^{222}Rn emanation based material measurement and selection for the SuperNEMO 0ν2β experiment

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on behalf of the SuperNEMO collaboration

LRT2015, 18-20 March 2015, Washington University, Seattle

Outline

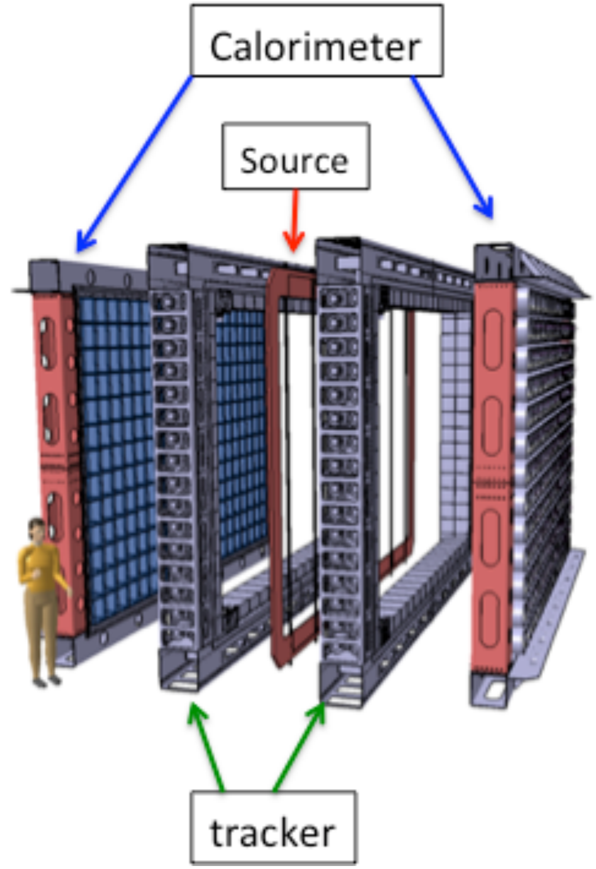
* SuperNEMO $0\nu2\beta$ experiment
  * Physics goal, background Requirement & construction status
  * Low background global strategy

* Large samples emanation setup facility

* Dedicated studies :
  * Photomultipliers radiopurity
  * Aluminized mylar ^{222}Rn emanation qualification

SuperNemo

	Phase 1	Phase 2
Mass	7kg	up to 100kg
Isotope	^{82}Se, ^{150}Nd	^{82}Se, ^{150}Nd, ^{48}Ca
Energy resolution (σ / FWHM) @ 3MeV	1.7 / 4%	
Radon in tracker $\mathcal{A}(^{222}Rn)$	0.15 mBq/m³	
Source contamination	→ *See talk of Dr. X.Sarazin yesterday*	
$\mathcal{A}(^{208}Tl)$	< 2μBq/kg	
$\mathcal{A}(^{214}Bi)$	< 10μBq/kg	
Background index Cts•keV^{-1}•kg^{-1}•y^{-1}	5×10^{-5} R.O.I. [2.8-3.1 MeV]	
Sensitivity		
$\mathcal{T}^{0\nu}_{1/2}$	$> 6.5 \times 10^{24}$y	$> 10^{26}$y
$<m_\nu>$	<0.20 – 0.40 eV	<0.04 – 0.10 eV



- Direct reconstruction of the 2e- cinematic
  - Individual electrons energies
  - Time of flight
  - Curvature in magnetic field
  - Emission vertex and angle
- Modest energy resolution and efficiency
- Background for the 0ν2β equivalent to the best calorimeter experiments

A particle physicist's nuclear physics experiment

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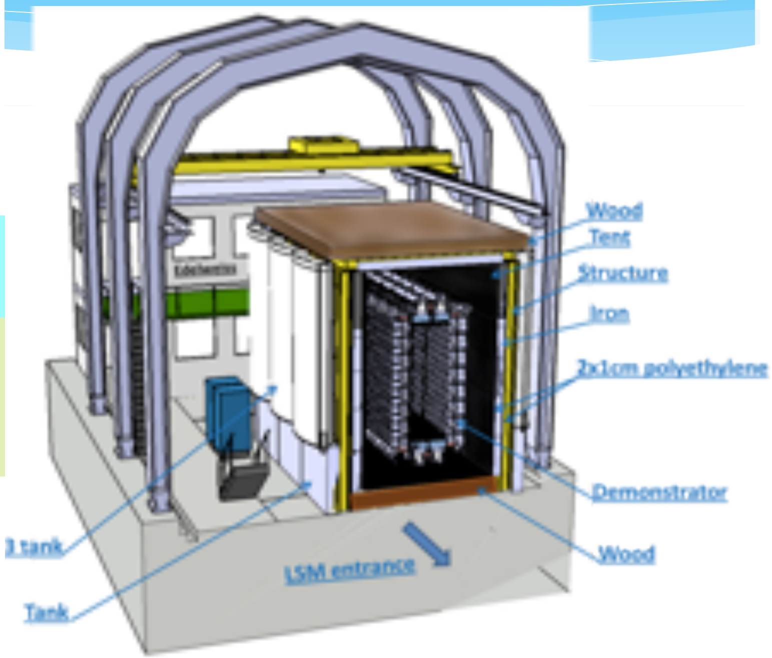


- Ultra low background detector
- Modular detector with 3 main components :
  - Central source foil frame : 7 kg of isotope
  - Tracking : 2 000 drift chambers
  - Calorimeter : 712 scintillators+ PMTs
- Shielded by iron (300 tons) and water
- **Major project to be installed @ Modane Underground Laboratory**

