Canfranc Underground Laboratory

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Abstract. We review the infrastructures and research activities at the Canfranc Underground Laboratory.

1. Introduction

The Canfranc Laboratory (LSC) is located at about 1100 m above sea level in the Spanish Pyrenees. In 1985, A. Morales and collaborators from the University of Zaragoza started using the abandoned train tunnel at Canfranc to carry out Astroparticle Physics experiments. At that time only old service cavities were used. At present, this space is known with the name LAB780, taking into account the distance to the train tunnel entrance from the Spanish side. In 1994, a 8-km road tunnel was excavated to connect Spain and France, the so-called Somport tunnel. During the excavation an experimental hall of 118 m^2 was built at about 2500 m away from the Spanish entrance on a side of the train tunnel. This cavity is known as LAB2500. In 2006, a larger excavation was started with the idea to make at Canfranc an international underground facility for Astroparticle Physics. This excavation is divided into two halls, named A and B. The new laboratory is known as LAB2400. Fig. 1 shows a layout of the underground laboratory at Canfranc. At present, LSC consists of three main infrastructures located between the train and road tunnels: LAB2400, the largest excavation, LAB2500 and LAB780. In LAB2400 hall A and B have dimensions, respectively: $40 \times 15 \times 12(H)$ m^3 and $15 \times 10 \times 8(H)$ m^3. The total underground space available for research activities at Canfranc is about 10000 m^3 which corresponds to a total surface of 1600 m^2.

The LSC is equipped with a number of service facilities underground:

- screening facility with 7 high purity germanium detectors for gamma spectroscopy;
- clean room ISO7 and ISO6 in a sector;
- workshop;
- a radon abatement system to delivery radon-free air;
- general utilities.

In Tab. 1 we summarize the background counting rate in units of day^{-1} of some of the high purity germanium detectors at LSC.

In the underground laboratory LAB2400 the radon level is about 50-80 Bq/m^3 due to a forced ventilation which provides about 20000 $\text{m}^3\text{/h}$ of air from outside. The muon flux is $\sim 4 \times 10^3$ $\text{m}^{-2}\text{s}^{-1}$ (2500 m.w.e). The neutron background below 10 MeV and the gamma-ray flux are $\sim 3.5 \times 10^{-6}$ $\text{cm}^{-2}\text{s}^{-1}$ and ~ 2 $\text{cm}^{-2}\text{s}^{-1}$, respectively.

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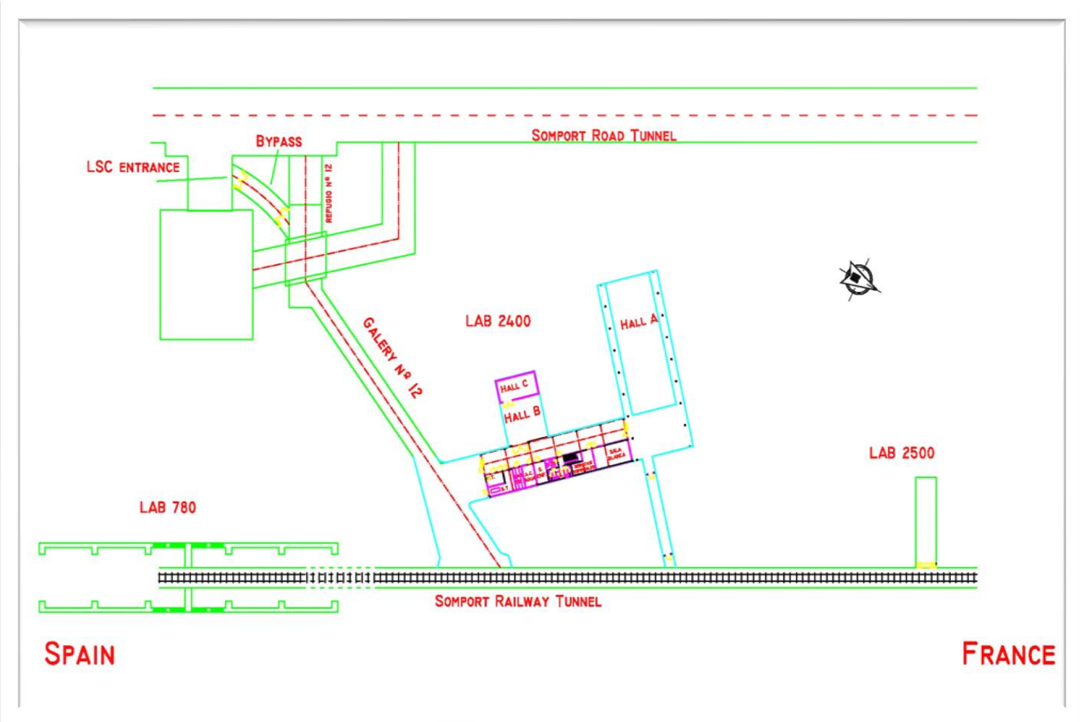

Figure 1. Layout of the underground Laboratory at Canfranc.

Table 1. Background counting rate in counts/day for high purity germanium detectors at LSC.

Detector	100-2700 keV
GeOroel	148 ± 1
GeTobazo	436 ± 2
GeLatuca	314 ± 2
GeAspe	433 ± 1

At surface LSC is equipped with a main building with offices, conference rooms, workshop, electroformed copper facility, chemistry and electronics laboratories.

Regularly at LSC a series of monitoring measurements are performed: convergences for the rock stability underground, radon and water quality. Environmental monitoring is done in collaboration with the close University of Zaragoza.

2. Research activities at the Canfranc Underground Laboratory

The main research activity at LSC is about dark matter and neutrinoless double beta decay. In addition support activities for projects performed in other laboratories are carried out by means of the facilities reported in the previous Section. In Tab. 2 we summarize the experimental

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activities and their status at LSC.

Table 2. Experimental projects at LSC. DM = dark matter. DBD = double beta decay.

Project	Status
ROSEBUD [1] (DM R&D)	stopped
ANAIS (DM)	running
ArDM (DM)	running
NEXT-NEW (DBD)	running
BiPo (DBD R&D)	running
SuperKGd (R&D)	running

ANAIS [2] is a project to search for DM looking for the annual modulation of the counting rate expected due to the rotation of the Sun around the center of the galaxy. This characteristic is model independent and of great interest for the study and understanding of DM. ANAIS will make use in 2016 of 112 kg of high purity NaI(Tl) to search for the annual modulation observed in DAMA/LIBRA. Crystals are inside a copper and lead shielding with an external muon veto [3].

ArDM [4] makes use of 2 tons of liquid argon in a two-phase TPC to search for WIMPs recoils. The detector consists of a cylindrical vessel with an array of photomultipliers at the bottom (cathode) and at the top side. An electric field is present inside the vessel to drift electrons toward the upper side of the vessel. The scintillation in the liquid argon makes the prompt signal (S1). Close to the array of photomultipliers at the top of the vessel a small argon gas layer makes the delayed signal (S2). In this detector a WIMP is expected to interact by elastic scattering on argon nuclei. The different characteristics of S1 and S2 allow to disentangle nuclear recoils due to WIMPs to electron recoils due to background sources. Moreover, in liquid argon the scintillation light emitted by nuclear recoils has a characteristic timing very different than that from electron recoils. This allows to perform pulse shape discrimination. At present ArDM has been operated in single phase exploiting the excellent pulse shape discrimination of liquid argon for electron recoil events, mainly from the β decay of ^{39}Ar. The two-phase mode will start within 2016.

NEXT [5] aims to search for neutrinoless double beta decay with 100 kg of Xe enriched at 90% in ^{136}Xe. The enriched xenon is already stored underground at LSC. At present NEXT is running a demonstrator called NEW. NEW is a 10 kg active region Xe gas TPC at 15 bar and two readout planes: the cathode with 12 photomultipliers to detect the energy deposited in the Xe gas; the anode with 1800 SiPMs to determine the topology of the event by means of the secondary scintillation produced by drifted ionization electrons. The secondary scintillation light is also detected by the photomultipliers to improve the energy resolution. NEXT technology will be able to distinguish signals from double electrons (DBD) with respect to signals with single electrons (background). This feature improves the background subtraction for DBD search. The goal of NEW to be accomplished by 2016 is to measure the energy resolution and confirm the Monte Carlo calculation about the expected background from detector components.

BiPo is a set-up to measure ^{214}Bi and ^{208}Tl contamination at μBq/kg level on planar geometry. The experimental set-up allows to tag Bi-Po space and time $\beta - \alpha$ correlated coincidences in the ^{238}U and ^{232}Th chains. The set-up has an active surface of 3.6 m^2 equipped with 24 sectors, each with two photomultipliers and scintillators. At present BiPo is used to determine the contamination of ^{82}Se foils for the SuperNEMO project [6]. Due to the high sensitivity the BiPo facility is of interest for screening components from a number of experimental projects planned and operated in underground laboratories.

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SuperKGd is an experimental activity which aims to select a low radioactivity salt with gadolinium, $Gd_2(SO_4)_3$ for SuperKamiokande. SuperKGd makes use of the screening facility at LSC. The SuperKamiokande with gadolinium is a very important project in the field of neutrino physics. LSC has carried out a huge number of measurements for the SuperKamiokande collaboration.

At LSC there is also an interest to make an underground infrastructure for nuclear astrophysics. This effort is known as the Canfranc Underground Nuclear Astrophysics (CUNA) project. The main goal of CUNA is the measurement of (α, n) reactions on ^{13}C and ^{22}Ne. The measurement is performed by tagging the neutron produced. Therefore, the neutron background is limiting the sensitivity of the project. For this reason the CUNA collaboration has carried out measurements in hall A at LSC to determine the neutron background from the underground environment at Canfranc. The measured neutron flux is $(3.47 \pm 0.3) \times 10^{-6}$ cm^{-2}s^{-1} [7]. CUNA needs a new excavation. This proposal is under review and funding request.

LSC is equipped with a geodynamic facility which aims to study local and teleseismic events. The facility consists of: 1) a broadband seismometer and accelerometer: 2) two 70 m long laser strainmeters; 3) two GPS stations on surface in the surrounding of the underground site. The two lasers are installed in LAB780 and in one by-pass gallery (gal-16) between the road and train tunnels, respectively. The LSC site is exceptionally low noise and the strainmeters set-up has studied non-linear ocean load tides at 120 km distance in the Gulf of Biscay. The observed amplitude and phase are well in agreement with predictions.

Life in extreme environment [8] is also studied at LSC with the project GOLLUM. Canfranc railway tunnel offers a unique opportunity to study microorganism communities. The GOLLUM project aims to characterize microbial communities by extraction of DNA in rock samples. In 2016 a number of drilling tests along the train tunnel are planned to collect samples and finalize the protocol for DNA characterization.

3. Conclusions

In conclusion LSC is the second largest underground laboratory in Europe after LNGS. It is a multidisciplinary facility equipped with a number of services to support scientists and underground installations. At present, the research activity at LSC goes from dark matter and neutrinoless double beta decay, to geophysics and biology in the subsurface. At LSC new space is available to carry out new research projects.

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