Supplementary Material for "Excitation of superconducting qubits from hot non-equilibrium quasiparticles"

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Here, we present experimental details along with a description of the phase qubits used.

TABLE S1: Experimental parameters. The injection voltage V_{inj} is provided assuming a junction superconducting gap $\Delta/e = 2$K as for aluminum. We also include parameters measured independently without quasiparticle injection: excited state probability P_e^0, qubit decay rate $\Gamma_\downarrow^0$, qubit frequency E_{ge}/h, and qubit critical current I_c. Symbols are as used in Figs. 4-5.

Data	V_{inj}	P_e^0	$1/\Gamma_\downarrow^0$	E_{ge}/h	I_c
(1) Triangles	0.57 mV,3.5Δ/e	3-4%	880 ns	5.8 GHz	1.0 μA
(1) Circles	0.57 mV,3.5Δ/e	1-9%	880 ns	5.5 GHz	1.0 μA
(2) Open	0.41 mV,2.6Δ/e	4.0%	380 ns	6.1 GHz	1.7 μA
(2) Closed	0.59 mV,3.7Δ/e	4.7%	380 ns	6.1 GHz	1.7 μA

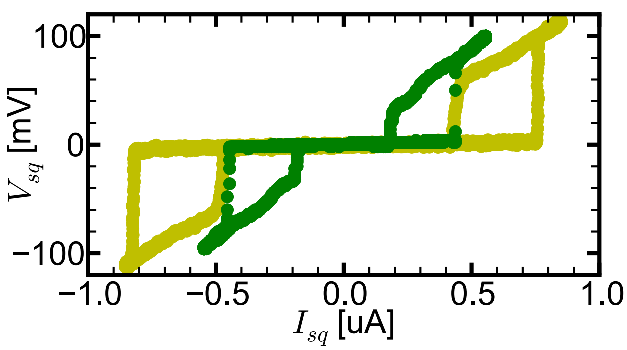

FIG. S1: (Color online) SQUID voltage V_{sq} vs current I_{sq}. The SQUIDs are shunted by a 30 Ω resistor, as shown in Fig. 3(a). The qubits are labeled as in Table S1 and Figs. 4-5.

Both qubits tested were fabricated using a multi-layer process with optical lithography. The qubit and SQUID junctions are Al/AlO_x/Al on a sapphire substrate, while the parallel-plate capacitor shunting the qubit had a hydrogenated amorphous silicon dielectric with a capacitance of 1 pF.

In Fig. S1 and Table S1, we present the qubit and SQUID parameters for qubits 1 (Ref. [1]) and 2 (Ref. [2]). The SQUID current vs. voltage for both devices is shown in Fig. S1, whereas the qubit junction critical current and qubit frequency are in Table S1. Further, we include in Table S1 the qubit decay rate and excited state probabilities without quasiparticle injection to which the data with quasiparticle injection is compared; the range in excited state probabilities for Qubit (1) indicates different no-injection values correspond to different data points.

In Figs. 4-5, we only present data where the second excited state is not appreciably populated. To do this, we use the measurement fidelities for the ground and first and second excited states as measured without quasiparticle injection to correct the probabilities of being in these states with quasiparticle injection [3]. We then compare the resulting quasiparticle-induced excited state probability with the raw increase in the excited state probability due to quasiparticle injection and exclude data where these are significantly different.

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[2] Y. Yin *et al.*, arXiv:1208.2950.
[3] R. C. Bialczak *et al.*, Nature Phys., **6**, 409 (2010).