Milano 21 e 22 Settembre 2017

The second radon-in-field international intercomparison for passive measurement devices: dwellings and workplaces

New experimental activity at ENEA INMRI radon laboratory

Francesco Cardellini

ENEA – Istituto Nazionale di Metrologia delle Radiazioni Ionizzanti
Francesco.cardellini@enea.it

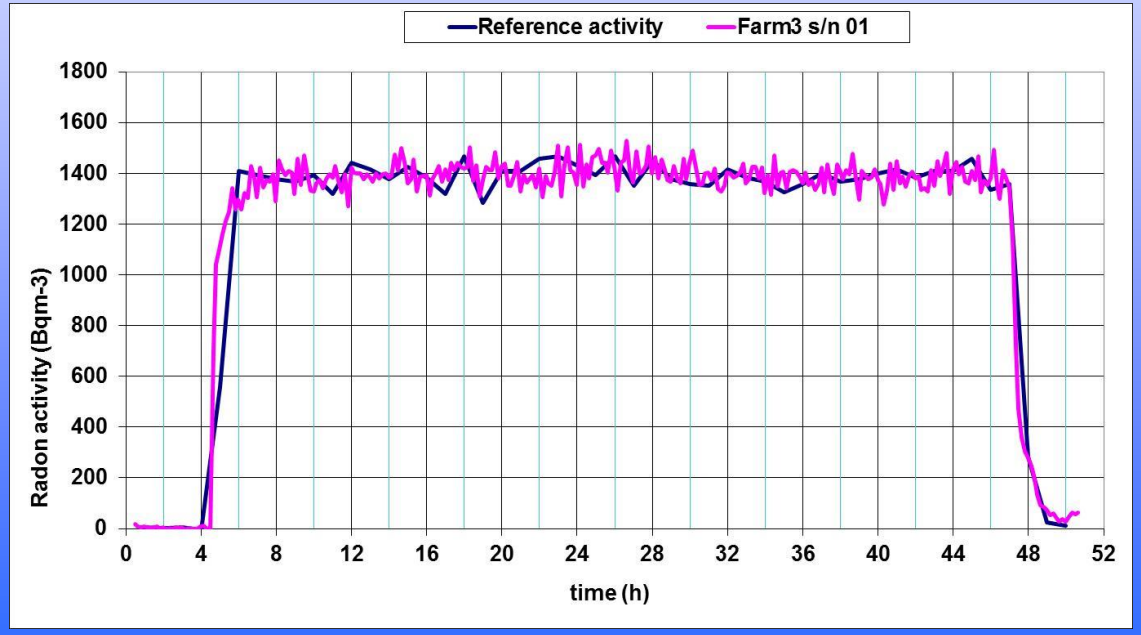
Main topics of the presentation

- Test and calibration of new radon devices
- Test of a new monitor of airborne radioactive areosol
- Radon in water measurement
- Test of new routine for thoron measurement with commercial radon monitor
- Effects of thoron on standard radon measurement

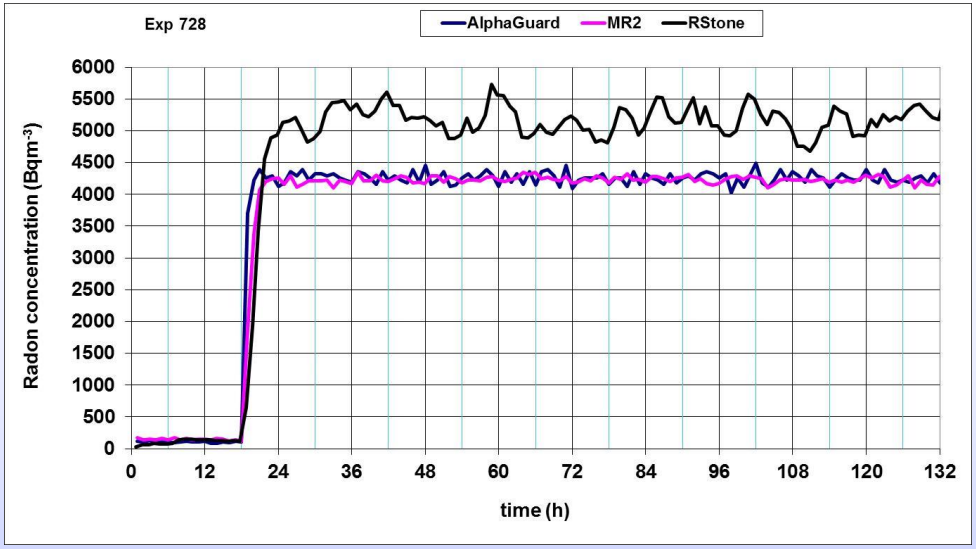
In recent time new devices for radon measurement where developed in Italy and tested at ENEA INMRI radon chamber

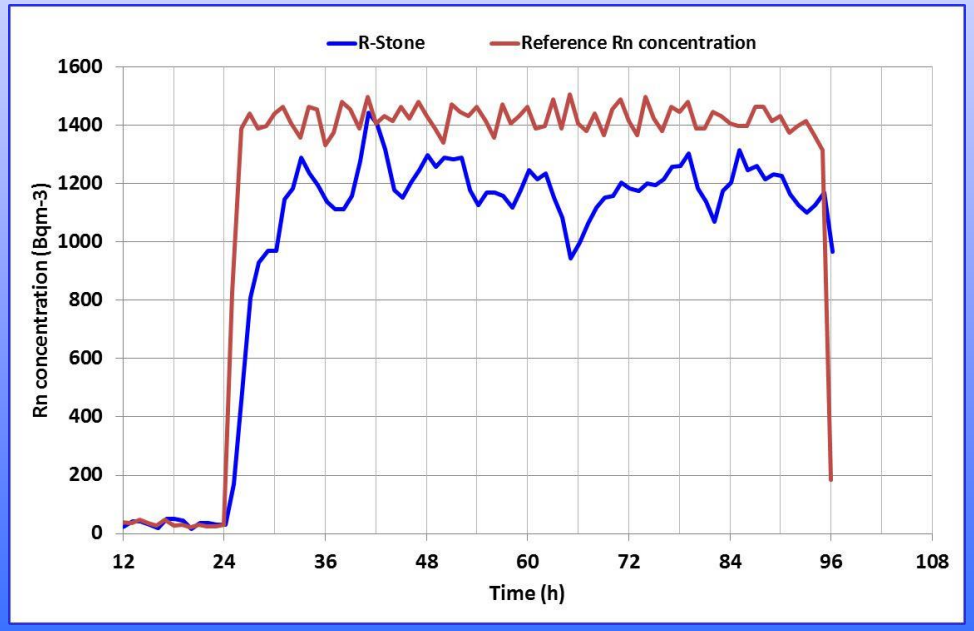
Radon monitor FARM3 developed by Federico Botter on behalf of “Friulana Costruzioni”.
The device is based on 3 ionization chamber

Two prototype of FARM3 radon monitor inside one cubic meter radon chamber for a test.



Result of measurement at constant radon concentration in 1 m^3 radon chamber at ENEA INMRI laboratory

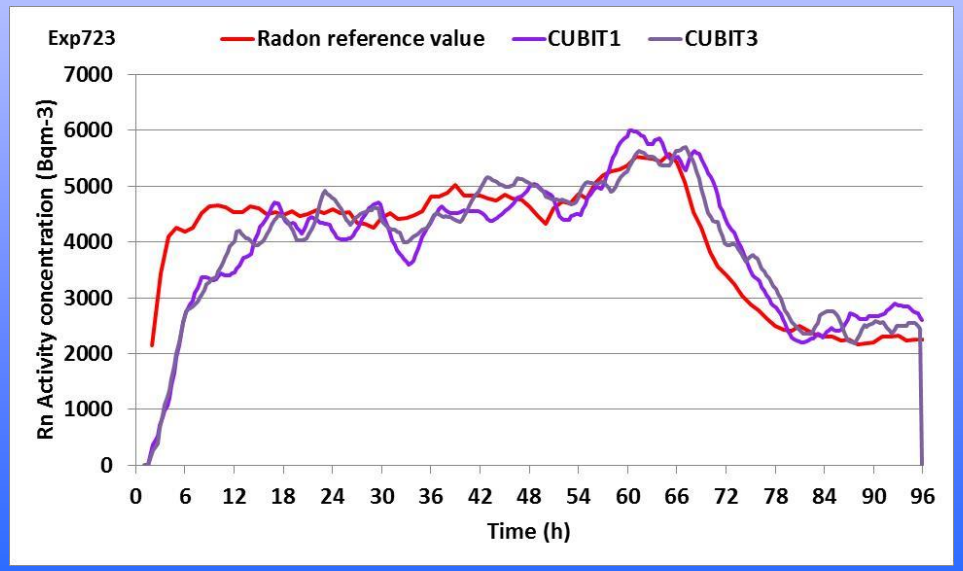




Test of radon monitor R-Stone by R-Sens in INMRI-ENEA radon chamber

The monitor is based on electrostatic collection cell and photodiode.

Each monitor need an individual calibration that is applied by the manufacturer after radon test at INMRI - ENEA



Test of ″QBOLIFE″ by CUBIT-Nuvap

Measurement of
Radon Gas
Methane
Carbon monoxide
Fine dust

Measure of radon are based on R-Stone thecnology and experience.

