The $N_f = 3$ critical endpoint at $\mu = 0$ with smeared staggered quarks

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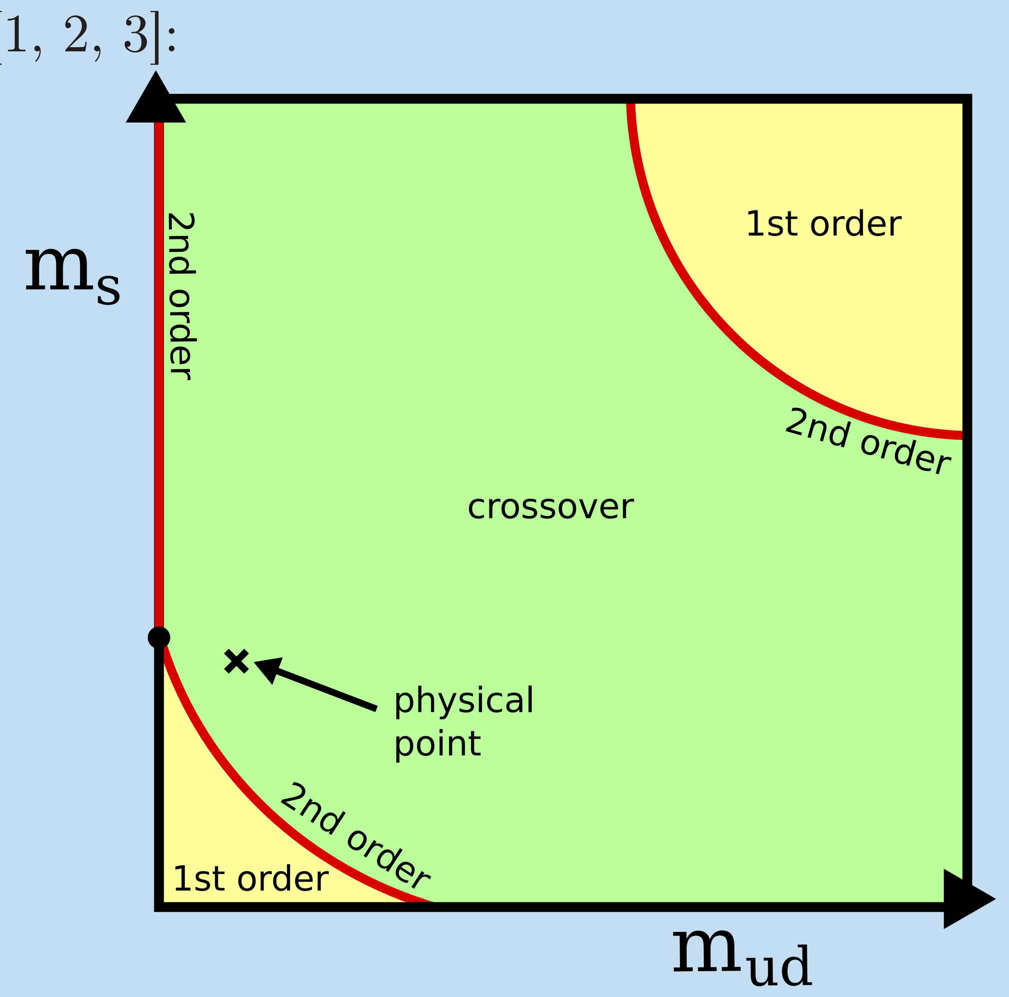
Abstract

Preliminary results for the determination of the critical endpoint of the chiral transition in $N_f = 3$ QCD with $\mu = 0$ at small N_t are presented. An unimproved Wilson gauge action with staggered fermions, for which previous results on the critical endpoint are available, was employed in this study. As an extension of these previous results the dependence of the critical mass on the strength of the stout smearing was studied.

Introduction

The order of the QCD phase transition depends on the number of light quarks and their masses [1, 2, 3]:



In this study an attempt was made to determine the critical quark mass on the $m_{ud} = m_s$ line.

Previous studies

Previous studies where performed with different actions:

N_t	action	$m_{\pi,c}$	Ref.
4	stagg.,unimproved	260 MeV	[4]
6	stagg.,unimproved	150 MeV	[5]
4	stagg.,p4	70 MeV	[6]
6	stagg.,stout	$\leq$ 50 MeV	[7]
6	stagg.,HISQ	$\leq$ 45 MeV	[8]
6	Wilson-Clover	$<$ 500 MeV*	[9]

* According to the update [10] $m_{PS}/m_{vec} \approx 0.43$

(Table from [11], with extensions)

General behavior: The smaller the discretization effects are, the smaller is the critical quark mass.

