



Quantum Sensors

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Superconducting Qubits

Quantum bits (qubits) are the quantum counterpart of the classical bit.

Many proposed technologies for their implementation

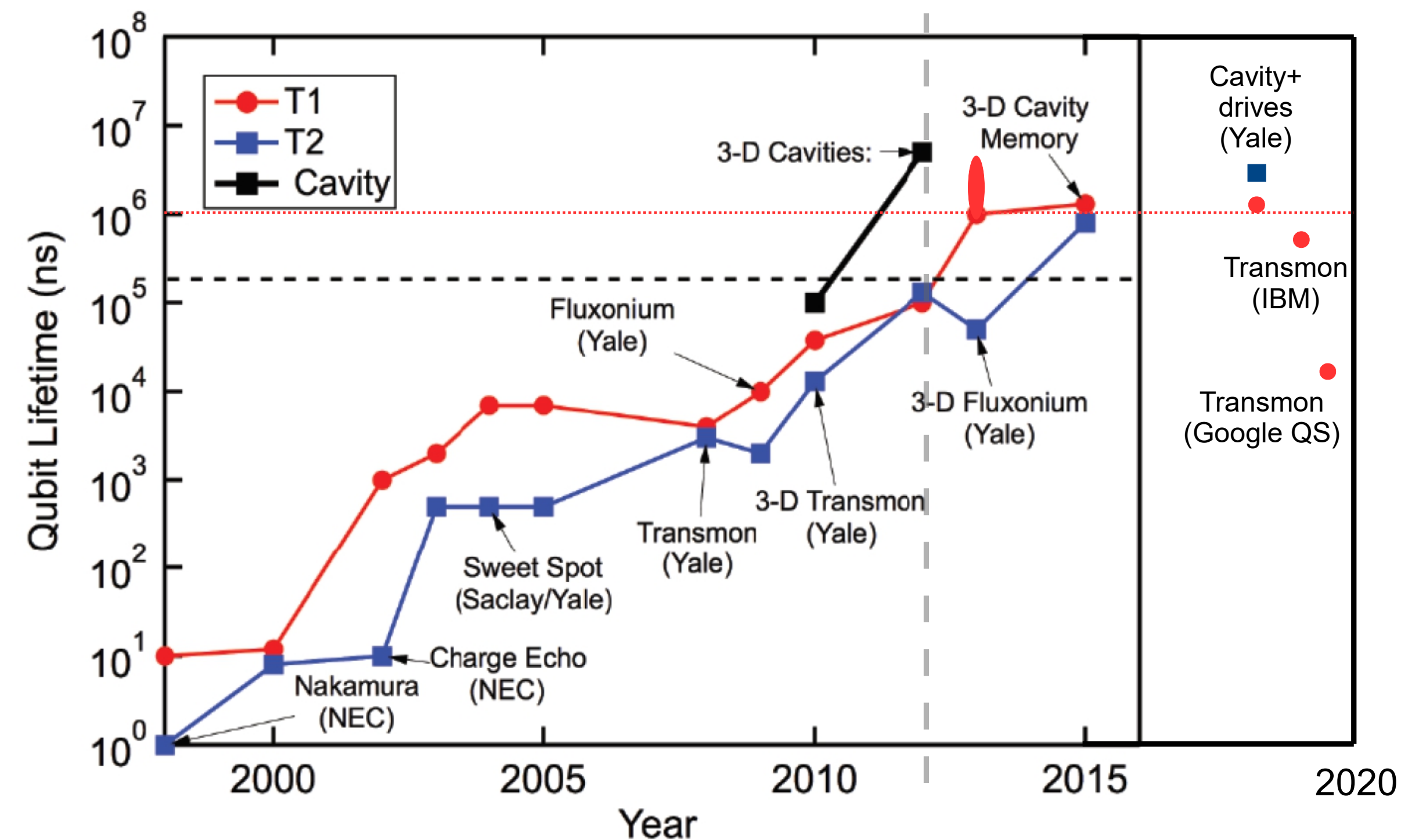
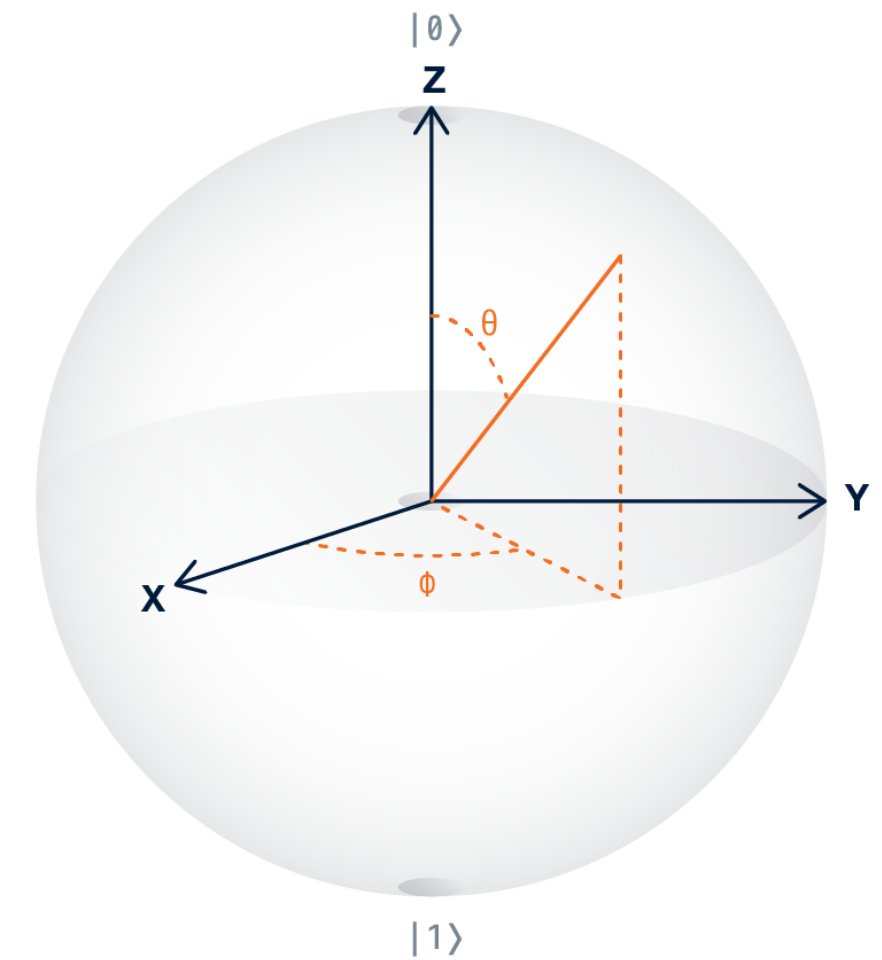
An ideal qubit must be:

1. Coupled to other qubits [entanglement]

n classical bits = string with n [0,1]

n entangled qubits = $2^n - 1$ complex nums

2. Decoupled from the world [quantum coherence]

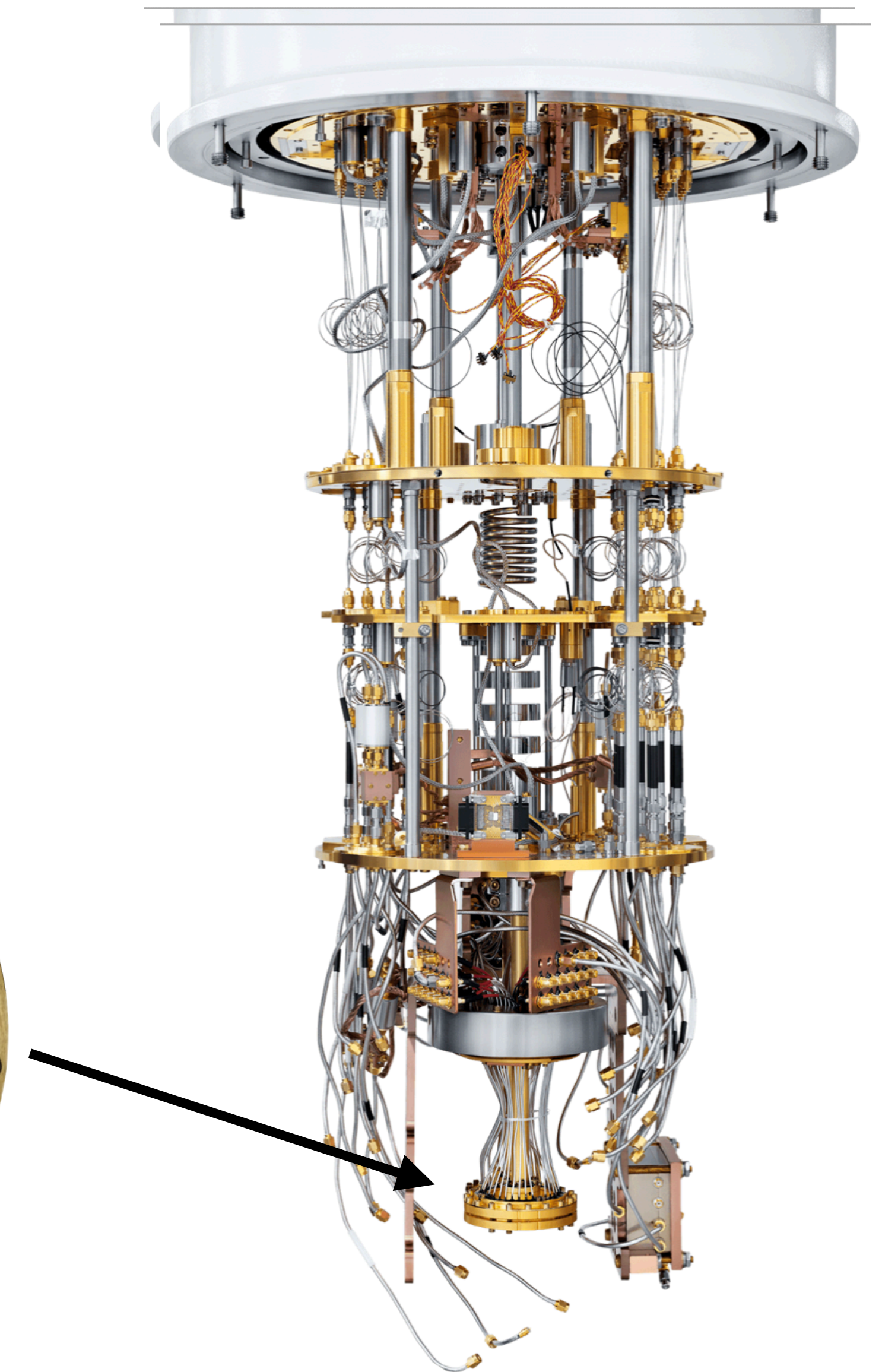
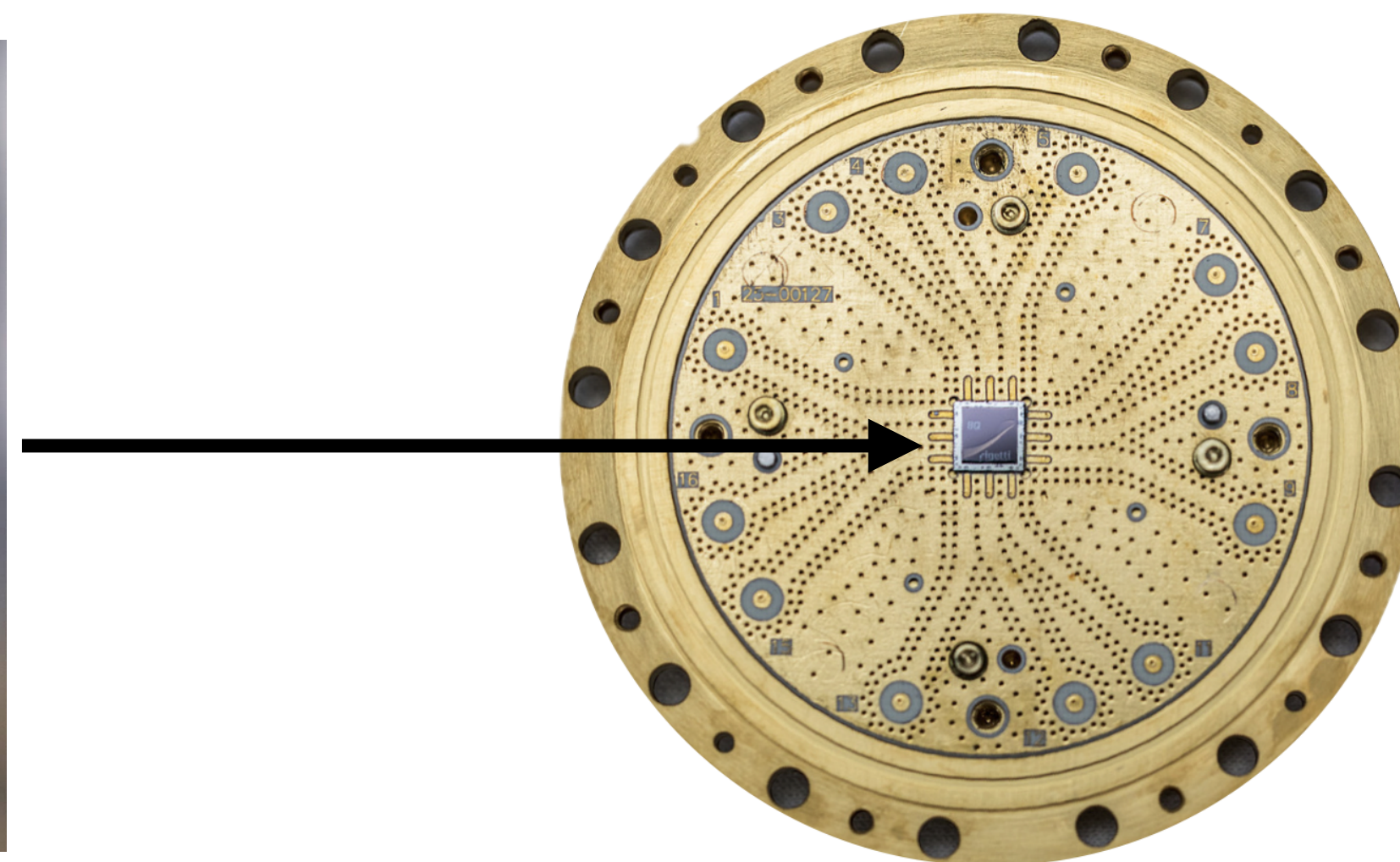
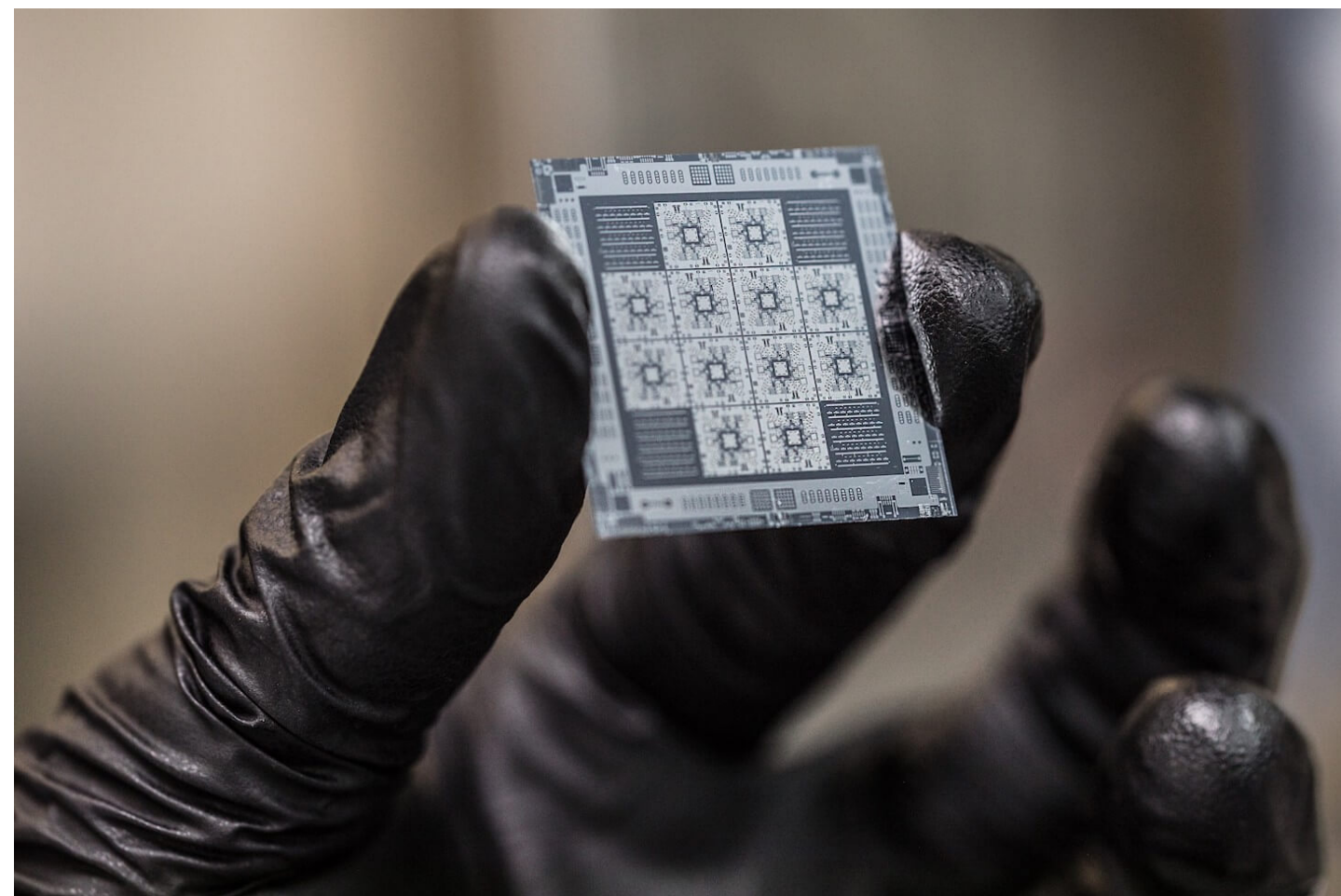


