Open heavy-flavor diffusion at LHC, RHIC, and FAIR

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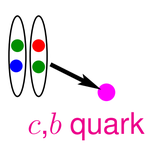
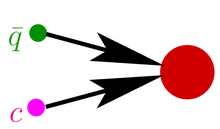
Introduction

- Strongly coupled quark-gluon plasma:
  - ultrarelativistic heavy-ion collsions: bulk of produced particles well described by (nearly) ideal hydro dynamics
  - collective radial and elliptic flow (v_2); constituent-quark number scaling of v_2
  - low-viscosity strongly coupled quark-gluon plasma
- heavy-quark probes
  - heavy charm and bottom quarks produced in primordial hard collisions
  - calibrated initial conditions from pp collisions
  - conserved in strong interactions with bulk medium of light quarks and gluons
  - large mass ⇒ longer equilibration time
  - R_{AA} and v_2 of D, B mesons and non-photonic single electrons ⇔ transport properties of the sQGP
  - can be described in relativistic Fokker-Planck/Langevin model
- theory scheme for heavy quarks

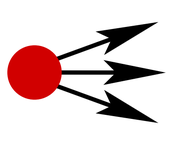


initial collisions: UrQMD + (3+1) hydro; Glauber model
hard production of HQs
described by PDF's + pQCD (PYTHIA)

HQ rescattering in QGP: Langevin simulation
drag and diffusion coefficients from
microscopic model for HQ interactions in the sQGP
description of bulk matter: UrQMD + (3+1)-dim hydro



Hadronization to D,B mesons via
quark coalescence + fragmentation



semileptonic decay ⇒
"non-photonic" electron observables
$R_{AA}^{e^+e^-}(p_T)$, $v_2^{e^+e^-}(p_T)$

Description of the bulk medium in AA collisions

- primordial hard collisions
  - first UrQMD run: geometry of NN collisions (Glauber approach)
  - second UrQMD run: particle production, non-equilibrium dynamics of early stage
  - at $t \sim t_{\text{start}} = 2R/\sqrt{\gamma_{\text{cm}}^2 - 1}$: mapping to a hydro grid
- hydrodynamical evolution
  - full (3+1)-dimensional ideal hydrodynamics (SHASTA algorithm

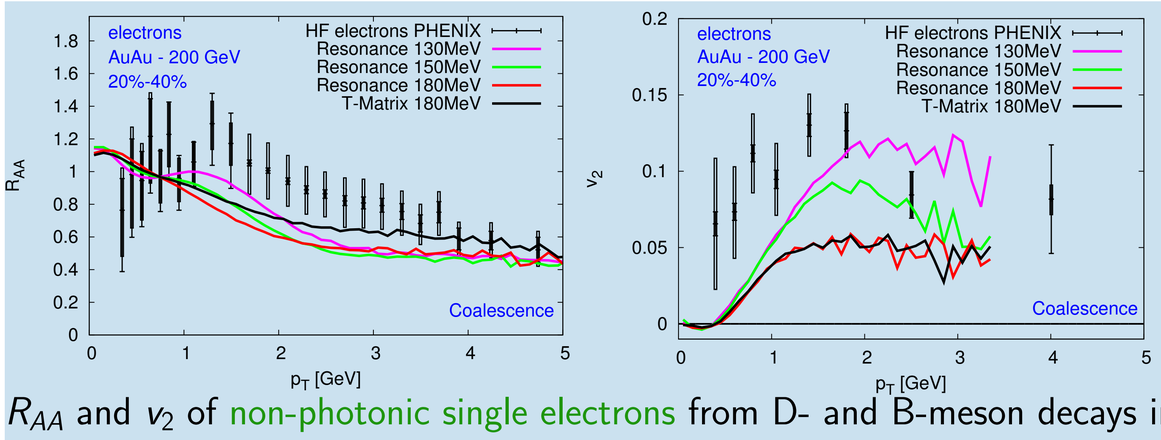
Heavy-quark diffusion

- Relativistic Langevin simulation
  - heavy-quark diffusion in hydrodynamic background

$$\mathrm{d}\vec{x} = \frac{\vec{p}}{E}\mathrm{d}t, \quad \mathrm{d}\vec{p} = -\Gamma\vec{p}\mathrm{d}t + \sqrt{\mathrm{d}t}\hat{C}\vec{\rho}$$

