H1prelim-10-035 Submitted to

XVIII International Workshop on Deep Inelastic Scattering, DIS2010, April 19-23, 2010, Florence
Parallel Session **QCD and Final States**

Electronic Access: www-h1.desy.de/publications/H1preliminary.short_list.html

Transverse momentum of charged particles at low Q^2 at HERA (H1)

H1 Collaboration

Abstract

The electron-proton collider HERA allows deep inelastic scattering (DIS) at very small bjorken x of about 10^{-5}. At such a small x a new parton dynamics beyond DGLAP are expected to become important. Charged particle spectra are measured in DIS ($\mathrm{Q}^2 > 5$ GeV^2) in different regions of pseudorapidity using the increased statistics. The measurements are compared to calculations based on different Monte Carlo generators. It is shown, that the region of small transverse momenta is related to hadronization whereas the region of large transverse momenta are driven by perturbative parton radiation It is demonstrated, that the observed hardness of the spectra at relative high hadron's transverse momenta tells in favor of parton dynamic beyond DGLAP.

1 Introduction

The accessibility of very small x at the HERA collider stimulated the discussion on the physics in this region. Measured in an inclusive experiment, $ep \rightarrow e'X$, the structure function $F_2(x, Q^2)$, which is related to the x-distributions of the partons in proton, is described by DGLAP evolution, but cannot exclude significant contribution from BFKL evolution. The structure function data are too inclusive to resolve the question of non-DGLAP evolution. One has to resort to less inclusive measurement, where, in addition to scattered electron, also charged hadrons are measured. DGLAP corresponds to a strong ordering of transverse momenta k_T in the parton cascade from proton side towards the virtual photon, while in BFKL the k_T follow a random walk. Measurements of the hadronic final state emerging from the cascade is thought to be sensitive to such ordering.

One of the direct measure of the partonic activity is *charged particle transverse momentum spectra*.

2 Event Selection

2.1 DIS and detector level selection

The data taken in 2006 with a positron beam energy of 27.5 GeV and a proton beam energy of 920 GeV are used in the analysis. This data set corresponds to an integrated luminosity of $L = 88.64$ pb^{-1}. The calorimeter SPACAL was used to measure the energy of the scattered positron in the angular range $155^o < \theta_e < 175^o$. The scattered positron was identified as the most energetic SPACAL cluster in an event with an energy E' larger than 12 GeV.

The *phase space* of this analysis is defined by $5 < Q^2 < 100$ GeV^2, $0.05 < y < 0.6$, for bjorken x this corresponds $0.0001 < x < 0.01$.

Additionally, some other cuts were applied in order to ensure a well identified scattered positron and to suppress the background:

- The energy in the hadronic part of the SPACAL behind the electromagnetic cluster was required to satisfy the cut: $E_{\text{had}} < 0.5$ GeV;
- The radial distance between the track in the backward drift chamber (BDC) and the electron cluster in the SPACAL was required to be less than 3 cm;
- The energy deposit in a region close to the edge of the detector should be below 1 GeV: $E_{\text{veto}} < 1.0$ GeV.
- The radius of the electron candidate cluster in the SPACAL was required to be smaller than 4 cm

In order to suppress background events, the cut $|z_{\mathrm{vertex}}| < 35$ cm was applied.

In addition, for the reconstructed $\sum_i (E_i - p_{z,i})$ the following cut was applied: $35 < \sum_i (E_i - p_{z,i}) < 75$ GeV, where i runs over all final state objects including the scattered positron.

2.2 Tracks Selection

Only central tracks are analysed in this analysis, which means that the tracks were reconstructed using the central tracking devices. The reconstruction in the central region is based on two drift chambers, CJC1 and CJC2. The tracks are used to define the event vertex. In this analysis only tracks from the primary vertex were considered.

In order to provide a higher efficiency of the track reconstruction, the following cuts were applied:

- The transverse momentum p_T of a track has to be larger than 0.15 GeV. This cut selects tracks which can traverse both CJC rings and do not curl back.
- The polar angular range is required to be $20^o < \theta < 155^o$.
- Tracks are required to have a radial length L (the radial distance between the first and the last hit) larger than 10 cm for the full θ range to ensure good momentum resolution.
- Starting point of a track is required to be in CJC1.

