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Radon diffusion through different materials and first prototype of the hemispherical detector for measurements of low activity of radon

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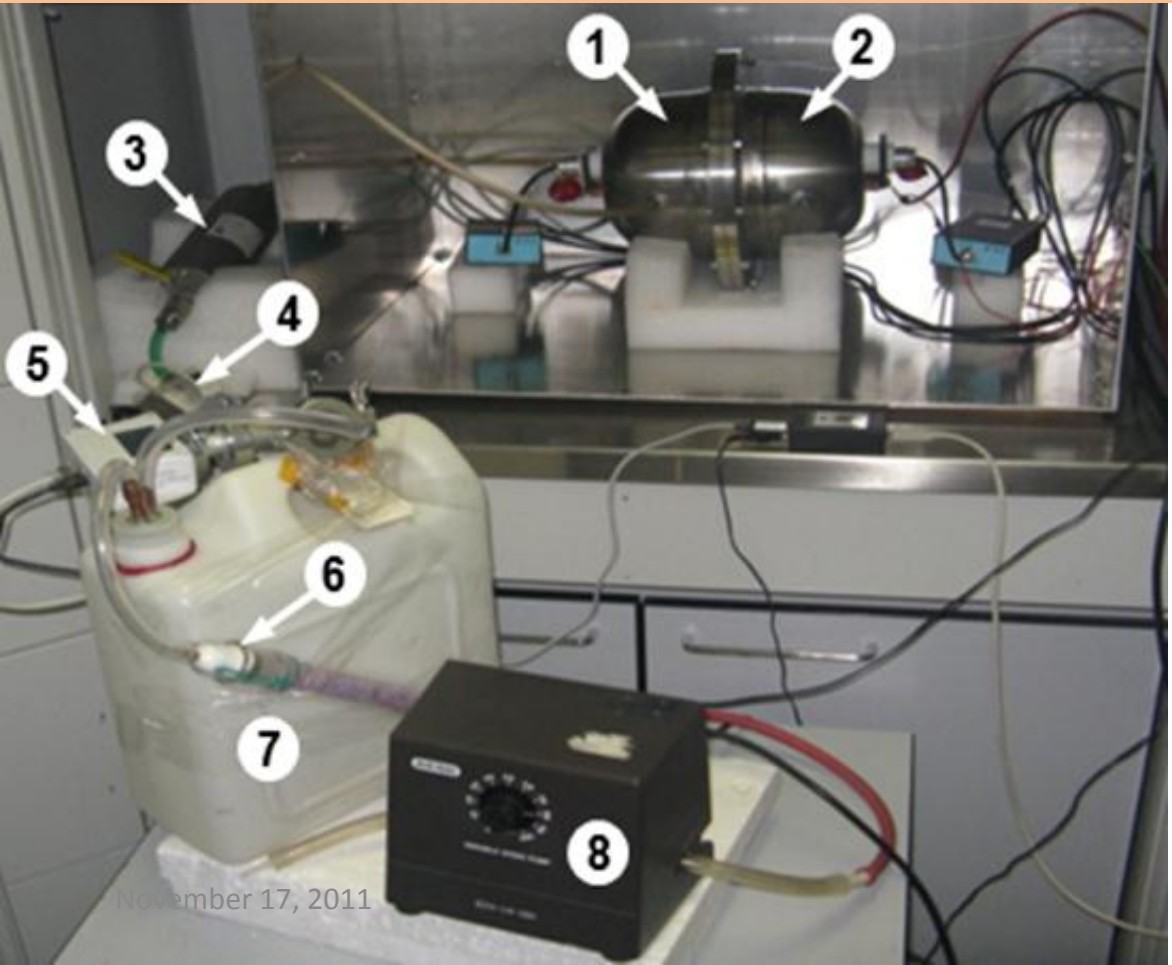
- **Radon diffusion – measurement of new materials**

a)	PVC 2 mm	from MSSL UK ***Tom Hunt***
b)	Delrin sheets 1 mm	from University of Mancheter ***David Urner***
c)	Resin UR6 manufacturer KEMICA 2.1 mm	from Modane ***Michel Zampalo***
d)	SBR+Acrylic on stainless steel sheet 2 mm	from MSSL UK ***Tom Hunt***
e)	Emultex 518 on stainless steel sheet 2 mm	from MSSL UK ***Tom Hunt***
f)	Neoprene 1 mm	from LAL
g)	Bovlon film 15 μm	from MSSL UK ***Tom Hunt***

- **First prototype of the hemispherical detector for measurements of low activity of radon**
- **Conclusions & Future plans**

Apparatus for measurement of radon diffusion

-Left side = high Rn activity
[activity Rn 38 kBq/m^3 , dry air flow through Rn source 0.34 l/min],
-Right side =low Rn activity
[background 7±3 events per day],
-Both sides are divided by testing foils,
-Long term measurements of Rn activities on both sides.
(After achieving a stationary state, lower limit of detection (LLD) of the radon diffusion *D* at the level ~10^{-18} m^2s^{-1} for foil thickness of 15 μm and for time of measurement 3 weeks)



