Project EIVIC2020 (EC, DG-ENER)

"European In-vivo Counting Intercomparison Exercise 2020-2021"

WP. 2.3 – ANALYSIS OF RESULTS
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EC Contract ENER/2019/NUCL/SI2.811157

WEBINAR EURADOS 04.12.2023

INTRODUCTION

Objective of the WP. 2.3 – Collecting and analysis of results

- ✓ Developing a specific template dedicated to collect results
- ✓ Collecting and checking data of participants
- ✓ Performing statistic analysis of results according to the International Standard (ISO)
- ✓ The conformity and performance of the facilities for *in vivo* monitoring

The EIVIC Intercomparison

- ✓ 41 facilities from 35 laboratories and 21 countries
- ✓ 5 configurations covering the range of such possible measurements associated to different intake scenarios

  - ✓ Task 1 – Victor *(suitable for NaI(Tl) and germanium detectors: P5 phantom)*

  - ✓ Task 2 – Emergency *(suitable for NaI(Tl) and germanium detectors: P4 phantom)*

  - ✓ Task 3 – Medicine *(suitable for NaI(Tl) and germanium detectors: P5 phantom)*

  - ✓ Task 4 – Calibration *(suitable only with germanium detectors: P4 and P5 phantom)*

Date of the beginning of the analysis

- ✓ 5th May 2022 : receipt of the latest results
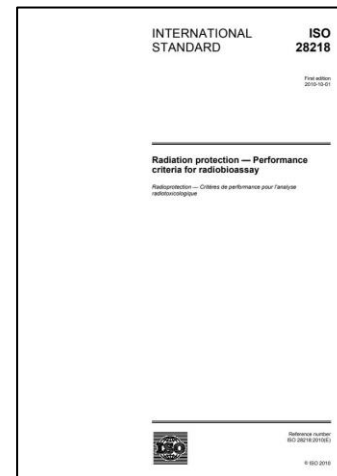
PROCESS OF DATA EVALUATION (1/2)

- Downloading of the measurement results (type of radionuclides and activity) by the participants on the **BfS Cloud.**

- Use a link between the download templates on the cloud and the IRSN analysis template:
    - To limit the input error
    - To reduce the check

- Statistical treatment by proficiency tests carried out with **Prolab™ Software** according to international standards **ISO 13528** and **ISO 28218**
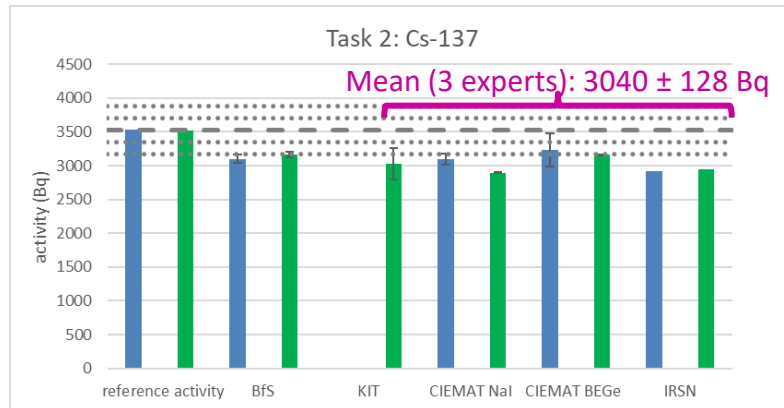
PROCESS OF DATA EVALUATION (2/2)

Assigned value (ISO 13 528):

There are many options to determine the assigned values, as example used of:
- ✓ The reference value of the certificate

- ✓ The consensus value from expert laboratories (arithmetic mean)

- Only 3 experts laboratories : KIT, CIEMAT and IRSN

- **Task 1, 2 and 4** : measurements performed by 3 experts

- **Task 3**: nuclear medicine (*short half-life radionuclide*), measurement performed by **1 expert** (CIEMAT)

- ✓ The consensus value from participant results (determined with robust method)

Lot of data : 41 facilities

The robust mean was used to guarantee a **homogeneous analyze** between tasks.

