Finite temperature lattice QCD with Nf=2+1 Wilson quark action

WHOT-QCD Collaboration

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(1) Introduction

Recent calculations for Finite temperature QCD (Tc calculations)

RBC-Bielefeld: Nt=4,6,(8) Staggered (p4) quark
$m_{pi}/m_{rho} \geq 0.2$, Nf=2+1

MILC: Nt=4,6,8 Staggered (Asqtad) quark
$m_{pi}/m_{rho} \geq 0.3$, Nf=2+1

Wuppertal: Nt=4,6,8,10 Staggered (stout) quark
$m_{pi}/m_{rho} = 0.18$, Nf=2+1

DIK: Nt=8,10 Wilson (NPI Clover) quark
$m_{pi}/m_{rho} \geq 0.77$, Nf=2

WHOT-QCD: Nt=4,6 Wilson (MFI Clover) quark
$m_{pi}/m_{rho} \geq 0.65$, Nf=2

(2) Our strategy for Nf=2+1 FT-QCD

FT-QCD simulations based on CP-PACS/JLQCD/PACS-CS results
→ Temperature is controlled by varying Nt (fixed lattice spacing)

$$T = \frac{1}{N_t a}$$

CP-PACS/JLQCD configurations

beta	mpi/mrho	# m_{ud}xm_s	a[fm]	Ns^3xNt	Nt@Tc
1.83	0.6 – 0.78	5 x 2	0.122	16^3x32	6 – 8
1.90	0.6 – 0.78	5 x 2	0.100	20^3x40	8 – 10
2.05	0.6 – 0.78	5 x 2	0.076	28^3x56	12 – 16

PACS-CS configurations

beta	mpi/mrho	# m_{ud}xm_s	a[fm]	Ns^3xNt	Nt@Tc
1.90	0.3? – 0.55	4 x 1	0.100	32^3x64	10 – 12

