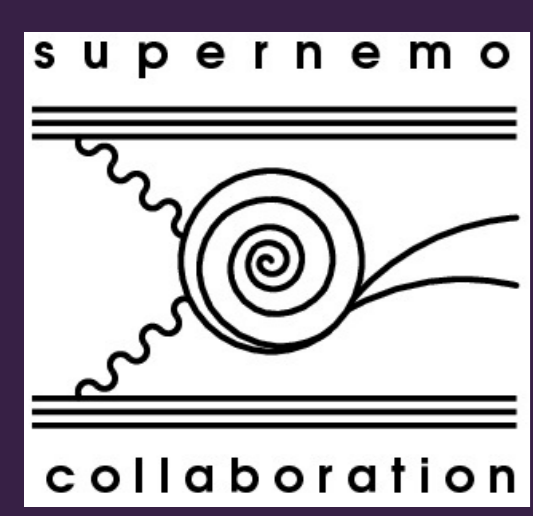


Low background techniques for SuperNEMO



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on behalf of the SuperNEMO collaboration



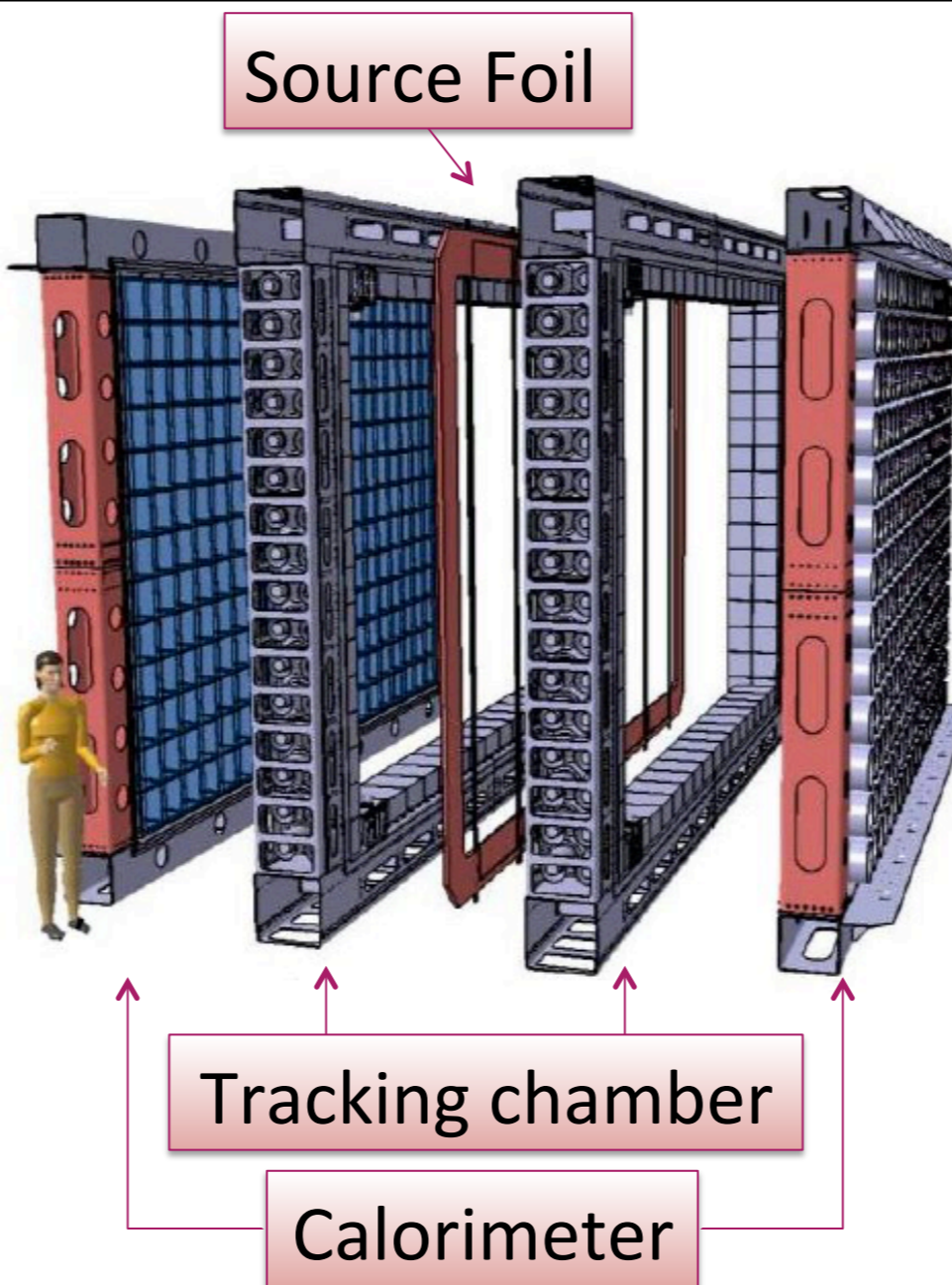
UCL

The SuperNEMO experiment

SuperNEMO is a next generation neutrinoless double beta decay ($0\nu\beta\beta$) experiment based on the NEMO-3 tracker-calorimeter design. The main experimental objective is to achieve a half-life sensitivity of 10^{26} years corresponding to an effective Majorana neutrino mass of $m_{\beta\beta} < 50 - 100$ meV.

SuperNEMO consists of 20 identical modules, each containing;

- **Source Foil:** 5 kg of double beta decay isotope, currently ^{82}Se . Other options such as ^{150}Nd and ^{48}Ca are also being considered.
- **Gas Tracking Chamber:** 2000 wire drift cells operated in Geiger mode within a gas mixture consisting of 95% He, 4% $\text{C}_2\text{H}_5\text{OH}$ and 1% Ar.



- **Calorimeter:** Consists of 712 PMTs and scintillator blocks.

One of the main challenges is the strict radiopurity requirement for both the construction material and gas in the tracking chamber.