| Task 2– Emergency	^{137}Cs
Reference value (BFS)	3225 ± 42
Robust mean	2996.18 ± 60.40
Difference (%)	-7.09%

STATISTICAL TREATMENT

Bias (ISO 28 218) :

According to the recommendations of **ISO 28218** "Performance criteria for radiobioassay", the **relative bias** statistic shall be **between [-25% to +50%]** relative to the target value. The relative bias statistic is defined as:

$$Bias(\%) = \frac{a - A}{A} \times 100$$

a: Result of the participating facility
A: Activity of the assigned value
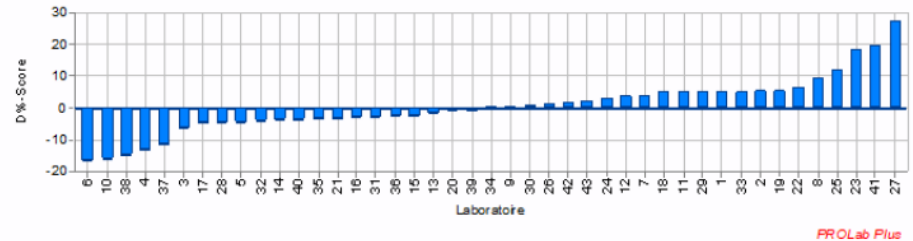
Statistic test on the distribution of results: the research of **outliers** (Grubbs test)

Z-score (ISO 13 528):

The Z-score is **an indicator of the laboratory proficiency** compared to that of the other laboratories.

According to the recommendations of ISO 13528 "Statistical methods for use in proficiency testing by intercomparison", the current Z-score criteria are:

✓ $|Zscore| \le 2$: the result is acceptable;
✓ $2 < |Zscore| \le 3$: The result give a warning signal;
✓ $|Zscore| > 3$: The result give an action signal.
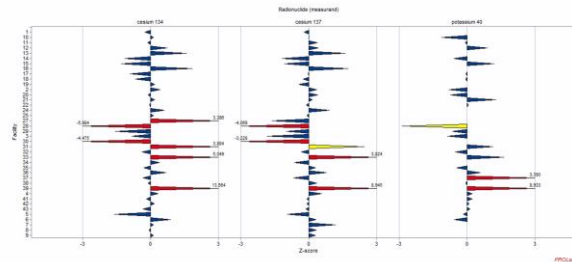
The Z-score depends **directly on the dispersion of the results from the laboratories.**

EXAMPLES OF RESULTS

RESULTS

TASK 2 : EMERGENCY

^{134}Cs, ^{137}Cs, ^{40}K

P5 90KG

RESULTS – RAW DATA OF PARTICIPANTS

Assigned value (ISO 13 528):

