STRUCTURE FUNCTIONS AND $E_\perp$-FLOW IN THE LINKED DIPOLE CHAIN MODEL

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Abstract

In this talk I will present some results from The Linked Dipole Chain Model (LDC) for DIS. The model which has as its starting point results by Catani, Ciafaloni, Fiorani and Marchesini, (CCFM), provides an interpolation between regions of high Q^2 (DGLAP) and low x - moderate Q^2 (BFKL). It gives a unified treatment of conventional DIS, boson-gluon fusion and hard photon-proton scattering. It is also very suitable for MC simulations.

I will start with a short description of the dipole formalism in e^+e^- annihilation. I continue with the DIS process; first the basic concepts, and then I describe briefly the CCFM Model and the transition to the LDC Model. Finally I will present some of the results that we have obtained with a computer implementation of the LDC model. All of the results are related to the structure function, and I put special emphasis on the $E_\perp$-flow and the differences that occur when going from a constant coupling to a running coupling.

The Linked Dipole Chain Model has been developed together with Bo Andersson, Gösta Gustafson and Hamid Kharraziha.

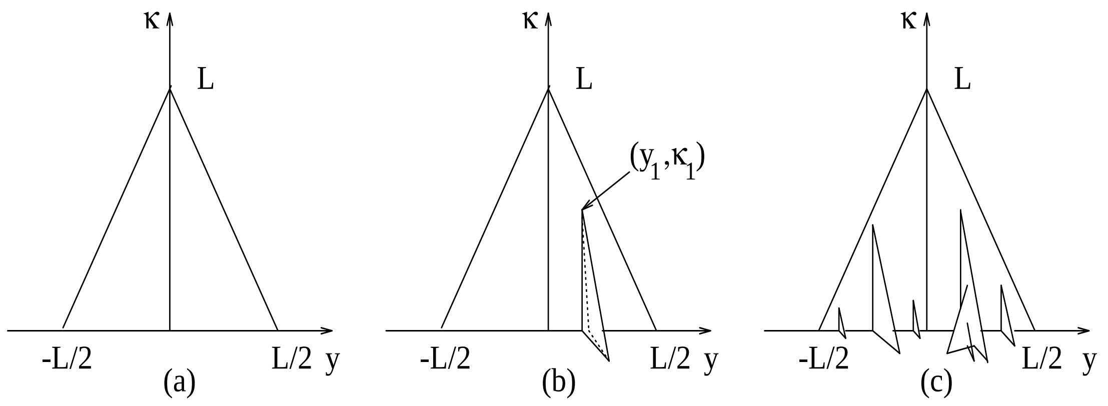

Figure 1: *(a) The phase space available for a gluon emitted by a high energy $q\bar{q}$ system is a triangular region in the y-κ plane. $L = \log(W^2)$ (b) If one gluon is emitted at (y_1, κ_1) the phase space for a second (softer) gluon is represented by the area of this folded surface. (c) Each emitted gluon increases the phase space for the softer gluons. The total gluonic phase space can be described by this multifaceted surface.*

1 The dipole formalism in e^+e^- annihilation

The cross section for *single gluon* emission is similar to the photon emission from a classical dipole[1)]. Building on results from the St. Petersburg group[2)], this dipole scheme has been generalized to multigluon emission[3)]. If we introduce the Lorentz invariant transverse momentum $k_\perp^2 = W^2(1-x_1)(1-x_3)$ and rapidity $y = \log((1-x_1)/(1-x_3))$, where W is the cms energy and x_1 and x_3 are the cms energy fractions of the q and $\bar{q}$, and define $\kappa = \log(k_\perp^2)$, the cross section can now be written as $dp \simeq (4\alpha_s/3\pi)\cdot d\kappa \cdot dy$. We also get that the available phase space for emission of a single gluon is approximately a triangle in the (y,κ)-plane, cf fig 1a. Emission of the first gluon means adding a folded triangle to the first, cf fig 1b, and after several emissions we obtain a complex figure with many folds "sticking out" as in fig 1c.

