Initial stage jet momentum broadening and energy loss in tBLFQ formalism

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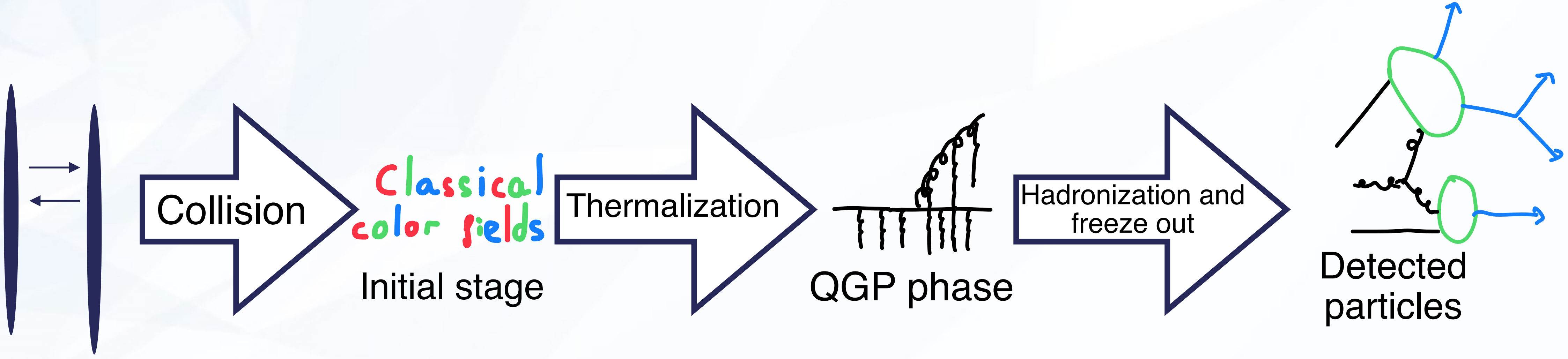
1. Motivation of this work

Heavy ion collisions

High density **quark and gluon matter** is created

Different states before reaching our detectors

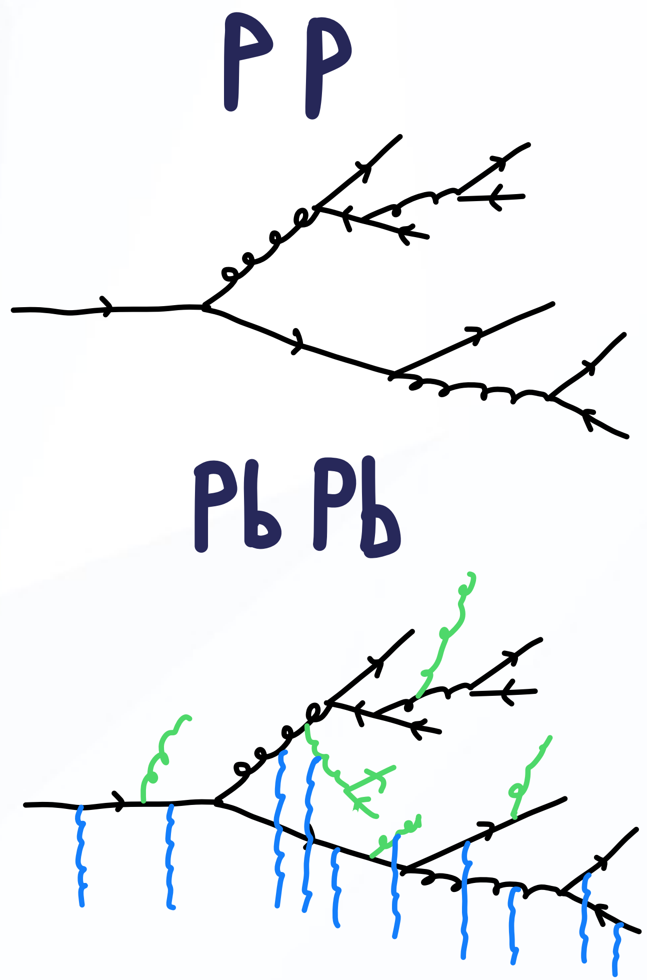


Jet quenching

Jets **probe** the different stages of nuclear matter

Jet momentum distribution and energy gets modified, **jet quenching**

$$\hat{q} = \frac{d\langle q_{\perp}^{2}\rangle}{dL}$$



Jet quenching in the initial stage

Claims that $\hat{q}$ must be **suppressed** in the initial stage [Phys. Lett. B 803 (2020) 135318]

Classical jet analysis shows that it is in fact $\hat{q}$ is **very large** [Phys. Lett. B 810 (2020) 135810]

