# Pseud critical temperature in $N_f = 2$ full QCD


Y. Nakamura[1], V.G. Bornyakov[2], M.N. Chernodub[3], Y. Mori[1], S.M. Morozov[3], M.I. Polikarpov[3], G. Schierholz[4], A.A. Slavnov[5], H. Stüben[6], and T. Suzuki[1]

[1] *Kanazawa University, Kanazawa 920-1192, Japan*

[2] *Institute for High Energy Physics, RU-142284 Protvino, Russia*

[3] *ITEP, B.Cheremushkinskaya 25, RU-117259 Moscow, Russia*

[4] *NIC/DESY Zeuthen, Platanenallee 6, D-15738 Zeuthen, Germany*

[5] *Steklov Mathematical Institute, Vavilova 42, RU-117333 Moscow, Russia*

[6] *Konrad-Zuse-Zentrum für Informationstechnik Berlin, D-14195 Berlin, Germany*


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. Recently the Bielefeld group [1] and the CP-PACS collaboration [2] using different fermion actions obtained consistent values for the critical temperature $T_c$ in the chiral limit, albeit on rather coarse lattices at $N_t = 4$ and 6. Edwards and Heller [3] 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.

We use non-perturbatively improved Wilson fermions with $c_{sw}$ was calculated in [4] and Wilson action. Configurations are generated on $16^3 \cdot 8$ and $24^3 \cdot 10$ lattices at various parameters. We use results obtained at T=0 to fix the scale. The contour plot of lines of constant $r_0/a$ and $m_\pi/m_\rho$ is shown in Ref. [5]. The Polyakov loop susceptibility is used to determine $T_c$. We get values for $T_c$: $T_c$=196(4)MeV($m_\pi/m_\rho$=0.64(3), $a/r_0$=0.201(4)), $T_c$=210(4)MeV($m_\pi/m_\rho$=0.77(3), $a/r_0$=0.234(4)), $T_c$=219(3)MeV($m_\pi/m_\rho$=0.81(4), $a/r_0$=0.225(4)). At small enough lattice spacing and quark mass one can extrapolate $T_c$ to the continuum and the chiral limits using formula:

$$T_c r_0 = T_c^0 r_0 + C_a\left(\frac{a}{r_0}\right)^2 + C_q\left(\frac{1}{\kappa} - \frac{1}{\kappa_c}\right)^{\frac{1}{\beta\delta}},$$

where $T_c^0$ corresponds to the extrapolated value of $T_c$ and $\beta$ and $\delta$ are critical indices. We make an attempt to fit four values for $T_c r_0$ (see Table 1), obtained at rather large quark masses, to estimate the parameters in this extrapolation expression.

| $T_c r_0$ | $a/r_0$ | $\beta$ | $\kappa_t$ | $L_t$ |
|---|---|---|---|---|
| 0.50(1) | 0.201(4) | 5.2 | 0.1354 | 10 |
| 0.53(1) | 0.234(4) | 5.2 | 0.1345 | 8 |
| 0.56(1) | 0.225(4) | 5.25 | 0.1341 | 8 |
| 0.57(2) | 0.29(1) | 5.2 | 0.1330 | 6 |

Table 1:Available data for $T_c r_0$.

| $\frac{1}{\beta\delta}$ | $T_c r_0$ | $C_a$ | $C_q$ | $\chi^2/dof$ |
|---|---|---|---|---|
| 0.54 | 0.44(2) | −0.9(5) | 0.5(1) | 0.26 |
| 1 | 0.51(3) | −1.3(7) | 0.9(2) | 0.13 |

Table 2:Fitting results.

We extrapolate the value of the critical temperature using different values of 0.54 and 1 as $1/\beta\delta$. If the transition in two-flavor QCD is second order, the transition is expected to belong to the universality class of the $3D$ $O(4)$ spin model with $1/\beta\delta \approx 0.54$. If the transition is first order, then $1/\beta\delta$=1. Table 2 presents fitting results. We get the critical temperature in the continuum and in the chiral limits. In the case of $1/\beta\delta$=0.54, $T_c^0 = 174(8)$MeV. This value agrees with values obtained in Refs.[1, 2]. In the case of $1/\beta\delta$=1, $T_c^0 = 201(12)$MeV. Although some lattice studies [1, 2] indicate second order chiral transition in two-flavor QCD, there are also results [6] supporting first order transition. Results of our fits do not allow to discriminate between first and second order transitions because of rather large errors in $T_c r_0$ values. We are continuing simulations on $24^3 \cdot 10$ lattice to get better precision of $T_c$ value on this lattice.


### acknowledgements

This work is supported by the SR8000 Supercomputer Project of High Energy Accelerator Research Organization (KEK) and SX-5 at Research Center for Nuclear Physics (RCNP) of Osaka University.


## References


[1] F. Karsch, A. Peikert, E. Laermann, Nucl. Phys. **B605** (2001) 579.

[2] A. Ali Khan et al., (CP-PACS), Phys. Rev. **D63** (2001) 034502.

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

[4] K. Jansen and R. Sommer (ALPHA collaboration), Nucl. Phys. **B530** (1998) 185.

[5] S. Booth et al., Phys. Lett. **B519** (2001) 229.

[6] M. D'Elia et al., hep-lat/0408008