Beyond state of the art within WP2: A module to compensate the temperature dependence of radon sensors+thoron interference+moisture/humidity influence

Dobromir Pressyanov (SUBG)

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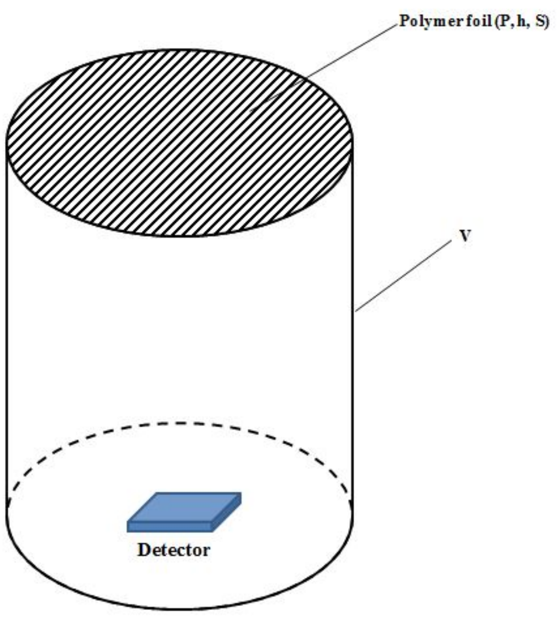
In the first diffusion chambers… the detector volume was protected by a polymer foil which serves as anti-thoron (and anti-humidity) barrier (W. J. Ward et al., *Rev. Sci. Instrum.* 48 (1977) 1440-1441)

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)

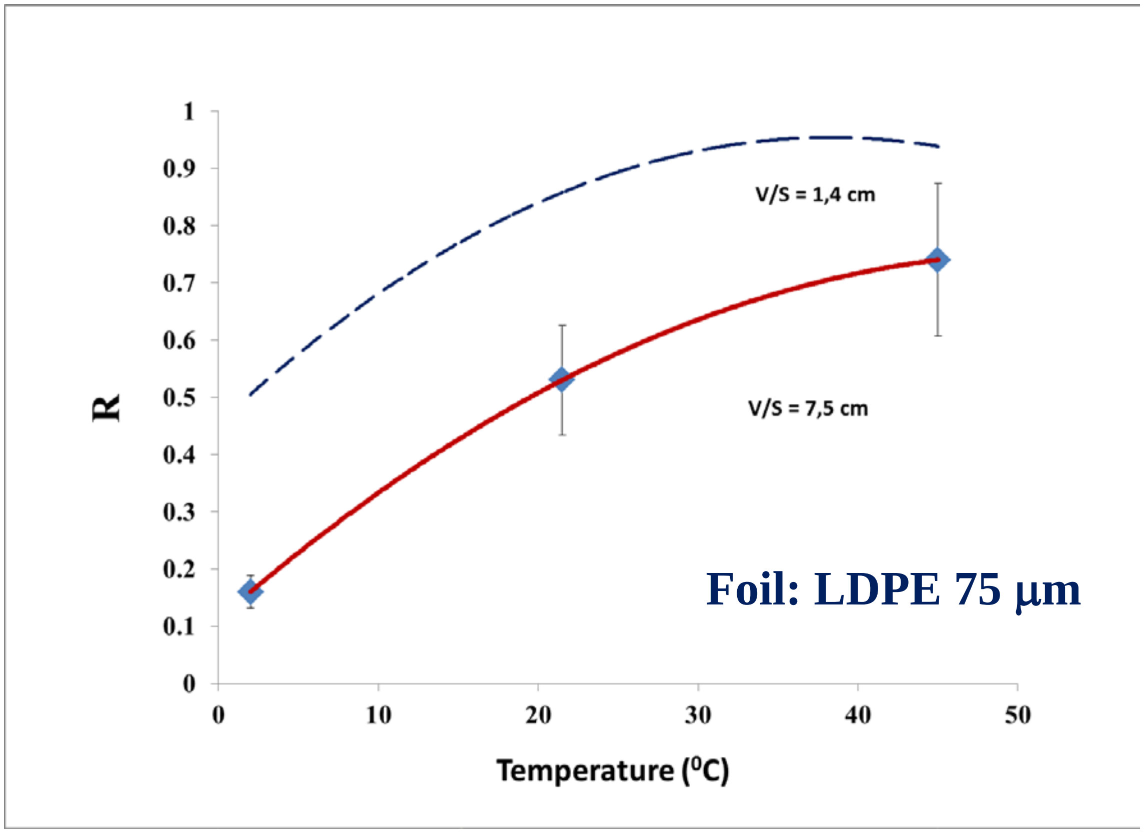
"Transmission ratio": $R = \frac{C_{in}}{C_{out}} = \frac{1}{1+\frac{\lambda h V}{SP}}$,

(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>**



The polymer foils may provide close to absolute anti-thoron and anti-humidity protection…however they introduce temperature-related bias in results.



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

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

However… if the temperature bias is substantially decreased (especially below 10%) the thoron interference rapidly increases…

The temperature dependence of radon transmission through polymer membranes is a problem that gives an (surprising) opportunity, because:

… many radon detectors have temperature dependence of the response which is reciprocal to that of the radon transmission (R), i.e. decreasing with increasing the temperature. Such detectors are e.g.:

- The most widely used track detectors: CR-39. These detectors show fading, and the (fading) decrease of the signal is larger at higher temperature (see e. g. H. Enomoto and N. Ishigure, 2011; M. Caresana et al., Radiat. Meas. 45 (2010) 183–189; unpublished joint research with RADONOVA).
- Some detectors that employ radon absorption/adsorption (e.g. detectors based on activated charcoal; radon film badges (Tommasino et al., 2009) etc.);