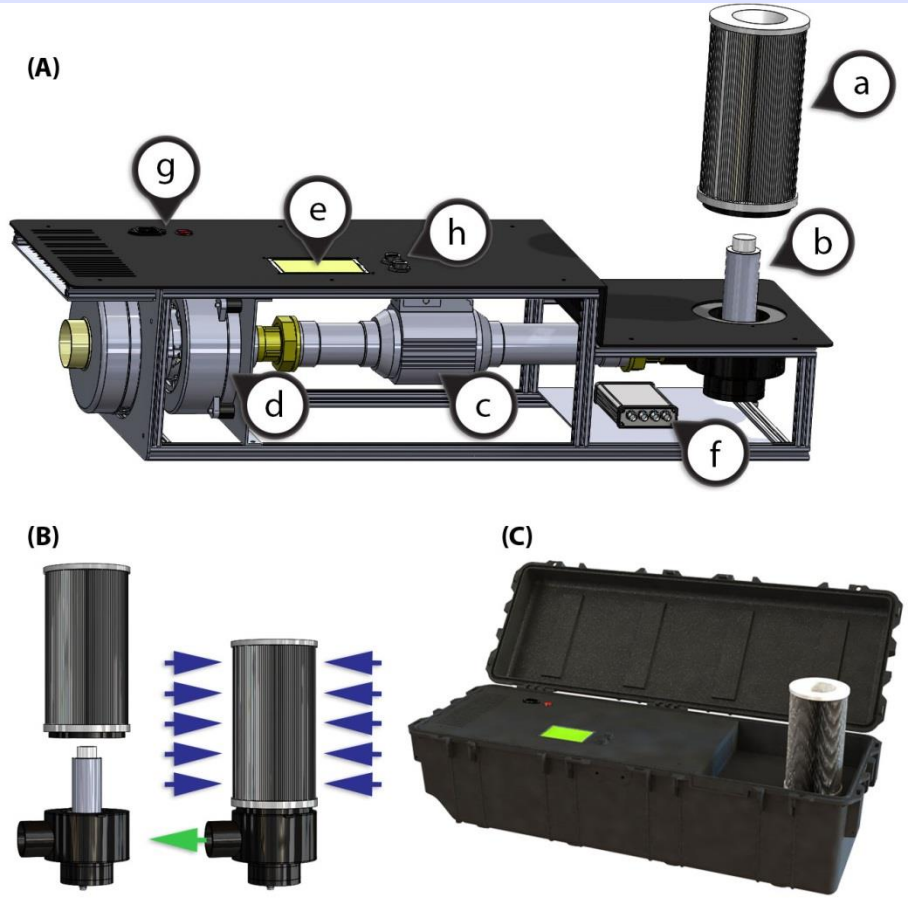
The Portable Monitoring Air Pump For Radiactive Aerosol (MARE),
developed at Jožef Stefan Institute, Ljubljana, Slovenia,
was tested inside the 150 m^3 walk-in radon chamber at ENEA-INMRI.

Device size **114 cm x 50 cm x 37 cm**

a) Concertinaed filter cartridge (h 250 mm, diam. 130 mm, active area ≈ 0.9 m^2)

b) Gamma ray detector (1 inch $CeBr_3$ scintillation detector), positioned within the filter .

The γ detector has a FWHM energy resolution of ~4% at 662 keV



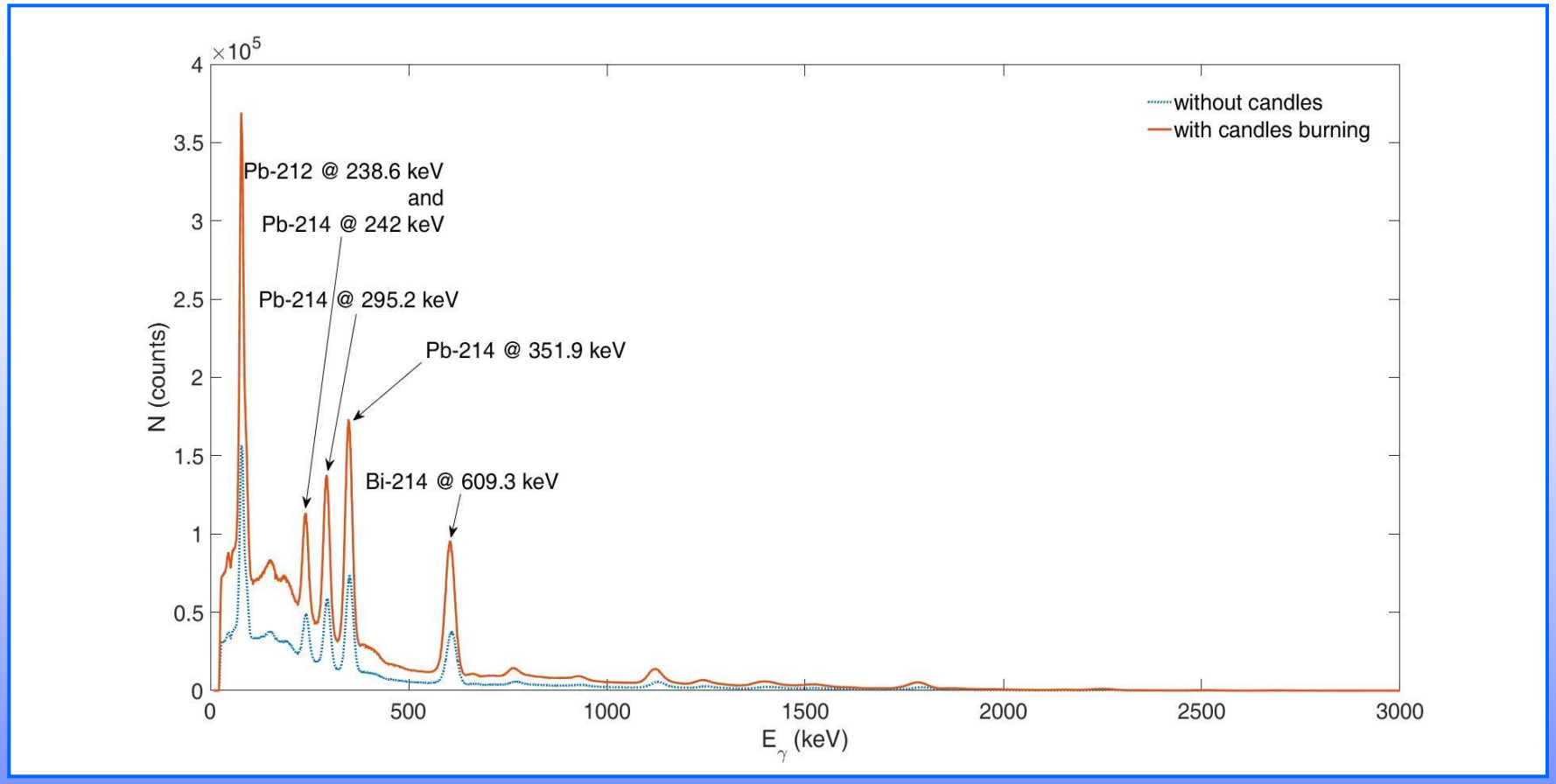
c) Flow meter
d) High flow air pump provides a stable flow rate up to 200 m^3/h throw the filter.

Measure of airborne radioactive performed by "Mare" was compared with the same measure carried out by BWLM Plus 2S Radon Daughter Monitor.

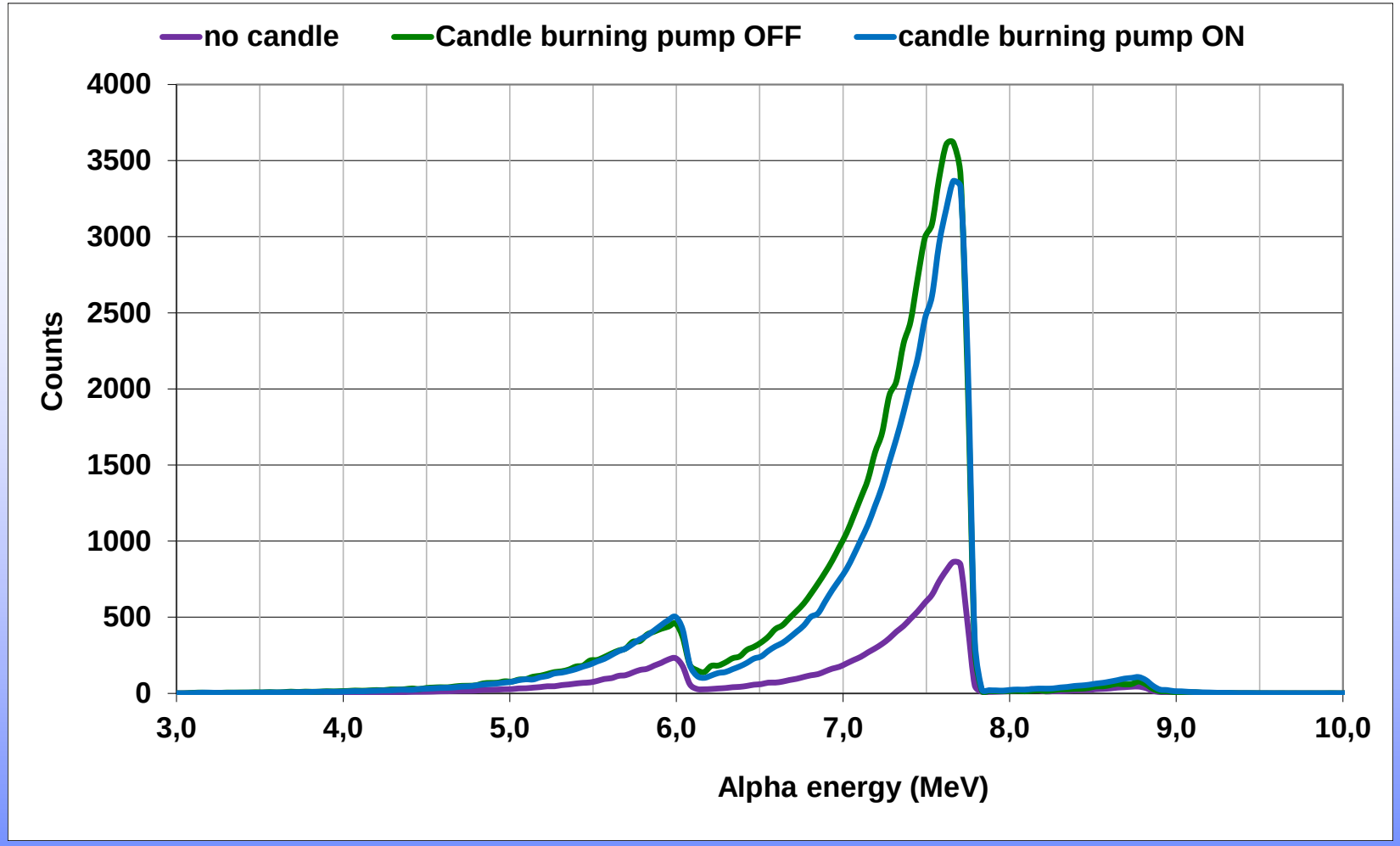
Tracerlab BWLR 2S radioactive aerosol monitor has two independent acquisition units. One for total airborne RDP is equipped with a cellulose sampling filter. Another, for unattached fraction solely, is equipped with a wire mesh filter. In each unit air is driven through filters by a pump, at a flow rate of 100 L h^{-1}. An alpha spectrometers, based on Si surface barrier detector, faces each filter. Energy resolution is 6.7 % at 7.687 MeV (Po-214)

