High sensitivity passive radon detector for measuring radon in low background underground nuclear/particle physics laboratories

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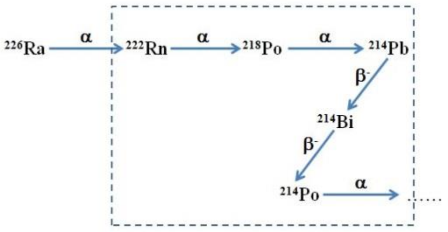
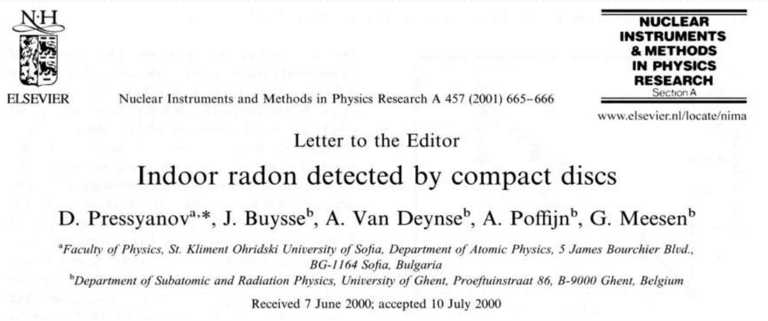
Front-line nuclear research laboratories…and their "radon problem"

- Deep underground placement of the laboratories eliminates the highly penetrating muon component in the background signal… however the problem with the radon/radon progeny contribution to the background signal remains.
- What should be done to minimize and control the "radon component" in the background?
  - To mitigate ^{222}Rn to low levels, preferably < 1 Bq m^{-3};
  - **To verify the time-average ^{222}Rn concentrations in all important points/places are low for the whole duration of the experiment/data acquisition.**



We propose a novel method for passive ^{222}Rn measurements with sufficient sensitivity for use in low background nuclear laboratories

The approach is based on a modification of the CD/DVD method for radon measurements:



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Letter to the Editor

Indoor radon detected by compact discs

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The novel method employs DVDs-based detector modules of:

- low background ($\boldsymbol{n_B}$),
- large total detection area ($\boldsymbol{S}$)
- increased sensitivity (***CF***)

$$MDAC = \frac{2.71+4.65\sqrt{n_B}}{CF.t.\sqrt{S}}$$

In result the achievable ***MDAC*** (Minimum Detectable Activity Concentration) can be significantly lower than that of the known state-of-the art passive radon detectors.

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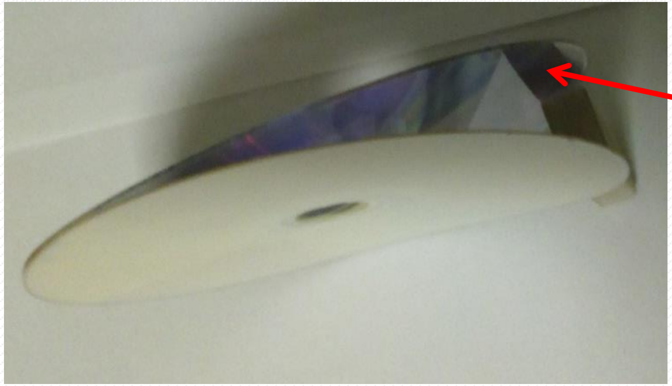
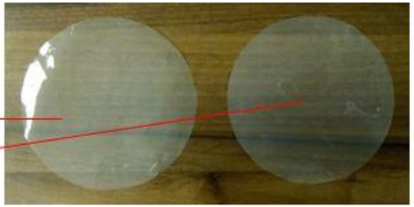
DVDs have a very low background on their internal polycarbonate surface



Surface with very low background: 1.1 ± 0.3 cm^{-2}

The background can be further reduced by thermal annealing and special modes of track-counting that discriminate defects different from alpha tracks

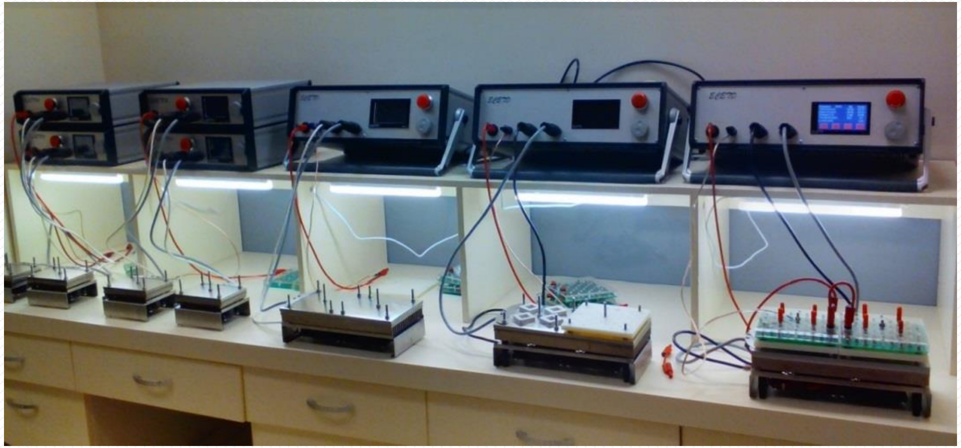
Detector element and detector modules

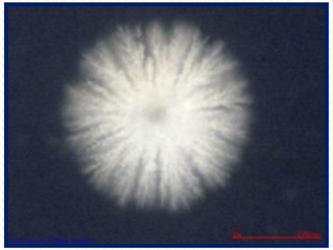


An idea about the size and shape of a module of 100 detector elements (total area of 20 000 cm^2 = 2 m^2)

Detector element of total area of 200 cm^2

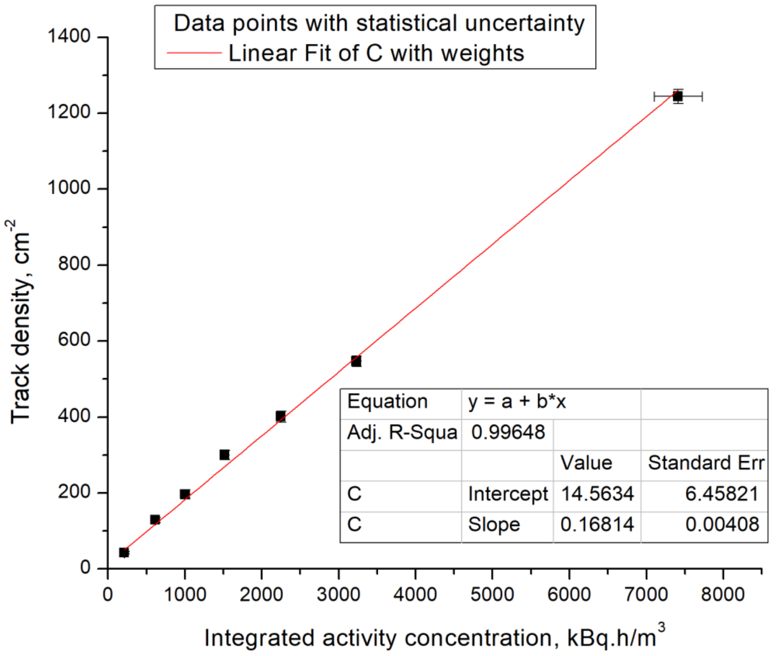
Etching of DVDs (infrastructure created within FP7-EURATOM Project DoReMi).





The calibration facility (FP7- EURATOM Project DoReMi)

