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

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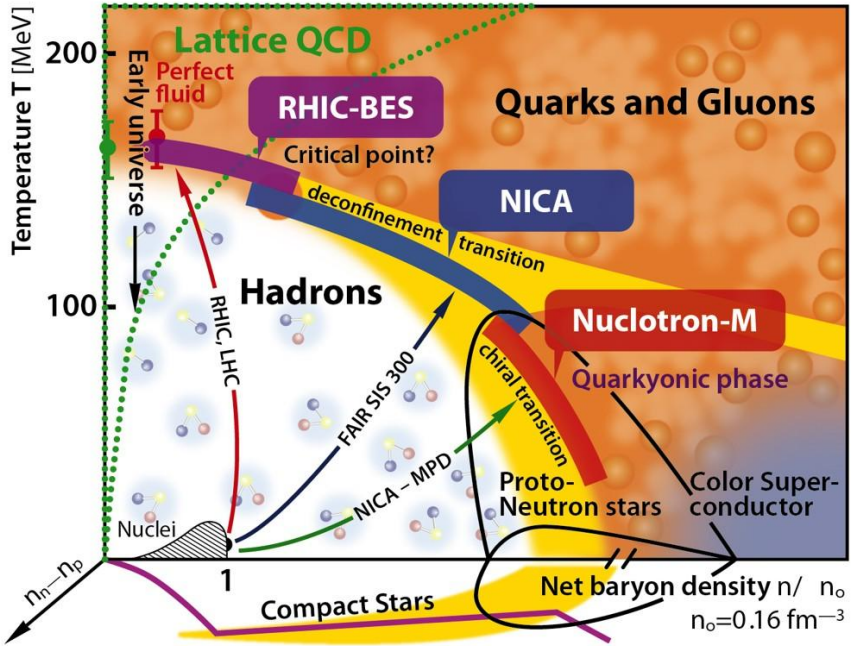
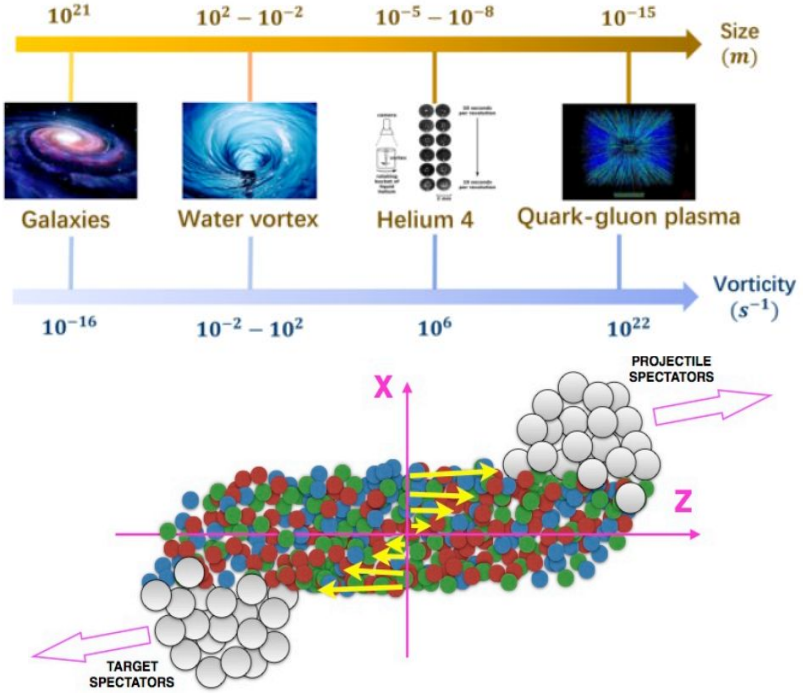
Instituto de Ciencias Nucleares UNAM

