Relaxation time for the alignment between the spin of a quark and the angular velocity in a rotation medium

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Phase diagram

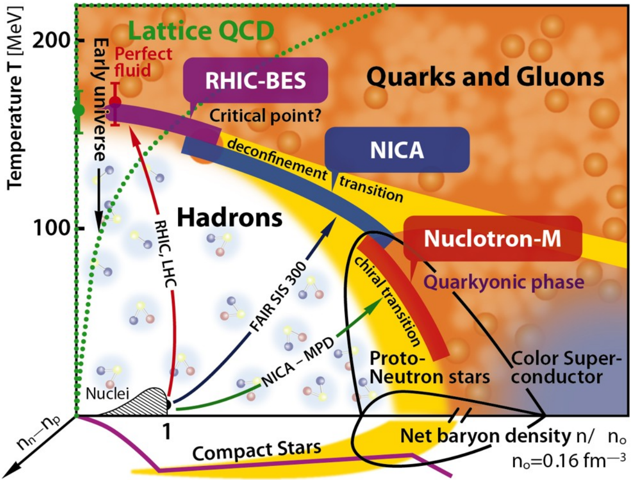


Figure: Phase diagram for the strong interacting matter[1].

[1]N. physics at JINR (official Web-Page), "NICA physics,

Vorticity

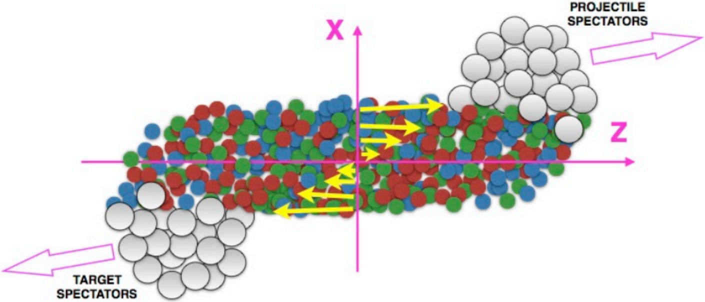


Figure: Diagram of a collision. Arrows denote the flux of the velocity[2].

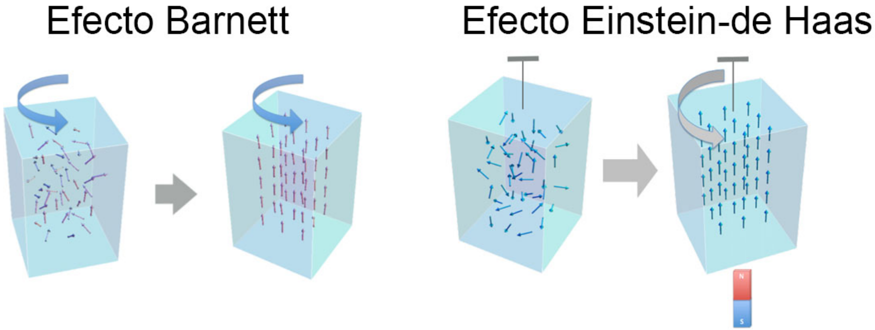
[2]Vorticity and polarization in heavy-ion collisions: Hydrodynamic models. In Strongly Interacting Matter under Rotation (pp. 247-280). Cham: Springer International Publishing.

Vorticity plays an important rol in different phenomena in the QGP evolution

- Vorticity lead to the chiral vortical effect[3] [4] [5].
- Vorticirty predicts the vortical chiral wave [6] [7] [8]
- Vorticity induces a local alignment of particles spin along its direction.[9].

[3] Phys. Rev. Lett. 103, 191601 (2009).
[4] Phys. Rev. Lett. 106, 062301 (2011).
[5] Progress in Particle and Nuclear Physics, vol. 88, pp. 1–28, 2016.
[6] Phys. Rev. C 82, 054910 (2010).
[7] Phys. Rev. C 88, 061901 (2013).
[8] Phys. Rev. D 92, 071501 (2015).
[9] Nature (London), vol. 548, no. BNL-114181-2017-JA, 2017.

Non relativistic analogous



Left, the Barnett effect. A magnetization is induced applying a rotation. Rigth, the Einstein-de Haas effect. An angular momentum is induced applying an external magnetic field[10] [11] [12].

[10] Physical review, 6(4), 239.

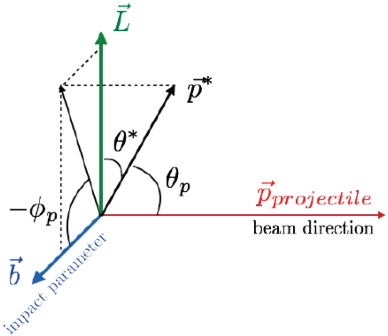
[11] In Proc. KNAW (Vol. 181, p. 696).

[12] Frontiers in Physics. 3. 10.3389/fphy.2015.00054, 2015.

