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Particle Production at HERA

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The lattest results on charged particle production in deep-inelastic ep scattering (DIS) at HERA are presented. Charged particle production is measured as a function of the pseudorapidity η^* and the transverse momenta p_T^* of charged particles in the hadronic centre-of-mass frame with the H1 detector in two kinematic regions: at invariant masses of the incident electron and proton $\sqrt{s}_{ep} = 319\ GeV$ with low photon virtuality Q^2 ($5 < Q^2 < 100\ GeV^2$) and small values of Bjorken x ($10^{-4} < x < 10^{-2}$) and at $\sqrt{s}_{ep} = 225\ GeV$ with $5 < Q^2 < 10\ GeV^2$ and inelasticity $0.35 < y < 0.8$. It turns out that the Colour Dipole Model (CDM) describes the data better than DGLAP-type models. When parameterising the data using analytic functions, a change of the shape of the transverse momentum spectra is observed as a function the pseudorapidity.

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1. Charged Particle Spectra at High $\sqrt{s_{ep}}$

Deep-inelastic scattering (DIS) processes at the ep collider HERA can access small values of Bjorken-x at low photon virtuality Q^2. At the low x region, which is characterised by high densities of gluons and sea quarks in the proton, the parton interacting with the virtual photon may be part of a cascade of partons emitted prior to the interaction. It is expected, that the transverse momentum spectrum of charged particles provides a rather direct probe of the underlying parton dynamics. To investigate the cascade dynamics, charged particle densities as a function of transverse mo-

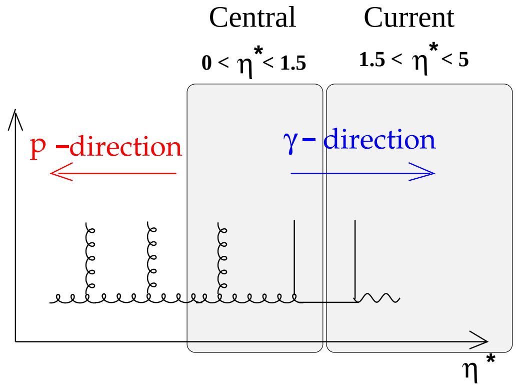

Figure 1: The two pseudorapidity regions: "central" ($0 < \eta^* < 1.5$) and "current" ($1.5 < \eta^* < 5$).

mentum and pseudorapidity were measured in semi-inclusive DIS $ep \rightarrow e^{'}hX$ with H1 detector at DESY for invariant mass of incident electron and proton $\sqrt{s_{ep}} = 319$ GeV [1] in the kinematic range of low photon virtuality Q^2 ($5 < Q^2 < 100$ GeV^2) and small Bjorken x ($10^{-4} < x < 10^{-2}$). To distinguish hadronisation effects from effects related to the parton evolution the measurements are divided into two regions: low p_T^* ($0 < p_T^* < 1$ GeV, predominantly sensitive to hadronisation effects) and high p_T^* ($1 < p_T^* < 10$ GeV, predominantly sensitive to parton dynamics). The p_T^* dependence of the charged particle densities is studied in two different pseudorapidity intervals $0 < \eta^* < 1.5$ and $1.5 < \eta^* < 5$, referred to as the "central region" and "current region" respectively (figure 1). The target region, $\eta^* < 0$, is not accessible in this analysis. In figure 2 are shown the charged particle densities as a function of η^* for two p_T^* ranges with the predictions of the DGLAP-like model RAPGAP [2] based on different Parton Distribution Function (PDF) sets. In the soft p_T^* region, sensible to hadronisation effects, alternative NLO PDFs (HERAPDF1.0 [3], CTEQ6.6 [4], GRV98NLO [5]) show similar results although they predict a somewhat smaller number of particles as compared to calculations using the default LO PDF set CTEQ6L(LO). In general, the predictions are close to the data. At the region, sensitive to parton dynamics (large p_T^*), again differences between the NLO PDF sets are observed, with CTEQ6L(LO) being closest to the data. The differences to the data, however, are larger than the differences between the various PDF predictions. Similar PDF uncertainties are observed when using the CDM model as implemented in DJANGOH. To check the sensitivity to hadronisation effects three sets of fragmentation parameters (ALEPH [6], the Professor tuning tool [7] and default PYTHIA6.424 fragmentation), implemented in the RAPGAP, are compared to the data in figure 3. Significant differences between these three sets are seen in the hadronisation region (soft p_T^*), where the data are best described by

