ALPHAGUARD - PROFESSIONAL RADON MONITORING

METRO RADON, IGG MEETING,
PHYSIKALISCH-TECHNISCHE BUNDESANSTALT, 18.06.2019

BERTIN GMBH IN FRANKFURT/ GERMANY

- Up to 2008: Genitron GmbH
- 2008 -2018: Saphymo GmbH
- Since 2015: daughter of Bertin Technologies with headquarter in Paris/France (part of the CNIM group)
- Since 2018: Bertin GmbH
- Manufacturer of a wide range of measurement equipment for ionizing radiation:
  - Radon (AlphaGUARD and AlphaE)
  - ERMS (e.g. networks for $\alpha/\beta/\gamma$ environmental monitoring)
  - Handheld devices for contamination and dose rate measurement
  - Portal monitors

BERTIN'S RADON PRODUCT RANGE

- Two product lines:

ALPHAGUARD - INTRODUCTION

More than 30 years of experience in RADON

> 2500 monitors AlphaGUARD operating worldwide

In more than 90 countries

Reference instrument at Radon Calibration facilities in ~20 countries

Continuous Innovation

New AlphaGUARD since 2016

Accessories

Prestigious customer references

- PTB, BfS
- IRSN, CEA
- NIM
- STUK
- US EPA
- CARER
- ANSTO
- PHE
- NIRS
- SCE

Made in Germany

ALPHAGUARD – WIDE FIELD OF APPLICATIONS

Research

Public & Professional Exposure

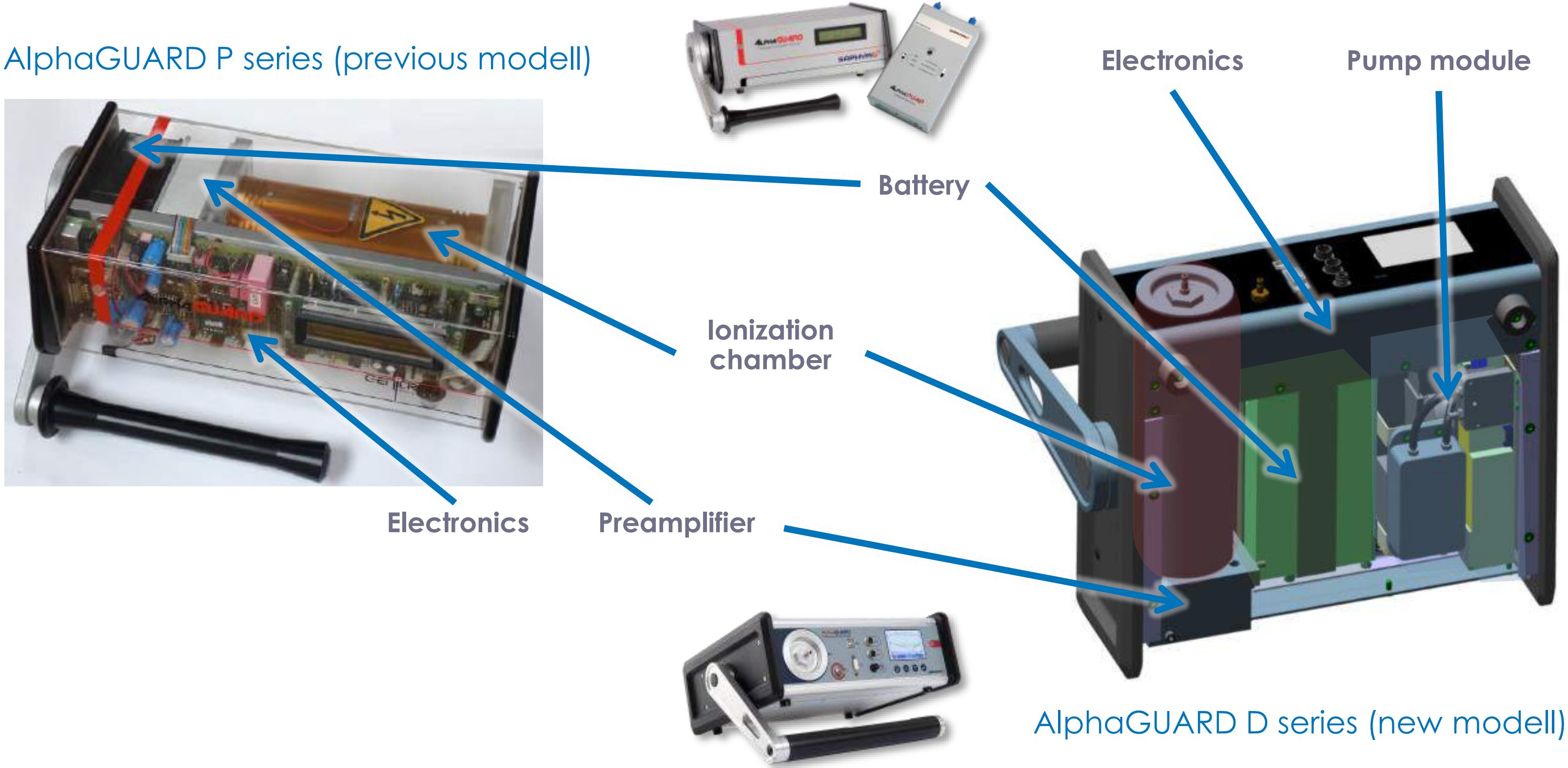
Radon Calibration Facilities

Research & specific applications

Rn in workplace and homes

Rn in NORM, nuclear industry

SETUP OF THE ALPHAGUARD



ALPHAGUARD – HIGH PERFORMANCE

- High sensitivity (1 CPM at 20 Bq/m^3) due to optimal volume of the ionization chamber
- High measuring range (2… 2 000 000 Bq/m^3) and low susceptibility (e.g. to EM fields or microphonics) due to powerful signal processing
- Insensitive to high air humidity due to special treatment of the components
- Insensitive to gamma radiation up to 0,2 mSv/h
- Long-term stability of the calibration over 5 years guaranteed

AQUAKIT - RADON MEASUREMENT IN WATER SAMPLES

AquaKIT is a complete setup for measuring radon in water samples with the AlphaGUARD

- Portable for laboratory and field measurements
- Fully described sampling method, proven in numerous applications by a wide range of customers

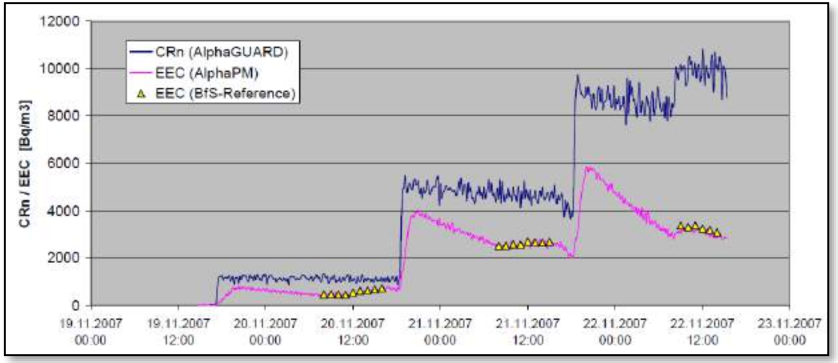
SOIL GAS PROBE - RADON IN SOIL GAS MEASUREMENT

Easy-to-use soil gas measuring probe for sampling as well as for continuous monitoring of radon in soil gas

- Sampling and continuous monitoring
- Robust and reliable set-up for long-term use
- Field-proven sampling method and protocol
- Option: Differential Pressure Sensor

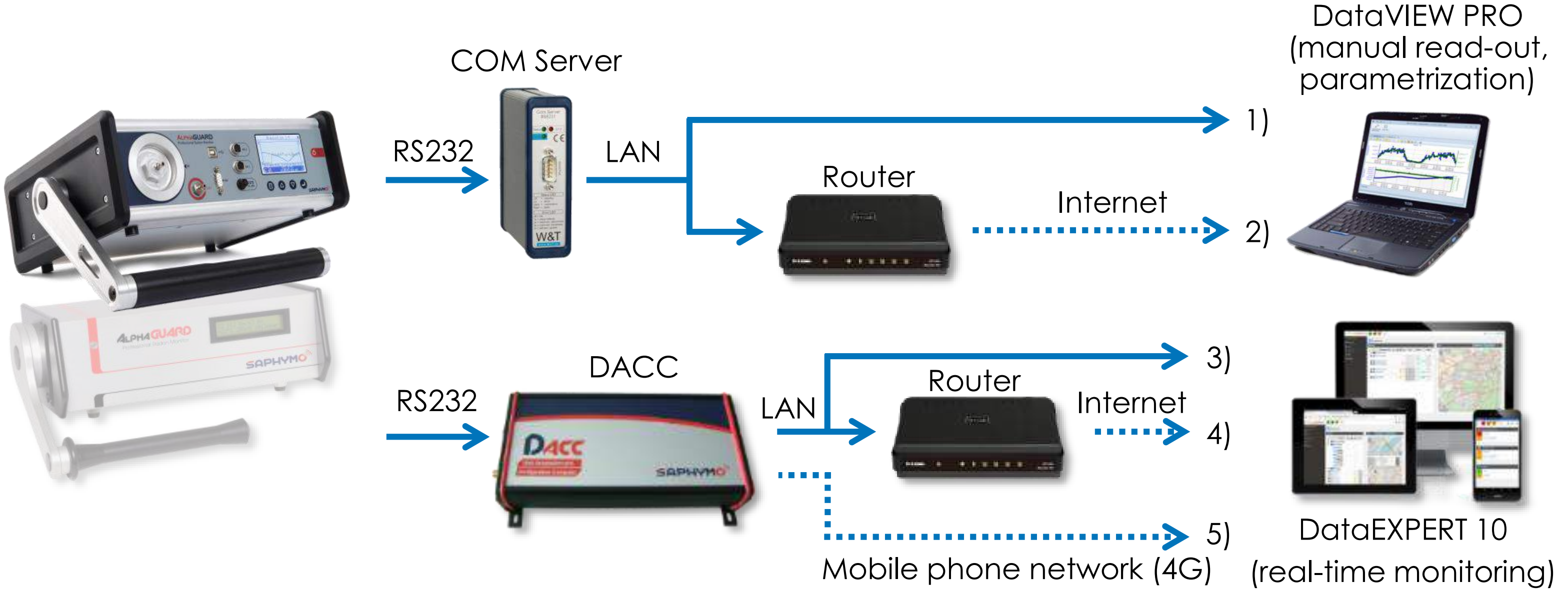
ALPHAPM - RADON PROGENY MONITOR

- Active monitor with high sensitivity for time-resolved measurement of the airborn radon progeny concentration
  - The measured values are stored in the AlphaGUARD storage
  - Monitoring of the equilibrium factor
  - Sensitive semi conductor (PIPS)
  - Optimized for easy accurate performance



REMOTE MONITORING

- Manual read out with DataVIEW PRO: vial LAN (1), via internet (2)
- Real-time monitoring with DataEXPERT 10: via LAN (3), via internet (4), Via mobile phone network (4G) ➔ on request! (5)



STATIONARY MONITORING

- Remote data transmission via LAN / internet / mobile phone network
- Outdoor cabinet and accessories adapted to customer needs

S. Buonmestieri et al.

CALIBRATION EQUIPMENT

- Calibration and emanation containers (50 – 300 l)
- Calibration source: RF-RN-222 Flow Through Source
- Active coal filter (1 l, 30 l)
- Additional equipment on request (transport carts, etc.)

Complete calibration facility with 300 l calibration container, 30 l active coal filter and radon source

Radon calibration source

Calibration container

Active coal filter

Franz Anton Rößler
Radon Product Manager

E.MAIL
franz.roessler@bertin-gmbh.de

PHONE
+49(0)69-976 514-20

OFFICE FRANKFURT/GERMANY
Heerstrasse 149
60488 Frankfurt a.M.
Germany

LIST OF REVISIONS

REV.	DATE	MODIFICATIONS (main reasons, sections and affected pages)	WRITER / CHECKER
A	18.06.2019	First Issue	Franz Rößler

radonova

The global leader in radon measurement

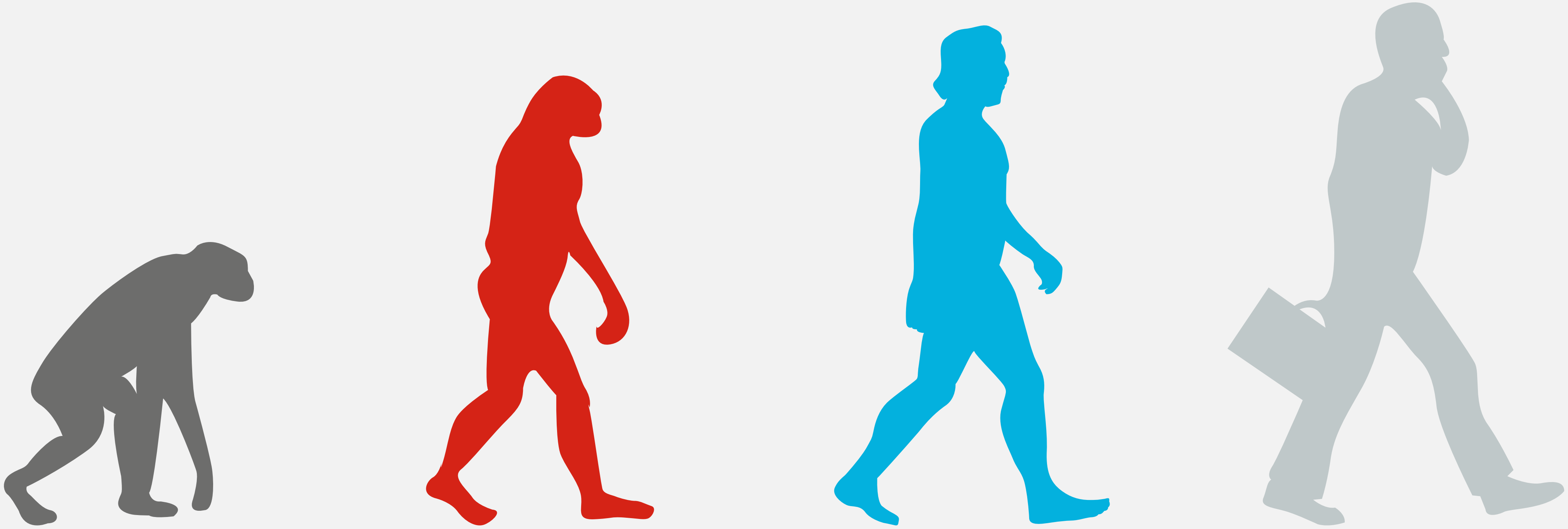
Dr. José – Luis Gutiérrez Villanueva

Specialist Radon Measurement Advisor

radonova
The global leader in radon measurement

History of Radonova

Commitment – Loyalty – Humbleness - Professionalism

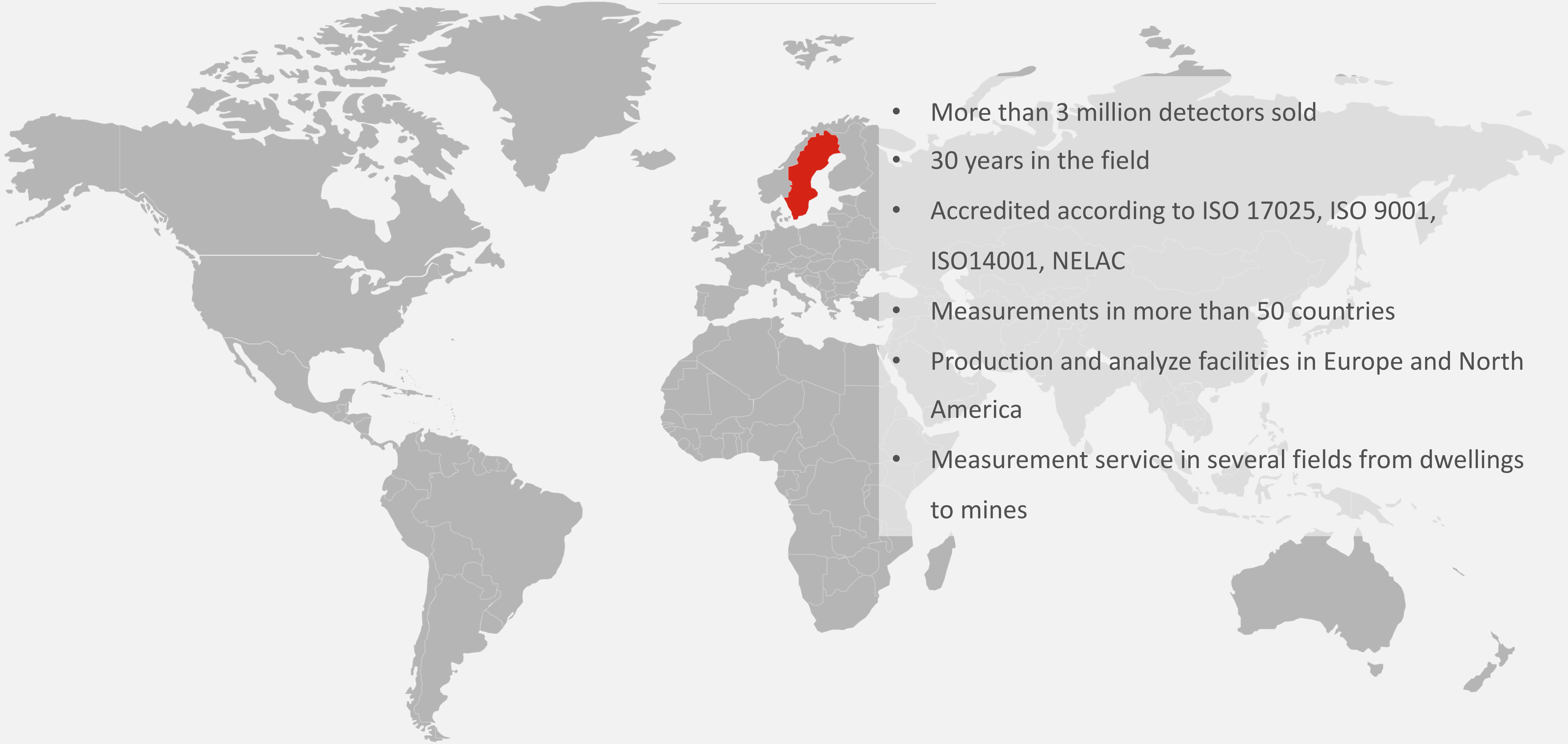


Gammadata	Gammadata Mätteknik	Landauer Nordic	Radonova Laboratories
1986-1989	1989-2009	2009-2015	2015->
	Owner: Gammadata Holding	Owner: Landauer Inc	Owner: Lagercrantz Group

Radonova Laboratories

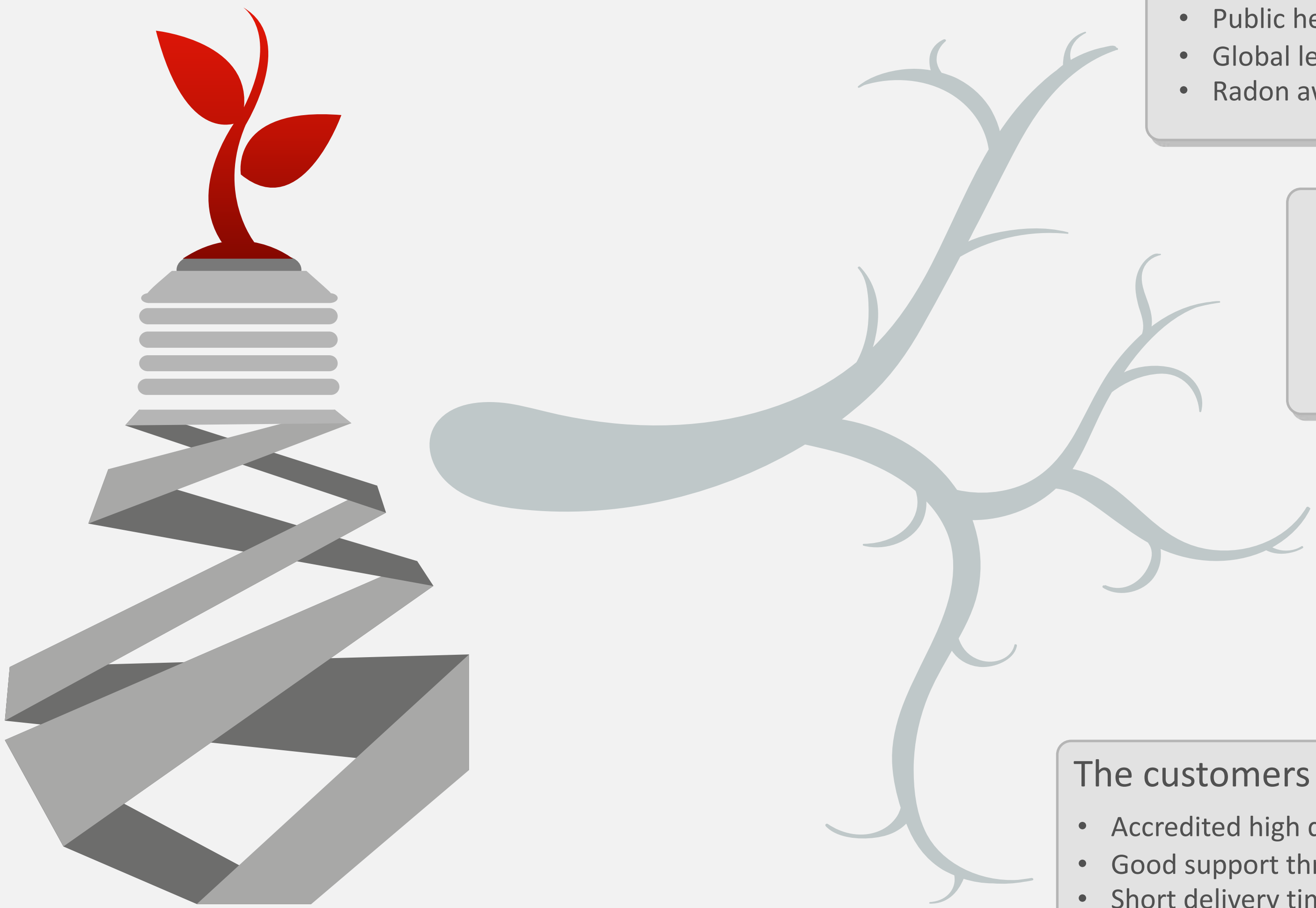
The global leader in radon measurement

- More than 3 million detectors sold
- 30 years in the field
- Accredited according to ISO 17025, ISO 9001, ISO14001, NELAC
- Measurements in more than 50 countries
- Production and analyze facilities in Europe and North America
- Measurement service in several fields from dwellings to mines



radonova
The global leader in radon measurement

The pilars of Radonova



Vision

- Public health
- Global leader
- Radon awareness.

Mission

- High competence on radon measurements
- Efficient systems

Business idea

- Advanced radon measurement and warranty services
- Domestic exposures
- Occupational exposures

The customers benefit

- Accredited high quality measurements
- Good support through online systems
- Short delivery times.

Quality and experience

radonova
The global leader in radon measurement

Our Concept

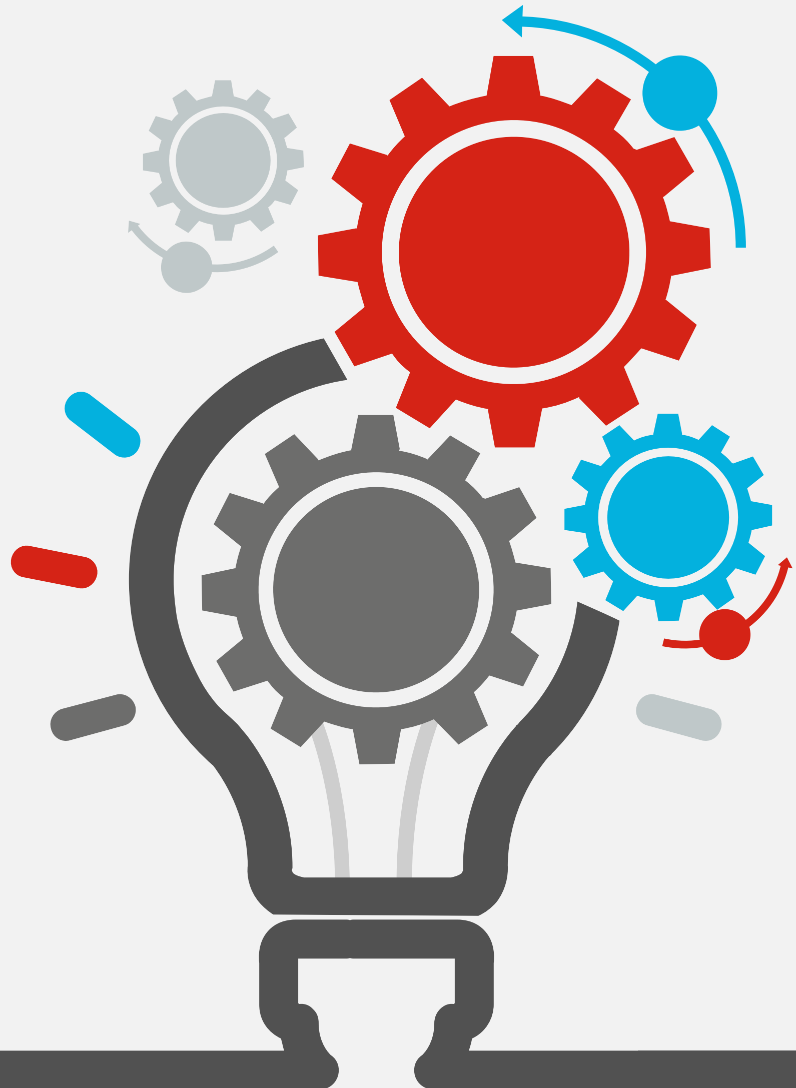
All our products are accredited according to iso 17025 standard

Skill
The laboratory is accredited to the ISO 17025 standard by SWEDAC and to the NELAP standard by the state of New York. The laboratory is certified by AARST/NRPP (107831 AL) and CARST/CNRPP (CRT 201475).

Administration
The laboratory is accredited to the ISO 17025 standard by SWEDAC and to the NELAP standard by the state of New York. The laboratory is certified by AARST/NRPP (107831 AL) and CARST/CNRPP (CRT 201475).

Market
Since the start, the laboratory has analysed more than 3’000’000 passive radon detectors in more than 50 different countries.

Revenue
Radtrak2 long-term – 250’000-300’000 detectors
Rapidos short-term and HS – 15’000 detectors (5%).



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The global leader in radon measurement

Organisation

Quality & Environment

Expertise in national approvals
Fulfillment of ISO 17025,
ISO 9001, ISO 14001, NELAC

Logistics

Logistics centers in Sweden & US

Production

Automatic production in robot
Film cutting and pre-etching facilities

Sales

Sales offices in Sweden and US
Representation in many European countries and Canada

Analyze

Automatic reading with help of software
Quality checks with extra detectors and transportation kits

R&D

Development of new measurement methods
New IT & Software solutions

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The global leader in radon measurement

Membership

international organizations

ERA
European Radon Association

CARST Rn ACSTR
Canadian Association of Radon Scientists and Technologists
Helping Canadians Reduce Radon Risk

Products for your needs

radonova
The global leader in radon measurement

Duotrak®
Two position measurements
5 days - 3 months

Radtrak²®
Long term measurement, 2-12 months
Occupational radon dosimetry

Rapidos®
Short term measurement, 5-10 days
High Sensitive measurements
Environmental measurements

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Our workplace

Radonova

radonova
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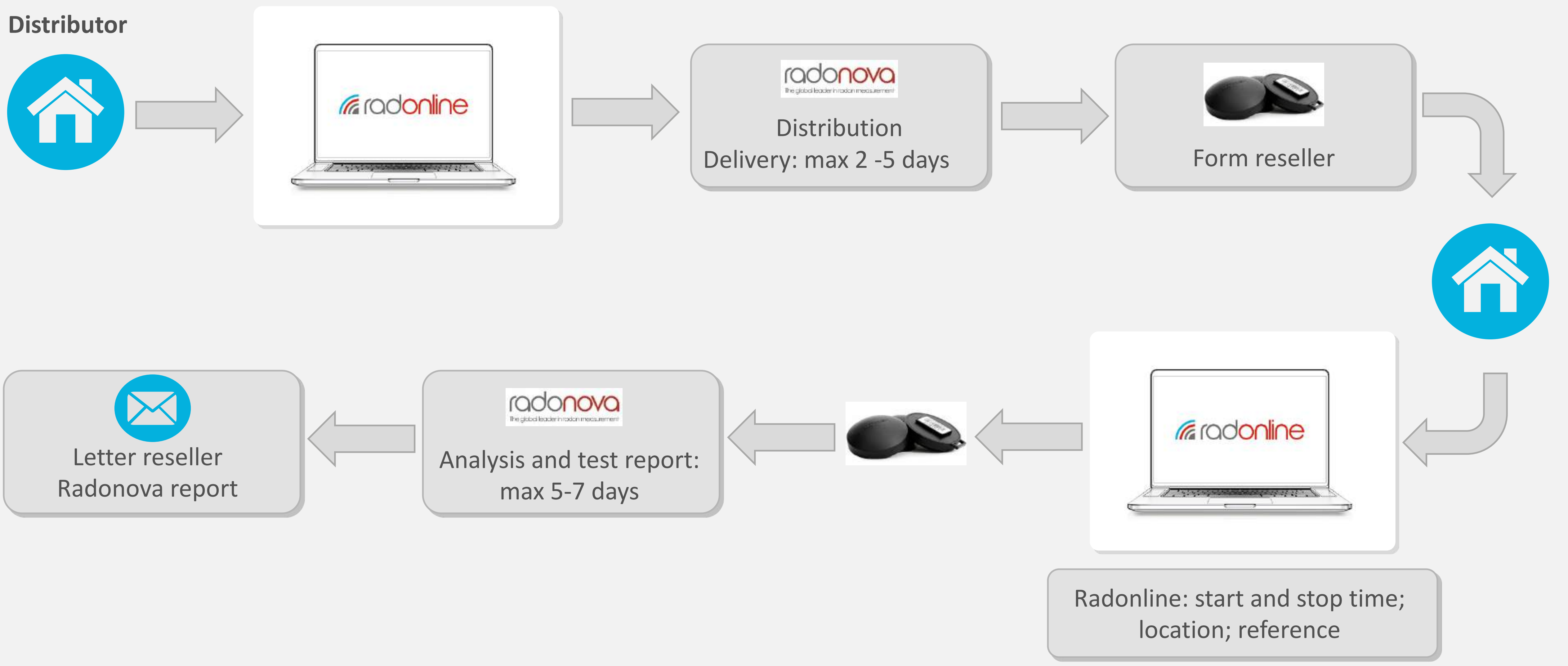
Radonova

reseller

Working together

Times, Radonline ...



Radonova

Digitalization

Internal procedures

Customer service

Social media; websites

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References

Ask them

scored with the use of TrackEtch software at Landauer Laboratories, which is accredited by the C-NRPP (ISO 17025 certified). Controls included duplicates to ensure device reproduc-

CMAJ Open 2017. DOI:10.9778/cmajo.20160142

Public Health England (UK)

SSM (Sverige)

THANK YOU

joseluis.gutierrez@radonova.com

www.linkedin.com/company/radonova

www.linkedin.com/in/joseluis-gutierrez

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

CCRI(II)-Rn-222 gas standard intercomparison - status

6.1 Radioactivity
6.13 α- and γ-spectrometry

Anja Honig, Florian Mertes, Rainer Dersch
Stefan Röttger

Outline

1) CCRI(II) - key comparison
2) Participants
3) Rn-222 gas standard and traceability
4) Measurements
5) Result

CCRI(II)-key comparison

Bureau International des Poids et Mesures – the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

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> You are here: worldwide metrology > Metre Convention

The Metre Convention

Metre Convention

The Metre Convention (*Convention du Mètre*) is the treaty that created the International Bureau of Weights and Measures (BIPM), an intergovernmental organization under the authority of the General Conference on Weights and Measures (CGPM) and the supervision of the International Committee for Weights and Measures (CIPM).

20 May 1875

The Convention was signed in Paris on 20 May 1875 by representatives of seventeen nations. As well as founding the BIPM and laying down the way in which the activities of the BIPM should be financed and managed, the Metre Convention established a permanent organizational structure for member governments to act in common accord on all matters relating to units of measurement.

The Convention follows a format used at the turn of the nineteenth century and is based on the understanding of the governance of international organisations at that time. A note on some other examples of international organizations established with the name "Bureau" at that time is available:

- Use of the term bureau or office

The Convention, modified slightly in 1921, remains the basis of international agreement on units of measurement.

- States Parties to the Metre Convention (generally referred to as "Member States")
- The original signatories
- The International Metre Commission (1870-1872)
- Official and explanatory texts

Summary

- States Parties to the Metre Convention
- The original signatories
- The International Metre Commission
- Official and explanatory texts

Governance

- Official and explanatory texts
- Notice of Contributions
- CIPM publications

EM | L | M | PR | QM | RI | T | TF | U

BIPM - Pavillon de Breteuil F-92312 Sèvres Cedex FRANCE

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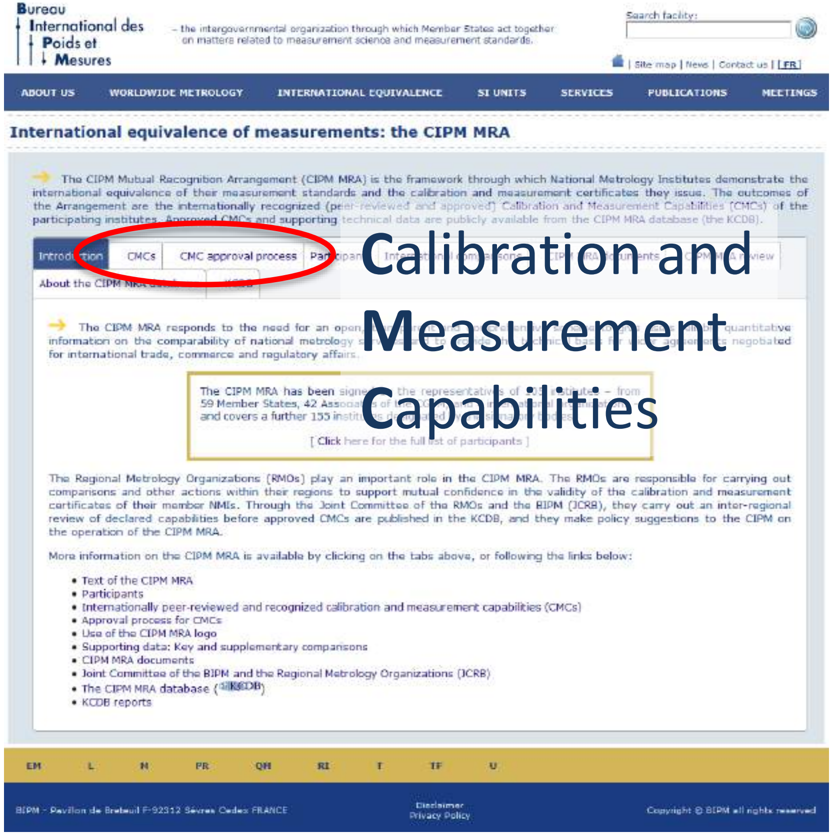
CCRI(II)-key comparison

International equivalence of measurements (CIPM MRA)

CCRI(II)-key comparison



Calibration and Measurement Capabilities

CCRI(II)-key comparison

Approval process

Bureau International des Poids et Mesures

- the intergovernmental organization through which Member States act together on matters related to measurement science and measurement standards.

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> You are here: International equivalence: the CIPM MRA > approval of CMCs

Approval process

→ The outcomes of the CIPM MRA are the internationally recognized (peer-reviewed and approved) Calibration and Measurement Capabilities (CMCs) of the participating institutes. Approved CMCs are publicly available in the CIPM MRA database (KCDB).

→ The three fundamental elements leading to approval of an institute's CMCs are:

1. participation by the institute in reviewed and approved scientific comparisons;
2. operation by the institute of an appropriate and approved quality management system;
3. international peer-review (regional and inter-regional) of claimed calibration and measurement capabilities.

A generalized overview of the process is given below; for full details please refer to the text of the CIPM MRA.

1. Scientific comparisons | 2. Quality management system | 3. Review of CMCs

→ The technical basis of the CIPM MRA is the set of results obtained over the course of time through scientific key comparisons carried out by the Consultative Committees of the CIPM, the BIPM and the regional metrology organizations (RMOs), and published by the BIPM and maintained in the KCDB.

The key comparisons are essentially of two types:

- **CIPM key comparisons**, of international scope, are carried out by those participants having the highest level of skills in the measurement involved, and are restricted to laboratories of Member States. The CIPM key comparisons deliver "the reference value" for the chosen key quantity.
- **RMO key comparisons**, of regional scope, are organized at the level of regions and may include additional participants from other regions) and are open to laboratories of Associates as well as Member States. These key comparisons deliver complementary information without changing the reference value.

The comparisons underpin the development of the Calibration and Measurement Capabilities (CMCs) which are stated in terms of a measurand and its uncertainty, and may include advice about the instrumentation used.

