Thermalization and Flow of Heavy Quarks in the Quark-Gluon Plasma

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Outline

Motivation

- Measured p_T spectra and v_2 of non-photonic single electrons
- coalescence model describes data under assumption of thermalized c quarks, flowing with the bulk medium

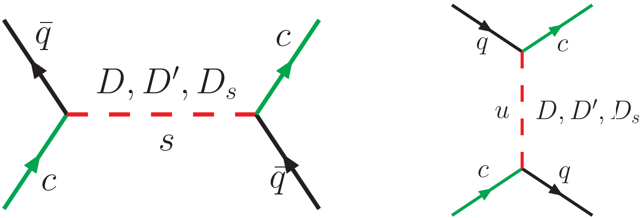
Motivation

- Measured p_T spectra and v_2 of non-photonic single electrons
- coalescence model describes data under assumption of thermalized c quarks, flowing with the bulk medium
- What is the underlying microscopic mechanism for thermalization?
    - pQCD elastic HQ scattering: need unrealistically large α_s [Moore, Teaney '04]
    - Gluon-radiative energy loss: need to enhance transport coefficient $\hat{q}$ by large factor [Armesto et al '05]

Elastic Heavy-quark resonance rescattering

- Possible non-perturbative mechanism: Survival of "D- and B-mesonic resonances" above T_c
- suggestive from lattice QCD (Umeda et al '02, Datta et al '03)
- provides elastic resonant rescattering of heavy quarks in the QGP
- effective field-theory model based on
  - chiral symmetry
  - spin symmetry of heavy-quark effective theory

Elastic Resonance Scattering

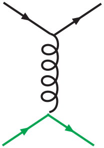


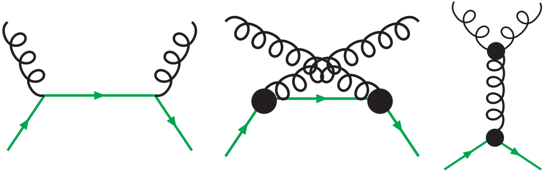
- D-meson propagators dressed with one-loop self energies
- Only two model parameters:
  - mass of resonances: $m_D = 2$ GeV
  - coupling constant $\Rightarrow$ $\Gamma_B = 0.4\ldots$ GeV
- Same model for B mesons

  $m_B = 5$ GeV, $\Gamma_B = 0.4 \ldots 0.75$ GeV

Contributions from pQCD

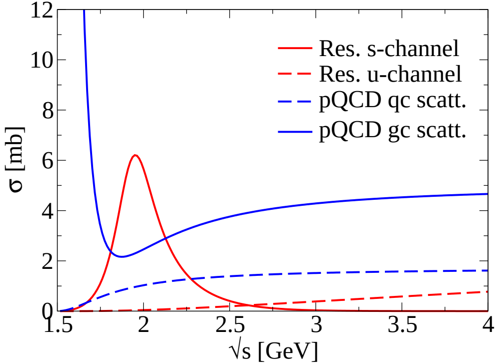
Lowest-order matrix elements (Combridge '79)





In-medium Debye-screening mass for t-channel gluon exchange:
$\mu_g = gT$, $\alpha_s = 0.4$

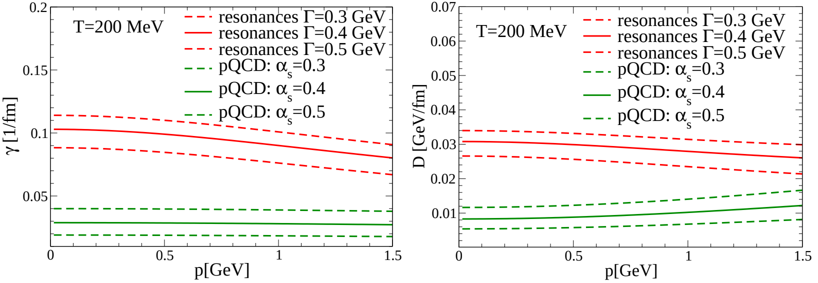
Cross sections



- pQCD and resonance cross sections: comparable in size
- BUT pQCD forward peaked ↔ resonance isotropic
- resonance scattering more effective for friction and diffusion

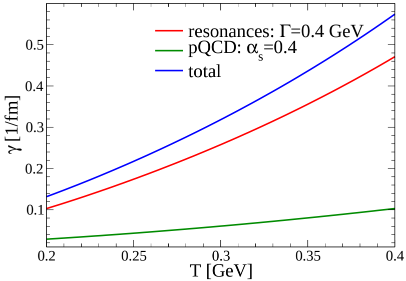
Drag and Diffusion coefficients

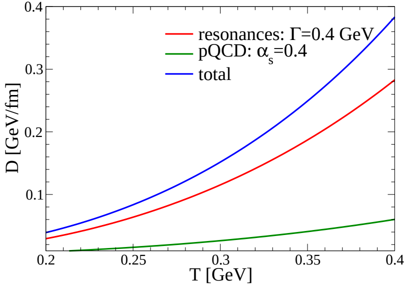
- use Fokker-Planck ansatz to calculate drag and diffusion coefficients



- resonance contributions factor $\sim 2\ldots 3$ higher than pQCD
- shortens equilibration times $\tau_{\text{eq}} = 1/\gamma$

