LU TP 89-17

October 1989

Effects of Gluon Radiation in Hadronic Collisions

Gösta Gustafson
Department of Theoretical Physics, University of Lund
Sölvegatan 14A. S-22362 Lund, Sweden

In this talk I discuss effects of gluon emission in soft collisions, the so-called "soft radiation" in the Fritiof model. It is seen e.g. that the p_T in the fragmentation regions, the seagull effect, increases with energy in fair agreement with experiments. I also discuss the content of strange and heavier quarks in high-p_T gluon jets. Within the dipole scheme for QCD cascades one finds a larger production of heavier quarks than in previous approaches. Qualitative agreement with data is obtained for the K/π ratio and D meson production.

The results presented in this talk have been obtained in collaboration with B. Andersson, L. Lönnblad and U. Pettersson in Lund.

I. Gluon Emission in Soft Hadronic Collisions

In the Fritiof model for hadronic collisions [1] it is assumed that the confining colour field behaves like a vortex line in a superconductor. When two hadrons collide in a soft collision it is assumed that there is a (dominantly) longitudinal momentum exchange but no colour exchange. The exchange of colour would imply a recoupling of the colour charges and would necessarily involve the cores of the vortex lines and not only the more extended colour field surrounding them. After the momentum exchange the colour charges in each hadron are going apart, and this is expected to cause gluon bremsstrahlung in a way similar to that in e^+e^- annihilation or DIS.

The colour charges in a hadron are however not expected to be localized to points as in e^+e^- annihilation, and this implies that short wavelengths are suppressed. The wavelength of emitted radiation must be longer than the antenna size. A similar effct is present also in DIS as discussed in ref. [2]. If a gluon is radiated with a certain k_T, then we imagine an effective antenna with transverse size $\lambda_T = 2\pi/k_T$ which can radiate coherently. If the energy is distributed linearly, as expected for a vortex line, then the kinematical limit for radiation from this effective antenna is $k_T^2 \lesssim mMe^{-|y|}$, where M is the excited hadron mass. This should be compared with the total kinematical limit $k_T^2 \lesssim M^2e^{-2|y|}$. As a result the maximum possible k_T for an emitted gluon is $\sim \sqrt{M}$ rather than $\sim M$. Gluons with higher transverse momentum can thus only come from hard scattering.

A new version of the Fritiof Monte Carlo (Fritiof 5) includes gluon cascades with this constraint. This "soft bremsstrahlung" was only crudely implemented in earlier Monte Carlo versions. Hard parton scattering is, however, not yet included in this version.

As an example fig. 1 shows preliminary results for the seagull effect. We note that "the seagull lifts its wings" as the energy is increased in fair agreement with experiments.

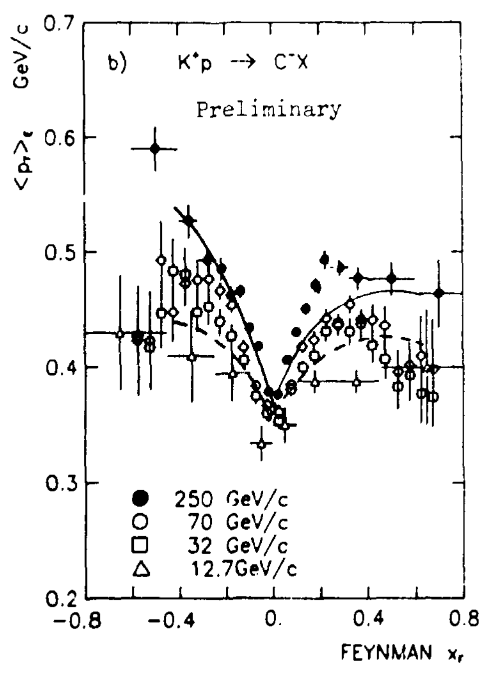

Figure 1: Energy weighted average p_T, $< p_T >_E$, as a function of x_F for $K^+p \to C^- + X$ between 12.7 and 250 GeV/c [10]. The curves are preliminary results from "soft gluon bremsstrahlung" for 32 $(- - -)$ and 250 GeV/c (—).

Talk presented at the EPS Conference on High Energy and Particle Physics, Madrid, September 1989

II. The Process $g \to q\bar{q}$ in Pert. QCD Showers

In perturbative QCD gluons are emitted according to dipole formulae. For a $q\bar{q}g$ system the gluon distribution corresponds to a dipole spanned between the q and the $\bar{q}$. Also for a $q\bar{q}gg$ system the distribution of the hardes gluon, g_1, corresponds to the $q\bar{q}$ dipole while the distribution of the second, softer, gluon g_2 corresponds to two dipoles, one between q and g_1 and one between g_1 and $\bar{q}$ [3]. In the same way a third, still softer, gluon is distributed in accordance with three dipoles qg_1, g_1g_2, g_2q, and so on. Thus in the *dipole approximation* to the QCD shower the dipoles are successively split into smaller and smaller pieces [4].

