Universität Zürich[UZH]

Physik Intitut

BEDRETTO LAB UNDERGROUND PHYSICS

1500 Meters Beneath the Alps:

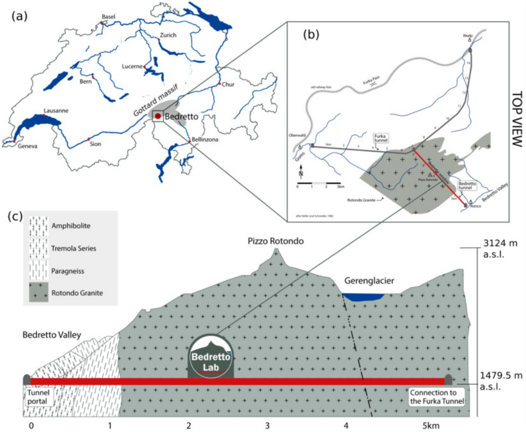
Toward a Swiss Low-Background Laboratory in the Bedretto Tunnel

Florian Jörg `florian.joerg@physik.uzh.ch`
on behalf of the BedrettoLab Physics team

September 21, 2026 - Low Radioactivity Techniques (York)

The Setting

- 5.2 km long, connecting the Furka train tunnel & Bedretto valley, 1000 - 1600m overburden
- Excellent accessibility (2.5hrs from Zürich) two tunnel exits (safety)
- Good infrastructure available (400kVA, optical fiber)
- May 2019: inauguration of the BedrettoLab operated by ETH Zürich
- Research focus: Geothermal energy and earthquake physics



Welcome to 3500 meters inside the mountain

Characterization campaign

Eur.Phys.J.C 86 (2026) 7, 866

- Comprehensive background characterization in bare rock cavern
- Muons, neutrons, gammas, radon
- Vibration
  EMI

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THE EUROPEAN PHYSICAL JOURNAL C

Check for updates

Regular Article - Experimental Physics

Characterisation of the Bedretto underground site for fundamental physics experiments

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Abstract Underground laboratories provide the ultra-low background and low-vibration environments essential for rare-event searches, gravitational-wave detection, and quantum-sensing technologies. We report a comprehensive environmental characterisation of the Bedretto tunnel in Ticino, Switzerland, a site offering horizontal access, excellent infrastructure, and the potential to be Europe's second-deepest and quietest underground laboratory. At the prospective physics site, located beneath a granite overburden exceeding 1400 m, we measure fluxes of: cosmic-muon $(2.54 \pm 0.97) \times 10^{-8}\ \mu/\mathrm{s}/\mathrm{cm}^2$, γ-ray $5.67 \pm 0.37\ \gamma/\mathrm{cm}^2/\mathrm{sec}$, and neutron fluxes $(5.56 \pm 0.26) \times 10^{-5}$ neutrons/cm^2/sec, as well as the radon concentration, magnetic-field power spectrum, and seismic backgrounds. The muon flux is suppressed by six orders of magnitude relative to the surface, consistent with an effective depth of about 4000 m water equivalent. Gamma-ray and neutron measurements reflect the local geology and guide shielding requirements for future particle and nuclear physics experiments. Magnetic and seismic noise levels are found to be exceptionally low, meeting or exceeding the criteria for next-generation atom-interferometric gravitational-wave detectors. These results establish the site as a highly competitive, accessible deep-underground location for fundamental-physics experiments.

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1 Introduction

Underground laboratories provide uniquely reduced background environments and are indispensable tools to understand fundamental physics processes. The massive rock overburden shields effectively even from the highest energetic cosmic rays, they are seismically very quiet since most vibrations travel at the surface and are attenuated quickly at depth, thus also reducing local gravity fluctuations (Newtonian noise). Examples of underground experiments include rare-event searches such as the search for dark matter and neutrinoless double beta decay, rare-decay nuclear physics measurements, low-background material assay, environmental monitoring, and optimal sensitivity and stability of quantum sensors. Furthermore, the stable, low-background, and low-vibration environment offered by underground locations is highly beneficial for gravitational wave detection. Several major deep underground laboratories exist, but none in Switzerland. These facilities often have to prioritise large-scale experiments and offer only limited space for R&D setups and prototyping. Furthermore, their often remote locations and necessary travel lead to logistical and practical over-

