Development of anti-Radon strategies in SuperNEMO

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On behalf of the SuperNEMO Collaboration

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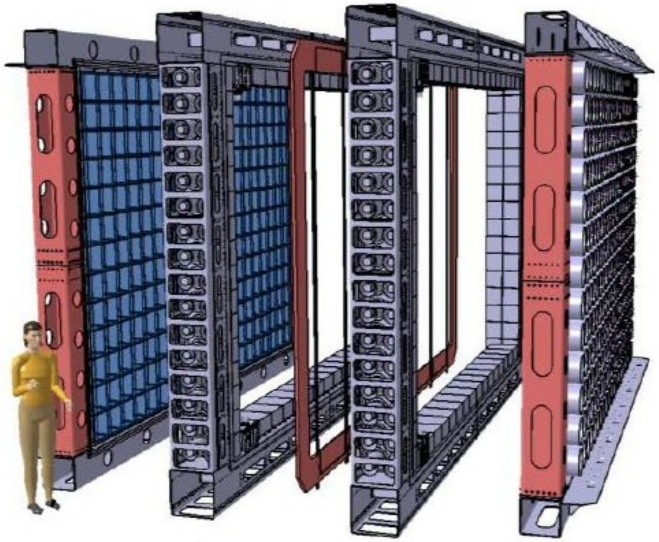


GDR NEUTRINO

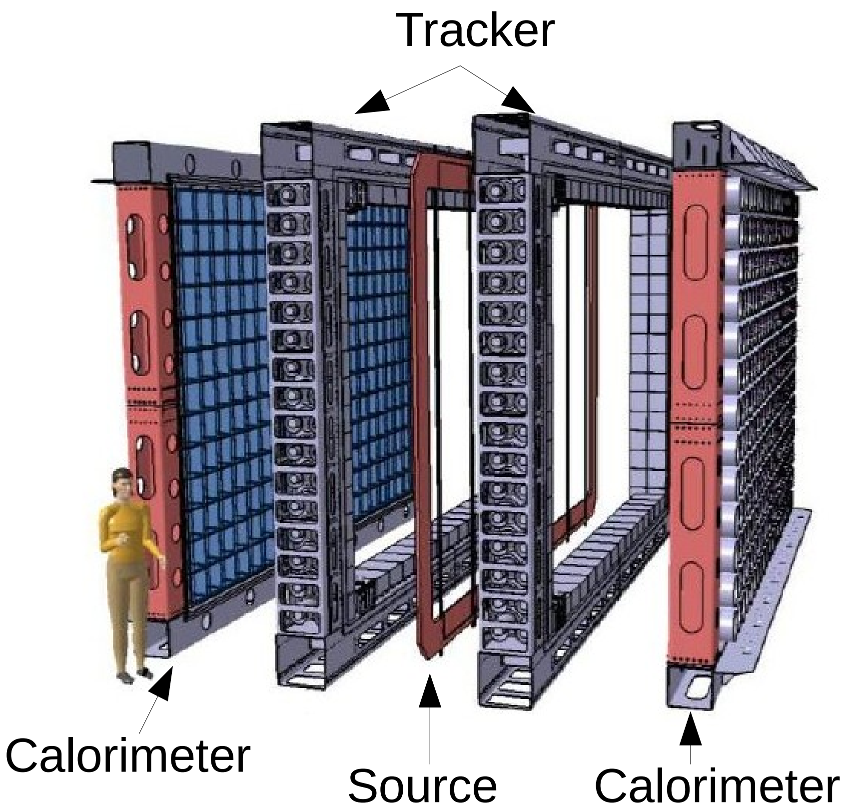
June 17th, 2014

Outline

- The SuperNEMO experiment, its specifications
- Radon issues in NEMO experiments
- Anti-Radon strategies in SuperNEMO
- Low background techniques developed for SuperNEMO
  - Radon trapping
  - Diffusion measurements
  - Emanation measurements
- Overall gas contamination

From NEMO-3 to SuperNEMO

- SuperNEMO : next generation of 0ν2β decay experiment



- **Source foils**
  7 kg of ^{82}Se
- **Tracker**
  2032 Geiger cells
- **Calorimeter**
  712 PMT + Scintillators
- **Shielding**
  Against γ and neutrons
- **Magnetic Field**
  For charged particles topology
- **Anti-Radon strategies**
  Tent, has purification

- Phase 1 : Demonstrator module (7 kg of ^{82}Se)
  → Start of data taking **mid-2015** in **LSM**

- Phase 2 : 20 identical modules (100 kg of sources)

From NEMO-3 to SuperNEMO

	NEMO-3	SuperNEMO *20 modules*	SuperNEMO *Demonstrator*
Mass	6.9 kg x 5 y	100 kg x 5 y	7 kg x 2 y
Isotopes	^{100}Mo (7 isotopes)	^{82}Se (^{150}Nd, ^{48}Ca)	^{82}Se
Energy resolution FWHM @ 3 MeV	8 %	4 %	-
Radon activity inside tracker	5.0 $mBq.m^{-3}$	0.15 $mBq.m^{-3}$	-
Sources contamination			
^{208}Tl	~ 100 $\mu Bq.kg^{-1}$	< 2 $\mu Bq.kg^{-1}$	-
^{214}Bi	60 - 300 $\mu Bq.kg^{-1}$	< 10 $\mu Bq.kg^{-1}$	-
Total Background ($cts.keV^{-1}.kg^{-1}.y^{-1}$)	1.3×10^{-3}	5×10^{-5}	-
Sensitivity (90 % CL)			
$T_{1/2}(0\upsilon)$	$> 1.1 \times 10^{24}$	$> 1 \times 10^{26}$	$> 6.6 \times 10^{24}$
$<m_{\upsilon}>$	< 0.33 – 0.87 eV	< 0.04 – 0.10 eV	< 0.15 – 0.40 eV

From NEMO-3 to SuperNEMO

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		20 modules	***Demonstrator***
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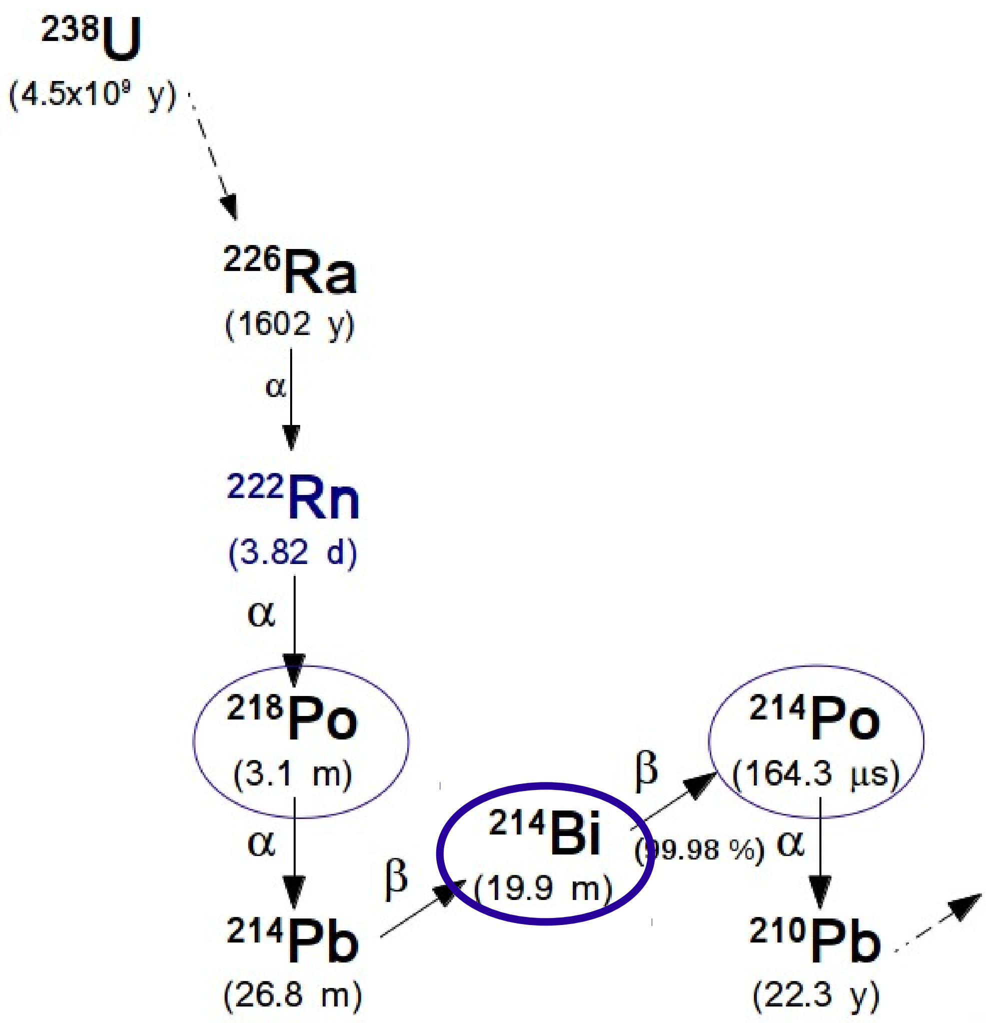
Radon



- **Radioactive gas (noble)**
  Few tens of Bq/m^3 in air

  Main isotope is ^{222}Rn

- **Part of ^{238}U decay chain**
  Produced from the decay of ^{226}Ra
  → $T_{1/2}(^{226}Ra)$ ~ 1600 y

  Half-life long enough for diffusion
  → $T_{1/2}(^{222}Rn)$ ~ 3.82 days

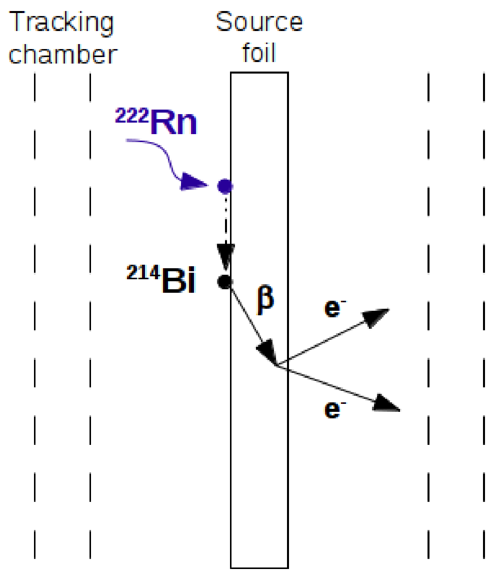
- **Many radioactive daughters**
  α and β decays
  → Issue for many low background physics experiments

^{214}Bi Q_β = 3.27 MeV → **Around $Q_{\beta\beta}$**

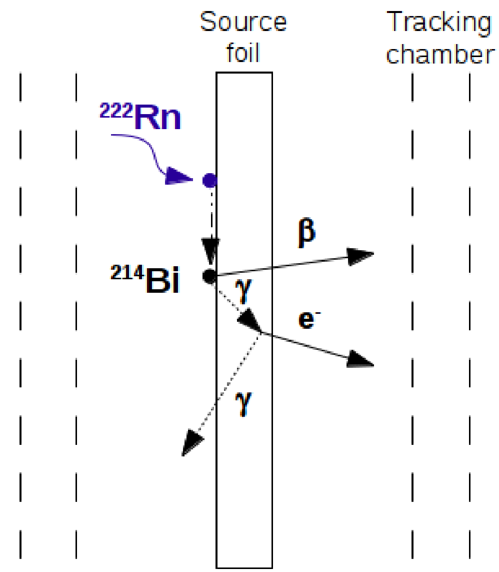
α emitters Q_α ~ [5 ; 9] MeV

Radon in NEMO experiments

- Radon deposition on source foils or tracking wires



Beta decay + Möller



Beta decay + Compton

Radon

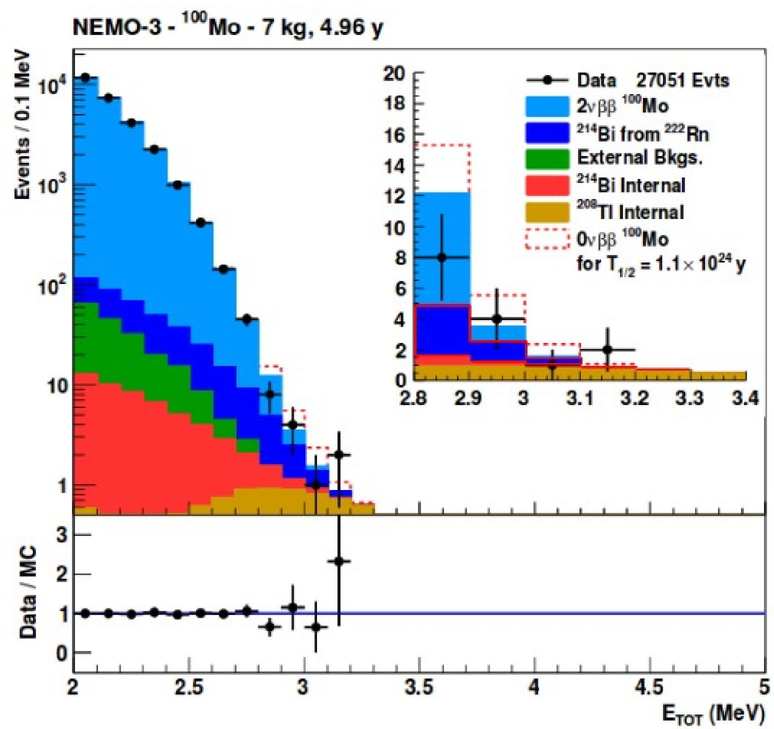
$Q_\beta(^{214}Bi)$ = 3.27 MeV

0νββ

$E_{e1} + E_{e2}$ ~ **[2.8 ; 3.2] MeV**

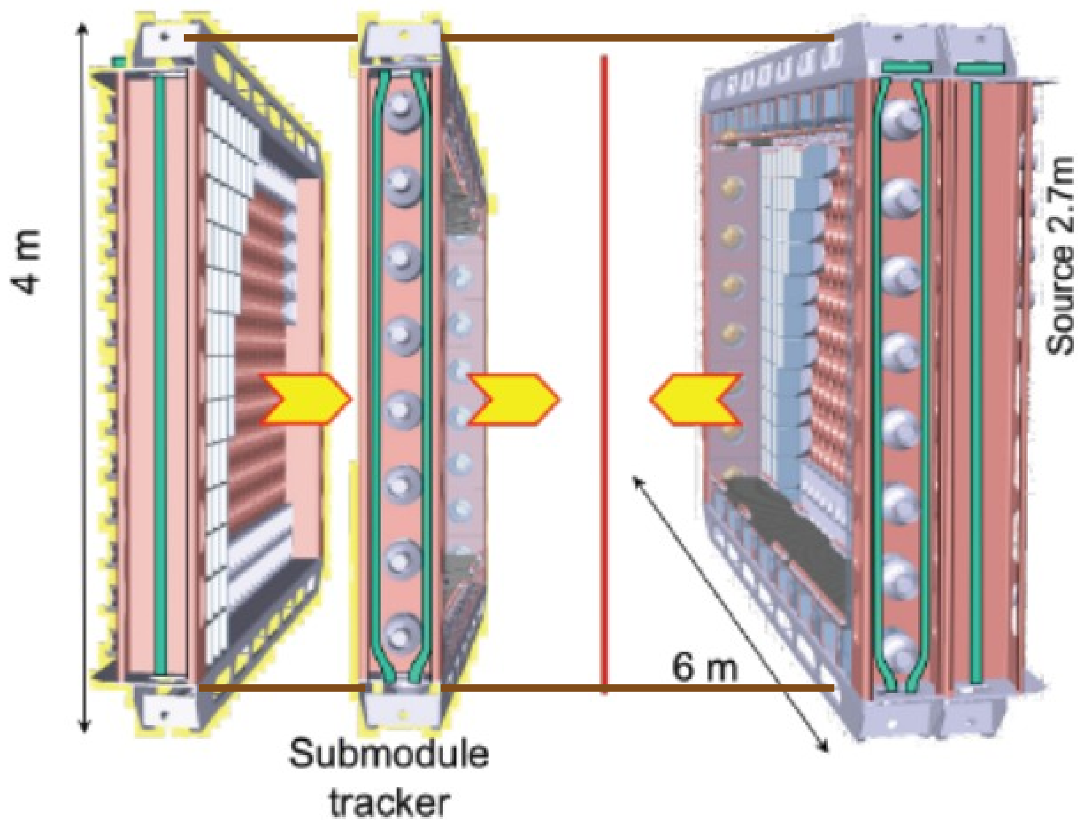
$Q_{\beta\beta}(^{82}Se)$ = 2.995 MeV

- 2β energy measurement over **5 years** (NEMO-3 results)



- **5.2 ± 0.5 events** attributed to Radon in [2.8 ; 3.2] Mev region

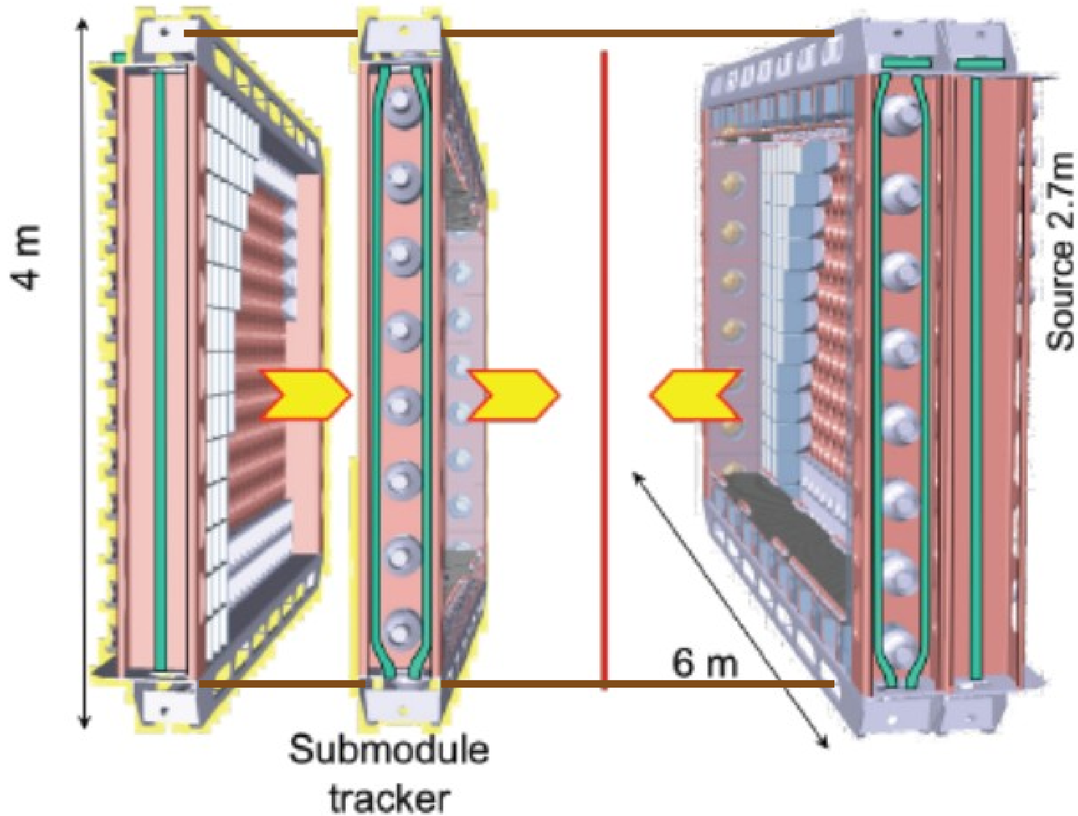
Radon issues in SuperNEMO



Radon concentration in LSM air → **~ 15 000 mBq/m³**

Objective in Tracker gas → **0.15 mBq/m³**

Radon issues in SuperNEMO



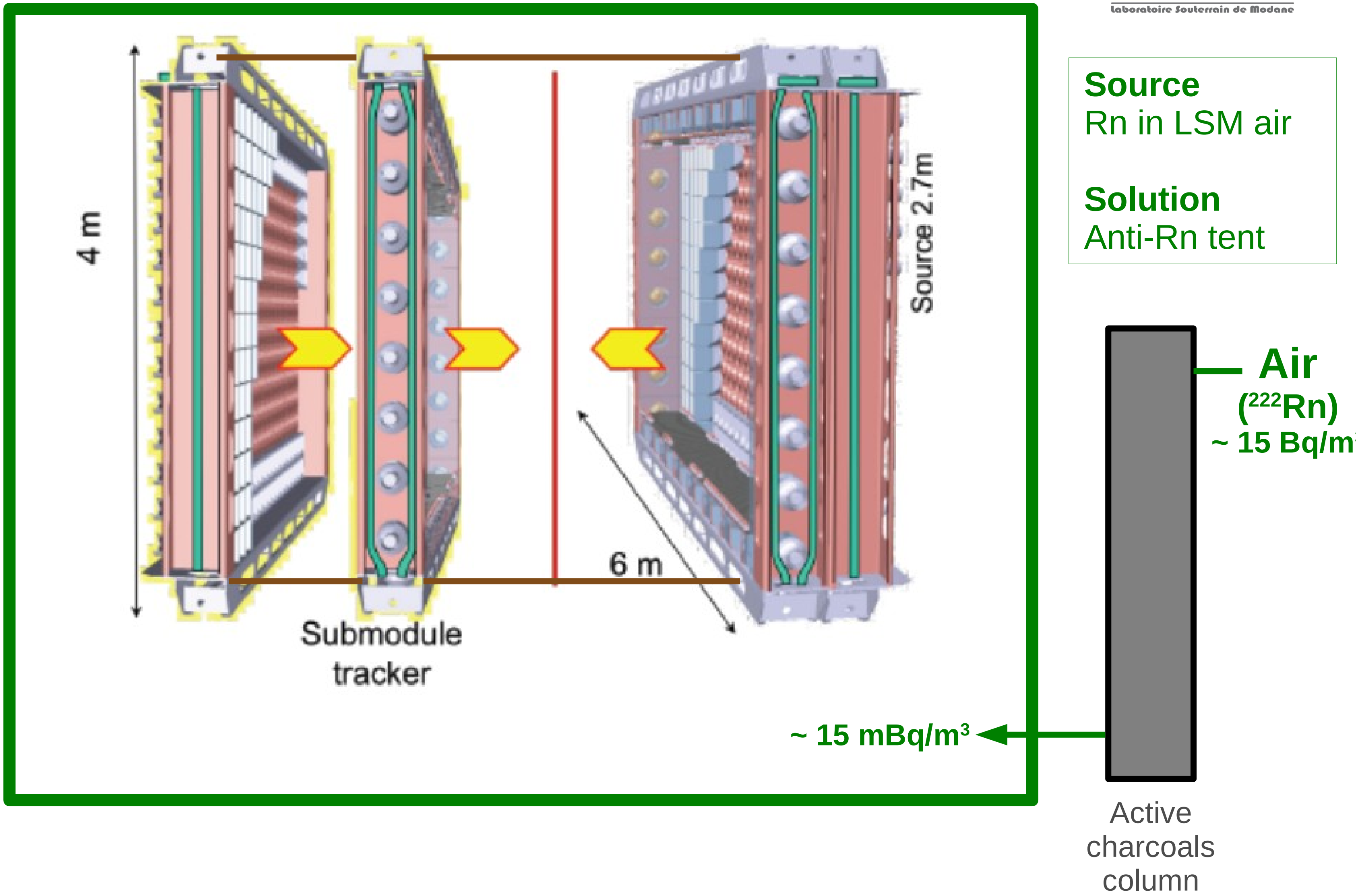
Source
Rn in LSM air

Air
(^{222}Rn)
~ 15 Bq/m^3

Radon issues in SuperNEMO

Source
Rn in LSM air

Solution
Anti-Rn tent



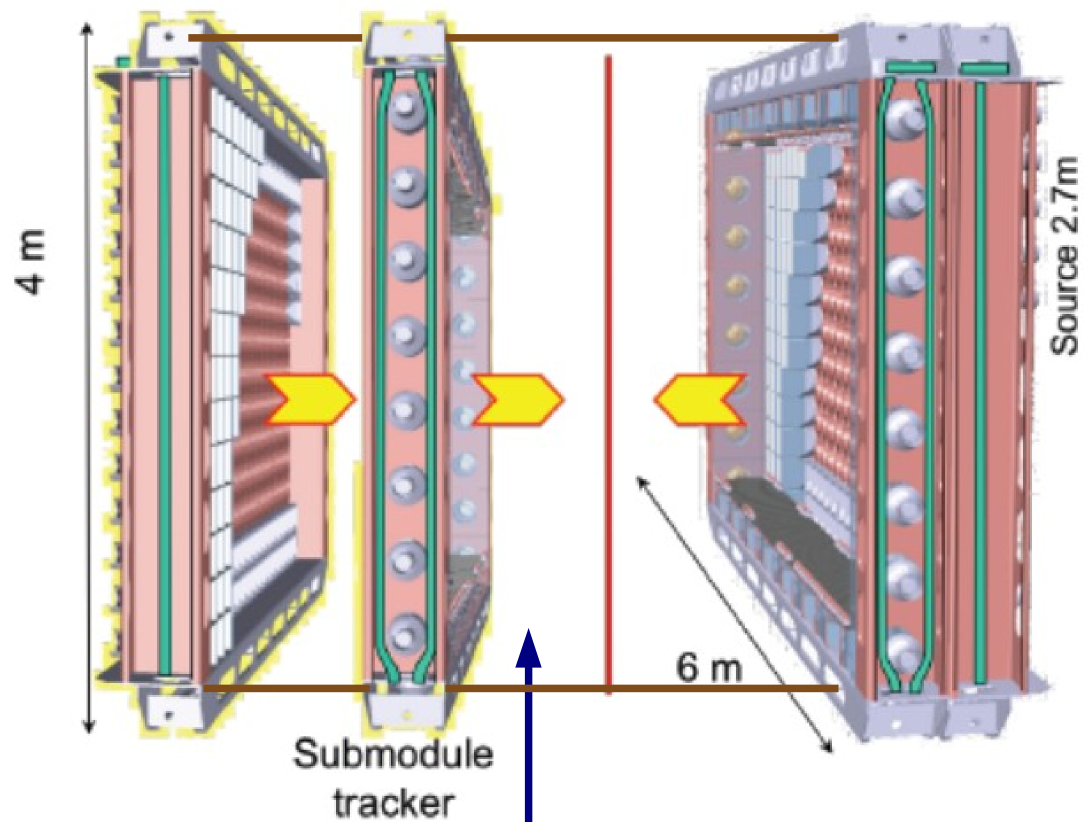
Radon issues in SuperNEMO

Source
Input gas contamination

~ 100 µBq/m^3

He bottle

Tracker input gas



~ 15 mBq/m^3

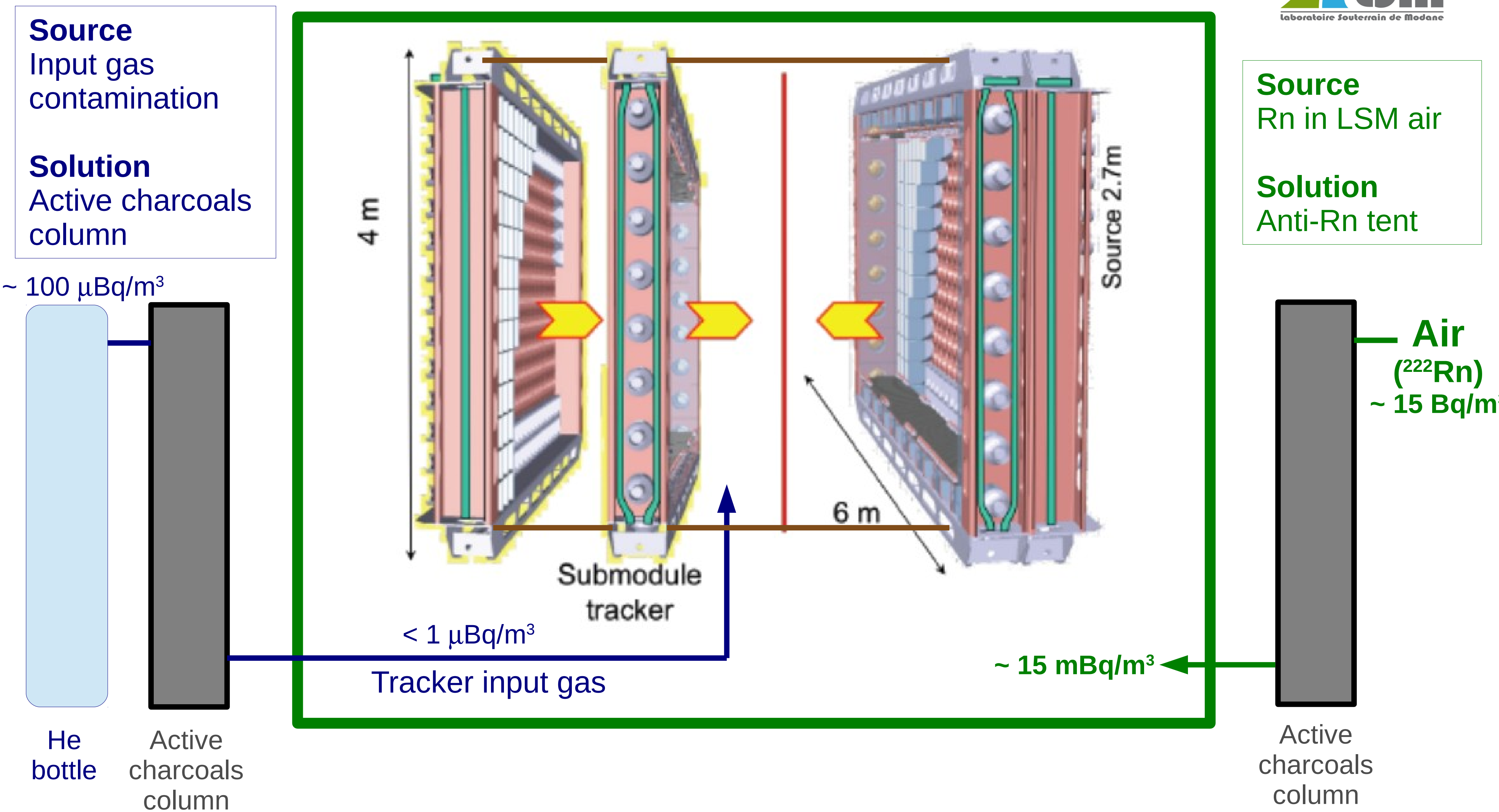
Source
Rn in LSM air

Solution
Anti-Rn tent

Air
(^{222}Rn)
~ 15 Bq/m^3

Active charcoals column

Radon issues in SuperNEMO



Radon issues in SuperNEMO

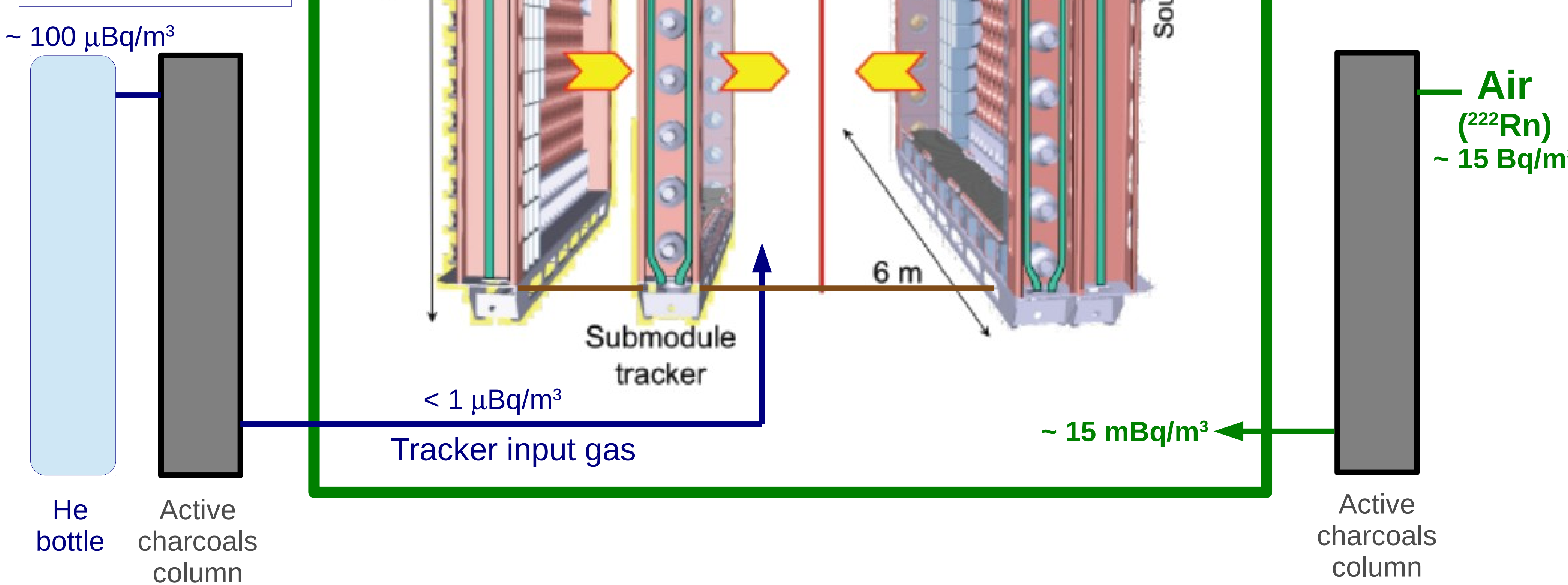
Source
Diffusion through materials

Source
Input gas contamination

Solution
Active charcoals column

Source
Rn in LSM air

Solution
Anti-Rn tent



Radon issues in SuperNEMO

Source
Diffusion through materials

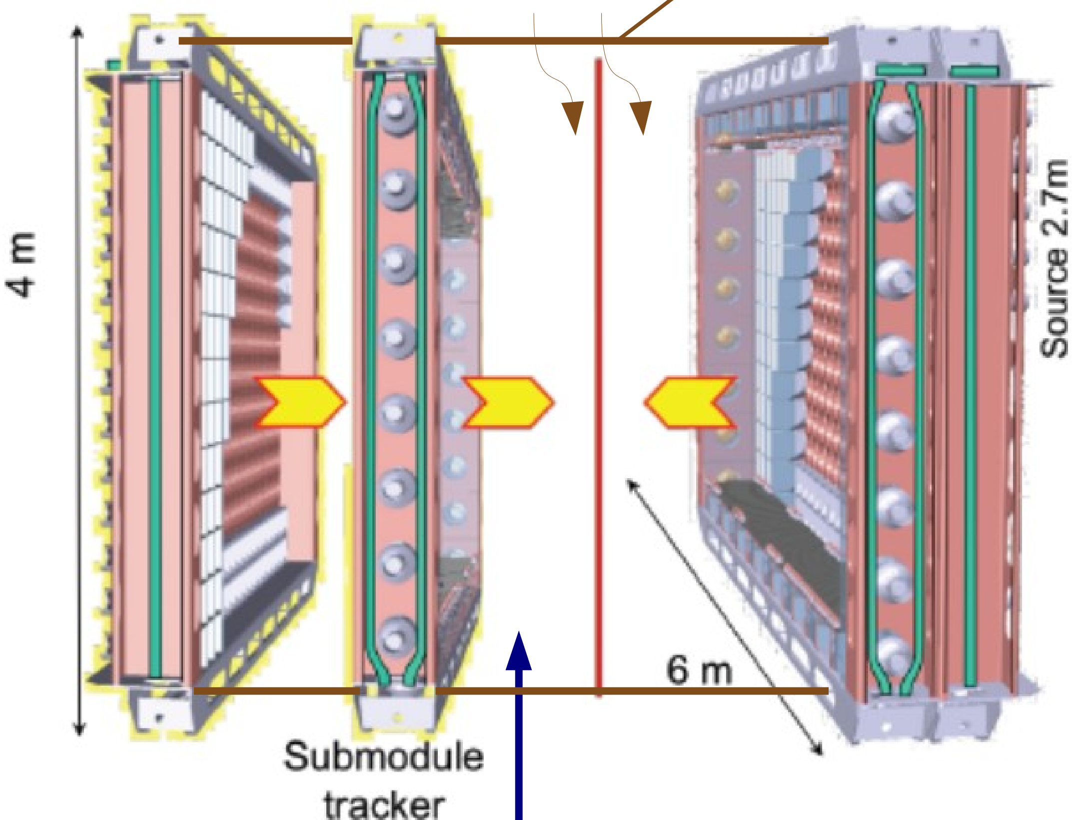
Solution
Material screening (diffusion)

Source
Input gas contamination

Solution
Active charcoals column

Source
Rn in LSM air

Solution
Anti-Rn tent



~ 100 μBq/m³

He bottle

Active charcoals column

< 1 μBq/m³

Tracker input gas

~ 15 mBq/m³

Air (^{222}Rn) ~ 15 Bq/m³

Active charcoals column

Radon issues in SuperNEMO

Source
Diffusion through materials

Solution
Material screening (diffusion)

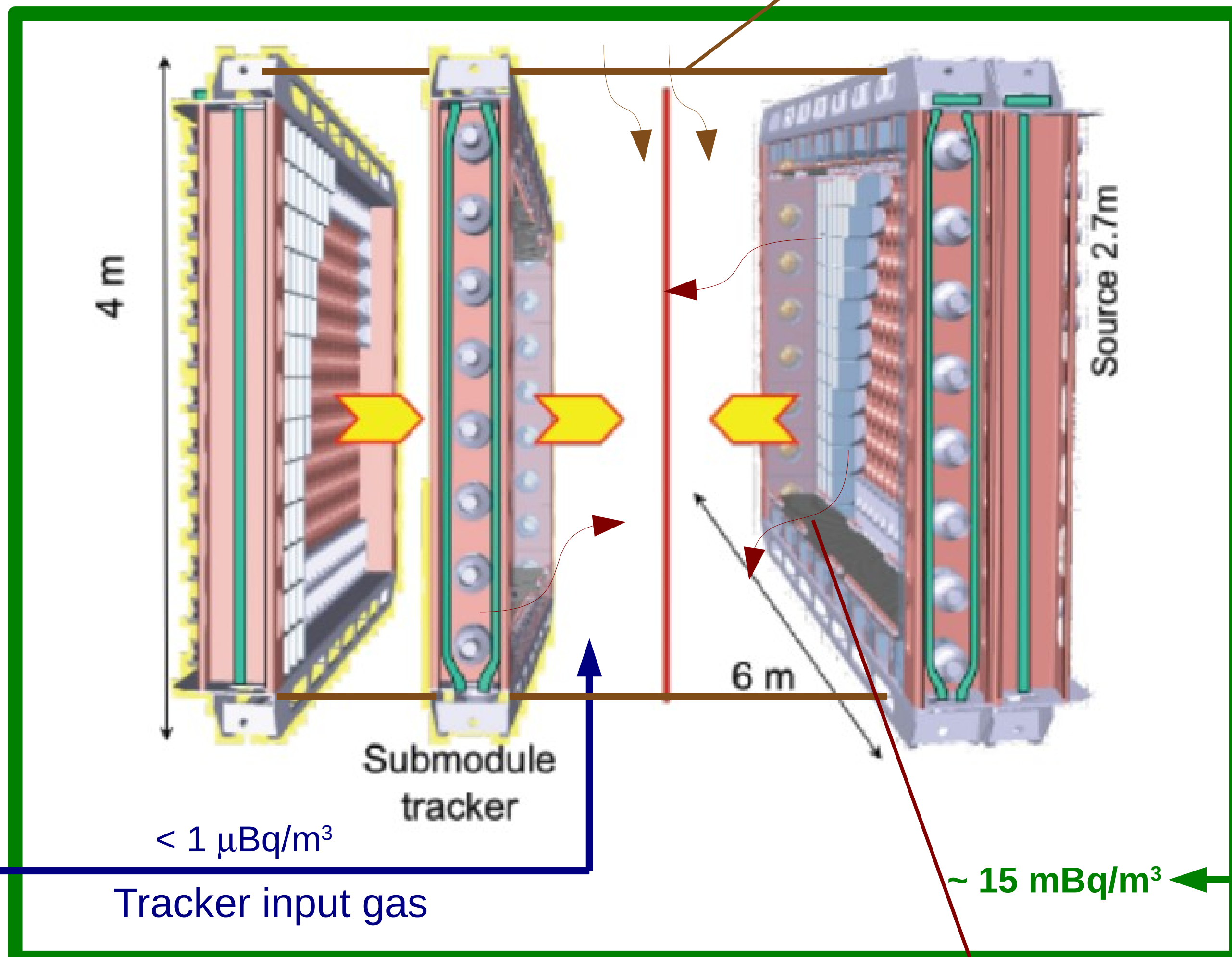
Source
Input gas contamination

Solution
Active charcoals column

Source
Rn in LSM air

Solution
Anti-Rn tent

~ 100 µBq/m³



Air (^{222}Rn)
~ 15 Bq/m³

He bottle

Active charcoals column

Active charcoals column

Source
Emanation from materials

Solution
Material screening (emanation)

Radon issues in SuperNEMO

Source
Diffusion through materials

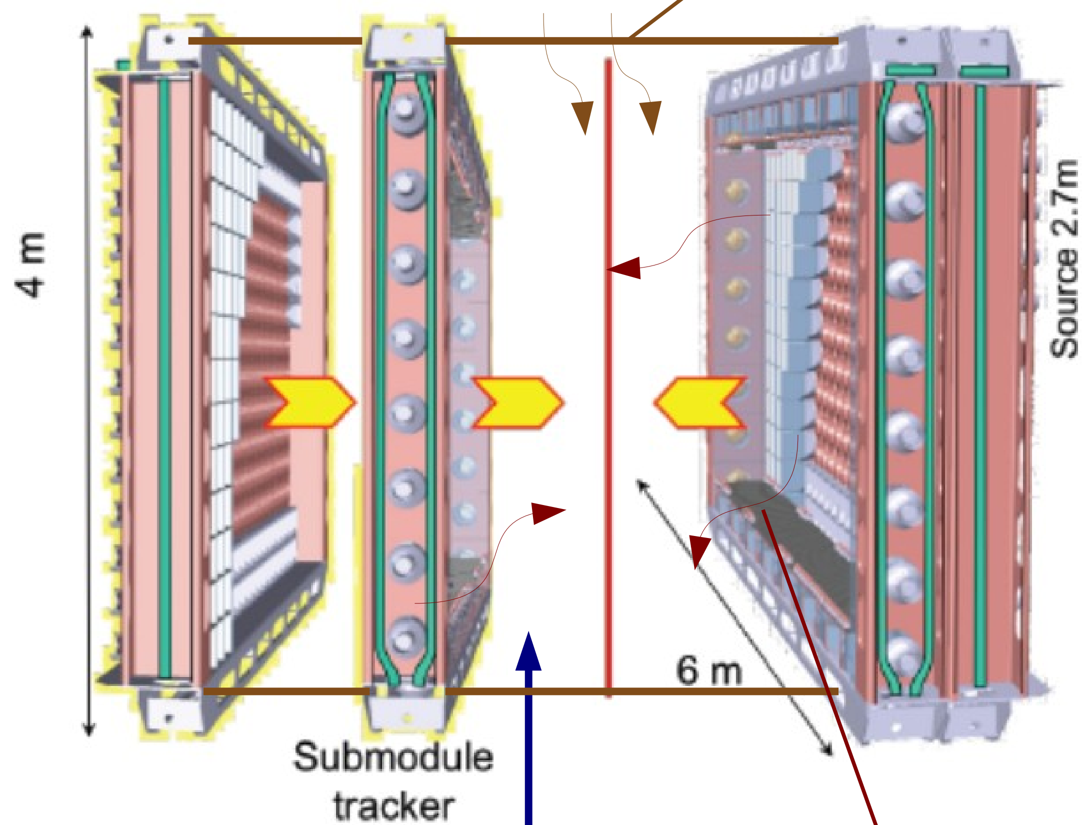
Solution
Material screening (diffusion)

Source
Input gas contamination

Solution
Active charcoals column

Source
Rn in LSM air

Solution
Anti-Rn tent



~ 100 µBq/m³

He bottle

Active charcoals column

< 1 µBq/m³

Tracker input gas

~ 15 mBq/m³

Air (^{222}Rn) ~ 15 Bq/m³

Active charcoals column

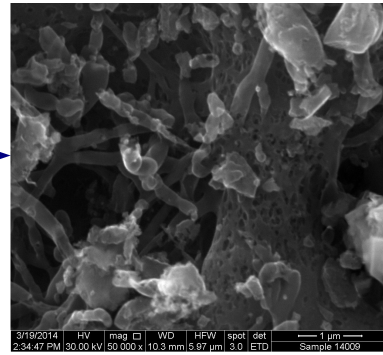
Source
Emanation from materials

Solution
Material screening (emanation)

Radon trapping

Gas + **Rn**

Active charcoals



5 µm

Gas + Rn

Definition of a
K factor (m^3/kg)

NEMO-3 Radon Trapping Facility

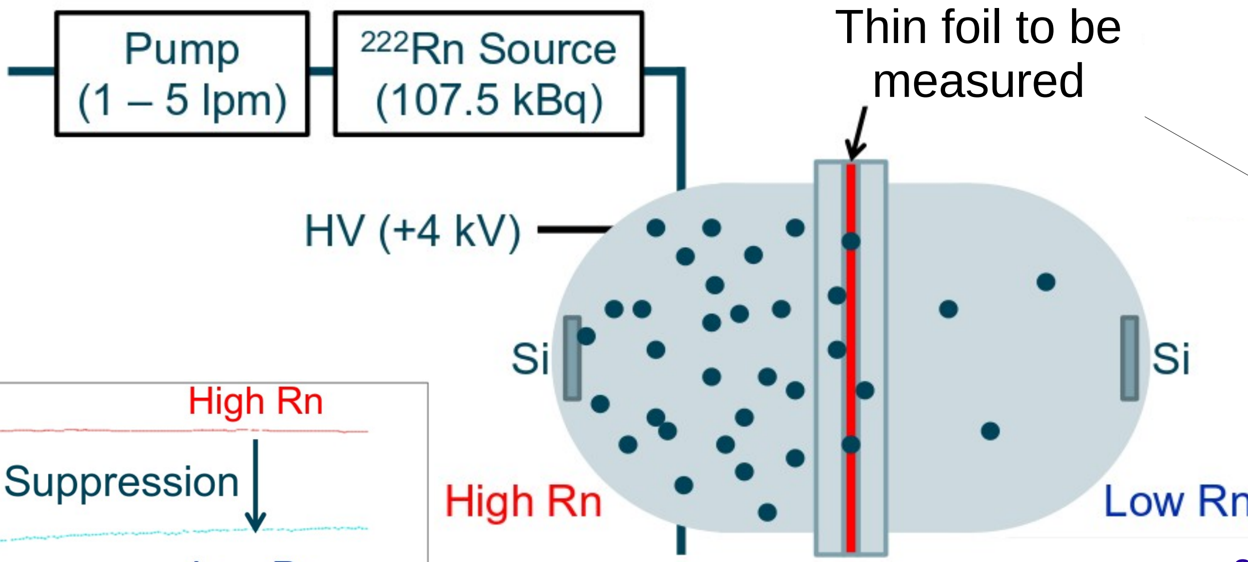
- Ongoing study of Rn behavior in the active charcoals column (2.5 m)
- Rn “adsorption length” (for **K48**) **~ 20 cm**

Study of best adsorbing materials in CPPM

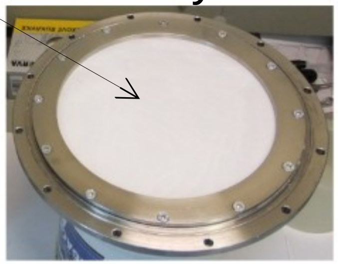
- **K factor measurements**
  ~ 700 – 1000 at -30 °C
- **Effect of temperature**
  factor 100 – 1000 from 20 to -50 °C
- **Engineering of new nanoporous materials**

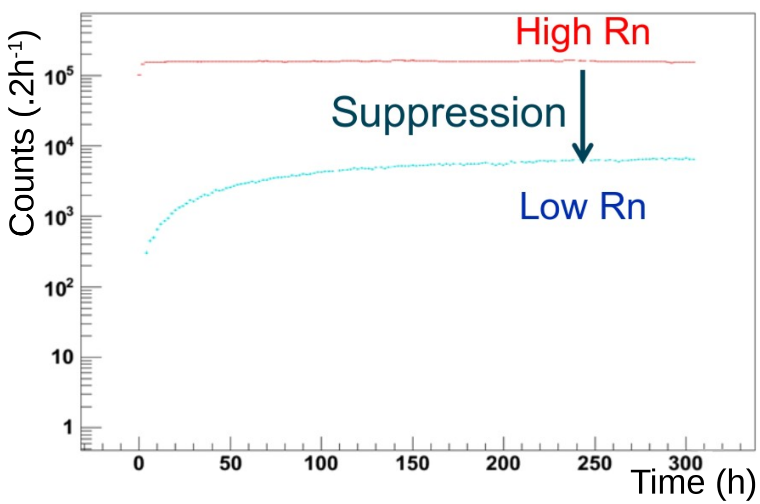
Radon diffusion measurements

- Materials screening with diffusion measurements in CTU (Prague)



