An absolute ^{222}Rn activity measurement system at LNE-LNHB

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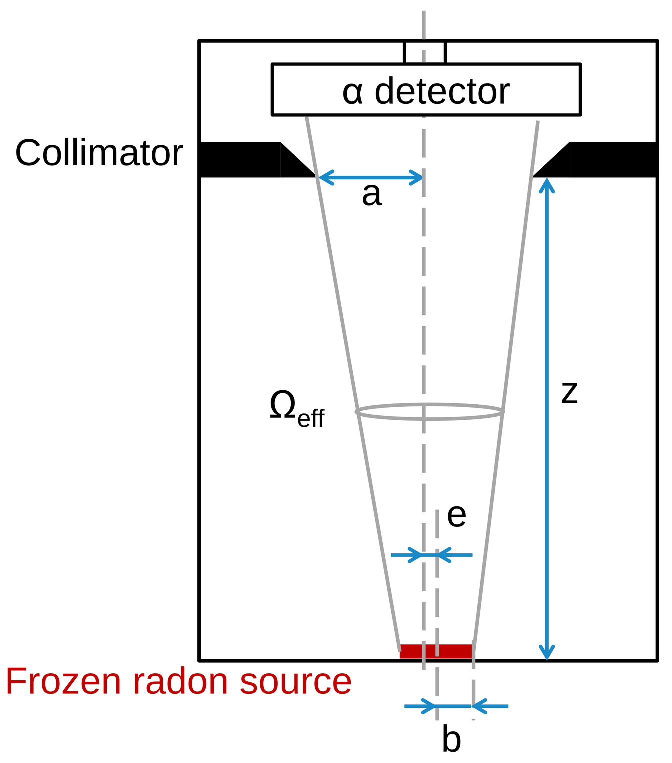
A good metrological traceability of radon and progenies is necessary to accurately measure the radon concentration. In 1995, at the LNE-LNHB, J.L. Picolo developed a reference method using a defined-solid angle (DSA) alpha spectrometer to measure a frozen radon source. With this method it was possible to measure radon standards with a relative standard uncertainty of 0.5%. We present the design and the characterization of a new upgraded measurement system; all parameters and their uncertainties are discussed. This new system allows the measurement of radon sources from 100 Bq to 4 MBq with a relative standard uncertainty of 0.3%.

➔ The defined solid angle (DSA) method applied to radon



Defined solid angle parameters

The DSA efficiency is defined by *G* assuming:

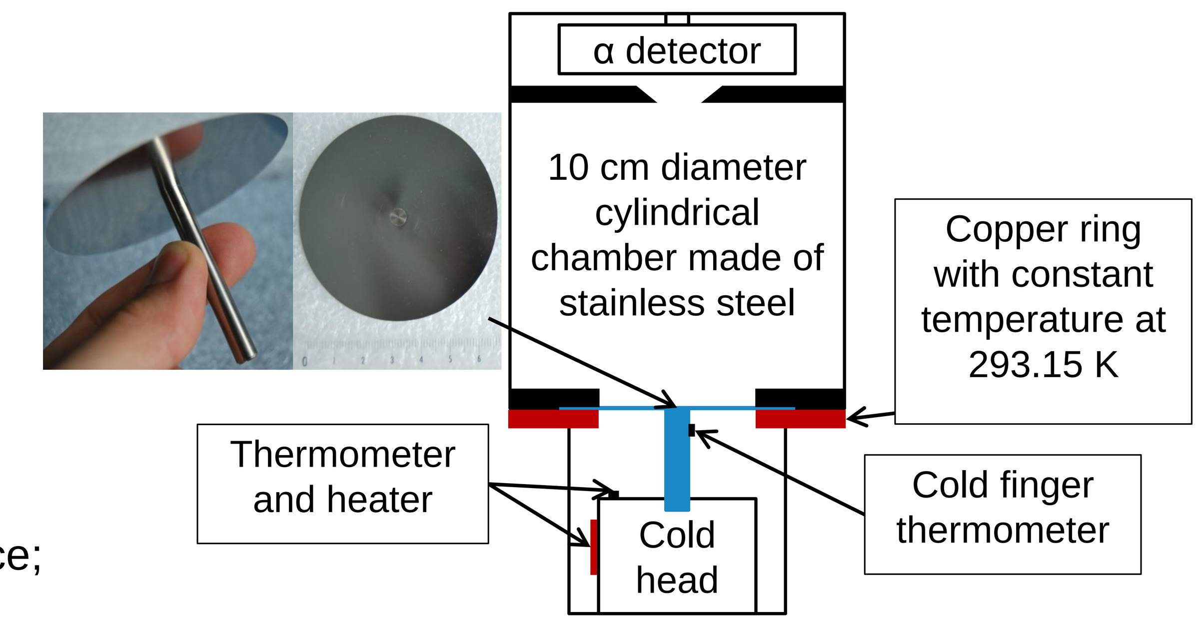
- Emission of alpha particle is isotropic.
- Only the alpha particles passing through the collimator are counted.
- Every alpha particle reaching the detector is counted.

