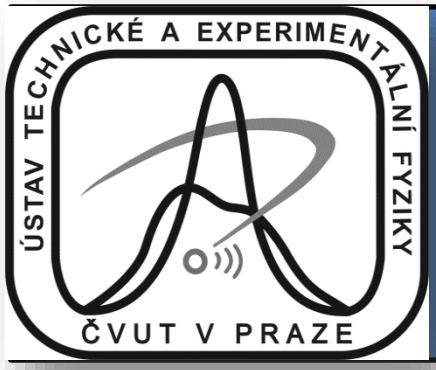

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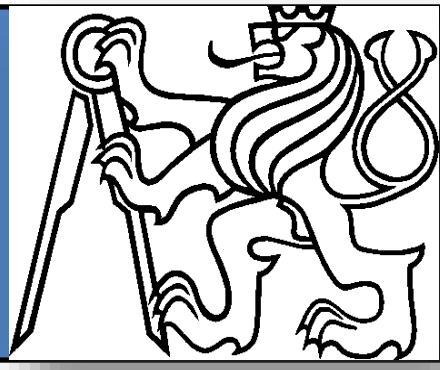


Měření difúze, ultranízké koncentrace a emanace radonu pro podzemní laboratoř

Fadahat Mamedov, Ivan Štekl, Karel Smolek

Outline

- **Introduction**
- **Rn diffusion apparatus**
- **Apparatus for measurement of low activity of radon**
- **Radon emanation apparatus**
- **Conclusions & Future plans**

Introduction

Radon R&D for SuperNEMO experiment

Goal : A(222 Rn) < 0.1 mBq/m3 in the tracking chamber

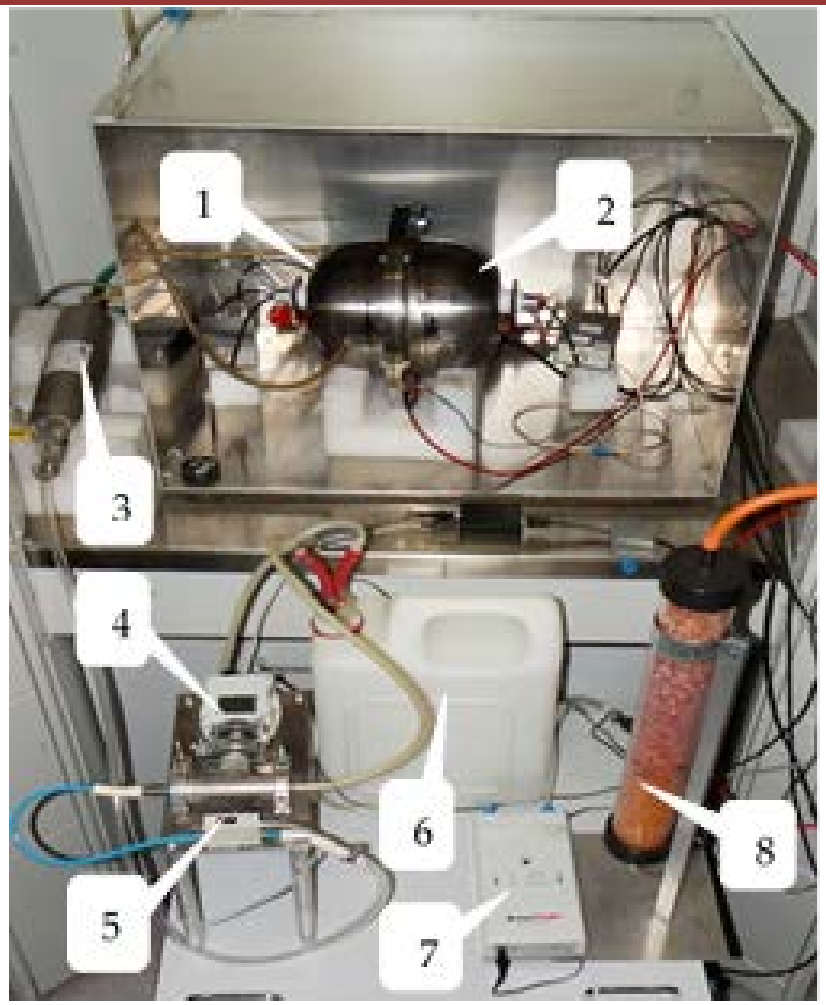
Main sources of the radon background:

- Diffusion of the radon coming from outside the detector
- Emanation from the materials inside the detector
- Radiopurity of the gas in the tracking chamber

Possible solutions :

- Isolation of the tracking chamber from the calorimeter part using thin foils with low radon diffusion coefficient - Rn diffusion apparatus
- Development of radon detectors sensitive to ~0.1 mBq/m3 - Rn sensitive detector
- Emanation measurements of some crucial materials that will be installed inside the detector (glass from PMT, wires…)- Rn emanation apparatus
- Increase of the gas flow by a factor up to 10 to lower the radon level in the tracking chamber→ recycling of the gas
- Purification of the gas before entering the tracking chamber

Apparatus for measurement of radon diffusion



The device uses the electrostatic collection of charged particles for the detection of Rn decay products

- Two stainless steel hemispheres separated by tested material foil

Left side hemisphere with high Rn activity *[activity Rn 38 kBq/m^3 , dry air flow through Rn source 0.34 l/min],*