1/2 - Left/right vessel

3 - Radon source

4 - Flow-meter

5 - Sensors of temperature, humidity, and pressure

6 - Air dryer

7 - Air buffer

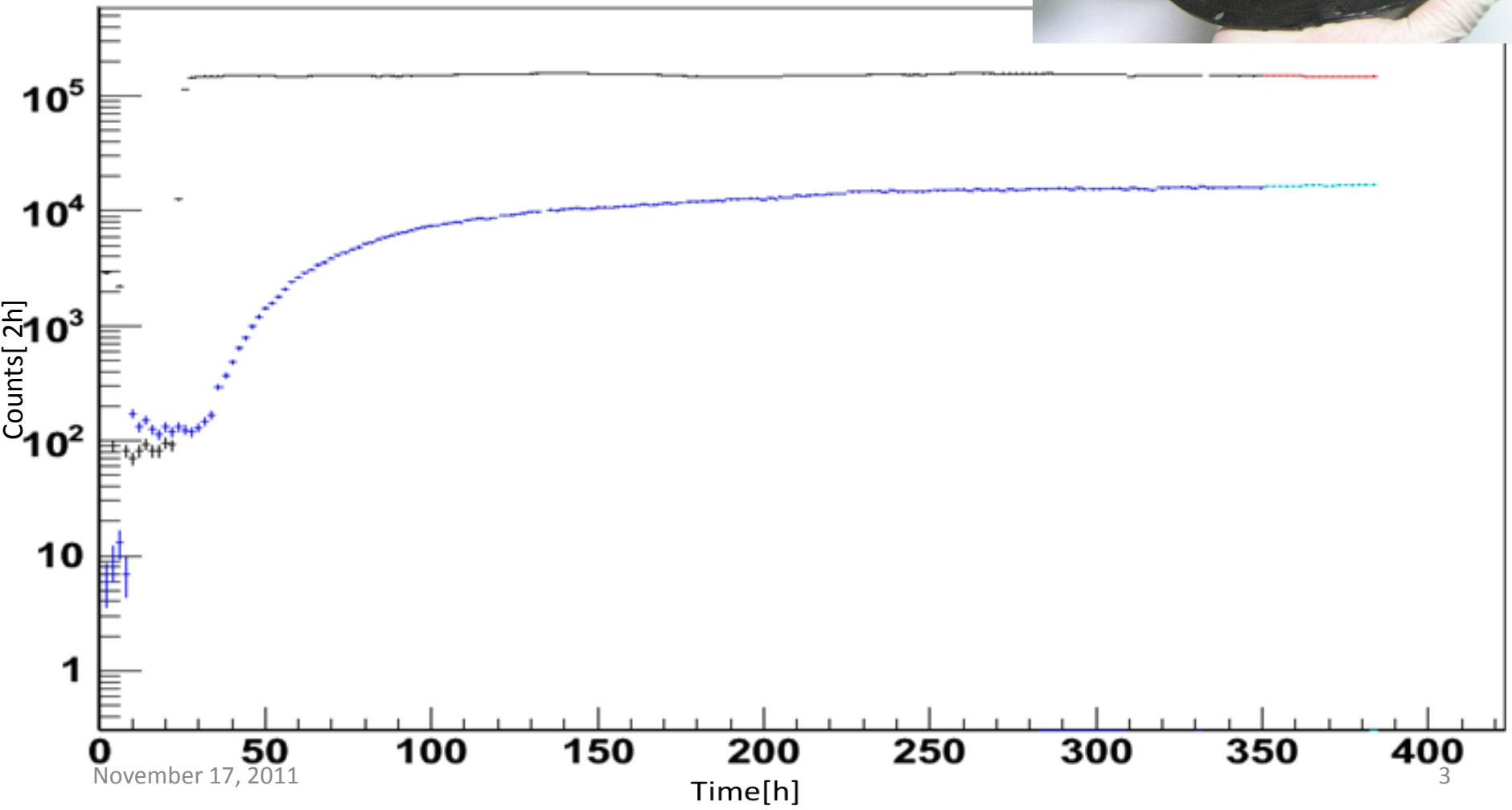
8 - Air pump, 0.5 l/min

Measurement Rn diffusion through PVC

Thickness 2 mm

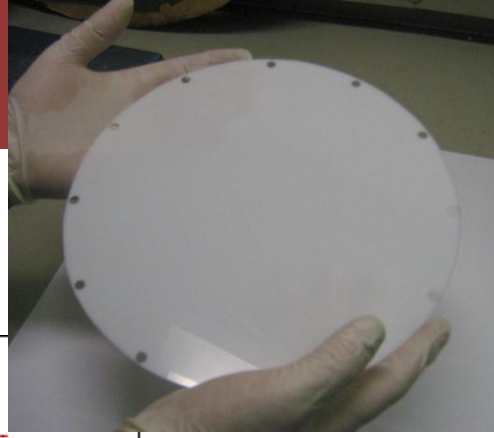
Rn suppression factor C1/C2 = 9

Diffusion coefficient $D = 4.4 \cdot 10^{-11}\ m^2 s^{-1}$



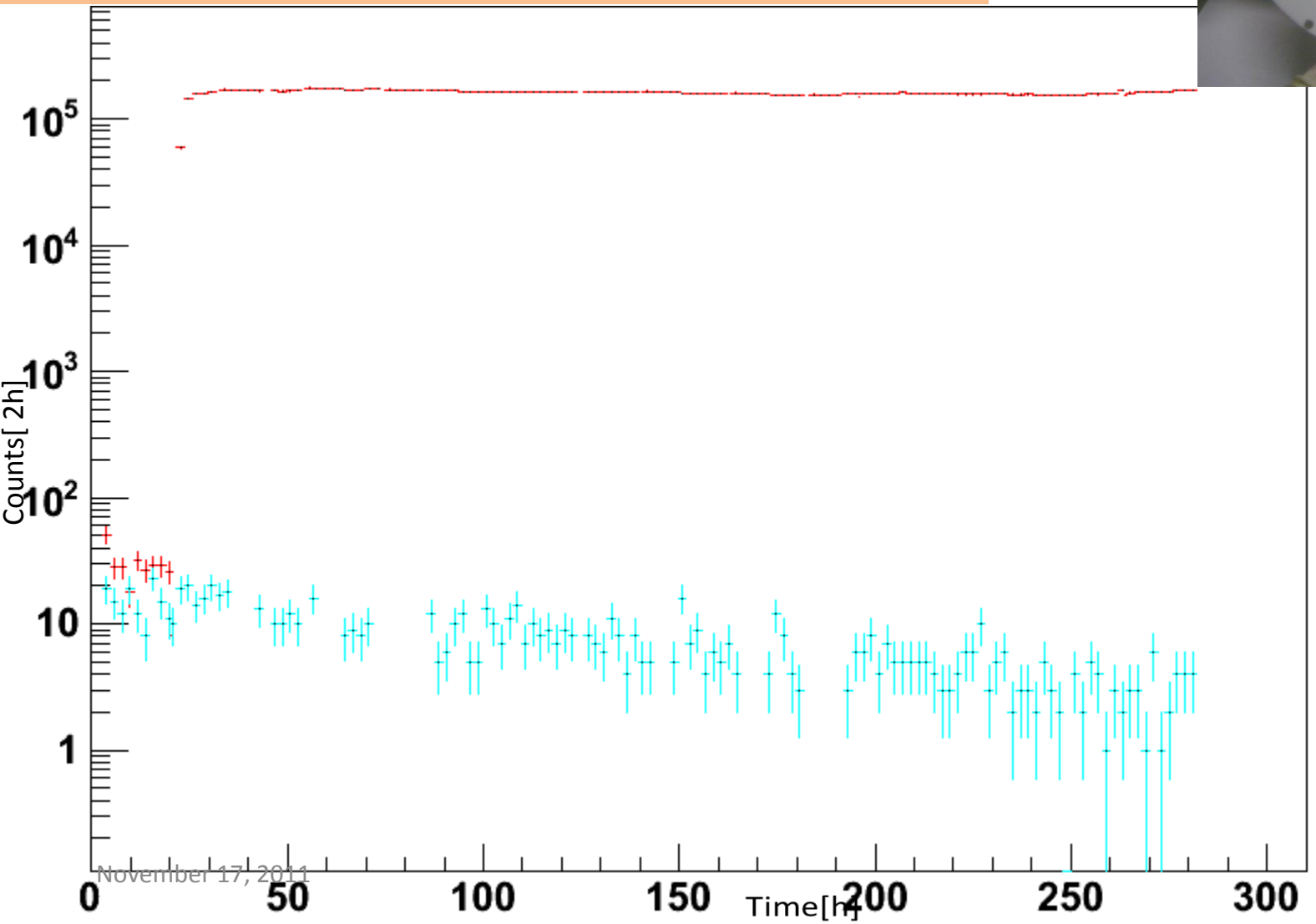
Measurement Rn diffusion through Delrin sheets

Thickness 1 mm



Rn suppression factor C1/C2 = 47 860

Diffusion coefficient $D = 7.2 \cdot 10^{-14}\ m^2 s^{-1}$



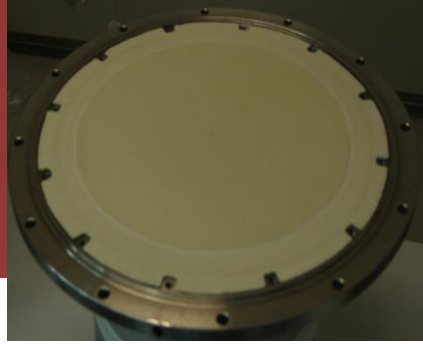
Measurement Rn diffusion through resin UR6

