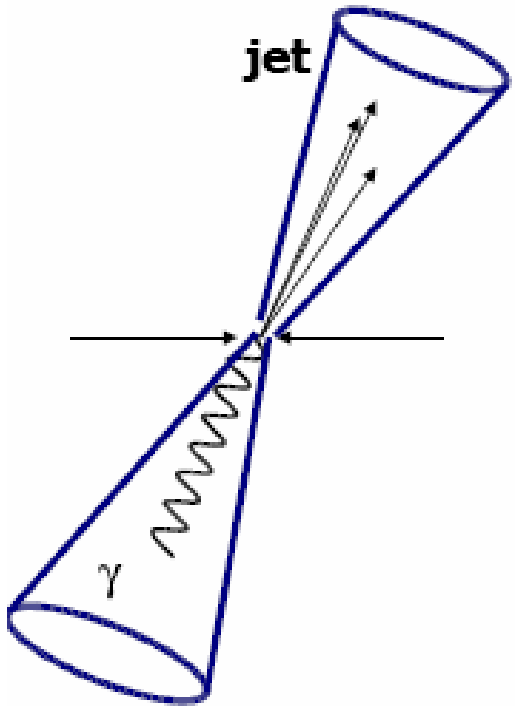
$\sigma(e^{\pm}p \rightarrow e^{\pm} + \text{prompt} + \text{jet} + X) = 33.1 \pm 3.0\,(\text{stat.})\ ^{+4.6}_{-4.2}\ (\text{syst.})\ pb$

- $Q^2 < 1\ GeV^2$, $0.2 \leq Y_{JB} \leq 0.8$
- $5.0 \leq E_t^{\gamma} \leq 16.0\ GeV$, $-0.7 \leq \eta^{\gamma} \leq 1.1$, $(E_t^{\gamma} / E_t^{\gamma\text{-total}}) > 0.9$
- $6.0 \leq E_t^{jet} \leq 17.0\ GeV$, $-1.6 \leq \eta^{jet} \leq 2.4$

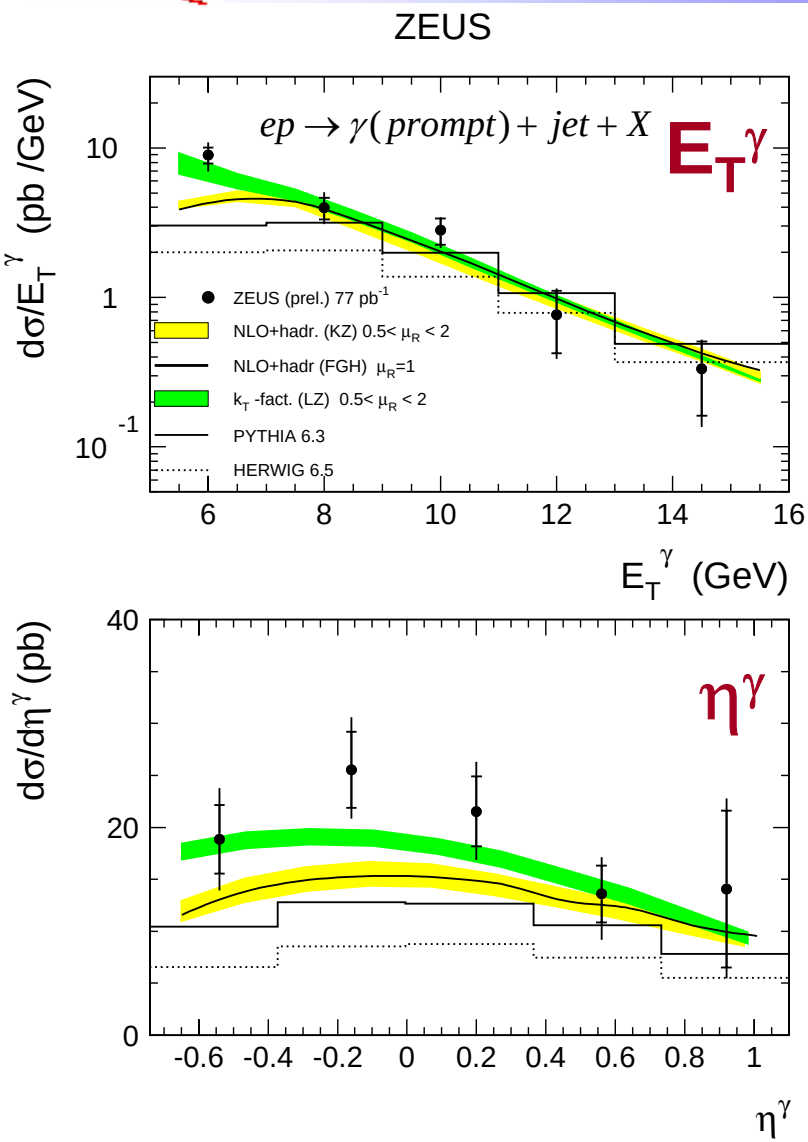
Theoretical predictions:

- (After hadronisation Correction)

PYTHIA	19.98 pb
HERWIG	13.54 pb
KZ	23.31 pb
FGH	23.52 pb
LZ	30.73 pb



Compare Photon Kinematics



Data:

- Corrected for acceptance to the hadron level

HERWIG & PYTHIA:

- Do not rise as steeply as data at low E_t^γ
- Underestimate the measured cross section

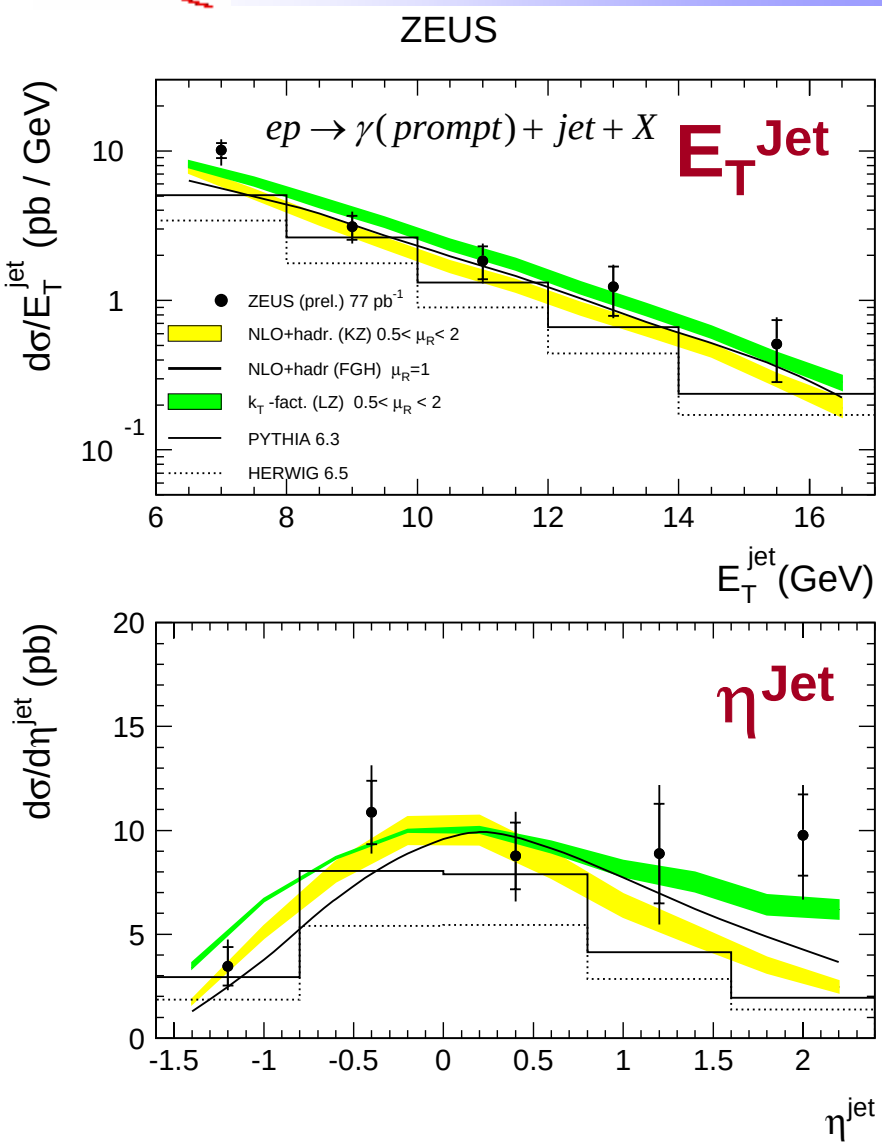
KZ & FGH:

- Improved agreement with the measured cross section, but deviates at low E_t^γ

LZ:

- Improves description for E_t^γ and low η^γ

Compare Jet Kinematics



Data:

- Corrected for acceptance to the hadron level

HERWIG & PYTHIA:

- Low E_t^{jet} & Forward jets not well described
- Significantly underestimate the measured cross section

