Physikalisch-Technische Bundesanstalt
Braunschweig and Berlin
National Metrology Institute

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)

Workshop on New Procedures for radon Monitoring
PTB, 12 October 2020

D. Arnold

WP1 partner: BFKH, CEA, CMI, IFIN-HH, METAS, PTB
BfS, IRSN, JRC, SUJCHBO

Overview

1. State of the art before MetroRadon starts
2. Need for novel calibration methods
3. Development of reference radon sources with constant, stable measured emanations traceable to primary standards
4. Development of a method for direct and traceable measurement of radon activity concentration in an air flow
5. Establishment of constant and stable radon activity concentrations in reference chambers
6. Development of calibration procedures for radon measurement instruments
7. *Comparisons*

State of the art before MetroRadon starts

- Connect a Radon-gas activity standard with a Radon-chamber of known (certified) volume in order to create a traceable activity concentration and follow the radioactive decay of Rn-222 with $T_{1/2}$ = 3.8232 (8) days

PTB radon gas activity standards

BfS Radon chamber

Need for novel calibration methods

- The influence of the counting statistic within the calibration of an Rn-222 measurement device should have a low contribution.

- If you want to reach 1 % uncertainty for the counting statistic, you need at least 10000 measured counts.

- Rough estimation under following conditions:
  Active volume of the device: 1L counting efficiency: 100 %

a. Activity concentration: 1 kBq/m^3 = 1 Bq/L corresponds to countrate 1 s^{-1}
   10000 measured counts are reached at 10000 s = 2 hours and 47 minutes.

b. Activity concentration: 100 Bq/m^3 = 0.1 Bq/L corresponds to countrate 0.1 s^{-1}
   10000 measured counts are reached at 100000 s = 27 hours and 47 minutes.

- The time needed for a calibration must be regarded in relation to the half-life $T_{1/2}$ (Rn-222) = 3.8 days.

- Clear advantage of stable Rn-222 emanation sources compared with decaying Rn-222 gas sources.

Development of reference radon sources with constant, stable measured emanations traceable to primary standards

The following types of emanation sources were produced:

- Quantitative drop deposition of Ra-226 by JRC and PTB
- Chemical adsorption of Ra-226 on MnO_2 by JRC
- Electrodeposition of Ra-226 and defined solid angle alpha-particle spectrometry by PTB
- Ra-226 Implantation (using a mass spectrometer) and defined solid angle alpha-particle spectrometry by PTB
- Ra-226 fixed in a barium stearate coprecipitate (powder) placed between two special membranes (cellulose acetate mixed with glass fibres) by CEA
- Quantitative amount of Ra-226 in an emulsion of fatty acids in silicon rubber, polymerized in a steel tray by CMI

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Development of reference radon sources with constant, stable measured emanations traceable to primary standards

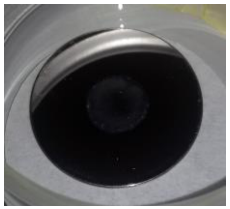
The following setups were produced:

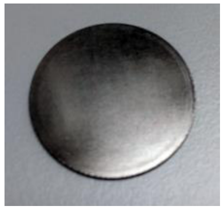
<u>by CMI:</u>
Flow-through low-level radon source with a measured (by gamma-ray spectrometry) Radon emanation power of 0.999 (10)

Development of reference radon sources with constant, stable measured emanations traceable to primary standards

The following setups were produced:

<u>by PTB:</u>
PTB-sources inside a housing and permanently measured by gamma-ray spectrometry (HPGe-, $LaBr_3$-, $CeBr_3$- detector)





Development of reference radon sources with constant, stable measured emanations traceable to primary standards

