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Construction and commissioning of the SuperNEMO detector tracker

Michele Cascella, On behalf of the SuperNEMO collaboration

University College London, United Kingdom

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ABSTRACT

The SuperNEMO detector will search for neutrinoless double beta decay at the Modane Underground Laboratory; the detector design allows complete topological reconstruction of the decay event enabling excellent levels of background rejection and, in the event of a discovery, the ability to determine the nature of the lepton number violating process.

In order to demonstrate the feasibility of the full experiment, we are building a Demonstrator Module containing 7 kg of ^{82}Se , with an expected sensitivity of $|m_{\beta\beta}| < 0.2 - 0.4$ eV after 2.5 yr.

The demonstrator tracker is currently being assembled in the UK; the main challenge in the tracker design is the high radiopurity required to limit the background. For this reason the cell wiring is automated and every step of the tracker assembly happens in a clean environment. All components are carefully screened for radiopurity and each section of the tracker, once assembled, is sealed and checked for Radon emanation.

We present the detector design, the current status of the construction and present the first results from the surface commissioning of one section of the Demonstrator Module tracker.

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1. Introduction

SuperNEMO [1] is an experiment designed to search for neutrinoless double beta decay ($0\nu 2\beta$) in ^{82}Se (but ^{150}Nd and ^{48}Ca are also being taken into consideration); the detector consists of 20 identical planar modules, each contains 15 m² (5–7 kg) of $\beta\beta$ isotope, hosted at the Modane Underground Laboratory on the French-Italian border. The half-life sensitivity goal is 10²⁶ years, corresponding to an effective Majorana neutrino mass of 50–100 meV.

The observation of the $0\nu 2\beta$ decay mode 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. Majorana neutrinos hold the promise of explaining the origin of ν mass and probing GUT scale physics.

2. The SuperNEMO detector and the Demonstrator Module

SuperNEMO builds on NEMO3 idea [2] of a design that decouples the 2β source element from the particle detector.

In a SuperNEMO module (see Fig. 1) a source foil is suspended in the middle of an electron tracker surrounded in turn by a calorimeter. This geometry allows effective separation between electrons, positrons, α and γ particles; this enables, in turn, the

complete reconstruction of the decay event topology and an unprecedented levels of background rejection.

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 other focus of the experiment design is on radiopurity; the expected background in the region of interest is 10⁻⁴ events/keV/kg/yr. Each detector component has been carefully selected and screened for activity in the signal energy region, and every step of the construction and assembly of the detector happens in a cleanroom environment to avoid accidental contamination from untested material.

The first SuperNEMO module is currently under construction. It is known as the Demonstrator Module, and it aims to prove that the stringent radiopurity levels required to reach the experiment sensitivity goal can be achieved. The Demonstrator will host 7 kg of ^{82}Se , and has an expected sensitivity of $T_{1/2}^{0\nu} > 6.6 \times 10^{24}$ yr (corresponding to $|m_{\beta\beta}| < 0.2 - 0.4$ eV) after 2.5 yr.

3. The demonstrator tracker

Each SuperNEMO module has a tracker with 2034 octagonal drift cells operated in Geiger mode, the drift gas is He with an addition of 1% Ar and 4% ethanol as quencher.

The distance of closest approach of the track with respect to the anode wire is measured from the time of the anode signal; the

E-mail address: m.cascella@ucl.ac.uk

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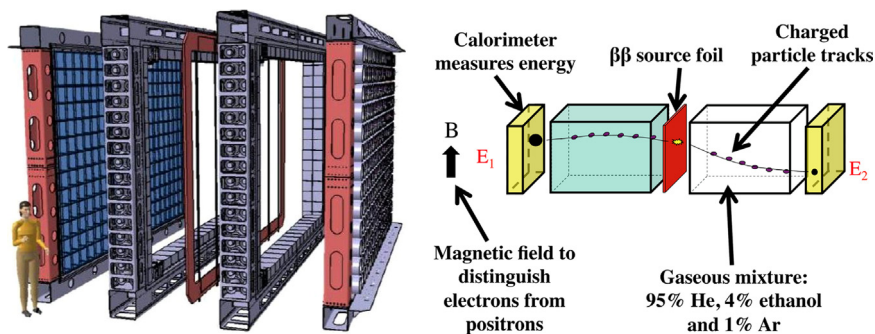


Fig. 1. CAD model of SuperNEMO module (left), and a scheme of the detector working principles (right).

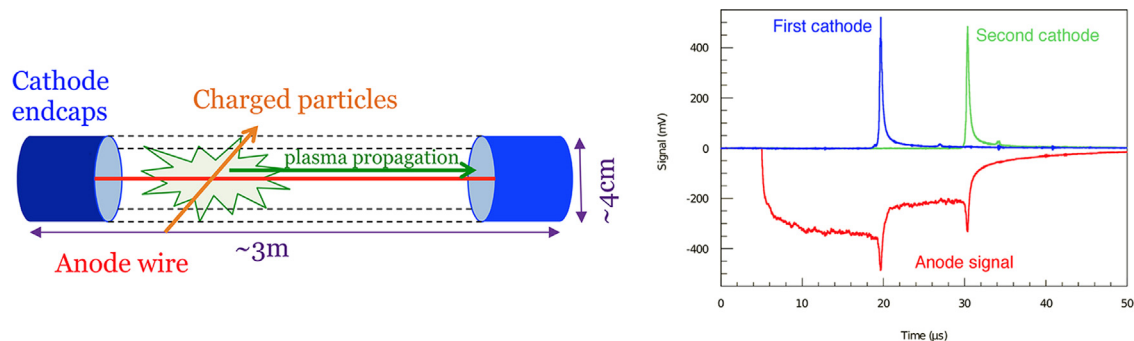


Fig. 2. A SuperNEMO tracker cell (left) and a depiction of the electrical signal (right) measured for the anode (negative) and cathodes (positive).



