

Detectors used in the intercomparison

The second radon-in-field international intercomparison for passive measurement devices: dwellings and workplaces

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Campus Bovisa - Politecnico di Milano

Milan (ITALY)

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Intercomparison's working group:

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The measurement campaigns



S1: low radon concentrations and 5 months of exposition (*office*);



S2: medium radon concentrations and 5 months of exposition (*storage room*);



S3: high radon concentrations and 9 days of exposition in a mixed radon/ thoron atmosphere (*cellar*).

The detectors

In order to achieve a complete characterization of the three sites we have to:

- provide the three reference values of Rn concentration/exposure;
- evaluate the possible radon concentration inhomogeneity;
- evaluate the Thoron presence / influence in the Rn/Th mixed atmosphere exposure
- evaluate the equilibrium factor (spot for the long exposures and average for the mixed Rn/Th exposure)



26 continuous radon monitors used in field



Intercomparison of active instruments

The detectors



- 5 ALPHAGUARD, pulse-counting ionization chamber, Saphymo GmbH, Germany
- 1 NG ALPHAGUARD, pulse-counting ionization chamber, Saphymo GmbH, Germany
- 11 RADIM 5B, semiconductor detector , Jiry Plch, Czech Republic
- 1 THORON SCOUT, semiconductor detector, SARAD GmbH, Germany
- 1 EQF 3220, semiconductor detector, SARAD GmbH, Germany
- 5 Lucas Cells monitors, alpha scintillation chamber, MI.AM S.r.l, Italy
- 1 AER+, semiconductor detector, Algade-Dosirad, France
- 1 Corentium Pro, semiconductor detector, AirThings, Norway

+ Reference and comparison instruments

The detectors

Radon	Radon Thoron	Radon and progeny
5 Alphaguard	1 Thoron scout	1 EQF 3220
11 Radim 5B	1 NG Alphaguard	
5 Lucas cells	1 EQF3220	
1 AER+		
1 Corentium pro		

Operational modes:

- *Integration time: 1h*
 10 min: NG Alphaguard
- *Sampling: diffusion*
 in flow: EQF 3220 - 1.5 l/min, NG Alphaguard - 2 l/min, 1 MR1 Lucas cell - 0.4 l/min

The detectors background

Radon concentrations are low (S1,S2)  instruments background is very important

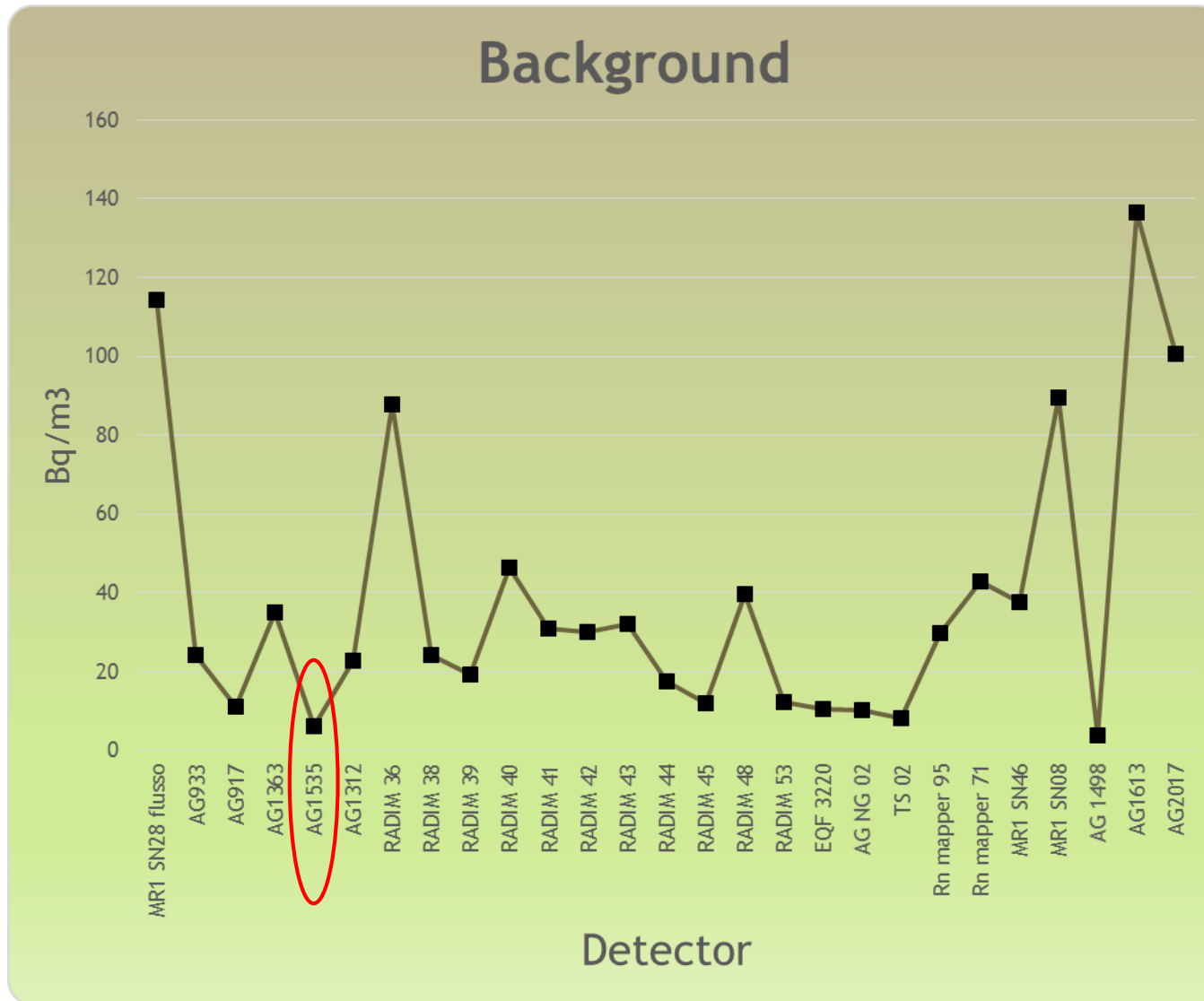
The steps we followed:

- ARPA Piedmont Radon Chamber: exposure to N₂
- CESNEF Radon Chamber: exposure to N₂ and air with low radon concentration
- ENEA - INMRI Radon Chamber: exposure to radon-free air of selected detectors



“*best estimate*” of detectors background

The detectors background



Decision threshold ...
Detection limits ...

The detectors calibration

The initial situation

- Rn
- 1 not calibrated
 - 11 Internal certificates (performed by the owners)
 - 10 Company certificates
 - 1 Accredited laboratory certificate
 - 3 Primary body certificates (ENEA-INMRI)

- 10 certificates during 2016-2017
- 1 certificate during 2015
- 14 certificates older than 5 years

Th

3 Company certificates (2017)

Rn progeny

1 Company certificate (2017)

The detectors calibration

The step we followed:

Rn

ARPA Piedmont Radon Chamber → initial situation

CESNEF Radon Chamber → first intercalibration

ENEA - INMRI Radon Chamber → reference exposure for calibration of selected detectors

