Longitudinal dependence of B and D mesons nuclear modification factor in relativistic heavy ion collisions

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Outline

Introduction

Monte-Carlo simulation

Results

Summary
**Heavy quarks in heavy ion collisions**

- **Heavy Ion Collisions**
  - Experimental assessment of nuclear matter
  - Properties of the Quark Gluon Plasma

- **The case for heavy flavor**:
  - Pre-equilibrium production (hard scattering)
  - Long relaxation times
  - \( m_Q > A_{qcd} \Rightarrow pQCD \) calculations
  - Strongly affected by QGP
  - Weakly affected by late time evolution
  - Hard fragmentation

- **Nuclear modification factor**:

  \[
  R_{AA}(p_T, y) = \frac{1}{N} \frac{dN_{AA}/dp_T}{dN_{pp}/dp_T} dy,
  \]
Simultaneous description between $R_{AA}$ and $v_2$?

Multiple models with different physics seems to only qualitatively describe the data

How can we further constraint the models to better understand what’s really going on?

One alternative: bet on new observables not very well explored yet (higher order harmonics, event shape engineering, soft-heavy correlations, longitudinal dependence, ...)
Introduction
Exploring the longitudinal dependence

- So far longitudinal dependence of observables are still in development;
- The medium dynamics can be very different at large rapidity: temperature, size, ...
- Is it possible to discriminate similar models on an analysis of the large rapidity spectra?
Monte-Carlo simulation

General framework

- Coding of the simulation:
  - C++/Fortran, ROOT and PYTHIA
  - Modular programming (QCD factorization)
  - Freedom in executing different hydro backgrounds.

- Transport model
  - Relativistic Langevin equation: \[ \frac{dp}{dt} = -\eta_D(p)p + \xi + f_g \]
  - Classic fluctuation-dissipation relation with \( D(2\pi T) = 7 \)
  - \( f_g \): recoil due to gluon emission.

- Hadronization
  - Hybrid fragmentation plus coalescence:
    - \( T_c = 165 \) MeV.
    - No re-scattering in the final hadronic phase.

- Heavy quarks probes:
  - Sampled at the beginning of the simulation
  - No medium response is implemented.
Monte-Carlo simulation

Initial Conditions and Hydrodynamics

- Input of the program;
- 3D profiles for the hydro:
  - Energy density;
  - Temperature;
  - Transverse velocity;
  - Longitudinal velocity;
- Trento initial conditions (IP-Glasma);
- Quarks position given by Glauber Model;
  - Initial momentum distribution given by \( p_{\text{QCD}}(\text{LO}) \).
- Viscous average 3D+1 hydrodynamics: \( \text{CLVisc} \)
  - \( \eta/s = 0.15 \);
  - \( T_{t_0} = 165 \text{ MeV} \);
  - \( \tau_0 = 0.6 \text{ fm/c} \);
  - s95p-pce EoS.
Heavy quark density distribution

Initial position

$|\eta| \leq 1.0$
$1.0 \leq |\eta| \leq 2.5$
$2.5 \leq |\eta| \leq 4.0$

Final position

$|\eta| \leq 1.0$
$1.0 \leq |\eta| \leq 2.5$
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Production spectra reaches lower $p_T$ with large rapidity.
**Nuclear modification factor**

- Good agreement with CMS experimental data for $D^0$
- Behavior dominated by the steeper yield spectra
- Low $p_T$ regime involves much complicated physics
Results

Nuclear modification factor

- Good agreement with CMS data for D mesons
- Data from ALICE disagrees with CMS
- Behavior similar to that of $\sqrt{s_{NN}} = 5.02$ TeV collision
Agreement with data only on the higher $p_T$ regime

Due to lower collision energy, large rapidity is limited on $p_T$
Simulation results matches both electrons and muons data.

Larger $p_T$ range of experimental data allows for more clearer separation in rapidity.

In the low $p_T$ regime, simulation underestimates the data.
For large $p_T$ we observe good agreement with data for both electrons and muons

Experimental error bars cover all the three curves for muon

In the low $p_T$ regime, simulation still underestimates the data
Results

Nuclear modification factor

- Good agreement with data for electrons despite the previous D meson results
- Overall behavior from B and D is propagated to electrons
With increasing rapidity, $R_{AA}$ tends to decrease

- Interplay between medium and production spectra
- Production spectra prevails and generates more suppression
Summary

- Longitudinal dependence of $R_{AA}$ of charm quarks and D mesons:
  - Interplay between heavy flavor production spectra and medium size compete at large rapidity
  - Production spectra dominates $R_{AA}$ results at large rapidity
  - Nuclear modification factor becomes flat with $p_T$ at large rapidity
  - Different behavior depending on $p_T$ regime
  - Further exploring the large rapidity regime might be able to provide further constraints on phenomenological models

- Future prospects:
  - Include comparison for other transport models
  - Study elliptic azimuthal anisotropy for heavy mesons
  - Event-by-event computations.