Letter of Interest for locating the SuperNEMO neutrinoless double beta decay experiment in the extended LSM underground laboratory

The SuperNEMO Collaboration

E. Chauveau, Ph. Hubert, C. Marquete, F. Piquemal, J-S Ricol
Centre d'Etudes Nucléaires de Bordeaux Gradignan, Université Bordeaux, France

V. Vorobel, A. Zukauskas
Charles University, Prague, Czech Republic

F. Mamedov, I. Stekl, L. Vala
Czech Technical University, Prague, Czech Republic

P. Povinec, F. Simkovic
FMFI, Comenius University, Bratislava, Slovakia

Y. Tamagawa
Fukui University, Japan

J. Diaz, N. Yahlali
IFIC, University of Valencia, Spain

J. Sedgbeer, Y. Shitov
Imperial College, London, UK

V. Tretyak
Institute for Nuclear Research, Kiev, Ukraine

R. Arnold
IPHC, Université Louis Pasteur (Strasbourg, France)

A. Barabash, S. Konovalov, I. Vanushin, V. Umatov
ITEP, Moscow, Russia

V. Brudanin, V. Beillet-Kovalenko, V. Egorov, O. Kochetov, I. Nemchenok, Yu. Shitov, A. Smolnikov, E. Shevchik, M. Shirchenko, V. Timkin, V. Tretyak, D. Zinatulina
JINR, Dubna, Russia

M. Bongrand, X.Garrido, S. Jullian, X. Sarazin, L. Simard
LAL, Université Paris Sud, Orsay, France

A. Chapon, D. Durand, B. Guillon, F. Mauger
LPC/ENSICAEN, Caen, France

S. Sutton
Mount Holyoke College, South Hadley, USA

M. Nomachi, M. Saka
Osaka University, Japan

H. Ohsumi
Saga University, Japan

K. Fushimi
Tokushima University, Japan

F. Nova, F. Sanchez
University of Barcelona, Spain

A.Basharina-Freshville, M.Carter, T.Hunt, R.Flack, M.Kauer, B.Richards, R.Saakyan, J.Thomas, D. Waters
University College London, UK

J. Suhonen
University of Jyväskylä, Finland

C. Jackson, S. Kolya, I. Nasteva, S. Soldner-Rembold, R. Thompson
University of Manchester, UK

K. Lang, Z. Liptak, B. Pahlka, M. Proga
University of Texas, Austin, USA

S. Cebrian, I. Garcia-Irastorza
University of Zaragoza, Spain

Abstract

The SuperNEMO experiment will search for neutrinoless double beta decay to explore fundamental questions of particle physics associated with the nature of neutrino mass. The experiment will have a sensitivity to the Majorana neutrino mass at the level of 50-100 meV. The unique features of SuperNEMO are the ability to study any double beta decay isotope and reconstruction of the event topology which not only produces a “smoking gun” evidence for the process but also may allow the underlying physics mechanism to be disentangled.
A comprehensive design study has been carried out in the last 4 years during which major technological challenges have been successfully addressed. SuperNEMO is now entering its construction phase and the first super-module will be ready to be installed in an underground laboratory in 2013. In this letter we express our strong interest in using the new extended underground laboratory at Modane (the new LSM) as the location for the SuperNEMO detector. The letter describes the science addressed by SuperNEMO and its physics reach. The current state of the project and an overview of the proposed programme and its schedule are given. The requirements of the experiment such as the space, infrastructure, special services and facilities are outlined.

-

September 2009

1.0 Physics case for SuperNEMO

1.1 Double beta decay and new physics

Neutrinoless double beta decay ($0\nu\beta\beta$) is a lepton-number-violating transition in which the parent nucleus (Z,A) decays to the daughter nucleus (Z+2,A) emitting two electrons. A related transition allowed in the standard model called two-neutrino double beta decay ($2\nu\beta\beta$) is accompanied by the emission of two electrons and two anti-neutrinos.

The development of effective field theory and grand unification schemes has led to the expectation that, unlike all the other fermions of the standard model, neutrinos are identical to their anti-particles and have non-zero rest mass [1]. The latter was spectacularly demonstrated by neutrino oscillation experiments [2]. However neutrino oscillations can only measure the difference between squared neutrino masses and not their absolute value. Thus, the search for $0\nu\beta\beta$ addresses two of the most fundamental questions of particle physics:

1. The nature of the neutrino (Majorana or Dirac).
2. The absolute value of the neutrino mass.

$0\nu\beta\beta$ decay is the only practical way to answer the first question and is probably the most sensitive method to measure the absolute neutrino mass in a laboratory environment.

There are different mechanisms that can lead to $0\nu\beta\beta$. The mechanism most commonly discussed is the one shown in Figure 1.1, in which a light Majorana neutrino is exchanged. In this case, the probability (or the inverse half-life) of the process can be expressed as:

$$[T_{1/2}(0\nu)]^{-1} = G^{0\nu} \; |M^{0\nu}|^2 \; \langle m_\nu \rangle^2 \qquad (1)$$

where $G^{0\nu}$ is the phase space and $M^{0\nu}$ is the nuclear matrix element for the transition. $\langle m_\nu \rangle$ is the effective Majorana neutrino mass, described below.

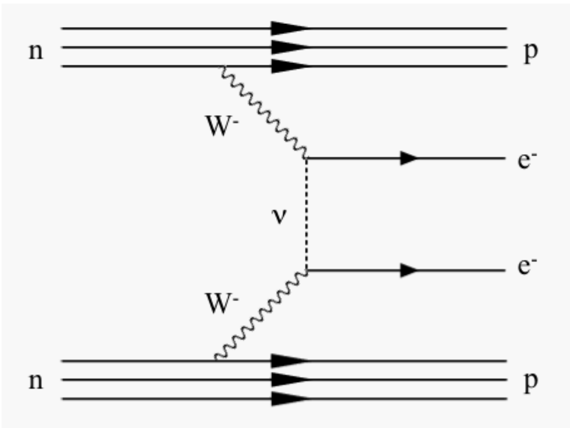

Figure 1.1: Double beta decay via the exchange of a Majorana type neutrino.

However other mechanisms are possible, to name a few:

1. A right handed (V+A) weak current interaction mediated by a W_R boson.
2. Emission of a massless Goldstone boson, the Majoron.
3. R-parity violating SUSY models.
4. Exchange of a doubly-charged Higgs boson.

Therefore the $<m_\nu>$ term in Equation (1) should be treated as a lepton number violating parameter, which can have a different form according to the underlying physics mechanism. Clearly the focus now is on finding the first clear evidence for this process but, once this is established, the most important question will be to disentangle the physics behind 0νββ.

Assuming the neutrino mass is the dominant mechanism, the information from 0νββ, neutrino oscillations and kinematic neutrino mass measurements can be combined to create a complete picture of neutrino properties. The effective mass is given by:

$$<m_\nu> = m_1|U_{e1}|^2 + m_2|U_{e2}|^2\, e^{i\alpha_{21}} + m_3|U_{e3}|^2\, e^{i\alpha_{31}} \qquad (2)$$

where m_i are the mass eigenstates, U_{ei} are elements of the PMNS neutrino mixing matrix derived from oscillation experiments, α_i are the two Majorana CP-violating phases. As one can see from Fig. 1.2, a measurement of $<m_\nu>$ and the lightest neutrino mass (which, for example, can be obtained from tritium end-point experiments combined with neutrino oscillation results) will provide an answer to the question of the neutrino mass hierarchy. Light may also be shed on the question of CP-violation in the neutrino sector.

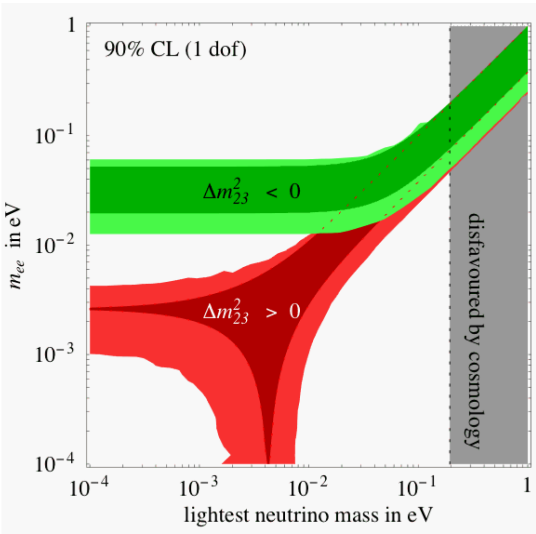

Figure 1.2 : A plot of the effective double-beta decay neutrino mass as a function of the lightest neutrino mass for normal (red) and inverse (green) hierarchies. From [3]

The accuracy of the $<m_\nu>$ determination depends on the phase space factor $G^{0\nu}$ and the nuclear matrix element $M^{0\nu}$. While the phase space factor is known precisely, there are significant uncertainties associated with $M^{0\nu}$. The calculation of nuclear matrix elements is extremely difficult and requires input from nuclear theory. The two main techniques for calculating the matrix elements are the Quasi-particle Random Phase Approximation (QRPA) and the Nuclear Shell Model (NSM). There has been significant progress in both approaches in recent years and the uncertainties are shrinking. Nevertheless, we have no way of knowing which calculation gives the right result, at least until the process is discovered experimentally. The existence of NME uncertainties also significantly strengthens the case for searching for 0νββ in *several different nuclei*.

We note that the above-mentioned uncertainties do not make 0νββ less appealing, since its discovery will probe directly physics beyond the standard model (through full lepton number violation). Also, as was shown in [4], the discovery of 0νββ implies unambiguously that neutrinos are Majorana particles, regardless of the dominating mechanism.

Alongside 0νββ, it is important to study 2-neutrino double beta decay. The half-life for this process is given by:

$$[T_{1/2}(2\nu)]^{-1} = G^{2\nu}\ |M^{2\nu}|^2 \qquad (3)$$

By measuring $T_{1/2}(2\nu)$, one can therefore determine the corresponding matrix element $M^{2\nu}$ experimentally. Although there is no one-to-one correspondence between $M^{2\nu}$ and $M^{0\nu}$, the information obtained from 2νββ leads to a development of theoretical schemes that can be used for both 0νββ and 2νββ calculations. In addition, 2νββ is the ultimate background for 0νββ and an accurate knowledge of the 2νββ spectrum shape and other characteristics is of paramount importance to understand this background. The measurement and characterization of the 2νββ process is another unique feature of the NEMO approach.

