Momentum Broadening in a Highly Diluted Glasma

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1 Motivation

Jet Quenching

- Modification of jets by a medium

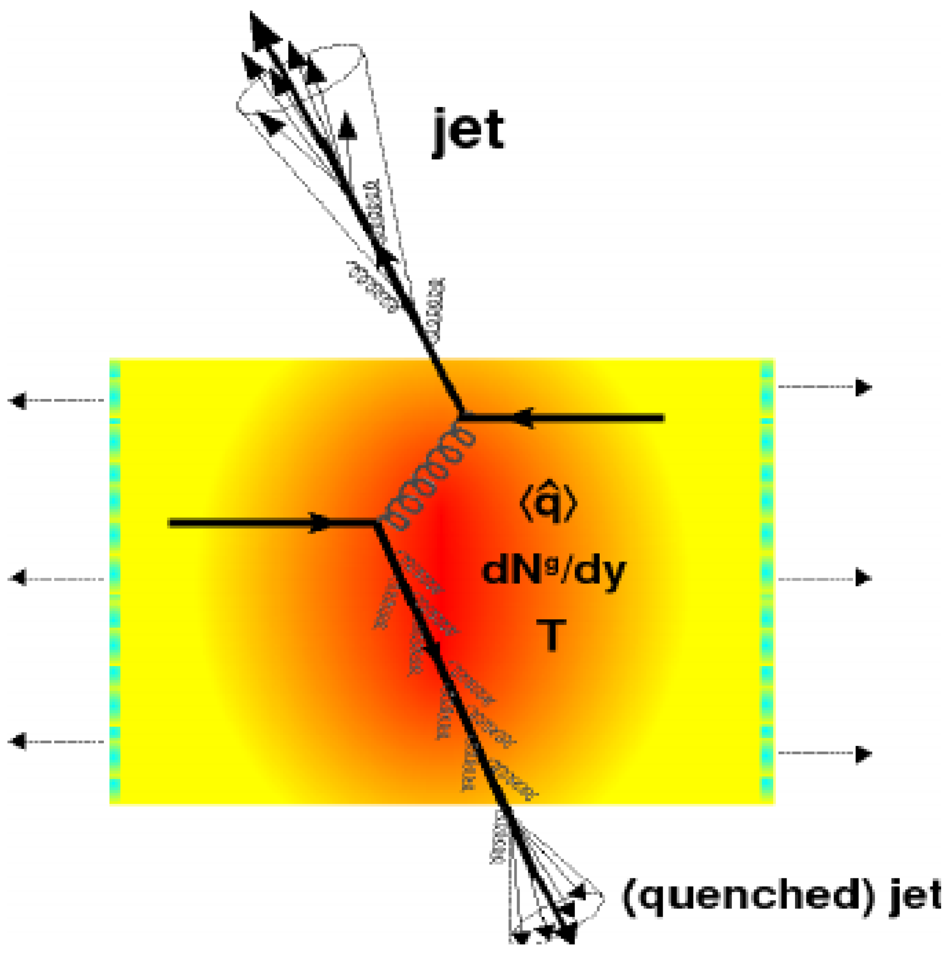
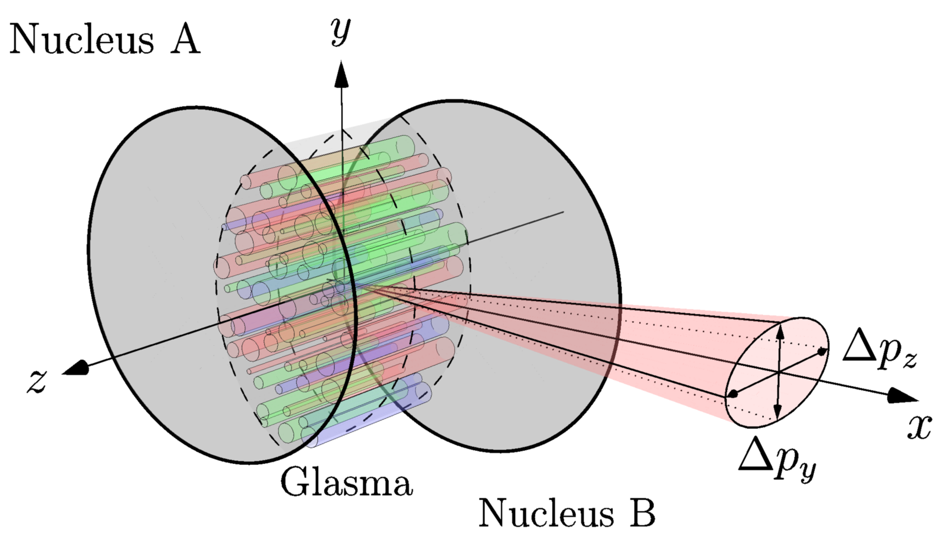


