



A new CR-39 based passive device for Radon/Thoron measurements

STUDY - DEVELOPMENT - CALIBRATION

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**The II radon-in-field international intercomparison for passive measurement devices
dwellings and workplaces**

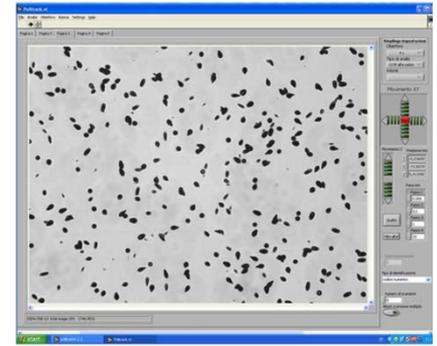
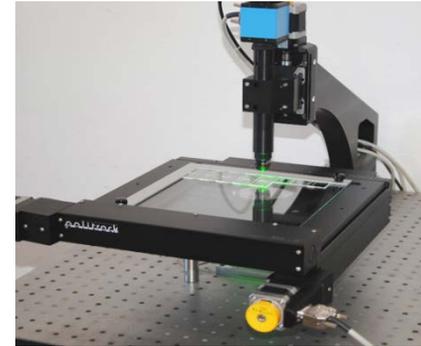
2017 SEPT 21-22, MILAN

TARGET

Combined passive measurements of Radon and Thoron exposures

INSTRUMENTS AND DEVICES

- Mi.am Politrack[®] multi purpose track reading system
- 25x25 CR-39 nuclear track detectors
- Mi.am design Radout[®] holder
 - Radon diffusion estimated time:
30/45 min



RADON/THORON PASSIVE MEASURE METHODS

- Single dosimeter method: track analysis
- Double dosimeter method: exposure difference

PROPOSED METHOD

Multi-dosimeter device – Rn/Tn exposure difference → Issues:

1. Separate Rn-222 and Rn-220 contributes to exposure
2. Device calibration in pure Thoron and Mixed Rn/Tn conditions

+

3. Evaluation of Rn-220 interference in our standard Radout[®] dosimeter

MI.AM TRIPLET DEVICE – STUDY PURPOSE

- **Modified Radout®** → maximize Rn-220 penetration → Rn-222+Rn-220 Measure
- **Sealed Radout®** → avoid Thoron penetration → Rn-222 only Measure
- **Radout® Holder** → Mi.am standard for Radon → Rn-220 interference evaluation



SEALED



RADOUT



MODIFIED



MI.AM TRIPLET DEVICE - Sealed Radout®

- Sealed in low density polyethylene bags (No Rn-220 - Diffusion time \approx hours)
- Tested in pure Rn-222 Vs Mi.am standard Radout® in CESNEF Radon Chamber



REFERENCE VALUES	
Exposure (kBqh/m ³)	753,1
Uncert. (95%)	76,1
READINGS (10 DEVICES)	
Average	797
St.dev.	18,7
St.dev. %	2,3
TRS	25
Net Value	772
Difference %	2,5



REFERENCE VALUES	
Exposure (kBqh/m ³)	753,1
Uncert. (95%)	76,1
READINGS (10 DEVICES)	
Average	779
St.dev.	14,6
St.dev. %	1,9
TRS	25
Net Value	754
Difference %	0,1

FOCUS POINTS

- Mi.am dosimetry system is calibrated in BFS-CESNEF-INMRI
- CF confirmed by very good results in 2017 BFS Intercomparison

No significant difference between Sealed dosimeter compared to Mi.am standard Radout® dosimeter

MI.AM TRIPLET DEVICE - Modified Radout®

- Modified: top hole + **conductive tyvek** = Increase Rn-220 penetration
- Tested in pure Rn-222 Vs Mi.am standard Radout® Dosimeter in CESNEF Radon Chamber



REFERENCE VALUES	
Exposure (kBqh/m ³)	1962
Uncert. (95%)	197
READINGS (10 DEVICES)	
Average	2021
St.dev.	56
St.dev. %	2,8
TRS	54
Net Value	1967
Difference %	0,2



