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Non-perturbative heavy quark difusion in a weakly magnetized QGP

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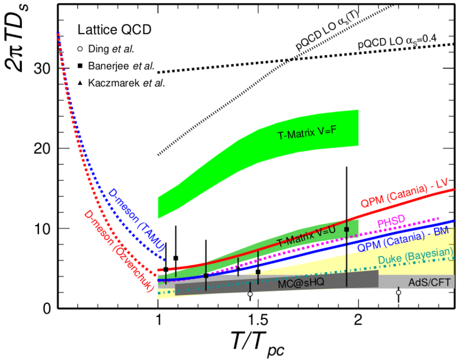
Motivation

- Mismatch of spatial diffusion coefficient magnitudes ($2\pi T D_s$) between LO pQCD and LQCD by a factor ~ 10.



- To check the impact of incorporating non-perturbative physics in the analysis.

The HQ potential

- Non-perturbative effect incorporated via in-medium HQ potential.

In vacuum: $$V_0(r) = \underbrace{-\frac{4}{3}\frac{\alpha_s}{r}}_{\text{perturbative}} + \underbrace{\sigma r}_{\text{non-perturbative}}$$

In a medium: $$V(r) = \underbrace{-\frac{4}{3}\alpha_s\frac{e^{-m_D r}}{r}}_{\text{Yukawa type}} - \sigma\frac{e^{-m_s r}}{m_s}.$$

The medium: QGP in a weak background magnetic field.

- The potential is evaluated in momentum space.
- The effects of the medium are incorporated via a complex dielectric function $\epsilon(q)$.

In-medium potential

$$V(q) = V_0(q)\mathrm{Im}\frac{1}{\epsilon(q)}$$

$$V_0(q) \equiv \text{FT of } V_0^{\text{pert}}(r) = -\frac{4}{3}4\pi\alpha_s\frac{1}{q^2}$$

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- Dielectric function $\epsilon(q)$ evaluated from the resummed gauge boson propagator

$$\frac{1}{\epsilon(q)} = -q^2 D^{00}(q_0, q)$$

$$D^{00}(q_0, q) = D^{00}_{\rm p}(q_0, q) + \underbrace{D^{00}_{\rm np}(q_0, q)}_{\text{dimension-2 gluon condensate}}$$

Resummed gauge boson propagator

$$D^{p}_{00}(q_0, q) = \left[q^2 - \Pi_{00}(q_0, q)\right]^{-1}, \qquad D^{np}_{00}(q_0, q) = m_G^2 \left[q^2 - \Pi_{00}(q_0, q)\right]^{-2}$$

- $D^{np}_{00}(q_0, q)$ is written as a minimal extension of $D^{p}_{00}(q_0, q)$
- $m_G^2 \rightarrow$ constant of dimension M^2. Related to the string tension as $\sigma = \alpha_s m_G^2/2$.

$${\rm Im} D^{00}_{\rm np}(\omega = 0, q) = \frac{-\pi T \left[-m_D^2 + \sum_f \frac{g^2 (q_f B)^2}{2\pi^2} \left\{F_1(1 + \cos^2\theta) + F_2(7/3 + \cos^2\theta)\right\}\right]}{q(q^2 + M_D^2)^2}$$

Scattering rate from HQ potential

- $V(q) = V_Y(q) + V_S(q)$
- Resummed gluon propagator $D^{\mu\nu}$ is replaced with the in-medium HQ potential $V(q)$.
- In particular, the replacement is $g^2 D^{\mu\nu} \to V(q)$.