Up: Sampling filters of Tracerlab

Left: MARE collects nuclides on a cylindrical filter and perform γ spectrometry

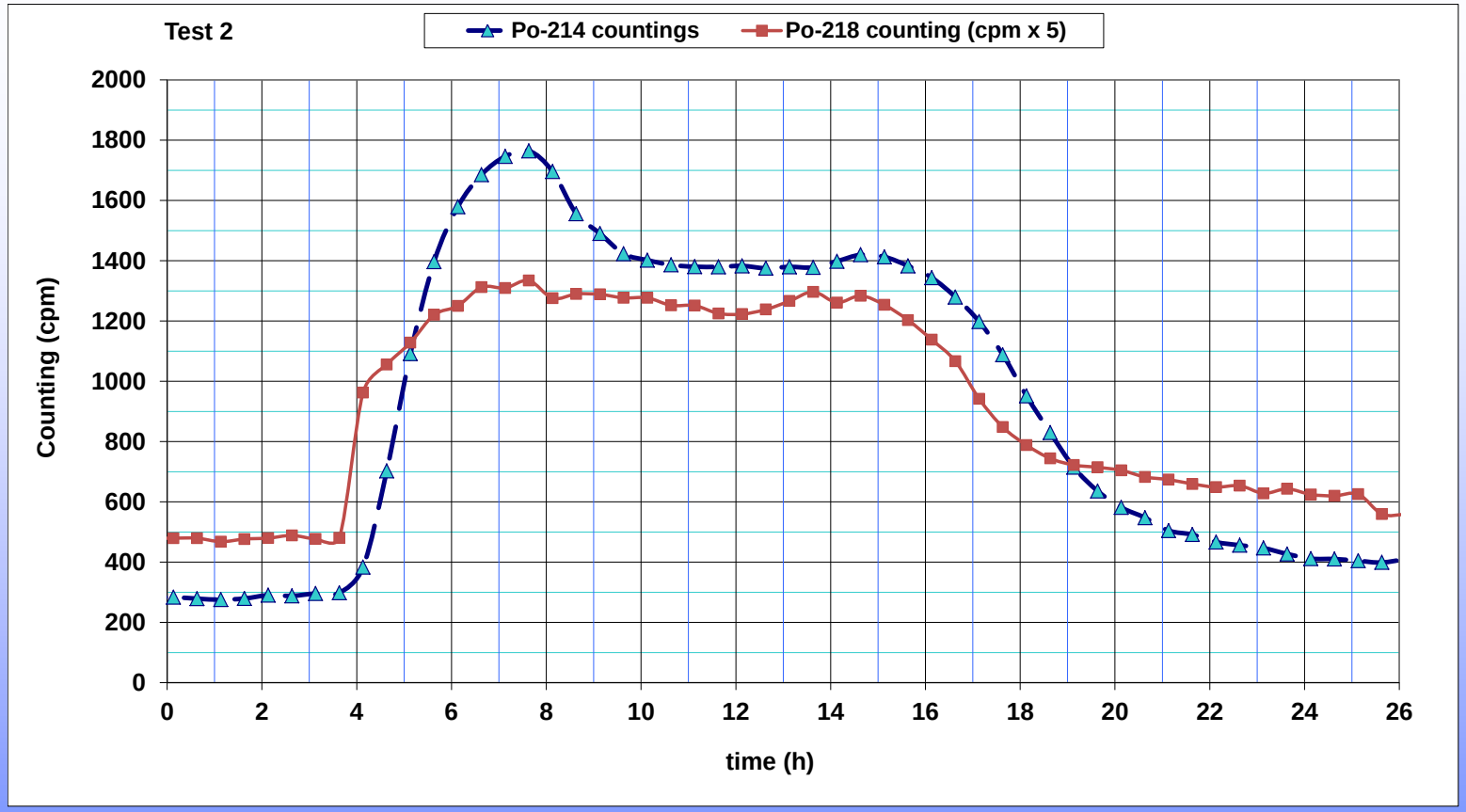


Gamma emission spectra of airborne radionuclides collected on the concertinaed filter of MARE. Bi-214 activity is proportional to the sum of the short living radon decay product in air. Pb-212 belongs to Rn-220 decay chain and was present only in small traces.

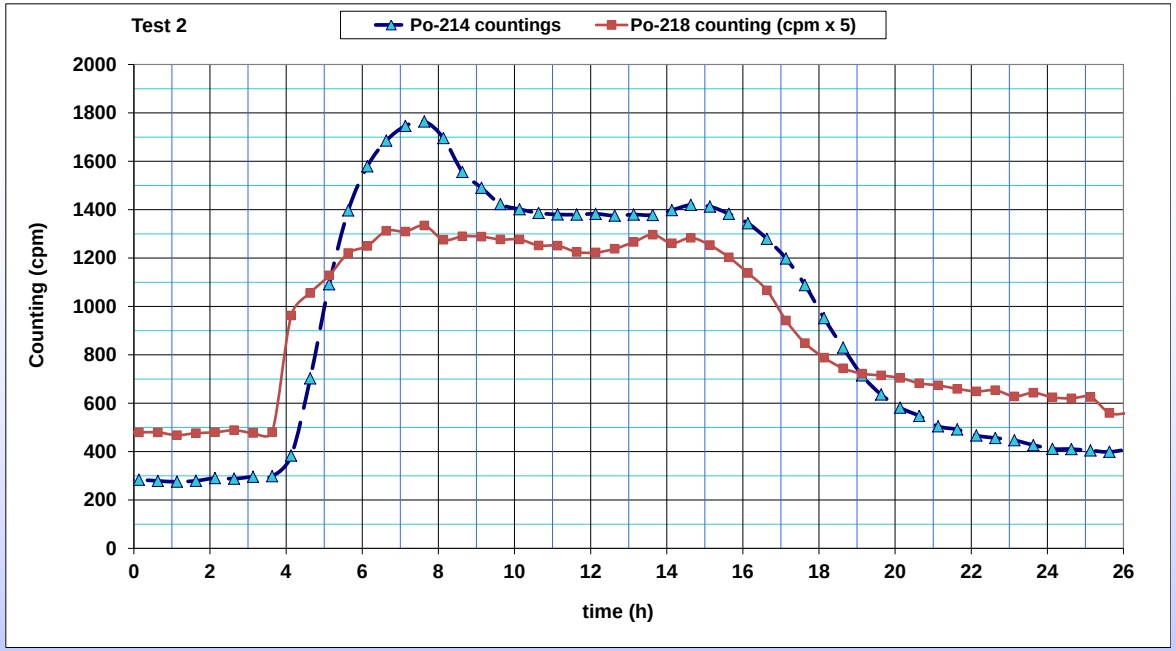


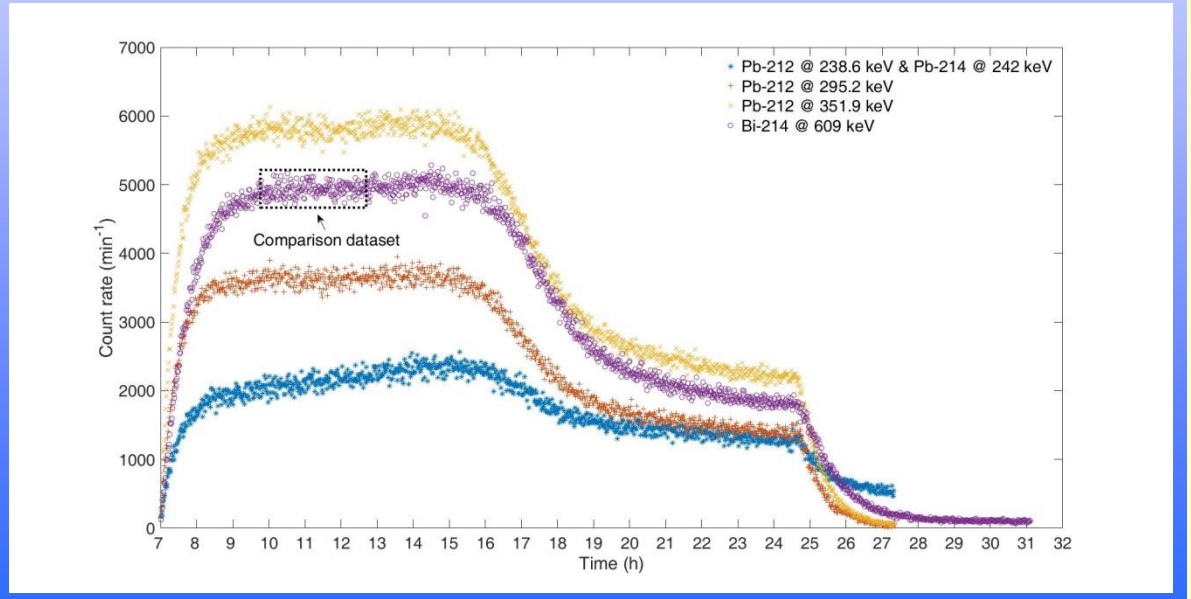
Alpha spectra of airborne radionuclides collected on the paper filter of Tracerlab in three different time of the test. 1st spectrum: no candle burning; 2nd spectrum: candle burning for aerosol production and MARE pump off; 3rd spectrum: MARE pump on.
Alpha peak from left: Po-218, Po-214 (Rn-222 decay chain) and Po-212 (Rn-220 decay chain)
Po-214 activity is proportional to the sum of the short living radon decay product in air.

Test in walk-in radon chamber with Rn activity of 3000 Bqm^{-3} and candle smoke.



Counting rate of Po-218 and Po-214 by Tracerlab BWLM Plus.
Candle are lighted at 9:30 (4.0 in timescale of the figure) to enhance aerosol concentration and airborne radon progeny.
At ≈ 13:00 MARE pump is switched ON and removes part of the aerosol.
Po-218 is not effected by MARE pump due to his short mean life time.
At ≈ 21:00 (16.0 in timescale of the figure) candle are burned off and airborne radon progeny get lower.





Bi-214 and Po-214 activity are always in equilibrium, due to the short mean life of Po-214.