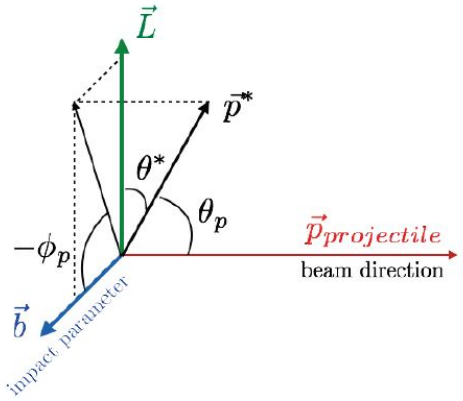
Heavy-ion collisions



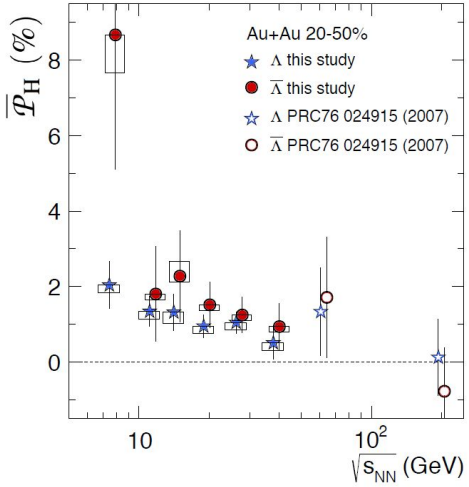


- N. physics at JINR (official Web-Page), "NICA physics, https://nica.jinr.ru/physics.php,."
- {Vorticity and polarization in heavy-ion collisions: Hydrodynamic models. In Strongly Interacting Matter under Rotation (pp. 247-280). Cham: Springer International Publishing.
- X.-G. Huang, "Vorticity and spin polarization—a theoretical perspective," Nuclear Physics A, vol. 1005, p. 121752, 2021.

Polarization induced by the vorticity

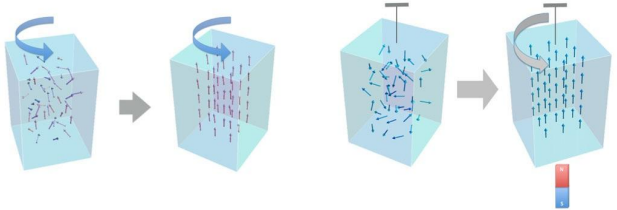


$$\frac{dN}{d\Omega} = \frac{N}{4\pi}\left(1 + \alpha P \cos\theta^*\right)$$



Barnett effect

Einstein-De Haas effect



Classical analogus

- Matsuo, M., Ieda, J. I., & Maekawa, S. (2015). Mechanical generation of spin current. *Frontiers in Physics*, *3*, 54.
- STAR collaboration. (2017). Erratum: Global polarization measurement in Au+ Au collisions [Phys. Rev. C 76, 024915 (2007)]. *Physical Review C*, *95*(3), 039906.

System in rotation

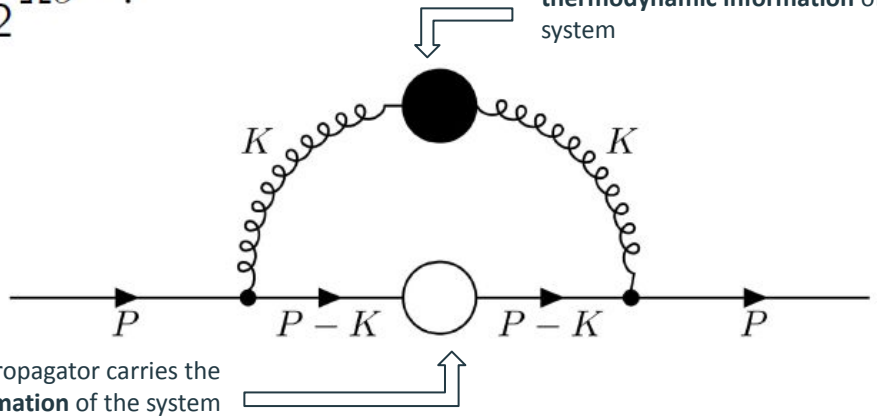
Dirac Ec. in a rotation environment

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

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

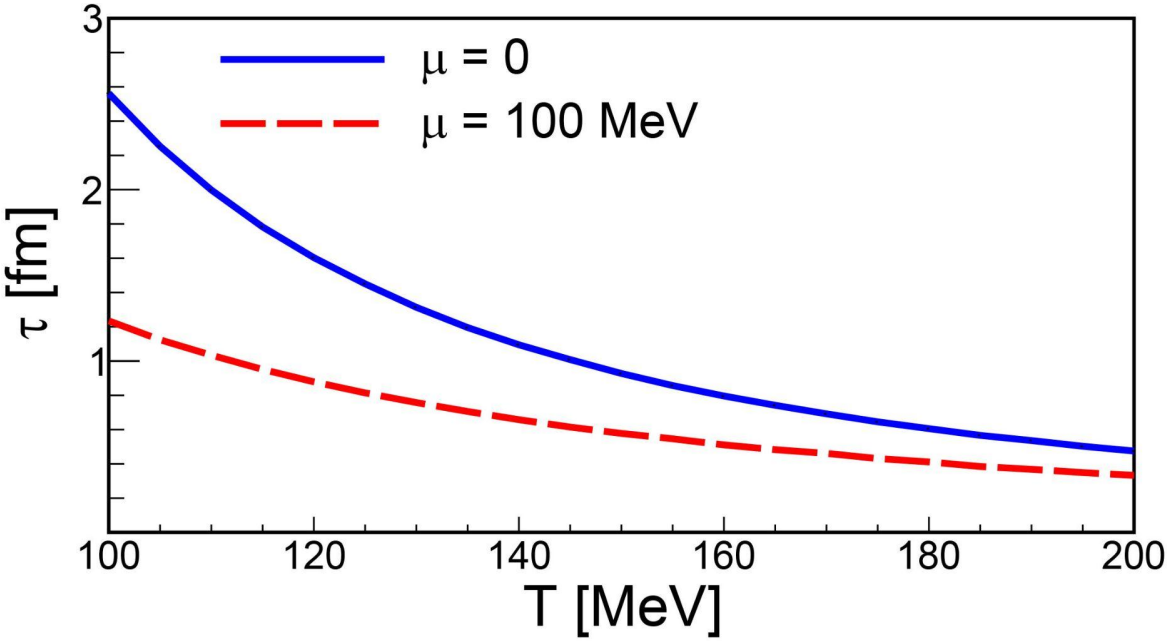
- Ayala, A., Hernández, L. A., Raya, K., & Zamora, R. (2021). Fermion propagator in a rotating environment. *Physical Review D*, *103*(7), 076021.
- Chernodub, M. N., & Gongyo, S. (2017). Interacting fermions in rotation: chiral symmetry restoration, moment of inertia and thermodynamics. *Journal of High Energy Physics*, *2017*(1), 1-32.
- Iablokov, S. N., & Kuznetsov, A. V. (2019, November). Exponential operator method for finding exact solutions of the propagator equation in the presence of a magnetic field. In *Journal of Physics: Conference Series* (Vol. 1390, No. 1, p. 012078). IOP Publishing.

