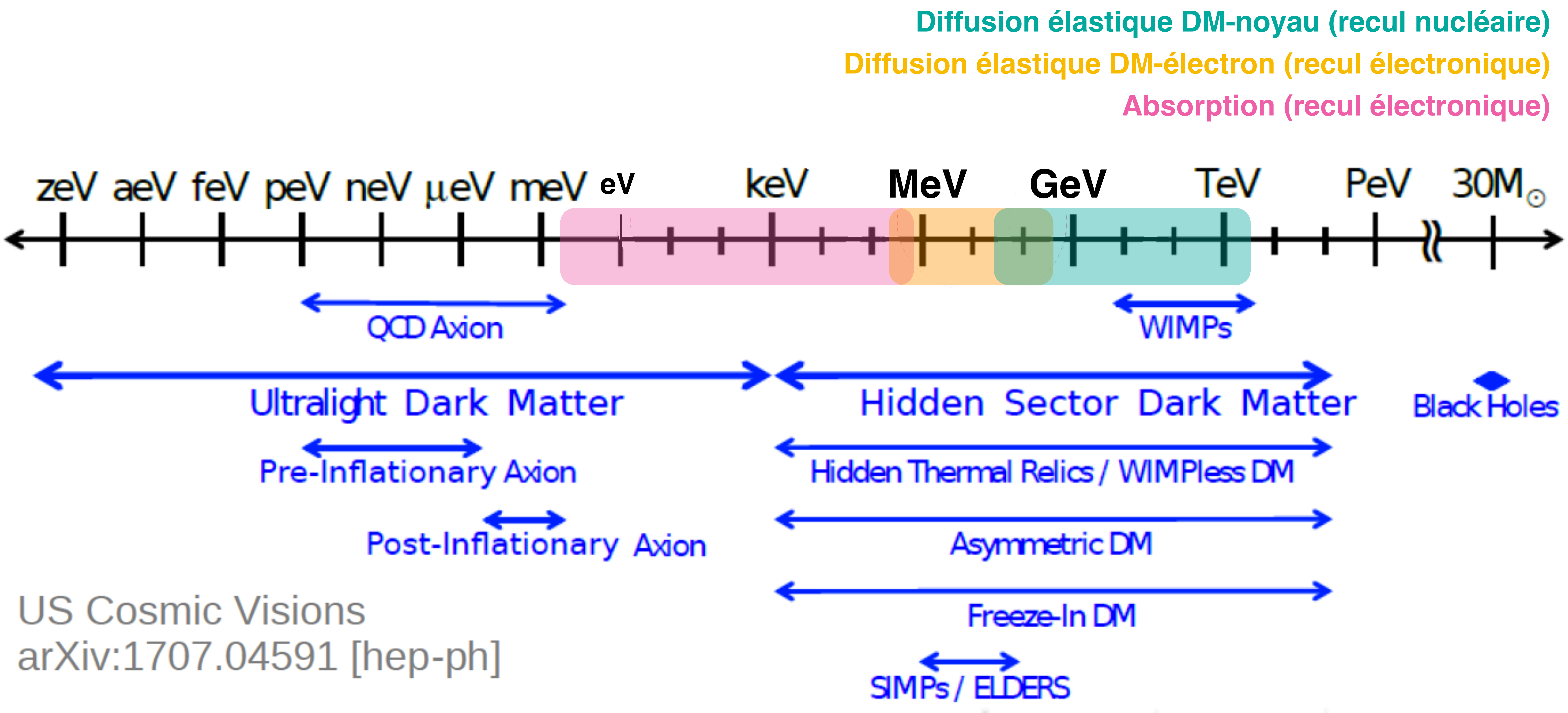
INTERPLAY
QBITS AND (LIGHT) DARK MATTER

