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Prompt Photon Production in Deep Inelastic Scattering and Photoproduction at HERA

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Three recent measurements of prompt photon production performed by the H1 and ZEUS collaborations using HERA ep collider data are presented. The prompt photon rates measured by H1 and ZEUS in deep inelastic scattering are compared to QCD calculations and to MC predictions. A preliminary H1 measurement in photoproduction is presented and results are compared to NLO collinear calculation and the calculation based on to a k_T-factorisation approach.

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1. Introduction

Isolated photons produced in deep inelastic scattering (DIS) and photoproduction together with the hadronic final state X, $ep \rightarrow e\gamma X$, so called prompt photons, are a powerful probe of the underlying dynamics. They generally require smaller corrections for hadronisation effects than measurements relying on jets. A good understanding of the Standard Model prompt photon production mechanism is also important for searches of new particles decaying into photons in hadron colliders.

2. Prompt photon production in DIS

There are two contributions to prompt photon production in DIS. Final state photons may originate from the quark (QQ contribution) or may be emitted from the lepton (LL contribution). The interference contribution (LQ) is expected to be small. The QQ part may arise from direct radiation of the photon from the quark or from quark-to-photon fragmentation of the quark. In the case of the studies presented below, the fragmentation part is suppressed by the photon isolation requirement.

Events with isolated photons in DIS have been measured [1] by the H1 collaboration. Isolated photons with transverse energy $3 < E_T^\gamma < 10$ GeV and in the pseudorapidity range $-1.2 < \eta^\gamma < 1.8$ are studied within the kinematic region $4 < Q^2 < 150$ GeV^2 and $y > 0.05$ using an integrated luminosity of 227 pb^{-1}. Background from elastic Compton scattering has been suppressed by a cut on the invariant mass of the hadronic system $W_X > 50$ GeV. A photon candidate is identified as a cluster in the electromagnetic section of the calorimeter. Candidates with a track geometrically matching the cluster with a distance of closest approach of less than 20 cm are rejected. In order to suppress the background coming from neutral hadrons (predominantly $\pi^0 \rightarrow \gamma\gamma$) the transverse radius of the cluster is required to be below 6 cm. The isolation of the photon is ensured by requiring that it carries at least 90% of the transverse momentum of the jet containing the photon. The remaining neutral hadron contamination is estimated with a multivariate analysis statistically exploring the cluster shape differences between clusters originating from genuine photons and clusters produced by neutral hadron decay products.

The differential cross sections in bins of transverse energy of the photon E_T^γ, its pseudorapidity η^γ and negative four-momentum transfer squared Q^2 are presented in figure 1 compared to leading order QCD calculation [2] and to predictions of the Monte Carlo models PYTHIA (QQ) and RAPGAP (LL). Both predictions underestimate the data cross sections roughly by a factor of two, with the difference being the most significant at low Q^2.

New preliminary results from the ZEUS collaboration are reported as well. The results are based on data with integrated luminosity of 320 pb^{-1} within the kinematic range of $10 < Q^2 < 350$ GeV^2. Isolated photon candidates with transverse energy $4 < E_T^\gamma < 15$ GeV and in the pseudorapidity range $-0.7 < \eta^\gamma < 0.9$ are selected in the electromagnetic part of the calorimeter with no track assigned to it. The signal is extracted from the dominant neutral hadron background by a cluster shape analysis. The measured cross sections are compared to the two sets of calculations and to the Monte Carlo predictions. The leading order QCD calculation [2] (LO) is the full collinear calculation including QQ terms as well as LL contributions. The MRST approach [3] calculates the

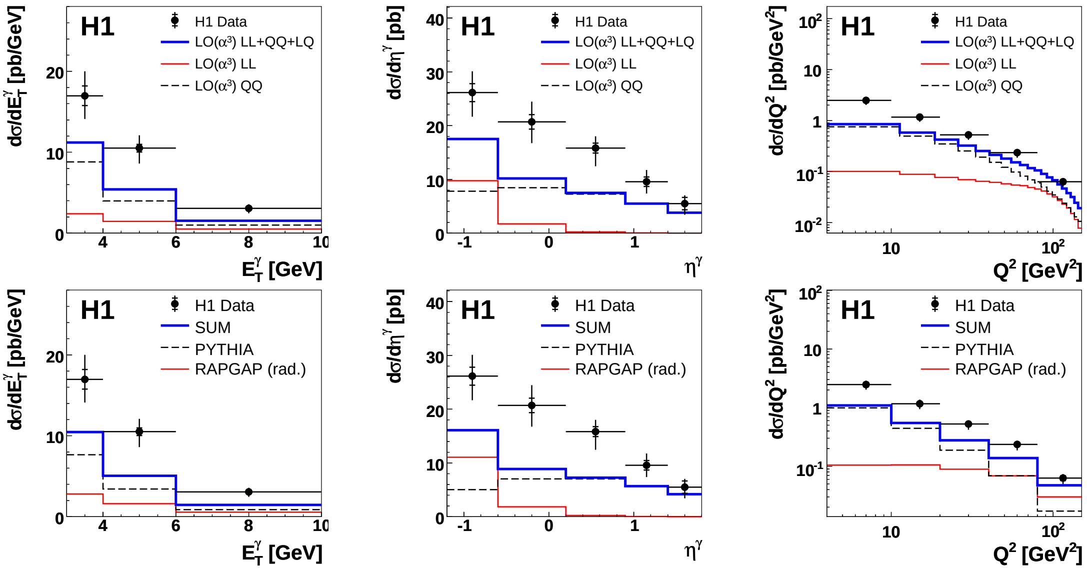

Figure 1: Differential prompt photon cross section in DIS compared to the LO calculation (top) and to the MC prediction (bottom) as measured by the H1 collaboration [1].

