Sub-Sharvin Josephson effect in ballistic graphene

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We analyze numerically the tunneling of Cooper pairs through superconductor-graphene-superconductor (S-g-S) junctions [1] in which the longitudinal electrostatic potential profile is tuned (within gates electrodes) from a rectangular to a parabolic one [2]. In the unipolar regime (i.e., when the chemical potential is above the top of a barrier, $\mu > 0$), it is found that $I_c R_N$ gradually evolves from the graphene-specific to the ballistic value [3]. At the same time, the normal-state conductance increases from the sub-Sharvin value of $1/R_N \approx (\pi/4)\, G_{\text{Sharvin}}$ towards to the Sharvin value $G_{\text{Sharvin}} = g_0|\mu|W/(\pi\hbar v_F)$, with the conductance quantum $g_0 = 4e^2/h$, the junction width W, and the Fermi velocity in graphene v_F. In contrast, in the tripolar regime ($\mu < 0$), both normal-state conductance and the critical current are suppressed when smoothing the potential; however, $I_c R_N$ remains close to the graphene-specific range, ie., between $I_c R_N \approx 2.1$ and $I_c R_N \approx 2.4$ in units of e/Δ_0, where Δ_0 is the superconducting gap, even for a parabolic potential. The effects of a system geometry, inluding the Corbino setup, are also disscussed.

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References:

[1] M. Titov and C. W. J. Beenakker, Phys. Rev. B 74, 041401(R) (2006).
[2] A. Rycerz and P. Witkowski, Phys. Rev. B 104, 165413 (2021).
[3] A. Rycerz, in preparation.