On Study of Quarkonium Melting using Lattice Correlators

Saumen Datta
(Based on works with F. Karsch, P. Petreczky, I. Wetzorke, and with D. Banerjee)

Tata Institute of Fundamental Research, Mumbai

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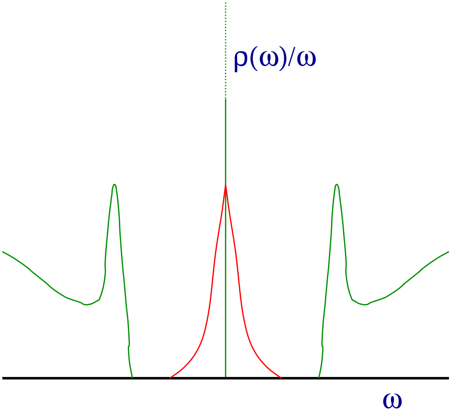
Introduction

Problem at hand: find spectral function, e.g., $\rho_{\bar{c}\gamma_i c}(\omega)$ and the melting of the J/ψ peak in the dilepton channel.



From the lattice: look at Matsubara correlators

$\Rightarrow$ invert $G_{\bar{c}\gamma_i c}(\tau) \;=\; \int d\omega\, \rho(\omega)\, \frac{\cosh \omega(\tau - \frac{1}{2T})}{\sinh \frac{\omega}{2T}}$.

Charmonia using MEM

Most popular: maximum entropy method: use prior information to keep in check uncontrolled directions in search space.

default model dependence; sensitivity on other parameters.

To get stable $\rho(\omega)$ from $\mathcal{O}(20)$ data points: need to give ultraviolet information to get infrared.
First studies: 1S charmonia survive till quite deep in plasma, while the 1P states dissolve early.

Datta, Karsch, Petreczky, Wetzorke, 2004; Asakawa & Hatsuda, 2004

But correlators are completely consistent with other scenarios.

Umeda, 2007; Mocsy and Petreczky, 2007-2009.

Would be very useful to have other analysis techniques.

Cuniberti et al approach

An interesting approach, using detailed analyticity properties of Green's functions.

Cuniberti, Micheli, Viano, 2001; Burnier, Laine, Mether, 2011

$$\rho(\omega) \;=\; \int_0^\infty dt\; \sin\omega t\; J^+(t), \qquad J^+(t) \;=\; e^{-e^{-t}} \sum_{l=0}^{\infty} a_l\, L_l(2e^{-t})$$

Extraction of electric conductivity from UV-subtracted vector correlator data.

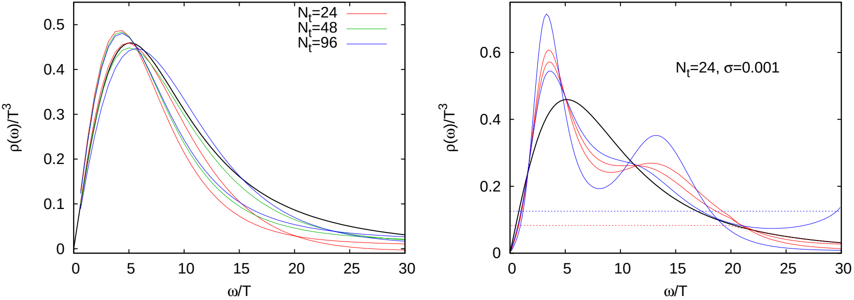
Burnier and Laine 2012

Can this work in future for quarkonia?
How do the two methods perform for per-mille accuracy correlator, $N_t \sim 24-48$?

Toy example: electric field correlator, simplified

Burnier, Laine, Mether, 2011

$$\frac{\rho(\omega)}{16\pi^2 T^3} = \frac{2\pi\omega}{(\omega^2 + 8\pi^2)^2}$$



MEM: Brian's algorithm, with modified kernel to avoid problems at $\omega \to 0$ (Aarts et al. '07).

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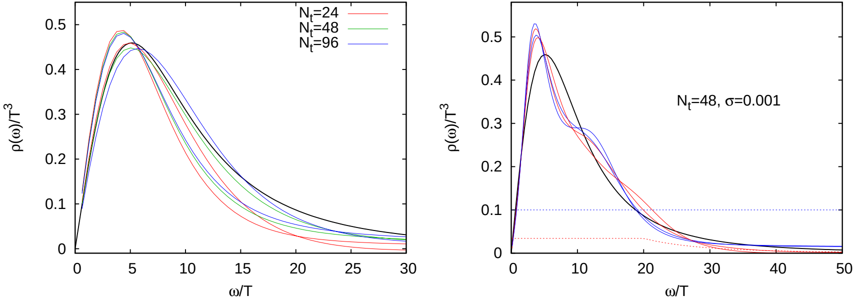

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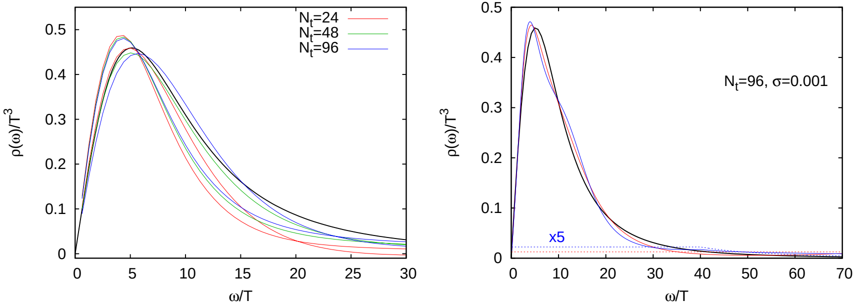

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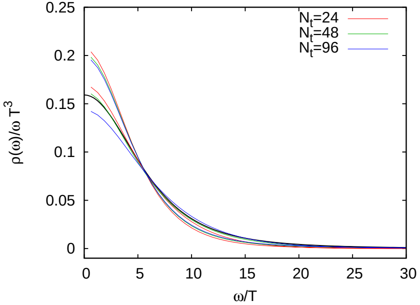

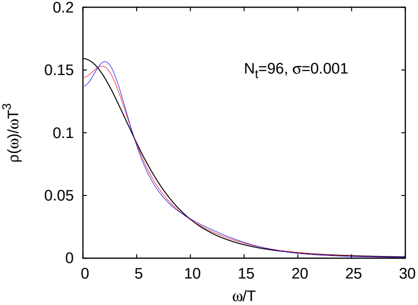

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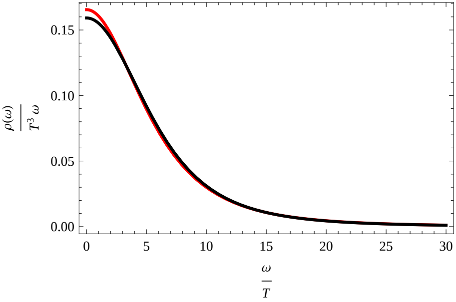
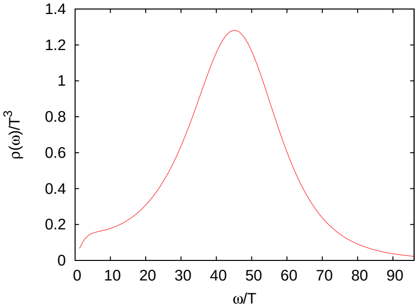
Toy example: electric field correlator, simplified

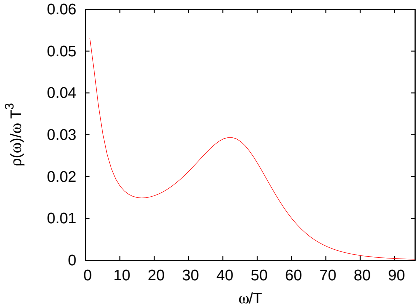
For this simple example, Pade method also works well $\Rightarrow$ fit $G(\omega_n)$ with a rational fit form, and get $\rho(\omega) = \frac{1}{\pi}\mathrm{Im}\, G(\omega \to -i\omega)$.



Toy Example: Gunnarsson et al.

Unfortunately, Cuniberti's method does not work so well in more complicated examples.