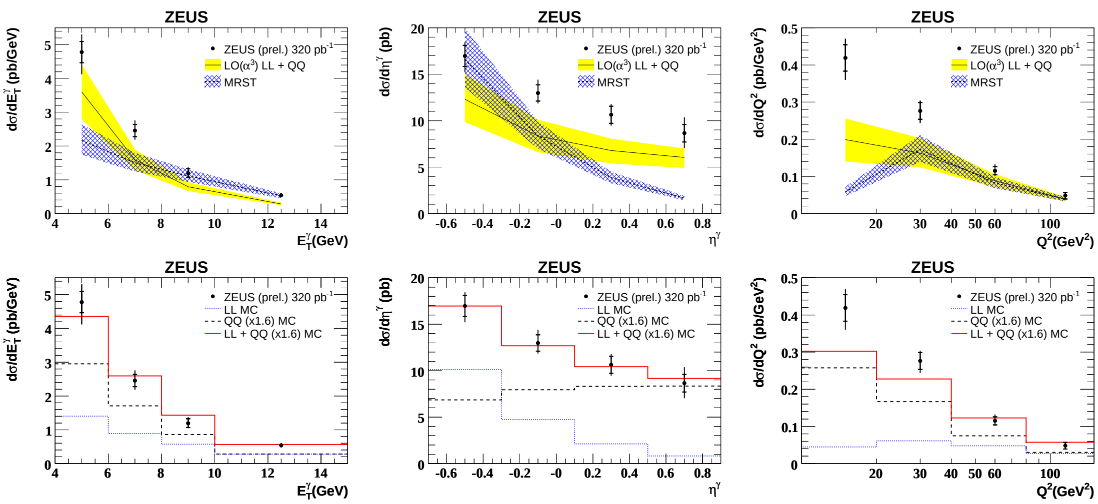

Figure 2: Differential prompt photon cross section in DIS compared to the calculations (top) and to the MC prediction (bottom) as measured by ZEUS collaboration.

resumed version of the *LL* contribution including the QED Compton scattering $\gamma_p e \to \gamma e$, where γ_p is a constituent of the proton. At the same time its validity is limited due to the fact the *QQ* compontent was neglected. The MC PYTHIA model is used to model the *QQ* contribution together with DJANGOH for the *LL* part.

Figure 2 presents the differential prompt photon cross sections in bins of E_T^γ, η^γ and Q^2. Similar conclusions can be drawn with the LO calculation underestimating the data cross sections most significantly at low Q^2. The MRST calculation agrees with the measurement at large Q^2 and low η^γ where the *LL* contribution is expected to dominate. MC models again underestimate prompt photon production and the *QQ* part needs to be scaled by a factor of 1.6 in order to properly describe the cross section.

A next-to-leading order calculation [4] is available for the production of a prompt photon in a conjunction with a jet. The hadronic jet is required to be found in the pseudorapidity range $-1.0 < \eta^{jet} < 2.1$ and with the transverse energy above 2.5 GeV. The calculation was compared to the H1 measurement [1] and though higher than the leading order cross sections by roughly 20%, it still significantly underestimates the measured cross sections.

3. Prompt photon production in photoproduction

The H1 collaboration reported preliminary results on a prompt photon cross section measurement in the photoproduction regime within the kinematic range given by $Q^2 < 1$ GeV^2 and $0.1 < y < 0.7$. The isolated photons with transverse energy $6 < E_T^\gamma < 15$ GeV and pseudorapidity $-1.0 < \eta^\gamma < 2.43$ are studied using data with 340 pb^{-1} of integrated luminosity.

The photon candidates are defined as electromagnetic clusters with transverse radius below 6 cm and without associated signal in the H1 tracking devices. Low Q^2 DIS events are removed by excluding events with reconstructed scattered electron in the main H1 apparatus. It is additionally suppressed by removing events with inelasticity estimator y_h being close to unity, where events with misidentified scattered electron accumulate. The DIS background is estimated to be below 1.5% in the final selection.