There are over 30 isotopes that can undergo ββ decay but only 9 of them are "serious contenders". An important criterion for the isotope selection is the $Q_{\beta\beta}$ value of the process, with higher values being preferred. One reason for this is a strong dependence of the phase space and therefore the probability of the process on $Q_{\beta\beta}$ ($G^{0\nu} \propto Q_{\beta\beta}{}^5$, $G^{2\nu} \propto Q_{\beta\beta}{}^{11}$). The other reason is due to the natural background, which is mostly situated below a 2.6 MeV line of ^{208}Tl (a progeny of the ^{232}Th decay-chain). Other considerations include the isotope's natural abundance, feasibility of enrichment and purification, the half-life of the 2νββ decay mode, etc. The main isotopes considered in current and future ββ experiments and their main characteristics are shown in Table 1.1

Isotope	**%**	**$Q_{\beta\beta}$ (keV)**	**$T_{1/2}(2\nu)$ (10^{19} yrs)**
^{48}Ca	0.19	4271	4.2 ± 0.5*
^{76}Ge	7.4	2039	150 ± 10
^{82}Se	9.2	2995	9.6 ± 1.0*
^{96}Zr	2.8	3350	2.35 ± 0.24*
^{100}Mo	9.6	3034	0.71 ± 0.05*
^{116}Cd	7.49	2802	2.8 ± 0.3*
^{130}Te	33.8	2533	69 ± 13*
^{150}Nd	5.6	3367	0.9 ± 0.06*
^{136}Xe	8.9	2479	> 1000

Table 1.1 : Isotopes used in the search for neutrinoless double-beta decay. The second column shows the natural abundance of the isotope, the third column the energy released in the double-beta transition and the final column shows the half-life of the 2-neutrino decay mode.

* - Results from the NEMO-3 experiments.

1.2 Experimental approaches

The spectra of the energy sum of two electrons emitted in the decay are shown in Figure 1.3 for different mechanisms of ββ decay. The standard model 2νββ decay has a continuous spectrum due to anti-neutrinos carrying away a part of the energy, while the 0νββ decay has a distinct delta-function peak (smeared by the energy resolution of the detector) for all decay modes except for the one accompanied by Majoron emission.

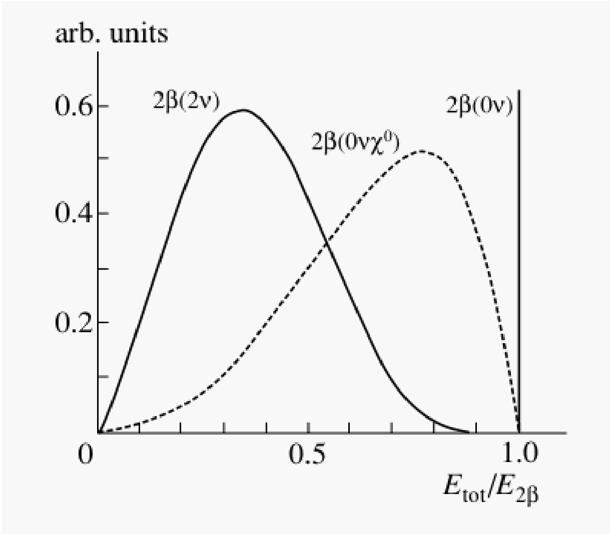

Figure 1.3 : The spectra of the summed electron energies, as a fraction of the total energy available in the decay. The standard model 2ν decay mode produces a continuous spectrum, while the 0ν mode is a delta-funtion at 1. Majoron emission can generate different spectra. From [5].

Searching for 0νββ decay is difficult. Most ββ experiments face U and Th decay-chain isotopes as their limiting background component. The problem comes from the extreme rarity of the process. The experiments carried out so far have established that the half-life of 0νββ is greater than ~10^{25} years while U and Th half lives are of the order of 10^{10} years. A continuous spectrum arising from Compton scattered gamma rays, beta rays and alpha particles from the naturally occurring decay chains can overwhelm any peak for the 0νββ signal. The most dangerous isotopes are ^{214}Bi ($Q_{\beta\beta}$ = 3.27 MeV) and ^{208}Tl ($Q_{\beta\beta}$ = 4.99 MeV) from ^{238}U and ^{232}Th decay chains respectively. The contamination is present in the detector materials and in the laboratory outside the detector. In addition cosmic ray muons, either directly or through neutron production, can create a background mimicking the 0νββ signal. The ββ detectors are therefore always placed underground and extreme care is taken during the materials selection process.

There are two distinct experimental approaches in the search for 0νββ. The first approach is when the ββ source is itself the detector, such as in Germanium detectors or TeO_2 bolometers. The other is when the source is not part of the detector and a multi-purpose detector suite is arranged around it. The first type is characterised by high efficiency and an impressive energy resolution. This excellent energy resolution allows a powerful discrimination between 2νββ and 0νββ events but may not be sufficient to eliminate non-ββ backgrounds since *any* energy deposition in the end-point region will fake the signal. In addition, this approach does not produce a "smoking gun" signature of the ββ signal and restricts the choice to a single isotope. The second approach has a worse energy resolution but the advantage of particle identification and event topology recognition. The topology and individual electron energy reconstruction may also be used to disentangle the underlying physics mechanism of 0νββ. It is this approach which is adopted by the NEMO-III and SuperNEMO experiments.

1.3 NEMO-III

The SuperNEMO design follows and improves upon the tried and tested technology of the previous NEMO experiments, in particular the technology employed in the NEMO-III detector currently taking data in the Modane underground laboratory (LSM) at a depth of 4800 m.w.e. (metres of water equivalent).

