

Context

Certified laboratories are an essential component of the IMS network. One of their duties is to perform in-depth analysis of anomalous radionuclide samples collected in the field. Radioxenon analysis is by far more challenging than analysis of particulate filters: samples are gaseous which makes them prone to leaks and memory effect, procedures have to accommodate the three significantly different types of archive bottles in operation on the network, purification of the gas mixture is needed prior to measurement, half-lives of radionuclides are short...

Sample pre-treatment

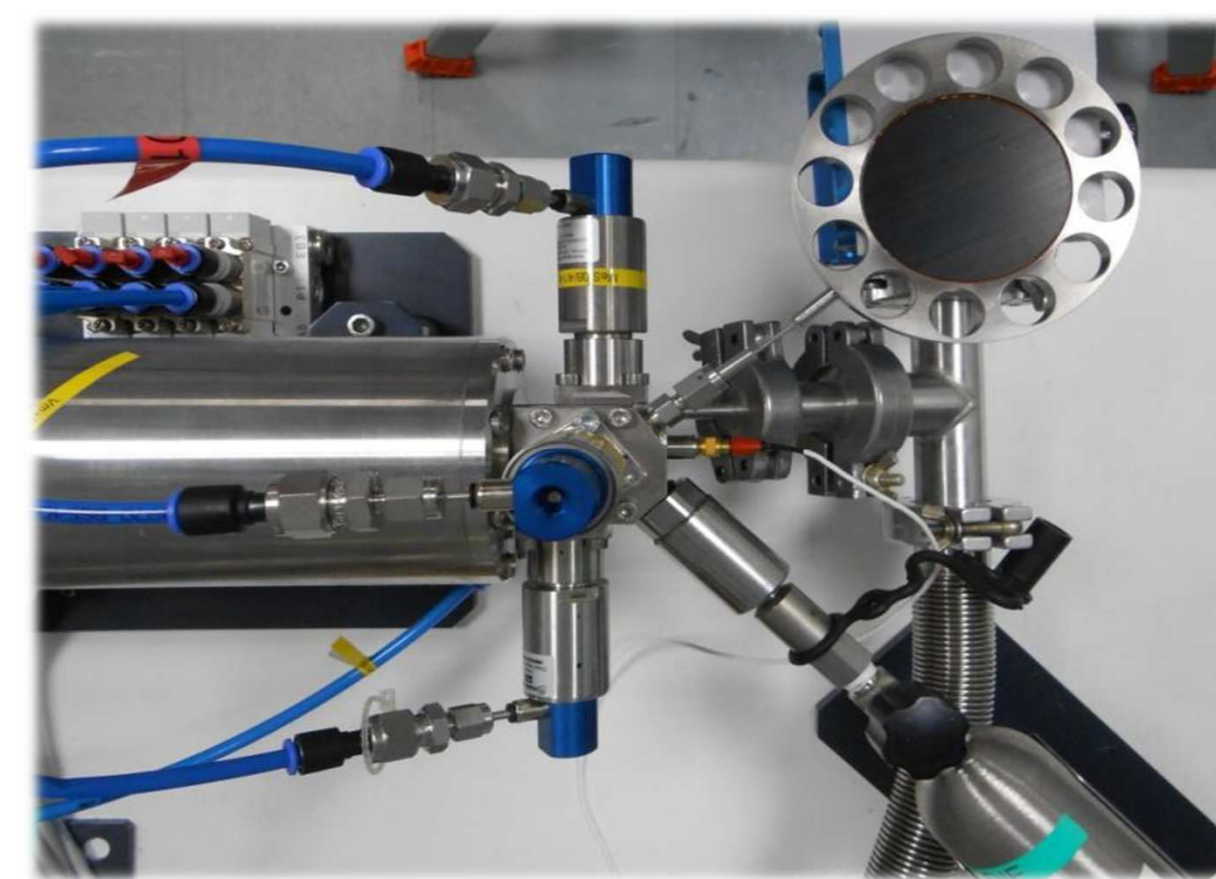
Sample cryogenic purification

Three different archive bottle types are in use on IMS noble gas monitoring stations. They differ by their shapes, pressure and gas composition. In any case radioactive xenon has to be extracted from the carrier gas (He/N₂) and transferred to a measurement cell.

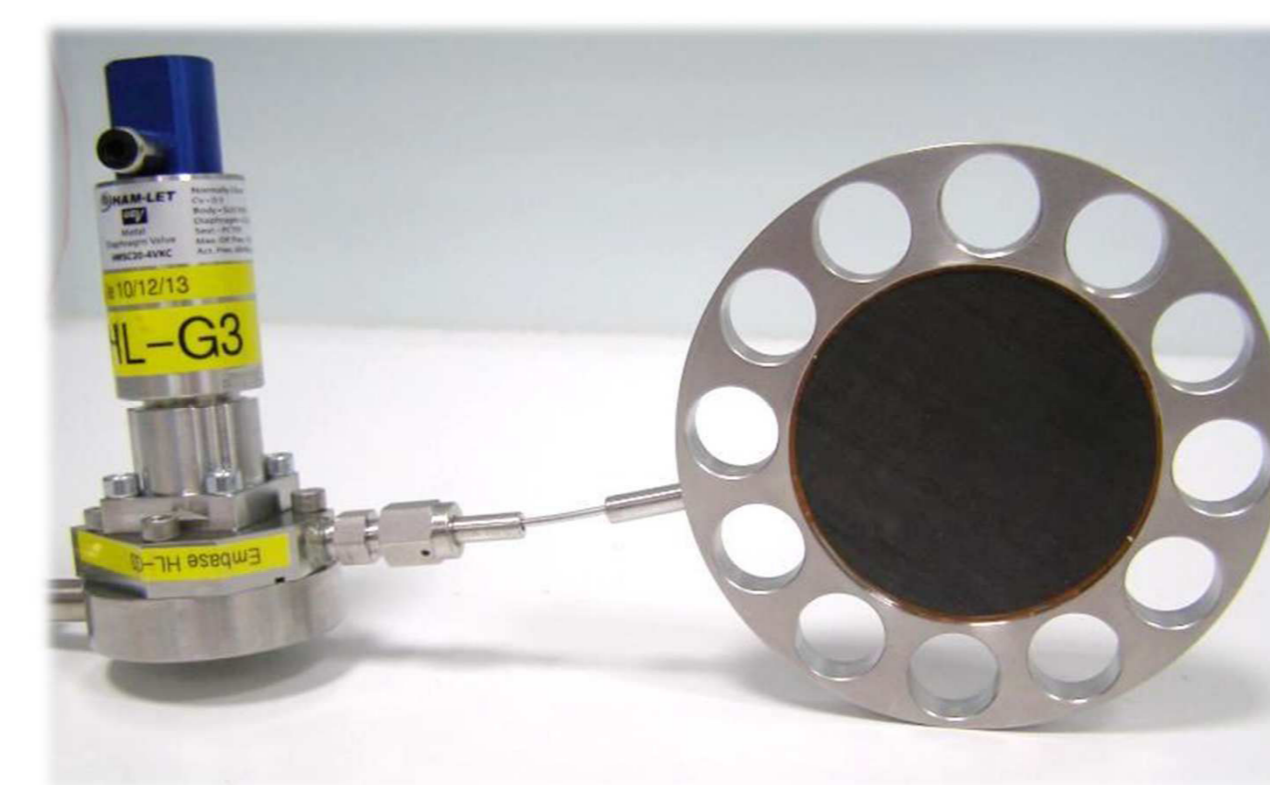
Xenon extraction is performed by a **cryogenic trap** (LN₂).



Cryogenic extraction



Gas transfer



Measurement cell (left: pneumatic valve)



IMS archive bottles

Taking benefit of differences in state diagrams, Xe can be extracted selectively from the gas mixture with **high recovery yield** (>70%) and **free of memory effect**.

Stable xenon measurement

Sample volume determination

Air-equivalent volume is derived from the sample stable xenon volume determination.

An automated Gas Phase Chromatograph (GPC) is used in combination with a **volume determination** bench.

$$A_c(^{133}\text{Xe})[\text{Bq}/\text{m}^3] = \frac{A_{\text{cell}}(^{133}\text{Xe})[\text{Bq}]}{V_{\text{Xe, cell}}[\text{cm}^3]} \times 0.087 \times 10^{-6} \rightarrow V_{\text{Xe, cell}}[\text{cm}^3] = [\text{Xe}]_{\text{cell}} \times V_{\text{cell}} \times \left(\frac{p \cdot T_0}{p_0 \cdot T} \right)$$



Automated GPC



Volume determination bench

- **<±2% uncertainty** for [Xe] determination
- Calibration with **standard mixtures**
- **Imbedded pressure gauge**
- Principle of volume determination: Gay-Lussac **gas expansion** (N₂)
- Calibrated p, T probes
- Range: 10-500 cm³. **<±2 % uncertainty**
- Calibration with **reference volumes**

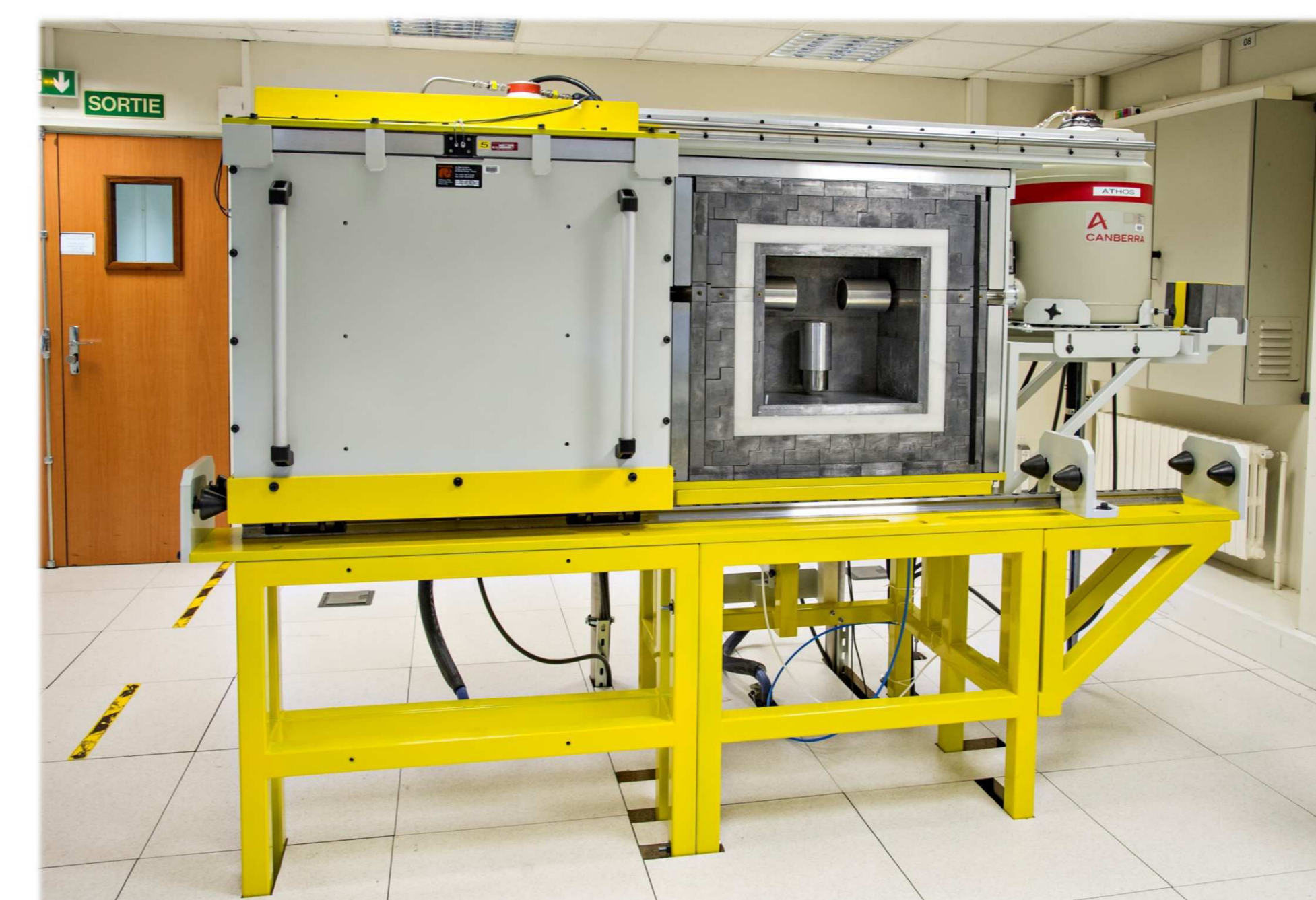
Activity measurement

Radioxenon detection and measurement

- **4 radioactive isotopes of Xenon** have to be analyzed : ¹³³Xe, ^{133m}Xe, ^{131m}Xe, ¹³⁵Xe.
- **γ/X-ray** measurement route has been chosen
- **High detection efficiency** and **low-background** instrumentation is necessary in order to meet the Data Quality Objectives.

Gamma³ spectrometer

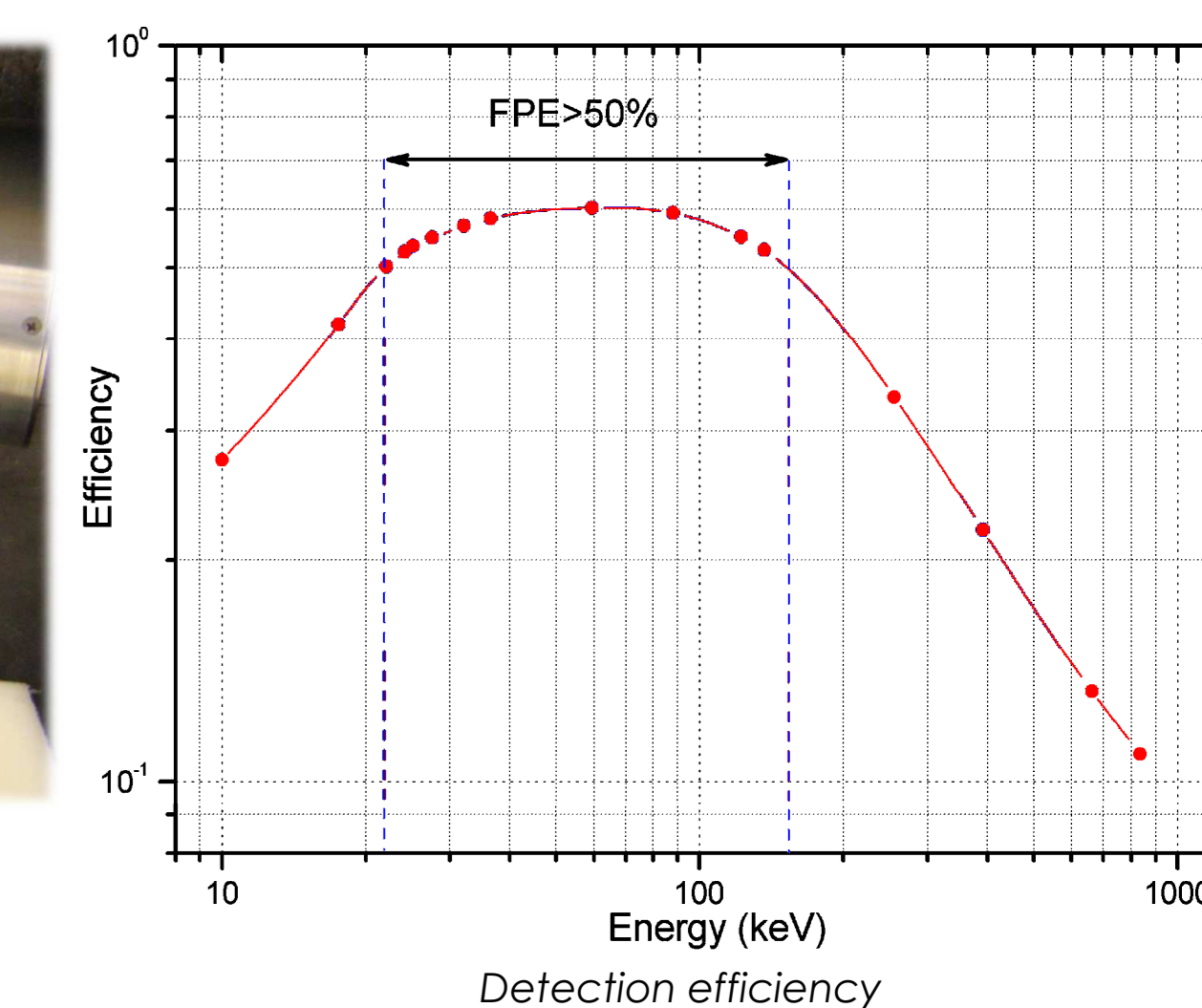
- 3xBEGe 5030P γ-spectrometers in an **improved passive & active shielding**
- XIA-PIXIE4 **digital acquisition** electronics, listmode operation