3 Results

The final measurements are corrected for detector effects as well as for QED radiation. The results below are shown in the hadronic center of mass system (HCM), i.e. in the proton photon rest frame. Transverse momenta are measured in the central pseudo-rapidity interval $1.5 < \eta^* < 2.5$ [1].

3.1 Charged particle transverse momenta

The phase space of this analysis (see section 2.1) was divided into 8 kinematic intervals. From bin 1 to 8 the value of x and Q^2 are increasing. All distributions below are normalized to the number of DIS events N, satisfying the DIS phase space requirements : $\frac{1}{N}\frac{dn}{dp_T}$, where $\frac{dn}{dp_T}$ is the number of charged particles in the bin dp_T. Summing up all bins dp_T we obtain: $\frac{n}{N}$ - the average multiplicity of charged particles in the event.

[1] p_T^* and η^* refer to HCM system. $\eta^* = -\ln(\tan(\theta^*/2))$, where θ^* is the angle with respect to the virtual photon direction, i.e. the positive z^* direction

The measured p_T^*-spectra of charged particles are presented in Fig. 1. It can be seen that DJANGOH describes data fairy well for whole p_T^* spectra and RAPGAP is below the data for $p_T^* > 1$ GeV. Additionaly the CASCADE prediction is shown (dashed green line), it can be seen that CASCADE is above the date almost for whole p_T^* range. The same p_T^* spectra but for different x and Q^2 bins is shown in Fig. 2 (the bin sizes are indicated on the plots). The ratios of p_T^* spectra in each x and Q^2 bins is shown in Fig. 3.

At small x and Q^2 RAPGAP predictions are below the data points for $p_T^* > 1$ GeV (especially for fist two bins). This discrepancy between MC and data at small x may be due to insufficient description of the gluon radiation. This discrepancy disappears when increasing x and Q^2 ($x \gtrsim 0.001$), where gluons cease to dominate among other partons. Data are well described by the DJANGOH over the full kinematic range, in which parton radiation is not ordered in k_T.

The average multiplicity of charged particle as a function of η^* for soft ($p_T^* > 1$ GeV) and for hard ($p_T^* > 1$ GeV) p_T regions is shown in Fig. 4. The best description of the data is achieved by DJANGOH for both samples. On the plots two curves for RAPGAP are shown: RAPGAP using default PYTHIA fragmentation parameters (violet dashed line) and RAPGAP with parameters from the ALEPH tuning to LEP data (blue line).

Additionally, the same distributions but for 8 kinematical bins are shown in Fig. 5 for the soft p_T^* region ($p_T^* < 1$ GeV) and in Fig. 6 for the hard p_T^* region ($p_T^* > 1$ GeV) . In the latter case it can be seen that the DGLAP-like model (RAPGAP) predicts fewer particles at small x for $\eta^* < 2$.

4 Discussion. Summary

We have studied the hadronic final state in deep-inelastic scattering by measuring the transverse momentum and rapidity spectra of charged particles in DIS with the H1 detector at HERA, using data taken during the 2006 running period with an integrated luminosity of 88.64 pb^{-1}. The analysis has been performed in the kinematical region $5 < Q^2 < 100$ GeV^2 and $0.05 < y < 0.7$. The measured transverse momentum spectra are presented as a function of x and Q^2 in the central region of the pseudo-rapidity, $1.5 < \eta^* < 2.5$. The measurements are compared to two QCD models corresponding to the different scenarios of the parton dynamics: the DGLAP and BFKL-like (Color Dipole Model) evolution schemes. At large x ($x \gtrsim 0.001$) both models give a satisfactory description of the measured p_T^* spectra. At small x the QCD model predictions by RAPGAP, based on the conventional DGLAP equations, falls below the data for $p_T^* > 1$ GeV. However, data are well described over the full kinematic ranges by the approach based on the Color Dipole Model, in which parton radiation is not ordered in p_T (very small x).

