The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

Overview on Radon Metrology

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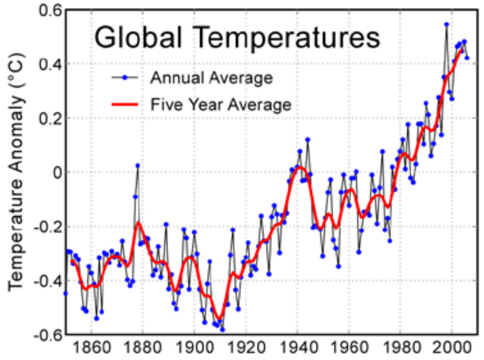
A. Röttger, Coordinator of 19ENV01 traceRadon | ICOS Science Conference 2022

Metrology: Why we need it

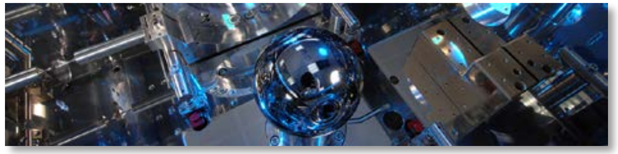
Sound and reliable measurements

Do you get what you paid for?

Are thresholds and regulations observed?



Should we trust data to inform decision-making?

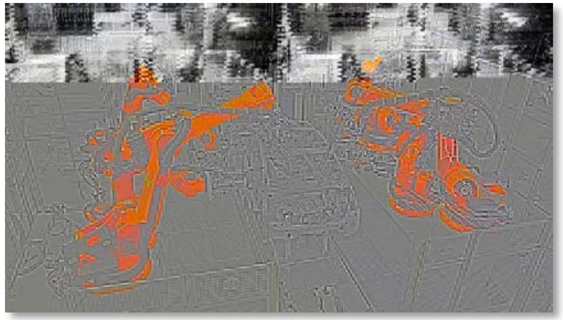


Are the constants constant?

Efficiency?

Quality monitoring

Competitive edge owing to precision



Technology transfer

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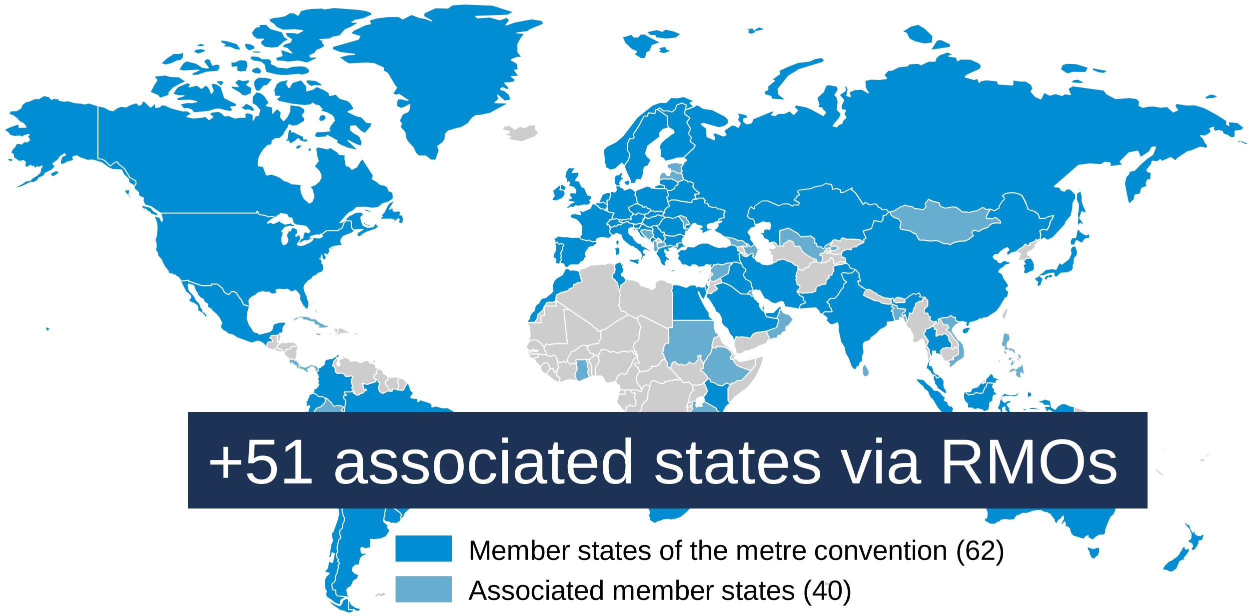
Metre convention



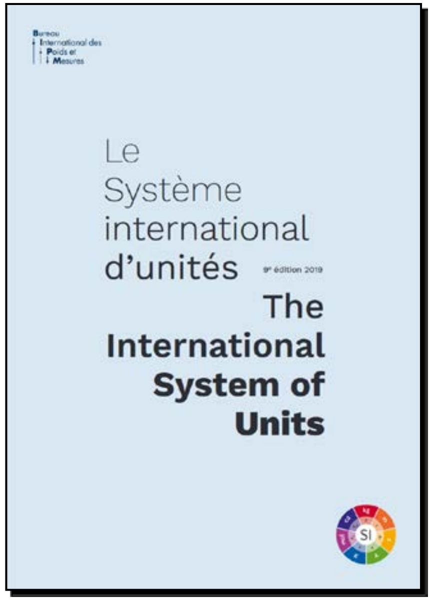
+51 associated states via RMOs

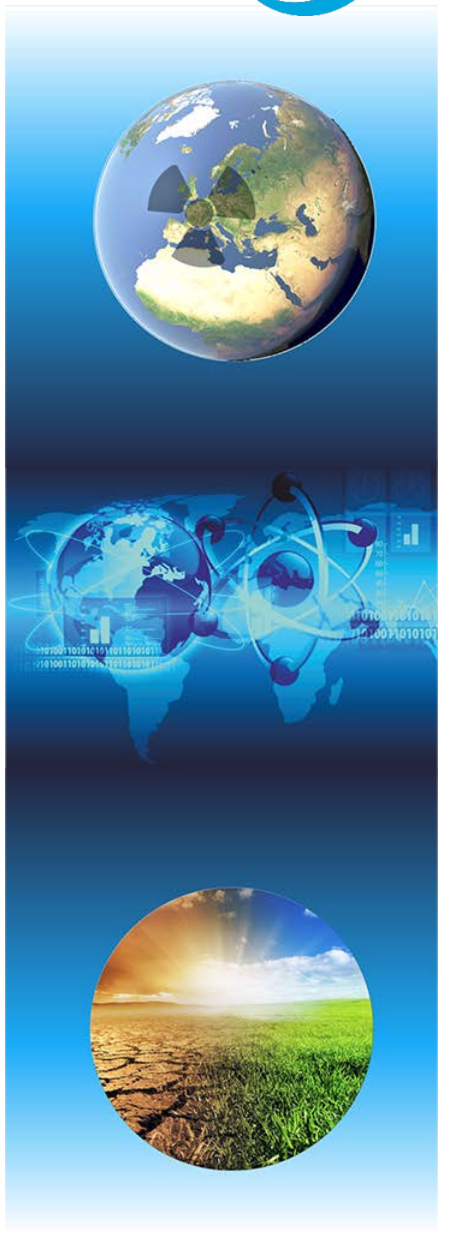
- Global metrology infrastructure
- Valid world-wide: **CIPM-MRA**
  - **102** members and associated states
  - **4** international organisations
  - includes **155** designated institutes (DI)

Basis of global trade

97,6% of global economy

Pillar of International Quality Infrastructure (QI)





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The SI System: Revised

26. General Conference on Weights and Measures
16th November 2018 (Versailles)

A **historic** moment!