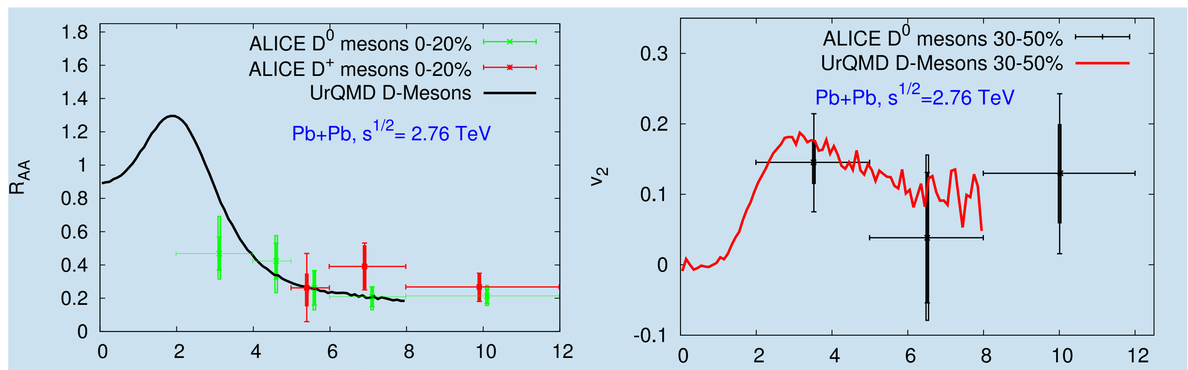
  - $\vec{\rho}$: Gaussian noise, Γ: drag (friction) coefficient, $\hat{C} = \sqrt{\hat{D}}$ with $\hat{D}$: diffusion coefficients
  - post-point Ito realization of stochastic process with diffusion coefficient $D_{\parallel} = EmT$
  - drag and diffusion coefficients: from microscopic models for elastic HQ scattering
  - D/B-like resonance formation above T_c or T-matrix approach with lQCD qQ potentials
  - extrapolate cross section into hadronic phase
- hadronization
  - coalescence at T_{dec} to recombine c/b quarks with light antiquarks to D/B mesons
  - PYTHIA for semileptonic decay of D/B mesons to "non-photonic" electrons

Non-photonic single electrons at RHIC [1]



R_{AA} and v_2 of non-photonic single electrons from D- and B-meson decays in $\sqrt{s_{\text{NN}}} = 200$ GeV-Au Au collisions at RHIC, assuming different decoupling temperatures. Using coalescence for hadronization process crucial for consistency between R_{AA} and v_2 (data: PHENIX)

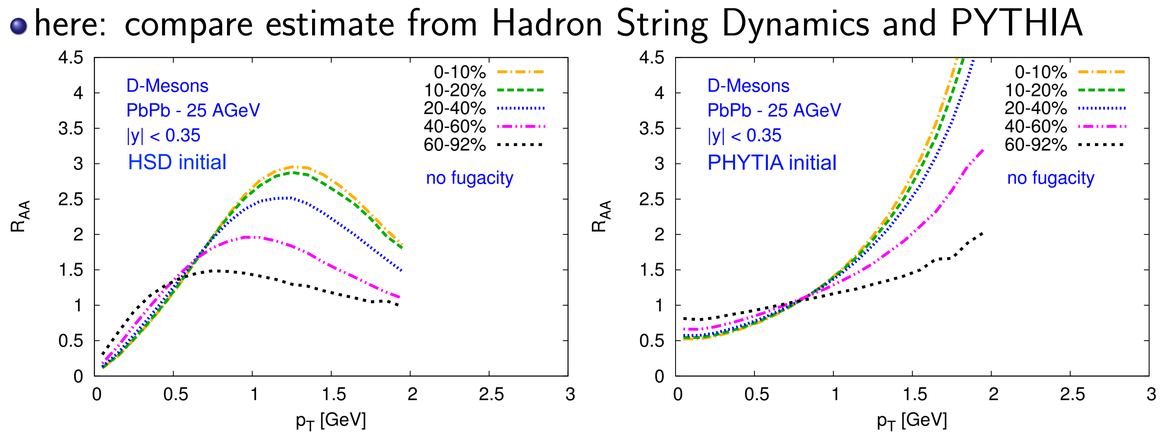
D-mesons at LHC [1]