Construction Installation

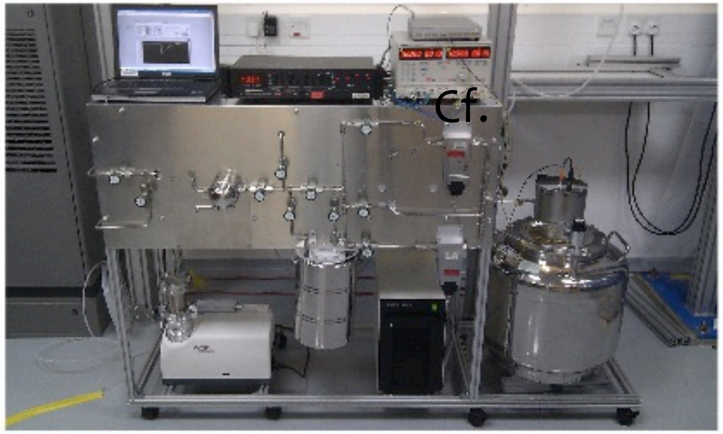
- Construction in progress in all the involved laboratories
- Installation and commissioning at Modane Underground Laboratory 2015 – 16

Global anti-Rn strategy for SuperNEMO

Goal: reduce and measure the internal ^{222}Rn bckg down to 150µBq/m^3

→ Facilities to measure the radon level in the detector or gases

Several electrostatic detectors

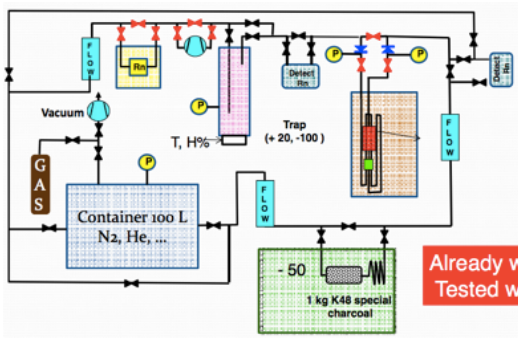


Cf.

London concentration line

→ Talk today X.Liu

→ Facilities to select Rn barriers and material of construction



Marseille Rn trap studies

→ Talk today N.Raymond

Prague permeability setup

→ Poster F.Mamedov

Bordeaux emanation setup

→ This Talk

During the construction of SuperNEMO Phase 1 we do not only want to qualify small portion of the material batchs, but try to qualify as large number of construction pieces than we can

→ large emanation chamber

Radon emanate from surfaces, so in order to increase the sensitivity of a qualification setup we need to get as much surface as we can in contact with the setup

