Heavy-Quark Kinetics in the QGP at LHC

Hendrik van Hees

Texas A&M University

June 1, 2007

with Vincenzo Greco and Ralf Rapp

Outline

Heavy-quark observables at RHIC

- non-photonic single electrons in HIC (from D and B decays)
- large supression (small R_{AA}) at high p_T
- large anisotropic flow (v_2)
- Heavy quarks thermalize $\Rightarrow$ Strong interactions with bulk matter!

Heavy Quarks in the QGP

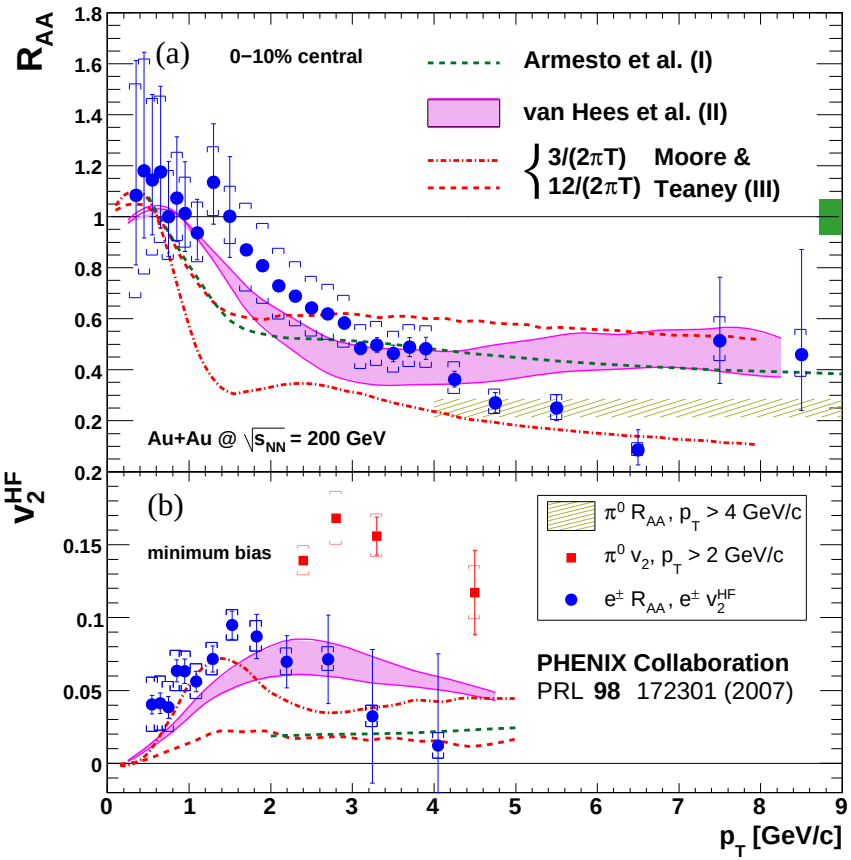
- initial hard production
- interaction with the flowing plasma treated dynamically!
  - Langevin simulations for heavy quarks in expanding fireball
  - non-perturbative mechanism for elastic scattering
- Hadronization via quark coalescence + fragmentation
- Consistency between R_{AA} and v_2

Predictions for LHC

- non-photonic single electrons
- D and B mesons

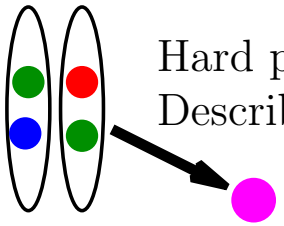
A glance at J/Ψ

Heavy-quark observables at RHIC



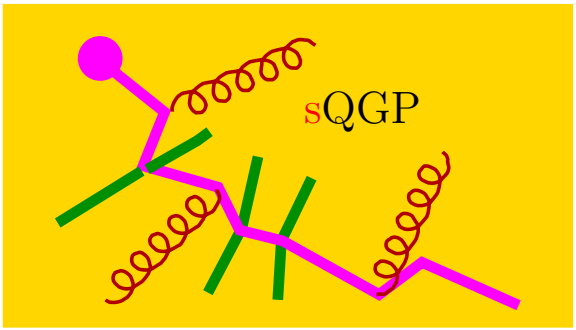
- non-photonic single electrons from D- and B-meson decays
- observables for heavy quarks in QGP!
- large suppression and v_2
- HQs thermalize with medium
- Challenge for theory
- sQGP: non-perturbative effects

