

DEMETRA

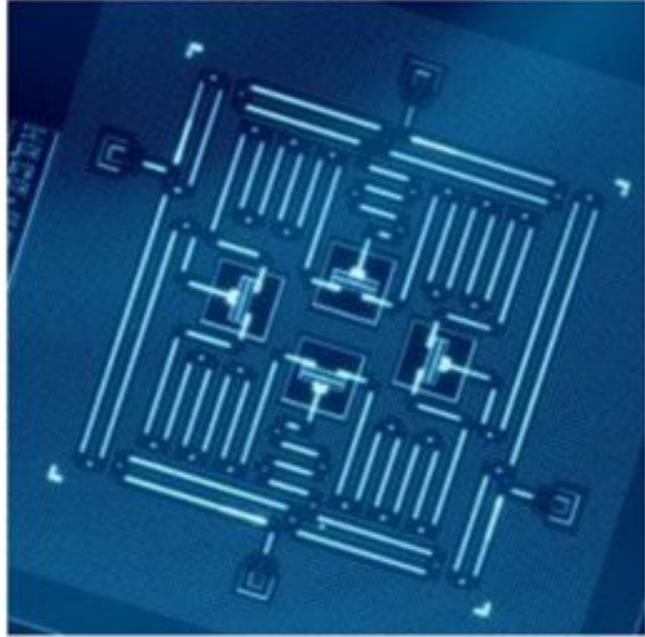
Mitigation of the Radioactivity Effects in Quantum Bits

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Istituto Nazionale di Fisica Nucleare - Roma
12/02/2020 LNGS, Italy



Istituto Nazionale di Fisica Nucleare

Goal of DEMETRA



Superconducting circuits

emerging as one of the leading techniques for qubits

(easy to design, fabricate, operate, and now also to scale)

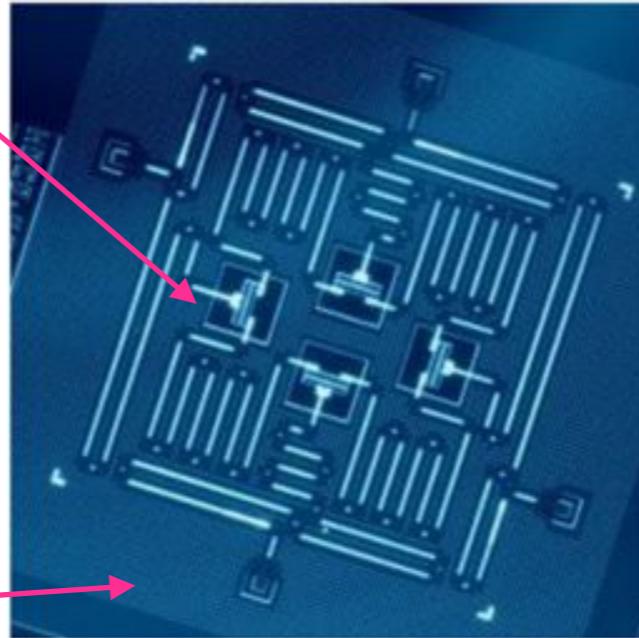
DEMETRA

[INFN starting grant 2017]

does **radioactivity** impact these devices?