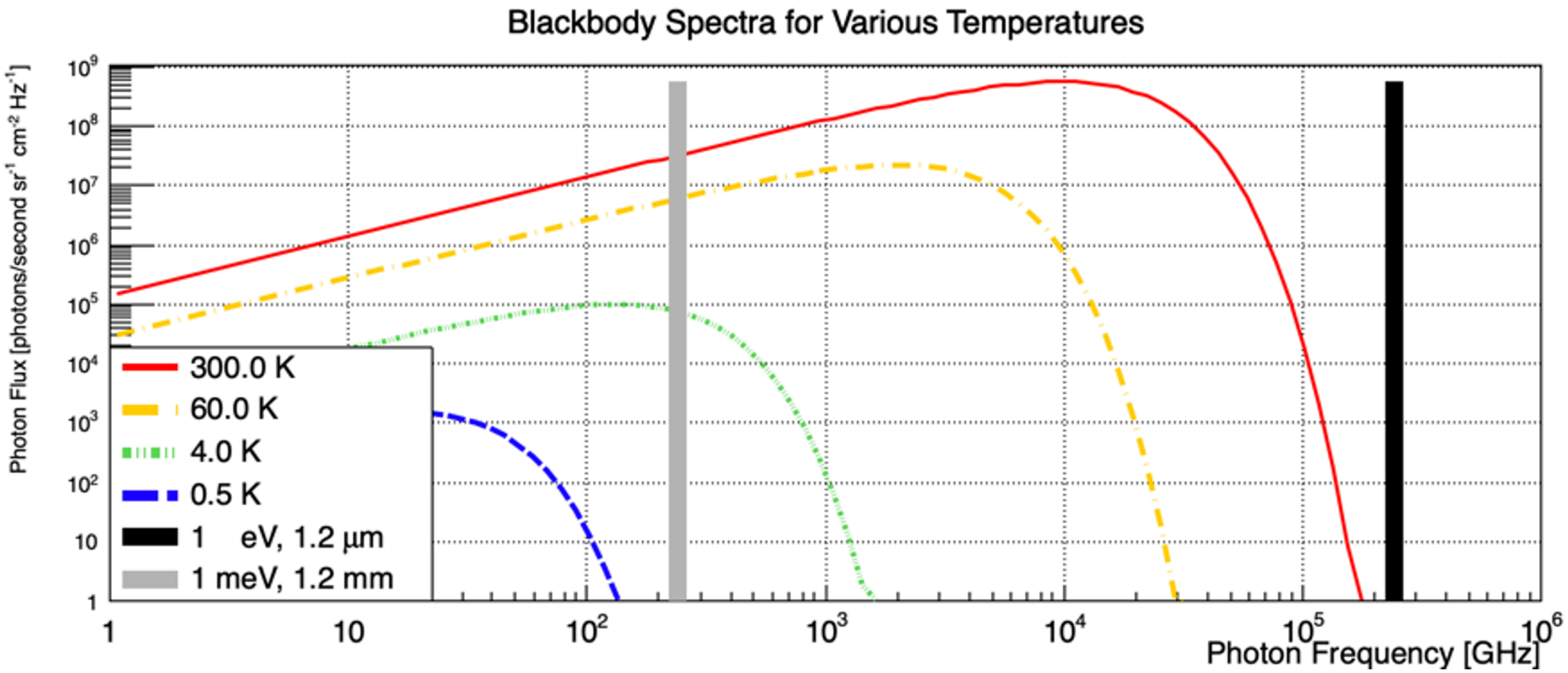
DM CANDIDATES



US Cosmic Visions
arXiv:1707.04591 [hep-ph]