The gluon propagator carries the **thermodynamic information** of the system



The fermion propagator carries the **rotation information** of the system

Relaxation time for quarks as function of temperature with Ω=0.052 fm^-1

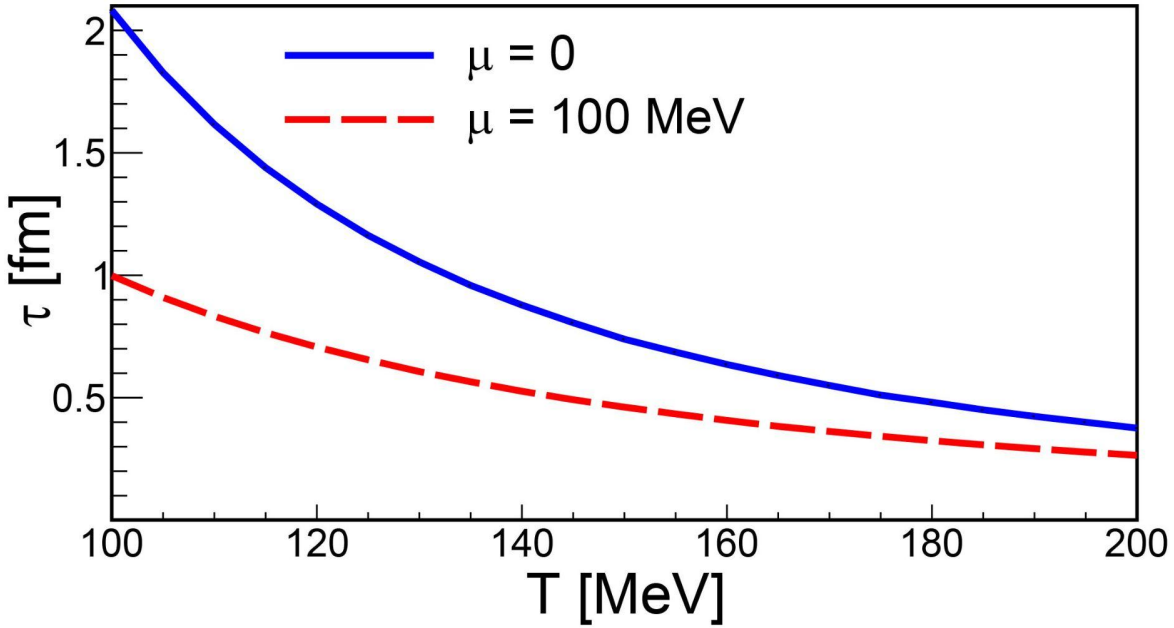


Parameters of the system

- Energy of collision: 200 GeV
- Impact parameter: 10 fm
- Angular velocity: 0.052 fm^-1

- Ayala, A., Bernal-Langarica, S., Jiménez, I. D., Maldonado, I., Medina-Serna, J. J., Rendón, J., & Tejeda-Yeomans, M. E. (2024). Relaxation time for the alignment between quark spin and angular velocity in a rotating QCD medium. *Physical Review D*, *109*(7), 074018.

Relaxation time for quarks as function of temperature with Ω=0.071 fm^-1



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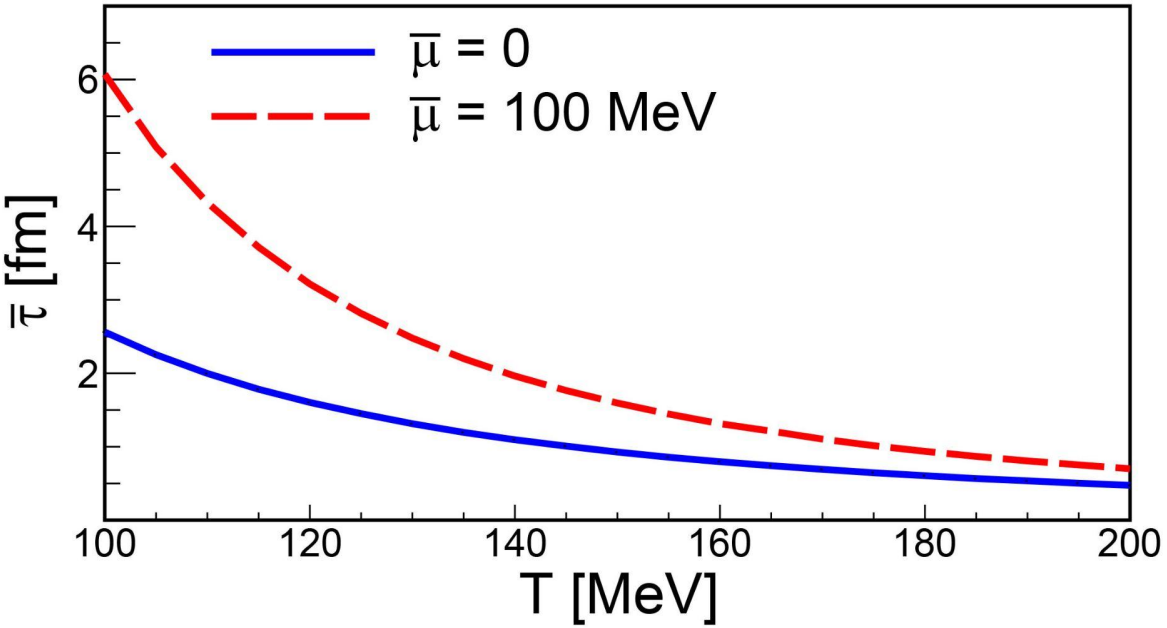
Relaxation time for antiquarks as function of temperature with Ω=0.052 fm^-1