2 The DIS process

2.1 Basic concepts

The essential features of the DIS process can be illustrated in a *fan diagram*, which is shown in fig 2a. The almost vertical lines, denoted by k:s, describe the *propagators*. These are gluons that while connecting the photon and the proton regions emit other gluons, the *initial state radiation*. These initial state gluons, denoted by q:s, will in their turn emit new gluons, the *final state radiation*. For a DIS process, we want to calculate the partonic flux, or equivalently the structure function F. The procedure to do this is often formulated in terms of the DGLAP equations[4)]. The process can also be formulated as laying out chains in the logarithmic phase

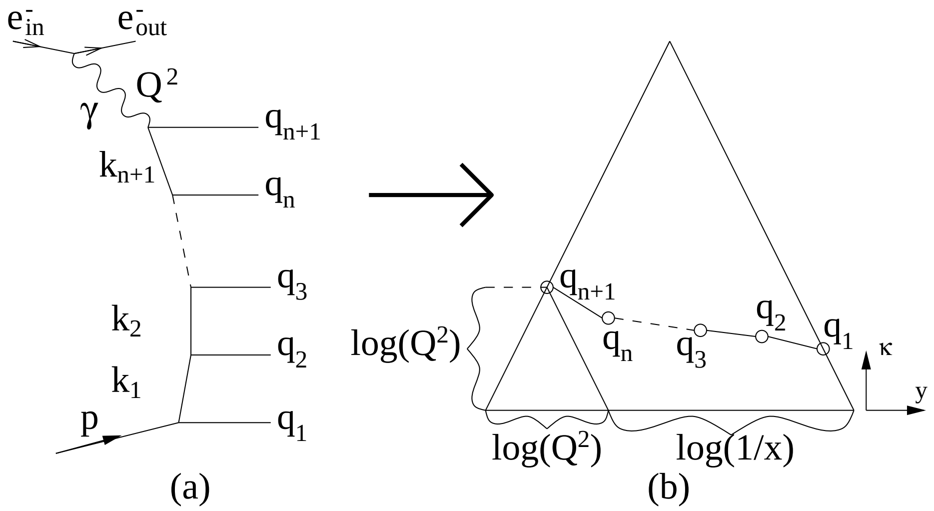

Figure 2: *A DIS process illustrated (a): by a fan diagram and (b): in the logarithmic phase space.*

space. This is shown in fig 2b. For every emission along the chain we get a weight, and the contribution from one chain to the structure function is a product of the weights for the emissions along the chain. The value of the structure function for given Q^2 and x, ie a given triangle, is a sum over the contributions from the different chains that can be laid out inside the triangle.

2.2 The CCFM Model

The CCFM Model[5)] is an interpolation between the DGLAP scheme[1)] and the BFKL approach[6)]. This means that it covers large and small values of x *and* Q^2. A central result in the CCFM Model is an expression for the weight for a propagator to emit a gluon as initial state radiation. This expression is a product of the conventional bremsstrahlung probability and a non-eikonal formfactor. This factor can be interpreted as a Sudakov factor which prohibits initial state radiation in certain parts of the phase space.

2.3 The LDC Model

By considering the initial state gluons as constituents of colour dipoles, the Linked Dipole Chain Model[7)], includes more gluons into the final state radiation compared to the CCFM Model. It also means that in the LDC Model there is an ordering of the real gluons (the dipole constituents) not only in $p_+ = p_0 + p_l$ as in the CCFM Model, but also an ordering in $p_- = p_0 - p_l$. Since the set of initial state gluons in the LDC model is smaller than the corresponding set in the CCFM Model, we have to sum over all those CCFM contributions that give the same set in the LDC Model. It turns out that by doing that we get rid of the non-eikonal formfactor, and we are now left with a chain of steps up and down in transverse momentum, fig 3.

