Abstract of Laurea Thesis:

Soft Gluon Resummation in Drell-Yan processes in QCD

by Marco Cirelli

Internal Advisor: prof. Giuseppe Marchesini
External Advisor: dott. Paolo Nason

This thesis work deals with Elementary Particle Phenomenology. The theory of Quantum ChromoDynamics (QCD) of strong interactions is applied with the aim of getting theoretical predictions for some quantities that can be measured in hadron-hadron collision experiments at large accelerators (e.g. Tevatron-Fermilab, LHC-Cern).

1. Drell-Yan processes in perturbative QCD
The Drell-Yan process consists in the production of a lepton-antilepton pair with large invariant mass Q (for instance: $\mu^+\mu^-$) from the collision of two hadrons (for instance: $p\ \overline{p}$, proton-antiproton). Each hadron is represented, following the principles of the Parton Model, as a weakly-tied system of quarks, antiquarks and gluons. The production mainly proceeds through the annihilation of a quark and an antiquark, both 'contained' in the hadron, into a virtual photon, which eventually decays into the lepton pair:

$$p + \overline{p} \to \gamma^* + X \qquad \gamma^* \to \mu^+\mu^-$$

The condition of large invariant mass ($Q \gg \Lambda_{QCD}$, where Λ_{QCD} is the characteristic scale of strong interactions) guarantees the energy of the strong interaction to be high, a crucial feature which makes this process an ideal testing ground for perturbative QCD, as it was realized and successfully carried out since the 1970s. The Drell-Yan process, however, is only the paradigm of a set of similar reactions in hadronic collisions: most important are the production of $W^\pm$ and Z^0 (instead of the virtual photon) and the production of a pair of heavy quarks ($b\bar{b}$, *top-antitop*, instead of the $\mu^+\mu^-$ pair).

2. Interesting kinematic limits: the small transverse momentum region and the total cross section at threshold

Among the quantities that it is interesting to analyse in this kind of processes, two in particular have been the subject of intense studies during the last few years:

- the distribution of transverse momentum $q_\perp$ (with respect to the beam collision axis) of the leptonic pair, in the regime of small transverse momentum ($q_\perp \ll Q^2$);

- the total cross section at threshold, i.e. in the limit in which the invariant mass of the leptonic pair absorbs almost all the energy of the hadronic collision.

In these particular kinematic regimes large corrections are generated, in the form of logarithms ℓ (for instance: $\ell = \ln(q_\perp^2/Q^2)$), at every order of the perturbative series: they are essentially the consequence of soft gluons emissions from incident partons.

The presence of these corrections requires a reorganization of perturbative computations: indeed, if usually one chooses to cut the perturbative series in the strong coupling α_s at a certain order, in the present case it becomes necessary to *resum* the contributions of these emissions at each perturbative order to obtain a reliable prediction. The resummation yields an exponential factor which is known as 'Sudakov factor'.

The scheme of Leading Logarith Approximation (LLA) amounts to select and resum all the terms in which the power of the logarithm is larger (terms like $\alpha_s^n \ell^{n+1}$ in the Sudakov exponent), while neglecting the following ones. The scheme of Next-to-Leading Logarithms (NLL), instead, prescribes to include the terms like $\alpha_s^n \ell^n$ also.

In the literature, resummed formulae for both quantities have been obtained: Collins, Soper and Sterman (1984) for the case of small transverse momentum distribution; Catani e Trentadue (1989) for the case of threshold cross section.

3. Motivations e original result of the thesis work: consistent treatment in LLA of both regimes

In this thesis work, after a deep analysis of the results present in literature for the two different regimes, we consider the intersection of the two limit regions.

Such an analysis is suggested, for instance, by the stimulating need to produce reliable theoretical predictions for the transverse momentum distribution of a pair of *top* quarks, produced at Tevatron or, in a near future, at the LHC: given the large mass of the *top* quark recently observed, indeed, this is a quantity that lies in threshold conditions, besides being measurable at small transverse momentum. A different example, interesting as well, is given by the study of the transverse momentum of electroweak bosons $W^{\pm}$ e Z^0 produced in hadronic collisions.

The *result* that we obtain is an original formula, accurate at the level of LLA, for the distribution at small transverse momentum in threshold conditions.

This formula gives back those quoted above if restricted to each of the two different limit regimes.

The *numerical estimations* that we realize confirm that the difference between the predictions of this formula and the previous ones is sizable as soon as one enters the threshold regime. Namely, we predict the narrowing of the transverse momentum distributions (in favour of very small transverse momenta) while approaching the threshold and, more generally, a different absolute value between the distributions computed with and without threshold effects.

We are confident that a refinement of the formula up to NLL accuracy is affordable, a scheme for which the formulae for the two limit regimes are already known.