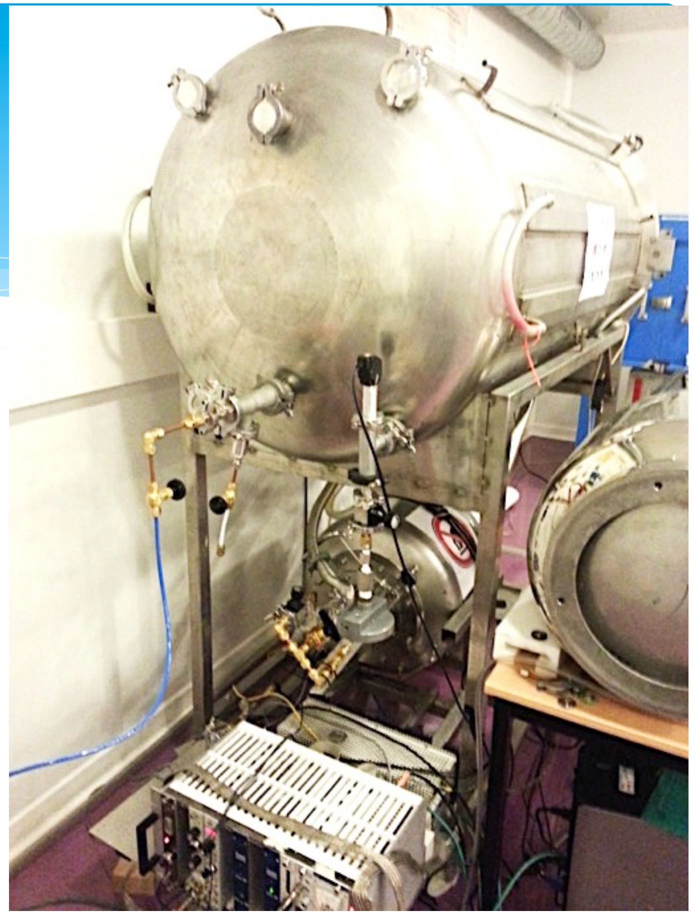
→ large emanation chamber

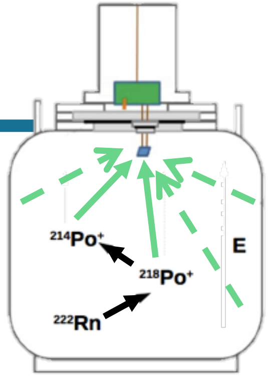
Large samples emanation setup

Emanation chamber

710L stainless steel tank

^{222}Rn





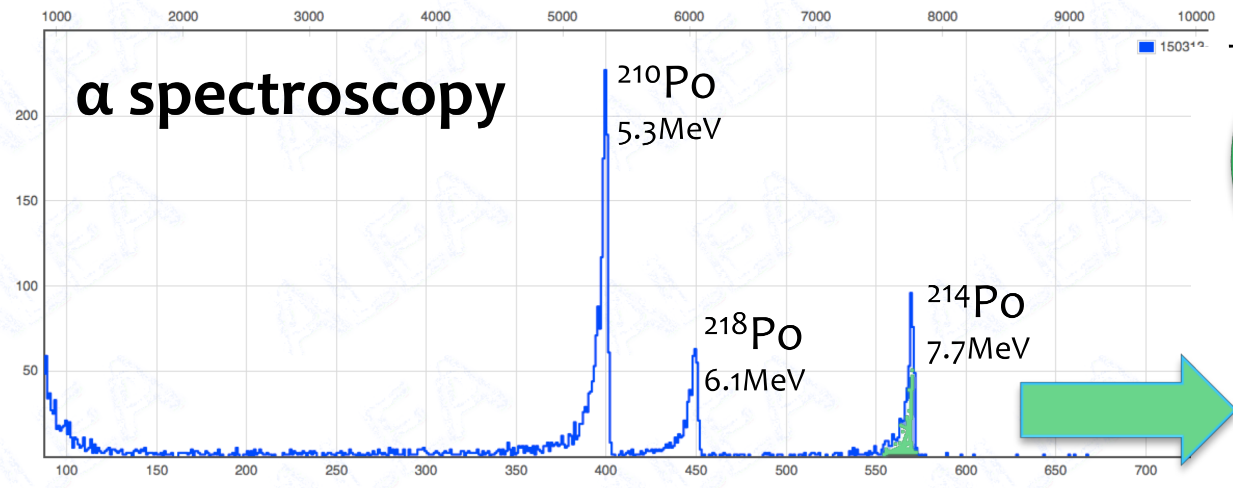
Radon detector

70L stainless electrostatic detector
α spectroscopy : Si Pin diode

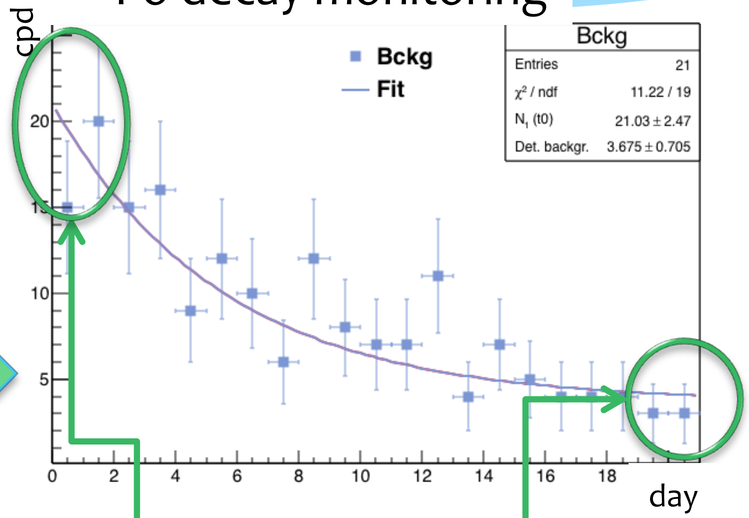
Operating mode :

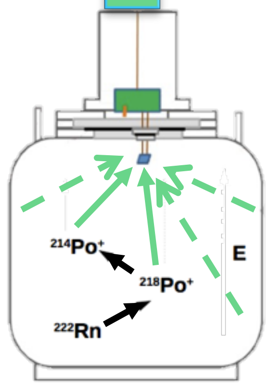
1. Sample in tank
2. Emanation during 3 weeks
3. Transfert of 1/10 from the tank to the detector
4. Counting during 1-2 weeks

