Research Topic:

Mitigating effect of Ionizing Radiations on Transmon Qubits by Phonon Traps

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UNIVERSITÀ DEGLI STUDI DI PADOVA

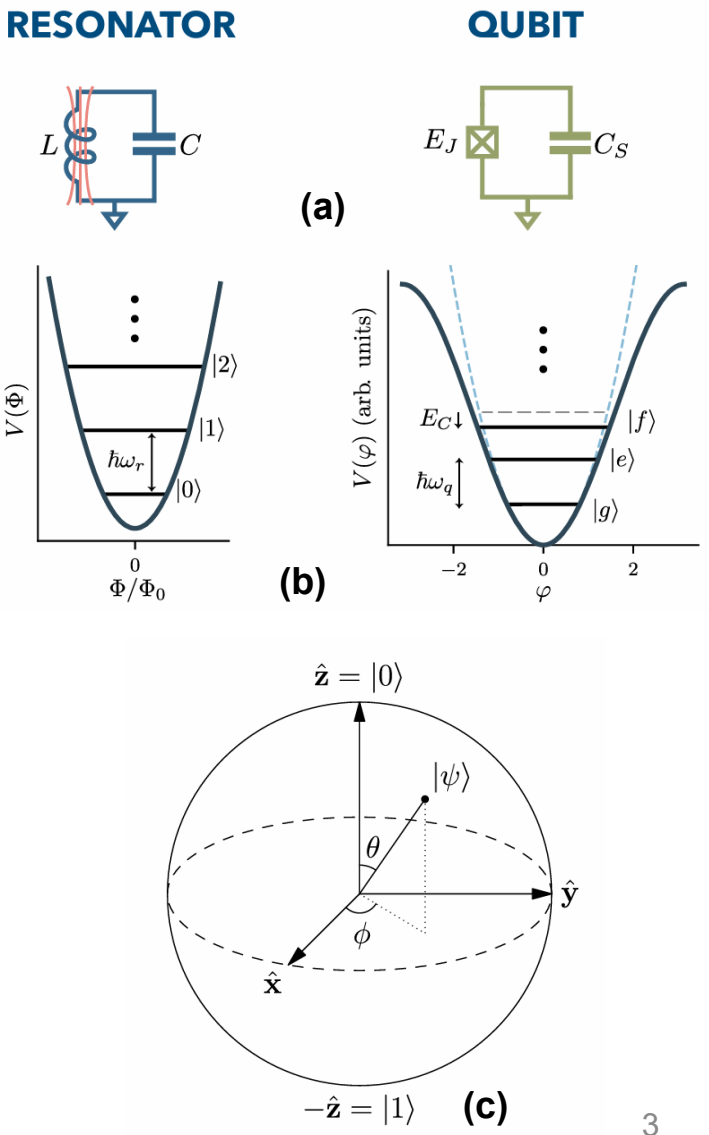
Contents

Introduction

- Superconducting circuit with a **Josephson Junction**;
- The Josephson Junction acts as a **non-linear inductor** that produces an **anharmonic energy spectrum**;
- The anharmonic energy spectrum allows us to populate only the first **two energy levels**, operating the circuit as an effective qubit.
- Quantum counterpart of classical bit;
- Possibility to have superposition states:

$$|\psi\rangle=\alpha|0\rangle+\beta|1\rangle$$

$$|\psi\rangle=\cos(\tfrac{\theta}{2})|0\rangle+e^{i\phi}\sin(\tfrac{\theta}{2})|1\rangle$$



Blais et al., Rev. Mod. Phys ***93***, *025005 (2021)*

Introduction

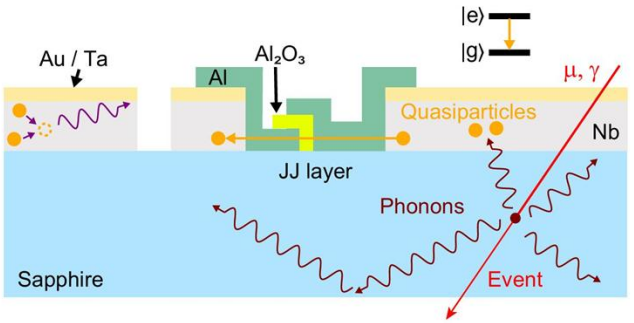
Qubit Decoherence and Effect of Radioactivity

