J. Puputti
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TAUP VIENNA 2023

# CALLIO LAB

## Underground Center for Science and R & D

and above ground

Finland
Established 2015

*(2000 - 2015 Centre for Underground Physics in Pyhäsalmi)*


**Traveling to Callio Lab in Pyhäjärvi:**

- 1 hour flight from Helsinki-Vantaa International Airport to Oulu, then 2 hour drive to Pyhäjärvi

**Traveling to University of Oulu main campus:**

- 1 hour flight from Helsinki-Vantaa International Airport to Oulu airport

  or

- 6 hour train ride from Helsinki to Oulu

*Flight from Helsinki to Vienna: 2 hrs 20 min*

# before CALLIO LAB there was CUPP

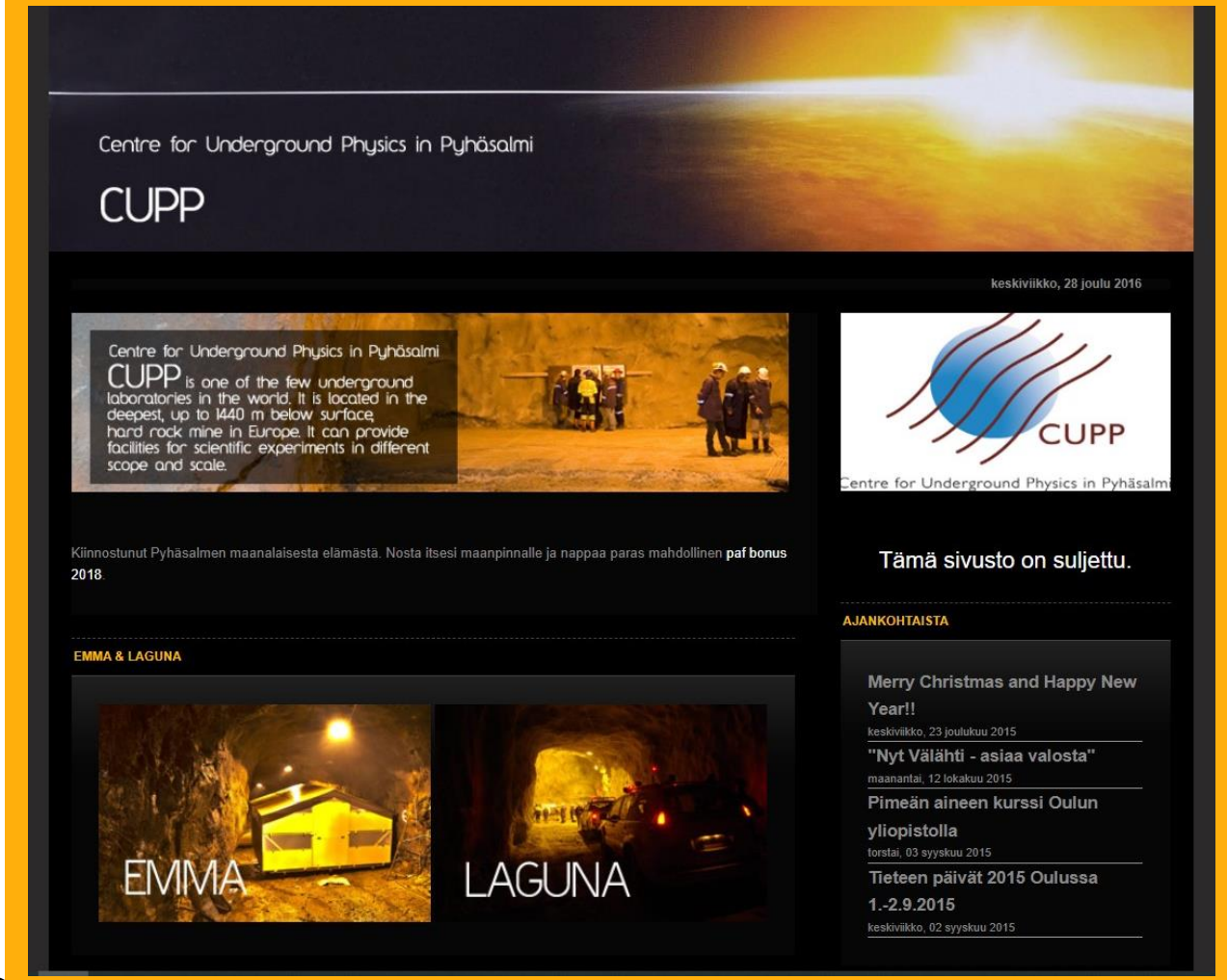
**In 2000, the Centre for Underground Physics in Pyhäsalmi (CUPP) began operation.**

Projects included:

- **Muons UnderGround experiment (MUG)**
- **Mobile Underground Detector (MUD)**
- **Experiment with MultiMuon Array (EMMA)**

- **Two FP7 design studies of a pan-European Infrastructure for Large Apparatus studying Grand Unification and Neutrino Astrophysics (LAGUNA DS and LAGUNA LBNO DS)**

*The LAGUNA and LAGUNA LBNO design studies found the Pyhäsalmi mine site to be the most ideal location.*




***Spin-off*** → MUON SOLUTIONS

# CALLIO LAB at the Pyhäsalmi Mine, in Pyhäjärvi Finland

***New developments at Pyhäsalmi mine:***

- **Underground mining ended after 60 years (1962-2022)**
- **Mill processing pyrite from tailings**
- **New use for underground mine as pumped hydro storage (2024-2074)**

