Isolated photon production in Deep Inelastic Scattering at HERA with ZEUS

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Isolated hard photons have been measured accompanied by jets in Deep Inelastic Scattering using the ZEUS detector at HERA. Preliminary results for the cross sections are presented.

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1. Introduction

Photons with high transverse momentum, p_T, may be produced in Deep Inelastic Scattering of electrons (or positrons) by protons in various ways. They may be (i) produced in a hard partonic scattering process, (ii) radiated from the incoming or the outgoing lepton, (iii) radiated from a quark that has been produced at high p_T, or (iv) a decay product of a high energy hadron. Processes (i) and (ii) generate outgoing photons that tend to be isolated from the other particles in the final state, and the photons from processes of type (i) are conventionally known as "prompt" photons. Some typical Feynman diagrams for processes (i) and (ii) are shown in figure 1.

These processes are of interest, since they give a distinctive perspective on QCD physics. In particular, the prompt photons are produced and detected directly from the basic parton scatter and are not formed through a jet fragmentation process. Particular theoretical models can be tested. In a previous publication, the ZEUS collaboration presented inclusive measurements of isolated hard photons in DIS processes [1]. Here, preliminary results are presented for measurements in which a jet is observed in addition to a hard photon [2]. This enhances the prompt component in the data sample.

2. Apparatus and measurement

The ZEUS detector operated at the HERA collider, in which electrons and positrons at 27.5 GeV collided with protons at 920 GeV. The principal components of the ZEUS detector used in this analysis were a central drift-chamber tracker within a solenoidal magnetic field, surrounded by a uranium-scintillator calorimeter. The calorimeter was divided into three regions, forward, barrel and rear, and each region consisted of a finely segmented electromagnetic section outside which was a hadronic section with larger cells. "Forward" refers to the proton beam direction.

The present analysis uses 332 pb^{-1} of data taken during 2004-2007. A photon candidate in an event corresponds to a closely-spaced cluster of barrel calorimeter cells that have fired, giving a total transverse energy E_T^γ of at least 4 GeV. The pseudorapidity η^γ of the photon candidate must lie in the range -0.7 to 0.9, within the barrel calorimeter acceptance. Jets are reconstructed from ZEUS energy flow objects [3], which combine tracking and calorimeter information, and the k_T
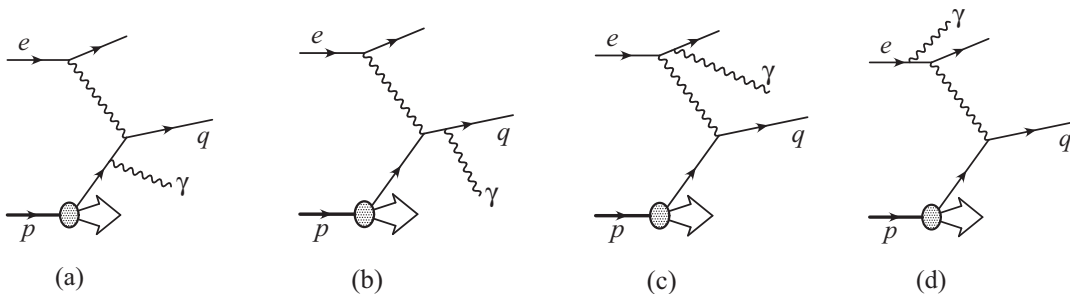

Figure 1: Diagrams for hard photon processes in DIS. Processes (a), (b) are for "prompt" photons, which are radiated from a quark, referred to here as QQ processes. In processes (c), (d) the photon is radiated from a lepton, referred to here as LL processes.
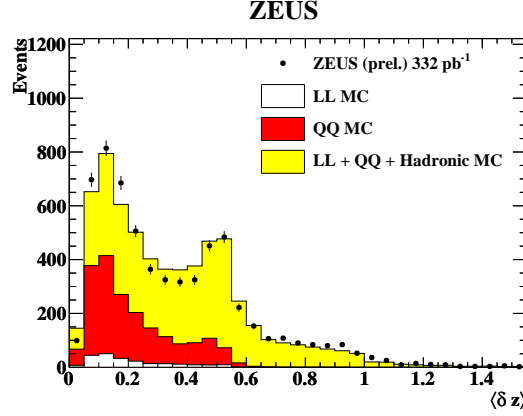
Figure 2: Distribution of the mean longitudinal width measure $<\delta z>$ of the electromagnetic calorimeter cells forming the photon candidate, fitted to a combination of background, LL photons and QQ photons.

clustering algorithm is used [4]. The jet must have a transverse energy $E_{T\text{jet}}$ of at least 2.5 GeV and a pseudorapidity η_{jet} in the range -1.5 to 1.8. The photon candidate must have at least 90% of its energy in the electromagnetic calorimeter cells, and must be isolated in the sense that in the reconstructed jet-like object containing mainly the photon candidate, the latter must take at least 90% of the transverse energy. To reduce photoproduction background, the scattered beam electron (positron) must have an energy of at least 10 GeV, must be scattered at an angle of at least 140° from the proton direction, and must correspond to a transverse momentum squared, Q^2 of between 10 and 350 GeV^2.

