Associazione Italiana di Radioprotezione

Scuola Superiore di Radioprotezione “Carlo Polvani”

67th Course of the Radiation Protecion High School "Carlo Polvani"
"The Use of New technologies in Education and Training”
Milan, 24th - 27th June 2025

Environmental monitoring during nuclear emergencies

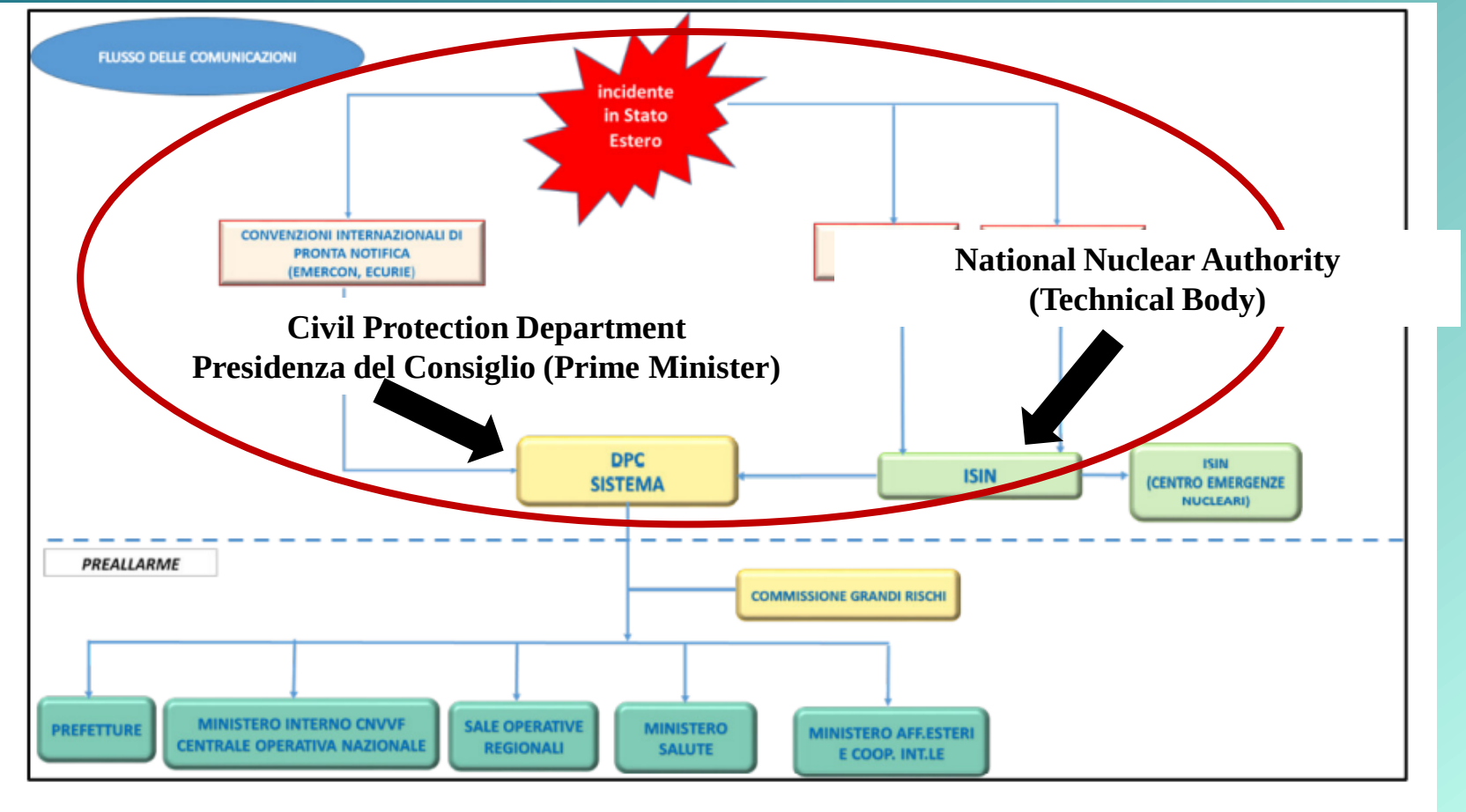
Mauro Magnoni
ARPA Piemonte – Dipartimento Rischi Fisici e Tecnologici
Via Jervis, 30, 10015 Ivrea (TO)

Summary

- My brief talk deals with the planned environmental radioactivity monitoring procedures established in Italy as a response to a Nuclear or Radiological Emergency

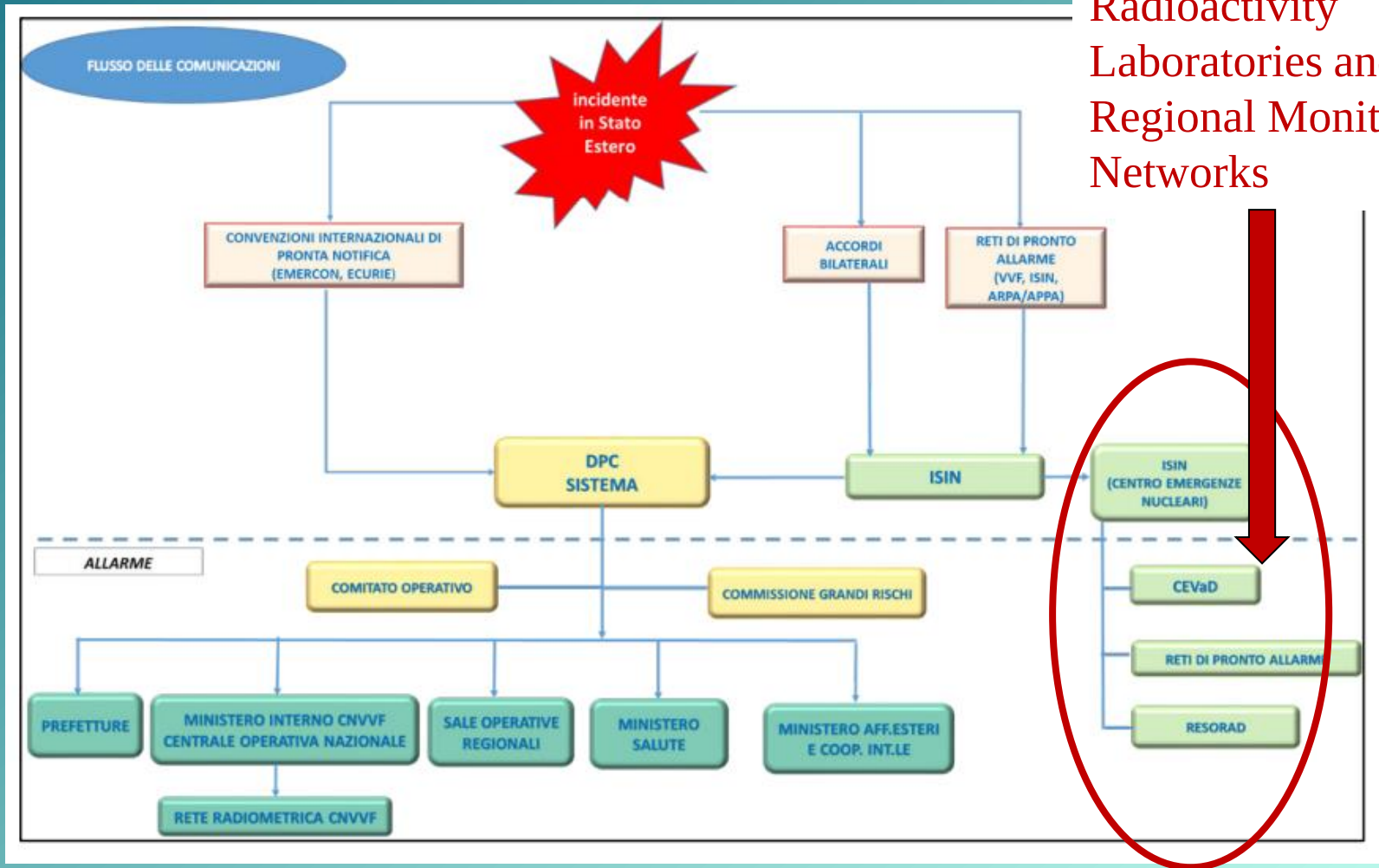
- This matter is regulated by the provisions of the Legislative Decree n. 101/2020 and by the related National Nuclear Emergency Plan, quite recently updated (DPCM 14th May 2022)