**About the Pyhäsalmi mine:**

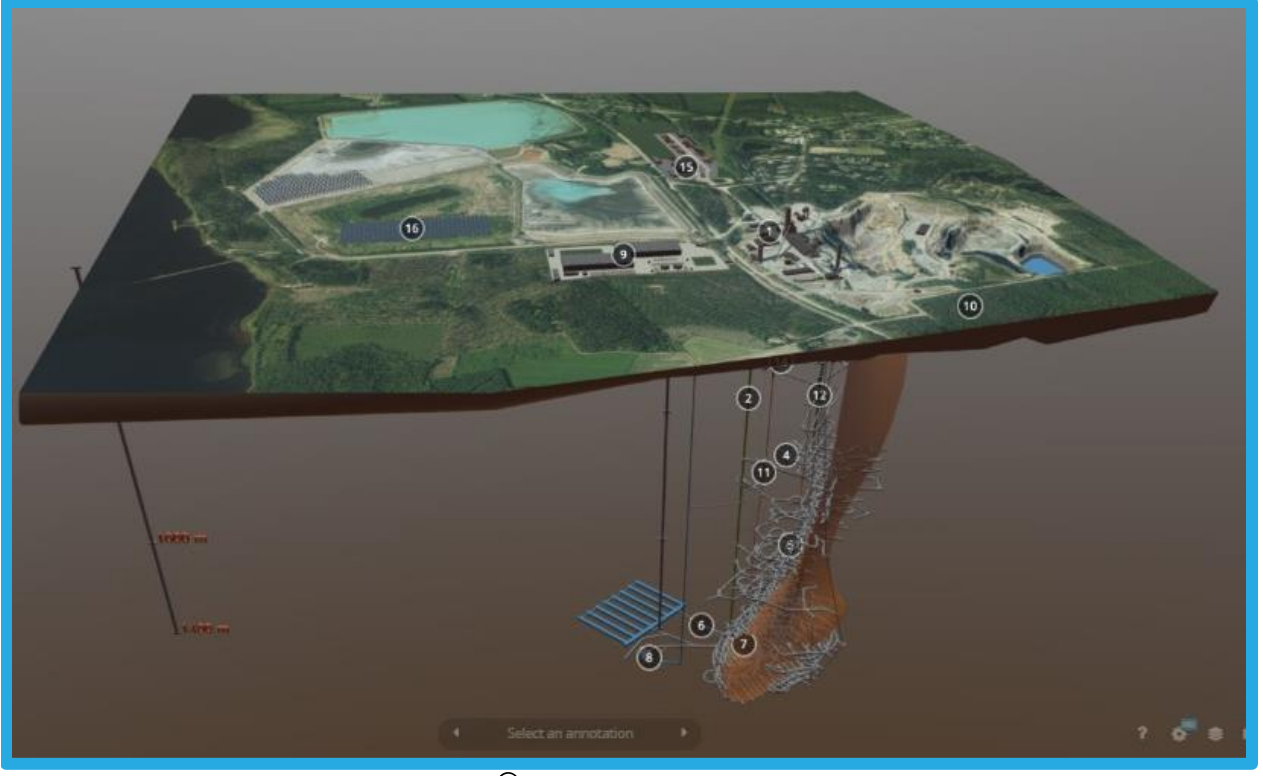
- 1430 meters deep (~4000 m.w.e.)
- Underground mining 1962-2022 (copper & zinc)

- **Owned by** Pyhäsalmi Mine Oy (First Quantum Minerals Ltd)
- **Post-mining activities** coordinated by the Pyhäjärvi town-owned Callio-Mine for Business
- **Scientific activities** are coordinated by the University of Oulu Callio Lab

Pyhäsalmi Mine

MINE FOR BUSINESS CALLIO PYHÄJÄRVI, FINLAND

KERTTU SAALASTI INSTITUTE UNIVERSITY OF OULU



3D-model on Sketchfab

**Owner of mining site:** Pyhäsalmi Mine Oy (PMO)
**Reuse coordinator:** Callio Mine for Business (Callio)
**Scientific coordination:** Callio Lab (CLab)

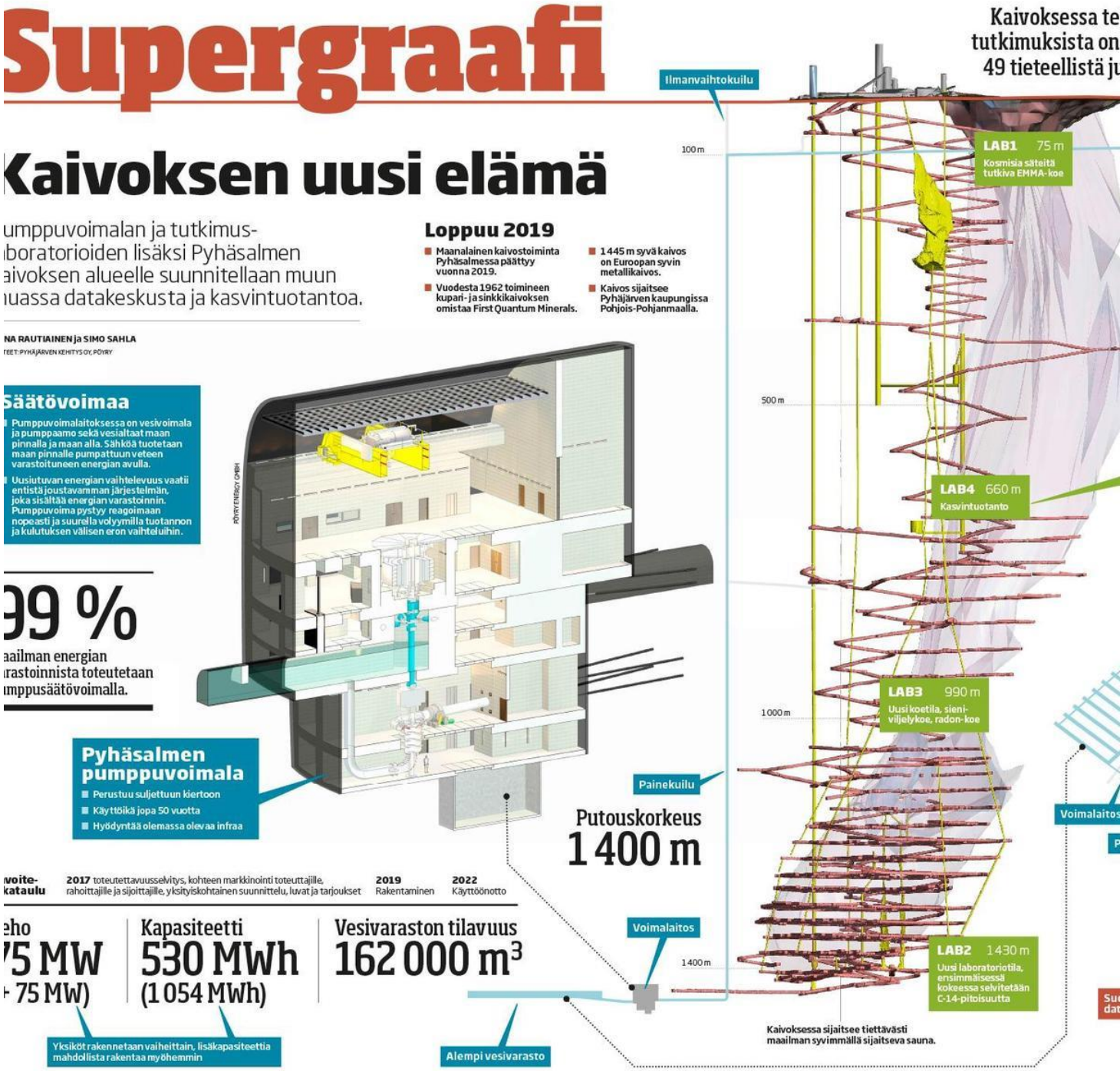
**New life for Pyhäsalmi underground mine as a pumped hydro energy storage**


www.callio.info

## Pumped hydro energy storage:

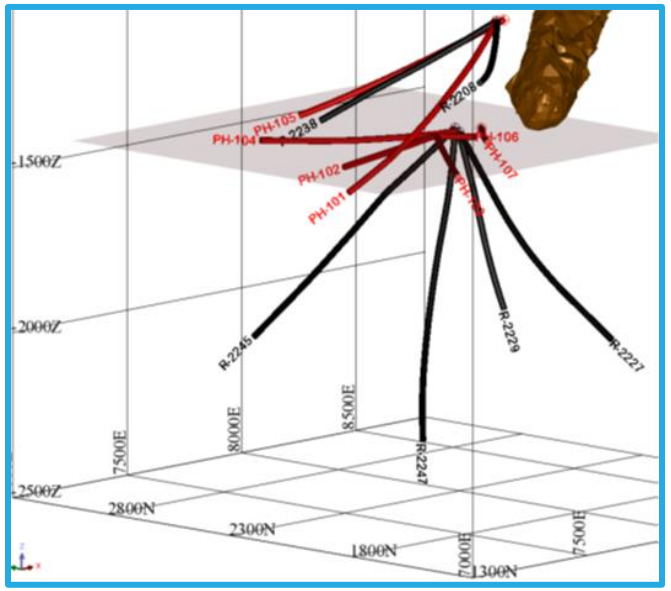
- **Planned mode of operation is continuous**
- **7/9 h cycle (generation/pumping)**
- **50 year lifetime**
- **Building would take 3-4 years**
- **Power 75 MW, capacity of 530 MWh**
- **Cost 125 MEUR + inflation**
- **EU commission approved 26MEUR Finnish measure to support construction**


