POLITECNICO
MILANO 1863

Intercomparison results – part II

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

Summary

1. Radon exposure values
   - REF
   - Youden plot
   - Mandel index
2. Z-score
3. Normalized error E_n
4. Some special cases
5. Conclusions

References

Final report of Lurisia intercomparison

Intercomparison report:

- Spain (L. Gutierrez-Villanueva, International intercomparison exercise on natural radiation measurements under field conditions, 2012 and 2014);
- **BfS** - Germany (E. Foerster , Instruments to Measure Radon Activity concentration or Exposure to Radon – Interlaboratory Comparison 2012);
- **PHE** - UK (Z. Daraktchieva, Result of the 2013 PHE Intercomparison of Passive Radon Detectors).

ISO

- **ISO/IEC 17043**:2010. Conformity assessment - General requirements for proficiency testing;
- **ISO 13528**: 2005. Statistical methods for use in proficiency testing by interlaboratory comparisons.

Work hypothesis

3 values of devices exposed + 3 transit values

⬇

Transit mean

⬇

Net exposure = value – transit mean

⬇

Mean of net exposure

!!! Participant note !!!

Arithmetic mean and median

Exposure	Reference value	Mean	Median	Standard deviation
Exp 1	225±50	219	216	60
Exp 2	1731±152	1707	1690	446
Exp 3	516±85	590	510	315

REF

REF is the ratio between the mean of exposure ‹E› and the reference value E_R

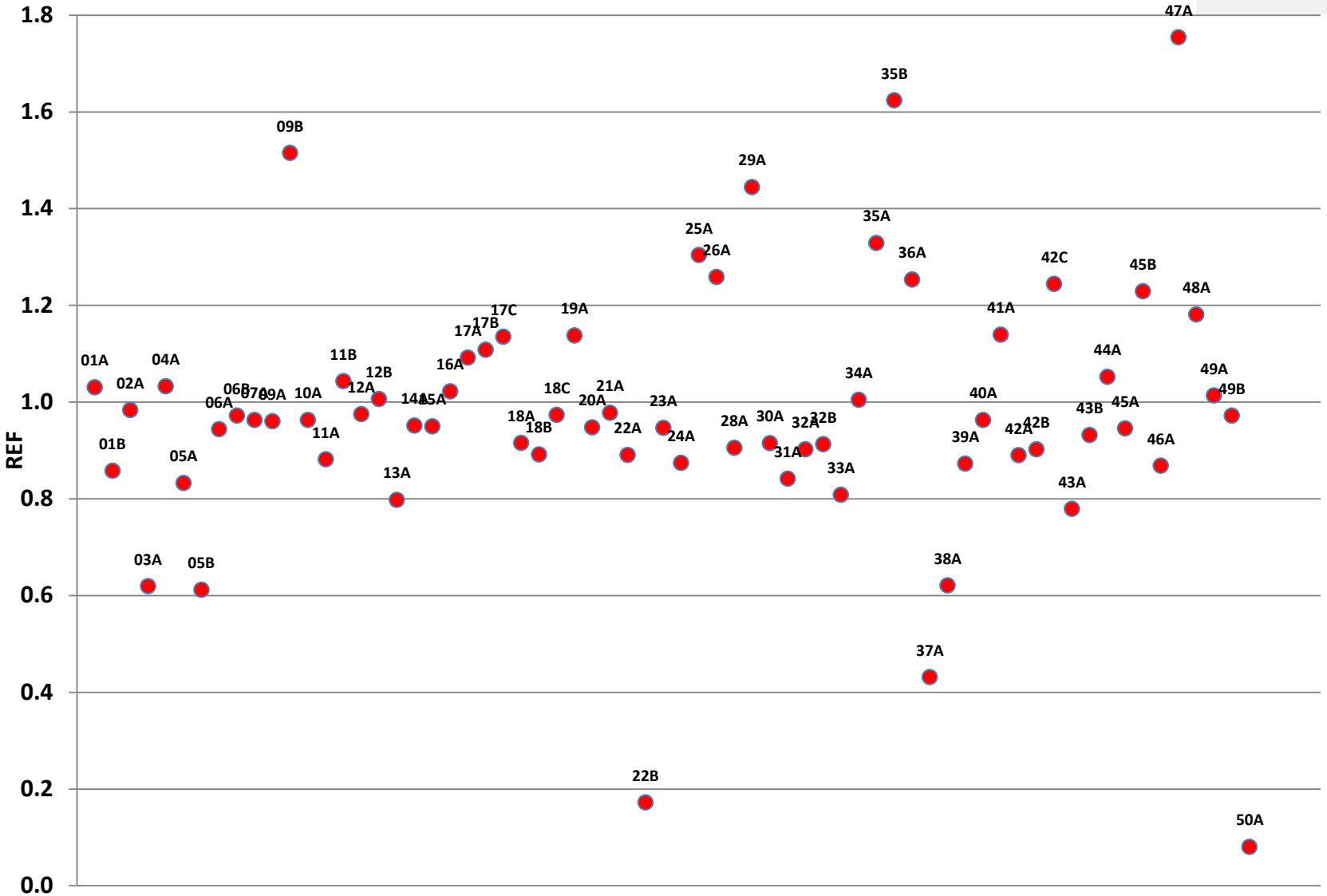
$$REF = \frac{\langle E \rangle}{E_R}$$

‹E› is the mean of the net exposures.

One value of ‹E› for each exposure.

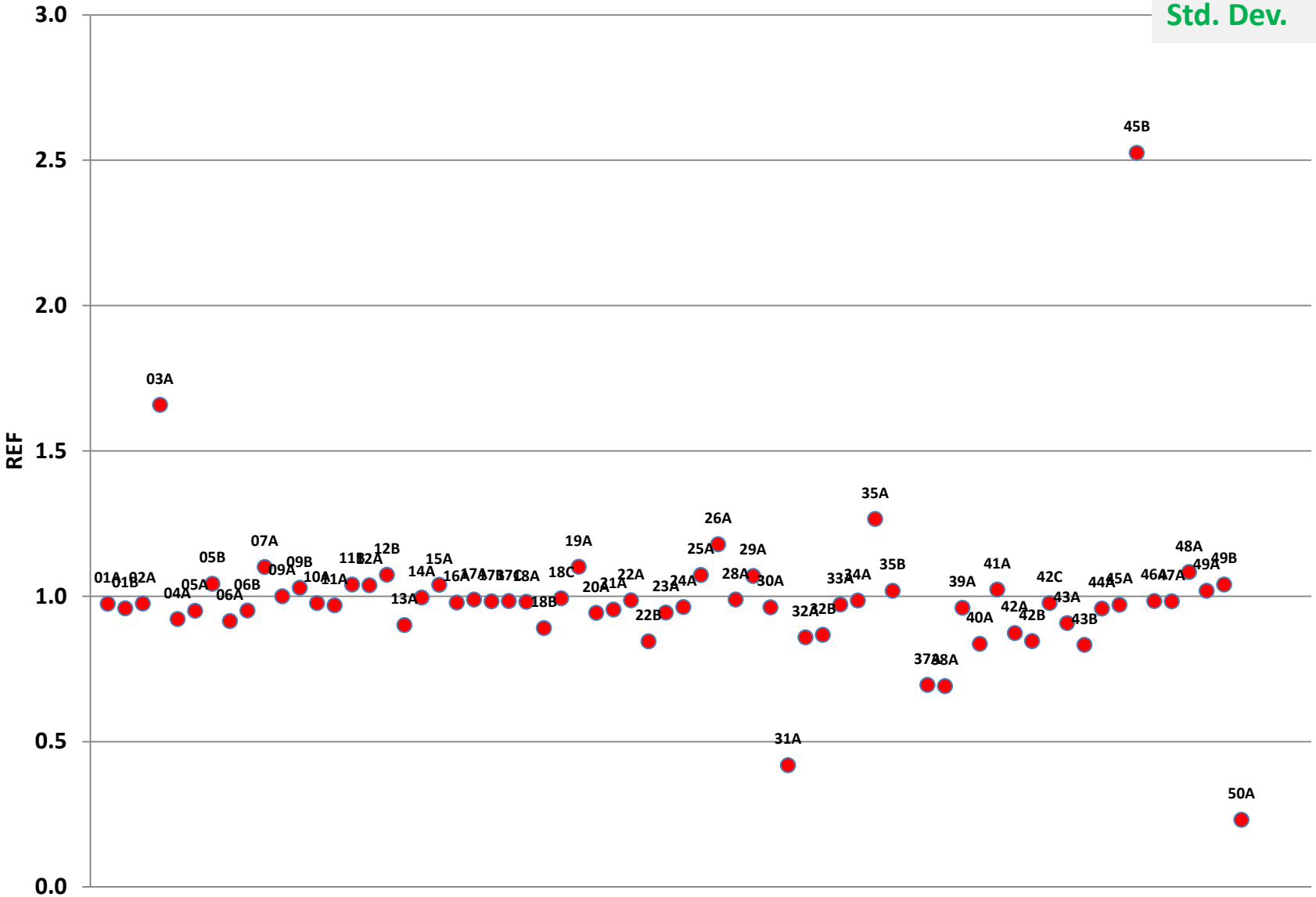
REF – Exposure 1 – Office on the ground floor