Polarization analysis with Λ baryon

In the decay $\Lambda \to p + \pi^-$, the proton tends to be emitted along the direction of the spin of the Λ[13]. Then, the global polarization can be determined from the angular distribution of hyperon decay products[14]

$$\frac{dN}{d\Omega} = \frac{N}{4\pi}\left(1 + \alpha P \cos\theta^*\right) \quad (1)$$



[13] Physics Reports, vol. 122, no. 2-3, pp. 57–172, 1985.
[14] Physical Review C, vol. 76, no. 2, p. 024915, 2007.

Core-Corona model for polarization

We assume two different regions: a high-density corona and a less dense corona. Global polarization can be calculated through the difference of Λ produced in these regions[15].

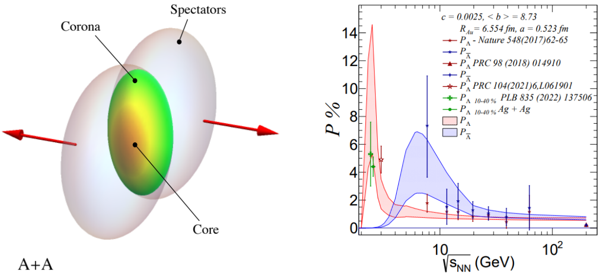


Table: Left, Sketch of a non-central heavy-ion collision. Rigth, red and blue shaded regions represent the global polarization for Λ and $\bar{\Lambda}$ as a functio nof the collision energy for the centrality range 20–50% obtained from the core-corona model.

[15] Particles 2023, 6, 405-415.

Core-Corona model for polarization

$$\mathcal{P}^{\Lambda} = \frac{\mathcal{P}^{\Lambda}_{REC} + z\frac{N_{\Lambda\ QGP}}{N_{\Lambda\ REC}}}{\left(1+\frac{N_{\Lambda\ QGP}}{N_{\Lambda\ REC}}\right)}, \quad \mathcal{P}^{\bar{\Lambda}} = \frac{\mathcal{P}^{\bar{\Lambda}}_{REC} + \bar{z}\left(\frac{w'}{w}\right)\frac{N_{\Lambda\ QGP}}{N_{\Lambda\ REC}}}{\left(1+\left(\frac{w'}{w}\right)\frac{N_{\Lambda\ QGP}}{N_{\Lambda\ REC}}\right)} \tag{2}$$

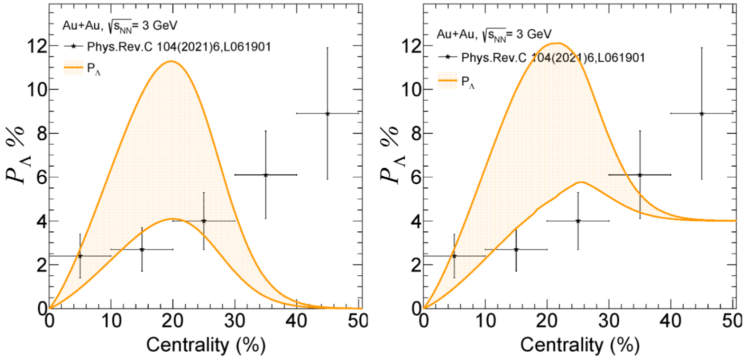


Figure: Λ global polarization as a function of centrality. With (right plot) and without (left plot) $\mathcal{P}^{\Lambda}_{REC}$=4%contribution for all centrality bins. Data for Au+Au at $\sqrt{s_{NN}}$ =3 GeV.

Intrinsic polarization

The alignment between the spin and vorticity is not instantaneous, it requires a relaxion time to occur. The intrinsic polarization relates the relaxion time with the life time of the system.

$$
\begin{aligned}
z &= 1 - \exp\left[-t/\tau\right] \\
\bar{z} &= 1 - \exp\left[-t/\bar{\tau}\right]
\end{aligned} \tag{3}
$$

Relaxion time is related with the interaction rate[16]

$$\tau = 1/\Gamma \tag{4}$$

[16] Phys. Rev. D 28, 2007 (1983)

Fermion in a rotating medium

The rotation provides the system a preferred direction, this can be seen in the metric tensor

$$g_{\mu\nu} = \begin{pmatrix} 1-(x^2+y^2)\Omega^2 & y\Omega & -x\Omega & 0 \\ y\Omega & -1 & 0 & 0 \\ -x\Omega & 0 & -1 & 0 \\ 0 & 0 & 0 & -1 \end{pmatrix}. \quad (5)$$

