Sofia University
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Results for the influence of thoron on the passive radon detectors (studied at SUBG)

Detectors provided by Radonova, ISS (Italy), LaRUC (Spain), AGES (Austria) and SUBG (Bulgaria)

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MetroRADON workshop, 25-26 February 2020, BEV, Vienna

Task 2.2: Investigation of the influence of thoron on radon measurements and calibrations

Activity 2.2.2: Study of the influence of thoron on passive integrating radon detectors

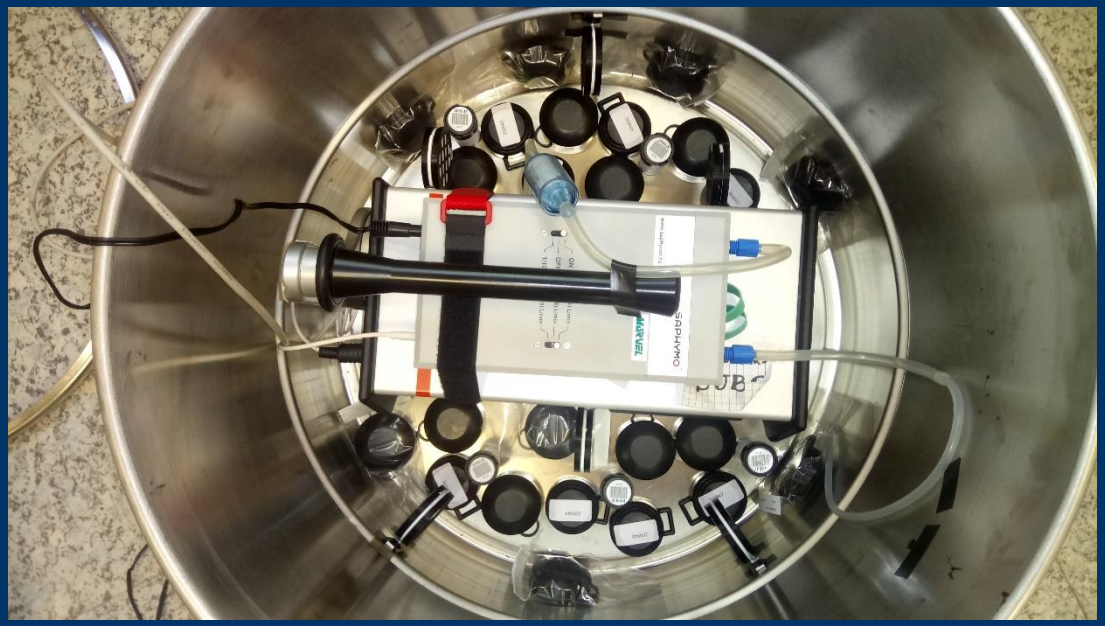
- Studied detectors – 10 types at SUBG, SSNTD based, not published data available for most: Diffusion chambers: Radosys (RSKS and Raduet), Radonova (Radtrak2, Rapidos, Duotrak), 2 types of assembled diffusion chambers and SUBG; DVD detectors – 2 types;
- Cross interference of thoron on radon signal: $CI = \frac{E_{Rn}}{E_{Tn}} \times 100\%$

E_{Rn} – reported integrated radon activity, background corrected by blank detectors' signal;

E_{Tn} – integrated thoron activity concentration as measured by the reference instrument.

Exposure methodology

- Thoron source from Pylon Electronics Inc.;
- Exposure in flow-through system with 50 L hermetic vessel;

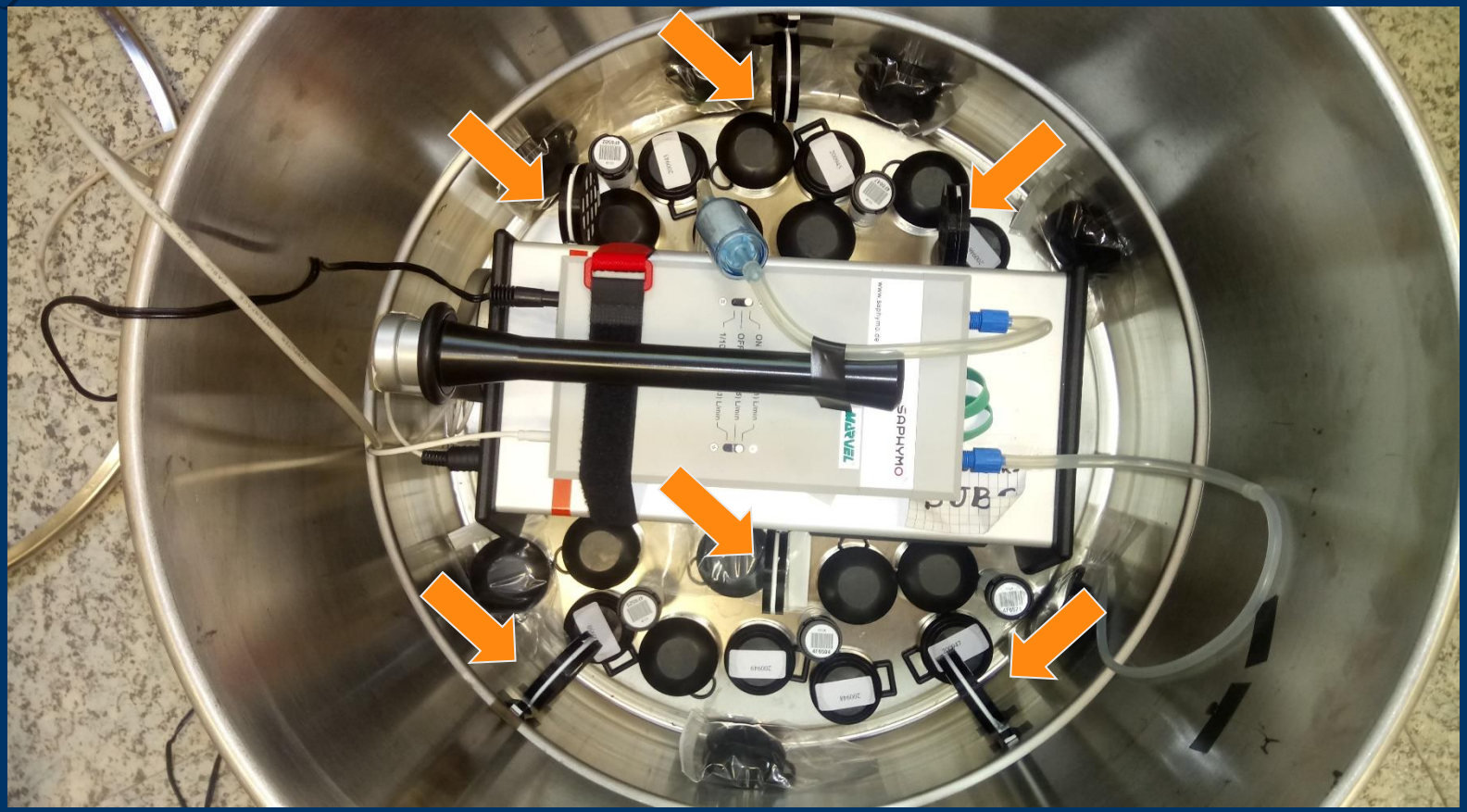


- AlphaGuard PQ2000 RnTn – used in the intercomparison at IRSN (May 2018);

➢ Exposure at 2 different activity concentrations (in the range 2 – 14 MBq.h/m^3) achieved in less than 48 hours;

➢ In each exposure 4 or more identical detectors spread in the exposure volume.