Communication flow: alert phase



Communication flow: alarm phase

Activation of the Regional Environmental Radioactivity Laboratories and Regional Monitoring Networks



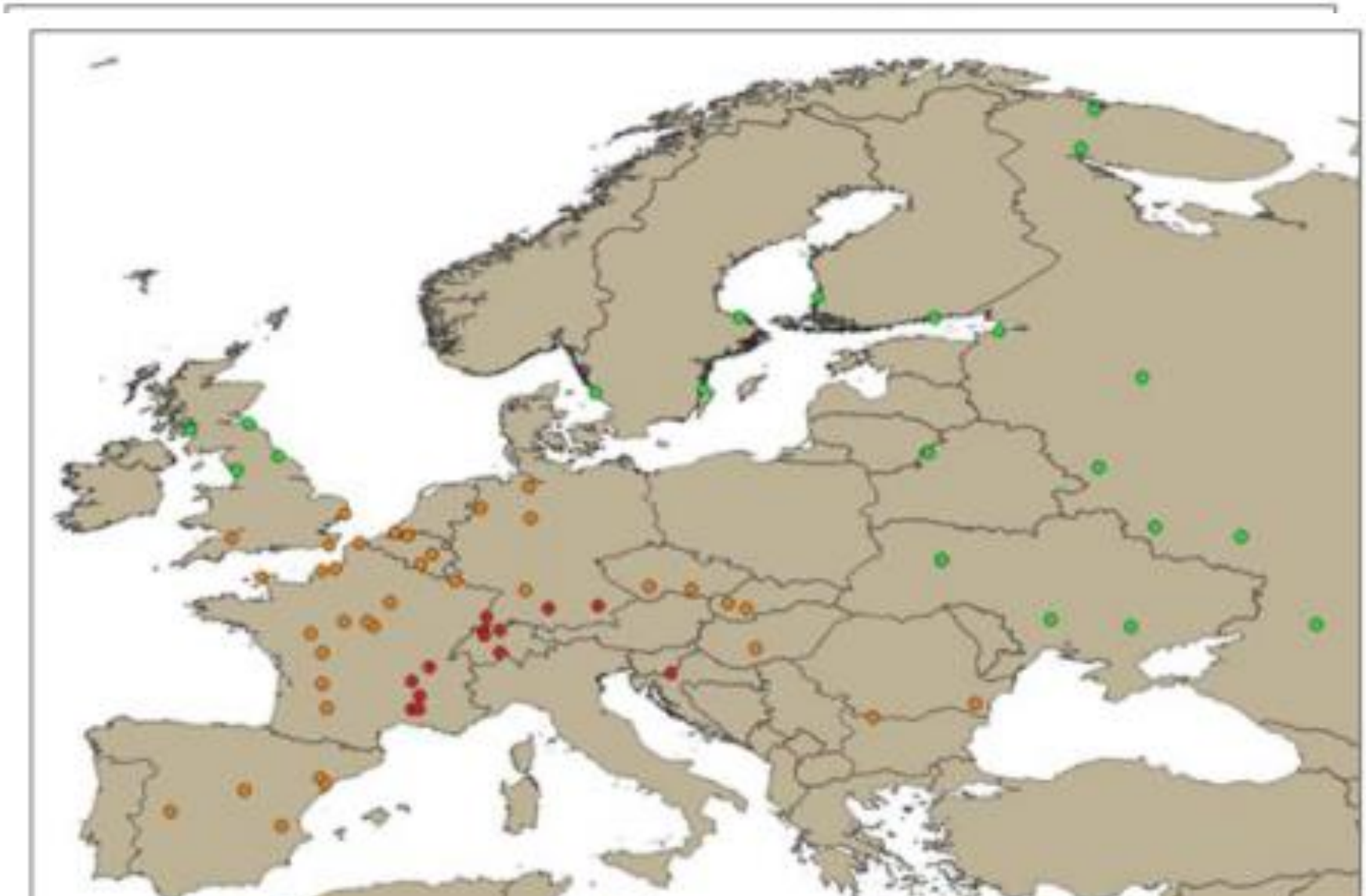
Scenarios

- The Italian National Nuclear and Radiological Emergency Plan is based on a scenario of a major nuclear accident (relaese of $\approx 10^{19}$ Bq of fission products) involving the operating NPPs that are closest to the Italian border:

- St. Alban (France)
- Krško (Slovenia)
- Goesgen (Switzerland)

Operating NPPs and distances to the Italian border

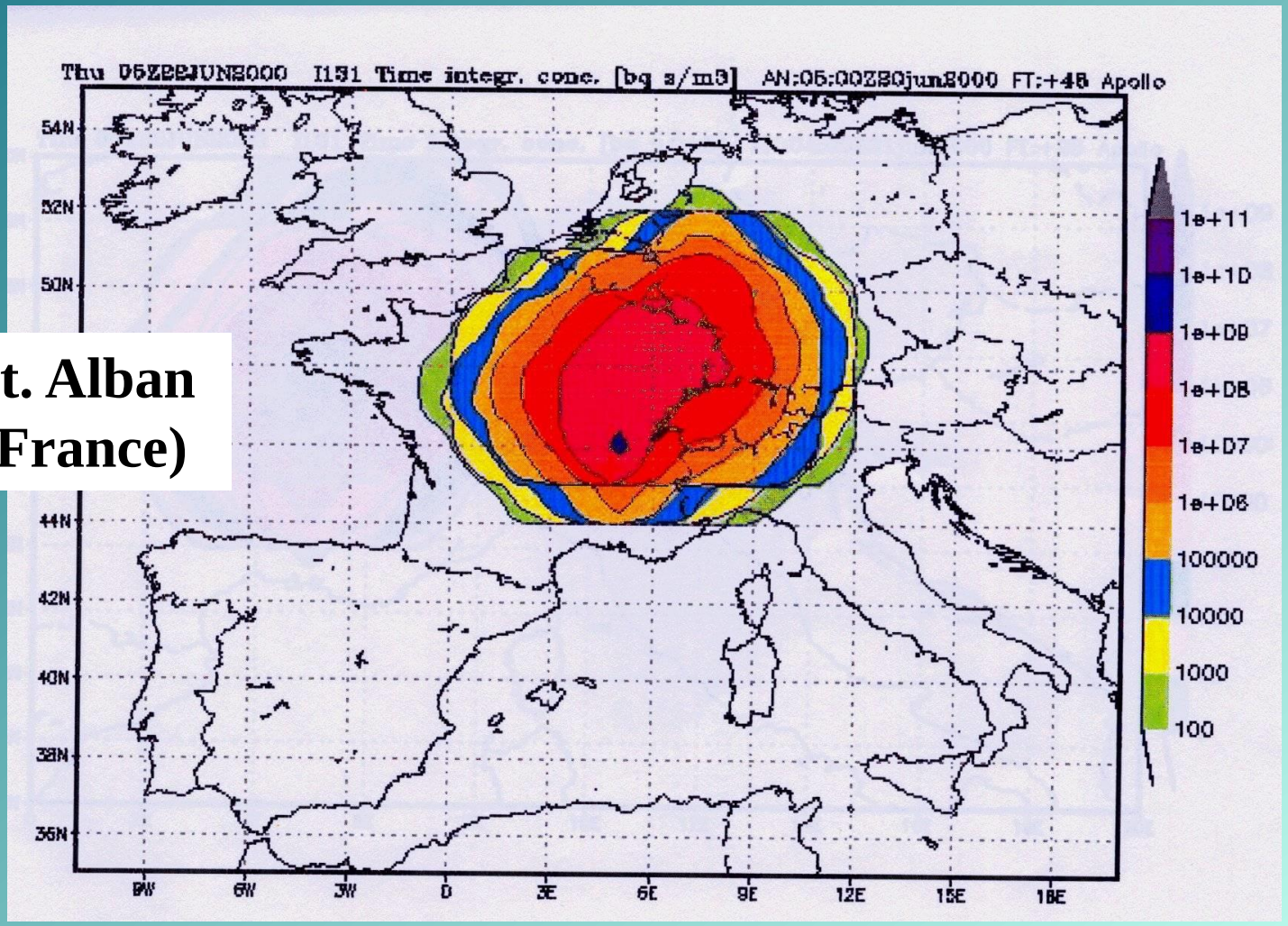
(red < 200 km, orange between 200 -1000 km, green > 1000 km



