



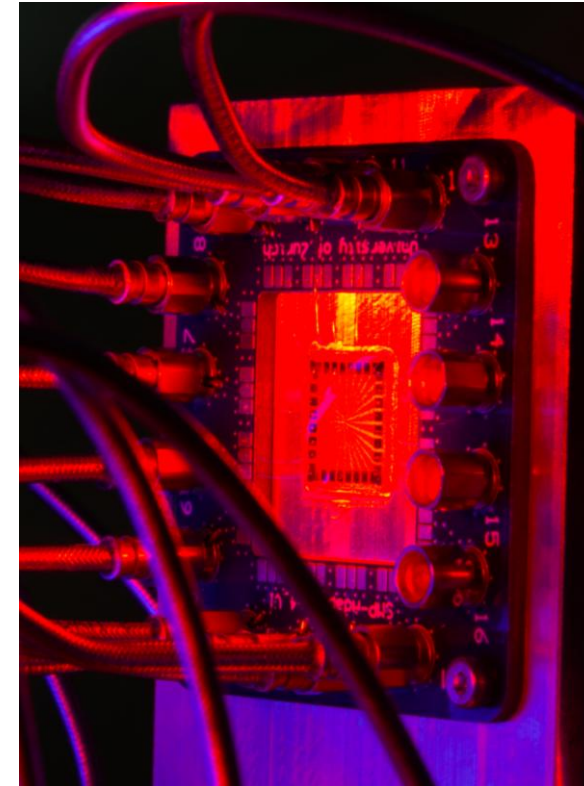
University of
Zurich^{UZH}

Physics-Institute. Particle Astrophysics

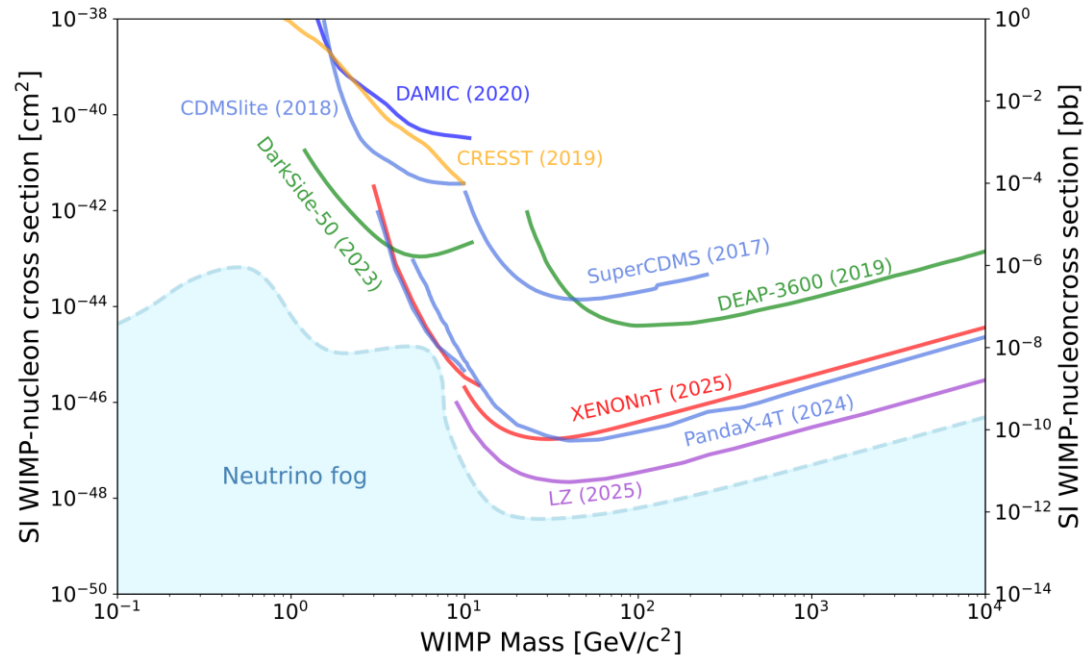
QROCODILE: searching for Dark Matter with SNSPDs