$$G = \frac{\Omega_{eff}}{4\pi}$$

- Ω_{eff} is the solid angle defined by: *a*, radius of the collimator; *b*, radius of the source; *z*, distance between source and diaphragm; *e*, eccentricity of the source.

➔ The activity of the source is then given by: $A = \frac{Counting\ rate}{G}$

The DSA method requires a disc source; in the case of radon gas we need a specific cooled system to produce it.



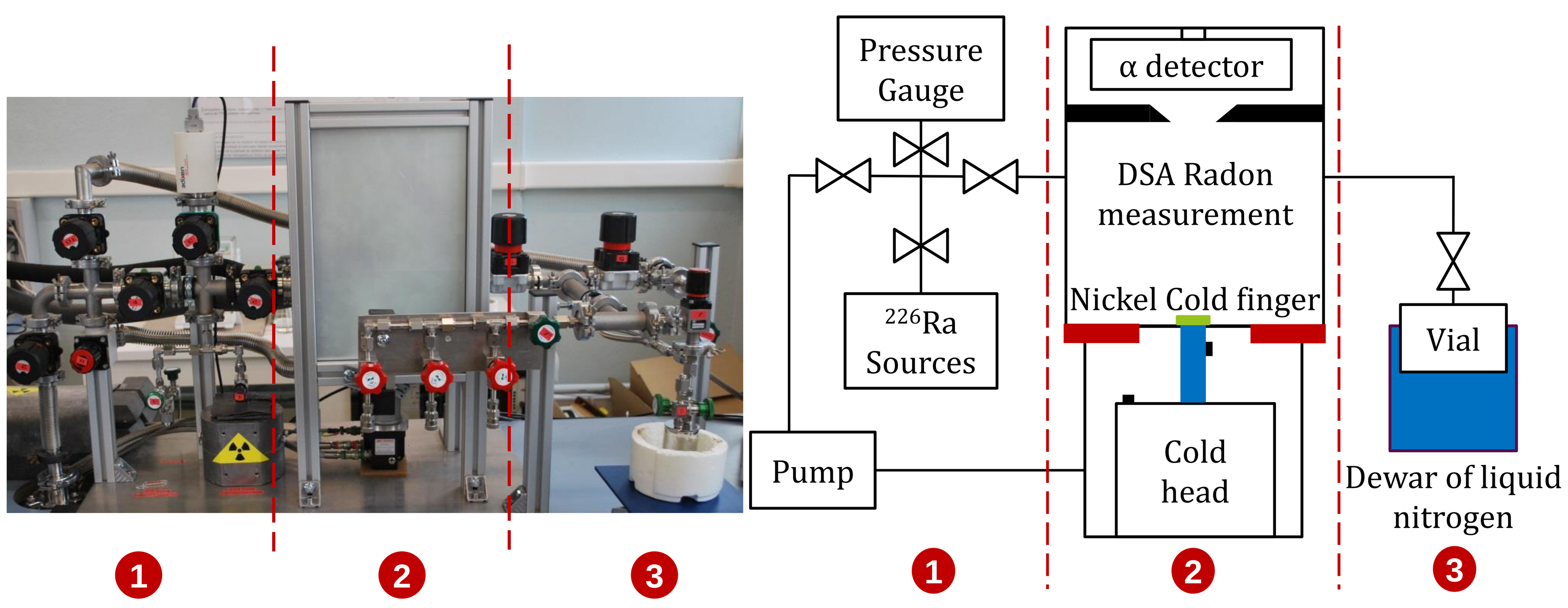
Frozen disc radon source production

The radon disc source is produced with a cold finger at a temperature of 80 K at the center.

➔ The measurement system

The measurement system is divided in 3 parts:

- The first part (1) includes radon production with a ^{226}Ra source and the pumping system. Activity up to 4.3 MBq of ^{222}Rn and pressure below 10^{-5} hPa.
- The second part (2) is the measurement system itself with the DSA and the cold finger.
- The third part (3) is used to store the radon in a glass or metal vial, once the measurement is finished.



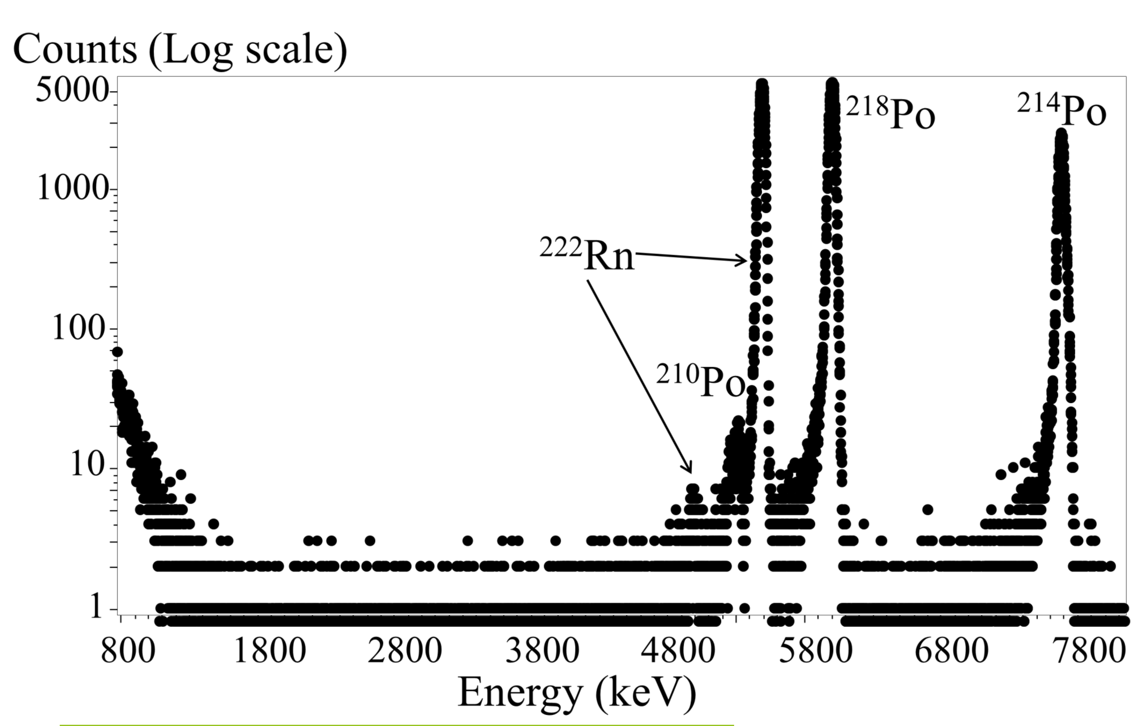
Picture and diagram of the measurement system

For each measurement step, the setup is under vacuum:

- The ^{222}Rn is accumulated in the ^{226}Ra source.
- The cold finger is set at a temperature of 80 K and the source valve is opened just for 1 min.
- The radon is immediately frozen at the cold finger surface and can be measured with a classic multi channel analyzer.
- Once measured the cold finger is heated and the recipient is cooled in liquid nitrogen to catch the radon.

➔ After the radon transfer, a second measurement is done to quantify any remaining radon. It also corresponds to a blank measurement to remove any contamination from long live radon decay product, ^{210}Po, which appears after some years of utilization.

➔ Measurement and spectra



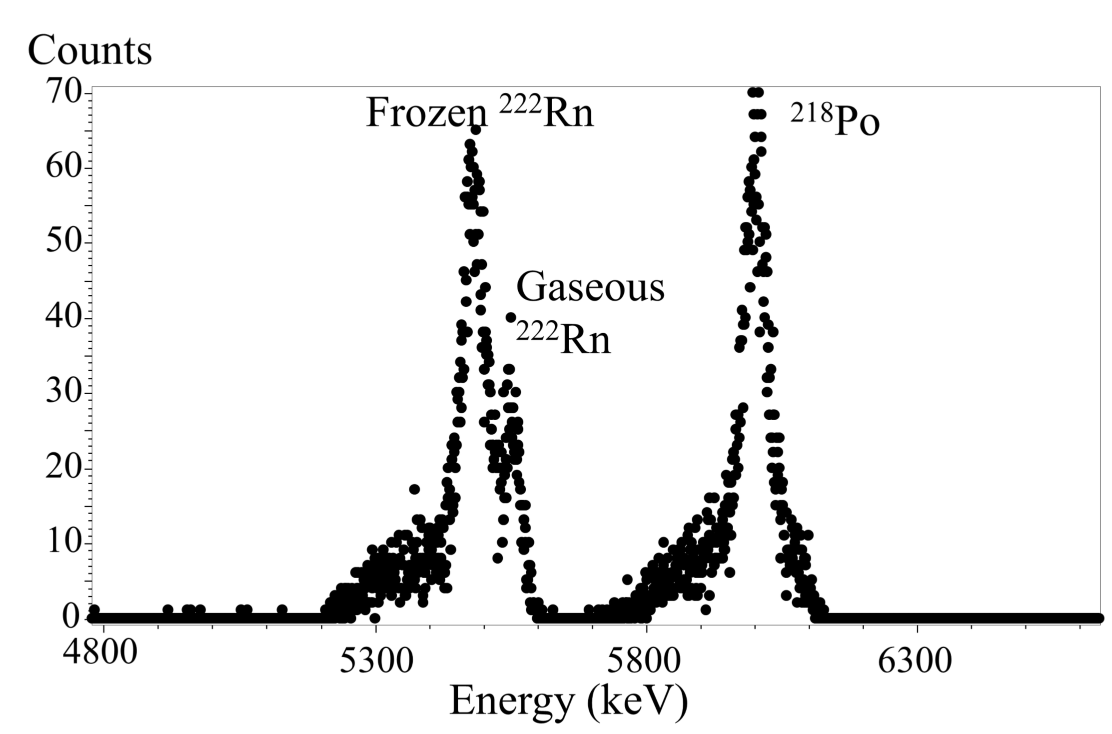
Example of spectrum
Duration = 6000 s, Activity = 17 kBq

- The source corresponds just to some atoms deposited on the cold finger surface.

➔ The spectra obtained with the system have a very good resolution compared to the typical alpha sources (depends on the vacuum quality).

