THE CANFRANC UNDERGROUND LABORATORY. PRESENT AND FUTURE

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A brief history of the Canfranc Underground Laboratory is presented together with its current status. The description of a new, enlarged underground facility with a main experimental hall of $40 \times 15 \times 11$ m^3 and a total surface of about $1,500$ m^2 at a depth of 2,450 m.w.e. is outlined as well.

1. Introduction

Underground science includes a wide range of exciting disciplines in both fundamental and practical subjects in fields as diverse as Elementary Particle Physics, Nuclear Physics, Astrophysics, Cosmology, Geology, Biology, Material Science, etc.

By using underground laboratories one reaches the low radioactive background environment needed to look for rare event physics which allows us to study, amongst many other amazing research fields, the fundamental laws of physics such as those governing the stability of the proton or the particle-antiparticle properties of the neutrino; we can probe the interior of the Sun or determine the nature of the dark matter.

Figure 1 shows an incomplete list of the underground laboratories around the world, the most outstanding ones in Europe being the L*aboratori Nazionali del Gran Sasso (LNGS)* in Italy, the *Laboratoire Souterrain de Modane (Frejus) (LSM)* in France and *The Boulby Mine Underground Physics Facility* in UK.

*Deceased

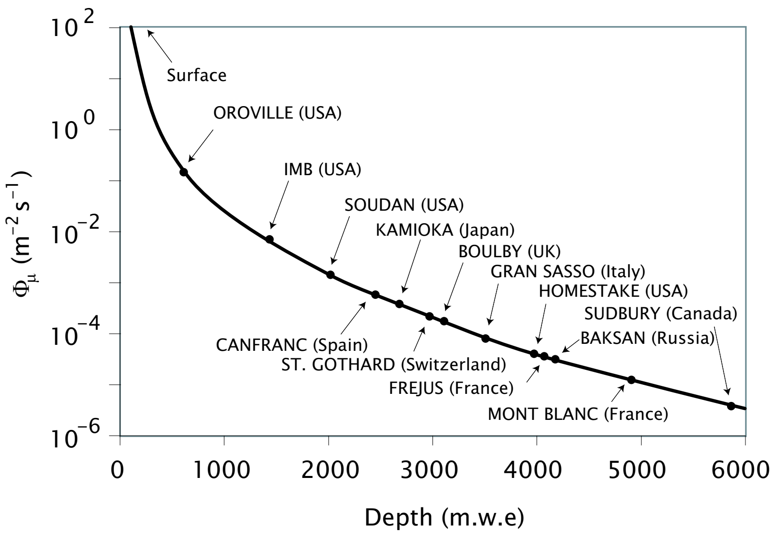

Figure 1. Underground laboratories around the world

In the following, we will briefly draft the history of the Canfranc Underground Laboratory and summarize its experimental program. Finally, the new underground facility which is being constructed at the same location with a total surface of nearly 1,500 m^2 is shortly described.

2. The Canfranc Underground Laboratory (LSC)

In the mid eighties, there was no infrastructure in the Canfranc railway tunnel[a] except for two small halls (about 12 m^2 each plus two 35 m^2, 1 m high galleries) located 780 m from the Spanish entrance below a rock overburden of 675 meters of water equivalent (m.w.e.). In 1986, preliminary measurements of radioactive contamination and cosmic radiation were carried out with a mobile platform along the railway; conditioning works started shortly after (cleaning, electrical power installation, telephone, humidity and temperature control, and ventilation) and the two halls became what we now call Lab-1.

By 1988, the LSC consisted of the two small halls plus a prefabricated cabin, especially reinforced, of about 15 m^2 and installed over the railway

[a]LSC is located in a railway tunnel of ∼6 km long (not in use) crossing the Pyrenees (entrance at ∼1080 m above sea level close to the Canfranc Station, in the Spanish side, 175 km from Zaragoza).

