

Measurement of Photon Production in the Very Forward Direction in Deep-Inelastic Scattering at HERA

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Recent measurements of the forward photon production in Deep Inelastic Scattering obtained by the H1 Collaboration using the Forward Neutron Calorimeter are presented. Results are compared with Monte Carlo models used in inclusive DIS analyses and with several Cosmic Ray hadronic interaction models.

1 Introduction

Measurements of particle production at very small angles with respect to the proton beam direction (forward direction) in ep collisions are important for the theoretical understanding of proton fragmentation. Measurements of forward particle production also provide important constraints for the modeling of the high energy air showers and thereby are very valuable for the understanding of high energy cosmic ray data.

The production of forward photons is studied in deep-inelastic positron-proton scattering (DIS) at HERA [1]. The data are taken with the H1 detector in the years 2006 and 2007 and correspond to an integrated luminosity of 126 pb^{-1} . The analysis covers the kinematic range of negative four momentum transfer squared at the positron vertex $6 < Q^2 < 100 \text{ GeV}^2$ and inelasticity $0.05 < y < 0.6$. The photons are detected in the Forward Neutron Calorimeter (FNC), which is situated at a polar angle of 0° at $z = 106 \text{ m}$ from the interaction point. The acceptance of the FNC is defined by the aperture of the HERA beam-line magnets and is limited to scattering angles of $\theta \lesssim 0.8 \text{ mrad}$, corresponding to the pseudorapidity range $\eta > 7.9$.

2 Forward Photon Spectra in DIS

The measured differential cross sections for the production of very forward photon, normalised to the total inclusive DIS cross sections in the kinematic range defined above, are presented Figures 1 - 3. Figures 1 and 2 show the measurement as a function of longitudinal momentum fraction of the leading photon to the incoming proton, x_L^{lead} , and the transverse momentum of leading photon, p_T^{lead} .

In the Figure 3 the cross section is also presented as a function of the sum of longitudinal momentum fraction x_L^{sum} of all photons in the acceptance of the FNC. Two or more photons entering the FNC are reconstructed as a single cluster due to the relatively large size of the FNC

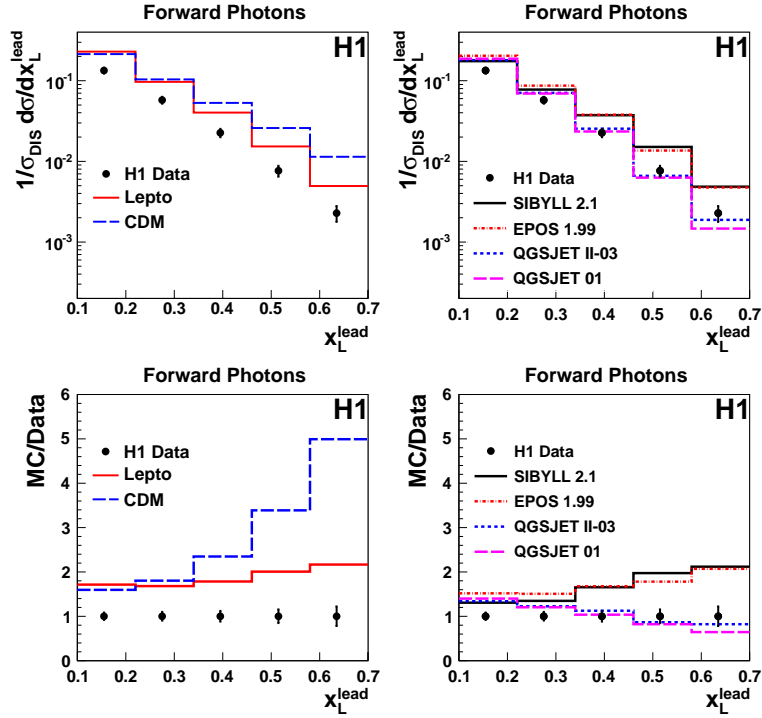


Figure 1: The DIS normalized cross sections for the production of forward photons as a function of x_L^{lead} for the data and the MC model predictions (upper row) and normalised to data distributions (lower row). The left side plots show the comparison with LEPTO and CDM models. The right side plots show the comparison with CR models.

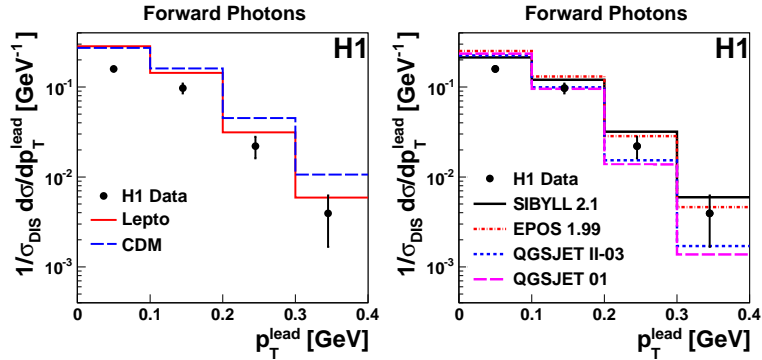


Figure 2: The DIS normalized cross sections for the production of forward photons as a function of p_T^{lead} for the data and the MC model predictions.