- If there is still some gaseous radon, a second peak appears on the spectra and the counting increases, since the detection efficiency of gas is 10 times higher than the detection efficiency of the frozen source.
- Each decay product is measured and reach equilibrium with ^{222}Rn after 30 min for ^{218}Po and after 4 h for ^{214}Po. Activity of ^{222}Rn can be measured using the decay products with the following activity ratio (DDEP recommended data):

$$\frac{A_{^{218}Po}}{A_{^{222}Rn}} = 1.00056; \quad \frac{A_{^{214}Po}}{A_{^{222}Rn}} = 1.00910$$



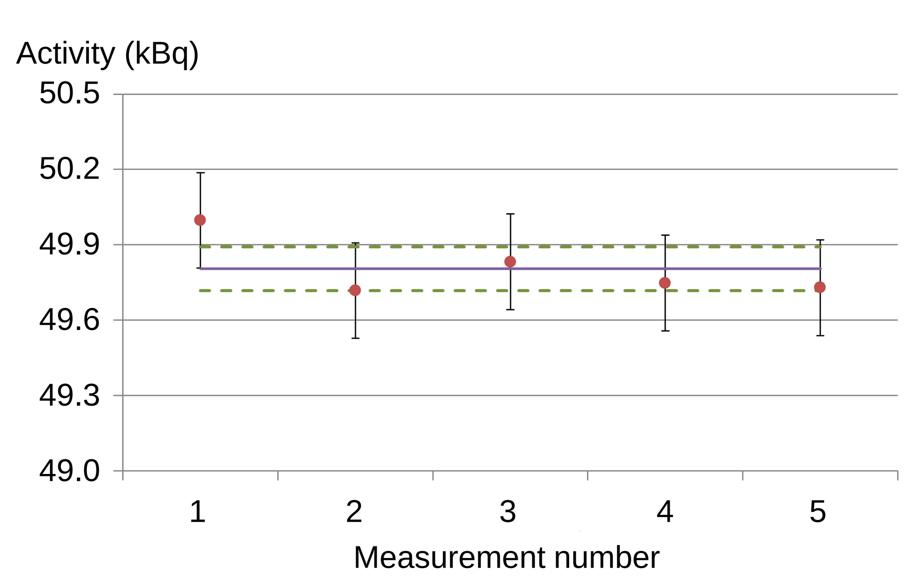
Example of spectrum with the cold finger at 100 K, a second peak starts to appear.

➔ Results and uncertainties

- The DSA method to produce ^{222}Rn standard gives the smallest uncertainty achievable for now.
- Multiple measurements of a same standard have shown a good reproducibility with a standard deviation of 0.18% (uncertainty on each measurement 0.38%).

Results of comparison with IRA-METAS

	Activity measured at the LNE-LNHB (kBq)	Activity measured at the IRA-METAS (kBq)
IRA-METAS standard 9/11/2012 12:00 UTC	256.6 (11)	256.8 (11)
LNE-LNHB standard 9/11/2012 8:00 UTC	224.7 (10)	224.2 (9)



Reproducibility for the same standard

Example of uncertainty budget for a measurement of 50 kBq during 1 h

Component	Details	Relative standard uncertainty (%)
Detection efficiency (G)	Depends on *z* = 100.12 (14) mm; *a* = 9.0277 (11) mm; *b* = 3.23 (13) mm; *e* < 1 mm	0.28
Counting statistics of radon measurements	Can be reduced with a long measurement	0.14
Correction factor for decay to the reference time	Value : 1.015	0.0003
Correction factor for decay during the measurement	Value : 1.004	0.04
Blank measurement	Very low value and negligible compared to the activity measured	0.1
Combined relative standard uncertainty (%)		0.3

- A double comparison was performed with the National Metrology Institute of Switzerland (IRA-METAS). One standard was produced at the LNE-LNHB and the second at IRA-METAS; both results are consistent.
- This measurement method can be used from 100 Bq to 4.3 MBq. However, at high activity, coincidence summing effect has to be taken into account in the spectrum analysis to determine the activity.

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