Study of the conformal phase in the SU(3) gauge theory with domain-wall fermions

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JICFuS

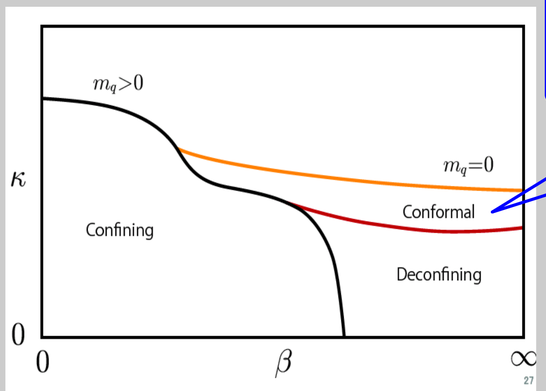
Study of conformal QCD as BSM candidate by Wilson fermions

Ishikawa, Iwasaki, Nakayama and Yoshie, 2012-

- **SU(3) fundamental rep, N_f = 7-16**
  - phase structure in the simulation parameter space (κ, β)
- **characteristics of the conformal phase**
  - meson decays with modified Yukawa-type form

conjecture by RG argument : $G_H(t) = c\,t^{-\alpha} \quad \overset{V=\text{finite}}{\longrightarrow} \quad G_H(t) = c\,t^{-\alpha} e^{-m_H t}$

  - Z(3) -twisted Polyakov loop ← effective potential to 1-loop



better access to the conformal phase?
- without tuning the mass parameter
- good chiral symmetry

massless domain-wall fermions

N_f = 8 massless domain-wall fermions

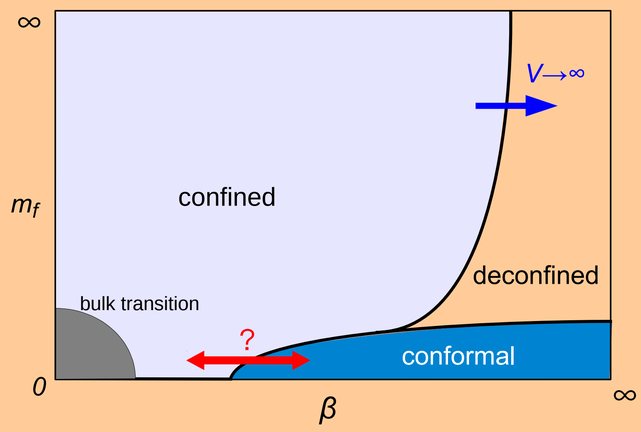
- Iwasaki gauge action + original Shamir's kernel, M = 1.6
- m_f = 0.0, residual mass is negligiblly small
- APBC in t-dir of fermion, PBC for others
- carried out on BlueGene/Q @ KEK

IROIRO++

size	*β*
8^3x32	2.0, 2.3, 2.6, 4.2, 4.7, 6.0
16^3x64	2.6, 3.4, 4.2, 4.7, 6.0

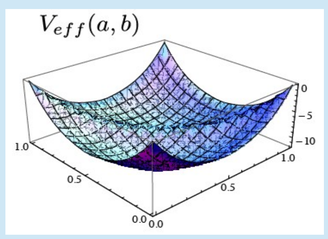
Inspection of the finding by IINY

- phase structure: confined ↔ conformal transition
- property of the conformal phase
  - Polyakov loop → twisted vacuum
  - PP correlator → power law corrected Yukawa
    → location of IRFP
  - Dirac spectrum → anomalous dimension