Radioactivity in Qubits

Direct Interaction in Qubit

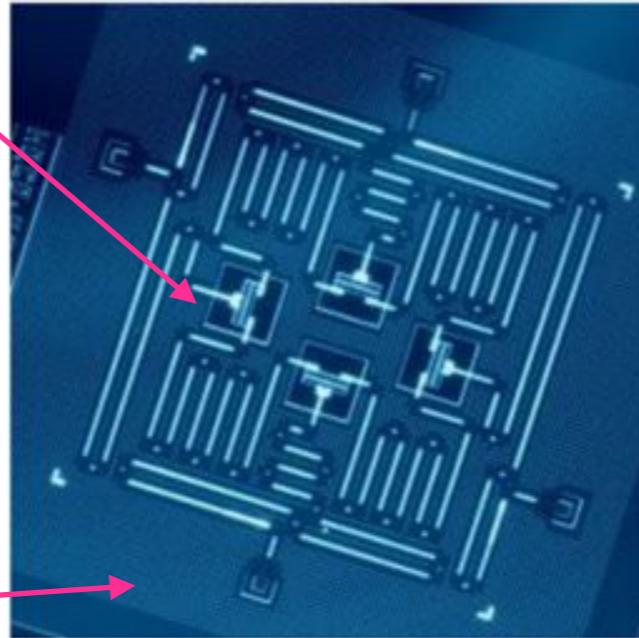


Interaction in the substrate

- Energy deposits in the substrate produce phonons
- Phonons travel until they are absorbed by the active material
- Observed in KIDs
- Now (24/01) observed in qubits

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We hypothesised two **effects**

Quantum Error Correction
arrays of qubits encoding a single logical qubit
Must be un-correlated!

Energy dissipation in qubit causes **decoherence**
Today hundreds of μs , should reach ms
Is radioactivity a limit?

DEMETRA group



Istituto Nazionale di Fisica Nucleare

Roma: **L. Cardani**, N. Casali, A. Cruciani, M. Vignati

MIB: M. Clemenza, L. Gironi



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S. Pirro, C. Rusconi



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T. Charpentier, L. Gruenhaupt, D. Gusenkova, F. Henriques,
M. Lagoin, **I. Pop**, F. Valenti, W. Wernsdorfer, A. Ustinov