(3) Good/Bad points of the fixed lattice spacing approach

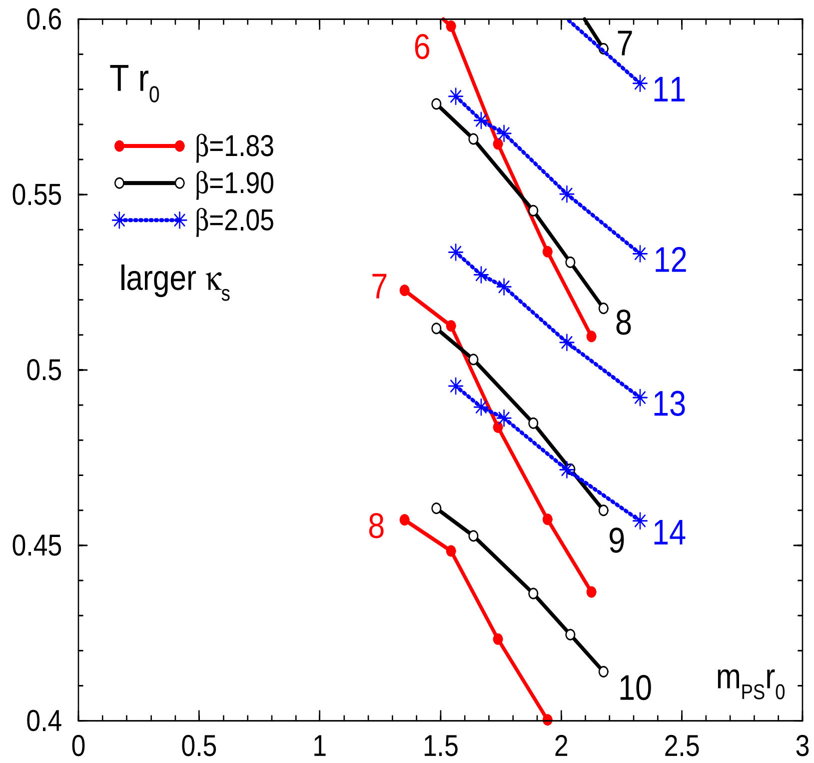
--- Good points ---

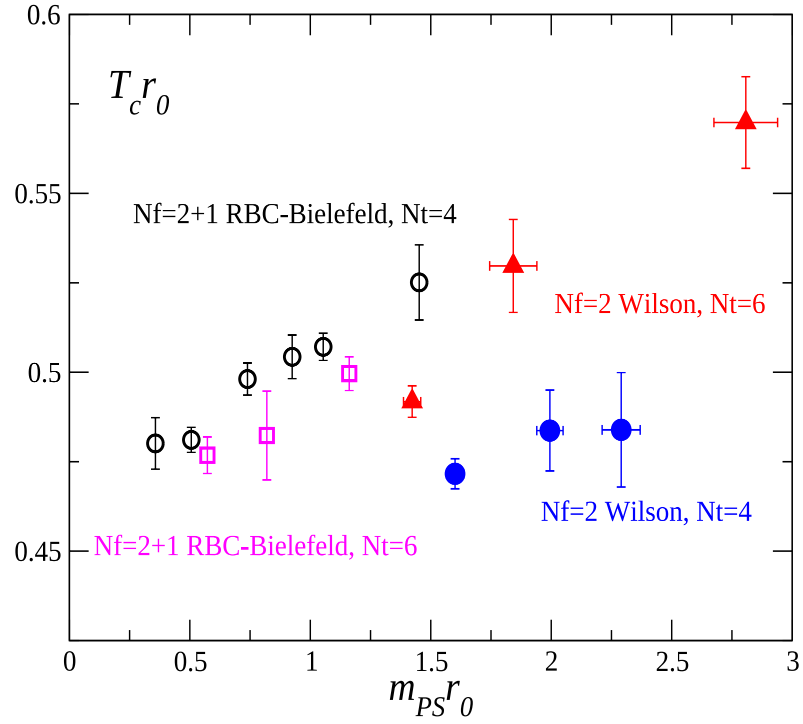
- no T=0 simulation is necessary
  T=0 calculations are performed by CP-PACS/JLQCD
  high statistics and reliable results !!
- no parameter search
- nonperturbative improved Clover, Nf=2+1 QCD with physical ms
- small lattice artifacts : a=0.122,0.100,0.076fm
  Nt=6-14 (=1/Ta) near Tc
- Identification of Hot/Cold phase → lower/upper bound of Tc
  calculation of susceptibility by reweighting method

--- Bad points ---

- low resolution in Temp. (= 1/aNt)
- odd number Nt simulation is difficult (?)
- only upper/lower bound for Tc (reweighting??)

(4) Temperatures with various Nt





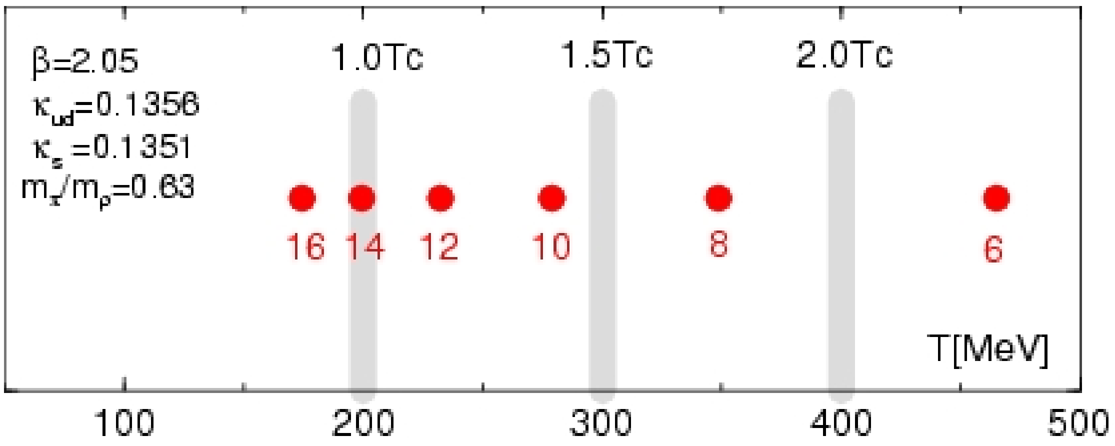
PACS-CS simulations at beta=1.90
are searching around $m_{PS}r_0 \geq 0.5$!

(5) Temperature resolution with fixed lattice spacing

- The fixed lattice spacing approach is useful
  for other obserbables.

e.g. at beta=2.05 Nt=16,14,12,10,8,6 are correspond
to (roughly) T/Tc=0.9,1.0,1.2,1.4,1.7,2.3

→ charmonium dissociation temperatures
→ static quark free energy
→ finite chemical potential



(6) Numerical results (Transition temperature)

Simulation details

Nf=2+1, Wilson (NPI Clover) quark + Iwasaki gauge
RHMC algorithm (based on CPS code)
simulation performed on KEK systemB (BlueGene/L)

16^3 x Nt, beta=1.83, (Ls=2fm)

(1) $k_{ud}=0.13800$, $k_s=0.13710$, $m_{pi}/m_{rho}=0.65$
Nt=8 T=177 MeV 5000traj.

(2) $k_{ud}=0.13800$, $k_s=0.13710$, $m_{pi}/m_{rho}=0.65$
Nt=6 T=236 MeV 5000traj.

(3) $k_{ud}=0.13655$, $k_s=0.13710$, $m_{pi}/m_{rho}=0.78$
Nt=6 T=201 MeV 5000traj.

(6) Numerical results (Transition temperature)

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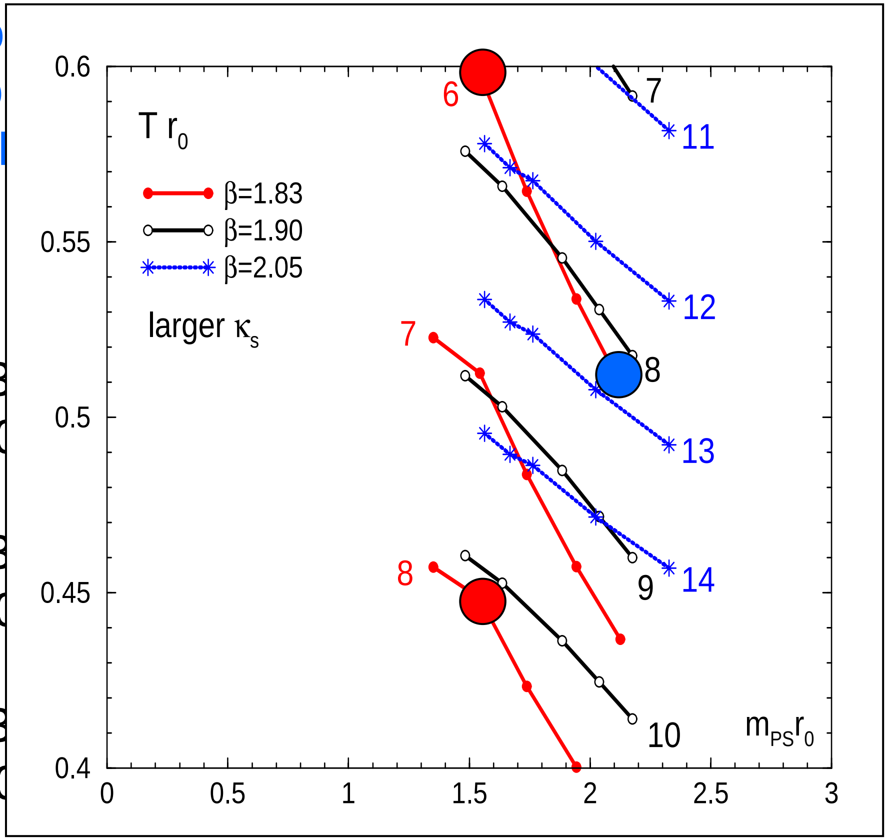
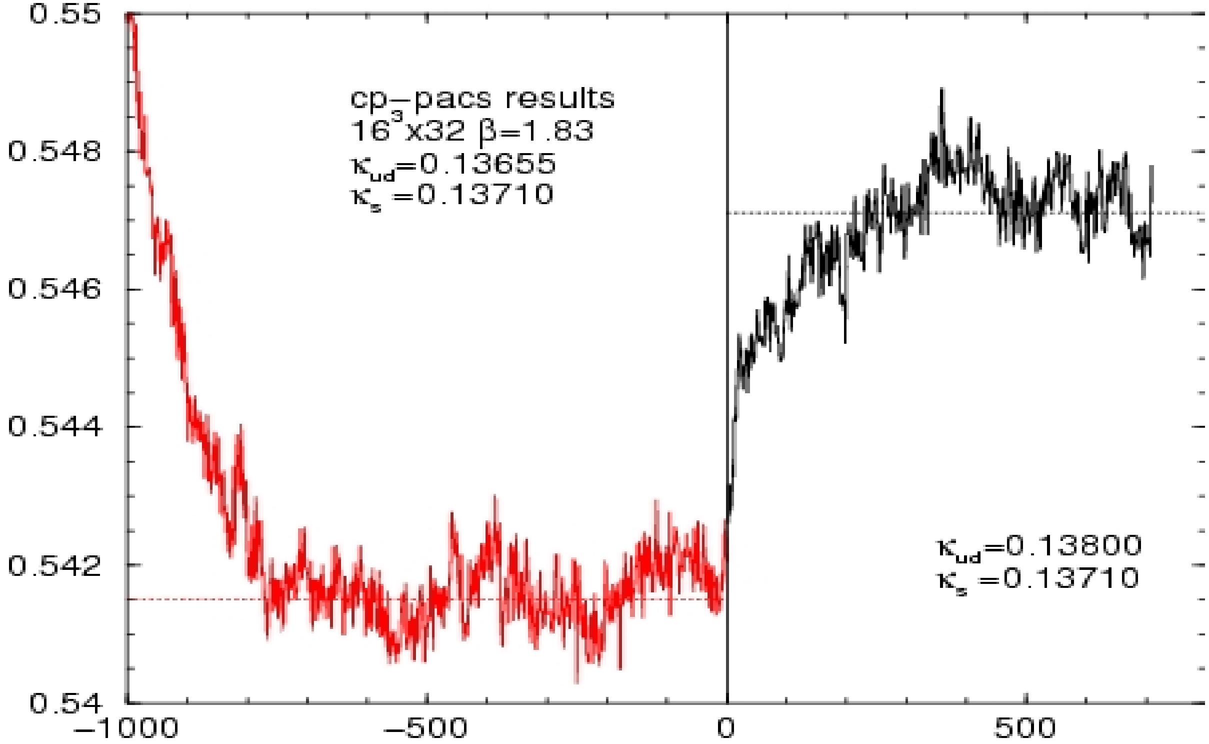


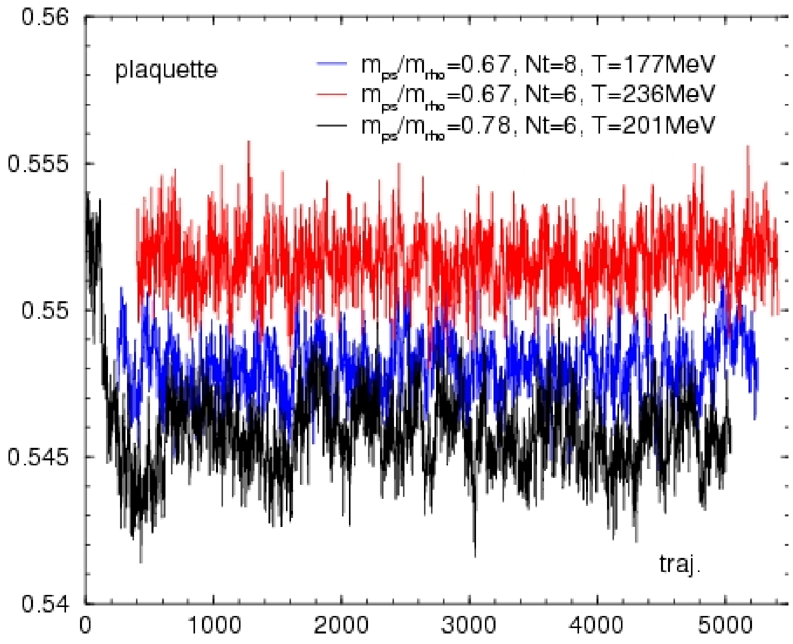
(7) Code check with CP-PACS/JLQCD results

Nonperturbative C_{sw} Clover + Iwasaki gauge
beta=1.83, C_{sw}=1.781, 16^3 x 32
k_{ud} = 0.13650/0.13800, k_s = 0.13710

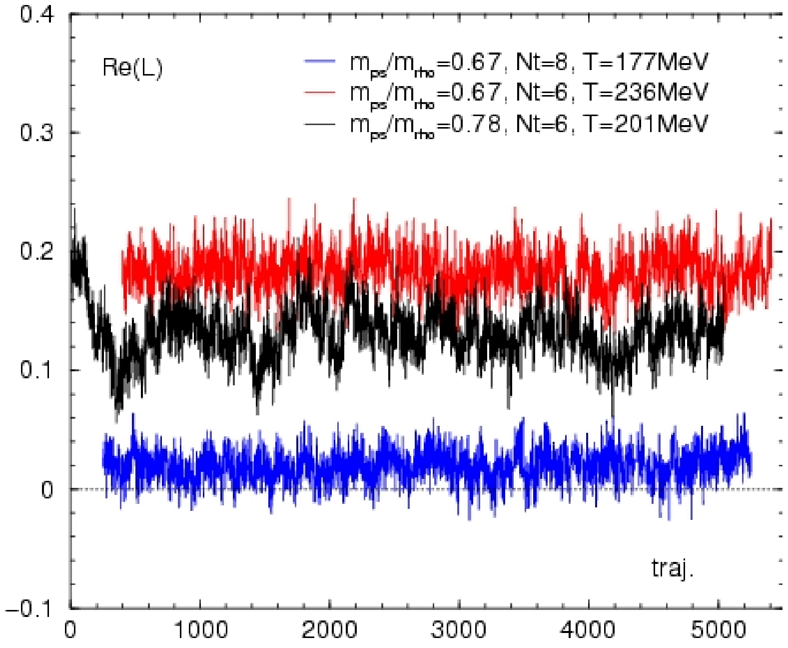


(8) Time histories for T>0 simulations

plaquette time histories



Polyakov loop time histories

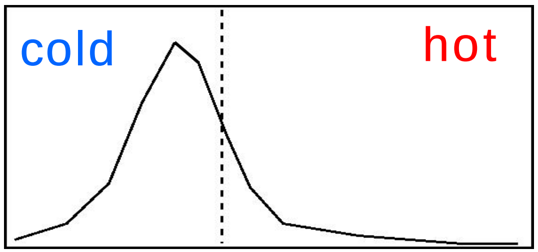


(9) Identification of confined/deconfined phase

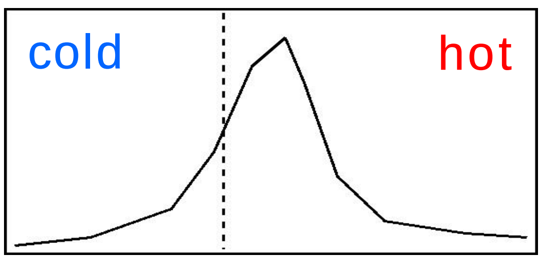
beta reweighting method

$$\langle O \rangle_\beta = \frac{\langle O e^{-(\beta-\beta_0)S_G} \rangle_{\beta_0}}{\langle e^{-(\beta-\beta_0)S_G} \rangle_{\beta_0}}$$

