Critical endline of the finite temperature phase transition for 2+1 flavor QCD around the SU(3)-flavor symmetric point

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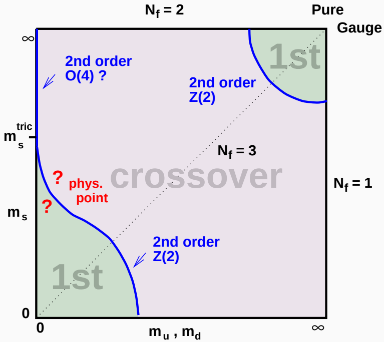
Motivation

- the critical endline at zero chemical potential for small quark mass region has not determined



[Laermann, Philipsen, '03]

Taylor expansion of kurtosis at critical endpoint around m^{sym} $(=m_{\mathrm{l}}=m_{\mathrm{s}})$

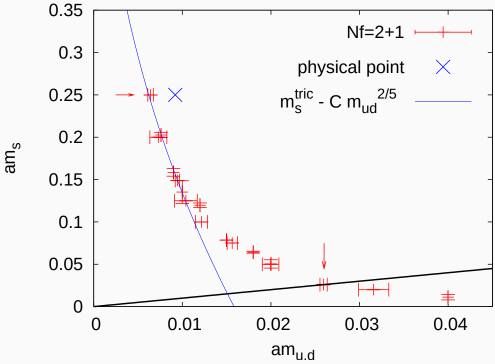
$$K_E + c(\delta m_{\mathrm{u}} + \delta m_{\mathrm{d}} + \delta m_{\mathrm{s}}) + O(\delta m^2)$$

when changing quark mass as $\delta m_{\mathrm{s}} = -2\delta m_{\mathrm{l}}$, K_E remains unchanged up to $O(\delta m^2)$

So, slope for the critical endline at m^{sym} should be - 2

- we determine the critical endline around m^{sym} with clover fermions

Previous study with staggered fermions



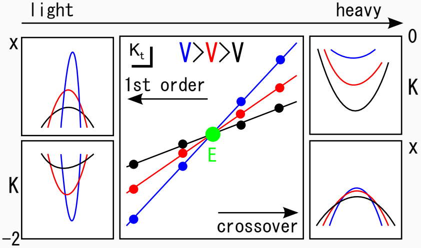
[de Forcrand, Philipsen, '06]

- $N_T = 4$, $a \approx 0.3$ fm
- data exhibits that slope at m^{sym} is not - 2
- $am_s^{crit} \approx 0.7$ (roughly **5** times larger than m_s^{phy})

Simulations

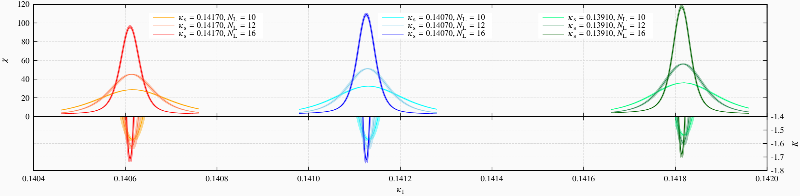
- Iwasaki gauge + NP O(a) improved Wilson fermions
- chiral condensate (10 - 20 noises for $\mathrm{Tr}D^{-1,-2.-3,-4}$)
- kurtosis intersection method to determine the critical endpoint
- reweighting method to obtain more critical endpoints
- $N_t = 6$ ($a \approx 0.19$fm)
- $N_l = 10, 16, 20, 24$

β	κ
1.715	0.140900 – 0.141100
1.73	0.140420 – 0.140450
1.75	0.139620 – 0.139700

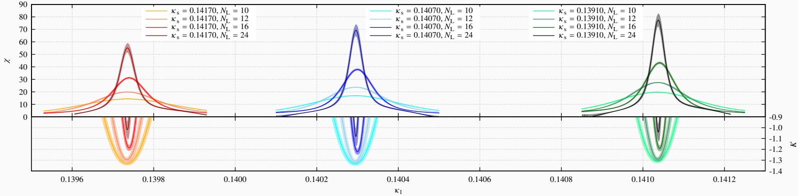


Susceptibility and kurtosis

$\beta = 1.715$



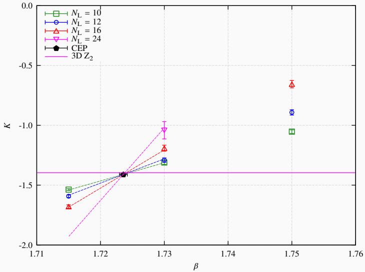
$\beta = 1.73$



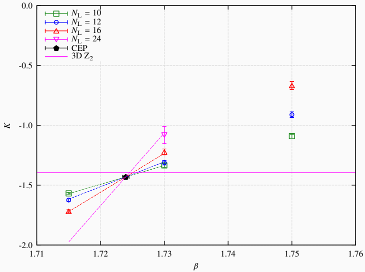
↑ $\kappa_s = 0.1417$ ↑ $\kappa_s = 0.1407$ ↑ $\kappa_s = 0.1391$

