华中师范大学
CENTRAL CHINA NORMAL UNIVERSITY
Institute of Particle Physics

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

Caio A. G. Prado

with Wen-Jing Xing, Shanshan Cao, Guang-You Qin, Xin-Nian Wang

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Outline

Introduction

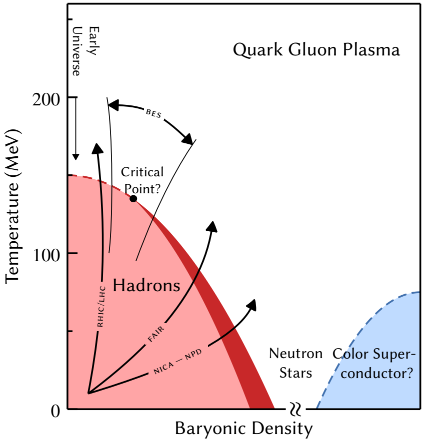
Monte-Carlo simulation

Results

Summary

Heavy quarks in heavy ion collisions

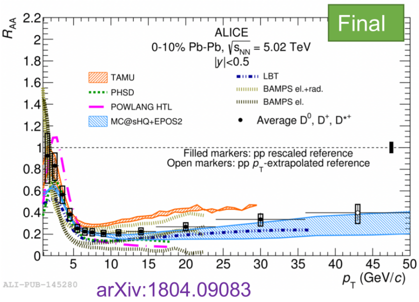
QCD phase diagram

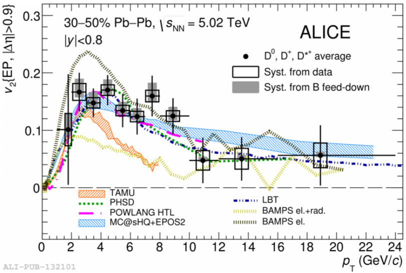


- Heavy Ion Collisions
  - Experimental assessment of nuclear matter
  - Properties of the Quark Gluon Plasma
- The case for heavy flavor:
  - Pre-equilibrium production (hard scattering)
  - Long relaxation times
  - $m_Q > \Lambda_{QCD} \Rightarrow$ pQCD calculations
  - Strongly affected by QGP
  - Weakly affected by late time evolution
  - Hard fragmentation
- Nuclear modification factor:

$$R_{AA}(p_T, y) = \frac{1}{\mathcal{N}} \frac{dN_{AA}/dp_T\,dy}{dN_{pp}/dp_T\,dy},$$

Current status





- Simultaneous description between R_{AA} and v_2?
- Multiple models with different physics seems to 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, ...)

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?

General framework

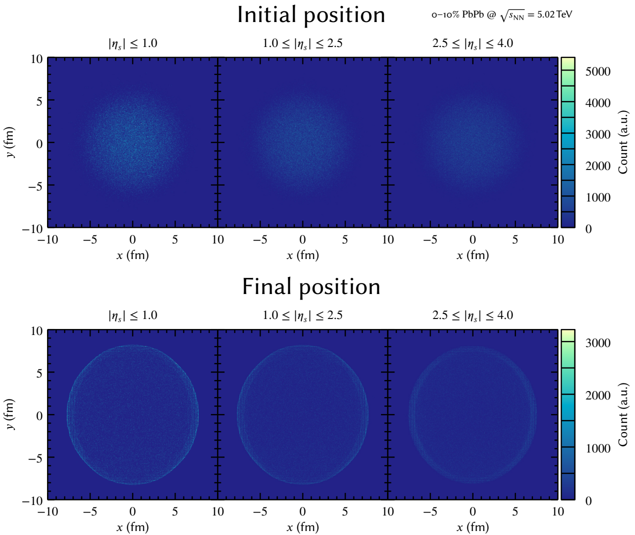
- Coding of the simulation:
  - C++/Fortran, ROOT and PYTHIA
  - Modular programming (QCD factorization)
  - Freedom in executing different hydro backgrounds.
- Transport model
  - Relativistic Langevin equation: $\frac{\mathrm{d}\boldsymbol{p}}{\mathrm{d}t} = -\eta_D(\boldsymbol{p})\boldsymbol{p} + \boldsymbol{\xi} + \boldsymbol{f}_{\mathrm{g}}$
  - Classic fluctuation-dissipation relation with $D(2\pi T) = 7$
  - $\boldsymbol{f}_{\mathrm{g}}$: 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.