susceptibility



β_0



β_0

beta direction
≠ Line of Constant Physics

cp-pacs, PRD64(2001)074510

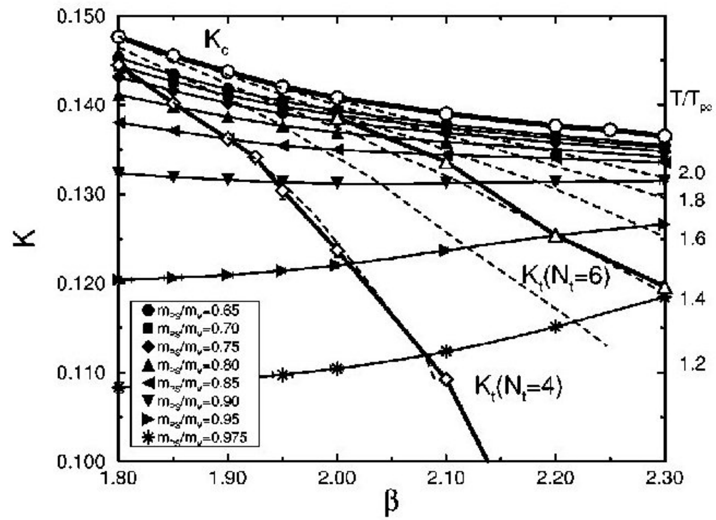
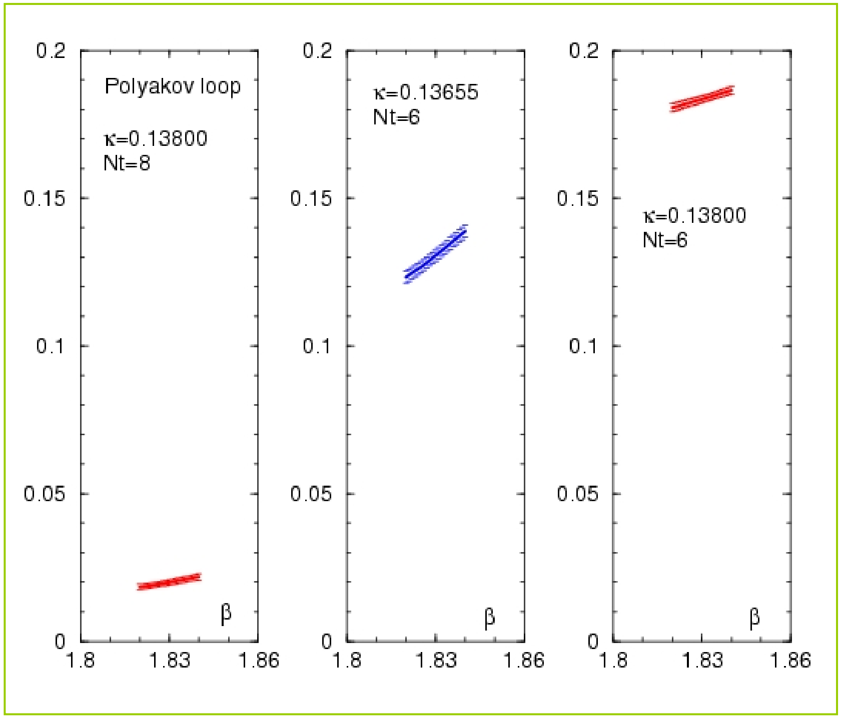


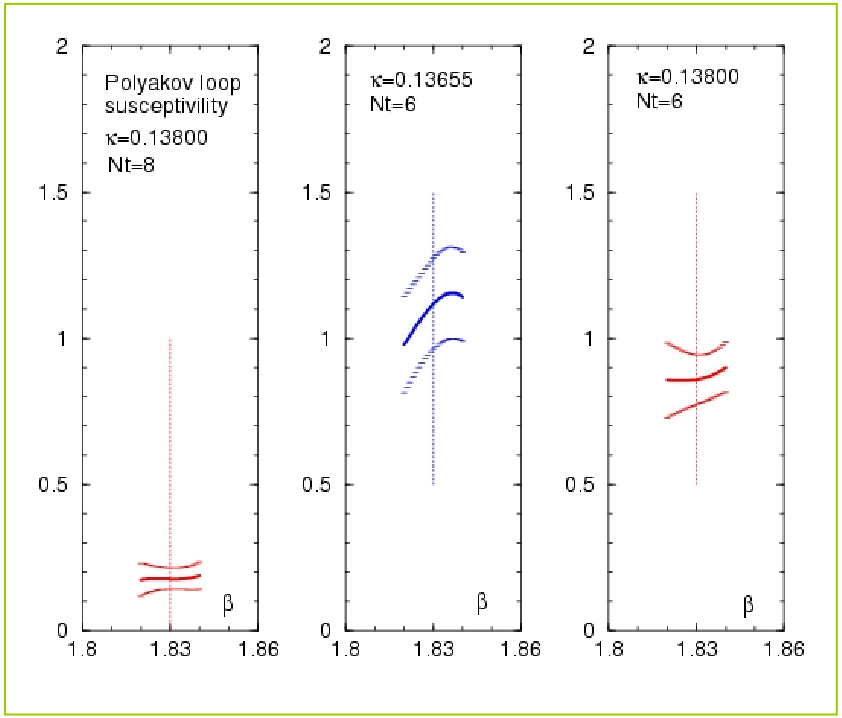
FIG. 7. Lines of constant physics and constant temperature. Solid lines are m_{PS}/m_V constant lines, and dashed lines are T/T_{pc} constant lines for $N_t=4$. The values of T/T_{pc} for the dashed lines are given on the right edge of the figure.

