Jet momentum broadening in real-time lattice simulations of the glasma

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Based on

[1] A. Ipp, D. I. Müller and D. Schuh, PRD 102 (2020) 074001, [arXiv:2001.10001]
[2] A. Ipp, D. I. Müller and D. Schuh, PLB 810 (2020) 135810, [arXiv:2009.14206]

Code: gitlab.com/openpixi/curraun

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Der Wissenschaftsfonds.

Jets in the glasma

- Jets: highly energetic, focused particle "sprays" that originate from hard scatterings of partons during the collision
- Jets interact with all stages of the medium, including the pre-equilibrium glasma phase

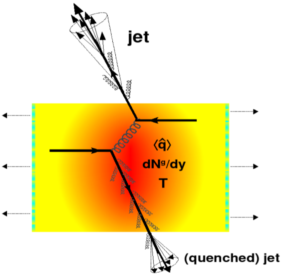


Fig. from D. d'Enterria, *Jet quenching*, Landolt-Bornstein (2010) [arXiv:0902.2011]

Jets in the glasma

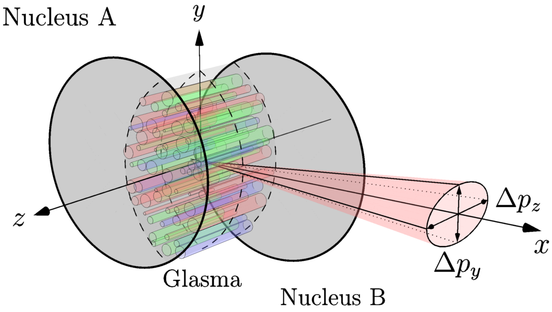


Fig. from A. Ipp, D. I. Müller, D. Schuh, PRD (2020) [arXiv:2001.10001]

Momentum broadening

- Model early-time jet as single parton (quark or gluon)
- No backreaction, color field of glasma as background
- Very high initial momentum, no deflection
- McLerran-Venugopalan model

Wong equations

$$\frac{dp_\mu}{dt} = g\, Q^a(t)\frac{dx^\nu}{dt} F^a_{\mu\nu}(x(t))$$
$$\frac{dQ^a}{dt} = g\frac{dx^\mu}{dt} f^{abc} A^b_\mu(x(t))Q^c(t)$$

Momentum broadening

- Integrate Wong's equations
- Average over color charges of the jet and background field

Main result for a quark moving along x-axis ($i = y, z$):

$$\left\langle p_i^2(\tau) \right\rangle_q = \frac{g^2}{N_c} \int_0^\tau d\tau' \int_0^\tau d\tau'' \left\langle \mathrm{Tr}\left[f^i(\tau') f^i(\tau'') \right] \right\rangle$$

$$f^y(\tau) = U(\tau) \left(E_y(\tau) - B_z(\tau) \right) U^\dagger(\tau)$$

$$f^z(\tau) = U(\tau) \left(E_z(\tau) + B_y(\tau) \right) U^\dagger(\tau)$$

Color rotation matrix in temporal gauge $A^\tau = 0$:

$$U(\tau) = \mathcal{P} \exp \left(-ig \int_0^\tau d\tau' A_x(\tau') \right)$$

Results

- Accumulated momenta at transition time $\tau_0 = 0.6\,\mathrm{fm}/c$

$$\langle p_\perp^2 \rangle \approx Q_s^2$$

- Infrared dependence m
- Gluonic jets

$$\frac{\langle p_\perp^2 \rangle_g}{\langle p_\perp^2 \rangle_q} = \frac{C_A}{C_F} = \frac{2N_c^2}{N_c^2 - 1}$$

- Broadening is anisotropic

$$\langle p_z^2 \rangle / \langle p_y^2 \rangle \approx 2$$

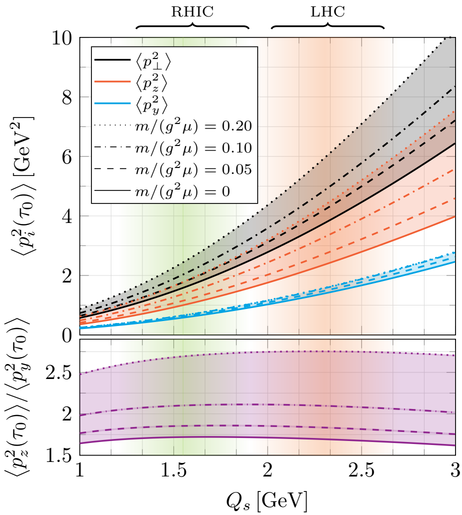
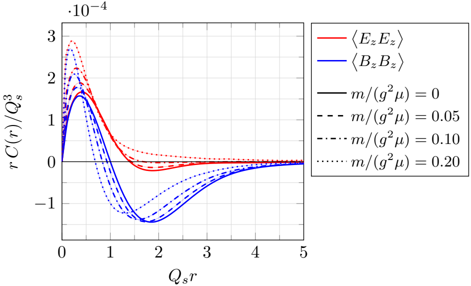


Fig. from A. Ipp, D. I. Müller, D. Schuh, PLB (2020) [arXiv:2009.14206]

Anisotropy

Weak field approximation:
Initial field correlations related to momentum broadening
(see talk by D. Schuh)

- Difference in electric and magnetic correlators
- Anti-correlated regions surrounding magnetic flux tubes
- Result: momentum broadening anisotropy



Initial correlation functions for E_z and B_z

Fig. from A. Ipp, D. I. Müller, D. Schuh, PRD (2020) [arXiv:2001.10001]

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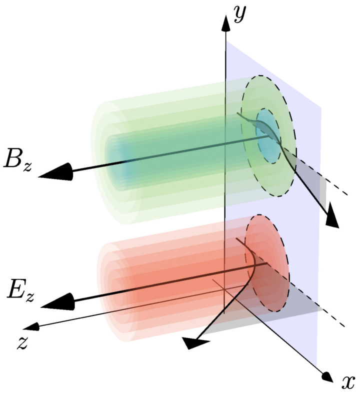

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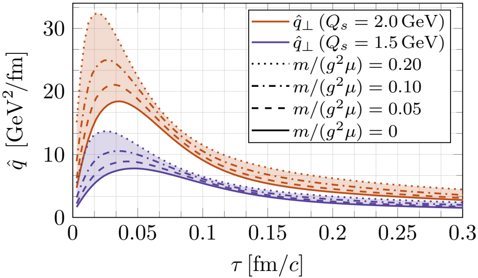
Jet broadening parameter $\hat{q}$

Jet broadening parameter $\hat{q}$: accumulated (squared) momentum per unit time

$$\hat{q}_\perp(\tau) = \frac{d\langle p_\perp^2 \rangle}{d\tau}$$



Most momentum is accumulated in the earliest stages of the glasma!

Fig. from A. Ipp, D. I. Müller, D. Schuh, PLB (2020) [arXiv:2009.14206]