The dependence of the response on the temperature of many radon detectors is reciprocal to that of *R*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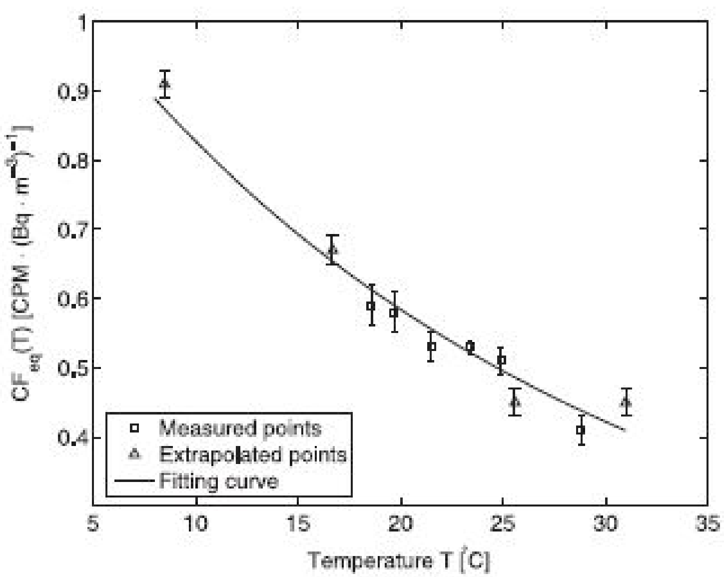
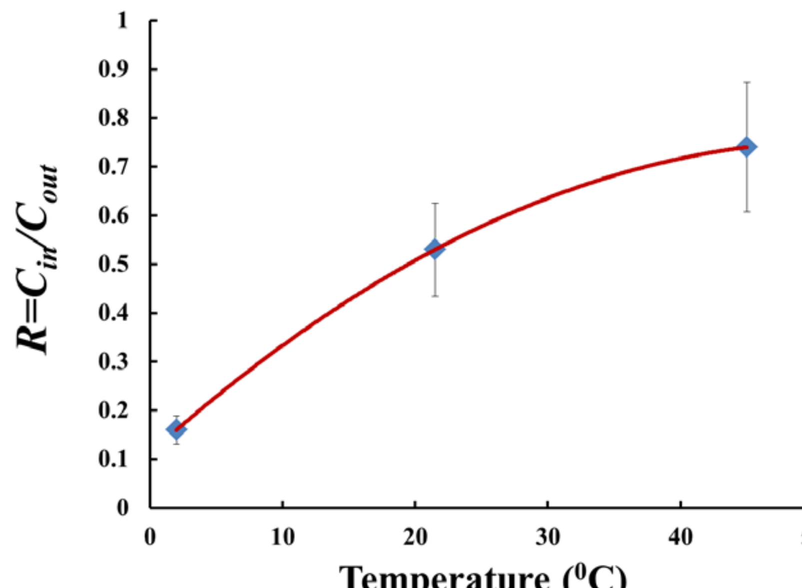
Temperature calibration formula for activated charcoal radon collectors

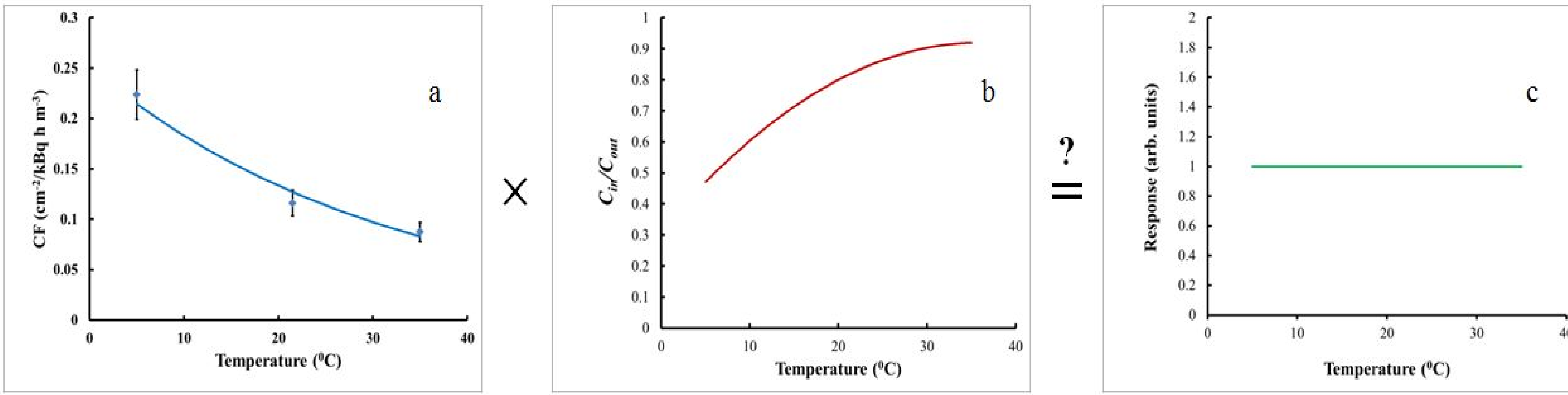
Alexandre Cooper[a,*], Thiem Ngoc Le[b], Takeshi Iimoto[a], Toshiso Kosako[a]

[a]Graduate School of Engineering, The University of Tokyo, 2-11-16 Yayoi, Bunkyo-ku, Tokyo 113-0032, Japan
[b]Institute of Nuclear Science and Technology, Vietnam Atomic Energy Commission, 59 Ly Thuong Kiet, Hanoi, Viet Nam