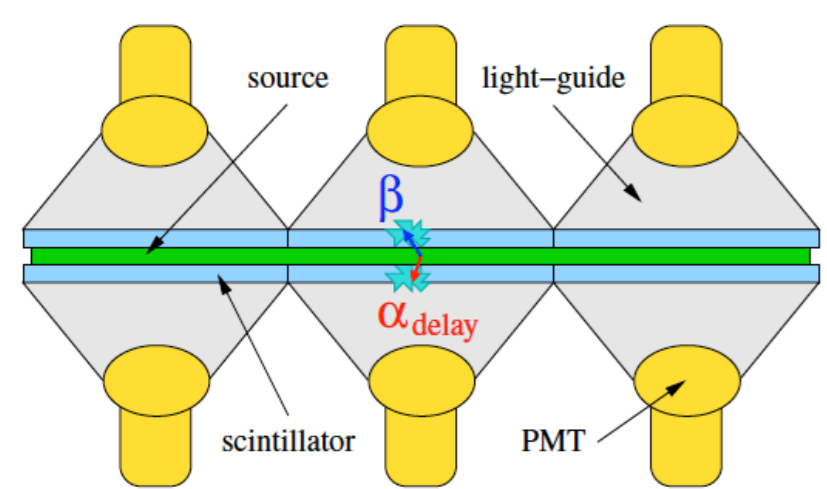
A **demonstrator module**, up to 7 kg ^{82}Se (other isotopes possible), is under construction with radiopurity requirements as follows:

- **Source Foil:** $A(^{214}\text{Bi}) < 10 \mu\text{Bq/kg}$, $A(^{208}\text{Tl}) < 2 \mu\text{Bq/kg}$
- **Tracker Gas:** $A(^{222}\text{Rn}) < 0.15 \text{ mBq/m}^3$ for the gas in the tracker.
- **Construction Materials:** All construction material used are screened using High-Purity Germanium (HPGe) detectors to varying levels of sensitivity, depending on location.

Radiopurity strategy for demonstrator module

Source Foil

- Source foil materials and source frame components are screened using **HPGe detectors** with a sensitivity of 0.1-1 mB/kg for ^{238}U (^{226}Ra), ^{232}Th chains and ^{40}K .



- A dedicated **BiPo** detector was constructed to reach the final level of sensitivity required for the **source foil** of 2-10 $\mu\text{Bq/kg}$ for ^{208}Tl and ^{214}Bi .

Tracker (Radon Barrier)

- Materials in direct contact with the tracker gas are screened using **HPGe detectors** to similar sensitivities as the source foil.

- **Emanation chambers** are then used to test for radon emanation.

- A **radon concentration line (RnCL)** was built to measure and study the radon levels of all tracker modules to the required sensitivity of $< 0.15 \text{ mBq/m}^3$.

- Extensive R&D are underway to identify more efficient and radiopure radon absorbents to filter radon from the tracker gas.

Calorimeter

- Calorimeter components inside the tracker are screened with 0.1-1 mBq/kg.

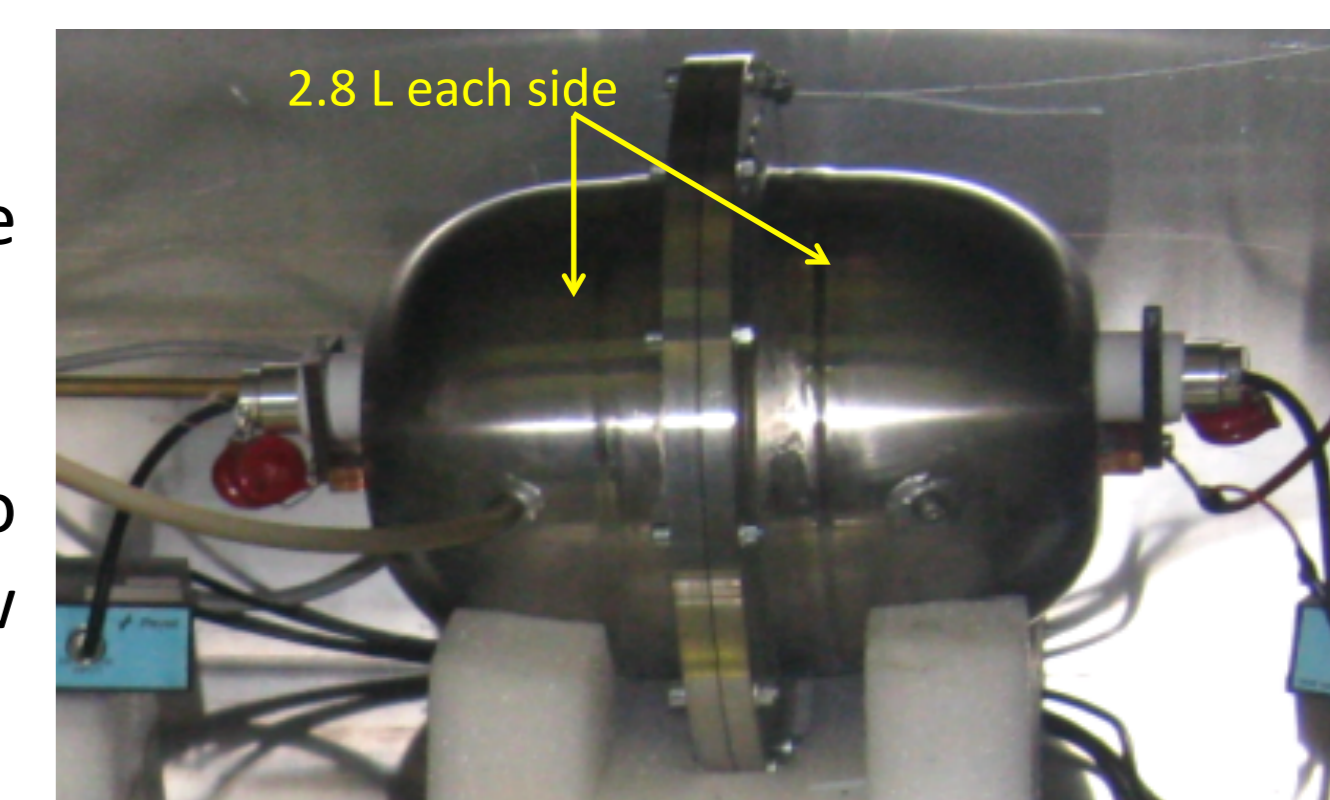
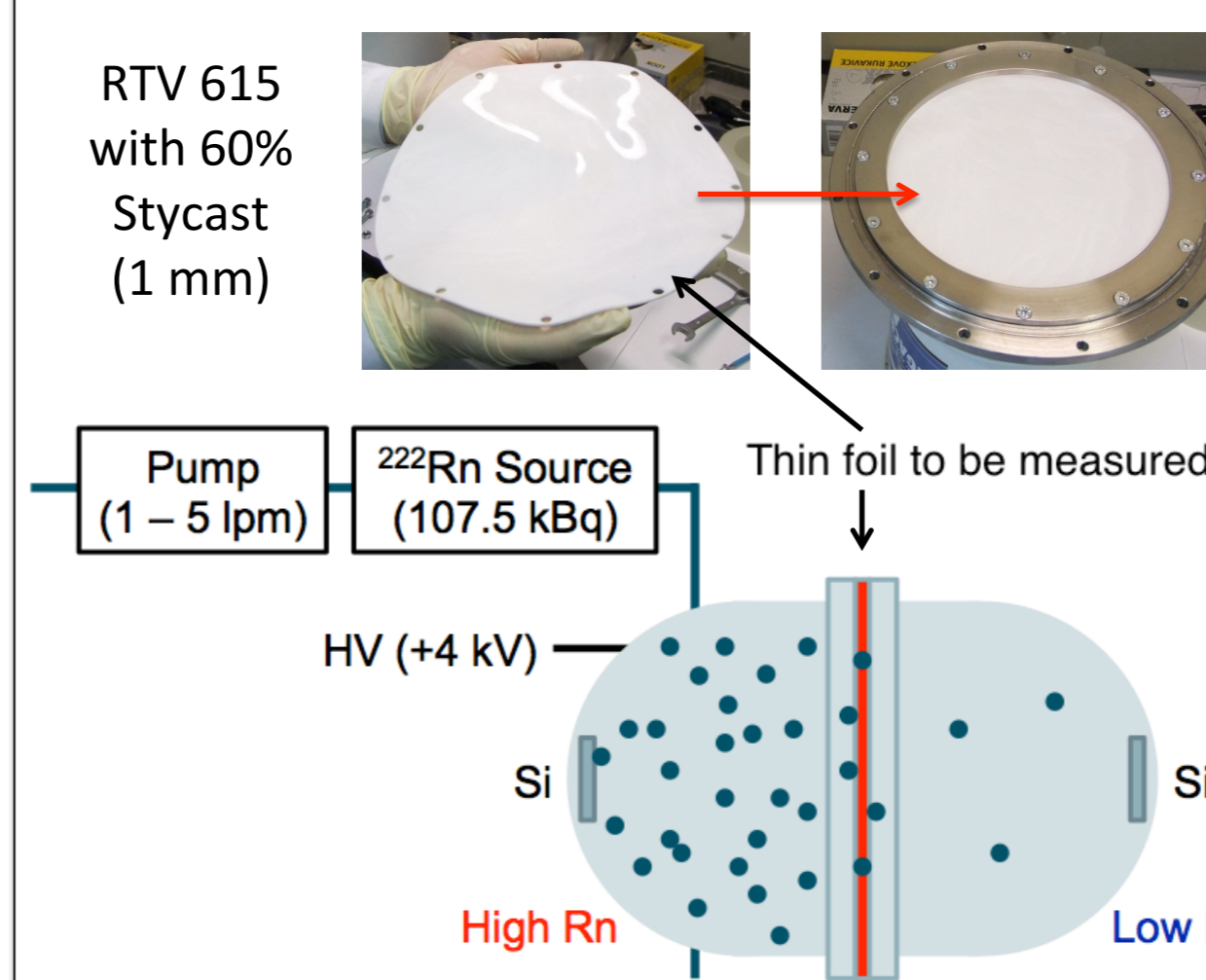


