Radiological Emergency Program of Valencia Region

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Outline

Introduction

Radiological Emergencies

According to the World Health Organization ([WHO], 2022), radiological emergencies are non-routine situations or events that require a prompt action to mitigate a radio-nuclear hazard or its adverse consequences for human life, health, property or the environment.
Radiological emergencies may result from:

- Misuse of radioactive sources during industrial, medical or research applications.
- Accidental exposure to uncontrolled (abandoned, lost or stolen) radiation sources.
- Accidents during transport of radioactive materials.
- A fire radioactive source or a release of chemical substances.
- Natural disasters in radiological installations.
- Military conflicts.
- Malicious acts involving radiation sources.

Radiological Protection

An action protocol is necessary in case of radiological accident to protect the people and the environment from possible harmful effects of radiation.

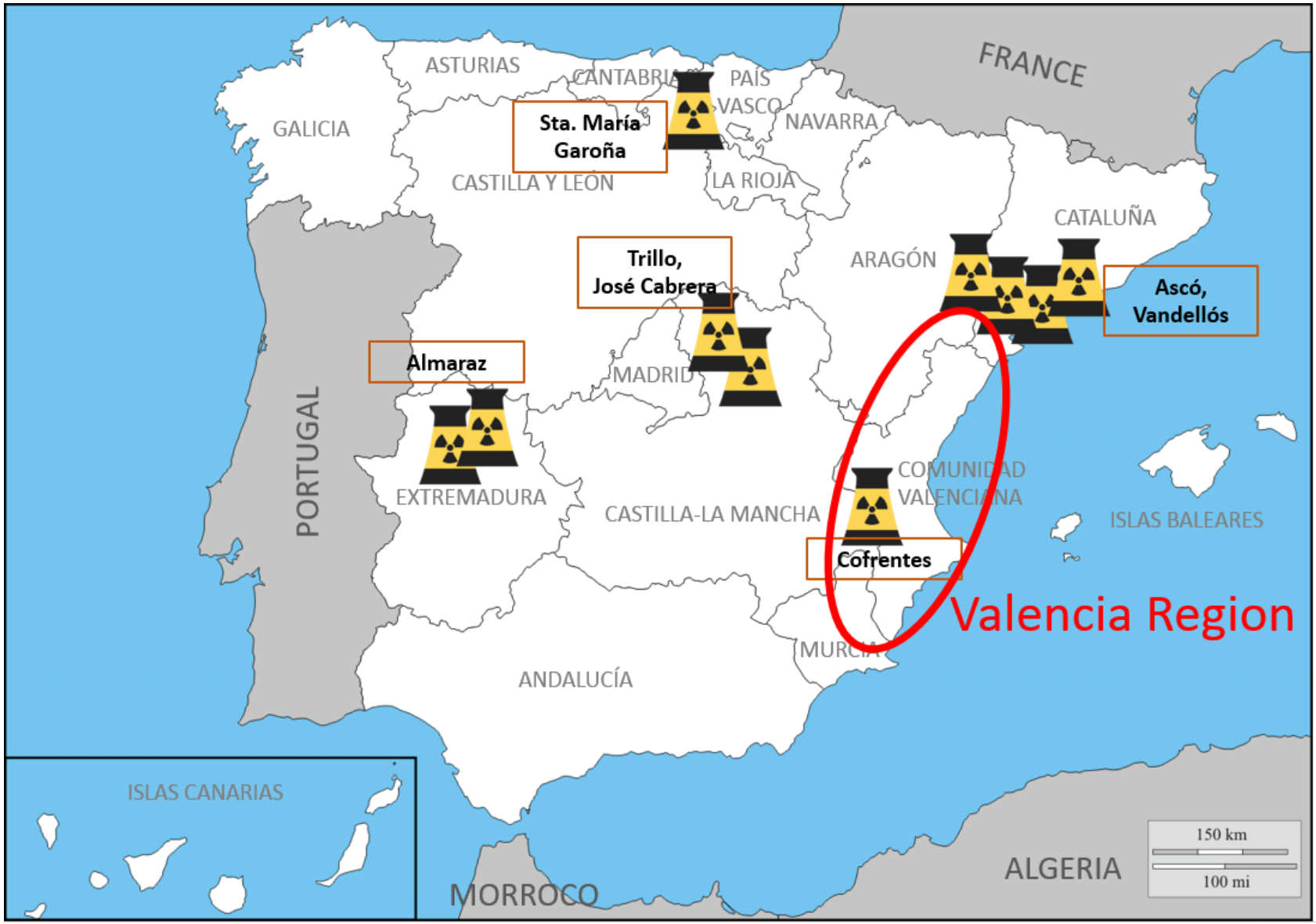
Objectives of Radiological Emergency Program of Valencia Region

The Laboratory of Environmental Radioactivity of the University of Valencia (LARAM) has an agreement with the Generalitat Valenciana (Regional Government) since 2016.

Agreement objectives:

- Design and construction of an in situ measurement and analysis gamma detection system.
- Develop an action protocol in case of radiological emergency.
- Characterize the environmental radioactive background of the Valencia region to assess the recovery level in case of radiological accident.
- Run simulations with JRODOS to assess the risks to the population in the first hours after the radiological accident.

Radiological Installations in Valencia Region



Map of Spain and València region.

Radiological Installations in Valencia Region

Map of the radiological installations in Valencia region.

Radiological Industries

1. SGS Tecnos S.A.
2. Kartogrup España S.L.
3. Clarina S.A.
4. Compañía Valenciana Aluminio Baux
6. Barrachina Inversiones y Servicios
7. UBE Chemical Europe S.A.
8. BP Oil España S.A.U.
12. Acelormital Sagunto S.L.
13. Thyssenkrupp Galmed S.A
14. Infia Plastic S.L.
15. Font Salem S.L.
16. Applus Norcontrol S.L.U.
17. SGS Tecnos S.A.
19. Plásticos Vidal S.L.
20. Intercontrol Levante
21. Roquette Laisa España S.A.
25. Red Pet Iberia
26. Curium Pharma
27. Flejes Industriales
34. Gestión Hospidos S.L..

Nuclear Medicine

11. Hospital Provincial de Castellón
23. Hospital Universitario Dr. Peset
24. Hospital Politécnico La Fe
28. Hospital IMED de Levante
29. Hospital General de Alicante
32. Hospital Quirón de Torrevieja
33. Elche-Crevillent Salud S.A.
35. Hospital Universitario San Juan de Alicante

Investigation

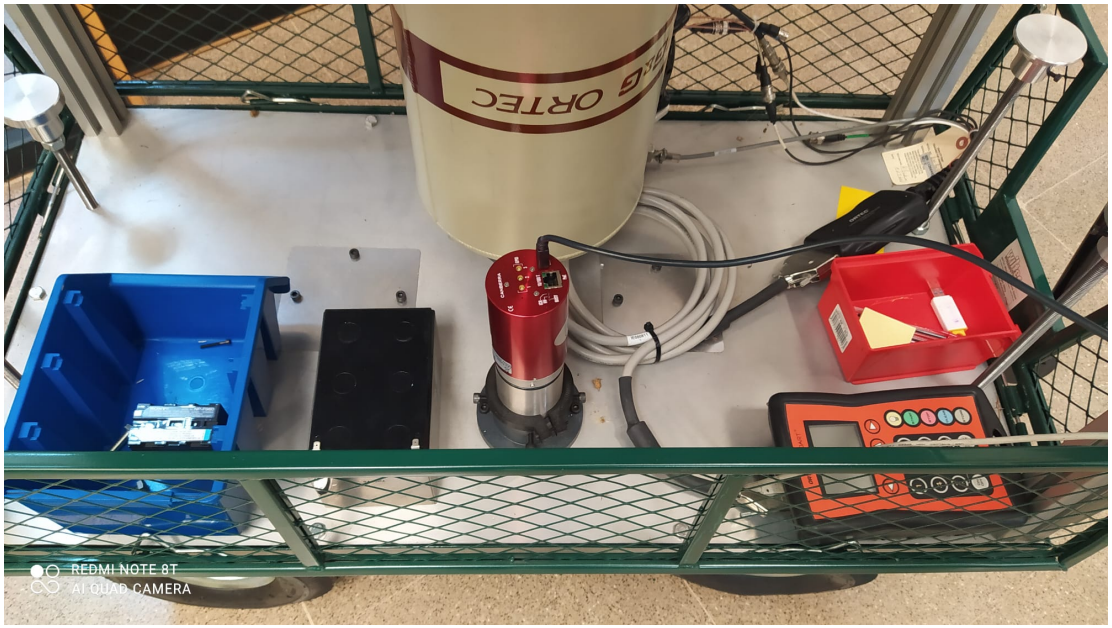
5. Instituto Acuicultura Torre la Sal
9. Asociación Investigaciones Cerámicas
10. Universidad Jaume I
22. Parque Científico (UV)
30. Instituto Alicantino de Oncología
31. Universidad Miguel Hernández

The LARAM In-situ Gamma Detection System

- Design and Construction of the LARAM In-situ Gamma Detection System

Design and Construction

Two gamma portable detectors (NaI and HPGe) calibrated in energy and characterized in efficiency, energy resolution and dead time in the laboratory.

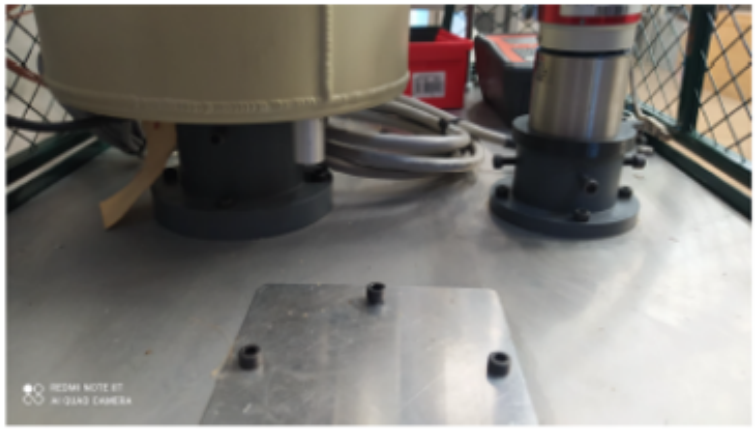


Detectors included in the in situ measurement and analysis gamma system.

- The HPGe has better resolution power than the NaI detector.
- The NaI detector has less dead time than the HPGe detector.
- The HPGe detector has to be cooled using liquid nitrogen.

Design and Construction

(a) Complete system.



(b) Grip elements for gamma detectors.

(c) Stability system.

The LARAM In-situ Gamma Detection System.

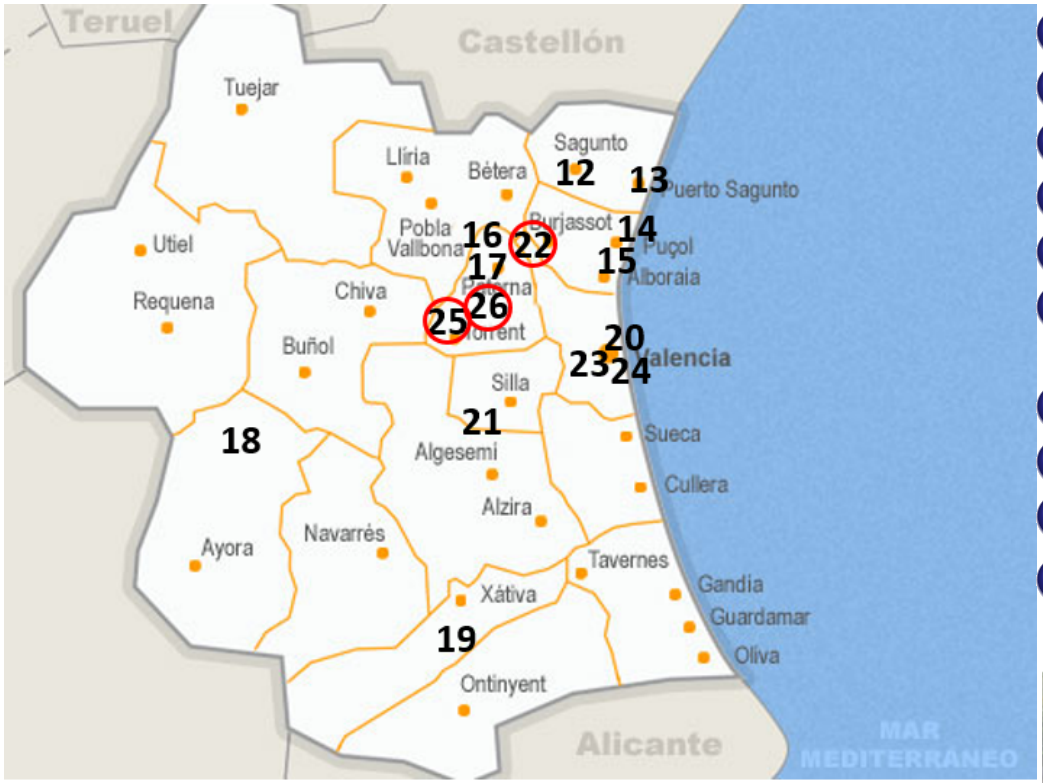
Field Measurements. Province of Castellón

A few radiological areas have been recently profiled using the in situ measurement and analysis gamma detector system.

Radiological installations in Castellon.

1. SGS Tecnos S.A (Almassora)
2. Kartogrup España S.L (Burriana)
3. Clarina S.A.(Vila-real)
4. Compañia Valenciana de Aluminio Baux S.L.(Segorbe)
5. Instituto de Acuicultura Torre la Sal (Cabanes)
6. Barrachina Inversiones i Servicios S.L. (Vinarós)
7. UBE Chenical Europe S.A.(Castelló de la Plana)
8. BP Oil España S.A.U (Castelló de la Plana)
9. Asociación Investigación Industrias Cerámicas (Castelló de la Plana)
10. Universidad Jaume I (Castelló de la Plana)
11. Consorcio Hospital Provincial de Castellón (Castelló de la Plana)

Field Measurements. Province of Valencia



Radiological installations in Valencia.