Setup background



^{214}Po decay monitoring





Level of Rn from the tank

Rn bckg of the electrostatic detector

Radon detector

70L stainless electrostatic detector

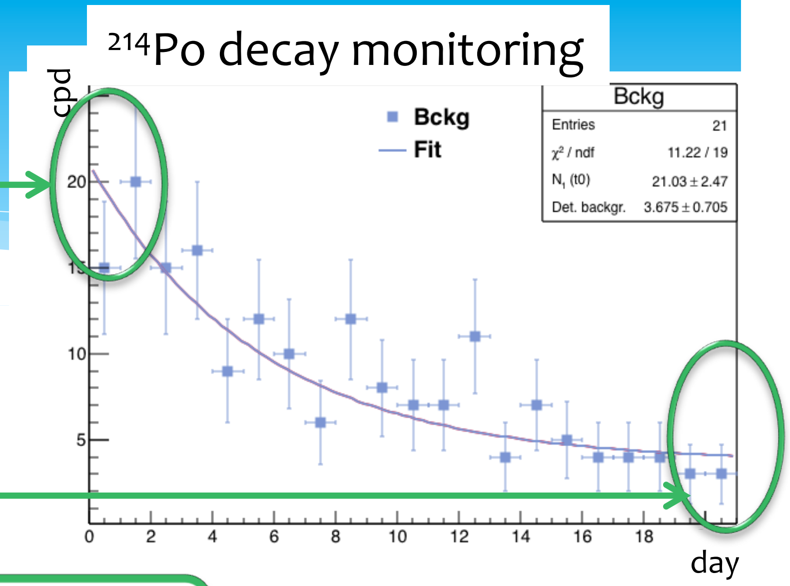
α spectroscopy : Si Pin diode

Efficiencies

Calibrated with a radium source

Limitation factors

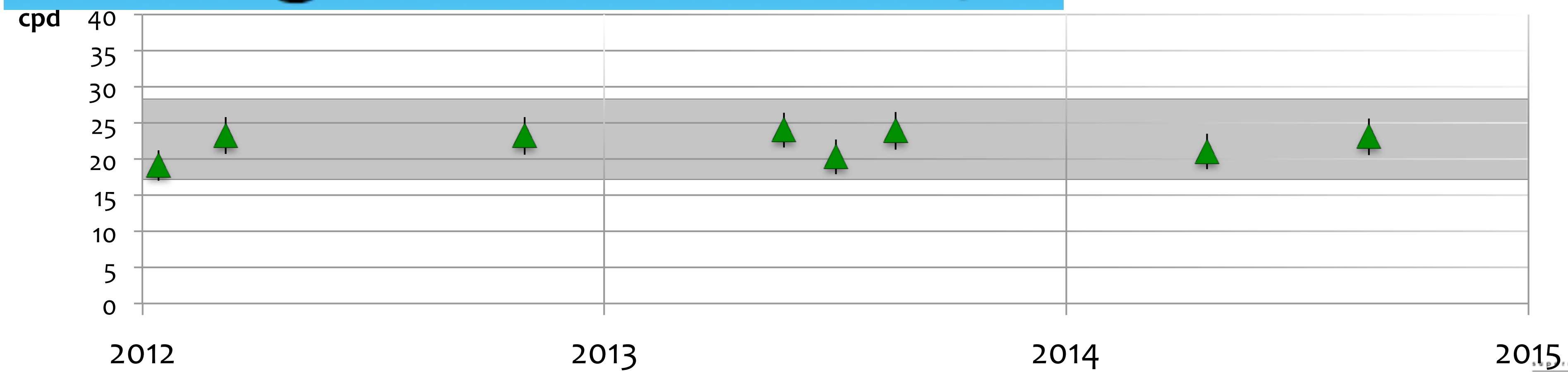
- **Transfered volume**
  1/10 of the emanation volume is measured
- **Transfer efficiency 70%**
- **Detection efficiency 35%**



Level of ^{222}Rn from the tank → **11mBq**

Level of ^{222}Rn from the detector→ **100µBq**

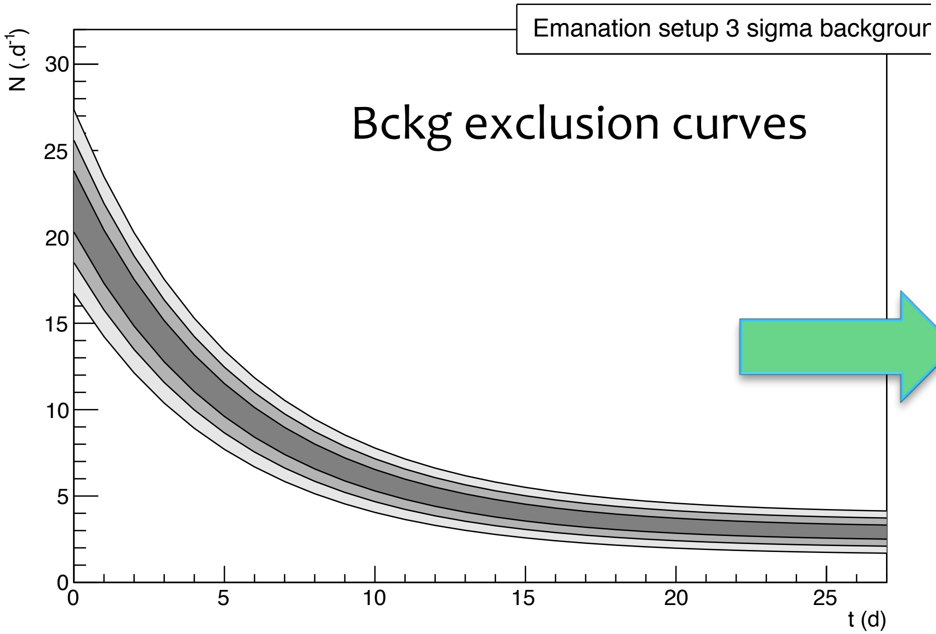
Background Stability

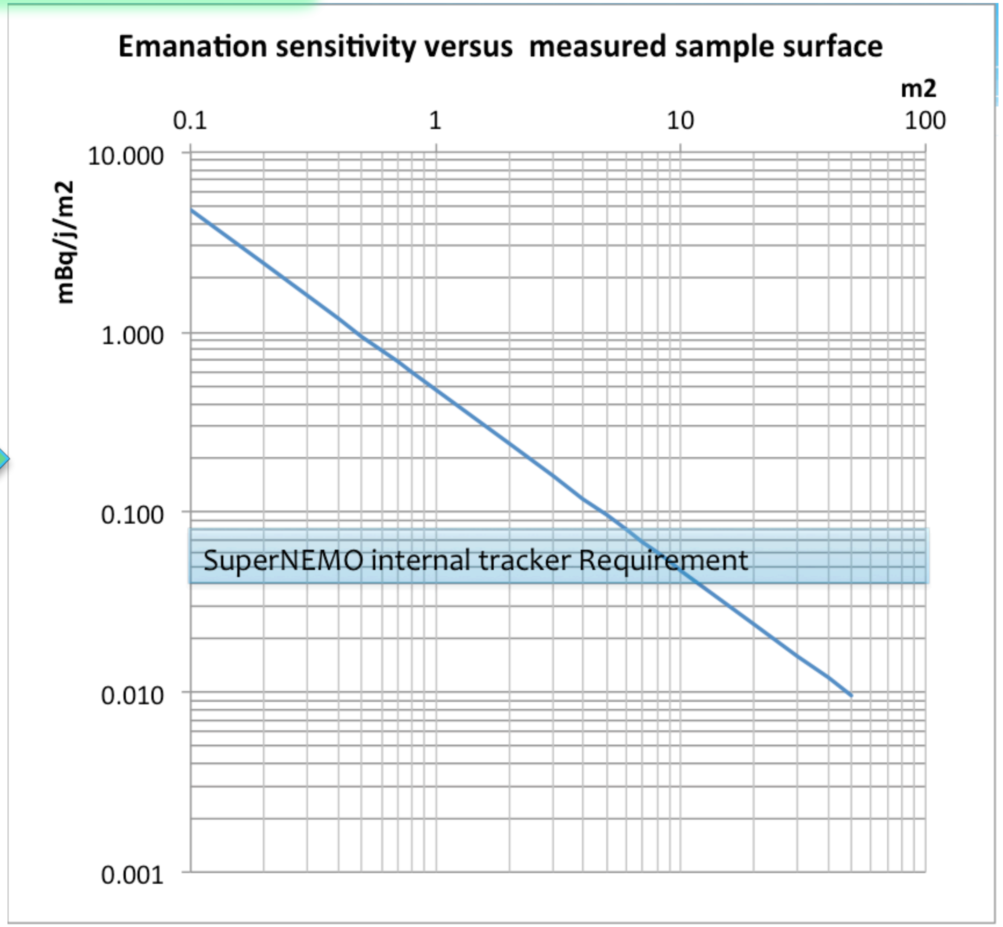


Expected sensitivity

- Transfered volume
  1/10 of the emanation volume is measured
- Transfer efficiency 70%
- Detection efficiency 35%

When a sample has emanated
→ check for deviations above that bckg





Focus on 2 particular studies important for SuperNEMO but also interesting for the community

The amount of radon emanation from

- → Low background Photomultipliers
- → Aluminized mylar

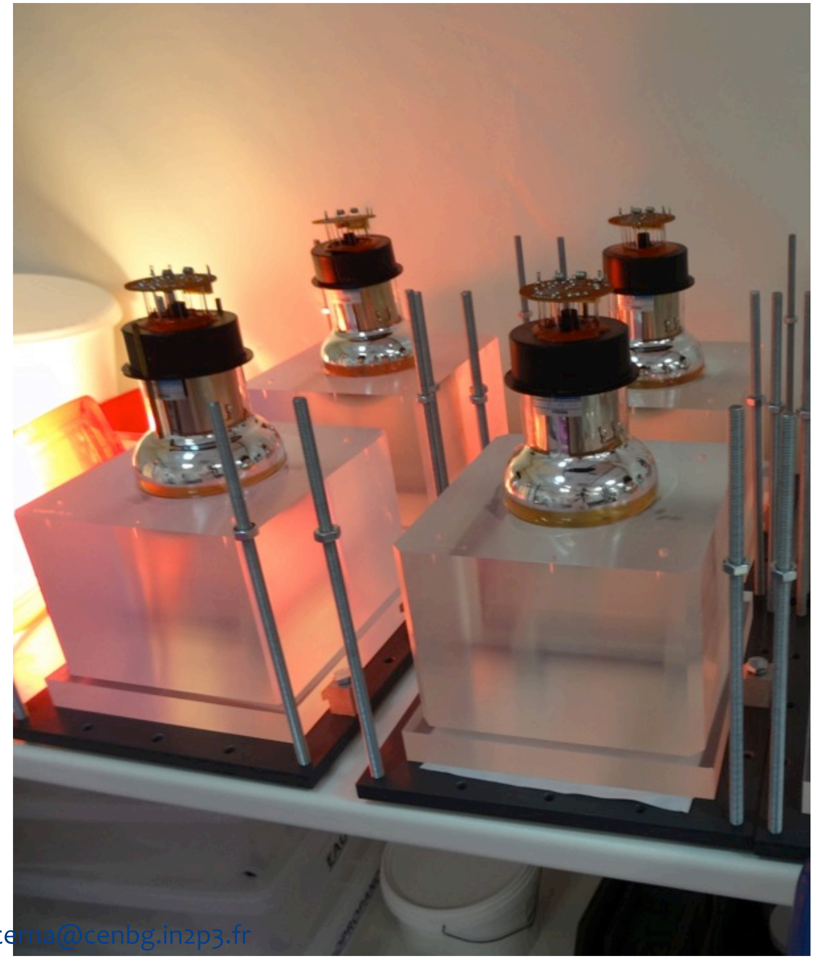
Low background Photomultipliers

Study of 5” PMT R6594 recovered from NEMO3

Study of 5” PMT R6594 recovered from NEMO3

mBq / PMT	214Bi	208Tl	# pieces / SNEMO module
5” PMTs R6594	244	14	192
8” PMTs R5912-Mod03	250	80	440

Main source of internal γ background



long-standing belief to be a large contribution of the internal 222Rn of NEMO3 experiment (2.000 PMTs)

Study of 5” PMT R6594

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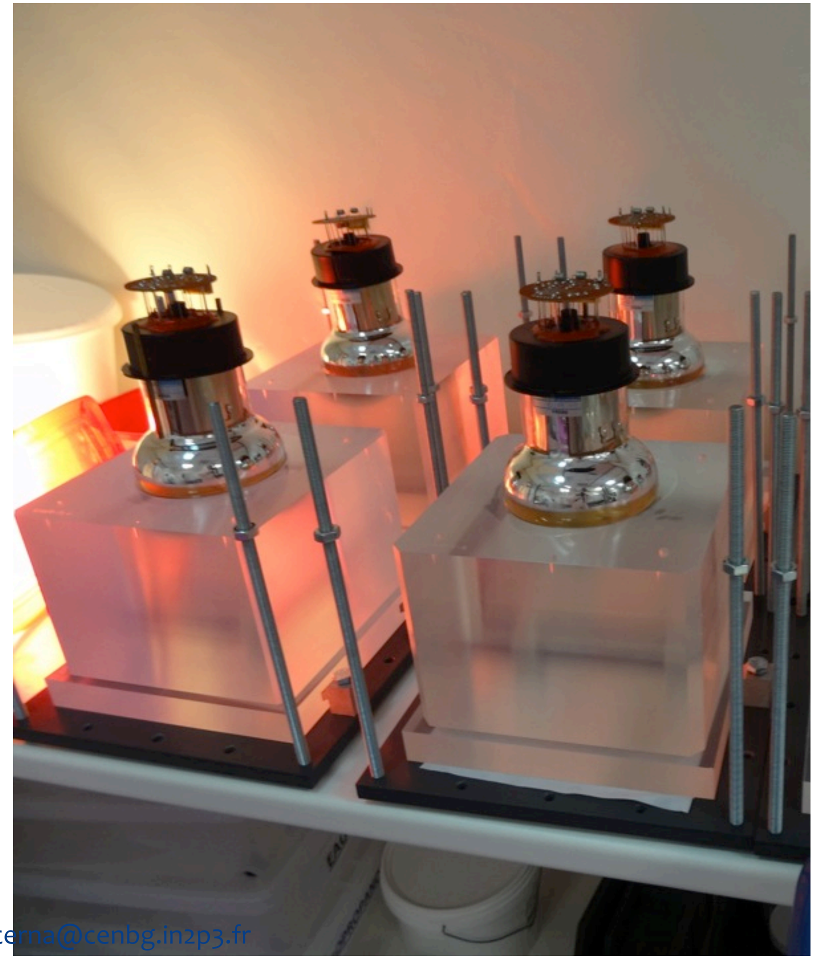
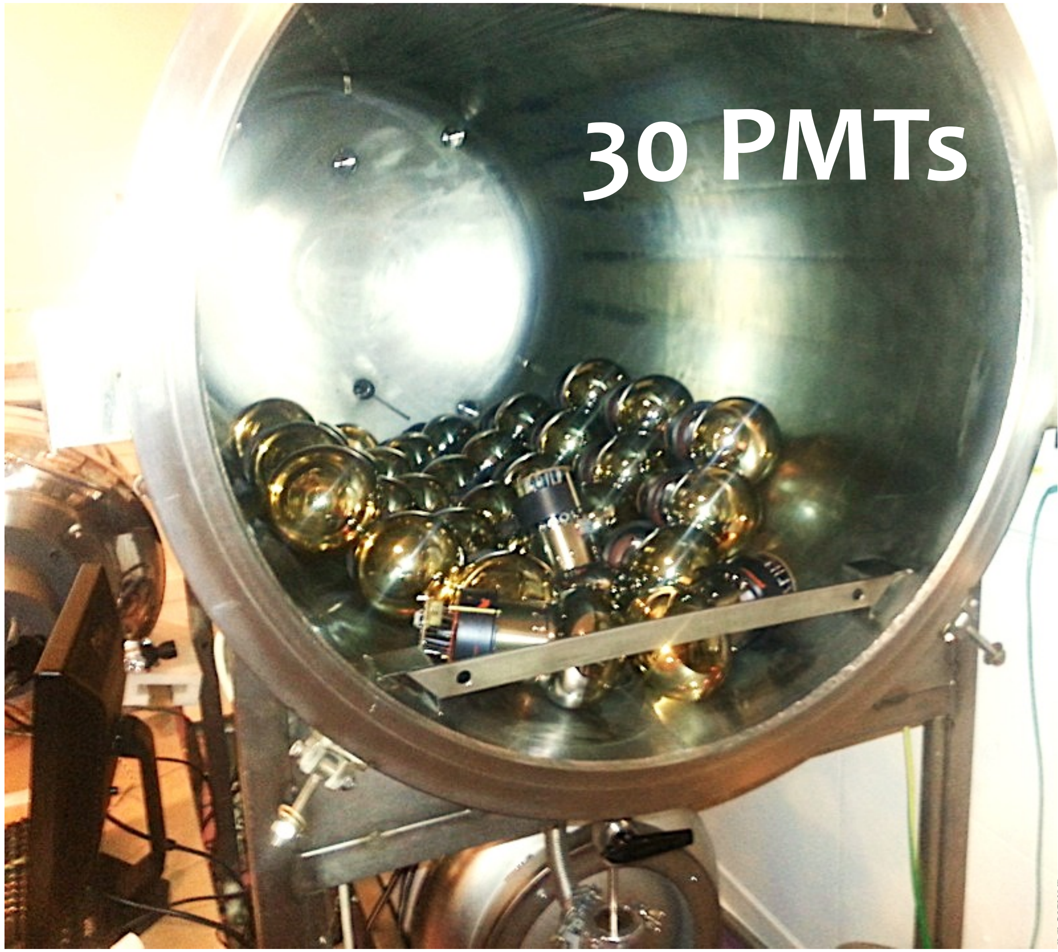
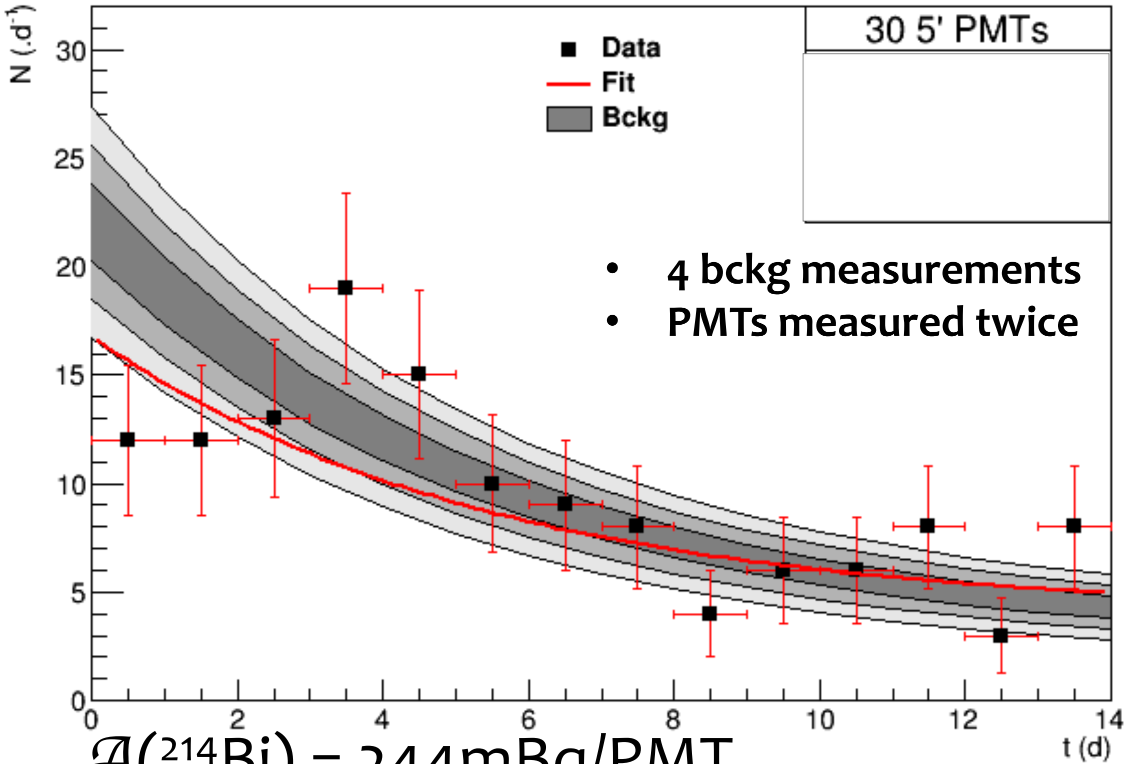




cerna@cenbg.in2p3.fr

Study of 5'' PMT R6594



- 4 bckg measurements
- PMTs measured twice

$\mathcal{A}(^{214}\mathrm{Bi}) = 244$mBq/PMT

But we found only **$\mathcal{A}(^{222}\mathrm{Rn}) < 120\mu$Bq/PMT (95% C.L.)**

$\mathcal{E}(^{222}\mathrm{Rn}) < 22\ \mu$Bq/d/PMT (95% C.L.)

→ **PMTs are emanating much less than we thought !**

→ Consequences on Rn tightness strategy in SuperNEMO

Need to complete this study with other PMT glass

Aluminized Mylar

Aluminized mylar study

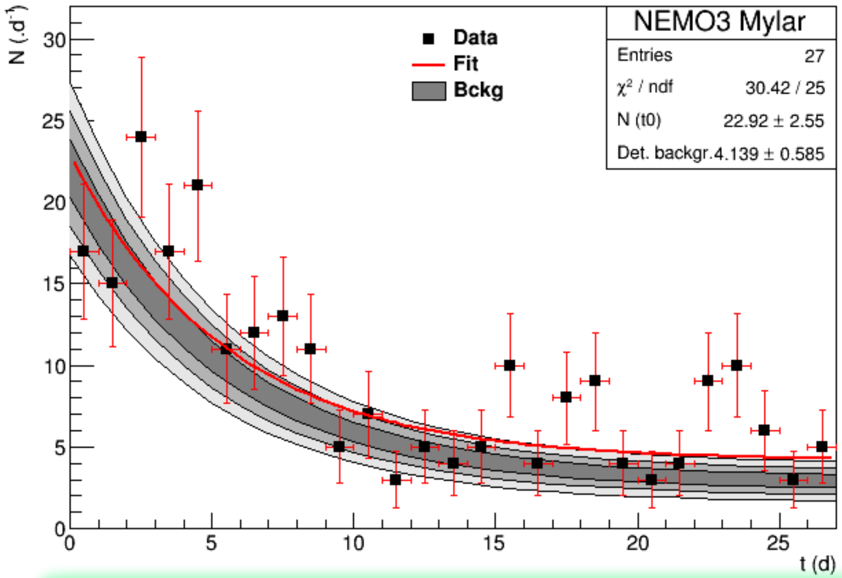
	mBq / kg	214Bi	208Tl
One side aluminized	**NEMO 3 batch**	2.6 ± 1.3	0.5 ± 0.2
6µm mylar	**New batch**	55 ± 3	1.7 ± 0.7

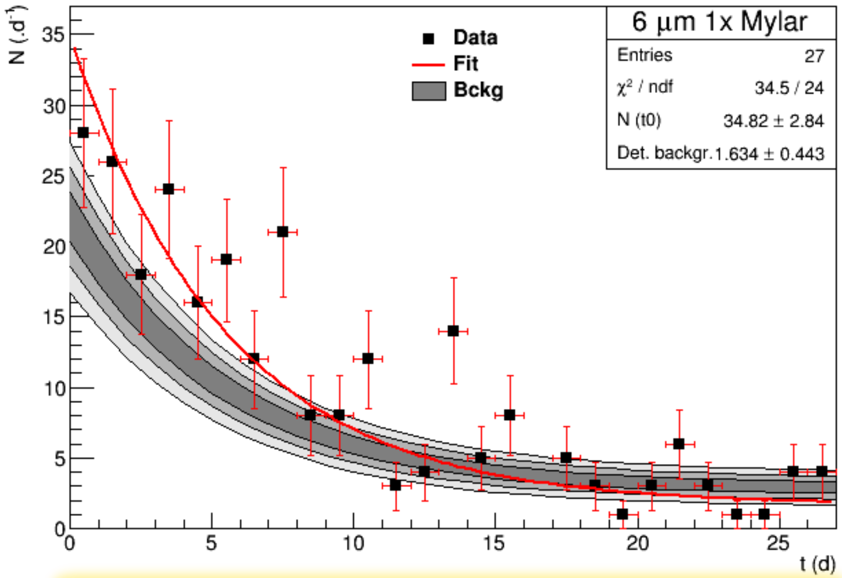
SuperNEMO Phase 1 Calorimeter we use **6kg of mylar**