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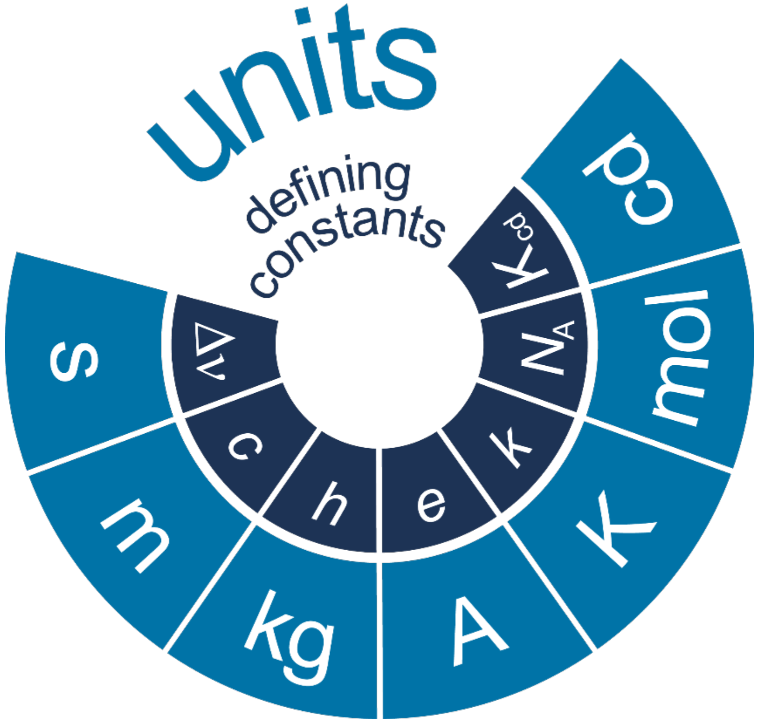
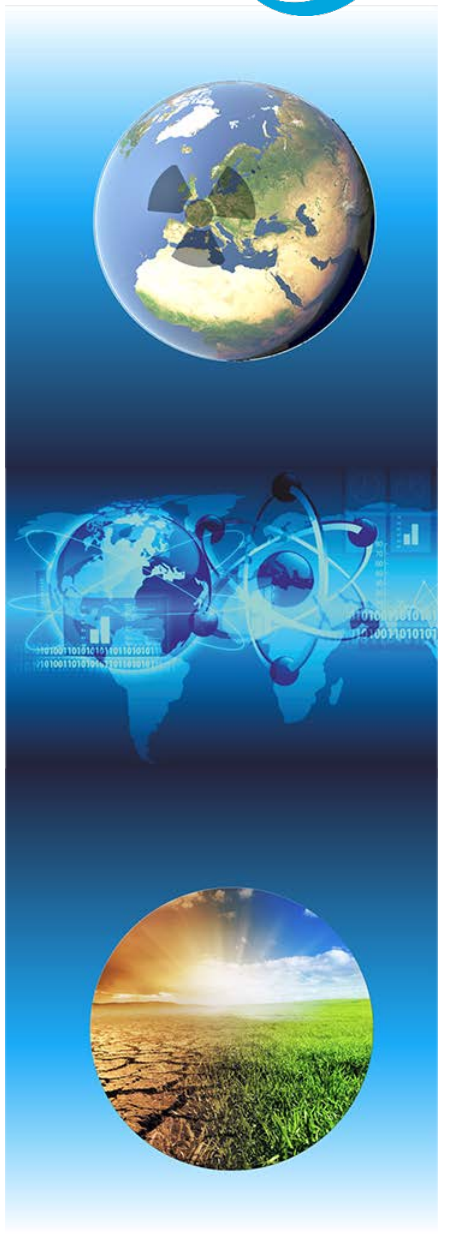
The SI System: Revised



Hyperfine transition freq. ^{133}Cs	$\Delta\nu$
Speed of light	c
Planck constant	h
Elementary charge	e
Boltzmann constant	k
Avogadro constant	N_A
Luminous efficacy	K_{cd}



Previously in the “old” SI:
Fix units → Measure constants of nature (uncertainty)

Since 20th May 2019 in the revised SI:
Fix values of constants → Derive units from constants

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RMO: BIPM & EURAMET

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EMPIR: Funding 2019, Start 2020

EUROPEAN METROLOGY PROGRAMME FOR INNOVATION AND RESEARCH (EMPIR)

EMPIR is the main programme for European research on metrology. It coordinates research projects to address grand challenges, while supporting and developing the SI system of measurement units.

EMPIR follows on from the successful European Metrology Research Programme (EMRP), which issued its final call for projects in 2013. There is an increased focus within EMPIR on innovation activities to target the needs of industry and accelerate the uptake of research outputs.

The inclusion of capacity-building activities in EMPIR is helping to bridge the gap between countries with emerging metrology systems and those with more developed capabilities.

To take part in EMPIR, please visit the EMPIR F

- see the current plan for calls in EMPIR
- submit ideas for metrology research in re
- submit project proposals in response to a
- register as an expert to help EURAMET e
- read guides to the call, evaluation, negoti

EMPIR EU

The EMPIR initiative is co-funded by the European Union's H
research and innovation programme and the EMPIR Particip

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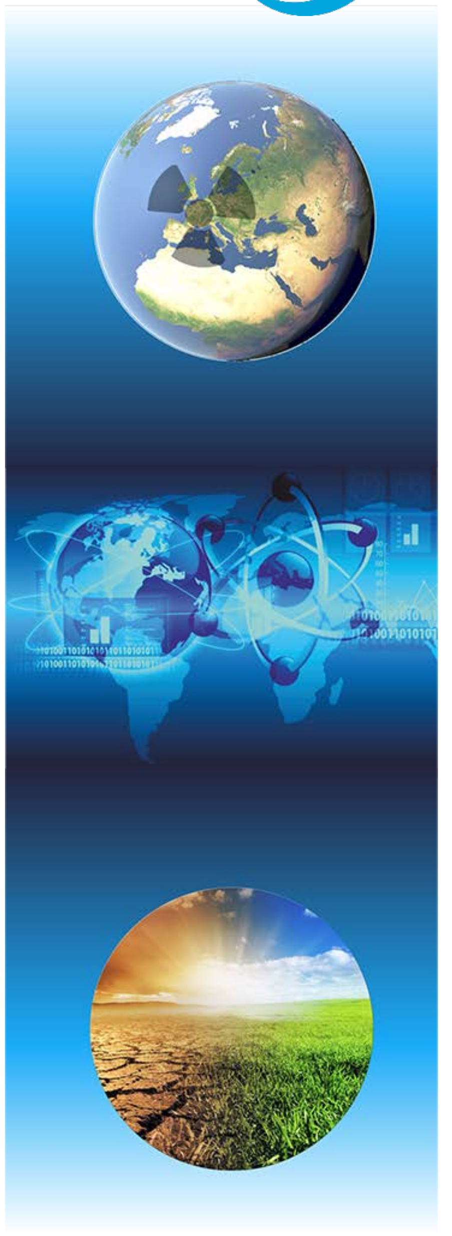
About EMPIR
EMPIR Calls and Projects
EMPIR Publicity
Events
EMRP
Strategic Research Agenda

