The Potential Episode of the Heavy Quark Story

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Why

Deconfinement T_c - heavy q bound states could exist above

1986: screening prevents $c\bar{c}$ binding above T_c Matsui,Satz

1988: sequential dissolution Karsch, Mehr, Satz

2001: J/ψ disappears at $1.1T_c$ Digal, Petreczky, Satz

however

2004: charmonia J/ψ, η_c survive ~ $1.5T_c$

χ_c^0, χ_c^1 dissolve ~ $1.1T_c$

Umeda; Asakawa, Hatsuda

Datta, Karsch, Petreczky, Wetzorke

bottomonia see talk by K. Petrov

moreover

J/ψ, η_c properties – mass, amplitude - do not change

A New Puzzle

hence

We study the (non)dissolution
&
(non)changes in the properties
of $c\bar{c}$ & $b\bar{b}$ states
via their
correlators & spectral functions
in a potential model with
different screened potentials.

How

Euclidean correlator $G(\tau, T) = \langle j(\tau)\, j^{\dagger}(0) \rangle$

current $j = \bar{q}\, \Gamma\, q$

determines the channel

$$\int d\omega\, \sigma(\omega, T)\, K(\tau, \omega, T)$$

Spectral function

bound state mass

decay constant

threshold $2m_{pole}$

$$\sum 2 M_i(T) F_i^2(T) \delta(\omega^2 - M_i^2(T)) + m_0 \omega^2 \Theta(\omega - s_0(T))$$

continuum

resonances

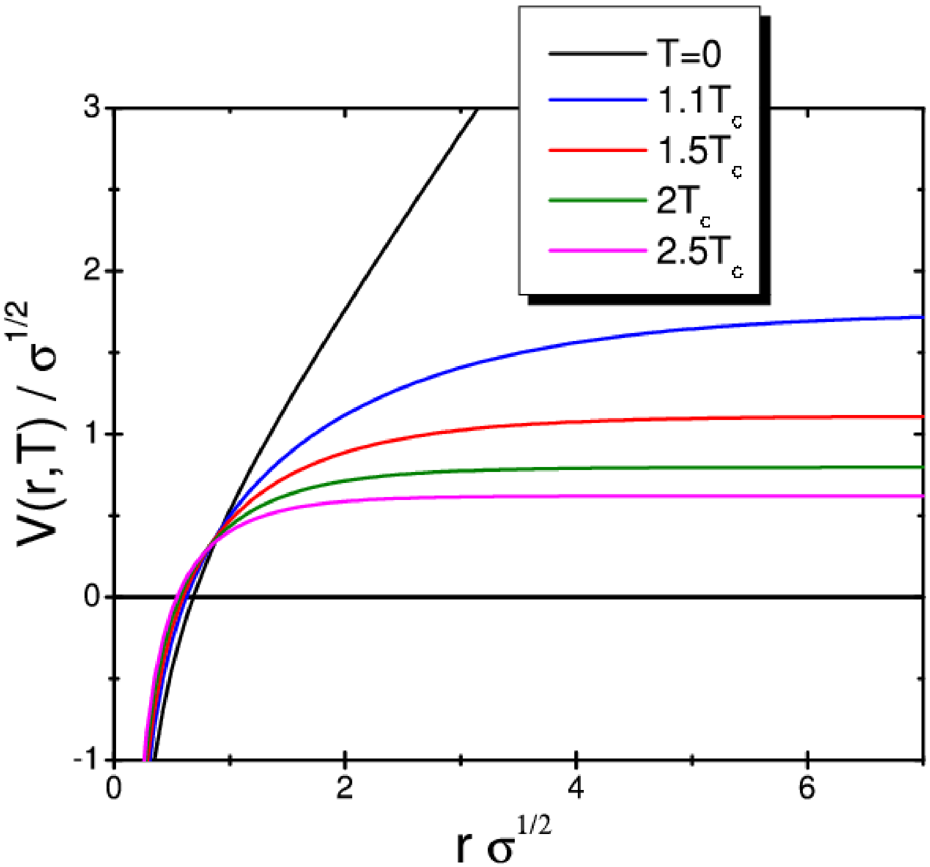
following Shuryak '93

Potential model

@ T= 0 Cornell pot. $$V(r) = -\frac{a}{r} + \sigma r$$ Success

@ T≠ 0 Screened pot. $$V(r,T) = -\frac{a}{r} e^{-\mu(T)\, r} + \frac{\sigma}{\mu(T)}\left(1 - e^{-\mu(T)\, r}\right)$$

Karsch, Mehr, Satz '88



screening mass

$$\mu(T) = 0.24 + 0.31\left(\frac{T}{T_c} - 1\right) \text{GeV}$$

AM, Petreczky, in prep.

Asymptotic value $V_1(T)$

||

thermal energy for q-$\bar{q}$ pair

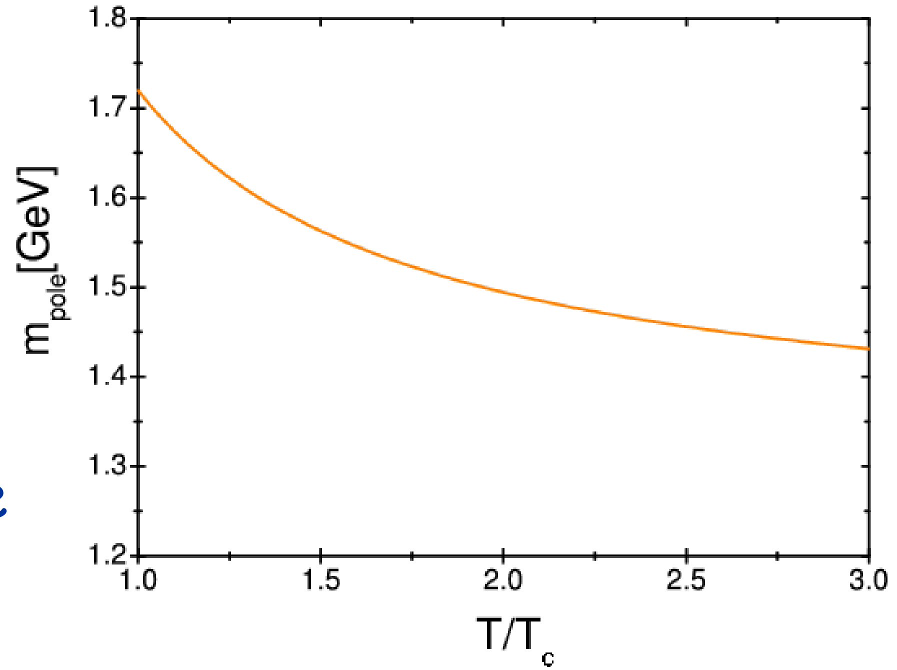
Digal, Petreczky, Satz '01

$$m_{pole}(T) = m_{c,b} + \frac{V_\infty(T)}{2}$$

Decrease of m_{pole} independent of details of the potential.

Qualitative agreement w/ lattice in quasiparticle picture.

Petreczky et al '01



AM, Petreczky, in prep.

$s_0(T) = 2m_{pole}$

+ solve Schroedinger eq.

⇓ binding energy

$M_i = 2m_{c,b} + E_i$

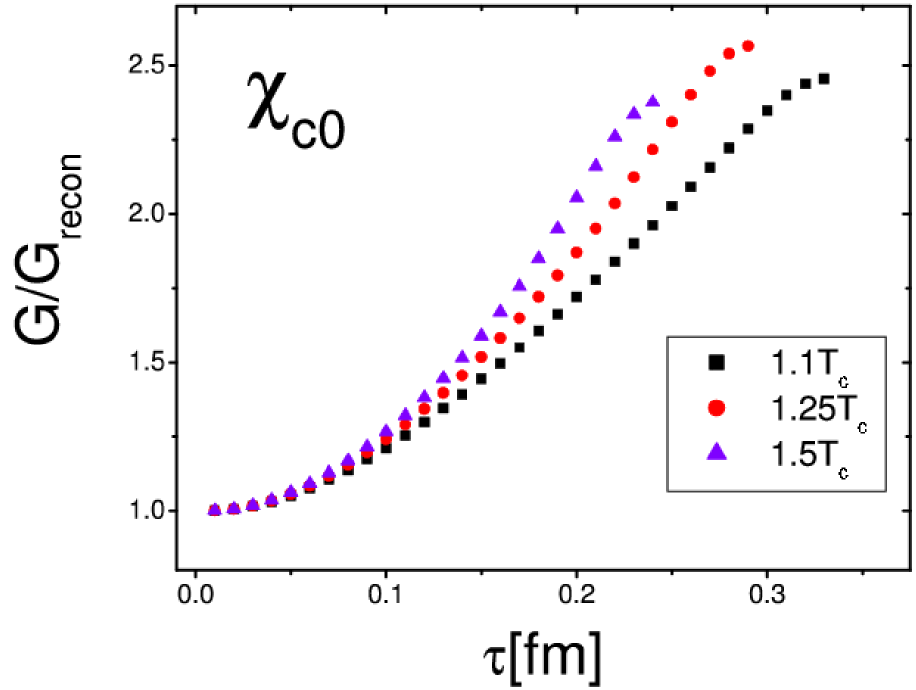
⇓ radial wave fct. in origin

$$F_i^2 \propto \begin{cases} |R_i(0)|^2 & \text{S} \\ |R_i'(0)|^2 & \text{P} \end{cases}$$

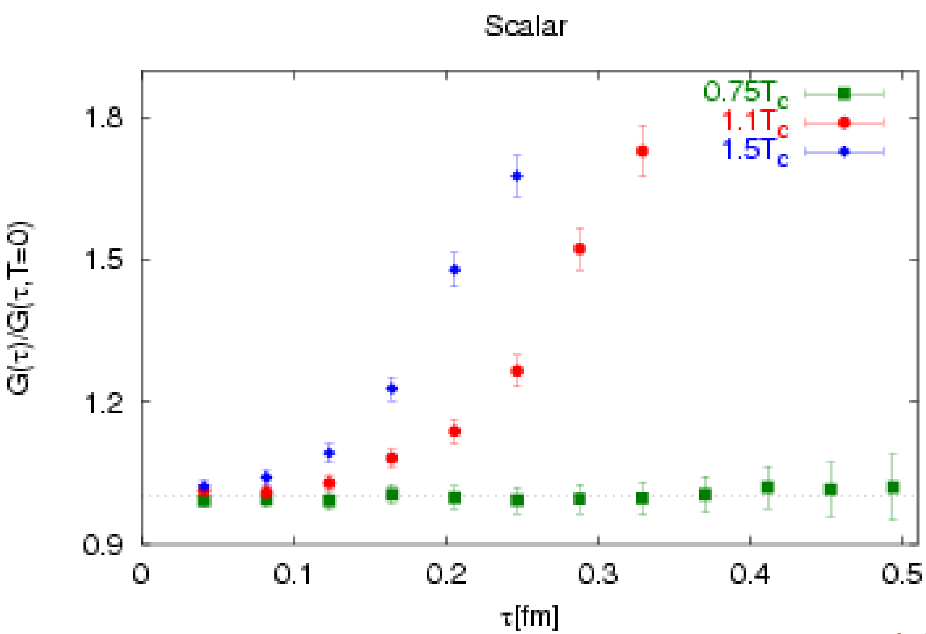
What do we get

Charmonium 1P scalar

$$\frac{\int d\omega\, \sigma(\omega, T)\, K(\tau, \omega, T)}{\int d\omega\, \sigma(\omega, T{=}0)\, K(\tau, \omega, T)}$$



Properties modified ~ 1.1T$_c$ at all distances.



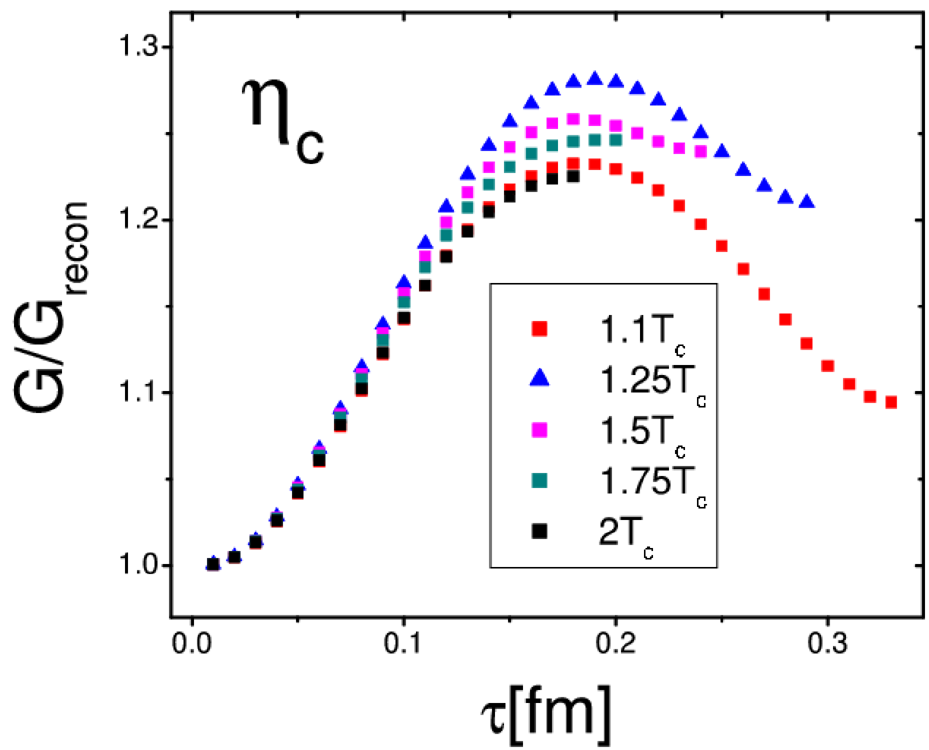
Datta et al '04

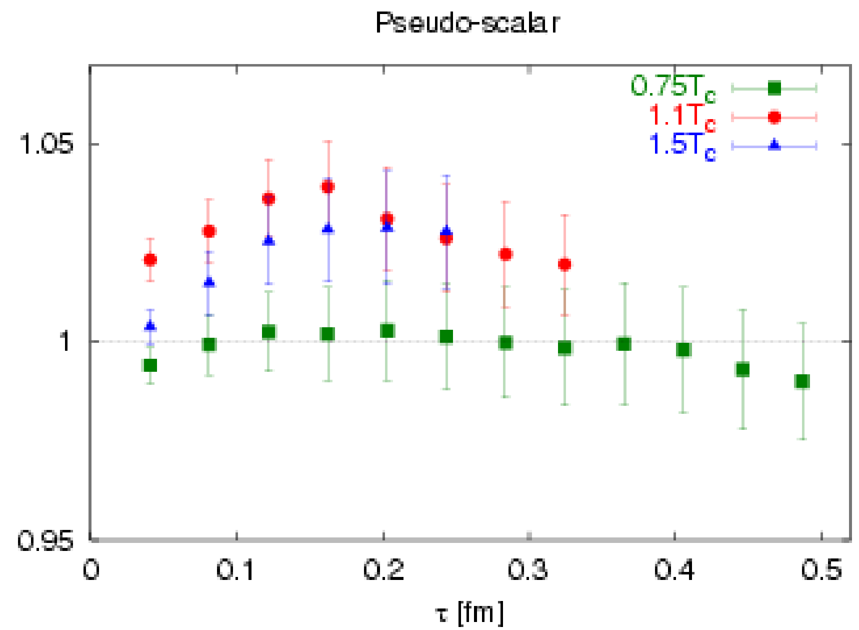
Qualitative agreement w/ lattice.

A. Mocsy

Hard Probes 2004

Charmonium 1S pseudoscalar



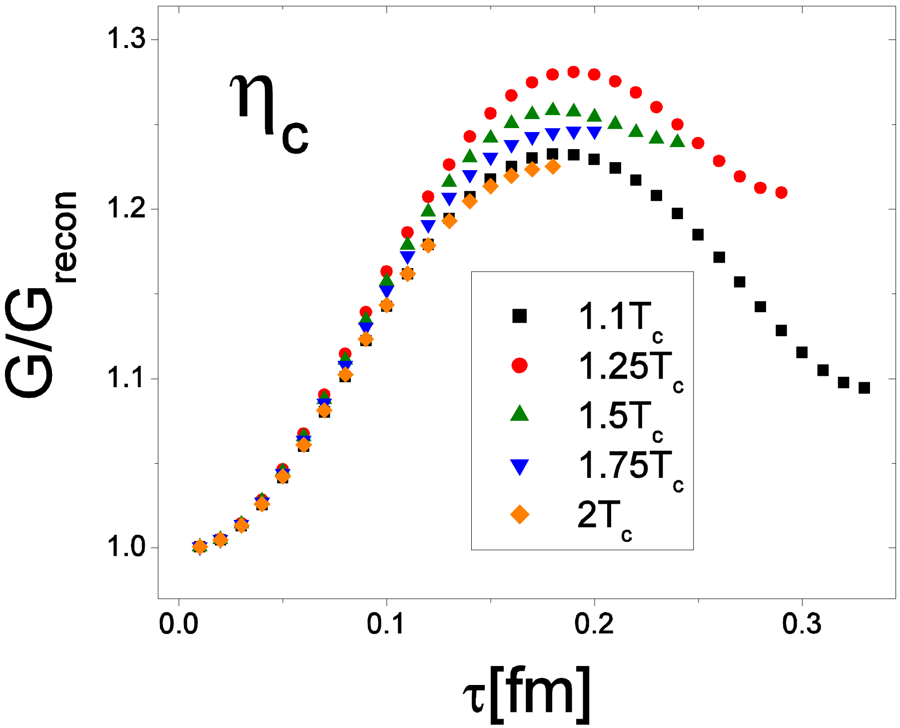


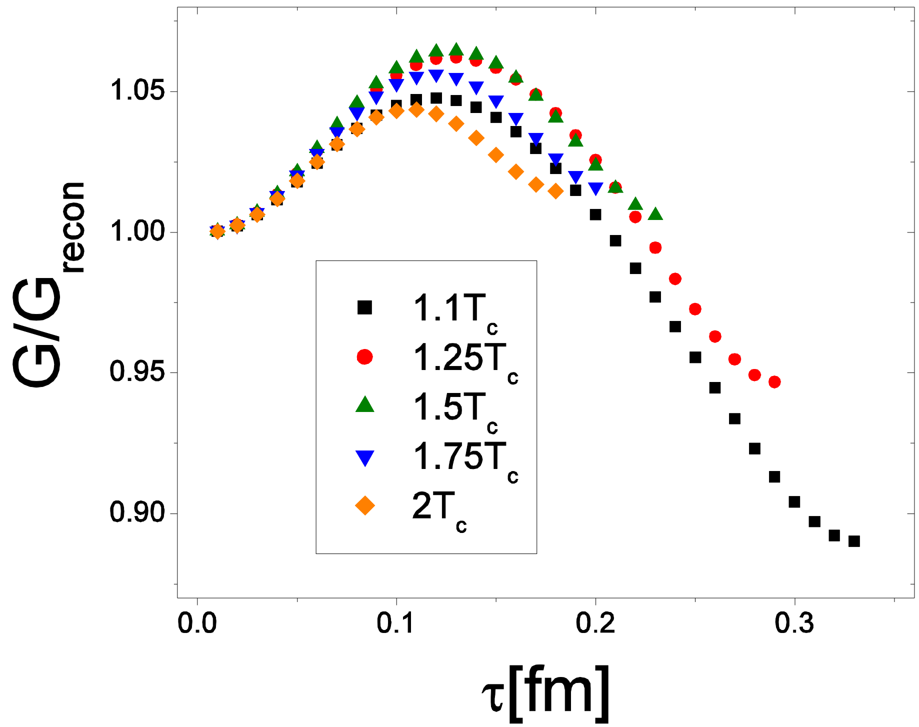
Datta et al '04

Extra feature: Important contribution from continuum due to threshold reduction.

Not detected on lattice.

Including also 2S in T=0 pseudoscalar correlator



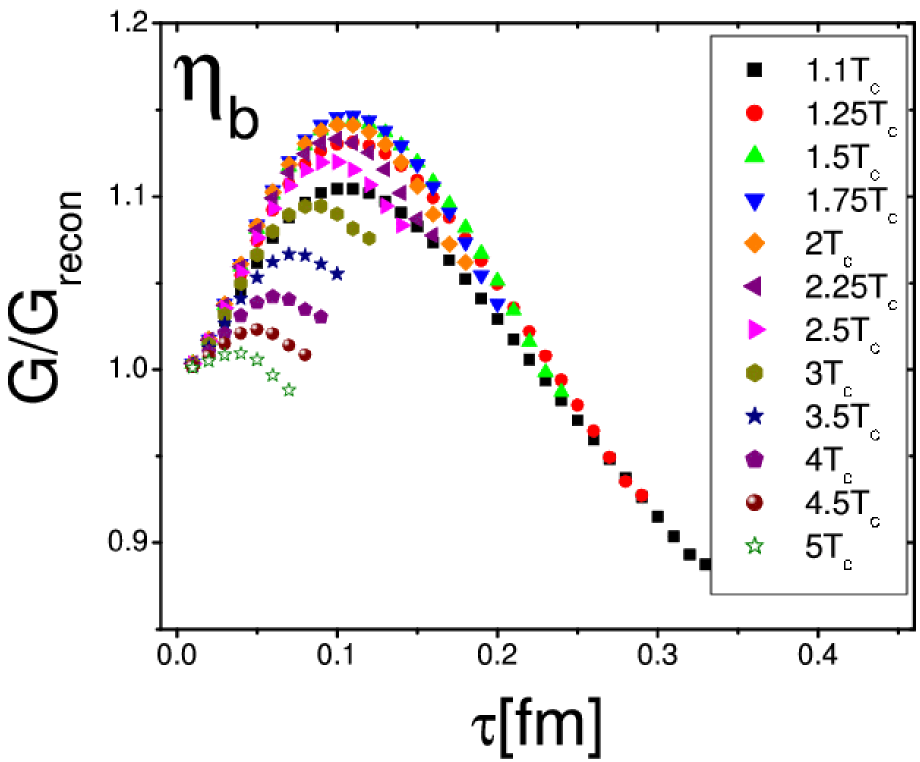


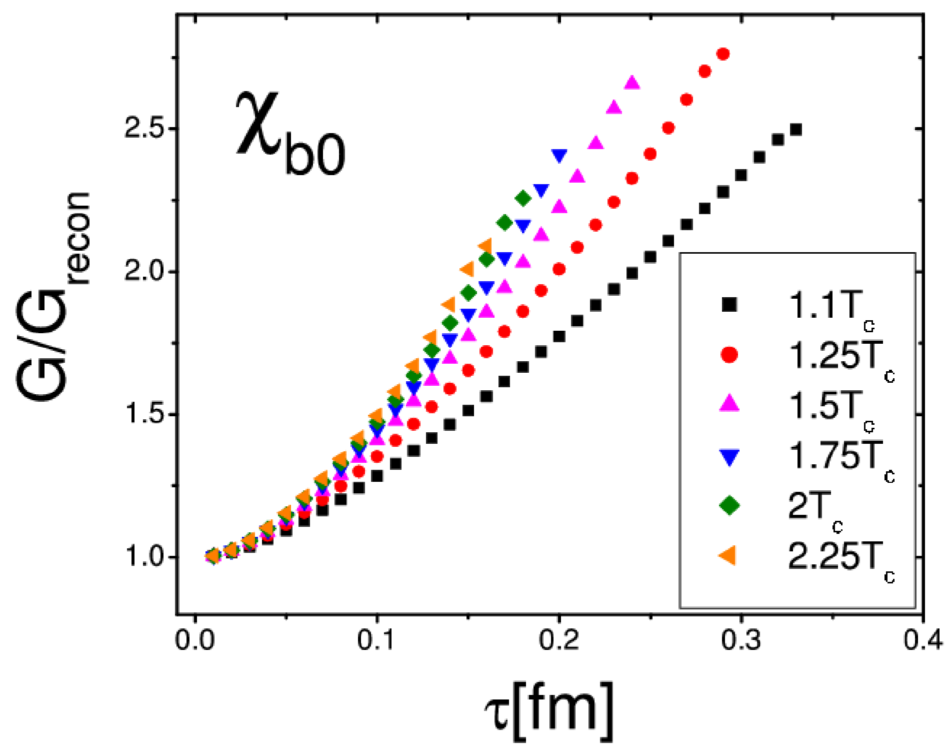
25 % drop in the pseudoscalar correlator
due to melting of the 2S state

