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FORM FACTOR OF EXCITED BARYON AT FINITE TEMPERATURE

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Abstract: In this paper, we investigate the temperature dependence of excited baryon's form factor is considered in the framework of the soft-wall model of Anti–de - Sitter/Quantum Chromodynamic. Profile functions of the baryons and the bulk-to-boundary propagator at finite temperature were applied in the model with thermal dilaton field. The temperature dependence of the excited baryon's form factor is plotted. It was found that on increasing temperature the value of form factor decreases and near the Hawking temperature form factor becomes zero.

Keywords: AdS/CFT duality, soft-wall model, grade state, background geometry, excited baryon, form factor.

1. Introduction

There are various methods for calculating form factors, strong coupling constants, mass, etc. of elementary particles. One of them is AdS/QCD models which is a way of using the AdS/CFT correspondence as motivation for modeling QCD starting from a 5D space [1-14]. QCD is not a conformal field theory, so one needs to break a corresponding symmetry in the AdS space, to obtain, for example, the form factor of baryons. The study of the temperature dependence of the baryon form factor allows getting a deeper understanding of several physical phenomena, such as phase transitions in nuclear matter, evaluation of early universe and etc. In Ref [12] it was calculated and plotted temperature dependence of baryons form factor at finite temperature in the ground state. We aim is to calculate and plot temperature dependence of excited baryon form factor in the n=1 and n=2 excited state using Ref [12] and [13] in the AdS/QCD soft-wall model.

Including temperature dependence of the dilaton and the warping of the anti–de Sitter (AdS) metric due to temperature, it is possible to reproduce a temperature behavior of the quark condensate. So, there are two sources of temperature dependence: (1) the warping of the AdS metric due to temperature, (2) the temperature dependence of the dilaton-background field. The dilation produces confinement and is responsible for the breaking of conformal invariance and the spontaneous breaking of chiral symmetry in AdS/QCD soft-wall model.

2. The form factor of excited baryons at finite temperature.

The action reads [13]:

$$S = \int d^4x\, dz\; e^{-\Phi(z,\ T)}\sqrt{g}\,\mathcal{L}_{q/t}\,. \tag{1}$$

where determinant $\sqrt{g}$ is specified by

$$\sqrt{|g|} = \sqrt{\left|\begin{matrix} f(z,T)e^{2A(z)} & 0 & 0 & 0 & 0 \\ 0 & -e^{2A(z)} & 0 & 0 & 0 \\ 0 & 0 & -e^{2A(z)} & 0 & 0 \\ 0 & 0 & 0 & e^{2A(z)} & 0 \\ 0 & 0 & 0 & 0 & -1/f(z,T)e^{2A(z)} \end{matrix}\right|} \tag{2}$$

where, z is the holographic coordinate, $A(z) = log(R/z)$, R is the AdS radius and thermal factor $f(z,\ T) = 1 - (\ z^4/\ H^4)$, H is the position of the event horizon, which is related to the black-hole Hawking temperature by $T = 1/H\ \pi$. where κ=383 is a scale parameter.

The dilaton field at a finite temperature [13].

$$\Phi(z,\ \ T) = K(T)^2 z^2 \tag{3}$$

Here

$$K(T) = k * (1 + \Delta_T) \tag{4}$$

$$\Delta_T = -\frac{N_f^2 T^2 - T^2}{12 N_f F^2} - \frac{N_f^2 T^4 - T^4}{144 N_f^2 F^4} \tag{5}$$

$N_f = 2$ is the number of quark flavors, *F=0.087 GeV* is the pseudoscalar meson decay constant in the chiral limit at finite temperature.