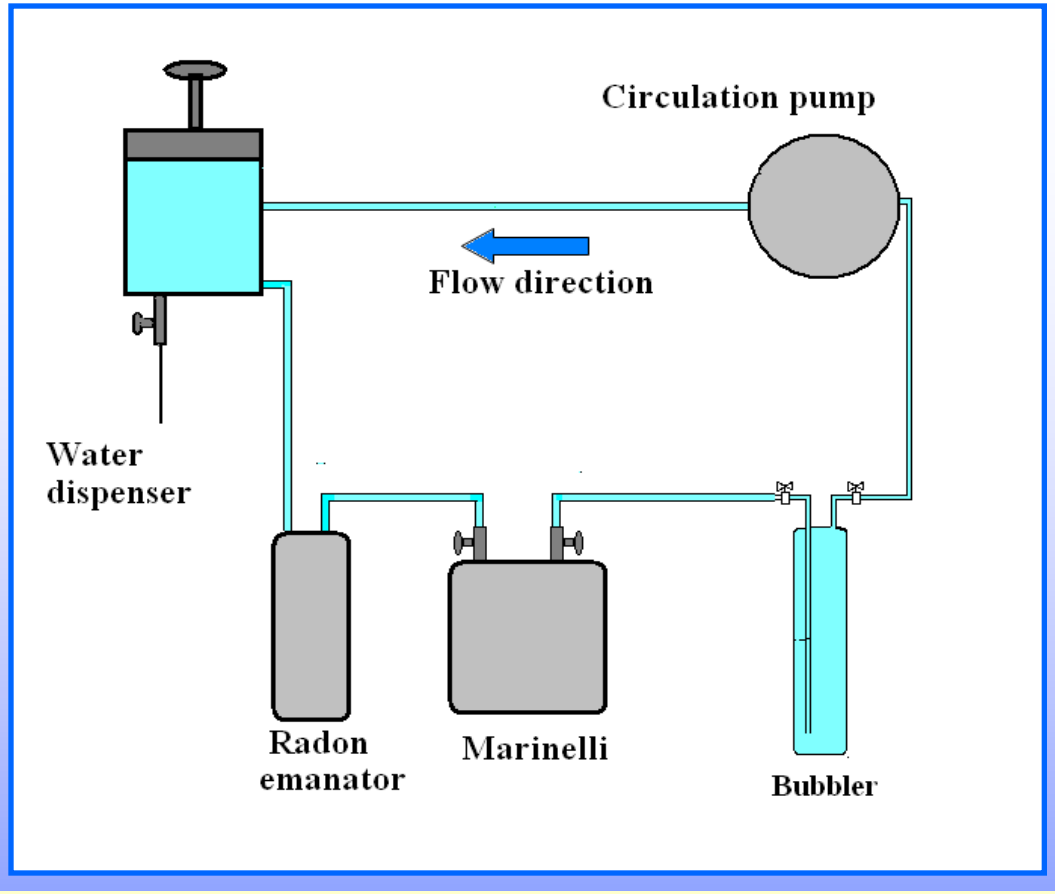
The amount of these nuclides collected on the filter is proportional to the sum of the concentration of Po-218, Pb-214 and Bi-214 in air.

Thus, from the γ activity of Bi-214 measured by MARE and/or from the Po-214 α activity measured with BWLM it is possible to compute the concentration in air of Rn progeny

From α: $N_{tot} = 4700 \pm 400\ L^{-1}$

From γ: $N_{tot} = 4100 \pm 1000\ L^{-1}$

The results are in agreement



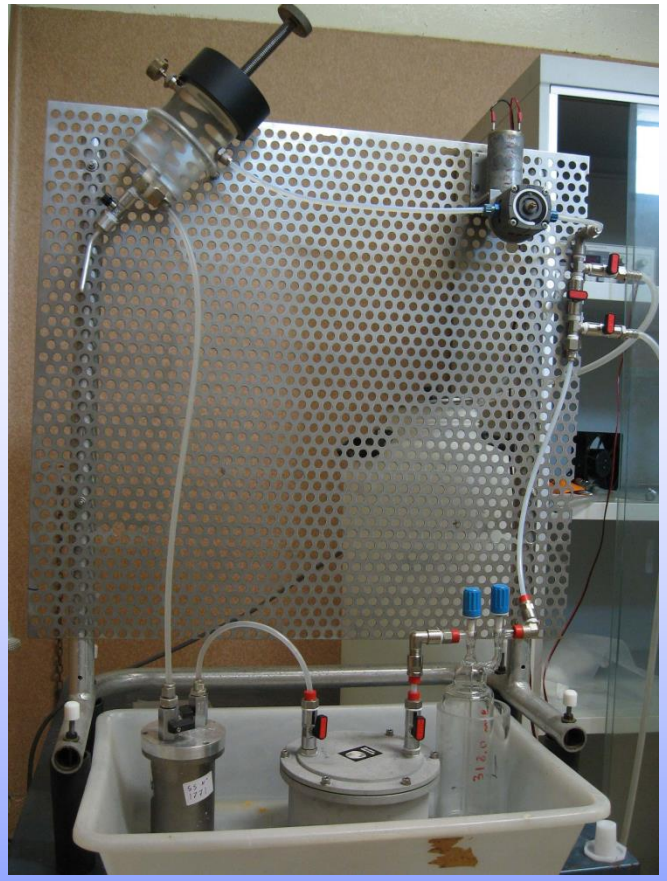


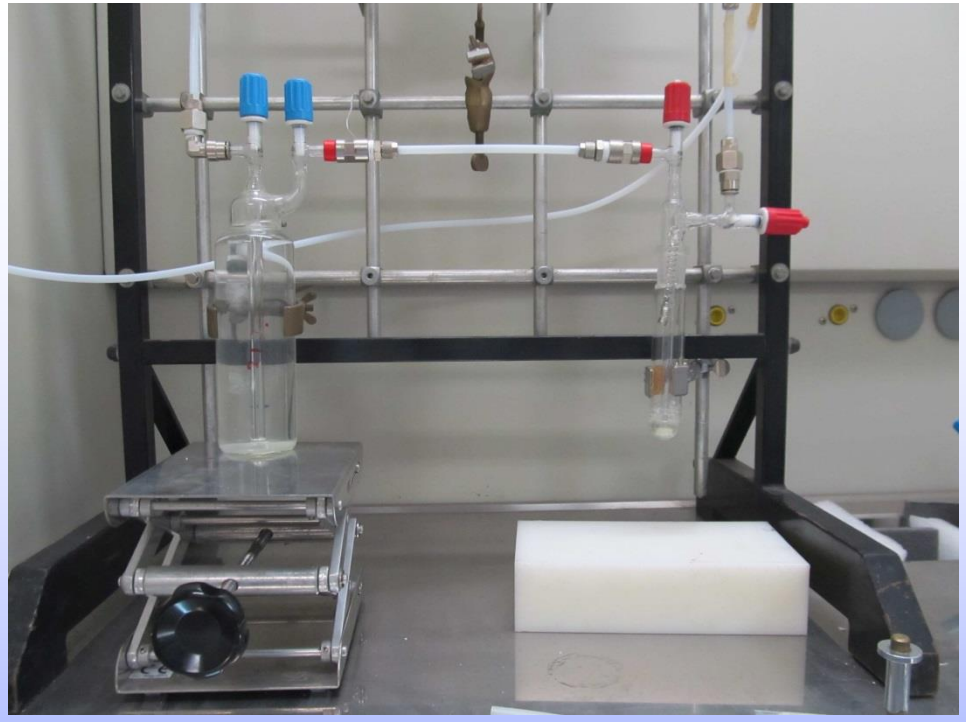
Diagram and picture of the Standard Generator of Rn in Water Solution.

The aim of the circuit is to provide a set of water samples, all with the same radon concentration, to be measured by different measuring systems, without leakage of radon. In the actual configuration are present:

1) Bubbler for measurement of Rn in water activity in the primary radon standard

2) Dispenser mainly used for filling the vials for liquid scintillation counter

3) Marinelli beaker for gamma ray spectrometry.



Left: Glass bubbler is placed in the primary radon standard operating at INMRI ENEA to measure the achieved activity of Rn in water (small bubbler at left is only a water trap).

Right: Water dispenser (a cylindrical vessel with a piston) is used to purge water in glass vials for liquid scintillation measurement (LSC) .

The dispenser is also used to fill the aqua-kit of Tesys MR1 or AlphaGuard.

Three water samples were measured by LSC at ENEA INMRI with two different instrument:

HIDEX 300SL TDCR (Triple to Double Coincidence Ratio)

TRI-CARB 3100 TR (Ciemat NIST)

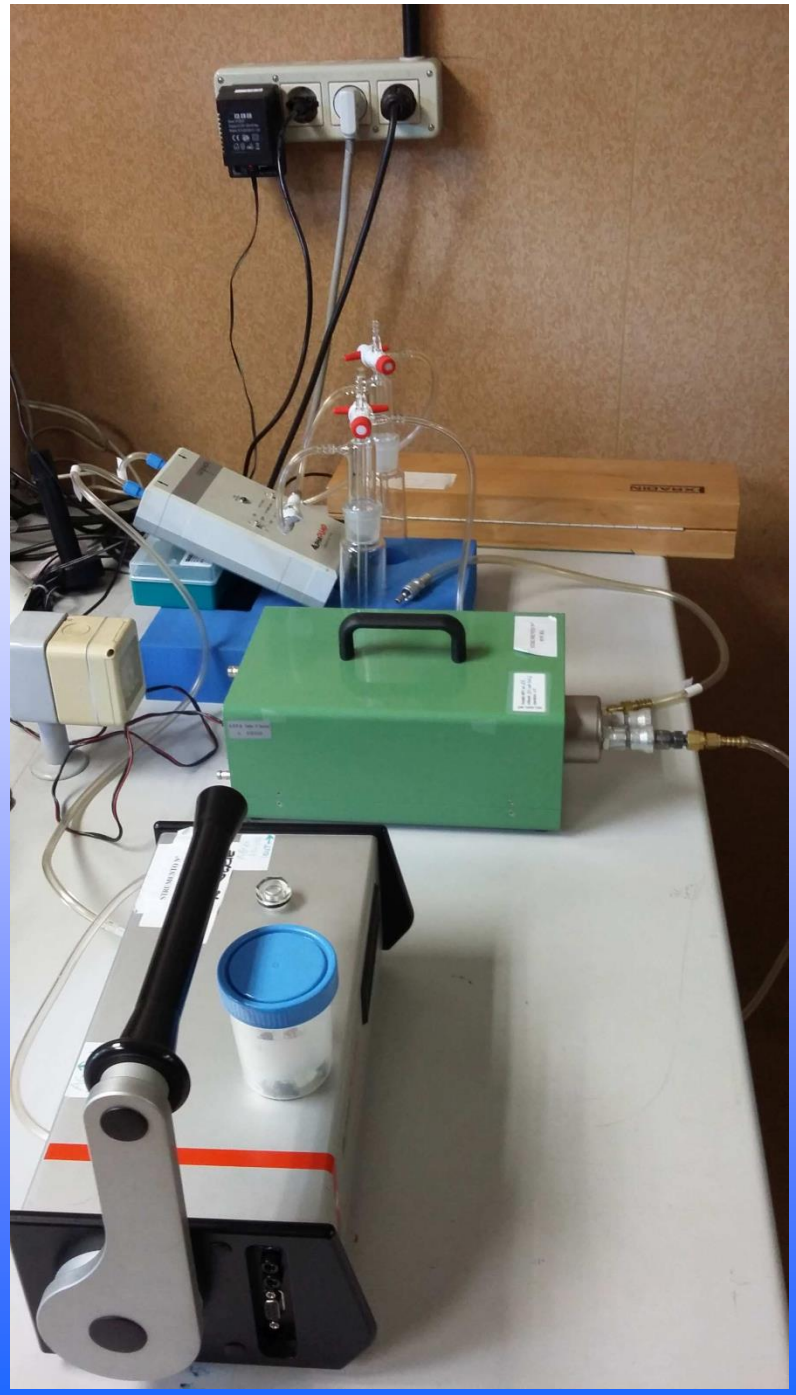
Measurement with Liquid Scintillation Counter			
Water sample	Reference activity (Bq/l)	Tricarb measure (Bq/l)	HIDEX measure (Bq/l)
Sample 1	16971	16693	16640
Sample 2	15117	15160	14780
Sample 3	15363	15280	15150

