Resonance Recombination model for Quarks in the Quark-Gluon Plasma

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with

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Outline

1. Motivation
2. Transport approach to quark coalescence
   - Constituent-quark number and KE_T scaling
   - Meson spectra
3. Conclusions

Motivation

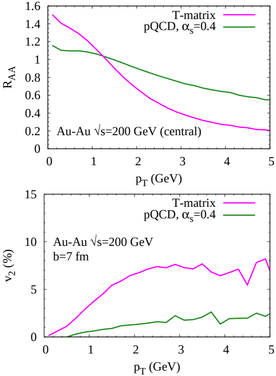
- Strongly interacting medium in relativistic heavy-ion collisions (HICs)
  - (ideal) hydrodynamics describes low-p_T spectra of hadrons
  - collective radial and elliptic flow
  - medium close to local thermal equilibrium
  - very small viscosity ⇒ strongly coupled Quark-Gluon Plasma (sQGP)
- Success of quark-coalescence models
  - recombination of quarks to hadrons at the QGP phase transition
  - describes observed constituent-quark number scaling of elliptic flow:

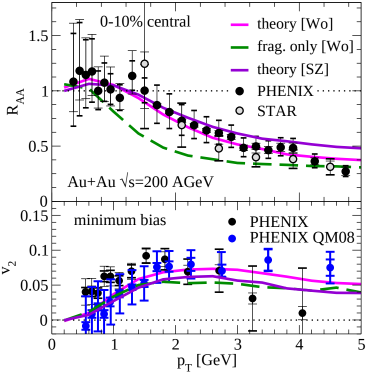
$$v_2^{\text{hadrons}}(p_T) \simeq n v_2^{(\text{quarks})}(p_T/n_q)$$

    ⇒ recombination of comoving quarks to hadrons
  - describes large baryon/meson ratio in HICs compared to pp collisions
- Shortcomings
  - violates energy conservation
  - violates 2^{nd} Law of Thermodynamics
  - CQNS with $\text{KE}_T = m_T - m = \sqrt{p_T^2 + m^2} - m$ than with p_T

Motivation

- Possible explanation for strong interactions in QGP close to T_c: formation of hadron-like resonances
- successful description of non-photonic $e^{\pm}$ data at RHIC
  - heavy-quark diffusion in QGP ⇔ Fokker-Planck equation
  - non-perturbative elastic collisions close to T_c
  - facilitated by resonance formation in T-matrix approach
  - coalescence + fragmentation to D and B-mesons





[HvH, M. Mannarelli, V. Greco, Phys. Rev. Lett. **100**, 192301 (2008)]

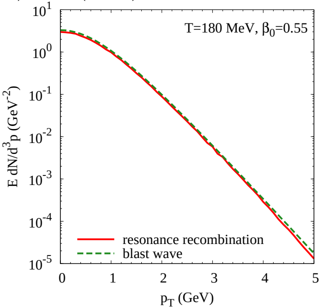
Resonance-Recombination Model

- transport approach for hadronization by $q + \bar{q} \leftrightarrows$ meson resonance

$$\frac{\partial}{\partial t} f_M(t,p) = -\frac{\Gamma}{\gamma_p} f_M(t,p) + g(p) \Rightarrow f_M^{(\text{eq})}(p) = \frac{\gamma_p}{\Gamma} g(p)$$

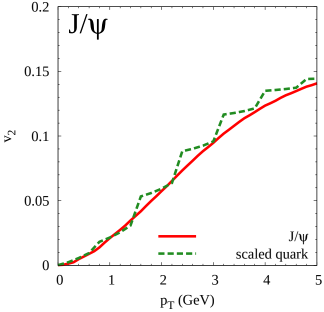
$$g(p) = \int \frac{\mathrm{d}^3 p_1 \mathrm{d}^3 p_2}{(2\pi)^6} \int \mathrm{d}^3 x f_q(x,p_1) f_{\bar{q}}(x,p_2) \sigma(s) v_{\text{rel}} \delta^{(3)}(p - p_1 - p_2)$$

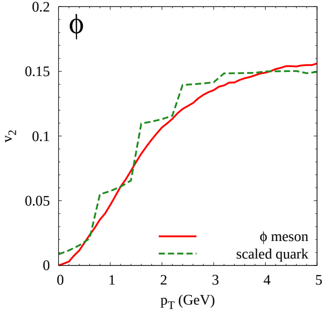
$$\sigma(s) = g_\sigma \frac{4\pi}{k_{\text{cm}}^2} \frac{(\Gamma m)^2}{(s-m^2)^2 + (\Gamma m)^2}$$

