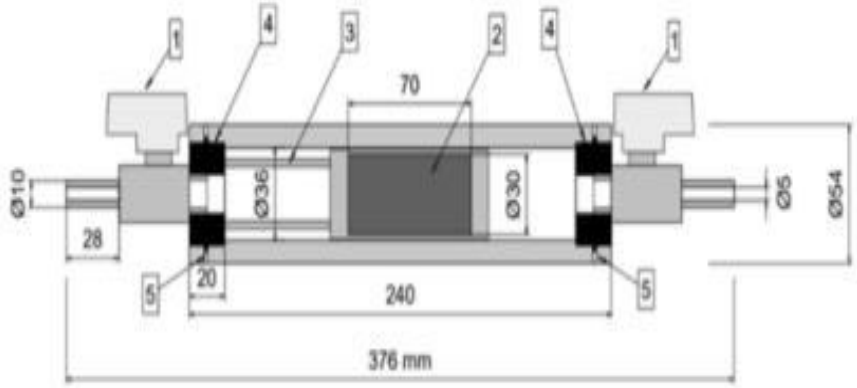
Validation of Traceability of European Radon Calibration Facilities

Monika Mazánová, CMI

CMI and ^{222}Rn Source

fundamental metrology transfer of units legal metrology



1 – ball valve
2 – emanator
3 – holder
4 – flange
5 – retaining screw
Material: Dural, brass, stainless steel, Teflon, epoxy resin

Questionnaire

Each institute puts its own letterhead to this box and sends it in its own name!

EMPIR

Joint Research Project 16ENV10 MetroRADON "Metrology for radon monitoring"

Questionnaire

to selected European calibration facilities for radon concentration measurement in air

Conducted within the Joint Research Project 16ENV10 (metrology for radon monitoring) in the framework of EMPIR (European Metrology Programme for Innovation and Research) under the auspice of EURAMET

Background

The member states of the European Union together with the European Commission are funding research in the field of metrology (measurement science). This is conducted under the EMPIR-programme (European Metrology Programme for Innovation and Research), which is administered by EURAMET. The European Association of National Metrology Institutes (EURAMET) is a Regional Metrology Organisation (RMO) of Europe. It coordinates the cooperation of National Metrology Institutes (NMI) of Europe in fields like research in metrology, traceability of measurements to the SI units, international recognition of national measurement standards and related Calibration and Measurement Capabilities (CMC) of its members. Through knowledge transfer and cooperation among its members, EURAMET facilitates the development of the national metrology infrastructures. EURAMET is responsible for the elaboration and execution of EMPIR which is designed to encourage collaboration between European National Metrology Institutes (NMIs) and partners in industry, environment, health or academia. The programme funds joint research projects in specific fields of metrology with over 50 projects selected for funding so far and many more expected over the coming years "(https://www.euramet.org/about-euramet/)".

In the 2016 call metrology for environment a consortium of European institutes (composed of BEV/PTP, Austria; BFKH, Hungary; CEA, France; CMI, Czech Republic; IFIN-HH, Romania; PTB, Germany; STUK, Finland; VINS, Serbia; AGES, Austria; BfS, Germany; CLOR, Poland; IRSN, France; JRC, European Commission; SURO, Bulgaria; SUJCHBO, Czech Republic; UC, Spain; METAS, Switzerland) were granted 3-year funding for a project named MetroRADON. For more information visit: www.metroradon.eu.

A main objective of this project is to develop reliable techniques and methodologies to enable traceable radon activity concentration measurements and calibrations at low radon concentrations (100 - 300 Bq·m^{-3}) and high radon concentrations (300 – 10.000 Bq·m^{-3}).

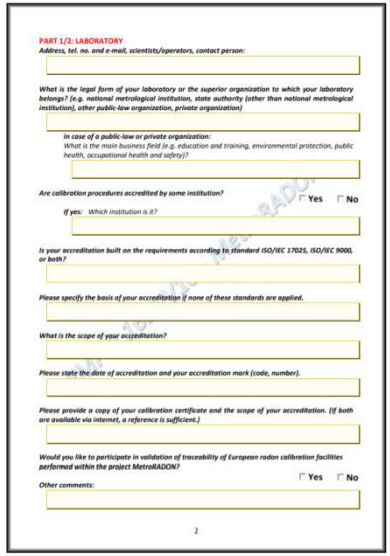
Objective of the questionnaire and the related study

The main objective of this questionnaire is to be able to serve European radon calibration facilities in a better way by identifying needs and work on solutions to that. We are very open to your requests and suggestions on what needs to be improved in your company with regards to measurements and monitoring of radon. It is much appreciated if you describe more than is asked for and particularly if you can bring up issues that you need external support to improve.

Confidentiality

Each partner institute is in charge of collecting data from European radon calibration facilities in its country (and in some cases neighbouring country). The data will then be transferred to the BFKH, Hungary, who will compile the data. They will ensure that data is handled confidentially and that individual answers will not be distributed further.

1



PART 1/2: LABORATORY

Address, tel. no. and e-mail, scientists/operators, contact person:

What is the legal form of your laboratory or the superior organization to which your laboratory belongs? (e.g. national metrological institution, state authority (other than national metrological institution), other public-law organization, private organization)

In case of a public-law or private organization:
What is the main business field (e.g. education and training, environmental protection, public health, occupational health and safety)?

Are calibration procedures accredited by some institution? ☐ Yes ☐ No

If yes: *Which institution is it?*

Is your accreditation built on the requirements according to standard ISO/IEC 17025, ISO/IEC 9000, or both?

Please specify the basis of your accreditation if none of these standards are applied.

What is the scope of your accreditation?

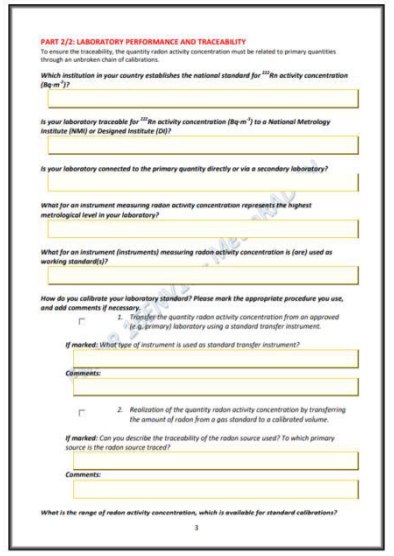
Please state the date of accreditation and your accreditation mark (code, number).

Please provide a copy of your calibration certificate and the scope of your accreditation. (If both are available via internet, a reference is sufficient.)

Would you like to participate in validation of traceability of European radon calibration facilities performed within the project MetroRADON? ☐ Yes ☐ No

Other comments:

2



PART 2/2: LABORATORY PERFORMANCE AND TRACEABILITY

To ensure the traceability, the quantity radon activity concentration must be related to primary quantities through an unbroken chain of calibrations.

Which institution in your country establishes the national standard for ^{222}Rn activity concentration (Bq·m^{-3})?

Is your laboratory traceable for ^{222}Rn activity concentration (Bq·m^{-3}) to a National Metrology Institute (NMI) or Designed Institute (DI)?

Is your laboratory connected to the primary quantity directly or via a secondary laboratory?

What for an instrument measuring radon activity concentration represents the highest metrological level in your laboratory?

What for an instrument (instruments) measuring radon activity concentration is (are) used as working standard(s)?

How do you calibrate your laboratory standard? Please mark the appropriate procedure you use, and add comments if necessary.

☐ 1. *Transfer the quantity radon activity concentration from an approved (e.g. primary) laboratory using a standard transfer instrument.*

If marked: *What type of instrument is used as standard transfer instrument?*

Comments:

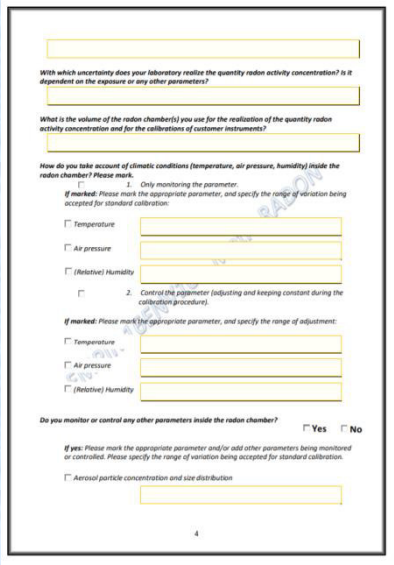
☐ 2. *Realization of the quantity radon activity concentration by transferring the amount of radon from a gas standard to a calibrated volume.*

If marked: *Can you describe the traceability of the radon source used? To which primary source is the radon source traced?*

Comments:

What is the range of radon activity concentration, which is available for standard calibrations?

3



With which uncertainty does your laboratory realize the quantity radon activity concentration? Is it dependent on the exposure or any other parameters?

What is the volume of the radon chamber(s) you use for the realization of the quantity radon activity concentration and for the calibrations of customer instruments?

How do you take account of climatic conditions (temperature, air pressure, humidity) inside the radon chamber? Please mark.

☐ 1. *Only monitoring the parameter.*

If marked: *Please mark the appropriate parameter, and specify the range of variation being accepted for standard calibration:*

☐ *Temperature*
☐ *Air pressure*
☐ *(Relative) Humidity*

☐ 2. *Control the parameter (adjusting and keeping constant during the calibration procedure).*

If marked: *Please mark the appropriate parameter, and specify the range of adjustment:*

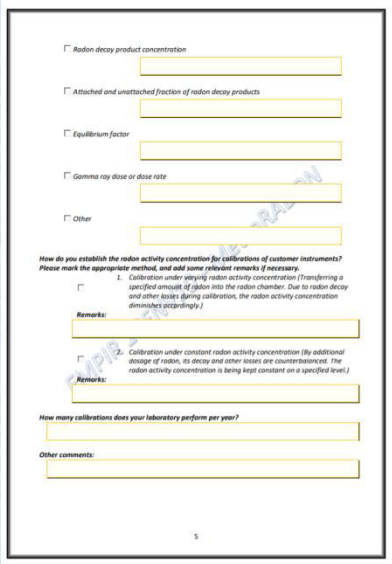
☐ *Temperature*
☐ *Air pressure*
☐ *(Relative) Humidity*

Do you monitor or control any other parameters inside the radon chamber? ☐ Yes ☐ No

If yes: *Please mark the appropriate parameter and/or add other parameters being monitored or controlled. Please specify the range of variation being accepted for standard calibration.*

☐ *Aerosol particle concentration and size distribution*

4



☐ *Radon decay product concentration*
☐ *Attached and unattached fraction of radon decay products*
☐ *Equilibrium factor*
☐ *Gamma ray dose or dose rate*
☐ *Other*

How do you establish the radon activity concentration for calibrations of customer instruments? Please mark the appropriate method, and add some relevant remarks if necessary.

☐ 1. *Calibration under varying radon activity concentration (Transferring a specified amount of radon into the radon chamber. Due to radon decay and other losses during calibration, the radon activity concentration diminishes accordingly.)*

Remarks:

☐ 2. *Calibration under constant radon activity concentration (By additional dosage of radon, its decay and other losses are counterbalanced. The radon activity concentration is being kept constant on a specified level.)*

Remarks:

How many calibrations does your laboratory perform per year?

Other comments:

5

Interlaboratory Comparisons

- 300 Bq/m^3 to 10 000 Bq/m^3 (coordinator BfS)
- 100 Bq/m^3 to 300 Bq/m^3 (coordinator SUJCHBO)
- Determine degree of agreement in realization of activity concentration of radon-222 in air in facilities of participating laboratories or in reference laboratory

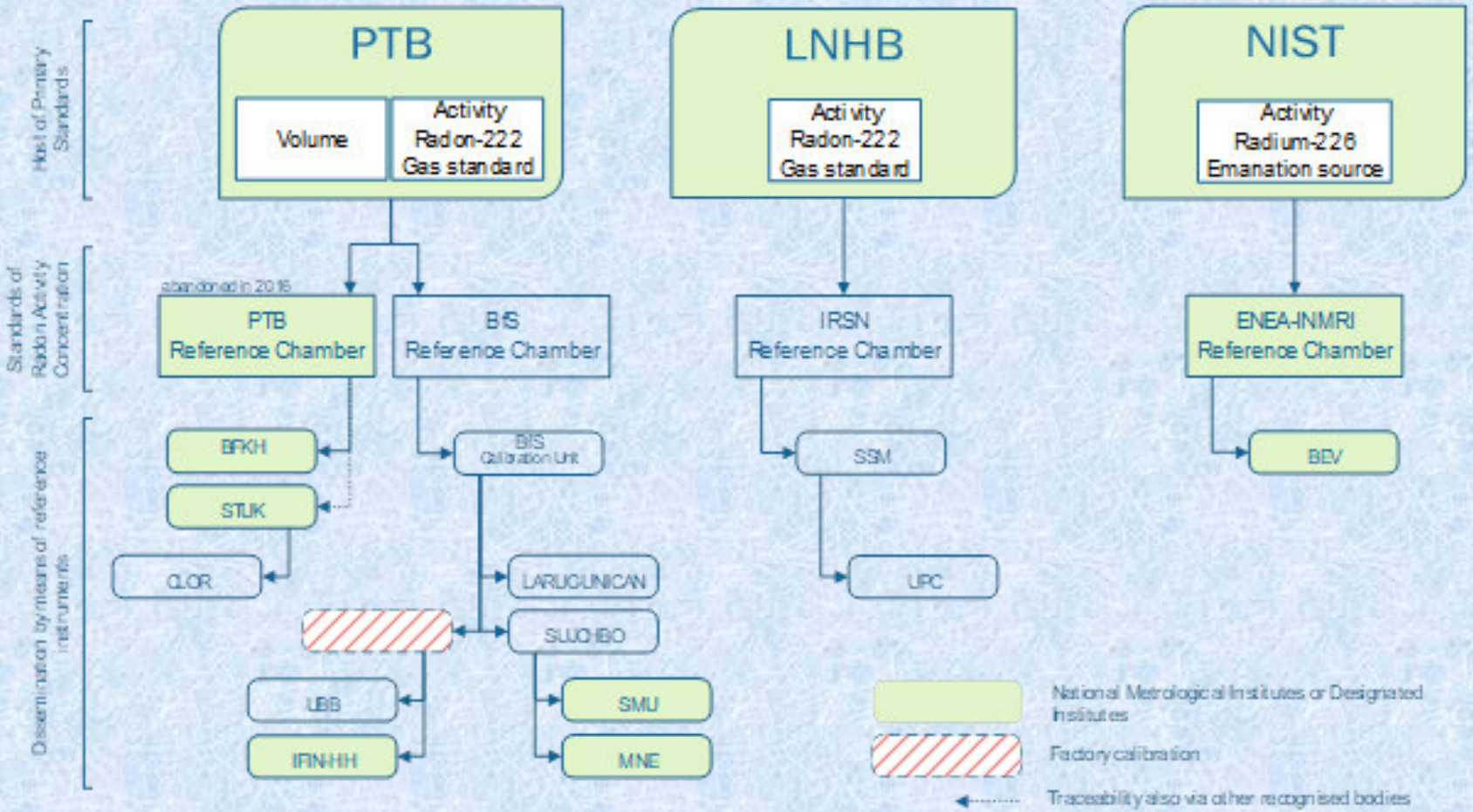
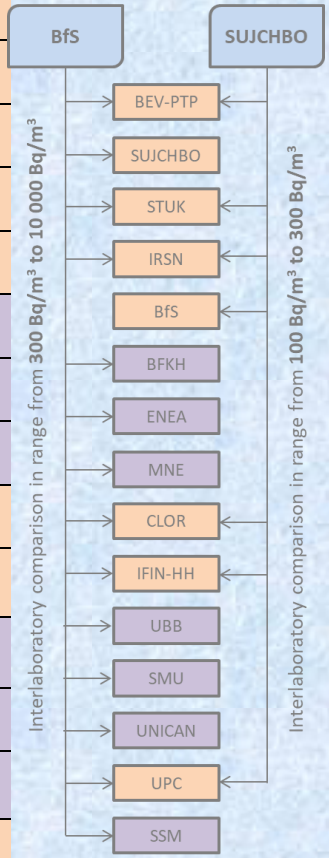
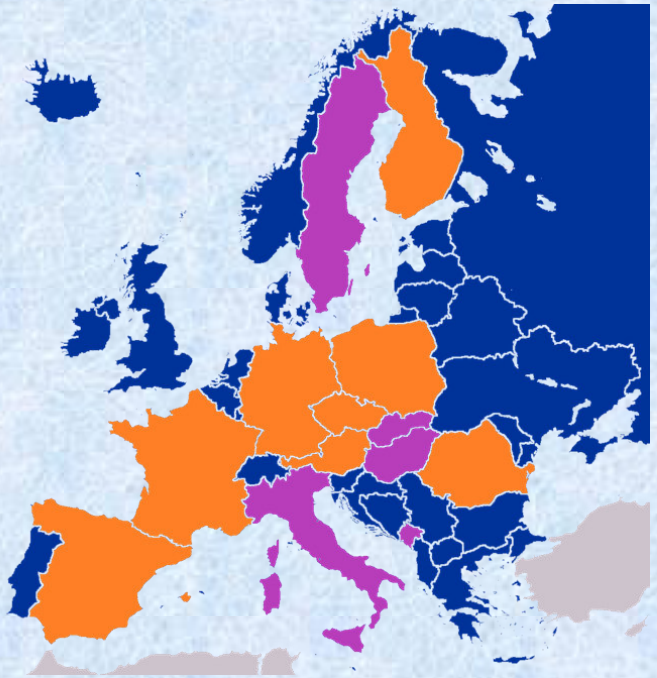


Chart of traceability of European calibration facilities for radon, status at start of the interlaboratory comparison (2018)

Short Name	Institute and Address	Country
BEV-PTP	BEV-PTB, Physikalisch-technischer Prüfdienst, Bundesamt für Eich- und Vermessungswesen Arltgasse 35, 1160 Wien	Austria
SUJCHBO (Coordinator)	Státní ústav jaderné, chemické a biologické ochrany Kamenna 71, 262 31 Milin	Czech Republic
STUK	Radiation and Nuclear Safety Authority Laippatie 4, 00880 Helsinki	Finland
IRSN	Institut de Radioprotection et de Sûreté Nucléaire 31 avenue de la division Leclerc, 92262 Fontenay-aux-Roses	France
BfS (Coordinator)	German Federal Office for Radiation Protection Köpenicker Allee 120 – 130, 10318 Berlin	Germany
BFKH	Budapest Főváros Kormányhivatala Németvölgyi út 37-39, 1024 Budapest	Hungary
ENEA	CRE ENEA Casaccia via Anguillarese, 123 - Santa Maria di Galeri, 00123 Roma	Italy
MNE	Bureau of Metrology Arsenija Boljevića bb, 81000 Podgorica	Montenegro
CLOR	Central Laboratory for Radiological Protection Konwaliowa 7, PL 03-194 Warsaw	Poland
IFIN-HH	Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara "Horia Hulubei" 30 Reactorului St., 077125 Magurele, Ilfov County, POB MG-6	Romania
UBB	"CONSTANTIN COSMA" RADON LABORATORY, Babes – Bolyai University, Faculty of Environmental Science and Engineering Fantanele 30, 400294 Cluj-Napoca	Romania
SMU	Slovak Institute of Metrology, Dept. of Ionizing Radiation Karloveská 63, 842 55 Bratislava	Slovak Republic
LARUC-UNICAN	Radon Group, Laboratory of Environmental Radioactivity of the University of Cantabria (LARUC) C/ Cardenal Herrera Oria S/N, 39011 Santander, Cantabria	Spain
UPC	Laboratory of 222Rn studies (LER) of the Institut de Tècniques Energètiques (INTE) of the Universitat Politècnica de Catalunya (UPC), Campus Diagonal Sud, Edificio PC (Pavelló C) Av. Diagonal, 647, 08028 Barcelona	Spain
SSM	Strålsäkerhetsmyndigheten (Swedish Radiation Safety Authority), Mätning av joniserande strålning (Radiation Measurements) Solna strandväg 96, SE-171 16 Stockholm	Sweden





Thank you for your attention!

THE PERFORMANCE OF EUROPEAN CALIBRATION SERVICES REGARDING RADON IN AIR & VALIDATION OF TRACEABILITY

- EMPIR Project *Metrology for Radon* -

T. R. Beck

German Federal Office for Radiation Protection (BfS)

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

Metro RADON

EMPIR Project *Metrology for Radon*

Radon Intercomparison & Validation of Traceability

Aim:

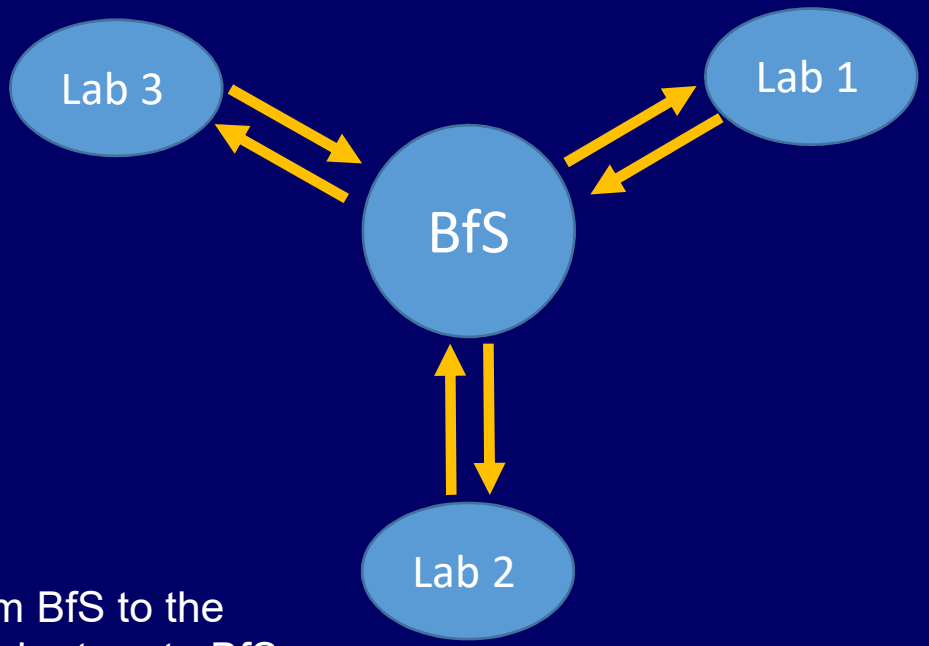
Validation of the traceability of existing European radon calibration facilities at NMI/DI and other calibration laboratories over the range from 300 Bq/m^3 to 10 000 Bq/m^3.

- Comparison of the radon activity concentration in the air realized in different European calibration facilities (Radon Intercomparison).
- Verification that calibrations for airborne radon activity concentration are traceable to appropriate primary standards through an unbroken chain.

EMPIR Radon Intercomparison

Procedure:

Comparison device calibrated with a primary radon gas standard was shipped to European radon calibration facilities for a comparison with their existing secondary standards.



Shipment from BfS to the participant and return to BfS

EMPIR Radon Intercomparison

Transfer comparison device: AlphaGUARD PQ 2000 PRO TTL

EMPIR Radon Intercomparison

Participants

15 Laboratories
(12 EU countries + Montenegro)

NMI & DI: 7
National Authorities: 5
Universities/Research: 3

MNE	Montenegro
BEV-PTP	Austria
IRSN	France
STUK	Finland
SUJCHBO	Czech Rep.
BFKH	Hungary
CLOR	Poland
SSM	Sweden
UNICAN	Spain
SMU	Slovakia
UBB	Romania
IFIN-HH	Romania
UPC	Spain
BfS	Germany ← Coordinator
ENEA	Italy

EMPIR Radon Intercomparison

Laboratory Reference (Status 2018/2019)

No. of Participants	Laboratory Reference
13	AlphaGUARD (various models), 3 participants use additional instruments like scintillation cells (2 participants) or Atmos (1 participant) as working standards or for other verification purposes.
1	Atmos
1	Radon Scout

EMPIR Radon Intercomparison

Exposure levels

	Nominal value	Accepted deviation
1	400 $Bq \cdot m^{-3}$	350 $Bq \cdot m^{-3}$ – 450 $Bq \cdot m^{-3}$
2	1000 $Bq \cdot m^{-3}$	900 $Bq \cdot m^{-3}$ – 1100 $Bq \cdot m^{-3}$
3	6000 $Bq \cdot m^{-3}$	5500 $Bq \cdot m^{-3}$ – 6500 $Bq \cdot m^{-3}$

EMPIR Radon Intercomparison: Data Assessment

Quantity of Comparison, R_i, R_i^*

Ratio of radon activity concentrations determined by participant i and by transfer device

$$R_i = \frac{\bar{C}_{Participant,i}}{\bar{C}_{transfer,i}}$$

Quantity for Comparison

$$R_i^* = \frac{R_i}{\bar{R}_i}$$

Expectation value equal to 1

$$E(R_i^*) = 1$$

Mea

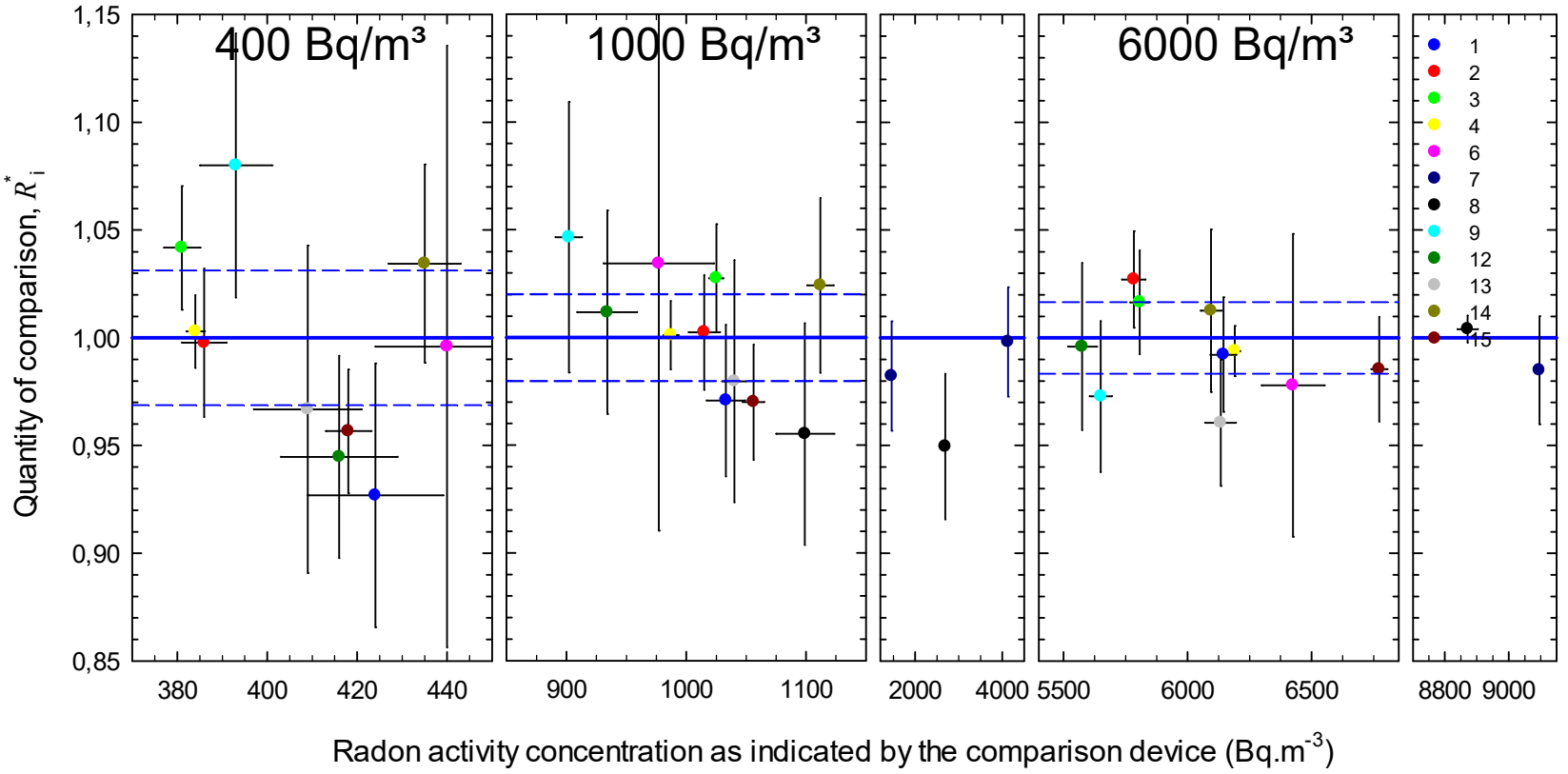
Weighting: calculated from reciprocal squared uncertainties

Variance of R_i^*

$$\sigma^2(R_i^*) = \sum_{i=1}^{n} w_i (R_i^* - 1)^2$$

Performance of European calibration services

Results indicating the deviations from the common mean



All uncertainties are given with the extension k=1.

Performance of European calibration services

Variance of R_i^* for quantifying the closeness of agreement

Radon Level [Bq/m³]	Variance extended by a factor of 2 (k=2)*
400	6,3
1000	4,0
6000	3,4
All levels including the singular exposures	3,4

* Confidence interval for a coverage of 95%

The radon activity concentrations realized by the European calibration facilities fluctuate around a common mean value.
The range of variation is about 4 % for above 1000 Bq/m³ and about 6 % for a level of 400 Bq/m³.

Performance of European calibration services

Comparison with the results of the EUROMET Project 657

(final report 2005)

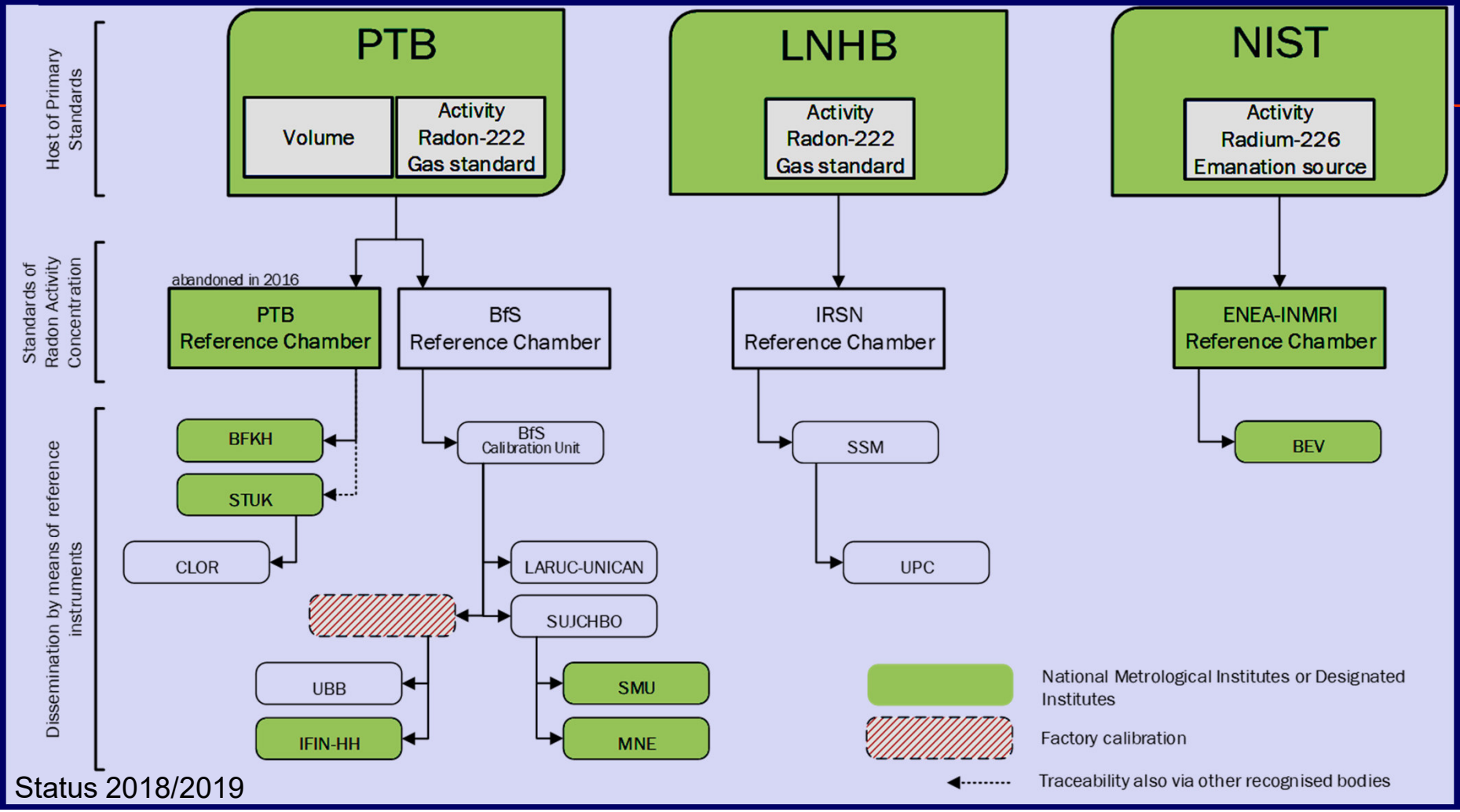
Radon Level [Bq/m³]	Confidence Interval at 95% (k=2)	
	This work (all participants)	Project 657
400	0,063	--
1000	0,040	0,057
3000	--	0,075
6000	0,034	--
10000	--	0,081

As lower the concentration as higher the deviations
Little improvement comparted to the former comparison

Verification of Traceability

Information on traceability was taken from participants' reports.

Chart of traceability of European calibration services for radon



Status 2018/2019

Test for Correlations between the Participants

Coefficient of Determination

Pearson correlation coefficient between participants x and y

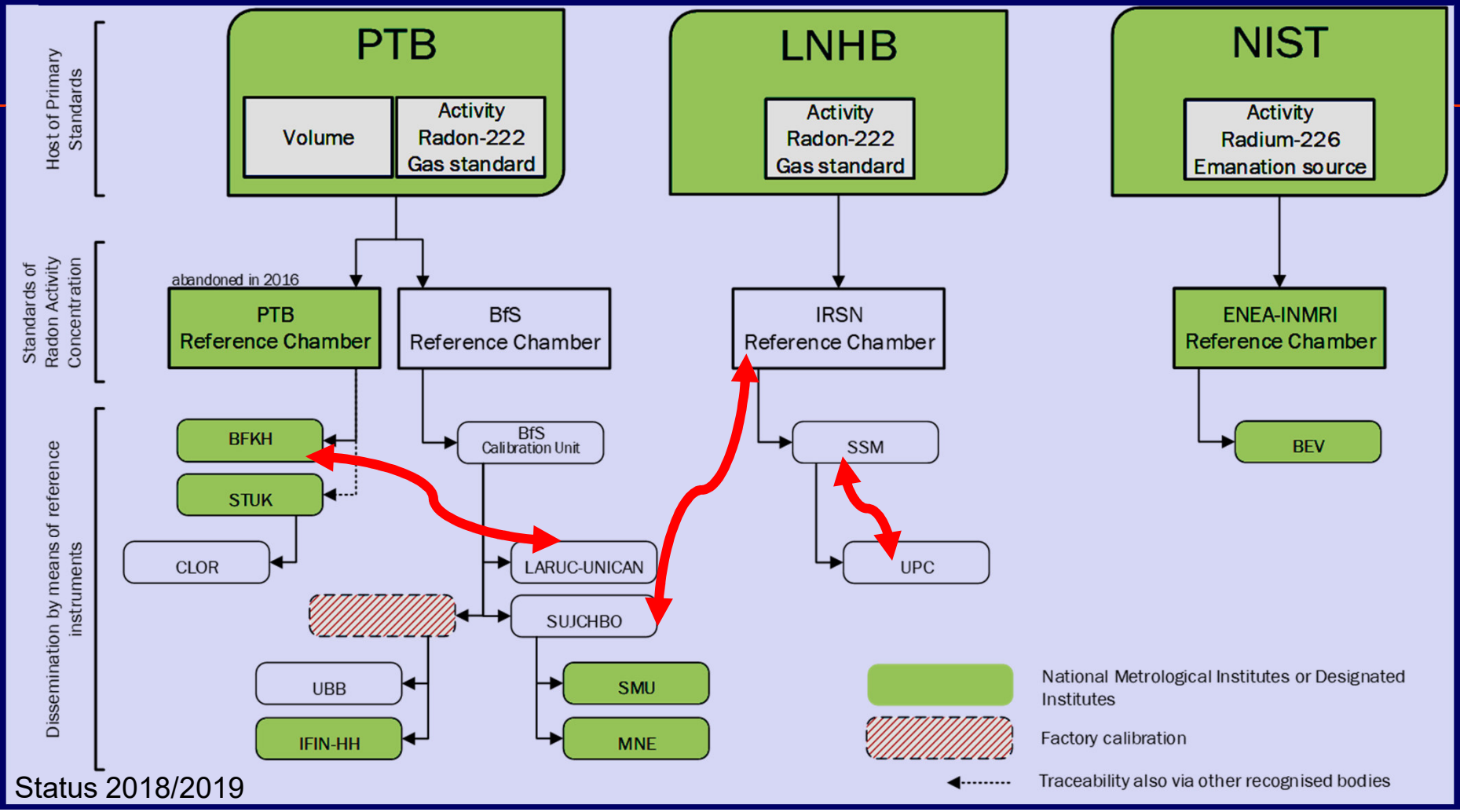
$$r_{x,y} = \frac{\sum_{i=1}^{o}(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum_{i=1}^{o}(x_i - \bar{x})^2 \sum_{i=1}^{o}(y_i - \bar{y})^2}}$$

o: Number of observations, radon levels (o=3)

Coefficient of determination: $r_{x,y}^2 = r_{x,y}\, r_{x,y}$

Quantile of the t distribution for the significance level $1 - \frac{\alpha}{2}$ (two-sided t-test) is used for testing the hypothesis of no correlation between the participants x and y

Chart of traceability of European calibration services for radon

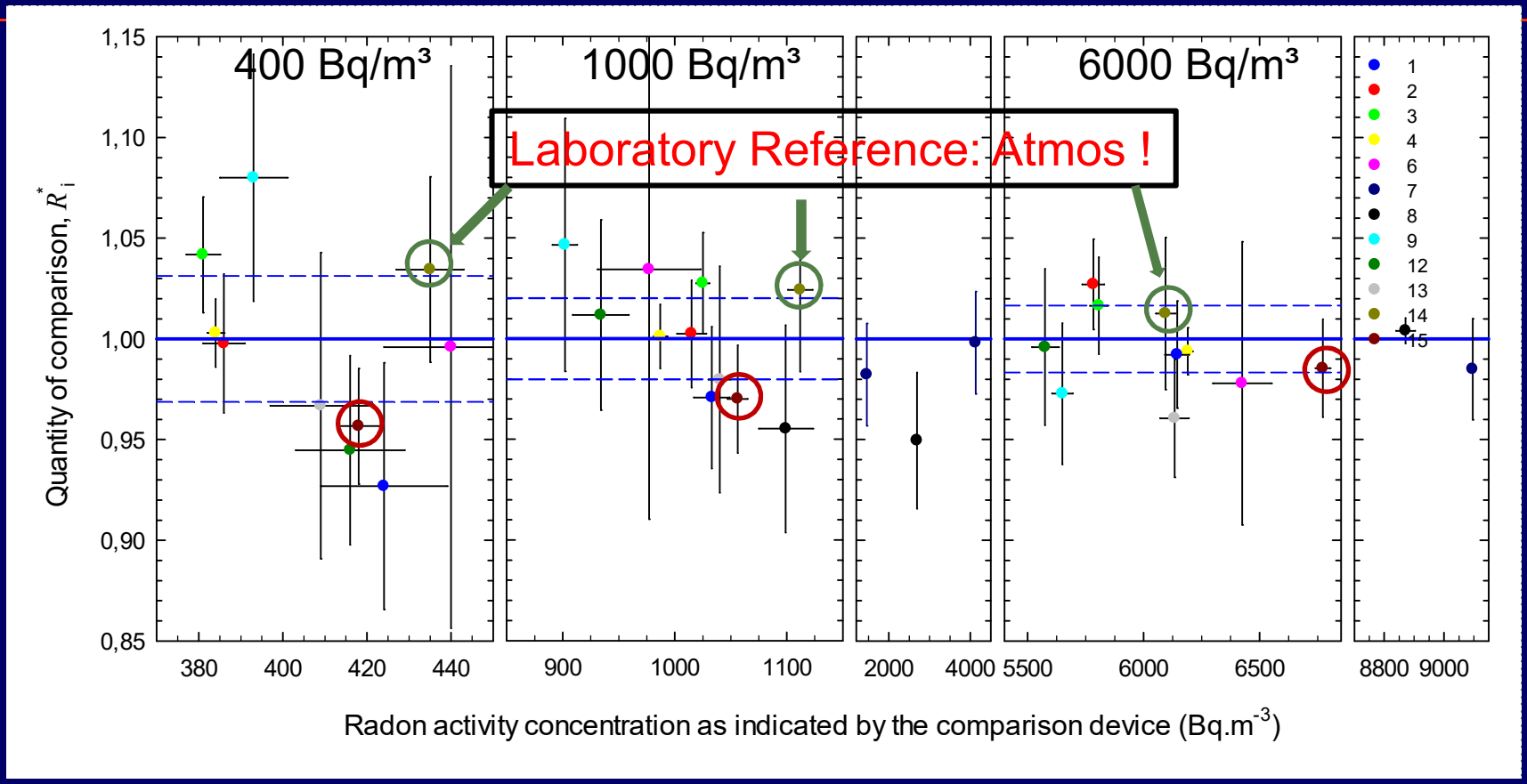


For a significance level of $\alpha = 0{,}05$, correlations between SUJCHBO and IRSN, BFKH and LARUC-UNICAN, and SSM and UPC are observed.

Bundesamt für Strahlenschutz

Performance of European calibration services

Results indicating the deviations from the common mean



All uncertainties are given with the extension k=1.

Verification of Traceability

Correlations between participants

The different calibration hierarchies and the associated different traceability chains do not influence the quality of calibrations.

Conclusions

- European calibration services realize the quantity radon activity concentration within a range of 4 % to 6 % (k=2) around the common mean value.
- AlphaGUARD instruments are often used as reference standards. In some cases other types of instruments are also used.
- Calibrations are traceable to primary activity and volume standards housed at PTB, LNHB and NIST. The standards are passed on to secondary laboratories, which realize the combined quantity of radon activity concentration. Secondary laboratories are operated at BfS, IRSN and ENEA.