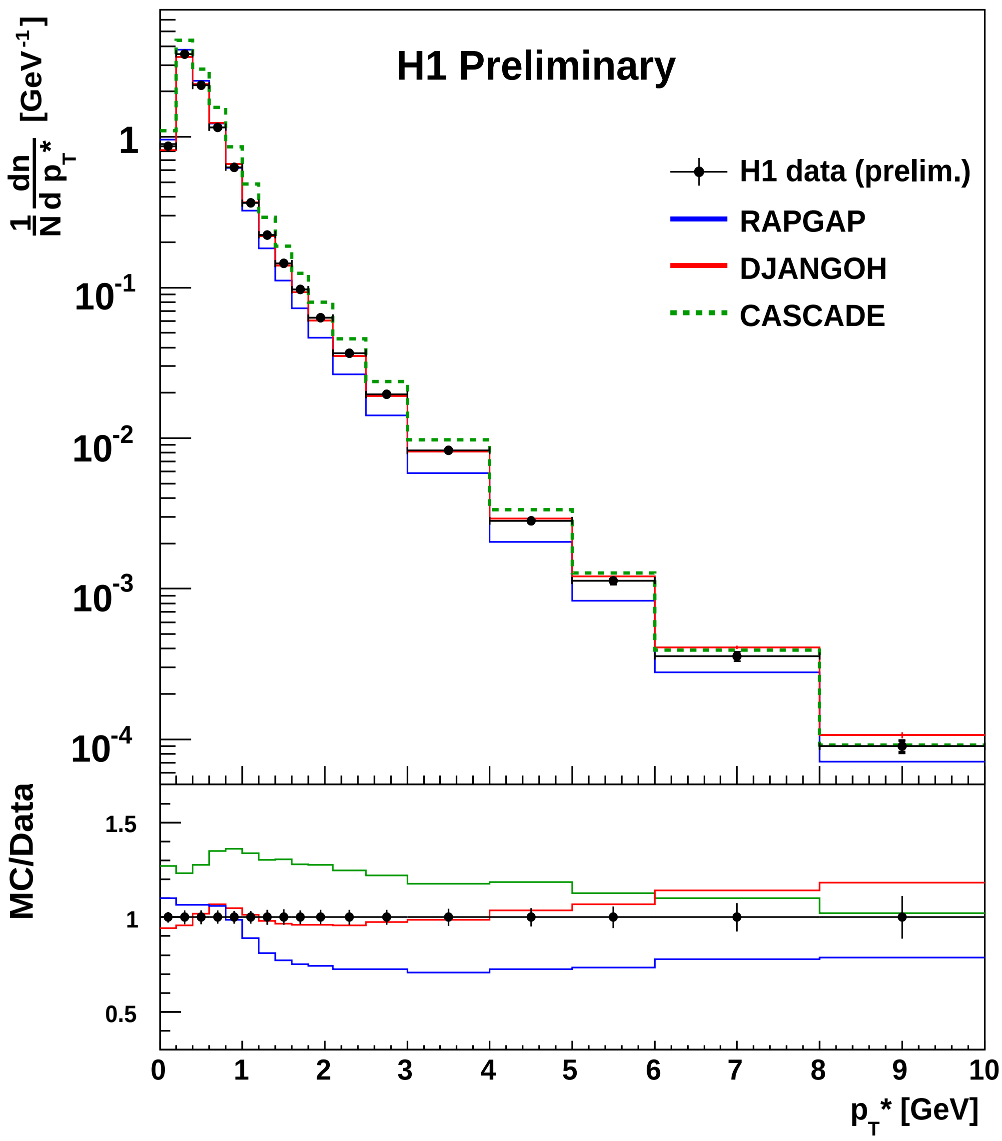

Figure 1: Measured p_T^* spectra and MC predictions of charged particles in the central region of the pseudo-rapidity, $1.5 < \eta^* < 2.5$, for the hadronic center of mass system (HCM). Data are compared to RAPGAP, DJANGOH and CASCADE.