*The existence of such a facility would ensure the future of scientific activity underground. Final decision due in 2023.*



# CALLIO LAB

# Geology and seismicity



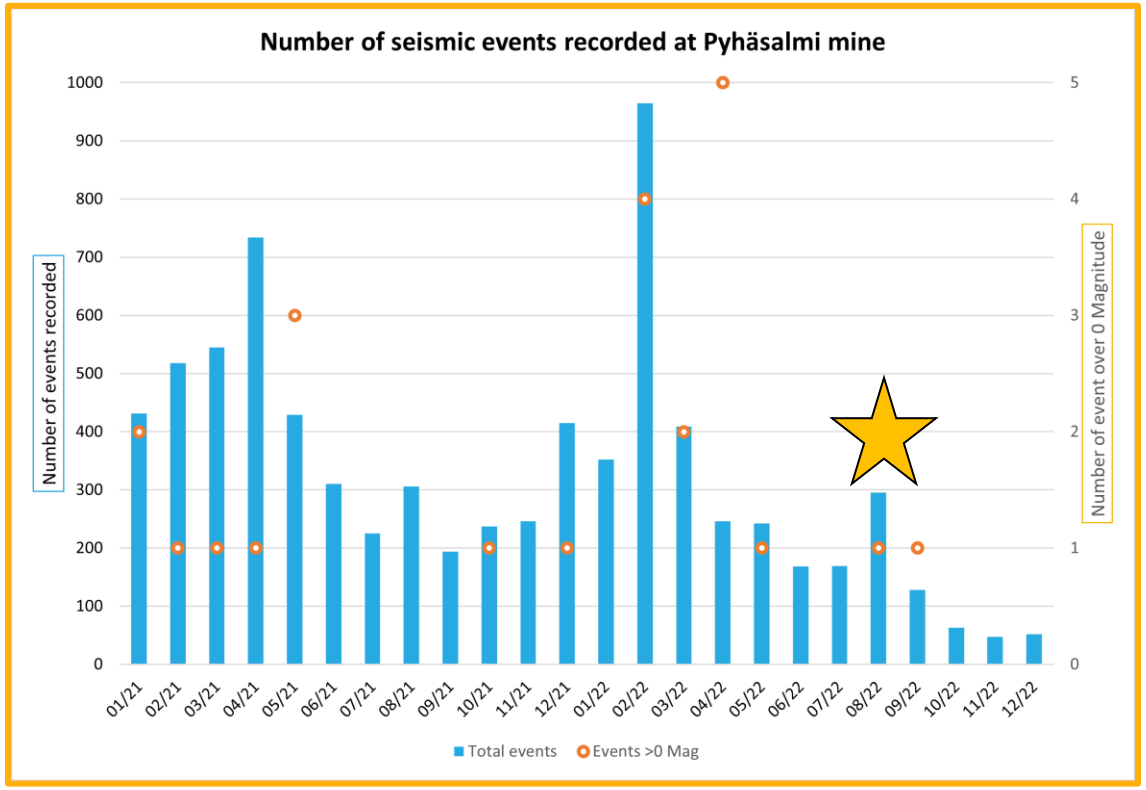

Major rock types:

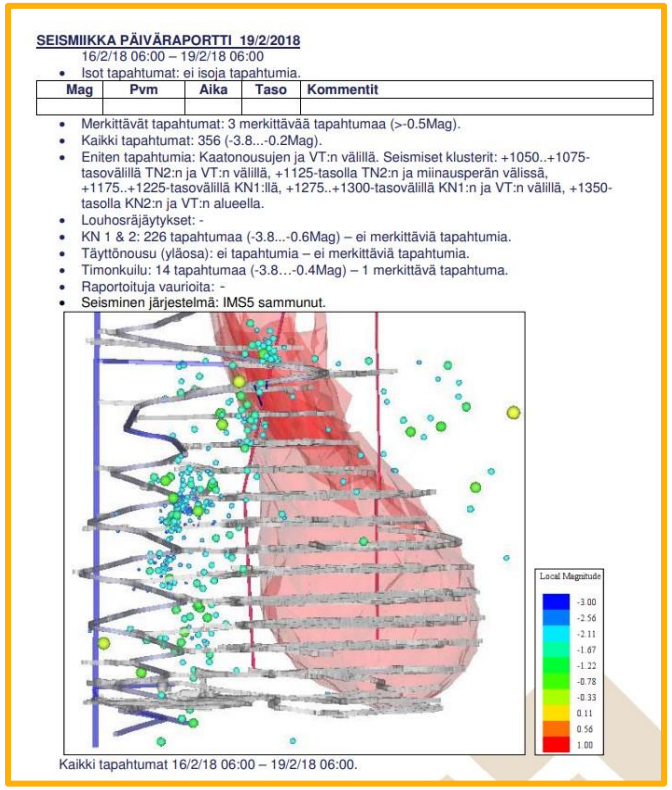
- Mafic volcanic 47.2%
- Felsic volcanic 36.6%
- Pegmatite 7.1%

Since underground mining ended, the seismicity has been observed to settle quite dramatically. Preliminary reports suggest a 70-90% decrease in number of seismic events.

January 2023, there were 46 events between –1.5…-0.6 Mag.

★ *Deepest exploration boreholes reach a depth of 2.4 km, enabling the study of rock mechanics, geochemical composition, microbiome composition*



SEISMIIKKA PÄIVÄRAPORTTI 19/2/2018

16/2/18 06:00 – 19/2/18 06:00

- Isot tapahtumat: ei isoja tapahtumia.

| Mag | Pvm | Aika | Taso | Kommentit |
|---|---|---|---|---|
| | | | | |

- Merkittävät tapahtumat: 3 merkittävää tapahtumaa (>-0.5Mag).
- Kaikki tapahtumat: 356 (-3.8...-0.2Mag).
- Eniten tapahtumia: Kaatonousujen ja VT:n välillä. Seismiset klusterit: +1050..+1075-tasovälillä TN2:n ja VT:n välillä, +1125-tasolla TN2:n ja miinausperän välissä, +1175..+1225-tasovälillä KN1:llä, +1275..+1300-tasovälillä KN1:n ja VT:n välillä, +1350-tasolla KN2:n ja VT:n alueella.
- Louhosräjäytykset: -
- KN 1 & 2: 226 tapahtumaa (-3.8...-0.6Mag) – ei merkittäviä tapahtumia.
- Täyttönousu (yläosa): ei tapahtumia – ei merkittäviä tapahtumia.
- Timonkuilu: 14 tapahtumaa (-3.8…-0.4Mag) – 1 merkittävä tapahtuma.
- Raportoituja vaurioita: -
- Seisminen järjestelmä: IMS5 sammunut.

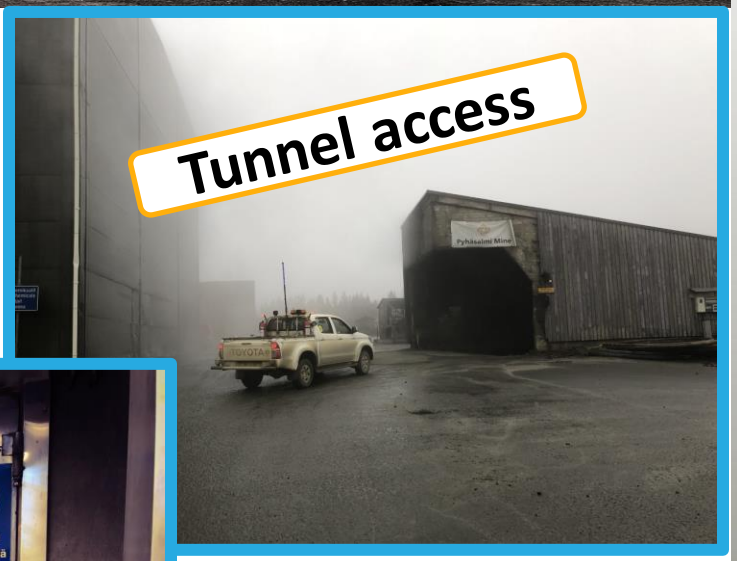


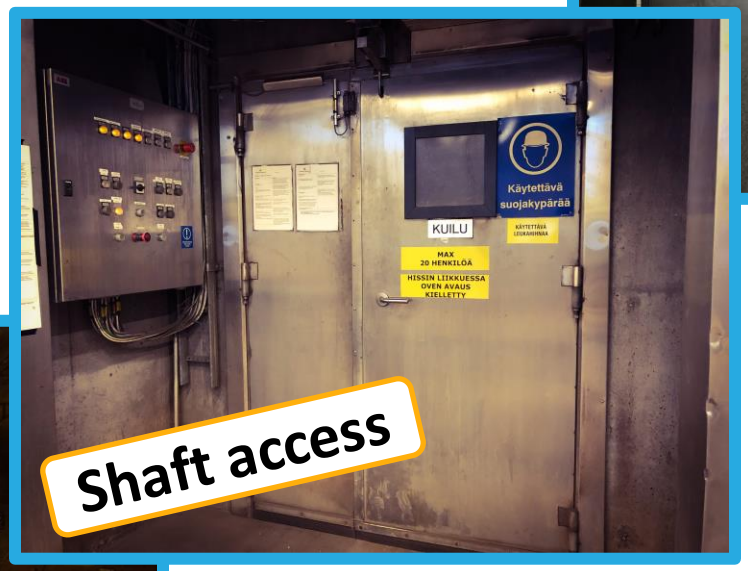
Kaikki tapahtumat 16/2/18 06:00 – 19/2/18 06:00.

# CALLIO LAB Access and transport

Elevator from surface to main level takes 3 minutes

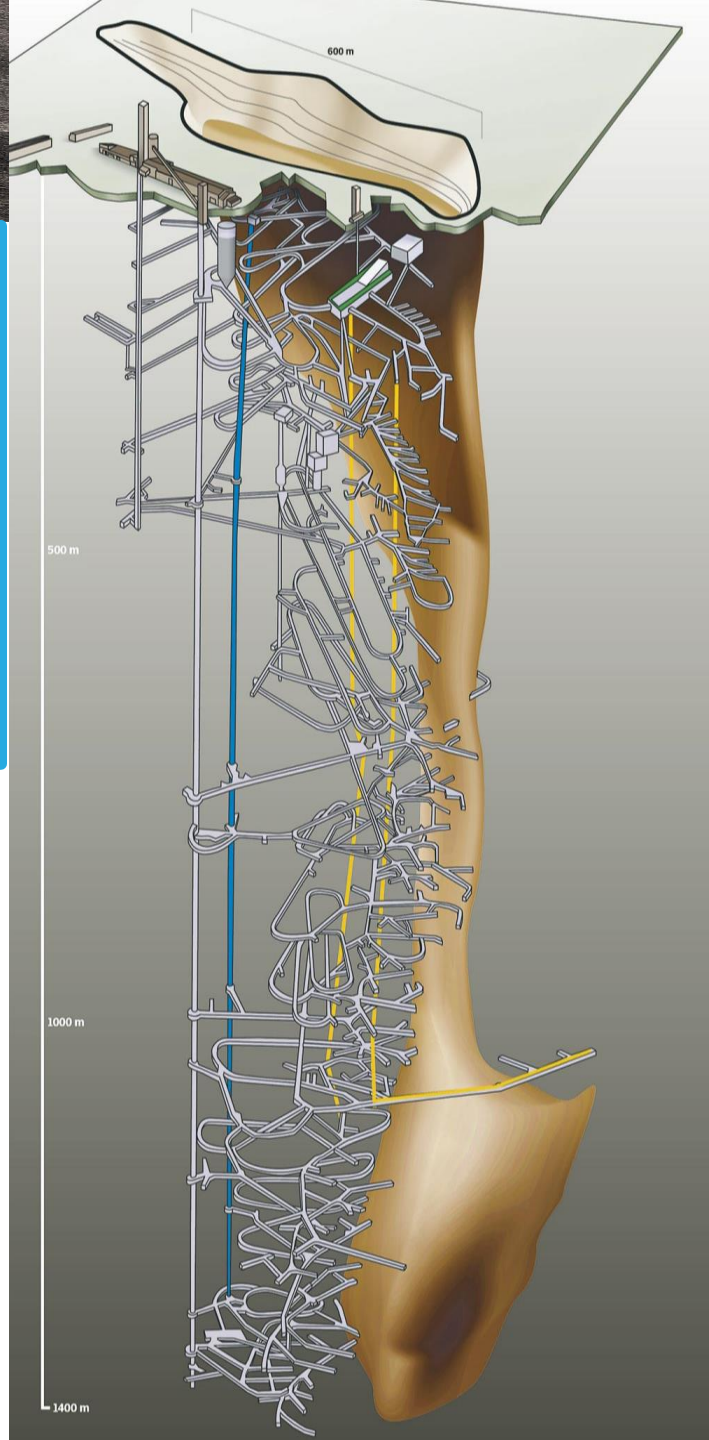
Incline tunnel leads from the surface to the bottom, is 11 km long and takes about 30-40 minutes to drive




