PROMPT PHOTON PRODUCTION AT HERA *

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Results are presented on the production of isolated prompt photons in photoproduction (virtuality $Q^2 < 1 \text{ GeV}^2$) and in deep inelastic scattering ($Q^2 > 35 \text{ GeV}^2$). The results are reasonably well described by pQCD calculations in next to leading order. Comparisons to the Monte Carlo models PYTHIA and HERWIG are also presented.

1 Introduction

The production of isolated prompt photons is studied at HERA in photoproduction and in deep inelastic scattering (DIS). In electron\(^1\) proton scattering, photons are emitted by the incoming electron and interact with the proton which are quasi real (photoproduction) or have substantial virtuality (DIS). These photon-proton interactions can lead to the process of so called prompt photon emission which is sensitive to the partonic substructure of the proton and, in case of resolved photon interactions, also to that of the exchanged photon. It is an advantage of this reaction that an isolated photon at large transverse energy $E_T^\gamma$ can be related directly to the partonic event structure. In contrast to jet measurements, here the partonic structure is not hidden behind the non perturbative hadronisation process. Further information on the dynamics of the process can be obtained if prompt photons are measured together with jets.

Preliminary results on inclusive prompt photon production have previously been presented by the H1 collaboration [1]. In the present report, photoproduction results are presented where in addition to the prompt photon a jet is detected. These measurements are confronted with NLO calculations using the program of Fontannaz, Guillet and Heinrich [2]. Also presented are first

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\(^1\)The term “electron” is used both for electrons and positrons.
results on prompt photon production in DIS by the ZEUS collaboration, which are compared with the event generators PYTHIA [3] and HERWIG and with pQCD NLO calculations by Kramer and Spiesberger based on [4]. In DIS the resolved photon contribution is suppressed and, in contrast to photoproduction, is not taken into account in the calculation.

2 Experimental Conditions

The data were taken in the years 1996-2000 and correspond to more than 100 pb\(^{-1}\) for each experiment.

The prompt photons are identified by dense calorimetric clusters without associated tracks. The main experimental difficulty is the separation of the prompt photons from hadronic background, in particular from signals due to \(\pi^0\) mesons and, to less extent, from \(\eta\)’s, as for those, at high energies, the two energetic decay photons cannot be resolved in the calorimeters. The neutral mesons are predominantly produced in jets. Therefore an isolation condition is imposed that the transverse energy, \(E_T^{cone}\), in a cone around the \(\gamma\) candidate in the plane of pseudorapidity and azimuth, \(\Delta r = (\Delta \eta^2 + \Delta \phi^2)^{1/2} < 1\), does not exceed 10% of the transverse energy \(E_T^\gamma\) of the prompt photon candidate. Minimal \(E_T^\gamma\) is 5 GeV for both experiments. After these cuts, the background is still of similar size as the prompt photon signal. The signal is thus extracted by a combination of discriminating shower shape functions exploiting the fact the prompt \(\gamma\) showers are more compact than the \(\pi^0\) and \(\eta\) showers.

The H1 results are given for \(142 < W < 266\) GeV and \(Q^2 < 1\) GeV\(^2\), where \(W\) is the \(\gamma p\) center of mass energy, and \(Q^2\) the virtuality of the exchanged photon. Associated jets are reconstructed using the inclusive \(k_T\) algorithm [5] with the conditions \(E_{Tjet}^\gamma > 4.5\) GeV and \(-1 < \eta_{jet} < 2.3\) for the jet energy and pseudorapidity respectively. The ZEUS DIS results are given for \(Q^2 > 35\) GeV\(^2\), the associated jets are reconstructed using the cone algorithm with \(\Delta r < 0.7\) and \(E_{Tjet}^\gamma > 6\) GeV and \(-1.5 < \eta_{jet} < 1.8\).
3 Photoproduction Results

