# Design and Field Tests of Scintillation Spectrometer for Continuous $^{222}$Rn in Soil-gas Monitoring

K. Mitev[1], Ch. Dutsov[1], L. Tsankov[1], S. Georgiev[1], M. Mitev[2], N. Markov[3], T. Todorov[4]

[1] Sofia University "St. Kliment Ohridski", Faculty of Physics, Sofia 1164, Bulgaria
[2]Technical University - Sofia, Department of Electronic Technique, Sofia, Bulgaria
[3]Festo Production EOOD, Sofia, Bulgaria
[4]Formerly with DZU Stara Zagora, Bulgaria

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## 1. Introduction

$^{222}$Rn in soil-gas studies are important for geology, seismology, radiation protection and NORM activities. The objective of this work is to present the realization and the results of pilot field tests of a detector, designed for continuous, unperturbed monitoring of $^{222}$Rn in soil-gas. Hereafter the detector is called Polyphemus.

## 2. Methods and materials

By design, the Polyphemus detector consists of an optical chamber, which is optically coupled to a hermetic volume which contains a photomultiplier tube (PMT, Hamamatsu R7600U-200), high voltage supply (Hamamatsu C9001 mod +HV), nanoPSD digital spectrometer with an embedded pulse-shape analyzer (produced by the labZY company) and an outside board with chip-controlled sensors for pressure, temperature, humidity and an accelerometer (Figure 1). The optical chamber is a truncated regular pyramid with its base opposite to the PMT. It is produced by 3D printing from PLA and painted with $TiO_2$. It has holes on its sides to allow free $^{222}$Rn diffusion in it. An EJ-212 plastic scintillator foil with thickness 250 μm is glued with optical grease in front the PMT. A certain part of the α- and β- particles produced by $^{222}$Rn and its progeny in the optical chamber can reach the plastic scintillator and produce light in it. The light is collected at the PMT, whose anode chain is directly connected to the input of the nanoPSD analyzer. The EJ-212 PSD performance is far from perfect, but still good enough to allow practical application (Figure 2).