REFERENCE VALUES	
Exposure (kBqh/m ³)	1962
Uncert. (95%)	197
READINGS (8 DEVICES)	
Average	2237
St.dev.	87
St.dev. %	3,9
TRS	33
Net Value	2204
Difference %	12,3

Significative difference between Modified dosimeter and standard Radout (avg. +12%)

→ Possible explanation: different internal chamber geometry

MI.AM TRIPLET DEVICE – Rn-220 TESTING



Well characterized in Rn-222 atmosphere

Exposure in Thoron atmosphere:

- ✓ Separate Rn-222 and Rn-220 contributes to exposure with Sealed and Modified dosimeters
- ✓ Find proper formulation for Thoron exposure calculation

- ✓ Evaluate Thoron penetration in Radout[®] dosimeter

MI.AM TRIPLET DEVICE – NAPLES October 2016

- Prof. Roca **Thoron Chamber** – Reference Exposure 3145 kBqh/m³
- 6 Triplets exposed in Rn-220 chamber + 1 transit Triplet

RESULTS - EXPOSURE kBqh/m ³							TRANSIT
TIPLET #	1	2	3	4	5	6	7
MODIFIED RADOUT	1488,7	1628,5	1812,3	1446,6	1321,4	1377,6	32,7
SEALED RADOUT	38,8	14,7	21,8	19,4	36,1	28,8	9,5
STD RADOUT	139,0	141,2	108,0	181,1	451,1	458,9	12,3

MODIFIED RADOUT (Radon CF)		
AVG	DEV.ST %	AVG NET
1513	11,9%	1480
Reference Rn-220 Exposure		
		3145 kBqh/m³
Formulation and Thoron CF to be determined		

SEALED RADOUT		
AVG	DEV.ST %	AVG NET
27	36,2%	17,1
% AVG Rn-220 Penetration		0,5 %
<i>*Environmental Rn-222 must be considered</i>		

STD RADOUT		
AVG	DEV.ST %	AVG NET
247	66,2%	234,3
% AVG Rn-220 Interference		7,4 %
% MAX Rn-220 Interference		14,1 %

MI.AM TRIPLET DEVICE – THORON CALIBRATION

$$DIFF = (M - T_M) - 1,12 * (S - T_S)$$

$$EXP_{THORON} = K * DIFF$$

- **DIFF** = Exposure Modified Radout (**M**) minus Exposure Sealed Radout (**S**)
- Modified dosimeter overestimates Rn-222 (+12%)
- T_M and T_S = Transits

TIPLET #	1	2	3	4	5	6
DIFF	1423	1590	1766	1403	1259	1323

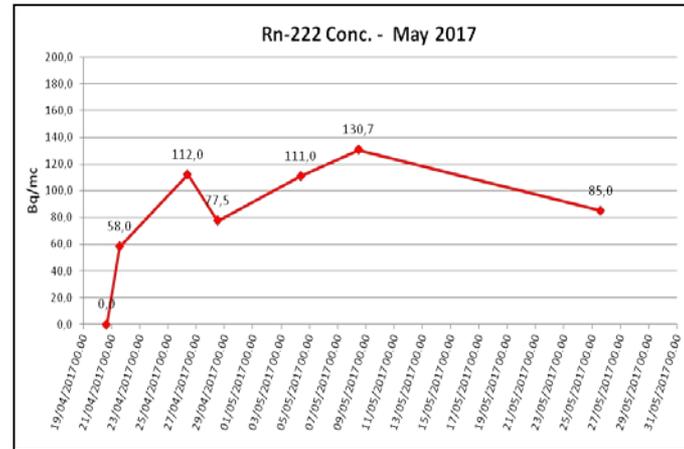
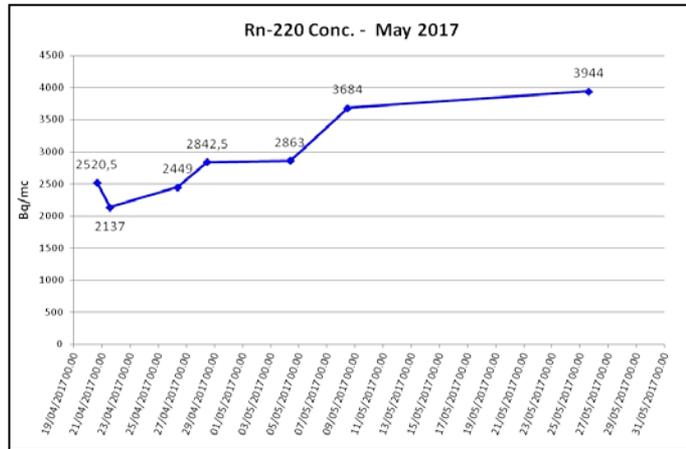
<i>AVG DIFF</i>	1461
<i>% St.dev. DIFF</i>	12,8%