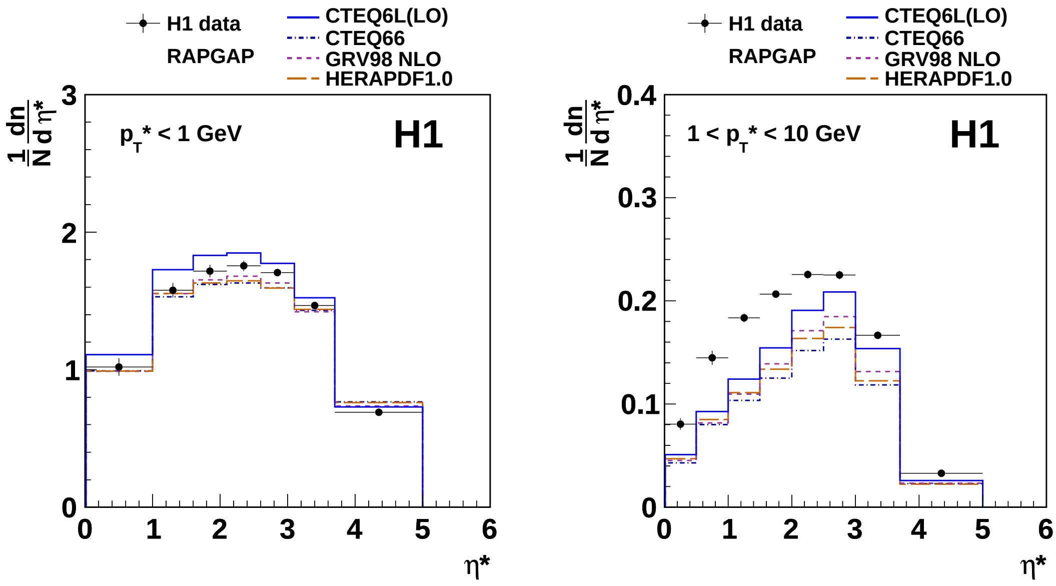

Figure 2: Charged particle density as a function of η^* for $0 < p_T^* < 1$ *GeV* (left) and for $1 < p_T^* < 10$ *GeV* (right) compared to RAPGAP predictions with different proton PDFs.