Fig. 3. The wiring robot (left), a cassette being inspected before installation (center), and the first quarter of the Demonstrator Module after completion (right).

time difference between the Geiger discharge arriving at each end of the cell provides the longitudinal location of the track (see Fig. 2); two electrodes are placed at the ends of each Geiger cell to pick up the signal from the avalanche.

To keep the background level under control only a few selected materials (copper, stainless steel, Duracon and PTFE) are used in the construction.

3.1. Cell production

All tracker components are cleaned, and, where needed, passivated to prevent corrosion in a cleanroom environment. The drift cells are then assembled by a semi automated wiring robot (shown in Fig. 3) at Manchester University. Two columns of 9 drift cells are then assembled into a cassette which constitutes the basic readout unit. After production each cassette is operated in a test tank for a few days; the goal is to detect and remove small impurities on the wires that can become self-triggering points at high voltage or prevent the plasma discharge from propagating along the length of the wire. Conditioning at high voltage continues until all this issues are eliminated and a wide Geiger plateau is observed on all cells. Fig. 3 shows the wiring robot and an assembled cassette ready to be installed.

3.1.1. Radiopurity

The main background source for the $0\nu 2\beta$ search is expected to be the radon emanated inside the tracker volume. Rn electrons, in fact, can have enough energy to mimic a double- β event. For this reason every component of detector is screened for radiopurity, first with an HPGe detector then specifically for Rn emanation. The radon level inside the tracker must be kept below 0.15 mBq/m^3 .

One of these Rn detectors is the Rn Concentration Line at MSSL. In the RnCL gas is pumped from the sample through a cold carbon trap that adsorbs Rn which is later released and transferred to a detector. The detector sensitivity is shown in Fig. 4.

The radon concentration in the gas source is non negligible, thus a cold charcoal Rn trap has been realized, capable of achieving a suppression factor of 20 in N_2 ; the suppression factor for He is expected to be $> 10^{10}$ (see Table 1).

3.1.2. Tracker assembly and commissioning

The SuperNEMO tracker is made of 4 sections of 56 columns (28 cassettes) of cells each. The tracker assembly takes place in a large clean tent in the Mullard Space Science Laboratory where each cassette is tested, inspected, installed on the tracker frame.

The first section has been completed in December 2014 (Fig. 3) and is currently being tested using refurbished NEMO3 electronics.

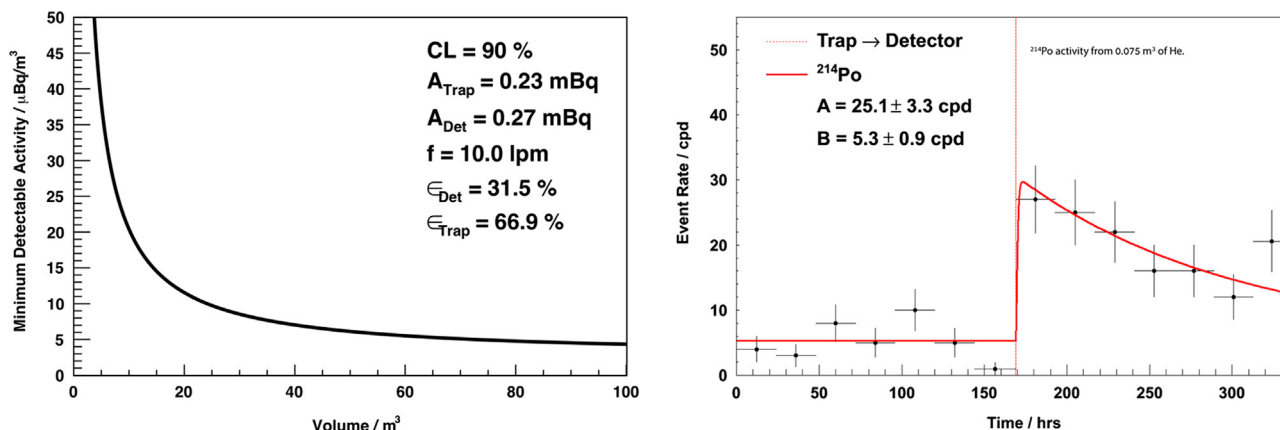


Fig. 4. Sensitivity of the Rn Concentration Line as a function of the volume of gas transferred (left); activity of ^{214}Po before and after radon from 0.075 m^3 of He is transferred into the detector (right).

Table 1

Radon levels measures for various gas sources.

Gas	Source	Rn level ($\mu\text{Bq}/\text{m}^3$)
He	Cylinder	70 – 100
N ₂	Cylinder	400 – 1000
N ₂	Boil-off	90 – 140
N ₂	Cylinder + Rn trap	20 ± 12
He	Cylinder + Rn trap	< 5

In the mean time the second section has been completed and is ready to be sealed.

4. Summary

The SuperNEMO experiment will search for the $0\nu 2\beta$ decay mode in ^{82}Se . To reach its sensitivity goal a low background rate is the key. For this reason the experiment has a dedicated tracking and calorimetry section separated from the source element; material selection, cleanliness of the assembly chain, is also of paramount importance.

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

Acknowledgments

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