Glasma in a "capacitor"

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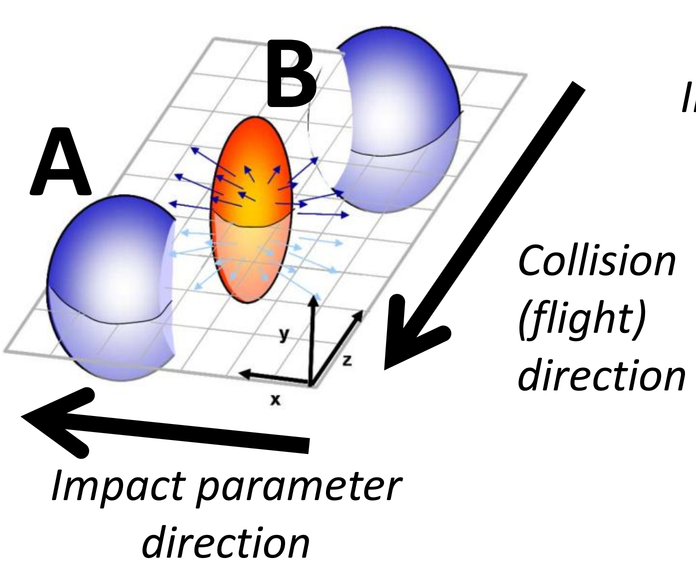
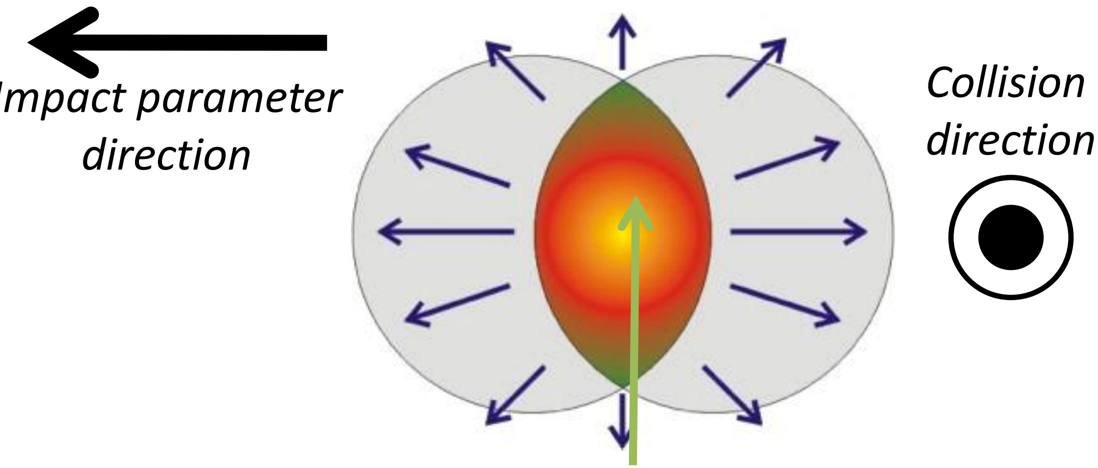
Relativistic Heavy Ion Collisions





Hot and dense expanding
QUARK-GLUON-PLASMA (QGP)
T about 10^{12} K, t about 10^{-23} seconds

A,B: Cu, Au (RHIC@BNL)
Pb (LHC@CERN).

