Thermodynamics with Möbius domain wall fermions near physical point II

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(JLQCD collaboration)

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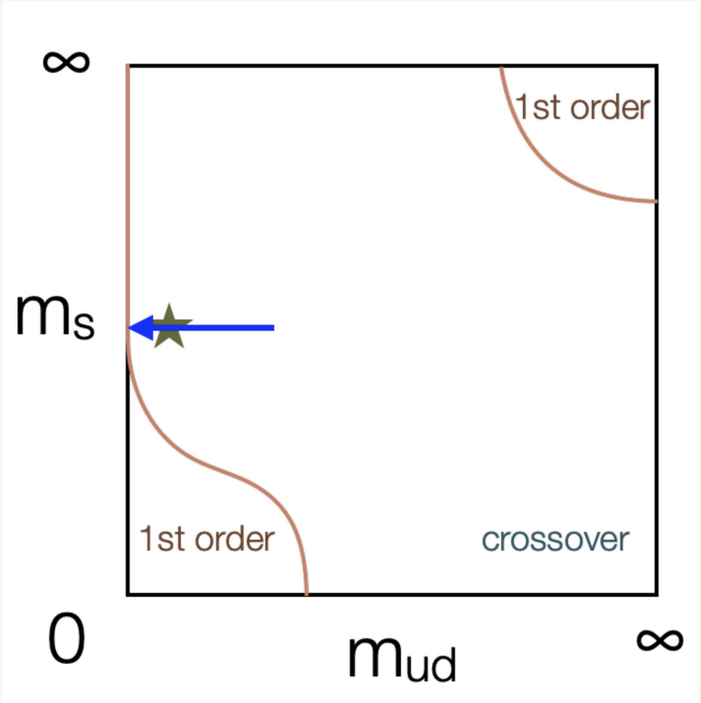
(12 slides in total)

Introduction

Motivation: QCD phase diagram

- Does the 1st-order region extend to the physical m_s?
- If yes, which side of the boundary does physical m_{ud} locate, and the value of the critical m_{ud}?



This talk

simulation results with $m_l = 0.1 m_s$ configurations with m_{res} corrected

Outline:

1. Setup
2. Simulation Results
3. Summary and Discussions

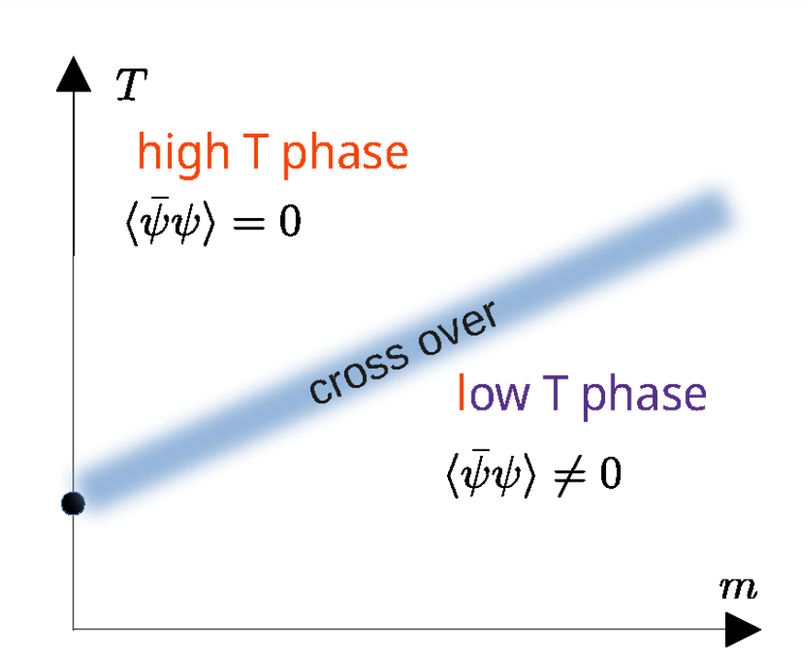
Setup

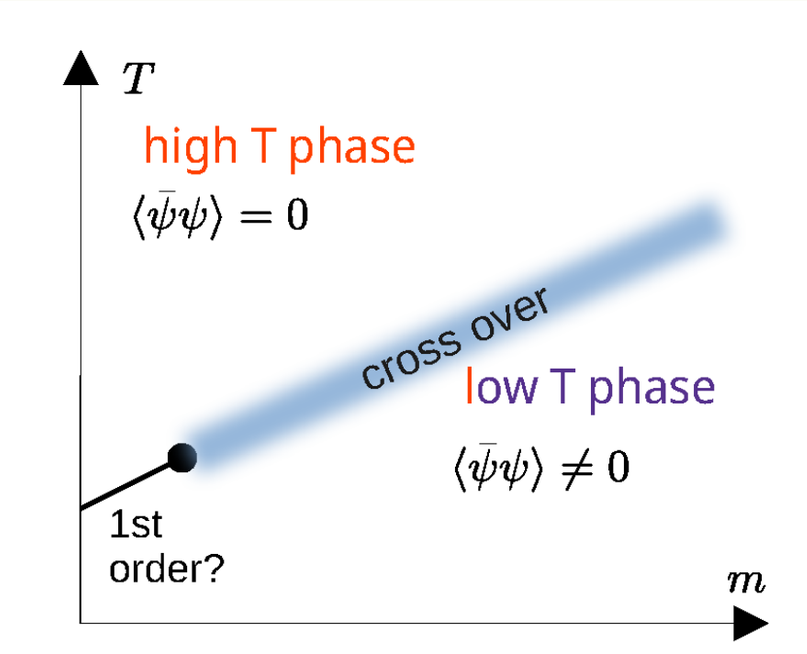
- action: Symanzik + $N_f = 2 + 1$ Möbius Domainwall fermion
  strategy: keep the chiral sym. as much as possible
- $L_s = 12$ for the Domainwall fermion
- code set: GRID, Hadrons, Bridge++
- resources: Fugaku (hp200130, hp210165)and Oakforest-PACS (hp200130), Polaire and Grand Chariot (hp200130)

