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

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

J Joutsenvaara[1], M Holma[1], O Kotavaara[1] and H J Puputti[1]

[1] Kerttu Saalasti Institute, University of Oulu, Finland

Jari.Joutsenvaara@Oulu.fi

Abstract. Pyhäsalmi, in the Town of Pyhäjärvi, hosts one of the northernmost deep underground laboratories in Europe, the Callio Lab. Its origins are in underground physics (Centre for Underground Physics in Pyhäsalmi, CUPP), but gradually it has turned into a multi- and transdisciplinary research environment utilising both the surface and underground. Besides research, the infrastructure is open for business and innovation under the Callio – Mine for Business. The pre-investment for an underground pumped-hydro storage facility to be built at the area utilising the existing tunnel network for construction has been made. This investment ensures the existing and future utilisation of the underground and surface facilities.

1. Background of Callio Lab

Located just below the Polar circle, Callio Lab is one of the northernmost underground laboratories in Europe (1,2). The underground research centre has developed from underground physics (formerly known as the Centre for Underground Physics in Pyhäsalmi, CUPP (3)). Over the years, its strategy has been shifted to a multi-and transdisciplinary research centre, now known as Callio Lab.

The Callio Lab is physically located at the 1.44 km deep Pyhäsalmi mine, Pyhäjärvi, Finland. The mine is owned by First Quantum Minerals Ltd and operated by Pyhäsalmi Mine Oy. The main products are zinc, copper, and pyrite. The deposit is geologically located within a 1.9 bn-year-old seafloor and belongs to the class of volcanogenic massive sulphide (VMS) deposits (4). Seismically the bedrock is stable, and possible tremors are mainly induced by the mining activities. The mine has a flat overburden with two open pits, the old and the backfill rock open pits (Fig. 1.) The access to the mine is through an 11

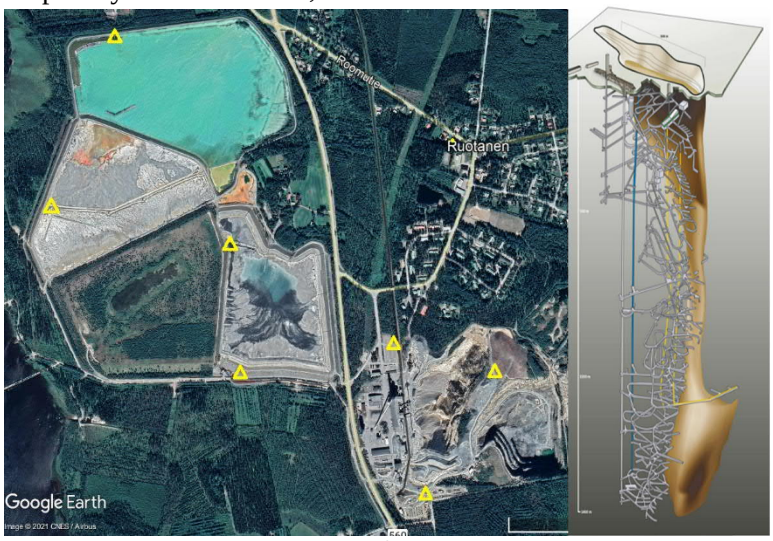

Figure 1. Pyhäsalmi mine area taken from Google Earth. Yellow triangles indicate the positions of corner reflectors designed for Copernicus earth observation satellites. The Callio Lab research activities utilise both the surface and the underground facilities of the 1.44 km deep base metal mine.

km incline or the 1.4 km deep elevator shaft. The travel times are 30 minutes and 2.5 minutes, respectively (5).

2. Multi- and transdisciplinary research centre

The development of underground research facilities in the Pyhäsalmi mine started in the late 1990s at the margin of the then known ore resources. However, with the discovery of a new deposit below the old one, the life span of the underground mining was extended year by year. However, it is expected that mining will cease in the near future. The eventual end of underground extraction will give more room both in physical facilities and in terms of extended or even 24/7 access times. These increase the possibilities for science, research, and business. The latter is governed by the Callio – Mine for business (6), owned by the town of Pyhäjärvi. The scientific activities of Callio Lab are coordinated by the University of Oulu, Finland. Depending on the research proposal and its maturity, Callio Lab can act as a gateway and networker between research and industry, helping the researchers find industrial partners and industries to find research partners for their projects. Callio Lab can provide full coordination, cooperation, or facilitation for research initiatives based on the project´s needs. With long-term activities, the possibility of using local onsite staff and 1+ Gb/s secure and remote accessible internet connection compared to full-time own staff is a major cost-benefit.

The future of the Pyhäsalmi mine infrastructure looks bright for both business operations and scientific activities. The pre-investment for an underground pumped-hydro storage facility to be built at the area utilising the existing tunnel network for construction has been made. This investment ensures the existing and future utilisation of the underground and surface facilities.

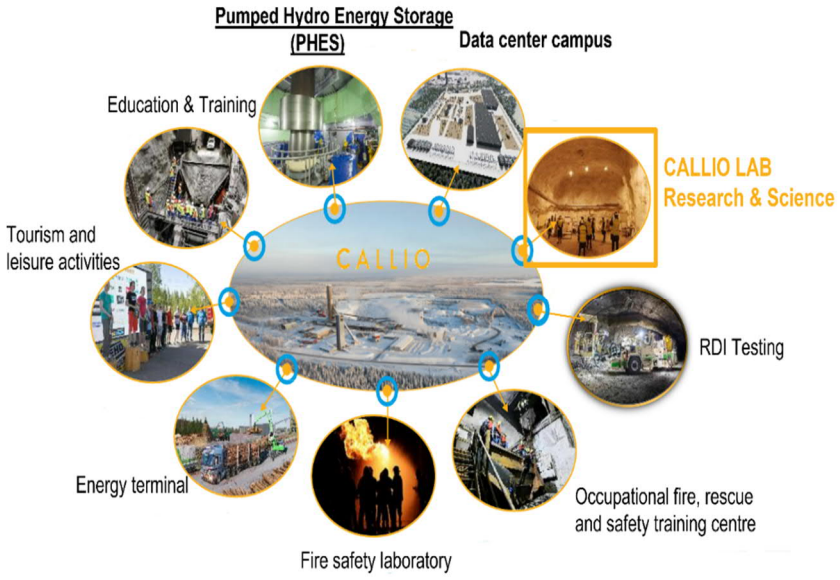

Figure 2. Callio Lab is one of the cornerstones of Callio - Mine for business. The Callio Lab is both an underground research infrastructure and a network of underground researchers. The research is an overlapping activity offering cooperative science, research, and innovation projects. The pre-investment plan for the PHES has secured the future of the mine infrastructure for re-use purposes. Research activities are coordinated by the University of Oulu, Kerttu Saalasti Institute, Finland. The coordinator for the business activities and the facilities and facility services provider is the Callio – Mine for business, and it is owned by the Town of Pyhäjärvi.

2.1. Research and research facilities

Throughout the years the various scientific activities and research initiatives have been started at the Callio Lab. The scientific activities that utilise the Callio lab research infrastructure range from mining and mining-related training to geothermal concept and technology testing, underground food production, working environment research, and particle physics (Fig. 3.). The activities are project-based, so research conducted or the general use at the different facilities can change over time. For example, Lab 2 at a depth of 1 436 m was designed as a multipurpose, low muon background

underground facility. The first user was underground physics, and later it was followed by developers of underground food production.

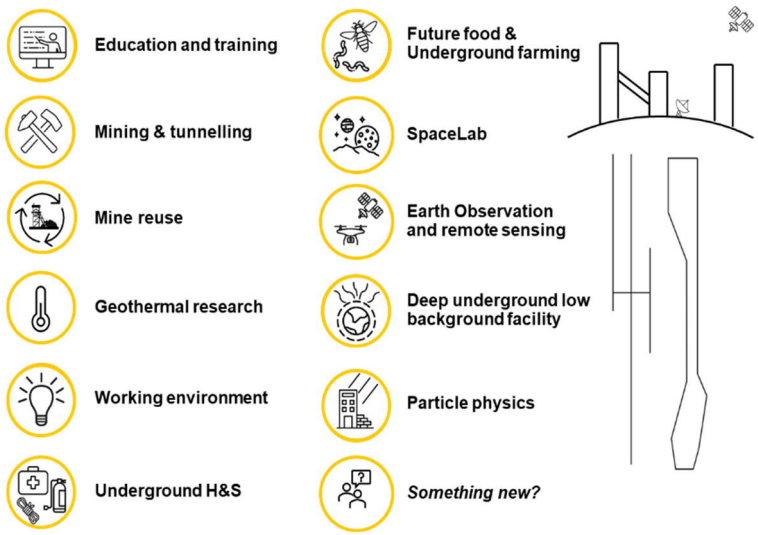

Figure 3. Callio Lab´s research fields have expanded from underground physics into a multi- and transdisciplinary research centre.

