Update of N_f =3 finite temperature QCD phase structure with Wilson-Clover fermions

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Phase structure of 3-flavor QCD at finite temperature

Columbia plot

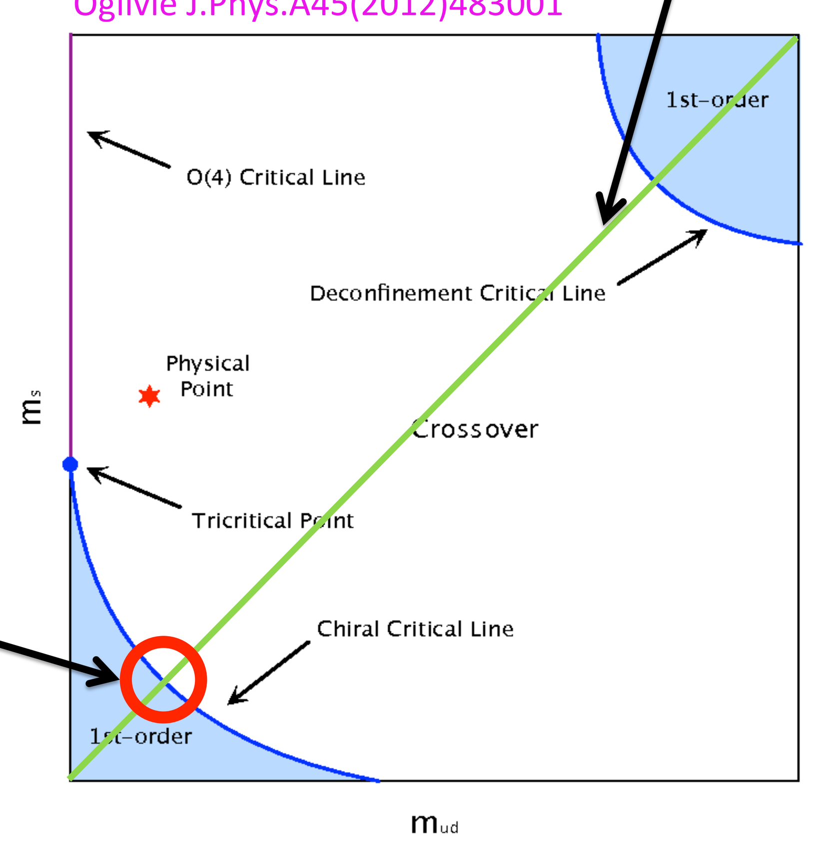
N_f=3 flavor symmetric line

Ogilvie J.Phys.A45(2012)483001

1st order region in chiral region has been reported to be so small! in KS fermion study