CONTACT US

- Calls:
  - Health
  - Energy
  - Environment
  - Industry
  - Fundamental Metrology
  - Standardisation
  - Capacity Building
  - Dissemination



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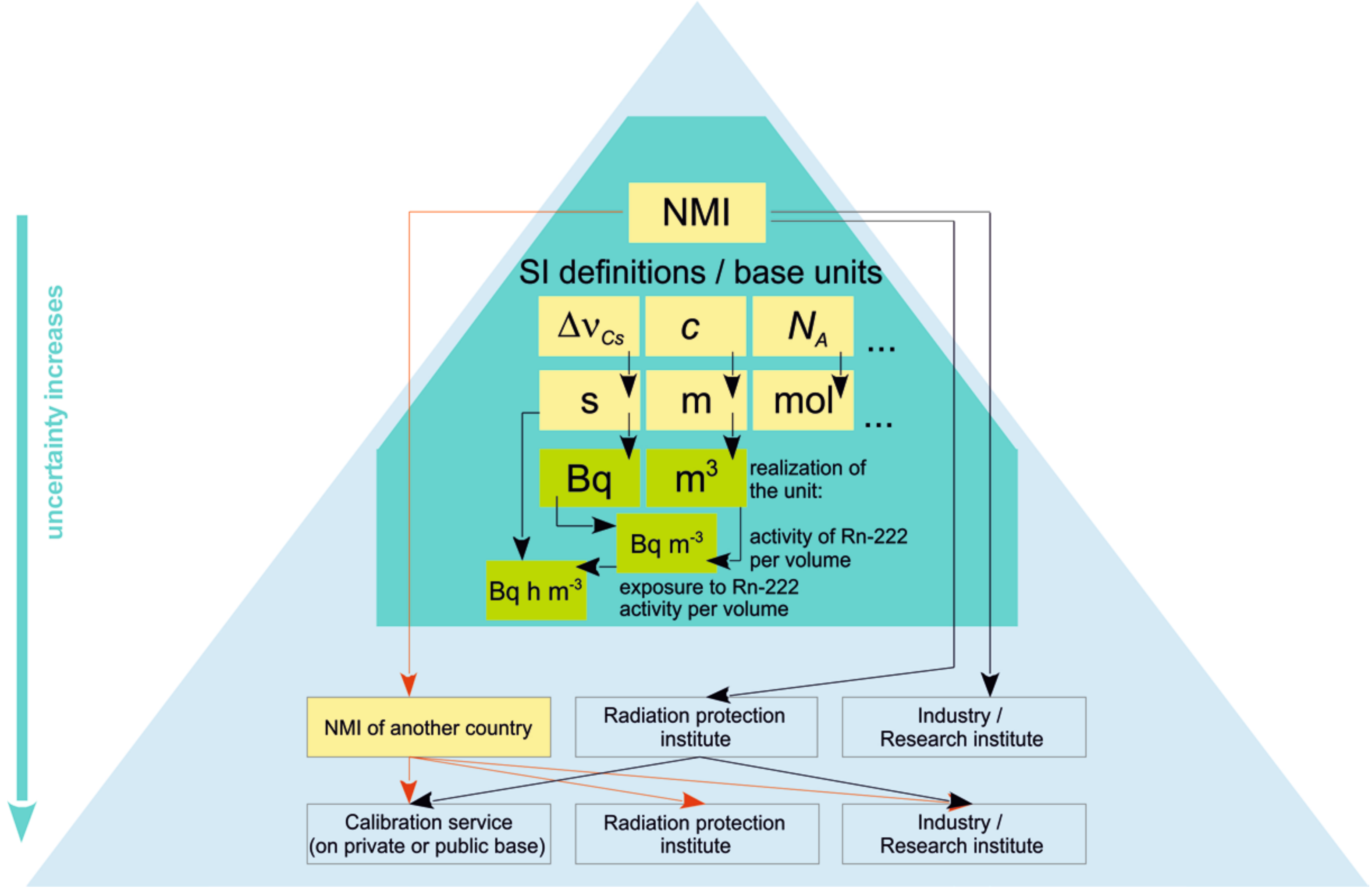
Traceable activity concentration



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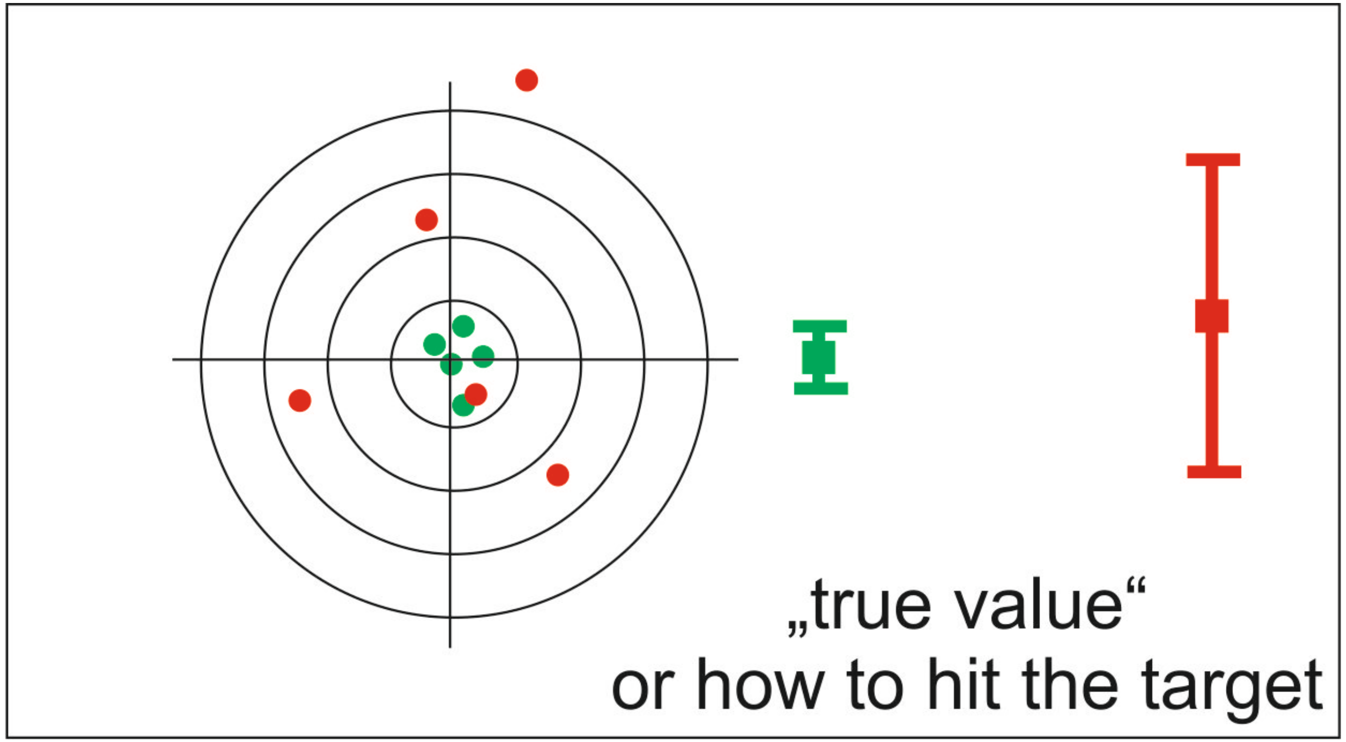
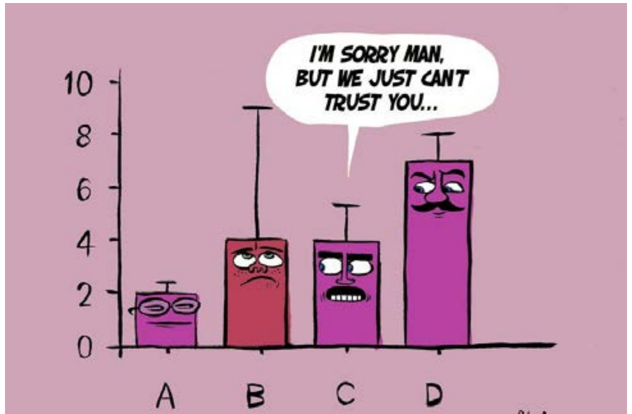
Traceability & Uncertainty