The Role of Particle Physics

Currently, superconducting qubits look a lot like particle detectors

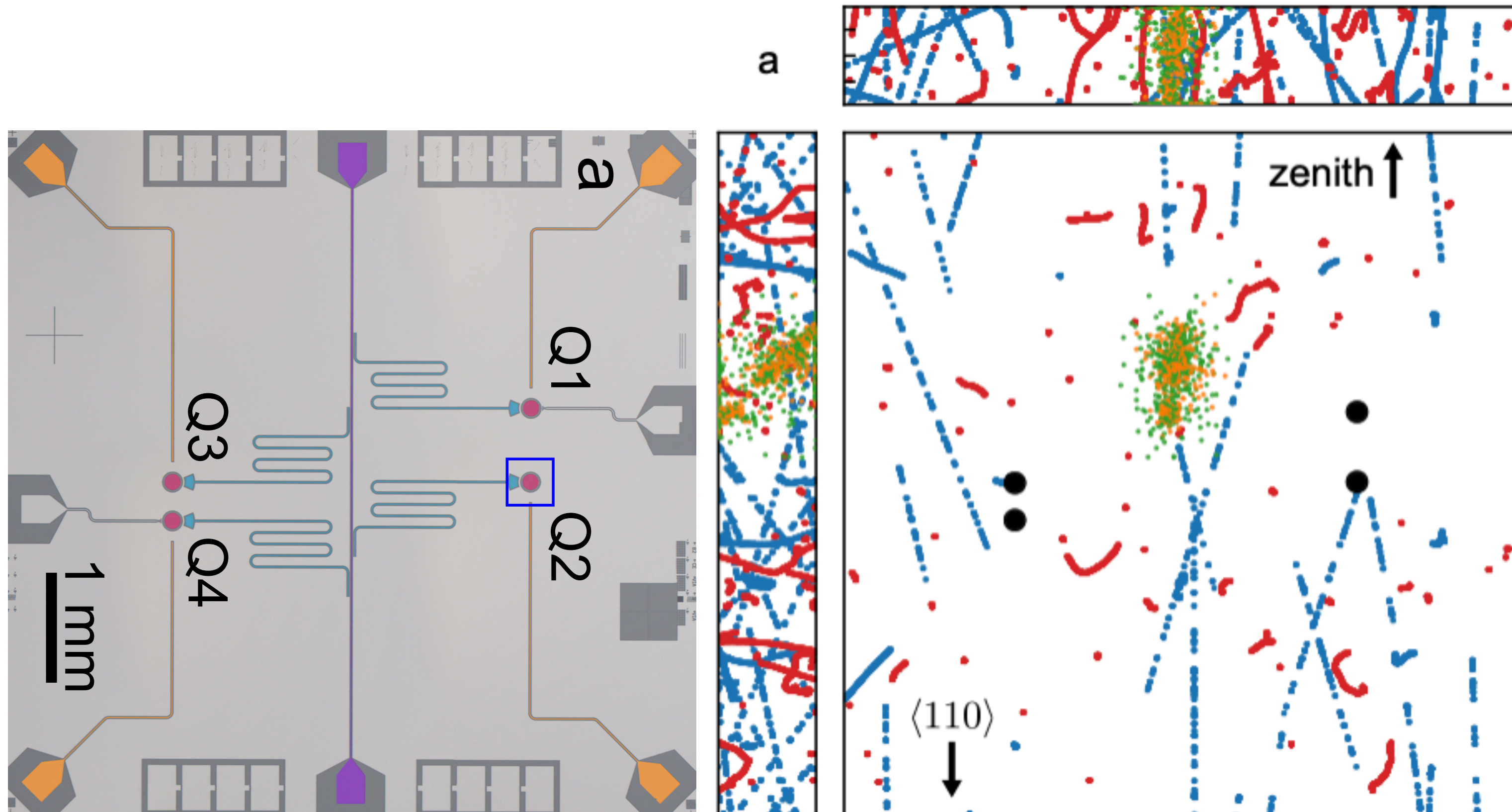
But if we use similar devices to detect particle ... how can we state that qubits are isolated from the external world?

Cosmic rays, particles, ... can interact with it!