readout moduls and the small geometrical acceptance window. According to the Monte Carlo (MC) simulation, low energetic clusters ($x_L < 0.7$) reconstructed in the FNC mainly originate from single photons, while at high energies two or more photons may form a cluster. Therefore,

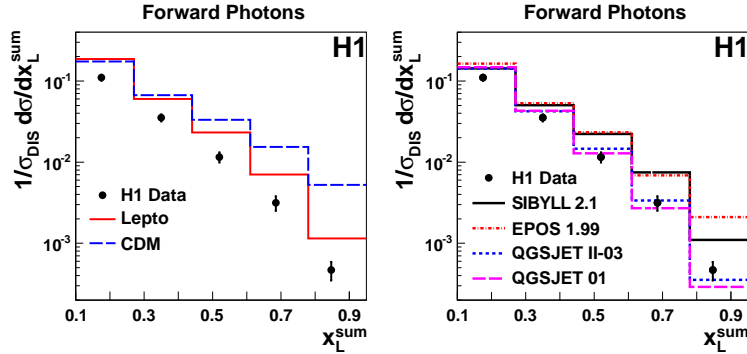


Figure 3: The normalized cross sections for the production of forward photons as a function of x_L^{sum} for the data and the MC model predictions.

the measurement of the cross section of single photon production is limited to $x_L^{lead} < 0.7$, while the measurement of the total forward photon production cross section is extended to larger $x_L^{sum} < 0.95$.

The data are compared with the predictions of different MC models. The DJANGO [2] program is used to generate inclusive DIS events. Higher order QCD effects are simulated using leading log parton showers as implemented in LEPTO [3], or using the Colour Dipole Model (CDM) as implemented in ARIADNE [4]. The measurements are also compared to the predictions of several hadronic interaction models which are commonly used for the simulation of Cosmic Ray (CR) air shower cascades: EPOS [5], QGSJET 01 [6], QGSJET II [7] and SIBYLL [8]. In all these models the main source of forward photons is the $\pi^0 \rightarrow 2\gamma$ decay. All models overestimate the total rate of forward photons. The LEPTO and CDM models predict by about 70% more photons than are measured, while the CR models (EPOS, SIBILL and QGSJET) overestimate the rate of photons by about 30 – 50%. The shapes of all measured distributions are well described by LEPTO. The CDM predicts harder x_L and p_T spectra. The QGSJET models overestimate the measured cross sections by about 40% at lowest x_L and p_T , but are consistent with the data within the experimental uncertainties elsewhere. The EPOS and SIBYLL models predict harder x_L spectra, but describe reasonably well the shape of the p_T distribution.

3 Fraction of DIS events with forward photon

The measurement of forward photons allows a test of the limiting fragmentation hypothesis, which implies that the production of forward photons in DIS is insensitive to Q^2 and the Bjorken x variable, x_{Bj} . To investigate this prediction, the ratio of the forward photon production cross section to the inclusive DIS cross section is studied as a function of Q^2 and x_{Bj} (Figure 4).

Within the uncertainties the fraction of DIS events with photons is independent from Q^2 and x_{Bj} . The LEPTO and CDM models display significant differences in normalization compared to the data as well as slight dependences as a function of Q^2 and x_{Bj} .

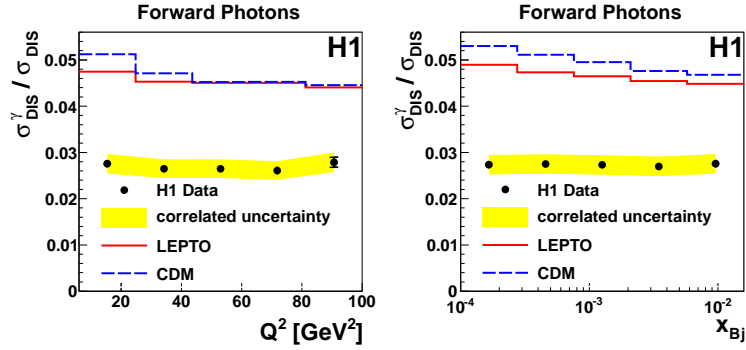


Figure 4: Fraction of the DIS events with the forward photons as a function of Q^2 and x_{Bj}

4 Summary

The production of forward photons has been studied in DIS positron-proton scattering in the kinematic region $6 < Q^2 < 100 \text{ GeV}^2$, $0.05 < y < 0.6$ in the pseudorapidity range $\eta > 7.9$. The DIS normalized cross sections are presented for the production of the most energetic photons as a function of the longitudinal momentum fraction in the range $0.1 < x_L^{lead} < 0.7$ and transverse momentum p_T^{lead} and as a fraction of the sum of all forward photons in the range $0.1 < x_L^{sum} < 0.95$. The predictions of Monte Carlo models overestimate the rate of photons. LEPTO describe the shapes well, while CDM predict harder spectra for x_L and p_T . The measurements also compared with CR models commonly used for simulation of air shower cascades. None of them can describe the data in rate and in shape. Within the measured kinematic range, the relative rate of forward photons in DIS events is observed to be independent of Q^2 and x_{Bj} , in agreement with the hypothesis of limiting fragmentation.

The measurements may lead to further understanding of proton fragmentation and can be used for model tuning.

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