The JRC-Geel and the HADES underground laboratory

Harmonisation of radioactivity measurements

JRC=Joint Research Centre

Mikael Hult, team-leader

CELLAR, Dresden 28-30 Nov. 2022

CELLAR – 14 June 2007 at JRC-Geel (IRMM)

CELLAR meetings

Year	Event	Organiser and place		Special events (In addition to lab visit)
1998	Inofficial discussions PTB-IRMM-VKTA	PTB and IRMM	Braunschweig & Geel	
1999	During ICRM-LLRMT - 1st inofficial meeting	SCK CEN	Mol, Belgium	
2000	1st Official meeting	VKTA	Dresden	Koenigstein
2001	Paralell to ICRM conference	PTB	Braunschweig	
2002	After Radioecology conf.	IAEA	Monaco	
2003	After ICRM-LLRMT	ARC	Vienna, Austria	Lloyd Currie
2004	After Aquatic forum	IAEA	Monaco	
2006	6th CELLAR meeting	LNGS	Assergi	Corno Grande
2007	7th CELLAR meeting (after GERDA meeting)	JRC-Geel (IRMM)	Geel	
2008	8th CELLAR meeting	IFIN-HH	Bucharest & Unirea (Slanic)	Storm

CELLAR meetings				Special events (In addition to lab visit)
Year	Event	Organiser and place		
2010	9/10th CELLAR meeting	VKTA	Dresden	Fire
2012	10/11th CELLAR meeting	Canberra-France (Areva?/Mirion	Lingolsheim	Flammkuchen
2015	12th CELLAR meeting	IAEA	Monaco	
2017	13th CELLAR meeting	IFIN-HH	Bucharest	
2018	14th CELLAR meeting	IAEA + EC-JRC	Monaco	JEILORA
2022	15th CELLAR meeting	VKTA	Rossendorf	

JRC sites

Headquarters in **Brussels** and research facilities located in **5 Member States:**

- Belgium (Geel)
- Germany (Karlsruhe)
- Italy (Ispra)
- The Netherlands (Petten)
- Spain (Seville)

European Commission

Evolution of JRC-Geel site

1957	Euratom Treaty (signed)
1960	Central Bureau for Nuclear Measurements (CBNM)
1993	Renamed 'Institute for Reference Materials and Measurements' (IRMM)
2016	Renamed “JRC-Geel” Hosting 5 JRC-Directorates: JRC.A / JRC.E / JRC.F / **JRC.G** / JRC.R + AMC-8 (DG HR)
2020	Hosting 7 JRC-Directorates: JRC.A / JRC.D / JRC.E / JRC.F / **JRC.G** / JRC.I / JRC.R + AMC-8 (DG HR)

European Commission

Support to the Euratom treaty

- To ensure a uniform nuclear terminology and a standard system of measurements (Article 8)
- Support of Article 35 (specific) and radioprotection (Chapter 3, i.e. Articles 30-39) in general (Art. 39)
- Carry out the research programme assigned by the Commission (Article 4)
- Place installation at the disposal of member states (Article 6)

Work by the Radionuclide Metrology Team of JRC-Geel

- Realise the unit Bq *(Primary standardisation)*
- Verification of environmental radioactivity monitoring in Europe *(Organisation of proficiency tests, ISO/IEC 17043)*
- Produce radioactive reference materials *(food, feed, crop metals, air-filters, water etc.)*
- Perform radioactive reference measurements *(decay data, characterisation of reference materials etc.) ISO 17025 for gamma-spec.*
- Open access *(Metrology lab and 225 m deep underground lab)*

HADES

- 8 ultra low-background HPGe-detecor systems
  - SAGe-well detectors, BEGe, REGe, XtRa
- 2 systems for scanning deadlayers (via LEGEND)
- 2 Systems for detector testing (via LEGEND)
- Storage of materials (including a “normal” freezer)
- ISO/IEC 17025

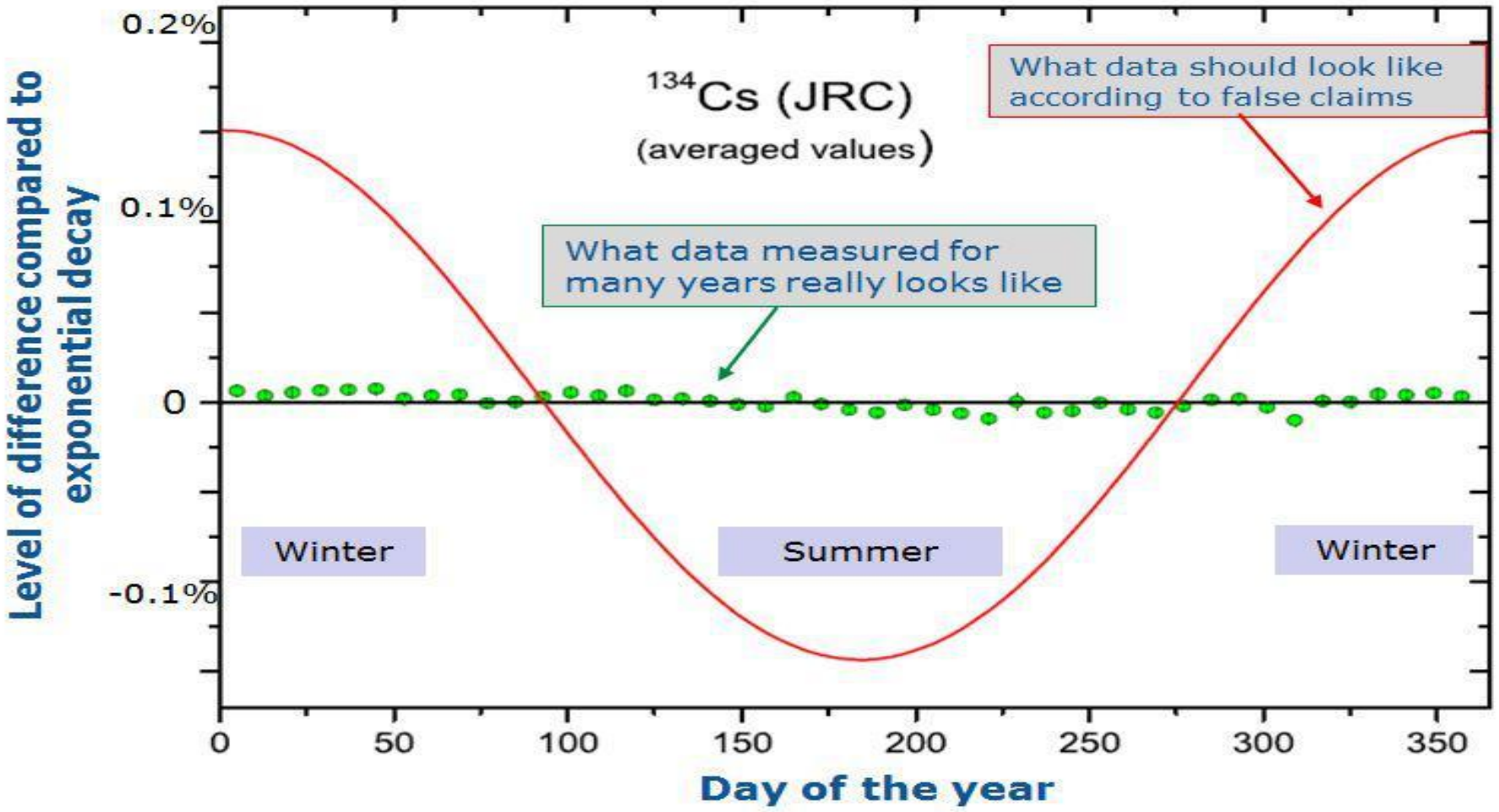
- Science in the deep underground. Short version – YouTube

RADMET

- 8 HPGe-detector systems
  - BEGe, XtRa, standard coaxial
- Pressurised proportional counters
- Liquid Scintillation counters
- Detectors for primary standardisation (Propostional counters, $4\pi\beta$-γ coincidence counters, defined alpha solid angle,…)
- Ionisation chambers
- Alpha-particle spectrometers
- ISO/IEC 17043 (17034, 9001,…)

Example of collaboration with SCK CEN:

Invariability of decay constants



- With 14 NMIs!
- Endorsed by CCRI
- Disproving claims of permille level
- solar influence on radioactive decay
- -
- Immense impact, (which will not reach the news)

6 recent articles in, Phys. Lett. B 761 + Metrologia 54 + Solar Phys. 292 + Astropart. Phys. 97

European Commission

Proficiency tests – Combing realisation of Articles 8, 35 and 39

Reference material

Measurement by laboratory

Reports results to JRC

JRC Collates and evaluate submitted data

JRC

- Reports to participants
- Informs DG ENER
- Follow-up workshop/training
- Input to standards

