Measurement of hadron production in Deep Inelastic Scattering

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Measurements of charged particle densities and K_s^0 and Λ production in deep inelastic scattering at HERA are presented and compared to Monte Carlo event generator predictions. The measurements provide sensitive tests for the initial state parton radiation process as well as for the hadronization process.

1. Introduction

In deep inelastic scattering (DIS) at the *ep* collider HERA small values of Bjorken-x can be accessed where the interaction with the virtual photon may originate from a cascade of partons as illustrated in Fig. 1(left). The transverse momentum spectrum of charged particles measured in deep inelastic scattering is a sensitive probe to parton radiation at the high p_T tail of the spectrum while at small p_T the contribution from hadronization becomes significant. The measurement of strange particle production provides additional information on the hadronization process.

2. Charged Particle Spectra

The charged particle spectra [1] are presented in the hadronic centre-of-mass frame (HCM), to minimize the effect of the transverse boost from the virtual photon. Particles with $\eta^* > 0$ belong to the current hemisphere and particles with $\eta^* < 0$ originate from the target (proton remnant) hemisphere (Fig.1 right).

The charged particle densities as a function of η^* are shown separately for $p_T < 1$ GeV and for $1 < p_T < 10$ GeV in Fig. 2. The sensitivity to hadronization effects obtained with RAPGAP [2] (based on the DGLAP shower evolution) with three sets of fragmentation parameters are compared to the data in Fig. 2: parameters tuned by ALEPH [3], by the Professor collaboration [4] and from default PYTHIA6.424 [5]. Significant differences are visible in the soft p_T region: the data are best described by the ALEPH

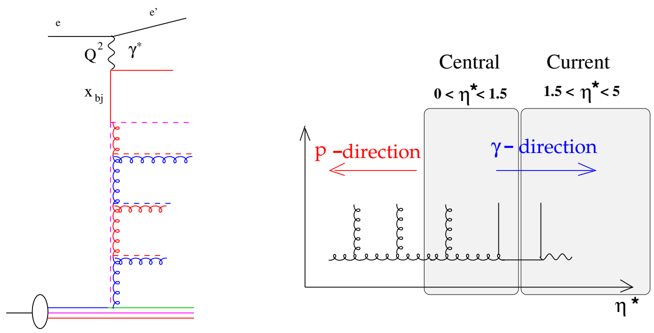

Fig. 1. Left: Schematic diagram for DIS at small x. Right: pseudorapidity regions relevant for charged particle spectra

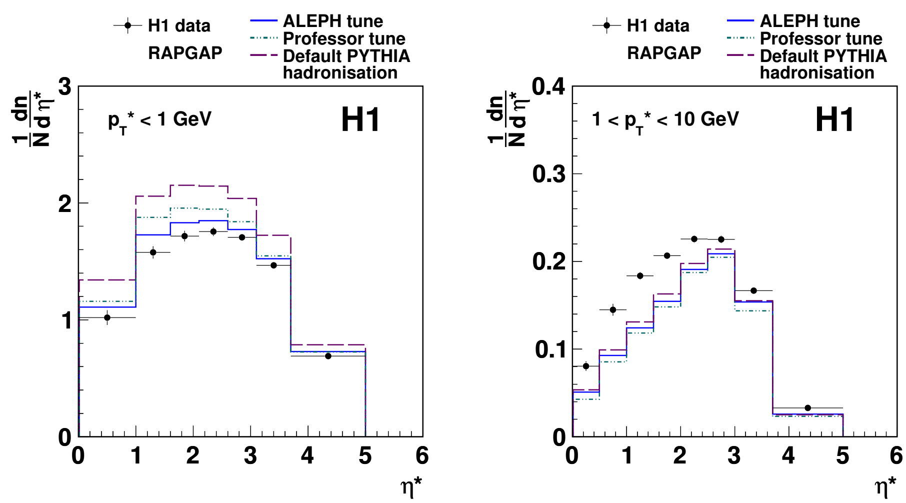

Fig. 2. Charged particle density as a function of η^* compared to RAPGAP predictions for three different sets of fragmentation parameters. The predictions are obtained using CTEQ6L(LO) PDF.

tune. At large transverse momenta none of the fragmentation parameter sets describes the data. In Fig. 3 the charged particle densities are shown as a function of η^* in (x, Q^2) intervals for the range $1 < p_T < 10$ GeV. The shape of the distributions changes with x and Q^2. At small values of x and Q^2 the measured distributions are less dependent on η^* compared to the region at high x and Q^2. However, none of the models describes all aspects of the data. The prediction of CASCADE [6] (based on CCFM) agrees reasonably well with the measurement at low x and Q^2, but overshoots the

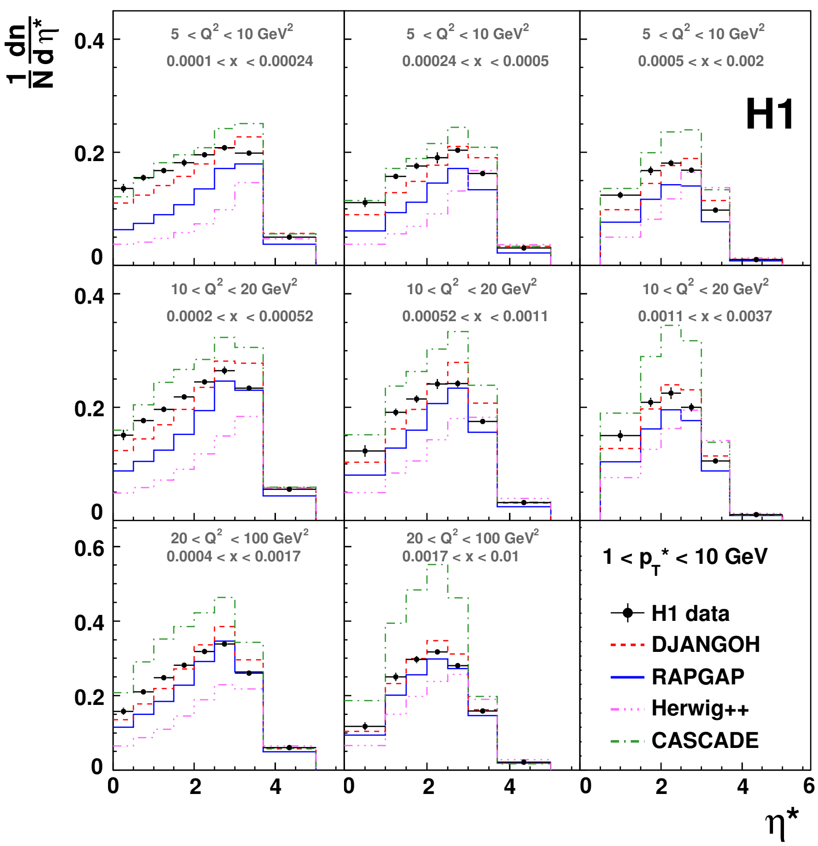

Fig. 3. Charged particle density as a function of η^* for $1 < p_T < 10$ GeV for eight intervals of Q^2 and x compared to different Monte Carlo generator predictions.

data significantly as x or Q^2 increases.

In Fig. 4 the charged particle densities are shown for two pseudorapidity intervals, $0 < \eta^* < 1.5$ (central) and $1.5 < \eta^* < 5$ (current) as a function p_T. The shapes of the distributions in the two pseudorapidity ranges are similar. Only DJANGOH [7] (based on the Color Dipole Model) describes reasonably well the data but shows deviations from the measurements at high pt in the current region. The other models fail to describe the data, with the strongest deviations being observed in the central region. CASCADE in general produces higher particle densities than measured. In summary, at small p_T , the data are reasonably well described by DJANGOH, as well as by RAPGAP. At high p_T and at low η^*, RAPGAP severely undershoots the data. The differences are most pronounced at lowest x and Q^2, and decrease

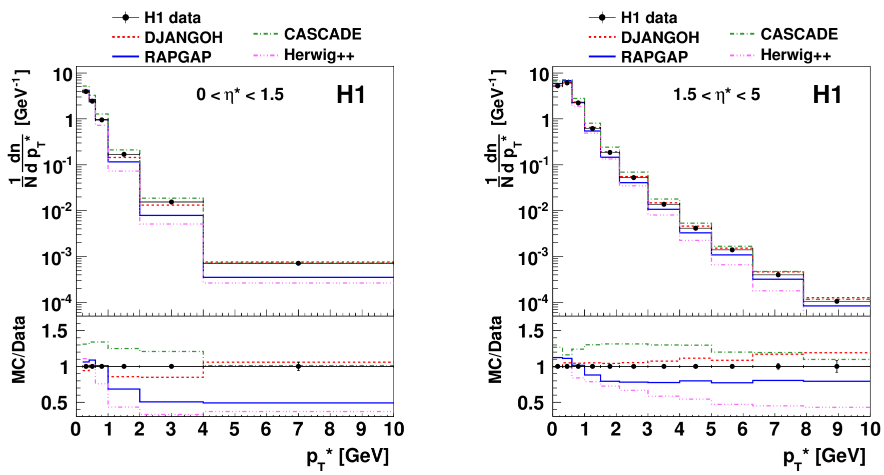

Fig. 4. Charged particle density as a function of p_T for different η^* ranges compared to different Monte Carlo generator predictions.

with increasing x and Q^2 values. CASCADE gives a reasonable description only at the lowest x and Q^2, but overall predicts higher charged particle densities than observed in data. The Color Dipole Model implemented in DJANGOH is the best among the considered models and provides a reasonable description of the data.