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

Jose Cuenca-García,
on behalf of the QROCODILE team



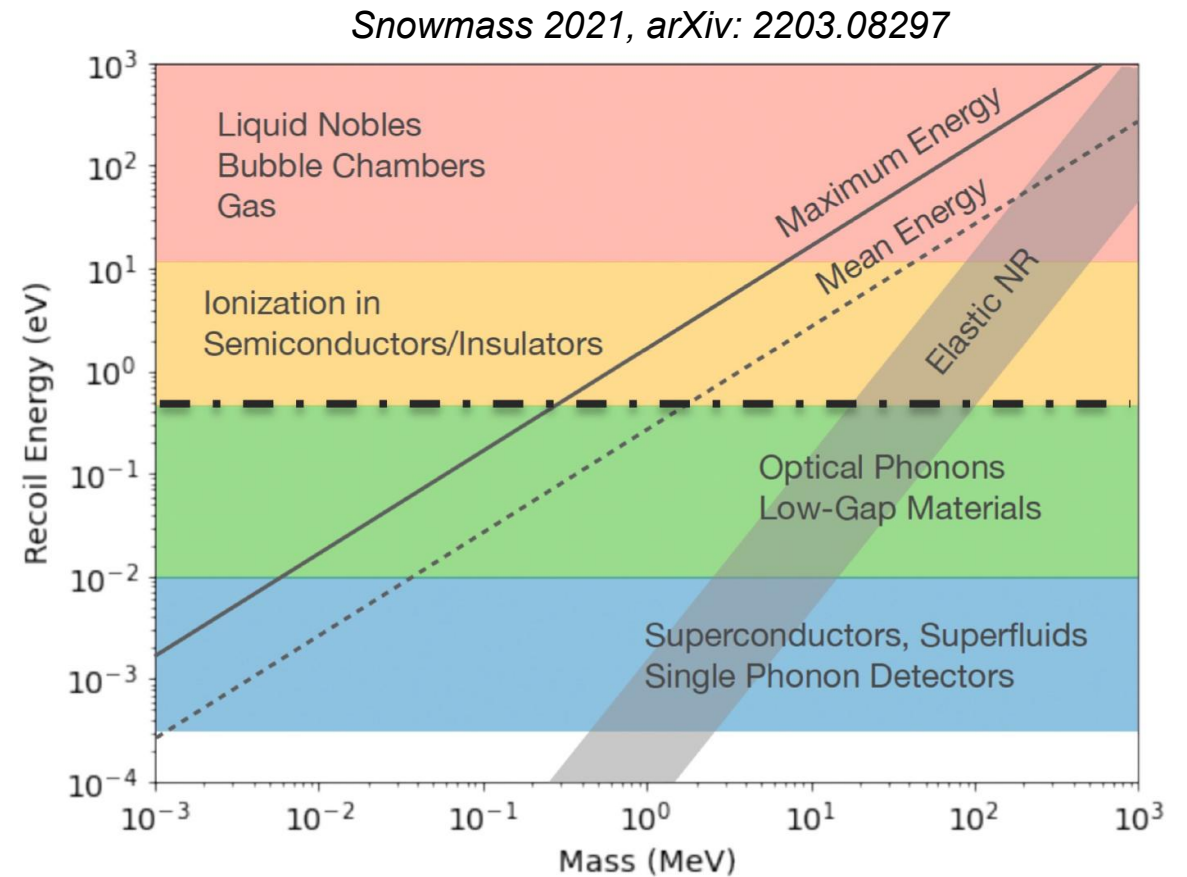
Low mass DM scenario



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

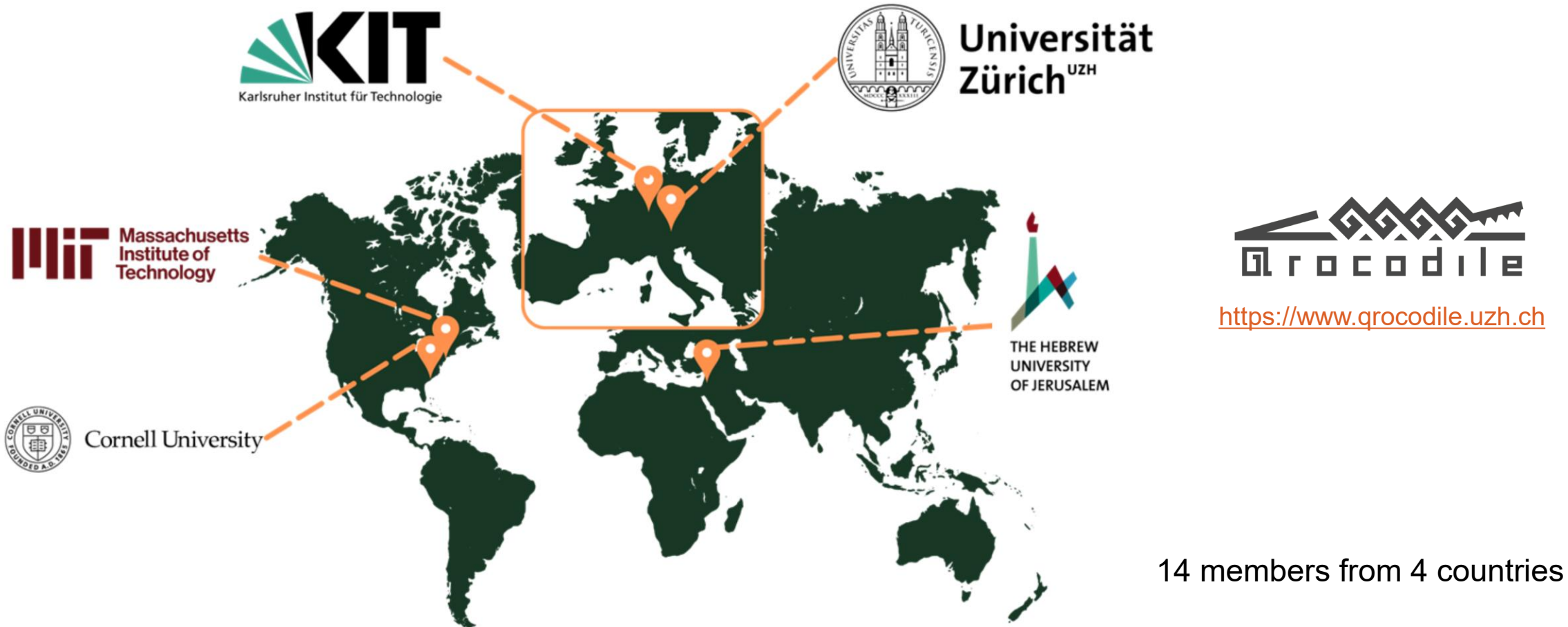
Max. Energy for DM moving at escape velocity ~544 km/s

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



The QROCODILE collaboration

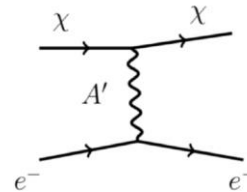
Quantum Resolution-Optimized Cryogenic Observatory for Dark matter Incident at Low Energy



The QROCODILE experiment

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

dark photon ϵ_γ $\times$ photon



Our first publication:

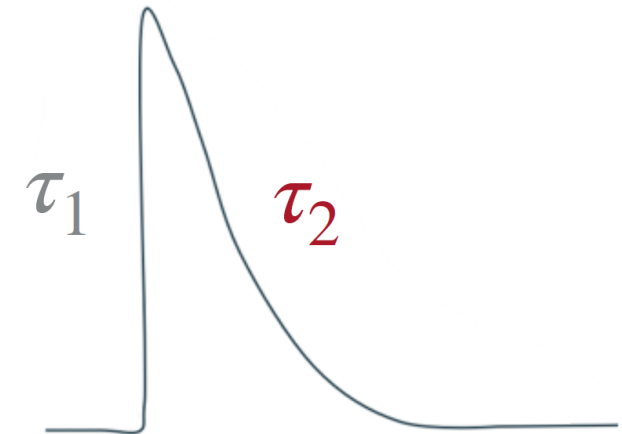
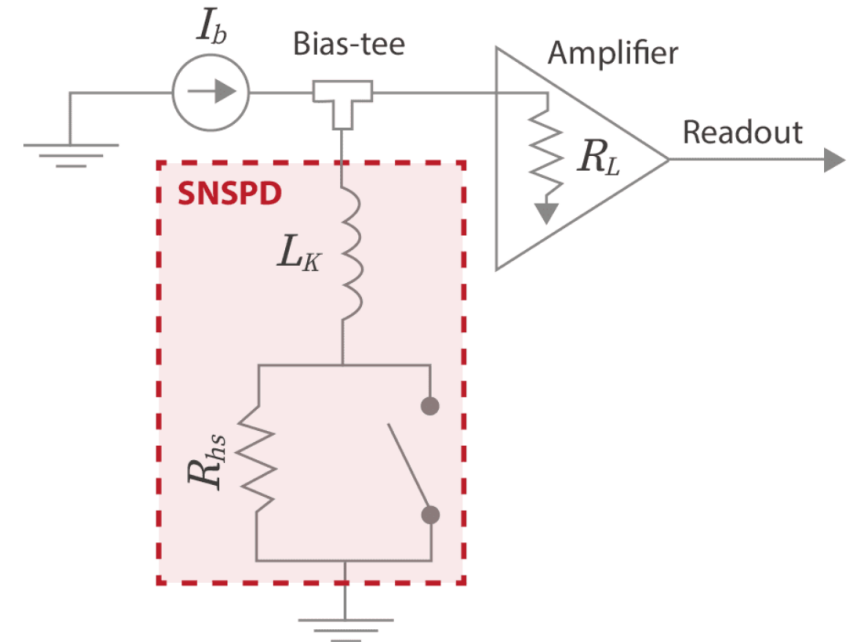
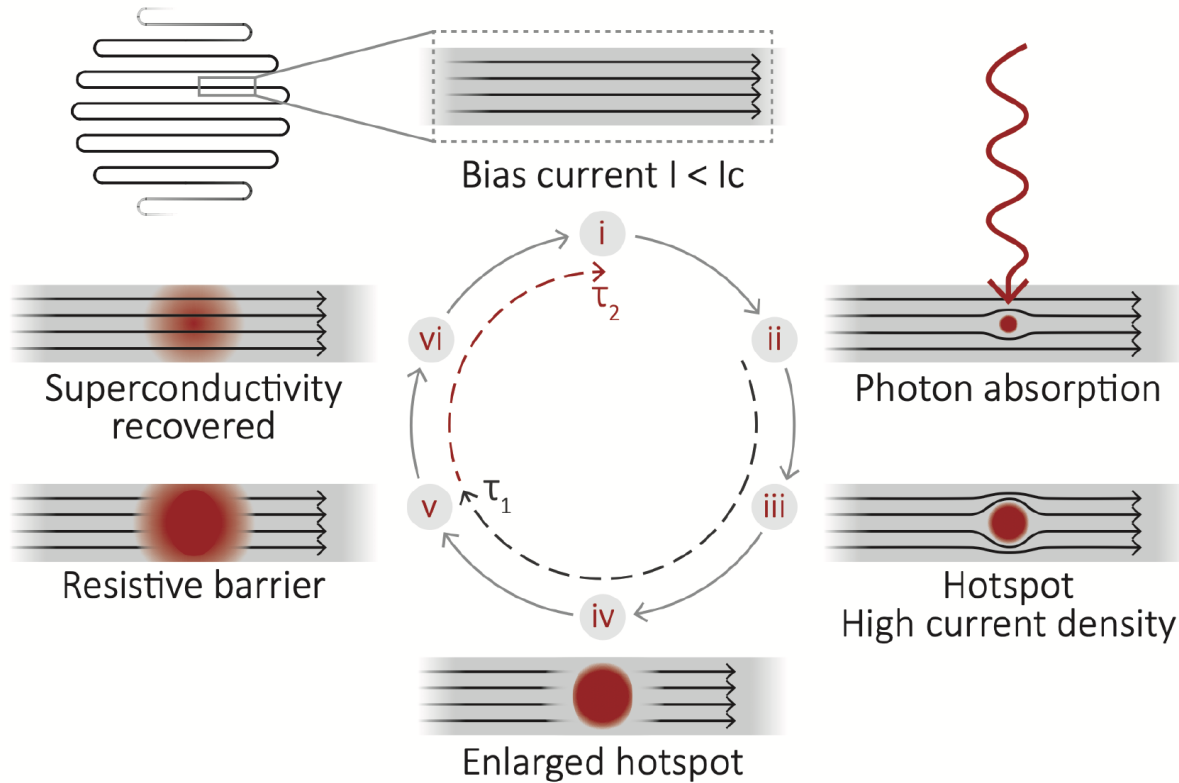
[Phys. Rev. Lett. 135 \(2025\) 8, 081002](#)

QROCODILE @ UZH cryostat



SNSPD working principle

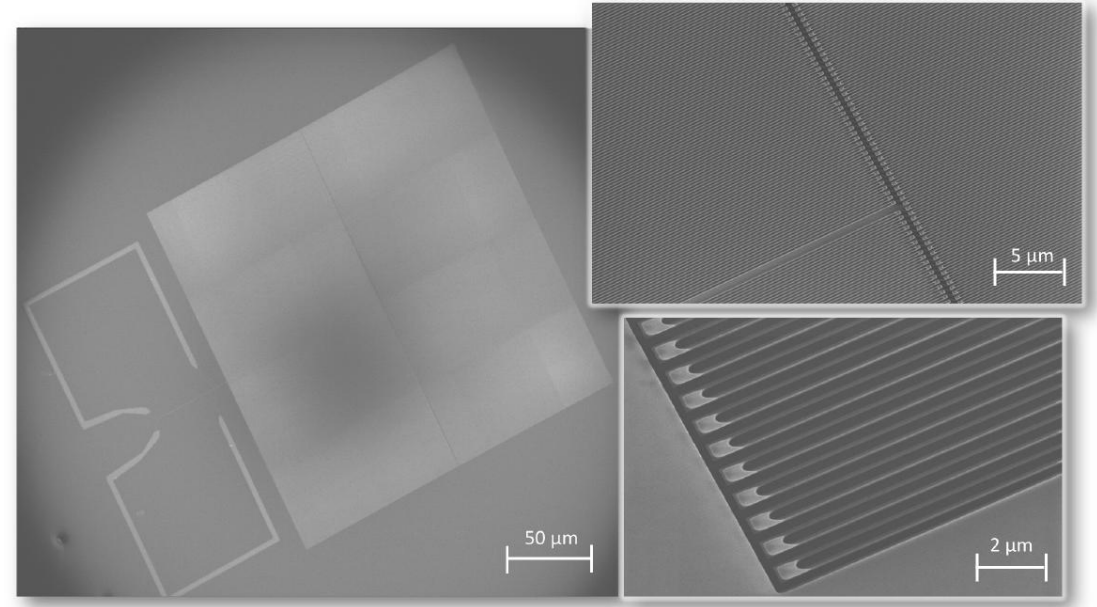
Superconducting Nanowire Single-Photon Detectors



<https://www.singlequantum.com/technology/>
<https://www.idquantique.com/quantum-detection-systems/snsdp-technology/>