(10) Results of beta-reweighting method

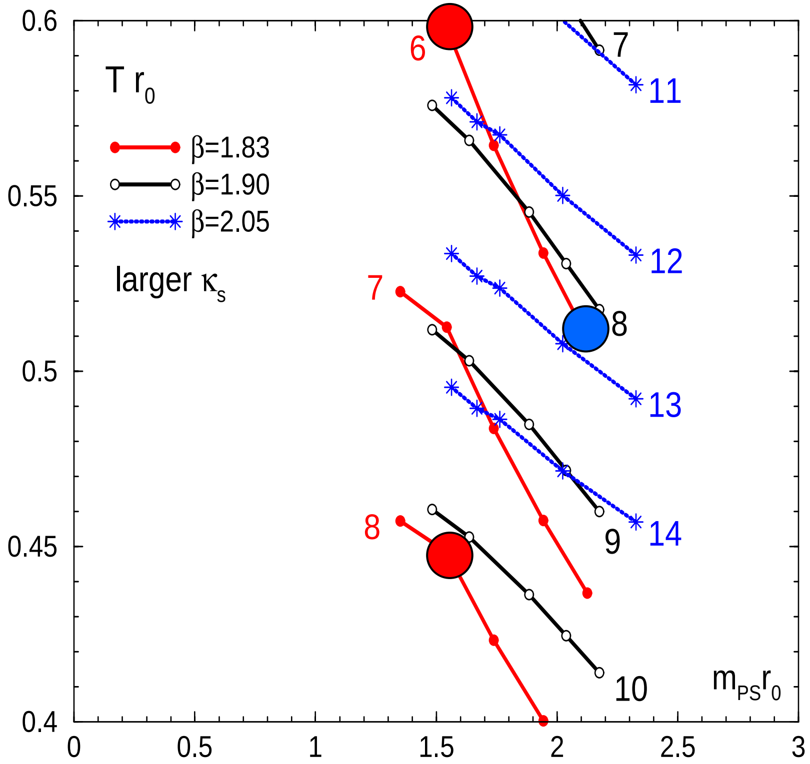
Polyakov loop

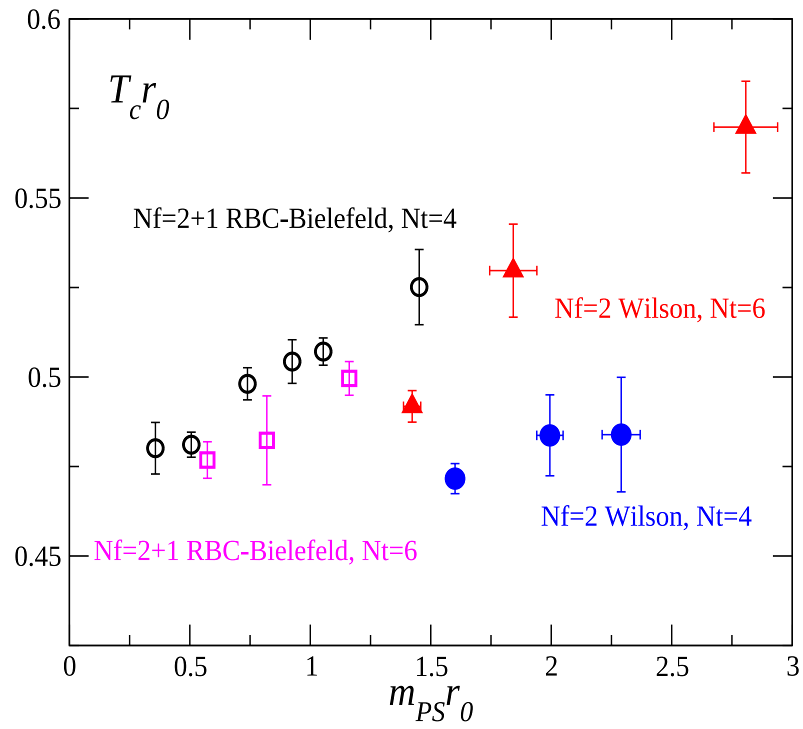


Polyakov loop susceptivility



(11) Temperatures with various Nt





PACS-CS simulations at beta=1.90
are searching around $m_{PS}r_0 \geq 0.5$!

(12) Summary

We consider the FT-QCD study
based on CP-PACS/JLQCD/PACS-CS T=0 results

Temp. is controlled by Nt with fixed lattice spacings

- Transition temperature
  - Low resolution in Temperature
- Studies of temperature dependence
  - Charmonium dissociation temperatures
  - Static quark free energy
  - finite density ...