LSC measurement by: Dr. ANTOHE Andrei Horia Hulubei National Institute for R&D in Physics and Nuclear Engineering, IFIN-HH, Romania.

Two different samples were measured in ENEA in cooperation with ARPA Piemonte and ARPA Valle di Aosta (picture right) .

Result are listed in the tables below.

Measurement with Acua Kit and HPGe				
Water sample	Reference activity (Bq/l)	MR1 (Bq/l)	Alpha Guard (Bq/l)	HPGe (Bq/l)
Sample 4	15215	14974	15391	16056
Sample 5	2900	2920	2951	--



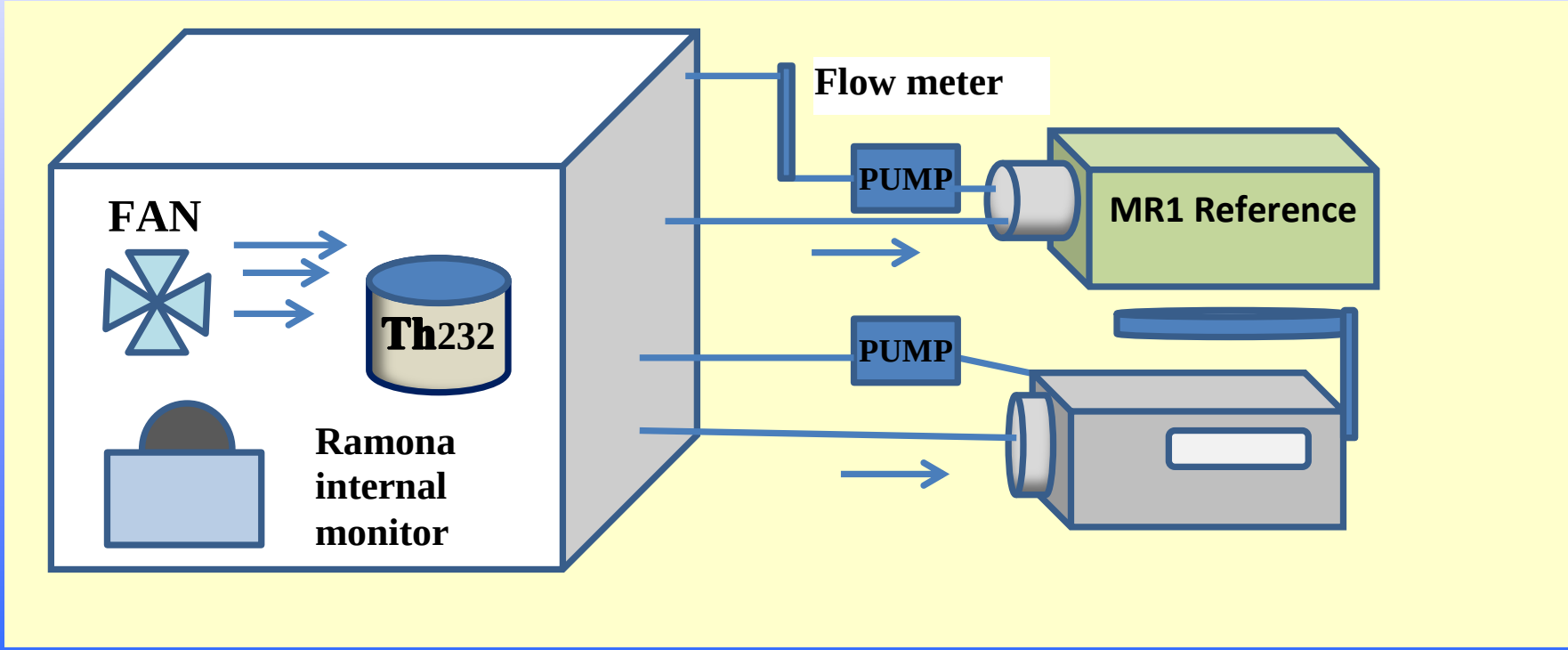
Experimental setup for Thoron (Rn-220) measurement at ENEA-INMRI.

Volume of the thoron chamber is 220 L.

Reference Rn-220 activity is given by MR1 Tesys MIAM .

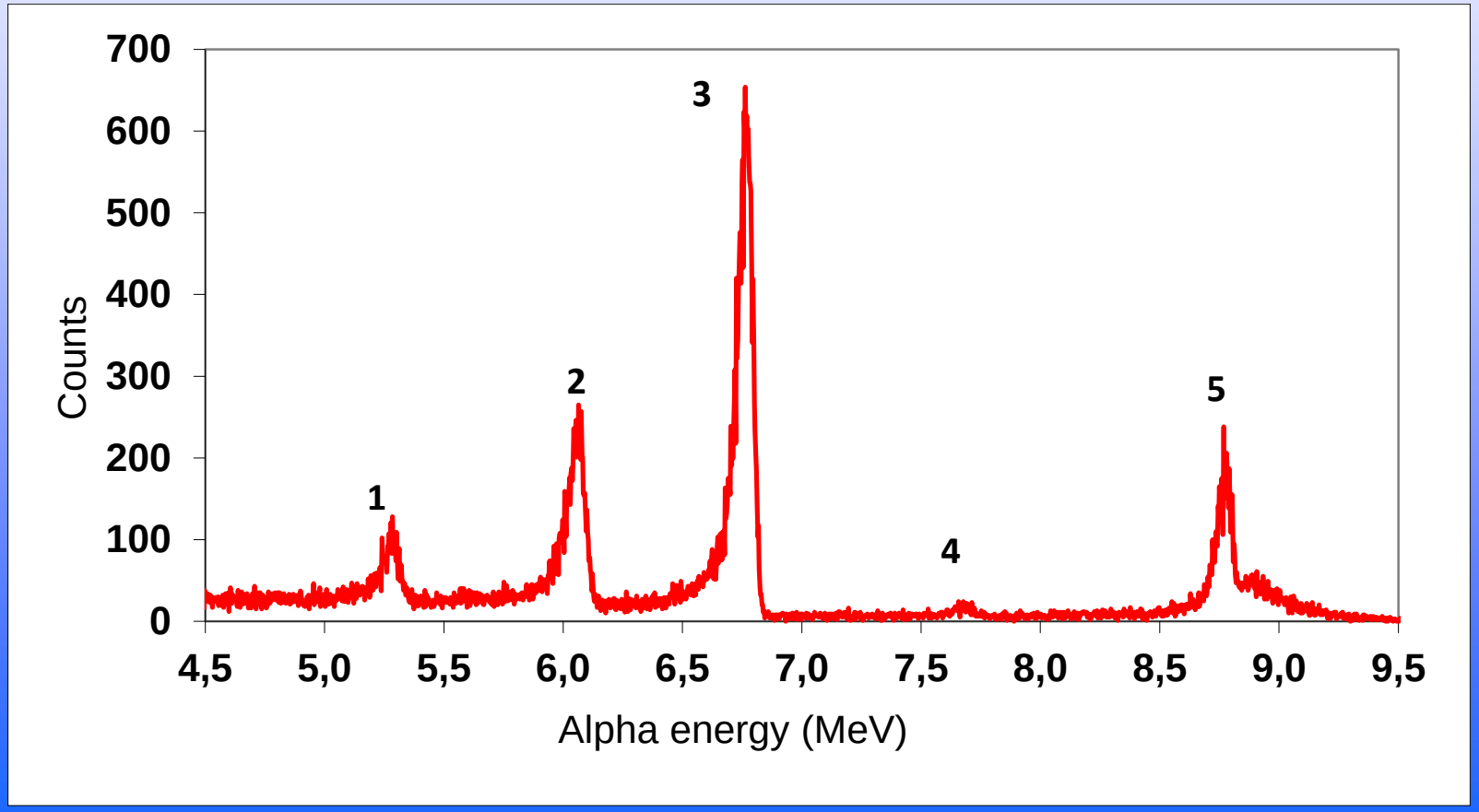
Rn-222 to Rn-220 ratio is monitored with Ramona monitor