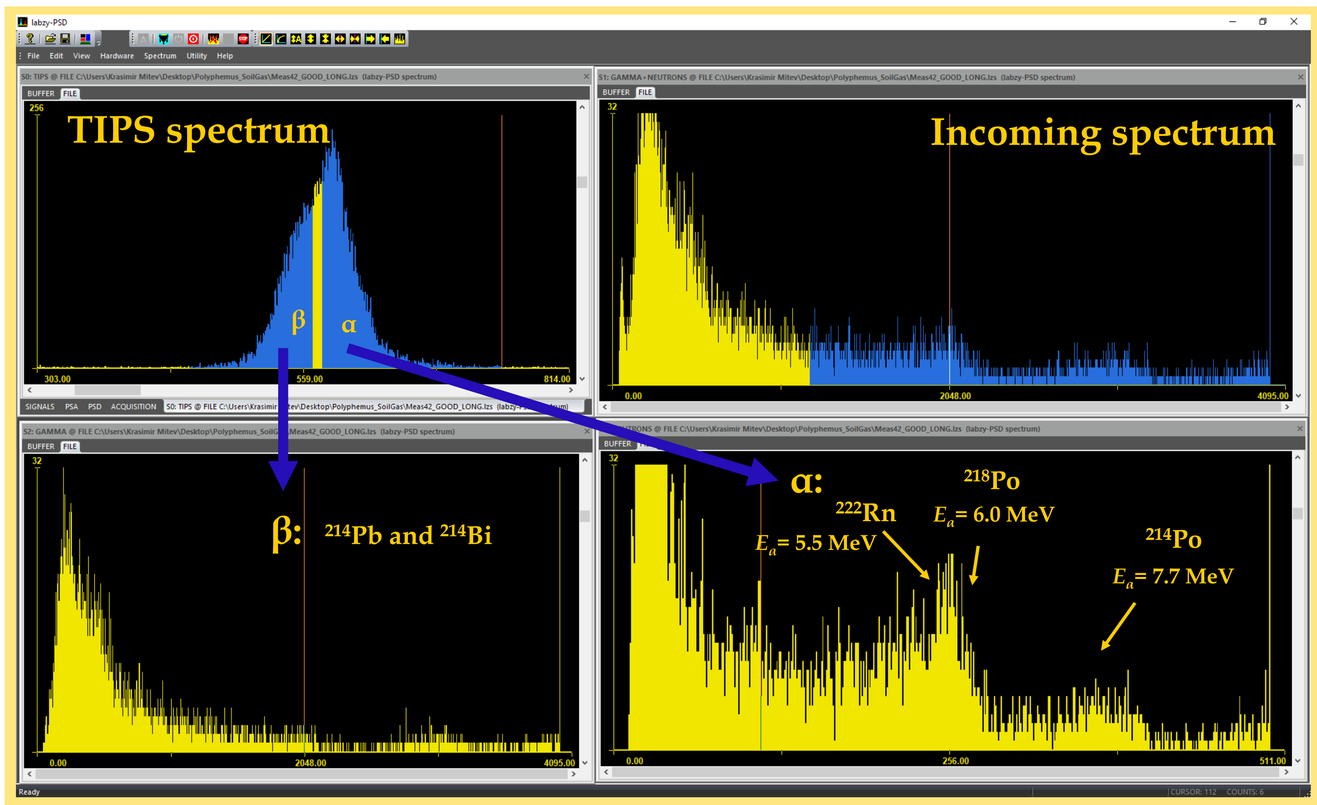



**Figure 1. Example of a $^{222}$Rn in soil gas measurement with Polyphemus and the nanoPSD module. The marked ROI (top left) is used for PSD.**

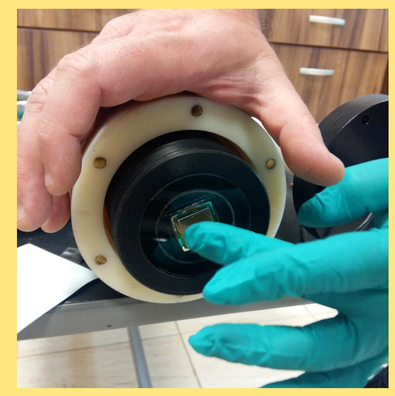


**Figure 3. Assembly of the optical chamber Polyphemus. Placing the plastic scintillator.**

**Polyphemus assembled (left). Placing the detector in the soil (middle). The detector measuring $^{222}$Rn in soil-gas concentrations (right).**

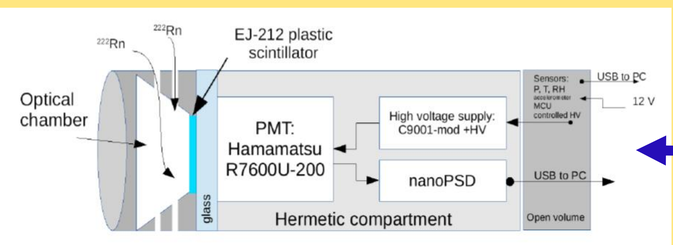
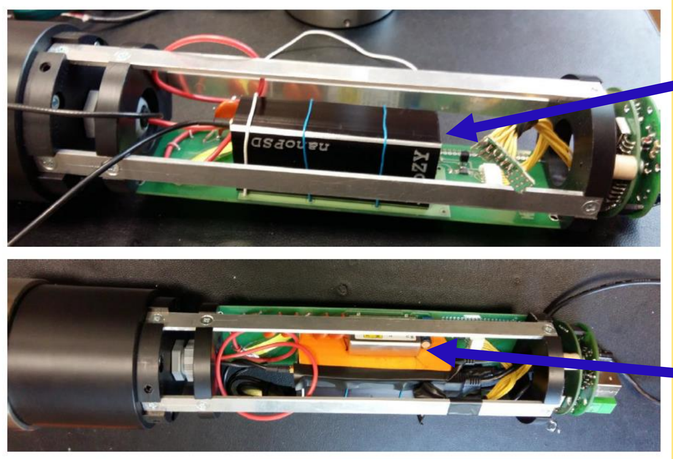
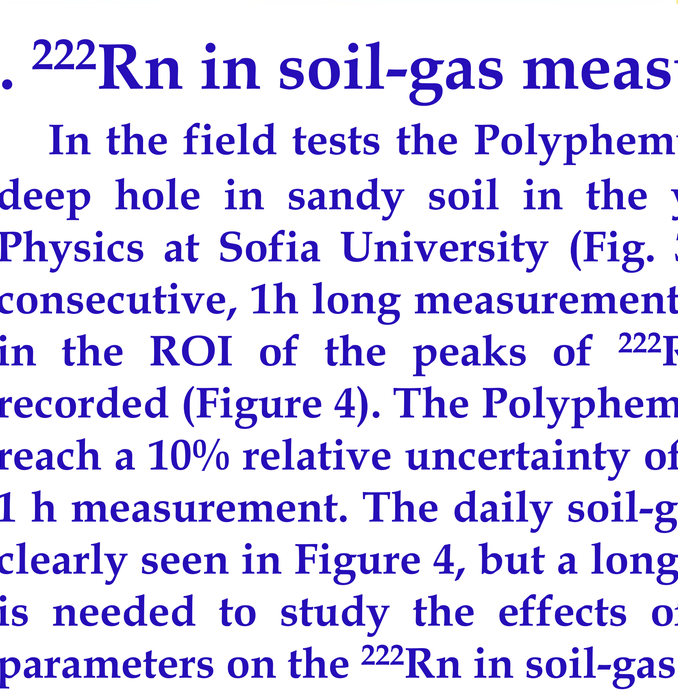