The detector is cylindrically subdivided into 20 identical sectors containing thin source foils (~ 50 mg/cm^2) situated in the middle of the tracking volume surrounded by the calorimeter. The source foils are composed 6.9 kg of ^{100}Mo, 1 kg of ^{82}Se and smaller amounts of ^{116}Cd, ^{150}Nd, ^{96}Zr, ^{48}Ca and ^{130}Te. One of the sectors contains a "blank" copper foil for external background evaluation. Observation of the ββ decay is accomplished by fully reconstructing the tracks of the two electrons and measuring their energy. A tracking chamber, containing 6180 open drift cells, operates in the Geiger mode and provides a vertex resolution of about 1 cm. A 25 Gauss magnetic field is used to curve the tracks for charge identification. A calorimeter consisting of 1940 plastic scintillator blocks coupled to Hamamatsu low radioactive PMTs gives an energy resolution of 14% to 17% (FWHM) at 1 MeV. A time resolution of 250 ps allows excellent suppression of the external background due to electrons crossing the detector. The detector is capable of identifying e-, e+, gamma and alpha particles and allows good discrimination between signal and background events. The detector is covered by two layers of passive shielding against external gamma rays and neutrons.

NEMO-III is in its physics exploitation phase and has produced a series of world class ββ measurements [6]. Apart from delivering important physics results, NEMO-III is an invaluable test bench for SuperNEMO. NEMO-III has proved to be crucial to our understanding of the backgrounds that we may expect to see in SuperNEMO. It is anticipated that the NEMO-III detector will continue to take data until the end of 2010 and will reach a sensitivity to the Majorana effective mass at the level of 300-600 meV.

1.4 SuperNEMO detector

SuperNEMO will build upon the NEMO-III technology choice of combining calorimetry and tracking but will have a planar geometry. The baseline SuperNEMO design envisages about twenty identical super-modules, each housing around ~5 kg of isotope. A conceptual design of a SuperNEMO detector module is shown in Figure 1.4. The source is a thin (~ 40 mg/cm^2) foil inside the detector. It is surrounded by a gas tracking chamber followed by calorimeter walls. The tracking volume contains around 2000 wire drift cells operated in Geiger mode which are arranged in nine layers parallel to the foil. The calorimeter is divided into 700 plastic scintillator hexagonal blocks (~ 25 cm diameter) which cover most of the detector outer area and are coupled to low radioactive 8" PMTs. A super-module will have a footprint of 6m x 2m and a height of 4m.

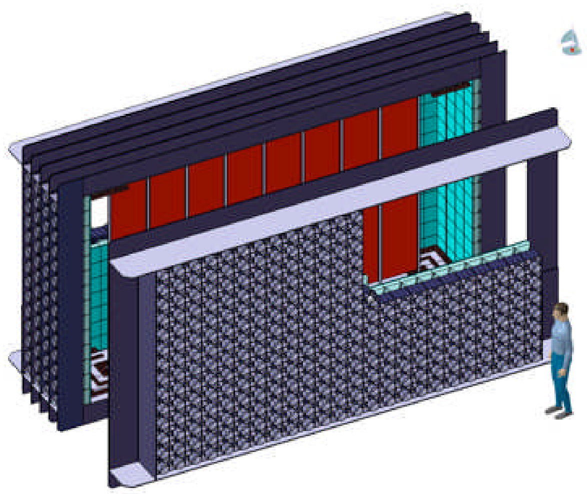

Figure 1.4 : schematic of a proposed SuperNEMO module showing the source foil (red) surrounded by a tracking volume and scintillator blocks read out by PMT's.

In parallel with the baseline design, an alternative design is being investigated. The latter is based on long (2 m) scintillator bars read out from both ends by two 3” PMTs. In this case, the detector is split into much bigger super-modules (between 3 and 6 to host 100 kg of isotope) with calorimeter walls and source foils “sandwiched” between each other (Figure 1.5). The energy resolution with the bars will inevitably be worse than with the block design. However this might be compensated by a better background rejection (due to self-shielding) and lower overall background due to a smaller number of PMTs. The bar design will have a significantly lower number of calorimeter channels and, as a result, should be significantly cheaper. Intensive Monte Carlo simulations and test bench studies are currently underway to compare the sensitivities of the two designs. The final decision on the bars versus blocks approach will be made by the end of 2009.

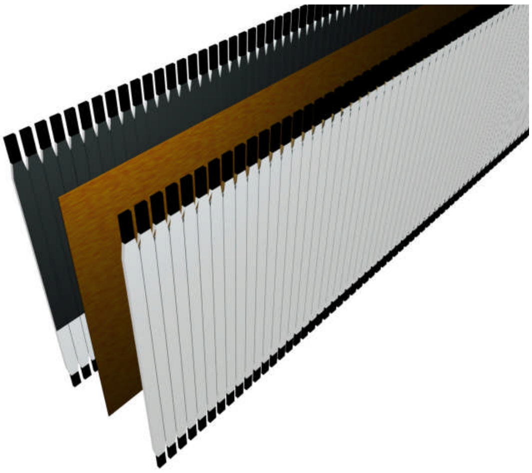

Figure1.5 : Schematic of the bar design, with walls of long scintillator bars read out at each end by PMT’s. The source foil sits inside the same tracking volume as in the block design. The final detector would be a repeated array of such elements.

