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Fighting qubit loss in topological QEC codes: theory and experiment

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The loss of qubits poses one of the fundamental obstacles towards large-scale and fault-tolerant quantum information processors. In this work, we design and characterize a complete toolbox for a full cycle of qubit loss detection and correction on a minimal instance of a topological surface code. This includes a quantum non-demolition measurement of a qubit loss event that conditionally triggers a restoration procedure, mapping the logical qubit onto a new encoding on the remaining qubits. The demonstrated methods, implemented here in a trapped-ion quantum processor, are applicable to other quantum computing architectures and codes, including leading 2D and 3D topological quantum error correcting codes. These tools complement previously demonstrated techniques to correct computational errors, and in combination constitute essential building blocks for complete and scalable quantum error correction.

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