**Figure 1. The Polyphemus detector**

**Scheme of the Polyphemus detector**



**Snapshot of the content of the hermetic compartment with the nanoPSD module**



**The high voltage supply.**

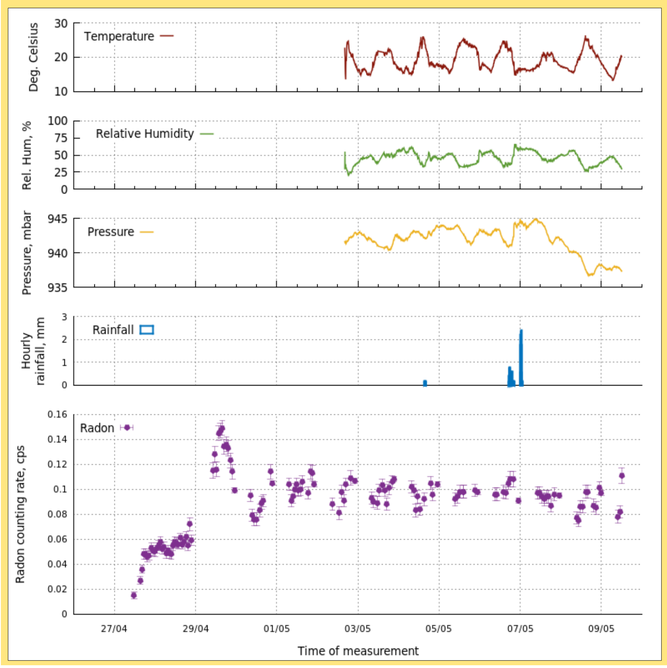



**Figure 4. Results of the 12 days monitoring of the dynamics of $^{222}$Rn concentration in the soil.**

**Weather parameters: temperature, humidity and atmospheric pressure.**

**Polyphemus $^{222}$Rn in soil-gas readings. The error bars in the radon readings (cps) indicate the estimated statistical uncertainties at the level of one standard deviation.**

## 3. $^{222}$Rn in soil-gas measurements

In the field tests the Polyphemus was placed in a 1 m deep hole in sandy soil in the yard of the Faculty of Physics at Sofia University (Fig. 3). The detector makes consecutive, 1h long measurements and the counting rate in the ROI of the peaks of $^{222}$Rn and its progeny is recorded (Figure 4). The Polyphemus sensitivity allows to reach a 10% relative uncertainty of the counting rate for a 1 h measurement. The daily soil-gas $^{222}$Rn oscillations are clearly seen in Figure 4, but a longer measurement period is needed to study the effects of rainfall and weather parameters on the $^{222}$Rn in soil-gas concentration.

## 4. Conclusions

This work demonstrates the salient features of a newly developed detector for $^{222}$Rn in soil-gas measurements, which does not use any kind of air sampling and allows unperturbed $^{222}$Rn in soil-gas menitoring. Due to its advantageous design and PSD discrimination capabilities, the detector has low background, good sensitivity and allows continuous monitoring of $^{222}$Rn in soil-gas concentrations. It can be useful for experimental studies of the potential relationship between $^{222}$Rn in soil-gas anomalies and seismic activity.

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