Line of Constant Physics

Phases in m-T plane

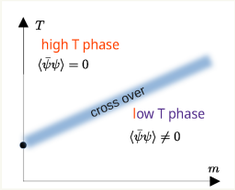
- The (pseudo) critical temperature depends on m ($= m_{ud}$)
- larger $m \Rightarrow T_c$ becomes higher
  mass breaks chiral symmetry explicitly

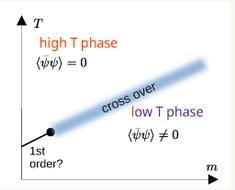


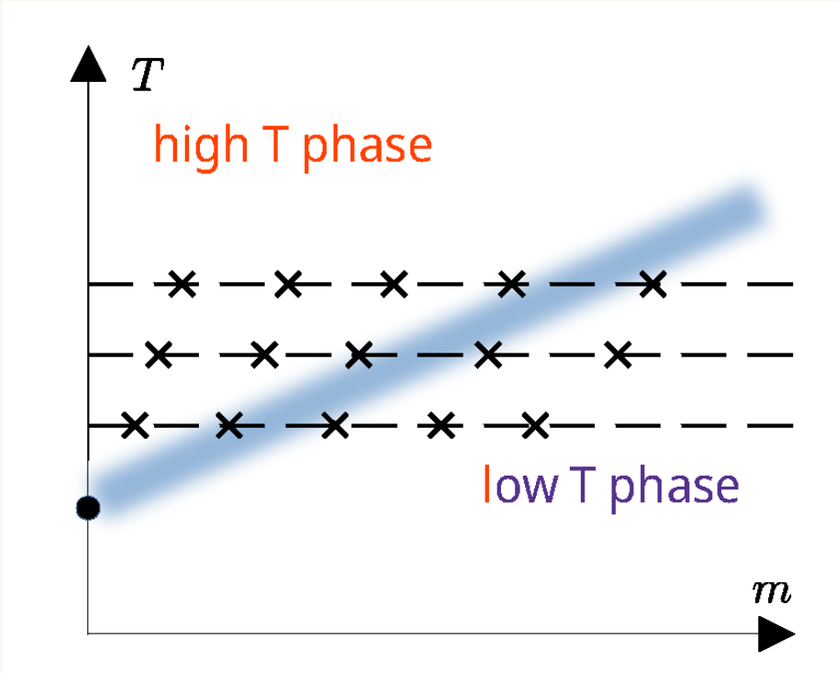


Line of Constant Physics

Phases in m-T plane





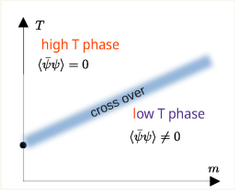


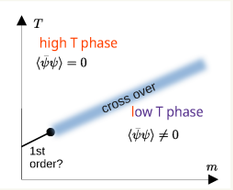
T ($1/(aN_T)$) is fixed.

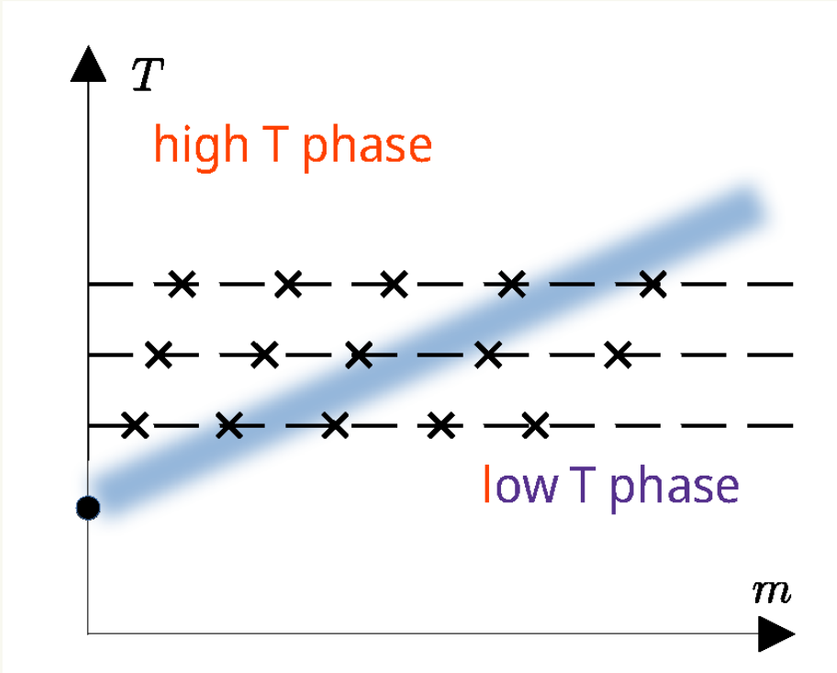
a is also fixed in this talk so $T \sim 1/N_T$ with integer N_T