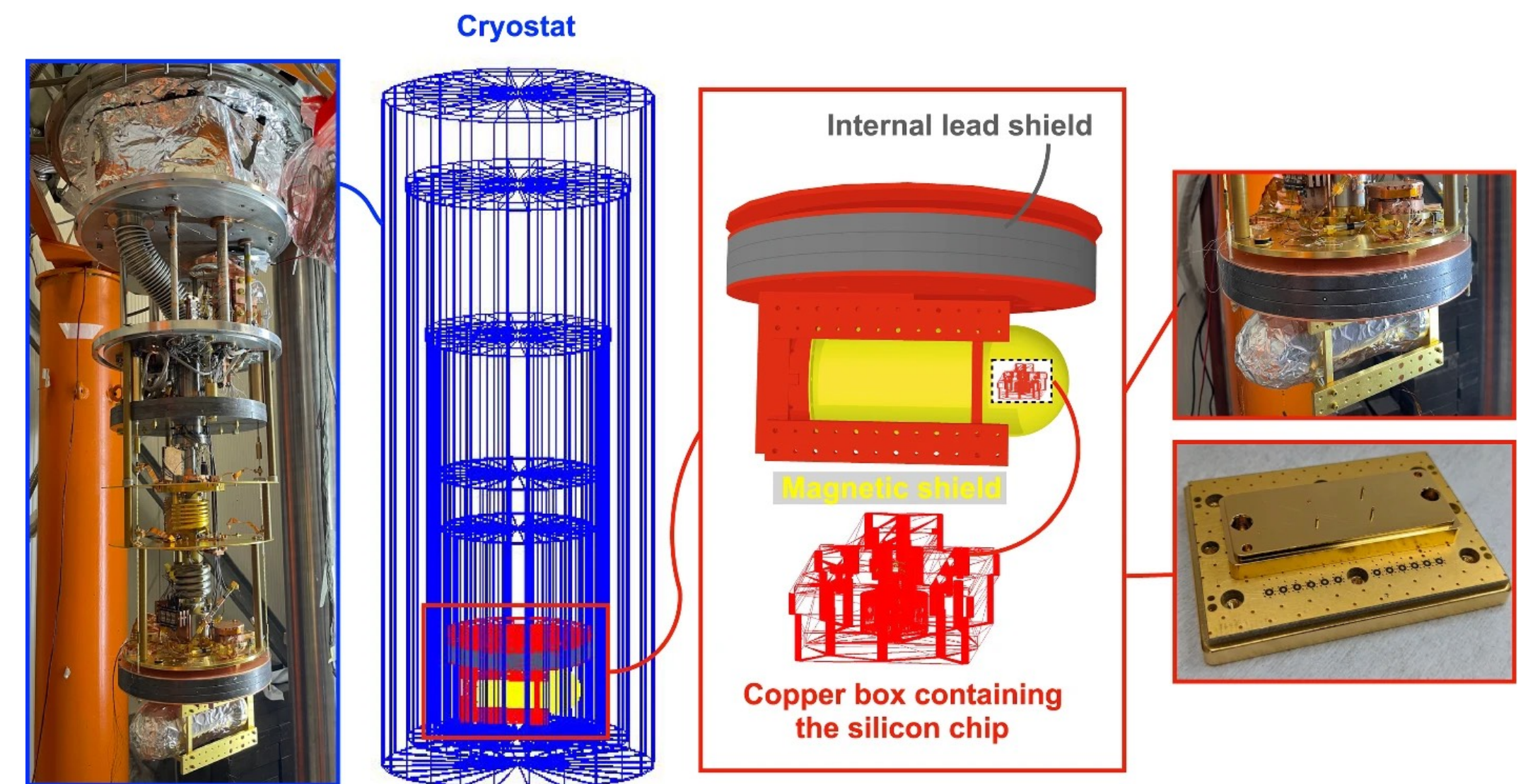
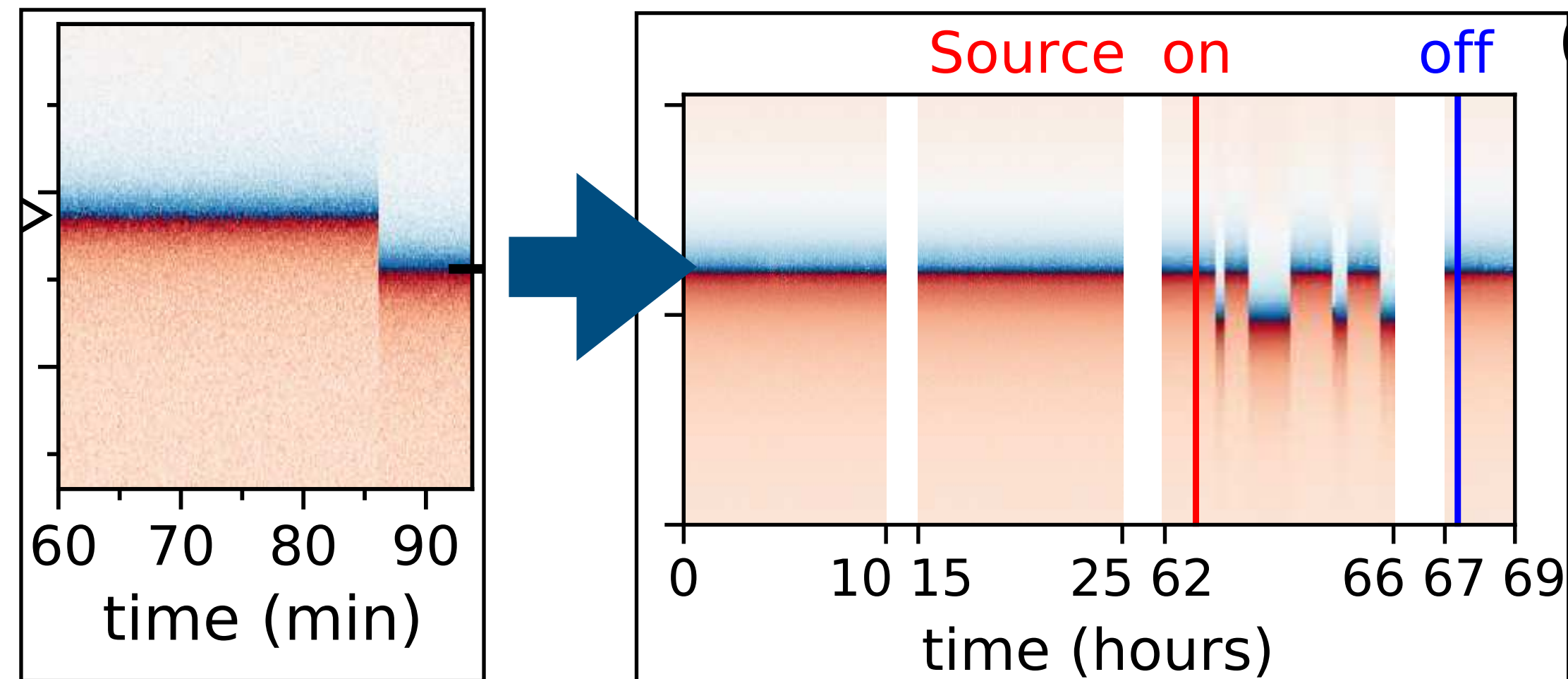
Where are we now (1)