The choice of isotope for SuperNEMO is aimed at maximising the neutrinoless signal over the background of two-neutrino double beta decay and other nuclear decays mimicking the process. Therefore the isotope must have a long two-neutrino half-life, a high endpoint energy and a large phase space factor. The possibility of isotopic enrichment on a large scale is also a factor in selecting the isotope. The baseline candidate isotope for SuperNEMO is ^{82}Se. The SuperNEMO collaboration is also investigating the possibility of enriching large amounts of ^{150}Nd and ^{48}Ca.

1.5 SuperNEMO sensitivity

SuperNEMO is one of three projects (together with CUORE and GERDA) on the European road map for future generation neutrinoless DBD experiments (ASPERA-ApPEC). These experiments, as well as the US-based experiments EXO and Majorana and SNO+ based in Canada, have similar timescales to reach sensitivity to a Majorana neutrino mass at the level of 0.05 eV by 2016-2018. There is inevitably a healthy competition between these experiments but they are actually very complementary as they measure different isotopes, which is crucial in light of existing uncertainties in nuclear matrix element (NME) calculations and due to the elusive nature of the signal. There are also a number of R&D projects (COBRA, DCBA, CANDLES, CAMEO, etc.) but they are at much earlier stages and will have significantly longer lead times.

The sensitivity of SuperNEMO has been studied extensively during the current design study phase. A full chain of GEANT4 based simulation software has been developed and commissioned and the sensitivity was studied as a function of various detector parameters such as the calorimeter energy resolution, source foil radio-purity, tracking detector configuration, etc. (see Figure 1.6). With the target detector parameters and 500 kg-yr exposure (100 kg for 5 years of running), the calculated sensitivity is at the level of 10^{26} yrs (50-110 meV). Data taking will start with the first demonstrator super-module (see below) in 2013 and will reach the final target sensitivity in 2018/19. The time scales and sensitivities are therefore at the level of the competitor projects.

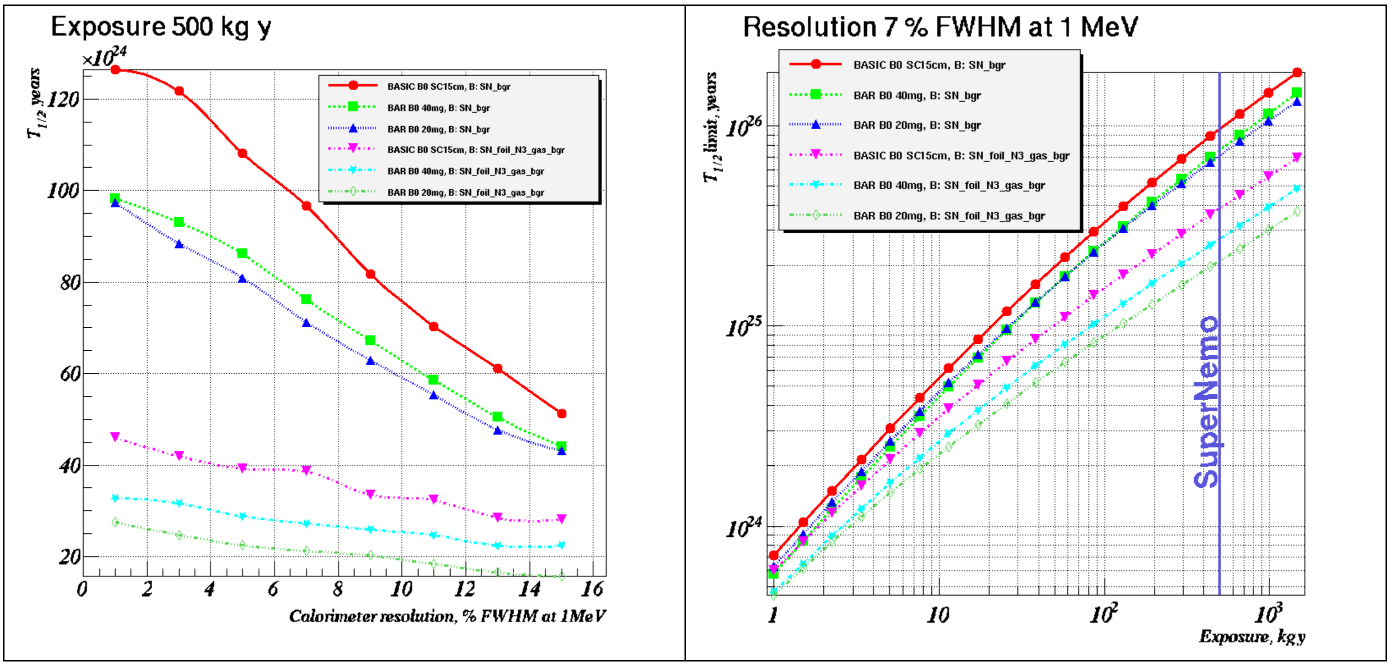

Figure 1.6: SuperNEMO half-life sensitivity for different detector layouts, background conditions and other parameters . Left: sensitivity as a function of the calorimeter energy resolution; Right: Sensitivity as a function of exposure.

We stress that the SuperNEMO approach is unique as it is the ***only*** next generation 0νββ experiment that uses the topological signature to select the ββ events. The ***unique*** features of SuperNEMO are:

1. Source and detector are separated. This allows a measurement of any ββ isotope or several isotopes at the same time.
2. Topological reconstruction of two electron tracks emitted from the same vertex.
3. Efficient particle identification (e-, e+, gamma rays, alpha-particles).
4. Measurement of most final state observables: individual electron energies and angular distributions between two electrons.

