Highly sensitive passive radon detector with compensated temperature dependence and thoron interference

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Two problems that challenge radon measurements:

- The response of many radon detectors depends on the temperature, e. g.:
  - Activated charcoal detectors;
  - Track detectors that show fading (e. g. CR-39). The fading-rate depends on the temperature
- Many widely used radon detectors are sensitive also to thoron and this interference can bias the results (Tokonami S., *Radiat. Prot. Dosim.* 141 (2010) 335-339);

Our target (inspired by the aims of the MetroRADON project): To design sensitive radon detectors with compensated temperature dependence and eliminated thoron interference.

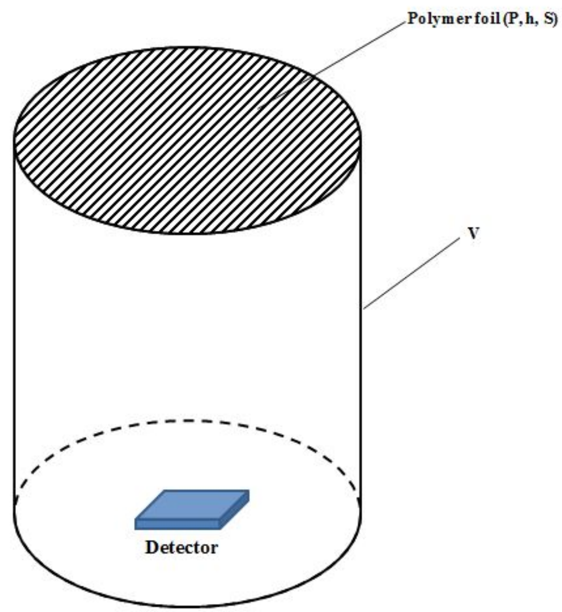
In the first diffusion chambers… the detector volume was protected by a polymer foil which serves as anti-thoron (and anti-humidity) barrier (W. J. Ward et al., *Rev. Sci. Instrum.* 48 (1977) 1440-1441)

Polymer membranes are efficient barriers against thoron and humidity… however they DO AFFECT the response of detectors to radon at different temperatures (R. L. Fleischer et al. *Radiat. Meas.* 32 (2000) 325-328; L. Tommasino, presentation at Radon 2016 conference in Prague)

"Penetrated ratio": $R = \frac{C_{in}}{C_{out}} = \frac{1}{1+\frac{\lambda h V}{SP}}$,

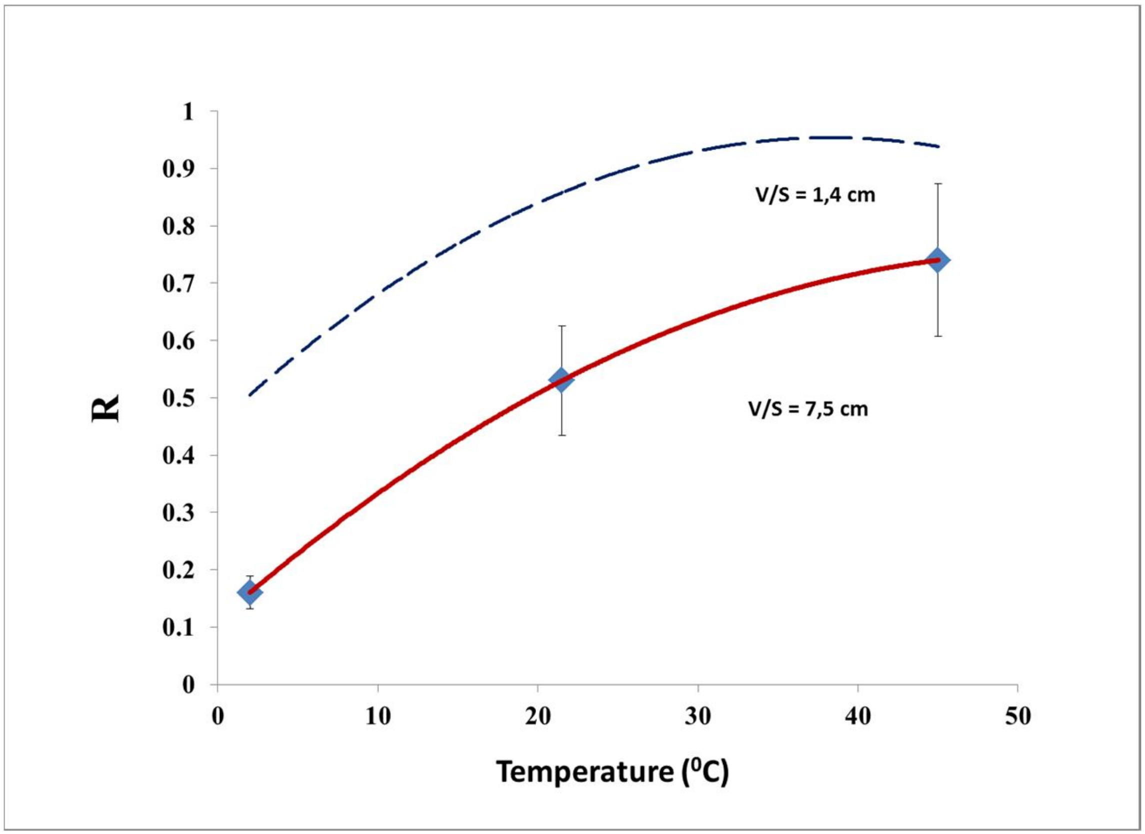
(valid when $h \ll L_D$; ($L_D = \sqrt{D/\lambda}$))