Initial Conditions and Hydrodynamics

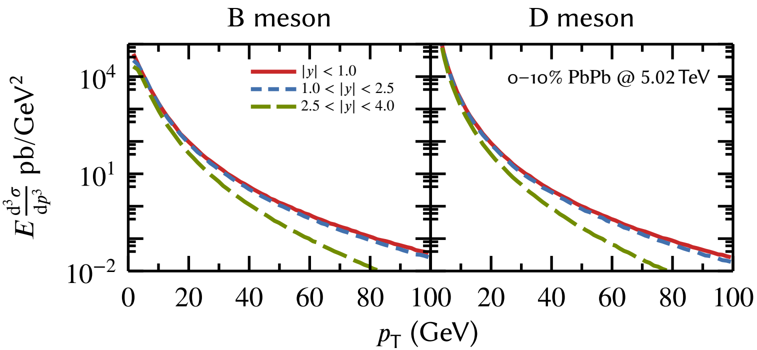
- Input of the program;
- 3D profiles for the hydro:
  - Energy density;
  - Temperature;
  - Transverse velocity;
  - Longitudinal velocity;
- TRENTO initial conditions (IP-Glasma);
- Quarks position given by Glauber Model;
  - Initial momentum distribution given by pQCD (LO).
- Viscous average 3D+1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

arXiv:1802.04449

Heavy quark density distribution

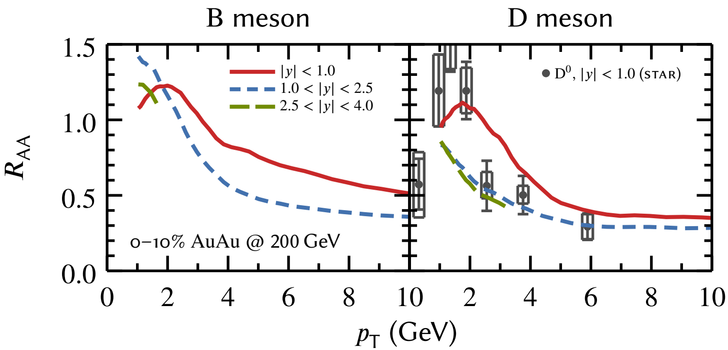


Transverse momentum distribution



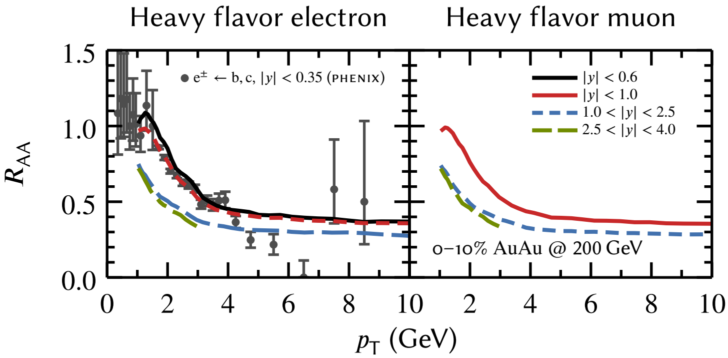
- Production spectra reaches lower p_T with large rapidity.

Nuclear modification factor



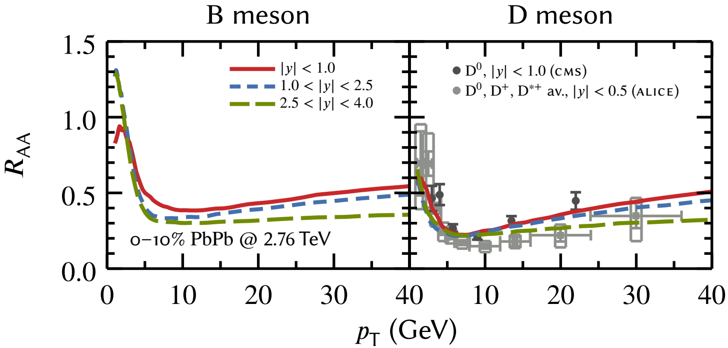
- Good agreement with data for D meson
- Crossing of R_{AA} curves at low p_T only clear for B meson
- Due to lower collision energy, large rapidity is limited on p_T