Environmental consequences: the simulations

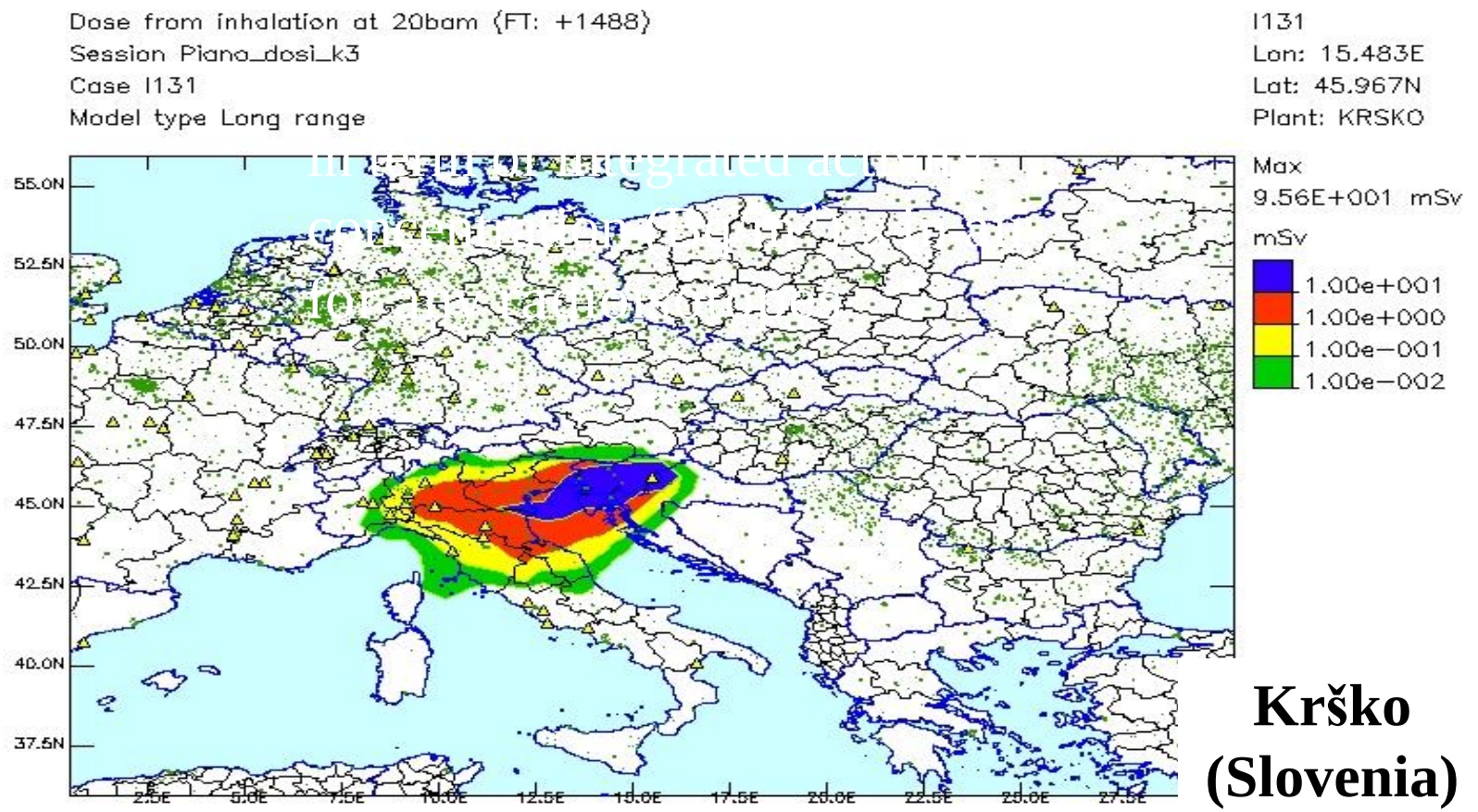
- The simulations, carried out by ISIN, hypotize the release of a huge quantity of fission products (10^{19} Bq) following a major nuclear accident and the dispersion of radioactivity into the environment
- The software performing such simulations is based on a lagrangian model describing the motion of the air particles; the model is feed by real meteo data updated every 6 hours
- Typical simulation runs give forecasts for the next 24 – 48 hours, a suitable time for the radiation protection assessments and for advising purposes to decision makers

The output of the software can be expressed in term of integrated activity concentration $(Bq/m^3)\cdot s$ in air for any radioisotopes



St. Alban (France)

…or in term of equivalent or effective dose (mSv) for a reference radioisotope (typically ^{131}I)



Krško (Slovenia)

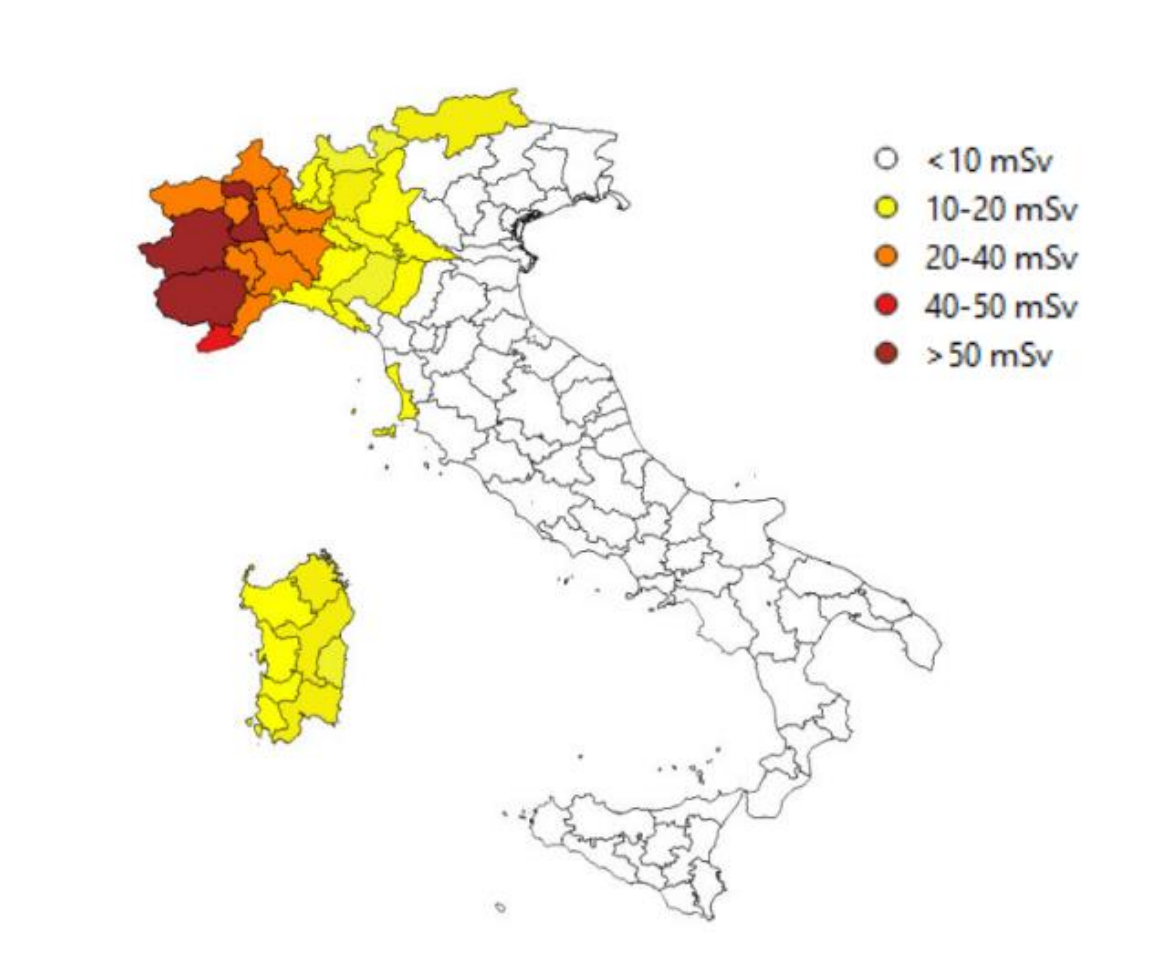
- The software runs spanned more than 1 year of real meteo data. The highest dose value was found for the St. Alban NPP while slighly lower values were found for Krško and Goesgen
- Nevertheless an important point other than the dose must to be taken into account: ***the frequencies of significant impacts on the National territory***:

Krško 17%

St. Alban 3%

Goesgen 3%

St. Alban – thyroid equivalent dose ^{131}I and $^{132}Te/^{132}I$



Effective dose (inhalation), mSv

Population groups	Krško	St. Alban	Goesgen
Adults	1.42	2.01	1.09
Children	3.42	4.60	2.48

Total effective dose, adults

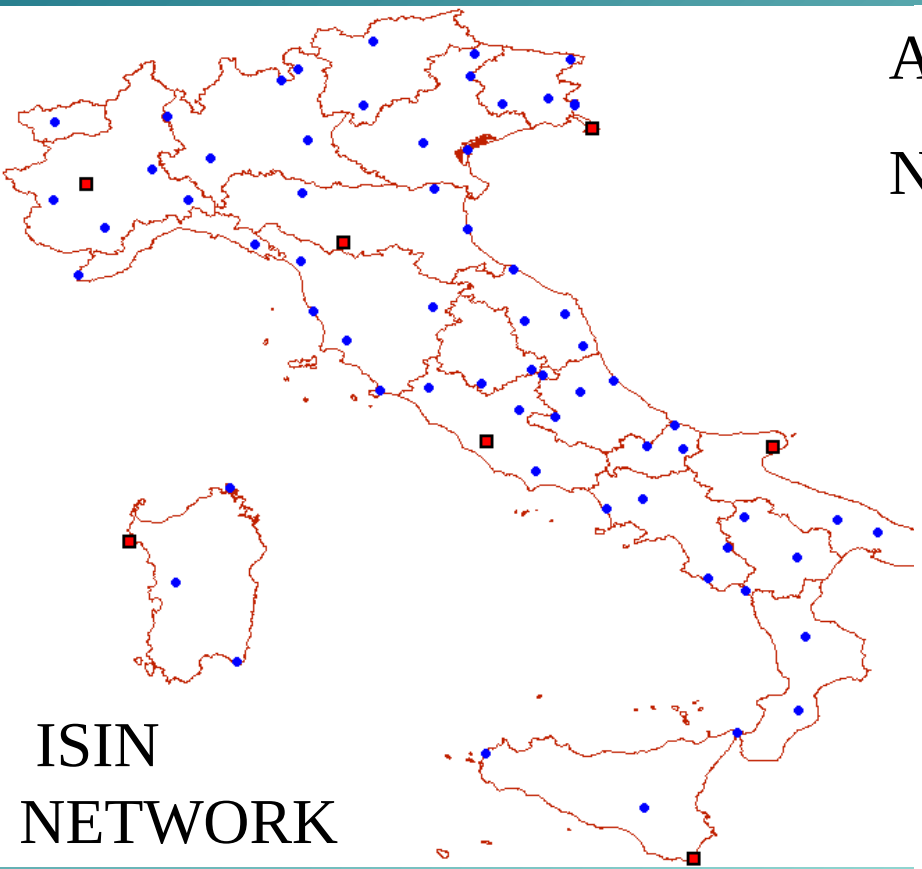
Exposure routes	Effective Dose	Relative contribution	Main Isotopes
Irradiation from the cloud	0.14	2.16 %	$^{132}Te/^{132}I$
Inhalation	2.92	45.06 %	^{131}I
Groundshine (2 days)	3.42	52.78 %	$^{132}Te/^{132}I$
Total Dose	**6.48**		

Total effective dose, children

Exposure routes	Effective Dose	Relative contribution	Main Isotopes
Irradiation from the cloud	0.14	1.72 %	$^{132}Te/^{132}I$
Inhalation	4.58	56.27 %	^{131}I
Groundshine (2 days)	3.42	42.01 %	$^{132}Te/^{132}I$
Total Dose	**8.14**		

Environmental radioactivity measurements in during emergencis

- Real time γ dose rate monitoring networks (National and Regional)



ISIN NETWORK

ARPA PIEMONTE NETWORK

Real time γ radiation networks

Geiger-Mueller Detector

GM + spectrometer (LaBr)

Limits of the γ dose rate networks

- Despite their good sensitivity (≈ **5-10 nSv/h**), they are not able to detect significant atmospheric contamination
- Being usually based on Geiger-Mueller detectors they cannot give information on the radioisotope characterization of the "radioactive cloud"
- Therefore, **in the Early Phase** of an Emergency other more sensitive and informative measurements must be enforced

1. **ATMOSPHERIC PARTICULATE**

2. **WET AND DRY DEPOSITION (FALLOUT)**

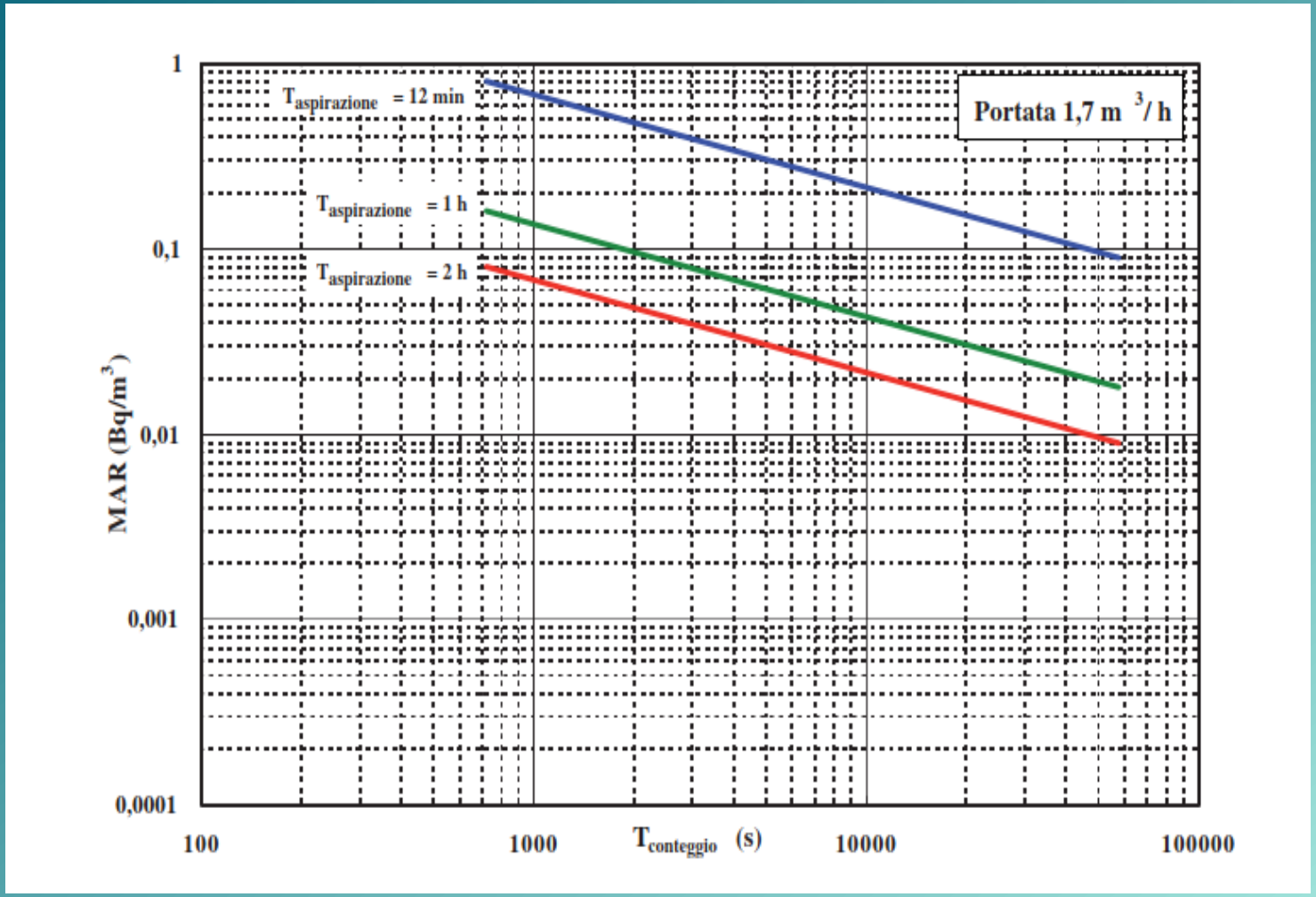
Measurements of fine and ultafine atmospheric particulate

