Spin Polarization and Magnetic Field in Relativistic Heavy-Ion Collisions

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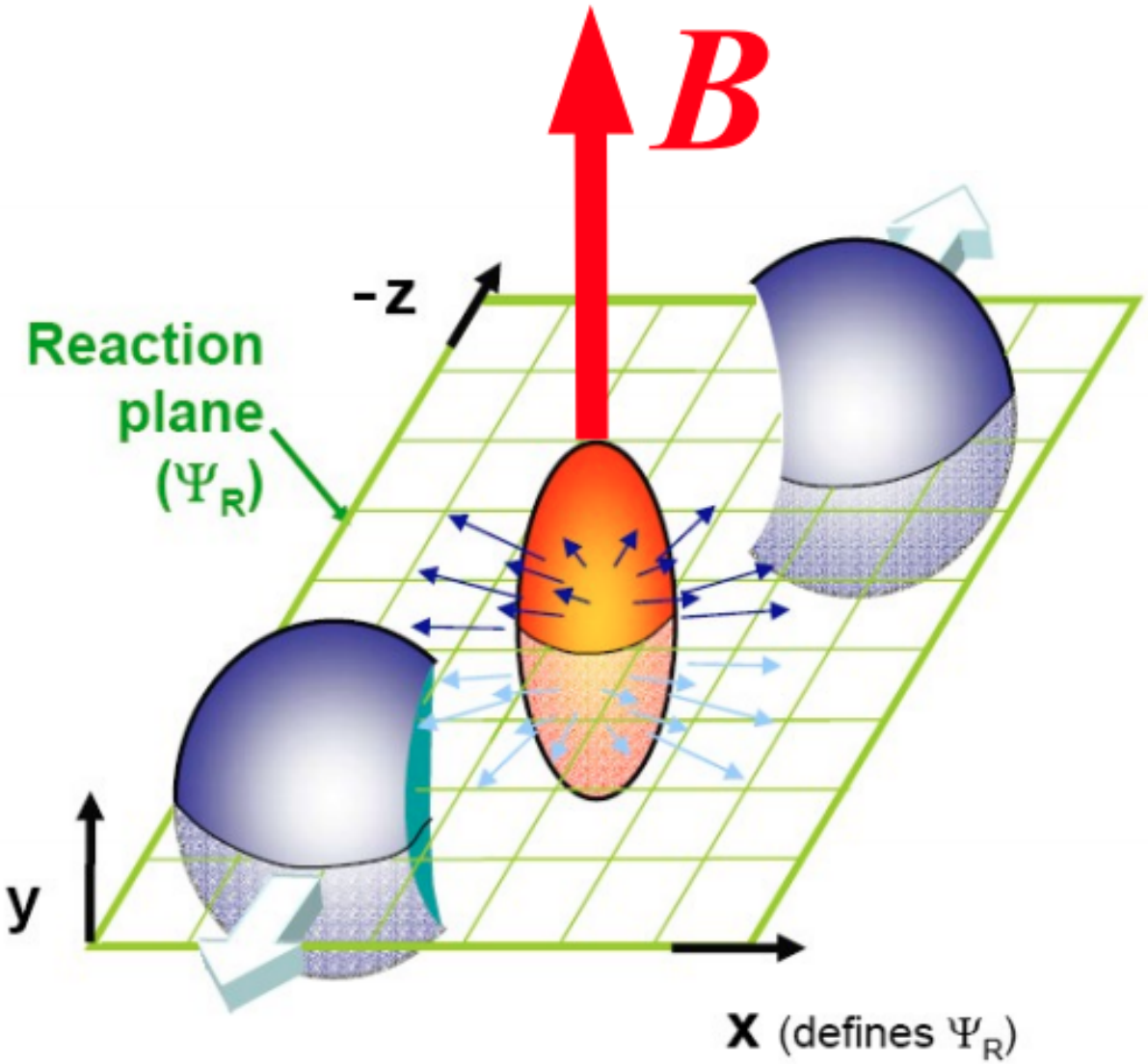
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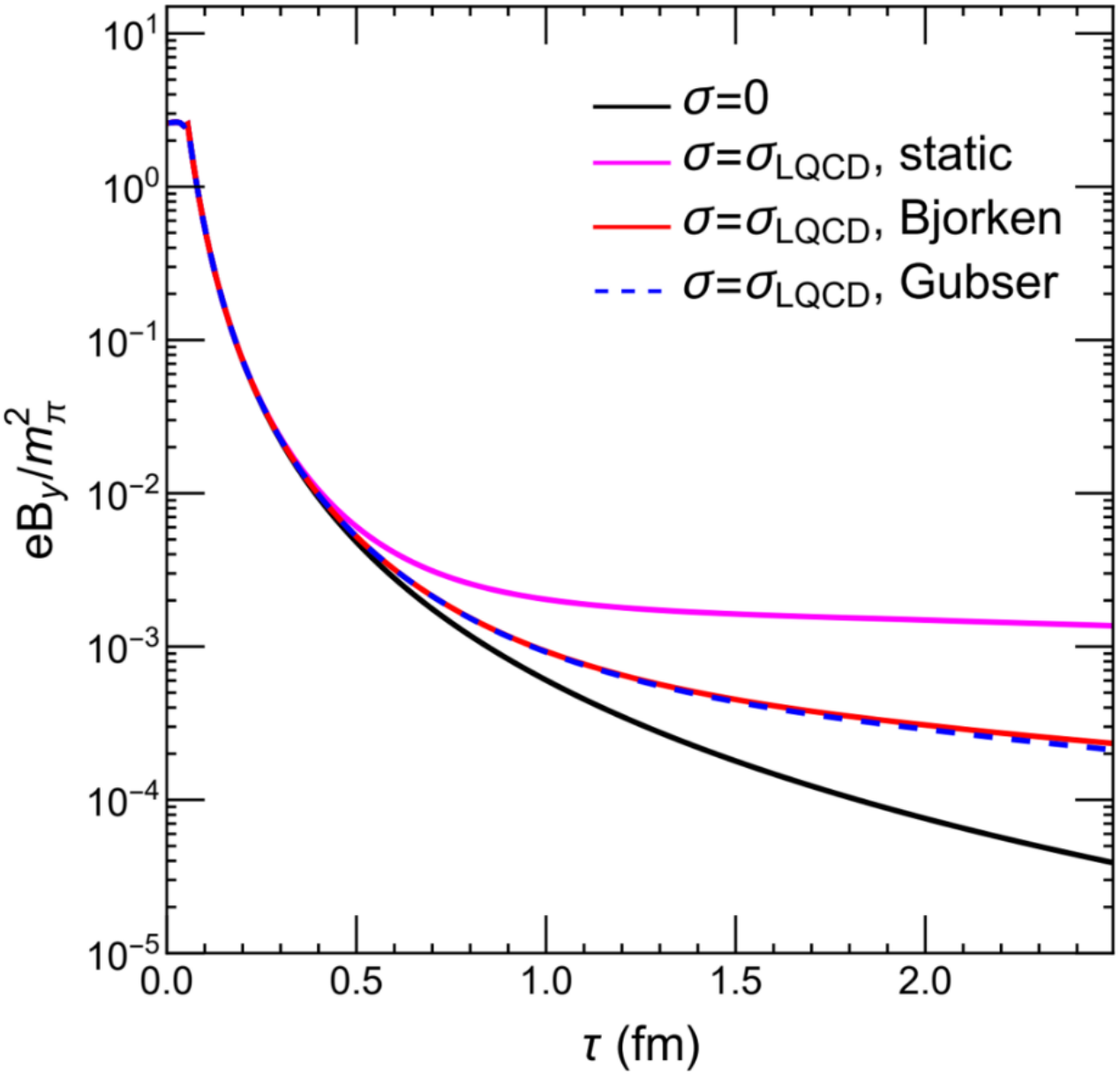
JINR Dubna

Magnetic field in heavy ion collisions



[Adapted from D. Kharzeev @ CPOD 2013.]

Magnetic field time evolution



[A. Huang, D. She, S. Shi, M. Huang and J. Liao, Phys. Rev. C 107, 034901 (2023).]

