

Suppression of D-mesons production at relativistic heavy ion collisions

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ABSTRACT

The medium induced energy loss of heavy quarks has been regarded as a promising probe for the properties of Quark Gluon Plasma. We consider the fragmentation of the charm quarks/antiquarks, produced from the initial fusion of light quarks and gluons, into D mesons. Further we calculate the nuclear suppression, R_{AA} of D mesons thus produced at LHC energies. The energy loss of charm quarks/antiquarks and the shadowing effect have been accounted for to calculate R_{AA} . We compare the predicted R_{AA} of D mesons at 2.76 ATeV with recent experimental measurements. Our result at RHIC energy is compared with the single-electron data at 200 AGeV.

Why D mesons?

Charm quarks/antiquarks produced at the early stage of heavy ion collisions pass through the QGP phase and combine with light quarks/antiquarks to produce D mesons.

As the charm quarks/antiquarks are massive, while propagating through the medium they do not change direction much from the scatterings with light quarks and gluons. There production is also very small. So, charm quarks/antiquarks and in turn D mesons are believed to be an excellent probe for the QGP phase.

The cross-section for the production of charm quarks from pp collisions at LO:

$$\frac{d\sigma}{dy_1 dy_2 dp_T} = 2x_1 x_2 p_T \sum_{ij} [f_i^{(1)}(x_1, Q^2) f_j^{(2)}(x_2, Q^2) \delta_{ij}(\hat{s}, \hat{t}, \hat{u}) + f_j^{(1)}(x_1, Q^2) f_i^{(2)}(x_2, Q^2) \delta_{ij}(\hat{s}, \hat{t}, \hat{u})] / (1 + \delta_{ij})$$

The fractional momenta of the interacting hadrons carried out by the partons can be expressed as:

$$x_1 = \frac{m_T}{\sqrt{s}} (e^{y_1} + e^{y_2}), \quad x_2 = \frac{m_T}{\sqrt{s}} (e^{-y_1} + e^{-y_2}) \quad \text{where} \quad m_T = \sqrt{M^2 + p_T^2}$$

The short-range subprocesses for the charm quark production are defined as:

$$\frac{d\sigma}{dt} = \frac{1}{16\pi s^2} |\mathcal{M}|^2$$

The average distance covered by the charm quark in the plasma, $\langle L \rangle$, is given by:

$$\langle L \rangle = \frac{\int_0^R r dr \int_0^{2\pi} L(\phi, r) T_{AA}(r, b=0) d\phi}{\int_0^R r dr \int_0^{2\pi} T_{AA}(r, b=0) d\phi}$$

where $L(\phi, r) = \sqrt{R^2 - r^2 \sin^2 \phi} - r \cos \phi$

The temperature of the plasma varies with rapidity (y) as:

$$T(\tau) = \left(\frac{\pi^2}{1.202} \frac{\rho(\tau)}{9n_f + 16} \right)^{1/3}, \quad \rho(\tau) = \frac{1}{\pi R^2 \tau} \frac{dN_g}{dy}$$

$v_T = p_T / m_T \Rightarrow \tau_L = \langle L \rangle / v_T$, m_T is the transverse mass of the charm quark.

If $\tau_c \geq \tau_L$, the charm quark would be inside QGP during the entire period 0 to τ_L .

If $\tau_c < \tau_L$, the charm quark would be inside QGP only while covering the distance $v_T \times \tau_c$.

$\langle \tau \rangle = \langle L \rangle_{eff} / 2$, where $\langle L \rangle_{eff} = \min[\langle L \rangle, v_T \times \tau_c]$.

The initial conditions:

Mass of the charm (bottom) quark = 1.5(4.5) GeV

Running coupling constant $\alpha_s = 0.3$,

$\tau_0 = 0.2$ fm/c and τ_c at $T_c = 170$ GeV,

Average path length $\langle L \rangle \approx 5.78$ fm for Au+Au collisions and 6.14 fm for Pb+Pb collisions,

