PRODUCTION OF ELECTRON-POSITRON PAIR IN COULOMB FIELD ON DE SITTER SPACE-TIME

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The first order transition amplitude corresponding to the de Sitter QED is:

$$\mathcal{A}_{e^-e^+} = -ie\int d^4x\,[-g(x)]^{1/2}\,\bar{U}_{\vec{p},\,\lambda}(x)\gamma_\mu A^{\widehat{\mu}}(x)V_{\vec{p}\,',\,\lambda'}(x) \tag{1}$$

The Coulomb field in this geometry is $A^{\widehat{0}}(x) = \frac{Ze}{|\vec{x}|}e^{-\omega t}$. The amplitude of electron-positron production in Coulomb field is given by:

$$\begin{aligned}
&\mathcal{A}_{e^-e^+} = i\frac{e^2 Z}{16\pi|\vec{p}+\vec{p}\,'|^2}\\
&\times\left[-sgn(\lambda')\left(p^{-1}\theta(p-p\,')f_{-k}\left(\frac{p\,'}{p}\right)+p\,'^{-1}\theta(p\,'-p)f_k\left(\frac{p}{p\,'}\right)\right)\right.\\
&\left.+sgn(\lambda)\left(p^{-1}\theta(p-p\,')f_k\left(\frac{p\,'}{p}\right)+p\,'^{-1}\theta(p\,'-p)f_{-k}\left(\frac{p}{p\,'}\right)\right)\right]\xi^+_\lambda(\vec{p})\eta_{\lambda'}(\vec{p}\,').
\end{aligned} \tag{2}$$

where $k = \frac{m}{\omega}$

The functions $f_k\left(\frac{p}{p'}\right)$, are defined as:

$$
\begin{aligned}
f_k\left(\frac{p}{p'}\right) &= ie^{-\pi k}\frac{\left(\frac{p}{p'}\right)^{1+ik}}{ch^2(\pi k)}\frac{{}_2F_1\left(\frac{3}{2},1+ik;\frac{3}{2}+ik;\left(\frac{p}{p'}\right)^2\right)}{B\left(-\frac{1}{2},\frac{3}{2}+ik\right)} \\
&+\frac{\left(\frac{p}{p'}\right)^{1+ik}}{ch^2(\pi k)}\frac{{}_2F_1\left(\frac{3}{2},1+ik;\frac{3}{2}+ik;\left(\frac{p}{p'}\right)^2\right)}{B\left(-ik,\frac{3}{2}+ik\right)} \\
&-\frac{\left(\frac{p}{p'}\right)^{-ik}}{ch^2(\pi k)}\frac{{}_2F_1\left(\frac{1}{2},1-ik;\frac{1}{2}-ik;\left(\frac{p}{p'}\right)^2\right)}{B\left(ik,\frac{1}{2}-ik\right)} \\
&+ie^{\pi k}\frac{\left(\frac{p}{p'}\right)^{-ik}}{ch^2(\pi k)}\frac{{}_2F_1\left(\frac{1}{2},1-ik;\frac{1}{2}-ik;\left(\frac{p}{p'}\right)^2\right)}{B\left(\frac{1}{2},\frac{1}{2}-ik\right)}\ . \qquad (3)
\end{aligned}
$$

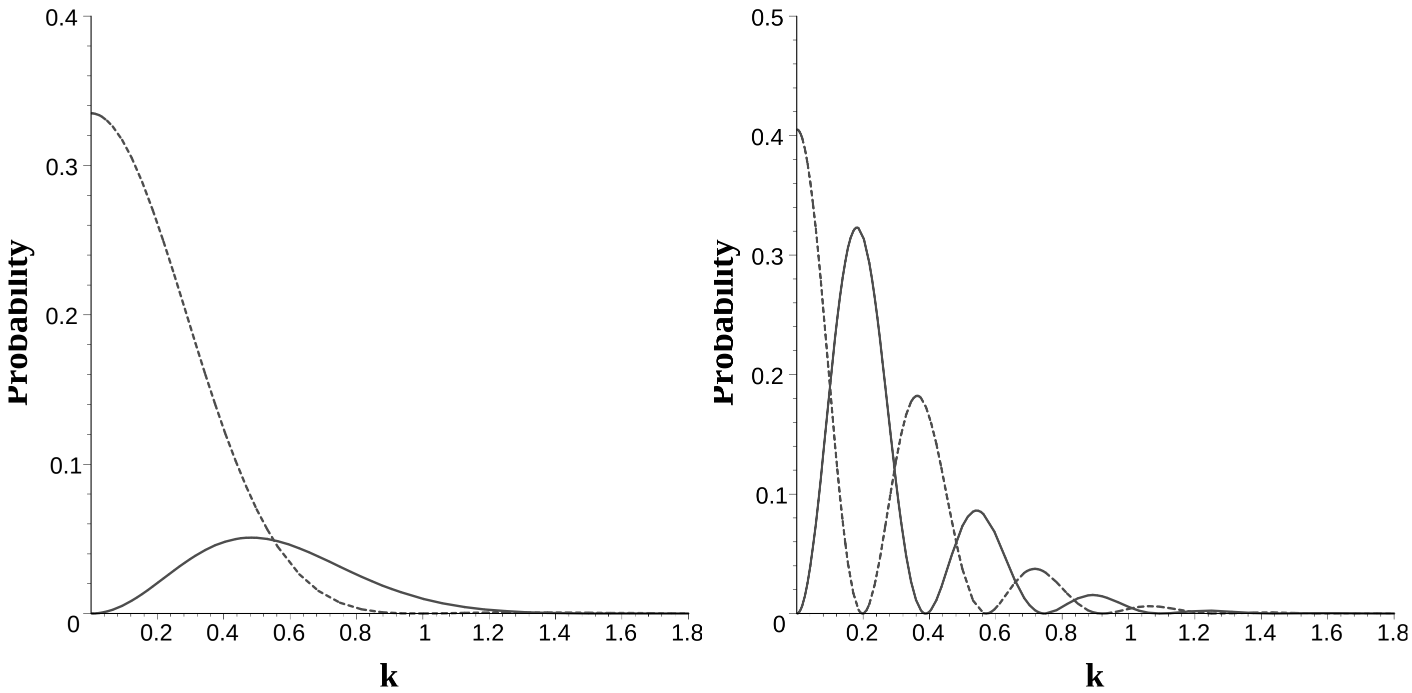
From the final result given in (2) and (3), it is obvious that the transition amplitude is nonvanishing only for $p \neq p'$ and from here we conclude that the law of conservation for the modulus of the momentum is lost for the process of pair production in Coulomb field in de Sitter space.

We also observe that there are nonvanishing probabilities for processes that does not conserve the helicity.

The probability of pair production:

$$\mathcal{P}_{e^-e^+} = \frac{1}{2}\sum_{\lambda\lambda'} |\mathcal{A}_{e^-e^+}|^2 \tag{4}$$

Our numerical and graphical analysis prove that the probability for pair production with opposite helicities $\lambda = -\lambda'$ (helicity conservation) is sensibly bigger than the probability for production of pair with equal helicities $\lambda = \lambda'$ (helicity non-conserving case) in the case $\omega > m$.



Probability as function of parameter k for different values of momenta ratios : $p/p' = 0.1$ left panel and $p/p' = 0.0001$ right panel. The point line represents the case of helicity conservation and the solid line the case when helicity is not conserved.