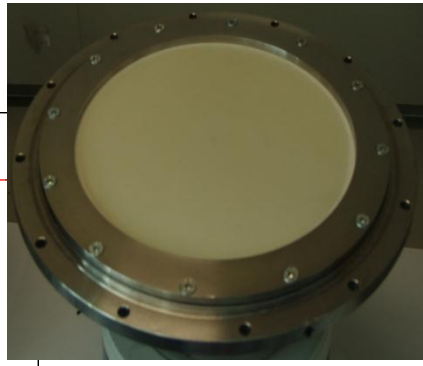
manufacturer KEMICA

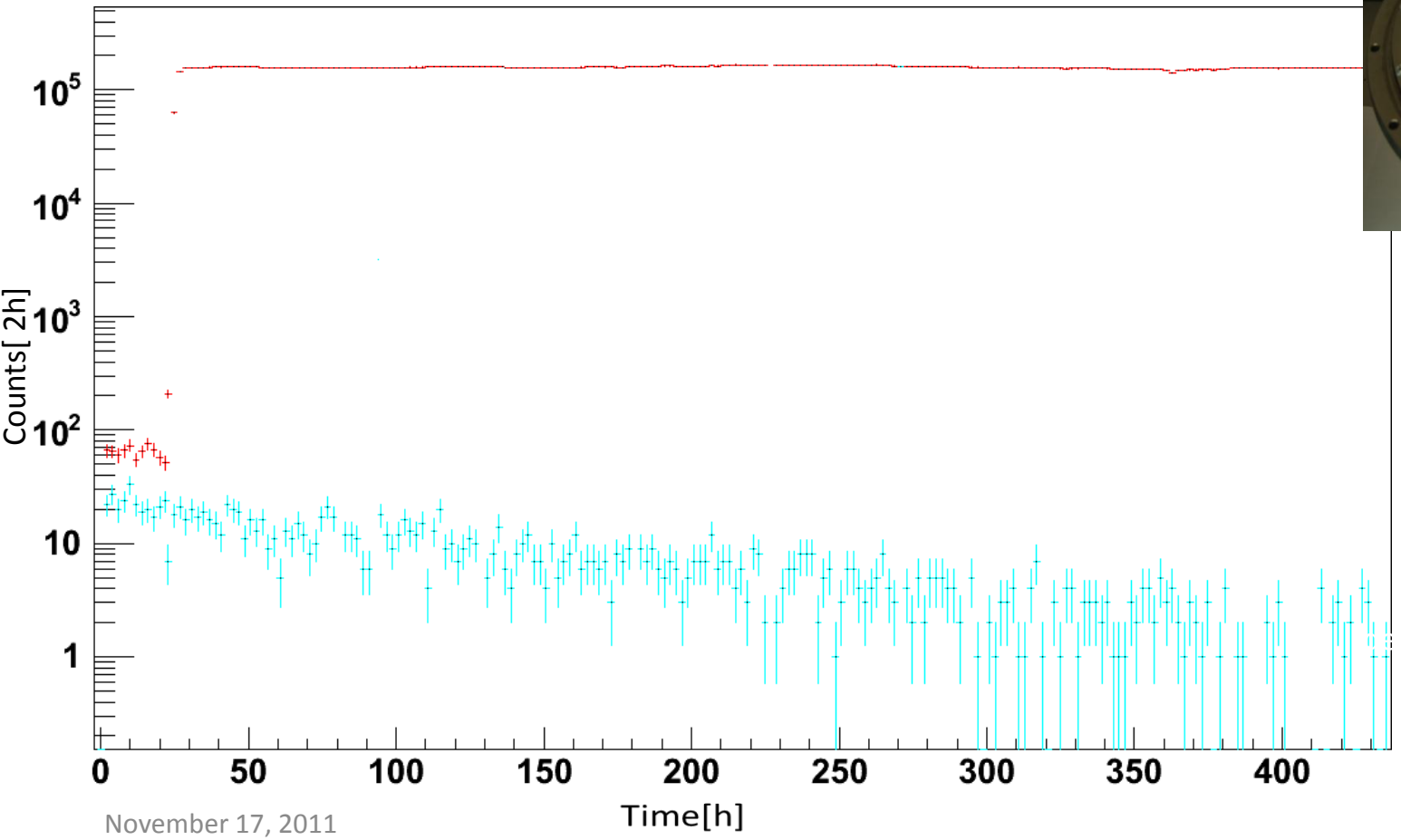
Thickness 2.1 mm

Rn suppression factor C1/C2 = 159 000

Diffusion coefficient $D = 1.9 \cdot 10^{-13}\ m^2 s^{-1}$



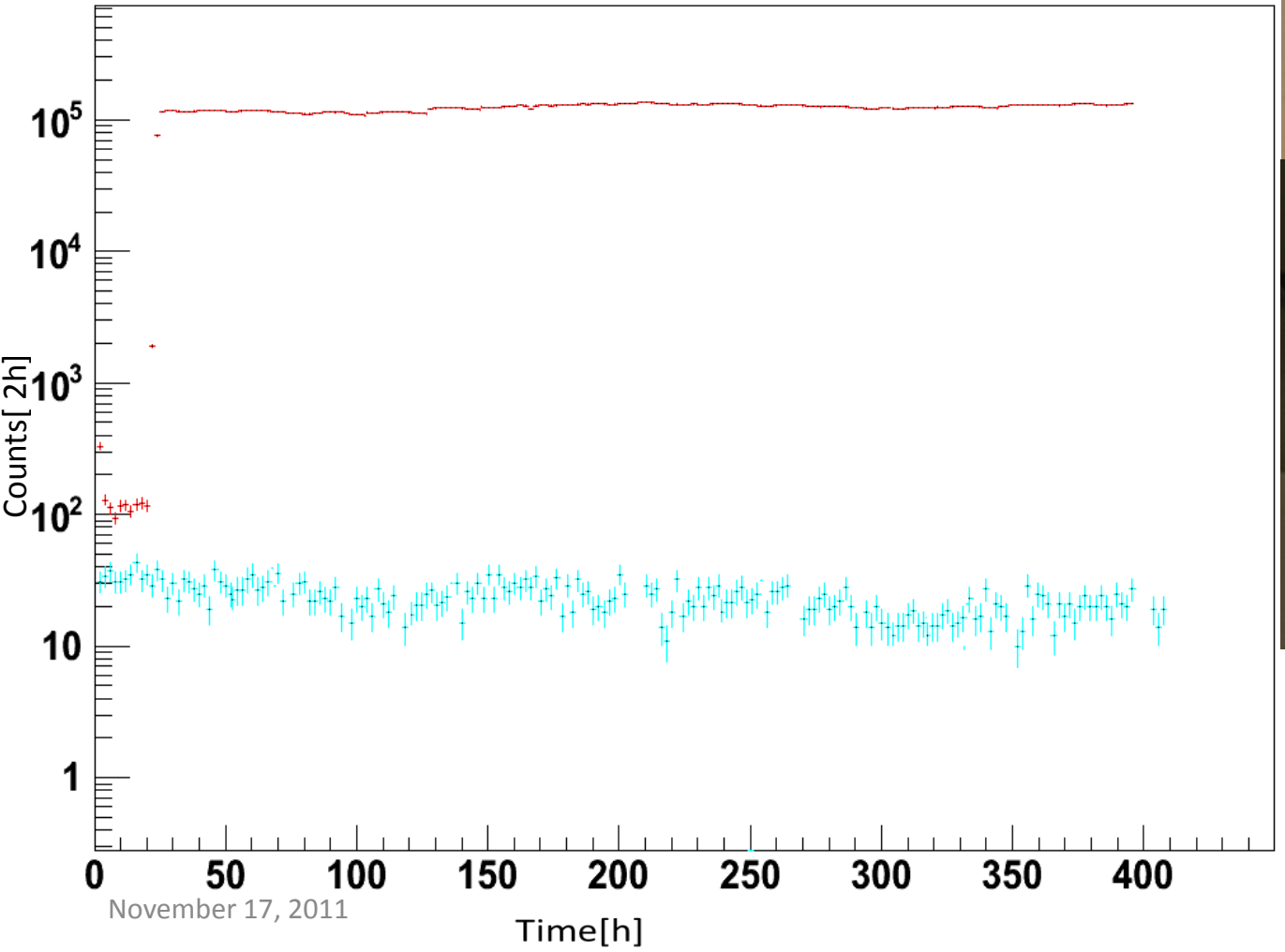


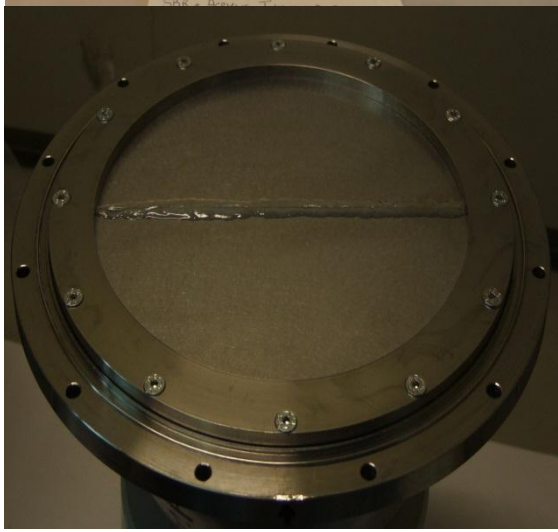


