



## Recent work with electronic radon detectors for continuous Radon-222 monitoring

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ET D'ESSAIS



# Recent work with electronic radon detectors for continuous Radon-222 monitoring

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c) Université Paris-Saclay, CEA, LIST, Laboratoire National Henri Becquerel (LNE-LNHB), F-91120 Palaiseau, France.

# Motivation

Towards *continuous, metrologically assured, real-time* monitoring of  $^{222}\text{Rn}$  in dwellings and workplaces.



01

Significant number of electronic radon monitors have emerged in the last two decades.



02

These detectors offer an interesting possibility for continuous radon monitoring in dwellings and workplaces



03

Can we perform long term (>1y), continuous measurements with these devices? How sensitive they are? How is it working for data collection, storage and analysis? Can we derive specific quantities with these devices (e.g. seasonal correction factors)? Can these be applied in radon mitigation activities, etc



# Motivation

**Table 2.** Cross-interference signals for all cross-interference tests carried out at STUK and SUBG

Instrument	Tested at	s/n	Test dates	ICI (initial)	FCI (final)
AlphaE	STUK	000260	5–10 Jun 2019 31 Jul–5 Aug 2019	6.5% <sup>a</sup> 8.9% <sup>a</sup>	9.3% <sup>a</sup> 12% <sup>a</sup>
		000542	11–17 Jun 2019 31 Jul–5 Aug 2019	5.6% <sup>a</sup> 8.7% <sup>a</sup>	9.2% <sup>a</sup> 13% <sup>a</sup>
		000499	5–9 Dec 2019	5.7% <sup>a</sup>	8.6% <sup>a</sup>
AlphaE	SUBG	000499	14–17 Oct 2019 22–28 Oct 2019 16–20 Sep 2019 26–30 Sep 2019 4–8 Nov 2019	4.5% 11.5% 10.0% 12.7% 15.5%	13.7% 17.0% 17.1% 18.7% 20.2%
		EF1641	6–9 Aug 2019	5.1–11%	7.2%
		EF0408	22–27 Jan 2020	4.6–9.2%	6.0%
		EF2283	18–22 May 2018 22–24 May 2018		1.1% 0.6%
		PE21812110009 PE21904100016	20–23 August 2019 28 Nov–1 Dec 2019	28% 27%	42% 37%
RadonEye + <sup>2</sup>	SUBG	PE21904100016	14–17 Oct 2019 22–28 Oct 2019 4–8 Nov 2019	32.6% 38.7% 18.7%	52.7% 54.7% 42.3%
		2403008304	20–24 Jun 2019 24–29 Jul 2019		1.8% 2.5%
		2900151289	28 Jun–2 Jul 2019 6–9 Aug 2019		1.3% 2.3%
Airthings Wave Plus	STUK	2930	24–28 Jun 2019 24–29 Jul 2019		2.7% 3.6%
		2700007355 2700007357	3–5 Sep 2018 3–5 Sep 2018	0.2% 0.0%	1.2% 1.6%
TSR3 – Fast mode	SUBG	16014	16–20 Sep 2019 26–30 Sep 2019	1.0% 1.2%	7.7% 12.3%
TSR3 – Slow mode	SUBG	16014	22–28 Oct 2019	2.7%	15.3%
TSR4M – Fast mode	SUBG	19015	22–28 Oct 2019 16–20 Sep 2019 26–30 Sep 2019 4–8 Nov 2019	6.2% – – 11.2%	125% 127% 186% 114%
		19015	22–28 Oct 2019 16–20 Sep 2019 26–30 Sep 2019 4–8 Nov 2019	15.9% – 7.9% 18.7%	85.8% 69.5% 115% 76.4%
		DM357	18–22 May 2018 22–24 May 2018	11% 18%	36% 39%
		DM357	18–22 May 2018 22–24 May 2018	14% 26%	41% 48%
DoseMan Fast Mode	IRSN	DM357			
DoseMan Slow Mode	IRSN	DM357			

The image shows the front cover of a scientific journal article. The title is "Testing of thoron cross-interference of continuous radon measuring instruments". The authors listed are Tuukka Turtiainen\*<sup>1</sup>, Krasimir Mitev<sup>2</sup>, Rohafza Dehqanzada<sup>1</sup>, Olli Holmgren<sup>1</sup> and Strahil Georgiev<sup>2</sup>. The journal logo "UERA" is at the top left, and the subtitle "ORIGINAL RESEARCH" is below it. The journal's name "UERA" is also part of the logo. The background of the cover features a stylized globe graphic.

We purchased 36 RadonEye+2 (RE) detectors



Range: from 7 to 9,435 Bq/m<sup>3</sup>,  
Wifi Access (each 10 min),  
internal storage (1 hour measurement)

Courtesy to Tuukka Turtiainen from STUK for the useful discussions and the information provided for the various detectors.

