The SuperNEMO tracking detector

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1 Introduction

The SuperNEMO detector \[1\] will search for neutrinoless double beta decay at the Modane Underground Laboratory on the French-Italian border. This decay mode, if observed, would be proof that the neutrino is its own antiparticle, would constitute evidence for total lepton number violation, and could allow a measurement of the absolute neutrino mass.

The SuperNEMO experiment is conceived as 20 identical planar modules, each contains 5-7 kg of \(\beta\beta\) isotope (the baseline isotope is \(^{82}\text{Se}\) but \(^{150}\text{Nd}\) and \(^{48}\text{Ca}\) are also candidates); it is designed to reach a half-life sensitivity of \(10^{26}\) years corresponding to an effective Majorana neutrino mass of \(50 – 100\) meV.

The fist module of the SuperNEMO detector is currently under construction and the first quarter of the tracking detector has recently been completed and is being commissioned.

2 Neutrinoless Double Beta Decay

Double beta decay is a rare but well-understood process. It has been observed in 11 nuclei for which the simultaneous \(\beta\) decay of two nucleons is an energetically advantageous process. The neutrino-less (0\(\nu\)) version of this process is potentially a window to observe two Majorana neutrinos annihilating with each other.

Neutrinos are the only neutral fermions, their masses are much lighter than any other massive particles. Ettore Majorana observed that if the neutrino is truly neutral, it is possible to write a Lagrangian in which the neutrino is its own antiparticle. The Majorana mass term is very different from the Dirac term that describes all other fermions, allowing for the neutrino mass to be generated with only the left handed antineutrinos and right handed antineutrinos, and violating absolute lepton number conservation.

The Majorana mass generation mechanism enables the creation of see-saw models. These models explain the unnatural lightness of neutrinos through the introduction of additional heavy neutrinos at the GUT scale. If proven, these models would offer a way of probing GUT-scale physics at accessible energies.
Figure 1: A SuperNEMO module (left), and a scheme of the detector geometry (right). This geometry allows full event topology reconstruction ($e^\pm/\alpha/\gamma$ separation) and the freedom to choose the source element.

3 The SuperNEMO detector and the Demonstrator Module

The main feature that separates the SuperNEMO experiment from the other $0\nu\beta\beta$ experiments is the fact that the source element is completely decoupled from the detector. Building on the NEMO3 experience [2] a SuperNEMO module (shown in figure 1) has an electron tracker and a calorimeter, allowing for the complete reconstruction of the decay event topology. This allows unprecedented levels of background rejection: electrons can be effectively separated from positrons, $\alpha$ and $\gamma$ particles.

Great attention has also been given to material selection and screening in order to achieve unprecedented radiopurity. For the same reason every step of the construction and assembly of the detector happens in a cleanroom environment. Thanks to these efforts the expected background in the region of interest is $10^{-4}$ events/keV/kg/yr.

This detector design also allows complete topological reconstruction of the double beta decay event; in the event of a discovery, such topological measurements will be essential in determining the nature of the lepton number violating process.

The first module, called the Demonstrator Module, is currently under construction with the aim of proving the feasibility of the full experiment. This module will host 7 kg of $^{82}$Se, and has an expected sensitivity of $T_{1/2}^{0\nu} > 6.6 \times 10^{24}$ y (corresponding to $|m_{\beta\beta}| < 0.2 - 0.4$ eV) after 2.5 y.

4 The Demonstrator tracker

The Demonstrator Module tracker has 2034 2 m long octagonal drift cells operating in Geiger mode in a He/ethanol/Ar (95:4:1) mixture.

In NEMO3 the main background for the $0\nu 2\beta$ search is the radon inside the tracker volume whose electrons have enough energy to mimic a double-$\beta$ event. For this reason only selected materials (copper, steel, Duracon and PTFE) are allowed, the construction process and most components of the tracker have been screened with ultra sensitive Rn detectors [3]. For the same reason the tracker gas is also purified with a Rn trap using cold carbon filters.

The distance of closest approach of the track with respect to the anode wire is measured from the time of the anode signal; the time difference between the Geiger discharge arriving
at each end of the cell provides the longitudinal location of the track (see figure 2).

**Cell production**  To ensure the radiopurity goal is not compromised all tracker components are cleaned, and, where needed, passivated to prevent corrosion. To minimize the contamination, the drift cells are assembled by a wiring robot (pictured in figure 3), in a cleanroom environment at the University of Manchester.

The fundamental production unit is a cassette made of 2 columns of 9 drift cells. Each cassette is conditioned immediately after production to eliminate self-triggering or plasma-blocking points that can be caused by the presence of small impurities on the wires. The conditioning is prolonged until a wide enough Geiger plateau is observed on all cells.

**Tracker assembly and commissioning**  The tracking detector is divided in 4 sections each containing 56 rows of drift cells (28 cassettes). After conditioning the cassettes are transferred to the Mullard Space Science Laboratory where a clean tent large enough to host the a whole section of the tracker has been erected. There each cassette is tested, inspected, installed on the tracker frame and connected to the feedthroughs that transport the electrical signals outside the gas volume.

Each section has been designed so that it can be sealed, tested and shipped to the LSM independently. The first SuperNEMO section has already been assembled, sealed and is now ready to for surface commissioning; a picture of the first tracker section just before sealing is shown in figure 3.
Figure 4: The commissioning system; the arrows show the path of the gas that is filtered by the Rn trap, flown through the tracker section and then passed to the Rn concentration line to measure the tracker intrinsic emanation.

The Rn emanated by the tracker will be monitored for several weeks to make sure that the background is within the requirements (see figure 4 as well as 3). After Rn testing the tracker will be powered in stages using refurbished NEMO3 electronics and commissioned using cosmic rays. While the the first section is tested for radio-purity and commissioned the frame for the second section to be built, is being assembled.

5 Summary

SuperNEMO is a detector to search for neutrinoless double beta decay mode in one or more isotopes. To reach an extremely low background rate in the signal region the experiment has a separate tracking and calorimetric section; great care is also devoted to the material selection, the cleanliness of the construction and assembly chain, and the testing of each component.

The Demonstrator Module is currently under construction and is scheduled to be completed by the end of 2015; the commissioning will begin in 2016 in Modane.

References

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