P is the radon permeability through the polymer material; <u>***P* depends on the temperature**</u>



Experimental determination of *R*: Exposures at 2^0 C, $21{,}5^0$ C and 45^0 C at Sofia University exposure facility

Experimental results with a membrane of 75 μm thick low density polyethylene foil and *V/S* = 7.5 cm

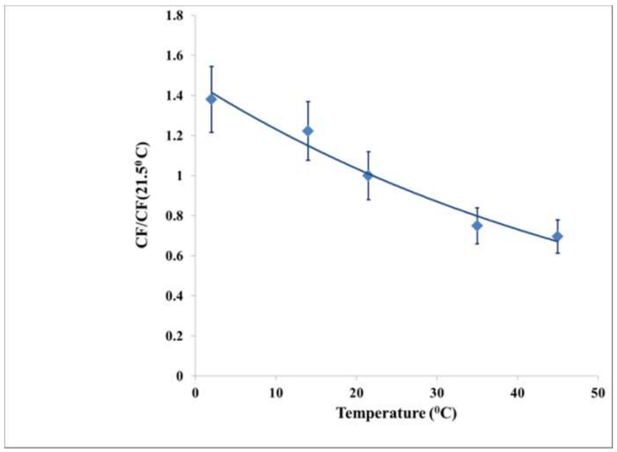


The temperature dependence might be manipulated by varying $\frac{hV}{S}$ and the polymer material

$$R = \frac{C_{in}}{C_{out}} = \frac{1}{1 + \frac{\lambda h V}{SP}},$$

The dependence of the response on the temperature of many radon detectors is reciprocal to that of *R*

The temperature dependence of the response of some radon detectors (e.g. track detectors with absorbers/radiators (L. Tommasino, Radiat. Meas. 44 (2009) 719-723) is reciprocal to that of *R*… Can one arrange:



***CF* = net track density/integrated ^{222}Rn concentration**

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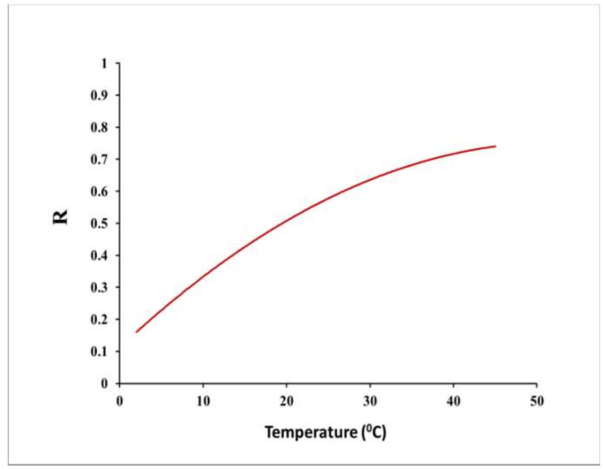
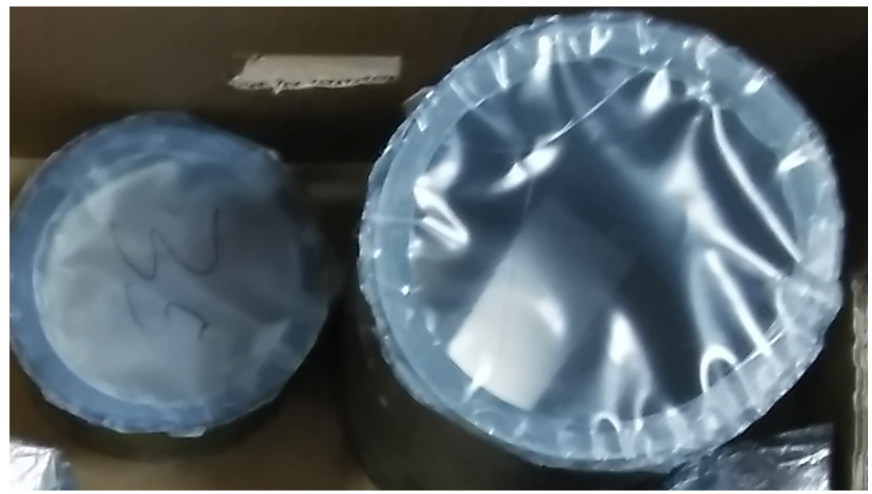


= const?

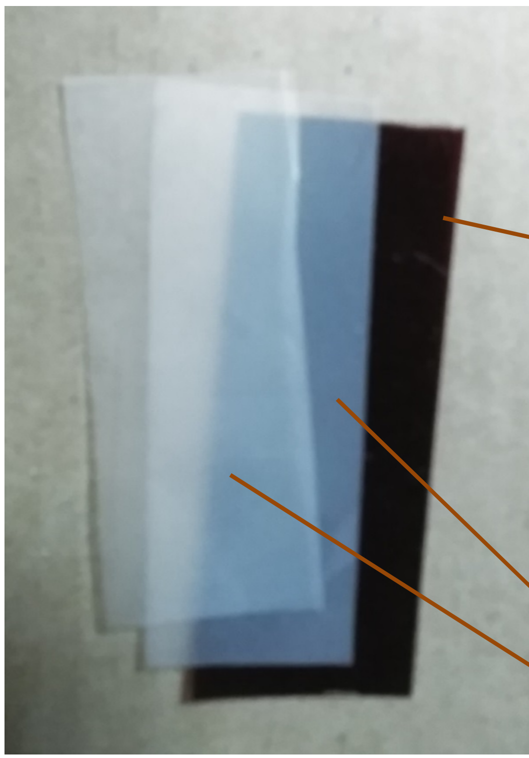
Answer: YES

By modeling "compensated modules" can be designed of size (i. e. *V, S, h*) and with a polymer membrane that are proper to compensate the temperature dependence of the detectors



<u>Protection of the intellectual property</u>: Patent application filed and registered (Bulg. Pat. Appl. Reg. Nr. 112897/19.03.2019). MetroRADON project was acknowledged.

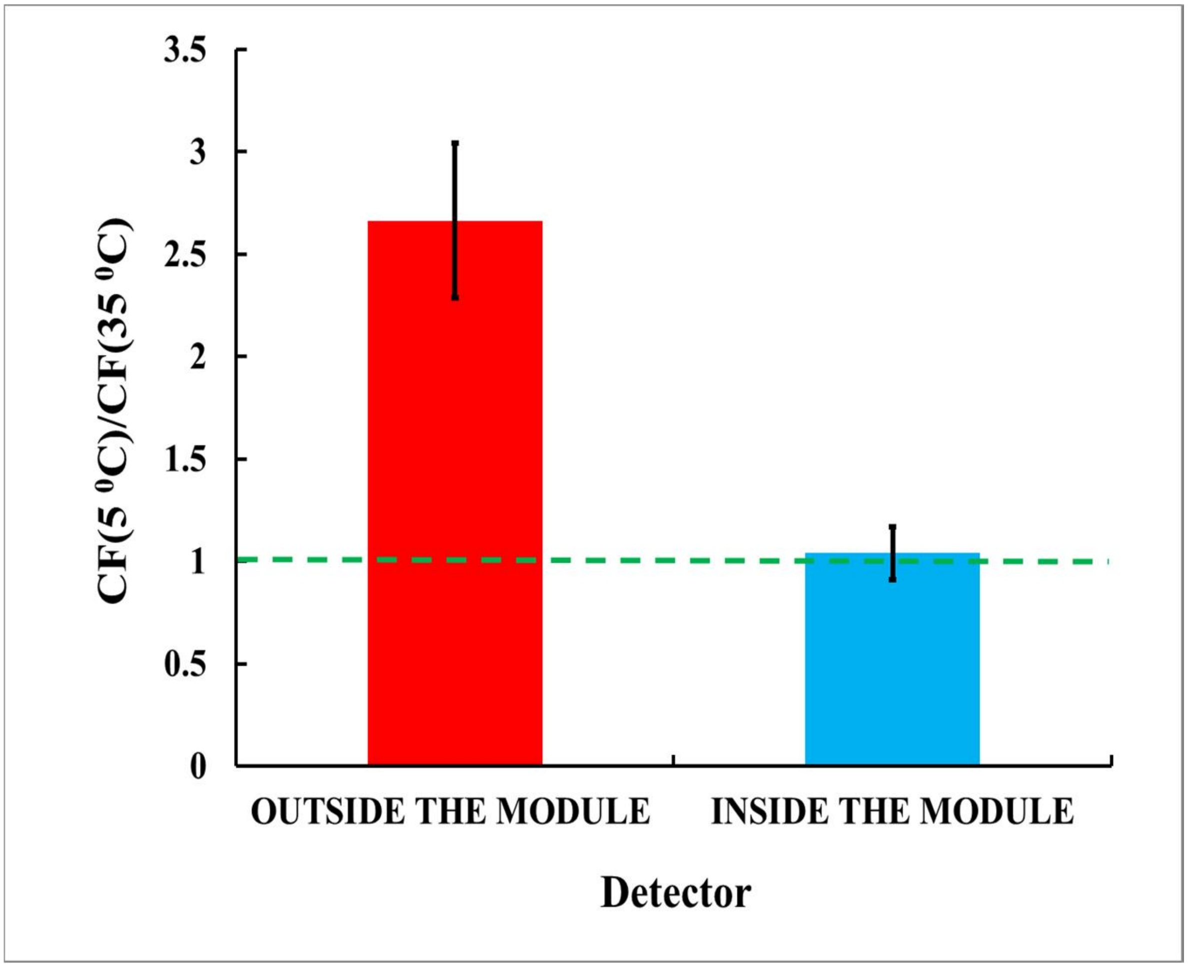
Experiment 1: Alpha track detectors of Kodak Pathe LR-115/II with absorbers/radiators of Makrofol N (L. Tommasino et al. *Radiat. Meas. 44 (2009) 719-723*).



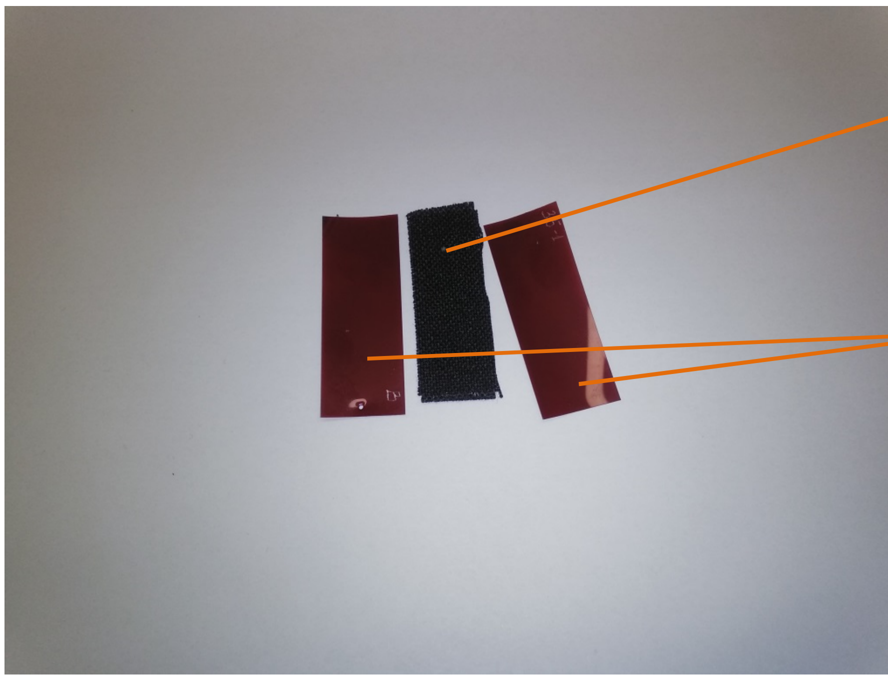
Kodak-Pathe LR-115/II

absorbers of 2×43 μm Makrofol N (Makrofol N is of unique high radon absorption ability and serves as absorber/radiator)

<u>Experiment 1 results</u>: The compensated module is of *V/S* = 4.5 cm and covered with 75 μm thick low density polyethylene



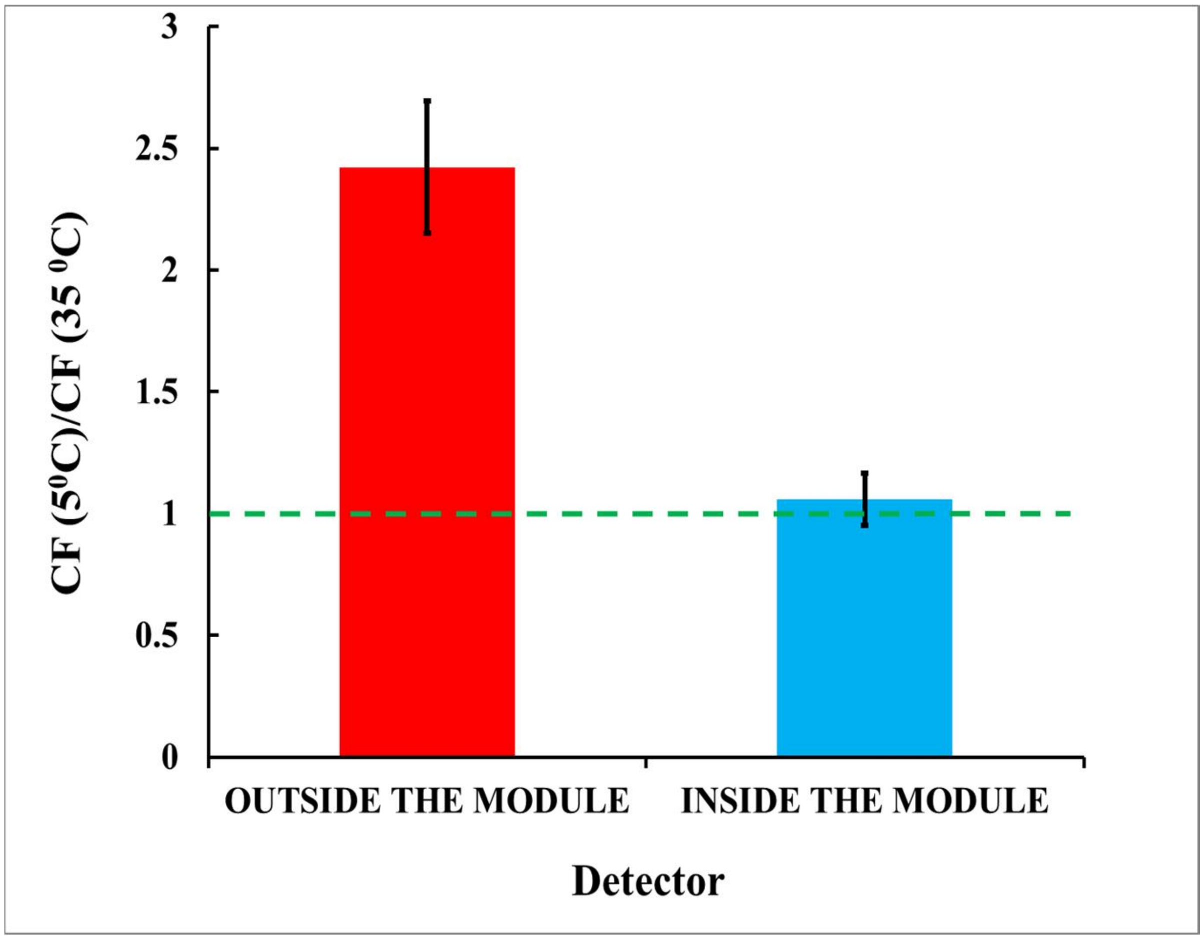
Experiment 2:Kodak Pathe LR-115/II + sheet of fiber-like activated carbon (sheet of activated carbon fibers Kynol 507-10 with thickness 20 mg cm^{-2})



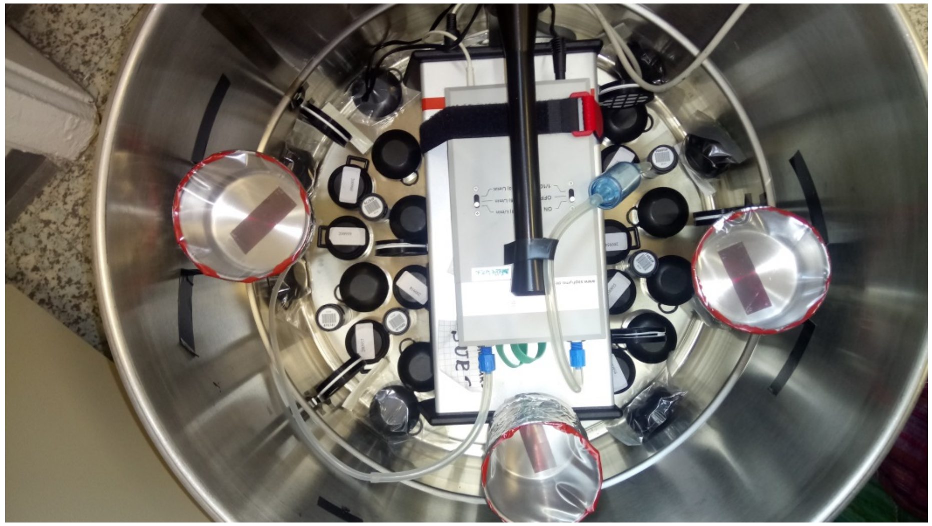
Kynol 507-10

Kodak-Pathe LR-115/II

Experiment 2 results: The compensated module is of V/S = 5.5 cm and covered with 50 μm thick low density polyethylene



Property of the modules to eliminate thoron interference on the signal…



Experiment at ^{220}Rn exposure: 13.84 ± 0.91 MBq h m^{-3}

Chambers of *V/S* = 7.5 cm, covered with 50 µm thick low density polyethylene foil

***CF*(^{220}Rn) : *CF*(^{222}Rn) < 0.07% ⇒ Protection against thoron is almost absolute**

The polymer membranes are also an efficient barrier against moisture/humidity

Sensitivity

- *CF* (Kynol 507-10) = 3.5 ± 0.3 cm^{-2}/kBq h m^{-3}
- *CF* (Makrofol N) = 0.36 ± 0.03 cm^{-2}/kBq h m^{-3}
- *CF* (Diffusion Chambers) = 1.65 ± 0.14 cm^{-2}/kBq h m^{-3}

With track detectors covered by radiator of sheet of activated carbon fibers Kynol 507-10 the *CF* (and therefore the minimum detectable integrated radon concentration) can be improved more than 2 times compared to that of the conventional diffusion chambers.

Conclusions:

- When using polymer foils as anti-thoron and anti-humidity barriers of radon detectors a temperature bias in the results may be expected. It is due to the increasing, along with the temperature increase, permeability of the polymers used.
- Many widely used radon detectors show decreasing response along with the temperature increase;
- A step beyond state of the art is proposed: by placing such detectors in modules in which volume radon penetrates by diffusion through a polymer membrane to compensate the temperature dependence of the detector's response with a reciprocal temperature dependence of the radon penetration in the module;
- Pilot experiments with track detectors of Kodak Pathe LR-115/II coupled with absorbers of Makrofol N and of adsorbers of activated carbon fibers demonstrated that the temperature bias over 5 – 35 ^{0}C interval can be reduced from 240 – 270% to less than 10%;
- By these novel compensating modules it is possible to compensate the thoron dependence and the dependence of sensitivity on the temperature of many widespread radon detectors. In the same time the module provides an efficient anti-humidity protection;
- Using this approach a new design of passive detectors becomes possible: with enhanced sensitivity, compensated temperature dependence and practically eliminated thoron interference.

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Thank you!

Metro RADON