# Contents

- Laboratory tests of the response of detectors
- Data collection, handling and analysis
- First results of real-time monitoring of radon dynamics with these detectors
- Summary

# Laboratory tests of the response of RE detectors @ LNHB

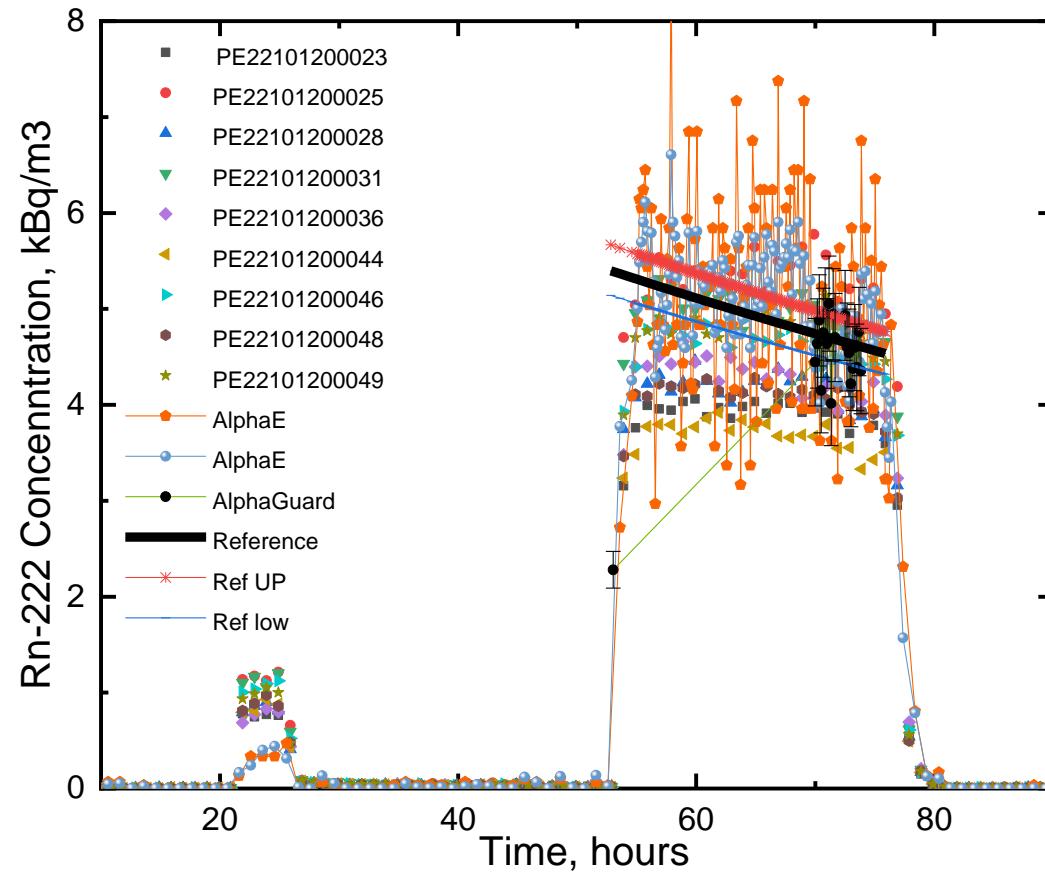


Experimental facility for the production of reference atmosphere of radioactive gases (Rn, Xe, Kr, and H isotopes)

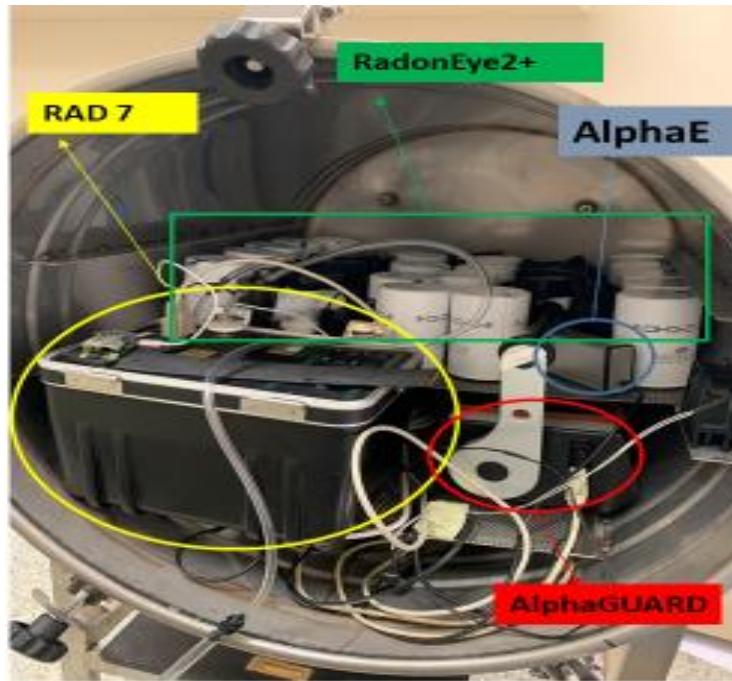
B. Sabot\*, M. Rodrigues, S. Pierre  
CEA LIST, Laboratoire National Henri Becquerel (LNE/LNHB), 91191, Gif-sur-Yvette Cedex, France



AlphaE Sensitivity:  
3 cph at 100 Bq/m<sup>3</sup>



# Laboratory tests of the response of RE detectors @ Sofia University



Journal of Environmental Radioactivity 166 (2017) 181–187  
Contents lists available at ScienceDirect  
**Journal of Environmental Radioactivity**  
journal homepage: [www.elsevier.com/locate/jenvrad](http://www.elsevier.com/locate/jenvrad)

Laboratory facility to create reference radon + thoron atmosphere under dynamic exposure conditions

