Measurement of extremely low radioactive contaminations for the SuperNEMO project

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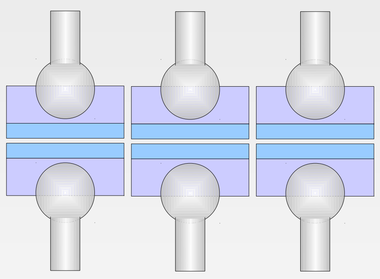
Abstract: The SuperNEMO experiment is being designed to search for neutrinoless double beta decay to check the Majorana nature of the neutrino. This experiment aims to reach a sensitivity up to 10^{26} years on the half-life of neutrinoless double beta decay (50 meV effective Majorana neutrino mass). One of the most technical constraints of this project is the radio-purity in ^{208}Tl and ^{214}Bi of the beta-beta source foils, that is why the BiPo detector, dedicated to measurements of radiocontamination at the level of 1 to 10 µBq/kg, is currently under development. A modular BiPo1 prototype has been running in the Modane Underground Laboratory since February, 2008. The goal is to study the surface radiopurity of plastic scintillators in order to validate this technology.

The design of BiPo1 and the results of background measurement are presented in this poster.

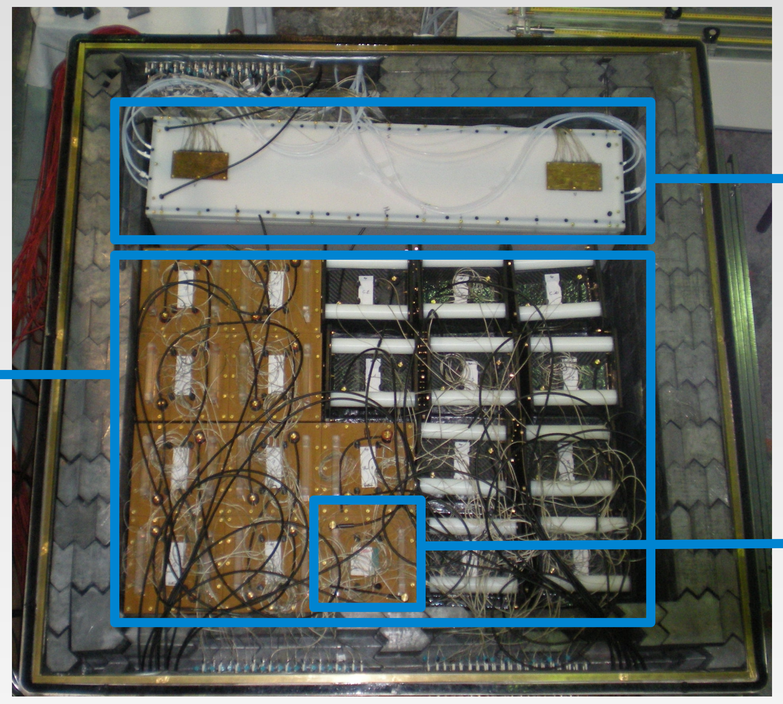
Acquisition boards: Photomultiplier (PMT) signals are sampled with a 12 bits resolution on 1V and at 1GHz in 2.5µs by MATACQ VME boards.
A trigger board for ^{214}Bi BiPo measurement is also available.

BiPo1: 20 capsules (S = 0,8 m²) composed of 3 mm thick scintillators coupled to 5” PMTs.

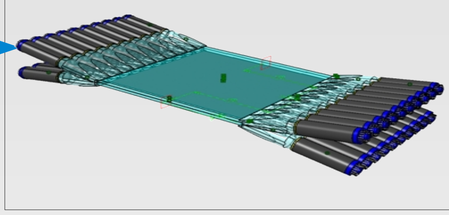


Running at Modane since February 2008.

Main advantages:
+ Standard technique
+ Very good proven sensibility
+ Good β/α discrimination



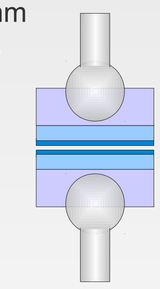
BiPo2: 2 scintillator plates (S = 0,56 m²) coupled each to 10 3” PMTs.



Running at Modane since July 2008.

Main advantages:
+ Compact design
+ Less number of PMTs
+ Spatial resolution

Phoswich: 1 capsule (S = 0,04 m²) composed of a 300 µm thick fast scintillator and a 10 mm thick slow scintillator assiociated to 5” PMTs.

