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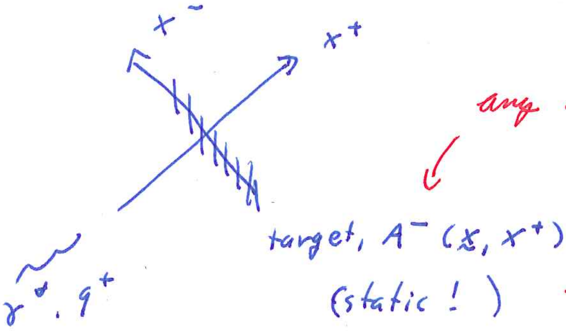
Collision of CYM fields

CYM = Classical Yang-Mills

We had a γ^*-target collision



any x^--dependence is negligible compared to $e^{iq^+x^-}$ of probe.

→ Target is seen as static in x^-, its own light cone time. In other words: the target is probed at a ~~time~~ timescale $\Delta x^- \sim \frac{1}{q^+}$ which is very short compared to its own natural timescale

Timescale of target $\Delta x^- \sim \frac{1}{p^+} \sim \frac{p^-}{m^2} \sim \frac{p^- q^+}{m^2} \frac{1}{q^+}$

$$\sim \underbrace{\frac{Q^2}{x\, m^2}}_{\gg 1} \frac{1}{q^+}.$$

This kind of a system is called a glass.
(A glass is a liquid that flows so slowly that it looks like a solid on human timescales).

Class field ← color current $J^-(\underset{\sim}{x}, x^+)$

$$[D_\mu, F^{\mu\nu}] = J^\mu \rightarrow A^-_a(\underset{\sim}{x}, x^+) = \frac{-1}{\underset{\sim}{\partial}^2} J_a^-(\underset{\sim}{x}, x^+)$$

LC wavef. / parton picture of target?

→ target LC-gauge $A^- = 0$

$$A_\mu \rightarrow U A_\mu U^\dagger - \frac{i}{g} U \partial_\mu U^\dagger$$

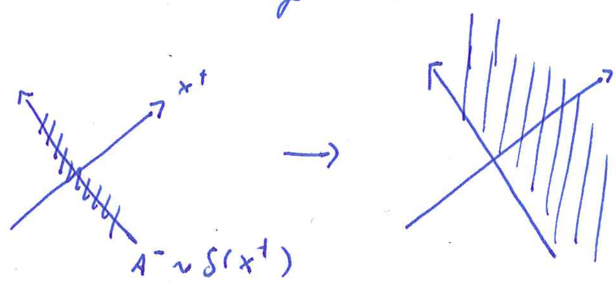
$$A^- \rightarrow U A^- U^\dagger - \frac{i}{g} U \partial_+ U^\dagger = 0 \rightarrow \underline{U^\dagger = P e^{ig\int^{x^+} dy^+ A^-(y^+, \underset{\sim}{x})}}$$

Same Wilson line as in DIS cross section.

Now we are in the target LC gauge. What are the new nonzero components?

$A^+ : 0 \to -\frac{i}{g} U \partial_- U^+ \approx 0$ (no x^--dependence in static target)

$A_i : 0 \to -\frac{i}{g} U \partial_i U^+$ = pure gauge

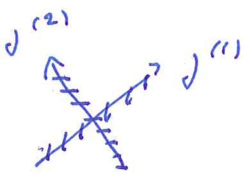


$A_i \sim \Theta(x^+)$ → the field is $\neq 0$, but $F_{\mu\nu} \sim \partial_+ \Theta(x^+) \sim \delta(x^+)$

→ only lives on the light cone.

What about a collision of 2 such field configurations? Note the ~~field~~ field only has transverse components, so we can ~~..~~ write down the fields for both targets.

$$J^\mu(x) = \delta^{\mu +} J^{(1)}(\underset{\sim}{x}, x^-) + \delta^{\mu -} J^{(2)}(\underset{\sim}{x}, x^+)$$



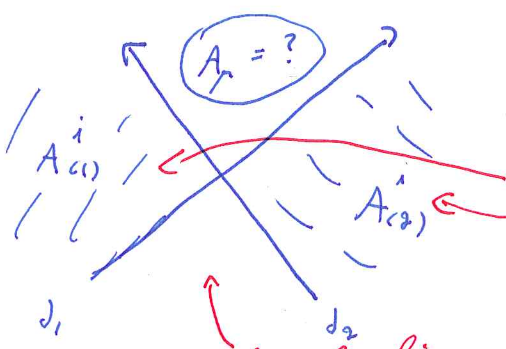
Both currents independent on their respective light cone times.

