2+1 Flavor Fine Lattice Simulations for Finite Temperature with Domainwall Fermions

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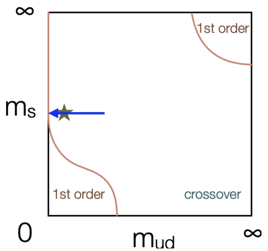
ref. talk by Y.Aoki, at Lattice 2021 conference, 2021 Jul.
talk by. I.K., at JPS meeting, 2021 Sep.

Introduction

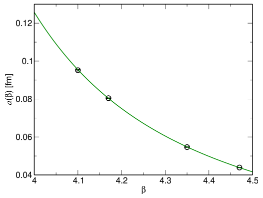
How was the early universe (high T)?
Order of the phase transition?
Quark mass dependence?
is the physical point really cross over?



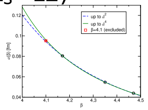
This work: simulation with quark masses fixed in the physical unit (line of the constant physics)
Important: simulation with fine lattice and good chiral symmetry
recent works imply as the lattice becomes finer, the 1st order region at the left bottom shrinks!?
(e.g. plenary talk by Anirban Lahirat at Lattice2021 conference)

Parameter Settings

action: Symnzik + (2+1) flavor Moebius Domainwall fermion (L_s=12)

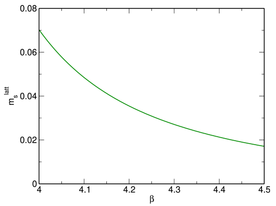


lattice spacing vs. beta: fit works fine
including extrapolation to beta=4.0



t_0 from JLQCD T=0 configurations
and parameterizaiton by Edwards et al. (1998)

$$a = c_0 f(g^2)\left(1 + c_2\hat{a}(g)^2 + c_4\hat{a}(g)^4\right)$$
$$(g)^2 \equiv \left[f(g^2)/f(g_0^2)\right]^2 \quad f(g^2) \equiv (b_0 g^2)^{-b_1/2b_0^2} \exp\left[-\frac{1}{2b_0 g^2}\right]$$
$$b_0 = \frac{1}{(4\pi)^2}\left(11 - \frac{2}{3}N_f\right),\ b_1 = \frac{1}{(4\pi)^2}\left(102 - \frac{38 N_f}{3}\right)$$

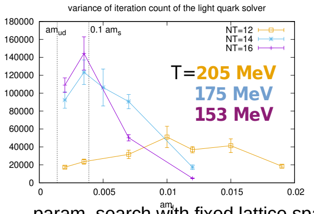


bare quark mass vs. beta

input: ms=92 MeV(MSbar 2GeV), ms/mud=27.4
non-perturbative renormalization by Tomii et al. (2016)

Acknowledgments:
code set: GRID, Hadron, BQCD, Bridge++
resources: Fugaku (hp200130, hp210165), Oakforest-PACS (hp20086, hp210104), Polarie/Grand Chariot (hp200130) from HPCI
MEXT for 'Program for Promoting Researches on the Supercomputer Fugaku' (Simulation for basic science: from fundamental laws of particles to creation of nuclei), and Joint Institute for Computational Fundamental Science (JICFuS)

Choice of the parameter ranges

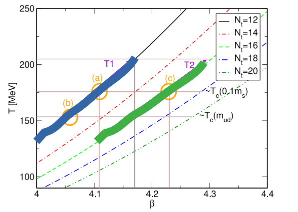


CG iteration counts reflect the existence of the near zero mode
Large fluctuations imply (near) pseudo critical point
no clear information from plaquette or topological charge

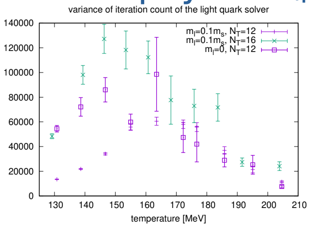
$m_l = 0.1 m_s,\ 0\,(+m_{\rm res})$ $\quad 130\,{\rm MeV} \lesssim T \lesssim 205\,{\rm MeV}$

param. search with fixed lattice spacing 1/a ~ 2.5 GeV

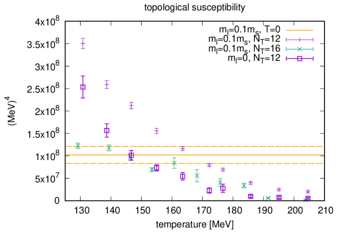
Target T and range of beta



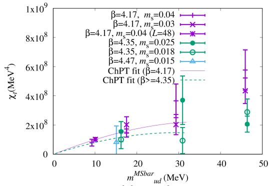
Result along the line of the constant physics (preliminary)



CG iteration counts:
the large variance indicates that the simulation points cover the pseudo critical point



topological susceptibility
N_T=12(1/a=1.6~2.5 GeV): large m_{res} at low T
N_T=16(1/a=2.1~3.3 GeV): m_{res} is small enough
$m_{phys}=m_l+m_{res}$, top. susc. has a large m-dep.
(cf. talk by S.Hashimoto)



S.Aoki et al. PTEP(2018) 4, 043B07

Summary

search for pseudo critical temperature with fixed m_l

- parameter search is done
- detailed simulation is going on