CIPM MRA docs.
- Policy documents
- Guidance on CMCs
- Guidance on comparisons
- Complementary info.
- Use of the CIPM MRA logo
- See also: JCRB

Summary
- KCDB leaflet
- Approval process
- Historical development of the CIPM MRA
- Organizational structure of the CIPM MRA
- The essential points of the CIPM MRA
- Potential economic impact of the CIPM MRA
- Reports on the KCDB

KCDB

Governance
- Official and explanatory texts

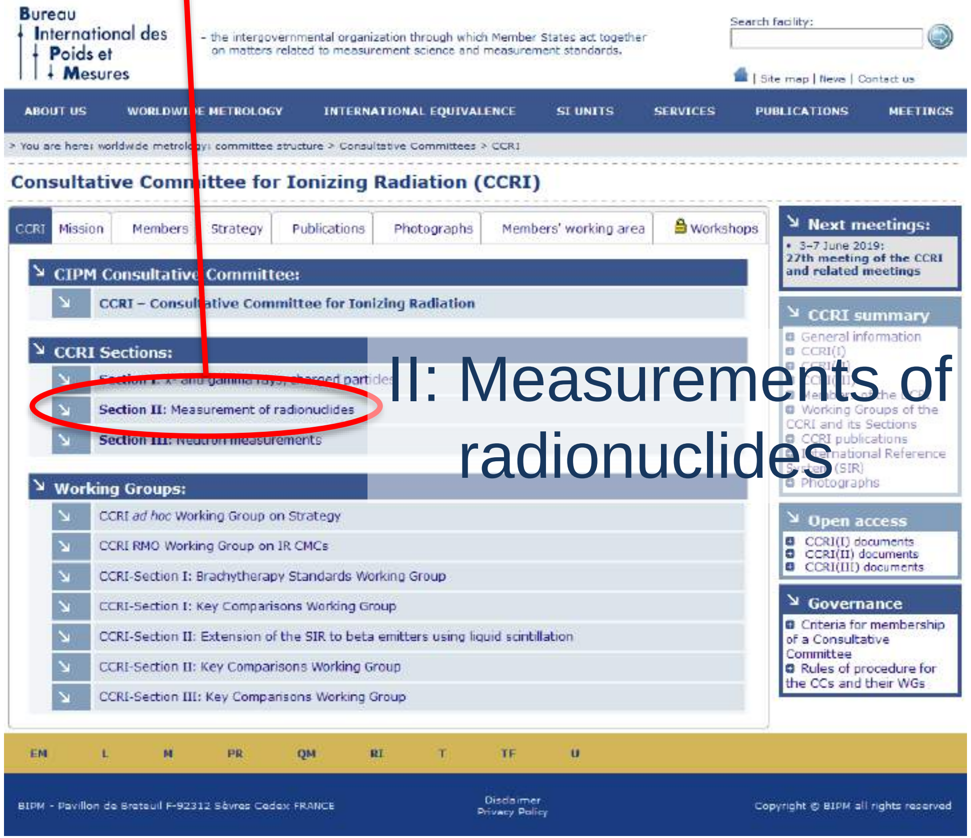
key comparison

CCRI(II)-key comparison

International Committee for Weights and Measures CIPM

CCRI: Consultative Committee for Ionizing Radiation

CCRI(II)-key comparison



CCRI(II) Rn-222 key comparisons

1) 1992, 1994 by NPL (Ra-226 emanation, γ-spectrometry)
2) 2005, 2012 by SIR (BIPM)
3) 2015 by LNHB still in progress
4) 2019 by LNHB

CCRI(II) Rn-222 participants

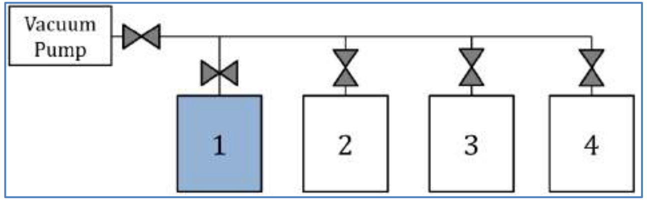
1) LNE-LNHB (France) - pilot laboratory
2) BEV (Austria)
3) BFKH (Hungary)
4) IRA (Switzerland)
5) ENEA (Italy)
6) IFIN-HH (Romania)
7) PTB (Germany)
8) SIM (Slovakia)

CCRI(II) Rn-222 key comparison

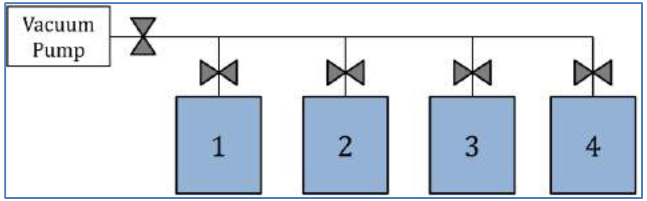
1) Stainless steel container
2) 106 cm^3
3) 10^{-2} Pa nitrogen
4) 30 kBq to 60 kBq at time of shipment
5) Half-live of 3.8232(8) d (DDEP)
6) Reference date 15.04.2019 12:00 UTC
7) Each participant uses his own setup

CCRI(II) Rn-222 key comparison

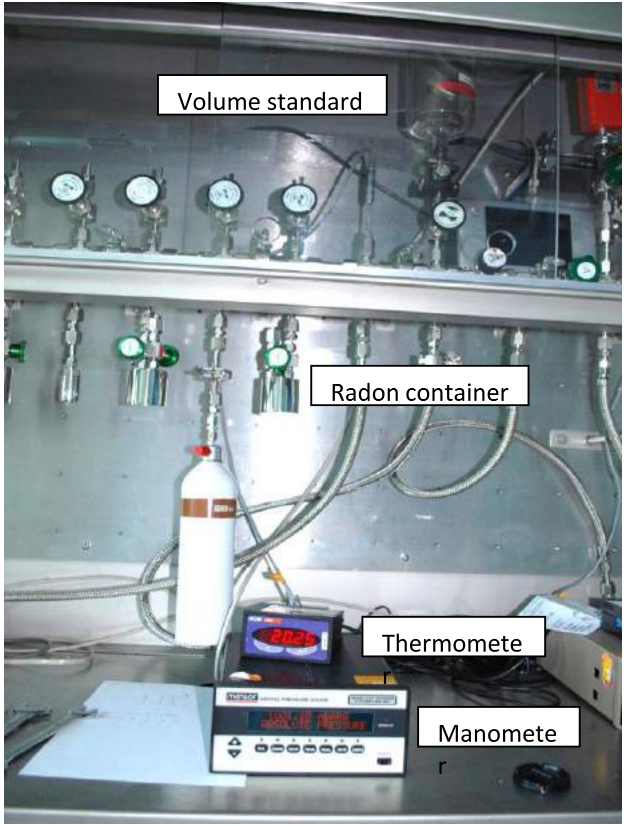
- preparation of the sources
  - container 1 filled with radon, rest is under vacuum



  - vacuum pump isolated, all containers open to allow homogeneous diffusion of radon



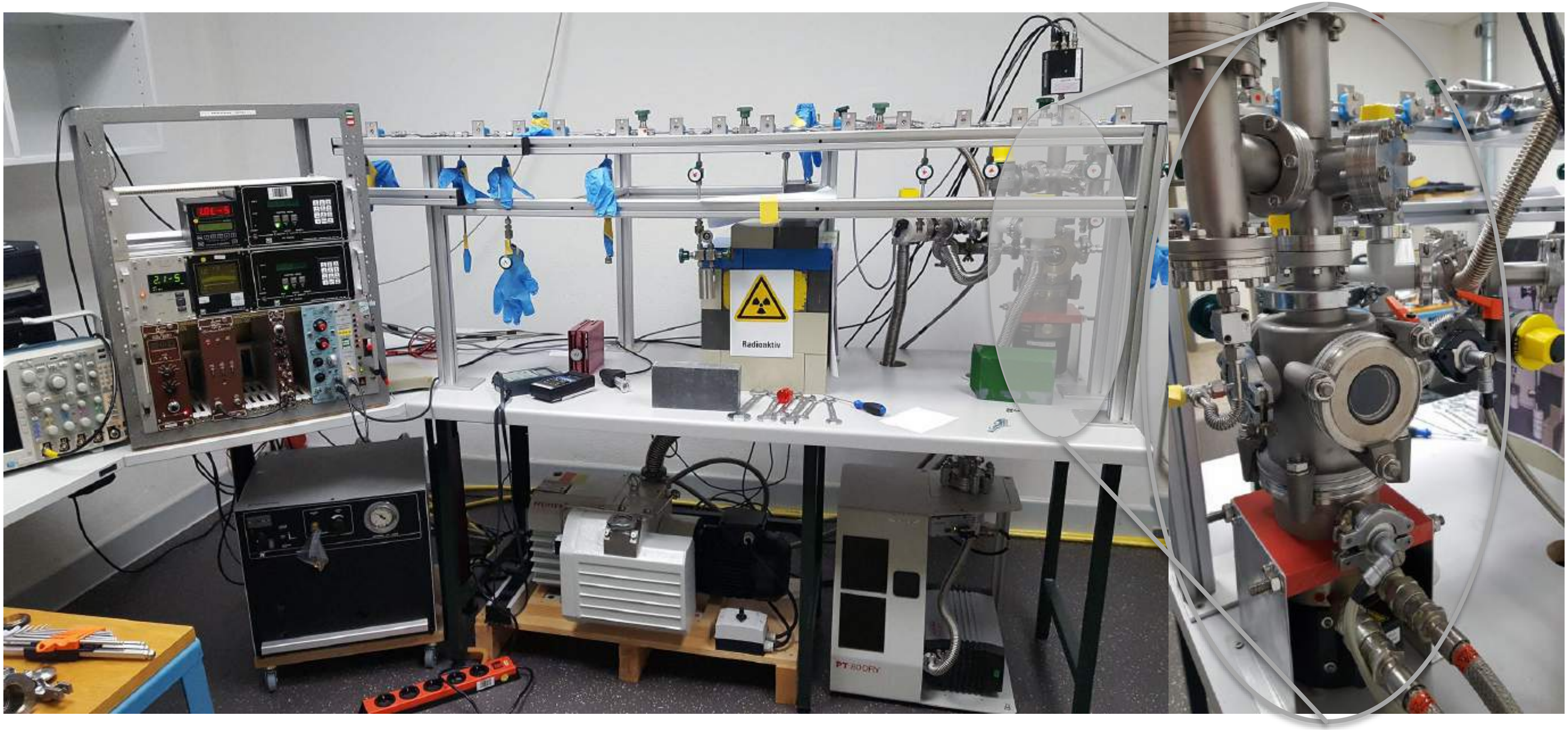
CCRI(II) Rn-222 key comparison



CCRI(II) Rn-222 procedure

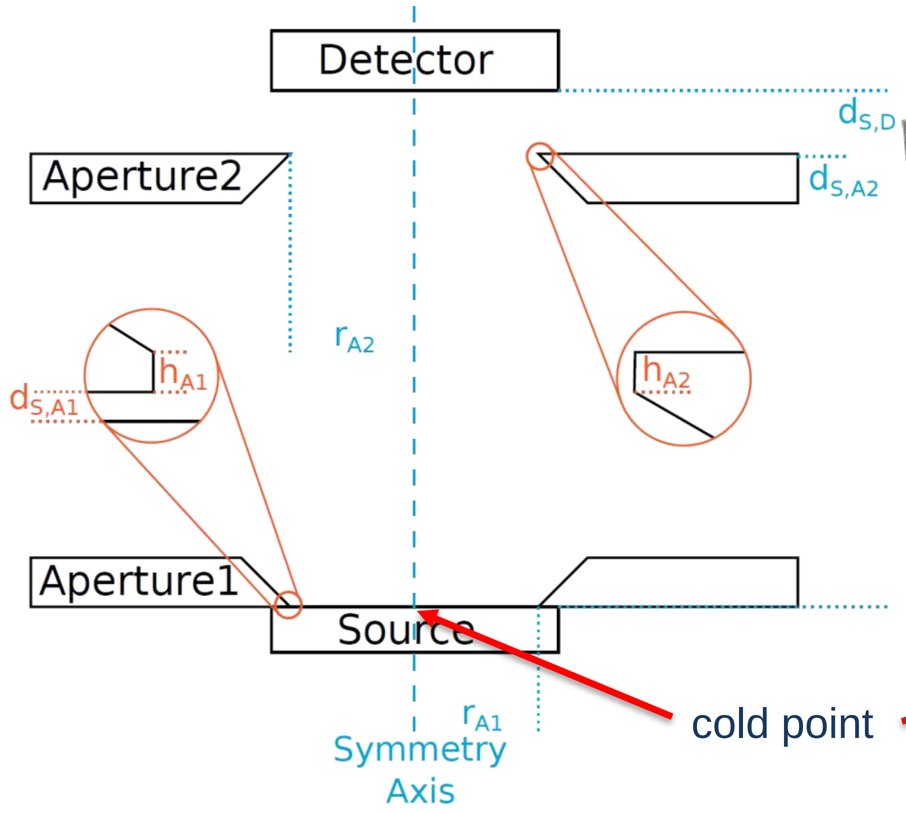
1) Pilot lab (LNE-LNHB) ships container
2) Each participant measures total Rn-222 activity in container
3) LNHB sends own results to CCRI Executive Secretary, EURAMET TC-IR Chair and notification to participants
4) Participants send their own results and uncertainty budgets to LNHB
5) LNHB evaluation and reporting (Draft A, B and Final report)

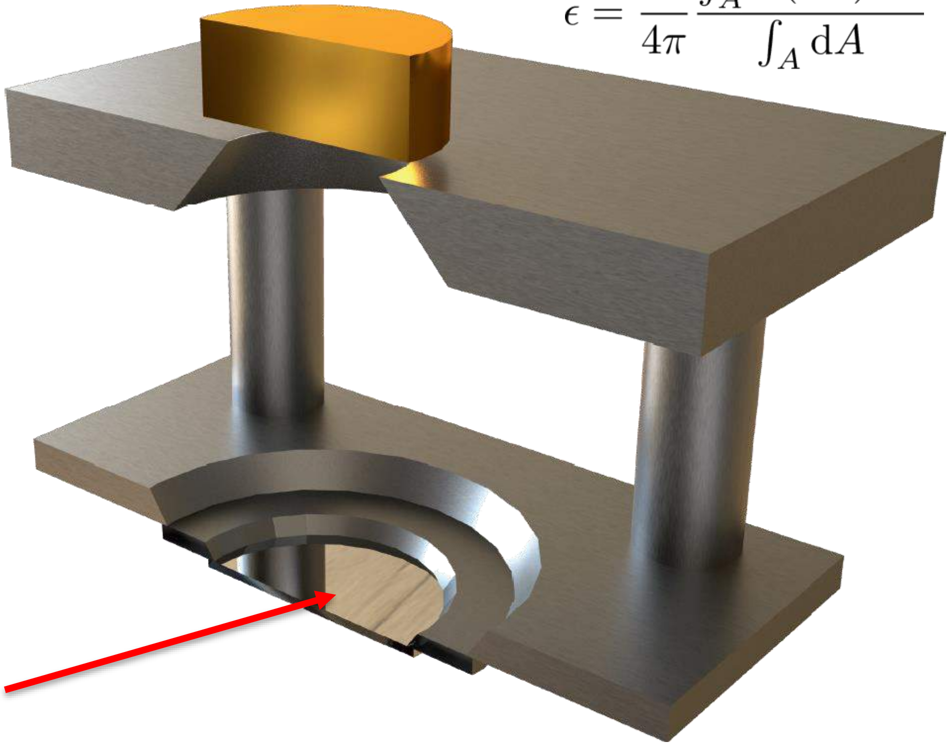
M19 – primary Rn-222 gas standard



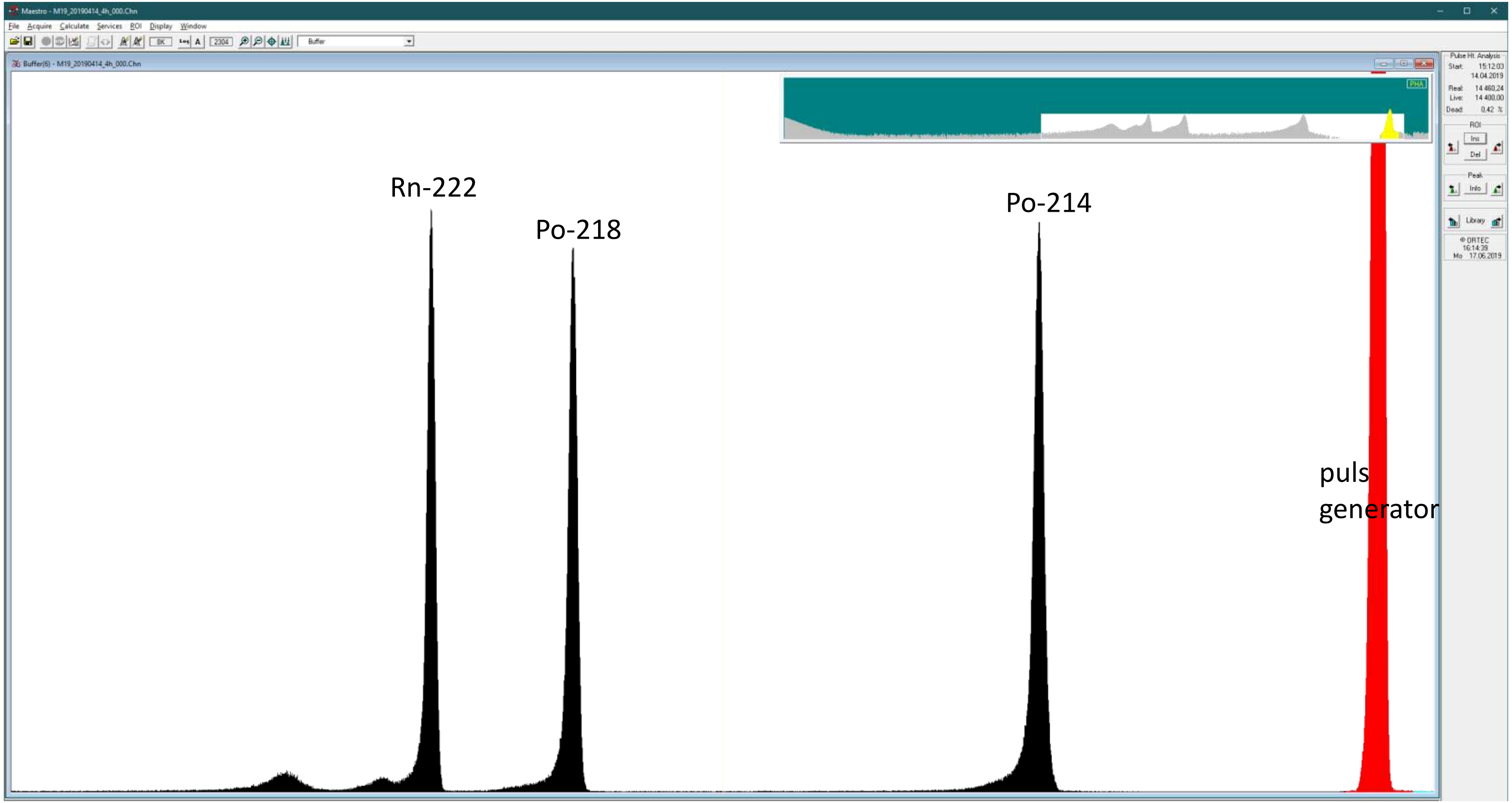
M19 – geometrical setup

$$\epsilon = \frac{1}{4\pi}\frac{\int_A \Omega(\mathrm{d}A)\mathrm{d}A}{\int_A \mathrm{d}A}$$

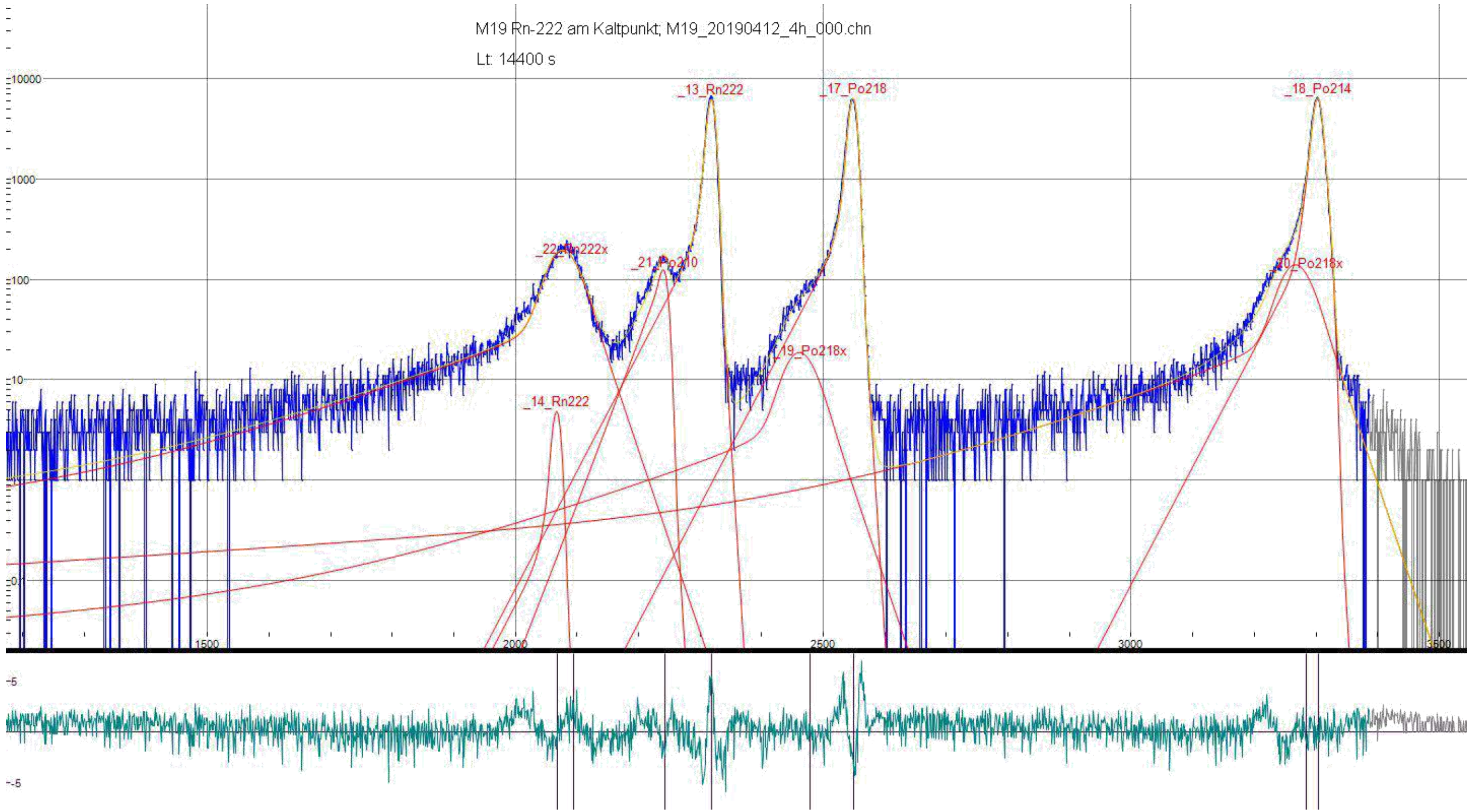




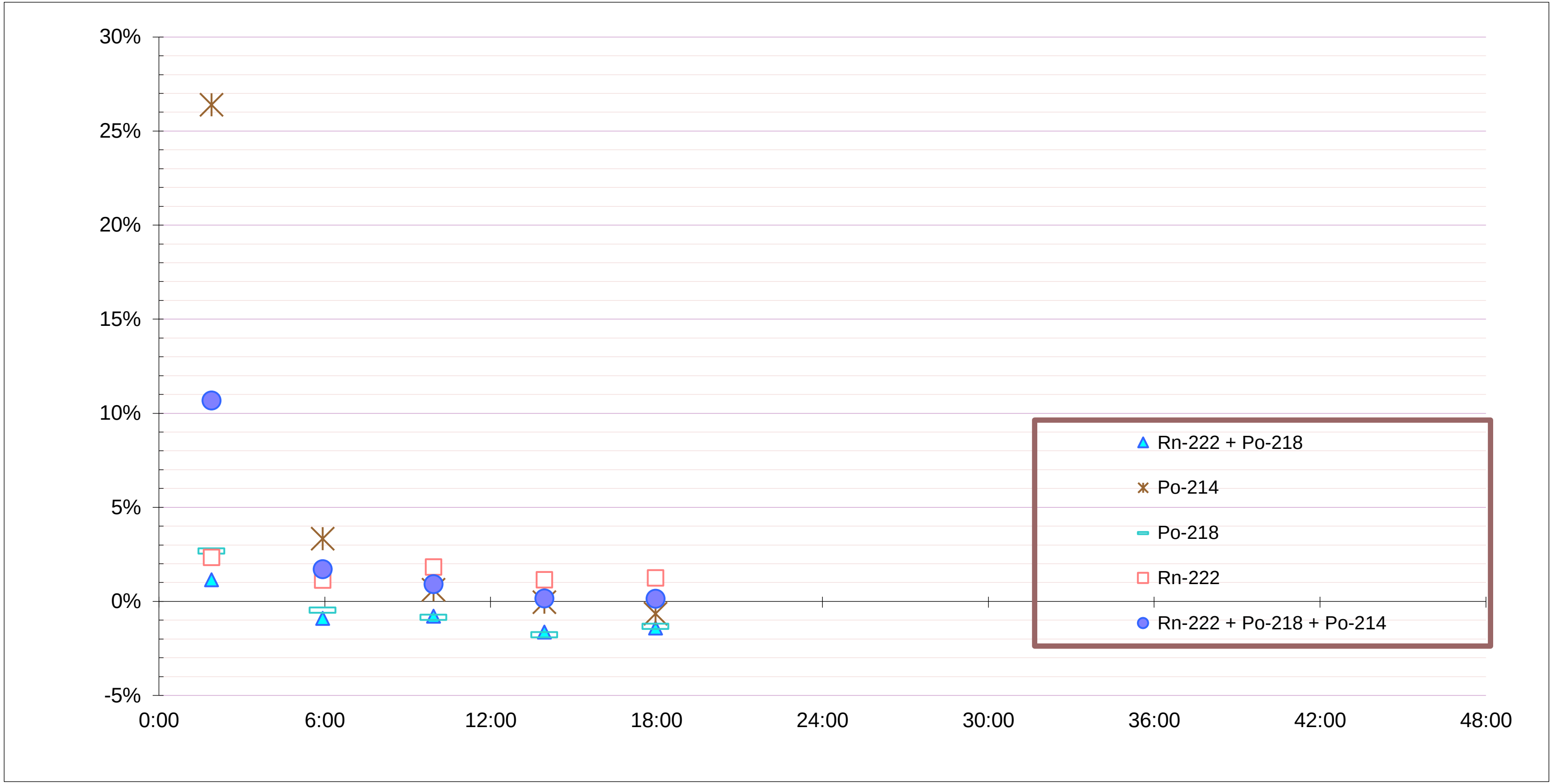
M19 - α-spectrum



M19 - α-spectrum



M19 - DSAS



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36:00
42:00
48:00
Rn-222 + Po-218
Po-214
Po-218
Rn-222
Rn-222 + Po-218 + Po-214

M19 - Radom sampling of geometry

$$\boldsymbol{W} = \begin{pmatrix} w_{0,0} & \cdots & w_{0,j} \\ \vdots & \ddots & \vdots \\ w_{i,0} & \cdots & w_{i,j} \end{pmatrix}$$

$$\boldsymbol{F_y} = \sum_{k,l=0}^{i,j} w_{k,l} \cdot \begin{pmatrix} \sum_{n=0}^{j} w_{0,n} \\ \vdots \\ \sum_{n=0}^{j} w_{i,n} \end{pmatrix}$$

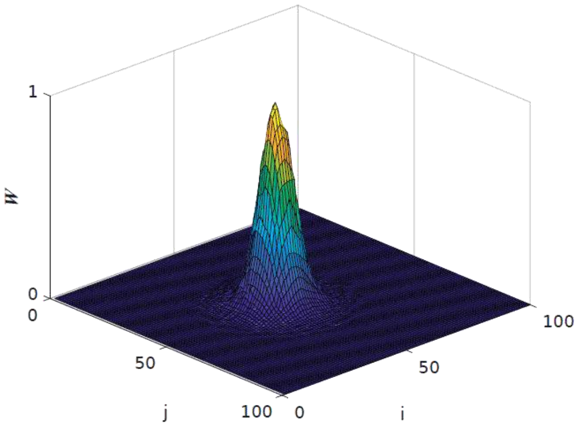
$$\boldsymbol{F_x} = \begin{pmatrix} \frac{w_{0,0}}{\sum_{l=0}^{j} w_{0,l}} & \cdots & \frac{\sum_{k=0}^{j} w_{0,k}}{\sum_{l=0}^{j} w_{0,l}} \\ \vdots & \ddots & \vdots \\ \frac{w_{i,0}}{\sum_{l=0}^{j} w_{i,l}} & \cdots & \frac{\sum_{k=0}^{j} w_{i,k}}{\sum_{l=0}^{j} w_{i,l}} \end{pmatrix}$$

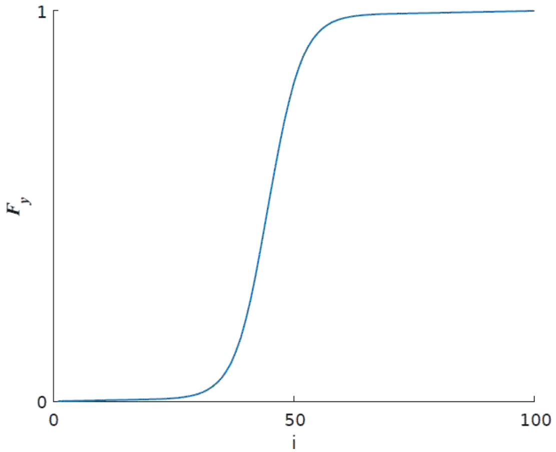
$$i_y = \operatorname{argmin}(|\boldsymbol{F_y} - r_y|)$$

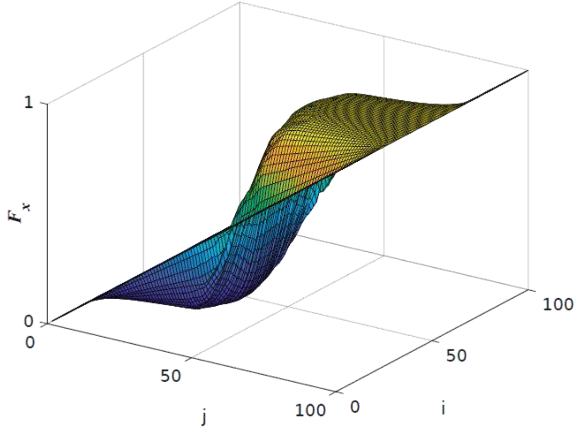
$$i_x = \operatorname{argmin}(|\boldsymbol{F_x}(i_y) - r_x|)$$

$$x = -j \cdot p \cdot \frac{p}{2} + i_x \cdot p$$

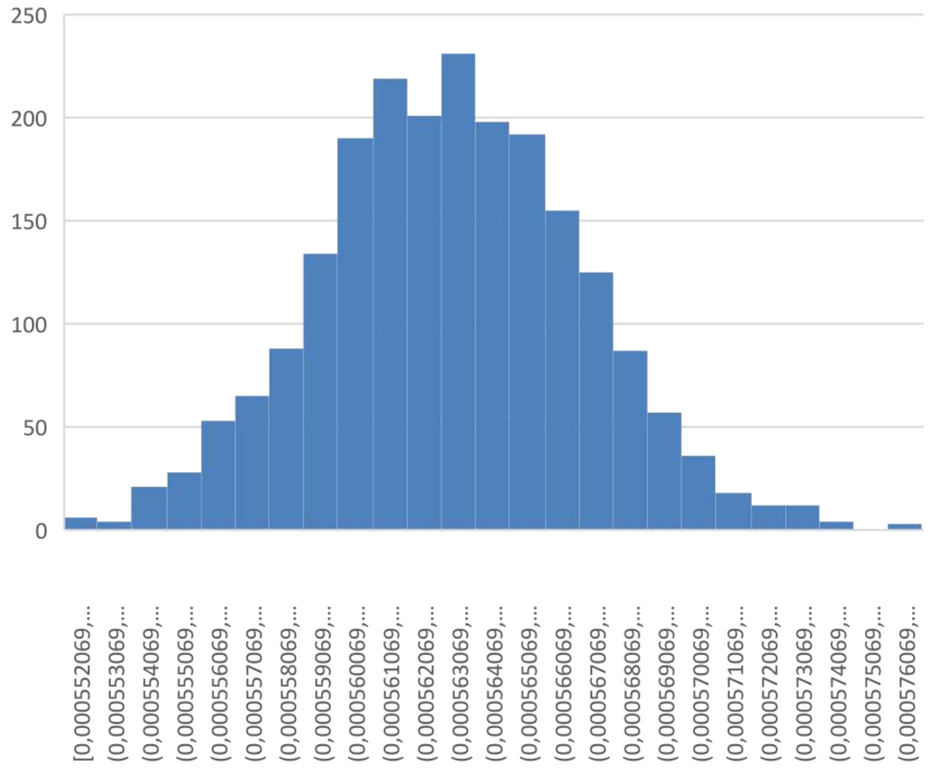
$$y = -i \cdot p \cdot \frac{p}{2} + i_y \cdot p$$







M19 - Radom sampling of geometry



Histogram of Monte-Carlo Results for geometry of M19 (Picolo)

Geometry factor:

0,000563(4)

0.68 % (k=1)

M19 - Uncertainty budget

Gleichung:

$$A_{BZP} = A*\exp(-\ln(2)/T_{HWZ}*t_{BZP});$$
$$A = (Imp_{Ges}/(K_0*Imp_{Pulser})-N_{Po210}/(K_0*f))*1/K_{Zerfall}/\Omega*k_{transfer};$$
$$K_0=\exp(-\lambda_0*t_h)+\lambda_1*\exp(-\lambda_0*t_h)/(\lambda_1-\lambda_0)+\exp(-\lambda_1*t_h)/(\lambda_0-\lambda_1)+c_0*\exp(-\lambda_0*t_h)+c_1*\exp(-\lambda_1*t_h)+c_2*\exp(-\lambda_2*t_h)+c_3*\exp(-\lambda_3*t_h)+c_4*\exp(-\lambda_4*t_h);$$
$$c_0=\lambda_1*\lambda_2*\lambda_3*\lambda_4/((\lambda_1-\lambda_0)*(\lambda_2-\lambda_0)*(\lambda_3-\lambda_0)*(\lambda_4-\lambda_0));$$
$$c_1=\lambda_1*\lambda_2*\lambda_3*\lambda_4/((\lambda_0-\lambda_1)*(\lambda_2-\lambda_1)*(\lambda_3-\lambda_1)*(\lambda_4-\lambda_1));$$
$$c_2=\lambda_1*\lambda_2*\lambda_3*\lambda_4/((\lambda_0-\lambda_2)*(\lambda_1-\lambda_2)*(\lambda_3-\lambda_2)*(\lambda_4-\lambda_2));$$
$$c_3=\lambda_1*\lambda_2*\lambda_3*\lambda_4/((\lambda_0-\lambda_3)*(\lambda_1-\lambda_3)*(\lambda_2-\lambda_3)*(\lambda_4-\lambda_3));$$
$$c_4=\lambda_1*\lambda_2*\lambda_3*\lambda_4/((\lambda_0-\lambda_4)*(\lambda_1-\lambda_4)*(\lambda_2-\lambda_4)*(\lambda_3-\lambda_4));$$
$$\lambda_0=\ln(2)/(T_0*86400);$$
$$\lambda_1=\ln(2)/(T_1*86400);$$
$$\lambda_2=\ln(2)/(T_2*86400);$$
$$\lambda_3=\ln(2)/(T_3*86400);$$
$$\lambda_4=\ln(2)/(T_4*86400);$$
$$t_h=\Delta t_0+Imp_{Pulser}/f/2;$$
$$T_{HWZ}=T_0*86400;$$

Bateman equation

Größe	Einheit	Definition
A	Bq	
Ω		Raumwinkel
Imp_{Ges}		Anzahl Impulse aller Alpha-Strahler
Imp_{Pulser}		Anzahl der Impulse des Pulsers
K_0		Zerfallsfaktor für den Zeitpunkt der Mitte der Messzeit bezogen auf den Zeitpunkt des Radoneinlasses
$K_{Zerfall}$		Korrektion auf Zerfall während der Messung
N_{Po210}	1/s	Zählrate des Po-210 Untergrundes
f	1/s	
Δt_0	s	Zeit zwischen Radoneinlass und Messbeginn
λ_0	1/s	Zerfallskonstante Rn-222
λ_1	1/s	Zerfallskonstante Po-218
λ_2		
λ_3		
λ_4		
c_0		
c_1		
c_2		
c_3		
c_4		
t_h	s	Zeitdifferenz Radoneilass bis zur Hälfte der Messzeit
T_0	d	Rn-222 Halbwertszeit
T_1	d	Po-218 Halbwertszeit
T_2		
T_3		
T_4		
A_{BZP}	Bq	Ergebnis für Radon Aktivität am Bezugszeitpunkt
T_{HWZ}	s	Halbwertszeit 222Rn in s
t_{BZP}	s	Zeitdifferenz zwischen Bezugszeitpunkt und Einspülen
$k_{transfer}$		

M19 - Uncertainty budget

Ergebnis für Radon Aktivität am Bezugszeitpunkt

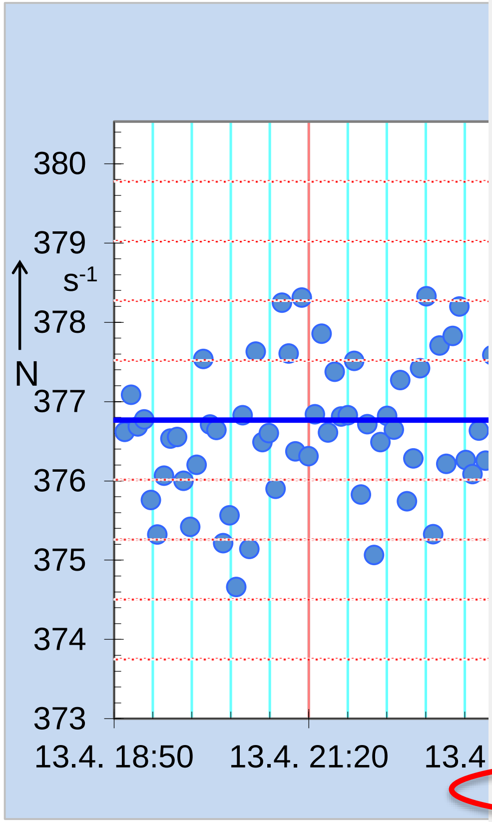
Messunsicherheits-Budget:

Größe	Wert	Standardmess-unsicherheit	Freiheits-grad	Verteilung	Sensitivitäts-koeffizient	Unsicherheits-beitrag	Korr.-Koeff.	Index
Ω	$563.37\cdot10^{-6}$	$3.80\cdot10^{-6}$	100	Normal	$-23\cdot10^{6}$	-87 Bq	-0.948	89.9 %
Imp_{Ges}	$1.07034\cdot10^{6}$	$1.57\cdot10^{3}$	3	Normal	0.013	20 Bq	0.2194	4.8 %
Imp_{Pulser}	$2.16629\cdot10^{6}$	$1.00\cdot10^{3}$	100	Normal	-0.0061	-6.1 Bq	-0.0660	0.4 %
K_0	2.668374	$377\cdot10^{-6}$	150					
$K_{Zerfall}$	0.9996557000	$40.0\cdot10^{-9}$	100	Normal	$13\cdot10^{3}$	$520\cdot10^{-6}$ Bq	0.0	0.0 %
N_{Po210}	1.4630 1/s	0.0181 1/s	100	Normal	-550	-10 Bq	-0.1094	1.2 %
f	50.0020 1/s	0.0100 1/s	100	Normal	260	2.6 Bq	0.0286	0.0 %
Δt_0	$35.7000\cdot10^{3}$ s	60.0 s	100	Normal	0.027	1.6 Bq	0.0177	0.0 %
λ_0	$2.098218\cdot10^{-6}$ 1/s	$165\cdot10^{-12}$ 1/s	100					
λ_1	0.0037262 1/s	$12.1\cdot10^{-6}$ 1/s	100					
λ_2	$431.3\cdot10^{-6}$	$13.9\cdot10^{-6}$	100					
λ_3	$581.3\cdot10^{-6}$	$12.6\cdot10^{-6}$	100					
λ_4	$4.2179\cdot10^{3}$	53.2	100					
c_0	1.009097	$178\cdot10^{-6}$	150					
c_1	-0.02421	0.00110	190					
c_2	-4.404	0.514	170					
c_3	3.419	0.514	170					
c_4	$12.451\cdot10^{-21}$	$677\cdot10^{-24}$	260					
t_h	$57.3620\cdot10^{3}$ s	61.0 s	110					
T_0	3.823500 d	$300\cdot10^{-6}$ d	100	Normal	220	0.065 Bq	0.0	0.0 %
T_1	0.00215300 d	$7.00\cdot10^{-6}$ d	100	Normal	$-2.3\cdot10^{3}$	-0.016 Bq	0.0	0.0 %
T_2	0.018600	$600\cdot10^{-6}$	100	Normal	$-1.1\cdot10^{3}$	-0.68 Bq	-0.0074	0.0 %
T_3	0.013800	$300\cdot10^{-6}$	100	Normal	$-1.1\cdot10^{3}$	-0.34 Bq	-0.0037	0.0 %
T_4	$1.9020\cdot10^{-9}$	$24.0\cdot10^{-12}$	100	Normal	$-1.1\cdot10^{3}$	$-27\cdot10^{-9}$ Bq	0.0	0.0 %
T_{HWZ}	$330.3504\cdot10^{3}$ s	25.9 s	100					
t_{BZP}	$86.3500\cdot10^{3}$ s	34.6 s	∞	Rechteck	-0.027	-0.94 Bq	-0.0102	0.0 %
$k_{transfer}$	1.00000	0.00134	∞	Rechteck	$13\cdot10^{3}$	17 Bq	0.1887	3.6 %
A_{BZP}	$12.8945\cdot10^{3}$ Bq	91.8 Bq	110					

Ergebnis:

Wert:		Erw. Messunsicherheit:	Erweiterungsfaktor:	Überdeckung:
$12.89\cdot10^{3}$ Bq	±	180 Bq	2.00	95% (t-Tabelle 95.45%)

M07 - secondary standard



A

Aktivität

Messunsicherheits-Budget:

Größe	Wert	Standardmess-unsicherheit	Freiheits-grad	Verteilung	Sensitivitäts-koeffizient	Unsicherheits-beitrag	Korr.-Koeff.	Index
$A_{Transfer}$	12.897 kBq	0.117 kBq	100					
N	373.3146 1/s	0.0760 1/s	170	Normal	0.035	0.0026 kBq	0.0225	0.0 %
K_{RN12}	29.222 1/s 1/kBq	0.263 1/s 1/kBq	100	Normal	-0.44	-0.12 kBq	-0.9962	99.0 %
K_{Me369}	1.009221	$645\cdot10^{-6}$	100					
$K_{Zerfall}$	1.00031477	$1.05\cdot10^{-6}$	100					
K_{NE}	1.0000000	$46.2\cdot10^{-6}$	∞	Rechteck	13	$600\cdot10^{-6}$ kBq	0.0051	0.0 %
$K_{Transfer}$	1.000000	$577\cdot10^{-6}$	∞	Rechteck	13	0.0074 kBq	0.0638	0.4 %
λ	$2.098218\cdot10^{-6}$ 1/s	$165\cdot10^{-12}$ 1/s	100					
t	300.00 s	1.00 s	100	Normal	$14\cdot10^{-6}$	$14\cdot10^{-6}$ kBq	0.0	0.0 %
HWZ	3.823500 d	$300\cdot10^{-6}$ d	100	Normal	-0.0011	$-320\cdot10^{-9}$ kBq	0.0	0.0 %
N_0	$10.476000\cdot10^{3}$ 1/s	0.500 1/s	100	Normal	0.0012	$620\cdot10^{-6}$ kBq	0.0053	0.0 %
N_{ME369}	$10.38029\cdot10^{3}$ 1/s	6.61 1/s	100	Normal	-0.0012	-0.0082 kBq	-0.0704	0.5 %
A	12.897 kBq	0.117 kBq	100					

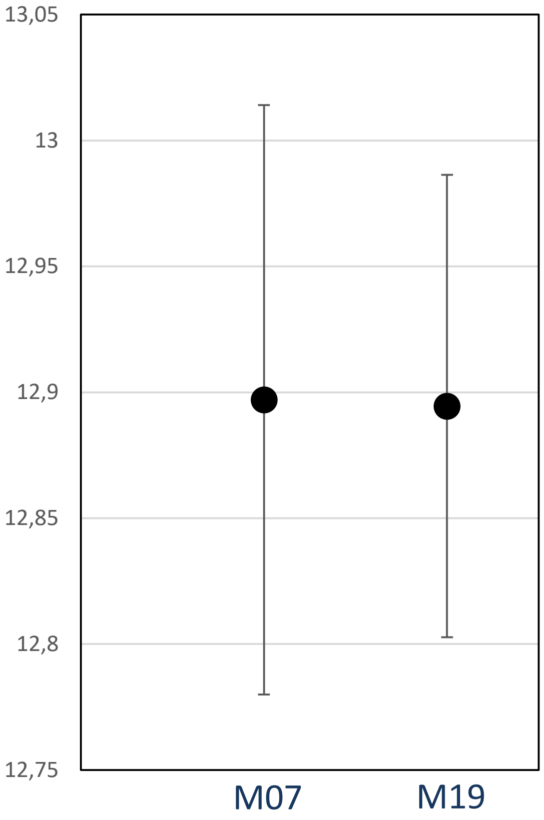
Ergebnis:

Wert:		Erw. Messunsicherheit:	Erweiterungsfaktor:	Überdeckung:
12.90 kBq	±	0.23 kBq	2.00	95% (t-Tabelle 95.45%)

M19 - M07 - comparison

Reference time: 15.04.2019 13:00 MEZ

	A kBq	u(A) kBq	rel u(A) %
M07	12.8970	0.1170	0.907%
M19	12.8945	0.0918	0.712%



CCRI(II) – Rn-222 – key comparison

Measurement method in this Excel file: Picolo - defined solid angle a-particle counting with a PIPS detector

Acronym: SA-PS-AP-00-00-00

MEASUREMENT RESULT 12.895 kBq at reference date

std uncertainty 0.092 kBq

If several results (different dilutions, energy windows, repetitive measurements, …) were combined, please explain below:

UNCERTAINTY BUDGET (standard uncertainties)
Add more components, as necessary; please be as specific as possible.
Please comment how you evaluated the uncertainties.