Number of facilities reporting results: 40
Statistic robust method: Q/Hampel

$$^{137}Cs$$

Task: : Emergency phantom 90 kg   Assigned value: 2996,181 Bq (empiric value)
Radionuclide: cesium 137   Limits (-25% - +50%): 2247,000 - 4494,000 Bq
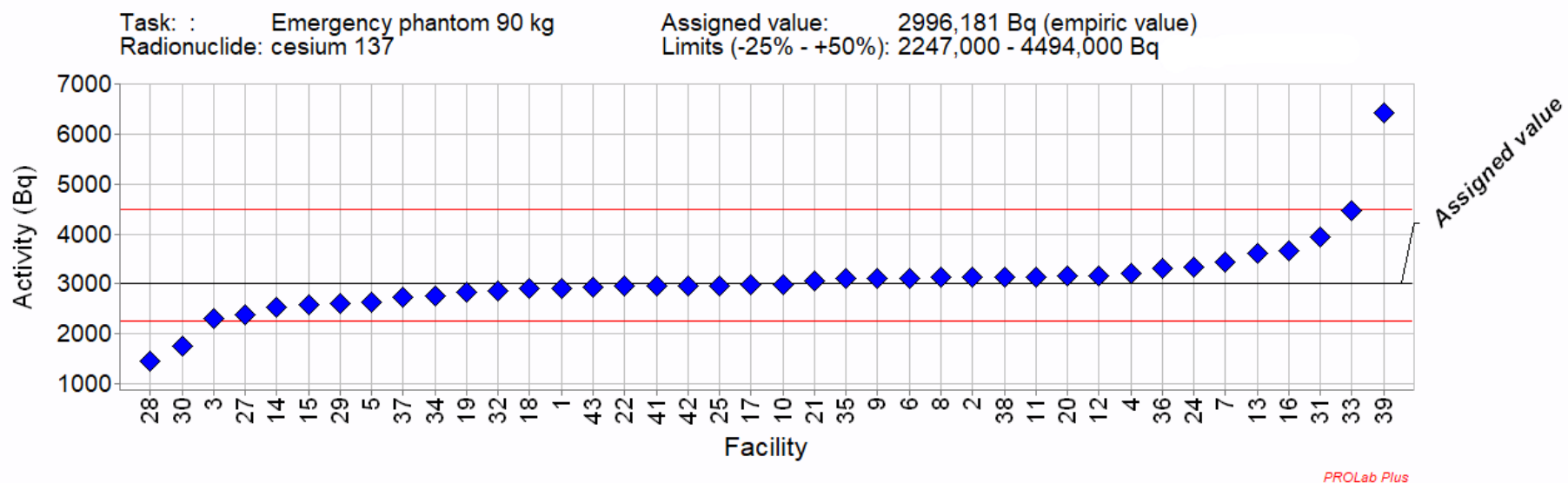
PROLab Plus

Task 2– Emergency	^{137}Cs
Reference value (BFS)	3225 ± 42
Robust mean	2996.18 ± 60.40
Difference (%)	-7.09%

RESULTS – BIAS

Bias (ISO 28 218) :

$$\left[\,^{137}\text{Cs} \, \right]$$

Task: :   Emergency phantom 90 kg   Assigned value: 2996,181 Bq (empiric value)
Radionuclide: cesium 137
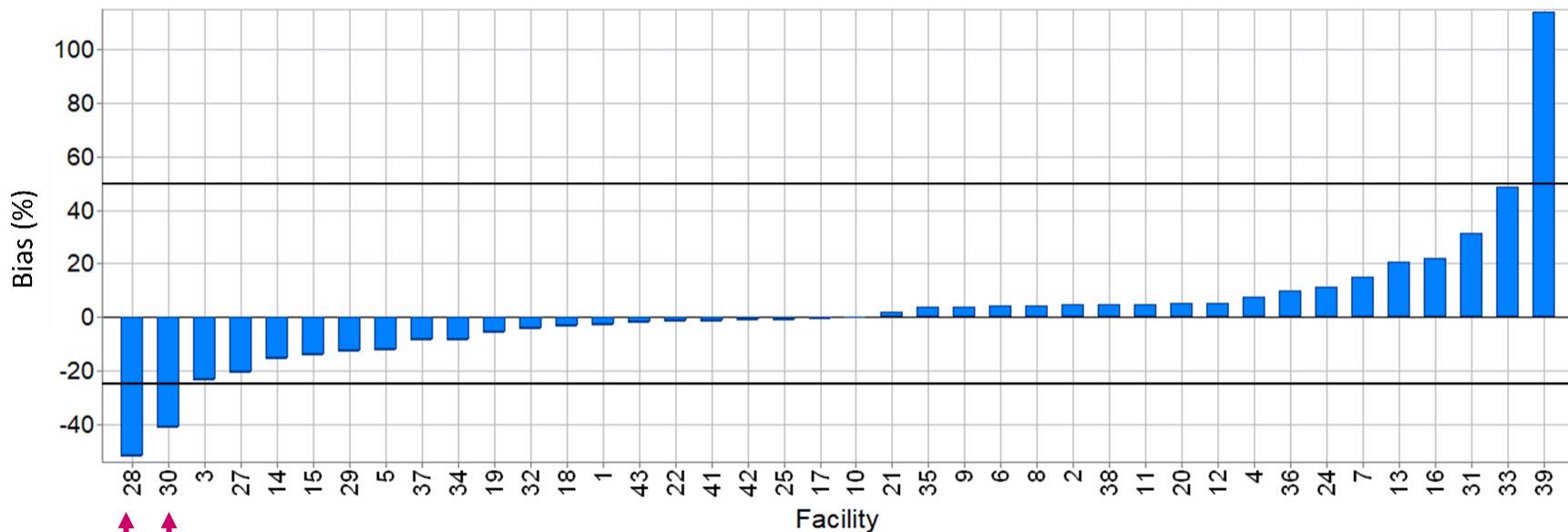
PROLab Plus