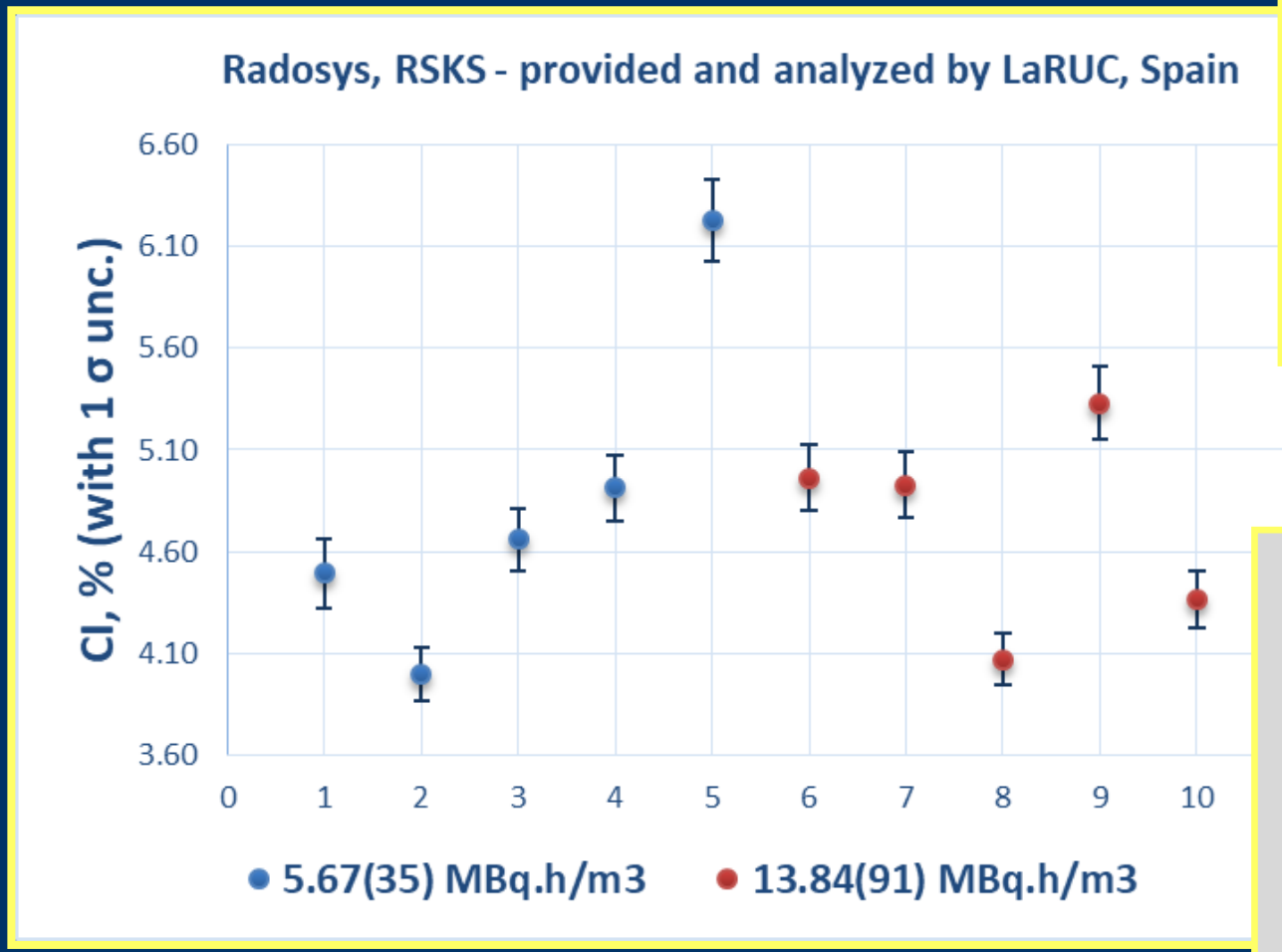
Exposure methodology



Homogeneity controlled by 6 or more aerogel samplers in each exposure – maximum difference b/w signal and the average between 2.2 and 3.6 %.

Results - RSKS

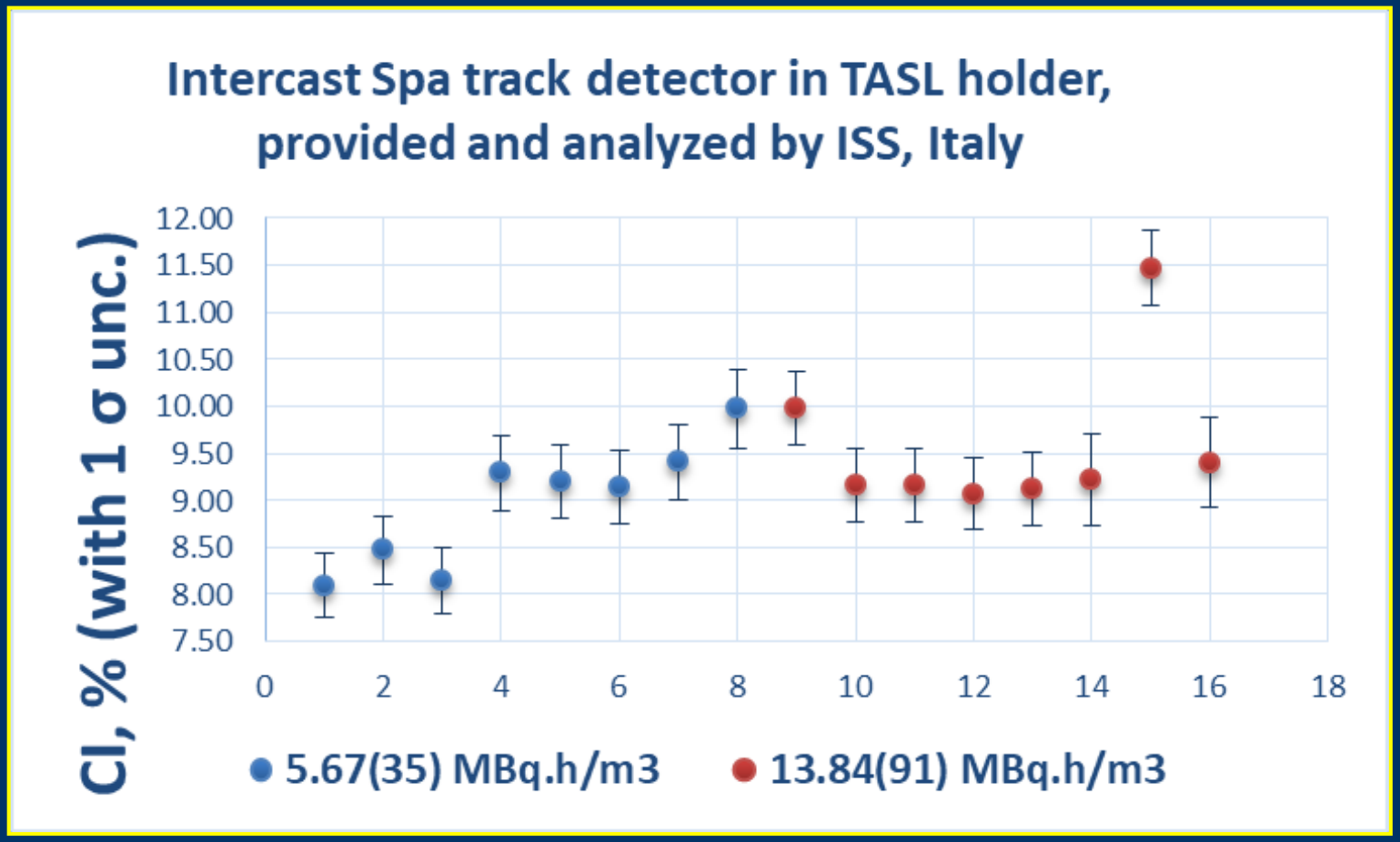
V= 29 cm^3



Average (st. dev): *CI* = 4.80(65) %

Results – track detector by Intercast Spa, Italy in TASL holder

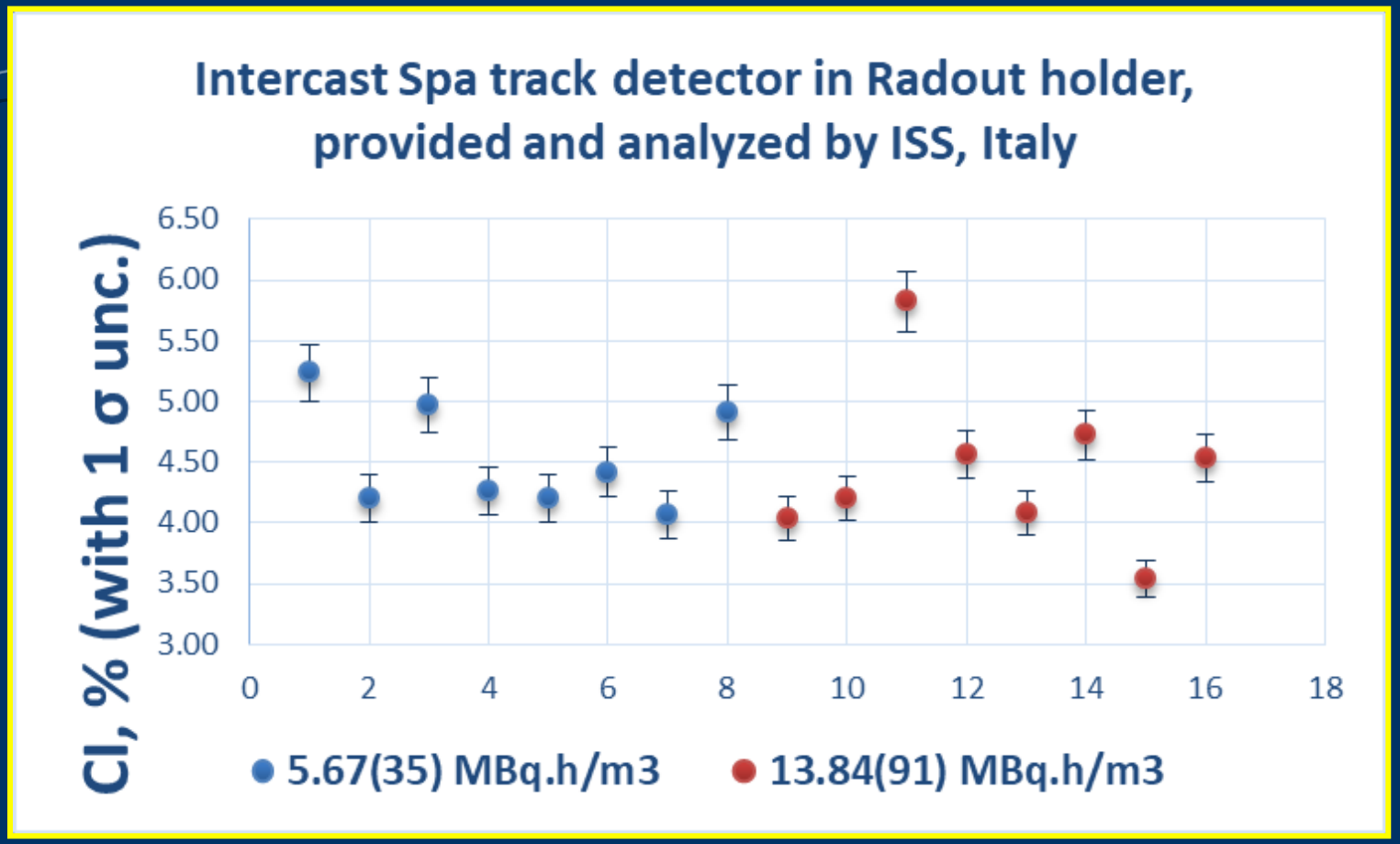
≈ 5 cm diameter; CR-39 detector



Average (st. dev): *CI* = 9.35(93) %

Results - track detector by Intercast Spa, Italy in Radout holder

