High resolution low background calorimeter for SuperNEMO

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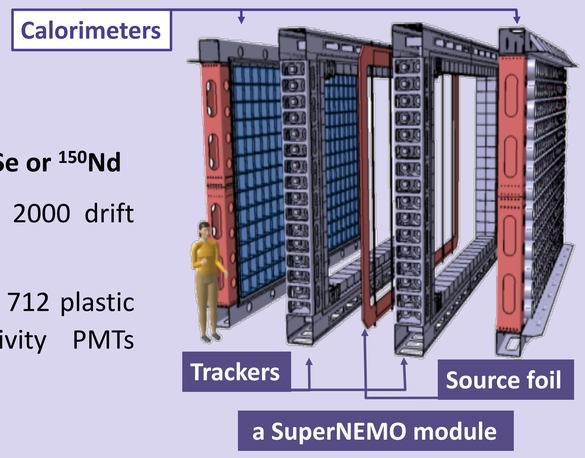
The SuperNEMO detector

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



20 modules each containing in:

- a central thin **source of 5 kg ^{82}Se or ^{150}Nd**
- a **tracking chamber** made of 2000 drift cells in Geiger mode
- an **e- calorimeter** made up of 712 plastic scintillators and low-radioactivity PMTs acting also as a gamma tagger

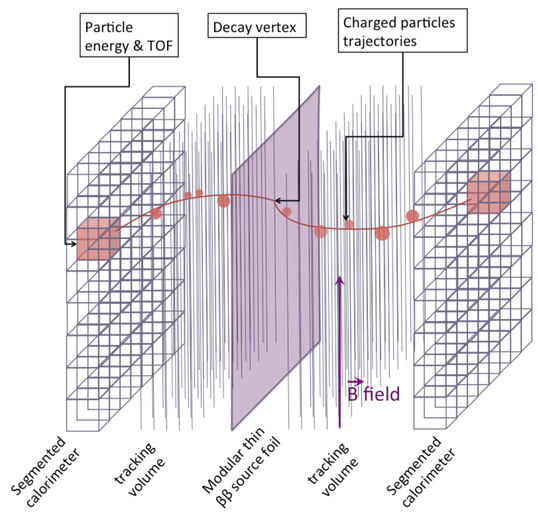
The demonstrator:

Intermediate phase to test the technical feasibility of the experiment and the background levels with **1 module :**

- 7 kg x 2 years of ^{82}Se
- **$T_{1/2}(\beta\beta0\nu) > 6.6\ 10^{24}$ years**
- $\langle m_\nu \rangle < (0.15 - 0.4)$ eV

Starts running in 2017 in LSM

A tracker-calorimeter detector



A calorimeter to measure the:

- Individual deposited **energy**
- **Time of flight** difference between each fired counter

The main wall calorimeter design

520 Optical Modules each made up of

- 10 L NUVIA polystyrene **scintillator**
- R5912-03mod Hamamatsu Photonics 8'' **PMT**
- Teflon and mylar wrapping
- Individual pure iron magnetic shields (25 G)

Requirements

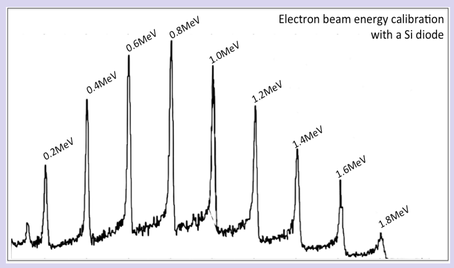
- **Resolution ≲ 8 % [FWHM] /√E [MeV]**
  note : NEMO3 ≃ 16 % [FWHM] /√E [MeV]
- Time resolution 400 ps (σ) @ 1 MeV
- No ageing in 5 years
- Gain survey with an accuracy < 1 %
- Low background PMT (Radon emanation)
- Low backscattering
- 4π γ tagging 50 % @ 1 MeV

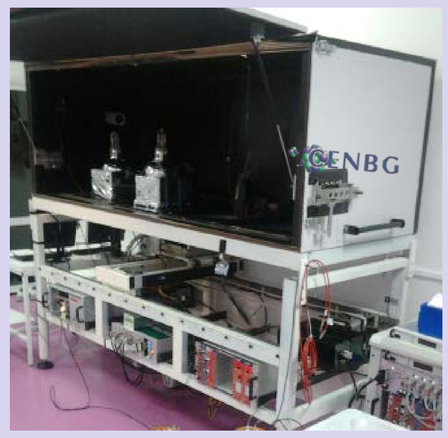
Relative time/energy **calibration with LED**
Absolute energy **calibration with ^{207}Bi sources**

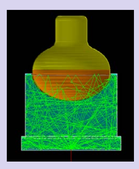
Unique characterisation tools

➢ 2 electron beam spectrometers to qualify the optical modules

- Mono-energetic electron beam from a ^{90}Sr 370 MBq β source
  - $\sigma_{x,y} \approx 3$ mm
  - Energy range [0.4-2.0] MeV
  - **FWHM @ 1 MeV = 1.0 ± 0.2 %**
- Automated X/Y scanning [2 m x 1 m]







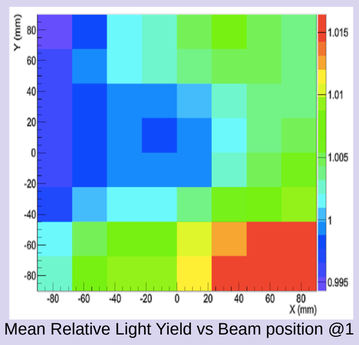
And a fine tuned optical simulations based on GEANT4

