SIGNATURES OF THE YANG-MILLS DECONFINEMENT TRANSITION FROM THE GLUON TWO-POINT CORRELATOR

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arXiv:2206.03841 [hep-ph]

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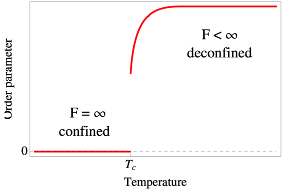
INTRODUCTION

- At some very high temperature T_c, hadrons become free quarks and gluons → quark-gluon plasma.
- An order parameter for this transition is the Polyakov loop:

$$\ell \sim \left\langle P e^{i \int_0^\beta d\tau A_0(\tau, x)} \right\rangle \sim e^{-\beta F}$$



- Under center symmetry, $\ell \to Z_N \ell$, so deconfinement is signaled by a broken center symmetry (in pure Yang-Mills).
- Confirmed by lattice data: second order transition for $SU(2)$, first order for $SU(3)$.

ENCODING OF THE TRANSITION

Polyakov loop:

$$\ell \sim \langle P e^{i\int_0^\beta d\tau A_0(\tau,x)} \rangle \sim e^{-\beta F}.$$

Because the Polyakov loop is related to A_0, it is expected that the transition is encoded in (the tower of)

$$\langle A_0 \rangle, \langle A_0 A_0 \rangle, \ldots, \langle A_0^n \rangle.$$

For the appropriate choice of gauge, can the transition be reflected in the lowest order correlators?

LANDAU GAUGE CORRELATOR

In principle:

- $\langle A \rangle$ is found by minimizing the effective action $\Gamma[A]$. It represents the state of the system . $\langle A_0 \rangle \rightarrow$ order parameter.
- The two-point correlator derives from the effective action

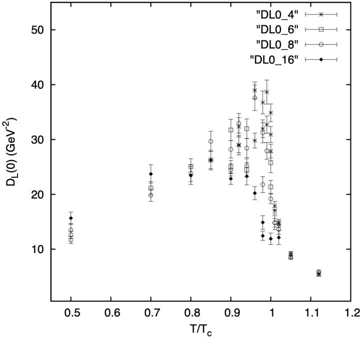
$$1 \Big/ \left.\frac{\partial^2 \Gamma}{\partial A^2}\right|_{A=\langle A \rangle} = \langle AA \rangle_c,$$

so for $SU(2)$, $\langle A_0 A_0 \rangle$ should diverge at T_c.

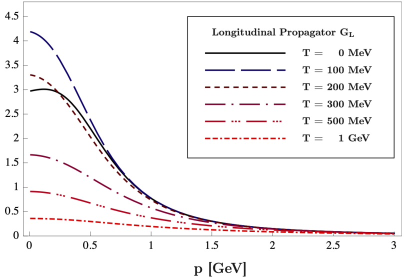
In practice:

- In the Landau gauge, $\partial_\mu A_\mu = 0$, then $\langle A_0 \rangle = 0$. $\rightarrow$ no order parameter.
- No evidence of divergence of $\langle A_0 A_0 \rangle$ was found on the (gauge-fixed) lattice and in the continuum.

$SU(2)$ LANDAU GAUGE CORRELATORS



Electric susceptibility (zero momentum longitudinal propagator)



Longitudinal gluon propagator

*T. Mendes and A. Cucchieri, PoS LATTICE2014, 183 (2015).

*L. Fister and J. M. Pawlowski, [arXiv:1112.5440 [hep- ph]](2012).

BACKGROUND FIELD GAUGES

- In the Landau gauge the effective action is not center-symmetric $\Gamma[A] \neq \Gamma[A^U]$.
- Introducing a background field $\bar{A}$, the effective action is gauge-invariant $\Gamma_{\bar{A}}[A] = \Gamma_{\bar{A}^U}[A^U]$. Landau-deWitt gauge:

$$\bar{D}_\mu(A_\mu - \bar{A}_\mu) = 0, \text{ with } \bar{D}_\mu \equiv \partial_\mu - \left[\bar{A}_\mu, \cdot\right].$$

- In the Background field effective action one looks at $\tilde{\Gamma}[\bar{A}] = \Gamma_{\bar{A}}[\bar{A}]$.
  - The two-point function $\langle AA \rangle_c$ is not directly accessible from $\tilde{\Gamma}_{\bar{A}}$.
  - Relies on the strict background independence of $\tilde{\Gamma}[\bar{A}]$, which is not easy to maintain in the presence of truncations.
- We propose the Center-symmetric Landau gauge, which fixes $\bar{A} = \bar{A}_c$. Then $\Gamma_{\bar{A}}[A] = \Gamma_{\bar{A}^{U^c}}[A^{U^c}]$.