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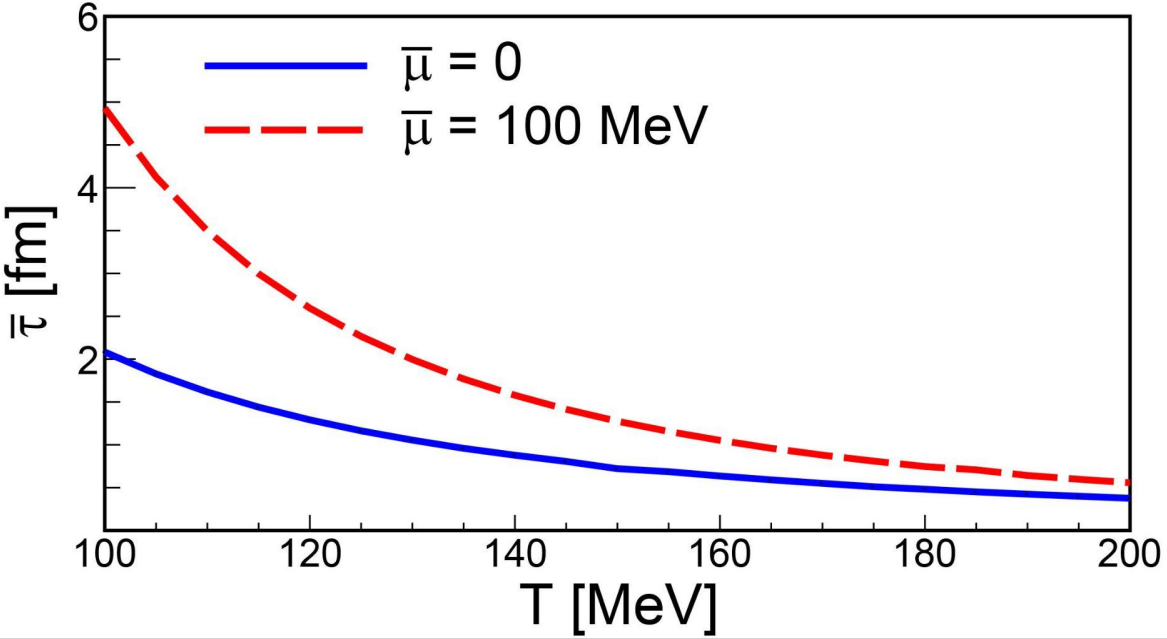