Measurement Rn diffusion through SBR

Thickness ~2 mm, width of the hole~0,5 mm, length 200 mm

Diffusion coefficient $D = 1.6 \cdot 10^{-11}\ m^2 s^{-1}$

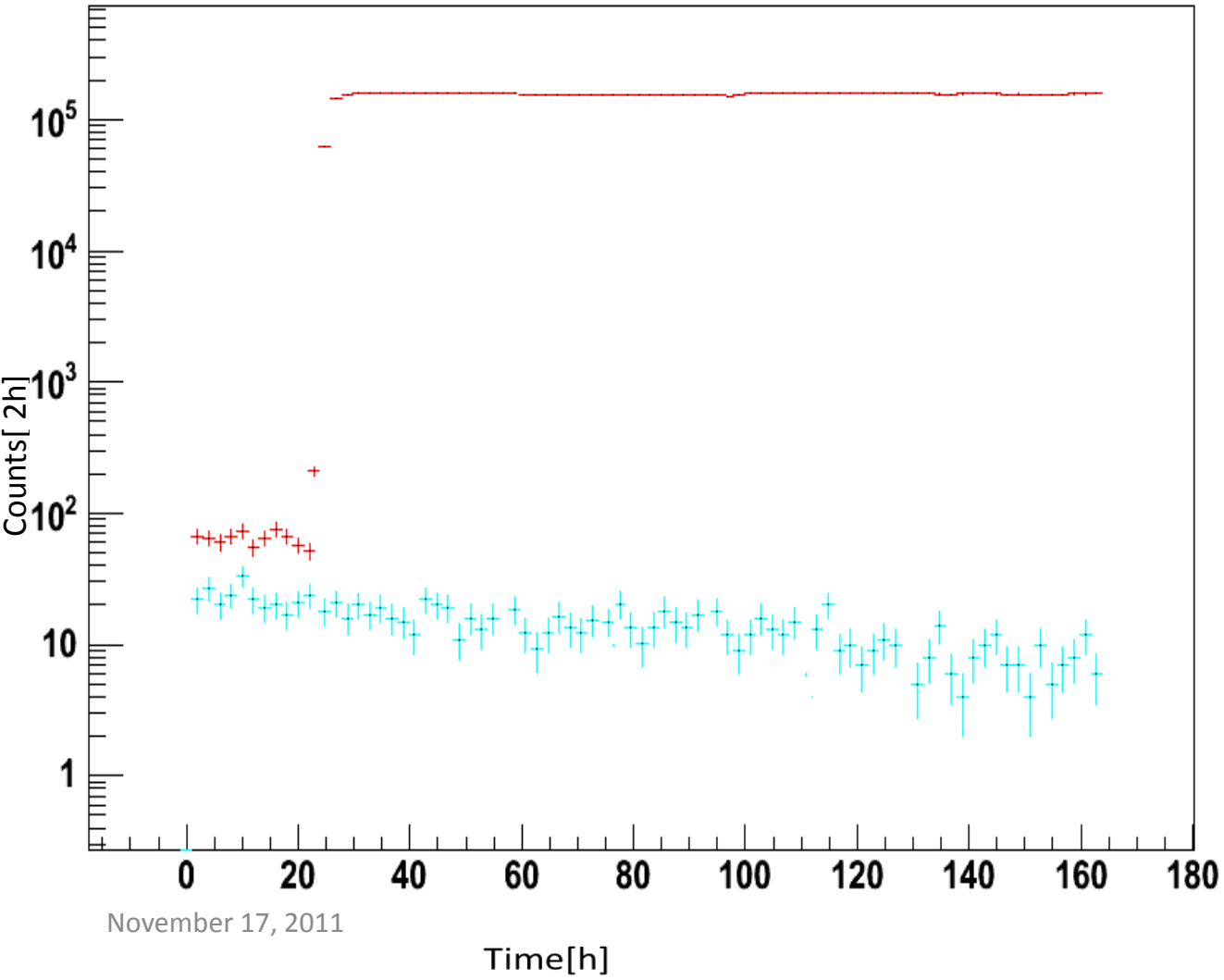


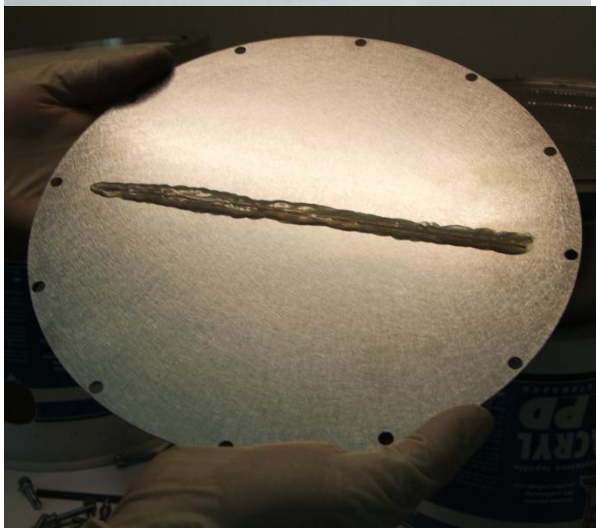


Measurement Rn diffusion through Emultex 518

