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FRÉJUS SITE FOR THE LAGUNA PROJECTS*

Luigi Mosca

LSM-Fréjus — Laboratoire Souterrain de Modane
(CNRS/IN2P3 and CEA/DSM/IRFU)
Carré Sciences, 1125 route de Bardonne'che, 73500 Modane, France

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After a brief review of the present laboratory (LSM) at the Fréjus site and of the project of a first extension of it, mainly devoted to the next generation of Dark Matter and Double β Decay experiments, a short introduction to the LAGUNA Design Study is presented. Seven underground sites in Europe are considered in LAGUNA and are under study as candidates for the installation of (10^5–10^6) ton scale detectors using three different techniques: a liquid Argon TPC (GLACIER), a liquid scintillator detector (LENA) and a water Čerenkov (MEMPHYS), all mainly aimed at investigation of proton decay and properties of neutrinos from SuperNovae and other astrophysical sources as well as from accelerators (Super-beams and/or Beta-beams from CERN). One of the seven sites is located at Fréjus, near the present LSM laboratory, and the results of the feasibility study for it are presented and discussed.

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1. Introduction

The present LSM (Laboratoire Souterrain de Modane) is situated at the middle of the Fréjus road tunnel connecting France (Modane) and Italy (Bardonecchia) at a depth of about 4800 m.w.e., with a volume of 3500 m^3. Two main experiments are presently running in this laboratory: EDELWEISS-II for the Dark Matter direct detection and NEMO-3 aimed at neutrino studies through Double β Decay detection. In addition, a setup of 15 Germanium test-benches is dedicated to low radioactivity measurements for different purposes: materials selection, environment investigations, dating, *etc.* A project of a first extension of the present LSM (volume $\sim 60\,000$ m^3), mainly devoted to the next generation of Dark Matter and Double β Decay experiments, is currently under study and hopefully close to be founded.

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The Fréjus site is also one of the seven candidate sites in Europe for the installation of Megaton scale detectors aimed at the investigation of proton decay and neutrinos properties from SuperNovae and other astrophysical sources as well as from accelerators. The study of the overall project is under way in the frame of the LAGUNA network.

2. A brief reminder of the LAGUNA program

The LAGUNA acronym indicates both a European cooperation and an FP7 Design Study Network.

(a) The European Cooperation Project LAGUNA, gathering 30 Institutions from 10 countries, is essentially aimed to the following physics goals:

1. exploring Proton Decay lifetime up to $\sim 10^{35}$ years as a fundamental probe of Grand Unification theories;
2. detection of neutrino bursts from individual Supernovae explosion and diffuse neutrinos from all past Supernovae explosions;
3. solar neutrinos and atmospheric neutrinos (from cosmic rays) further investigations with high statistics;
4. detection of neutrinos from inside the Earth (geo-neutrinos);
5. neutrino oscillations study by using accelerator super-beams and/or beta-beams.

In the LAGUNA European Cooperation the main Physics goals are common, while three different detection techniques are proposed, represented by: GLACIER (Liquid Argon TPC), LENA (Liquid Scintillator), and MEMPHYS (water Čerenkov). There is, in fact, a strong complementarity among the three detector approaches, to be better investigated by LAGUNA.

These gigantic detectors will need a very large underground laboratory. For this purpose seven candidate sites have been considered in Europe: Boulby (UK), Fréjus (France/Italy), Umbria (Italy), LSC (Spain), Pyhäsalmi (Finland), Polkowice–Sieroszowice (Poland), and Slanic (Romania).

(b) LAGUNA as an FP7 Design Study Network is organized in four Work Packages:

WP1 for management and coordination; WP2 for Underground Infrastructures and engineering studies (including tanks and liquids handling);

WP3 for Safety as well as environmental and socio-economic issues; and WP4 for Science Impact and Outreach.

The main deliverable of this Design Study will be a *conceptual design report* on the feasibility of a megaton-scale underground infrastructure addressed to policy makers defining the European strategy in this field of research.

The main topics to be addressed in this feasibility study, for each site and each type of experiment on the basis of their requirements, are:

1. the determination of the best shape for very large cavities and of their possible dimensions (using simulations constrained by the knowledge of the type, structure and stress of the rock);

2. the definition of the basic equipment and facilities: ventilation, air-filtering and conditioning, liquid production (if not purchased), transportation and continuous purification, electrical power supply, clean rooms, computing facilities, *etc.*;

3. the incorporation of the relevant safety conditions and equipments (for long term stability of the cavities, for fire, liquid leaks, evaporation risks, *etc.*);

4. an evaluation of the cost and time of realisation of the different parts of each site's infrastructure (and also maintenance cost).

3. Study of the Fréjus site

Now let us consider the study of the Fréjus site as a candidate for the LAGUNA Project, currently performed by the LOMBARDI Company (LOMBARDI Engineering, 6648 Minusio Switzerland) and presently at an advanced stage.

In Fig. 1 are presented the shapes and dimensions of the cavities as required for each one of the 3 types of LAGUNA experiments: GLACIER, LENA and MEMPHYS.

Then, in Fig. 2 is shown an "artistic view" of the possible installation for each one of these three experiments near the present LSM.

3.0.1. Geo-mechanical feasibility of the caverns

The GLACIER, LENA and MEMPHYS detector options are all feasible at the Fréjus site and this feasibility remains valid also for small changes of the size of the excavations, both in diameter and height of the cavern. The geomechanical conditions at the Fréjus site are well known and further investigations are basically not required. Nevertheless, the safety tunnel under construction will provide further information.