- The samples of atmospheric particulate are collected with pumps onto filters (paper or fiber glass); the total air volume filtered is typically about 50-100 m^3 in a day
- The filters are then counted with HPGe detectors
- The sensitivy of such measurements are generally quite high; it depends on 3 factors:

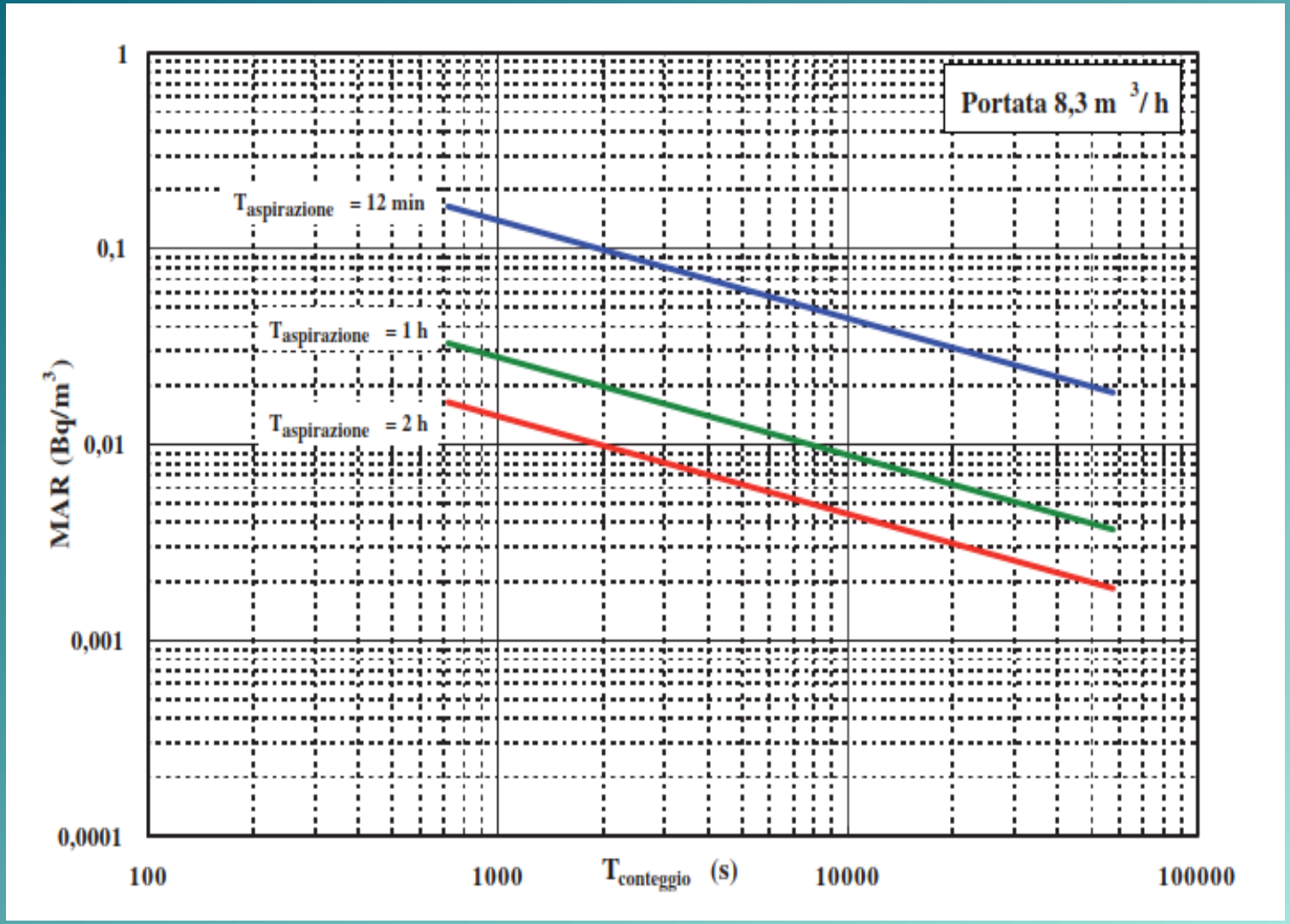
a) The flow rate of the pump

b) The time of sampling

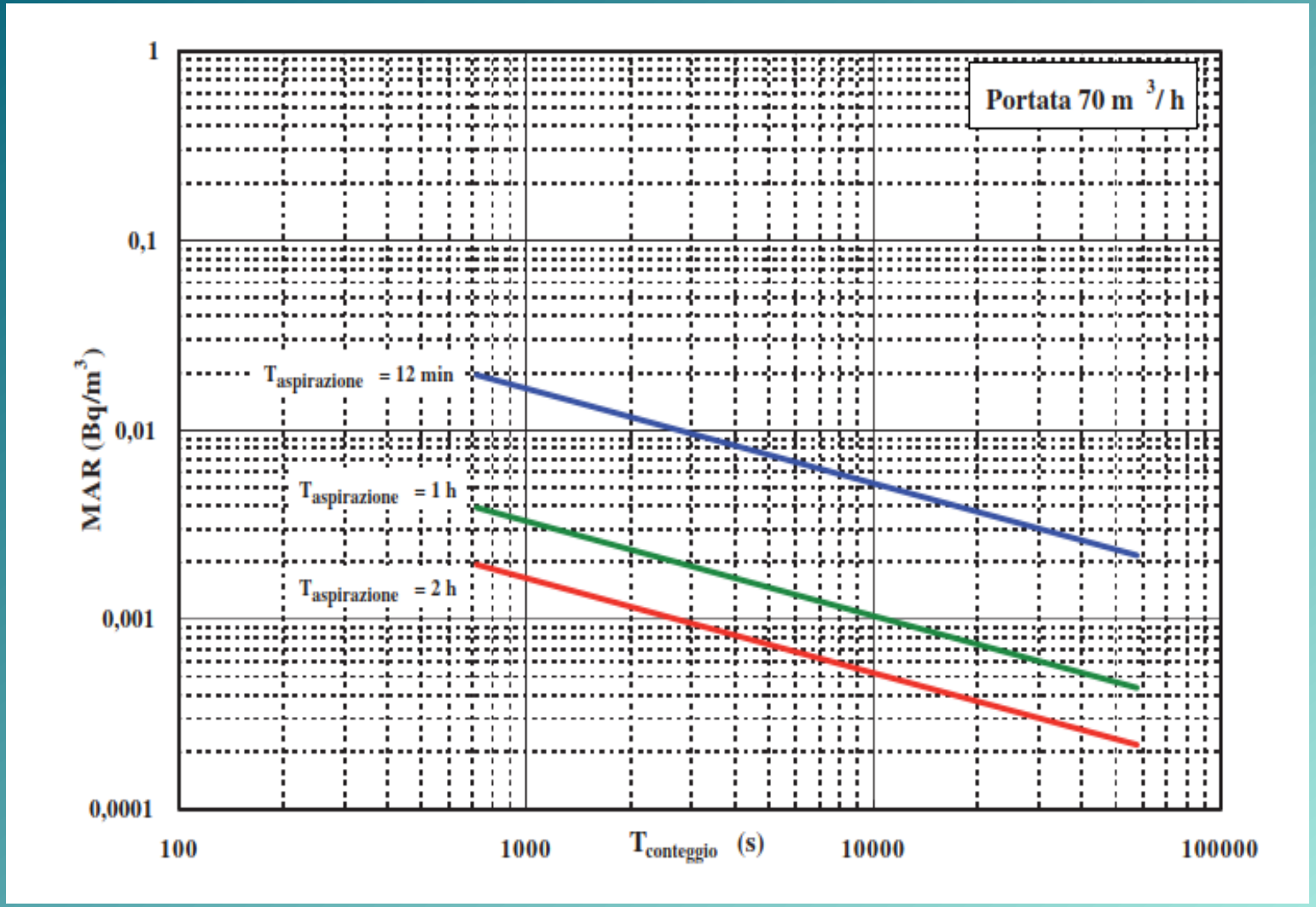
c) The counting time



Flow rate: 1.7 $m^3/h \longrightarrow$ volume sampled in 24 hours $\approx 41\ m^3$



Flow rate: 8.3 $m^3/h \longrightarrow$ volume sampled in 24 hours $\approx 200\ m^3$



Flow rate: 70 $m^3/h \longrightarrow$ volume sampled in 24 hours $\approx$ 1700 m^3