Th

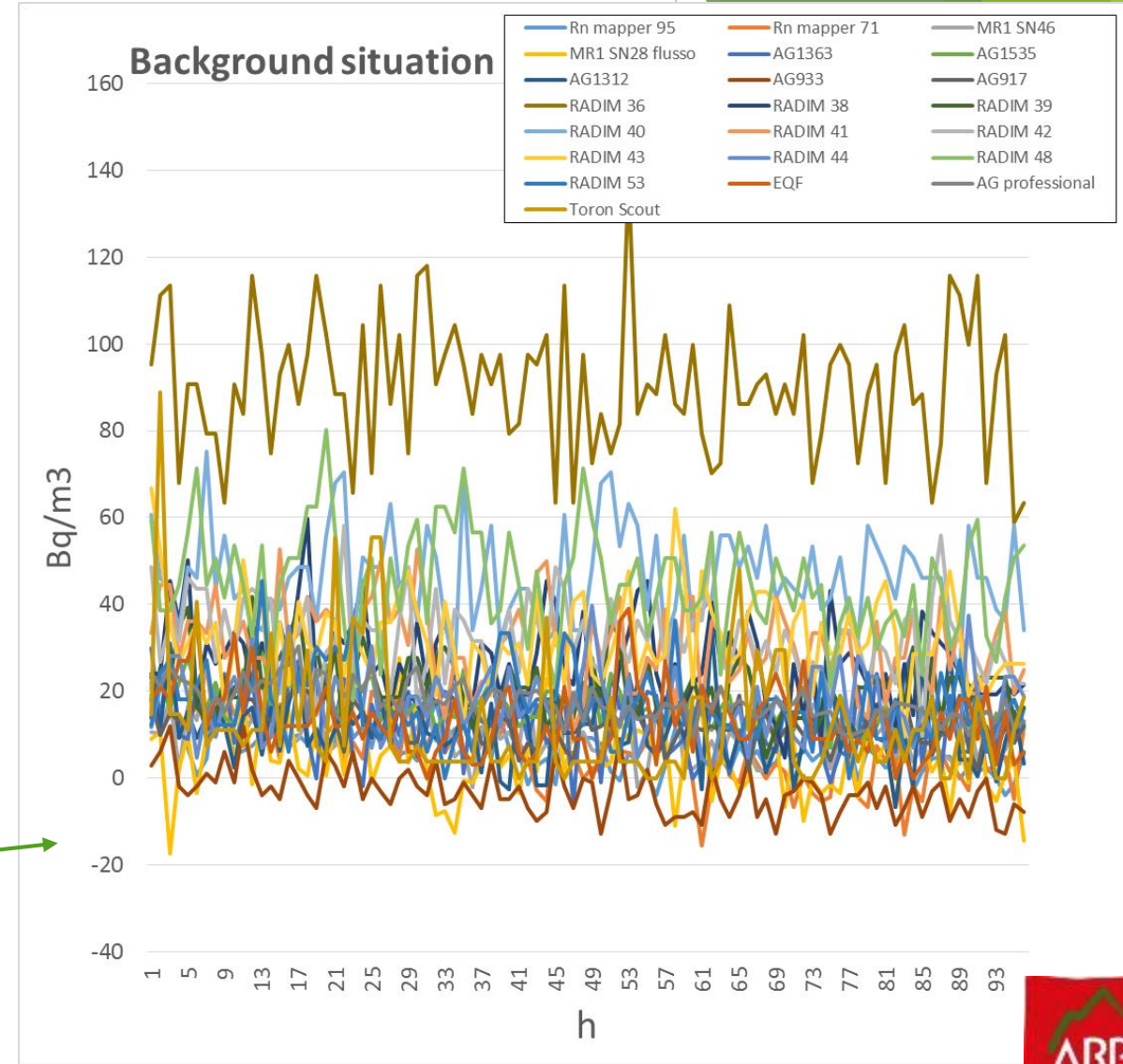
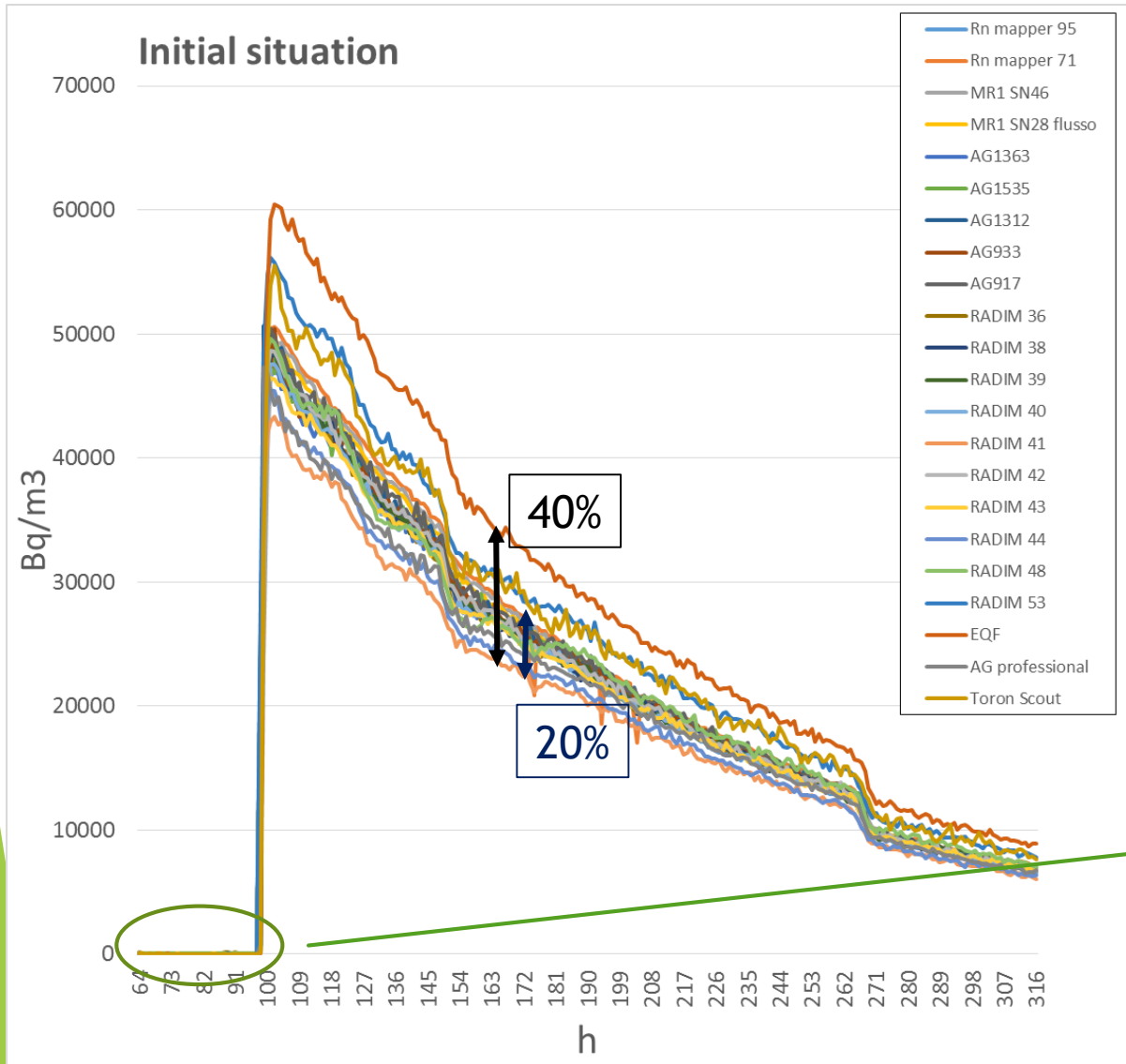
ENEA - INMRI Thoron Chamber → first Thoron measurements

ARPA Piedmont Radon Chamber → Radon / Thoron mixture measurements

Rn progeny

ENEA - INMRI → PAEC measurements comparison of 2 instruments

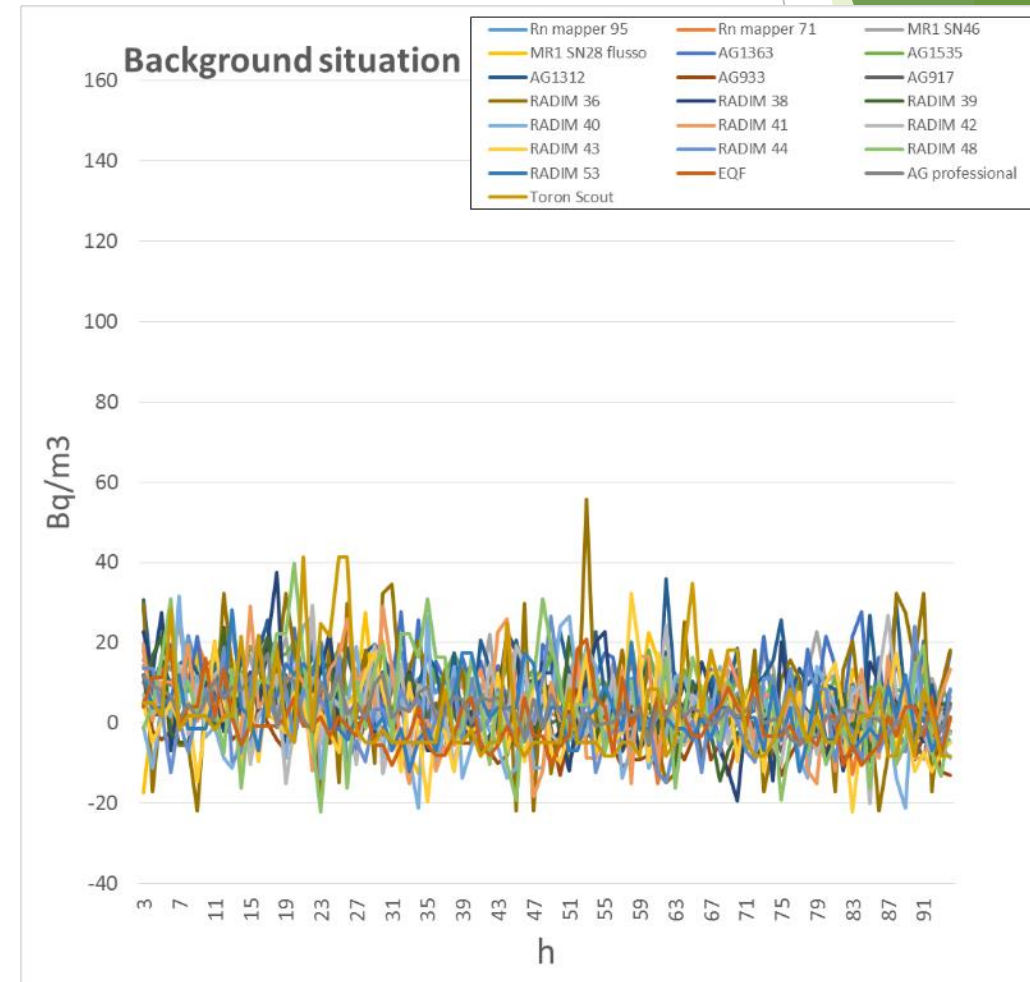
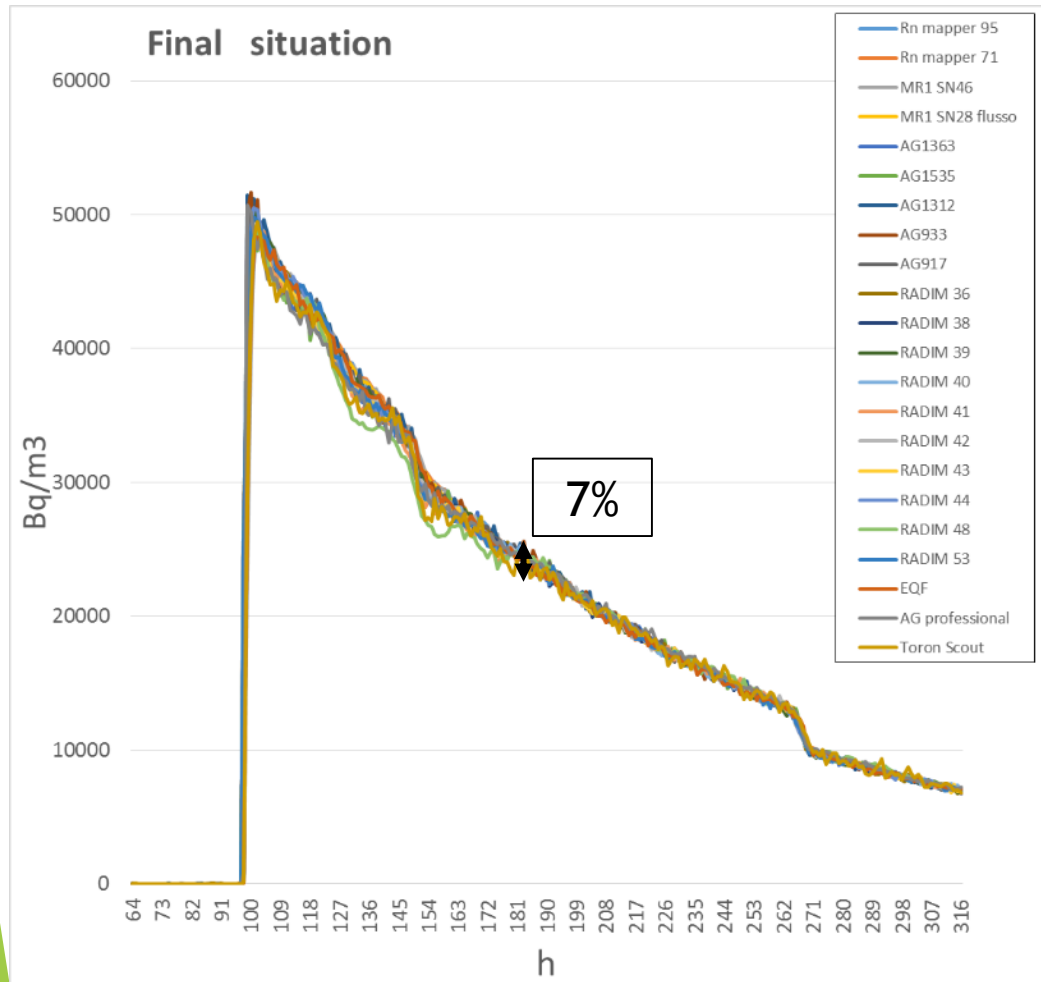
Initial situation @ CESNEF