OUR SETUP

- We work in the Landau-deWitt gauge with a background field $\bar{A}_\mu$:

$$\bar{D}_\mu(A_\mu - \bar{A}_\mu) = 0, \text{ with } \bar{D}_\mu \equiv \partial_\mu - \left[\bar{A}_\mu, \cdot\right].$$

- We take A^a_μ and $\bar{A}^a_\mu$ in the temporal direction, $\propto \delta_{\mu 0}$, and along the diagonal color directions (σ^3 for $SU(2)$, (λ^3, λ^8) for $SU(3)$), so that $\Gamma[A, \bar{A}] \propto V(A, \bar{A})$.
- The center-symmetric values for A^a_μ and $\bar{A}^a_\mu$ are found by Weyl chambers. For example in $SU(2)$, $A_{c,\mu} = \bar{A}_{c,\mu} = \delta_{\mu 0}\frac{T}{g}\pi\frac{\sigma^3}{2}$.
- We fix $\bar{A} = \bar{A}_c$: Center-symmetric Landau gauge.
  Center-symmetric phase when $\langle A \rangle = A_c$, $\rightarrow$ order parameter.

CURCI-FERRARI MODEL

We have computed $\langle A \rangle$ and $\langle A(0,p)A(0,-p) \rangle$ up to first loop order in the finite temperature Curci-Ferrari model:

$$S = S_{YM} + S_{gf} + \int_{x,\tau} \frac{m^2}{2}(A_\mu^a - \bar{A}_\mu^a)^2$$

Several motivations:

- Perturbative gauge-fixed Yang-Mills breaks down at low energies (Landau pole, Gribov copies...), there is no analytical model for this region.
- A gluon mass term seems to dominate the (unknown) gauge-fixed action in the IR; decoupling behaviour on the lattice. CF could be an effective model.
- The CF model is renormalizable, avoids the Landau pole and lifts the degeneracy between Gribov copies. Perturbative window into non-perturbative region.

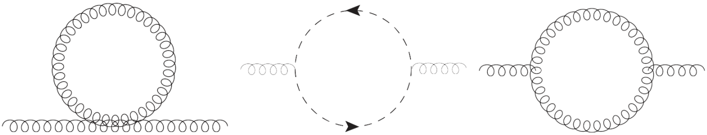
RESULTS - $T_c(MeV)$

	Lattice	FRG-BG [1]	CF-BG, 1-lp [2]	CF-BG, 2-lp [3]	CF-CS, 1-lp
SU(2)	295	230	238	284	**265**
SU(3)	270	275	185	254	**267**

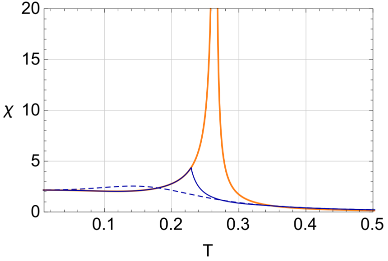
BG: Background effective action
CS: Centersymmetric Landau gauge

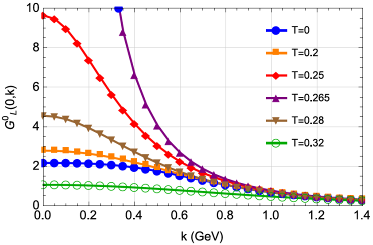
[1] L. Fister and J. M. Pawlowski, Phys.Rev. D88 (2013) 045010
[2] U. Reinosa, J. Serreau, M. Tissier and N. Wschebor, Phys.Lett. B742 (2015) 61-68.
[3] U. Reinosa, J. Serreau, M. Tissier and N. Wschebor, Phys.Rev. D93 (2016) 105002.

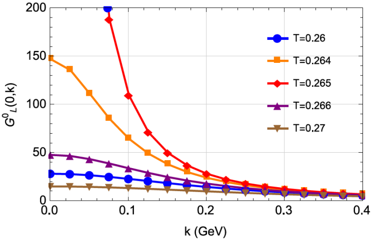
FEYNMAN DIAGRAMS GLUON PROPAGATOR



RESULTS: SU(2) GLUON PROPAGATOR





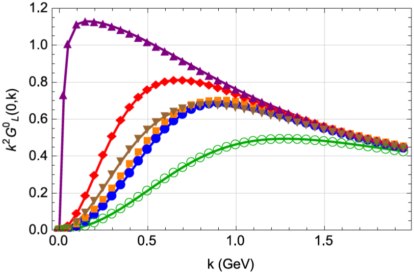


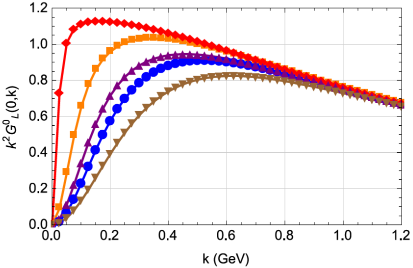
Landau gauge
Background field effective action
Centersymmetric Landau gauge

m=0.68 GeV, μ=1 GeV, g=7.5

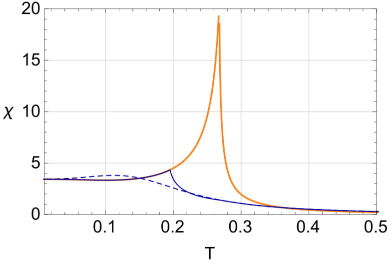
*DvE, U. Reinosa, J. Serreau and M. Tissier, SciPost Phys. 12, 087 (2022).