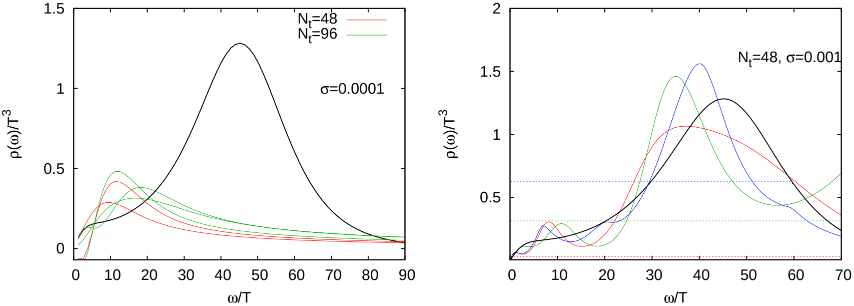




Model for current-current correlator in 2D Hubbard model.

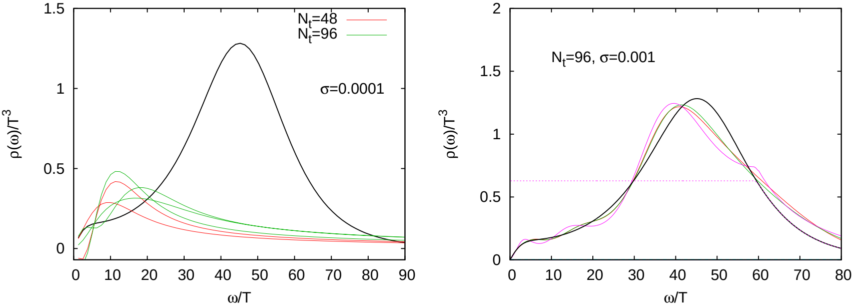
Gunnarsson, Haverkort, Sangiovanni, PR B 82, 165125 ('10)

Toy Example: Gunnarsson et al, Contd.



Similar results found for a two-peak spectral function.

Toy Example: Gunnarsson et al, Contd.



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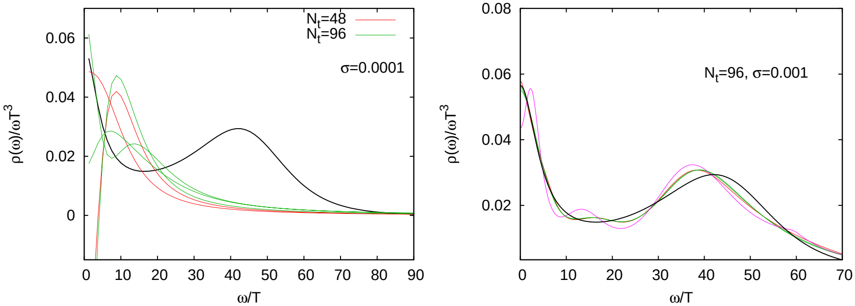
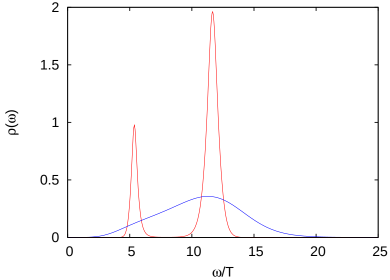


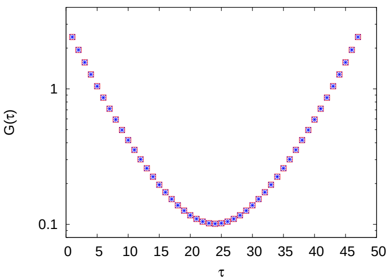
Similar results found for a two-peak spectral function.

Current status

Cuniberti's method in current form probably suitable when the subtracted correlator has little structure, e.g., a diffusive peak.

Maximum entropy method: qualitative features reproduced, but prone to create structures : for $N_t = 48$ or less, need to put in sufficient information, specially about the ultraviolet, and use any other reliable theoretical input.



