Proficiency Test

QAiST testing of solar collectors and solar systems 2010-2011

Final Report

May, 29th 2012

Institut für Eignungsprüfung GmbH
Daimlerstraße 8, D-45770 Marl

DAkkS Deutsche Akkreditierungsstelle D-EP-11183-01-00

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Content

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1 Introduction

In 2010 - 2012, the Institut für Eignungsprüfung (IfEP GmbH) evaluated results of a proficiency test which was organized in the framework of the EU funded QAiST (**Q**uality **A**ssurance **i**n **S**olar Thermal Heating and Cooling **T**echnology) project.
12 laboratories participated in this project.

This proficiency test was planned, carried out, assessed and documented in this report on the basis of ISO/IEC 17043 “Conformity assessment - General requirements for proficiency testing” [1] by IfEP GmbH. By 11th April 2011 (date of the deed) the IfEP GmbH got certified to have the competence to work in accordance to this worldwide valid standard.
Acc. to EN ISO/IEC 17025 [2], chapter 5.9, a laboratory shall have quality procedures at its disposal, which are able to control the validation of done tests. The yielded data shall be recorded in a way which makes tendencies visible. Where applicable, statistical techniques for the evaluation of the results shall be used by the participants.

The coordinator of this proficiency test is Dipl.-Ing. Christian Weißmüller, Daimlerstraße 8, D-45770 Marl, Phone +49 (0) 23 65 / 209 00 09.
This final report overall covers 114 pages (including 22 pages report and 92 pages annex) and was authorised by the head of the institute.
The purpose of this report is the presentation of results and performance of the participants. The report is valid with certificate only. A third party issuing of the report is only allowed with permission of IfEP. The content is not for confidentiality.

2 Program

2.1 Test procedure

The tests should be performed according to EN 12975 [3] and ISO 9459-5 [4]. Two different collector types / systems were used per standard:

- 12 collectors type FPC, Buderus,
- 12 collectors type ETC, Ritter,
- 9 systems, thermosyphon, Solahart,
- 9 systems, forced circulation system, Vaillant.

The collectors / systems were send to the laboratories in 2010, the test period was one year. After this period, the collectors / systems were send directly to the next participant, where they were retested in 2011. The sending of the collectors / systems were organized by the members of the QAiST group.

IfEPs main part was to collect the data and evaluate and asses them.

2.2 Participants

The proficiency test was exclusively done for the members of the QAiST group (see table 1). Additional three participants were accepted. They are not influencing the results of the statistical evaluation.

Table 1: QAiST participants coming from the following countries

Austria	1		Germany	5		Spain	2
France	1		Portugal	1		Sweden	1
Greece	1		Poland	1			

2.3 Homogeneity Testing

The homogeneity testing was not done before the start of the proficiency test. All material used was directly taken from the manufacturer, insuring that they come from one batch. By testing every artefact twice, it was easily possible to find deviations in the result caused by the heterogeneity of the artefacts. As there were no such effects, the material was suitable for the use in this proficiency test.

3 Statistical design

The statistical design is based on ISO 13528 [5] and ISO/IEC 17043 [1].
The deviation of laboratory's mean MW_{LAB} value from the assigned value X was evaluated.

3.1 Determination of assigned value

The assigned value X is determined as a consensus value of the results of all participating laboratories of 2010 and 2011. It is calculated as a robust mean value. For each test parameter an assigned value was calculated. The respective assigned value X is the median of all laboratories results MW_{LAB}. The values of the additional participants (Lab. 14, Lab. 15, Lab. 16), are not used for the following calculations.

The normalised interquartile range ($nIQR$) is used as standard deviation for the proficiency assessment $\hat{\sigma}$ ($nIQR$):

$$nIQR = 0{,}7413\ (Q3 - Q1) \qquad (1)$$

75 % of all values are lower than $Q3$, 25 % of all values are lower than $Q1$. ($Q3$-$Q1$) is called interquartile range (IQR). The factor 0,7413 derives from the standard normal distribution, which has a mean of zero and a standard deviation equal to one. The width of the interquartile range of such a distribution is 1,34898 and results to 1 / 1,34898 = 0,7413. Multiplying IQR by this factor makes it comparable to a standard deviation [6].

The results of this proficiency test are assessed with the help of a Z-score that is calculated for each laboratory and each test parameter according to equation (2):

$$Z = \frac{MW_{LAB} - X}{\hat{\sigma}} \qquad (2)$$

According to ISO/IEC 17043 [1] the following judgements are made:

- **$|Z| \leq 2$ satisfactory participated**
- **$|Z| \geq 3$ unsatisfactory participated**
- **$2 < |Z| < 3$ result questionable**.

Table 2a – 2d gives a review of the respective assigned values X and the standard deviations for proficiency assessment $\hat{\sigma}$ that were used in equation (2) of each element.

For a better view the results are rounded to the last digit.

Table 2a: Compilation of assigned values X and standard deviations of proficiency test $\hat{\sigma}$, FPC Buderus

Para-meter	X	$\hat{\sigma}$	u_{EP}, k = 1, p = 68 %	Z = - 3	Z = - 2	Z = 2	Z = 3
Aperture area [m²]	2,251	0,004	0,001	2,240	2,244	2,258	2,262
η0	0,722	0,007	0,002	0,702	0,709	0,735	0,742
IAM (50°)	0,840	0,013	0,003	0,800	0,813	0,867	0,880
0°K*	1626	18,5	4,3	1570	1589	1663	1682
10°K*	1539	23,7	5,5	1468	1492	1586	1610
30°K*	1344	28,9	6,7	1257	1286	1402	1431
50°K*	1128	36,3	8,4	1019	1055	1201	1237

* Power output at 1000 W/m² for dT = xx K

Table 2b: Compilation of assigned values X and standard deviations of proficiency test $\hat{\sigma}$, ETC Ritter

Para-meter	X	$\hat{\sigma}$	u_{EP}, **k = 1, p = 68 %**	**Z = - 3**	**Z = - 2**	**Z = 2**	**Z = 3**
Aperture area [m²]	1,997	0,009	0,002	1,970	1,979	2,015	2,024
η0	0,609	0,009	0,002	0,581	0,590	0,627	0,636
IAML (50°)	0,901	0,029	0,007	0,823	0,852	0,968	0,997
IAMT (30°)	1,020	0,009	0,002	0,994	1,003	1,037	1,046
IAMT (40°)	1,020	0,013	0,003	0,981	0,994	1,046	1,059
IAMT (50°)	1,007	0,025	0,006	0,931	0,957	1,057	1,083
IAMT (60°)	1,090	0,022	0,006	1,024	1,046	1,134	1,156
0°K*	1218	18,7	4,6	1162	1181	1255	1274
10°K*	1202	21,1	5,2	1138	1159	1244	1265
30°K*	1160	27,6	6,8	1077	1105	1215	1243
50°K*	1111	30,0	7,4	1020	1050	1171	1201

* Power output at 1000 W/m² for dT = xx K

Table 2c: Compilation of assigned values X and standard deviations of proficiency test $\hat{\sigma}$, system Solahart

Para-meter	X	$\hat{\sigma}$	u_{EP}, **k = 1, p = 68 %**	**Z = - 3**	**Z = - 2**	**Z = 2**	**Z = 3**
Stockholm*	40,8	3,7	1,1	29,8	33,5	48,1	51,8
Würzburg*	44,2	2,5	0,7	36,6	39,2	49,2	51,8
Davos*	52,9	3,1	0,9	43,5	46,6	59,2	62,3
Athens*	74,2	2,9	0,9	65,4	68,3	80,1	83,0

* F_{sol} at 170 l/day in %

Table 2d: Compilation of assigned values X and standard deviations of proficiency test $\hat{\sigma}$, system Vaillant

Para-meter	X	$\hat{\sigma}$	u_{EP}, k = 1, p = 68 %	Z = - 3	Z = - 2	Z = 2	Z = 3
Stockholm*	53,7	2,3	0,7	46,9	49,1	58,2	60,4
Würzburg*	56,3	2,3	0,7	49,4	51,7	60,8	63,1
Davos*	72,5	4,7	1,5	58,5	63,1	81,8	86,4
Athens*	86,0	2,4	0,7	78,9	81,3	90,7	93,1
Stockholm**	41,9	2,5	0,9	34,3	36,9	46,9	49,5
Würzburg**	45,8	2,7	1,0	37,8	40,5	51,1	53,8
Davos**	60,6	3,1	1,2	51,3	54,4	66,8	69,8
Athens**	75,9	2,2	0,8	69,2	71,5	80,3	82,6

* F_{sol} at 400 l/day, SOS, in %; ** F_{sol} at 400 l/day, SPSS, in %

4 Results

The results of this proficiency test are summarized in table 3a – table 3e and graphically presented in appendix A - D. A summary of the proficiency test can be found in table 4. In table 3a – table 3d analysis with questionable or unsatisfactory results are summarised. Participants outside the QAiST project are excluded in table 3.

Table 3a: Summary of results, FPC Buderus

Parameter	Number of results	Number |Z|≥3	Number 2<|Z|<3
Aperture area	29	0	4
η0	29	1	4
IAM (50°)	23	3	3
0°K*	29	0	2
10°K*	29	0	0
30°K*	29	0	2
50°K*	29	0	1

* Power output at 1000 W/m² for dT = xx K

Table 3b: Summary of results, ETC Ritter

Parameter	Number of results	Number $\lvert Z \rvert \geq 3$	Number $2 < \lvert Z \rvert < 3$
Aperture area	26	0	0
η0	26	0	3
IAML (50°)	24	0	4
IAMT (30°)	24	1	2
IAMT (40°)	23	0	3
IAMT (50°)	25	0	0
IAMT (60°)	23	3	1
0°K*	26	1	2
10°K*	26	0	3
30°K*	26	0	1
50°K*	26	0	2

* Power output at 1000 W/m² for dT = xx K

Table 3c: Summary of results, System Solahart

Parameter	Number of results	Number $\lvert Z \rvert \geq 3$	Number $2 < \lvert Z \rvert < 3$
Stockholm*	18	0	0
Würzburg*	18	0	1
Davos*	18	1	0
Athens*	18	0	2

* F_{sol} at 170 l/day

Table 3d: Summary of results, System Vaillant

Parameter	Number of results	Number $\lvert Z \rvert \geq 3$	Number $2 < \lvert Z \rvert < 3$
Stockholm*	16	2	0
Würzburg*	16	1	0
Davos*	16	1	0
Athens*	16	1	1
Stockholm**	11	1	1
Würzburg**	11	1	0
Davos**	11	1	0
Athens**	11	1	2

* F_{sol} at 400 l/day, SOS; ** F_{sol} at 400 l/day, SPSS

Additionally Annex A – C show the single results of every round (2010 and 2011). The limits given there are only for information and were not assessed by the organiser.

Table 4a – table 4d show all laboratories which had a questionable or unsatisfactory result for at least one Parameter. Laboratories not present in table 4a – 4d have completed all parameter satisfactory.

