Status report of SuperNEMO Demonstrator

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supernemo collaboration

January 2011 : NEMO3 stopped taking data

LSM is partially empty now ...

From NEMO3 to SuperNEMO

Performances :

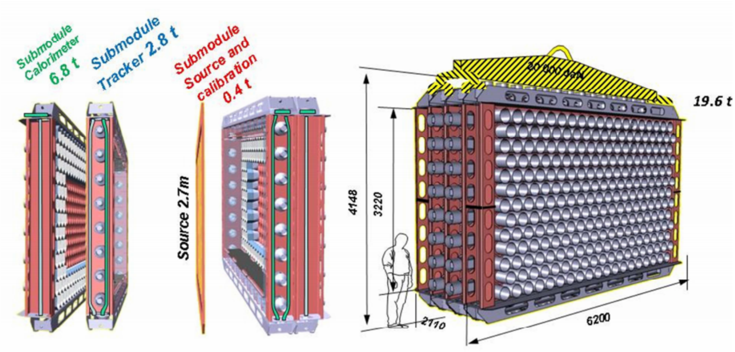
	NEMO3	SuperNEMO
Mass	7 kg	100 kg
Isotope	^{100}Mo	^{82}**Se** (^{150}Nd, ^{48}Ca)
Calorimeter energy resolution		
@ 1 MeV	15 %	**7 %**
@ 3 MeV	8 %	**4 %**
Source contamination		
$\mathcal{A}(^{208}\mathrm{Tl})$	$< 20\ \mu$Bq/kg	$< \mathbf{2\ \mu Bq/kg}$
$\mathcal{A}(^{214}\mathrm{Bi})$	$< 300\ \mu$Bq/kg	$< \mathbf{10\ \mu Bq/kg}$
Radon (^{222}Rn)	~ 5.0 mBq/m^3	$\sim \mathbf{0.1\ mBq/m^3}$
Sensitivity	$T^{0\nu}_{1/2} > 2 \cdot 10^{24}$ years	$T^{0\nu}_{1/2} > 10^{26}$ years

From NEMO3 to SuperNEMO

Geometry :

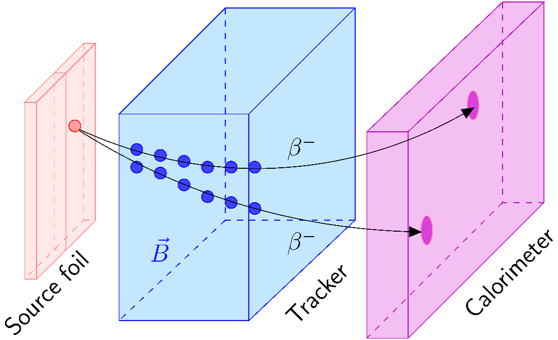
This time we chose a planar shape instead of a cylindrical one.

In order to have enough source mass there will be 20 modules containing about 5 kg of isotopes each.



Detection principle

Charged particles from the source foil are detected by the tracker, then the energy and arrival time are measured in the calorimeter.
The charge of the particle is identified thanks to a magnetic field.



Demonstrator

The construction of the first module called demonstrator has been recommanded by IN2P3 in Spring 2011.
Whereas in the UK the project is funded since 2010 (1.5 M€) for the tracker delivery in 2013.

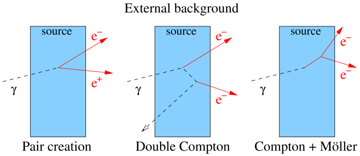
It will work with 7 kg ^{82}Se foils and be installed in the LSM.
In 2 years of data taking it will reach the sensitivity $T^{0\nu}_{1/2} > 6.5 \cdot 10^{24}$ years (equivalent to $3 \cdot 10^{25}$ year for ^{76}Ge).

Milestones :

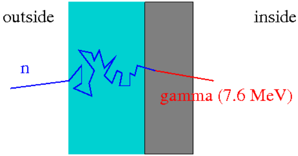
- BiPo ready by mid 2012 to start source foils measurement;
- electronics ready for mid 2013 for the arrival of the tracker in LSM, assembly with the integration of the different detectors;
- calorimeter mechanics ready for beginning 2013;
- first half of calorimeter optical modules will be integrated by the end of 2013;
- second half for end of 2014.

Shielding

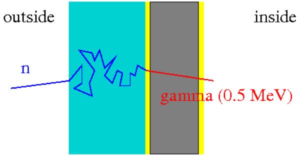
The dominant external background is the neutron flux from the laboratory rocks. In NEMO3 the shielding was made of borated water against neutrons (30 cm) and iron against gammas (19 cm).
Problem : neutron capture can produce high energy gammas in the iron for example (up to 7.6 MeV) that can mimic a 2-electrons event :



One idea is to isolate iron with 1 cm of borated polyethylene on each side (boron has an high neutron capture cross section and lower energy gammas).



NEMO3



SuperNEMO

Calorimeter

France's responsability.

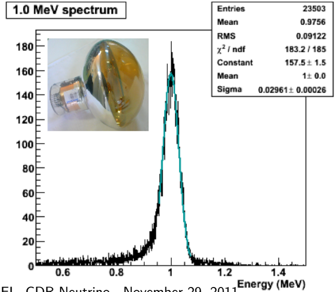
Resolution (FWHM $\sim 7\%$ at 1 MeV) :

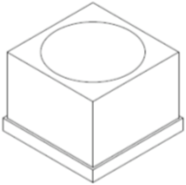
- $\sim$ 500 8 inchs PMTs with better quantum efficiency ($\sim$ 45%);
- large cubic PVT scintillator (256 mm) without light guide.

Electronic : 1 GS/s for $\sim 1\,\mu$s duration.
$\Rightarrow$ pulse shape analysis (already tested on BiPo).

Radioactive background rejection :

- high purity glass ($\mathcal{A}(^{238}U) = 0.128$ Bq/PMT and $\mathcal{A}(^{232}Th) = 0.058$ Bq/PMT);
- radon barrier;
- time resolution : 250 ps at 1 MeV;
- with x-calo and g-veto block almost 4π radian coverage for gammas;

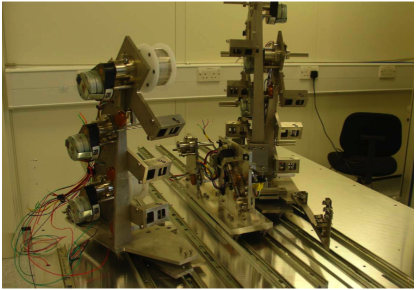


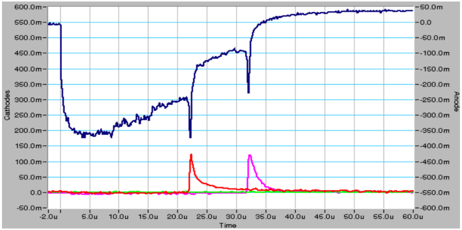


Tracker

UK's responsability.

- $\sim$ 2000 cells in Geiger mode;
- double cathodes readout;
- resolution : 0.7 mm transverse, 1 cm longitudinal;
- efficiency : 98 %;
- automated wiring robot;
- performances tested with cosmic muons.





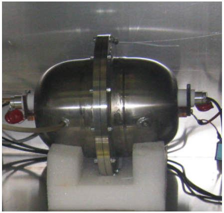
Strategy against Radon

Czech Republic, UK, and France's responsability.

- development of a Radon emanation detector and a Radon detector (sensitive to few $0.1\,\mathrm{mBq/m^3}$);

Radon concentration line

Radon electrostatic detector



Setup for Radon diffusion measurements

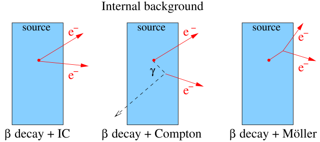
- isolate the tracker from the calorimeter using a thin foil tight to Radon (Nylon, EVOH, ...).

Material	Thickness d [μm]	C_1/C_2	C_1/C_2 normalized to 15 μm	Diff. coefficient D [10^{-12} m^2s^{-1}]	Diff. length L [μm]
TROPAC III	102	> 8300	> 600	< 0.0043	< 46
EVOH (2 layers)	2×15	> 31000	> 8900	< 0.00035	< 13
PET	1 000	> 41 136	> 35	< 0.076	< 190

Source foil

Russia, France, and USA's responsability.

- dimension : $4.9 \times 2.7\,\mathrm{m}^2$;
- surface density : $\sim 53\,\mathrm{mg/cm}^2$;
- isotope : we already have 5.5 kg of ^{82}Se ($Q_{\beta\beta} = 3\,\mathrm{MeV}$, $T_{1/2} = 9.2 \cdot 10^{19}$ years, can be enriched);
- current R&D on enrichment of ^{48}Ca and ^{150}Nd (both have high $Q_{\beta\beta}$ value but cannot be enriched by centrifugation);
- these foils have to be ultrapure to avoid internal background.

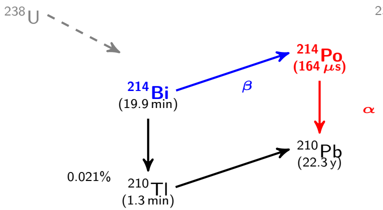


The main requirement is $\mathcal{A}(^{208}Tl) < 2\,\mu\mathrm{Bq/kg}$ (60 decays per year), 20 times lower than the limit with Germanium detectors.
$\Rightarrow$ We need a dedicated detector.

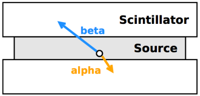
BiPo3

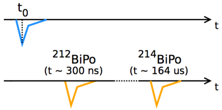
Goal :

The requirements for the source foils are : $\mathcal{A}(^{208}Tl) < 2\,\mu\text{Bq/kg}$ and $\mathcal{A}(^{214}Bi) < 10\,\mu\text{Bq/kg}$.