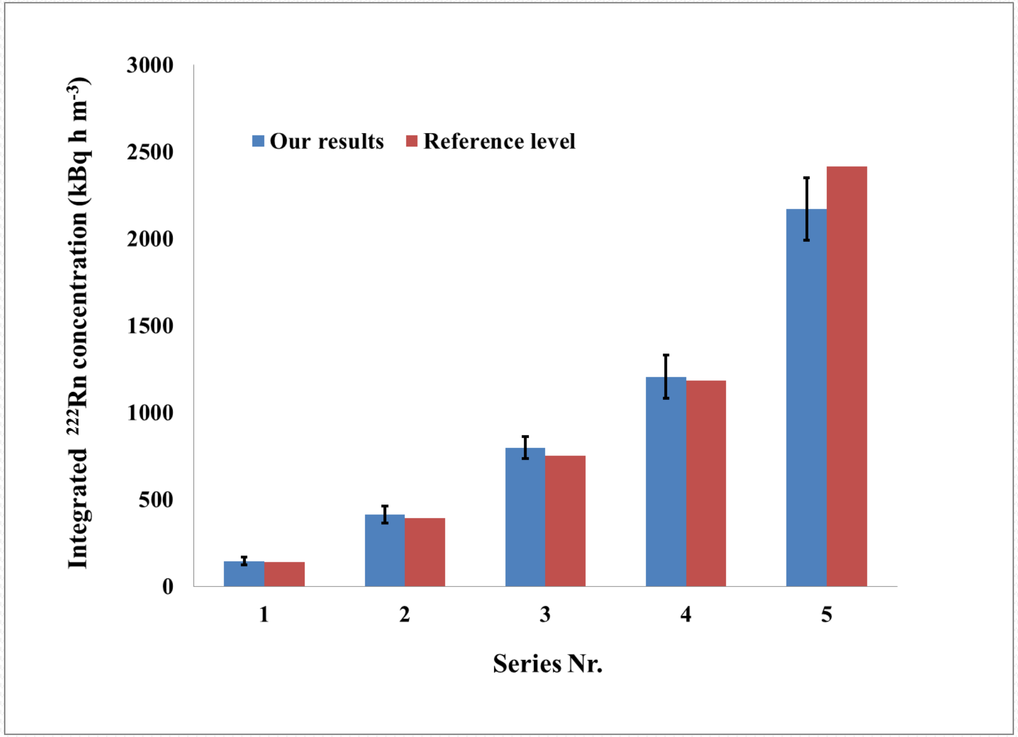
Calibration of the detectors:



$$C_A = \frac{n - n_b}{CF.T_{exp}}$$

$$\eta(C_A) = \sqrt{\eta^2(CF) + \eta^2(T_{exp}) + \frac{u^2(n) + u^2(n_b)}{(n - n_b)^2}}$$

QA of the method: performance at the Public Health England (PHE-UK) 2017/2018 radon inter-comparison



The need of blanc detectors:

The components of the detector background:

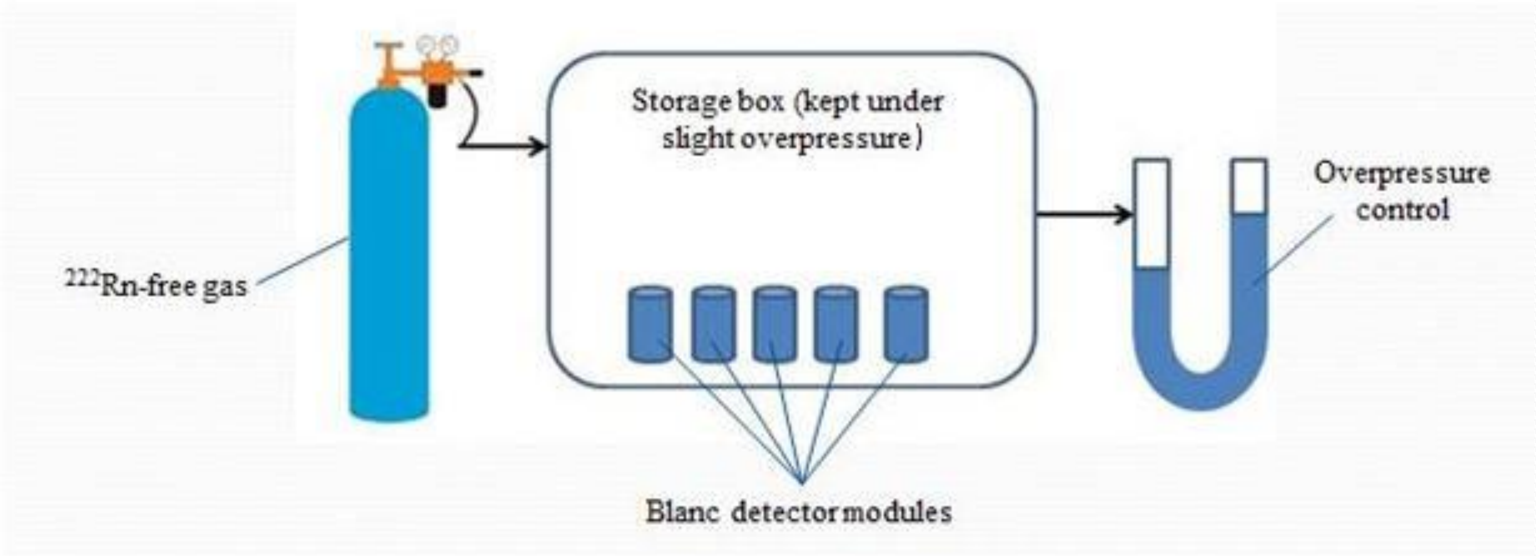
- Intrinsic background (due to e.g. radioactive impurities of the material);
- Non-radiation defects (they usually differ from the etched tracks and can be discriminated by special modes of track counting (e. g. *G. Vancraeynest et al. NIM B 129 (1997) 65-72*));
- Flux of neutrons from the cosmic component of the natural background (can be a problem at high altitudes but it is not expected at underground laboratories);
- **Radon in air in the place of storage… However, the levels of the environmental radon are usually higher than those that should be measured.**