Table 1. Experimental parameters and infrastructure of the site

Depth (max.)	2,450 meters of water equivalent (m.w.e.)
Composition of the rock	limestone, mainly calcium carbonate
Average density	2.7 g·cm^{-3}
Muon flux	2×10^{-7} cm^{-2}·s^{-1}
Radon concentration	20 to 70 Bq·m^{-3}
Neutron flux	a few$\times10^{-6}$ cm^{-2}·s^{-1} (depending on energy)
Ambient photon flux	2×10^{-2} cm^{-2}·s^{-1}
Infrastructure	30 kW independent electric power supply
	Air conditioning and thermalization
	Air extraction and forced ventilation in/from outside
	Low temperature facility (12-20 mK)
	Antivibrational cabin and Faraday cages
	Floor reinforced for supporting heavy shielding
	Tons of archaeological lead
	Ultra-low bkg HpGe detectors for radiopurity measurements

next to the two halls. In August 1988, as a result of a collaboration with the University of South Carolina (USC) and the Pacific Northwest National Laboratory (PNNL), the first ultralow background detector came to Canfranc: a germanium hyperpure detector. With this detector preliminary measurements of materials (lead, copper, polyethylene, etc.) were carried out and fifteen months later (November 1989) the first experiment started in the Canfranc Underground Laboratory, a multidetector system with 14 NaI scintillators and the germanium detector looking for the double beta decay of ^{76}Ge. Since then, many other experiments have been operating in the Canfranc Underground Laboratory, which has undergone important modifications and improvements.

In 1991 a new prefabricated cabin (about 27 m^2) was added to the one already in operation and they were both moved to a new location (1,200 m from the Spanish entrance below an overburden of 1,380 m.w.e.). In this location and with the convenient conditioning of both cabins (electrical power installation, telephone, ventilation), they became Lab-2. In 1994, taking advantage of the excavation works for the new Somport road tunnel, a new experimental hall, 118 m^2, at 2,520 m from the Spanish entrance and below an overburden of 2,450 m.w.e. was excavated. It was named Lab-3 (or main Lab), and has been in operation since the beginning of 1995. This new hall, much larger and deeper underground, has provided for a quantitative and qualitative progress in the research activities of the group; it allowed to start new experiments and to reach a clear improvement in the radioactive backgrounds. With the setting-up of this new hall, Lab-2 was dismounted. The small cabin was installed inside Lab-3 and the large one outside the tunnel for remote control of the experiments and communications. Lab-1 is used now only to store detectors and other materials (which are so kept shielded from the cosmic radiation). Table 1 shows the most relevant experimental parameters of the laboratory as well as the current infrastructure of the site.

The scientific program of the Laboratory includes:

- Neutrino Physics, looking for the double beta decay of ^{76}Ge by using both natural and enriched germanium detectors,
- Dark matter searches, looking for the direct detection of galactic WIMPs by comparing the expected signal rate with the recorded background (using scintillation, ionization and cryogenic detectors) and by searching distinctive signatures as the annual modulation of the WIMP signal, and
- Solar Axion searches through Bragg-scattering in the detector.

A list of experiments already performed or being currently in operation at LSC is presented in Table 2.

Table 2. Experiments already performed or in operation at LSC

Name	**Description**	**Ref.**
$2\beta/\gamma$	Decay of ^{76}Ge to excited states of ^{76}Se (coincidence exp.)	[1]
^{78}Kr exp.	Double positron decay of ^{78}Kr	[2]
COSME 1	Looking for WIMPs of low mass	[3]
NaI 32	Search for annual modulation of WIMPs signals with scintillators	[4]
COSME 2	Detection of solar axions through Bragg-scattering	[5]
COSME 2	Looking for WIMPs with a small natural Ge detector	[5]
IGEX	Double Beta Decay of ^{76}Ge	[6]
IGEX-DM	Direct search for WIMPs with an enriched Ge detector	[7,8]
ROSEBUD-I	Direct search for WIMPs with thermal detectors	[9]
ROSEBUD-II	Search for WIMPs with scintillating bolometers	[10 - 12]
ANAIS	Search for annual modulation of WIMP signals with large masses of NaI	[13,14]
GEDEON	Set of GErmanium DEtectors in ONe cryostat (in project)	[15]

In the last fifteen years more than fifty scientists from twelve institutions from eight countries (Argentina, Armenia, France, Italy, Portugal, Russia, Spain and USA) have participated in the LSC Scientific Program. The research infrastructures built in the tunnel, the investments on experimental equipment, the running costs and other scientific activities of the LSC are funded by the Spanish National Programs of High Energy Physics, and of Particle Physics and Accelerators of the Ministry of Science and Technology.