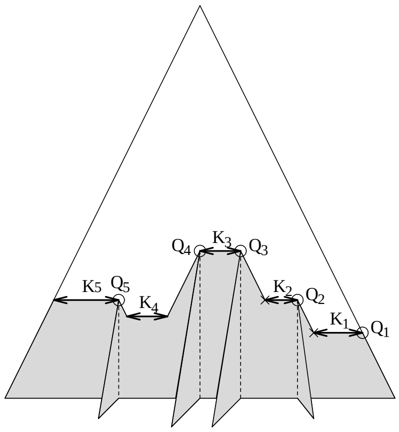

Figure 3: *A gluon chain in the LDC Model. The arrows K_i represent the propagators or links that connect the real initial state gluons Q_i. These real gluons are the constituents of the primary dipoles that will emit the final state radiation (in the shaded area) .*

3 Results

We start by studying the structure function itself. In fig 4a we compare the x dependence for the whole structure function to that part of the structure function where only the DGLAP contribution is included. We note that for large x there is not much difference, but for small x the difference is significant and we notice that we get a BFKL-like behaviour for the structure function. In fig 4b we compare the result for the stucture function when using a constant and a running coupling. In fig 5 we study the mean path and the deviations from the mean for two different sizes of the available phase space. We note that for large $\log(Q^2)$ and moderate x we get a DGLAP like behaviour, but when $\log(Q^2)$ is small and x small we see there is a large part of the rapdity interval where we have a limited $E_\perp$-flow. In fig 6 we plot the structure function as a function of $\kappa = \log(k_\perp^2)$. In order to get this result we have put $\log(Q^2) = 0$ and study the situation for $\log(1/x)$ =15, 20, 30 and 40. We have included only those chains where the right edge of one of the links is in the central rapidity bin. κ is the $\log(k_\perp^2)$ of this central link. We see that by going from a constant coupling (in the left figure), to a running (in the right figure), we also change the shape of the structure function from a Gaussian (random walk) to an exponential. Finally in fig 7 we plot for $\log(Q^2) = 6$ and $\log(1/x) = 6$ the transverse energy of the primary gluons as a function of their rapidity. In fig 7a we have used a constant coupling and in fig 7b a running coupling. We have taken Λ to be $200MeV$. We note that a *running coupling favours a more limited $E_\perp$-flow.*

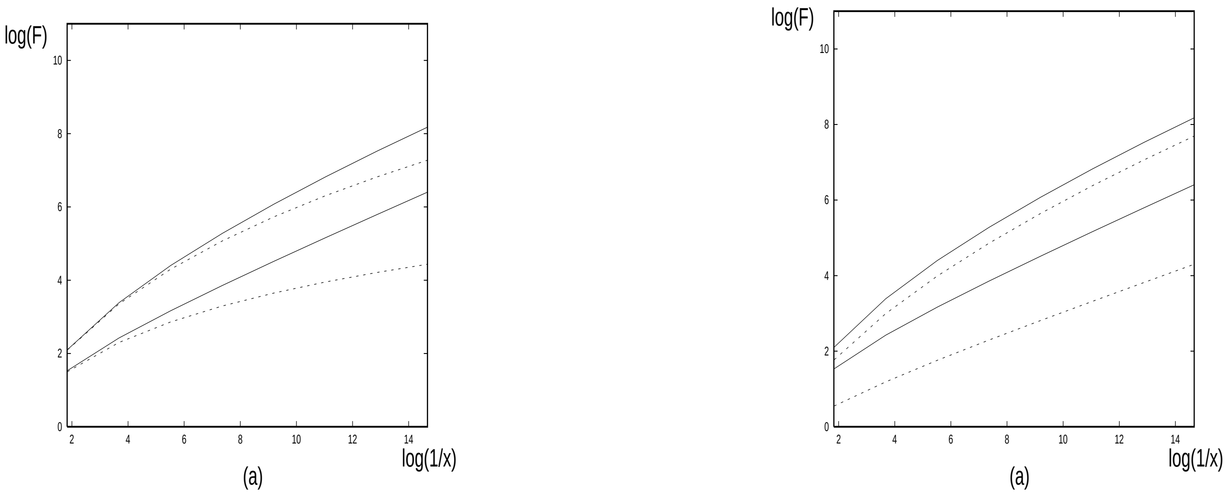

Figure 4: *(a) The* $\log(1/x)$ *dependence for the logarithm of the structure function F, when the coupling is running. Dashed lines (lower:* $\log(Q^2) \approx 4$*, upper:* $\log(Q^2) \approx 12$*) denote the DGLAP contribution and solid lines (lower:* $\log(Q^2) \approx 4$*, upper:* $\log(Q^2) \approx 12$*) all contributions. (b) The* $\log(1/x)$ *dependence for the logarithm of the structure function F, when all contributions are included. Dashed lines (lower:* $\log(Q^2) \approx 4$*, upper:* $\log(Q^2) \approx 12$*) denote the result for constant coupling and solid lines (lower:* $\log(Q^2) \approx 4$*, upper:* $\log(Q^2) \approx 12$ *) denote running coupling*

