The order of the deconfinement phase transition in a heavy quark region
- Dependence on the number of flavors -

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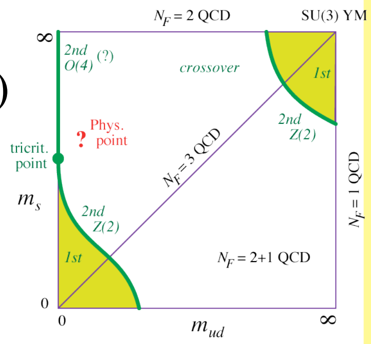
Phase diagram

The order of the deconfinement phase transition is a fundamental topic. The order of the transition depends on the quark mass.

We investigate the end point of 1st order transition in the (m_{ud}, m_s) plane of $N_f = 2+1$ by using lattice QCD simulation. In this study, we discuss it in a heavy quark mass region.



Probability distribution function

Probability distribution function is useful to identify the order of a phase transition.

❖ **Probability distribution function**:

$$w(P') = \int \mathcal{D}U\mathcal{D}\psi\mathcal{D}\bar{\psi}\delta(P(U) - P')e^{-S(\beta,\kappa)}$$

β : coupling

❖ **An effective potential**:

$$V(P) = -\ln w(P)$$

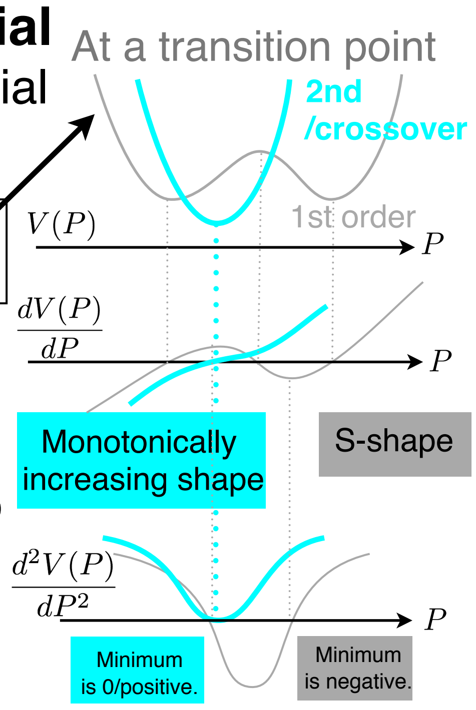
❖ **Nature of the potential**

✦The shape of the potential ⇔ order of the transition

double-well : 1st order
single well : 2nd/crossover

✦ The derivative of the potential

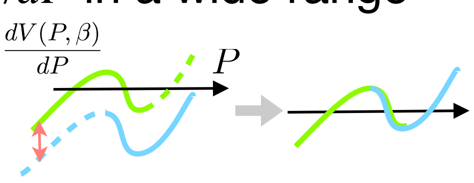
✦ Turning point in the two shapes ⇔ End point of 1st order



❖ **Reweighting method**

(i) ***β-Direction*** : To get dV/dP in a wide range

$$\frac{dV(P,\beta)}{dP} = \frac{dV(P,\beta')}{dP} - 6N_{\rm site}(\beta-\beta')$$



(ii) ***κ-Direction*** : To evaluate the end point

$$V(P,\kappa,\beta) = -\ln R(P,\kappa) + V_0(P,\beta)$$

Reweighting term : $R(P',\kappa) = \frac{\int \mathcal{D}U\delta(P(U)-P')[\det M(U,\kappa)]}{\int \mathcal{D}U\delta(P(U)-P')}$

The change of the order is caused by dynamical quark effect which is included by the quark determinant factor.

$$V_0(P',\beta) = -\ln\left[\int \mathcal{D}U\delta(P(U)-P')e^{-S_g(\beta)}\right]$$

HS talk in Lattice2010

N_f=2+1 phase diagram

The N_f - dependence appears in the quark determinant:

$$R(P',\kappa) = \frac{\int \mathcal{D}U\delta(P(U)-P')\left[\{\det M(U,\kappa_{ud})\}^2 \det M(U,\kappa_s)\right]}{\int \mathcal{D}U\delta(P(U)-P')}$$

We can consider the many flavors case by replacing into $[\det M(U,\kappa)]^{N_f}$.

Lattice setup

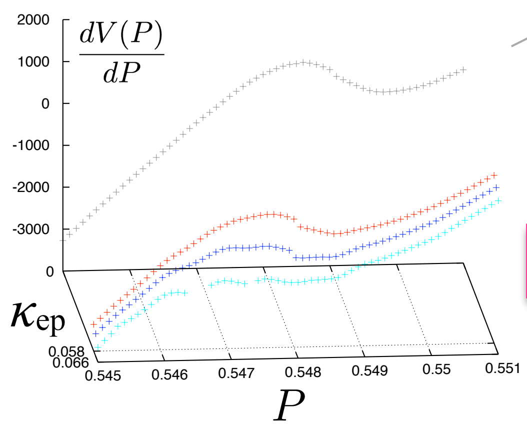
- Action : Standard wilson fermion (hopping parameter $\kappa \approx m_q^{-1}$) and Plaquette action
- HeatBath / • Simulation Setup
- The $\det M(\kappa)$ is evaluated by using a hopping parameter expansion.

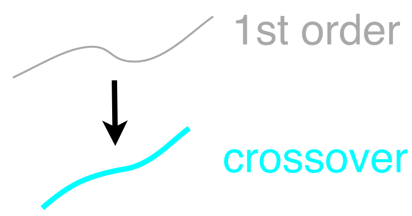
The LO of the quark determinant factor has a coefficient $N_f\kappa_{ep}$. The shape of the potential is unchanged when the coefficient is constant.

β	Confs
5.68	100,000
5.685	430,000
5.69	500,000
5.6925	670,000
5.7	100,000

Result

❖ **The order of the deconfinement phase transition**

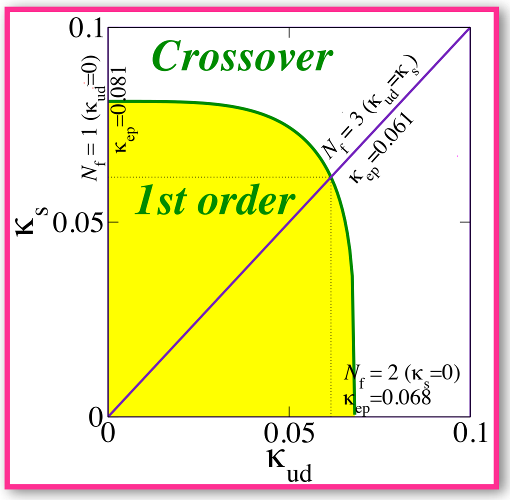




κ_{ep} =0.068(7) for $N_f = 2$

❖ **The $N_f = 2+1$ phase diagram**

The result is consistent with the result of Z(3) model reported by Alexandrou *et al*(1990).



Summary & Future prospect

i. The κ_{ep} value decreases as N_f increases.

ii. The method can be applied to the case of non-zero μ. S. Ejiri's talk

iii. The method of probability distribution function to identify the order of the transition works well.