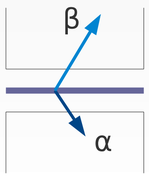


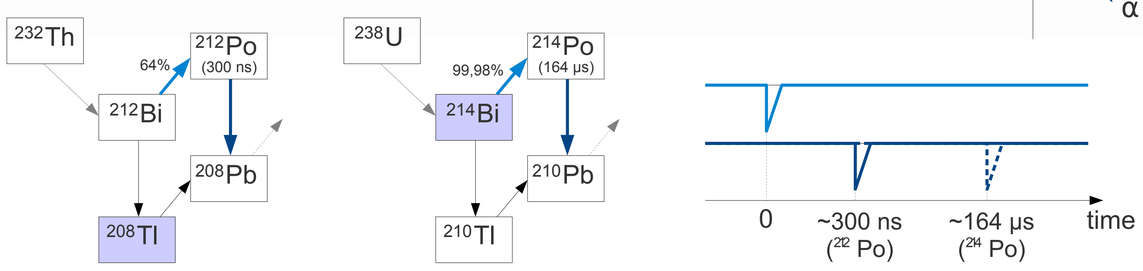
Running at Modane since July 2008.

Main advantages:
+ Possible running with only one PMT
+ Powerful β/α discrimination

Goal: To measure ultra-low levels of ^{208}Tl and ^{214}Bi in double-beta source foils reaching activities A(^{208}Tl) < 2 µBq/kg and A(^{214}Bi) < 10 µBq/kg.

Method: BiPo events are registerd in the natural chains as a delayed coincidence between electrons and alpha particles using a sandwich of two plastic scintillators.





^{208}Tl measurement: The ^{207}Tl contamination of some foils has been measured this summer:
- 100 µm thickness of mylar foils for 9.4 days.m²
- 120 µm thickness of stycast foils for 25.0 days.m²

6 events have been measured from mylar samples while 0.5 can be explained by surface contamination. According to Cousin Feldman tables: 1.90 < N < 10.97 (90% CL).

The ^{208}Tl contamination of this mylar samples is also:

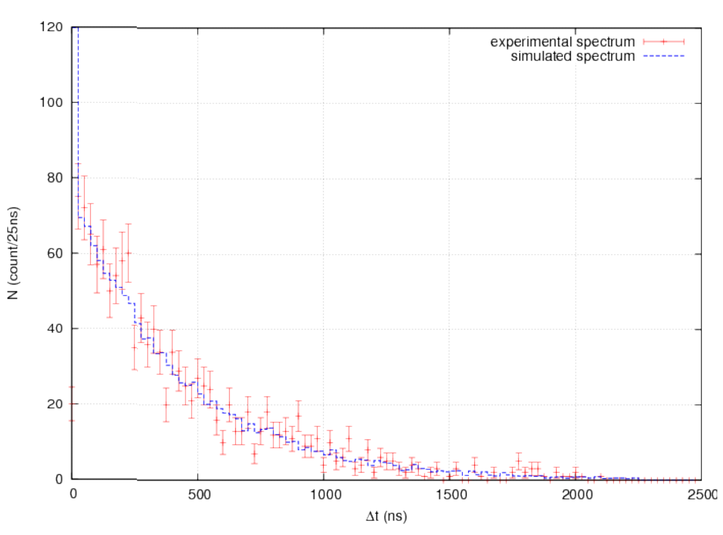
90 µBq/kg < A_{myl} (^{208}Tl) < 540 µBq/kg (90% CL)

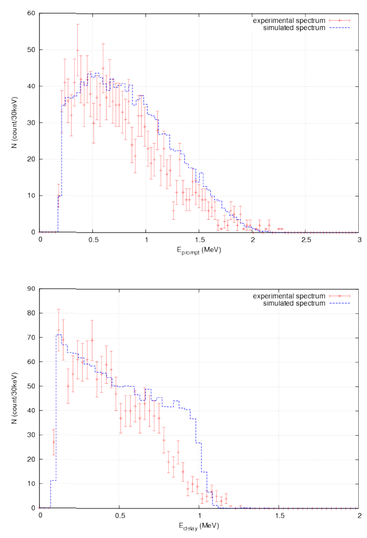
24 events have been measured from stycast samples while 1.2 can be explained by surface contamination. According to Cousin Feldman tables: 15.16 < N < 32.68 (90% CL).

The ^{208}Tl contamination of this stycast samples is also:

290 µBq/kg < A_{sty} (^{208}Tl) < 630 µBq/kg (90% CL)

Technique and efficiency validation: A 40 mg/cm² thick Aluminium foil of known ^{208}Tl activity (HPGe measurement: (0.19 ± 0.03) Bq/kg) has been measured by a BiPo1 module during six months (6.4 days.m²).
1309 events have been detected with a beta energy greater than 200 keV deposited in a scintillator and a alpha energy greater than 100 keV deposited in the other one.
The resulting ^{208}Tl contamination is A(^{208}Tl) = (0.16 ± 0.02) Bq/kg