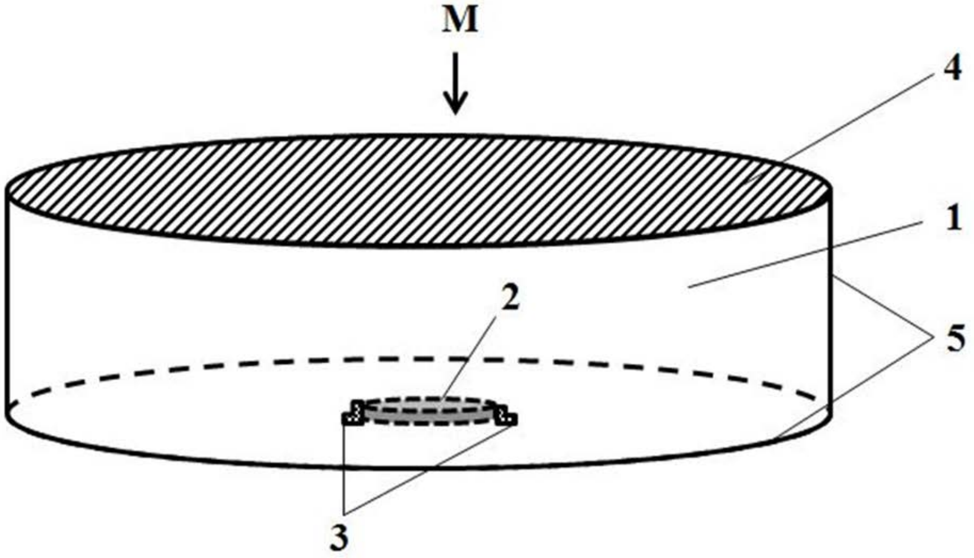


<u>Beyond state-of-the art</u>: A module can be designed with *R(T)* that compensates that of *CF(T)* so that $CF \times R \approx$ const.:



The temperature dependence of the detector response may be employed to design the “compensation module” by which thoron interference can be eliminated + temperature dependence + humidity/moisture influence.

The compensation module: By a proper design it should (and can) ensure: compensation of the temperature dependence + elimination of thoron influence + protection from moisture/humidity



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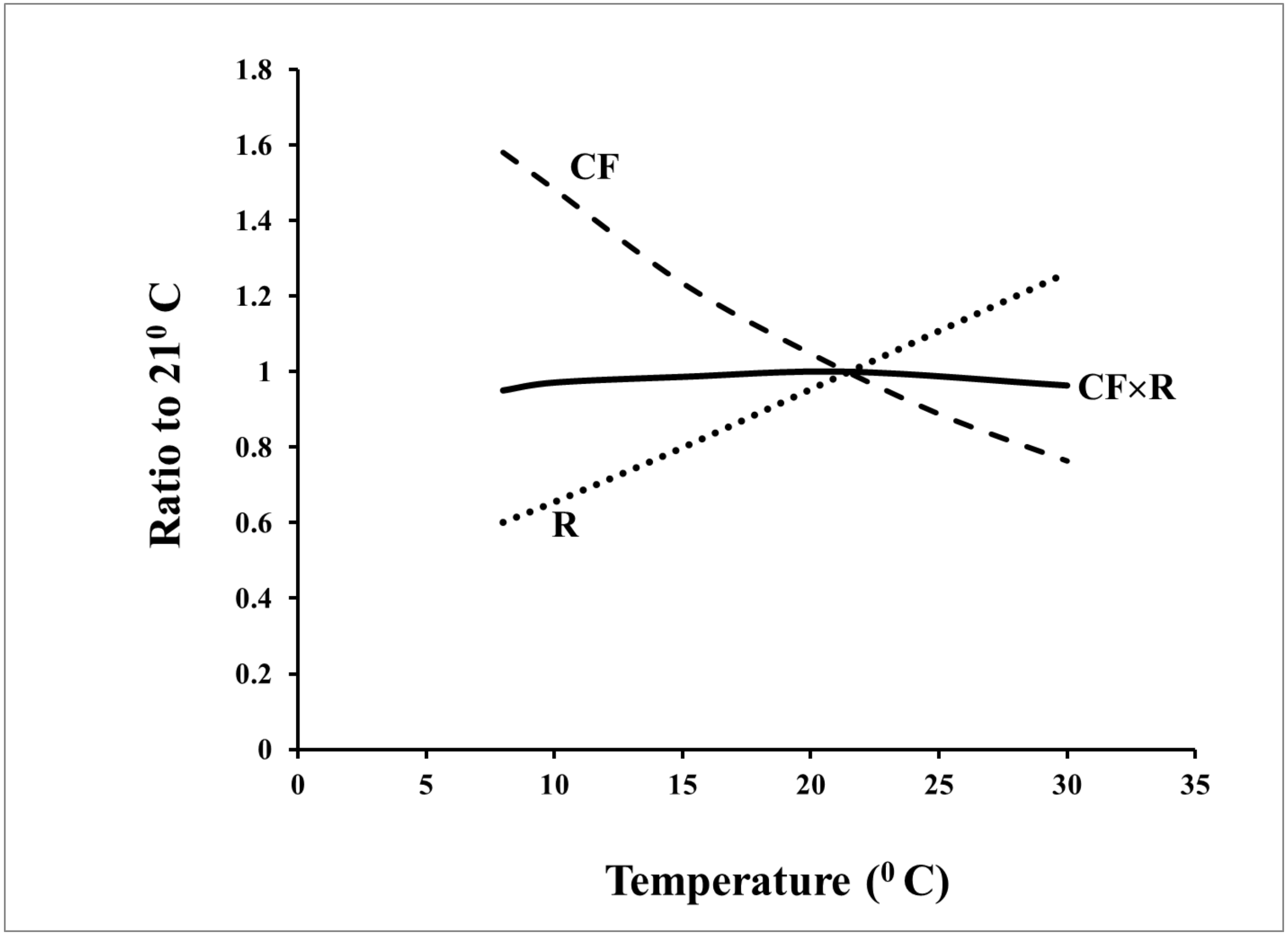
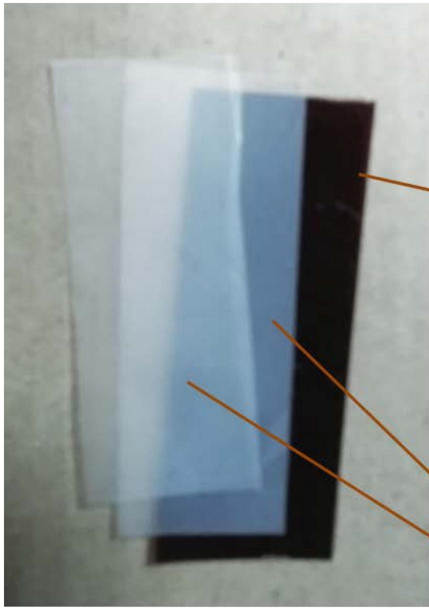
<u>Patent application submitted</u> (Bulg. Pat. Appl. Reg. Nr. 112897, WIPO Appl. Reg. Nr. PCT/BG2020/000003, priority: 19.03.2019. MetroRADON project was acknowledged.