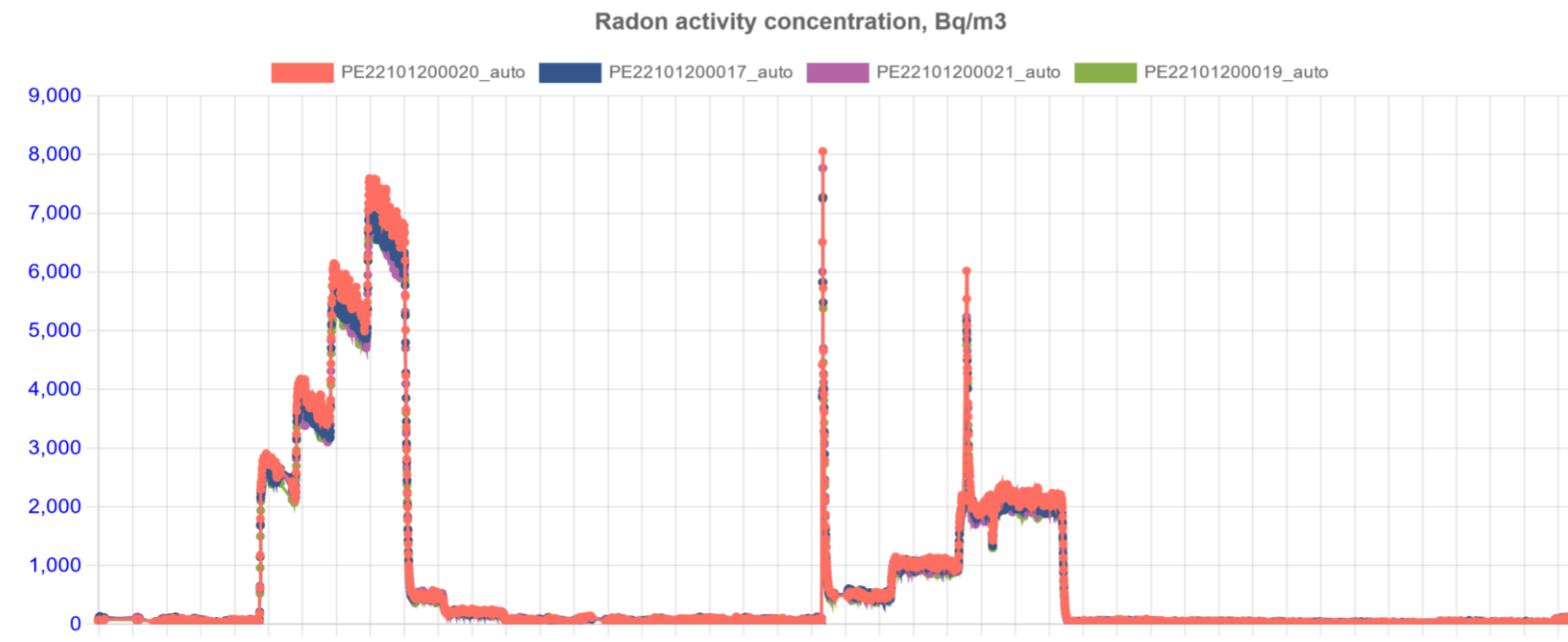
D. Pressyanov <sup>a,\*</sup>, K. Mitev <sup>a</sup>, S. Georgiev <sup>a</sup>, I. Dimitrova <sup>a</sup>, J. Kolev <sup>b</sup>

<sup>a</sup> Faculty of Physics, Sofia University "St. Kliment Ohridski", Sofia 1164, Bulgaria

<sup>b</sup> Micon K Ltd., Varna 9000, Bulgaria

Upgraded:

- to host 40+ detectors
- Constant  $^{222}\text{Rn}$  concentrations in the lower  $A_V$  range