→ Totaly acceptable from gamma bckg point of view for SuperNEMO (3-5% of internal bckg)

6kg mylar ≈ 700 m² that can emanate from both surfaces

Aluminized mylar study





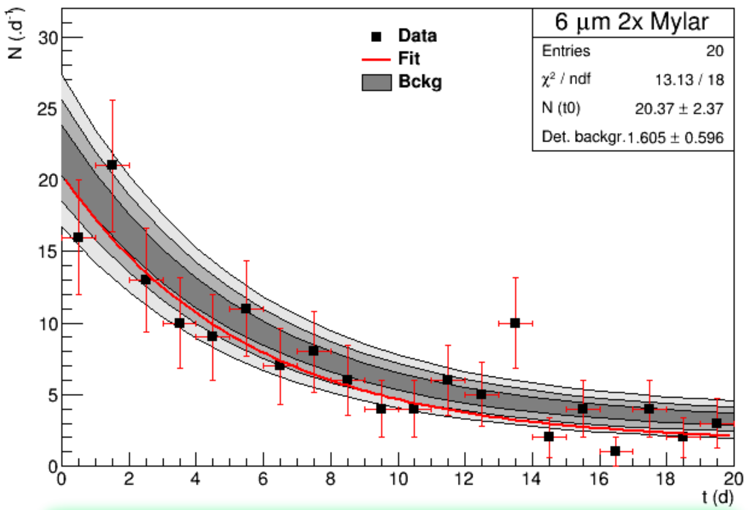
→ 36 m² of mylar "**NEMO3 batch**"
→ No excess
$\mathcal{A}$(^{222}Rn) < 119 μBq/m²
$\mathcal{E}$(^{222}Rn) < 22 μBq/m²/d

→ 42 m² of mylar "**new batch**"
→ 13 cpd excess
$\mathcal{A}$(^{222}Rn) = 280 ± 80 μBq/m²
$\mathcal{E}$(^{222}Rn) = 50 ± 14 μBq/m²/d

The two batchs comes from the same provider, same process, same machinery
We tested another roll of single side aluminized mylar (12μm thickness) from the same provider : same conclusion

Aluminized mylar study

		^{214}Bi mBq/kg	^{208}Tl mBq/kg	$\mathcal{E}$(^{222}Rn) µBq/m²/d	$\mathcal{A}$ (^{222}Rn) µBq/m²
1 side aluminized 6µm mylar	NEMO 3	2.6 ± 1.3	0.5 ± 0.2	<22	<119
	New 1 side	55 ± 3	1.7 ± 0.7	50 ± 14	280 ± 80
2 sides aluminized 6µm mylar	New 2 sides	62 ± 6	<1.6	<24	<130



→ 42 m² of mylar **2 sides**

→ No excess !!!

$\mathcal{A}$(^{222}Rn) < 130 µBq/m²

$\mathcal{E}$(^{222}Rn) < 24 µBq/m²/d

Why so?

Aluminized mylar study

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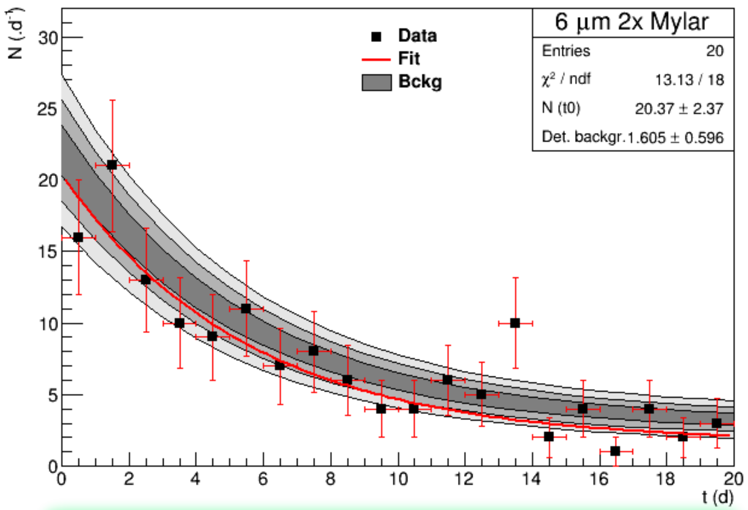

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Why so?

- Several authors* estimate the diffusion length of ^{222}Rn through mylar to about 100-1000µm >> 6µm mylar thickness
- $\mathcal{A}$(^{214}Bi) = 55 mBq/kg ➔ $\mathcal{A}$ (^{222}Rn) 460µBq/m²
  If 100% of the Rn emanate
- Only about half of that is observed
- And while twice aluminized, none of that is seen

→ The 400Å Al coating stop the Rn

→ One should take advantage of that

* J.Bigu, E.D. Hallman & L.Kendrick / Elliot lake laboratory / 1991
F. Mamedov, P.Cermak, K. Smolek & I.Stekl / CTU Prague / 2011

Summary

- SuperNEMO Phase 1 in construction. Installation started.
- Requirements in terms of ^{222}**Rn** very strong : 0.15 mBq/m^3 into the tracker and around the ββ sources

→ Need for a dedicated material qualification setup able to measure:
  - large number of pieces
  - Large material surfaces

- Dedicated studies have been conducted
  - PMT emanation
    →glass almost not emanate
  - Aluminized mylar
    →whatever is in emanate
    →Al coating blocks the Rn

- A lot of critical material of construction have been measured