For the purpose of the proof-of-the-concept experiments modules were designed by computer modelling



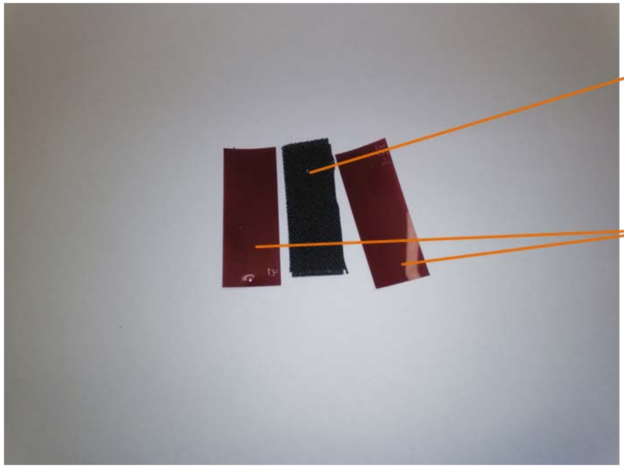
The evidence that this concept works: pilot experiments…

Sensitive radon detectors with huge temperature dependence of the response…



Kodak-Pathe LR-115/II

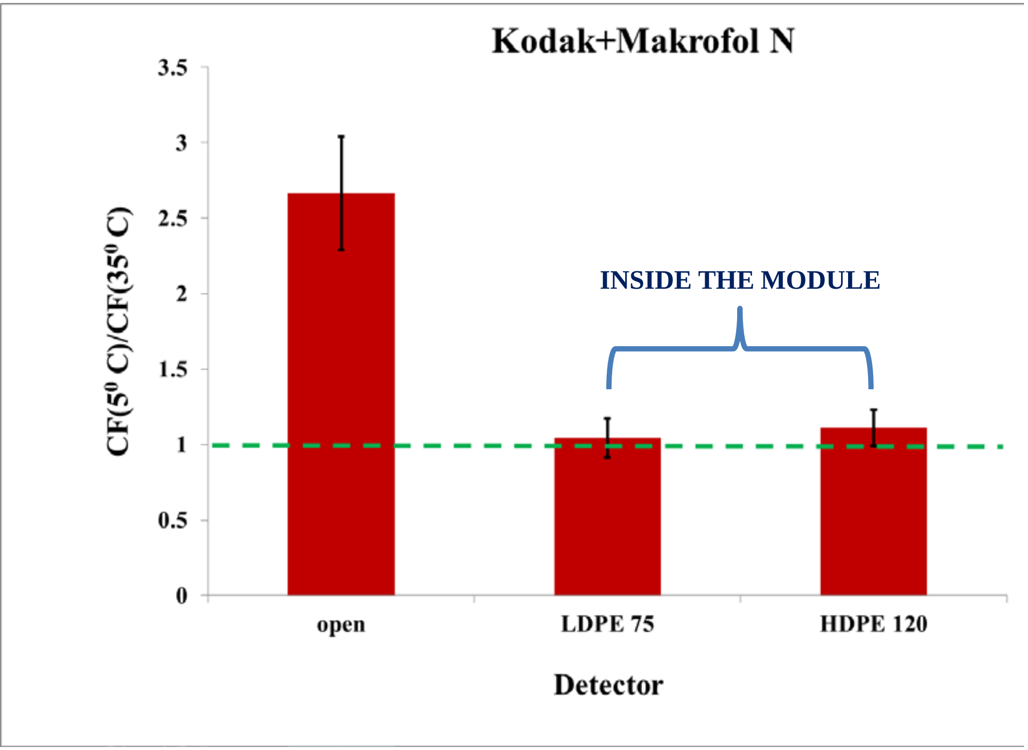
absorbers of 2×43 μm Makrofol N (Makrofol N is of unique high radon absorption ability and serves as absorber/radiator)