HQ's hard production – diffusion in sQGP – hadronization



Hard production
Described by PDF's + pQCD (PYTHIA)

c, b quark

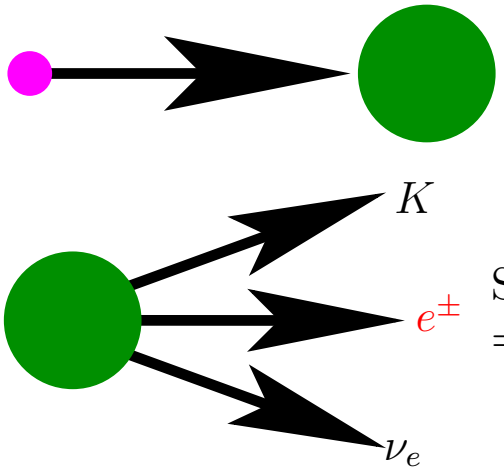


HQ rescattering in QGP: Langevin

here: collisional energy loss

non-perturbative effects (sQGP)

HvH, V. Greco, R. Rapp, PRC **73**, 034913 (2006)



Hadronization to D, B mesons

via quark coalescence + Fragmentation

V. Greco, C. M. Ko, R. Rapp, PL **B595**, 202 (2004)

LQ's: cascade with 2-body coll. ($\langle v_2 \rangle$=7%)

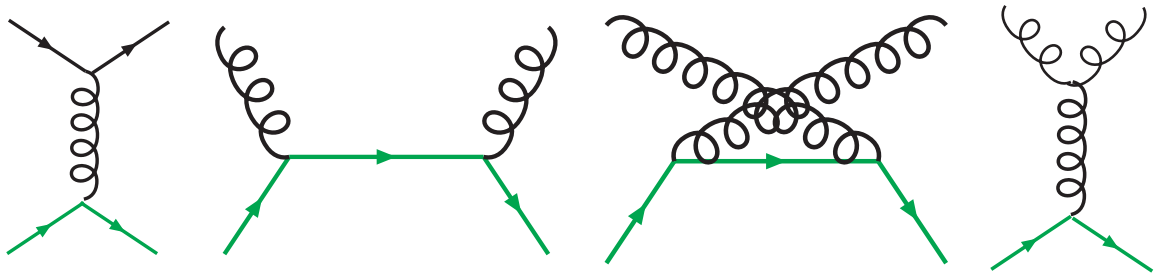
(M. Colonna, G. Ferini, M. Di Toro)

Semileptonic decay

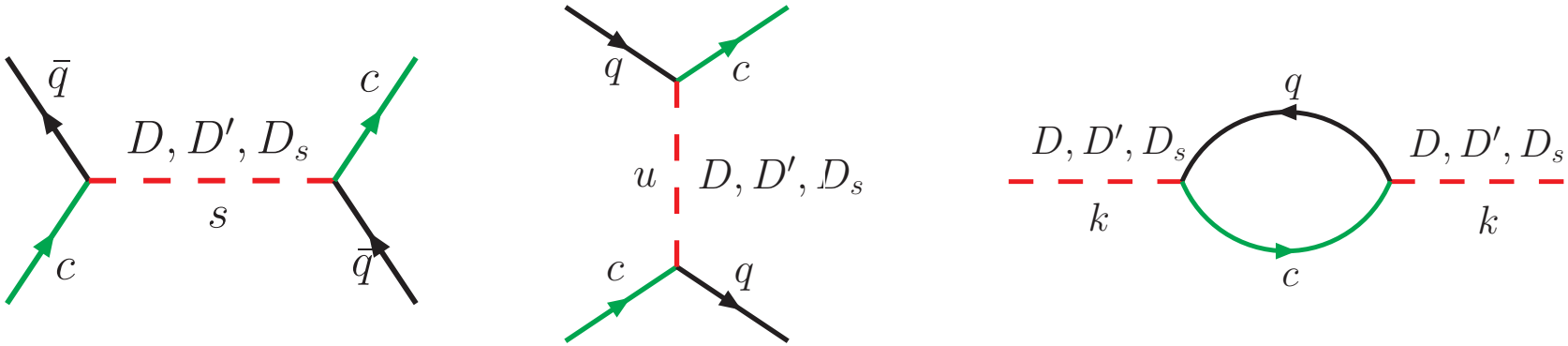
$\Rightarrow$ "non-photonic" electron observables

Elastic scattering of heavy quarks in the QGP

- PQCD scattering: $\alpha_s = 0.4$, $\mu_g = gT$



- Non-perturbative c-$\bar{q}, q$ scattering via resonances in sQGP
  HvH, R. Rapp, PRC **71**, 034907 (2005)

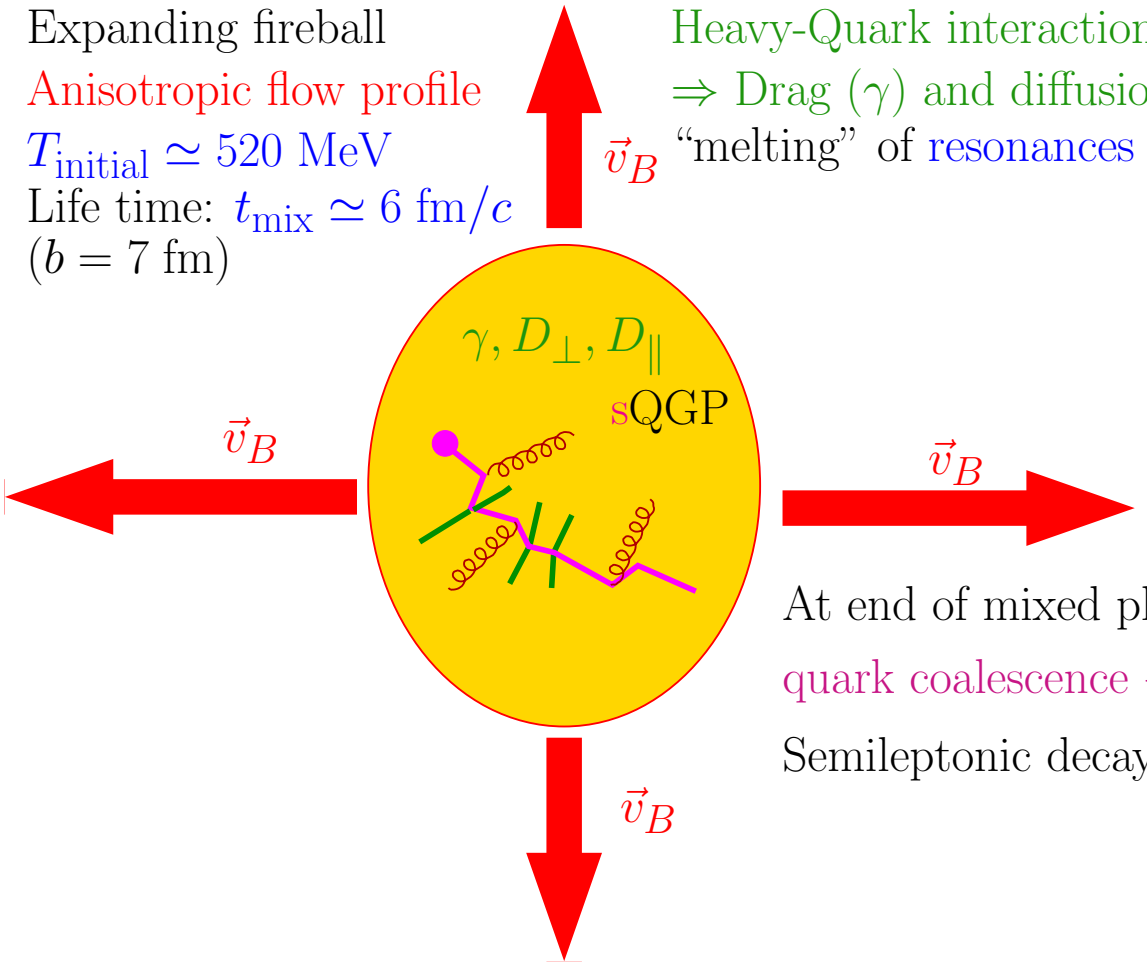


- $m_c = 1.5$ GeV, $m_D = 2$ GeV, $\Gamma_D = 0.4 \ldots 0.75$ GeV
- $m_b = 4.5$ GeV, $m_B = 5$ GeV, $\Gamma_B = 0.4 \ldots 0.75$ GeV

Relativistic Langevin in fireball with anisotropic flow

Expanding fireball
Anisotropic flow profile
$T_{\text{initial}} \simeq 520$ MeV
Life time: $t_{\text{mix}} \simeq 6$ fm/c
($b = 7$ fm)