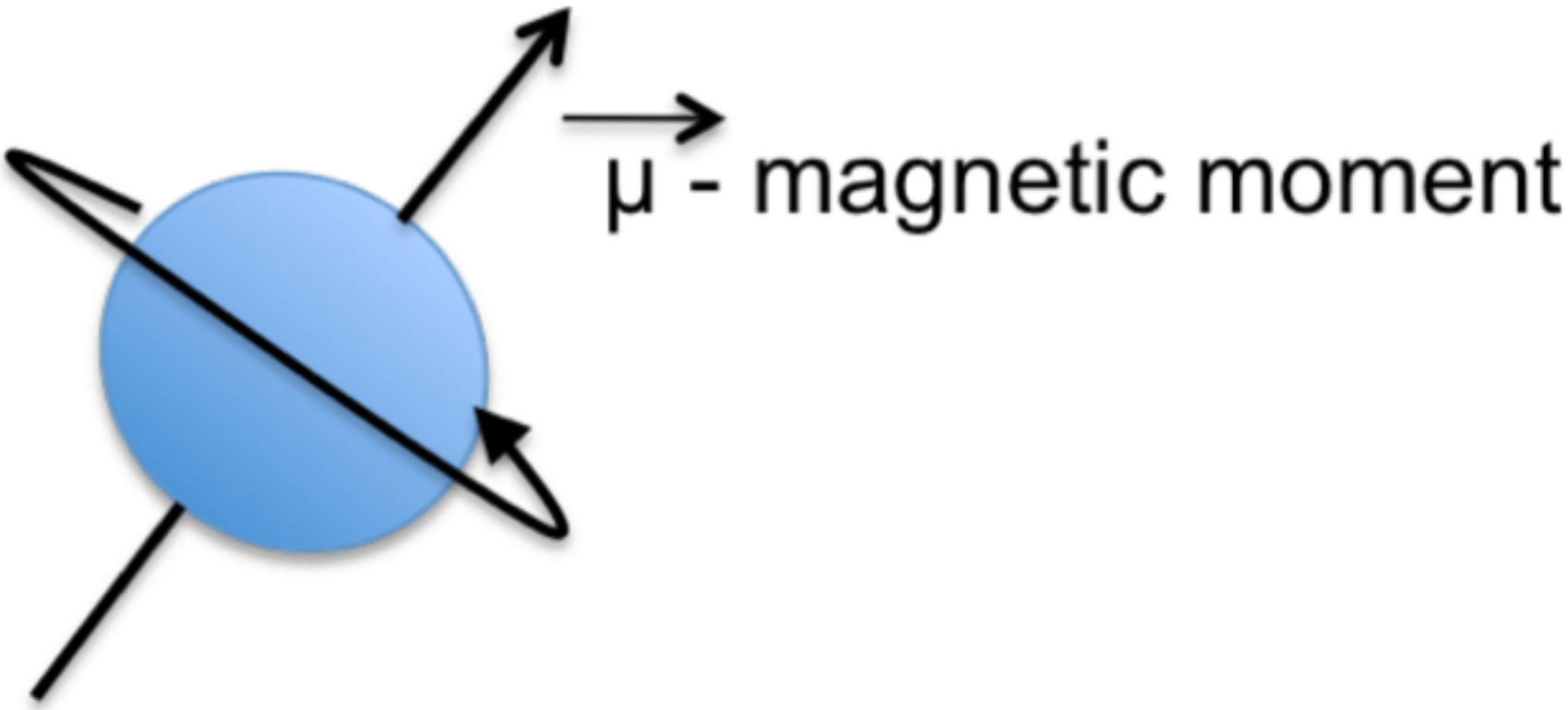
Magnetic field and heavy quark spin polarization

[S. Dey and AJ, PLB 873 (2026) 140202]

Heavy quarks in relativistic heavy-ion collisions

- Heavy quarks (charm and bottom) has long been recognized as an excellent probe of transport properties of QCD medium. [D. Banerjee, S. Datta, R. Gavai, and P. Majumdar, PRD 85 (2012) 014510; S. K. Das, S. Plumari, S. Chatterjee, et. al. PLB 768 (2017) 260-264; $\cdots$]
- Heavy quarks are primarily generated in the initial hard scatterings of partons.
- Clean probe of the early-stage properties of heavy-ion collisions.
- Strong transient magnetic fields produced which are significant only during the early stages of the collision.
- Polarized production of heavy quarks in strong field environment.
- Heavy quark polarization: signals of initial magnetic field.

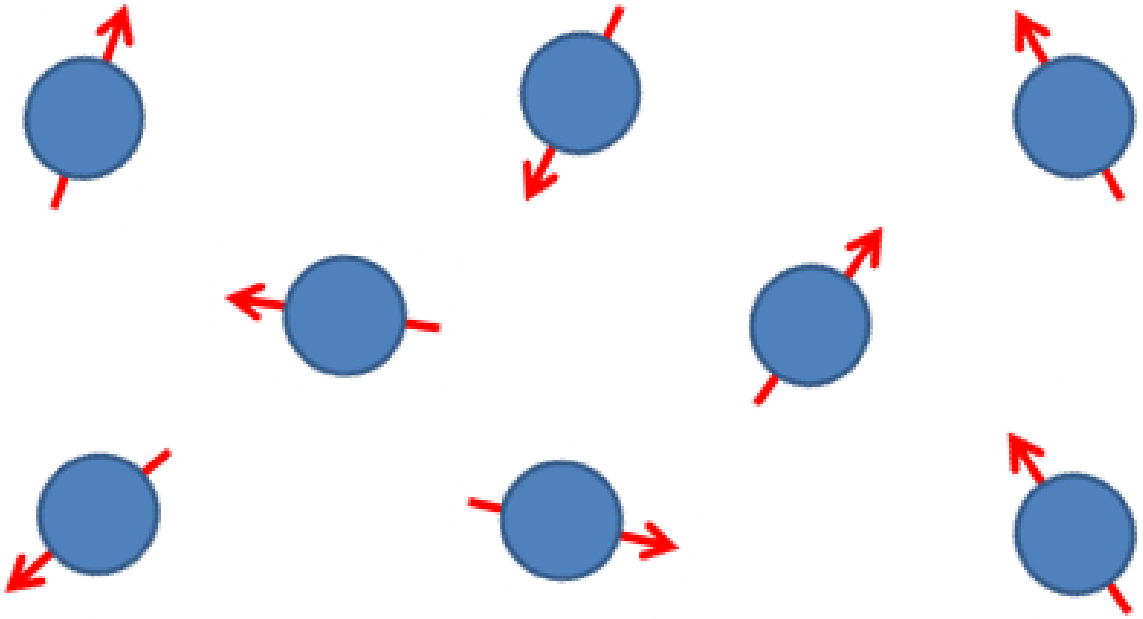
Heavy quarks: charged, spin-1/2 particles



Interaction with magnetic field: $\mathcal{H} = -\vec{\mu} \cdot \vec{B}$

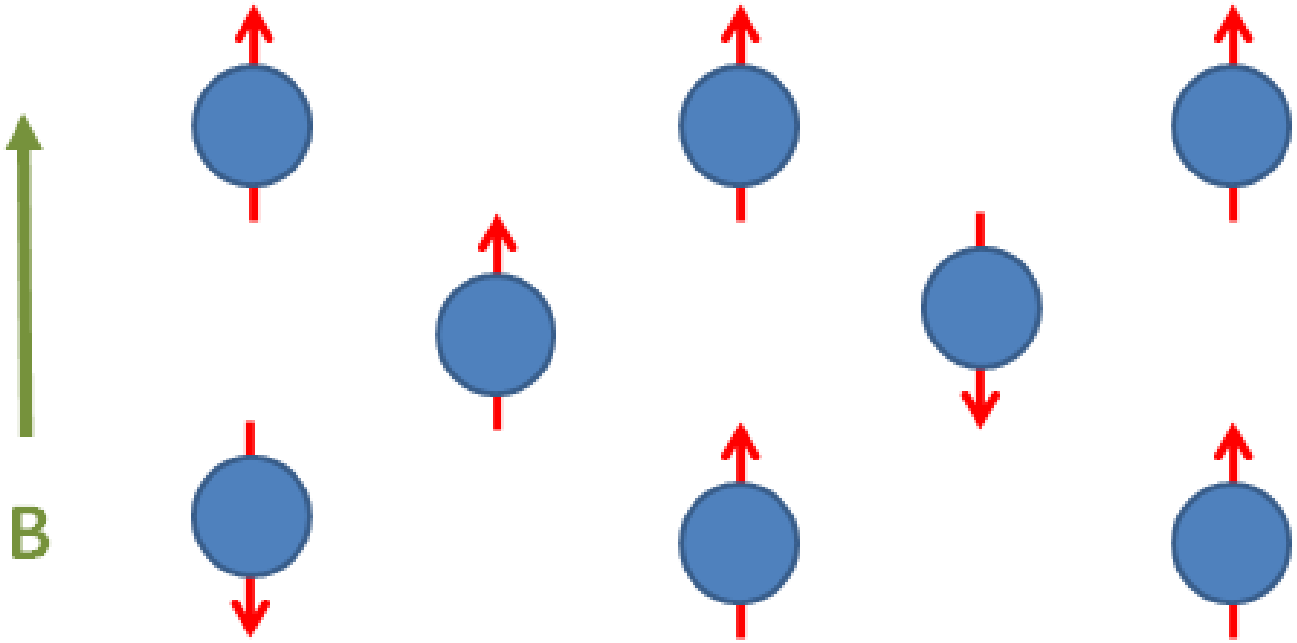
Magnetic moment and spin: $\vec{\mu} = \gamma \vec{s}$

