# Energy loss and longitudinal dependent $R_{AA}$ of $D^0$ mesons in $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ PbPb collisions

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## Introduction

Heavy flavor nuclear modification factor $R_{AA}$ and azimuthal anisotropy $v_n\{m\}$ have been previously calculated in an event-by-event framework at mid-rapidity[1]. Those results showed that exploring new observables in the heavy flavor sector can lead to further constraints on the properties of the QGP. Furthermore, longitudinal dependence of the heavy flavor observables has not yet been explored. In this work we expand the previous framework to a 3D + 1 smooth viscous hydrodynamic medium background. We obtain $D^0$ meson nuclear modification factor for rapidity bins in the range $|y| \leq 5.0$ for $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ PbPb collisions.

## Development and results

The simulation was performed using the DABMod Monte Carlo code[1] which implements the evolution of heavy quarks on top of an evolving background medium. The heavy quark energy loss has been parameterized using $\frac{dE}{dx}(T, v) = -\alpha$, with $\alpha$ being a constant which is matched with experimental data. In order to obtain results dependent on the rapidity, a full 3D + 1 simulation is necessary, for this first investigation we used the CLVisc hydro code[2] average event for 0–10% PbPb collision at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ with $\tau_0 = 0.2\,\text{fm/c}$, $\eta/s = 0.08$, freeze-out temperature $T_0 = 137\,\text{MeV}$ and equation of state s95p-PCE. For the initial condition we use Glauber Monte Carlo. The position distribution of the charm quarks is shown in figure 1 for different rapidity ranges. The figure also shows how the quarks are distributed after the diffusion through the medium.