Other funding contributions come from the University of Zaragoza, the TMR Program of the European Union and the Regional Government of Aragon. Occasional contributions are those of the DOE (USA) and NSF (USA), the INFN (Italy) and CNRS (France) and INR and ITEP (Russia). Since 2004, the European Community is contributing to the development of the Laboratory through the ILIAS project within the 6^{th} framework programme.

3. The Future: The new Canfranc Underground Laboratory

Civil works for the construction of the new Canfranc Underground Laboratory are underway. Two experimental halls are being excavated 50 m from the old facility: the main one ($40\times15\times11$ m^3) oriented towards CERN to allow the possibility to use neutrino beams coming from there and an ultra low background facility ($15\times10\times8$ m^3). An access corridor housing offices, clear room and workshops for a total of about 1,000 m^2 completes the facility which should be finished next summer 2005. The first call for proposals will be announced soon.

Fig. 2 shows an drawing of the new facility and Table 3 summarizes its characteristics.

Table 3. Characteristics of the new LSC.

Depth (max.)	2,450 meters of water equivalent (m.w.e.)
Main experimental hall	600 m^2 (40x15), 11 m high (oriented to CERN)
Low-background lab	150 m^2 (15x10), 8 m high
Clean room	45 m^2 (100/1000 type)
General services	135 m^2
Offices	80 m^2
Ventilation	11,000 m^3/h (air from outside of the tunnel)
	25,000 m^3/h (air conditioning and filtered)
Electric power	500 kW + 50 kW generator + 15 kW UPS
Infrastructure	Low Temperature facility
	Tons of archaeological lead
	Sensors for NO, NO_2 and CO concentration
	Automatic control of temperature and humidity
	Active control of Rn
	Management of dangerous chemical products

There is no room here to describe with a minimum detail the safety regulations established for the new Laboratory. A complete protocol for access, stay in the lab, fire control and evacuation procedures has been included in the safety regulations of the road tunnel.

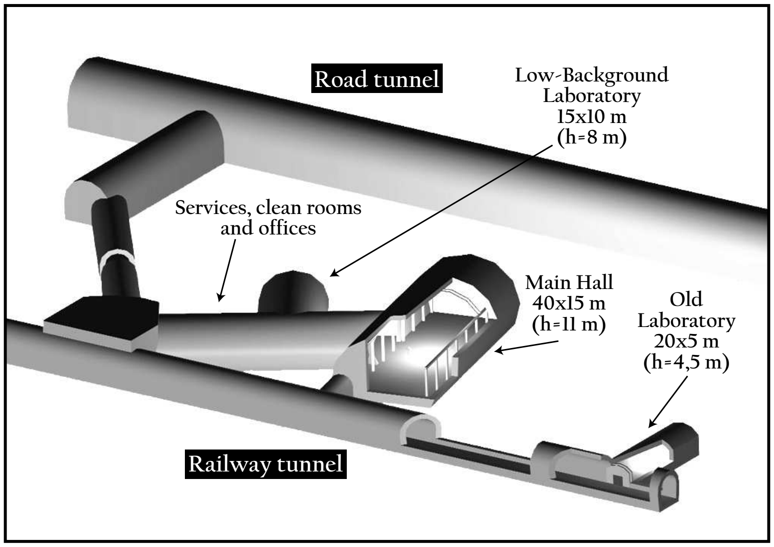

Figure 2. Artistic view of the new facility

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