Available online at www.sciencedirect.com

ScienceDirect

Nuclear Physics A 932 (2014) 269–273

NUCLEAR PHYSICS A

www.elsevier.com/locate/nuclphysa

Radiation spectrum of a massive quark–gluon antenna

M.R. Calvo [a,b,*], M.R. Moldes [a,c], C.A. Salgado [a]

[a] *Departamento de Física de Partículas and IGFAE, Universidade de Santiago de Compostela, E-15706 Santiago de Compostela, Galicia, Spain*

[b] *Institut de Physique Théorique de Saclay, F-91191, Gif-sur-Yvette, France*

[c] *Centre de Physique Théorique, École Polytechnique, CNRS, 91128 Palaiseau, France*

Received 18 April 2014; received in revised form 1 October 2014; accepted 3 October 2014

Abstract

We compute the color coherence effects for soft gluon radiation off antennas containing heavy quarks in the presence of a QCD medium. The analysis is performed resumming the multiple scattering of the partonic system with the medium. The main conclusion is that decorrelation due to color rotation is more effective in the case in which at least one of the emitters of the antenna is a heavy quark.

Keywords: Jet quenching; Perturbative QCD; Massive quark

---

1. Introduction

Jets traversing QCD matter created in high-energy nuclear collisions have been experimentally studied for the last ten years, first at the RHIC at BNL [1] and then at the LHC at CERN [2–4]. The most successful model for this jet quenching effect is the one based on the enhancement of the gluon radiation spectrum induced by the medium [5–13].

Nevertheless, a more complete theory, suitable for a consistent and rigorous interpretation of the reconstructed jet data, is still being developed. On the theoretical side, several improvements have been made in the recent years [14–17]. Also, efforts have been made so as to compute

---

[*] Corresponding author.

E-mail addresses: manoel.rodriguez@usc.es (M.R. Calvo), manoel.rodriguez-moldes@usc.es (M.R. Moldes), carlos.salgado@usc.es (C.A. Salgado).

http://dx.doi.org/10.1016/j.nuclphysa.2014.10.016

intra-jet color coherence effects [23–29], known to play a significant role in the vacuum case [18–22] where they lead to the well-known fact that subsequent emissions are angular ordered.

The mass of the heavy quarks is known to modify the role of color coherence, i.e. introducing a dead-cone angle where radiation is strongly suppressed, or removing the strict angular ordering in the vacuum. The dead cone angle effect might lead to a reduction of the radiation spectrum in the medium case. On the other hand, RHIC data on the suppression of the non-photonic electrons (expected to be dominated by heavy quark decays) is compatible, taking it at face value, with no mass effect in the radiation [1].

Motivated by the above considerations, we compute in this work the color coherence effects for antennas containing heavy quarks. We perform the calculation using a semiclassical approach, and resuming the multiple scatterings of the partons involved with the medium. The main conclusion of the paper is that coherence is more easily lost when one of the emitters is a heavy quark. The loss of coherence is an effect that in general implies a larger energy loss.

2. Calculation of the amplitude

The amplitude for one gluon emission can be calculated using the reduction formula [25]

$$\mathcal{M}^a(k) = -\sum_\lambda \int\limits_{x^+=+\infty} dx^-\, d^2\mathbf{x}\, e^{ik\cdot x} 2\partial_x^+ \mathbf{A}^a(x)\cdot \boldsymbol{\epsilon}_\lambda(\vec{k}) \tag{1}$$

with $k^\mu = (\omega, \vec{k})$ being the 4-momentum of the emitted gluon and $\mathbf{A}$ the transverse gauge field. The gauge field is obtained from the classical Yang–Mills (CYM) equations

$$\left[D_\mu, F^{\mu\nu}\right] = J^\nu \tag{2}$$

where $D_\mu \equiv \partial_\mu - igA_\mu$ and $F_{\mu\nu} \equiv \partial_\mu A_\nu - \partial_\nu A_\mu - ig[A_\mu, A_\nu]$, and with the current J^μ being covariantly conserved, i.e.,

$$\left[D_\mu, J^\mu\right] = 0 \tag{3}$$

The initial state of a component of the antenna with momentum $p^\mu = (E, \vec{p})$ and charge color vector Q^a is represented by this vacuum current:

$$J_{(0)}^{\mu,a}(x) = g\frac{p^\mu}{E}\delta^{(3)}\left(\vec{x} - \frac{\vec{p}}{E}t\right)\theta(t)Q^a \tag{4}$$

The medium will affect this vacuum current by inducing a color rotation:

$$J^\mu(x) = U_p\left(x^+, 0\right)J_{(0)}^\mu(x) \tag{5}$$

described by a Wilson line:

$$U_p\left(x^+, 0; \mathbf{r}\right) \equiv \mathcal{P}\exp\left\{\int\limits_0^{x^+} d\xi\, T\cdot A_{\mathrm{med}}^-\left(\xi, \mathbf{p}\xi/p^+\right)\right\} \tag{6}$$

Leaving only terms that are linear on the medium induced field and performing the calculation in the light-cone gauge ($A^+ = 0$, with light-cone coordinates defined as $A^\pm = (A^0 \pm A^3)/\sqrt{2}$ and $\mathbf{A} = (A^1, A^2)$), we get the following expression for the amplitude: