Measurement of the radon activity concentration at the environmental level traceRadon (19ENV01)

Public exposure to natural radiation
Total average individual dose: 3 mSv/a
UNSCEAR, 2008

Calibration from lab to field

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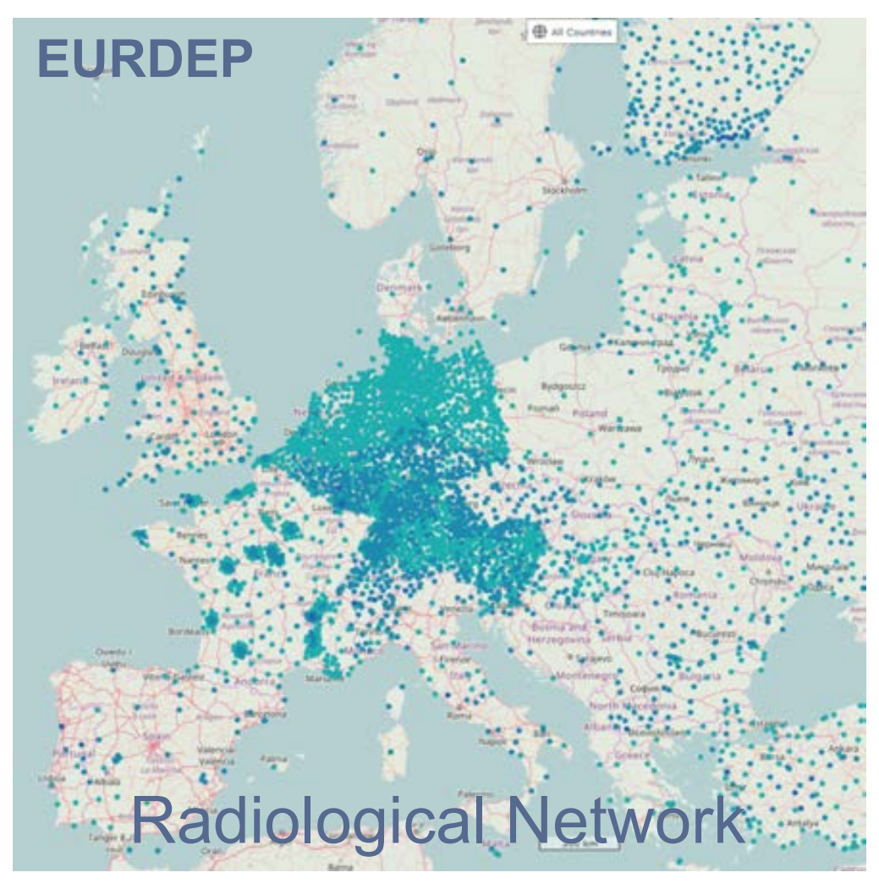
Abstract:

Climate Observation Network

- Radon gas is the largest source of public exposure to naturally occurring radioactivity. Radon can also be used as a tracer to evaluate dispersal models important for supporting successful greenhouse gas (GHG) mitigation strategies. To increase the accuracy of both radiation protection measurements and those used for GHG modelling, traceability to SI units for radon exhalation rate from soil and its concentration in the atmosphere are needed.
- Atmospheric measurements of radon activity concentrations are also used for the assessment and improvement of atmospheric transport models.
- An overlapping need exists between the climate research and radiation protection communities for improved traceable low-level outdoor radon measurements, combining the challenges of collating and modelling large datasets, with setting up new radiation protection services. The EMPIR project traceRadon started to provide the necessary measurement infrastructure.
- Therefore, measurements of radon activity concentration at the environmental level (below 100 Bq·m^{-3}) need to be performed at national standard institutes as well as calibration laboratories and need to be transferred to the detectors operated at atmospheric measurements stations or within radiation protection networks.
- With this presentation, an overview of possible national calibration techniques, as well as possible traceability chains for the transfer of the calibration to the detectors in field will be presented and first proof of principle will be shown, as well as their applicability will be discussed.