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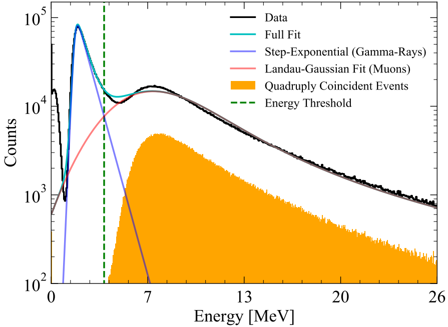
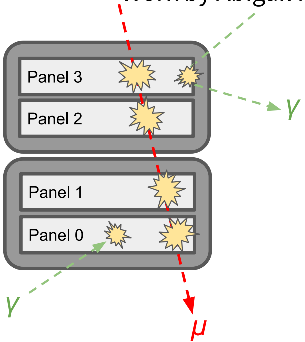
Springer

Cosmogenic background

- Muon flux measurement using 4 plastic scintillator panels read out with SiPMs
- 4-fold coincidence requirement to have negligible background
- Above ground measurement @ UZH





Cosmogenic background

Work by Abigail Flowers

- Muon flux measurement using 4 plastic scintillator panels read out with SiPMs
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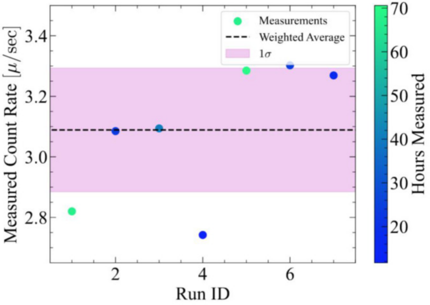
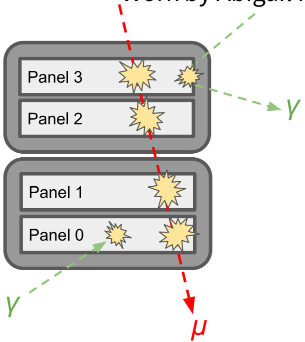
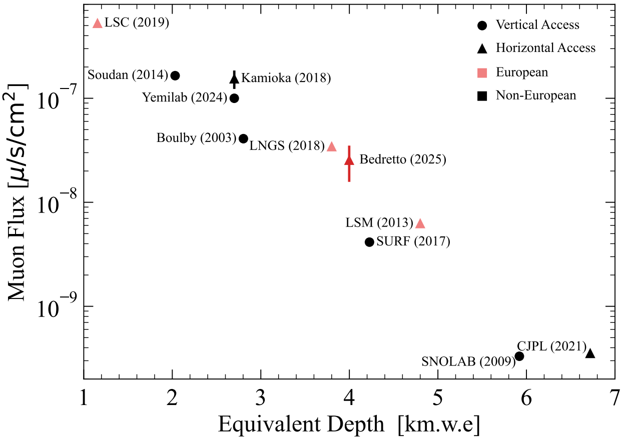




Cosmogenic background

- 21-day measurement underground at TM3500 (472 hours exposure)
- 8 detected muons
- Estimated muon flux: $(2.54 \pm 0.90_{\mathrm{stat}} \pm 0.17_{\mathrm{syst}}) \times 10^{-8} \, \frac{\mu}{\mathrm{sec} \cdot \mathrm{cm}^2}$



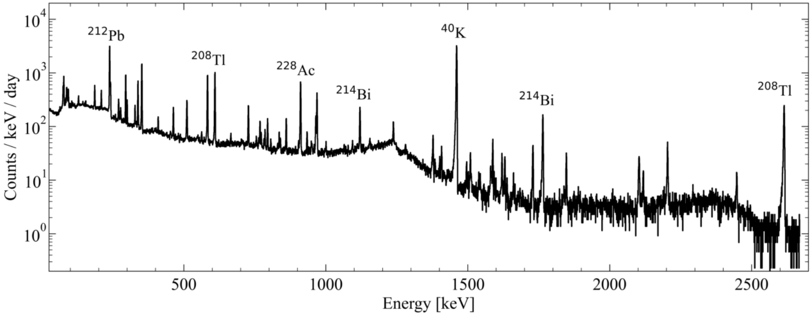
- Good agreement with MC simulations
- Depth of 4km (water equivalent)
- Slightly deeper than Laboratori Nazionali del Gran Sasso (LNGS, Italy)