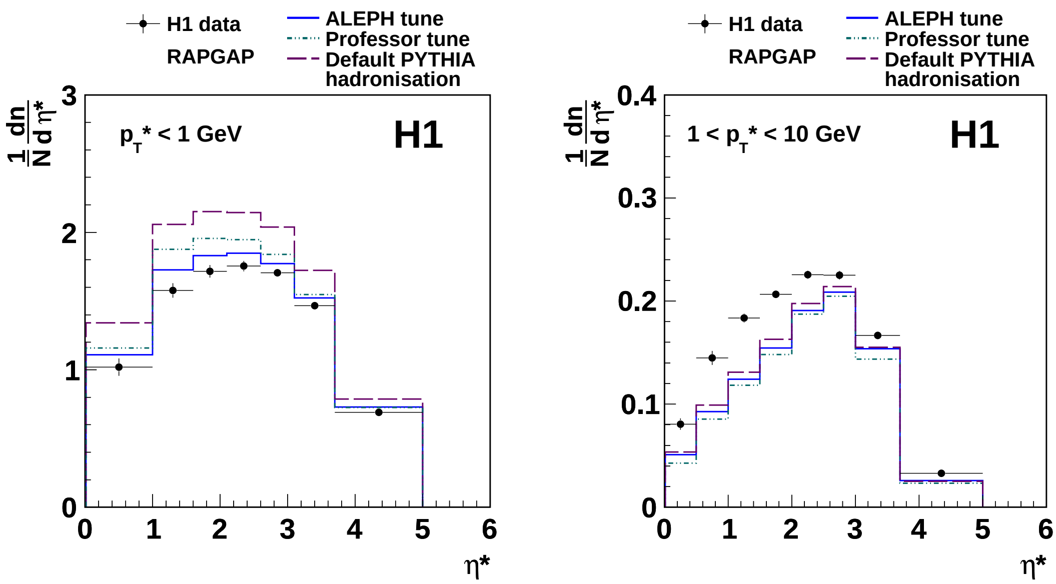

Figure 3: Charged particle density as a function of η^* for $0 < p_T^* < 1$ *GeV* (left) and for $1 < p_T^* < 10$ *GeV* (right) compared to RAPGAP predictions for three different sets of fragmentation parameters.

the ALEPH tune. At large transverse momenta the three sets give similar predictions but none of them describes the data. In figure 4 the charged particle densities as a function of p_T^* are shown for two pseudorapidity ranges: central ($0 < \eta^* < 1.5$) and current ($1.5 < \eta^* < 5$). The measurements are compared to the predictions of the DJANGOH [8], RAPGAP, HERWIG++ [9] and CASCADE [10] generators. DJANGOH provides in general a good description of the data, while only at high p_T^* in the current region deviations from the measurement are observed. The other models fail to

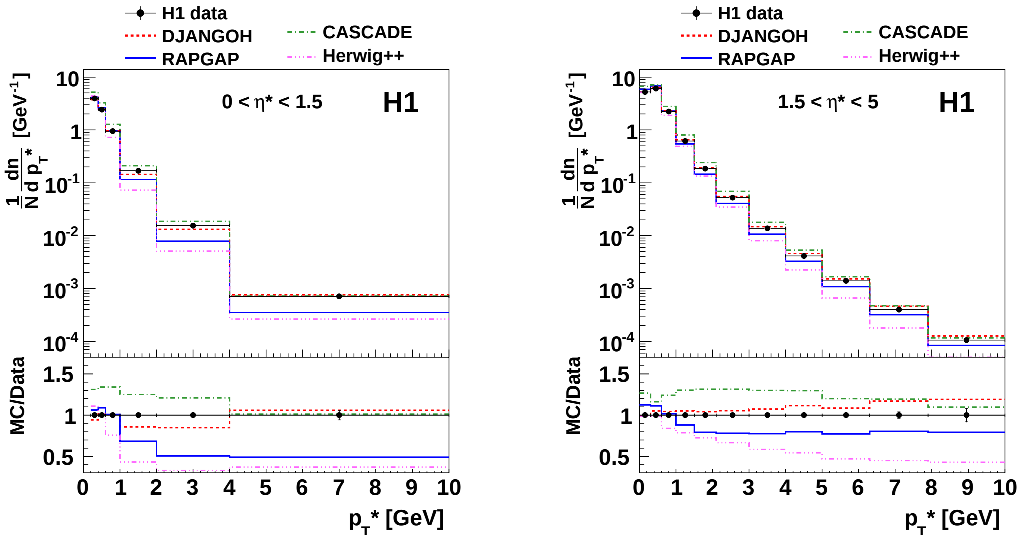

Figure 4: Charged particle density as a function of η^* for $0 < p_T^* < 1$ GeV (left) and for $1 < p_T^* < 10$ GeV (right) compared to RAPGAP predictions for three different sets of fragmentation parameters.

describe the data, with the strongest deviations being observed in the central region. The ratio of RAPGAP to data shows a sharp drop at $p_T^* \approx 1GeV$. The p_T^* spectra predicted by HERWIG++ are even softer than those predicted by RAPGAP. CASCADE in general produces higher particle densities than measured. At $\sqrt{s_{ep}} = 319$ GeV at small p_T^*, the data are reasonably well described by DJANGOH (based on the Colour Dipole Model), as well as by RAPGAP (based on the DGLAP shower evolution). The Colour Dipole Model implemented in DJANGOH is the best among the considered models and provides a reasonable description of the data, but still not good.