- Outside the gas volume radiopurity is normalised to PMT contribution: no more than 10% of PMTs. Typical sensitivity 1-10 mBq/kg.

Radon Diffusion R&D

- Radon barrier required to reduce emanation into the tracker.

- Required a thin material, to maintain energy resolution, with low diffusion coefficient.



Diffusion test chamber at CTU Prague

Material	Thickness (μm)	Diffusion Coefficient ($10^{12} \text{ m}^2 \text{ s}^{-1}$)	Diffusion Length (μm)
Adhesives/Sealants			
Silicone (RTV 615)	2100	1080	22800
Stycast 1264	2000	< 0.43	< 455
PET	1000	< 0.076	< 190
SBR (Synthomer 47B40) + HDPE	700 + 120	0.27	400
PVA (Emultex 518) + HDPE	6 + 11	< 0.00038	< 13
Butyl	1000	1.2	7500
Folios			
HDPE (2 layers)	2 x 144	19	3000
EVOH (2 layers)	2 x 15	< 0.00035	< 13
Mylar (2 layers)	2 x 20	< 0.0012	< 24
TROPAC III	102	< 0.0043	< 46
NYLON	50	0.00047	15

Radon levels in each chamber with time

Radon Emanation Chambers

- Critical detector components are tested for radon emanation.