Mean	0.97
Median	0.96
Std. Dev.	0.27



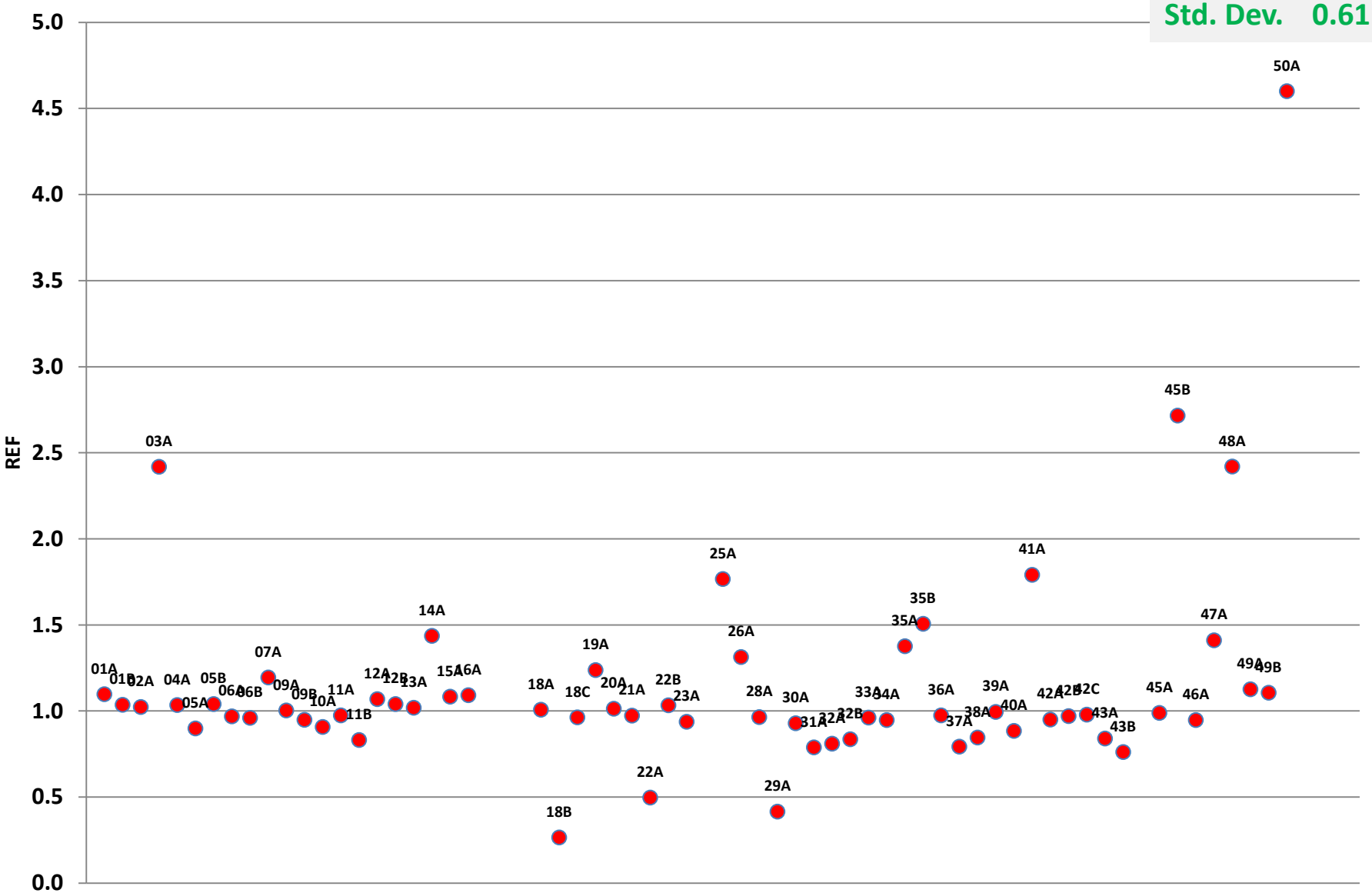
REF – Exposure 2 – Storage room on the basement

Mean	0.99
Median	0.98
Std. Dev.	0.26

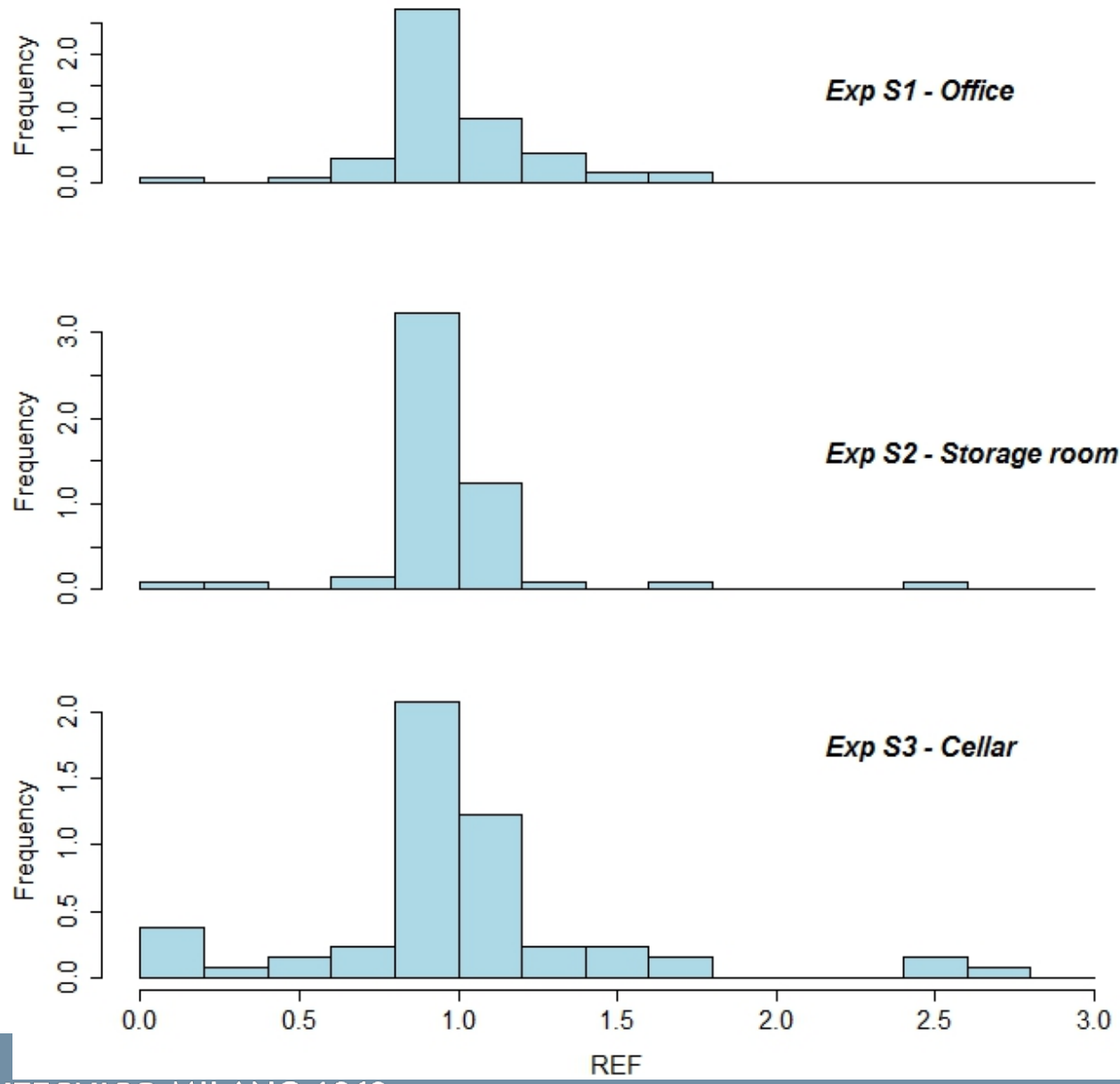


REF – Exposure 3 – Wine cellar on the basement

Mean	1.14
Median	0.99
Std. Dev.	0.61



REF – F


Frequency
0.0
1.0
2.0
Exp S1 - Office
Frequency
0.0
1.0
2.0
3.0
Exp S2 - Storage room
Frequency
0.0
0.5
1.0
1.5
2.0
Exp S3 - Cellar
0.0
0.5
1.0
1.5
2.0
2.5
3.0
REF

REF

Exposure	N. Set	REF < 1	REF > 1	0.75 < REF < 1.25
Exp 1	66	42	24	52 (79%)
Exp 2	65	46	19	58 (89%)
Exp 3	61	32	29	47 (77%)

REF – Youden plot

In order to evaluate the performance of the labs, taking into account at the same time two exposures, it is possible to use the Youden plot.

With this technique, the performance of the laboratory is measured by the distance between a point, whose coordinate are given by the experimental values of the two exposures and the centre of a circle/ellipse.

In this plot, the distance from the bisector quantifies the relevance of the systematic errors.

REF – Youden plot

The area 0 is limited by a ellipse representing the 95% confidence interval: these data can therefore be considered acceptable.

The laboratories, whose values are outside the ellipse but are close to the bisector (areas 1 and 3 of the plot), show a good reproducibility but poor accuracy.

