Charmonium near the deconfining transition on the lattice

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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

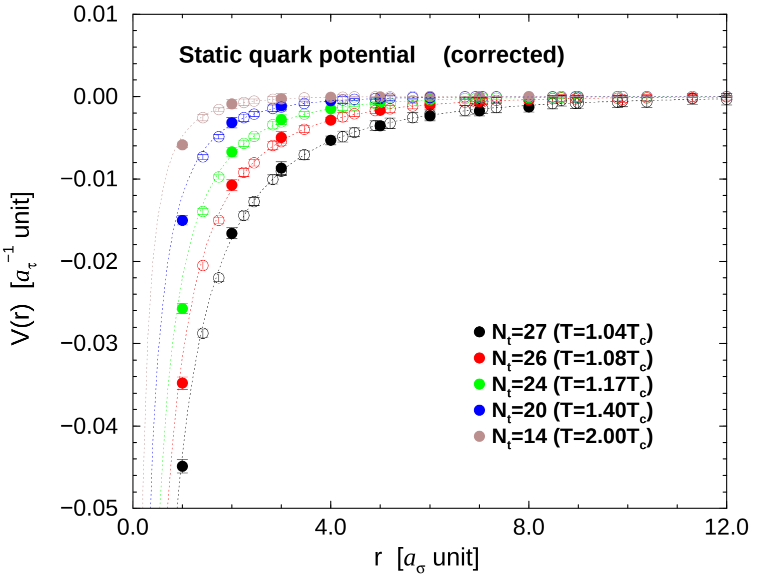
    Static quark potential on the lattice
  - Spatial c-$\bar{c}$ correlation
- Spectral function (SPF)
  - Maximum Entropy Method
  - Fit with ansatz for SPFs form

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

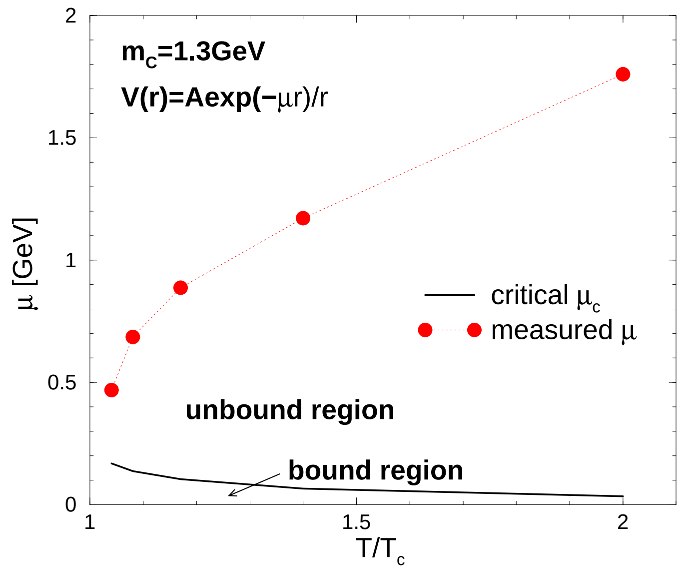


$$V(r) = C - A\exp(-\mu r)/r$$

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)

■ Schrëdinger 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

$m_q = 1.3$ GeV

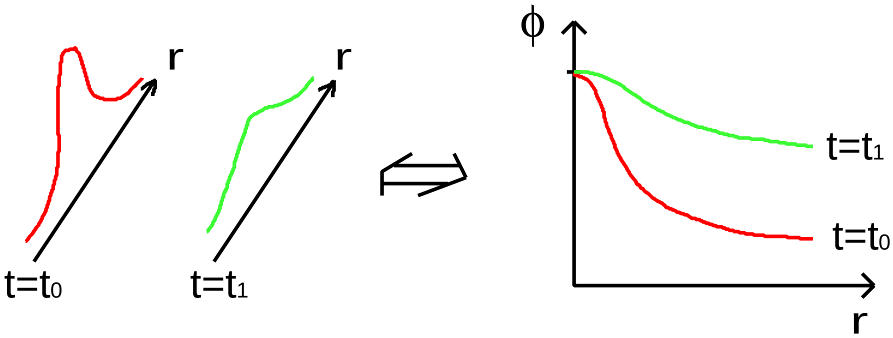
▶ No bound state at $T > 1.05T_c$

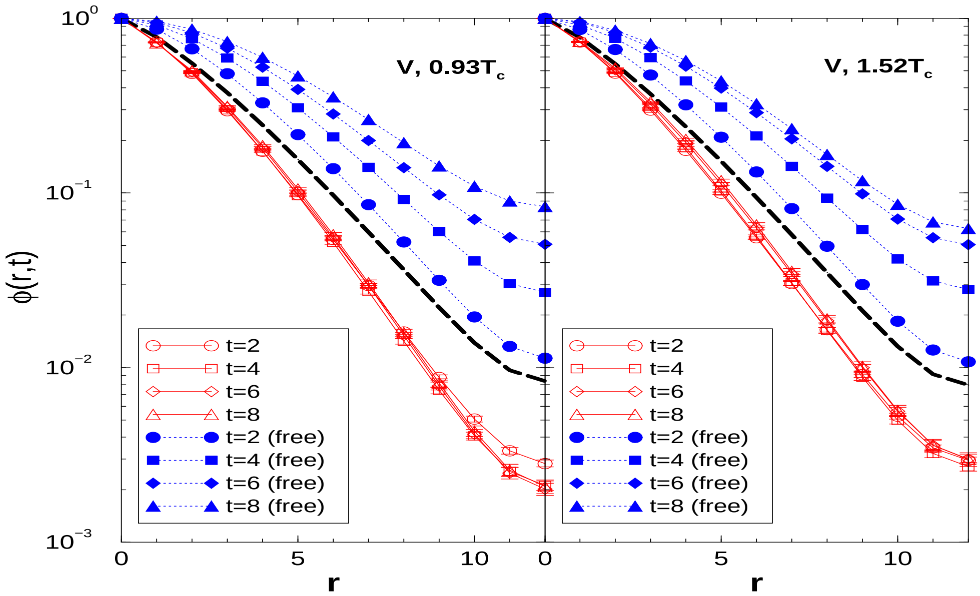
Spatial $c\bar{c}$ correlation

"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





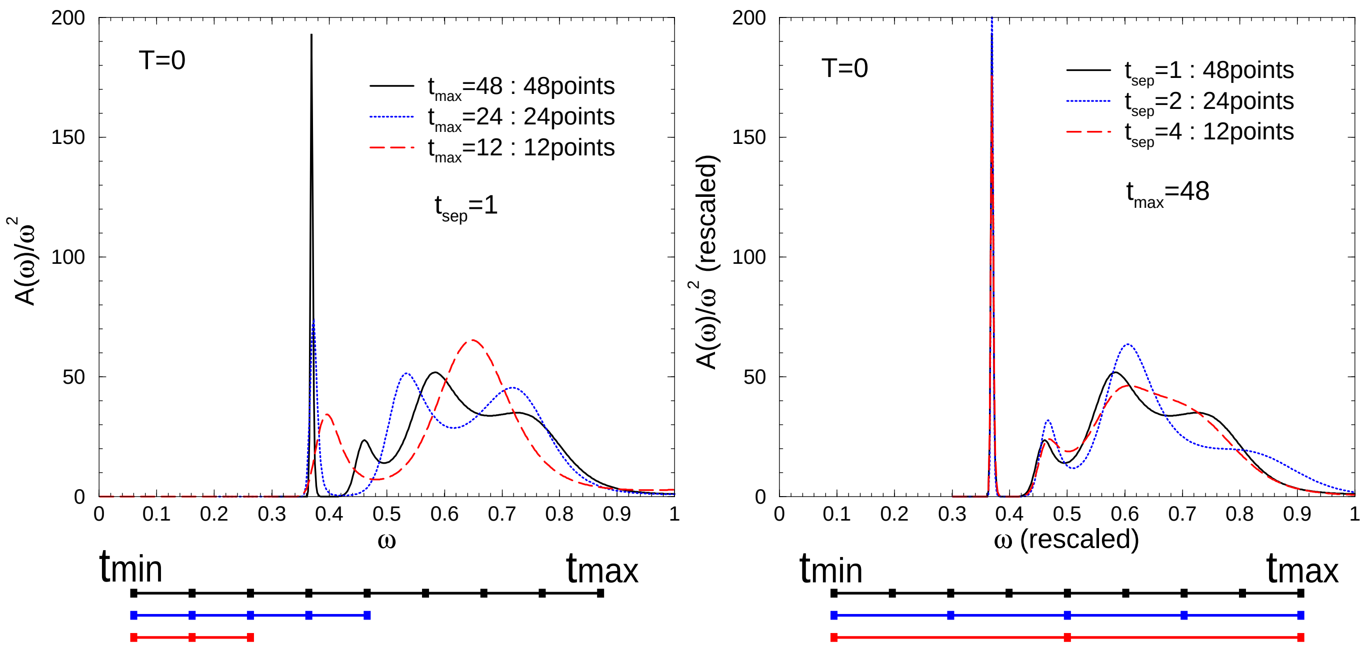
T. Umeda et al., Int.J.Mod.Phys.A16(2000)2215

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

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

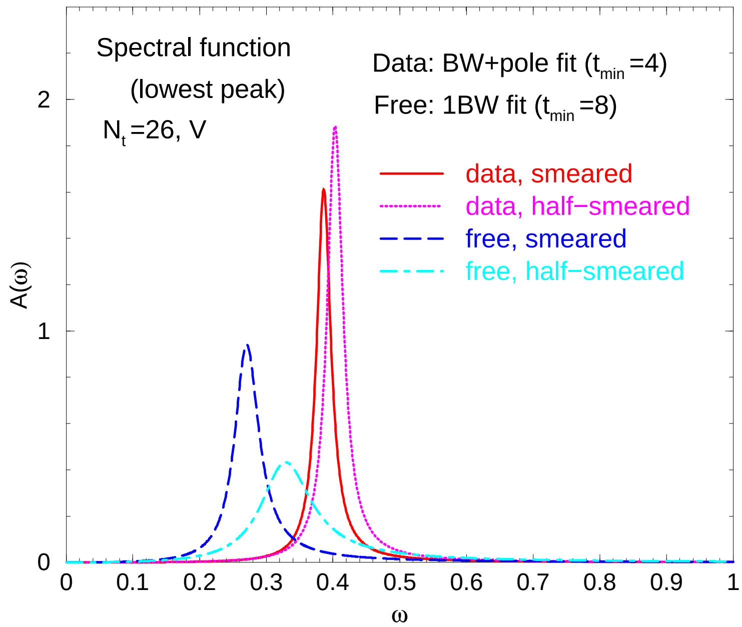
check with 1/1 smear, 1/2 smear

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