MANCHESTER 1824

The University of Manchester

The SuperNEMO Experiment

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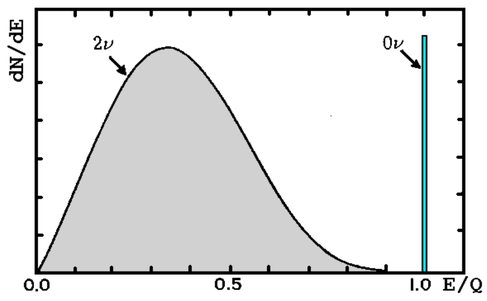
Neutrinoless double beta decay

Neutrinoless double beta decay ($0\nu\beta\beta$) is a process beyond the Standard Model, which violates lepton number conservation. It is only possible if neutrinos are massive Majorana particles, i.e. the neutrino and antineutrino are identical.

In the Standard Model, two-neutrino double beta decay ($2\nu\beta\beta$) can occur in nuclei for which beta decay is energetically suppressed.

The signature of neutrinoless double beta decay is a peak at the end point of the energy sum spectrum of electrons from the $2\nu\beta\beta$ process.

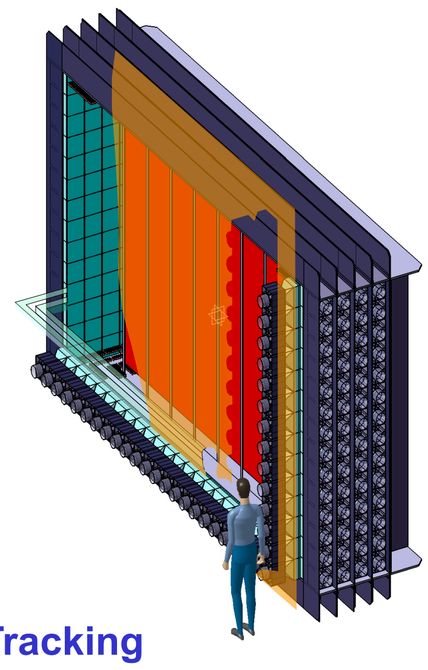


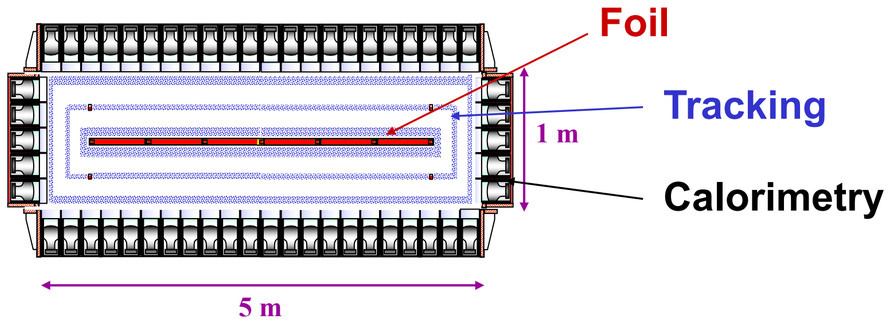
SuperNEMO will detect double beta decay events by measuring the energies, trajectories and vertices of electrons. It will use particle identification of photons and alpha particles to reject backgrounds.

SuperNEMO detector design

SuperNEMO is a next-generation $0\nu\beta\beta$ experiment based on the NEMO-3 technique of tracking and calorimetry. It will search for neutrinoless double beta decay in ~100 kg of enriched isotopes, reaching a sensitivity for the half-life of $T_{1/2} \approx 10^{26}$ years, which corresponds to neutrino mass sensitivity of ~50 meV.

The SuperNEMO detector will consist of 20 identical modules, each housing ~5 kg of isotope. The source is a thin foil of double beta emitter (^{82}Se or ^{150}Nd). It is surrounded by a tracking chamber, containing 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.



