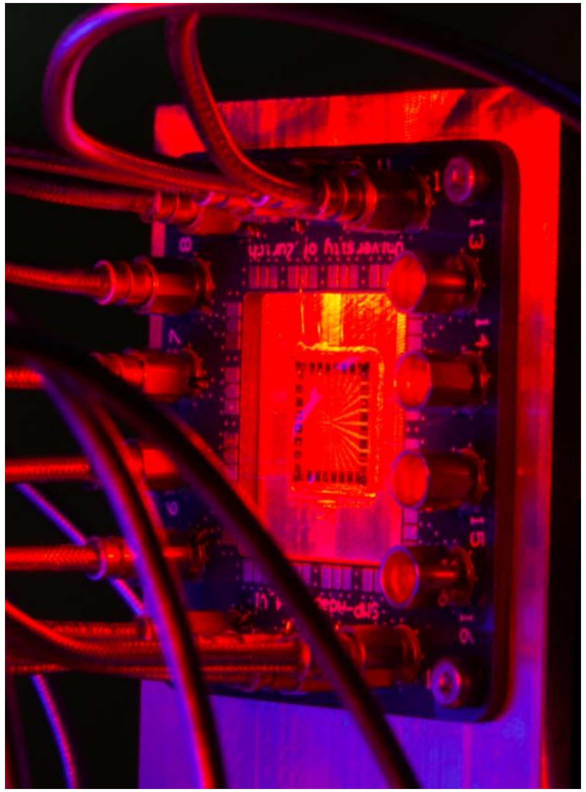
University of Zurich[UZH]

Physics-Institute. Particle Astrophysics

QROCODILE: searching for Dark Matter with SNSPDs



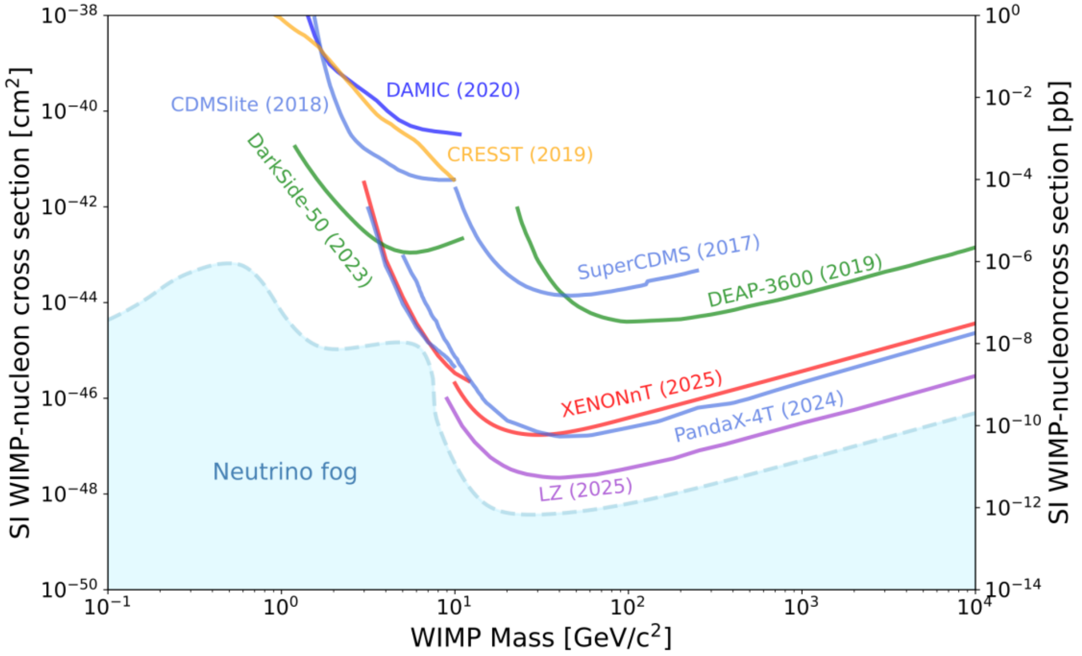
1st BiCoQ Conference: from gravity to particles
15–19 June 2026, University of Milano-Bicocca

Jose Cuenca-García,
on behalf of the QROCODILE team

Swiss National Science Foundation

Qrocodile

Low mass DM scenario

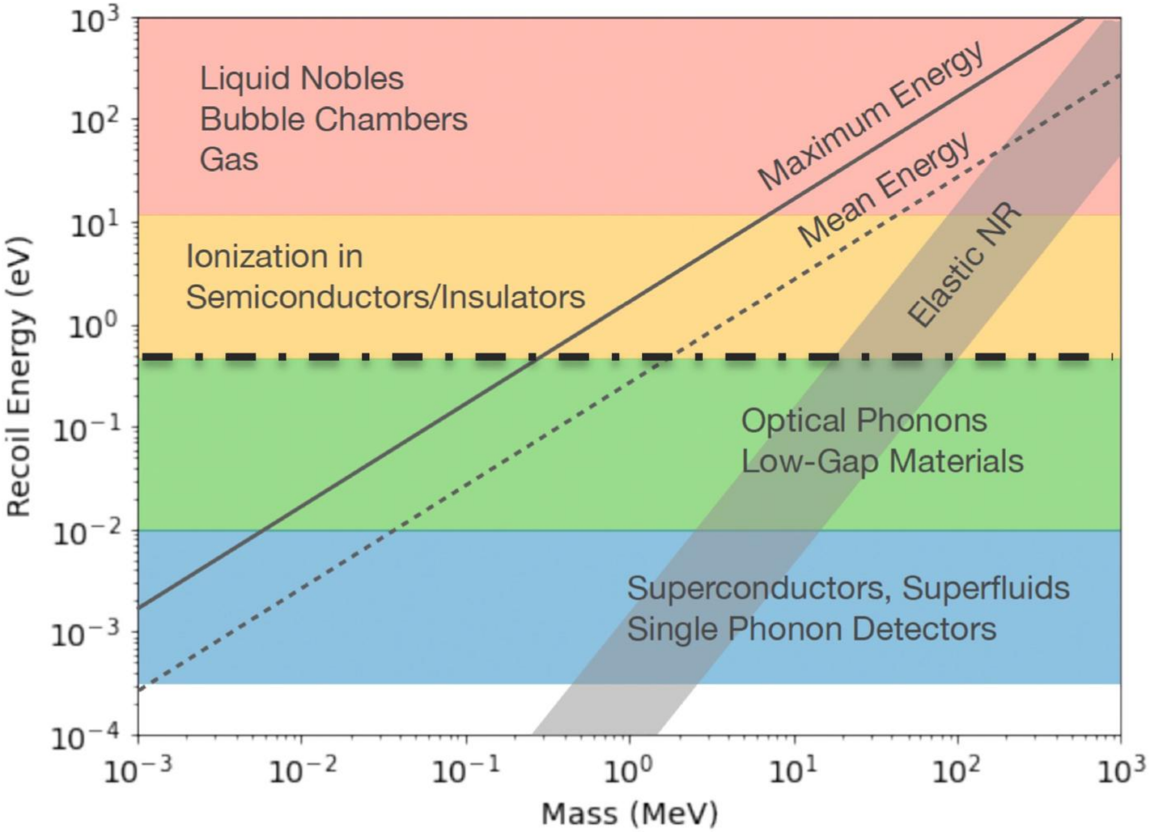


- Development of new technologies required to explore lower masses
- For sub-MeV masses needed sub-eV threshold