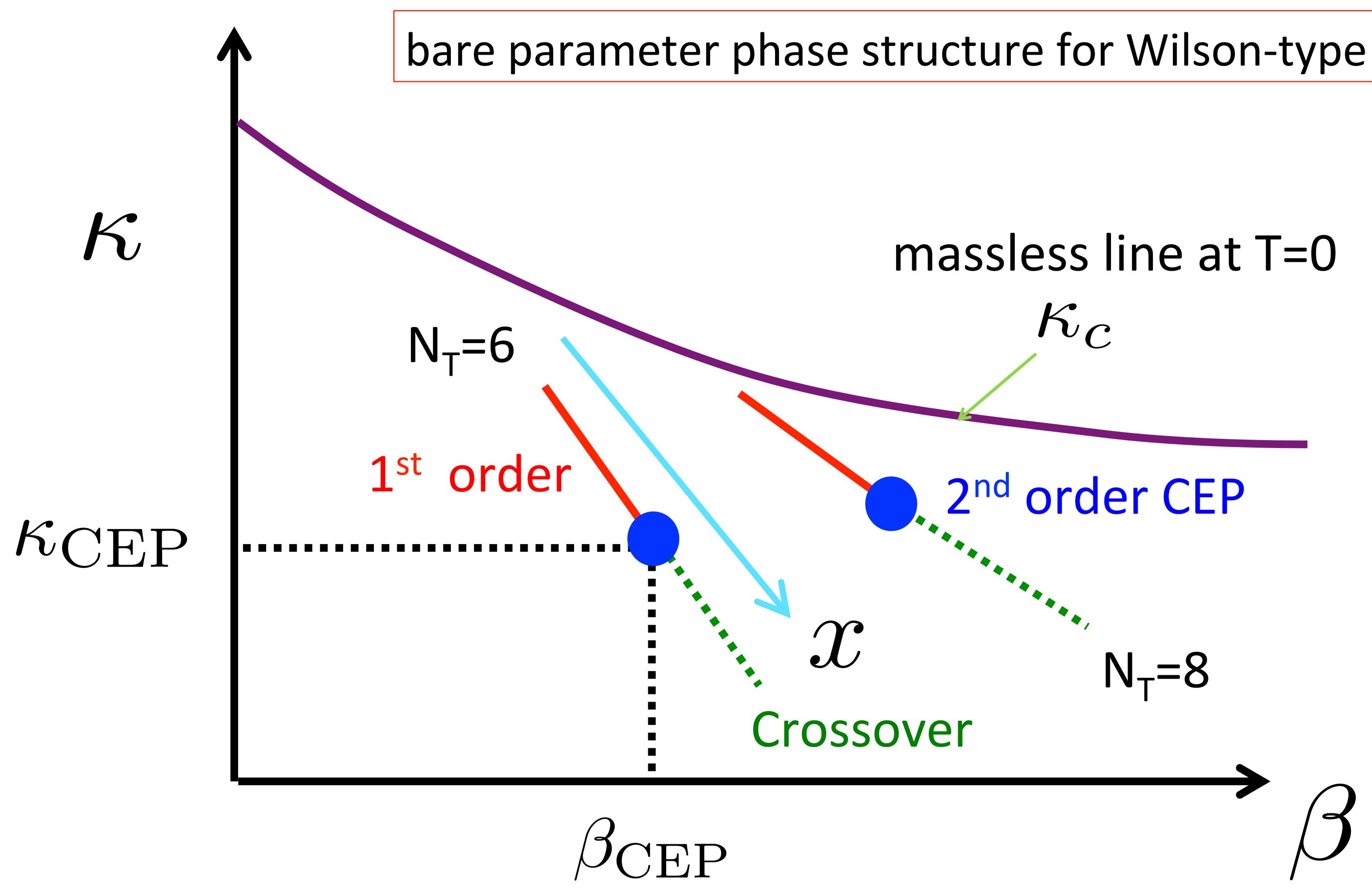
Endrodi PoS LAT2007, 182
de Forcrand & Philipsen 2007
Ding PoS LAT2011, 191

