Correlation functions of QC_2D at finite density

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Granada

UNI GRAZ

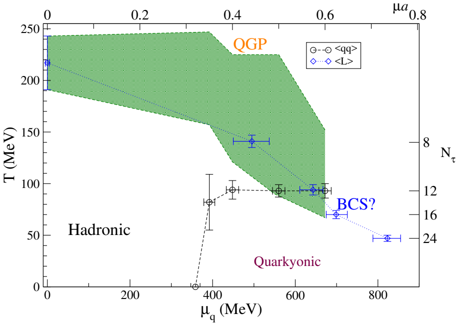
FWF Der Wissenschaftsfonds.

NAWI Graz

Why QC_2D?

- the simplest non-abelian gauge theory with fermions
- accessible at finite density on the lattice
- benchmark for other non-perturbative approaches to study QCD in different thermodynamic regimes.

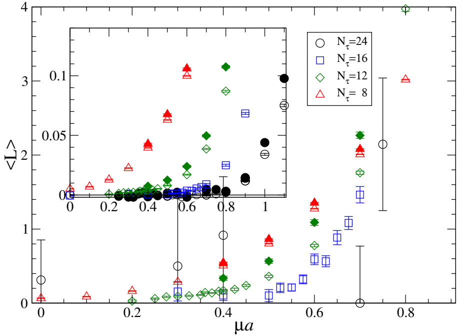
Phase Diagram



(Tamer Boz, Seamus Cotter, Leonard Fister, Dhagash Mehta ,Jon-Ivar Skullerud, EPJ 2013)

- hadronic phase at low density and temperature
- QGP at high temperature and/or density
- quarkyonic phase at medium density and low temperature

Polyakov loop



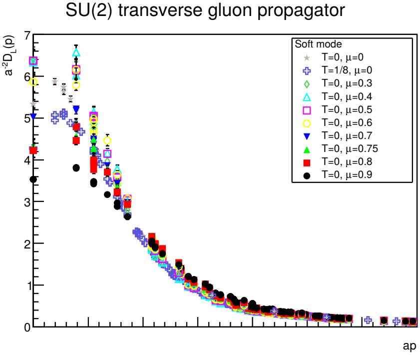
(S. Cotter, P. Giudice, S. Hands, J-I. Skullerud, Phys. Rev. D87 034507 (2013))

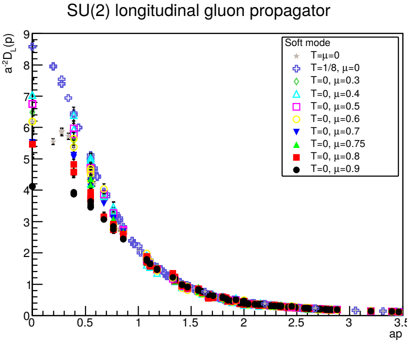
- a dramatic increase in $< L >$ resembling the "deconfinement" transition in YM theory. for large T and/or μ at $T = 0$ for $\mu > \mu_d$

Phase diagram vs correlation functions

- phase diagram in terms of fundamental degrees freedom
- correlation functions may contain information on thermodynamic features, e.g. phase transitions
- phase transitions occurs in medium at finite T and μ
- heat bath has a preferred direction - decomposition of Lorentz tensors necessary (transverse/longitudinal or magnetic/electric)

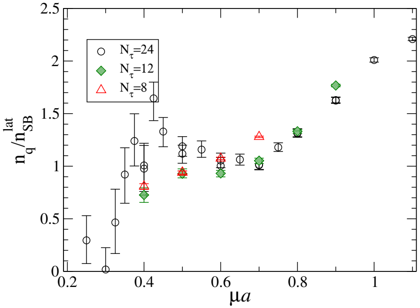
Gluon propagator at finite density

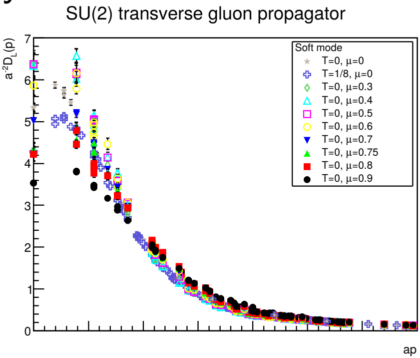




- IR enhancement for medium chemical potentials ($\mu_0 < \mu < \mu_d$) compared to the vacuum, within this region: almost μ independence
- IR screening of large μ ($\mu > \mu_d$)