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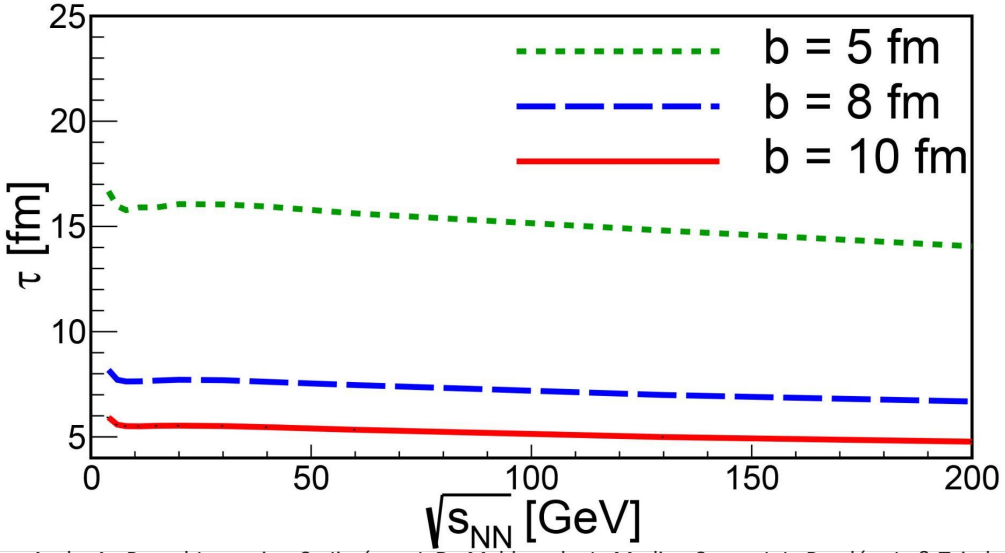
Relaxation time for quarks as function of collision energy



Parameterization

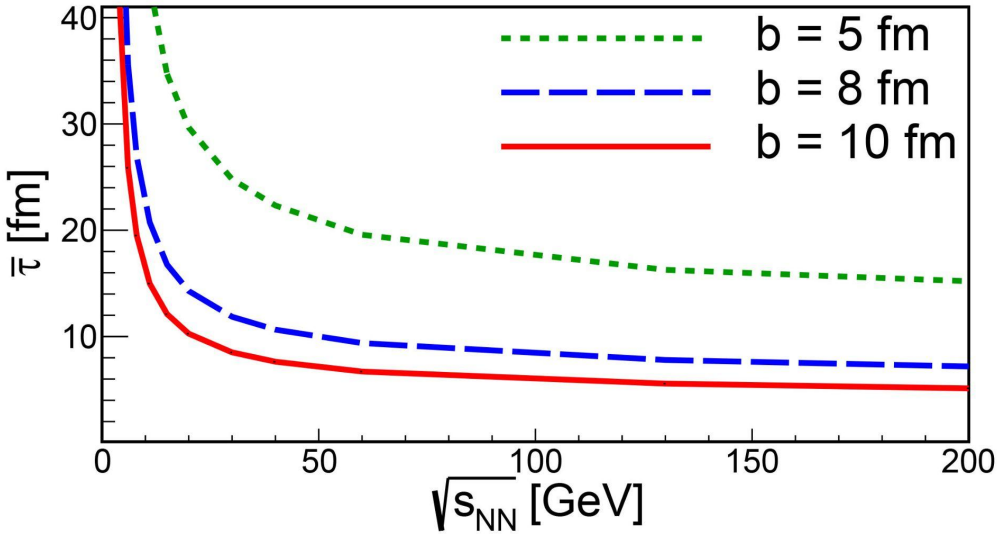
$$T(\mu_B) = 0{,}166 - 0{,}139\mu_B^2 - 0{,}053\mu_B^4,$$

$$\mu_B(\sqrt{s_{NN}}) = \frac{1{,}308}{1 + 0{,}273\sqrt{s_{NN}}},$$

$$\Omega = \frac{b^2}{2V_N}\left[1 + 2\left(\frac{m_N}{\sqrt{s_{NN}}}\right)^{1/2}\right],$$