Figure 1: Graphical illustration of jet quenching [1]

Jet Shape

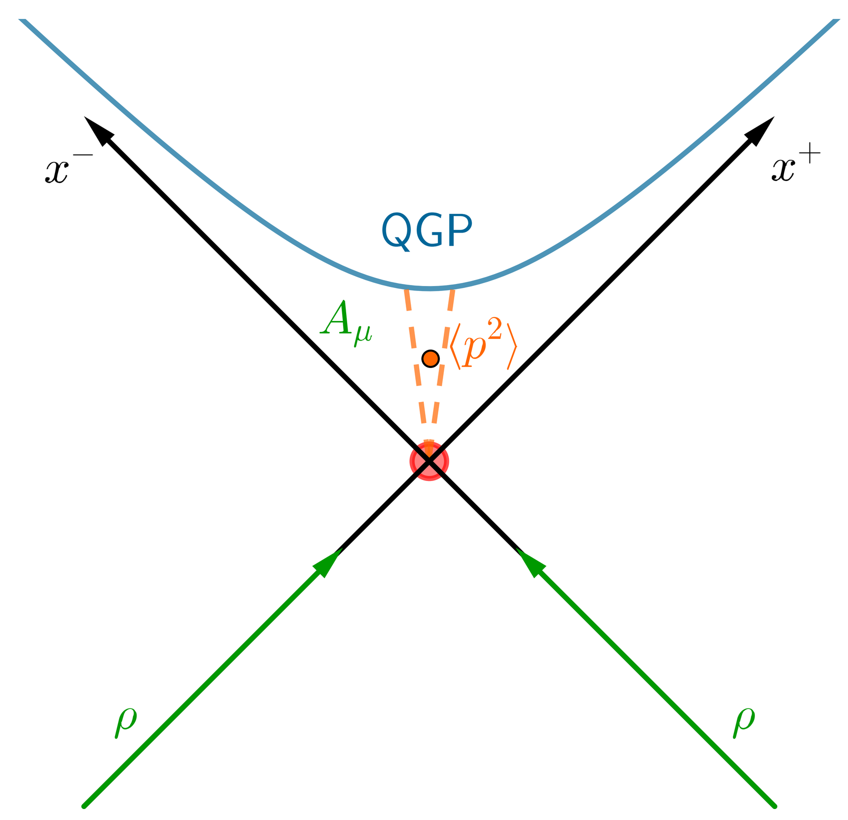
- Particle jets from high energy nuclei collisions show elliptic shape in the detector
- $\Rightarrow$ Their broadening is different in different spatial directions
- $\Rightarrow$ Investigate, how much of the momentum broadening can be attributed to the Glasma



2 The Glasma

The Colour Glass Condensate (CGC)

- Effective theory of QCD that describes high energy nuclei in the framework of a classical field theory
- Each nucleus is highly contracted and consists of
  - Hard partons (high momentum, valence quarks and high energy gluons, ρ)
  - Soft partons (low momentum, low energy gluons, A_μ)
- Dynamics at leading order governed by classical Yang-Mills equations $D_\mu F^{\mu\nu} = J^\nu(\rho)$
- Collision of two CGCs creates the Glasma
- Successor state of the Glasma is the quark gluon plasma (QGP)



