# Some Properties of the CCFM Monte Carlo - SMALLX

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**Abstract**

Properties of the B.Webber Monte-Carlo generator for DIS - SMALLX are investigated. We compare CCFM evolution implemented by the generator with the structure function $F_2$ measured at HERA. In addition, having implemented JETSET hadronization of the final partonic state provided by SMALLX we compare basic characteristics of the hadronic states with the HERA data.

In a recent paper [1] we described a study of the Monte Carlo program SMALLX [3]. This program generates the deep inelastic lepton-nucleon scattering (DIS) events at small values of the Bjorken variable $x_B$ using CCFM [6] branching scheme with angular ordering of the gluon emissions. Our study was confined to open charm production and the partonic final states. We fixed the generation parameters by requirement that charm structure function $F_2^{c\bar{c}}(x, Q^2)$ measured at HERA [2] is correctly described. This includes the parameters of the initial gluon distribution $\mathcal{F}^0$, for which the following form is postulated:

$$x_0 \mathcal{F}^0(x_0, \mathbf{k}_{\perp 0}, Q_s) = A_0 x_0^{-p_0} (1 - x_0)^{p_1} exp(-2\mathbf{k}_{\perp 0}^2 / Q_s^2)$$

where the parameter $Q_s$ also plays the role of the collinear cutoff $q_0$ for the first real gluon emission, and the normalization constant $A_0$ is determined from the momentum sum rule

$$P(Q_s) = \int_0^1 dx \; xF(x, Q_s) = 0.5.$$

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Above $F(x,Q)$ is the usual gluon structure function (gluon density) :

$$F(x,Q) = F(x,Q,q_0) \equiv \int d^2\mathbf{k}_\perp \ \mathcal{F}(x,\mathbf{k}_\perp,Q,q_0)\Theta(Q-|\mathbf{k}_\perp|).$$

We have fixed $Q_s = 1$ GeV and $p_1 = 5$ motivated by large $x$ behavior of the conventional gluon distribution. The parameter $p_0 = 0$ was chosen to obtain best possible description of $F_2^{c\bar{c}}$ at $Q^2 = 12$ GeV$^2$. The infrared cutoff parameter $Q_0$ has been set to 1 GeV.

Our studies have shown relevance of the CCFM approximation in the description of exclusive processes in DIS at HERA. The most spectacular results are the azimuthal angle decorrelation for the heavy quarks - a direct consequence of $k_\perp$ - diffusion along the gluon chain in CCFM scheme, and forward jet production.

The present study is an extension of the previous work to production of the light quarks. In addition we provided the original Webber code with hadronisation via JETSET7.4. This has been done in the usual way, by connection of the quark and the diquark in the proton remnant with anti-quark and quark from boson gluon fusion into two chains which include gluons emitted along the chain.

The first obstacle we encountered was inability to find any set of parameters $p_0, p_1, Q_s$ and $Q_0$ which would provide a good or even passable description of the proton structure function $F_2(x,Q^2)$. In general $F_2$ is much too steep at very small values of $x$. In principle we could achieve some reduction of the cross section at small $x$ increasing the value of $Q_0$ however even 1 GeV seems to be rather high for the infrared cutoff. In addition such a change makes the discrepancy at high values of $x$ even worse. The fact that SMALLX gives a passable description of $F_2^{c\bar{c}}$ and at the same time completely misses $F_2$ data (Fig. 1) can be only partially attributed to the higher $x$-range covered by the charm production data and much bigger errors on the data points. In spite of the failure to explain the differential cross section for DIS, we decided to investigate some properties of the final hadronic states produced by the SMALLX generator. In Fig.2 we show the transverse energy flow in several bins of $x$ and $Q^2$ compared with the H1 data [13], ARIADNE [11] and LEPTO [12] simulations. While ARIADNE describes the data very well indeed, SMALLX gives too much transverse energy in the central and forward (i.e. in the direction of incoming proton) region of pseudorapidity.

