Extension of the LSM: report of the Scientific Advisory Committee

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Executive summary

The Scientific Advisory Committee (SAC) considers that the extension of the Modane underground laboratory (Laboratoire Souterrain de Modane, LSM) represents an excellent opportunity for Europe to gain new space for the next generation of underground experiments. The prime advantages of the site are its depth and the easy horizontal access. This has allowed the new laboratory to attract in this first expression of interest some of the main actors in the field, as the letters of intent received testify. This should allow for a cutting edge scientific program at Modane in the decades to come. *The SAC thus strongly recommends the extension of the Modane laboratory, which will provide one of the leading underground infrastructures in the world, with a potential for providing outstanding scientific results on some of the basic questions of fundamental research : what is the universe made of? what is dark matter ? what is the origin of mass for neutrinos ? is matter stable ?*

The SAC has reviewed the 12 letters of intent received. A few of them originate from some of the major projects, identified as such by the ASPERA European roadmap : two of them look for detecting dark matter in the form of weakly interacting massive particles, EURECA and DARWIN ; and one, SUPERNEMO, aims at identifying the nature of the neutrino particle.

EURECA is the European cryogenic second generation (ton-scale) experiment: it builds on the expertise of the EDELWEISS and CRESST experiments, the former, a long term host of LSM, providing the baseline approach. Given the past experience accumulated at LSM, the Committee considers it a very reasonable step to keep the cryogenic approach for a second generation detector. A promising alternative, yet to receive full confirmation, is provided by noble liquid detectors, as proposed by the DARWIN project, which sent an expression of interest. The DARWIN project proposes to combine the use of xenon and argon: it remains to be seen whether there are significant advantages in doing so. The presence of both EURECA and DARWIN would make LSM a strategic place to choose the technology of the future (third generation) dark matter detectors.

SUPERNEMO represents the new generation of the NEMO experiment, already present on site: it is looking for neutrinoless double beta decay, a key process to understand the nature of neutrinos. Compared to other similar projects, it has the advantage of measuring the two electrons produced in this process, which provides basic knowledge of the interaction. This is at the cost of a lower energy resolution. The timescale for SuperNEMO is online with other similar efforts but the SAC recommends to make every effort to speed up the program.

Other letters of interest are associated with R&D efforts. They show the road towards a coherent R&D programme in the LSM extension. The Committee strongly recommends such a programme and correspondingly supports a specific call for R&D proposals. Priority should be given to efforts which best exploit the unique features of the site, especially its depth.

A certain number of proposals are of an interdisciplinary nature. This is an important spin-off and it should be developed as a complementary programme. The Committee encourages the laboratory to develop a systematic approach, building the strength of this programme particularly on deeper contacts with the local scientific community, as already started. The future SAC should include the necessary expertise to judge the interdisciplinary projects proposed.

In view of these expressions of interest, the Committee considers as a minimal solution a 100m long cavern since it would allow one dark matter experiment, one neutrino experiment and sufficient space for R&D and interdisciplinary programs. However, it strongly recommends to add space in order to fit yet another experiment and thus considers a 120m cavern as optimal.

Report

The Scientific Advisory Committee has reviewed the 12 letters of intent (plus 1 expression of interest) received and presented at the workshop held in Modane on September 16, 2009. A certain number of additional questions were addressed to the proponents; the answers were reviewed by the Committee in a closed meeting on February 12, 2010. Conclusions were reached at the same meeting.

The Scientific Advisory Committee (SAC) considers that the extension of the Modane underground laboratory (Laboratoire Souterrain de Modane, LSM) represents an excellent opportunity for Europe to gain new space for the next generation of underground experiments. The prime advantages of the site are its depth and the easy horizontal access. This has allowed the new laboratory to attract in this first expression of interest some of the main actors in the field, as testified by the letters of intent received.
The construction of a safety tunnel in the Frejus complex is a unique opportunity to dig a cavern that would fit the next (second) generation of underground experiments. This would build on the technical expertise accumulated at the LSM over 23 years. This would also profit from the many advantages of the site: primarily its depth (4800 metres of water equivalent), but also its accessibility (through its good connections as well as its horizontal access) and its overall quality (low convergence, dry, stiff rocks). This is thus an outstanding opportunity for Europe to gain new underground space to satisfy the needs of the second generation of experiments as well as host prototypes of the third generation experiments. This should allow for a cutting edge scientific program at Modane in the decades to come.

Recommendation: The SAC strongly recommends the extension of the Modane laboratory, which will provide one of the leading underground infrastructures in the world. Such an infrastructure has a real potential for providing outstanding scientific results on some of the basic questions of fundamental research, such as:

- What is the Universe made of? In particular: What is dark matter?
- Do protons have a finite life time?
- What are the properties of neutrinos? What is their role in cosmic evolution?
- What do neutrinos tell us about the interior of the Sun and the Earth, and about Supernova explosions?

These are four of the six fundamental questions identified by the ASPERA European roadmap in astroparticle physics.

It is in fact a positive sign that several of the letters of intent originate from some of the major European projects, identified as such by the ASPERA roadmap : two of them look for detecting dark matter in the form of weakly interacting massive particles (wimps), EURECA using cryogenic detectors and DARWIN using noble gas detectors; and one, SuperNEMO, aims at identifying the nature of the neutrino particle.

EURECA is the European cryogenic ton-scale experiment looking for wimps, set out to explore scalar cross sections down to the 10^{-10} pb level. It builds on the expertise of the EDELWEISS experiment using germanium detectors and the CRESST experiment using solid crystal scintillators. EURECA will have a multi-element target using both. The proposed EURECA set up is composed of two circular water shields of 8 m diameter and 10 m height. EDELWEISS has made significant progress recently, exhibiting excellent rejection of signals from surface electrons. It provides the baseline target material and detector type for the EURECA project.