12. Arcelormittal Sagunto S.L. (Sagunto)
13. Thyssenkkrupp Glamed S.A. (Puerto de Sagunto)
14. Infia Plastic S.L. (Puzol)
15. Font Salem S.L. (El Puig)
16. Applus Norcontrol S.L.U. (Mas Camarena)
17. SGS Tecnos S.A (Paterna)
18. Central Nuclear de Cofrentes
19. Plásticos Videl S.L. (Ollería)
20. Intercontrol Levante (Valencia)
21. Roquette Laisa España S.A. (Benifayó)
22. Parque Científico. Universidad de Valencia,Campus Burjass
23. Hospital Universitario Dr.Peset (Valencia)
24. Hospital Universitari i Politécnic La Fe (Valencia)
25. Red Pet Iberia (Aldaia)
26. Curium Pharma (Aldaia)

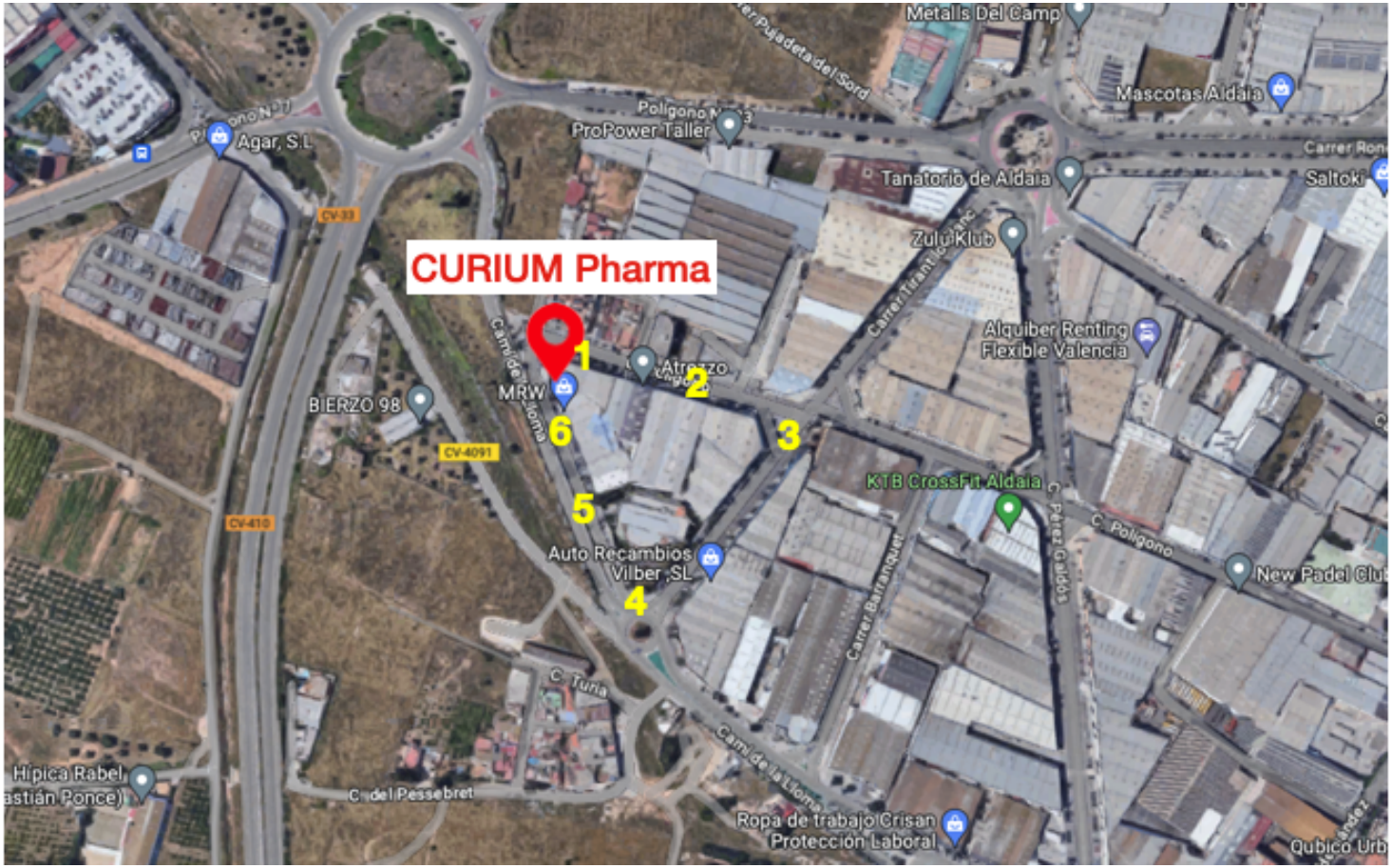
Field Measurements. Province of Alicante

Radiological installations in Alicante.

27 Flejes Industriales (Ibi)
28 Hospital IMED de Levante (Benidorm)
29 Hospital General de Alicante (Alicante)
30 Instituto Alicantino de Oncología (Alicante)
31 Universidad Miguel Hernández (Elche)
32 Hospital Quirón (Torrevieja)
33 Elche-Crevillent Salud
34 Gestión Hóspidos S.L.(Elche)
35 Hospital Universitario San Juan de Alicante (Alicante)

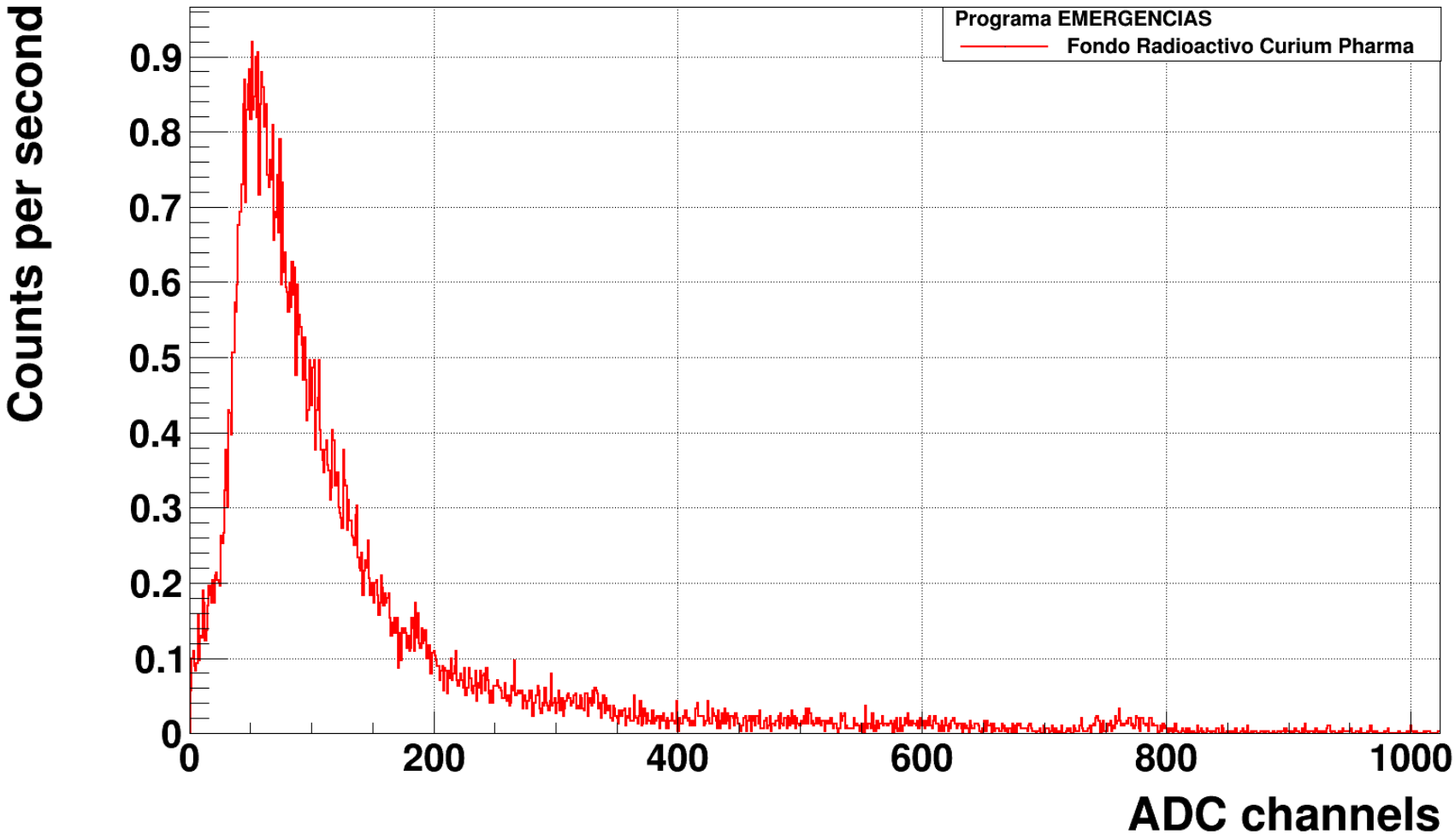
CURIUM Pharma (Aldaia, Valencia)

