

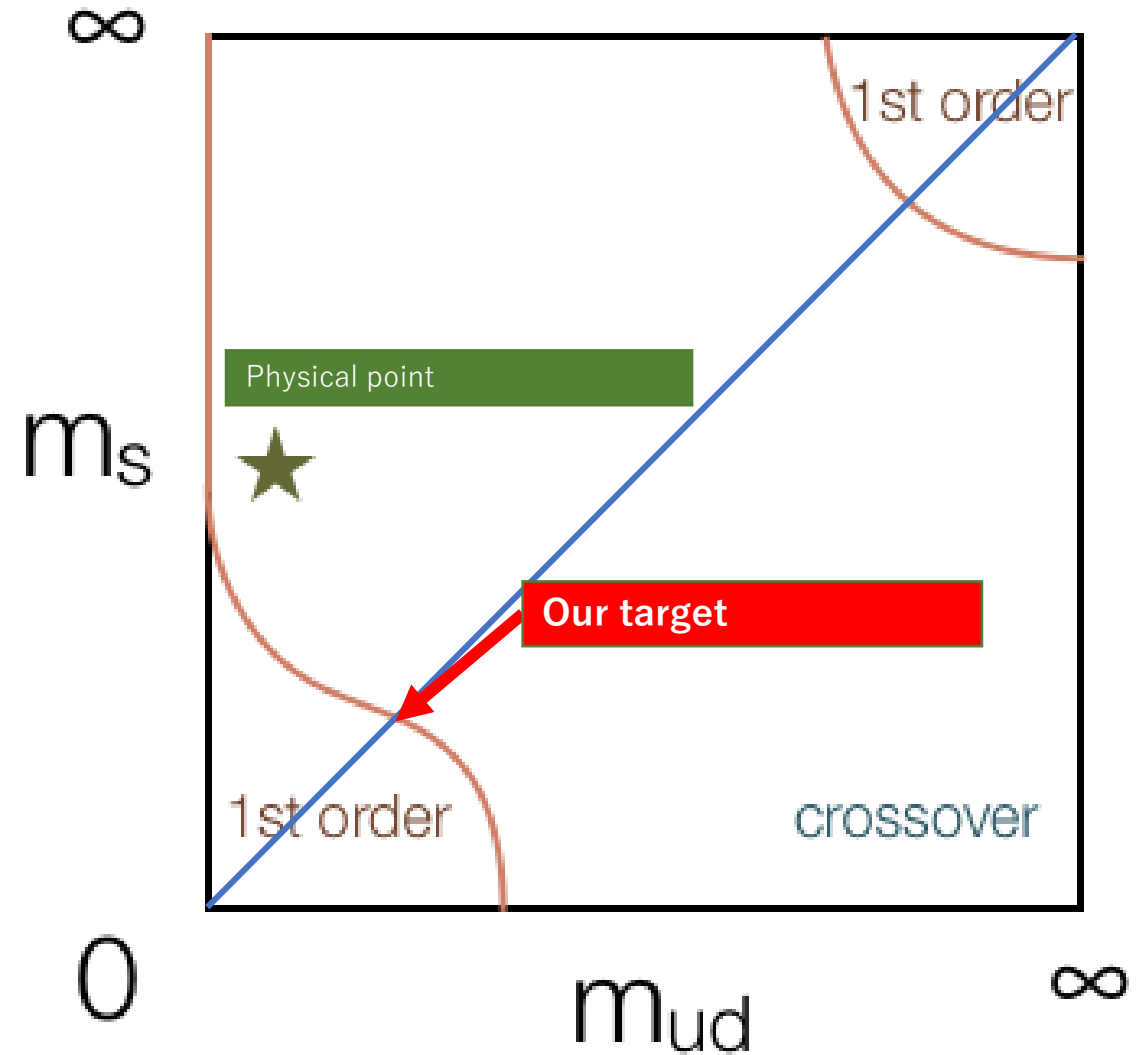
Finite temperature phase transition for three flavor QCD with Möbius-domain wall fermions

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Columbia plot

- The nature of the finite temperature phase transition in 2+1 flavor QCD depends on the quark mass, and the order and universal class of the phase transition are shown.



