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Prompt Photons in Photoproduction at HERA

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Abstract

First inclusive measurements of isolated prompt photons in photoproduction at HERA have been made with the ZEUS detector. Cross sections are given as a function of the pseudorapidity and the transverse energy of the photon, for $E_T^\gamma > 5$ GeV in the γp centre-of-mass energy range 134–285 GeV. Comparisons are made with predictions from LO Monte Carlo models and NLO QCD calculations. For forward η^γ (proton direction) good agreement is found, but in the rear direction all predictions fall below the data.

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1 Introduction

Isolated high transverse energy (“prompt”) photon processes at HERA could yield information about the quark and gluon content of the photon, together with the gluon structure of the proton. The particular virtue of prompt photon processes is that the observed final state photon emerges directly from a QCD diagram without the subsequent hadronisation which complicates the study of high E_T quarks and gluons.

In a ZEUS paper [1] the observation of prompt photons was first confirmed at HERA. More recently [2], ZEUS collaboration has measured the cross sections of inclusive prompt photons in photoproduction reactions, using an integrated luminosity of 38.4 pb^{-1} . Comparisons are made with predictions from Monte Carlo models containing leading-logarithm parton showers, and with next-to-leading-order QCD calculations, using currently available parameterisations of the photon structure.

2 Evaluation of the photon signal

The data used here were obtained from e^+p running in 1996–97 at HERA, with $E_e = 27.5 \text{ GeV}$, $E_p = 820 \text{ GeV}$.

The major components in the analysis are the central tracking detector(CTD) and the uranium calorimeter(UCAL). Prompt photons are detected in the barrel section of the calorimeter, which consists of an electromagnetic section (BEMC) followed by two hadronic sections. It enable a partial discrimination between single γ signals and the decay product of neutral mesons. A typical high- E_T photon signal is observed in a small cluster of BEMC cells, with no associated CTD track. An isolation cone was also imposed around photon candidates within a cone of unit radius in (η, ϕ) , to reduce backgrounds from dijet events with part of one jet misidentified as a single photon.

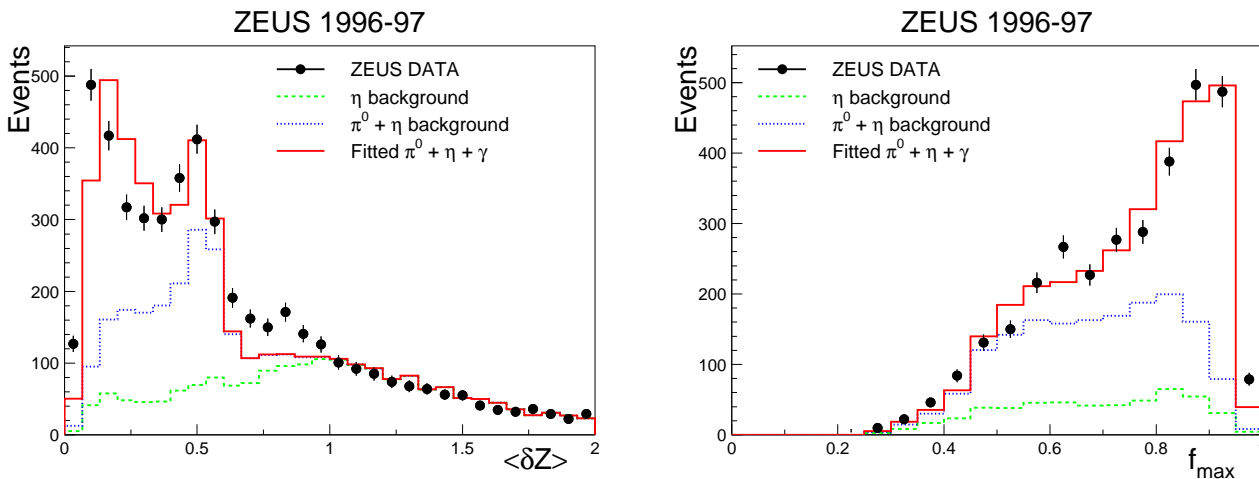


Figure 1: Distribution of (a) $\langle\delta Z\rangle$ and (b) f_{max} for prompt photon candidates in selected events. Also given in both cases are fitted MC distributions for γ , π^0 and η mesons.

Two shape-dependent quantities were studied in order to further distinguish γ , π^0 and η signals. These were (1) the mean width $\langle\delta Z\rangle$ of the BEMC cluster in Z and (2) the fraction f_{max} of the cluster energy found in the most energetic cell in the cluster. The $\langle\delta Z\rangle$ distribution is shown in Figure 1(a), in which peaks due to the γ and π^0 contributions are clearly visible. The tail quantified the η background; photon candidates in this region were removed.