Analytical Solution of the Glasma

- Glasma is described by A_μ in the forward light cone of the collision
- Series expansion $A_\mu = \sum_{n=1}^{\infty} A_{\mu(n)}$ in ρ [2]
- Solve $D_\mu F^{\mu\nu} = 0$ with matching conditions as boundary conditions
- $A_{\mu(2)}$ is lowest order that is not pure gauge

3 Momentum Broadening in the Glasma

- $\langle p^2 \rangle$ and its change in time are of interest
- Use the McLerran Venugopalan model [3,4] to calculate the average $\langle\rangle$, but introduce an infrared regulator m and an ultraviolet cut-off Λ_{UV}
- View Glasma as a non-Abelian background field
- Equations of motion of a test parton in the Glasma are the Wong equations
- Solve them and average over colour charges [5] to get

$$\langle p^{\underline{i}} p^{\underline{i}} \rangle_{(4)}(t) = 2g^2 \widetilde{A} \int_{t_0}^{t} \mathrm{d}t' \int_{t_0}^{t} \mathrm{d}t'' \, \langle \mathrm{Tr}(F^{\underline{i}}_{(2)}(x^j(t'), t') F^{\underline{i}}_{(2)}(x^j(t''), t'')) \rangle$$

- Force on the test parton depends on its trajectory
- Solve resulting integrals numerically, which are e.g. for $\langle p_z^2 \rangle_{\kappa\,(4)}(t)$

$$\frac{\langle p_z^2 \rangle_{\kappa\,(4)}(t)}{2\pi B} = \int_0^{\Lambda_{UV}} \mathrm{d}r_l \int_0^{\Lambda_{UV}} \mathrm{d}r_q \int_0^{2\pi} \mathrm{d}\varphi \, \frac{(r_q r_l)^3}{\omega^2} \left(\frac{\cos\varphi}{(r_q^2+m^2)(r_l^2+m^2)} f_z(\omega t) \right)^2$$

- $\widetilde{A}$ and B depend on the test parton and on the used symmetry group $SU(N)$