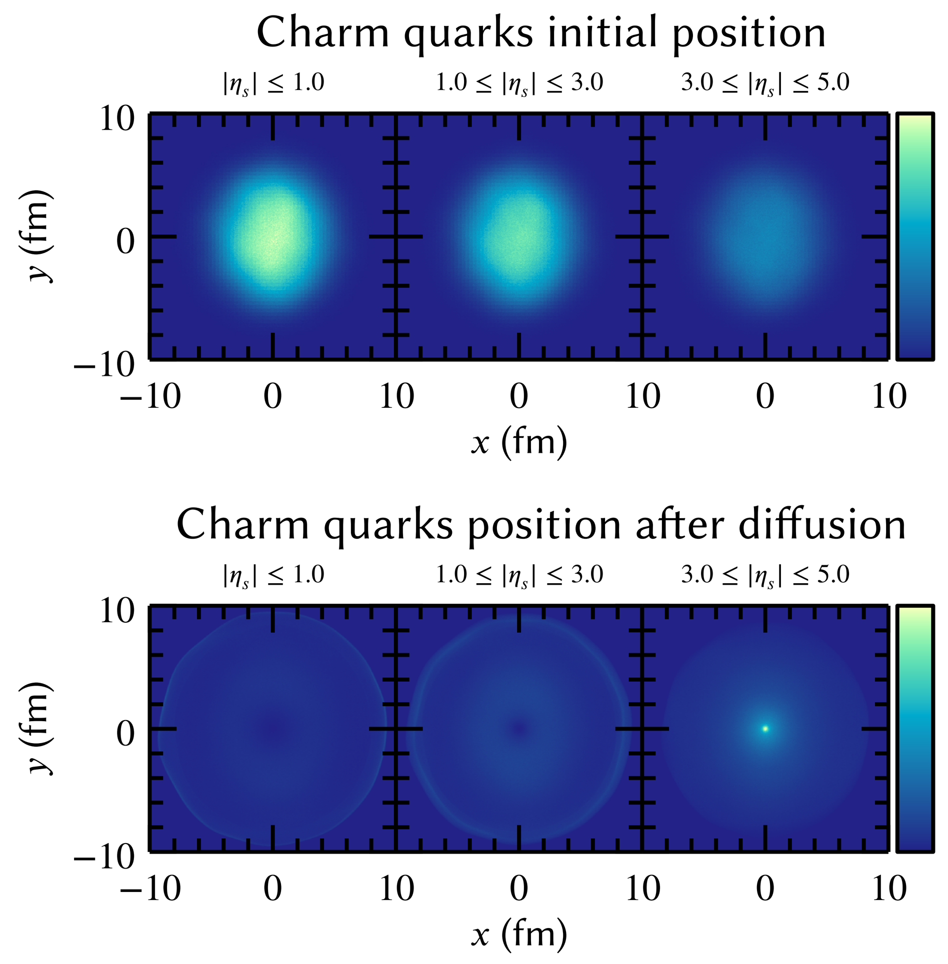


*Figure 1: Distribution of charm quarks for different rapidity ranges. The upper panel shows the initial position of the quarks prior to their diffusion through the QGP medium. The lower panel shows the position of the same charm quarks after their diffusion through the medium.*

Firstly, we study the flow effect on the $R_{AA}$ at mid-rapidity using this setup and use it as a consistency test for the simulation. There are two effects to be considered due to the expanding medium: the Lorentz boost of the 4-momentum of the heavy quark, as well as the time interval dilation due to the change of frames. The comparison of the $D^0$ $R_{AA}$ considering these two factors is shown in figure 2. The figure shows that the 4-momentum boost makes $R_{AA}$ grow slower with $p_T$ in comparison with the absence of flow effects, however, the opposite effect is observed when adding the time dilation effect. The effect is observed as expected from previous calculations.

Figure 3 we show the calculation of the $D^0$ meson $R_{AA}$ for different rapidity ranges. The mid-rapidity regime is compared to experimental data and it is consistent with previous calculations using 2D + 1 hydrodynamical backgrounds. It is observed that for higher rapidity both in the forward and backward regimes lead to a flatter $R_{AA}$, removing the difference between lower and higher $p_T$. This observation can be explained due to the reduced size of the medium which leads to the faster decrease of temperature below the freeze-out. The curves in figure 4 shows this effect for different $p_T$ regimes where the extremity converge.

Furthermore, it is observed by figure 4 that the $R_{AA}$ dependency with rapidity have different behavior for different $p_T$ sectors. In the low $p_T$ regime up to approximately $p_T \approx 20\,\text{GeV}$, $R_{AA}$ increases with rapidity, however the opposite is observed for $p_T \gtrsim 40\,\text{GeV}$. A transition regime is observed between these two extremes in which the $R_{AA}$ first decreases and then increases with the rapidity.

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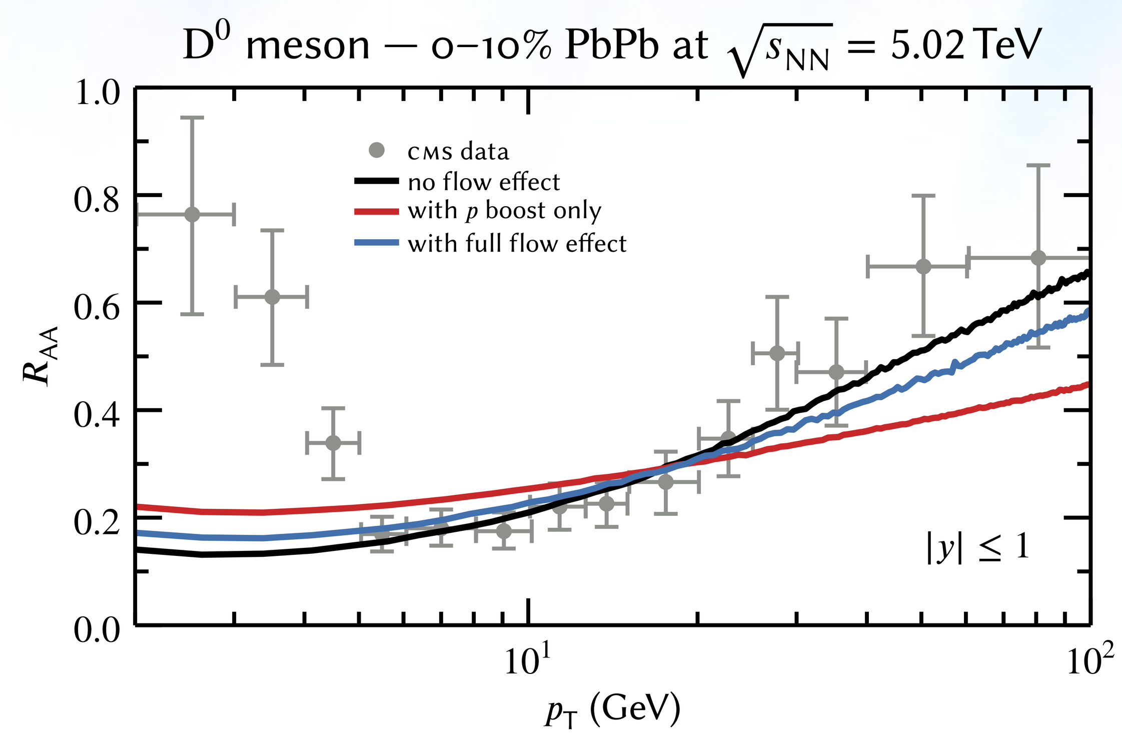