Optimisation of the MDA

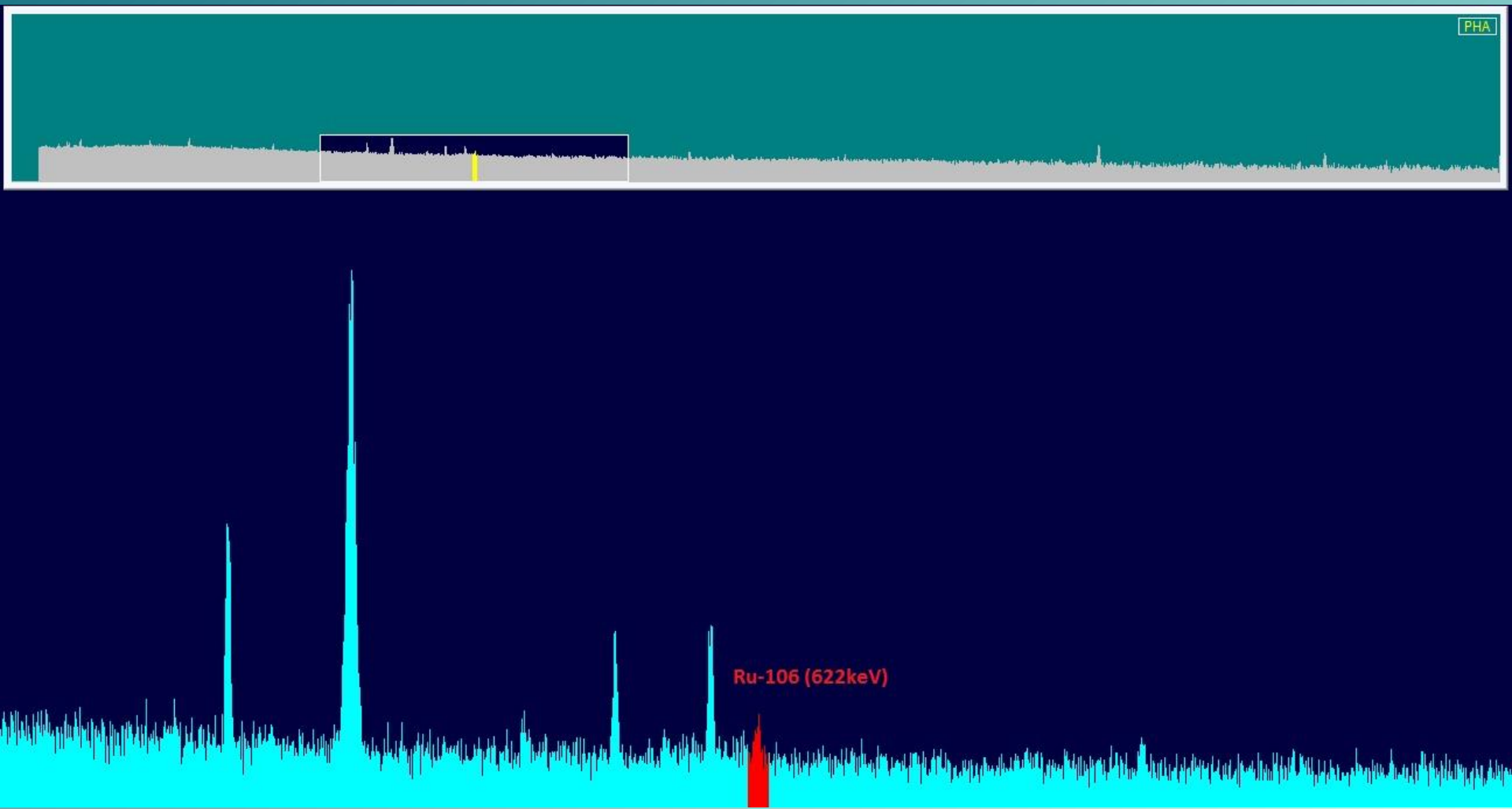
- A pump working at a constant flow rate ϕ (m^3/h) filters a volume of air V during a sampling time: $t_S = V/\phi$
- The time needed to produce a data is given by: $t = t_S + t_C$ where t_C is the counting time t_C
- An approximate expression of MDA for a generic radionuclide was given by Currie (1968):

$$MDA \approx \frac{4.66 \cdot \sigma_B}{\varepsilon \cdot y_\gamma \cdot V \cdot t_c}$$

$$\frac{\partial MDA}{\partial tc} = 0$$

- Assuming a Poisson like behaviour of the background and with a few algebraic calculation we get: $tc = \frac{t}{3}$
- This result gives us the interesting information that the best choice for the MDA optimization is to divide the time interval *t* into 2/3 sampling time *ts*=(2/3)·*t* and 1/3 counting time *tc*=(1/3)·*t*

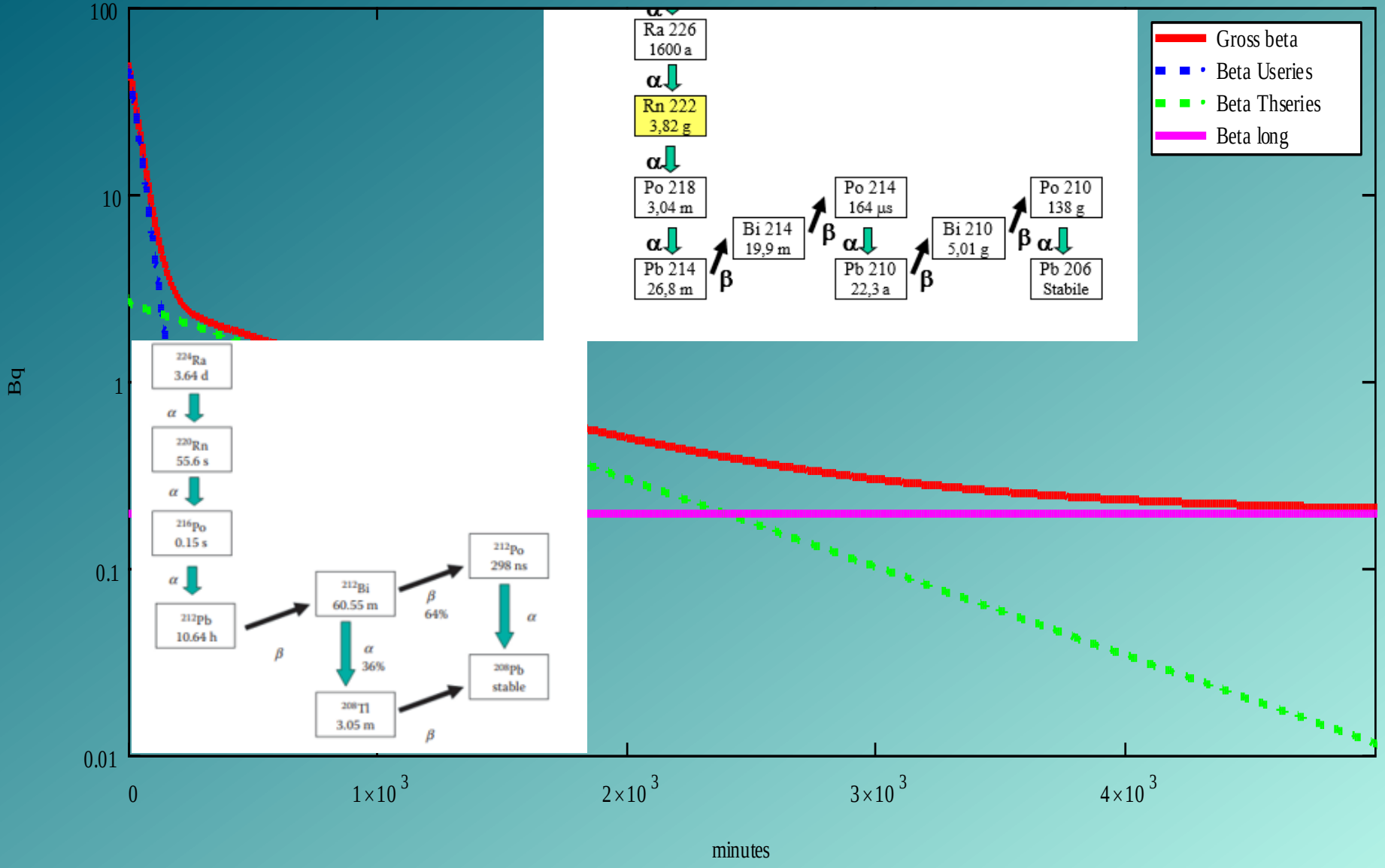
October 2017: trace of ^{106}Ru (Russian origin ≈ mBq/m^3)