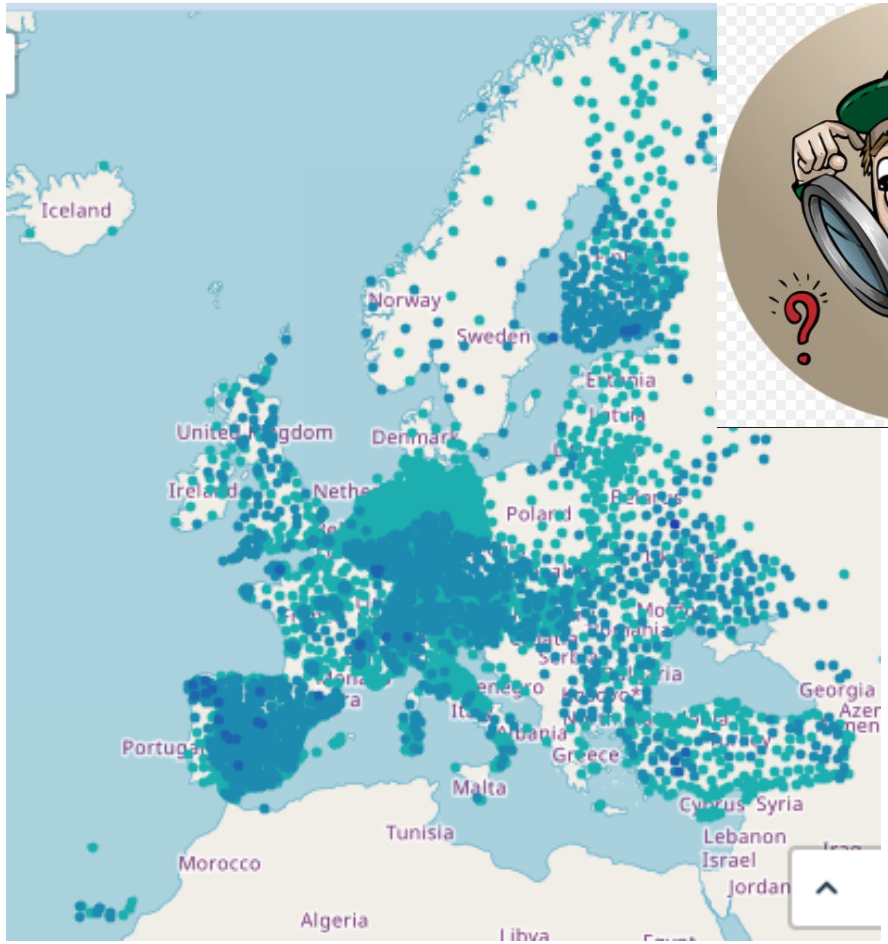
European Commission

RN Key activity-1

PTs and RMs for ~ 300 labs

It enables:…..

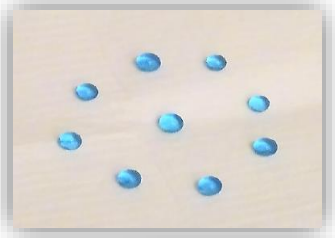
- DG ENER and national authorities to check labs – each year!
- Labs to obtain accreditation
- Labs to discover errors and improve
- Input for European standards
- Realisation of Euratom treaty Art. 35 &39

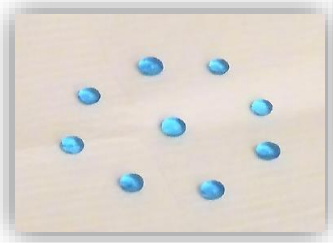


PT=Proficiency Test, RM=Reference material, CRM = Certified RM, MS=Member States

European Commission

Year	Matrix	Radionuclide(s)
2003	Air filter	^{137}Cs
2005	Milk powder	^{40}K, ^{90}Sr, ^{137}Cs
2008	Mineral water	^{226}Ra, ^{228}Ra, ^{234}U, ^{238}U
2010	Soil	^{40}K, ^{137}Cs, $^{212,214}Bi$, ^{226}Ra, $^{230,232}Th$, $^{234,235,238}U$, $^{238,239,240}Pu$, ^{90}Sr
2011	Dried bilberries	^{40}K, ^{90}Sr, ^{137}Cs
2012	Mineral water	Gross alpha, gross beta
2014	Air filter	^{137}Cs
2016	Air filter	^{134}Cs, ^{137}Cs, ^{131}I
2017	Dried maize	^{134}Cs, ^{137}Cs, ^{131}I (^{40}K)
2018	Drinking water	^{222}Rn
2019	Drinking water	Gross alpha, gross beta
2020	Building materials	^{226}Ra, ^{228}Ra, ^{228}Th, ^{210}Pb, ^{238}U, ^{40}K
2023 ?	Air filter ?	^{134}Cs, ^{137}Cs, ^{106}Ru