This procedure takes automatically into account the angular ordering due to soft gluon interference. It is implemented in the Monte Carlo simulation program ARIADNE [5]. Previous versions of ARIADNE neglected the gluon splitting process $g \to q\bar{q}$ in the cascade but this process is included in the new version ARIADNE 3.

In the dipole formulation the natural ordering variable in the cascade is transverse momentum k_T, rather than the virtual mass Q^2, used in conventional treatments of the QCD shower. These quantities are connected by the relation $k_T^2 = Q^2 \cdot z(1-z)$. If we compare the two competing processes in the cascade, $g \to gg$ and $g \to q\bar{q}$, we note that the distributions have the following singularity structure

$$dP \sim \frac{dQ^2}{Q^2} \cdot \frac{dz}{z(1-z)} \quad (g \to gg) \tag{1}$$

$$dP \sim \frac{dQ^2}{Q^2} \cdot dz \quad (g \to q\bar{q}) \tag{2}$$

At each step in the cascade the "hardest" breakup is chosen by means of a Sudakhov form factor. If "hardest" is defined by an ordering in Q^2 we see that there is a high probability to pick a small z-value in the process $g \to gg$ while it is less likely to pick the process $g \to q\bar{q}$. If instead we order in k_T^2, these cases with small z-values will be treated as "softer" and it will be more likely to pick the process $g \to q\bar{q}$.

For u- and d-quarks this hard production in the perturbative cascade is swamped by the larger quark production in the soft hadronization process. For strange and heavier quarks there is, however, a significant effect. Thus in the dipole approximation we find many more D and B mesons than in the conventional approach to the parton cascade and also the K/π ratio is increased at the "tips" of gluon jets [9].

Some results are presented in fig. 2 which shows the results for K/π and D/π ratios in high-p_T jets produced in $\bar{p}p$ collisions at 1.8 TeV. Our results are in qualitative agreement with experimental data on the K/π ratio at high p_T from the CDHW collaboration at ISR [6] and on D* production in high-p_T gluon jets presented at this conference by the CDF and UA1 collaborations [7].

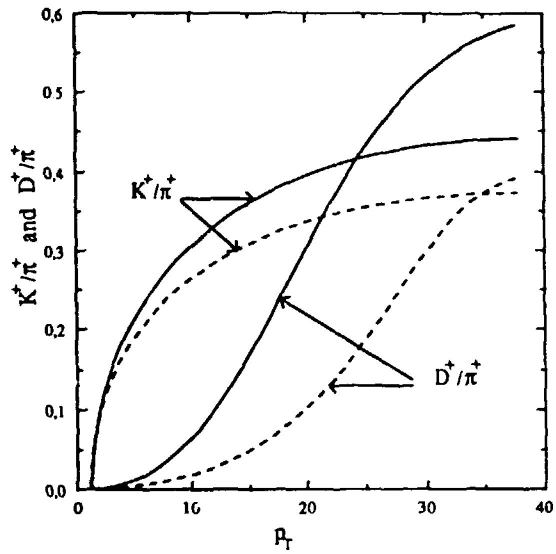

Figure 2: K/π and D/π ratios in high p_T jets produced in $\bar{p}p$ collisions at 1.8 TeV (solid lines). For comparison results using the PYTHIA MC [8] are also shown (dashed lines).

References

1 B. Andersson, G. Gustafson, B. Nilsson-Almqvist, *Nucl. Phys.* **B281** (1987) 289

2 B. Andersson, G. Gustafson, L. Lönnblad, U. Pettersson, *Z. Physik* **C43** (1989) 625

3 Ya.I. Azimov et al., *Phys. Lett.* **165B** (1985) 147; *Sov. J. Nucl. Phys.* **43** (1986) 95

4 G. Gustafson, *Phys. Lett.* **B175** (1986) 453; G. Gustafson, U. Pettersson, *Nucl. Phys.* **B306** (1988) 746

5 L. Lönnblad, U. Pettersson, Preprint LU TP 89-10 (1989)

6 A. Breakstone et al., *Phys. Lett.* **135B** (1984) 510

7 A.F. Garfinkel, Talk presented at this. conf. S. Wimpenny, *ibid.*

8 H.-U. Bengtsson, T. Sjöstrand, *Comp. Phys. Comm.* **46** (1987) 43 and priv. comm.

9 B. Andersson, G. Gustafson, L. Lönnblad, Preprint LU TP 89-14 (1989), LU TP 89-9 (1989)

10 A. Adamus et al., *Phys. Lett.* **B197** (1987) 457