Measurement of prompt photon cross sections in photoproduction at H1

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Abstract. Cross section measurements of isolated prompt photons, inclusively and associated with jets, have been made at the HERA *ep* collider with the H1 detector, using the data taken in the years 1996-2000 corresponding to an integrated luminosity of 105 pb^{-1}. The results are compared to a perturbative QCD calculations in next to leading order and to predictions of the event generators PYTHIA and HERWIG.

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INTRODUCTION

An inclusive prompt photon measurement, tagging only the final-state hard photon, may be directly compared with perturbative QCD calculations with no need for a jet definition matching theory and experiment and without hadronisation uncertainties. The photon's momentum reflects the collision kinematics since such photons are produced at the elementary interaction vertex. This contrasts with jet production, where the hadronisation process obscures the measurement of energy and direction of the outgoing parton. Therefore prompt photon events provide an interesting tool to test QCD, in a way which is complementary to jets. Further understanding of the production process may be obtained by detecting the prompt photon together with a jet.

The main experimental difficulty is the separation of the prompt photons from hadronic background, in particular from signals due to π^0 mesons and, to less extent, due to η's when at high energies the two energetic decay photons cannot be resolved in the detector. In order to suppress this background one looks for energetic and isolated photons.

RESULTS

In the H1 analysis [1] an isolation cone was imposed around the photon candidate: within a cone of unit radius in the (η, ϕ) plane, the total transverse energy E_T from other particles was required not to exceed 10% of the transverse energy E_T^γ of the photon. A typical signal is a compact energy deposition in the calorimeter, with no track pointing to it. The prompt photon fractions are determined in a likelihood analysis using shower shape observables for prompt photons, and for photons from π^0 and η decays. In the following the results are presented as bin averaged *ep* cross sections in the kinematic region:

$$\sqrt{s} = 319\,\text{GeV},\ \ 0.2 < y < 0.7,\ \ Q^2 < 1\,\text{GeV}^2,\ \ 5 < E_T^\gamma < 10\,\text{GeV}\ \text{ and }\ -1 < \eta^\gamma < 0.9\ .$$

Inclusive prompt photons. Differential cross sections for inclusive prompt photons as a function of E_T^γ and pseudorapidity η^γ are shown in Fig. 1 and compared with the predictions of PYTHIA [2] and HERWIG [3].

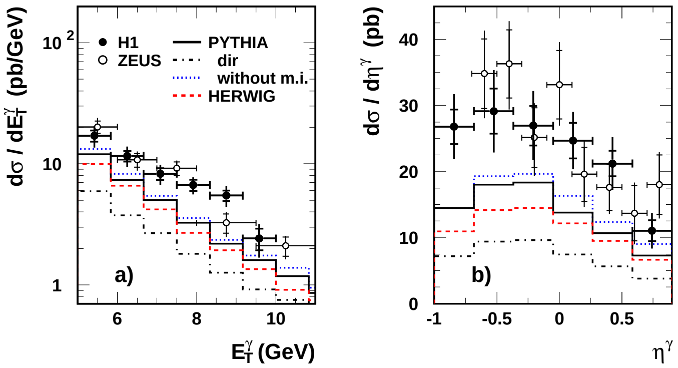

FIGURE 1. The prompt photon cross section measured by H1 [1] and ZEUS [4] are compared with the predictions of HERWIG and PYTHIA including multiple interactions. The contribution of direct interactions (dir) and the full PYTHIA predictions without multiple interactions (without m.i.) are also shown.

The distributions are also compared to the NLO pQCD calculations (Fig.2a,b) by Fontannaz, Guillet and Heinrich (FGH) [5] and Krawczyk and Zembruski (K&Z) [6, 7].

