Vol. 41 (2010) *ACTA PHYSICA POLONICA B* No 7

LAGUNA AND THE LSC*

Luis Labarga

University Autónoma Madrid
Ciudad Universitaria de Cantoblanco
28049 Madrid, Spain

(Received May 31, 2010)

In this paper an overall view of the Feasibility Study to host a LAGUNA detector in the Canfranc Underground Laboratory is presented.

PACS numbers: 13.15.+g, 14.60.Lm, 14.60.Pq, 14.60.St

1. Introduction

The Canfranc Underground Laboratory (LSC, *Laboratorio Subterráneo de Canfranc*) is located on the Spanish side of the Pyrenees, under the mountain of El Tobazo (2000 m), in the approximate plane defined by the recently constructed Somport road tunnel, and an old railway tunnel connecting France and Spain which is used nowadays as emergency escape of the road tunnel. The Spanish entrances of both tunnels are in Canfranc, a medium-sized village ($\sim$ 600 inhabitants) of the province of Huesca, region of Aragón, which is located in the Aragón Valley, at 5 km distance of two major sky resorts: Candanchú and Astún, and at $\sim$ 23 km distance from the lively city of Jaca ($\sim$ 23 000 inhabitants), see Fig. 1.

As detailed in another contribution to these proceedings [2], the European Consortium LAGUNA is formed by the LSC, the University Autonoma Madrid (UAM) and 21 other European research institutes. LAGUNA has been funded by the EU with 1.7 M€ for its start, with the explicit request of focusing on the Feasibility Studies (FS), mainly geotechnical, of such facility in the seven considered sites, taking into account the three possible detection technologies.

The FS of the LSC is co-funded by LAGUNA (142 K€ for the LSC and 31 K€ for the UAM) and the LSC (101 K€) and UAM (7 K€) themselves. It is coordinated by L. Labarga (UAM) with the help of the LSC staff. The technical work has been done mostly by the Spanish Geotechnical Companies *Iberica de Estudios e Ingeniería S.A.* (IBERINSA) and *Servicios Técnicos*

* Presented at the Cracow Epiphany Conference on Physics in Underground Laboratories and Its Connection with LHC, Cracow, Poland, January 5–8, 2010.

de Mecánica de Rocas (STMR). They were chosen after a careful search of suitable Companies, mostly within Spain, followed by the corresponding bidding process.

The work is almost finished. It is documented in the yet preliminary LAGUNA-WP2s Interim Report for the LSC which can be accessed from the LSC public web (`http://www.lsc-canfranc.es/pagina-279/`).

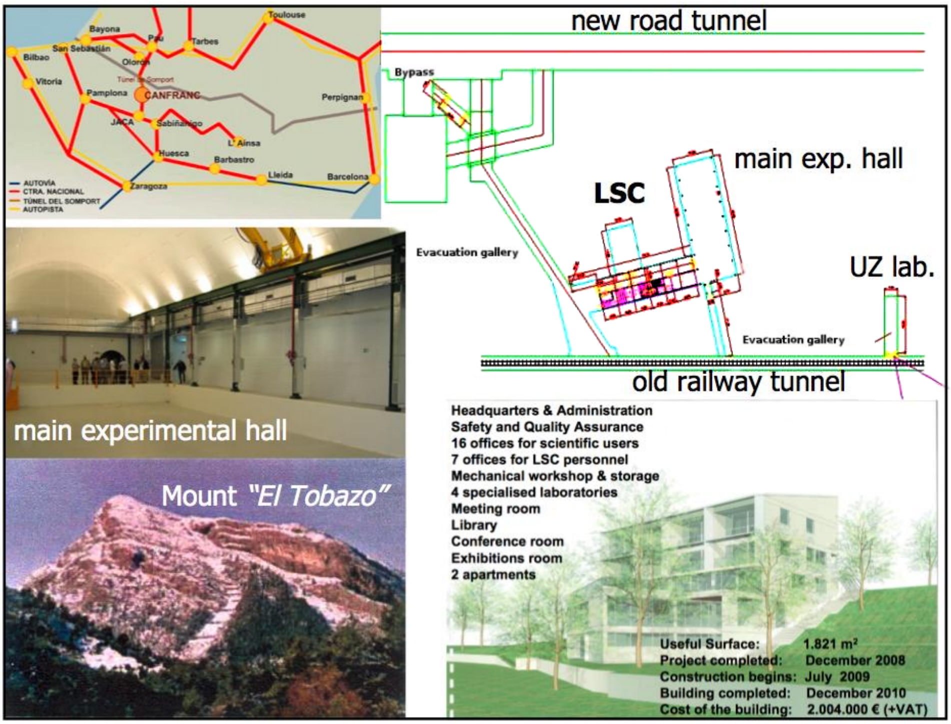

Fig. 1. Some aspects of the Canfranc Underground Laboratory.

