Charmonia formation in QGP

PRC 89, 044903 (2014)

Taesoo Song

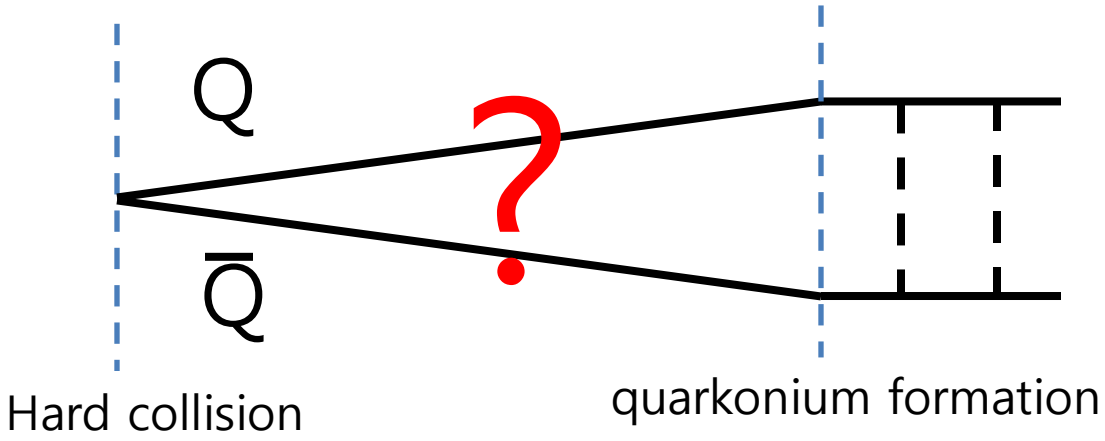
(Johann Wolfgang Goethe University)

Motivation

- It takes much longer time for quarkonium to be formed in QGP compared to in vacuum.

  T. Song, S. H. Lee, and C. M. Ko, PRC 87, 034910 (2013)

- It is not well known nuclear medium effect on quarkonium production before its formation.