There was done no overall assessment by the organizer. If a laboratory received more than 25 % unsatisfactory results per collector / system and year, it should start corrective actions to find the reason for this deviation.

Table 4a: Laboratories which reported at least one questionable or unsatisfactory result, FPC Buderus

	Aperture area	**η0**	**IAM (50°)**	**0°K***	**10°K***	**30°K***	**50°K***
1a10so			X				
1a11so			X				
3b10si		O					
4a10si			O				
5a10so		X		O			
6a10si	O			O			
6a11si	O	O					
8a10so						O	
8a11so		O				O	O
9a10qd			O				
9a11qd			X				
10a11so			O				
12a10so	O						
12a11so	O	O					
(14a10so)			O				
(15a10so)	X	X		X			
(16a10si)		X		X	O	O	X

Legend: * Power output at 1000 W/m² for dT = xx K
(xx xx) Laboratory outside the project
X Analysis with a Z-Score |Z|≥3
O Analysis with a Z-Score 2<|Z|<3

Table 4b: Laboratories which reported at least one questionable or unsatisfactory result, ETC Ritter

	Aper-ture area	**η0**	**IAML (50°)**	**IAMT (30°)**	**IAMT (40°)**	**IAMT (50°)**	**IAMT (60°)**	**0°K***	**10°K***	**30°K***	**50°K***
1a10so			O	X							
1a11so			O								
3a10qd				O							
3a11qd					O		X				
3b11qd							O				
4a10so							X				
6a10si							X				
7a11so					O						
8a11so		O						X	O		
9a10qd			O								
9a11qd					O						
10a11so				O							
12a10so		O	O					O	O	O	O
12a11so		O						O	O		O
(14a10so)				O							
(14a11so)		O						O	O	O	O
(15a10so)									O	X	X

Legend: * Power output at 1000 W/m² for dT = xx K
(xx xx) Laboratory outside the project
X Analysis with a Z-Score |Z|≥3
O Analysis with a Z-Score 2<|Z|<3

Table 4c: Laboratories which reported at least one questionable or unsatisfactory result, system Solahart

	Stockholm*	**Würzburg***	**Davos***	**Athens***
1_10				O
6_10		O	X	O

Legend: * F_{sol} at 170 l/day
X Analysis with a Z-Score |Z|≥3
O Analysis with a Z-Score 2<|Z|<3

Table 4d: Laboratories which reported at least one questionable or unsatisfactory result, system Vaillant

	Stock-holm*	**Würz-burg***	**Davos***	**Athens***	**Stock-holm****	**Würz-burg****	**Davos****	**Athens****
5b10	---	---	---	---				O
5b11	---	---	---	---	X	X	X	X
7a10	X	X	X	X	---	---	---	---
7a11	X				---	---	---	---
8b10	---	---	---	---	O		O	O
13a11				O	---	---	---	---

Legend:
* F_{sol} at 400 l/day, SOS, in %;
** F_{sol} at 400 l/day, SPSS, in %
X Analysis with a Z-Score |Z|≥3
O Analysis with a Z-Score 2<|Z|<3

Additionally the participants calculated the collector capacity C_{eff}, or in case of quasi dynamic testing, C_5. The results are shown in table 4e. They are for information only and were not assessed by the organiser.

Table 4e: Parameters Ceff / C5, Results of all participants

FPC Buderus	ceff / c5	ETC Ritter	ceff / c5
1a10so	18,23	1a10so	16,56
1a11so	14,63	1a11so	16,68
3a10qd	12250	3a10qd	32686
3a11si	6790	3a11qd	33456
3b10si	6790	3b11qd	32126
3b11qd	9160	4a10so	16,83
3c10so	6790	4a11so	16,82
4a10si	6,38	5a10so	70,4
4a11si	6,38	5a11so	75
5a10so	13,9	5b11qd	30889
5a11so	14,9	6a10si	12,4
5b11qd	7620	6a11si	12,4
6a10si	6,6	7a10so	49,15
6a11si	6,6	7a11so	28,37
7a10so	5,61	7b11si	kA
7a11so	19	8a10so	17,311
7b11si	kA	8a11so	17,311
8a10so	6825	9a10qd	28400
8a11so	6825	9a11qd	35145
9a10qd	5490	10a11so	18
9a11qd	6093	11a10so	18,35
10a10so	6,9	11a11so	18,35
10a11so	6,9	12a10so	72
11a10so	18,42	12a11so	73
11a11so	18,42	13a10qd	28922
12a10so	17,1	13a11qd	23992
12a11so	17,8	14a10so	13,14
13a10si	9,159	14a11so	13,14
13a11si	9,118	15a10so	kA
14a10so	9,95	15a11so	kA
14a11so	9,95	16a10si	kA
15a10so	kA	16a11si	kA
15a11so	kA		
16a10si	6,89		
16a11si	6,89		

5 Determination of measurement uncertainty

5.1 Declaration of the measurement uncertainty by the laboratories

The participants were asked to declare their measurement uncertainty for certain parameters of the collector tests. The assessed parameters of the systems were delivered without a statement to the measurement uncertainty.

Figures E1 to E18, appendix E, show the results. Table 5a and 5b give a survey of mean values (calculated as a median) of the declared measurement uncertainties.

Table 5a: Declaration uncertainty by the laboratories, FPC Buderus

Parameter	Aperture area	η0	IAM (50°)	0°K*	10°K*	30°K*	50°K*
Mean value MU	± 0,003	± 0,006	± 0,012	± 15,0	± 17,0	± 22,4	± 28,0

* Power output at 1000 W/m² for dT = xx K

Table 5b: Declaration uncertainty by the laboratories, ETC Ritter

Parameter	Ap. area	η0	IAML (50°)	IAMT (30°)	IAMT (40°)	IAMT (50°)	IAMT (60°)	0°K*	10°K*	30°K*	50°K*
Mean value MU	± 0,003	± 0,007	± 0,022	± 0,014	± 0,023	± 0,021	± 0,025	± 14,0	± 17,5	± 18,7	± 22,5

* Power output at 1000 W/m² for dT = xx K

There was no statement done by the participants to the level of confidence and the coverage factor as well as the corresponding way of determination (estimation or calculation) for the measurement uncertainty.

5.2 Calculation of the measurement uncertainty acc. to EUROLAB TR 1/2006

The measurement uncertainty for each parameter can be calculated on the basis of the technical report EUROLAB TR 1/2006 [7].

The formula for the expanded measurement uncertainty U on a confidence level of app. 95 % (k = 2) is shown in equation (3):

$$U = 2 * \sqrt{u_{EP}^2 + \left(\frac{s_{lab}}{\sqrt{n}}\right)^2 + b^2} \qquad (3)$$

Thereby b is the deviation of the laboratories' results from the consensus value of the proficiency test and s_{lab} the standard deviation of the laboratory.

u_{EP} is the uncertainty of the proficiency test for each element and is calculated as shown in equation (4) acc. to ISO 13528 [5]:

$$u_{EP} = 1,25 * \frac{\hat{\sigma}}{\sqrt{n}} \qquad (4)$$

Standard deviations of proficiency test $\hat{\sigma}$, consensus values as well as the measurement uncertainty for each parameter can be taken from table 2.

Depending on the bias b of a laboratories result, this factor becomes the main influence of equation (3). For a rough estimate of the uncertainty of the results, the standard deviation of the proficiency test according to table 2 can be multiplied by three (3). This is a good estimate for all laboratories inside the permissible limits shown in table 2.

6 Summary

12 laboratories from 8 European nations participated in the proficiency test "QAiST testing of solar collectors and solar systems 2010-2011" that was evaluated by Institut für Eignungsprüfung (IfEP GmbH) in Marl, Germany.

The results submitted in 2010 and 2011 were evaluated on basis of a robust statistical method, in order to minimize the influence of outliers regarding individual laboratory mean values. The total results show very good results. Although the tasks were very complex, the results were close together.

Compared to other proficiency tests in the field of mechanical testing the results are clearly better. The number of unsatisfactory results is clearly lower.

This shows a very good quality of work in the participating laboratories. It give a conclusion of the high level of training of personnel and the high quality of the standards used.

7 Literature

[1] ISO/IEC 17043:2010, Conformity assessment - General requirements for proficiency testing. International Organisation for Standardization, Genève, February 2010.

[2] EN ISO/IEC 17025:2005, General requirements for the competence of testing and calibration laboratories - trilingual version. Beuth Verlag, Berlin, April 2005.

[3] EN 12975-1:2011, Thermal solar systems and components - Solar collectors - Part 1: General requirements; Beuth Verlag, Berlin, January 2011.

[4] ISO 9459-5:2007, Solar heating - Domestic water heating systems - Part 5: System performance characterization by means of whole-system tests and computer simulation. International Organisation for Standardization, Genève, May 2007.

[5] ISO 13528:2005, Statistical methods for use in proficiency testing by interlaboratory comparisons. International Organisation for Standardization, Genève, September 2005.

[6] PTPM 1.1, Guide to Proficiency Testing Australia, PTA. Australia, April 2008.

[7] Technical Committee for Quality Assurance in Testing - TCQA: EUROLAB Technical Report 1/2006 - Guide to the Evaluation of Measurement Uncertainty for Quantitative Test Results, Paris, August 2006.

8 Participants

There is no relation between the laboratory code and the position on the following list.

AIT Austrian Institute of Technology	Vienna	Austria
Centro Nacional de Energías Renovables (CENER) - Fundación CENER-CIEMAT	Sarriguren (Navarra)	Spain
CSTB Centre Scientifique et Technique du Bâtiment	Sophia Antipolis Cedex	France
IPIEO	Warsawa	Poland
ISE	Freiburg	Germany
ISFH	Emmerthal	Germany
ITC Instituto Tecnológico de Canarias, S.A.	Santa Lucía Las Palmas	Spain
ITW	Stuttgart	Germany
IZES	Saarbrücken	Germany
LNEG (INETI)	Lisboa	Portugal
Solar & Energy Systems Laboratory (SESL) NCSR "Demokritos"	Aghia Paraskevi, Athens	Greece
SP Energy Technology	BORÅS	Sweden
TÜV Rheinland Energie und Umwelt GmbH	Cologne	Germany