Work by Aravind Sreekala

Gamma flux

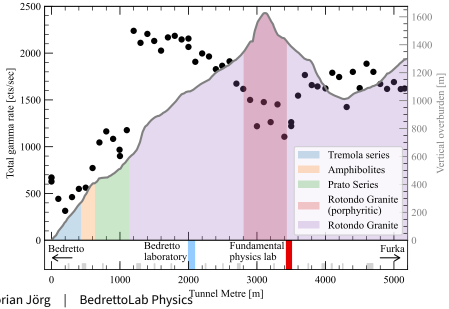
- Gator high purity germanium (HPGe) spectrometer at LNGS (see Aravind's talk on Thursday!)
- Granite rock samples from two different locations in the tunnel
- Primordial radioisotopes ^{40}K, uranium and thorium dominate the activity
- Some variation in activity depending on the location

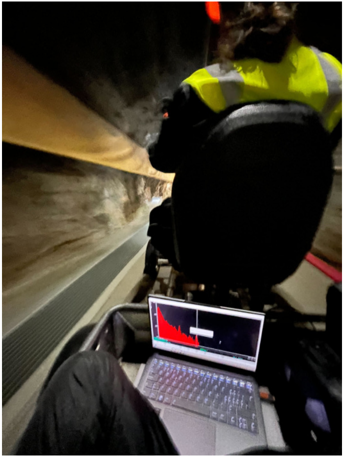
Isotope	Activity [Bq/kg]	
	TM3500	TM2500
^{235}U Chain	1.8 ± 0.1	10.0 ± 0.6
^{232}Th Chain	83.8 ± 1.9	118 ± 3
^{238}U - ^{230}Th	77.4 ± 6.8	221 ± 18
^{226}Ra - ^{206}Pb	56.6 ± 1.3	161 ± 4
^{40}K	1090 ± 50	1130 ± 70



Gamma backgrounds

- Conduct systematic scan of gamma flux along the tunnel
- Using a portable 3”x3” NaI(Tl) scintillation detector
- Clear correlation of flux with with rock type
- The target site at TM3500 is conveniently located at a minimum of the gamma flux!



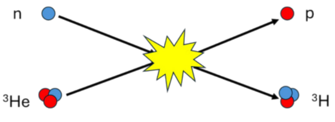


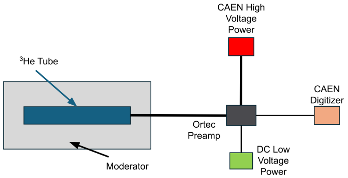
- Flux from ^{40}K about $(3.7 \pm 0.3)\frac{\gamma}{\mathrm{sec \cdot cm^2}}$ (bare rock cavern)
- About $10\times\gamma$-flux at LNGS
- Can be reduced to levels comparable to other underground labs by about 15cm of concrete

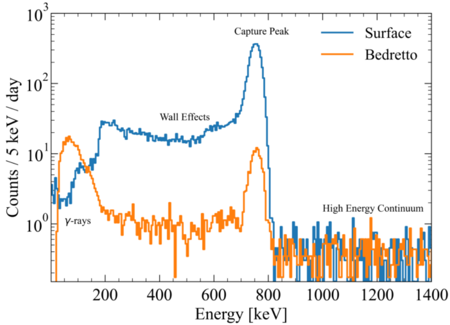
Work by Alexander Kavner

Neutron Flux

- Using a ^{3}He filled proportional counter
- Thermal neutron capture on ^{3}He: Release of 764 keV reaction energy
- Polyoxymethylene (POM) neutron moderator
- Independently confirmed using a LiI(Eu) scintillation detector