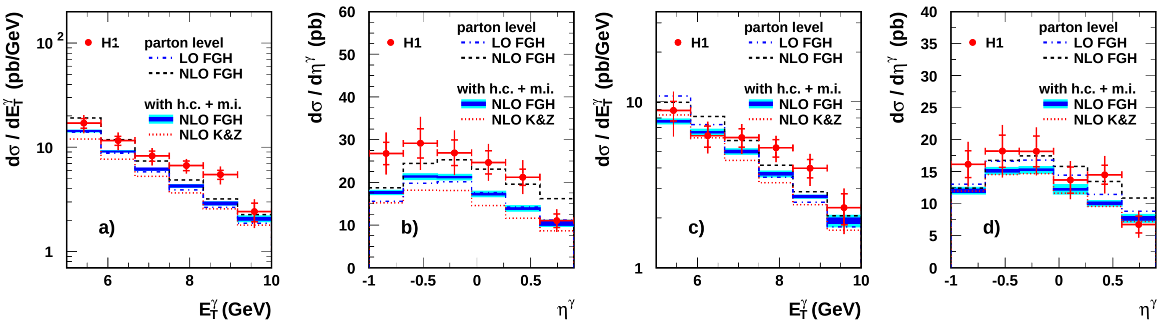

FIGURE 2. Inclusive prompt photon cross sections (a,b) and with an additional jet requirement (c,d) compared with NLO pQCD calculations: FGH [5] and K&Z [7]. The NLO results are corrected for hadronisation and multiple interactions (h.c. + m.i.). The FGH results are also shown without corrections for hadronisation and multiple interactions (parton level).

Prompt photons with jets. Cross sections for the production of a prompt photon associated with a jet ($E_T^{jet} > 4.5$ GeV, $-1 < \eta^{jet} < 2.3$) are presented in Figs. 2c,d as a function of the variables E_T^γ and η^γ and in Fig. 3 as function of $E_T^{jet}, \eta^{jet}, x_\gamma^{LO}$ and x_p^{LO}. The estimators $x_\gamma^{LO} = E_T^\gamma(e^{-\eta^{jet}} + e^{-\eta^\gamma})/2yE_e$ and $x_p^{LO} = E_T^\gamma(e^{\eta^{jet}} + e^{\eta^\gamma})/2E_p$ for the momentum fractions of constituents of the incident photon and proton, respectively, participating in the hard process make explicit use only of the photon energy and are most easily interpreted in leading (LO) order approximation [8].

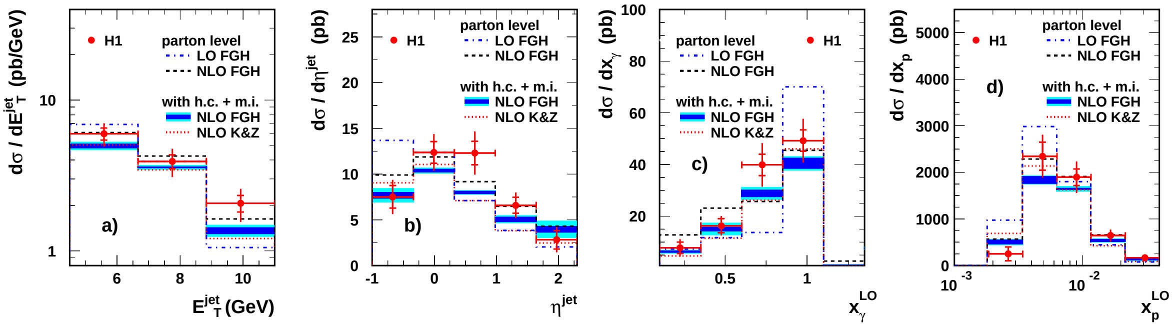

FIGURE 3. Prompt photon cross sections with an additional jet requirement differential in E_T^{jet}, η^{jet}, x_γ^{LO} and x_p^{LO}. The data are compared with NLO pQCD calculations by K&Z [7] and FGH [5, 8]. The NLO results are corrected for hadronisation and multiple interaction (h.c.+ m.i.) effects. The FGH results are also shown without corrections for h.c. and m.i. at NLO and LO.

In the absence of higher order processes and of intrinsic transverse momentum (k_T) of the incoming parton inside the proton, the photon and jet would be balanced in p_T. The observation of p_T imbalance between the photon and the jet thus allows a measurement of the mixed influence of the higher order processes and the intrinsic k_T of partons in the photon [9]. The distribution of the component of the prompt photon's momentum perpendicular to the jet direction in the transverse plane, $p_\perp \equiv |\vec{p}_T^{\,\gamma} \times \vec{p}_T^{\,jet}| / |\vec{p}_T^{\,jet}| = E_T^\gamma \cdot \sin(\Delta\phi)$, where $\Delta\phi$ is the difference in azimuth between the photon and the jet, is therefore sensitive to effects beyond LO. The normalised $p_\perp$ distribution is shown in Fig. 4 separately for the regions $x_\gamma^{LO} > 0.85$ and $x_\gamma^{LO} < 0.85$, where direct and resolved photon induced processes dominate, respectively.

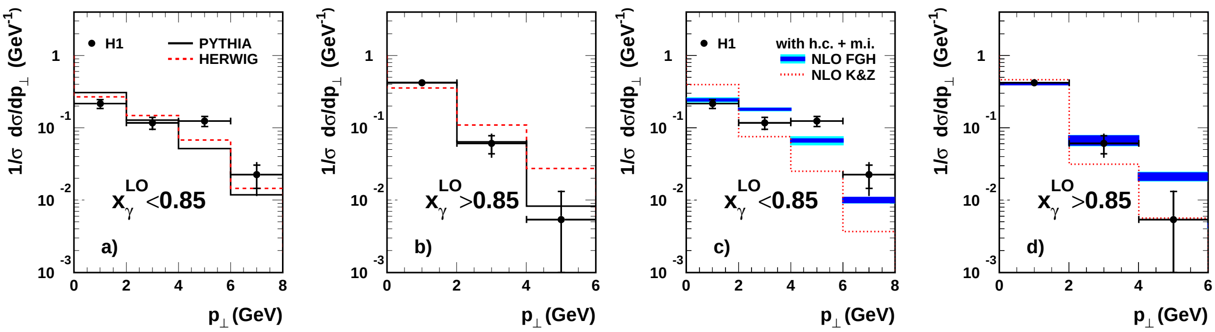

FIGURE 4. Distribution of the prompt photon momentum component, perpendicular to the jet direction in the transverse plane, for $x_\gamma^{LO} < 0.85$, a) and c), and $x_\gamma^{LO} > 0.85$, b) and d). In a) and b) the data are compared with PYTHIA and HERWIG. In c) and d) the data are compared with NLO pQCD calculations by K&Z [7] and FGH [5, 8]. The NLO results are corrected for hadronisation and multiple interactions.

CONCLUSIONS

The production of inclusive prompt photons and associated with jets has been studied in γp interactions. The cross sections predicted by the PYTHIA and HERWIG event generators describe the distributions well in shape but the normalisations are by about 40% – 50% too low. Multiple interactions tend to reduce the cross section due to the isolation requirement. H1 and ZEUS measurements are consistent within the errors. The η^γ and E_T^γ distributions of the inclusive prompt photons are reasonably well described in shape by NLO pQCD calculations, but after corrections for hadronisation and multiple interactions the predictions are 30%(40%) below the data for FGH (K&Z) calculations.

The distributions for prompt photons associated with a jet are better described by the NLO calculations including corrections for hadronisation and multiple interactions than the inclusive prompt photon distributions. The NLO corrections are smaller on average than in the inclusive case, which suggests that contributions beyond NLO are less important if an energetic jet is required together with the prompt photon.

PYTHIA describes the normalised $p_\perp$ distributions well. In contrast HERWIG predicts too hard $p_\perp$ distribution at large x_γ^{LO}, where direct photon interactions dominate. At low x_γ^{LO}, the $p_\perp$ distribution is better described by the NLO calculations if NLO QCD corrections are also applied for the resolved photon interactions, as is the case in the FGH calculations.

The large differences between the predictions of the various NLO calculations and Monte Carlo models in the present comparisons preclude a reliable conclusion on the intrinsic k_T of initial state partons in the proton.

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