No external magnetic field



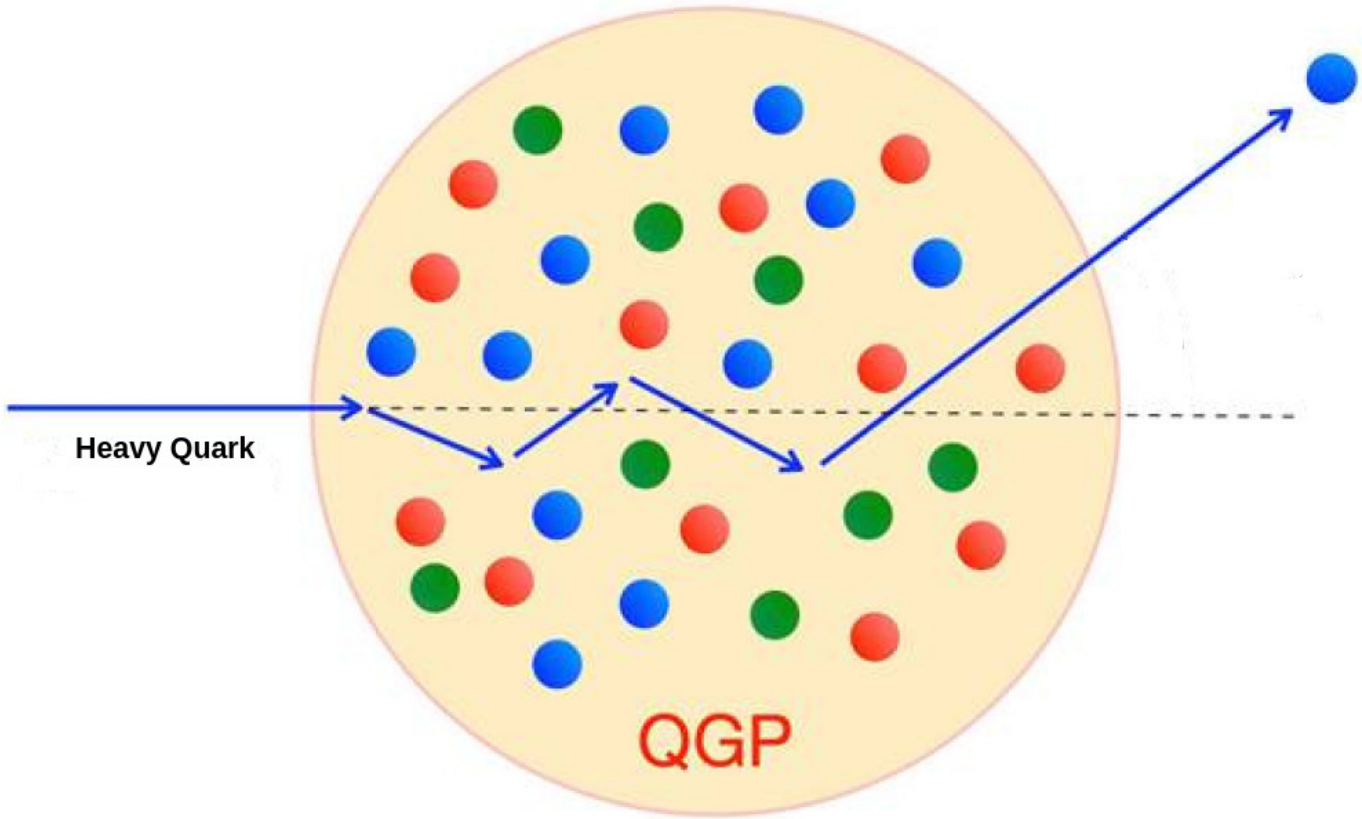
Un-aligned spins of heavy quarks.

Heavy quarks in magnetic field



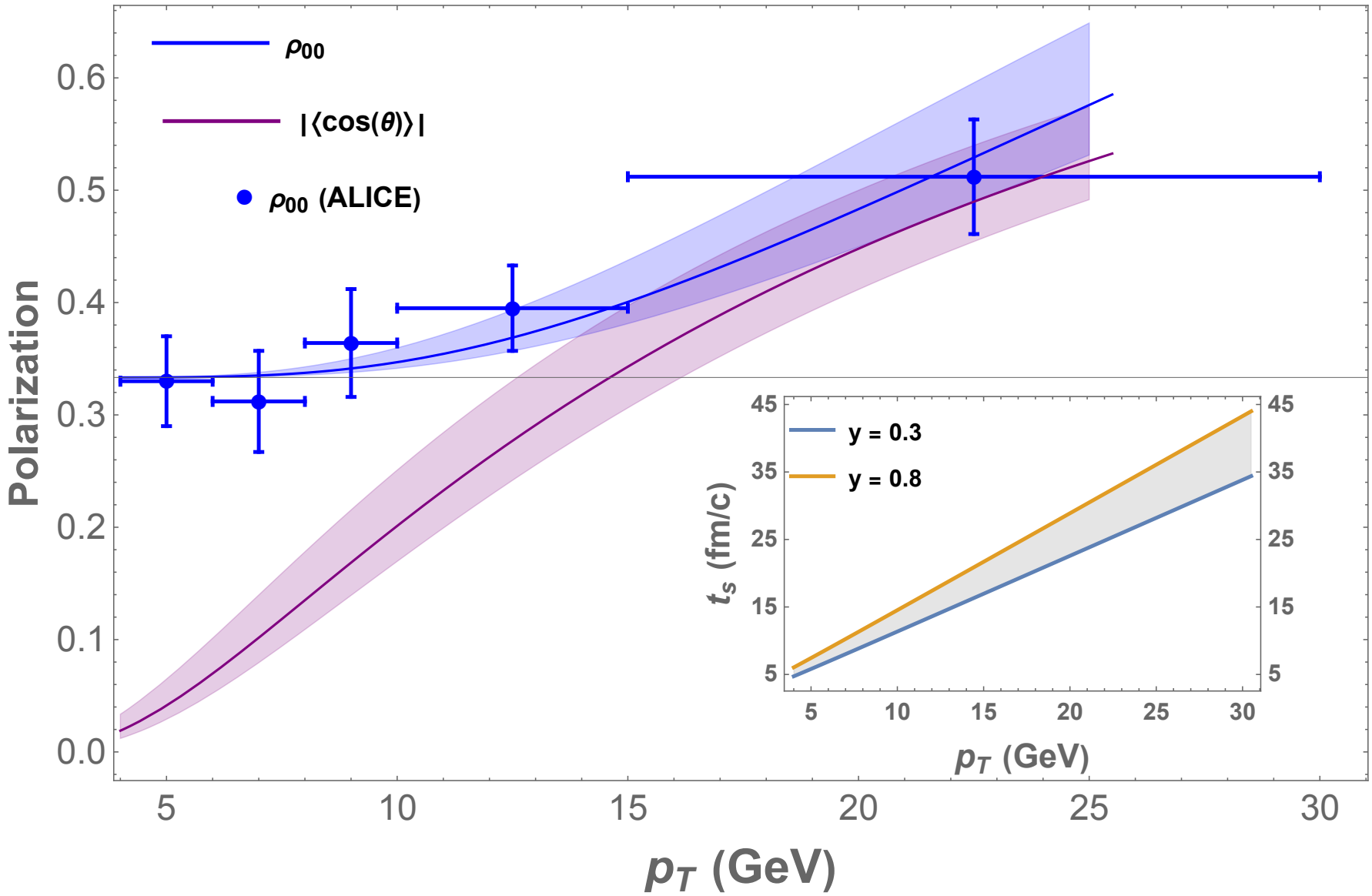
Aligned spins in presence of magnetic field due to polarized production of heavy quarks.

Heavy quarks in QGP



Polarized heavy quarks propagates through QGP.

Open heavy hadron polarization



Prediction: [S. Dey and AJ, 2502.20352], Observed: [ALICE, 2504.00714].

