The infrastructure of the Centre for Underground Physics in Pyhäsalmi mine

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Abstract

The aim of the CUPP-project is the construction of an international underground laboratory for the scientific research in particle physics and cosmology in the Pyhäsalmi mine.

The Pyhäsalmi mine is the deepest operational base-metal mine in Europe. It provides excellent opportunities for the research of underground physics by having very stable bedrock, low background radiation level, modern infrastructure, and good traffic conditions all around a year.

The present conditions and the current infrastructure of the Pyhäsalmi mine for scientific purposes are described. Plans for future constructions are also presented.

1 Introduction

The Pyhäsalmi mine is the oldest operational base metal mine in Finland. It is run by Pyhäsalmi Mine Ltd (owned by Inmet Mining Corporation, Canada), and it produces zinc, copper and pyrites. The new mine extends down to 1440 m, being the deepest metal mine in Europe. The mining operation in the new mine, after the excavation, was started in 2001 and continue probably until 2015 at least. There are no more mining operation in the old mine.

The project to host an underground laboratory in the mine was started in 1993, and the Centre for Underground Physics in Pyhäsalmi (CUPP) was physically established in 2001. A pre-feasibility study, including some background measurement [1] and rock analysis [2], has been made. A general risk analysis has also been prepared [3].

This document describes the current status and plans for the scientific infrastructure. A scientific programme is described in Ref. [4].

2 Location

The Pyhäsalmi mine is located in Pyhäjärvi which is a small town in the central Finland between the areal centres and university towns Oulu and Jyväskylä, both of which have an (inter)national airport (see Fig. 1). The driving time to either of these towns is about 2 hours, and there are also regular train and bus connections, and to Helsinki as well. The main roads are in good condition around a year. There is also an airfield in Pyhäjärvi, equipped for instrument flying, but not ment for regular passenger flights.

The municipality of Pyhäjärvi has about 7000 inhabitants. It has the usual services, including a hotel, banks, a post office, supermarkets, pharmacy, medical centre, bookstore and some restaurants. The distance from the centre of the town to the mine is a couple of kilometers. In addition to mining, the town has some traditional metal and wood industry, and some arising new enterprises specialising in higher technology. It is easy to find houses and apartments to rent or to buy.

There are various possibilities for recreation. These include rafting, cross-country skiing, wandering, swimming, sailing, rowing, golfing, bird watching, fishing and hunting. There is also a dance floor, and a famous dance festival every summer.

Pyhäjärvi belongs to an objective 1 area in the European Union which guarantees several advantages to business enterprises. Hence it is possible to get financial support from the European Union Regional Development Fund.

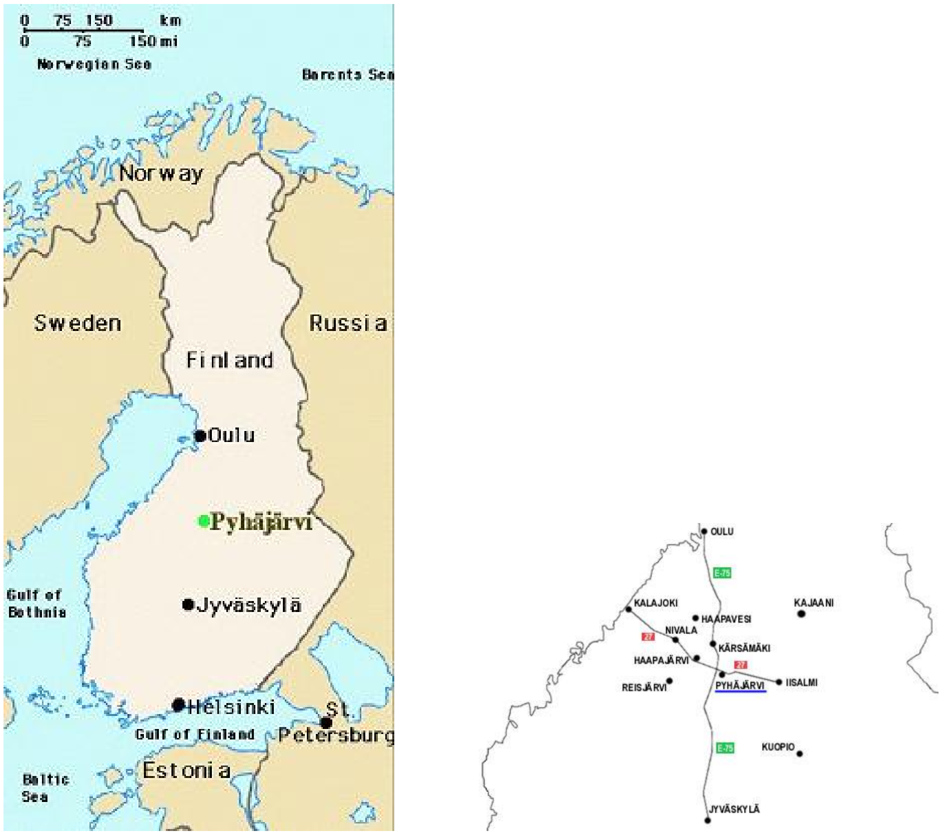

Figure 1: Pyhäjärvi is located in the middle of Finland along the highway 4 (E75) between Jyväskylä and Oulu. The distances are: 165 km to Oulu, 180 km to Jyväskylä and 475 km to Helsinki.

3 Surface space in the Pyhäsalmi mine area

The laboratory offices are located in an old service building, mildly refurbished for the laboratory. They are equipped with the usual computing facilities and stable data connections.

An instrument laboratory, a mechanical workshop and storagerooms may later be located in a nearby service building. They will be equipped with the usual tools. New laboratory buildings can be constructed close to the new lift when there is enough need and funding.

Surface detectors can be installed on the ground level. Support structures for them can be constructed in the mechanical workshop of the mine, or in private companies nearby.

Otherwise most of the surface over the underground experimental areas will be occupied by structures related to ore handling. There is also an open pit mine, with a maximum depth of 130 m, and a length of some hundreds of metres. It is not available for any use.

A photograph taken from a helicopter about the mine area is shown in Fig. 12 (in the Appendix).

4 The old mine and the shallow underground laboratory

The old part of the mine, showing schematically in Fig. 2, extends down to the depth of 1050 m (3000 mwe). The mining in the old mine was stopped in the autumn 2001, and many of the caverns are now available for scientific use. The mining company may still need some caverns for service purposes.

The old mine can be accessed by the old lift or by car or truck via the spiral-shaped decline going all the way down into 1440 metres. The old lift, however, will be closed any time, since it is not used for mining any more and the maintenance expences are large. The new lift, which goes down to 1440 metres, will in practice not serve the old mine. Hence the access will be by car or by truck via the spiral-shaped decline. The tunnel will no more be used for transporting ore, but must be kept free. The official load size is $2.6 \times 2.8 \times 8$ m^3. Larger equipments may be transported only to specific sections. The CUPP project has a Toyota Land Cruiser for accessing the experimental caverns.

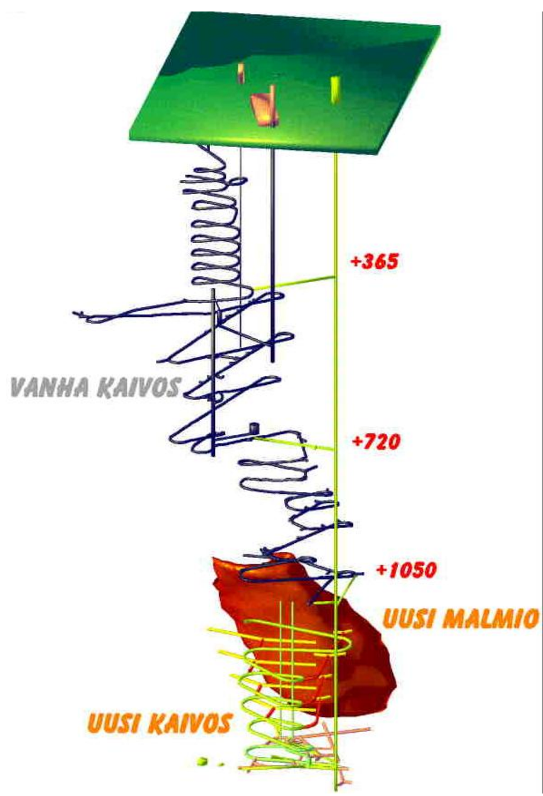

Figure 2: Schematic layout of the Pyhäsalmi mine, including the old and new parts. The tunnels of the old part extend from the ground level to +1050 metres underground. The straigth vertical lines indicate the elevator shafts. The depths are given in metres down from the surface. (Vanha kaivos = the old mine, uusi kaivos = the new mine, uusi malmio = the new ore).

At the upper levels water leakage through rock is possible, also gases may escape through rock if in direct contact. This problem disappears mostly at the depth of several hundreds of metres where the rock is tighter.

The temperature of the rock at the 100-m level is about 6°C and at the 990-m level it might be about 16°C. The humidity is high at the upper levels. The ventilation will be operative.

All caverns used for scientific measurements will be provided, at least, with electricity and data connection. It will be possible to arrange a remote control via internet. Clean air and water can be supplied.

The level of background radiation of radioactive isotopes of the rock was measured at several depths underground in co-operation between the local group and the China University of Geosciences, Beijing (CUGB) [1]. The activity concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{40}K isotopes of the rock in the mine were measured as follows: ^{238}U: 27.8–44.5 Bq/m^3, ^{232}Th: 4.0-18.7 Bq/m^3, ^{226}Ra: 9.9–26.0 Bq/m^3 and ^{40}K: 267–625 Bq/m^3. The results indicate the low background-isotope concentrations in the mine. Also measured radon concentrations in the mine were low, varying between 10 and 148 Bq/m^3. Typical values for gamma-dose rate in the mine varies between 71 and 146 nGy/h, the highest dose rate being measured at the depth of 150 m.

In the old mine there will be plenty of free space to host experiments, as well as for storage, service and manufacturing at different levels. Also new caverns can be excavated if necessary. In the following, the most useful possible research sites are described in detail and cross-sectional view is shown from each level down to 400 metres. The cross-sectional views of levels between 400 and 1050 metres have not yet been produced.

4.1 Depth level of 90 metres

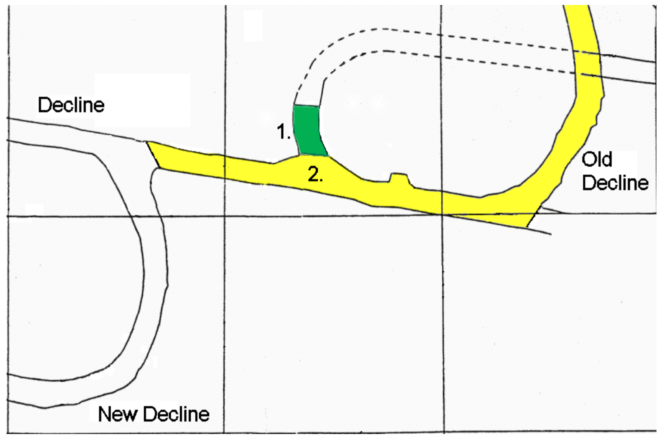

Figure 3: Possible measurement stations at the level of 90 metres.

The measurement station at the depth of 90 metres has been built on a wooden standard-size container, hosting the muon experiment (MUG) at the moment. The measurement devices has been connected to the local power network. The container is also equipped with a phoneline for the use of adsl modems to transfer data. The container has been protected against moisture and it includes a heater.

Fig. 3 shows possible places at the level of 90 metres that can be used to set up detectors. The MUG-experiment uses now the position 1. showed in Fig. 3. Detectors can be placed also in the old decline (region 2 in Fig. 3), but it must not be blocked from trucks or emergency cars.

4.2 Depth level of 210 metres

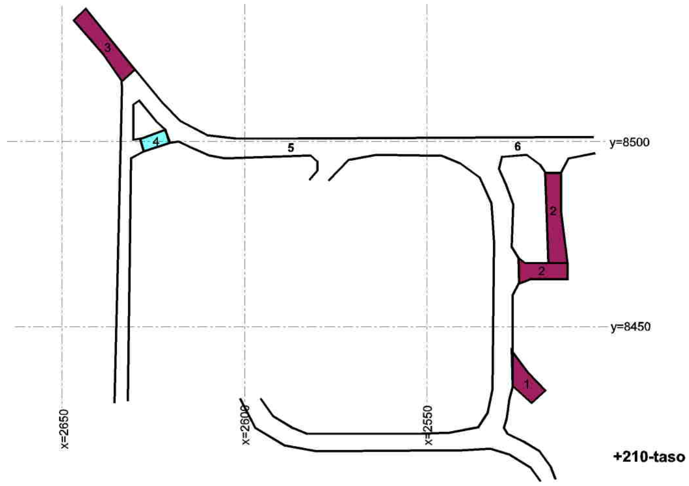

Figure 4: Existing (4) and possible new (1-3) measurement stations at 210-m level. A photograph of the long tunnel at the left-hand side is shown in Fig. 13

(1) End of a tunnel near the old explosive mixing room, requires leveling of the ground. Distance from the surface is 200 metres. The size is 7.0 m × 4.6 m × 3.0 m.

(2) An old and obsolete explosive mixing room with two levels. This is ready for use. Distances from the surface: upper end 140 metres and lower end 150 metres. The sizes are: upper end 7.0 m × 4.0 m × 5.0 m and lower end 8.0 m × 3.0 m × 2.7 m.

(3) End of a tunnel near the old dining room. Requires removal of loose rocks from the roof, leveling of the ground and some gravel. Very damp place. Bedrock between surface and room about 145 metres. The width is 3.9 m and height is 2.8 m.

(4) This is currently used for the MUG (Muons UnderGround) experiment. There is a small room of size 7.5 m × 4 m × 2 m. There is not much extra space available.

(5,6) Tunnel (5): Width 3.9 metres and height 2.8 metres.
Tunnel (6): Width 4.0 metres and height 3.0 metres.

The corridor between the elevator shaft and the dining room would possible be a good place to install measuring devices, but it is damp and has occasionally been flooded by water due to broken waterlines that run there.

4.3 Depth levels of 270 and 300 metres

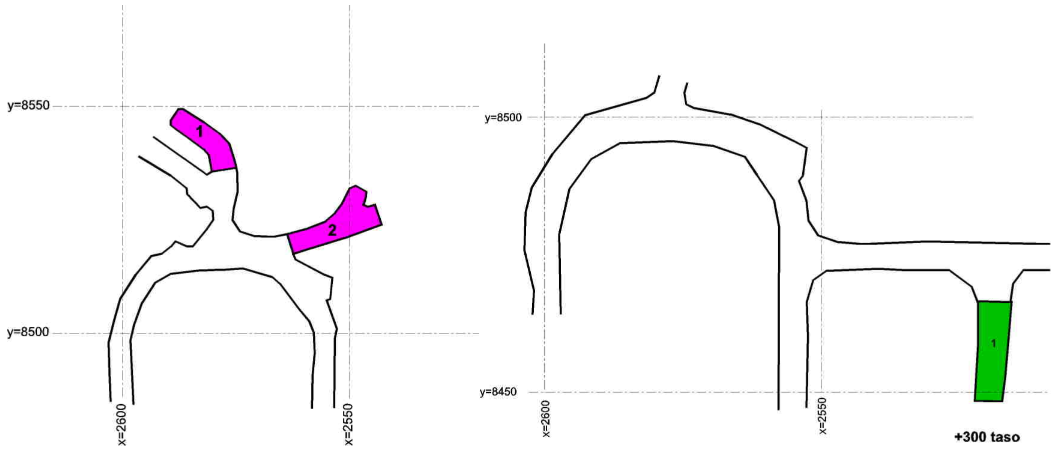

Figure 5: Possible measurement positions at the depths of 270 m (left) and 300 m (right).

270 metres

(1) End of a tunnel near the sloping tunnel. Requires removal of the stones and some gravel. The distance from the surface is 175 metres. The size is 10.0 m × 4.6 m × 4.0 m.

(2) End of a tunnel near sloping tunnel. Requires some gravel. The distance from the surface is 175 metres. The size is 15.0 m × 4.0 m × 4.0 m.

300 metres

End near the sloping tunnel. Requires leveling of the end, and some gravel. The distance from the surface is 205 metres. The size is 16.0 m × 5.4 m × 3.5 m.

4.4 Depth level of 400 metres

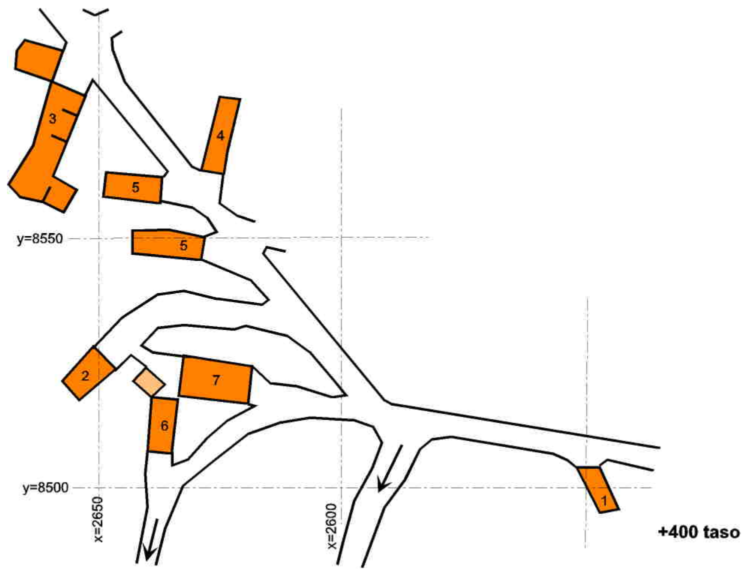

Figure 6: Possible measurement stations at 400-m level.

(1) A former place for emergency car. This is ready for use. The distance from the surface is 350 metres. The size is 8.0 m × 3.0 m × 2.7 m.

(2) Dining room of an old repair center. This is large and dry place ready for use, includes electricity and phoneline. The distance from the surface is 350 metres. The size is 10.0 m × 6.0 m × 3.0 m.

(3) This is an old storage area at the end of the tunnel. The distance from the surface is 350 metres. The size is 9.0 m × 5.0 m × 4.3 m. A photograph of the area is shown in Fig. 14.

(4) Parking area. Distance from the surface is 350 metres. The size is 10.0 m × 4.0 m × 3.7 m.

(5) Air rise. Distance from the surface is 350 metres. The size is 16.0 m × 4.7 m × 3.0 m.

(6)+(7) Repairing hall. There are 350 metres of bedrock between this place and the surface. The size is 13.0 m × 5.0 m × 4.0 m. Doorway of the hall; the width is 3.6 metres and height is 3.6 metres.

There is a connection between (6) and (7), and the both of the halls include cranes capable of lifting several tons. The halls are used to repair big trucks.

