The Colour-Dipole model and the ARIADNE program at high Q^2

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Abstract: I present a modification of the Colour Dipole Model for DIS as implemented in ARIADNE to better describe events at high Q^2.

1 Introduction

Since the start of the HERA machine, the ARIADNE [1] program has generally been regarded the event generator giving the best overall description of the measured DIS hadronic final states. For most observables it gives a better reproduction of experimental results than more conventional generators such as HERWIG [2] and LEPTO [3] which implements initial- and final-state parton showers based on DGLAP evolution [4]. This has in particular been true in the region of small x and Q^2, and it has often been taken as an indication that DGLAP evolution is inappropriate for this region. The fact that ARIADNE has the feature of *non-ordering of transverse momenta* in common with the BFKL evolution [5], has also been taken as an indication that the latter is a more correct description of small-x evolution

As the experimental statistics increased also for events at high Q^2, where we assume that our description of the underlying physics is on more solid theoretical grounds, it became apparent that the ARIADNE program was unable to describe this data [6]. Even in the so-called Current Breit Hemisphere (CBH), where the events are expected to look much like half an event in an e^+e^- collision at the same Q^2 [7], the ARIADNE program gave far too little transverse momentum, despite the fact that the same program gives a very good description of e^+e^- data e.g. from LEP.

In this paper I will comment on the reason of this poor description of data at high Q^2, and present a modification of the underlying Colour-Dipole Model (CDM) for DIS [8]. The resulting improvement in the reproduction of measured data is presented elsewhere in these proceedings.

2 The problem

In the CDM, it is assumed that all gluon radiation in a DIS event can be described in terms of dipole radiation between the struck quark and the proton remnant, much in the same way as the radiation in a hadronic e^+e^- collision can be described as dipole radiation from the initial quark and anti-quark. The main difference is that, while in e^+e^- the initial $q\bar{q}$-pair is essentially point-like, the proton remnant in a DIS event is an extended object.

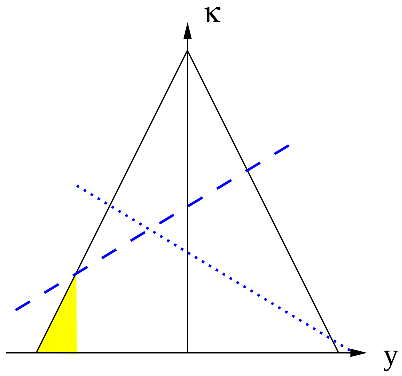

Figure 1: *The phase space available for final state particles in DIS in the* (κ, y) *plane.* $\kappa = \ln(q_\perp^2/\Lambda^2)$, *y is rapidity in the hadronic CMS.*

Looking at the phase space available for gluon radiation in a DIS event (conveniently described as an approximately triangular area in the plane of rapidity and logarithm of the transverse momentum of the emitted gluon in figure 1), it is ultimately limited by the momenta (given here in light-cone components) of the incoming virtual photon $(Q_+, -xP_-, \vec{0})$ and proton $(0, P_-, \vec{0})$. In the emission of a gluon with momentum $(q_+, q_-, \vec{q}_\perp)$, the phase space restriction is given by $q_+ = q_\perp e^y < Q_+$ and $q_- = q_\perp e^{-y} < P_-$. But since the proton remnant is an extended object, say with transverse extension $1/\mu \sim 1$ fm, it is reasonable to assume that the gluon only can access a fraction of the negative light-cone momentum of the remnant. Just as radiation of short wavelengths from an extended antenna is suppressed, we get an extra phase space restriction from the condition that the gluon with a transverse wavelength $\propto 1/q_\perp$ can only resolve a fraction $(\mu/q_\perp)^\alpha$ of the remnants momentum (where α is the dimensionality of the remnant)

$$q_\perp e^{-y} < (\mu/q_\perp)^\alpha P_-, \tag{1}$$

corresponding to the dotted line in figure 1.

For small values of Q^2 the struck quark can no longer be considered point like, and one can argue that emissions of gluons with $q_\perp > Q$ should also be suppressed, since the gluon only can resolve a fraction $\propto (Q/q_\perp)^{\alpha'}$ of the positive light-cone component of the virtual photon. This gives an extra phase-space restriction corresponding to the dashed line in figure 1. In this way the concept of a resolved virtual photon is present in ARIADNE.

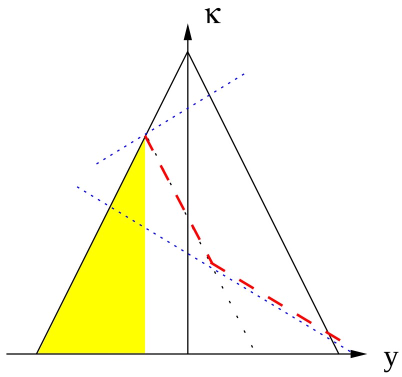

Figure 2: *The phase space available for final state particles in DIS at high* Q^2.

At high Q^2, we expect the radiation in the CBH, which corresponds to the shaded area in figure 2, to look very much like half an e^+e^- event. But the phase space restriction due to the extension of the proton remnant actually cuts away part of this region. This is most likely the reason why ARIADNE has given too little radiation in high-Q^2 events.

3 The solution

To solve this deficiency in the model we note that in the quark-parton model we have a collision between a virtual photon and an incoming quark with momentum $(0, xP_-, \vec{0})$. So in some sense a fraction x of the incoming protons momentum has already been localized, and this fraction should be easily available for gluon emission. We can then rewrite the condition in eq. (1)

$$q_\perp e^{-y} < \max(x, (\mu/q_\perp)^\alpha)P_-, \tag{2}$$

and the restriction on the phase space would instead correspond to the dashed line in figure 2.

It could, of course, be argued that the whole of the negative light-cone momentum xP_- of the incoming quark is needed to put the quark on-shell, due to the virtuality of the incoming photon with a negative light-cone momentum of $-xP_-$. And that to radiate an extra gluon, more negative light-cone momenta has to be accessed from the proton remnant. But we should remember that the picture of the proton remnant, where the momentum is spread out evenly over its transverse extension, certainly is an oversimplification. It is not unnatural to assume that in the vicinity where the struck quark was localized, the momentum is more concentrated. In any case it is clear that the restriction in eq. (1) is too hard, and seems like eq. (2) is a reasonable modification. Indeed, as reported in [9], it seems that this modification is approximately what is needed to make CDM reproduce measured data at high Q^2.

4 Conclusions

The modification of the colour dipole model for DIS presented here does fix the most serious problems with the reproduction of data at high Q^2 for ARIADNE. All problems are, however, not completely solved. Elsewhere in these proceedings [9], it has been proven to be difficult to find a parameter set which at the same time can describe general event shapes and jet observables. Jet shapes seem to be particularly difficult to describe with ARIADNE. Whether this can be solved with small adjustments or if it is due to an inherent flaw in the model remains to be seen.

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