Annex A: Results, FPC Buderus

Annex B: Results, ETC Ritter

Annex C: System Solahart

Annex D: System Vaillant

Annex E: Measurement uncertainty, statements of the laboratories

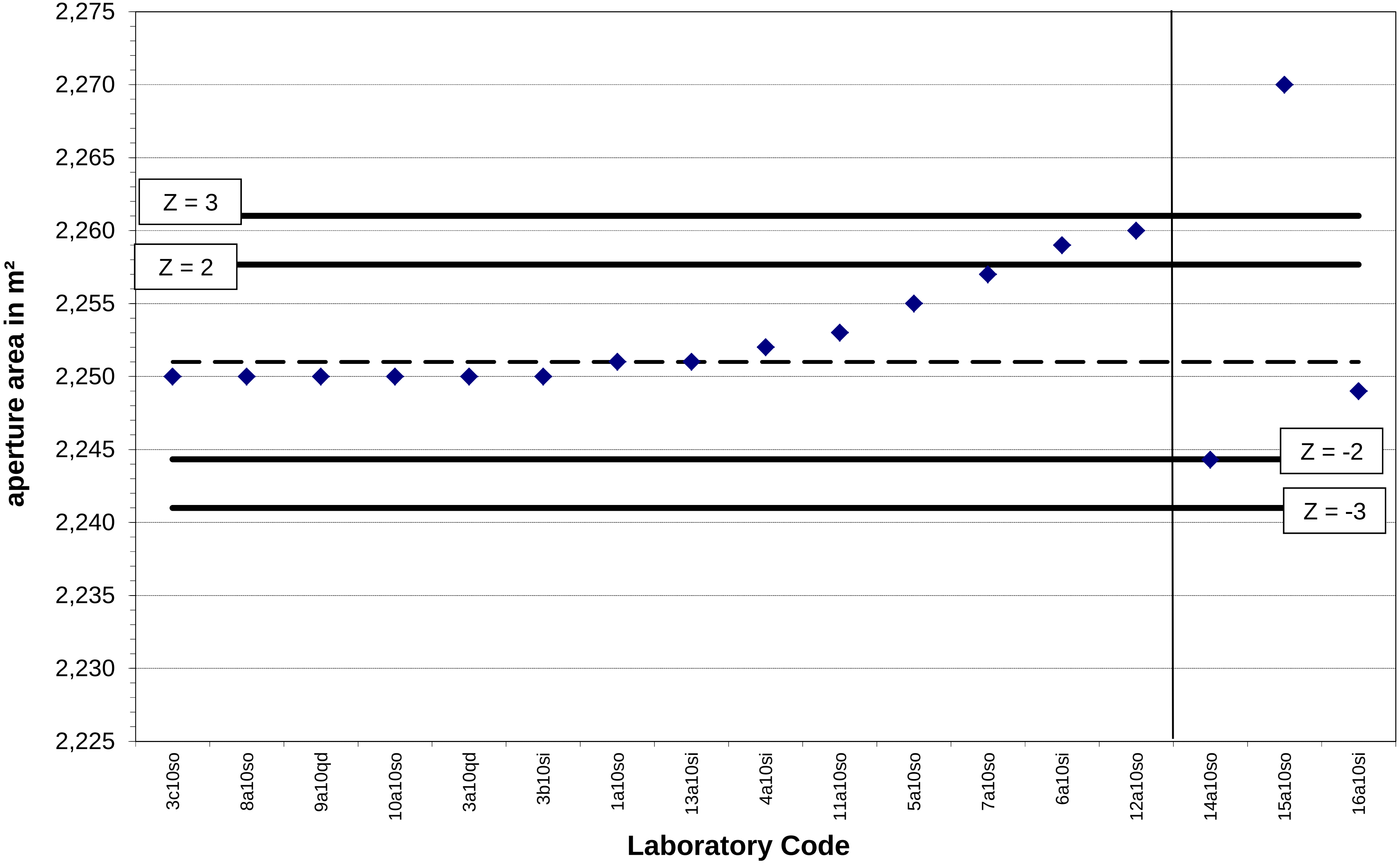

Figure A1: Aperture area; values of 2010

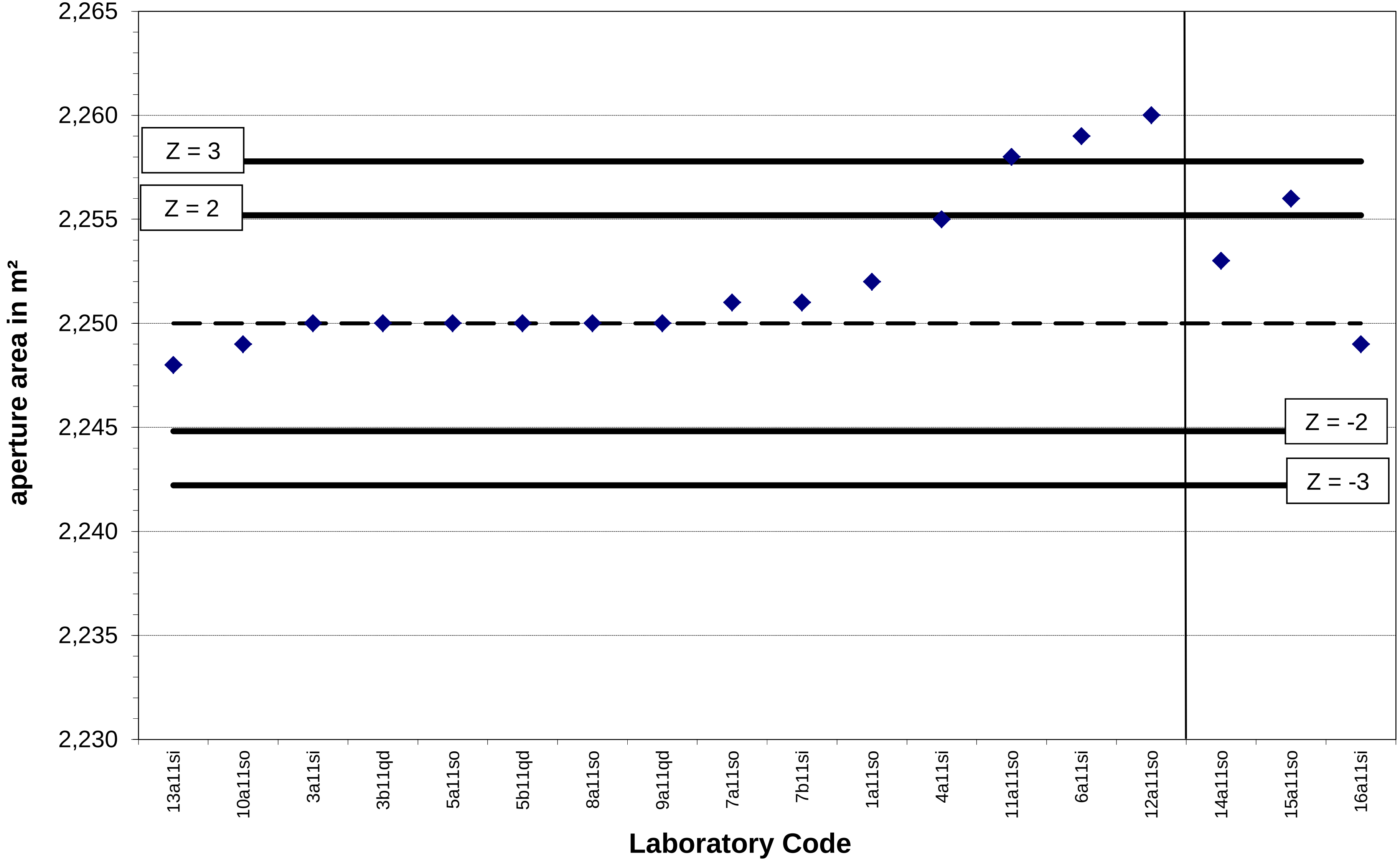

Figure A2: Aperture area; values of 2011