European Commission


Reference
Materials

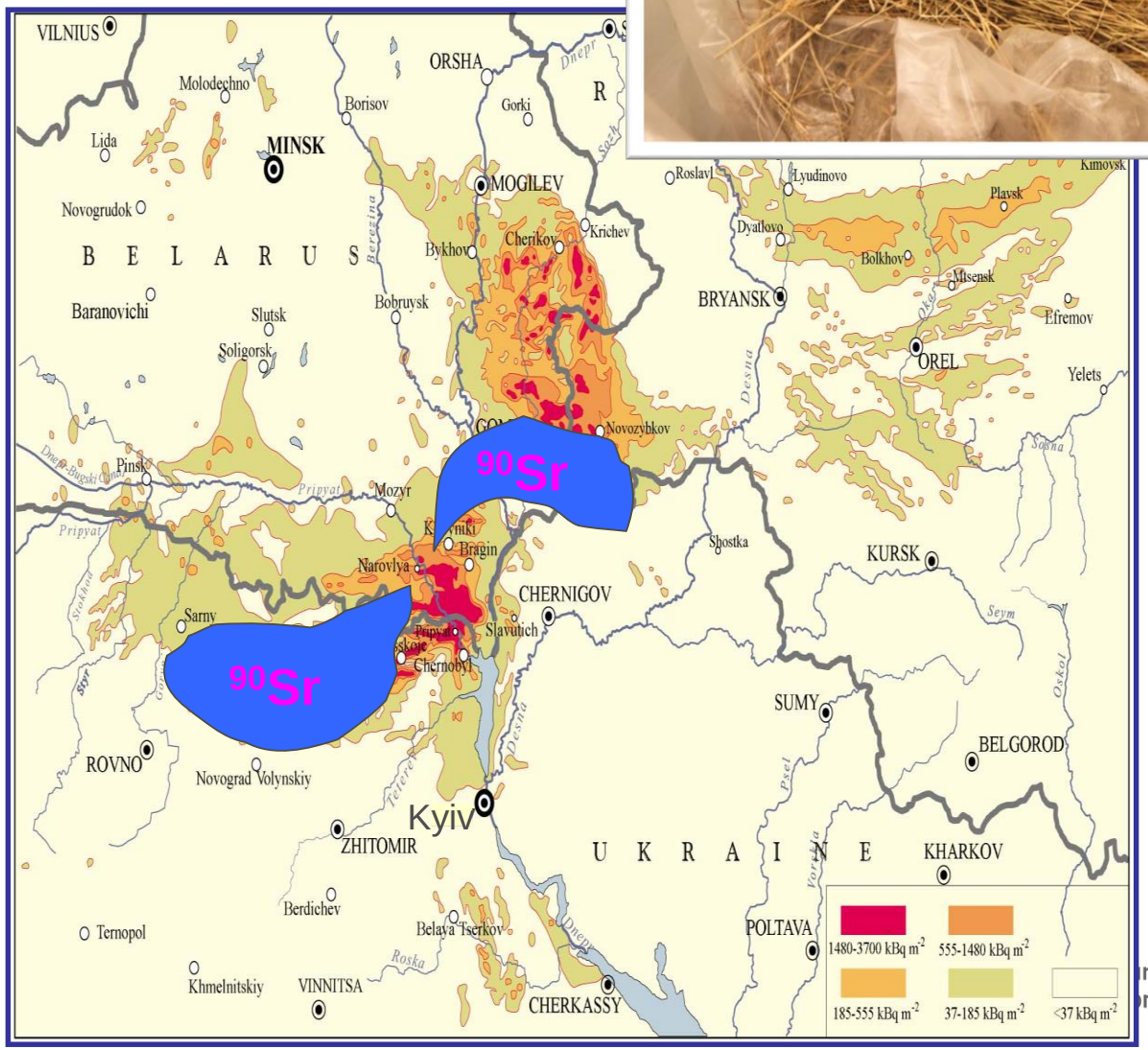

Naturally
contaminated


Spiked

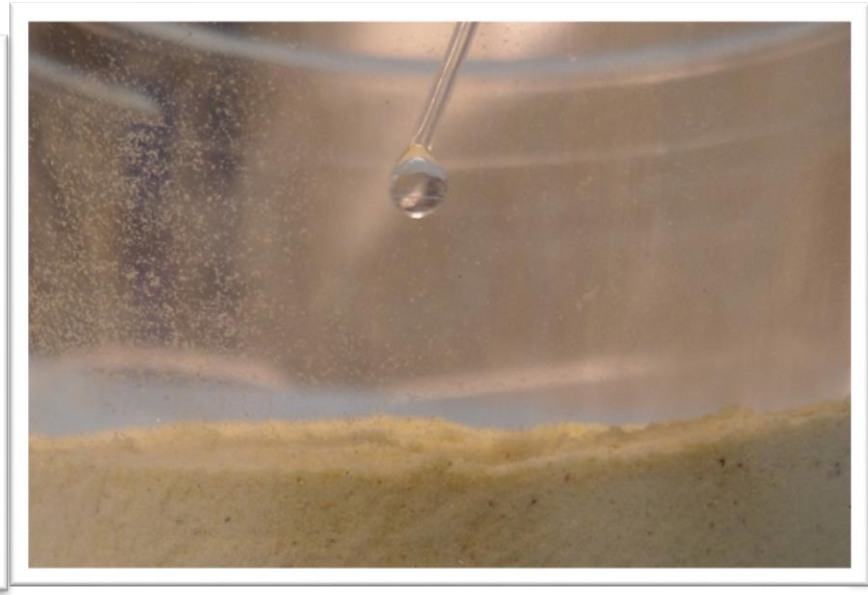
Natural reference materials

Collected in a region "preferentially" affected by Sr deposition

Certified activities of ^{90}Sr, ^{137}Cs and ^{40}K



Spiking of maize

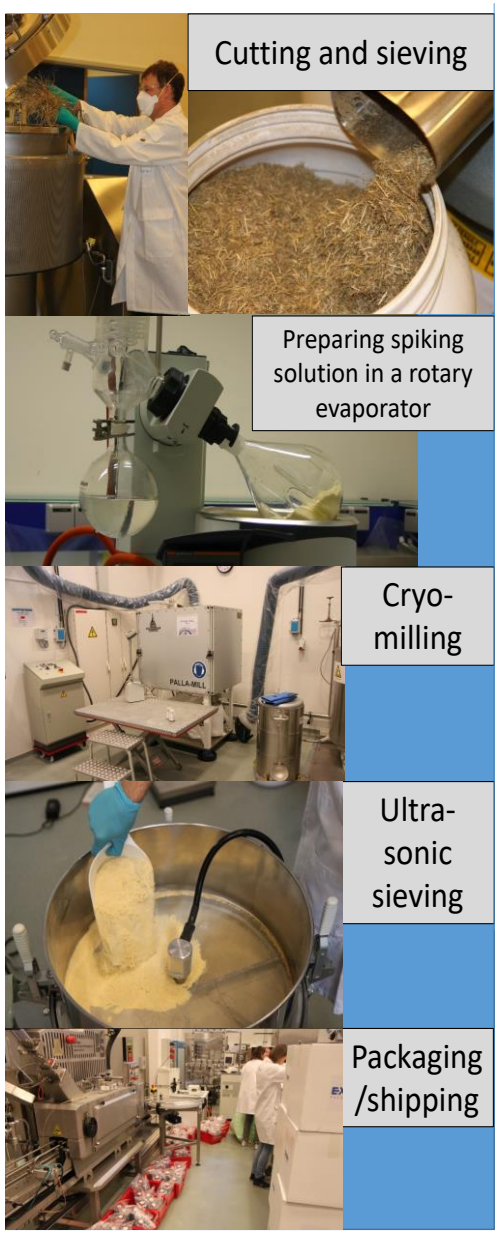


- Spiking enables use of short-lived radionuclides and “unusual radionuclides”
- Can lead to “surprises” – important to make preparations before emergency occur

World-leading lab for reference materials production

2011-2021:

- 30,000 units CRM
- 6,000 units radioactive CRM
  - 30 different matrices



Reference materials

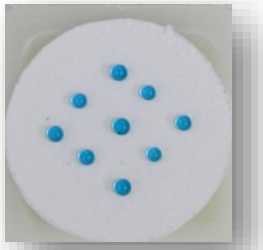
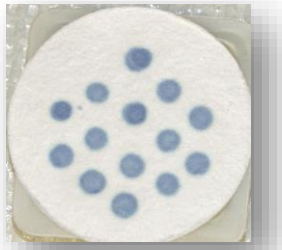
1100 sources ^{60}Co

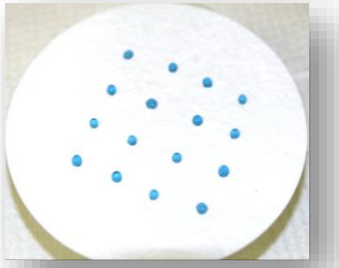
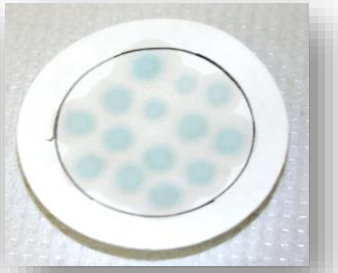
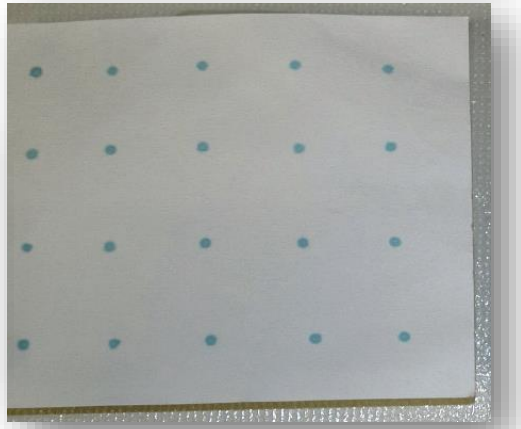
- Automatic production with robot dispenser
- First SI-traceable calibration standards for free-release measurement facilities

Air filters spiked with ^{137}Cs

Active spots are blue to help in folding or cutting

The participants' own filters are prepared! – many different types!!

Services

Installing Widgets

Proficiency Tests

All REM PT reports also available here:
https://remon.jrc.ec.europa.eu/About/Environmental-Monitoring/Proficiency-Tests

EC-JRC Proficiency Tests for Radi… Monitoring Laboratories

On the basis … one of … in carrying out … the comparability of … organises Proficiency Tests (PTs) on the … laboratories. The EC-JRC REM (Radioactivity Environmental … from the European Commission's Directorate-General for Energy. A … that summarised the results of the PTs since 2003 download.

… PT: ^{232}Th, ^{226}Ra, ^{40}K in building materials

Table1. Summary of EC-JRC proficiency tests.

Year	Matrix	Radionuclide(s)	Status	Report
2020	Building materials	^{232}Th, ^{226}Ra, ^{40}K	Ongoing	
2019	Water	Gross alpha/beta activity	Completed	Link
2018	Water	^{222}Rn	Completed	Link
2017	Maize powder	$^{134/137}$Cs, ^{131}I	Completed	Link
2016**	Air filter	$^{134/137}$Cs, ^{131}I	Completed	Link

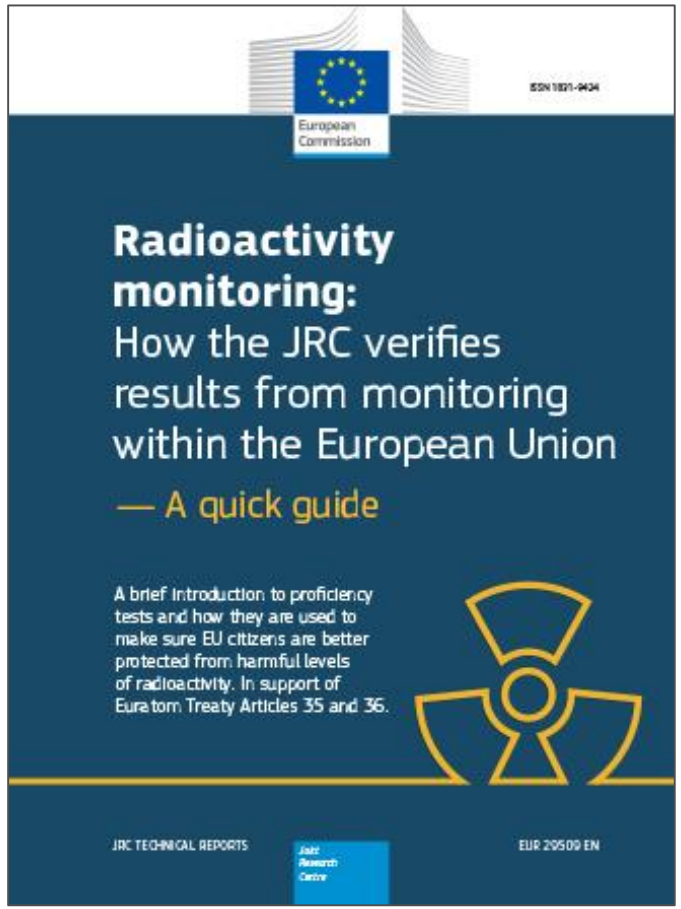
Brief overview 2003-2018

How is the status of radioactivity monitoring in Europe?

Can we only detect major releases?

Can we use monitoring data for science?

What if Chernobyl happened today?