Previous studies for critical endpoint/line

Found	Nf	Sg	Sf	Nt	Endpoint	Ref.
Y	3	W	W	4	$m_{\text{PS}} > 1 \text{ GeV}$	Iwasaki et al, '96
Y	3	W	KS	4	$m_{\text{PS}} \sim 290 \text{ MeV}$	Karsch et al, '01
Y	3	I	p4	4	$m_{\text{PS}} \sim 190 \text{ MeV}$	Karsch et al, '01
Y	3	W	KS	4	$m_{\text{PS}} = 290(20) \text{ MeV}$	Karsch et al, '04
Y	3	I	p4	4	$m_{\text{PS}} = 67(17) \text{ MeV}$	Karsch et al, '04
Y	3	W	KS	4	$am_q \approx 0.033$	Karsch et al, '04
Y	3	W	KS	4	$am_q \approx 0.0260(5)$	de Forcrand et al, '07
Y	3	W	KS	4	$m_{\text{PS}}/T = 1.680(4)$	de Forcrand et al, '07
Y	3	W	KS	6	$m_{\text{PS}}/T = 0.954(12)$	de Forcrand et al, '07
N	2+1	I	Stout	4	$m_q/m^{\text{phy}} \leq 0.07$	Endrodi et al, '07
N	2+1	I	Stout	6	$m_q/m^{\text{phy}} \leq 0.12$	Endrodi et al, '07
Y	3	I	Clover	4, 6, 8	$m_{\text{PS}} \sim 300 \text{ MeV}$	Kuramashi et al, '14
Y	3	I	Clover	8, 10	$m_{\text{PS}} \leq 170 \text{ MeV}$	Kuramashi et al, '17
Y	3	I	Clover	8, 10, 12	$m_{\text{PS}} \leq 110 \text{ MeV}$	Kuramashi et al, '20
N	3	I	HISQ	6	$m_{\text{PS}} \leq 50 \text{ MeV}$	Bazavov et al, '17
N	2+1	I	HISQ	6, 8 (, 12)	$m_{\text{PS}} \leq 80 \text{ MeV}$	Ding et al, '18, '19
Y	3, 2+1				$m_q = 0$	Cuteri et al, '21

- Increasing the time direction lattice size N_T decreases the pseudoscalar mass m_{PS} at the critical endpoint
- In the continuum limit, only the upper limit of m_{PS} at the critical endpoint is fixed
- Recent studies using staggered fermions have not found the first-order phase transition

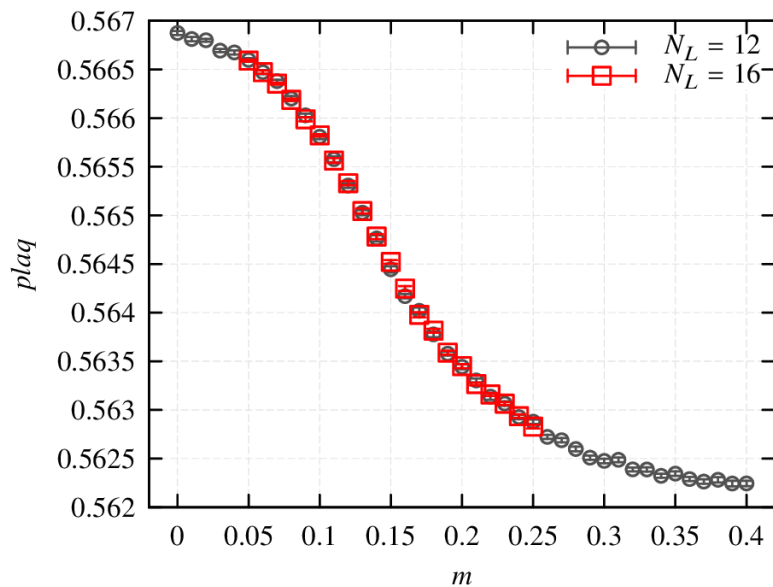
Endrodi : $\frac{m_l}{m_s} = \frac{m_l^{\text{phy}}}{m_s^{\text{phy}}}$, Ding et al, '18, '19 : $m_s = m_s^{\text{phy}}$, Cuteri: comprehensive study (beta, am, Nt, Nf)