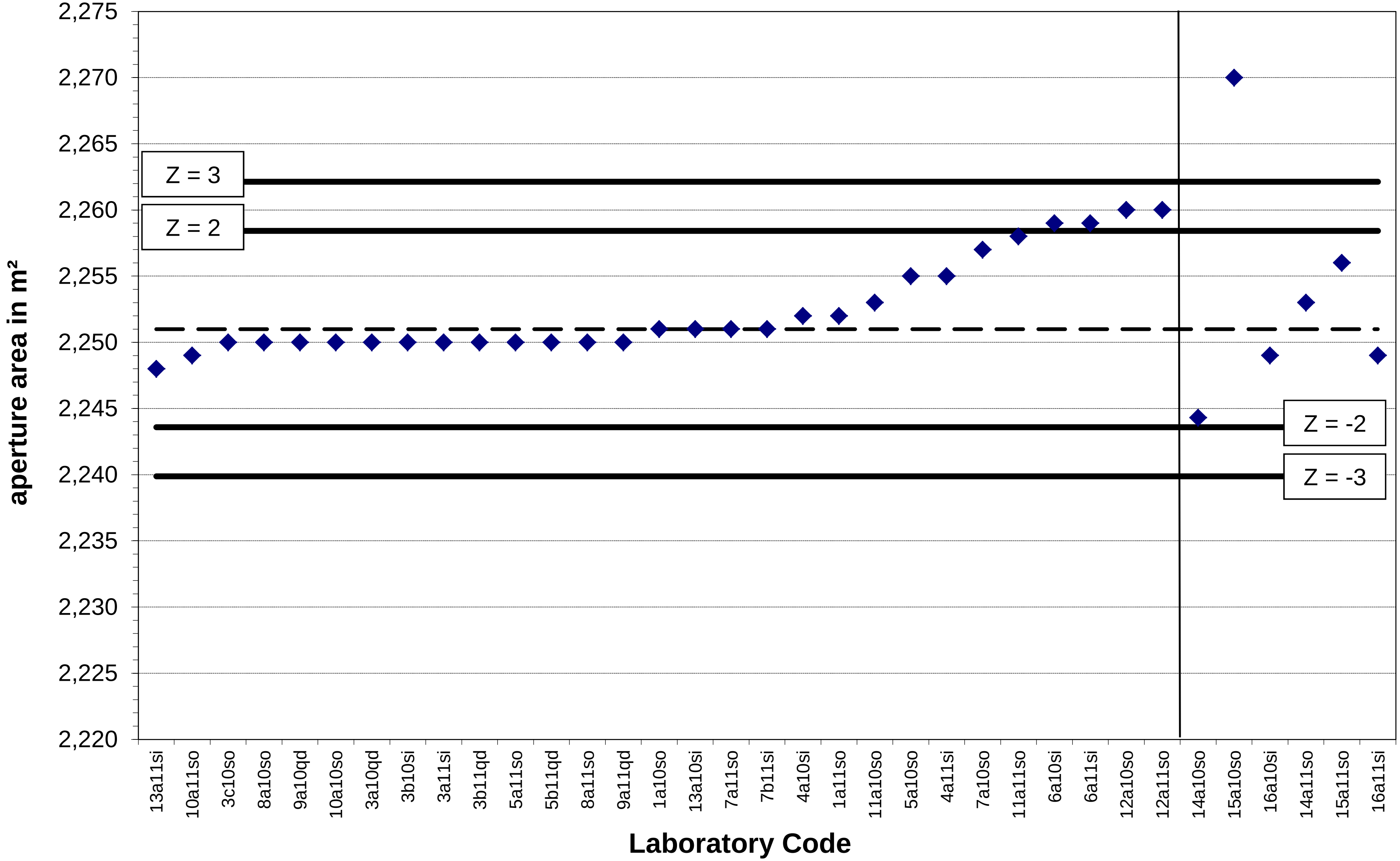

Figure A3: Aperture area; all values

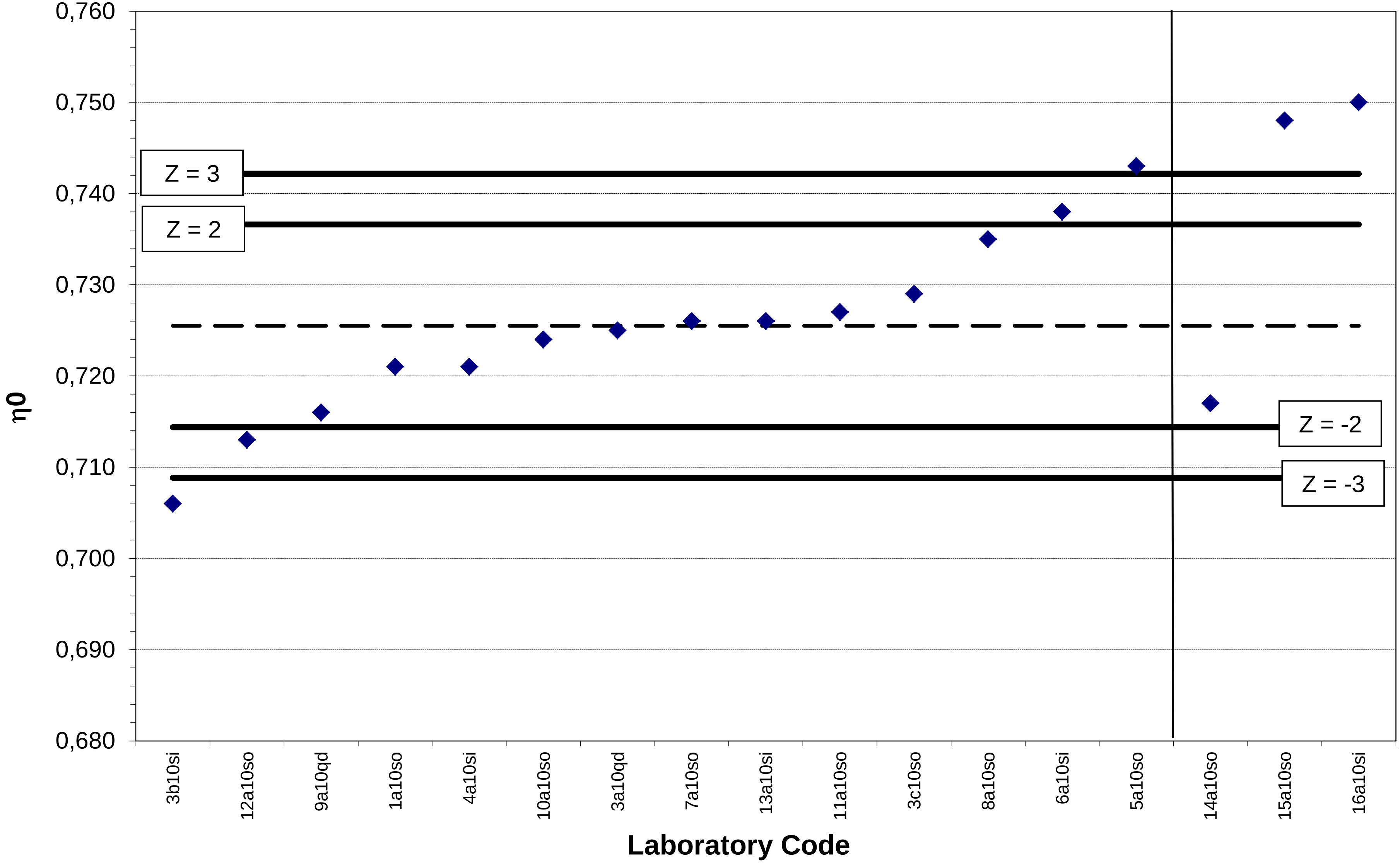

Figure A4: eta (η) 0; values of 2010

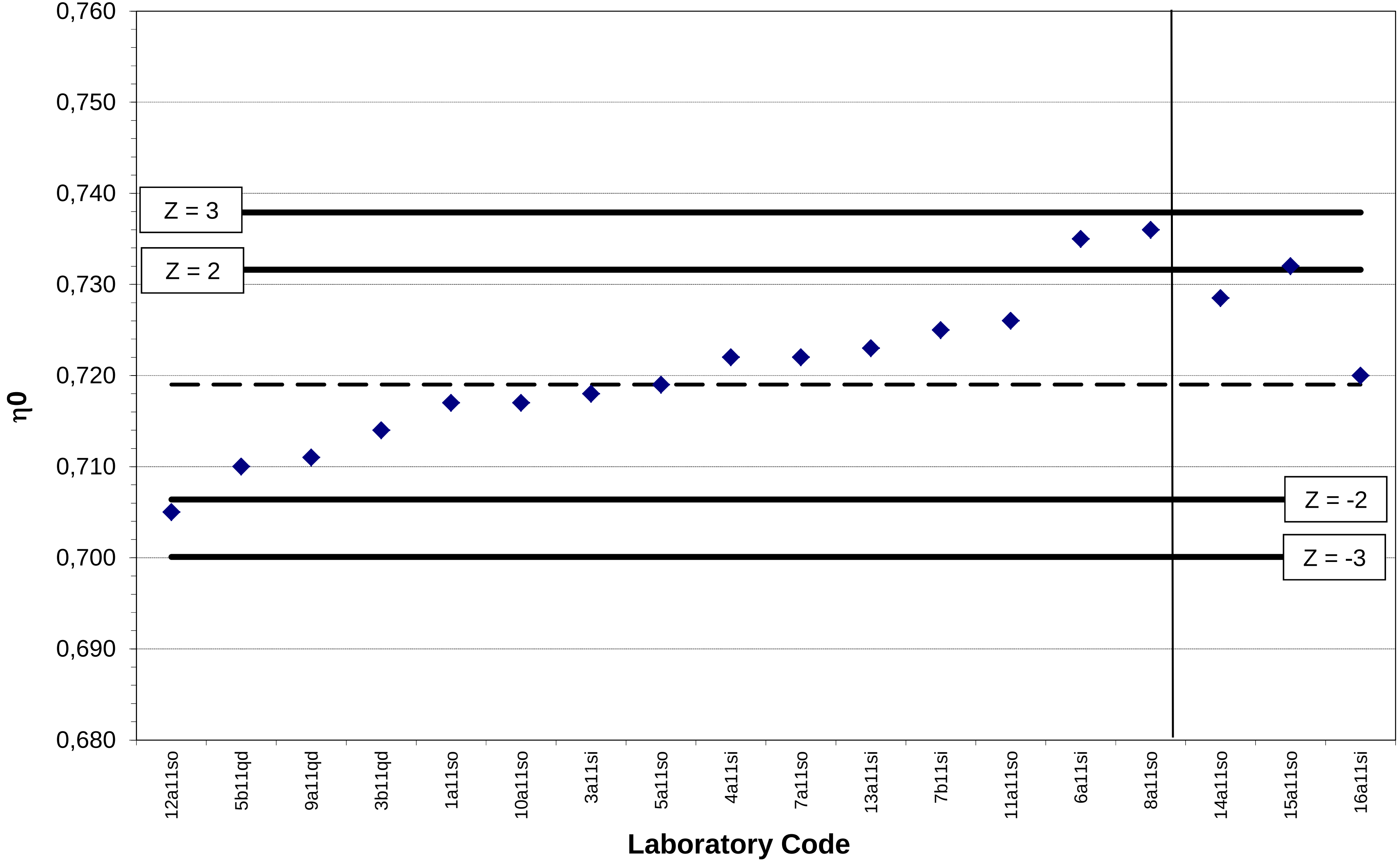

Figure A5: eta (η) 0; values of 2011

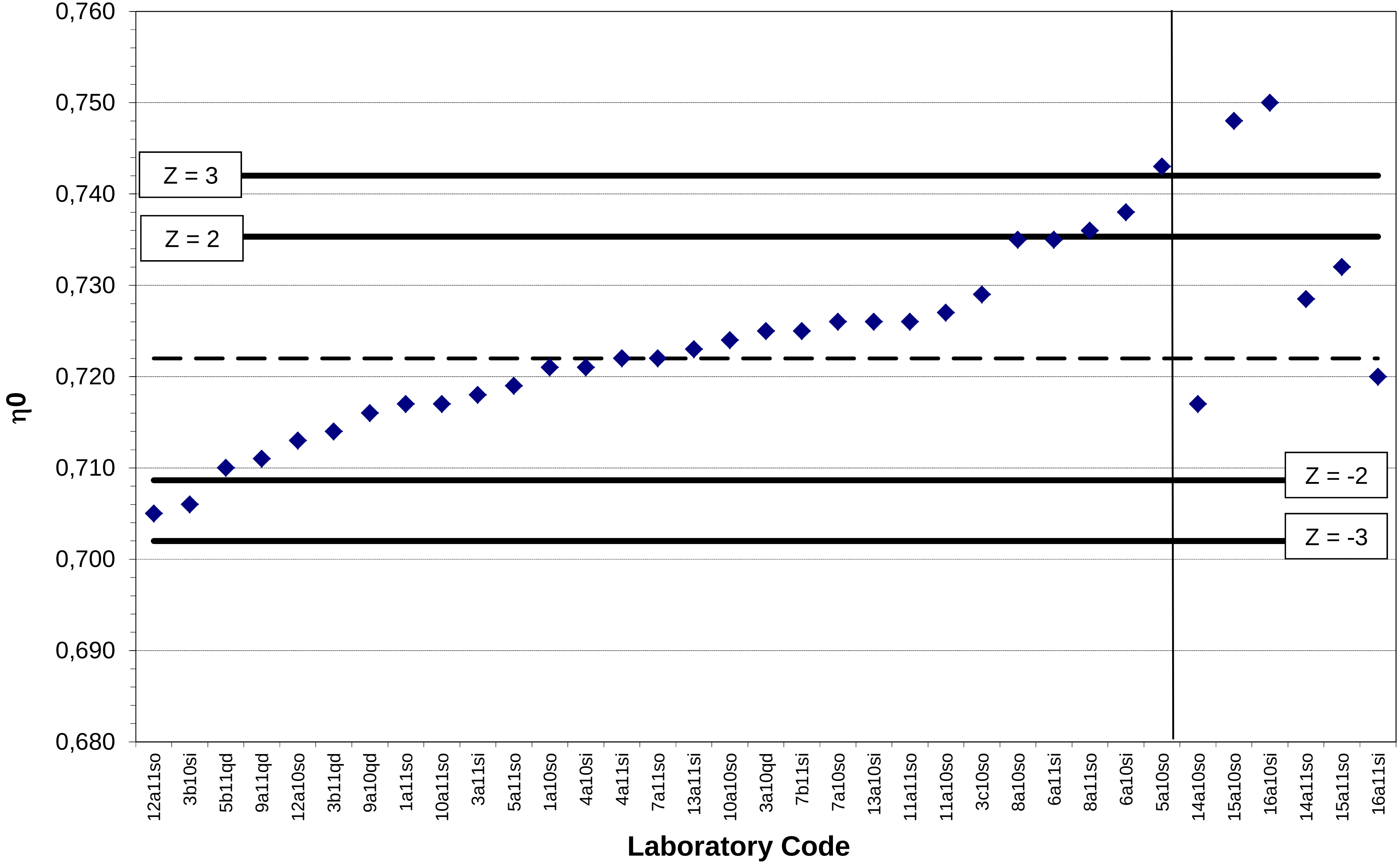

Figure A6: eta (η) 0; all values

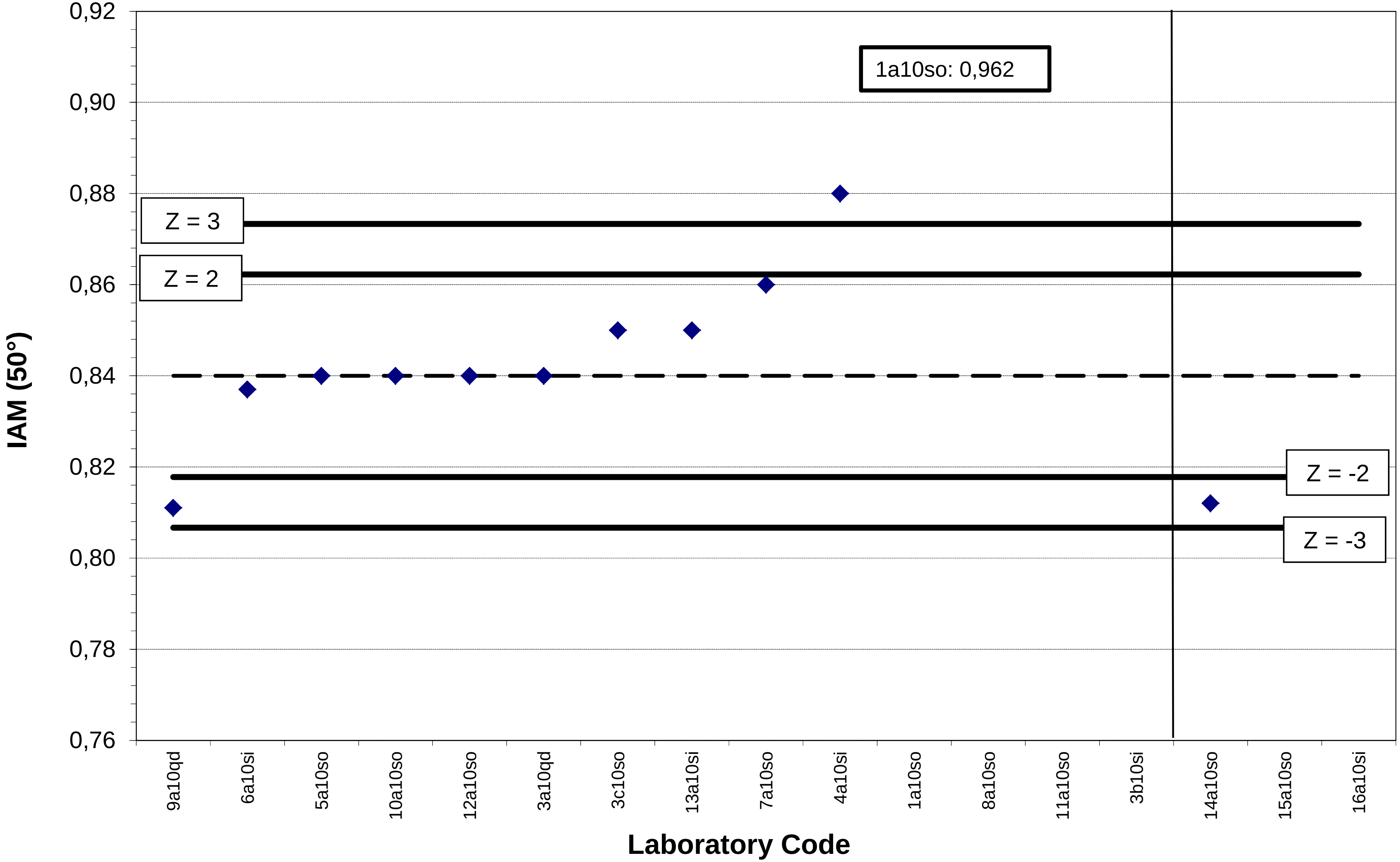

Figure A7: Incidence angle modifier, IAM 50°; values of 2010. Labs w/o data points: not stated

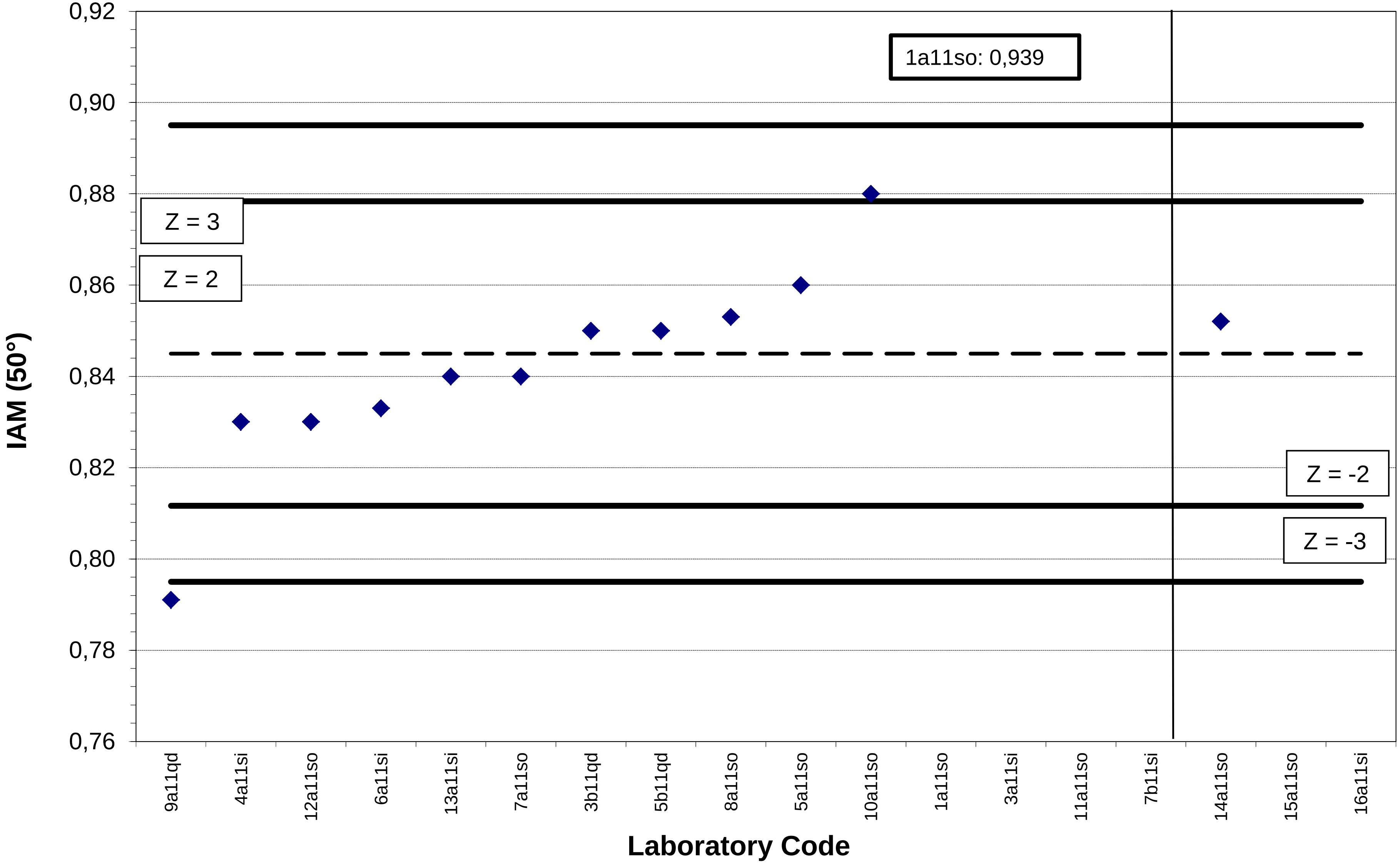

Figure A8: Incidence angle modifier, IAM 50°; values of 2011. Labs w/o data points: not stated

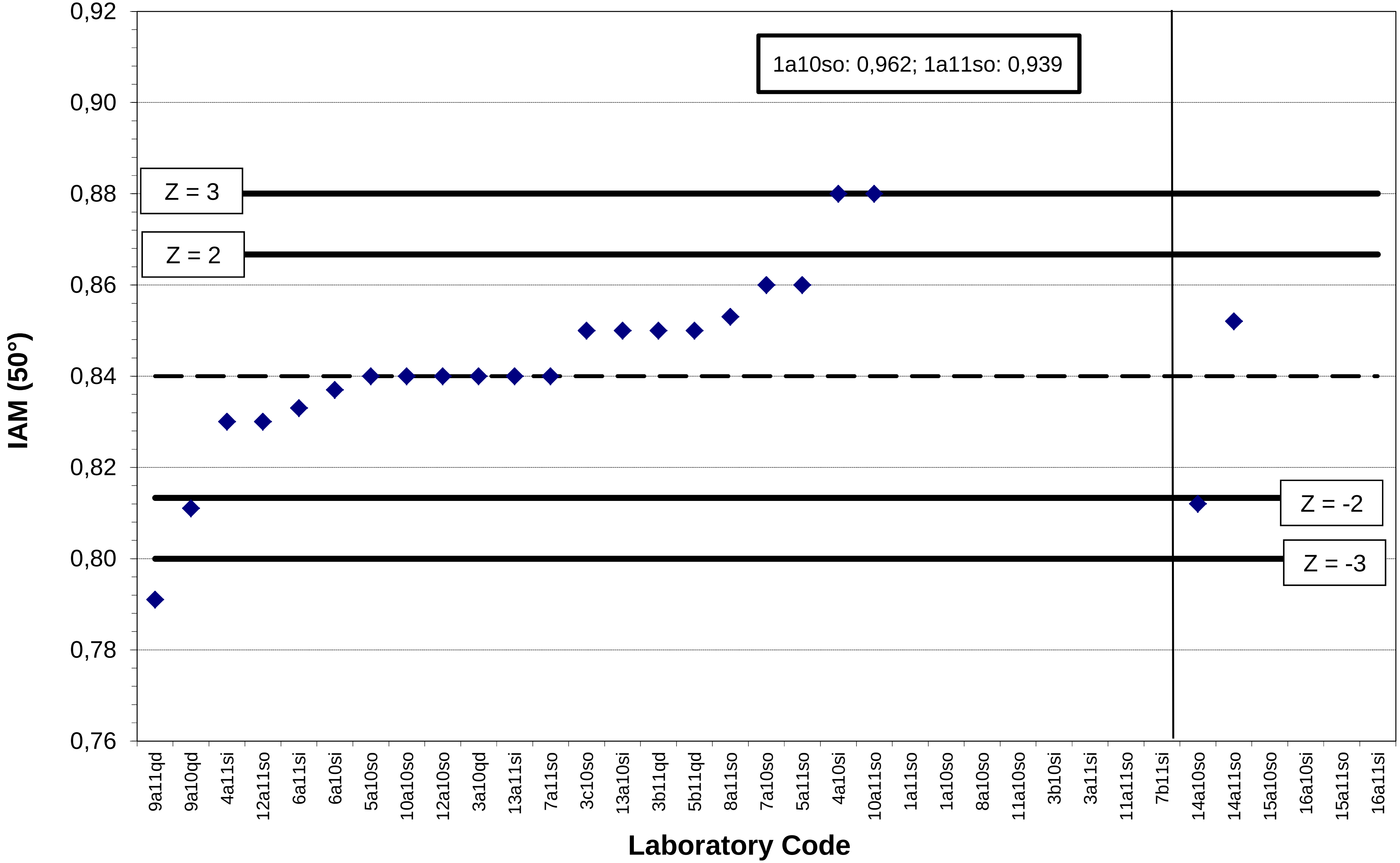

Figure A9: Incidence angle modifier, IAM 50°; all values. Labs w/o data points: not stated

