



Effects of Time Evolution and Fluctuating Initial Conditions on Heavy Flavor electron R_{AA} in Event-by-Event Relativistic Hydrodynamics

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Introduction

Central Au+Au collisions at RHIC exhibit a strong particle suppression when compared to p+p collisions, which is usually associated with jet quenching or energy loss of partons inside the quark-gluon-plasma (QGP). One question that arises from this observation concerns the relative behavior between heavy and light quarks. Experimental data from RHIC and LHC indicates that heavy quarks are as suppressed as light ones.

We aim in this work to investigate the effect of initial state fluctuations in the energy loss of heavy quarks. These fluctuations may lead to very high density spots that could enhance the heavy quark suppression at the early stages of the collision. Furthermore, we study the effect of medium expansion with time as it might cause these high density spots to expand differently from the rest of the plasma, affecting heavy quark energy loss as well.

This work consists of computational simulations of charm and bottom quarks propagating through the medium until they fragment and hadronize as they reach the freeze-out temperature. The resulting mesons are forced to decay, giving us the electron p_T spectrum that is used to estimate the nuclear modification factor R_{AA} and v_2 . We use a newly developed 2D+1 Lagrangian ideal hydrodynamic code which is based on the Smoothed Particle Hydrodynamics (SPH) algorithm and investigate heavy quark quenching in an event-by-event basis. The simulations are performed on two different scenarios: fluctuating and smooth initial conditions (ic) events.

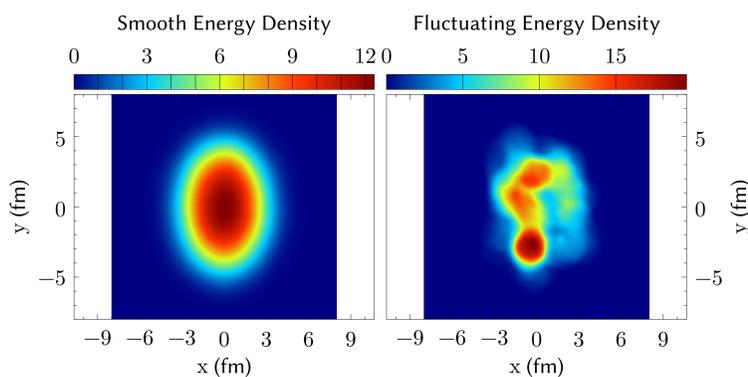


FIGURE 1: Fluctuating initial condition examples used during simulations, we show the energy density for smooth condition (left) and for fluctuating condition (right). A short movie showing the medium evolution can be viewed at <https://www.youtube.com/watch?v=WNzCGPUH3FU> or by scanning the QRcode presented on the right.

Figure 1 shows two ic examples to illustrate the smooth and fluctuating scenarios used during simulations. We can then compare the effects of changing the ic scenario on the results.

Simulation

There are a number of processes between the quark creation inside the plasma and the eventual measurement of heavy flavor electrons (single e^\pm):

Production spectrum: First-Order Next-to-Leading-Logs (FONLL) calculations^{1,2},

Energy loss: Mustafa radiative energy loss³ plus Dead Cone effect⁴,

Fragmentation: Peterson model⁵ fitted to FONLL predictions,

Decay: PYTHIA⁶ algorithms.

As a consistency check for the simulation we show in Figure 2 a comparison of R_{AA} spectrum between expanding and static medium in order to verify that, due to the medium fast cooling, the simulation with an expanding medium results in less energy loss. Another consistency check that can be done is by showing that v_2 is compatible with zero when the medium is perfectly symmetric. Figure 3 shows this case using a perfectly circular Woods-Saxon distribution.

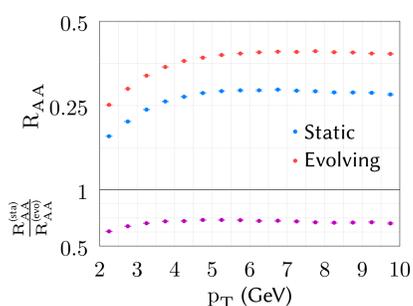


FIGURE 2: Comparison of R_{AA} spectrum between evolving and static initial conditions.