Reference Rn-220 Exposure	3145	kBqh/m ³
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Estimated K coefficient	2,15
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MI.AM THORON DRUM – Rn-220 Measurement Test

- Originally intended for a different study
- Little volume + fan → Hypotesis: uniform Thoron conc.
- Spot monitoring - Miam Rn/Tn Routines
- Raw estimation of Rn and Tn Exposure



Non-constant Rn-220 concentration: environmental effects (RH)?

MIAM THORON DRUM – TEST RESULTS

MODIFIED RADOUT (Radon CF)				AVG MOD
Exposure kBqh/m ³	1254	1229	1367	1283

STD RADOUT				AVG
Exposure kBqh/m ³	400	398	401	399,5

RAW EXPOSURES FROM SPOT MONITORING		
THORON	2788	kBqh/m ³
RADON	90	kBqh/m ³

Evaluation of Rn-220 penetration in Radout®

$$Contamin_{Rn-220} = \frac{[399,5 - 90]}{2788} = 11,1 \%$$

Thoron exposure calculation

$$EXP_{Rn-220} = K * [(1283) - 1,12 * (90)] = 2542 \text{ kBqh/m}^3$$

$$^{220}\text{Rn REF Deviation} = -8,8 \%$$

RADON/THORON MEASURING METHODS

- Techniques properly tested in Rn+Tn chamber (**SURO Prague**)

ROUTINES TEST IN SURO LABORATORY - PRAGUE

26/06/2015

Monitor: MR-1 PLUS s/n 34

GRAB SAMPLING			Result % Deviation
Rn-220 Reference 1	84467 ± 3084	Bq/m ³	-0,3%
Rn-220 Reference 2	83628 ± 2956	Bq/m ³	-1,4%

FLUX SAMPLING			Result % Deviation
Rn-220 Reference 1	2953 ± 266	Bq/m ³	8,4%
Rn-222 Reference 1	6965 ± 348	Bq/m ³	-6,6%
Rn-220 Reference 2	3289 ± 230	Bq/m ³	3,8%
Rn-220 Reference 3	3369 ± 269	Bq/m ³	0,7%
Rn-220 Reference 4	3036 ± 273	Bq/m ³	31,3%
Rn-222 Reference 4	6838 ± 339	Bq/m ³	-8,9%

GRAB SAMPLING

- Simple discriminative measurement technique for radon and thoron concentrations with a single scintillation cell
Shinji Tokonami, Mingli Yang, Hidenori Yonehara, Yuji Yamada
- Simultaneous measurement of radon and thoron using Lucas scintillation cell
K.P. Eappen, R.N. Nair, Y.S. Mayya

FLUX SAMPLING

- Measurement of radon (²²²Rn) and thoron (²²⁰Rn) concentration with a single scintillation cell
Bronisław Machaj, Piotr Urbański, Jakub Bartak

