Finite temperature QCD with two flavors of dynamical quarks

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We present results for QCD with $N_f = 2$ flavors of dynamical quarks using nonperturbatively improved Wilson fermions at finite temperature on $24^3 \times 10$ lattice. We determine the transition temperature in the range of quark masses $0.6 < m_\pi/m_\rho < 0.8$.

1 INTRODUCTION

In order to obtain predictions for the real world from lattice QCD, we have to extrapolate the lattice data to the continuum and to the chiral limits. Edwards and Heller [1] determined T_c for $N_t = 4$, 6 using nonperturbatively improved Wilson fermions. We compute T_c on finer lattices with $N_t = 8$ and 10 with high statistics. Our results for $N_t = 8$ were reported in Ref. [2].

2 SIMULATION

We use fermionic action for nonperturbatively $O(a)$ improved Wilson fermions. Configurations are generated on $16^3 \times 8$ ($\beta = 5.2$ and 5.25) and $24^3 \times 10$ ($\beta = 5.2$) lattices at various κ. The values of κ and corresponding number of trajectories for $16^3 \times 8$ and $24^3 \times 10$ lattices can be found in Ref. [2] and Table 1, respectively. The number of configurations for $24^3 \times 10$ lattice is not large enough and results for this lattice are preliminary. We use results obtained at T=0 to fix the scale.

κ	0.1352	0.1354	0.1356	0.1358
# traj.	5,400	7,400	3,130	1,650

Table 1:*Simulation statistics on* $24^3 \times 10$.

3 CRITICAL TEMPERATURE

We use the Polyakov loops to determine the transition temperature. The Polyakov loop susceptibility is used to determine the transition point. In Fig.1 the Polyakov loop and its susceptibility are depicted. We get the following values for the critical temperature:

$$T_c \sim 196(8)\text{MeV}, \quad m_\pi/m_\rho \sim 0.64 \quad \texttt{(Preliminary)}$$
$$T_c = 210(4)\text{MeV}, \quad m_\pi/m_\rho = 0.77$$
$$T_c = 219(3)\text{MeV}, \quad m_\pi/m_\rho = 0.81$$

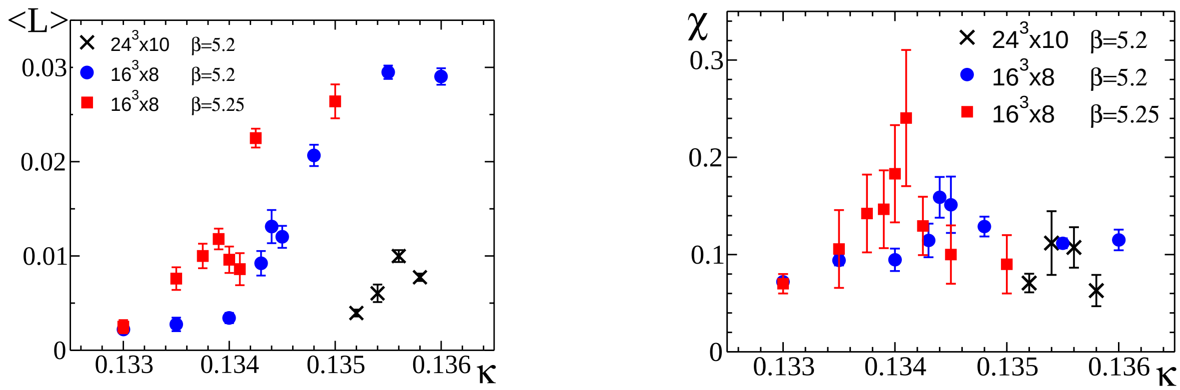

Fig.1: Polyakov loop (left) and its susceptibility (right).

4 CONTINUUM LIMIT

At small enough lattice spacing and quark mass one can extrapolate the critical temperature T_c to the continuum and the chiral limits using formula:

$$T_c r_0 = (T_c r_0)^{m_q, a \to 0} + C_a (a/r_0)^2 + C_q (\frac{1}{\kappa} - \frac{1}{\kappa_c})^{\alpha},$$

where $r_0 = 0.5$ fm and $(T_c r_0)^{m_q, a \to 0}$ corresponds to the extrapolated value. We are brave enough to use four values for $T_c r_0$ (see Table 3), obtained at rather large quark masses, to estimate the parameters in this extrapolation expression. A fit gives $(T_c)^{m_q, a \to 0}$ and α with large errors: $(T_c)^{m_q, a \to 0} \sim 190$ MeV, $\alpha \sim 0.8$. In $N_f = 2$ QCD the critical indices are expected to belong to the universality class of the $3D$ $O(4)$ spin model for which one expects $\alpha = 0.55$. Fixing α to this value we get the extrapolated temperature with a higher accuracy $T_c^{m_q, a \to 0} \sim 172.5(3.3)$ MeV.

$T_c r_0$	a/r_0	
0.50(2)	0.20(1)	$N_t = 10, \beta = 5.2$ (prelim.)
0.53(1)	0.234(5)	$N_t = 8,\ \beta = 5.2$
0.55(1)	0.225(5)	$N_t = 8,\ \beta = 5.25$
0.57(2)	0.29(1)	$N_t = 6,\ \beta = 5.2$ (Ref. [1])

Table 3:*Available data for $T_c r_0$.*

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References

[1] R. G. Edwards, U. M. Heller, Phys. Lett. **B462** (1999) 132.

[2] V. Bornyakov et al., hep-lat/0301003, Nucl. Phys. **B** (Proc.Suppl.) **119** (2003) 703.