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Prompt Photons in Deep Inelastic Scattering at HERA

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Abstract

Recent ZEUS results on the production of isolated high energy photons in Deep Inelastic Scattering are presented.

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1 Introduction

In the study of high energy collisions involving hadrons, events in which an isolated high-energy photon is observed can provide a direct probe of the underlying parton process, since the emission of these photons is largely unaffected by parton hadronisation. The study of such "prompt" photons gives new perspectives on QCD processes, allowing theoretical models to be tested from new viewpoints.

In this talk [1], I present new results from the ZEUS experiment on prompt photons produced in Deep Inelastic Scattering (DIS) at HERA. The process studied is $ep \rightarrow e\gamma X$, where e denotes an electron or positron. (Both electrons and positrons will here be referred to as electrons.) The data were taken between 2003 and 2007 with the ZEUS detector and correspond to a total integrated luminosity of 320 ± 8 pb^{-1}. The results are compared to two theoretical calculations, from Gehrmann-De Ridder et al. [2] and Martin et al. [3].

2 Experiment and analysis

Outgoing photons and electrons were detected in the ZEUS electromagnetic calorimeter. This was used to identify electrons scattered in the angular range 140° - 172° as measured relative to the forward (proton) direction Z. The outgoing electron was required to have an energy of at least 10 GeV, and was distinguished from other particles by means of a standard ZEUS neural net tool. A standard definition was taken of the virtuality of the exchanged photon, namely $Q^2 = (k - k')^2)$, where k, k' are the four-momenta of the incoming and outgoing electrons. The quantity $x = Q^2/2P.(k - k')$ is also employed where P is the four-momentum of the incoming proton. DIS electrons with $10 < Q^2 < 350$ GeV^2 were used here. Well-measured DIS events were selected by requiring the sum of $E - p_Z$ for the final state particles to be in the range 35 - 65 GeV.

The central region of the ZEUS calorimeter was used to identify photons emerging in the rapidity (η) range -0.7 - 0.9. Photon candidates were initially identified as signals in clusters of cells in the fine-grained electromagnetic part of the calorimeter, with little energy in the hadronic part. Their transverse energy E_T was required to be in the range 4 - 15 GeV. To remove diffractive Compton events, and elastic Bethe-Heitler events, at least one charged track other than that of the electron was demanded. To separate the photons of interest from those closely associated with electrons or jets, two isolation criteria were imposed. For the first, the photon was required not to lie close to a reconstructed track. For the second, a k_T-clustering jet reconstruction algorithm was applied. The photon candidate was rejected if it comprised part of a jet-like object such that its energy was less than 0.9 of the total jet energy,

Photons are distinguished from the background arising from decay products of mesons by the fact that the latter give rise to broader clusters of calorimeter cells than single photons, usually with less energy in a single cell. The quantity $\langle \delta Z \rangle$ is defined as the energy-weighted mean width in Z of the cluster relative to its centroid. The quantity f_{max} is the fraction of the total electromagnetic energy in the cell with highest energy. To separate the photon signal from the background, the latter was represented by a Monte Carlo calculation of neutral current DIS events, passed through a simulation of the ZEUS detector.

Two types of photon signal are simulated: events where the photon is radiated from an incoming or outgoing lepton (LL) and the true "prompt photons" that are emitted from a quark as part of a QCD process (QQ). The event distributions were fitted as the sum of a fixed theoretical LL contribution together with variable amounts of QQ and of hadronic background. These components to the fit were evaluated from Monte Carlo event samples, passed through a simulation of the apparatus. Figure 1 shows the fitted $\langle \delta Z \rangle$ and f_{max} distributions for the full data sample. The good fits to these shape parameters confirm that the showers are well modelled, and in the case of $\langle \delta Z \rangle$ show a strong peak around 0.5 due to π^0 decays into two photons that are recorded strongly in two neighbouring cells. The photon signal shows itself at low $\langle \delta Z \rangle$ and at high f_{max}. For each of the kinematic variables studied in the analysis, namely E_T, Q^2, η and x, fits of this kind were performed in each bin of the measured variable to evaluate the acceptance and hence the differential cross sections.

3 Results and conclusions

Results of the fit to the signal and background are presented as differential cross sections. Figure 2 shows the present results compared to earlier ZEUS results and results from H1, using a common range of $Q^2 > 35$ GeV^2 and $5 < E_T < 10$ GeV for all three analyses. All three sets of results are in agreement. In Fig. 3, cross sections are presented as functions of Q^2, E_T, photon rapidity η and x within the selected kinematic range. The removal of diffractive Compton and elastic Bethe-Heitler events was incorporated by applying to the truth-level Monte Carlo a requirement that the mass W_X of the final state should be less than 5 GeV after subtracting out the photon and scattered electron. The agreement with the Monte Carlo is good for the photon variables, but the Monte Carlo is too high at low values of the electron variables Q^2 and x. The largest contribution to the

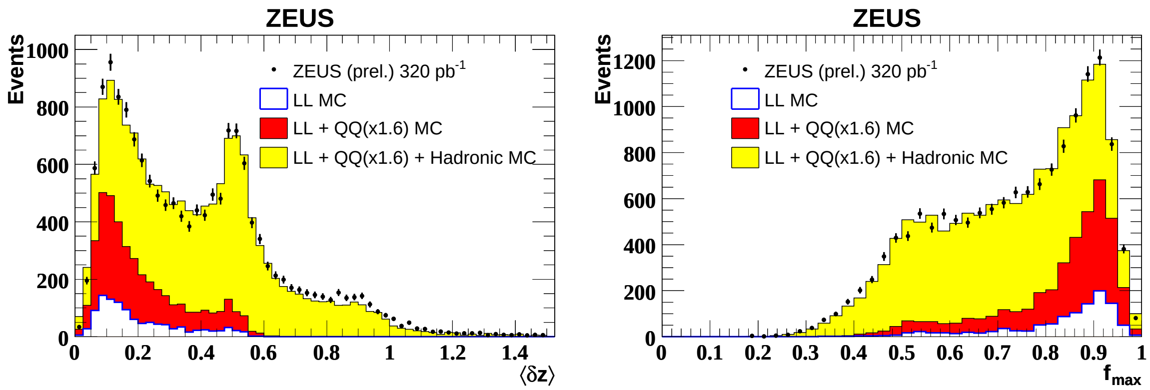

Figure 1: Distributions of $\langle \delta Z \rangle$ and f_{max}, with statistical error bars. In ascending order, the cumulative histograms include the predicted number of LL photons and the fitted numbers of QQ photons and the fitted background. The f_{max} distribution includes the requirement of $\langle \delta Z \rangle < 0.8$.

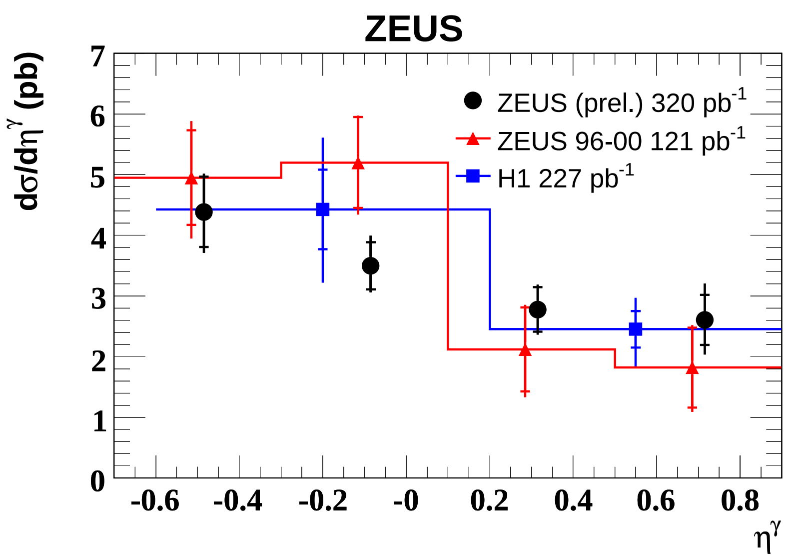

Figure 2: Present results compared to previous ZEUS analysis [4] and results of H1 [5]. Additional kinematic constraints $Q^2 > 35$ GeV^2 and $5 < E_T < 10$ GeV are applied.

systematic uncertainties arises from uncertainty in the precise shape of the hadronic background to the photon signal.

In Fig. 4 the results are compared to the theories of Gehrmann-De Ridder et al. (GGP) and of Martin et al. (MRST). The approach of GGP is to evaluate prompt photons radiated from the quark line (QQ) and photons radiated from the lepton (LL) at leading order in the electromagnetic coupling. There is an interference term, but it is small. The MRST calculation neglects the QQ component but provides a fuller, resummed version of the LL component by assigning an effective photon density to the proton. It is seen from the figure that the GGP calculation describes the shape of most of the distributions but is too low, while MRST comes close to the data at regions where the LL contribution is predicted to be largest. A combination of the two approaches would seem recommended; unfortunately, there is an overlap in the calculations which means that the MRST cross sections cannot be simply added to the QQ part of GGP. However, in any case, at low Q^2 and low x the theory appears to be too low.