Not detected on lattice.

also

Bottomonium 1S and 1P

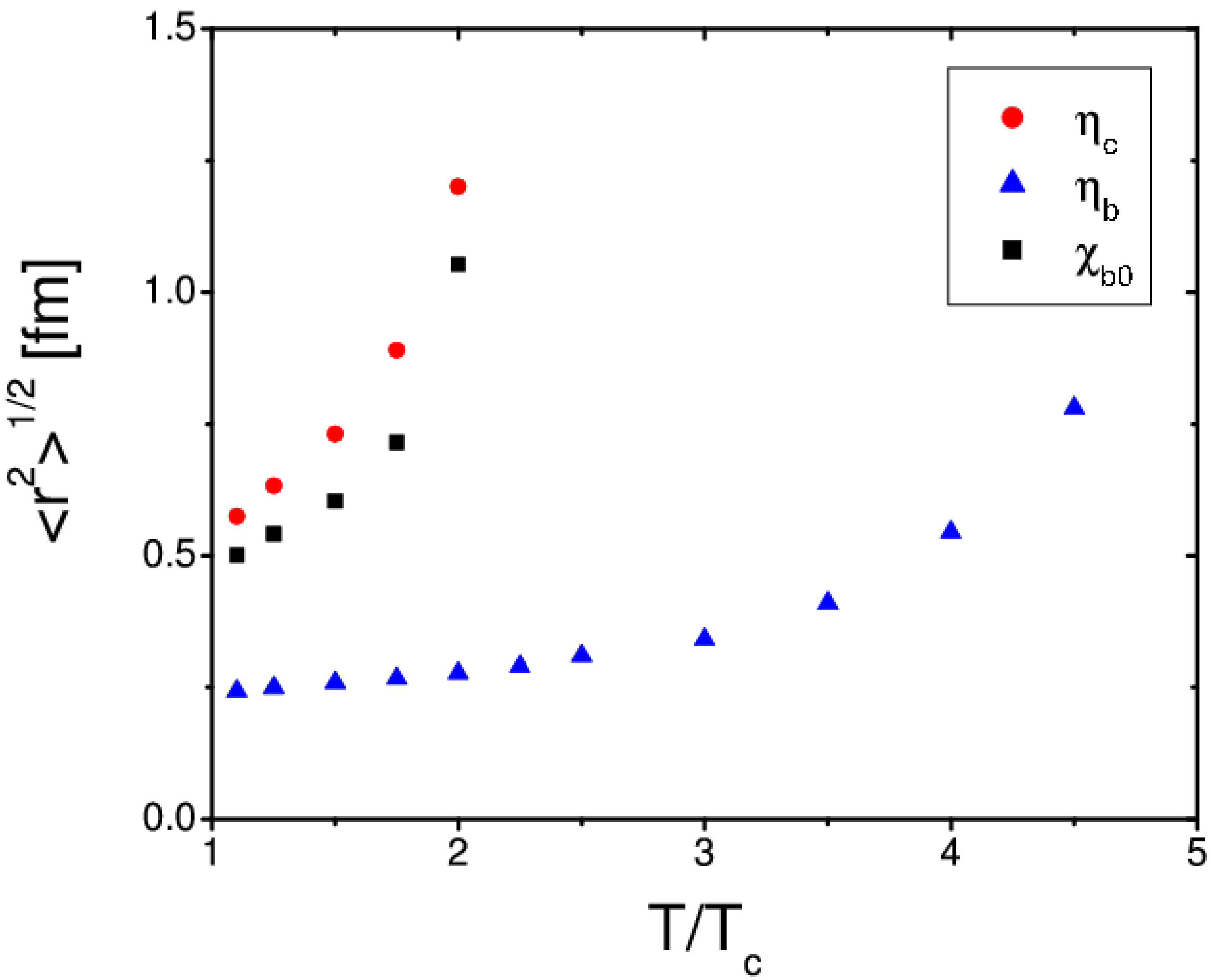




Qualitatively similar behavior

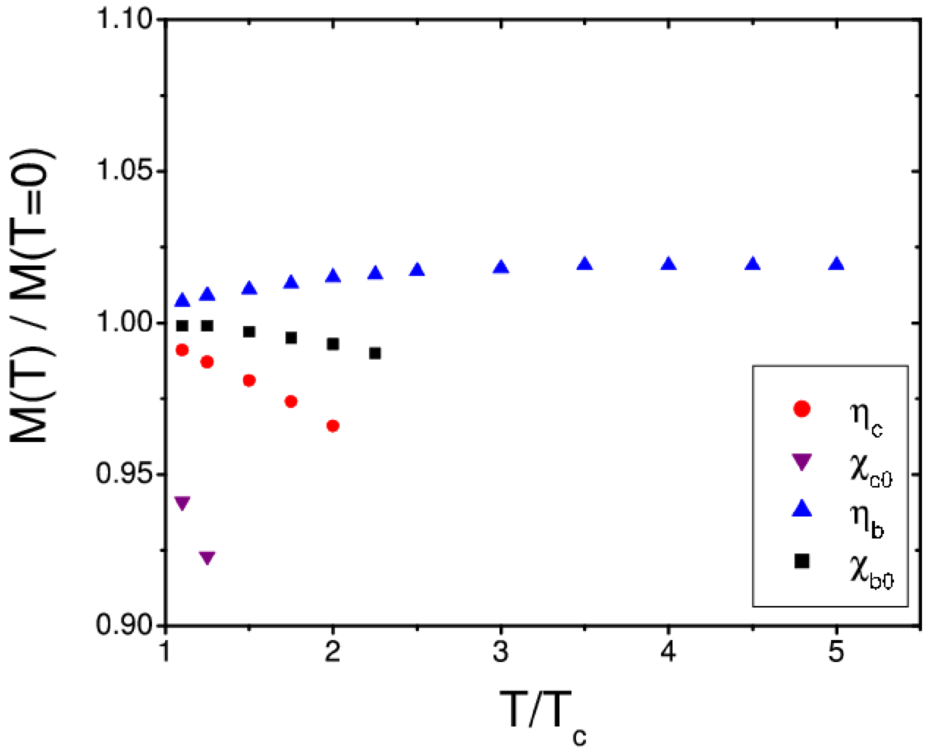
meanwhile

the radii

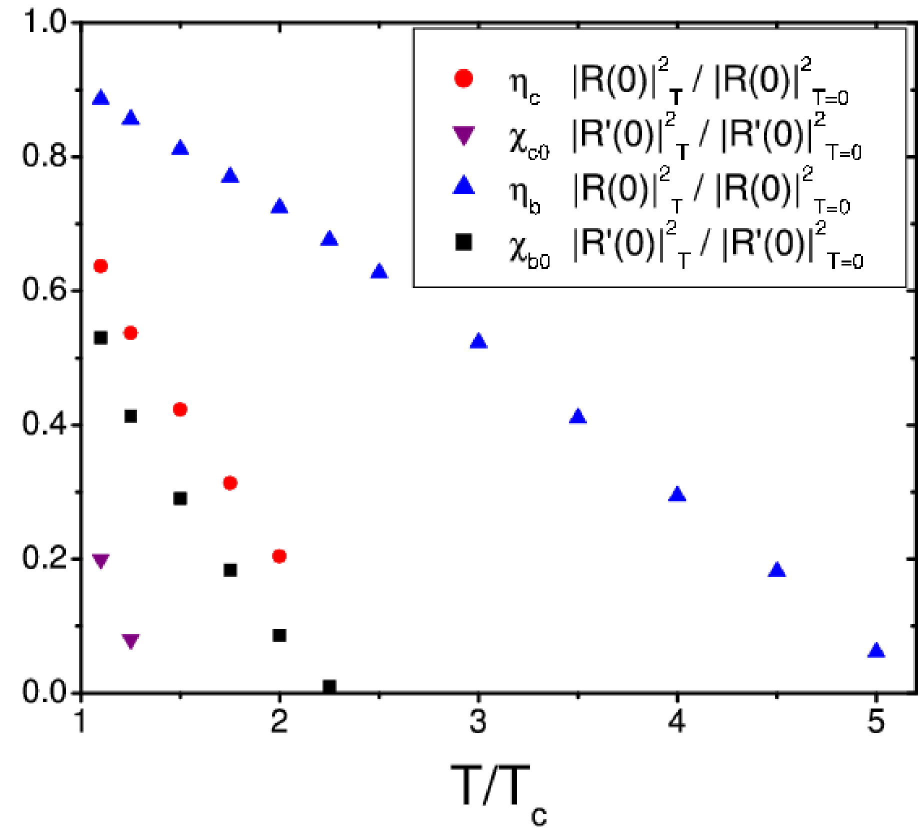


$b\bar{b}$ states hang in there longer than $c\bar{c}$

the masses



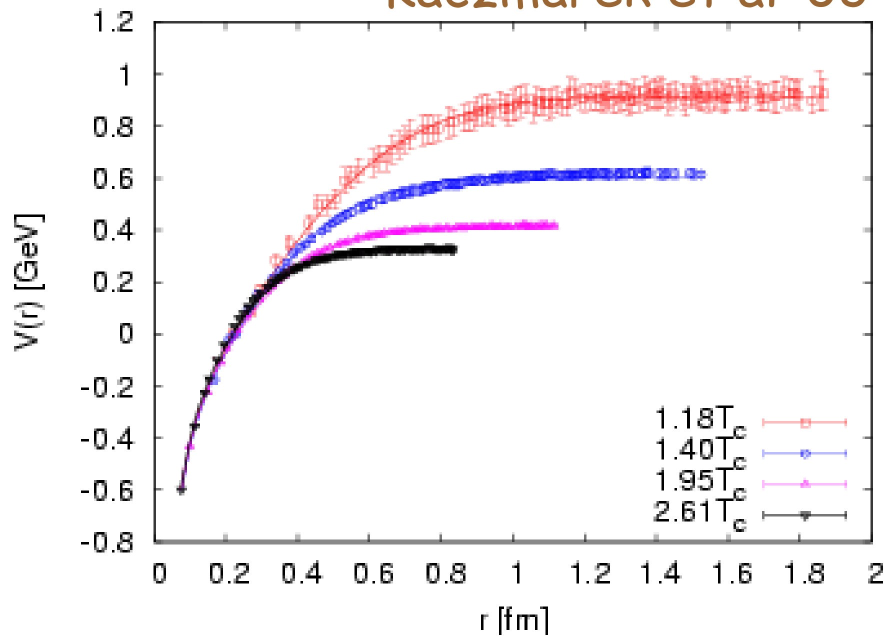
the amplitudes



furthermore

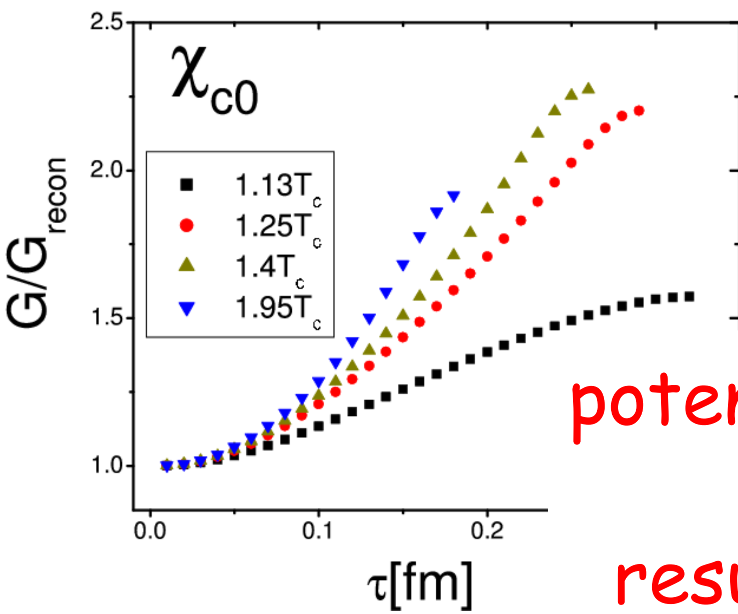
see talk by Kaczmarek

Kaczmarek et al '03

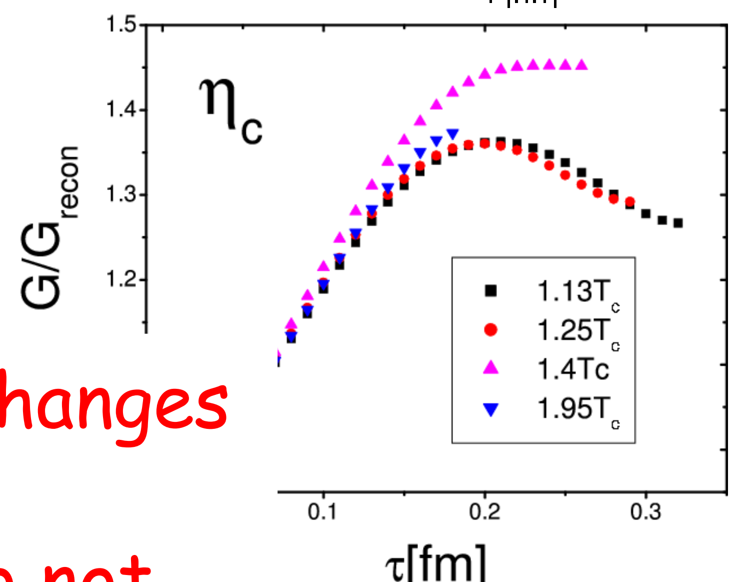


Yet another potential
- fit to lattice

$$V(r,T) = -\frac{\alpha}{r} e^{-\mu_1 r^2} + \sigma\, r\, e^{-\mu_2 r^2} + C\left(1 - e^{-\mu_3 r^2}\right)$$



potential changes
BUT
results do not



Where are we?

First analysis of
quarkonia correlators in potential models

Qualitative, but no quantitative agreement w/ lattice

We found extra features – lattice doesn't see.

Threshold decrease

Importance of continuum on correlators.

Quarkonia masses – as on lattice

Tested w/ different potentials – robust results !

… where to now?

Analyze the excited bottomonia states 2S, 3S, 2P

Extra effects *transport* for J/ψ

Understanding why it's different than η_c

Include thermal width due to gluon dissociation

To be continued …