Transverse momentum of charged particles at low Q^2 at HERA

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Abstract.
The electron-proton collider HERA allows deep-inelastic scattering (DIS) at very small Bjorken-x of about 10^{-5}. At such small x new parton dynamics beyond DGLAP are expected to become important. Charged particle spectra are measured in DIS ($Q^2 > 5$ GeV^2), in different regions of pseudorapidity. Compared to previous publications this analysis uses the increased statistics of the HERA-II data taking period. This analysis covers a pseudorapidity range in the forward region (towards the proton remnant), where deviations from models based on DGLAP evolution are expected to be more pronounced. The measurements are compared to simulations based on different Monte Carlo generators. It is shown that the region of small transverse momenta is primarily sensitive to hadronisation, whereas the region of large transverse momenta is mainly driven by perturbative parton radiation. The best description of the data is achieved by the Color Dipole Model.

Keywords: DIS, DGLAP, BFKL, low-x
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INTRODUCTION

In the region of small x at the HERA collider effects from non-p_T-ordered parton radiation might become visible.

Compared to the measurements of the structure function $F_2(x,Q^2)$, a less inclusive measurement where, in addition to the scattered electron, charged hadrons are measured may be more sensitive to the underlying parton dynamics. In [1] it has been proposed that a measurement of the transverse momentum spectrum of charged particles is sensitive to whether the partons are emitted in a p_T-ordered cascade (DGLAP) or in a unordered way (beyond DGLAP).

We present a measurement of charged particle transverse momenta in different regions of of x and Q^2, and compare it with predictions from different Monte Carlo (MC) event generators. In addition we discuss the question of the sensitivity to the hadronisation parameters.

MONTE CARLO GENERATORS

Various Monte Carlo generators using different approaches to simulate the parton cascade are used in this analysis: the RAPGAP generator [2] based on leading-log DGLAP parton showers; the DJANGOH generator [3] based on the Color Dipole Model (CDM), a description of parton emission which is similar to that of the BFKL evolution; the CASCADE generator [4] based on the CCFM model, which unifies the BFKL and DGLAP approaches and requires angular ordering of the emitted quanta w.r.t the proton beam. In the CDM and the CCFM approaches the p_T of the emitted partons in a parton shower is not ordered. All generators use the Lund string model [5] for hadronisation as it is implemented in PYTHIA [6], with parameters tuned by the ALEPH collaboration to fit LEP data [7].

EVENT SELECTION AND RECONSTRUCTION

The data taken with the H1 detector in 2006 with a positron beam energy of 27.5 GeV and a proton beam energy of 920 GeV are used in the analysis. The analysed data set corresponds to an integrated luminosity of $L = 88.64\,\mathrm{pb}^{-1}$. The phase space of this analysis is defined by $5 < Q^2 < 100$ GeV^2, $0.05 < y < 0.6$, $155^\circ < \theta_e < 175^\circ$ and $E_e > 12$ GeV, with θ_e and E_e being the polar angle and energy of the scattered positron, respectively.

For this analysis, the tracks measured in the central tracking detector (CTD) and the tracks from the combination of CTD and the forward tracking detector measurement, are used. Tracks are required to originate from the primary vertex, to lay within the angular range $10^\circ < \theta_{lab} < 155^\circ$ and have transverse momenta above 150 MeV.

The data are corrected for detector acceptance, efficiency and resolution effects, as well as for the charged decay products of K_S^0, Λ and for other weakly decaying particles.

RESULTS

The results are presented in the hadronic center-of-mass system (HCM), i.e. in the proton photon rest frame. The transverse momentum and pseudorapidity of charged particles in the HCM are labeled as p_T^* and η^*, respectively. All distributions shown are normalized to the total number of DIS events in the analysed phase space.

Transverse momenta of charged particle

The transverse momentum spectra (p_T^*) of charged particles are presented in Fig. 1 for two pseudorapidity intervals: in $1.5 < \eta^* < 4$, where the current fragmentation in strongly dominated, and in more central region, $0 < \eta^* < 1.5$, where the fraction of target fragmentation is increasing. The DJANGOH predictions, based on the CDM, describes the data fairy well for the whole p_T^* range, whereas RAPGAP is below the data for $p_T^* > 1$ GeV, especially in the central pseudorapidity interval. In contrast, CASCADE is above the data for almost the whole p_T^* range.

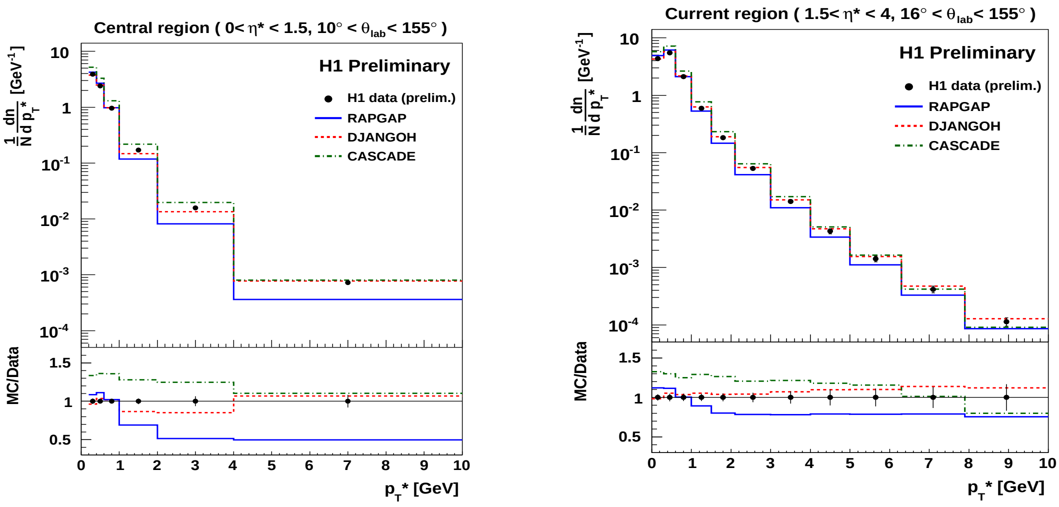

FIGURE 1. Measured p_T^* spectra and Monte Carlo predictions of charged particles in the hadronic center of mass system (HCM) in the two pseudorapidity intervals: $0.5 < \eta^* < 1.5$ and $1.5 < \eta^* < 4$. Data are compared to RAPGAP, DJANGOH and CASCADE predictions.

