Enabling Measurements of Qubit Errors at NEXUS

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Motivation

As qubit technology progresses, one intriguing application involves their use as low noise single photon detectors. By measuring how the readout frequency of a resonator coupled to the qubit shifts in the presence of a photon, faint signals can be distinguished from mK-scale thermal noise. With this sensitivity, phenomena such as axion conversion to photons may be detectable.

Though they have long been viewed a promising dark matter candidate, some DM-plausible axion mass values have thus far been difficult to probe via conventional photon counting techniques due to weak signal strength relative to noise.

Objective

Recent scholarship suggests that ionizing radiation may cause major issues in qubits, namely decoherence and ‘catastrophic’ correlated errors across time and space. Compromised coherence constrains all qubit applications, while such multi-qubit errors break current error-correction algorithms. We are using NEXUS—Northwestern EXperimental Underground Site at Fermilab—to measure the impact of a low-radiation environment on qubit experiments. If a material difference in coherence time and/or error rate is detected, future qubit applications may need to be designed with such conclusions in mind.

Qubit Spectroscopy

To investigate these errors, we prepare and monitor quantum states. By transmitting tailored signals across the feedline shared by our 4 qubit-resonator pairs, we can identify errors, track their correlations, and monitor their impact on coherence time. The figure below is taken from a collaborator’s paper [1] and depicts a set of pulses they employed; we soon will repeat the procedure using precisely the same chip. This controlled study should ensure that any differences in error rate and associated deleterious effects will represent evidence to quantify the impact of radiation shielding on qubit operations.

This panel [1] depicts a pulse sequence we will perform in which a qubit plays the role of ‘listener’ for charge bursts indicative of energy deposition by ionizing radiation. It is prepared in the [\|\rangle state and induced to transition to the [\|\rangle state via a tuned pulse-idle-pulse sequence. The rate of time evolution about the Bloch sphere between the first and second pulse depends on the offset charge on the qubit, which remains roughly constant under ordinary operation. When a burst occurs, however, the pulse sequence will result in aliased [\|\rangle occupancy rates due to the new charge level. Above ground (with the same qubits) a strong correlation was observed between large charge jumps in nearby qubits, and the rate of bursts was noted. If that correlation persists yet error events are less frequent, it is likely that ionizing radiation is noticeably harming qubit function. Additionally, measurements of coherence time during bursts will be conducted with the same equipment.

Acknowledgements

This manuscript has been authored by Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. Department of Energy, Office of Science, Office of High Energy Physics.

References