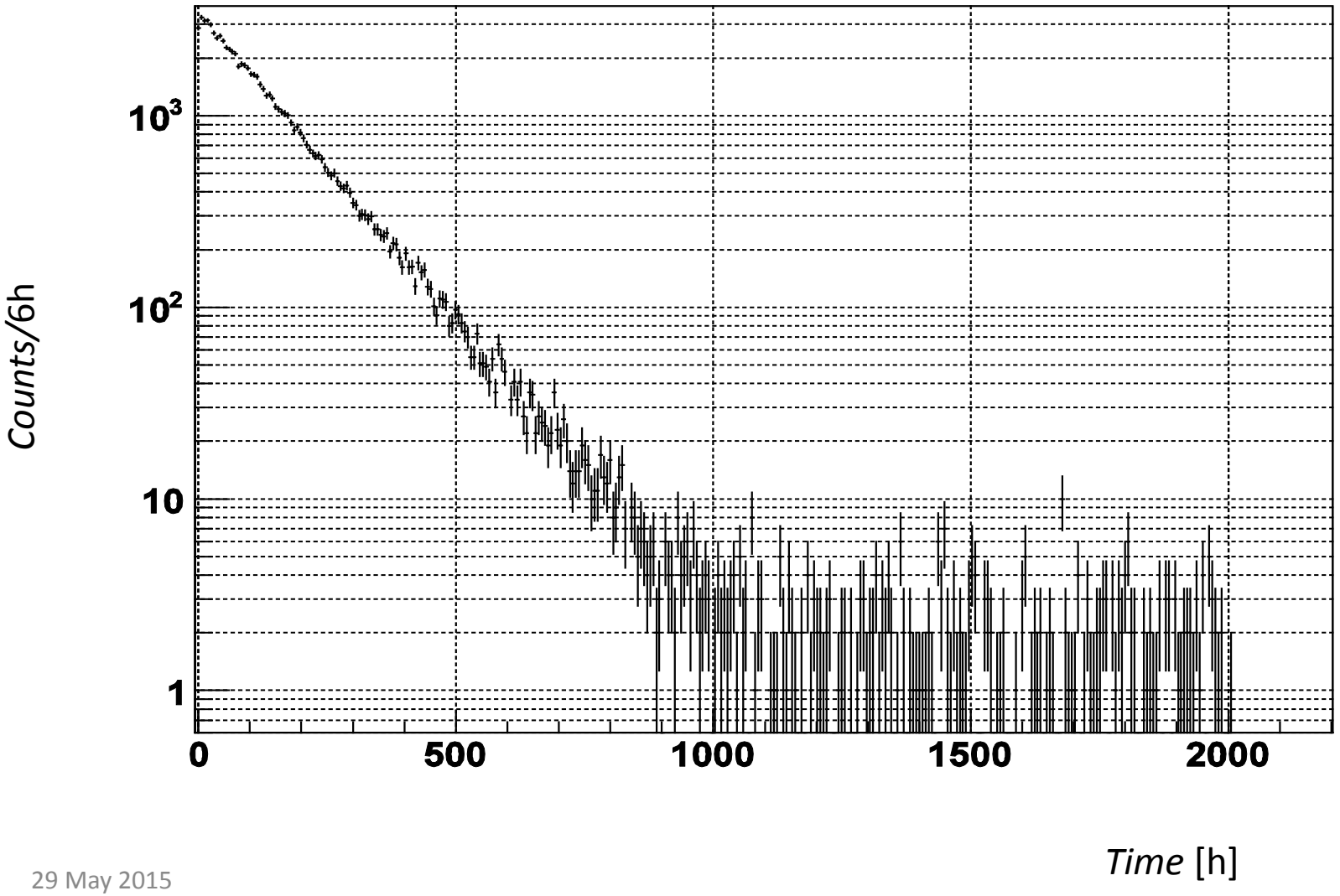
- Right side hemisphere with low Rn activity *[background 7±3 events per day],*
- Airflow controlled by air pump and monitored by temperature and humidity sensors.

For the evaluation of the Rn diffusion through tested foil a long term measurements of Rn activities on both sides is needed.

- Lowest Limit of Detection (LLD) of the device reaches the sensitivity of the radon diffusion D at the level ~10^{-18} m^{2}s^{-1}
- Efficiency of detector 40% [RH=0% +4 kV]

1/2 - Left/right vessel,
3 - Radon source,
4 - Sensors of temperature, humidity, and pressure,
5 - Flow-meter,
6 - Air buffer,
7 - Air pump, 0.34 l/min
8 - Air dryer

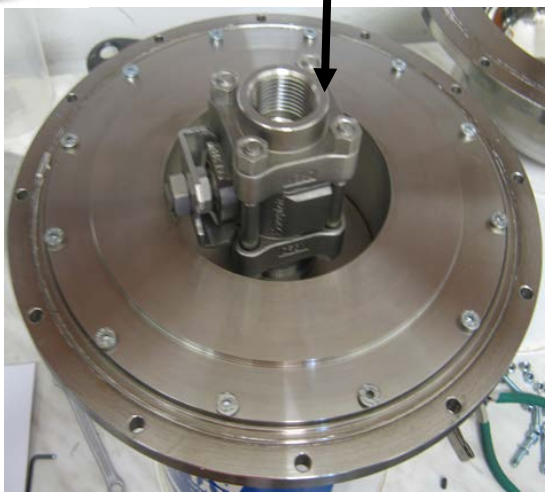
Measurement of background in radon diffusion apparatus:
B = 7.0 ± 3 counts/day