Gamma³ spectrometer



Measurement configuration



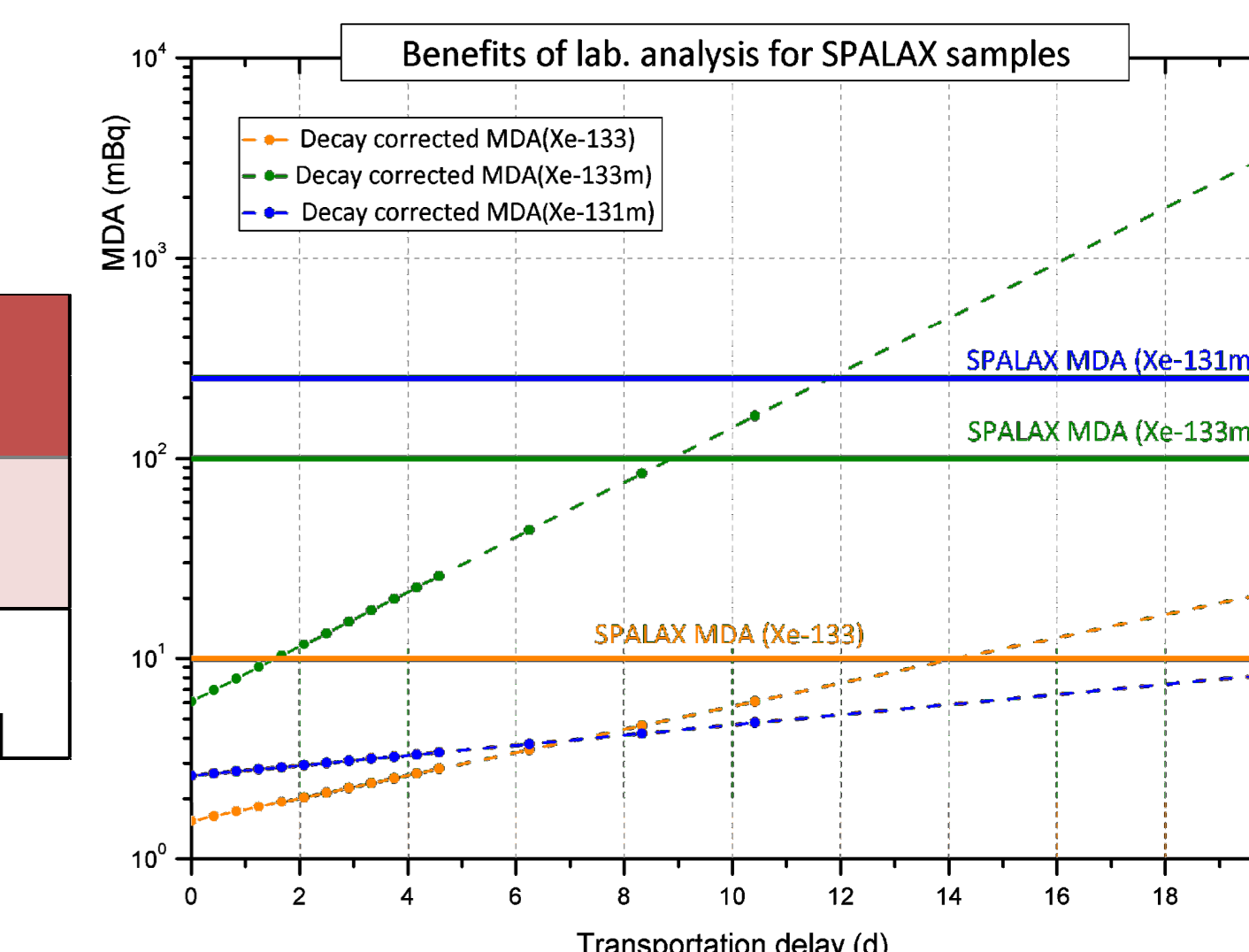
- **Large detection solid angle**
- **Improved detection efficiency**, the system acts as a "virtual single spectrometer"

- **High-purity Pb** shield combined with a PE-B neutron absorber and a **4π cosmic veto + N₂ flushing** results in very low background: **<2x2.1 cpm** [20-1000 keV]

- **Minimum detectable activities (MDAs)** are estimated following a 3d long blank sample measurement.

	MDA Xe-133	MDA Xe-133m	MDA Xe-131m	MDA Xe-135
Certification criteria (3 d)	5 mBq	10 mBq	10 mBq	15 mBq
FRL08	γ 0.9 mBq	X 1.2 mBq	γ 7.0 mBq	X 0.9 mBq
			γ 21 mBq	γ 2.9 mBq

FRL08 Minimum Detectable Activities (MDA)



Laboratory MDAs vs transportation time for SPALAX archives

- **Certification criteria are met.**
- In some specific cases, laboratory sensitivity is large enough to compensate for unavoidable radioactive decay during transportation **improving therefore the IMS network sensitivity.**

Conclusion

Xenon measurement capabilities have been developed at RL08 laboratory as a support of the IMS network. Extensive analytical procedures and related instrumentations have been designed and optimized. Accuracy and sensitivity have been demonstrated thanks to several PTS Proficiency Test Exercises. Special efforts have also been put on measurement traceability in order guarantee the highest quality level of the analysis to States Parties. RL08 will undergo formal noble gas certification in September 2017.