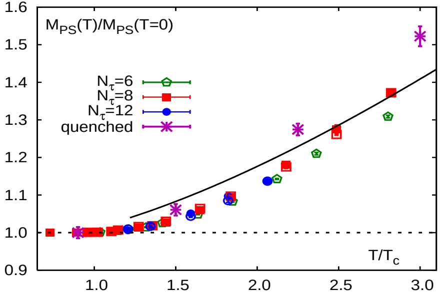


Spatial "screening" correlator

Can one look at "screening correlators" instead?

$$G(z, T) = \int \frac{dk_z}{\pi} e^{ik_z z} \int d\omega \frac{\rho(\omega, k_\perp = 0, k_z)}{\omega}$$

Study of correlator easier, but interpretation in terms of spectral function more difficult.

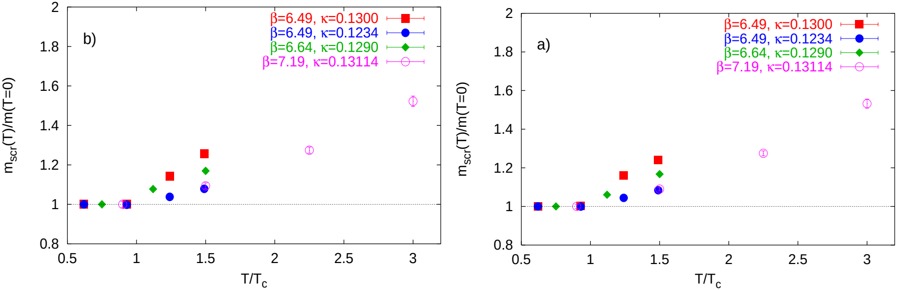


Indicative of dissolution of J/ψ around $T \sim 1.5\, T_c$.

Karsch, Laermann, Mukherjee, Petreczky, PRD 85('12) 114501

Quenched study

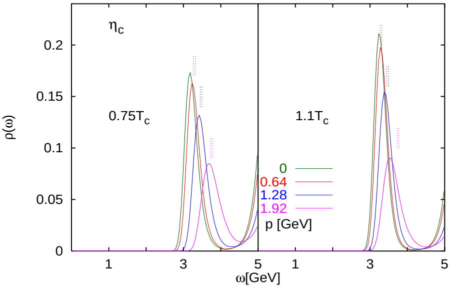
Similar behavior observed earlier in quenched QCD, where spatial correlator was seen to show temperature effect already at 1.1 T_c.

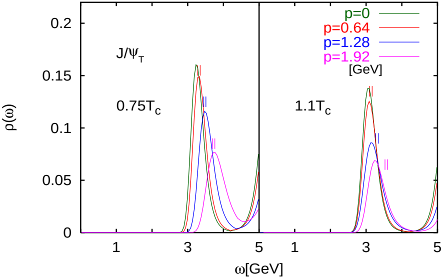


Datta, Karsch, Petreczky, Wetzorke, PRD ('04)

Change in screening mass does not directly imply ground state modification, e.g., one can have a spectral function peak $\delta(\omega^2 - A^2(T)\vec{p}^2) \Rrightarrow m_{\rm scr}(T) = m/A(T)$

Momentum modification?



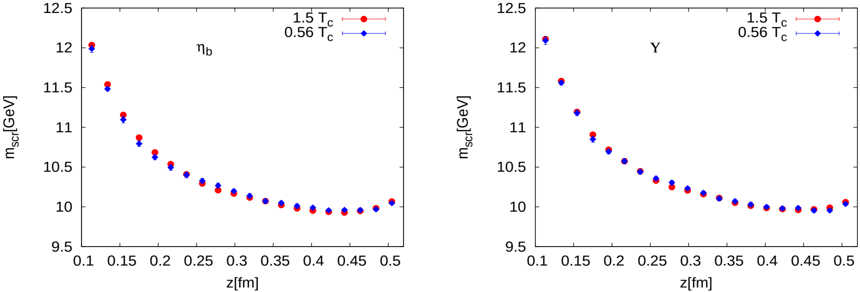


Datta, Karsch, Petreczky, Wetzorke, J.Phys. G 31 ('05) S351.

One can study more detailed properties of the screening correlator to isolate the cause.

