Effect of energy loss on nuclear modification factor of heavy mesons in pPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV

Kapil Saraswat[1,2],* Deependra Singh Rawat[1], and H.C. Chandola[1]
[1] *Department of Physics (UGC-CAS), Kumaun University, Nainital-263001, INDIA. and*
[2] *Institute of Physics, Academia Sinica, Taipei-11529, TAIWAN.*

Introduction

QCD predicts the existence of Quark-Gluon Plasma (QGP), a deconfined form of quarks and gluons at very high temperature or baryon density[1]. On theoretical ground the color flux-tube interaction in terms of their annihilation or unification under extreme conditions of temperature and density provides an interesting scenario of the formation of such color conducting state of hadronic constituents[1]. On the other hand, various heavy ion collisions (AuAu, PbPb, XeXe and CuCu) are performed to create QGP at relativistic energies. Many worldwide experiments such as STAR, PHENIX, CMS, ATLAS, ALICE and LHCb are studying the properties of QGP. Jet quenching, dilepton and photon productions, elliptic flow, hadron spectra, J/ψ suppression and heavy quarks are the signatures of the QGP. Here we will focus only heavy quarks. Most of the heavy quarks are produced in the early phase of relativistic heavy ion collisions when the parton momenta are high before the formation of QGP. The small production of heavy quarks make it special probe of QGP. Heavy quarks interact with the medium and do not become part of the medium and thus probe the opacity of the medium. Heavy quarks loose their energy when they travel in QGP medium. They loose energy either due to the collisions with the plasma partons or by radiating gluons. In this article, we study the transverse momentum (p_{T}) spectra, energy loss and the nuclear modification factor (R_{pPb}) of heavy quarks in pPb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV and compare our calculations with the heavy meson measurements.

*Electronic address: `kapilsaraswatbhu@gmail.com`

Methodology

pQCD approach [2] is used to calculate the differential cross-section of the heavy quarks in proton-proton (pp) collisions. CT14NLO parton distribution sets [3] is used to obtain the parton distribution functions (PDFs). For the modification of inside the nucleus, EPPS16 packagec [4] is used. We use Peterson fragmentation function [5] for the fragmentation of the heavy quarks into the heavy mesons for the pp and pPb collisions. We use the generalised dead cone approach (Present) [6] and the reactor operator formalism (DGLV) [7] to calculate the radiative energy loss and we use Peigne and Peshier (PP) formalism [8] to calculate the collisional energy loss. We also calculate the energy gain due to the chromoelectric field fluctuation using CMT formalism [9]. The path length and initial temperature is obtained using theevolution model which is described in Refs. [2, 10].

Results and Discussions

Figure 1 shows the pQCD LO calculation of differential cross section of D mesons as a function of p_{T} for the centre of mass frame rapidity $-0.96 < |y_{\mathrm{CMS}}| < 0.04$ in pPb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV and is compared with the ALICE measurements [11].

Figure 2 shows the energy loss of charm quark as a function of quark energy in the pPb collisions at $\sqrt{s_{NN}} = 5.02$ TeV using PP, DGLV, Present and CMT formalisms. The radiative energy loss calculated by present approach is larger than the energy loss by DGLV, PP and CMT.

Figure 3 shows R_{pPb} for D^0 meson as a function of the transverse momentum p_{T} obtained including shadowing and energy loss (PP, Present, DGLV, PP + Present and PP + DGLV calculations) for the centre of mass frame rapidity range $-0.96 < |y_{\mathrm{CMS}}| < 0.04$ in p-Pb collisions at $\sqrt{s_{\mathrm{NN}}}$ = 5.02 TeV. The calculations are compared with the measured data of the ALICE experiment [11].

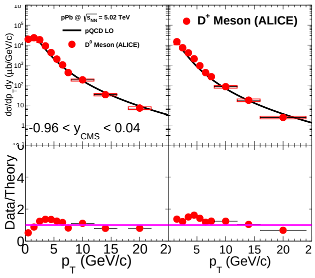

FIG. 1: $d\sigma/dp_{\rm T}dy$ of D meson as a function of $p_{\rm T}$.

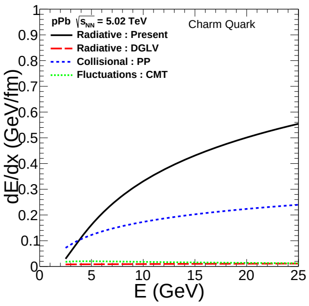

FIG. 2: dE/dx of charm quark as a function of energy E

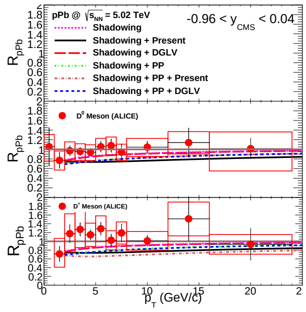

FIG. 3: $R_{\rm pPb}$ as a function of $p_{\rm T}$.

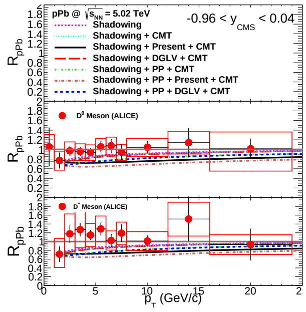

FIG. 4: $R_{\rm pPb}$ as a function of $p_{\rm T}$.

Figure 3 is same as Figure 4 but it includes CMT in the energy loss. Upper panel in both figures is for D^0 meson and lower panel is for D^+ meson. PP, DGLV, Present, PP + DGLV and PP + Present overestimate the D^+ and D^0 ALICE data within the uncertainties of the data at low $p_{\rm T}$ but these describe the ALICE data within the uncertainties of the data at high $p_{\rm T}$. The effect of the fluctuations by CMT with or without including energy loss on $R_{\rm pPb}$ is negligible.

Conclusion

In our study, we found that the effect of the energy loss (both collisional and radiative) and fluctuations on $R_{\rm pPb}$ is negligible as comapred to shadowing $R_{\rm pPb}$. We can see that D meson $R_{\rm pPb}$ is consistent with unity within uncertainties in the measured transverse momentum regions. It can be seen that we did not find any significant modification in pPb collisions as compared to pp collisions where pQCD calculation is scaled by the mass number of the nucleus.

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