Color evaporation model

In vauum

- $\sigma_{NN\to charmonium} = \int_{2m_c}^{2m_D} dM\, f_{c\bar{c}}(M)$

M : invariant mass of $c\bar{c}$

$f_{c\bar{c}}(M)$: M distribution of $c\bar{c}$

In QGP

- $\sigma_{NN\to charmonium} = \int_{2m_c}^{2m_c^*(T)} dM\, f_{c\bar{c}}^*(M)$

$m_c^* = m_c + \frac{1}{2}\mathrm{V}(\mathrm{r}=\infty, T)$

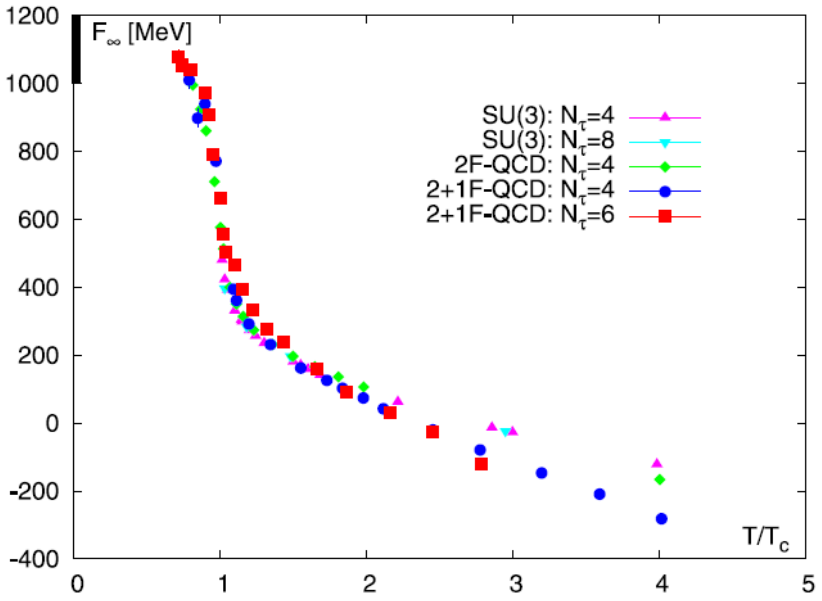
: c quark mass in QGP

$f_{c\bar{c}}^*(M)$: M distribution of $c\bar{c}$

at charmonium formation time in QGP

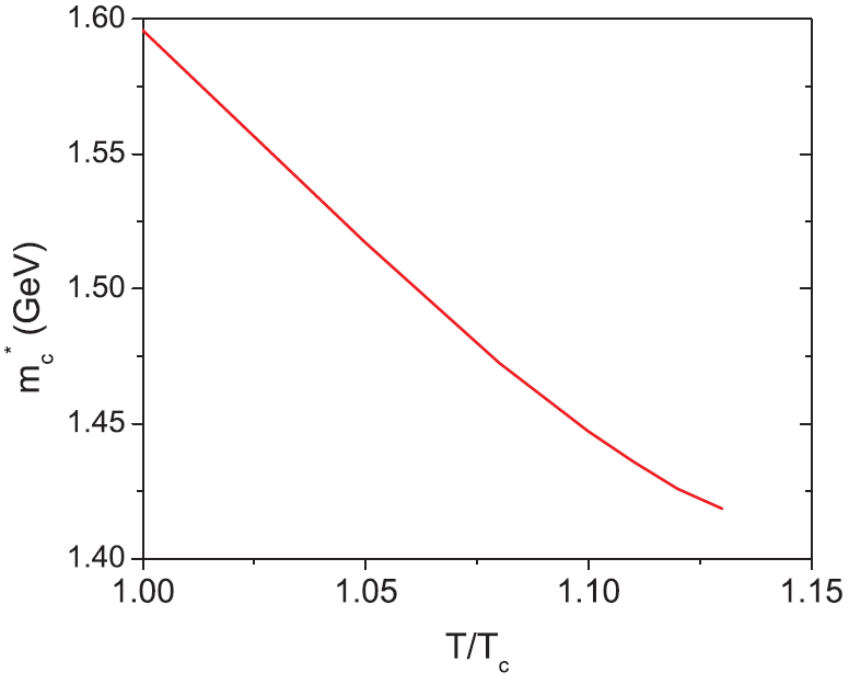
m_c^* from lattice free energy

F(r=∞,T)



Eur. Phys. J. C61:811 (2009)

decreasing m_c^* with T



$f^*_{c\bar{c}}(M)$ from Langevin equation

(anti-)charm distribution in QGP

$$f_c(\vec{p}) = \frac{1}{(2\pi)^{3/2}\sigma_L\sigma_T^2} \exp\left[-\frac{\{p_L - p_c(t)\}^2}{2\sigma_L^2} - \frac{p_T^2}{2\sigma_T^2} \right], \quad (15)$$

which is centered at

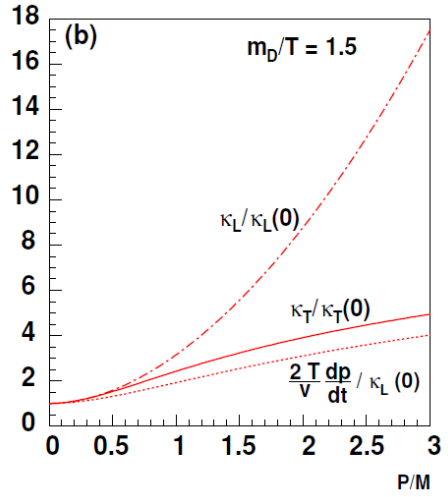
$$p_c(t) = p(t_0)e^{-\eta_D(t-t_0)}, \quad (16)$$

with the longitudinal and transverse widths being, respectively,

$$\sigma_L^2 = \int_{t_0}^{t} dt' \kappa_L(t') e^{-2\eta_D(t-t')},$$
$$\sigma_T^2 = 2\int_{t_0}^{t} dt' \kappa_T(t') e^{-2\eta_D(t-t')}. \quad (17)$$