Magnetic field in HQ rest frame

- Lorentz transform initial electromagnetic field to HQ rest frame

$$\boldsymbol{B} = \gamma_v \left(\boldsymbol{B}_{\mathbf{Lab}} - \boldsymbol{E}_{\mathbf{Lab}} \times \boldsymbol{v}\right) + (1 - \gamma_v) \left(\frac{\boldsymbol{B}_{\mathbf{Lab}} \cdot \boldsymbol{v}}{|\boldsymbol{v}|^2}\right) \boldsymbol{v}.$$

- $\gamma_v \equiv E/m_Q$ – Lorentz gamma factor ; $\boldsymbol{v} = \boldsymbol{p}/E$ – velocity of HQ.
- $\boldsymbol{E}_{\mathbf{Lab}}$ and $\boldsymbol{B}_{\mathbf{Lab}}$: laboratory-frame electric and magnetic fields.
- For a given p_T, the magnetic field component along the y-direction in the heavy quark's rest frame increases with rapidity.
- Direction of the magnetic field in the heavy-quark rest frame generally differs from that in the laboratory frame.
- Ensemble average of magnetic field experienced by the HQ:

$$\langle \mathbf{B} \rangle = \int \frac{d^2\Omega_v}{4\pi} f_Q(\theta_v, \phi_v) \left[\gamma_v (\boldsymbol{B}_{\mathbf{Lab}} - \boldsymbol{E}_{\mathbf{Lab}} \times \boldsymbol{v}) + (1 - \gamma_v) \left(\frac{\boldsymbol{B}_{\mathbf{Lab}} \cdot \boldsymbol{v}}{|\boldsymbol{v}|^2}\right) \boldsymbol{v}\right].$$

- Assuming isotropic velocity distribution, $\langle \mathbf{B} \rangle = \frac{1}{3}(1 + 2\gamma_v)\boldsymbol{B}_{\mathbf{Lab}}$.

Rotational Brownian motion

- Random rotational motion (orientation and angular velocity) of a microscopic particle due to thermal fluctuations caused by collisions with surrounding medium particles.
- Rotational Brownian motion problem: first considered by Debye.
- For classical spins, the Langevin equation corresponds to the stochastic Landau–Lifshitz-Gilbert equation

$$\frac{d\mathbf{s}}{d\tau} = \mathbf{s} \times \left[\tilde{\mathbf{B}} + \boldsymbol{\xi}(\tau)\right] - \lambda\, \mathbf{s} \times \left(\mathbf{s} \times \tilde{\mathbf{B}}\right)$$

- Here $\tilde{\mathbf{B}} \equiv \gamma \mathbf{B} = -\frac{\partial \mathcal{H}}{\partial \mathbf{s}}$ and γ is the gyromagnetic ratio $\boldsymbol{\mu} = \gamma\, \mathbf{s}$.
- $\mathbf{s} \times \tilde{\mathbf{B}}$ represents precession dynamics of the system.
- $\boldsymbol{\xi}(\tau)$ is the random torque on the particle by the medium.
- λ is the damping coefficient.

Langevin and Fokker-Planck equations

- Generalized multivariate Langevin equation

$$\frac{dy_i}{d\tau} = A_i(y,\tau) + C_{ik}(y,\tau)\,\xi_k(\tau).$$

- Reduces to Landau–Lifshitz-Gilbert equation with $s_i = y_i$ and

$$A_i = \epsilon_{ijk} s_j \tilde{B}_k + \lambda\,(s^2\delta_{ik} - s_i s_k)\tilde{B}_k, \qquad C_{ik} = \epsilon_{ijk} s_j.$$

- Assume statistical properties of white noise for the random torque

$$\langle \xi_k(\tau) \rangle = 0, \qquad \langle \xi_k(\tau_1)\,\xi_l(\tau_2) \rangle = 2\,D\,\delta_{kl}\,\delta(\tau_1 - \tau_2).$$

- Using the Kramers–Moyal expansion, one arrives at the Fokker–Planck equation

$$\frac{\partial \mathcal{P}}{\partial \tau} = -\frac{\partial}{\partial y_i}\left[A_i(y,\tau) + D C_{jk}(y,\tau)\frac{\partial C_{ik}(y,\tau)}{\partial y_j}\right]\mathcal{P} + D\frac{\partial^2}{\partial y_i \partial y_j}[C_{ik}(y,\tau)C_{jk}(y,\tau)\mathcal{P}]$$

Heavy quark polarization

- Assume all heavy quarks are initially spin polarized along $\theta = \theta_0$ direction, i.e., for the initial cond. $\mathcal{P}(\theta, 0) = \frac{1}{2\pi}\delta(\cos\theta - \cos\theta_0)$.
- With $B(\tau) = B_0\, e^{-\tau/\tau_B}$ and $\tau_s = \frac{1}{D}$, vector polarization (baryons):

$$\langle\cos\theta\rangle = \cos\theta_0 e^{-\frac{2\tau}{\tau_s}} - \frac{2\alpha\tau_B}{3} e^{-\frac{2\tau}{\tau_s}} \left[\frac{1-\exp\left[-\frac{(\tau_s-2\tau_B)\tau}{\tau_s\tau_B}\right]}{\tau_s - 2\tau_B} - \frac{1-\exp\left[-\frac{(4\tau_B+\tau_s)\tau}{\tau_s\tau_B}\right]}{4\tau_B + \tau_s} \right]$$

- Tensor polarization (vector mesons) is

$$\langle\cos^2\theta\rangle = \frac{1}{3} + \frac{2}{3} e^{-\frac{6\tau}{\tau_s}} + \frac{2\alpha\tau_B}{5} e^{-\frac{6\tau}{\tau_s}} \left[\frac{1}{(\tau_s - 4\tau_B)} \left(1 - \exp\left[-\frac{(\tau_s - 4\tau_B)\tau}{\tau_s\tau_B} \right] \right) \right.$$
$$\left. - \frac{1}{(\tau_s + 6\tau_B)} \left(1 - \exp\left[-\frac{(\tau_s + 6\tau_B)\tau}{\tau_s\tau_B} \right] \right) \right] \cos\theta_0$$

- So far classical treatment. Similar results at leading order by considering transition between two spin states [arXiv:2605.06461].

Heavy baryon and meson polarization

- For baryons, the angular distribution of one of the decay daughter

$$\frac{dN}{d\cos\theta^*} = \frac{1}{2}\left(1 + \alpha_B |\vec{P}_B| \cos\theta^*\right)$$

- α_B is decay parameter. Using this distribution, one gets

$$\langle \cos\theta^* \rangle = \int \cos\theta^* \frac{dN}{d\cos\theta^*} d\cos\theta^* \implies |\vec{P}_B| = \frac{3}{\alpha_B} \langle \cos\theta^* \rangle$$

- Similarly, for mesons, the angular distribution is

$$\frac{dN}{d\cos\theta^*} = \frac{3}{4}\left[1 - \rho_{00} + \left(3\rho_{00} - 1\right)\cos^2\theta^*\right]$$

- ρ_{00} is element of spin density matrix; unpolarized $\implies$ $\rho_{00} = 1/3$.
- Using this distribution, one gets

$$\langle \cos^2\theta^* \rangle = \int \cos^2\theta^* \frac{dN}{d\cos\theta^*} d\cos\theta^* \implies \Delta\rho_{00} = \frac{5}{2}\left[\langle \cos^2\theta^* \rangle - \frac{1}{3}\right]$$

- Here $\Delta\rho_{00} \equiv \rho_{00} - 1/3$

Ensemble average of angular anisotropy

- Consider leading terms in the polarization

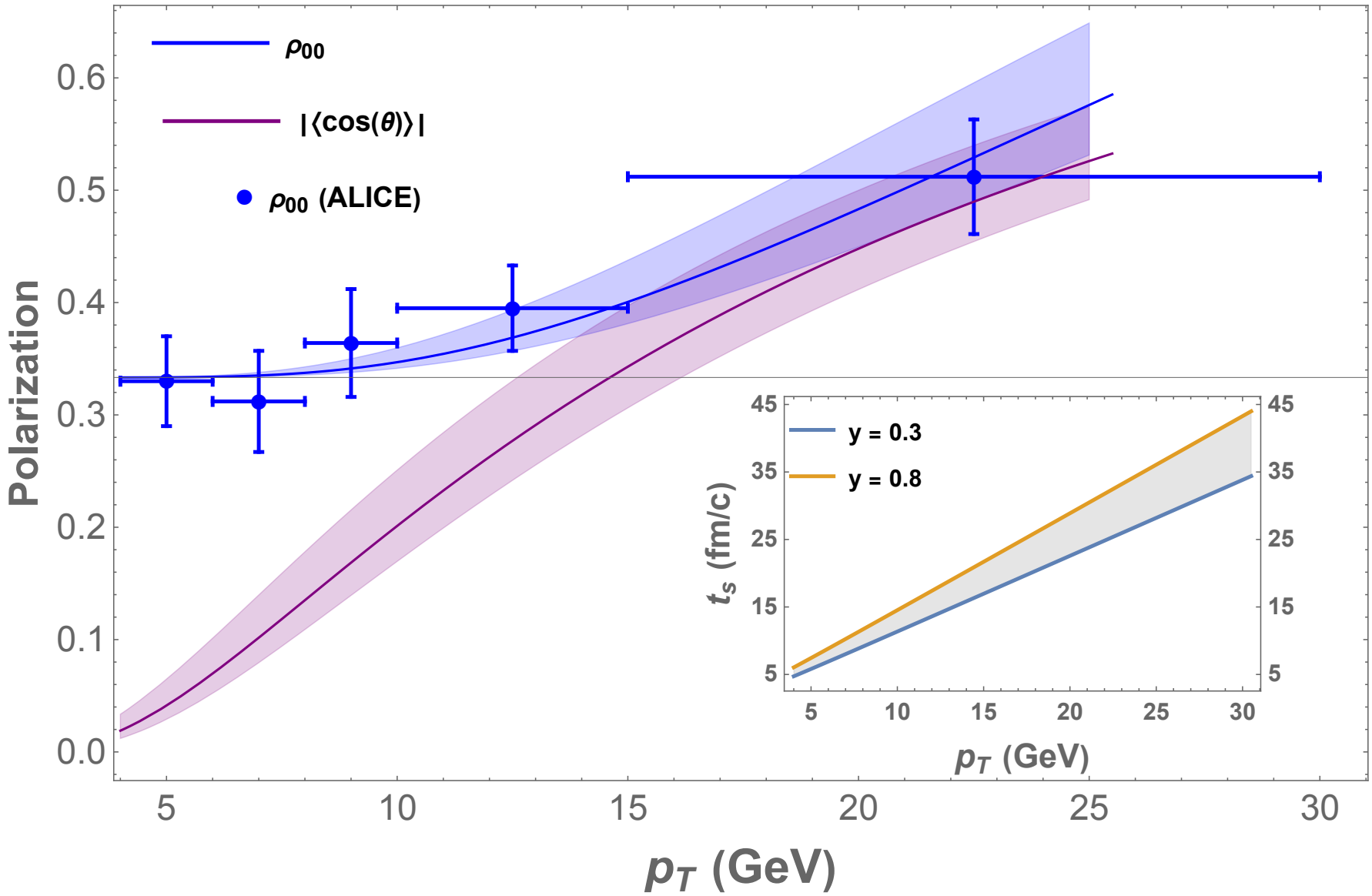
$$\langle \cos\theta \rangle = \cos\theta_0\, e^{-2\tau/\tau_s}, \qquad \langle \cos^2\theta \rangle = \frac{1}{3} + \frac{2}{3}\, e^{-6\tau/\tau_s}.$$