Dirac equation in a rotating environment

Then, the fermion is ruled by the Dirac equation in the rotation framework[17] [18]

$$\left[i\gamma^{\mu}\left(\partial_{\mu}+\Gamma_{\mu}\right)-m\right]\Psi=0, \tag{6}$$

where Γ_{μ} is the affine connection. In this context, the γ^{μ} in Eq. (6) corresponds to the Dirac matrices in the curved space-time, which satisfy the usual anticommutation relations

$$\{\gamma^{\mu},\gamma^{\nu}\}=2g^{\mu\nu}. \tag{7}$$

The relation between the gamma matrices in the rotating frame and the usual gamma matrices are

$$\begin{aligned} \gamma^{t} &= \gamma^{0}, \qquad & \gamma^{x} &= \gamma^{1}+y\Omega\gamma^{0}, \\ \gamma^{z} &= \gamma^{3}, \qquad & \gamma^{y} &= \gamma^{2}-x\Omega\gamma^{0}. \end{aligned} \tag{8}$$

[17] J. High Energ. Phys. 2017, 136 (2017).
[18] Phys. Rev. D 93, 104052 (2016)

Solution to Dirac equation in a rotating environment

$$\left[i\gamma^0\left(\partial_t+\Omega\hat{J}_z\right)+i\vec{\gamma}\cdot\vec{\nabla}-m\right]\Psi=0, \tag{9}$$

where

$$\hat{J}_z\equiv\hat{L}_z+\hat{S}_z=-i(x\Omega\partial_y-y\Omega\partial_x)-\frac{i}{2}\Omega\sigma^{12}. \tag{10}$$

This expression defines the total angular momentum in the $\hat{z}$ direction. The term $\hat{L}_z$ represents the orbital angular whereas $\hat{S}_z$ is the spin. On the other hand, the term $-i\vec{\nabla}$ is the usual momentum operator. We can find solutions to Eq. (9) in the form

$$\Psi(x)=\left[i\gamma^0\left(\partial_t+\Omega\hat{J}_z\right)+i\vec{\gamma}\cdot\vec{\nabla}+m\right]\phi(x), \tag{11}$$

and then, the function $\phi(x)$ satisfies a Klein-Gordon like equation

$$\left[\left(i\partial_t+\Omega\hat{J}_z\right)^2+\partial_x^2+\partial_y^2+\partial_z^2-m^2\right]\phi(x)=0. \tag{12}$$

Complete set of solutions

The solution of Eq. (12) can be written in cylindrical coordinates as

$$\phi(x) = \begin{pmatrix} J_l(k_\perp \rho) \\ J_{l+1}(k_\perp \rho) e^{i\varphi} \\ J_l(k_\perp \rho) \\ J_{l+1}(k_\perp \rho) e^{i\varphi} \end{pmatrix} e^{-Et + ik_z z + il\varphi}, \tag{13}$$

where J_l are Bessel functions of first kind,

$$k_\perp^2 = \tilde{E}^2 - k_z^2 - m^2, \tag{14}$$

$$\Psi(x) = \begin{pmatrix} [E + j\Omega + m - k_z + ik_\perp] \, J_l(k_\perp \rho) \\ [E + j\Omega + m + k_z - ik_\perp] \, J_{l+1}(k_\perp \rho) e^{i\varphi} \\ [-E - j\Omega + m - k_z + ik_\perp] \, J_l(k_\perp \rho) \\ [-E - j\Omega + m + k_z - ik_\perp] \, J_{l+1}(k_\perp \rho) e^{i\varphi} \end{pmatrix} \times e^{-(E+j\Omega)t + ik_z z + il\varphi}. \tag{15}$$

Green function for Dirac equation

$$S(x,x') = \left[i\gamma^0\left(\partial_t + \Omega\hat{J}_z\right) + i\vec{\gamma}\cdot\vec{\nabla} + m\right]G(x,x'), \tag{16}$$

where

$$G(x,x') = (-i)\int_{\infty}^{0}\sum_{\lambda}\exp\left[-i\tau\lambda\right]\phi_\lambda(x)\phi_\lambda^\dagger(x). \tag{17}$$

In this last expression, λ and $\phi_\lambda(x)$ represent the eigenvalue and eigenvector of Eq. (12). Taking $E, k_\perp, k_z, l$ as independent quantum numbers, the closure relation is written as

$$\begin{aligned}\sum_{\lambda}\phi_\lambda(x)\phi_\lambda^\dagger(x) &= \sum_{l=\infty}^{\infty}\int\frac{dEdk_z dk_\perp k_\perp}{(2\pi)^3}\phi(x)\phi^\dagger(x)\\ &= \begin{pmatrix}1 & 0 & 1 & 0\\ 0 & 1 & 0 & 1\\ 1 & 0 & 1 & 0\\ 0 & 1 & 0 & 1\end{pmatrix}\delta^4(x-x').\end{aligned} \tag{18}$$