4 Results & Outlook

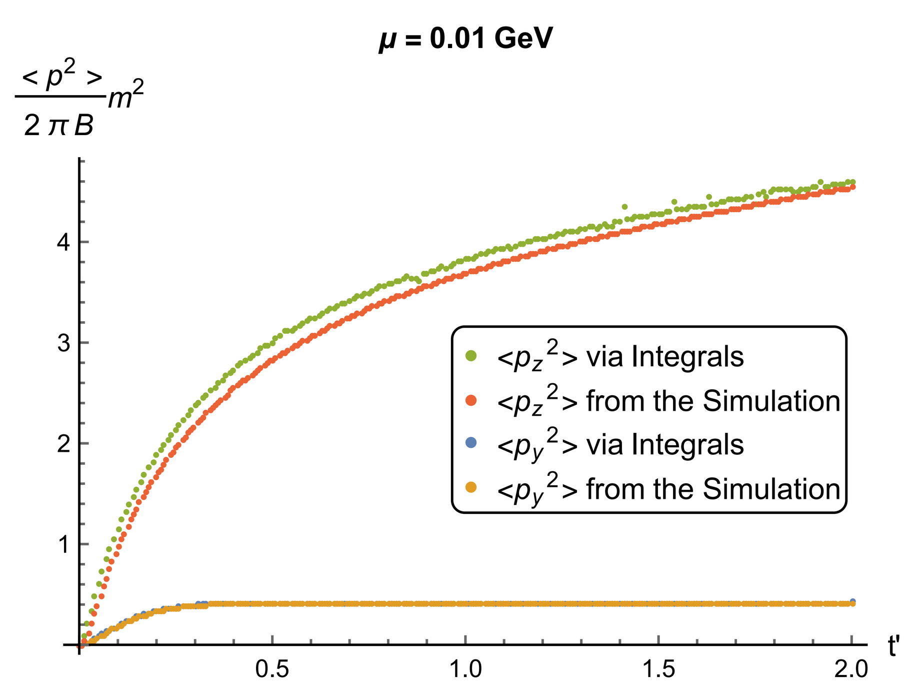


Figure 2: $\langle p_T^2 \rangle_{\kappa\,(4)}$ and $\langle p_z^2 \rangle_{\kappa\,(4)}$, $\kappa = \mathrm{d}\langle p^2 \rangle_\kappa / \mathrm{d}t$, resting test parton, z axis is the beam axis

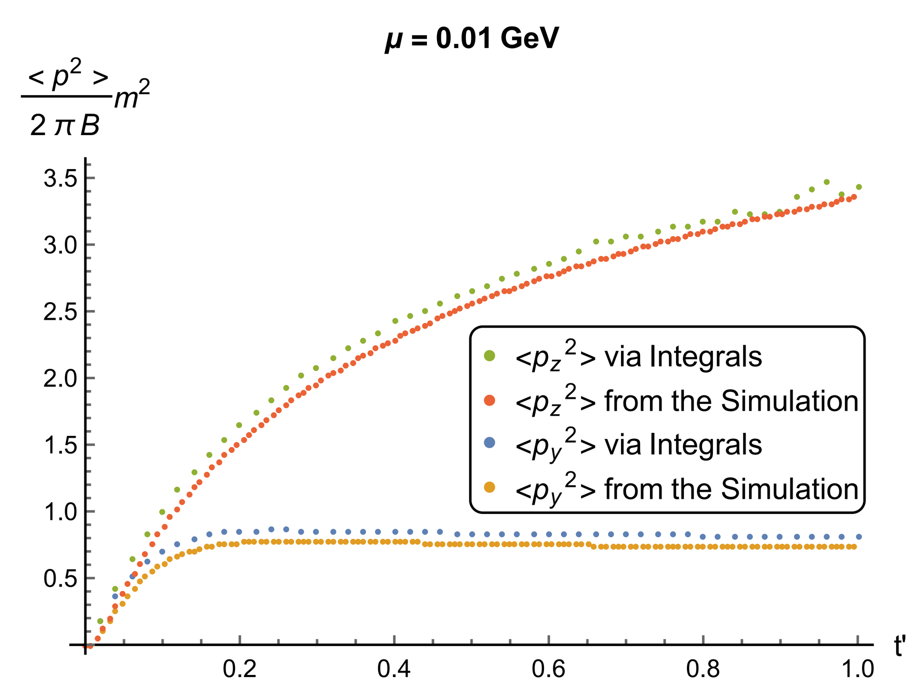


Figure 3: $\langle p_y^2 \rangle_{\hat{q}\,(4)}$ and $\langle p_z^2 \rangle_{\hat{q}\,(4)}$, $\hat{q} = \mathrm{d}\langle p^2 \rangle_{\hat{q}} / \mathrm{d}t$, test parton moving at c in x direction (perpendicular to the beam axis)

- Analytical result of second order is in agreement with the weak field limit of the lattice simulation [6]
- Large anisotropy of momentum broadening $\Rightarrow$ elliptical shape of the resulting jet
- $\langle p_z^2 \rangle_{(4)}$ is the largest component and grows logarithmically
- $\langle p_T^2 \rangle_{\kappa\,(4)}$ and $\langle p_y^2 \rangle_{\hat{q}\,(4)}$ decrease after a finite time $\Rightarrow$ $\kappa_{x,y\,(4)}$ and $\hat{q}_{y\,(4)}$ become negative in that region
- Use the lattice simulation to investigate denser Glasmas (which are more realistic)
- Future goal: parton energy loss in the Glasma

5 References

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