$\sqrt{s}$ up to $200 \times A$ GeV , RHIC

$\sqrt{s}$ up to $2.76 \times A$ TeV , LHC

QGP formation time

- RHIC $\approx$ 0.6 fm/c
- LHC $\approx$ 0.2 fm/c

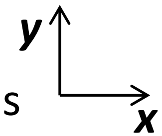
QGP lifetime

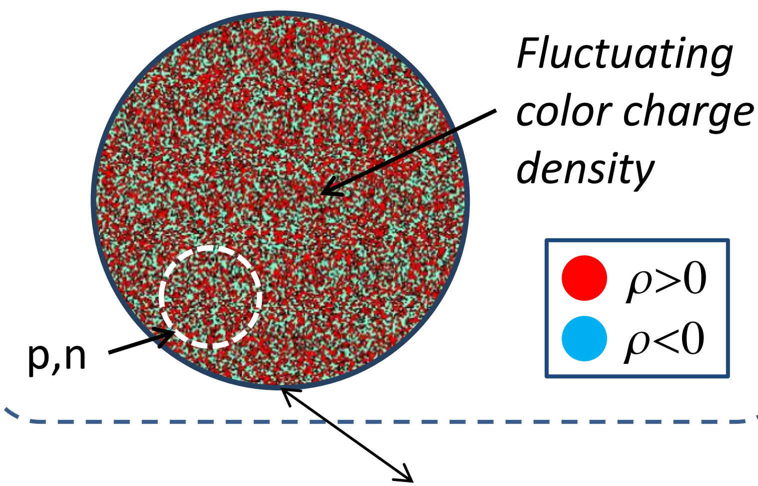
- RHIC $\approx$ 5 fm/c
- LHC $\approx$ 10 fm/c

Initial condition, *aka* Glasma

Transverse plane view of a nucleus

- Globally: color neutral
- Locally: color charge fluctuates



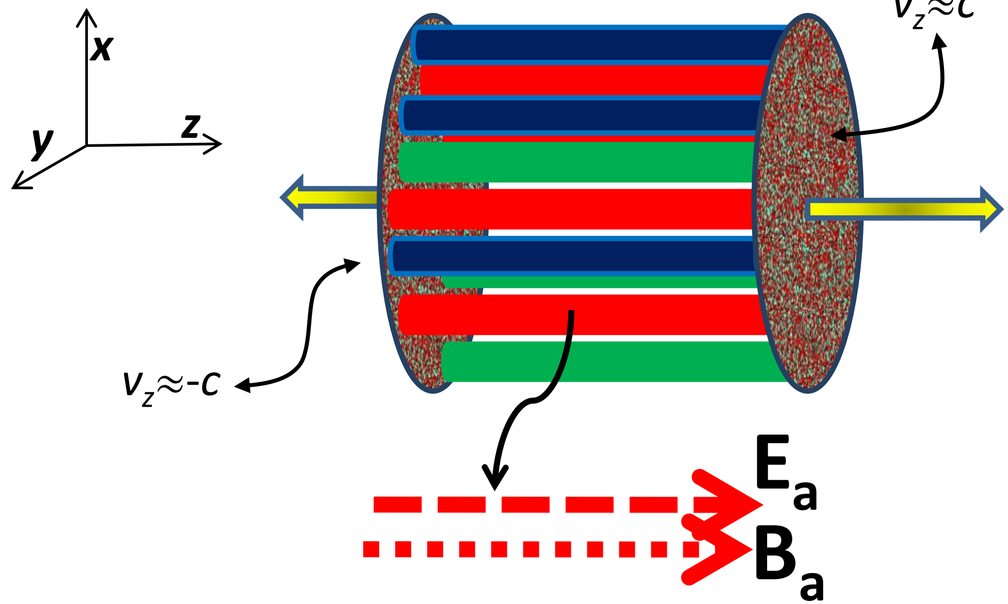


In RHICs: ≈ on the light cone, hence
very fast with respect to the central region