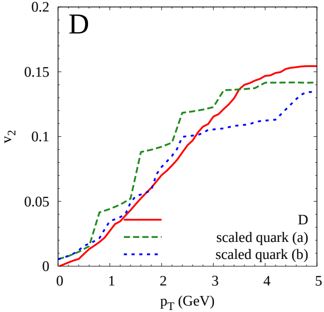


[L. Ravagli, R. Rapp, Phys. Lett. B **655**, 126, (2007); L. Ravagli, HvH, R. Rapp arXiv:0806.2055 [hep-ph]]

Constituent-quark number scaling







Scaling relations

(a) $$v_{2,M}(p_T) \simeq v_{2,q_1}\left(\frac{p_T}{2}\right) + v_{2,q_2}\left(\frac{p_T}{2}\right)$$

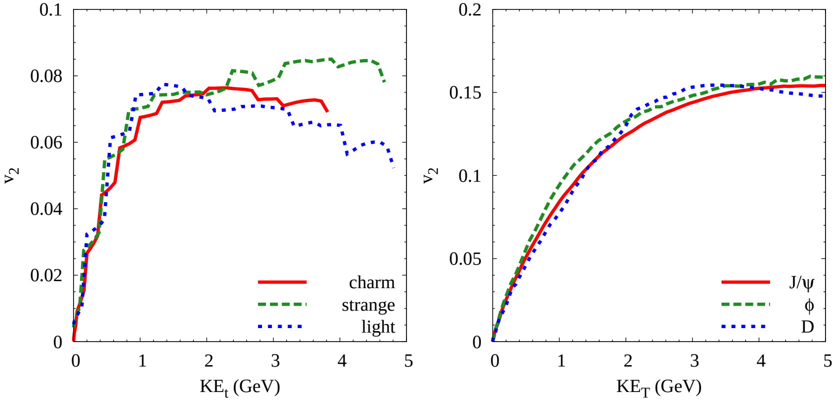
(b) $$v_{2,M}(p_T) \simeq v_{2,q_1}\left(\frac{m_{q_1} p_T}{m_{q_1}+m_{q_2}}\right) + v_{2,q_2}\left(\frac{m_{q_2} p_T}{m_{q_1}+m_{q_2}}\right)$$

Constituent-quark number scaling

- usual coalescence models: factorization ansatz

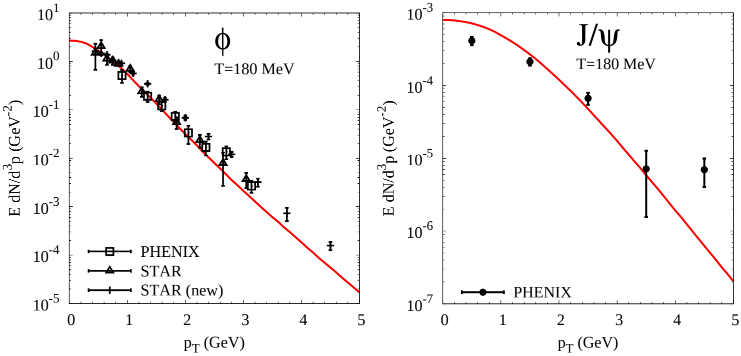
$$f_q(p, x, \varphi) = f_q(p, x)[1 + 2v_2^q(p_T)\cos(2\varphi)]$$

- CQNS usually not robust with more realistic parametrizations of v_2
- here: q input from relativistic Fokker-Planck-Langevin simulation
  - "background medium": elliptic thermal fireball



Meson spectra

- q-$\bar{q}$ input: Fokker-Planck-Langevin
- meson output: resonance-recombination model



Data from [A. Adare et al. (PHENIX) PRL **98**, 232301 (2007); S. S. Adler et al. (PHENIX) PRC **72**, 014903 (2005); J. Adams et al. (STAR) PLB **612**, 181 (2005) B. I. Abelev et al. (STAR) PRL **99**, 112301 (2007)]

Conclusions and Outlook

- quark recombination into meson-resonance states in the QGP at T_c
- based on Boltzmann transport approach
  - energy-momentum conservation
  - detailed balance
  - 2nd Law of Thermodynamics
- quark input from Fokker-Planck (FP) simulation
  - realistic space-momentum correlations (v_2)
- results in CQNS and KET scaling of meson spectra
- for more details: arXiv:0806.2055 [hep-ph]
- Problems and outlook
  - FP approach for light (and strange?) quarks problematic (self-consistency problem between "bulk medium" in FP simulation and quark distributions used in recombination)
  - Resonance recombination should be combined with fragmentation (particularly at higher p_T)
  - analogous treatment of baryons (quark-diquark recombination!?)