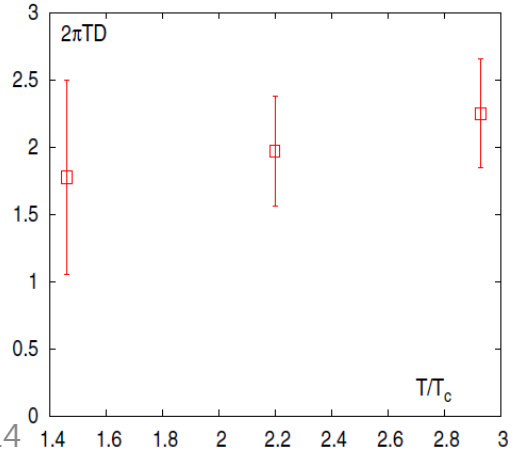
$$\eta_D = \frac{T}{m_c D}, \qquad \kappa_L = \kappa_T = \frac{2T^2}{D}.$$

p dependence of K_L and K_T from pQCD



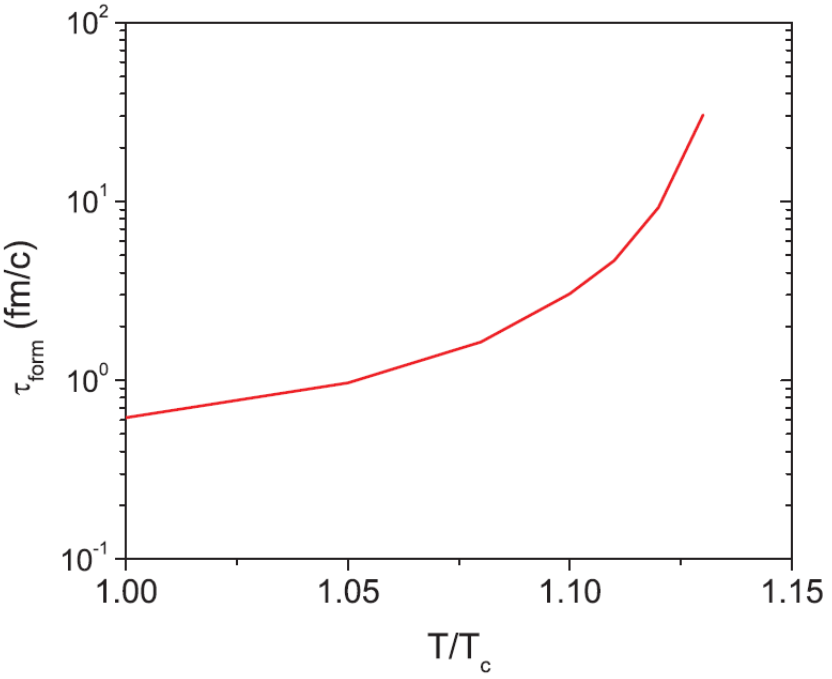
G. Moore, D. Teaney, PRC71, 064904 (2005)