2. The LSC

The previous, first underground facility under the Pyrenees, close to the dismissed railway tunnel, was created in the 1980s by A. Morales and the Nuclear and High-Energy Physics Department of the University of Zaragoza. Taking profit of the excavation of the parallel Somport road tunnel (opened in 2003), the new laboratory was later built. The underground structures were completed in 2005. However, more recently a few design and construction defects did emerge and the reparation works are under way, to be completed by spring 2010. The LSC is managed by a consortium between the Spanish Ministry of Science, the Government of Aragon and the University of Saragossa.

The underground area available sums up to $1000\,\mathrm{m}^2$ approximately, divided between two experimental halls, Hall-A of $40 \times 15 \times 12[\mathrm{h}]\,\mathrm{m}^3$ and Hall-B of $15 \times 10 \times 8\,[\mathrm{h}]\,\mathrm{m}^3$, one Clean Room of $45\,\mathrm{m}^2$; and another $215\,\mathrm{m}^2$ for services. The access is horizontal using either the road or the railway tunnel. Within the current protocol, the entrance must be communicated to the road tunnel control. The rock coverage is typically 850 m (2.4 km w.e.) with a muon flux of $\sim 3 \times 10^{-3}\,\mathrm{m}^{-2}\mathrm{s}^{-1}$. The approximate neutron flux is $\sim 2 \times 10^{-2}\,\mathrm{m}^{-2}\mathrm{s}^{-1}$ [1].

The main surface building is presently being constructed. It will contain headquarters, administration, a library, meeting room, offices, laboratories, storages and a mechanical workshop, safety structures and management, for a total of approximately 1500 m^2 (see Fig. 1). A dozen of employees are being hired.

The following experimental proposals have been submitted or shown interest in, and are being discussed and followed by the Scientific Committee.

Approved:

1. *Anais*: to search for annual modulation of cold Dark Matter,
2. *Rosebud*: test facility for bolometer R&D cryogenic detectors,
3. the *BiPo* test series within the *super-Nemo* program for $0\nu2\beta$,
4. *Next*: time-projection-chamber (TPC) experiment for $0\nu2\beta$,
5. *Ultima*: ultra cold prototype detector for the search for the super-fluid phase of a ^{3}He–^{4}He mixture,
6. *SuperKGd*: “mass production” of very low background measurements for the Super-Kamiokande R&D program on neutron tagging by dissolving gadolinium in water.

Under study:

1. The *ArDM*: Dark Matter search with a liquid Argon TPC,
2. An enlargement of the laboratory to host next-generation nuclear astrophysics experiments and the potentiality of the underground environment for geological and biological sciences are under study.

Regarding the possibility of the LSC hosting a very large underground research infrastructure as LAGUNA, it is important to stress that:

1. The Somport tunnel is binational (5.7 km Spain and 2.9 km France) and therefore it is managed by two administrations from two nations,
2. it is state of the art on safety features (after EU directive 2004),
3. the railway tunnel is used as its service and emergency tunnel,
4. for that there are safety galleries connecting both tunnels every 400 m.

3. The LSC feasibility study for LAGUNA

3.1. General considerations

Two aspects have been pivotal during the realization of the FS. The first one was to attain the best compromise between overburden, rock quality, knowledge (at a FS level) and expectations of rock quality and centralization of services. Based on this, the following decisions were taken (see Fig. 2):

(i) the LAGUNA experiment should be close to the current LSC location,

(ii) MEMPHYS and LENA should be placed where the overburden is largest. GLACIER is special in several aspects. On one hand its 75 m Ø dome makes it, indeed, the most challenging option from a geotechnic point of view; on the other, its peculiar way of functioning makes it less demanding in terms of overburden. Finally, there is a region along the railway tunnel which is well known for featuring rock of superb quality. Accordingly it was decided:

(iii) to place GLACIER at that, shallower, best quality rock location along the railway tunnel.

The second pivotal aspect was to interfere neither with the regular running of the road tunnel nor with the emergency and service purposes of the railway tunnel. The main layouts in the three experiments have been designed accordingly. Of course, they try to take the maximum profit of both tunnels, but at the same time they are conceived to operate independently if necessary. Based on the above it is foreseen (see Fig. 2):

(iv) to build an independent access tunnel (2–3 km long, $\sim$ 4–7% downwards) almost parallel to the existing ones, for construction access, for regular operation/running and maintenance access, for radon-less air conduction, for regular supplies (energy, water, others) for truck supply down to the detector site Liquid-Scintillator or Liquid-Argon in the case of LENA or GLACIER, and for ventilation (regular operation/running and fire emergency modes),

(v) to build a permanent connection with the road and railway tunnels and the LSC, for normal operation (connection to LSC) and as emergency escape route,

(vi) to build another tunnel followed by a vertical shaft to the surface for ventilation, both in regular operation/running and fire emergency modes.

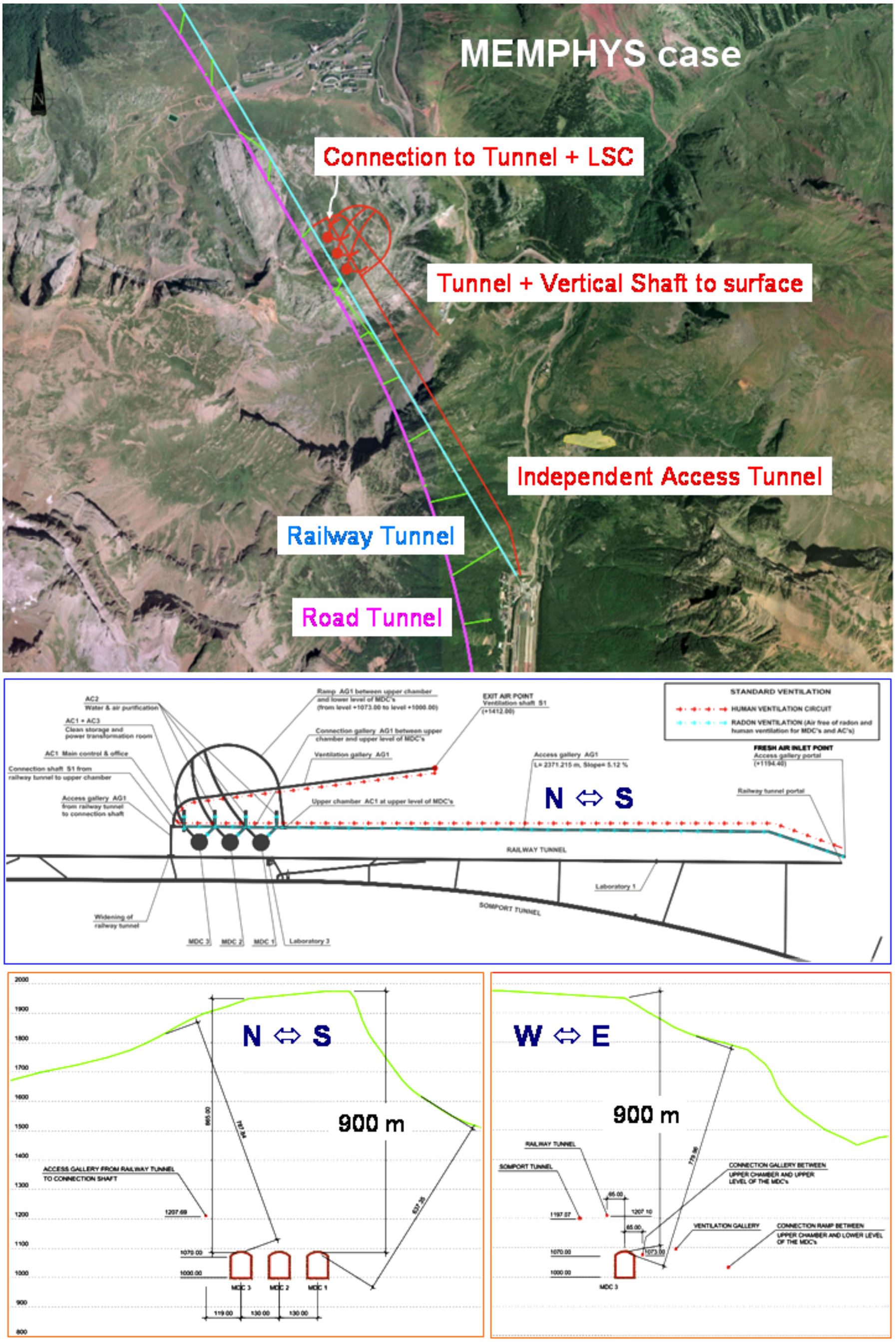

Fig. 2. General layout of the MEMPHYS option at the LSC.

