The SuperNEMO experiment is being designed to search for neutrinoless double beta decay to test if neutrinos are Majorana particles. The unique experimental technique follows that of the currently running NEMO-3 experiment, which successfully combines tracking and calorimetry to measure the topology and energy of the final state electrons. SuperNEMO will employ about 100kg of ^{82}Se to reach sensitivity to a half-life time of about 10^{26} years, which corresponds to Majorana neutrino masses of about 53 - 145 meV, depending on the calculated value of the nuclear matrix element. The construction of the demonstrator module with 7 kg of ^{82}Se is about to begin and, if successful, will be followed by 19 more of similar modules. We will present the current status of the SuperNEMO project including results of the R&D phase of the project.

The SuperNEMO Experiment

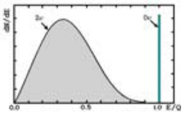
Federico Nova, IFAE - Instituto de Fisica de Altas Energias (Barcelona, Spain)

On behalf of the SuperNEMO Collaboration

Neutrinoless double-beta decay

Neutrinoless double beta decay ($0\nu\beta\beta$) is a process beyond the Standard Model which, if observed, will imply at once that neutrinos are Majorana particles, i.e. identical to their own antiparticles, that their mass is non-vanishing and that lepton number is not conserved.
Measurement of $0\nu\beta\beta$ decay is the most sensitive probe of the absolute mass scale of the neutrinos, and the only way to determine its nature.

The competing two-neutrino double beta decay ($2\nu\beta\beta$) is allowed in the Standard Model. The two processes are distinguished by the distribution of the energy-sum of the two electrons: in $0\nu\beta\beta$ decay, the electron energy sum is a spike at the Q-value of the decay; by contrast, the $2\nu\beta\beta$ distribution has a continuous spectrum.



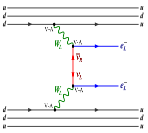


Diagram of the $0\nu\beta\beta$ decay through mass mechanism

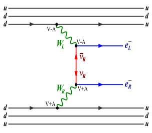
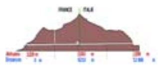


Diagram of the $0\nu\beta\beta$ decay through right-handed currents

The $0\nu\beta\beta$ decay can take place through several mechanisms, notably the light Majorana neutrino exchange and the existence of right-handed currents. Identifying the specific decay mechanism has deep implications on particle physics and cosmology.

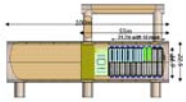
SuperNEMO detector design

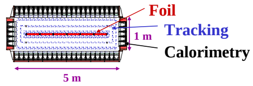
SuperNEMO is a next-generation $0\nu\beta\beta$ experiment based on the technique of tracking and calorimetry of the NEMO-3 detector, which is running since 2003 in the LSM laboratories (Laboratoire Souterrain de Modane) near Modane, France.



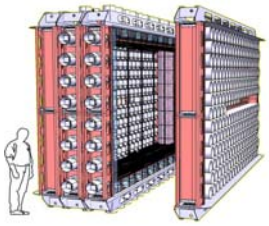
The lab is placed at a depth of 4800~m of water equivalent.

The LSM laboratories and the new extension where SuperNEMO will be hosted.





The SuperNEMO detector has a modular design. It will consist of 20 identical modules, each housing ~5 kg of source isotope in the shape of a thin foil, surrounded by a tracking chamber and enclosed in a calorimeter.



The source is a thin foil of enriched and purified $\beta\beta$-emitting isotope (^{82}Se, ^{150}Nd and ^{48}Ca are being considered).

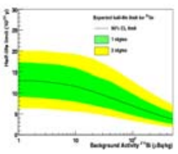
The tracking chamber contains drift cells operating in Geiger mode. A small magnetic field of ~25 G is applied for e+/e– discrimination.

The outer walls of the module make up the calorimeter, consisting of scintillators and low-radioactivity PMTs.