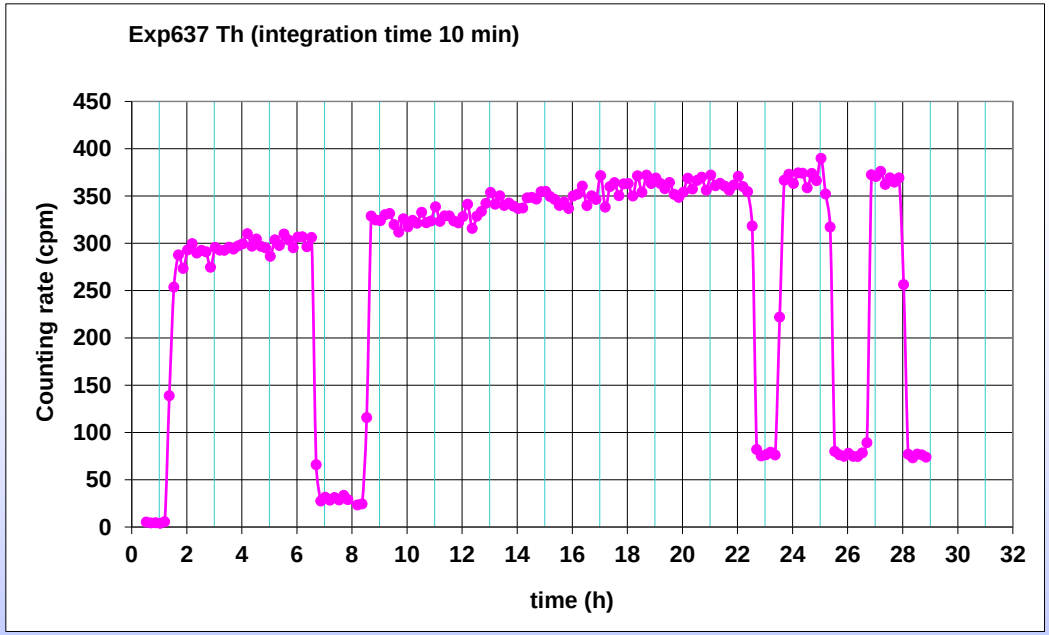
Designed by INFN Università Federico 2° Napoli

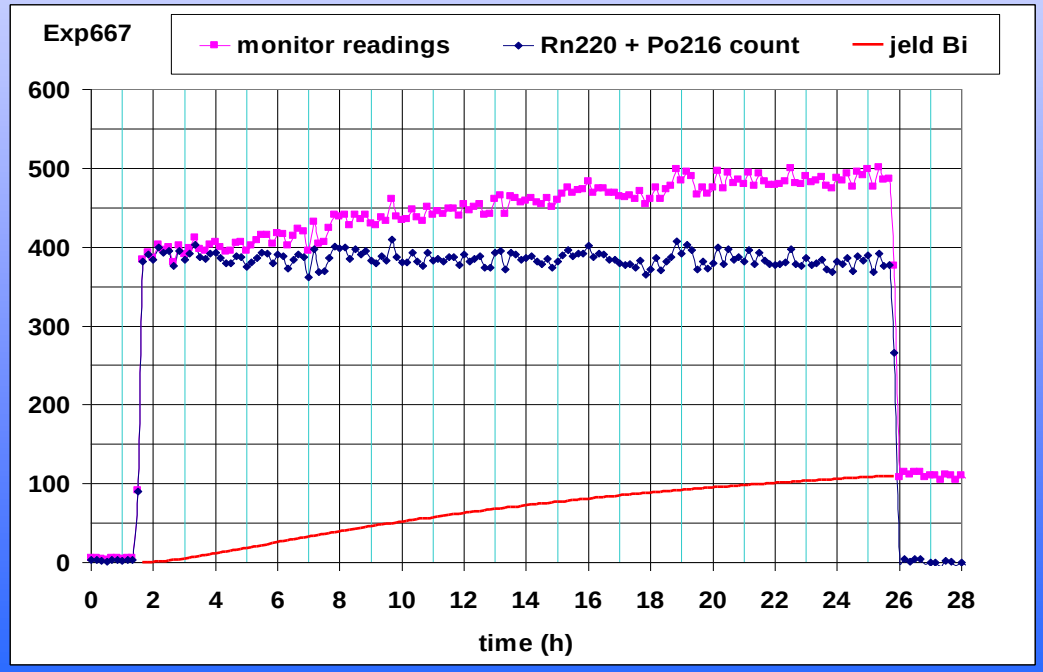


Alpha emission spectra of thoron progeny collected with "Ramona" monitor.

- Peak list: 1) ^{210}Pb contamination; 2) ^{212}Bi; 3) ^{216}Po; 4) ^{214}Po from radon; 5) ^{212}Po
- Tail on the left of last peak is due to α β coincidence from ^{212}Po and ^{212}Bi
- Background at the left side of the spectra is due to alpha emission from thoron distributed in the volume of the monitor
- Calibration problem: Not available Rn-220 reference atmosphere, Not available theoretical efficiency computation by Montecarlo simulation.







Measurement with Lucas scintillation cell:

Half life of Rn-220 and Po-216 are very short (55.8 s and 0.15). Counting rate get low very fast when sampling is stopped (upper fig.) and residual counting are due to residual Pb-212 and Bi-212 or Rn-222 eventually present in air.

Thanks to this feature of Rn-220 decay scheme, it is possible to distinguish and separate the counts due only to Rn-220 and Po-216 (lower figure).

Efficiency of Lucas cell may be computed by Montecarlo simulation (next slide).

Model of the scintillation cell for thoron measurement

- Rn-220 and Po-216 are distributed in the cell volume
- α particles are emitted at random direction
- α particles travel in a strait line with a range fixed by their initial energy, thus by the emitting nuclide
- Trheshold energy for ZnS (Ag) activation is 0,15 MeV (minimum energy for α particles detection)

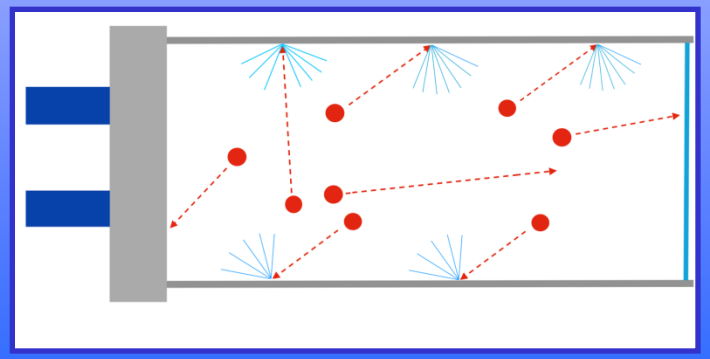
The detection efficiencies computed by Montecarlo simulation are:

$\varepsilon 1$ = 79,4% and $\varepsilon 2$ = 84.3% for Rn-220 and Pb-216 respectively.

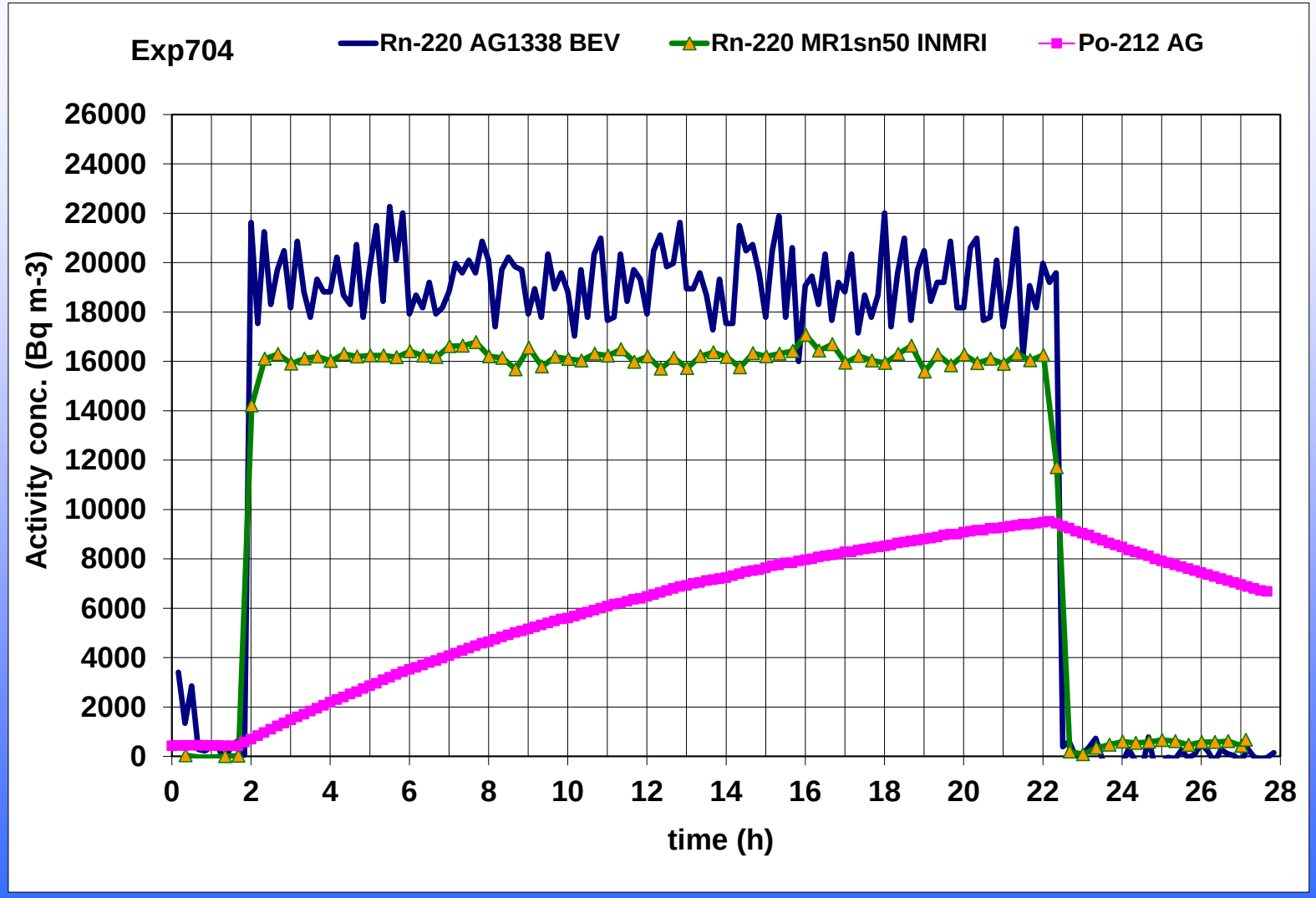
Computed calibration factor of the cell is 42.02 Bqm^{-3}/cpm

Main problem: Rn-220 decays during sampling and diffusion inside the cell, for this reason average Rn-220 concentration in cell is lower than ambient concentration.

Proper correction has to be applied according to suitable model of air flow in the cell. This is the most relevant component of uncertainty.



Calibration of AlphaGuard monitor for thoron measurement, reference value is provided by Tesys MR1 scintillation cell.