- ☑ The rate of errors in a qubit is compatible with the rate of radioactive interactions
- ☑ The effect of radioactivity will be long (millisecond scale)



Where are we now (2)

- ☑ Diminishing the radioactivity improves the frequency stability of a qubit
- ☑ Understanding the different sources of radioactivity is crucial to suppress them



D. Gusenkova et al,
Appl. Phys. Lett 120 054001 (2022)

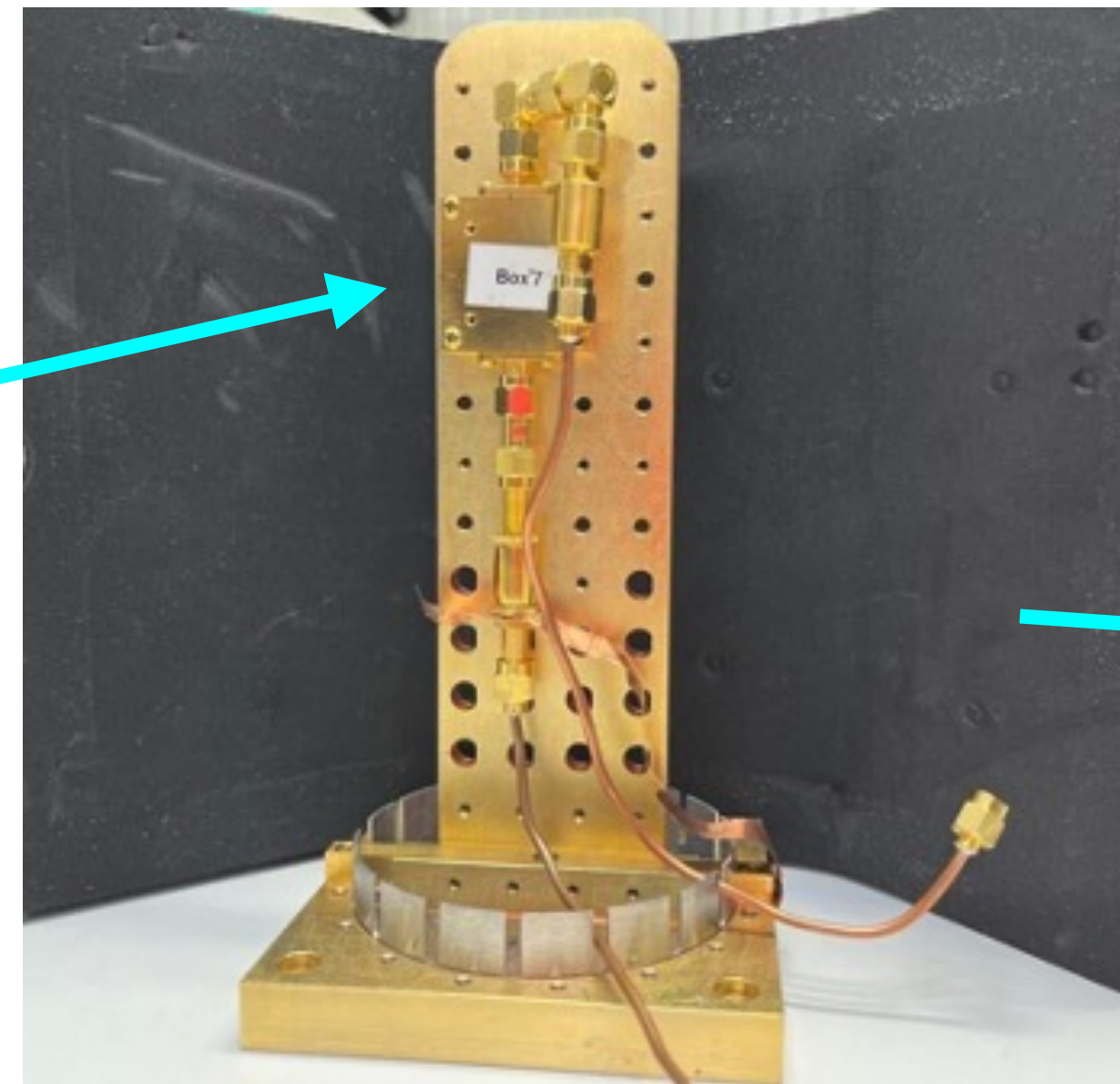
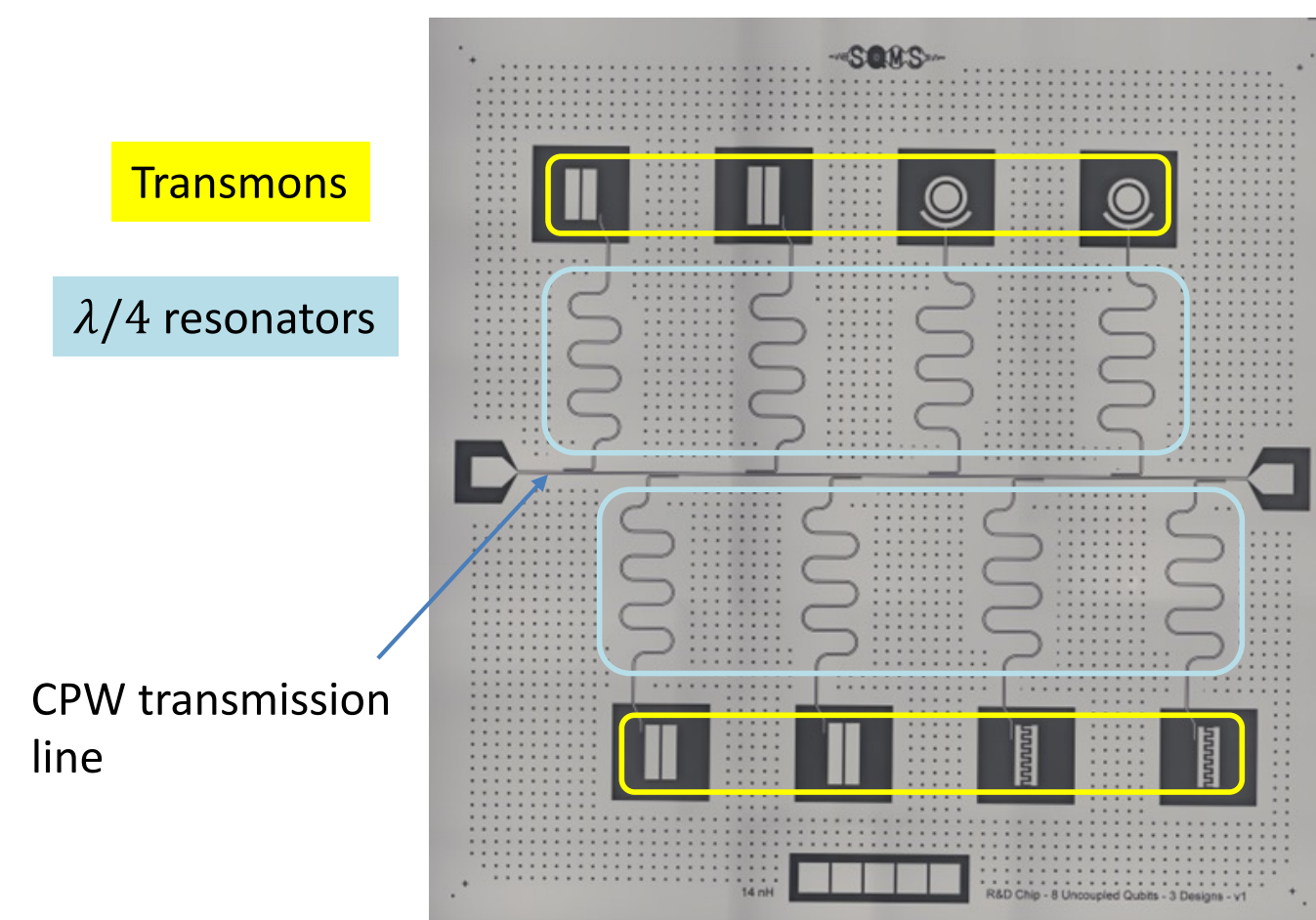
F. De Dominicis, A.Mariani et al,
Eur. Phys. Journ C 83, n.o 94 (2023)