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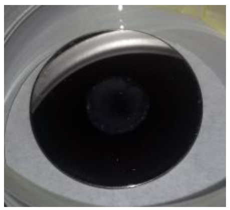
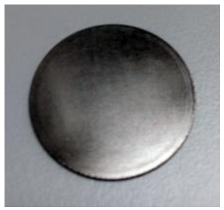
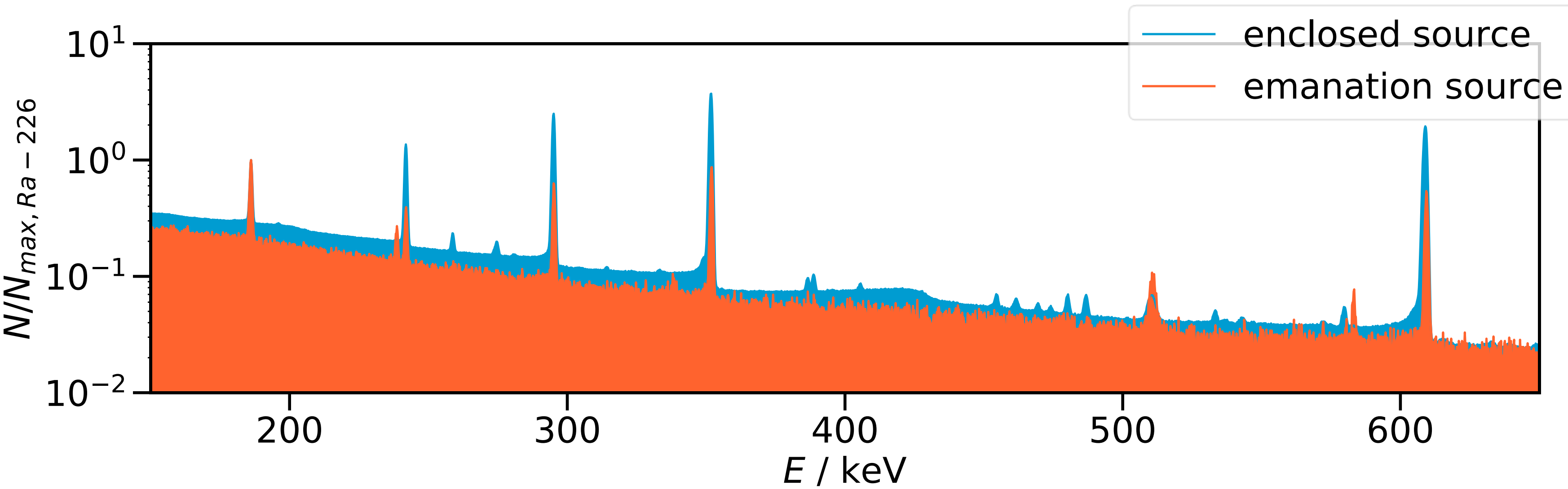
<u>by PTB:</u>
PTB-sources inside a housing and permanently measured by gamma-ray spectrometry (HPGe-, $LaBr_3$-, $CeBr_2$- detector)







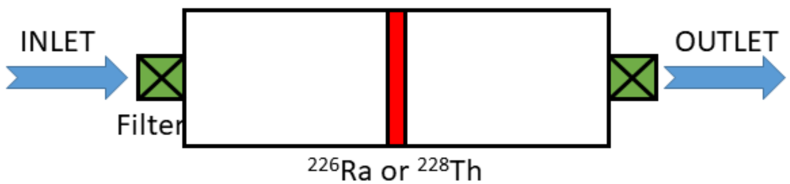
Development of reference radon sources with constant, stable measured emanations traceable to primary standards

The following setups were produced:

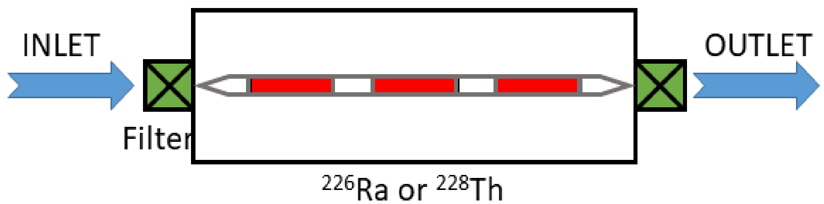
by LNHB:

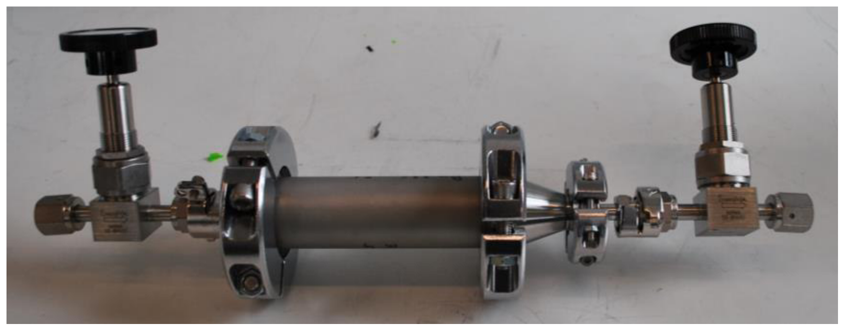
LNHB-source with Ra-226 activity measured by gamma-ray spectrometry inside a special source holder (“unknown” Rn-222 emanation)