- One can show: $\dfrac{\langle \cos\theta^* \rangle}{\langle \cos\theta \rangle} = C_B$, $\dfrac{\langle \cos^2\theta^* \rangle - 1/3}{\langle \cos^2\theta \rangle - 1/3} = C_M$ [arXiv:2605.12554].

$$\implies |\vec{P}_B| = \frac{3\cos\theta_0}{\alpha_B}\, C_B\, e^{-2\tau/\tau_s}, \quad \Delta\rho_{00} = \frac{5}{3}\, C_M\, e^{-6\tau/\tau_s}$$

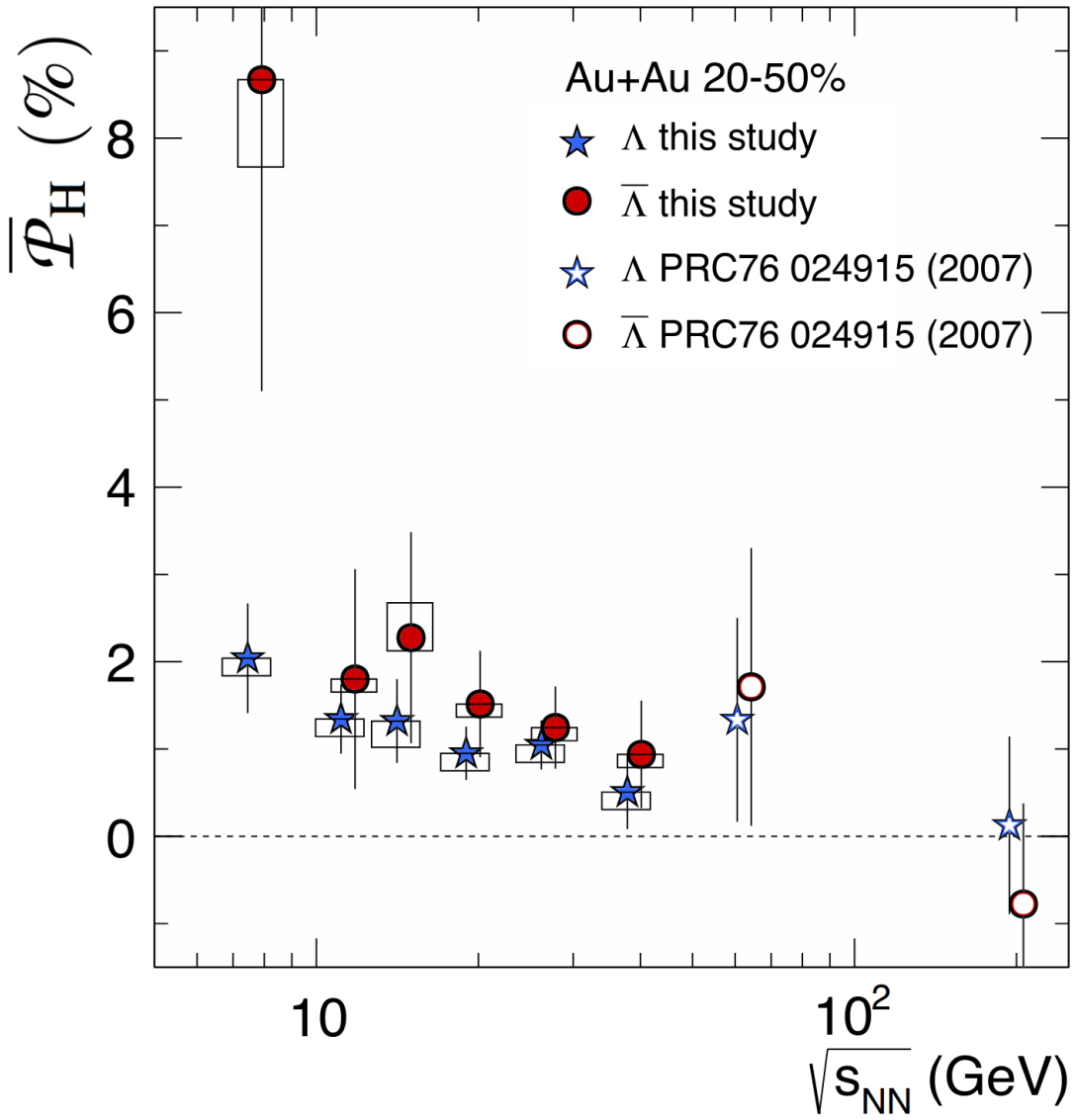
- Here τ_s: spin relaxation time. Treated as a fit parameter.
- Initially $\theta_0 = 0, \pi$ depending on charge of the quark.
- Baryon, anti-baryon: opposite sign; meson, anti-meson: same sign
- Quarkonium pol. small: heavy quark and anti-quark opp. pol.
- Static uniform fireball of constant temperature, $\tau = \dfrac{(R/\gamma_v)}{v_T}$.
- In the mid-rapidity region, $v_T = \frac{p_T}{E}$ and $\gamma_v = \frac{E}{m_Q}$.

Open heavy hadron polarization



Heavy quarks polarized along initial magnetic field direction.

