The properties of airtight membranes to control indoor radon levels using a scale model-room and a new approach to calculate radon diffusion coefficients.

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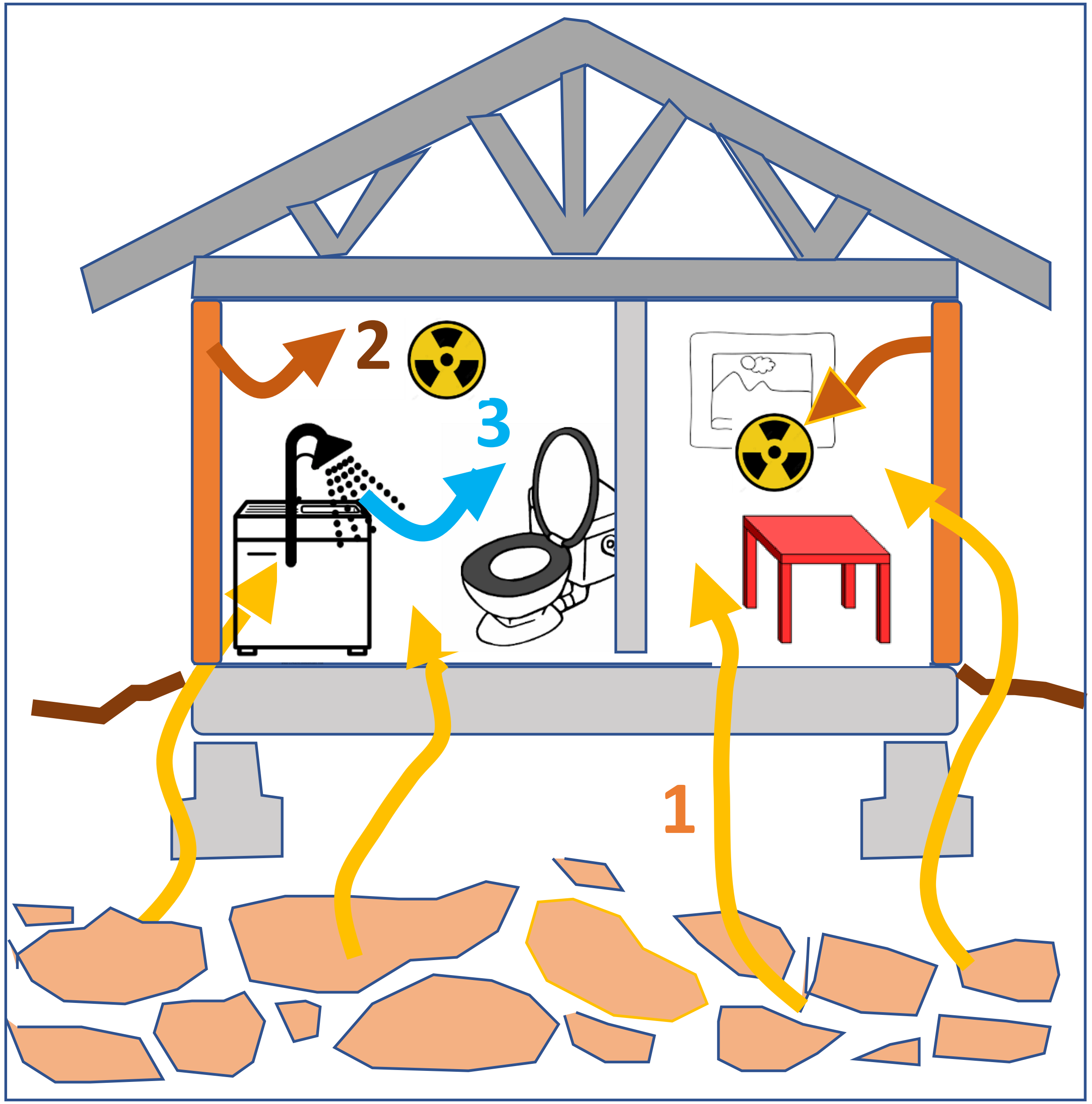
Outline of the presentation

- ❑ Indoor radon
- ❑ Mitigation and radon barriers
- ❑ Experiments with the scale model room
- ❑ Experiments with the TESTMAT
- ❑ Final considerations



Sources of indoor radon

1 Geological bedrock
2 Building materials
3 Domestic water

A pressure/temperature gradient between the building and the soil draws air (and radon) from the ground inwards.

What are the effects of Radon ?

Lung cancer !

1. Inhalation introduces radon and radon daughter products (RDP) into the lungs
2. RDP are deposited in the lung
3. Alpha particles irradiate cells causing physical and/or chemical damage to DNA

Radon is included in group 1 of carcinogens by the Agency for Research on Cancer

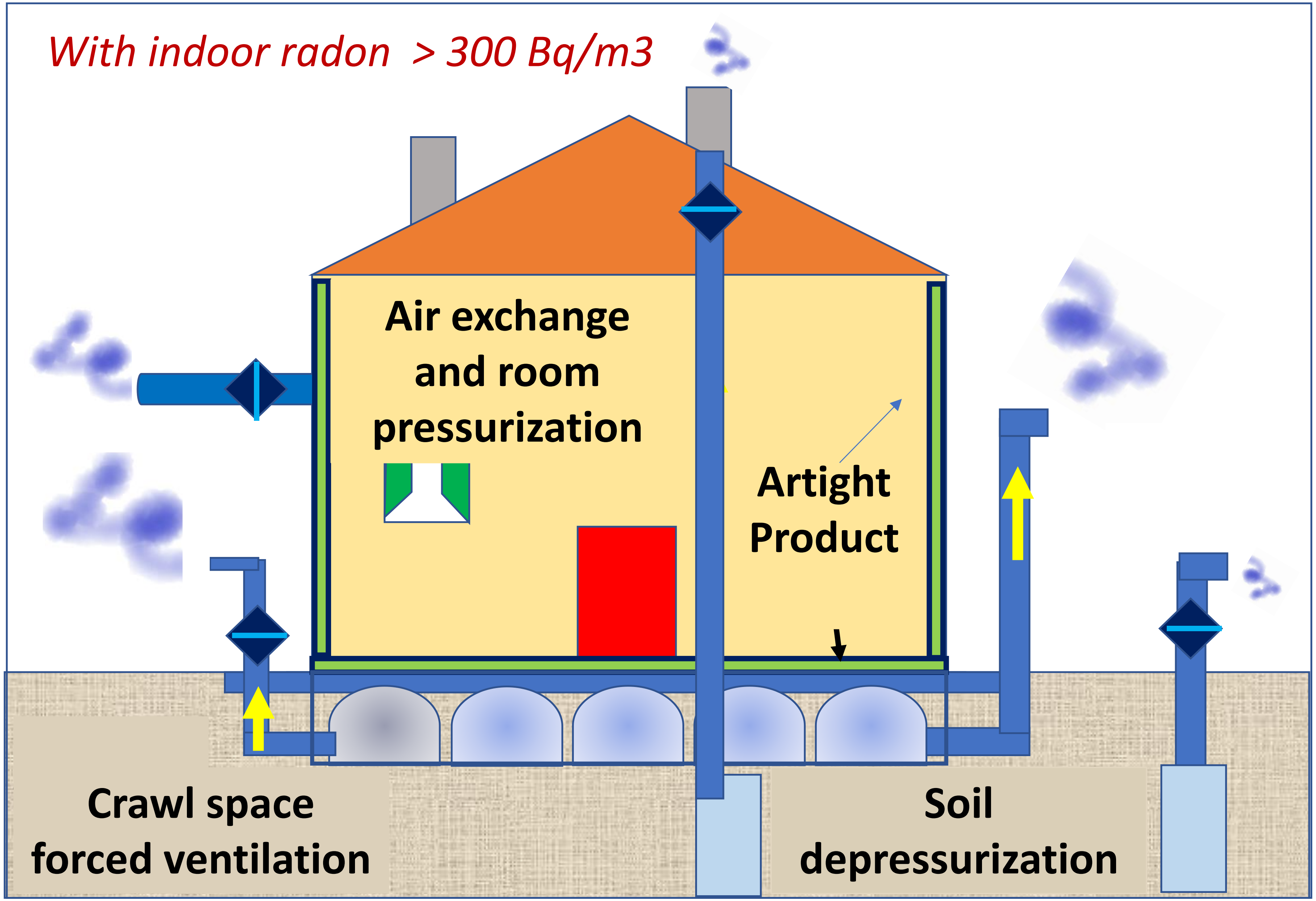
D. Lgs. 101/2020

- **D. Lgs. 101/2020 establishes the safety standards for the protection of people from the dangers deriving from ionizing radiation and, in particular, in Title IV, Chapter I, from radon gas in the workplace and in homes**

- **“Reference levels" for workplaces and homes (300 Bq/m^3) are introduced.**

Risk Mitigation

In the case of buildings with high radon levels, proper mitigation actions must be taken