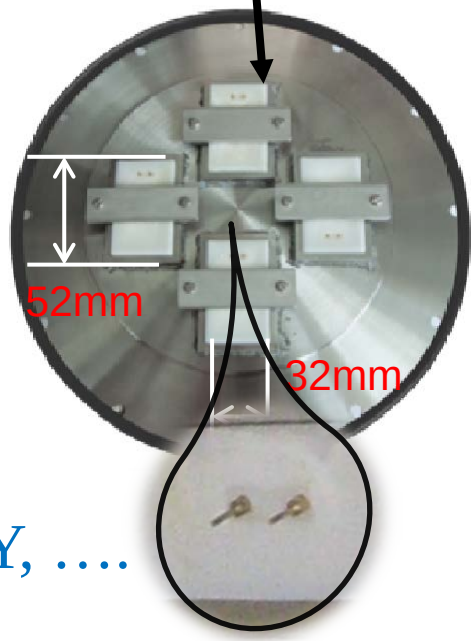
Measurements of Rn diffusion for different type of materials for the SuperNEMO detector

- Foils: Mylar, TROPAC III, EVOCH, PET, HDPE, Mylar junction, TROPAC III junction, Bovlon, EVOCH+PET, Al foils, Nylon, …..
- Glue :SILICON, STYCAST 1264, Glue, SBR, Emultex 5018, Glue + PE, Synthomer 47B40 +PE ….
- Rubbers: RTV615, RTV ECOO, WB 50T, UR 6, PVC, ….
- Sealing of construction part of SuperNEMO detector:

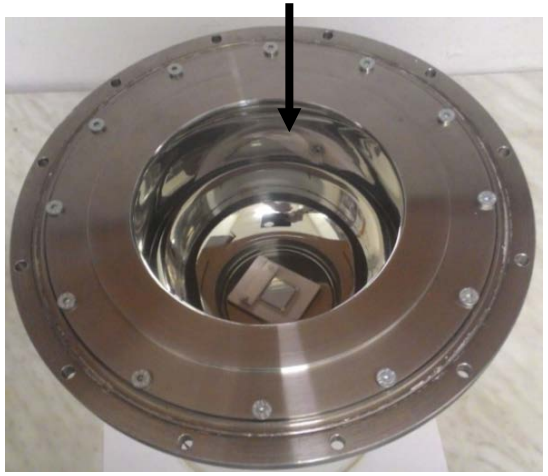
Valve



PIN+Delrin

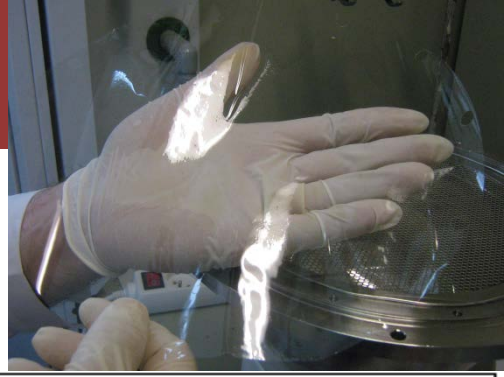


Glass



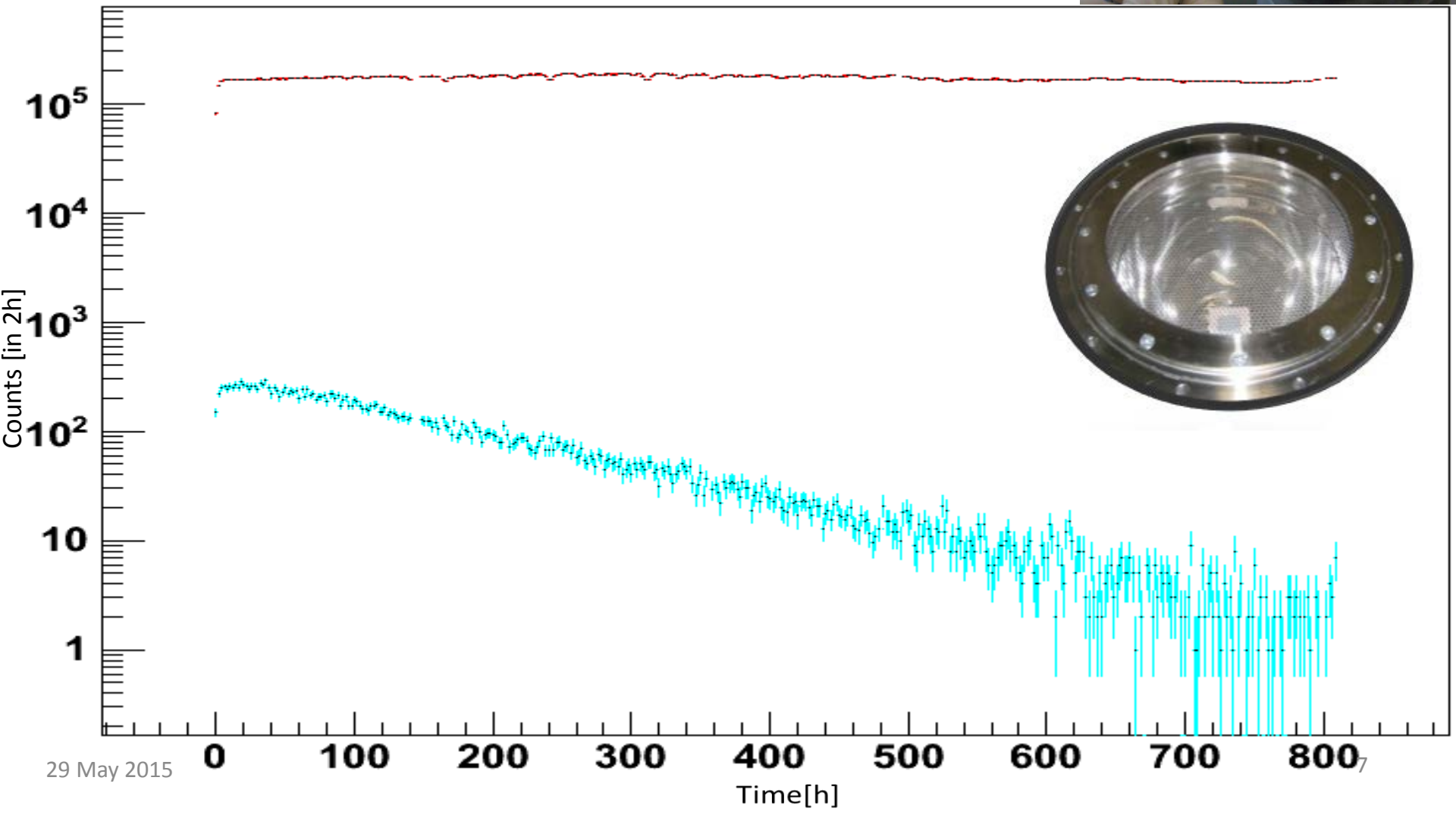
- Sheets: Delrin, PLEXY, ….