The central particle rapidity densities (dN_g/dy),

≈ 1125 for Au+Au collisions @ 200 AGeV,

≈ 2855 for Pb+Pb collisions @ 2.76 ATeV,

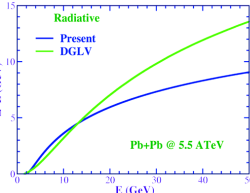
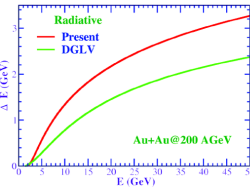
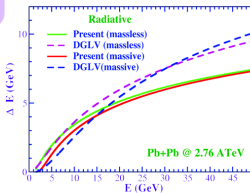
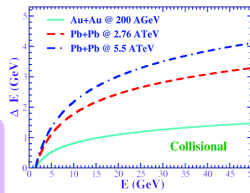
≈ 4050 for Pb+Pb collisions @ 5.5 ATeV

Nuclear thickness function $T_{AA}(b=0)$

≈ 292 fm² for Pb+Pb collisions and

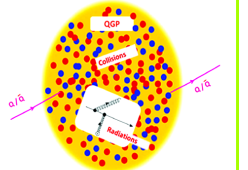
≈ 286 fm² for Au+Au collisions.

Energy loss of a charm quark at RHIC and LHC energies.



There are different energy loss formalisms in the literature.

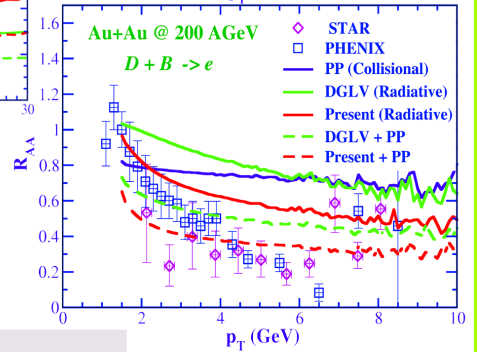
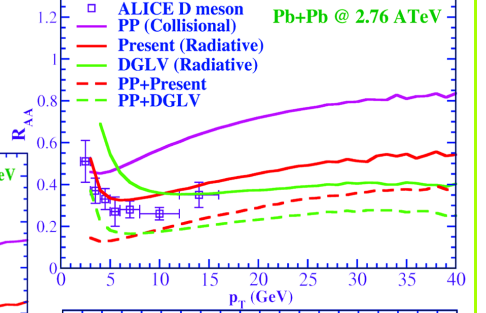
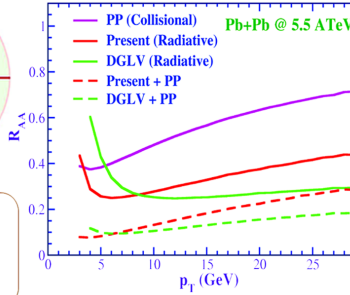
We consider a recent formalism, which we refer as 'Present' (see ref.[1]) to calculate the radiative energy loss of charm quarks/antiquarks. In the 'Present' formalism we obtain radiative energy loss in a canonical way using the most generalized form of gluon emission off a heavy quark [2]. We also consider Djordjevic, Gyulassy, Leval and Vitev (DGLV) formulation for the radiative energy loss calculation of charm quarks/antiquarks. We consider the Peigne and Peshier (PP) formulation to calculate the collisional energy loss of charm quarks/antiquarks.



The nuclear modification factor at impact parameter b:

$$R_{AA}(b) = \frac{dN^{AA}/d\vec{p}_T dy}{T_{AA}(b) d\sigma^{NN}/d\vec{p}_T dy}$$

Introducing the energy loss and also the shadowing effect (EKS 98 parameterization) of the charm quark distributions, we study the suppression in the nuclear modification factor of D-mesons at LHC energies.



Suppression in the nuclear modification factor of single electrons from D and B mesons at RHIC energy.

CONCLUSIONS

Within our theoretical assumptions, we find that the nuclear modification factor R_{AA} changes substantially in going from RHIC to LHC.

The nuclear modification factor R_{AA} predicted by present and DGLV formalisms are quite different.

The present formalism has an increasing trend towards high p_T region.

We have noted that the suppression of single electrons observed at RHIC is well supported by the present formalism.

The nuclear modification factor R_{AA} of D mesons predicted by the present formalism has shown very good agreement with the ALICE data for p_T upto 15 GeV.

Our prediction for R_{AA} shows more suppression while we take into account the collisional energy loss along with radiative energy loss.

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