Finite temperature QCD with SLiNC fermions

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1 Introduction

Recent results for the critical temperature T_c for N_f=3

T_c [MeV]	Fermion	observable	–
196(3)	KS	$\bar{\psi}\psi$	RBC/Bielefeld [1]
170(7)	KS	L	Wuppertal [2]
146(5)	KS	$\bar{\psi}\psi$	Wuppertal [2]
155-185	DWF	L	M. Cheng *et at.* [3]
171(10)(17)	DWF	$\bar{\psi}\psi$	M. Cheng *et at.* [3]

Motivation:

- determination T_c with dynamical u-, d-, s-quarks of Wilson type fermions
- to find cheap way to get T_c at the physical point
- to test fixed $m_u + m_d + m_s$ simulations at $T > 0$

2 Simulation

Tree level Symanzik glue + 3 flavors of SLiNC fermions [4]

$$S_G = \frac{6}{g^2}\left[c_0 \sum_{\rm plaq} \frac{1}{3}\,\mathrm{Re\,Tr}\,(1 - U_{\rm plaquette}) + c_1 \sum_{\rm rect} \frac{1}{3}\,\mathrm{Re\,Tr}\,(1 - U_{\rm rectangle})\right] ,$$

$$\frac{c_1}{c_0} = -\frac{1}{20} , \quad c_0 + 8c_1 = 1 .$$

$$S_F = \sum_x \Big\{ \bar{\psi}(x)\psi(x) - \kappa\,\bar{\psi}(x) U_\mu{}^\dagger(x-\hat{\mu})[1+\gamma_\mu]\psi(x-\hat{\mu}) - \kappa\,\bar{\psi}(x) U_\mu(x)[1-\gamma_\mu]\psi(x+\hat{\mu}) + \frac{i}{2}\kappa\, c_{\rm SW}\,\bar{\psi}(x)\sigma_{\mu\nu}F_{\mu\nu}(x)\psi(x)\Big\} ,$$

U_μ is replaced by stout link $e^{iQ_\mu(x)}\,U_\mu(x)$.

$$Q_\mu(x) = \frac{\alpha}{2i}\left[V_\mu(x)U_\mu^\dagger(x) - U_\mu(x)V_\mu^\dagger(x) - \frac{1}{3}\mathrm{Tr}\,\left(V_\mu(x)U_\mu^\dagger(x) - U_\mu(x)V_\mu^\dagger(x)\right)\right] ,$$

with smearing parameter $\alpha = 0.1, n = 1$. Simulations have performed by BQCD [5].

2.1 Results

$L_s^3 \times L_t = 32^3 \times 12$, $\beta = 5.50$, $\kappa = 0.1200, 0.1203, 0.1205, 0.1207, 0.1209$ (degenerate), $O(5000)$ trajectories. The critical point is around κ=0.1207 (cf. m_{PS} ∼600 MeV, a ∼0.09 fm, T ∼ 180 MeV). More statistics is needed.

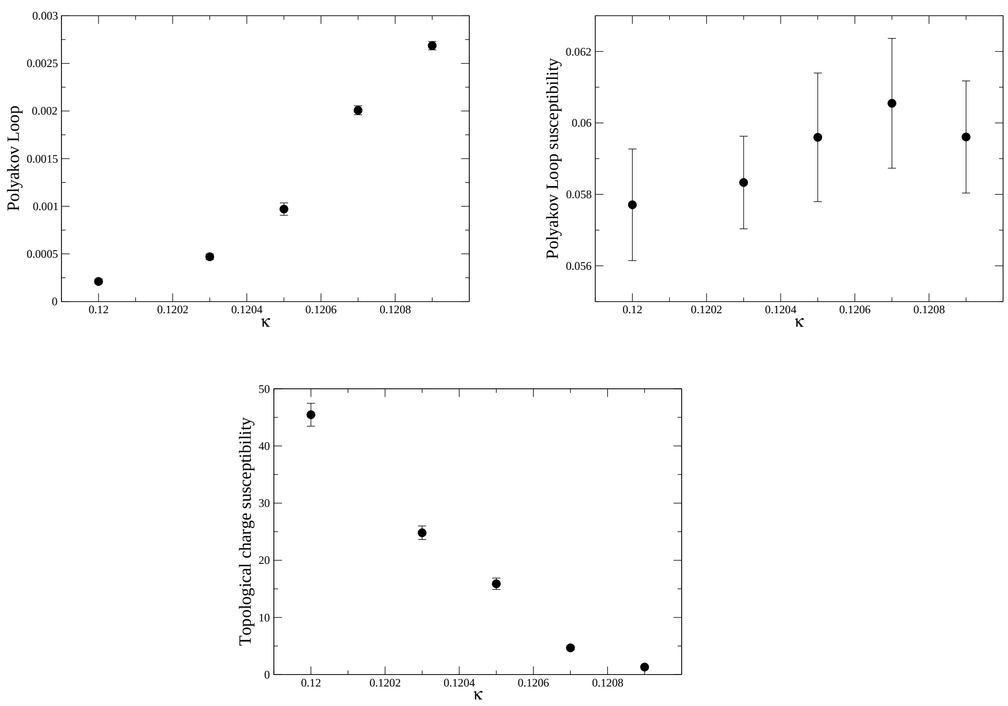

Figure 1: Polyakov loop (top left) and its susceptibility (top right) Topological charge susceptibility (bottom) as a function of κ at $L_t = 12$, β=5.50.