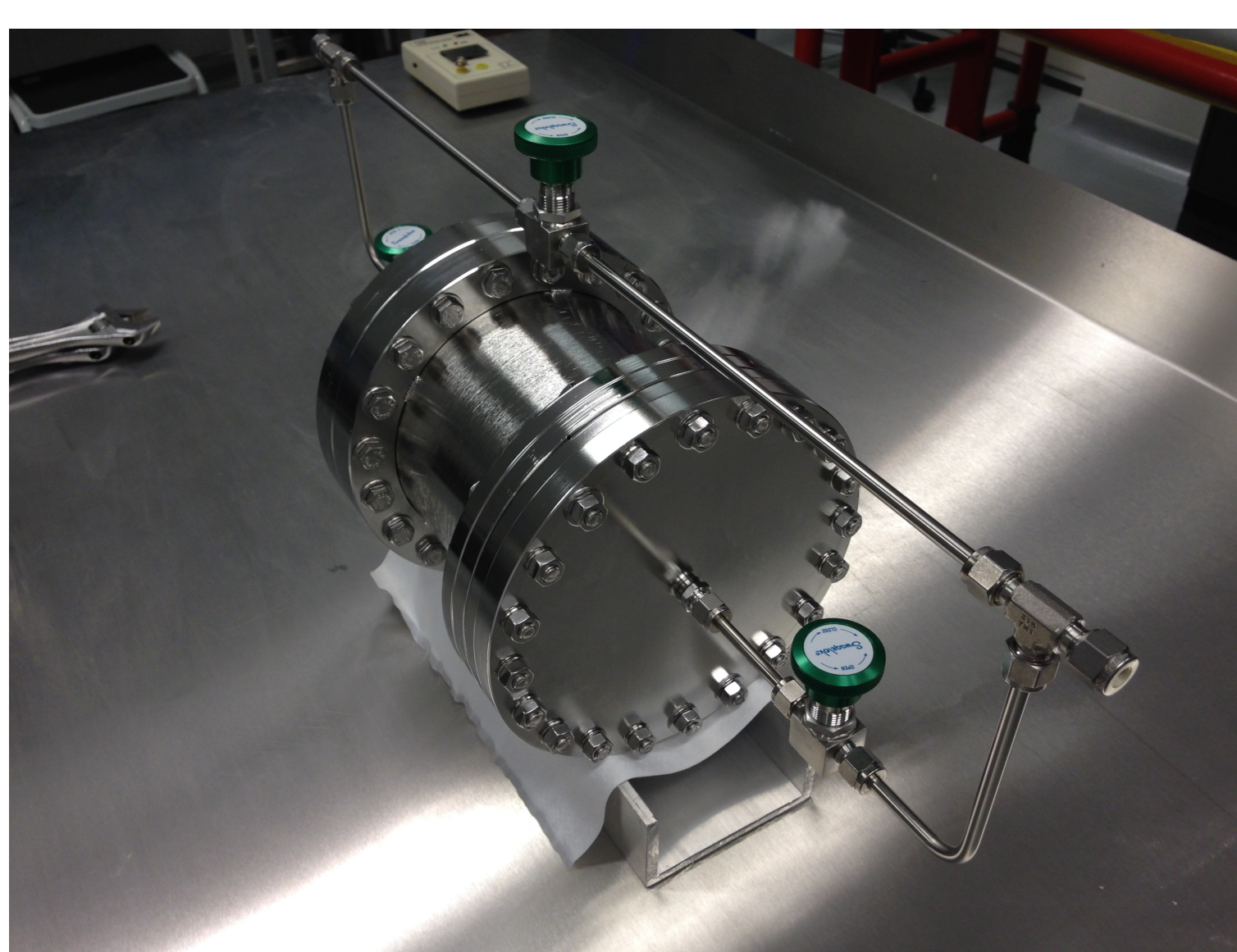
- Large emanation tank, 0.7 m^3 , was made at CENBG with sensitivity of 2.8 mBq/sample.



Large emanation tank - CENBG

- A small emanation chamber, 2.6 litres, was developed at UCL with sensitivity of 190 $\mu\text{Bq/sample}$.

- Useful for measuring small samples to a higher sensitivity.

