$B_c$ mesons in the deconfined phase

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Overview

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Introduction

Early production of heavy quarkonia and their survival while crossing the deconfined medium in relativistic heavy ion collisions.

Enhancement of the $B_c$ production in A-A collisions.

Modification of binding energy of $B_c$ meson due to the increasing temperature of the plasma.

Non-relativistic potential model for a mass evaluation and energy eigenvalues.
Free energy of a heavy quark-antiquark pair placed at a distance $r$ in a thermal bath of gluons and light dynamical fermions is extracted in lattice calculations from the Polyakov loop correlation function and is fitted to:

$$F(r, T) = -\frac{4}{3} \frac{\alpha(r, T)}{r} e^{m_D(T)r} + C(T).$$

The coupling $\alpha$ is fixed by the customary RGE, but employing a temperature dependent scale, with coefficients determined, at each temperature.
The singlet internal energy is calculated

\[ U = -T^2 \frac{\partial (F/T)}{\partial T}. \]

Heavy quarks are acting as static sources of the color field. The internal energy coincides with the potential.

\[ V(r, T) = U(r, T) - U(r \to \infty, T). \]

\[ V(r, T) \] is then inserted into the Schrödinger equation, from which the binding energy of the different stable states and their evolution with the temperature are obtained.
The radial wave function $R(0)$ (or of its first derivative $R'(0)$ for the P wave state) evaluated in the origin for the $B_c$ and $\chi_{B_c}$ states respectively are used to build the spectral functions at different temperatures. The spectral function for a generic meson channel $\sigma_M(\omega, T)$ can be written as

$$\sigma_M(\omega, T) = \sum_n |\langle 0 \mid j_M \mid n \rangle|^2 \delta(\omega - E_n) = \sum_n F_{M,n}^2 \delta(\omega - E_n) + \theta(\omega - s_0) F_{M,\epsilon}^2,$$

where

$$F_{PS}^2 = \frac{N_c}{2\pi} |R(0)|^2 \text{ for the pseudo-scalar state and}$$

$$F_S^2 = \frac{9N_c}{2\pi m^2} |R'(0)|^2 \text{ for the P-wave scalar state.}$$
Mass as a function of temperature of the lowest $S$-wave, first $S$-wave excited and lowest $P$-wave $b\bar{c}(c\bar{b})$ states as a function of temperature.

The dissociation temperatures obtained for the various states, in units of the critical temperature $T_c = 202$ MeV.

<table>
<thead>
<tr>
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<th>$m_c = 1.4$ GeV</th>
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<th>$m_c = 1.6$ GeV</th>
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<tbody>
<tr>
<td></td>
<td>$m_b = 4.3$ GeV</td>
<td>$m_b = 4.7$ GeV</td>
<td>$m_b = 4.3$ GeV</td>
<td>$m_b = 4.7$ GeV</td>
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<tr>
<td>$B_c$</td>
<td>1.87</td>
<td>1.90</td>
<td>1.99</td>
<td>2.02</td>
</tr>
<tr>
<td>$\chi_{B_c}$</td>
<td>1.05</td>
<td>1.05</td>
<td>1.06</td>
<td>1.06</td>
</tr>
<tr>
<td>$B'_c$</td>
<td>1.03</td>
<td>1.04</td>
<td>1.04</td>
<td>1.05</td>
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</table>
Squared value in the origin, for the $b\bar{c}$ system of the $S$-wave radial wave function and of the first derivative of the $P$-wave radial wave function, as a function of temperature.
The $b\bar{c}$ $S$-wave channel spectral function divided by $\omega^2$ as a function of $\omega$ at different temperatures.
The $b\bar{c}$ $P$-wave channel spectral function divided by $\omega^2$ as a function of $\omega$ at different temperatures.
We have investigated the survival above the critical temperature of a few special quarkonium states, the ones of the $B_c$ family, with the main purpose of drawing the attention of the on-going experiments at LHC on these intriguing heavy quarkonia.

$B_c$ mesons can survive above the temperature for deconfinement of the medium and give important information on the properties of the hot medium itself.
References

W.M. Alberico, S. Carignano, P. Czerski, A. De Pace, M. Nardi, C. Ratti

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