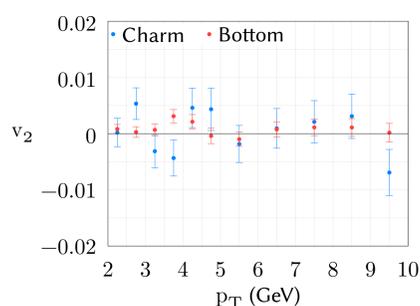


FIGURE 3: Values of v_2 for a perfectly symmetric Woods-Saxon distribution.

Results

Figure 4 compares the R_{AA} spectrum between smooth and fluctuating initial conditions. We observe a small difference between them as shown by the ratio presented in the figure.

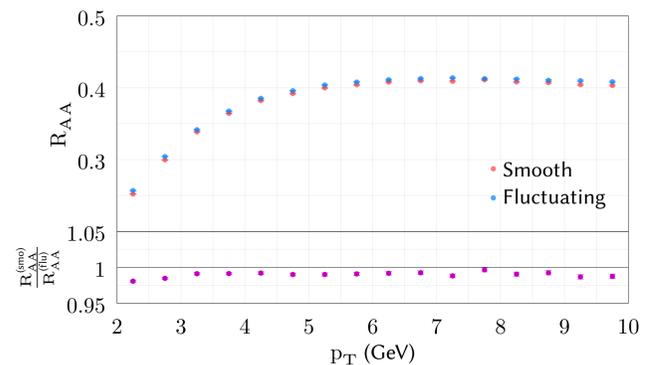


FIGURE 4: Comparison of R_{AA} spectrum between smooth and fluctuating initial conditions.

Figures 5 and 6 show the v_2 calculations for both, central and semi-central, initial conditions. The central simulation shows no difference between smooth and fluctuating ic. However it is possible to note that for the semi-central simulation the fluctuating conditions result in slightly higher values of v_2 .

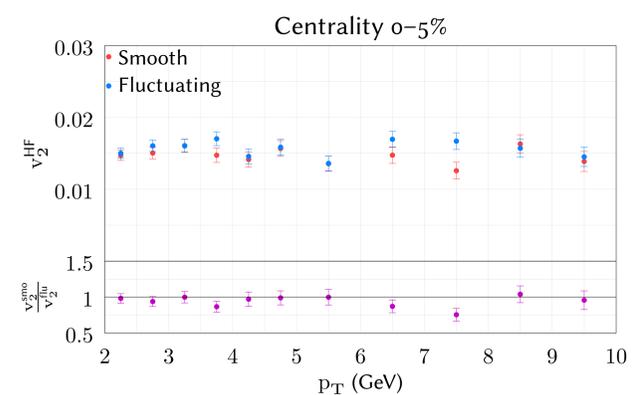


FIGURE 5: Comparison of v_2 calculations between smooth and fluctuating central initial conditions.

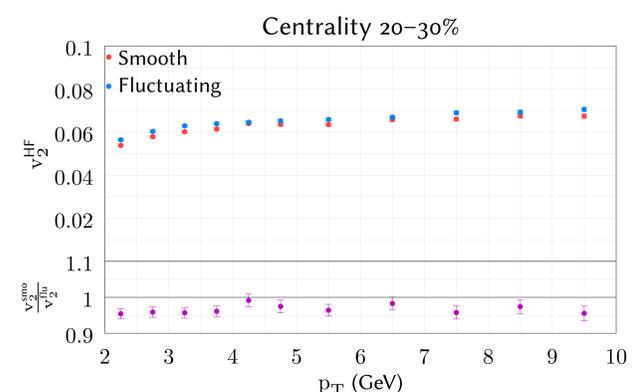


FIGURE 6: Comparison of v_2 calculations between smooth and fluctuating semi-central initial conditions.

Conclusions

We performed simulations of the evolution of charm and bottom quarks inside an expanding plasma in order to study the influence of fluctuations in the initial conditions over the quark suppression and anisotropy. The results showed a small difference for the R_{AA} spectrum and for the v_2 values for semi-central collisions. Although these differences are small, they are present for all the range in p_T . They may indicate an influence on the azimuthal symmetry due to the ic fluctuations.

References

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