Radiological Network

Traceability through absolute ^{226}Ra source:

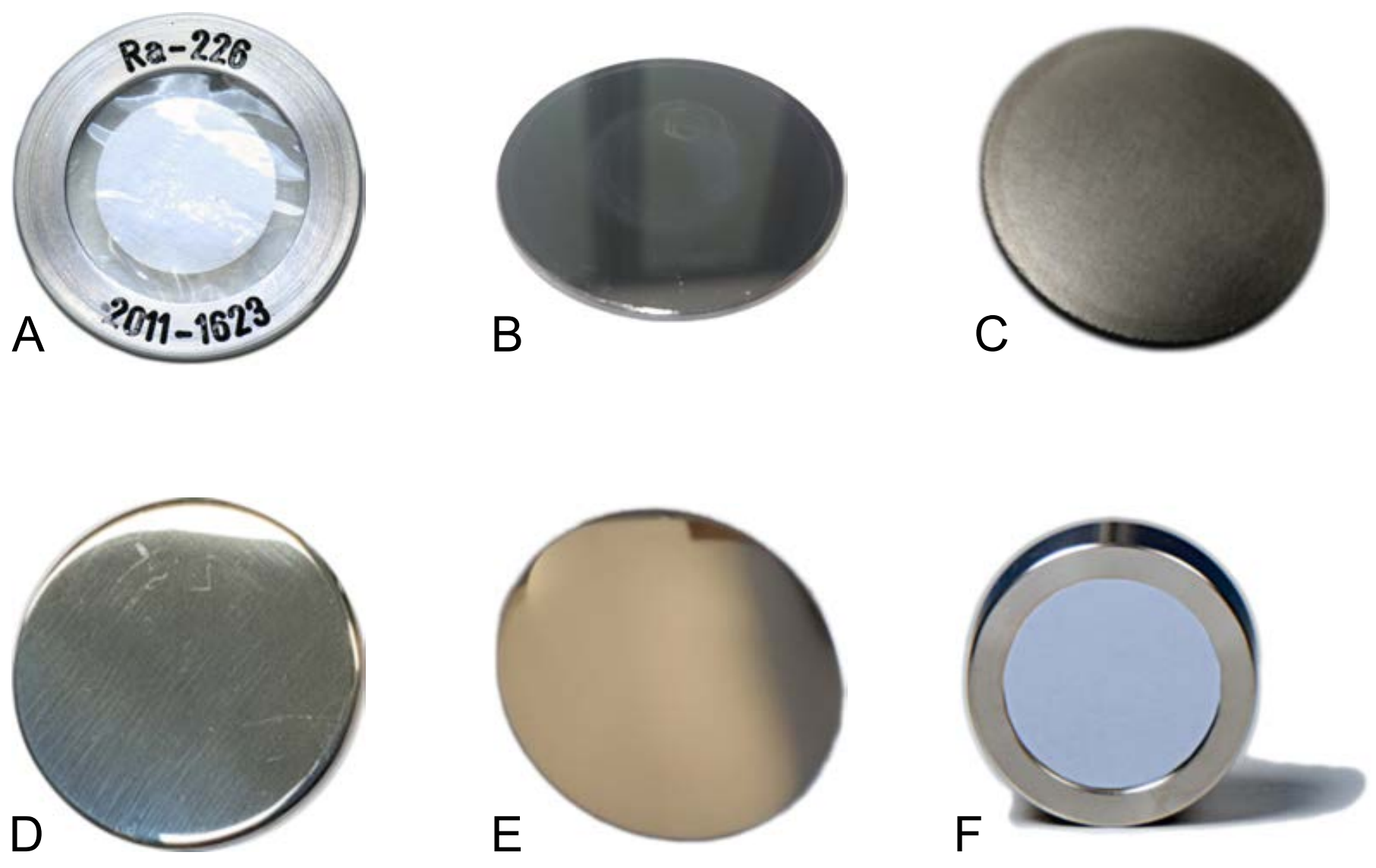


Figure 1: Overview of radon emanation sources. Historical development from upper-left to lower-right.
(A) ^{226}Ra solution drop-cast to fibre filter enclosed between polyethylene foils.
(B) ^{226}Ra solution electrodeposit to a stainless steel backing.
(C) Mass separated ion-implanted ^{226}Ra onto a tungsten backing (W or Al).
(D) thermal physical vapor deposition of $^{226}RaCl_2$ onto stainless steel backing.
(E) thermal physical vapor deposition of $^{226}RaCl_2$ onto a 1" diameter silicon wafer.
(F) thermal physical vapor deposition of $^{226}RaCl_2$ onto a 450 mm^2 ion-implanted silicon detector (PIPS), which is called the Integrated Radon Source Detector (IRSD).