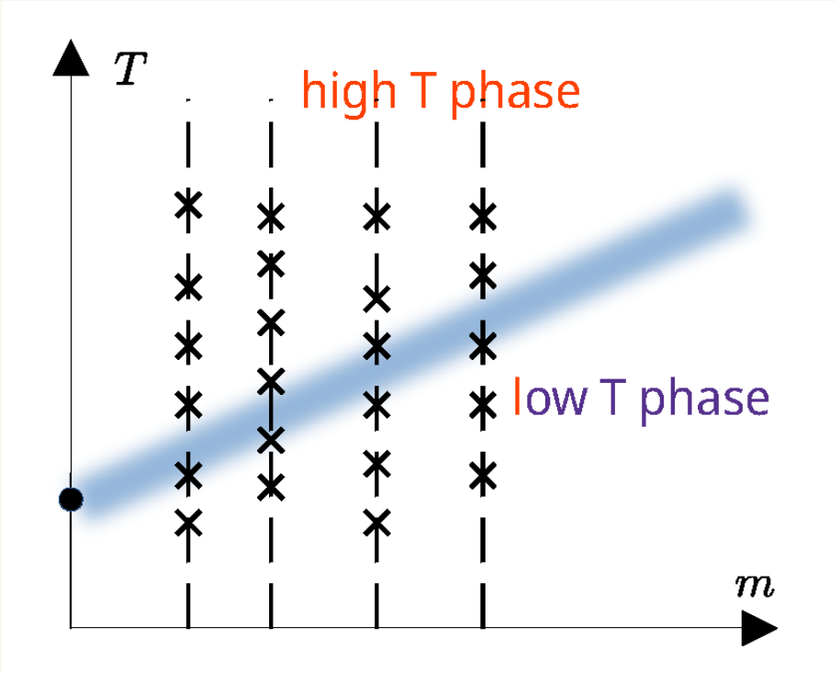
Line of Constant Physics

Phases in m-T plane









T ($1/(aN_T)$) is fixed.

a is also fixed in this talk so $T \sim 1/N_T$ with integer N_T

m is fixed. vary a to change $T \sim 1/a$

need to change am accordingly

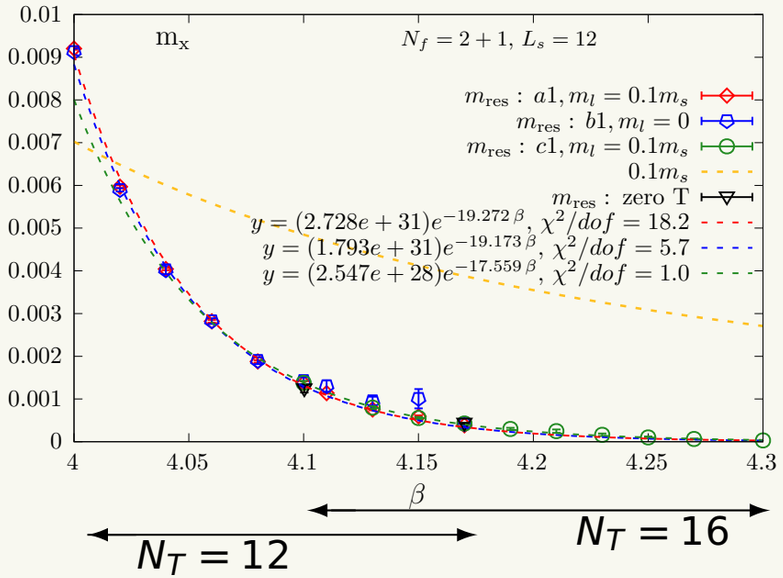
Line of Constant Physics

Residual mass

- chiral sym. becomes “exact” in $L_s \to \infty$

L_s: 5-dim extent of the Domainwall fermion

- at finite L_s (and finite a): the quark mass is lifted by m_{res}
- $m_{res} = R(t) = \dfrac{\sum_{\vec{x}} \langle J_{5q}(\vec{x}, t) P(\vec{0}, 0) \rangle}{\sum_{\vec{x}} \langle P(\vec{x}, 0) P(\vec{0}, 0) \rangle}$ J_{5q}: PS density at $s = L_s/2$



$m_{\mathrm{res}} \gtrsim 0.1 m_s$ at $\beta \sim 4.0$

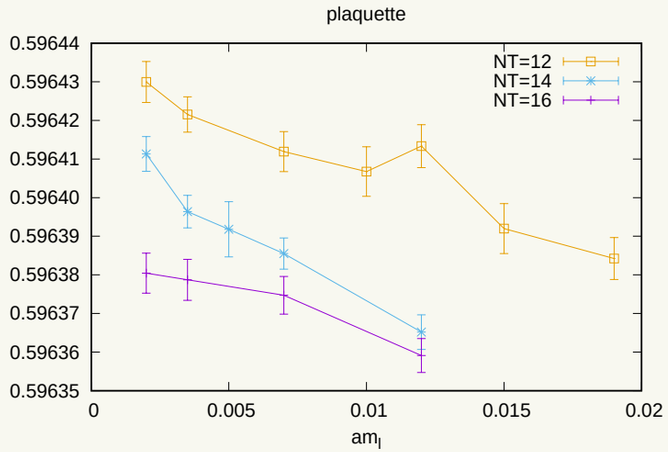
range of β

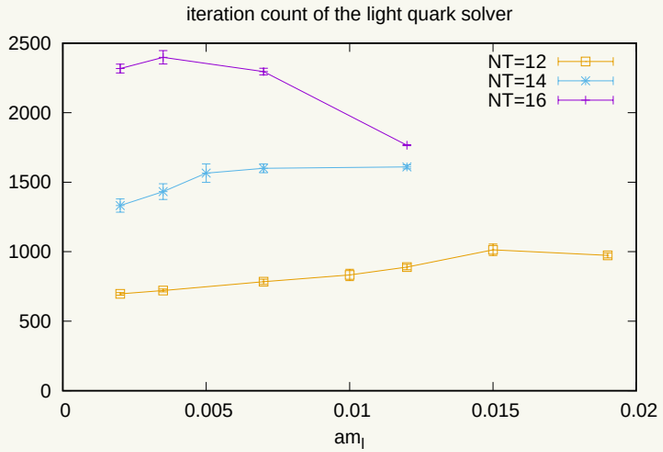
- $N_T = 12$: $4.00 \leq \beta \leq 4.17$
- $N_T = 16$: $4.10 \leq \beta \leq 4.30$

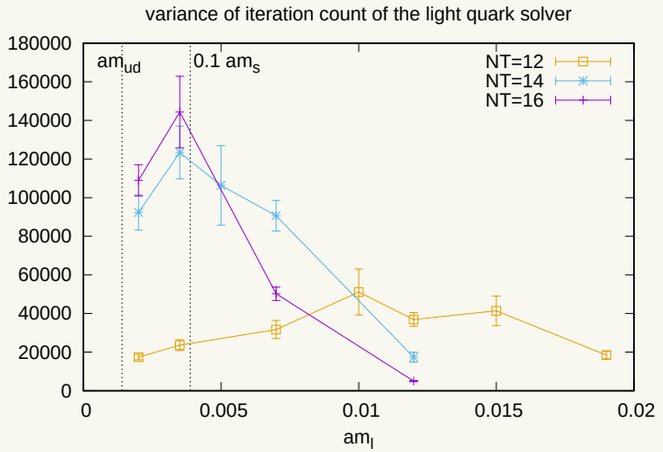
$N_T = 12$ data may suffer from finite m_{res} effects: $m_{\mathrm{phys}} = m + m_{\mathrm{res}}$

Parameter range: information from fixed T simulation

pilot study $\beta = 4.17$, $N_t = 12, 14, 16 \Rightarrow T = 205, 175, 153$ MeV

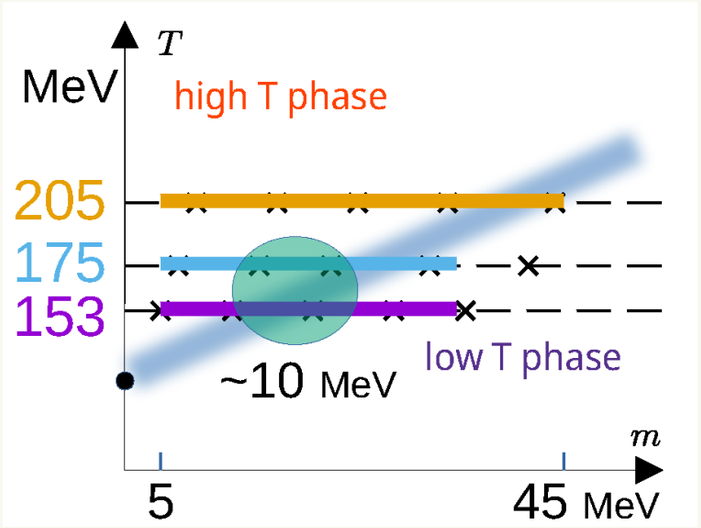




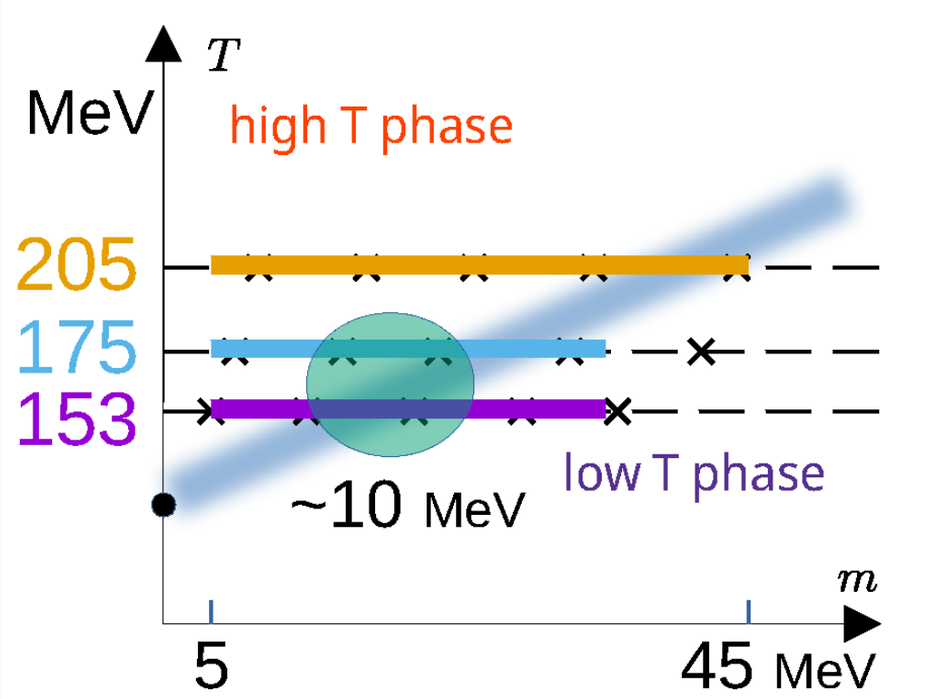


new target

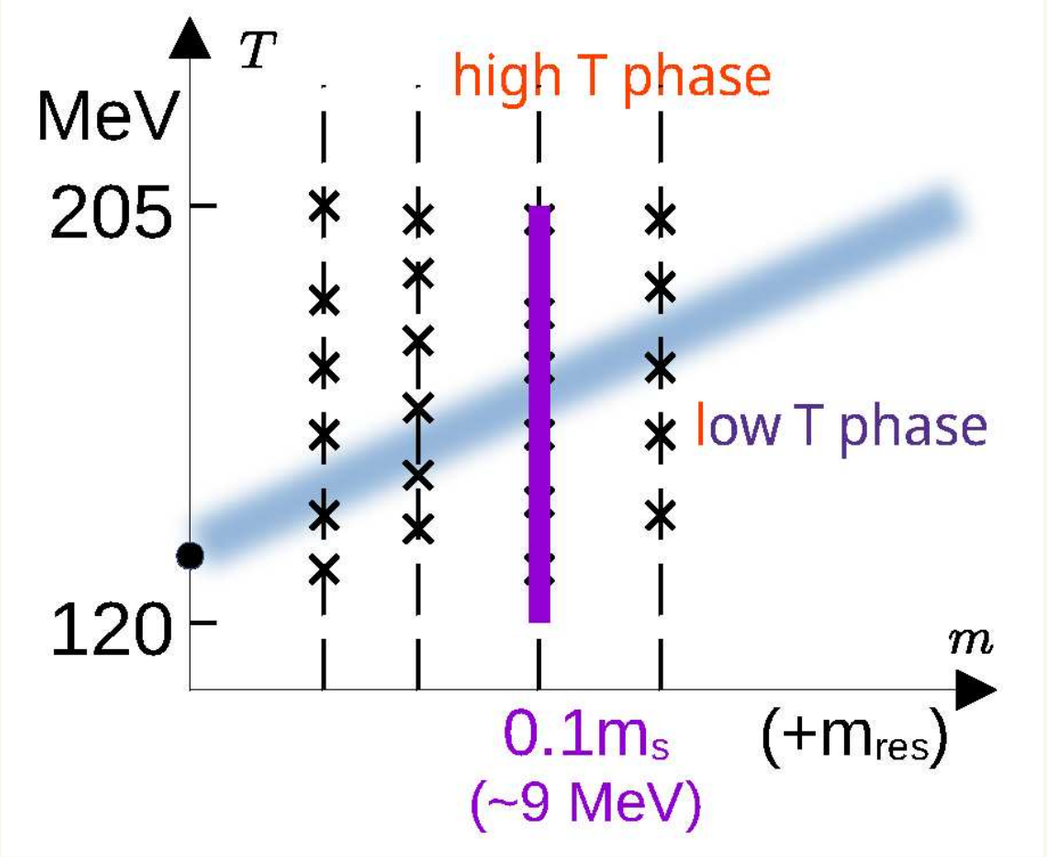
- $m_l = 0.1 m_s$
- 130 MeV $\lesssim T \lesssim$ 205 MeV
- coarse lattice:
  $24^3 \times 12$, $36^3 \times 12$
  m_l and m_s: w/ m_{res} correction
- fine lattice:
  $32^3 \times 16$
  mass reweighting for m_l



Results

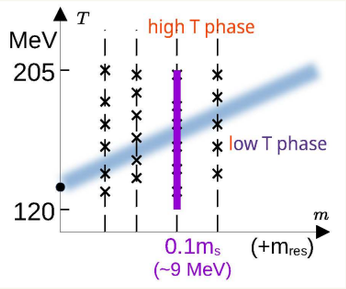

T
MeV
high T phase
205
175
153
low T phase
~10 MeV
m
5
45 MeV

⇒

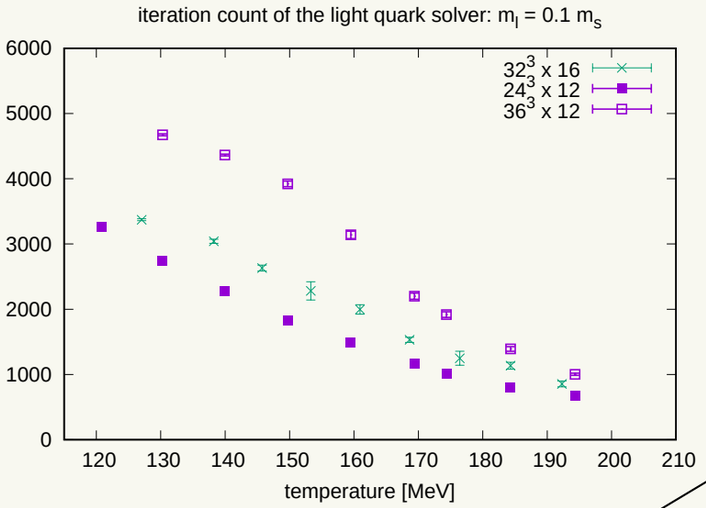

T
MeV
high T phase
205
low T phase
120
m
0.1m_s
(~9 MeV)
(+m_res)

Results: iteration counts

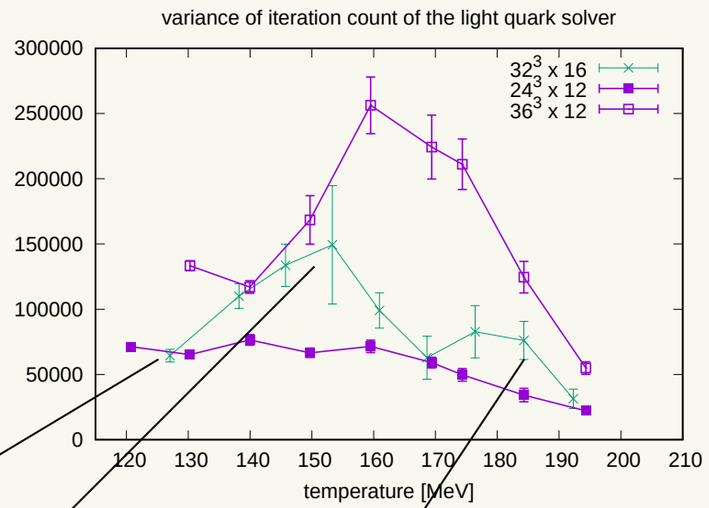
preliminary



iteration counts

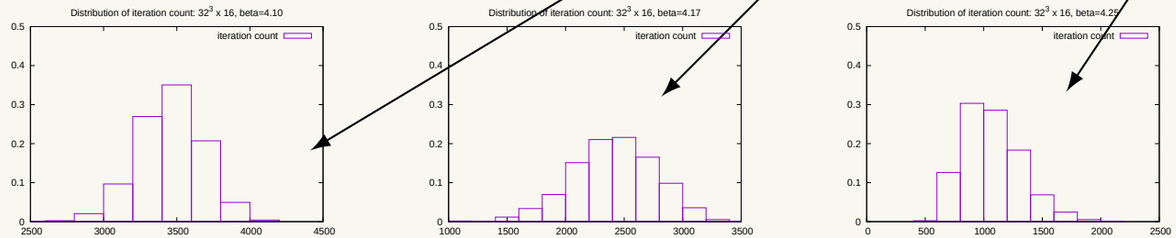


variance of the iter. count

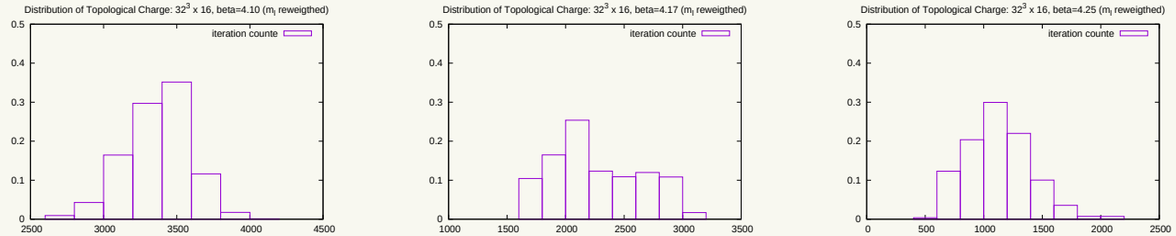


peak of the var.
150–170 MeV $(36^3 \times 12)$
reweighting works

distribtuion of the iteration counts



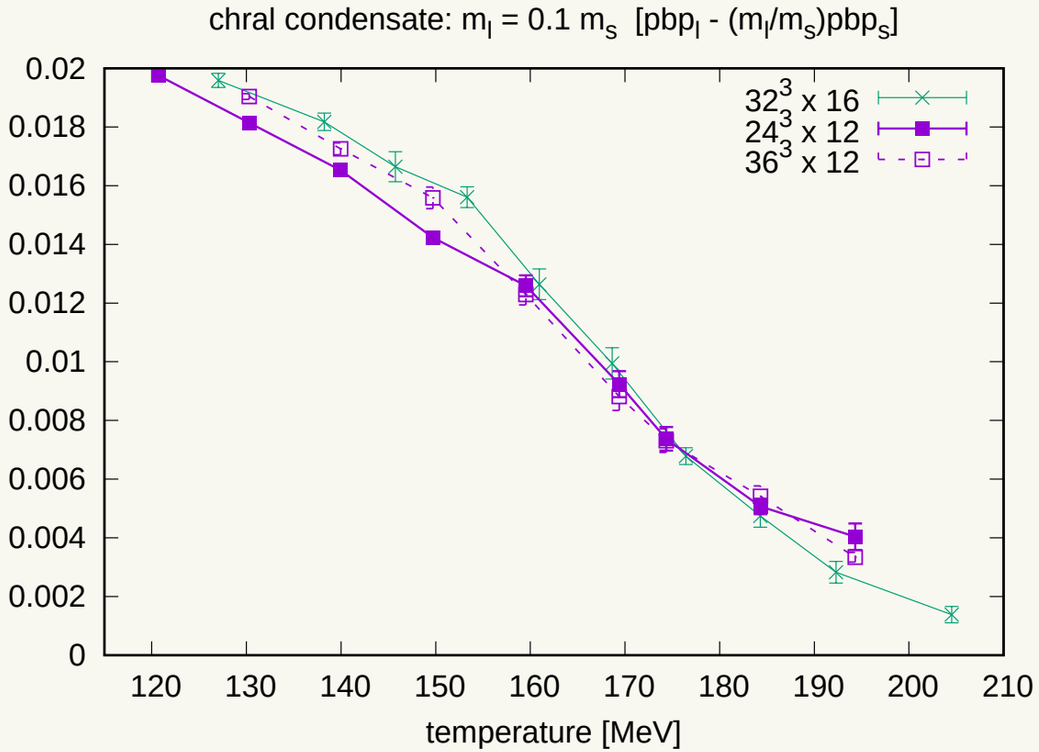
before reweighting



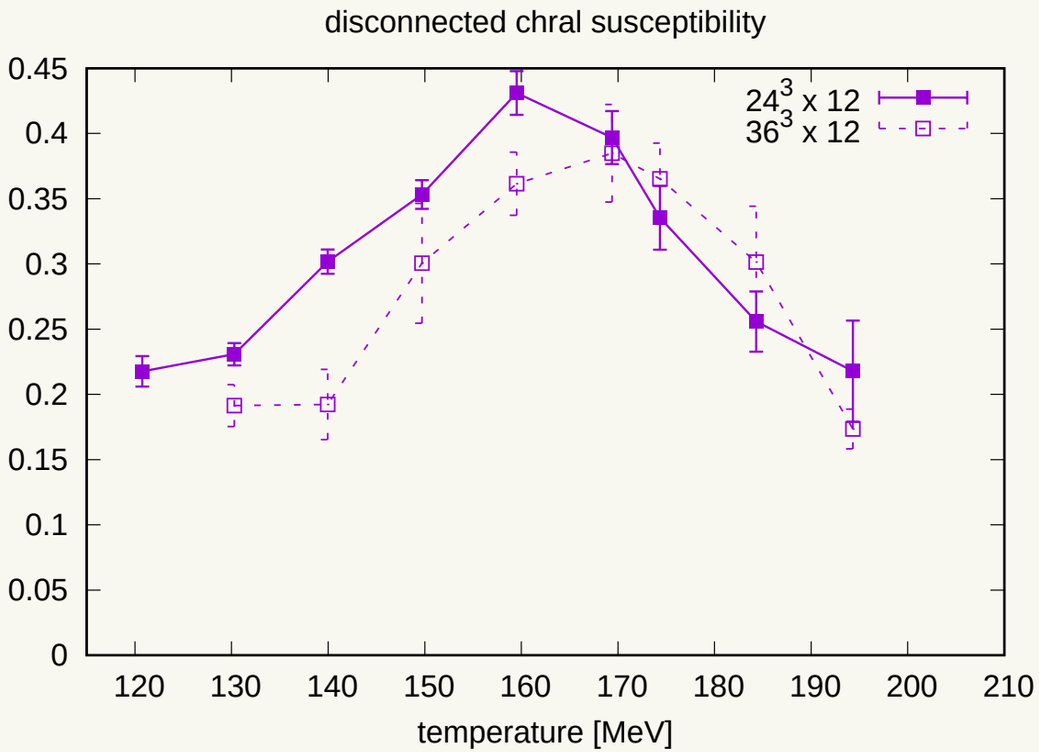
after reweighting

Results: chiral condensate and susceptibility

preliminary



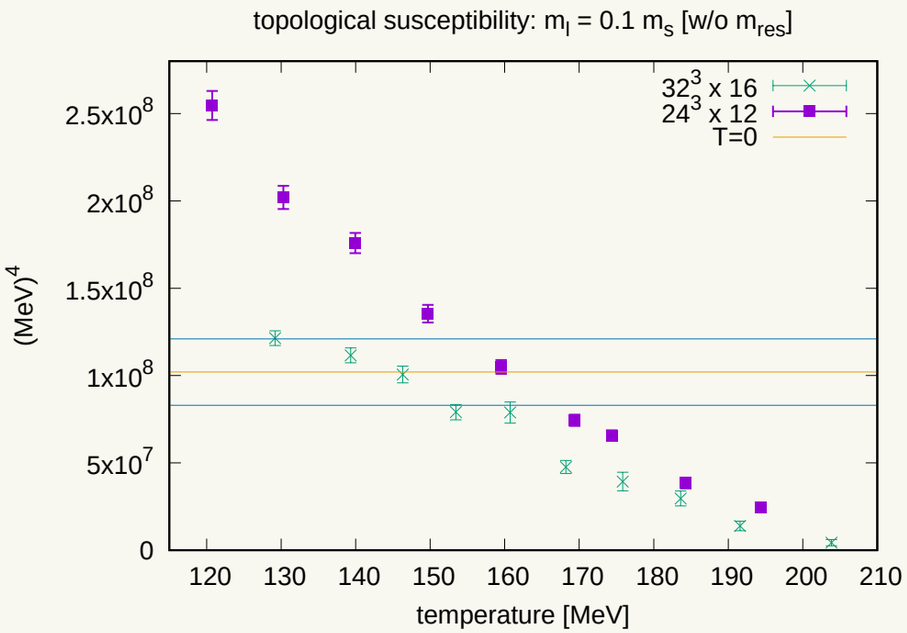
renomalized $\langle\bar{\psi}\psi\rangle_l - \frac{m_l}{m_s}\langle\bar{\psi}\psi\rangle_s$

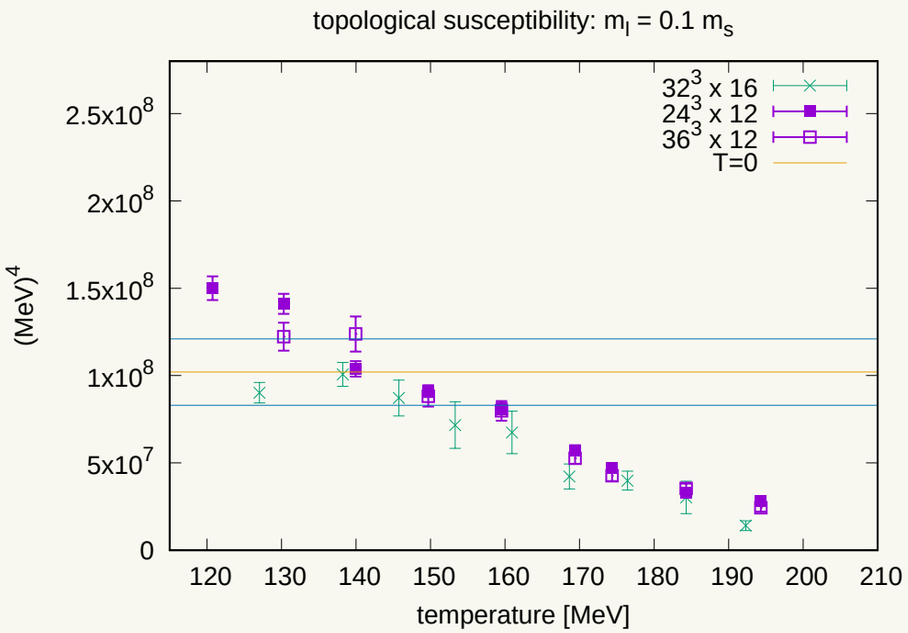


chiral susceptibility

The peak of the susceptibility is again around 150-170 MeV

Results: topological susceptibility

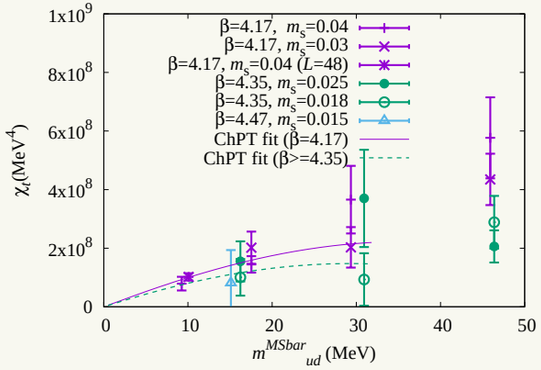




preliminary

input mass: w/o m_{res} correction

w/ m_{res} correction



- at high-T and *intermediate* T
  - fine and coarse results agree after m_{res} correction
  - no volume dependence
- at low-T: finite a effect, maybe
  - $1/a \sim 1.5$ GeV at low-T end

m_l-dep. of χ_{top} is large S.Aoki et al., PTEP 2018 (2018) 4, 043B07

Summary and Discussion

Summary and Discussion

search for pseudo critical temperature with fixed $m_{ud} = 0.1 m_s^{\text{phys}}$