Id	^{137}Cs
28	-51.87%
30	-41.16%
39	114.04%

3 facilities [28, 30 and 39] *are in **nonconformity***
37 facilities** are **conform
*according to the **ISO 28 218 criteria** '[-25%:+50%]'*

RESULTS – Z-SCORE
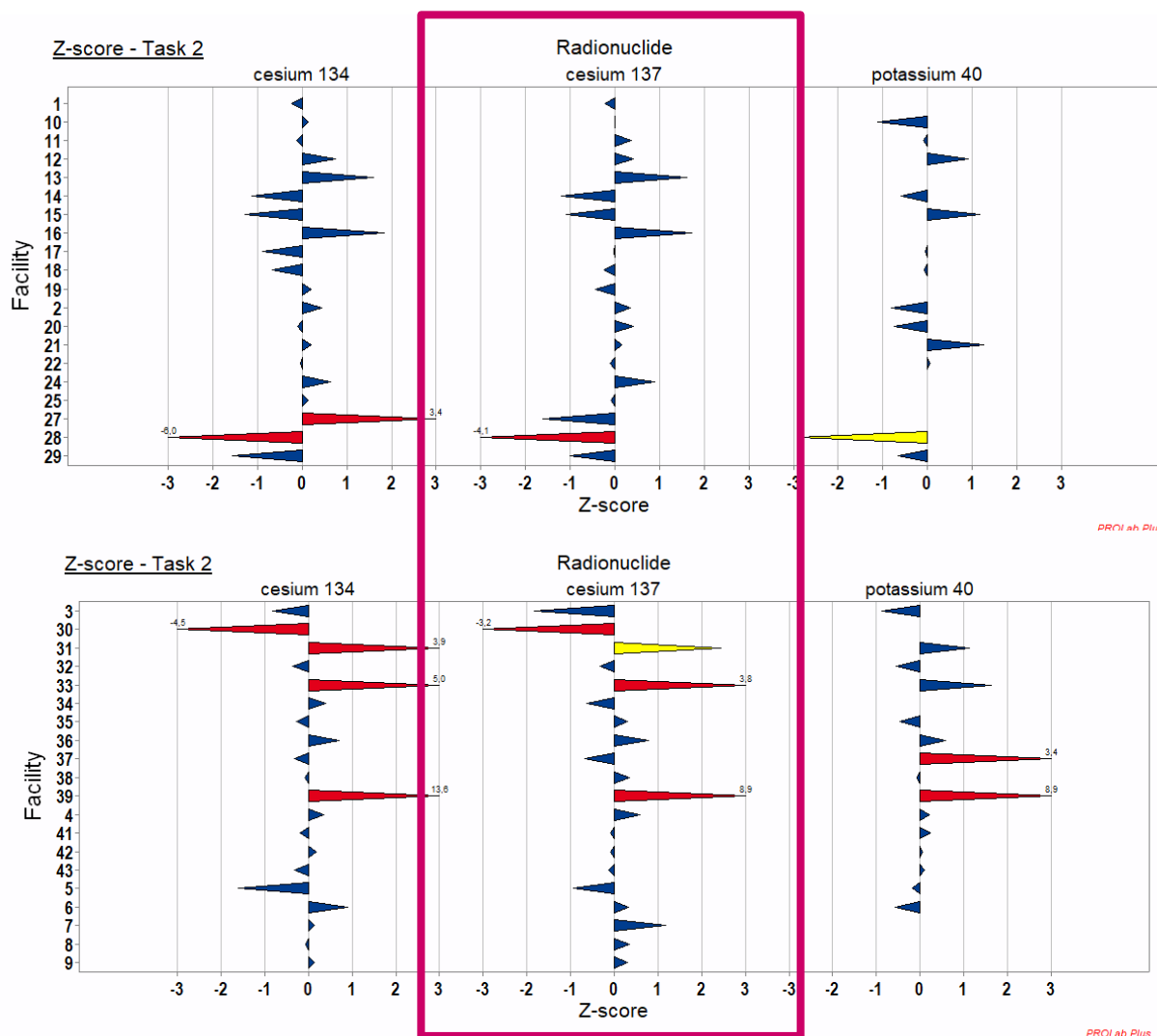
$|Zscore| \leq 2$: acceptable