2. Charged Particle Spectra at Low $\sqrt{s_{ep}}$

Charged particle production is investigated at H1 at $\sqrt{s_{ep}} = 225$ GeV [11] as well. Aiming to have higher acceptance and better track reconstruction for η^* in the central region, the phase space $5 < Q^2 < 10$ GeV^2, $0.35 < y < 0.8$, $0 < \eta^* < 3.5$ has been chosen. To study the hadroproduction dynamics a phenomenological model is used. According to this model the shape of p_T^* spectra can be described as the sum of exponential (Boltzmann-like) and power-law distributions. The model provides a much better description (figure 5) of the data than the one traditionally used one [12]. The relative contribution of the exponential and power-law terms of the model can be characterized by ratio R of the power-law term alone to the total contribution. In figure 6 the relative contributions R of the power-law term to the charge particle transverse momentum spectra are shown as function of the charged particle rapidity η^*. Close to the virtual photon direction (large values of η^*) the p_T^* spectrum can be described by a power-law term only (its contribution is more than 90%), while at central rapidities the data require a significant exponential (about 45%) contribution. Moreover, the smaller η^*, the larger the exponential contribution which is required to describe the charged particle spectrum.

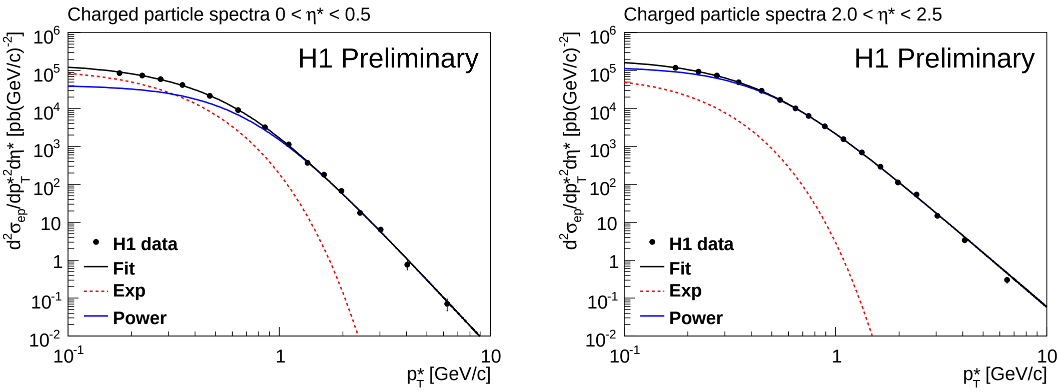

Figure 5: Charged particle double differential cross section, compared to the phenomenologycal model: the red line shows the exponential term contribution and the blue one - the power-law term contribution.

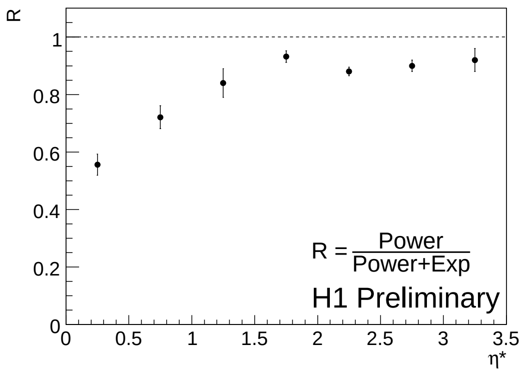

Figure 6: The relative contribution of power-law term.

3. Conclusion

The charged hadron spectra at two invariant mass values of incident electron/positron and proton at low Q^2 and small x are measured in DIS. The data are compared to QCD models with different evolution approaches for simulating the parton cascade and with different hadronisation schemes. The Colour Dipole Model implemented in DJANGOH is the best among the other considered MC models and provides a reasonable though not perfect description of the data. The shape of the transverse momentum spectra is investigated using a phenomenological parameterisation. A significant change of the shape is observed as a function of the pseudorapidity of the charged particles.

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