First, one gets the vector bulk-to-boundary propagator at finite temperature using the universal action. In the Euclidean metric,$(Q^2 = -\ q^2)$, the corresponding *EOM* for the Fourier transform of the bulk-to-boundary propagator $V(Q,z,T)$ reads:

$$\partial_z\left(\frac{e^{-\Phi(z,\ T)}}{z}\partial_z B(Q,z,T)\right) - Q^2\frac{e^{-\Phi(z,\ T)}}{z}B(Q,z,T) = 0 \tag{6}$$

So, the solution for the bulk-to-boundary propagator at finite temperature reads:

$$V(Q,z,T) = \Phi(z,\ \ T)\int_0^1 \frac{dx}{(1-x)^2}\ x^{a(Q,T)}\ e^{-\Phi(z,\ T)\frac{x}{1-x}}\ . \tag{7}$$

$$a(Q,T) = \frac{Q^2}{4K^2(T)}$$

The general formula for finding the exciting baryon form factors at finite temperature is the following integral:

$$F_n(Q^2,T) = \int_0^\infty dz B_n^L(z,T) B_n^R(z,T) V(Q,z,T) \tag{8}$$

where $B_n^L(z,T)$ and $B_n^R(z,T)$ are left/right profile functions as below:

$$\begin{aligned} B_{1L}^n(z,T) = K^{mL+1}(T) z^{mL+1/2}\sqrt{2\Gamma(n+1)/\Gamma(n+mL+1)} \times \\ \times L_1^{(mL)}(K^2(T)z^2), \end{aligned} \tag{9}$$

$$B_{1R}^{(n)}(z,T) = K^{mR+1}(T)z^{mR+1/2}\sqrt{2\Gamma(n+1)/\Gamma(n+mL+1)}\times$$
$$\times L_1^{(mR)}(K^2(T)z^2). \qquad (10)$$

here

$$mL = N + L - 1$$
$$mR = N + L - 2$$

where $N = 3$, $L = 0$ are partonic number and magnetic angle momentum of baryons.

Profile functions of baryons obey normalization conditions.

$$\int_0^\infty dz \frac{e^{\frac{-K^2(T)z^2}{2}}}{z^2} B_{1L}^n(z,T)B_{1R}^m(z,T) = \delta_{nm} \qquad (11)$$

which corresponds to the mass spectrum

$$M = M^2\,(0)(1+\Delta_T) + (6n-1)(n+m+1)\frac{\pi^4T^4}{k^2} \qquad (12)$$

Results the form factor of excited baryon for radial excitations with n=1 is obtained.

$$F_1(Q^2,T) = \frac{\Gamma(a(Q,T)+1)\Gamma(m+4)}{\Gamma(a(Q,T)+m+4)} + (a(Q,T)+m)\frac{\Gamma(a(Q,T)+2)\Gamma(m+2)}{\Gamma(a(Q,T)+m+4)} \qquad (13)$$

If n=2, then profile a function:

$$F_2(Q^2,T) = \frac{\Gamma(a(Q,T)+1)\Gamma(m+6)}{\Gamma(a(Q,T)+m+6)} + a(Q,T)\frac{\Gamma(a(Q,T)+2)*\Gamma(m+3)}{\Gamma(a(Q,T)+m+6)}*$$

$$*\,[(\mathrm{m}+5)(2\mathrm{m}+3)+\frac{1}{2}a(Q,T)(a(Q,T)+5) \qquad (14)$$

The temperature dependence of right $F_{1R}(Q^2,T)$, $F_{2R}(Q^2,T)$ and left $F_{1L}(Q^2,T)$, $F_{2L}(Q^2,T)$ baryon form factors corresponding to n = 1, 2 states are shown following pictures.

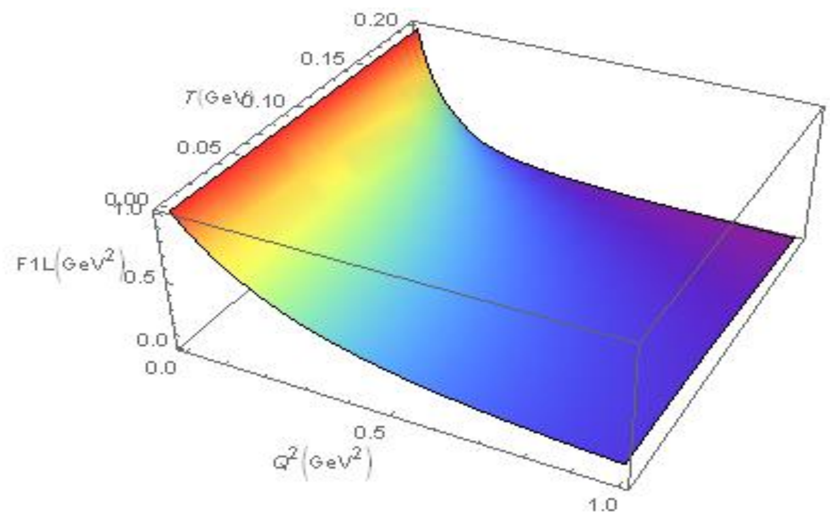

Fig. 1. The temperature dependence of excited $F_{1L}(Q^2,T)$ left baryon form factor at n = 1 state.

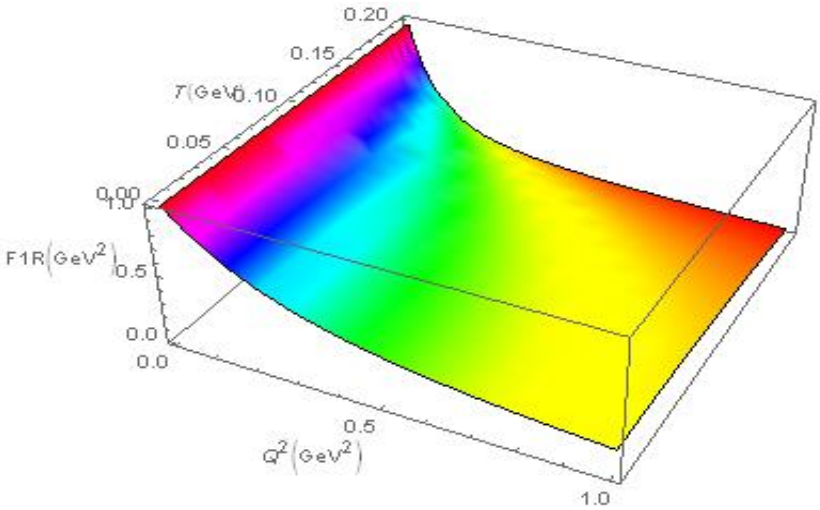

Fig. 2. The temperature dependence of excited $F_{1R}(Q^2, T)$ right baryon form factor at n = 1 state.

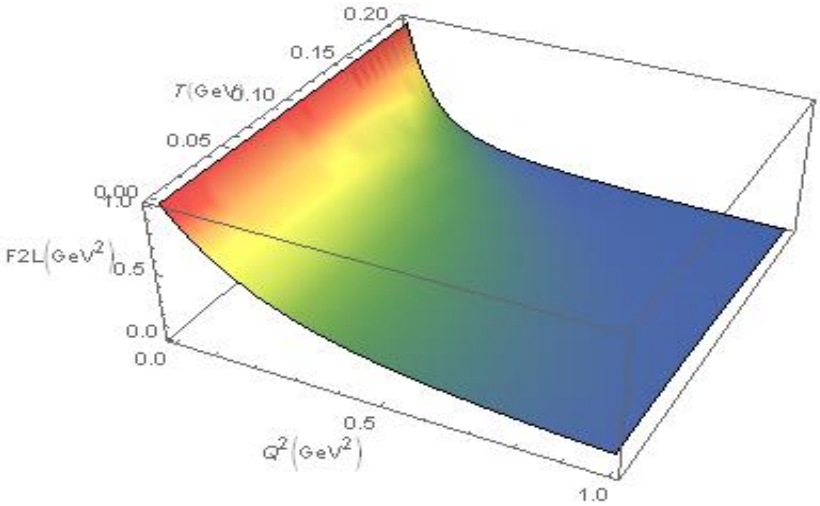

Fig. 3. The temperature dependence of excited $F_{2L}(Q^2, T)$ left baryon form factor at n = 2 state.