Our goal: Complete **quantum treatment** of the jet in tBLFQ formalism

2. The Glasma fields

The high energy nuclei

Model the colliding nuclei using **CGC**

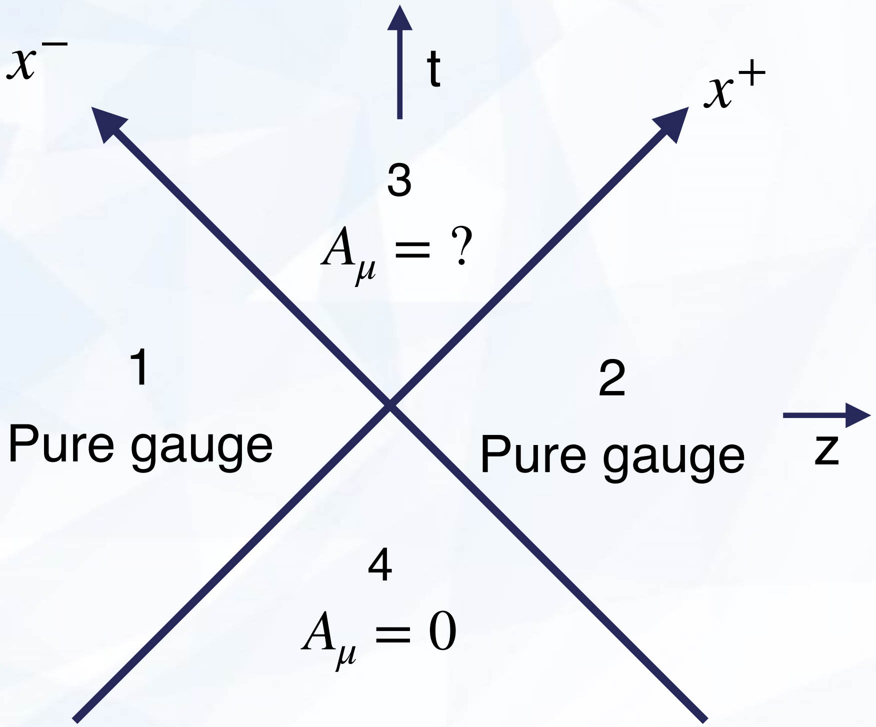
- Large x → Static color charges
- Small x → Classical color fields

Color fields obey **classical Yang-Mills** equation $[D_\mu, F^{\mu\nu}] = J^\nu$

↓ LC gauge

Transverse **pure gauge** fields

Initial condition of the Glasma



Natural to use **Fock-Swinger gauge**

$$A_\tau = \frac{x^+A^- + x^-A^+}{\tau} = 0$$

Imposing **boost invariance**

$$A_i^{(3)}(\tau = 0) = A_i^{(1)} + A_i^{(2)}$$

$$A^\eta(\tau = 0) = \frac{ig}{2}[A_i^{(i)}, A_i^{(2)}]$$

[Phys. Rev. D **52**, 6231]

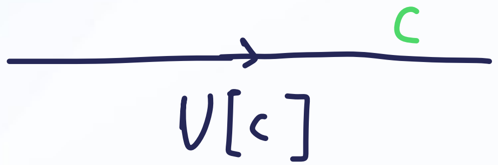
Evolution of the Glasma fields

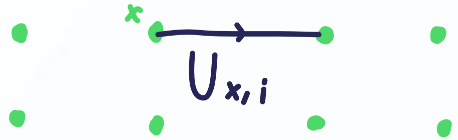
The Glasma fields evolve according to **free Young-Mills** $[D_\mu, F^{\mu\nu}] = 0$

Solved numerically we use **real-time lattice gauge theory**

Gauge fields | **Wilson lines** | **Gauge links**

$A_\mu(x)$ —Exponentiation→ $U[c] = \mathcal{P}\exp\left(-ig\int_c dx^\mu A_\mu(x)\right)$ —Discretization→ $U_{x,\mu} \simeq \left(ig\, a^\mu A_\mu\left(x + \frac{a^\mu}{2}\right)\right)$





3. The tBLFQ formalism

time-dependent Basis Light Front Quantinzation

Construction of the jet wave-function

Exploit the QFT <-> QM isomorphism in **LC quantization**

Construct the eigenstates of the Hamiltonian using BLFQ

[Phys. Rev. C 81, 035205]

→

Make the states evolve under the action of the external field

$$|\psi; x^+\rangle_I = T_+ e^{-\frac{i}{2}\int_0^{x^+} V_I} |\psi; 0\rangle_I$$

[Phys. Rev. D 88 (2013) 065014]

Successfully applied to $|q\rangle$ and $|q\rangle + |qg\rangle$ evolution in a MV field