A substantial background arises from high energy neutral mesons, in particular π^0 mesons. To extract the photon signal, the quantity $<\delta z>$ is used, defined as the E_T-weighted mean of the distance of the Z position of the electromagnetic cells in the cluster from the mean Z of the cluster. This is illustrated for the entire sample in figure 2, where the distribution is fitted to the sum of the LL contribution and a freely scaled background contribution, both evaluated from the Ariadne 4.12 Monte Carlo [5], and a freely scaled QQ contribution, evaluated using Pythia 6.416 [6]. The photon contributions have a peak at low $<\delta z>$, plotted in units of electromagnetic calorimeter cell widths, indicating that most of the energy is found in one cell. The background is broader, and peaks around a value of approximately 0.5, where the cluster energy is mostly divided between two contiguous cells. Fits of this kind are performed to the data in each bin of each quantity whose cross section is to be evaluated, to extract the photon signal.

3. Results

The resulting cross sections as functions of Q^2, Bjorken x, E_T^γ, η^γ, $E_{T\text{jet}}$ and η_{jet} are shown in figure 3. Also shown is the sum of the LL contribution, the QQ contribution from Pythia, scaled by a factor 1.6, and the Ariadne generated background, scaled by the same factor. The Q^2 distributions of the fitted contributions have been scaled to fit the data. Systematic uncertainties are dominated by the photon and jet energy scales, and the modelling of the background. The overall agreement between the data and this model is very good.

4. Conclusions

We have presented preliminary measurements of cross sections for the production of isolated hard photons accompanied by jets in Deep Inelastic Scattering, made with the ZEUS detector at HERA. The results are compared with the predictions of the Pythia Monte Carlo and agree well in shape but not in absolute magnitude. This is a common situation. Comparison with predictions from NLO models will now be possible as the next step.
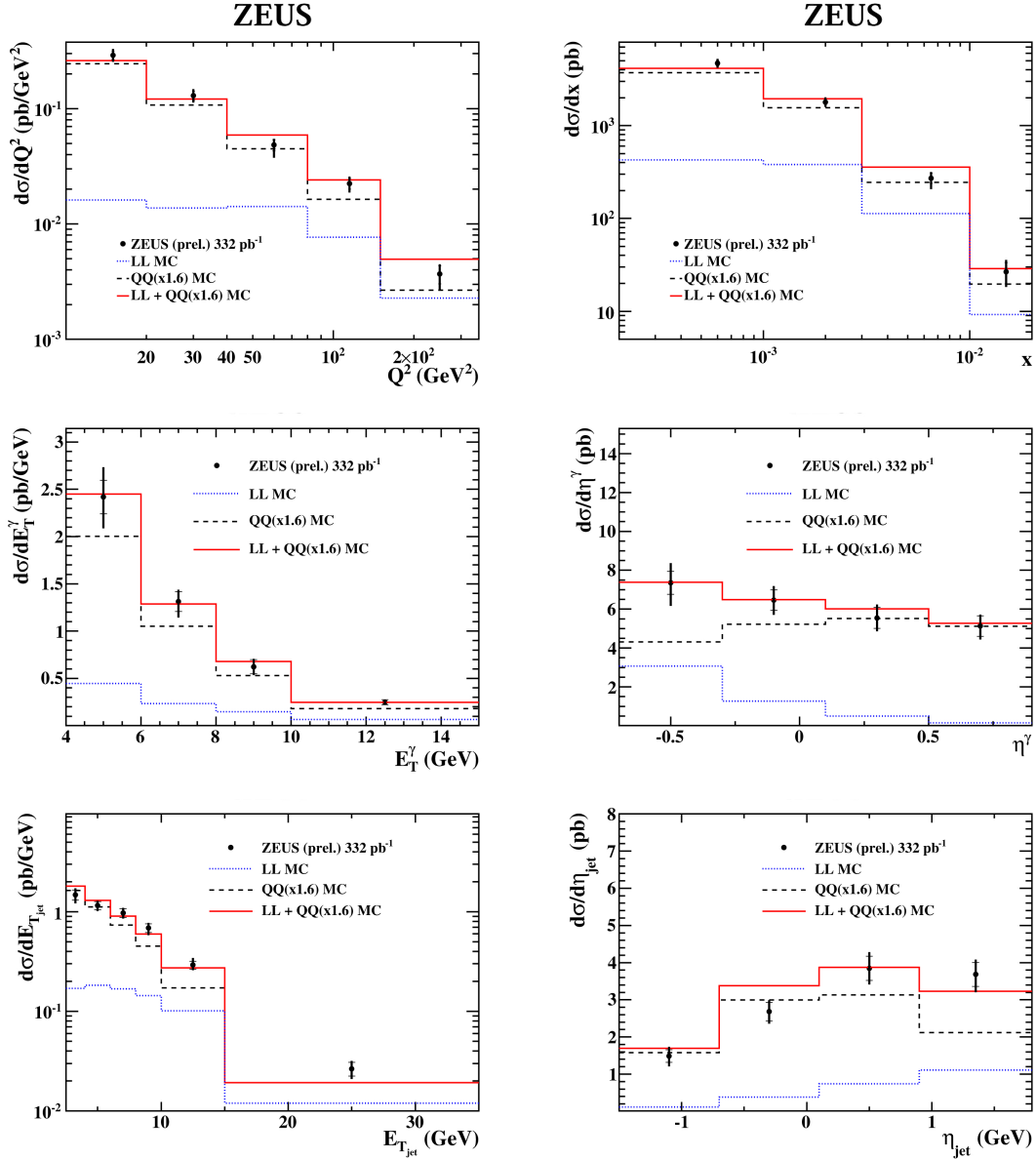
Figure 3: Cross sections for kinematic quantities described in the text, compared to the fitted phenomenological model.

References

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