I. Colantoni



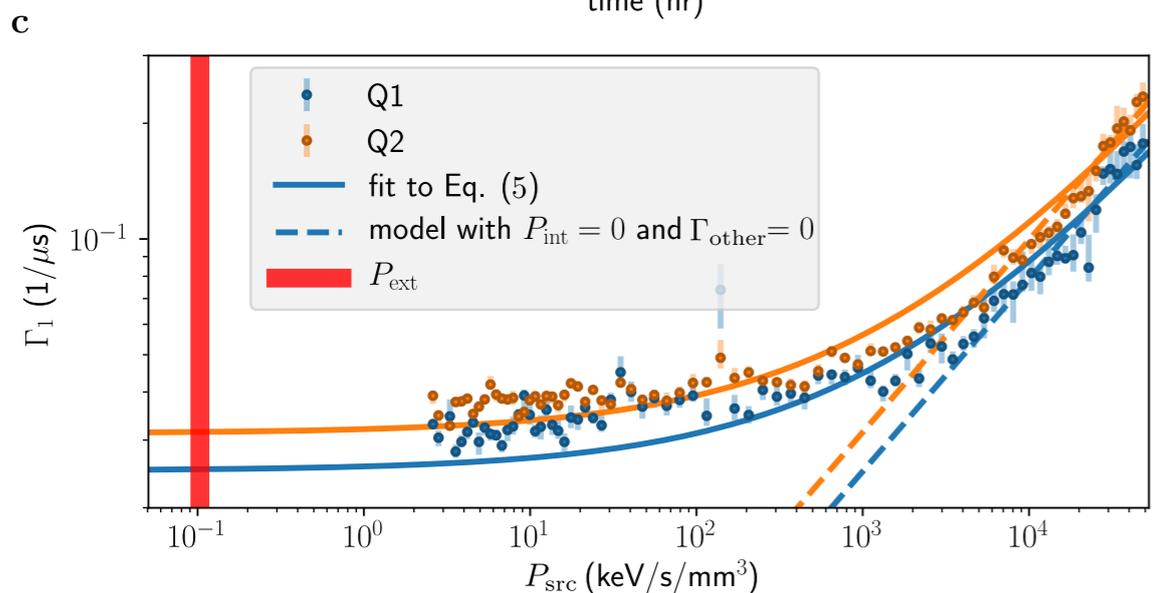
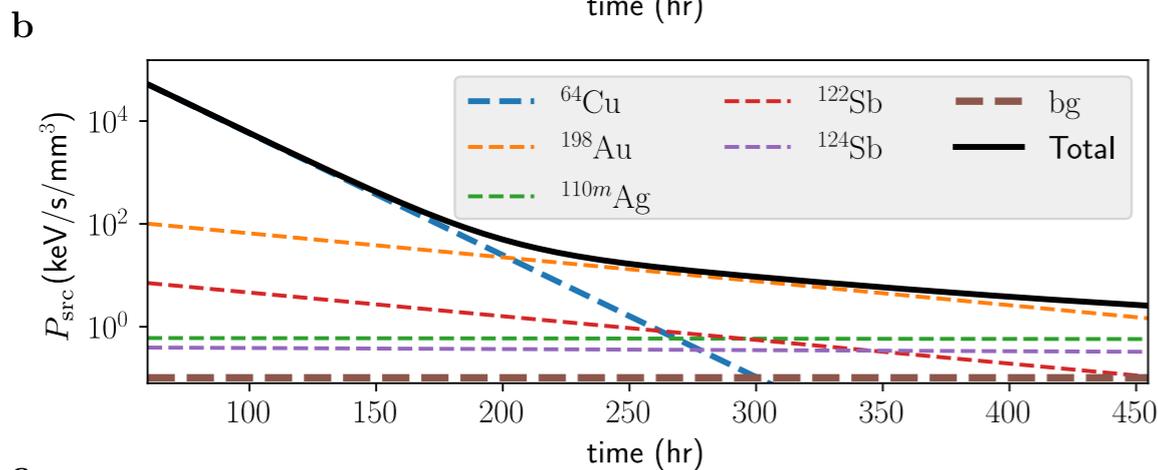
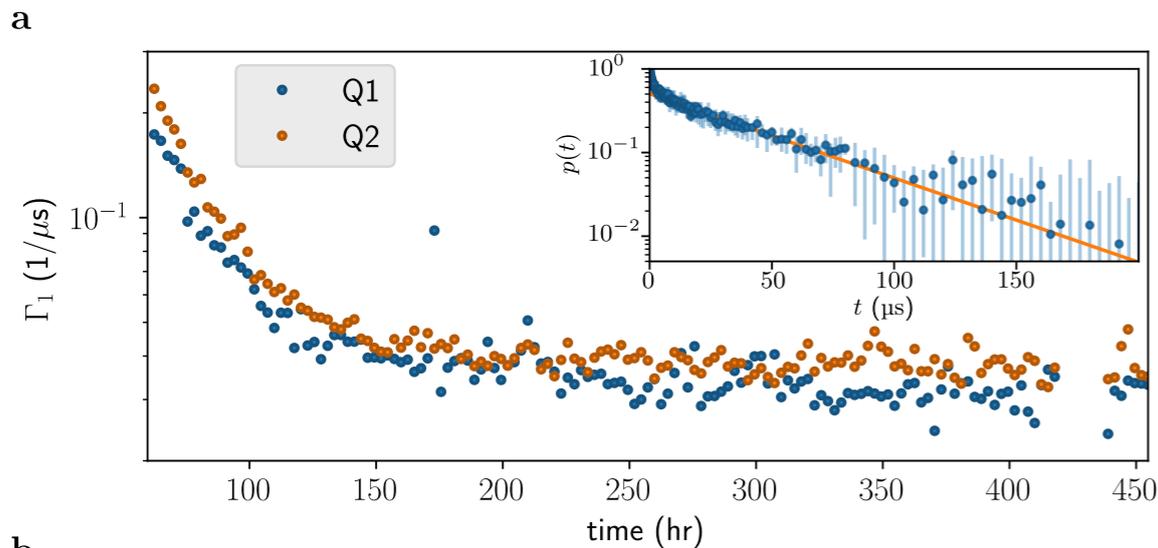
M. Martinez