Download from:
https://publications.jrc.ec.europa.eu/repository/handle/JRC117258

European Commission

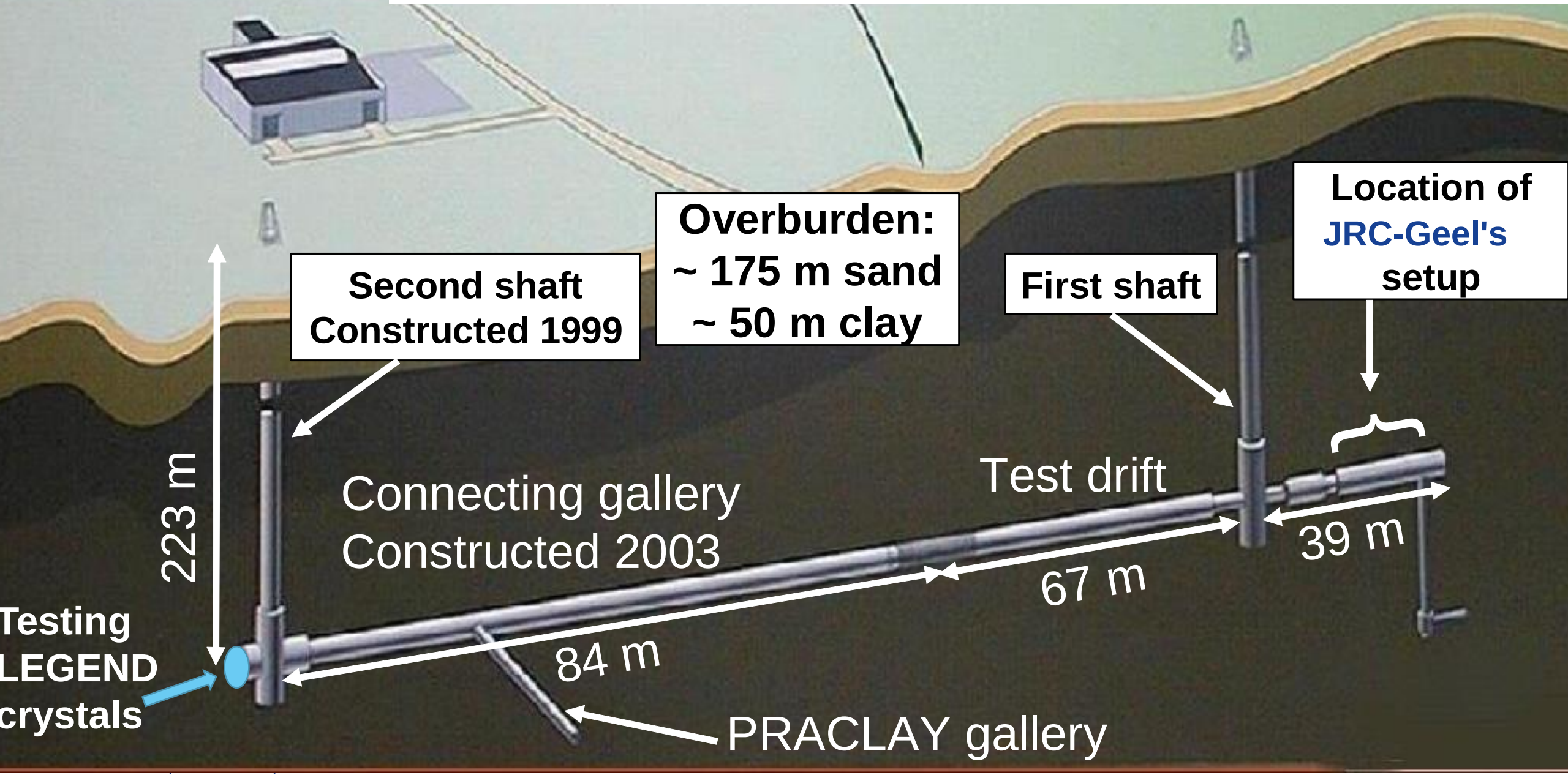
Standardisation (written standards)

- Testing of standards – collaborative trials: These are similar to PTs but a certain method must be used (tested)
- Contributed to 22 standards in H-2020* (lead 2, initiated 2)
- Big need for the future!
  - Lack of experts in standardisation committees. JRC can provide leadership
  - More standards (New instruments, more radionuclides, more stringent legislation,…)

**H-2020 = Horizon-2020, framework programme 2014-2020*

HADES

HADES = High Activity Disposal Experimental Site
– Operated by EURIDICE and located at SCK•CEN in Mol