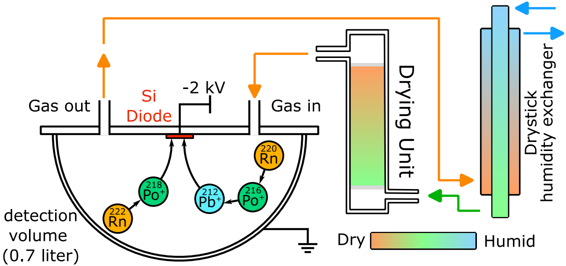


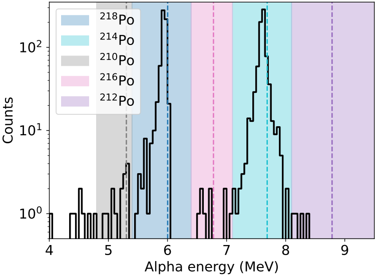


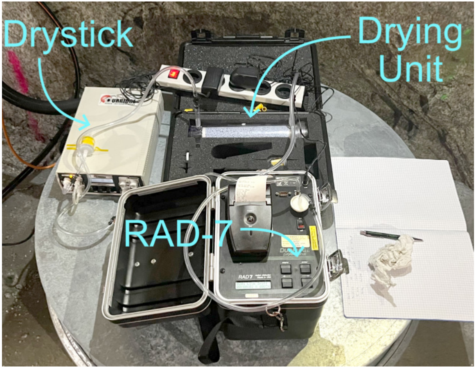
- Measured thermal neutron flux: $(5.6 \pm 0.3) \times 10^{-5} \frac{\mathrm{n}}{\mathrm{sec{\cdot}cm^2}}$
- Almost 2 orders of magnitude lower than above ground neutron flux
- For now (bare rock cavern): Higher than other underground labs. Can be mitigated by concrete cladding of the tunnel

Radon measurement

- RAD-7 commercial radon monitor
- Electrostatic collection of radon progeny
- Humidity diminishes detection efficiency
  - Use of Drydrite desiccant
  - Reduction of desiccant consumption using a Drystick

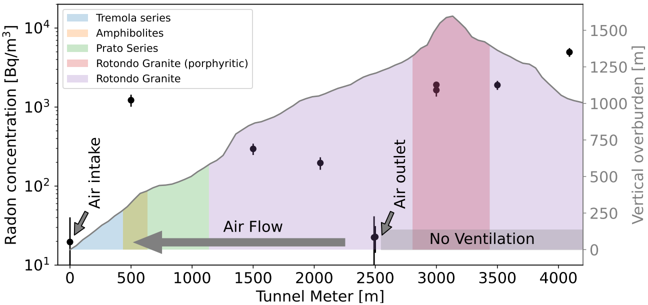


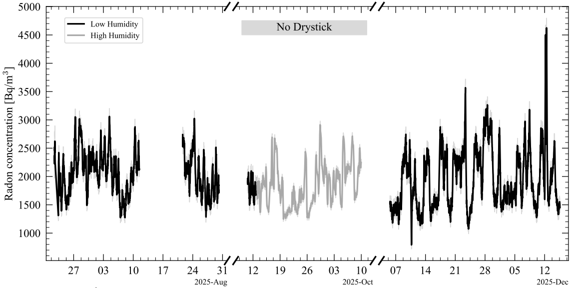




Radon

- Measurements at various locations along tunnel
- At ventilation outlet: Compatible with outside
- High concentration in unventilated section



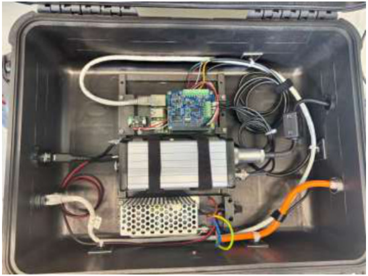


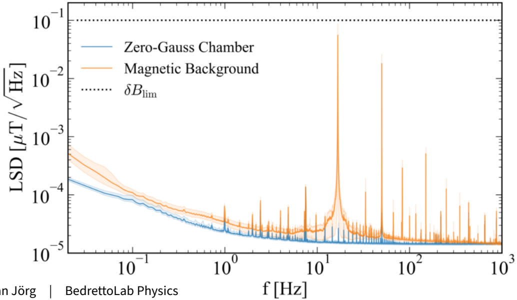
- Long term measurement at TM3500 (since July 2025)
- **Extension of ventilation required!**
- **Possible to reduce radon to ambient level (10s of Bq/m^3)**