G. Catelani

Measurements at MIT

Paper in Review
[2001.09190v1]



Faced a rapidly decaying **source** to a qubit: proved that it impacts its coherence time [confirmed our results]

Without source:

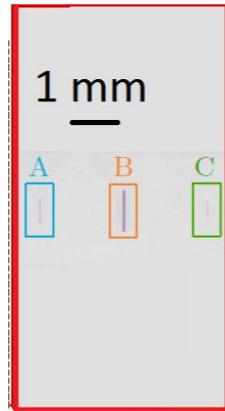
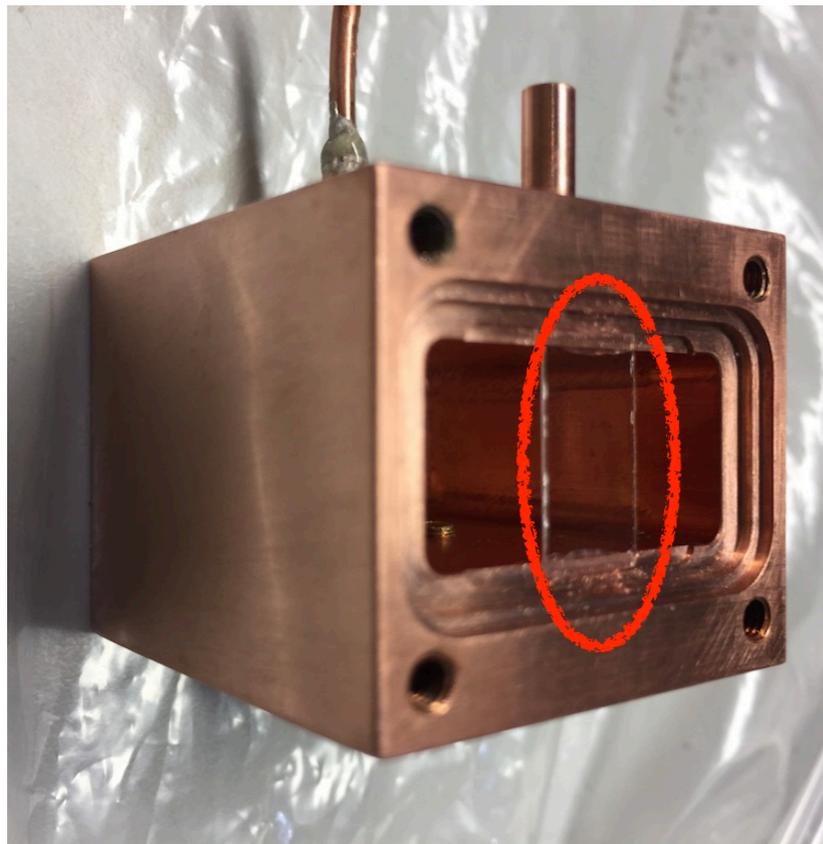
- Estimate 40% from cosmic rays, 60% from environmental radioactivity
- Total contribution to decoherence of **THEIR** sample $\sim 0.2\%$
- Shielding the qubit resulted in a statistically significant improvement (but $0.2\% \dots$)

Conclusion:

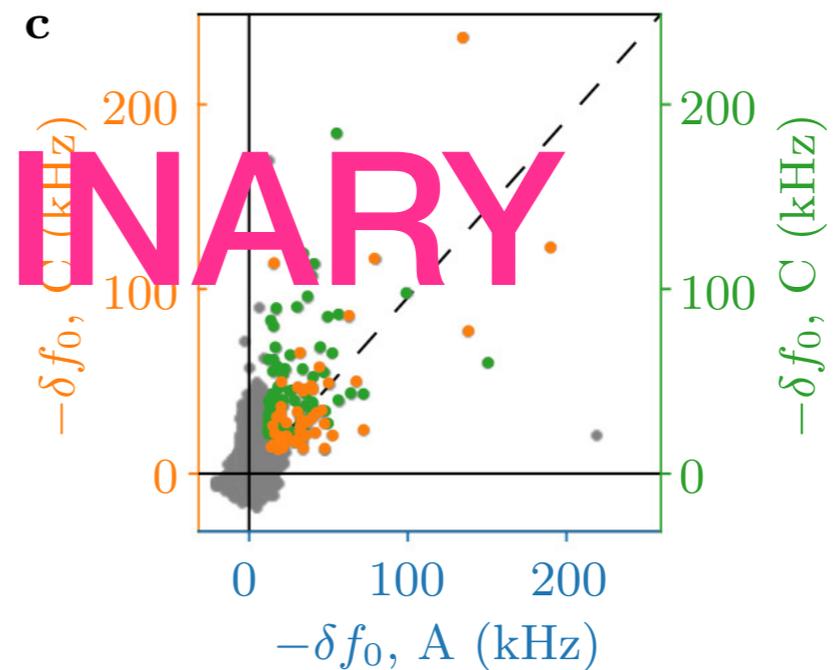
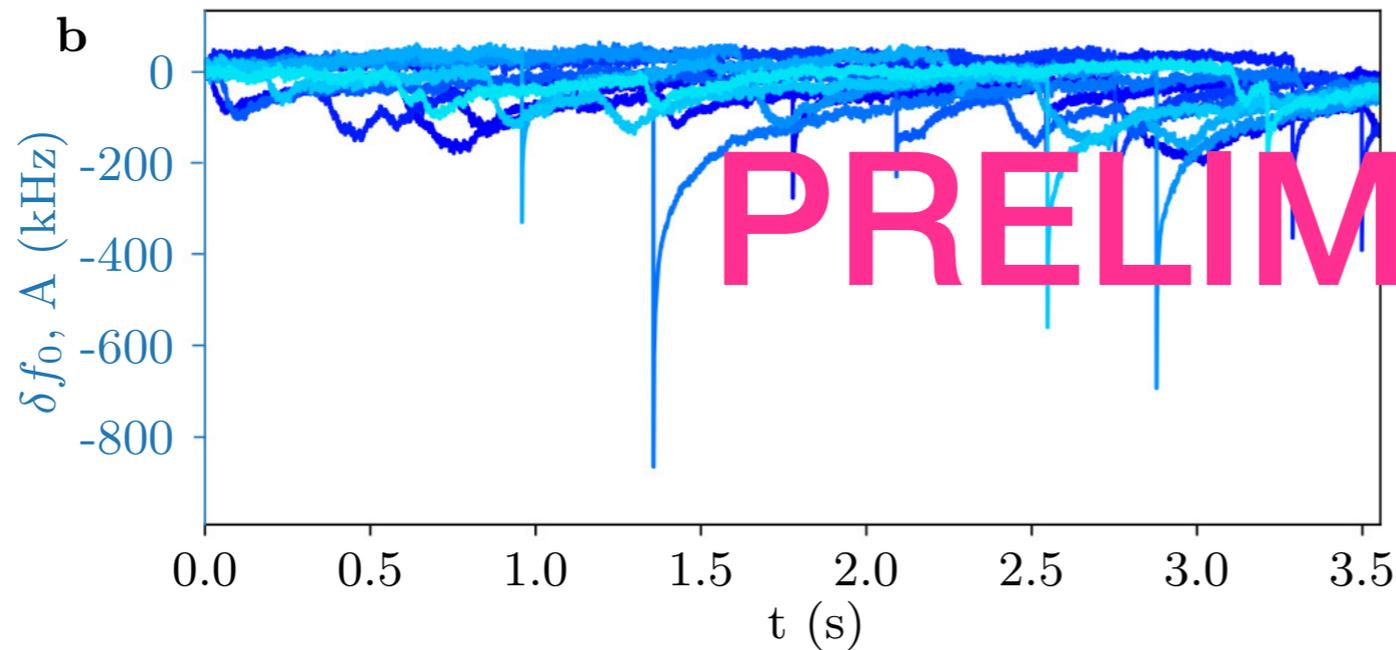
“Albeit a small effect for today’s qubit, reducing the impact of ionising radiation will be critical for realising fault-tolerant superconducting quantum computers”