Max. Energy for DM moving at escape velocity ~544 km/s

Mean energy for DM moving at mean velocity ~220 km/s

Snowmass 2021, arXiv: 2203.08297



The QROCODILE collaboration

Quantum Resolution-Optimized Cryogenic Observatory for Dark matter Incident at Low Energy

Qrocodile

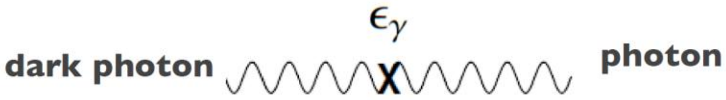
https://www.qrocodile.uzh.ch

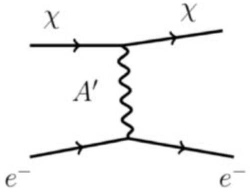
14 members from 4 countries

The QROCODILE experiment

QROCODILE @ UZH cryostat

- DM particle with mass down to 20 keV
- SNSPD as target → sensor
- Sensitive to scatter and absorption of Dark Matter
- Coupling between phonons and quasiparticles in the detector → interaction with electrons and nucleons
- Directionality from anisotropy in the geometry of the device → reject background and select DM from Galactic halo

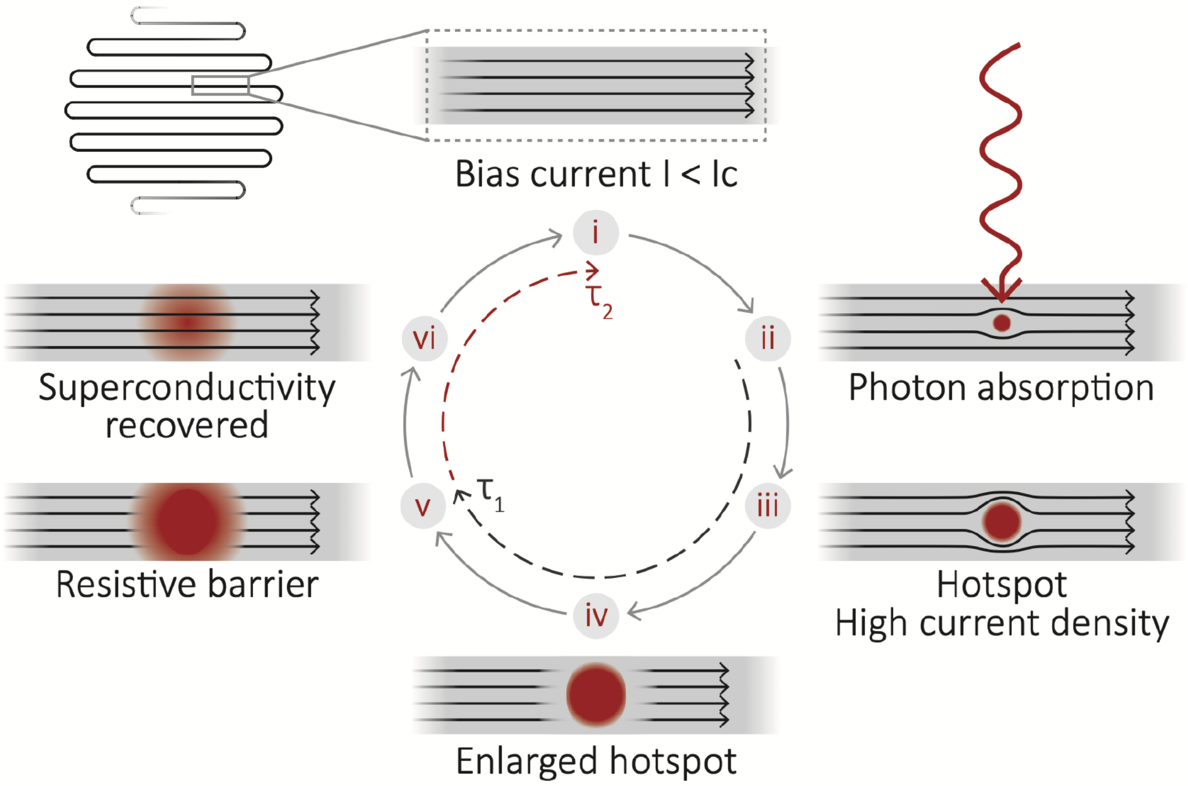


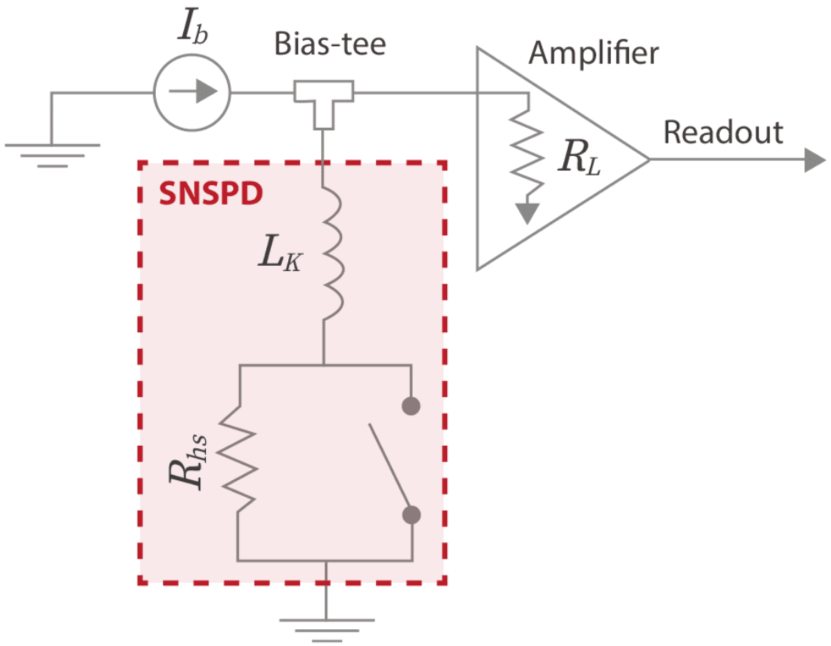