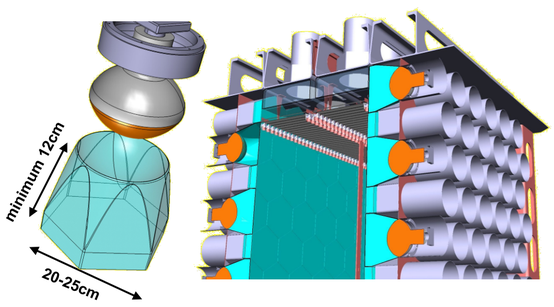


The SuperNEMO technical design report is due in 2009, with construction finishing in 2012.

Calorimeter R&D

Energy resolution is a combination of energy losses in the foil and light collection in the calorimeter. The goal of the calorimeter R&D is to achieve resolution of 7% FWHM at 1 MeV. Two possible designs are investigated:

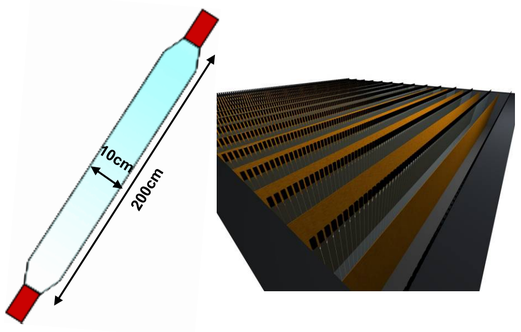
Block Design



Hexagonal PVT Block + 8" PMT

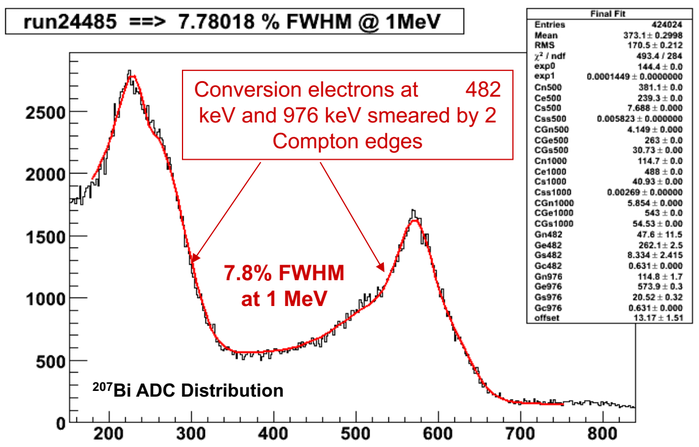
+ Excellent energy resolution: 7% FWHM at 1 MeV
+ Well understood technology from NEMO-3 experience
+ Good time resolution
– High number of channels makes it expensive and could lead to more radioactivity

Bar Design



PVT Bar (2m x 10cm x 2.5cm) + 3" PMT at Each End

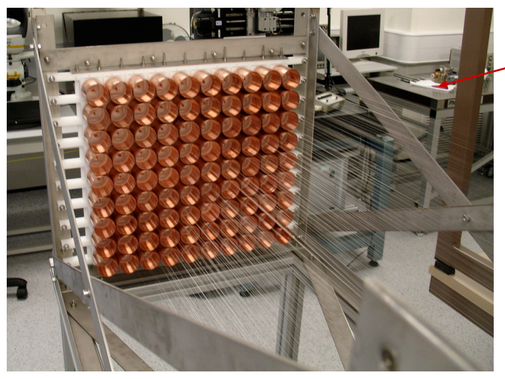
+ Efficient γ tagging
+ Less channels are required, meaning much lower price and less radioactivity
– Worse energy resolution: –10% FWHM at 1 MeV
– Possible ageing problems
– More difficult to extrapolate from NEMO-3



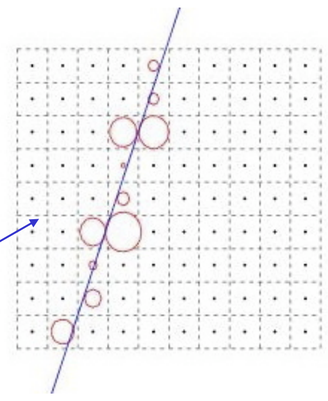
Energy resolution of 7% at 1 MeV has been achieved with 10-cm thick hexagonal blocks coupled to high-QE PMTs.