Light quark polarization due to angular momentum

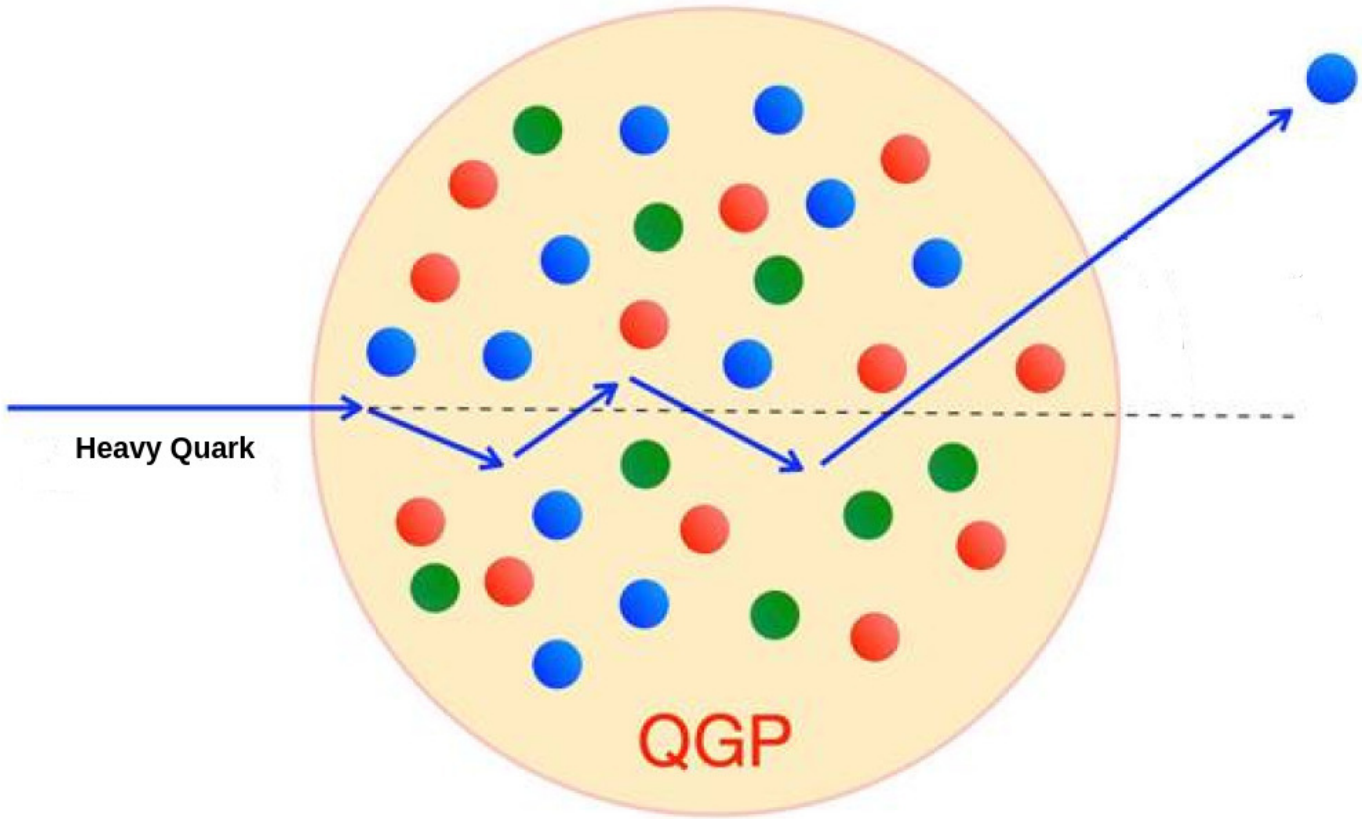


[STAR collaboration, Nature 548 (2017) 62-65]

Polarization harmonics for fireball geometry

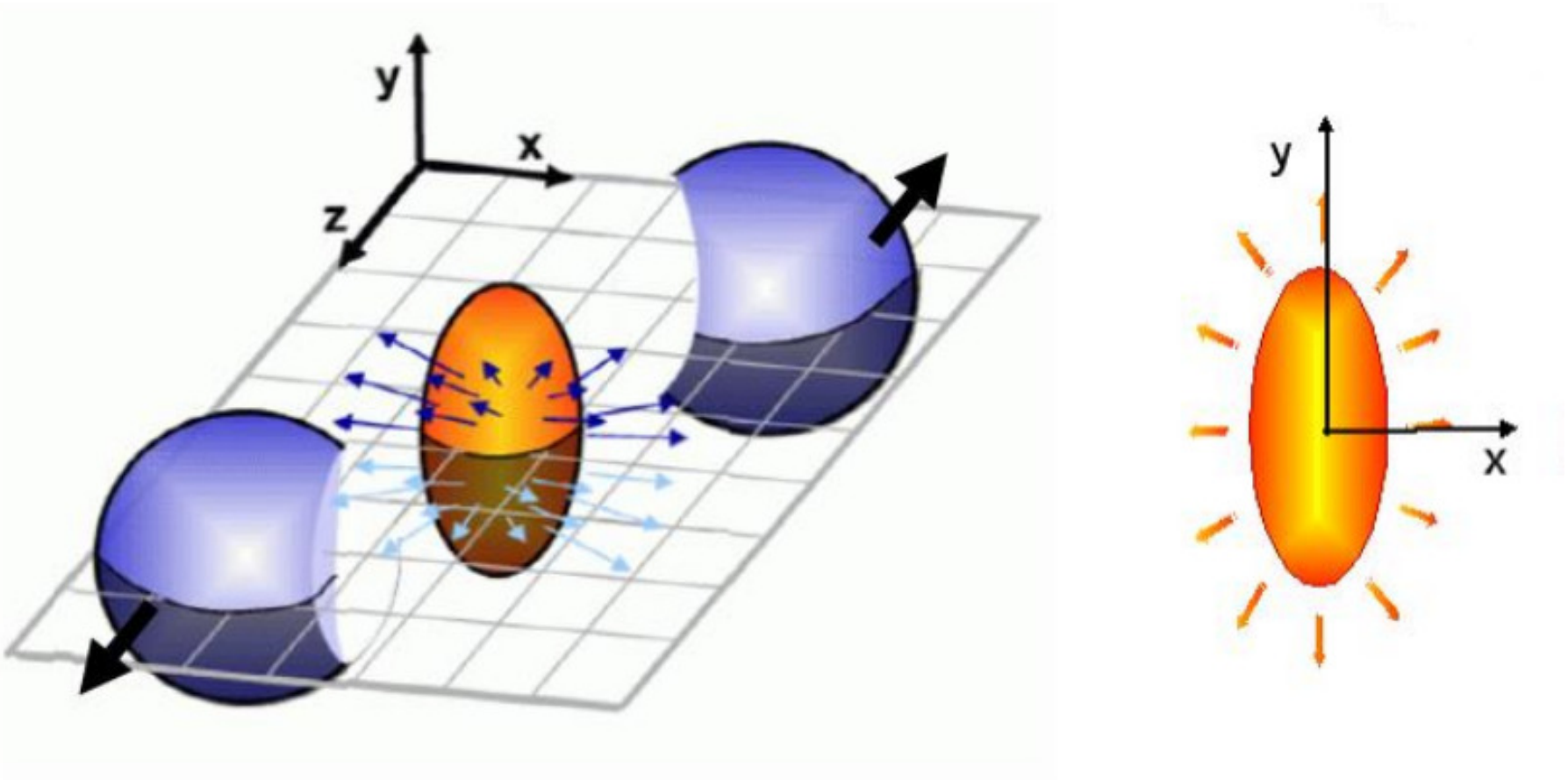
[AJ, arXiv:2601.22882]

Heavy quarks in QGP



Polarized heavy quarks propagates through QGP.

Heavy quarks in QGP



Propagation through anisotropic QGP.

Fireball geometry and path length

- Average path length can be written as a Fourier series,

$$\langle L(\phi)\rangle = L_0\left[1+\sum_{n=2}^{\infty} 2\,\ell_n \cos n(\phi-\Psi_n)\right]$$

- Transverse geometry whose boundary is parametrized as

$$R(\varphi) = R_0\left[1+\sum_{n=2}^{\infty} a_n \cos n(\varphi-\Phi_n)\right], \quad |a_n| \ll 1$$

- For convex geometries with weak anisotropies, one has

$$\frac{\delta\langle L(\phi)\rangle}{L_0} \approx \frac{\delta R(\phi)}{R_0} \implies 2\,\ell_n = a_n$$

- Initial state in HICs are characterized by

$$\epsilon_n\, e^{in\Phi_n} \equiv -\frac{\langle r^n\, e^{in\varphi}\rangle}{\langle r^n\rangle}, \qquad n \geq 2$$

- For weakly deformed & smooth transverse profile, $\ell_n = -\dfrac{\epsilon_n}{2\,(n+2)}$

Polarization harmonics

- Spin polarization/alignment can be written in the generic form as

$$P(\boldsymbol{p}) = A\, e^{-\alpha\,\tau/\tau_s}, \quad \alpha = 2,\, 6 \text{ for baryons, mesons}$$

- Duration for which the heavy quark undergoes Brownian motion:

$$\tau = \frac{[\langle L(\phi)\rangle\, m_Q]}{|\boldsymbol{p}|}, \qquad |\boldsymbol{p}| = \sqrt{p_T^2 \cosh^2 y + m_Q^2 \sinh^2 y}$$

- Substituting in $P(\boldsymbol{p}) = A\, e^{-\alpha\,\tau/\tau_s}$, one obtains

$$P(p_T,\, \phi,\, y) = A \exp\left(-\frac{\alpha\, m_Q\, L_0}{|\boldsymbol{p}|\tau_s}\right)\left[1 + \sum_{n=2}^{\infty} 2\, p_n \cos n\,(\phi - \Psi_n)\right]$$