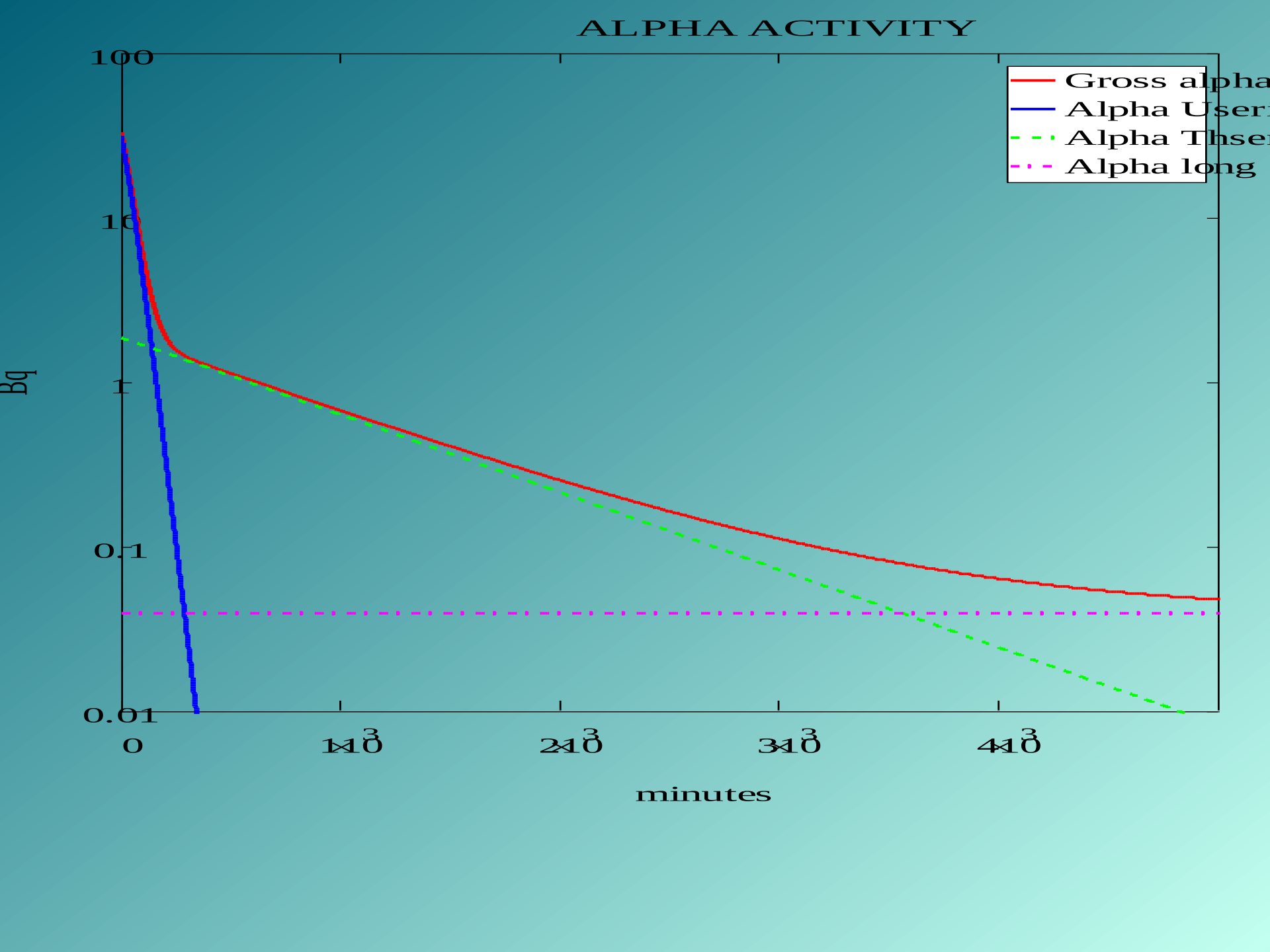


- Gross α and gross β counting can be also useful: they are quite simple measurements (cheaper instrumentation)
- In these cases, however, some care has to be taken in order avoid misleading interpretation of the data
- In fact, if the sampling volume is 100 m^3, and the outdoor concentrations of radon and thoron levels are respectively 5-6 Bq/m^3 and 1 Bq/m^3 (standard conditions in our environment), immediately after the end of sampling, onto the filters significant quantities of natural radioactivity are present :

  about 30 Bq for the α component and 50 Bq for the β
- However, this activities are short lived and decay very rapidly

BETA ACTIVITY




ALPHA ACTIVITY
100
10
1
0.1
0.01
Bq
0
1×10^3
2×10^3
3×10^3
4×10^3
minutes
Gross alpha
Alpha User
Alpha Thse
Alpha long

Wet & Dry Deposition

Sampling of wet and dry deposition on the roof of the laboratory building

Container:
4 m^2 stainless steel tank

Deposition and re-suspention

DEPOSITION

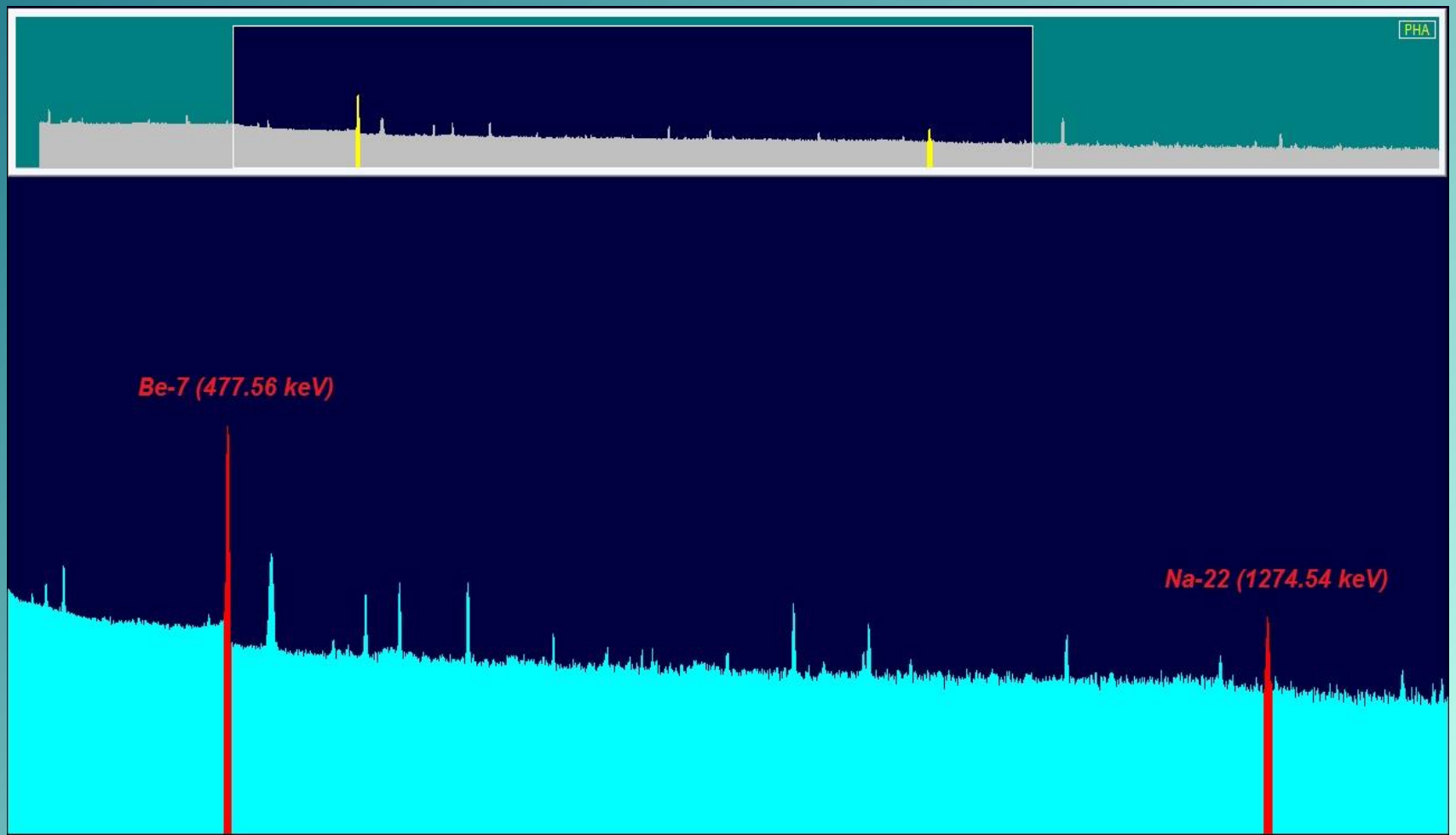
RESUSPENTION

$$C_{aria} = K \cdot I_{suolo}$$

$$K = \frac{D_{suolo}}{v_d \cdot \tau \cdot I_{suolo}}$$

SOIL

^{22}Na, a cosmogenic radionuclides found in a deposition sample: equivalent to air activity concentration of the order of **0.3-0.4 μBq/m^3**