This approach gives a very powerful rejection of non-ββ background events, leaving the 2νββ decay as one of the main backgrounds for SuperNEMO. Moreover it produces a “smoking gun” signature of the ββ signal. If 0νββ is discovered with sufficient statistics, the measurement of the individual electron energies and angular distributions may enable us to disentangle the underlying physics mechanism. An example of this is shown in Figure 1.7.

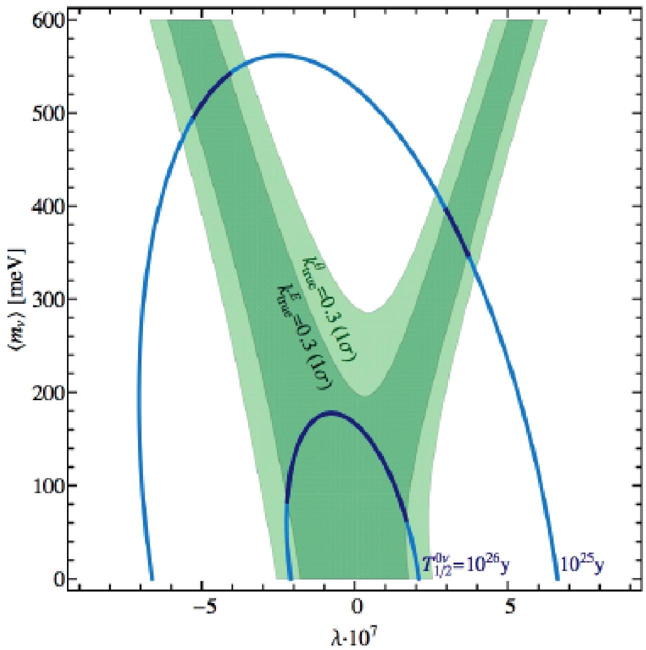

Figure 1.7 : Effective neutrino mass vs. the parameter λ which measures the contribution from right-handed currents. The contours are the results of a preliminary SuperNEMO simulation that takes into account the measurement of the angular asymmetry parameter k

A key concept of the SuperNEMO physics strategy is an attempt to produce as open minded a measurement of $0\nu\beta\beta$ as possible, without restricting the physics of the process to a particular mechanism. For example, if Majoron emission is indeed the dominating mechanism, then the spectrum of the sum of the two electron's energies is continuous and energy resolution becomes less important, while non-$\beta\beta$ background rejection is still crucial. Indeed, the currently running NEMO-III experiment holds the world's best limits on this mechanism of $0\nu\beta\beta$ decay.
SuperNEMO will also study $0\nu\beta\beta$ (as well as $2\nu\beta\beta$) decay to excited states. Although this mode is suppressed due to a smaller phase space compared to the ground state decay it may offer a background free environment due to a distinct topology of the events (two electron tracks and two gamma rays in coincidence). The excited state decay can also shed light on the physics mechanism of $0\nu\beta\beta$ decay.

An important feature of the SuperNEMO design is the possibility of a "last minute change" of the isotope if necessary. For example, if CUORE observes a significant signal at a relatively early stage (e.g. $<m_\nu> = \sim 0.1$ eV), then ^{130}Te can be introduced in SuperNEMO and all characteristics of the decay ($\beta\beta$ "smoking gun" signature, individual electron energies, angular correlations) can be studied and, possibly, the underlying physics mechanism uncovered.

2. SuperNEMO Experimental Programme.

2.1 SuperNEMO design study

SuperNEMO is currently finishing a 4 year design study phase during which major technological challenges have been successfully addressed. In particular

- A full chain of MC simulation software has been designed and commissioned. The SuperNEMO sensitivity has been studied as a function of various detector parameters such as the calorimeter energy resolution, source foil radio-purity, tracking detector configuration, etc. The target sensitivity of 50-100 meV has been confirmed.
- A tracker detector design has been developed as well as the concept of its automated wiring. The design performance has been verified with a dedicated 90-cell prototype.
- The target energy resolution of 7-8% (FWHM at 1 MeV) has been demonstrated with a baseline design large PVT block and Photonis and Hamamatsu 8" PMTs.
- A record energy resolution has been obtained for the alternative bar design (10% at 1 MeV). The final choice between the two designs will be made by the end of 2009.
- A conceptual mechanical design of the SuperNEMO super-module has been developed (for both block and bar designs)
- A specialised detector was built to measure foil surface contaminations at an extremely low level (the "BiPo" detector). The detector has been successfully commissioned and the target sensitivity at the level of few μBq/kg for ^{238}U and ^{232}Th has been demonstrated.
- A sample of 4kg of ^{82}Se has been enriched. A design for thin source foil production is being developed.

2.2 SuperNEMO construction and operation schedule.

SuperNEMO is entering its construction phase. It will require large scale production of detector components under challenging ultra-low background conditions. The performance of the calorimeter, tracker and other components of the detector achieved under the R&D programme must be highly repeatable. Between full-scale detector construction and the R&D, there has to be an intermediate step to demonstrate the feasibility of mass production for such a detector. To accomplish this in the first phase of the construction programme a single super-module will be built. This *demonstrator* super-module will have all the components of the final design, including low background materials used for the construction. Apart from technology demonstration and in-situ background measurement the first super-module will produce a competitive physics result.