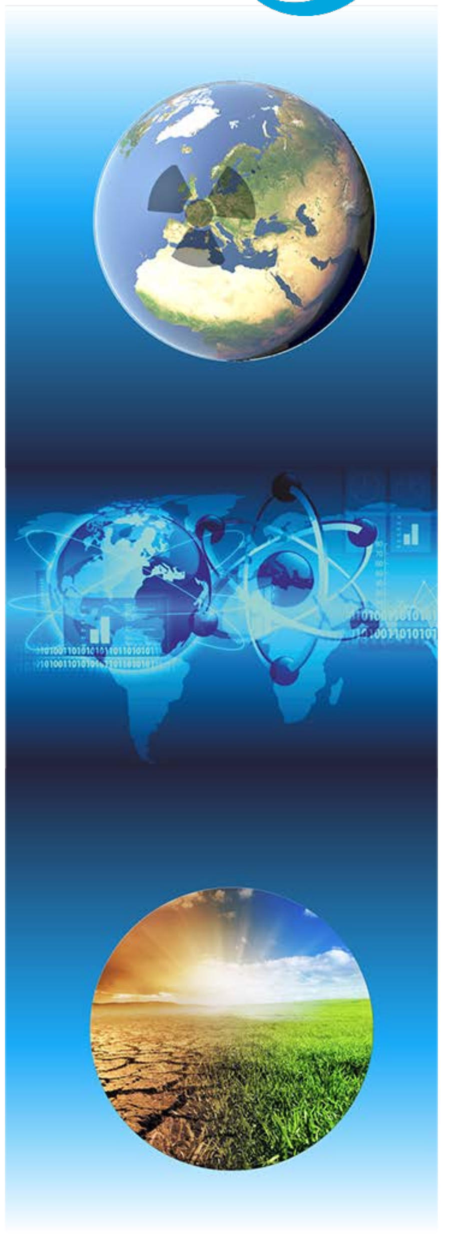
Motivation for dealing with uncertainty:

- compare results
- benchmark results
- accomplishment of decisions
- development of metrological infrastructure…





The Berkeley Science Review



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ISO and IEC

ISO/IEC 17025: General requirements for the competence of testing and calibration laboratories

- ISO/IEC 17025 was first released in 1999
- Based on ISO Guide 25:1990;
  Originally published in 1978, labeled a guide originally; CASCO (CASCO - Committee on conformity assessment) was not given the authority to publish International Standards until late 1980’s
- In 2005, ISO/IEC 17025 had minor revision to harmonize with ISO 9000:2000
- ISO/IEC 17025 was now 16 years old: Finally international majority for revision
- New in 2017

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ISO and IEC

ISO/IEC 17025: Why is it so important?

The CIPM (International Committee for Weights and Measures) agreed on a “Mutual Recognition Arrangement” (MRA) with the following objectives:

- to establish the degree of equivalence of national measurement standards maintained by NMIs;
- to provide for the mutual recognition of calibration and measurement certificates issued by NMIs;
- and to provide governments and other parties with a secure technical foundation for wider agreements related to international trade, commerce and regulatory affairs.

The process through whic

- international comparisons of
- regional comparisons of me
- other regional or bilateral co
- review of the technical comp
- the implementation and revi

The participating institutes are required to operate an appropriate quality management system which is subject to an approval process run by the relevant regional metrology organization.

The accepted standards are ISO/IEC 17025 and ISO Guide 34 (for those institutes producing or assigning values to reference materials).

http://www.bipm.org/en/cipm-mra/approval-process.html

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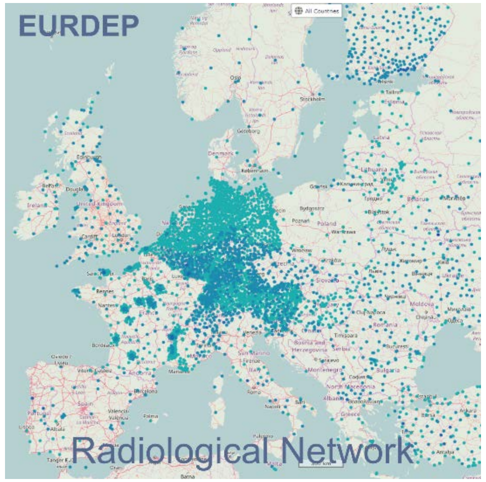
New traceablity needed?



Climate change is one of the greatest challenges of our time.

The temperature rise of the atmosphere of our planet, due to the greenhouse effect, is caused by the increase of GHG emissions.

- ICOS: Monitoring of GHG emissions, the dispersion of GHGs and the resulting GHG concentrations in air, is of utmost importance for appropriate climate change mitigation measures.
- EURDEP: Collection and exchange of radiological monitoring data between participating countries of the radiation in the environment.

Both networks could profit from radon measurements at the outdoor level. But **traceability to the SI system** is not established yet.

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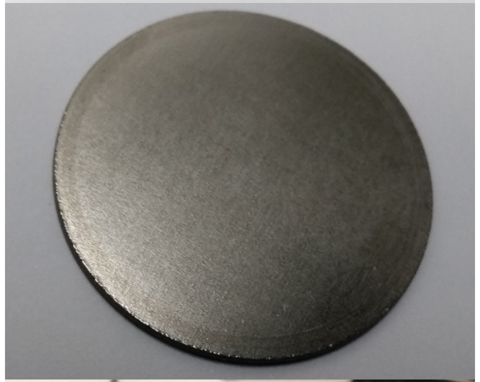
New Sources