Tunnel can accomodate 20 ft containers

Train tracks directly to mine site from Kokkola port









# Main level at +1410 meters underground

# CALLIO LAB

Multidisciplinary research and experiments since 2015

## Basic information:

- Research space rented from mine reuse operator on project basis
- 2 permanent staff, 40+ visiting researchers per year
- Project-based and utilising whole mine environment
- An EPOS Research Infrastructure (ESFRI, 2020)
- A FIN-EPOS Infrastructure (FIRI, 2020)
- Member of DULIA network and collaborating with CELLAR network
- Founding member of European Underground Laboratories Association (EUL, BSUIN projects) Undergroundlabs.network

*For more information on past research and experiments, please visit:*
www.calliolab.com
www.oulu.fi/en/callio-lab

**Education and training**

**Future food & Underground farming**

**Mining & tunnelling**

**SpaceLab**

**Mine reuse**

**Earth Observation and remote sensing**

**Geothermal research**

**Deep underground low background facility**

**Working environment**

**Particle physics & muography**

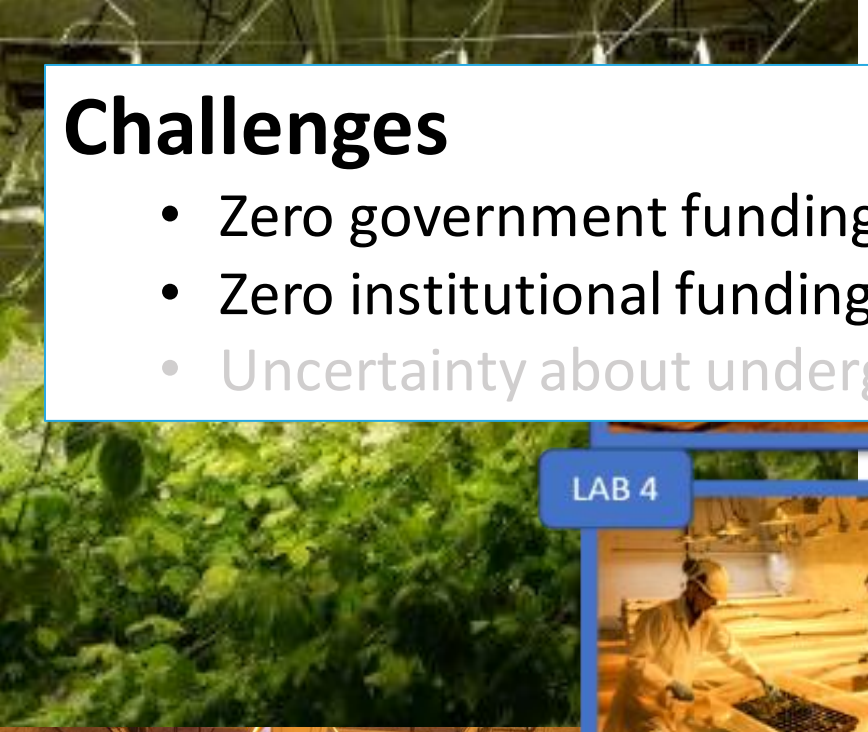
**Underground H&S**

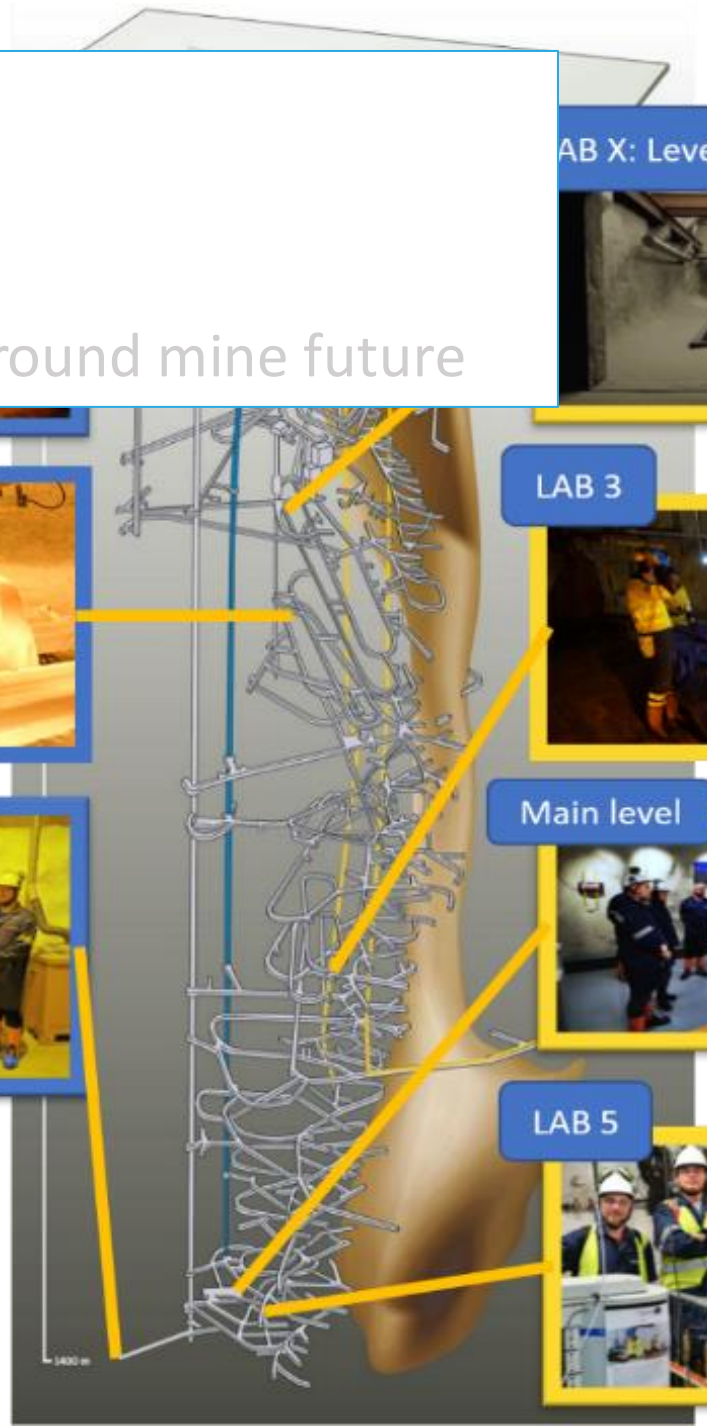
***Something new?***


CALLIO LAB
Underground Centre for Science and R & D
LAB 2
KAMERA
-VALVONTA
LAB X: Lev
LAB 4
LAB 3
LAB 2
Main level
LAB 5
GREENHOUSE LA
Muon flux [cm$^{-2}$ s$^{-1}$]
$10^{-6}$
$10^{-7}$
$10^{-8}$
CallioLab 400
LSC
CallioLab 660
Soudan
Kamioka
CallioLab 990
LNGS
Boulby 1100
Boulby 1400
CallioLab 1390
LSM
SURF
SNOLAB
CJPL
Overburden
Flat
Mountain
2000 3000 4000 5000 6000 7000 8000
Vertical depth [m w.e.]