Gluon propagator vs quark density

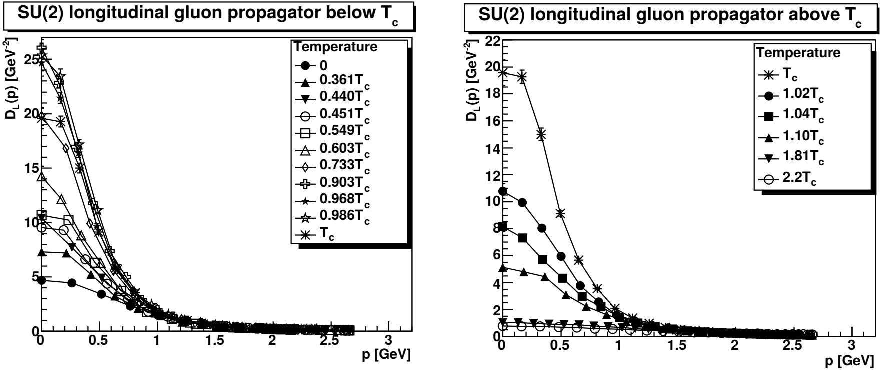




(Simon Hands, Seamus Cotter, Pietro Giudice and Jon-Ivar Skullerud, XQCD 2012)

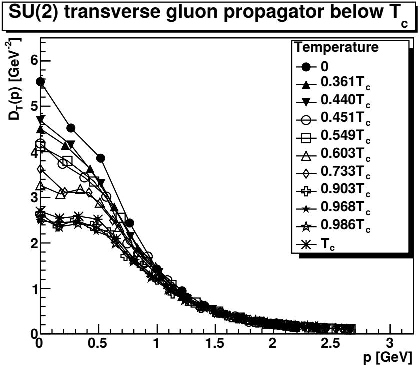
- the screening region of chemical potential for gluon propagator corresponds to the region of strongly interacting quark matter for $\mu > \mu_d$ $(\frac{n_q}{n_{SB}} > 1)$
- the region $\mu_d > \mu > \mu_0$ with almost constant value for the gluon propagator covers the "weakly" interacting region $n_q \sim n_{SB}$

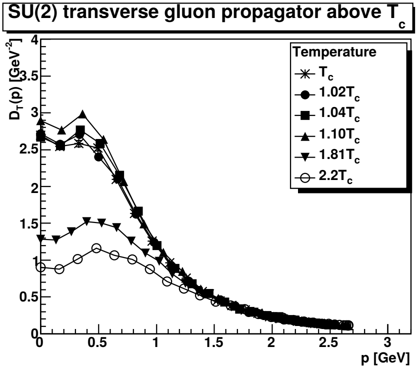
Gluon Propagator at finite temperature YM



(Christian S. Fischer, Axel Maas, and Jens A. Mueller, EPJ 2010)

- IR limit of longitudinal propagator responds strongly to the phase transition: the drop above T_c

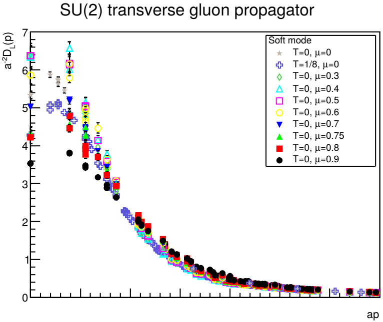


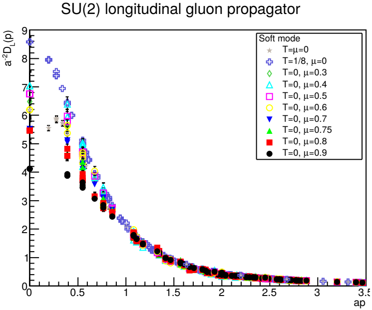


(Christian S. Fischer, Axel Maas, and Jens A. Mueller, EPJ 2010)