Propagator for fermion in rotating envirnment

$$S(p) = \begin{pmatrix} \frac{p_0+\Omega/2-p_z+m+ip_\perp}{(p_0+\Omega/2)^2-p^2-m^2+i\epsilon} & 0 & \frac{p_0+\Omega/2-p_z+m+ip_\perp}{(p_0+\Omega/2)^2-p^2-m^2+i\epsilon} & 0 \\ 0 & \frac{p_0+\Omega/2+p_z+m-ip_\perp}{(p_0-\Omega/2)^2-p^2-m^2+i\epsilon} & 0 & \frac{p_0+\Omega/2+p_z+m-ip_\perp}{(p_0-\Omega/2)^2-p^2-m^2+i\epsilon} \\ \frac{-(p_0+\Omega/2)-p_z+m+ip_\perp}{(p_0+\Omega/2)^2-p^2-m^2+i\epsilon} & 0 & \frac{-(p_0+\Omega/2)-p_z+m+ip_\perp}{(p_0+\Omega/2)^2-p^2-m^2+i\epsilon} & 0 \\ 0 & \frac{-(p_0+\Omega/2)+p_z+m-ip_\perp}{(p_0-\Omega/2)^2-p^2-m^2+i\epsilon} & 0 & \frac{-(p_0+\Omega/2)+p_z+m-ip_\perp}{(p_0-\Omega/2)^2-p^2-m^2+i\epsilon} \end{pmatrix}. \tag{19}$$

We can write Eq. (19) in terms of the Dirac-gamma matrices as[19]

$$\begin{aligned} S(P) = &\frac{(p_0 + \Omega/2 - p_z + ip_\perp)(\gamma_0 + \gamma_3) + m(1 + \gamma_5)}{(p_0 + \Omega/2)^2 - p^2 - m^2 + i\epsilon}\mathcal{O}^+ \\ &+ \frac{(p_0 - \Omega/2 + p_z - ip_\perp)(\gamma_0 - \gamma_3) + m(1 + \gamma_5)}{(p_0 - \Omega/2)^2 - p^2 - m^2 + i\epsilon}\mathcal{O}^-, \end{aligned} \tag{20}$$

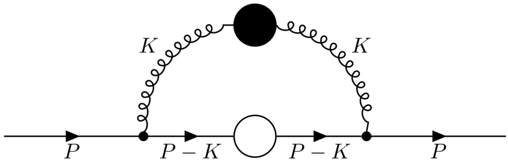
where

$$\mathcal{O}^\pm = \frac{1}{2}\left[1 \pm i\gamma^1\gamma^2\right] \tag{21}$$

[19] Phys. Rev. D 104, 039901 (2021)

Interaction rate for fermion in a rotating medium

Interaction rate can be obtained from the self-energy as[20] [21]



$$\Gamma^{\pm}(p_0) = f_F(p_0)\mathrm{Tr}\left[(O^{\pm})\mathrm{Im}\Sigma^{\pm}\right], \tag{22}$$

$$\Sigma^{\pm} = T\sum_n \int \frac{d^3k}{(2\pi)^3}\lambda_a^{\mu}\left[S^{\pm}(P-K))\right]\lambda_b^{\nu *} G_{\mu\nu}^{ab} \tag{23}$$

[20] Rev. D 52, 2987 (1995)

[21] Int. J. Mod. Phys. A 15, 2953 (2000)

$$\Gamma^{\pm}(p_0) = \frac{g^2 C_F \pi m_q}{2} \int_0^{\infty} \frac{dk\, k^2}{(2\pi)^3} \int_0^{2\pi} d\phi \int_{\mathcal{R}^{\pm}} \frac{dk_0}{2\pi} \frac{f(k_0)}{2pk} \times \tilde{f}\left(p_0 - k_0 - \mu \mp \Omega\right)\left(8\rho_T(k_0) + 4\rho_L(k_0)\right), \tag{24}$$

where $\mathcal{R}^{\pm}$ are the regions defined by

$$\begin{aligned} k_0 &\geq p_0 - \sqrt{(p+k)^2 + m_q^2} \pm \Omega/2, \\ k_0 &\leq p_0 - \sqrt{(p-k)^2 + m_q^2} \pm \Omega/2. \end{aligned} \tag{25}$$

The total interaction rate can be obtained integration over all the phase space

$$\Gamma = V \int \frac{d^3p}{(2\pi)^3} \left(\Gamma^{+}(p_0) - \Gamma^{-}(p0)\right), \tag{26}$$

with[22]

$$V = \pi R^2 \Delta\tau_{QGP} \tag{27}$$

[22] Phys. Rev. C 105, 034907 (2022)