The extraction of the photon signal from the mixture of photons and a neutral meson background was done by means of the f_{max} distribution. Figure 1(b) shows the shape of the f_{max} distribution for the final event sample, after the $\langle\delta Z\rangle$ cut, fitted to the η component determined from the $\langle\delta Z\rangle$ distribution and freely-varying γ and π^0 contributions. Above an f_{max} value of 0.75, the distribution is dominated by the photons; below this value it consists mainly of meson background. The numbers of candidates with $f_{max} \geq 0.75$ and $f_{max} < 0.75$ were calculated for the sample of events occurring in each bin of any measured quantity. From these numbers, and the ratios of the corresponding numbers for the f_{max} distributions of the single particle samples, the number of photon events in the given bin was evaluated. Further details of the background subtraction method are given in reference. [1, 2]

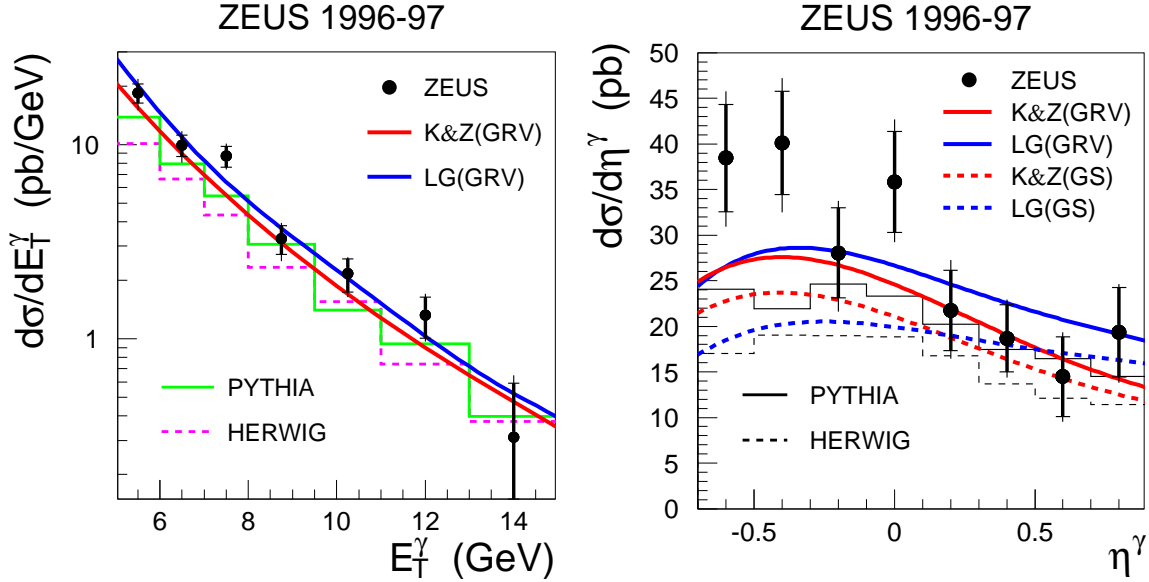


Figure 2: Differential cross section (a) $d\sigma/dE_T^\gamma$ and (b) $d\sigma/d\eta^\gamma$ for isolated prompt photons produced over $-0.7 < \eta^\gamma < 0.9$.

3 Results

We evaluate cross sections for prompt photon production corrected by means of PYTHIA using GRV photon structure functions [3]. A bin-by-bin correction factors were applied to the detector-level measurements so as to correct to cross sections in the γp centre-of-mass energy 134 – 285 GeV. The systematic error of 15% were taken into account and were finally combined in quadrature. The main contributions are from the energy scale of the calorimeter and the background subtraction. In presenting cross sections, comparison is made with two types of theoretical calculation, in which the pdf sets taken for both the photon and proton can be varied. These are (1) PYTHIA and HERWIG calculations evaluated at the final-state hadron level and (2) NLO parton-level calculations of Gordon [5](LG) and of Krawczyk and Zembrzusi [6](K&Z).

Figure 2 (a) gives the inclusive cross-section $d\sigma/dE_T^\gamma$ for isolated prompt photons in the range $-0.7 < \eta^\gamma < 0.9$. All the theoretical models describe the shape of the data well; however the predictions of PYTHIA and especially HERWIG are too low in magnitude. The LG and K&Z calculations give better agreement with the data.

The inclusive cross-section $d\sigma/d\eta^\gamma$ for isolated prompt photons in the range $5 < E_T^\gamma < 10$ GeV is shown in figure 2 (b) and compared with theoretical calculations, using two sets of photon pdf, GS [4] and GRV. The LG and K&Z calculations gives a good description of the data for forward (proton direction) η^γ range and are similar to PYTHIA prediction. However all the calculations lie below the data in the lower η^γ range, where the curves using the GS parton densities give poorer agreement than those using GRV.

The discrepancy between data and theory at negative η^γ is found to be relatively strongest at low γp centre-of-mass energy range. In the lowest W range (134–170 GeV), both theory and data show a peaking at negative η^γ , but it is stronger in the data. In the highest W range (212–285 GeV), agreement is found between theory and data. The movement of the peak can be qualitatively understood by noting that for fixed values of E_T and x_γ , where x_γ is the fraction of the incident photon energy that contributes to the resolved QCD subprocesses, measurements at increasing y correspond on average to decreasing values of pseudorapidity. By varying the theoretical parameters, the discrepancy was found to correspond in the K&Z calculation to insufficient high x_γ partons in the resolved photon.

4 Conclusions

The photoproduction of isolated prompt photons within the γp centre-of-mass energy range 134–285 GeV has been measured in the ZEUS detector at HERA. Inclusive cross sections have been presented as a function of E_T^γ for photons in $-0.7 < \eta^\gamma < 0.9$, and as a function of η^γ for photons with $5 < E_T^\gamma < 10$ GeV.

Comparisons have been made with predictions from LO Monte Carlos, and from NLO calculations. The models are able to describe the data well for forward η^γ , but are low in the rear direction. None of the available variations of the model parameters was found to be capable of removing the discrepancy with the data. This

result would appear to indicate a need to review the present theoretical modelling of the parton structure of the photon.

Acknowledgments

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