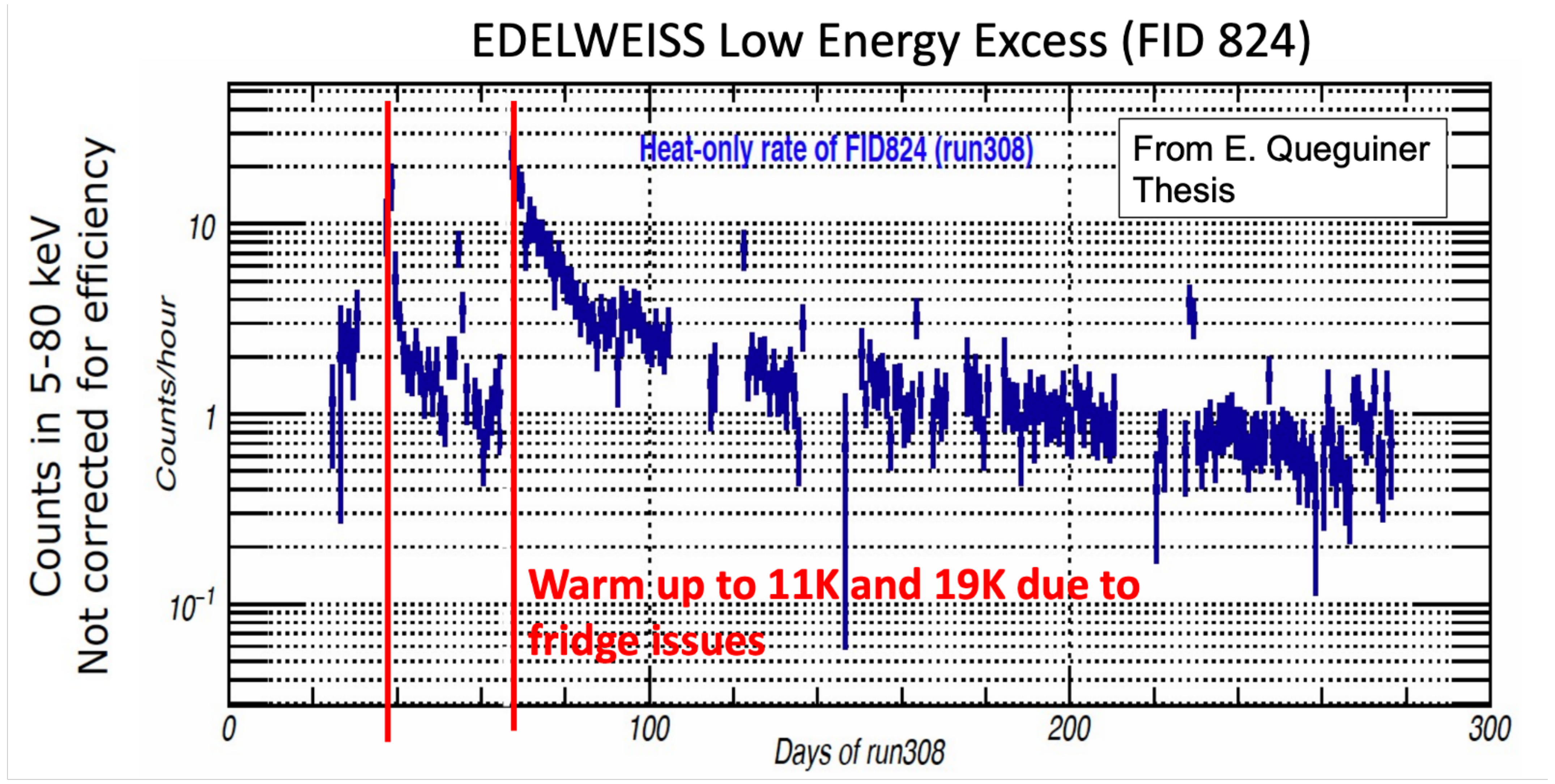
MILLIEV BACKGROUNDS INCLUDE KNOWN AND UNKNOWN SOURCES

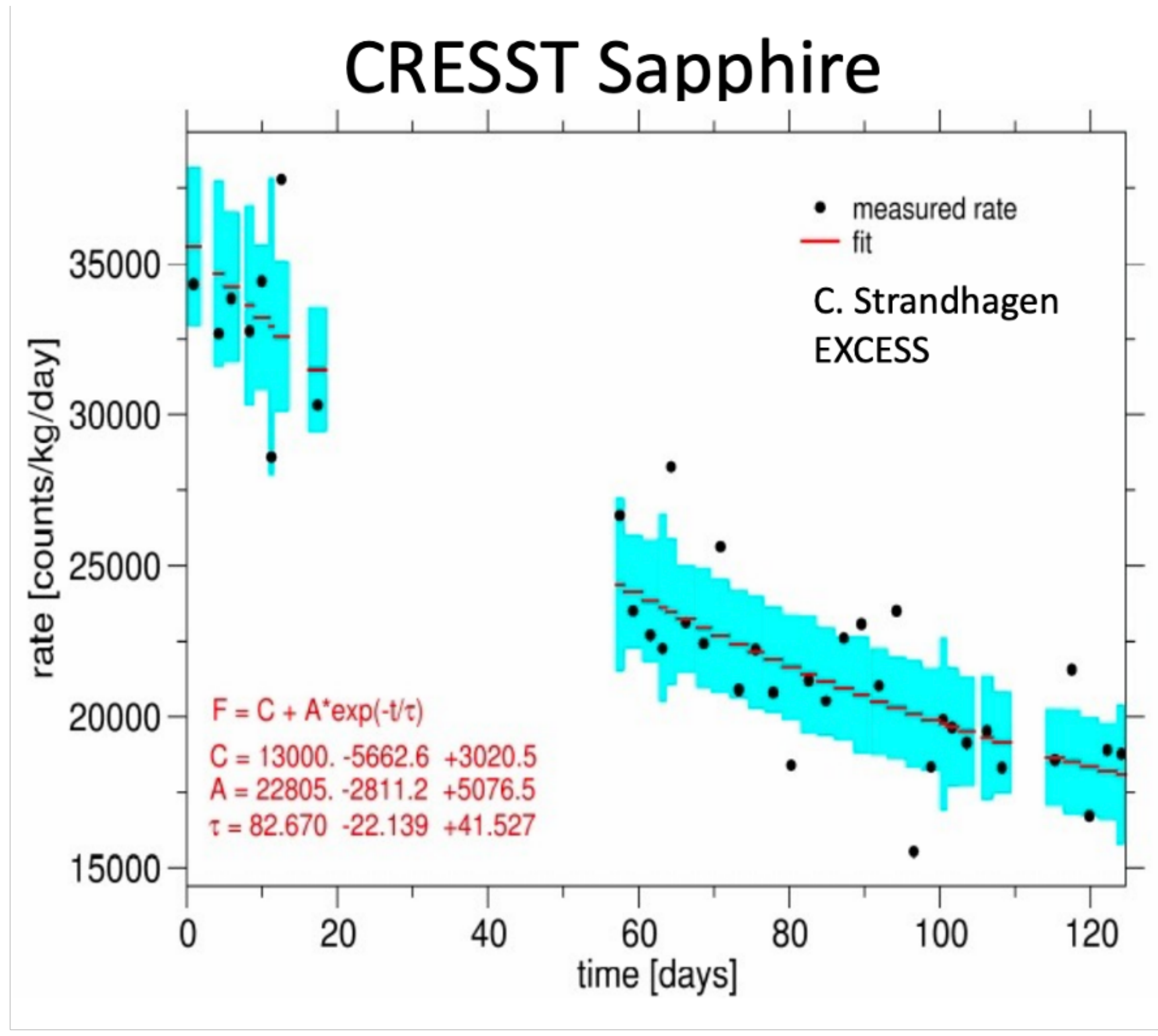
- Ionizing radiation
- Non-ionizing radiation
- Stray fields
- Vibrations
- Material stress
- Everything…
- Neutrino annihilation
- Dark matter

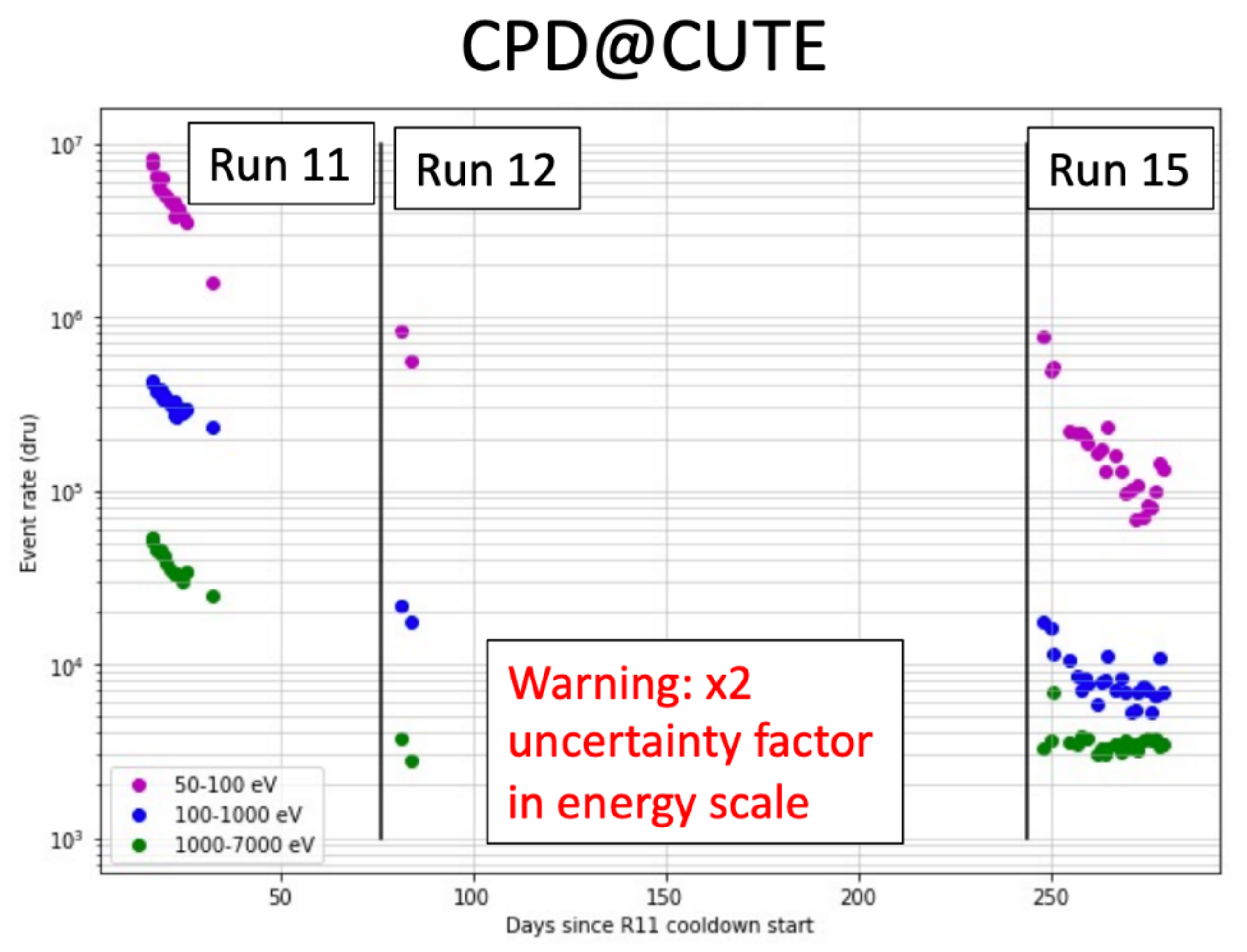


LOW THRESHOLD DARK MATTER SEARCHES ALL OBSERVE LOW ENERGY EXCESSES

- Most low-temperature results show the low energy backgrounds decay over long timescales.
- Seen at low e/h counts in CCDs, but also some non-ionizing components in CPD/HVeV
- Prediction: The low mass dark matter searches will be grappling with new low energy backgrounds for the next decade