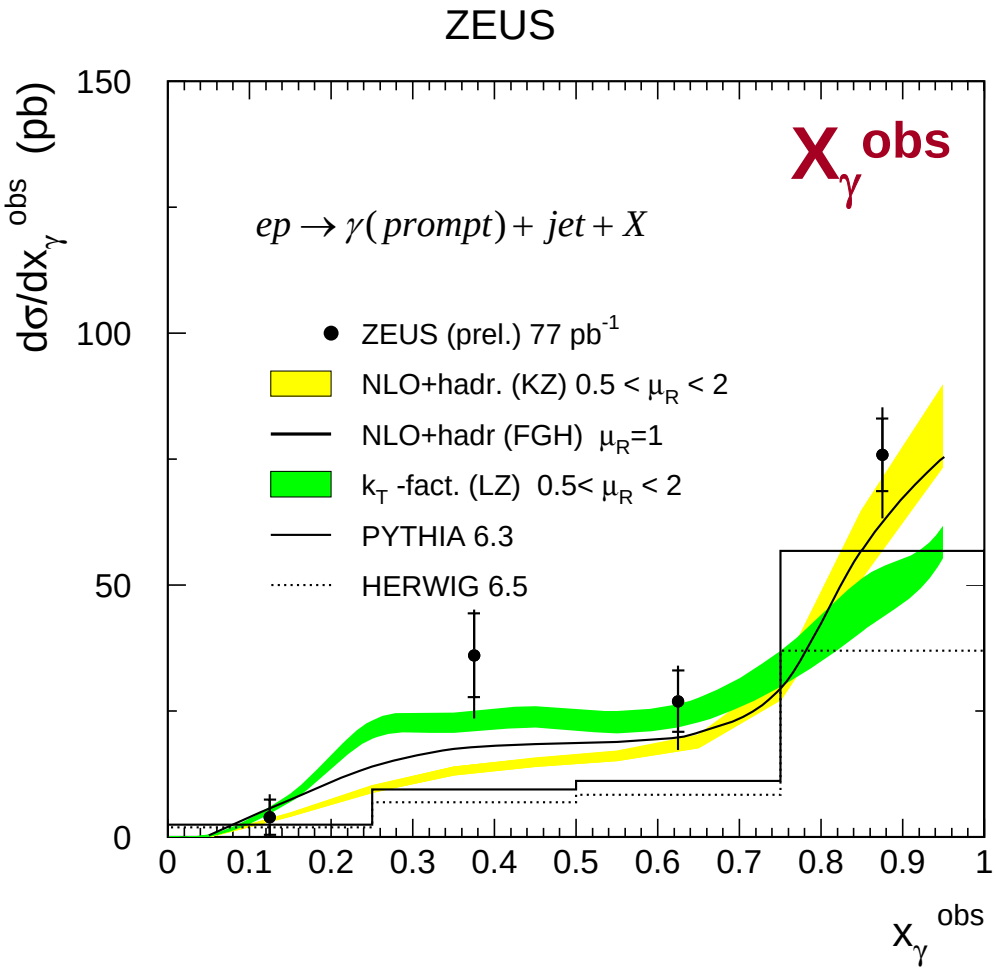
KZ & FGH:

- Improved agreement with the measured cross section, below data for Low E_t^{jet}

LZ:

- Improved description of forward jet region

X_γ Cross Section



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

Data:

- Corrected for acceptance to the hadron level

HERWIG & PYTHIA:

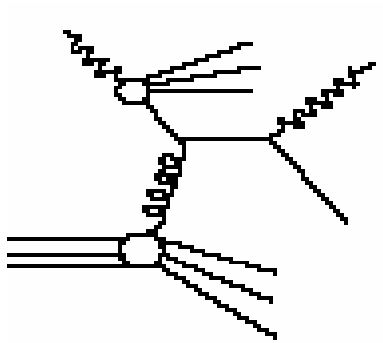
- Significantly underestimate the measured cross section

KZ & FGH:

- Improvement compared to LO MC, particularly at high X_γ (Direct contribution)

LZ:

- Improvement for low X_γ (Resolved contribution)



Resolved initial photon

$\alpha_s\alpha_{em}$

Summary

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$\sigma(e^{\pm}p \rightarrow e^{\pm} + \text{prompt} + \text{jet} + X) = 33.1 \pm 3.0\ (\text{stat.})\ ^{+4.6}_{-4.2}\ (\text{syst.})\ pb$

First time ZEUS used a preshower detector to identify prompt photons

PYTHIA & HERWIG have different shapes and normalizations than the data

Difference with KZ calculations, especially in the forward jet region (low E_t region)

FGH NLO calculations agree better in the forward jet region than KZ NLO QCD

- Possible indication for high-order QCD contributions

K_t-factorization calculations (LZ) closer to the data than the traditional NLO