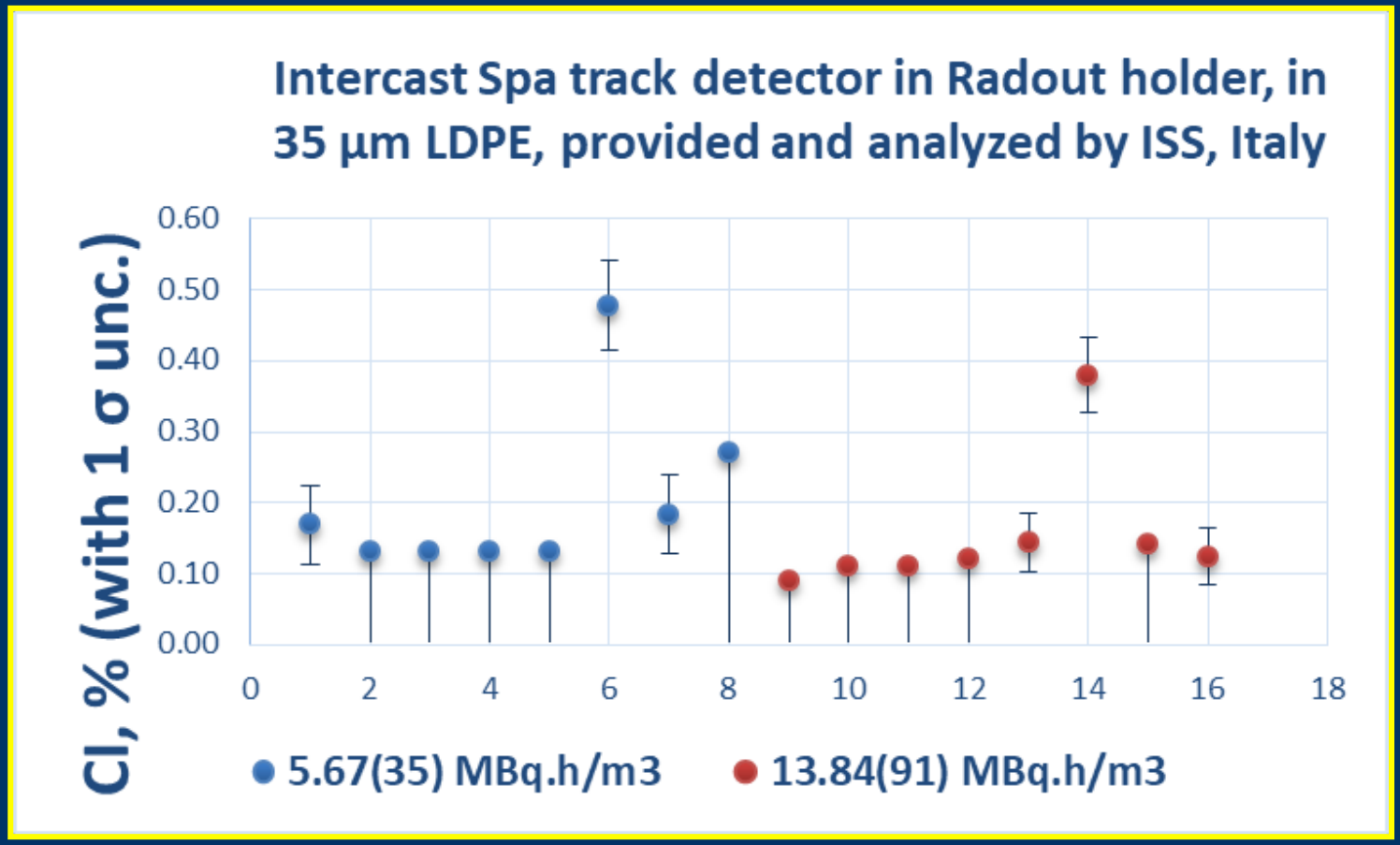
5 cm diameter, 2 cm height; CR-39



Average (st. dev): *CI* = 4.48(55) %

Packed in 35 µm LDPE envelope

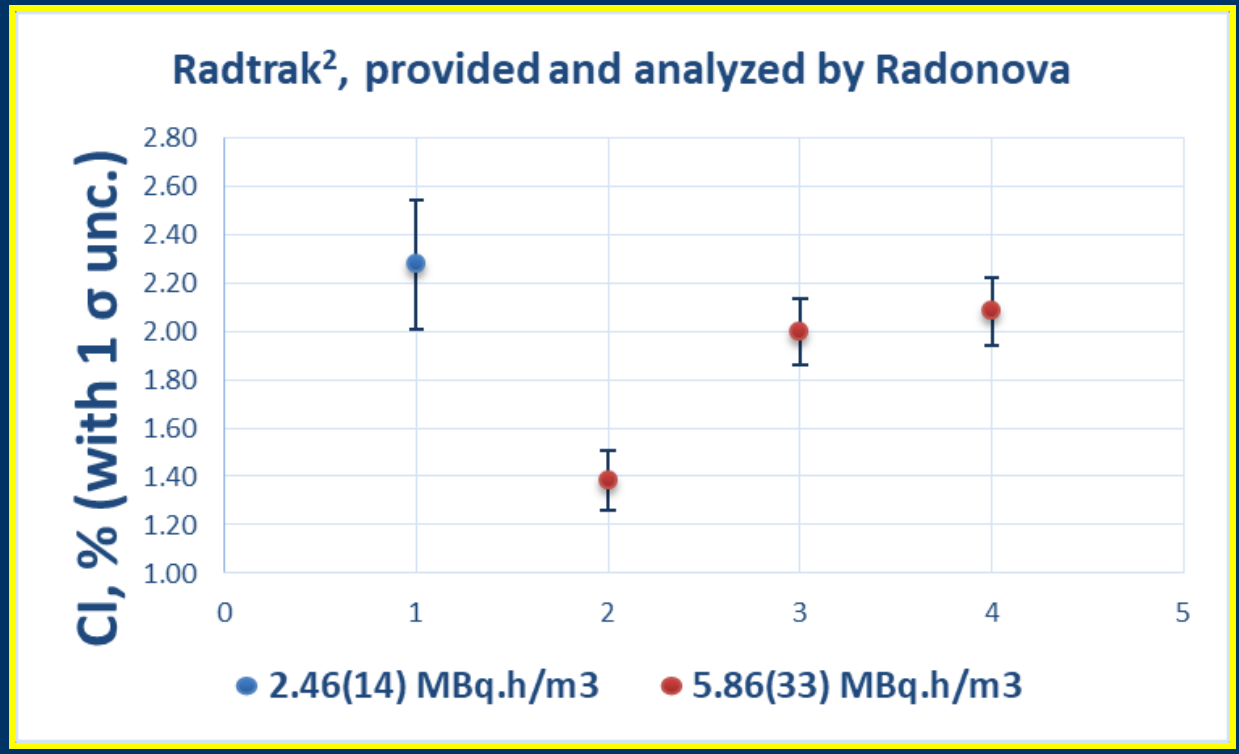
Thoron diffusion length at 21 degrees in LDPE – **16 µm**
(*Georgiev et al., Int. J. Environ. Res. Public Health 2019, 16, p.4523*)