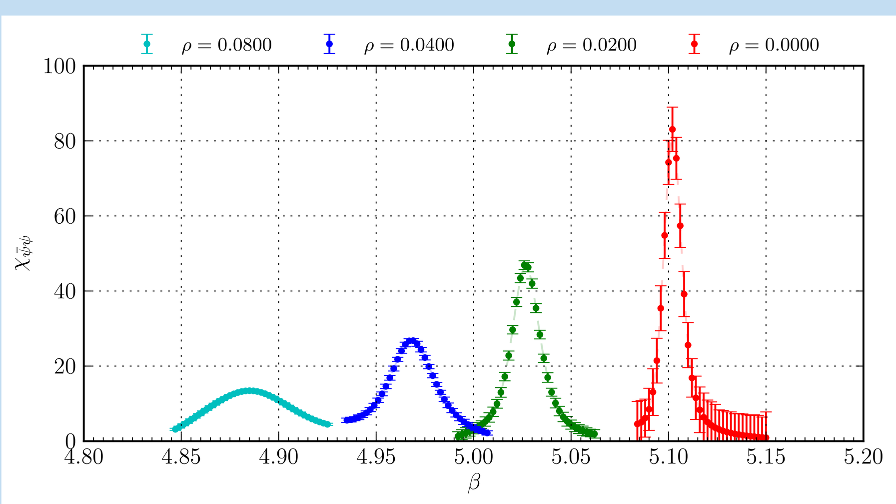
The idea

Starting with an unimproved action at coarse lattices, where the critical point can be located, the smearing is continually increased.

In this work Wilson gauge action with $N_f = 3$ staggered fermions with two levels of stout-smearing are used. The Smearing-parameter ρ is varied.

Hope: Smearing should bring the theory closer to the continuum theory and informations how to approach the continuum can be extracted.

$\chi_{\bar\psi\psi}$ at $ma = 0.01$

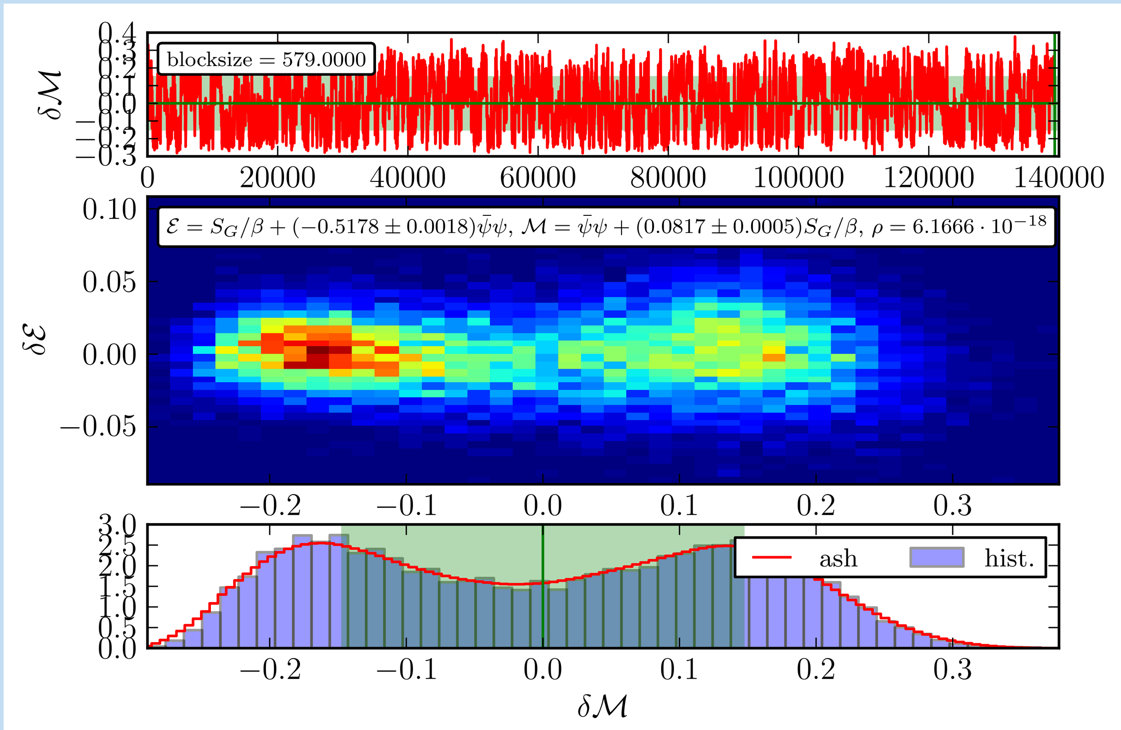


The order parameter

The order parameter $\mathcal{M}$ can be constructed using

$$\mathcal{E} = S_G/\beta + a\bar\psi\psi \quad \text{and} \quad \mathcal{M} = \bar\psi\psi + bS_G$$

by imposing the condition $\rho = \frac{\langle \delta\mathcal{E}\delta\mathcal{M}\rangle}{\sqrt{\langle\delta\mathcal{M}^2\rangle\langle\delta\mathcal{E}^2\rangle}} = 0$:



Finite size scaling

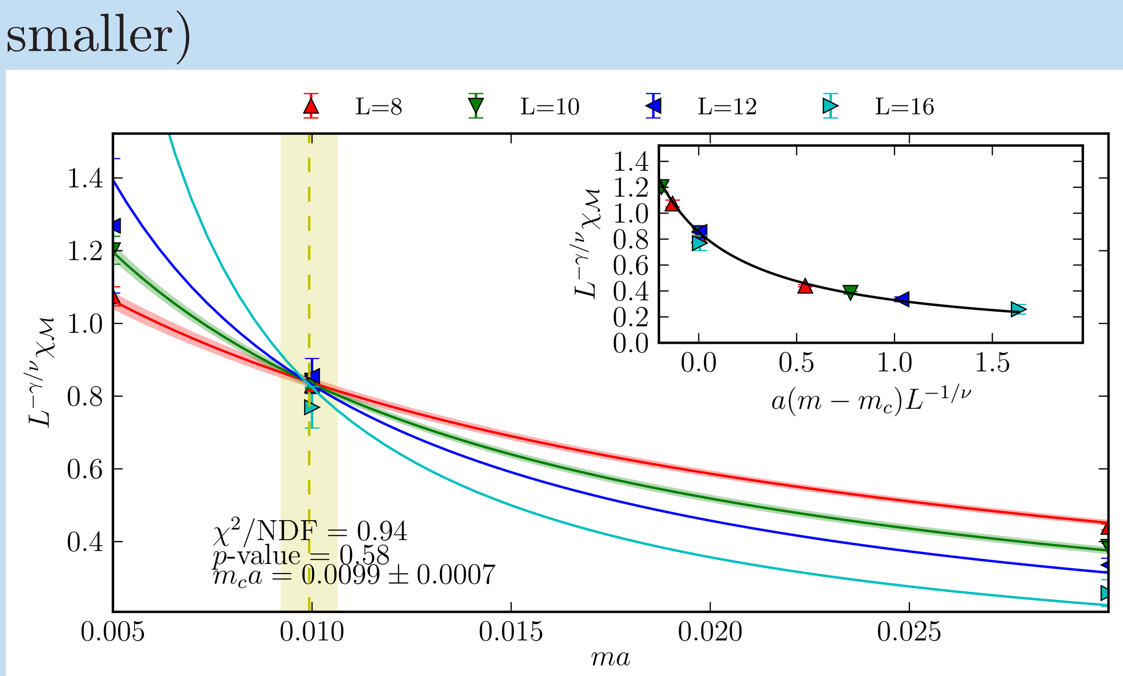
Close to a second order transition the free energy obeys

$$f(t,h,L) = b^{-1} f(tb^{y_t}, hb^{y_h}, Lb^{-1})$$

with t and h being mixtures of β and ma. From this the finite size scaling of the susceptibility can be derived:

$$\chi_{\mathcal{M}} = L^{-\frac{\gamma}{\nu}} \phi^{\text{fss}}_{\chi_{\mathcal{M}}}(ca(m - m_c)L^{\frac{1}{\nu}})$$