old design



new design

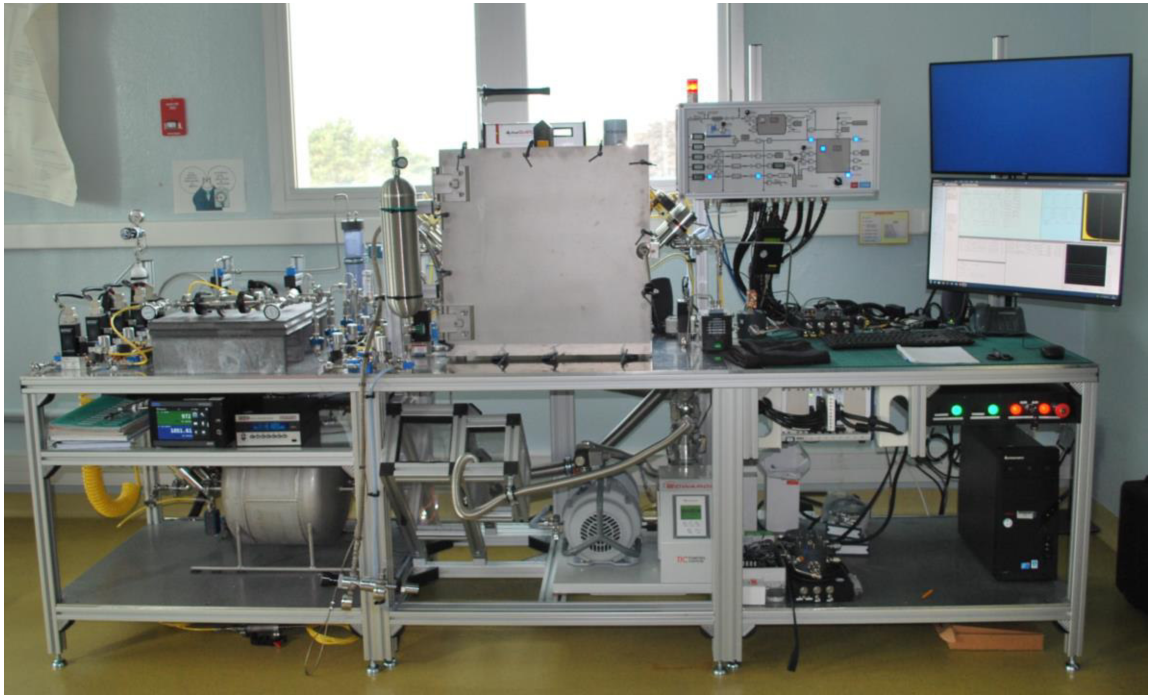


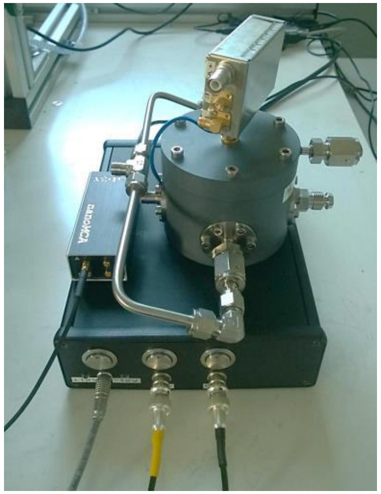


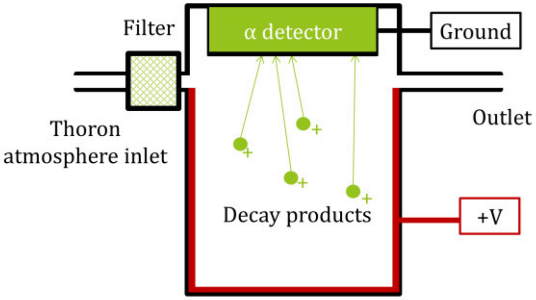
Development of a method for direct and traceable measurement of radon activity concentration in an air flow

The following setup was developed at LNHB

- Based on an alpha-particle detector in a defined volume with an electric field to trap solid progenies
- The system is calibrated using a primary Radon source

