Quasiparticle anisotropic hydrodynamics

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Introduction

- Quark Gluon Plasma (QGP) is a momentum-space anisotropic plasma ($\mathcal{P}_L \neq \mathcal{P}_T$)
- By QCD calculations, like hard thermal loop (HTL) resummation, quarks and gluons have temperature dependent masses ($m \sim T$).
- Here we assume that the QGP can be described as a gas of non-interacting quasiparticles with zero width at all temperatures.
- The mass is a function of temperature using realistic equation of state (EoS) provided from lattice calculations.
- The effects of full non-conformality (quasiparticle aHydro) and approximate conformality (standard aHydro) are studied.

Boltzmann Equation

- Boltzmann equation

$$p^\mu \partial_\mu f + \frac{1}{2}\partial_i m^2 \partial^i_{(p)} f = -\mathcal{C}[f]$$

- When adding medium-dependent masses, thermodynamic consistency is not guaranteed, due to the gradients of m, i.e, $\mathcal{S}_{\rm eq} \neq \partial P_{\rm eq}/\partial T$.
- $T^{\mu\nu}$ is not conserved, i.e, $\partial_\mu T^{\mu\nu} \neq 0 \implies$ introduce a background field

$$T^{\mu\nu} = T^{\mu\nu}_{\rm kinetic} + g^{\mu\nu} B$$

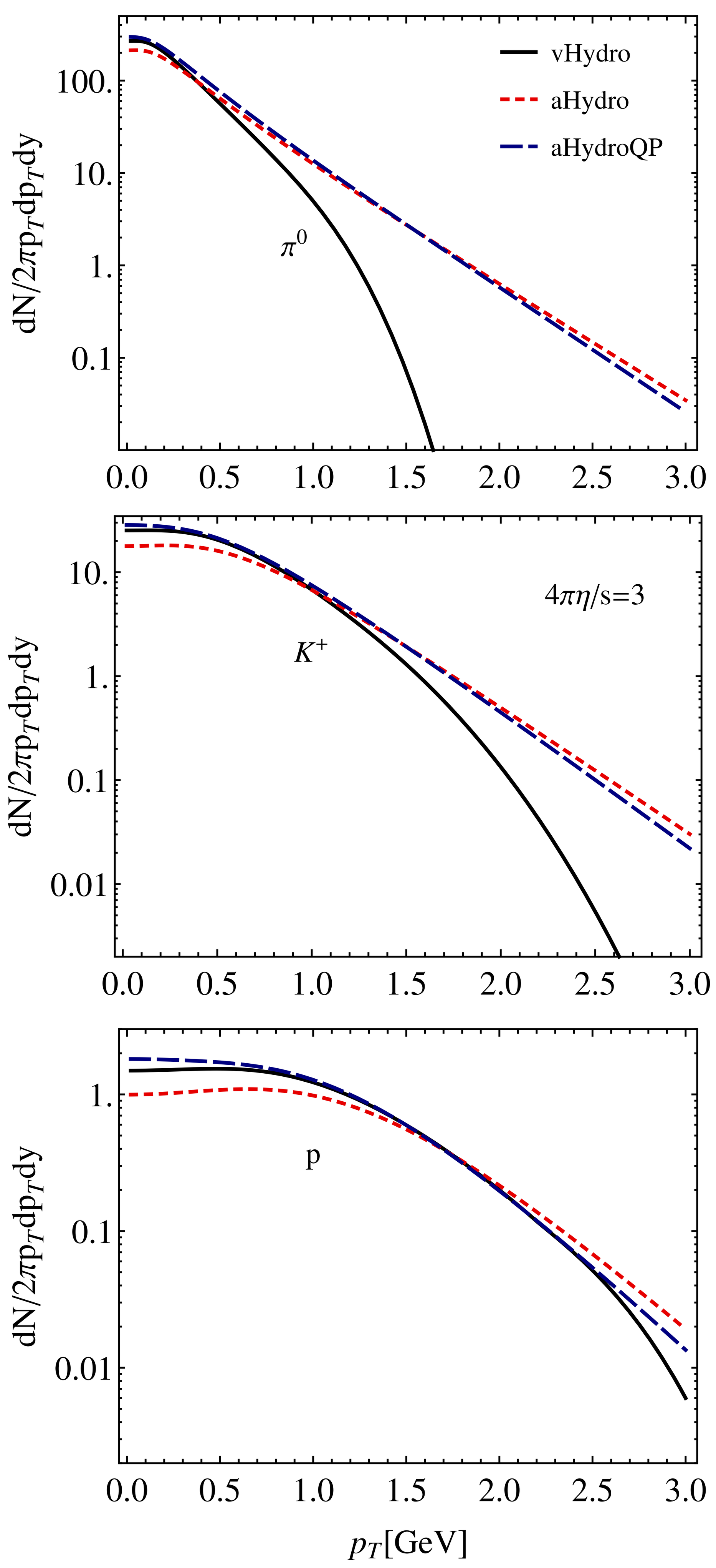
- Then, Boltzmann Eq. keeps $T^{\mu\nu}$ conserved and takes into account gradients in the mass.
- Moments of Boltzmann Eq.