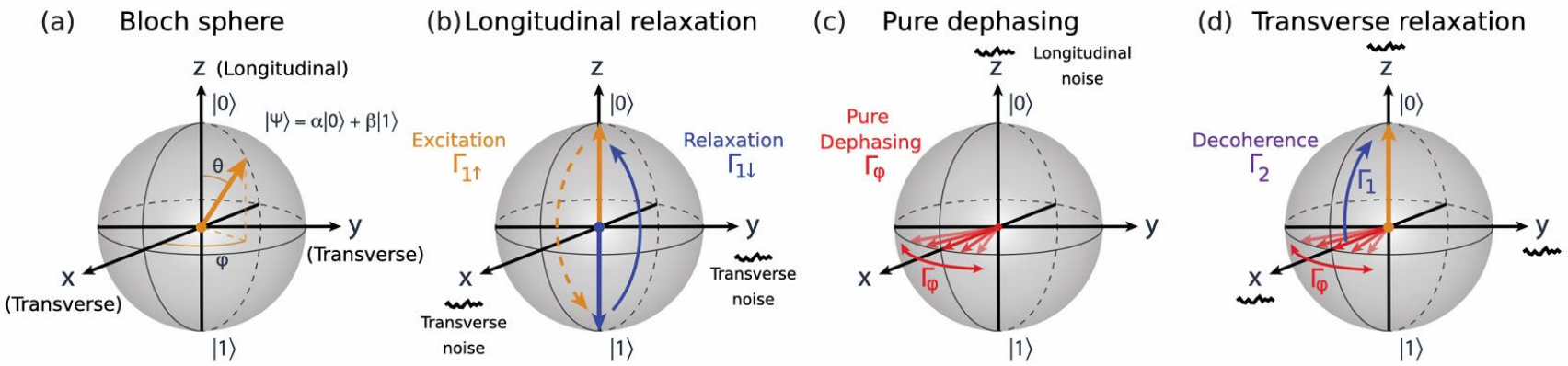
Interactions with the environment make the qubit state change unpredictably;

When they occur, the information stored by the qubit is lost;

This phenomenon is called **state decoherence;**

Ionizing radiation was also found to affect the **stability of qubits** by producing **high-energy phonons** in the chip substrate.