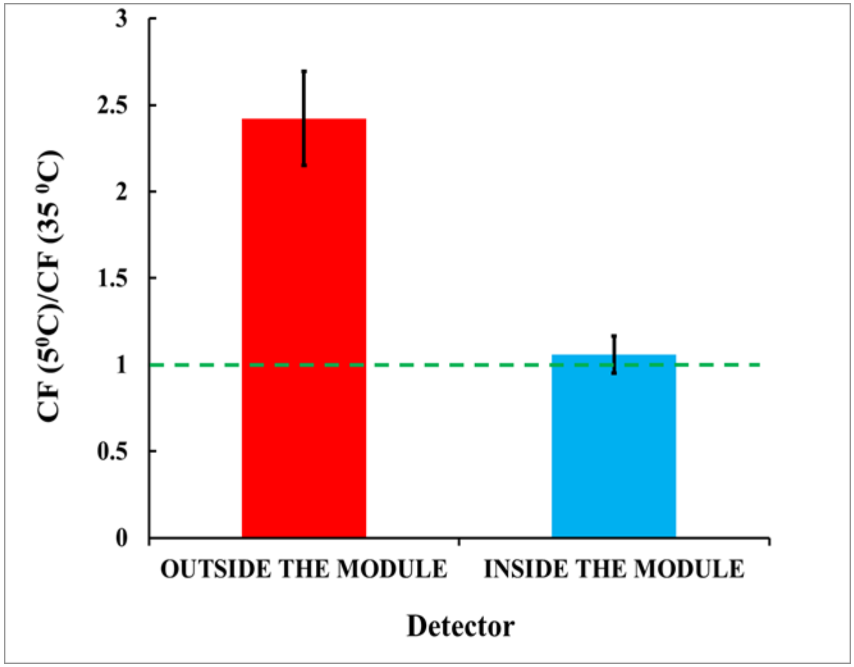
Kynol 507-10

Kodak-Pathe LR-115/II

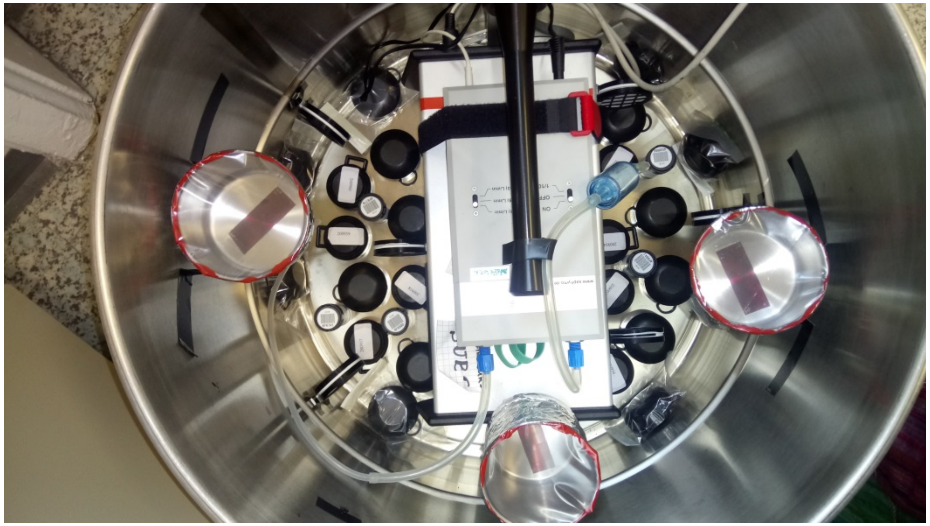
Experimental exposure at 5^0 C and 35^0 C.



Activated carbon + SSNTD



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

$CF(^{220}\mathrm{Rn}) : CF(^{222}\mathrm{Rn}) < 0.07\% \Rightarrow$ <u>Protection against thoron is almost absolute</u>

<u>The compensation module provides also an efficient barrier against moisture/humidity</u>

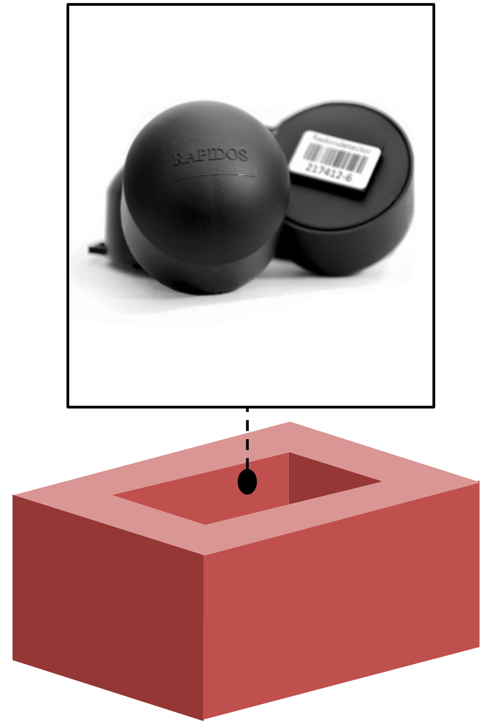
Sensitivity

- *CF* (AC+SSNTD) = 3.5 ± 0.3 cm^{-2}/kBq h m^{-3} (may be improved by optimisation of the design and proper AC-sheet choice)
- *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} (no room for improvement)

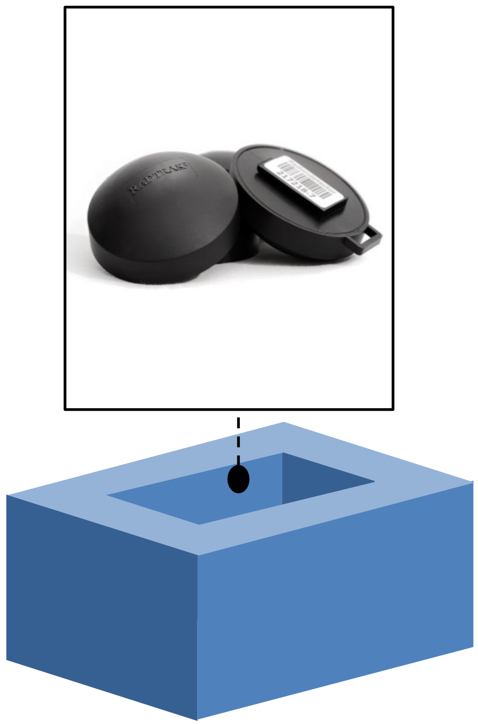
With track detectors covered by radiator of sheet of activated carbon the *CF* (and therefore the minimum detectable integrated radon concentration) can be improved more than 2 times compared to that of the conventional diffusion chambers.

But the approach can be applied with much more widely used passive monitors that use CR-39 detectors

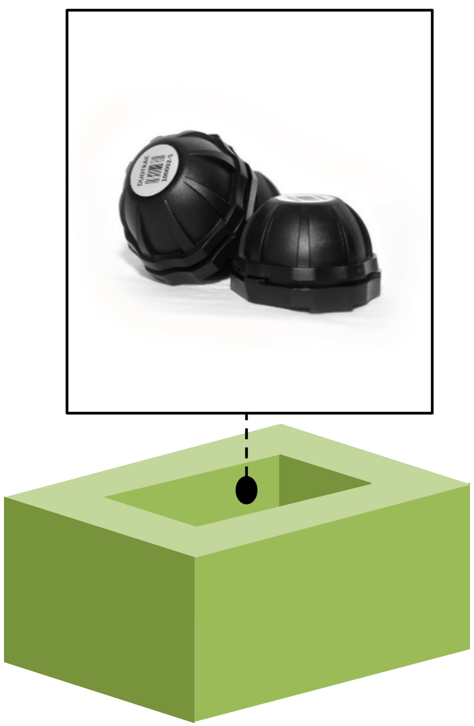
Rapidos®



Radtrak²®

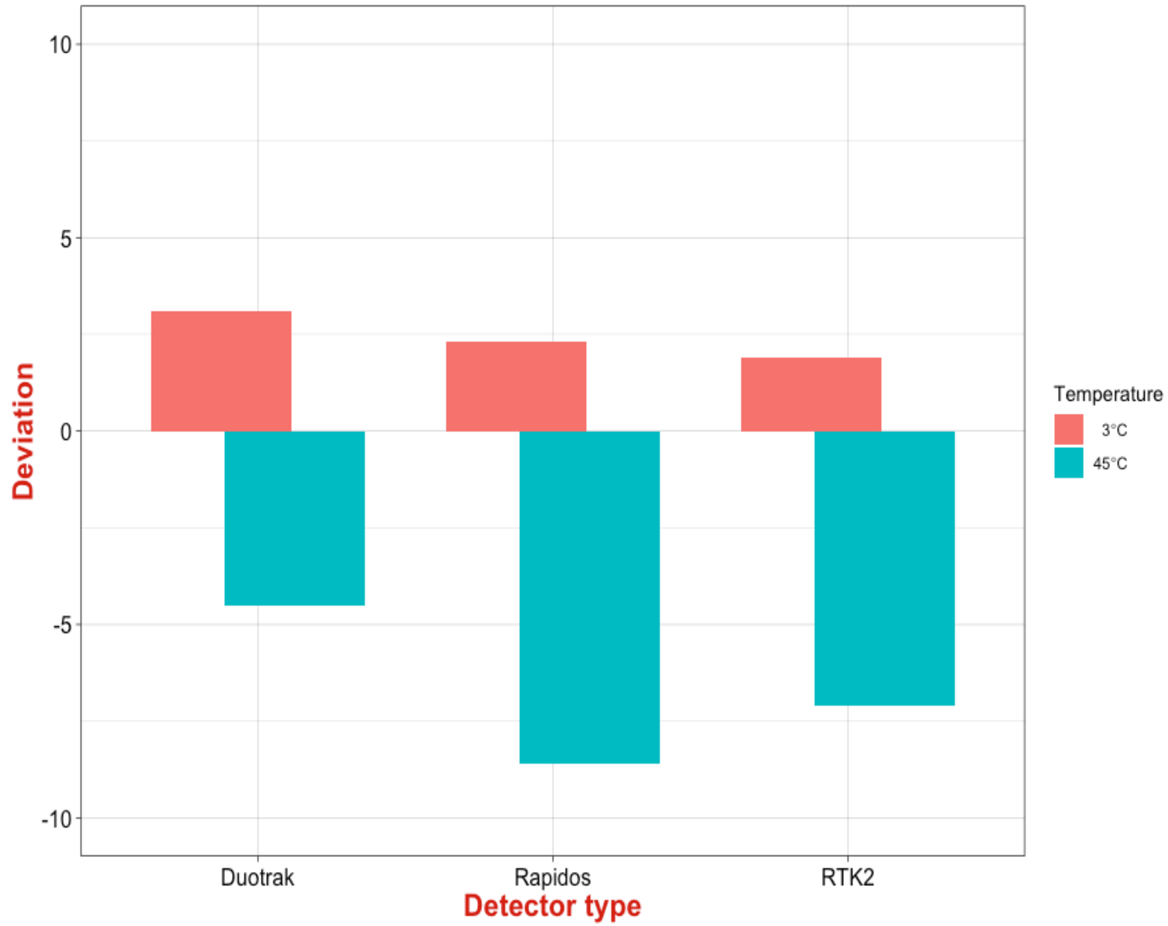


Duotrak®

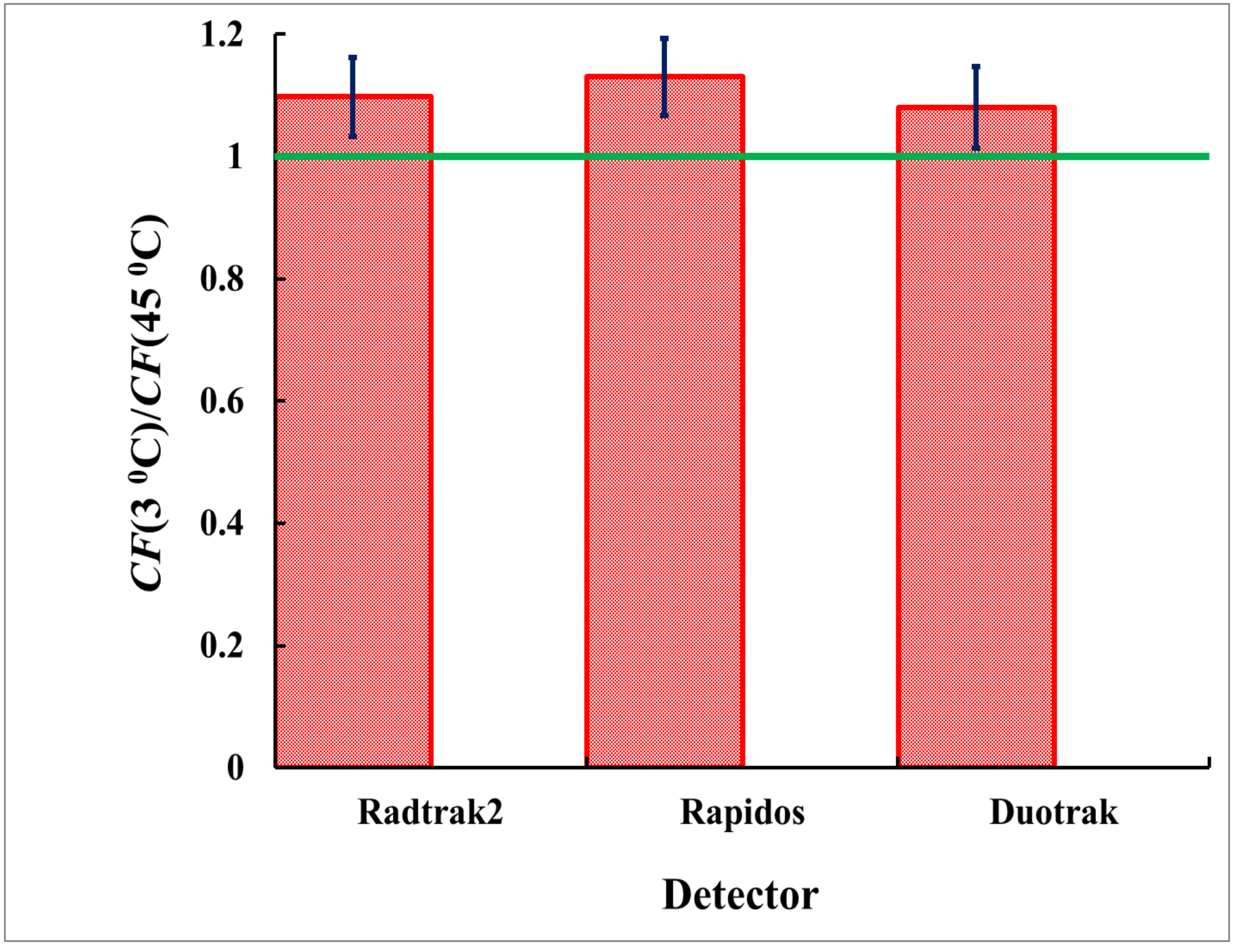


D. Pressyanov, T. Ronnqvist, J.-L. Gutiérrez-Villanueva, **Report on MetroRADON Meeting Paris, Sep. 2019**

Exposures at 3 ^{0}C and 45 ^{0}C were made at SUBG (D. Pressyanov, T. Ronnqvist, J.