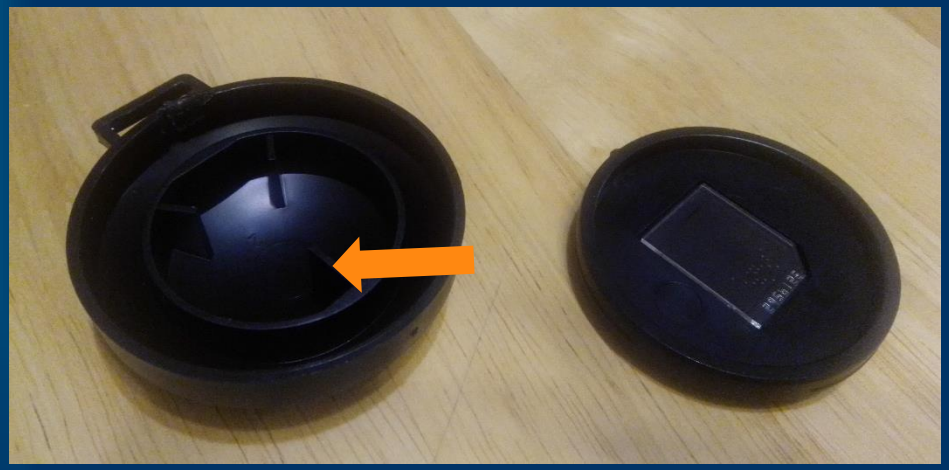


Average of the 6 above critical level: CI = 0.23(14) %

Results – Radtrak^2

Diameter 5.4 cm, Volume 25 cm^3 with CR-39





SUBG - Average of all 4	STUK - average of 6
CI = 1.93(39) %	*CI* = 1.46(50) %

Results – Rapidos

Diameter 5.4 cm, Volume 65 cm^3 with CR-39

Rapidos (provided and analyzed by Radonova)	Estimated radon exposure at 2.46(14) MBq.h/m^3 integrated thoron activity				Cross interference
	E_{Rn} (k Bq h m^{-3})	$u(E_{Rn})$ (k Bq h m^{-3}) (k =1)	$Enet_{Rn}$ (k Bq h m^{-3})		CI, %
134832-5 (blank)	66	6	-	-	
126927-1	55	6	< 14	MDA	**< 0.57**
135752-4	73	7	< 14	MDA	**< 0.57**
130957-4	63	6	< 14	MDA	**< 0.57**

Results – Duotrak

Diameter 5.4 cm, Volume 60 cm^3 with CR-39

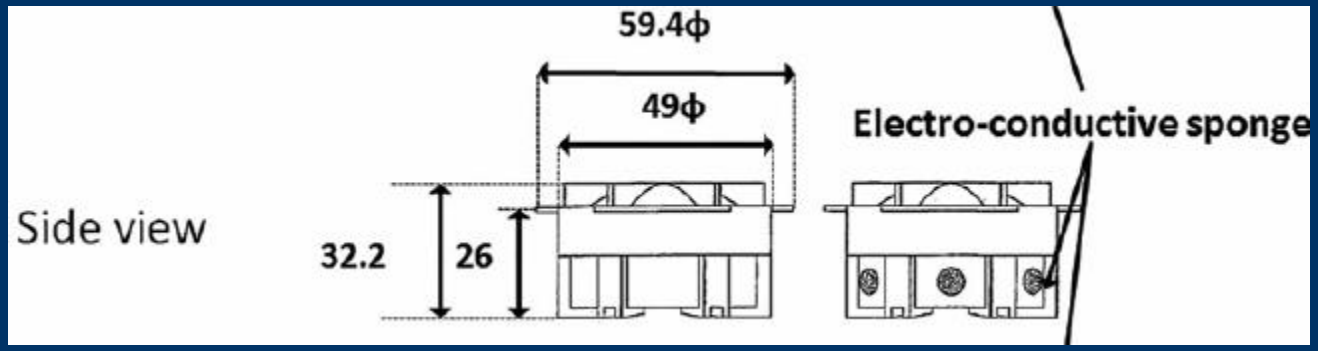
Exposed at 2.46(14) MBq.h/m^3 integrated thoron activity concentration

Detector	Duotrak ON		Duotrak OFF	
	CI, %	u(CI), %	CI, %	u(CI), %
539771-6 (blank)				
539310-3	**11.5**	1.3	**1.79**	0.31
539770-8	**4.07**	0.64	**1.71**	0.31

Results – Raduet (preliminary)

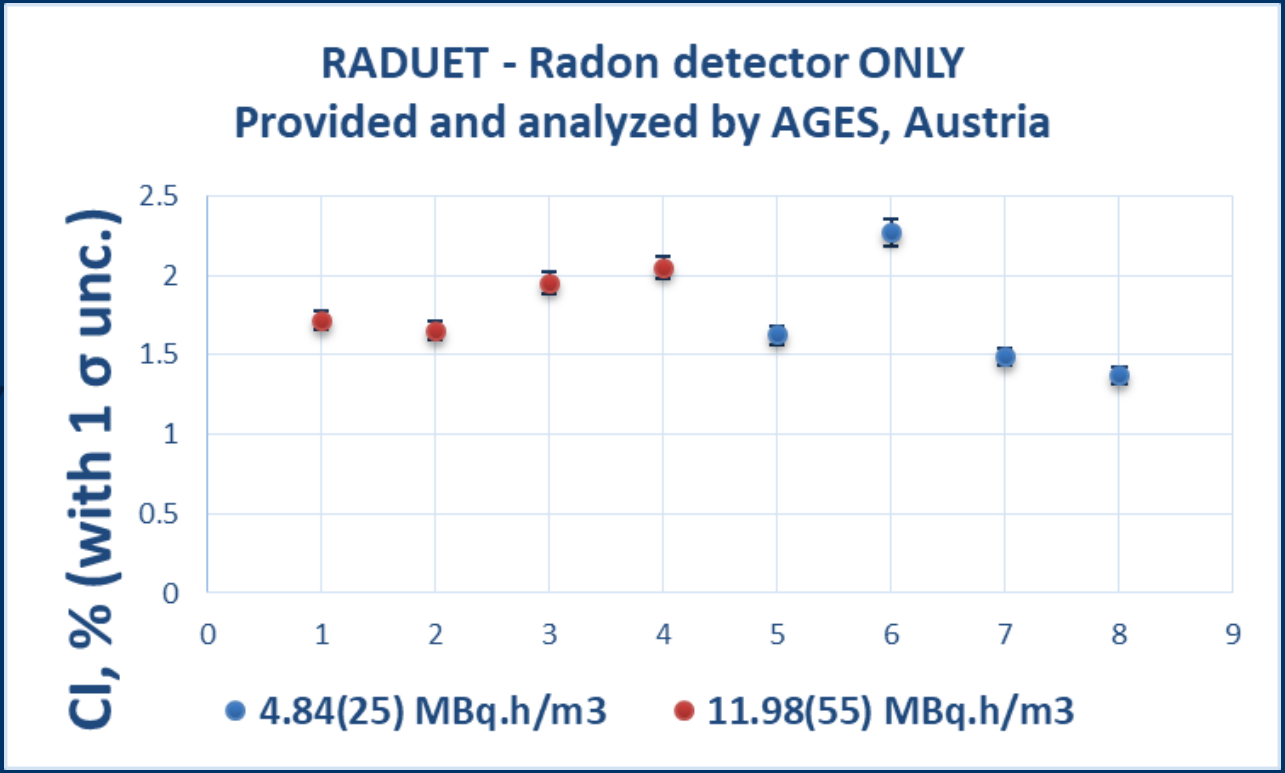
Raduet - Diameter ≈ 5 cm, height ≈ 2.5 cm, Volume 25 cm^3 with CR-39