Some definitions

$$P = (i\omega_m + \mu, \vec{p})$$

$$K = (i\omega_n, \vec{k})$$

$$\lambda_a^\mu = g\gamma^\mu t_a$$

$$^*G_{\mu\nu}(K) = \Delta_L(K)P_{L,\mu\nu} + \Delta_T(K)P_{T,\mu\nu}$$

$$\Delta_L^{-1}(K) = K^2 + 2m^2\frac{K^2}{k^2}[1 - \frac{i\omega_n}{k}Q_0(\frac{i\omega_n}{k})]$$

$$\Delta_T^{-1}(K) = -K^2 - m^2(\frac{i\omega_n}{k})\{[1 - (\frac{i\omega_n}{k})^2]Q_0(\frac{i\omega_n}{k}) + (\frac{i\omega_n}{k})\}$$

$$Q_0(x) = \frac{1}{2}ln(\frac{x+1}{x-1})$$

$$m = \frac{1}{6}g^2C_AT^2 + \frac{1}{12}g^2C_F(T^2 + \frac{3}{\pi^2}\mu^2)$$

Computation of Matsubara sum

Now,

$$\Sigma = \int \frac{d^3k}{(2\pi)^3} \sum_i (2\pi)^3 \lambda^\mu (S_i P_{i,\mu\nu}) \lambda_\nu \tag{28}$$

Where we have defined

$$S_i = T \sum_n \Delta_i(i\omega_n, \vec{k}) \Delta_F(i(\omega - \omega_n), \vec{p} - \vec{k}) \tag{29}$$

$i =$L,T

This sum can be perform in terms of the spectral densities and making the analytic continuation $i\omega \to p_0' + i\eta$. Then we get

$$\begin{aligned} Im(S_i) =& \pi(e^{(p_0-\mu)\beta} + 1) \int_{-\infty}^{\infty} \frac{dk_0}{2\pi} \frac{dp_0'}{2\pi} f(k_0) f_F(p_0' - \mu) \\ & \times \delta(p_0 - k_0 - p_0') \rho_i(k_0, k) \rho_F(p_0', p - k) \end{aligned} \tag{30}$$

Spectral density for fermion

The spectral densities can be obtained form the imaginary part of the propagator,

$$\rho(p_0, p) = 2\text{Im}(\Delta_F(p_0 + i\eta, p)). \tag{31}$$

Then,

$$\begin{aligned} \rho^+ &= -2\pi\delta((p_0 + \Omega/2)^2 - E^2) \\ &= \frac{-\pi}{E - (\pm\Omega/2)} \left[\delta((p_0 + \Omega/2) - E) + \delta((p_0 + \Omega/2) + E)\right], \end{aligned} \tag{32}$$

$$\begin{aligned} \rho^- &= -2\pi\delta((p_0 - \Omega/2)^2 - E^2) \\ &= \frac{-\pi}{E - (\pm\Omega/2)} \left[\delta((p_0 - \Omega/2) - E) + \delta((p_0 - \Omega/2) + E)\right]. \end{aligned} \tag{33}$$

Spectral densties for Hard Thermal Loop gluon

$$\rho_L(k_0, k) = \frac{x}{1-x^2} \frac{2\pi m^2 \theta(k^2 - k_0^2)}{[k^2 + m^2(1-(x/2))Ln(|(1+x)/(1-x)|)]^2 + [\pi m^2 x]^2} \tag{34}$$

$$\rho_T(k_0, k) = \frac{2\pi m^2 x(1-x^2)\theta(k^2 - k_0^2)}{[k^2(1-x^2) + m^2(x^2 + (x/2)(1-x^2)Ln(|(1+x)/(1-x)|)]^2 + [(\pi/2)m^2 x(1-x^2)]^2} \tag{35}$$

Interaction rate

Then,

$$\Gamma^{\pm}(p_0) = g^2 C_F f_F(p_0 - \mu)\pi \left(e^{\beta(p_0-\mu)} + 1\right)$$
$$\int \frac{k^2 dk d(\cos\theta) d\phi}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{dk_0}{2\pi} \int_{-\infty}^{\infty} \frac{dp_0'}{2\pi} \delta(p_0 - k_0 - p_0')$$
$$\times \; f(k_0) f_F(p_0' - \mu) 2\pi\delta\left(\left(p_0' \pm \frac{\Omega}{2}\right)^2 - E^2\right)$$
$$\times \sum_{i=L,T} \mathcal{C}_i^{\pm} \rho_i(k_0).$$

with

$$E^2 = |\vec{p} - \vec{k}|^2 + m_q^2 \tag{36}$$

Kinematic restrictions

The integral over θ impose some kinematic restrictions over the values of k_0. To see this, consider the identity

$$\delta(f(x)) = \frac{1}{f'(x_0)}\delta(x - x_0), \quad f(x_0) = 0. \tag{37}$$

Then,

$$\begin{aligned}
&\frac{1}{E - (\pm\Omega/2)}\delta\left(p_0 \pm \Omega/2 - k_0 - \sqrt{p^2 +^2 - 2pk\cos\theta + m_q^2}\right) \\
&= \frac{1}{2pk}\delta(\cos\theta - \cos\theta_0), \\
&\cos\theta_0 = \frac{p^2 + k^2 - (p_0 \pm \Omega/2 - k_0)^2 + m_q^2}{2pk}, \quad p_0 \pm \Omega/2 - k_0 \geq 0.
\end{aligned} \tag{38}$$