QUANTITY Q	Relative uncert. of Q	Relative uncertun	Evaluation type (A/B)	Comment
solid angle	6.8E-03	6.75E-03	A	random sampling
counting statistics	1.5E-03	1.55E-03	A	repeated measurements
dead time	4.6E-04	4.70E-04	A	pulser
decay correction during measurement	4.0E-08	4.00E-08	A	
background	1.2E-02	7.76E-04	A	Po-214
frequence standard	2.0E-04	2.00E-04	B	
time to start of measurement	1.7E-03	1.24E-04	A	
nuclear data	1.4E-04	1.4E-04	B	
time to reference date	4.0E-04	7.29E-05	A	
transfer losses	1.3E-03	1.32E-03	A	
combined				

4.56E-05	8.70E-02	7.58E-03
2.40E-06	2.00E-02	3.99E-04
2.21E-07	6.06E-03	3.67E-05
1.60E-15	5.16E-07	2.66E-13
6.02E-07	1.00E-02	1.00E-04
4.00E-08	2.58E-03	6.65E-06
1.54E-08	1.60E-03	2.56E-06
1.99E-08	1.82E-03	3.31E-06
5.31E-09	9.40E-04	8.84E-07
1.74E-06	1.70E-02	2.90E-04
5.06E-05	1.47E-01	8.42E-03
0.00711414	0.38347595	0.09173689

Rn-222 intercomparison MetroRADON 2019 EURAMET SC 1475

Laboratory: Physukalisch-Technische Bundesanstalt — acronym: PTB

Address: Bundesallee 100, 38116 Braunschweig

Name of the contact person: Stefan Röttger
e-mail address: Stefan.Roettger@PTB.de

Date of receipt of sample (DD-MM-YYYY): 12.04.2019
Date of report to BIPM (DD-MM-YYYY):

Reference date: 12:00 UTC 15 April 2019 — Half-life 3.8232 d; *u* 0.0008 d (1 a = 365.2422 d)

List of all the standardization methods used and the name of the corresponding reporting files:
Please, use a separate file for each method

Method (acronym)	Used for the final result (Y/N)	Filename	Name(s) of the person(s) who carried out the measurements
SA-PS-AP-00-00-00	yes		Anja Honig, Rainer Dersch, Stefan Röttger

Final result for the MRA *Please, give only one final result per Laboratory*

Activity kBq	Standard uncertainty kBq	Relative std uncertainty %
12.895	0.092	0.71

If the final result is obtained by a combination of results from several measurement methods, please explain the procedure below (weighted mean, correlations, ...):

CCRI(II) Rn-222 procedure

1) Pilot lab (LNE-LNHB) ships container ✔
2) Each participant measures total Rn-222 activity in container ✔
3) LNHB sends own results to CCRI Executive Secretary, EURAMET TC-IR Chair and notification to participants ✔
4) Participants send their own results and uncertainty budgets to LNHB
5) LNHB evaluation and reporting (Draft A, B and Final report)

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
Bundesallee 100
38116 Braunschweig

Stefan Röttger
Telefon: 0531 592-6130
E-Mail: Stefan.Roettger@PTB.de
www.ptb.de

IIG Meeting, 18 June 2019

PTB, Brunswick, Bothe-Bau, Room 311

AGENDA

WHEN	WHAT	WHO
9:30 – 10:00	Welcome + Introduction of participants	Dr. Stefan Neumaier
10:00 – 10:30 10:30 – 11:00	Presentation of MetroRadon Radon: Quantities and Units	Dr. Michael Stietka, Dr. Valeria Gruber Dr. Annette Röttger
11:00 – 11:30	**Coffee break**	
11:30 – 12:30	First results of WP1 + discussions: • The CCRI Rn-222 gas standard intercomparison-status • New primary Ra-226 emanation sources for stable low-level Rn-222 activity concentration	Dr. Dirk Arnold, Dr. Stefan Röttger, Florian Mertes, Dr. Annette Röttger
12:30 – 13:30	**Lunch**	
13:30 – 14:30	First results of WP3 and WP2 + discussions: • Analysis of questionnaire data on indoor radon survey • First results and outcomes of potential interest for industry	WP-Leader WP3: Giorgia Cinelli, JRC, Ispra, Italy WP2: Prof. Dobromir S. Pressyanov, Sofia University, Sofia, Bulgaria
14:30 – 15:00	Presentations by IIG members: • Radonova Laboratories AB	Dr. José-Luis Gutiérrez Villanueva, Radonova, Uppsala, Sweden

	• Indoor and soil radon measurements using LR115 nuclear track film	Maria Jönsson, Radonanalys GJAB, Lund, Sweden
15:00 – 15:30	**Coffee break**	
15:30 – 16:30	Presentations by IIG members • Professional radon monitoring in air/soil/water with the AlphaGUARD • Overview of DURRIDGE Company	Franz Rößler, Bertin GmbH, Frankfurt, Germany Dr. Francesca Mazzone, U-series S.r.l., Bologna, Italy Dr. Stephen Sadler, Durridge UK Ltd., Sheffield, UK
16:30 – 17:00	First results of WP4 and WP5 + discussions • At the end of the QA chain- Decision on Radon Priority Areas • Validation of traceability, performance and precision of European radon calibration facilities	WP-Leader WP4 + 5: Sebastian Feige, BfS, Berlin, Germany
17:00 – 17:30	Conclusions and next steps	All
17:30	**End**	

Metro Radon WP4:

At the end of the QA chain - Decision on Radon Priority Areas

Sebastian Feige, **Peter Bossew**

18.06.2019, IIG-Meeting MetroRadon

PTB, Braunschweig

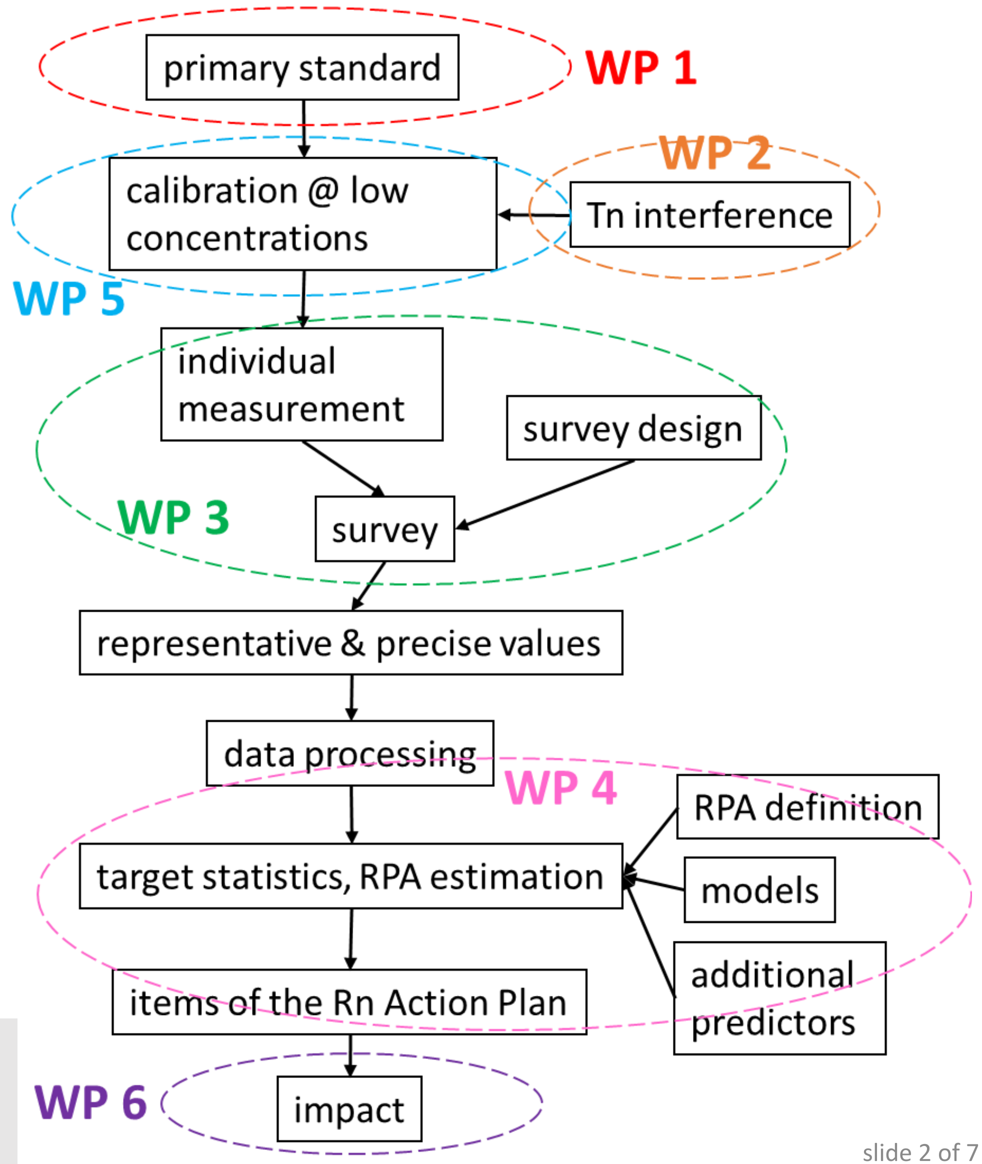
The EMPIR initiative is co-funded by the European Union's Horizon 2020 research and innovation programme and the EMPIR Participating States

rationale: WP4 in the framework of Metro Radon

"supply chain" which leads to a QAed "end product", e.g.,

- Decision about compliance with Reference Levels;
- Delineation of Radon Priority Areas (BSS Art. 103) satisfying a certain level of confidence;
- …
- general: Items of Rn Action Plan

$\Rightarrow$ **All links of the chain must be quality assured!** – starting from "classical metrology"

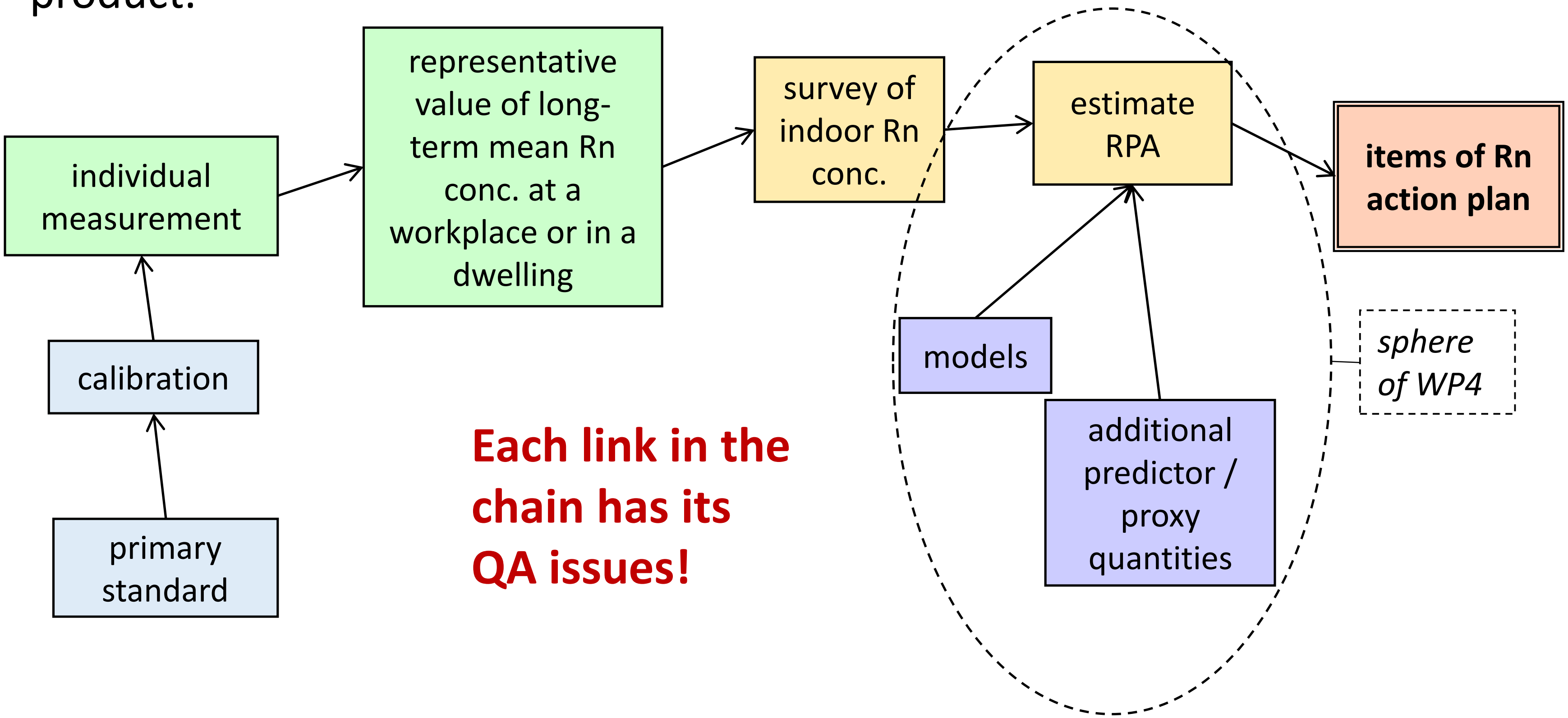


From the point of view of BSS, not a particular value of Rn conc. is the requested end product, but certain action.

Some – but not all – links addressed in Metro Radon.
WP1,2,5: "classical" metrological tasks;
WP3,4: high aggregation levels.

"Supply Chain"

- Pathway from correctly measured individual Rn concentrations to a reliable end-user product, i.e. items of Rn action plans aimed to reduce Rn exposure.
- For the overall purpose of reduction of Rn exposure, one is not interested in actual Rn concentrations; but these being correctly measured, is a condition of the validity of all subsequent aggregation steps, which serve the end-user product.



Tasks of WP4

4.1 Concept and purpose of RPA

- role of stakeholders in RPA definition;
- RPA from dwellings // workplaces;
- case studies

4.2 Relation geogenic – indoor radon

4.3 Recent developments in RPA definition

- Estimation and uncertainty of RPAs;
- Retrospective RPA estimation, CD/DVD method
- RPA based on extremes
- Geogenic Radon Hazard Index GRHI

4.4 Harmonization of RPAs across borders

- Mapping exercise

Highlights 1

- **Stakeholder role:**
  - Which are the stakeholders involved in RPA definition?
  - Which are their interests?
  - How do they enforce their interests?

  $\rightarrow$ Case studies from several countries.

- **RPA from dwellings // workplaces:**
  RPA delineation is most relevant for workplaces (BSS Art.54; Annex XVIII: obligatory measurements, prevention, mitigation, remediation $\Rightarrow$ €€ !), but mostly estimated from dwellings, because of data availability.
  - Are dwellings and workplaces comparable?
  - High diversity of workplaces with different Rn characteristic.

  $\rightarrow$ Study about relation between Rn in dwellings and workplaces under same geogenic control; data from several countries (IT, AT, DE, FI) being analyzed.

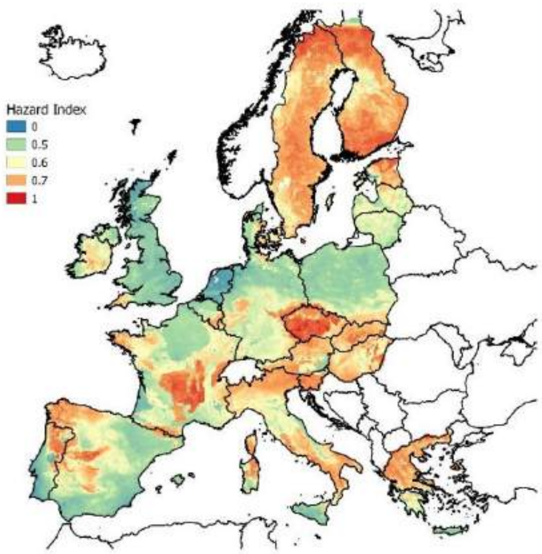
- **Mapping exercise:**
  Regions in AT and ES mapped by different teams. Dependence of results on methodology!

Highlights 2

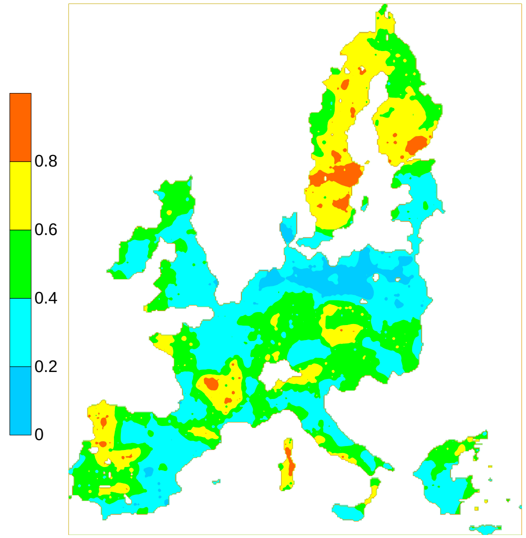
- **Retrospective estimation:**
  Rn decay generates tracks on CDs and DVDs – can they be used to define long-term Rn levels, and consequently RPAs?
- **Geogenic Radon hazard index GRHI:**
  A measure of "Rn priorityness" of a region for geogenic reasons

<u>Two trials:</u>

Machine learning (MARS)



General linear model:



- From geogenic predictors (geology, U concentration, etc.)
- Combined such as to optimally predict indoor Rn (taken from database underlying the European Rn Map)
- Model → GRHI

Thank you!

WP4 participants (unusually many! – shows high interest):

AGES

European Commission

IRSN
INSTITUT
DE RADIOPROTECTION
ET DE SÛRETÉ NUCLÉAIRE

Bundesamt für Strahlenschutz

INAIL
ISTITUTO NAZIONALE PER L'ASSICURAZIONE
CONTRO GLI INFORTUNI SUL LAVORO

UC UNIVERSIDAD DE CANTABRIA LaRUC
Laboratorio de Radiactividad Ambiental

Consiglio Nazionale delle Ricerche IGAG
Institute of Environmental Geology and Geoengineering

Vinča Institute of Nuclear Science

FACULTY OF SCIENCES
University of Novi Sad

SUBG
Uni Sofia

BFKH
Budapest

UNIVERSIDADE D COIMBRA

Thanks for your attention!

DURRIDGE

Radon Capture & Analytics

Dr. Stephen W. Sadler
stephen@durridge.co.uk

MetroRADON IIG Meeting

18 June 2019 Braunschweig, Germany

Contents

Company Overview

- Founded 1997.
- Continuous Radon Monitors for Scientific and Professional use.
- RAD7 - Developed at MIT, deployed around the world.
- HQ in the Boston Tech Hub, USA – Engineering, Production, Sales and Marketing, calibration and repairs.
- European Branch in Sheffield, UK – Calibration and repairs, R&D, technical support.

CE CERTIFIED

National Radon Safety Board NRSB Certified Radon Professionals

RAD7 Continuous Radon Monitor

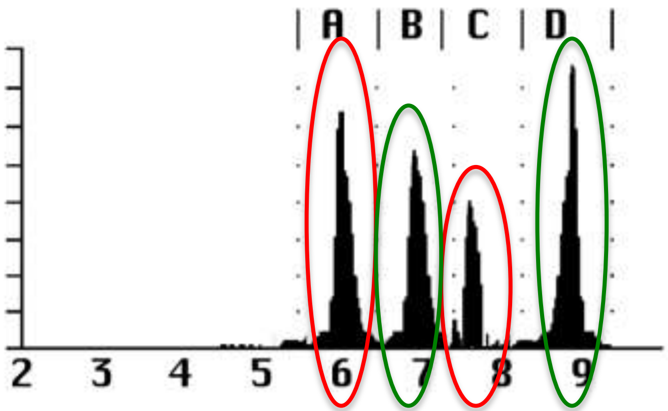
For Scientific & Professional Use

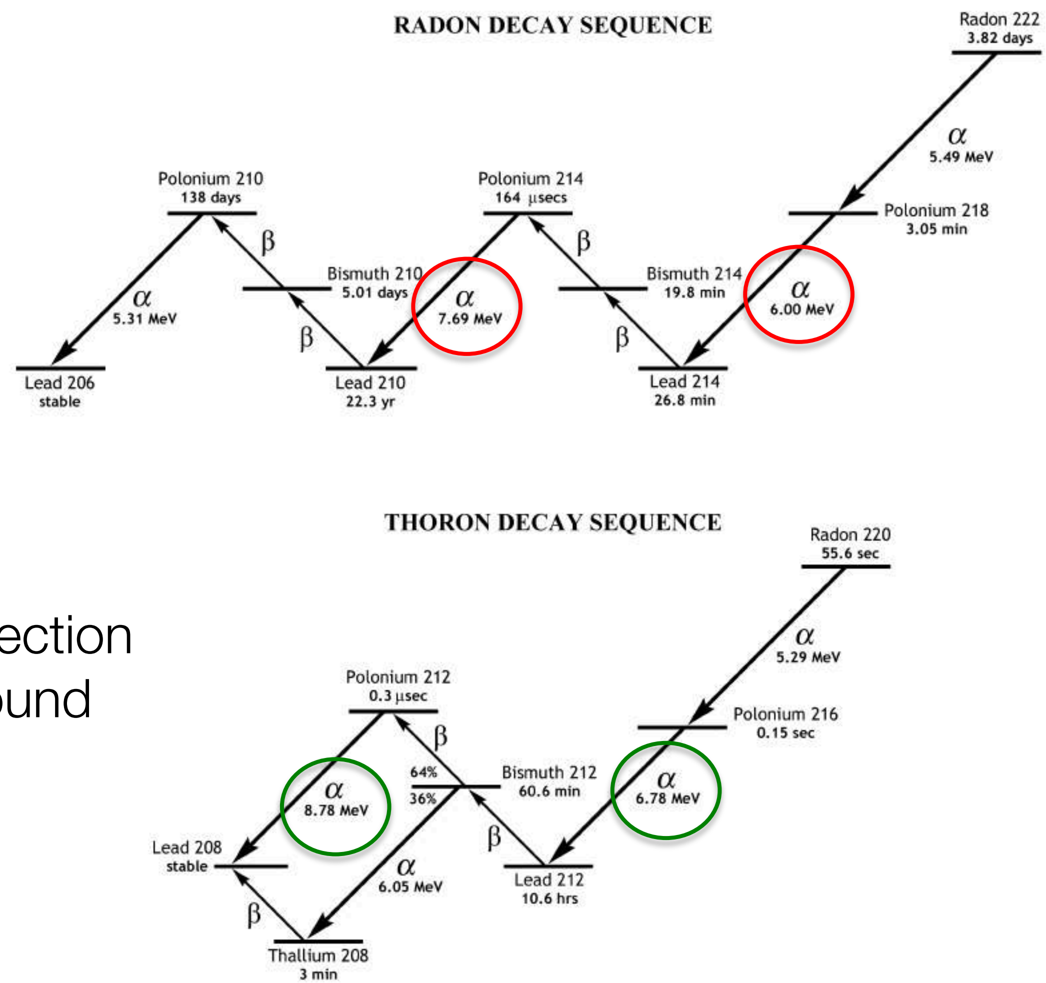
- Active instrument: sample air is pumped into the measurement chamber.
- Electrostatic collection of radon daughters on a silicon detector, followed by high-resolution alpha spectrometry.
- Sniff Mode Sensitivity (using 218Po decays) :
  6.7 cpm/kBq/m^3.
- Normal Mode Sensitivity (using 218Po and 214Po decays) :
  13 cpm/kBq/m^3.
- Intrinsic Background:
  0.2 Bq/m^3 for the lifetime of the instrument.

RAD7 Additional Specs & Features

Type of Detector	Silicon semiconductor
Independent radon and thoron measurement	Yes
Simultaneous radon and thoron measurement	Yes
Battery Life	72 hours in Normal mode
Weight	4.35 kg
Software (PC & Mac)	CAPTURE software for powerful data visualization and analysis.

Superior Energy Resolution





- Near-perfect background rejection (including long-lived background from ^{210}Po).
- Near-perfect radon/thoron discrimination.

RAD7s in the Field

- Over 5000 RAD7s sold.
- Used on all seven continents.
- Used in over 2500 published scientific papers.
- Applications include: human health risk, nuclear research, groundwater tracing, dark matter searches, etc.

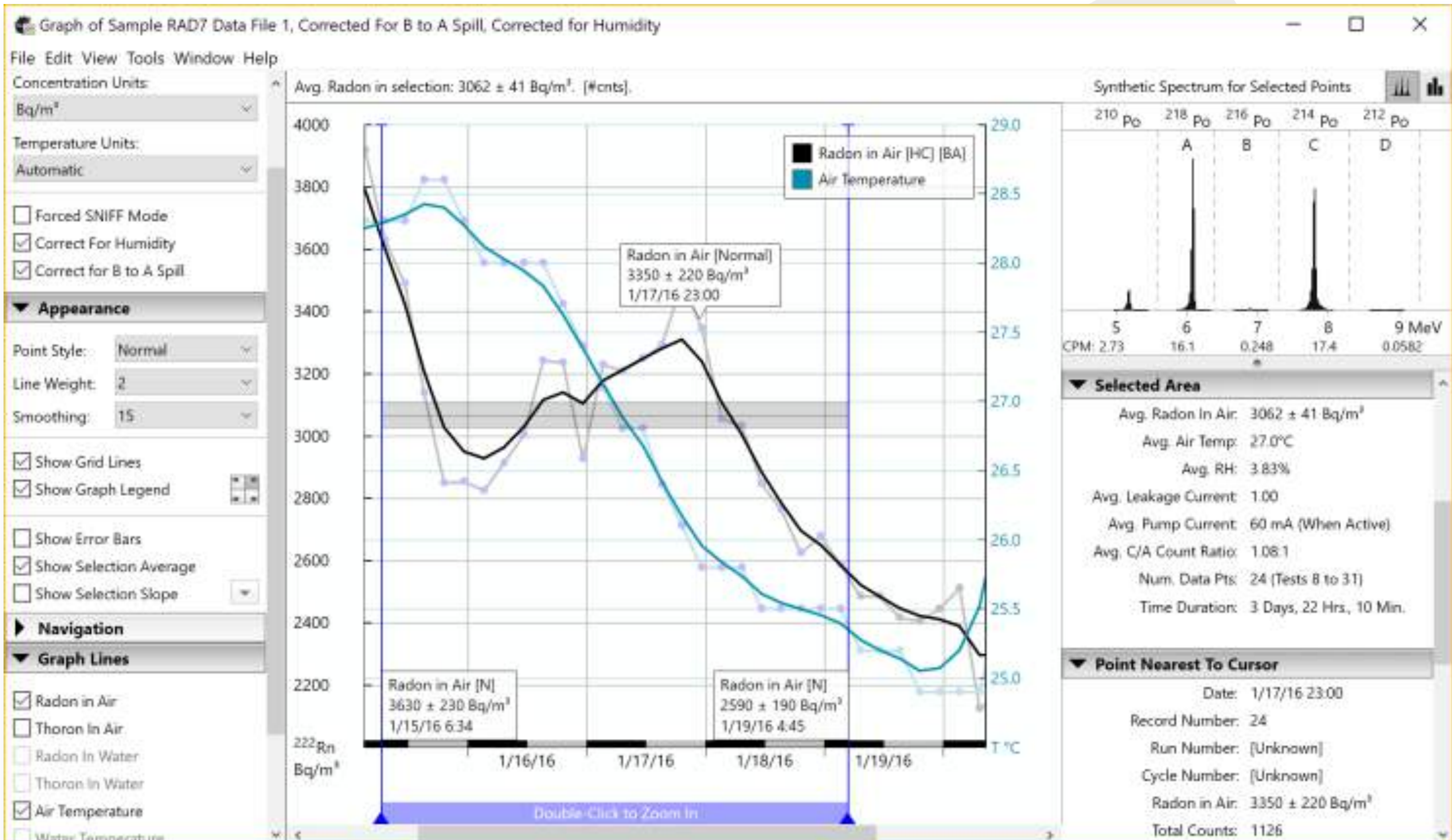
Geologist Kenneth Sims using a RAD7 on the rim of a volcano. Photo by John Catto.

[CAPTURE

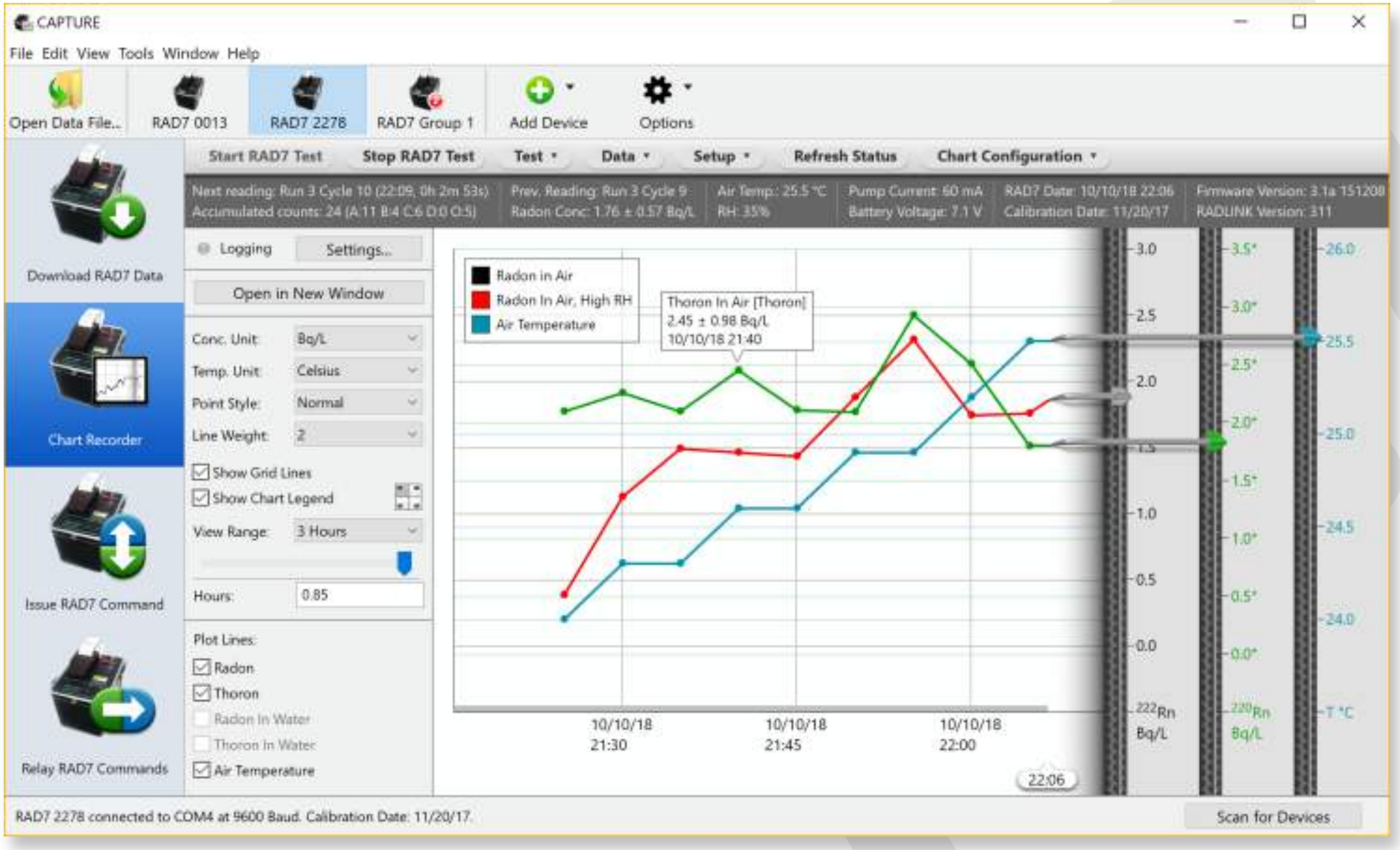
Data Acquisition and Analysis Software

- Data download, graphing, and processing
- Chart Recorder Mode plots data in real time
- Sophisticated feature set for data analysis

CAPTURE Graph Window



CAPTURE Chart Recorder Mode

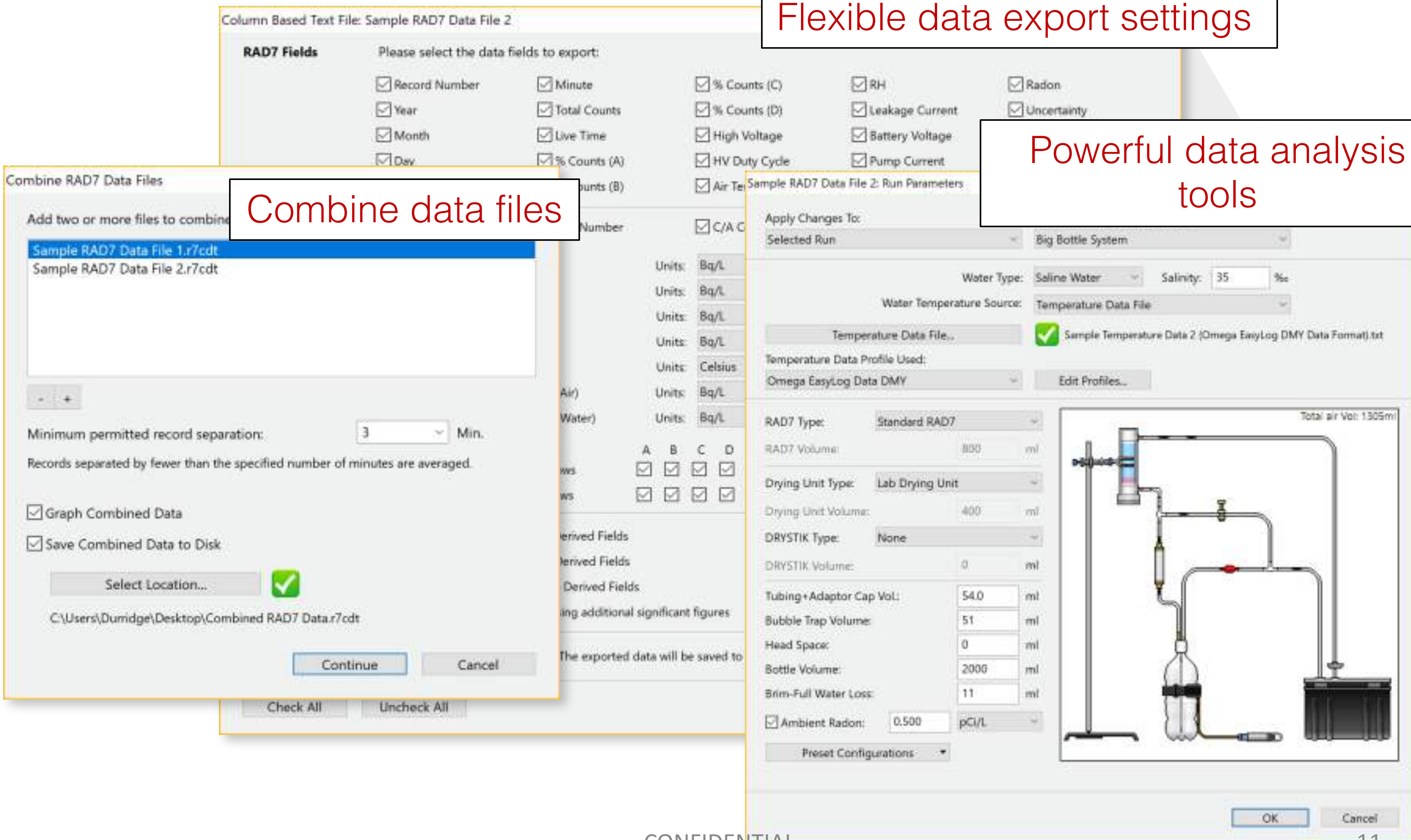


CAPTURE's Sophisticated Feature Set

Flexible data export settings

Combine data files

Powerful data analysis tools



Summary

- RAD7 achieves its superior energy resolution by collecting radon daughters on a silicon detector, and measuring their full alpha decay energy.
- This allows complete separation of radon and thoron peaks, both from each other and from background.
- RAD7 comes bundled with our powerful CAPTURE software, which is still in active development and evolving in response to user feedback.
- Calibration and repair facilities in Europe and the USA.
- Complimented by a full suite of accessories for measuring radon in water, soil, and from materials (see backup slides for details).

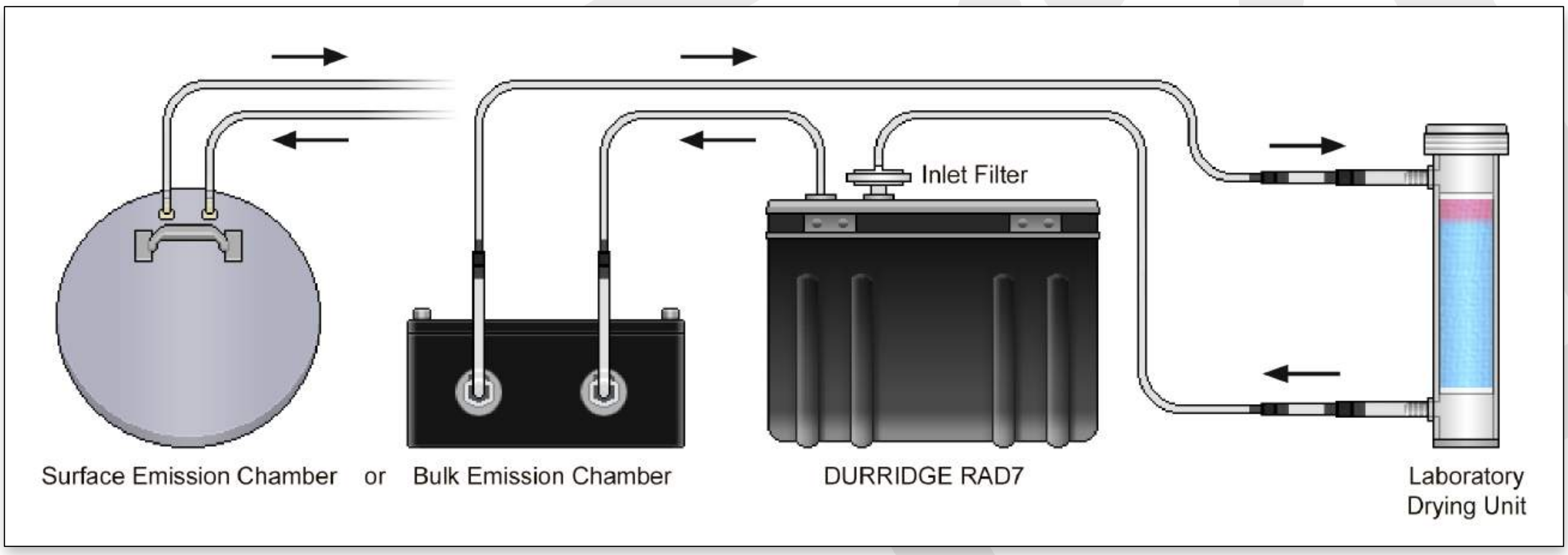
DURRIDGE
Radon Capture & Analytics

Thanks for listening!

Dr. Stephen W. Sadler
stephen@durridge.co.uk

Emission Chambers

- Soil Surface Chamber with steel skirt
- Hard Surface Chamber with soft sealant
- Bulk Emission Chamber for enclosing samples (various sizes available)

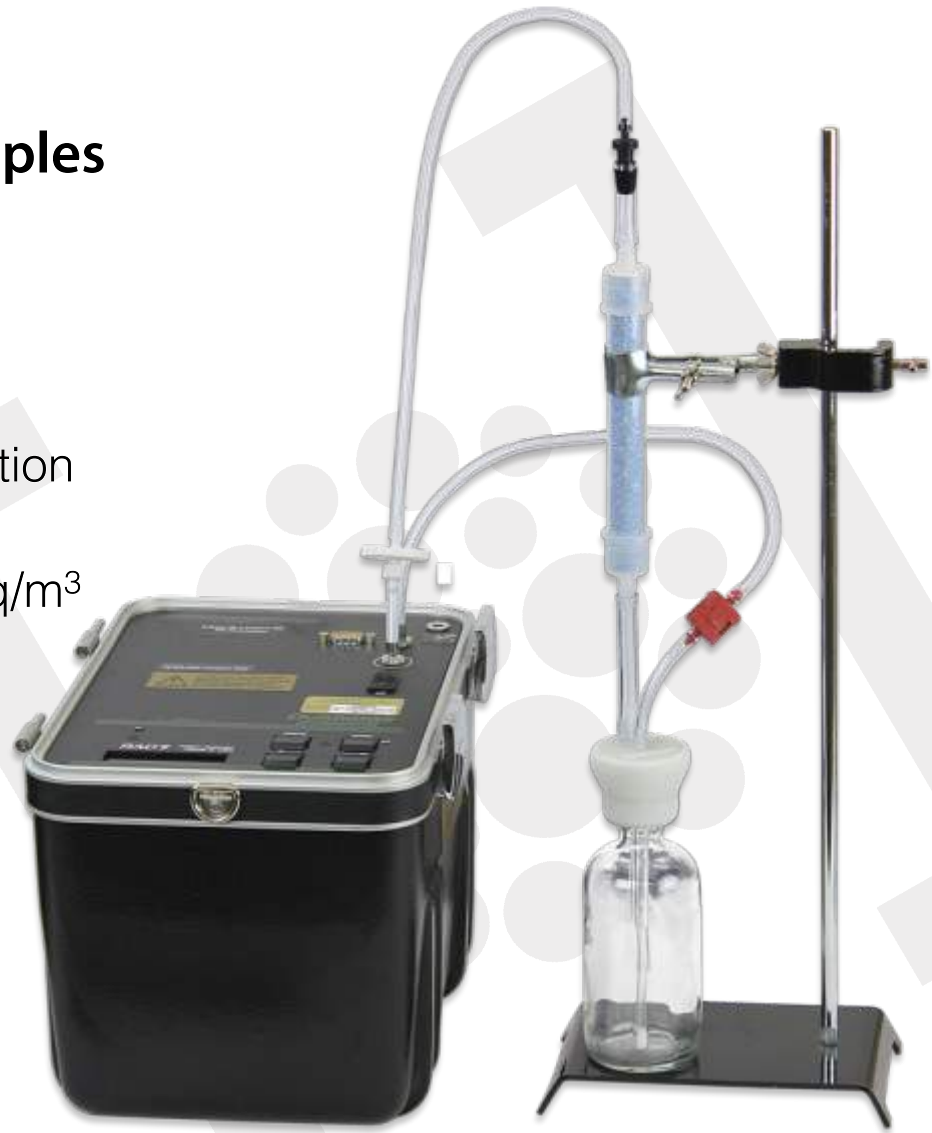


Closed-loop Configuration

[RAD H_2O

Measure Radon in Water Samples

- **Portable:** Fitted case, only 6kg.
- **Automatic:** Controlled by RAD7
- **Fast:** Complete analysis in 1 hr.
- **Accurate:** Equal to liquid scintillation
- **Sensitive:** Better than liquid scintillation. Lower limit of 370 Bq/m^3
- **Clean and Safe:** No hazardous materials
- **Proven:** Used by labs around the world for over 10 years
- **Great Value:** Minimal running costs



RAD Aqua

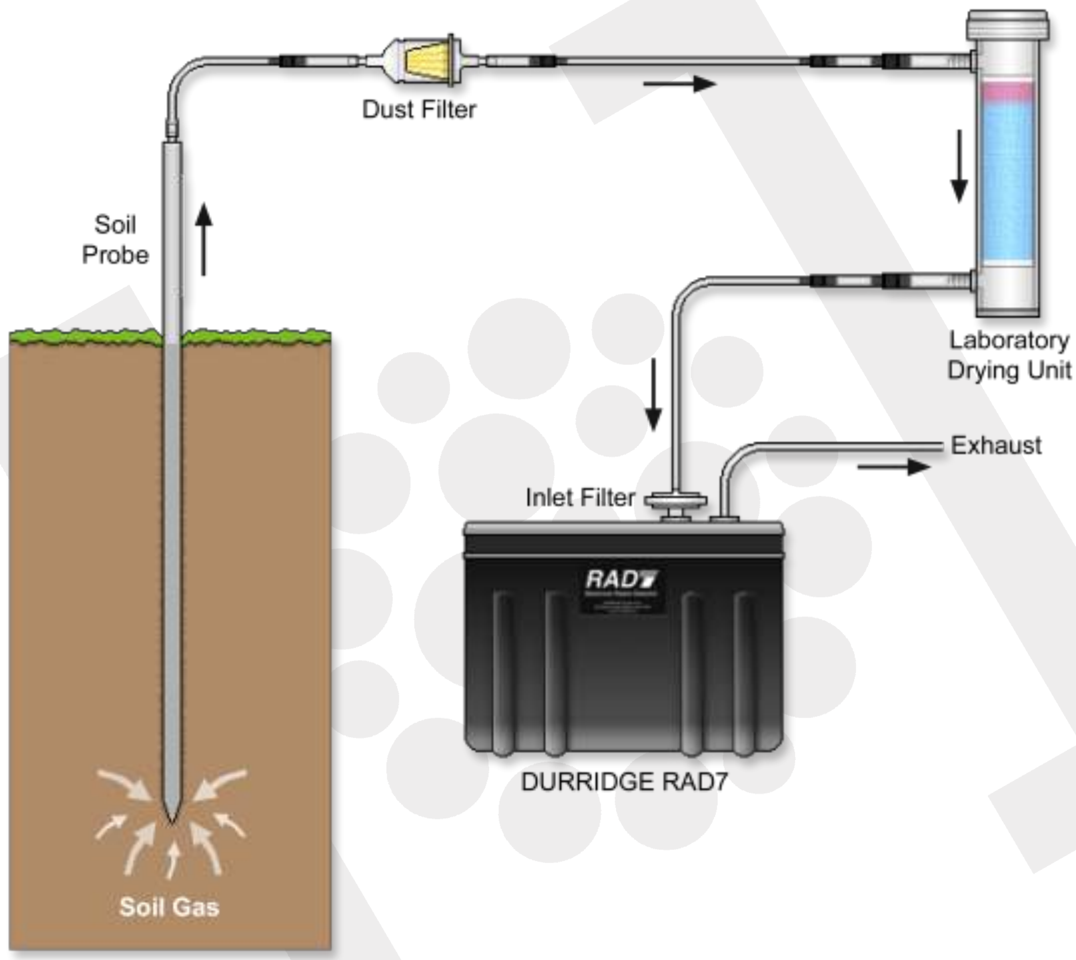
Measure Radon in Water at the Source

- **Radon and Thoron Measurement**: Continuous monitoring in water
- **Simple to Use**: Connect to tap and RAD7
- **Fast**: 95% response in 30 minutes
- **Sensitive**: Can monitor concentrations <0.04 Bq/L
- **Accurate**: Measurements precise within ±5%
- **Clean and Safe**: No hazardous chemicals
- **Complete**: Includes temperature logger
- **Great Value**: Practically no running costs

Soil Gas Probe

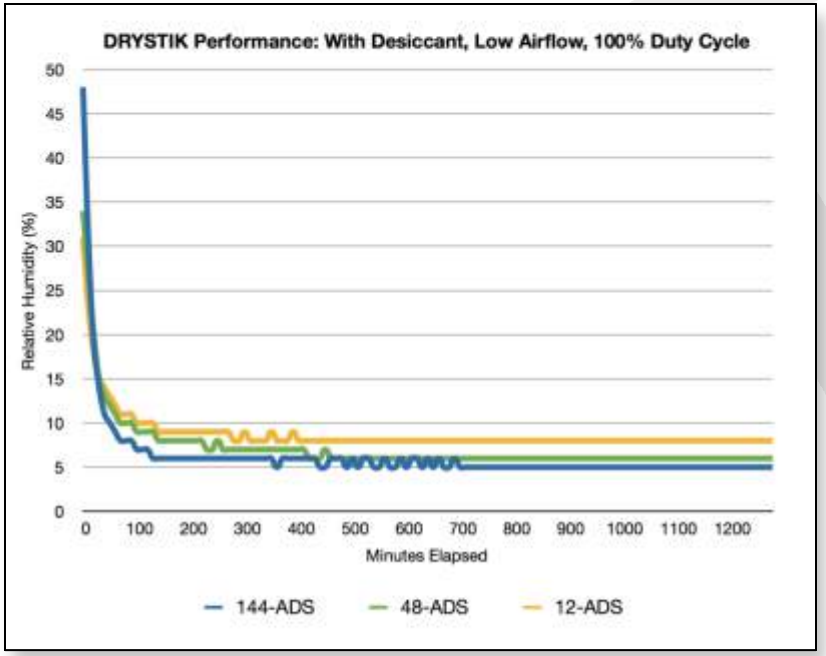
Measure Radon in Soil

- Push into ground to draw soil gas
- Includes Water Stop Valve and Vacuum Gauge (not shown)
- Must ensure that air is not drawn in from the surface



Active DRYSTIK

Nafion humidity exchanger with pump, variable/fixed flow rates, and programmable duty cycle controller



Drastically reduce humidity without consuming desiccant!

Range Extender

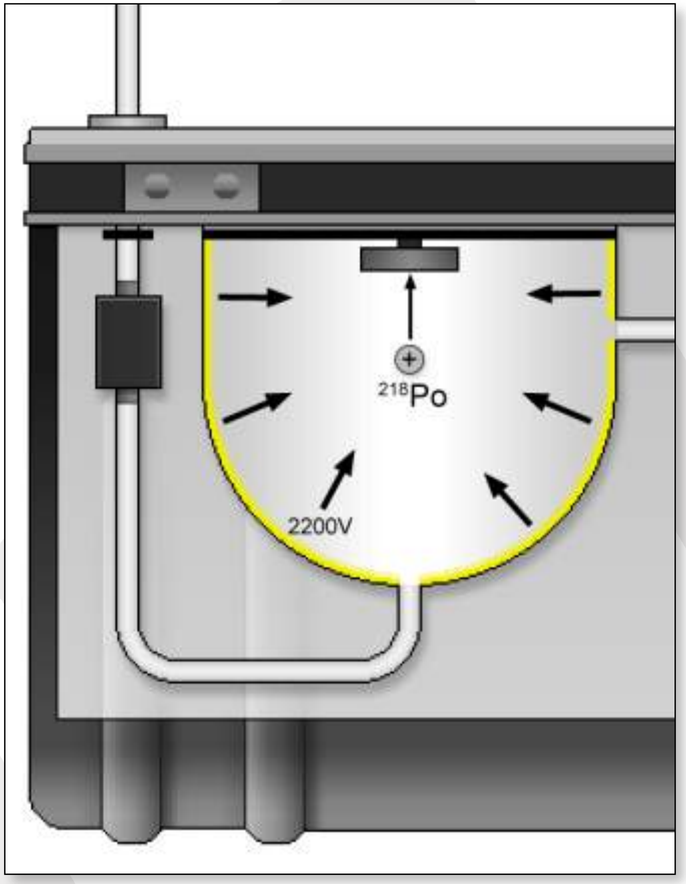
Enables Measurement of Very High Radon Concentrations

- Extends RAD7 Range 10X: From 750,000 Bq/m^3 to 7,500,000 Bq/m^3
- Parallel capillary tubes mix sample and fresh air at known ratio
- Passive device with battery-operated pressure check

Measurement Technology

Alpha Spectrometry

- Radon admitted, progeny blocked
- Radon decays to charged ^{218}Po
- ^{218}Po swept onto PIPS detector by high voltage electric field
- ^{218}Po decays to ^{214}Po, 50% chance to be measured (due to geometry)
- ^{214}Po decays, 50% chance to be measured
- Radon concentration calculated by:
  Sniff Mode: Rate of decay of ^{218}Po
  Normal Mode: Rate of decay of ^{218}Po + ^{214}Po



RAD7 Measurement Chamber

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

MetroRADON – Metrology for Radon Monitoring
WP6 - **Impact**

Valeria Gruber, on behalf of MetroRADON consortium

IIG-Meeting, Braunschweig, 18 June 2019

WP6 – Creating Impact

Structure

- Task 6.1. **Knowledge transfer**
- Task 6.2 **Training**
- Task 6.3 **Uptake and exploitation**

WP6 – Creating Impact

Knowledge Transfer

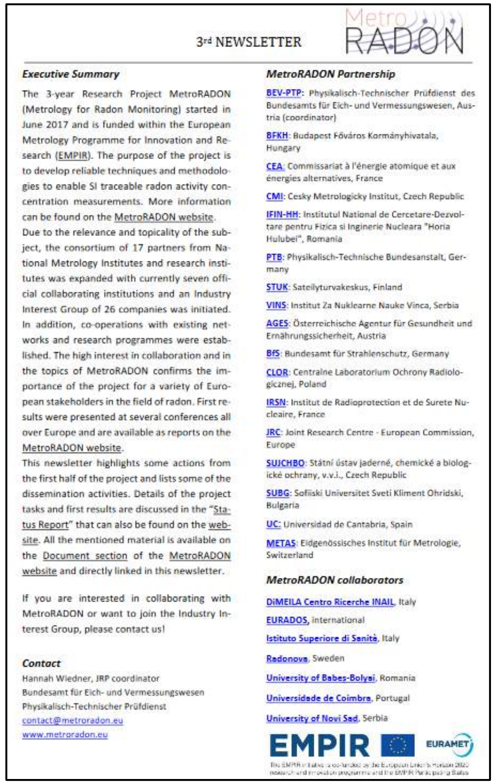
- At least 10 conference presentations (status: >30)
- At least 10 peer reviewed papers (status: 2 published, several in prep.)
- 2 newsletter/year (status: 3 newsletters and status reports; next: July 2019) – registration at website!
- Newsletter, reports, presentations, papers etc. – available at website:

www.metroradon.eu

- Research Gate

> MetroRADON - Metrology for Radon Monitoring (EMPIR 16ENV10)
>
> F. J. Maringer · Philippe Cassette · Nathalie Michielsen · Show all 41 collaborators
>
> **Goal:** 1. Development of novel procedures for the traceable calibration of radon (222Rn) measurement instruments at low activity concentrations (100 Bq/m3 to 300 Bq/m3) with relative uncertainties ≤ 5 % (k=1)

contact@metroradon.eu



3rd NEWSLETTER — MetroRADON

Executive Summary

The 3-year Research Project MetroRADON (Metrology for Radon Monitoring) started in June 2017 and is funded within the European Metrology Programme for Innovation and Research (EMPIR). The purpose of the project is to develop reliable techniques and methodologies to enable SI traceable radon activity concentration measurements. More information can be found on the MetroRADON website.

Due to the relevance and topicality of the subject, the consortium of 17 partners from National Metrology Institutes and research institutes was expanded with currently seven official collaborating institutions and an Industry Interest Group of 26 companies was initiated. In addition, co-operations with existing networks and research programmes were established. The high interest in collaboration and in the topics of MetroRADON confirms the importance of the project for a variety of European stakeholders in the field of radon. First results were presented at several conferences all over Europe and are available as reports on the MetroRADON website.

This newsletter highlights some actions from the first half of the project and lists some of the dissemination activities. Details of the project tasks and first results are discussed in the "Status Report" that can also be found on the website. All the mentioned material is available on the Document section of the MetroRADON website and directly linked in this newsletter.

If you are interested in collaborating with MetroRADON or want to join the Industry Interest Group, please contact us!

Contact

Hannah Wiedner, JRP coordinator
Bundesamt für Eich- und Vermessungswesen
Physikalisch-Technischer Prüfdienst
contact@metroradon.eu
www.metroradon.eu

MetroRADON Partnership

BEV-PTP: Physikalisch-Technischer Prüfdienst des Bundesamts für Eich- und Vermessungswesen, Austria (coordinator)

BFKH: Budapest Főváros Kormányhivatala, Hungary

CEA: Commissariat à l'énergie atomique et aux énergies alternatives, France

CMI: Cesky Metrologicky Institut, Czech Republic

IFIN-HH: Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara "Horia Hulubei", Romania

PTB: Physikalisch-Technische Bundesanstalt, Germany

STUK: Sateilyturvakeskus, Finland

VINS: Institut Za Nuklearne Nauke Vinca, Serbia

AGES: Österreichische Agentur für Gesundheit und Ernährungssicherheit, Austria

BfS: Bundesamt für Strahlenschutz, Germany

CLOR: Centralne Laboratorium Ochrony Radiologicznej, Poland

IRSN: Institut de Radioprotection et de Surete Nucleaire, France

JRC: Joint Research Centre - European Commission, Europe

SUJCHBO: Státní ústav jaderné, chemické a biologické ochrany, v.v.i., Czech Republic

SUBG: Sofiiski Universitet Sveti Kliment Ohridski, Bulgaria

UC: Universidad de Cantabria, Spain

METAS: Eidgenössisches Institut für Metrologie, Switzerland

MetroRADON collaborators

DiMEILA Centro Ricerche INAIL, Italy

EURADOS, international

Istituto Superiore di Sanità, Italy

Radonova, Sweden

University of Babes-Bolyai, Romania

Universidade de Coimbra, Portugal

University of Novi Sad, Serbia

EMPIR EURAMET

WP6 – Creating Impact

Knowledge Transfer

- Stakeholder Involvement
  - National Authorities
  - European and International Bodies (IAEA, WHO, ERA, ICRP, IRPA, HERCA, EURADOS etc.)
  - Standard Bodies and Committees
  - Industry

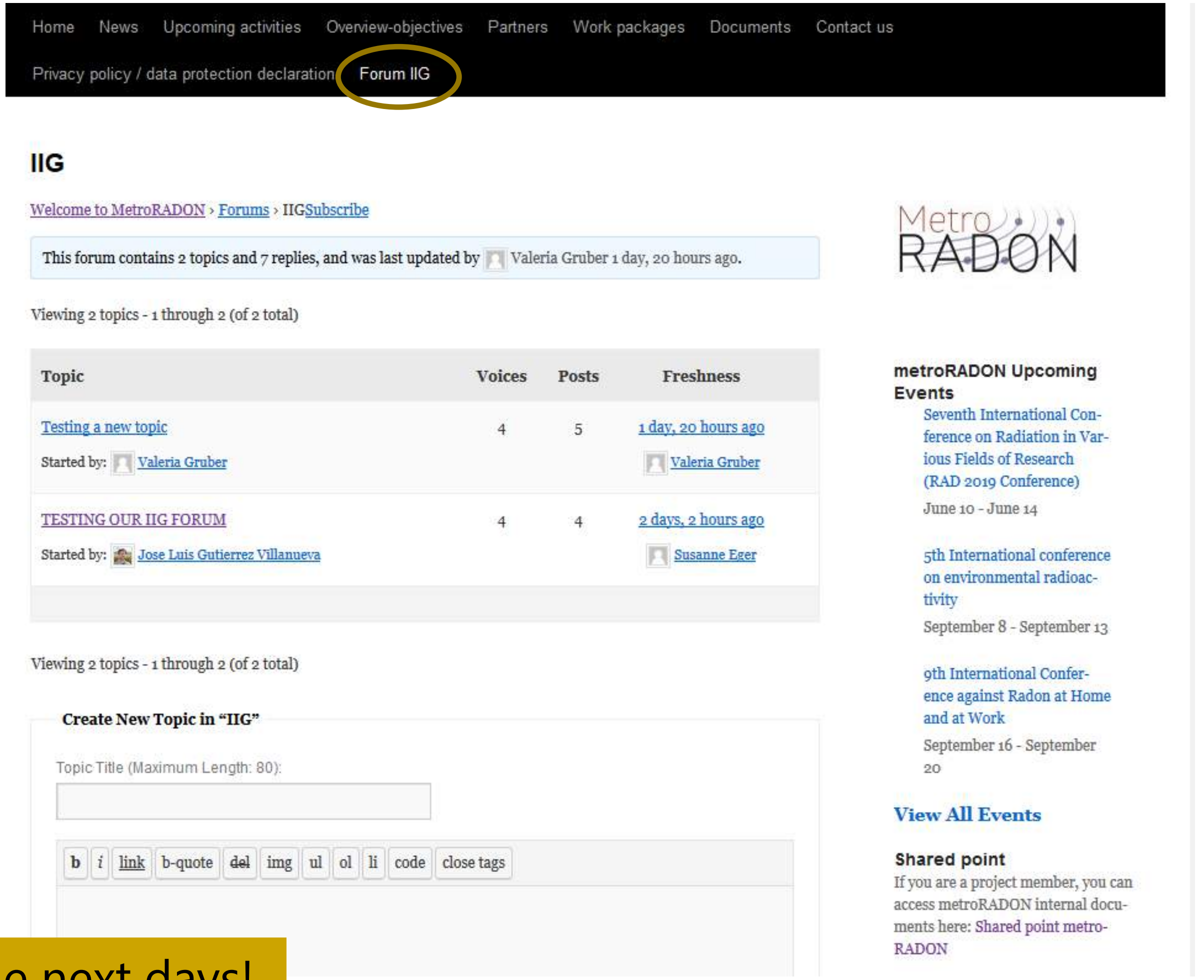
- Industry Interest Group - PTB
  - >60 companies invited
  - 27 members (at the moment)
  - Keep industry informed on developments in the project and obtain feedback
  - Networking possibility among industry

WP6 – Creating Impact

Knowledge Transfer - IIG

- Newsletter
- Project documents available at website (Reports, Presentations, Papers)
- IIG meeting
- IIG Forum
  - Discussion
  - Share documents

metroradon.eu



We will send log-in details to all IIG-members in the next days!

contact@metroradon.eu

WP6 – Creating Impact

Training

- 3 Workshops/Training for interested stakeholders planned in the last 6 months of project

  - Workshop for results of WP2/WP3/WP4; combined with JRC-workshop (national authorities, scientific sector)

    25.-28. February 2020, Vienna (AGES, JRC)

  - Workshop for results of WP1/WP2/WP5 (industry, authorities, scientific sector)

    12. May 2020, Berlin (PTB)

  - Training seminar for radon instrument calibration and measurements WP2/WP5 (end users)

    13. May 2020, Berlin (UC)

Save the date!

WP6 – Creating Impact

Uptake and Exploitation

- **Network** of European calibration laboratories for radon concentration in air measurements

- Contact with international bodies (e.g. JRC, IAEA, WHO, ERA) to facilitate the creation of a **best practice guideline** for **radon mapping**

- **Guideline** which summarises the constituents of the chain „from primary standards to radon maps" and the links between them - for a **sound metrology for radon calibrations at low levels** (target audience: radon calibration laboratories and end-users)

www.metroradon.eu
contact@metroradon.eu

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

Dr. Valeria Gruber
Senior Expert

AGES – Österreichische Agentur für Gesundheit und Ernährungssicherheit GmbH

Wieningerstraße 8
A-4020 Linz
T +43 (0) 50 555-41906

valeria.gruber@ages.at
www.ages.at

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

A new primary emanation standard for Radon-222

Florian Mertes, Stefan Röttger, Annette Röttger

Motivation

- Dose estimation is based on the activity concentration (Bq/m³) of Rn-222 in a given environment

- **Traceable**, and stable **reference atmospheres** are needed to calibrate Rn-222 monitoring devices / transfer standards

- Revision of ICRP dose conversion coefficients

- EURATOM 2013/59 established reference level of 300 Bq/m³ for Rn-222

Calibration of monitors - Methods

Gaseous Rn-222 standard	Emanation source, static mode	Emanation source, dynamic mode
Activity concentration is given by activity of standard and volume	Activity concentration is given by Emanation power (χ), Activity and Volume	Activity concentration is given by Flow rate and Activity, χ
Activity concentration decays with $e^{-\lambda \cdot t}$	Stable activity concentration (after approx. 40 days)	Stable activity concentration, much faster equilibration
Not applicable for low activity concentrations ($\sigma \propto \sqrt{N}$)	Suitable for low activity concentrations (< 300 Bq/m³)	Suitable for low activity concentrations (< 300 Bq/m³)

Emanation Sources - Overview

Old design

Polyester-Foil

Drop-cast Ra-226 wrapped in PE-Foil

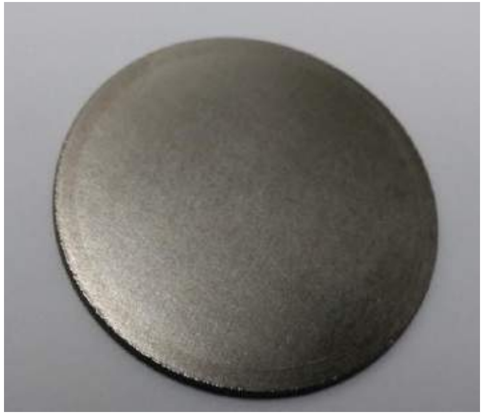
Diffusion

Electrodeposited Sources

Deposition at $30\ V < U < 200\ V$

Implanted Ra-226

Implantation of Ra-226 into W / Al



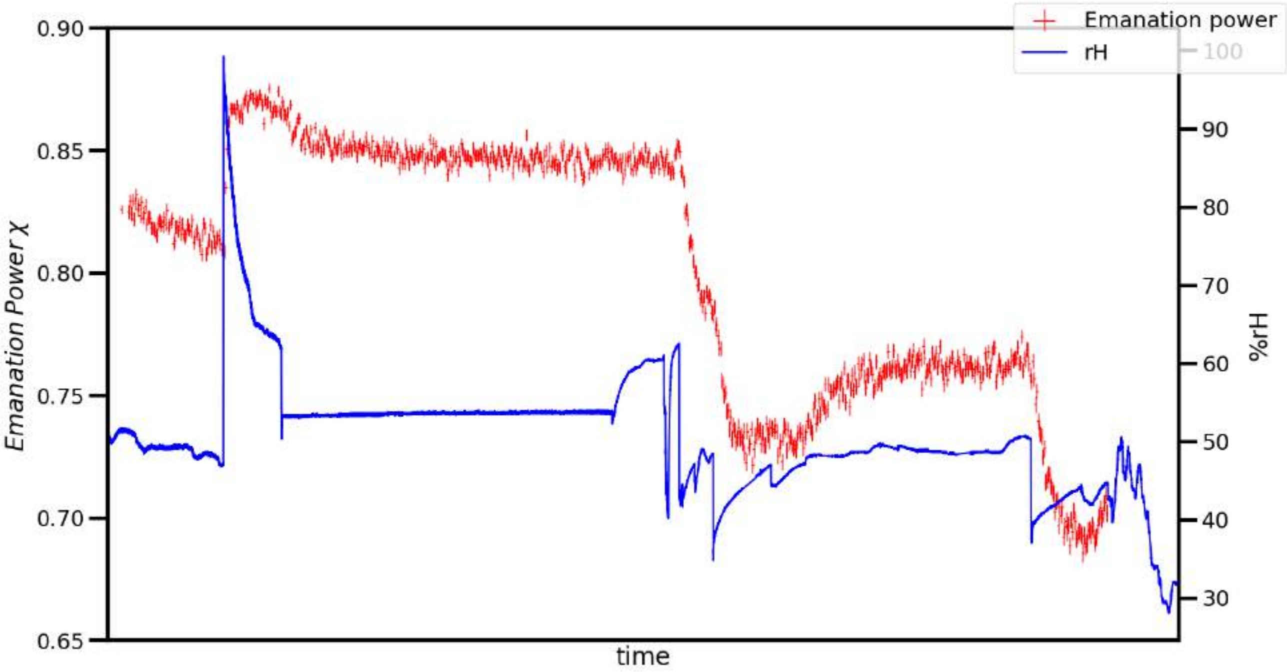
α-Recoil

Drawback of old design

Diffusion

$$J = -D \cdot \nabla c$$

$$D \propto T$$
$$D \propto \%rH$$



Characterisation of new Sources

Ra-226 Activity:

- DSA α-Spectrometry
- Autoradiography

Primary Rn-222 Source

Emanation Power χ:

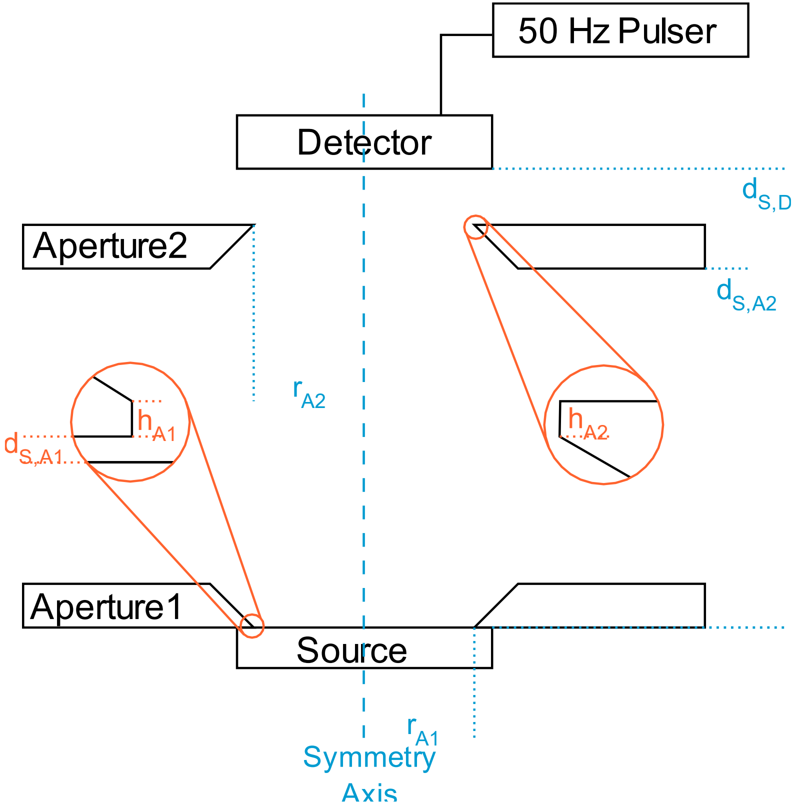
- γ-Spectrometry (HPGe)

$$\bar{c} = \frac{\chi \cdot A_{Ra-226}}{V}$$

- Comparison with enclosed source of the same type

- Stability against environmental parameters:
  $LaBr_3$:Ce, $CeBr_3$ inside climate chamber

DSA α-spectrometry



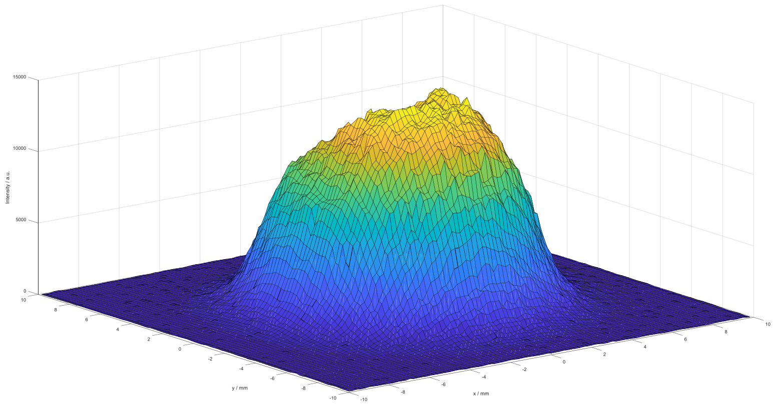
- Live time given by pulse-generator events in the spectrum
- Counting efficiency calculated by numerical integration
- Operated at 10^{-3} mbar to suppress recoil implantation
- Efficiency traceable to m, live time traceable to s

Activity distributions

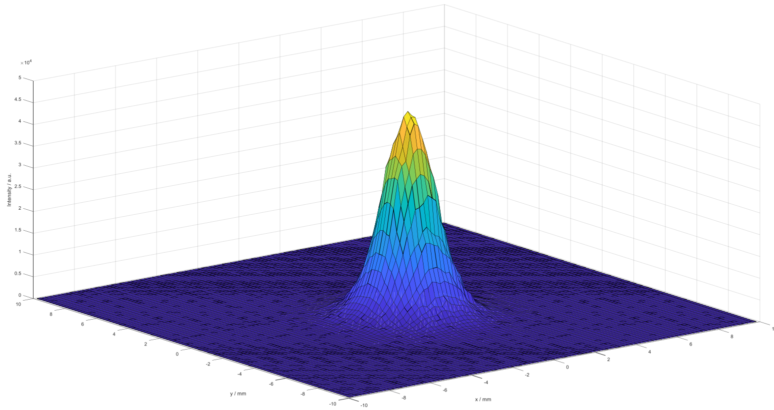
Activity distributions assessed with autoradiography

→ relative activity distribution on source (per 0.04 mm² pixel)

Electrodeposition

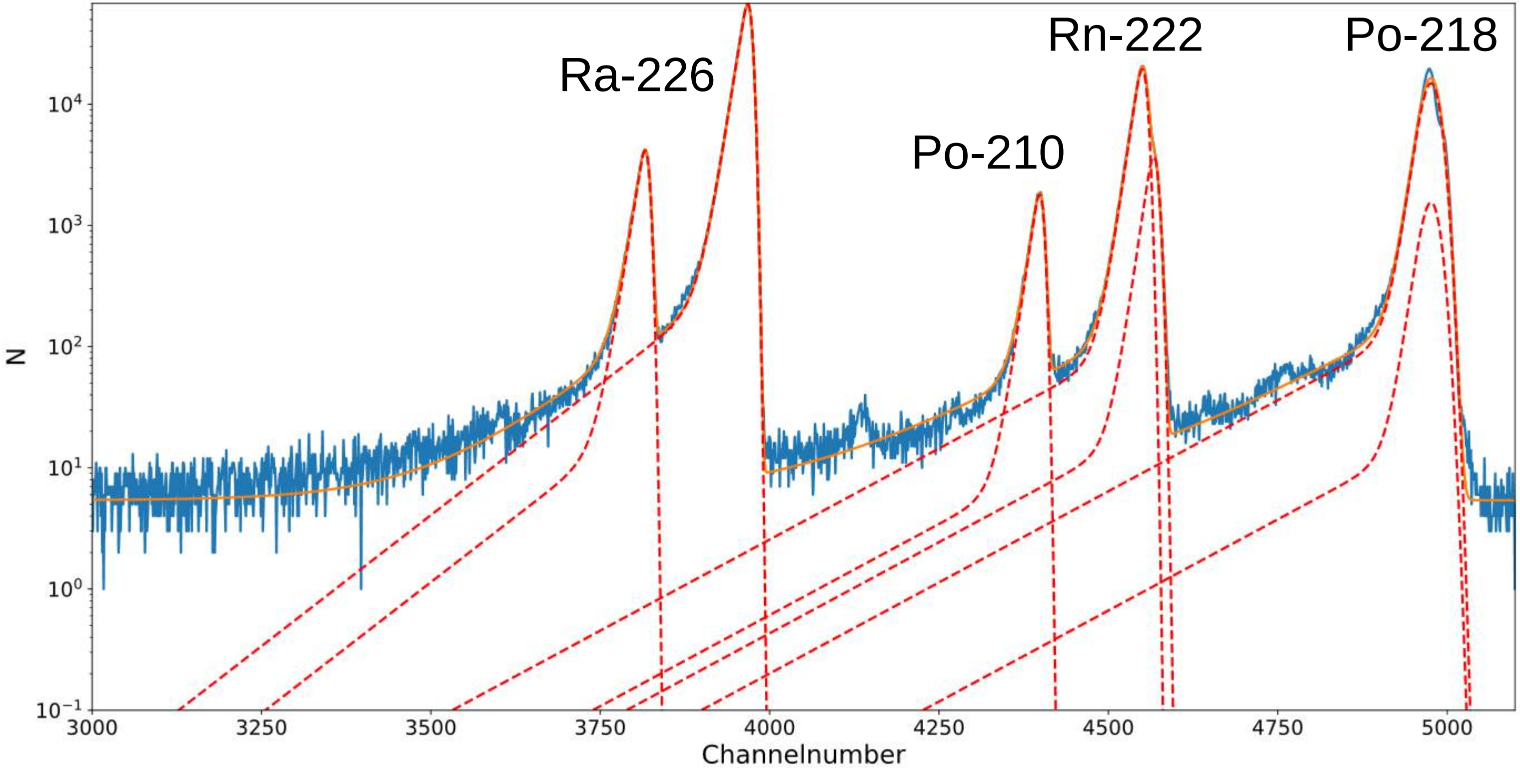


Implantation



α-Spectrum

FWHM Ra-226 typically 20-30 keV (17 keV detector limit)



Uncertainty Budget Ra-226 Activity

Quantity	Value	Relative Contribution
$N_{Ra\text{-}226}$	$198.9 \cdot 10^3 \pm 6 \cdot 10^2$	62.9 %
N_{Pulser}	$21.595 \cdot 10^6 \pm 5 \cdot 10^3$	3.4 %
$N_{Ra\text{-}226,bg}$	$1.1 \cdot 10^3 \pm 4 \cdot 102$	6.1 %
$N_{Pulser,bg}$	$129.5737 \cdot 10^6 \pm 1.14 \cdot 10^4$	0 %
f_{Pulser}	$(49.995670 \pm 5 \cdot 10^{-6}) \cdot s^{-1}$	0 %
ε	$0.959 \cdot 10^{-3} \pm 1.8 \cdot 10^{-5}$	23.3 %
$c_{scattering}$	0.002	4.2 %
A / Bq	47.95 ± 0.19 (0.4 %)	