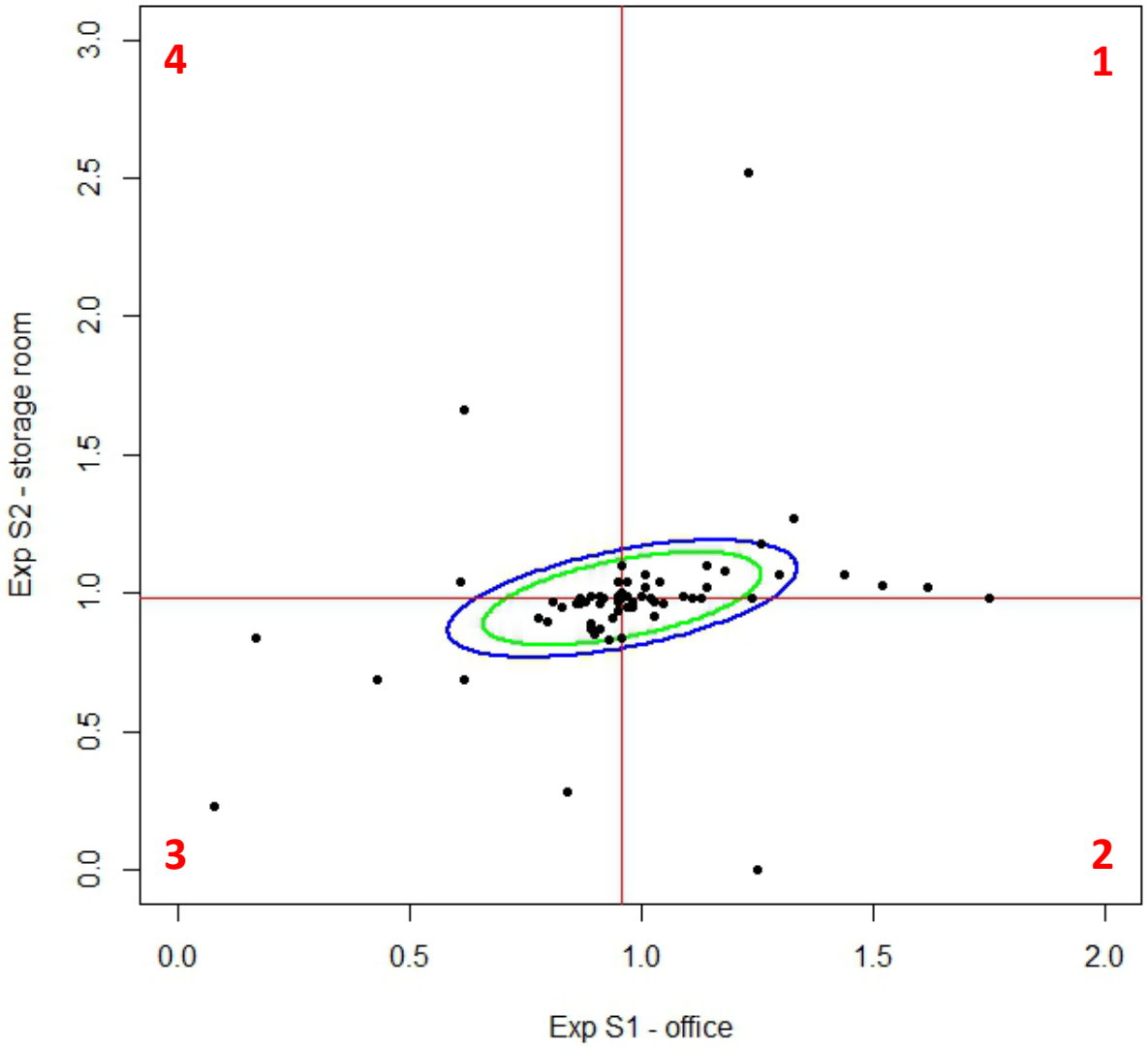
The laboratories in the areas 2 and 4 gave totally unacceptable data, having at the same time poor accuracy and poor reproducibility.

REF – Youden plot – REF 1 vs REF 2

79 % lie in the area inside the ellipse

21 % outside the ellipse: 5% in 2 and 4 areas

<u>Warning:</u>
1 value missing for exp 2

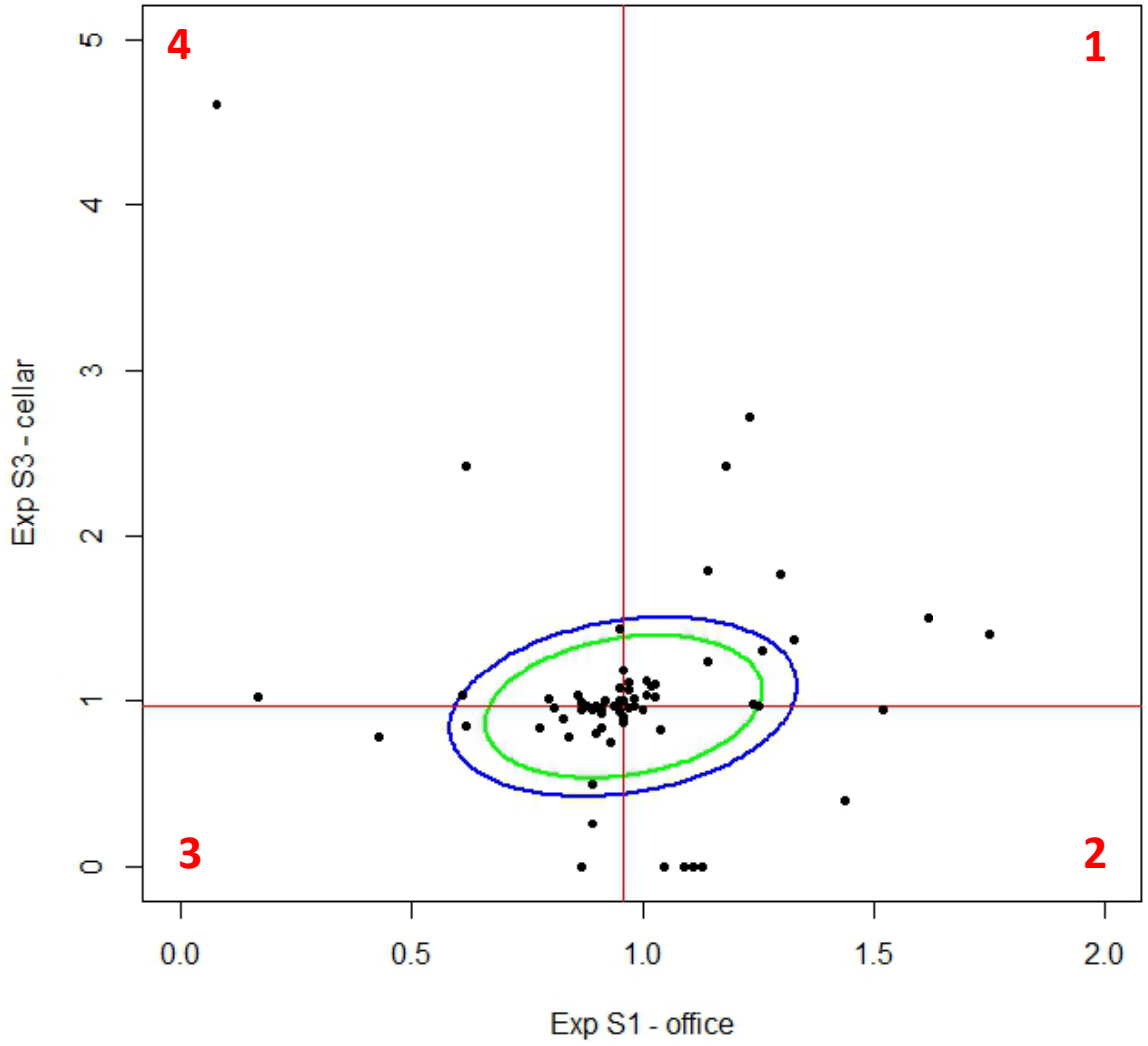


REF – Youden plot – REF 1 vs REF 3

71 % lie in the area inside the ellipse

29 % outside the ellipse: 14% in 2 and 4 areas

Warning:
5 value missing for exp 3

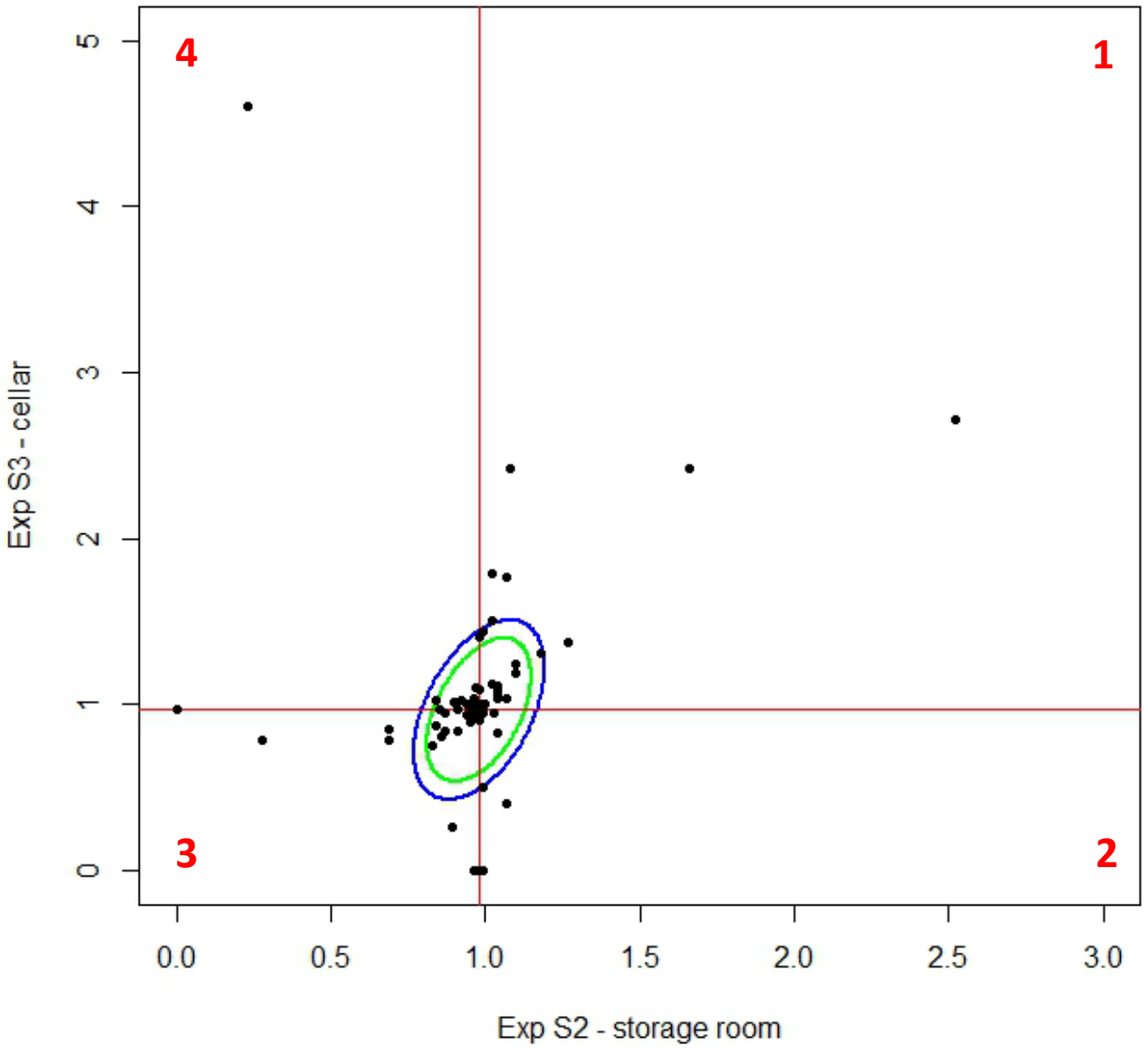


REF – Youden plot – REF 2 vs REF 3

73 % lie in the area inside the ellipse

27 % outside the ellipse: 3% in 2 and 4 areas

Warning:
5 value missing for exp 3 and 1 value for exp 2



REF – Mandel index *h*

The Mandel index *h* is a parameter used for the evaluation of the consistency between laboratories.