Tracker R&D

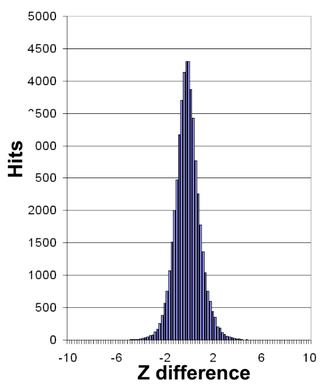
The R&D programme of the tracker aims to optimise its operating parameters: wire length, material and configuration, detector readout and endcap design. Several small prototypes were constructed and tested. A 90-cell prototype has been commissioned and is taking data with cosmics.



The 90-cell prototype during construction

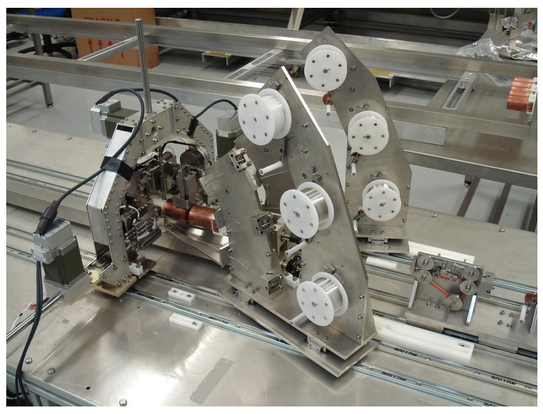


Event display of a cosmic muon track



The best achieved resolution is 0.7 mm in the transverse direction and 1.3 cm longitudinally.

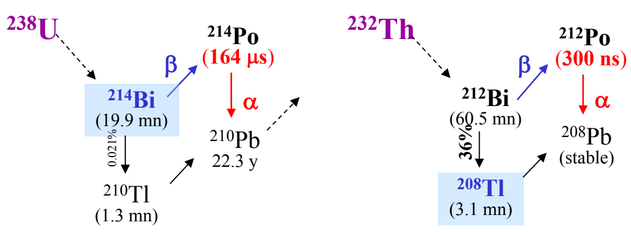
A dedicated wiring robot is being developed for mass production of drift cells.

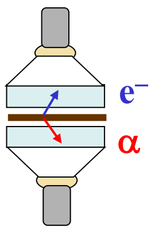


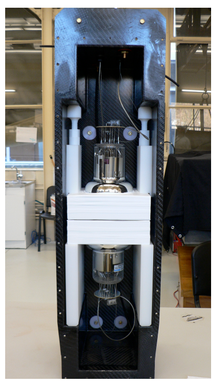
Source purity and the BiPo detector

The BiPo detector is dedicated to measuring the purity of source foils for SuperNEMO. It will be able to measure the radiopurity of 10m^2 of isotope source in a month with a sensitivity to ultra-low radioactive contaminations of <2 μBq/kg for ^{208}Tl and <10 μBq/kg for ^{214}Bi.

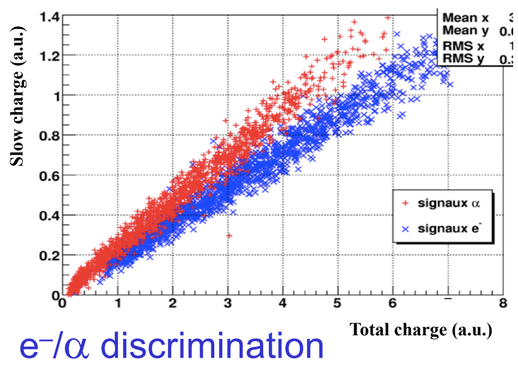
The detector reconstructs the BiPo cascade of a beta decay followed by a delayed alpha decay:







The BiPo-1 detector has been running in LSM Modane since February 2008, measuring a background level of A(^{208}Tl) = 1 μBq/m^2. A larger BiPo detector will be constructed in 2010 to measure the purity of ^{82}Se source foils.



e^-/α discrimination