*Figure 2: Nuclear modification factor of $D^0$ mesons for PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ at the mid-rapidity range $|y| \leq 1$ and 0–10% centrality class compared with experimental data from CMS collaboration[3]. The different curves show a comparison of different flow effects on the simulation.*

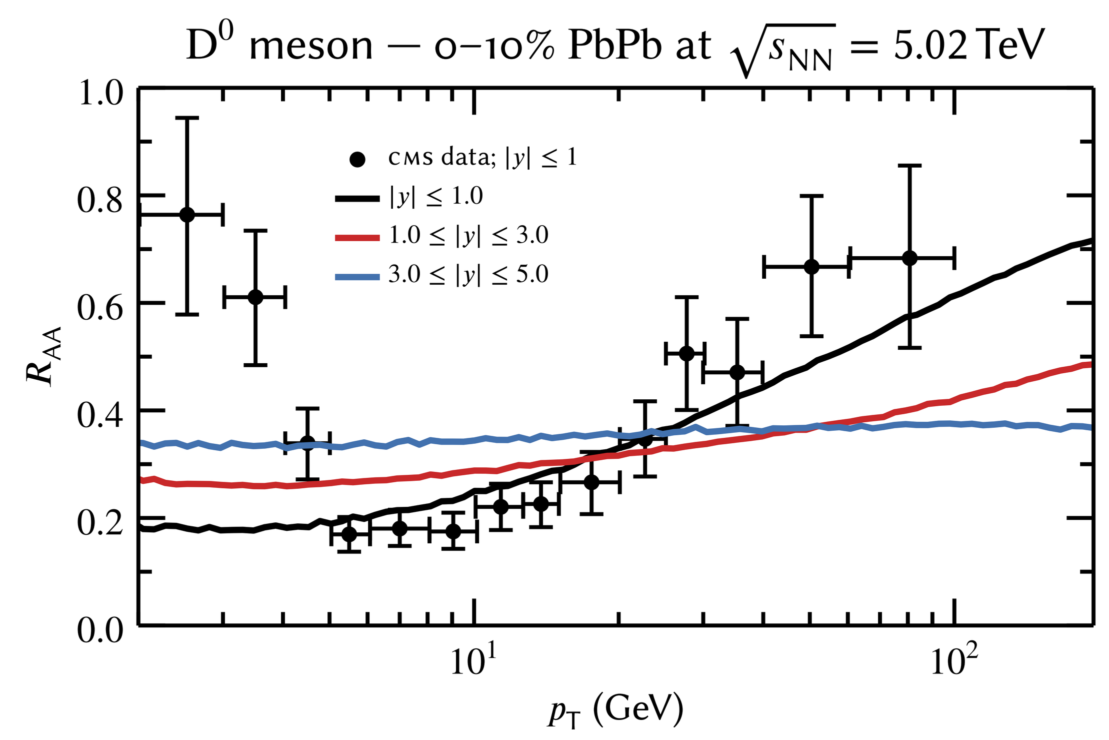


*Figure 3: Nuclear modification factor of $D^0$ mesons for PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ in the 0–10% centrality class for different rapidity ranges. The mid-rapidity result is compared to recent experimental data from the CMS collaboration[4].*

