Current transport properties and phase diagram of a Kitaev chain with long-range pairing

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We describe a method to probe the quantum phase transition between the short-range topological phase and the long-range topological phase in the superconducting Kitaev chain with long-range pairing, both exhibiting subgap modes localized at the edges. The method relies on the effects of the finite mass of the subgap edge modes in the long-range regime (which survives in the thermodynamic limit) on the single-particle scattering coefficients through the chain connected to two normal leads. Specifically, we show that, when the leads are biased at a voltage V with respect to the superconducting chain, the Fano factor is either zero (in the short-range correlated phase) or 2e (in the long-range correlated phase). As a result, we find that the Fano factor works as a directly measurable quantity to probe the quantum phase transition between the two phases. In addition, we note a remarkable "critical fractionalization effect" in the Fano factor, which is exactly equal to e along the quantum critical line. Finally, we note that a dual implementation of our proposed device makes it suitable as a generator of large-distance entangled two-particle states. Throughout our work, we evidence the strict connection between the emergence of a long-range topological phase and the onset of a remarkable nonzero crossed Andreev reflection at the Fermi level. On taking the complementary point of view in which one injects Cooper pairs into the circuit through the central superconducting region, this provides a potential source to generate nonlocal particle-hole highly entangled states, that is, thanks to the CAR our device can stabilize the emission of two correlated particles, one per each lead. For this reason, when working in the long-range regime, our model can be regarded as an efficient generator of pairs of strongly entangled particles, distant in real space. Finally, we consider possible practical realizations of our system with long-range correlations in cold-atom devices, as well as in solid-state platforms.

References

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