Drag and Diffusion coefficients

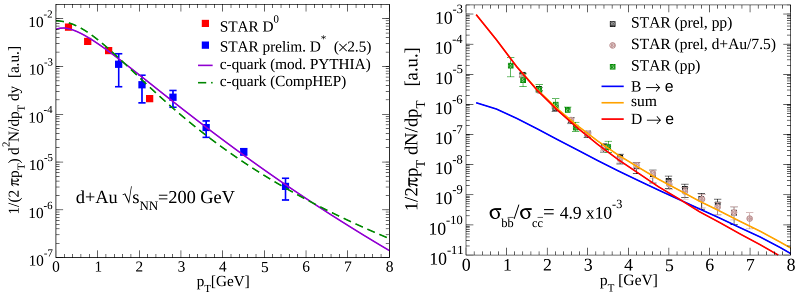




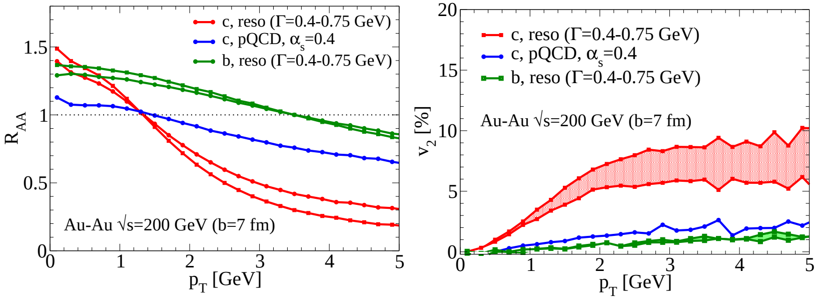
- heavy quarks in the QGP
  - thermal elliptic fireball parametrization for QGP
  - Fokker-Planck coefficients time dependent
  - Relativistic Langevin simulation for motion of heavy quarks

Initial conditions

- need initial p_T-spectra of charm and bottom quarks
  - (modified) PYTHIA to describe exp. D meson spectra, assuming δ-function fragmentation
  - exp. non-photonic single-$e^{\pm}$ spectra: Fix bottom/charm ratio

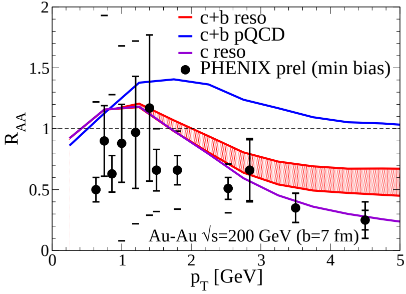


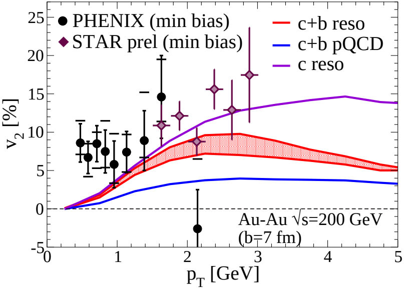
Spectra and elliptic flow for heavy quarks



Observables: p_T-spectra (R_{AA}), v_2

- Hadronization: Coalescence + fragmentation
- single electrons from decay of D- and B-mesons





Data before Quark Matter '05

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- Hadronization: Coalescence + fragmentation
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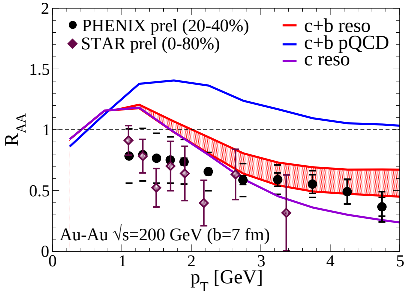
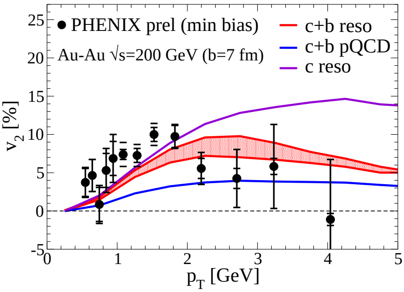
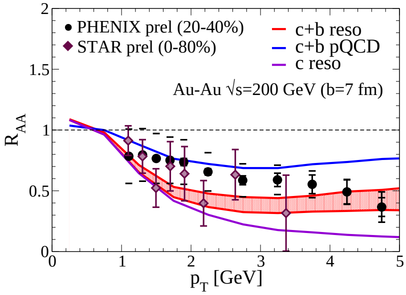


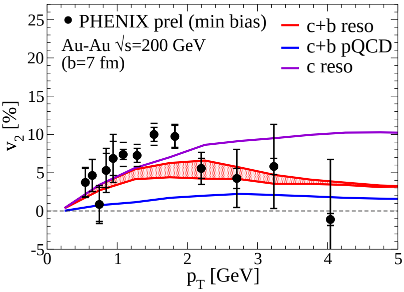


Data presented at Quark Matter '05

Observables: p_T-spectra (R_{AA}), v_2

- Hadronization: Fragmentation only
- single electrons from decay of D- and B-mesons





Conclusions and Outlook

- Assumption: survival of resonances in the (s)QGP
- possible mechanism for nonperturbative interactions
- Equilibration of heavy quarks in QGP
- Observables via Langevin approach and coalescence

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- Further investigations have to be done:
  - Langevin for D (B)-mesons in hadronic phase?
  - more realistic (softer) fragmentation
  - better control of coalescence/fragmentation ratio
  - implementation of gluon-radiation processes