The available values of θ are

$$-1 \leq \cos\theta_0 \leq 1. \tag{39}$$

In terms of kinematic variables,

$$-1 \leq \frac{p^2 + k^2 - (p_0 \pm \Omega/2 - k_0)^2 + m_q^2}{2pk} \leq 1 \tag{40}$$

This implies two inequalities,

$$\begin{aligned} \sqrt{(p+k)^2 + m_q^2} \geq |p_0 \pm \Omega/2 - k_0| = p_0 + \Omega/2 - k_0, \\ k_0 \geq p_0 \pm \Omega/2 - \sqrt{(p+k)^2 + m_q^2}. \end{aligned} \tag{41}$$

The second,

$$\begin{aligned} \sqrt{(p-k)^2 + m_q^2} \leq |p_0 \pm \Omega/2 - k_0| = p_0 \pm \Omega/2 - k_0 \\ k_0 \leq p_0 \pm \Omega/2 - \sqrt{(p-k)^2 + m_q^2} \end{aligned} \tag{42}$$

Both inequalities are satisficed in the region

$$p_0 - \sqrt{(p+k)^2 + m_q^2} \pm \Omega/2 \leq k_0 \leq p_0 - \sqrt{(p-k)^2 + m_q^2} \pm \Omega/2. \quad (43)$$

For the other Dirac delta, $\delta(p_0 - k_0 \pm \Omega/2 + E)$, we can do the same strategy and obtain the region

$$p_0 + \sqrt{(p-k)^2 + m_q^2} \pm \Omega/2 \leq k_0 \leq p_0 + \sqrt{(p+k)^2 + m_q^2} \pm \Omega/2 \quad (44)$$

Trace factors

Now, we introduce the projection tensors,

$$P^T_{\mu\nu} = -g_{\mu\nu} - \frac{K_\mu K_\nu}{k^2} + \frac{K \cdot U}{k^2}(K_\mu U_\nu + K_\nu U_\mu) - \frac{K^2}{k^2} U_\mu U_\nu, \tag{45}$$

$$P^L_{\mu\nu} = -g_{\mu\nu} + \frac{K_\mu K_\nu}{K^2} - P^T_{\mu\nu}, \tag{46}$$

Then, the trace factors $\mathcal{C}_i^{\pm}$ are

$$\begin{aligned} \mathcal{C}_T^{\pm} &= P^T_{\mu\nu} \mathrm{Tr}\left[\gamma^\mu A^\pm \gamma^\nu\right] = 8m_q, \\ \mathcal{C}_L^{\pm} &= P^L_{\mu\nu} \mathrm{Tr}\left[\gamma^\mu A^\pm \gamma^\nu\right] = 4m_q, \end{aligned} \tag{47}$$

Interaction rate

With all these ingredients, the interaction rate is

$$\begin{aligned}\Gamma^{\pm}(p_0) = \frac{g^2 C_F \pi m_q}{2} \int_0^{\infty} \frac{dk\, k^2}{(2\pi)^3} \int_0^{2\pi} d\phi \int_{\mathcal{R}^{\pm}} \frac{dk_0}{2\pi} \frac{f(k_0)}{2pk} \\ \times \left[\tilde{f}\,(p_0 - k_0 - \mu) + \left(1 - \tilde{f}\,(-p_0 + k_0 + \mu)\right)\right] \\ \times \left(8\rho_T(k_0) + 4\rho_L(k_0)\right),\end{aligned} \tag{48}$$

where $\mathcal{R}^{\pm}$ are the regions defined by

$$\begin{aligned} k_0 \geq p_0 - \sqrt{(p+k)^2 + m_q^2} \pm \Omega/2, \\ k_0 \leq p_0 - \sqrt{(p-k)^2 + m_q^2} \pm \Omega/2. \end{aligned} \tag{49}$$

The total interaction rate can be obtained integration over all the phase space

$$\Gamma = V \int \frac{d^3p}{(2\pi)^3} \left(\Gamma^+(p_0) - \Gamma^-(p0)\right), \qquad (50)$$