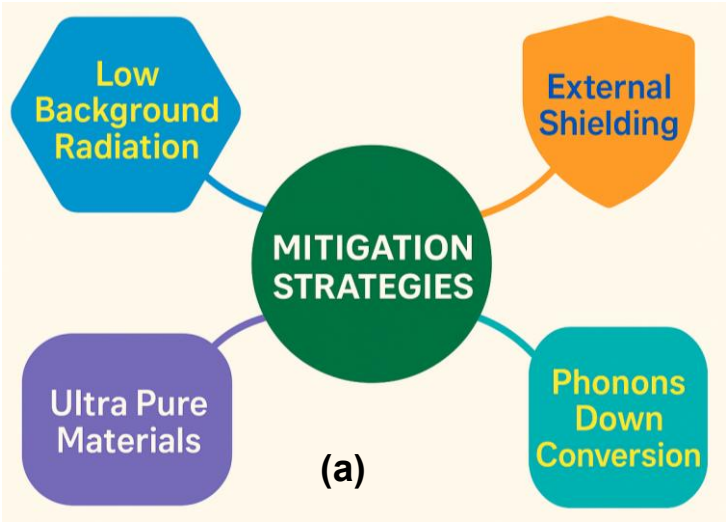




Krantz et al., Appl. Phys. Rev. ***6****, 021318 (2019)*

Introduction

Mitigation Strategies and Phonon Traps



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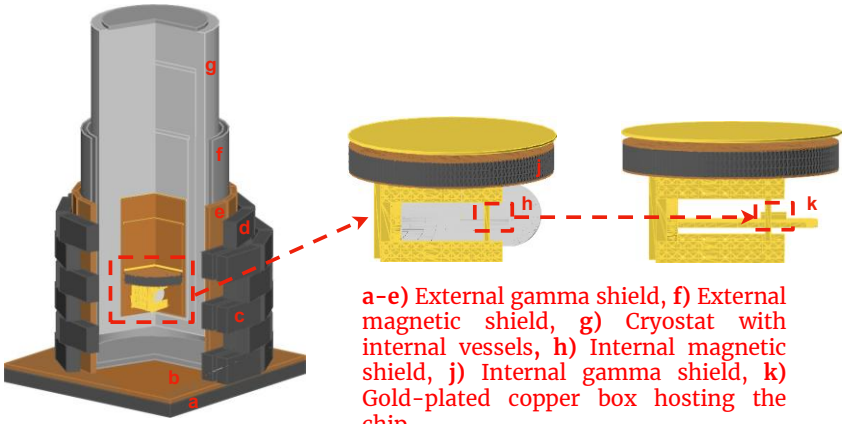
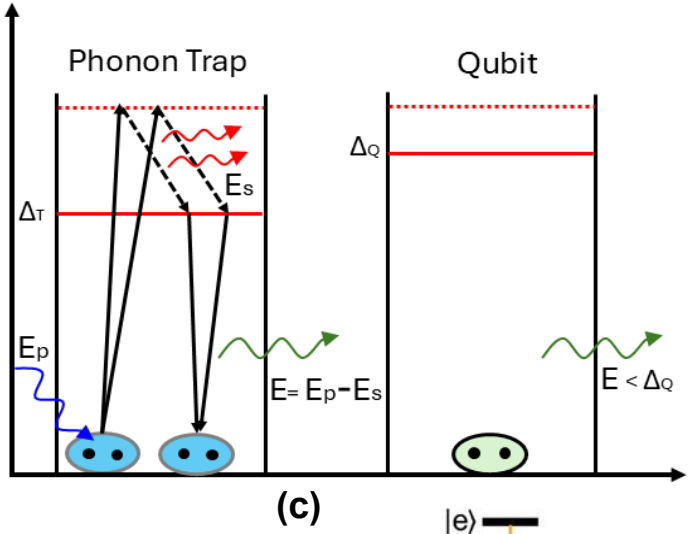


(b)

a-e) External gamma shield, **f)** External magnetic shield, **g)** Cryostat with internal vessels, **h)** Internal magnetic shield, **j)** Internal gamma shield, **k)** Gold-plated copper box hosting the chip.



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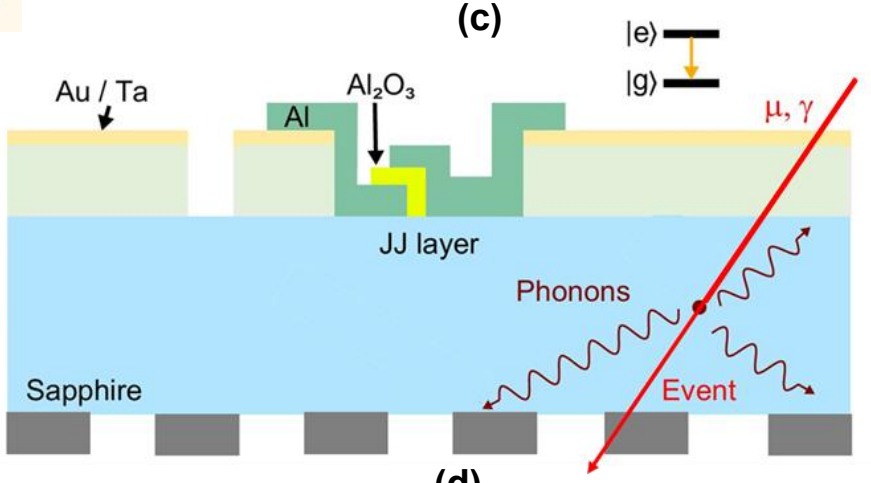


(d)

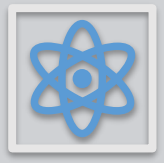
De Dominicis et al., arxiv.org/abs/2405.18355v3 (2024)

Laia et al, Nature Communications 13, no. 1 (2022) : 6425.