Provided by AGES, Austria



The two detectors are used in combination. Radon signal is corrected for thoron presence. The corrected values showed no significant thoron *CI* on the radon signal.

Results – Raduet (only low-air exchange)



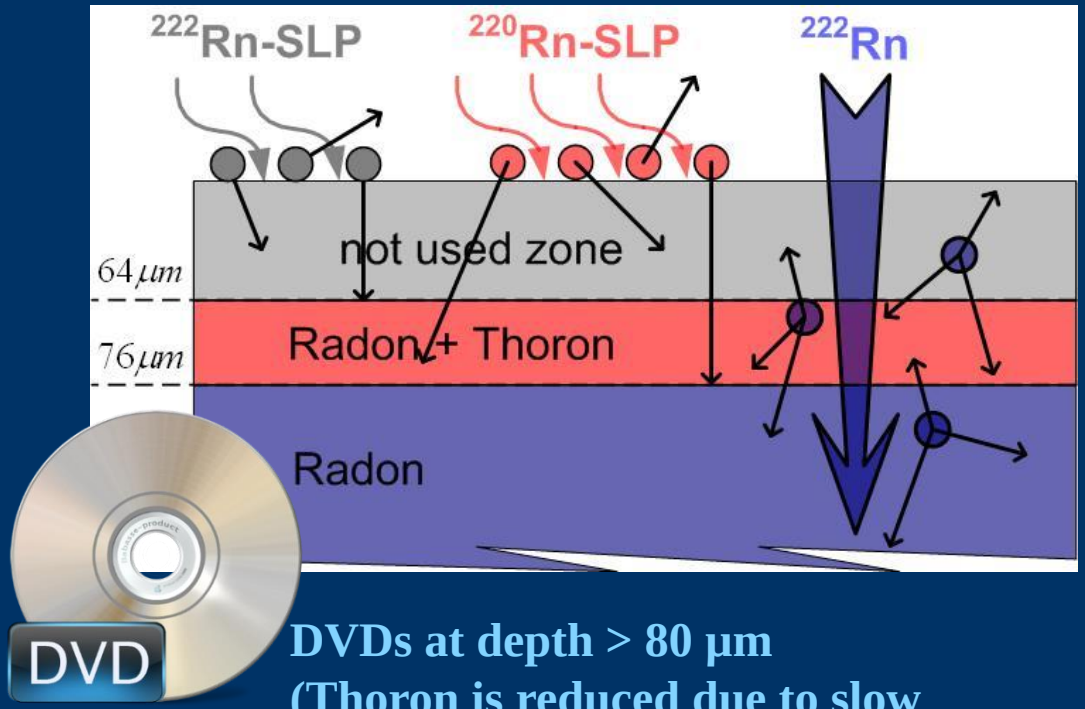
Thoron activity concentration, MBq.h/m3	CI (1 st. dev.), %
Average of all 8	1.76(30)
Average of a set of 8 "old"	1.18(40)
Tokonami et al., J. Environ. Radioact.2015, 150, p. 242.	1.75

Results – SUBG chambers and DVDs

Exposed at 4.84(25) MBq.h/m^3 and 11.98(55) MBq.h/m^3 integrated thoron activity concentration.
All values below critical level. CI value based on MDA is estimated.

