Charmonium near the deconfining transition on the lattice

Takashi Umeda, (CCP, Univ. of Tsukuba)
Hideo Matsufuru, (YITP Kyoto Univ.)
Osamu Miyamura, (Dept. Phys. Hiroshima Univ. deceased)
Kouji Nomura, (Dept. Phys. Hiroshima Univ.)

The XVI Particles and Nuclei International Conference
30 September – 4 October 2002, Osaka i-House, JAPAN

Introduction

- J/ψ (charmonium) states
  - important signal for formation of QGP

    heavy ion experiment at CERN(SPS),BNL(RHIC)

    c.f. NA50 Phys.Lett.B477(2000)28

- Theoretical understanding
  - Potential model

    Mass shift near T_c

    T. Hashimoto et al., Phys.Rev.Lett.57(1986)2123

    J/ψ suppression above T_c

    T.Matsui and H.Satz, Phys.Lett.B178(1986)416

    $\Longrightarrow$ no bound state at $T \gtrsim 1.1T_c$
  - Lattice QCD
    - ▷ Meson correlators

      T. Umeda et al., Int.J.Mod.Phys.A16(2000)2215

      $\Longrightarrow$ not free behavior at $T \sim 1.5T_c$

Study of Charmonium at $T > 0$ using lattice QCD

Our approach

We perform a combined study of lattice QCD and phenomenological approaches for definite understanding of charmonium properties at $T > 0$.

- Phenomenological approach
  - Potential model analysis

    Static quark potential on the lattice
  - Spatial c-$\bar{c}$ correlation
- Spectral function (SPF)
  - Maximum Entropy Method
  - Fit with ansatz for SPFs form

Lattice setup

We employ the anisotropic lattice $a_s/a_t = 4$ without dynamical quarks

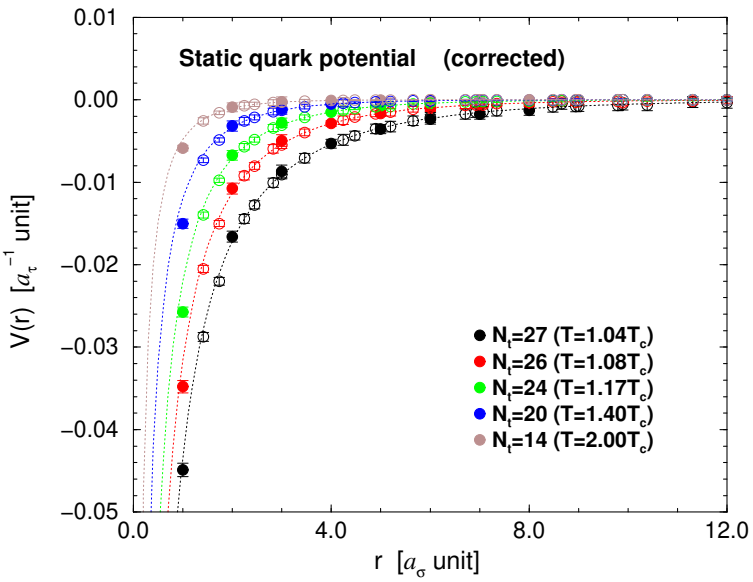
Plaquette gauge + O(a) improved Wilson quark

$20^3 \times N_t$, $T = 1/(N_t a_t)$

$a_s^{-1} = 2.030(13)$GeV, $L_s \simeq 2$fm

Potential model analysis

- Static quark potential at $T > T_c$ on the lattice

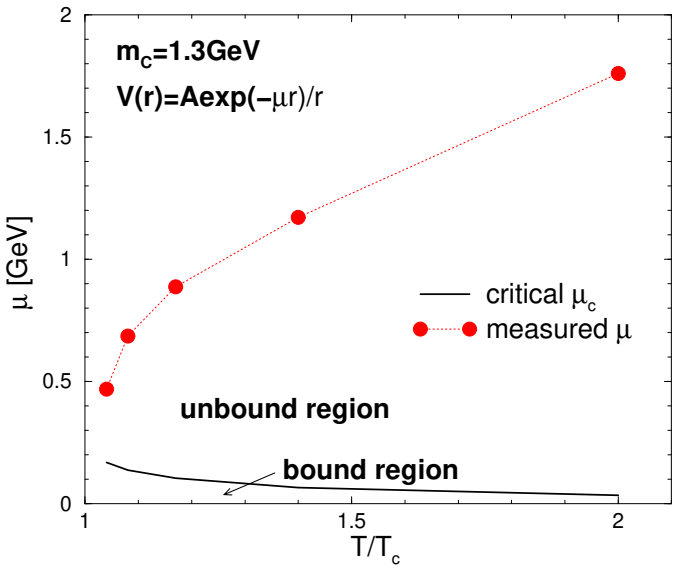


$$V(r) = C - A\exp(-\mu r)/r$$

T/T_c	A_{phys}	μ[GeV]
1.05	0.2176(35)	0.469(19)
1.10	0.1770(30)	0.686(18)
1.15	0.1361(28)	0.887(19)
1.40	0.0849(19)	1.171(20)
2.00	0.0456(22)	1.760(38)

- Schrödinger equation for a stationary state

$$\left(-\frac{\Delta}{2m_R} + V(r)\right)\phi(r) = E\phi(r): \quad m_R = m_q/2$$



T-dep. of μ and μ_c:

For a charmonium state

$$m_q = 1.3 \text{ GeV}$$

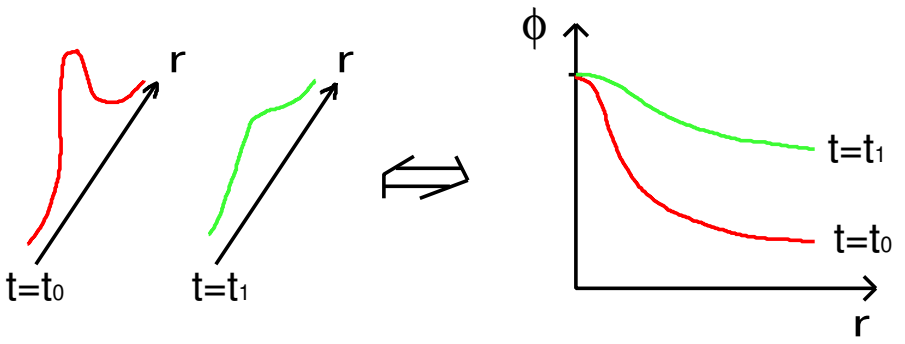
- No bound state at $T > 1.05T_c$

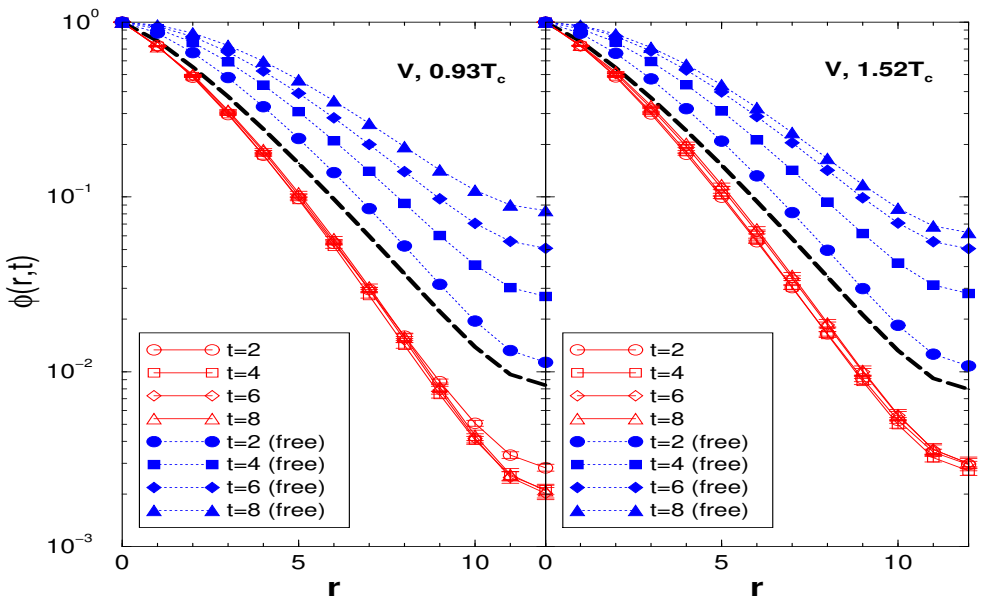
Spatial $c\bar{c}$ correlation

"Wave function" on the Coulomb gauge

$$w_\Gamma(r,t) = \sum_{\vec{x}} \langle \bar{c}(\vec{x}+\vec{r},t)\Gamma c(\vec{x},t) O^\dagger(0)\rangle$$

$\phi(r,t)$: normalized at the spatial origin





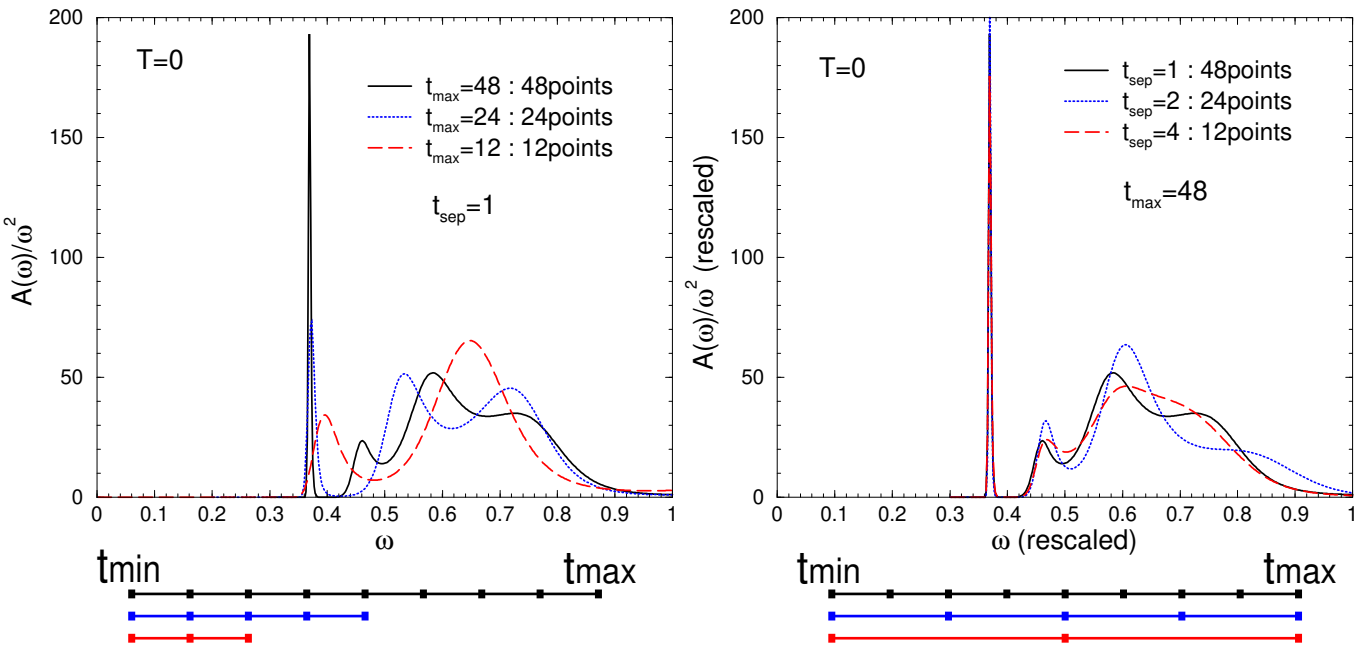
T. Umeda et al., Int.J.Mod.Phys.A16(2000)2215

- c-$\bar{c}$ strongly correlate even at $T \simeq 1.5 T_c$

Spectral function (SPF) at $T = 0$

- Maximal Entropy Method (MEM)

$\Longrightarrow$ Necessary conditions for the SPFs at $T > T_c$



- d.o.f. is enough ($\gtrsim 10$ points)
- MEM needs $N_t a_t \sim 1$ fm ($\sim 1/T_c$)

  $\Longrightarrow$ MEM doesn't work at $T > T_c$

- We focus on low energy part of SPFs.

  $\Longrightarrow$ smearing technique

  check with $1/1$ smear, $1/2$ smear

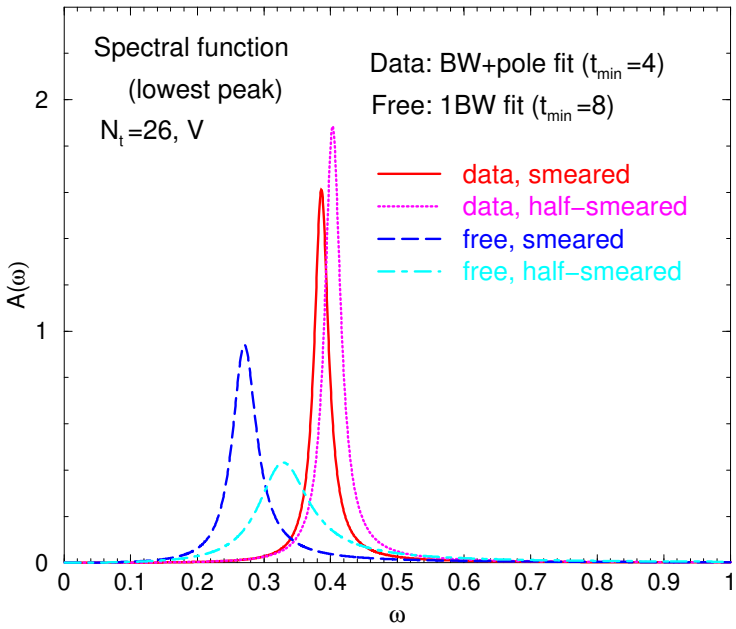
Spectral function at $T > 0$

MEM $\longrightarrow$ global feature (estimation of the SPF form)

Fit with ansatz $\longrightarrow$ quantitative analysis

- ▷ Breit-Wigner (BW) type / BW + pole type fit

- lowest peak of SPFs at $T \sim 1.1T_c$ from fit results



	mass $(T = 0)$	mass $(1.1T_c)$	width $(1.1T_c)$
η_c	2.993(19)GeV	3.057(31)GeV	0.119(25)GeV
J/ψ	3.067(20)GeV	3.133(26)GeV	0.210(19)GeV

- ▶ SPFs has strong peaks at almost same position and finite width at $T \sim 1.1T_c$.

Conclusion

- Potential model analysis

  No bound state at $T \gtrsim 1.05T_c$
- Spatial $c\bar{c}$ correlation

  Strong spatial correlation of $c\bar{c}$ at $T \sim 1.5T_c$
- Spectral function

  $(0.9T_c)$: Almost same results as $T = 0$

  $(1.1T_c)$: Still strong peaks at same position and finite width

$$\Downarrow$$

The existence of quasi-stable bound state-like structure above T_c (at least $1.1T_c$)

Outlook

MEM & Fit analysis in wider range of temperature

Dynamical quark effects