Thickness ~2 mm, width of the hole~0,5 mm, length 200mm

Diffusion coefficient $D < 5.9 \cdot 10^{-12}\ m^2 s^{-1}$

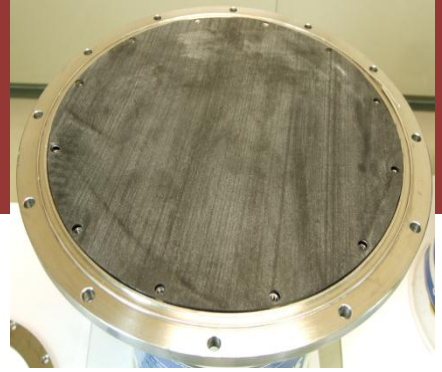


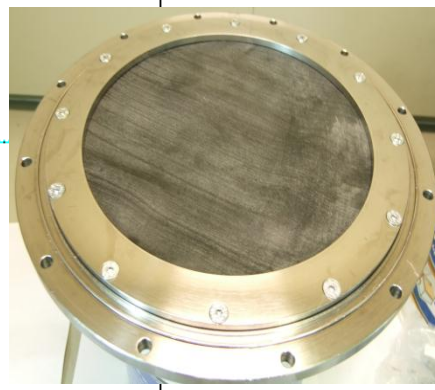


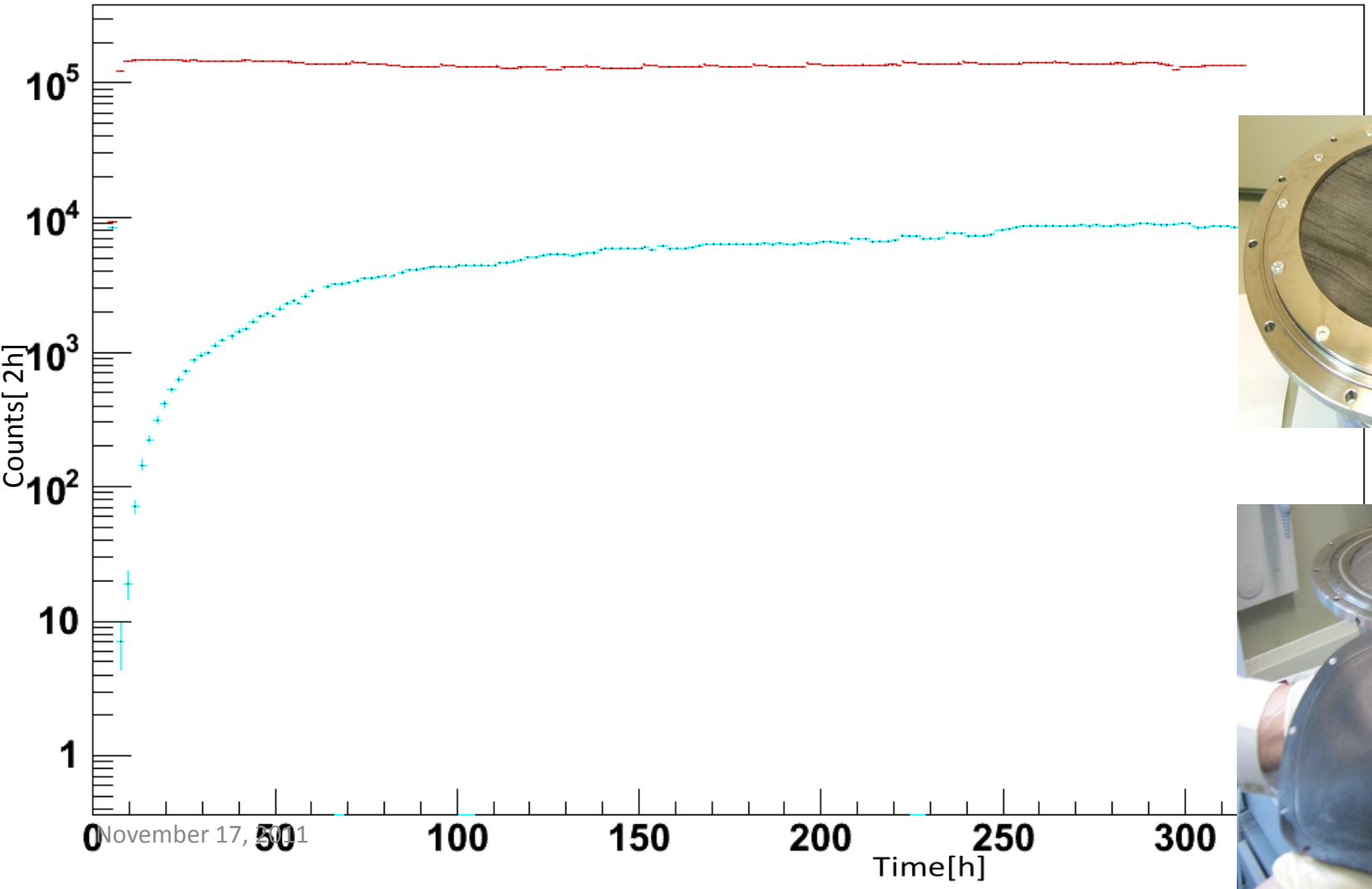
Measurement Rn diffusion through foil Neoprene
Thickness 1mm