Charged particle spectra in DIS

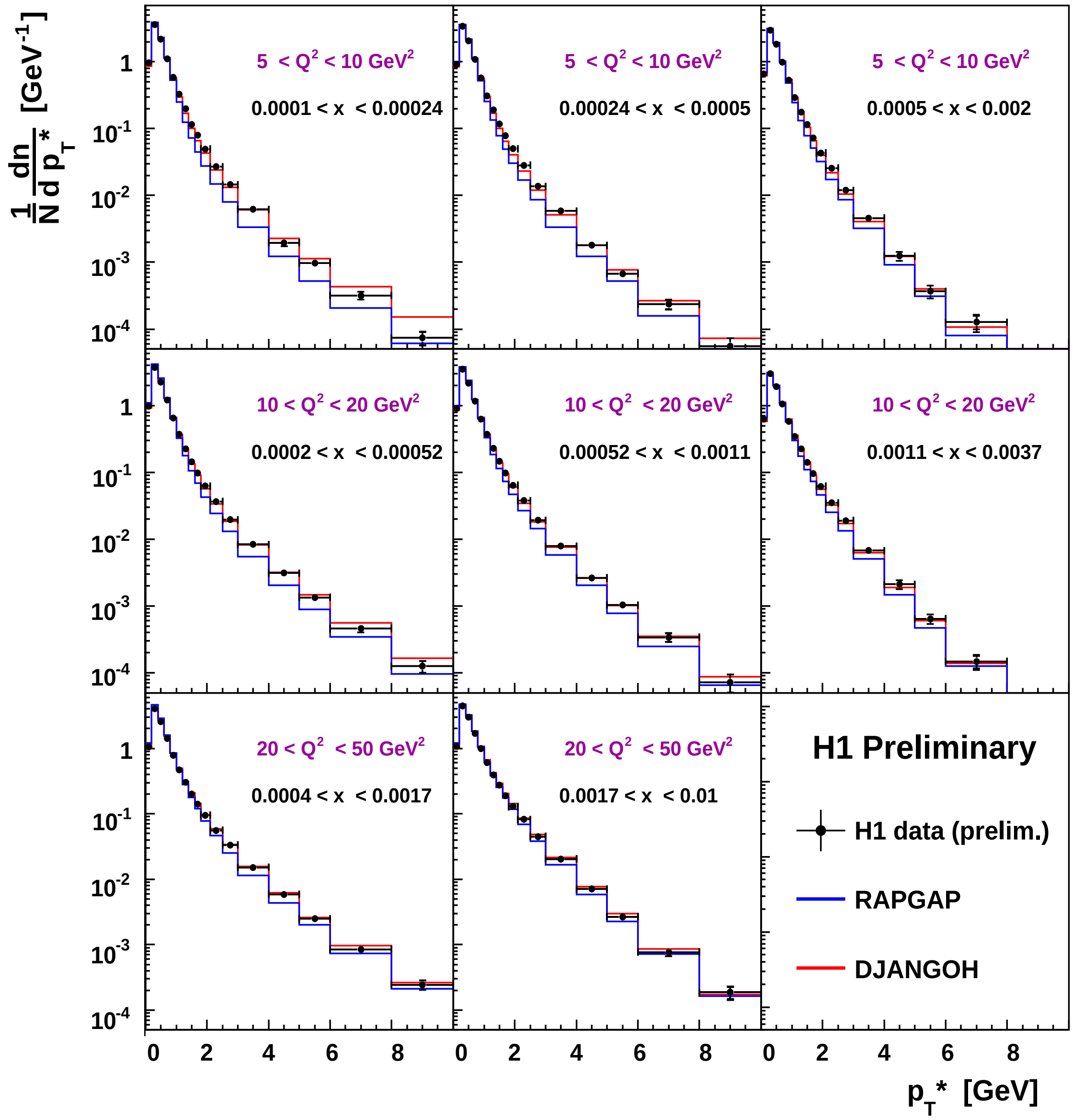

Figure 2: Measured p_T^* spectra and MC predictions of charged particles in the central region of the pseudo-rapidity, $1.5 < \eta^* < 2.5$, for the hadronic center of mass system (HCM), for 8 kinematical regions. Data are compared to RAPGAP and DJANGOH.