$2 \leq |Zscore| \leq 3$: warning signal

$|Zscore| > 3$: action signal

The z-score was calculated and according to the Z-score criteria of ISO 13528, there are:

- ✓ ^{134}Cs:
  - ✓ *34 facilities 'acceptable'*
  - ✓ *6 'unacceptable'*
- ✓ ^{137}Cs:
  - ✓ *35 facilities 'acceptable', 1 'warning signal'*
  - ✓ *4 'unacceptable'*
- ✓ ^{40}K:
  - ✓ *25 facilities 'acceptable', 1 'warning signal'*
  - ✓ *2 'unacceptable'*

CONCLUSION ON THE RESULTS FOR THE TASK 2

Id	Task 2 - Emergency ISO 28 218	Task 2 - Emergency ISO 13 528
1	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
2	Conform	Acceptable
3	Conform	Acceptable
4	Conform	Acceptable
5	Conform	Acceptable
6	Conform	Acceptable
7	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
8	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
9	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
10	Conform	Acceptable
11	Conform	Acceptable
12	Conform	Acceptable
13	Conform	Acceptable
14	Conform	Acceptable
15	Conform	Acceptable
16	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
17	Conform	Acceptable
18	Conform	Acceptable
19	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
20	Conform	Acceptable
21	Conform	Acceptable
22	Conform	Acceptable
23	-	-
24	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
25	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)

Id	Task 2 - Emergency ISO 28 218	Task 2 - Emergency ISO 13 528
26	-	-
27	Conform ($^{134}Cs/^{137}Cs$)	Acceptable (^{137}Cs)
		Action signal (^{134}Cs)
28	Not conform ($^{134}Cs/^{137}Cs/^{40}K$)	Warning signal (^{40}K)
		Action signal ($^{134}Cs/^{137}Cs$)
29	Conform	Acceptable
30	Not conform ($^{134}Cs/^{137}Cs$)	Action signal ($^{134}Cs/^{137}Cs$)
31	Conform	Warning signal (^{137}Cs)
		Action signal (^{134}Cs)
32	Conform	Acceptable
33	Conform	Acceptable (^{40}K)
		Action signal ($^{134}Cs/^{137}Cs$)
34	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
35	Conform	Acceptable
36	Conform	Acceptable
37	Conform ($^{134}Cs/^{137}Cs$)	Acceptable ($^{134}Cs/^{137}Cs$)
	Not conform (^{40}K)	Action signal (^{40}K)
38	Conform	Acceptable
39	Not conform ($^{134}Cs/^{137}Cs/^{40}K$)	Action signal ($^{134}Cs/^{137}Cs/^{40}K$)
40	-	-
41	Conform	Acceptable
42	Conform	Acceptable
43	Conform	Acceptable

The tolerance intervals are **more restrictive** according to **ISO 13528 (bias)** than to **ISO 28218 (Z-score)**

STATISTICAL TESTS (1/3)

STATISTICAL TESTS REGARDING INFLUENCING PARAMETERS

Measurements not carried out under equal conditions and with equal installations :

- Detection system : NaI(Tl) or HPGe detector
- Type of participation: attended tour or shipment
- Type of calibration phantom : more or less realistic phantom
- Calibration curves (70 kg systematic or adapted)

- Measurement geometry: sitting, lying or standing.
- Duration of the measurement
- Detector-subject distances

Statistical tests were performed using R software and regarding:

✓ The central tendency:
Mann-Whitney U test "Do values A tend to be greater or smaller than values B?"