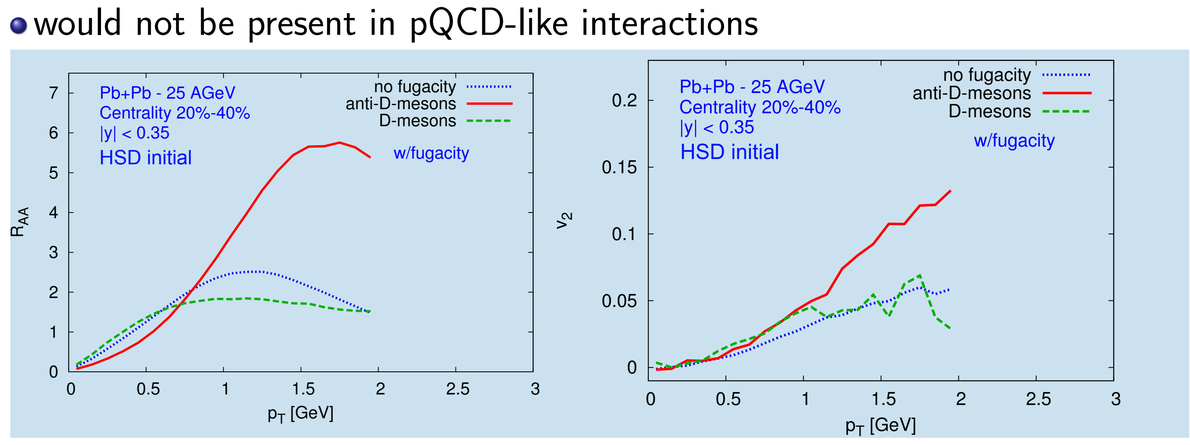
R_{AA} and v_2 of D mesons in $\sqrt{s_{\text{NN}}} = 2.76$ TeV-Pb Pb collisions at LHC, assuming a decoupling temperature of $T_{\text{dec}} = 130$ MeV (data: ALICE) [1].

D-mesons at FAIR [2]

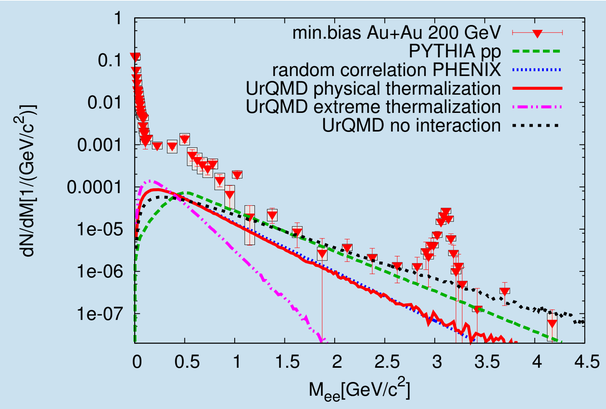
- sensitivity of R_{AA} to (unknown!) initial heavy-flavor p_T distribution
- here: compare estimate from Hadron String Dynamics and PYTHIA



- in v_2 large effect from large μ_B in resonance-scattering model
- would not be present in pQCD-like interactions



Dileptons at RHIC: D$\overline{\text{D}}$-angle correlations [3]



Invariant e^+e^- mass spectrum from correlated D and $\overline{\text{D}}$ decays in Au-Au collisions at $\sqrt{s_{NN}} = 200$ GeV, assuming different degrees of thermalization of D and $\overline{\text{D}}$. (data: PHENIX)

Conclusions and outlook

- medium modifications of heavy-quark spectra
  - UrQMD+hydro hybrid model for realistic description of the bulk medium
  - heavy c+b-quark diffusion via Langevin process
  - elastic resonance scattering of heavy quarks in strongly interacting matter
  - coalescence ⇒ consistency of R_{AA} and v_2 of D mesons in comparison to data
  - predictions for future CBM experiment at FAIR
  - impact on correlated D$\overline{\text{D}}$ decays [3]
- outlook
  - implement inelastic (radiative) scattering processes for HQ diffusion
  - use true hadronic cross sections for D- and B-mesons in hadronic phase
- References

[1] T. Lang, H. van Hees, J. Steinheimer, M. Bleicher, arXiv: 1211.6912 [hep-ph]
[2] T. Lang, H. van Hees, J. Steinheimer, M. Bleicher, arXiv: 1305.1797 [hep-ph]
[3] T. Lang, H. van Hees, J. Steinheimer, M. Bleicher, arXiv: 1305.7377 [hep-ph]

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