Vol. 39 (2008) *ACTA PHYSICA POLONICA B* No 9

HADROCHEMISTRY OF JET QUENCHING AT THE LHC*

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(Received May 12, 2008)

We point out that jets propagating through the medium created in heavy ion collisions can be modified not only in the longitudinal and transverse multiplicity distributions, but also in the hadrochemical composition. We use the theoretical framework of the MLLA+LPHD formalism, supplemented by medium-modified splitting functions.

PACS numbers: 25.75.–q, 13.87.–a, 12.38.Mh

1. Introduction

In heavy ion collisions at the LHC one expects to observe jets of energies which will allow to separate them from the soft background. Such highly energetic jets propagating through the strongly interacting medium may be modified both in their longitudinal and transverse distributions. In addition, we expect that these interactions affect also the hadrochemical composition of jets.

There are several mechanisms which may lead to such modification. For instance, color transfer between projectile and the medium may occur. One can also imagine the exchange of other quantum numbers like baryon number or strangeness. Similarly, recombination of partons from the jet with partons from the medium is conceivable. If recoil effects are non-negligible then one should, in principle, take into account the mechanism in which the medium components are kicked into the jet cone.

* Presented at the School on QCD, Low-x Physics, Saturation and Diffraction, Copanello, Calabria, Italy, July 1–14, 2007.

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All the above effects may require serious modeling. In the following, we consider the framework which does not implement those mechanisms but takes into account only the exchange of momentum between the medium and the developing partonic cascade, which leads to the enhanced parton splitting.

It is conceivable that in our study medium effects are underestimated. We observe however that the modification of the fragmentation pattern alone is sufficient to significantly affect the hadronic composition of jets. Hence, our study can be treated as a baseline on top of which other mechanisms may be established.

2. The formalism

To calculate multiplicities of the identified hadrons we use the framework of Modified Leading Logarithmic Approximation (MLLA) [1]. This perturbative approach supplemented by the hypothesis of Local Parton–Hadron Duality (LPHD) was shown to reproduce correctly the single inclusive hadron spectra in jets both in e^+e^- and $pp/p\bar{p}$ collisions. It provides good description not only for the distributions of all charged particles but also for the spectra of identified hadrons such as pions, kaons and protons [2, 3]. Moreover, the dependence on jet opening angle can be implemented. The general form of the multiplicity of hadrons of mass M_h in the jet of energy $E_{\rm jet}$ and opening angle θ_c is given by

$$\frac{dN^h}{d\xi} = K_{\rm LPHD}\, D(\xi, E_{\rm jet}, \theta_c, M_h, \Lambda)\,, \tag{1}$$

where $\xi = \ln 1/x$ and $x = p/E_{\rm jet}$ is the fraction of the jet energy carried by the hadron h. The regularization scale Λ is a parameter of the model. The characteristic shape of the distribution (1) known as the hump-backed plateau follows from taking into account the effects of destructive quantum interference. The hadron mass M_h marks the end-point of the partonic cascade. With increasing M_h, the position of the hump moves towards lower ξ (the distribution stiffens) and the overall normalization decreases.

To model the medium-modification of jets we supplement the above formalism by the formulation of parton energy loss proposed in [4]. The effects of medium-induced gluon radiation are introduced by enhancing the singular parts of the LO splitting functions by the factor $1 + f_{\rm med}$. This leads to the softening of hadron spectra. The model accounts for the nuclear modification factor at RHIC when $f_{\rm med}$ is of the order of 1.

3. Results

One of the main results of our studies is shown in Fig. 1. We have chosen the jet opening angle to be $\theta_c = 0.28$ rad. The local parton–hadron duality parameter was taken as $K_{\rm LPHD} = 0.5$ and the kaon multiplicity was in addition suppressed by 0.73 following [3]. We observe a significant difference of the $K^{\pm}/\pi^{\pm}$ and $p^{\pm}/\pi^{\pm}$ ratios for medium-modified (with $f_{\rm med} = 1$) and unmodified (vacuum) jets. In the presence of the medium the ratios increase up to 50% for kaons and 100% for protons. This enhancement seems to be a generic feature for jet quenching models (see [5]). We notice also only mild dependence on the jet energy in Fig. 1. In addition, we have checked that the ratios depend very weakly on the value of θ_c.