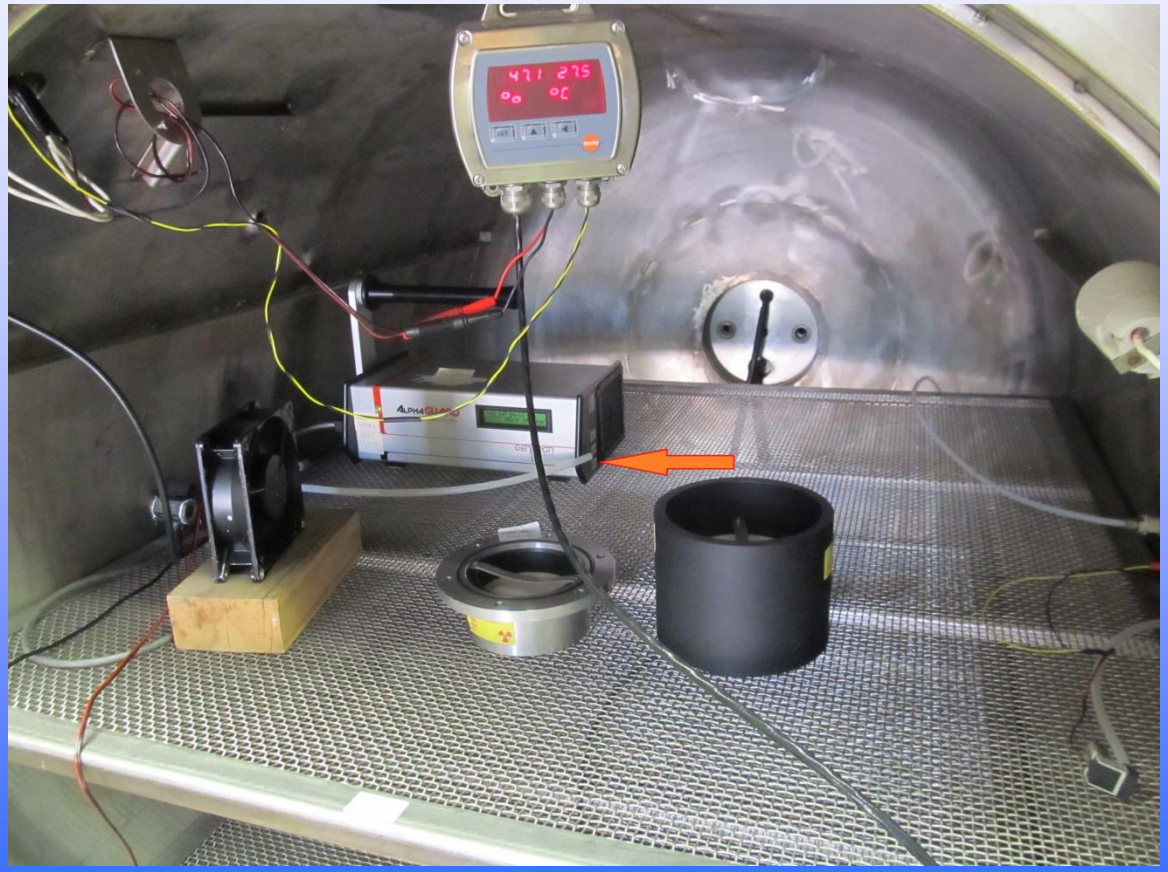
Calibration of AlphaGuard monitor for thoron measurement.

Exp n°	Reference Th activity (Bqm-3)	AG 1338 readings Th activity (Bqm-3)	number of lecture	calib. Factor
701	17988	21795	51	0,825
702	18793	22515	40	0,835
704	16195	19252	115	0,841
706	16584	19839	120	0,836
average	17576	20850		0,83
Std. dev.	1129	1554		0,01
Std. dev.%	6,4%	7,5%		0,8%

Picture of experimental setup for testing the sensibility of standard Radon monitor to Thoron gas, chamber volume is $1m^3$.

Tesys MR1 monitor was also placed in the chamber.

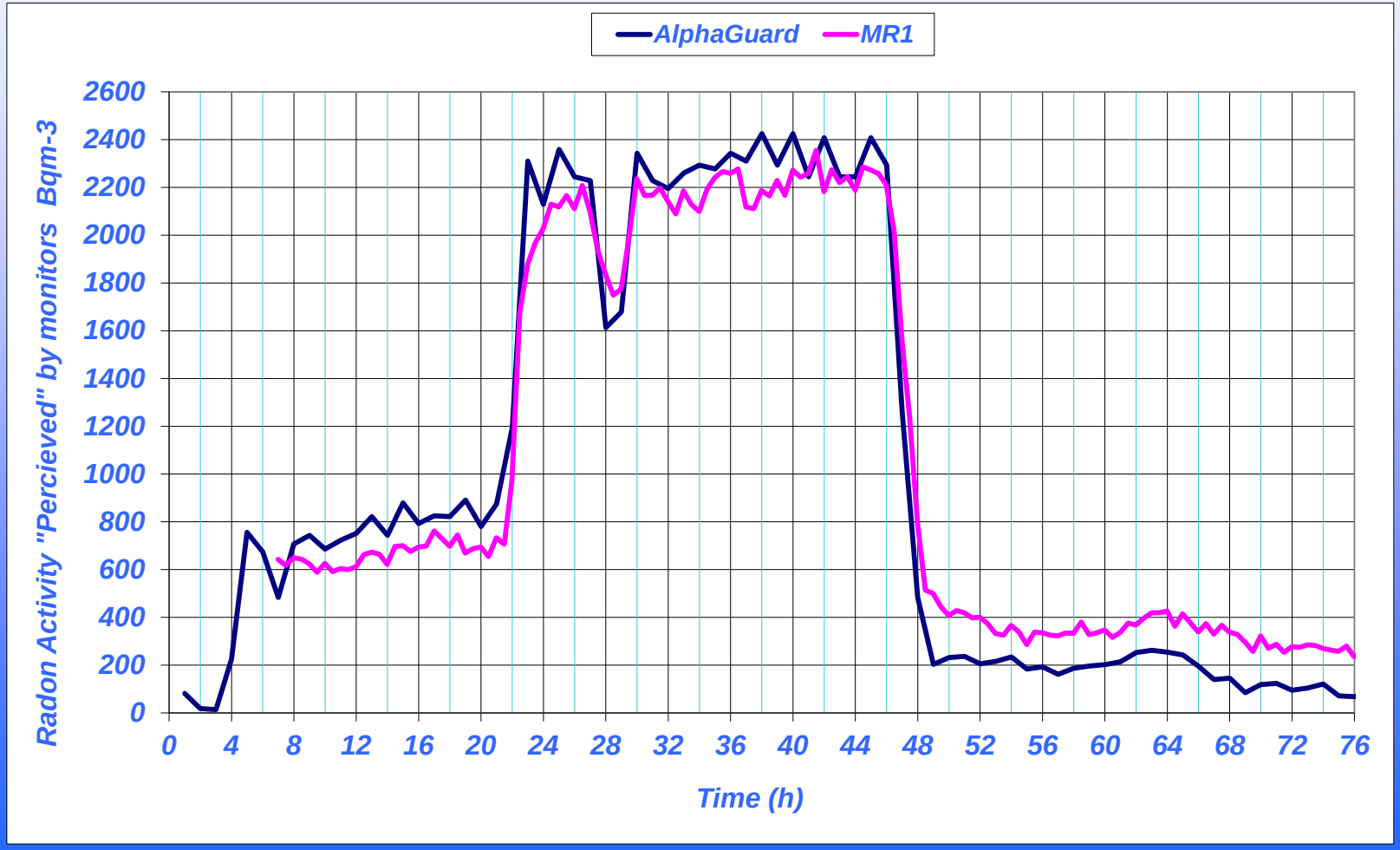
Thoron sources, fan and monitor are all placed in the upper grid of the chamber.



The orange arrow points the sampling pipe for external monitor.

The pipe may be moved in different positions inside the chamber to check Thoron distribution.

Rn-220 was percieved as a Radon concentration ≈ 800 Bqm^{-3}.
At time t=21 1.4 kBq of Rn-222 were casted inside the radon chamber.
At t=28 the fan was switched off and Th did not reach the monitor.
Countings at the end of the experiment are due to Bi-212 plated inside the detector .



Alpha emission spectra of Rn-220 and Rn-222 progeny collected with Durridge RAD7 monitor

Peak list from left: 1) ^{212}Bi and ^{218}Po; 2) ^{216}Po; 3) ^{214}Po from radon; 4) ^{212}Po
Rn-222 activity is 1450 Bqm^{-3} and, by comparing the area of ^{216}Po and ^{214}Po peak, Rn-220 activity may be estimated ≈ 3500 Bqm^{-3} .
The result is in good agreement with the activity achieved in 220 L thoron chamber.