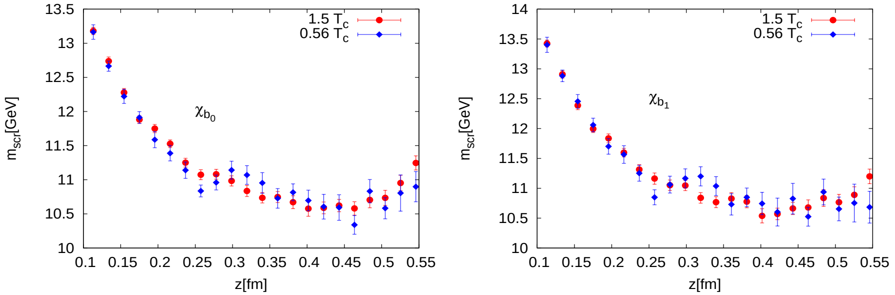
Screening of $\bar{b}b$ charges

What does the screening correlator tell us about $\bar{b}b$ mesons?



Expectedly, no modification of 1S screening length at 1.5 T_c.

Screening of $\bar{b}b$ charges Contd.

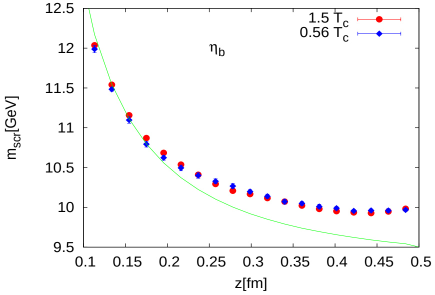


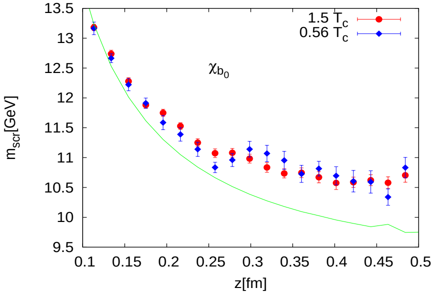
Interestingly, no modification of χ_b screening length at 1.5 T_c either.

Counterintuitive, if χ_b is dissolved?

Screening of $\bar{b}b$ charges

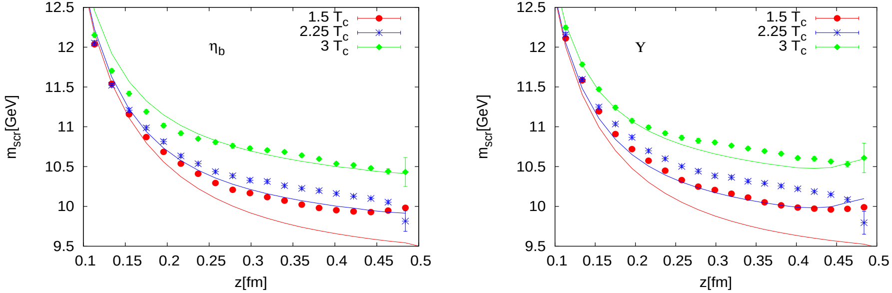
The behavior of $m(z)$ very different from free theory.





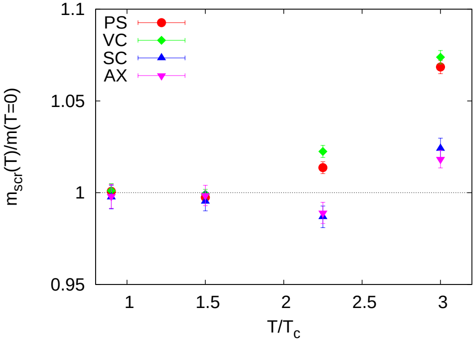
Screening of 1S $\bar{b}b$ above T_c

At 2.25 T_c, the 1S states also show a temperature dependence.



(m_b^{bare} tuned to give agreement at 3 T_c.)

Combined plot of screening mass of $\bar{b}b$ sources



Discussion

- Study of quarkonia melting on lattice is a nontrivial problem.
- Combination of fine lattices and maximum entropy based analysis is the leading strategy now.

  Kaczmarek et al; Aarts, Skullerud, et al.

  But important to explore, in particular, other analysis strategies, and utilize the other theoretical results.
- In particular, it is important to look at both the temporal and spatial correlation functions.

  This may be particularly important for bottomonia.