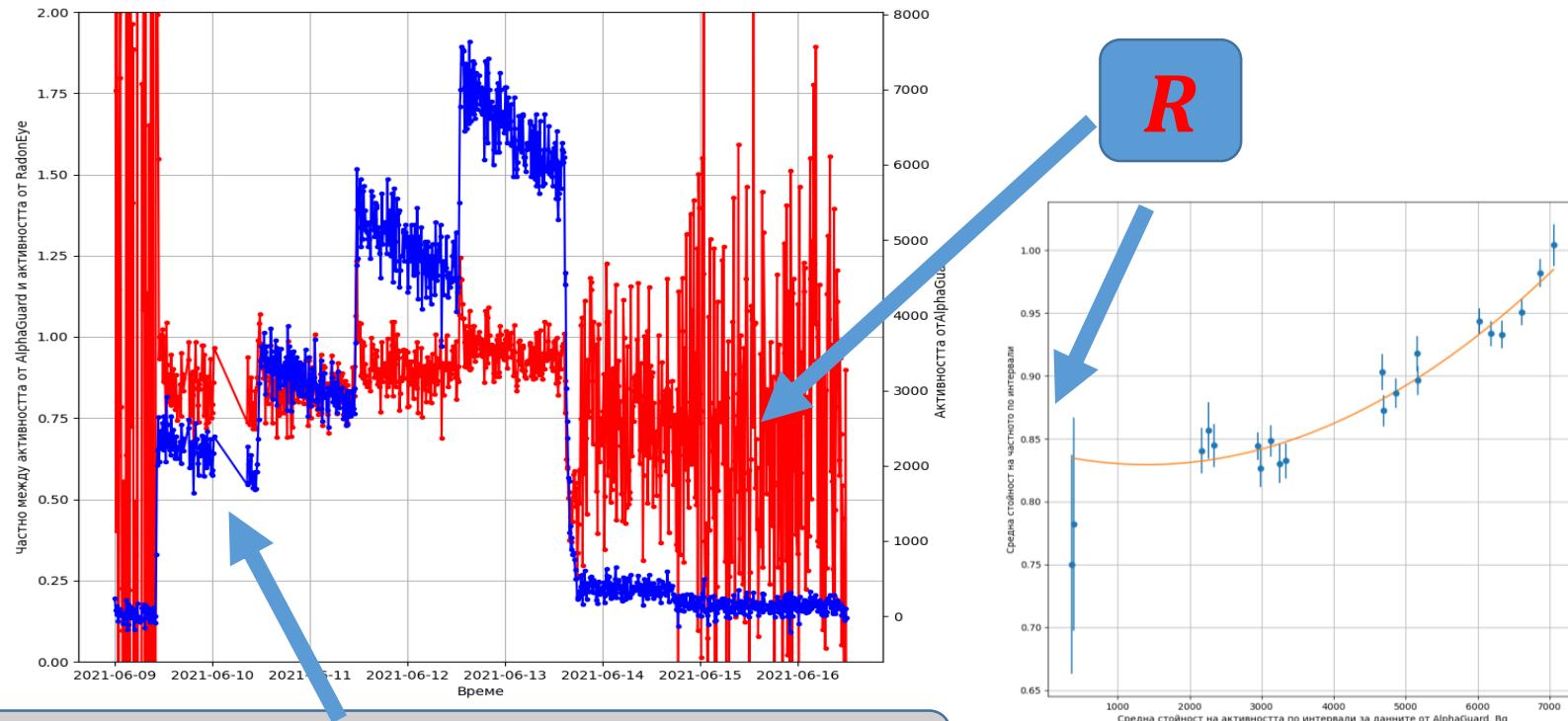
# Results of the laboratory tests of the response of RadonEye+2 detectors

$$R = \frac{A_{V,ref}}{A_{V,RadonEye}}$$



Radon Eye No	AG LNHB	
	R	$\sigma_R$
PE22101200023	1.210	0.066
PE22101200025	0.876	0.056
PE22101200028	1.155	0.070
PE22101200031	0.959	0.052
PE22101200036	1.138	0.063
PE22101200044	1.306	0.074
PE22101200046	1.025	0.054
PE22101200048	1.159	0.061
PE22101200049	0.976	0.055