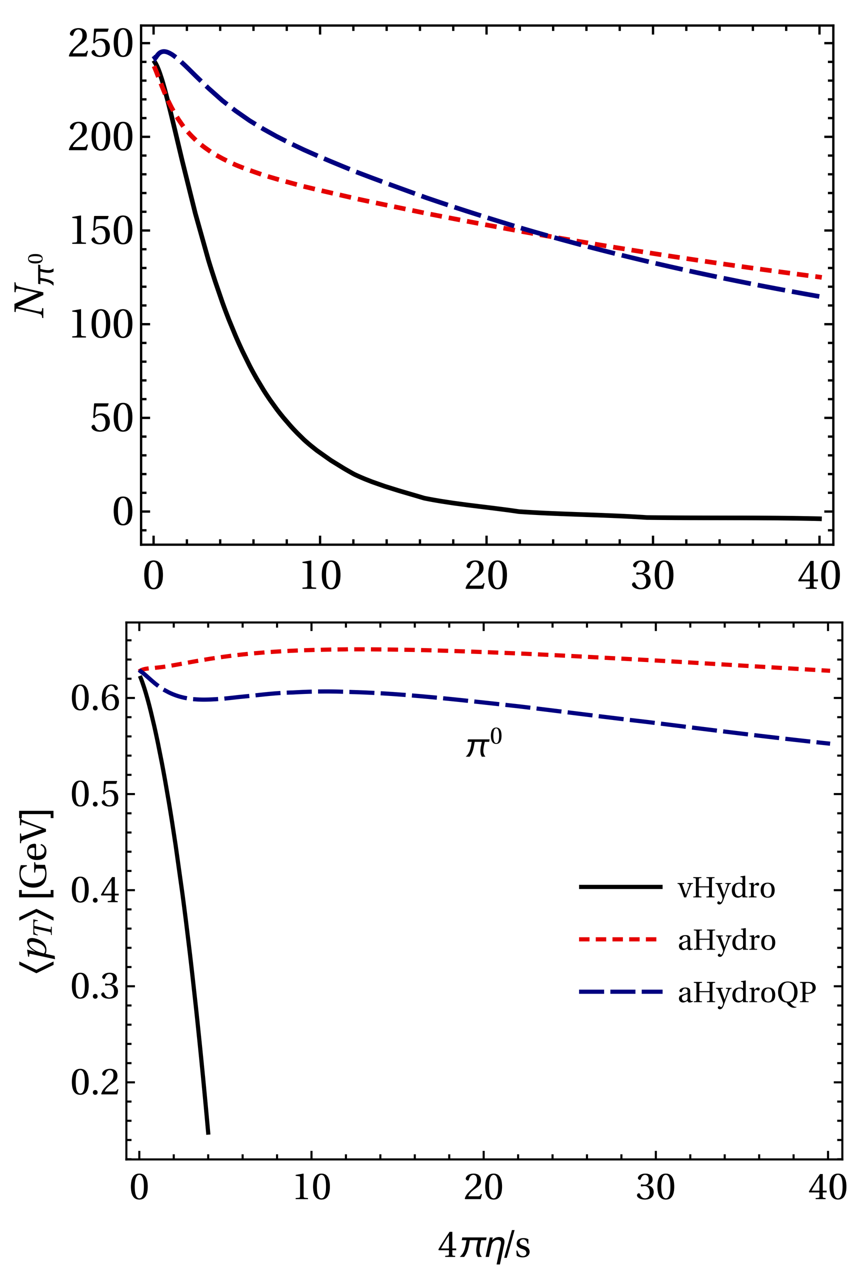
$$\partial_\mu J^\mu = -\int dP\, \mathcal{C}[f]$$

$$\partial_\mu T^{\mu\nu} = -\int dP\, p^\nu \mathcal{C}[f] = 0$$

$$\partial_\mu \mathcal{I}^{\mu\nu\lambda} - J^{(\nu}\partial^{\lambda)} m^2 = -\int dP\, p^\nu p^\lambda \mathcal{C}[f]$$

Final Results





- LHC initial conditions
- Pb-Pb collisions with $\sqrt{s_{NN}}$ = 2.76 GeV
- Glauber wounded-nucleon overlap to set the energy density
- $T_0 = 600$ MeV
- $\tau_0 = 0.25$ fm/c
- Anisotropic "Cooper-Frye freeze-out"
- $T_{FO} = 150$ MeV

Anisotropic hydrodynamics

- The aHydro distribution function

$$f(x,p) = f_{\rm eq}\left(\frac{1}{\lambda}\sqrt{\sum_i \frac{p_i^2}{\alpha_i^2} + m^2}\right)$$

- When ($\alpha_x = \alpha_y = \alpha_z = 1$) and $\lambda \longrightarrow T \implies$ isotropic equilibrium limit.

The background field

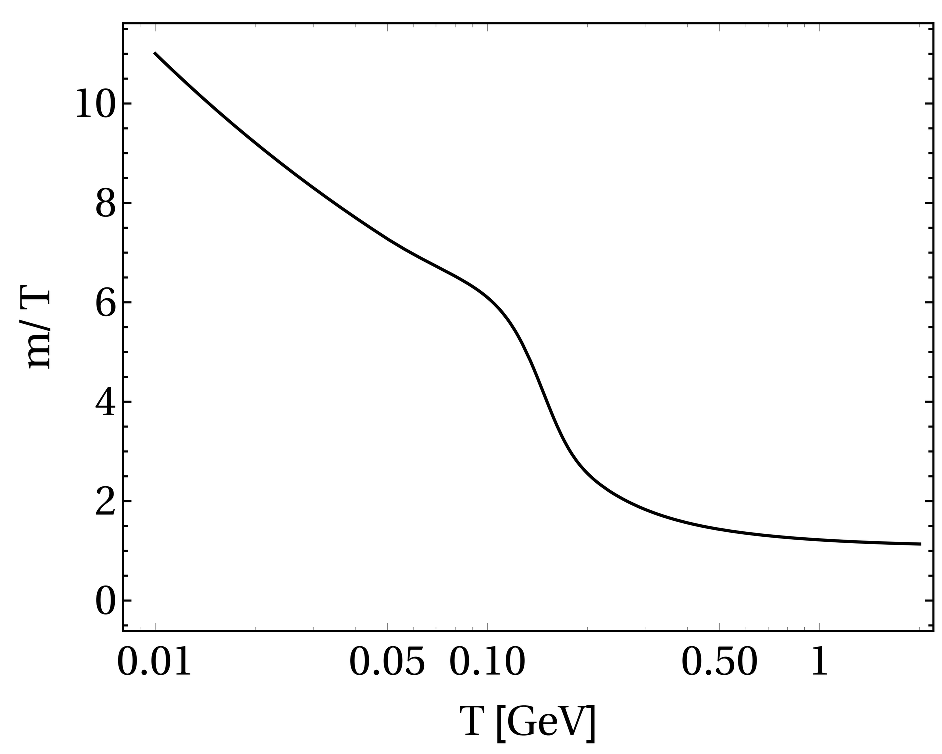
- Using lattice results one can get $m(T)$

$$\mathcal{E}_{\rm eq} + \mathcal{P}_{\rm eq} = T\mathcal{S}_{\rm eq} = T\frac{\partial P_{\rm eq}}{\partial T} = 4\pi \tilde{N} T^4 \hat{m}^3_{\rm eq} K_3(\hat{m}_{\rm eq})$$

- Using thermodynamic consistency $B_{\rm eq}(T)$,

$$\frac{dB_{\rm eq}}{dT} = -4\pi\tilde{N} m^2 T K_1(\hat{m}_{\rm eq})\frac{dm}{dT}$$

One boundary condition to use $B_{\rm eq}(0) = 0$



Discussions

- We studied quasiparticle aHydro, standard aHydro and second order viscous hydrodynamics and looked at their predictions.
- Both shear and bulk viscosities are included.
- Here, we show only $\eta/s = 3/(4\pi)$ where there are some differences, however all models agree quite well for small η/s.
- At low p_T, the standard aHydro method shows a suppressed production compared with other methods.
- The pion spectra in vHydro went negative at $p_T \sim 1.6$ GeV (for $\eta/s = 3/(4\pi)$)
- The number of pions in vHydro went negative at $4\pi\eta/s \sim 22$.
- vHydro shows a negative mean transverse average at small $\eta/s = 5/(4\pi)$.

Conclusions

- All models agree well for small η/s.
- The standard method shows a suppressed production at low transverse-momentum compared with other methods.
- The bulk viscous correction in vhydro can drive the primordial particle spectra negative.

Acknowledgements/References

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- M. Alqahtani, M. Nopoush, and M. Strickland, arXiv:1509.02913
- M. Alqahtani, M. Nopoush, and M. Strickland, arXiv:1605.02101