# Development of an optical simulation for the SuperNEMO calorimeter

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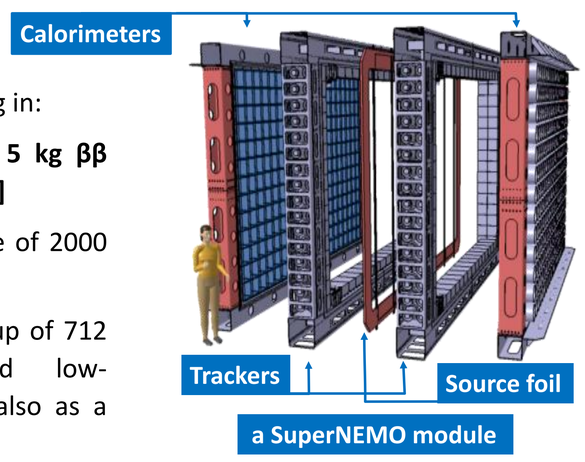
## The SuperNEMO detector

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 ββ isotope [baseline with $^{82}$Se]**
- 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 2.5 years of $^{82}$Se
- **$T_{1/2}(\beta\beta 0\nu) > 6\ 10^{24}$ years**
- $\langle m_\nu \rangle < (0.2 - 0.4)$ eV

Starts running in 2017 in LSM

## The main wall calorimeter design

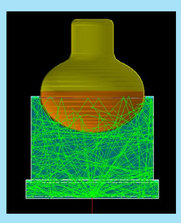
**520 Optical Modules** each made up of

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

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

### Requirements

- **Resolution ≲ 8 % [FWHM] /√E [MeV]**
  **note : NEMO3 ≃ 16 % [FWHM] /√E [MeV]**
  **Time resolution 400 ps (σ) @ 1 MeV**

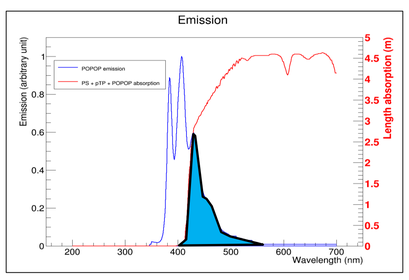
## Optical Simulation

GEANT4 + G4OpticalPhoton processes

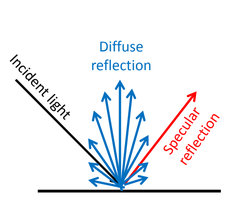
- **Goal : Modeling of the Optical Module response (energy, time) regarding the interaction location**
- **How ? : With addition of some available classes in GEANT4 & inputs in order to simulate all the optical processes**

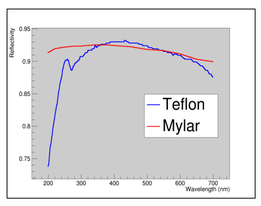
### Scintillator :

- Simulation **emission properties** :
  - Lightyield
  - Primary emission spectrum
  - Secondary emission spectrum
  - Absorption spectrum

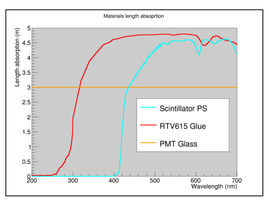


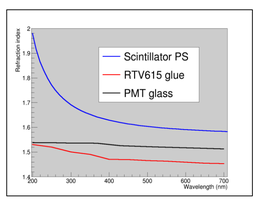

- Simulation **reflective properties** :
  - Diffuse reflection [Teflon]
  - Specular reflection [Mylar]
  - Reflectivity spectrum



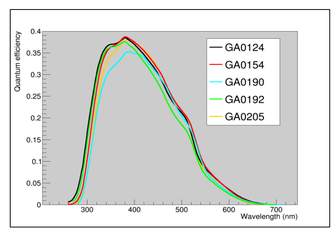

- Simulation **light path** :
  - Refraction index spectrum
  - Absorption length spectrum