Measurement of Rn diffusion through 50 μm NYLON film



Rn suppression factor C1/C2 > 76 500

Diffusion coefficient $D = 4.7 \cdot 10^{-16}\ m^2 s^{-1}$

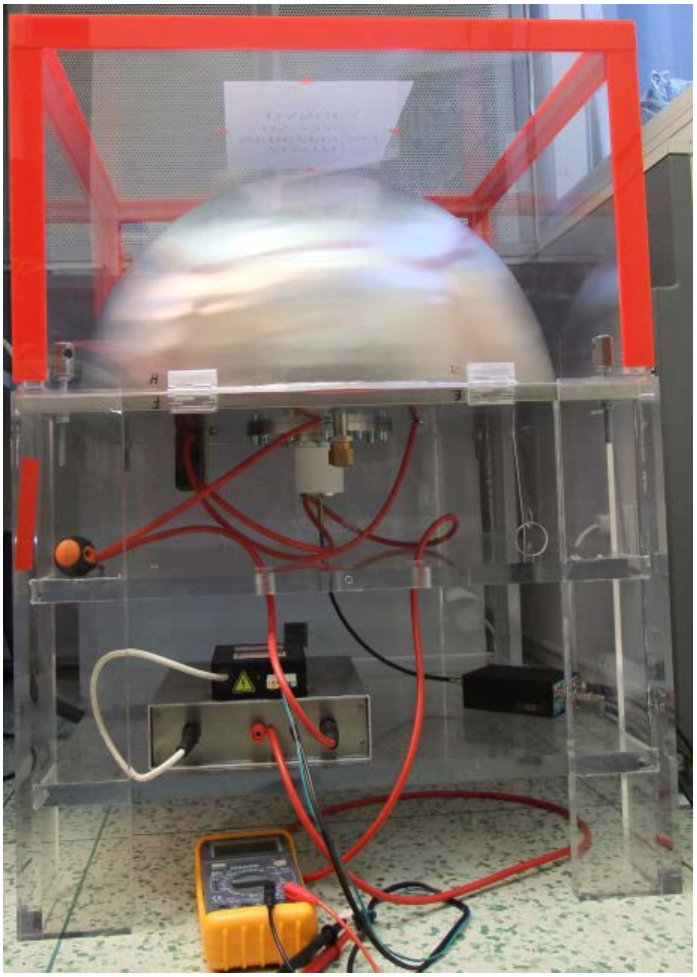


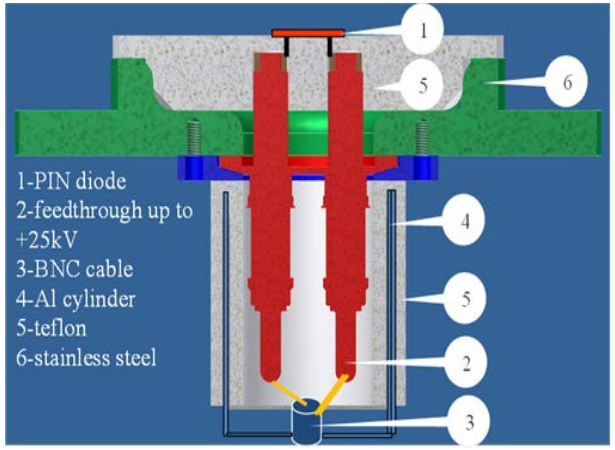
Experimental results of radon penetration through different types of materials. C1 and C2 are concentrations of radon in the left and right chamber of the radon diffusion apparatus. Providing of the coefficient of diffusion D or the diffusion length L for the junctions of two materials is not meaningful, therefore we do not provide them in the table.

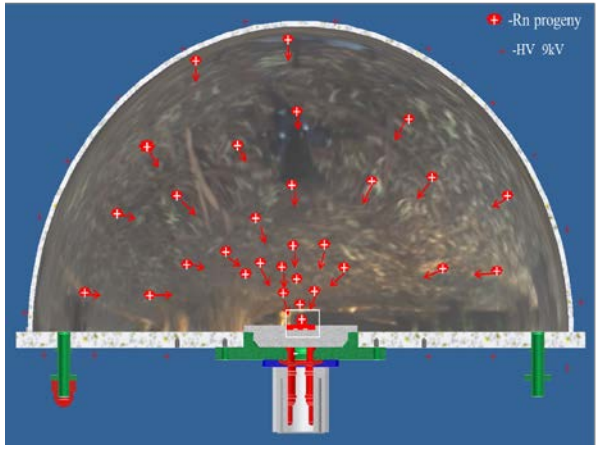
	Thickness d [μm]	C_1/C_2	C_1/C_2 normalized to 15 μm	Diff. coefficient D [10^{-12} m^2s^{-1}]	Diff. length L[μm]
HDPE (2 layers)	2×144	3.5	1.1	19	3000
TROPAC III	102	> 8300	> 600	< 0.0043	< 46
Mylar (2 layers)	2×20	> 9100	> 2300	< 0.0012	< 24
EVOH (2 layers)	2×15	> 31000	> 8900	< 0.00035	< 13
EVOH + 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 (on stainless steel sheet)	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
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
NYLON	50	76 500	6 380	0.00047	15
Synthomer 47B40+PE	700+120	739	8.3	0.27	406

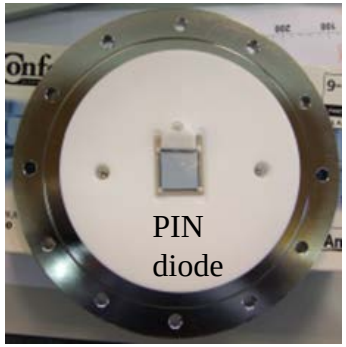
First prototype of the hemispherical detector for measurement of low activity of radon

-Volume 50 l
-Inner surface is electrochemically polished to level of 0.4 µm
-HV up to +12kV
Efficiency of radon detection 32% (+ 8kV)