3.2. Geology

We have achieved a rather good knowledge of the local geology (at the level of a FS). Its main sources were (a) the Official Geological Spanish Mapping, (b) the measurements and experience from the Somport tunnel, (c) *ditto* from the construction of the LSC and the incidents occurred afterwards, and (d) three probing boreholes made (at the candidate locations for GLACIER and MEMPHYS/LENA) and analyzed during this FS.

The rock in the mountain "*El Tobazo*" is mostly of good quality marine coralline limestone (Fig. 3). There is, however, the so-called "*Atxerito*" formation, composed of interbedded layers of mudstones slates and limestones located at the base of the limestones with a smooth transition between both. Of course, should it be decided to built LAGUNA in Canfranc, a further campaign of geological–geotechnical bore holing to detail the rock mass configuration at the precise location of the detector at larger depths will be necessary.

Fig. 3 shows the candidate locations of the three detectors. To be on the conservative side, all the calculations carried out along this FS have assumed the worst possible conditions: "*Atxerito*" formation for MEMPHYS and LENA.

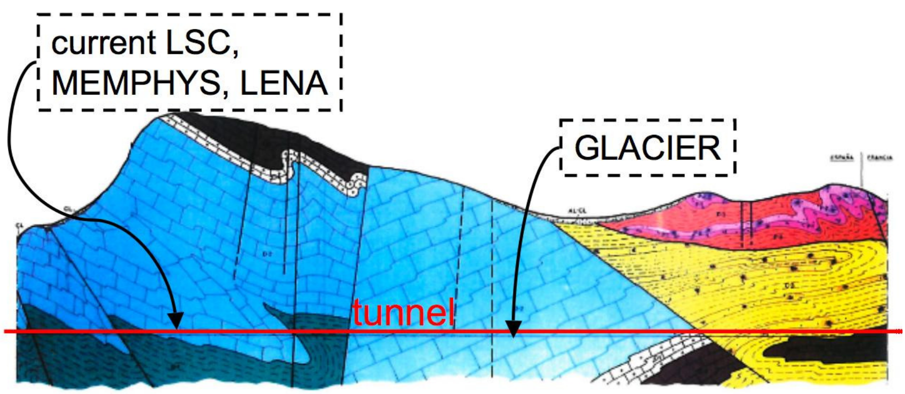

Fig. 3. Gross features of the geology of the site, and proposed location for the three detector options.

3.3. Conceptual design of the support structure

For the MEMPHYS and GLACIER options, one has to bear always in mind that there are no precedents of vaults with such a large spans (65 m or 75 m Ø). Therefore, one should assume that they can not be supported by conventional methods like < 20 m cables, bolts, shotcrete *etc.* Those are presumably able to cope with rock stresses near excavation limits and with relatively (w.r.t. the span) minor wedges. But nothing can be extrapolated about "major" wedges. To safely deal with them, it has been chosen to go to a partially concrete structure as sketched in Fig. 4.