-L. Gutiérrez-Villanueva, ***Report on MetroRADON Meeting Paris, Sep. 2019***)



The ratio of calibration factors at 3 ^{0}C to 45 ^{0}C



Preliminary conclusions

01

Temperature
Low and high temperature

02

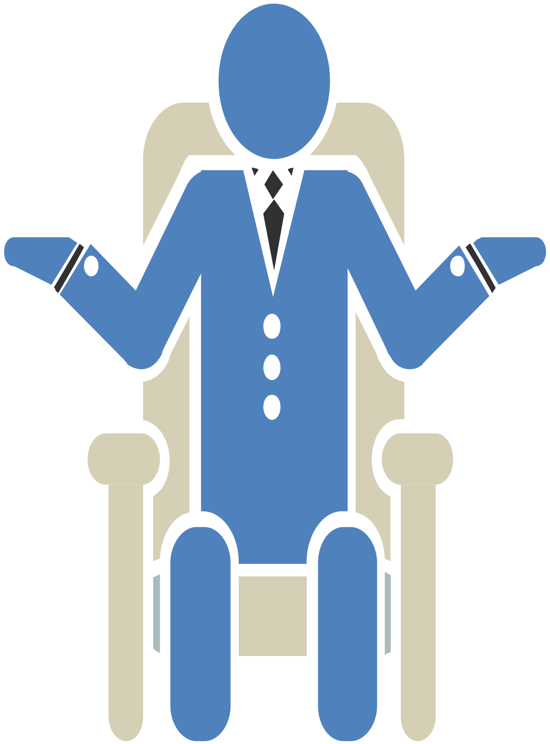
Detector type
3 different detector types.

03

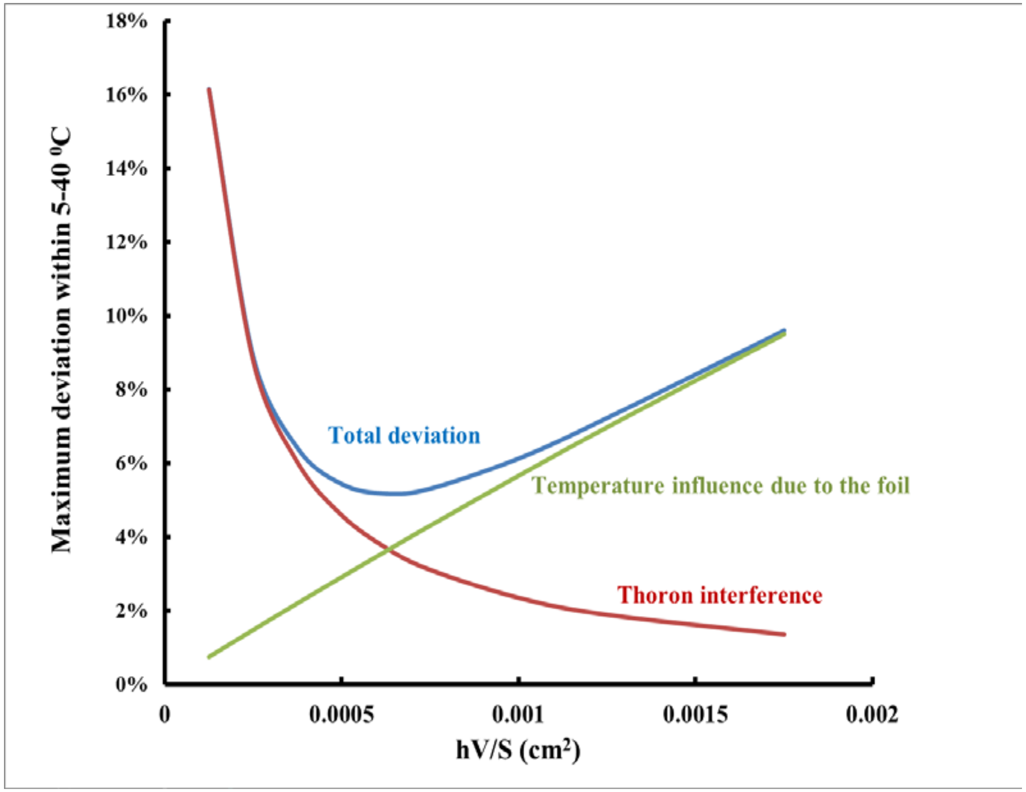
Exposures
2018 and 2611 kBq h m^{-3} (total rel. uncertainty 6%, meas. uncertainty 3.5%)