[Phys. Rev. D 101 (2020), 076016] [Phys. Rev. D 104 (2021), 056014]

3. Gauge transformation of the Glasma fields

Need to gauge transform the Glasma fields

The Glasma and jet evolution have different natural gauges

Glasma	**Jet**
↓	↓
Temporal gauge	LC gauge

To use tBLFQ we need to **gauge transform** the Glasma gauge links to LC gauge

Gauge transformation operator

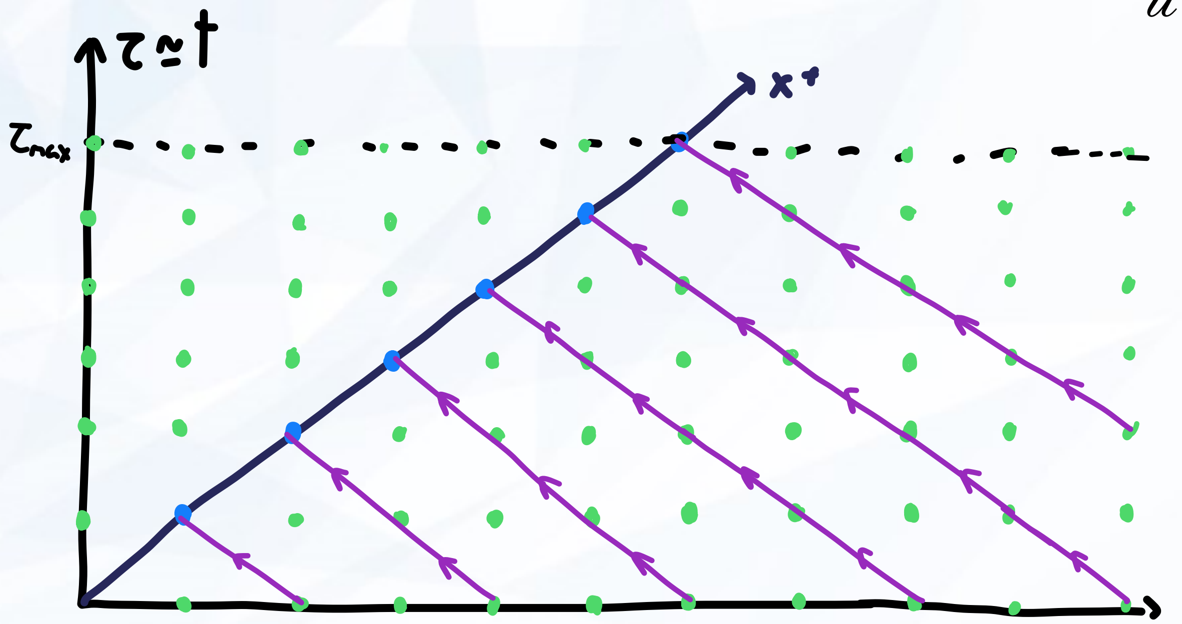
$$\mathcal{U}^{\dagger}_{LC}(x_{LC}) = P\exp\left\{ ig\int_{-\infty}^{0} dx^{-} A^{+}_{temp}(x^{+}, x^{-}, y, z)\right\}$$

Discretizing →

$$\mathcal{U}^{\dagger}_{LC}(x^{+}, y, z) = \prod_{k} \mathcal{U}^{\dagger}_{LC}(x^{+}, x^{-}_{k}, y, z)$$

where

$$\mathcal{U}^{\dagger}_{LC}(x^{+}, x^{-}_{k}, y, z) = \exp\left\{ \frac{za}{\tau^{2}} A^{latt}_{\eta}(x^{+}, x^{-}, y, z \right\} U_{x}(x^{+}, x^{-}, y, z)$$



Only z dependence we are considering, restricted to jets at approximately mid-rapidity