- $T_c \sim 150$–170 MeV
  - iteration counts of light quark solver
  - chiral susceptibility, chiral condensate
- topological susceptibility: m_{res} correction is essential for the corarse lattice
- mass rewighting works for the fine lattice

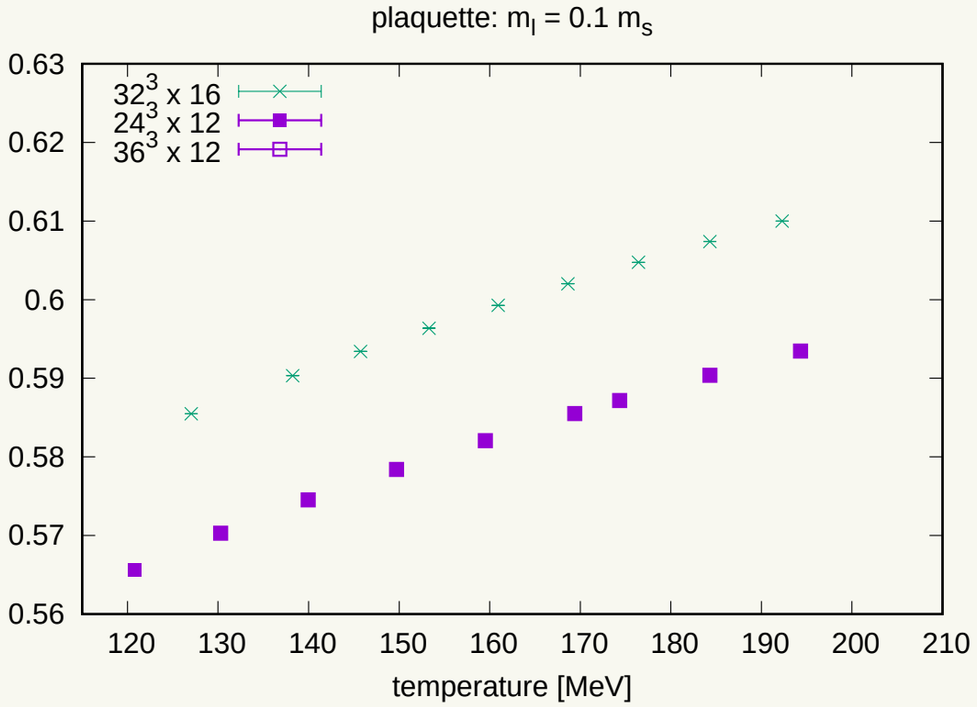
Outlook

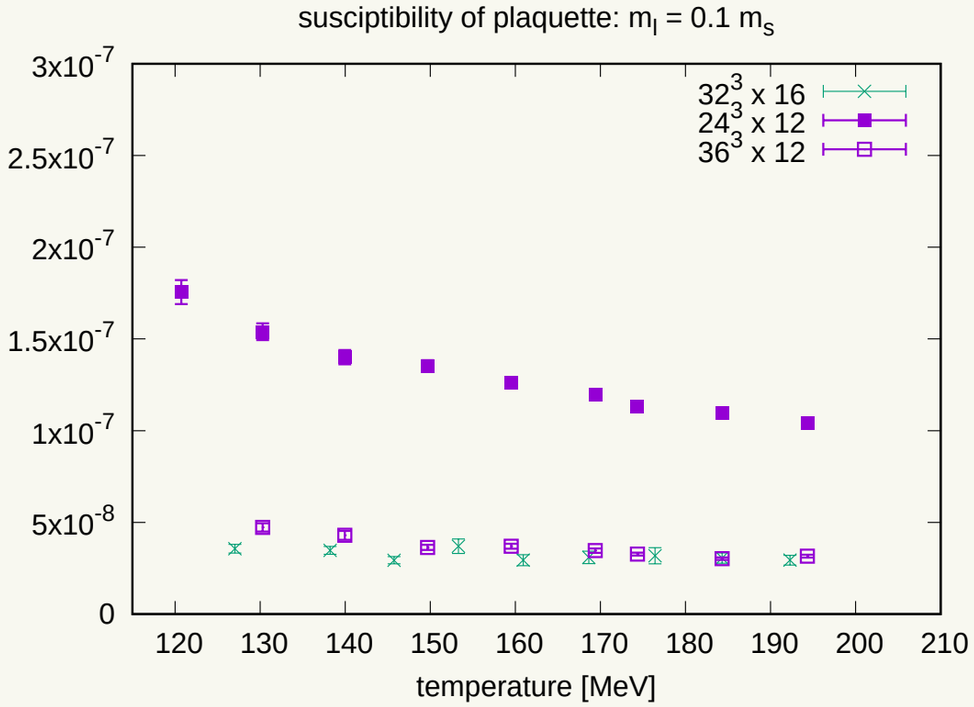
- $N_T = 12$: $m_l = m^{\text{phys}}$ is coming soon
  the coarse lattice end (low temperature): may need mass reweighting
- $N_T = 16$: m_{res} correction is small
  mass rewighting for the sea quarks and new measurements with coreected valance quarks
- larger spacial volume

Acknowledgments: Program of Promoting Researches on the Supercomputer Fugaku ” (Simulation for basic science: from fundamental laws of particles to creation of nuclei) JPMXP1020200105; JSPS Kakenshi 20k03961

Backup Slides

Results: plaquette





Results: Polyakov loop