3 To the physical point

Traditionally, m_{ud} is decreased with fixing m_s as the physical value. It is difficult to tune parameters. Simulations are expensive around m_{ud}^{phy}.

3.1 New approach

Chiral perturbation theory, flavor singlet, e.g.

$$2m_K^2 + m_\pi^2 = 2(2B_0 m_s^R + 2B_0 m_l^R) + 2B_0 m_l^R + 2B_0 m_l^R + O((m_{q\in u,d,s}^R)^2) = 12B_0 m_q^R + O((m_{q\in u,d,s}^R)^2)$$

where $m_q^R = (2m_l^R + m_s^R)/3$.

Considering the Taylor expansion at $m_l^R = m_s^R = m_q^R$ with $\delta m_u^R + \delta m_d^R + \delta m_s^R = 0$ (for Wilson type fermion $1/\kappa_u + 1/\kappa_d + 1/\kappa_s =$ const)

- $O(\delta m_{q\in u,d,s}^R)$ vanishes
- $O((\delta m_{q\in u,d,s}^R)^2)$ does not vanish
- a/r_0 does not depend on δm_q^R

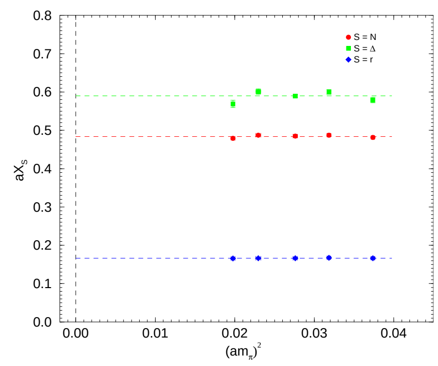

Figure 2: Some flavor singlet v.s. $(am_\pi)^2$ with $m_u + m_d + m_s =$ const. $X_r = 1/r_0$, $X_N = \frac{1}{3}(m_N + m_\Sigma + m_\Xi)$, $X_\Delta = \frac{1}{3}(2m_\Delta + m_\Omega)$ [6].

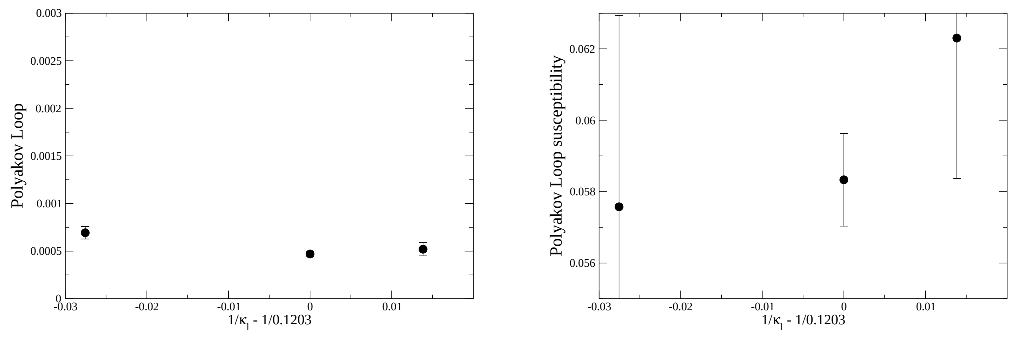

Figure 3: Polyakov loop and its susceptibility v.s. $(1/\kappa_l - 1/0.1203)$ (non-degenerate). O(500) trajectories except for one at $(1/\kappa_l - 1/0.1203)$=0.

If flavor blind quantities, flavor singlet such as Polyakov loop and chiral condensate do not depend on δm_q when $m_u + m_d + m_s =$ const,

$$T_c(m_u^{phy}, m_d^{phy}, m_s^{phy}) = T_c(m_q^{sym}) \quad \text{or} \quad T_c(m_\pi^{phy}, m_K^{phy}) = T_c(m_{PS}^{sym}) ,$$

wherer $m_{PS}^{sym} = \sqrt{(2(m_K^{phy})^2 + (m_\pi^{phy})^2)/3} \sim 413$ MeV).

4 Conclusion

We have performed finite temperature QCD simulations with 3 flavors of SLiNC fermions and presented preliminary results. New approach to the physical point for the critical temperature is described.

- more statistics to check $T_c(m_\pi, m_K) = T_c(m_{PS}^{sym}, m_{PS}^{sym})$
- more statistics and data point to determine T_c at β=5.50, L_t=12
- planing simulation for $a \to 0$, $m_{PS} \to 413$ MeV

5 Acknowledgements

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References

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