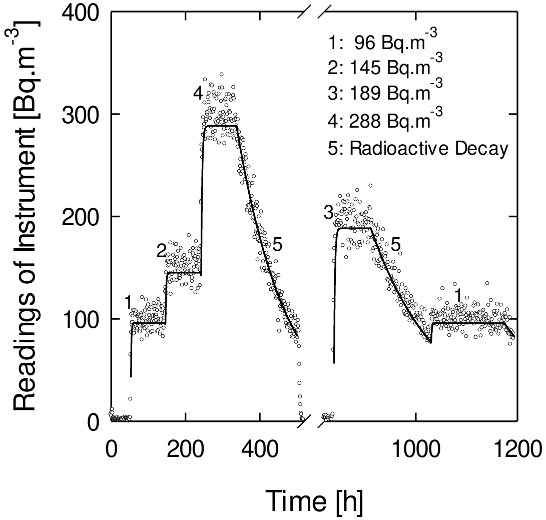






Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

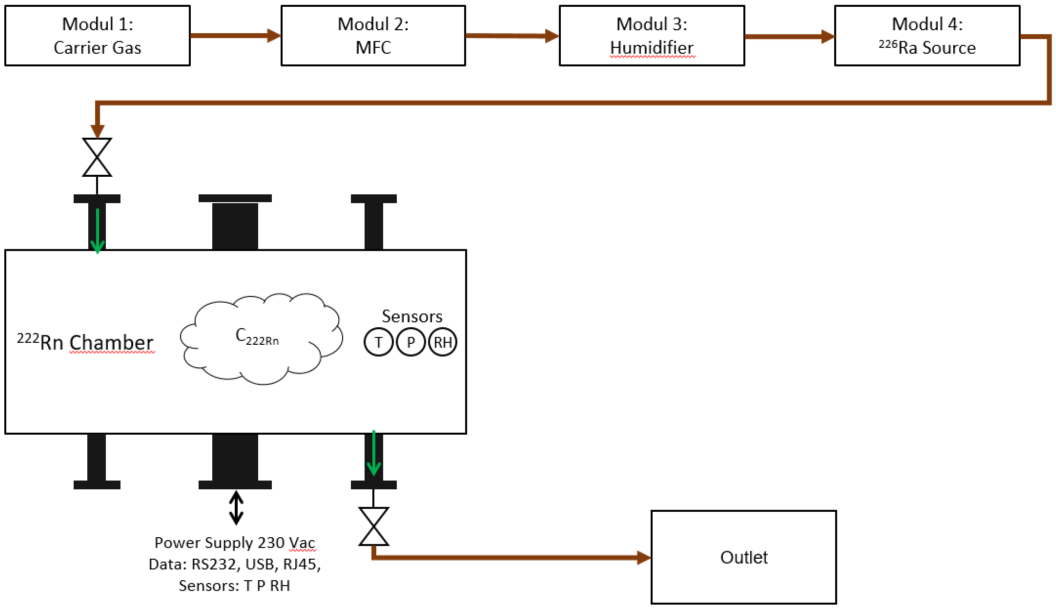
- BfS chamber with a reference volume of 168 litres with an uncertainty of 0.7% (k = 2)
- Possibility to connect different flow through Radon sources
- Example shows four different calibration exposures



Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

- METAS chamber with a reference volume of 130 litres with an uncertainty of 1% (k = 1)