The calibration @ CESNEF

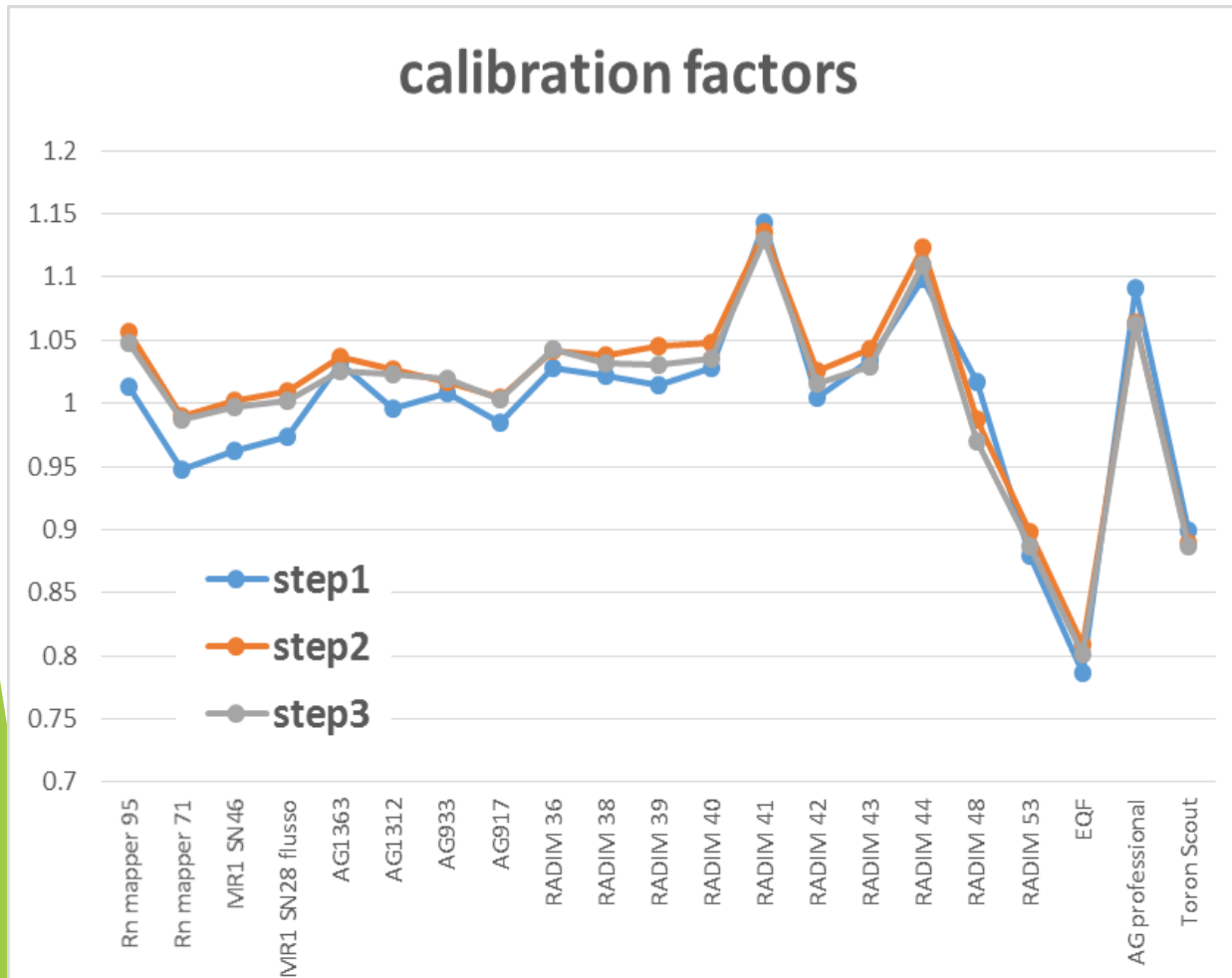
3 steps calibration: very high concentrations
low/medium exposures

Step1	Step2	Step3	
38000	14000	8000	Bq/m ³
1400	500	300	kBqh/m ³



The calibration

The final calibration factors (after exposure @ ENEA-INMRI of selected detectors)



Sometimes:

- $CF \neq 1$
- CF depending on the concentration



- Calibration function ?
- Extrapolation at low concentrations?

Radon / Thoron mixed atmosphere

Aims:

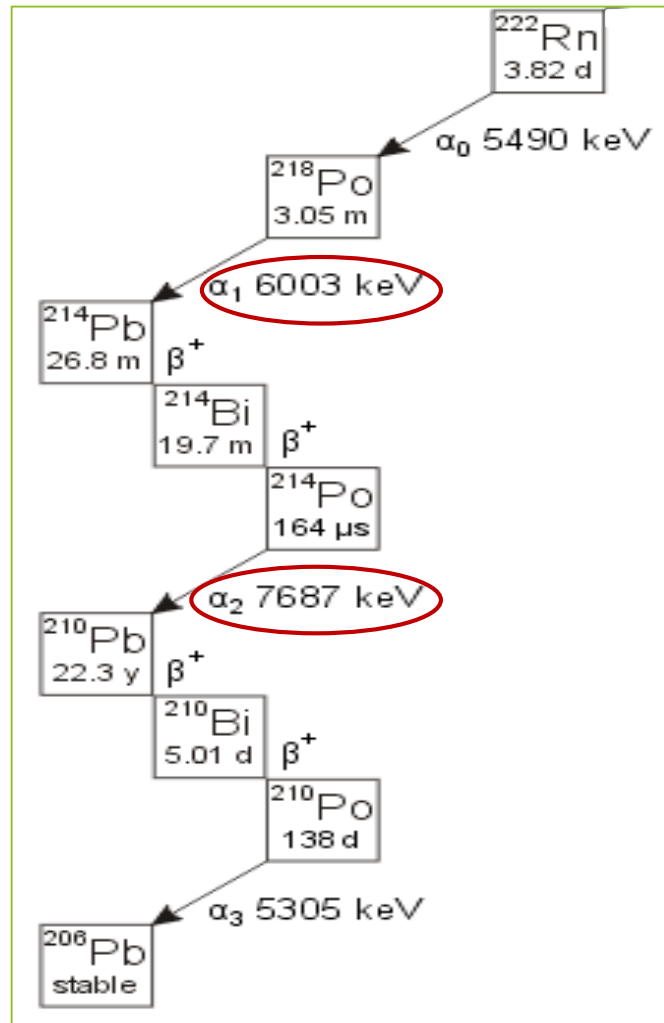
- correct measurement of Radon concentration in presence of Thoron
- evaluation of Thoron influence on continuous Radon monitors
- measurement of Thoron concentration (?)
- instrument calibration for Thoron (?)

Instruments:

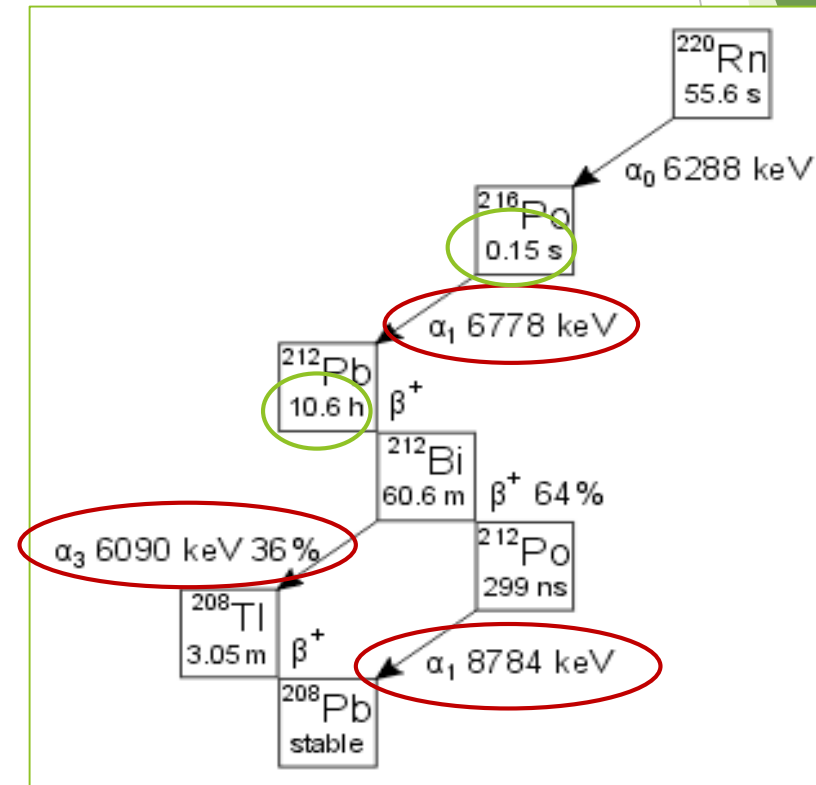
- 1 Thoron Scout, semiconductor detector, diffusion mode
- 1 EQF3220, semiconductor detector, flow mode
- 1 NG Alphaguard, pulse-counting ionization chamber, flow mode
- 1 MR2 , Lucas Cell with Thoron cycle ← used in radon chamber only

Radon / Thoron mixed atmosphere

Radon

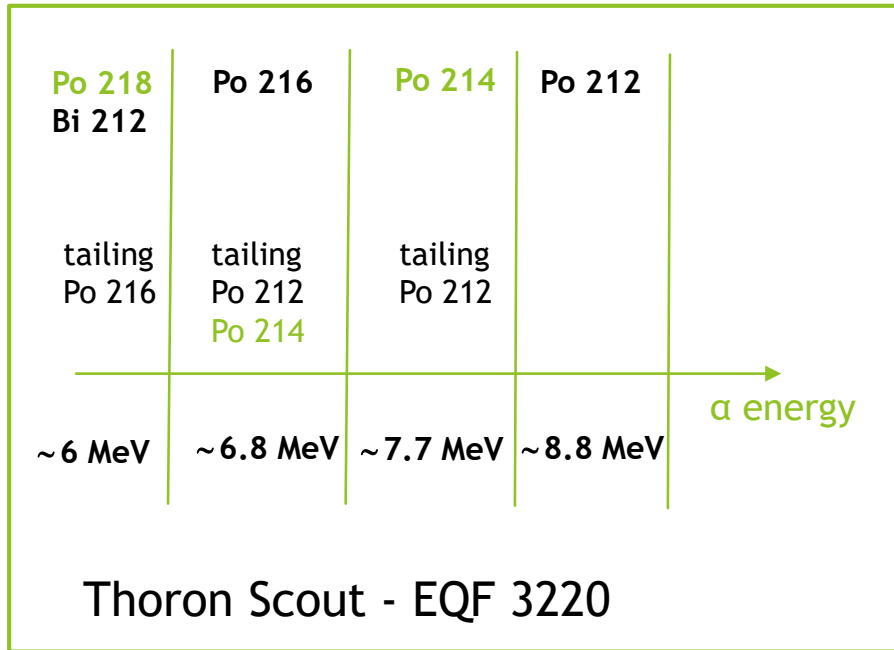


Thoron

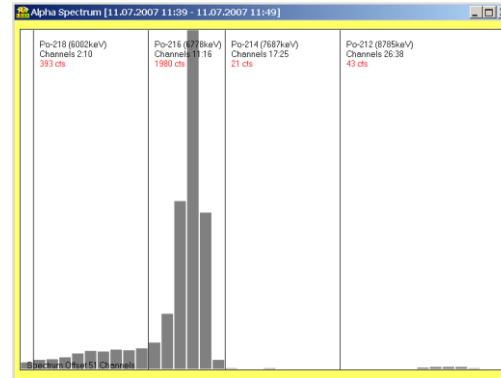


Radon/Thoron mixed atmosphere: instrumental techniques for continuous measurements

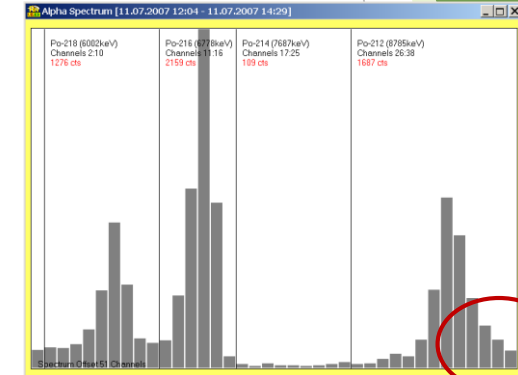
α spectrum



Th spectrum during the first hours

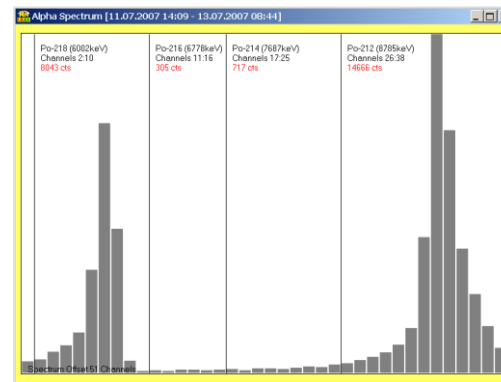


Th spectrum in the activity equilibrium

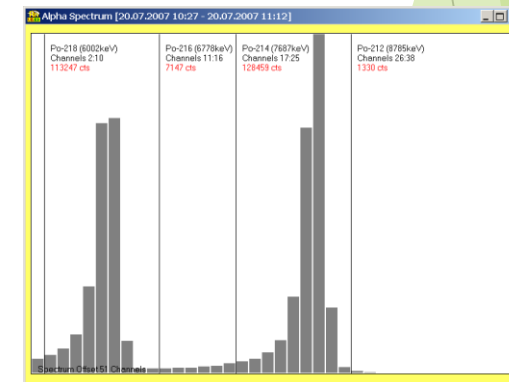


Bi 212 B decay

Spectrum after Th exposure



Rn spectrum in equilibrium state



Rn Fast

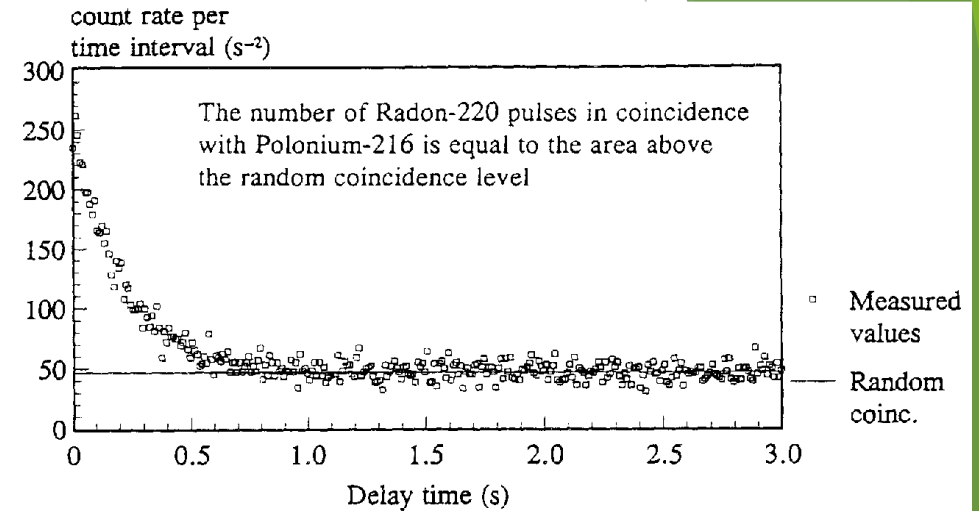
Rn Slow

Radon/Thoron mixed atmosphere: instrumental techniques for continuous measurements

Delayed coincidences method

Time interval distributions between the events
("Time spectrum" of alpha decays)

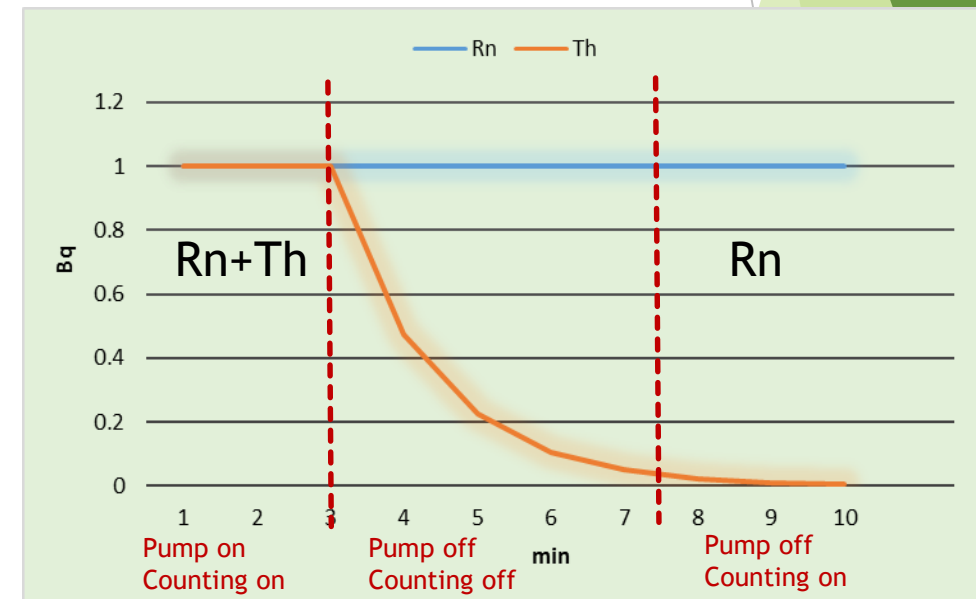
MR2 → flow mode (30 min cycle)
only Th by now



Double counting interval method

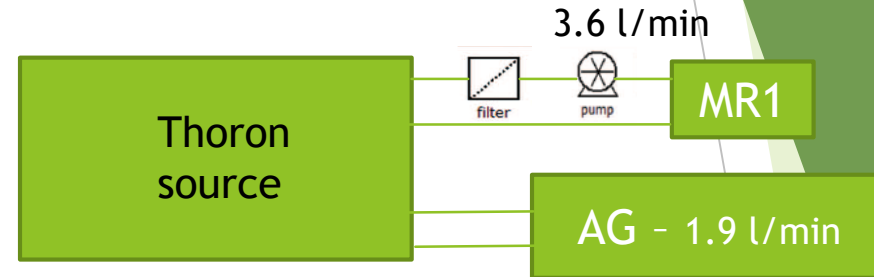
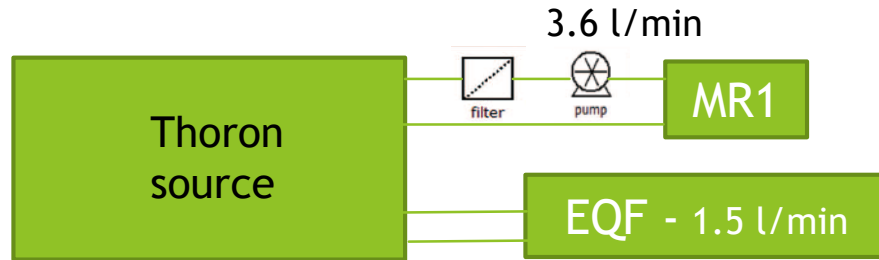
It makes use of the difference in half lives of Rn and Th

NG Alphaguard → flow mode (10 min cycle)



Thoron measurements

ENEA - INMRI



Reference value : **20169** Bq/m³ ± 5%



Measured value EQF: **27000** Bq/m³ ± 4%



Difference from reference: 34%
(CF: 0,75)

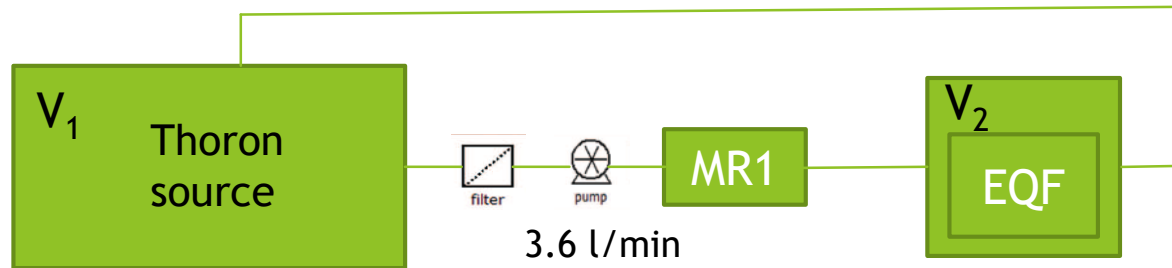
Measured value AG: **30465** Bq/m³ ± 15%



Difference from reference: 51%
(CF: 0,66)

Thoron measurements

ENEA - INMRI



Reference value in V₁ : **20169** Bq/m³ ± 5%

Calculated value in V₂: **6454** Bq/m³ ± 5%

Measured value in V₂ : **7801** Bq/m³ ± 11%

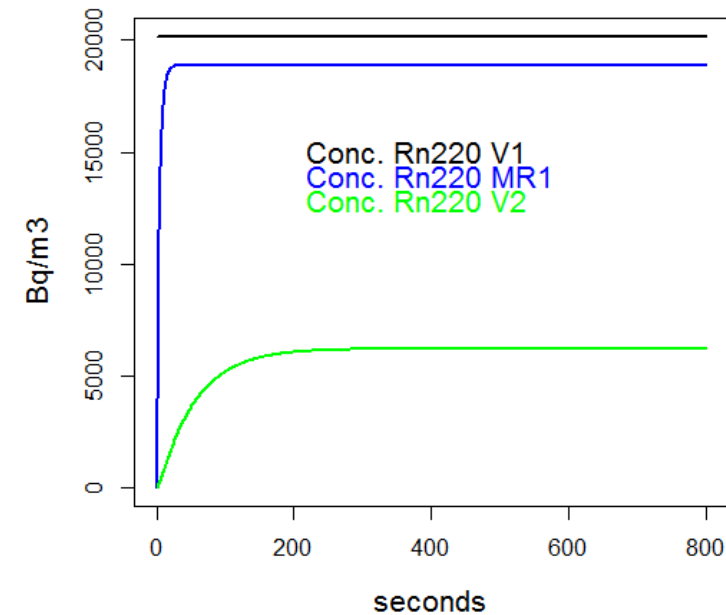
21 % diff



We have to improve hardware configuration in order to be sure about the Th uniformity in V₂

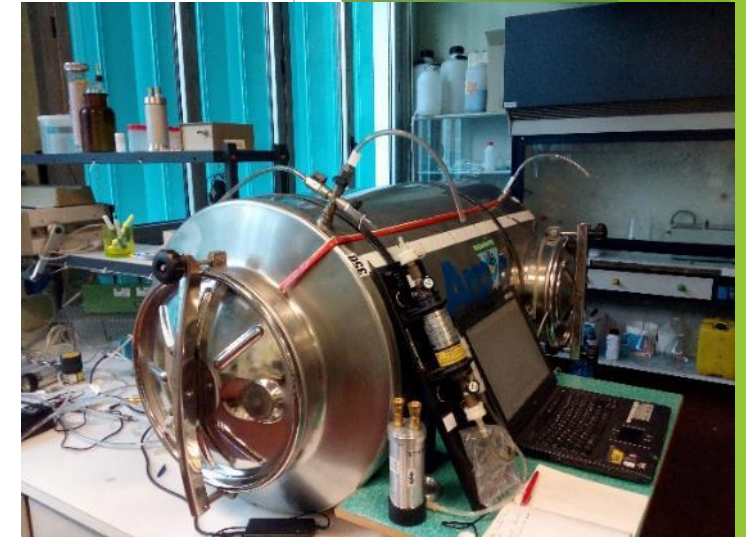
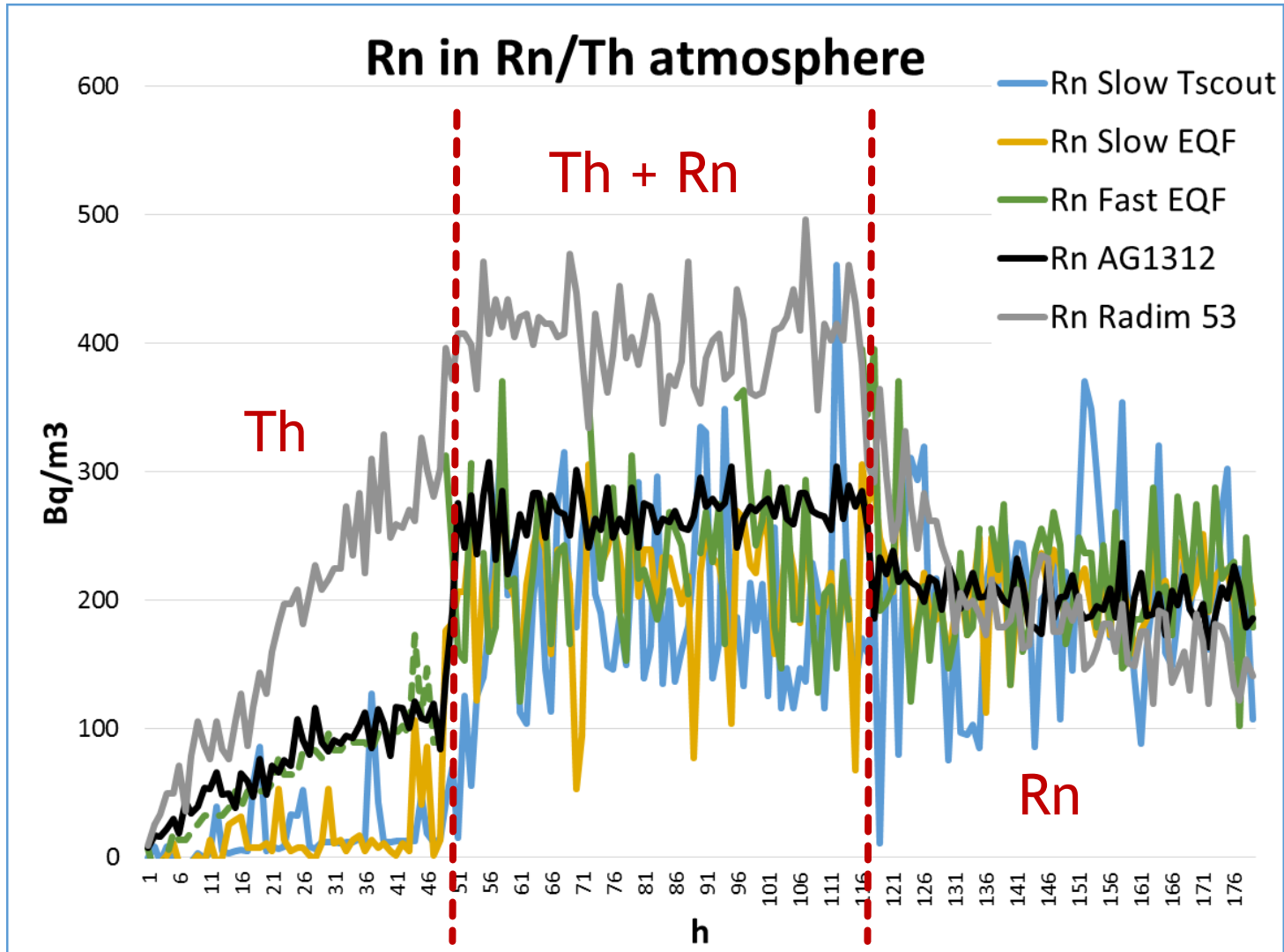


Th concentration in the circuit



Radon / Thoron mixed atmosphere

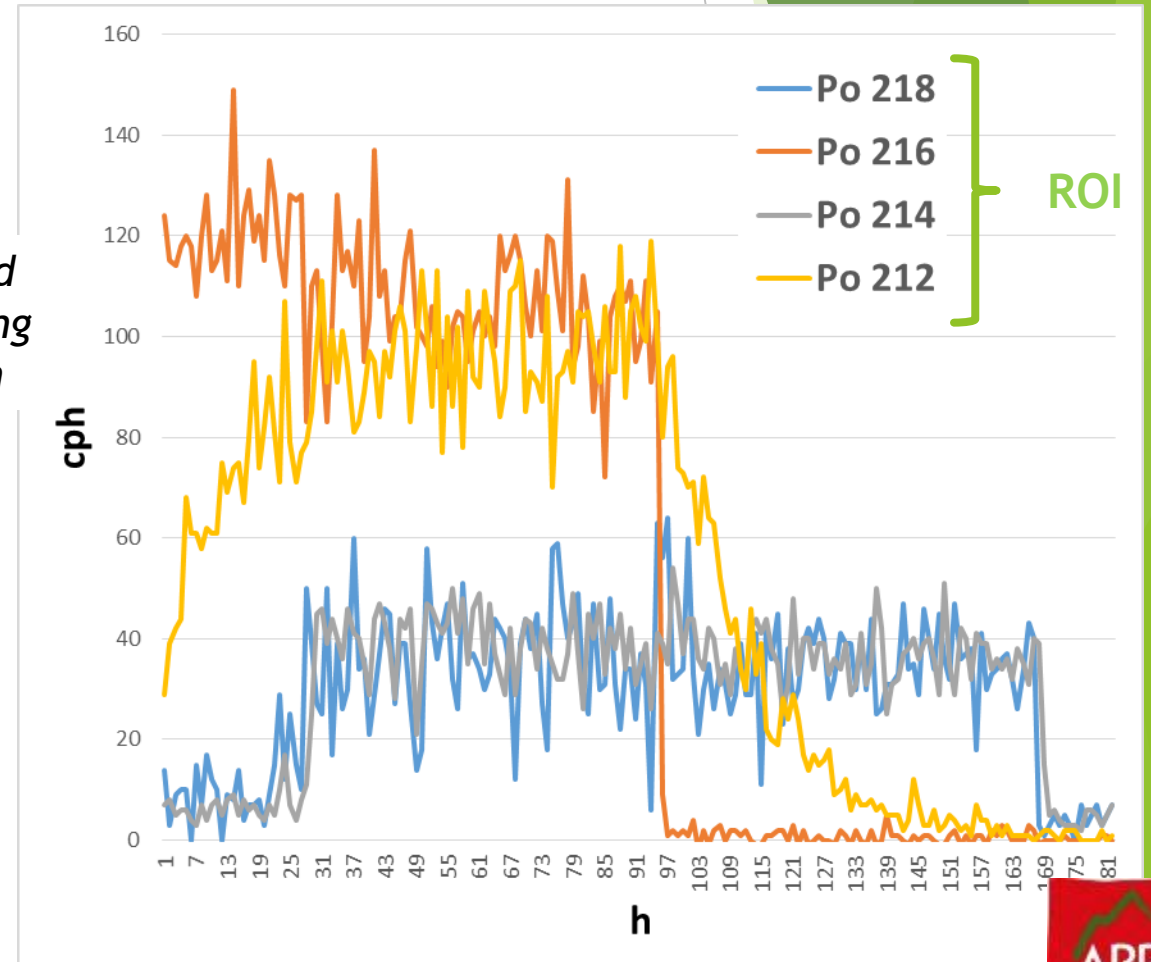
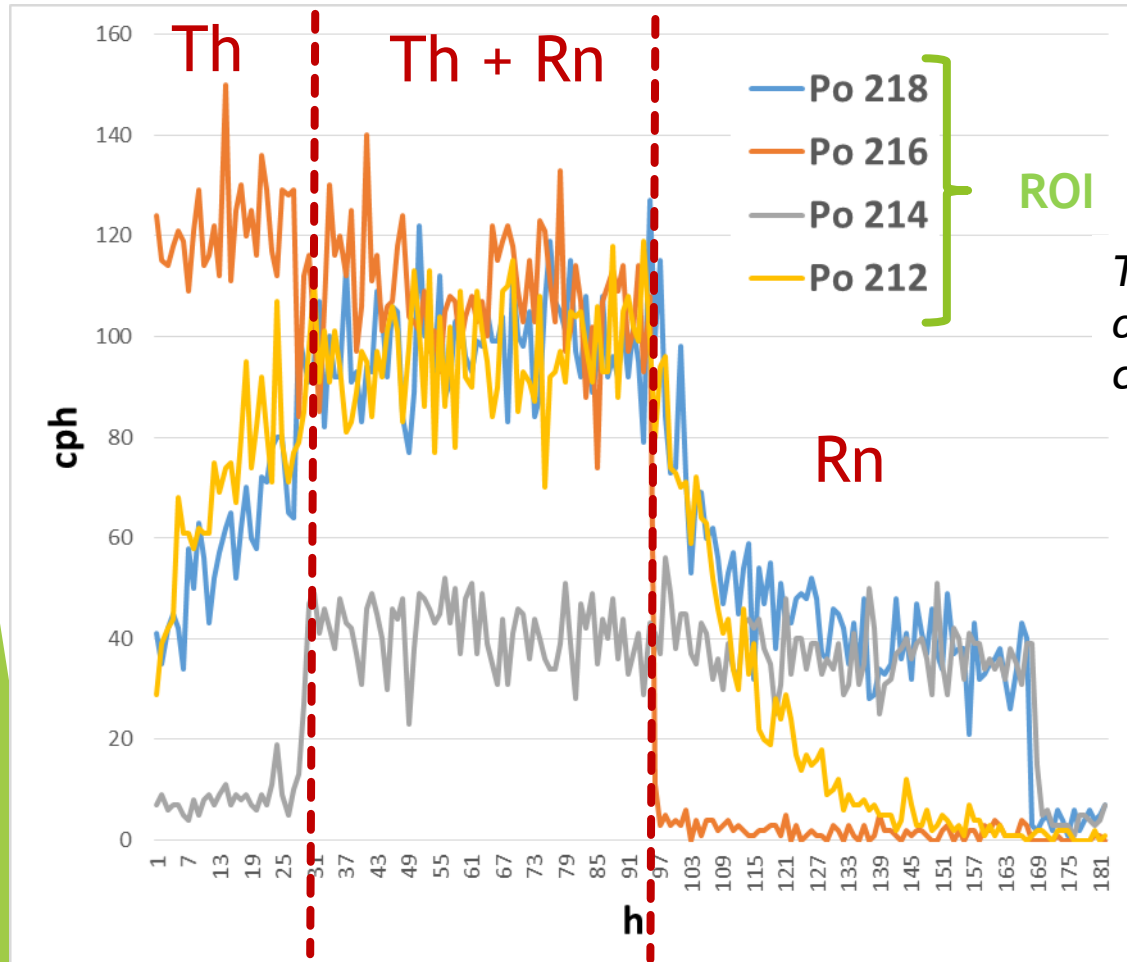
ARPA Radon Chamber