Kurtosis intersection plot

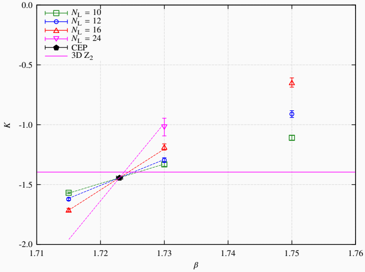
$\kappa_s = 0.1391$



$\kappa_s = 0.1407$

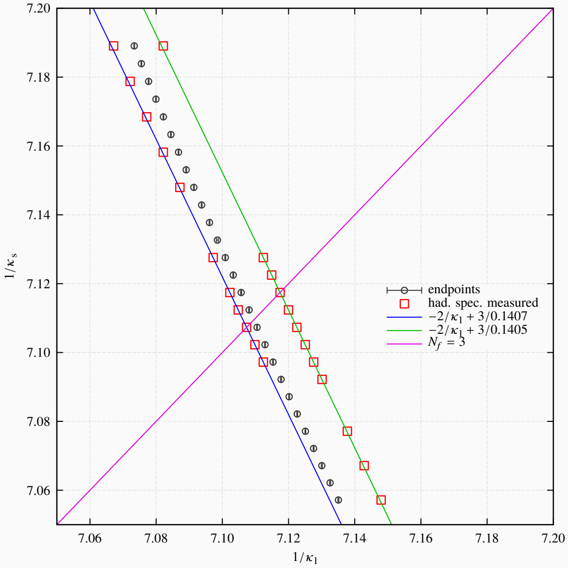


$\kappa_s = 0.1417$

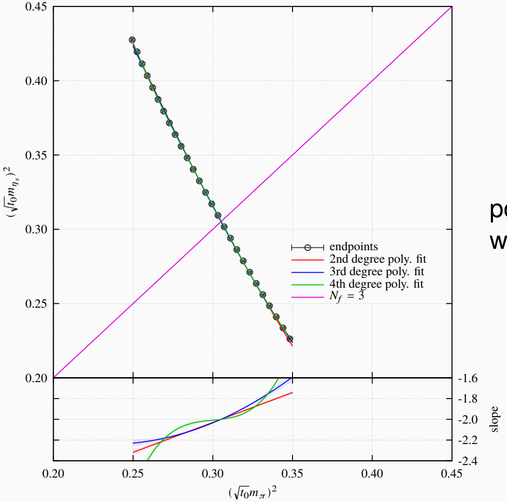


fit : $K_{\mathrm{E}} + aN_l^{1/\nu}(\beta - \beta_{\mathrm{E}})$

Critical endpoints in bare parameter plane



Critical endline

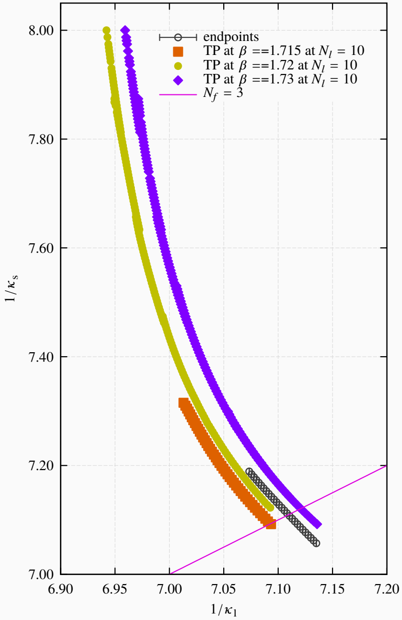


polynomial fits
with slope -2 at $\boldsymbol{m}^{\mathbf{sym}}$

- χ^2/d.o.f. $\sim$ **1**
- positive 2nd derivative

(cf. $\mathbf{1/\sqrt{t_0} = 1.347(30)}$ GeV [Borsanyi et al. '12])

Critical endpoints away from m^{sym}(preliminary)



We have determined the critical end-points (black points) by using $N_f = 3$ configurations

We are doing same analysis by using $N_f = 2 + 1$ configurations, so far only transition points at $N_t = 10$ are determined

Question : $m_s - m_s^{\text{tric}} \sim m_l^{2/5}$?

[Rajagopal '95]

Summary

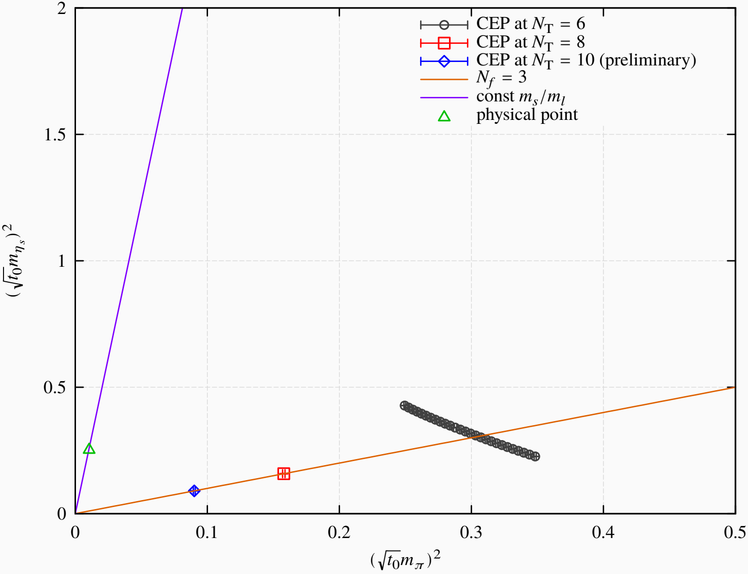
We have determined the critical endline around the SU(3)-flavor symmetric point at $N_t = 6$ with NP O(a) improved Wilson fermions

- we have confirmed slope -2 of the critical endline at symmetric point
- we have found positive 2nd derivative of the critical endline at symmetric point

Future plans

- critical endpoints away from symmetric point
- larger N_t for the continuum limit

Backup slides


CEP at N_T = 6
CEP at N_T = 8
CEP at N_T = 10 (preliminary)
N_f = 3
const m_s/m_l
physical point
$(\sqrt{t_0} m_{\eta_s})^2$
$(\sqrt{t_0} m_\pi)^2$
0
0.1
0.2
0.3
0.4
0.5
0.5
1
1.5
2