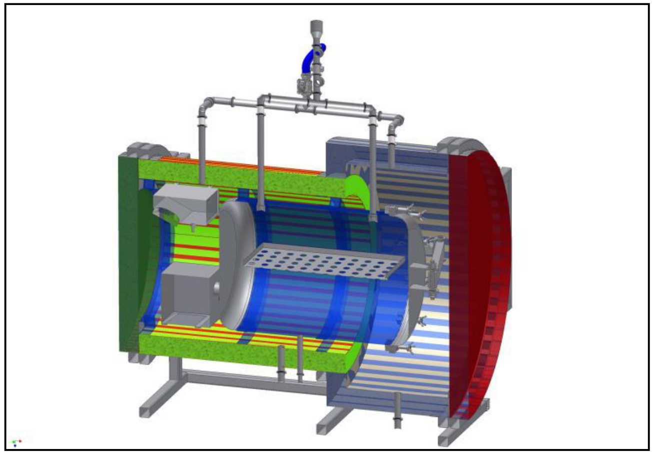
METAS ^{222}Rn test site



Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

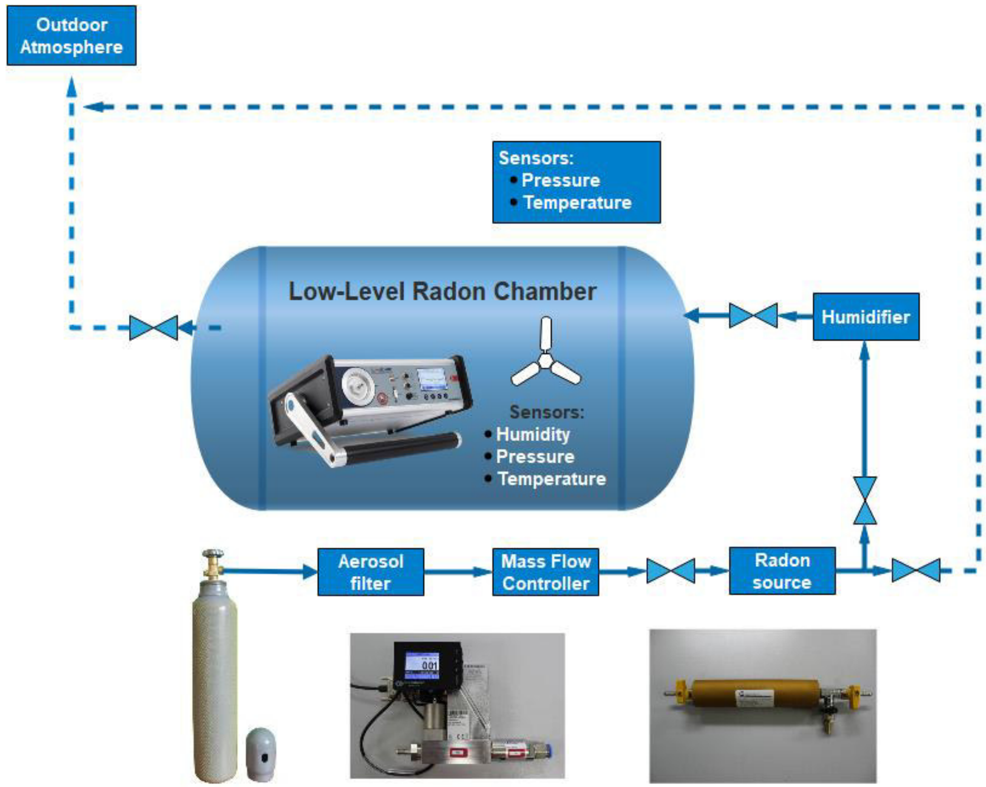
- IFIN-HH chamber with a reference volume of 1 m^3 with an uncertainty of 5% (k = 1); precisely calibration in preparation

- Up to now, the reference is a Radon Scout monitor



Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

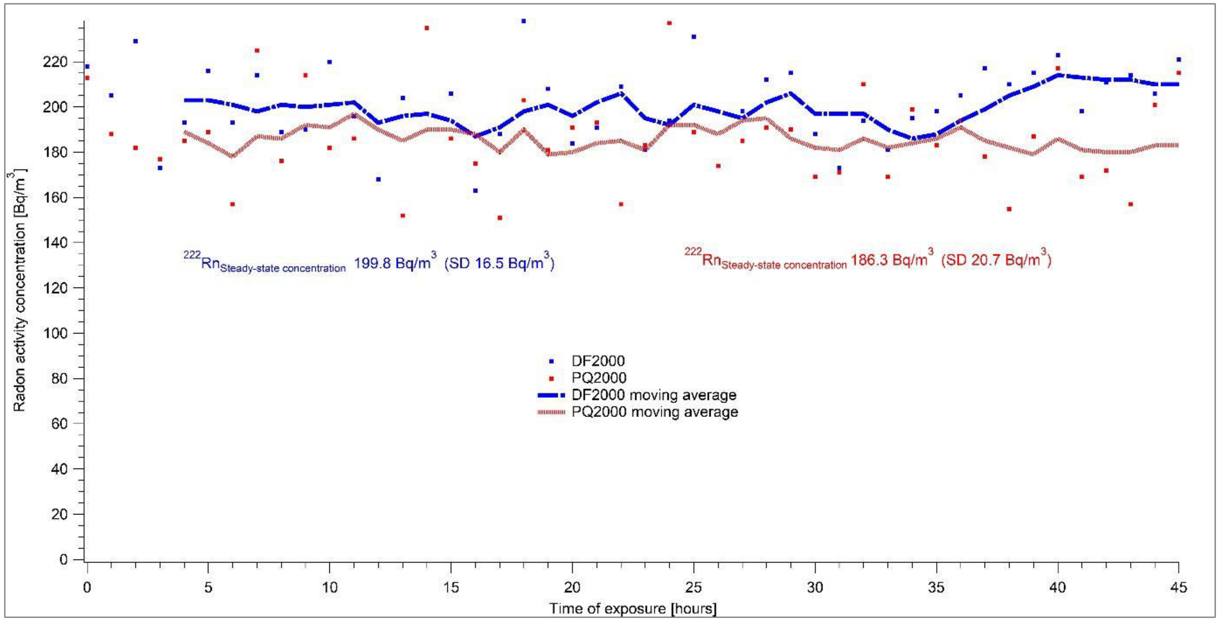
- SUJCHBO chamber with a reference volume of 324 liters with an uncertainty of 0.6 % (k = 1)



Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

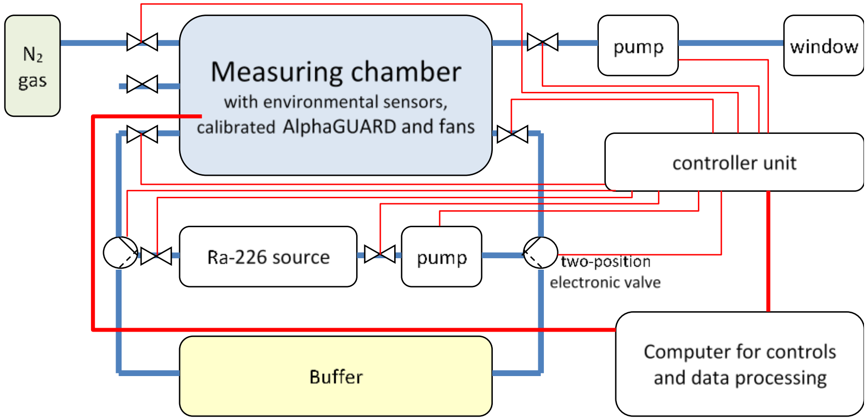
- SUJCHBO chamber with a reference volume of 324 litres with an uncertainty of 0.6 % (k = 1)

- Example shows the readings of two different AlphaGuards at a level of 200 Bq/m³



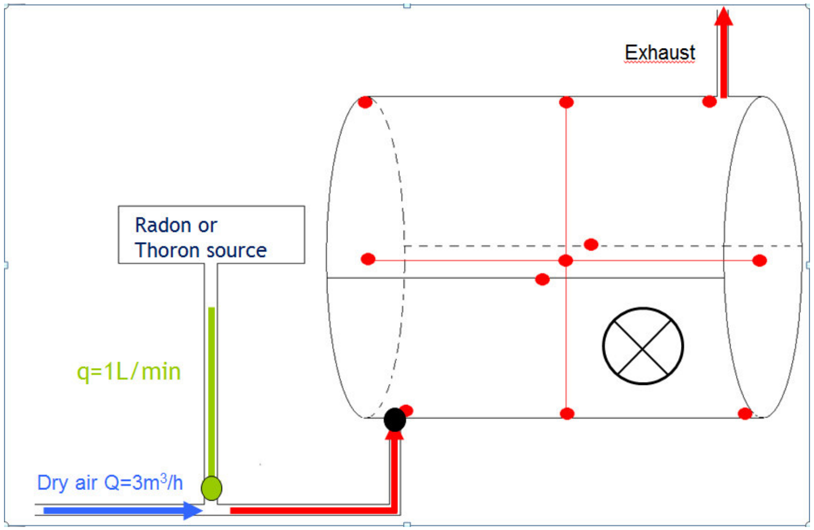
Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

