Holographic Schwinger effect in confining theories

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Based on PRD 89. 101901 (R) and work in progress in collaboration with D. Kawai & K. Yoshida (Kyoto Univ.)

Abstract : We study the Schwinger pair production in confining theories and obtain the production rate in an external electric field . There exist two kinds of critical values of the electric field. We argue the universal exponents associated with the critical behaviours.

Introduction

The Schwinger effect is pair creations of electron and positron in an external electric field. [Schwinger, PR 82(1951) 664]

More generally, pair creations of particle and anti-particles in an external field.

It is interesting to consider the Schwinger effect in confining gauge theories as a new mechanism of deconfinement in QCD.

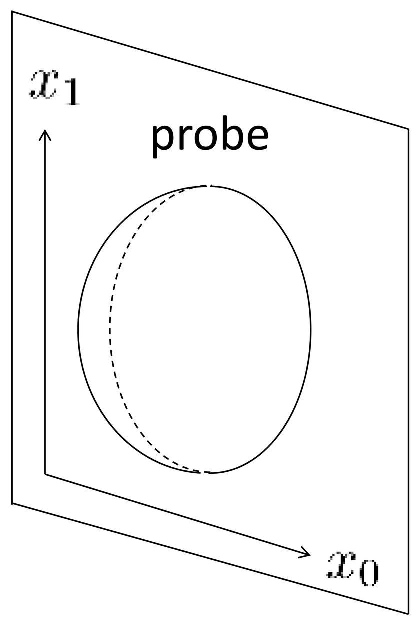
Note that the application of lattice gauge theories is difficult.

Recently, Semenoff and Zarembo proposed the holographic description of the Schwinger effect. [Semenoff-Zarembo, PRL 107 (2011) 171601]

The production rate is evaluated by (i) put a probe brane at a position between the horizon and the boundary

(ii) introducing NS-NS 2-form

(iii) caluclating the expectation value of a circular Wilson loop on a probe.



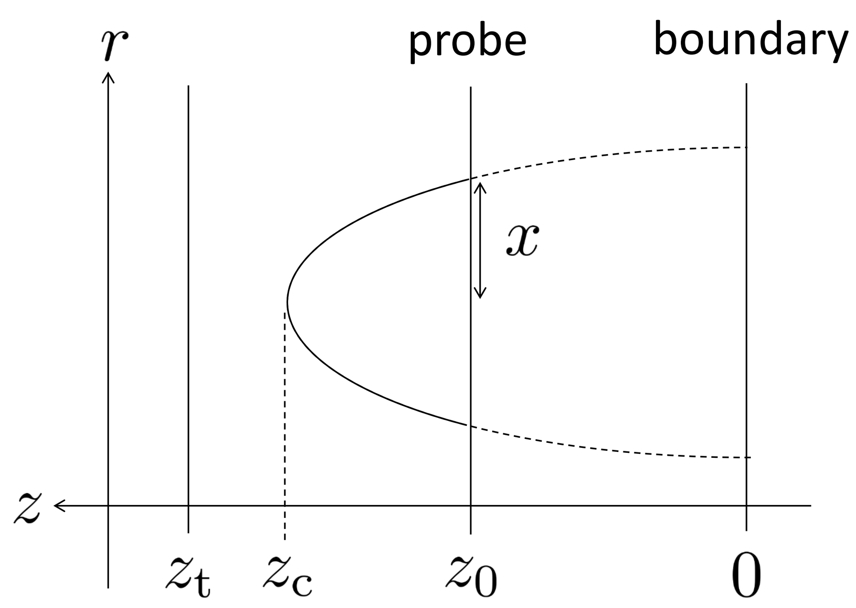
Production rate : $\Gamma \sim \mathrm{e}^{-S}$, $S = S_{\mathrm{NG}} + S_{B_2}$

$$\Gamma \sim \exp\left[-\frac{\sqrt{\lambda}}{2}\left(\sqrt{\frac{E_c}{E}} - \sqrt{\frac{E}{E_c}}\right)^2\right] \quad \text{where} \quad E_c = \frac{2\pi m^2}{\sqrt{\lambda}}$$

Setup and Strategy of our computations

For simplicity, we concentrate on a D3-solton background. [Kawai-YS-Yoshida, PRD 89 (2014) 101901]

The dual gauge theory is 1+2 dim. gauge theory with a confining string tension $T_F \frac{L^2}{z_t^2}$.



The metric (AdS-Soliton) : [Horowitz-Myers, PRD 59 (1998) 026005]

$$\mathrm{d}s^2 = \frac{L^2}{z^2}\left[-(\mathrm{d}x^0)^2 + \sum_{i=1}^{2}(\mathrm{d}x^i)^2 + f(z)(\mathrm{d}x^3)^2 + \frac{\mathrm{d}z^2}{f(z)}\right] + L^2 \mathrm{d}\Omega_5^2 \quad \text{where} \quad f(z) = 1 - \left(\frac{z}{z_t}\right)^4$$