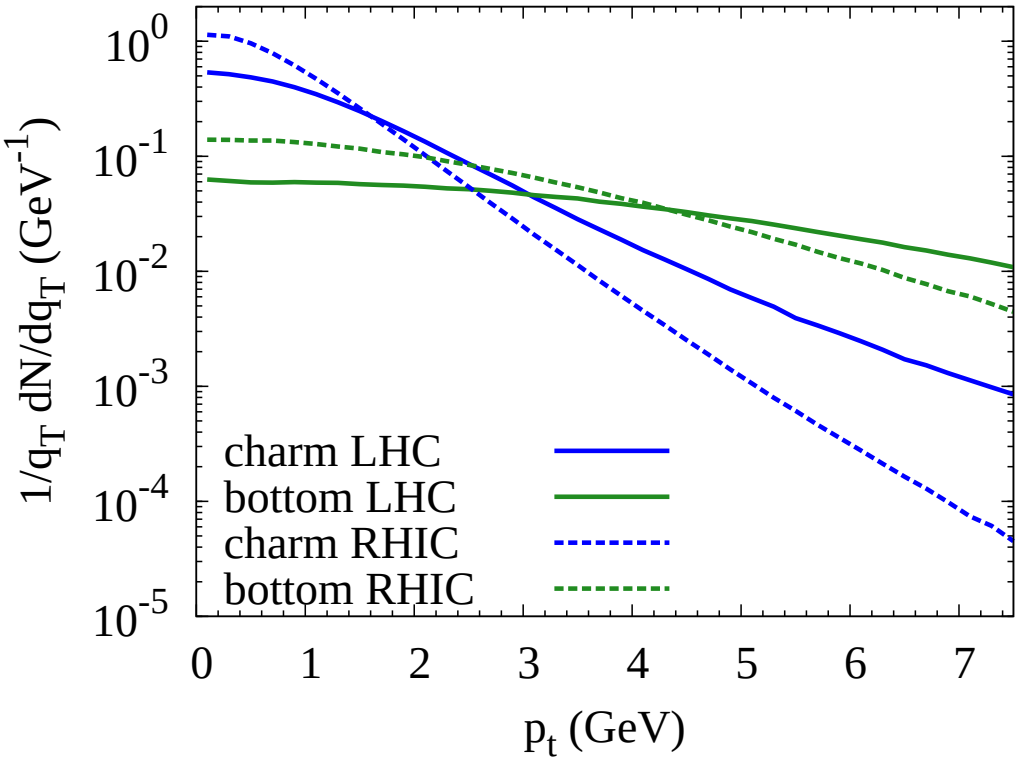
Heavy-Quark interactions
$\Rightarrow$ Drag (γ) and diffusion coefficients ($D_\perp$, $D_\parallel$)
"melting" of resonances at $T = 2T_c$



At end of mixed phase:
quark coalescence + fragmentation
Semileptonic decay of D/B to $e^\pm$

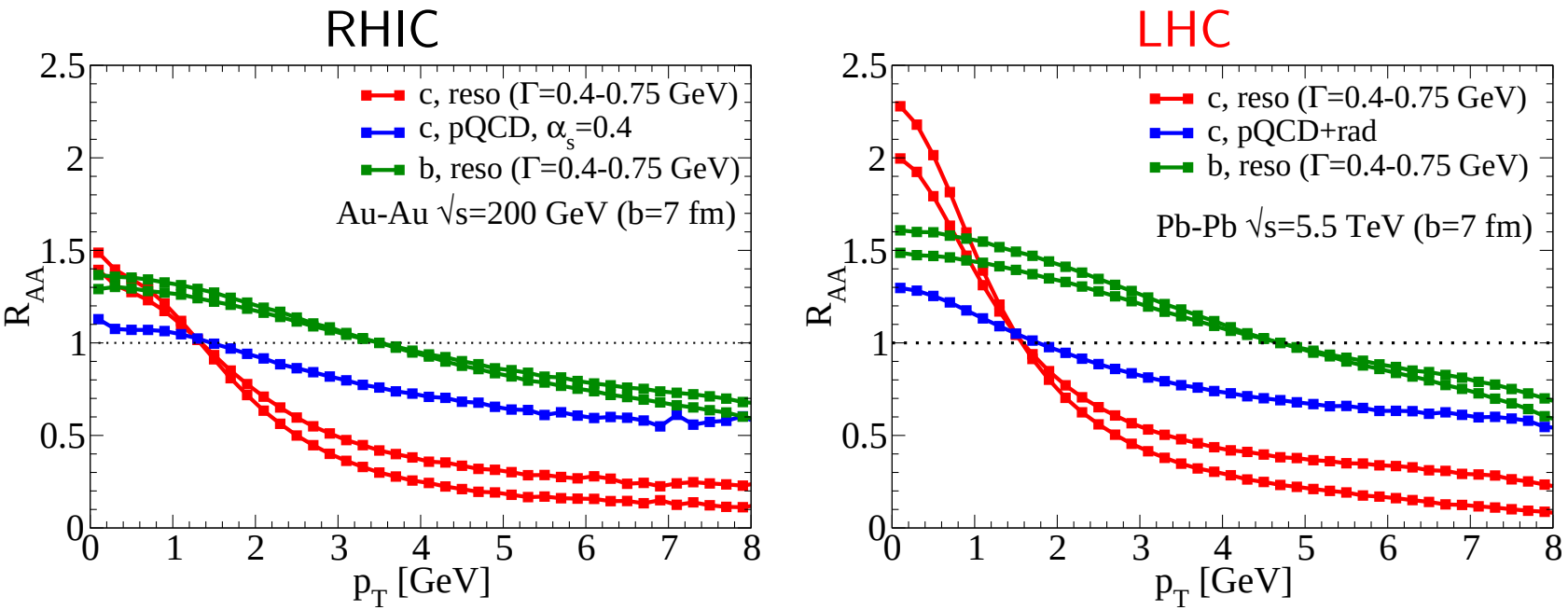
$$\frac{\partial f(t,\vec{p})}{\partial t} = \frac{\partial}{\partial p_i}\left[p_i \gamma(t,|\vec{p}|) + \frac{\partial}{\partial p_j} D_{ij}(t,\vec{p})\right] f(t,\vec{p})$$

