Heavy Flavor Energy Loss and D-Mesons in ALICE@LHC

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In a recent work [1] the probability of gluon emission off a heavy quark has been generalised by relaxing some of the constraints, *e.g.*, related to the gluon emission angle and to mass of the heavy quark, which were imposed in earlier calculations [2, 3]. It resulted in a very compact and elegant expression for the gluon radiation spectrum off a heavy quark (*e.g.*, $Qq \to Qqg$) as [1],

$$\frac{dn_g}{d\eta dk_\perp^2} = \frac{C_A\alpha_s}{\pi}\frac{1}{k_\perp^2}\mathcal{D} \ , \qquad (1)$$

where the transverse momentum of the emitted massless gluon is related to its energy by $k_\perp = \omega\sin\theta$, and the rapidity, $\eta = -\ln[\tan(\theta/2)]$, is related to the emission angle. The generalised dead cone is given by

$$\mathcal{D} = \left(1+\frac{M^2}{s}e^{2\eta}\right)^{-2} = \left(1+\frac{M^2}{s\tan^2(\frac{\theta}{2})}\right)^{-2} .$$

Being the Mandelstam variable s is given as, $s = 2E^2+2E\sqrt{E^2-M^2}-M^2$, with E and M, respectively, the energy and mass of the heavy quark. C_A is the Casimir factor for adjoint representation and α_s is the strong coupling constant. In the small angle limit, $\theta \ll \theta_0(= M/E) \ll 1$, the dead cone in (2) reduces to that in Ref. [2, 3] as $(1+\theta_0^2/\theta^2)^{-2}$ whereas for massless case it becomes unity and (1) reduces to the Gunion Bertsch formula [4]. We have used this generalised dead cone expression to calculate radiative energy loss of heavy quark and studied nuclear modification factor of D mesons in Pb-Pb collisons at 2.76 AGeV in LHC.

Among the interactions that a charged particle undergoes, as it traverses a dense matter, inelastic (i.e. radiative) scattering is undoubtedly the most important and interesting one. A number of different energy loss models has also been formulated in the literature. The basic differences among the different models are the various constraints (*e.g.*, kinematic cuts, large angle radiation etc.) implemented to make the calculations manageable. Here we define the rate of radiative energy loss of a parton with energy E, due to inelastic scatterings with the medium partons in a very canonical way as

$$\frac{dE}{dx} = \frac{\langle\omega\rangle}{\langle\lambda\rangle}, \qquad (2)$$

where $\langle\omega\rangle$ and $\langle\lambda\rangle$ are the mean energy of emitted gluons and the mean free path of the traversing quark, respectively. The magnitude of mean free path depends on the characteristics of the system in which the energetic particle is traversing, and it is defined as

$$\langle\lambda\rangle = 1/(\sigma_{2\to3}\ \rho_{\rm qgp}) \ , \qquad (3)$$

Also, It is easy to find mean energy of the emitted soft gluons from the GB formula together with new generalised dead cone factor

At this point it is important to note that the hierarchy employed in obtaining (1) in Ref. [1] reads as

$$\sqrt{s}, E \gg \sqrt{|t|} \sim q_\perp \gg \omega > k_\perp \gg m_D \ , \qquad (4)$$

where s, u, t are the usual Mandelstam variables and m_D is the Debye screening mass of the thermal gluons [5].

We have obtained spatial dependence of energy loss as follows, with all appropriate momentum and angle cuts,

$$\frac{dE}{dx} = 12\ \alpha_s^3\ \rho_{\rm qgp} \int_{q_\perp^2|_{min}}^{q_\perp^2|_{max}} \frac{1}{(q_\perp^2)^2}dq_\perp^2 \int_{\omega_{min}}^{\omega_{max}} d\omega\ 2\int_{\eta_{min}}^{\eta_{max}} \mathcal{D}\ d\eta \ ,$$

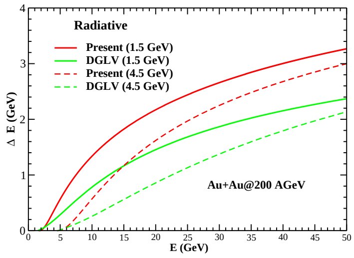

FIG. 1: Radiative energy loss suffered by charm and bottom quarks while passing through the QGP.

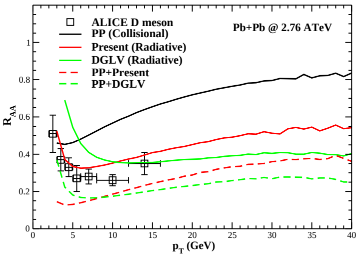

FIG. 2: Nuclear modification factor of D mesons in Pb+Pb collision at 2.76 ATeV.

where a factor of 2 has been introduced in η integral to cover both upper and lower hemisphere, for gluon emission.

In Fig. 1, we plot the transverse energy loss of charm and bottom quarks by radiative processes as a function of transverse energy at $\sqrt{s}_{NN}$=200 ATeV at RHIC. The energy loss predicted by present formalism [5] is much more compared to the prediction by DGLV formalism. The consequences have important concequences on phenomenological studies of D mesons suppresions, as shown in Fig[2], where we have have plotted nuclear modification factor of D meson in Pb-Pb collision in 2.76 ATeV.

To compute the nuclear suppression factor for D-meson we consider both radiative and collision energy loss along with longitudinal expansion of the medium. The nuclear modification factor for D-meson with radiative energy loss obtained in the present formalism [5] has an increasing trend at high $p_\perp$ and found to agree closely with the very recent data from ALICE collaboration at 2.76 ATeV. When the collisional counter part is added independently, the further suppression is obtained in the nuclear modification factor. In addition, this suggests that there could be some of energy gain by heavy quark due to the field fluctuations. However, it is necessary to obtain both radiative and collisional energy loss from the same formalism to minimize the various uncertainties, which is indeed a difficult task. Moreover, data at high $p_\perp$ region with improved statistics are required to remove prejudice on different energy loss and jet quenching models.

References

[1] R. Abir, C. Greiner, M. Mauricio, M. G. Mustafa, and J. Uphoff, Phys. Rev. D**85**, 054012 (2012), ⟨arXiv:1109.5539[hep-ph]⟩.

[2] Y. L. Dokshitzer and D. E. Kharzeev, Phys. Lett. B**519**, 199 (2001).

[3] Y. L. Dokshitzer, V. A. Khoze, and S. I. Troian, J. Phys. G**17**, 1602 (1991).

[4] J.F. Gunion and G. Bertsch, Phys. Rev. D**25**, 746 (1982).

[5] R. Abir, U. Jamil, M. G. Mustafa, D. K. Srivastava, Phys. Lett. B (in press), arXiv:1203.5221 (2012).