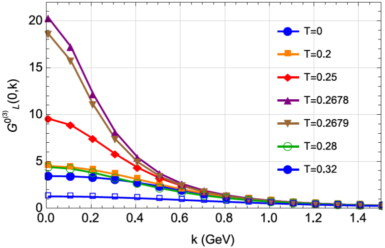
SU(2) DRESSING FUNCTION

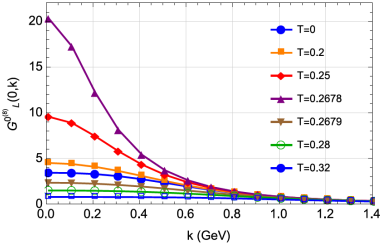




RESULTS: SU(3) GLUON PROPAGATOR





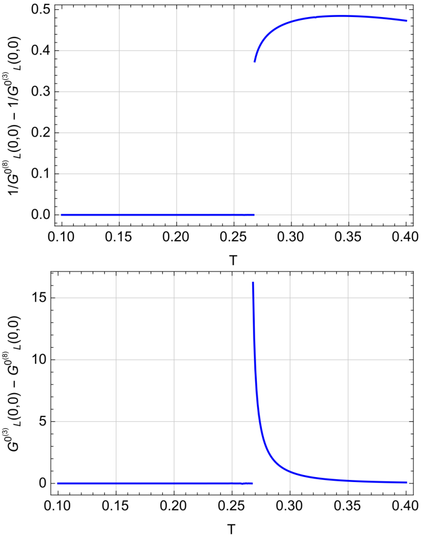


Landau gauge
Background field effective action
Centersymmetric Landau gauge

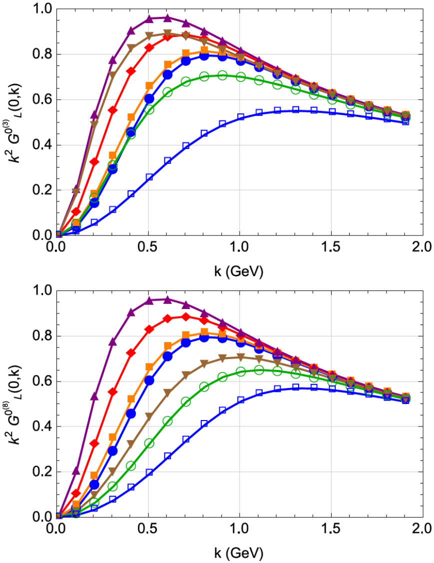
m=0.54 GeV, μ=1 GeV, g=4.9

*DvE, U. Reinosa, J. Serreau and M. Tissier, SciPost Phys. 12, 087 (2022).

SU(3) PROPAGATOR DIFFERENCE



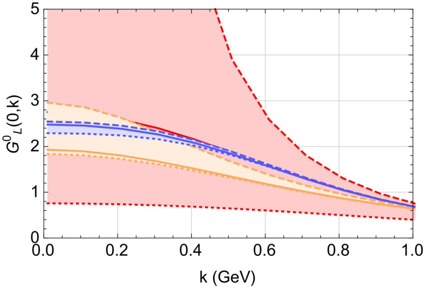
SU(3) DRESSING FUNCTION



CONCLUSION AND OUTLOOK

- We have performed, for the first time, calculations of the gluon one-and two-point correlator in the centersymmetric Landau gauge.
- We find a good agreement with lattice data for T_c.
- We find that for $SU(2)$, the deconfinement transition is signaled by a divergence of the longitudinal gluon propagator for $k \to 0$.
- For $SU(3)$, the difference between the propagators in the neutral color mode is an order parameter for the transition.
- This model can be tested on the lattice by changing the boundary conditions in the Landau gauge [with O. Oliveira and P. Silva].
- Ideas for future works: RG improvement, transversal propagator and two-loop calculation.

DISCUSSION

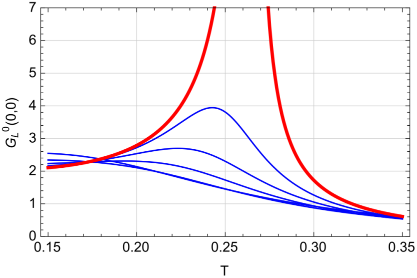


Landau gauge

Self-consistent Landau gauge

Center-symmetric Landau Gauge

DISCUSSION



DISCUSSION