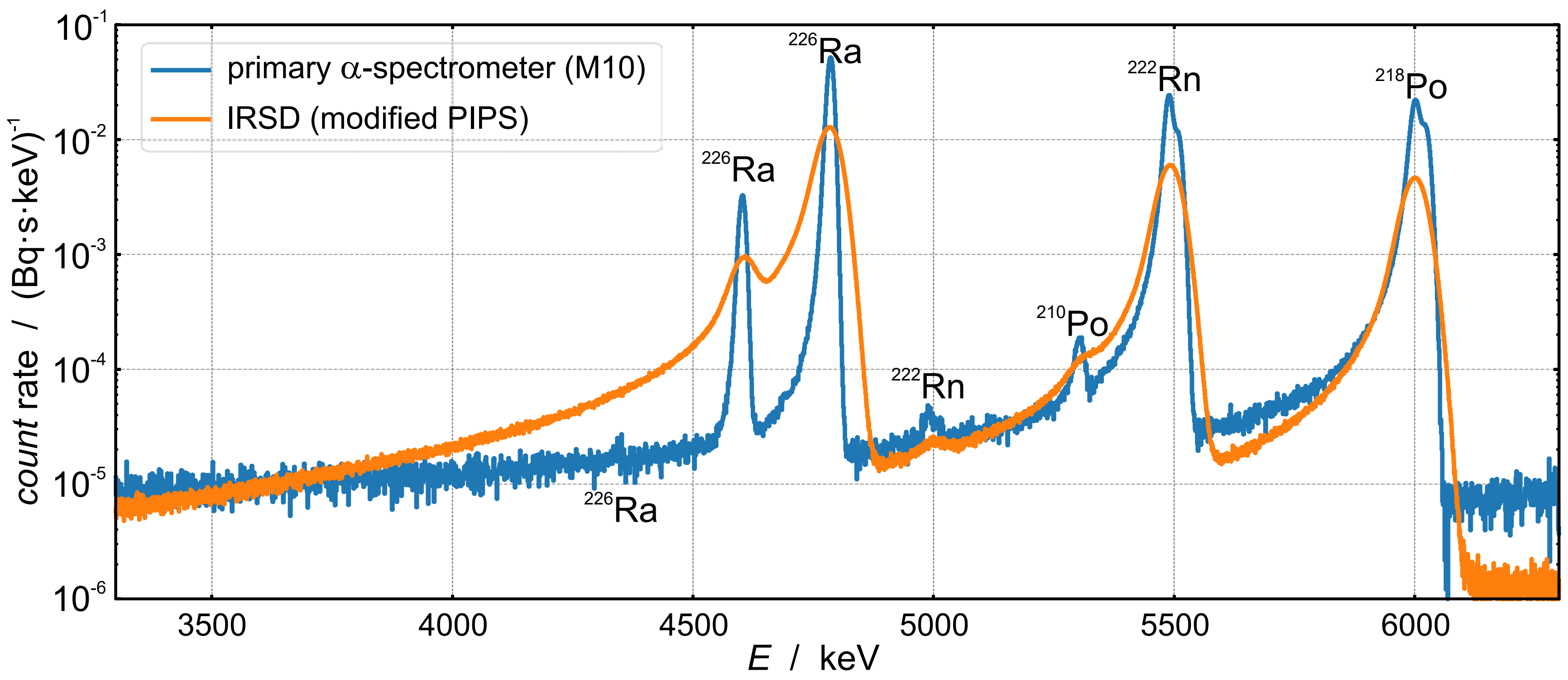


Figure 2: Absolute α particle count rate energy spectra, recorded with the primary α-spectrometer of PTB (M10, traceable to the SI) and an IRSD (modified PIPS) at the same time in the same setup. The resolution of the IRSD is less (FWHM is larger) and the count rate is higher as for the M10, because of the much larger solid angle of detection regarding the ^{226}Ra deposite.

Description and type	*Value and uncertainty*	*Rel. uncertainty*	*Rel. contribution*
Solid angle (systematic)	(0.00940 ± 0.00006) 4π sr	0.6 %	28.4 %
Backscattering DSA (systematic)	1 ± 0.002	0.2 %	3%
Tailing DSA (systematic)	1 ± 0.003	0.3 %	6.7 %
Tailing Si (systematic)	1 ± 0.003	0.3 %	6.7 %
^{226}Ra rate DSA (stochastic)	(0.01796 ± 0.00015) s-1	0.8 %	55.1 %
^{226}Ra rate Si (stochastic)	(0.9595 ± 0.0004) s-1	0.04 %	0.1 %
$\varepsilon_{P\alpha\text{-}226}$	0.502 ± 0.006	1.2 %	

Table 1: Full uncertainty budget of a typical IRSD type radon emanation source (uncertainties assigned are with expansion factor *k*=1. Main contributions of uncertainty, which are going to be improved, are due to the solid angle determination and the statistics of the ^{226}Ra activity determination using the DSA technique.

Conclusion Sources:

- ion implantation: + highest quality, least dependency
  - difficult to produce, expensive, up-to-now not active
- integrated Radon Source/Detector: + high quality, active, easy to produce, not too expensive, high sensitivity
  - slight dependence, more difficult to use
- Wish list: mass separated ion implanted IRSD with soft landing

Traceability through transfer standard instrument:

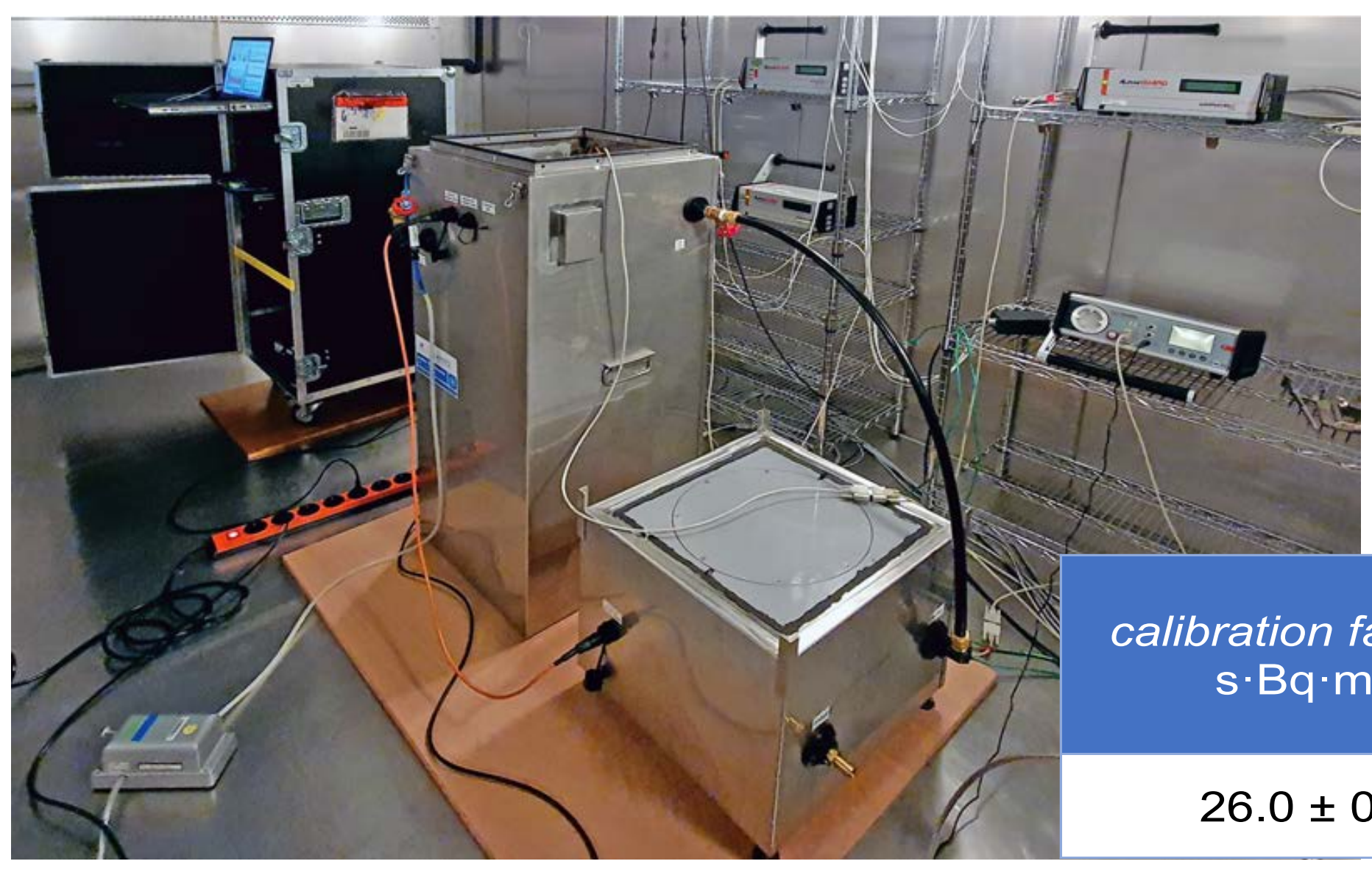


Figure 3: Overview of a calibration exercise at the PTB climate chamber with two possible scientific transfer standards for the traceable calibration of AMNS radon activity concentration monitors, as well as several different commercial indoor radon activity concentration monitors of type AlphaGurad in the shelves. From left to right, the ARMON system developed at UPC and the ANSTO 200 L system developed by ANSTO.

calibration factor k s·Bq·m^{-3}	*sensitivity k_c* (s·Bq·m^{-3})$^{-1}$	*intrinsic background in the chamber* s^{-1}
26.0 ± 0.5	0.0385 ± 0.0013	0.03107 ± 0.00015

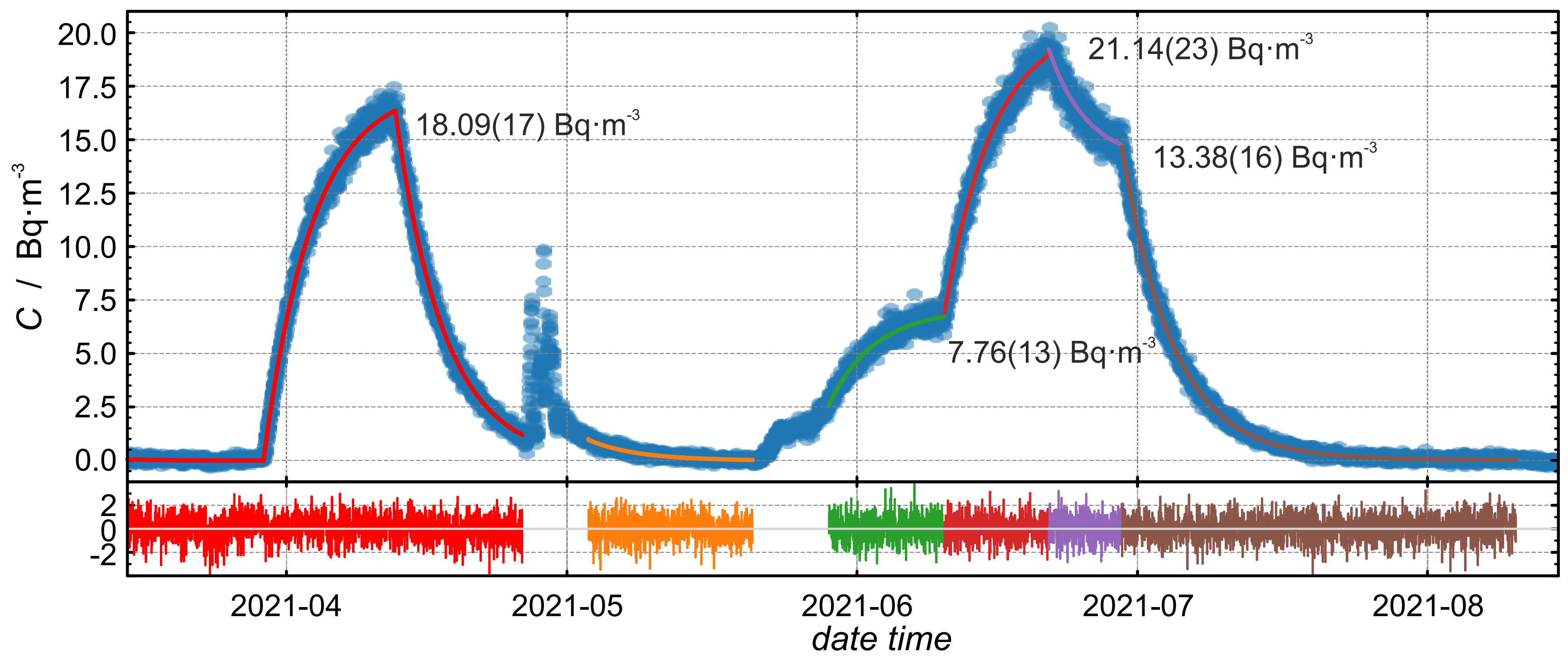


Figure 4: Calibration of a highly-sensitive radon detector (ANSTO 200 L) using different, well characterised radon emanation sources in a large volume climate chamber with traceable volume. Three different radon emanating calibration sources have been used in different combinations during this calibration run, indicated by the different colours in the figure. The y-axis presents the calibrated activity concentration *C*, detected by the detector. The respective radon activity concentration in equilibrium of the respective source in this volume with the assigned uncertainty (*k* = 1) is given by the values placed at the according positions.