$$\bar{R} = 1.09(14) \text{ @ } 4.6 \text{ kBq/m}^3$$

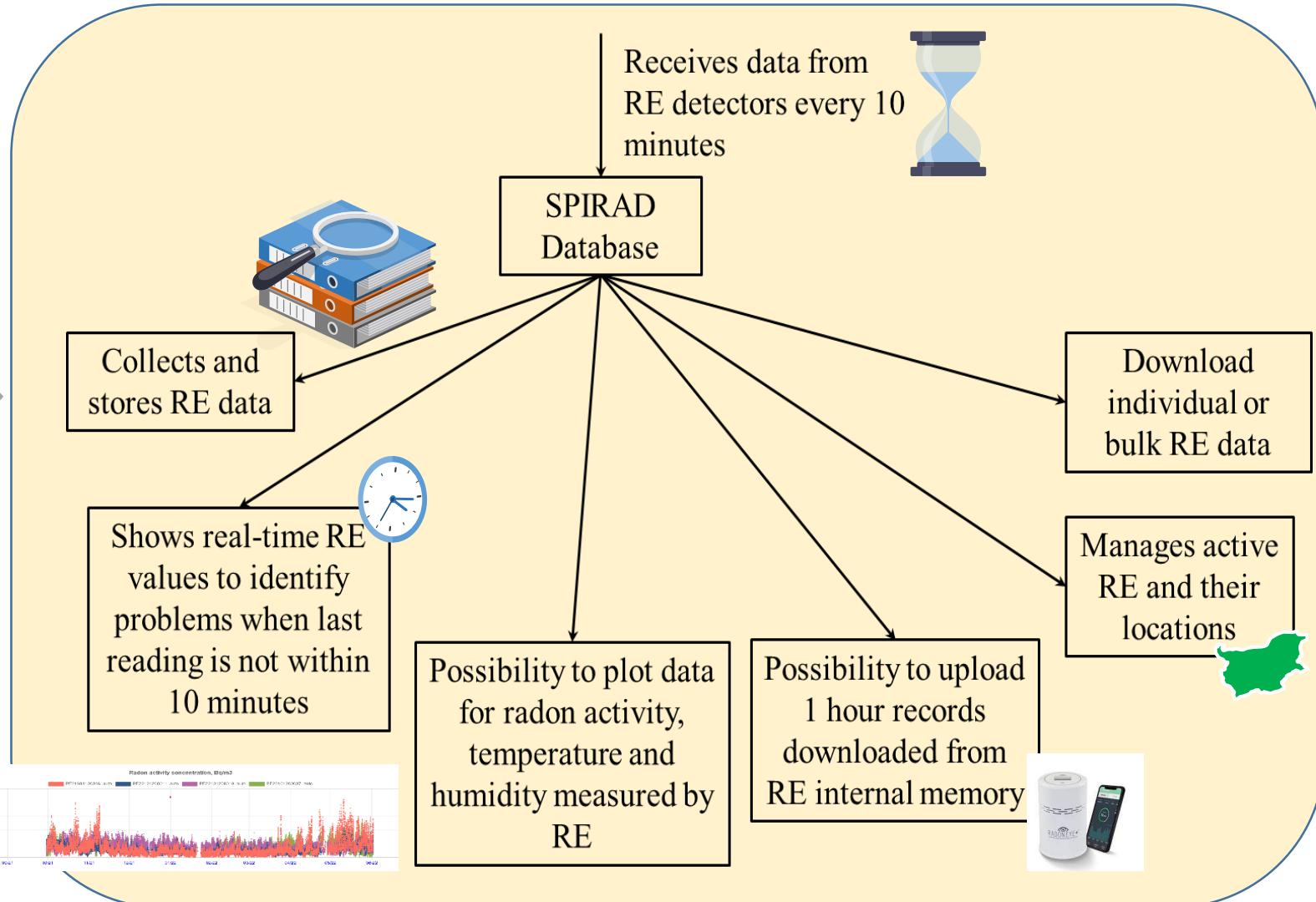


*Radon activity concentration*

*Linear response in the range 0 – 3.5 kBq/m<sup>3</sup>*

*Slight non – linearity in the range 3.5 – 7 kBq/m<sup>3</sup> (<15 %)*

# Data collection, handling and analysis – the SPIRAD database



# Data collection, handling and analysis – the SPIRAD database

Select detectors

Write nicknames OR Add from list

Nickname, Nickname2, ...  
RE01 PE21904100016, RadonEye 2+  
RE02 PE22101200007, RadonEye 2+  
RE03 PE22101200011, RadonEye 2+  
RE04 PE22101200017, RadonEye 2+  
RE05 PE22101200019, RadonEye 2+  
RE06 PE22101200020, RadonEye 2+

Input Type (For RadonEye)  
auto  
Start Date (Optional)  
05 / 10 / 2022 UTC time  
End Date (Optional)  
05 / 15 / 2022 UTC time