4.5 Depth level of 660 metres

There exists also free and available space below 400 metres. Some possibilities are given below, but more comprehensive and systematical mapping of the places is still needed, and will be made. If necessary, new caverns can be excavated also above 1050 metres.

At the depth of 660 metres, there are an old lunch room, and many service and storage rooms, largest of them is of the size of 30 m × 10 m × 8 m. The marked areas in Fig. 7 are available, but some other areas can also be obtained.

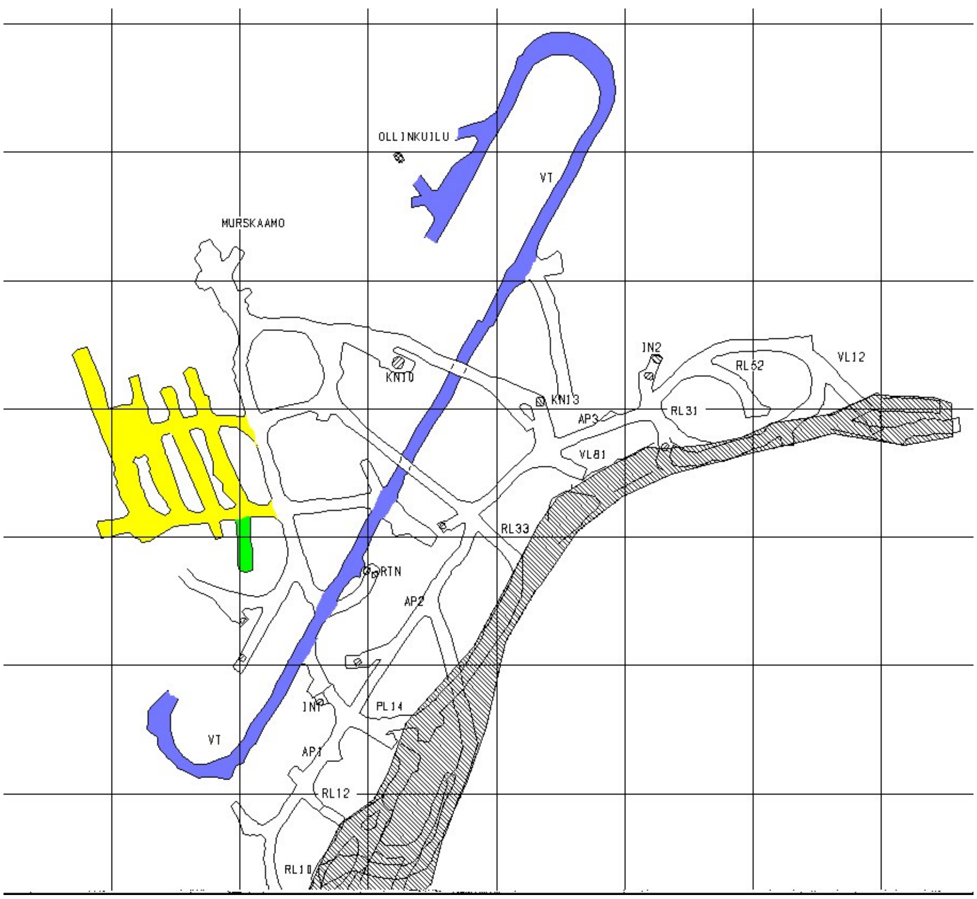

Figure 7: Possible measurement stations at the level of 660 metres (marked by yellow) are situated at the left from the decline (marked by blue).

4.6 Depth levels of 970 and 1050 metres

970 metres

A lunch room and service rooms: 2 rooms of 20 m × 7 m × 5 m, one room of 20 m × 7 m × 7 m, and several smaller rooms. A photograph from the 970-level is shown in Fig. 15 (in the Appendix).

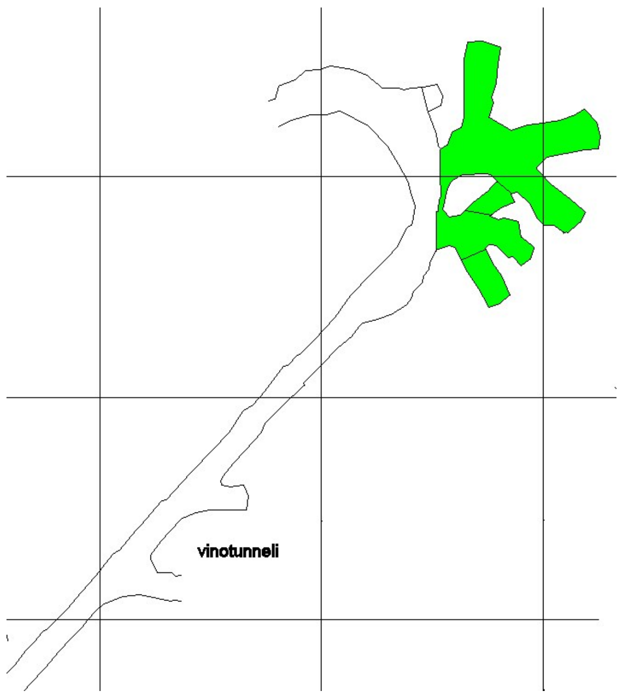

Figure 8: Possible measurement stations at the level of 970 metres.

1050 metres

Some very small caverns.

4.7 Cross section down to 400 metres

In Fig. 9 a cross sectional view of possible experimental measurement positions below the open mine (*avolouhos*) . The coloured areas have been described in detail in previous subsections.

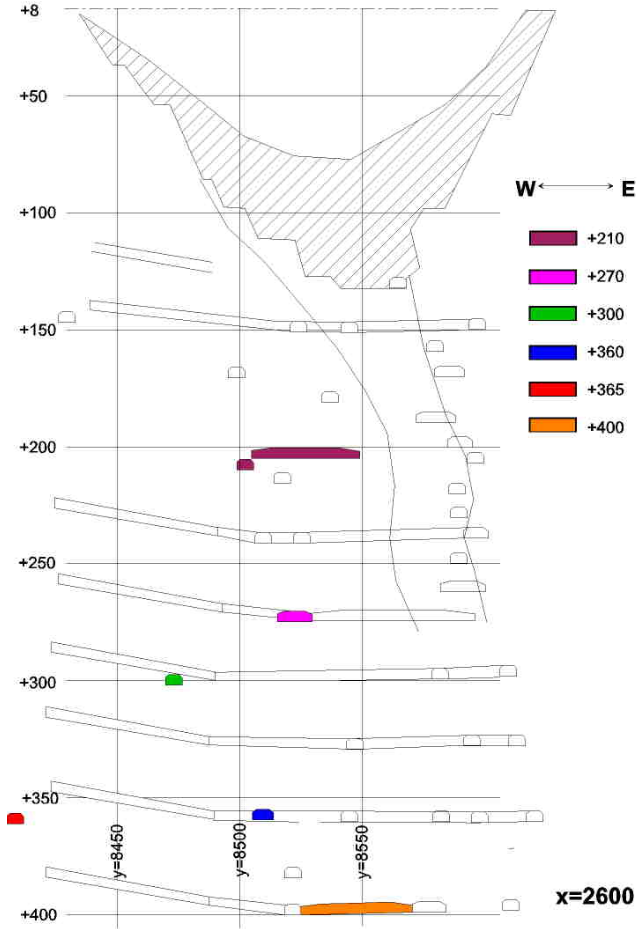

Figure 9: Cross sectional view from surface down to 400 metres.

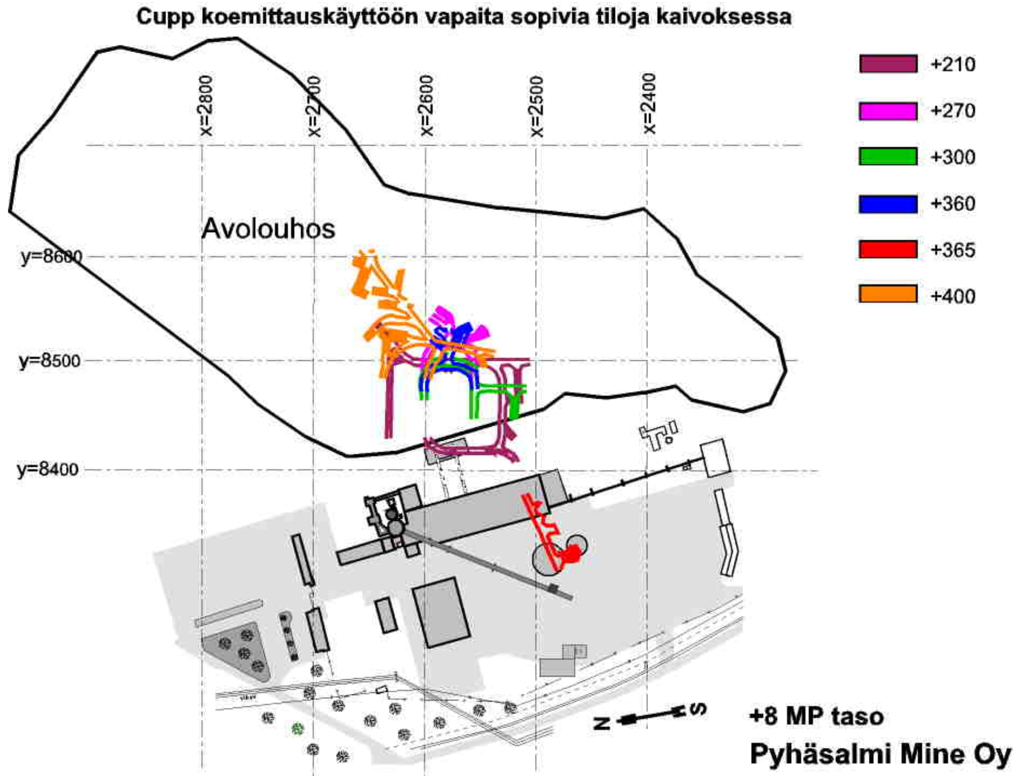

Figure 10: A drawing of the possible measuring positions at different depth levels. (Avolouhos = open pit mine).

In Fig. 10 caverns to be used for the experiments in the old mine are shown as a drawing showing different layers overlaid.

5 The new mine and the deep underground laboratory

The new mine started to operate in July 2001. It extends to the depth of 1440 m (4000 mwe), and it can be really referred to as a new mine, although it is connected to the old mine. The new mine can be accessed via a fast lift which can transport both people and heavy equipments. The lift has predefined schedules and the priority is for mining purposes. Also the truckway goes all the way down. The largest objects must be transported by trucks or special vehicles via the decline.

Mining will go on presumably until 2015 at least. There will be blasts every night at around 22:00. The safety regulations require that no one must stay in the mine during explosions. Otherwise the explosions are not expected to disturb the experiments excessively. So far all the measurement devices and related electronics have been unaffected by the explosions.

The temperature at the 1440 m level is about 23 °C. The humidity depends on the ventilation and outside-air temperature. The rock is very tight, so there is not much water leakage through the walls. On the other hand, the water has a high concentration of metal ions and sulphur which prevents the growth of harmful organisms.

There are no free caverns for research purposes in the new mine. Hence everything needed for the scientific work must be excavated. The cost will be 70 – 100 euros/m^3, depending on the depth, the size and the shape of the cavern. The largest cavern that can be easily constructed is 100 m $\times$ 15 m $\times$ 20 m. Because of a high stress-field in deep mine, larger caverns require careful planning and expensive support structures. The excavated rock can be used to replace ore in the stopes, and the maximum amount of rock that can be taken away is about 100000 m^3/year (3 litres per second).

The preliminary-design report of the deep underground laboratory has been done by an engineer company [2]. The report includes a complete excavation plan, including required infrastructure as air-conditioning and electricity, for the first phase having caverns for two big experiments and several smaller devices, common service facilities and connecting tunnels. Fig. 11 shows as a schematic drawing an example-case of the possible new experimental halls to be excavated at the level of 1440 metres.

The measurements can be continued after the mining stops. However, the maintenance of the mine may then be the responsibility of the scientific community. The annual cost of maintenance is estimated to be at least 1 million euros.

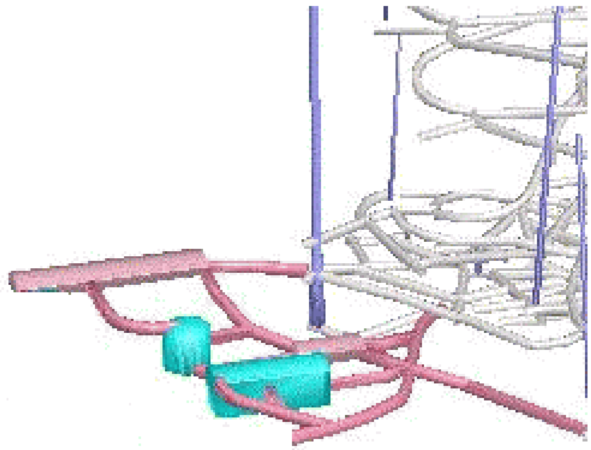

Figure 11: An example of the layout of experimental caves at the deep underground laboratory at the depth of 1440 metres.

6 Oulu unit

The CUPP-project headquarters have been situated in Oulu. The project occupy a whole building (see Fig. 16) by the main campus of the University of Oulu where it has office space for 5 to 10 persons, a test laboratory and some storage room. An old neutron monitor remains in the same premises which has been used to study cosmic rays since 1973.

Oulu is a rapidly growing town of some 120 000 inhabitants. It is well known for its high technology, and it is frequently listed among the 20 most promising technology centres in the world. It is well connected to the outside world, with 16 daily flights to Helsinki and 3 direct flights to Stockholm.

7 Disclaimers

The mining company reserves the right to change their plans, depending on their economic conditions and global metal markets. All information regarding the mining and other works may be inaccurate. This report should not be used for making any conclusions about the business activities of the mining company.

The references to the future construction of the scientific centre are based on the assumption that the funding will be granted as will be applied.

Acknowledgments

Most of the information regarding the properties of the mine and its use has been provided by Pyhäsalmi Mine Ltd.

TE acknowledge the Department of Physics of the University of Jyväskylä for providing excellent working conditions.

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References

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[2] Centre for Underground Physics in Pyhäsalmi Mine, General Design, Phase 1, Pre-Design Phase and Preliminary Design. Rockplan Ltd, April 2002

[3] Risk Analysis of CUPP Project, DMT-Montan Consulting GmbH, August 2003

[4] T. Enqvist et al., A proposal to Study Underground Multimuon Events, CUPP-04/2003

Appendix: Photographs

Figure 12: A photograph about the mine area. The CUPP-project offices situates close to the uppermost tower in the photo. Courtesy of the Pyhäsalmi mine.

Figure 13: A photograph of a long cavern at 210-m level.

Figure 14: A photograph from the level of 400 metres.

Figure 15: A photograph from the level of 970 metres.

Figure 16: Our headquarters by the University of Oulu. Today the surroundings are being urbanised, and a very beautiful modern wooden barrier is arising around it. The building is fully renovated. In front, there is the Toyota Land Cruiser belonging to the project.

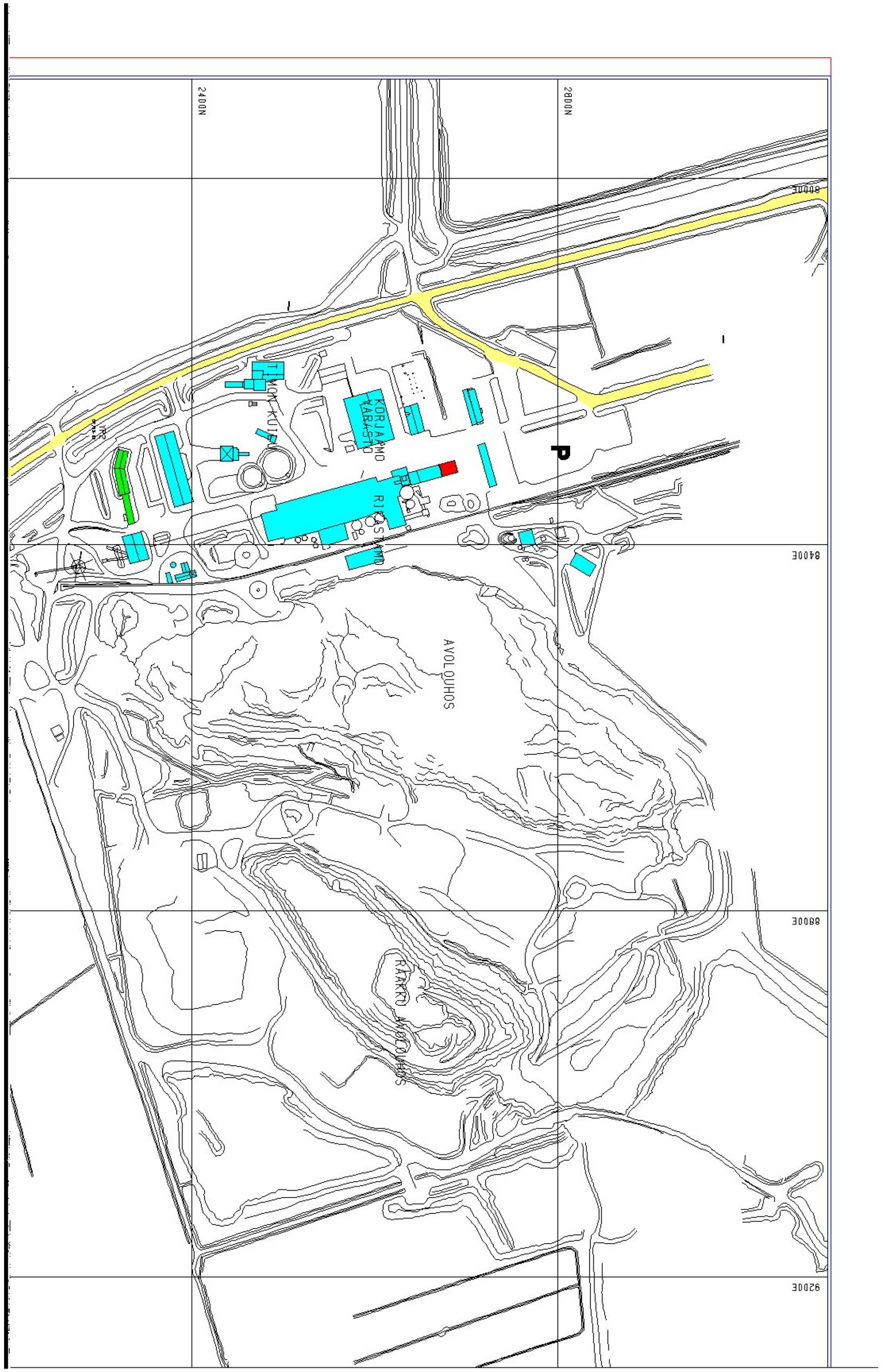

Figure 17: Surface layout of the Pyhäsalmi mine.