Ansatz for a string : $x^0 = r(\sigma)\cos\tau\,,\quad x^1 = r(\sigma)\sin\tau\,,\quad z = z(\sigma)$

$$S_{\mathrm{NG}} = 2\pi L^2 \int_0^x \mathrm{d}r\, \frac{r}{z^2}\sqrt{1 + \frac{z'^2}{f(z)}}\ ,\quad S_{B_2} = -2\pi T_F B_{01}\int_0^x \mathrm{d}r\, r = -\pi E x^2$$

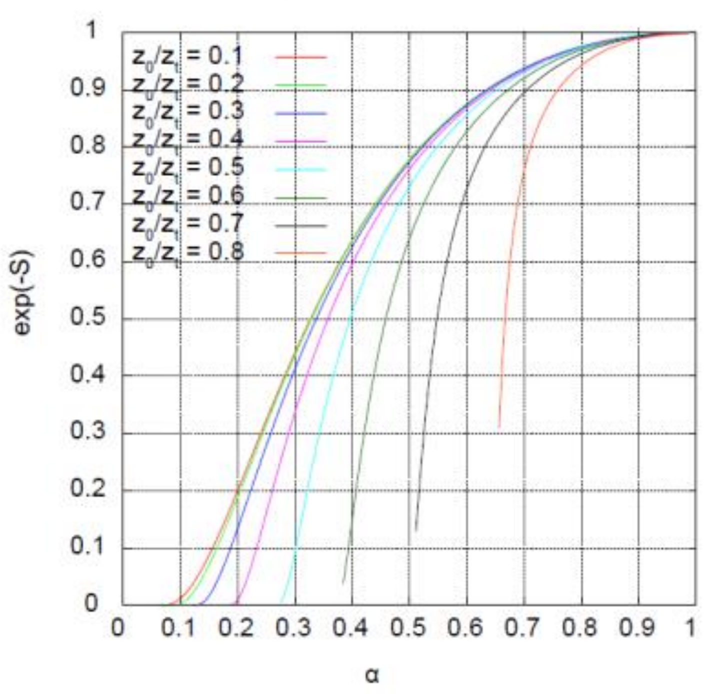
EOM : $z' + \frac{2rf(z)}{z} + rz'' - \frac{rz'^2}{2f(z)}\frac{\mathrm{d}f}{\mathrm{d}z}(z) + \frac{z'^3}{f(z)} + \frac{2rz'^2}{z} = 0$

Boundary condition : $z' = -\sqrt{f(z)\left(\frac{1}{\alpha^2} - 1\right)}\Bigg|_{z=z_0}$ where $\alpha := \frac{E}{E_c}\,,\quad E_c := T_F \frac{L^2}{z_0^2}$

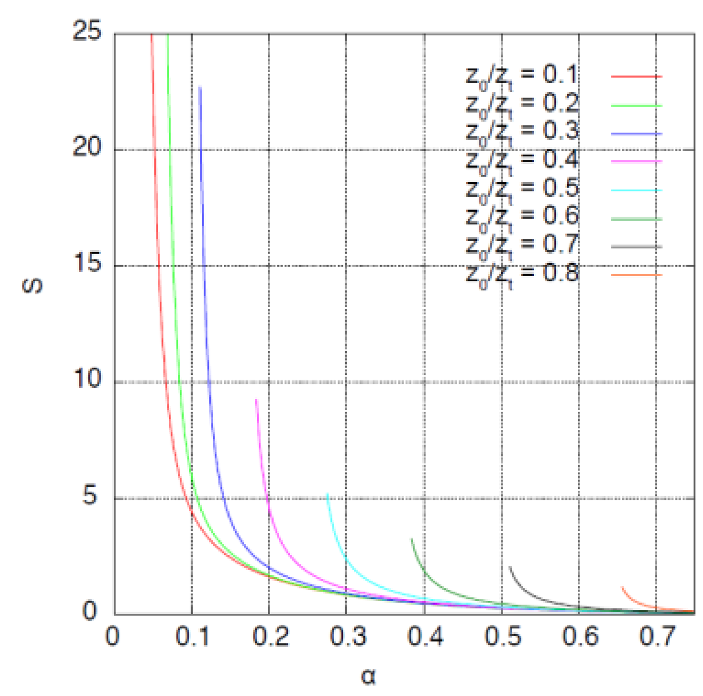
Results

We obtain the production rate and the classical action as functions of α numerically.

The production rate



The classical action



confining string tension

The production rate becomes nonzero at $\alpha = \alpha_s\,(E = E_s)$.

The production rate is not exponentially suppressed at $\alpha = 1\,(E = E_c)$.

Two critical electric field exist!!

Critical behaviours at $\alpha = \alpha_s$ and $\alpha = 1$ are coincidence with the result of potential analysisour previous work. [YS-Yoshida, JHEP 1309 (2013) 134 & JHEP 1312 (2013) 051]

$E \to E_s$ limit, $S = \frac{C(\alpha_s)\,\alpha}{(\alpha - \alpha_s)^2} + \frac{D(\alpha_s)}{\alpha - \alpha_s} + \text{the regular}$

Critical exponent $\gamma_s = 2$

$E \to E_c$ limit, $S = B(\alpha_s)(1-\alpha)^2 + \mathcal{O}\big((1-\alpha)^3\big)$

$\gamma_c = 2$

The exponents are the same for D4-soliton background. [Kawai-YS-Yoshida, work in progress]

We argue that these exponents are universal.