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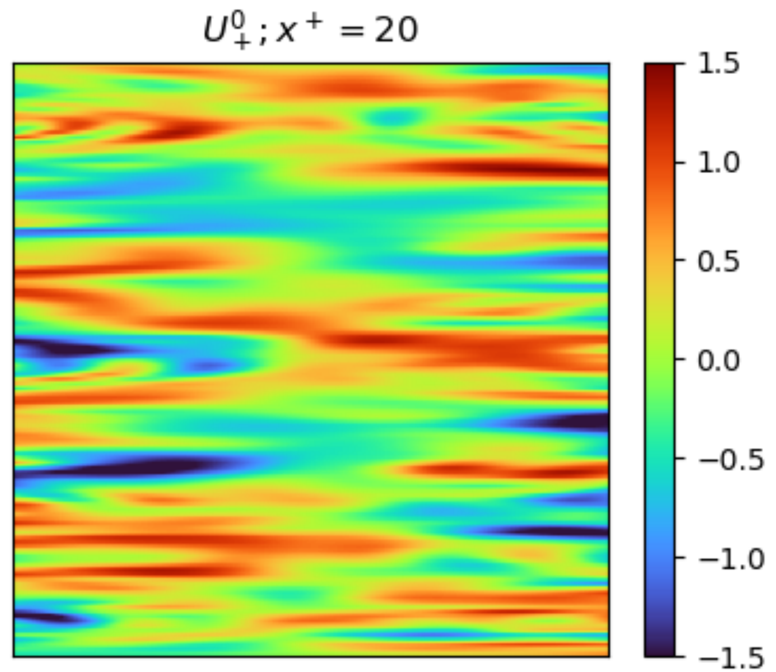
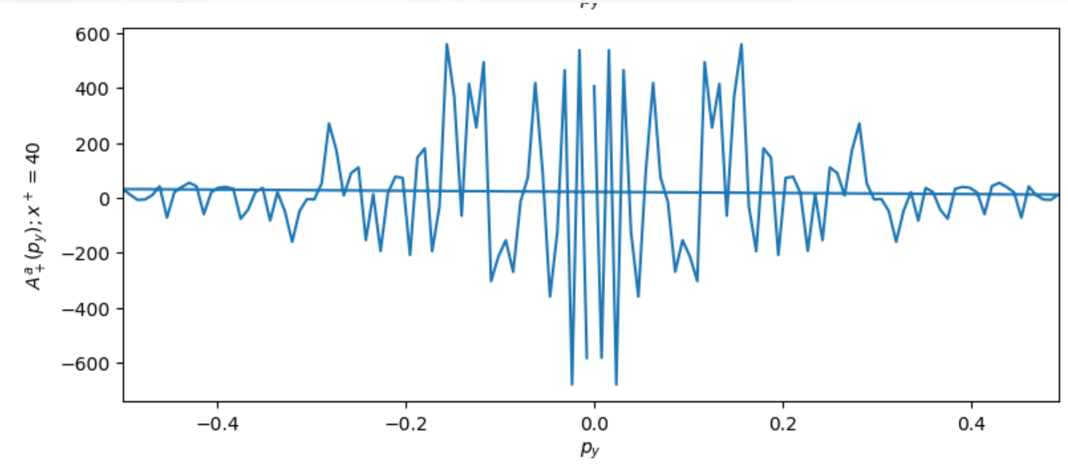
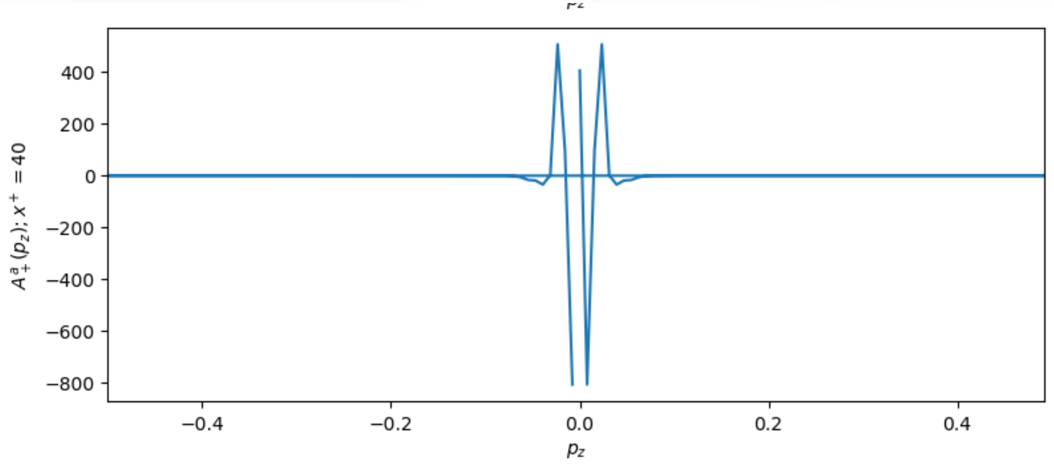
Gauge transformation of the fields

$$U(x,y) \to U(x)U(x,y)U^\dagger(y) \longrightarrow U_{x,\hat{\mu}} \to \mathcal{U}_{x+\mu} U_{x,\hat{\mu}} \mathcal{U}_x$$

Transform U_+ link over the x^+ axis
(perp components subeikonal)







4. Outlook

Future work

- Adapt the jet evolution code to suit our analysis
- Initialize the wave-package in such a way that it is insensitive to boundary conditions
- Get results for both jet momentum broadening and energy loss
- Compare our results to classical analysis and experimental data and check the validity of our approximations