ORDINATEURS QUANTIQUES

- On suspect la radioactivité comme une limite importante pour les futurs ordinateurs quantiques (perte de cohérence)
- Défi commun aux détecteurs cryogeniques pour la recherche des événements rares, mieux équipés pour étudier le phénomène
- Le très faible flux cosmique au LSM en fait un site intéressant pour cette excellent synergie multidisciplinaire

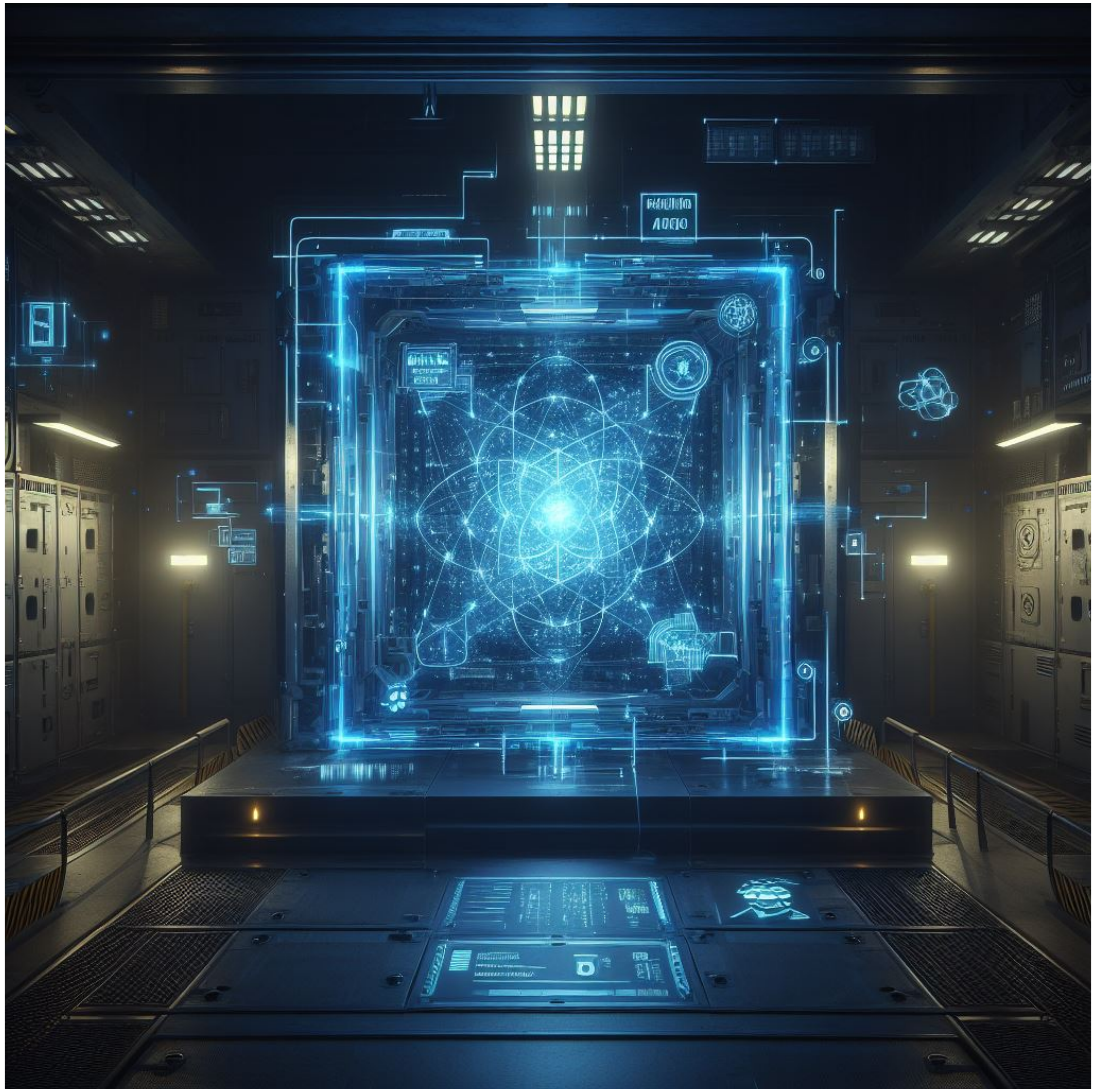


Image crée via AI “quantum computing in underground laboratories”

MILLIMEV BACKGROUNDS NOW ENTANGLES WITH QUANTUM COMPUTING

- Quantum computers are based on qubits
- Qubits are made from low energy systems
- Environmental backgrounds are a source of decoherence in qubits
- There are no radiation-hard design rules for quantum technologies

EXPERIMENTALISTS HAVE SHOWN THAT IONIZING RADIATION DEGRADES QUBIT PERFORMANCE

Radioactivity as Source of Decoherence

When we proposed the DEMETRA project (2018, starting grant of INFN), this was just a hypothesis. Today we have many papers stating that:

1. Radioactivity will be (or already is) the ultimate limit for the coherence of qubits

   [Vepsäläinen, Nature 2020]

2. Radioactivity limits quantum error correction in a matrix of qubits

   [Wilen, Nature 2021] and [McEwen, arXiv:2104.05219]

3. Suppressing radioactivity improves the performance of quantum circuits

   [Cardani, Nat. Comm. 2021]

BEYOND IONIZING RADIATION, SUPERCONDUCTING DEVICES AND DARK MATTER EXPERIMENTS ARE LIMITED BY THE SAME PHENOMENON

- Still struggling to understand in 2022
- Evidence of similar background issues: “here, we observe the number of quasiparticle breaking events reduced by a factor of 4 over a period of weeks”
- Identical to the slowly decreasing excess events in light dark matter searches

MILLIEV BACKGROUNDS NOW ENTANGLES WITH QUANTUM COMPUTING

Quantum systems are sensitive to radiation from the environment

Particle physics researchers are gaining an understanding of modern quantum systems by collaborating on background reduction

New detector concepts are coming based on these collaboration

NEW COLLABORATION

PHYSICAL REVIEW LETTERS **125,** 181102 (2020)

Search for Composite Dark Matter with Optically Levitated Sensors

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(Received 24 July 2020; accepted 2 October 2020; published 28 October 2020)

Detecting Dark Matter with Superconducting Nanowires

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Searches for light dark matter using condensed matter systems

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(Dated: May 31, 2022)

Detection of Light Dark Matter With Optical Phonons in Polar Materials

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- **meV energy detection is a theoretical and experimental challenge that people are tackling**
- **Quantum 2.0 technologies are enabling new detection concepts**
- **This is *not* an exhaustive list**