# Challenges

- Zero government funding
- Zero institutional funding
- Uncertainty about underground mine future

















## Challenges

- Zero government funding
- Zero institutional funding
- Uncertainty about underground mine future

## Approved funding applications since establishment in 2015

- BSUIN/Baltic Sea Underground Innovation Network 2017-2020 (Interreg)
- Underground farming 2017-2018 (EU ERDF)
- Energy Mine 2017-2020 (EU ERDF)
- Intelligent Lighting in Mine 2018-2019 (Finnish Work Environment Fund)
- Edible Insects 2018-2021 (EU ERDF)
- MINETRAIN 2018-2021 (EIT Raw Materials)
- Underground Rescue 2019-2022 (EU ERDF)
- Empowering Underground Labs 2020-2021 (Interreg)
- GoldenEye 2020-2023 (Horizon 2020)
- NordicEPOS 2020-2023
- Mine.io 2023-2026 (Horizon Europe)

# CALLIO LAB 2023

# Earth Observation & remote sensing

## H2020 GoldenEye project:

- Platform for satellites, drones, and in-situ sensors to collect high-resolution data of mine sites, which can be processed and converted into actionable intelligence for safety, environmental monitoring and overall productivity, allowing more efficient exploration, extraction and closure.
- VTT coordinated 10.7 M€ H2020 Innovation Action –project


### *Callio Lab partner role:*

- Provide ground truths and reference data
- Evaluate piloted techniques
- Installations and preparations
- Characterise process and protocols
- Define measuring areas and regions of interest
- Facilitators and operators on-site to assist partners
- Liaison connecting academia, project collaborations, mine stakeholders and society.

# CALLIO LAB 2023

# Earth Observation & remote sensing

## Horizon Europe Mine.io project:

- A Holistic Digital Mine 4.0 Ecosystem is a project focused on industrialization, informatization and sustainable development of the mining sector
- GFT Italy Coordinated 14 M€ Horizon Europe –project
- University of Oulu Mining School will develop and apply a combination of electric resistivity imaging (ERI) and active- and passive-source seismic imaging to map the subsurface structure of tailings embankment and retrieve hydrogeological and elastic parameters


### *Callio Lab partner role:*

- Provide ground truths and reference data
- Evaluate piloted techniques
- Installations and preparations
- Characterise process and protocols
- Define measuring areas and regions of interest
- Facilitators and operators on-site to assist partners
- Liaison connecting academia, project collaborations, mine stakeholders and society.

*Honorary mention to Callio Lab's own Jari Joutsenvaara, who is busy coordinating his own Horizon Europe project AGEMERA*

# CALLIO LAB 2023

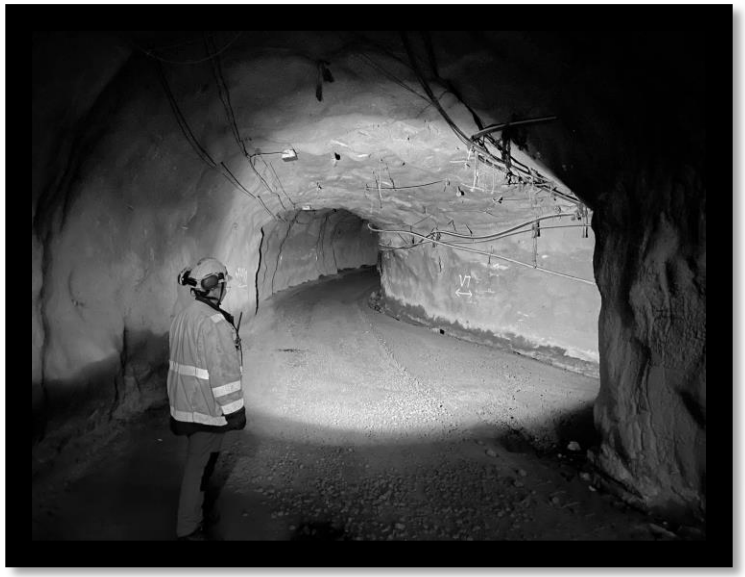
## Collaborative, transdisciplinary research

***Callio Lab role:***

- is to host art residences, events underground
- More-than-Planet DeepLAB symposium 2023
- More-than-Planet residencies 2023-2024

## More-than-Planet project:

- re-examine the way people understand and picture the environment on the level of the planet as a conceptual whole
- Develop societal awareness of environmental urgencies, through novel environmental narratives in cultural and public spaces as well as in specific critical zones.
- Develop collaborative and art-driven innovation approaches with critical and creative tools for addressing today's environmental troubles.
- facilitate collaborative, transdisciplinary (artistic) research by conducting open calls, conferences, exhibitions and publications.



Pictures by A. Tenetz

# CALLIO LAB 2023

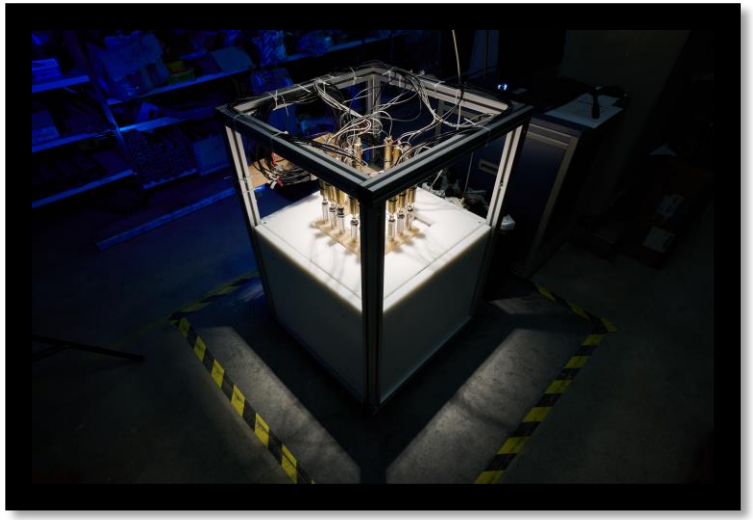
# Particle physics

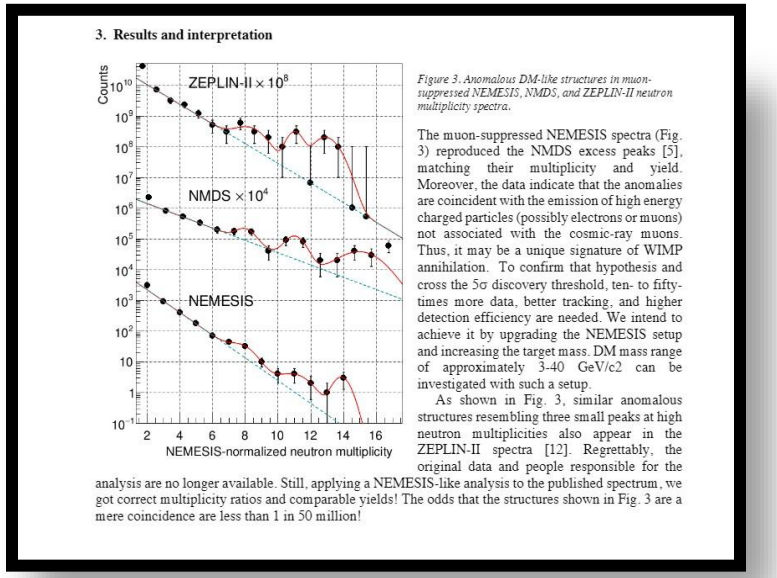
***Callio Lab role:***

- Facilitate and assist with experiment deployment, installation, and maintenance
- we offer coordination, collaboration, networking, and facilitation
- Provide access to facilities on-site and remotely
- Established operating methods for fast deployment of new activities, especially as a site for Proof-of-Concept research

## NEMESIS 1.4 DM-experiment:

- NEutron MEasurementS In Sub-terrestrial locations
- Evidence for DM-like anomalies in neutron multiplicity spectra collected underground with Pb targets by three independent experiments: NEMESIS (at 210 m.w.e.) NMDS (at 583 m.w.e.), and ZEPLIN-II (at 2850 m.w.e.)
- new analysis shows small but persistent anomalies at high neutron multiplicities
- Upgraded setup moved to main level at 4000 m.w.e.