✓ The dispersion:
Siegel-Tukey test "Do values A tend to be more or less dispersed than values B?"

✓ <u>Data used</u>: **all reported z-scores** (except outliers) from all **tasks (1-4)** that involved phantoms

STATISTICAL TESTS (2/3)

## MEASUREMENT OF A 90 KG PHANTOM WITH A 70 KG CALIBRATION CURVE

Task 2 '**Emergency**' used a phantom of **90 kg**

Two calibration methods:
- 70 kg calibration curve applied systematically for measuring all sizes of people and phantoms
- Adapted calibration curves applied for measuring

Results:
- Significantly different when the 70kg calibration curve is systematically used. (p=2,5E-4)
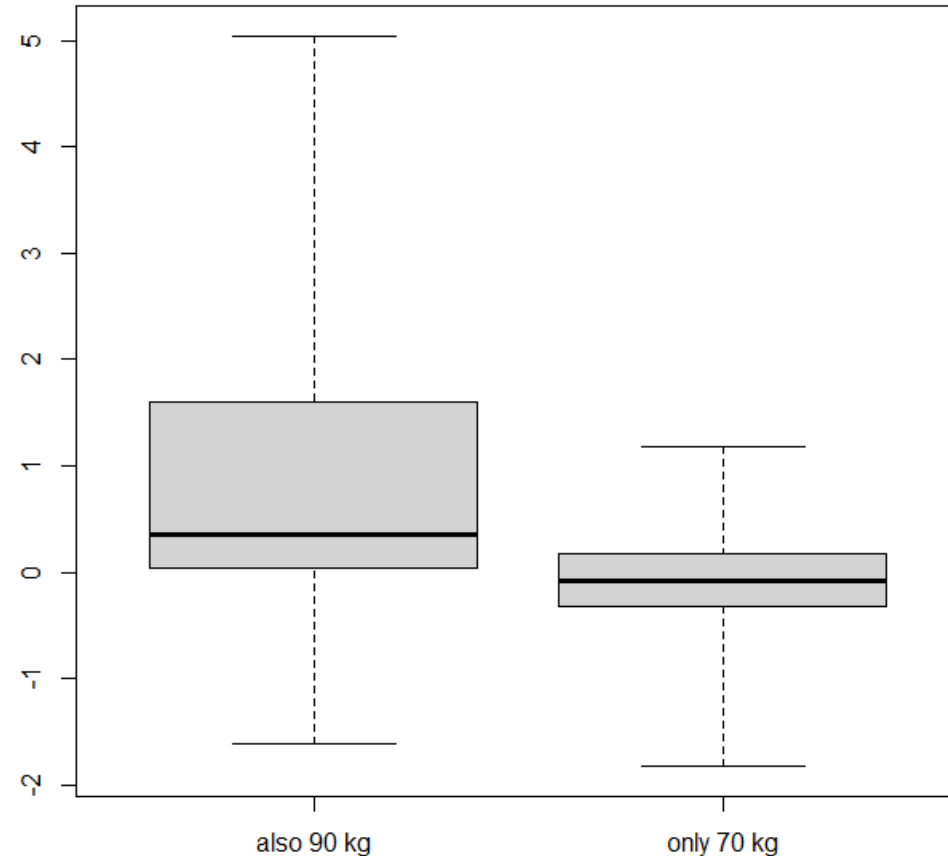
Z-score discriminated according to the phantom masses for calibration measurements (data of Task 2 'Emergency')

STATISTICAL TESTS (3/3)

TYPE OF CALIBRATION PHANTOM

Bottle phantom vs. brick phantom:

- Similar results with the central tendency (p-value 0,59)
- Different results with the dispersion (p-value 9,3E-4)