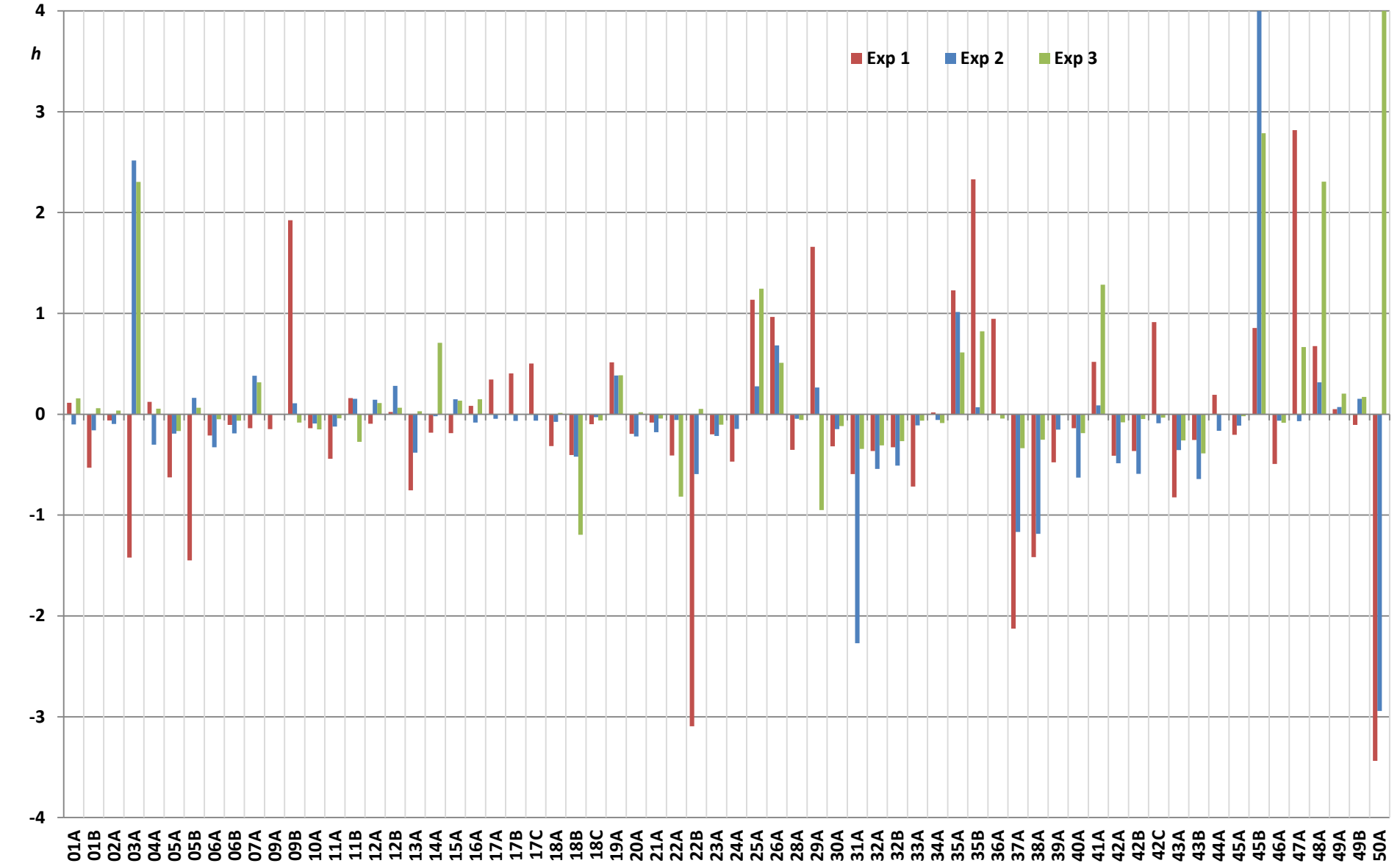
This index, is defined for the generic *j*-th laboratory, by the following formula:

$$h_j = \frac{\langle E \rangle_j - E_R}{S_{Ej}}$$

where S_{Ej} corresponds to the standard deviation for normally distributed data.

REF – Mandel index *h*

h (5%)=1.91 *h* (1%)= 2.45



Z - score

Z-score index is defined by the following equation:

$$z = \left(\langle E \rangle - E_R \right) / \sigma_R$$

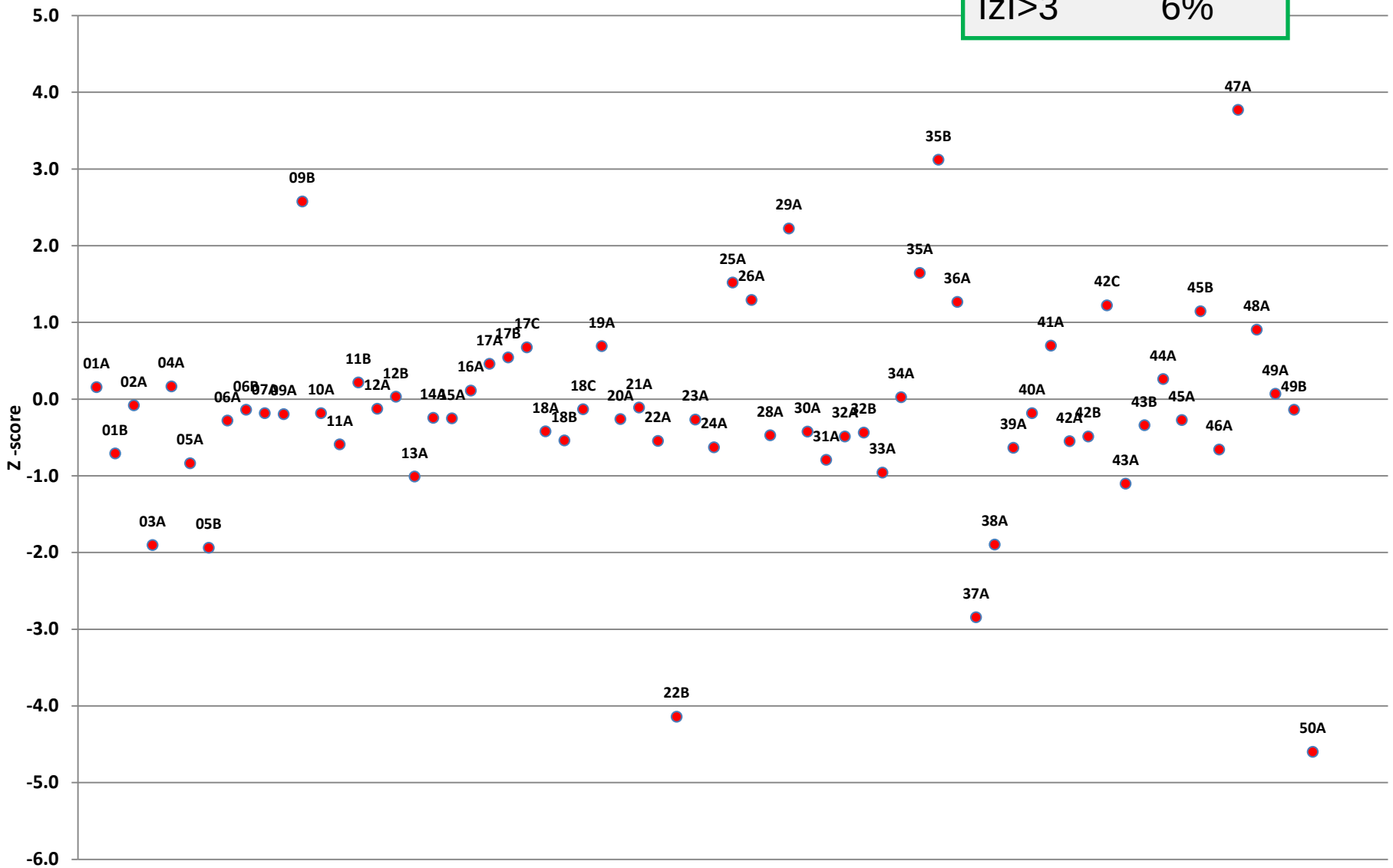
σ_R is the standard deviation for proficiency assessment:

in our case was set as 20% of the reference value.

According the ISO 13528:2005:
- Results with I *z* I <2 are considered acceptable
- Results with 2< I *z* I <3 are not completely acceptable
- Results with I *z* I > 3 are not acceptable