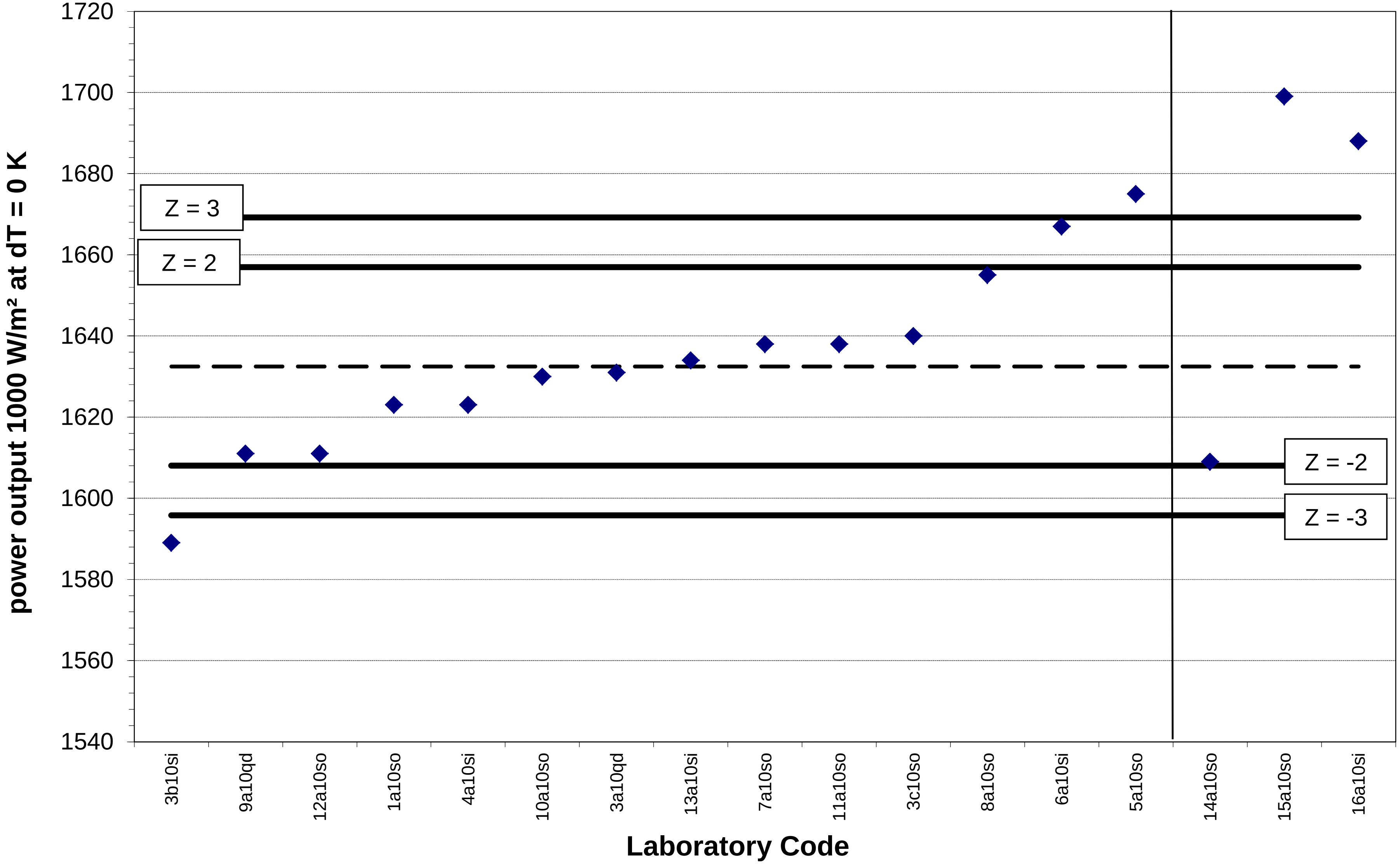

Figure A10: Power output at 1000 W/m² for dT = 0 K; values of 2010.

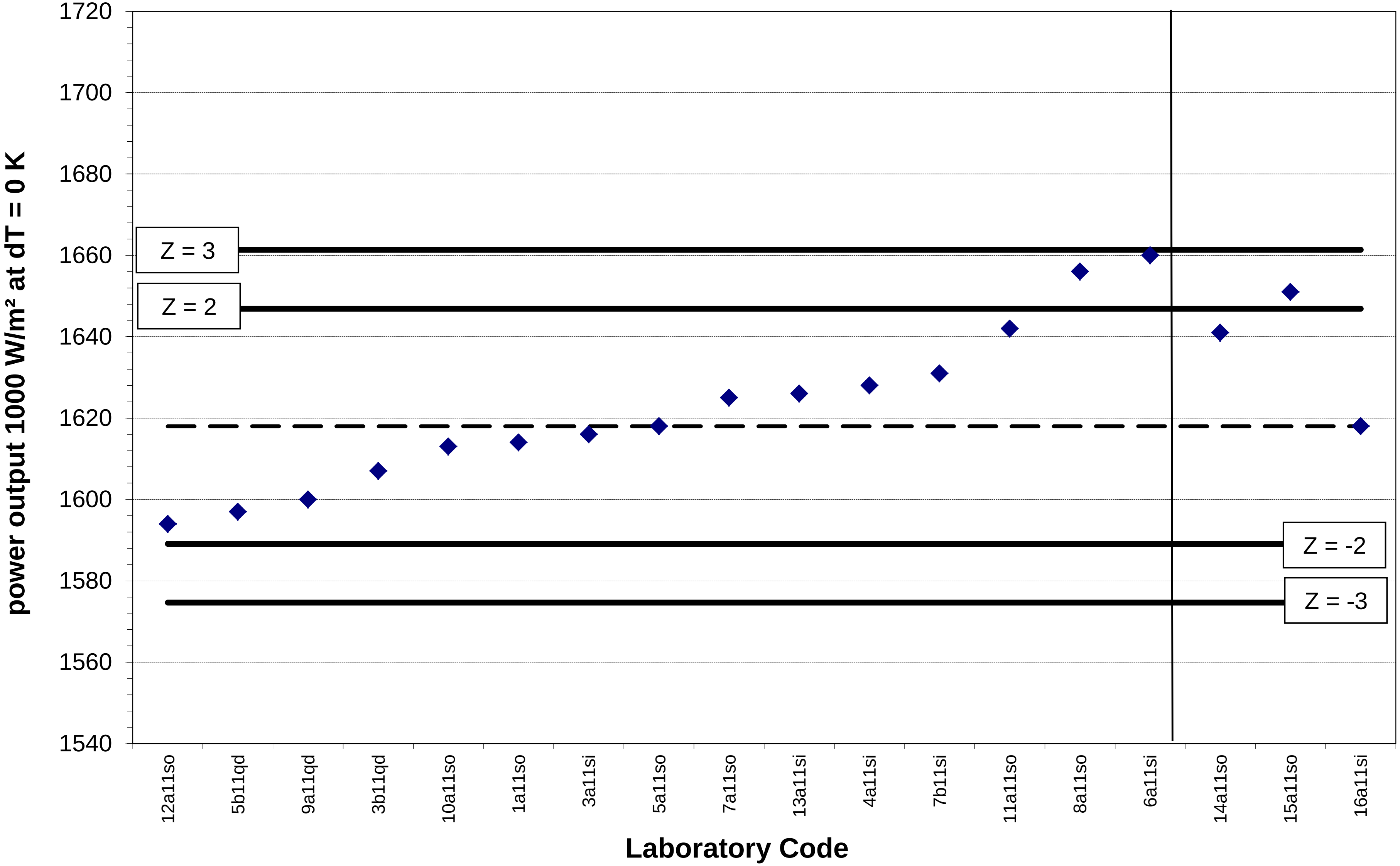

Figure A11: Power output at 1000 W/m² for dT = 0 K; values of 2011.

