Thermal transition temperature from twisted mass QCD

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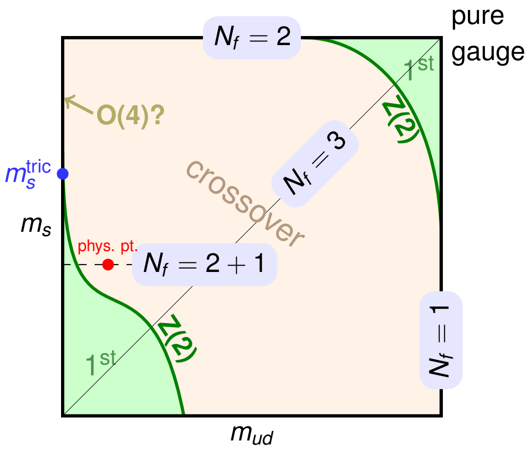
The thermal transition of QCD



- Investigate the thermal transition by means of LQCD.
- Here: $N_f = 2$ and vanishing chemical potential.
- Expect a crossover.

Choice of fermion action

staggered fermions

- Have been mostly (and fruitfully) applied up to now.
- Rooting issue: how sure can we be to have physical results for light fermions?

Wilson fermions

- Different symmetry problems (chiral symmetry).
- Completely different systematic effects.

Here: Use maximally twisted mass Wilson fermions (with automatic $\mathcal{O}(a)$ improvement).

Maximally twisted mass action

$$M_{\mathrm{mtm}} = 1 - \kappa_c D_{\mathrm{Wilson}} + \mathrm{i} a\mu\gamma_5\tau^3$$

$N_f = 2$

- standard Wilson part with critical hopping parameter $\kappa_c(\beta)$
- twisted mass term to determine the mass
- gauge action tree-level Symanzik improved
- for scales and masses ETMC results can be used

Finite temperature twisted mass QCD

Action properties

- $\mathcal{O}(a)$ improved at maximal twist.
- $N_f = 2$ ($N_f = 2 + 1 + 1$ possible in the near future)

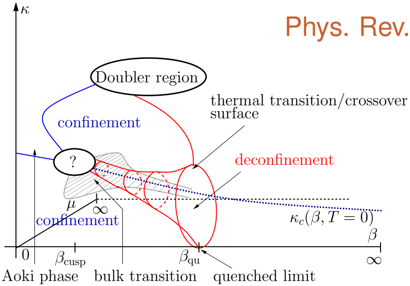
Physics goals

- Get information about the thermal transition, especially T_c.
- Try to make a statement on the $N_f = 2$ chiral universality class from
  - fits to $T_c(m_\pi)$.
  - splitting patterns of screening masses.

Twisted mass phase space

- Off maximal twist, the relation $m_q^2 = m^2 + \mu^2$ implies a thermal transition surface in (κ, μ, β)-space.

Phys. Rev. D80: 094502, 2009

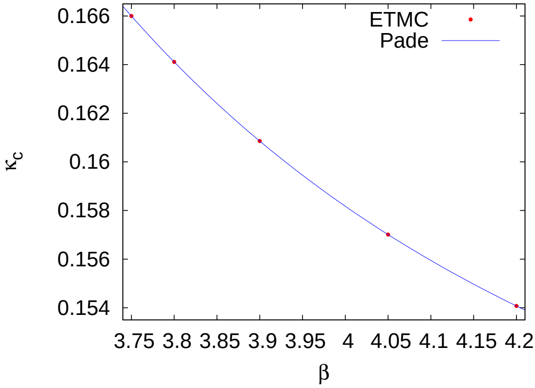


PoS(Lat2009)266:

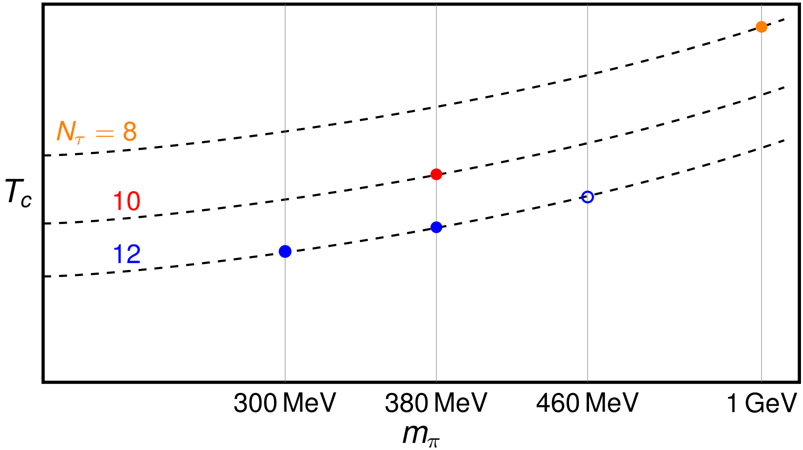
- Numerical check of $\mathcal{O}(a)$ improvement for maximal twist at finite temperature in the quenched case.
- First β-scan as feasibility check at $m_\pi \approx 1\,\mathrm{GeV}$.

Current simulation setup

- Scans in β at maximal twist.
- Keep a light pion mass fixed for each scan.
- $a(\beta)$, $\kappa_c(\beta)$ and $\mu(m_\pi, \beta)$ from ETMC data (see arXiv:0911.5061).



Physical simulation parameters



- $N_\tau = 8$ ($m_\pi \approx$1 GeV) and 10 (380 MeV) are finished.
- Current masses at $N_\tau = 12$: 300, 380, 460 MeV

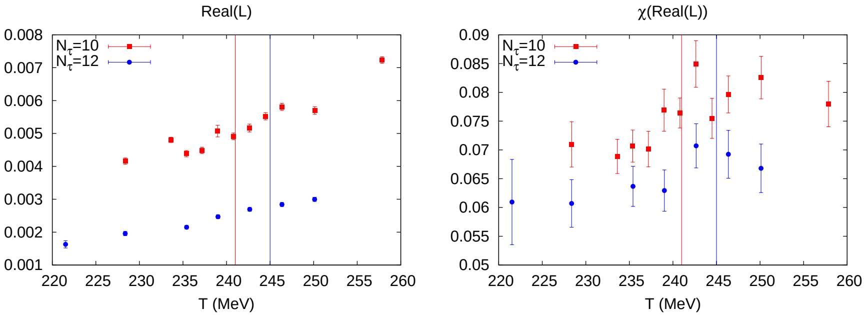
Observables

- real part of Polyakov loop
- plaquette
- pion norm
- chiral condensate
- (pseudo scalar flavour non-singlet) screening mass

Typical statistics

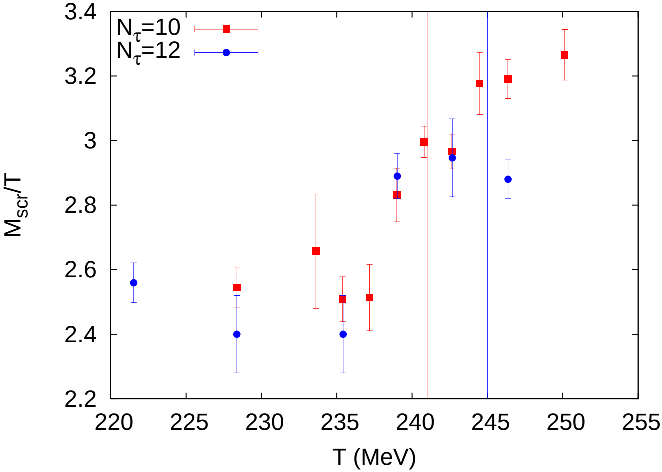
- $N_\tau = 10$: O(4k) measurements per β-value
- $N_\tau = 12$: O(3k) measurements per β-value