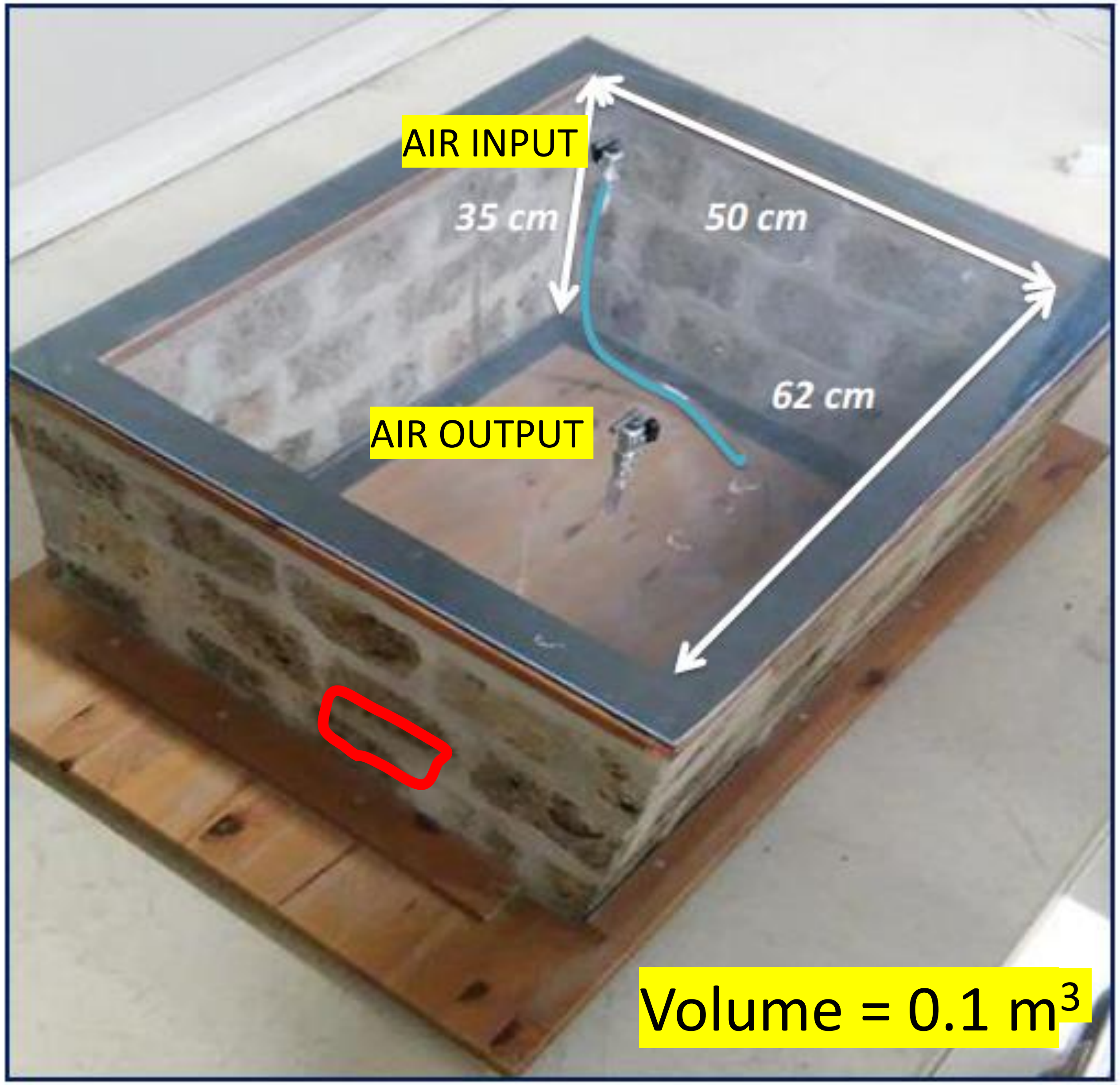


Properties of airtight membranes to control indoor radon

1. **Model room approach**

2. Determination of radon diffusion coefficient (D), radon diffusion length and radon resistance (R) using the TESTMAT

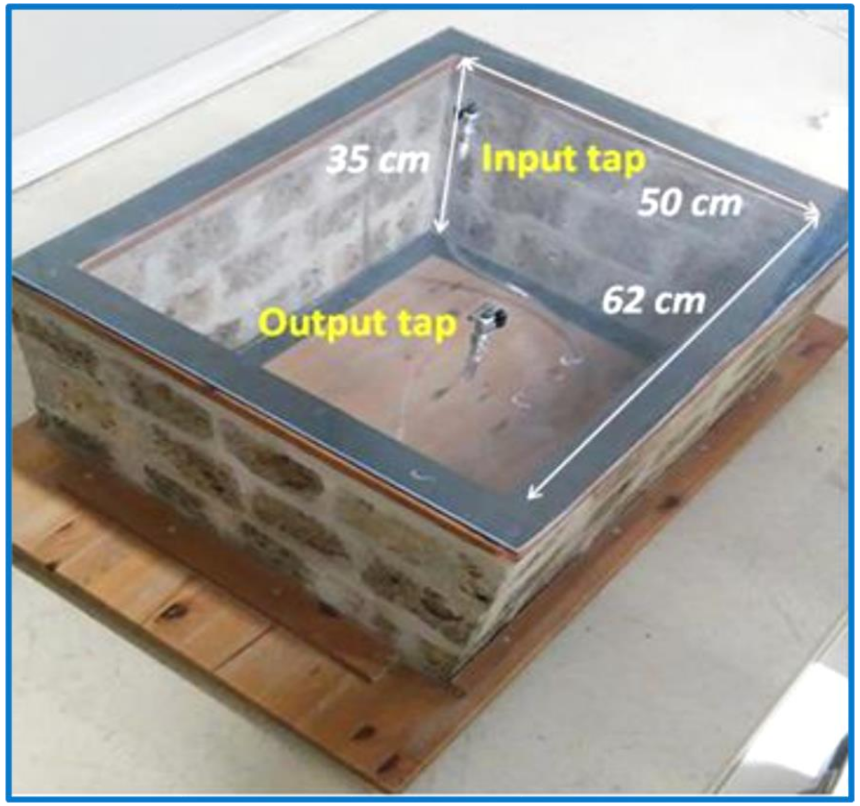
THE SCALE MODEL ROOM



Ignimbrite with:

-High radon exhalation rates
-High porosity (43%)

Esperiments with the Scale Model Room



Lucchetti et al., 2020.

Scale Model Room

Removable plasterboard support

Waterproofing material applied to plasterboard

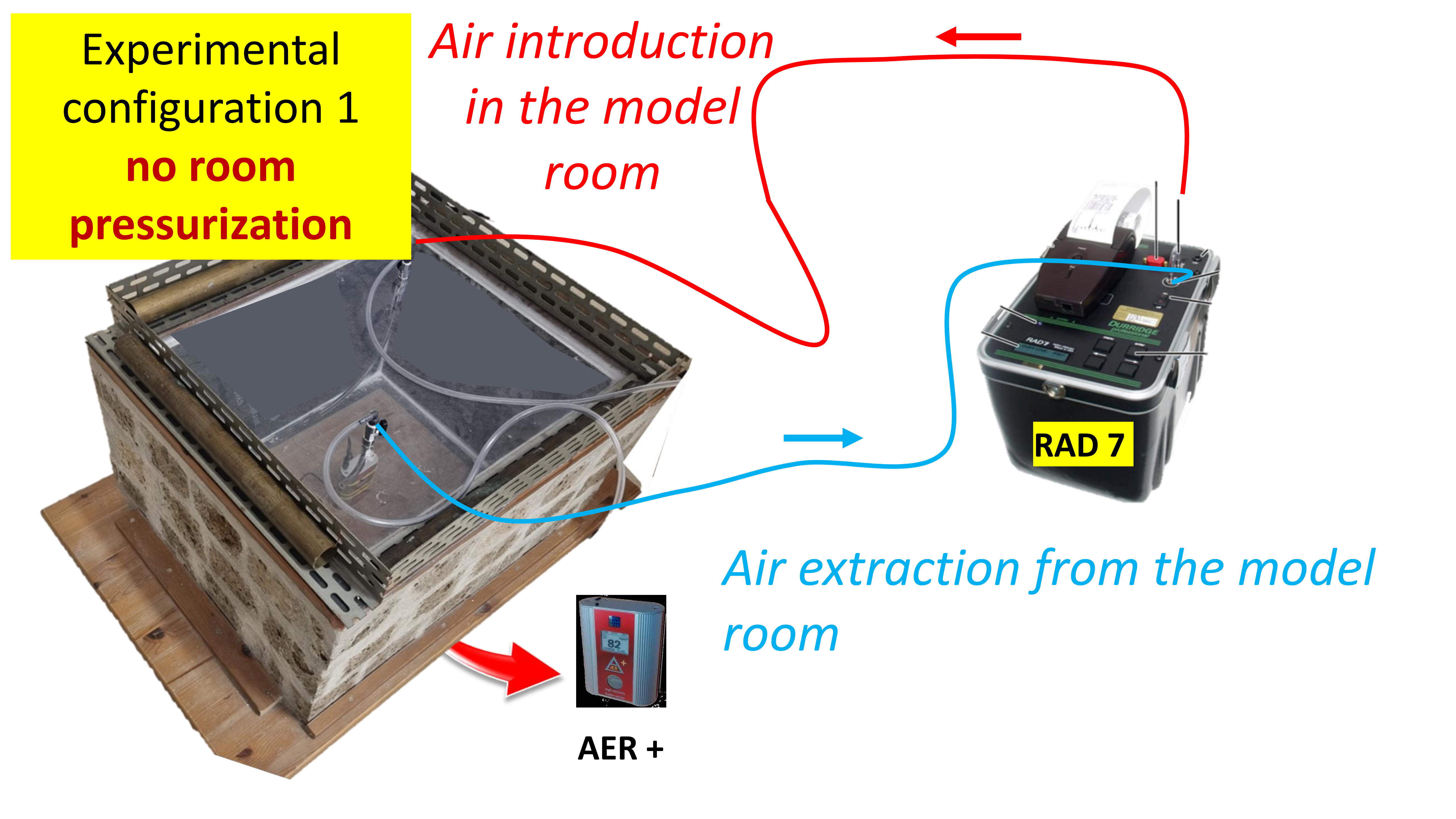
Tested products

- **Plasterboard support (11 mm tick)**

- **Different products available on the market, applied on plasterboard**

Polymers
Bituminous membranes and emulsions
Epoxy resins
High density polyethylene
……..

For reasons of confidentiality, more detailed information on the products will not be provided


Experimental configuration 1
no room pressurization
Air introduction in the model room
RAD 7
Air extraction from the model room
AER +

CALIBRATION AND STANDARDIZATION

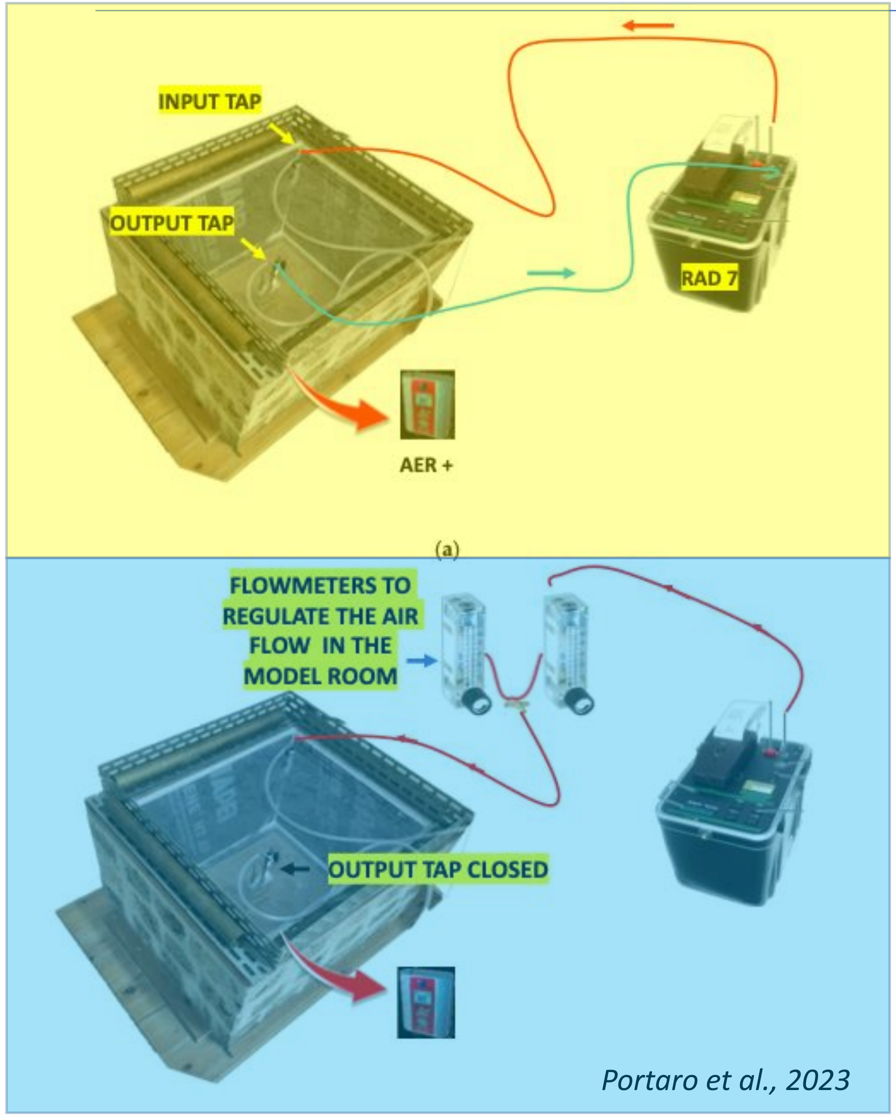
- The two radonometers (the RAD7 and the AER+) were intercalibrated with respect to the INGV radon chamber, in variable temperature and humidity conditions

- All radon data were reported at a constant exhalation temperature (23°C)

Experimental configuration 2 **with room pressurization**

Air introduction at different flow rates (0.2 and 0.8 L/min)

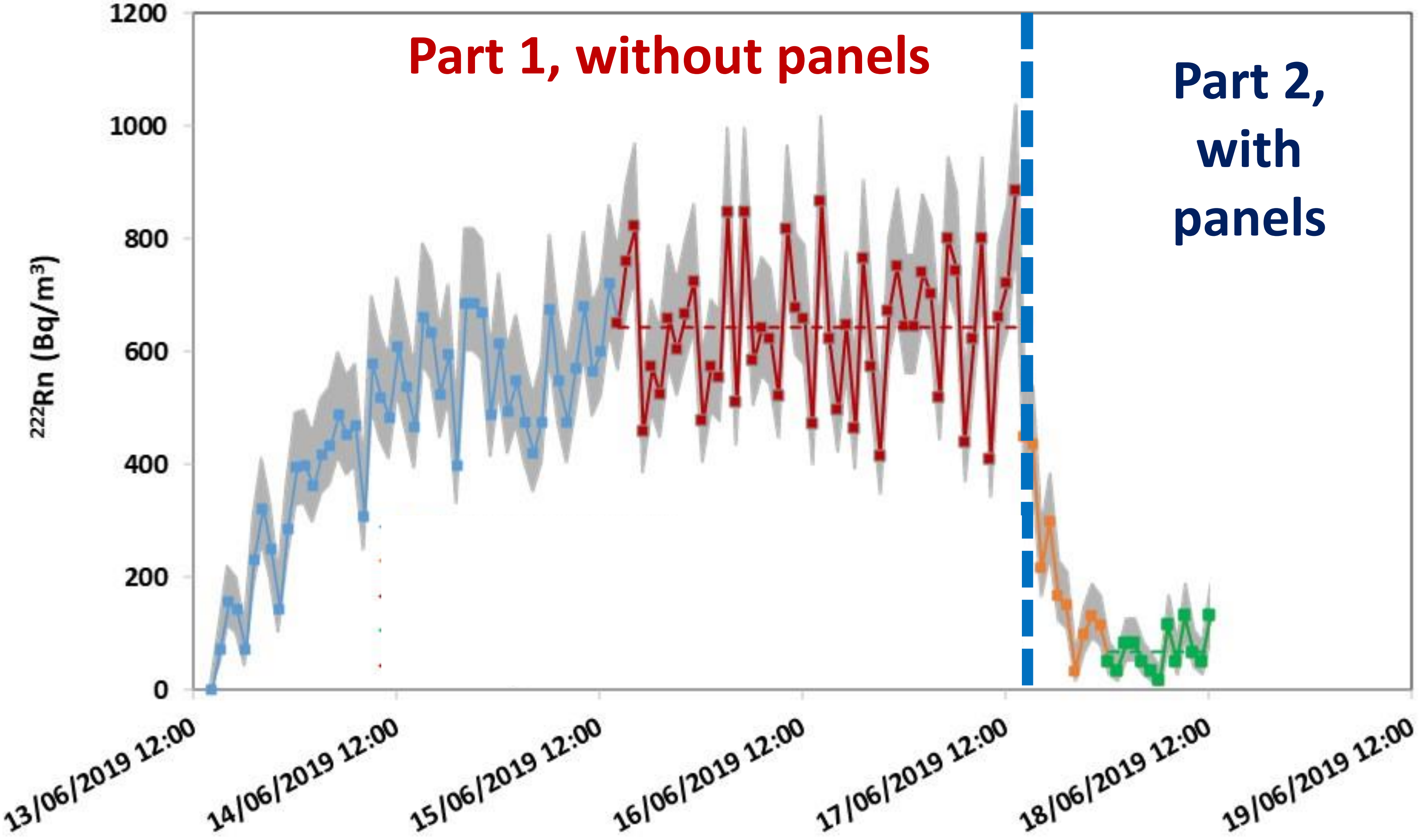
Esperiments



Esperiments were divided into five parts:

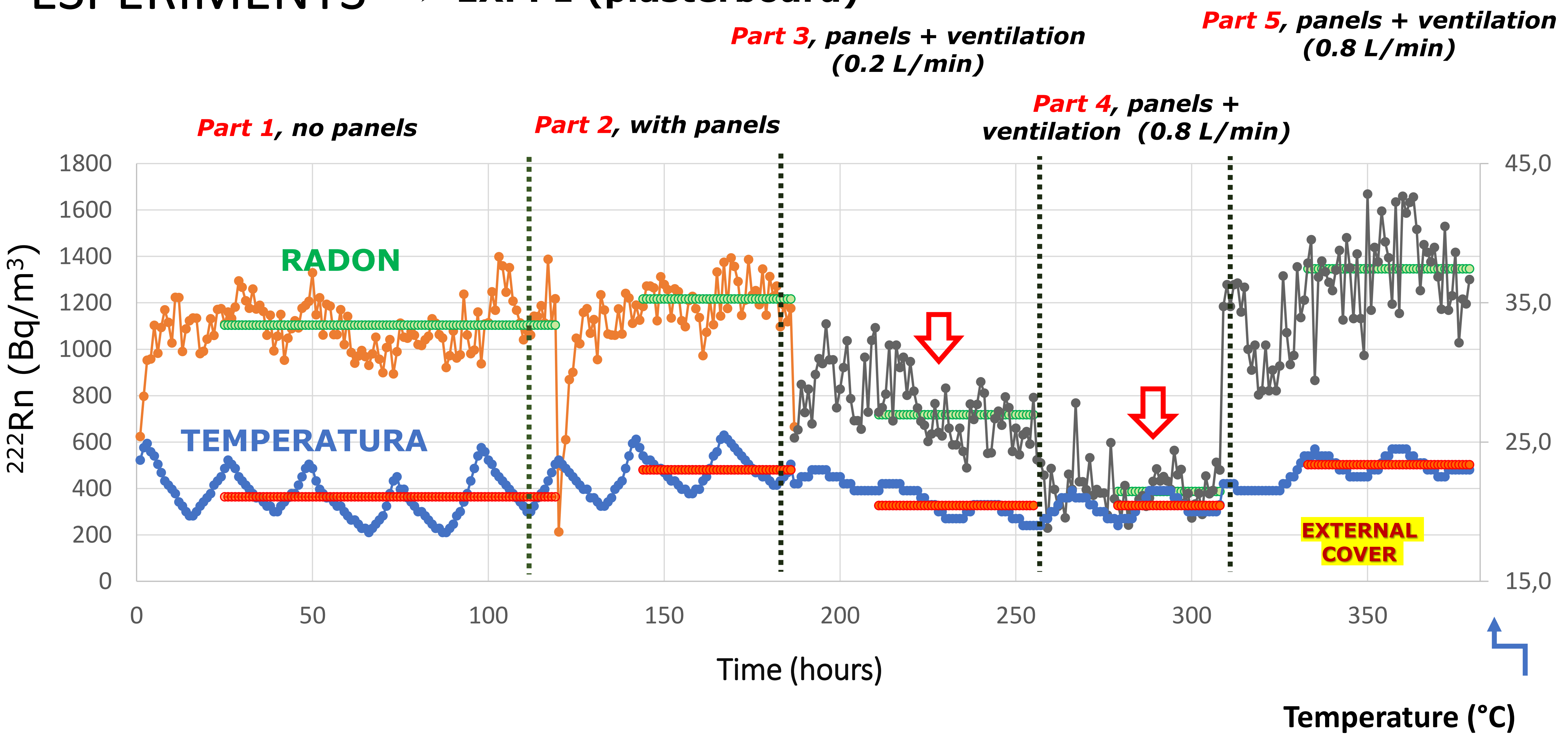
1. Without panels
2. With panels
3. Air flow of 0.2 L/min
4. Air flow of 0.8 L/min
5. External plastic cover

^{222}Rn activity concentration versus time

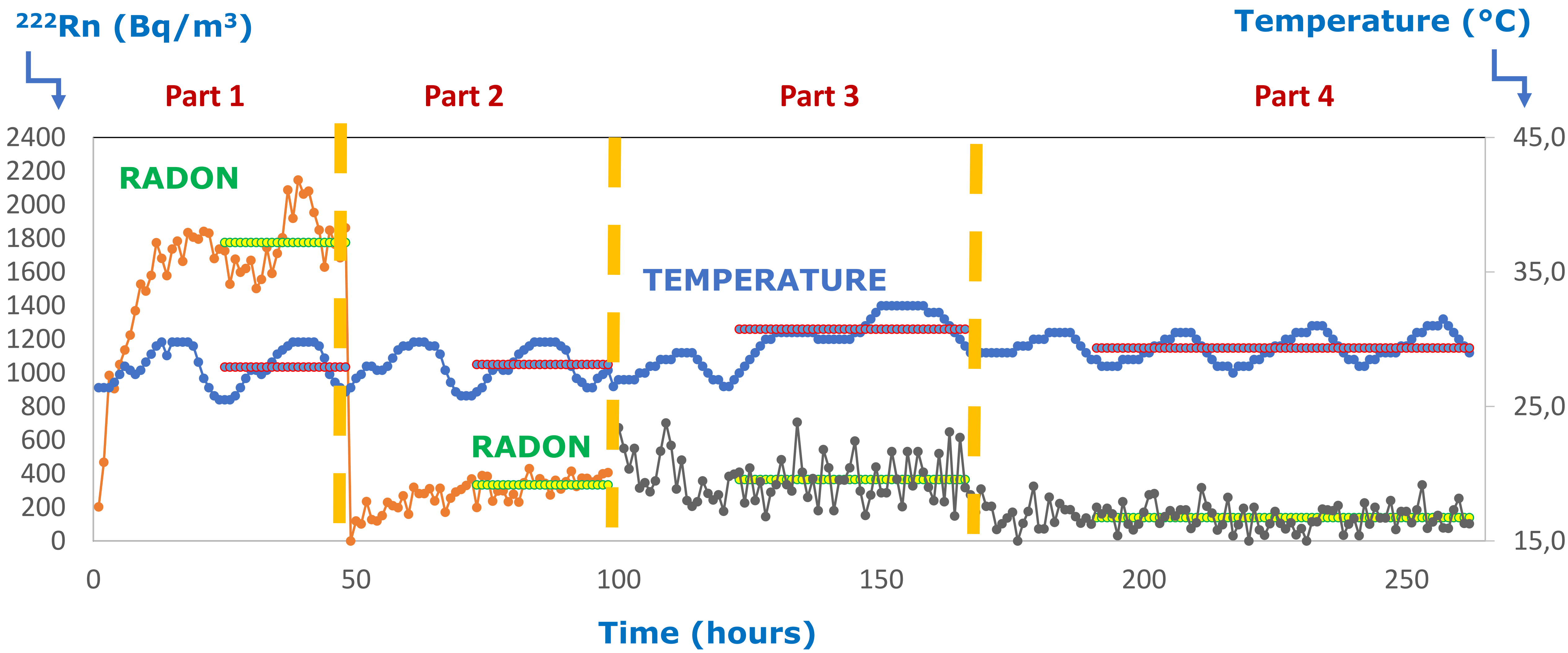


ESPERIMENTS

➢ **EXP. 1 (plasterboard)**



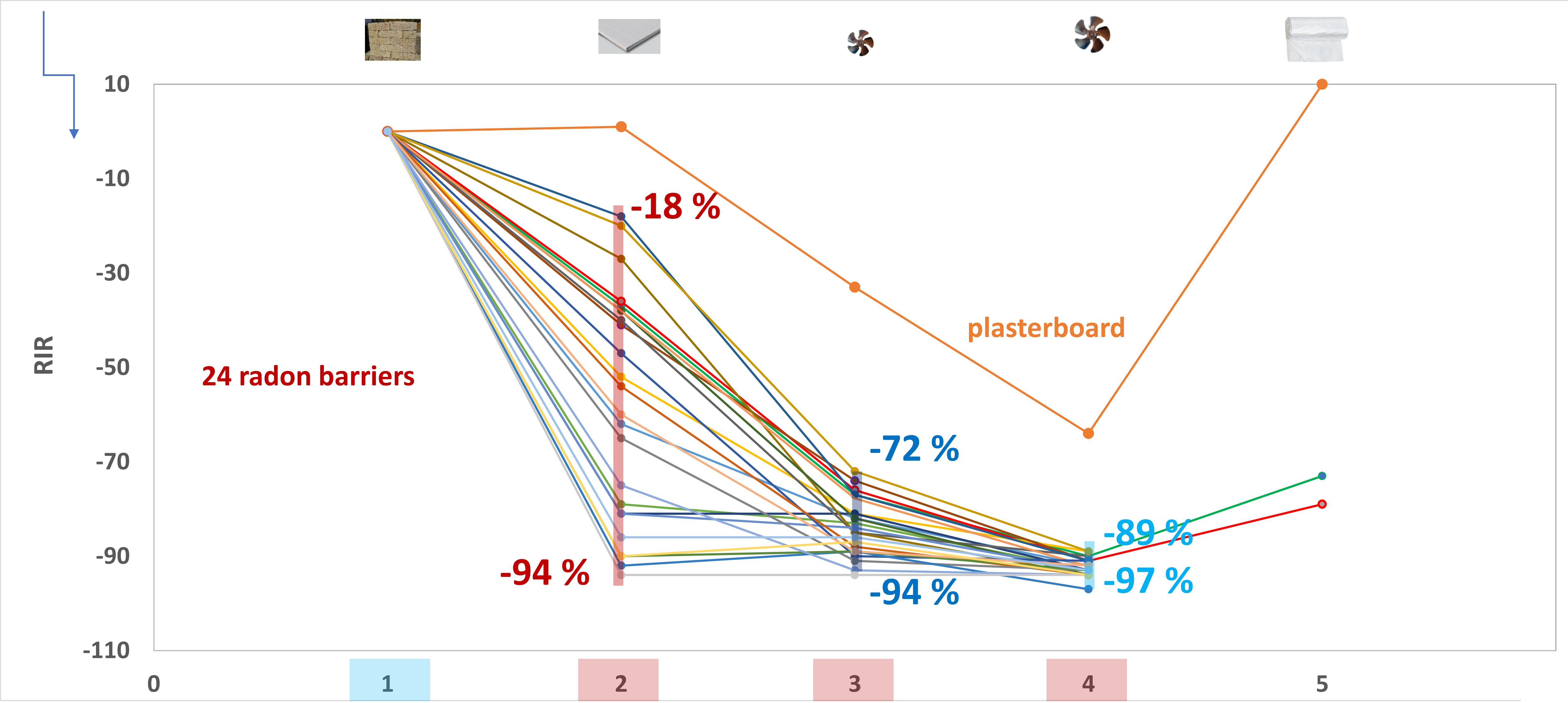
➢ ESPERIMENTS **EXP. 8**



RELATIVE CHANGE IN INDOOR RADON

RESULTS

$$RIR = (Rn_B - Rn_A) / Rn_A \times 100$$



SOME CONSIDERATIONS …

- Plasterboard is a good support for waterproofing products because it does not influence indoor radon levels, allowing the specific properties of each material to be highlighted.

- Among the materials tested so far, we have found products that reduce indoor radon by 18 to 94%. These first data seem to be in agreement with the known radon diffusion coefficients (to be explored furtherly).

- The introduction of forced ventilation tends to improve the performance of the materials, especially with higher flow rates. However, the differences between materials tend to decrease.

- The best performing materials do not require the (expensive) use of ventilation.

THE PROPERTIES OF AIRTIGHT MEMBRANES – TESTMAT

- Radon diffusion coefficients, D ($m^2 s^{-1}$)
- Radon diffusion length, l (m)
- Radon resistance, R ($s m^{-1}$)

$R_1 = d / D$ if the radon distribution in the membrane is linear → with $d/l < 0.8$

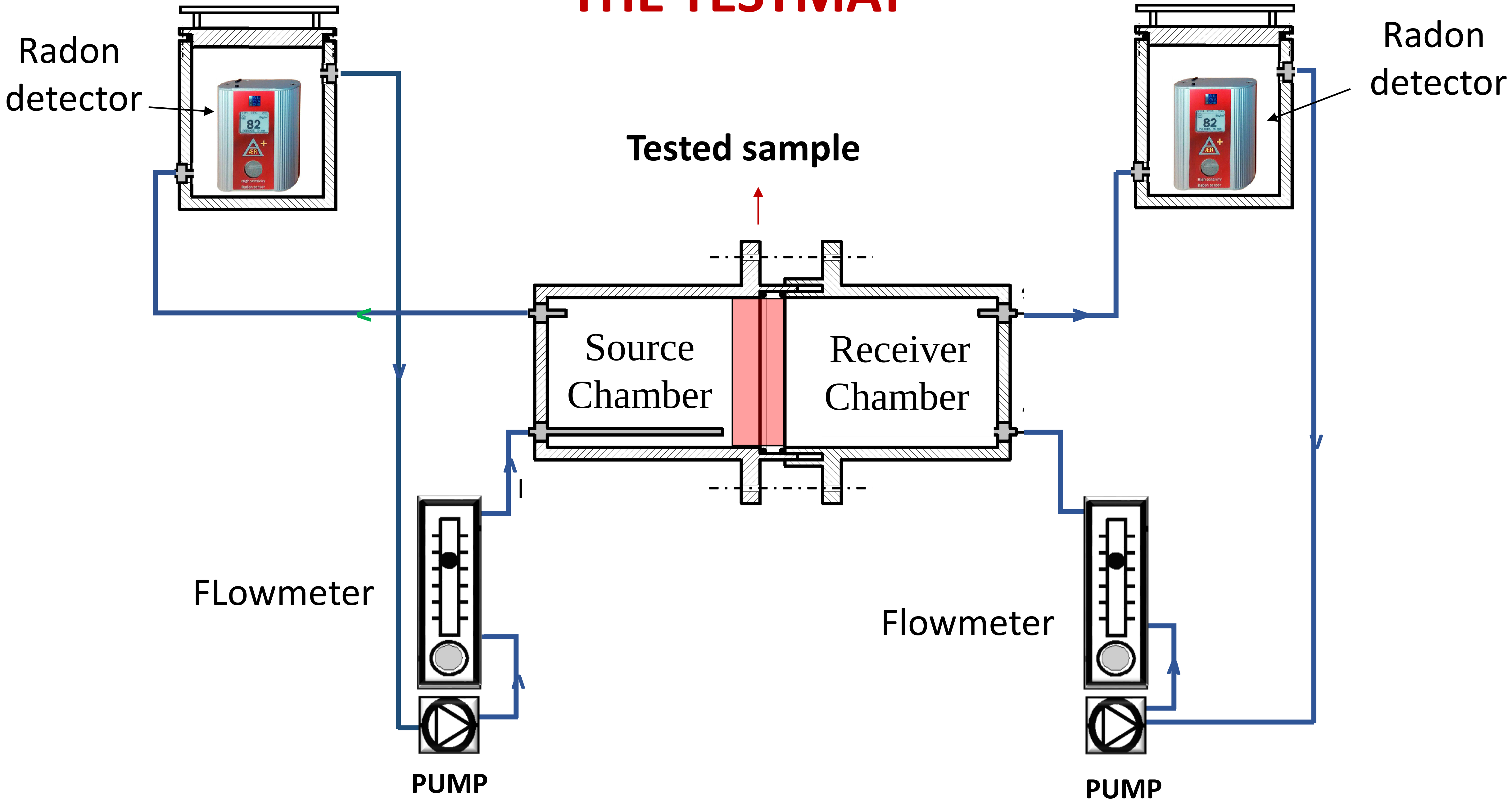
$R_2 = \frac{\sinh d / l}{\lambda l}$ if the radon distribution in the membrane is not linear → with $d/l > 0.8$

where:

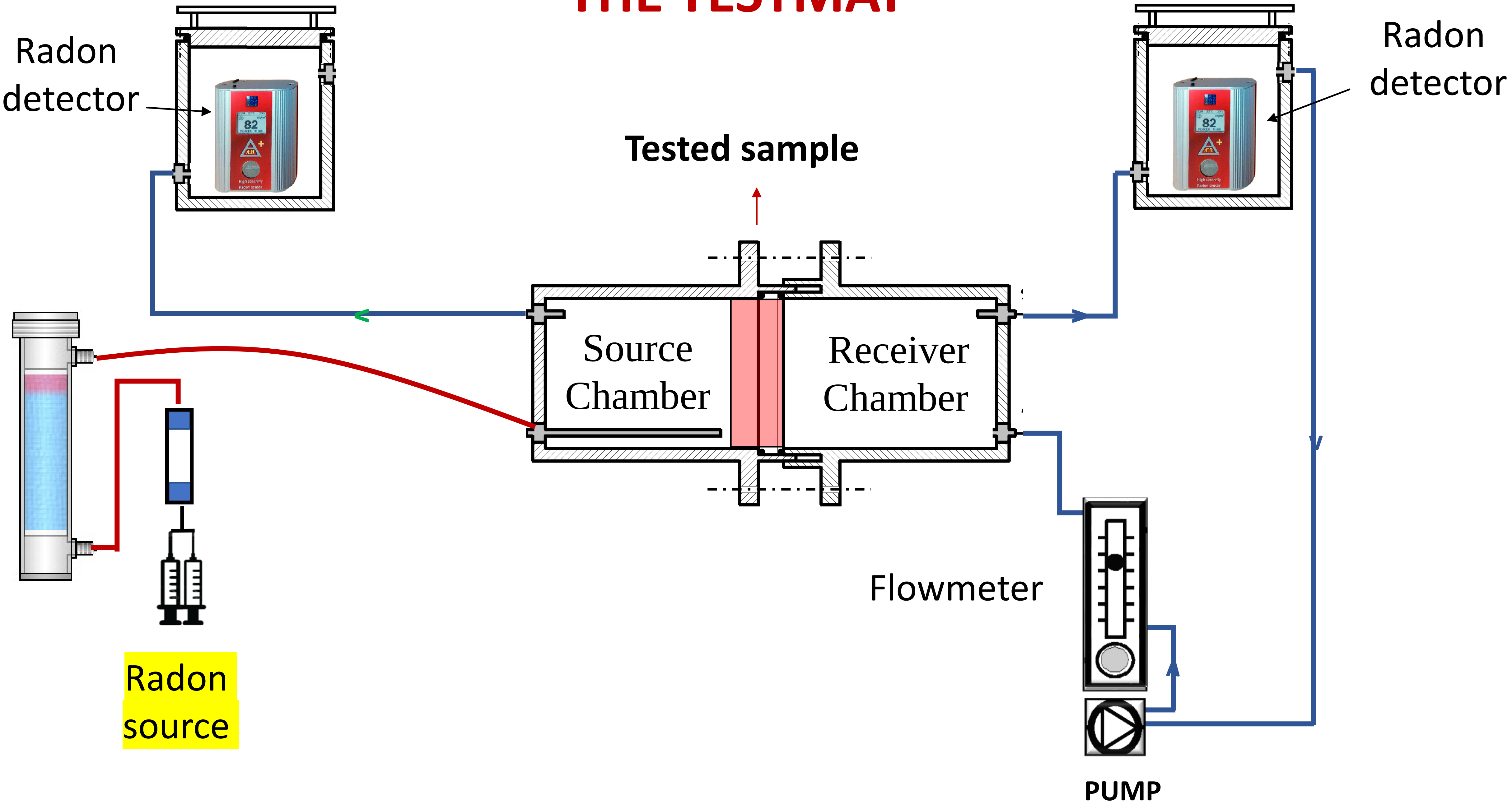
d = tickness of insulation

λ = radon decay

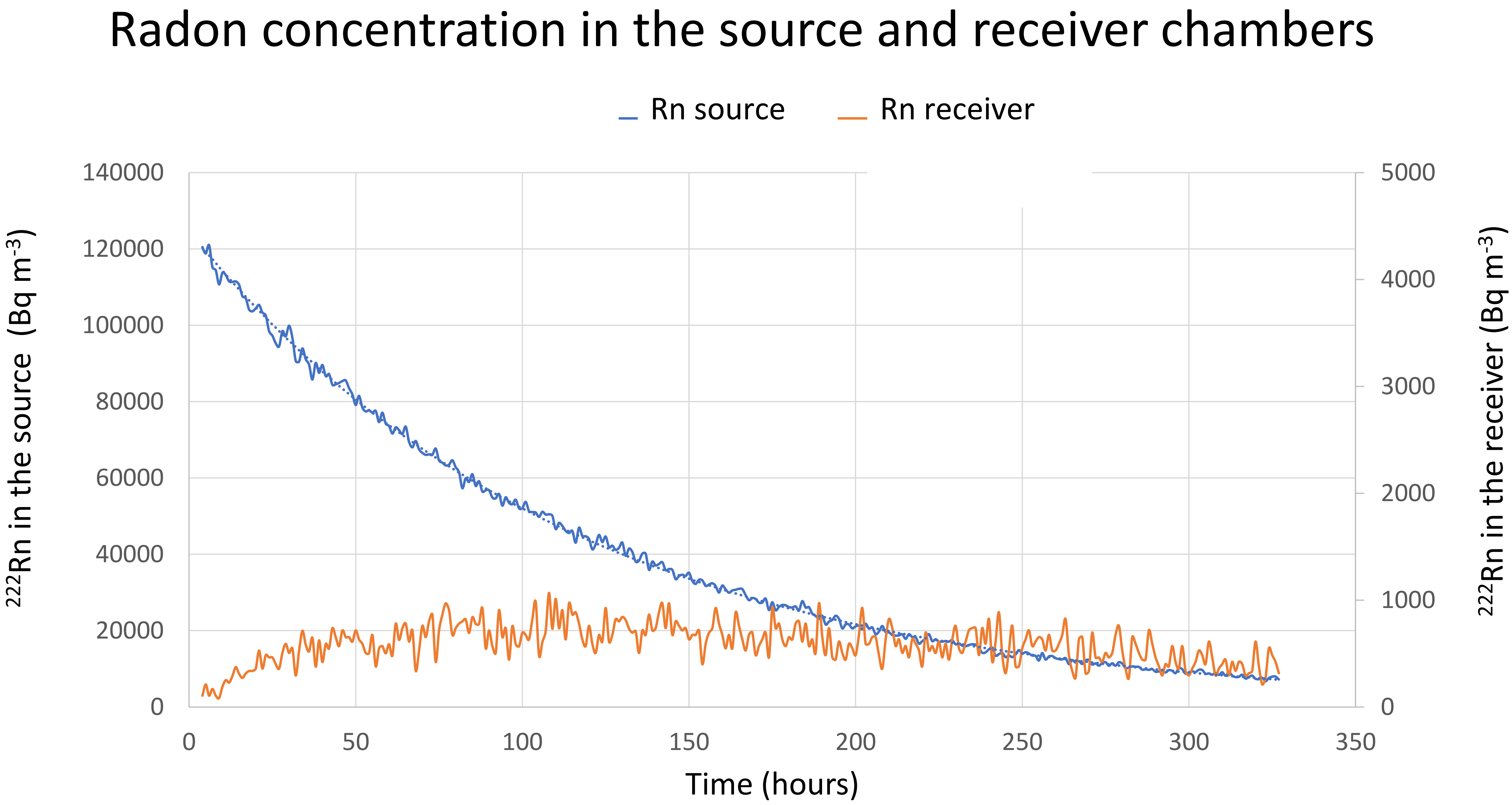
THE TESTMAT


Radon
detector
Radon
detector
Tested sample
Source
Chamber
Receiver
Chamber
FLowmeter
Flowmeter
PUMP
PUMP

THE TESTMAT



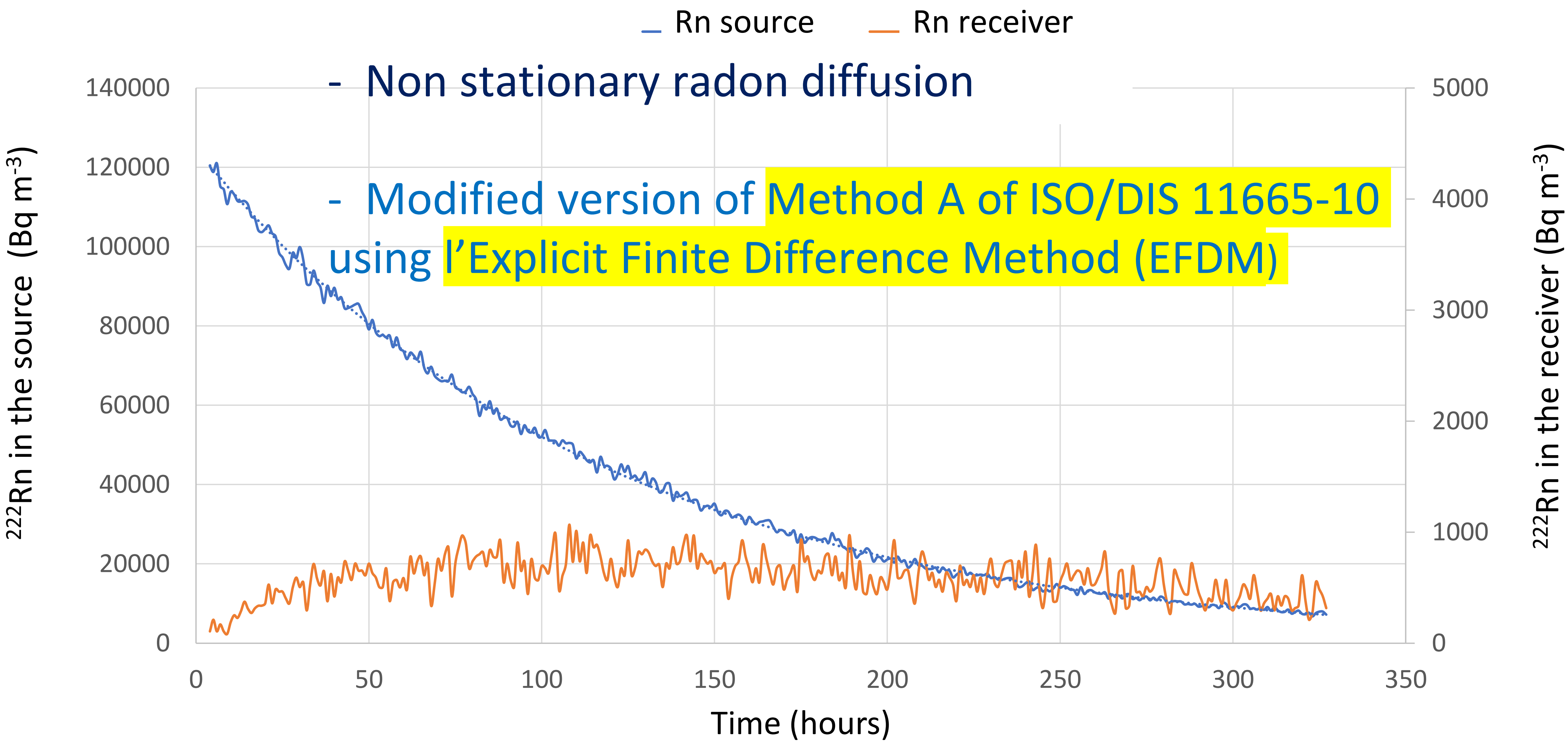
Radon detector
Radon detector
Tested sample
Source Chamber
Receiver Chamber
Flowmeter
Radon source
PUMP



Radon concentration in the source and receiver chambers
Rn source
Rn receiver
140000
120000
100000
80000
60000
40000
20000
0
5000
4000
3000
2000
1000
0
0
50
100
150
200
250
300
350
Time (hours)
222Rn in the source (Bq m-3)
222Rn in the receiver (Bq m-3)

Radon concentration in the source and receiver chambers

- Non stationary radon diffusion
- Modified version of Method A of ISO/DIS 11665-10 using l'Explicit Finite Difference Method (EFDM)



Radon diffusion in a medium in which it is not produced is described by the following differential equation:

$$\frac{\partial C(x,t)}{\partial t} = D\frac{\partial^2 C(x,t)}{\partial x^2} - \lambda C(x,t)$$

where C (x, t) is the radon concentration in the pore space of the medium (Bq m^{-3}) that depends on location x and time t

D is the radon diffusion coefficient (m^2 s^{-1})

λ is the radon decay constant (s^{-1}).

The solution of the diffusion equation through the membrane is provided using the explicit finite difference (EFDM) method:

$$C_j^D = C_{j-1}^D e^{-\Delta t/\tau} + D\,S\left(\frac{C_{d-\Delta x,j} - C_{d,j}}{\Delta x}\right)\Delta t\,/\,V^D$$

$$C_0^D = D\,S\left(\frac{C_{d-\Delta x,0} - C_{d,0}}{\Delta x}\right)\Delta t\,/\,V^D$$

C^D = radon concentration in the receiver chamber;

i and j = the discrete positions and times determined by step lengths Dx and Dt;

S = surface of the sample;

V^D= volume of the receiver chamber;