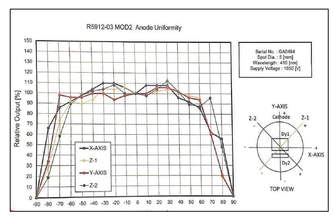



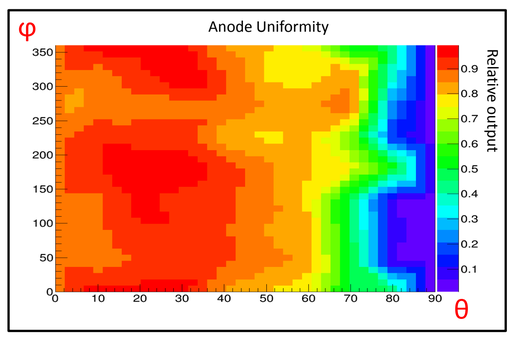

### Photomultiplier :

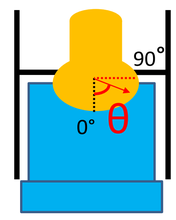
- Simulation **quantum efficiency** :

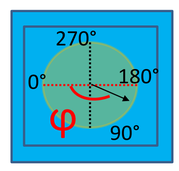



- Simulation **anode uniformity :**
  - Photocathode uniformity & Collection efficiency convolution



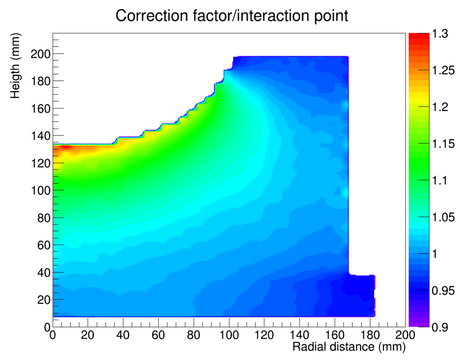




## Results

### Energy performances

Elaboration of a scintillator map taking into account the
**Non uniformity of the light collection**



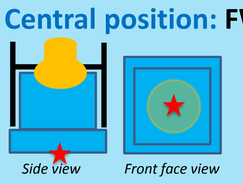

**deposited energy ≠ visible energy**

**Depending on the:**

- **Block geometry**
- **PMT's uniformity**

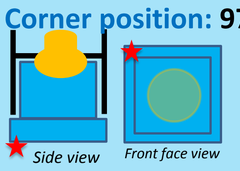
#### Validation with e⁻ beam/sources

**Central position: FWHM @1 MeV electron**



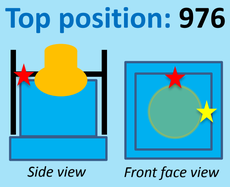

| PMT Number | GA0124 | GA0154 | GA0192 | GA0205 |
|---|---|---|---|---|
| Experimental | 8.5 ± 0.2 | 8.4 ± 0.2 | 8.1 ± 0.2 | 8.1 ± 0.2 |
| Optical Simulation | 8.4 ± 0.1 | 8.4 ± 0.1 | 8.2 ± 0.1 | 8.1 ± 0.1 |

**Corner position: 976 keV e⁻ peak ($^{207}$Bi)**

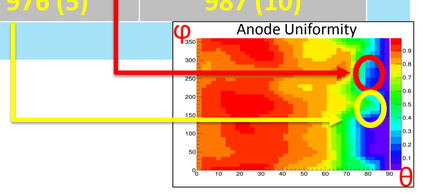



| Basic GEANT4 [keV] | + Optical [keV] | EXPERIMENTAL [keV] |
|---|---|---|
| 980 (5) | 933 (5) | 934 (10) |

**Top position: 976 keV e⁻ peak ( $^{207}$Bi)**




| | Basic GEANT4 [keV] | + Optical [keV] | EXPERIMENTAL [keV] |
|---|---|---|---|
| North | 983 (5) | 909 (5) | 851 (10) |
| East | 979 (5) | 976 (5) | 987 (10) |




**Optical Simulation is able to reproduce geometry & photocathode effects**

### Test on the Single rate spectrum (due to radioactive contaminations) for 1 optical module at LSM







**Optical Simulation is essential to reproduce data**

### Timing performances

- Emission time
- Propagation time
- PMt transit time
- *HV Divider transfer function [preliminary]*




**Good representation of rise time**
**[most important parameter for trigger study]**