**3. Results and interpretation**



*Figure 3. Anomalous DM-like structures in muon-suppressed NEMESIS, NMDS, and ZEPLIN-II neutron multiplicity spectra.*

The muon-suppressed NEMESIS spectra (Fig. 3) reproduced the NMDS excess peaks [5], matching their multiplicity and yield. Moreover, the data indicate that the anomalies are coincident with the emission of high energy charged particles (possibly electrons or muons) not associated with the cosmic-ray muons. Thus, it may be a unique signature of WIMP annihilation. To confirm that hypothesis and cross the 5σ discovery threshold, ten- to fifty-times more data, better tracking, and higher detection efficiency are needed. We intend to achieve it by upgrading the NEMESIS setup and increasing the target mass. DM mass range of approximately 3-40 GeV/c2 can be investigated with such a setup.

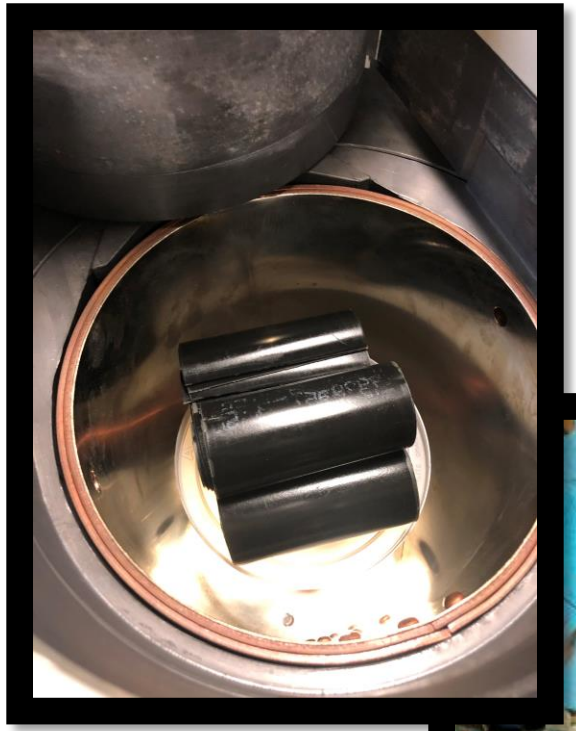
As shown in Fig. 3, similar anomalous structures resembling three small peaks at high neutron multiplicities also appear in the ZEPLIN-II spectra [12]. Regrettably, the original data and people responsible for the analysis are no longer available. Still, applying a NEMESIS-like analysis to the published spectrum, we got correct multiplicity ratios and comparable yields! The odds that the structures shown in Fig. 3 are a mere coincidence are less than 1 in 50 million!

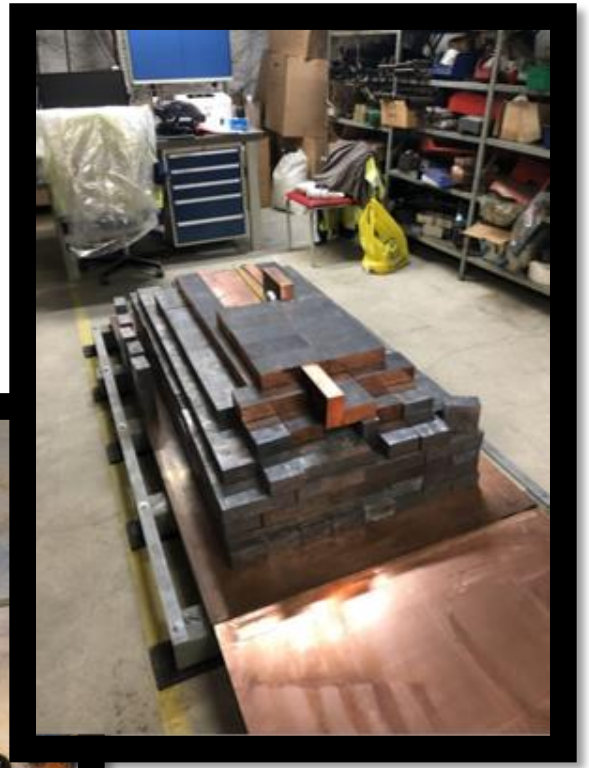

Pictures by S. Trzaska

# Particle physics

## C14-experiment:

- Measuring radioactive purity of liquid scintillator samples in respect with the concentration of $^{14}C$ isotope in an oil-based liquid scintillator.
- has been used to test neutrino detector samples for Jiangmen Underground Neutrino Observatory (JUNO) and for the JUNO pre-detector OSIRIS.
- The goal of the experiment is to push the detection limit of 14C concentrations down to 10E-20 or less.





★ *Status: in-between funding applications*

# CALLIO LAB

# Site descriptions & data sets

## Site description and data

- Use and access
- Competencies and quality control
- R&D possibilities
- Geological bedrock data and properties
- Stress field conditions
- Strength and deformation properties of the rock
- Hydrological data and properties
- 3D point clouds
- Lists of data sources

## Natural background radiation scheme

- Neutron flux
- Muon flux
- Gamma ray background
- Radioisotope content in rock and water
- Radon concentration in air

## LAGUNA LBNO site investigations

*available on request*

Links to articles:

Natural background radiation at Lab 2 of Callio Lab, Pyhäsalmi mine in Finland

Measurements of gamma-ray background in Pyhäsalmi Mine

Callio Lab – the deep underground research centre in Finland, Europe

Characteristics of natural radiation background at the Callio Lab (Finland) performed within the BSUIN project

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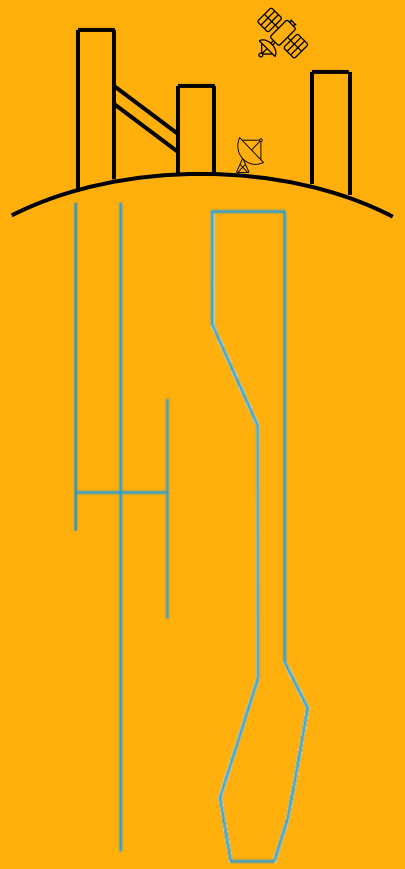