Initial quark spectra



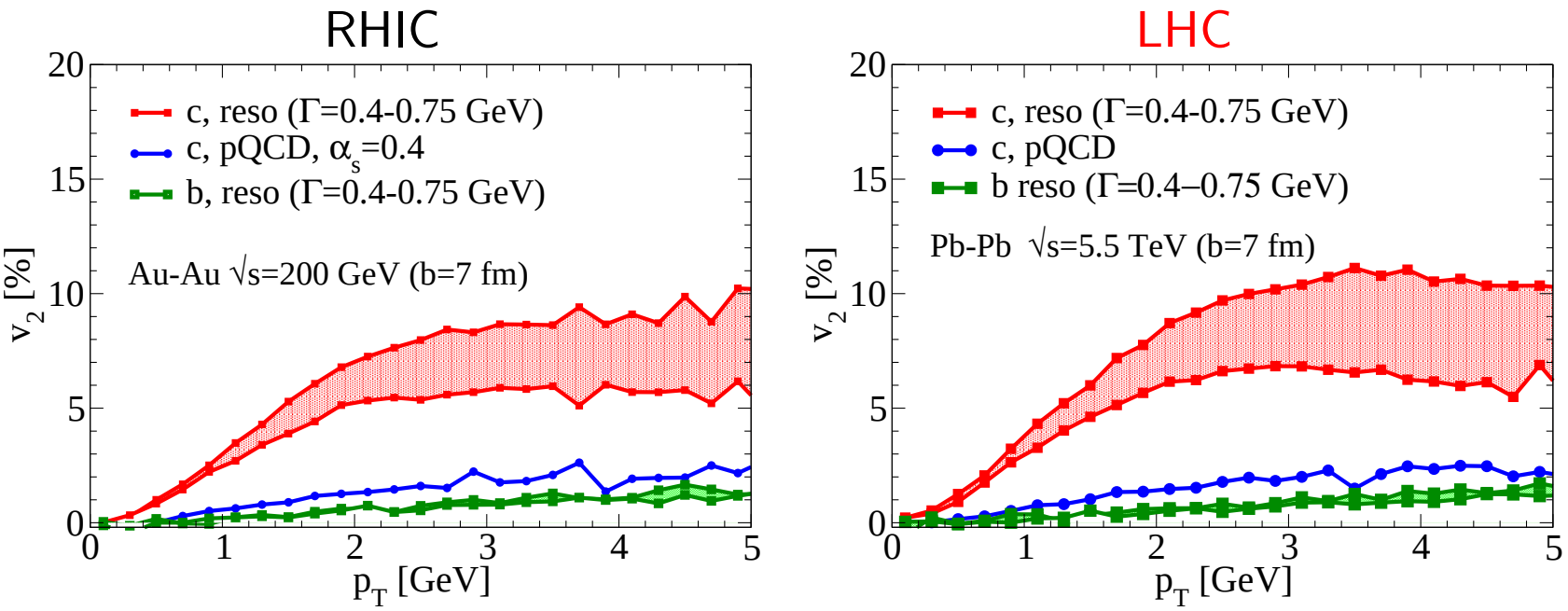
- here: normalized to 1
- from PYTHIA
- LHC spectra considerably harder!

Heavy-quark R_{AA}



- Suppression: $R_{AA} \sim$ the same at RHIC and LHC!
  - Reason: initial spectra harder at LHC
  - Resonances ineffective ("melted") at early stages!