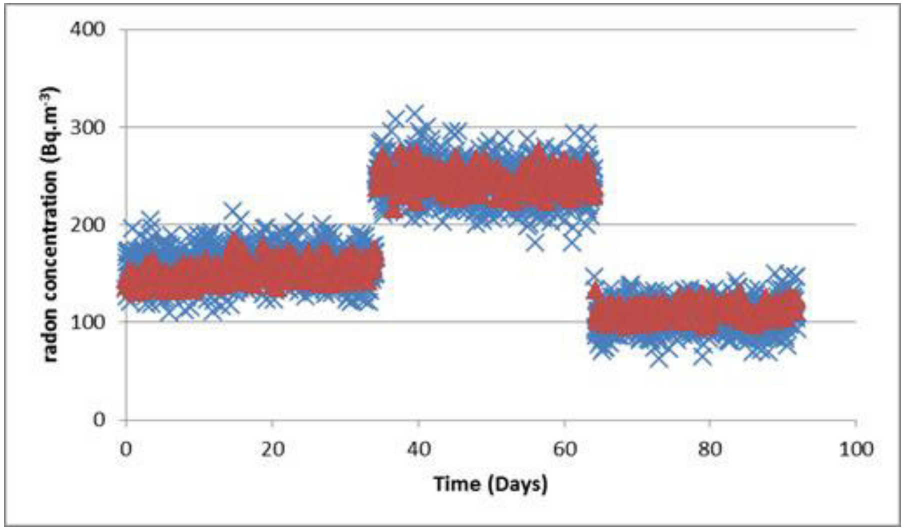
- BFKH chamber with a reference volume of 845 litres with an uncertainty of 0.7 % (k = 1)
- Up to now, the reference is a calibrated AlphaGuard



Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

- IRSN chamber (BACCARA) with a reference volume of 1 m^3
- Traceability via Rn-222 activity gas standards from LNHB for the calibration of an AlphaGuard
- The example shows the data measurement of two instruments





Establishment of constant and stable radon activity concentrations in reference chambers of BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN

- The goal was 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)

- Time stable activity concentrations in this range have been established with the following uncertainties (k = 1) at:

  BfS 1.0%
  IRSN 2%
  METAS 1.5%
  SJUCHBO 2%

Development of calibration procedures for radon measurement instruments

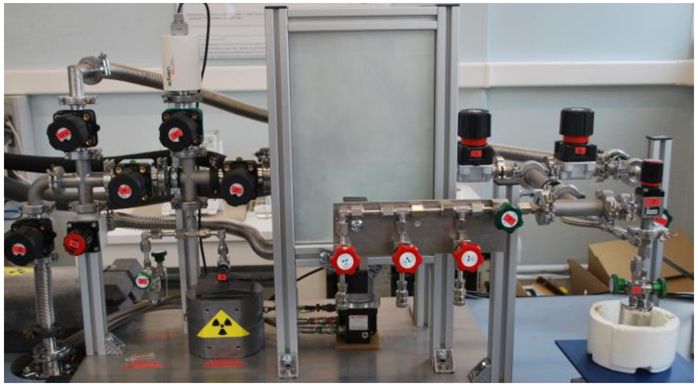
- Due to the different setups of the radon calibration chambers at BfS, METAS, IFIN-HH, SUJCHBO, BFKH, IRSN there is not one common calibration procedure but six methods customized to the individual setups.

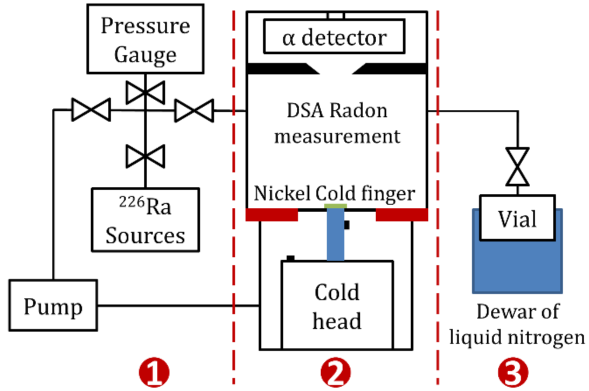
- In four of the six chambers, time stable Rn-222 activity concentrations are now available with uncertainties between 1% and 2% (k = 1)

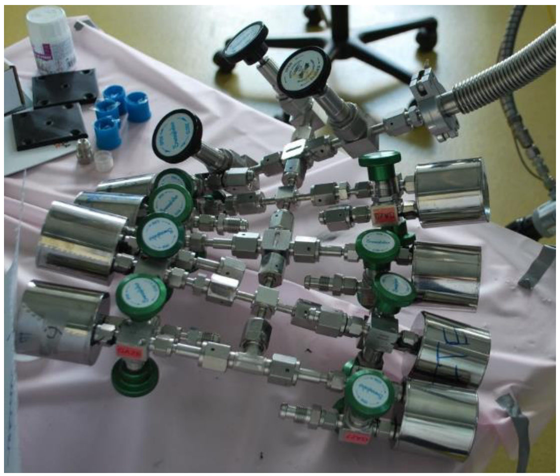
- Within a calibration of a radon measurement instrument further uncertainty contributions occur like counting statistic and background contribution.