For each radioactive facility a set of measurements was carried out in it's neighborhood.



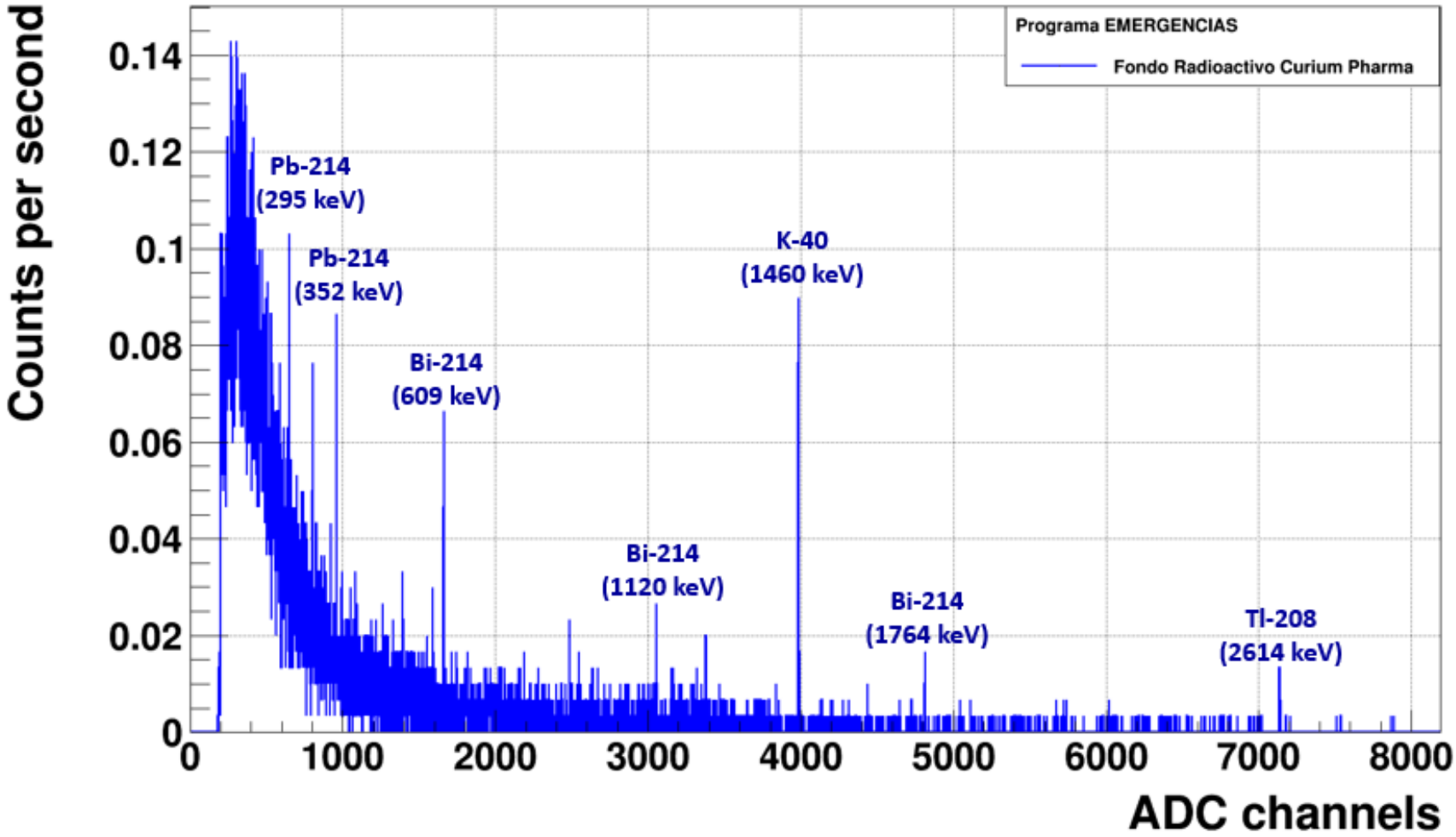
Location of the measurement points.

CURIUM Pharma (Aldaia, Valencia)



Energy spectrum measured at point 1 with the NaI detector.

CURIUM Pharma (Aldaia, Valencia)



Energy spectrum measured at point 1 with the HPGe detector.

Background Maps

Mapping areas.

For the radiological mapping, the average of all the measured points was considered.

Zone	NaI (C/s)	HPGe (C/s)
Ins. Acuicultura	79.8 ± 1.4	50.6 ± 1.1
Parc Científic (UV)	79.8 ± 1.4	50.6 ± 1.1
Red Pet Iberia	76.1 ± 1.2	48.6 ± 1.0
Curium Pharma	77.4 ± 1.2	47.1 ± 1.0
U.M.H	58.4 ± 1.2	39.0 ± 1.0

Average gamma activity screened in different radiological installation.

JRODOS Simulations

JRODOS Program is used to simulate possible accidents in the radiactive installations in Valencia Region. This allows us:

- Assess the risks to the population during the first hours after the radiological accident.
- To know the extencion of the contaminated area and the environmental consequences.
- To facilitate decision making for the Regional Governement.

A case study: Simulation Conditions

Location

CURIUM PHARMA, Aldaia, Valencia, Spain.
Latitude=39.46952 , Longitude=−0.47375.