Rn suppression factor C1/C2 = 15.6

Diffusion coefficient $D = 1.2 \cdot 10^{-11}\ m^2 s^{-1}$



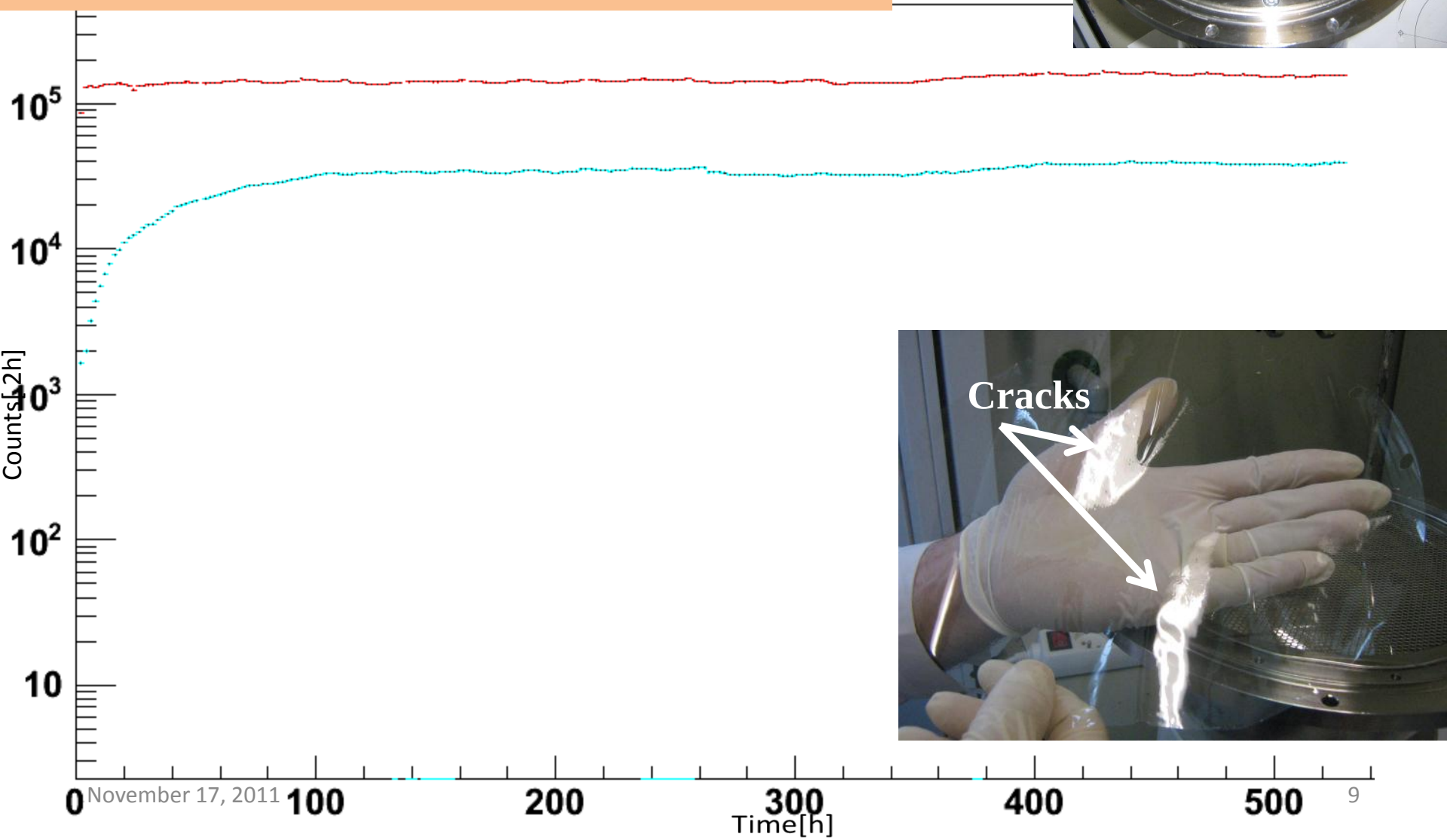




Measurement Rn diffusion through Bovlon film 15 μm

Rn suppression factor C1/C2 = 4

Diffusion coefficient $D = 8.4 \cdot 10^{-13}\ m^2 s^{-1}$



Result of measurements of new samples

Material	Thickness d [mm]	C_1/C_2	C_1/C_2 normalized to 15 µm	Diff. coefficient D [10^{-12} m^2s^{-1}]	Diff. length L [µm]
PVC 2mm	2	9	1.1	44	4 600
Derlin sheets	1	47 860	36	0.072	186
Resin UR6 manufacturer KEMICA	2.1	159 000	15	0.19	297
Neoprene	1	15.6	1.2	12.4	2 430
Bovlon film	0.015	4.0	4.0	0.84	633
SBR+Acrylic on stainless steel sheet	2	6 680	47	16	2 760
Emultex 518 on stainless steel sheet	2	>20 900	>126	<5.9	<1 680

Measurements with foils and slit on metallic sheet are not comparable (due to extremely small area of testing material for slit and consequently small amount of Rn penetrating into the second measuring chamber) !!!

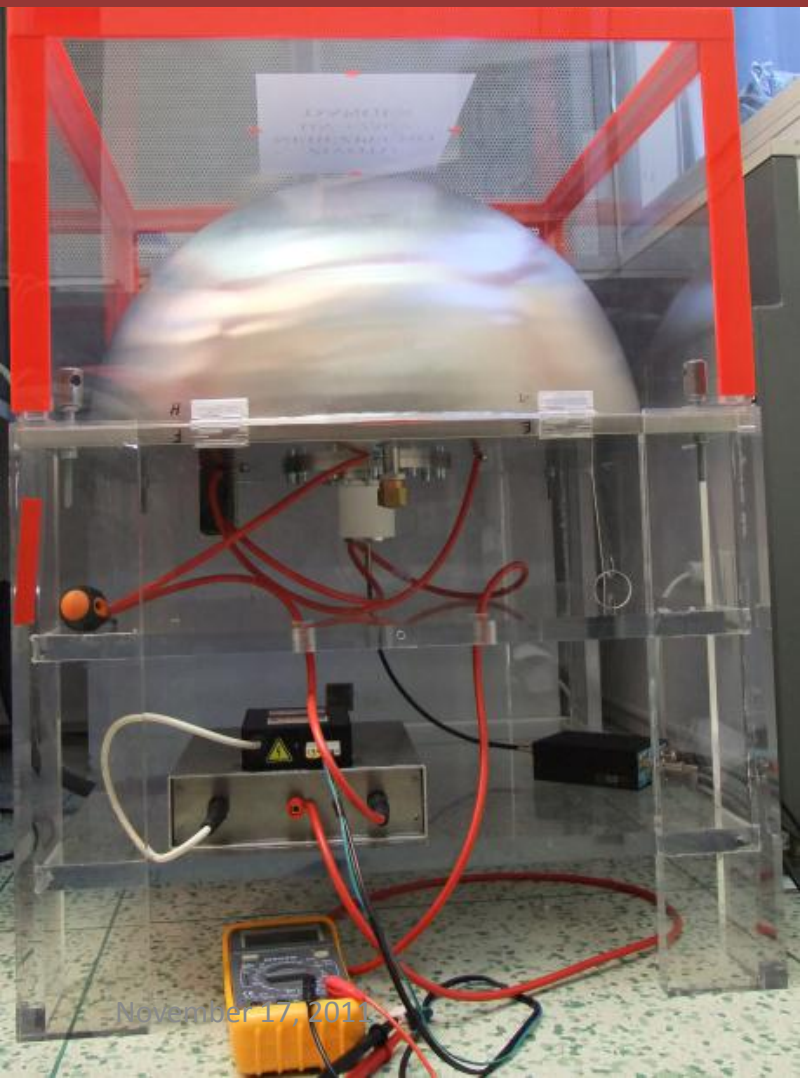
Tests with slit means extremely long time of measurements to reach precise value of D as well as high uncertainty !!!!

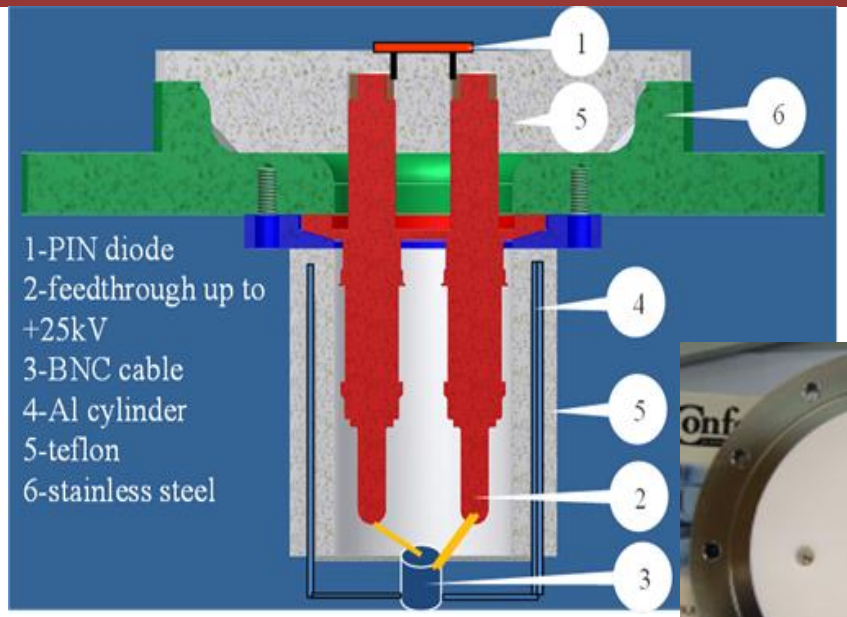
Material	Thickness d [μm]	C_1/C_2	C_1/C_2 normalized to 15 μm	Diff. coefficient D [10^{-12} m^2s^{-1}]	Diff. length L [μm]
HDPE (2 layers)	2×144	3.5	1.1	19	3000
EVOH*	15	4.7	4.7	0.68	570
TROPAC III	102	> 8300	> 600	< 0.0043	< 46
Mylar (2 layers)	2×20	> 9100	> 2300	< 0.0012	< 24
EVOH (2 layers)	2×15	> 31000	> 8900	< 0.00035	< 13
EVOH + PE	125	165	20	0.013	254
Silicon	2 800	2.5	1.008	320	12 000
RTV 615	2 100	1.33	1.002	1084	22 747
RTV 116 (in the metal)	3.5	25	1.1	7201	58599
RTV ECOO	2 000	1.5	1.002	1 030	22 200
STYCAST 1264	2 000	> 7268	> 6.9	< 0.43	< 455
PET	1 000	> 41 136	> 35	< 0.076	< 190
PLEXY	1 000	1 617	9.8	0.29	371
Butyl	1 000	2.5	1.02	1180	7 496
Emultex 518 (6 μm)+ PE (11 μm)	17	> 9 985	> 8 261	< 0.00038	<13
WB 50T	50	12.5	4.4	0.74	593
RTV 615 with 60% resin Stycast	1 000	1.3	1.005	521	15 765
Mylar junction	20	110	85	0.030	120
TROPAC junction	102	> 6300	> 500	< 0.0051	< 50