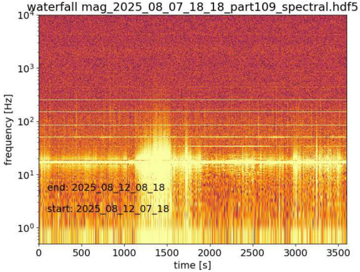
Work by Guandi Zhao

Electromagnetic

- Measurement of the 3-axis magnetic field background (310 hours)
- Instrument sensitivity determined using a zero-Gauss chamber (161 hours)
- Peaks in power spectrum stem from AC power line (50Hz) and train power line (16.7Hz) $\Rightarrow$ Day/Night difference
- Exceeding requirement for atomic interferometry gravitational wave searches



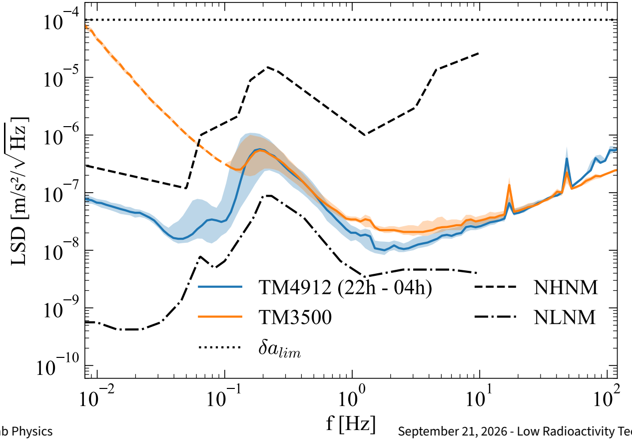




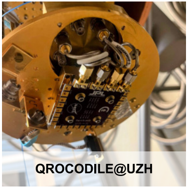
Vibration

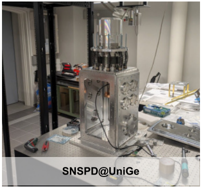
Work by Johannes Wüthrich

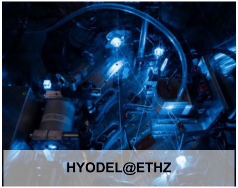
- Using data provided by the Swiss Seismological Service
- Note: Sensor at TM3500 has no sensitivity below 100 mHz
- Seismic noise also shows a spectrum comparable or better than prospective ET sites
- Also very quiet (and predictable) in terms of EMI and vibrations

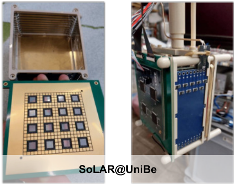


Which physics can be done at Bedretto?







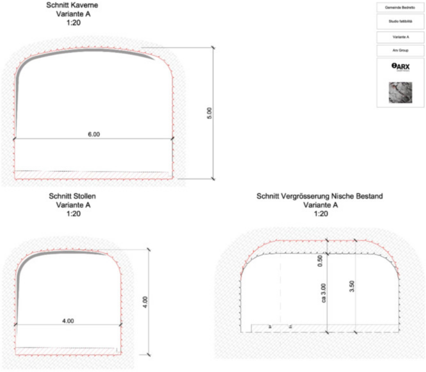


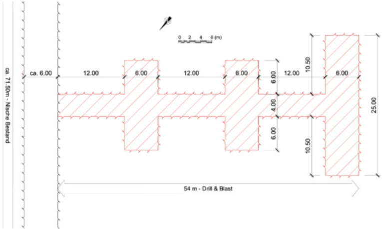
Many more interdisciplinary cross-links (Radionuclide monitoring, Space exploration, etc)

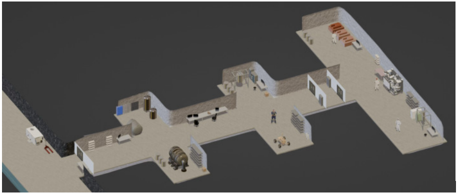
Uni Zürich	Uni Geneva	Uni Bern	ETH Zürich
Penning, Baudis, Soares-Santos	Sanchez, Schramm	Weber, Tuflani	Crivelli, Wiemer