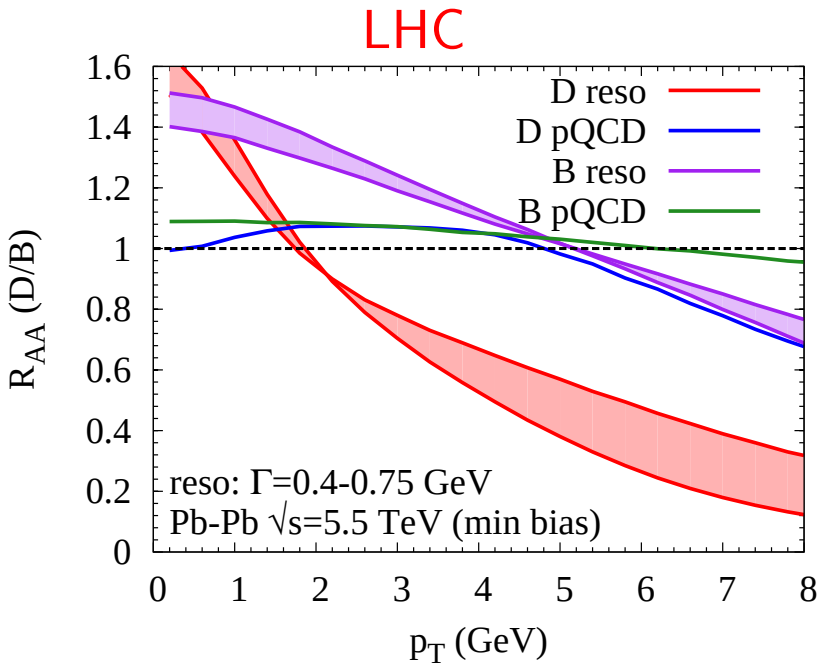
Heavy-quark v_2

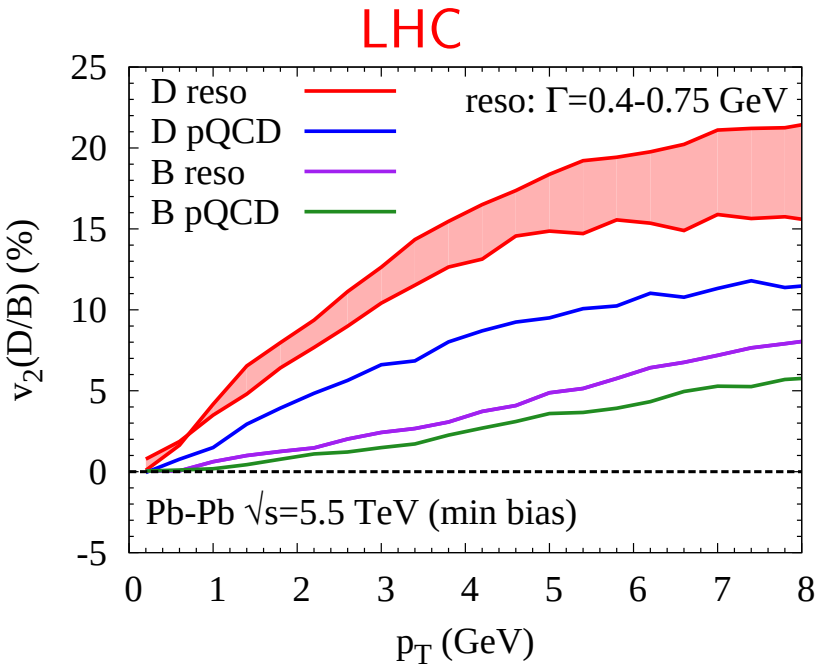


- $v_2 \sim$ the same at RHIC and LHC
  - NB: resonances become effective after anisotropic flow has built up
  - HQ's dragged with the flow at later stages