Electro-deposited

Deposition at
30 V < U < 200 V

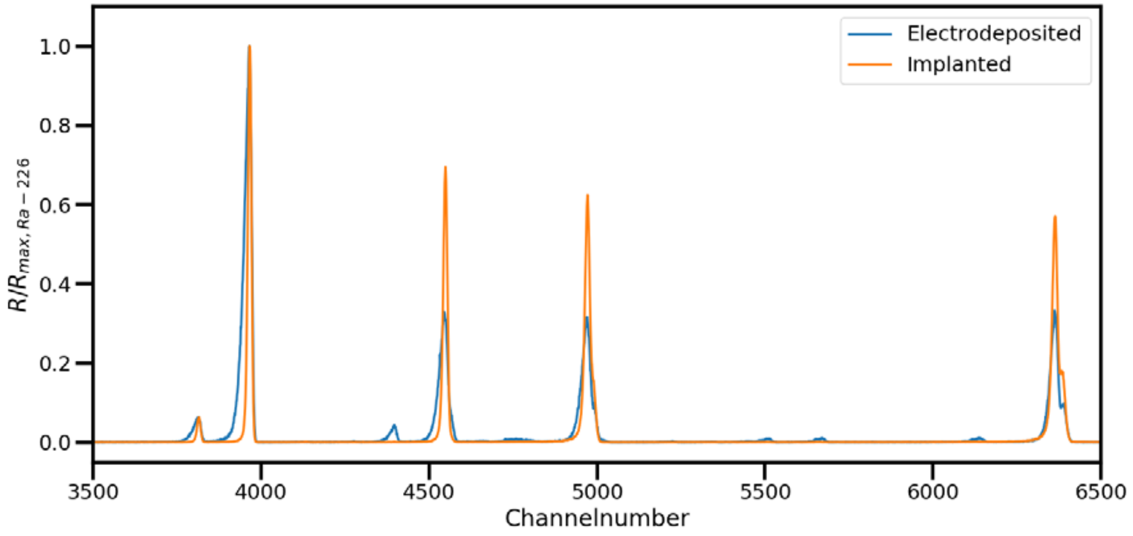


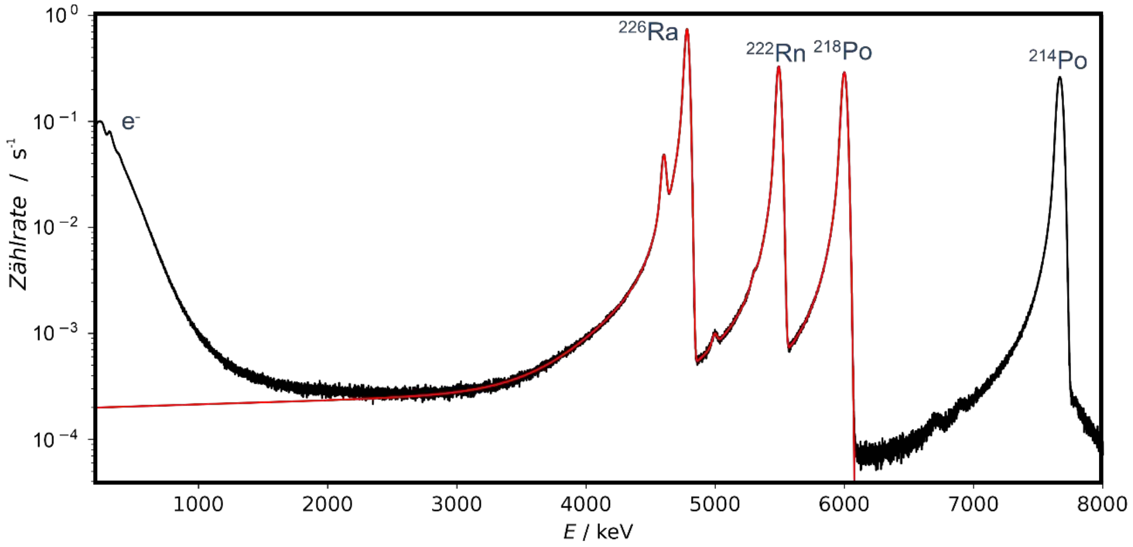
Implanted

Implantation of Ra-226 into W / Al after mass separation

PIPS

450 mm², 300 µm with 150 Bq ^{226}Ra layer





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Source detector combination

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International Journal of *Environmental Research and Public Health*

MDPI

Article

Development of ^{222}Rn Emanation Sources with Integrated Quasi 2π Active Monitoring

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Abstract: In this work, a novel approach for the standardization of low-level ^{222}Rn emanation is presented. The technique is based on the integration of a ^{222}Rn source, directly, with an α-particle detector, which allows the residual ^{222}Rn to be continuously monitored. Preparation of the device entails thermal physical vapor deposition of $^{226}RaCl_2$ directly onto the surface of a commercially available ion implanted Si-diode detector, resulting in a thin-layer geometry. This enables continuous collection of well resolved α-particle spectra of the nuclei, decaying within the deposited layer, with a detection efficiency of approximately 0.5 in a quasi 2π geometry. The continuously sampled α-particle spectra are used to derive the emanation by statistical inversion. It is possible to achieve this with high temporal resolution due to the small background and the high counting efficiency of the presented technique. The emanation derived in this way exhibits a dependence on the relative humidity of up to 15% in the range from 20% rH to 90% rH. Traceability to the SI is provided by employing defined solid-angle α-particle spectrometry to characterize the counting efficiency of the modified detectors. The presented technique is demonstrated to apply to a range covering the release of at least 1 to 210 ^{222}Rn atoms per second, and it results in SI-traceable emanation values with a combined standard uncertainty not exceeding 2%. This provides a pathway for the realization of reference atmospheres covering typical environmental ^{222}Rn levels and thus drastically improves the realization and the dissemination of the derived unit of the activity concentration concerning ^{222}Rn in air.

Keywords: ^{222}Rn emanation; physical vapor deposition; silicon detectors

check for updates

Citation: Mertes, F.; Röttger, S.; Röttger, A. Development of ^{222}Rn Emanation Sources with Integrated Quasi 2π Active Monitoring. *Int. J. Environ. Res. Public Health* **2022**, *19*, 840. https://doi.org/10.3390/ijerph19020840

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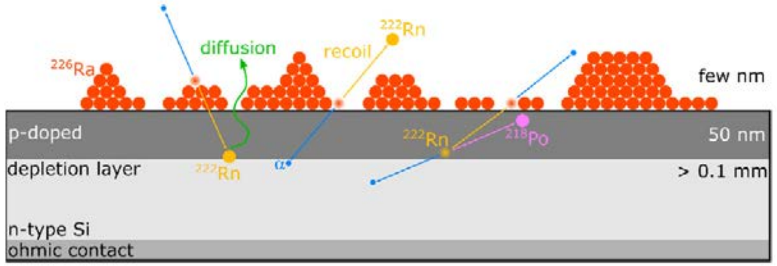
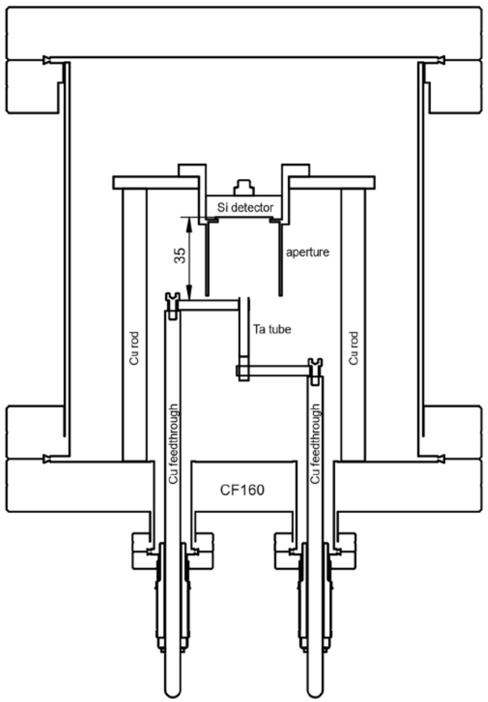
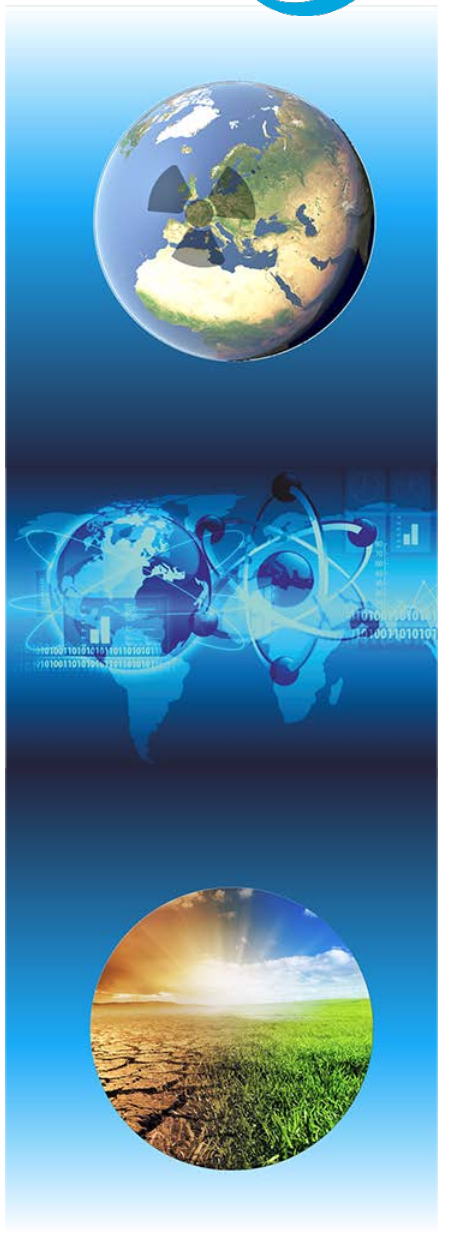
https://www.mdpi.com/1660-4601/19/2/840







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Established traceability for devices

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Measurement Science and Technology
Meas. Sci. Technol. 32 (2021) 124008 (13pp)
https://doi.org/10.1088/1361-6501/ac298d

New metrology for radon at the environmental level

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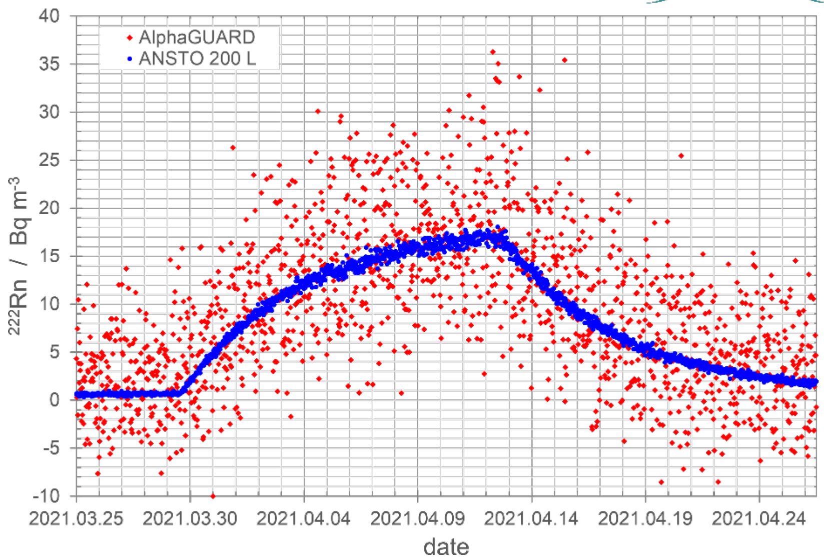
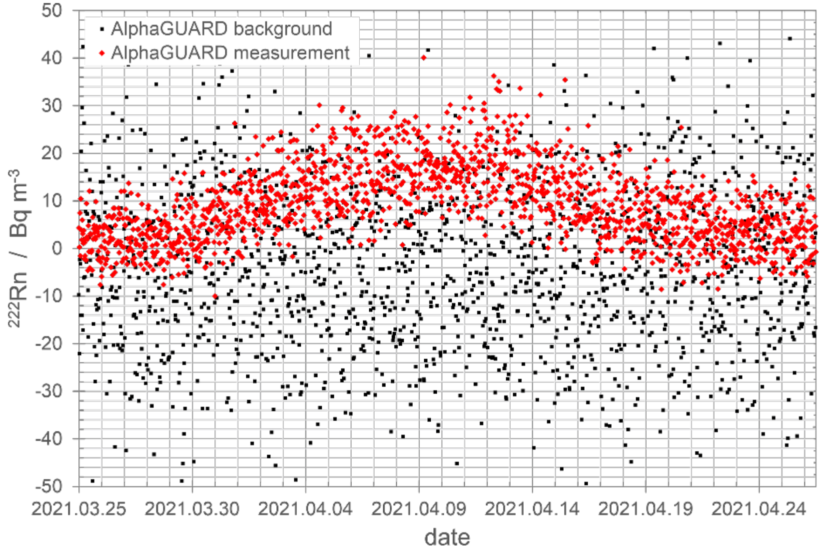
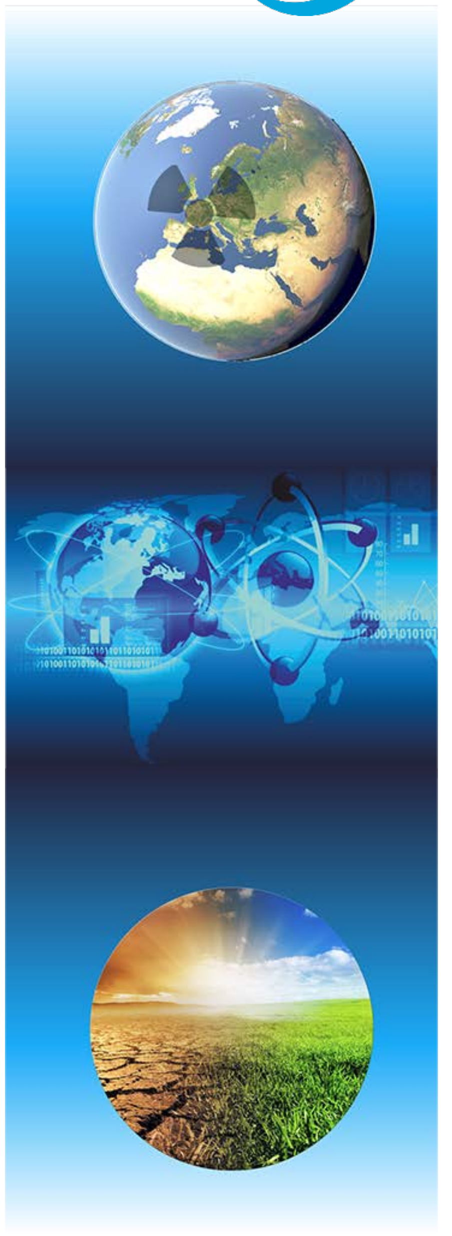
Received 21 June 2021, revised 11 August 2021
Accepted for publication 23 September 2021
Published 8 October 2021

CrossMark







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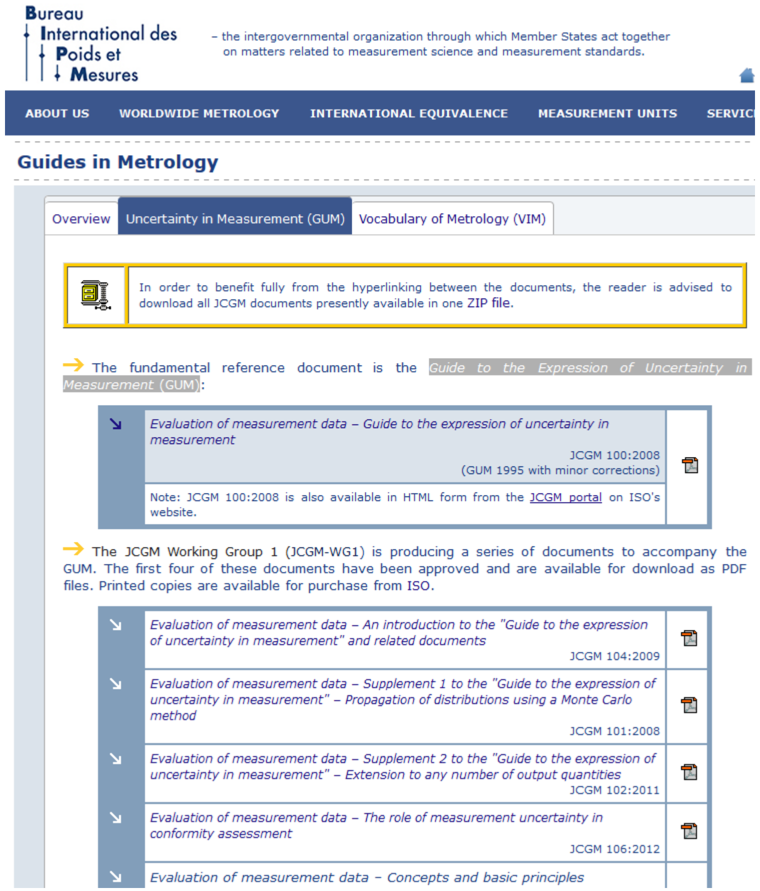
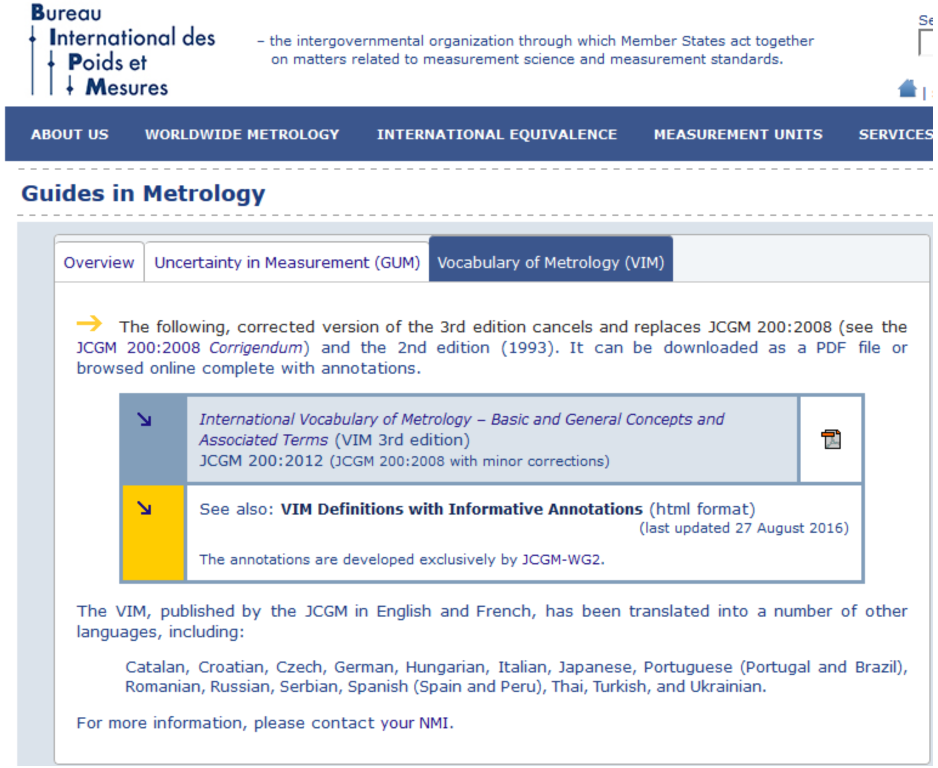
GUM & VIM

ISO/IEC 17025 is fundamental for the quality assurance, it is supported by the Guide to the Expression of Uncertainty in Measurement (GUM) and the International Vocabulary of Metrology (VIM)



Free download of GUM and VIM!

http://www.bipm.org/en/publications/guides/#gum



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Formulation and calculation

Uncertainty is of fundamental importance

- Need for **concepts and basic principles**
- Need for **procedures**: Stages of uncertainty evaluation!
  - ✓ The formulation stage
  - ✓ The calculation stage

Doing measurements is obtaining random numbers from a distribution.

All input quantities and the measurand are a sample from a probability distribution.

Example (formulation stage):

$$C_i = k_k\ (C_m - C_{bg})$$

Output quantity

Input quantities

C_i	activity concentration	Probability distribution
C_m	measured activity concentration (indication value)	normal
C_{bg}	background reading	rectangular
k_k	calibration factor	normal

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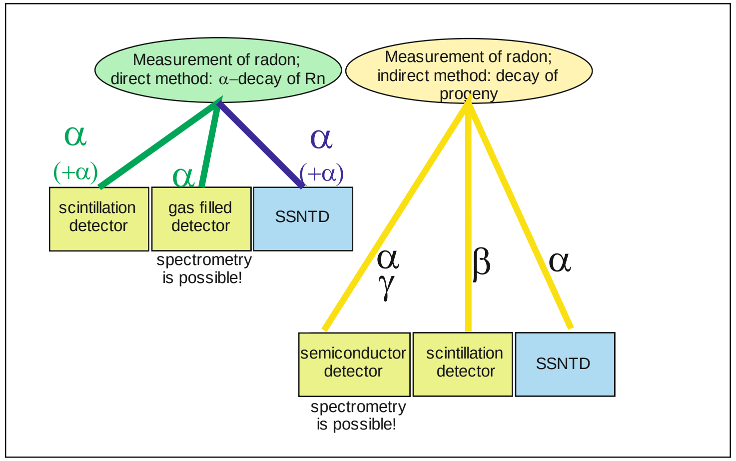
Uncertainty budget

Field measurement of Rn-222



Determination of C or $\frac{\int C \cdot dt}{t}$

Traceable calibration

$C = \frac{A}{V}$

$$k_c = \frac{1}{k}; \quad k = \frac{c}{(\Delta M - \Delta M_0)}; \qquad \Delta M = \frac{M}{\Delta t}; \qquad \Delta M_0 = \frac{M_0}{\Delta t};$$

$$C = C_s - C_{bg} - \Delta C; \qquad C_s = \frac{\chi_{1220}\, A_{1220}}{V}$$

quantity	value	standard uncertainty	distribution
A_{Ra1133}	603 Bq	3 Bq	normal
c_{1133}	0.273	$4 \cdot 10^{-3}$	normal
M	593	1	normal
M_0	55.92	0.13	rectangular
Δt	1800 s	1 s	normal
ΔM	0.322530 s^{-1}	$6 \cdot 10^{-4}$ s^{-1}	
ΔM_0	0.0310702 s^{-1}	$8 \cdot 10^{-5}$ s^{-1}	
C_s	7.76 $Bq \cdot m^{-3}$	0.12 $Bq \cdot m^{-3}$	
C_{bg}	0.0 $Bq \cdot m^{-3}$	$5.77 \cdot 10^{-3}$ $Bq \cdot m^{-3}$	rectangular
ΔC	0.0 $Bq \cdot m^{-3}$	0.05 $Bq \cdot m^{-3}$	
V_{RNK}	21.2240 m^{-3}	0.0163 m^{-3}	normal
k_c	0.0385 1/(s·$Bq \cdot m^{-3}$)	$7 \cdot 10^{-4}$ 1/(s·$Bq \cdot m^{-3}$)	

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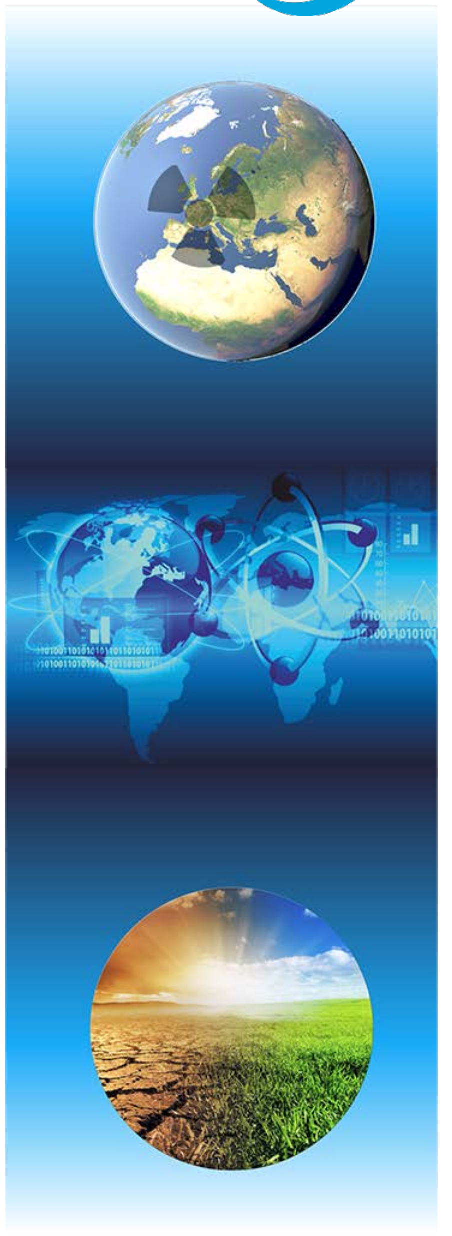
Summary

The key targets to be reached by the end of this project (and to be exploited in the 5 years that follow the end of the project) are as follows:

- **New SI traceability** for measurement quantities used in climate observation and radiation protection;
- **New customer calibration services** for new types of measurement and new types of device. To develop a **first standard protocol for the application of the radon tracer method** (RTM) to enable retrieval of greenhouse gas fluxes at atmospheric climate gas monitoring stations and to use radon flux data for the identification of **Radon Priority Areas** (RPA);
- To **validate current radon flux models and inventories** by the new traceable measurements of radon activity concentration and radon flux. To **support the validation with dosimetric and spectrometric data from the radiological early warning networks** in Europe;
- To provide easy to use **dynamic radon activity concentration and radon flux maps** for climate change research and radiation protection in line with Council Directive 2013/59/EURATOM, including their use to identify RPA and radon wash-out peaks;
- To facilitate the **take up of the technology and measurement infrastructure**.



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Scientific details: Publications

1. Mertes, F et. al.: D3.3 Approximate sequential Bayesian filtering to estimate Rn-222 emanation from Ra-226 sources from spectra, https://doi.org/10.5162/SMSI2021/D3.3
2. Röttger, A. *et al: New metrology for radon at the environmental level 2021 Meas. Sci. Technol.* 32, 124008, https://doi.org/10.1088/1361-6501/ac298d
3. Radulescu, I et al.: Inter-comparison of commercial continuous radon monitors responses, Nuclear Instruments and Methods in Physics Research Section A, Volume 1021, 2022, 165927, https://doi.org/10.1016/j.nima.2021.165927
4. Mertes, F. et. al.: Ion implantation of ^{226}Ra for a primary ^{222}Rn emanation standard, Applied Radiation and Isotopes, Volume 181, March 2022, 110093, https://doi.org/10.1016/j.apradiso.2021.110093
5. Čeliković, I. et. al.: Outdoor Radon as a Tool to Estimate Radon Priority Areas - A Literature Overview, Int. J. Environ. Res. Public Health 2022, 19, 662, https://doi.org/10.3390/ijerph19020662
6. Mertes, F et. al.: Development of 222Rn emanation sources with integrated quasi 2π active monitoring, Int. J. Environ. Res. Public Health 2022, 19, 840, https://doi.org/10.3390/ijerph19020840
7. Rábago, D. et al.: Intercomparison of Radon Flux Monitors at Low and at High Radium Content Areas under Field Conditions, Int. J. Environ. Res. Public Health 2022, 19, 4213, https://doi.org/10.3390/ijerph19074213
8. Röttger, S. et al: Radon metrology for use in climate change observation and radiation protection at the environmental level, Adv. Geosci., 57, 37–47, 2022, https://doi.org/10.5194/adgeo-57-37-2022
9. Chambers, S. et al: Portable two-filter dual-flow-loop 222Rn detector: stand-alone monitor and calibration transfer device, Adv. Geosci., 57, 63–80, 2022, https://doi.org/10.5194/adgeo-57-63-2022

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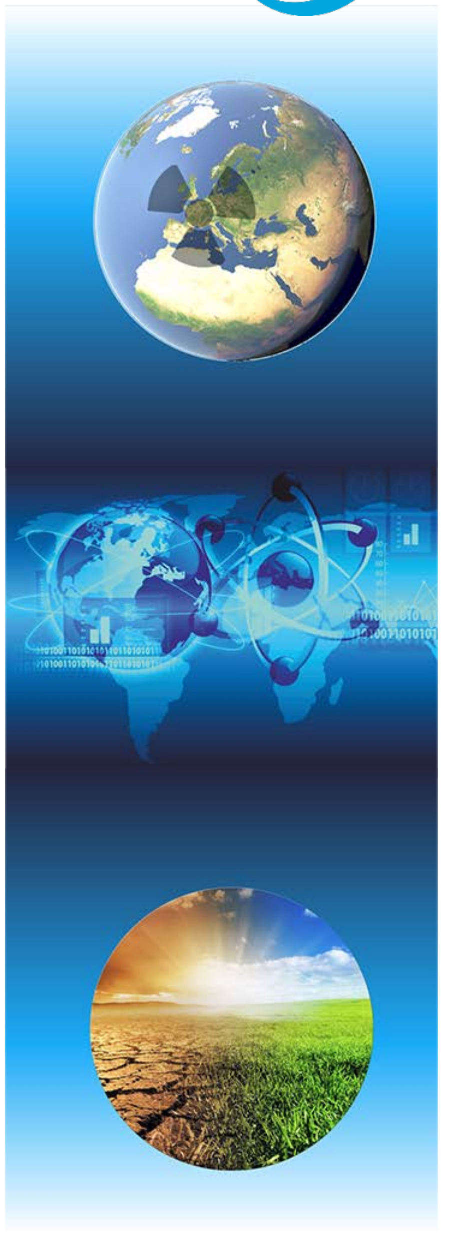

*This project 19ENV01 traceRadon has received funding from the EMPIR programme co-financed by the Participating States and from the European Union's Horizon 2020 research and innovation programme. **19ENV01 traceRadon** denotes the EMPIR project reference.*

Thanks…

… to the 18 traceRadon-project partners:

… to the 13 traceRadon-project collaborators:

… to the traceRadon-project Stakeholder Committee, Stakeholders, MSU, EURAMET,

… and for your attention!