04

Within 3 – 45 ^{0}C the calibration factor drops by 8 – 13%

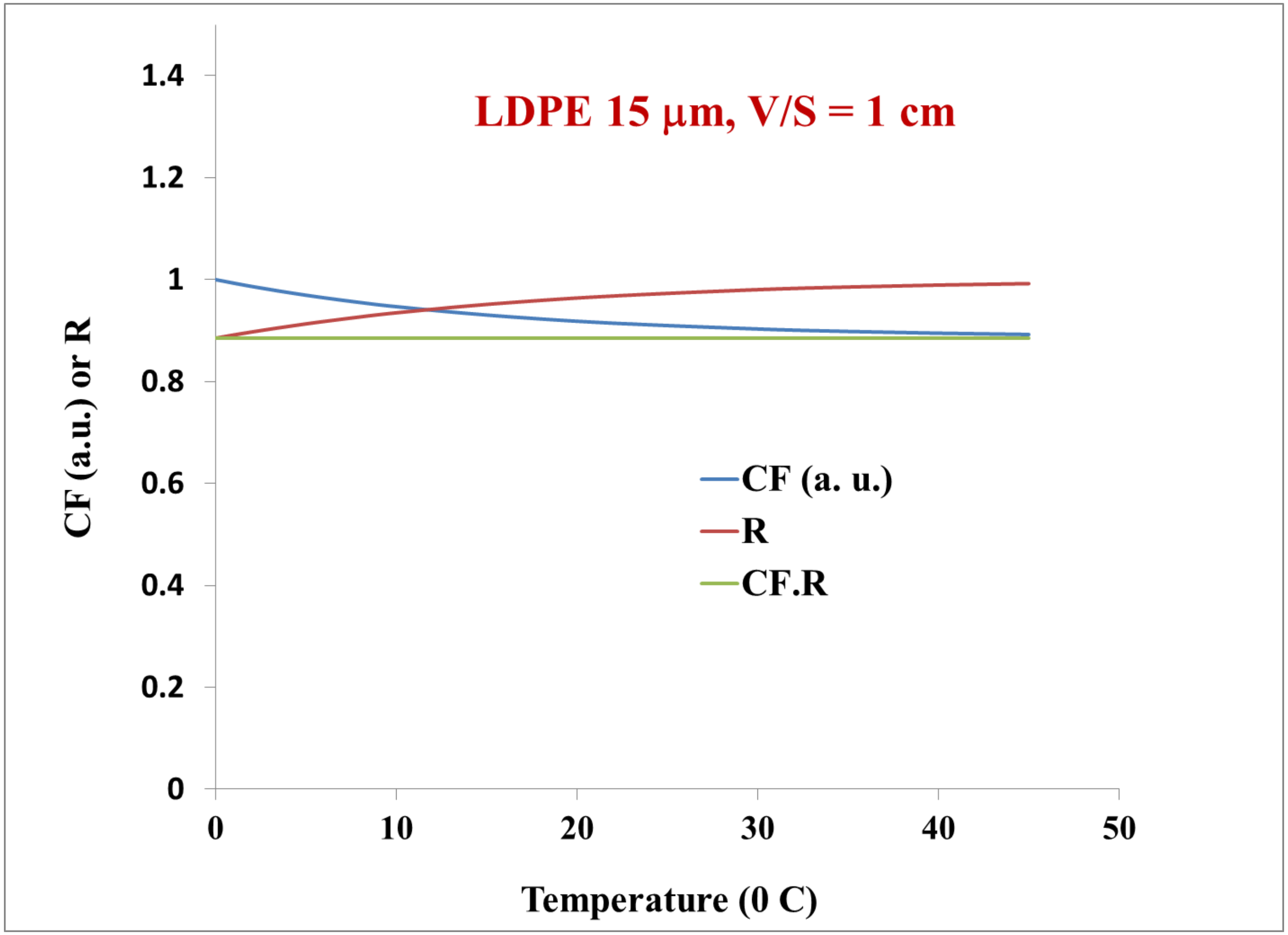


For detectors without temperature dependence the total bias cannot be reduced to less than 5%…



However:

The temperature dependence of detectors can be useful… For instance in "packed" diffusion chambers with CR-39 both thoron interference can be cancelled-out and the temperature dependence eliminated…



What could be the benefit from packaging pin-hole diffusion chamber …

Thoron interference < 5%
Temperature bias: 10%

Thoron interference << 1%
Temperature bias: ~ 2-3%
and… no influence of humidity

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.**

Thank you!

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