Nuclear modification factor



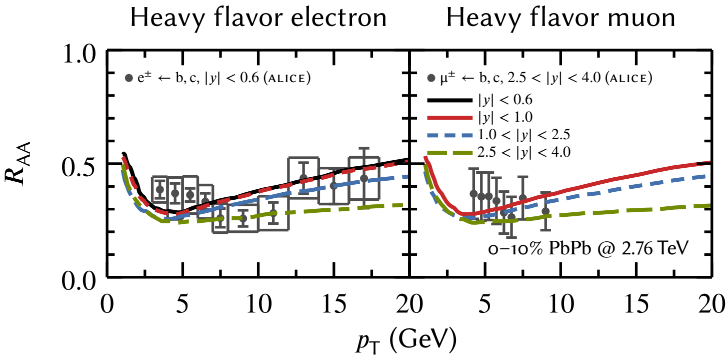
- Good agreement with data for electrons
- Overall behavior from B and D is propagated to electrons

Nuclear modification factor



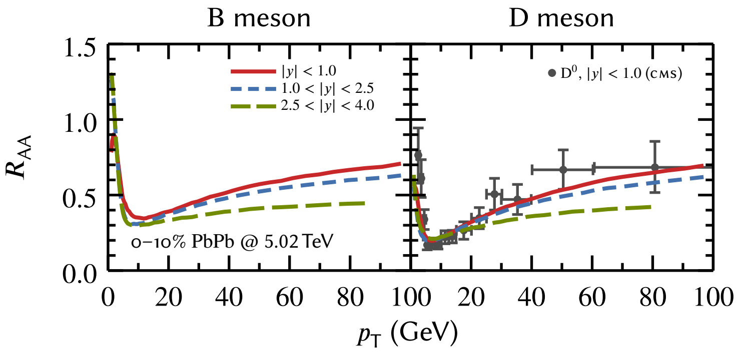
- Good agreement with CMS data for D mesons
- Data from ALICE disagrees with CMS.
- Again we observe crossing happening at low p_T for B meson

Nuclear modification factor



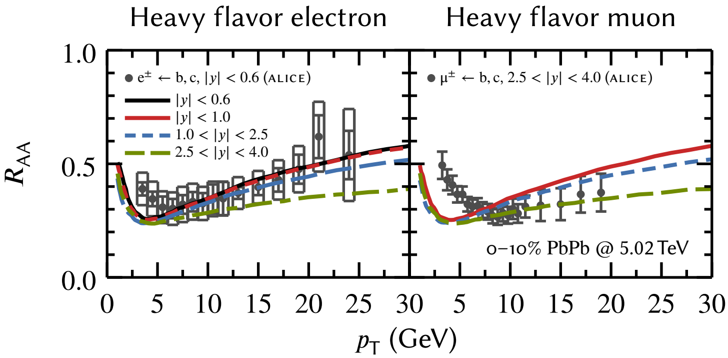
- For large p_T we observe good agreement with data for both electrons and muons
- Experimental error bars cover all the three curves for muon
- In the low p_T regime, simulation underestimates the data

Nuclear modification factor



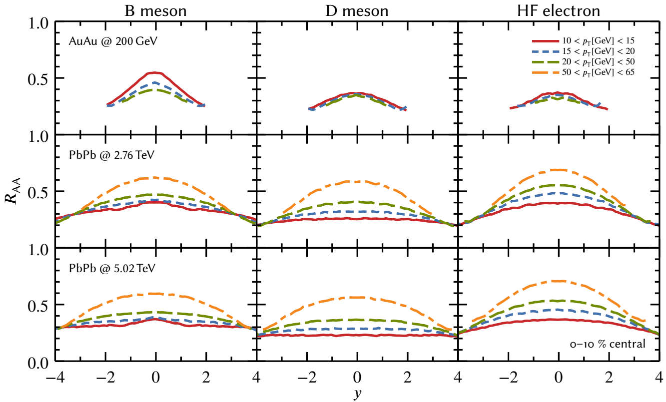
- We observe the same behavior as for $\sqrt{s_{NN}} = 2.76$ TeV
- Good agreement with CMS experimental data

Nuclear modification factor



- Simulation results matches both electrons and muons data.
- Larger p_T range of experimental data allows for more clearer separation in rapidity

Nuclear modification factor



- 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.