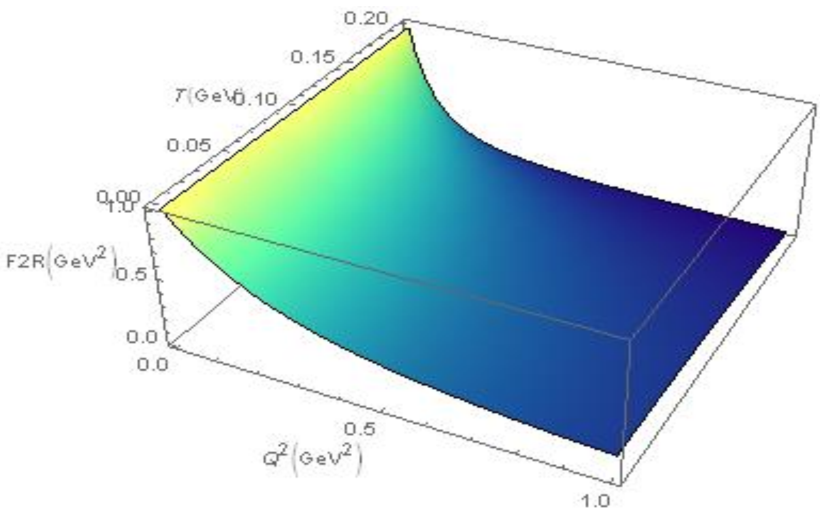

Fig. 4. The temperature dependence of excited $F_{2R}(Q^2, T)$ right baryon form factor at n=2 state.

It can be seen from both figures that the graphs are in the positive region, and as the temperature increases, the value of the form factor decreases and finally the temperature approaches zero at T = 0.20 MeV.

3. Summary

Thus, by constructing the temperature dependence of the excited baryon form factors, we found that at a temperature close to Hawking's temperature approximately T = 221 MEV, the value of the form factor approaches zero, indicating that the particles interact still that temperature. The higher temperatures than Hawking temperature indicates that the baryons are completely dissolved, the quark-gluon plasma is formed, and there are no interactions.

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ФОРМ ФАКТОР ВОЗБУЖДЕННЫХ БАРИОН ПРИ КОНЕЧНОЙ ТЕМПЕРАТУРЕ

Н.А. Насибова

Резюме: В данной работе исследуется температурная зависимость форм-фактора возбужденного бариона, рассматриваемая в рамках модели мягкой стенки Анти-де-Ситтер / Квантовая Хромодинамика. Профильные функции барионов и пропагатора от объема до границы при конечной температуре были применены в модели с термодилатонным полем. Построена температурная зависимость формфактора возбужденного бариона. Было обнаружено, что с повышением температуры значение форм-фактора уменьшается и вблизи температурного форм-фактора Хокинга становится равным нулю.

Ключевые слова: AdS/CFT-дуальность, модель мягкой стены, возбужденный барион, основной состояние, геометрия фона, форм-фактор.

SONLU TEMPERATURDA HƏYƏCANLAŞMIŞ HALDA OLAN BARION FORM FAKTORU

N.Ə. Nəsibova

Xülasə: Məqalədə sonlu temperaturda həyəcanlaşmış halda olan barionun form faktoruna Anti-de-Sitter /Kvant Xromodinamikası yumşaq divar modelində araşdırılmışdır. Baryonların profil funksiyaları və daxil-sərhəd propaqatoru sonlu temperaturda termal dilatonla birgə modelə daxil edilmişdir Həyəcanlaşmış barionun form faktorunun temperaturdan asılılıq qrafiki qurulmuşdur. Müəyyən olunmuşdur ki, temperaturun artması ilə form faktorun qiyməti azalır və Havking temperaturunun yaxınlığında form faktorun qiyməti sıfır olur.

Açar sözlər: AdS/KSN duallığı, yumşaq divar modeli, əsas hal, həyəcanlaşmış baryon, arxafon həndəsəsi, form faktor.