Rapidity distribution

To separate the effects of fragmentation and parton evolution the normalised rapidity distributions were measured for $p_T^* < 1$ GeV and for $p_T^* > 1$ GeV, shown separately in Fig. 2.

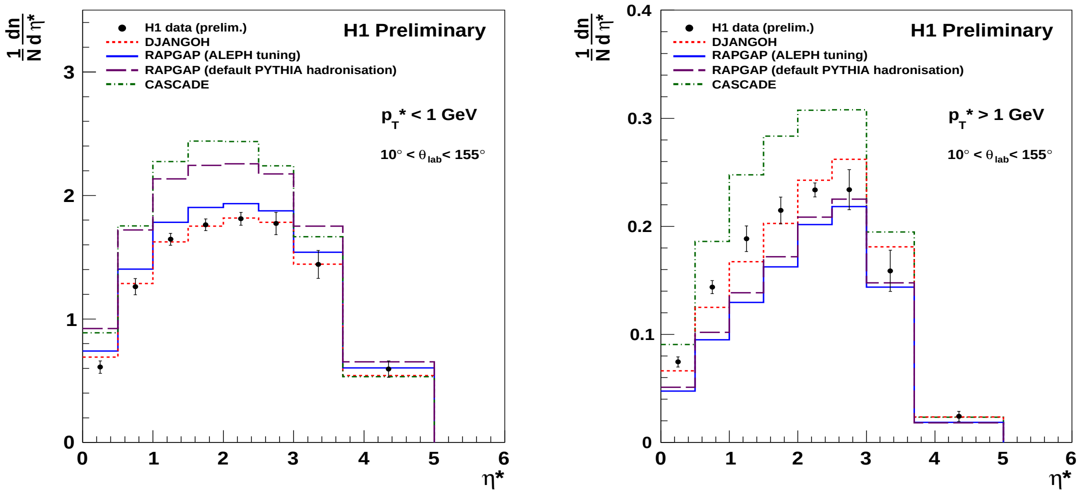

FIGURE 2. Measured η^* spectra and Monte Carlo predictions of charged particles in the hadronic center of mass system for $p_T^* < 1$ GeV (left) and for $p_T^* > 1$ GeV (right), separately. Data are compared to RAPGAP, DJANGOH and CASCADE predictions. The proton remnant direction is to the left.

As argued in [8], hadronisation effects should be relevant at small p_T, while parton radiation should manifest itself in the tail of the p_T distribution. To check the sensitivity to the hadronisation effects the RAPGAP prediction with default PYTHIA fragmentation parameters and with parameters tuned by ALEPH are shown in Fig. 2. Significant differences between these two models are seen in the soft p_T^* region, while for particles with harder transverse momenta this discrepancy is much smaller. Comparing predictions from generators with different QCD scenarios for parton cascades, at large p_T^* the influence of the fragmentation is much smaller, but clear differences between the models with different parton cascade are observed.

The charged particle multiplicity as a function of pseudorapidity in different x and Q^2 bins are shown in Fig. 3 for $p_T^* > 1$ GeV. The surplus of the hard particles in data over the DGLAP model RAPGAP at small x and towards the proton remnant is observed. The CASCADE is above the data everywhere, especially at large values of x and Q^2.

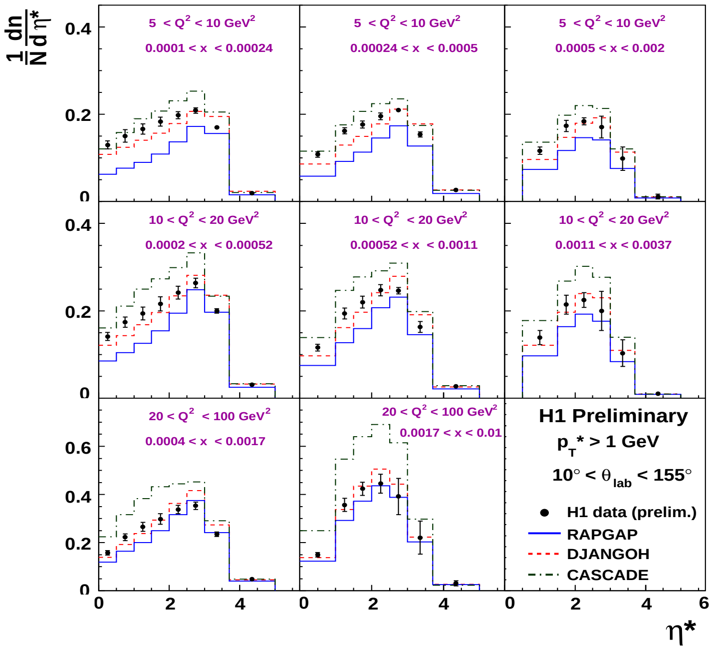

FIGURE 3. Measured η^* spectra and Monte Carlo predictions of charged particles in the hadronic center-of-mass system for $p_T^* > 1$ GeV, for eight intervals of Q^2 and Bjorken-x as indicated on the plot. The proton remnant direction is to the left.

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