diffusion constant D from lQCD

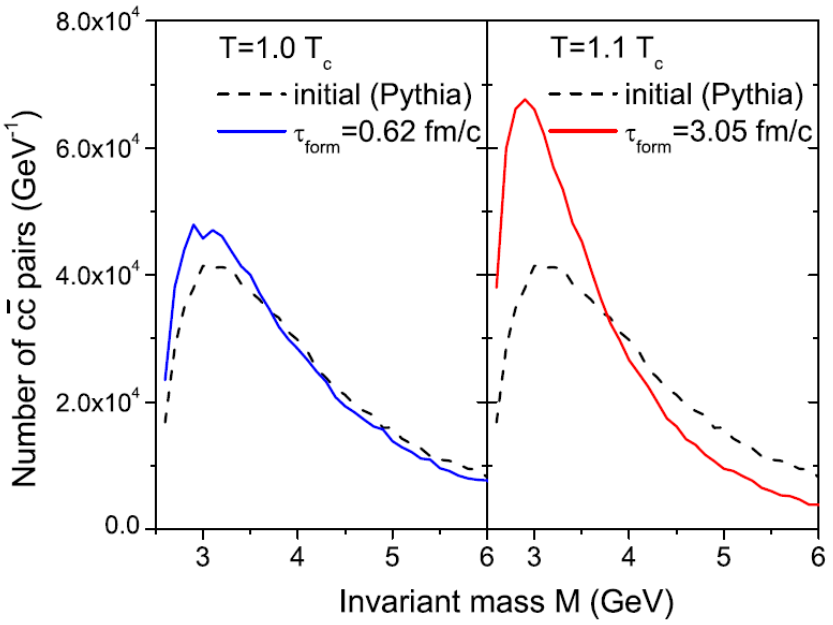


H. T. Ding, et al. PRD86, 014509 (2012)

J/Ψ formation time in QGP



$f^*_{c\bar{c}}(M)$ at formation time in QGP



T. Song, C. M. Ko, S. H. Lee, PRC87, 034901 (2013)

Results

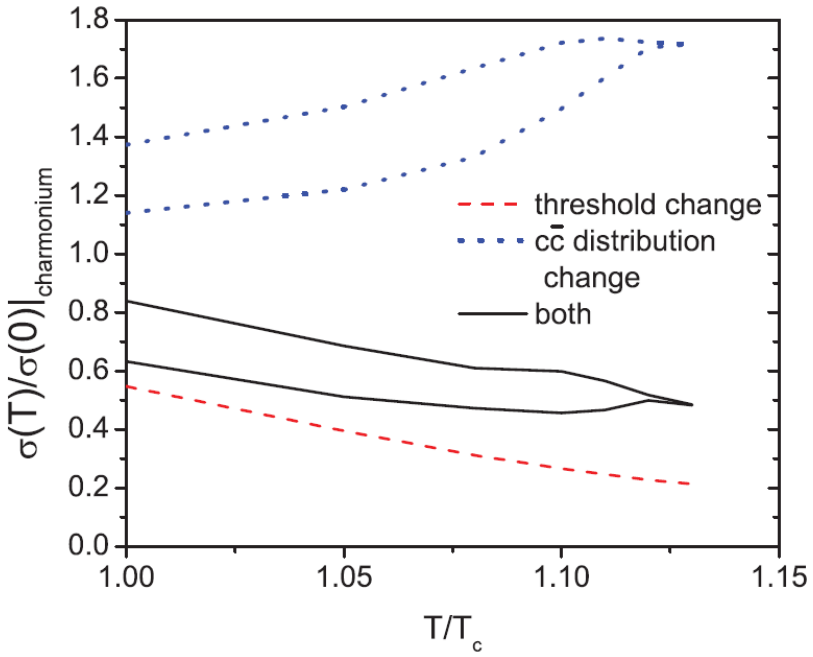


FIG. 4. (Color online) The ratios of charmonium production cross section in QGP to that in vacuum as functions of temperature at $\sqrt{s} = 200$ GeV in p + p collision. The dashed line is the ratio from the threshold energy change, the dotted lines are from the invariant mass change, and the solid lines are from both. The upper dotted and solid lines are for $2\pi TD = 1$ and the lower ones are for $2\pi TD = 3$.

- Decreasing m_c^* with T suppresses charomina formation
- Softened $c\bar{c}$ spectrum, $f_{c\bar{c}}^*(M)$, enhances charmonia formation
- As a result, charmonia production is suppressed about by a half.
- Considering J/Ψ is the only survived charmonium in QGP, its production is not suppressed in QGP.
  (50 % of charmonia are J/Ψ in vacuum)
- Rather it is enhanced taking into account feed-down effect.
  $(\psi', \chi_c \rightarrow 40\ \%\ \text{of}\ J/\psi)$

Summary

- Using the color evaporation model, charmonia formation in QGP is calculated.
- Charm quark mass decreasing with temperature suppresses the charmonium formation.
- The invariant mass of $c\bar{c}$ pair which decreases in QGP due to scattering enhances the charmonium formation.
- As a result, charmonium production is suppressed by a half in QGP.
- However, J/Ψ production is not suppressed, because it is the only survived charmonium in QGP, and rather enhanced considering the feed-down effect.