Lattice setup

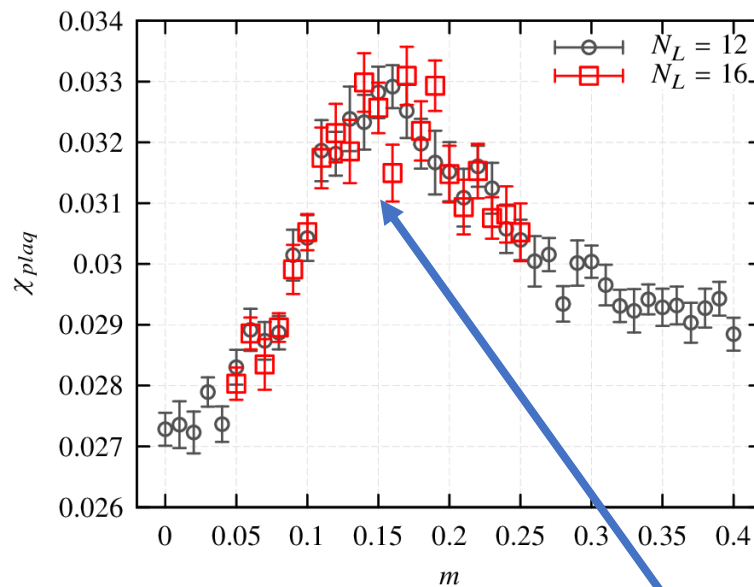
- Action
 - $N_F=3$ Möbius-domain wall fermion with $L_s=16$
 - Symanzik gauge at $\beta=4.0$ ($1/a=1.57(16)$ GeV)
- Size
 - $N_T = 6, N_L = 12, 16, \quad T = 262(27)$ MeV
 - $N_T = 8, N_L = 16, \quad T = 196(20)$ MeV
- Statistics : 100K traj for each
- Measurement
 - Plaquette
 - Topological charge
- Computational resources
 - Fugaku (RIKEN)
 - Ito (Kyushu, used in preparatory research)

$$N_T = 6, \beta = 4.0$$

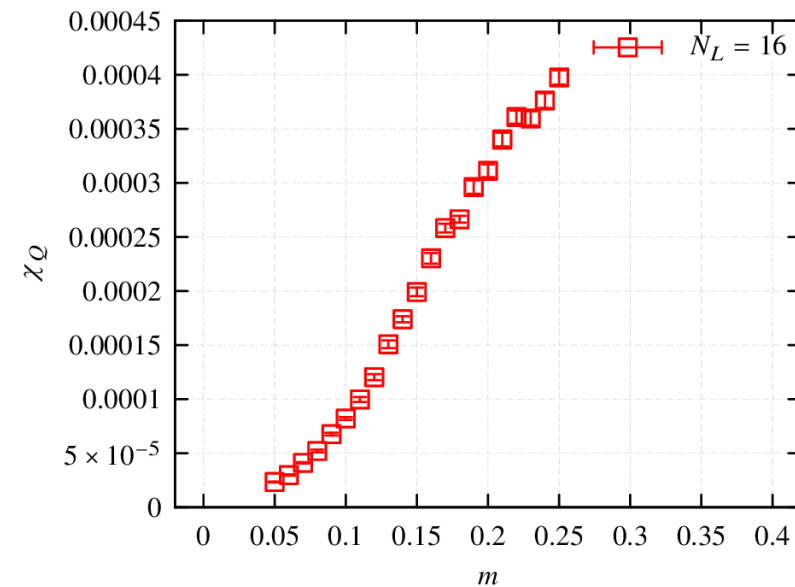
Plaquette



Plaquette susceptibility



Topological susceptibility

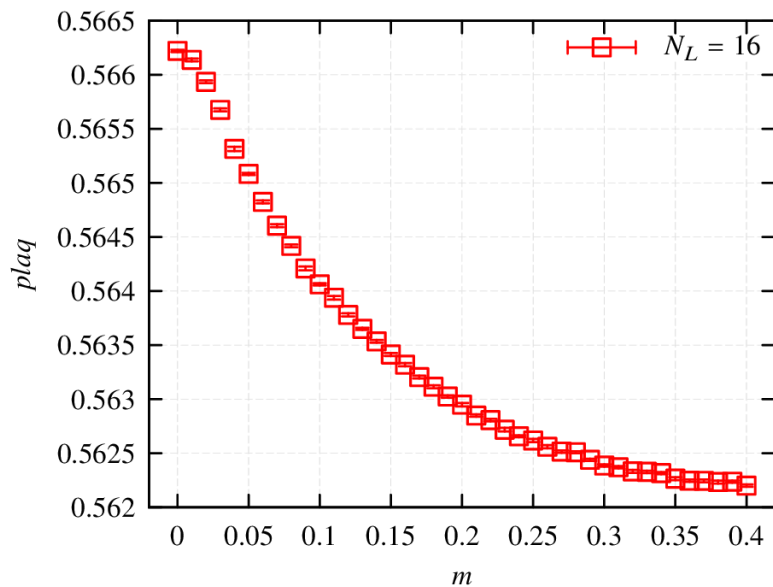


It seems to be a crossover at $m=0.15$?