  $\Rightarrow$ v_2 slightly higher for low p_T

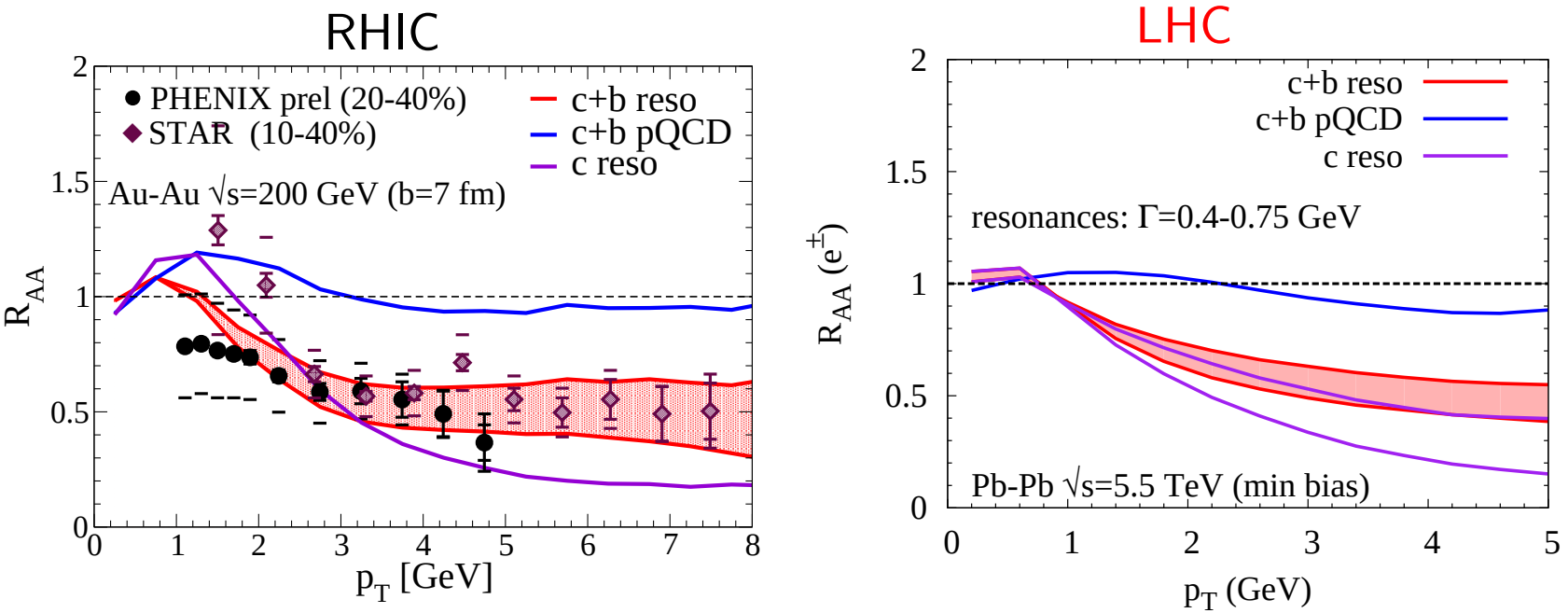
R_{AA} and v_2 for D/B mesons at LHC





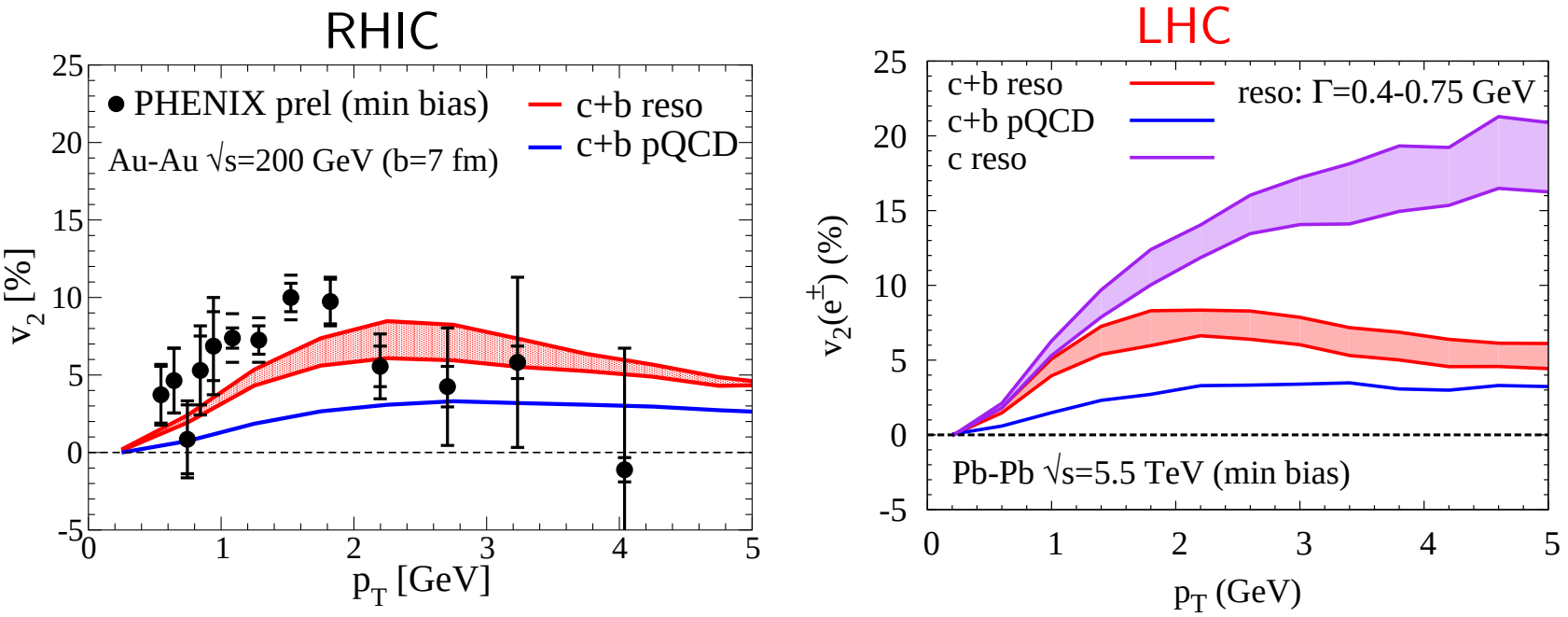
- D and B mesons via coalescence + fragmentation
- coalescence leads to increase in both, R_{AA} and v_2