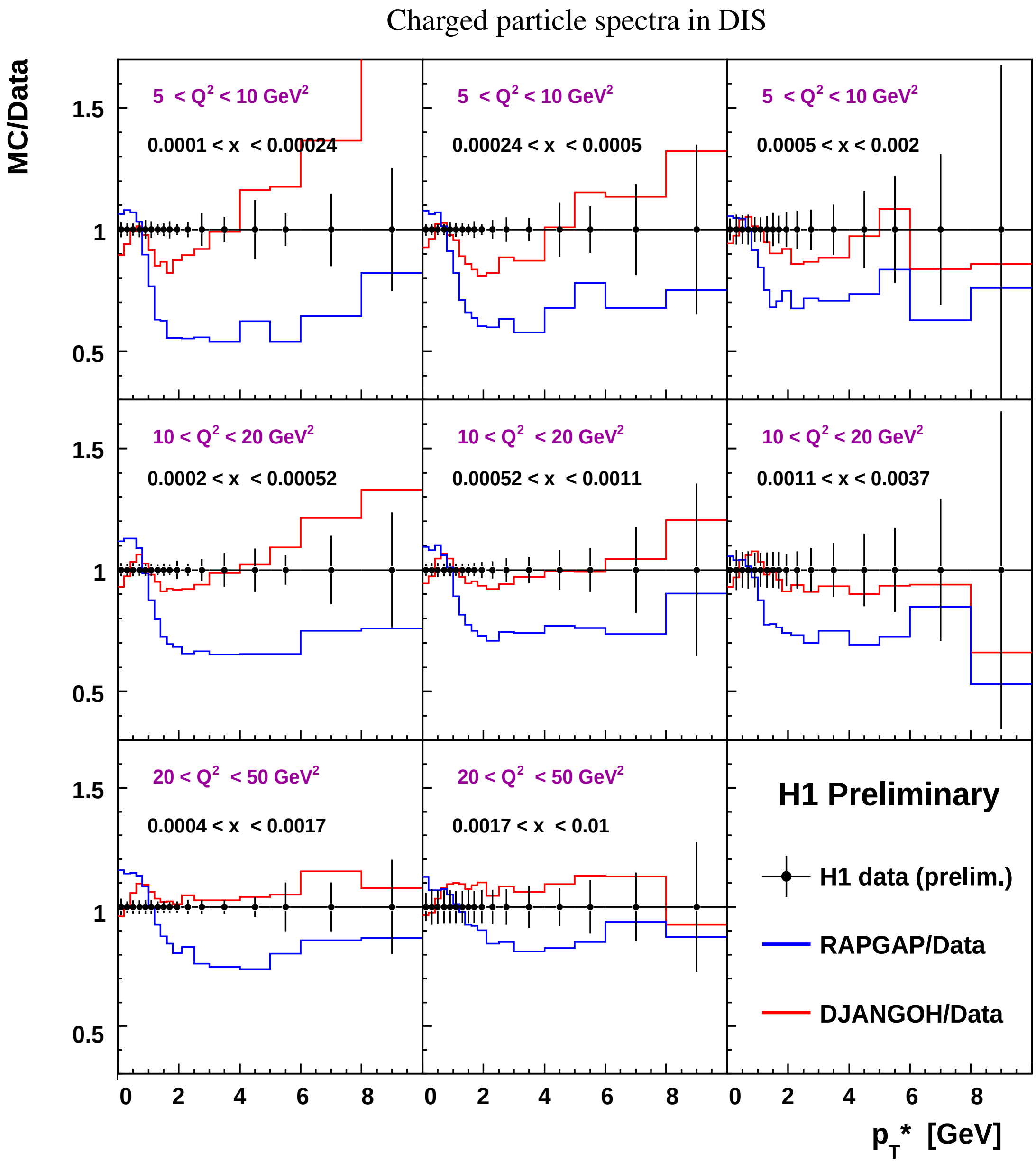

Figure 3: Ratios of the MC predictions over the measured p_T^* spectra of charged particles in the central region of the pseudo-rapidity, $1.5 < \eta^* < 2.5$, for the hadronic center of mass system (HCM), for 8 kinematical regions.