How much can we improve the performance of qubits in low radioactivity environment?

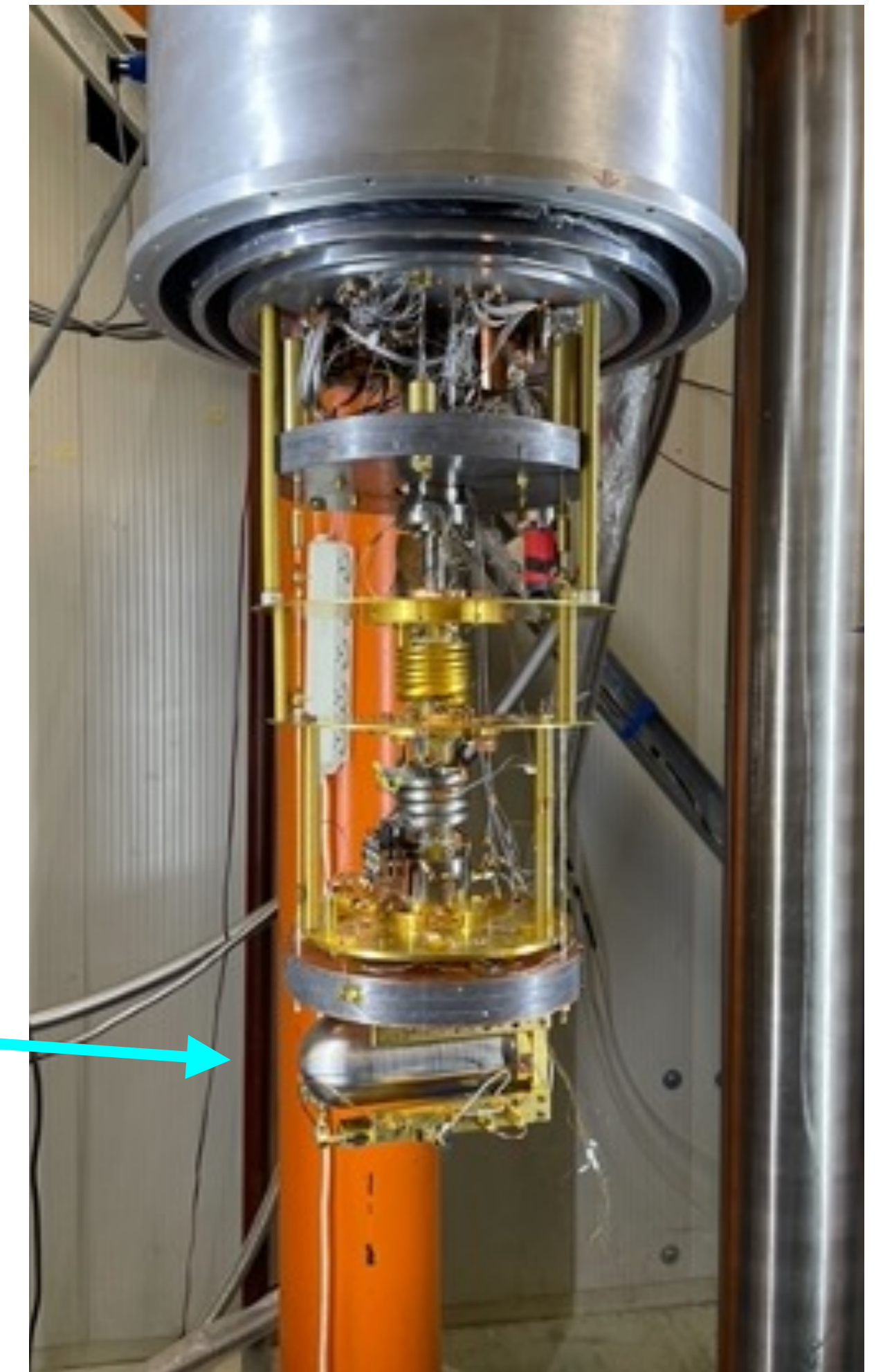
What Next - 2025/...