Optical module performances

Polystyrene scintillator

NUVIA

- ➢ 10 L volume
- ➢ Highly uniform



Mean Relative Light Yield vs Beam position @1 MeV

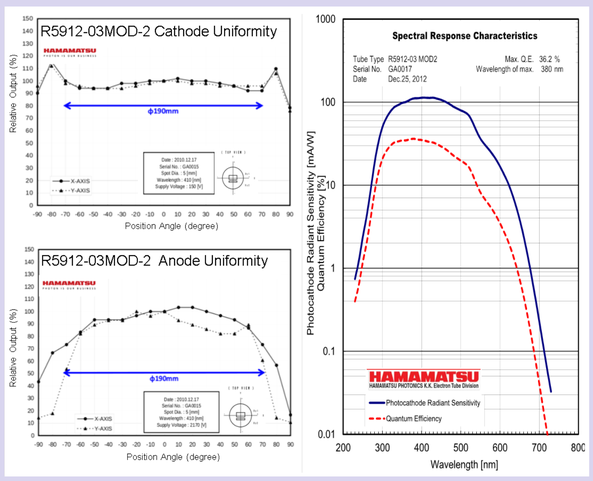
Enhanced Polystyrene scintillator

- ➢ New composition/production procedure
- ➢ 10 000 γ/MeV

8'' PMt (R5912-03 mod02)

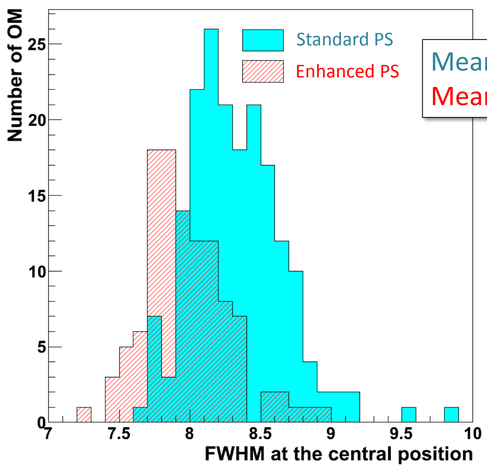
HAMAMATSU PHOTON IS OUR BUSINESS

- ➢ 8 stages → G = 10^6
- ➢ QE > 30 % @ 420 nm
- ➢ High uniformity



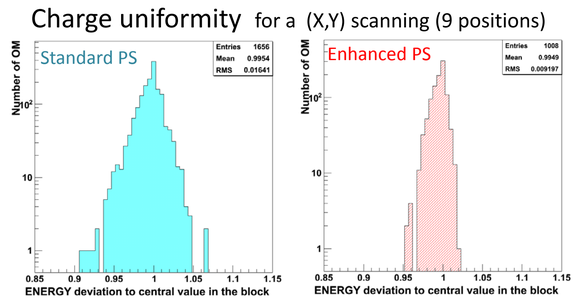
Calorimeter production

92% of Optical modules are produced



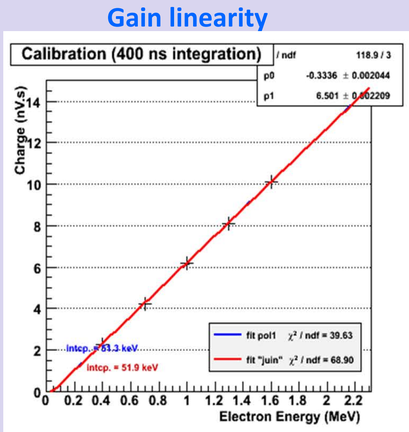
Mean FWHM =8.3%, RMS=0.3 (Standard PS)
Mean FWHM =8.0%, RMS=0.3 (Enhanced PS)

Charge uniformity for a (X,Y) scanning (9 positions)

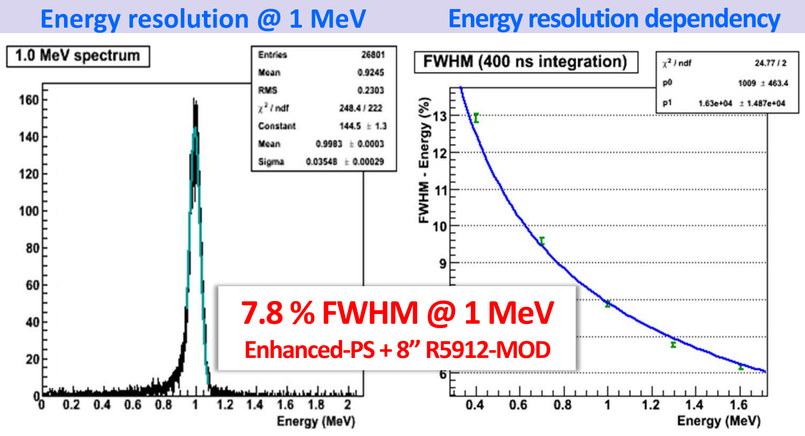


Example of Optical Module result

Gain linearity



Energy resolution @ 1 MeV



7.8 % FWHM @ 1 MeV
Enhanced-PS + 8'' R5912-MOD

Energy resolution dependency

Radiopurity

- 850mBq/kg for ^{40}K
- 380mBq/kg for ^{214}Bi
- 150mBq/kg for ^{208}Tl

The total activity of the **10 tons** of SuperNEMO materials will be less than 20 % of the PMT's activity (350 kg).
New glass composition under progress (Primeverre Cie)

First wall is integrated

at the Laboratoire Souterrain de Modane

2d wall integrated in automn 2016