Nuclear suppression of charm quarks at central rapidity in relativistic heavy-ion collisions

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Introduction

The production of charm quarks at the initial stage of relativistic heavy-ion collisions and their further propagation is believed to be an excellent probe for the existence of Quark Gluon Plasma (QGP). As they are massive, their production at later times of collisions is negligible. After production, they will pass through the QGP colliding with quarks and gluons and also radiating gluons. Thus they will loose energy before they fragment in to charm mesons or baryons. These hadrons would carry information on the energy loss suffered by the charm quarks.

As the energy loss increases with temperature, a valuable test of different energy loss treatments, available in the literature, can be performed by studying charm quarks energy loss at RHIC and LHC energies.

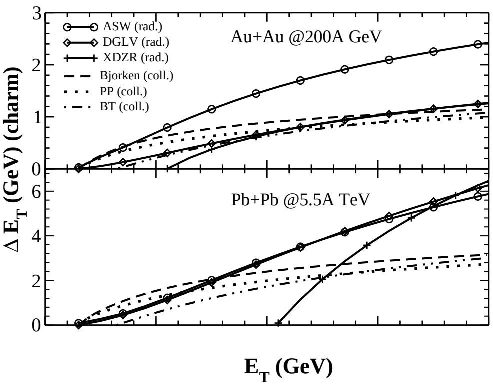

FIG. 1: Collisional and radiative energy loss suffered by a charm quark while passing through the QGP at midrapidity

Production of charm quarks in pp collisions

We calculate the differential cross section for charm quark production, considering the production from fusion of gluons ($gg \rightarrow Q\overline{Q}$) or light quarks ($q\overline{q} \rightarrow Q\overline{Q}$), from pp collisions at LO as given in the references [1]. The factorization and renormalization scales are taken as $Q = m_T$, where m_T is the transverse mass. We also calculate the differential cross section for charm quark in pp collision at NLO in pQCD using the treatment developed by Mangano, Nason, and Ridolfi (MNR-NLO) [2]. We compare our LO results with the results obtained using MNR-NLO treatment and find a K factor of ≈ 2.5 [3]. Here, we neglect the intrinsic transverse momentum of the partons. The nuclear shadowing effect is introduced by using EKS 98 parameterization [4] for nucleon structure functions. We take central particle density as ≈ 900 for Au+Au collisions at RHIC and ≈ 3300 for Pb+Pb collisions at LHC. We consider 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 as 5.78 fm (radius of Au nuclei $\approx$ 6.38 fm) for central Au+Au collisions at RHIC and 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

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temperature.

Energy loss of charm quarks

For the collisional energy loss mechanisms we consider the formalisms developed by Bjorken, Braaten and Thoma (BT), and Peigne and Peshier (PP). For the 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). For a more detailed discussion of these energy loss mechanisms please see ref. [3].

We plot the transverse energy loss of charm quark, ΔE_T as a function of transverse energy E_T in Fig. 1 at RHIC and LHC energies. As expected both the collisional and radiative energy loss show more degradation while going from RHIC to LHC energy. Except ASW formalism, radiative energy loss is comparable with collisional energy loss at RHIC energy but at LHC energy after $E_T \approx 5$ GeV radiative energy loss dominates over the collisional energy loss.

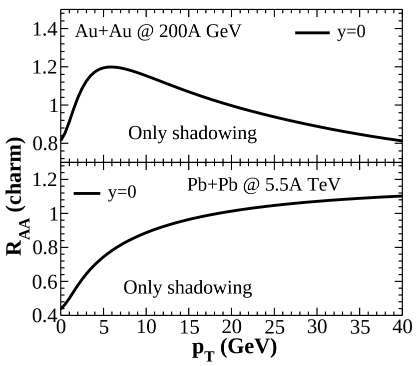

FIG. 2: R_{AA} of charm quark considering only the nuclear shadowing effect.

Results and discussions

We calculate the nuclear modification factor of charm quarks considering the energy loss of charm quarks as well as the shadowing effect. We calculate the nuclear overlap function $T_{AA} \approx$ 280 fm^{-2} for central Au+Au collisions at RHIC and ≈ 290 fm^{-2} for central Pb+Pb collisions at LHC. In Fig. 2 we show our results for R_{AA} considering only the shadowing effect at RHIC and LHC energies. At RHIC energy, we see a suppression at lower p_T, an enhancement at intermediate p_T, and again a suppression at larger p_T but due to the increased energy at LHC R_{AA} shows a larger suppression at low p_T and then rises beyond 1 at $p_T \approx 20$ GeV.

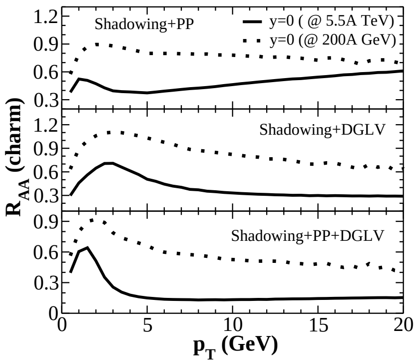

FIG. 3: R_{AA} of charm quark considering both the nuclear shadowing effect and the energy loss at midrapidity.

In Fig. 3 we discuss our results for R_{AA} with the additional inclusion of collisional and radiative energy losses at RHIC and LHC energies. We can see that the p_T distributions of R_{AA} at RHIC and LHC energies behave in the same manner but it shows more suppression while going from RHIC to LHC energy.

References

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