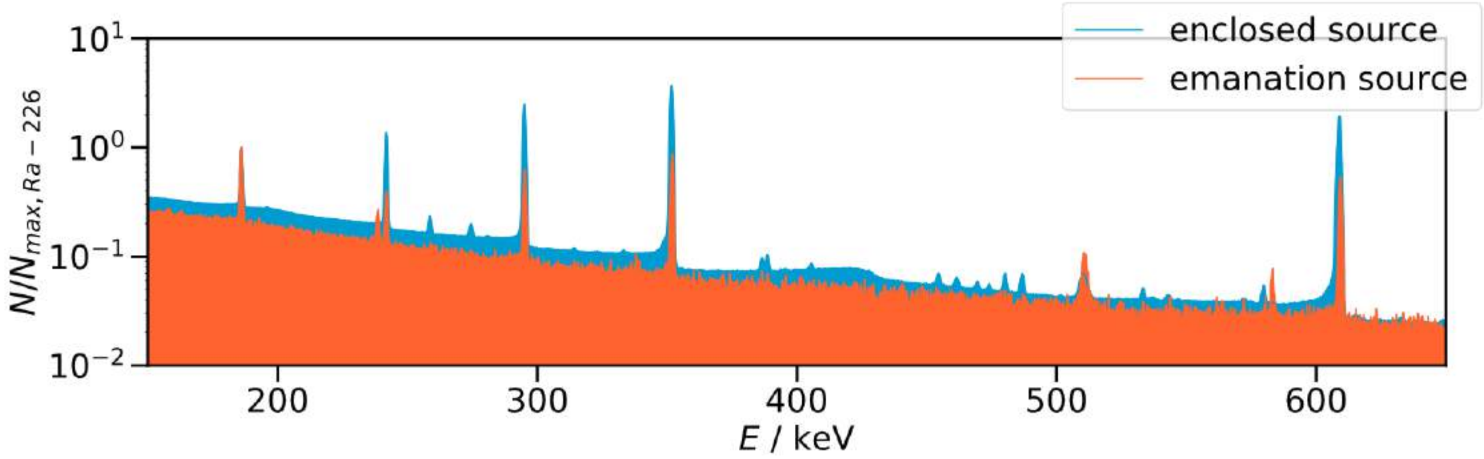
Measuring the emanation power χ

– γ-Spectrometry
 → HPGe

Source

Holder with KF-connections

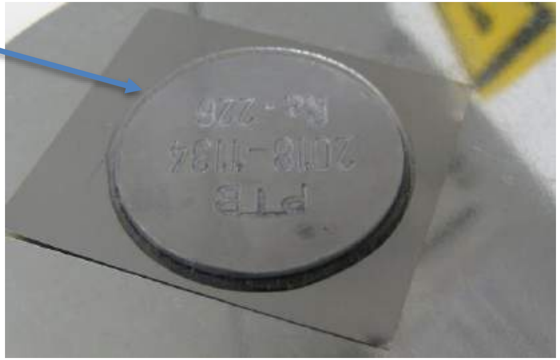
Noble-gas tight loop



Measuring the emanation power χ

$$\chi = \frac{A_{Rn-222}}{A_{Ra-226}} = 1 - \frac{A_{Pb-214}}{A_{Ra-226}}$$

2c epoxy-resin



sealed emanation source (χ = 0)

when second source in secular equilibrium (χ = 0) is available:

$$\chi = 1 - \frac{R_{equilbrium}(Ra-226)}{R_{equilibrium}(Pb-214)} \frac{R_{emanation}(Pb-214)}{R_{emanation}(Ra-226)}$$

Seal is checked with AlphaGuard inside noble gas-tight container

Ref.: A. Röttger et al., Appl. Radiat. Isot. 87, 2014

Uncertainty Budget χ

Quantity	Value	Relative Contribution
R_{cal}(Ra-226) / s^{-1}	1.3305 ± 0.0019	0.7 %
R_{cal}(Pb-214) / s^{-1}	8.6387 ± 0.0027	0.1 %
R_{eman}(Ra-226) / s^{-1}	0.0857 ± 0.0009	58.2 %
R_{eman}(Pb-214) / s^{-1}	0.0819 ± 0.0008	34.8 %
R_{bg}(Ra-226) / s^{-1}	0.01464 ± 0.00026	4.0 %
R_{bg}(Pb-214) / s^{-1}	0.00233 ± 0.00021	2.2 %
χ	0.829 ± 0.003 (0.4 %)	

Electrodeposited Sources

Source ID	A Ra-226 / Bq (Recovery in %)	Emanation Factor (N)	Deposition Characteristics
2017-1709	47.95 ± 0.19 (49 %)	0.804 ± 0.011 (25)	dU/dt = 0, 35 V, EtOH
2017-1710	58.5 ± 1.7 (17 %)	0.727 ± 0.005 (9)	dU/dt = 0, 35 V, EtOH
2017-1074	57.5 ± 2.5 (29 %)	0.869 ± 0.007 (13)	dU/dt = 0, 35 V, EtOH
2018-1437	104.40 ± 0.4 (36 %)	0.637 ± 0.006 (3)	dj/dt = 0, 1 mA/cm^2, IPA
2018-1438	182.2 ± 0.7 (43 %)	0.782 ± 0.003 (4)	dj/dt = 0, 1 mA/cm^2, IPA
2018-1439	184.3 ± 0.5 (81 %)	0.654 ± 0.005 (9)	dU/dt = 0, 200 V, IPA
2018-1440	193.9 ± 0.7 (65 %)	0.654 ± 0.005 (10)	dU/dt = 0, 200 V, IPA
2018-1441	665.5 ± 1.9 (67 %)	0.7650 ± 0.0023 (32)	dU/dt = 0, 90 V, IPA

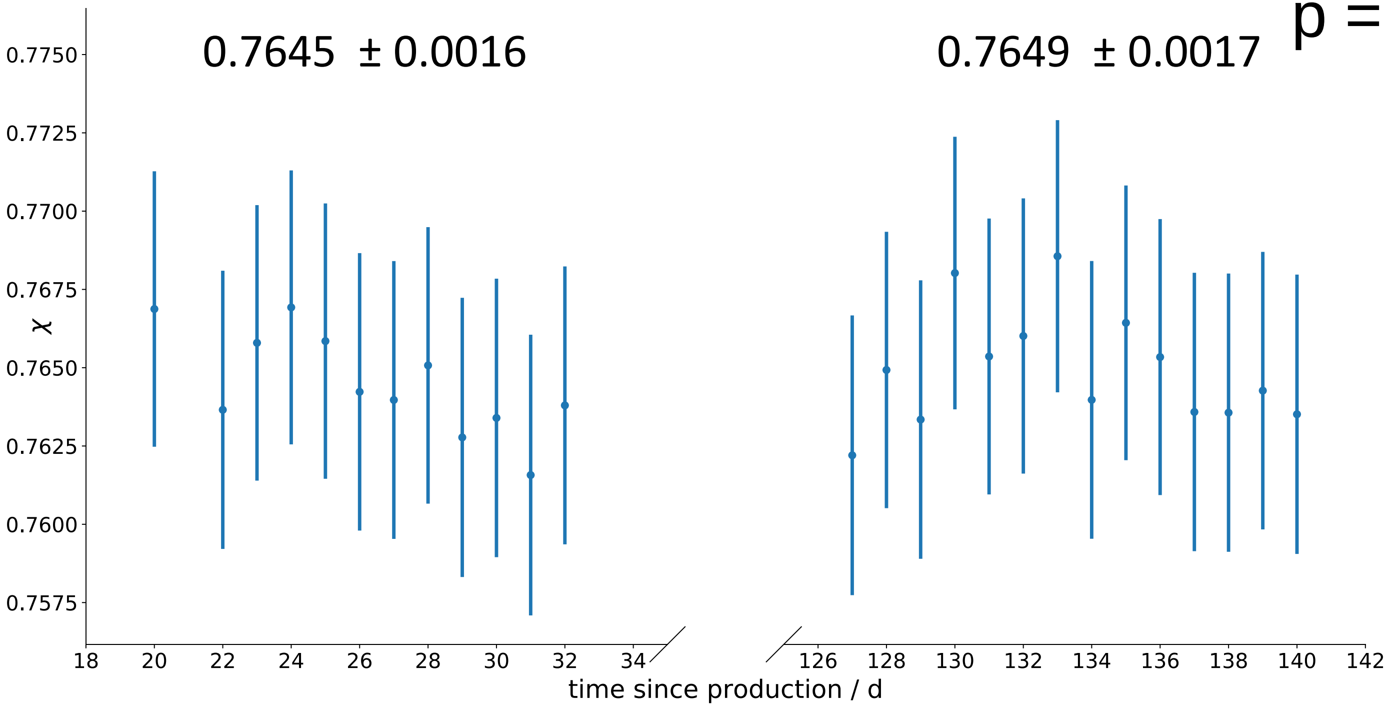
Implanted Sources

Source ID	A Ra-226 / Bq	Emanation Factor	Target Material	Implant. E / keV
2018-1120	925 ± 4	0.323 ± 0.003 [1]	W 99.95 %	30
2018-1121	1139 ± 14	0.342 ± 0.003 [1]	W 99.95 %	30
2018-1122	672 ± 3	0.306 ± 0.003 [1]	W 99.95 %	30
2018-1133	605 ± 3	0.322 ± 0.006 [1]	Al 99.999 %	30
2018-1134	518 ± 3	0.304 ± 0.006 [1]	Al 99.999 %	30
2018-1128	837 ± 10	0.271 ± 0.006 [1]	Al 99.999 %	30

1: Preliminary

Time stability of χ

two-tailed t-test:
p = 0.51



no control of
% rH, T, p

Conclusion

- Stable reference atmospheres < 300 Bq/m³ can be generated with new sources
- Uncertainties of approx. 2 % (k = 1) in the resulting activity concentrations can be achieved
- Sources are characterized by absolute techniques

- Clear **traceability chain** to the national standards

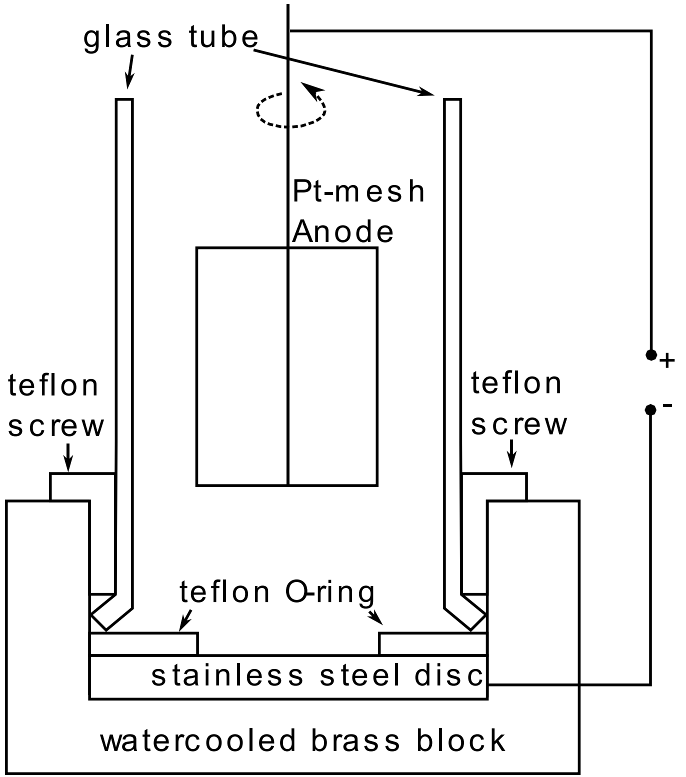
- Outlook: Increase statistical power, assess dependence on environmental parameters

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
Bundesallee 100
38116 Braunschweig

Florian Mertes

E-Mail: florian.mertes@ptb.de
www.ptb.de

Deposition Ra-226 - Apparatus



Deposition Ra-226 - Experimental

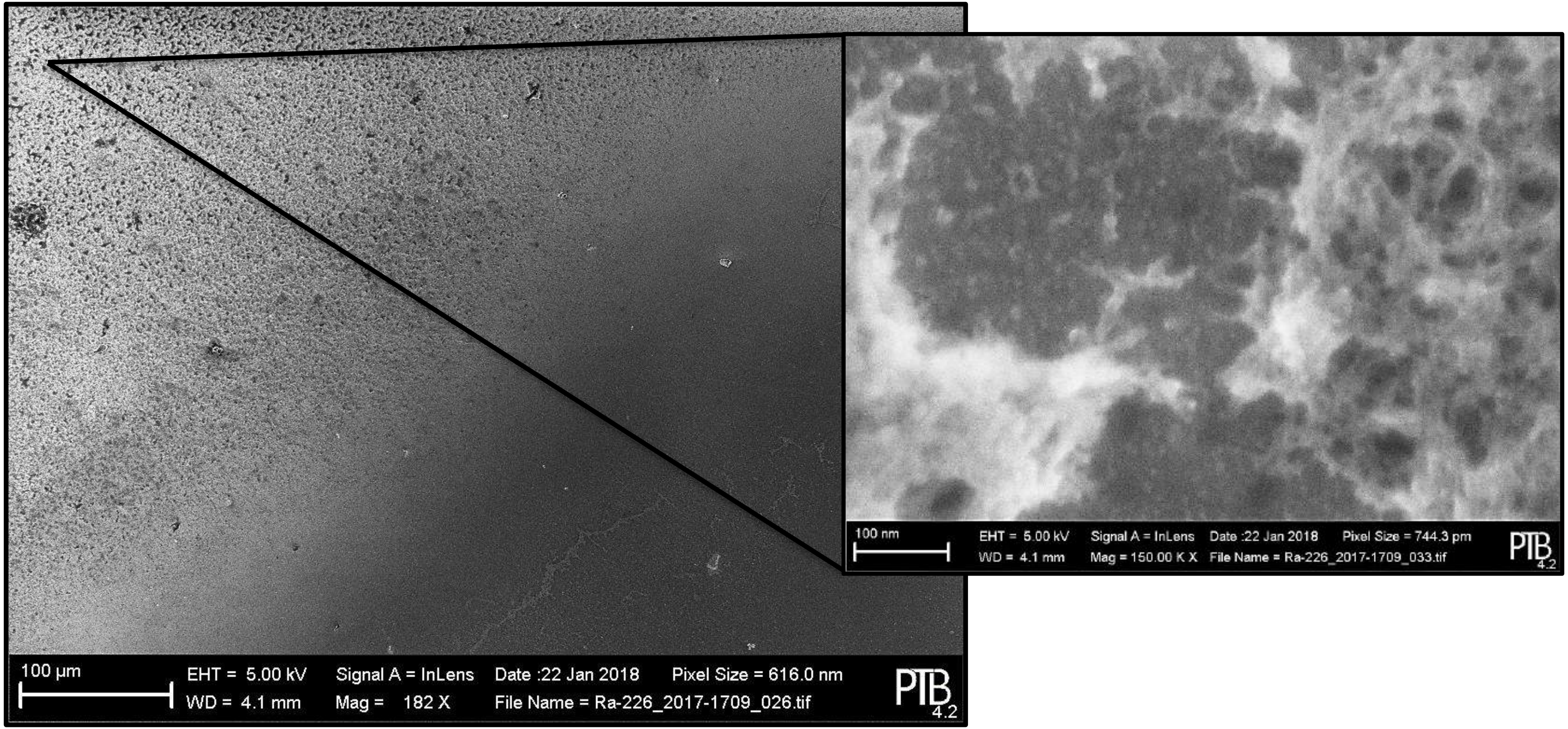
1. Reduce Ba^{2+} carrier content in Ra-226 solution by extraction chromatography (Sr-Resin)
   → m/m ratio of approx. 1 of Ba^{2+} and Ra^{2+}
   (γ-Spectrometry, ICP-MS)

2. Transfer desired amount to deposition cell into 9 mL of organic solvent (EtOH, IPA)

3. Apply DC current (up to 200 V) between rotating anode and metal disc (source backing) at 25 °C

Ref.: Whitehead, J. Radioanal. Nucl. Chem. Artic., 160, 1992
Hancock, Int. J. Radiat. Appl. Instrumentation, 42, 1991

SEM



100 µm
EHT = 5.00 kV
WD = 4.1 mm
Signal A = InLens
Mag = 182 X
Date :22 Jan 2018
File Name = Ra-226_2017-1709_026.tif
Pixel Size = 616.0 nm
PTB 4.2
100 nm
EHT = 5.00 kV
WD = 4.1 mm
Signal A = InLens
Mag = 150.00 K X
Date :22 Jan 2018
File Name = Ra-226_2017-1709_033.tif
Pixel Size = 744.3 pm
PTB 4.2

Namaste
مرحبا
Willkommen
Bem Vindo
Selamat Datang
Welcome
Namaste
Bienvenue
Croeso
Bienvenue
Bienvenidos
Welcome
Bienvenidos
أهلا وسهلا
Benvenuti
Welkom
Bem Vindo
Bienvenue
مرحبا
مرحبا
Welcome
Welkom
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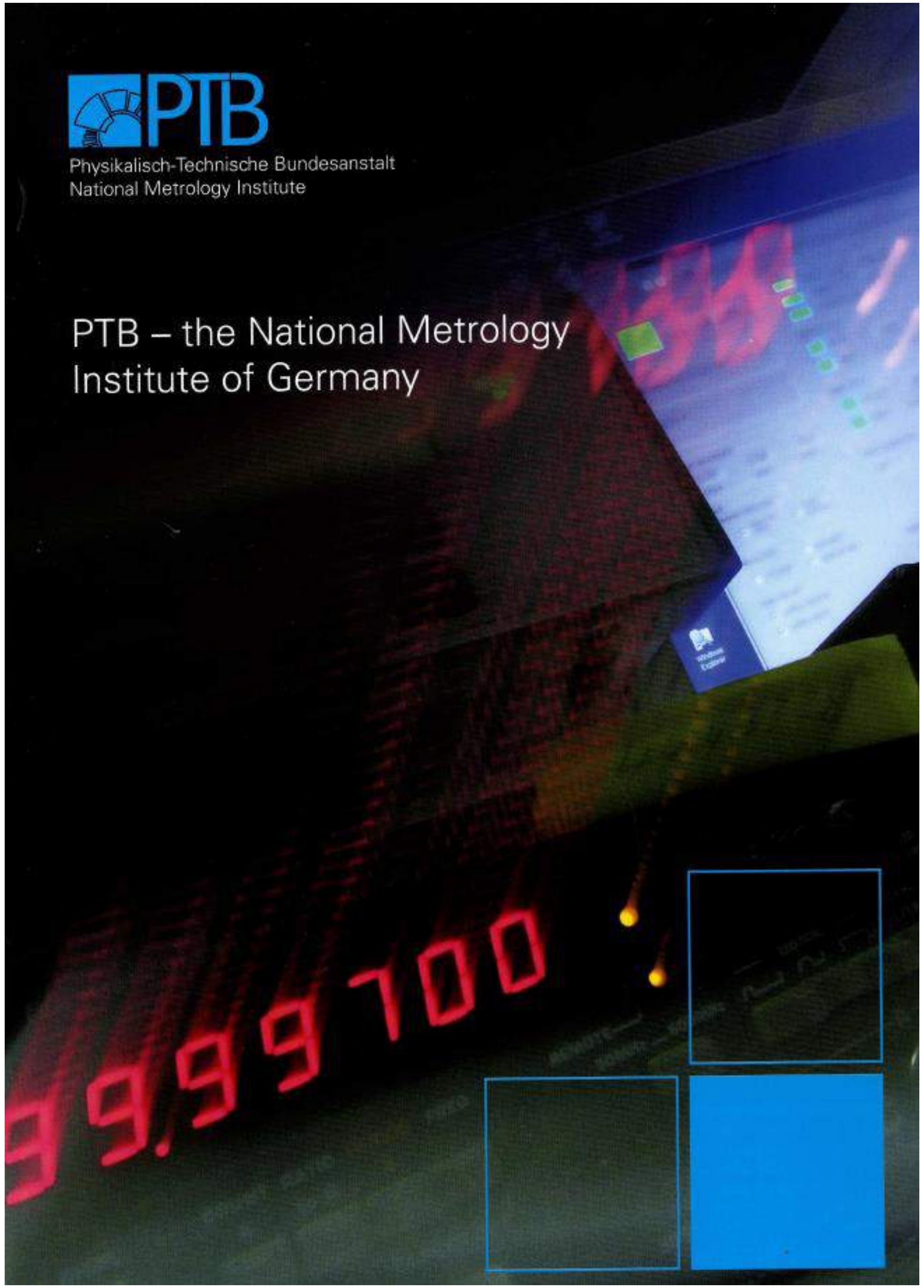
Selamat Datang
Bienvenue
Welcome
Bem Vindo
Willkommen
Willkommen
Selamat Datang
Croeso
добре дошъл
Benvenuti
Willkommen
Καλώς ήλθατε
Benvenuti

MetroRADON

Industry Interest Group meeting

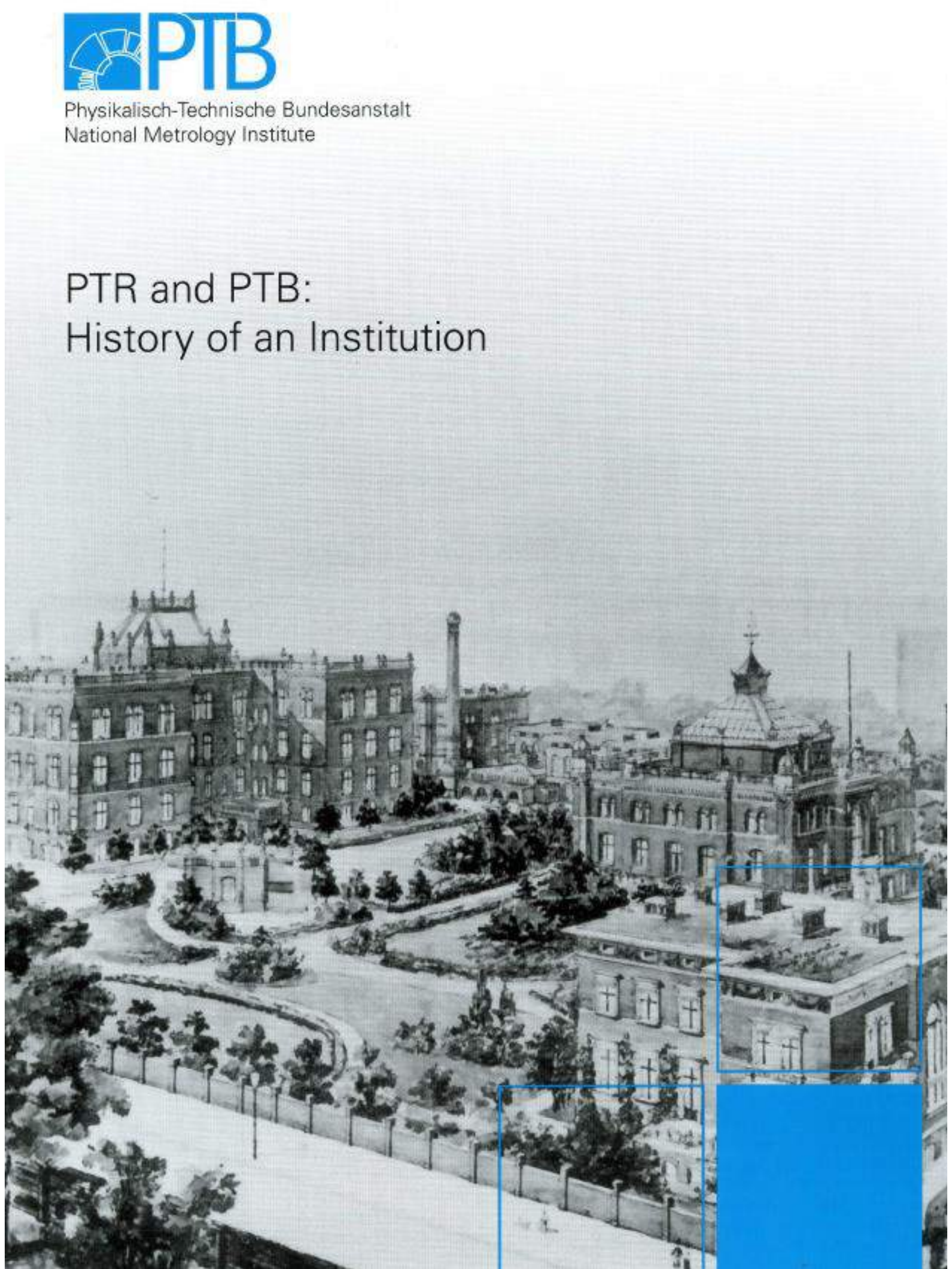
June 18, 2019 at PTB



The main site of today's PTB is located in the western section of Braunschweig. Approximately 1500 staff members work here.

The Charlottenburg campus – the founding site of PTB – accommodates the Berlin Institute with approximately 450 staff members.

Founded in 1887



Hermann von Helmholtz

Werner von Siemens

Seven basic quantities (and its units):

- time (s)
- length (m)
- mass (kg)
- electric current (A)
- temperature (K)
- amount of substance (mol)
- luminous intensity (cd)

"Time is made at PTB in Braunschweig"

PTB's main tasks:
Realization, maintenance *and dissemination* of the *units!*

IIG Meeting, 18 June 2019

PTB, Brunswick, Bothe-Bau, Room 311

AGENDA

WHEN	WHAT	WHO
9:30 – 10:00	Welcome + Introduction of participants	Dr. Stefan Neumaier
10:00 – 10:30	Presentation of MetroRadon	Dr. Michael Stietka, Dr. Valeria Gruber
10:30 – 11:00	Radon: Quantities and Units	Dr. Annette Röttger
11:00 – 11:30	**Coffee break**	
11:30 – 12:30	First results of WP1 + discussions: • The CCRI Rn-222 gas standard intercomparison-status • New primary Ra-226 emanation sources for stable low-level Rn-222 activity concentration	Dr. Dirk Arnold, Dr. Stefan Röttger, Florian Mertes, Dr. Annette Röttger
12:30 – 13:30	**Lunch**	
13:30 – 14:30	Presentations by IIG members: • Radonova Laboratories AB • Indoor and soil radon measurements using LR115 nuclear track film	All Dr. José-Luis Gutiérrez Villanueva, Radonova, Uppsala, Sweden Maria Jönsson, Radonanalys GJAB, Lund, Sweden
14:30 – 15:00	First results of WP2 and WP3 + discussions: • First results and outcomes of potential interest for industry	WP-Leader WP2: Prof. Dobromir S. Pressyanov, Sofia University, Sofia, Bulgaria

Division 6 “**Ionizing Radiation**” of PTB

- Department 6.1: Radioactivity* (Dirk Arnold)
- Department 6.2: Dosimetry for radiation therapy and diagnostic radiology (Ulrike Ankerhold)
- Department 6.3: Radiation protection dosimetry* (Annette Röttger)
- Department 6.4: Neutron radiation (Andreas Zimbal)
- Department 6.5: Radiation effects (Hans Rabus)
- Section 6.71: Operational radiation protection (Rolf Simmer)

* Coworkers in MetroRadon!

IIG Meeting, 18 June 2019

PTB, Brunswick, Bothe-Bau, Room 311

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14:30 – 15:00	First results of WP2 and WP3 + discussions: • First results and outcomes of potential interest for industry	WP-Leader WP2: Prof. Dobromir S. Pressyanov, Sofia University, Sofia, Bulgaria

	• Analysis of questionnaire data on indoor radon survey	WP3: Giorgia Cinelli, JRC, Ispra, Italy
15:00 – 15:30	**Coffee break**	
15:30 – 16:30	Presentations by IIG members • Professional radon monitoring in air/soil/water with the AlphaGUARD • Overview of DURRIDGE Company	Franz Rößler, Bertin GmbH, Frankfurt, Germany Dr. Francesca Mazzone, U-series S.r.l., Bologna, Italy Dr. Stephen Sadler, Durridge UK Ltd., Sheffield, UK
16:30 – 17:00	First results of WP4 and WP5 + discussions • At the end of the QA chain- Decision on Radon Priority Areas • Validation of traceability, performance and precision of European radon calibration facilities	WP-Leader WP4 + 5: Sebastian Feige, BfS, Berlin, Germany
17:00 – 17:30	Conclusions and next steps	All
17:30	**End**	

IIG Meeting, 18 June 2019

PTB, Brunswick, Bothe-Bau, Room 311

AGENDA

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11:00 – 11:30	**Coffee break**	

Again !

Please introduce yourself!

MetroRadon IIG meeting
18 June 2019

U-SERIES

Francesca Mazzone
francesca@u-series.com

U-Series s.r.l.
Via Ferrarese, 131 - 40128 Bologna
Tel. 051 6312418 - Fax. 051 368645
info@u-series.com **www.u-series.com**

Company presentation

U-Series was born as ENEA spin-off and it was founded to pursue **scientific research** and **technological innovation.**

The company operates in the radioactivity field focusing its resources on radiation protection and development of competitive technology products.

U-Series deals with all **aspects of radioactivity**:
- prevention and risk,
- analysis and mitigation,
- nationally and internationally research in all area of radiation protection

Quality of Measurements

Certifications and **accreditation**:

- Certification **ISO 9001:2015**;
- accreditation **ISO 17025:2005** by ACCREDIA as testing laboratory;
- accreditation for radon measurements by METAS;
- accreditation for radon measurements by PHE.

Technical quality of measurement is verified by internal procedures involving the use of national and international official reference sources.

Quality of measurement results is verified by **international intercomparison**:

- IAEA,
- Procorad (France);
- BfS(Germany),
- PHE (England),
- AIRP (ENEA collaboration, Italy)

Company activities

Activities:

- Radiometric Analysis,
- Radioactivity measurements in situ and in various matrix samples (environmental, biota, food, industrial, ecc...);
- Collection of samples for radioactivity measurements;
- Radiation Protection Consultancy;
- Training activity in radioactivity field.

U-Series has a long experience of geochronological measures, with particular attention for techniques related to U-Th and 14-C disequilibrium.
This determinate a particular attention in the definition of the procedures and in the precise quantification and reduction of MDA and measurements uncertain.

Equipment resources

U-Series has **4 laboratories** equipped to conduct determination of numerous radioactive isotopes.

Equipment:
- 4 chemical hood
- 1 biological hood
- Laboratories for samples preparation.

Equipment resources

Alpha spectrometry:
32 solid state detectors

Beta Spectrometry:
2 spectrometeres (LSC)

Tritium Enrichment
used in combination of beta spectrometry (tritium contents in water)

Equipment resources

P-type: 50 keV – 2 MeV, Efficiency 50%

C profile: 3 keV - 2 MeV, Efficiency 66%

Gamma Spectrometry: 3 HPGe Crystals

Isotope ratio mass spectrometry (IRMS): determination of isotopic ratio of 13C/14C, 18O/16O 15N/14N on solid and liquid matrix.

Equipment resources

SSNTD ~30000 analysis per year

Nuclear track detectors:
1.acceptance of supply
2.calibration at BfS and ENEA;
- yearly attendance for intercomparisons and blind test: BfS, PHE, AIRP, NIRS

2 systems independent e separate:
-2 optical microscopes;
-automatic track counting system development by U-Series;
-solution for overlapped track.

Equipment resources

ELECTRETS ~ 200 available

-2 type of electrets: **ST** and **LT**;
-2 type for chamber **S** and **L-OO**.
4 configurations are available with different exercise range for exposition:

- -SST: 3-7 days;
- -LST-OO: 15 – 30 days;
- -SLT: 1-3 months;
- -LLST-OO: 3-6 months.

Master’s thesis ongoing for improve e developed terms’ uncertain from ISO 11665-4

Equipment resources

~ 50 devices

Electronic devices for radon measurements:

-Solid state detector

-Passive sampling

-1 measurements per hour

1 devices:

- ionization chamber,
- active sampling,

-measurement of thoron.

Database: Banca Radon

Italy Map shows measurements for all our customers

Banca Radon:
-document, report and analysis results;
-it shows all measurements ongoing divided for all customers;
-all customers are able to login, they can check their measurement and download the reports.

Thanks for your attention

Francesca Mazzone
francesca@u-series.com

U-Series s.r.l.
Via Ferrarese, 131 - 40128 Bologna
Tel. 051 6312418 - Fax. 051 368645
info@u-series.com
www.u-series.com

Validation of traceability, performance and precision of European radon calibration facilities WP 5.2

Sebastian Feige, Dr. Thomas Beck

18.06.2019, IIG-Meeting MetroRadon

PTB, Braunschweig

WP 5
Validation of European Radon Calibration Facilities

Task 5.1: Identification, evaluation and selection of European European Radon Calibration Facilities for validation of tracebility (TL CMI)

Task 5.2 Validation of tracebility in the range from 300 Bq/m³ - 10 000 Bq/m³ (TL BfS)

Task 5.3 Validation of tracebility in the range from 100 Bq/m³ - 300 Bq/m³ (TL CMI)

→ Allow the operators of Radon Calibration Facilities to reduce relative uncertainties related to their facilities below 5 % (k=1)

WP 5

Two principal options:

a) Use of the new radon activity standards traceable to primary standards developed in WP 1 to calibrate secondary standards used by European Radon Calibration Facilities (WP 5.3)

b) One reference device calibrated with a promary standard shipped to European Radon Calibration Facilities for comparison with their existing secondary standards (WP 5.2)

WP 5.2

Used primary Radon standards

Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

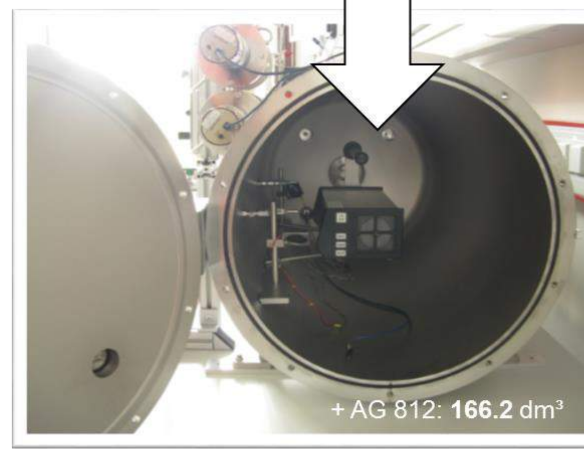
Seite 2 zum Kalibrierschein vom 12.12.2016, Kalibrierzeichen: PTB-6.13-11/2016
Page 2 of calibration certificate of 12.12.2016, calibration mark: PTB-6.13-11/2016

Gegenstand: *Object*	Aktivitätsnormal *Activity standard*
	Edelstahlzylinder mit Rn-222 *High-grade steel cylinder containing Rn-222*
Typ: *Type*	2016-1537
Kenn-Nummer: *Serial number*	Radon-222 *Radon-222*
Radionuklid: *Radionuclide*	
Kalibrierverfahren: *Method of calibration*	Die Aktivität des Rn-222-Gases wurde … sung der Gammastrahlung der kurz… Rn-222 im radioaktiven Gleichgewicht… Folgeprodukte mit einem kalibrier… Detektor bestimmt. Die Kalibrierkons… sen Detektor wurde mit Rn-222 Akti… der PTB ermittelt, deren Aktivitäts… mit einem Halbleiter-Alpha-Spektrometer mit bekanntem Raumwinkel erfolgten. *The activity of the Rn-222 gas was determined with a calibrated NaI(Tl) detector by measuring the gamma radiation emitted by the short-lived decay products, which were in radioactive equilibrium with Rn-222 at the time of measurement. The calibration constant of this detector was determined with Rn-222 standards. The activities of these standards were measured at the PTB with a semiconductor alpha spectrometer with defined solid angle.*
Aktivität: *Activity*	A = (6,59 ± 0,12) kBq
Bezugszeitpunkt: *Reference date*	21. September 2016, 00:00 Uhr MEZ *00:00 CET on 21 September 2016*

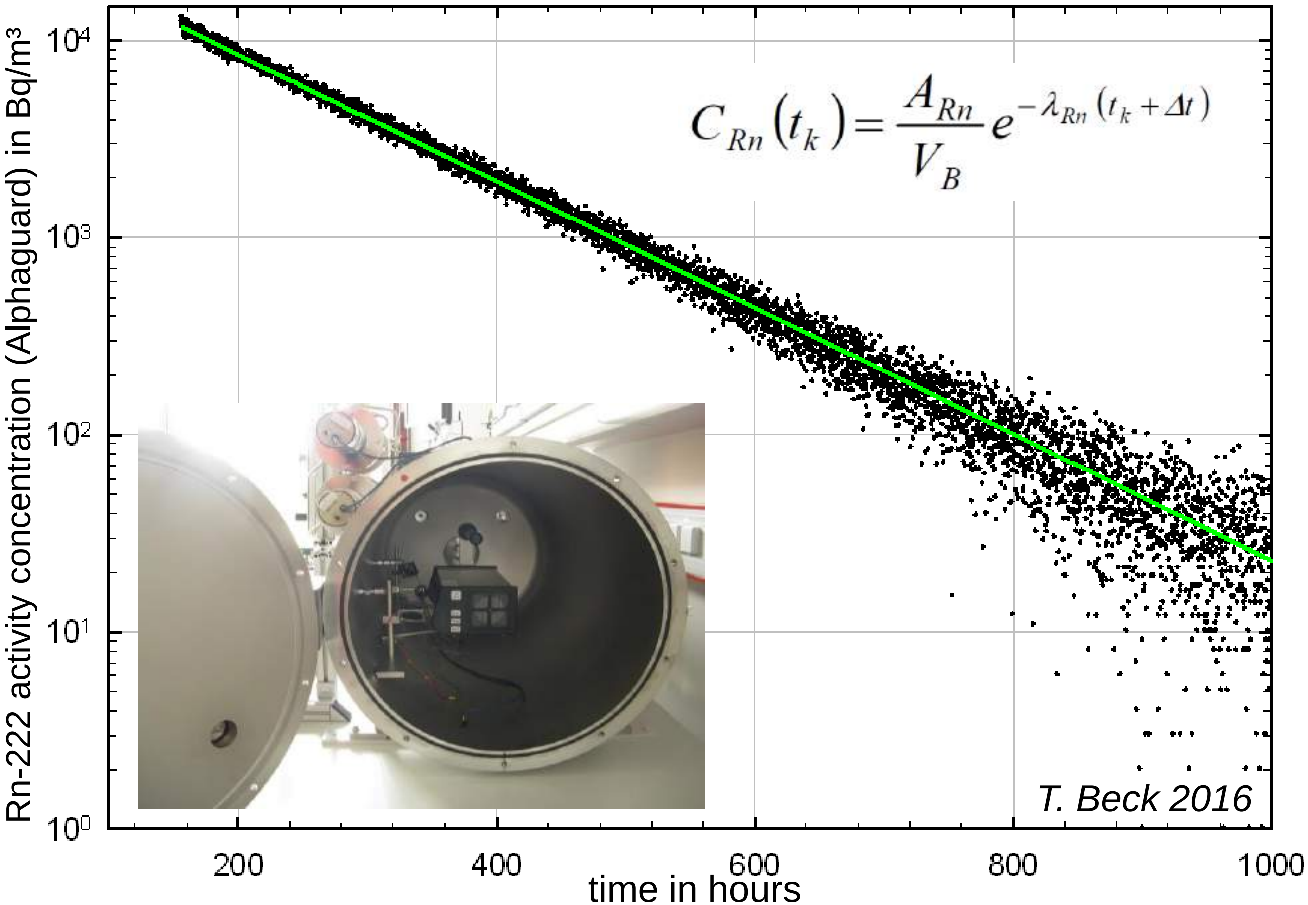
PTB certified
Reference volume

Activity transfer
(by vacuum)

pressure and temperature
controlled



WP 5.2



Lower limit of accreditation BfS: 50 Bq/m³
with 14%
k=2 uncertainty

(vs. 3% at 1000 Bq/m³)

WP 5.2.1

Instrument to be used for the intercomparison: ALPHAGUARD

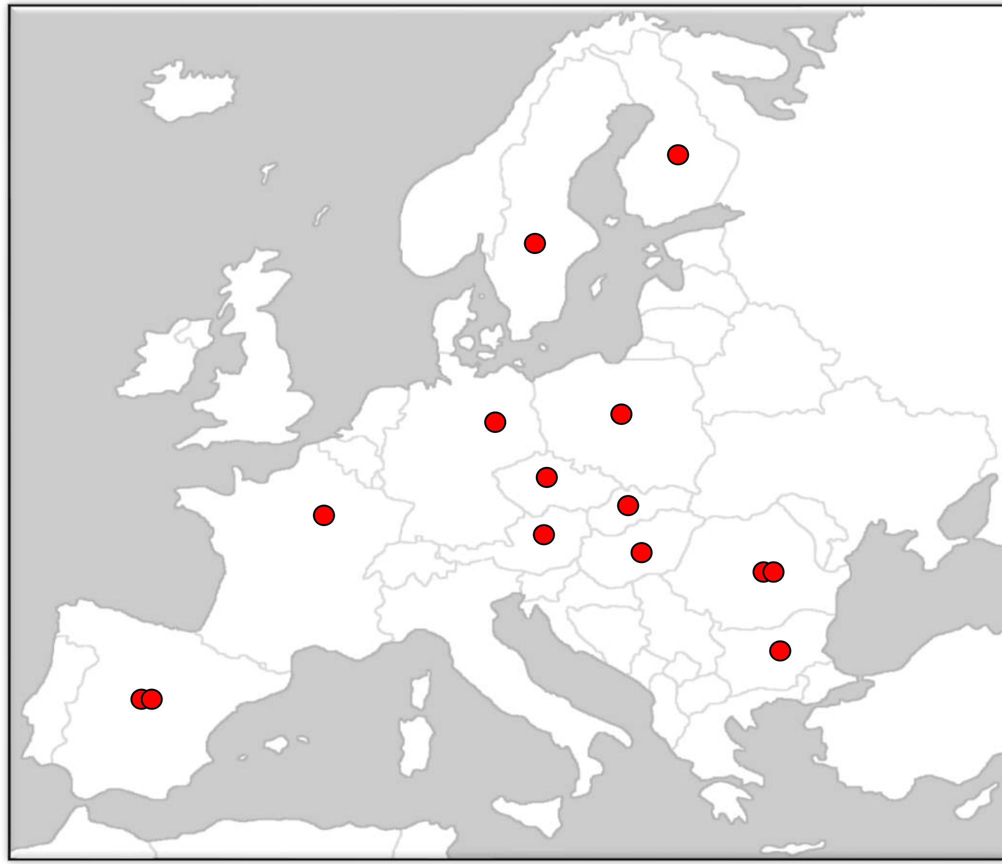
Diffusion mode

Integration time 10 min

WP 5.2.2

Participants from 16 Laboratories

• MNE	Montenegro
• BEV-PTP	Austria
• BFKH	Hungary
• **BfS**	**Germany**
CMI	Poland
• UPC	Spain
• UNICAN	Spain
• CLOR	Poland
• IFIN-HH	Romania
• UBB	Romania
• IRSN	France
• SSI	Sweden
• SMU	Slovakia
• STUK	Finland
• SUJCHBO	Czech Republic
• SUBG	Bulgaria



WP 5.2.3

The “very recent activity “: June 2018 – May 2019 (12 months)

BfS will send the reference instrument prepared in A5.2.1 to the selected radon calibration facilities that agreed to participate in A5.2.2 for them to carry out the calibrations.