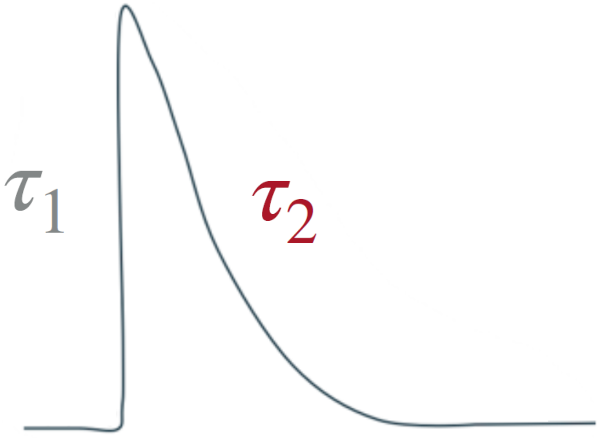
Our first publication:
Phys. Rev. Lett. 135 (2025) 8, 081002

SNSPD working principle

Superconducting Nanowire Single-Photon Detectors

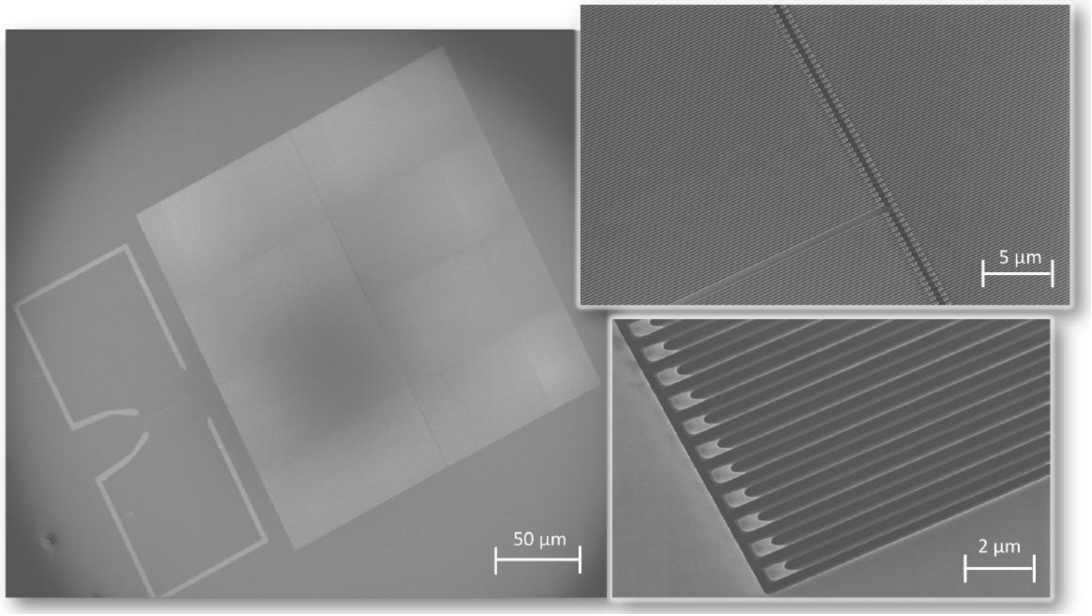




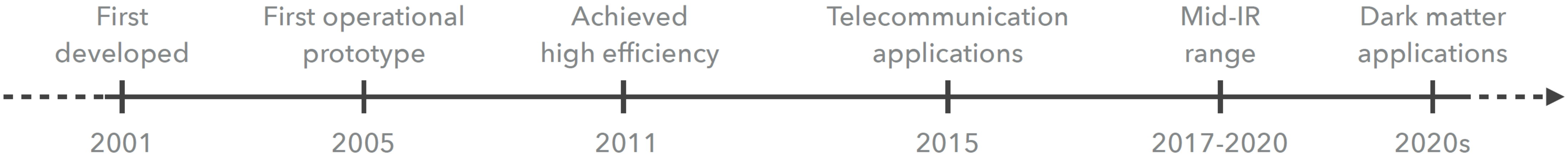


https://www.singlequantum.com/technology/
https://www.idquantique.com/quantum-detection-systems/snspd-technology/

Features of the SNSPDs



- High detection efficiency (>90%)
- Low dark count rates
- Picosecond timing resolution
- WSi, MoSi: lower-gap materials ⟶ more quasiparticles per absorbed photon but with slower diffusion and recovery times – used for IR region
- NbN, NbTiN: higher-gap materials ⟶ respond faster but with less intrinsic energy spread



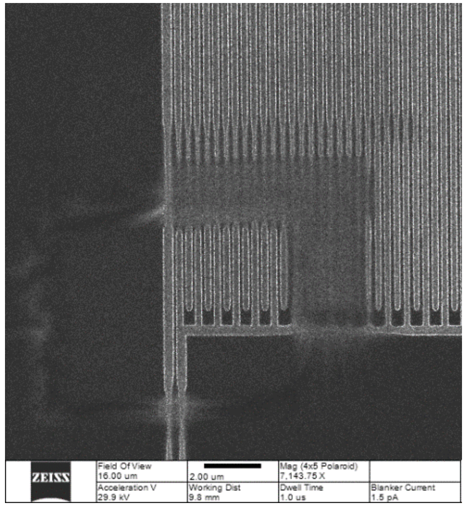
SNSPDs applied to Dark Matter searches

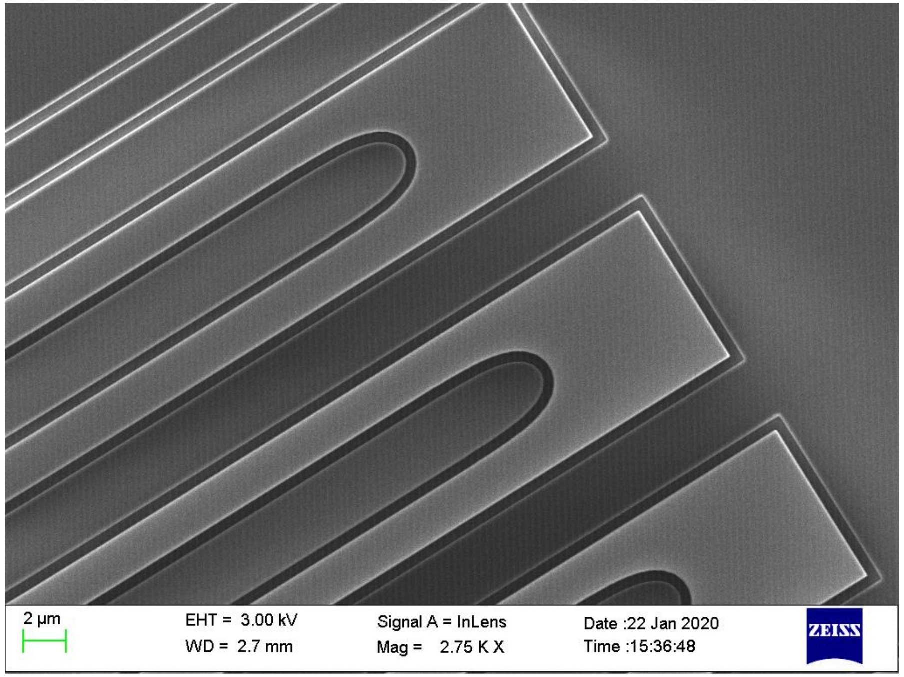
Requirements for dark matter search:

- Large detector mass
- Mid-infrared detection
- Low dark count rate
- Mitigation of background

- Small effective volume (active area 10 µm X 10 µm) ⟶ for DM microwires 1 µm wide on large area device >> 10 µm X 10 µm

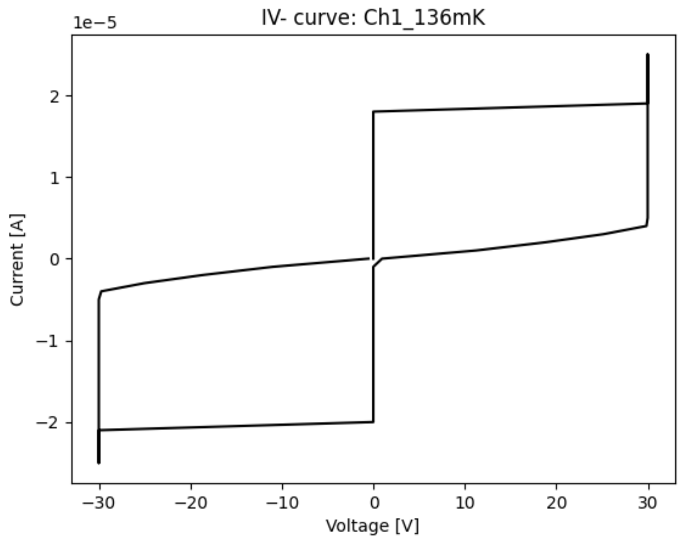
- Complex fabrication
  - Non uniformity of wire production that affects critical current
  - Edge or internal structure defects

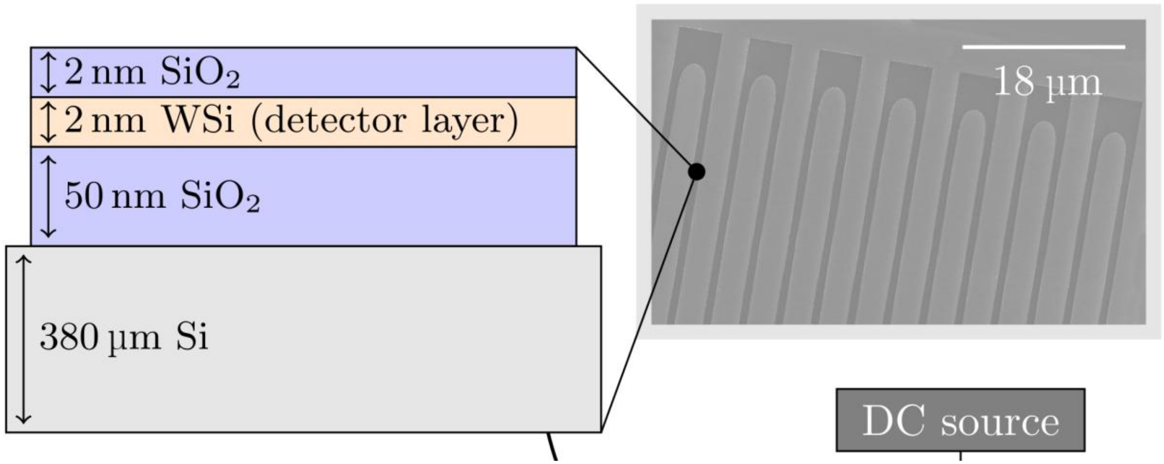


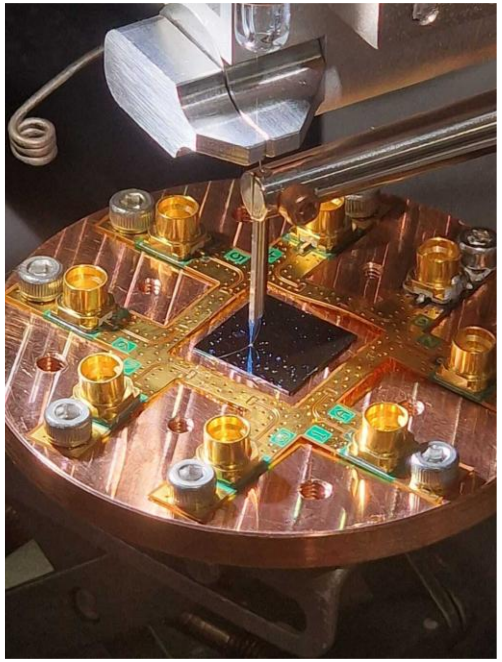


The sensor

- 10 mm X 10 mm chip size
- 600 µm X 600 µm active area with 1 µm wire width
- 25% filling factor
- WiSi 45:55 superconducting layer 2 nm thick
- Transition temperature at 1.73 K
- Si/SiO_2 substrate







