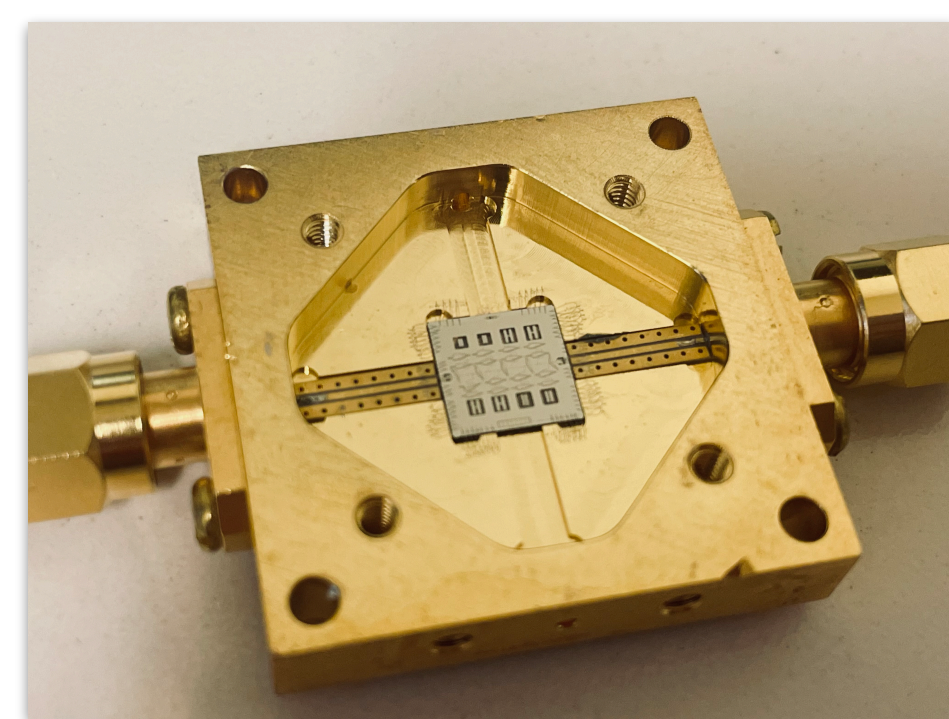
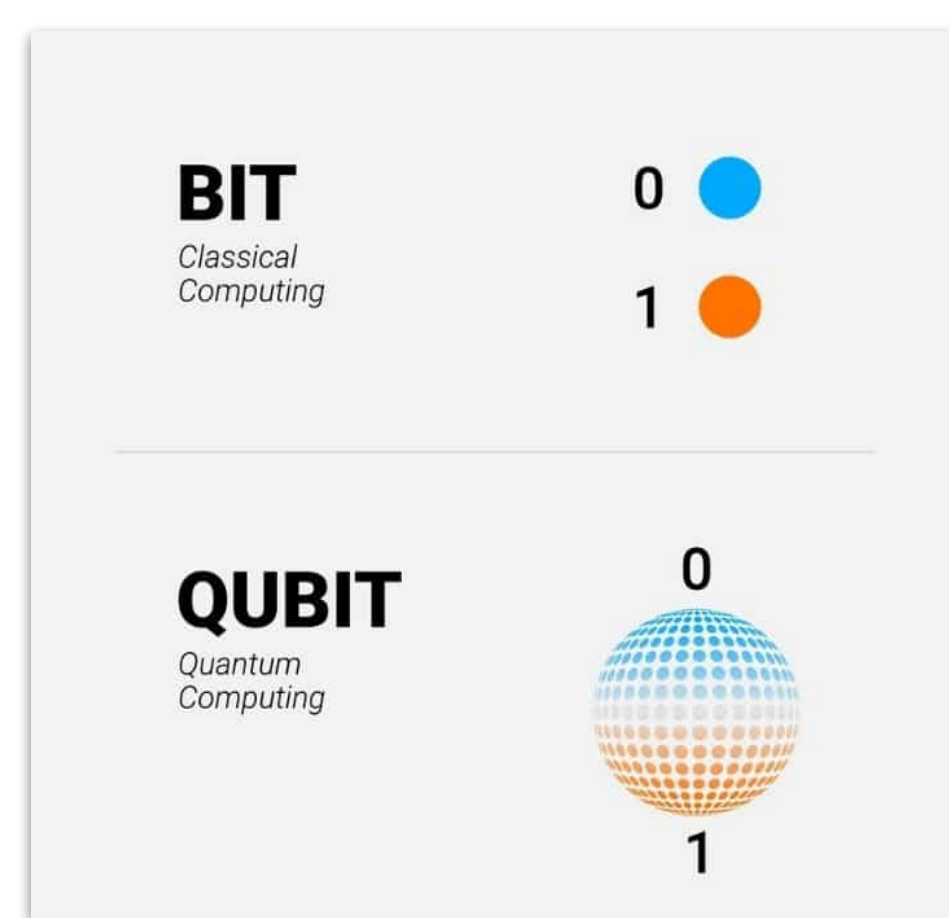