SUBG metal chambers with Kodak LR-115/II

***CI* < 0.29 %**

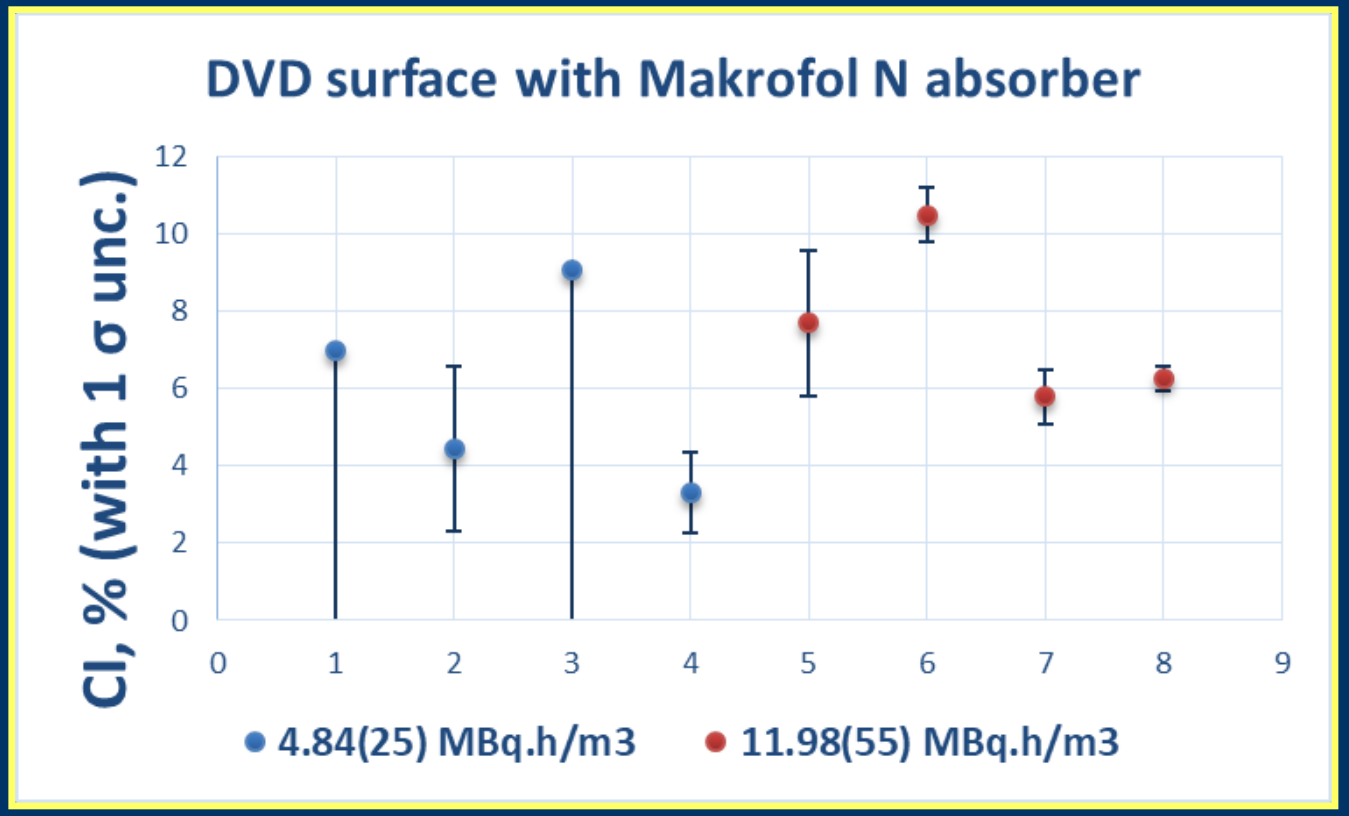


DVDs at depth > 80 μm (Thoron is reduced due to slow diffusion and maximum alfa range)

***CI* < 1.6 %**

Results – DVD + absorbers

Values of *CI*
3.3 – 10.5 %



Reasonable? – semi-quantitative comparison with the simplest model

Transmission factor:

$$R = \frac{C_{in}}{C_{out}} = \frac{1}{1 + \lambda \frac{Vd}{AD}}$$

λ – decay constant;
V – volume;
d – gap length;
A – gap area;
D – diffusion coefficient in air.

The model does not account for :

- slower thoron diffusion inside the detector (diffusion length is about 3 cm);
- different progeny distribution inside the chamber;
- different alpha-particle registration efficiency of the SSNTD.

Those factors are hard to model due to complex inner geometry of the chambers.

Thoron transmission factor – rough estimate

Radosys,
RSKS:
narrow gap,
29 cm^3

Detector	*R*, %	*CI*, %
RSKS	10	4.8
Radtrak^2	17	1.9
Rapidos	7	< 0.57 (MDA)
Duotrak (ON position)	20	4 - 12
SUBG metal chambers	2.0	< 0.29 (MDA)

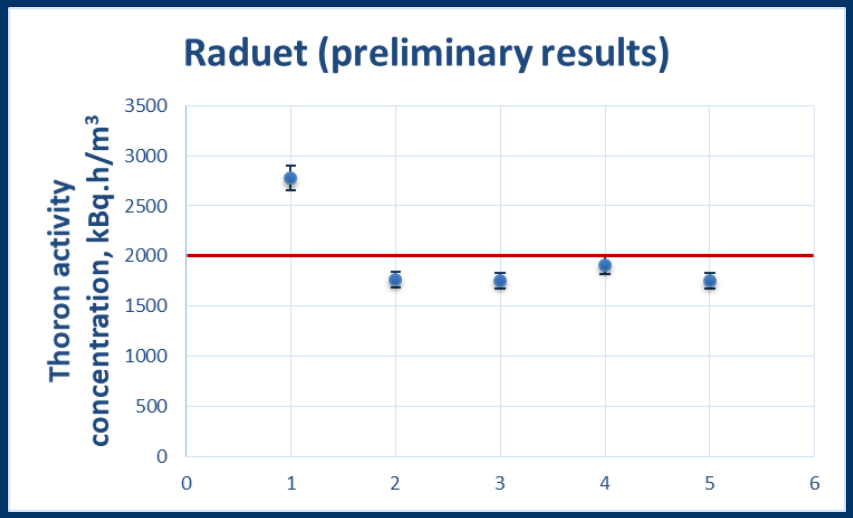
Radonova
Radtrak^2, Rapidos, Duotrak :

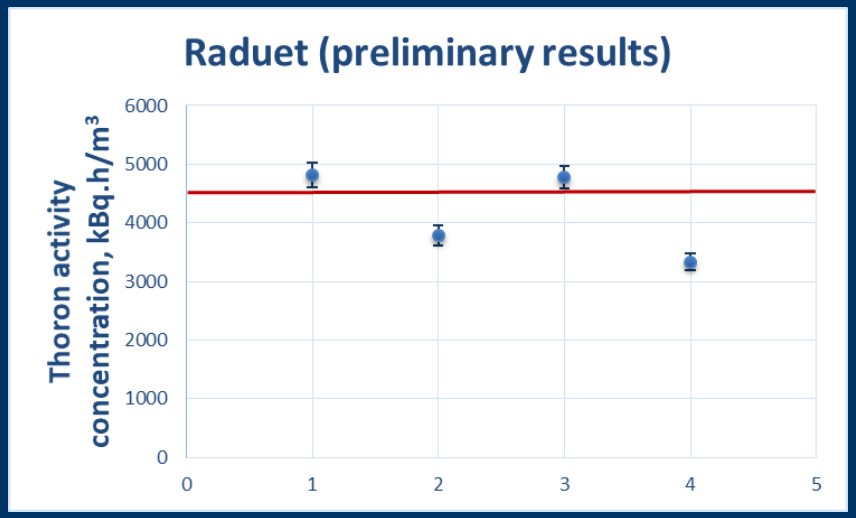
same gap	same gap	wider gap
25 cm^3	**65 cm^3**	**60 cm^3**

