Dynamically Assisted Pair Production by Three Fields

D Sah[1,2]

[1] *Theory and Simulations Lab, Raja Ramanna Centre for Advanced Technology, Indore, INDORE, India*
[2] *Training School Complex, Anushakti Nagar, Homi Bhabha National Institute, Mumbai, India*
Contact Email: dsah129@gmail.com

After Dirac predicted the existence of the positron, Sauter solved the Dirac equation for an electron in the presence of a static electric field, demonstrating the possibility of vacuum electron-positron pair production [1]. Building on this, Heisenberg and Euler developed the one-loop effective Lagrangian for a static electromagnetic field [2]. Schwinger later utilized this framework to determine the pair production rate [3], a phenomenon now referred to as the Schwinger effect. This rate's dependence on field strength is non-analytic, highlighting the inherently non-perturbative nature of quantum field theory.

Despite extensive theoretical studies using approaches such as the proper time formalism [4-6], the WKB method [7], and quantum kinetic theory [8-13], experimental observation remains elusive due to the immense critical field strength of $E_{\mathrm{cr}} = 1.32 \times 10^{18}$ V/m. To reduce the electric field threshold required for experimentally detecting the Schwinger effect, several strategies have been proposed. Among these, the dynamically assisted Schwinger mechanism [14] stands out as the most promising. This approach predicts a significantly enhanced pair production rate, corresponding to a lower field threshold, in configurations where a slowly varying electric field is superimposed with a rapidly oscillating one.

Studies have explored the dynamically assisted Schwinger mechanism in various scenarios, such as a plane-wave x-ray probe beam combined with a strongly focused optical laser pulse, the superposition of two periodic electric fields with a finite time interval [15], and bifrequent fields[16-18]. The process has also been investigated in spatially inhomogeneous fields [19], with further details provided in [20-22].

Previous studies on the Schwinger mechanism typically involve two fields: a fast, weak field and a strong, slow/static field. However, recent work [23] explores assistance by three fields: a perturbative weak field, a high-energy photon, and a strong field, potentially lowering the field threshold even further.

In this study, we examine the interaction of three electric fields with distinct time scales, incorporating time delays, using the quantum kinetic equation (QKE) for numerical analysis. By analyzing the momentum spectra of created pairs, we can distinguish between boson and fermion pair creation in complex backgrounds. Specifically, we investigate the longitudinal momentum spectra of created particles for time delays T in the presence of these three electric fields. The study further investigates the number density of created pairs within this electric field configuration.

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