AIR LUCHT
BRGM

HADES: Replacing lift in Shaft-1 and refurbishing the shaft

=> FINALISED in spring 2021

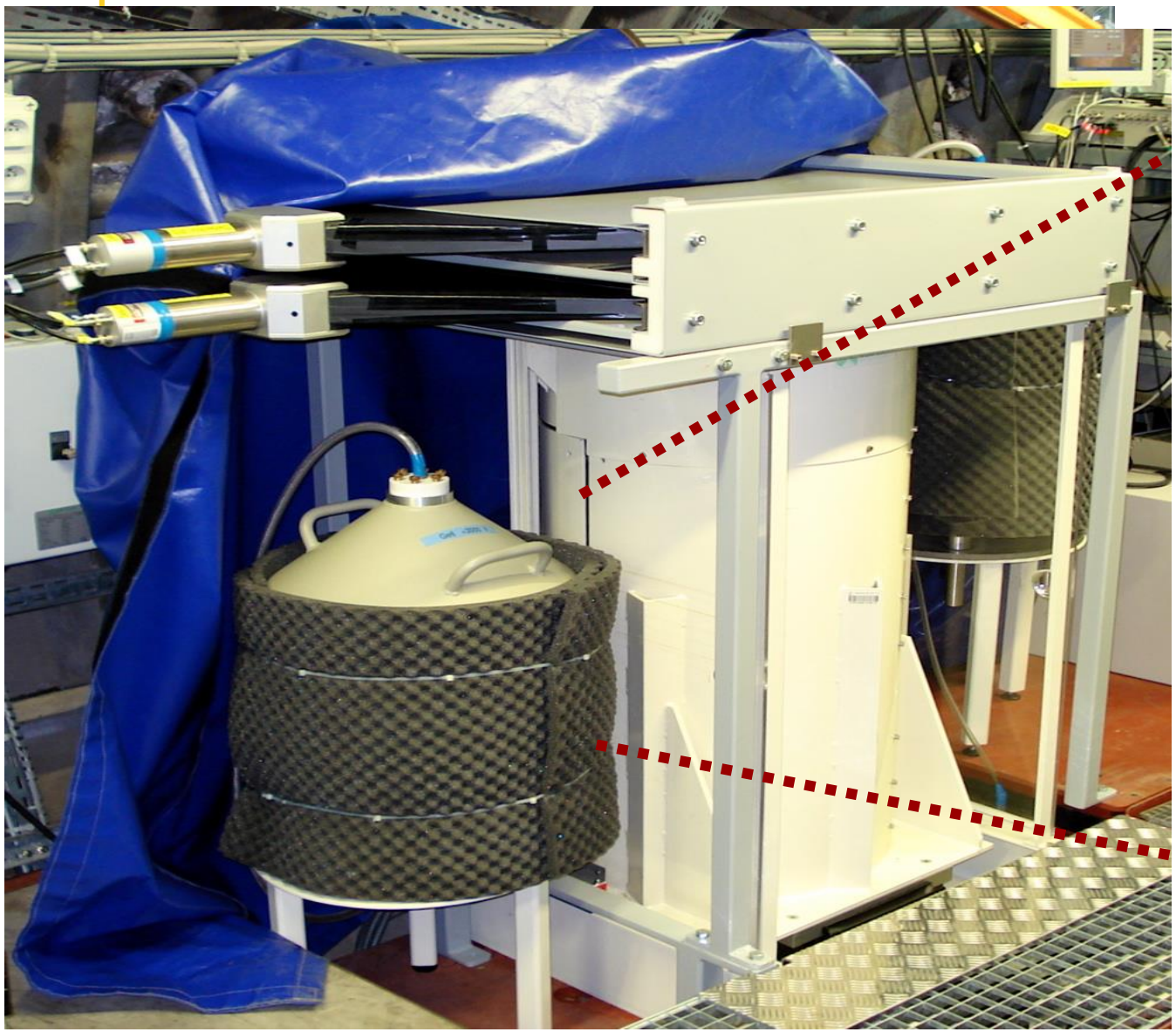
Old installation

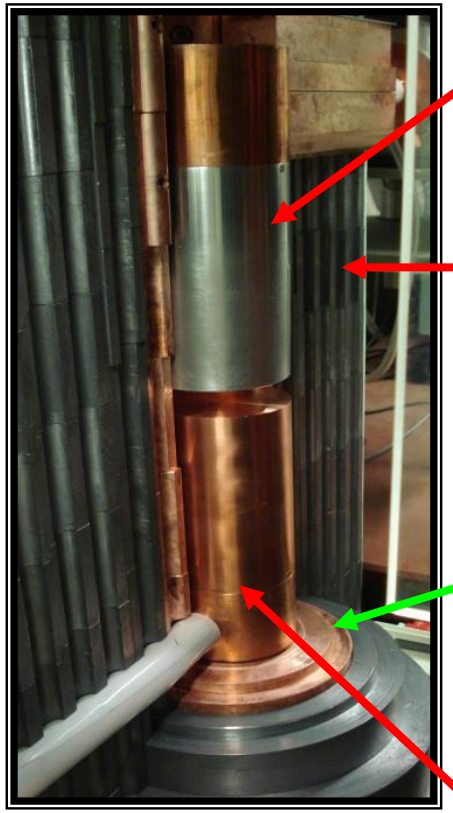
New installation

New installation

Temporary lift during refurbishment

The Sandwich spectrometer





Ge-7

Pb shield = 4 cm radiopure lead, 2.5 Bq/kg

+14.5 cm lead, 20 Bq/kg

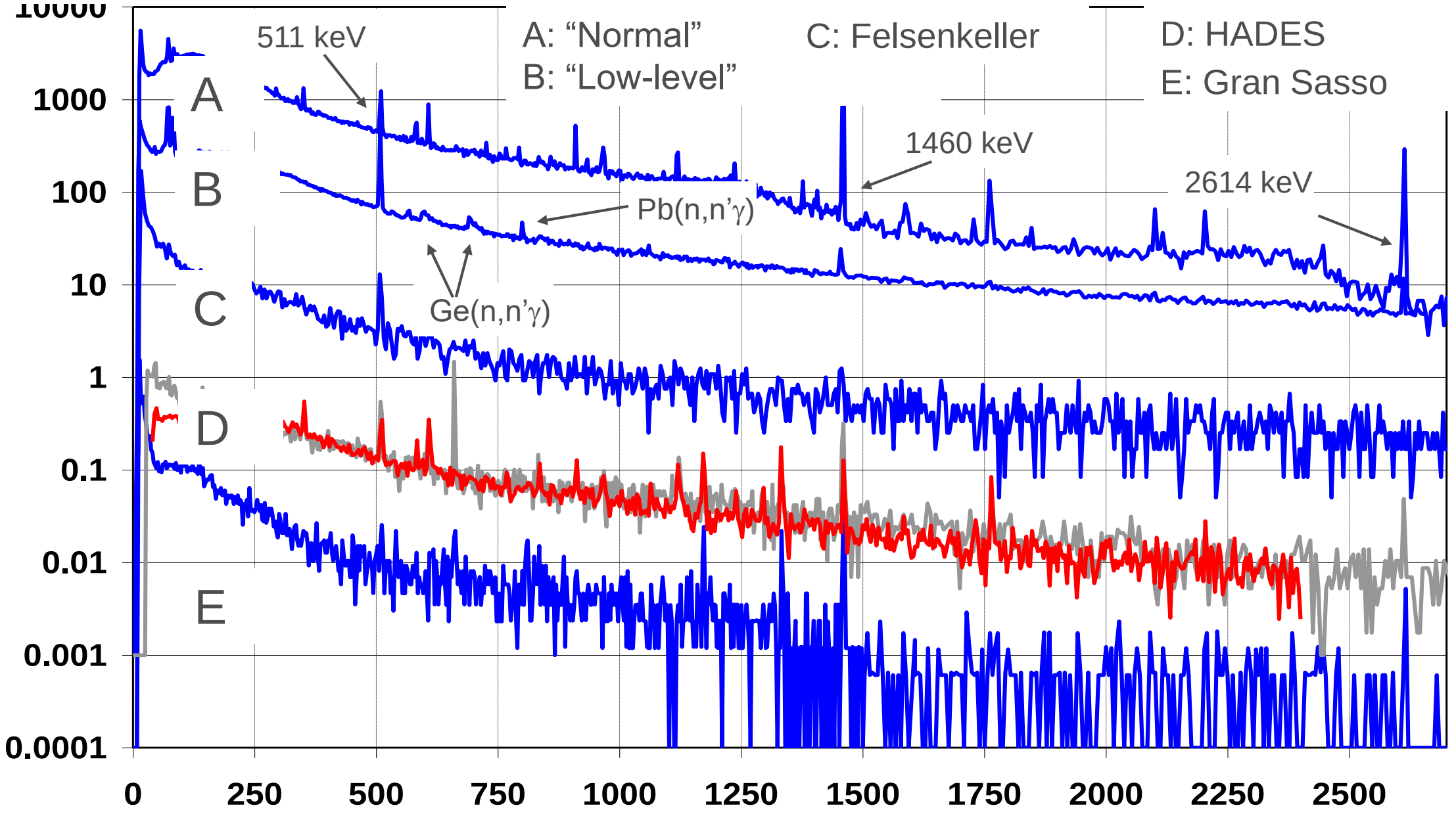
Cu lining = 3.5 cm radiopure copper

Ge-6

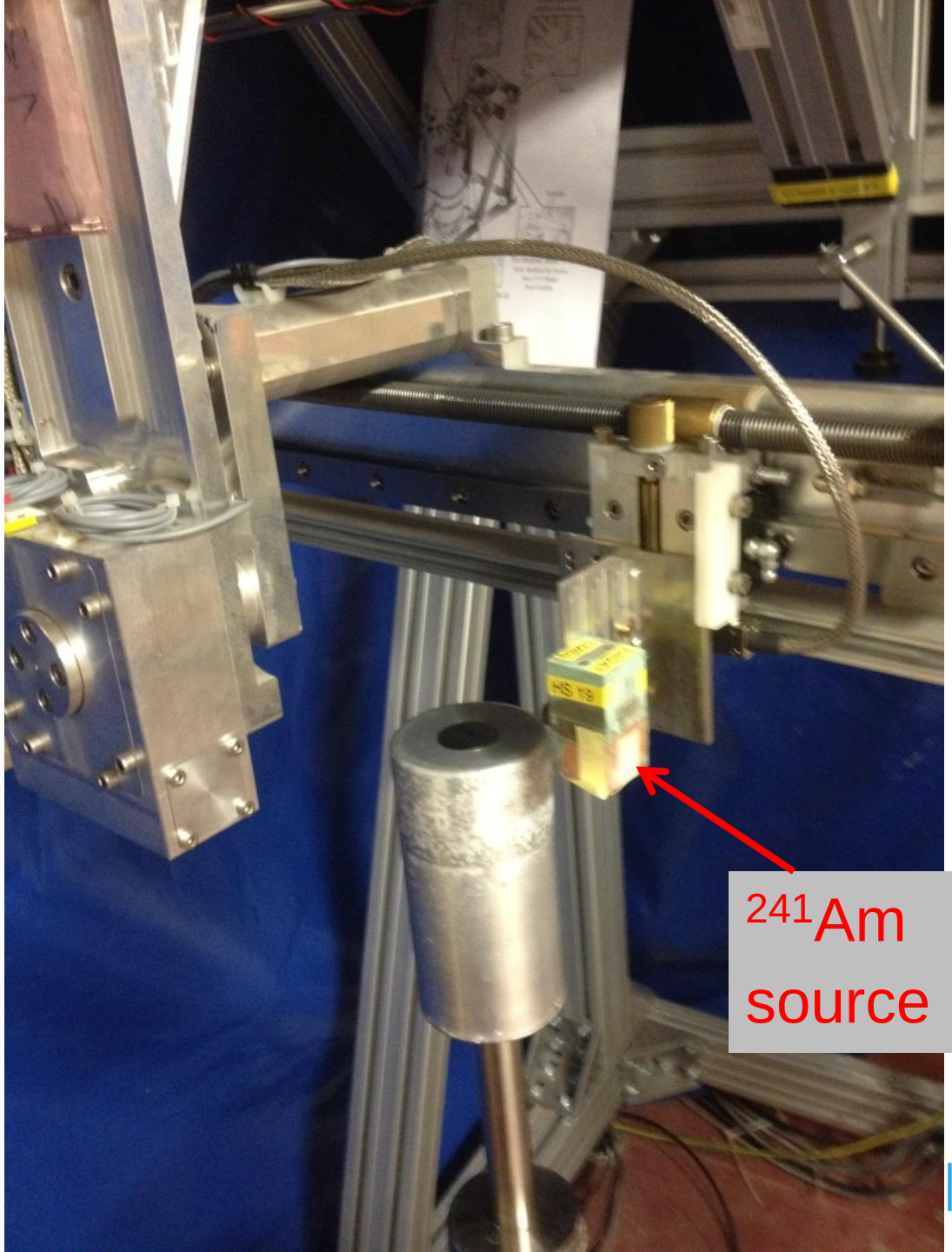
- Replaced w Ge15

Detector mass ~ 1.9 kg each

Background Comparison – Gamma-ray spectrometry

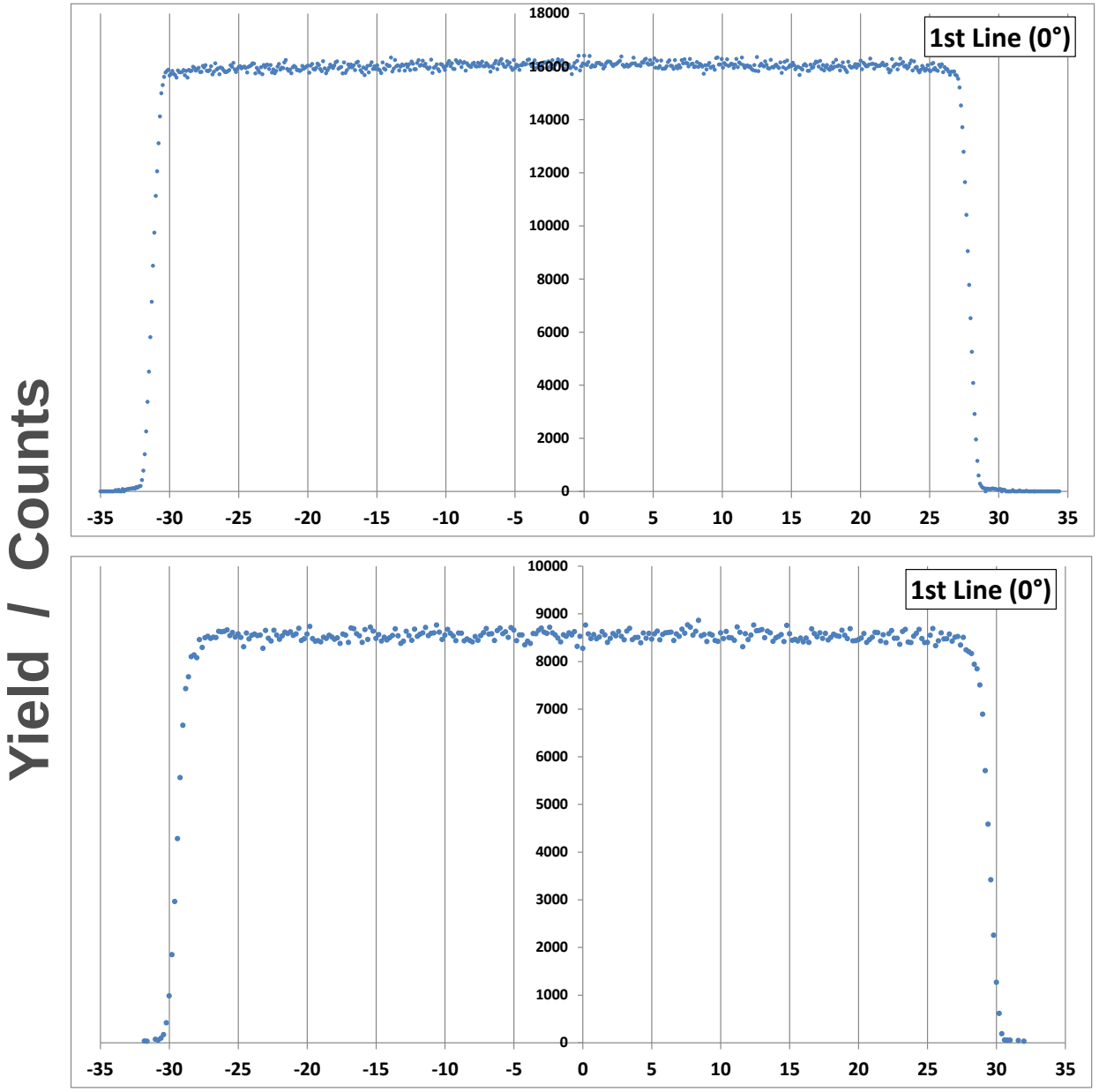


SCK•CEN
detector
"DET28"



^{241}Am
source

"New" detectors



Thin deadlayer

µm (probably not Li)

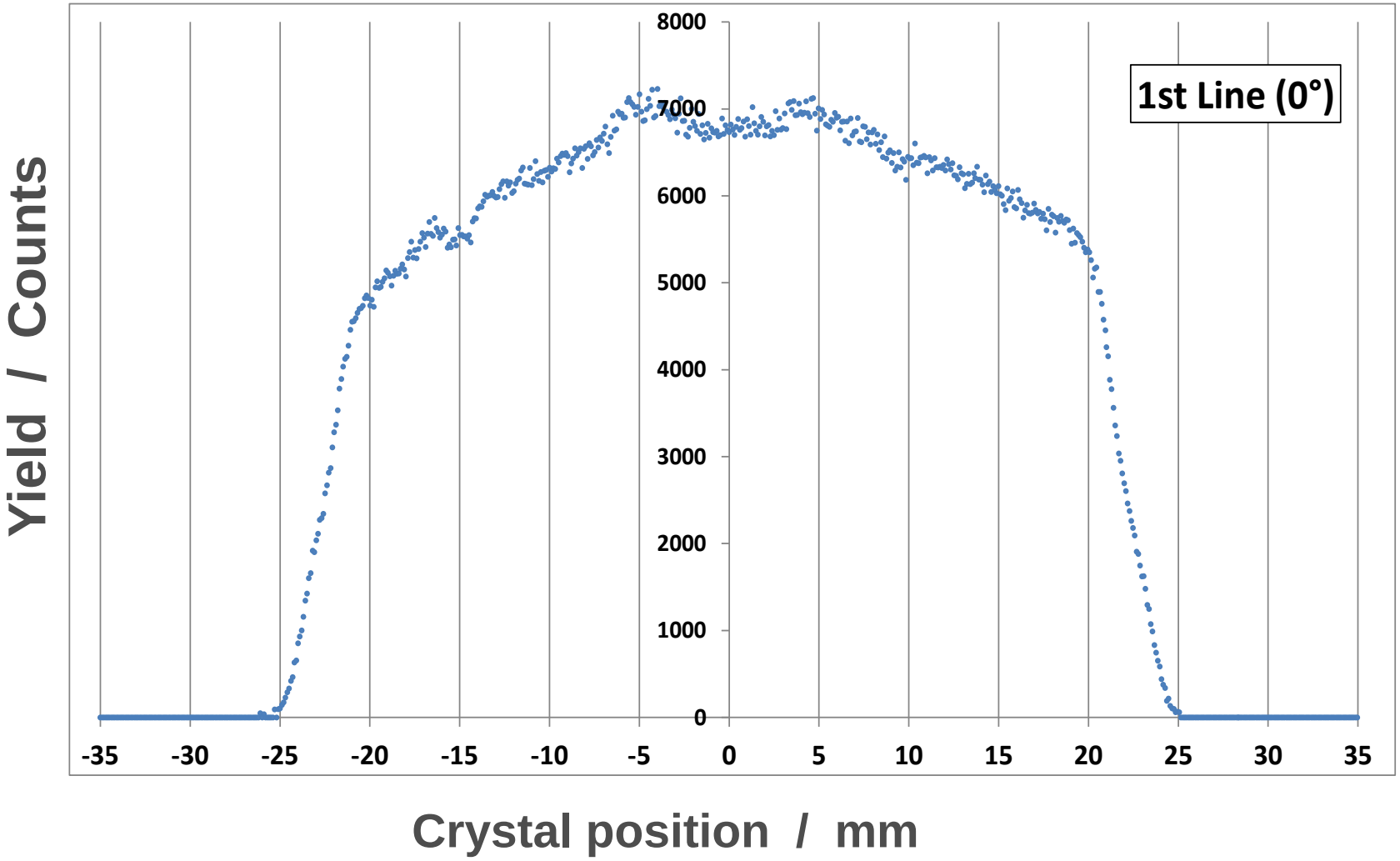
(JRC, 10 Years old)

Thick deadlayer

mm

(SCK, 13 Years old)

Scan of a 21 y old detector - EUFRAT #13-14 (Uhasselt)