The Invisible Enemies of Quantum Computing

How Ionizing Radiation Affects Superconducting Qubits

1. What is a Qubit?



- Classical computers use **bits**, which can be either **0** or **1**.
- Quantum computers use **qubits**, which can be **0**, **1**, or **both at the same time** — a property known as **superposition**.

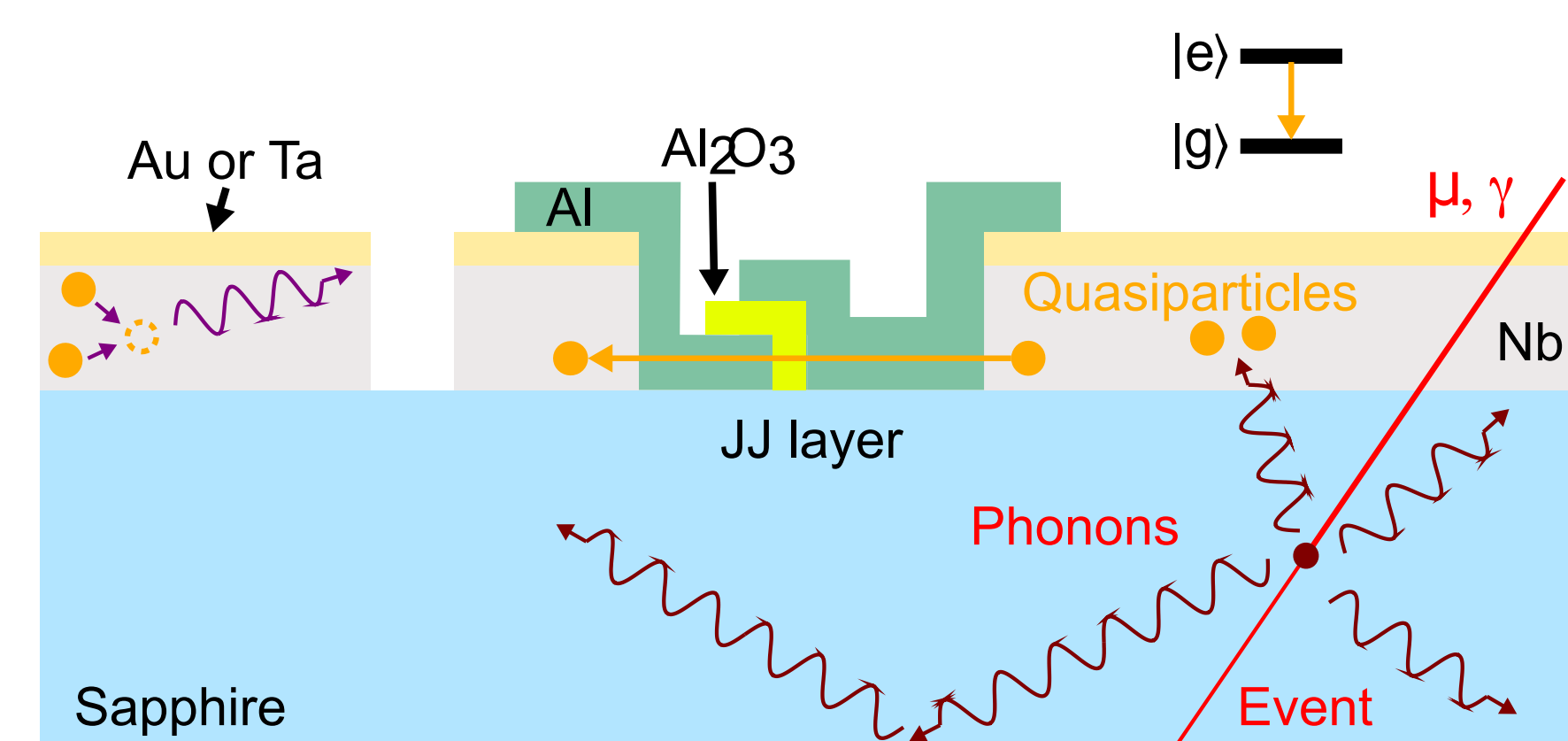
This makes quantum computers incredibly powerful, potentially solving problems that are too complex for today's machines.

But qubits are also extremely sensitive, and even tiny amounts of radiation can disrupt their behavior — a process known as **decoherence**.

Most quantum processors (Google, IBM) today use **superconducting qubits**, built from electrical circuits cooled near absolute zero.

2. The Threat: Ionizing Radiation

- Superconducting qubits** can be **vulnerable** to **particle interactions** within the chip substrate.
- Two **main sources**:
 - Gamma rays** from natural radioactivity;
 - Cosmic-ray muons** — energetic particles from space that reach the Earth's surface constantly.



[De Dominics et al., arXiv:2405.18355v3 (2025)]

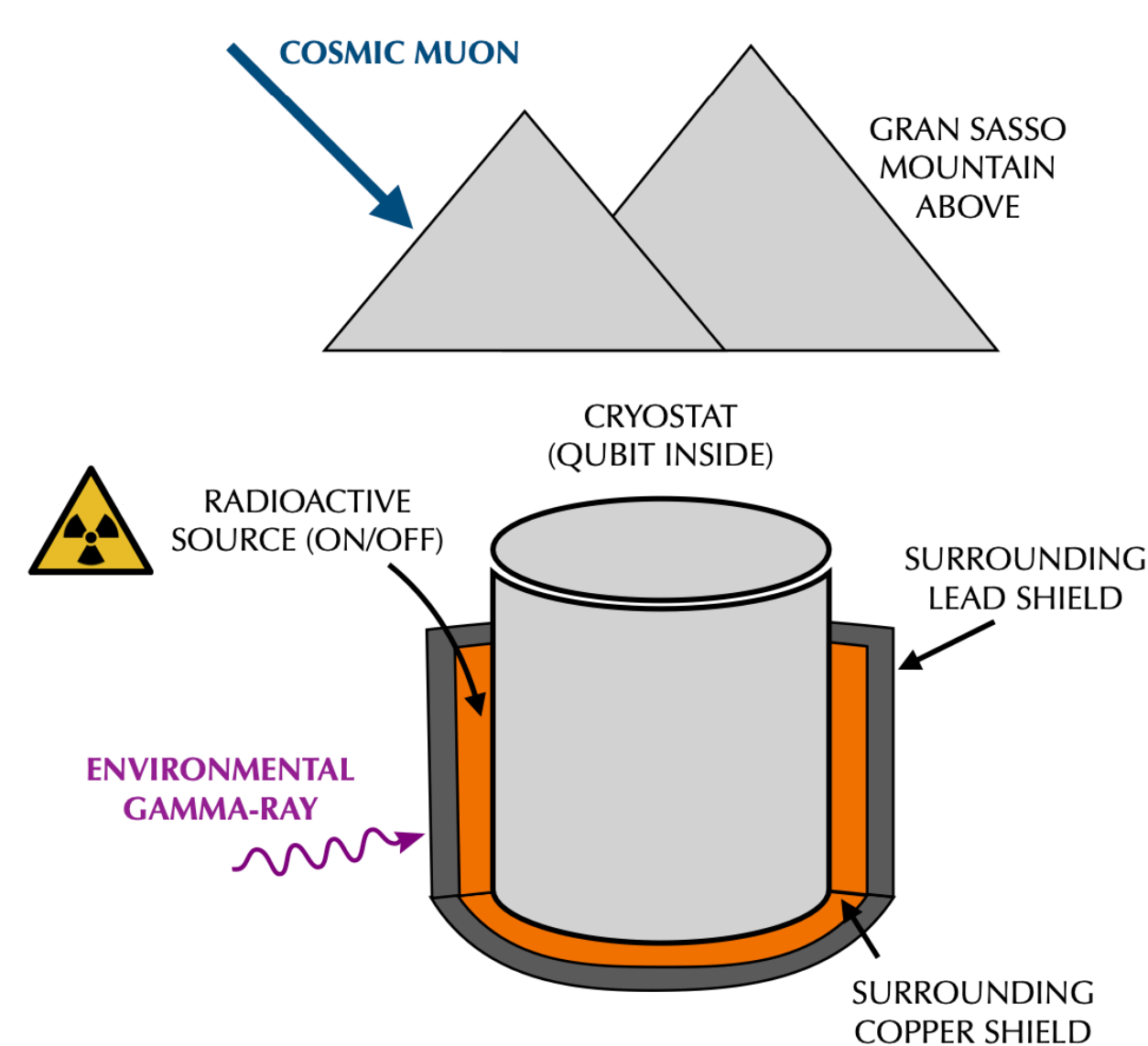
These particles can generate sudden bursts of quasiparticles inside the chip, causing **errors** across one or more qubits.

~ 2 events/min in a typical qubit chip (~1 cm²)!

3. What We Study at INFN

Our team investigates how radiation affects superconducting qubits using:

- Controlled experiments** with radioactive sources;
- Low-background measurements** in underground labs;
- Simulations** to model how particles interact with quantum chips.



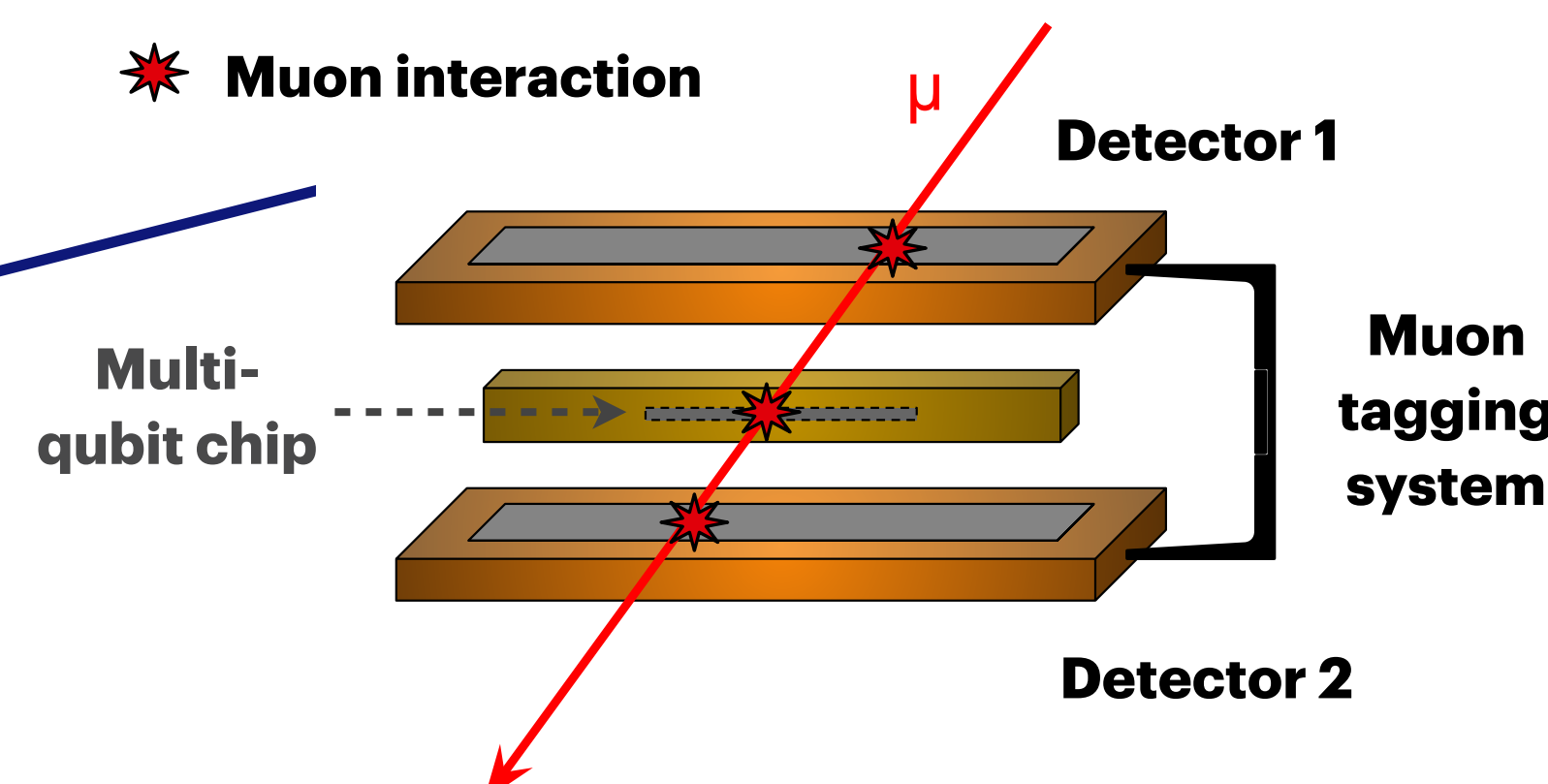
This helps us **understand where errors come from and how to prevent them**.



4. How Can We Protect Qubits?

We develop strategies to reduce/mitigate radiation-induced errors:

- Passive shielding**: placing layers of dense material around the chip to block gamma rays;
- Active tagging**: using Kinetic Inductance Detectors (KIDs) to identify when a muon passes through and reject the affected data.

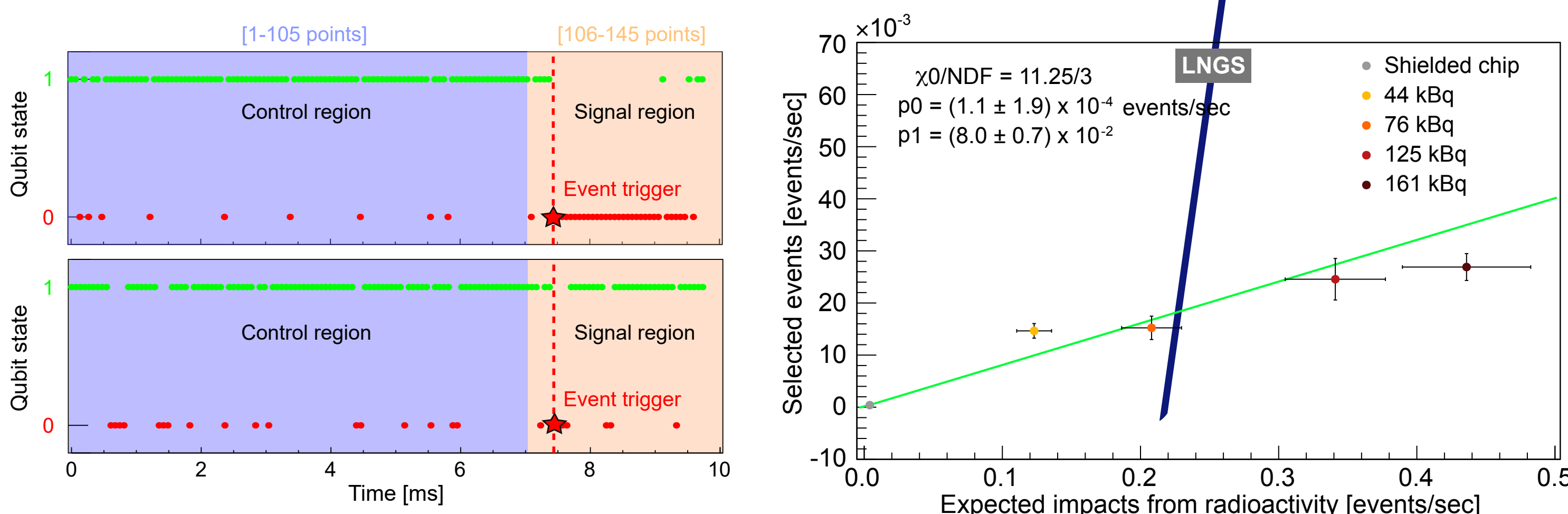


By combining these methods, we aim to make quantum computers more reliable in real-world environments.



5. Qubits as Particle Detectors

- Because superconducting qubits are extremely sensitive to energy deposition, we are also exploring their use as **novel particle detectors**.



[De Dominics et al., arXiv:2405.18355v3 (2025)]

By carefully measuring how a qubit responds to incoming radiation, it may be possible to detect single particle interactions — opening new possibilities for applications in **quantum sensing** and **fundamental physics**.

6. Collaborations and Future Directions

- We collaborate with leading institutions such as the **Superconducting Quantum Materials and System (SQMS) Center**, led by **Fermilab (USA)**, as part of international efforts to build robust quantum systems.



Our research contributes to the design of **next-generation quantum processors** that can operate stably, even in the presence of background radiation.

Contact Us

✉ laura.cardani@roma1.infn.it
✉ ambra.mariani@roma1.infn.it



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