CGC color fields and Lund strings

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Introduction

My background

- Classical Yang-Mills for heavy ion collisions
- CGC “dilute-dense” scattering: DIS, pA etc.

What I hope to learn:

- When is it enough to conserve color only on average?
- Where are Lund strings in space and in time?
- Where does energy come from and go to?

Apologies:

- Very formal, little to say about experiment, I’m leaving that to you. . .
- Images, I was somehow distracted preparing these slides. . .

Microcanonical vs canonical

Language difference

Monte Carlo

- Track color (at least large N_c)
- Conserve energy & momentum
  (I assume? At least approximately?)

Heavy ions

- CGC: color conserved on average
- Hydro: local thermal equilibrium, T, μ

- At high N_{ch}, is microcanonical approach too inefficent?
- What is the experimental signature of microcanonical color?
  (In addition to e^+e^- and jet fragmentation,
  i.e. in min. bias $h+h$ particle production)

The Heisenberg uncertainty principle

Glasma simulation

- Waves are particles
- Particles are waves
- Funny effects at $k_T \sim 1/R_p$

Strings

- Ends of strings have **x** & **p** (I assume?)
  Is one specifying too much?
- Strings have width, but never Fourier-transform

Which one is more important?

- Separate confinement & short length scales
  (only latter treated as momentum)
- Don't mess with Heisenberg?

One-component vs two-component

My favorite provocative (?) statement: PYTHIA is a saturation model

- Particle production is dominated by semihard cutoff p_0
- This cutoff depends on $\sqrt{s}$, i.e. is not a confinement scale

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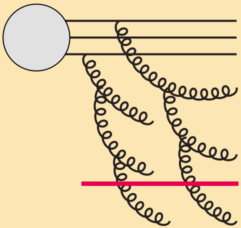
Difference between PYTHIA and CGC: 2-component vs 1-component model

- CGC: one scale Q_s, alternative descriptions: classical field/perturbative gluon
- PYTHIA: $p_T > p_0$ partons, $p_T < p_0$ strings . . . but these are degrees of freedom **away** from the dominant scales $\Longrightarrow$ discontinuity

- In a one-scale system, should't one use a one-component model?
- But of course "underlying event" for a 100GeV jet is not a one-scale problem. . .

Are virtual gluons real?

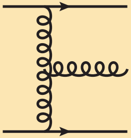


- Gluons that produce stuff at $y = 0$ come from a cascade (DGLAP, BK/BFKL, CCFM, ...)
- CGC: collision kicks them and they became real instantaneously
- Gluons have intrinsic $k_T \implies p_T$ of produced particles
- Collinear factorization=for producing the **hardest** particle intrinsic k_T does not matter $\implies$ treat virtual gluons as real

- Does the soft particle k_T come from intrinsic k_T or string fragmentation (Schwinger) ?
- Is collinear picture justified for initializing the "underlying event"?
  (Especially if it doesn't actually "underlie" anything?)

How is energy transported to $y = 0$?

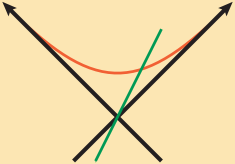
CGC



- Soft gluons interact in $2 \to 1$ process
- $\sim$ all the energy is the $\mathbf{k}$ of the gluons
- Energy is there at "$\tau = 0$"
  (or at least $\tau \sim 1/k_T$)

Strings

- Same process there in different guise
  ($2 \to 2$ scattering, but other parton is far in y)
- But there are also strings:
  - The string tension has energy
  - Tension is a force, does pulling the string transfer energy?



- $\varepsilon(\tau, \eta) = ?$ $\quad \varepsilon(\eta = 0)$ vs τ?
- How much of it is string tension?
- How much of it is momentum?
- If $\varepsilon > \varepsilon_{\text{crit}}$, isn't it a plasma?