Slower dynamics (time dilatation):
frozen, from the point of view of lab system

Static sources of color strings

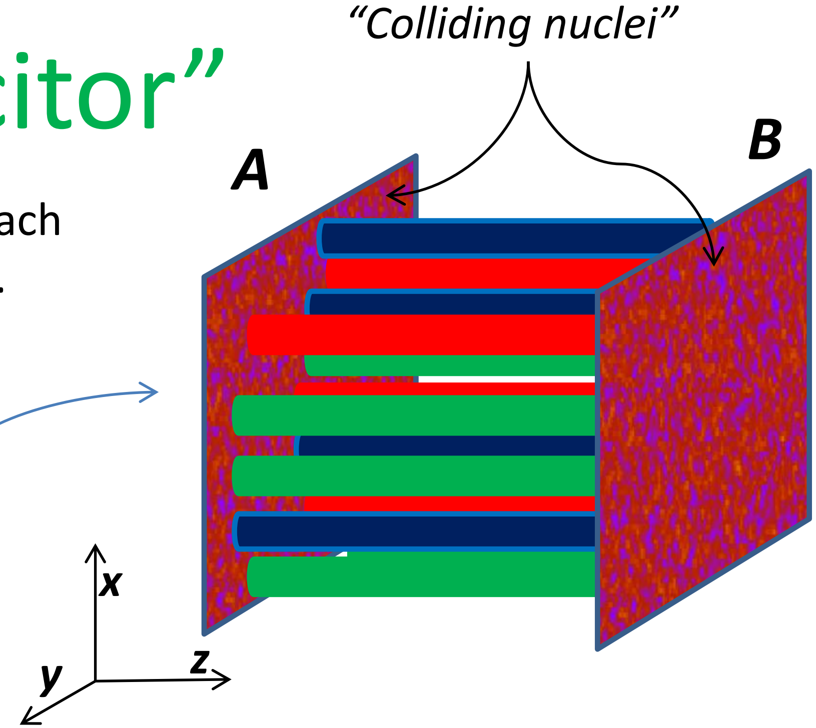
System after the collision: Glasma



Colored strings connect
color charges distributed in the two nuclei.

Evolution should convert Glasma to quark-gluon plasma.

Glasma in a "capacitor"



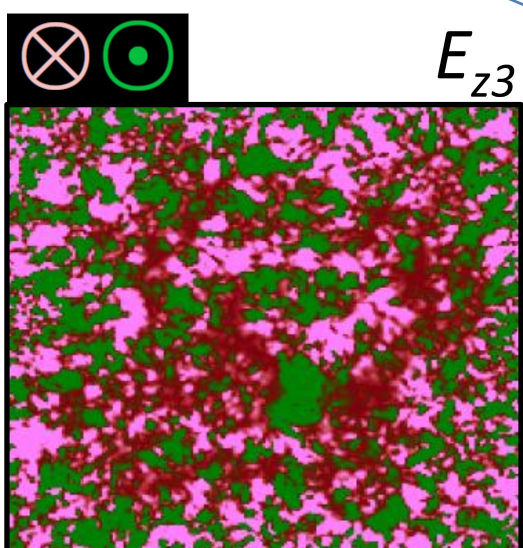
Gluon strings –Glasma are formed when nuclei pass each other because of color charge distributed in the nuclei.

Consider a simple configuration:

- Pure Yang-Mills
- SU(2) color group
- *Static box in 3+1 dimesions: "**Capacitor**"*
- *Uncorrelated color density fluctuations*

$$\langle \rho^a(\boldsymbol{x}_T) \rangle = 0$$

$$\langle \rho^a(\boldsymbol{x}_T)\rho^b(\boldsymbol{y}_T) \rangle = Q_s^2 \delta^{ab} \delta^{(2)}(\boldsymbol{x}_T - \boldsymbol{y}_T)$$

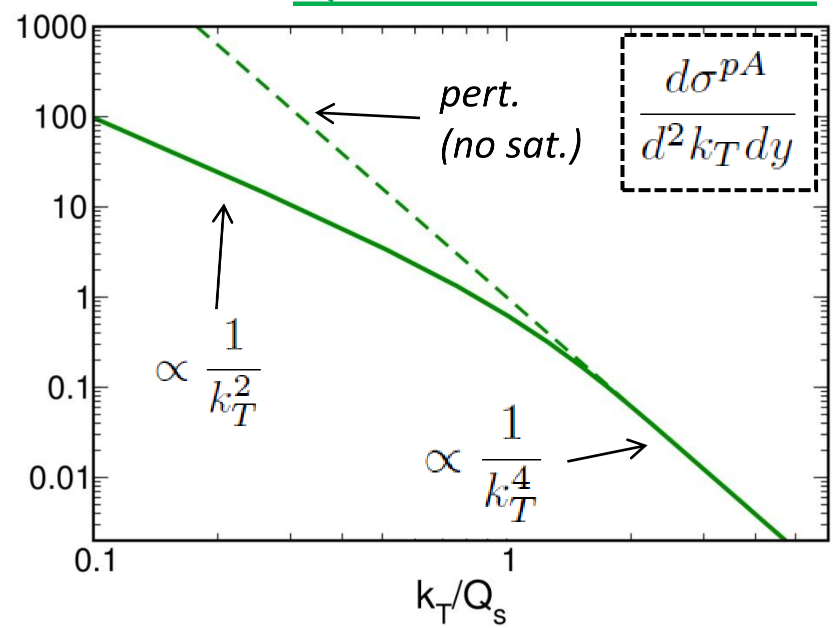


Longitudinal fields:

- Color Electric
- Color Magnetic

Evolve according to *Yang-Mills equations*

Qs: saturation scale

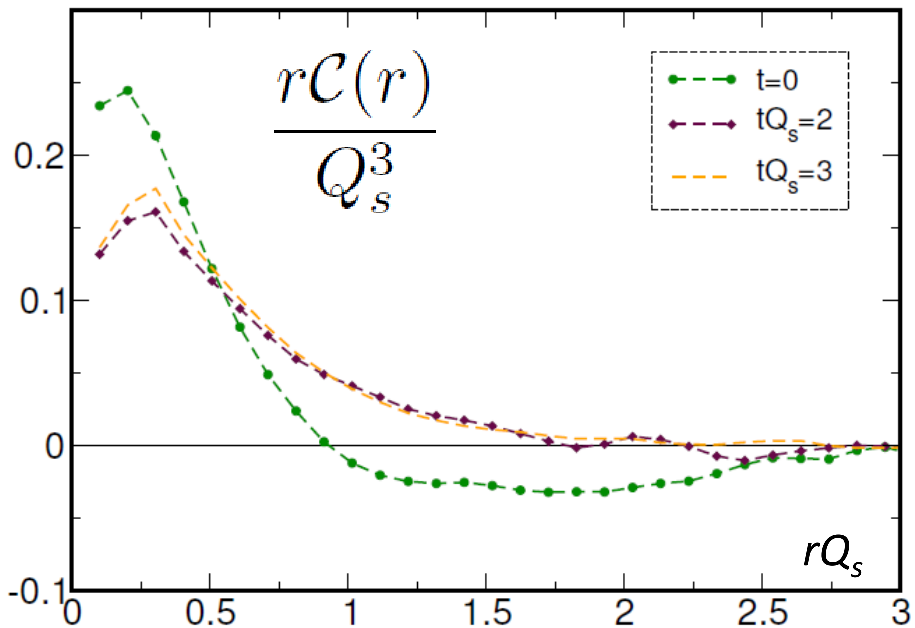


Evolving Glasma, 1

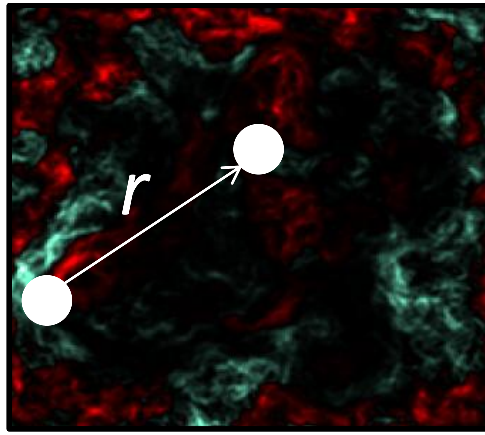
Lattice specifications:
Q_s=1 GeV, $\delta x*Q_s$=0.1, $L*Q_s$=30