Research Objectives

Studying the effect of **ionizing radiations** on **multiple qubits** simultaneously.

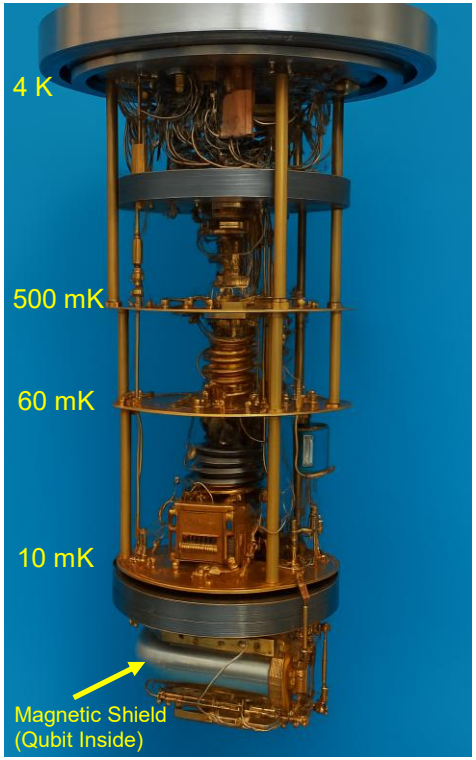
Fabrication of phonon traps on a qubit chip and its **characterization.**



Analyzing the effect of the **ionizing radiations** on **qubits** on the chip with the fabricated **phonon traps**.

Conducted Research Activities

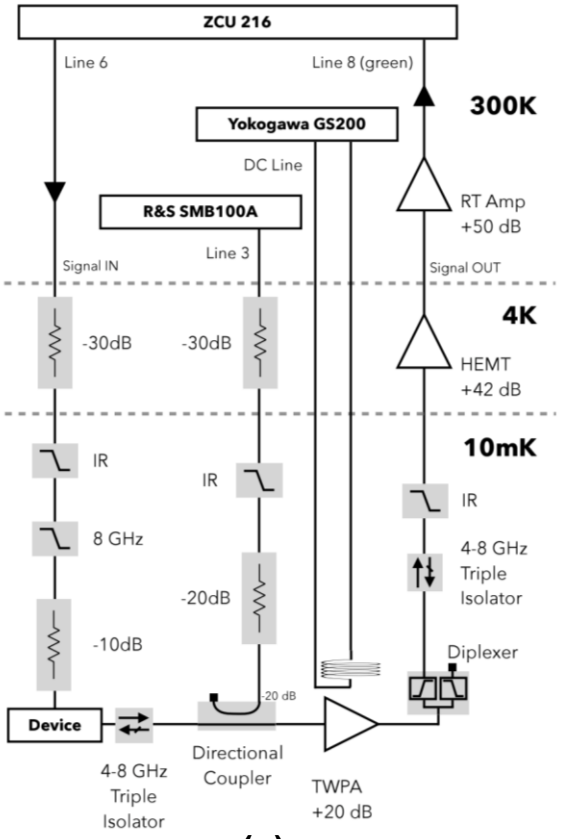
Effect of Radioactive Radiations on a Single and Multiple Qubits on a Chip



(a)