Results:

- with the **Canberra phantom** tended to be **underestimated** (p-value 3,5E-4)
- with **own phantoms** tended to be **overestimated** (p-value 6,3E-4)

→ Small dispersion : different makeups of these phantoms
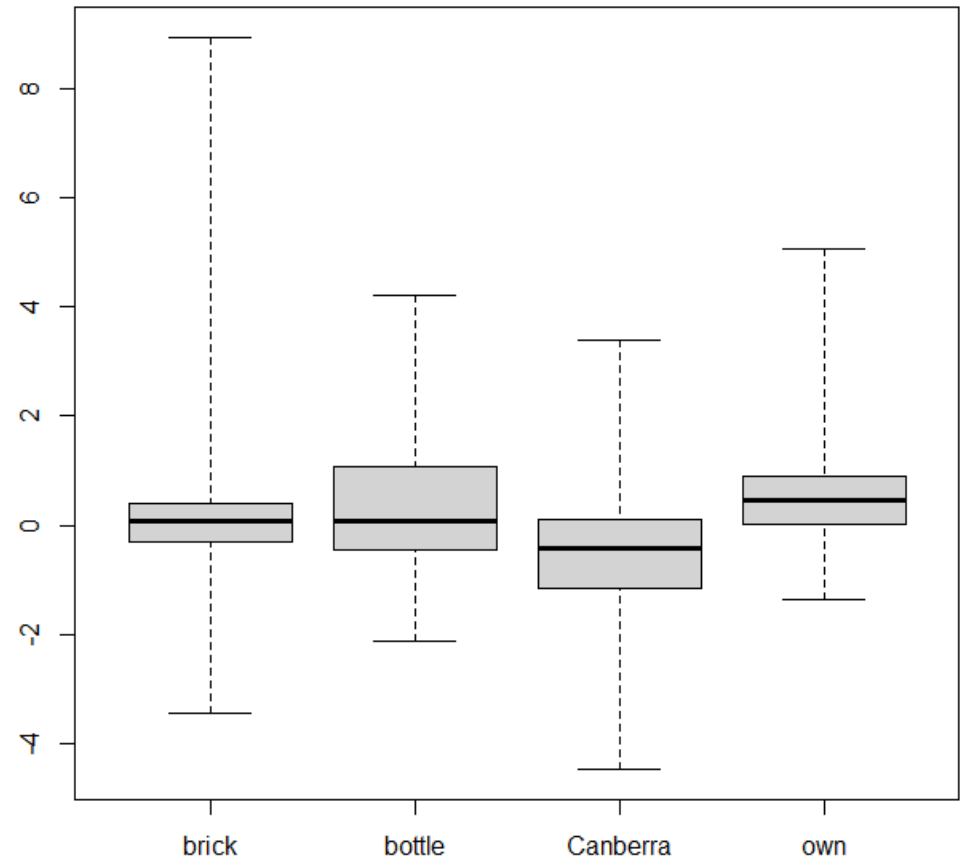
Z-score discriminated according to the type of calibration phantom (all data)

ERRATUM : TASK 3 MEDICINE #1 & #2

RESULTS

TASK 3 : MEDICINE #1

$^{68}Ge/^{68}Ga$, ^{88}Y, ^{40}K

P4 70KG

FACILITY NUMBER : 1, 3, 4, 5 ,6 , 8, 10, 13, 17, 22, 25, 30, 32, 34, 37, 38, 41, 42, 43

4 facilities [3, 6, 10 and 17] move from Task 3.1 to Task 3.2

RESULTS

TASK 3 : MEDICINE #2

$^{68}Ge/^{68}Ga$, ^{88}Y, ^{40}K

P4 70KG

FACILITY NUMBER : 2, 7, 9, 11, 12, 14, 18, 19, 20, 21, 24, 27, 28, 29, 31, 33, 35, 36 AND 39

ERRATUM : TASK 3 MEDICINE #1 & #2

Results

Task 3.1 – Medicine		Ga-68	Y-88	K40
NEW ANALYSIS	Assigned Value (Bq)	3741	4707	3862
	Uncertainty (Bq)	114	163	127
PREVIOUS ANALYSIS	Assigned Value (Bq)	3741	4852	3812
	Uncertainty (Bq)	114	194	127
$|\delta|$ (%) assigned value		-	**3.1**	**1.3**

- Differences are acceptable : 3.1% and 1.3%.
- Bias and z-score values slightly changed for all facilities expect for:
  - idLab 32 (^{40}K): acceptable (z-score = -1.8) and now, warning signal (z-score = -2.2).