Stage 1 - Excavation plan

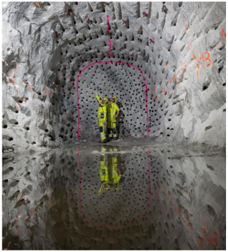
- **main tunnel:**
  55m long, 4m diameter
- **side niches:**
  4 times 6m x 6m area
- **main cavern:**
  - 6m x 25m (150 m^2) with 5m height
  - outfitted as a clean room (ISO7)
  - Dedicated areas for e.g. shielded HPGe counters, dilution fridge, liquid noble gas experiments & infrastructure - and underground micrscopy devices, etc.



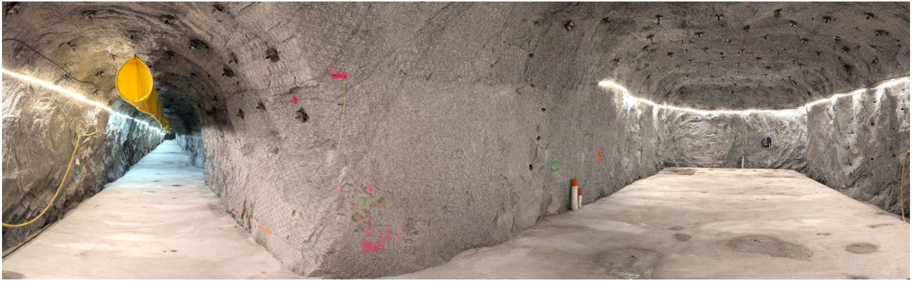




Easy excavation possible



- Common tunnelling methods "drilling and blasting"
- No need for tunnelling machines
- Bedretto tunnel is suitable - originally planned as railway connection



Existing BedrettoLab for Geosciences was excavated in < 1 year

Good news for the Bedretto project!

2027 Swiss Roadmap for Research Infrastructures
swissuniversities' internal process

swissuniversities

End of 2024

Preparation → GS provides information on contact persons at HEIs, selection criteria, governance, and process → Vice presidents inform their institutions about the process

March 2025

Phase A
Coordination
Objective: VPsRES use opportunities of coordination; early establishment of consortium structures.

→ Vice presidents submit project ideas to GS via online form → GS shares project list with VPsRES → **Initial discussion** Vice presidents exchange bilaterally / trilaterally for coordination

May - August 2025

Phase B
Prioritisation
Objective: VPsRES prioritise two-page proposals and make recommendations to the responsible bodies of swissuniversities; if necessary, the prioritisation leads to sensible merging of projects at the earliest possible stage.

→ Vice presidents submit two-page proposals to GS → GS shares two-page proposals with VPsRES → **Discussion/meeting** VPsRES prioritise/rate two-page proposals

Selected steps of the RM27 process organised by the State Secretariat for Education, Research and Innovation

September 2025 swissuniversities first selection of projects → Researchers submit project proposals to the SNSF → **First half of 2026** Scientific Evaluation done by the SNSF

Second half of 2026

Phase C
Pre Selection
Objective: VPsRES pre-select projects and give a recommendation to the responsible bodies of swissuniversities on which projects should be submitted for the Roadmap.

→ GS shares SNSF evaluation results with VPsRES → **Discussion/meeting** VPsRES pre-select projects on the basis of the SNSF evaluation report and the internal selection criteria

Until end of 2027 swissuniversities selects projects for RM27 on the basis of the financial feasibility assessment in consultation with the responsible HEIs → SERI publishes the RM27 for the attention of the Federal Council

We are here

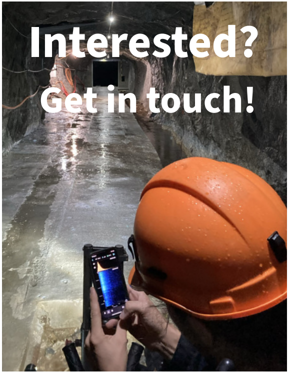
Abbreviations:
GS General Secretariat of swissuniversities **RM27** 2027 Swiss Roadmap for Research Infrastructures
SERI State Secretariat for Education Research and Innovation **Vice presidents** Vice presidents for research
VPsRES Vice presidents for research at the 10 cantonal universities and 2 federal institutes of technology, 1 representative from the universities of applied sciences and arts, 1 representative from the universities of teacher education, and 1 representative from the research institutions of the ETH Domain