⇒ We measure the BiPo process : one electron and one delayed alpha back to back from the source foil.





We want the measurement to be achieved within ~ 6 months.

BiPo3

Prototypes :

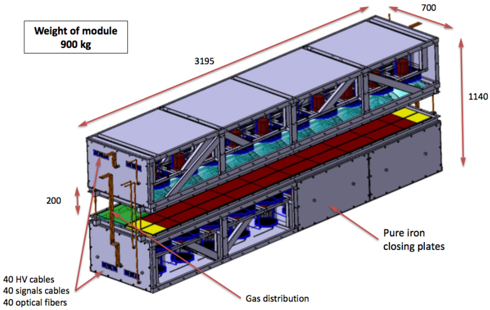
From 2006 to 2010 : BiPo R&D (ANR) to validate the experimental technique and the background level (Nucl. Inst. Meth. A 622 120-128 (2010)).

In March 2011 a final prototype has been installed in Canfranc to validate the geometry for the full detector.

BiPo3

Full Detector :

- 2 independants modules;
- total coverage $3.6\,\mathrm{m}^2$ of source foils;
- will be installed in LSC;
- frame and optical submodules (80 in total) construction already started in LAL;
- first module commissioning end of March 2012;
- full detector by mid 2012.



Conclusion

Demonstrator design is being finalized and the tracker construction has already started in the UK.

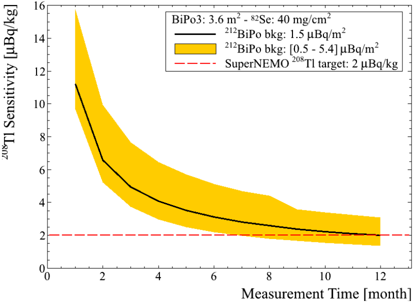
Within 2 years it will reach the Klapdor's claim sensitivity ($T_{1/2}^{0\nu} \sim 6.5 \cdot 10^{24}$ years).

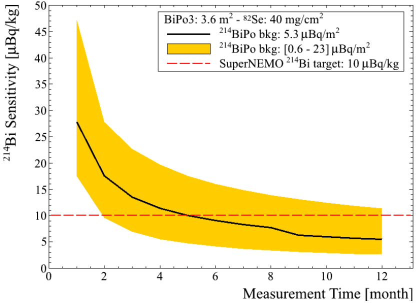
It will confirm the feasability of a quasi no-background double β experiment for the other 19 modules (2 expected events per year for 100 kg) :

- BiPo3 will check the internal purity of the source foils;
- the demonstrator should prove the Radon specification.

BackUp

BiPo Sensitivity :

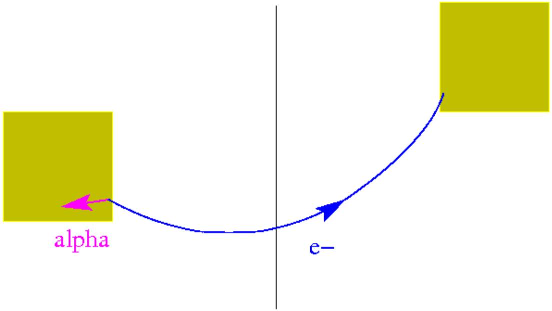




BackUp

Pulse Shape Analysis :

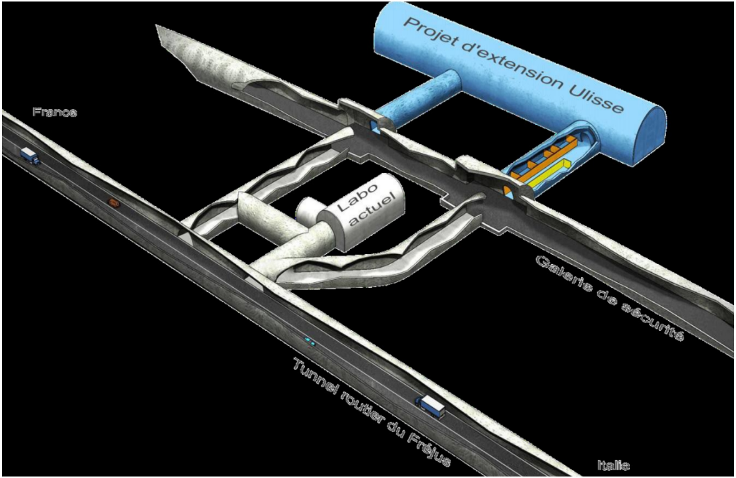
We can discriminine between electron and alpha particle in this kind of ^{212}Bi events ($T_{1/2}(^{212}Po) = 299\,\text{ns}$) :



$Q_\beta = 2.2\,\text{MeV}$, if we mistake on the curvature of the left side of the track and alpha particle deposits about $0.8\,\text{MeV}$ (without electron alpha discrimination) it mimics a $2\beta0\nu$ event.

BackUp

LSM Extension :



BackUp

Detailed Milestone :