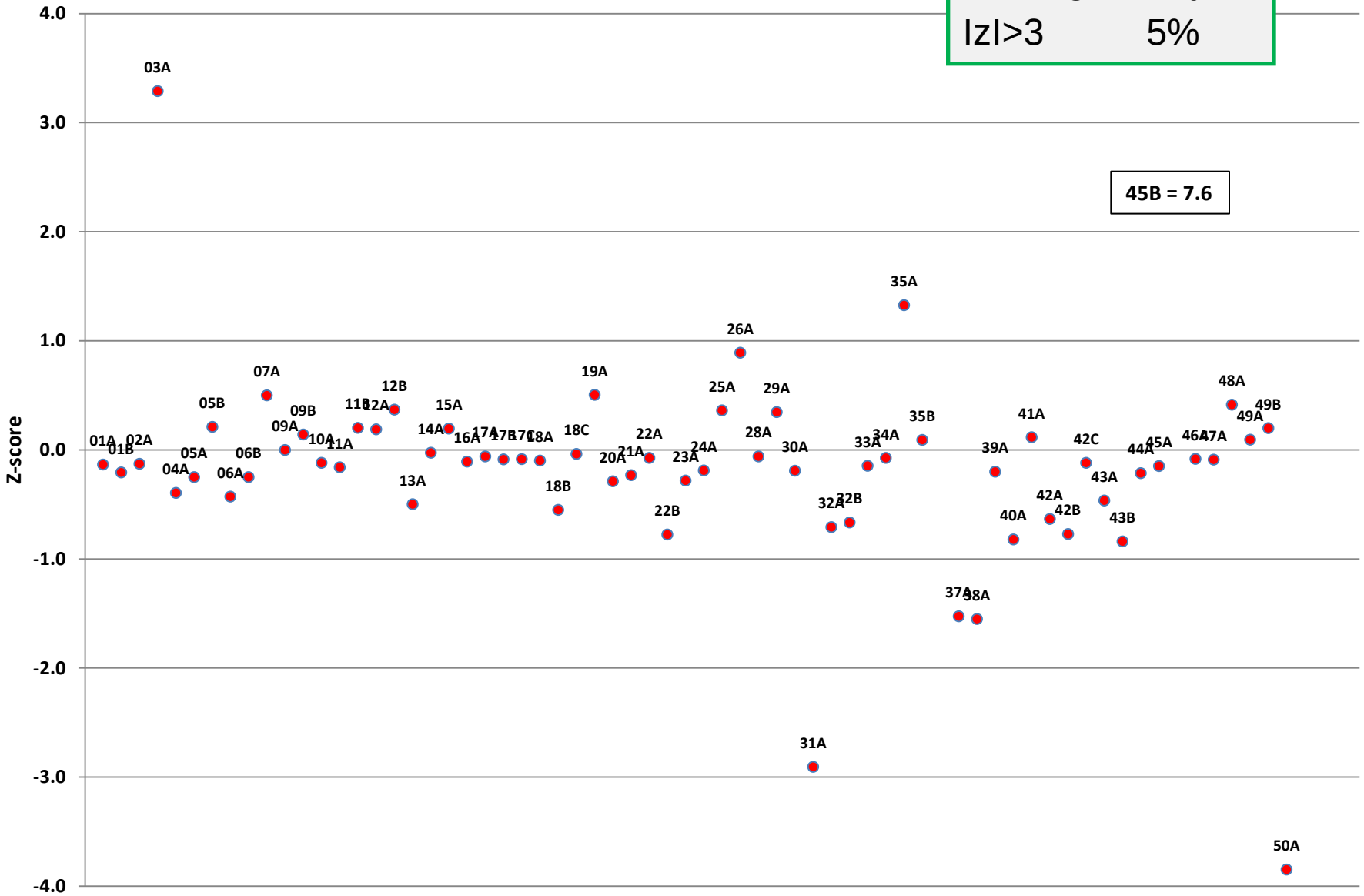
Z score – Exposure 1

|z|<2	89%
2<|z|<3	5%
|z|>3	6%



Z score – Exposure 2

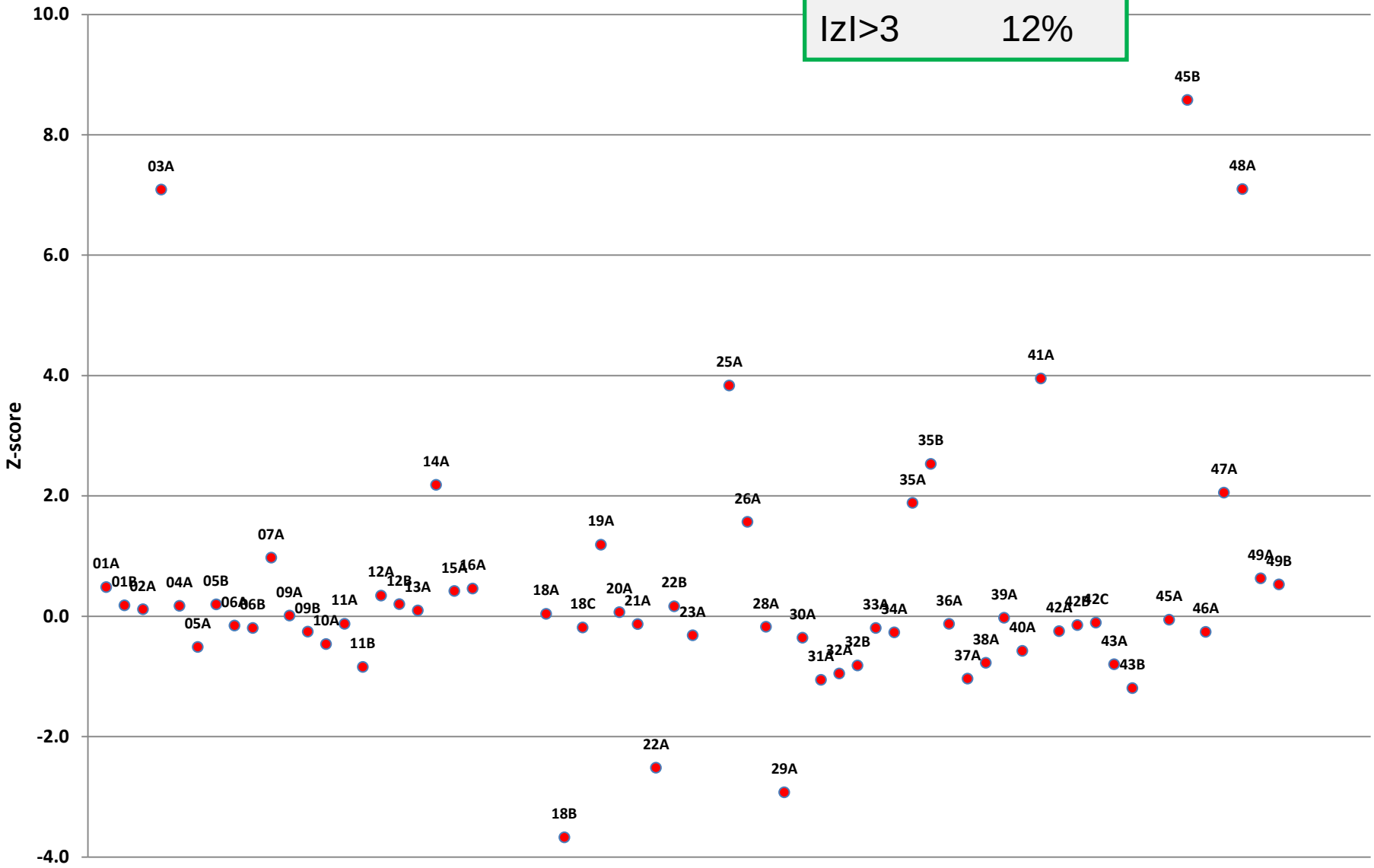
|z|<2	94%
2<|z|<3	2%
|z|>3	5%



Z score – Exposure 3

|z|<2	80%
2<|z|<3	8%
|z|>3	12%

50A = 18.0



Normalized error E_n

We use the normalized error to evaluate the laboratory ability to deliver a result close to the reference value, within the declared uncertainty.

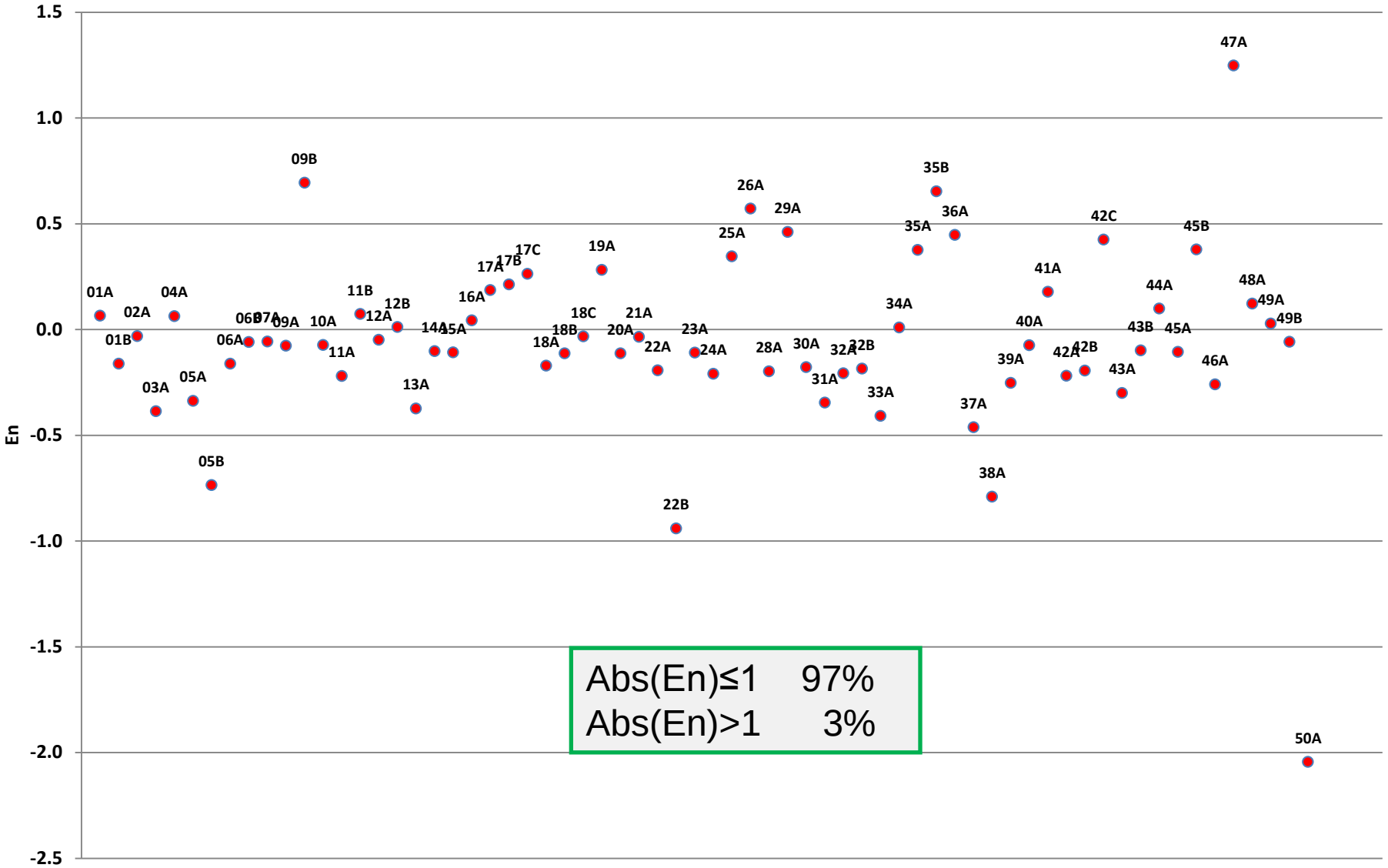
The normalized error is defined by the following equation:

$$E_n = \frac{\langle E \rangle - E_R}{\sqrt{U(E)^2 + U(E_R)^2}}$$

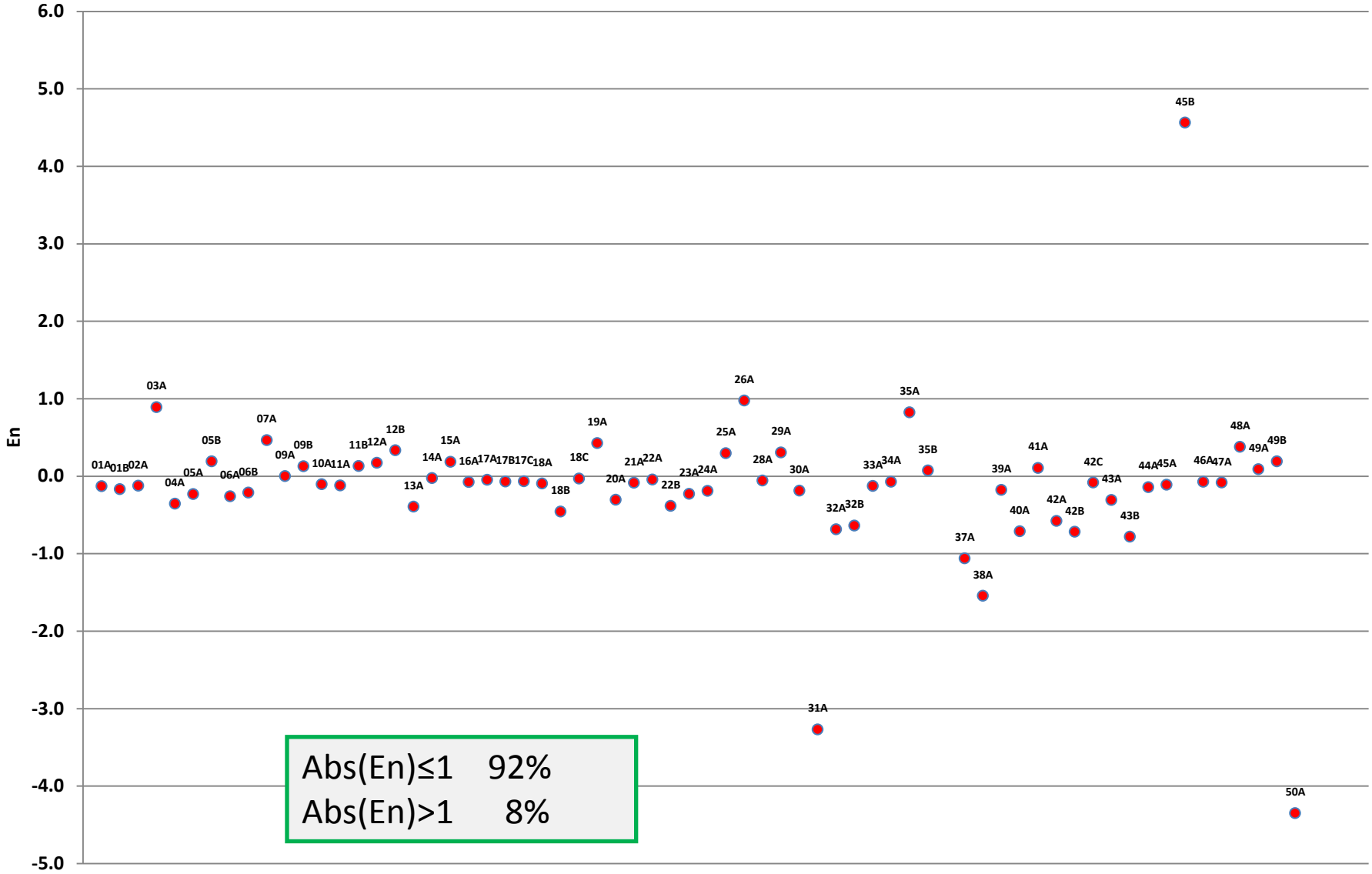
where U(E) is the laboratory uncertainty and $U(E_R)$ is the uncertainty of reference value.

For the normalized error E_n the acceptable values are those < 1 (absolute value).

