The Quark-Gluon Vertex from Lattice QCD at Finite Temperature

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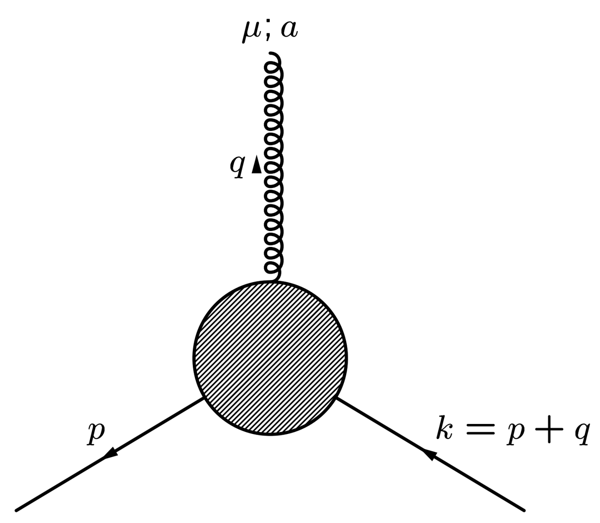
The Project

Calculate non-perturbative 2- and 3-point quark and gluon Green's functions on anisotropic lattices at finite temperature.

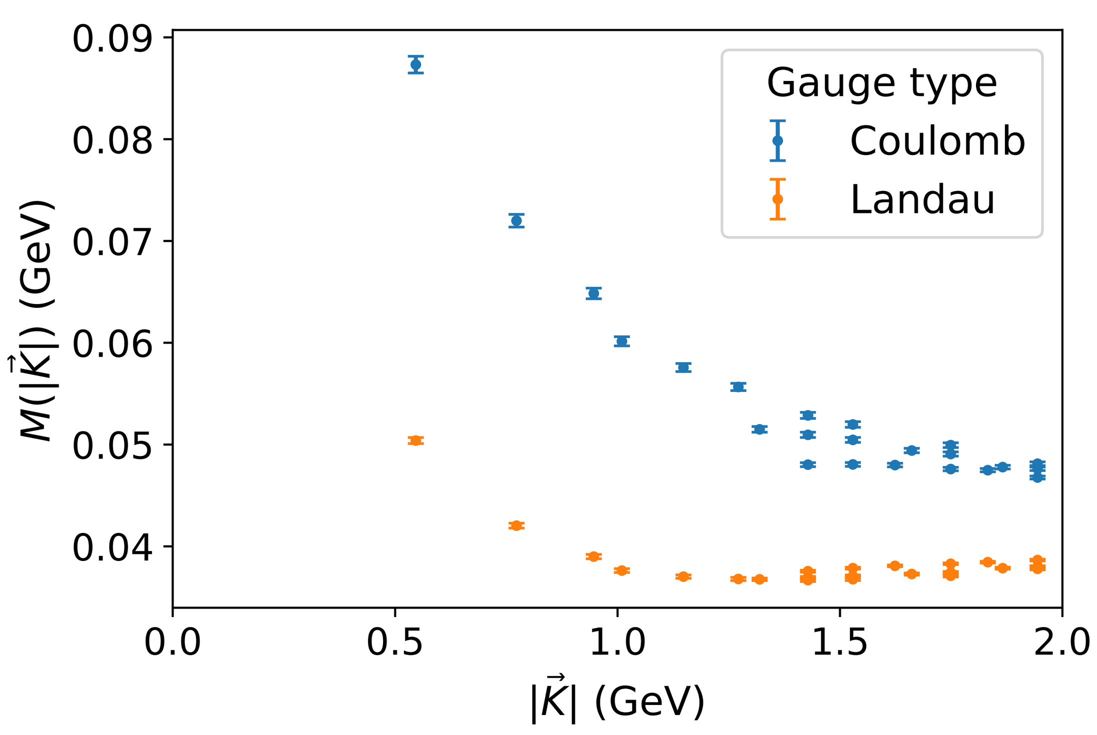


Our aim is contribute to answering:

- What is the manifestation of confinement and chiral-symmetry breaking on Green's Functions of QCD?
- How do Green's functions behave across the deconfinement/chiral-symmetry restoration transition?
- Behavior changes quantitatively or qualitatively for different gauges?
- Also provide cross-checks for other non-perturbative methods

Encouragement from SU(2)

In another project of our group at NUIM, the Coulomb and Landau quark propagators in SU(2) are being calculated.