CURIUM PHARMA is a company which manufactures and distributes radiopharmaceuticals used in Nuclear Medicine.

Source Term

Simulation Type: Radiological accident with fire
Radiological isotopes and activity:

- $^{99}Mo/^{99m}Tc$ ($3.7x10^5$ Bq)
- $^{137}Cs,^{90}Sr$ ($2x10^7$ Bq)
- $^{131}I,^{18}F,^{90}Y,^{89}Sr,^{51}Cr,^{59}Fe,^{58}Co,^{153}Sm$ ($1.11x10^{10}$ Bq)

A case study: Weather Conditions

Weather conditions

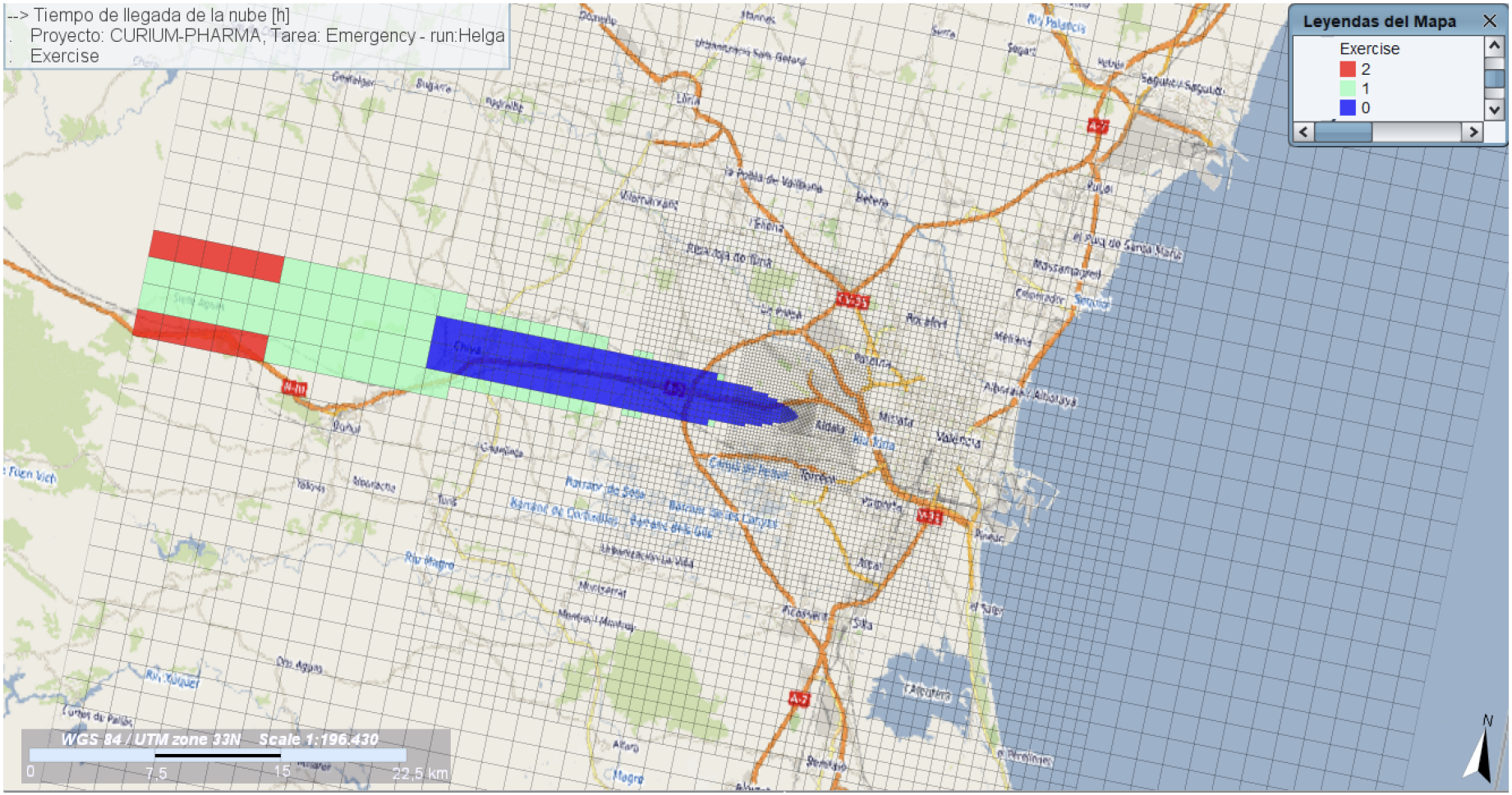
Common weather in autumn.

	Interval 1	Interval 2	Interval 3
Duration	6 hours	7 hours	11 hours
Wind direction	90°	130°	0°
Wind speed	$15 Km/h$	$10 Km/h$	$6 Km/h$
Dif. Category	D	A	F

Wind characteristics at each weather intervals.

A case study: Results

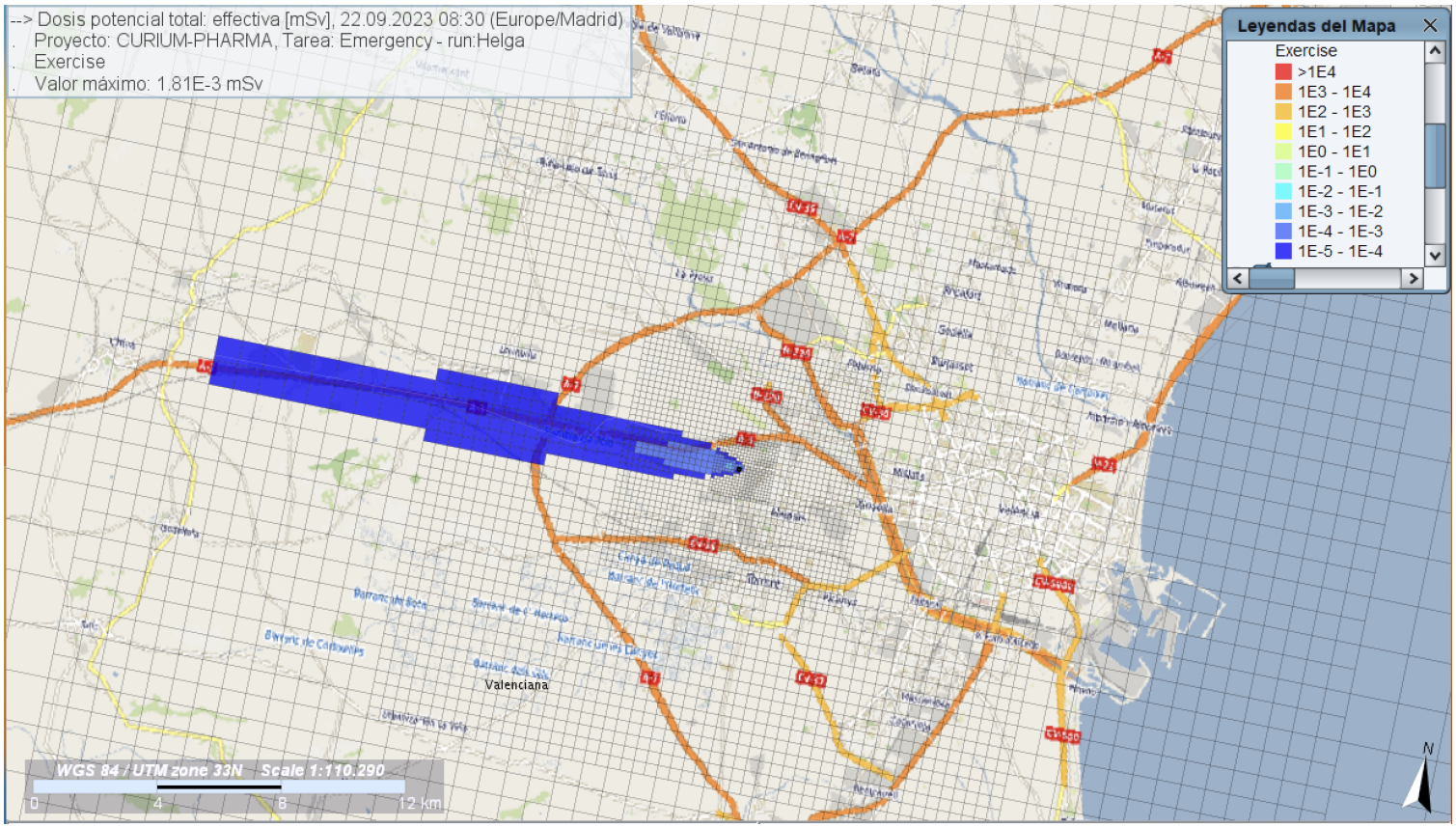
- After 2 hours the radioactive cloud would range 30 km (red grid).
- Changes in wind direction have important effects.