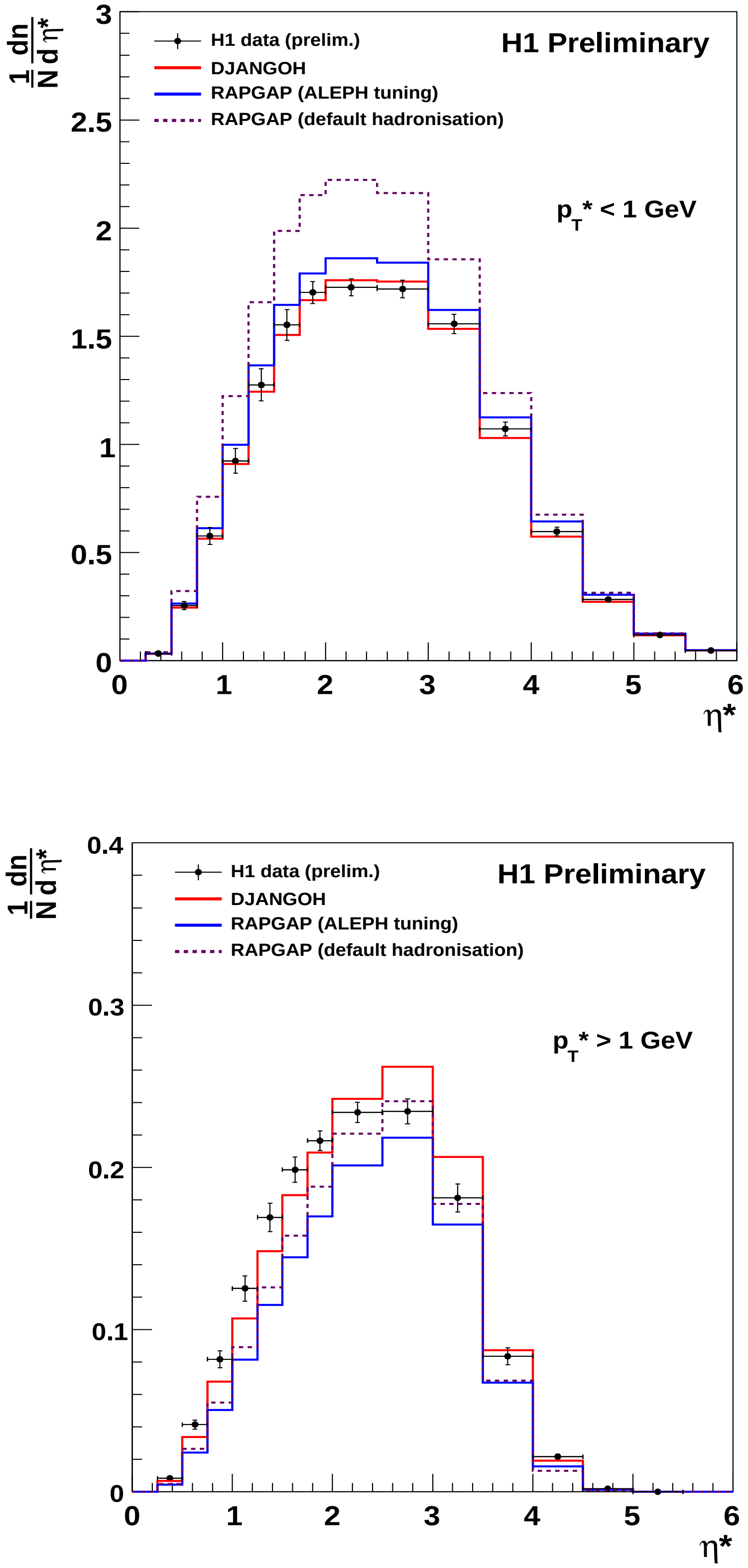

Figure 4: Measured η^* and MC predictions of charged particles for the hadronic center of mass system (HCM)