- transverse propagator is less sensitive to the phase transition
- below and above T_c almost temperature independent

Finite density propagator

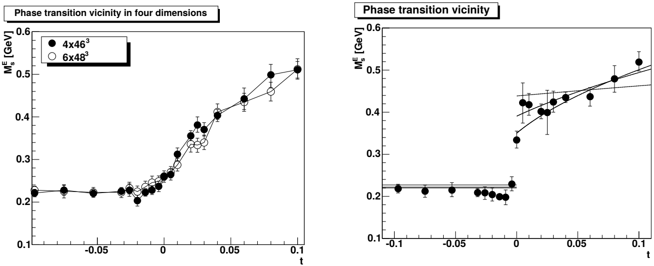




- no considerable difference between longitudinal and transverse propagator around μ_d.
- different from finite T case.

Screening mass at finite temperature

Screening mass: $M_s = \frac{1}{\sqrt{D(0)}}$, D(0) is the propagator at zero momentum.

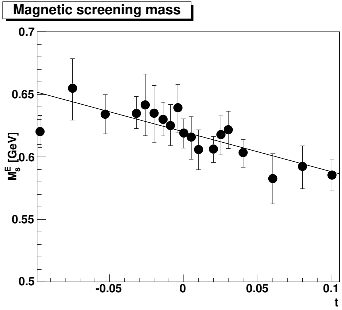


SU(2) left, SU(3) right

(Axel Maas, Jan M. Pawlowski, Lorenz von Smekal, Daniel Spielmann, Phys. Rev. D 85, 034037 (2012))

- the 2nd order phase transition is indicated by the continuous increase of the screening mass of SU(2) gluon propagator as well as the 1st order transition by a jump in the screening mass of SU(3) gluon propagator around T_c

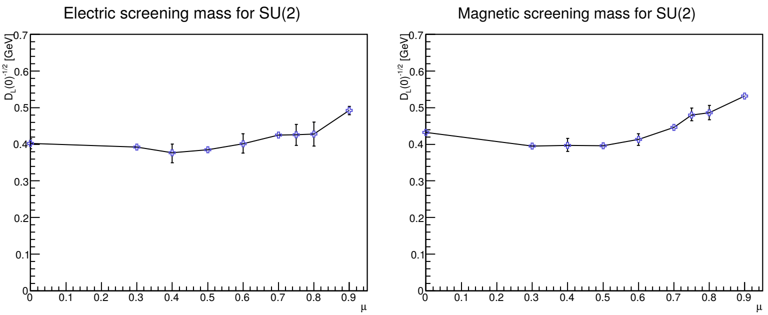
Screening mass at finite temperature



(Axel Maas, Jan M. Pawlowski, Lorenz von Smekal, Daniel Spielmann, Phys. Rev. D 85, 034037 (2012))

- magnetic screening mass does not indicate effects of the phase transition

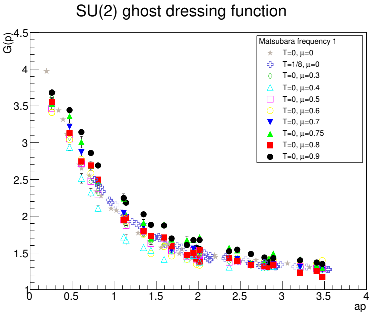
Screening mass at finite density



- no significant difference between electric (longitudinal) and magnetic (transverse) screening mass
- the effect of transition is not observed at finite density in the electric screening mass compared to finite T.
- the response of the magnetic screening mass to the phase transition is more observable than the electric part, in contrast to the finite T case.