Cloud arrival time map (in hours).

A case study: Results

- Areas with higher dose are those close to the radiactive installation and where the wind affects more time.
- Predicted maximum value of total efective gamma dose $= 1.81x10^{-3} mSv$



Total effective gamma dose map (in mSv).

Summary and Future prospects

Summary

- An agreement has been established between LARAM and the Valencia Government to develop a radiological emergency program.
- An in situ measurement and analysis gamma system has been designed and built.
- About 14% of Valencia region installations have been screened to the date.

Future prospects

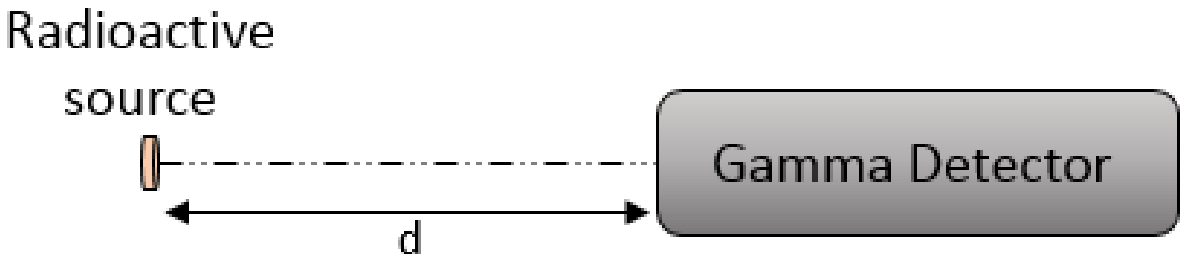
- Obtain a background map of all radiological installations in the Valencia region.
- Include this radiological mapping in a date base.
- Establish measurement protocols and case simulation studies to assess the local Authorities in case of radiological emergency.

- Acknowledgment of:

BACKUP

Laboratory Measurements

The gamma detectors of NaI and HPGe are calibrated in energy and characterized in efficiency, energy resolution and dead time.

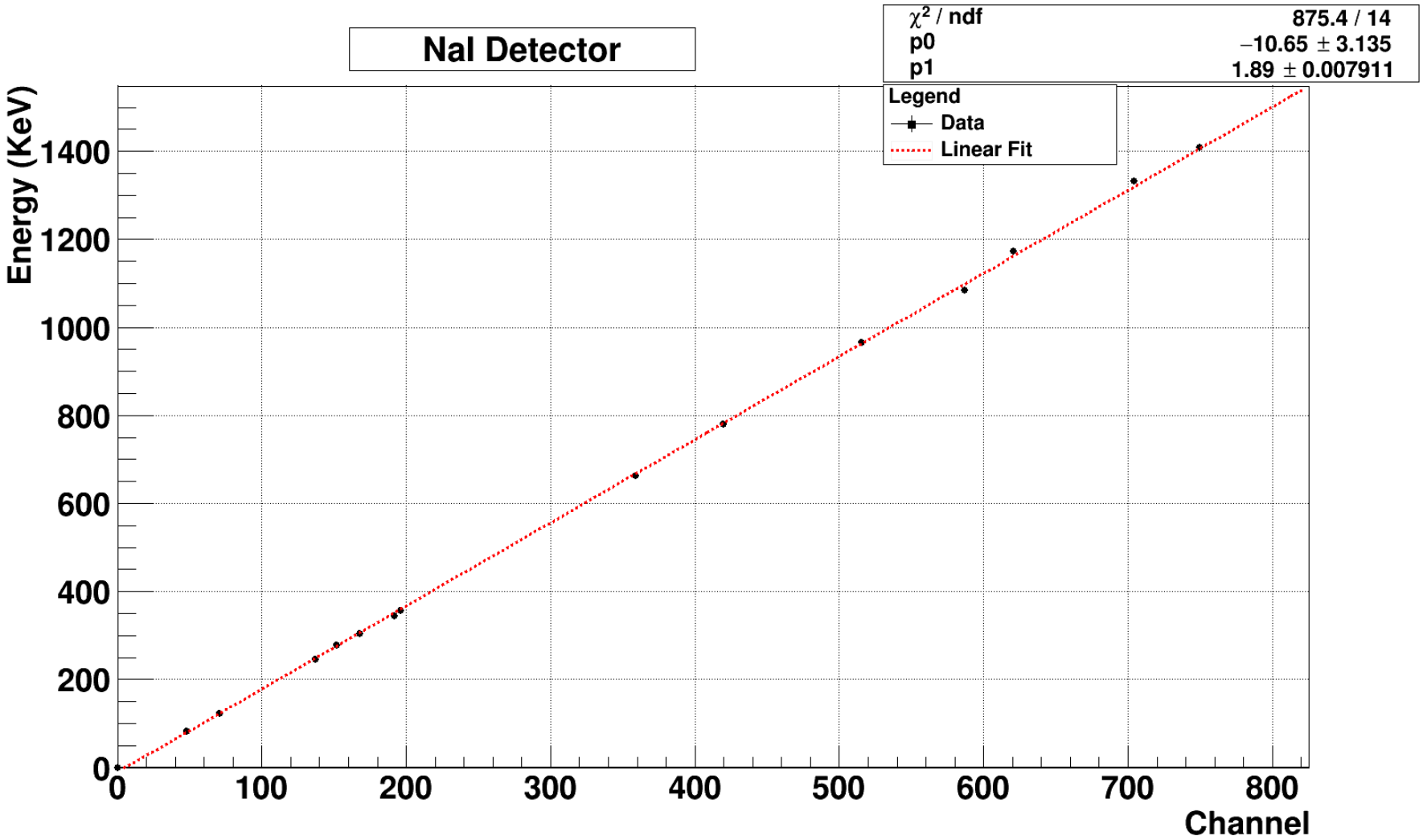


Experimental device used in the laboratory to calibrate and characterize the two gamma detectors.