Our First Results

Paper in Review
[confidential]



- 3 GrAl stripline resonators
- Sapphire substrate $\sim 1\text{ cm}^2 \times 300\mu\text{m}$
- Different refrigerators (including LNGS)

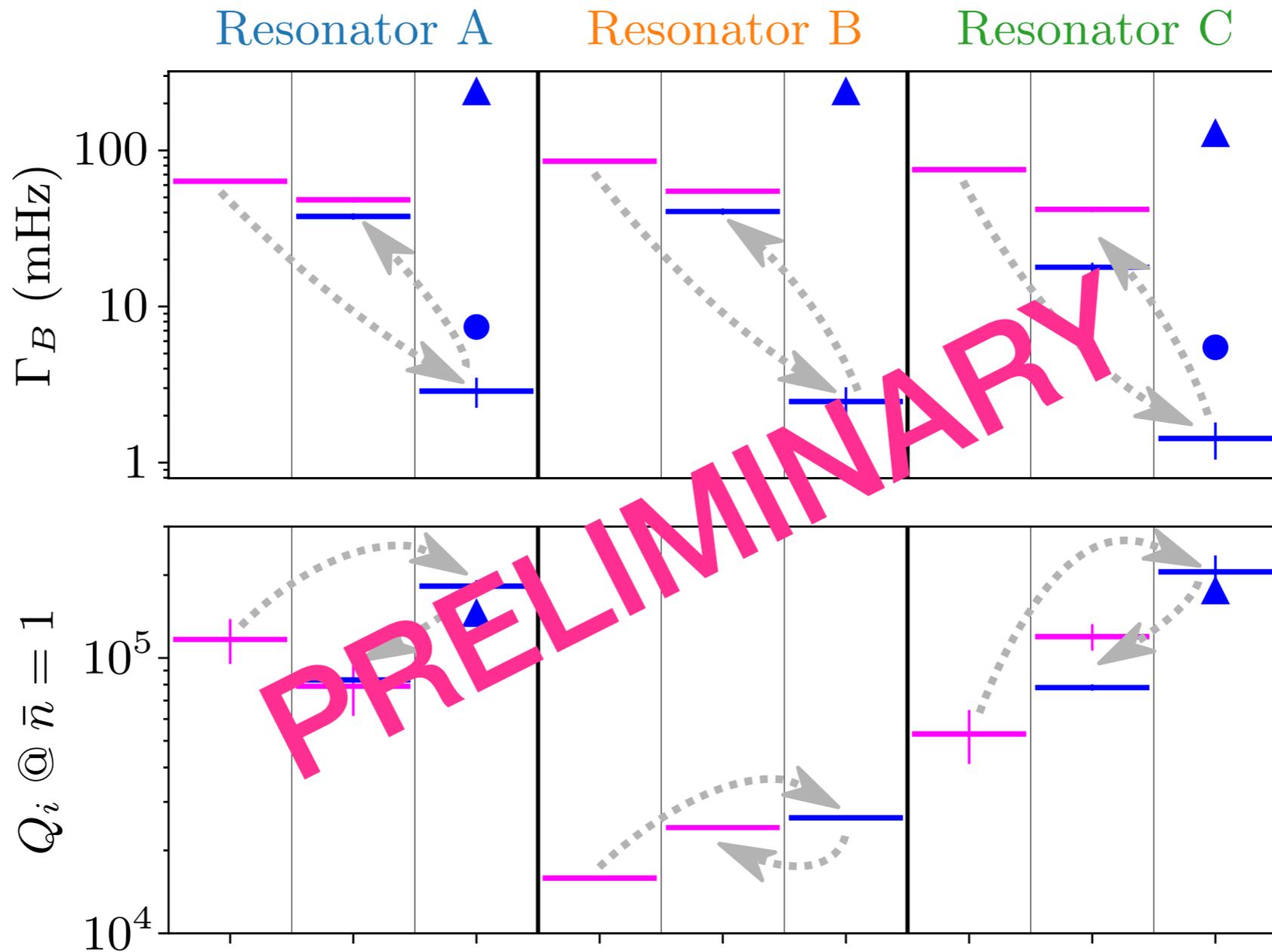


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Radioactivity in Qubits

Quantum Error Correction

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- **MIT: qubits sensitive to radioactivity**
- **DEMETRA: correlated interactions matter!**
- **Future activities planned or being proposed - new field for everyone**

Radioactivity in Qubits

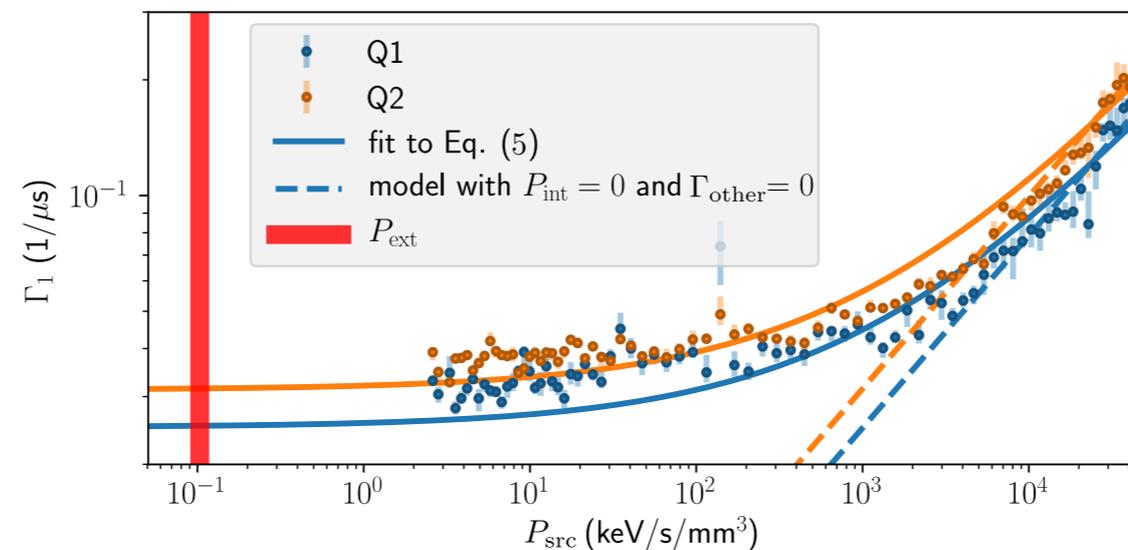
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- MIT: next-generation qubits will be limited by radioactivity
- DEMETRA - 1: we can handle radioactivity :)
- DEMETRA - 2: quality factors improve suppressing radioactivity
- Final impact of (or interest in) this discovery to be fully understood

What Next (DEMETRA)

- MIT qubit was limited mainly by two level system defect. KIT qubit is limited mainly by QPs
- Bringing KIT's qubit underground should prove an improvement by ~ 2 (MIT: 0.2%)
 - We are upgrading the HallC-leti cryostat for the operation of this transmon qubit
 - Measurements scheduled for June 2020



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- MIT qubit was limited mainly by two level system defect. KIT qubit is limited mainly by QPs
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 - We are upgrading the HallC-leti cryostat for the operation of this transmon qubit
 - Measurements scheduled for June 2020
- Quantum error correction: huge effort to establish the effects of radioactivity
 - We set up a simulation group in Roma (C. Tomei, F. Cappella, F. Collamati, G. D'Imperio) that will reconstruct energy deposits (GEANT package), and phonon transfer (GEANT package + tools to be validated).
 - G. Catelani (theorist from Jülich) will translate these results in decoherence