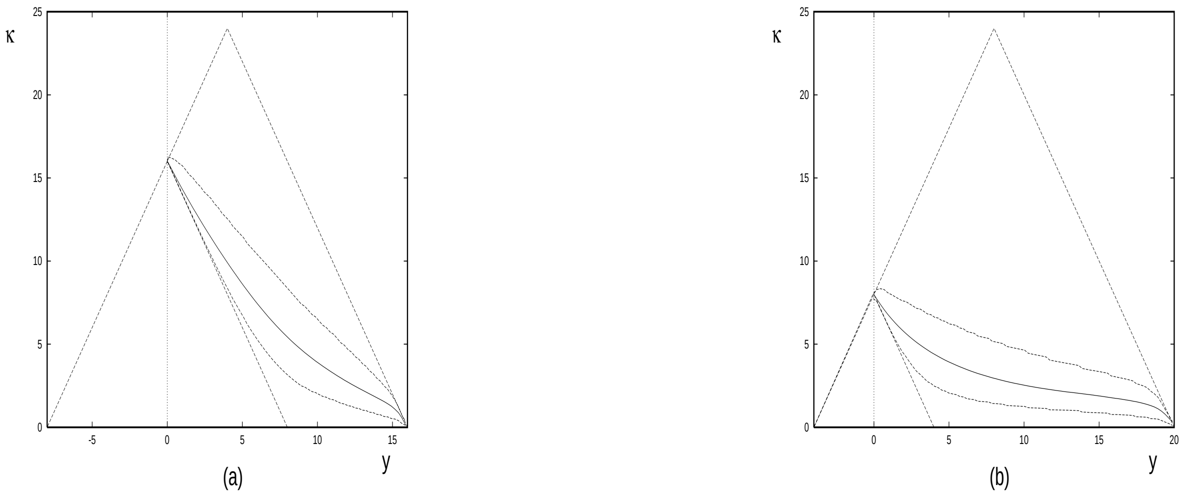

Figure 5: *The mean path and deviations from it, described in the phase space for (a)* $\log(Q^2) = 16$*,* $\log(1/x) = 8$ *and (b)* $\log(Q^2) = 8$*,* $\log(1/x) = 16$

4 References

1) For a review, see Yu.L. Dokshitzer, V.A. Khoze, A.H. Mueller and S.I. Troyan, Basics of Perturbative QCD (Editions Frontières, Gif-sur-Yvette, 1991)

2) Ya.I. Azimov, Yu.L. Dokshitzer, V.A. Khoze and S.I. Troyan, Phys. Lett. B165 (1985) 147

3) G. Gustafson, Phys. Lett. B175 (1986) 453; G. Gustafson and U. Pettersson, Nucl. Phys. B306 (1988) 746; B. Andersson, G. Gustafson and L. Lönnblad, Nucl. Phys. B339 (1990) 393