Each participant in the intercomparison:

- Calibration of the reference instrument over the measurement range from 300 Bq/m³ up to 10,000 Bq/m³.
- Reporting of results with calibration certificate and accompanying documentation to BfS.
- Return of the reference instrument to BfS for an intermediate check of the instrument before it is sent to the next participant.

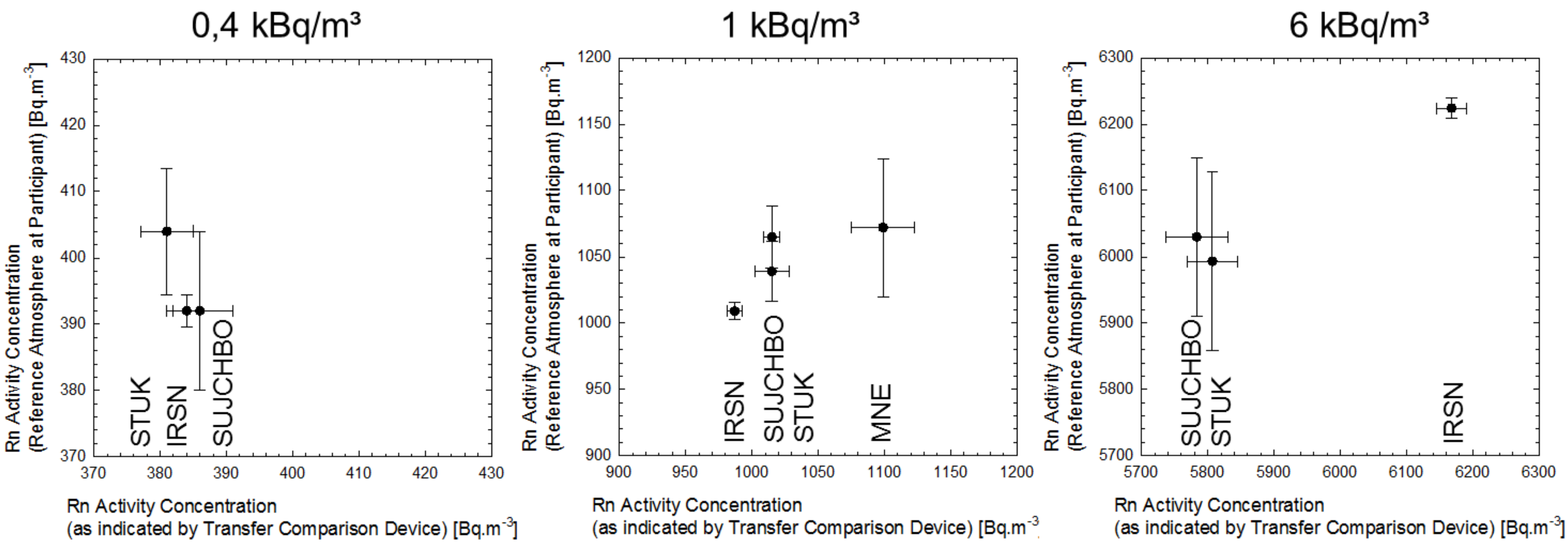
WP 5.2.3

Radon activity concentrations for intercomparison

	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 $Bq \cdot m^{-3}$

WP 5.2.4

Radon Intercomparison: First Results



Thanks for your attention!

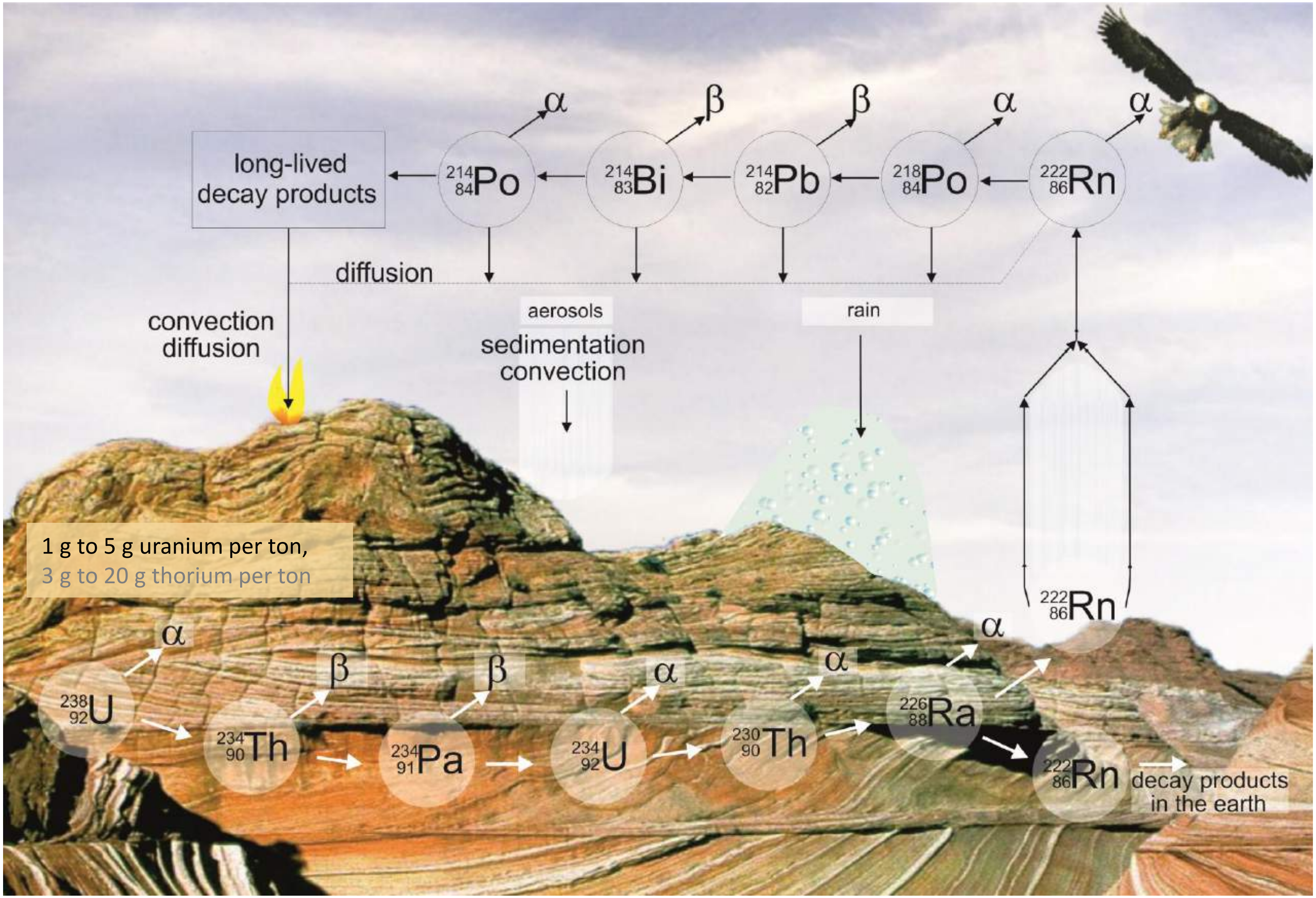
Physikalisch-Technische Bundesanstalt
Braunschweig und Berlin
Nationales Metrologieinstitut

Quantities and units for radon and radon progeny measurements

Annette Röttger

Industry Interest Group (IIG) meeting
PTB, Braunschweig, 2019-06-18
based on the presentation for SSK-A4, SSK-A1, SSK from 2017 to 2018

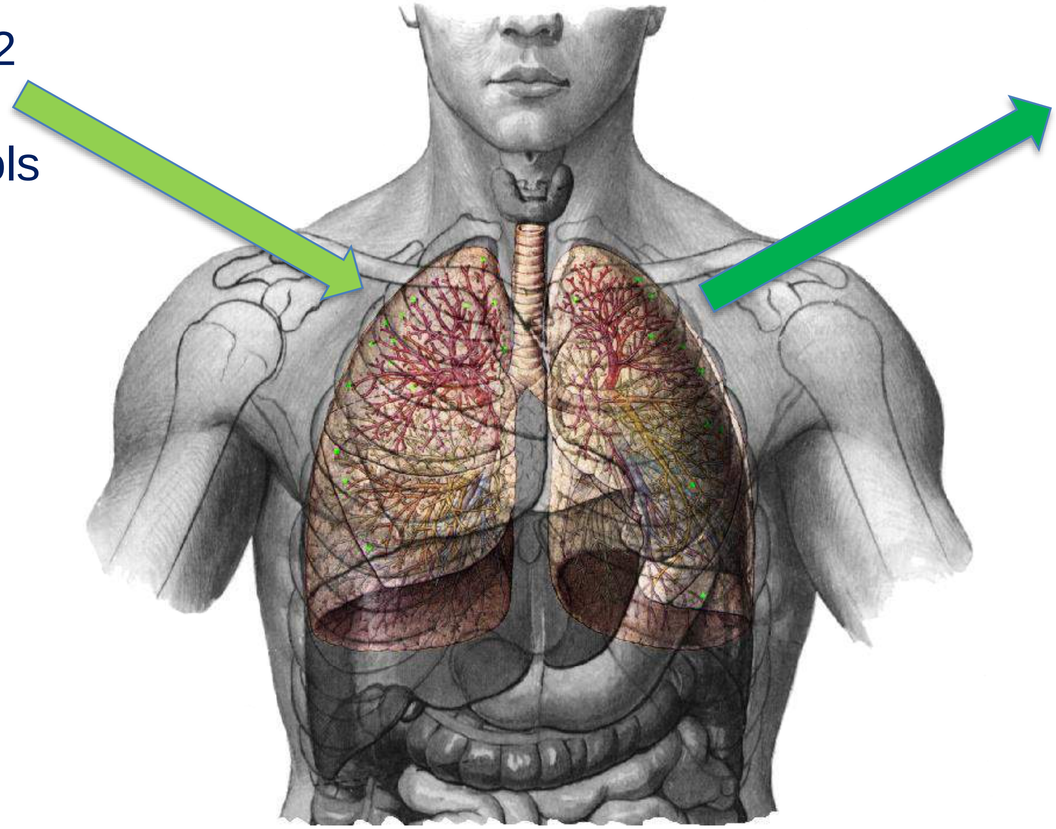
Quantities and units for radon…



Quantities and units for radon…

100 % Rn-222

100 % aerosols



100 % Rn-222

80 % aerosols

aerosols with attached progeny
and unattached progeny
stay for a longer time

Quantities and units for radon…

Find a point to start: **ICRU 88**

“The objective of this report is, therefore, to provide conceptual and practical guidance for radon measurements in air and in water. The recommendations include **guidance for the choice of strategies** for **radon and radon progeny measurements and surveys** and for **interpreting and reporting measurement results**, appropriate for the goal of the measurements. The report also addresses methods to **determine and reduce uncertainties** associated with these measurements and resulting dosimetric estimates.
It describes the **state-of-the-art of radon measurement techniques** which is expected to be of relevance in view of the **reduced reference levels in dwellings and in the workplace** as well as for epidemiological studies. The recommendations in this report are aimed at authorities planning radon surveys, at experts performing measurements and at scientists involved in epidemiological studies on lung cancer risk due to radon inhalation.“

Quantities and units for radon…

Why is the work in the field of radon so difficult?

- strange quantities, like potential alpha energy concentration
- strange units (a lot of non SI units) like WLM

- different approach in radiation protection:
  natural exposure varies over several orders of magnitude (1 Bq/m^3 to 100.000 Bq/m^3)

- short and long term studies provide a huge amount of data

  BUT: The data is often inconsistent!
  - special situation (smoking habits)
  - scientific interest without sustainable quality assurance

We can improve that!

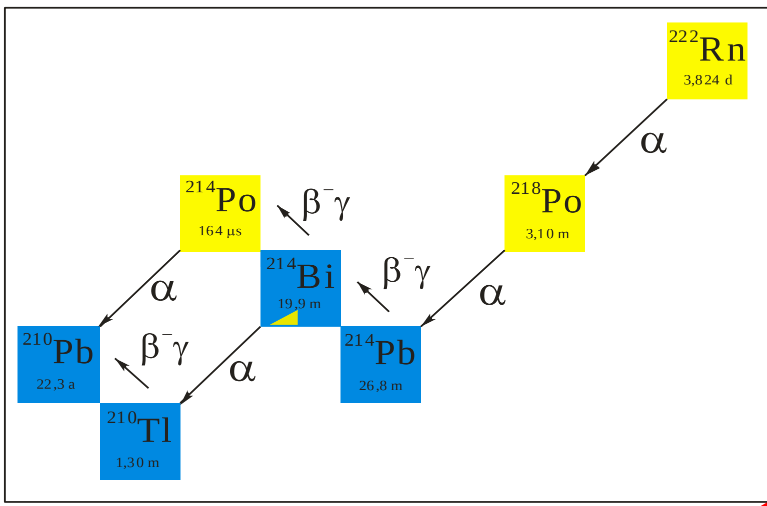
Quantities and units for radon…

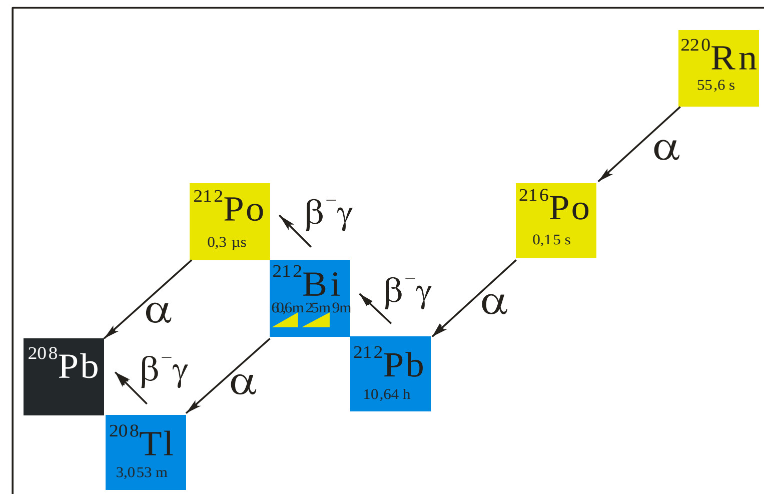
Activity Concentration

Activity A per unit volume V of the respective isotope.

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

Relevant activity concentrations can be marked by an index, for example, C_{deep} is used as radon activity concentration in deep soil air. The unit of activity concentration is Bq m^{-3}.





Bq/m^3

Quantities and units for radon...

Equilibrium Equivalent Activity Concentration

The activity concentration of radon, C_{Rn}, in radioactive equilibrium with its short-lived decay products that has the same potential alpha energy concentration C_p as the non-equilibrium mixture to which the C_{eq} refers:

$$C_{eq,Rn\text{-}222} = k_{Po\text{-}218}\ C(\text{Po-218}) + k_{Pb\text{-}214}\ C(\text{Pb-214}) + k_{Bi\text{-}214}\ C(\text{Bi-214}) + k_{Po\text{-}214}\ C(\text{Po-214})$$
$$C_{eq,Rn\text{-}220} = k_{Po\text{-}216}\ C(\text{Po-216}) + k_{Pb\text{-}212}\ C(\text{Pb-212}) + k_{Bi\text{-}212}\ C(\text{Bi-212}) + k_{Po\text{-}212}\ C(\text{Po-212}).$$

The weighting coefficients k are calculated by nuclear data and given in Table 1.

Table 1. Coefficients for the calculation of the equilibrium equivalent concentration from measured activity concentrations of radon progeny

$k_{Po\text{-}218}$	$u(k_{Po\text{-}218})$	$k_{Pb\text{-}214}$	$u(k_{Pb\text{-}214})$	$k_{Bi\text{-}214}$	$u(k_{Bi\text{-}214})$	$k_{Po\text{-}214}$	$u(k_{Po\text{-}214})$
0.106	0.002	0.513	0.010	0.381	0.009	5.2×10^{-8}	1×10^{-9}
$k_{Po\text{-}216}$	$u(k_{Po\text{-}216})$	$k_{Pb\text{-}212}$	$u(k_{Pb\text{-}212})$	$k_{Bi\text{-}212}$	$u(k_{Bi\text{-}212})$	$k_{Po\text{-}212}$	$u(k_{Po\text{-}212})$
6.684×10^{-6}	0.223×10^{-6}	0.9133	0.0001	0.0866	0.0001	8.05×10^{-12}	6×10^{-14}

Since $k_{Po\text{-}214} << 1$, $k_{Po\text{-}216} << 1$, and $k_{Po\text{-}212} << 1$, the corresponding activity concentration can be omitted.

$$C_{eq,Rn\text{-}222} = k_{Po\text{-}218}\ C(\text{Po-218}) + k_{Pb\text{-}214}\ C(\text{Pb-214}) + k_{Bi\text{-}214}\ C(\text{Bi-214})$$
$$C_{eq,Rn\text{-}220} = k_{Pb\text{-}212}\ C(\text{Pb-212}) + k_{Bi\text{-}212}\ C(\text{Bi-212}).$$

Bq/m^3

The unit of equilibrium equivalent activity concentration is Bq m^{-3}.

Note 1: For Rn-222, the following conversion is valid: $C_{eq} = C_p / [5.57(10) \times 10^{-9}\ \text{J Bq}^{-1}]$ or $C_{eq} = C_p / [3.47(7) \times 10^{10}\ \text{eV Bq}^{-1}]$.

Note 2: For Rn-220, the following conversion is valid: $C_{eq} = C_p / [7.565(8) \times 10^{-8}\ \text{J/Bq}]$ or $C_{eq} = C_p / [4.722(5) \times 10^{11}\ \text{eV Bq}^{-1}]$.

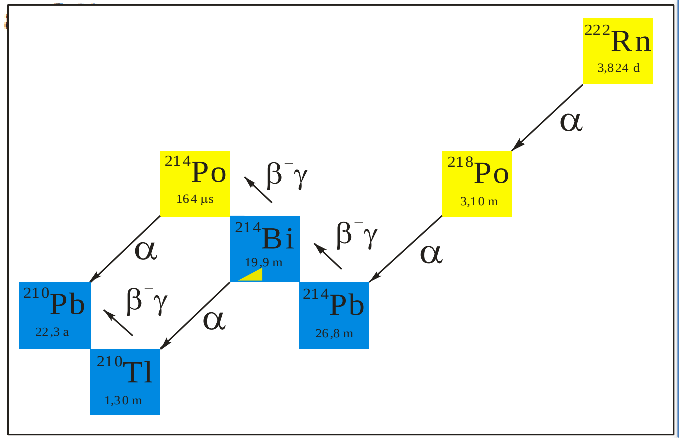
Quantities and units for radon…

Potential Alpha Energy (PAE)

The potential alpha energy, ε_p, is the total alpha energy emitted during the decay of a progeny atom along the decay chain up to ^{210}Pb or ^{208}Pb, respectively, for the decay chains of the ^{222}Rn and ^{220}Rn.

The potential alpha energy $\varepsilon_p(X-A)$ of a progeny is calculated by the following equations according to the decay chains of ^{222}Rn and ^{220}Rn.

The values for the transition probability p as well as the uncertainties assigned to the nuclear data are taken from the Monographie-5 of BIPM and the conversion from eV to J is by the data of CODATA (Tables 2



^{222}Rn:

$$\varepsilon_p(\text{Po-218}) = \Sigma_i p_i \varepsilon_i\,(\text{Po-218}) + \Sigma_k p_k \varepsilon_k\,(\text{Po-214}),$$
$$\varepsilon_p(\text{Pb-214}) = \Sigma_k p_k \varepsilon_k\,(\text{Po-214}),$$
$$\varepsilon_p(\text{Bi-214}) = \Sigma_k p_k\, \varepsilon_k\,(\text{Po-214}),$$
$$\varepsilon_p(\text{Po-214}) = \Sigma_k p_k \varepsilon_k\,(\text{Po-214}).$$

Rn-222

^{220}Rn: (including the branching of the decay of ^{212}Bi, $p_\Sigma = \Sigma_k p_k$):

$$\varepsilon_p(\text{Po-216}) = \Sigma_i p_i \varepsilon_i\,(\text{Po-216}) + \Sigma_k p_k \varepsilon_k\,(\text{Bi-212}) + (1 - p_\Sigma) \cong \Sigma_m p_m \varepsilon_m\,(\text{Po-212}),$$
$$\varepsilon_p(\text{Pb-212}) = \Sigma_k p_k \varepsilon_k\,(\text{Bi-212}) + (1 - p_\Sigma) \cong \Sigma_m p_m \varepsilon_m\,(\text{Po-212}),$$
$$\varepsilon_p(\text{Bi-212}) = \Sigma_k p_k\, \varepsilon_k\,(\text{Bi-212}) + (1 - p_\Sigma) \cong \Sigma_m p_m \varepsilon_m\,(\text{Po-212}),$$
$$\varepsilon_p(\text{Po-212}) = \Sigma_k p_k \varepsilon_k (\text{Bi-212}).$$

Rn-220

The potential alpha energy is a quantity for characterizing radon progeny atmospheres, not radon atmospheres. The index refers to the radon isotope and the decay chain.

Since $\varepsilon_p(\text{Pb-214}) = \varepsilon_p(\text{Bi-214}) \approx \varepsilon_p(\text{Po-214})$ and $\varepsilon_p(\text{Pb-212}) = \varepsilon_p(\text{Bi-212})$, the equations are rather simple:

$$\varepsilon_{p,\text{Rn-222}} = \varepsilon_p(\text{Po-218})\, N_{\text{Po-218}} + \varepsilon_p\,(\text{Pb-214})\,(N_{\text{Pb-214}} + N_{\text{Bi-214}} + N_{\text{Po-214}})$$
$$\varepsilon_{p,\text{Rn-220}} = \varepsilon_p(\text{Po-216})\, N_{\text{Po-216}} + \varepsilon_p(\text{Pb-212})\,(N_{\text{Pb-212}} + N_{\text{Bi-212}}) + \varepsilon_p(\text{Po-212})\, N_{\text{Po-212}}.$$

where N is the number of the respective atoms. Since the value is not directly connected with a measurand, in contrast to the potential alpha energy concentration, it should be used for theoretical work (modeling and simulation) only. The unit of potential alpha energy is J.

Quantities and units for radon...

Potential Alpha Energy Concentration (PAEC)

The concentration of any mixture of short-lived radon decay products in air in terms of the alpha energy released during complete decay through Pb-210 for Rn-222 progeny or through Pb-208 for Rn-220 progeny.

Since ε_p(Pb-214) = ε_p(Bi-214)≈ε_p(Po-214) and ε_p(Pb-212) = ε_p(Bi-212), the equations are rather simple:

Rn-222

$$C_{\mathrm{p,Rn\text{-}222}} = \frac{C(\text{Po-218})}{\lambda_{\text{Po-218}}}\varepsilon_\mathrm{p}(\text{Po-218}) + \left(\frac{C(\text{Pb-214})}{\lambda_{\text{Pb-214}}} + \frac{C(\text{Bi-214})}{\lambda_{\text{Bi-214}}} + \frac{C(\text{Po-214})}{\lambda_{\text{Po-214}}}\right)\varepsilon_\mathrm{p}(\text{Pb-214})$$

Rn-220

$$C_{\mathrm{p,Rn\text{-}220}} = \frac{C(\text{Po-216})}{\lambda_{\text{Po-216}}}\varepsilon_\mathrm{p}(\text{Po-216}) + \left(\frac{C(\text{Pb-212})}{\lambda_{\text{Pb-214}}} + \frac{C(\text{Bi-212})}{\lambda_{\text{Bi-214}}}\right)\varepsilon_\mathrm{p}(\text{Pb-212}) + \frac{C(\text{Po-212})}{\lambda_{\text{Po-212}}}\varepsilon_\mathrm{p}(\text{Po-212})$$

J/m^3

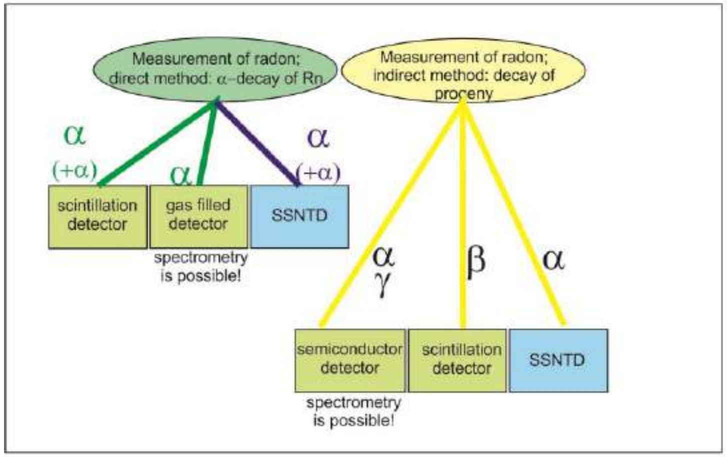
The unit of potential alpha energy concentration is $\mathrm{J\,m^{-3}}$.
Note: Due to the short half-lives of ^{216}Po and ^{212}Po, these isotopes are in activity equilibrium with their parent nuclide: C (Rn-220) = C (Po-216) and C (Bi-212) $(1 - p_\Sigma)$ = C (Po-212) with the transition probabilities p_k for the α-decays of ^{212}Bi resulting to $p_\Sigma = \Sigma_k p_k$, where C is the measurand, that is the activity concentration of the respective progeny.

"If confusion is the first step to knowledge, I must be a genius."

Larry Leissner

Quantities and units for radon…

Field measurement of Rn-222



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

Traceable calibration

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

Quantities and units for radon...

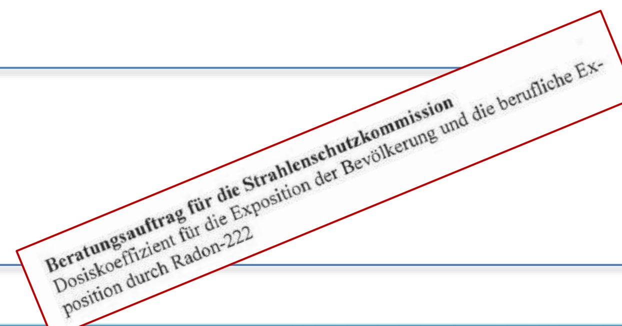
nuclide	half-life	number of atoms per Bq	energy of the alpha-emission	Potential alpha energy			
				per atom ε		per Bq ε / λ	
	$T_{1/2}$	$1/\lambda$	MeV	MeV	10^{-12} J	MeV	10^{-12} J
Po-218	3,05 min	264	6,00	13,69	2,19	3620	579
Pb-214	26,8 min	2320		7,69	1,23	17800	2860
Bi-214	19,9 min	1723		7,69	1,23	13100	2100
Po-214	164 µs	$2{,}37 \cdot 10^{-4}$	7,69	7,69	1,23	$1{,}8 \cdot 10^{-3}$	$2{,}9 \cdot 10^{-4}$

potential alpha energy concentration (PAEC):
unit: MeV m^{-3} or J m^{-3}

$$C_p = \sum_i \frac{\varepsilon_i}{\lambda_i} \cdot C_i$$

C_i : concentration of each progeny in Bq m^{-3}

Equivalent dose $H = \boxed{?} \cdot t \cdot C_p$


Beratungsauftrag für die Strahlenschutzkommission
Dosiskoeffizient für die Exposition der Bevölkerung und die berufliche Exposition durch Radon-222

Quantities and units for radon...

Effective dose for the non-SI unit 1 WLM with ICRP-65 conversion

Quantity	Value	Standard uncertainty	Contribution to uncertainty	Index
C	7400 Bq/m^3	10.0 Bq/m^3	6.8·10^{-3} mSv	0.0 %
t	170 h	11.5 h	0.34 mSv	21.8 %
F	0.5	0.0577	0.58 mSv	63.1 %
C_{eq}	3700 Bq/m^3	427 Bq/m^3		
C_p	20.60·10^{-3} mJ/m^3	2.38·10^{-3} mJ/m^3		
k_u	5.568·10^{-6} mJ/Bq	1·10^{-9} mJ/Bq	900·10^{-6} mSv	0.0 %
P_{RnF}	3.502 mJ h/m^3	0.469 mJ h/m^3		
$k_{ICRP-65}$	1.43 mSv ·m^3/(mJ·h)	0.08 mSv ·m^3/(mJ·h)	0.28 mSv	15.1 %
H	5.01 mSv	0.73 mSv		

All quantities k=1.

POTENTIAL ALPHA ENERGY CONCENTRATION
1 Working Level (WL) = 1.3 x 10^5 MeV.L^{-1}
= 2.08 x 10^{-5} J.m^{-3}
1 WL corresponds to radon progeny concentration in equilibrium with 100 pCi.L^{-1} radon (3700 Bq.m^{-3})

Quantities and units for radon…

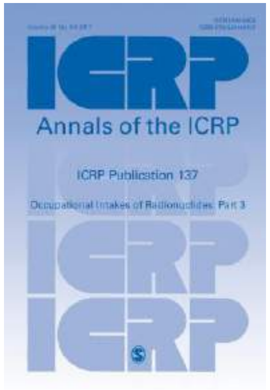
Effective dose for 2000 h at 300 Bq/m³ with ICRP-65 conversion

Quantity	Value	Standard uncertainty	Contribution to uncertainty	Index
C	300 Bq/m³	50 Bq/m³	0.32 mSv	53.6 %
t	2000 h	11.5 h	0.011 mSv	0.0 %
F	0.4	0.0577	0.28 mSv	40.2 %
C_{eq}	120 Bq/m³	26.5 Bq/m³		
C_p	$668 \cdot 10^{-6}$ mJ/m³	$147 \cdot 10^{-6}$ mJ/m³		
k_u	$5.5682 \cdot 10^{-6}$ mJ/JBq	$1 \cdot 10^{-9}$ mJ/JBq	$340 \cdot 10^{-6}$ mSv	0.0 %
P_{RnF}	1.34 mJ h/m³	0.30 mJ h/m³		
$k_{ICRP\text{-}65}$	1.43 mSv · m³/(mJ ·h)	0.081 mSv ·m³/(mJ ·h)	0.11 mSv	6.2 %
H	1.911 mSv	0.435 mSv		
$k_{Konv.\text{-}Neu?}$	3 mSv · m³/(mJ ·h)	0.5 mSv ·m³/(mJ ·h)	0.39 mSv	[illegible]
H	4.0 mSv	1.0 mSv		

From A. Röttger, SSK-A4, 2017

For 8700 h in 1 year: (17.4± 4.2) mSv

Quantities and units for radon…



ICRP Publication 137 (2018), Page 10:

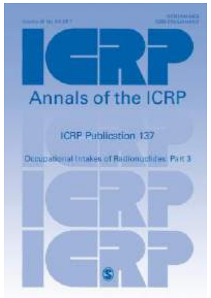
“The dose coefficients for inhalation of radon and progeny, calculated using biokinetic and dosimetric models using the average breathing rate for a reference worker, are

(1.43 → 3) mSv per mJ h m^{-3}
factor of 2, only significant digits, SI unit

3 mSv per mJ h m^{-3}
(approximately 10 mSv WLM^{-1}) for mines and the majority of indoor workplaces, and

6 mSv per mJ h m^{-3}
(approximately 20 mSv WLM^{-1}) for tourist caves and indoor workplaces where work involves substantial physical activity.”

Quantities and units for radon…



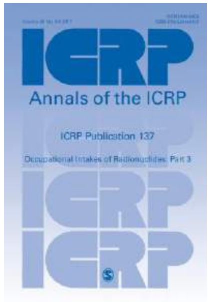
ICRP Publication 137 (2018), Page 317:

- The present situation is a remarkable **consistency between coefficients obtained by dosimetric calculations and conversion coefficients based on epidemiological comparisons**. Noting that inhaled ^{222}Rn and progeny is a special case for which there is good epidemiology as well as dosimetry, and taking account of the two methods of calculation of dose coefficients with their associated uncertainties, the Commission recommends the following rounded dose coefficients:

- For the calculation of doses following inhalation of radon and radon progeny in underground mines and in buildings, in most circumstances, the Commission recommends a dose coefficient of **3 mSv per mJ h m^{-3}**. The Commission considers this dose coefficient to be applicable to the majority of circumstances with no adjustment for aerosol characteristics.

- However, for indoor workplaces where workers are engaged in **substantial physical activities**, and for workers in tourist caves, the Commission recommends a dose coefficient of **6 mSv per mJ h m^{-3}**.

Quantities and units for radon…

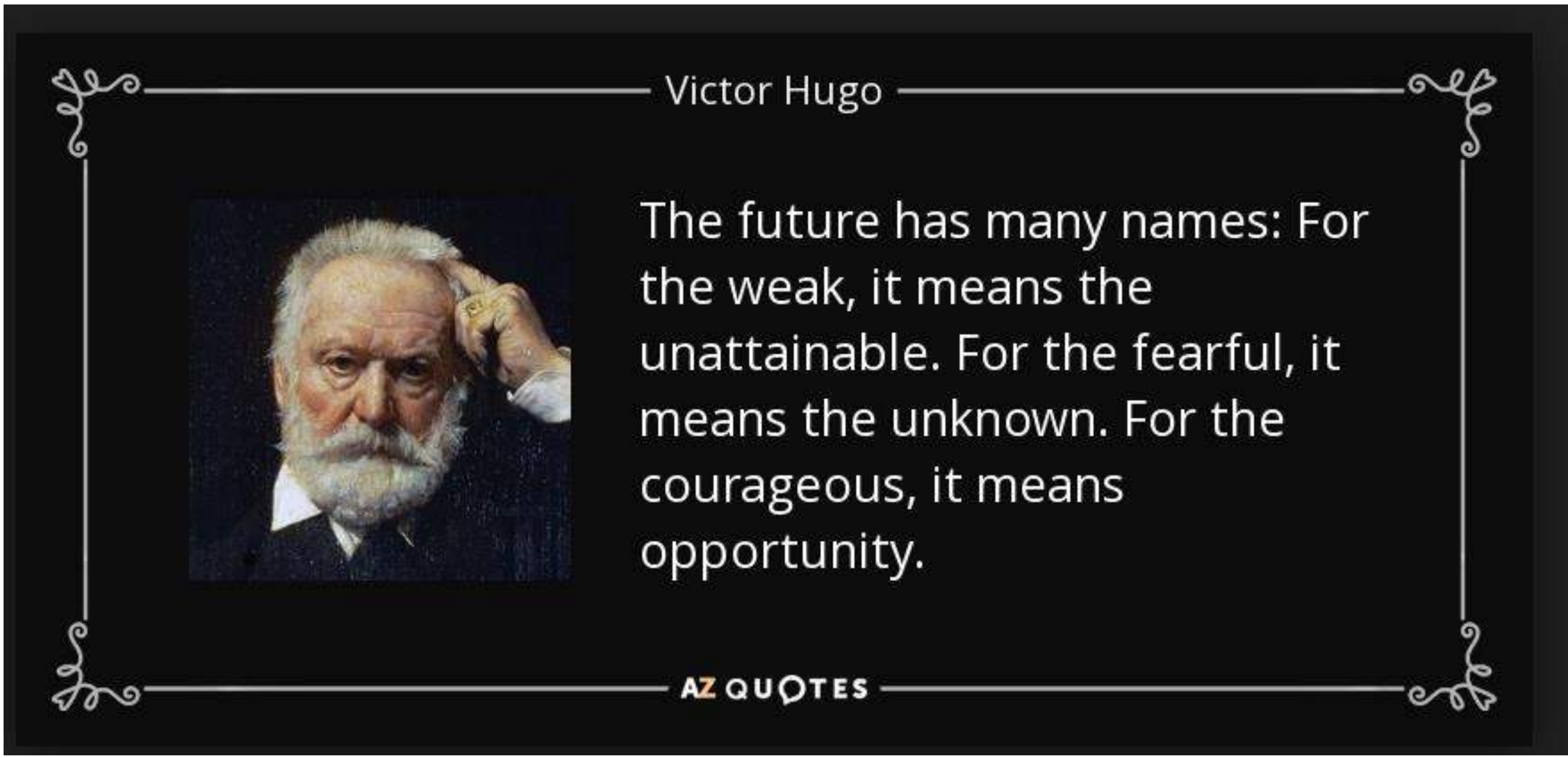


ICRP Publication 137 (2018), Page 317:

- In cases where **aerosol characteristics are significantly different from typical conditions**, sufficient, reliable aerosol data are available, and estimated doses warrant more detailed consideration, it is possible to **calculate site-specific dose coefficients** using the data provided in Annex A and the accompanying electronic annex.

- Dose coefficients for the **inhalation of thoron (^{220}Rn) progeny** are given for two situations of exposure: indoor workplaces and mines. On the basis of these calculations, it is recommended that a single rounded value of **1.5 mSv per mJ h m^{-3}** is used for all situations of occupational exposure. This dose coefficient is considered to be applicable to the majority of circumstances with no adjustment for aerosol characteristics. As in the case of inhalation of radon progeny, if sufficient, reliable aerosol data are available and estimated doses warrant more detailed consideration, calculation of site-specific dose coefficients can be carried out using the dosimetric data provided in Annex A and the accompanying electronic annex.

Quantities and units for radon…



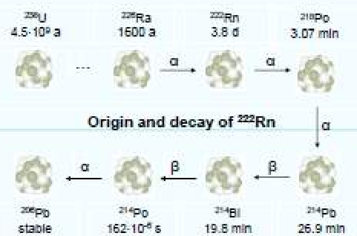
This is not going to be easy, but we are not alone…

Quantities and units for radon…

V03 MetroRadon
Metrology for radon monitoring

What is radon?

- Progeny of primordial ^{238}U and ^{232}Th
- The two radon isotopes of concern are
  - ^{222}Rn (approx. 90 % of natural isotopes) with a half life of 3.8 d and
  - ^{220}Rn (approx. 10 % of natural isotopes), also called thoron, with a half life of 55.8 s



Radioactive decay chain of ^{238}U.
Source: modified from AGES

- Decay products are elements that attach to aerosols
- Main sources of radon: soil, well water, outdoor air, building materials, public water supplies

Why does radon need monitoring?