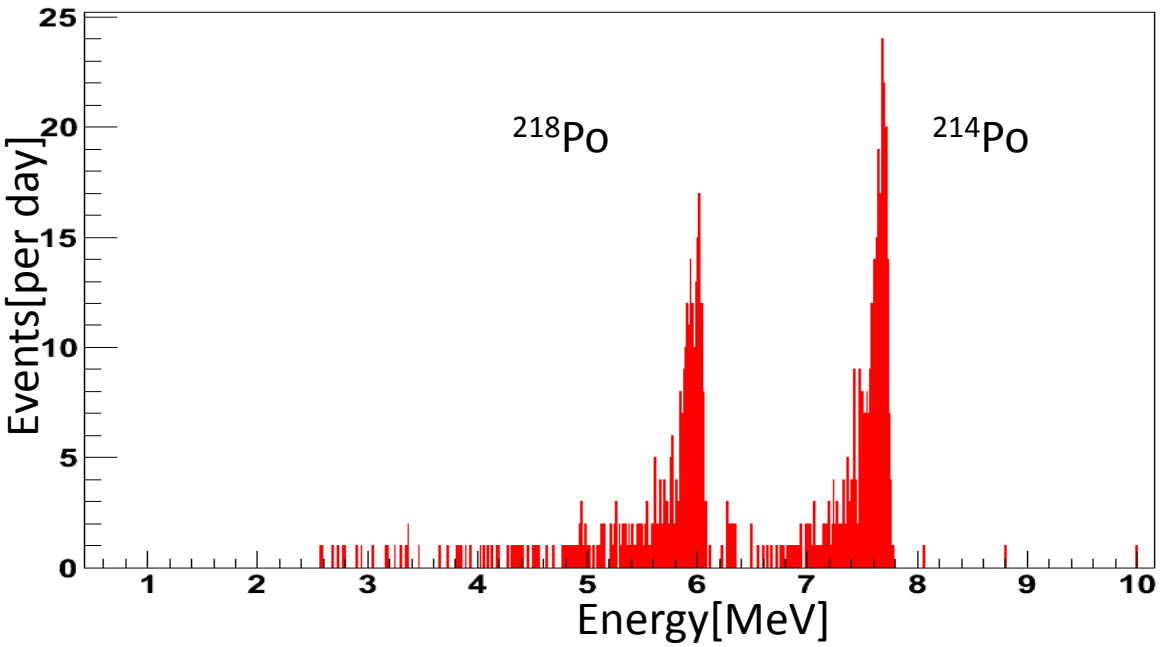




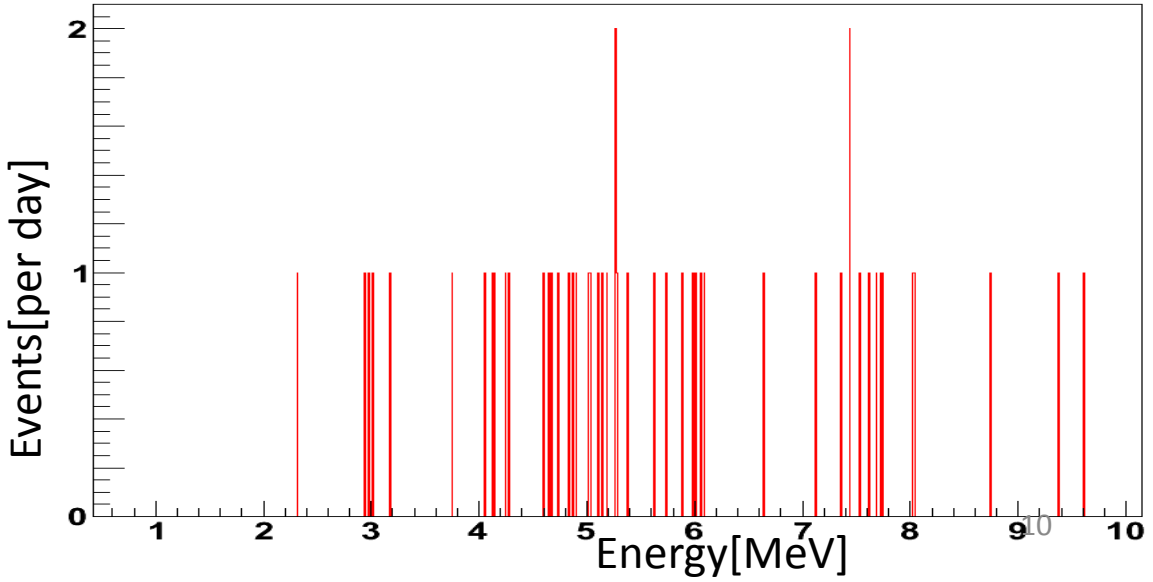
First prototype of the hemispherical detector with volume of 50 l (outer view on the left), schematic view of the HV feed-thorough (middle) and conduction of PIN diode (right)

Measurements of background for the hemispherical detector

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

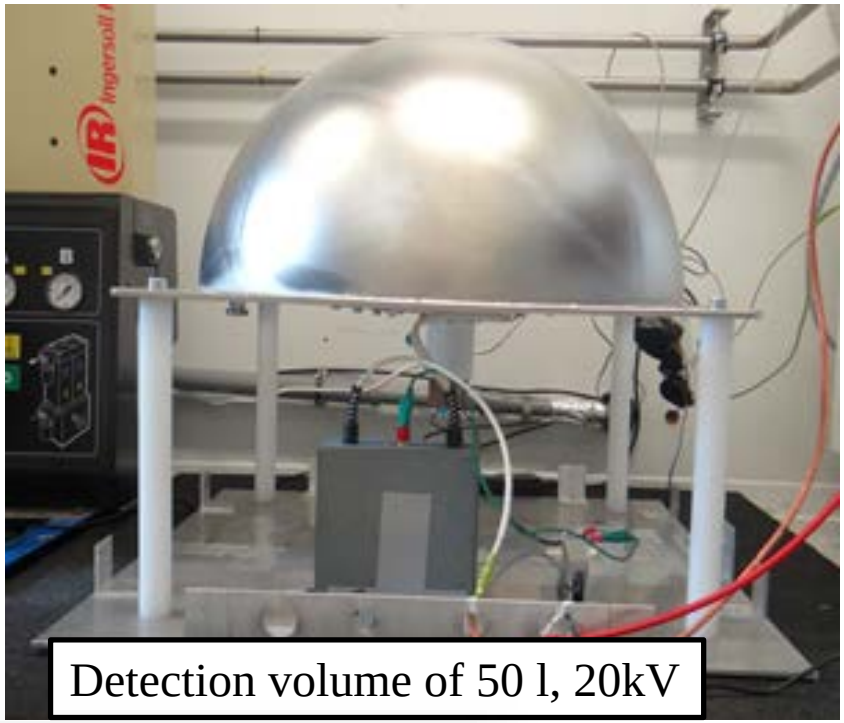


Energy spectrum measured after two months.

