Roles of fermions in the lattice Landau gauge and Coulomb gauge QCD

Sadataka Furui
School of Science and Engineering, Teikyo University, 320-8551 Japan.

We measured the effective coupling of QCD in Landau gauge and Coulomb gauge using the unquenched gauge configurations using the Kogut-Susskind fermion at zero tmperature (MILC)[1] and at finite temperature (MILC$_{ft}$)[2] produced by the MILC collaboration, and those using the domain wall fermion (DWF)[3] produced by of the RBC/UKQCD collaboration[4].

In Landau gauge, the effective coupling

$$\alpha_s(q) = q^6 D_G(q)^2 D_A(q).$$

shows infrared suppression but in Coulomb gauge

$$\alpha_I(\boldsymbol{q}) = \boldsymbol{q}^5 D_G(\boldsymbol{q})^2 D_A(\boldsymbol{q})$$

freezes in the infrared and $\alpha_I(\boldsymbol{q})/\pi \sim 1$. Here, $D_G(q)$ and $D_A(q)$ are the ghost propagator and the gluon propagator in 4-dimensional space, $D_G(\boldsymbol{q})$ and $D_A(\boldsymbol{q})$ are those in 3-dimensional space.

The result of Coulomb gauge agrees well with the data extracted from experiments by the JLAB group[5]. Enhancement of the effective coupling from the pQCD(dash-dotted lines) in a few GeV region is expected to be due to the A^2 condensates[6].

The infrared suppression of the effective coupling is caused by the weak singularity of the ghost propagator. We observed that the modulus of the color antisymmetric ghost prorpagator of the MILC, MILC$_{ft}$ and RBC/UKQCD in the infrared has steeper slope than that of the color diagonal ghost propagator[6]. Suppression of the effective coupling in Landau gauge is expected to be an artefact due to the color antisymmetric ghost propagator[7].

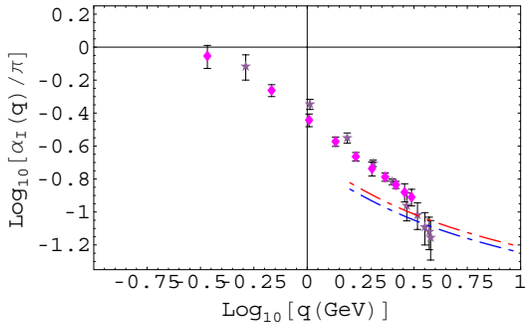

Figure 1: The running coupling $\alpha_I(\boldsymbol{q})/\pi$ of MILC$_{3f}$(red diamonds) and MILC$_{2f}$(blue stars) in Coulomb gauge. The pQCD result of $N_f = 3$ (upper dash-dotted line) and $N_f = 2$ (lower dashed line) are also plotted.

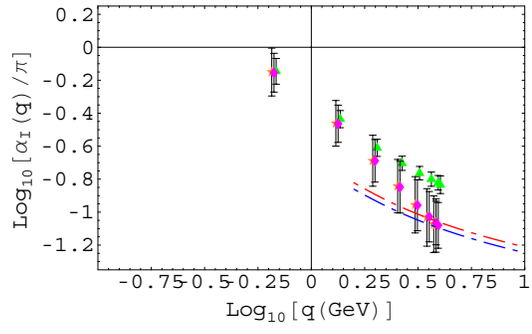

Figure 2: The running coupling $\alpha_I(\boldsymbol{q})/\pi$ of DWF $m = 0.01$(green triangles), 0.02(magenta diamonds) and 0.03(orange stars) in Coulomb gauge.

References

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