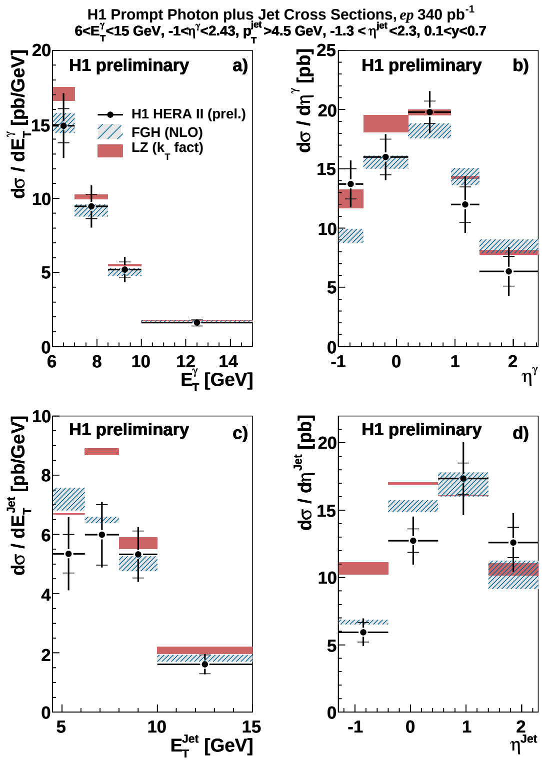

Figure 3: Preliminary differential prompt photon + jet cross section in photoproduction compared to the calculation predictions (see text) as measured by the H1 collaboration.

For the photon + jet case, the selection was based on the accompanying hadronic jet. Its transverse energy E_T^{jet} is required to be above 4.5 GeV and the jet itself must be found in the pseudorapidity range $-1.3 < \eta^{jet} < 2.3$.

Results are compared to a next-to-leading order collinear calculation (FGH) [5] and to a calculation based on the k_T-factorisation approach (LZ) [6]. Figure 3 presents the differential cross sections in bins of E_T^γ, η^γ, E_T^{jet} and η^{jet} in the photon + jet case. Both calculations give a reasonable description of the E_T^γ and η^γ, while only FGH calculation describes well E_T^{jet} and η^{jet} of the associated hadronic jet.

The correlations between the prompt photon and the hadronic jet were investigated by studying the cross sections in bins of the azimuthal acoplanarity between the photon and the jet $\Delta\Phi$, and the photon momentum perpendicular to the jet direction in the transverse plane $p_\perp$. Correlations are studied in the part of the phase space where direct events dominate ($x_\gamma^{LO} > 0.8$) and the supplementary one ($x_\gamma^{LO} < 0.8$) with enhanced contribution from resolved events. In this case x_γ^{LO} denotes the estimator of the longitudinal momentum fraction of the parton in the photon entering the hard interaction and is defined as $x_\gamma^{LO} = E_T^\gamma(e^{-\eta^{jet}} + e^{-\eta^\gamma})/(2y_h E_e)$, with E_e being the electron beam energy. The results of the study are presented in figure 4. Both predictions overestimate back-to-back configuration for the direct enhanced part of the phase space, but describe the tails reasonably well. The FGH calculation gives a reasonable description of the distributions for $x_\gamma^{LO} < 0.8$, except for the highest bins in $p_\perp$ and $\Delta\Phi$. The region $\Delta\Phi \to 180^\circ$ is sensitive to multiple soft gluon radiation which limits the validity of fixed order calculations. The LZ calculation includes multiple soft gluon radiation in the initial state before the hard subprocess and describes $\Delta\Phi > 170^\circ$ but predicts a significantly lower contribution of events in the tails of both distributions.

4. Conclusions

The measurement of prompt photons in *ep* collisions remains an interesting topic. The new results highlight the deficits of the available QCD calculations. In DIS as well as in photoproduction, the available calculations are not able to describe all aspects of the data. More theoretical investigations are needed to understand the observed discrepancies.

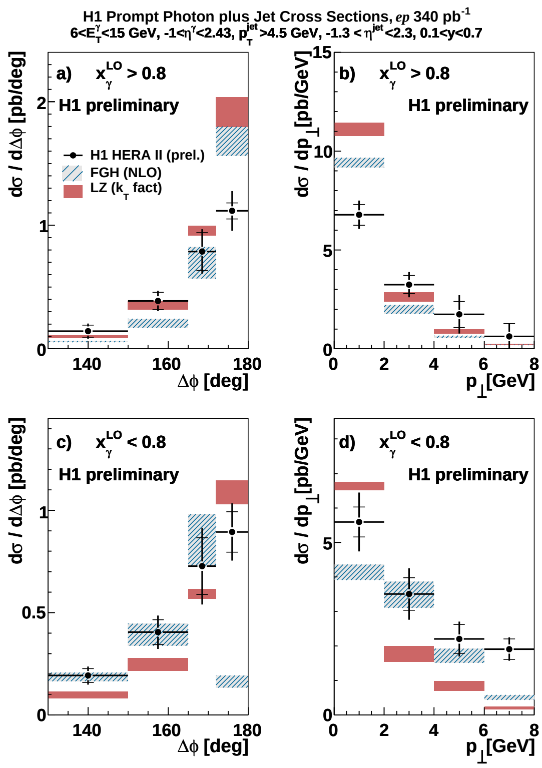

Figure 4: Preliminary differential prompt photon + jet cross section in photoproduction compared to the calculation predictions (see text) as measured by the H1 collaboration.

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