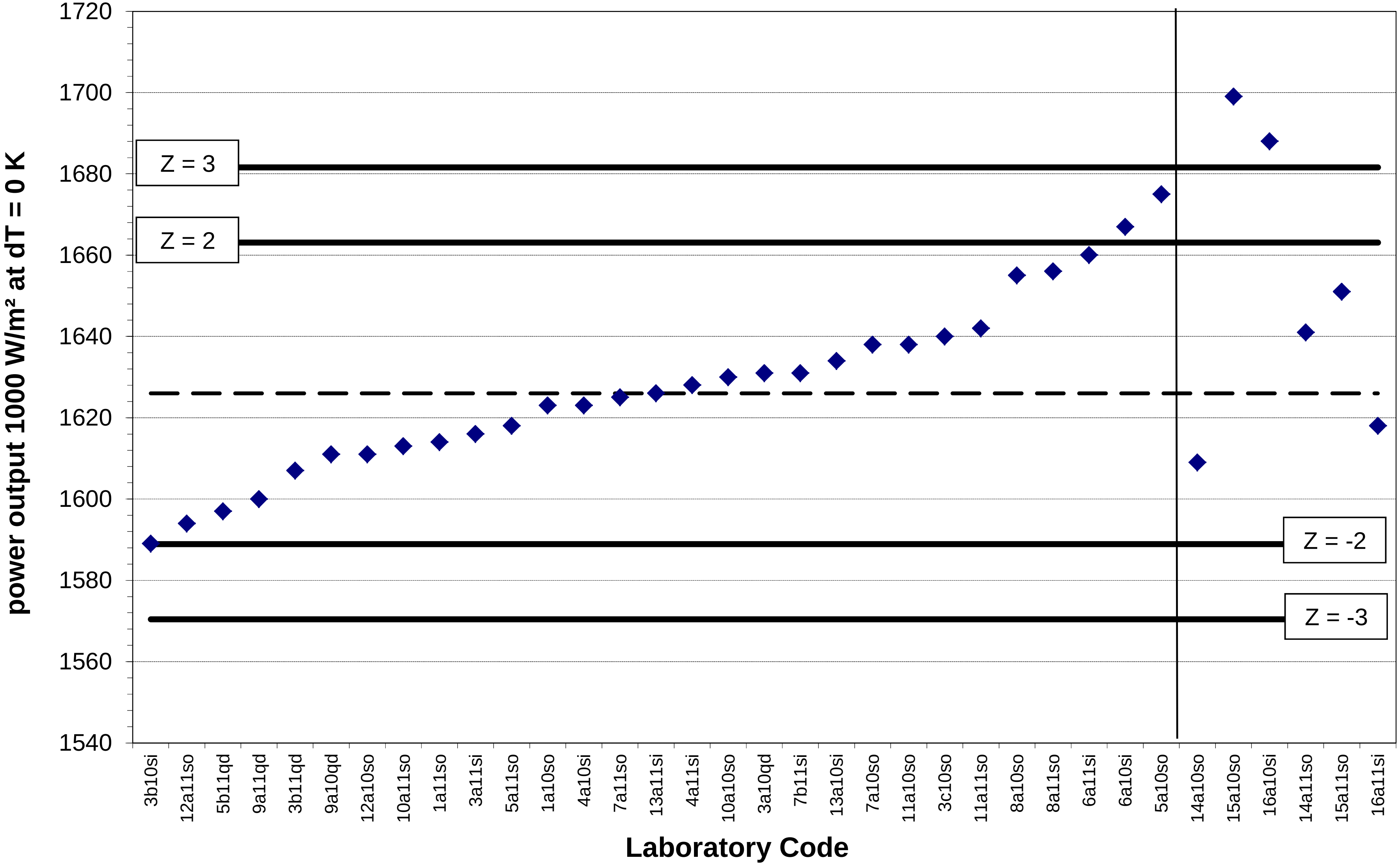

Figure A12: Power output at 1000 W/m² for dT = 0 K; all values.

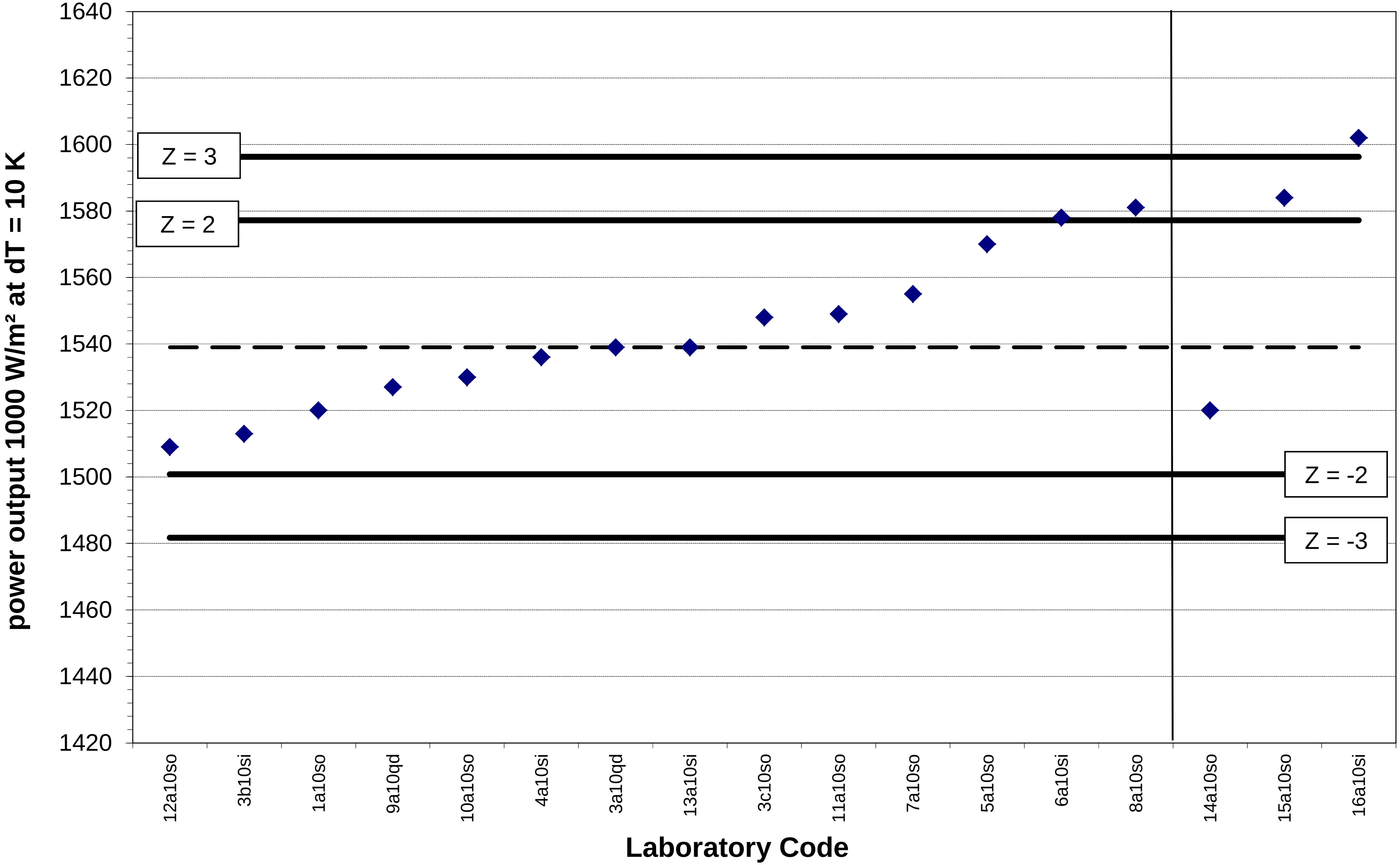

Figure A13: Power output at 1000 W/m² for dT = 10 K; values of 2010.

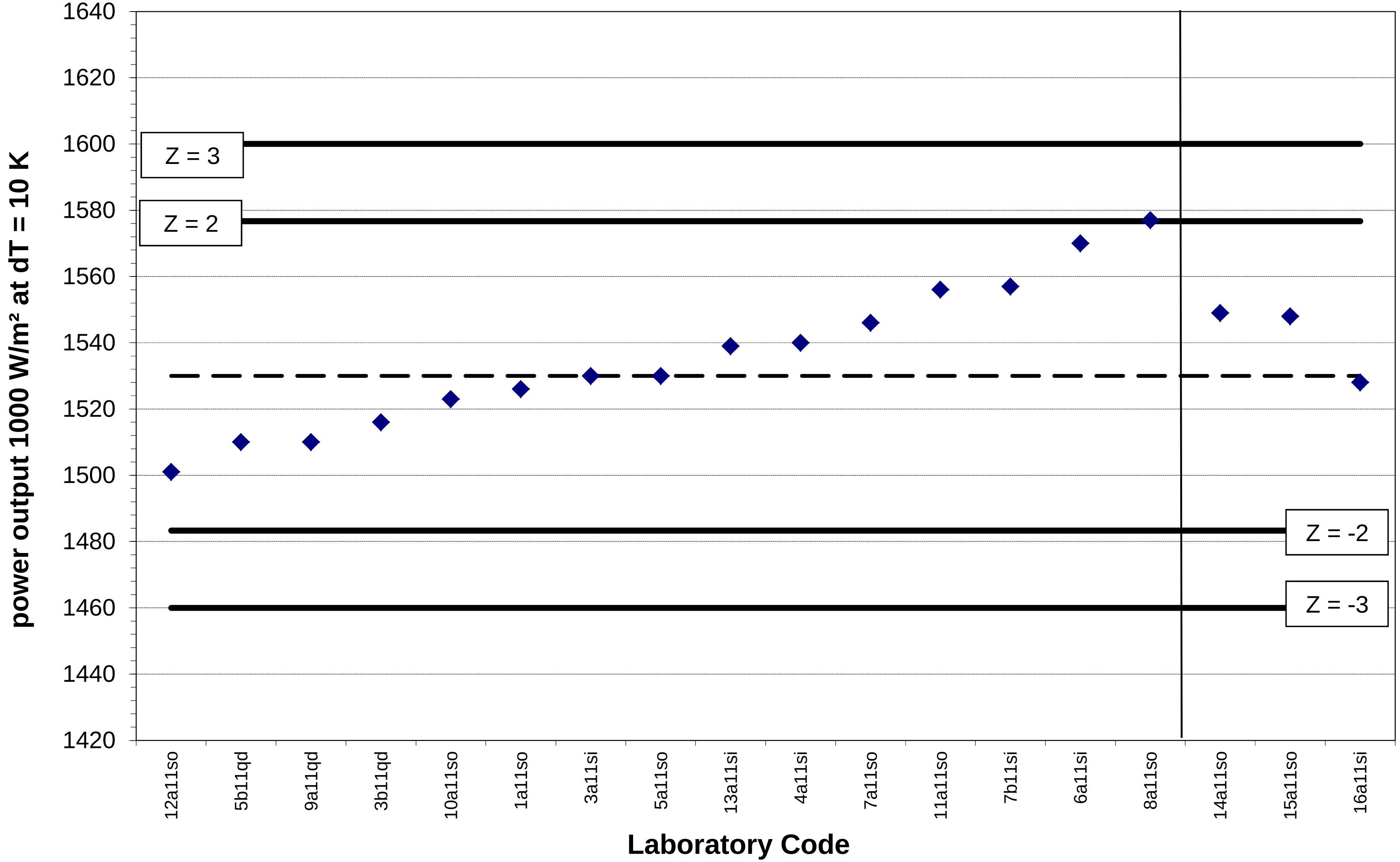

Figure A14: Power output at 1000 W/m² for dT = 10 K; values of 2011.