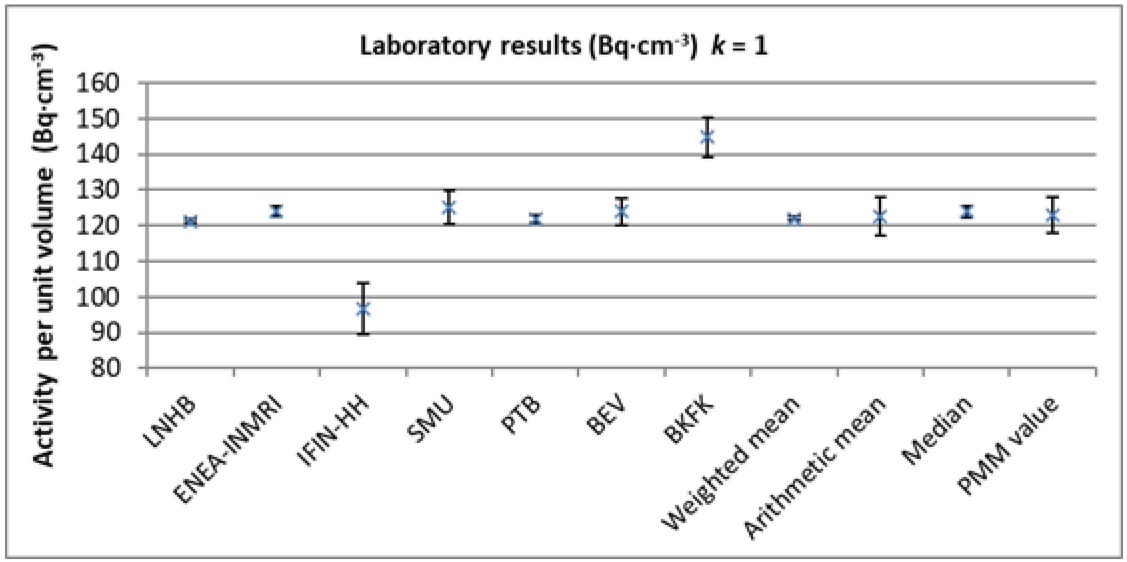
Comparisons

- Comparison of the activity of ^{222}Rn gas standards organized by LNHB





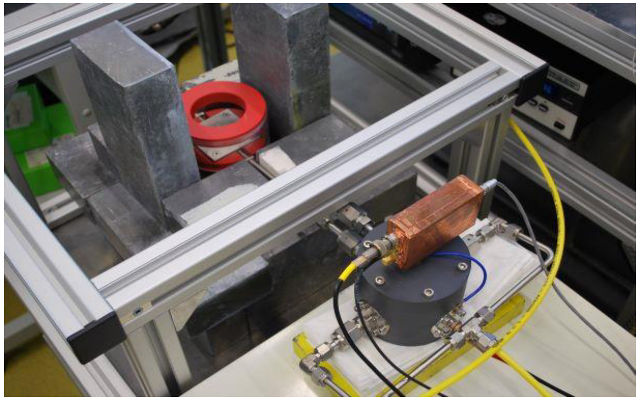


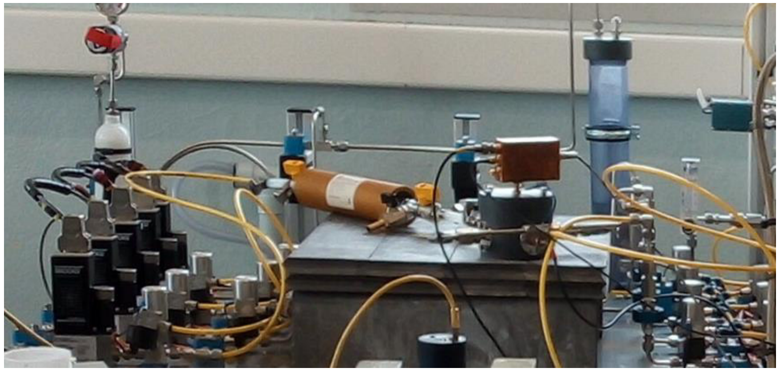


Comparisons

- Comparison of activity from ^{222}Rn measurements with emanations sources from CMI and PTB measured with the “in air flow system” from LNHB

- The results are not yet satisfactory; partly caused by Covid-19 shutdown





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