Prompt Photon Production
and Observation of
Deeply Virtual Compton Scattering

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Abstract
Two recent results in ep physics using the ZEUS detector at HERA are discussed:
am measurement of the prompt photon production cross section in photoproduction,
and the first observation of Deeply Virtual Compton Scattering in DIS.

1. Introduction
Two types of real photon production processes in ep collisions which are currently studied
using the ZEUS detector at HERA are prompt-γ production in photoproduction (γp) and
Deeply Virtual Compton Scattering (DVCS) in deep inelastic scattering (DIS).

Prompt-γ production in γp interactions is the production of a real γ directly from the hard
interaction of a quasi-real γ (invariant mass \( Q^2 \approx 0 \)) with the proton. At leading order, two kinds
of γp processes can be defined: direct, where the γ participates entirely in the hard interaction,
and resolved, where the γ first fluctuates into a hadronic system and a parton from this system then enters
into the hard interaction. Examples are depicted in Fig. 1. Prompt-γ production is less influenced by
hadronisation effects than, e.g., dijet production, although its production rate is down by a factor \( \alpha/\alpha_S \) in comparison. It is interesting because of its sensitivity to the parton density of the γ. The

\[ Q^2 = - (e - e')^2, \]

where e and e' are the initial and final positron four-momenta, respectively.

DVCS, depicted in Fig. 2, is the hard diffractive scattering of a γ off a proton, eγp \( \rightarrow \) eγp. This is a process which has never been seen before at high energies, but which is predicted by FFS to have a fairly high counting rate. DVCS is an exciting process because of its potential for accessing the skewed parton distributions (SPD’s) of the proton. SPD’s, which quantify two-particle correlations in the proton, are a generalisation of the usual proton parton distributions to the case where the squared momentum transfer to the proton is non-zero. The advantage of DVCS over processes where a hadron is diffractively produced is two-fold: the theoretical uncertainty in the hadronic wave function is avoided, and the DVCS rate is predicted to be less suppressed by a factor of \( Q^2 \). Furthermore, its final state is identical to that of QED Compton scattering (QEDC), and interference of the two processes potentially allows the measurement of the real part of a QCD amplitude.

A common feature of these two studies at ZEUS is that each involves the detection of a γ in the...
barrel part of the calorimeter (BCAL), which has its electromagnetic (EM) section segmented into $5 \times 20$ cm$^2$ cells. A potential background contribution to $\gamma$ candidates, i.e. those tagged EM clusters not associated with a track in the central tracking detector, arises from $\pi^0$ and $\eta$ production. However, these particles tend to produce broader clusters in the BCAL than single $\gamma$'s. Two shower shape variables are employed to exploit this difference: $Z_{\text{width}}$, which is the energy-weighted average of the width of the EM cluster in the $Z$-direction (the direction in which the BCAL is most finely segmented); and $f_{\text{max}}$, which is the fraction of the EM cluster energy carried by the most energetic cell in the cluster.

2. Prompt Photon Production

The $f_{\text{max}}$ distribution for the 1996/97 prompt-$\gamma$ photoproduction analysis is shown in Fig. 3. Overlaid are the expected contributions from $\eta$, $\pi^0$, and $\gamma$. A $\gamma$ signal at high $f_{\text{max}}$ values is evident. The prompt-$\gamma$ production cross section for $\gamma$ transverse energies $E_T^\gamma > 5$ GeV and $\gamma$ rapidity interval $-0.7 \leq \eta^\gamma \leq 0.9$ is shown in Fig. 4 as a function of $E_T^\gamma$ and $\eta^\gamma$. Overlaid are the NLO predictions of two groups of theorists, LG and KZ, each using two different $\gamma$ parton density parametrisations: GRV and GS. The predictions are in reasonable agreement with the data, although those based on the GS parametrisation tend to be low. This demonstrates the sensitivity of this type of analysis to the $\gamma$ parton density. With more data and further theoretical progress the prompt-$\gamma$ process will provide a valuable tool for studying NLO pQCD and measuring the $\gamma$ parton density.

3. Deeply Virtual Compton Scattering

For the DVCS analysis, events with only two EM clusters and at most one track (which must be matched to one of the clusters) are selected. The first (second) candidate, corresponding to the scattered $e^+$ ($e^-$) in the DVCS case, must have polar angles $\theta_1 > 2.8$ ($\theta_2 < 2.4$) radians and $E_1 > 10$ GeV ($E_2 > 2$ GeV). To suppress the QEDC process the polar angle difference must satisfy $|\theta_1 - \theta_2| > 0.8$ radians. Among the remaining requirements are a cut of $Q^2 > 6$ GeV$^2$, calculated using the first EM candidate, and a cut on the invariant mass of the two EM candidates, $M_{12} < 30$ GeV. From 37 pb$^{-1}$ of $e^+p$ data, 1954 events remain for further study after application of all cuts.

As an aid to studying DVCS, a MC generator GenDVCS based on the DVCS, QEDC, and interference term (int) cross sections as a function of $E_T^\gamma$ and $\eta^\gamma$. Overlaid are the NLO predictions of two groups of theorists, LG and KZ, each using two different $\gamma$ parton density parametrisations: GRV and GS. The predictions are in reasonable agreement with the data, although those based on the GS parametrisation tend to be low. This demonstrates the sensitivity of this type of analysis to the $\gamma$ parton density. With more data and further theoretical progress the prompt-$\gamma$ process will provide a valuable tool for studying NLO pQCD and measuring the $\gamma$ parton density.

Figure 3. $f_{\text{max}}$ distribution for prompt-$\gamma$ candidates.

Figure 4. Prompt-$\gamma$ cross sections as a function of $E_T^\gamma$ and $\eta^\gamma$, with NLO predictions overlaid.
Figure 5. Distribution of $\theta_2$ for the DVCS sample.

Figure 6. Shower shapes for DVCS $\gamma$ candidates.

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