NaI	HPGe
^{60}Co	^{60}Co
^{133}Ba	^{133}Ba
^{137}Cs	^{137}Cs
^{152}Eu	^{152}Eu
^{243}Am	^{54}Mn
-	^{22}Na

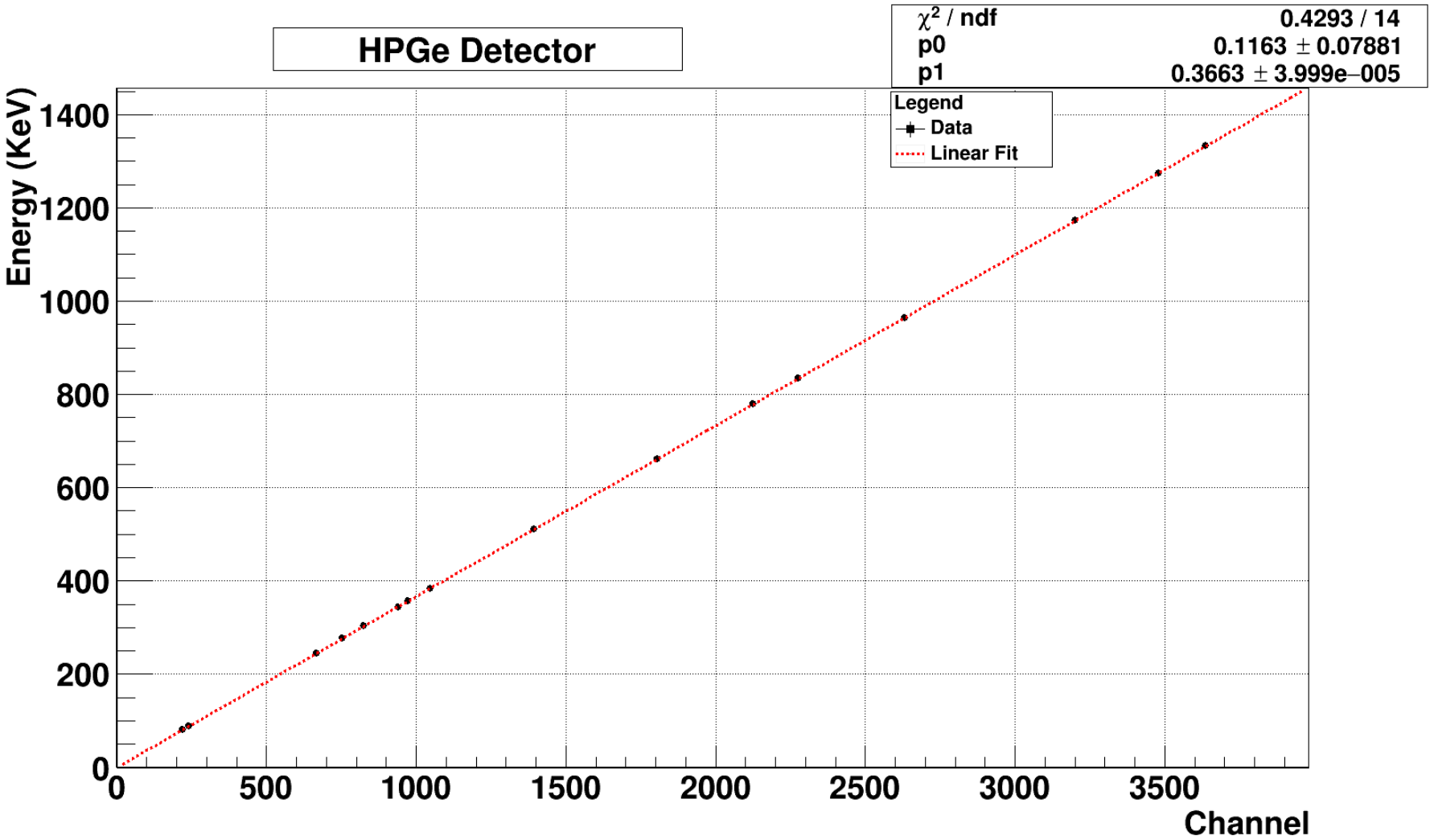
Radioactive sources used to calibrate and characterized the gamma detectors.

Energy Calibration



Linear fit for energy calibration of the NaI detector.

Energy Calibration



Linear fit for energy calibration of the HPGe detector.

Detection Efficiency

Source	Energy (KeV)	NaI (%)	HPGe (%)
^{109}Cd	88.03	66.1±0.3	17.87±0.17
^{22}Na	511	16.338±0.016	6.621±0.009
^{137}Cs	661.66	17.91±0.02	8.208±0.014
^{54}Mg	834.85	17.52±0.05	8.65±0.03
^{60}Co	1173.23	6.898±0.014	3.181±0.009
^{22}Na	1274.54	5.623±0.013	2.450±0.008
^{60}Co	1332.49	5.635±0.013	2.790±0.009

Detection efficiency of the NaI and HPGe detectors.

Energy Resolution

Source	Energy (KeV)	NaI ($\frac{FWHM}{E}(\%)$)	HPGe ($\frac{FWHM}{E}(\%)$)
^{109}Cd	88.08	8±2	0.83±0.04
^{22}Na	511	7.6±0.4	0.43±0.07
^{137}Cs	661.66	6.2±0.2	0.17±0.06
^{54}Mg	834.85	5.6±0.2	0.18±0.04
^{60}Co	1173.23	5.22±0.15	0.12±0.03
^{22}Na	1274.54	4.47±0.14	0.14±0.03
^{60}Co	1332.49	4.31±0.13	0.11±0.03

FWHM (Full Width Half Maximum) normalized to photopeak energy for the NaI and HPGe detectors as a function of energy.

