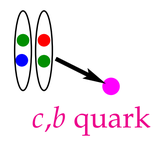
Heavy-quark diffusion at RHIC and LHC within a UrQMD-hydrodynamical hybrid model

H. van Hees[1], T. Lang[1], J. Steinheimer[2], M. Bleicher[1]

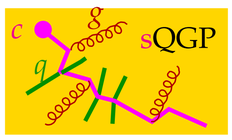
[1]Frankfurt Institute for Advanced Studies, Ruth-Moufang-Str. 1, D-60438 Frankfurt, Germany
[2]Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, CA 94720, USA

Introduction

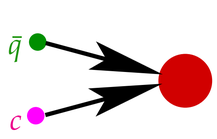
- Strongly coupled quark-gluon plasma:
  - ultrarelativistic heavy-ion collsions: bulk of produced particles well described by (nearly) ideal hydro dynamics
  - collective radial and elliptic flow (v_2); constituent-quark number scaling of v_2
  - low-viscosity strongly coupled quark-gluon plasma
- heavy-quark 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 $\Rightarrow$ longer equilibration time
  - R_{AA} and v_2 of D, B mesons and non-photonic single electrons $\Leftrightarrow$ transport properties of the sQGP
  - can be described in relativistic Fokker-Planck/Langevin model
- theory scheme for heavy quarks



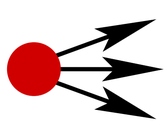
initial collisions: UrQMD + (3+1) hydro; Glauber model
hard production of HQs
described by PDF's + pQCD (PYTHIA)



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

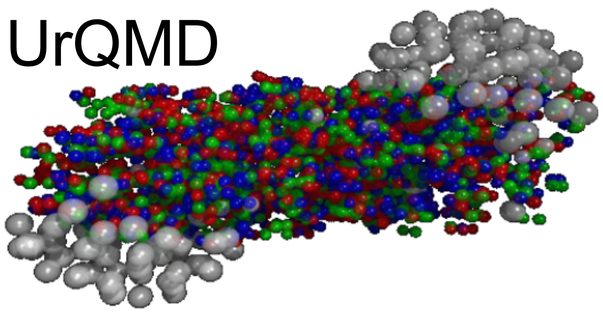


Hadronization to D,B mesons via
quark coalescence + fragmentation



semileptonic decay $\Rightarrow$
"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 [1, 2] 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
  - use full (3+1)-dimensional ideal hydrodynamics (SHASTA algorithm [3, 4])

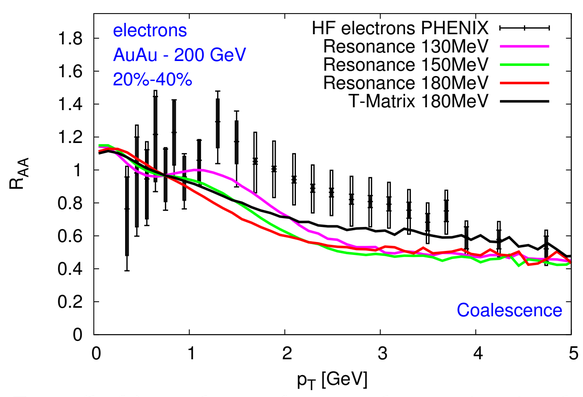
Heavy-quark diffusion

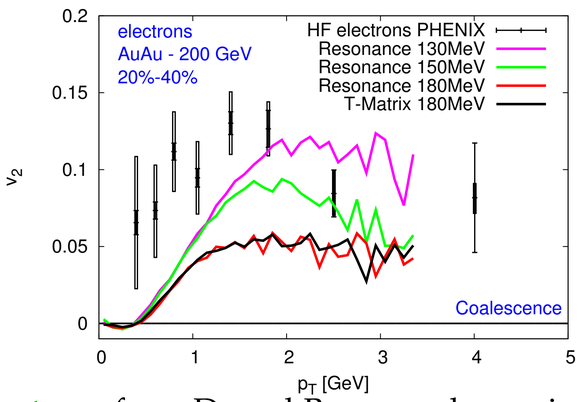
- Relativistic Langevin simulation
  - heavy-quark diffusion in hydrodynamic background