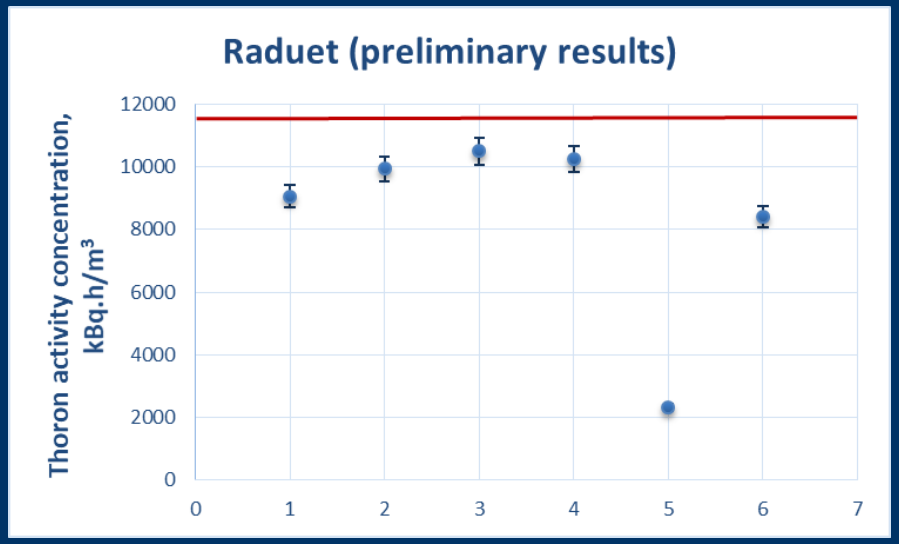
SU metal
chambers:
narrow gap,
290 cm^3

Results from thoron detectors

Raduet (preliminary results)

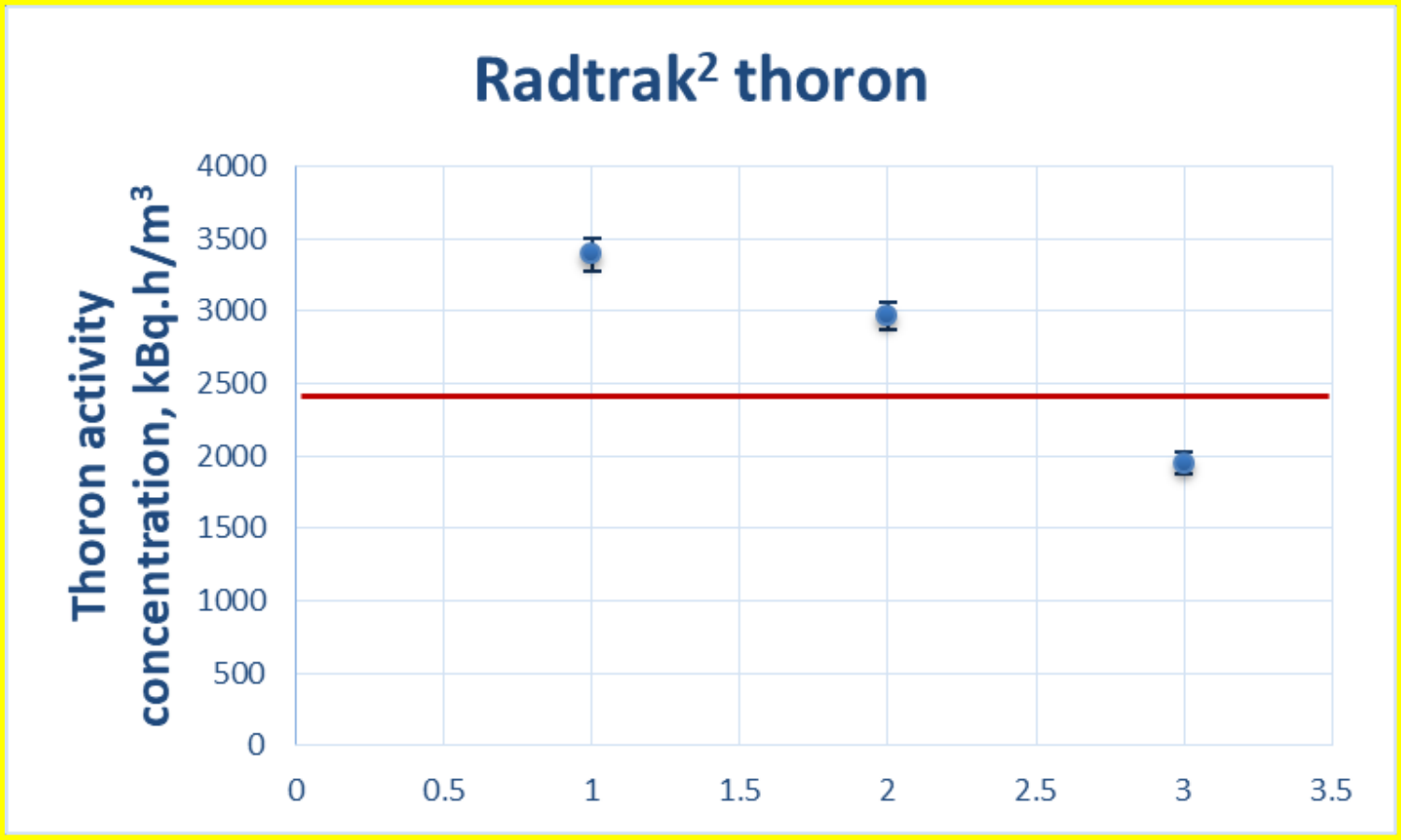






Results from thoron detectors

Radonova – Radtrak^2 thoron



Summary and discussion

- The estimated thoron *CI* on radon result up to 12 % (all below 20 % - the maximum by standard IEC 61577-2).
- Value of *CI* below 5 % can be achieved by diffusion chambers with different constructions varying in height, volume and inner partitions, but with thin gaps.
- For all detectors the standard deviation of the *CI* is larger than the individual uncertainties – Due to air circulation? Results valid for diffusion mode?
- Good agreement between the *CI* of identical detectors exposed in separate exposures;
- Good agreement between independent results for the Radtrak^2 detectors, obtained by SUBG and STUK.

Recommendations – detectors

- The cross interference of thoron on the radon signal should be studied experimentally for each specific detector type (not predicted by dimensions and simple modeling).

- The results should be used as indication for the thoron *CI* and not as a correction factor to be applied for measurements under diffusion mode. (Measures to reduce *CI* discussed in talks by Mitev and Pressyanov.)

Recommendations – *CI* study procedure

- For most diffusion chambers 5 MBq.h/m^3 integrated activity concentration is sufficient to estimate *CI* with adequate uncertainty or to set limits to it < 1 %. For less sensitive detectors like DVDs or for packed detectors 12 MBq.h/m^3 was sufficient.

- The studies should be conducted with care for the homogeneity of thoron in the exposure vessel (testing homogeneity) and the possible influence of the air flow on the results (use more detectors placed at different points and exposed in different sessions and/or with different exposure systems).

Acknowledgements

We are grateful for the provided detectors and their analysis! We would like to thank:

- Radonova and personally to Tryggve Rönnqvist
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Site for experiments at below 0 ºC
available in Bulgaria!
Thank you for
your attention!