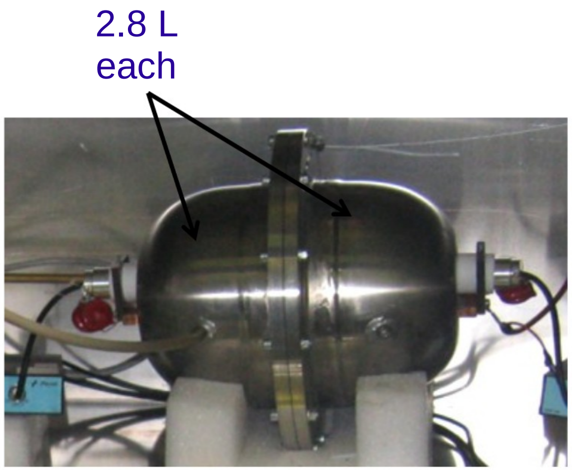
RTV 615 with 60% Stycast





- **Suppression factor**
  High Rn / Low Rn

- **Diffusion length**
  Sensitivity ~ 20 µm

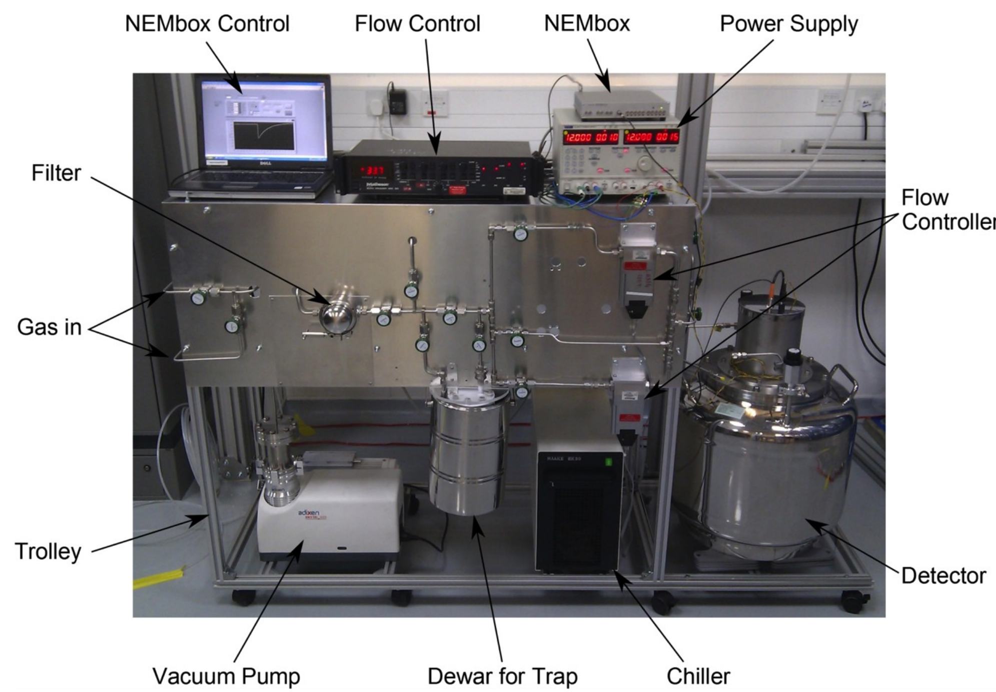


Radon emanation Measurements

- If contaminated with ^{226}Ra (HPGe measurements), materials may emanate Radon →critical for components in contact with the tracker

- Several setups developed in the NEMO collaboration

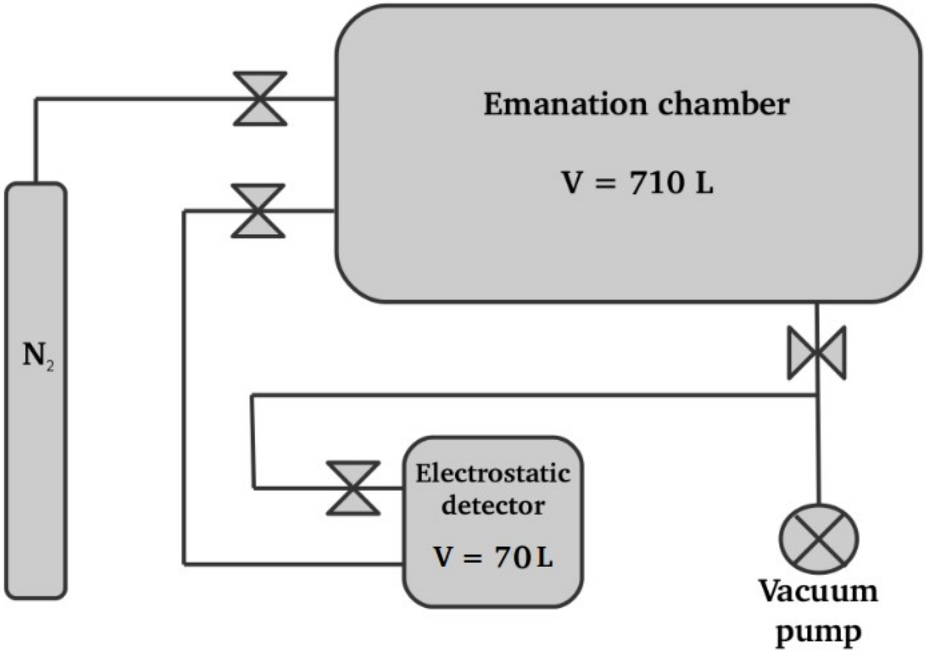
Large emanation tank
– 0.13 mBq/m^2
(for 30 m^2 sample)



Rn Concentration line
– 10 µBq/m^3
(for overall contamination)

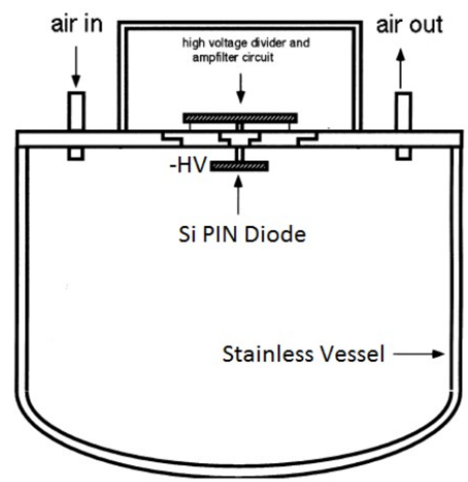
Radon emanation setup - CENBG

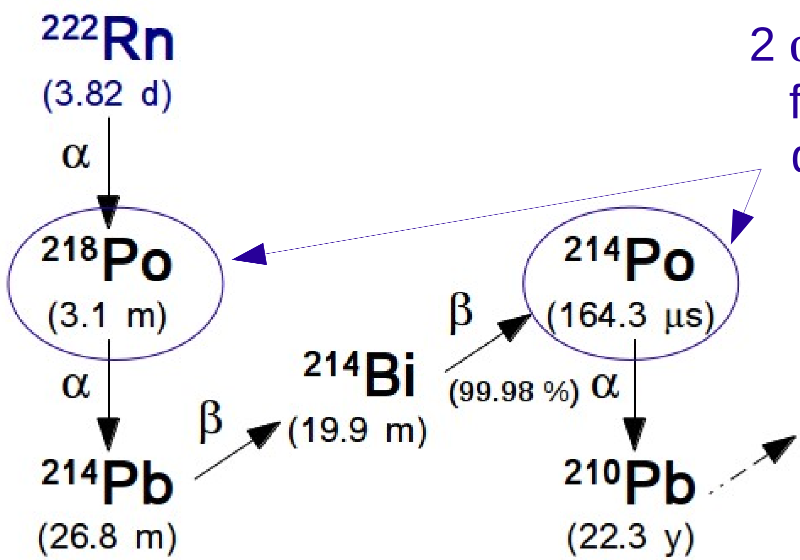
- **Emanation tank** (V = 710 L)
- **Electrostatic detector** (V = 70 L)
- Carrying gas : N_2



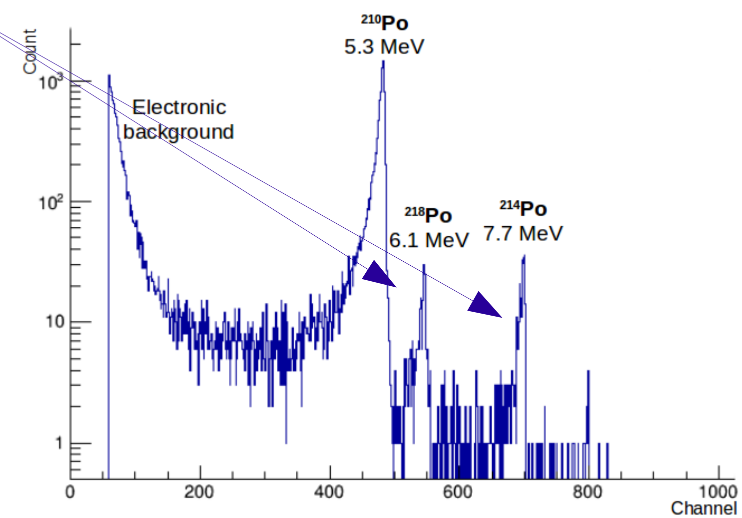
Radon emanation setup - CENBG

- Emanation tank connected to an electrostatic detector (KAMIOKANDE)
- Alpha spectroscopy [5 ; 9] MeV





2 α emissions from ^{222}Rn daughters



Radon emanation measurements

- Detector sensitive to ~ 3.8 mBq inside the emanation tank
- Setup suited for large samples

