Nuclear modification of production of charm quarks in Pb+Pb collision at $\sqrt{s}_{NN}$=2.76 TeV at LHC

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Introduction

Charm quarks are expected to be produced from the initial fusion of gluons or light quarks at a time, $1/2M_Q$, which is much less than 0.1 fm/c, i.e., much before the formation of QGP. At later times, their production can be neglected. After their production they will propagate through the medium and will lose energy in the process of collisions with the quarks and gluons and also by radiation of gluons. So the charm mesons or baryons, produced by the fragmentation of charm quarks would carry information of the energy loss suffered by the charm quarks while traversing the medium.

The increase of energy loss with temperature leads to a valuable test for studying different energy loss treatments, available in the literature, at LHC energy.

Charm quarks production in pp collisions

The differential cross section for charm quark production is calculated considering the fusion of gluons ($gg \to Q\overline{Q}$) or light quarks ($q\overline{q} \to Q\overline{Q}$), in pp collisions at LO [1]. We use the factorization and renormalization scales as $Q = m_T$, where m_T is the transverse mass. Our LO results are compared with the results obtained using NLO-MNR treatment developed by Mangano et al [2]. Here we find a K factor of ≈ 2.5 [3].

Initial conditions

In our calculation we introduce the nuclear shadowing effect by EKS 98 parameterization [4] for nucleon structure functions. The central particle rapidity density is taken as ≈ 2855 for Pb+Pb collisions at $\sqrt{s}_{NN}$=2.76 TeV at LHC. We calculate the nuclear overlap function $\approx$ 290 fm^{-2} for central Pb+Pb collisions at LHC. We consider a situation, where, a charm quark produced in a central collision, at the point (r, Φ), and moving at an angle ϕ with respect to $\hat{r}$ in the transverse plane. We find the average distance, $\langle$L$\rangle$ traversed by the charm quark 6.14 fm (radius of Pb nuclei $\approx$ 6.78 fm) for central Pb+Pb collisions at LHC. We consider that the QGP is formed at $\tau_0 = 0.2$ fm/c. We approximate the expanding and cooling plasma with one at a temperature of T at $\tau = \langle \mathrm{L} \rangle_{\mathrm{eff}}/2$, where $\langle \mathrm{L} \rangle_{\mathrm{eff}} = \min [\langle \mathrm{L} \rangle,\ v_T \times \tau_c]$, where v_T is the transverse velocity of the charm quark and τ_c is the critical temperature.

Energy loss of charm quarks

We consider the formalisms developed by Bjorken, Braaten and Thoma (BT), and Peigne and Peshier (PP) to calculate the collisional energy loss. And for the calculation of radiative energy loss, we consider the formalisms of Djordjevic, Gyulassy, Levai, and Vitev (DGLV), Armesto, Salgado, and Wiedemann (ASW), and Xiang, Ding, Zhou, and Rohrich (XDZR) (see ref. [3] for details).

In Fig. 1, we plot the transverse energy loss of charm quark, ΔE_T as a function of transverse energy E_T at $\sqrt{s}_{NN}$=2.76 TeV at LHC. The collisional energy loss for charm quarks show a weaker dependence on the rapidity whereas the radiative energy loss shows a complex dependence. As in our procedure, the change of rapidity means the change in temperature, we can see the weaker dependence of the collisional energy loss on the rapidity and also on the average path length tra-

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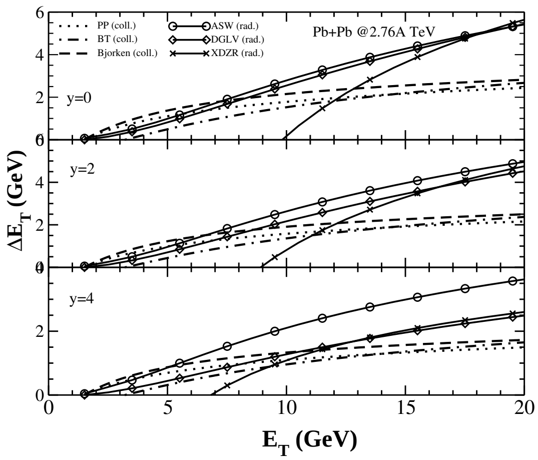

FIG. 1: Collisional and radiative energy loss suffered by a charm quark while passing through the QGP at forward rapidities

versed by the charm quarks. Among the radiative energy loss formalisms, the ASW formalism shows the maximum energy loss at all rapidities for higher E_T range. The ASW and DGLV formalisms give nearly identical results at y=0 and y=2 but the corresponding value at y=4 differs, which, we feel, is due the complex dependency of the ASW formalism on $\langle \mathrm{L} \rangle_{\mathrm{eff}}$.

R_{AA} of charm quarks

In Fig. 2 we discuss our results for R_{AA} with the additional inclusion of collisional and radiative energy losses. Here we will consider collisional energy loss using the PP formalism and the radiative energy loss using DGLV formalism.

We see that R_{AA} first increases from 0.4 to 0.7 at $p_T \approx 2$ GeV and then drops to 0.2 at $p_T \approx 5$ GeV, similar to the priliminary data obtained by ALICE experiment [5]. R_{AA} remains constant at 0.2 for the p_T range 5–20 GeV.

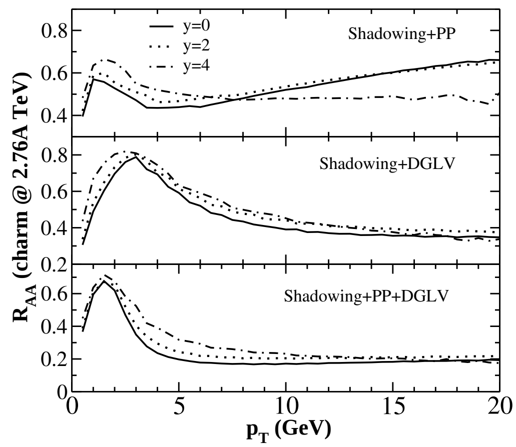

FIG. 2: R_{AA} of charm quark considering both the nuclear shadowing effect as well as the energy loss at forward rapidities.

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