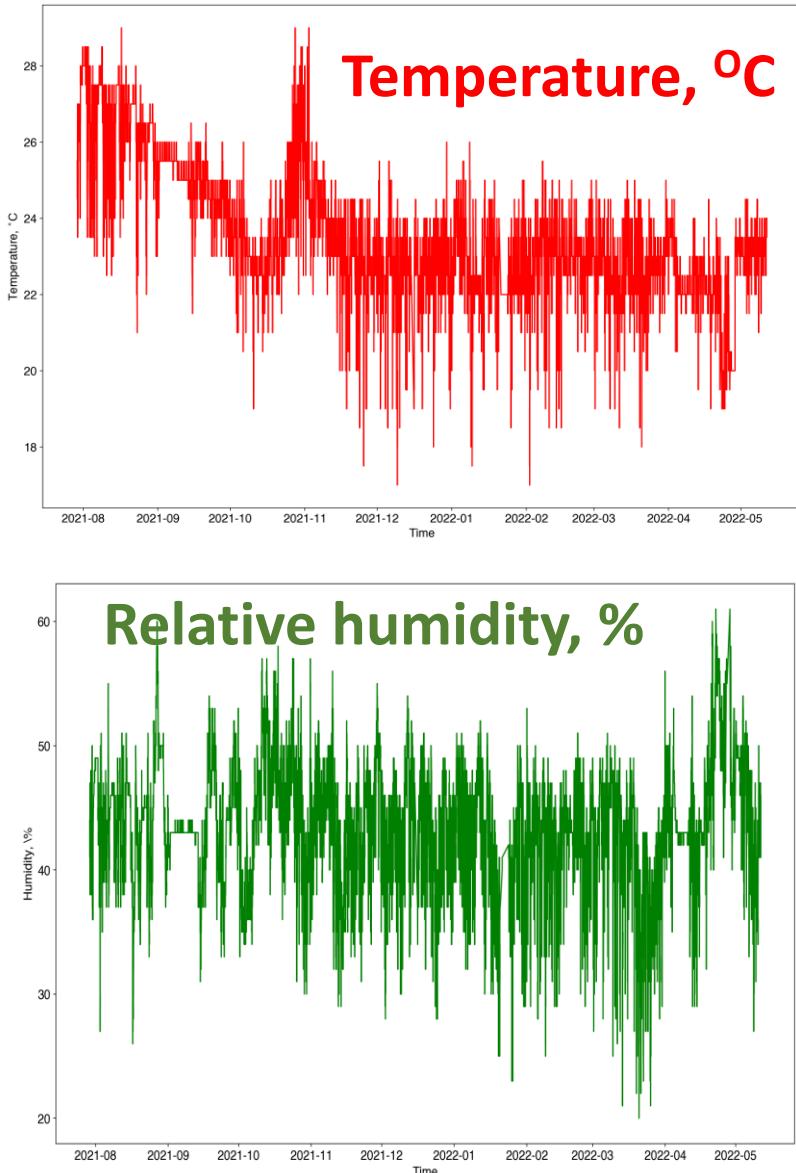
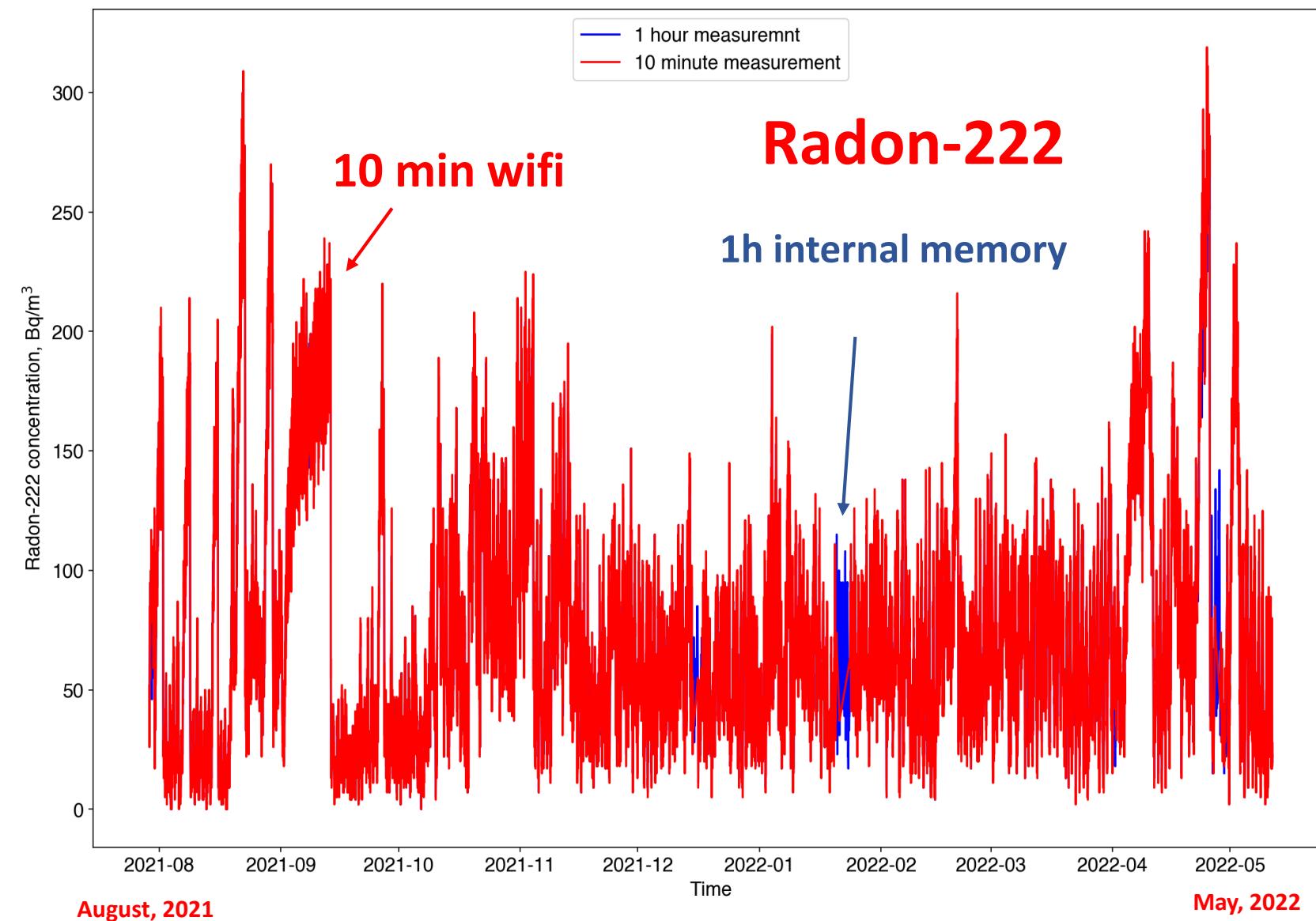
Show charts

Select



The SPIRAD database allows to output measurement data in formats convenient for application of machine learning algorithms, time series analysis, etc.

# Results: Example from a measurement in a house (10 months)



# Results: Uptime & Active (>90% of the total time)



RadonEye +2 Wifi broadcasting (10 min reports, uptime >91% of the total time)

Det	date placed at location	started broadcasting	uptime	downtime	Uptime, %
RE07	2021-07-28 10:30:00	2021-07-28 11:08:03	263 days 20:21:37	23 days 10:37:39	91.8
RE11	2021-07-29 11:55:00	2021-07-29 11:55:28	264 days 23:17:55	21 days 06:54:43	92.6
RE16	2021-06-10 08:30:00	2021-06-10 10:07:45	314 days 23:03:15	19 days 07:30:10	94.2
RE19	2021-07-28 13:00:00	2021-07-28 13:29:37	272 days 22:46:30	14 days 05:47:23	95.0
RE33	2021-07-29 10:00:00	2021-07-29 11:28:06	272 days 01:00:43	14 days 05:38:42	95.0
RE34	2022-02-18 07:00:00	2022-02-18 09:30:13	75 days 23:44:43	6 days 08:53:51	92.3