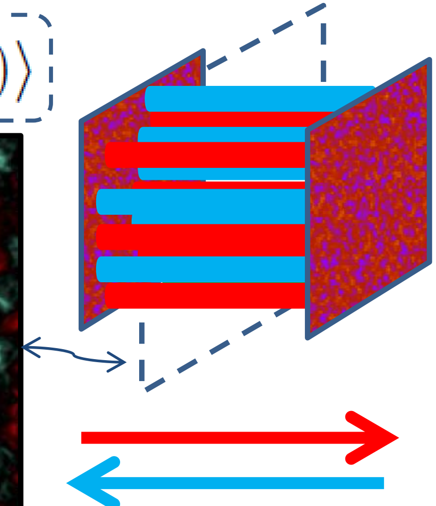
$$tQ_s = 1 \rightarrow t \approx 0.2\text{fm/c}$$

Gauge invariant magnetic correlator



$$\mathcal{C}(r) = \langle \tilde{B}_z^a(0)\tilde{B}_z^a(r)\rangle$$





Fitting form up to rQs≈1:

$$\mathcal{C}(r) \sim \sqrt{\frac{\xi}{r}}e^{-r/\xi}$$

ξ: correlation length

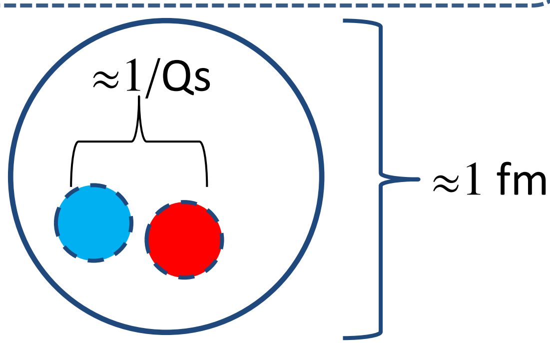
Initial time

- Correlation length ≈ 0.3/Qs ≈ 0.06 fm

  Nucleon size≈ 1 fm$\gg\xi$: *domains on sub-nuclear scale*

- Anti-correlation on length scale ≈ 1/Qs on the transverse plane

  Antiferromagnetic-like ordering on length scale ≈ 1/Qs



Evolving Glasma, 1.1

Lattice specifications:
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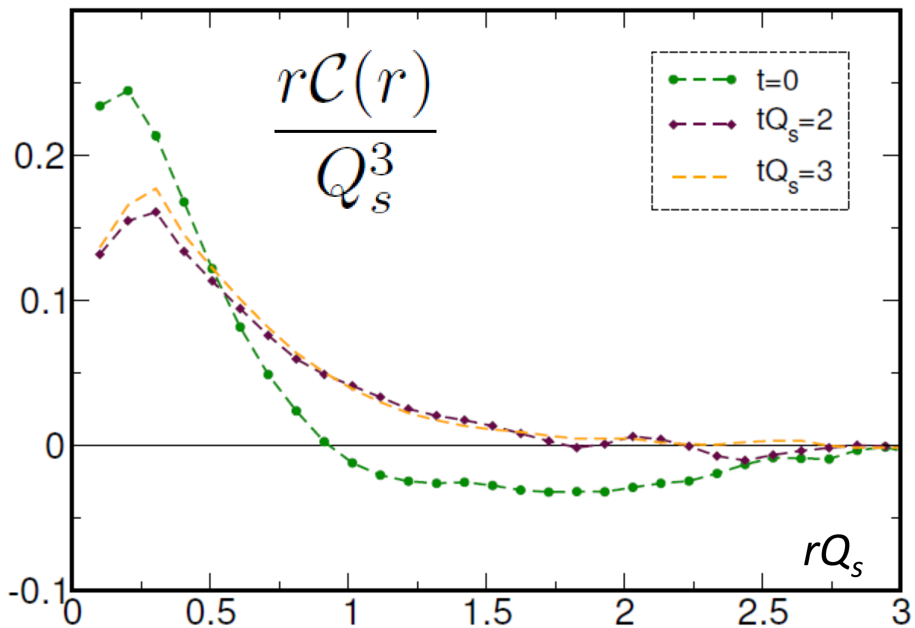
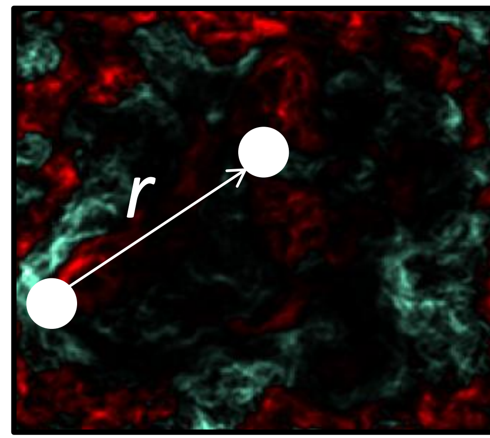
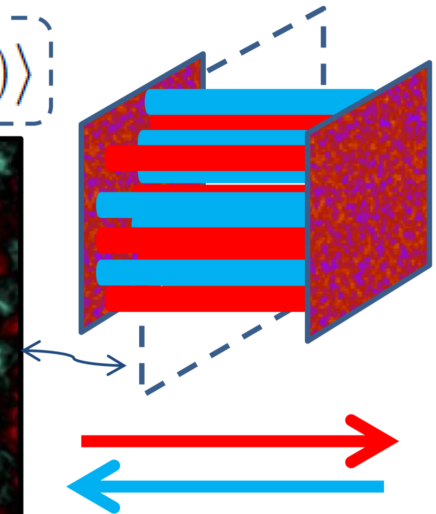
Gauge invariant magnetic correlator