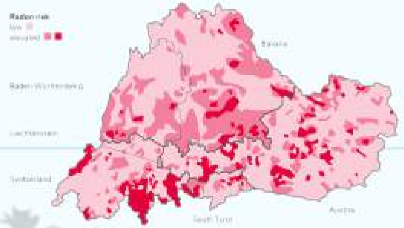
- Radon and its progeny are the second cause for lung cancer in the general public, after smoking
- Radon escapes mainly from the ground and from building materials and migrates through pores into dwellings where it is inhaled with its decay products by the occupants
- While most of the gaseous radon itself is exhaled, the aerosol bound radioactive progeny can deposit in the respiratory tract

Increased radon is a cause for concern.
Source: modified from BMLFUW

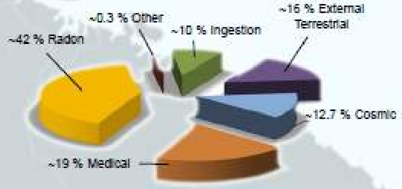
- Radon and its progeny is estimated to cause between 3 % and 14 % of all lung cancer cases (WHO, Fact sheet N°291, 2016). This corresponds to approx. 15 000 - 20 000 people dying per year in Europe by lung cancer caused by exposure to radon progeny

Main goals of the JRP

- Creation of a **coordinated metrological infrastructure** for radon monitoring and radon mapping in Europe suitable for the requirements of the **radon action plan** requested by the new European Directive
- Enable **SI traceable monitoring** of radon at low radon activity concentrations (≤ 300 Bq/m³), including calibration and radon mapping, essentially facilitating the **harmonised implementation of the new EU-BSS in Europe**
- Investigation of the **influence of thoron** on radon measurements and calibrations
- **Harmonisation** of indoor radon and soil exhalation radon measurements
- Development of new methodologies for identification and characterization of radon priority areas in Europe



Relative radon risk map of Austria, Liechtenstein, Switzerland and parts of Germany and Italy.
Source: Swiss Confederation



Public exposure to different radiation sources.
Source: UNSCEAR, 2008

WP 1	WP 2	WP 3	WP 4	WP 5
Development of novel procedures for the traceable calibration of radon measurement instruments at low activity concentrations	Influence of thoron (^{220}Rn) and its progeny on radon end-user measurements and radon calibrations	Comparison and harmonization of radon measurement procedures in Europe	Identification of radon priority areas and relationship between soil radon exhalation and indoor radon concentrations	Validation of traceability of European radon calibration facilities

Quantities and units for radon…

- European Council Directive 2013/59/EURATOM (EU-BSS): EU member states reference levels for annual average indoor activity concentrations ≤ 300 Bq/m³
- Implementation of EU-BSS into national legislation of the member states, including a national radon action plan, is mandatory by 2018
- Radon action plan: addresses long-term risks from radon exposure and identifies areas where a significant number of buildings is expected to exceed the relevant national reference level

The EU-BSS require a radon action plan that delineates radon priority areas.
Source: modified from CMI

Radon migration and lung exposure by radon and its progeny.
Source: AGES

Work beyond the state of the art

- A **traceability validation of existing European radon calibration facilities** will be performed. At present, secondary standards are calibrated at relatively high activity and are not adequately traceable to one primary radon gas standard
- The JRP will carry out **traceable inter-comparisons** on the quantities surface soil radon exhalation rate and radon concentrations in soil gas
- **Development of a unified index of geogenic Rn hazard:** consistent picture of susceptibility to geogenic Rn across Europe
- As a novelty, **methods for retrospective radon measurement by compact discs (CDs) and DVDs will be evaluated** for their potential to define radon priority areas.
- **New techniques** for measurement of radon exhalation from soil based on liquid scintillation counting of polymers and track-etching of CDs for indoor air retrospective radon measurement will be developed and evaluated
- **Evaluation of the sensitivity of radon monitors and detectors to thoron** with traceability to a primary thoron standard

Quality and Efficiency

- A consortium consisting of
  - experienced researchers from all over Europe
  - partners involved in the implementation of the EU-BSS in their respective countries
- Resources in line with objectives and deliverables
- State of the art facilities
- Immense stakeholder interest and involvement
- Excellent consortium capacity and effective WP lead
- Top level management and coordination

Left: inside view of the IRSN (France) radon/thoron chamber, right: stainless steel containers for the calibration of radon instruments at BfS (Germany).
Source: RGN/BfS

Taking a sample for soil gas radon measurements.
Source: FJ Maringer

Impact

- **Improvement of radiation protection and public health** due to reliable radon measurements as a basis for effective radon risk mitigation and prevention against radon progeny induced lung cancer in Europe and, therefore, **decreasing the lung cancer risk due to radon in Europe**
- The JRP will help to **establish** a basic European **metrological infrastructure** so that sound monitoring of radon becomes possible
- Provision of **harmonised metrological standards** for radon monitoring and radon protection in Europe, thus allowing comparison and merging of data sets
- **Provision of reliable radon mapping** methods for the **delineation of potential radon priority areas** in Europe
- **Enhance competitiveness of European building industry**
- **Coordination** of European calibration facilities regarding knowledge exchange
- **Development of the lead of European metrological facilities** in low-level radon monitoring and air-borne radon activity concentrations measurements
- **Development of advanced radon instrumentation**, resulting in a world-wide technological lead of European manufacturers

Quantities and units for radon…

New: EURADOS WG 3.3 Radon

A. Röttger (PTB)

The European Radiation Dosimetry Group (EURADOS e.V., www.eurados.org) is an established network of radiation dosimetry experts, dosimetry services and institutions mostly from Europe. At EURADOS Annual Meeting 2018 it was decided that “Radon” is such an important topic for EURADOS that a within WG3 a sub-group **WG3-S3 on “Radon”** was founded. Goals are:

- harmonisation of radon activity concentration measurements and related dose assessments
- Liason between MetroRadon and EURADOS
- development of a common strategy to apply the radon dose conversion factors published by ICRP in dose assessment at homes and at workplaces
- organisation of comparisons for calibration facilities and in-field intercomparisons as well
- support of knowledge transfer and scientific cooperation.

Bundesamt für Strahlenschutz

Physikalisch-Technische Bundesanstalt Braunschweig und Berlin

Quantities and units for radon…

EURADOS

- *Winter School 2019*

  Annual Meeting:

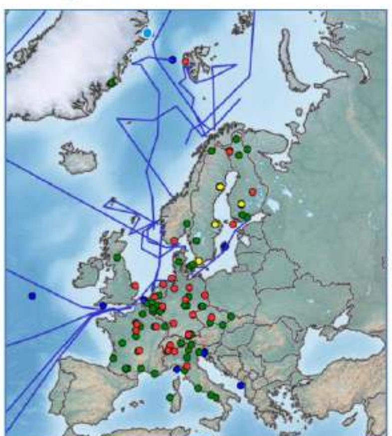
  Organising Committee:

  James Marsh, Pawel Olko,

  Annette Röttger and Arturo Vargas

EMPIR 2019 Environment

Improve Radon metrology for Multi-Approach Analysis for the atmospheric budget of Greenhouse Gases (IRMAG), C. Grossi, A. Röttger

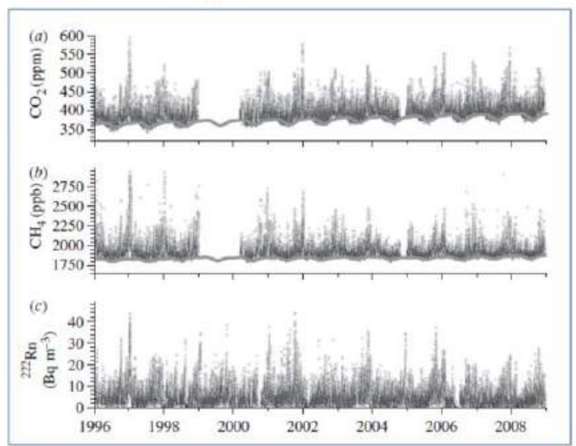


ICOS is a pan-European research infrastructure

ICOS Atmospheric Station Specifications:

Radon monitor: "At the present stage, Radon-222 measurements are not mandatory in ICOS. However, Radon-222 is recognized as a very valuable measurement, in particular for trace gas flux estimates."

- Determine source terms of GHG
- Environmental networks for climate observation and radiation protection networks (EURDEP)



Levin et al., 2011, doi: **10.1098/rsta.2010.0249**

EMPIR 2019 EMN

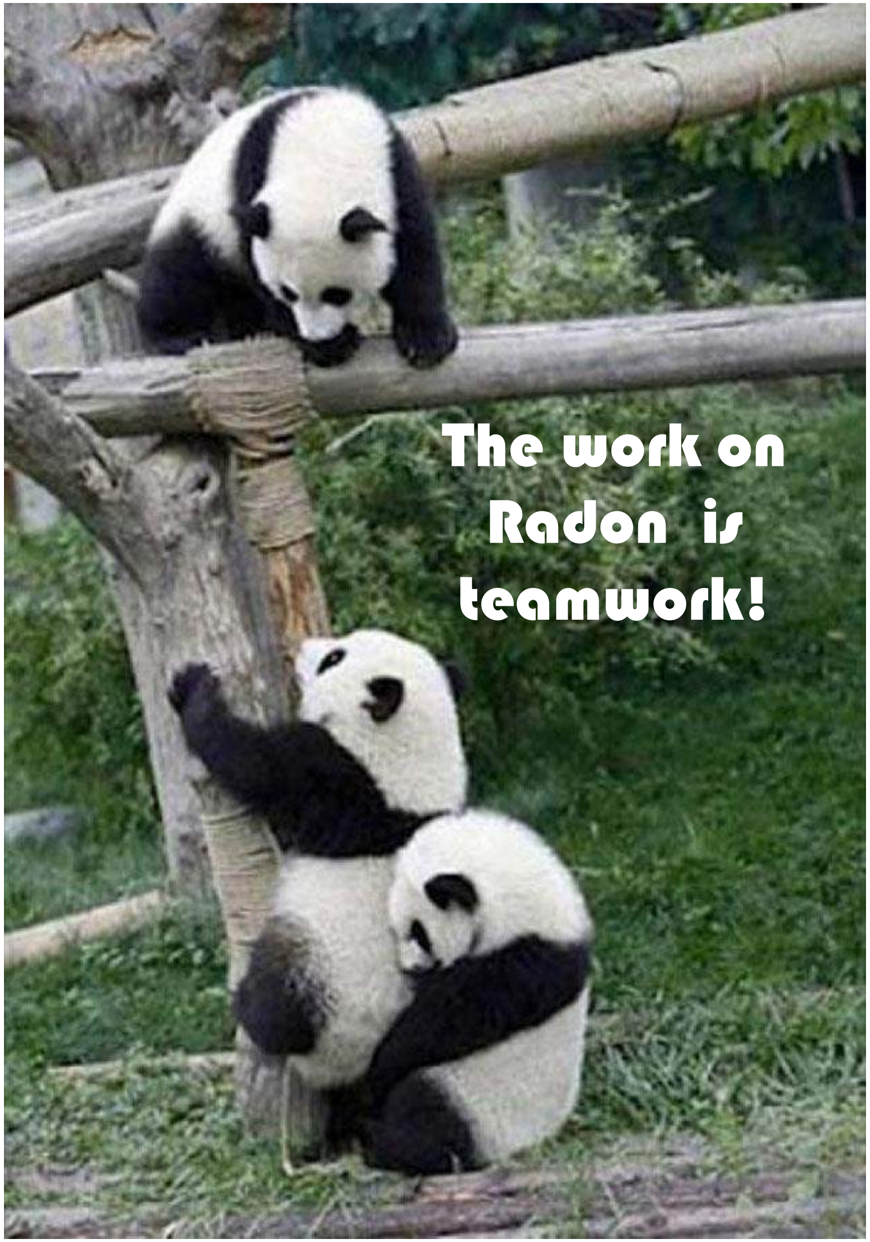
Radon is directly addressed in the **Basic Safety Standards Directive** through Article 54 concerning workplace radon levels, Article 74 concerning indoor radon levels, and Article 103 for the national action plan.

PhysikalischTechnische Bundesanstalt
Braunschweig und Berlin
Bundesallee 100
38116 Braunschweig

Annette Röttger
Fachbereich 6.3 *Strahlenschutzdosimetrie*

Telefon: +49 531 592 6300
eMail: annette.roettger@ptb.de
www.ptb.de

2018-10-30



RADONANALYS - GJAB

2019-06-17

Ackred. nr. 1989
Provning
ISO/IEC 17025

Indoor and soil radon measurement using LR 115 nuclear track film – a short presentation

The company

Radonanalys GJAB, Sweden, is accredited for indoor radon measurement according to ISO 17025.

Our services also include:

-radon measurement in soil

-inspection in buildings for radon mitigation

-education of radon consultants

-expert team for any radon related problem

Measurement technique

Indoor radon detector of our own construction

Soil radon detector of our own construction

Electronic devices for quick radon measurement indoors

Gamma-ray detectors for in situ inspection of building material

Scientifics

Among all projects we emphasize on our participation in an EU-project concerning radon measurement especially focused on soil radon. (Kiel, Barcelona, Rome, Montpellier, Leipzig-Halle, Debrecen, Lund).

Three of many of our scientific papers:

G Jönsson: Indoor Rn-22 measurements in Sweden with solid state nuclear track detector technique. Health Physics 54, 271 (1988).

G Jönsson, R Hellborg: Exposure of Pershore CR 39 and Kodak LR 115 films to helium ions of well-defined energy and angle of incidence. Nucl. Tracks Rad. Meas. 19, 335 (1987).

R Andriamanantena: Theoretische Berechnung und experimentelle Prüfung der Kalibration von Festkörperspurdetektoren für Radon Messungen in Räumen und im Erdboden. Dissertation Christian-Albrechts Universität, Kiel 1995.

RADONANALYS - GJAB
Ideon Science Park, Beta 2
223 70 LUND
Leveransadress:
Scheelevägen 17, LUND

Telefon: 046-286 28 80
Fax: 046-286 28 81
www.radonanalys.se
E-post: radonanalys@telia.com

Plusgiro:
103 25 61-1
Bankgiro:
5204-7297

EMPIR EURAMET

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

MetroRADON

AN INTRODUCTION TO THE METRORADON PROJECT METROLOGY FOR RADON MONITORING

M. Stietka, on behalf of the MetroRadon consortium

BEV - Bundesamt für Eich- und Vermessungswesen

Industry Interest Group Meeting – 18 June 2019

The MetroRADON Project

- Metrology research project: Radon monitoring
- Started 01 June 2017
- Duration: 3 years
- 17 European partner institutions
- EMPIR project
- Organised by EURAMET
- Co-funded by the European Union‘s Horizon 2020 programme and the EMPIR Participating States

EURAMET, as the Regional Metrology Organisation (RMO) of Europe, has 37 member countries. It leads cooperation of National Metrology Institutes (NMI) with nearly 6000 metrologists in the development of the European metrology infrastructure and services. It represents Europe in the international metrology forum of the CGPM (General Conference of Weights and Measures).

www.euramet.org

European Metrology Programme for Innovation and Research

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

part of Horizon 2020, the EU Framework Programme for Research and Innovation

EMPIR calls (2014 - 2020): total budget of 600 M € (300 M € from the participating states and up to 300 M € from the European Commission using Article 185 of the European Treaty)

EMPIR Joint Research Projects (JRPs) the EU's Grand Challenges in **Health, Energy, Environment and Industry**, and to progress fundamental measurement science

EMPIR Work Programme
Call Scope – Metrology for Environment (2016)

Document: P-PRG-GUI-033 Version: 1.0
Approved: EMPIR Committee 2015-12-01

This Call again focuses on metrological research to improve the quality of data to stimulate technological innovation, and to disseminate traceability to, and make traceable measurements in, the field. It also aims to underpin other environmental research initiatives through collaborative metrological research and development. It addresses both local environmental challenges such as those related to:

- contamination of water, air and soil
- radiation measurement and protection, and acoustic noise
- local pollutions and emissions measurements
- monitoring of key parameters to detect local climate evolution

and global metrological challenges for climate monitoring such as those related to:

- the essential climate variables of the atmosphere, land and water, including their constituents, contamination, transport and other parameters, and their time evolution and comparability
- emission control; measurement of gases and particles that have an effect on climate and health
- validated remote sensing data and products for environmental and climate monitoring, taking into account ground based instrumentation networks
- measurements in extreme environments and challenging conditions

Needs for the project

- ***European Council Directive 2013/59/EURATOM (EU-BSS)***
- The EU member states
  - are required to ensure that levels of relevant activity concentration laid down in the EU-BSS do not exceed 300 Bq/m^3
  - obliged to transpose the EU-BSS into national legislation by 2018
  - have to prepare their national radon action plan
  - define approaches, data and criteria to be used for defining radon priority areas
- **Reliable calibration and measurement methods** of activity concentrations between about 100 Bq/m^3 and 300 Bq/m^3
- Significant improvement of the **metrological infrastructure** for calibrations in Europe
- **Harmonisation** of radon concentration measurements
- Different methods to define the geogenic radon potential of an area need to be **compared and standardised**

Scope

- **EURATOM-BSS:**
  - require developing Rn action plans whose aim is reduction of Rn exposure
  - includes, among other, reference values and delineation of Rn priority areas

- **This implies QA**, in, among other:
  - measuring Rn (+Tn) concentrations incl. calibration in order to be able to verify **compliance with reference levels**;
  - methodology of determination of quantities which serve as geogenic **radon potential** or its proxies;
  - methodology of determination of **radon priority areas**.

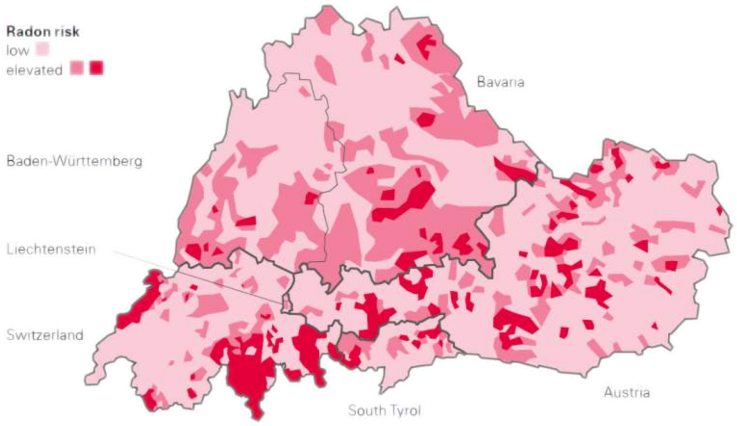
Put together:

QA of the compliance with rules, the delineation of Rn priority areas

implies QA calibrations and measurements

Main goals of the JRP

- Creation of a **coordinated metrological infrastructure** for radon monitoring and radon mapping in Europe suitable for the requirements of the **radon action plan** requested by the new European Directive
- Enable **SI traceable monitoring** of radon at low radon activity concentrations (≤ 300 Bq/m³), including calibration and radon mapping, essentially facilitating the **harmonised implementation of the new EU-BSS in Europe**
- Investigation of the **influence of thoron** on radon measurements and calibrations
- **Harmonisation** of indoor radon and soil exhalation radon measurements
- Development of new methodologies for identification and characterization of radon priority areas in Europe



Relative radon risk map of Austria, Liechtenstein, Switzerland and parts of Germany and Italy. Source: Swiss Confederation

Work beyond the state of the art

- A **traceability validation of existing European radon calibration facilities** will be performed. At present, secondary standards are calibrated at relatively high activity and are not adequately traceable to one primary radon gas standard
- The JRP will carry out **traceable inter-comparisons** on the quantities surface soil radon exhalation rate and radon concentrations in soil gas
- **Development of a unified index of geogenic Rn hazard:** consistent picture of susceptibility to geogenic Rn across Europe
- As a novelty, **methods for retrospective radon measurement by compact discs (CDs) and DVDs will be evaluated** for their potential to define radon priority areas.
- **New techniques** for measurement of radon exhalation from soil based on liquid scintillation counting of polymers and track-etching of CDs for indoor air retrospective radon measurement will be developed and evaluated
- **Evaluation of the sensitivity of radon monitors and detectors to thoron** with traceability to a primary thoron standard

Impact

- **Improvement of radiation protection and public health** due to reliable radon measurements as a basis for effective radon risk mitigation and prevention against radon progeny induced lung cancer in Europe and, therefore, **decreasing the lung cancer risk due to radon in Europe**
- The JRP will help to **establish** a basic European **metrological infrastructure** for radon monitoring.
- Provision of **harmonised metrological standards** for radon monitoring and radon protection in Europe, thus allowing comparison and merging of data sets
- **Provision of reliable radon mapping** methods for the **delineation of potential radon priority areas** in Europe
- **Coordination** of European calibration facilities regarding knowledge exchange
- Support of the competitiveness of the European **building industry** and the **measurement instrumentation manufacturers.**

Internal funded partners

National Metrology Institutes and Designated Institutes, from countries that have made a financial commitment to the Programme

no.	Participant Type	Short Name	Organisation legal full name	Country
1	Internal Funded Partner	BEV-PTP	Physikalisch-Technischer Pruefdienst des Bundesamt fuer Eich- und Vermessungswesen	Austria
2	Internal Funded Partner	BFKH	Budapest Főváros Kormányhivatala	Hungary
3	Internal Funded Partner	CEA	Commissariat à l'énergie atomique et aux énergies alternatives	France
4	Internal Funded Partner	CMI	Cesky Metrologicky Institut	Czech Republic
5	Internal Funded Partner	IFIN-HH	Institutul National de Cercetare-Dezvoltare pentru Fizica si Inginerie Nucleara "Horia Hulubei"	Romania
6	Internal Funded Partner	PTB	Physikalisch-Technische Bundesanstalt	Germany
7	Internal Funded Partner	STUK	Sateilyturvakeskus	Finland
8	Internal Funded Partner	VINS	Institut Za Nuklearne Nauke Vinca	Serbia

External funded and unfunded partners

External funded partners: All other legal entities established in:

- The Member States of the European Union, including their overseas departments
- The Overseas Countries and Territories (OCT) linked to Member States
- The countries automatically eligible for Horizon 2020 funding
- The countries associated to Horizon 2020

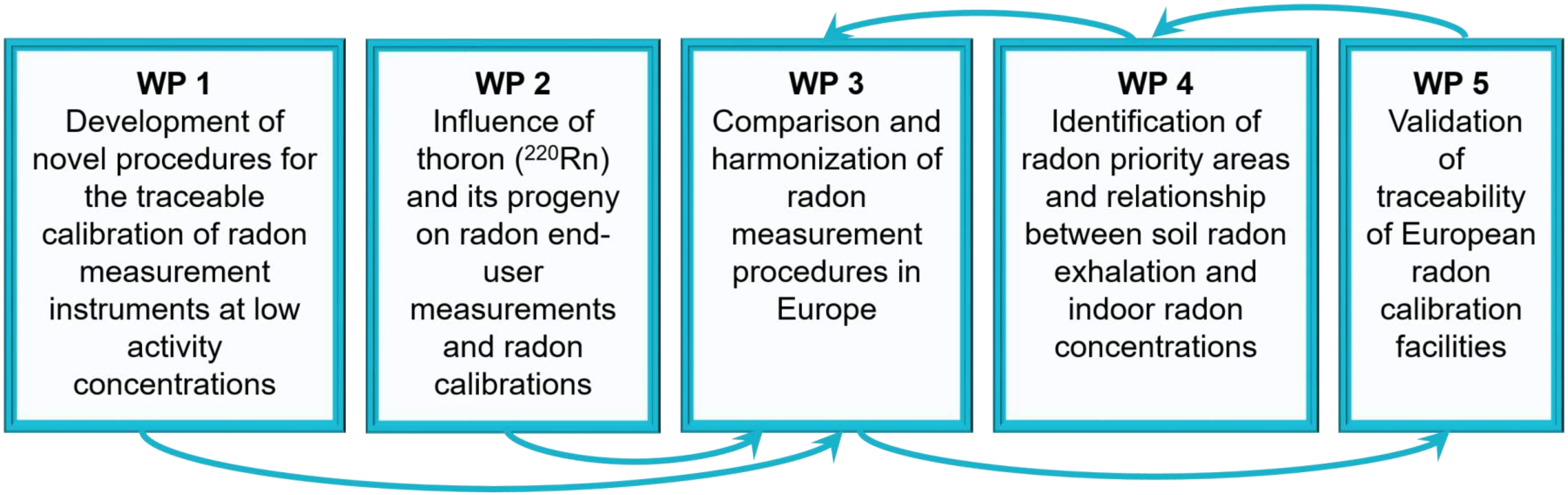
9	External Funded Partner	AGES	Oesterreichische Agentur fuer Gesundheit und Ernaehrungssicherheit GmbH	Austria
10	External Funded Partner	BfS	Bundesamt fuer Strahlenschutz	Germany
11	External Funded Partner	CLOR	Centralne Laboratorium Ochrony Radiologicznej	Poland
12	External Funded Partner	IRSN	Institut de Radioprotection et de Surete Nucleaire	France
13	External Funded Partner	JRC	JRC - Joint Research Centre - European Commission	European Commission
14	External Funded Partner	SUBG	Sofiiski Universitet Sveti Kliment Ohridski	Bulgaria
15	External Funded Partner	SUJCHBO	Státní ústav jaderné, chemické a biologické ochrany, v.v.i.	Czech Republic
16	External Funded Partner	UC	Universidad De Cantabria	Spain
17	Unfunded Partner	METAS	Eidgenössisches Institut für Metrologie METAS	Switzerland

The MetroRADON Consortium

MetroRADON – main objectives

- Novel procedures for the **traceable calibration** of radon (^{222}Rn) measurement instruments from 100 Bq/m^3 to 300 Bq/m^3 with **relative uncertainties ≤ 5 %** (k = 1)
- New radioactive **reference sources** with stable and known radon emanation rates
- **Influence of thoron (^{220}Rn) and its progeny on radon end-user measurements** and radon calibrations
- **Comparison of existing radon measurement procedures in different European countries**
- Measurement procedures for the determination of **radon concentration in air**
- **Optimisation of the consistency of indoor radon measurements and soil radon exhalation rate** measurements across Europe
- Analysis and development of methodologies for the **identification of radon priority areas**
- Development of the **concept of a Radon Hazard Index** (RHI)
- Relationship between **soil radon exhalation** rates and **indoor radon concentrations**
- To publish **guidelines and recommendations** on the findings

MetroRADON Work Package Structure



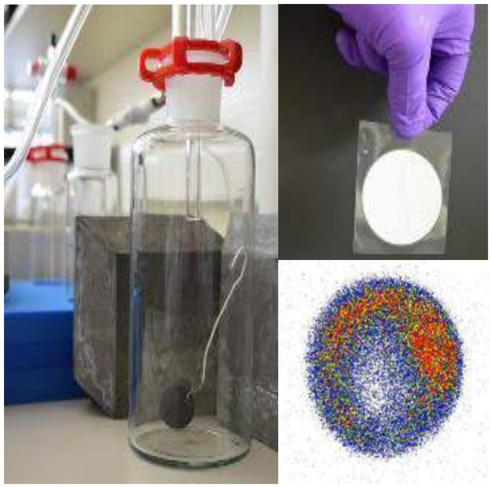
WP 1

Development of novel procedures for the traceable calibration of radon (^{222}Rn) measurement instruments at low activity concentrations (100 Bq/m^3 to 300 Bq/m^3) with relative uncertainties ≤ 5 % (k=1)

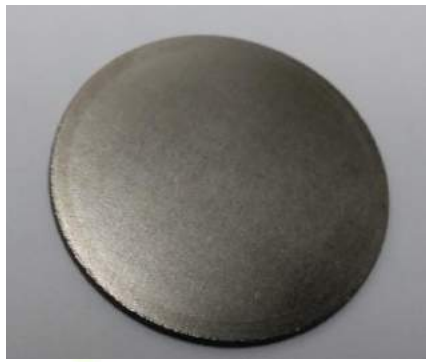
- Task 1.1: Development of new ^{222}Rn and ^{220}Rn radioactive reference sources with stable and known radon emanation capacity
- Task 1.2: Comparison of existing radon gas primary standards at European NMIs/DIs in the few kBq range
- Task 1.3: Establishment of constant ^{222}Rn activity concentrations in reference chambers and calibration of radon measurement instruments

First Results

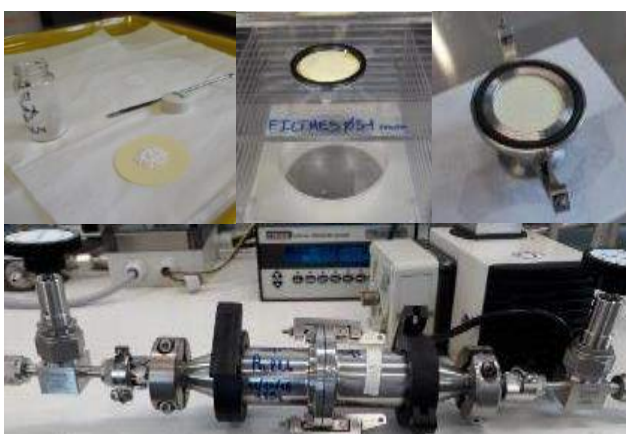
Chemisorption, JRC



Implanted Source, PTB



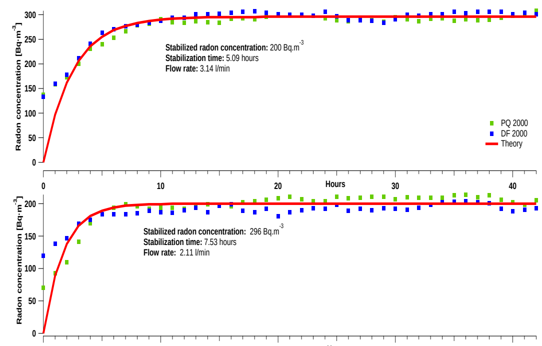
^{220}Rn flow-through source, CEA



Flow-through source, CMI

New sources in chambers

Evaluate stable and repeatable Rn-atmospheres in range 100-300 Bq/m,3



WP 2

Influence of thoron (^{220}Rn) and its progeny on radon end-user measurements and radon calibrations

- Task 2.1: Ensuring traceability of the secondary thoron reference instruments used in the experimental research to the primary thoron measurement system at IRSN

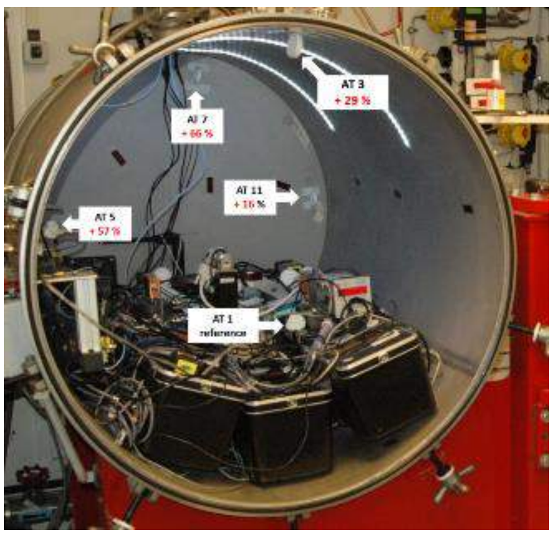
- Task 2.2: Investigation of the influence of thoron on radon measurements and calibrations
  - because Tn can introduce errors in Rn determination in certain techniques

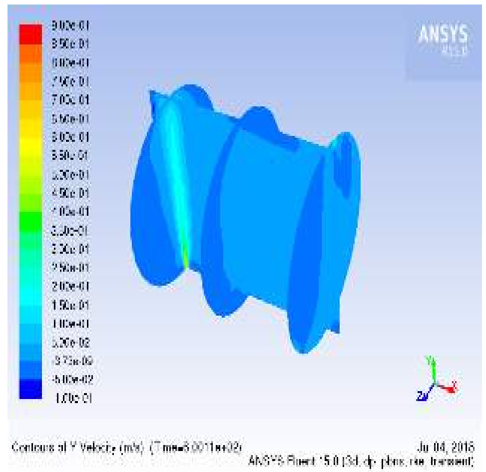
- Task 2.3: Development of techniques to reduce the influence of thoron on radon measurements and calibrations

First Results

Calibration of radon/thoron monitors

BACCARA chamber, IRSN





Homogeneity testing of Rn-220 atmosphere

Results will be presented at ICRM 2019 (Sofia University)

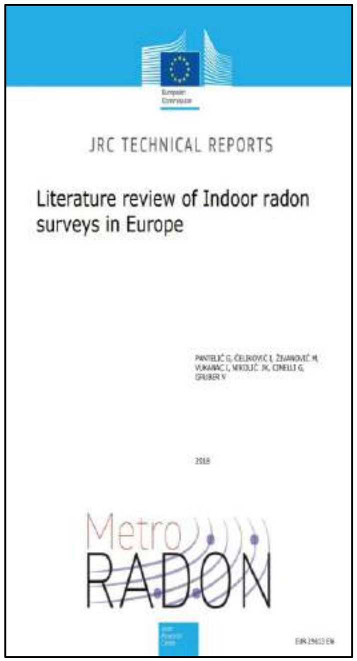
Field measurements to assess influence of thoron (BEV)

WP 3

Comparison and harmonisation of radon measurement methodologies in Europe

- Task 3.1: Overview and analysis of indoor radon surveys in Europe
- Task 3.2: Overview and analysis of geogenic radon surveys in Europe
- Task 3.3: Comparison of indoor radon and geogenic radon measurements under field conditions - different protocols and procedures exist
- Task 3.4: Development of options for harmonisation of indoor and geogenic radon data including practical examples to ensure comparability between data generated following different methodology

First Results



Literature Review of Indoor Radon surveys in Europe

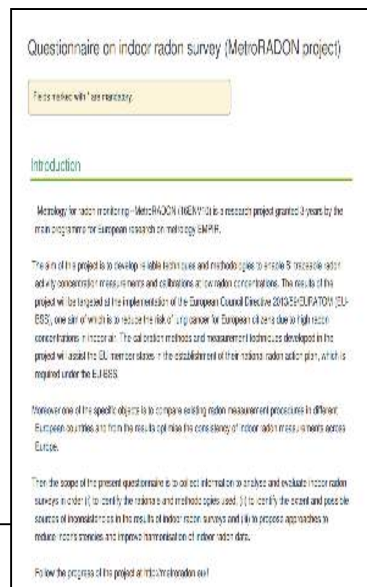
Published as JRC technical report

Intercomparison exercise under field conditions

LARUC, Spain (UC);

20 participants;

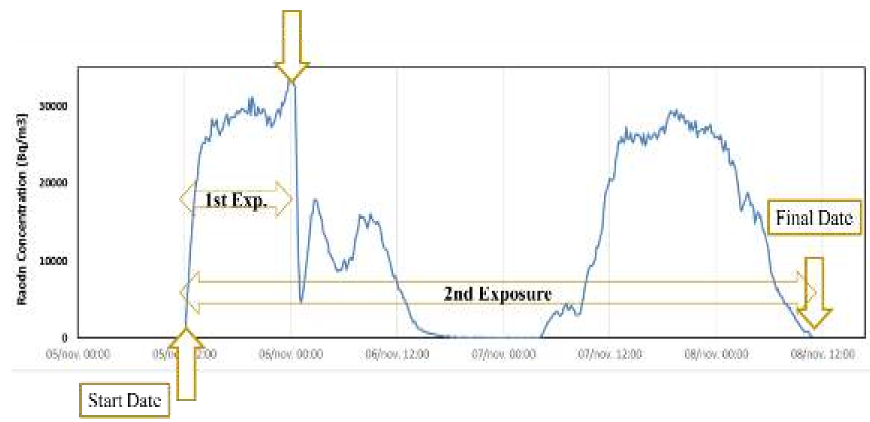
report available on website


Questionnaire on indoor radon survey (MetroRADON project)

Fields marked with * are mandatory

Introduction

Questionnaire on indoor surveys to national authorities



WP 4

Radon priority areas (RPAs) and the development of the concept of a "geogenic radon hazard index" (RHI)

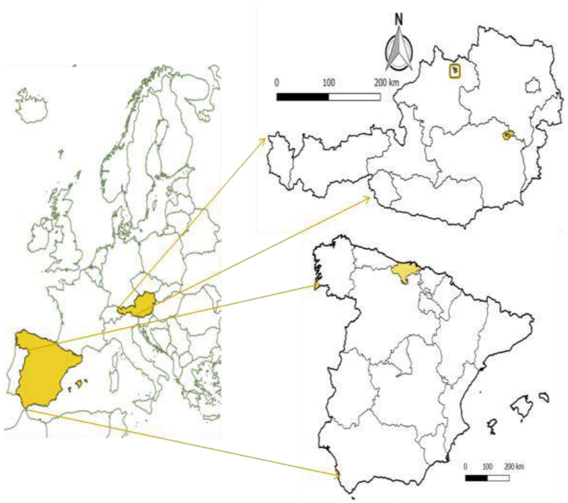
- Task 4.1: Evaluation of the concepts for the definitions of radon priority areas
  - different concepts have been proposed and partly implemented

- Task 4.2: Relationship between indoor radon concentration and geogenic radon
  - as a base to classify Rn priority areas based on geogenic quantities

- Task 4.3: New developments in estimation of radon priority areas
  - performance of the CD method for retrospective Rn measurement, RHI concept, classification questions, uncertainty etc.