II INTERCOMPARISON – MI.AM RESULTS

REFERENCE EXPOSURE	MIAM		Client-1		Client-2	
		AVG TRS		AVG TRS		AVG TRS
Site 1 225 kBq/m ³ Rn	206 kBq/m ³ -8,4%	38	220 kBq/m ³ -2,2%	21	204 kBq/m ³ -9,3%	29
Site 2 1731 kBq/m ³ Rn	1665 kBq/m ³ -3,8%	37	1685 kBq/m ³ -2,7%	17	1710 kBq/m ³ -1,2%	23
Site 3 516 kBq/m ³ Rn+Tn	479 kBq/m ³ -7,2% Sealed	32	566 kBq/m ³ 9,7% Radout	29	547 kBq/m ³ 6,0% Radout	42

RELEVANT POINTS

- Transits slightly higher than in other Lab Intercomparisons
- Used CR39 Batch was discovered to be affected by ageing/fading → Politrack Correction

GOOD NEWS

- Very good agreement to reference values
- Thoron % interference in Radout® can be considered limited to some percent

SITE 3 - NET EXPOSURE RESULTS kBq/m ³			
MI.AM TRIPLET	SEALED RADOUT	STD RADOUT	CALCULATED THORON
30A13	455,1	515,0	544,1
30A14	454,5	558,4	518,5
30A15	527,1	570,5	712,7
AVG	479	548	592

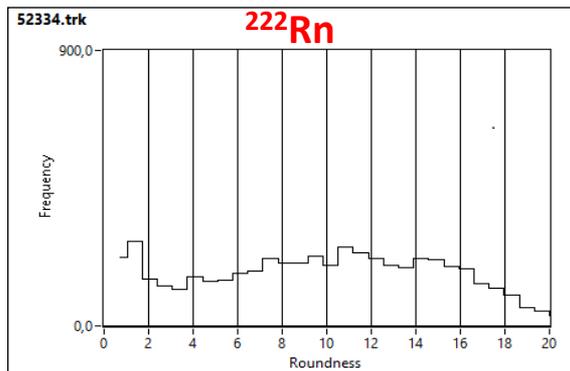
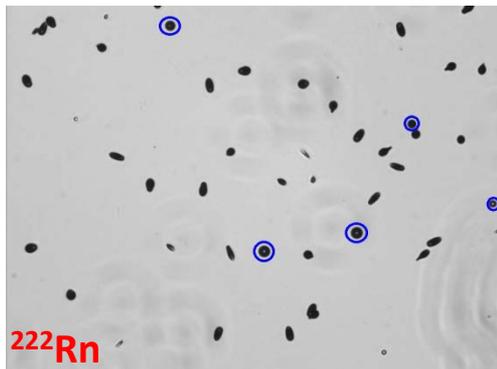
THORON ESTIMATED CONC.	
2752	Bq/m³

THORON RADOUT INTERF.
11,6 %

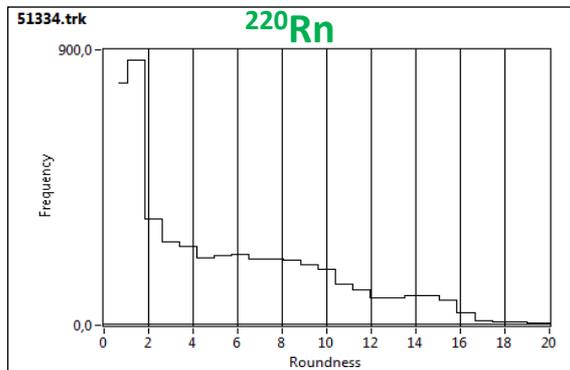
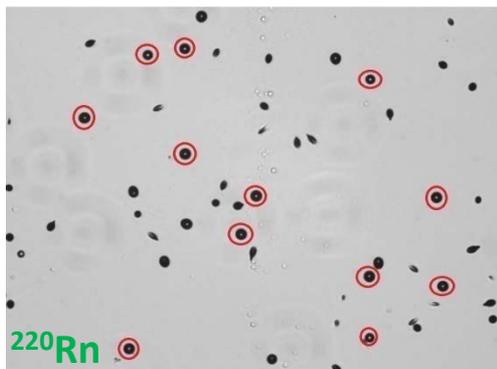
TRACK ISSUES IN MODIFIED RADOUT®