Polyakov loop

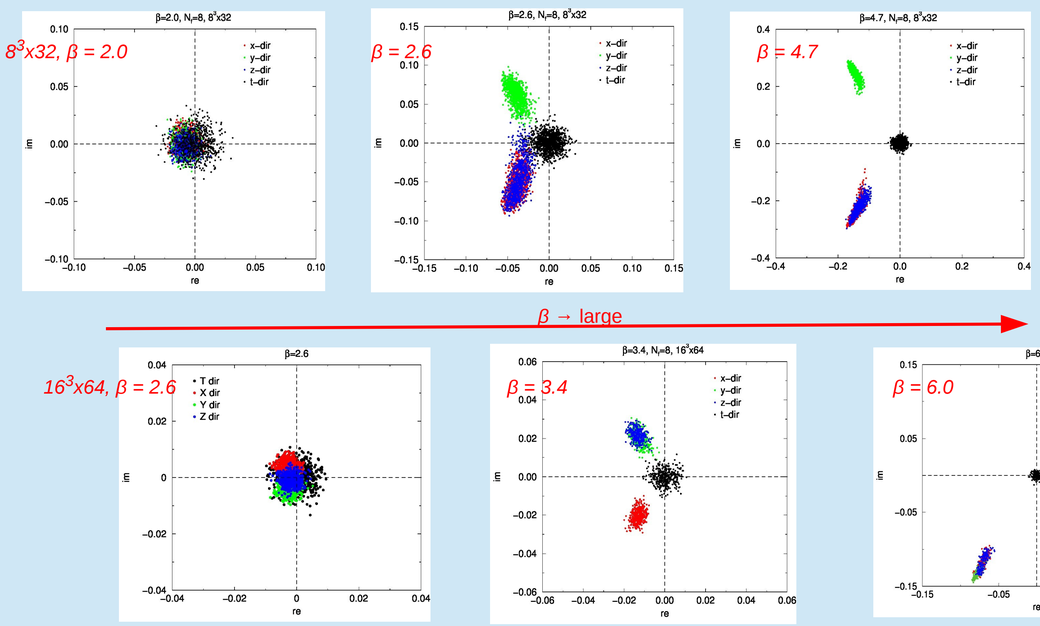
$$P_i = \mathrm{tr}\begin{bmatrix} e^{2\pi i a_i} & & \\ & e^{2\pi i b_i} & \\ & & e^{2\pi i (n-a_i-b_i)} \end{bmatrix}$$



$V_{\text{eff}}^{\text{1-loop}}(a, b)$ has minima at

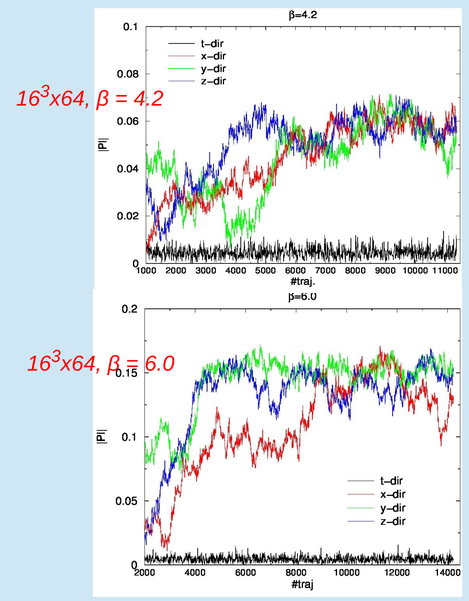
$a_i = b_i$ = ±1/3 or ±2/3 for $i = x, y, z$

in the conformal phase



predicted behaviors and β-shift depending on the size are observed.

very long thermalization / autocorrelation time in the conformal phase

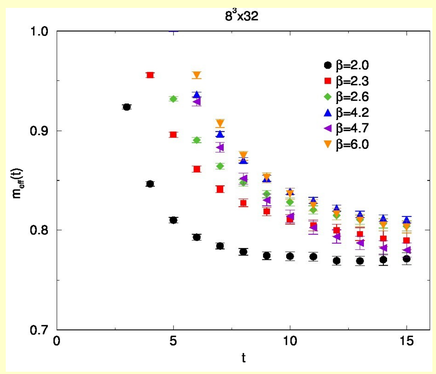


thermalization:
$|P_x| \approx |P_y| \approx |P_z|$ is a necessary cond.