Form Wilson lines from both currents separately:

$$U^+_{(1)}(\underset{\sim}{x}) = P e^{ig\int_{-\infty}^{\infty} dx^- J^{(1)}(\underset{\sim}{x}, x^-)} \quad \leftarrow \quad J^{(1)} \sim \delta(x^-)$$

$$U^+_{(2)}(\underset{\sim}{x}) = P e^{ig\int_{-\infty}^{\infty} dx^+ J^{(2)}(\underset{\sim}{x}, x^+)} \quad J^{(2)} \sim \delta(x^+)$$

integrating directly to $+\infty$



$$A^i_{(m)} = \frac{i}{g} U_{(m)} \partial_i U^+_{(m)}$$

pure gauge: field, but no energy density

causally disconnected, no field

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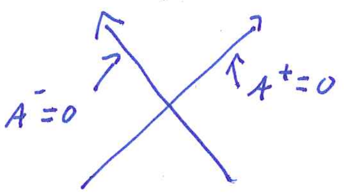
For $x^- > 0$, $x^+ > 0$ the field must be more complicated. This is the initial state that will evolve into a quark gluon plasma. In the classical field picture the field configurations are a solution of the Yang-Mills equation of motion

$$[D_\mu, F^{\mu\nu}] = 0$$ $\to$ nonlinear equation, not solvable ~~analytically~~ analytically. Cannot impose $A^+ = A^-$ any more, so one has to choose a less restrictive gauge condition:

$$A_\tau = \frac{1}{\tau}(x^+ A^- + x^- A^+) = 0 \qquad \boxed{\begin{aligned} \tau^2 &= 2x^+x^- \\ \eta &= \tfrac{1}{2}\ln\frac{x^+}{x^-} \end{aligned}}$$



$\to$ LC gauge on light cones.

The remaining orthogonal gauge field component is the η-component:

$$A^\pm = \pm x^\pm A^\eta$$

Ansatz: $$A^i = \theta(x^-)\,\theta(-x^+)\,A^i_{(1)} + \theta(-x^-)\theta(x^+)\,A^i_{(2)} + \theta(x^+)\theta(x^-)\,A^i$$

$$A^\pm = \pm x^\pm \theta(x^+)\theta(x^-)\,A^\eta$$

$[D_\mu, F^{\mu\nu}] = 0$, $\partial_- \theta(x^-) = \delta(x^-)$, $\partial_+ \theta(x^+) = \delta(x^+)$

Insert ansatz into equation, match coefficients of δ-functions to zero

$$\Rightarrow A^i(\tau = 0^+) = A^i_{(1)} + A^i_{(2)} \qquad \to B^z \neq 0 \;(HT)$$

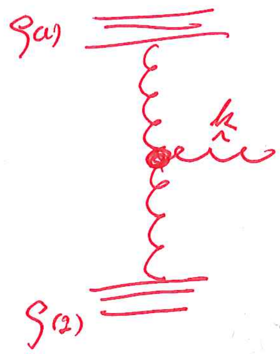
$$A^\eta(\tau = 0^+) = \frac{ig}{2}[A^i_{(1)}, A^i_{(2)}] \to E^z = F^{-+} = A^\eta(\tau = 0)$$

$B_\perp = E_\perp = 0 \quad (\tau = 0^+)$

There are the "glasma" fields (Kovner, McLerran, Weigert, -95; Lappi, McLerran, -06)

Initially longitudinal chromoelectric and -magnetic fields.

In the dilute limit they correspond to the field configurations of a gluon produced in the $2 \to 1$ mechanism with a Lipatov vertex



$A_i \sim J_0(|\underset{\sim}{k}|\tau)$

$A^2 \sim \frac{1}{\tau} J_1(|\underset{\sim}{k}|\tau)$

and unintegrated gluon distribution $\langle \rho_{(1)} \rho_{(1)} \rangle$, $\langle \rho_{(2)} \rho_{(2)} \rangle$ from the two colliding color charged objects.

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This is the end of the course. We have progressed from:

Optical diffraction (19^{th} century)

-> QM scattering theory

-> pre-QCD hadron scattering (Regge), -60's

-> QCD scattering -70's, resummed by BFKL, -80's

-> dipole model, high energy DIS phenomenology, BK -90's

-> classical field picture of heavy ion collisions, 2000's.