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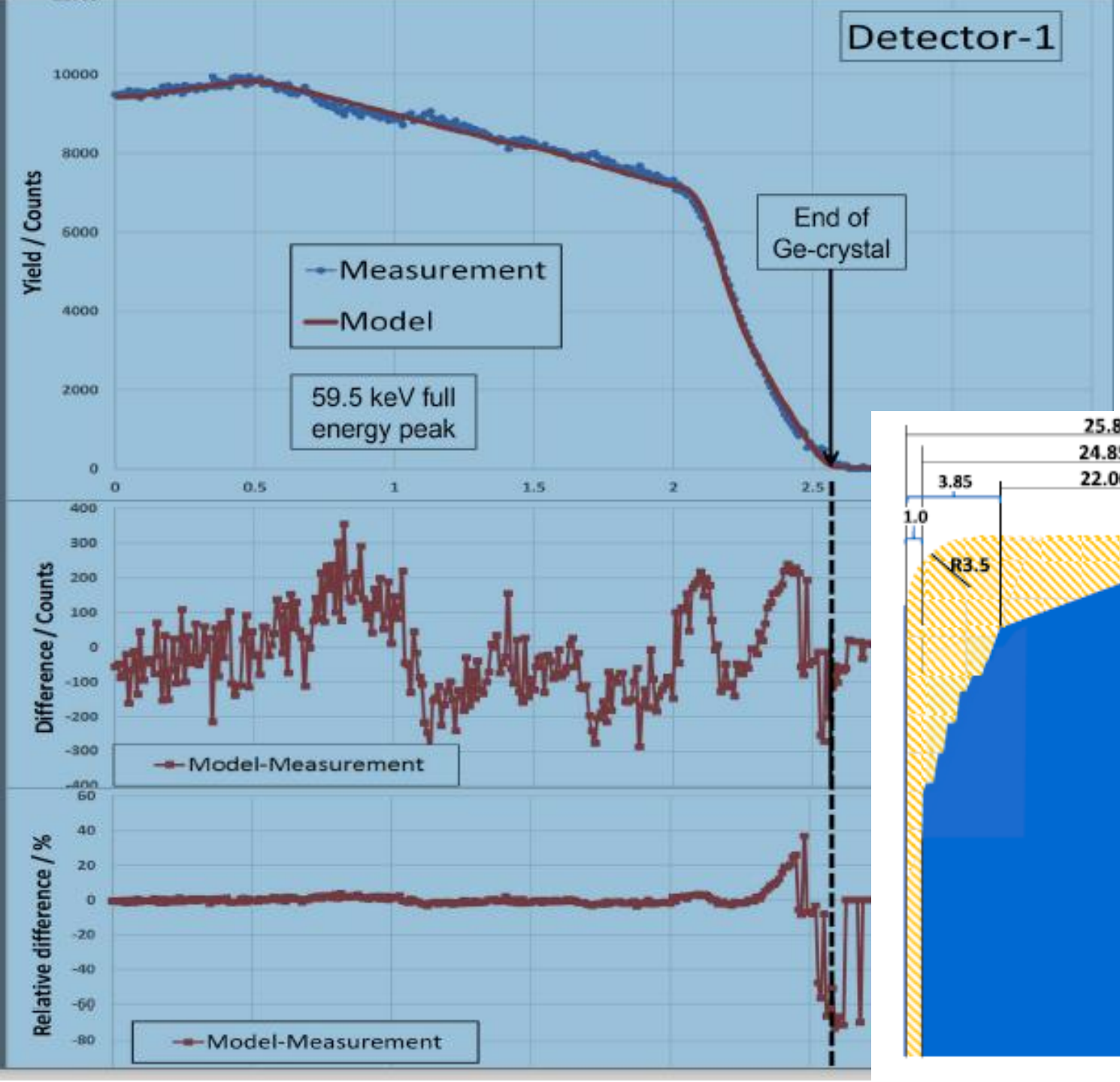
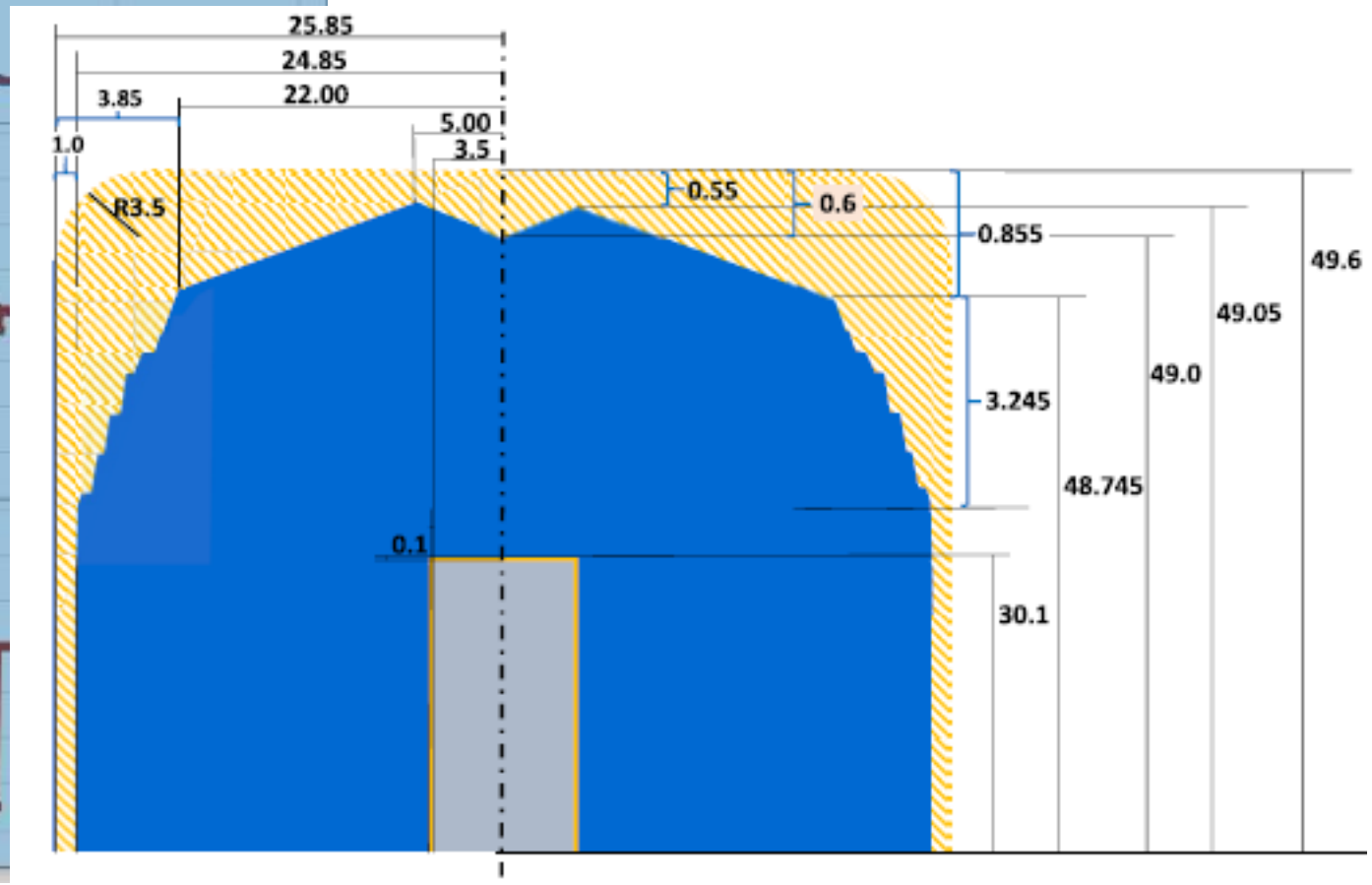
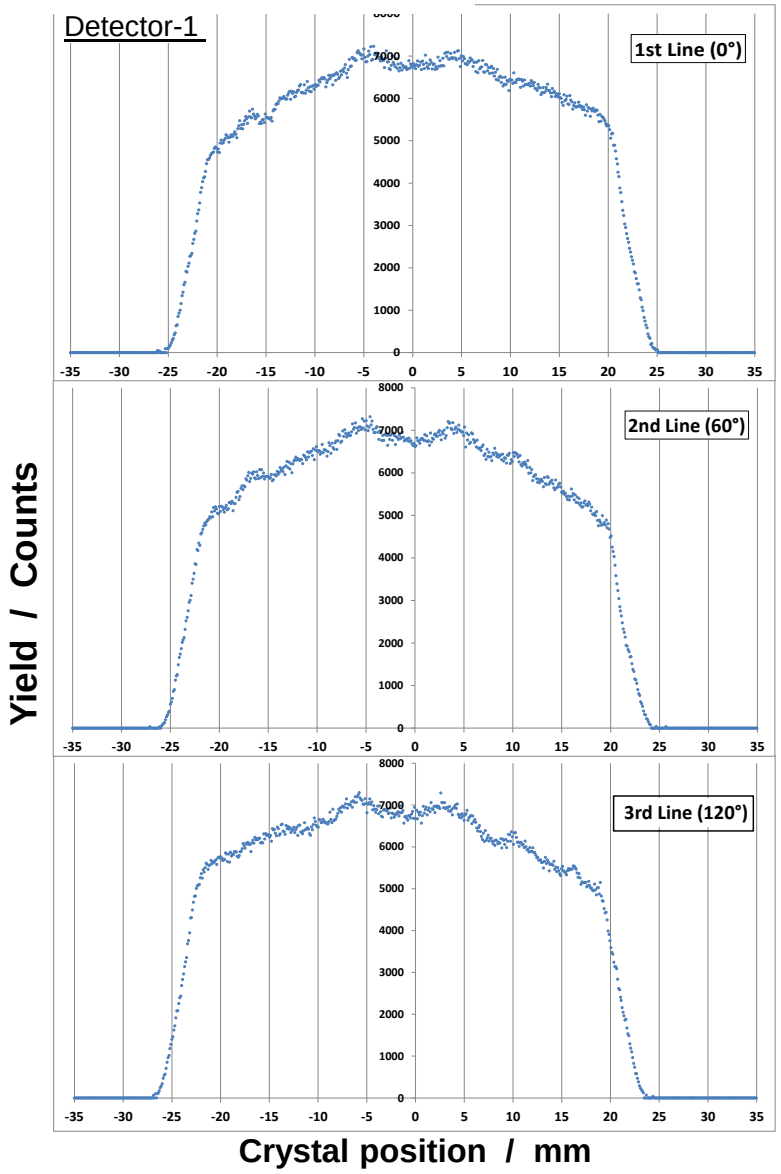
Example of non-homogeneous deadlayer

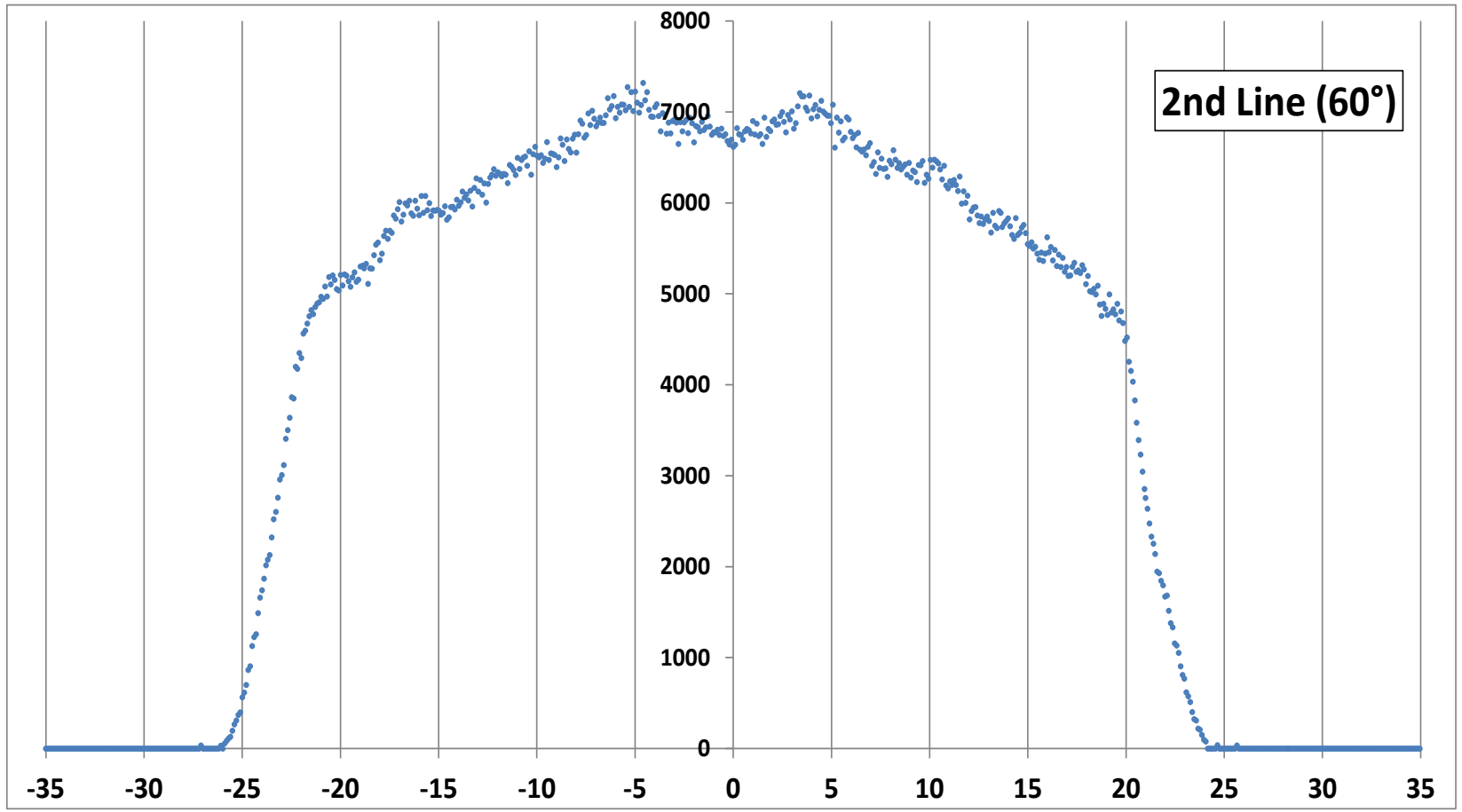
(Hult et al, ARI 147 (2019) 182-188)