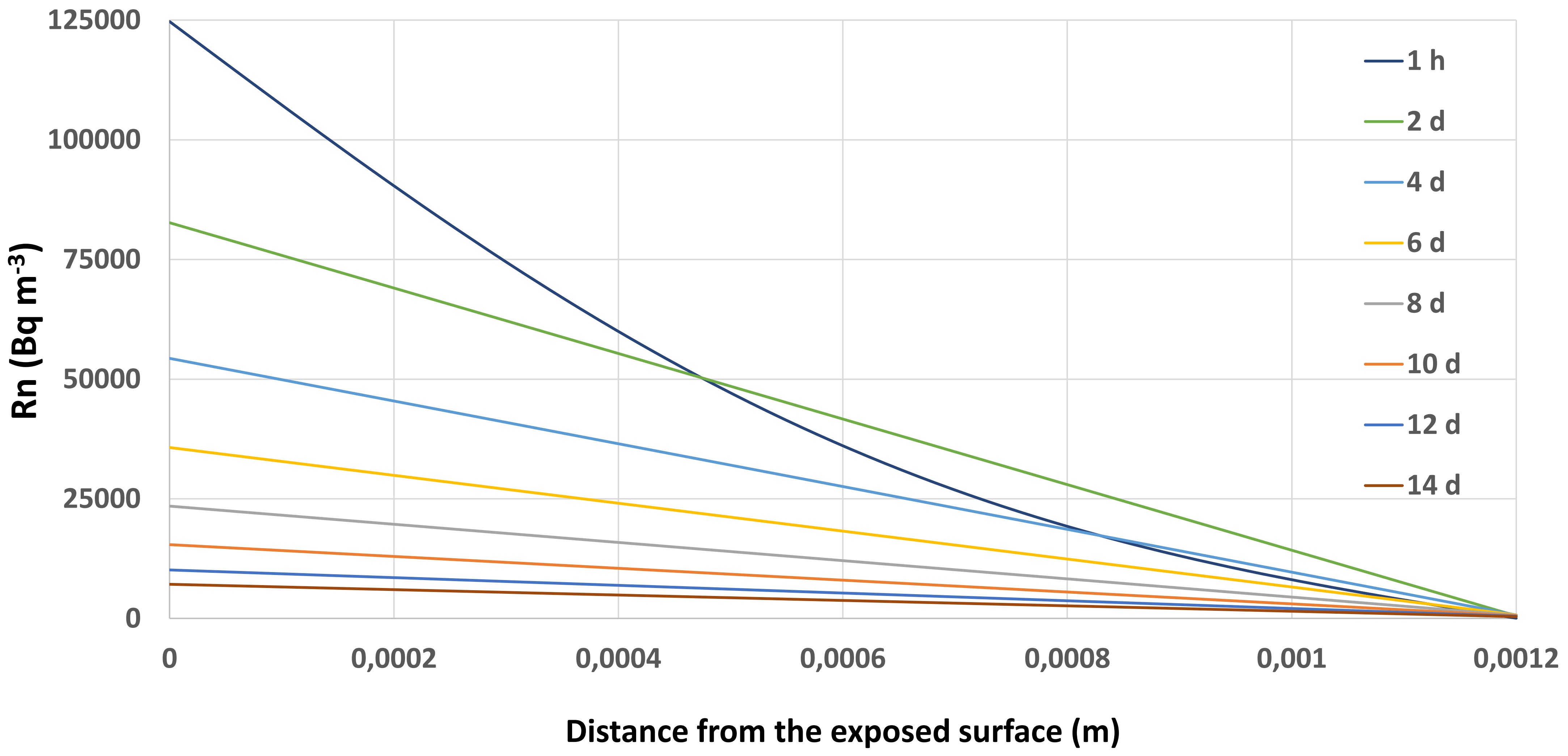
D = radon diffusion coefficient

τ = radon average life

Gradient of radon concentration in the mebrane at time j and zero

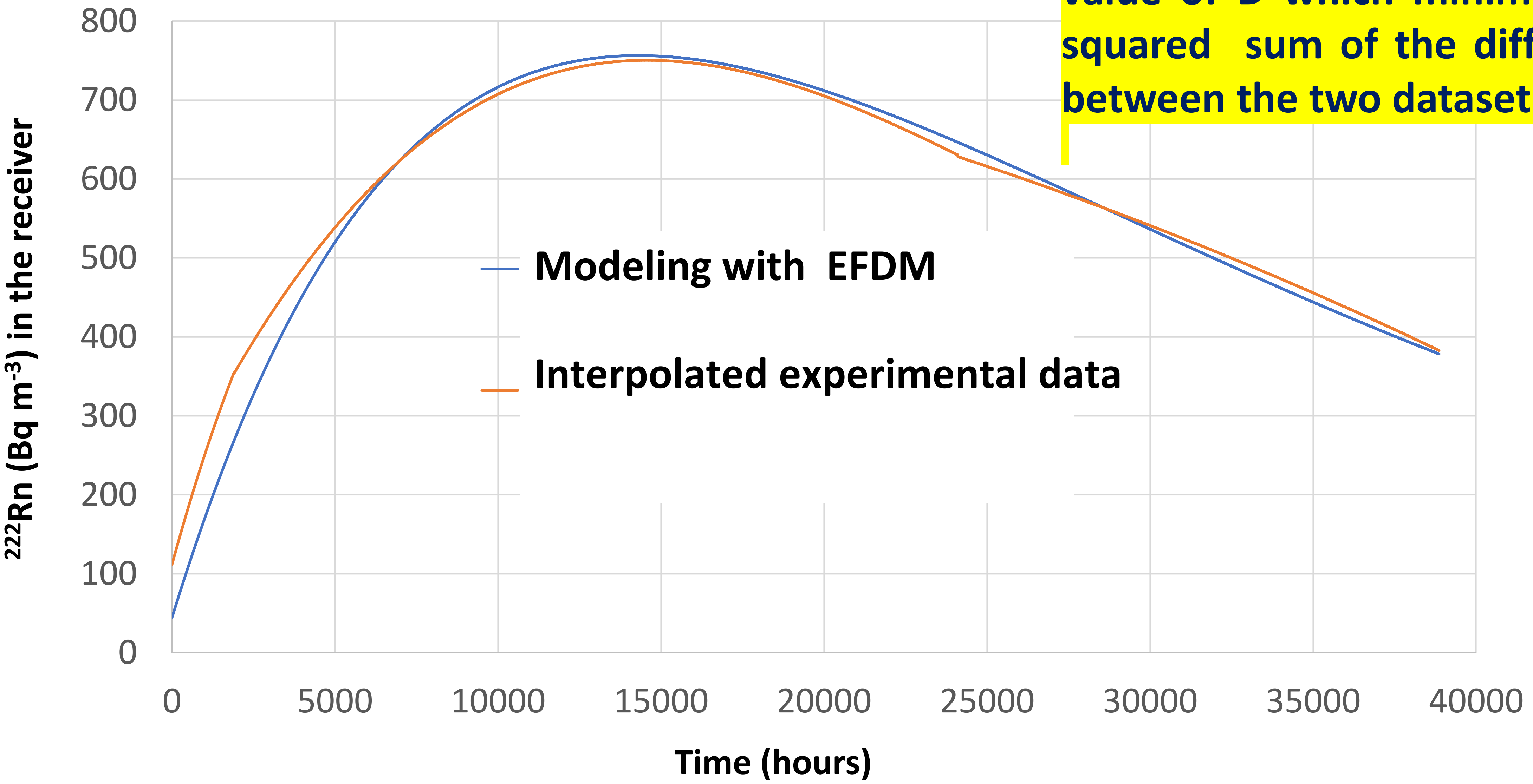
Modelling of radon diffusion within a HDPE membrane using the EFDM method