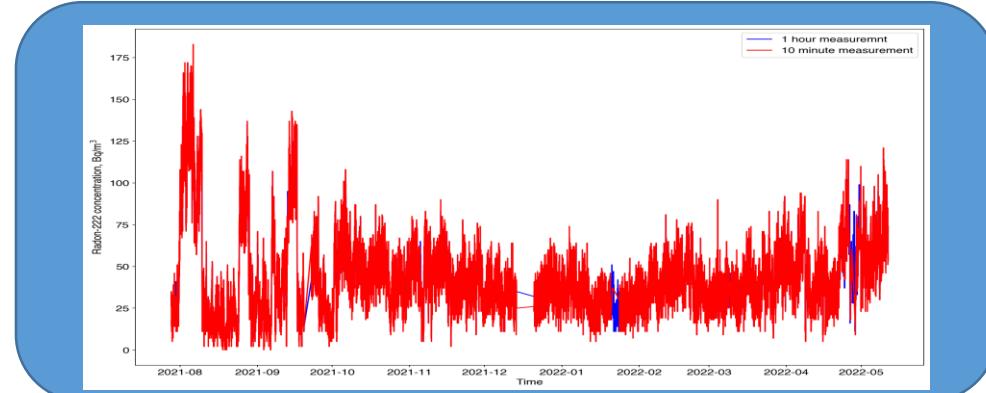
RadonEye +2 internal memory (1 hour record, uptime >96% of the total time)

Det	date placed at location	started broadcasting	uptime	downtime	Uptime, %
RE07	2021-07-28 10:30:00	2021-07-28 11:08:03	270 days 03:41:22	10 days 20:07:50	96.14
RE11	2021-07-29 11:55:00	2021-07-29 11:55:28	285 days 13:24:31	0 days 14:57:11	99.78
RE33	2021-07-29 10:00:00	2021-07-29 11:28:06	285 days 16:26:00	0 days 10:53:24	99.84

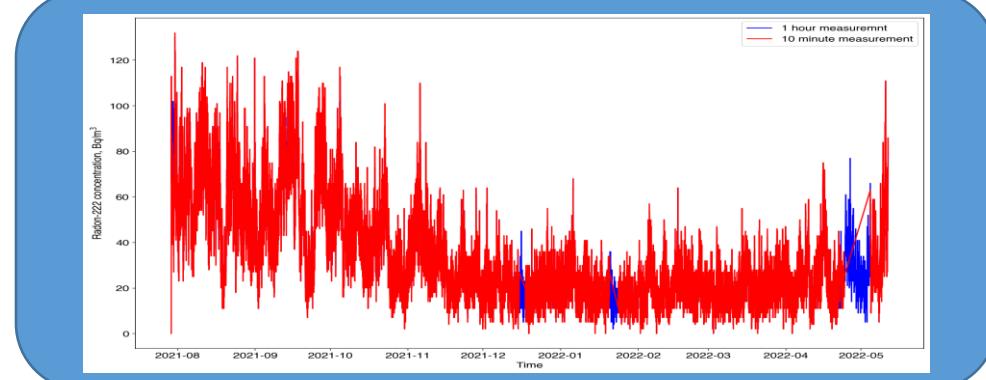
# Results: $^{222}\text{Rn}$ statistics (examples). Excellent agreement



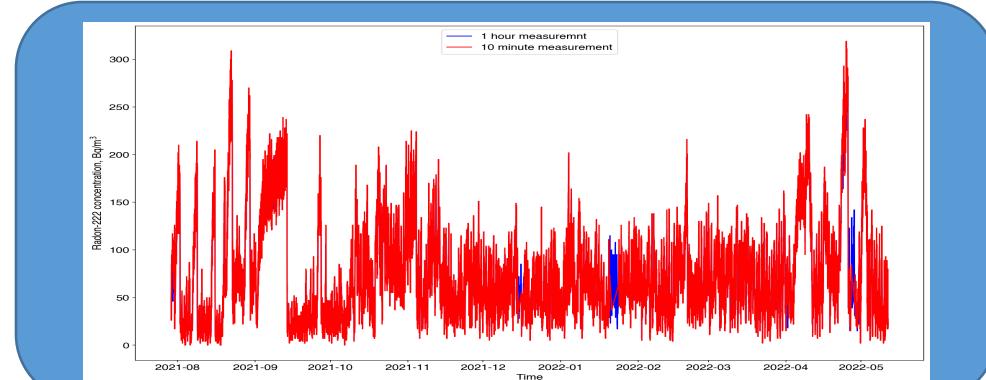
RE07	Wifi	Internal storage
	10 min measurements	1 h measurements
MEAN	42.5	42.6
STDEV	22.9	22.9
MEDIAN	39	39
MAD	12	12



RE11	Wifi	Internal storage
	10 min measurements	1 h measurements
MEAN	33.8	33.3
STDEV	21.6	21.4
MEDIAN	27	27
MAD	11	11