As SMALLX does not describe correctly DIS cross section, its results concerning cross section of the forward jet production, are not meaningful. However some features of the hadronic final states it generates are still of interest. As we have shown in [1], there are significantly more gluons in the angular ordering mode (CCFM) of the SMALLX generation in comparison with DGLAP-like mode. This leads directly to significant difference of the total forward jet cross sections for the two generation modes. Is it possible to observe enhanced gluon emission accompanying forward jet production ? How does CCFM compare in this respect with the other generation schemes (ARIADNE, LEPTO) ?

To answer these questions we studied the transverse energy flow in presence of the fast forward high transverse momentum $p_t$ particle. As shown in [14] a particle

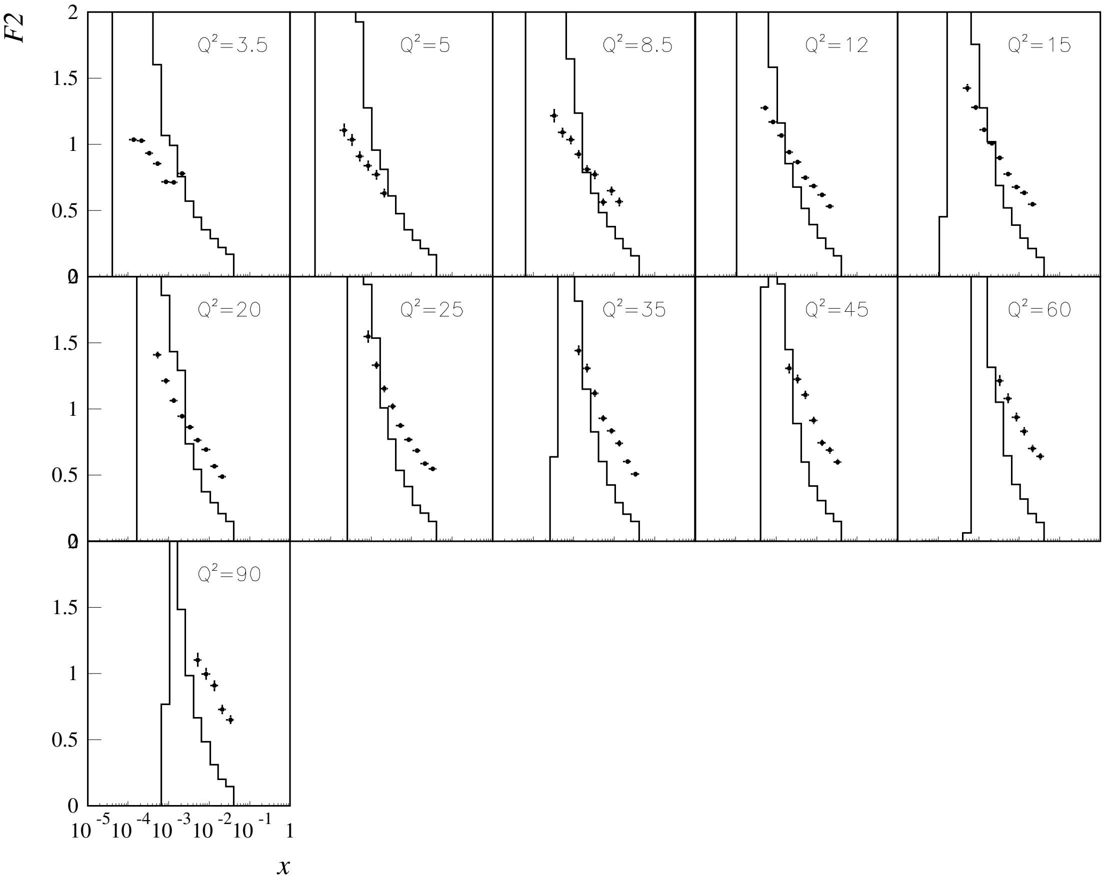


Figure 1: The $F_2(x, Q^2)$ structure function : H1 data compared to the SMALLX generator results (full line) in several $(x, Q^2)$ bins.

with $p_t \geq 1.0$ GeV, proton momentum fraction $p/p_{proton} \geq 0.01$ and the angle with respect to proton direction in the range $5 \leq \Theta \leq 25$ degree (LAB frame) is strongly correlated with presence of the forward jet. In Fig.3 we show the difference between the transverse energy flow for events which contain fast forward particle defined as above (excluding this particle) and the transverse energy flow for all events in the same kinematic range $(0.0002 \leq x \leq 0.00235)$. We may expect that substraction operation reduces effects of the above mentioned flaw in the description of $E_t$-flow by SMALLX and LEPTO. The curves representing SMALLX, ARIADNE and LEPTO generator results differ significantly. Comparing ARIADNE with LEPTO we see that in LEPTO case transverse momentum of the fast forward particle is compen-

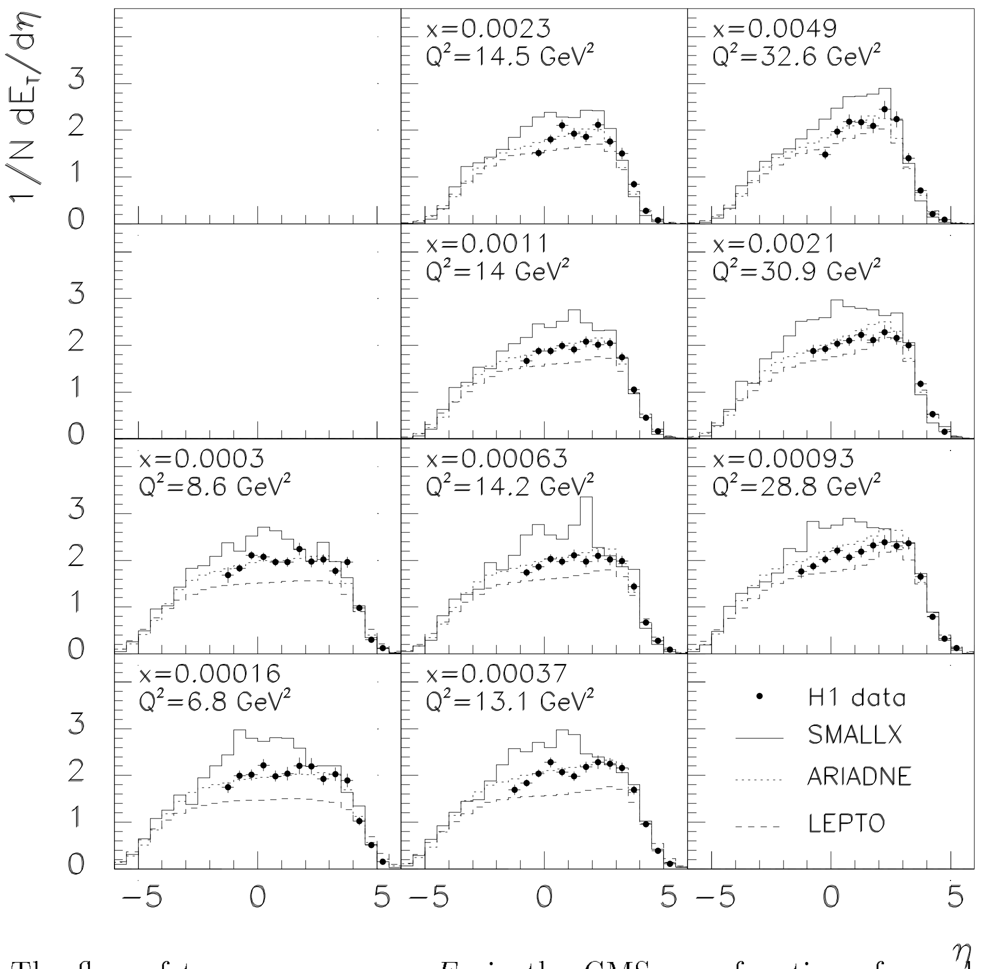


Figure 2: The flow of transverse energy $E_T$ in the CMS as a function of pseudorapidity $\eta$. The proton remnant direction is to the left. Shown are nine different kinematic bins. The distributions are normalized to the number of events $N$ in each case. Together with the H1 data points simulations by SMALLX, ARIADNE and LEPTO generators are shown.

sated mainly in the backward region ($\eta \geq 0$) while in ARIADNE case we observe increased emission of hadrons in the forward direction i.e. transverse momentum compensation is mostly local. This should be expected, because with $p_t$-ordered emission along the gluon ladder (LEPTO) large part of the transverse momentum compensation is due to the $q\bar{q}$ pair from the box. The compensation pattern in the SMALLX generator is similar to that of ARIADNE - the difference is mainly in the $E_t$-flow level.

