Holographic Schwinger effect with a deformed AdS background

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Introduction of Schwinger effect

Introduction of Schwinger effect

An interesting non-perturbative phenomena, which is production of pair in an external electric field in quantum electrodynamics (QED) is called Schwinger effect, where due to a presence of a strong electric field virtual electron-positron pair become real particles.
It is not restricted to QED and can be used for any charged particles in a strong external field such as an electromagnetic field. For the creation of a real pair which corresponds to the vacuum decay rate, the external field should reach to a critical value where the vacuum becomes totally unstable. In other words when the electric field is small the potential barrier is present and the pair production is described as a tunneling process. The potential barrier decreases as the electric field becomes greater and at a critical value of E the barrier vanishes and the production rate is catastrophic and is not exponentially suppressed.
Furthermore it can lead to the creation of a neutral pair of higher dimensional objects such as string and D-branes. In this work we study quark-qntiquark pair production by AdS/CFT approach.

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Schwinger effect in a deformed AdS background

Brief review of gauge/gravity duality

Holography principle: A theory of quantum gravity in a region of space should be described by a non-gravitational theory living at the boundary of that region.

R. Bousso, Rev. Mod. Phys. **74** (2002) 825

Simple example of a gauge/gravity duality

Gravity side:
Type IIB string theory on $AdS_5 \times S^5$
With charactristic parameters: $g_s \longrightarrow$ string coupling constant and $R \longrightarrow$ Size of AdS_5 and S^5 spaces
Gauge side:
$\mathcal{N} = 4SYM$ theory on 4dim. Minkowski space time.
With charactristic parameters: $N_c \longrightarrow$ rank of gauge group and $\lambda \longrightarrow$ 't Hooft coupling constant

Quark antiquark pair production in presence of an external field

- Supposition: we consider vacuum in presence of an external electric field.
- In QCD point of view, the vacuum decay rate for Schwinger effect is related to the quark antiquark pair creation in the presence of a strong field.
- Goal: the purpose of the current study is to determine the effects of deformation parameter of AdS space on total potential of a quark-antiquark pair in the Schwinger effect.

Which background are we interested in? a deformed AdS metric background

$$ds^2 = e^{2A(z)}[-f(z)dt^2 + \Sigma_{i=1}^{i=3} dx^2 + \frac{1}{f(z)} dz^2], \tag{1}$$

$$A(z) = -\ln\frac{z}{R} + \frac{1}{4}cz^2,$$

$$f(z) = 1 - (\frac{z}{z_h})^4, \quad 0 \le z \le z_h$$

$$z_h = \frac{1}{\pi T}.$$

O. Andreev, PRD **73** (2006) 107901
O. Andreev, PRD **74** (2006) 025023
O. Andreev, PLB **654** (2007) 473

Schwinger effect in a deformed AdS background

We proceed by considering an electric field in a deformed AdS background. In a very breif way, we review the process step by step.

We have string NG action
$\Longrightarrow$ we write lagrangian by our mentioned background
$\Longrightarrow$ we arrive to equation of motion
$\Longrightarrow$ from boundary conditions one can obtain the separation length of the test particles
$\Longrightarrow$ at the final step we consider total potential as sum of Coulomb potential, electrostatic potential, In addition an energy Ex where x is a separating distance of virtual pairs and E is an external electric field, should be taken into account.

We work by these quantities,

- E_{cr}, critical electric field which is the value beyond that pair production starts.
- $V_{tot} = V_{CP} + V_{SE} + Ex$ the total potential.
- we define a dimensionless value which depends on E_{cr} when the deformation parameter has exact value of zero as, $\alpha = \frac{E}{E_{cr}|_{c=0}}$,
- a, fraction of position of the probe to the deepest position of the string in the bulk,
- b, fraction of position of the probe to the horizon .