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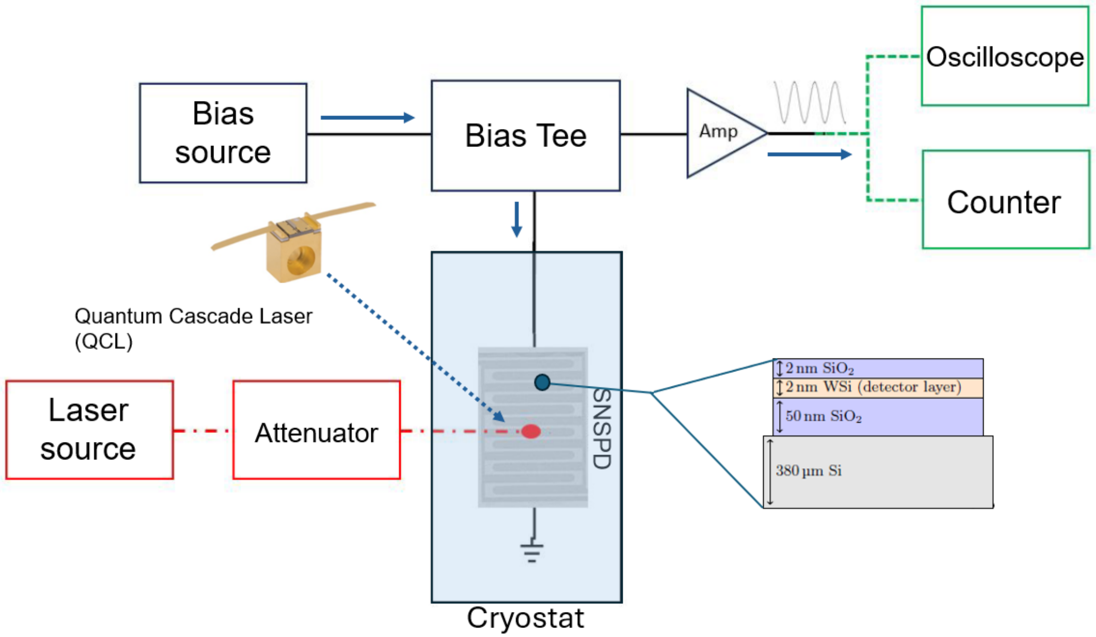
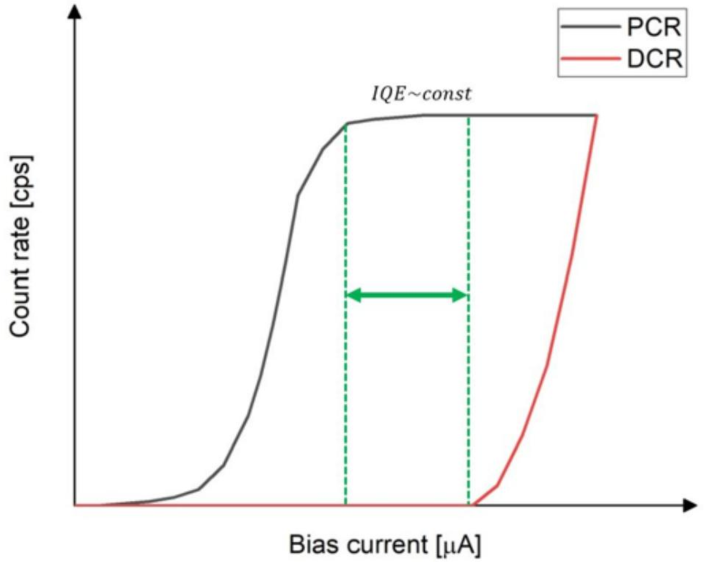
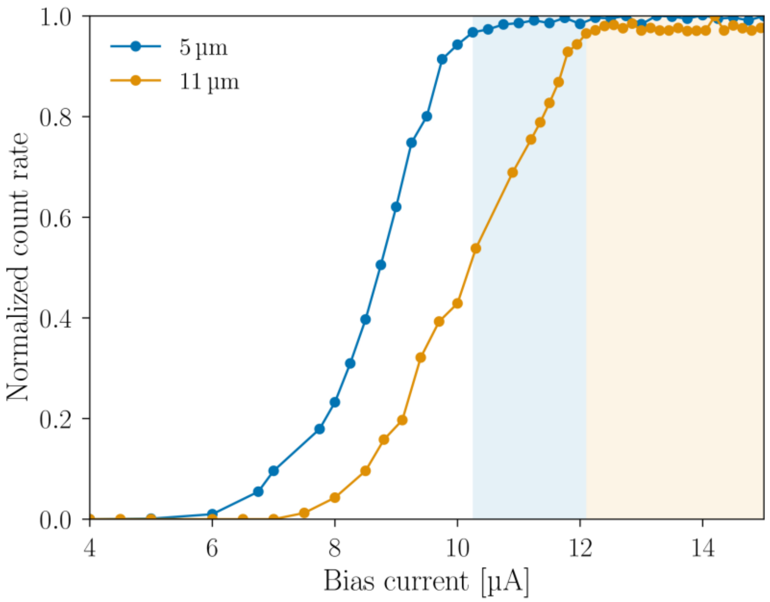
Calibration

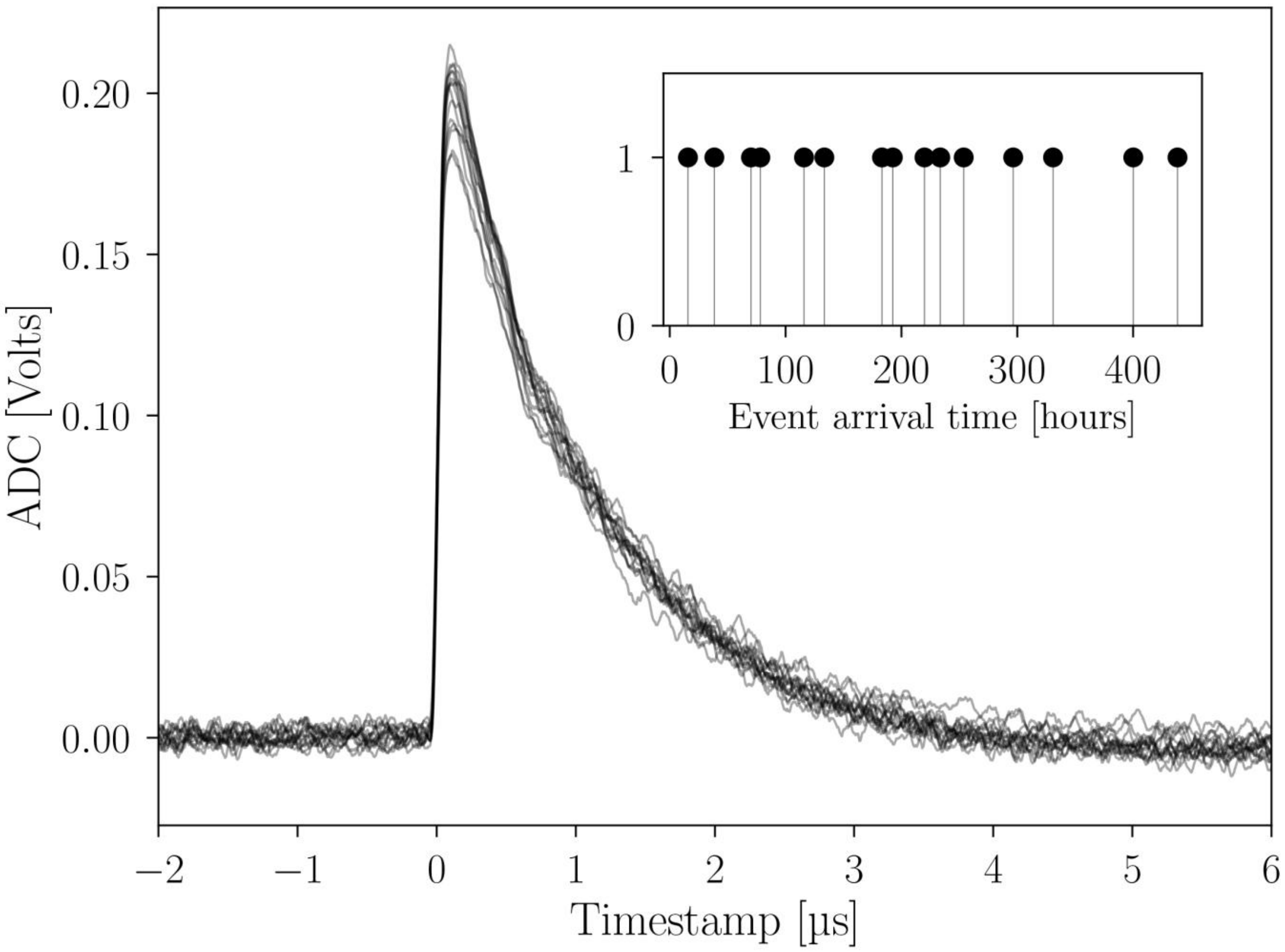
- Made in the mid-infrared region with 5 µm and 11 µm lasers (0.25 and 0.11 eV)
- Detection efficiency up to 98%
- Set working point at 12.2 µA and 100 mK





