Binder cumulant of the color anti-symmetric ghost propagator in the lattice Landau gauge QCD

Sadataka Furui[1] and Hideo Nakajima[2]
[1] *School of Science and Engineering, Teikyo University, 320-8551 Japan.*
[2] *Department of Information Science, Utsunomiya University, 321-8585 Japan.*

In lattice Landau gauge QCD simulation[1], we observed possible evidence of A^2 condensate in the QCD running coupling and in quark propagator. Since A^2 is not BRST invariant, presence of ghost condensates as the BRST partner was speculated in the modified maximal abelian approach[2] and the local composite operator (LCO) approach[3]. As the order parameter of the ghost condensates, in analogy to the Overhauser effect, the color anti-symmetric ghost propagator was proposed[3] and Cucchieri et al.,[4] measured the Binder cumulant $U(q) = 1 - \frac{\langle\vec{\phi}(q)^4\rangle}{3\langle\vec{\phi}(q)^2\rangle^2}$ where $\vec{\phi}(q)^2$ is square of the color antisymmetric ghost propagator. The factor 3 in the denominator is introduced such that for $\phi(q)$ with 1-dimensional Gaussian distribution the Binder cumulant $U(q)$ becomes 0.

When $\vec{\phi}(q)$ is a random d-dimensional vector with Gaussian distribution, the expectation value $\frac{\langle\phi(q)^4\rangle}{3\langle\phi(q)^2\rangle^2}$ becomes $\frac{d+2}{3d}$. We checked the results of [4] using the SU(2) gauge configurations gauge fixed by the parallel tempering (PT) method [5] and the first copy, and confirmed that $U(q) \sim 1 - \frac{5}{3\cdot 3} = \frac{4}{9}$, which means that the data can be explained by the Gaussian distribution. At the lowest momentum point, the first copy showed larger fluctuation than the PT samples.

In the case of unquenched SU(3) $20^3\times 64$ lattice configurations with use of Kogut-Susskind fermion produced by MILC collaboration, $U(q)$ in the $q > 0.8$GeV region is $\sim 0.63(3)$ which deviates from the value corresponding to the 8 dimensional Gaussian distribution : $1 - \frac{10}{3\cdot 8} = \frac{7}{12}$. The fluctuation is the largest not in the lowest momentum point but at the momentum whose one spacial component is 1 and other components are zero[6]. The difference from the quenched SU(2) could be due to the improvement in the Asqtad action used in the MILC$_c$ and/or the presence of dynamical fermions.

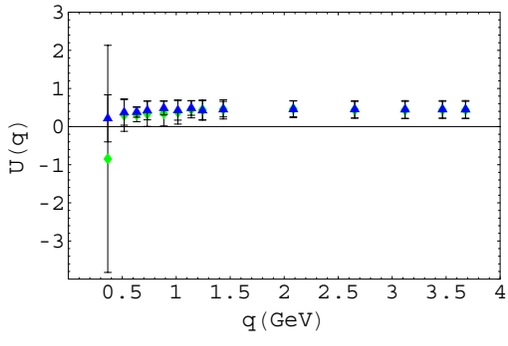

Figure 1: The Binder cumulant $U(q)$ of quenched SU(2), $\beta = 2.2$, $a = 1.07\text{GeV}^{-1}$ of PT samples (triangles) and first copy samples (diamonds).

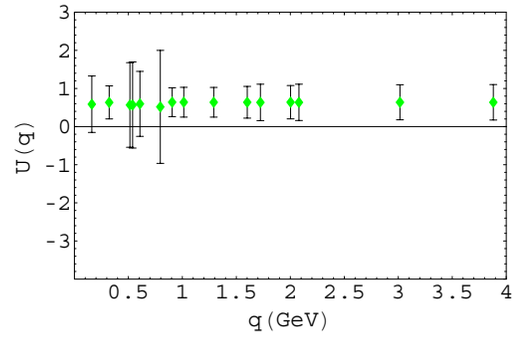

Figure 2: The Binder cumulant $U(q)$ of unquenched Asqtad action, MILC$_c$, $a = 0.61\text{GeV}^{-1}$.

References

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