Task 3.2 – Medicine		Ga-68	Y-88	K40
NEW ANALYSIS	Assigned Value (Bq)	4219	4263	4163
	Uncertainty (Bq)	151	127	201
PREVIOUS ANALYSIS	Assigned Value (Bq)	4219	4283	4313
	Uncertainty (Bq)	151	171	210
$|\delta|$ (%) assigned value		-	**0.5**	**3.6**

- Differences are acceptable : 0.5% and 3.6%.
- **4 facilities** [3 (^{88}Y, ^{40}K); 6 (^{88}Y, ^{40}K), 10 (^{40}K) and 17 (^{88}Y, ^{40}K)] are **now conform** (bias) and **acceptable** (z-score).
- Bias and z-score values slightly changed for all facilities expect for:
  - idLab28 (^{88}Y) : warning signal (2.7) and now, action signal (z-score=3.5)
  - idLab14 (^{40}K) : warning signal (-2.1) and now it is acceptable (z-score=-1.8)
  - idLab39 (^{40}K) : conform (+47.2%) and now it is not conform (bias = +52.5%)

ERRATUM : TASK 3 MEDICINE #1 & #2

- **Publications and communications on the Project take account these modifications:**

  o Pubishable Reports (EURADOS and RP Report)

    https://eurados.sckcen.be/news-overview/eurados-report-2023-03-published-eivic-2020-european-vivo-intercomparison-exercise-2020-organisation-european-interlaboratory-comparison-whole-body-counting

  o Journal(s)/conference(s):

    o Franck et al, Radiat Environ Biophys submitted,

    o Beaumont et al., IRPA (2024)

- **<u>Erratum</u> of participation certificates <u>for Task 3</u>** will be sent **next week**

GENERAL CONCLUSION

✓ **Objective**: to assess the implementation of the individual monitoring requirements in EU based on *in-vivo* measurements and receive an overview of the capabilities and performance of whole-body counters in Europe

✓ Measurements were carried out for **43 facilities** from 35 laboratories (+ European Commission and IAEA) and 21 countries (Only 2 facilities have not returned their results)

✓ Representing a very **important data base of European Laboratories** (5 exercises in 1 IC campaign)

✓ In general, there is a high participation:
  - ✓ **Task 1**: 40/41 facilities (^{137}Cs)
  - ✓ **Task 2** : 40/41 facilities (^{134}Cs)
  - ✓ **Task 3**: 17/41 facilities (^{68}Ga) more difficult because of not classical radionuclides.
  - ✓ **Task 4a**: 20/41 facilities (^{152}Eu), explain because this task was dedicated to germanium detector and not mandatory
  - ✓ **Task 4b**: 30/41 facilities (^{152}Eu), explain because this task was dedicated to germanium detector

GENERAL CONCLUSION

✓ The **analysis of results** was carried out and the **conformity report of the facilities** are given, for each configuration, according to the **criteria** of **ISO 28218** and **ISO 13 528**.

✓ **Results are quite good** (bias and z-score evaluation) and the most part of the facilities are conform according to the standards

✓ The EIVIC team could discuss with the laboratories in nonconformity to identify the sources of error

✓ Statistical tests were performed to test if they had a significant influence of the measurement parameters:
  ✓ Surprisingly the results are quite similar for all the laboratories,
  ✓ except for the phantom-size dependency, size-dependent calibration factors should be used.

✓ Erratum of participation certificates for Task 3 will be sent next week.

Thank you for your attention