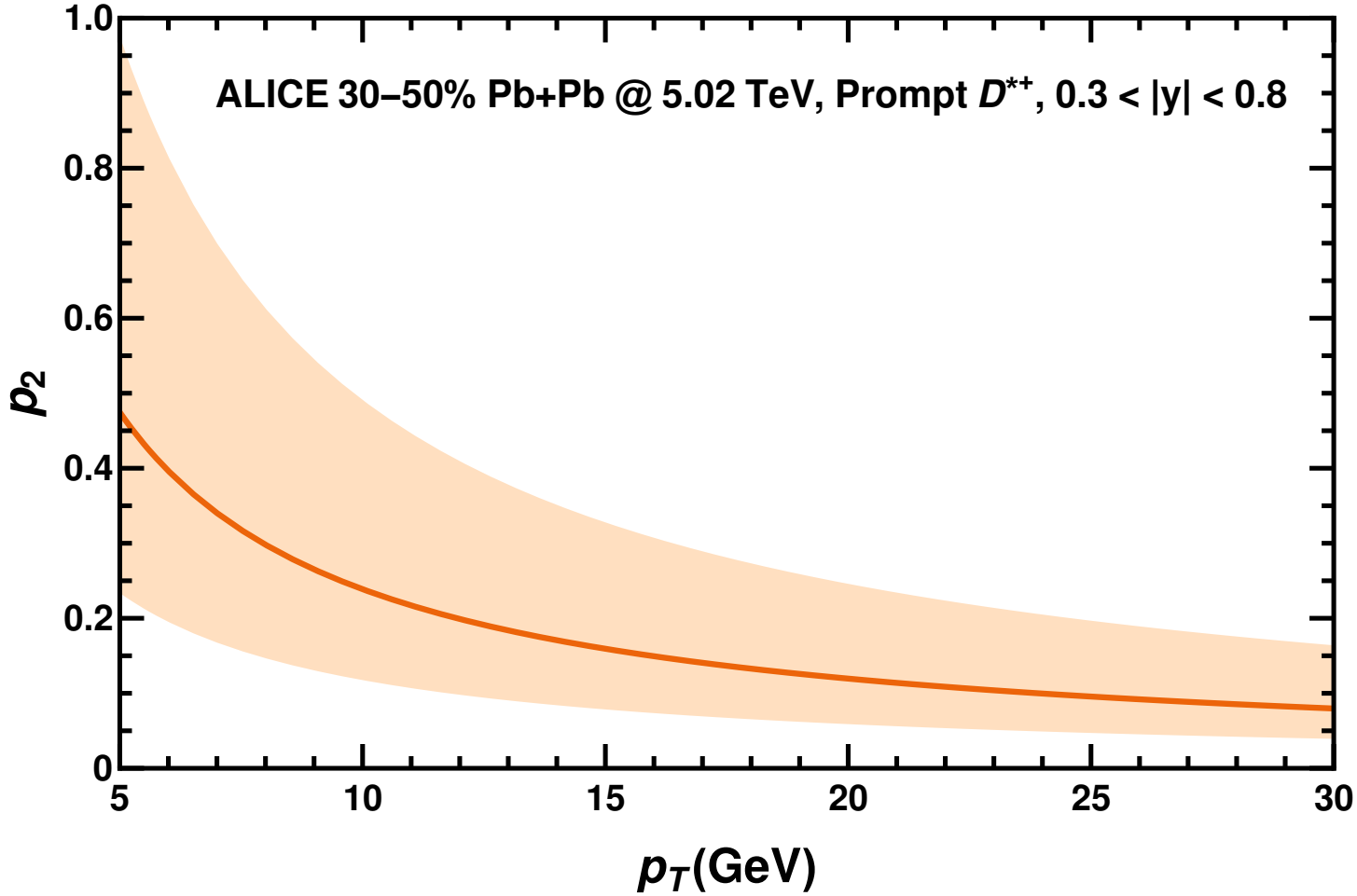
- The polarization harmonics are

$$p_n(p_T, y) = \frac{\alpha\, m_Q\, L_0\, \epsilon_n}{2\,(n+2)\,|\boldsymbol{p}|\,\tau_s}$$

- Differential polarization:

$$\frac{dP}{d^2p_T\, dy} = \left.\frac{dN}{d^2p_T\, dy}\right|_{\text{prompt}} \times P(p_T,\, \phi,\, y)$$

Elliptic polarization harmonic



$L_0 = 10$ fm, $\tau_s = 1.31$ fm, $\alpha = 6$ for mesons, $m_Q = 1.27$ GeV, $y = 0.55$ for rapidity, $\epsilon_2 = 0.38$ from M-C Glauber. The shaded band is obtained by varying L_0 and ϵ_2 by $\pm 20\%$ and τ_s by $\pm 30\%$.

Numerical estimates

- Fixed-Order + Next-to-Leading Logarithm parametrization [Liu, Plumari, Das, Greco, Ruggieri, PRC 102 (2020) 044902]:

$$\left.\frac{dN}{d^2p_T\,dy}\right|_{\rm prompt} = \frac{a_0}{m_Q^2\left[1+a_3\left(\frac{p_T}{m_Q}\right)^{a_1}\right]^{a_2}}$$

- The parameters are: $a_0 = 32.71558$, $a_1 = 1.95061$, $a_2 = 3.13695$, and $a_3 = 0.11981$.
- Use the fit parameters from earlier work, $L_0 = 10$ fm and $\tau_s = 1.31$ fm, $\alpha = 6$ for mesons, $\epsilon_2 = 0.38$ from Monte Carlo Glauber, charm-quark mass $m_Q = 1.27$ GeV, and $y = 0.55$.
- p_T averaged elliptic polarization harmonic:

$$\langle p_2\rangle = \frac{\int p_T\,dp_T\,d\phi\,\cos\left[2(\phi-\Psi_2)\right]\frac{dP}{d^2p_T\,dy}}{\int p_T\,dp_T\,d\phi\,\frac{dP}{d^2p_T\,dy}}$$

- The value is significant: $\langle p_2\rangle \simeq 0.17$. Need for measurement!

Quantum spin dynamics of heavy quarks

[S. Jaiswal, S. Dey and AJ, arXiv:2605.06461]

Quantum spin dynamics

- The spin density matrix of heavy quarks:

$$\rho(\tau, \mathbf{x}, \mathbf{p}) = \frac{1}{2}\left[\mathbf{1} + \boldsymbol{\mathcal{P}}(\tau, \mathbf{x}, \mathbf{p}) \cdot \boldsymbol{\sigma}\right]$$

- Magnetic field as the source of the initial spin polarization.
- Choose the quantization axis along the direction of the initial magnetic field and diagonalize the density matrix in this basis:

$$\rho(\tau) = \begin{pmatrix} P_\uparrow(\tau) & 0 \\ 0 & P_\downarrow(\tau) \end{pmatrix}, \quad P_\uparrow(\tau) = \frac{1 + \mathcal{P}(\tau)}{2}, \quad P_\downarrow(\tau) = \frac{1 - \mathcal{P}(\tau)}{2}$$

- Normalization: $P_\uparrow + P_\downarrow = 1$, define polarization: $\mathcal{P} = P_\uparrow - P_\downarrow$.
- Medium interactions can induce spin flip transitions between two states. Transition rate equations:

$$\frac{dP_\uparrow}{d\tau} = -\Gamma_{\uparrow\to\downarrow} P_\uparrow + \Gamma_{\downarrow\to\uparrow} P_\downarrow \quad , \qquad \frac{dP_\downarrow}{d\tau} = -\Gamma_{\downarrow\to\uparrow} P_\downarrow + \Gamma_{\uparrow\to\downarrow} P_\uparrow$$

- Evolution equation for the spin polarization:

$$\frac{d\mathcal{P}}{d\tau} = -\left(\Gamma_{\uparrow\to\downarrow} + \Gamma_{\downarrow\to\uparrow}\right)\mathcal{P} + \left(\Gamma_{\downarrow\to\uparrow} - \Gamma_{\uparrow\to\downarrow}\right)$$

Spin polarization evolution equation

- Spin-relaxation time and eq. polarization and evolution equation:

$$\tau_s \equiv \frac{1}{\Gamma_{\uparrow\to\downarrow} + \Gamma_{\downarrow\to\uparrow}}\,, \qquad \mathcal{P}_{\rm eq} \equiv \frac{\Gamma_{\downarrow\to\uparrow} - \Gamma_{\uparrow\to\downarrow}}{\Gamma_{\uparrow\to\downarrow} + \Gamma_{\downarrow\to\uparrow}}\,, \qquad \frac{d\mathcal{P}}{d\tau} = -\frac{\mathcal{P} - \mathcal{P}_{\rm eq}}{\tau_s}$$

- For constant transition rates, the solution is:

$$\mathcal{P}(\tau) = \mathcal{P}_{\rm eq} + (\mathcal{P}_0 - \mathcal{P}_{\rm eq})\, e^{-(\tau-\tau_0)/\tau_s}$$

- If two rates are equal, i.e., $\Gamma_{\uparrow\to\downarrow} = \Gamma_{\downarrow\to\uparrow} \equiv \Gamma_s$, then $\mathcal{P}_{\rm eq} = 0$ and

$$\mathcal{P}(\tau) = \mathcal{P}_0\, e^{-(\tau-\tau_0)/\tau_s}$$

- Open heavy mesons formed via coalescence/fragmentation:

$$\rho_{00}^{\rm coal} = \frac{1 - \mathcal{P}_Q \mathcal{P}_q}{3 + \mathcal{P}_Q \mathcal{P}_q}\,, \qquad \rho_{00}^{\rm frag} = \frac{1 + \beta \mathcal{P}_Q^2}{3 - \beta \mathcal{P}_Q^2}$$

[Z.-T. Liang, X.-N. Wang, Phys. Lett. B 629 (2005) 20-26]

- For very high energy, $\sqrt{s_{\rm NN}} = 5.02$ TeV, $\mathcal{P}_q \simeq 0$. Frag. dominant.