R_{AA} for non-photonic electrons



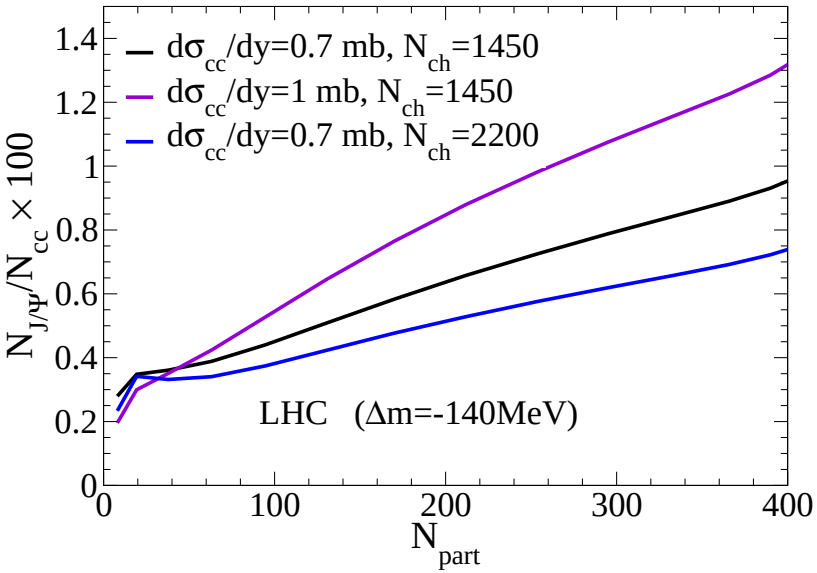
- D and B mesons via coalescence + fragmentation
- electrons from D- and B-meson decays
- coalescence leads to increase of v_2 compared to fragmentation only

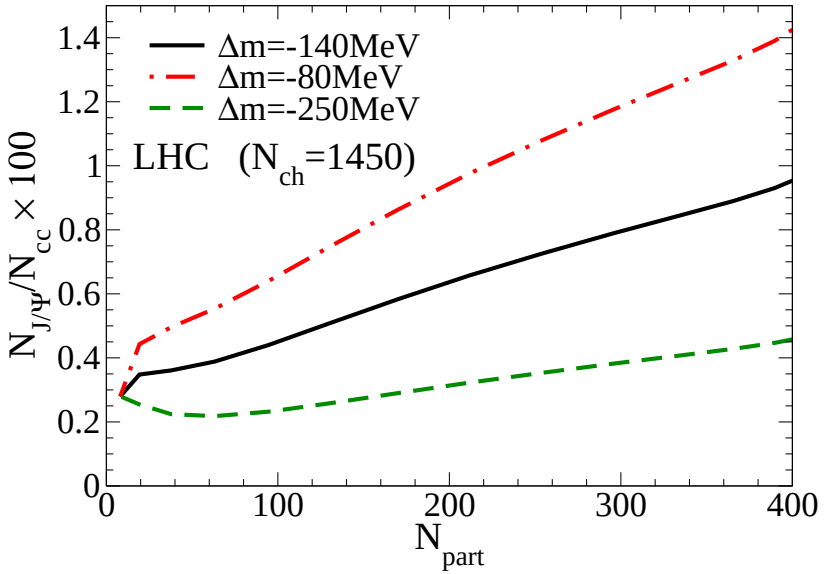
v_2 for non-photonic electrons



- D and B mesons via coalescence + fragmentation
- coalescence leads to increase of v_2 compared to fragmentation only

A glance at J/Ψ





- Work by X. Zhao, R. Rapp
- Uncertainty in $N_{\rm ch}$: $N_{\rm ch} \uparrow \Rightarrow V \uparrow \Rightarrow \gamma_c \downarrow$, $N_{J/\Psi} = \gamma_c^2 V n_{J/\Psi}$
- cross-section uncertainty: $\sigma_{cc} = 6 \ldots 9$ mb
- Δm: in-med. binding energies for open charm mesons: lower open-charm masses $\Rightarrow$ more c's in open charm
- includes feed down and incomplete-thermalization correction for Υ: L. Grandchamp et al, Phys. Rev. C **73**, 064906 (2006)

Conclusions

- Heavy Quarks in the sQGP
  - Heavy-quark kinetics with relativistic Langevin simulation
  - non-pert. elastic $Qq(\bar{q})$ collisions
  - Hadronization: Quark coalescence + fragmentation
  - Coalescence increases R_{AA} and v_2
- Predictions for LHC compared to RHIC
- D/B mesons / non-photonic electrons:
  - R_{AA} and v_2 very comparable with RHIC
  - reason: harder initial spectra
  - Resonances in sQGP only effective at temperatures $T \lesssim 2T_c$
- Predictions for J/Ψ