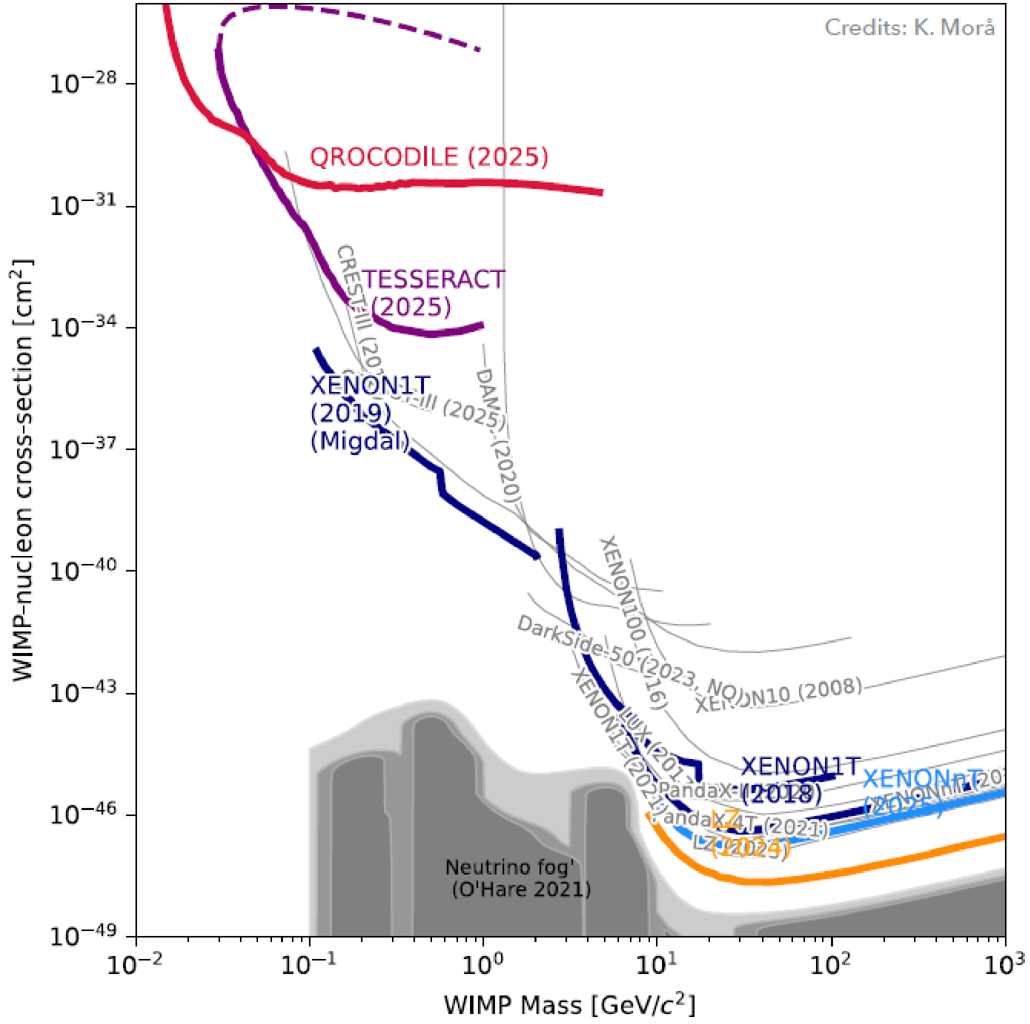


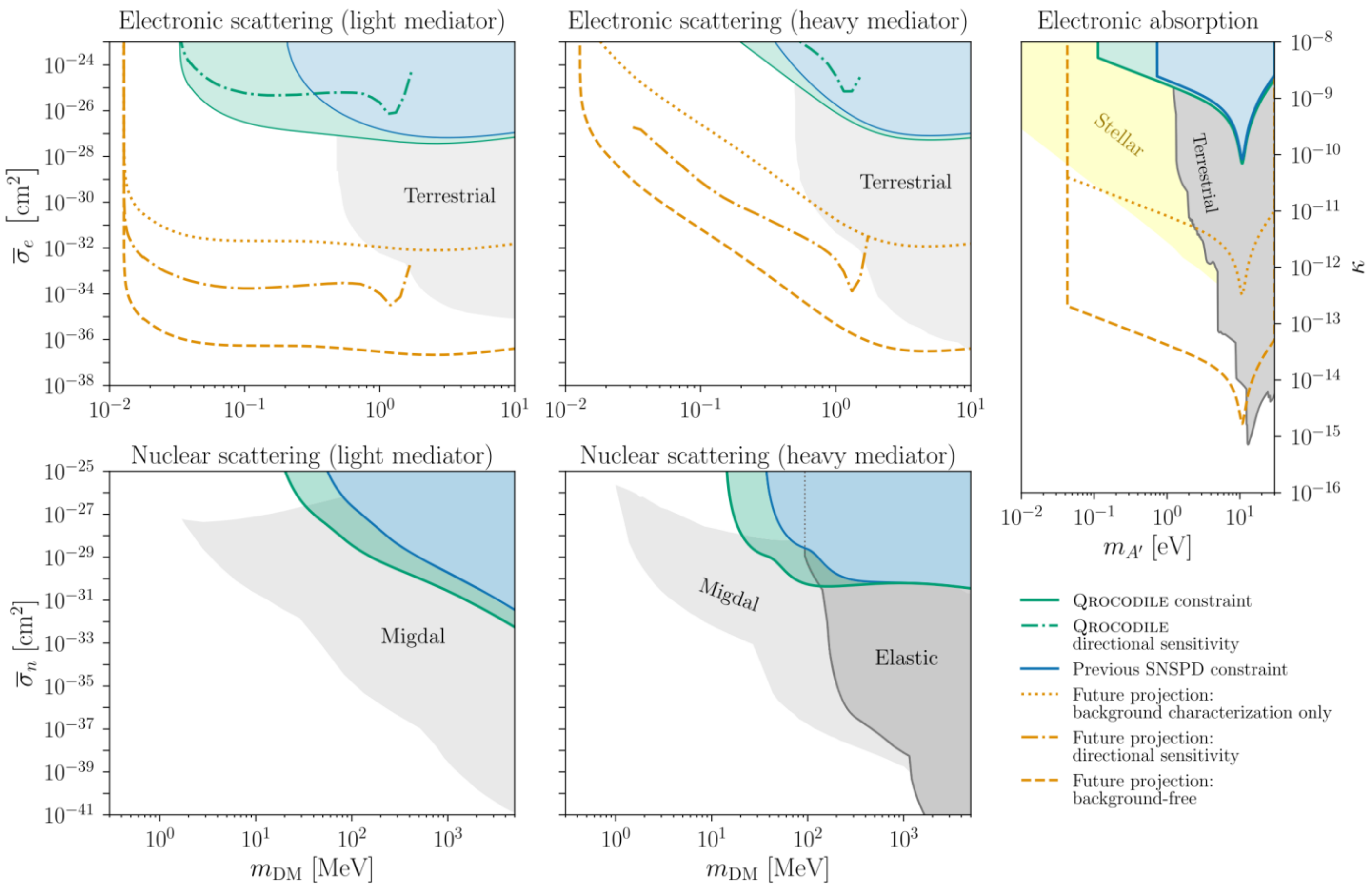
Data taking



- Livetime: 415.15 hours
- 15 individual non periodic pulses = 10^{-5} Hz
- Pulse shape not energy correlated
- Not enough statistics to detect anisotropy in rate
- Constraints from total count rate
- 95% C.L. from Feldman-Cousins
- Projection for 10^{7} pixels and threshold of 0.04 eV (29 µm)