d = 1.2 mm

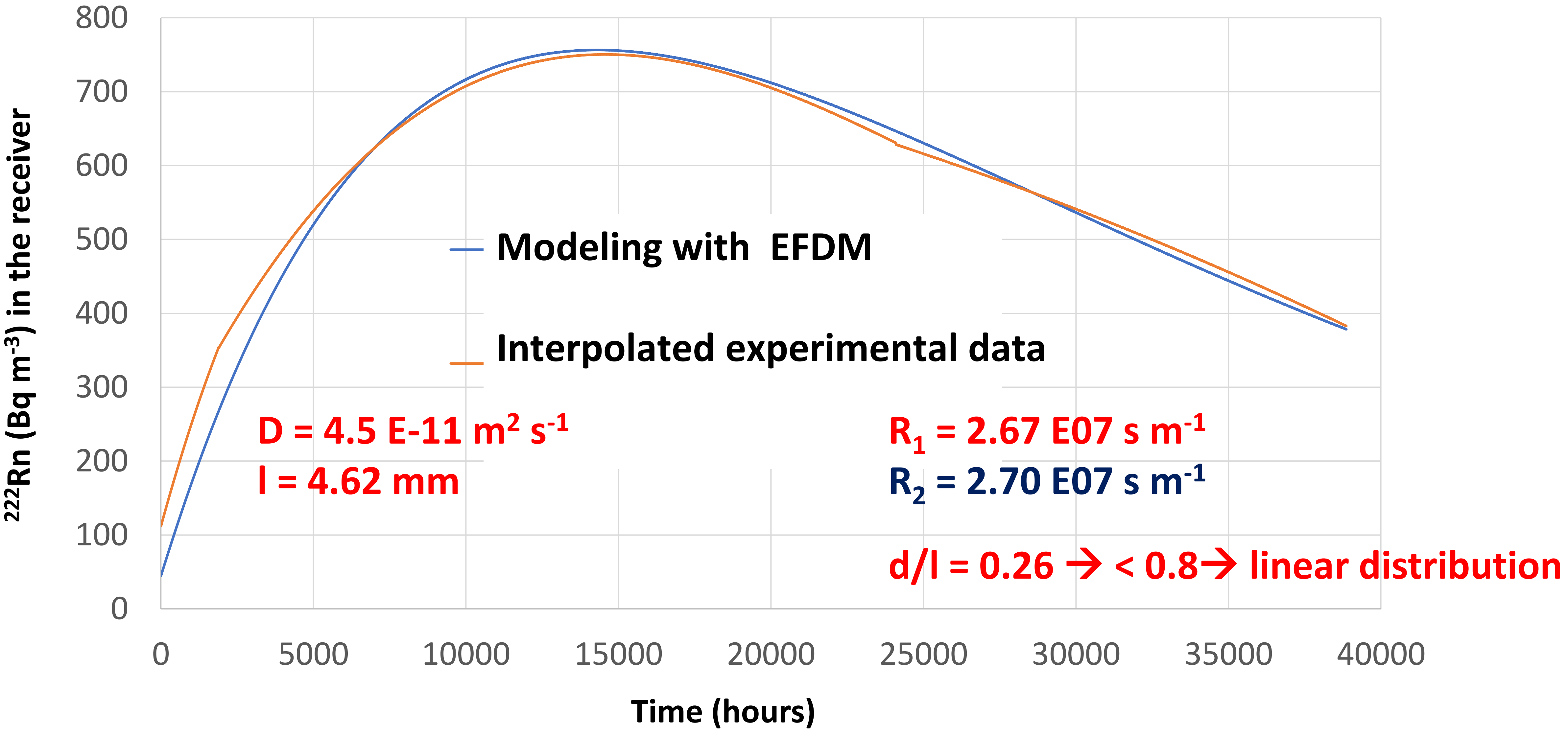


CHECKING THE MODELING THROUGH CURVE OVERLAYING

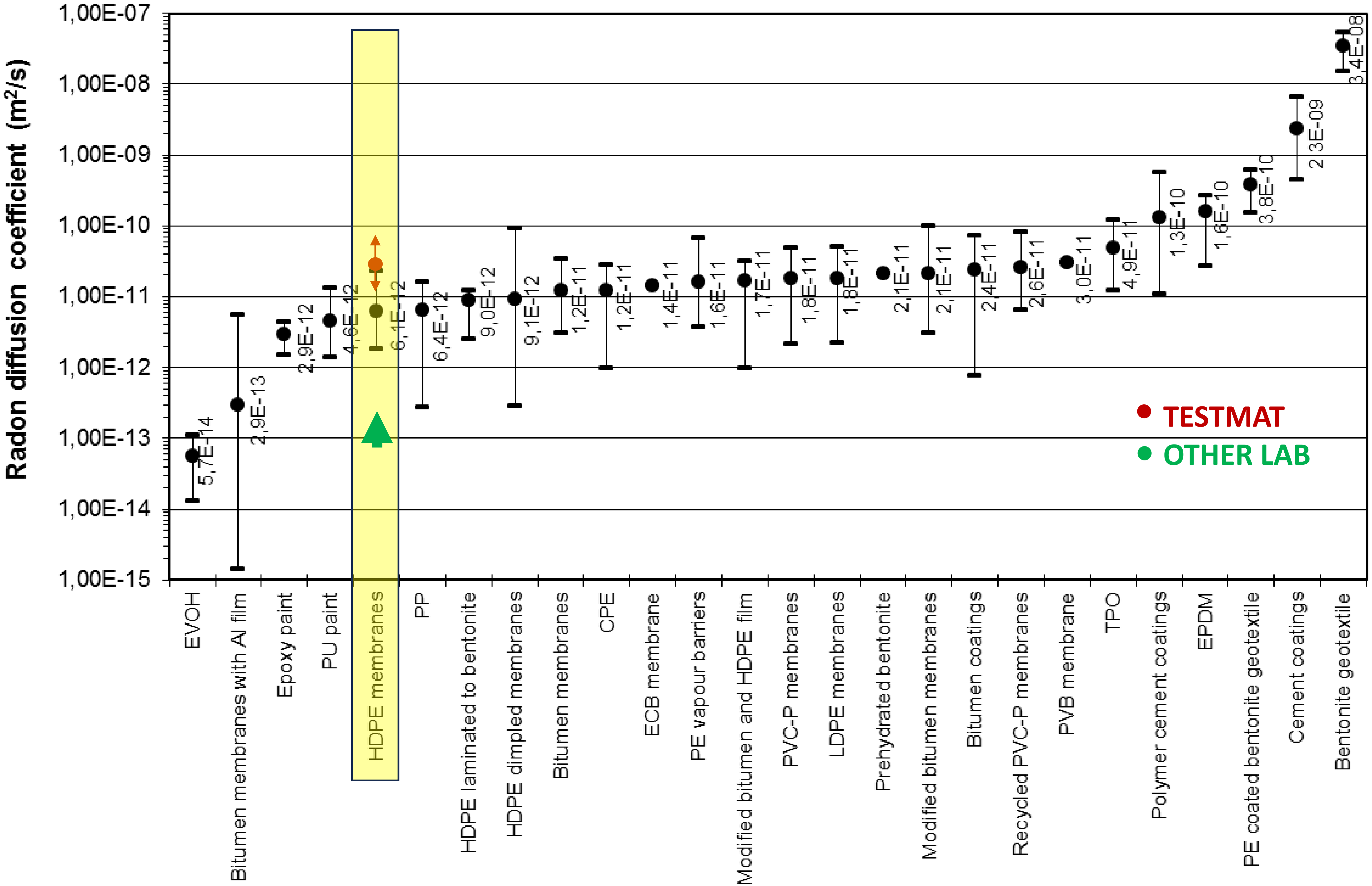
Iterative procedure based on the value of D which minimizes the squared sum of the differences between the two dataset



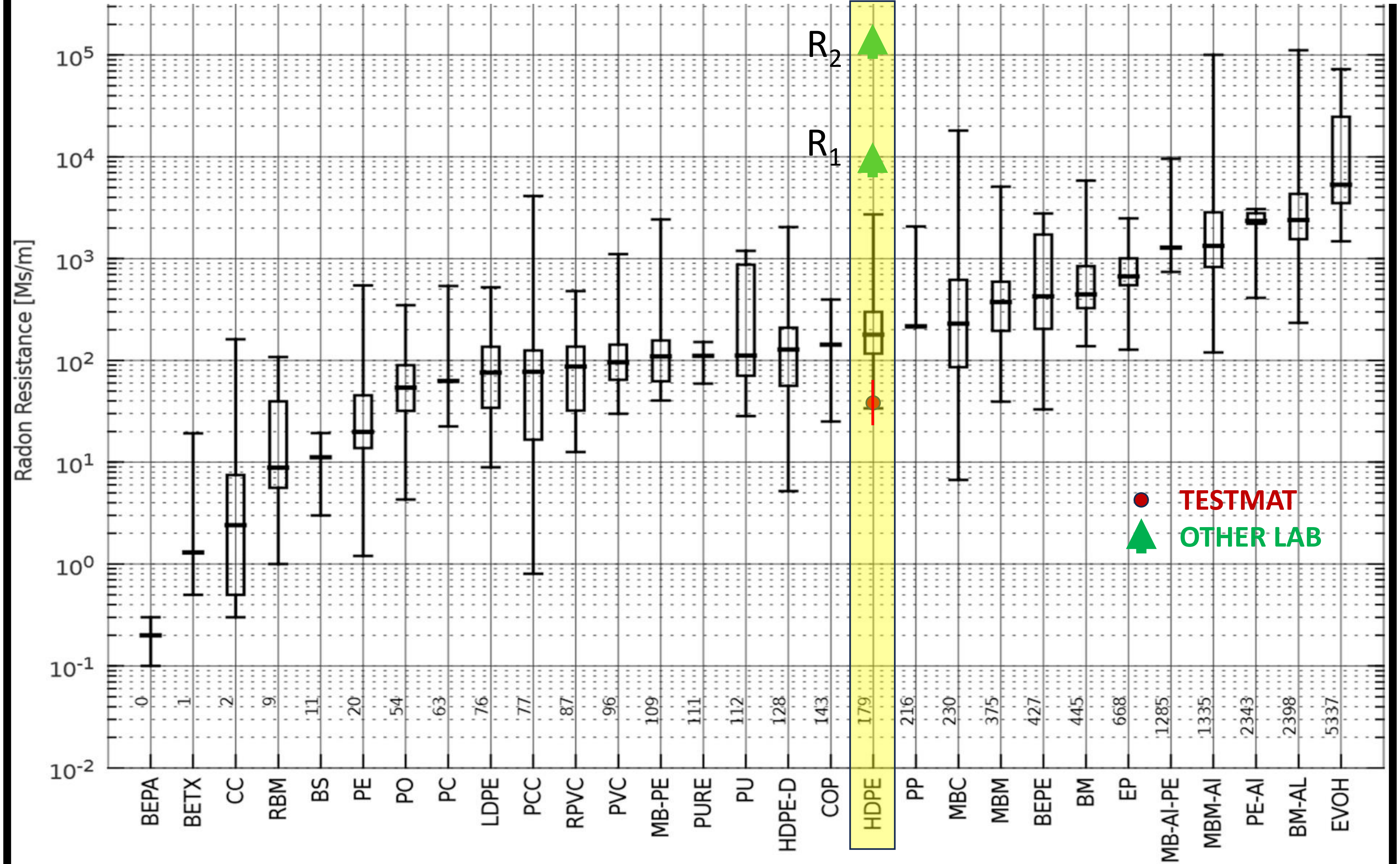
CHECKING THE MODELING THROUGH CURVE OVERLAYING



Radon diffusion coefficients of various waterproof materials (Jiranek, 2012)



Radon resistance of various waterproof materials Jiranek & Kačmařikova (2019)



FINAL CONSIDERATIONS

The properties of airtight membranes to control indoor radon can be assessed using the scale model-room and the TESTMAT approach.

The model room approach provided a wide range of indoor radon reductions (RIRs) for the 24 tested materials. The RIRs are, in a first approximation, coherent with the D values available in literature, for similar products.

The characterization of the products with the second approach is still being defined.

The first results show that the D and R values of the tested HDPE membrane are within the range of values reported in Jiranek (2012) for these materials, but it is very different from measurements performed by another laboratory on the same material.

This shows how «different» radon diffusion coefficient results can be, although ISO standards (ISO/DIS 11665-10) exist. Further experiments are necessary to validate our experimental apparatus and data treatment.

Thanks for your attention !!