- Track shape distributions in Rn-222 and Rn-220 exposures

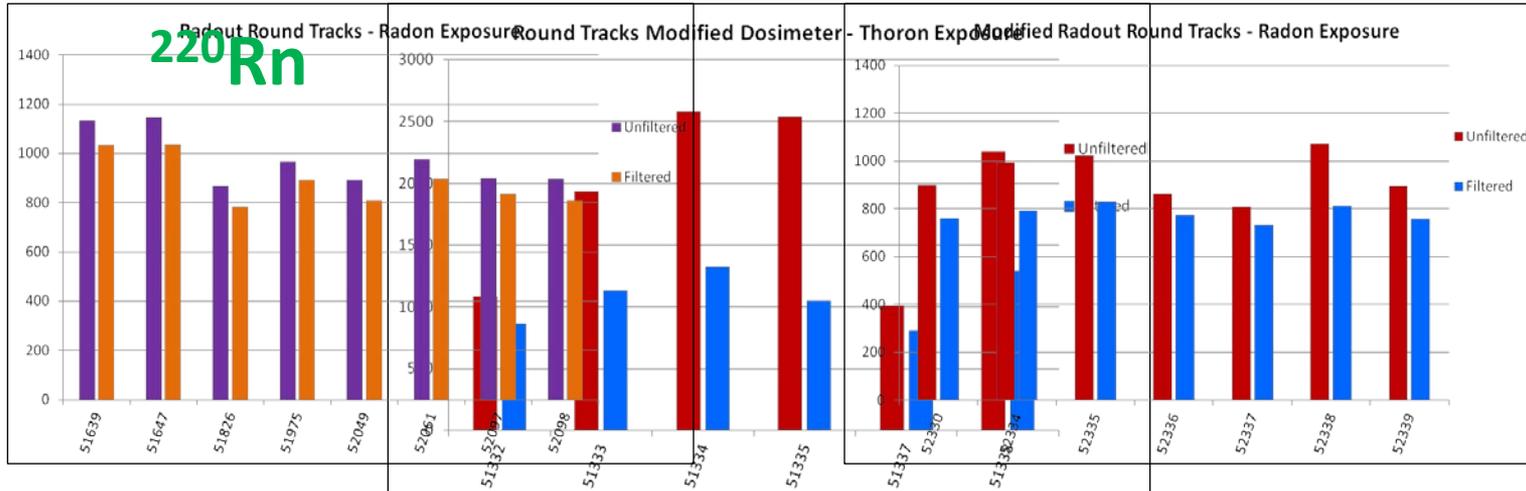


- Perfect Round ($R=1$)
- For Thoron there's a peak with $R < 3$
- Many round tracks have holes inside (filtering)