Charged particle spectra in DIS

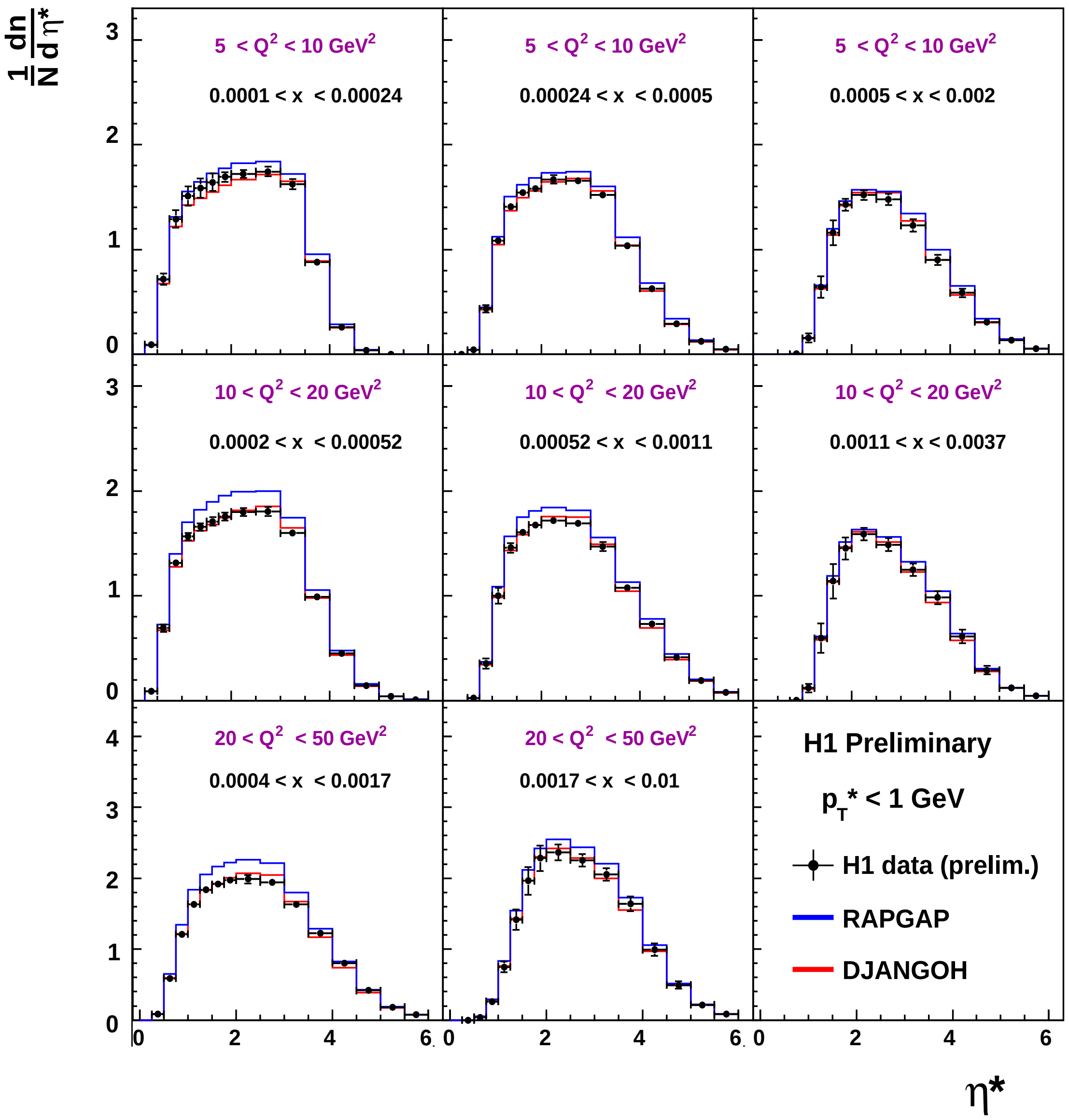

Figure 5: Measured η^* and MC predictions of charged particles for the hadronic center of mass system (HCM) , for $p_T^* < 1$ GeV. Data are compared to RAPGAP and DJANGOH.

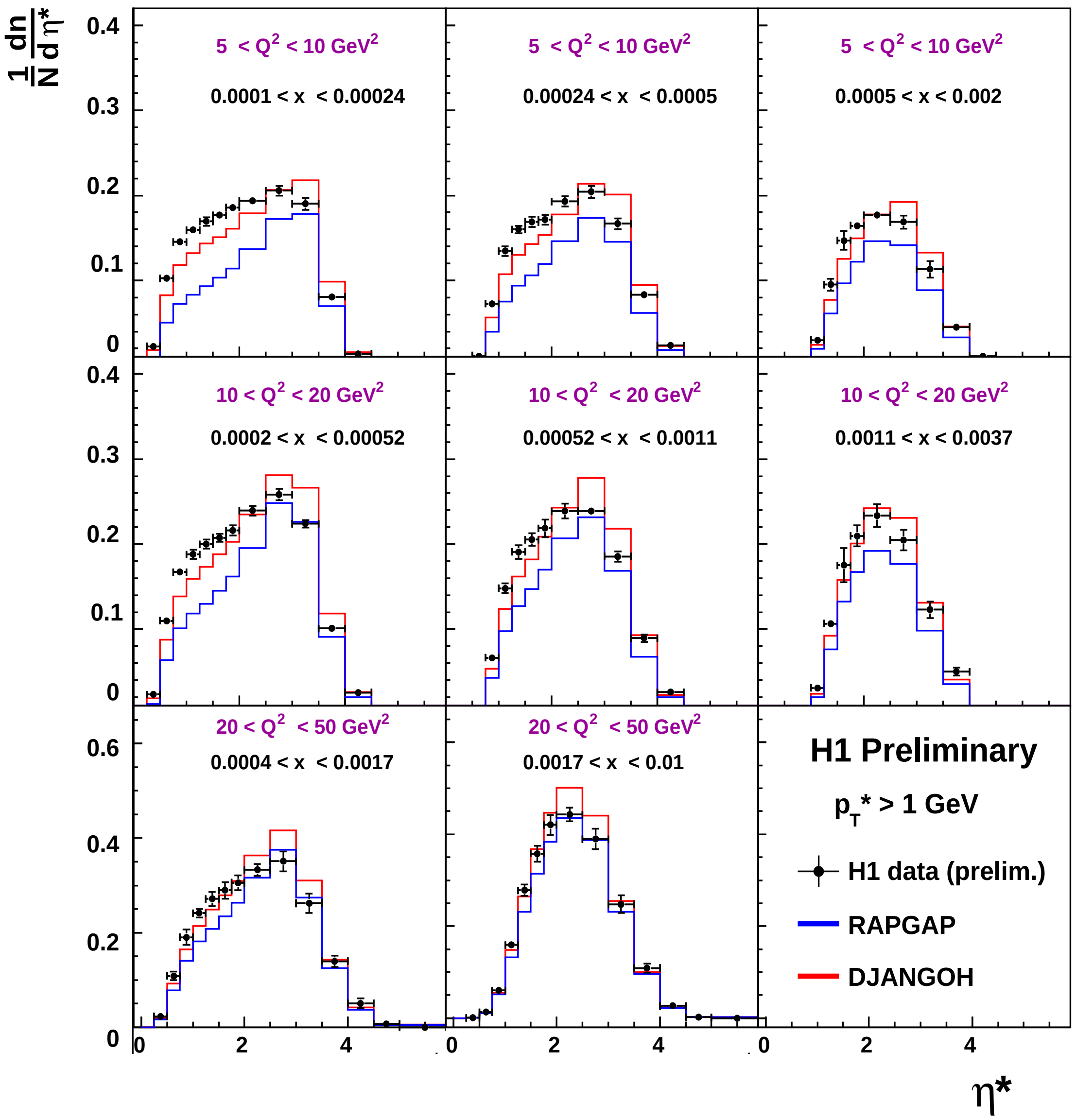

Figure 6: Measured η^* and MC predictions of charged particles for the hadronic center of mass system (HCM) , for $p_T^* > 1$ GeV. Data are compared to RAPGAP and DJANGOH.