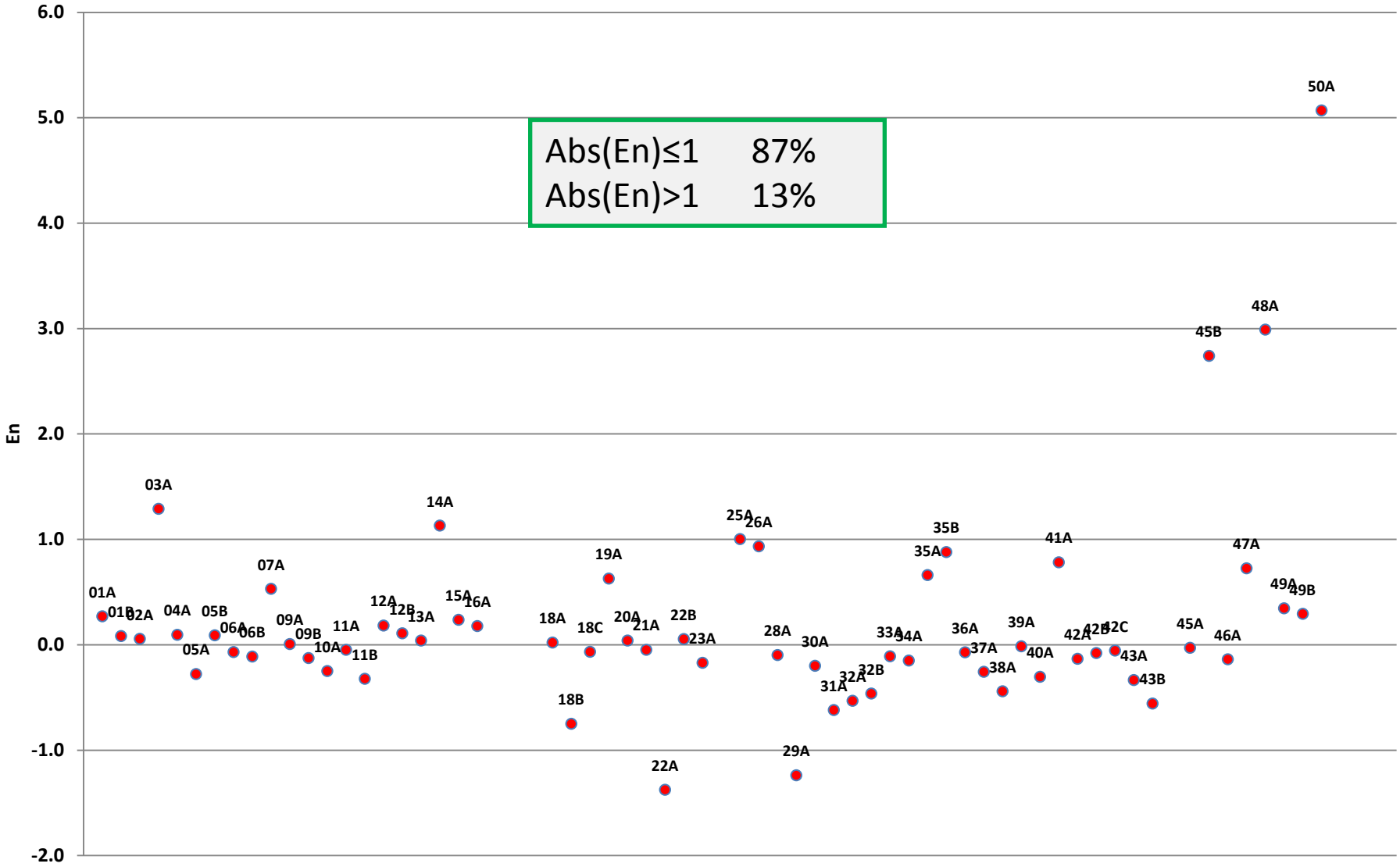
Normalized error E_n - Exposure 1



Normalized error E_n - Exposure 2



Normalized error E_n - Exposure 3



Box plot

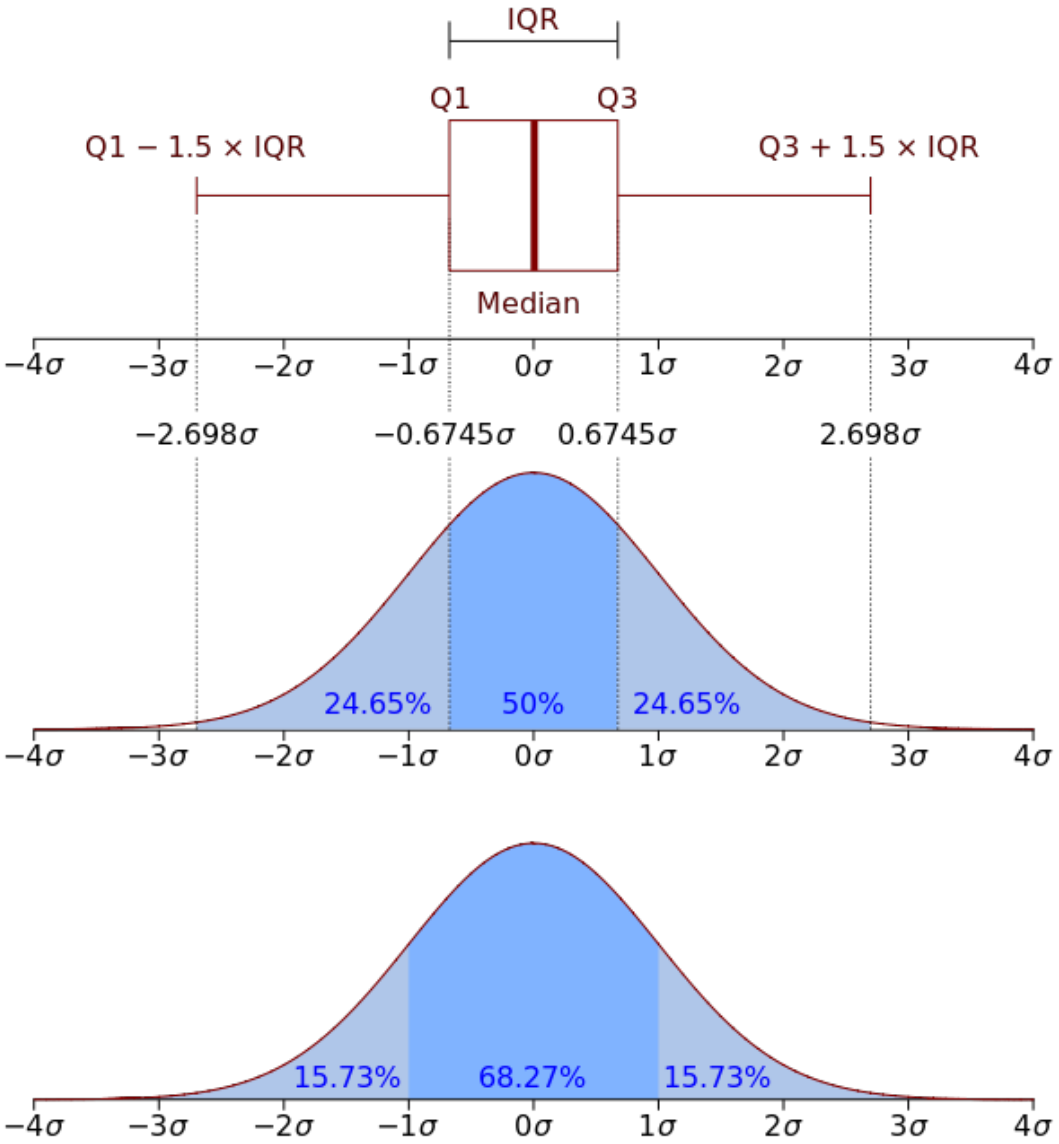
The box plot in descriptive statistics is used as a tool for representing graphically the distribution of the data by means of the quartiles.

The box contains the 50% of the data, being defined as the interquartile range IQR=Q3-Q1 (Q3 = 75° percentile; Q1= 25° percentile) and it is internally divided by the median.

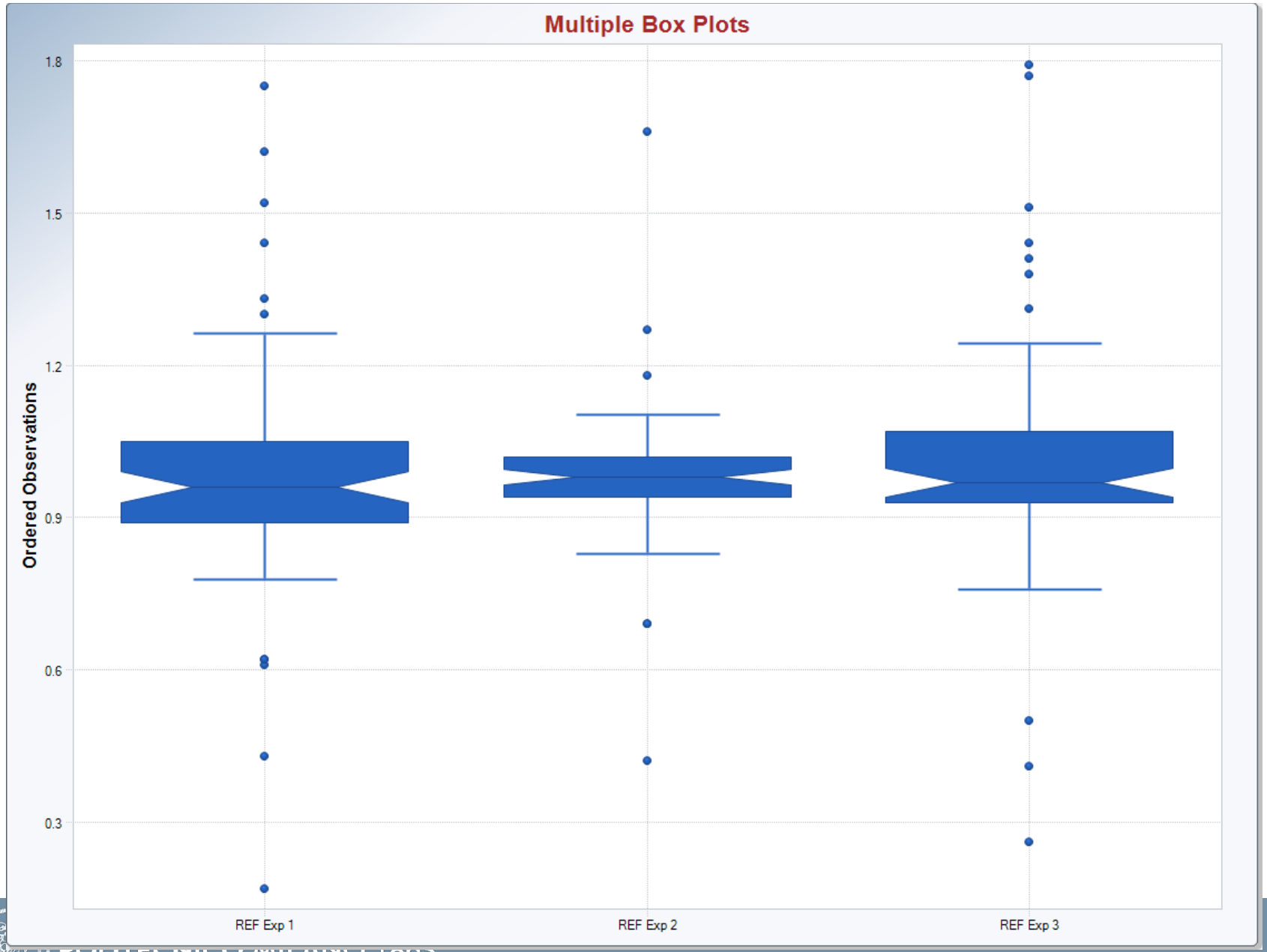
The two segments outside the box, called “whiskers” can be defined in many different ways: in our case, the lower whisker is defined as Q1-1.5·IQR, while the upper whisker is Q3+1.5·IQR.

In this way the box plot allows to graphically visualize the distribution of the data as well as the occurrence of some outliers, eventually displayed outside the whiskers.

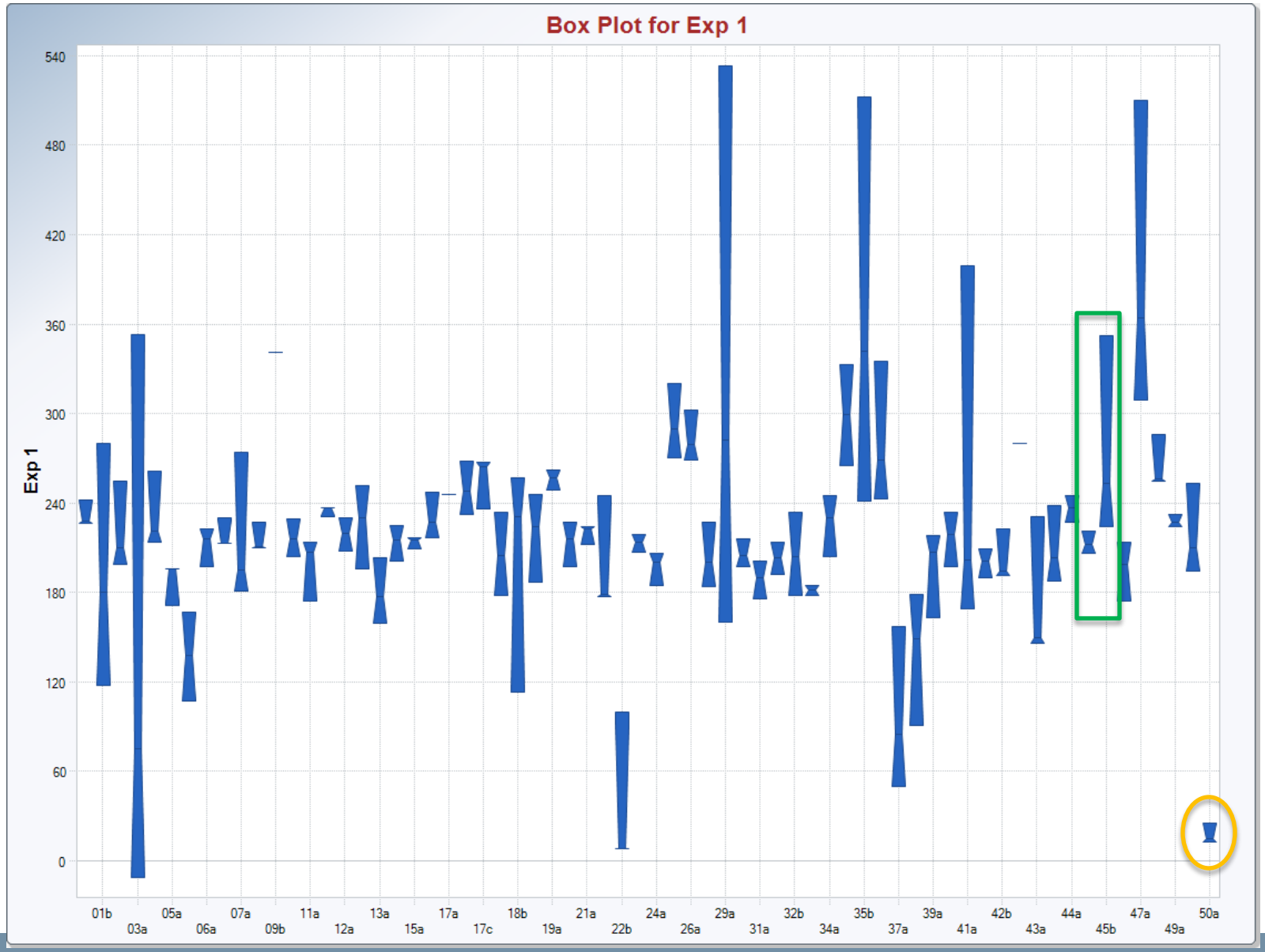
Box plot


IQR
Q1
Q3
Q1 − 1.5 × IQR
Q3 + 1.5 × IQR
Median
−4σ
−3σ
−2σ
−1σ
0σ
1σ
2σ
3σ
4σ
−2.698σ
−0.6745σ
0.6745σ
2.698σ
24.65%
50%
24.65%
15.73%
68.27%
15.73%