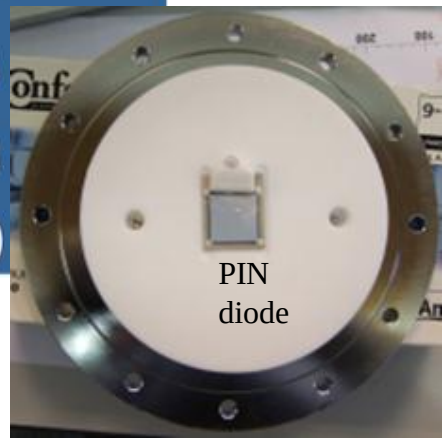
The result EVOH* was influenced by cracks in the foil

First prototype of the hemispherical detector for measurements of low activity of radon

-Volume 50 liters
-Inner surface is electrochemically polished to level of 0.4 μm
-HV up to +12kV





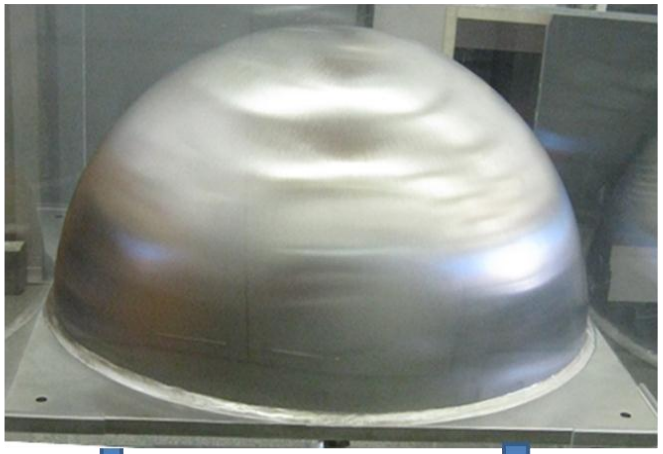


First prototype of the hemispherical detector with volume of 50 l (outer view on the left), schematic view of the HV feed-thorough (middle) and conduction of PIN diode (right)

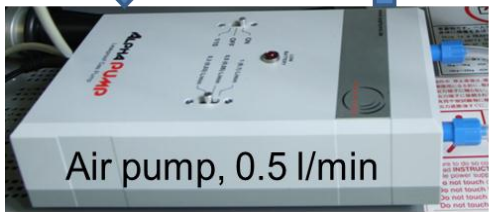
Experimental setup of apparatus.

Air dryer

Hemisphere made of stainless steel with a volume V =50 l



Sensors of temperature, humidity, and pressure



The setup of the measurement of the detection efficiency of the first prototype: The air from the laboratory goes through the air-dryer. The dry air (with the relative humidity at the level of 3%) is pumped (with the speed of 0.5 l/min) through the hemispheric detector. The air coming from the detector chamber is then measured in the detector of humidity, temperature and pressure. At the end of the detection chain, the radon concentration in the air is measured in the AlphaGUARD (commercial device for activities over 2 Bq/m^3).

Efficiencies of radon detection measured under different experimental conditions with the first prototype.

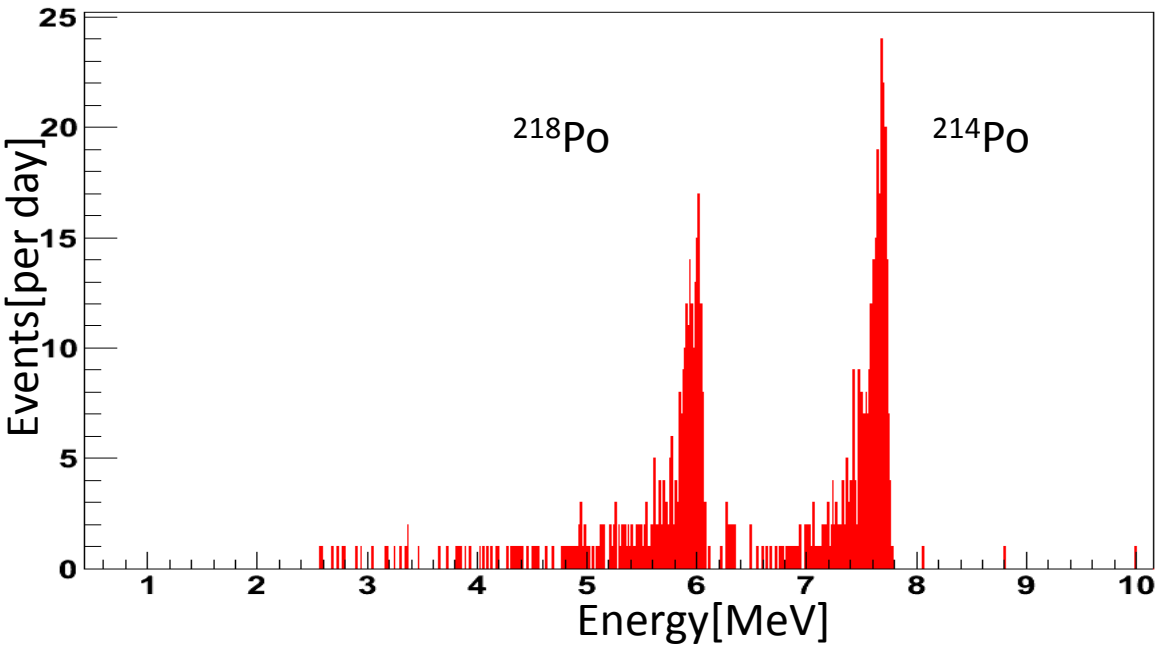
*Radon activity was measured by AlphaGUARD used as the reference equipment.

