Detectors used in the intercomparison

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

21 – 22 september 2017

Campus Bovisa – Politecnico di Milano

Milan (ITALY)

M. Faure Ragani - Environmental Protection Agency of Aosta Valley Region – www.arpa.vda.it

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.I, 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 11 Radim 5B 5 Lucas cells 1 AER+ 1 Corentium pro	1 Thoron scout 1 NG Alphaguard 1 EQF3220	1 EQF 3220

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 N_2

- CESNEF Radon Chamber: exposure to N_2 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
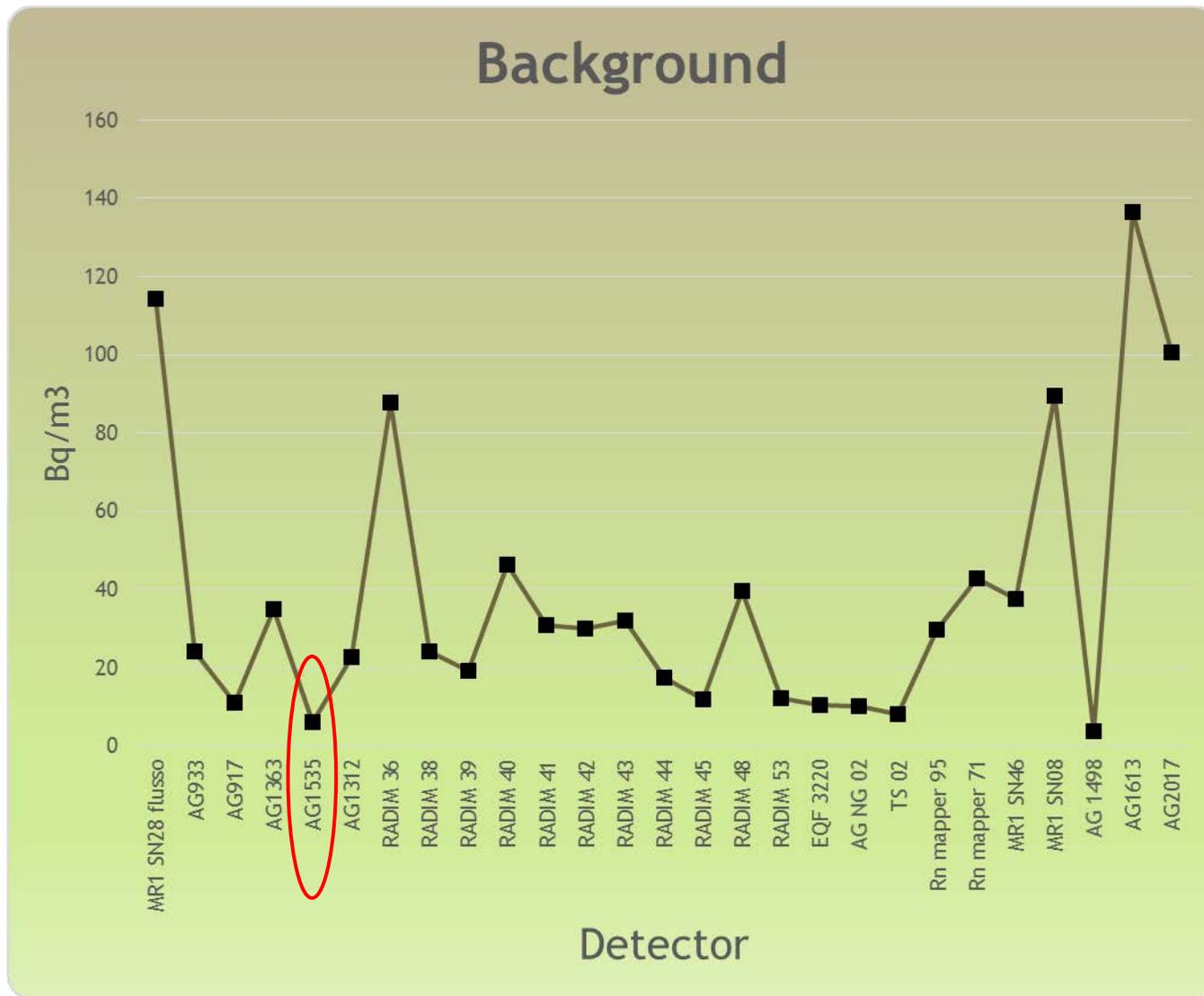
Decision threshold ...

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
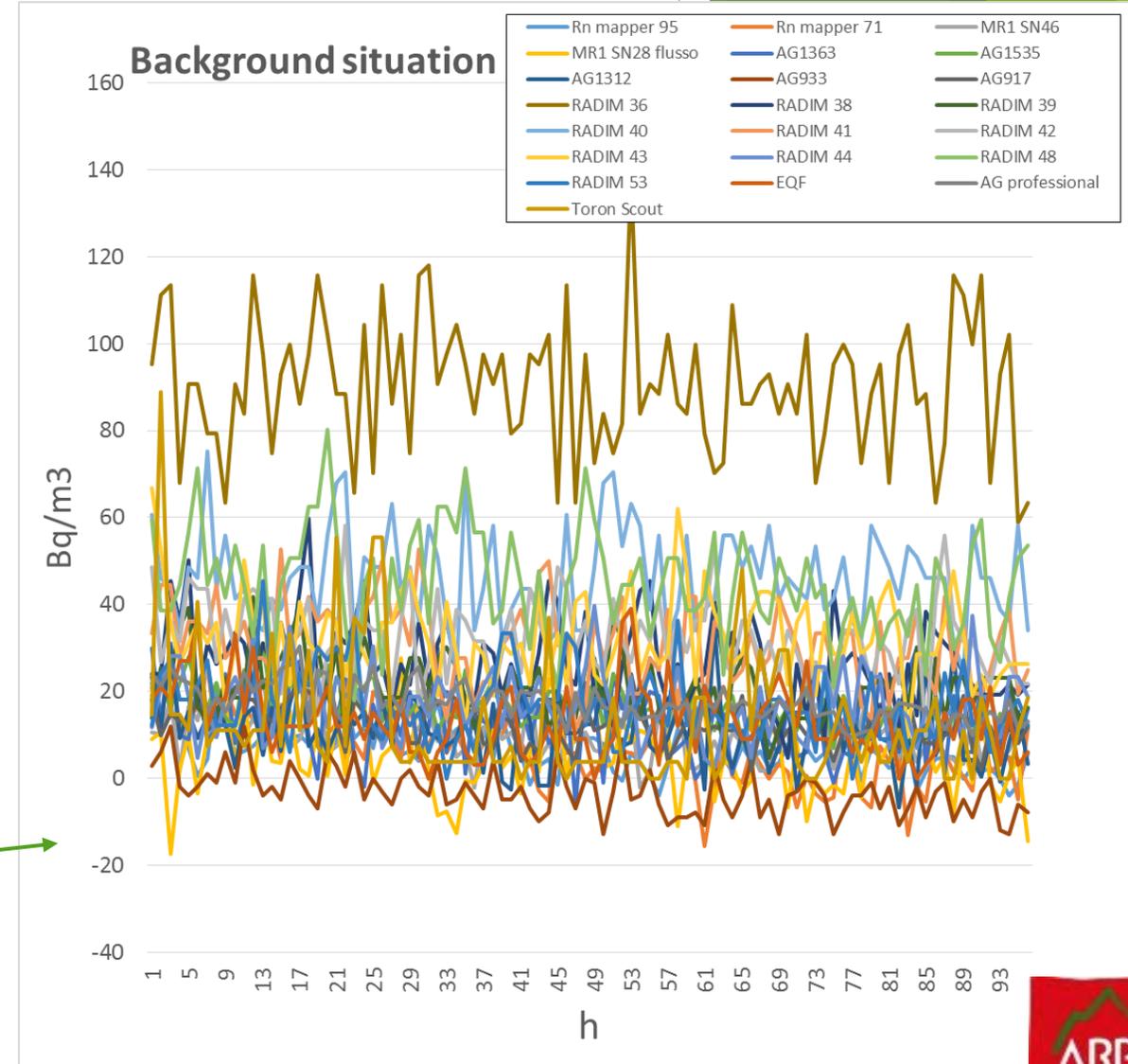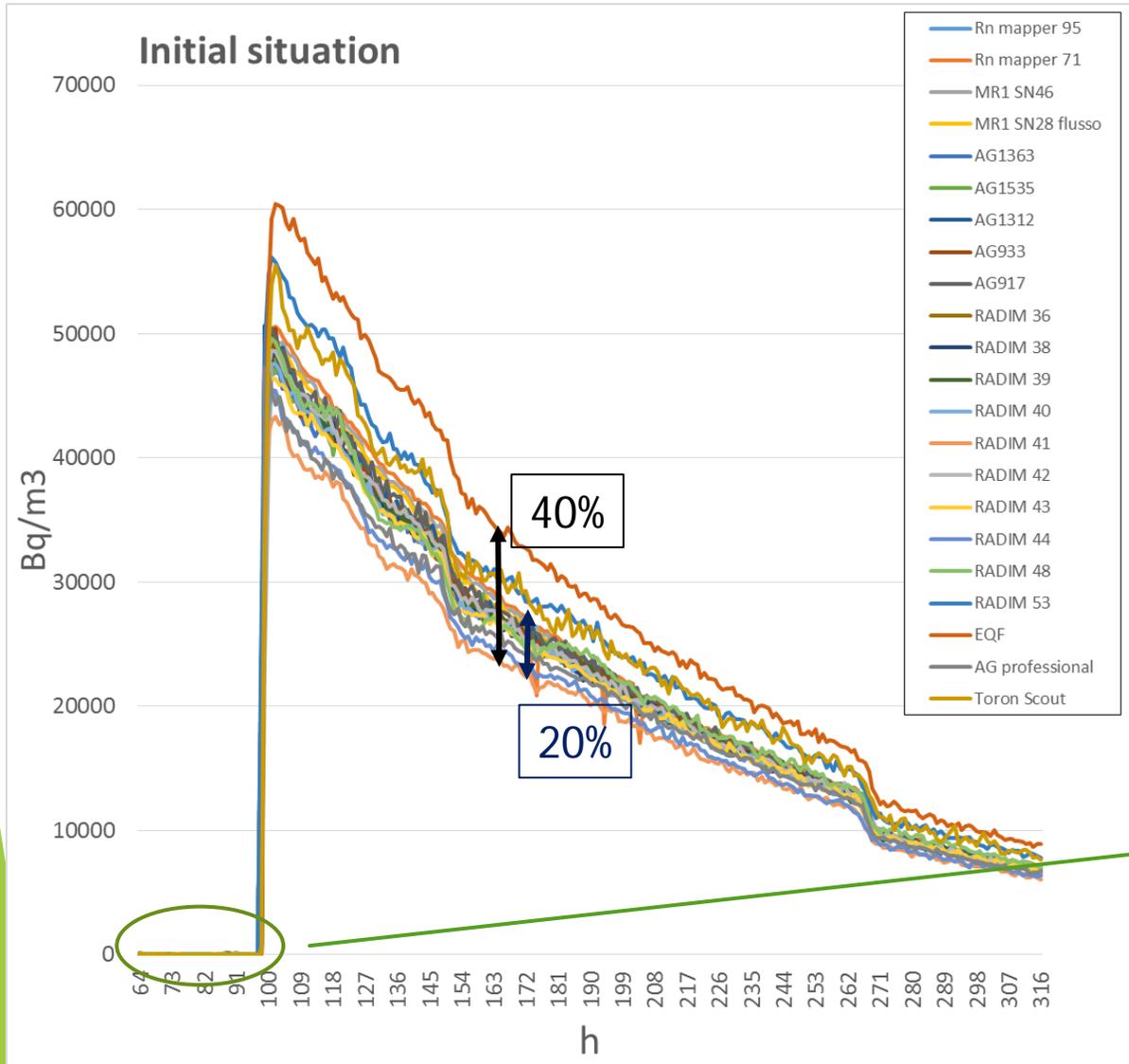
The calibration @ CESNEF

3 steps calibration: very high concentrations
low/medium exposures

Step1	Step2	Step3	
38000	14000	8000	Bq/m3
1400	500	300	kBqh/m3

7%
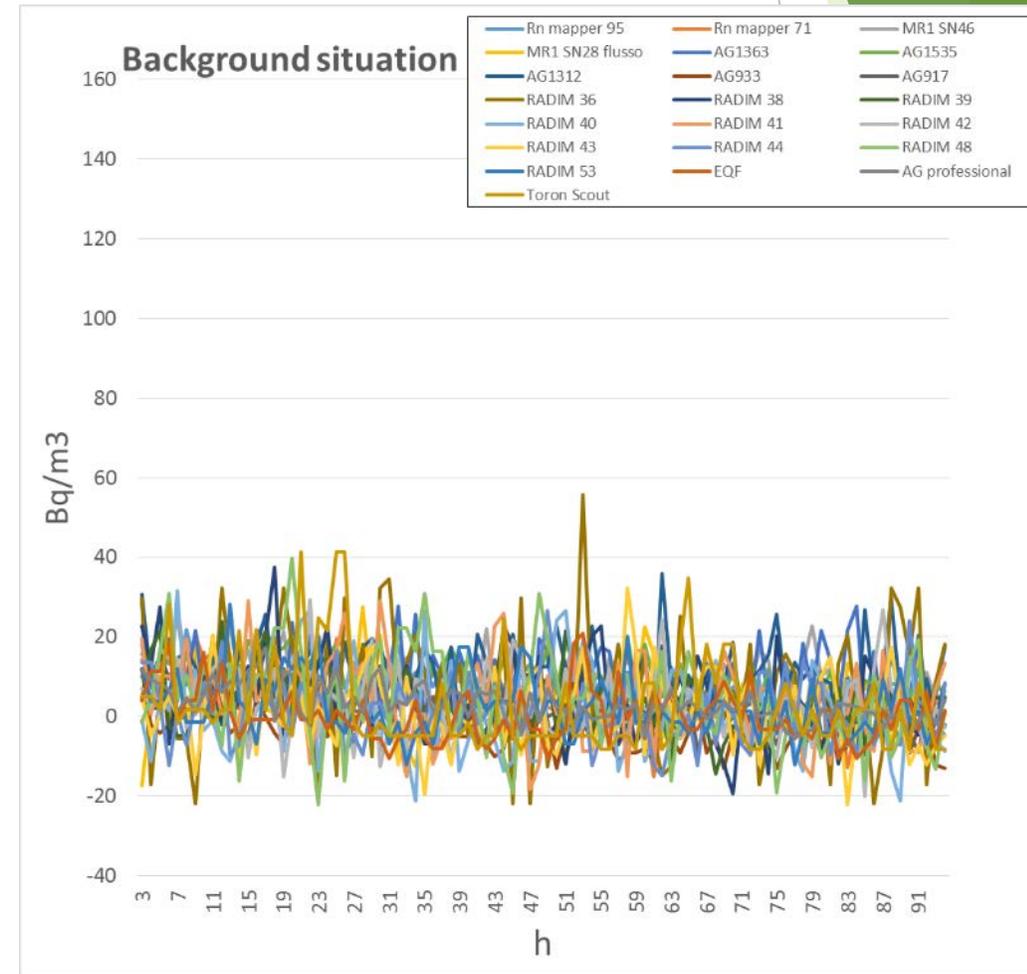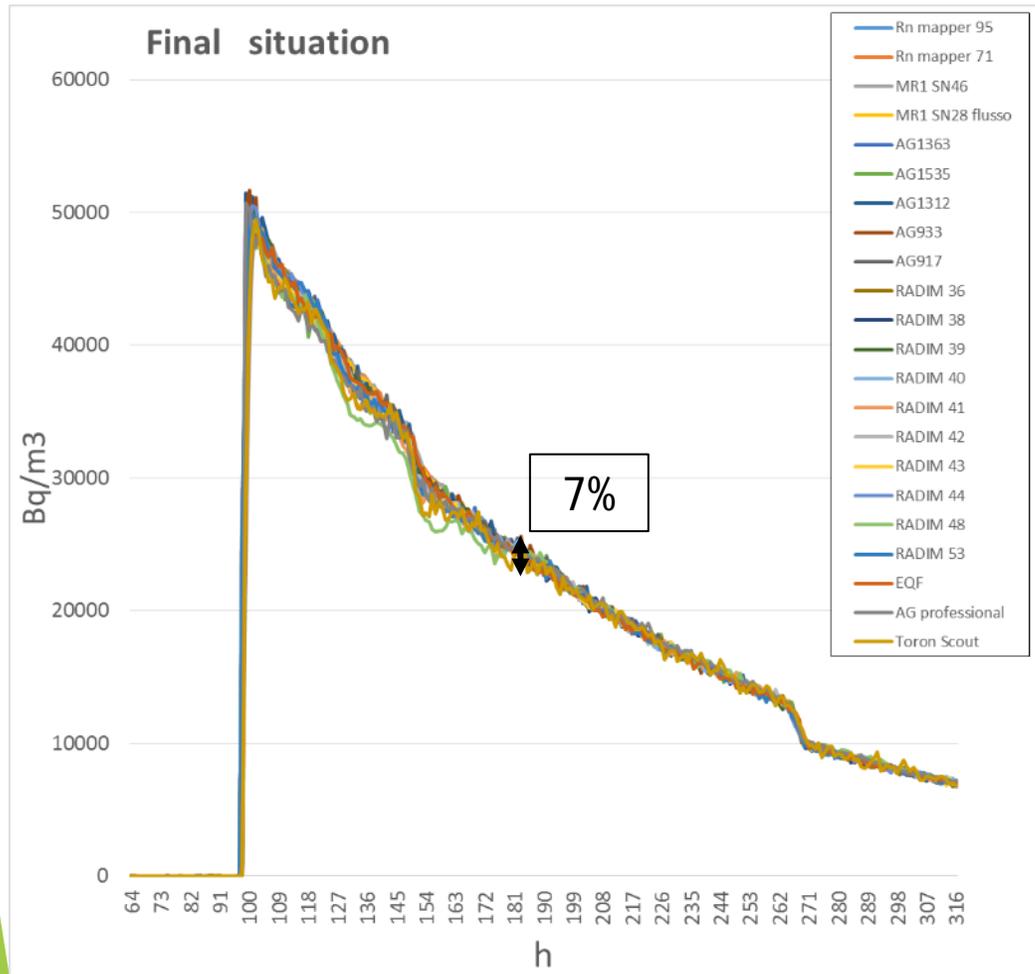
The calibration

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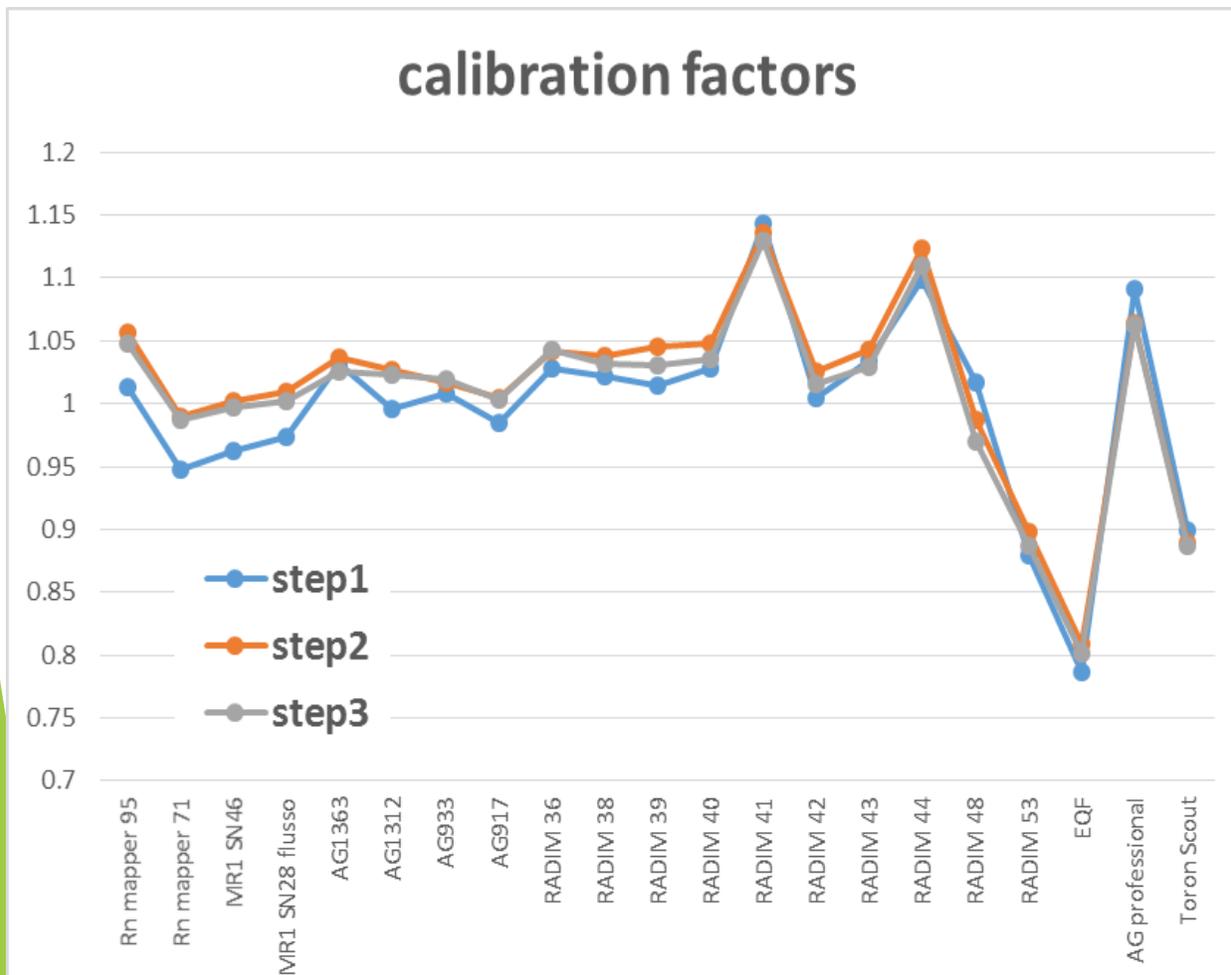
Sometimes:

- CF ≠ 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
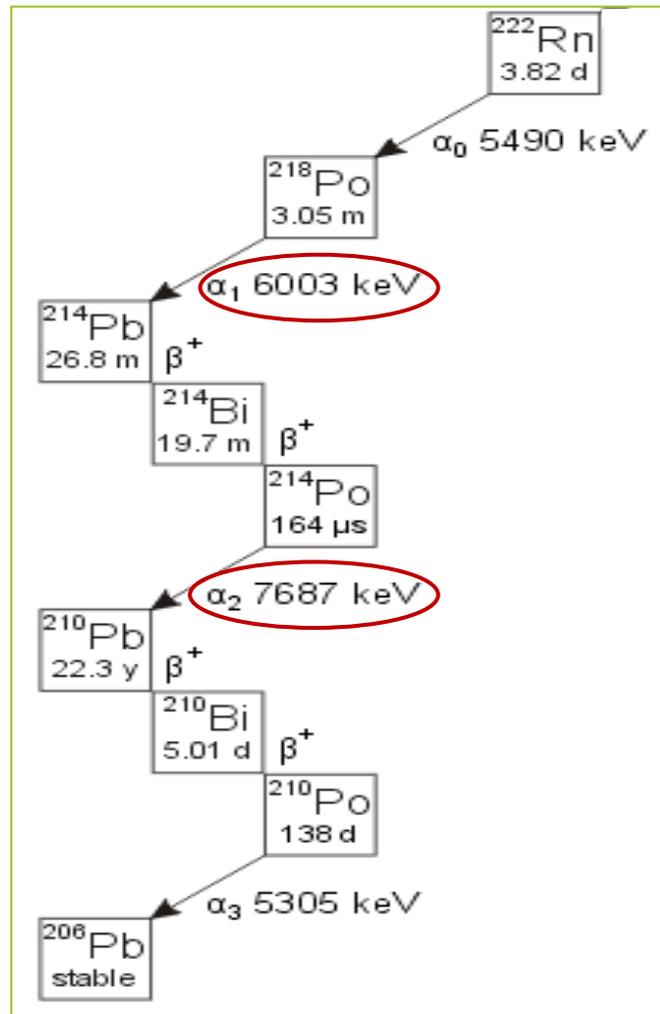
Thoron
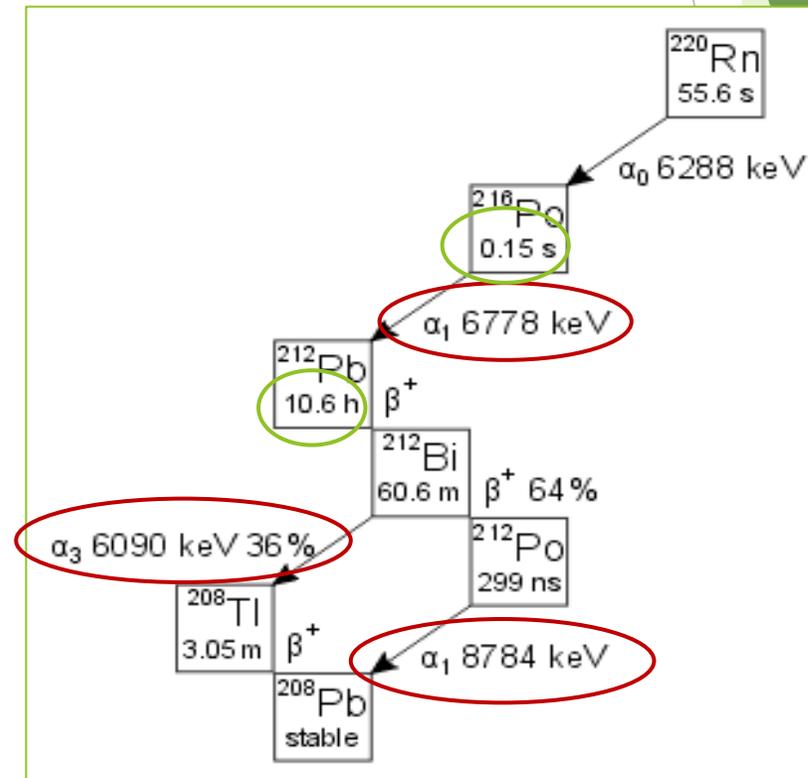
Radon/Thoron mixed atmosphere: instrumental techniques for continuous measurements

α spectrum

Po 218 Bi 212	Po 216	Po 214	Po 212
tailing Po 216	tailing Po 212 Po 214	tailing Po 212	
~6 MeV	~6.8 MeV	~7.7 MeV	~8.8 MeV

α energy

Thoron Scout - EQF 3220
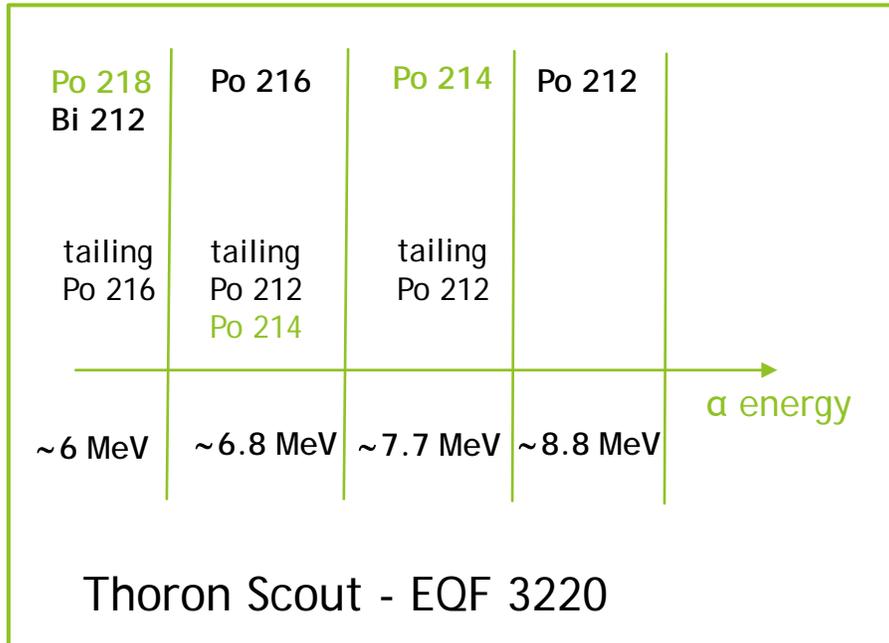
Th spectrum during the first hours

Spectrum after Th exposure
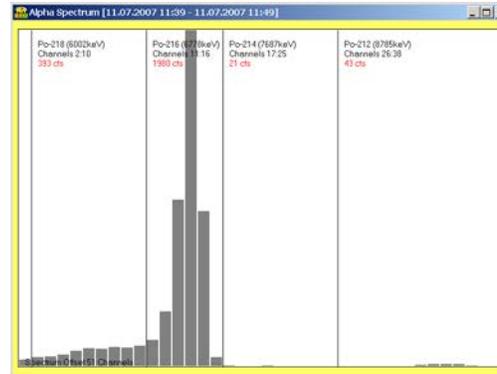
Th spectrum in the activity equilibrium

Bi 212 β decay
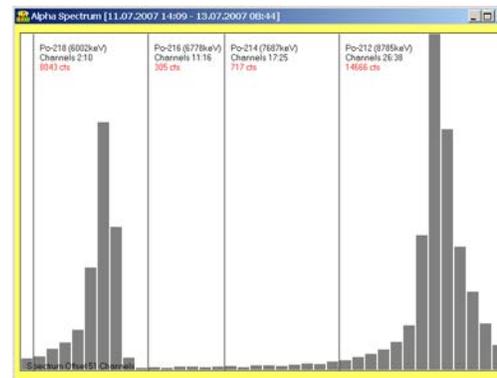
Rn spectrum in equilibrium state
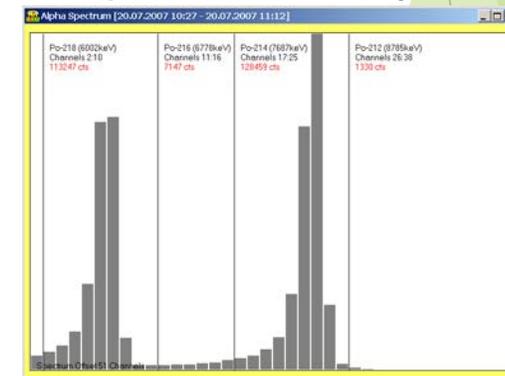
Rn Fast

Rn Slow

Radon/Thoron mixed atmosphere: instrumental techniques for continuous measurements

Delayed coincidences method

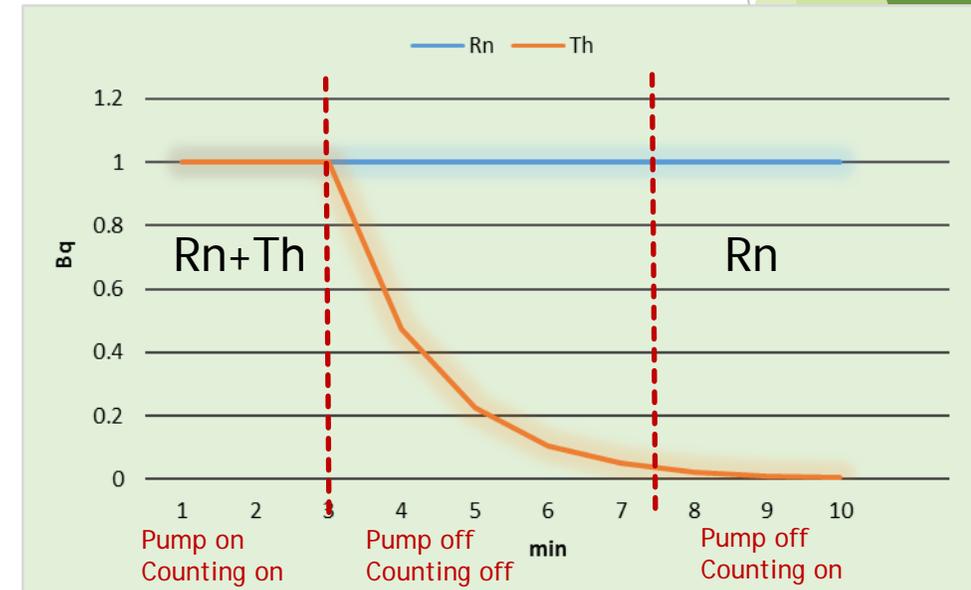Time interval distributions between the events ("Time spectrum" of alpha decays)

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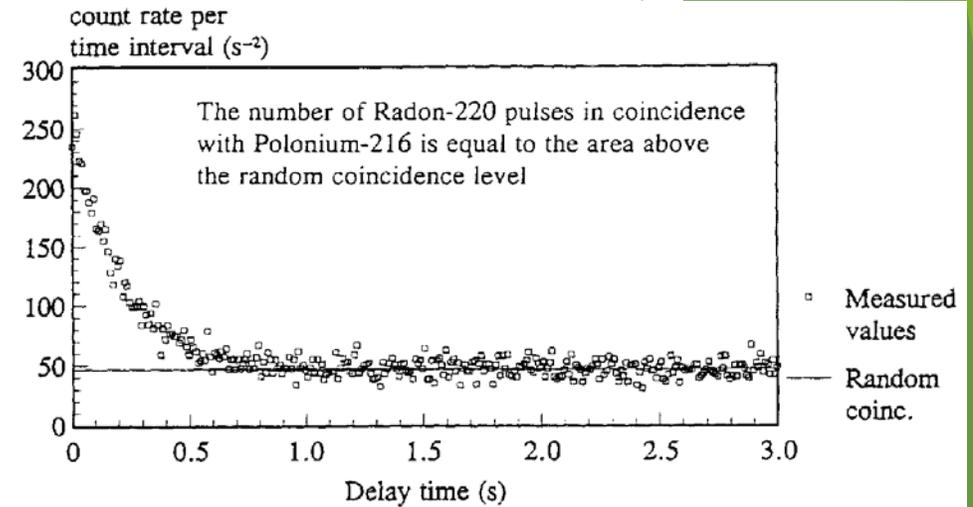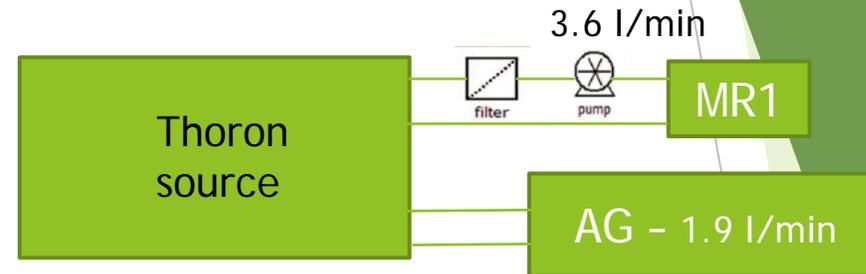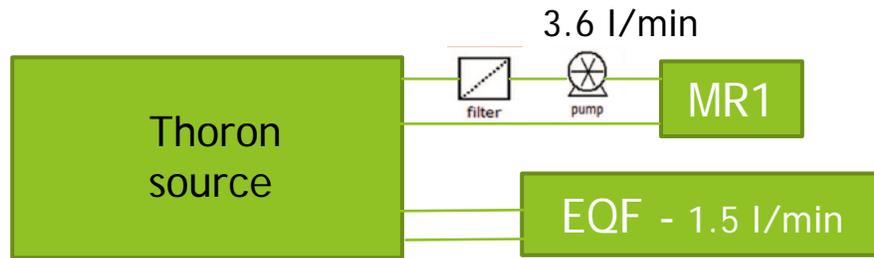

Double counting interval method

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/m^3 ± 5%

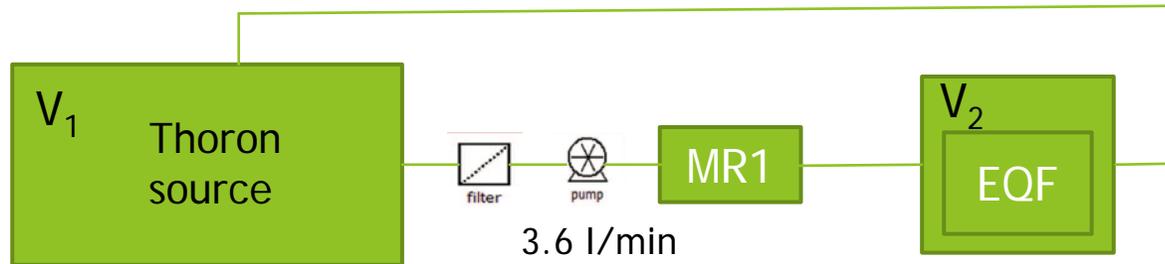Measured value EQF: *27000* Bq/m^3 ± 4%

Measured value AG: *30465* Bq/m^3 ± 15%

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

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

Thoron measurements

ENEA - INMRI

V$_1$ — Thoron source

filter — pump — 3.6 l/min — MR1 — V$_2$ EQF

Reference value in V$_1$: *20169* Bq/m^3 ± 5%

Calculated value in V$_2$: *6454* Bq/m^3 ± 5%

Measured value in V$_2$: *7801* Bq/m^3 ± 11%

21 % diff

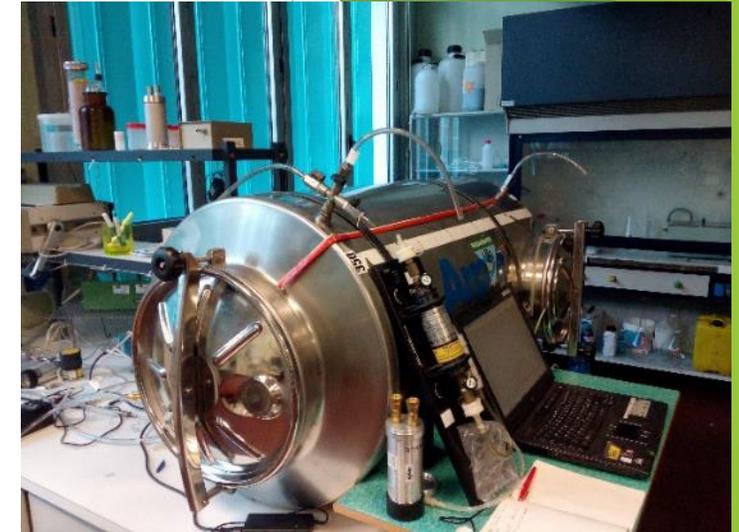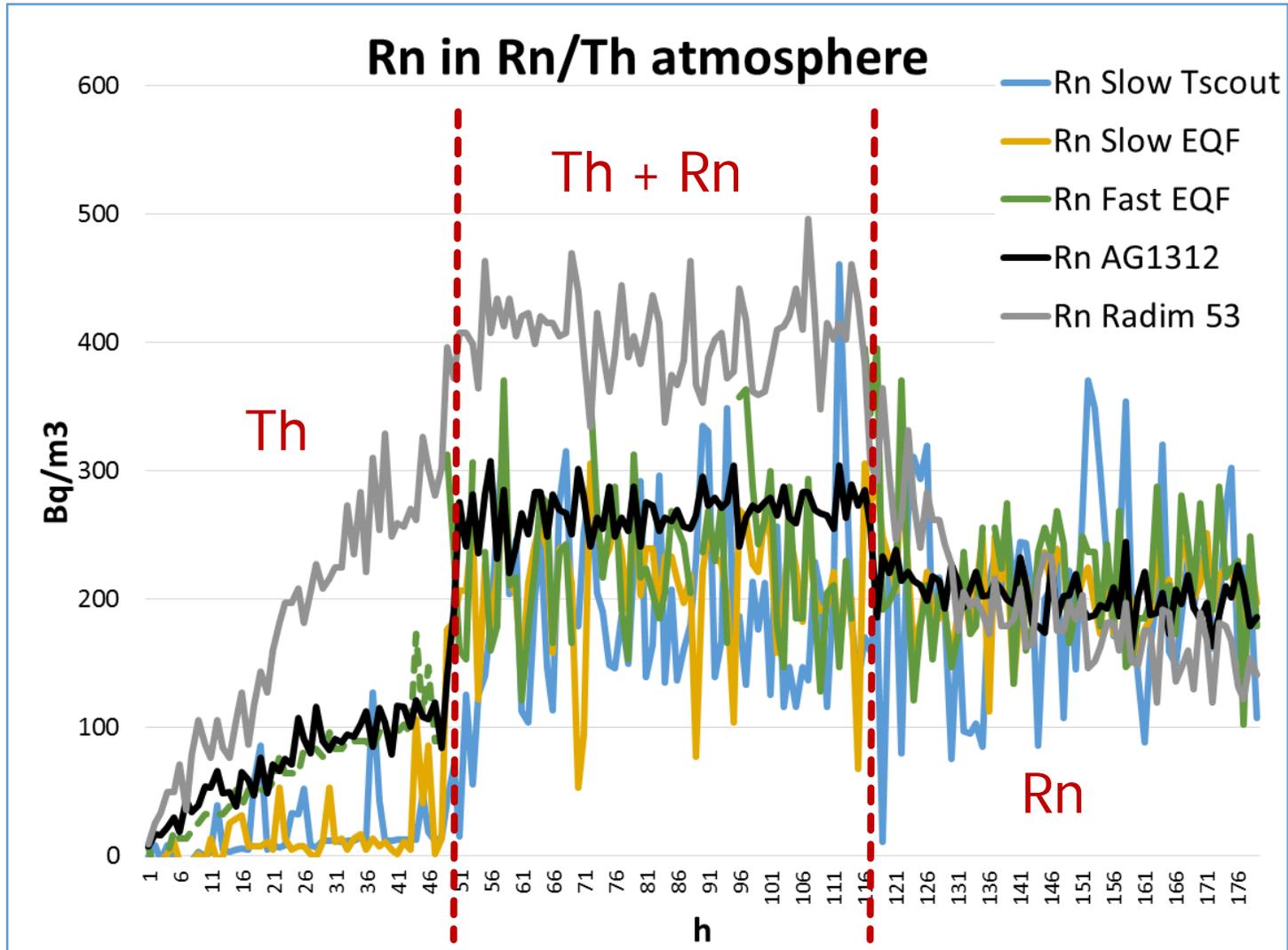Th concentration in the circuit

Conc. Rn220 V1
Conc. Rn220 MR1
Conc. Rn220 V2

We have to improve hardware configuration in order to be sure about the Th uniformity in V$_2$

Radon / Thoron mixed atmosphere
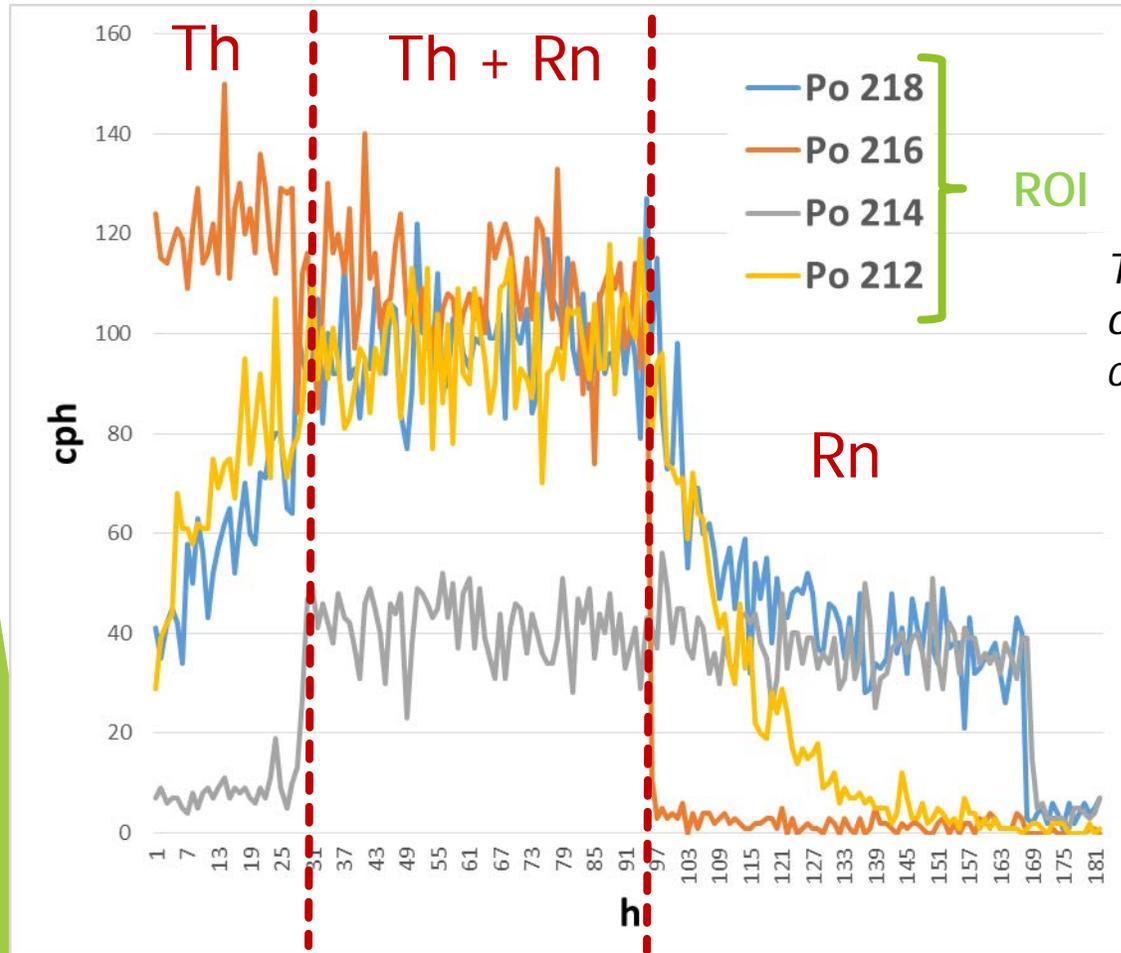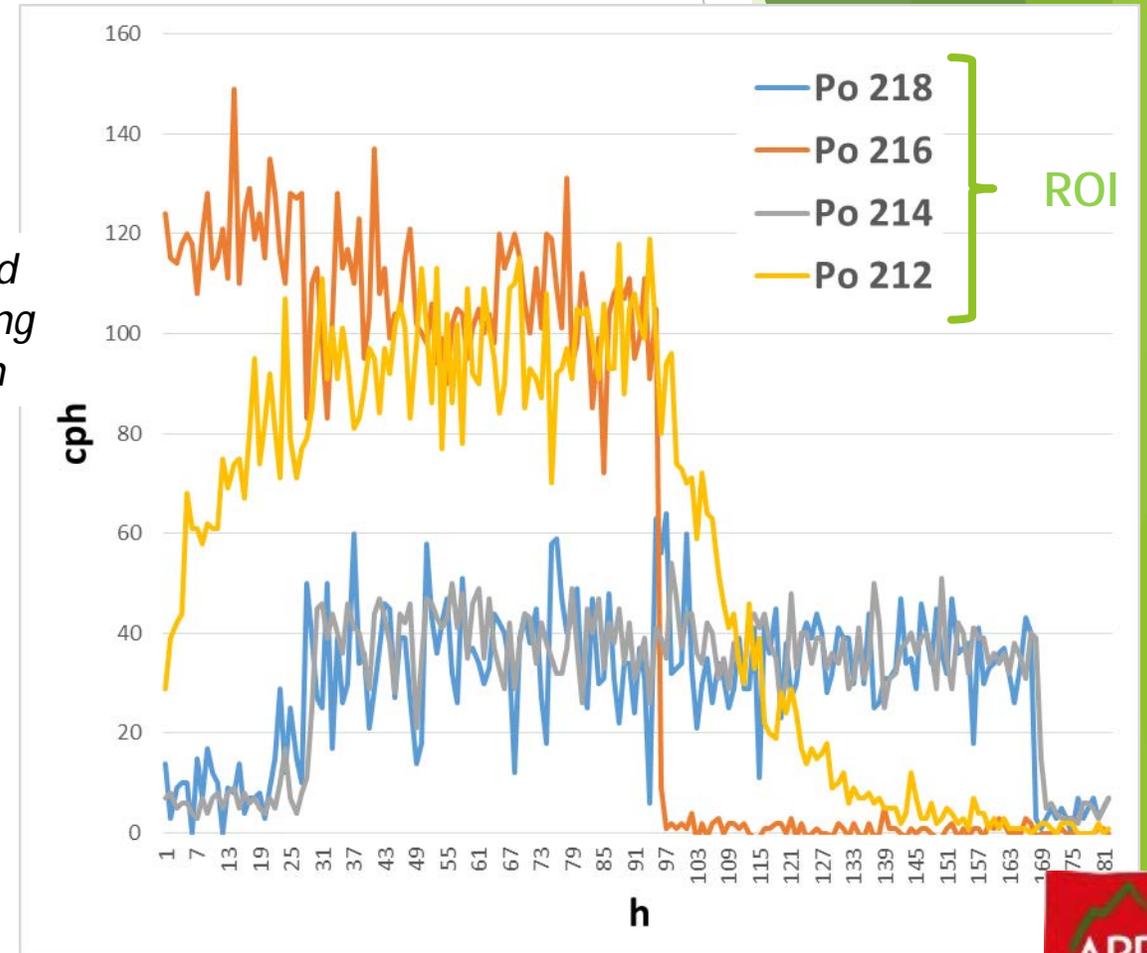
ARPA Radon Chamber

Rn in Rn/Th atmosphere

Th

Th + Rn

Rn

Legend:
- Rn Slow Tscout
- Rn Slow EQF
- Rn Fast EQF
- Rn AG1312
- Rn Radim 53
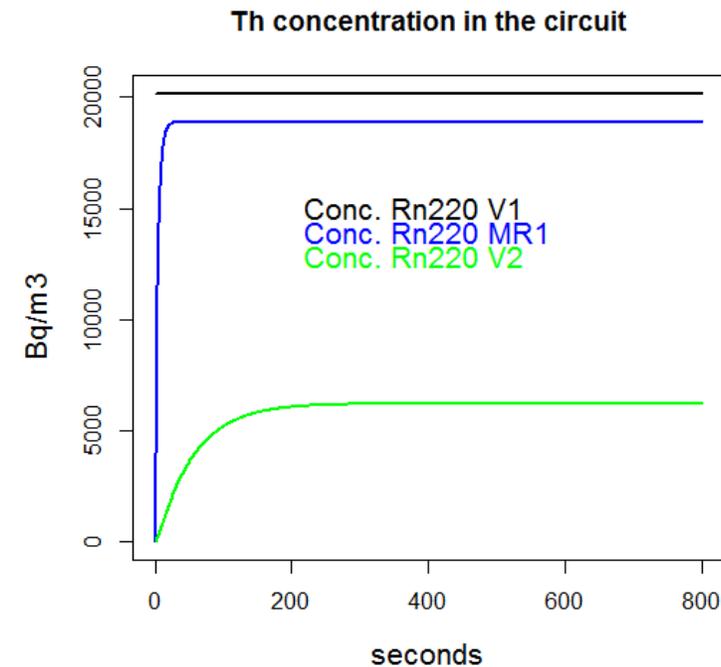
Rn concentration (Bq/m^3)			
	Th + Rn	Rn	Δ
AG	268	202	66±25
Radim	405	190	215±60

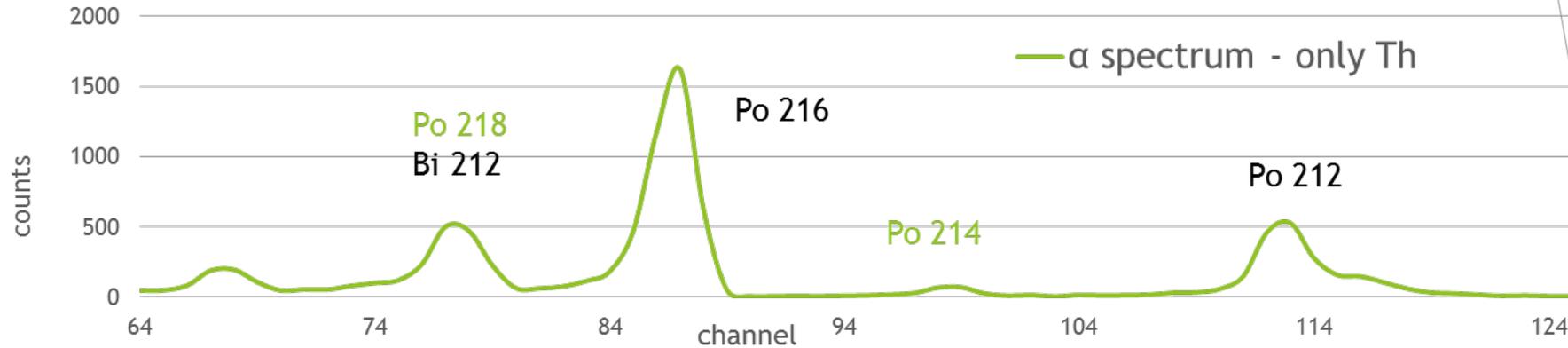# Radon / Thoron mixed atmosphere

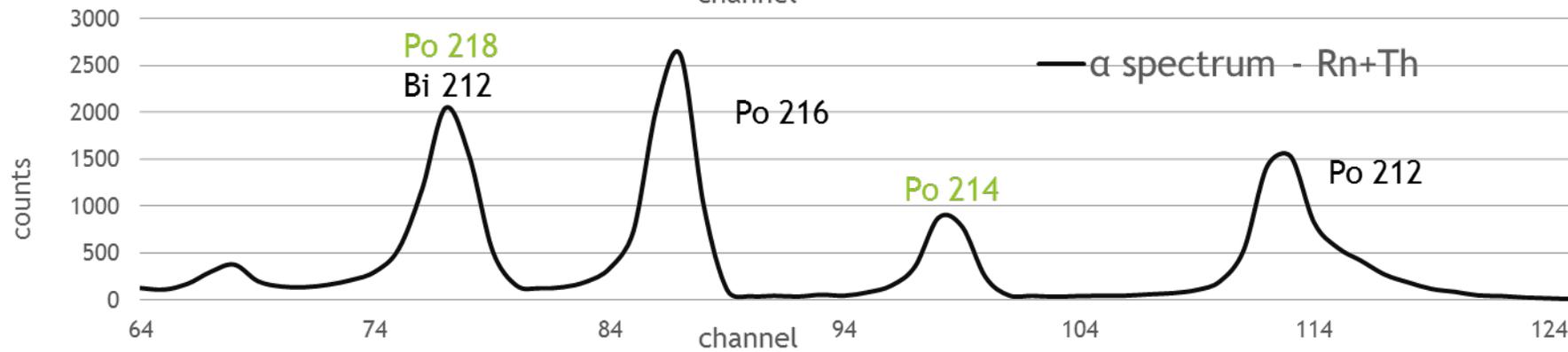## α spectrum - EQF

Tailing and overlapping correction
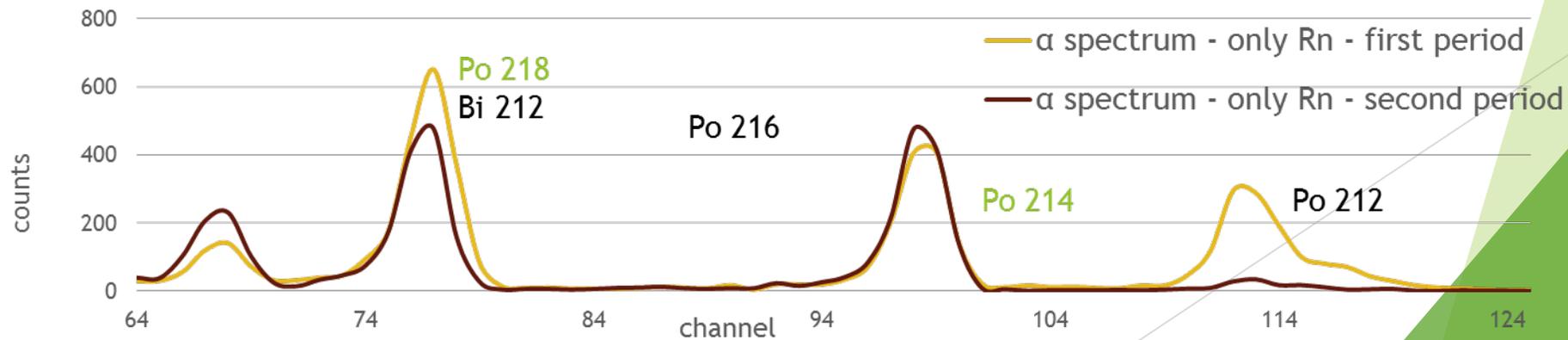
Radon / Thoron mixed atmosphere

α spectrum - EQF

Radon / Thoron mixed atmosphere

ARPA Radon Chamber
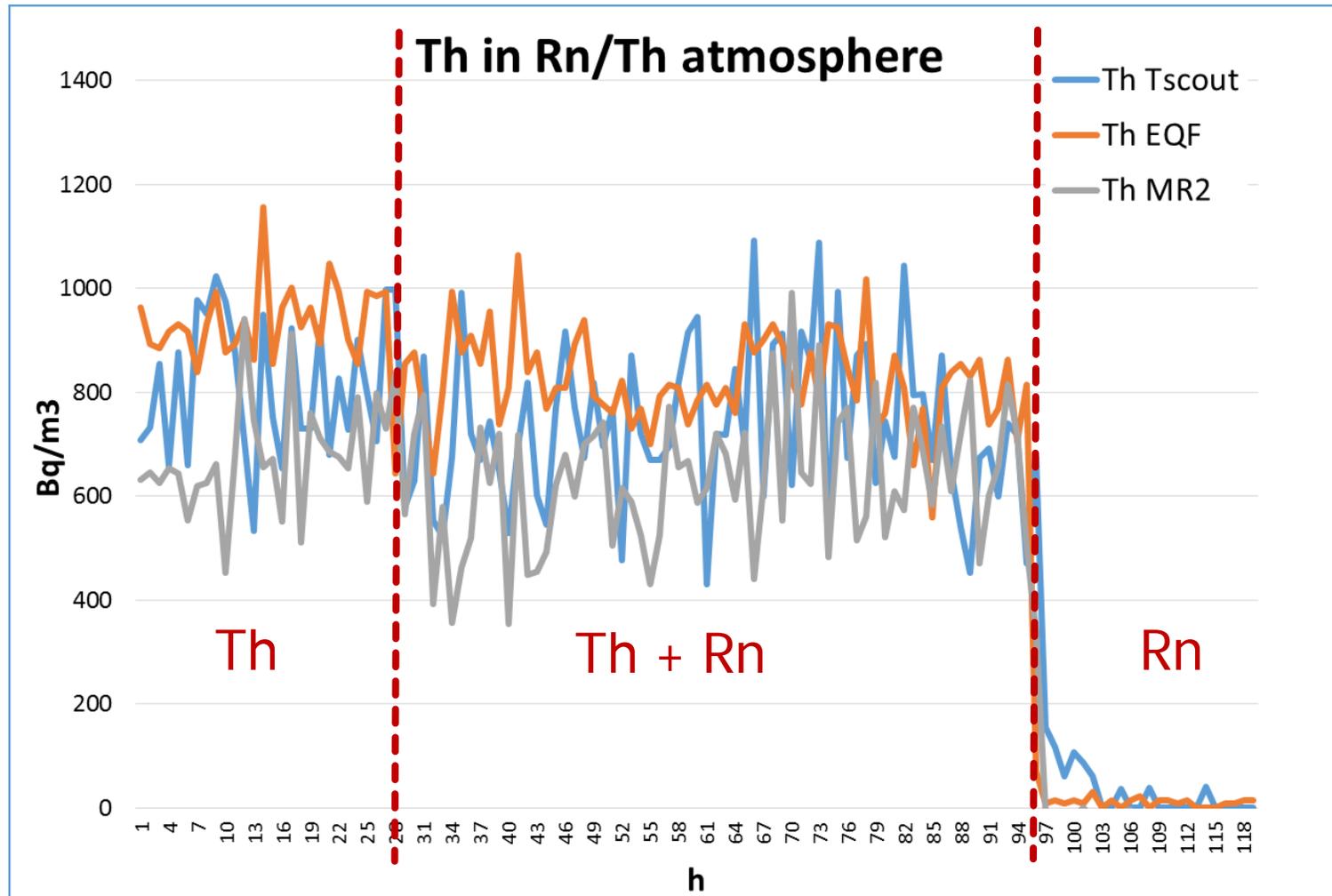
Th concentration (Bq/m³)			
	Th	Th+Rn	All period
Tscout	813	740 (91%)	760±151
EQF	939	821 (87%)	853±100
MR2	675	630 (93%)	645±127

No changes in Rn concentration

Radon / Thoron mixed atmosphere

Sensitivity to Thoron

Concentration (Bq/m³)			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 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 0.04 - 0.06 0.04 - 0.07	Radon free atmosphere Different Th concentration
Ishikawa [2004]	0.09 - 0.14	Rn free atm
	~ 0.07	Th/Rn 1:1

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
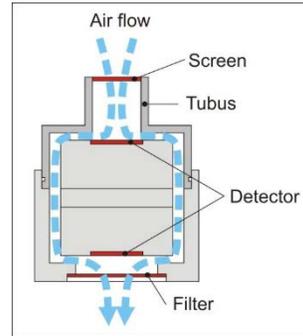
Radon PAEC: the instruments

EQF 3220 – SARAD
ARPA

EEC for attached, unattached and cluster Radon and Thoron daughter products
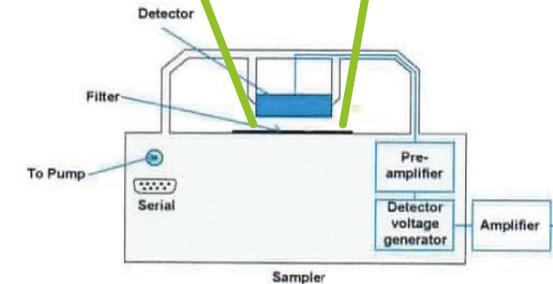
BWLM-PLUS-2S - TRACERLAB
ENEA - INMRI

mesh

filter

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
λj = decay constant

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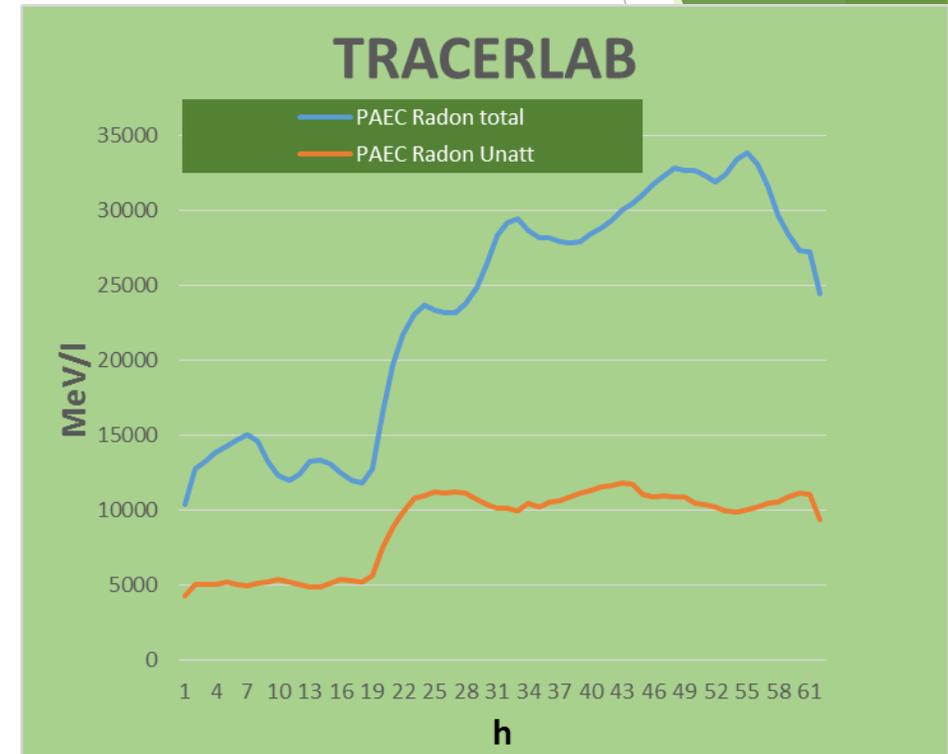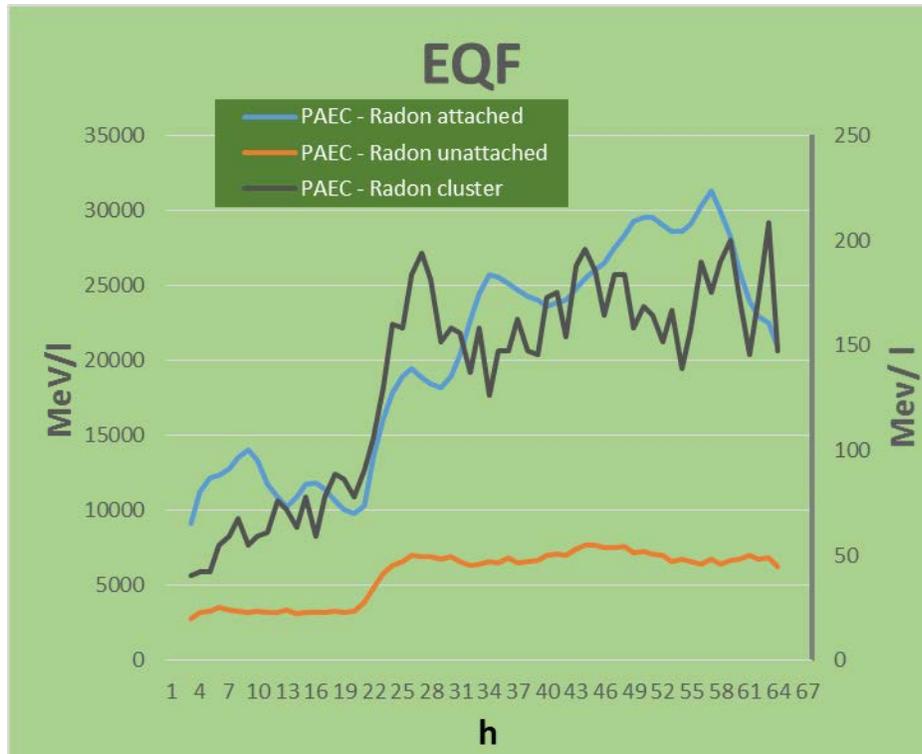
k_e=34735 Mev/Bq

Radon PAEC: the walk-in chamber

Measurements at ENEA – INMRI radon "walk-in chamber":
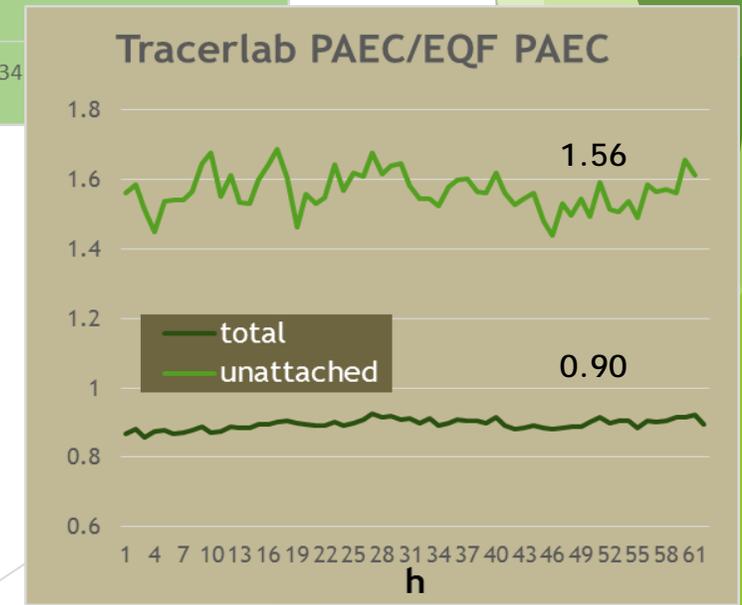

- 150 m^3

- Depression system ($\Delta P = 1\ mbar$)
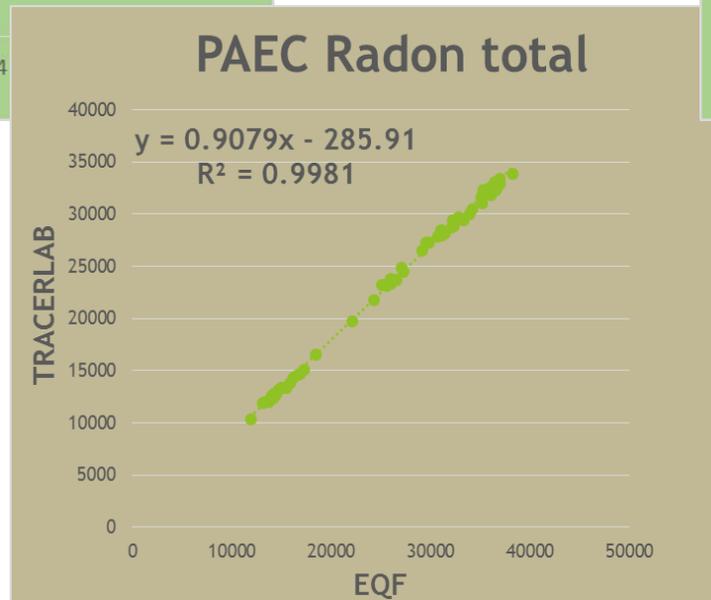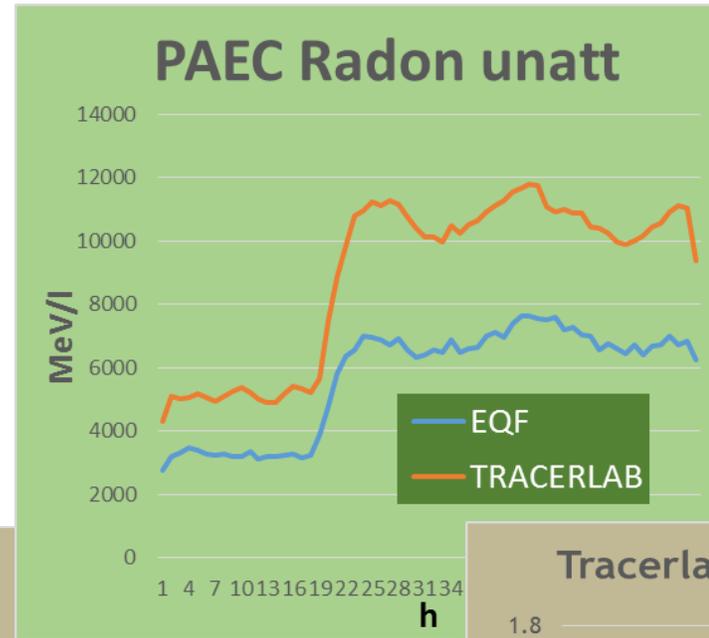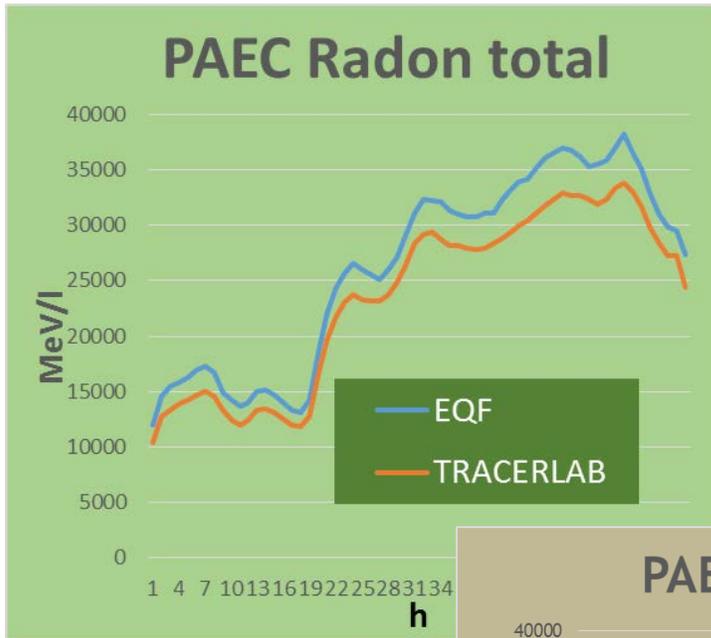
- Natural emanation of radon

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…)

- ……

Thank you