Features of the SNSPDs

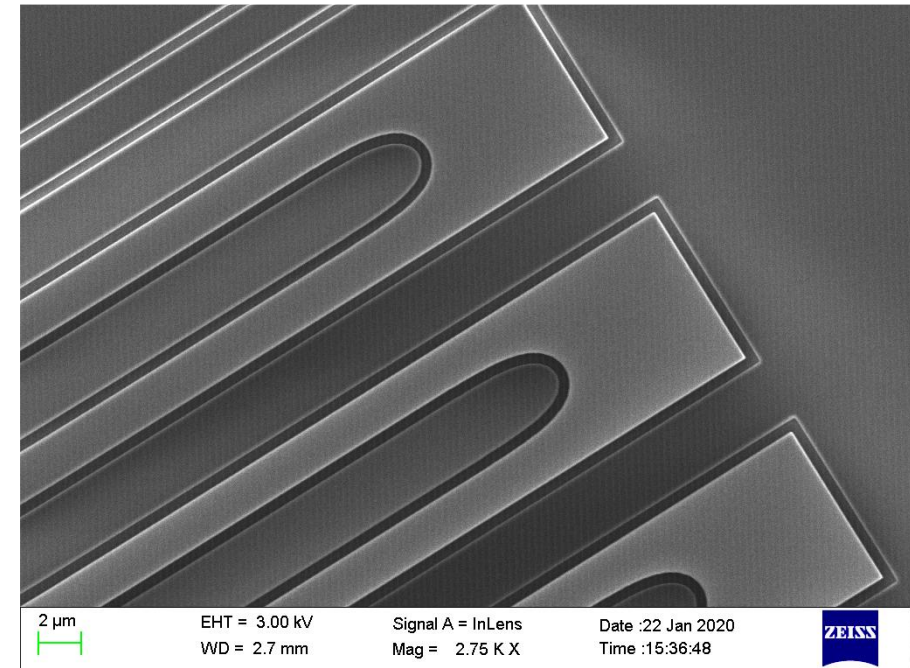
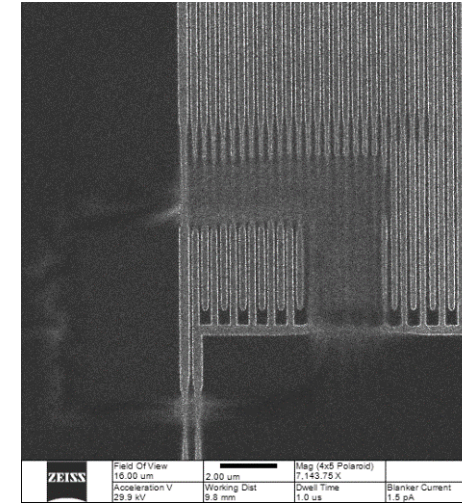
- High detection efficiency (>90%)
- Low dark count rates
- Picosecond timing resolution
- WSi, MoSi: lower-gap materials → more quasiparticles per absorbed photon but with slower diffusion and recovery times – used for IR region
- NbN, NbTiN: higher-gap materials → respond faster but with less intrinsic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



SNSPDs applied to Dark Matter searches

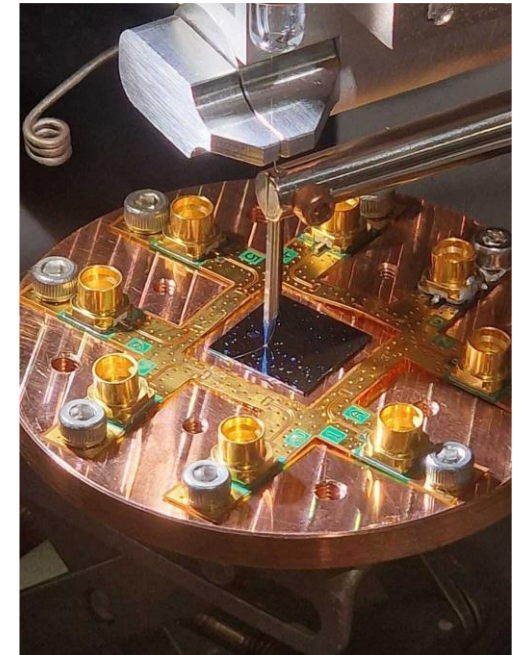
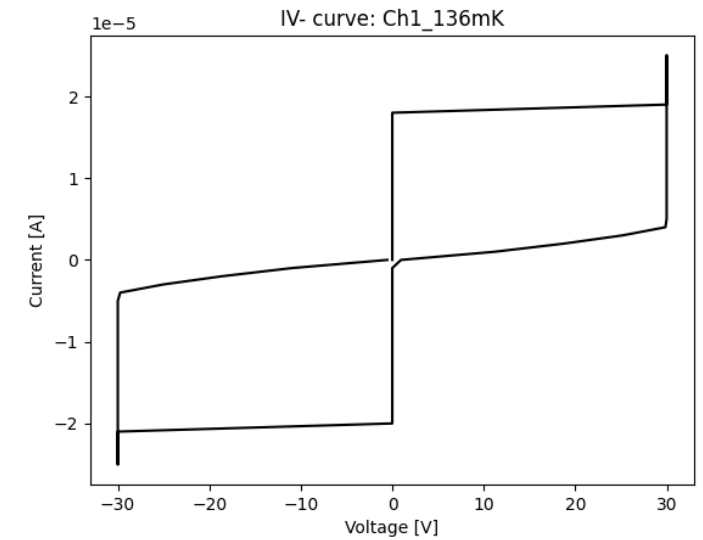
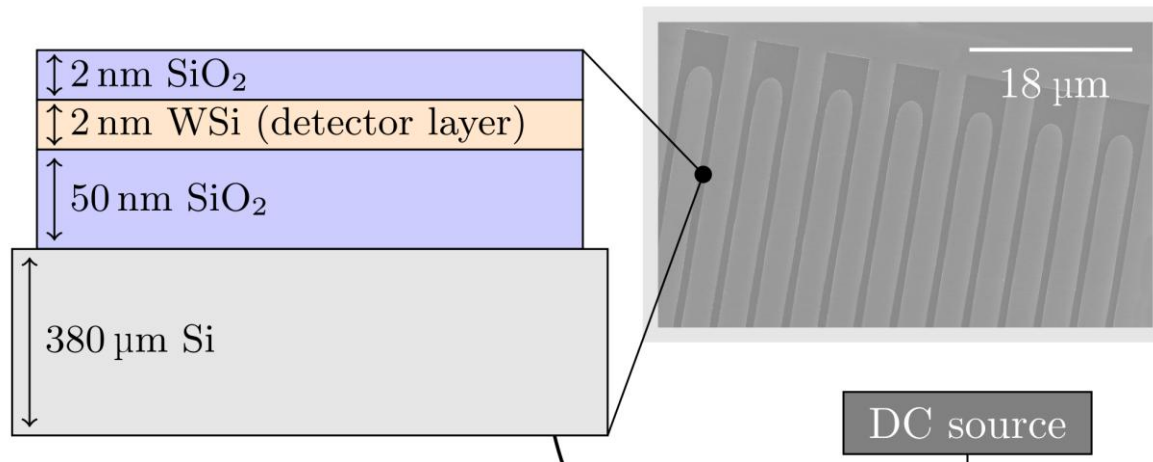
Requirements for dark matter search:

- Large detector mass
 - Mid-infrared detection
 - Low dark count rate
 - Mitigation of background
-
- Small effective volume (active area $10\text{ }\mu\text{m} \times 10\text{ }\mu\text{m}$) $\longrightarrow$ for DM microwires $1\text{ }\mu\text{m}$ wide on large area device $\gg 10\text{ }\mu\text{m} \times 10\text{ }\mu\text{m}$
 - Complex fabrication
 - Non uniformity of wire production that affects critical current
 - Edge or internal structure defects



The sensor

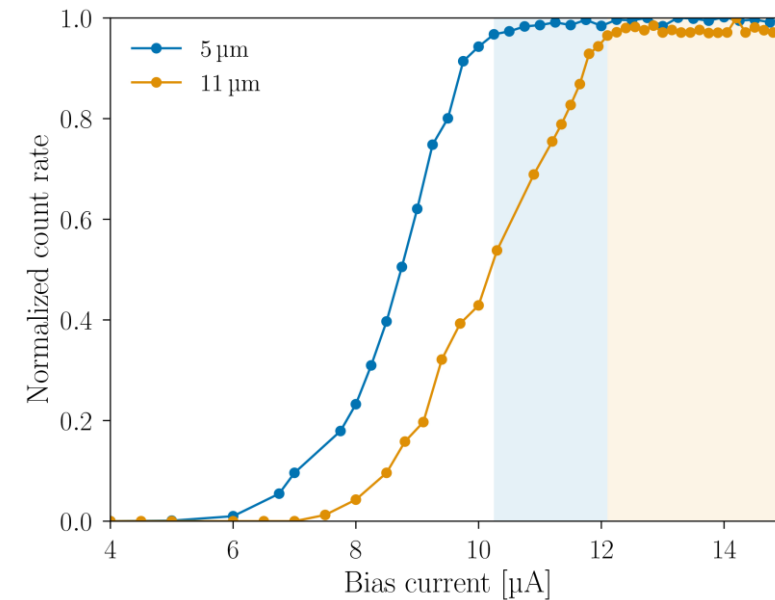
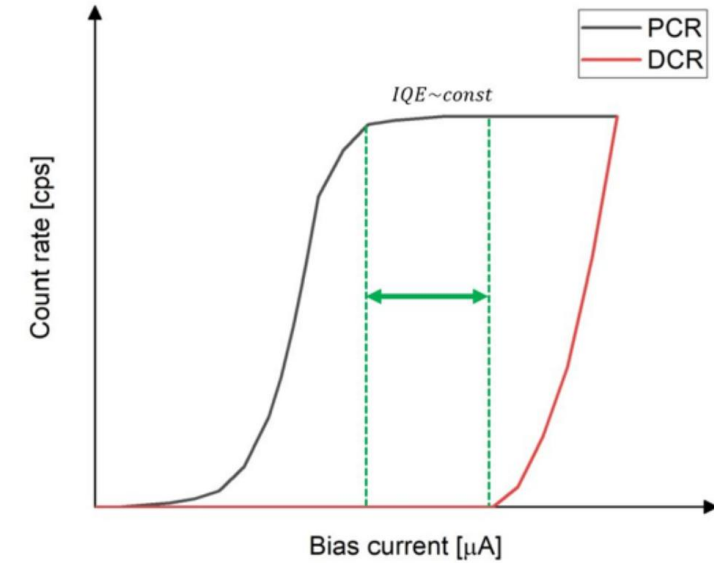
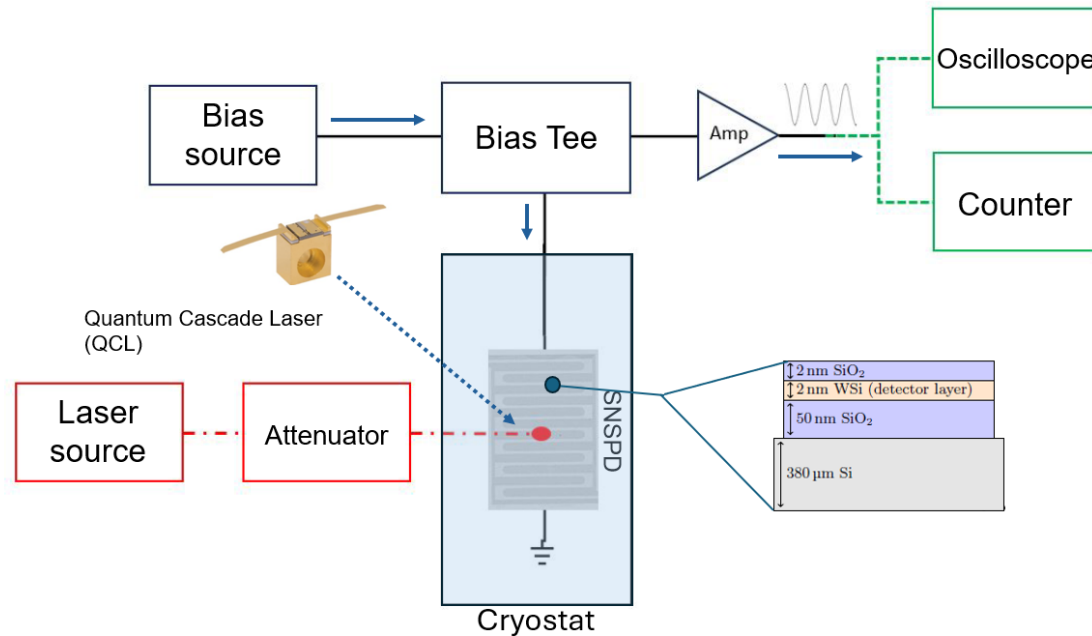
- 10 mm X 10 mm chip size
- 600 μm X 600 μm active area with 1 μm wire width
- 25% filling factor
- WSi 45:55 superconducting layer 2 nm thick
- Transition temperature at 1.73 K
- Si/SiO₂ substrate