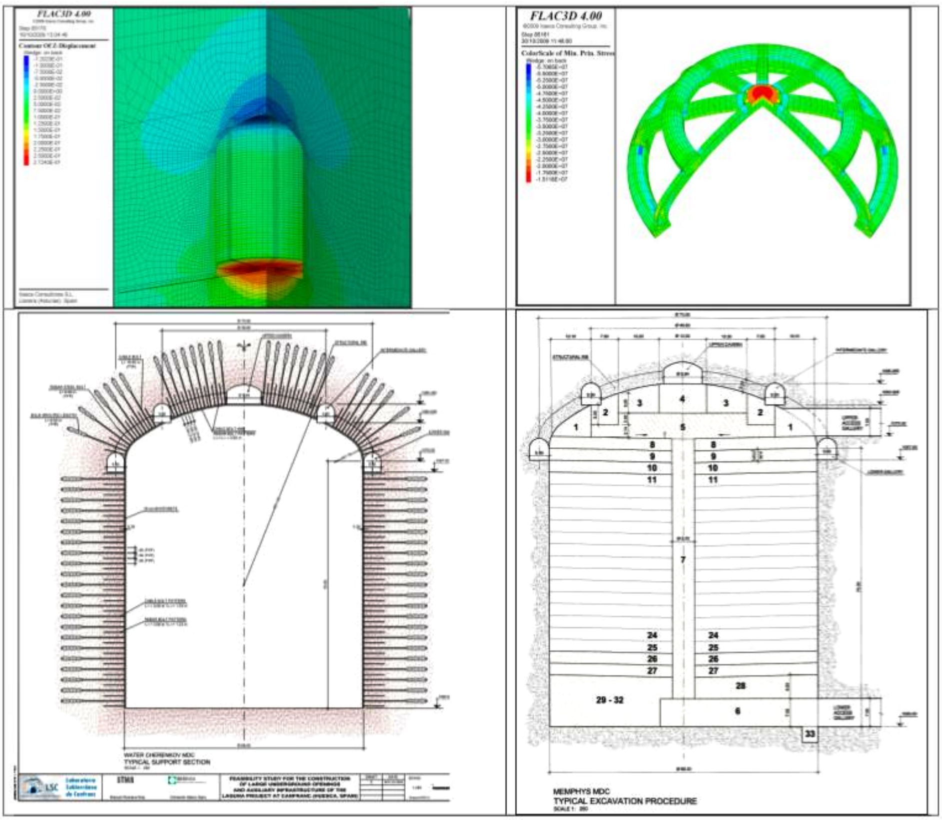

Fig. 4. Examples of calculations, pre-designs and excavation sequences.

On the contrary, there are precedents for LENA, the most respected one being probably the Mingtan cavern, built by Hoek and Collaborators in weak rock [3]. The translation into our case is foreseen as follows:
(1) excavate a circular gallery over the cavern, (2) insert downwards support cables from the circular gallery to approximately the place where the vault will be located, (3) start excavation of the vault, use the support cables as the main structural support of the roof, (4) add regular bolts, shotcrete *etc.* during the excavation.

3.4. Estimation of the feasibility of the caverns

At first, rough estimate of the feasibility of the construction of the caverns for the LAGUNA detectors, as well as the general features of the results of their construction, was carried out by elastic modeling. Three important conclusions from this study are worth mentioning: (1) the effect of the topographic features of the area (rather varying in some cases, see Fig. 2) is negligible, (2) the plasticity indicators of the three MEMPHYS caverns when they are together (at the appropriate distances) are positive, and (3) the plasticity indicators for the cavern of largest span, the GLACIER cavern, are positive.

For one of the MEMPHYS caverns a rather realistic elastic/plastic modeling program of calculations was carried out: it assumed the worst rock conditions and took into account almost all the constructions stages (slightly simplified). Three different behavior laws for the concrete were studied: elastic/plastic, brittle failure and softening. Also, two different concrete filling sequences were considered (prior to the excavation, and by stages along the excavation). It was concluded that the concrete needs some reinforcement in the lower-roof gallery. Typical displacements obtained were 12 cm in the vault, 14 cm in the walls an 27 cm in the invert (see Fig. 4 for details). These results can be safely extrapolated to the LENA and GLACIER pre-designs, using the results from the elastic modeling.

4. Epilogue

A very detailed feasibility study for LAGUNA at the LSC has been performed. It is documented in the yet preliminary LAGUNA-WP2s Interim Report for the LSC (`http://www.lsc-canfranc.es/pagina-279/`). Many items have not been presented here due to lack of time; of particular importance are environmental aspects, installations and auxiliary infrastructures. We strongly recommend to access above web page.

The Canfranc area is excellent to provide the social and living needs of the people forming a large collaboration like LAGUNA. The LSC is found to be very well suited to host any of the LAGUNA experiments.

However, much work is yet to be done to solve the "master" equation *technology* + *location* + *beam* = *excellent-physics*. The LSC and UAM are working hard to solve it.

REFERENCES

[1] A. Bettini, `arXiv:0712.1051v1`.

[2] A. Rubbia, *Acta Phys. Pol. B* **41**, 1727 (2010), this issue.

[3] D. Moy, E. Hoek, proceedings of Rock Cavern Seminar, Hong Kong, 8–9 Dec., 1989, Eds. A.W. Malone and P.G.D. Whiteside, pp. 235–245, London Institute of Mining and Metallurgy.