Lab 1 at a depth of 75 m is the first underground level that was transformed into more permanent scientific re-use. The experiments carried out there are cosmic ray experiments Muons UnderGround (MUG) and later Experiment with MultiMuon Array (EMMA). Now the Lab 1 is used for the NEMESIS experiment (New EMma Experiment Searching for Indirect Signals), which incorporates infrastructure from the EMMA experiment. Lab 3 at a depth of 990 m was initially used for testing mushroom farming, then for radon barrier testing, all happening in a single room. Now the whole level is for testing of next-generation mining equipment by Normet Ltd.

Lab 4 is located at a depth of 660 m, where the former maintenance and diner area was transformed into two underground hydroponic greenhouses. The greenhouses have been used to test the growth and chemical compositions of high-value-added plants. The steady and safe growing environment has provided up to five steady quality harvests per year.

Lab 5 at a depth of 1410 m, built inside a mine´s main storage facility with walking distance from the elevator, has been used for physics experiments and providing gamma spectrum analyses using the electrically cooled low background HPGe detector from Baltic Scientific Instruments. The facility provides sample analysis services for the EUL project laboratories (7), but other scientific institutions benefit from the facility too. Lab 6 consists of a former main level at a depth of 400 m. The activities there concentrate on underground occupational safety, fire and rescue training and related research.

Additional activities have taken advantage of the underground access and existing facilities, still used by the mining-related activities. E.g., drill holes reaching 2.5 km are used for deep geothermal energy research, the ancient deep, saline water pockets offer possibilities for the astrobiologist. The usage has not limited to the underground mine but also the surface infrastructure is used. The infrastructures, together with historical ground truth data sets, offer possibilities also for a wide range of multi- and transdisciplinary research activities.

2.2. The characterisation of the underground Labs

The characterisation of underground halls (i.e., Labs in the facility) has included technical, geological and natural background radiation characterisation (8–12). Detailed site description report is under preparation and subject to be later published in 2021.

As an active mine and an underground workplace, the radon levels are measured annually for occupational safety. A protocol was developed within the Baltic Sea Underground Innovation Network (BSUIN) to have comparable and re-doable measurements from each specific location for the natural background radiation measurements. To understand the different background sources in addition to the onsite gamma, neutron and radon measurements, samples from the shotcretes, drill cores, and water were analysed. Results from the measurements and a description of the protocol can be seen in the references (8–13).

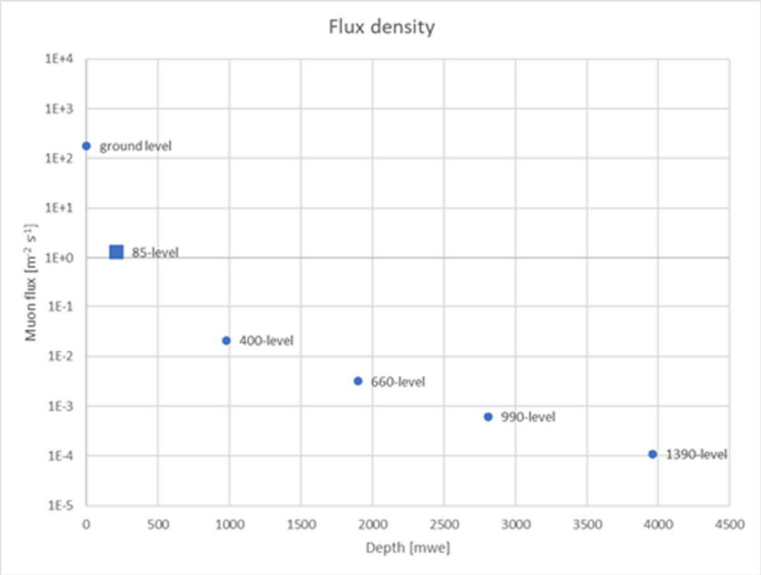

Figure 4. Measured muon flux at the Pyhäsalmi mine. Square maker is from the 2018 (14) *EMMA measurement and round markers from 2005 measurements using the MUD instrument* (15)*.*

The Pyhäsalmi mine has a flat overburden with an average side rock density of 2.75 kg/dm. The muon flux was measured in 2005 with a Movable Underground Muon detector (MUD) (15). See fig. 4. Results from the EMMA experiment from 2018 are also included in the plot (14). The muon background measurements were completed in 2005 (Fig. 4.) (15). The rock overburden at a depth of 1 390 m has been measured to be 4 000 m.w.e. Lab 2, located at a 1436 m, is estimated around 4 100 m.w.e (5). The deepest point of the mine reaches 1 441 m.