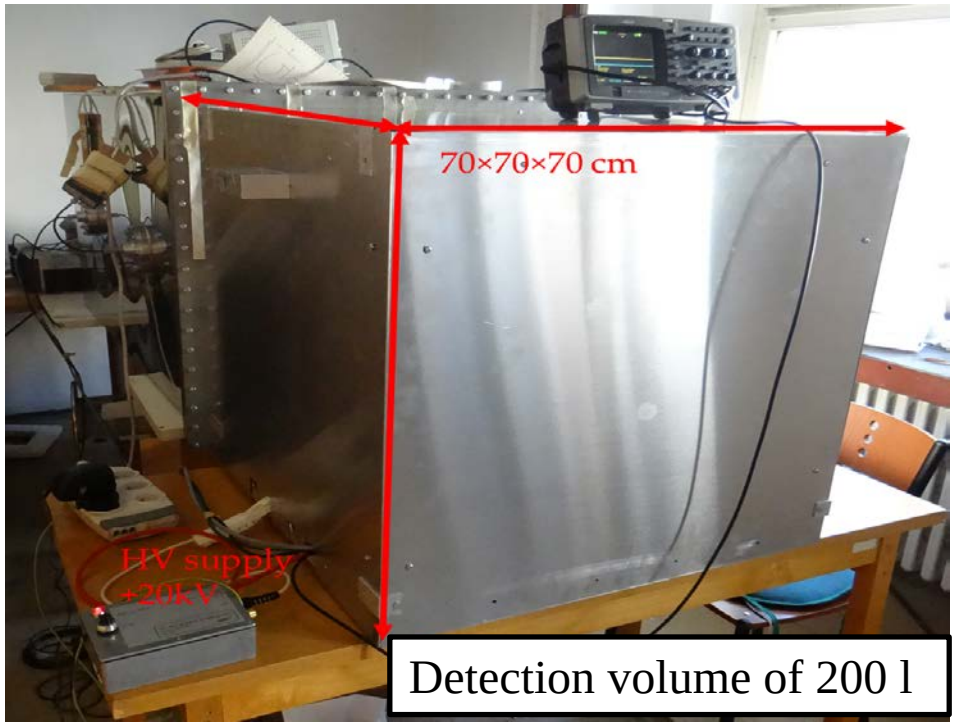


Background is 11±1 events/day in the ROI (6.2-7.8 MeV, ^{214}Po)

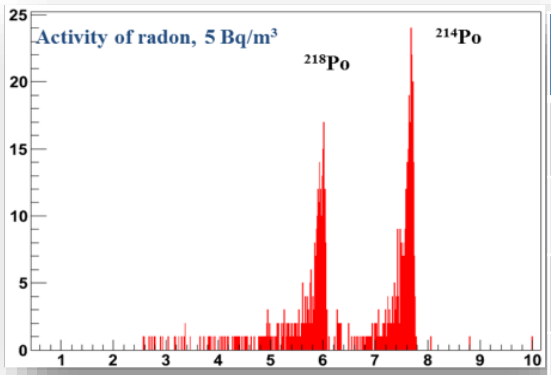
Construction of radon detector with different volume