UHassselt





European Commission

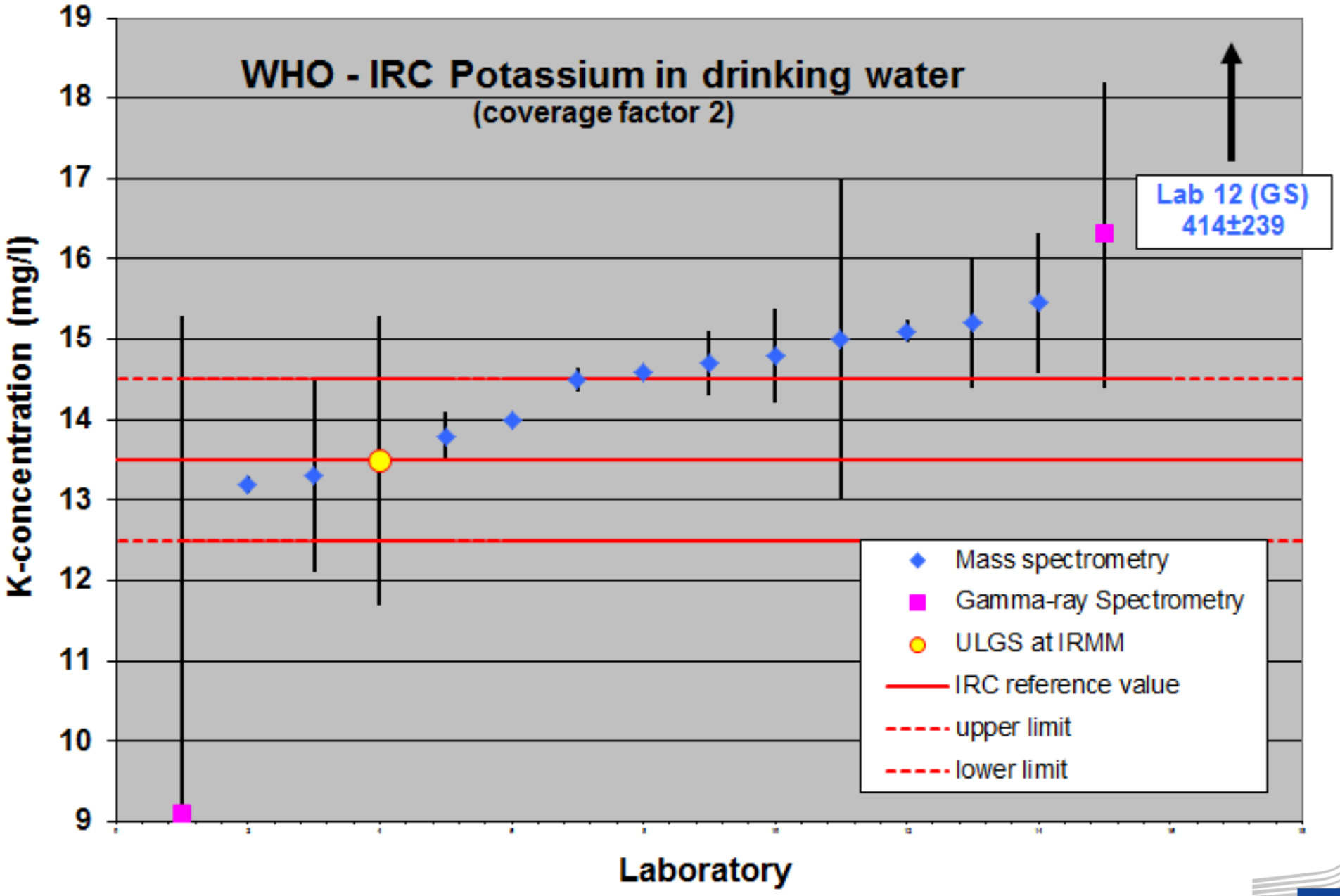
History: How we moved from Exploratory research to an analytical resource integrated in the JRC work programme

Three important projects:

1) K in water proficiency tests – could show robust, unbiased and important quantitative results

2) As impurities in GaAs – Important support to a Eurpean SME (Small/Medium sized company) in a competitive high-tech branch

3) Support to Japan after the Tokai-mura accident. The Head of the European Commission (Prodi) offered help to Japan. Only JRC-Geel could help. (with underground measurements of neutron activation products in table-spoons collected in homes of people.



My first PT-contribution! ☺
A mistake that became a success (with a little statistical luck)

European Commission

Determination of Zn in high-purity GaAs

Customer: Freiberger Compound Materials GmbH

Task: Reference measurements of Zn impurities in order to settle discrepancies in existing characterisation techniques

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Deliverable: IRMM could confirm that the GDMS measurements gave the correct results

EU-Policies (Anno 2000):

* Support to less favoured region
* Support to SME

Project initiated and performed by
Matthias Koehler (VKTA / IRMM)

European Commission

RNAA+ULGS

Radiochemical Neutron Activation Analysis + Ultra Low-level Gamma-ray Spectrometry

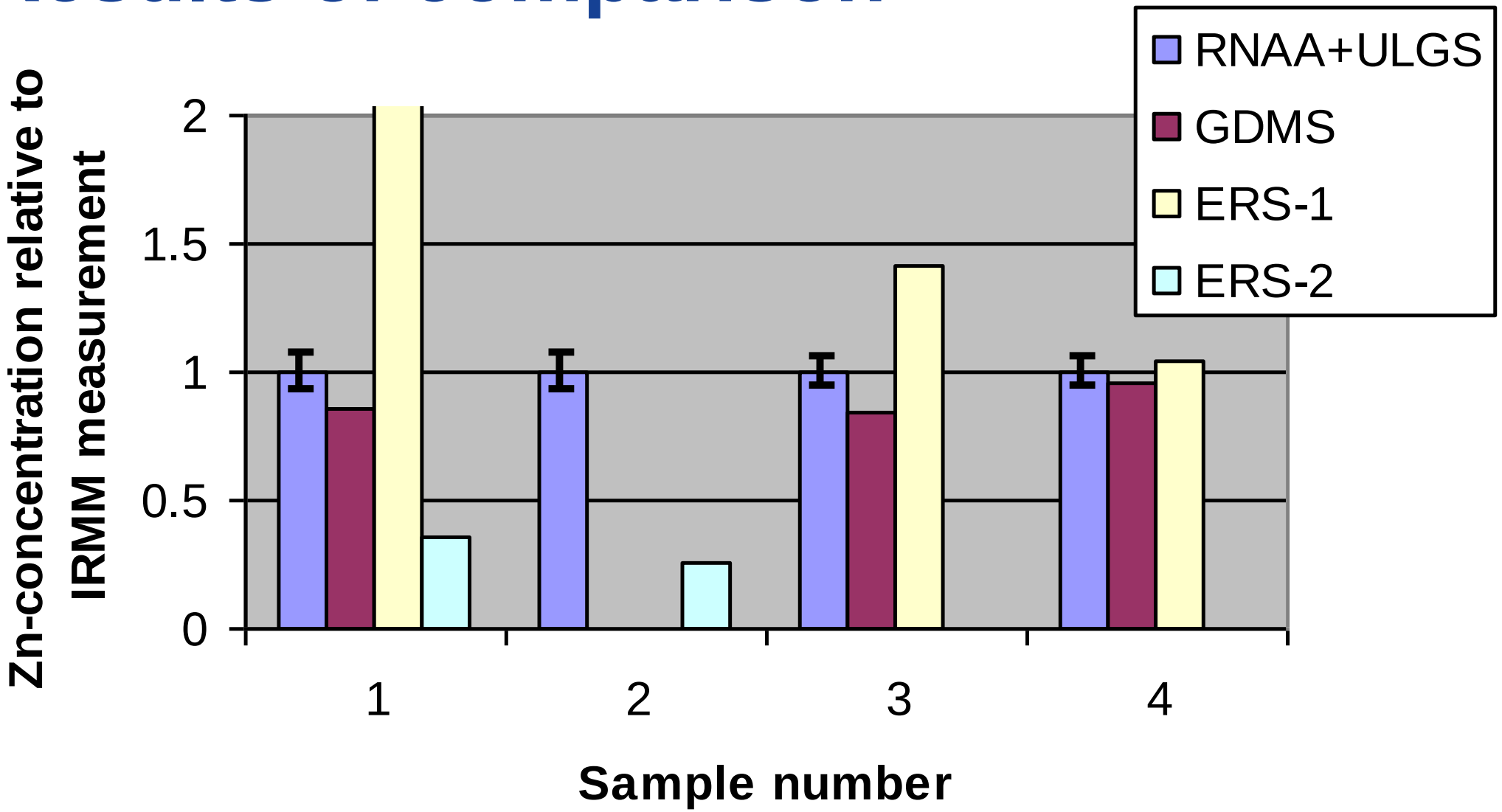
1. **Neutron activation of GaAs wafers in a reactor for 14 days**
   (neutron flux ~10^{14} cm^{-2} s^{-1})

2. **Leave the sample to cool for 54 days.**
   Remaining activity mainly from: $^{75}As(n,2n)^{74}As$ ($T_{½}$= 18 days)
   $^{64}Zn(n,\gamma)^{65}Zn$ ($T_{½}$=244 days)

3. **Chemical separation of Zn**

4. **Ultra low-level gamma-ray spectrometry in HADES**

Results of comparison



[Zn] / (ng/g) : 5.8 2.1 51 9.5

Detection limits of Zn in GaAs, c_{DL}, by different analytical methods

Method	c_{DL} [ng g^{-1}]
Rf GDMS [a]	0.9
ICP-MS [a]	1.8
INAA [b]	2.5
GDMS [c]	4
ERS [d]	10
SSMS [c]	9
RNAA+ULGS[e]	**0.008**

[a] (Becker et al., 1998),
[b] (Erdtmann et al., 1993),
[c] (Mykytiuk et al., 1990),
[d] (Wagner et al., 1988)
[e] This work (t_m= 1 day, m=50 mg)

Thank you

European Commission