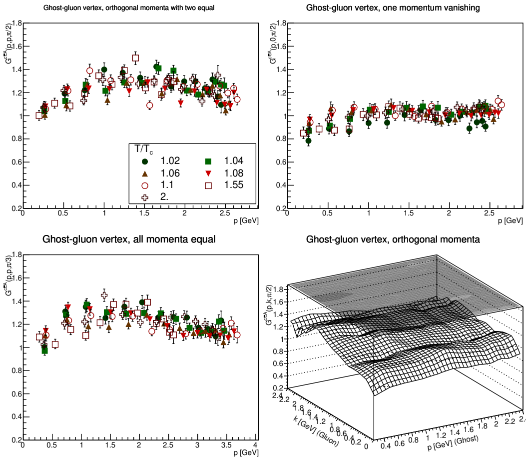
Ghost Dressing function

- no difference between finite T and μ caes.
- IR enhancement
- no obvious temperature dependence.



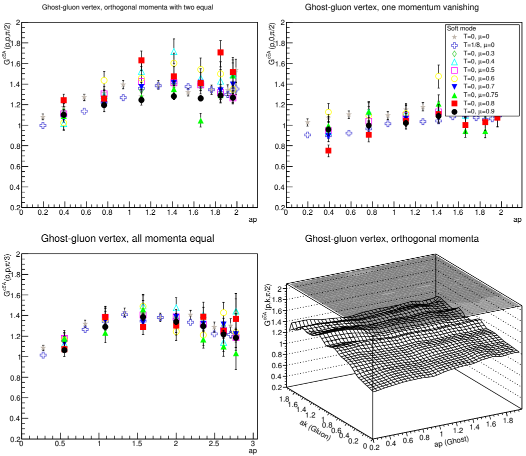
ghost-gluon vertex at finite temperature

no temperature dependence around the phase transition.



(Leonard Fister, Axel Maas, Phys. Rev. D 90, 056008 (2014))

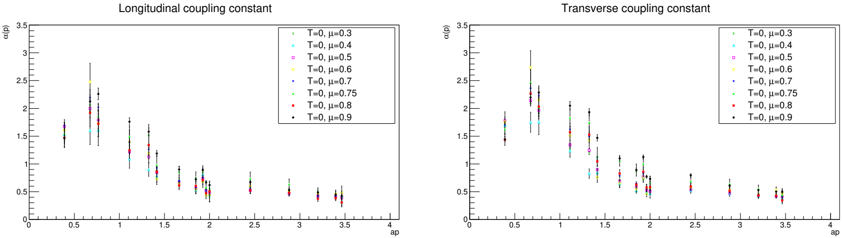
ghost-gluon vertex at finite density



- no significant difference between finite T and finite μ
- IR constant in all cases

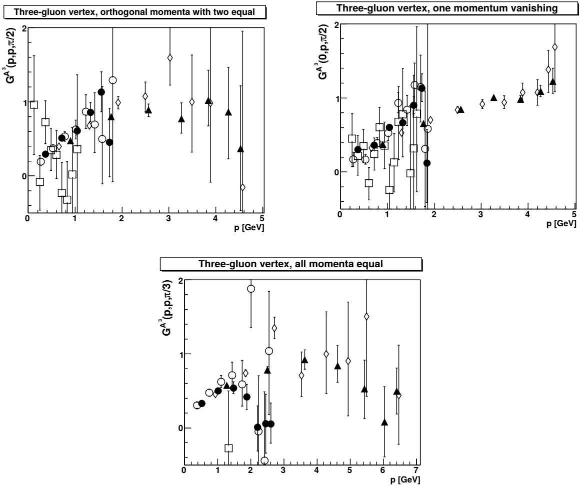
Running coupling

running coupling derived from ghost-gluon vertex



- similar to the coupling in the vacuum
- no signature of quarkyonic phase ($n_q \sim n_{SB}$)

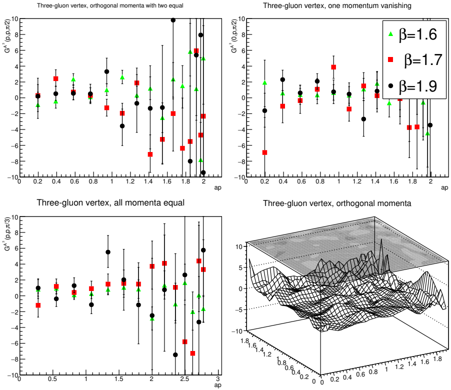
three gluon vertex of SU(2) YM in the vacuum, for different lattices