We study the location of critical point with N_f=3 by Wilson-type fermions



Strategy

bare parameter phase structure for Wilson-type fermions

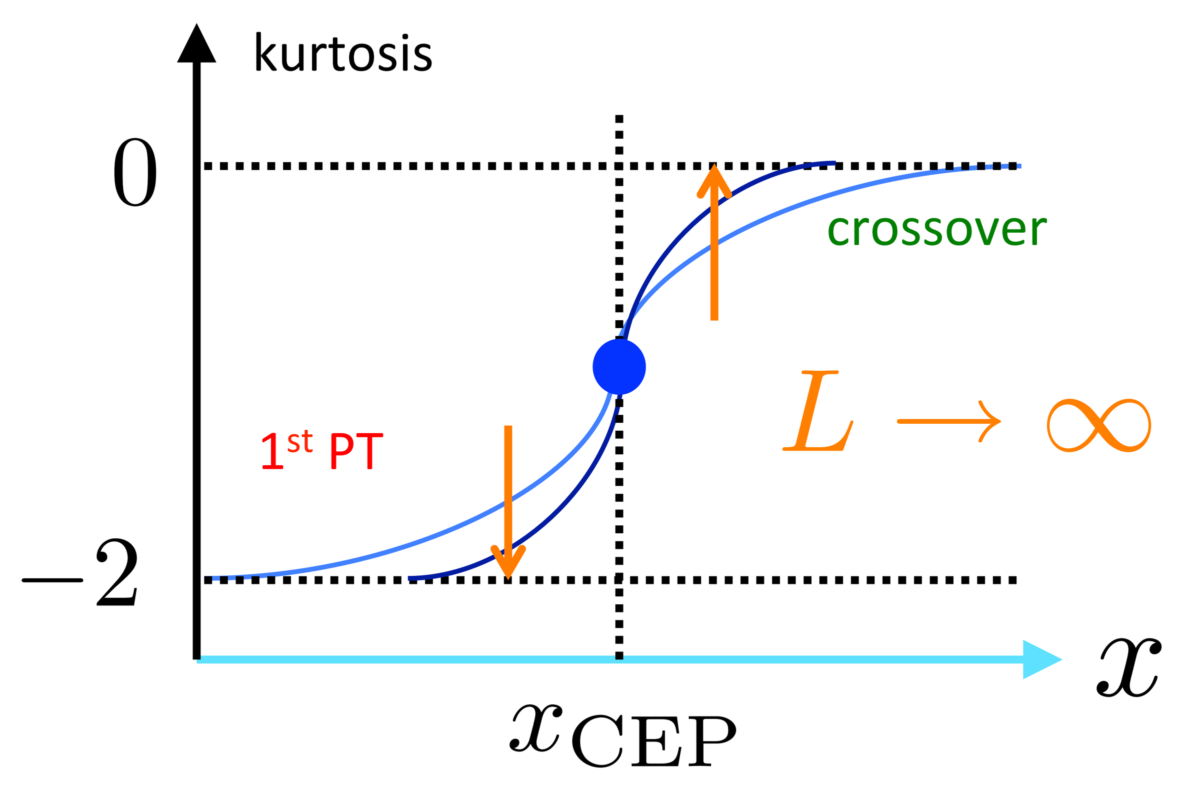


Kurtosis intersection

kurtosis

$$K = \frac{\kappa_4}{\kappa_2^2}$$

cumulants of order parameter



Set up & Simulation parameters

- NP O(a) improved Wilson fermions & Iwasaki gauge
- BQCD code
- RHMC, accept. rate is around 0.8
- measured naïve chiral condensate (order parameter)
- 10-20 noises (Z_2 noise) are used for estimating tr[$D^{-1,-2,-3,-4}$] needed for calculating cumulants

N_T	N_L	β	κ
6	10-24	1.715, 1.73, 1.75	0.139620 - 0.141020
8	16-24	1.74995, 1.76019	0.139950 - 0.140240
10	16-28	1.77, 1.78, 1.79	0.140000 – 0.139250

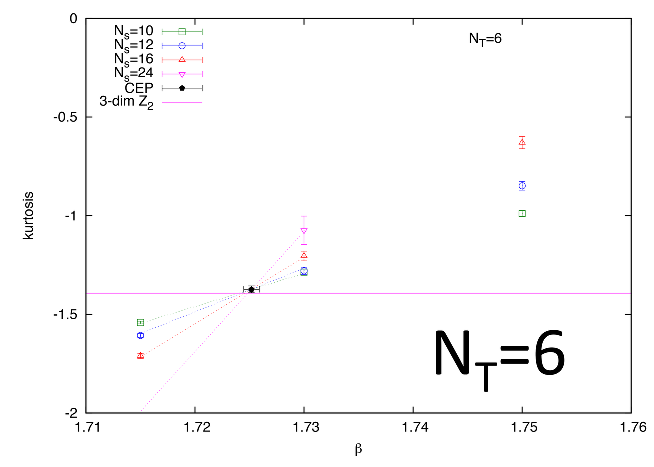
new data

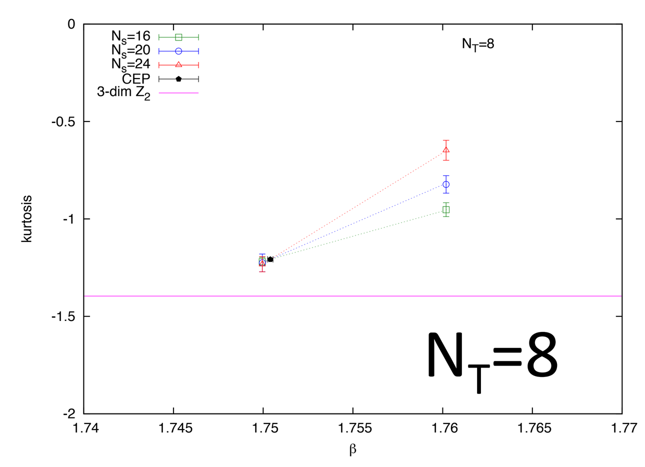
Results

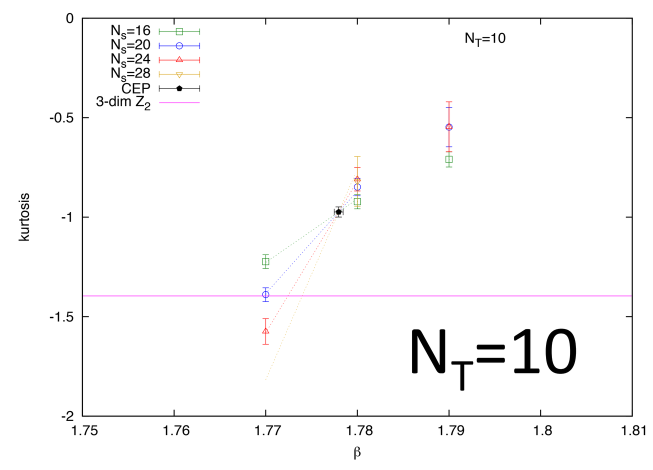
$$K = K_{\rm E} + A N_L^{1/\nu}(\beta - \beta_{\rm CEP})$$