Real part of Polyakov loop



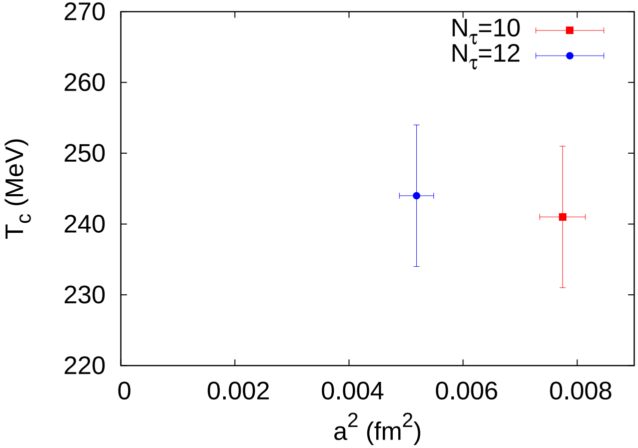
- $m_\pi = 380\,\mathrm{MeV}$
- Crossover temperatures:
  - $T_c(N_\tau = 10) = 241(10)\,\mathrm{MeV}$
  - $T_c(N_\tau = 12) = 244(10)\,\mathrm{MeV}$

Screening mass



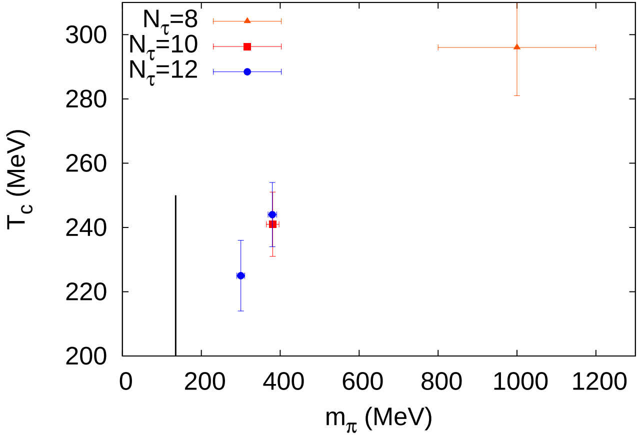
- Pseudoscalar flavour non-singlet screening mass.
- Starts rising at the onset of the transition region $T \sim 235 - 240\,\text{MeV}$.

Cutoff effects at $m_\pi = 380\,\mathrm{MeV}$



- $N_\tau = 12$ should be further refined.
- At least one more lattice spacing is needed.

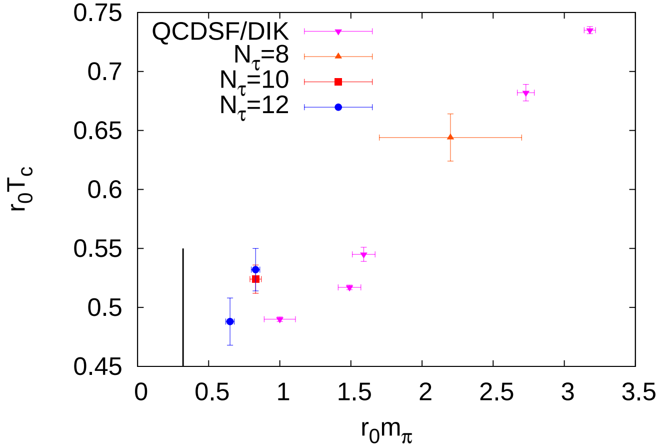
$T_c(m_\pi)$ from susceptibility of $Re(L)$



- Two lattice spacings at $m_\pi \approx 380\,\text{MeV}$, one at $300\,\text{MeV}$.
- $460\,\text{MeV}$ at $N_\tau = 12$ is on its way.

$T_c(m_\pi)$ from susceptibility of $Re(L)$

QCDSF/DIK, arXiv:0910.2392



- Two lattice spacings at $m_\pi \approx 380\,\text{MeV}$, one at $300\,\text{MeV}$.
- $460\,\text{MeV}$ at $N_\tau = 12$ is on its way.

Conclusions and outlook

Results on $T_c(m_\pi)$

- At $N_\tau = 10$, we have T_c for $m_\pi = 380\,\text{MeV}$.
- At $N_\tau = 12$, there are results for $m_\pi = 300\,\text{MeV}$ and $380\,\text{MeV}$.
- $m_\pi = 460\,\text{MeV}$ at $N_\tau = 12$ is on its way.
- Possibly go to $N_\tau = 14$ and $m_\pi < 300\,\text{MeV}$.

Outlook

- Determine further screening masses to get insight into symmetry splittings.
- $N_f = 2 + 1 + 1$