Lead and Copper Shield

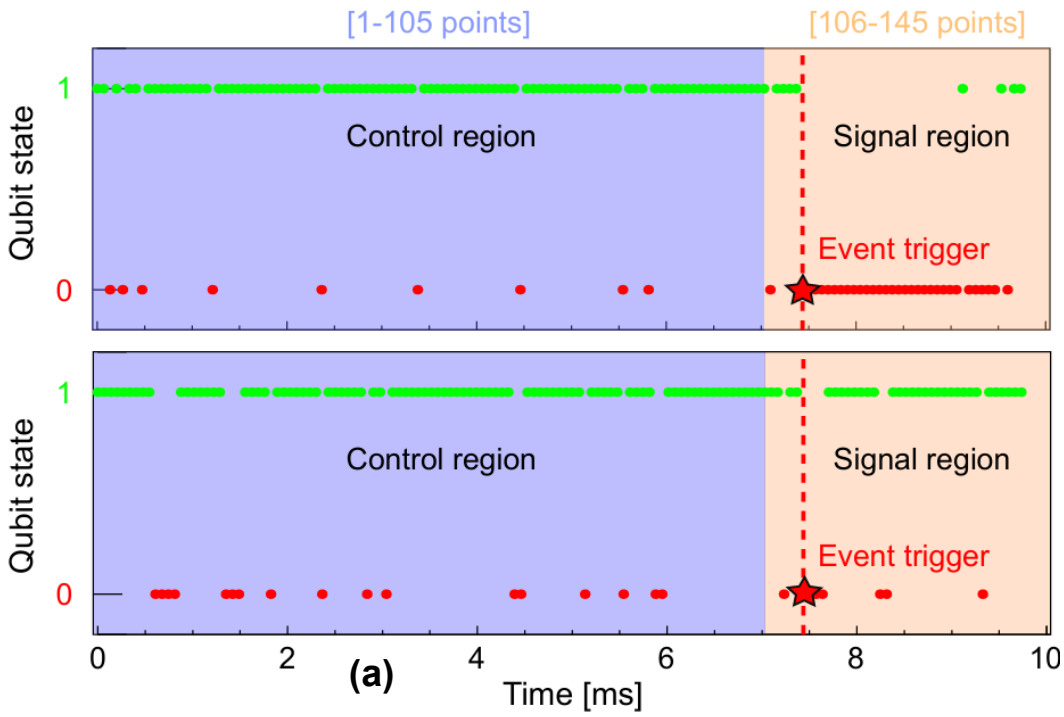
(b)

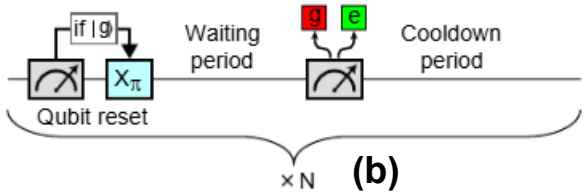


(c)

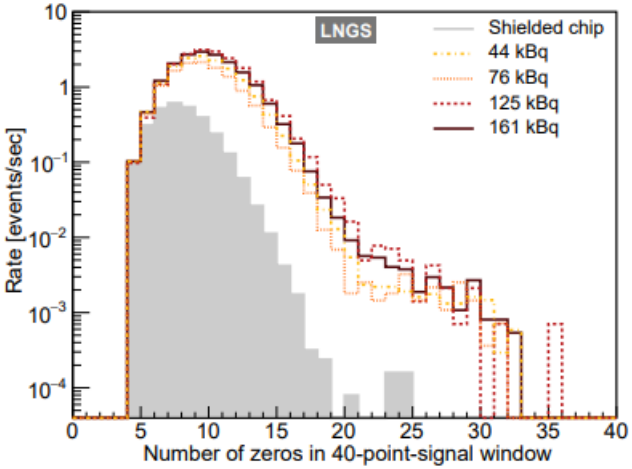
Conducted Research Activities

Single Qubit Data Analysis





Measurement Strategy



Limits on maximum number of zeros in control regions due to qubit relaxation have been computed by CDF and minimum number of zeros limit for signal have been computed by binomial probability (<1e-04).