Detection volume of 50 l, 20kV



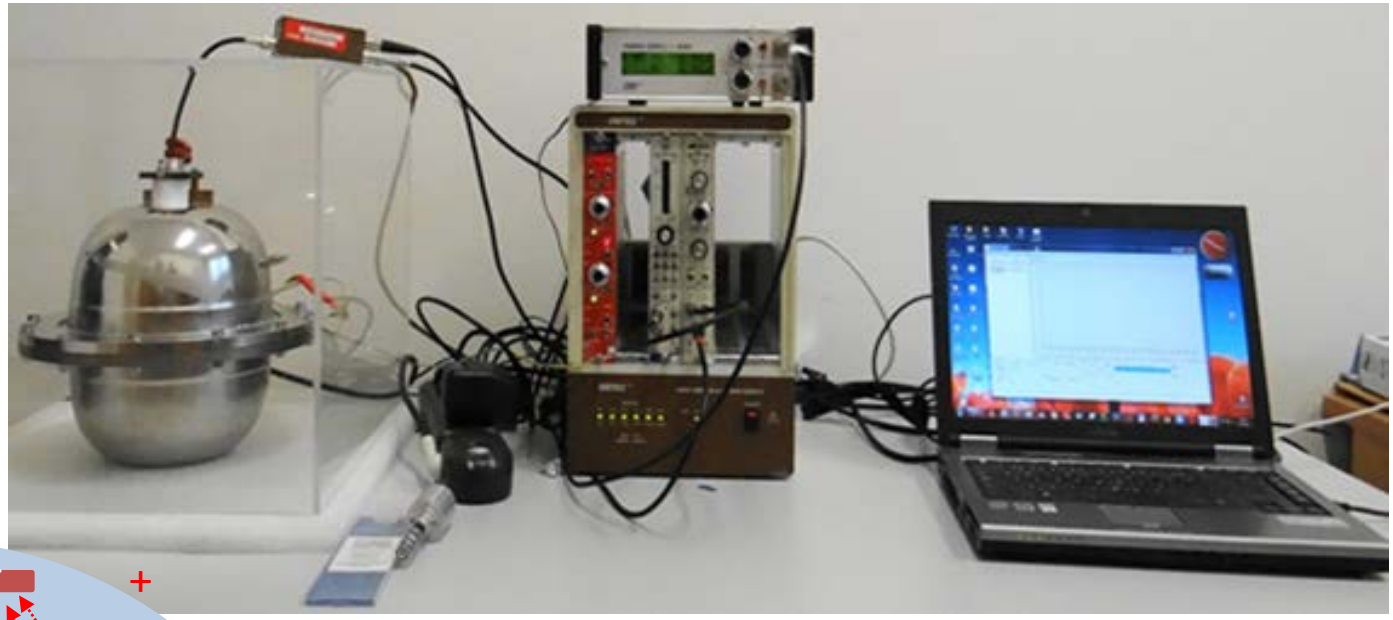
Detection volume of 200 l

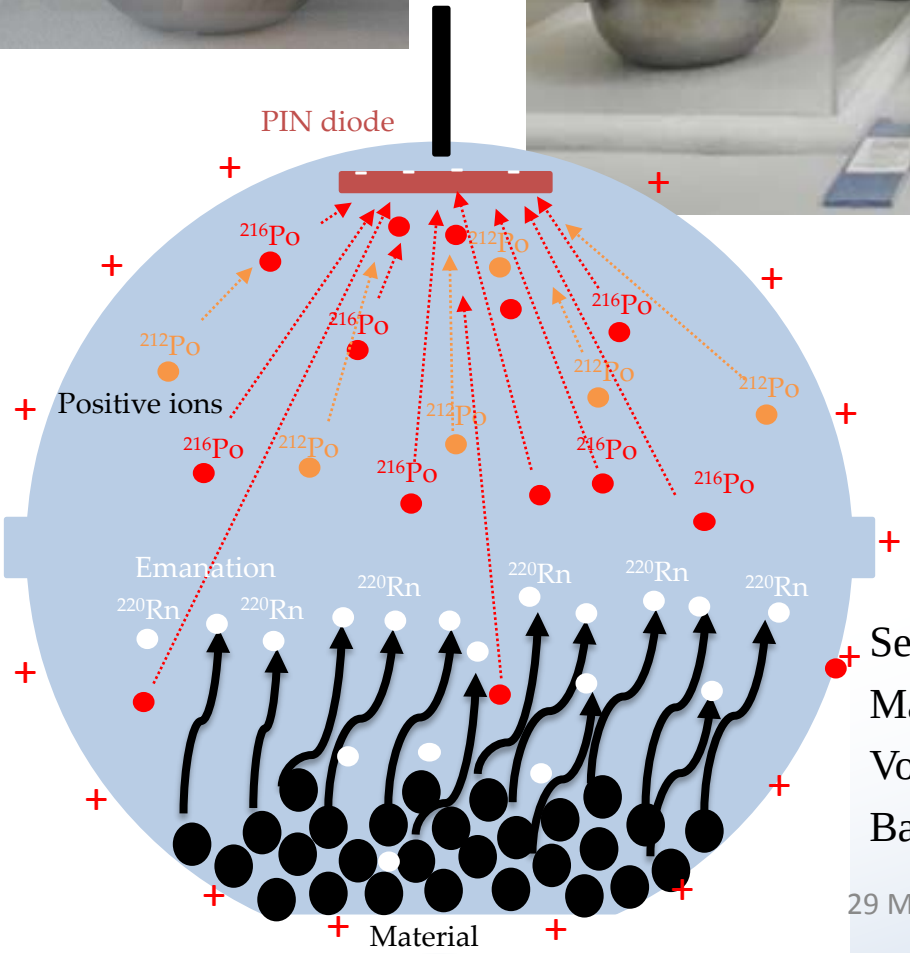


MEASUREMENT TIME	DETECTION LIMIT
1 day	10 mBq/m3
7 days	3,5 mBq/m3
30 days	1,6 mBq/m3
79 days	1,0 mBq/m3

Detection volume of 85 l

Apparatus for measurement of Rn emanation





Setup is based on diffusion apparatus

Made from stainless steel

Volume of detector 6 l , HV= 2.5 kV, PIN diode

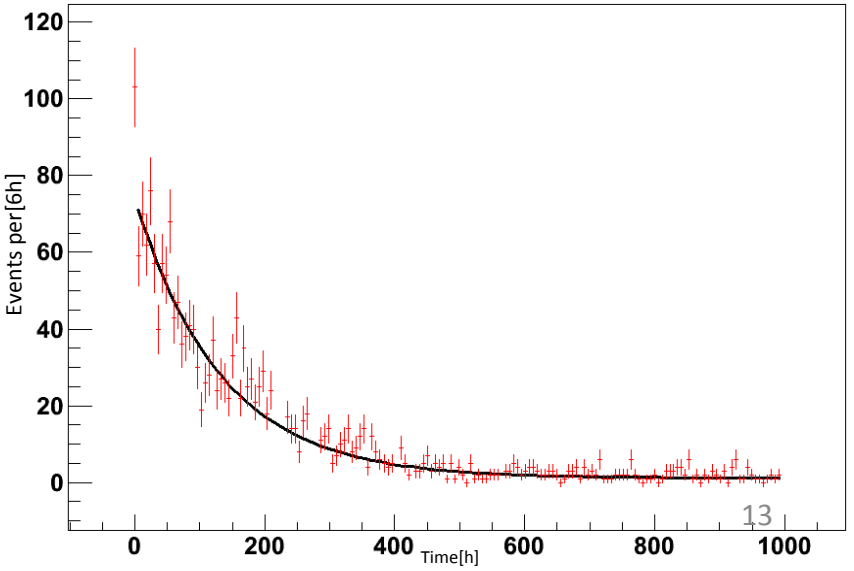
Background is B = 7.2 ± 0.5 events/day in the ROI

(6.2-7.8 MeV, ^{214}Po)

Examples for measurement of radon emanation from materials

Thoron emanation from tungsten electrodes

Measurements of Rn emanation from glass pellets



Conclusions & Future plans

1) **The radon diffusion apparatus identifies suitable material candidates for the inner and outer radon shielding for the SuperNEMO detector.**

- Several candidates for outer shielding – e.g. TROPAC, EVOH (more layers), .. SBR seal, Resin UR6
- Candidates for inner shielding (tracker) – Nylon (influence of humidity), EVOH, Emultex 518 (with PE), SBR seal

2) **Measurement of radon background in the SuperNEMO detector**

- The radon background in the detector will be extremely low.
- Our detector is able to measure activities ~10 mBq/m^3 in 1 day measurement

3) **Measurement of radon emanation from materials**

- Measurement of different types of materials for the SuperNEMO detector

Future plans

Increase of radon detector sensitivity to ~0.1 mBq/m3 for use with radon concentration line.

Thank you for your attention