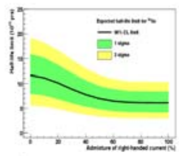
SuperNEMO sensitivity to neutrino mass and physics mechanism

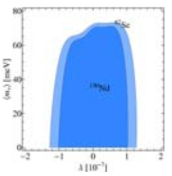
If $0\nu\beta\beta$ decay is not observed, SuperNEMO will set a limit on the half-life of ^{82}Se through mass-mechanism at 10^{26} y, corresponding to a neutrino mass m_ν = 53-145 meV (depending on the nuclear matrix element) and a right-handed currents parameter $\lambda = 10^{-7}$.
SuperNEMO sensitivity on the half-life of $0\nu\beta\beta$ decay in ^{82}Se is shown here as a function of::

a) background activity

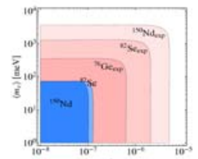


b) right-handed admixture





Constraints on m_ν and a λ for two different isotopes.

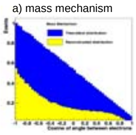


A comparison with current bounds shows that SuperNEMO will improve the current best limits by a factor of 5 and NEMO-3 limits by more than one order of magnitude.

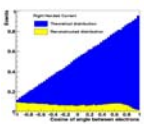
SuperNEMO's ability to study different isotopes and track the outgoing electrons provides the means to discriminate different underlying mechanisms for the $0\nu\beta\beta$ decay by measuring the decay half-life and the electron angular and energy distributions.

Theoretical and experimental distributions of the angle between electrons, for different mechanisms of $0\nu\beta\beta$ decay:

a) mass mechanism

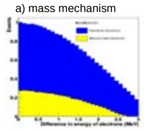


b) right-handed current.

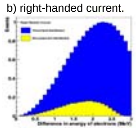


Theoretical and experimental distributions of the electrons' energy difference, for different mechanisms of $0\nu\beta\beta$ decay:

a) mass mechanism



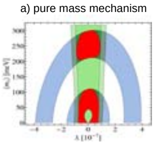
b) right-handed current.



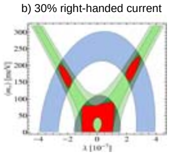
[published on arXiv:1005.1241]

In case of $0\nu\beta\beta$ discovery, SuperNEMO will set bounds on the parameters m_ν and λ by measuring the half-life (blue) and the angular and energy difference distributions (green). The bounds are shown here for:

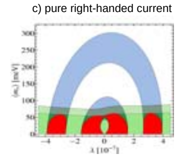
a) pure mass mechanism



b) 30% right-handed current



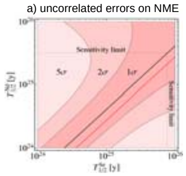
c) pure right-handed current



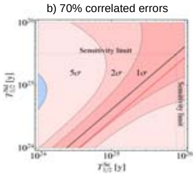
SuperNEMO is also capable of measuring the $0\nu\beta\beta$ decay in different nuclei: a comparison of the event rates in two isotopes allows to distinguish the decay mechanism.

A possibility is to construct the detector with 50% ^{82}Se and 50% ^{150}Nd. These figures show the $0\nu\beta\beta$ half-life of ^{150}Nd as a function of that of ^{82}Se, in a pure mass mechanism (black line) and pure right-handed currents (red line), with sensitivities for 250 kg y of exposure of each isotope. The three pictures are for different correlations between the errors of the nuclear matrix elements (NME):

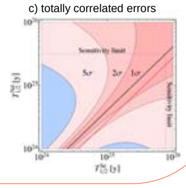
a) uncorrelated errors on NME



b) 70% correlated errors

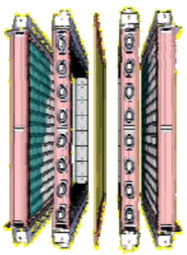


c) totally correlated errors



The demonstrator module

The construction of a demonstrator module is about to begin and, if successful, will be followed by 19 more of similar modules.