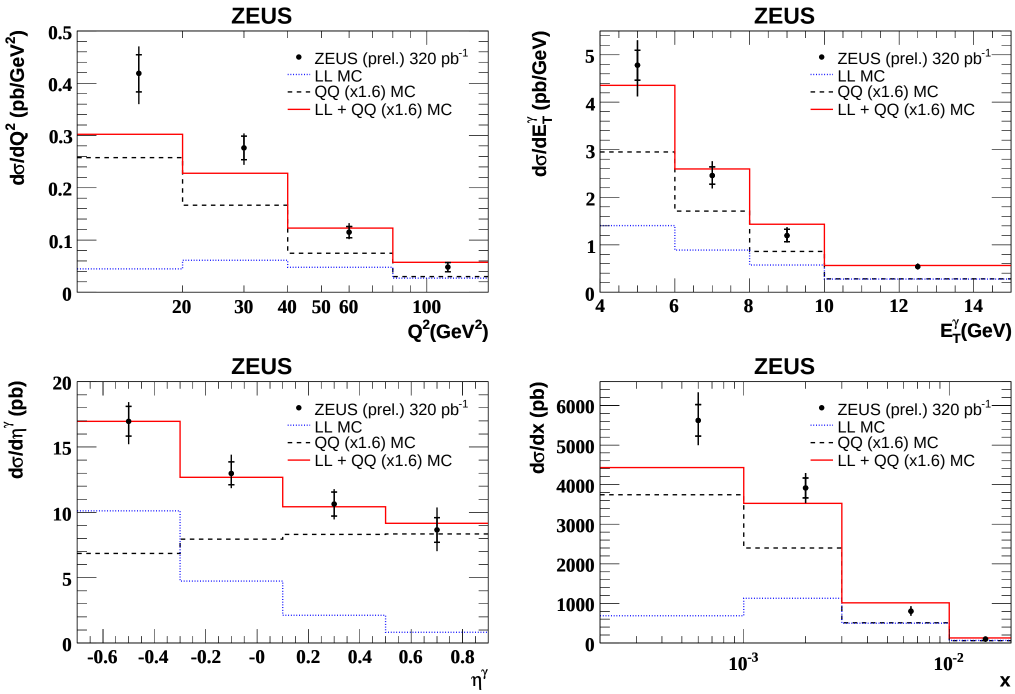

Figure 3: Measured cross sections for high energy isolated photons in DIS as functions of different kinematic variables, compared to the fitted Monte Carlo distributions. Statistical and (statistical + systematic) uncertainties are shown.

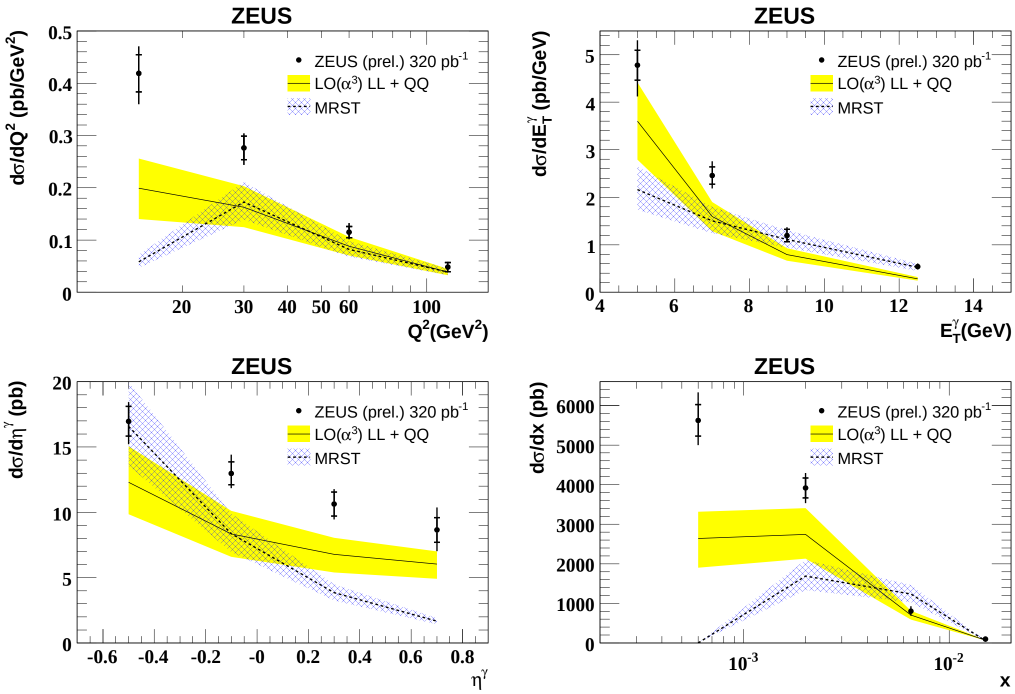

Figure 4: Measured cross sections for high energy isolated photons in DIS as functions of different kinematic variables, compared to the predictions of GGP and MRST (see text).

References

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