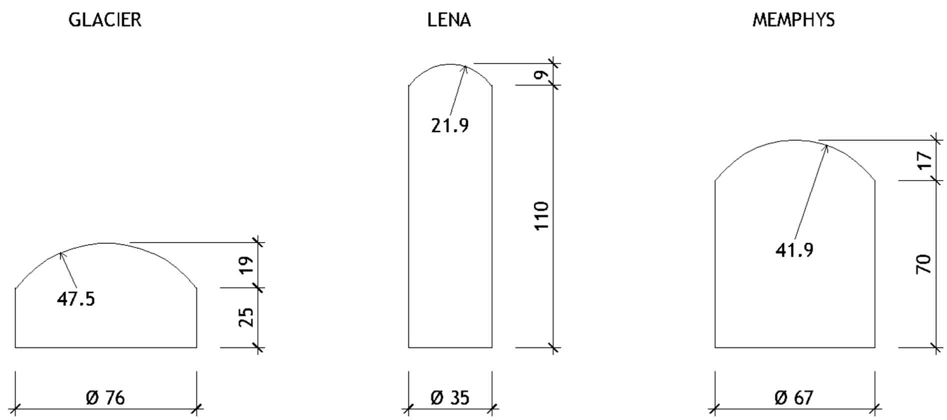

Fig. 1. Dimensions of the three detector cavities.

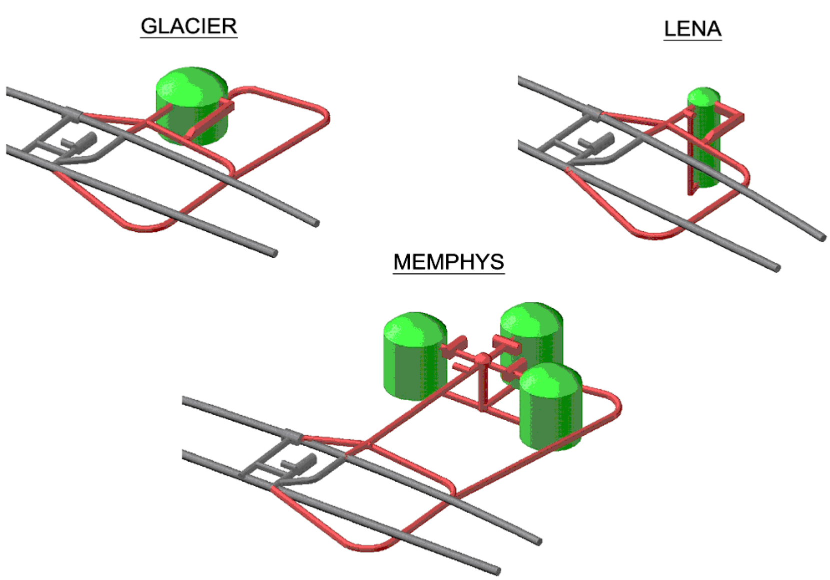

Fig. 2. Possible location near the LSM of each one of the 3 proposed experiments.

The support system proposed in this study guarantees the long term stability and the absence of significant time dependent displacement of the cavity. Moreover, the same support system has sufficient reserve to insure the stability of the cavern in case of earthquake.

3.0.2. Tank feasibility

Concerning the detector tanks feasibility and construction, the solution with the tank placed in contact with the rock mass is feasible at Fréjus site for the LENA and MEMPHYS options, while for the GLACIER option an independent tank configuration is preferable.

The solution with the tank placed in contact with the rock would reduce the amount of steel needed by 7200 Kg for the MEMPHYS option and 3600 Kg for the LENA option.

Both the solutions with insulation and without insulation are feasible at the Fréjus site, while in case of absence of water in the rock mass, the solution without the insulation is preferable from an economical point of view.

4. The distance of each site from CERN: A strategical issue

Concerning the distance of a given site from CERN two different strategies can be considered (see the Mauro Mezzetto talk):

A "short" long-baseline option, with "low" (less than $\sim$ 500 MeV) neutrino energy, which would imply:

— a low background, due to the absence of inelastic events;

— the need of a better knowledge of the low energy neutrino cross-sections (to be obtained in the meantime and/or during the experiment itself);

— a negligible matter effect, which is good for a clean CP-violation measurement;

— the "mass hierarchy" determined by combining the neutrino beam data with the atmospheric neutrino events;

— a super-beam and a beta-beam both feasible with the present CERN accelerators (PS and SPS).

A "long" long-baseline option, with "high" neutrino energy, which would imply:

— a higher background due to inelastic events;

— the "mass hierarchy" determination is possible also without atmospheric neutrinos, but with the need to disentangle it from CP-violation effects;

— and, last not least, the need of upgrade of the CERN accelerators.

5. Conclusion and outlook

— The main physics goals are common in the LAGUNA Cooperation.

— The LAGUNA programme aims at otherwise inaccessible fundamental phenomena.

— The 3 detector approaches are complementary.

— LAGUNA is a European cooperation, but it is also open to the world community!

— The FRÉJUS site (at the French/Italian border):

  — is the deepest in Europe (4800 m.w.e.);
  — GLACIER, LENA and MEMPHYS options are all possible from the geo-mechanical point of view (optimal type of rock) at this depth;
  — it has an independent horizontal access via the safety tunnel ($\Phi = 8$ m);
  — the long-distance access is optimal by highways, TGVs and airports;
  — the distance from CERN (130 km) is appropriate (even if not fully optimized) for a θ_{13} and CP-violation strategy with a "short" long-baseline;
  — it benefits from a strong support from the local authorities.

For more information

— On the LAGUNA Project, see the Website: `http://laguna.ethz.ch:8080/Plone/`

— On the present laboratory at the Fréjus site, LSM (Laboratoire Souterrain de Modane), see the Website: `http://www-lsm.in2p3.fr/`

— On the neutrino beams projects in Europe, see the EUROnu Website: `http://www.euronu.org/`