# Nuclear modification factor of average D meson in an anisotropic quark-gluon plasma at the LHC energies

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## Introduction

The heavy quark i.e., charm and bottom quarks, are produced in hard scattering processes at the initial stages of the heavy-ion collisions and pass through the whole space-time history of the transient matter. During the evaluation they can interact with the medium and lose energy via both inelastic processes (radiative energy loss) and elastic scatterings (collisional energy loss). The partonic energy loss mechanism in the deconfined QCD medium has been developed remarkably in recent years. Experimentally, it can be probed by measuring the high-$p_T$ hadrons emanating from ultrarelativistic heavy ion collisions.

The heavy quarks after lossing the energy fragment into open-charm (bottom) heavy mesons (D,B). The formation of QGP can be established by measuring the energy loss vis-a-vis the nuclear modification factors ($R_{\mathrm{AA}}$) of various heavy mesons such as D, B, J/$\Psi$, $\Upsilon$ etc. Experimental data for this quantity at various LHC energies shows suppression of these mesons in nucleus-nucleus collisions. Different theoretical models have also been exploited to explain the data. In this work we concentrate on the nuclear modification factors ($R_{\mathrm{AA}}$) within the ambit of anisotropic quark gluon plasma (aQGP) and extract the isotropization time, $\tau_{\mathrm{iso}}$ by comparing with ALICE data. In the following we are argue how an aQGP can be realised in relativistic heavy collisions.It is suggested that (momentum) anisotropy-driven plasma instabilities may speed up the process of isotropization [1], in which case one is allowed to use hydrodynamical evolution of the medium. However, instability-based isotropization is not yet proven at RHIC and LHC energies. During the rapid expansion in the longitudinal direction during the initial moment, the plasma cools faster in the longitudinal direction than in the transverse direction leading to $\langle p_z^2\rangle << \langle p_T^2\rangle$ . As aresult, the system becomes anisotropic in the momentum space. Thus for the time interval $\tau_i < \tau < \tau_{\mathrm{iso}}$ equilibrium hydrodynamics is not applicable. We use, for the simplicity (1+1) anisotropic hydrodynamics developed. In our work it is assumed that an isotropic GQP is formed at the time $\tau_i$ and temperature $T_i$. Soon after the rapid longitudinal expansion makes the system anisotropic which lasts till $T_{iso}$. After that it expands further where ideal hydro can be applied.

## Results

The nuclear modification factor ($R_{\mathrm{AA}}$) defined as [2]

$$R_{\mathrm{AA}} = \frac{\frac{d^2N}{dp_{\mathrm{T}}dy}}{\left[\frac{d^2N}{dp_{\mathrm{T}}dy}\right]_0} \qquad (1)$$

Where $\frac{d^2N}{dp_{\mathrm{T}}dy}$ is the distribution of initial momentum of jets. In the denominator, the suffix '0' indicates that energy loss has not been considered while evaluating the expression.

The results for $R_{\mathrm{AA}}$ as a function of $p_{\mathrm{T}}$ for average D meson in Pb-Pb collisions for

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various values of the isotropization time, $\tau_{\rm iso}$ have been compared with the ALICE data [3] for the centrality 0 - 10% at $\sqrt{s_{\rm NN}} = 2.76$ TeV in Fig. 1. It is observed that the value of $R_{AA}$ decreases by increasing the $\tau_{\rm iso}$. The same remarks can be obtained from Fig. 2 for 30 - 50% at $\sqrt{s_{\rm NN}} = 5$ TeV.

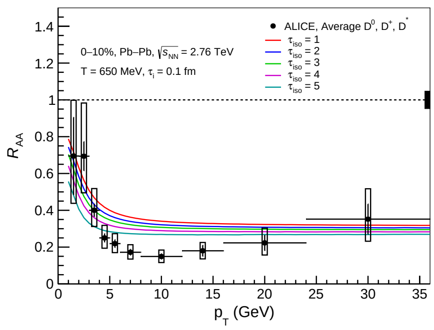


FIG. 1: $R_{\rm AA}$ of average D meson for (0-10)% at $\sqrt{s_{\rm NN}} = 2.76$ TeV

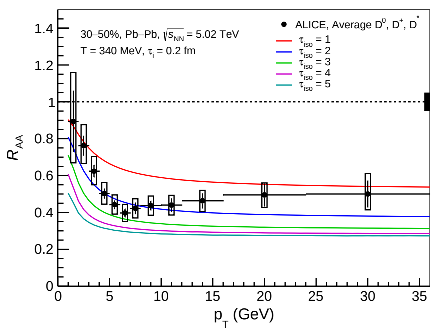


FIG. 2: $R_{\rm AA}$ of average D meson for (30-50)% at $\sqrt{s_{\rm NN}} = 5$ TeV

It is worth noting that the $p_{\rm T}$ spectra evalutded using our formalism reproduce the data reasonably well in the range $2 \leq \tau_{\rm iso} \leq 4$ fm/c at both energy and centrality classes.

The ratio of the $R_{\rm AA}$ at $\sqrt{s_{\rm NN}} = 5$ to 2.76 TeV as a function of $p_{\rm T}$ for the centrality class 0 - 10% is shown in Fig. 3 at different value of $\tau_{\rm iso}$. The ratio is decrease by about 6-8%,

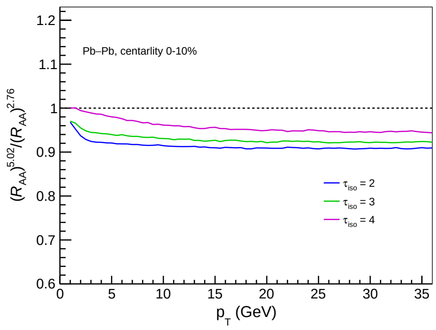


FIG. 3: Ratio of $R_{\rm AA}$ at $\sqrt{s_{\rm NN}} = 5.02$ TeV to $\sqrt{s_{\rm NN}} = 2.76$ TeV

with a harder $p_{\rm T}$ distribution and consistent with Djordjevic model prediction [4].

## Conclusion

We evaluate the nuclear modification factor ($R_{\rm AA}$) of average D meson at $\sqrt{s_{\rm NN}} = 2.76$ TeV and 5 TeV incorporating radiative energy loss in an anisotropic quark gluon plasma (aQGP) medium. We neglect the collisional energy loss as it will be small compared to radiative loss at high $p_{\rm T}$ of the parton. For simplicity , a (1+1)d anisotropic hydrodynamics as at the time scale over which the energy depleted heavy quarks fragments to hadrons, the effects of transverse expansion will be minimal. We then compare our results with the ALICE data at two centralities to extract the isotropization time, $\tau_{\rm iso}$ . It is found that the data for both the energies and centralites indicate that $\tau_{\rm iso}$ lies between $2 \leq \tau_{\rm iso} \leq 4$ fm/c. We also plot the ratio of $R_{\rm AA}$ at $\sqrt{s_{\rm NN}} = 5$ to 2.76 TeV and which is consistence with Djordjevic model prediction.

## References

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