IAEA Exercise Convex-3, 24-25 June 2025
A major nuclear accident at the NPP of Cernavoda, Romania

- The main objectives were:

1) Monitoring of the personal contamination of Italian citizen coming from the affected area;

2) Managing the trade of the foodstuff produced in the contaminated areas;

3) Activation of the monitoring procedures aiming to characterize the radioactive realease, the dosimetric impact to the population (measurements of environmental and food samples, dose estimation, etc,.); test of massive data sending from the labs to ISIN

The scenario: a LLOCA triggered by an earthquake

1) First message from ISIN

Data 24/06/2025 Ora: 09:32 (07:32 UTC) Messaggio n. 01

Questo Ispettorato alle ore 05:15 UTC ha ricevuto dal sistema di pronta notifica internazionale USIE, tramite l'Autorità di sicurezza rumena (CNCAN), la comunicazione di un evento sismico occorso presso la Centrale di Cernavoda in Romania avvenuto alle ore 04:20 UTC.

La notifica riporta un danno di tipo Large LOCA (LLOCA) all'Unità 1 dell'impianto, a seguito di tale rottura la funzione di refrigerazione del reattore potrebbe compromessa. Inoltre risulta che il sistema di emergenza per il raffreddamento del nocciolo, non è disponibile e anche il contenimento risulta degradato.

L'evento è stato classificato dal Paese incidentato come "General Emergency", con conseguente attivazione del Piano Nazionale delle emergenze radiologiche e nucleari allo stato di Allarme.

Al momento non sono segnalati rilasci all'esterno dell'impianto.

The evolution of the accident

2) Second Message from ISIN

Data 24/06/2025 Ora: 11:34 (09:34 UTC) Messaggio n. 02

A seguito dell'evento avvenuto oggi alle 4:20 UTC presso la Centrale di Cernavoda in Romania, già comunicato nel messaggio n. 01, si comunica che il Dipartimento della Protezione Civile ha richiesto l'attivazione del CeVAD che è ora operativo.

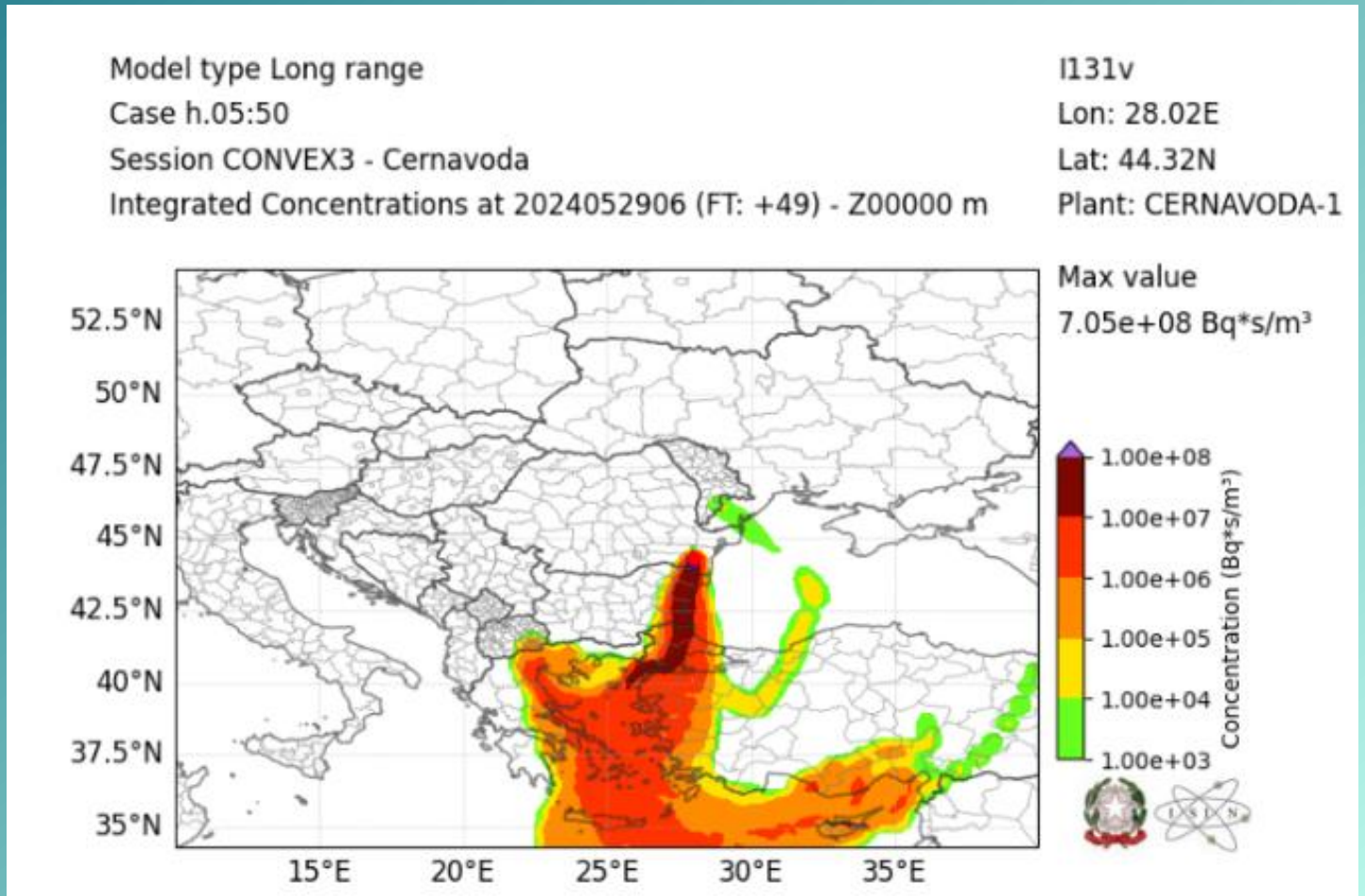
Si conferma che al momento non sono segnalati rilasci all'esterno dell'impianto.

Per quanto riguarda l'intensificazione delle misure di particolato atmosferico si conferma di procedere ad un nuovo campionamento e successiva misura da trasmettere nella giornata odierna come già richiesto e secondo le indicazioni operative del messaggio n. 01.

Si richiede, inoltre, di procedere al campionamento e all'analisi di spettrometria gamma ad alta risoluzione della **deposizione umida e secca** al suolo utilizzando i punti fissi di prelievo del monitoraggio di *routine*.

The evolution of the accident

3) Third message from ISIN: the beginning of release of radioactivity into the environment



The evolution of the accident

3) Fourth message from ISIN: first information about the source term

In riferimento all'evento avvenuto oggi alle 4:20 UTC presso la Centrale di Cernavoda in Romania, in aggiornamento a quanto già comunicato nei messaggi n. 01, 02, 03 si rende noto che è stato comunicato dall'autorità di sicurezza rumena, il termine di sorgente che risulta dell'ordine del centinaio dei TBq per gli isotopi dello iodio.

Dalle simulazioni della dispersione atmosferica effettua $\approx 10^{14}$ Bq lo di questo Ispettorato, al momento, non si ha un interessamento del territorio nazionale.

In accordo con il CEVaD e dall'analisi dei dati delle misure finora effettuate e caricati sul SINRAD, si conferma di continuare le attività di intensificazione del monitoraggio per le matrici già indicate nei messaggi n.01 e 02.

Some final consideration

- The exercise lasted two day, it stopped on Wednesday evening, 25th June
- It was very usuful, especially because we all were forced to work quickly, testing the standard technical procedures under a constant pressure from the «center»
- We will learn a lot and many specific interesting indications will certainly come out during the debriefing