Kurtosis intersection

Consistent with Z_2 universality class







Inconsistent with Z_2

Chiral condensate tends to largely overlap with energy-like obs. for N_T=8 & 10?

new data

Scaling of kurtosis for mixed observable

Any observable (say chiral condensate) can be considered as a mixture of magnetization (purely order parameter) and energy

Karsch et al., 2001

$$\mathcal{O} = c_{\rm M}\mathcal{M} + c_{\rm E}\mathcal{E}$$

For such an observable, the associated kurtosis shows the scaling behavior around the critical point

Jin et al., 2015

$$K_{\mathcal{O}} = \left(K_{\rm E} + A N_L^{1/\nu}(\beta - \beta_{\rm CEP})\right)\left(1 + B N_L^{y_t - y_h}\right)$$

new term

$y_t - y_h \approx -1$ for Z_2, O(2), O(4) in 3D $\qquad B \propto c_{\rm E}$

fit form	N_t	$\beta_{\rm E}$	$K_{\rm E}$	ν	A	B	$y_t - y_h$	χ^2/dof
Old-0	6	1.72518(71)	−1.373(17)	0.683(54)	0.58(17)	×	×	0.68
Old-1	6	1.72429(26)	−1.396	0.643(44)	0.45(12)	×	×	0.85
Old-2	6	1.72480(56)	−1.384(12)	0.63	0.420(11)	×	×	0.71
Old-3	6	1.72431(24)	−1.396	0.63	0.418(11)	×	×	0.70
New-0	6	1.7211(22)	−1.63(13)	0.777(70)	1.00(33)	−1.19(50)	−1	0.32
New-1	6	1.72489(44)	−1.396	0.696(55)	0.63(19)	−0.136(85)	−1	0.59
New-2	6	1.7245(20)	−1.41(12)	0.63	0.423(23)	−0.12(67)	−1	0.93
New-3	6	1.72461(39)	−1.396	0.63	0.422(12)	−0.065(65)	−1	0.70
New-4	6	1.72462(40)	−1.396	0.63	0.422(12)	−0.052(52)	−0.894	0.70
Old-0	8	1.75040(15)	−1.2075(55)	0.513(13)	0.116(18)	×	×	0.01
Old-1	8	1.7453(10)	−1.396	0.96(29)	1.7(1.7)	×	×	1.78
Old-2	8	1.74978(67)	−1.231(24)	0.63	0.345(12)	×	×	0.21
Old-3	8	1.7454(12)	−1.396	0.63	0.338(43)	×	×	2.60
New-0	8	1.7495(11)	−1.31(12)	0.529(25)	0.145(47)	−1.0(1.1)	−1	0.01
New-1	8	1.74876(11)	−1.396	0.543(13)	0.175(24)	−1.681(54)	−1	0.01
New-2	8	1.7460(17)	−1.69(21)	0.63	0.419(33)	−3.4(1.2)	−1	0.09
New-3	8	1.74836(36)	−1.396	0.63	0.374(10)	−1.47(15)	−1	0.12
New-4	8	1.74846(38)	−1.396	0.63	0.375(11)	−1.12(12)	−0.894	0.13
Old-0	10	1.77796(48)	−0.974(25)	0.466(45)	0.084(52)	×	×	0.22
Old-1	10	1.7690(14)	−1.396	2.8(5.4)	16(34)	×	×	7.08
Old-2	10	1.7785(10)	−0.940(51)	0.63	0.448(23)	×	×	0.61
Old-3	10	1.7694(16)	−1.396	0.63	0.421(95)	×	×	10.03
New-0	10	1.7796(18)	−0.70(30)	0.419(63)	0.032(43)	5.2(8.0)	−1	0.25
New-1	10	1.77529(52)	−1.396	0.554(92)	0.29(26)	−3.91(33)	−1	0.50
New-2	10	1.7757(29)	−1.33(41)	0.63	0.539(88)	−3.5(2.7)	−1	0.58
New-3	10	1.77524(52)	−1.396	0.63	0.552(28)	−3.90(34)	−1	0.44
New-4	10	1.77545(53)	−1.396	0.63	0.559(29)	−2.97(25)	−0.894	0.43

One additional parameter in the fitting form reduces the tension in large N_T=8, 10

Consistent with Z_2

Summary

- We derive a new fitting form of kurtosis intersection method including the effect of the energy-like observable
- New fitting result is consistent with Z_2 for larger N_T=8, 10
- We shall try the mixed observable analysis
- Continuum limit (N_T=6,8,10)
- N_f=2+1 and study the shape of critical line