Cross sections for a prompt photon associated with a jet are presented in Fig. 1 as function of the variables $E_T^\gamma, \eta^\gamma, \eta^{jet}, x_p$ and $x_\gamma$, where

$$x_p = (E_T^{jet} e^{\eta^{jet}} + E_T^\gamma e^- \eta^\gamma) / 2E_p \quad \text{and} \quad x_\gamma = (E_T^{jet} e^{-\eta^{jet}} + E_T^\gamma e^\eta^\gamma) / 2\gamma E_e$$

![Figure 1: Prompt photon differential cross sections with additional jet requirement ($E_T^{jet} > 4.5$ GeV) as a function of $E_T^\gamma, \eta^\gamma, \eta^{jet}, x_\gamma$, and $x_p$. The data are compared with pQCD in LO (dashed line) and NLO [2]. The bands show the effect of a variation of the renormalisation and factorisation scales from $0.5 \cdot E_T^\gamma$ to $2 \cdot E_T^\gamma$. Also shown is the NLO result corrected using the PYTHIA Monte Carlo for multiple interaction effects (NLO QCD (M.I.), dotted line).](image-url)
correspond to the energy fractions of the incident proton and of the exchanged photon participating in the hard process, respectively.

The data are compared to the NLO pQCD calculation of Fontannaz et al. [2]. In the NLO calculation $E_T^\gamma$ is used for the renormalisation and the factorisation scales. The photon and proton parton densities AFG [6] and MRST2 [7] are used, respectively. The NLO predictions are substantially different from LO and lead to a good description of the data. Taking into account the multiple interaction effects, as expected on the basis of PYTHIA, improves the data description in particular at $\eta^\gamma > 0$ and $x^\gamma < 0.5$. No corrections have been made to the NLO prediction for hadronisation effects.

4 DIS Results

First results on prompt photon production in DIS are presented by the ZEUS collaboration. Fig. 2 shows $E_T^\gamma$ and $\eta^\gamma$ distributions for inclusive prompt photon production (upper row) and associated with one jet (lower row). After application of normalisation factors of 2.4 and 8.3, respectively, PYTHIA and HERWIG describe the $E_T^\gamma$ distribution, but the $\eta^\gamma$ distribution is poorly described by PYTHIA. The pQCD NLO calculation gives an approximate description of the jet data with no need of an extra normalisation factor.

5 Conclusions

Production of prompt photons has been studied in $\gamma p$ interactions and in $ep$ DIS. The photoproduction results are quite well described by a NLO pQCD calculation, in particular if corrections for multiple interactions are applied. Also the DIS data are reasonably well described by a NLO pQCD calculation. The HERWIG and PYTHIA models need substantial normalisation factors.

References

[1] H1 Collab., contributed paper ICHEP2002 (Amsterdam), Abstract 1007.

[2] M. Fontannaz, J. P. Guillet and G. Heinrich, Eur. Phys. J. C 21 (2001) 303, Eur. Phys. J. C 22 (2001) 303.
Figure 2: Upper plots: inclusive $E_T^\gamma$ and $\eta^\gamma$ distributions compared with the PYTHIA and HERWIG generators. Lower plots: $E_T^\gamma$ and $\eta^\gamma$ distributions with jet requirement ($E_T^jet > 6$ GeV) compared with pQCD in NLO \cite{4}.

\cite{3} T. Sjöstrand, P. Edén, C. Friberg, L. Lönnblad, G. Miu, S. Mrenna and E. Norrbin, Comput. Phys. Commun. 135 (2001) 238.

\cite{4} A. Gehrmann-De Ridder, G. Kramer and H. Spiesberger, Nucl. Phys. B 578 (2000) 326.

\cite{5} S. D. Ellis and D. E. Soper, Phys. Rev. D 48 (1993) 3160.

\cite{6} P. Aurenche, J. P. Guillet and M. Fontannaz, Z. Phys. C 64 (1994) 621.

\cite{7} A. D. Martin, R. G. Roberts, W. J. Stirling and R. S. Thorne, Eur. Phys. J. C 14 (2000) 133.