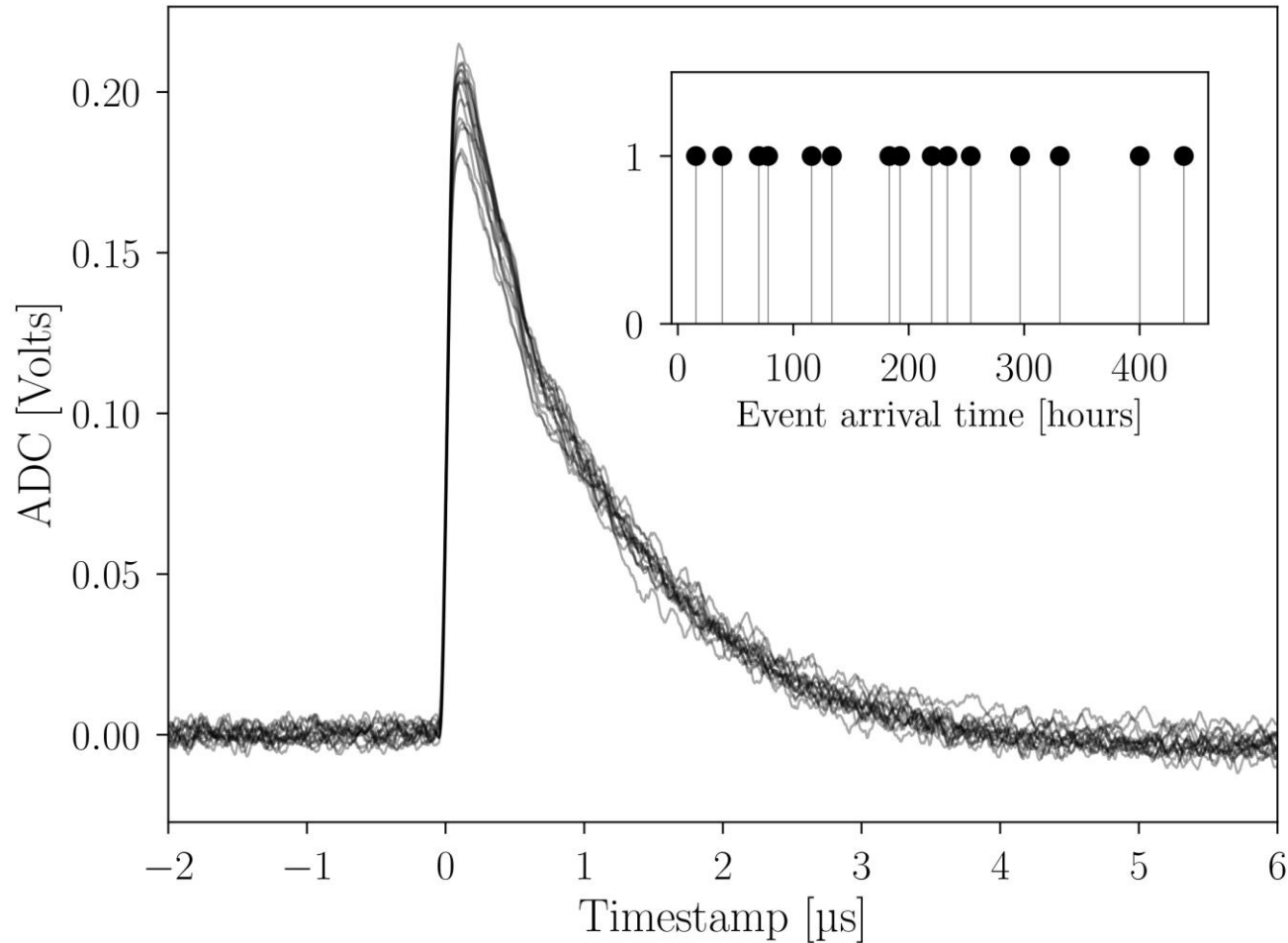
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Calibration

- 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

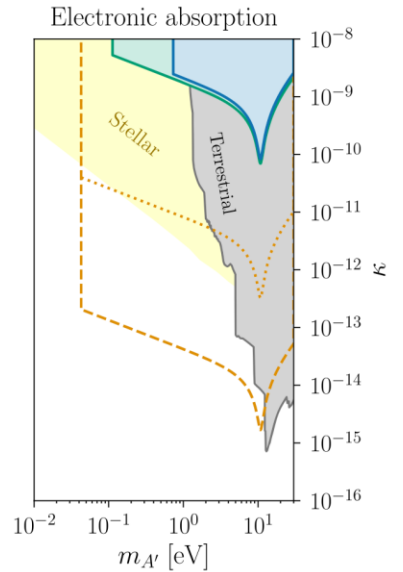
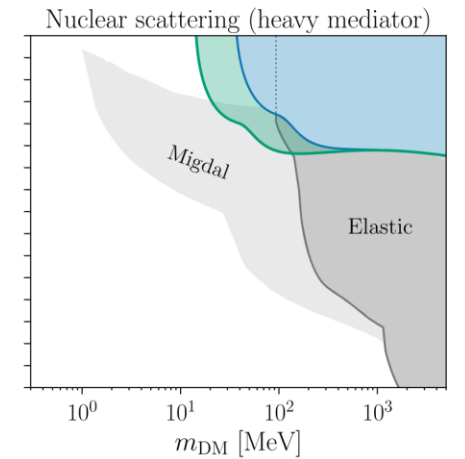
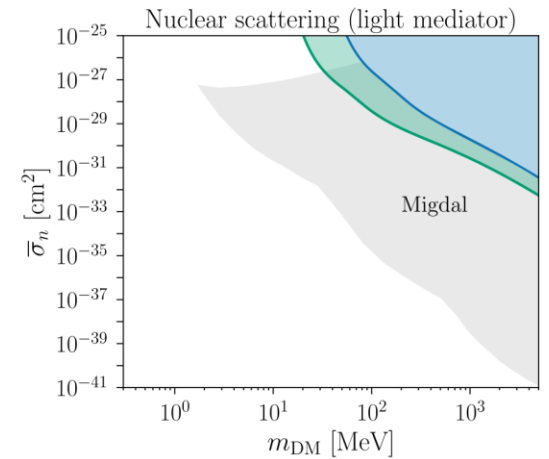
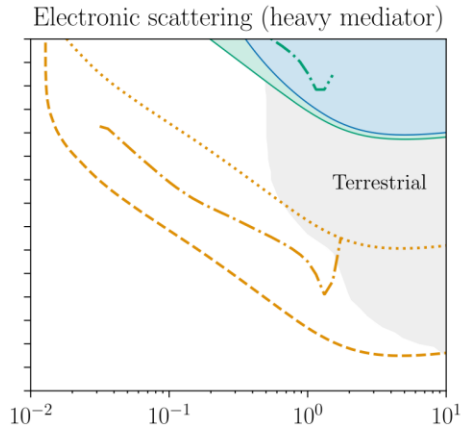
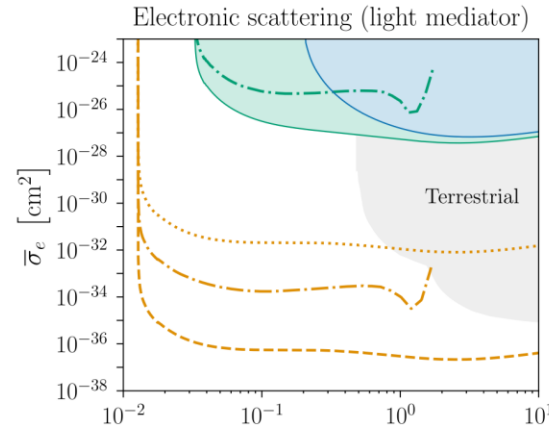
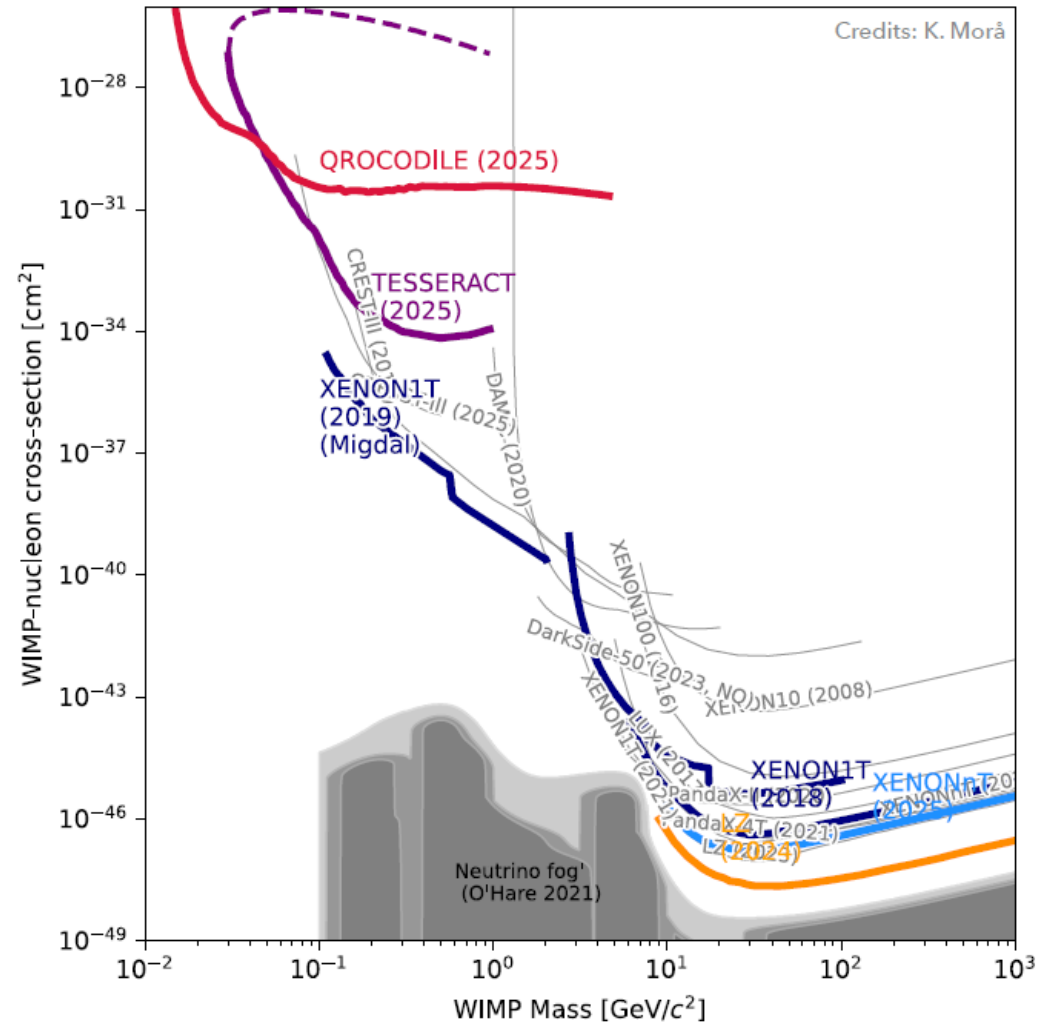


Data taking



- 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



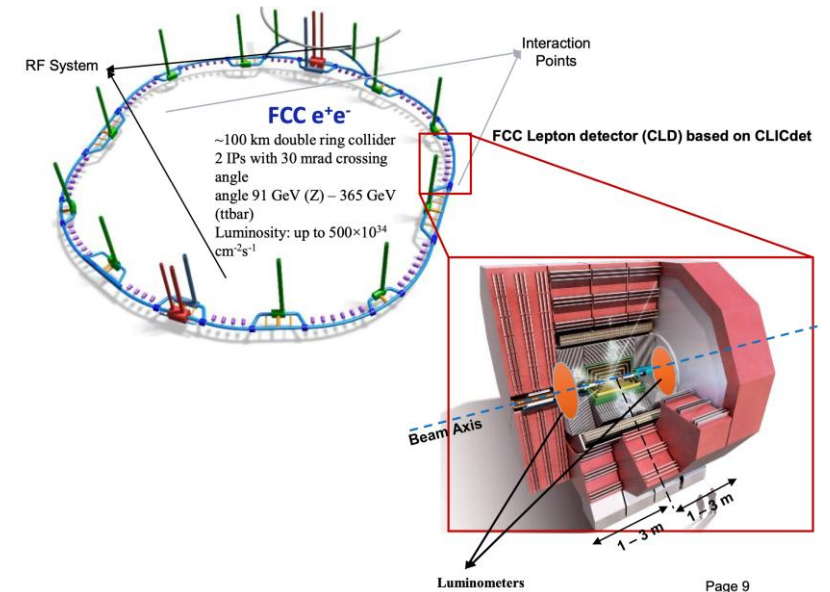
- QROCODILE constraint
- QROCODILE directional sensitivity
- Previous SNSPD constraint
- Future projection: background characterization only
- Future projection: directional sensitivity
- Future projection: background-free

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)

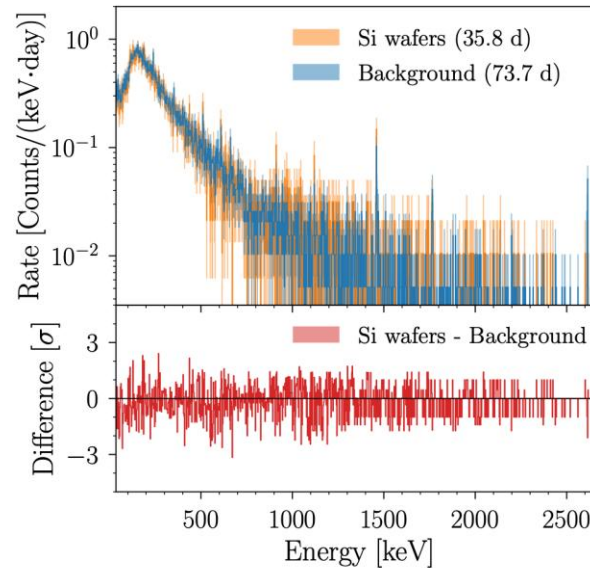


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QROCODILE underground

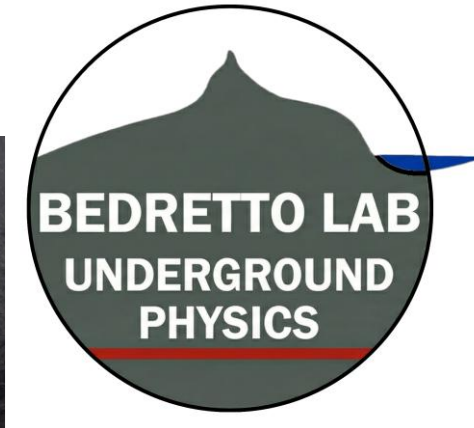
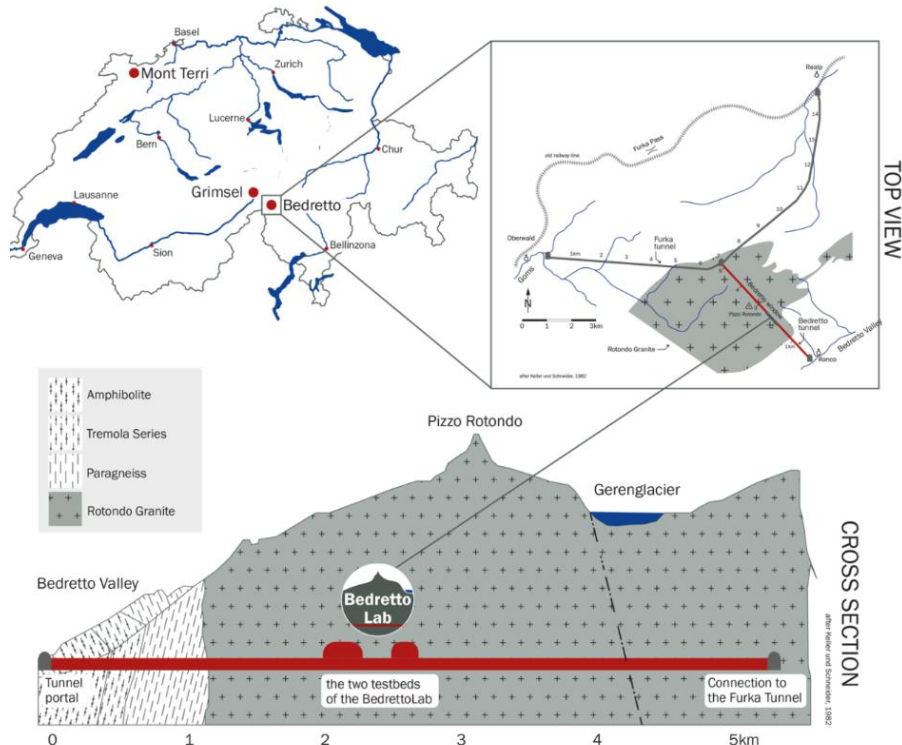
Origin of the events?

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



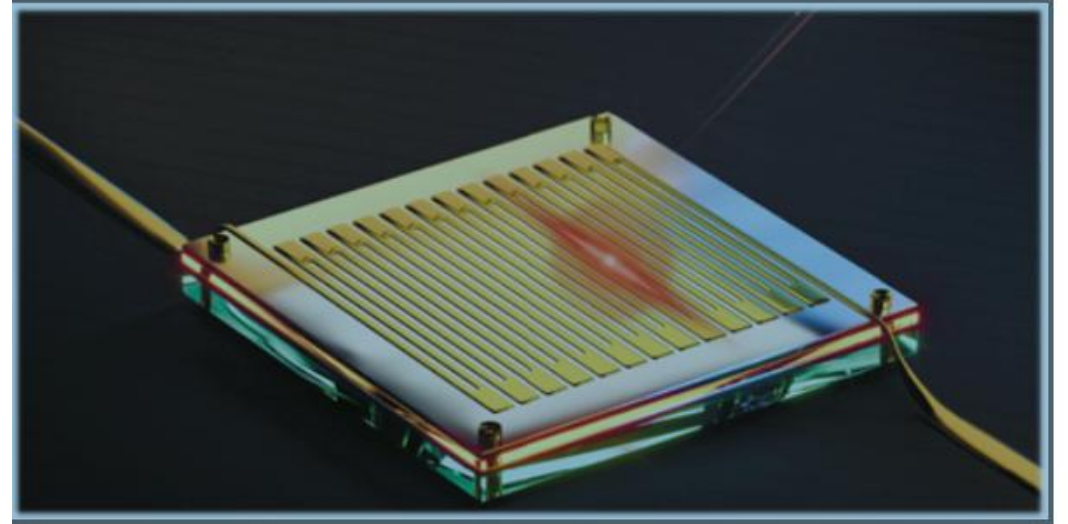
Bedretto lab

- 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



Phys.Rev.Lett. 135 (2025) 8, 081002