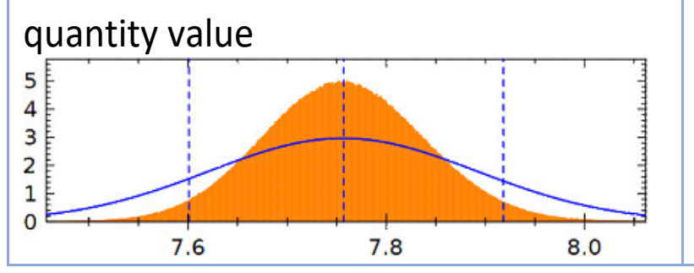
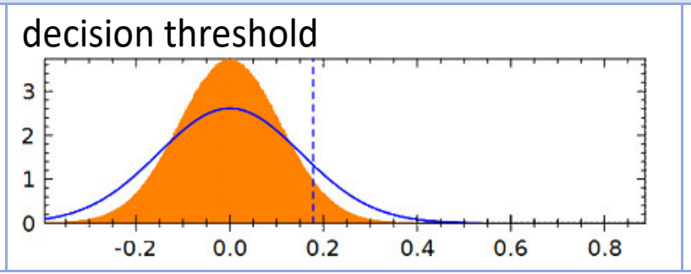
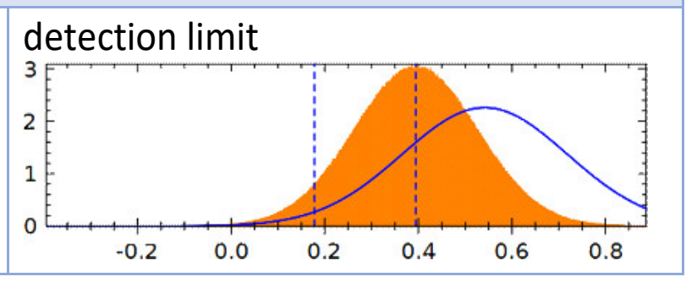
	decision threshold Bq·m^{-3}	*detection limit* Bq·m^{-3}
calculation method	0.26	0.55
MC simulation	0.18	0.40
quantity value	7.76 ± 0.13	7.76 ± 0.13
quantity value 	decision threshold 	detection limit 

Table 2: Determined values of decision threshold and detection limit for a possible transfer standard, regarding different techniques and according to ISO 11929:2012.

Publications:

- F. Mertes, N. Kneip, R. Heinke, T. Kieck, D. Studer, F. Weber, S. Röttger, A. Röttger, K. Wendt, C. Walther: **Ion implantation of ^{226}Ra for a primary ^{222}Rn emanation standard.** ARI 181 (2022) 110093, 31.12 (2021) https://doi.org/10.1016/j.apradiso.2021.110093
- F. Mertes, S. Röttger, A. Röttger: **Developement of ^{222}Rn Emanation Sources with Integrated Quasi 2π Active Monitoring.** International Journal of Environmental Research and Public Health IJERPH 2022, 19, 840, 13.01. (2022) https://doi.org/10.3390/ijerph19020840
- S. Röttger, A. Röttger, C. Grossi, A. Vargas, U. Karstens, G. Cinelli, E. Chung, D. Kikaj, C. Rennick, F. Mertes, I. Radulescu: **Radon metrology for use in climate change observation and radiation protection at the environmental level.** Advances in Geosciences, 57, 37–47, 10.03 (2022) https://doi.org/10.5194/adgeo-57-37-2022
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- C. Grossi, D. Arnold, J.A. Adame, I. López-Coto, J.P. Bolívar, B.A. de la Morena, A. Vargas, A.: **Atmospheric ^{222}Rn concentration and source term at El Arenosillo 100 m meteorological tower in southwest Spain.** Radiation Measurements, 47(2), 149–162 (2012) https://doi.org/10.1016/j.radmeas.2011.11.006

Conclusion traceability to the field:

The need to develop traceability for low radon activity concentrations has provided the impetus for a new technology for radionuclide sources with small or even very small activities (1 Bq·m^{-3} - 100 Bq·m^{-3}). This step prepares the way for environmental measurements in the field with uncertainties on a scale not previously achieved (<10 % for *k*=1): Although the measured quantity is now two orders of magnitude smaller, the uncertainties are comparable to those previously achieved in the medium activity range (100 Bq·m^{-3} - 300 Bq·m^{-3}). This result represents a milestone for the development of measurement technology for atmospheric measurement of radon activity concentration.

Two large scientific communities, climate change observation and radiological protection will benefit from the development. In the combat against both climate change and radiation exposure, measurements must be supported by traceable metrology infrastructure providing reliable data for scientists and decision makers. The EMPIR 19ENV01 traceRadon project supports the build-up of quality assured infrastructure in labs and in the field by which reliable data can be provided.

Funding:
This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme.