Lattice results on gluon and ghost propagators in Landau gauge

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Outline

Motivation

- Kugo-Ojima confinement criterion Kugo, Ojima, '78
  absence of colored physical states $\Longrightarrow$ ghost propagator more singular than simple pole at $p^2 = 0$
- Gribov-Zwanziger confinement scenario

  Gribov '78, Zwanziger '91

  gauge fields within the Gribov region

$$\Omega = \{A_\mu(x) : \partial_\mu A_\mu = 0,\ M_{FP} \equiv -\partial D(A) \geq 0\}$$

  are accumulated at the Gribov horizon $\partial\Omega$
  $\Longrightarrow$ for $p^2 \to 0$ $G(p^2) \to \infty,\ D(p^2) \to 0$
- Comparison with other methods, e.g. Dyson-Schwinger Equations (DSE)

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Questions to lattice QCD

- Do propagators show predicted infrared behavior ?
- Are formulated confinement criteria valid?
- What is the influence of Gribov copies on the propagators ?
  Large volume limit?
- Infrared limit of the running coupling $\alpha_s(p^2)$?

Main Problems, Present Situation

- Gribov problem:
  Existence of several gauge copies inside Ω
  What are the right copies ?
  Restriction to fundamental modular region Λ required?
  Zwanziger, '04:
  $\langle O \rangle_\Omega = \langle O \rangle_\Lambda$
  This is to be checked in lattice computations
- Finite volume problem
  - minimal available moment

    $$p_{min} = 2\pi/L, \text{ where } L - \text{ lattice size}$$

  - propagators at p_{min} are not correct, i.e. real p_{min} is larger than $2\pi/L$

Few definitions :

gluon propagator

$$D^{ab}_{\mu\nu}(p) = \langle A^a_\mu(p) A^b_\nu(-p) \rangle = \left(\delta_{\mu\nu} - \frac{p_\mu \, p_\nu}{p^2} \right) \delta^{ab} D(p^2)$$

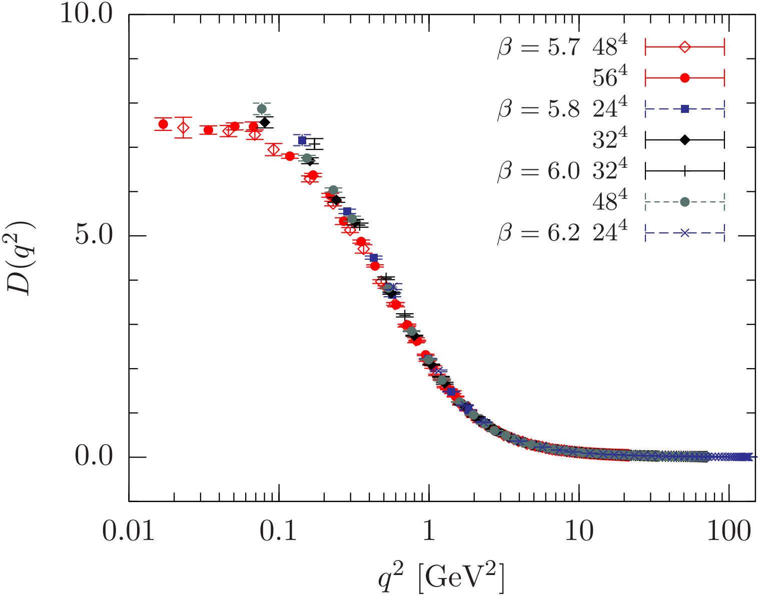
$$Z(p^2) \equiv p^2 D(p^2)$$

ghost propagator

$$\langle c(p) \bar{c}(-p) \rangle = G(p^2)$$

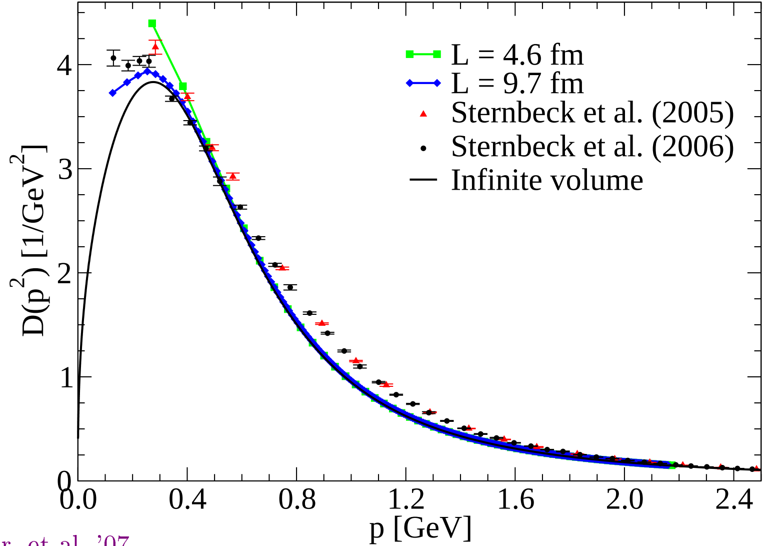
$$J(p^2) \equiv p^2 G(p^2)$$

Sternbeck et al. '06



Lattice vs. DSE (Gluon propagator)

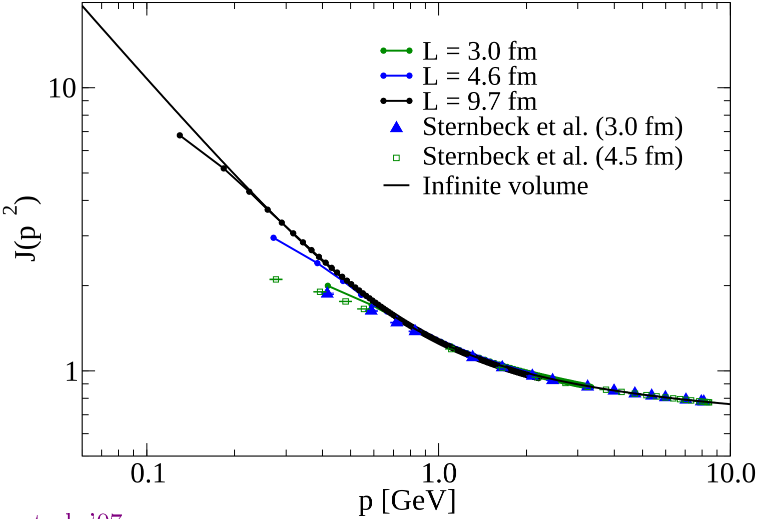
DSE: $D(p^2) \propto (p^2)^{\kappa_D - 1}$, $\kappa_D \approx 1.19$



Fischer, et al. '07

Lattice vs. DSE (Ghost propagator)

DSE: $G(p^2) \propto (p^2)^{-\kappa_G - 1}, \;\; \kappa_G = \kappa_D/2 \approx 0.595$



Fischer, et al. '07

New Results

Bogolubsky, VB, Burgio, Ilgenfritz, Mitryushkin, Müller-Preussker, '07

In $SU(N)$ gluodynamics the transformation, $Z \in Z_N$

$$U_\mu(..., x_\mu, ...) \longrightarrow Z\, U_\mu(..., x_\mu, ...), \;\; x_\mu - \text{fixed} \tag{1}$$

is equivalent to nonperiodic gauge transformation:

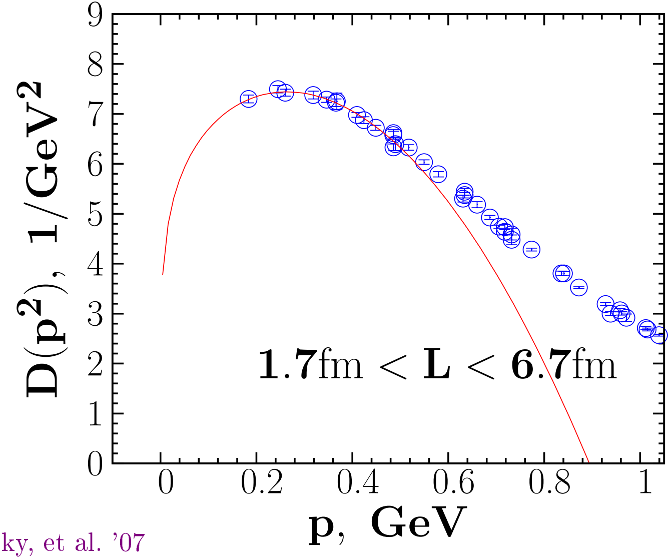
$$g(x + L\hat{\mu}) = Z\, g(x) \tag{2}$$

Gauge field configurations space is decomposed into N^4 sectors connected by such nonperiodic gauge transformations

Old procedure: all sectors are treated separately (N^4 gauge orbits)
New procedure: sectors are combined, i.e. one gauge copy

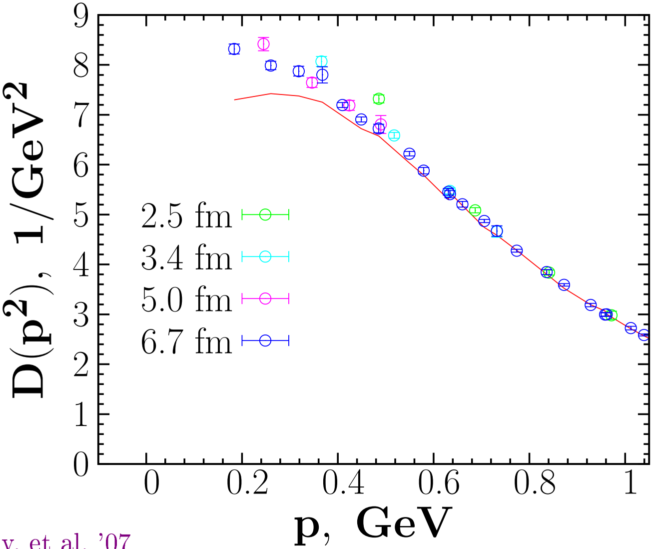
Additionally: few Gribov copies were generated for each sector and the best one was chosen

New procedure, lattice size up to 6.7 fm



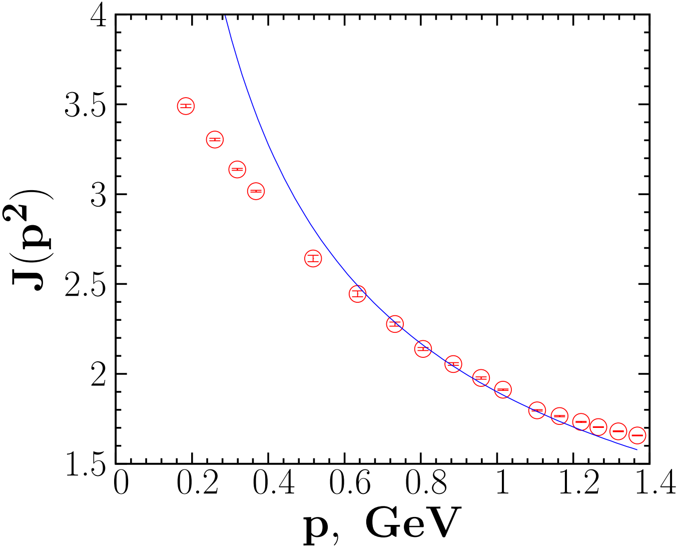
Bogolubsky, et al. '07

New procedure vs. old procedure



Bogolubsky, et al. '07

Ghost dressing function



Conclusions

- Gribov copies effects are very strong in the infrared region for both gluon and ghost propagators
- New procedure, combining N^4 gauge orbits into one gauge orbit, substantially reduces finite volume effects $\Longrightarrow$ for given L minimal accesible momenta are decreased by factor ~ 1.5
- For gluon propagator turning point is observed for the first time, thus agreement with DSE prediction becomes better. Needs further confirmation
- Lattice ghost propagator deviates from DSE prediction as before