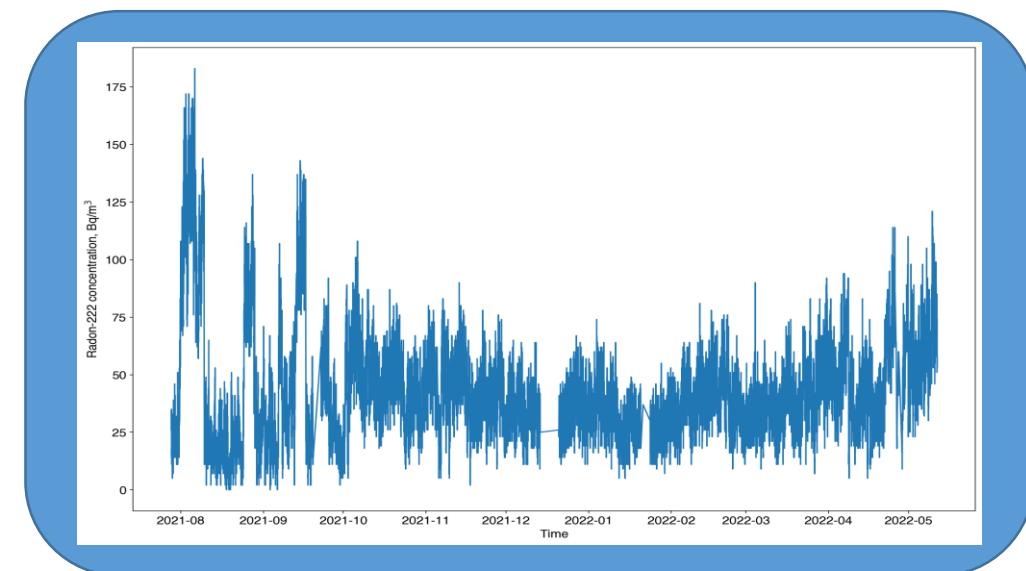


RE33	Wifi	Internal storage
	10 min measurements	1 measurements
MEAN	73.7	74.2
STDEV	49	49.5
MEDIAN	63	63
MAD	28	28

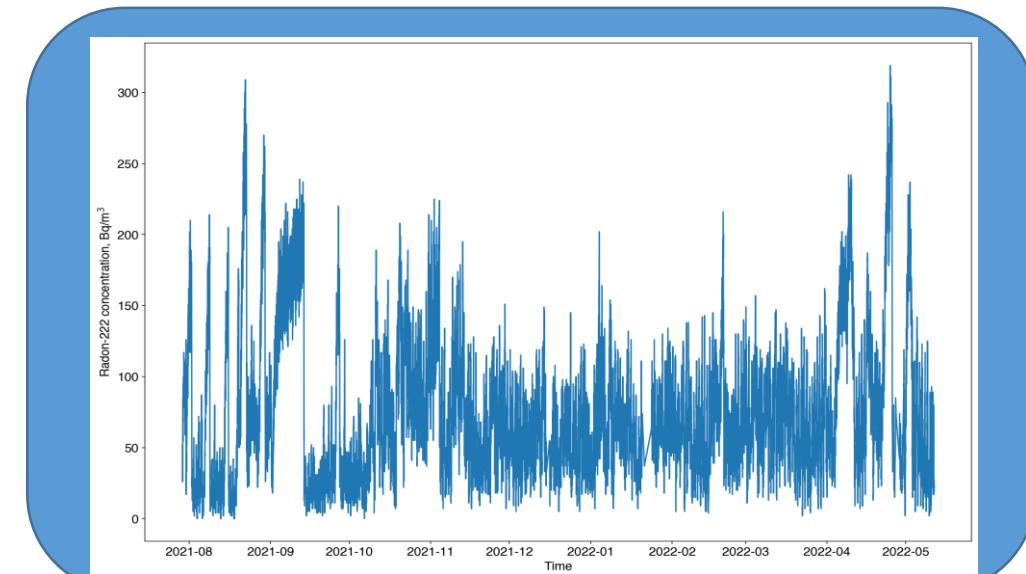


# Results: Studies of seasonal $^{222}\text{Rn}$ dynamics (examples)

	RE07 ( 9 months measurements)			
	Autumn	Winter	All	Autumn/All
MEAN	41.8	35.1	42.5	0.984
STDEV	15.3	11	22.9	
STDEV MEAN	0.1	0.1	0.1	
MEDIAN	41	35	39	1.051
MAD	10	7	12	



	RE33( 10 months measurements)			
	Autumn	Winter	All	Autumn/All
MEAN	68.4	65.7	73.7	0.928
STDEV	40.3	29.1	49	
STDEV MEAN	0.4	0.3	0.2	
MEDIAN	59	63	63	0.937
MAD	26	20	28	



# Summary



01

The RadonEye+2 are good instruments for continuous radon monitoring  
Calibration factor within 15% to the reference, linear below 3.5 Bq/m<sup>3</sup>, slight non-linearity for radon concentrations in the interval 3.5-7 kBq/m<sup>3</sup>

02

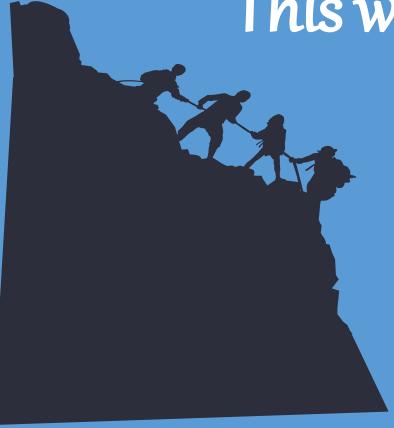
The online database is an important tool to collect, store and visualize radon data  
Monitors and assures reliable operation and data storage. Creates warnings when the connection with the detectors is lost. Enables real time radon monitoring at many places

03

Excellent data collection efficiency  
> 91 % uptime online, >96% uptime with internal storage. Convenient interface for data analysis (machine learning, AI, time series, etc.)

04

Provides reliable data for indoor radon dynamics, which is useful for various purposes  
E.g. Evaluation of early average radon concentration, seasonal correction factors, radon correlation with environmental factors, etc..



This work is supported by the Bulgarian National Science Fund under project  
“Surveillance and Perusal of Indoor Radon Dynamics (SPIRAD)”

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Thank you for your attention.