Fully characterise the response of qubits to radioactivity:

- Energy threshold
- Position-dependency
- Impact of different coating/geometries on sensitivity



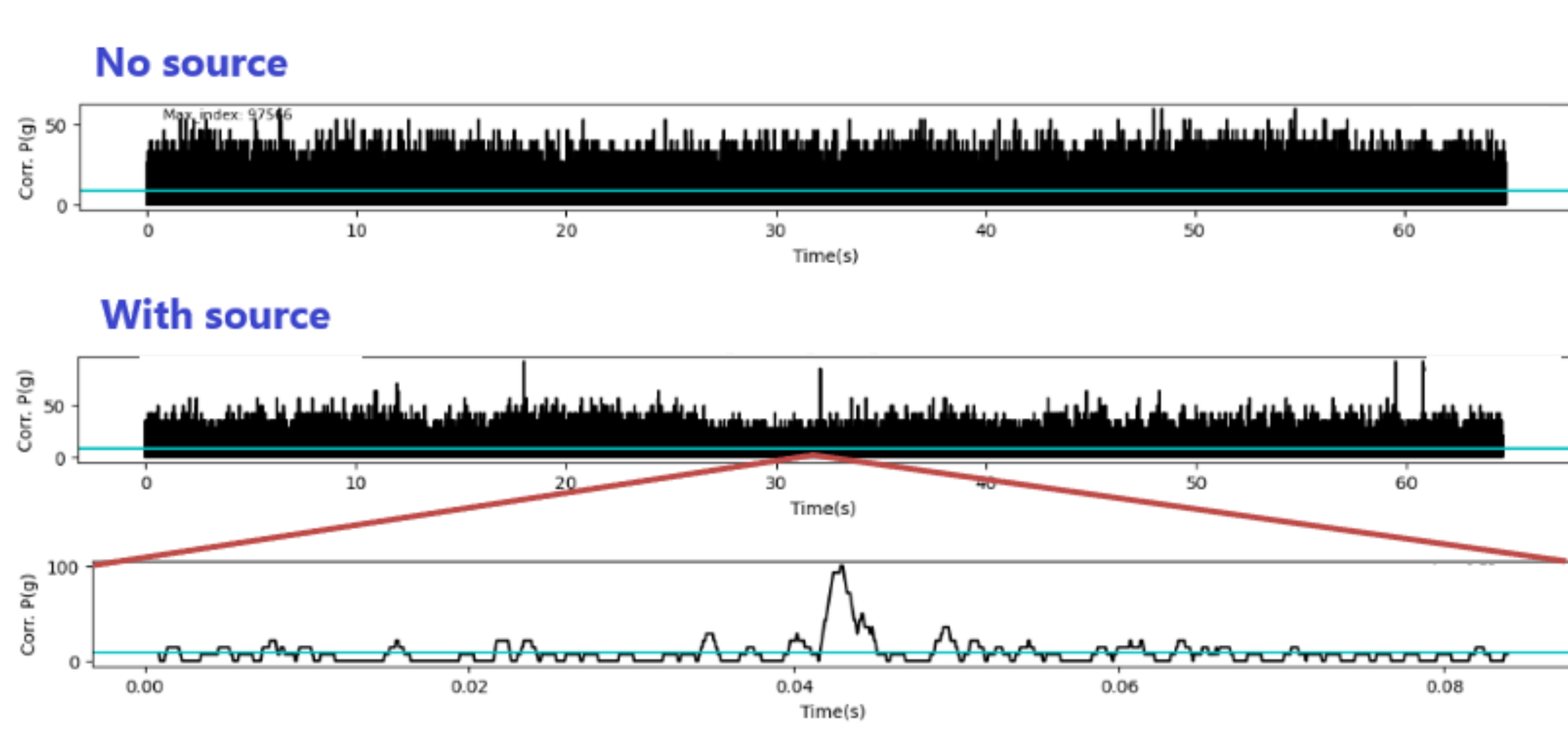
LNGS - "Ieti"



What Next - 2025/...

If qubits are so sensitive to radioactivity... can we turn them into particle detectors?

Preliminary results say so:



Ecosystem

Part of the SQMS Center at FermiLab: hundreds of researchers, 115 M\$ budget, possibility of 3-6 months internship at FermiLab.



- LNGS area: F. De Dominicis*, F. Ferroni, D. Helis, L. Pagnanini, S. Pirro (head of the Ieti facility), A. Puiu
- Roma area: L. Cardani (head of the project), I. Colantoni, A. Cruciani, N. Casali, A. Mariani, V. Pettinacci, M. Vignati
- FNAL area: A. Grassellino (head of the SQMS center), D. van Zanten, A. Romanenko, T. Roy, S. Zhu.

Come talk to him at the poster session!



Thanks for the attention

Contacts: [prof. L. Pagnanini](#)