Spin alignment and polarization harmonics

- For vector mesons, spin-alignment signal is $\Delta\rho_{00} = \rho_{00}^{\rm frag} - 1/3$

$$\Delta\rho_{00}(\phi, p_T, y) = \Delta\rho_{00}^{(0)}(p_T, y)\left[1 + 2\sum_{n=2}^{\infty} p_n^{D^{*+}}(p_T, y)\cos n(\phi - \Psi_n)\right]$$

- Here,

$$\Delta\rho_{00}^{(0)}(p_T, y) = \frac{4X(p_T, y)}{3[3 - X(p_T, y)]}, \quad X(p_T, y) \equiv A\exp\left[-2\kappa\frac{m_c}{|\mathbf{p}|}\right]$$

- Polarization harmonics coefficient:

$$p_n^{D^{*+}}(p_T, y) = \frac{6}{3 - X(p_T, y)}\frac{\kappa}{2}\frac{m_c}{|\mathbf{p}|}\frac{\epsilon_n}{n+2}$$

- Qulitatively similar features as the classical stochastic treatment.
- Open heavy-flavor spin observables are clean probes of early-time dynamics: initial magnetic field and geometric anisotropies.
- Dedicated measurements of open-charm hadrons polarization and polarization harmonics are needed.

Application of magnetic field in HIC

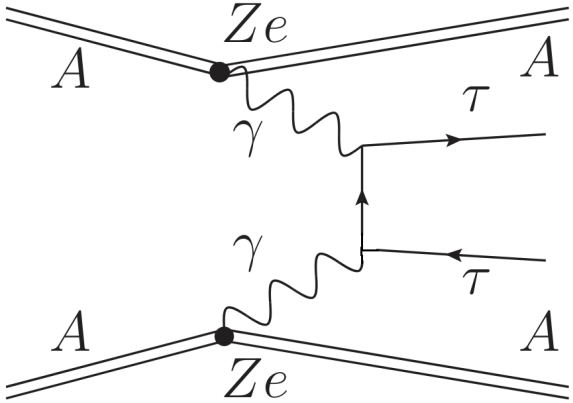
[AJ, Phys.Lett.B 876 (2026) 140383]

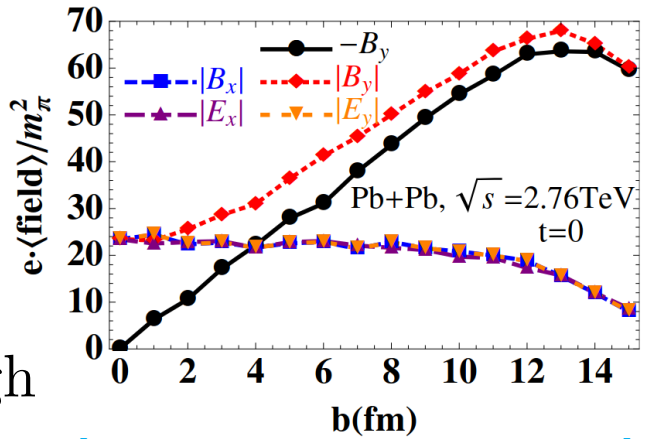
Tau leptons in heavy ion collisions

- Observation of CP violation in any decay of leptons: indication of physics beyond the Standard Model.
- Hint to the origin of matter–antimatter asymmetry in universe.
- τ-lepton: particularly sensitive probe for BSM physics.
- Polarized τ decay from polarized beam in e^+e^- colliders proposed for capturing CP violation signals [Y. S. Tsai, PRD 1994; PLB 1996].
- Heaviest lepton, mass: 1.777 GeV, lifetime: 2.9×10^{-13} s.
- Produced early in heavy ion collisions due to large mass.
- Should witness the strong magnetic field; similar to heavy quarks.
- Decays outside fireball but before reaching the detectors.
- Neutrinos in final state; too much background in HIC.

Ultraperipheral heavy ion collisions

- Ultraperipheral heavy-ion collisions (UPCs): $b > 2R$.
- Clean environment for investigating photon-induced processes.
- In UPCs, $\tau^+\tau^-$ pairs are produced exclusively via $\gamma\gamma$ fusion [ATLAS, CMS].
- Energy of τ leptons could be obtained using zero-degree calorimeter data.
- Use collinear approximation.
- In UPCs, the spectator nuclei generate strong magnetic fields.
- Spin polarization of τ-lepton pairs through alignment of their magnetic moments.





[Deng & Huang, 1201.5108]

- Anisotropic emission patterns of the decay products.
- Polarization asymmetry between $\tau^{\mp}$: probe for CP violation.

Magnetic field and τ polarization

- Lorentz-transformed magnetic field in the τ rest frame

$$\boldsymbol{B} = \gamma\left(\boldsymbol{B}_{\mathbf{Lab}} - \boldsymbol{E}_{\mathbf{Lab}} \times \boldsymbol{v}\right) + (1-\gamma)\left(\frac{\boldsymbol{B}_{\mathbf{Lab}} \cdot \boldsymbol{v}}{\beta^2}\right)\boldsymbol{v}$$

- τ polarization vector aligned along the magnetic field

$$\boldsymbol{P}_\tau = P_\tau\, \hat{\boldsymbol{B}}$$

- We adopt *helicity frame*: the spin quantization axis along τ momentum direction in its rest frame.
- Relevant component of the polarization vector is

$$P_\tau^{\mathrm{hel}} \equiv \boldsymbol{P}_\tau \cdot \hat{\boldsymbol{v}} = P_\tau \frac{|\boldsymbol{B}_{\mathbf{Lab}}|}{|\boldsymbol{B}|}\cos\psi$$

- Assuming electric field $\boldsymbol{E}_{\mathbf{Lab}}$ produced in UPCs is small

$$P_\tau^{\mathrm{hel}} = P_\tau \frac{\cos\psi}{\sqrt{\cos^2\psi + \gamma^2 \sin^2\psi}}$$

- For isotropic τ momenta, $P_\tau^{\mathrm{hel}} = 0$; consider "half"-ensemble.

Pion decay mode: $\tau \to \pi\, \nu_\tau$

- Normalized angular distribution for decay in τ rest frame is

$$\frac{1}{\Gamma_\tau}\frac{\mathrm{d}\Gamma_\pi}{\mathrm{d}\cos\theta_\pi} = \frac{1}{2}B_\pi\left(1 + P_\tau^{\mathrm{hel}}\cos\theta_\pi\right)$$

- Express the above equation in the form

$$\frac{1}{\Gamma_\tau}\frac{\mathrm{d}\Gamma_\pi}{\mathrm{d}\cos\theta_\pi}\left(\tau^\mp \to \pi^\mp\nu_\tau\right) = \frac{1}{2}B_\pi\left(1 + \alpha\, P_\tau^\mp\cos\theta_\pi\right)$$

- Here, $\alpha \equiv (|\boldsymbol{B}_{\mathbf{Lab}}|/|\boldsymbol{B}|)\cos\psi$ and $P_\tau^\mp$ is the polarization of $\tau^\mp$.
- In terms of pion energy fraction with collinear approximation,

$$\cos\theta_\pi = 2z_\pi - 1, \qquad \text{where } z_\pi \equiv E_\pi/E_\tau$$

- "half"-ensemble average over τ with complimentary ψ ranges

$$P_\tau^\mp = 3\,\frac{\langle 2z_\pi - 1\rangle_{\pi^\mp}}{B_\pi\,\langle\alpha\rangle_{\tau^\mp}}$$

- We propose the observable: $\Delta_\pi \equiv 1 - \left|\dfrac{P_\tau^-}{P_\tau^+}\right| = 1 - \left|\dfrac{\langle 2z_\pi - 1\rangle_{\pi^-}}{\langle 2z_\pi - 1\rangle_{\pi^+}}\right|$

UPCs as arena for BSM physics

- Novel application of electromagnetic fields generated in HICs.
- Polarized τ decay: new avenue to test fundamental symmetries.
- Leverages the unique strong-field environment of UPCs, not attainable in conventional collider experiments.
- Physics case for Zero Degree Calorimeter (ZDC) upgrades.
- Detailed analysis of higher-order QED and QCD corrections in $\gamma\gamma \to \tau^+\tau^-$ required.
- Feasibility of reconstructing τ polarization challenging due to limited production rates.
- More data for τ events in UPCs required to increase statistics for accurate measurements.
- Heavy ion collision experiments still have enormous potential for exciting physics.

Thank you!


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