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Construction and commissioning of the tracker module for the SuperNEMO experiment

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Abstract. The SuperNEMO experiment will search for neutrinoless double-beta decay in the Modane Underground Laboratory. This decay mode, if observed, confirms that neutrinos are Majorana fermions. It would be a new lepton violating process, and would provide a measurement of the absolute neutrino mass. The SuperNEMO experiment is designed to reach a half-life sensitivity of 10^{26} years corresponding to an effective Majorana neutrino mass of 50−100 meV. The SuperNEMO demonstrator module is the first stage of the experiment, containing 7kg of ^{82}Se, with an expected sensitivity of $T_{½}(0\nu) > 6.5\text{x}10^{24}$ y after 2.5 years. Full topological event reconstruction is achieved through the use of a wire tracker operating in Geiger mode combined with scintillator calorimeter modules. Construction of the demonstrator module is well underway. We present the design of the tracker, and the current status of the construction and commissioning efforts.

1. Introduction

For certain isotopes, the two neutrino double-beta decay process may be observed, consisting of the simultaneous beta decay of two neutrons.[1]

If the neutrino is a Majorana particle, a related process (neutrinoless double-beta decay) is possible. In this process a neutrino is first emitted, then reabsorbed as an antineutrino. Evidence for this process would manifest itself as a peak in the tail of the summed two-electron energy distribution as shown in Figure 1. [1]

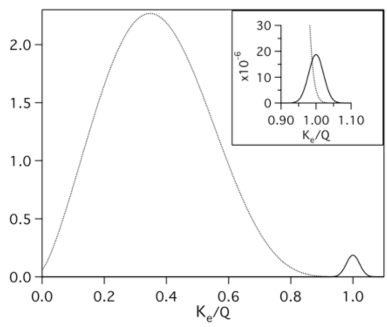

FIG 1: Expected experimental signature of neutrinoless double-beta decay, manifesting as a peak at the tail of the summed two-electron energy distribution.

A Majorana neutrino is required for the see-saw mechanism to provide an explanation for the very light neutrino masses.[1]

2. Detector Design

The demonstrator module will consist of a ^{82}Se source foil surrounded by a 2034 cell drift chamber and scintillator calorimeter in a planar geometry. 7kg of ^{82}Se will be used to achieve a sensitivity to the half life of the neutrinoless double-beta decay process of $T_{1/2}(0\nu) > 6.5\times10^{24}$ years after 2.5 years.
The design, shown in figure 2, provides a complete topological reconstruction of decay events, allowing for very high signal purity.

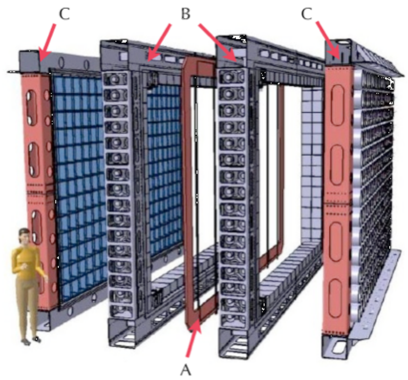

FIG2: The SuperNEMO demonstrator module, containing
A: Source frame, B: Drift chamber C: Calorimeter.

To maintain the tracking properties of the detector, the mixture ratio of the gas must be kept constant (95% Helium, 4% Ethanol and 1% Argon). Helium and argon are supplied to the gas system where the ethanol is added in two stages. Approximately 4% is added in the primary bubbler. This is left at room temperature and the ethanol fraction added to the gas is controlled by keeping it at a high pressure. The fraction is fine tuned in the secondary bubbler, kept at 14°C.

Stringent limits on radon activity within the tracker volume must be achieved to reach the target sensitivity. The activity target for the full demonstrator module is 0.15 mBq/m^3.

3. Tracker Module Status

3.1. Construction

The tracker cells are built and tested in Manchester before being transported for assembly. The tracker module is being assembled in four sections, in a clean room environment at UCL's Mullard Space Science Laboratory (MSSL). Three sections are fully constructed and commissioned, with construction of the fourth to be completed in the coming weeks. The complete demonstrator module is expected to be installed at the Laboratoire Souterrain de Modane (LSM) in the French-Italian Alps by the end of 2016.

3.2. Commissioning

We have used cosmic muons to commission the first three tracker sections. Two scintillator planes were placed below the tracker volume, and were used as a trigger (see figure 3). The relative occupancies of the cells were measured to ascertain the status of each anode channel in the tracker section.

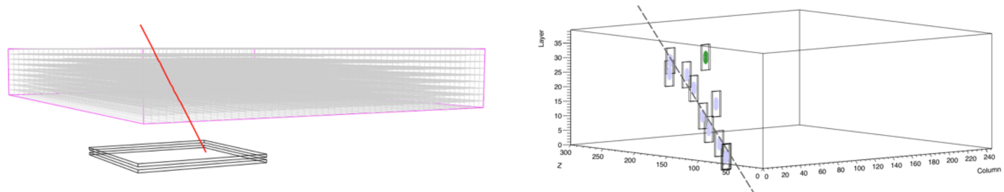

FIG3: A cosmic muon passing through the tracker. Left: Monte Carlo event, Right: Computer representation of a real event.

Of the 1512 tested cells, 11 were electrically disconnected and 5 drew a current above the safe limit. 74 cells showed an above expected hit rate, but are expected to be recovered during further conditioning at the LSM. The proportion of fully operational or recoverable channels is 99% over the first three tracker sections.

3.3. Gas System Automation

The gas system requires safe, remote operation underground with little human intervention. A RaspberryPi was chosen to readout temperature and pressure probes and to perform serial communication with mass flow controllers and other devices. RaspberryPi also provides a cheap and flexible solution, allowing for the future addition of cameras and screens to the system. The RaspberryPi was housed alongside several displays and electronic feedthroughs in a crate mounted on the gas system.

Simple Python scripts have been written and integrated with SuperNEMO's slow control and monitoring system (based on the OPCUA protocol): pressure in the primary bubbler and temperature in both bubblers are monitored to ensure a consistent ethanol fraction in the gas. Flow rates and the functioning of the temperature controller are also monitored. Alarms have been implemented to warn when system parameters deviate outside allowed ranges.

3.4. Transport

Two sections, comprising half of the tracker module, have now made the journey from MSSL in Surrey, UK to the LSM where the demonstrator module is being assembled 1700m underground. These tracker sections were mounted on a vibration damping frame and continually purged with dry air throughout the journey, with attached sensors monitoring humidity, pressure and temperature within the transport container.

Upon arrival at the LSM they were installed into the clean tent and tested for damage sustained during transport. The half-tracker and first calorimeter wall will be integrated and tested late 2016.

FIG4: Tracker section arriving at the LSM in the Fréjus road tunnel.

References

[1] R.Arnold, C.Augier, J.Baker et al. "Probing New Physics Models of Neutrinoless Double Beta Decay with SuperNEMO " Eur.Phys.J.C70:927-943,2010