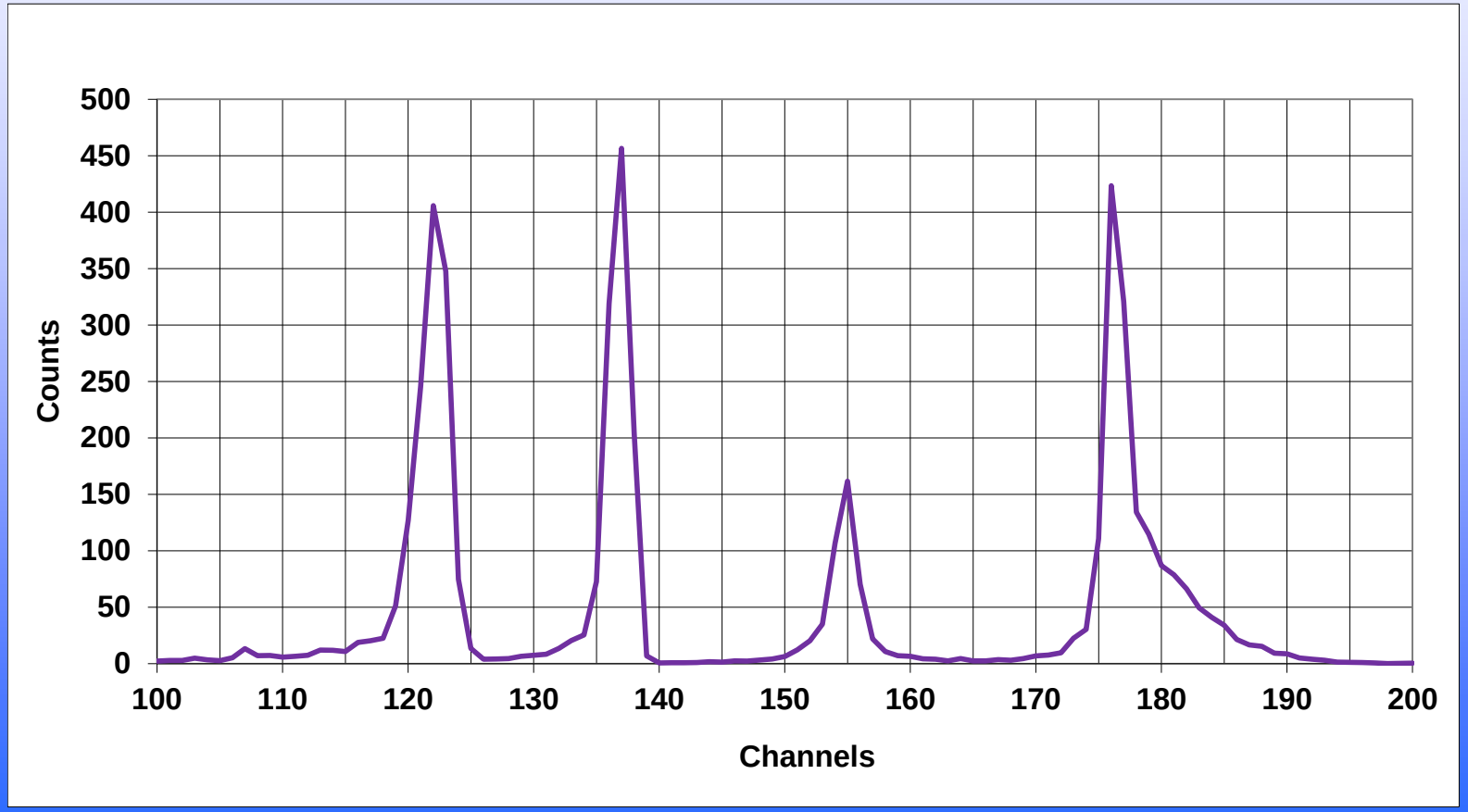
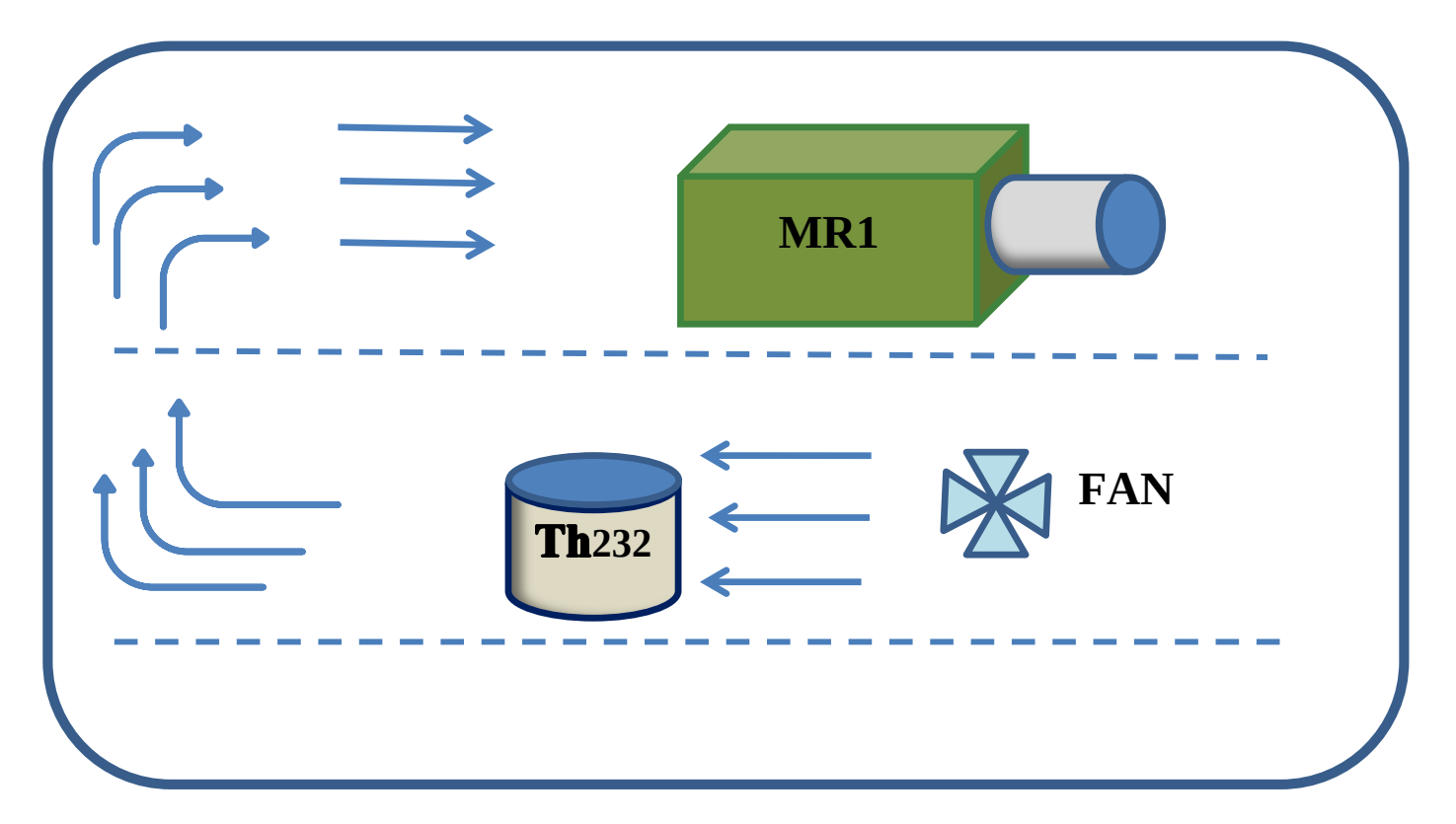


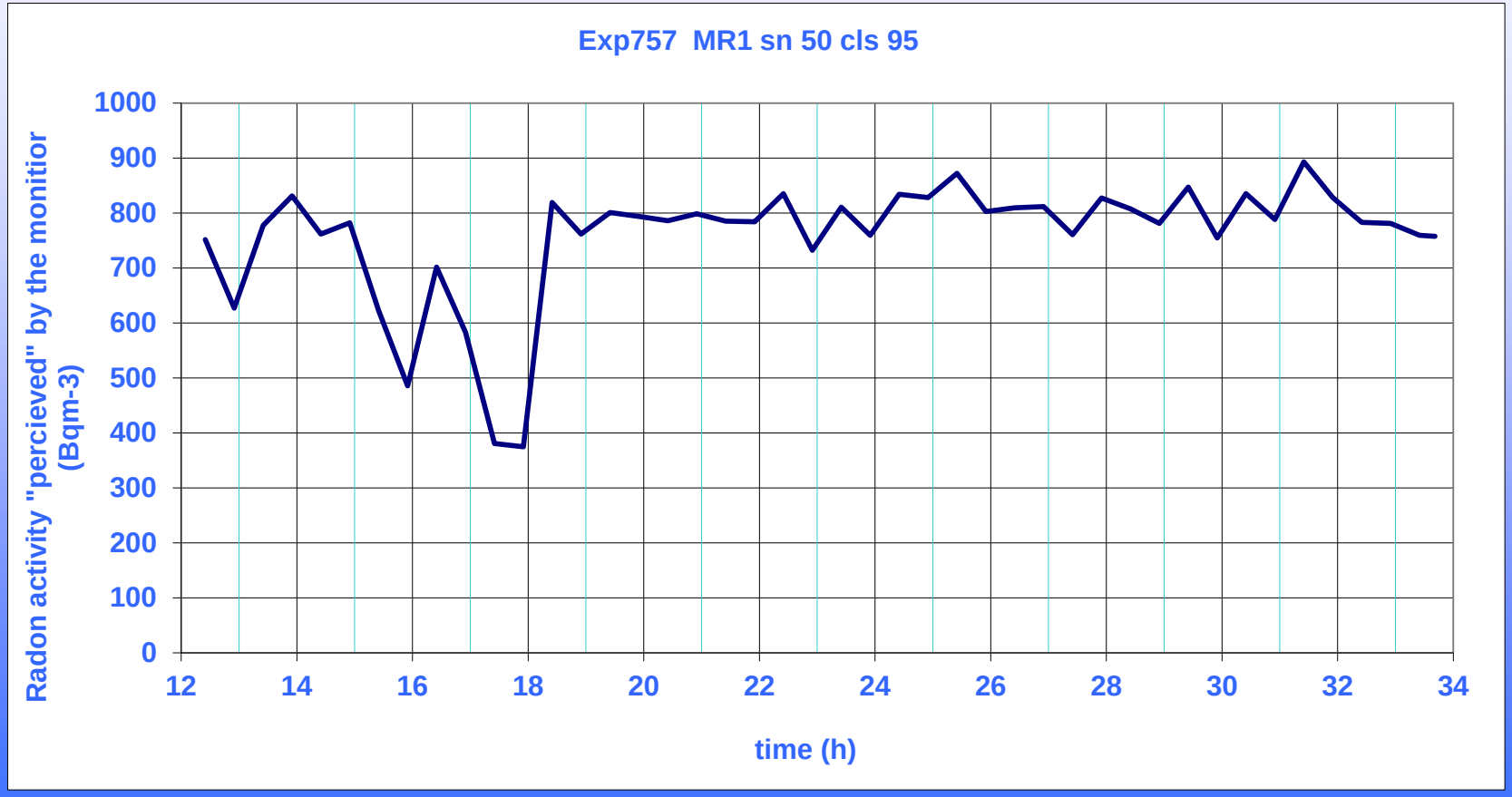
Diagram of experimental setup for the realization of a nearly uniform Thoron concentration in 1 m^3 thoron chamber.

Rn-220 sources are in the lower grid of the chamber and the thoron rich air flow is directed toward the bottom of the chamber.



MR1 measurement show a suitable thoron concentration in the upper grid of the thoron chamber.

A Radon / Thoron chamber with a volume 1 m^3 is now available for test of monitor and dosimeter in mixed Rn-222 and Rn-220 atmosphere.



Offering bred to seagull in Anguillara is a good beginnings for experimental campaign (but they are present only in winter). Thank you for your attention

Francesco Cardellini INMRI-ENEA