De Dominicis et al., arxiv.org/abs/2405.18355v3 (2024)

Conducted Research Activities

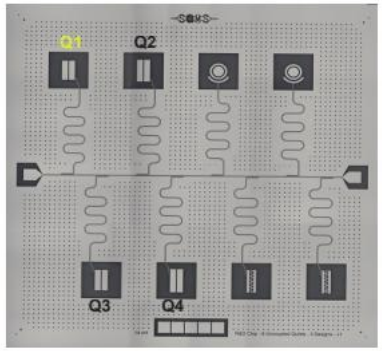
Exploring effect of Ionizing Radiations with Four Qubits

To investigate effect of radioactivity on multiple qubits simultaneously, we selected four qubits on a same chip for the experiment.

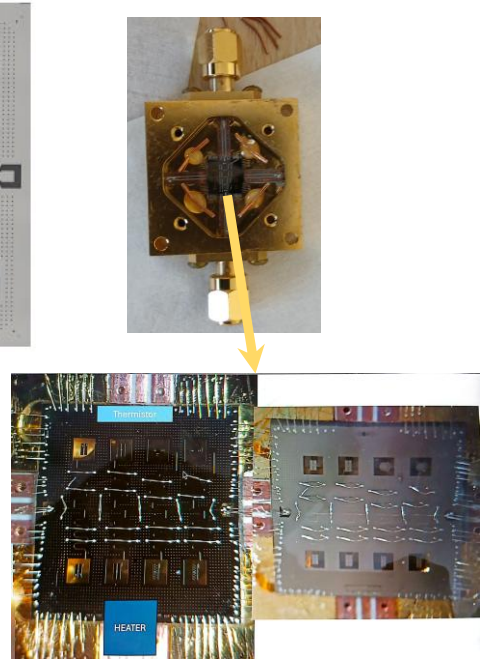
The qubits were operated in underground and shielded environment.

To infer effect of the radioactivity, an external Th-232 source of 161 KBq was used.

We observed a significant effect of radioactivity on all three operated qubits.



(a)



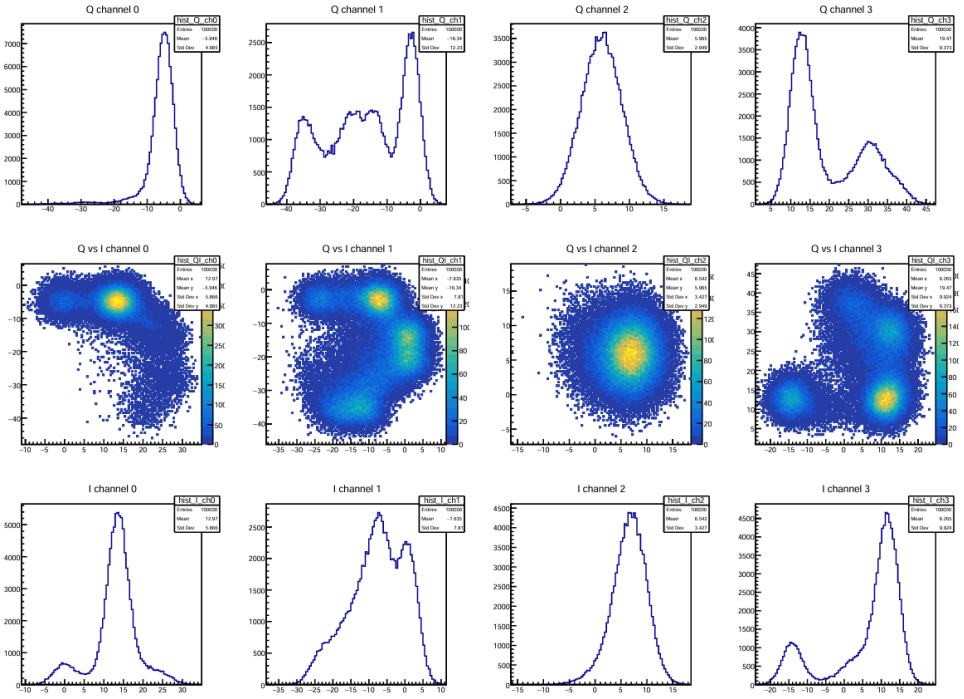
(b)