3. Measurement of K_s^0 and Λ Baryons

In DIS at HERA strange quarks may be created in the hard sub-process by originating directly from the strange sea of the proton in a quark-parton-model (QPM) like interaction, from boson-gluon-fusion or from the decays of heavy flavored hadrons. The dominant source for strange hadron production, however, is the creation of an $s\bar{s}$ pair in the non-perturbative fragmentation process. In the modeling of the fragmentation process strange quarks are suppressed compared to the production of light quarks, controlled by the strangeness suppression factor λ_s.

The K_s^0 mesons are measured by the kinematic reconstruction of its decay $K_s^0 \to \pi^+\pi^-$ in $7 < Q^2 < 100$ GeV^2, $0.1 < y < 0.6$. The ratio of the differential cross section for K_s^0 [8] production to inclusive charged particle production is shown in Fig. 5 as a function of η and p_T compared to DJANGOH using three different values of the suppression factor λ_s ranging from 0.220 to 0.35. The ratio as a function of η is well described and a high sensitivity on the value of λ_s is observed. However, the shape in p_T is not

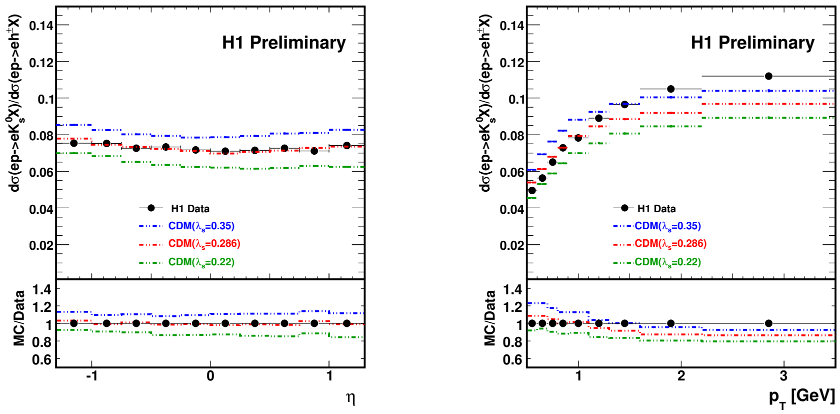

Fig. 5. Ratio of K_s^0 to charged particle production as a function of η and p_T in comparison to DJANGOH (CDM) for three different values of λ_s.

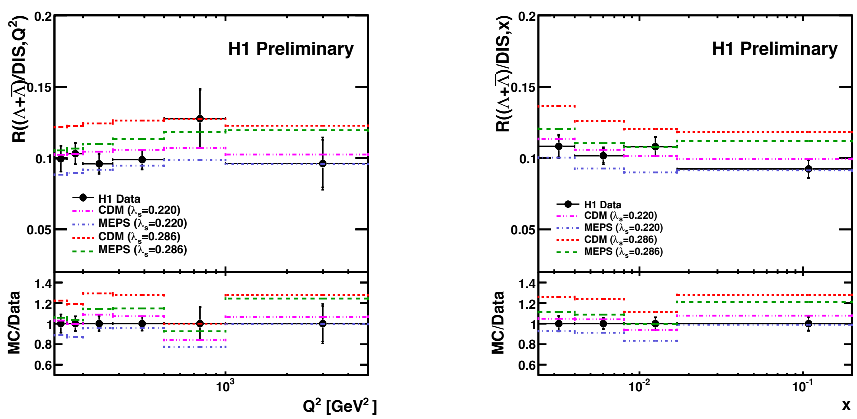

Fig. 6. Ratio R(DIS) of Λ production to the inclusive DIS cross section as a function of (left) the photon virtuality squared Q^2 and (right) Bjorken scaling variable x in comparison to RAPGAP (MEPS) and DJANGOH (CDM) with two different values of λ_s.

well reproduced.

Λ baryons are measured by their decay $\Lambda \to p\pi^-$ in $145 < Q^2 < 20000$ GeV^2, $0.2 < y < 0.6$. In Fig. 6 the ratio of Λ production to inclusive DIS [9] is shown as a function of x and Q^2 and compared to the expectations from RAPGAP and DJANGOH for $\lambda_s = 0.286$ and $\lambda_s = 0.220$. The best description is provided by DJANGHO using $\lambda_s = 0.220$, different to what is observed for K_s^0 production, where the best description is for $\lambda_s = 0.286$.

4. Summary

Charged particle densities in *ep* collisions have been measured and compared to Monte Carlo event generators. While at small p_T hadronization is dominant and the parameters can be tuned to describe the measurements, at larger p_T hadronization plays little role and parton radiation from the initial state becomes dominant. None of the Monte Carlo generators studied is able to describe the spectrum of charged particles over the full kinematic range.

Strange particle production in DIS is sensitive to the hadronization process and the measurements can be used to determine the suppression of strange particle production compared to pions. The suppression factors which best describe the measurements are different for K_s^0 and Λ baryons, indicating that the modeling of strange particle production is more complicated than implemented in the investigated models.

It is important to note, that charged and strange particle production in DIS does not suffer from contributions of multiparton interactions compared to hadron-hadron collisions at the LHC.

Acknowledgments

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