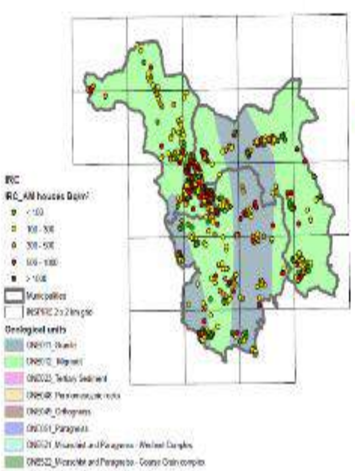
- Task 4.4: Harmonisation of radon priority areas across borders
  - how to deal with inconsistencies resulting from different Rn priority area definitions

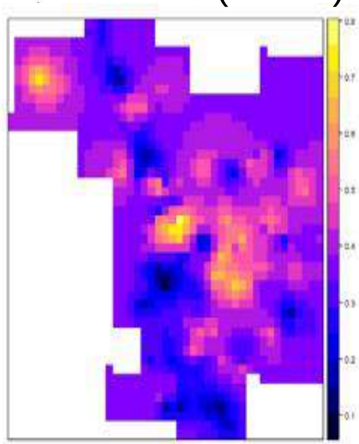
First Results



Radon mapping exercise

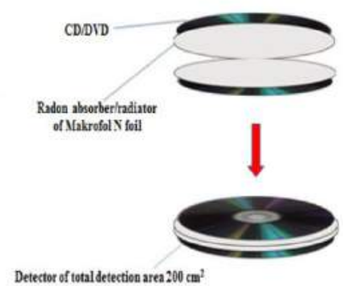
Presented at GARRM; report and paper in preparation (AGES)





Testing of CD/DVDs as retrospective radon detectors for radon mapping

Improvement of methodology (Sofia University) and long-term exposure at LARUC (UC)



Development of geogenic radon hazard index (RHI) (BfS)

WP 5

Validation of traceability of European radon calibration facilities

- Task 5.1: Selection and evaluation of European radon calibration facilities for validation of traceability
- Task 5.2: Validation of traceability, performance and precision of European radon calibration facilities in the range from 300 Bq/m3 to 10 000 Bq/m^3
- Task 5.3: Validation of traceability of European radon calibration facilities at stable radon atmospheres in the range from 100 Bq/m^3 to 300 Bq/m^3

First Results – Intercomparison exercise

- Questionnaire for identification and evaluation of European radon calibration facilities
- Validation Exercise in the range from 300 Bq/m³ – 10 000 Bq/m³ ongoing
  - AlphaGUARD reference instrument sent to all participants to perform calibration
  - Institutes use their usual calibration methods

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:

You are invited to collaborate or to follow the project

michael.stietka@bev.gv.at

www.metroradon.eu

Register for the project newsletter on our website

ResearchGate:

MetroRADON - Metrology for Radon Monitoring (EMPIR 16ENV10)

F. J. Maringer · Philippe Cassette · Nathalie Michielsen · Show all 41 collaborators

Goal: 1. Development of novel procedures for the traceable calibration of radon (222Rn) measurement instruments at low activity concentrations (100 Bq/m3 to 300 Bq/m3) with relative uncertainties ≤ 5 % (k=1)

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

MetroRADON

WP1 – Development of novel procedures for the traceable calibration of radon (^{222}Rn) measurement instruments at low activity concentrations (100 Bq/m^3 to 300 Bq/m^3) with relative uncertainties ≤ 5% (k = 1)

Meeting of the Industry Interest Group
PTB, 18 June 2019

D. Arnold, S. Röttger, F. Mertes

Task 1.1 Reference Sources

Activity number	Activity description	Partners (Lead in bold)
A1.1.1	**PTB, supported by JRC** who have experience of emanation sources, **will develop ^{222}Rn and ^{220}Rn emanation sources (relative target uncertainty ≤ 5 % (k=1)) at PTB**, including a detector system for the continuous monitoring of the emanated activity of ^{222}Rn relative to the activity of the ^{226}Ra source (and emanated ^{220}Rn relative to activity of ^{228}Th source) which is traceable to primary standards. The sources will consist of the radionuclide, based on a radium salt, and deposited on exchangeable carriers. Using the new emanation sources PTB and JRC then will evaluate the influence of changes in temperature, humidity and air pressure on the emanation rate.	**PTB**, JRC
A1.1.2	**CEA will develop ^{222}Rn and ^{220}Rn emanation sources (relative target uncertainty ≤ 5 % (k=1)) at CEA using polymers**. Using the new emanation sources CEA then will evaluate the influence of the changes of temperature, humidity and air pressure on the emanation rate.	**CEA**
A1.1.3	**CMI with support from SUJCHBO**, who will provide access to their facilities, **will develop a long term stable ^{222}Rn low activity emanation flow-through standard source at CMI** based on a metering flow controller and dispenser generating a known ^{222}Rn concentration in an air flow with the relative uncertainty ≤ 4 % (k=1).	**CMI**, SUJCHBO
A1.1.4	**CEA supported by METAS will develop a method for direct and traceable measurement of the activity concentration of ^{222}Rn and ^{220}Rn in an air flow.** This method for measurement of the activity concentration of ^{222}Rn and ^{220}Rn in an air flow will be implemented at both CEA and METAS.	**CEA,** METAS
A1.1.5	PTB, CEA and CMI will **compare** the activity from direct measurement of ^{222}Rn in an air flow developed in A1.1.4 with the ^{222}Rn activity of the emanation sources developed in A1.1.1, A1.1.2 and A1.1.3.	**PTB**, CEA, CMI
A1.1.6	CEA, PTB, CMI and SUJCHBO will **compare** the ^{222}Rn activity from stable emanation sources developed in A1.1.1-A1.1.3 with existing decaying ^{222}Rn gas standards using a known sample of radon as the transfer standard.	**CEA**, PTB, CMI, SUJCHBO

Task 1.2 Comparison

Activity number	Activity description	Partners (Lead in bold)
A1.2.1	**CEA, with support from BFKH, IFIN-HH, PTB and JRC, will organise a comparison of the activity of ^{222}Rn gas standards of a few kBq** following the international CCRI(II) rules. CEA will identify those organisations from amongst CCRI(II) members, in addition to BFKH, IFIN-HH, PTB and JRC that are interested in participating in the comparison. CEA, with input from BFKH, IFIN-HH, PTB and JRC will develop the comparison protocol and schedule the comparison in accordance with the CCRI(II) requirements and will register the comparison with BIPM. A suitable transfer standard will be identified and characterised. The transfer standard will then be circulated to the participants, including BFKH, CEA, IFIN-HH, PTB and JRC, according to the agreed schedule, and the participants will perform the measurements and provide CEA with their results. CEA will analyse the results and draft 'Draft A' of the comparison report, which will be circulated to the participants. CEA will then produce 'Draft B' of the comparison report which will be agreed by all the participants before it is submitted to BIPM.	**CEA,** BFKH, IFIN-HH, PTB, JRC
A1.2.2	**CEA, with support from IFIN-HH, TB and JRC, will organise a comparison of the activity of ^{220}Rn gas standards of a few kBq** following the international CCRI(II) rules. CEA will identify those organisations from amongst CCRI(II) members, in addition to IFIN-HH, PTB and JRC that are interested in participating in the comparison. CEA, with input from IFIN-HH, PTB and JRC will develop the comparison protocol and schedule the comparison in accordance with the CCRI(II) requirements and will register the comparison with BIPM. A suitable transfer standard will be identified and characterised.	**CEA**, IFIN-HH, PTB, JRC

Task 1.3 Radon in Reference chambers

Activity number	Activity description	Partners (Lead in bold)
A1.3.1	**The new ^{222}Rn emanation sources developed and compared in A1.1.1-A1.1.5 together with existing certified reference volumes will be installed at BfS, BFKH, IFIN-HH, IRSN, METAS and SUJCHBO reference chambers in order to establish constant and traceable ^{222}Rn activity concentrations.** The stability and the reproducibility of atmospheres under environmental conditions (room climate) and for long-term operation will be evaluated. The climatic parameters will be identical to the standard test conditions for type tests of instruments for radon and radon decay products as specified in the standard series IEC EN 61577, namely temperature 18 °C – 22 °C, relative humidity 50 %rh – 75 %rh and air pressure 90 kPa - 106 kPa.	**BfS**, BFKH, IFIN-HH, IRSN, SUJCHBO, METAS
A1.3.2	**BfS, IFIN-HH, BFKH, IRSN, SUJCHBO and METAS will develop calibration procedures for their reference chambers upgraded in A1.3.1 in the activity concentration range from 100 Bq/m³ to 300 Bq/m³ using ^{222}Rn gas and emanation standards developed and compared in A1.1.1-A1.1.6.** This will include analysis of the measurement uncertainties and standardisation of calibration procedures in order to transfer the quantity radon activity concentration at a high metrological level. The radon measurement instruments for use in A5.3.2 will be calibrated using these standardised procedures. The target relative uncertainty for the calibration of measurement instruments at low activity concentrations (100 Bq/m³ to 300 Bq/m³) is ≤ 5 % (*k*=1).	**BfS**, BFKH, IFIN-HH, IRSN, SUJCHBO, METAS

Task 1.3 Radon in Reference chambers

Activity number	Activity description	Partners (Lead in bold)
A1.3.3	**IRSN, IFIN-HH, BFKH, BfS, SUJCHBO and METAS will determine the accuracy of commonly used integrated radon measurement instruments (alpha-track detectors, electrets, etc.) and novel detectors using their radon reference chambers upgraded in A1.3.1 and the calibration procedures from A1.3.2.** Each partner will investigate the instruments available in their laboratory. The measurements will include tests for the background level of the instrument, and the linearity and reproducibility of the results over the ^{222}Rn activity concentration range from 100 Bq/m³ to 300 Bq/m³.	**IRSN,** BFKH, IFIN-HH, BfS, SUJCHBO, METAS
A1.3.4	Based on the results from A1.1.1-A1.1.6 and A1.3.1-A1.3.3, **PTB, BFKH CEA, CMI, IFIN-HH, BfS, IRSN, JRC, SUJCHBO and METAS will document a calibration method** for the traceable calibration of radon (^{222}Rn) measurement instruments at low activity concentrations (100 Bq/m³ to 300 Bq/m³) with relative uncertainties ≤ 5 % (k=1). Once the documented calibration method has been agreed by the consortium, the coordinator on behalf of PTB, BFKH, CEA, CMI, IFIN-HH, BfS, IRSN, JRC, SUJCHBO and METAS will then submit it to EURAMET as **D1** *'Method for the traceable calibration of radon (^{222}Rn) measurement instruments at low activity concentrations (100 Bq/m³ to 300 Bq/m³) with relative uncertainties ≤ 5 % (k=1)'*.	**PTB**, BEV-PTP, BFKH, CEA, CMI, IFIN-HH, BfS, IRSN, JRC, SUJCHBO, METAS

Summary

1. Development of reference radon sources with constant, stable measured emanations traceable to primary standards.
2. Development of a method for direct and traceable measurement of radon activity concentration in an air flow.
3. Comparisons
4. Establishment of constant and stable radon activity concentrations in reference chambers.
5. Development of calibration procedures for radon measurement instruments.
6. Documentation and report.

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

Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
Bundesallee 100
38116 Braunschweig

Dirk Arnold
Telefon: 0531 592-6100
E-Mail: Dirk.Arnold@ptb.de
www.ptb.de

WP2:
FIRST RESULTS AND OUTCOMES OF POTENTIAL INTEREST FOR INDUSTRY

WP2 partners: SUBG, IRSN, STUK, CEA, BEV-PTP

WP2 leader: Dobromir Pressyanov (SUBG)

MetroRADON WP2:

…technical concepts and solutions will be proposed to firstly potentially correct the thoron-related bias to the radon signal in radon monitors and secondly **to reduce the thoron-related bias to the radon signal in radon monitors through the use of membranes that act as a barrier to thoron…**

Experimental facilities for creating reference ^{220}Rn, ^{222}Rn and ^{222}Rn+^{220}Rn exposure conditions were arranged in:

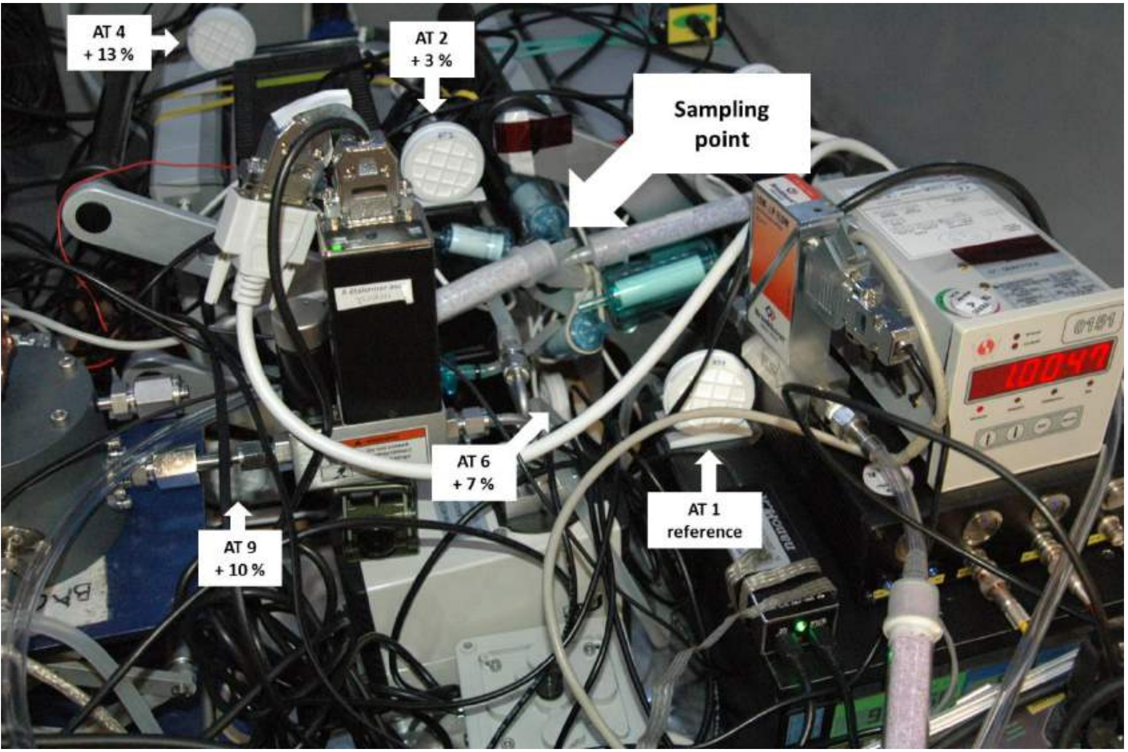
- **IRSN**
- **CEA**
- **SUBG**
- **STUK**

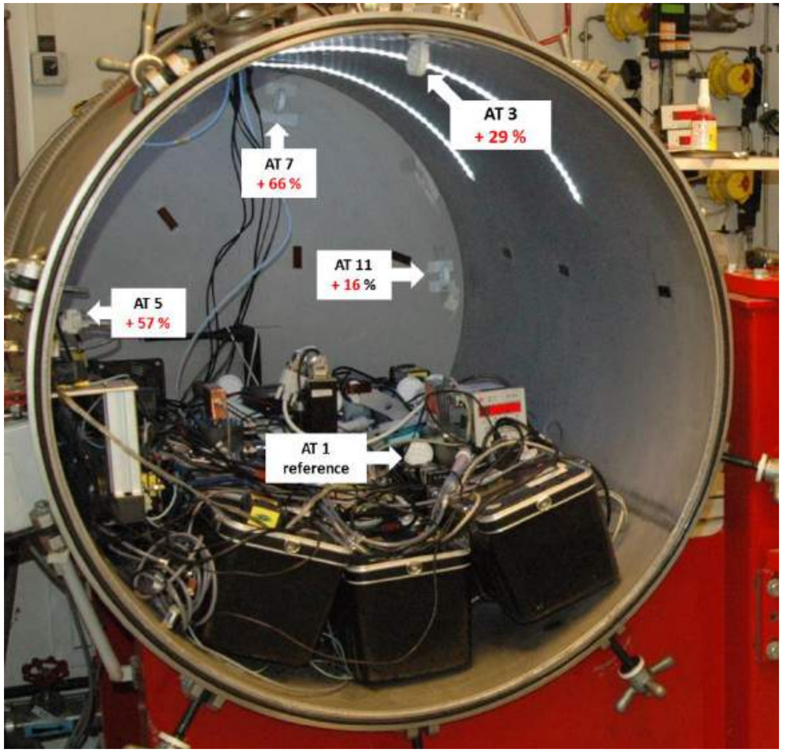
PRODUCTION OF MIXED RADIOACTIVE GAS ATMOSPHERE AND PROPOSITION OF SETUP TO TEST RN-220 AND RN-222 SEPARATION BY POLYMER FOILS

MetroRADON, Sofia Workshop | 21-22/03/2019 | Benoît SABOT

SUBG exposure facility: reference ^{222}Rn, ^{220}Rn, ^{222}Rn+^{220}Rn exposure conditions (static and dynamic) can be created at temperature within -15 to +60^{0}C

Thoron calibration exercise was organized (N. Michielsen et al.) and carried-out in IRSN in May 2018 (IRSN, SUBG, STUK, BEV-PTP). Recently developed primary thoron measurement system (B. Sabot, et al., *Applied Radiation and Isotopes* 118 (2016) 167-174) was used as a reference





- Thoron homogeneity checked (K, Mitev et al.): Less than 10 % variation around the instruments, up to 60% above.

Approaches to minimize thoron influence

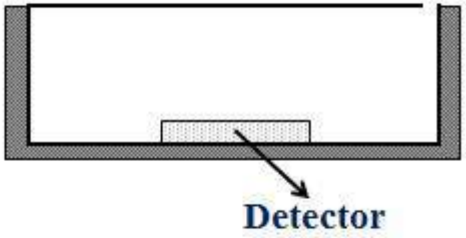
(O. Holmgren, T. Turtiainen, K. Mitev, D. Pressyanov, ***Review of potential techniques and materials to reduce the influence of thoron on radon measurements and calibrations**, **2018***):

- Diffusion through polymer foils (can eliminate thoron influence, eliminates also humidity);
- Diffusion through small hole (depending on the construction can reduce thoron influence to < 10%, however, detectors are affected by humidity);
- Delay due to air flow in a pipe (active method).

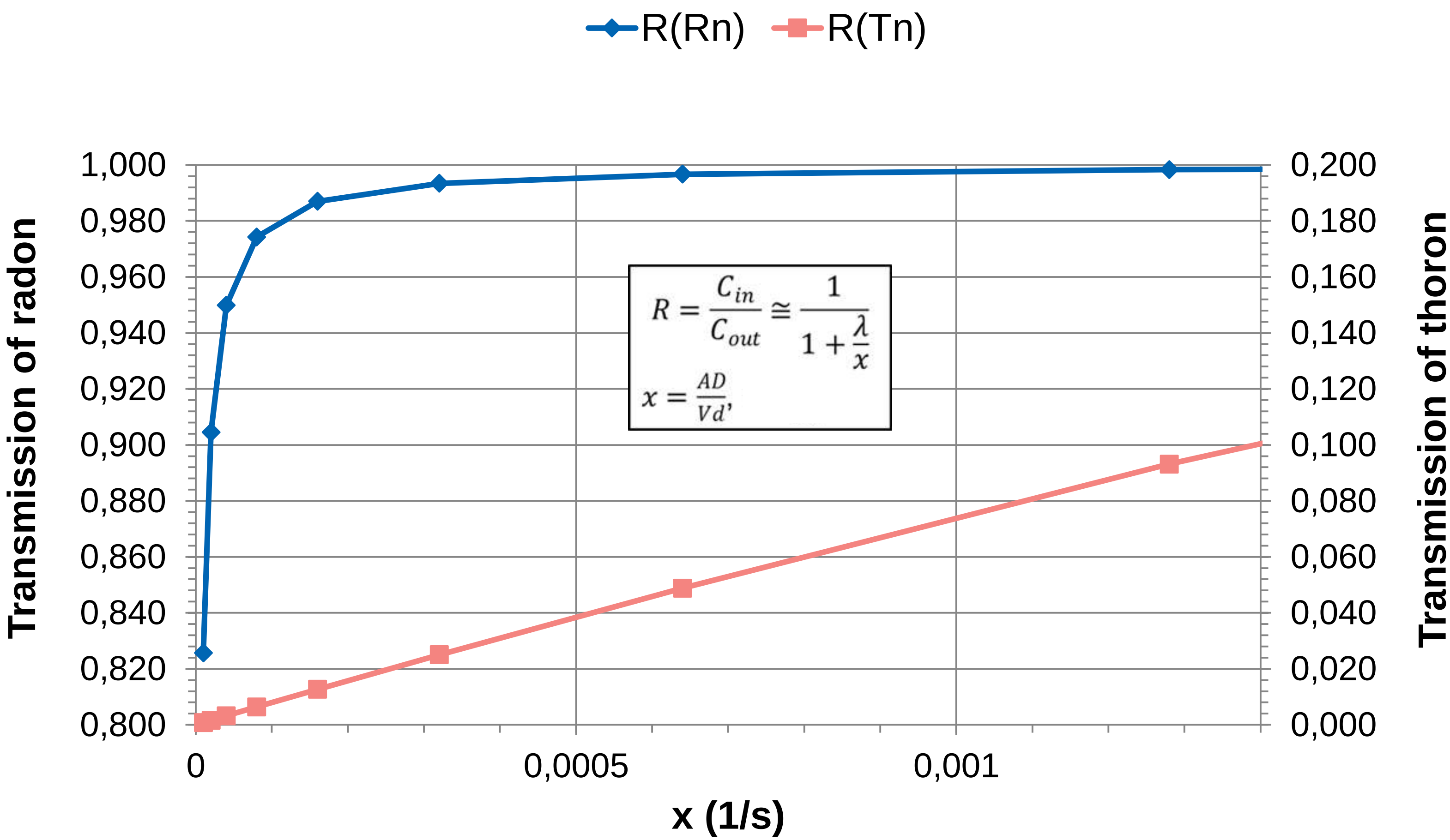
Most passive radon detectors employ «polymer foil barrier» or «diffusion through small holes»

Foil-based diffusion chamber (provides anti-thoron and anti-humidity protection)

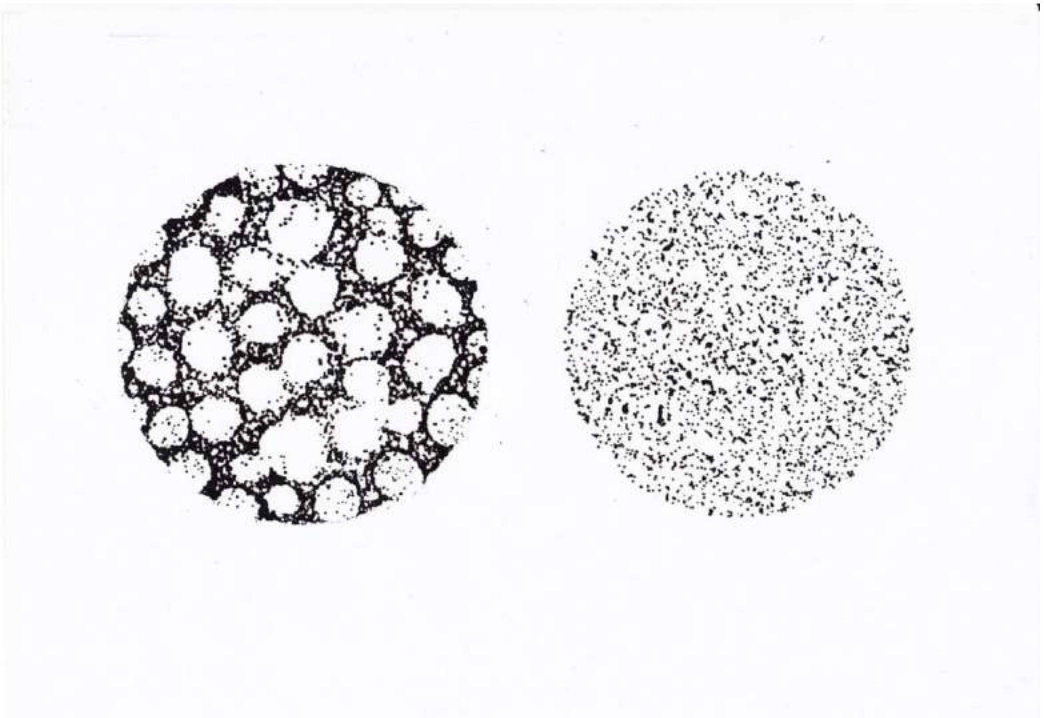
Pin-hole diffusion chambers (thoron influence can be reduced if the holes are sufficiently small)



Transmission of radon and thoron through pin-holes or membrane: transmission of thoron can be suppressed by both methods, but…



Problems of humidity for pin-holes diffusion-chambers, water can also block diffusion if the holes are small (small holes provide more efficient thoron reduction)



Polymer membranes: transmission of radon ($R=C_{in}/C_o$) and the response to radon of chambers with such anti-thoron barriers become temperature dependent (Tommasino, *8th Int. Conf. on Protection against Radon at Home and Work, Prague, 12-16 September 2016*):

TEMPERATURE (°C)	PERMEABILITY ($x10^{-7}cm^2/s$)	R Cup	R NRPB	R ENEA
0	0.15 ± 0.04	0.32	0.33	0.73
20	1.20 ± 0.04	0.80	0.80	0.96
40	3.60 ± 0.50	0.92	0.92	0.99

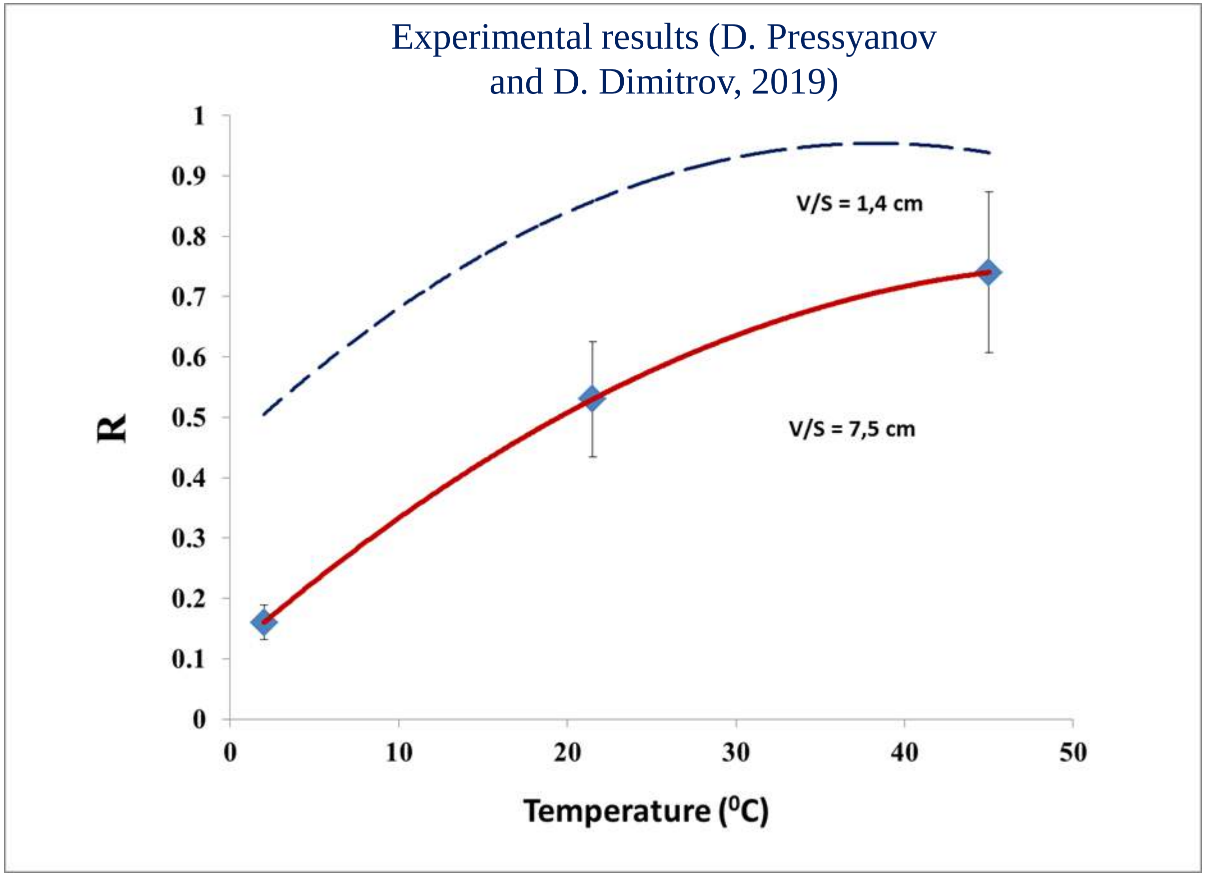
A workshop in the framework of activity A.2.3.3 of WP 2 of MetroRADON on **“Transport of Radon and Thoron in Polymers”** was organized (head organizer: K. Mitev) on 21-22 March 2019
at the Faculty of Physics, Sofia University “St. Kliment Ohridski”

Workshop materials are available on:

https://oc.tdcr.xyz/index.php/s/f8KMlkxQWEnwXrM

The MetroRADON WP2 principal goal was identified as a technical challenge.
A concept beyond state-of-the art was needed and … it was (possibly) found. For the first time it was reported on the workshop (D. Pressyanov).

Consider the temperature dependence of radon transmission ($R=C_{in}/C_o$) in chambers covered by polymer foils…



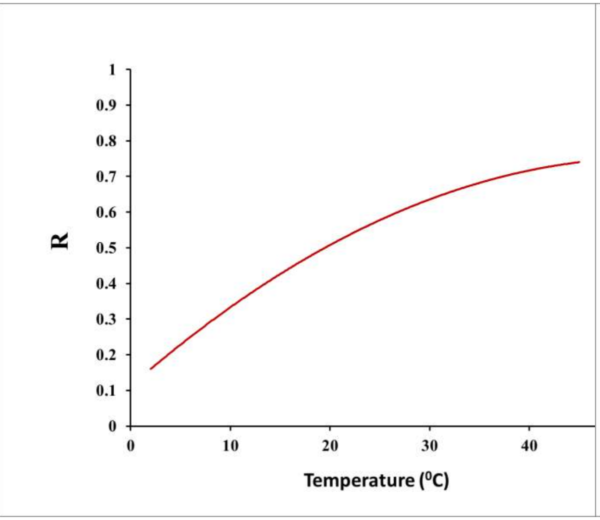
LDPE 75 μm

The temperature dependence of radon transmission through polymer membranes is a problem that gives an (surprising) opportunity, because:

… many radon detectors have temperature dependence of the response which is reciprocal to that of the radon transmission (R), i.e. decreasing with increasing the temperature. Such detectors are e.g.:

- The most widely used track detectors: CR-39. These detectors show fading, and the (fading) decrease of the signal is larger at higher temperature (see e. g. H. Enomoto and N. Ishigure, 2011; M. Caresana et al., Radiat. Meas. 45 (2010) 183–189).
- Some detectors that employ radon absorption/adsorption (e.g. detectors based on activated charcoal; radon film badges (Tommasino et al., 2009) etc.);

The key concept: Is it possible to arrange:



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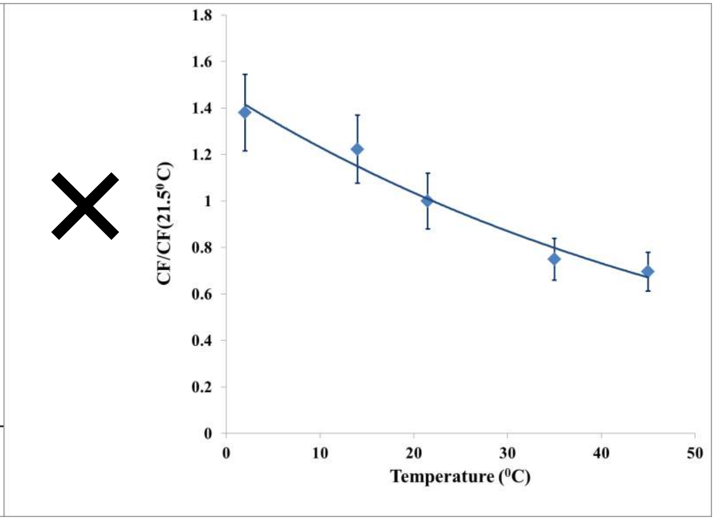
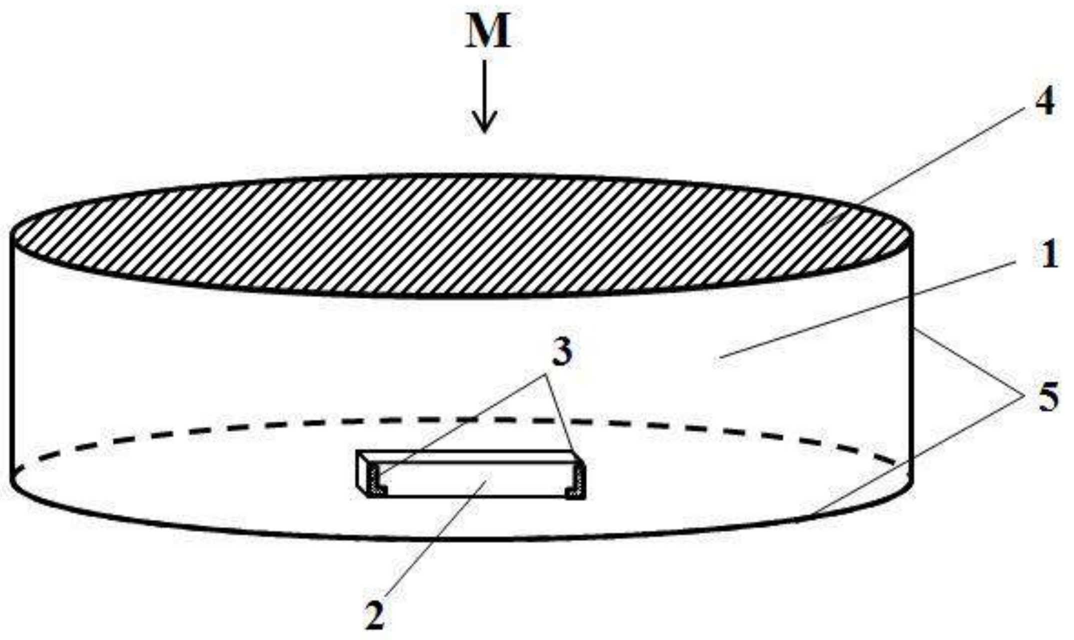


= const?

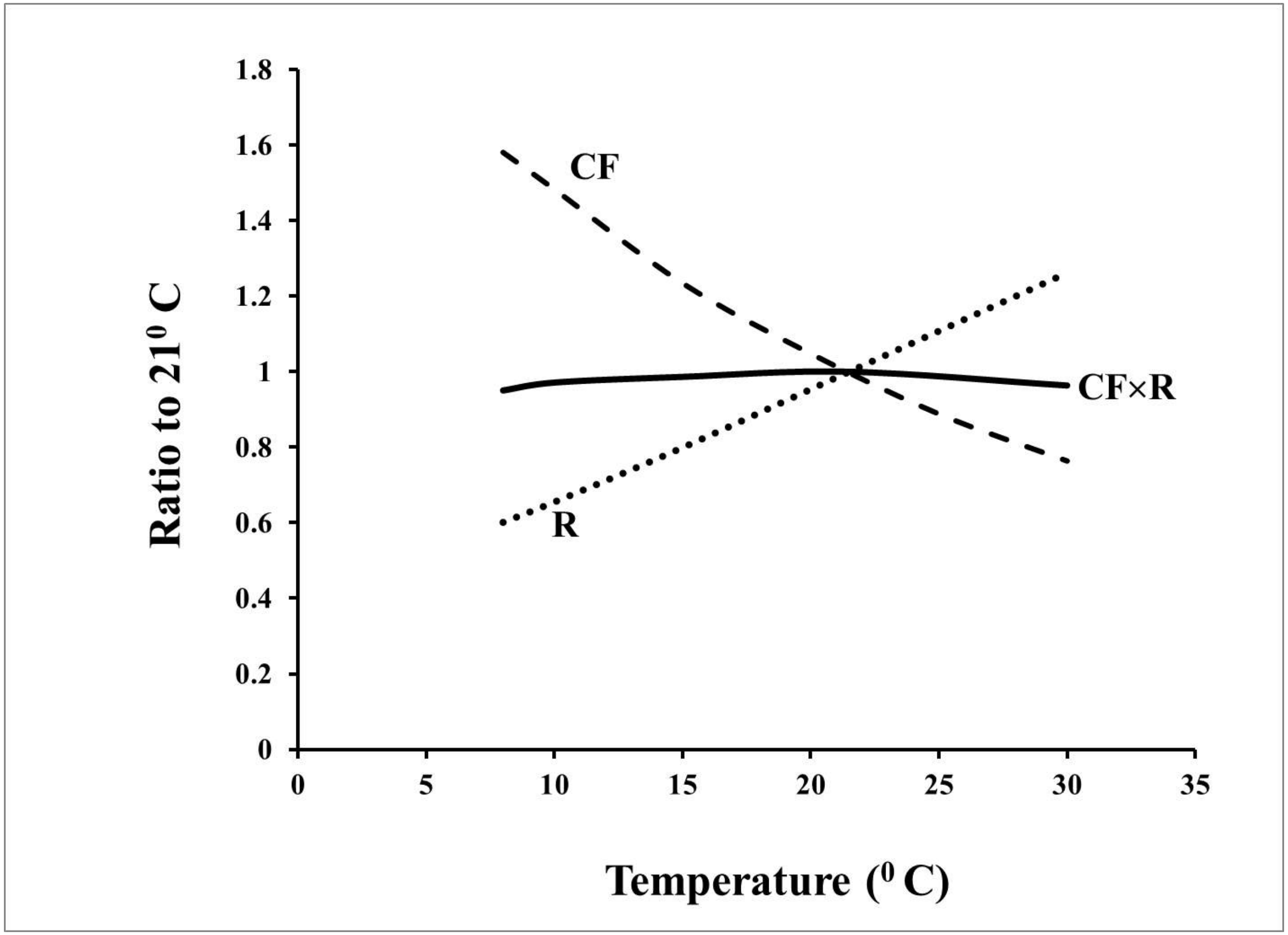
Answer: **YES!**

<u>Beyond state-of-the art:</u> A modules can be designed with *R(T)* that compensates that of *CF(T)* so that $CF \times R \approx$ const. The modules design depends on the type of radon sensor/detector:

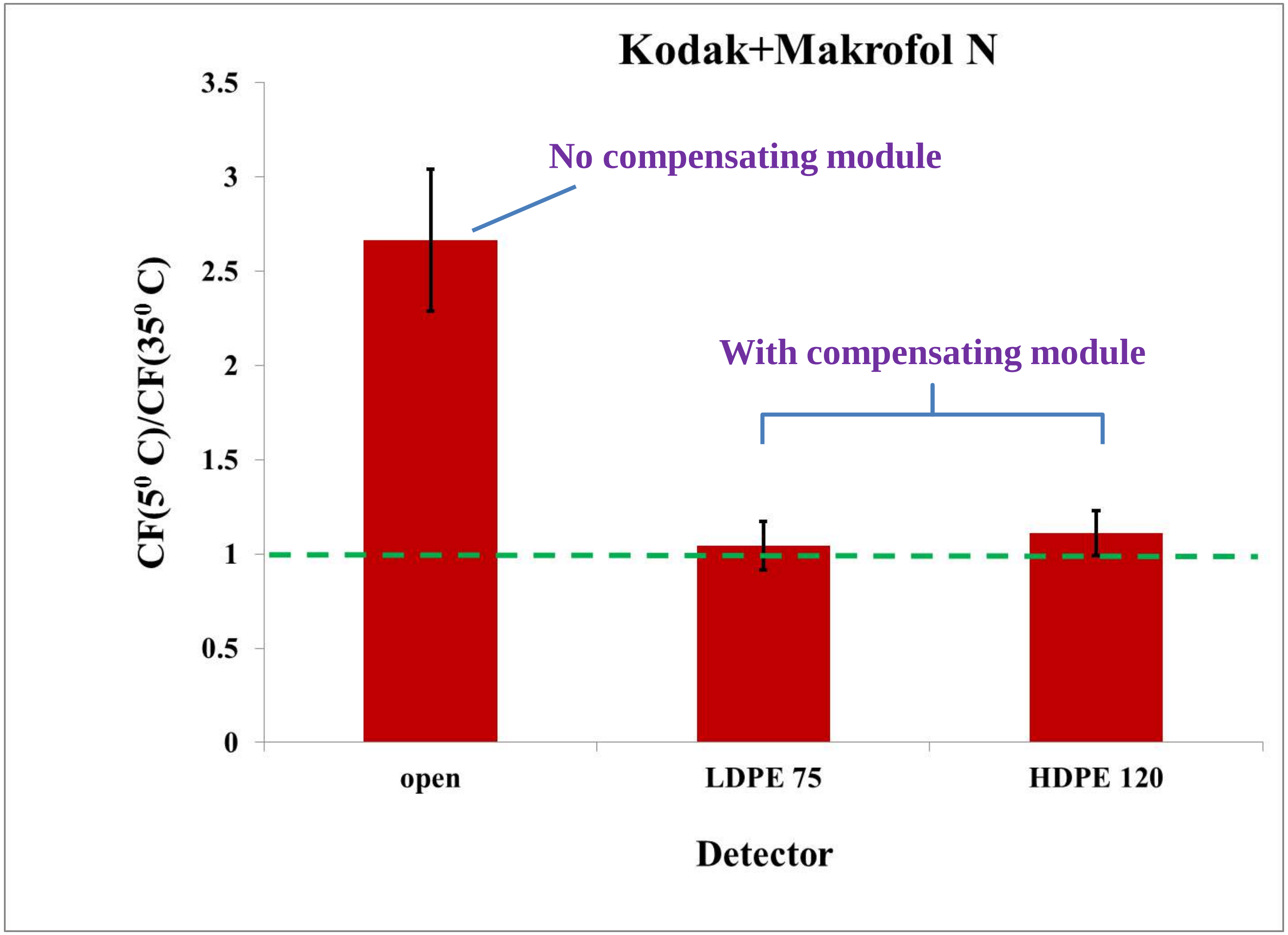


<u>Patent application submitted</u> (Bulg. Pat. Appl. Reg. Nr. 112897, priority: 19.03.2019; inventor: D. Pressyanov, assignee: SUBG). MetroRADON project was acknowledged.

Suitable modules were designed by computer modelling and tested experimentally



Experiments with radon film badges (Kodak-Pathe LR-115/II + external radiator of Makrofol N). Ratio of the response at 5 and 35^{0}C with and without compensating module.



Conclusions and outcomes

- **Within MetroRADON WP2 exposure facilities were built and inter-calibration of the reference instruments was made. Traceability to the primary reference thoron measurement system was ensured;**
- **Experimental and computer modeling research was focused on thoron homogeneity in the exposure chambers;**
- **A thorough review of methods to reduce the thoron interference on radon measurements was made;**
- **Dedicated experimental and theoretical work was focused on radon and thoron transport through polymer membranes;**
- **A technical challenge was identified and a step beyond state-of-the art was proposed: a compensating module (patent pending) that provides technical solution capable to reduce: thoron interference + temperature dependence + humidity influence.**

Thank you!

Metro RADON