TAKEN FROM J.HALL SEMINAR AT LPSC - SEPT 2023

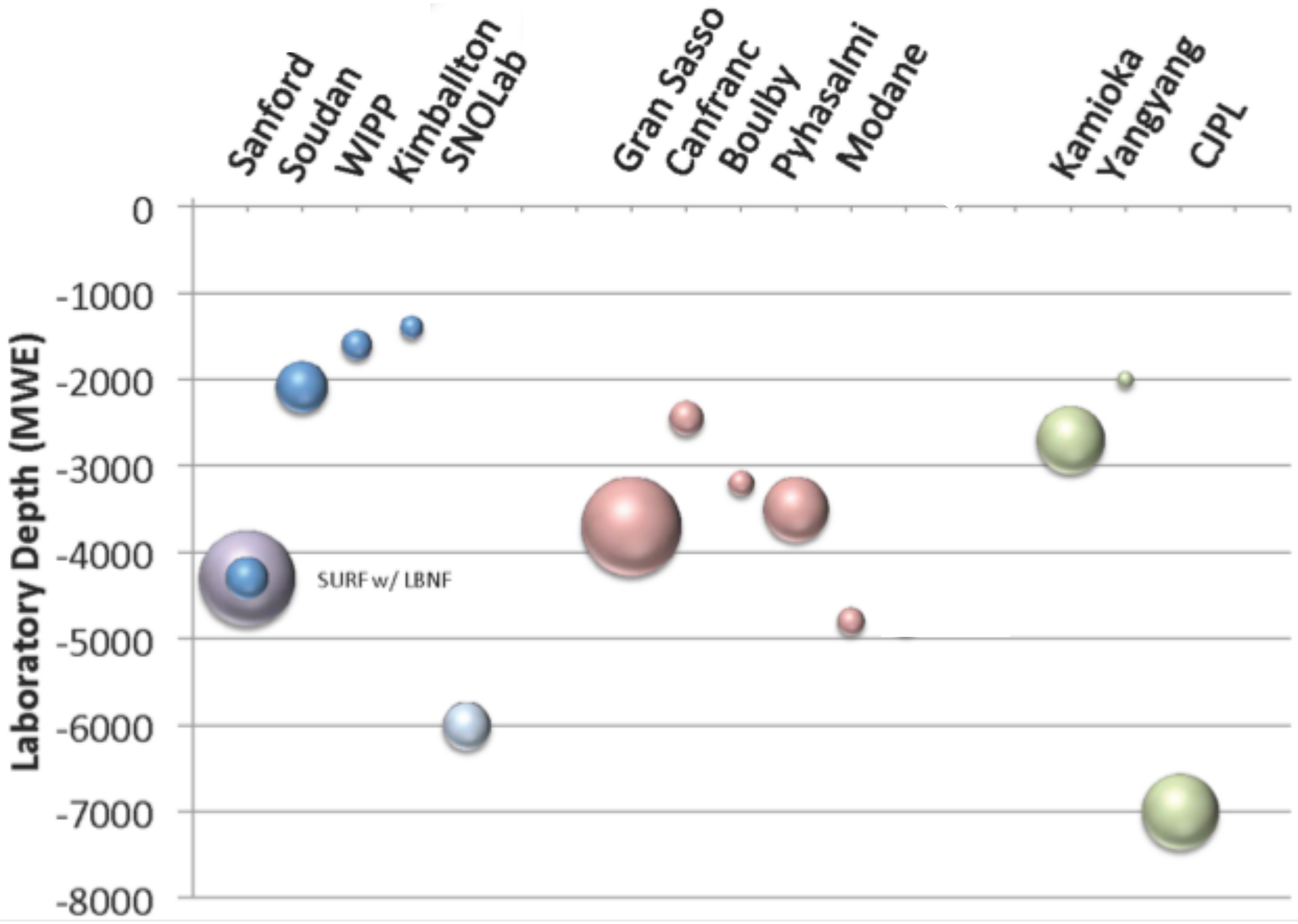
LIGHT DARK MATTER AND QUANTUM COMPUTING RESEARCHERS ARE IN A CORRELATED SUPERPOSITION OF RESEARCH OUTCOMES

- After we perform the research, we will be in one of two states:
  - Dark matter has been detected, but it is a fundamental limit to quantum device performance, OR
  - We have improved the performance of quantum devices, but we haven’t discovered the nature of dark matter

- AND DUL are the best place to conduct there research

UNDERGROUND FACILITIES FOR QBITS

- CUTE @SNOLAB
- NEXUS @NUMI Tunnel
- LNGS
- Why not at LSM?



PLATEFORME NATIONALE LSM

THANKS