- Ayala, A., Bernal-Langarica, S., Jiménez, I. D., Maldonado, I., Medina-Serna, J. J., Rendón, J., & Tejeda-Yeomans, M. E. (2024). Relaxation time for the alignment between quark spin and angular velocity in a rotating QCD medium. *Physical Review D*, *109*(7), 074018.
- Cleymans, J., Oeschler, H., Redlich, K., & Wheaton, S. (2006). Comparison of chemical freeze-out criteria in heavy-ion collisions. *Physical Review C*, *73*(3), 034905.
- Ayala, A., De La Cruz, D., Hernández-Ortíz, S., Hernández, L. A., & Salinas, J. (2020). Relaxation time for quark spin and thermal vorticity alignment in heavy-ion collisions. *Physics Letters B*, *801*, 135169.

Relaxation time for antiquarks as function of collision energy



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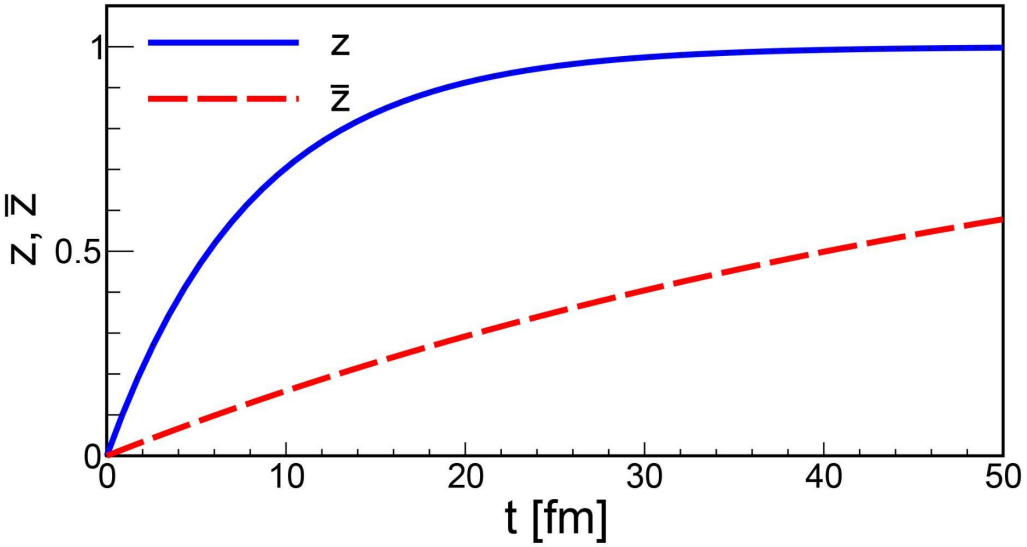
Intrinsic polarization as function of system life time



Definition of intrinsic polarization

$$z = 1 - \exp\left[-t/\tau\right]$$

$$\bar{z} = 1 - \exp\left[-t/\bar{\tau}\right]$$

- Ayala, A., Bernal-Langarica, S., Jiménez, I. D., Maldonado, I., Medina-Serna, J. J., Rendón, J., & Tejeda-Yeomans, M. E. (2024). Relaxation time for the alignment between quark spin and angular velocity in a rotating QCD medium. *Physical Review D*, *109*(7), 074018.
- Ayala, A., Domínguez, I., Maldonado, I., & Tejeda-Yeomans, M. E. (2022). Rise and fall of Λ and Λ¯ global polarization in semi-central heavy-ion collisions at HADES, NICA and RHIC energies from the core-corona model. *Physical Review C*, *105*(3), 034907.
- Ayala, A., Dominguez, I., Maldonado, I., & Tejeda-Yeomans, M. E. (2023). An improved core-corona model for λ and λ polarization in relativistic heavy-ion collisions. *Particles*, *6*(1), 405-415.

Thank you for your attention