Aluminized Mylar (36 m^2)
$A_{em}(^{222}Rn) < 97\ \mu Bq/m^2$

5” PMT from NEMO-3 (N = 30)
$A_{em}(^{222}Rn) < 119\ \mu Bq/PMT$

Radon emanation measurements

- Detector sensitive to ~ 3.8 mBq inside the emanation tank
- Setup suited for large samples

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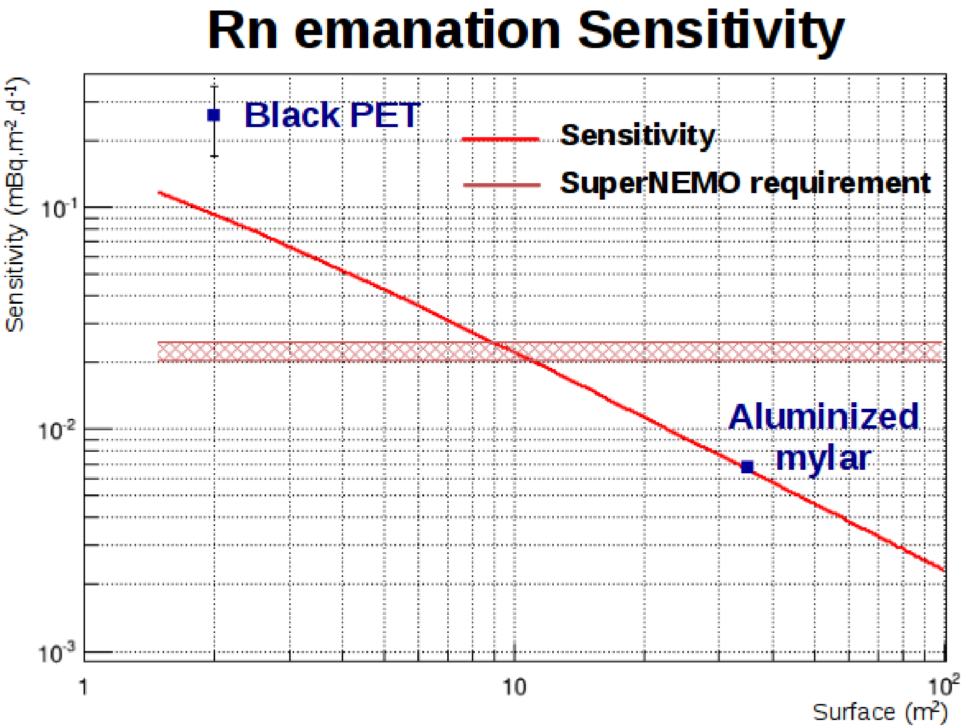


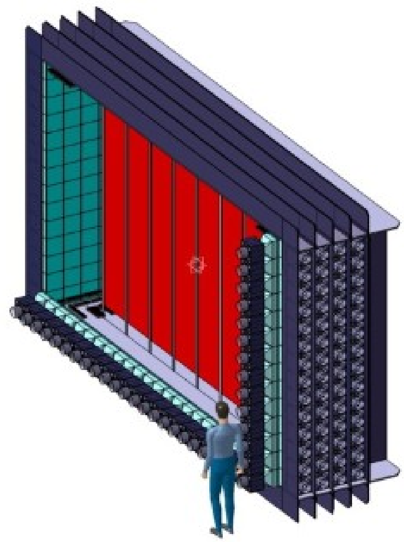
Radon concentration Line

- Monitor Rn concentration during construction :
  SuperNEMO specification : **A < 0.15 mBq.m^{-3}**

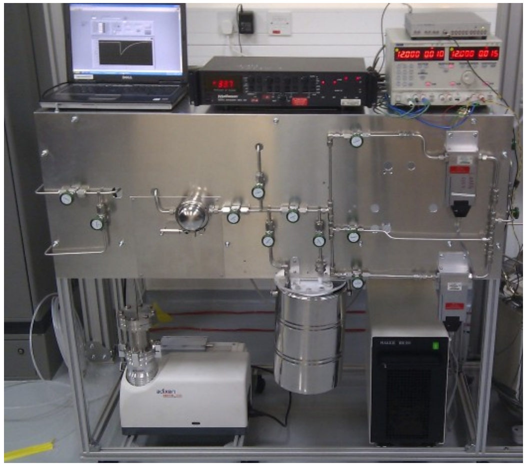
Flush

(12 – 24 L/min)

He bottle
(~ 0.1 mBq/m^3)



SuperNEMO tracker
(~ 16 m^3)
- Diffusion
- Contamination
-Emanation



Radon concentration line

Tracker gas flushed into a carbon trap (-30°C)

Trap is heated

Radon transfered

Electrostatic detector

Radon measurement

Overall sensitivity
~ 0.01 mBq/m^3

Summary

- **SuperNEMO** represents the **next generation** of 2β0υ decay experiment. One of its biggest challenge will be to reach a **“0” background level**.

- From the different **background source, Radon** was the most important in NEMO-3 (ignoring 2β2υ)

- Objective for SuperNEMO : reaching a tracker gas contamination **< 0.15 mBq.m^{-3}**

- Different **strategies** are established to **prevent Radon contamination** (purification of input gas, diffusion measurements...)

- **Emanation measurements** were **developed for SuperNEMO** and represent today an additional tool in the materials screening process.

Extra slides

Radon inside the tracking chamber

$$\frac{dA}{dt} = -\frac{\phi A}{V} - \frac{A}{\tau} + \frac{\omega S}{V} + \frac{DA_{out}}{V} \cdot \varepsilon + \frac{\phi A_{in}}{V}$$

- From the input gas contamination
  - He bottles → ~ 100 μBq.m^{-3}
  - active charcoals to "filter" the input gas

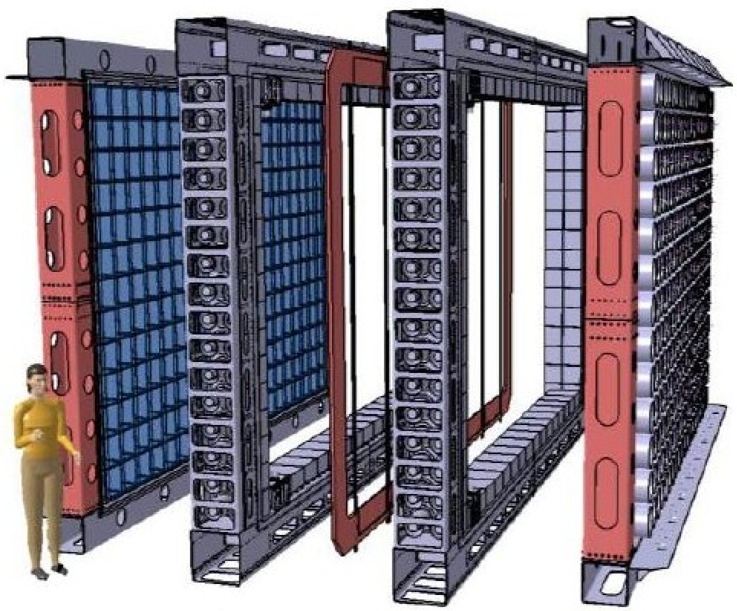
- From Diffusion inside the tracker (& potential leaks)
  - tracker impermeability tests
  - materials diffusion coefficients measurements

- From ^{222}Rn emanation from the materials
  - HPGe measurements to ensure a low ^{226}Ra contamination
  - emanation measurements for critical materials

Radon inside the tracking chamber

$$\frac{dA}{dt} = -\frac{\phi A}{V} - \frac{A}{\tau} + \frac{\omega S}{V} + \frac{D A_{out}}{V} \cdot \varepsilon + \frac{\phi A_{in}}{V}$$

- A activity inside the tracker
- A_{out} activity inside the radon free tent
- A_{in} activity of the input gas
- ω emanation rate (Bq/surface/time)
- ϕ gaz flux
- V tracker volume
- S emanating surfaces in the tracker
- D radon diffusion coefficient
- ε thickness
- τ radon mean lifetime



Background in NEMO-3 ([2.8 ; 3.2] MeV)

Expected background in [2.8 – 3.2] MeV	
$2\nu2\beta$	8.45 ± 0.05
^{214}Bi from radon	5.2 ± 0.5
External	< 0.2
^{214}Bi internal	1.0 ± 0.1
^{208}Tl internal	3.3 ± 0.3
Total	**18.0 ± 0.6**
Data	**15**

Total background

1.3×10^{-3} cts·keV^{-1}·kg^{-1}·y^{-1}