INCLUSIVE PROMPT PHOTON PRODUCTION AND DEEPLY VIRTUAL COMPTON SCATTERING AT HERA

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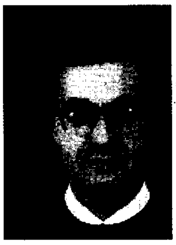

Measurements of inclusive prompt photon production using the ZEUS detector at HERA are presented, and compared with the predictions from hadronising Monte Carlo programs and from next-to-leading order QCD calculations. First measurements at HERA of Deeply Virtual Compton Scattering are shown; the preliminary results are in accord with expectations.

1 Introduction

High energy interactions which produce energetic photons are of interest because photons may emerge directly from the fundamental hard scattering process, without the intermediate hadronisation which complicates the study of partonic jets. In this talk, two recent measurements from ZEUS at HERA are presented in which high energy ('prompt') photons are produced, namely in photoproduction and in diffractive deep inelastic e^+p scattering. Only one kind of diagram contributes to the direct photoproduction process at lowest order (fig. 1(a)), corresponding to elastic photon scattering off a quark. The second type of process considered here, known as 'deeply virtual Compton scattering' (DVCS), is shown in fig. 1(c) and corresponds to elastic photon scattering off a diffractively exchanged object.

2 Prompt photons in photoproduction.

The ZEUS barrel calorimeter has good granularity along the beam direction. This enables a statistical separation to be made between those signals in its electromagnetic part that are due to high energy photons, and those arising from the decay of neutral mesons, principally π^0 and η. The two parameters used for this purpose are the transverse-energy (E_T) weighted width of the calorimeter signal, which typically comprises a cluster of several cells, and the fraction of

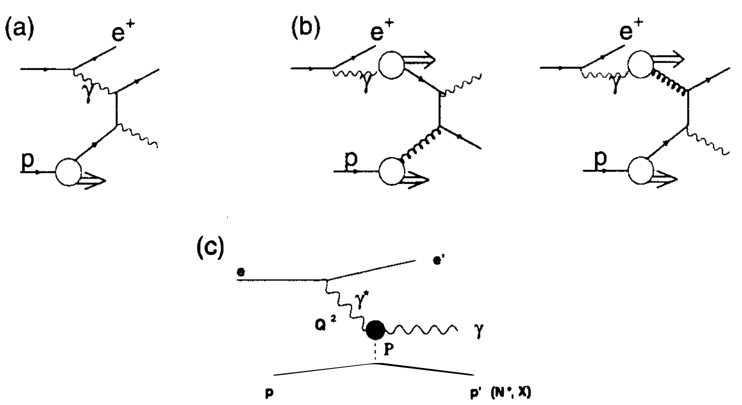

Figure 1: Examples of diagrams for (a) direct and (b) resolved photoproduction processes producing an outgoing 'prompt' photon. Diagram (c) represents the Deeply Virtual Compton Scattering process.

the total cluster energy in the cell with highest energy (f_{max}). Mesons give higher mean cluster widths than do photons, and lower mean values of f_{max}. More details of the analysis can be found elsewhere [1,2]. The present results are for photons with $E_T > 5$ GeV and pseudorapidity (η) in the approximate range (-0.7, +0.9).

To reduce the mesonic backgrounds, and contributions from photons accompanying jets, an isolation criterion is applied. Within a unit cone in azimuth and η surrounding the high-E_T photon, at most a further 0.1 of the photon E_T is permitted.

When a jet is measured as well as a photon, the observed quantity

$$x_\gamma^{meas} = \sum_{\gamma+jet} (E - p_z) \Big/ \sum_{all\ event} (E - p_z) \,,$$

can be evaluated. The indicated sums are taken over energy deposits in the calorimeter cells, each treated as corresponding to that of a massless particle. The variable x_γ^{meas} estimates the fraction of the initial-state photon energy that partakes in the hard QCD scatter. The prominent peak seen in fig. 2(a) near unity signifies a strong contribution from the direct process, while the flat region at lower x_γ^{meas} is due to the resolved processes including those where photons are radiated from high E_T quarks. PYTHIA gives a good description of this distribution.

Figures 2(b,c,d) show inclusive prompt photon distributions, corrected to the final state hadron level for γp c.m. energies in the range (134, 285) GeV. Here as below, an integrated luminosity of 38 pb^{-1} was used. The E_T distribution is fairly well described by PYTHIA, less well by HERWIG, but better by the NLO calculations of Gordon [4] and Krawczyk and Zembrzuski [5]. However the η distribution indicates a possible discrepancy between data and theory (fig. 2(c,d)). All models give a good description at high η, but at low η appear to lie low; improved statistics are needed to confirm this effect. In the inclusive measurement, the direct process by no means dominates the cross section. A need for further theoretical input may be indicated.