3. Callio Lab among the world´s underground laboratories

Callio Lab is a member of the European network of deep underground laboratories DULIA, and it is also a founding member of the European Underground Laboratories association (7). In 2020 Callio lab has been proposed as a candidate thematic core service for the European Plate Observation System (EPOS), which is an ESFRI status research infrastructure network (16). Callio Lab is also a member of Nordic and Finnish EPOS research infrastructures. It is also a strategic research infrastructure of the University of Oulu.

This work has been supported by grants by the Interreg Baltic Sea programme and Nordforsk.

References

[1] Puputti J, Joutsenvaara J, Kotavaara O, Niinikoski E-R. From Earth and beyond - Callio Lab underground centre for Science and R\&D. In: EGU General Assembly Conference Abstracts. 2021. p. EGU21-14229. (EGU General Assembly Conference Abstracts).
[2] Callio Lab [Internet]. 2021 [cited 2021 Apr 20]. Available from: https://calliolab.com/facilities-2/facilities/
[3] Enqvist T, Keränen P, Peltoniemi J, Joutsenvaara J, Jämsén T, Kulju T, et al. Research options in the pyhäsalmi underground facility. Nucl Phys B - Proc Suppl. 2005;143(1-3 SPEC. ISS.):561.
[4] Mäki T, Kousa J, Luukas J. The Vihanti-Pyhäsalmi VMS Belt. In: Mineral Deposits of Finland. Elsevier Inc.; 2015. p. 507–30.
[5] Joutsenvaara J (Jari). Deeper understanding at Lab 2:the new experimental hall at Callio Lab underground centre for science and R & D in the Pyhäsalmi Mine, Finland [Internet]. University of Oulu; 2016. Available from: http://urn.fi/URN:NBN:fi:oulu-201606042350
[6] Callio - Mine for Business [Internet]. 2021. Available from: https://callio.info
[7] Mischo H, Fuławka K, Joutsenvaara J. European Underground Laboratories Association EUL-An International Partner for Underground Research Opportunities. In: EGU General Assembly Conference Abstracts. 2021. p. EGU21--7730.
[8] Debicki Z, Jedrzejczak K, Kasztelan M, Marszal W, Orzechowski J, Szabelski J, et al. Measurements of thermal neutron flux in underground laboratories, a standard proposal for the BSUIN project. In: The multi-messenger astronomy: gamma-ray bursts, search for electromagnetic counterparts to neutrino events and gravitational waves. 2019. p. 48–54.
[9] Jedrzejczak K, Kasztelan M, Szabelski J, Tokarski P, Orzechowski J, Marszał W, et al. Characteristics of natural neutron radiation background performed within the BSUIN project. In: EGU General Assembly Conference Abstracts. 2020. p. 3353. (EGU General Assembly Conference Abstracts).
[10] Polaczek-Grelik K, Walencik-Łata A, Szkliniarz K, Kisiel J, Jędrzejczak K, Szabelski J, et al. Natural background radiation at Lab 2 of Callio Lab, Pyhäsalmi mine in Finland. Nucl Instruments Methods Phys Res Sect A Accel Spectrometers, Detect Assoc Equip. 2020 Jul 21;969:164015.
[11] Gostilo V, Sokolov A, Pohuliai S, Joutsenvaara J. Characterisation of the natural gamma-ray background in the underground Callio Lab facility. Appl Radiat Isot. 2020 Feb 1;156:108987.
[12] Pohuliai S, Sokolov A, Gostilo V, Joutsenvaara J, Puputti J. Measurements of gamma-ray background radiation in Pyhäsalmi mine. Appl Radiat Isot. 2020 Jul 1;161.
[13] Abdurashitov J. N. GVNMVLSAAYVEPJKT. Measurement of Neutron Background at the Pyhasalmi mine for CUPP Project, Finland. arXiv:nucl-ex [Internet]. 2006; Available from: arxiv:nucl-ex/0607024
[14] Kuusiniemi P, Bezrukov L, Dzaparova I, Enqvist T, Fynbo H, Inzhechik L, et al. Performance of tracking stations of the underground cosmic-ray detector array EMMA. Astropart Phys. 2018 Nov 1;102:67–76.
[15] Enqvist T, Mattila A, Föhr V, Jämsén T, Lehtola M, Narkilahti J, et al. Measurements of muon flux in the Pyhäsalmi underground laboratory. Nucl Instruments Methods Phys Res Sect A Accel Spectrometers, Detect Assoc Equip. 2005 Dec 1;554(1–3):286–90.
[16] Elger K, Lauterjung J, Ulbricht D, Cocco M, Atakan K, Bailo D, et al. Implementation of the European Plate Observing System (EPOS) Infrastructure. 2016.