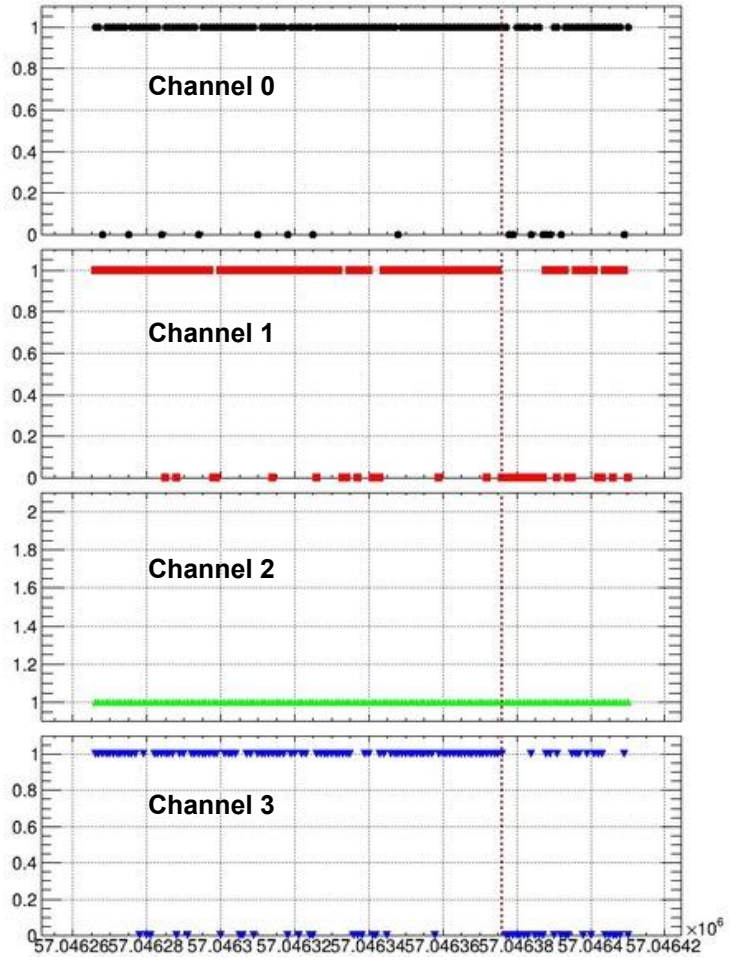
De Dominicis et al., arxiv.org/abs/2405.18355v3 (2024)

Conducted Research Activities

Exploring effect of Ionizing Radiations with Four Qubits

$$S = I + iQ$$





At **161 kBq,** the probability of the qubits being in the ground state increased for all four qubits compared to when they were exposed only to background radiation. This indicates that the radioactivity simultaneously affected all four qubits on the same chip.

Prospects

Quantitative analysis of effect of **radioactive radiations,** on multiple qubits simultaneously on a chip.

Materials selection for **phonon traps**.

Fabrication of **phonon traps** on a super conducting qubit chip.

Quantitative analysis of effect of **radioactive radiations on the qubits** on a chip with developed **phonon traps**.

Courses and Schools

Courses:

No.	Course Title	Credit Hrs.	Status
i.	Cryogenics sensors for astroparticle physics	02	Studied
ii.	Vacuum Technologies	02	Studied
iii.	Laboratory of low-energy radiation measurement	05	Studied
iv.	Quantum technologies	02	Studied
v.	Cabling and shielding for low noise applications		In plan

School:

No.	School Title	Status
i.	Benasque spring school on super conducting qubits (May 21-May 30, 2025)	Attended

Questions?
Feedback!
Suggestions.