Current limit



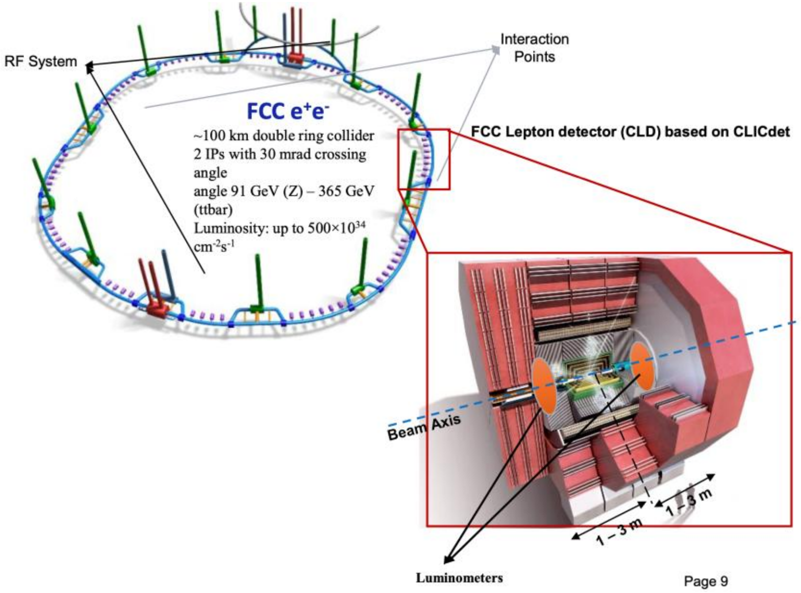


Next plans

Temporary downtime during migration to alternative sensor suppliers

New sensor production:

- Moving UZH production to EPFL facility
- WSi chip from JPL – 1 mm X 1 mm with 9 pixels
- Uni Geneva joining – production of MoN films, 800 um with 4 pixels
- Collaboration with DRD5 and the UZH CMS group (development for FCC)