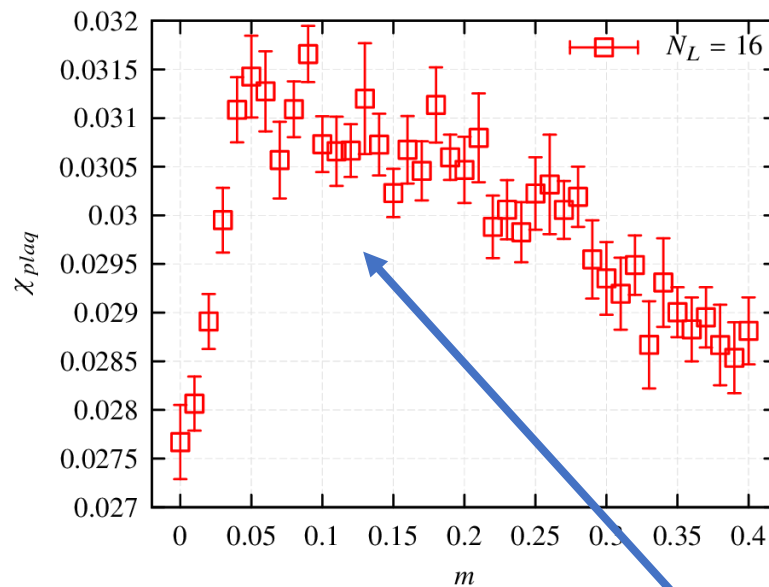
cf. $m_s \sim 0.07$ at $\beta = 4.0$

$$N_T = 8, \beta = 4.0$$

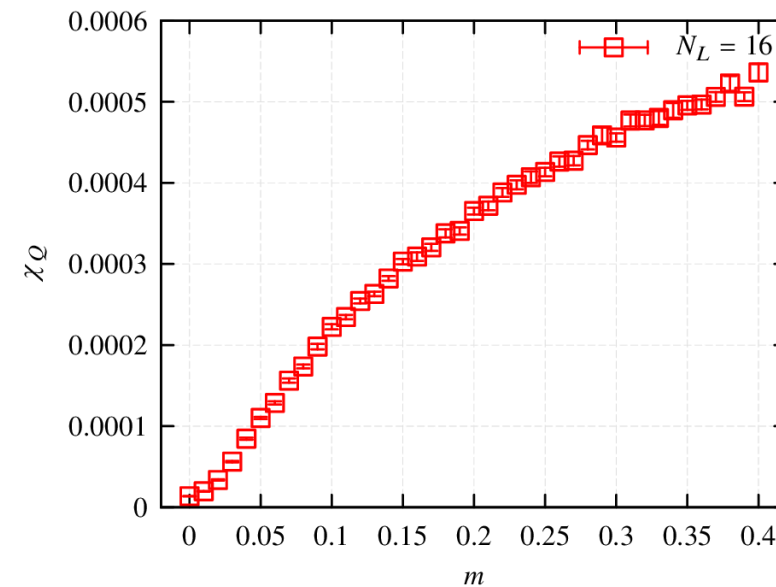
Plaquette



Plaquette susceptibility



Topological susceptibility



Sign of crossover or transition at $m=0.1$?
We need larger size simulations

cf. $m_s \sim 0.07$ at $\beta = 4.0$

Summary

- We are studying the finite temperature phase transition for three flavor QCD with Möbius-domain wall fermions at $N_T = 6$ and 8, and measured plaquette and topological charge so far.
- We found a peak in the plaquette susceptibility
 - at $N_T=6$, $\beta = 4.0$, $m \sim 0.15$ (it seems to be a crossover)
 - at $N_T=8$, $\beta = 4.0$, $m \sim 0.1$ (larger spatial size studies are needed)
- Plan
 - larger N_T simulations and measure fermionic observables.
 - simulations at $T=0$ to improve physical scale

Acknowledgments

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