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*For more information, please visit:*
www.calliolab.com
www.oulu.fi/en/callio-lab

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CALLIO LAB
Underground Center for Science and R & D

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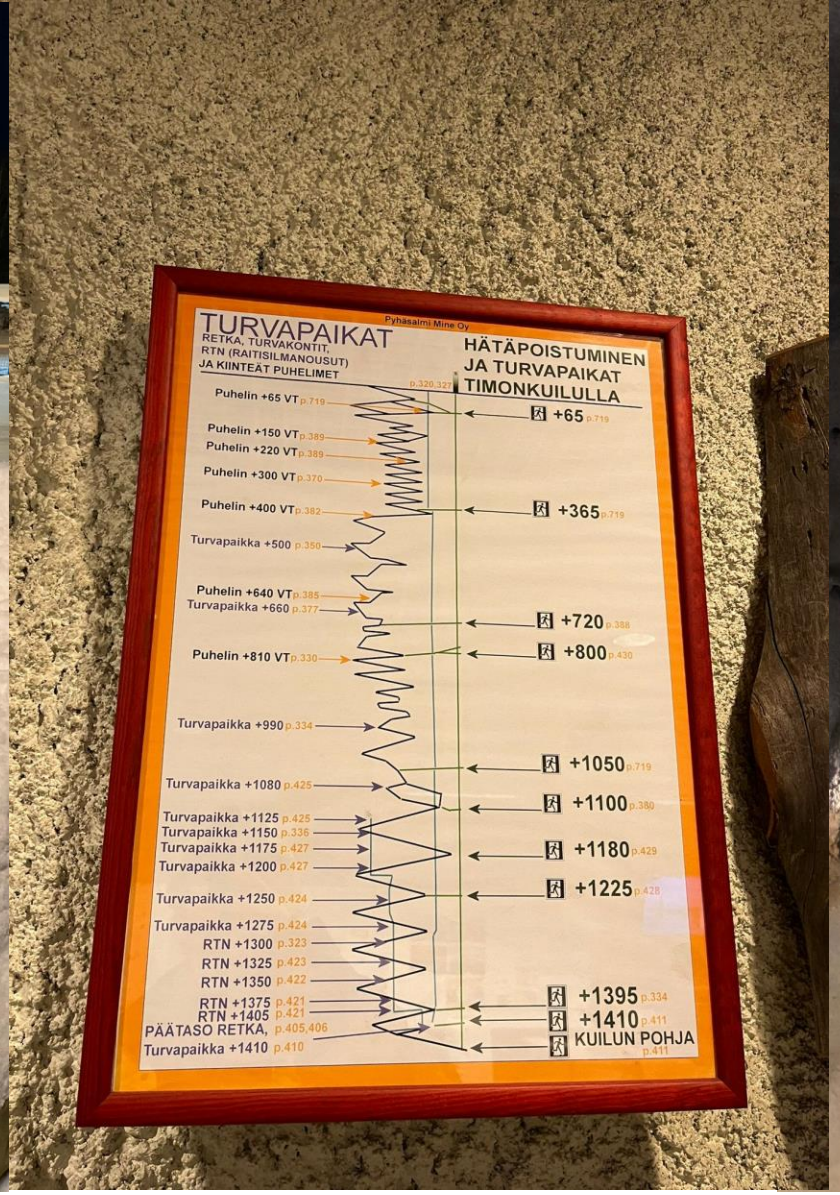


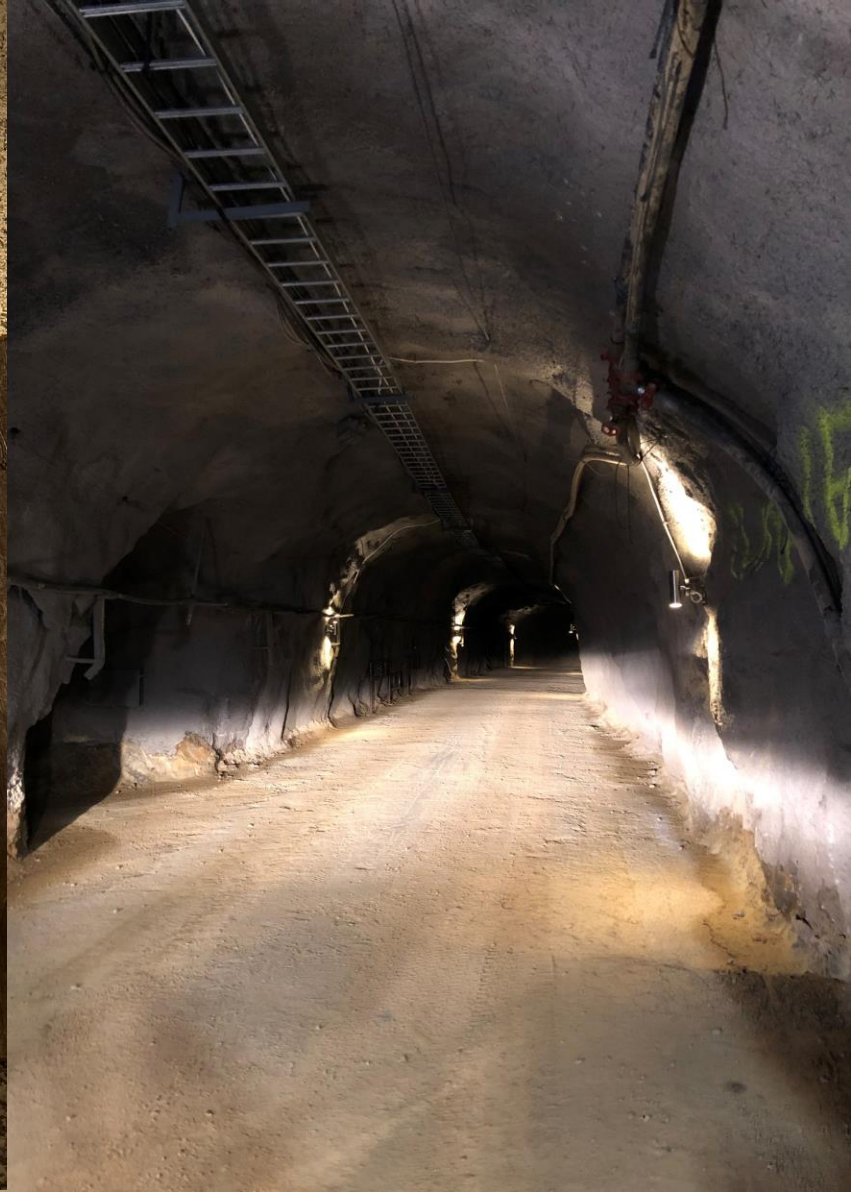

***VISITORS WELCOME YEAR-ROUND!***