3 Deeply Virtual Compton Scattering

The experimental signature for DVCS is a DIS e^+ accompanied by a wide-angle photon with no other particles observed in the detector. This signature, however, is also given by QED Compton processes (QEDC), which involve elastic e^+p scattering with hard photon radiation

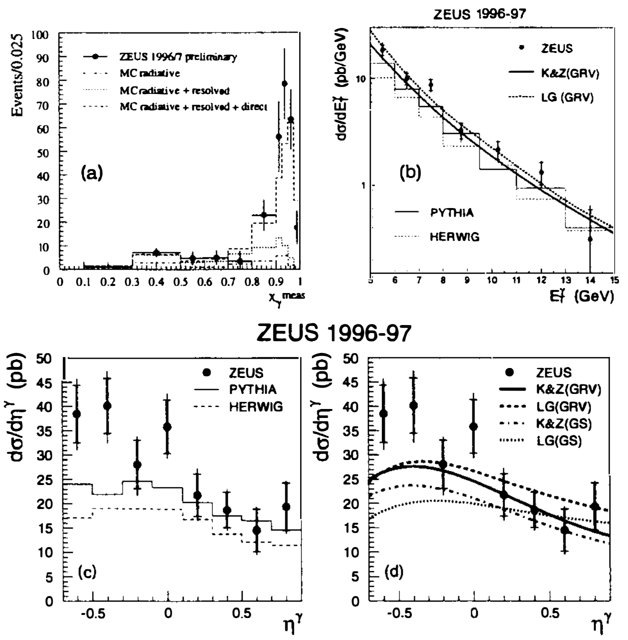

Figure 2: Results for prompt photons in photoproduction at HERA; the E_T distributions (b) are integrated over $-0.7 < \eta < 0.9$ while the η distributions (c,d) are integrated over $5 < E_T < 10$ GeV. GRV, GS refer to photon structure models.

from the initial or final state e^+. Such diagrams interfere with that for DVCS, and in order to identify DVCS unambiguously a kinematic region must be chosen in which it dominates. This was done by requiring a high-energy electromagnetic signal (> 10 GeV) in the rear direction (at angle θ_1), and a second wide-angle signal at angle $\theta_2 < 2.4$ radians (all angles are taken relative to the p direction). The second signal was required to correspond to an energy of at least 2 GeV. An absence of an observed track then indicates that the second signal could be that of a photon. It was also required that $|\theta_1 - \theta_2| > 0.8$ and that the invariant mass of the two outgoing particles be less than 30 GeV.

Calculations indicate that in DVCS, the wide-angle signal is nearly always from the photon, while in QEDC it is often from the scattered e^+. Figure 3 shows the numbers of events observed (a) not distinguishing between the γ and e candidates for $\theta_2 < 2.4$, and (b) rejecting the e candidates, which have an associated track. Figure 3(c) gives the ratio of (b) to (a). Taking this ratio largely removes systematic errors in the calorimeter energy scale; moreover a known process (QEDC) is being used as a measuring-device for the less known DVCS.

In each case, along with the data, theoretical predictions are plotted for the interfering sum of the DVCS and QEDC contributions [6], and for the QEDC contribution alone. The model taken for the DVCS process is that of Frankfurt, Freund and Strikman [7], in which the exchanged diffractive object is taken to be two gluons radiated from the proton. These couple to the incoming virtual photon and the outgoing real photon through a quark box diagram. Such processes are sensitive to the skewed (off-diagonal) parton distributions in the proton.

The combined theory gives a good description of the observations. However it is necessary to verify that the calorimeter signals that have been assigned to photons do not have a significant neutral-meson component. This has been checked using the cluster-shape variables used in the photoproduction measurements, which confirm that the present signals are at least largely due

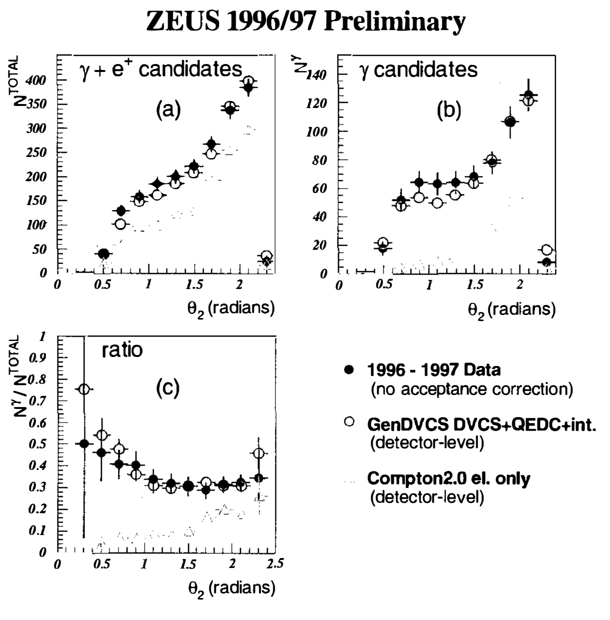

Figure 3: Distribution of θ_2 for the DVCS event sample, compared with theoretical calculations. The events have $Q^2 > 6$ GeV^2.

to photons. In a second check, the threshold energy for the second electromagnetic signal was raised to 5 GeV, which should have the effect of significantly reducing the fraction of any mesonic contribution. Apart from normalisation, the results were similar to those shown in fig. 3.

It is concluded that DVCS has been definitely observed at HERA, with a cross section at the expected level. These studies will be continued with the higher integrated luminosities now becoming available.

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