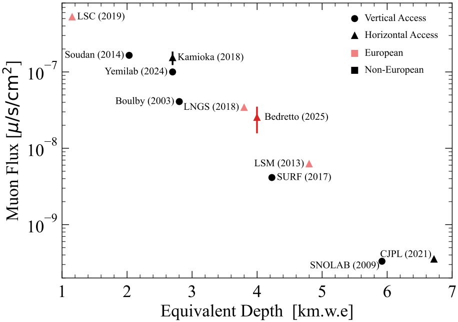
Information for projects of the ETH Domain:
The ETH Board is the responsible body for research infrastructure projects in the lead of institutions of the ETH Domain. The ETH Board takes its decisions according to its established internal process and in line with SERI's guidelines.

Status of the document:
The current process is subject to possible developments and decisions on the part of the responsible institutions.
Bereich Hochschulpolitik
Version 1.1, December 2024

Summary & Timeline

- BedrettoLab Physics will be one of the deepest underground labs
- Background mitigation schemes will be implemented in the design
- Easy horizontal access
- Fast & cost-effective excavations





- Project currently under evaluation for the 2027 Swiss Roadmap for Research Infrastructures
- Received best grade from both reviewers
- Excavations (Stage 1) would be finished in 2030
- First small-scale projects (Stage 0) can be already installed

Backup slides

Project stages

Stage 0 (Now)

- Background measurements
- ARGUS (4k Quantum sensing)
- Detailed Muon tomography
- Astrobiology
- Space Exploration

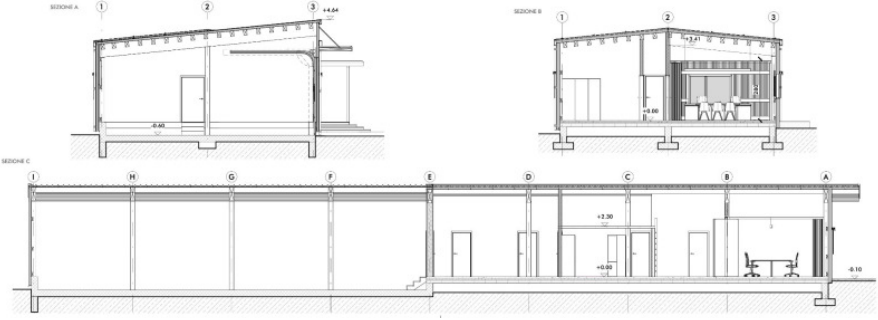
Stage 1 (∼2029)

- HPGe Counter
- mK Quantum Sensing
- Small TPC test-setups
- SoLAr
- Astrobiology
- Space Exploration
- Radionuclide Monitoring

Stage 2 (∼2033)

- HPGe Counter
- mK Quantum Sensing
- LXe full scale demonstrator
- Grav. waves R&D
- Atom Interferometry
- Astrobiology
- Space Exploration
- Radionuclide Monitoring

Surface Infrastructure

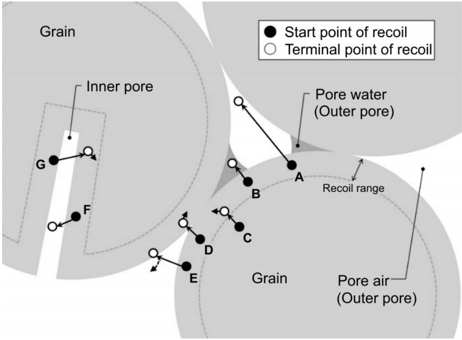


- Existing hut with meeting room, kitchen, network infrastructure, small workshop and storage
- Already planned upgraded building with increased office space, meeting rooms and large garage/assembly area.

How to get in and out?

Radon emanation from rock

- U/Th radioisotopes in rock
- Emanation due to:
  - Recoil
  - Diffusion
- Without air exchange: Radon activity approaches an equilibrium



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