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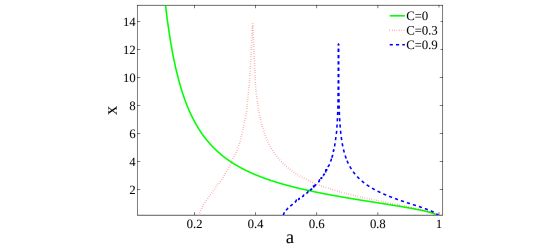
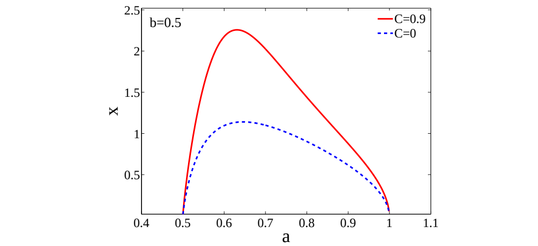
Results and discussion

Effect of deformation parameter on distance of quark antiquark pair in Schwinger effect context at zero temperature



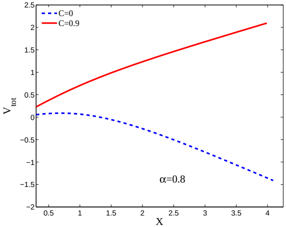
The parameter a shows the position of the tip of the string, so smaller a corresponds to closer region to the horizon.
In the case of $c = 0$, we can see x decreases with increasing a.
In case of $c \neq 0$ the distance between quark and antiquark finds a maxumum value. Therefore the contribution of nonzero deformation parameter leads to a degeneracy between x and a.

Effect of deformation parameter on distance of quark antiquark pair in Schwinger effect context at finite temperature



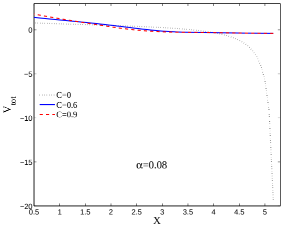
This figure represents the behavior of the distance x with respect to a for $b = 0.5$
In thermal case the behavior of x has a maximum value even with no deformation parameter.
The distance of quark and antiquark increases in the presence of deformation parameter.
In comparison with last case, at finite temperature there is degeneracy at any value of c. So here nonzero value of c or T have similar results phenomenologically.

Effect of deformation parameter on total potential in Schwinger effect context at zero temperature



Increasing deformation parameter increases value of potential at any specified x.
Therefore, the potential barrier at $c = 0$ vanishes by critical electric field.
It is interesting that for nonzero values of c the potential barrier does not vanish in this manner.
The pair production process or instability of the vacuum changes phenomenologically after the contribution of deformation parameter since there is tunneling process at any deformed AdS.

Effect of deformation parameter on total potential in Schwinger effect context at finite temperature



At the finite temperature the total potential does not have any potential barrier at deformed AdS. It is a strange result while the system with $c \neq 0$ is decaying by background electric field with any value.
It can be interpreted that in a deformed AdS at a high enough temperature, any value of electric fiel can lead to a pair production with no potential barrier.
In other words, there is a relation between c, T and E. When both temperature and deformation parameter are nonzero and at least one of them has a large enough value, then any value of electric field can be interpreted as critical value of electric field.

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Summary

Summary

- Finite temperature or nonzero value of deformation parameter lead to degeneracies between x and a. This degeneracies mean for any specified distance between quark and antiquark, there are two possible regions in the bulk. Therefore from theory, nonzero values of c or T have similar results phenomenologically.

- In consideration of the total potential at zero temperature, we have seen reverse behavior of the pair production process in the presence of electric field or deformation parameter, since to deform an AdS and to strength electric field have opposed effects. Therefore the deformation parameter can be used as a tuner to avoid from catstrophic pair production.

- At finite temperature, any value of electric field, can lead to a pair production with no potential barrier according to a relation between c, T and E. In this manner when both temperature and deformation parameter are nonzero and at least one of them has a large enough value, any value of electric field can be interpreted as the critical value of electric field which leads to a catastrophic pair production thereafter.

In memory of Maryam Mirzakhani (1977-2017), Iranian genius scientist and Fields Medal winner, anniversary of her death is in July...

Thanks for your attention