The (preliminary) mass function seems to have similar behavior in the infrared for both gauges, but with different scales.

Infrastructure and Software

- ICHEC - Kay: 336 nodes 40-core Intel Xeon Gold ea. For inversions and Fourier transform.

- Local Machines: 8-core Intel i3-10100 ea. For gauge-fixing, pre- and post-processing
- Using C++ USQCD-chroma and C openQCD libraries for inversions, and own C code for gauge-fixing, Fourier transform and form-factor extraction.

FASTSUM Ensembles

Anisotropic lattices $a_s = \xi a_t$ with improved (plaquettes+rectangles) gluon action given by

$$\frac{\beta}{N_c} S_G = \frac{1}{\gamma_g}\left[\sum_{n,i<i'} c_0 P_{ii'} + c_1\left(R_{ii'} + R_{i'i}\right)\right] + \gamma_g\left[\sum_{n,i}(c_0 + 4c_1)P_{i4} + c_1\left(R_{i4} + R_{4i}\right)\right] \quad (1)$$

and action for Wilson fermions ($N_f = 2+1$): $S_F = \sum_{x,y} \bar{\psi}_x \mathcal{M}_{xy} \psi_y$,

$$\mathcal{M}_{xy} = \left(a_t m_0 + 1 + \frac{3}{\gamma_f}\right)\delta_{x,y} - \frac{1}{\gamma_f}\sum_{i=1}^{3} H_{i;\,xy} - H_{4;\,xy} - \frac{c_t}{2}\sum_i \sigma_{i4}F_{i4} - \frac{c_s}{2}\sum_{i<i'}\sigma_{ii'}F_{ii'} \quad (2)$$

where H_μ are hopping terms.
Coeffs. tuned by HadSpec collab. Gen2's physical params. are: $a_s = 0.1205(8)$fm, $\xi = 3.444(6)$ and $m_\pi = 384(4)$MeV; and Gen2L's: $a_s = 0.1136(6)$fm, $\xi = 3.453(6)$ and $m_\pi = 236(2)$MeV.

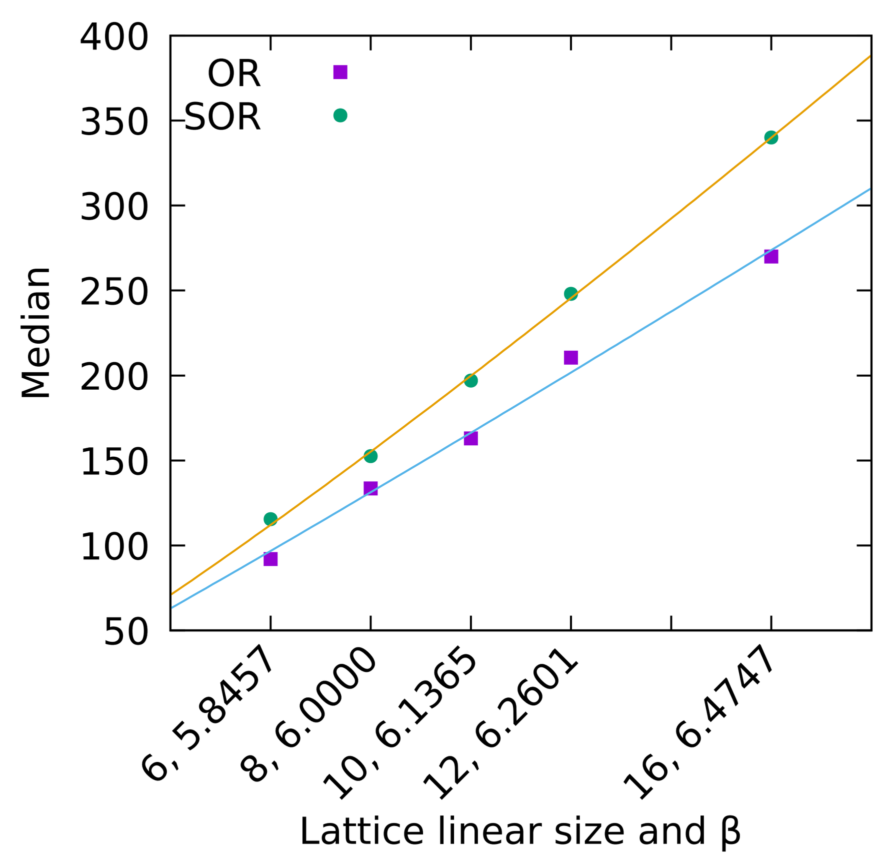
Gauge Fixing - Overrelaxation

Gauge-fixing is necessary to study Green's functions.
Number of sweeps to gauge-fix scales linearly with side of lattice when using overrelaxation(OR) algorithm. It is also faster than stochastic overrelaxation (SOR).

- Implemented MPI/OpenMP parallelized version of OR.
- Implemented Coulomb-gauge, more straightforward for anisotropic lattices;

$$\vec{\nabla}\cdot\vec{A} = 0 \iff \max_{\{g\}} \operatorname{Re}\operatorname{Tr}\sum_{i,n} U_i^g(n)$$

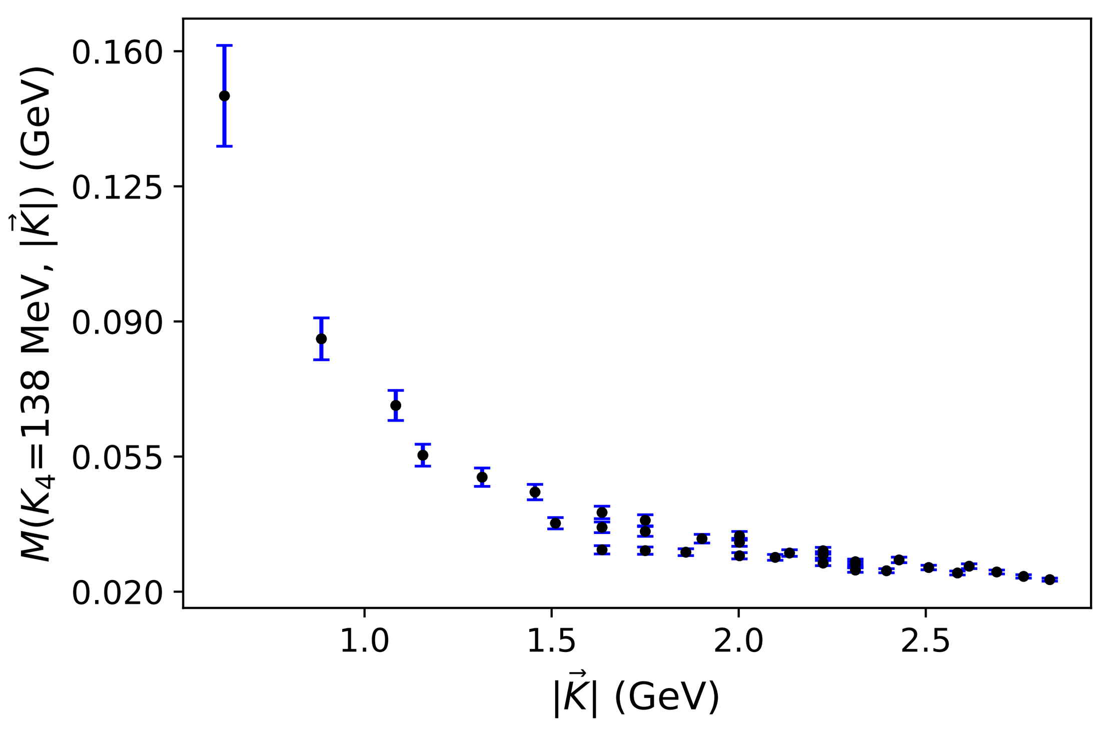
- Plan to implement Landau gauge.



Preliminary Results

In momentum space, expected form of the quark propagator is

$$S^{-1}(p_4, p) = i\vec{\gamma}\cdot\vec{p}\,A(p_4,\vec{p}) + B(p_4,\vec{p}) + i\gamma_4 p_4\,C(p_4,\vec{p}).$$



Displayed is our first result for the Coulomb-gauge quark mass function B/A for $16^3 \times 128$ lattice.

- Leading lattice artifacts subtracted.
- Seems to indicate the same behavior present in SU(2), but at a larger scale, showing the effect of χ-symmetry breaking in the infrared.
- Quark fields still need to be improved.

Next Steps

- Analysis of Coulomb propagator;
- Calculate vertex for selected kinematic configurations;
- Work out vertex tensor decomposition;
- Extend our study to high temperatures and larger volumes.

References

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[3] O. Oliveira and P. Silva. *Eur. Phys. J. C*, 79(9):793, 2019.

Acknowledgments

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