Given the expertise already present at LSM on cryogenic detectors for dark matter, keeping this technical solution for the second generation detector seems a very reasonable step. It is too early to choose the technology for the third generation detectors.

The Committee considers that the best argument for having two tanks is the possibility of using one as a general facility for R&D : this would bring some flexibility. But this option may be discarded if there is a need for space.

DARWIN explores the other alternative, a noble liquid Time Projection Chamber (TPC), which represents a promising technology, as shown by the first results of XENON 100. The DARWIN collaboration is proposing to combine both Argon and Xenon in a one-ton to multi-ton scale experiment. Both are worth investigating into. It remains to be seen whether there are significant advantages in combining them in the same experiment. The plans of the collaboration seem to be rather « fluid » at this time, with several potential sites in Europe. The clear advantage of Modane is its depth.

The two proposals just discussed show that dark matter experiments of this generation basically occupy the same space, irrespective of the technique considered.

Recommendation: the SAC recommends to have at least one second generation dark matter experiment in the extension. The presence of both EURECA and DARWIN would make LSM a strategic place to choose the technology of the future (third generation) dark matter detectors.

SuperNEMO represents the new generation of experiments looking for neutrinoless double beta decay, a key process to understand the nature of neutrinos. It should reach a sensitivity to the Majorana mass of the neutrino at the level of 50-100 MeV. It builds on the experience of the NEMO experiments, the latest of which is presently taking data on site. Compared to other similar projects, the technique used has the advantage of measuring the two electrons produced in this process, which provides basic knowledge of the interaction. This is at the cost of a lower energy resolution. The baseline SuperNEMO design consists of about 20 identical super-modules, each housing about 5 kg of ^{82}Se isotope. It requires some 55 m of the new cavern.
This is a field where there is a strong competition: in Europe, GERDA is in the commissioning phase and thus earlier but its sensitivity will not explore the full range of parameters; CUORE is starting in 2012 and ramping up to 740 kg of Tellurium; and in America, EXO, Majorana in the US and SNO+ in Canada have similar timescales. The schedule of SUPERNEMO is online with these efforts but the SAC recommends to make the best efforts to keep it as presented. In any case, even if SUPERNEMO does not lead to a discovery, it will provide a better understanding of the interaction.

Recommendation: the SAC recommends having one neutrino experiment in the extension, the obvious candidate being SUPERNEMO. It stresses the importance of keeping a tight schedule for this project.

The committee has reviewed the smaller proposals in the field of astroparticle physics. They are all at a stage which can still be considered as R&D. They are:

- COBRA, a large array of CdZnTe semiconductor crystals to measure double beta decay through double electron or positron emission,

- A low background gamma ray spectrometer to measure neutrinoless double electron capture,
- MIMAC-CYGNUS, a gas Time Proportional Chamber (TPC) for directional dark matter search,
- A spherical gaseous detector filled with Xenon, aimed at detecting supernova neutrinos through the coherent superposition of all neutrons in neutrino nucleus scattering,
- ULTIMA, an ultra-low superfluid ^{3}He system allowing to determine the physical parameters required for the next generation of cosmoparticle detectors.

It is not the intent of this Committee to review in depth these different proposals. Interesting ideas were presented, but they do not seem to be mature enough at this stage.

Recommendation: The Committee is convinced that there should be one strong R&D programme, and correspondingly a specific call for the R&D proposals. Priority should be given to efforts which best exploit the unique features off the site, especially its depth.

It might be considered as a possibility to host R&D in the old LSM lab to allow for more room dedicated in the new facility to the large scale experiments, for which the high ceiling is needed.

Finally, a certain number of interdisciplinary projects are envisaged, such as radioecology studies and regulatory surveillance of radioactivity levels, the dating of Alpine lake sediments or the susceptibility of integrated circuits to radiation. These projects appear to be interesting opportunities but the present members of the SAC have no real expertise to judge how relevant they are to their fields.

The Committee is convinced that these interdisciplinary projects are important although they should not become a driver of the scientific program. They also provide a good way to establish deeper contacts with the local scientific community (universities and research institutes). This encouraging first step suggests that the lab does a more systematic approach, for example by organising dedicated workshops. The future SAC should include the necessary expertise to judge the interdisciplinary projects proposed.

To conclude, the SAC has discussed what would be the minimal and optimal size for the extension, given the scientific programme that can be envisaged following the expressions of interest received from the community at large. It has reached the following conclusions.

Recommendation: The SAC considers a solution with a 100m long cavern as minimal since it fits one dark matter experiment, one neutrino experiment and sufficient space for R&D and interdisciplinary programs. However, the committee recommends to add space in order to fit yet another experiment and thus considers a 120m cavern as optimal. Moreover, in order to save some space, it encourages the lab to look for some possible dual uses of the facilities.

The extension presently considered will allow to test prototypes of the third generation experiments. This is important if a further extension allows to host these very large scale experiments. Modane is one of the few underground sites in the world which could pretend to play such a role. Of course, the type of mega-experiment present at Modane would depend on a global worldwide negotiation.

In the context of the present extension, the SAC urges the LSM to establish or strengthen contacts and possibly collaborations with other major underground laboratories on issues such as low background counting, geology, biology…

Finally, the SAC would like to draw the attention on a few technical points.
One should seriously consider having available on site some water system (for example by purifying the cooling water, or using water for fire hazards).
There is a need for an air purification system (radon).
A permanent shielding does not seem necessary.
Special attention should be paid on designing how to get around the experiments in the cavern.