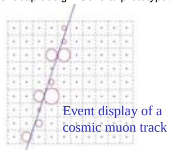
split view of the demonstrator module

This module, with all the components of the final design, including low background materials, will be built, installed and commissioned at the new UCL-MSSL Physics Lab, in the UK, then it will be moved to the Fréjus laboratories in France to replace the NEMO-3 detector (to be dismantled in 2011); in 2012 the module will be ready for physics measurement.

The module will also provide a competitive physics measurement covering the region of the Klapdor group claim, since 1 year of data-taking in the demonstrator module with 6 kg of ^{82}Se will have a similar sensitivity to phase I of the GERDA experiment.

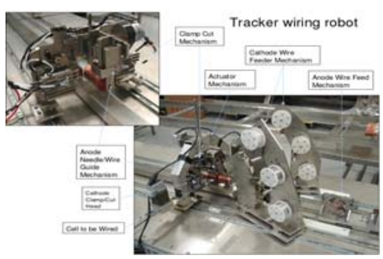
Tracker R&D

The R&D program of the tracker aims to optimize its operating parameters: wire length, material and configuration, detector readout and endcap design. Several prototypes have been constructed and tested.

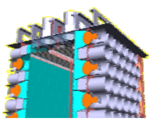


The 90-cell is the main tracker prototype and will be used to define the design of the SuperNEMO tracker. Cells have 44 mm pitch and 370 cm length; each cell has an anode of diameter 40 microns, which is surrounded by 12 ground wires of diameter 50 microns, arranged in an octagonal layout.
It has been commissioned in 2008 and is taking data with cosmic muons, radioactive sources and a UV laser. The measured space resolution is 0.7 mm (transverse direction) and 1.3 cm (longitudinal).

A dedicated wiring robot will be used for mass production of drift cells.



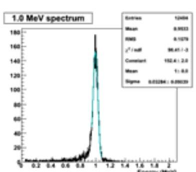
Calorimeter R&D

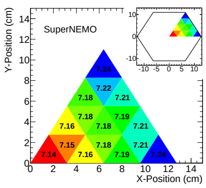


The SuperNEMO calorimeter will be composed of 25 * 25 cm^2 scintillator blocks coupled to 8 inches PMTs.

The R&D program aims to reach an energy resolution of 7% FWHM at 1 MeV. Energy resolution of 7.7% has been measured with 10 *22 cm^2 Eljen PVT blocks couplet to Hamamatsu PMTs.

Eljen PVT block



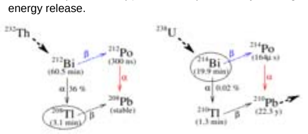


Spatial dependence of energy resolution (FWHM at 1~MeV) for one sextant of a SuperNEMO scintillator block.

Radiopurity R&D

In order to reach the desired sensitivity, SuperNEMO will require extreme radiopurity of all components.

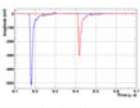
Particularly troublesome is the contamination from ^{208}Tl (Q = 4.99 MeV) and ^{214}Bi (Q = 3.27 MeV) that decay with high energy release.



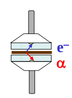
The contaminations of ^{208}Tl and ^{214}Bi can be monitored by the so-called BiPo process, which consists in the emission of an electron followed by a delayed α particle

The dedicated BiPo-1 detector (with 0.8 m^2 of sensitive area) is running since 2008 to measure the surface radiopurity of the plastic scintillators, for which we measure A(^{208}Tl) = 1.5 μBq/m^2.

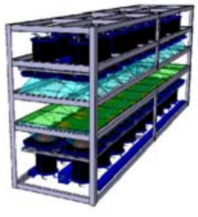
[published on arXiv:1005.0343]



Example of a BiPo event observed in BiPo-1.



A larger detector (12 m^2) will qualify the radiopurity of ^{82}Se foil with the requires sensitivity of A(^{208}Tl) < 2 μBq/kg (90% CL) in 6 months.



Radon contamination will be suppressed by isolating the tracker with a membrane and flushing the gas through a radon trap.

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