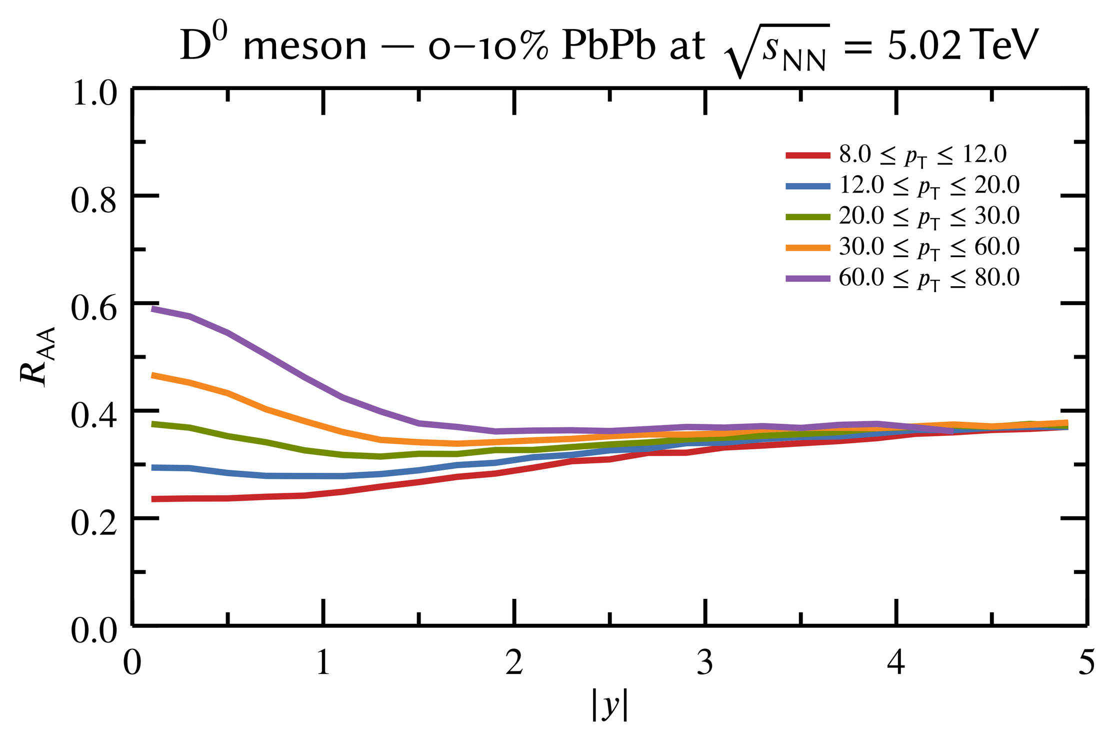


*Figure 4: Integrated nuclear modification factor of $D^0$ mesons for PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$ in the 0–10% centrality class dependent on the rapidity. Different regimes of $p_T$ have been selected for comparison.*

## Conclusions and perspectives

In this work we expanded previous calculations for $D^0$ meson to a 3D + 1 average medium background in order to investigate the longitudinal dependence of the $D^0$ meson nuclear modification factor. It was observed that the $R_{AA}$ depends differently on the rapidity for different $p_T$ ranges. This suggests that exploring the longitudinal dependency of heavy flavor observables can lead to new constraints for the study of the QGP.

Following this approach, a more realistic energy loss model is being currently developed. Furthermore, event-by-event simulations are also expected to be performed in order to obtain a longitudinal dependent azimuthal anisotropy of heavy quarks.

References

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[4] CMS Collaboration, "Nuclear modification factor of $D^0$ mesons in PbPb collisions at $\sqrt{s_{NN}} = 5.02\,\text{TeV}$," (2017), arXiv:1708.04962 [nucl-ex].