Relaxing time for quarks as funcion of temperature with ω =0.052

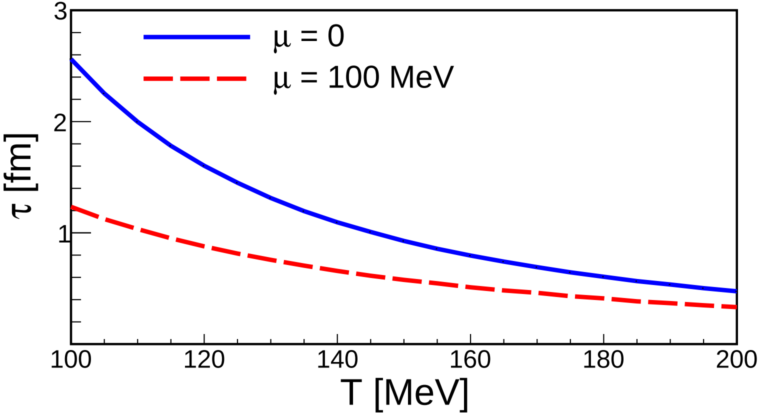


Figure: Relaxation time τ for quarks as a function of temperature T for semicentral collisions at an impact parameter b=10 fm for $\sqrt{s_{NN}} = 200$ GeV which correspons to a angular veolicty $\Omega = 0.052$ fm^{-1} with $\mu = 0$, 100 MeV.

Relaxing time for quarks as funcion of temperature with ω =0.071

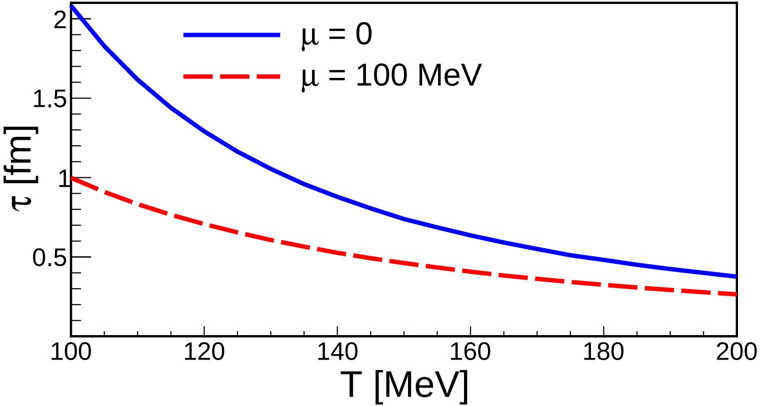


Figure: Relaxation time τ for quarks as a function of temperature T for semicentral collisions at an impact parameter b=10 fm for $\sqrt{s_{NN}}$ = 10 GeV which correspons to a angular veolicty Ω =0.071 fm^{-1} with μ =0, 100 MeV.

Relaxing time for antiquarks as funcion of temperature with ω =0.052

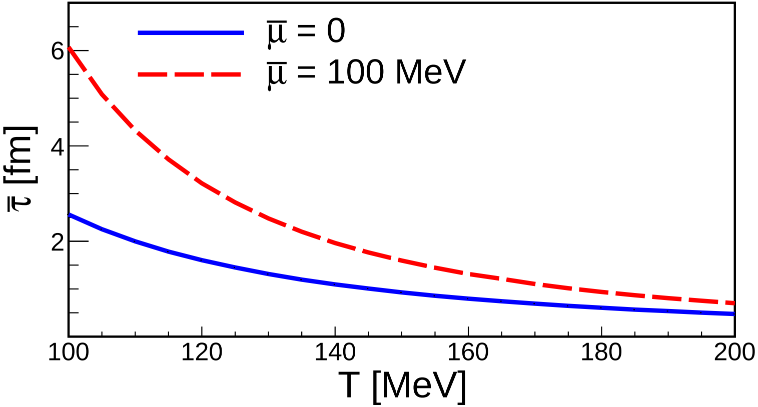


Figure: Relaxation time $\bar{\tau}$ for antiquarksquarks as a function of temperature T for semicentral collisions at an impact parameter b=10 fm for $\sqrt{s_{NN}} = 10$ GeV which correspons to a angular veolicty Ω =0.071 fm^{-1} with $\mu = 0$, 100 MeV.

Relaxing time for antiquarks as funcion of temperature with ω =0.071

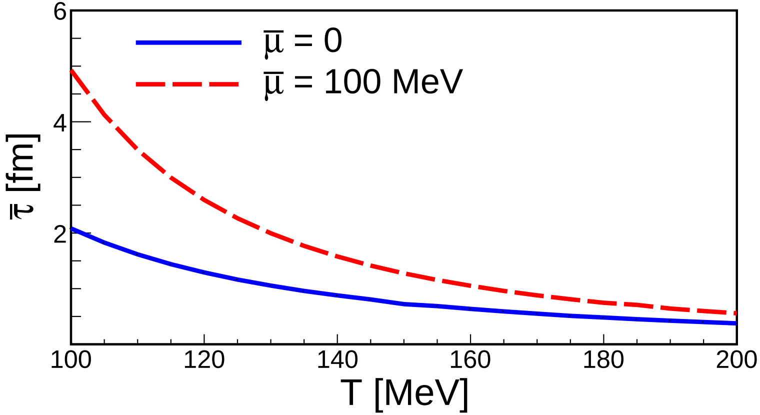


Figure: Relaxation time $\bar{\tau}$ for antiquarksquarks as a function of temperature T for semicentral collisions at an impact parameter b=10 fm for $\sqrt{s_{NN}} = 10$ GeV which correspons to a angular veolicty Ω =0.071, 0.052 fm^{-1} with μ =0, 100 MeV.

