Effect of Coriolis Force on Diffusion of D Meson

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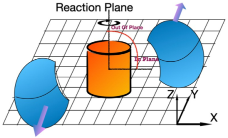


Motivation: off-central HIC and vorticity

- In off-central HIC, a huge magnetic field as well as angular velocity can be created.
  Becattini et al. Phys. Rev. C 77, 024906, Jiang et al. Phys. Rev. C 94, 044910

$$L_0 = A\, b \frac{\sqrt{S_{NN}}}{2}$$

- For Au-Au collision at $\sqrt{S_{NN}} = 200$ GeV, $b = 5$ fm, $A = 197 \implies L_0 \sim 10^5\ \hbar$
- Most of the angular momentum gets carried away by the spectators. Imagining only 10% or 0.1 part of this is deposited in the reaction zone,
  $\implies L = 0.1 L_0 \sim 10^4\ \hbar$.
- Average angular velocity $\Omega_{max} = 0.06 - 0.07\ \text{fm}^{-1}$

Literatures on the rotating nuclear matter

- Studies on the thermodynamics of the QCD matter rotating with a **global angular velocity $\vec{\Omega}$**

  NJL Model: Wang et al. Phys. Rev. D 99, 016018
  Quark-meson model: Chen et al. Phys. Rev. D 108, 054006
  linear sigma model: Singha et al. Phys. Rev. D 110, 094053
  lattice QCD: Yamamoto et al. Phys. Rev. Lett. 111, 081601

- Studies on transport properties like, shear viscosity, electrical conductivity, etc

  Dwibedi et al., Phys. Rev. C 109, 034913, Phys. Rev. C 109, 034914, Phys. Rev. C 110, 024904

- Question: What happens to a heavy quark/ meson diffusing in the rotating QCD matter?

Model description: The BTE in RTA

- D meson diffusing under the background of rotating nuclear matter

$$p^{\mu}\frac{\partial f^{0}+\delta f}{\partial x^{\mu}}-\Gamma^{\alpha}_{\mu\lambda}p^{\mu}p^{\lambda}\frac{\partial f^{0}+\delta f}{\partial p^{\alpha}}=-(u^{\alpha}p_{\alpha})\frac{\delta f}{\tau_c}, \quad (1)$$

eqbm. distribution$=f^0=\frac{1}{e^{(p^{\alpha}u_{\alpha}-\mu_D)/T}-1}$,

$u^{\alpha}=(\frac{1}{\sqrt{g_{00}}},0)$, $g_{\mu\nu}=$ metric tensor

Effective force $\equiv F^{\alpha}=-\frac{1}{m_D}\Gamma^{\alpha}_{\mu\lambda}p^{\mu}p^{\lambda}=\frac{dp^{\alpha}}{d\tau}$, $\tau=$ proper time

deviation from eqbm. $=\delta f$

relaxation time of D meson $=\tau_c$

Model description: heavy meson current and spatial diffusion coefficients

- Heavy meson current J^i coming from the variation of its chemical potential μ_D ,

$$J^i = \int \frac{d^3\vec{p}}{(2\pi)^3} \frac{p^i}{p_0} \delta f, \quad (2)$$

$$J^i = -\sigma^{ij} \nabla_j \mu_D, \quad (3)$$

σ^{ij} is heavy meson conductivity.

- Solving BTE for δf leads to J^i (equivalently σ^{ij}). Spatial diffusion coefficients can be evaluated using the relation

$$D^{ij} = \frac{\sigma^{ij}}{\chi}, \chi = \text{susceptibility} . \quad (4)$$

- Everything boils down to evaluate δf from BTE. Any force term in BTE?

Model description: Forces in rotating frame and expression of diffusion coefficients

- The relativistic EOM in the rotating frame,

$$\frac{d\vec{p}}{dt} = \gamma_v m_D(\vec{\Omega} \times \vec{r}) \times \vec{\Omega} + 2\gamma_v m_D(\vec{v} \times \vec{\Omega}), \quad (5)$$

$$\text{Centrifugal force} = \gamma_v m_D(\vec{\Omega} \times \vec{r}) \times \vec{\Omega},$$

$$\text{Coriolis force} = 2\gamma_v m_D(\vec{v} \times \vec{\Omega})$$

- Solving BTE with the inclusion of Coriolis force we get,

$$D^{||} = \frac{\int \frac{d^3p}{(2\pi)^3} \tau_c \times \frac{p^2}{E^2} f_0(1+f_0)}{3\int \frac{d^3p}{(2\pi)^3} f_0(1+f_0)}, \quad D^{\perp} = \frac{\int \frac{d^3p}{(2\pi)^3} \tau_c^{\perp} \times \frac{p^2}{E^2} f_0(1+f_0)}{3\int \frac{d^3p}{(2\pi)^3} f_0(1+f_0)},$$

$$D^{\times} = \frac{\int \frac{d^3p}{(2\pi)^3} \tau_c^{\times} \times \frac{p^2}{E^2} f_0(1+f_0)}{3\int \frac{d^3p}{(2\pi)^3} f_0(1+f_0)}, \text{defined relative to } \vec{\Omega} \quad (6)$$

Model description: Determination of τ_c

- Focus on the hadronic temperature domain

  The rotating hadron gas background $\xrightarrow{\text{modeled}}$ The ideal hadron resonance gas (HRG) model.

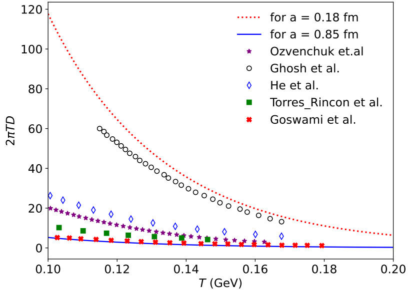
  τ_c of D meson-hadron scatterings $\xrightarrow{\text{modeled}}$ hard-sphere type scatterings,

$$\tau_c = 1/(n_{\rm HRG} v_{\rm av} \pi a^2), \tag{7}$$

$$n_{HRG} = \sum_B g_B \int_0^\infty \frac{d^3p}{(2\pi)^3} \frac{1}{e^{E/T}+1} + \sum_M g_M \int_0^\infty \frac{d^3p}{(2\pi)^3} \frac{1}{e^{E/T}-1}\,, \tag{8}$$

- a$=$ scattering legnth, $v_{\rm av}$ $=$thermal average velocity of D meson
- We will calibrate τ_c by changing a to cover the existing model calculations of $D^{||}$($\equiv$ diffusion coefficient at $\vec{\Omega} = 0$).

Result and Conclusion: variation of anisotropic diffusion coefficients



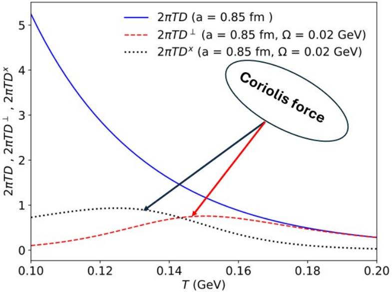


Figure: Calibration of relaxation time of D meson (left) and variation of anisotropic diffusion coefficients (right)

- Anisotropic spatial diffusion coefficients ($D^{\perp,\times}$) can differ significantly from $D^{||}$ at low temperatures. This can affect the experimental observables like R_{AA} and v_2 of D meson.

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Thank You!