HV [kV]	Rn activity* [Bq/m^3]	Number of ^{214}Po events [h^{-1}]	Temperature [°C]	Relative humidity [%]	Air flow [l/min]	Rn detection efficiency [%]
6.0	33	1 424	27	3.2	0.5	24.0
7.5	16	742	28	3.2	0.5	25.8
7.5	25	1 160	20	3.2	0.5	25.8
9.0	24	1 144	20	3.0	0.5	26.5
12.0	28	1 494	19	3.0	0.5	30.0

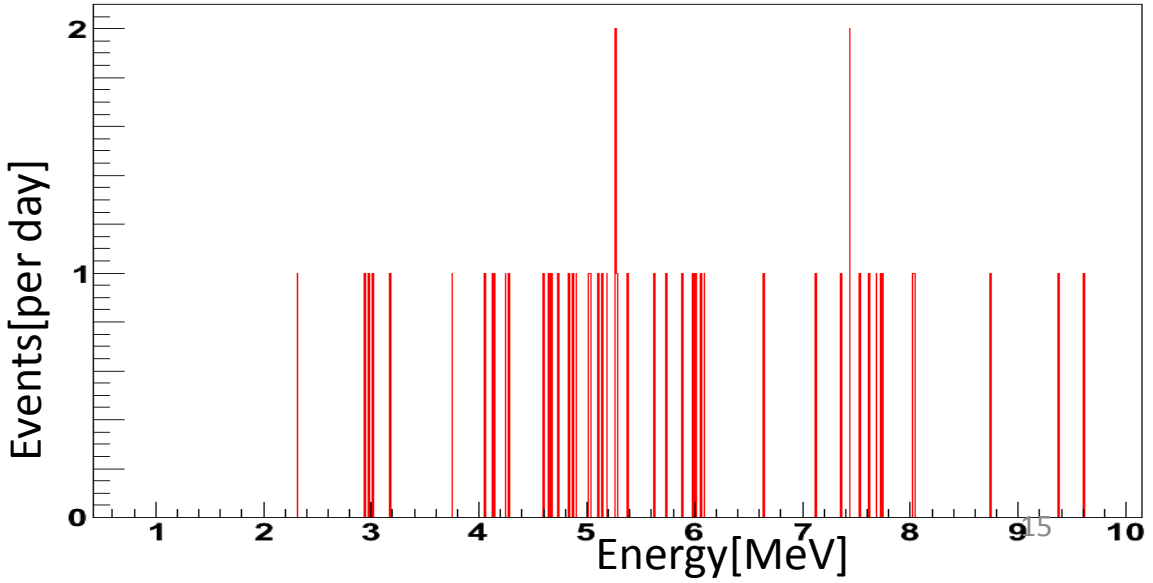
The detection limit of the apparatus is influenced by the level of background. The preliminary result of the background is 11±1 events/day in the region of our interest (6.2-7.8 MeV peal of ^{214}Po). Based on this preliminary result the estimation of the detection limit for the first prototype was calculated (see slide 16).

Measurements of background for the hemispherical detector

Energy spectrum measured at the beginning of background measurement (5 Bq/m^3)

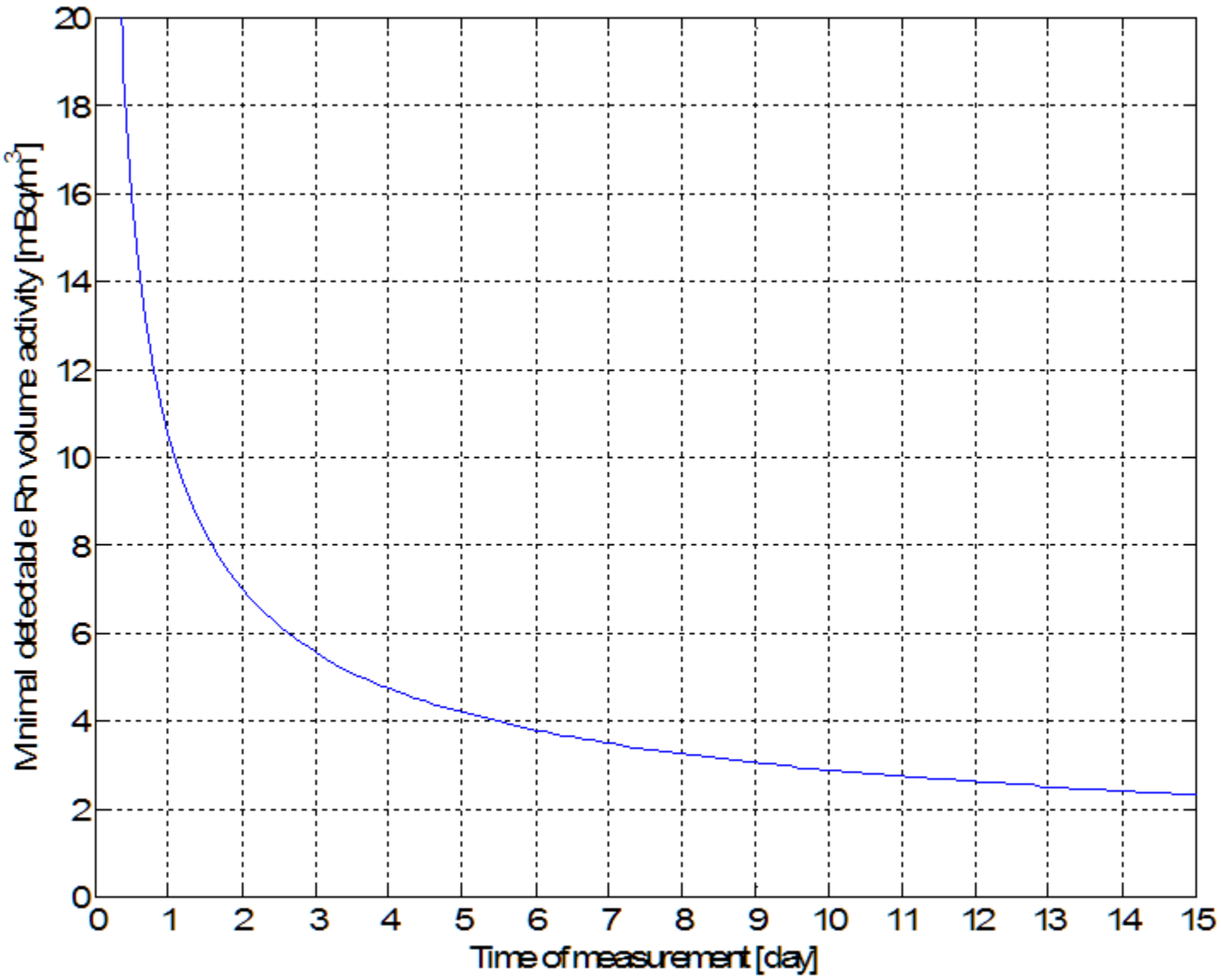


Energy spectrum measured after two months.



Background is 11±1 events/day in the ROI (6.2-7.8 MeV, ^{214}Po)

Minimal detectable radon volume activity as a function of the time of measurement. The background rate of the measurement is 11 events per day, volume of the chamber is 50 l and the measurement efficiency 30% was used. The confidence level 95% was chosen.



Time of measurement [day]	Sensitivity [mBq/m³]
1	11
7	3.5
30	1.6
75	1

Conclusion and future plans

1) **Radon shielding foils –** running task (new foils)

a) Several candidates for outer shielding – e.g. TROPAC, EVOH (more layers), .. SBR seal, Resin UR6

b) Candidates for inner shielding (tracker) – Nylon (influence of humidity), EVOH, Emultex 518 (with PE), SBR seal

2) **Rn detector –**

increase the HV in first prototype

new prototype with higher volume (300 litres)