Energy reconstruction in the SuperNEMO calorimeter

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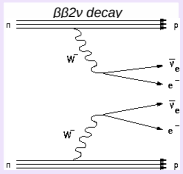
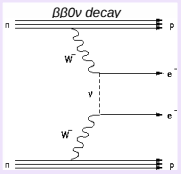
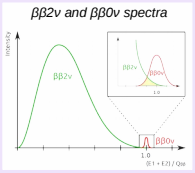
The SuperNEMO demonstrator

The SuperNEMO experiment aims to study the neutrinoless double beta decay (ββ0ν) and reach a sensitivity on this decay of 10^{26} years, i.e a Majorana neutrino mass of 50-100 meV.



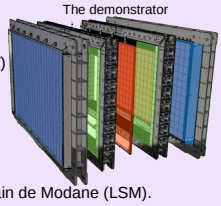




It is composed of:

- A **source foil** containing the ββ emitters: 7kg of ^{82}Se ($Q_{\beta\beta0\nu}$ = 2.99 MeV)
- A **tracker** to identify the particles and recontruct their trajectory: 2034 Geiger cells (14970 wires)
- A **calorimeter** to measure the energy and the time of flight (TOF) of particles: 712 optical modules (OMs)

The demonstrator



The demonstrator is currently being installed at the Laboratoire Souterrain de Modane (LSM).

The main wall calorimeter

The SuperNEMO main wall calorimeter: 520 Optical Modules (OMs).

Each OM is composed of [1] :

- 10 L NUVIA plastic scintillator
- *R5912-03 mod* HAMAMATSU 8 '' photomultiplier tube
- Teflon and Mylar wrapping
- *RTV615* optical coupling
- Individual pure iron magnetic shield

Optical module

Main wall calorimeter

Measured Resolution ≈ $\frac{8.3\%FWHM}{\sqrt{(E)MeV}}$ [2]

Other expected performances:

- Time resolution of 400 ps(σ) @ 1 MeV
- No ageing in 5 years
- Gain survey with an accuracy < 1 %
- Low background PMT
- Low backscattering
- 50 % γ tagging @ 1 MeV

Energy corrections with optical simulations

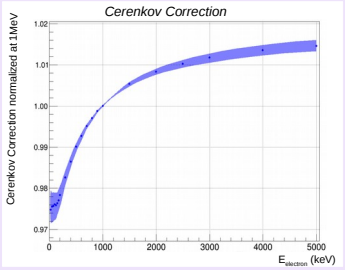
Goal: understand every effect in the calorimeter which can affect the true deposited energy and modify the measured energy [3] .

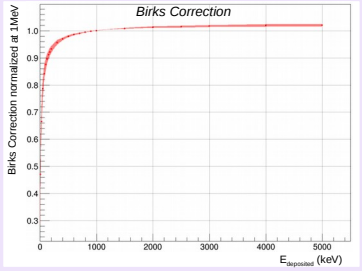
Non-linear effects : Birks and Cerenkov

Depends on the energy and the type of the particle → non-linearity of light production

2 main effects:

- **Birks**: local saturation of the scintillation light yield. Stronger at low energies and for γ-rays.
- **Cerenkov**: production of additional light for $E_{electrons}$ **>** 150 keV in the SuperNEMO scintillators.



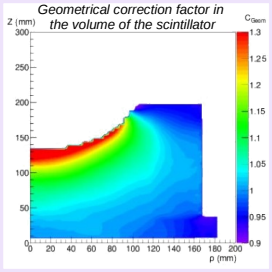


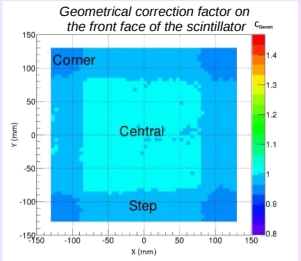
Non-uniformity effect : Geometrical

Depends on the interaction position of the particle → non-uniformity of light collection

2 main origins:

- **Geometry** of the scintillator (Step, corners).
- **Inhomogeneity** of the photocathode of the photomultiplier tube.

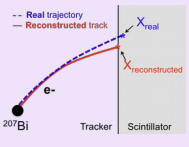




Improvement of the energy resolution of the SuperNEMO experiment

Goals: Demonstrate the capability to correct the non-uniformity effect of each electron energy deposit using the impact point on the calorimeter.

Optical simulation (previously described)



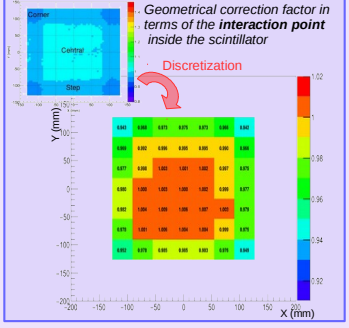
Use the SuperNEMO simulation software (FALAISE):

- Simulation of 100M ^{207}Bi events (calibration source of the experiment)
- 1 electron event = 1 track + 1 calorimeter hit

$Corr_{geom}$ = f(X_{real})
(MC true informations)

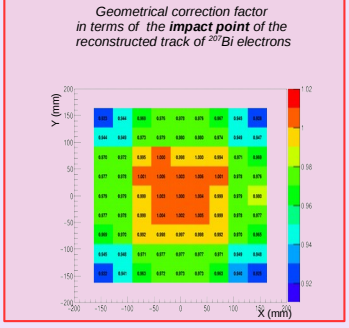
Geometrical correction factor in terms of the ***interaction point*** inside the scintillator

Discretization

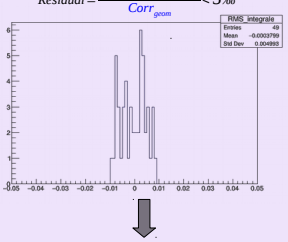


$Corr_{geom}$ = f($X_{reconstructed}$)
(MC reconstructed informations

Geometrical correction factor in terms of the ***impact point*** of the reconstructed track of ^{207}Bi electrons

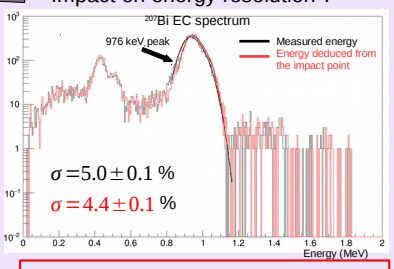


$Residual = \frac{Corr_{geom} - Corr_{geom}}{Corr_{geom}} < 5‰$



Ability to correct the measured energy using the impact points of the reconstructed tracks

Impact on energy resolution ?



Energy resolution improvement : ~ 12 %

Resolution σ @ 976 keV

Calorimeter	Calorimeter + tracker	Realistic* calorimeter + tracker
3.5 %	4.4 %	5.0 %

This work

*Realistic calorimeter model = Birks + Cerenkov + Geometrical

References

[1] E. Chauveau. PhD Thesis, Université de Bordeaux, 2010.
[2] Calorimeter development for the SuperNEMO double beta decay experiment, Nucl. Inst. Meth. A, 868 : 98-108 (2017).
[3] A. Huber. PhD Thesis, Université de Bordeaux, 2017.