Color Glass Condensate and Lund Strings

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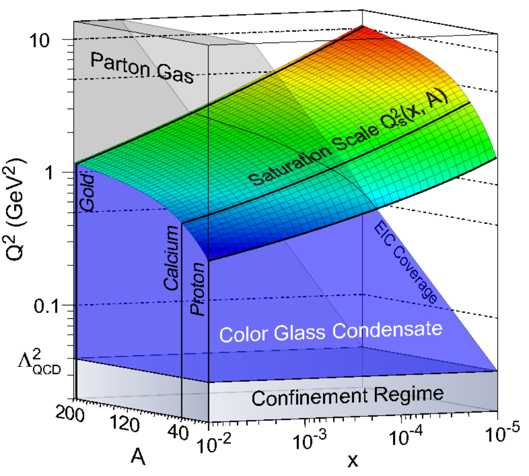
CGC PRIMER

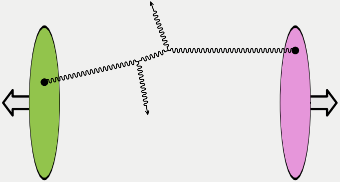
- At high energy, hadrons/nuclei are Lorentz contracted
- Their internal dynamics is time dilated
- For a given $p_\perp$, the typical momentum fraction goes like $1/\sqrt{s}$
- The number of gluons and sea quarks increases as $x \to 0$
- At fixed Q, their wavefunctions (of transverse extent Q^{-1}) will eventually overlap $\Rightarrow$ gluon saturation
- At (small) fixed x, there exists a scale $Q_s(x)$ such that, for $Q < Q_s(x)$, we have saturation

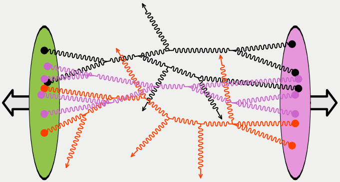
CGC PRIMER



10
1
0.1
Λ^2_{QCD}
Q^2 (GeV^2)
Parton Gas
Saturation Scale $Q_s^2(x, A)$
Gold
Calcium
Proton
EIC Coverage
Color Glass Condensate
Confinement Regime
200
120
40
A
10^{-2}
10^{-3}
10^{-4}
10^{-5}
x

- When parton densities are large, scattering probabilities are no longer linear in the densities:



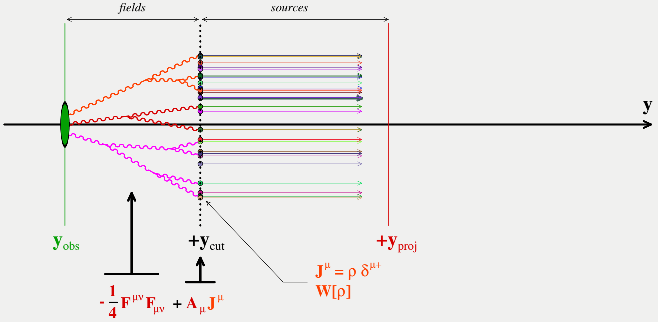


CGC PRIMER

- CGC = approximation of QCD valid in the saturation regime
- Incoming nucleus ≡ stream of color charges ("sources")
- Lorentz time dilation: static charges
- Lorentz contraction: 2-dimensional charge distribution

$$J_a^\mu(x) = \delta^{\mu +}\delta(x^-)\rho_a(\boldsymbol{x}_\perp)$$

- At rapidities close to the observer: normal gluon fields



- CGC at leading order $\Longleftrightarrow$ classical color fields given by Yang-Mills equations. Energy-momentum tensor reads:

$$T^{00}_{LO} = \frac{1}{2}\big[\underbrace{\mathbf{E}^2+\mathbf{B}^2}_{\text{class. fields}}\big], \qquad T^{0i}_{LO} = \big[\mathbf{E}\times\mathbf{B}\big]^i,$$

$$T^{ij}_{LO} = \frac{\delta^{ij}}{2}\big[\mathbf{E}^2+\mathbf{B}^2\big] - \big[\mathbf{E}^i\mathbf{E}^j+\mathbf{B}^i\mathbf{B}^j\big],$$

- E and B aligned with collision axis (at $\tau = 0$):

$$T^{0i}_{LO} = 0, \quad P_T = T^{00}, \quad P_L = -T^{00}$$

- The transverse size of these “strings” of color fields is $\sim 1/Q_s$

CGC versus Lund strings

- Is the shape similarity between Lund strings and the CGC color fields trivial (i.e., a mere consequence of the geometry of the problem), or has it a more dynamical origin?
- In the CGC, the negative longitudinal pressure is a consequence of $\mathbf{E} \parallel \mathbf{B} \parallel \widehat{z}$. Is any model implementing the same geometry bound to have that also?

CGC versus Lund strings

- In the CGC, the color fields interact via the non-linear term of the Yang-Mills equations when they become too strong. How are the interactions between strings handled?
- The Yang-Mills evolution tends to wash out the initial “stringy” organisation of the color fields. How long lived are the Lund strings?
- Loop corrections in the CGC fields lead to instabilities. Some of them are related to the Schwinger mechanism for particle creation, but some are not (e.g., Weibel instability).