The baseline version of the super-module will have a footprint of 6m x 2m and a height of 4m. A foil support is foreseen to initially hold a copper foil (or no foil for background measurements) and then eventually be replaced with a ^{82}Se foil. The module will house 5-7 kg of isotope. The tracker detector will have 2000 Geiger cells surrounded by 700 scintillator-PMT blocks. The demonstrator construction will start in early 2010. The super-module will be ready for moving in the underground lab in 2013 which matches very well the current schedule of the LSM extension.
The data taking will start in mid-2013 giving the information on SuperNEMO backgrounds within two-three months. With 7 kg of ^{82}Se by the end of 2014 the demonstrator super-module will reach a sensitivity of $T_{1/2} > 6.5\ 10^{24}$ yr (90% CL) corresponding to the lower bound on the Majorana neutrino mass of 200-400 meV. This sensitivity will allow us to address the controversial claim made by a subset of the Heidelberg-Moscow collaboration led by Klapdor-Kleingrothaus (a.k.a KKDK claim [7]) on a similar time scale with other experiments (e.g. GERDA-Phase I, SNO+).

The full detector construction is expected to start in 2013 and will proceed in parallel with data taking due to a modular approach adopted by SuperNEMO. The target sensitivity of 50-100 meV will be reached in 2018/19 on a competitive time scale with other leading NDBD experiments (GERDA, CUORE, EXO).

An overview of the SuperNEMO schedule is given in Fig 2.1

	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019
Finishing R&D	■	■									
Demonstrator construction		■	■	■							
Demonstrator operation					■	■	■	■	■	■	■
Full detector construction					■	■	■	■			
Data taking with main detector						■	■	■	■	■	■
Target sensitivity											■

Fig 2.1. SuperNEMO schedule overview

3. Technical requirements for underground laboratory

As current users of the existing LSM underground laboratory (the NEMO-3 experiment) the SuperNEMO collaboration has a good understanding of advantages offered by this location and has identified the new LSM as the primary destination of the detector. As shown in section 2 the SuperNEMO time schedule matches very well the time table of the new laboratory excavation and outfitting. The section outlines the main requirements of SuperNEMO to the underground laboratory facilities to ensure successful construction and operation of the experiment. We note that only estimates are possible at this stage. The detailed information will be submitted with the full proposal.

3.1 Location and space

The current LSM hall where the NEMO-3 detector is installed is protected by a rock overburden of 4800 m w.e. The extended laboratory will have a similar shielding against cosmic rays which is sufficient for the SuperNEMO experiment.
It is envisaged that the SuperNEMO detector will be placed in hall A, the larger hall of the two in the current plans. Therefore the requirements in this document will refer to hall A.

The SuperNEMO detector has a modular structure. The size of the module depends on the final calorimeter design (blocks or bars) and will be finalised by the end of the year. However to total floor area required by the detector is approximately the same for both options.
The layout of the baseline detector design is shown in Fig. 3.1 The layout takes into account a service area needed for the detector assembly as well as cleaning and component replacement operations, storage area and operator room. It also includes the electronic racks and water-based passive shielding. The detector modules and passive shielding will occupy a floor area of 50m x 24m. The minimum height (the distance from the floor to the ceiling along the central axis line) is 16.5m. This height is determined by the size of the module and assembly procedures and is necessary to pick up and install a module with a crane (see Fig 3.1). The service area dimensions is similar to that of the area occupied by the detector, i.e. 50m x 24m. Thus the total size of hall A is expected to be : 100m (length) x 25 m (width) x 17m (minimum height along the central axis).

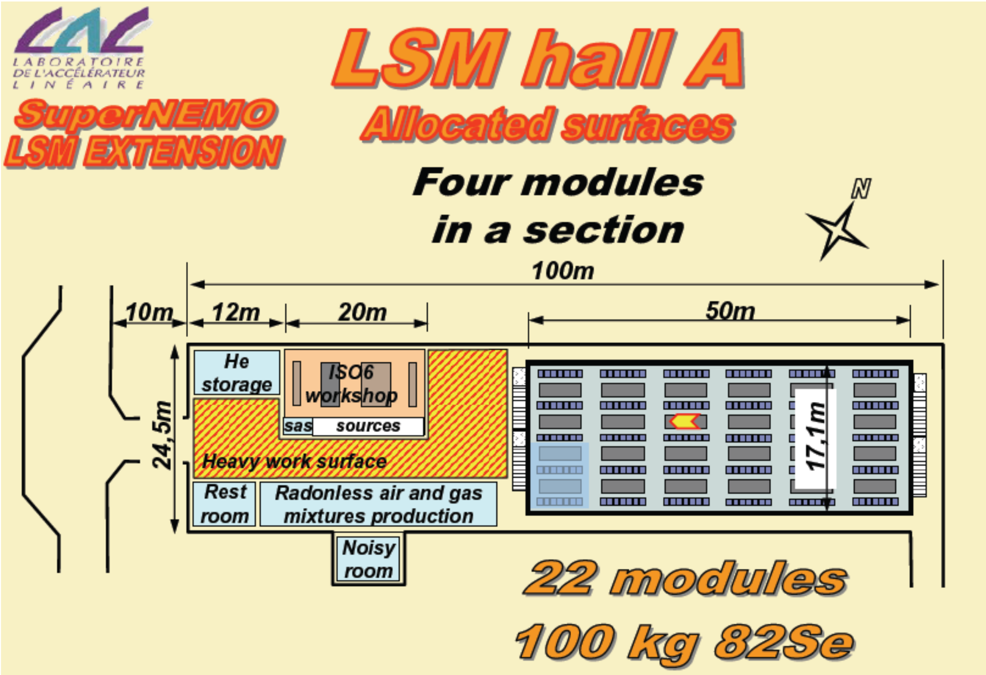

Fig 3.1 Block design layout

The layout of the detector version with the calorimeter based on scintillator bars is shown in Fig 3.2. The are two options under consideration, with 3 and 6 super-modules, both having the same total footprint which is somewhat smaller than in the block design case. It is 33m (length) x 24m width (see Fig 3.2)