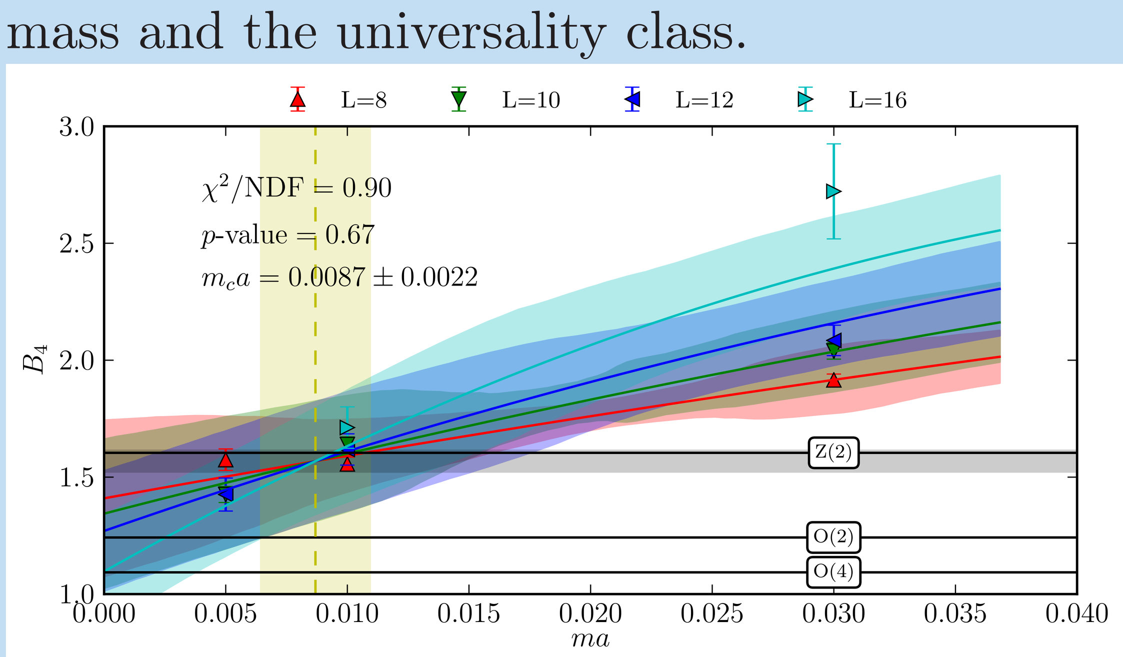
There are other exponents contributing to the scaling, but close to the transition this is the dominant contribution. (other exponents are smaller)



One can also use the intersection of the binder cummulants

$$B_4 = \frac{\langle\mathcal{M}^4\rangle}{\langle\mathcal{M}^2\rangle^2}$$

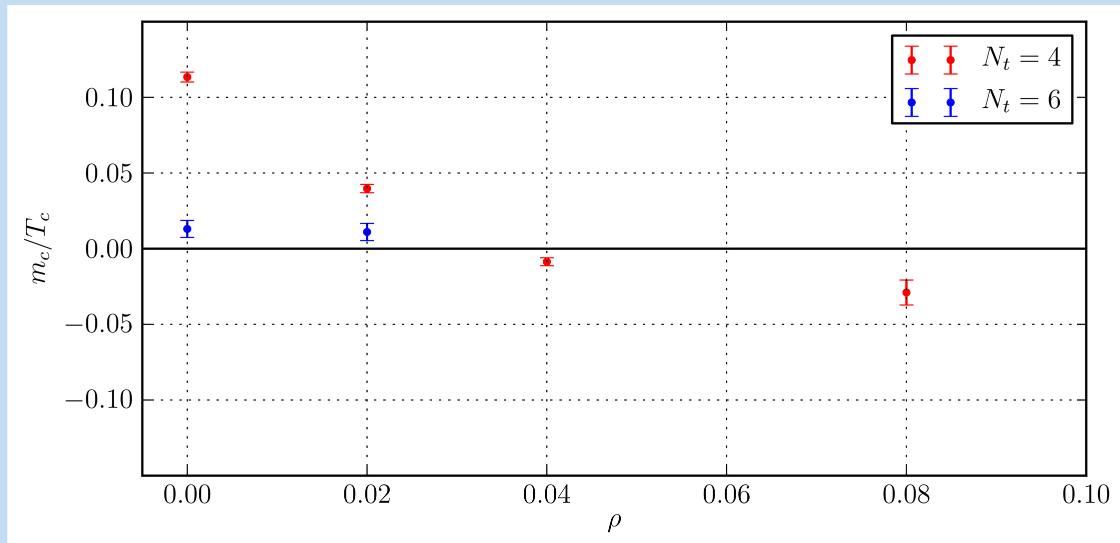
from several volumes to determine the critical mass and the universality class.



Results

The binder cummulant fit becomes unstable as soon as one needs to extrapolate in the quark mass. The fit to the susceptibilities is more stable.

Combining the results and using only the fit to the susceptibilities one obtains:



Results are very preliminary, especially the $N_t = 6$ values, where only two volumes where used.

Conclusions and prospects

Conclusions:

- The chiral phase transition has been studied at $N_t = 4$ and $N_t = 6$ lattices.
- The dependence of m_c at fixed N_t on the smearing parameter has been studied.
- The dependence on the smearing parameter is very large for coarse lattices and the transition eventually vanishes completely.
- On $N_t = 6$ this dependence is reduced drastically $\rightarrow$ Results are more reliable

Prospects:

- More volumes have to be added in order to rule out finite volume effects at small volumes.
- For this action a smearing parameter might be determined, at which we the N_t-dependence is small.

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