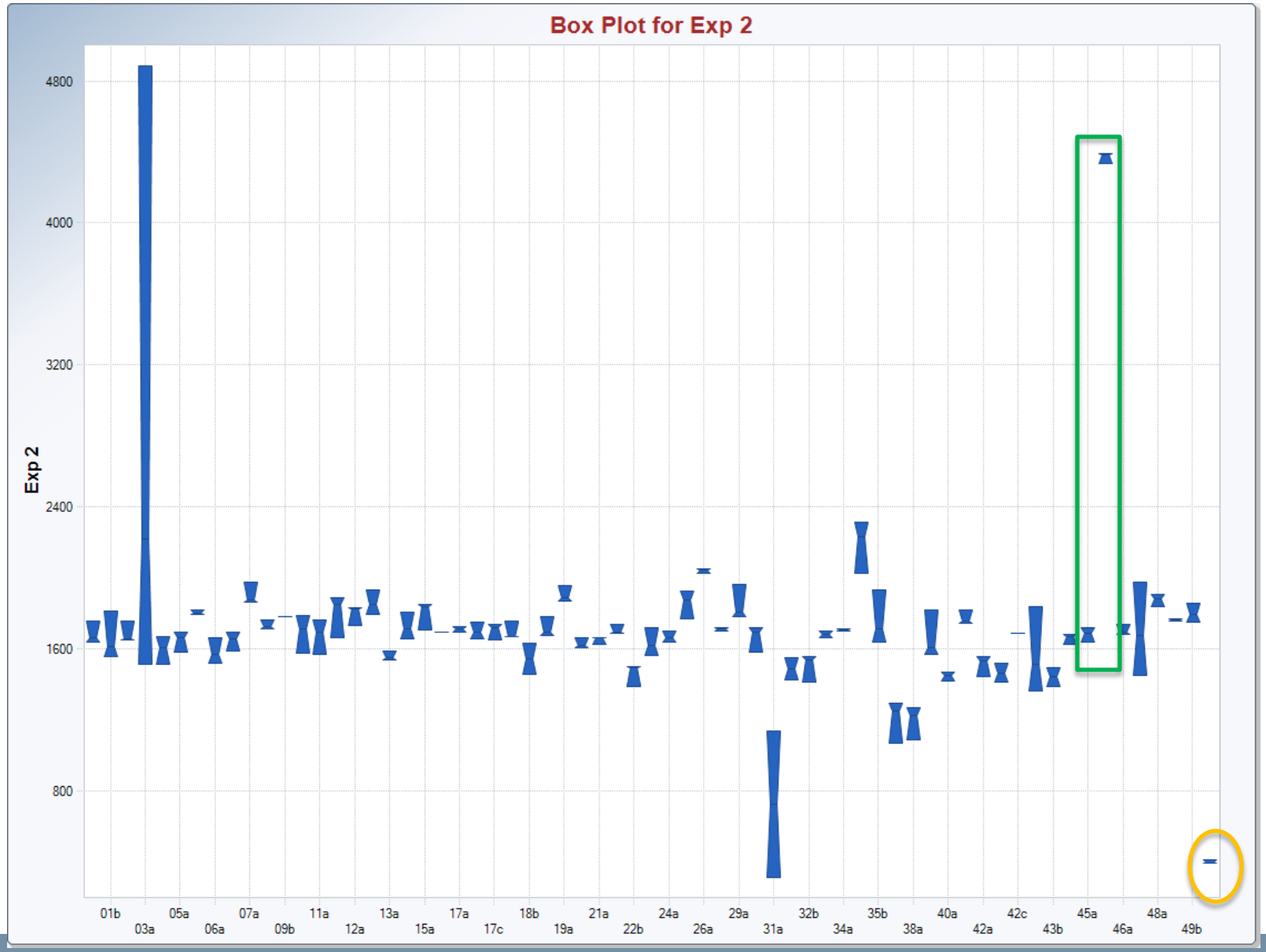
Box plot


Multiple Box Plots
Ordered Observations
1.8
1.5
1.2
0.9
0.6
0.3
REF Exp 1
REF Exp 2
REF Exp 3

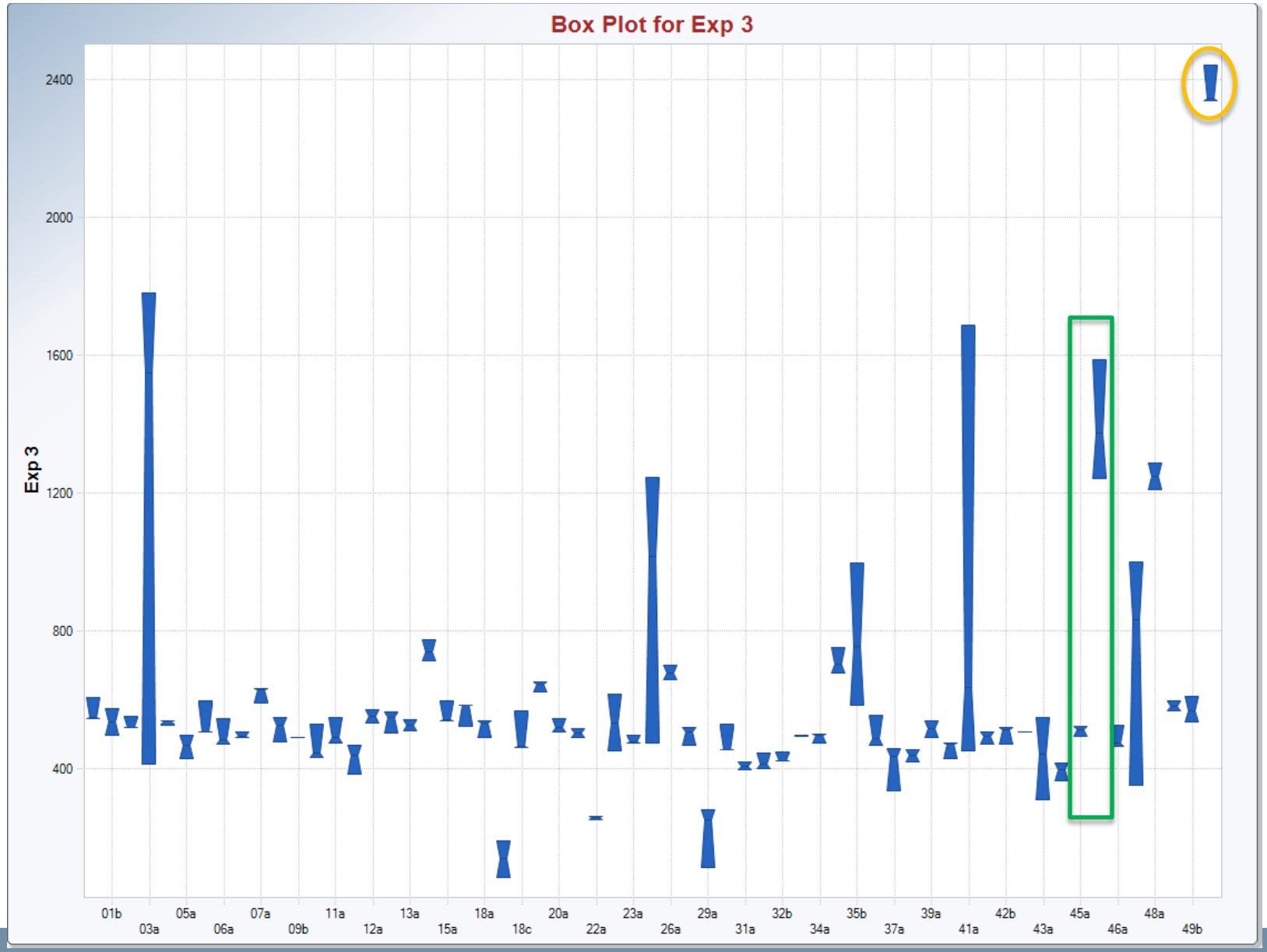
Box plot – Exposure 1



Box plot – Exposure 2



Box plot – Exposure 3



Some special case: transit of electrets

Set 18 B

Code	Exposure	Exp	Unc. exp	Unc. Exp %	Mean of exp.	Net exp.	Mean of net exp.
18B01	Rn - bassa	862	70	8.1%		231±92	**201±92**
18B02	Rn - bassa	888	71	8.0%		257±93	
18B03	Rn - bassa	744	66	8.9%		113±89	
18B04	TRn - bassa	1012	73.00	7.2%	631±60		
18B05	TRn - bassa	547	57.00	10.4%			
		333	51.00	15.3%			

Transit mean: 440±54

Mean of net exp.: 391±88

Transit mean: 780±69

Mean of net exp.: 52±95

Some special case: transit of electrets

Set 29 A

Transit mean: 442±45

Mean of net exp.: 221±70

Code	Exposure	Exp	Unc. exp	Unc. Exp %	Mean of exp.	Net exp.	Mean of net exp.
29A01	Rn - bassa	602	52	8.6%		160±69	**325±73**
29A02	Rn - bassa	975	63	6.5%		533±78	
29A03	Rn - bassa	724	55	7.6%		282±71	
29A04	TRn - bassa	377	44	11.7%	442±45		
29A05	TRn - bassa	569	48	8.4%			
29A06	TRn - bassa	380	44	11.6%			

Transit mean: 379±44

Mean of net exp.: 389±72 → 285±72

Conclusions

- Full availability of data made analysis easier;
- Good response, also with low exposure values;
- More difficulties working in mixed atmospheres (Rn + Tn);
- Better uncertainties evaluation from laboratories, compared to Lurisia intercomparison;
- Some problems working with electrets, due to transit management.