Relaxing time for quarks as function of energy collision

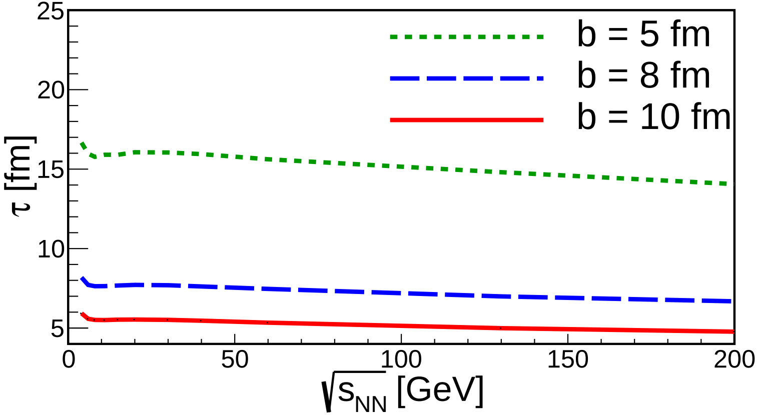


Figure: Relaxing time τ for quarks as a function of $\sqrt{s_{NN}}$ for semicentral collisions at impact parameter b=5, 8 and 10 fm.

Relaxing time for antiquarks as function of energy collision

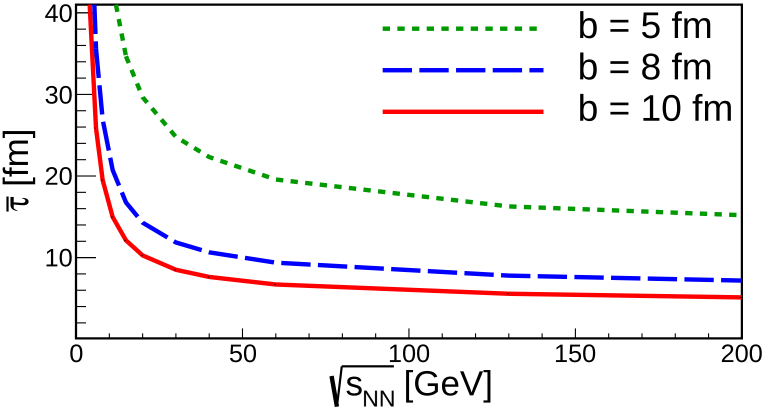


Figure: Relaxing time $\bar{\tau}$ for antiquarks as a function of $\sqrt{s_{NN}}$ for semicentral collisions at impact parameter b=5, 8 and 10 fm.

Intrinsic polarization

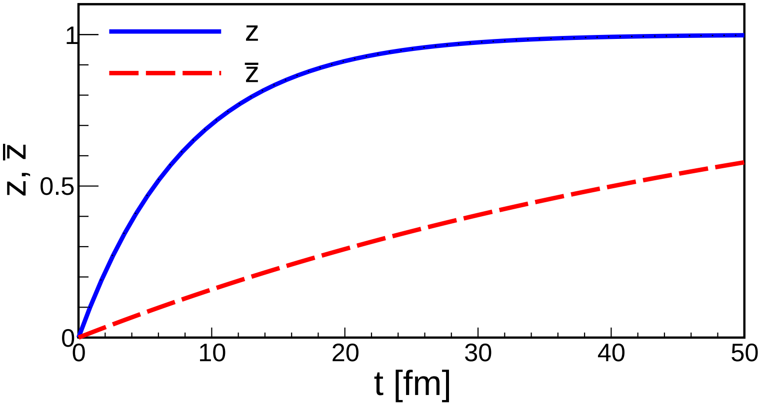


Figure: Intrinsic global polarization for quarks (z) and antiquarks ($\bar{z}$) as functions of time t for semicentral collisions at an impact parameter $b = 10$ fm for $\sqrt{s_{NN}} = 4$ GeV.

Summary

The analysis performed in this work can be summarized as follows

- We use a propagator for a fermion being dragged in a rotating environment to calculate the rate of spin projection of a quark along and opposite the angular velocity.
- The total rate to align the quark spin with the angular velocity is obtained by the difference between the rate to populate the spin projection along and opposite to the angular velocity
- The relaxation time is computed as the inverse of the interaction rate. For conditions resembling a heavy-ion collision the relaxation times for quarks are within the putative life-time of the QGP.
- We quantified these results in terms of the intrinsic quark and anti-quark polarization. Expecting this intrinsic polarization is preserved during the hadronization process, can be traduced into a global polarization for Λ, $\bar{\Lambda}$.

Thank you for your attention