High-Mobility Graphene Transistors Shed New Light on an old Quantum Field Theory Controversy

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A seminal result in high-energy quantum electrodynamics is the instability of the vacuum under a strong electric field, leading to the spontaneous creation of particle-antiparticle pairs. This phenomenon, known as the Schwinger effect, is one of the few non-perturbative results in quantum field theory, initially derived by Sauter and later by Schwinger in 1951. [1] It predicts the decay rate w of the false vacuum in $d+1$ dimensions. While many, including Schwinger, equated the vacuum decay rate with the pair creation rate Γ, this equality has remained controversial. Starting with Nikishov in 1970 [2], several authors have demonstrated through direct calculations of Γ that the relation $w=\Gamma$ holds only at low fields. [3,4]

The Schwinger instability, requiring electric fields around 10^{18} V.m^{-1}, was long considered experimentally inaccessible. A breakthrough occurred in 2023 when it was demonstrated that a mesoscopic variant of the Schwinger effect in 1+1 dimensions spontaneously manifests in high-mobility graphene under large bias. [5]

In this presentation, I will elucidate how this experimental setup provides empirical evidence to address the Schwinger-Nikishov controversy, supporting Schwinger's initial interpretation in the context of graphene. I will also discuss the insights this approach offers into the theoretical discrepancy.

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References

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Figures

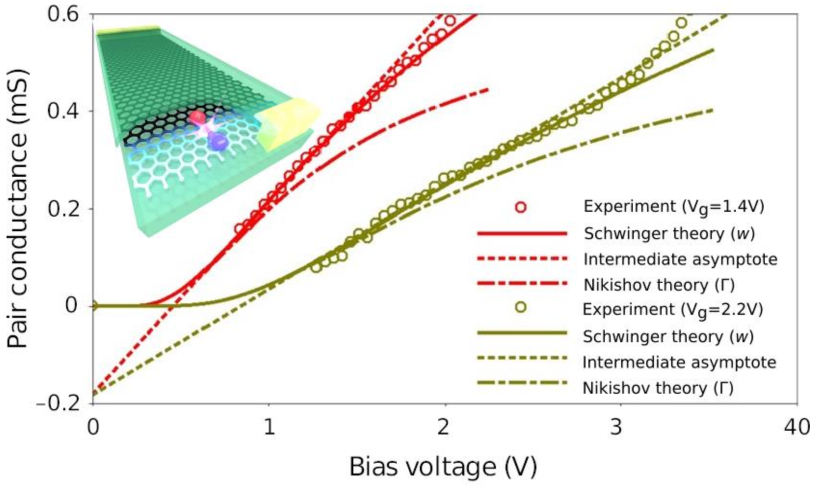

Figure 1: Comparison between the electron-hole pair creation conductance in the mesoscopic Schwinger effect in graphene according to Schwinger (full line), Nikishov (dashed-dotted line), and the experimental high-mobility graphene differential conductance (hollow circles). (Adapted from [5] - under license CC BY 4.0)