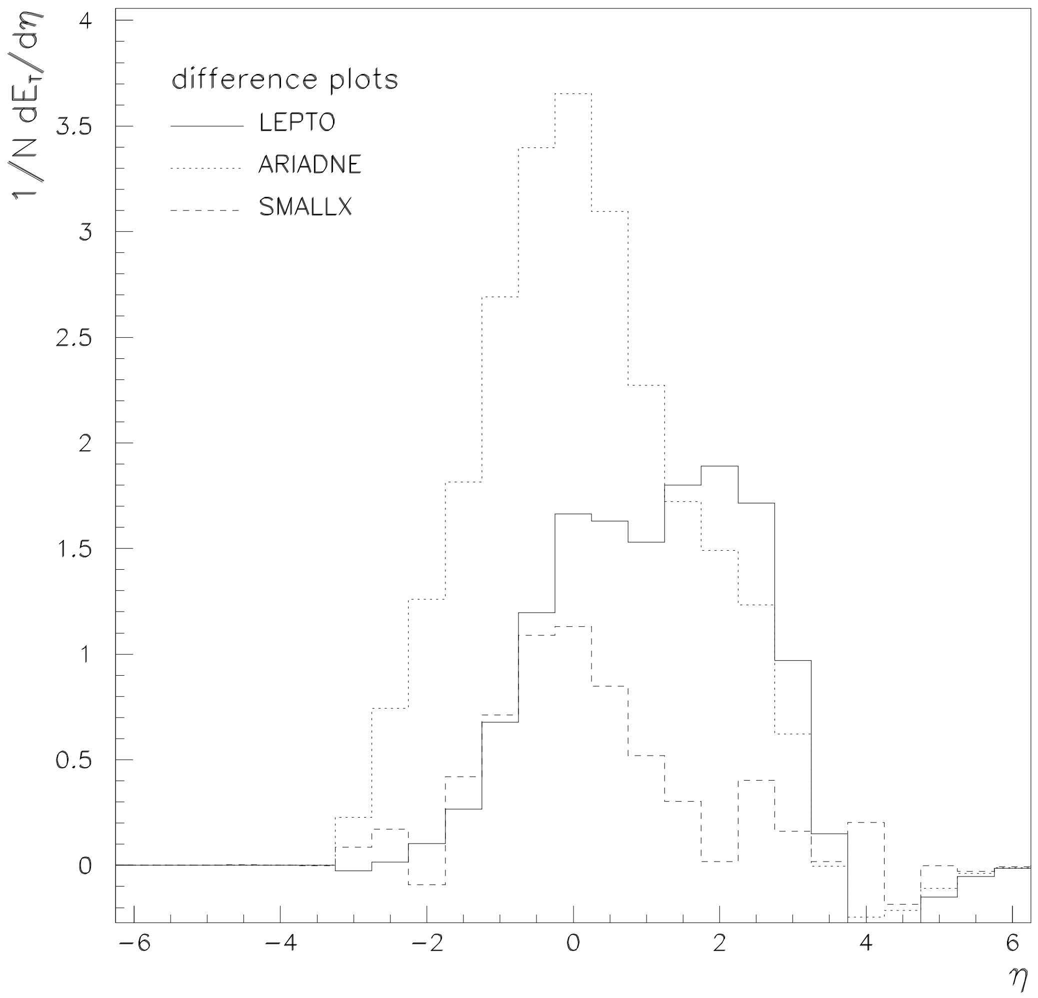


Figure 3: The difference between transverse energy flow for events selected by fast forward particle and events without selection. It is shown as a function of the $\gamma$p CMS pseudorapidity. The proton remnant is to the left.

The above example shows, that correlations provide powerful tool to discriminate between models of the particle production in DIS. The failure of the present version of SMALLX to describe the basic properties of the DIS at smallx $x$ in not a surprise (see e.g. [15]). The better implementation of the CCFM evolution scheme is on the way [16].

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