HQ self-energy (Yukawa part)

$$\Sigma_Y(P) = ig^2 \int \frac{d^4Q}{(2\pi)^4} \mathcal{D}^{\mu\nu}(Q)\gamma_\mu S(P-Q)\gamma_\nu$$

$$\downarrow$$

$$i \int \frac{d^4Q}{(2\pi)^4} V_Y(q)\gamma_\mu S(P-Q)\gamma^\mu$$

HQ self-energy (String part)

$$\Sigma_S(P) = ig^2 \int \frac{d^4Q}{(2\pi)^4} \mathcal{D}^{\mu\nu}(Q) S(P-Q)$$

$$\downarrow$$

$$i \int \frac{d^4Q}{(2\pi)^4} V_S(q) S(P-Q)$$

Weldon's formula of scattering rate

$$\Gamma_{Y/S}(E) = -\frac{1}{2E}\frac{1}{1+e^{-E/T}} \mathrm{Tr}\left[(\not{P} + M)\,\mathrm{Im}\,\Sigma_{Y/S}(p_0 + i\epsilon, \boldsymbol{p})\right]$$

Diffusion coefficients

Momentum diffusion coefficients

$$\kappa_L = \int d^3q \, \frac{d\Gamma(E,v)}{d^3q} q_z^2 \qquad \boldsymbol{\kappa}_\perp = \frac{1}{2}\int d^3q \, \frac{d\Gamma(E,v)}{d^3q} \boldsymbol{q}_\perp^2$$

$$(\kappa_L)_{Y/S} = \frac{1}{16\pi E^2 v}\int_0^{q_{\max}} dq \int_{-vq}^{vq} d\omega \, q^3 \left(\frac{\omega}{vq}\right)^2 A_{Y/S}(\omega)\rho_{Y/S}(q)$$

$$(\kappa_T)_{Y/S} = \frac{1}{32\pi E^2 v}\int_0^{q_{\max}} dq \int_{-vq}^{vq} d\omega \, q^3 \left(1 - \frac{\omega^2}{v^2 q^2}\right) A_{Y/S}(\omega)\rho_{Y/S}(q),$$

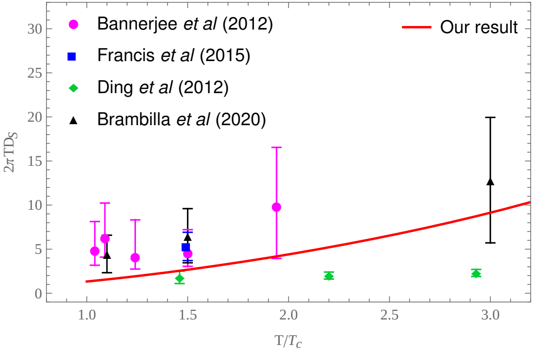
$$\rho_{Y/S}(q) = -\frac{\mathrm{Im}\, V_{Y/S}(q)}{\pi}, \qquad A_Y(\omega) = 8(M_Q^2 - E\omega), \quad A_S(\omega) = 4(2M_Q^2 + E\omega)$$

Spatial diffusion coefficient

$$D_s = \frac{T}{\eta_D(p=0)M_Q} = \frac{2T^2}{\kappa(p=0)}$$

Results

SCALED SPATIAL DIFFUSION COEFFICIENT



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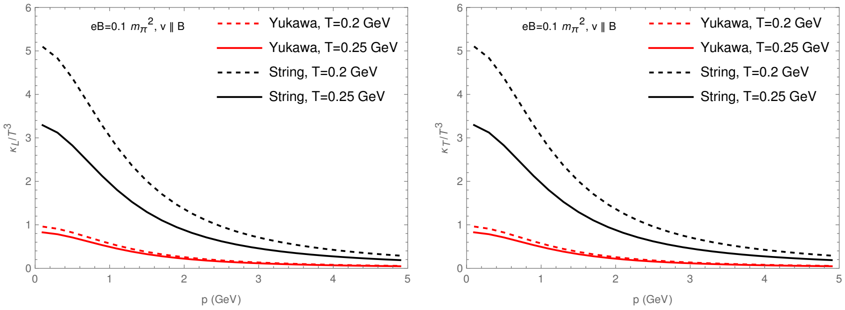
DYNAMIC MOMENTUM DIFFUSION COEFFICIENTs



Thank you.