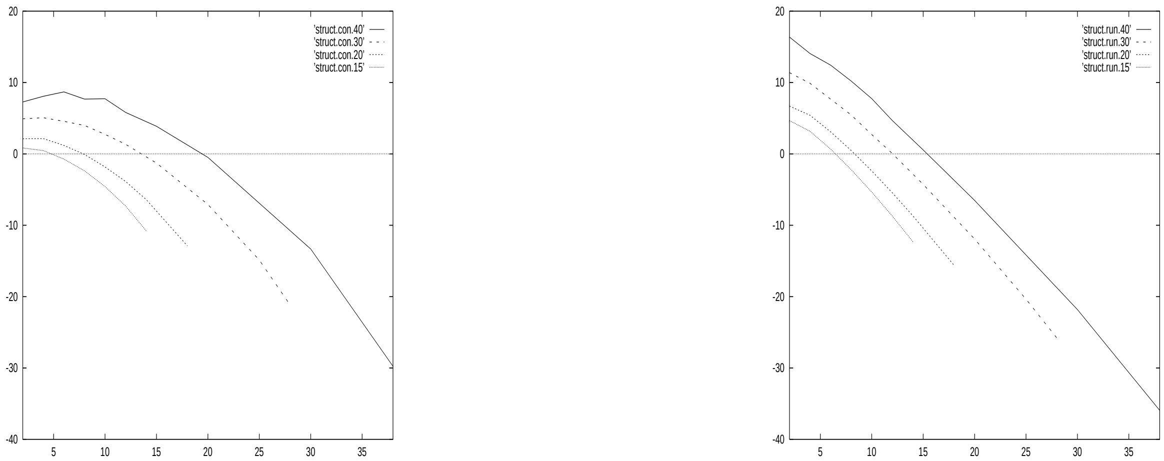

Figure 6: *The logarithm of the structure function (at the y-axis) as a function of* $\kappa = \log(k_\perp^2)$ *(at the x-axis), where* κ *is the height of the central link. The left figure is for constant coupling and the right figure is for running coupling.*

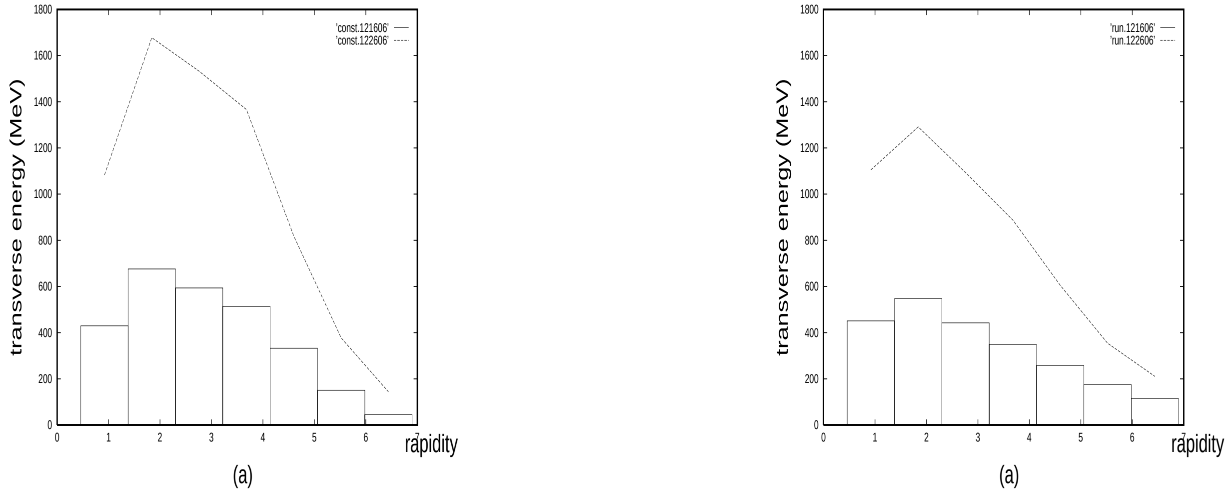

Figure 7: *The transverse energy (in MeV) as a function of rapidity. Boxes mark the average and the lines mark the deviations from the average. (a) is for constant coupling and (b) is for running coupling.*

4) G. Altarelli and G. Parisi, Nucl.Phys. B126 (1977) 298

5) M. Ciafaloni, Nucl. Phys. B296 (1988) 49; S. Catani, F. Fiorani and G. Marchesini, Phys. Lett. B234 (1990) 339; Nucl. Phys. B336 (1990) 18

6) E.A. Kuraev, L.N. Lipatov and V.S. Fadin, Zh. Eksp. Teor. Fiz. 72 (1977) 373 [Sov. Phys. JETP 45 (1977) 199]; Ya.Ya. Balitsky and L.N. Lipatov, Yad. Fiz. 28 (1978) 1597 [Sov. J. Nucl. Phys. 28 (1978) 822]

7) B. Andersson, G. Gustafson and J. Samuelsson, Lund preprint LU TP 95-13, to be published in Nuclear Physics B; B. Andersson, G. Gustafson, H. Kharraziha and J. Samuelsson, Lund preprint LU TP 95-34, to be published in Zetschrift für Physik