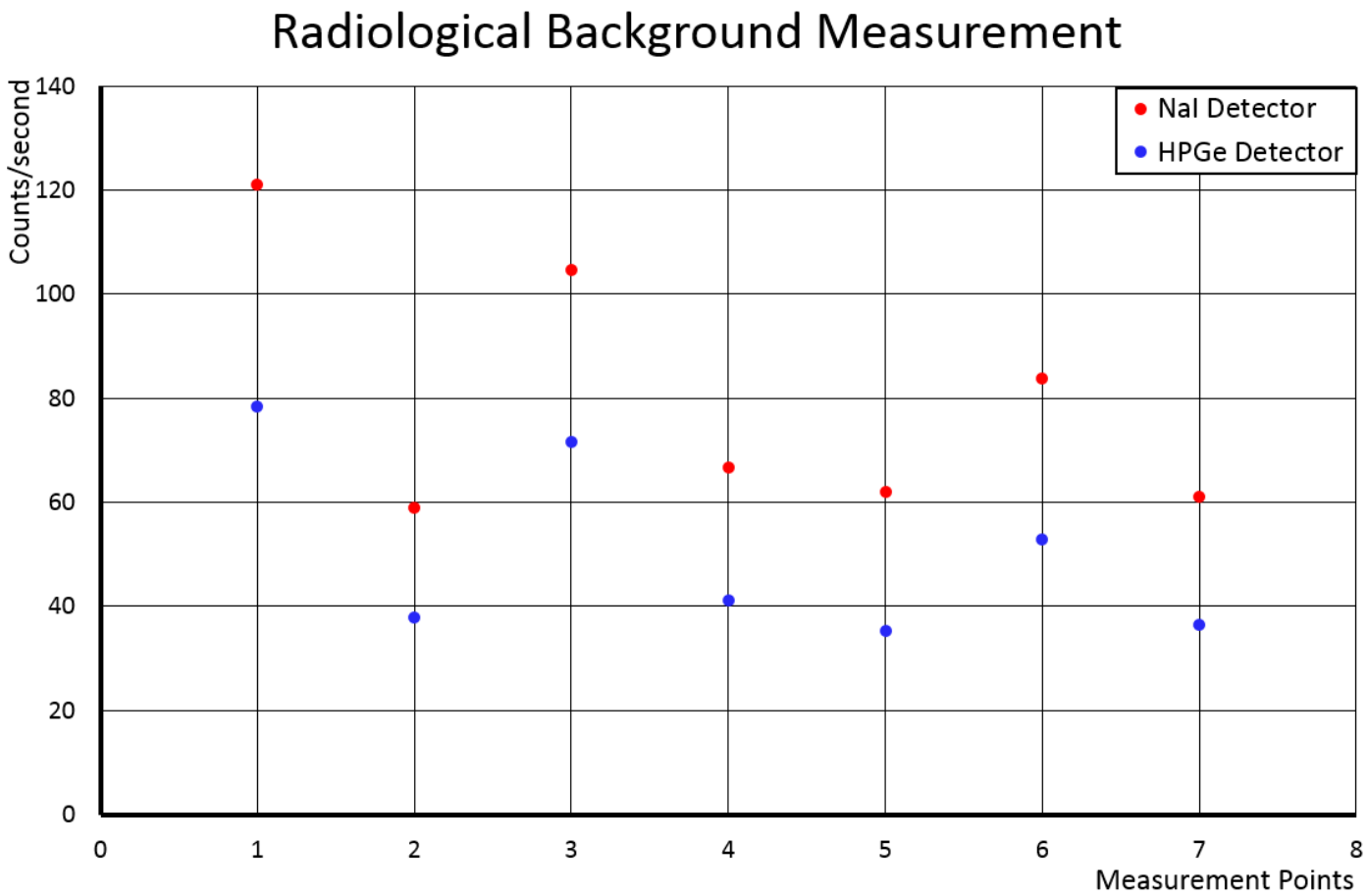
Dead Time

$$\tau = \frac{1}{g_{12}}\left[1 - \sqrt{1 - \frac{g_{12}}{g_1 g_2}(g_1 + g_2 - g_{12})}\right] \approx \frac{g_1 + g_2 - g_{12}}{2 g_1 g_2}$$

Detector	$\frac{Deadtime}{Event}(ms)$	$A_{max.}$(100% d.t)
NaI	0.402 ± 0.010	$\approx$ 50 kBq
HPGe	0.92 ± 0.04	$\approx$ 20 kBq

Dead time of the NaI and HPGe detectors and maximum activity (100% dead time) corrected by efficiency and solid angle.

Aquaculture Institute of Torre la Sal (Cabanes, Castellón)



Gamma counting rate of the radioactive background at several points in the Aquaculture Institute of Torre la Sal, Castellon.

JRODOS Simulations

What is JRODOS program?

JRODOS program[1] is a project developed by the *Karlsruhe Institute of Technology*[2] (KIT) in collaboration with the *European Platform on Preparedness for Nuclear and Radiological Emergency Response and Recovery*[3] (NERIS Platform). It is a support tool in the evaluation and decision-making in radiological emergency situations.
The JRODOS code allows to simulate different types of radiological accidents and provides a comprehensive information during all phases of the event.

Available situations implemented in JRODOS

- Nuclear power plant accident
- Explosion of radiological dispersal device
- Radiological accident with fire
- Wildfire model
- Tornado model

[1] https://resy5.iket.kit.edu/JRODOS/

[2] https://www.kit.edu/

[3] https://www.eu-neris.net/

JRODOS Simulations

Simulation requirements

- Location (GPS coordinates)
- Accident conditions (begin and duration of release, kg of explosives, fire power, etc.)
- Radiological isotopes involved in the accident
- Weather conditions

Possible simulation results

- Activity concentrations
- Affected areas
- Dose rates
- Cloud arrival time
- Tables of activity in food
- Meteorological information
- and much more...

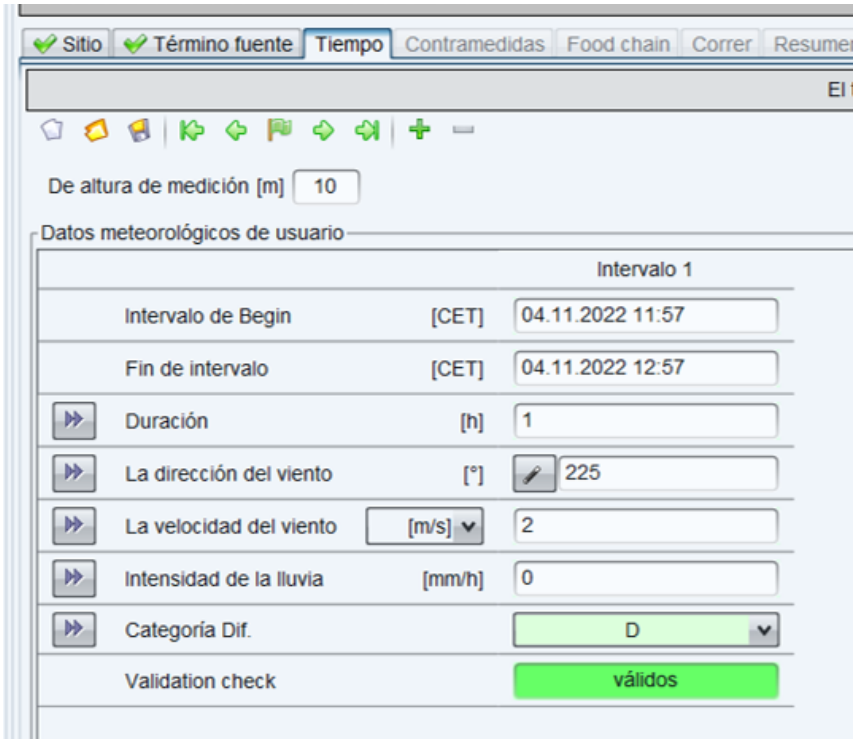
Weather conditions in JRODOS

Different options to establish weather conditions data:

- Manually enter data.
- JRodos supports use of the global numerical weather prediction (NWP) data from the American NOMADS Server.

Meteorological Data

- Windy direction (°)
- Wind speed (m/s)
- Rain intensity (mm/h)
- Percentage of clouds



JRODOS screenshot