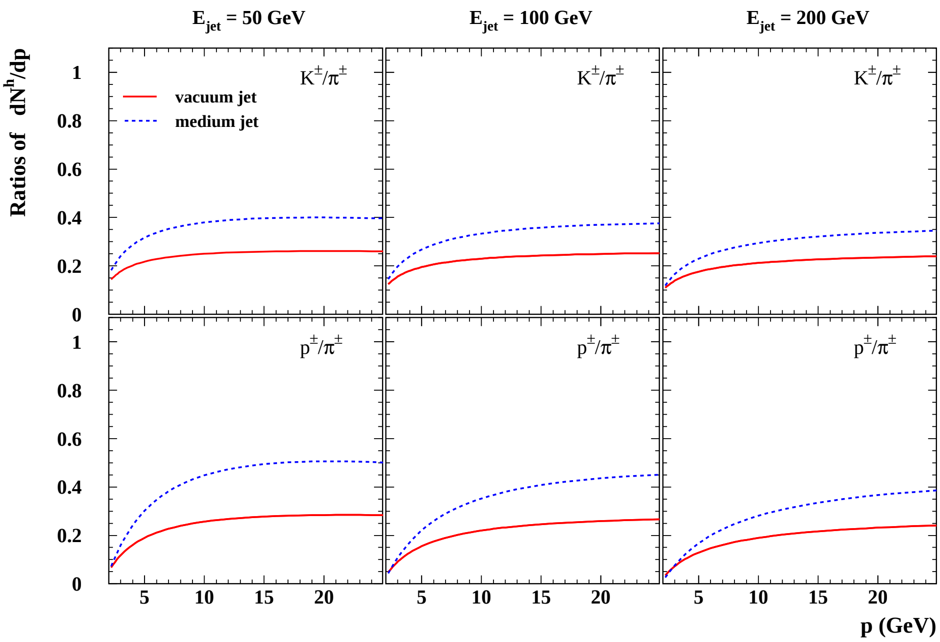

Fig. 1. Ratios of kaons and protons to pions in the jets of energy $E_{\rm jet}$ with or without medium modification.

The medium modified hadron spectra may be also superimposed on the high multiplicity environment of heavy ion collisions expected at the LHC. As we see in Fig. 2, the ratios remain largely unchanged even if we include the particles from the realistic soft background [6–8].

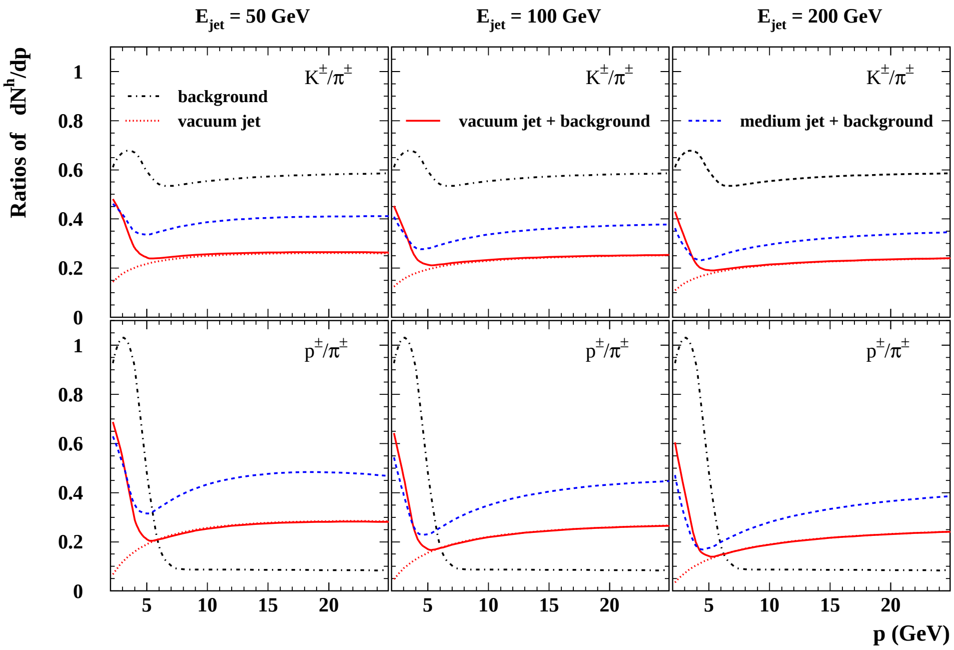

Fig. 2. Ratios of kaons and protons to pions coming both from the jets of energy $E_{\rm jet}$ (with or without medium modification) and the soft background.

4. Summary

We have studied the possible modification of the hadronic composition of jets propagating through the dense QCD matter. The MLLA+LPHD approach was used together with a simple model for extra medium-induced radiation.We observe that enhanced parton splitting alone is sufficient to produce a significant increase of the $K^{\pm}/\pi^{\pm}$ and $p^{\pm}/\pi^{\pm}$ ratios.

Our results show that the hadrochemical composition of jets may be very fragile to the medium effects and hence could be used as an additional handle to study microscopic mechanisms underlying jet quenching.

The original work described here was done in collaboration with Urs Achim Wiedemann. The support of the Marie Curie ESRT Fellowship of the European Community's Sixth Framework Programme under contract number (MEST-CT-2005-020238) is greatly acknowledged.

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