$$\mathcal{C}(r) = \langle \tilde{B}_z^a(0) \tilde{B}_z^a(r) \rangle$$





Fitting form up to rQs≈1:

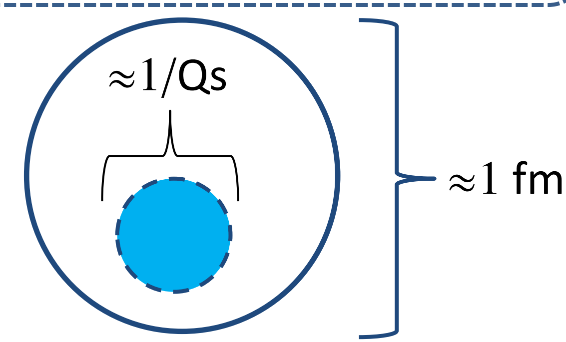
$$\mathcal{C}(r) \sim \sqrt{\frac{\xi}{r}} e^{-r/\xi}$$

ξ: correlation length

On a time scale O(1/Qs)

- Anticorrelation disappears: ***B*** aligns within a domain ≈1/Qs
- Correlation length increases up to≈1/Qs

Magnetic domains size grows up to O(1/Qs).
Magnetic domains still on lenght scale $\xi \approx 0.1 R_{nucleon}$



See also: Dumitru *et al.*, 1401.4124

Conclusions

- **Initial condition in relativistic nuclear collisions , *aka* Glasma:**
  - •Longitudinal classical color E and B
  - •Many hot spots, due to uncorrelation of color charge density in transverse plane
  - •Correlation over very small domains in transverse plane $\xi \ll R_{nucleon}$
  - •Anticorrelation on the length scale 1/Qs: anti-ferromagnetic like ordering of fields
  - •High pressure anisotropy: PL/PT=-1

- **Yang-Mills evolution leads to:**
  - •Transverse components of E and B
  - •Smoother fields
  - •Larger correlation length, up O(1/Qs), but modes still confined due to $\xi \ll R_{nucleon}$
  - •Lower, but still substantial, pressure anisotropy: PL/PT≈ 0.5

- **Fluctuations on the top of Glasma:**
  - •Allow quick isotropization: PL/PT≈ 1 for large enough seeds

Thanks for your attention

Acknowledgements
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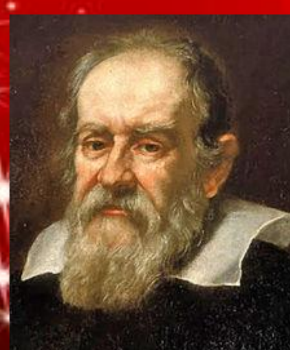

Io stimo più il trovar un vero, benché di cosa leggiera, che 'l disputar lungamente delle massime questioni senza conseguir verità nissuna.