P-P correlator (very preliminary)

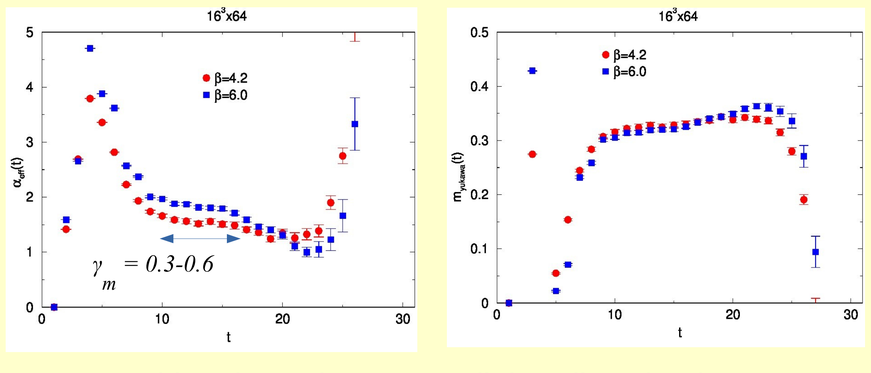
- effective mass by $A\cosh(-m_{\text{eff}}\,t)$

at a glance, no plateau for larger β



- effective alpha & effective Yukawa-mass by $t^{-\alpha}\,e^{-mt}$

$$\alpha_{\text{eff}} = \ln\frac{G(t-1)G(t+1)}{G(t)^2}\left(\ln\frac{t^2}{t^2-1}\right)^{-1} \qquad m_{\text{eff}} = \ln\frac{G(t)}{G(t+1)} - \alpha_{\text{eff}}\ln\frac{t+1}{t}$$



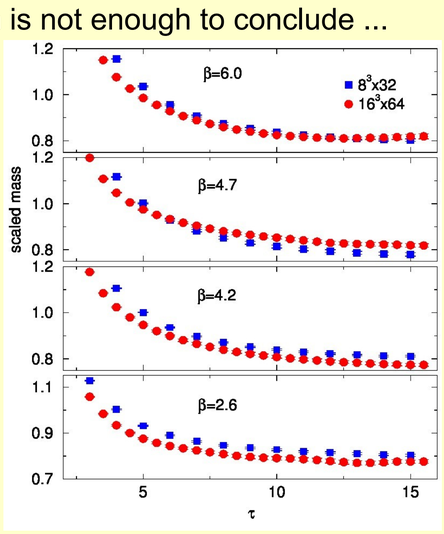
reasonable t-dependence → well describes the data

- location of the infrared fixed point (IRFP)
  Ishikawa, Iwasaki, Nakayama and Yoshié, 2015

- scaled correlator: $G(\tau = t/s; L)$ [ref. scale s , latice size L]

at IRFP, $G(\tau, L) = \left(\frac{L'}{L}\right)^{3-2\gamma^\star} G(\tau, L')$ ➡ size independent m_{eff}

however, current data is not enough to conclude ...



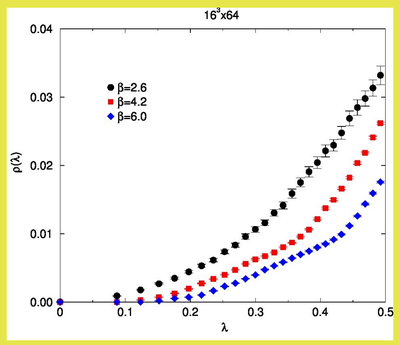
Spectral density by the stochastic method

Giusti & Luscher, see S. Hashimoto's poster, as well

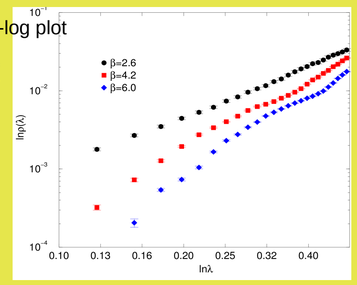
$$\rho(\lambda) = \frac{1}{2\delta V N_r}\sum_{i=1}^{N_r}\langle\xi_i^\dagger h_\delta(2D^\dagger D - 1)\xi_i\rangle \propto \lambda^\alpha$$

$h_\delta(X)$ is a polynomial filter for a certain range of width δ

- suffers from severe finite size effect
- no condensation → chiral symmetry unbroken



log-log plot



ln ρ= α lnλ +const → need larger vol.

Summary

- predicted vacuum structure observed w.r.t. Polyakov loop as well as a transition
- modified Yukawa-form describes the correlator data, more statistics needed to conclude
- obtaining anomalous dim. needs larger volume

Future plans

- locating IRFP by larger lattice
- study of other N_f's
- study with the N_f= 2 finite temperature