Jet momentum broadening in heavy-ion collisions from effective kinetic theory

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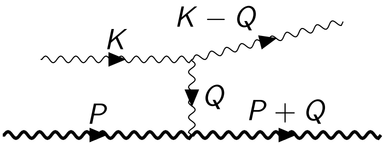
Jet quenching parameter $\hat{q}$

Transverse momentum broadening of jets is quantified by $\hat{q} = \hat{q}^{yy} + \hat{q}^{zz}$,

$$\hat{q}^{ij} = \int_{q_\perp < \Lambda_\perp} \mathrm{d}^2\vec{q}_\perp \, q_\perp^i q_\perp^j \frac{\mathrm{d}\Gamma_{\mathrm{el}}}{\mathrm{d}^2\vec{q}_\perp}. \tag{1}$$

The elastic collision rate of a high energetic jet particle (P) with plasma particles (K) is given by Γ_{el},
the transferred transverse momentum in such a single collision is $q_\perp$.



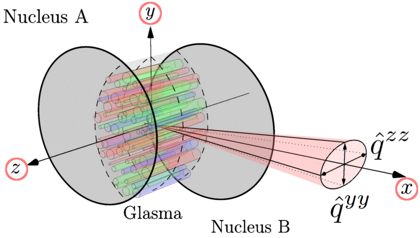


Figure: Ipp, Müller, and Schuh (2020), adapted

Formula for $\hat{q}$

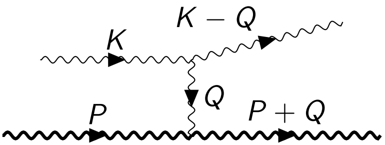
Derivation of a formula for $\hat{q}$ if the particle distribution $f(t;|\vec{k}|,\theta_k)$ is available, e.g. via AMY effective kinetic theory, [Arnold, Moore, and Yaffe (2003)],

$$\left(\frac{\partial}{\partial t}+\vec{v}\cdot\vec{\nabla}_x\right) f_s(t;\vec{x},\vec{p}) = -C_s[f], \tag{2}$$

results in

$$\hat{q}^{ij} = \int \mathrm{d}\Gamma_{PS}\theta(\Lambda_\perp - q_\perp)\, q^i q^j \frac{|\mathcal{M}|^2}{p^2} f_b(k,\theta_k)\,(1+f_d(k-\omega,\theta_{k'}))\,. \tag{3}$$

Integration over the phase space, $\mathcal{M}$ is matrix element for process:



Comparison in thermal equilibrium

Reproduces analytical limits in thermal equilibrium.

Implementation of screening in EKT in matrix element:

$$\lim_{p\to\infty} \frac{\left|\mathcal{M}^{gg}_{gg}\right|^2}{p^2 g^4} \sim \frac{1}{(q^2 + \xi^2 m_D^2)^2} \quad (4)$$

ξ chosen such that HTL limits are reproduced (isotropic screening)

- Previously used value $\xi = 0.814$ [Abraao York, Kurkela, Lu, and Moore (2014)] $\rightarrow$ long. p broadening
- Found: $\xi = 0.698 \rightarrow$ transv. p broadening

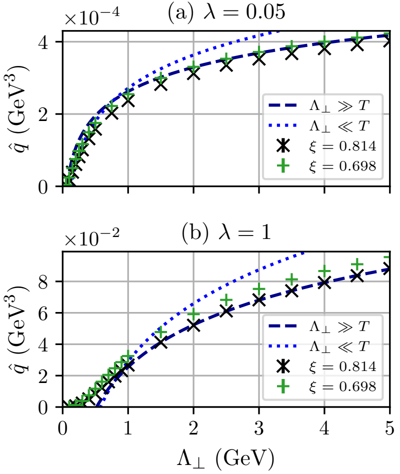


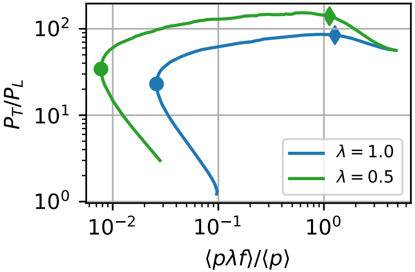
Figure: $\hat{q}$ for different $\lambda = N_C g^2$, $T = 1\,\mathrm{GeV}$ and different $\Lambda_\perp$. $\Lambda_\perp \gg T$ and $\Lambda_\perp \ll T$ denote analytic calculations [Arnold and Xiao (2008)].

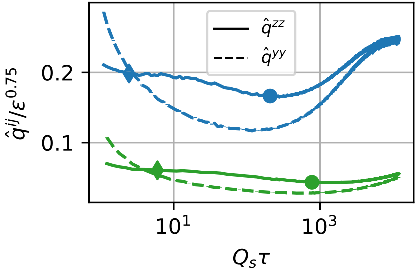
Expanding systems

(preliminary data)

- Initial condition with anisotropy
- Expanding system à la bottom up, as in [Kurkela and Zhu (2015)]
- Different stages of evolution separated by points
- $\hat{q}$ in beam direction ($\hat{q}^{zz}$) and in transverse direction ($\hat{q}^{yy}$) different (due to Bose-enhancement)

(Here $\Lambda_\perp = 10 Q_s$, $\varepsilon = \langle p \rangle$ is the energy density)





Summary and outlook

Summary:

- Generalized EKT formula for $\hat{q}$ in anisotropic systems
- Previously the screening parameter ξ was matched to long. p broadening, for $\hat{q}$ a different value has to be used
- Check with analytic results
- Evaluation of $\hat{q}$ in expanding system, ordering of $\hat{q}^{zz}$, $\hat{q}^{yy}$ depends on stage

Future:

- Compare $\hat{q}$ in other stages of the evolution for different anisotropies and coupling λ
- Improve screening for anisotropic systems

See also:

- $\hat{q}$ in Glasma (D. Schuh: Poster session 2: T01, Wednesday)
- κ from EKT (J. Peuron: Poster session 3: T11_5, Friday)

Ipp, Andreas, David I. Müller, and Daniel Schuh (2020). "Anisotropic momentum broadening in the 2+1D Glasma: analytic weak field approximation and lattice simulations". In: *Phys. Rev. D* 102.7, p. 074001. DOI: 10.1103/PhysRevD.102.074001. arXiv: 2001.10001 [hep-ph].

Arnold, Peter Brockway, Guy D. Moore, and Laurence G. Yaffe (2003). "Effective kinetic theory for high temperature gauge theories". In: *JHEP* 01, p. 030. DOI: 10.1088/1126-6708/2003/01/030. arXiv: hep-ph/0209353.

Abraao York, Mark C., Aleksi Kurkela, Egang Lu, and Guy D. Moore (2014). "UV cascade in classical Yang-Mills theory via kinetic theory". In: *Phys. Rev. D* 89.7, p. 074036. DOI: 10.1103/PhysRevD.89.074036. arXiv: 1401.3751 [hep-ph].

Arnold, Peter Brockway and Wei Xiao (2008). "High-energy jet quenching in weakly-coupled quark-gluon plasmas". In: *Phys. Rev. D* 78, p. 125008. DOI: 10.1103/PhysRevD.78.125008. arXiv: 0810.1026 [hep-ph].

Kurkela, Aleksi and Yan Zhu (2015). "Isotropization and hydrodynamization in weakly coupled heavy-ion collisions". In: *Phys. Rev. Lett.* 115.18, p. 182301. DOI: 10.1103/PhysRevLett.115.182301. arXiv: 1506.06647 [hep-ph].