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

  - $\vec{\rho}$: normal-distributed Gaussian noise, Γ: drag (friction) coefficient, $\hat{C} = \sqrt{\hat{D}}$ with $\hat{D}$: diffusion coefficient
  - use post-point Ito realization of stochastic process [5] with diffusion coefficient $D_{\parallel} = EmT \Rightarrow$ ensures correct Boltzmann equilibrium limit
  - drag and diffusion coefficients: from microscopic models for elastic HQ scattering
  - assume D/B-like resonance formation above T_c [6, 7] or T-matrix approach with lQCD in-medium qQ potentials [8]
  - extrapolate cross section into hadronic phase
- hadronization
  - use coalescence description at decoupling temperature T_{dec} to recombine c/b quarks with light antiquarks to D/B mesons
  - use PYTHIA for semileptonic decay of D/B mesons to "non-photonic" electrons

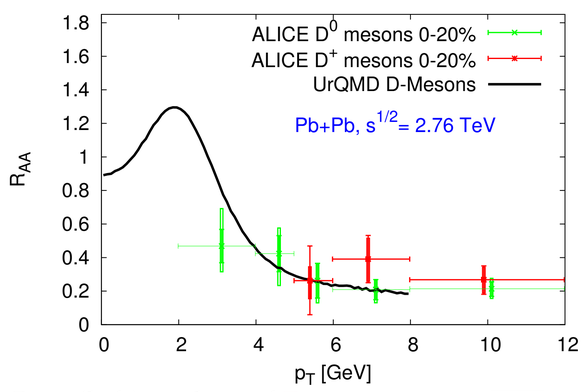
Non-photonic single electrons at RHIC

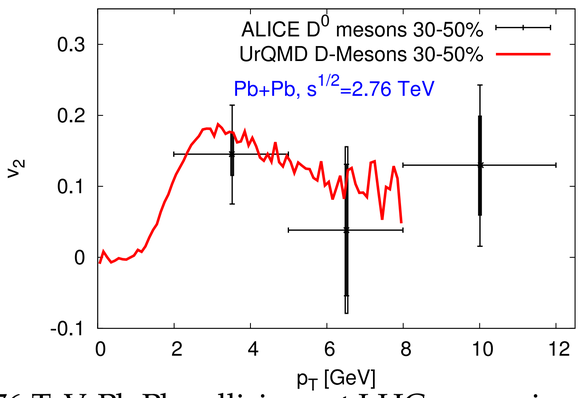




R_{AA} (left) and v_2 of non-photonic single electrons from D- and B-meson decays in $\sqrt{s_{\text{NN}}} = 200$ GeV-Au Au collisions at RHIC, assuming different decoupling temperatures. Using coalescence for hadronization process crucial for consistency between R_{AA} and v_2 (data from the PHENIX collaboration [9]).

D-mesons at LHC





R_{AA} (left) 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 from the ALICE collaboration [10, 11]).

Conclusions and outlook

- medium modifications of heavy-quark spectra
  - used UrQMD+hydro hybrid model for realistic description of the bulk medium
  - includes initial-state fluctuations
  - heavy c+b-quark diffusion via Langevin process
  - elastic resonance scattering of heavy quarks in strongly interacting matter
  - coalescence crucial for consistency of R_{AA} and v_2 of non-photonic single electrons at RHIC and D mesons at LHC
- future improvements
  - implement inelastic (radiative) scattering processes for HQ diffusion
  - use true hadronic cross sections for D- and B-mesons in hadronic phase
- further applications (work in progress)
  - use UrQMD+hydro hybrid model as universal tool at other energy $\Rightarrow$ predictions for the future FAIR experiments
  - investigate impact on correlated $D\overline{D}$ decays

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Hendrik van Hees (Goethe University Frankfurt and FIAS) hees@fias.uni-frankfurt.de