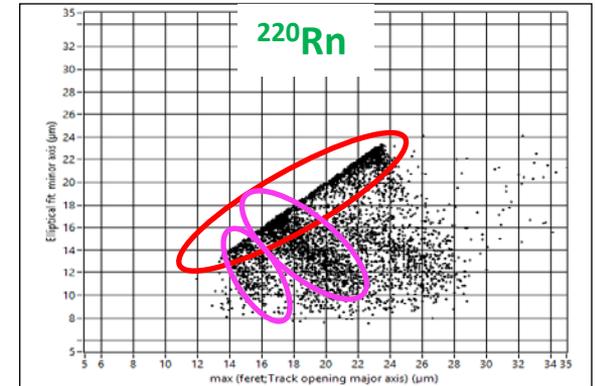
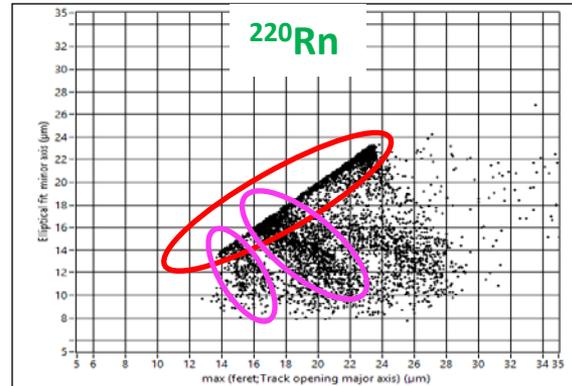
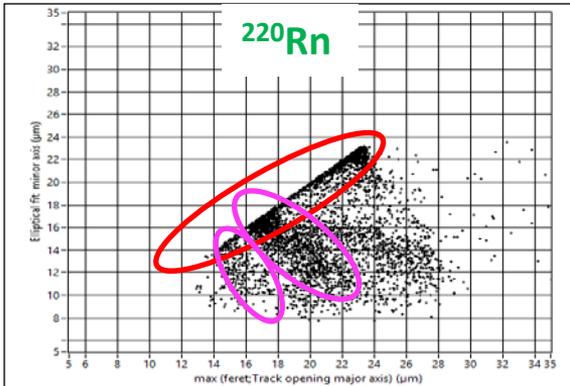
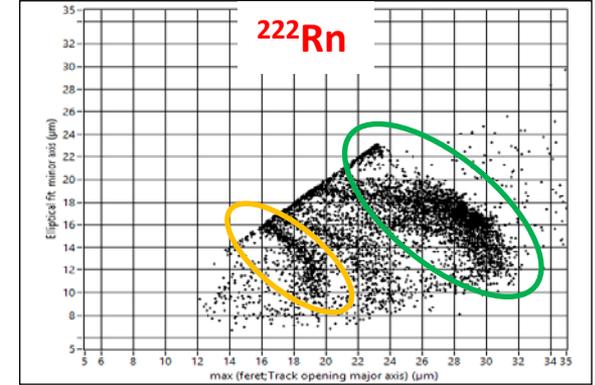
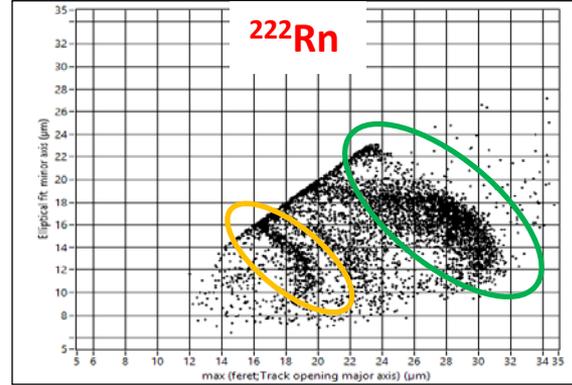
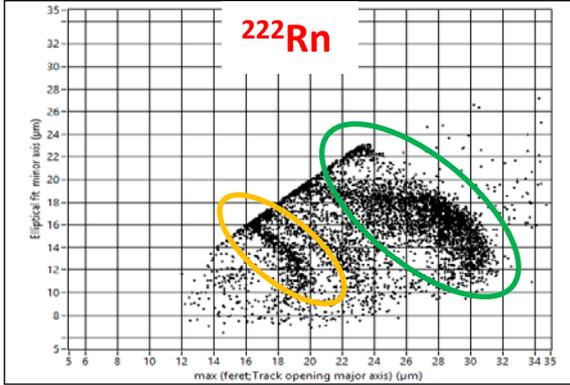
OBSERVATIONS

- Found a reliable 2 dosimeters method, but:
 - ❖ Big Thoron signal from round tracks → ***Rn-220 decay during tyvek diffusion?***
 - ❖ Part of round signal is still filtered: optimization needed for round tracks



Proper characterization of tyvek behaviour is still needed

TRACK DISTRIBUTIONS IN RADON AND THORON



FUTURE DEVELOPMENTS

- **Study of materials for top hole covering**
 - Work on Thoron diffusion (Trap it or let it in?)
- **Track analysis to develop a single dosimeter method for Rn/Tn discrimination:**
 - Use track analysis system tools for characterization (stats and graphs)
 - Define proper filter sets to separate Radon and Thoron tracks
 - Highly stable CR-39 detectors quality needed



THANK YOU!

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