Baryon number cumulant ratios at finite density in the strong-coupling lattice QCD
A. Ohnishi¹, T. Ichihara², K. Morita¹
1. Yukawa Inst. for Theoretical Physics, Kyoto U., 2. Dept. of Phys., Kyoto U.

Introduction

Critical point in QCD phase diagram connects Crossover trans. at low µ and first order trans. at high µ
Asakawa, Yazaki ('89)
→ CP could be accessible in BES.

Fluctuations of conserved charge = Promising signal of CP

\[ S^c = \frac{1}{N} \left( \sum_{x} V \bar{U}(x) \chi_{s} \right)^2 / \left( \sum_{x} \left( \chi_{s} V \right)^2 \right) \]

→ Contains information on earlier stage.
→ Remnant of O(4) criticality may cause non-monotonic behavior of the singular part.
Friman, Karsch, Redlich, Skokov ('11)

Larger fluctuation of order par. around CP → Negative κ
Stephanov ('11) [Z(2)]
→ Non-monotonic behavior of cumulant ratio is observed at BES.

We need calculation including regular part at finite µ!
This work:
Net baryon number cumulants at finite T and µ in the strong-coupling and chiral limit of lattice QCD

Strong-Coupling Lattice QCD

Lattice QCD action (unrooted staggered fermion)

\[ L = \frac{1}{2} \sum_{x} \left( V^+ \left( \chi_{s} \bar{U}(x) \chi_{s} \right) - \left( \chi_{s} \bar{U}(x) \chi_{s} \right) V^+ \right) + \frac{\alpha}{2N} \sum_{x, y} M_{s} M_{s} \chi_{s} \chi_{s} \]

→ Fermion action with four-Fermi int. (LO in 1/d expansion)

Extended Hubbard Stratonovich trans.

\[ S_{AF} = -\frac{1}{2} \sum_{x, y} \chi_{s} \left( \chi_{s} \bar{U}(x) \chi_{s} \right) \frac{1}{M} \sum_{x, y} M_{s} M_{s} \]

Results

Lattice setup
unrooted staggered fermion
[O(2) symmetry]

Strong-coupling and chiral limit

Auxiliary Field MC method on 4', 6' x 4', 8' lattices
Ichihara, Nakano, AO ('14)

\[ \mu/T = 0.2, 0.3, 0.5, 0.6, 0.8 \]

Size dependence
Amplitude show divergent behavior
Negative valley in κσ narrows with increasing lattice size.
[Singular part dominance]

Consistent with the O(4) scaling analysis
Friman, Karsch, Redlich, Skokov ('11)
[Qualitative behavior is similar in O(4) and O(2)]

Negative normalized kurtosis region in the QCD phase diagram
Negative kurtosis area exists around the phase boundary.

Expected to shrink in the chiral and thermodynamic limit.

Summary & Discussion

We investigate normalized skewness (Sσ) and kurtosis (κσ) in the chiral and strong coupling limit (5-6 lattice).

We find oscillatory behavior at large µ/T and negative kurtosis valley due to the finite size effect.

Peak heights of skewness and kurtosis increases and negative valley of kurtosis shrinks on larger lattices, as suggested in O(4) scaling analysis in the chiral limit.

Finite lattice size is found to smear the critical behavior of cumulants as the finite quark mass does.

Important next steps
Cumulants on larger lattices [Finite size scaling].
Finite mass effects [Negative region should survive on large lattice].

Ref: