Heavy flavour dynamics in event-by-event viscous hydrodynamic backgrounds

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Abstract: Heavy flavour probes provide important information about the in-medium properties of the quark gluon plasma produced in heavy-ion collisions. In this work, we investigate the effects of (2+1)d event-by-event fluctuating hydrodynamic backgrounds on the nuclear suppression factor and momentum anisotropies of heavy flavour mesons and non-pionic electrons [1]. Using the state-of-the-art D and B mesons modular simulation code (the so-called “DAB-Mod”), we perform a systematic comparison of different transport equations, including a few energy loss models - with and without energy loss fluctuations - and a relativistic Langevin model with different drag parametrizations.

We present the resulting D and B mesons R_{AA}, v_2, v_3, and v_4, as well as their multiparticle cumulants, in Au-Au collisions at 200 GeV and Pb-Pb collisions at 5.02 TeV, and compare them to the latest available experimental data. We also study the linearity of the resulting heavy meson and soft hadron flow correlations, as new experimental observables that could provide greater insight into flow fluctuations, and compare for the first time our predictions with ALICE preliminary measurements of D meson v2 vs q2 in Pb-Pb collisions at 5.02 TeV.


1. Motivations

- Develop a simulation (the so-called “DAB-Mod”) to study the production of open heavy mesons in heavy ion collisions.
- Explain simultaneously the nuclear modification factor R_{AA} and the elliptical anisotropy v_2, v_3, and v_4, as well as their multiparticle cumulants in Au-Au collisions at 200 GeV and Pb-Pb collisions at 5.02 TeV.
- Study the heavy flavour azimuthal anisotropies through the more rigorous cumulant method (unambiguous measurement and remove non-flow contributions; see arXiv:1209.2323).
- Explore new related observables, such as the correlations of soft hadron and heavy meson flows, which might help to distinguish between the different models.

2. The DAB-Mod simulation

Heavy flavor dynamics …

- Initial conditions:
  - Large oversampling of the heavy quarks for each hydro. event (~10 per event – necessary for the statistics) distributed spatially following initial QGP energy density.
  - Transverse momentum distribution given by FORNL spectra and random azimuthal direction.
  - No shadowing or cold nuclear matter effects considered.

- Transport equations: heavy quark interactions with the moving medium

Energy loss - E_{loss} = \text{parametric model}

\frac{dE}{dt} = -f(T,p,x)C_{L}\text{flow}

where the chosen parametrizations

f(T,p,x) = \alpha \text{ and } f(T,p,x) = 2T\text{led to relevant R}_{AA}\text{ results, where the effect of the moving medium on energy loss is given by:}

\Gamma_{\text{flow}} = \gamma \left(1 - \frac{T_{\text{flow}}}{T_{\text{QGP}}} \right)\text{Cos}(\vec{v}_{\text{flow}} \cdot \vec{\phi}_{\text{flow}})

and \(\gamma\) gives the energy loss fluctuations (only added to \(f(T,p,x)\) if \(\alpha = 0\) here, described by a uniform, linear or gaussian distribution:

\frac{d\phi}{dt} = \frac{p_0}{p_0 + 3T}\text{Langevin equation}

\frac{dp}{dt} = -\left(f(T,p,x) + \sqrt{\frac{Q}{D}}\right)\text{with the necessary boosts between global and fluid frames and with the classic fluctuation-dissipation relation for the encode the large uncertainties regarding hadronization.}

\alpha = \begin{cases} \text{Langevin: good at very low }p_T, \text{MT effective at low }K_T \text{ and MT+ at high }p_T \end{cases}

3. Results

Nuclear modification factor R_{AA}

Choosing B_{mass} models: good behaviour at high p_T, B_{mass} fluctuations lead to similar behaviour. Langevin: better at low p_T, MT also at high p_T

Flow anisotropies with the cumulants

We use the scalar product method: e.g. for the 2^nd cumulant:

\frac{\text{correlation of }v_2}{\text{some multiplicity}}\text{ weighted and where}

Soft-heavy flow correlations

Clear linear correlations between heavy quark and all charged particles elliptical and triangular flows whatever is the transport model. Average correlations: not more differentiative than cumulants

Future: Coalescence, other colliding systems (pPb, XeXe), 3D...