(Attilio Cucchieri, Axel Maas, Tereza Mendes,Phys.Rev.D77:094510,2008)

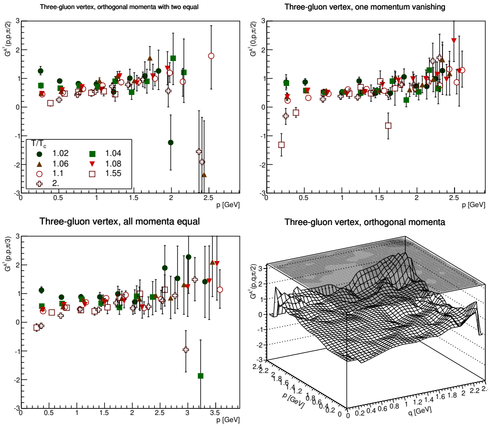
IR suppression of tree level element of the three gluon vertex for three different kinematics.

three gluon vertex of unquenched SU(2) in the vacuum



behavior compatible with the YM case

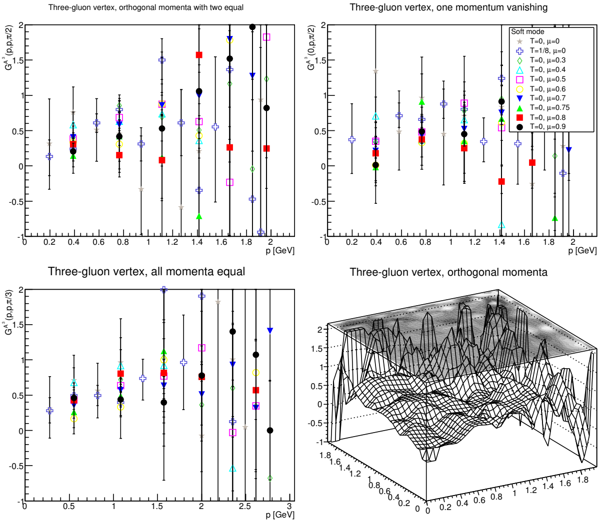
magnetic three gluon vertex at finite temperature



(Leonard Fister, Axel Maas, Phys. Rev. D 90, 056008 (2014))

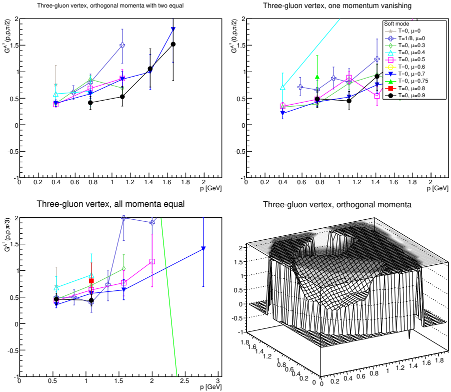
- pronounced temperature dependence
- IR enhancement close to T_c, in contrast to $T = 0$ case.
- sensitivity to the transition like electric propagator: surprising for the magnetic vertex

three gluon vertex at finite density



within the statistics no special trend is observed for the whole set of data

three gluon vertex at finite density, data with less than 50% error



- IR suppression
- no obvious trend, different from $T = 0$ and $\mu = 0$
- no dependence on the chemical potential in contrast to the effect of temperature.

conclusion

- significant difference between finite temperature and finite density behavior of gluonic sector close to the phase transition
- ghost sector is insensitive to medium: no significant temperature or density dependence for ghost-gluon vertex and ghost propagator
- no signal of free or weakly interacting region from the ggv
- remarkable simplification for functional methods due to the decoupling of ghosts and gluons from matter

outlook

- more extensive finite temperature study in the unquenched regime to be compared to the quenched data in order to determine the effect of the dynamical quarks in the medium on the gauge sector
- searching for the underlying mechanism responsible for qualitatively different critical behavior of gluonic sector at finite density and finite temperature