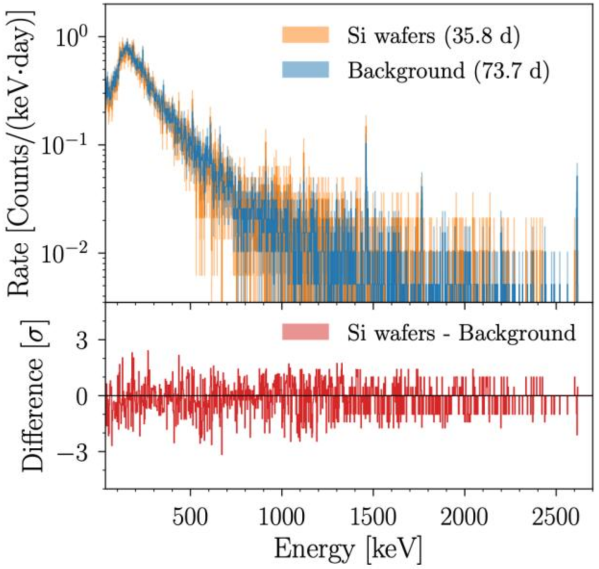
QROCODILE underground

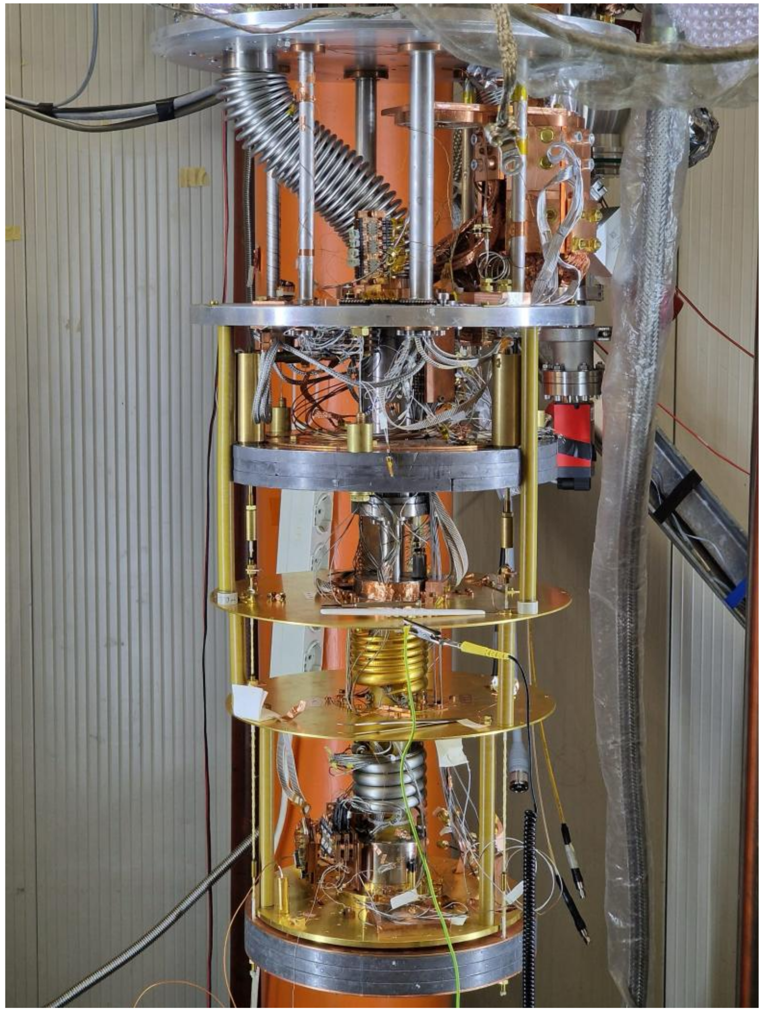
Origin of the events?

1. Measurement in underground lab to disentangle background contribution from cosmic rays
   - IETI facility at LNGS
   - Test runs to setup readout and electronics

2. Material radioessay for contaminant tracing

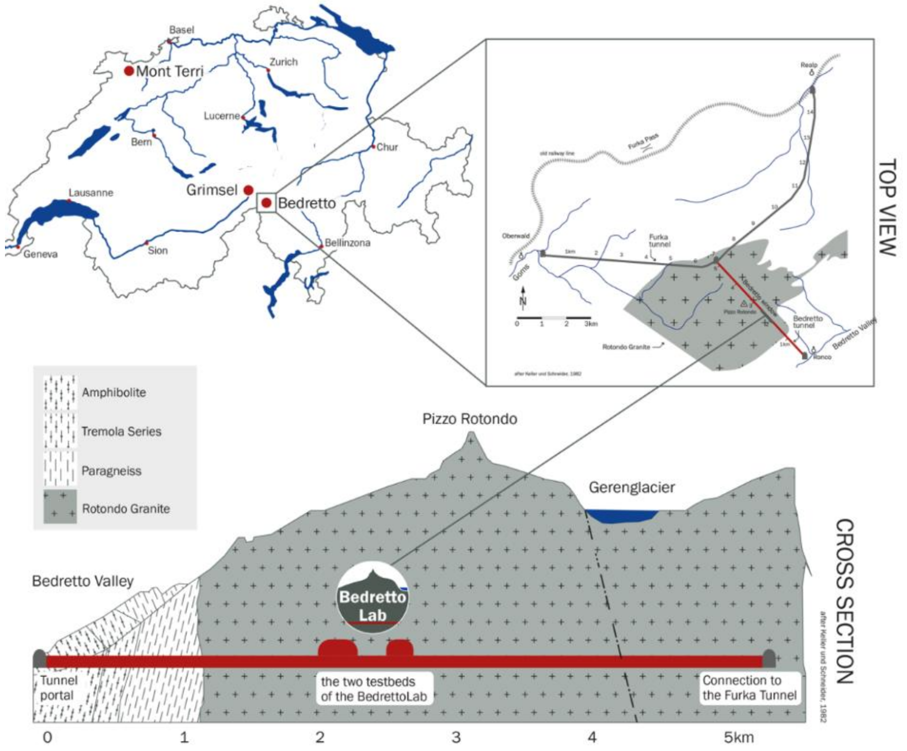
3. MonteCarlo simulations





Bedretto lab

- Underground tunnel in Switzerland – 5.2 km in side access of Furka train tunnel
- ~1000-1500 m deep, three caverns 6 m wide and 50-100 m long
- Since 2019 used by geophysics groups at ETH – since 2025 particle physics involved



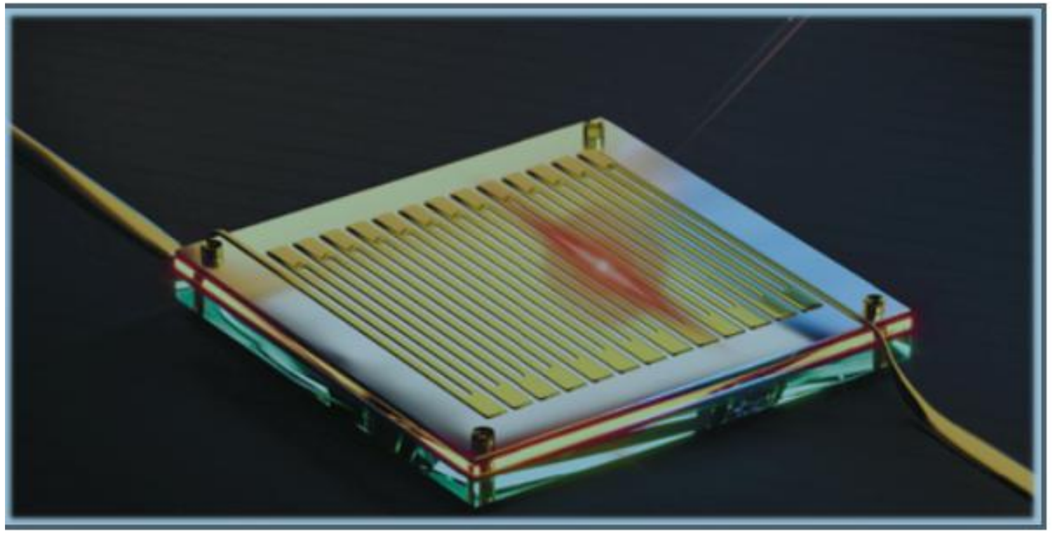
Conclusion and outlook

- Large area SNSPDs promising technology for low dark matter search
  - Simple readout
  - Easy scalable to larger masses

- First large area chip in aboveground measurement probed
  new parameter space

- Planned underground measurement

- Producing new sensors to optimise design and threshold



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