Rn concentration (Bq/m ³)			
	Th + Rn	Rn	Δ
AG	268	202	66±25
Radim	405	190	215±60

Radon / Thoron mixed atmosphere

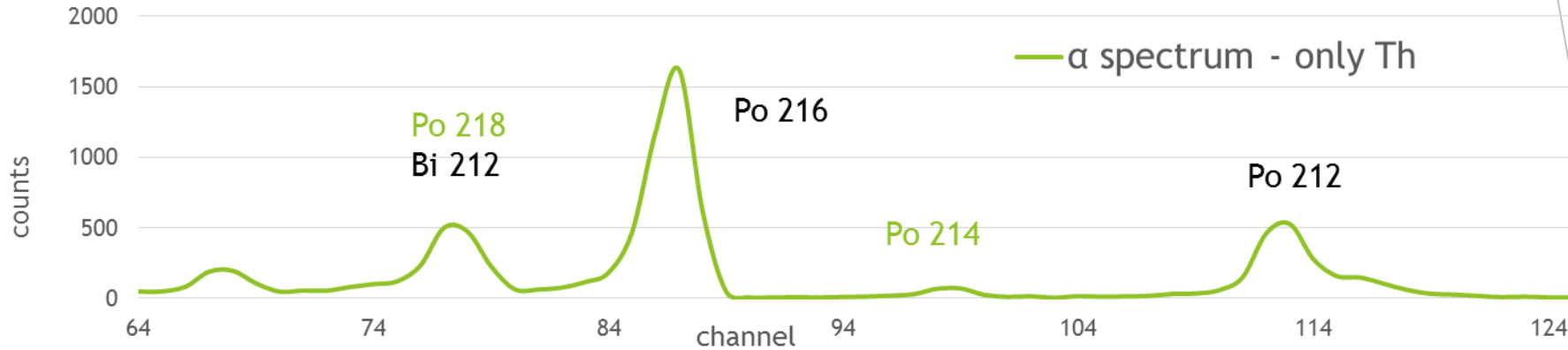
α spectrum - EQF



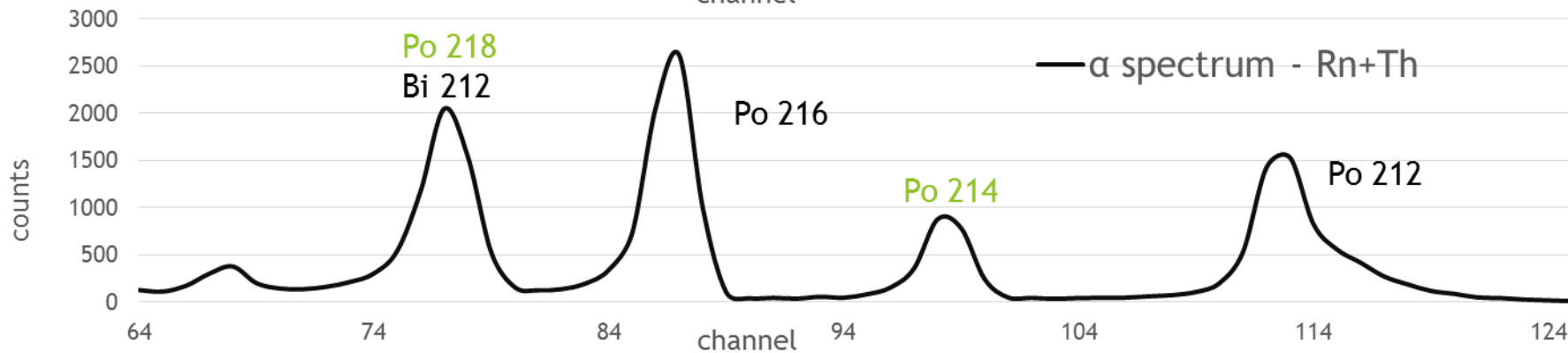
Radon / Thoron mixed atmosphere

α spectrum - EQF

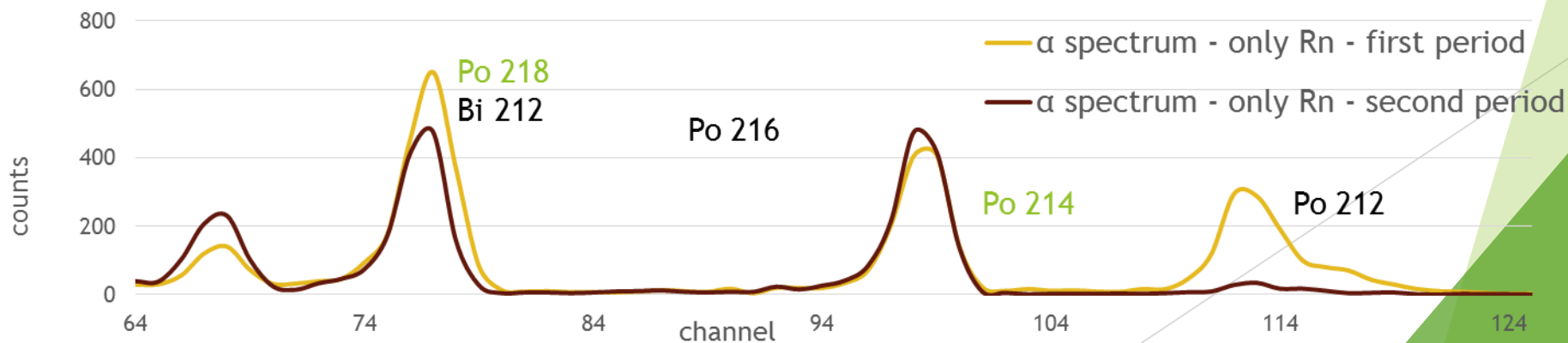
Th



Th + Rn

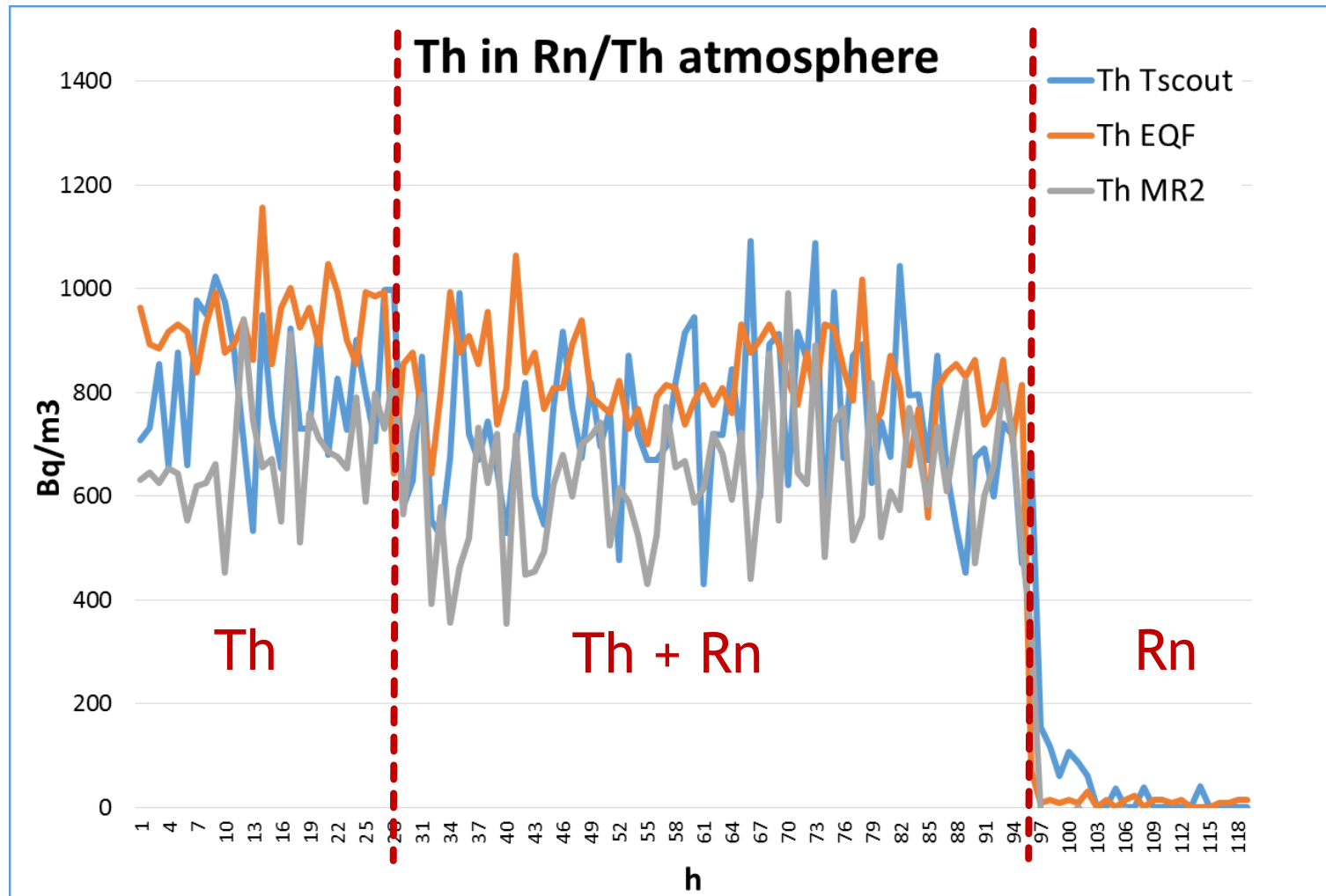


Rn



Radon / Thoron mixed atmosphere

ARPA Radon Chamber



Th concentration (Bq/m³)

	Th	Th+Rn	All period
Tscout	813	740 (91%)	760±151
EQF	939	821 (87%)	853±100
MR2	675	630 (93%)	645±127

No changes in Rn concentration

Radon / Thoron mixed atmosphere

Sensitivity to Thoron

Concentration (Bq/m ³)				Sensitivity (s)
	Δ^{Rn} (Th)	Th	Th/Rn	Δ^{Rn} (Th)/Th
AG	66±25	753±74	~ 4	0.09±0.04
Radim	215±60			0.29±0.11

Open questions:

- s is depending on the specific instruments?
- s is depending on Th/Rn ratio?
- s is depending on environmental parameters?

→ In S3 site we decided to set up a Rn measurement configuration with *Th free atmosphere*: MR1 in flow mode with 50 m of pipe in the inlet, in order to achieve complete Th decay

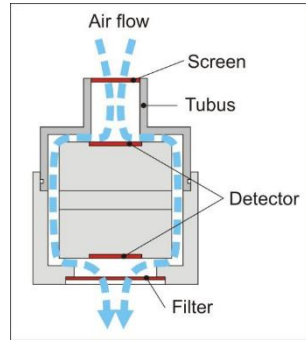
In bibliography for Alphaguard:

AG	s	info
Michielsen et al. [2015]	0.09±0.04	Different instruments Rn free atm
	0.11±0.04	
Sumesh et al. [2012]	0.06 - 0.08	Low Rn conc
	0.07 - 0.12	Low Rn conc
	0.08 - 0.17	Th/Rn ~ 4
Kochowska et al. [2009]	0.03 - 0.07	Radon free atmosphere Different Th concentration
	0.04 - 0.06	
	0.04 - 0.07	
Ishikawa [2004]	0.09 - 0.14	Rn free atm
	~ 0.07	Th/Rn 1:1



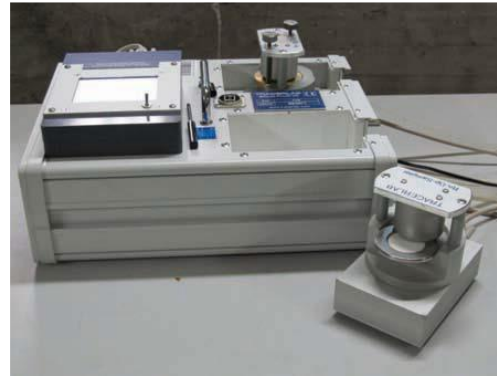
Radon PAEC: the instruments

EQF 3220 - SARAD
ARPA

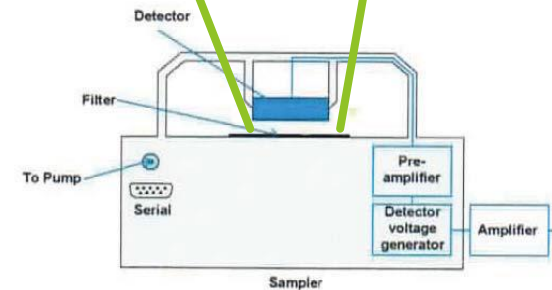


EEC for attached, unattached and cluster Radon and Thoron daughter products

BWLM-PLUS-2S - TRACERLAB
ENEA - INMRI



PAEC for attached and unattached Radon and Thoron daughter products



$$PAEC = \sum_{j=1}^4 n_j E_j = \sum_{j=1}^4 \lambda_j n_j \frac{E_j}{\lambda_j} = \sum_{j=1}^4 c_j \frac{E_j}{\lambda_j}$$

(Mev/l)

$j=1,2,3,4$ Po218, Pb214, Bi214, Po214
 n = number of atoms per unit of volume
 c = activity concentration
 E_j = PAE
 λ_j = decay constant

$$EEC = \frac{PAEC}{k_e} \quad k_e = 34735 \text{ Mev/Bq}$$

Radon PAEC: the walk-in chamber

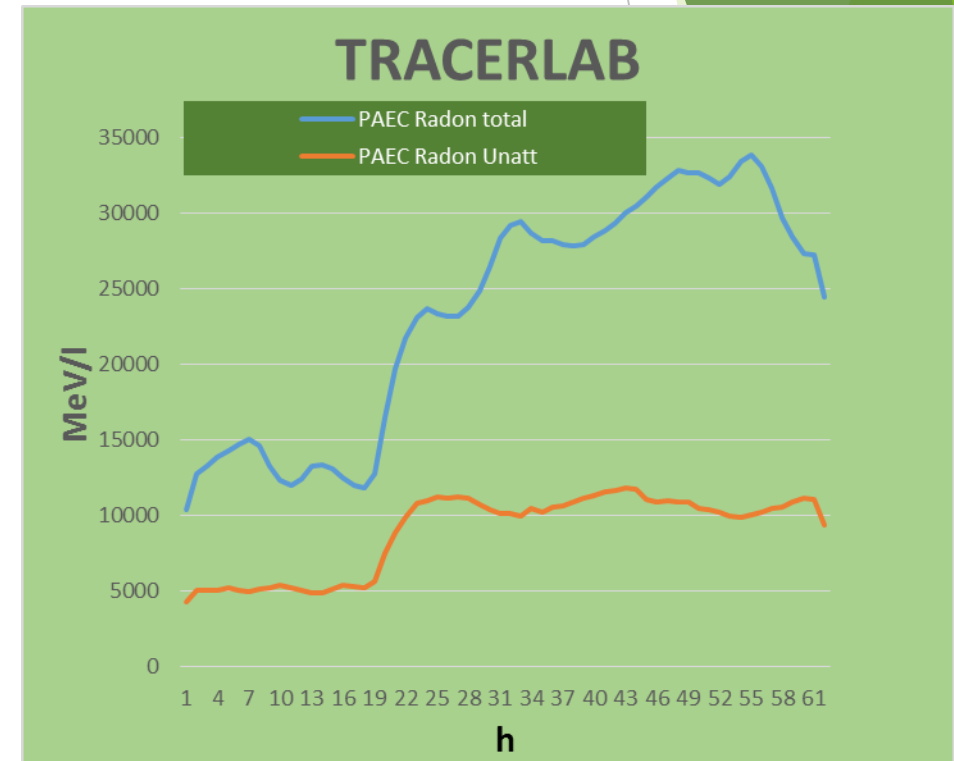
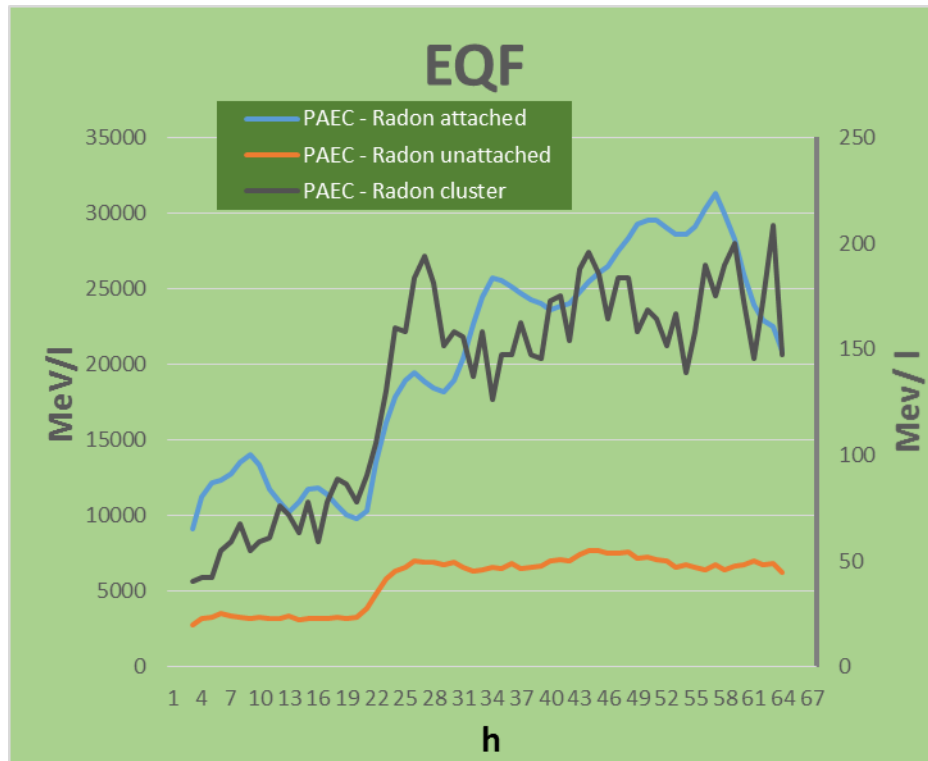
Measurements at ENEA - INMRI radon “walk-in chamber”:



- 150 m³
- Depression system ($\Delta P = 1 \text{ mbar}$)
- Natural emanation of radon

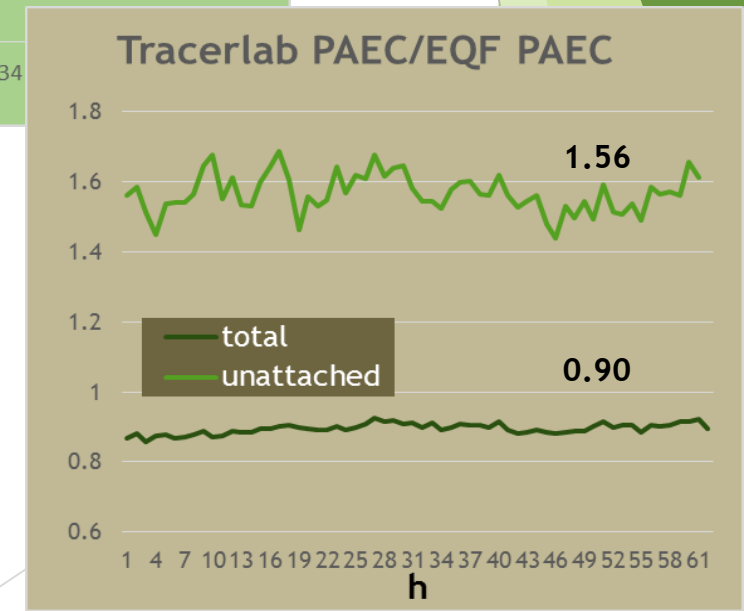
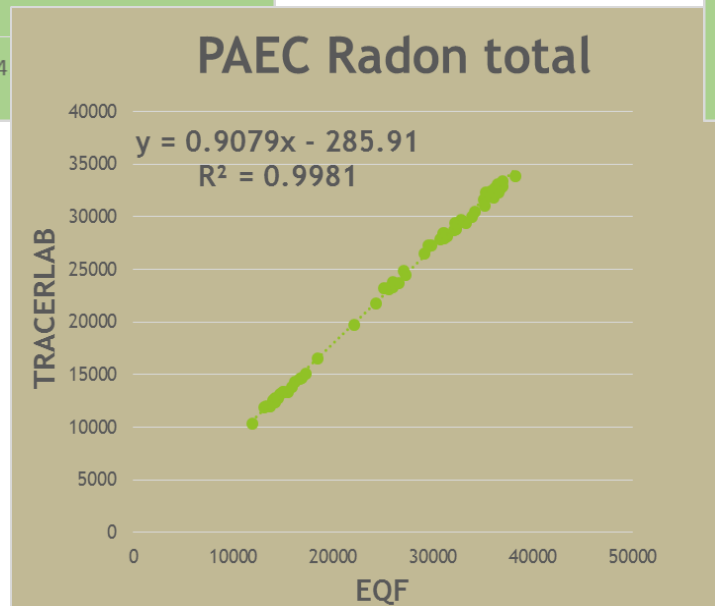
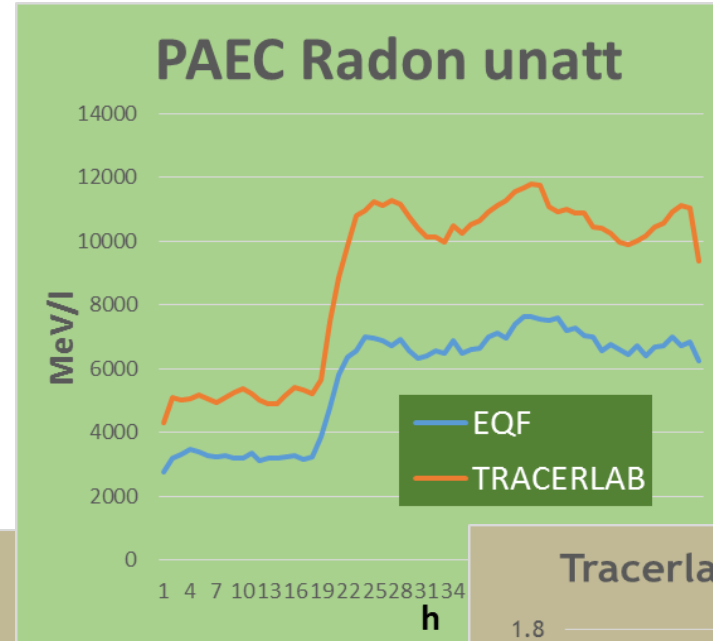
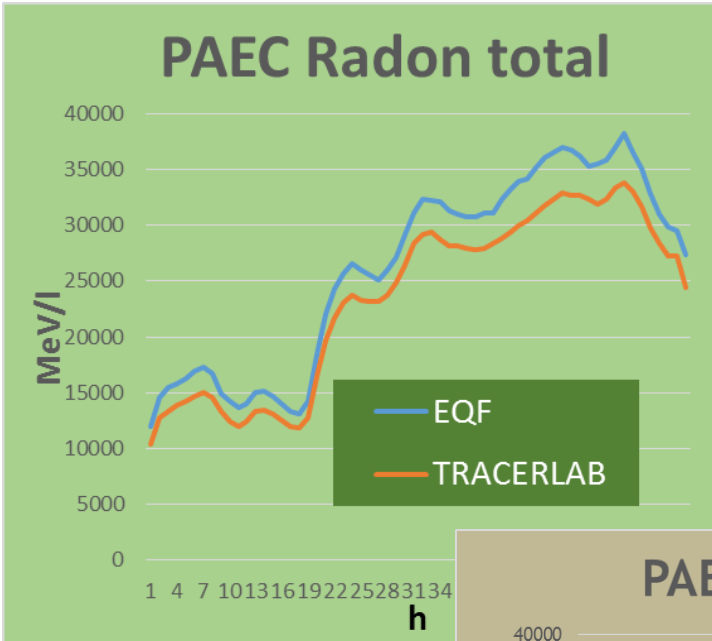
Radon PAEC

Measurements at ENEA - INMRI:



Radon PAEC

Measurements at ENEA - INMRI radon “walk-in chamber”:



Conclusions

Good exercise to understand instruments behaviour:

- Long measurement campaigns
- Rn/Th mixed atmosphere exposure
- In chamber intercomparison
- In field intercomparison
- Background measurements
- PAEC measurements
- Metrological critical aspects (references, calibrations...)
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Thank you