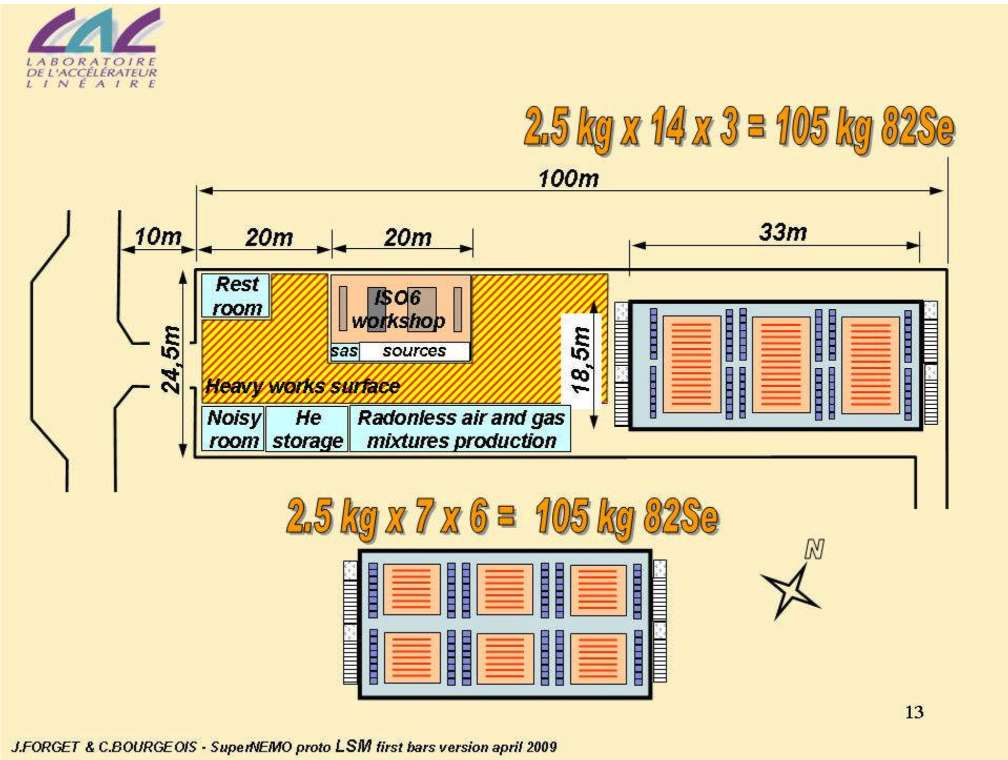

Fig 3.2 Bar design layout

3.2 Electric power requirements

Reliable power is an important requirement. Fully redundant power with two independent emergency generators will be required. The power required to operate a super-module is 20 kVA (220 V), there will be up to 22 super-modules in total in case of the block design. The anti-radon factory will require 45 kVA (380 V, 3-phase).

3.3 Services

To maintain a low radon level in the lab crucial for a low background experiment of this scale a reliable ventilation is a must. The ventilation rate should be 30,000 m^3/h.

The water has to be provided for equipment cooling. Each super-module will require 100 l/h (22 super-modules).

For detector installation and module replacement a crane infrastructure is necessary. The crane lifting capacity is 25t. The dimensions of the crane support frame: L = 96 m , W = 17 m, H = 14m.

3.4 Special services

An anti-radon factory similar in its operational principle to that currently installed in the existing LSM and used for NEMO-3 will be needed. For SuperNEMO six "NEMO3-like" units will be needed, each with a throughput of 150 m^3/h and a separate water cooling circuit.

3.5 Access

24/7 access time will be a requirement for the detector construction, commissioning and operation.

4.0 Bibliography

1. See for example "Massive Neutrinos in Physics & Astrophysics" (World Scientific Lecture Notes in Physics: Vol. 72), R.N. Mohapatra and P.B. Pal (World Scientific Publishing, 2002).

2. See for example the PDG review of neutrino mixing : http://pdg.lbl.gov/2008/reviews/rpp2008-rev-neutrino-mixing.pdf

3. F.Feruglio, A.Strumia and F.Vissani, "Neutrino oscillations and signals in β and 0νββ experiments," Nucl. Phys. B **637** (2002) 345.

4. J.Schechter and J.W.F.Valle, "Neutrinoless double-beta decay in SU(2) x U(1) theories," Phys. Rev. D **25**, 2951 (1982).

5. A.S.Barabash, "Double-beta-decay experiments: Present status and prospects for the future," Phys. Atom. Nucl. **67** (2004) 438.

6. http://nemo.in2p3.fr/publications/

7. H.V.Klapdor-Kleingrothaus, A.Dietz, H.L.Harney and I.V.Krivosheina, "Evidence for Neutrinoless Double Beta Decay," Mod. Phys. Lett. A **16** (2001) 2409.