The background can increase with time. The blanc detectors are needed to obtain the true background (i. e. at the end of exposure) of the exposed detectors.

How to arrange and handle the blanc detectors…

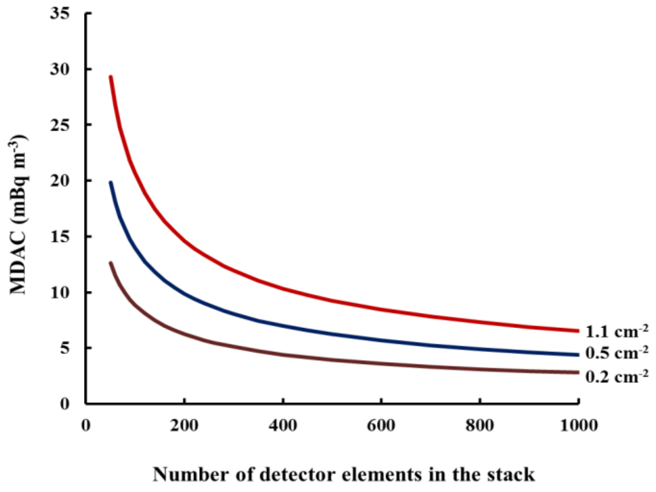
- The blanc detectors should be identical modules as those that are exposed, using the DVDs from the same stock and should be processed in parallel with exposed detectors, after exposure.
- **The set of blanc detectors should be stored under radon-free atmosphere, preferably close to the place of exposure;**
- A problem with the detector fading is not expected as previous research has shown that the fading of the detectors made from the same material as commercial DVDs is negligible (D. Pressyanov, IN: *Nuclear Track Detectors: Design, Methods and Applications*. Nova Science Publishers, Inc., New York (2010) pp. 155-176).

Storage of the set of blanc detector modules



Achievable minimum detectable activity concentration (MDAC) for one year exposure

$$MDAC = \frac{2.71+4.65\sqrt{n_B}}{CF.t.\sqrt{S}}$$



Summary:

- Novel methodology for integrated radon measurements of sufficient sensitivity for application in low-background nuclear research laboratories is proposed;
- It employs polycarbonate detectors (DVDs) with low background and large total detection area. The sensitivity is amplified by using external radiators of Makrofol N foil with very high radon absorption ability;
- Such monitors are cheap, sufficiently compact and can be positioned in many places;
- **When using the "true background" determined by blanc detector modules stored at radon free atmosphere the minimum detectable average ^{222}Rn concentration can be well below 1 Bq m^{-3} (e. g. less than 20 mBq m^{-3} with a module of 100 detector elements and one year exposure time).**

Thank you for your attention!

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