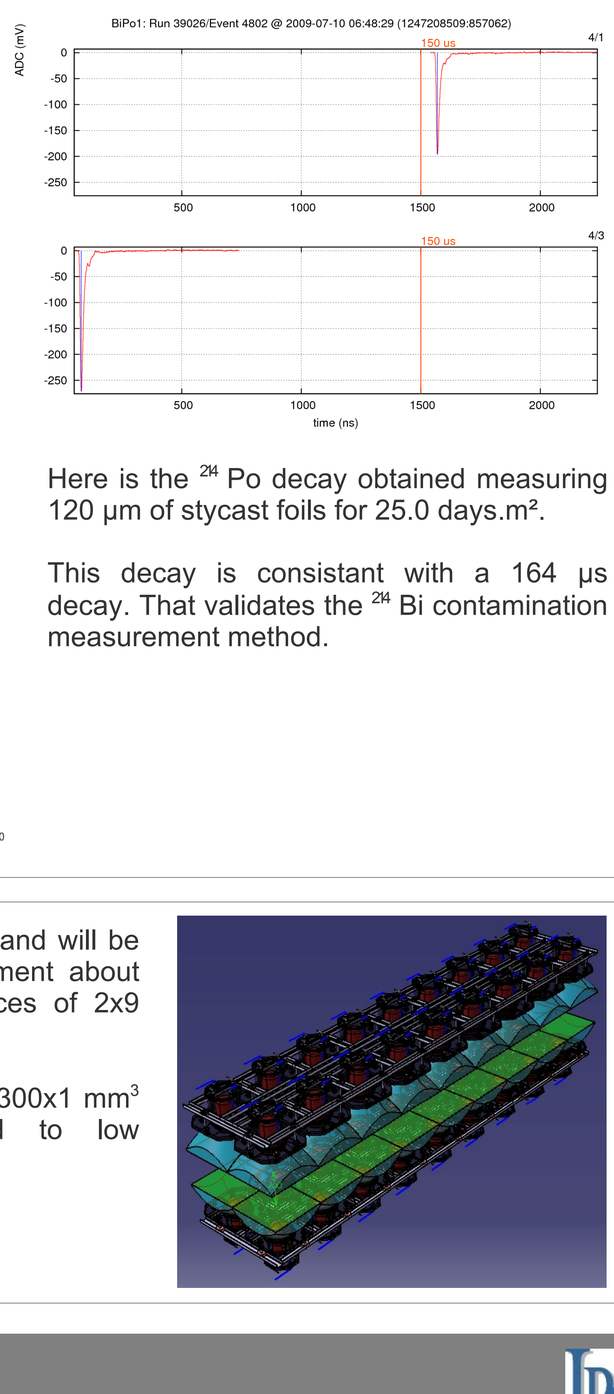


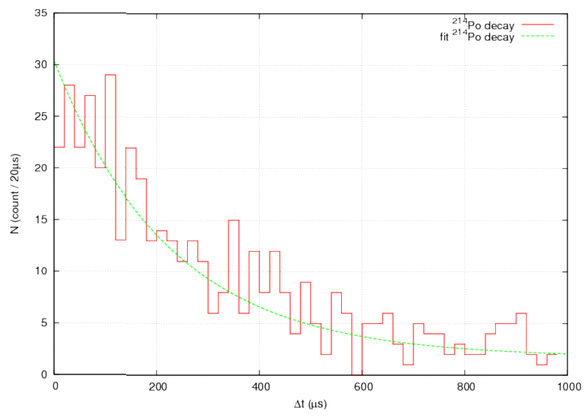


The energy spectra are consistent with those expeced, and the ^{212}Po decay well reproduce the 300 ns decay. The resulting ^{212}BiPo efficiency is 3.7%.

^{214}Bi measurement: A VME trigger board has been developed for ^{214}Bi contamination measurement. The BiPo1 acquisition is now provided with this board. The surface contamination of the scintillators is measuring.

An event is displayed here. The first 1500ns of MATACQ depth allow to save the first signal. The next 1000ns allow to save the second one.

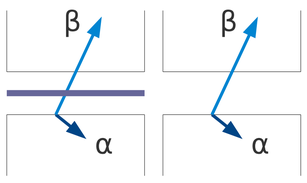




Here is the ^{214}Po decay obtained measuring 120 µm of stycast foils for 25.0 days.m².

This decay is consistant with a 164 µs decay. That validates the ^{214}Bi contamination measurement method.

Surface contamination measurement: To obtain the expected sensitivity with a lowest time measurement, the surface contamination of the scintillators has to be as low as possible.
Indeed, a BiPo event which comes from the scintillator surface has the same signature than a BiPo event which comes from the measured foil.



This surface contamination measurement has gone on 258 days.m². 32 ^{212}BiPo events have been detected, with an efficiency of 27.4%. The resulting ^{208}Tl activity is **(1.4 ± 0,3) µBq/m²**.

The expected sensitivity (2 µBq/kg) can also be processed by 3 months

Outlooks: A BiPo3 detector is developping and will be operational for foils contamination measurement about end 2010. It will be constituted by 2 devices of 2x9 BiPo1-like modules each.

Each module will be constituted by two 300x300x1 mm^3 plastic scintillators face-to-face bounded to low radioactivity 5” PMTs with light guides.