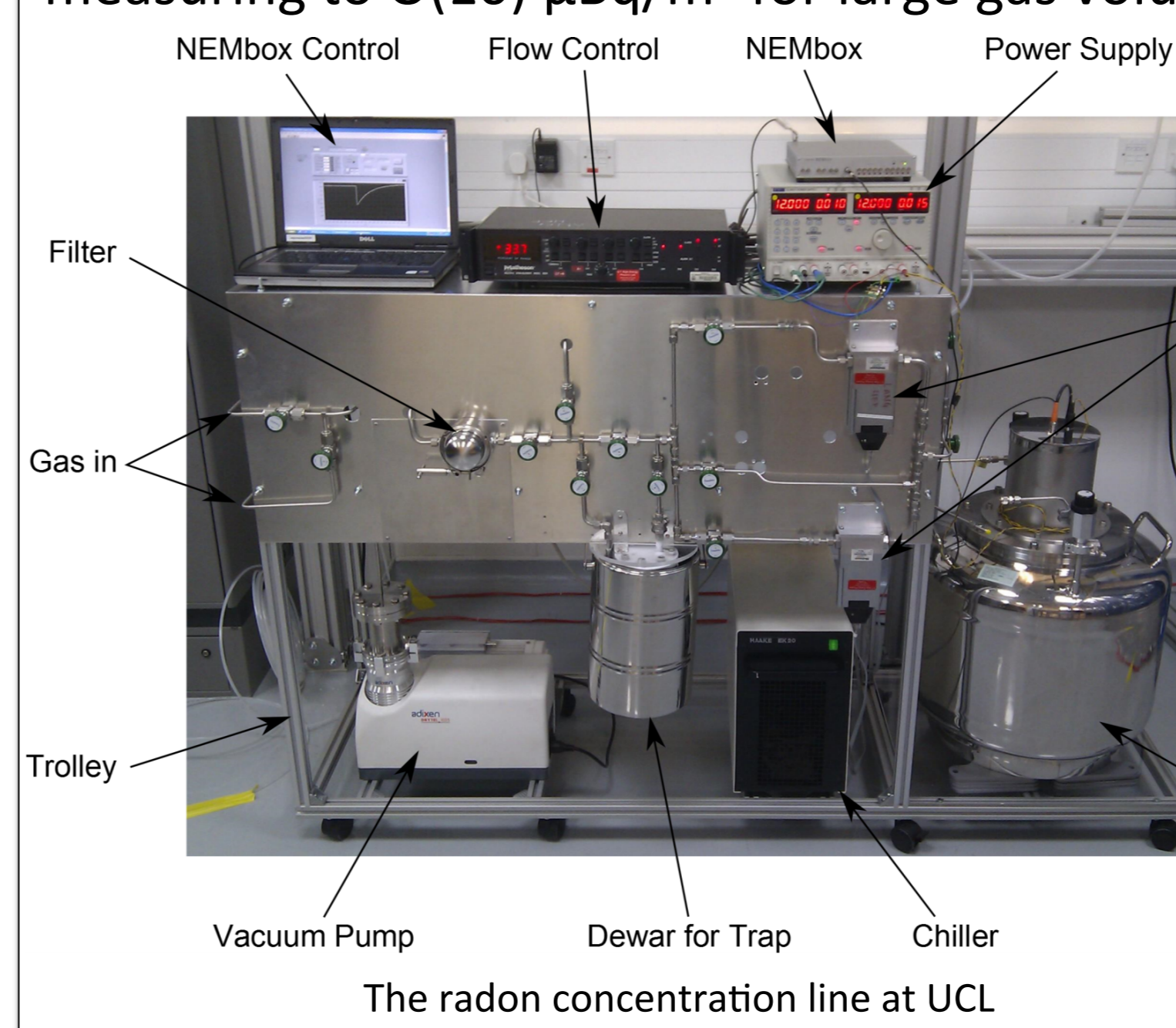


Small emanation chamber - UCL

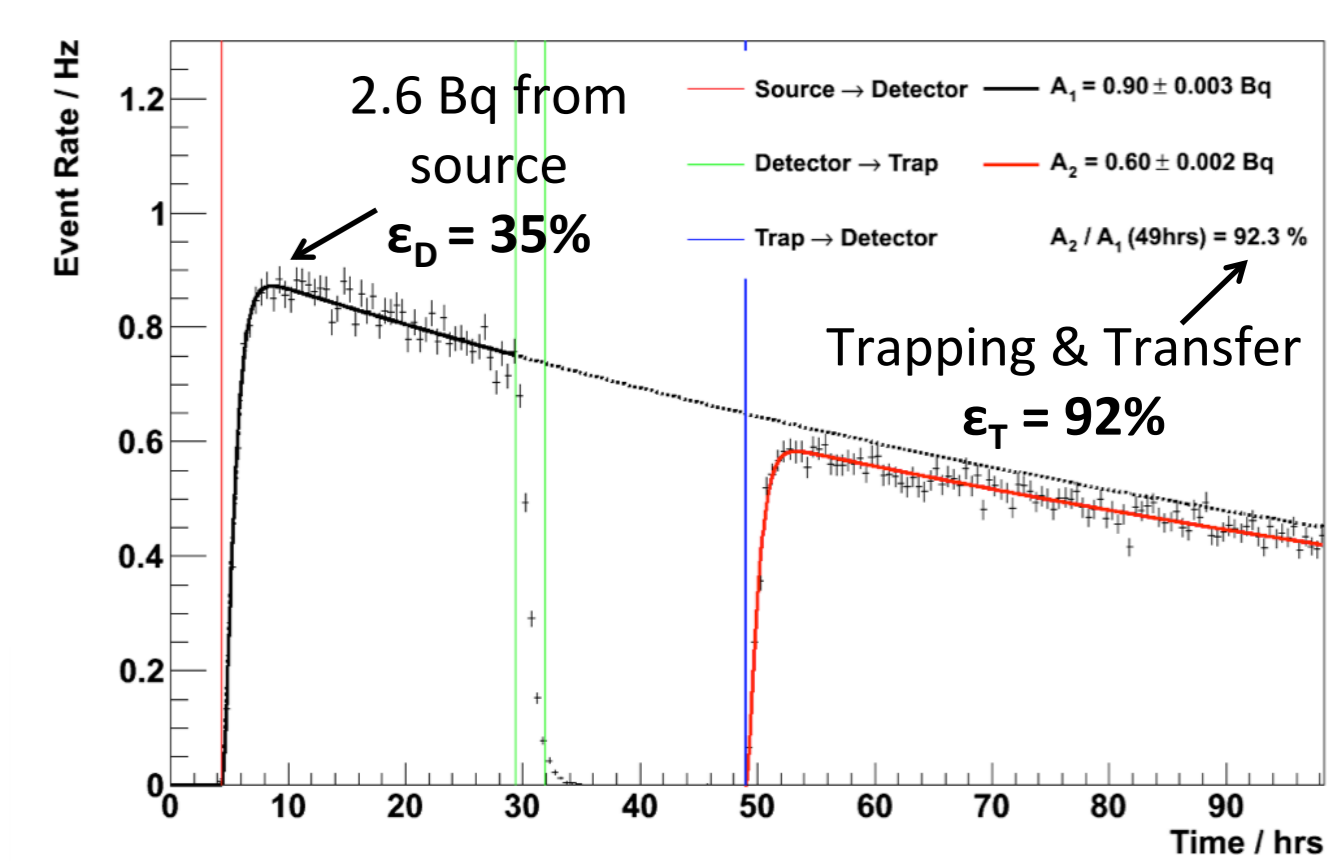
Radon Concentration Line

- Typical Electrostatic detectors are sensitive to $\sim 1 \text{ mBq/m}^3$.

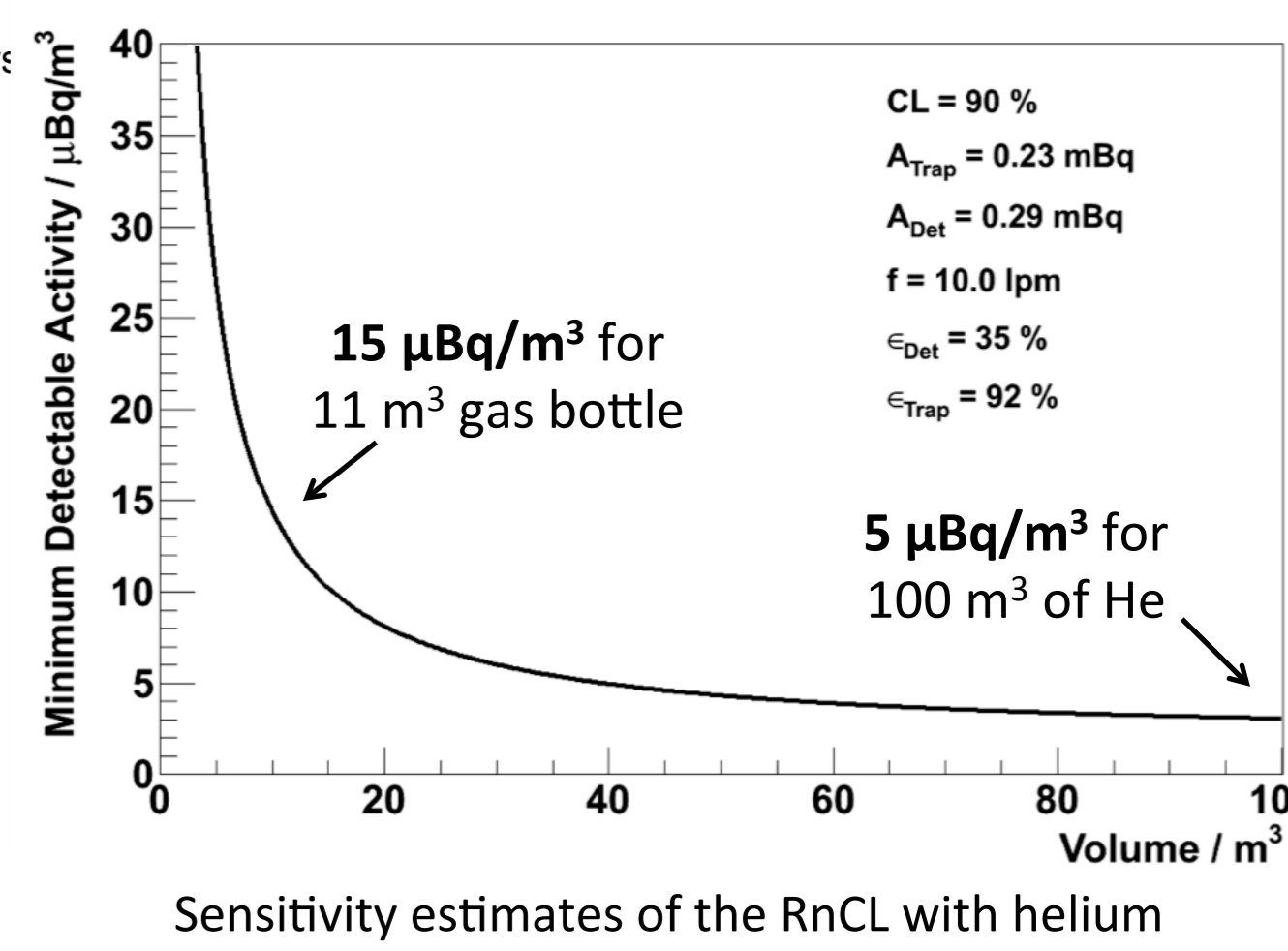
- A 'RnCL' has been developed capable of measuring to $O(10) \mu\text{Bq/m}^3$ for large gas volumes.



The radon concentration line at UCL



A trapping & transfer efficiency measurement with He



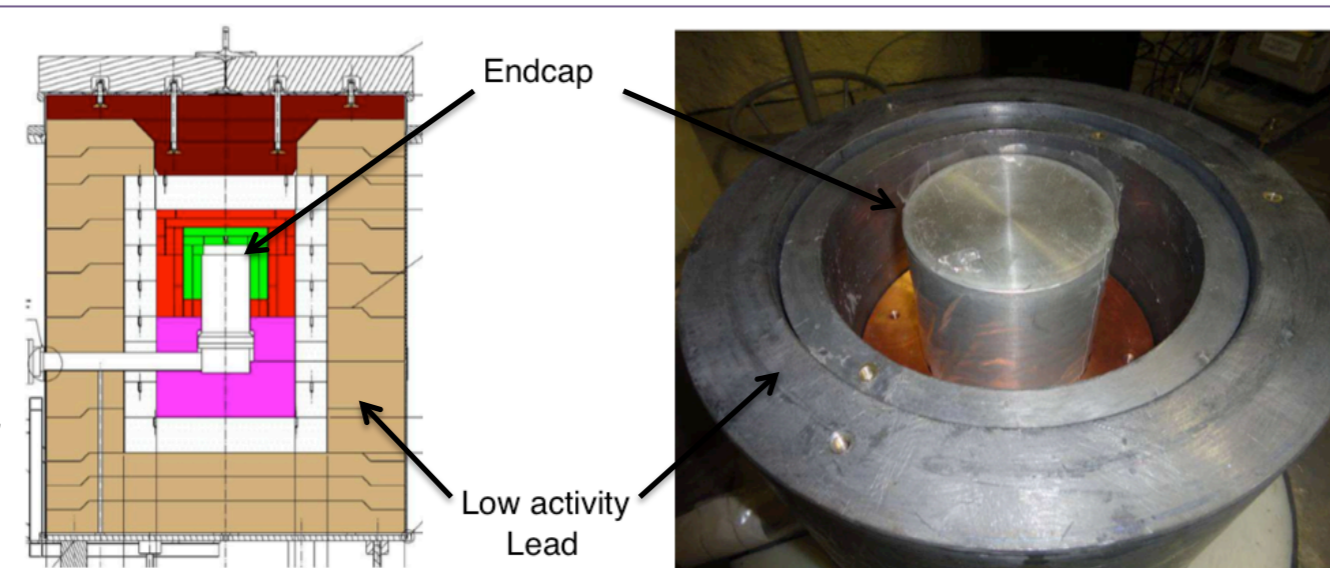
Sensitivity estimates of the RnCL with helium

Gamma-ray Spectroscopy Facilities

LSM Facility (Modane)

- 3 coaxial detectors for large samples (few 1000 cm^3) and $E_\gamma > 100 \text{ keV}$.

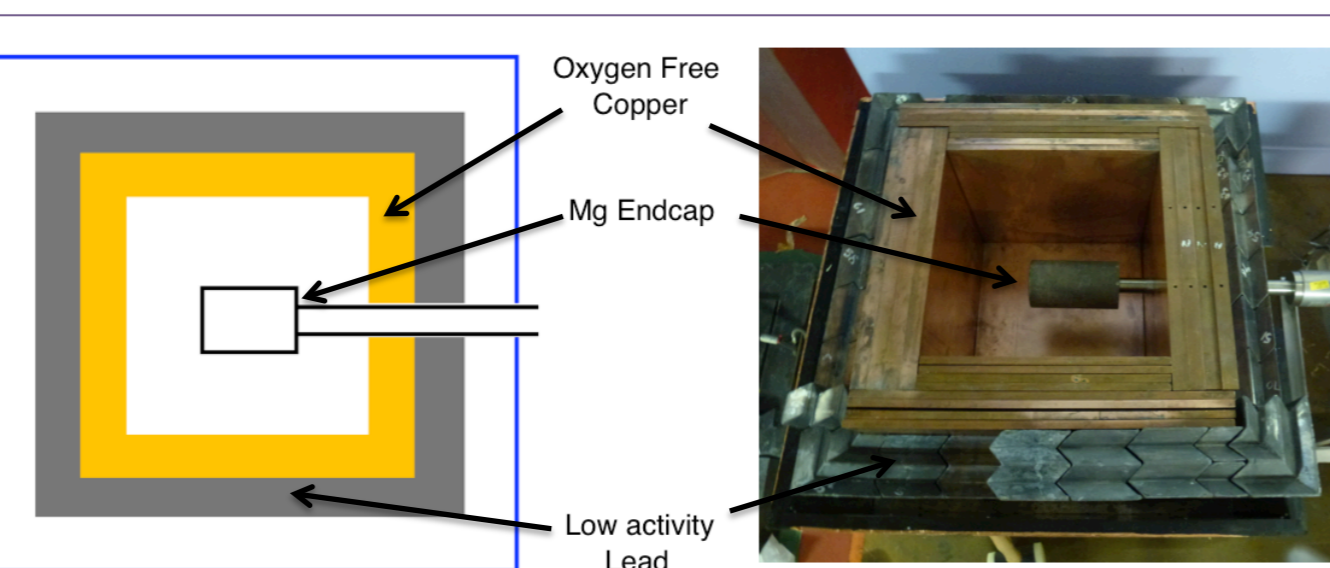
- 1 planar detector for thin samples (few mm) and $E_\gamma > 20 \text{ keV}$.



Boulby Facility (Cleveland)

- 1 coaxial detector for large samples ($\sim 60000 \text{ cm}^3$) and $E_\gamma > 150 \text{ keV}$.

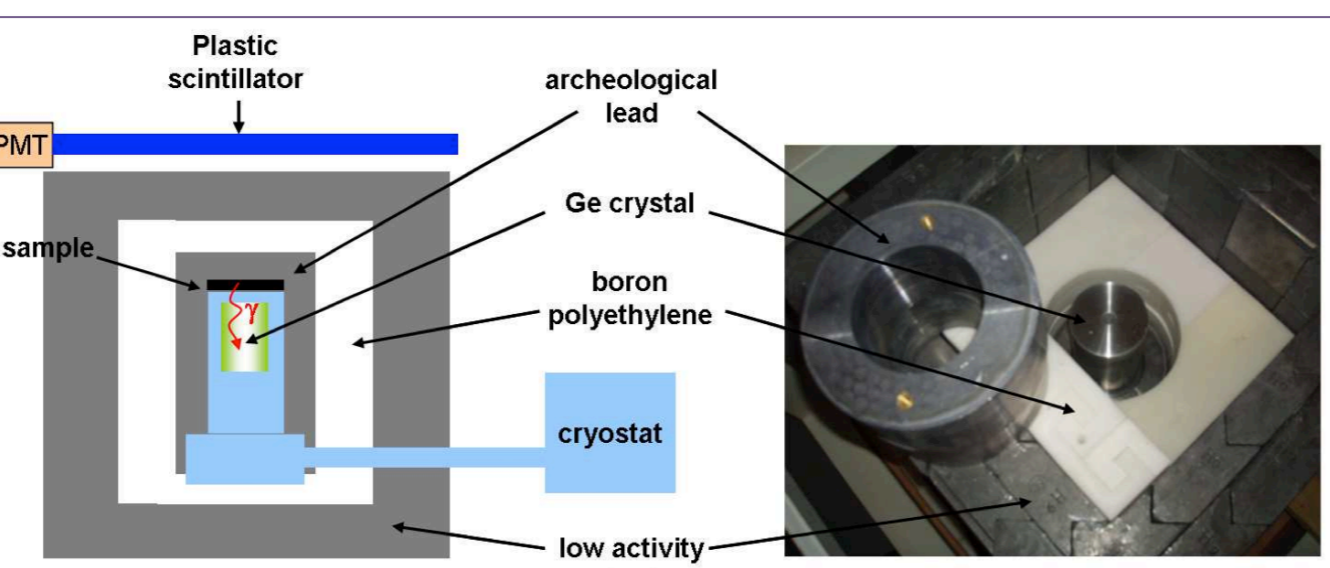
- 1 broad energy detector with high resolution ($\sim 1000 \text{ cm}^3$) and $E_\gamma > 40 \text{ keV}$.



PRISNA Facility (Bordeaux)

- 2 coaxial detectors for large samples (few 100 cm^3) and $E_\gamma > 100 \text{ keV}$.

- 2 well detectors for small samples (few cm^3) and $E_\gamma > 40 \text{ keV}$.



A series of dedicated Ge facilities have been established for the material screening and selection process.

Material	Post production source foils	Component in contact with tracker gas	Components not in contact with tracker gas (low mass)	Components not in contact with tracker gas (high mass)
Sensitivity (mBq/kg)	0.1 - 1	0.1 - 1	10 - 100	1 - 10
Facility	LSM	LSM	PRISNA/Boulby	PRISNA/Boulby

Summary of screening activity at each low background germanium facility.

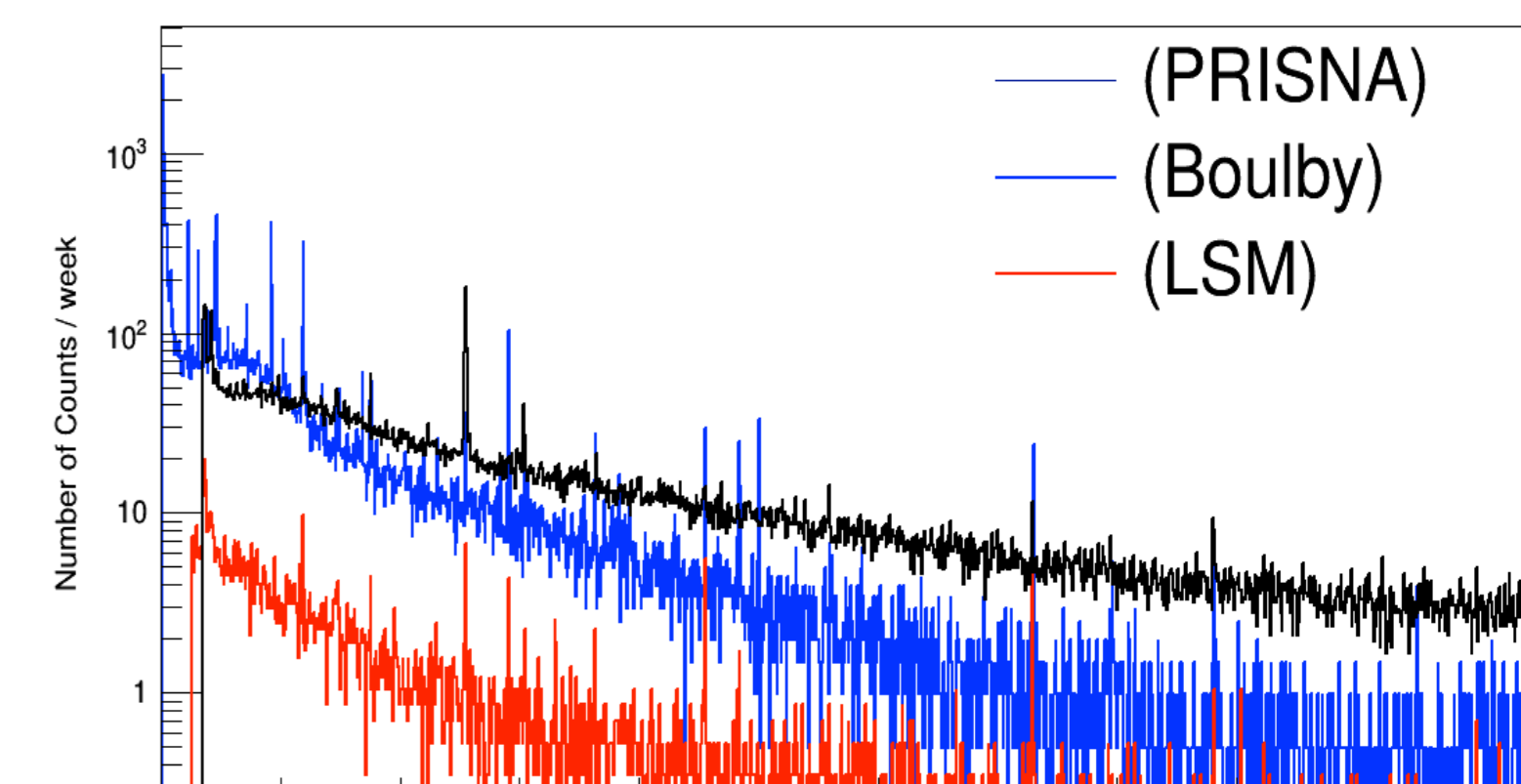
- The 3 principal facilities are LSM, Boulby and PRISNA with Boulby being the most recent.

Facility	Type	Ge Mass (kg)	Background (counts/mn)	Detection limit (mBq/kg)		
				^{214}Bi (352 keV)	^{208}Tl (238 keV)	^{210}Pb (46 keV)
Boulby	BEGe	0.6	1.96 ± 0.01	< 5	< 3	< 28
LSM	Coaxial	2.1	0.129 ± 0.002	< 2	< 1	-
PRISNA	Coaxial	0.5	2.80 ± 0.01	< 17	< 7	-

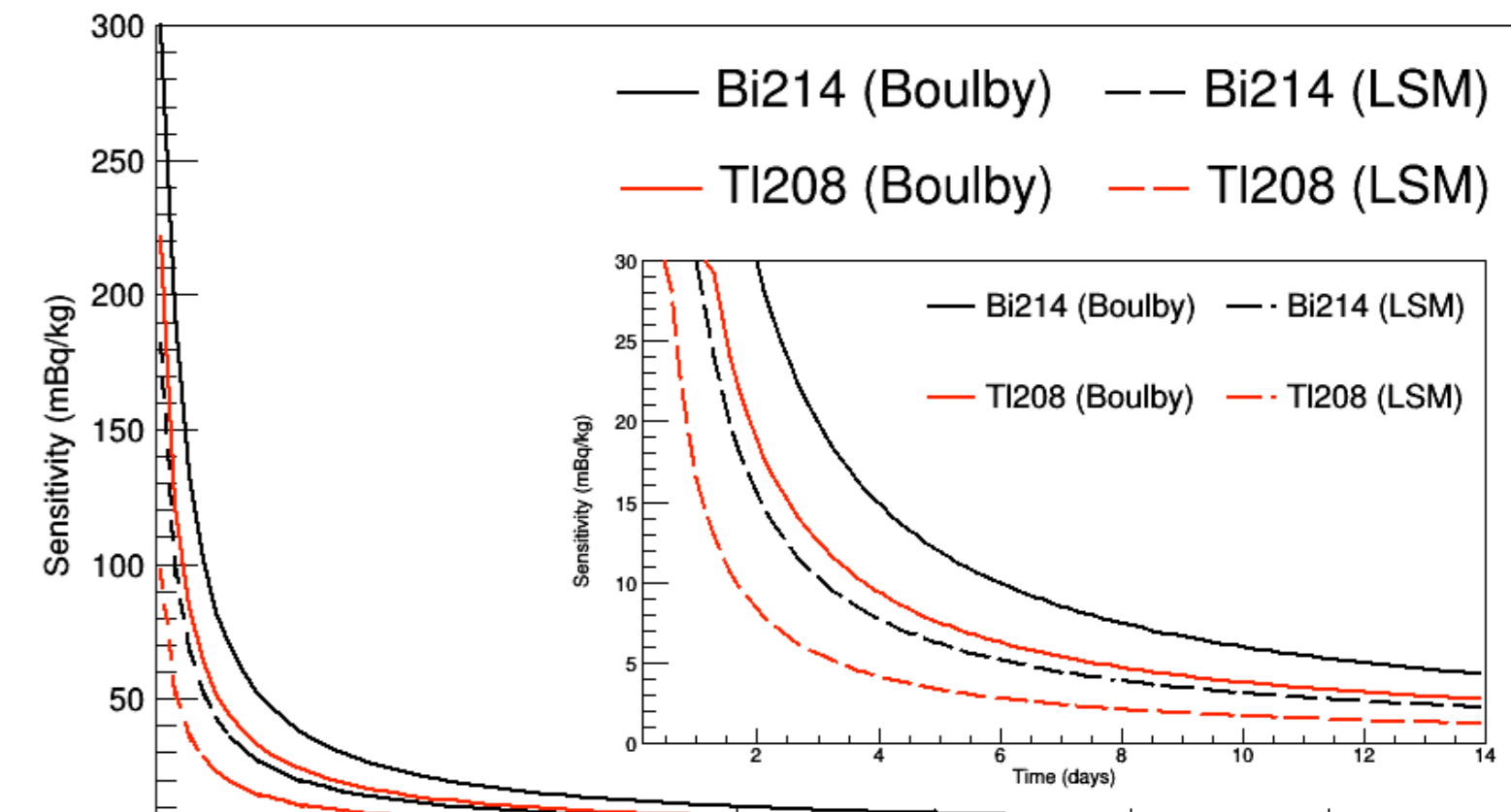
Comparison of detector sensitivities achieved based on measurement of the same sample, 150g glass slides.

*Best sensitivity reached measuring large mass samples.

- Other facilities in Canfranc and Bratislava can also contribute to the screening process.



Background gamma spectrum comparison of the PRISNA (black), Boulby (blue) and LSM (red) Ge detectors.



Minimum detectable activity comparison of the Boulby and LSM Ge detectors based on measurement of the same sample.