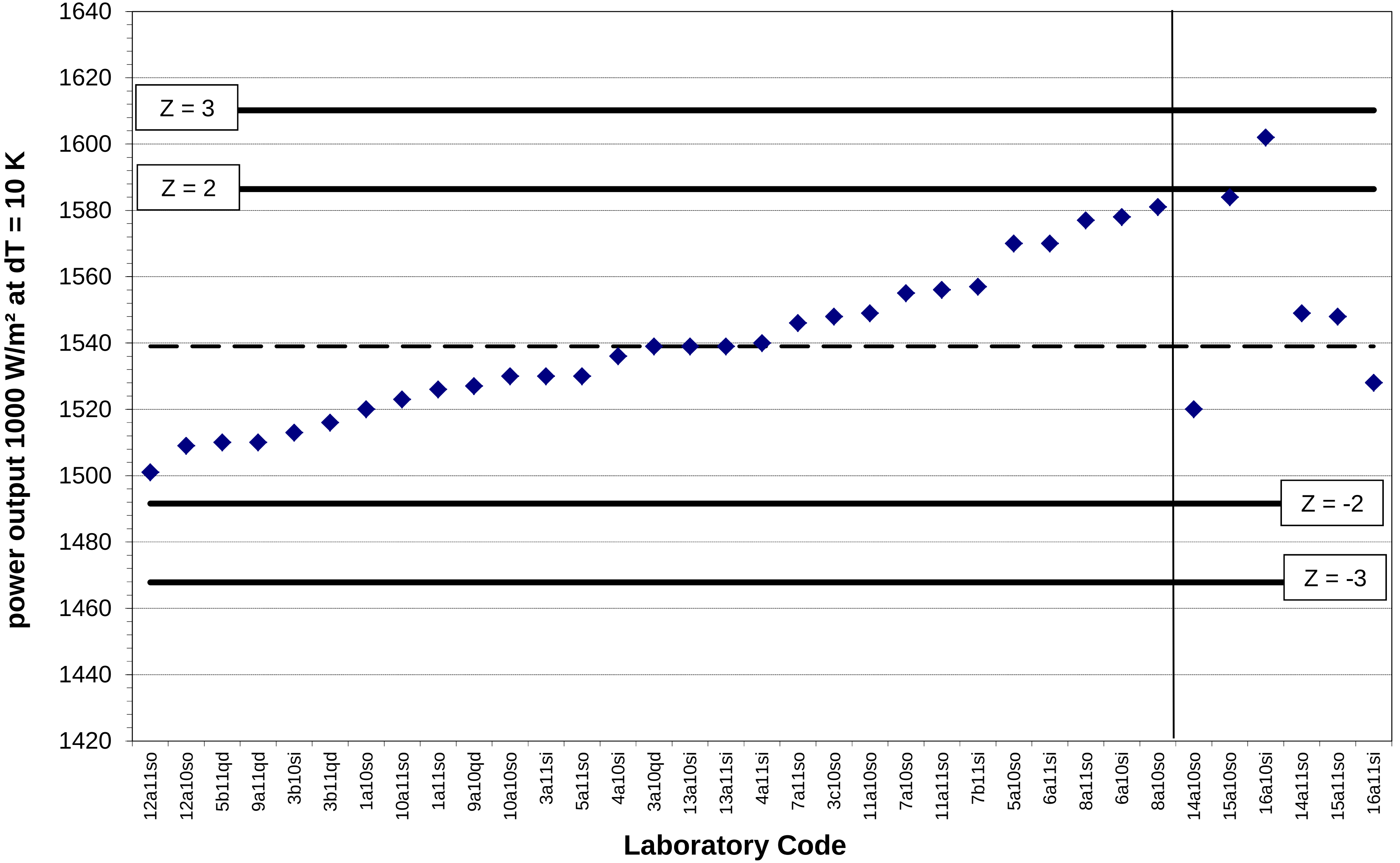

Figure A15: Power output at 1000 W/m² for dT = 10 K; all values.

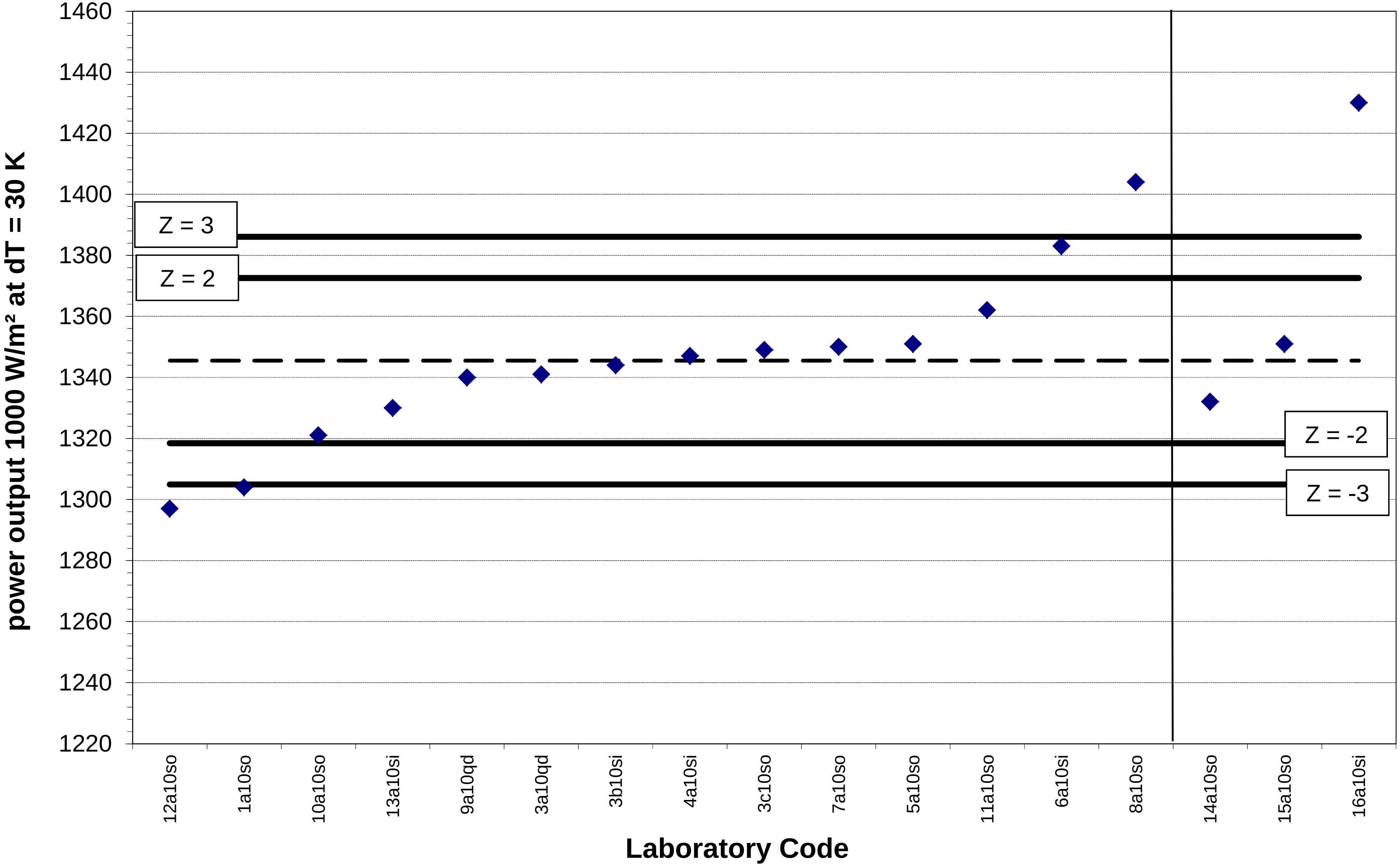

Figure A16: Power output at 1000 W/m² for dT = 30 K; values of 2010.

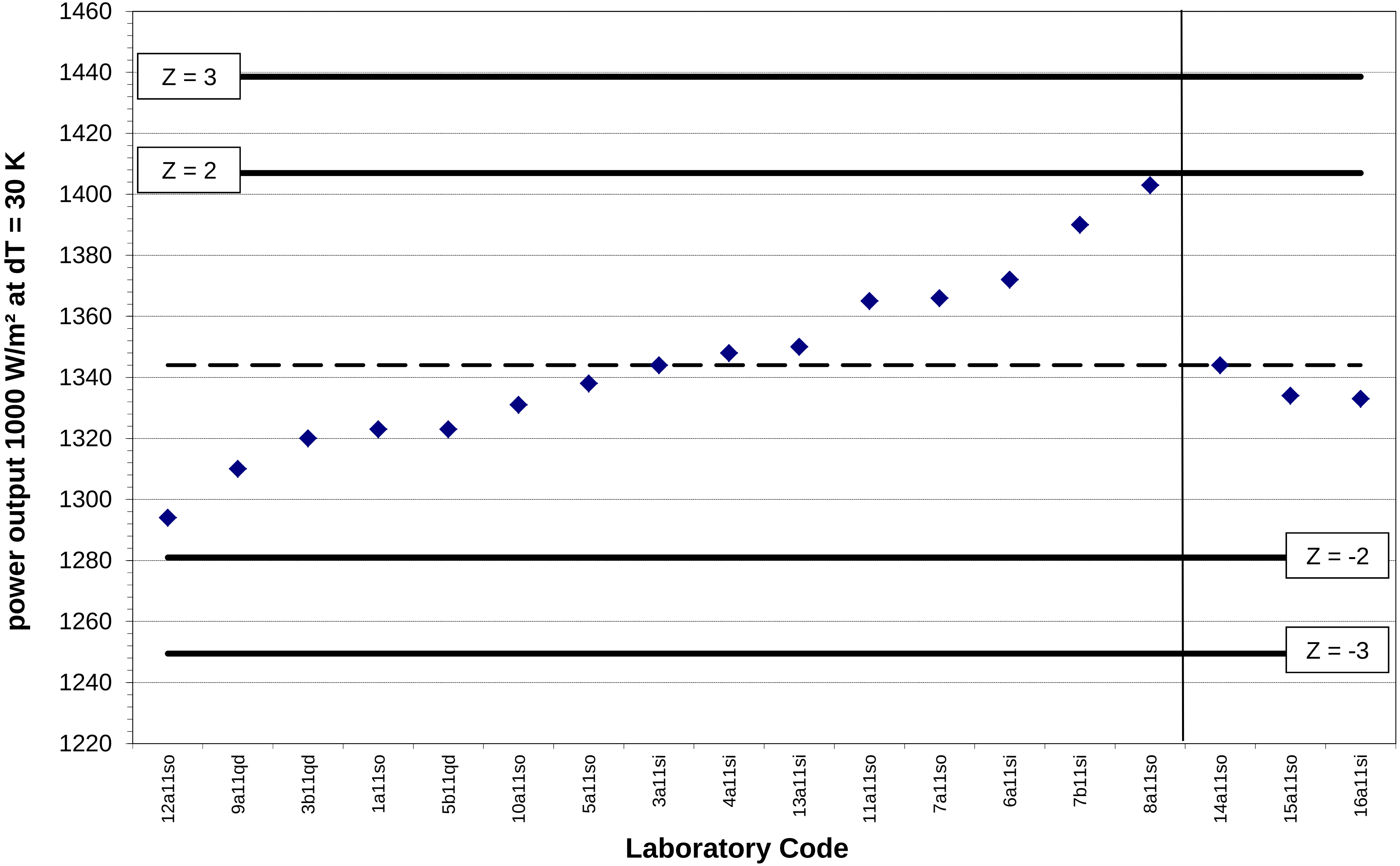

Figure A17: Power output at 1000 W/m² for dT = 30 K; values of 2011.

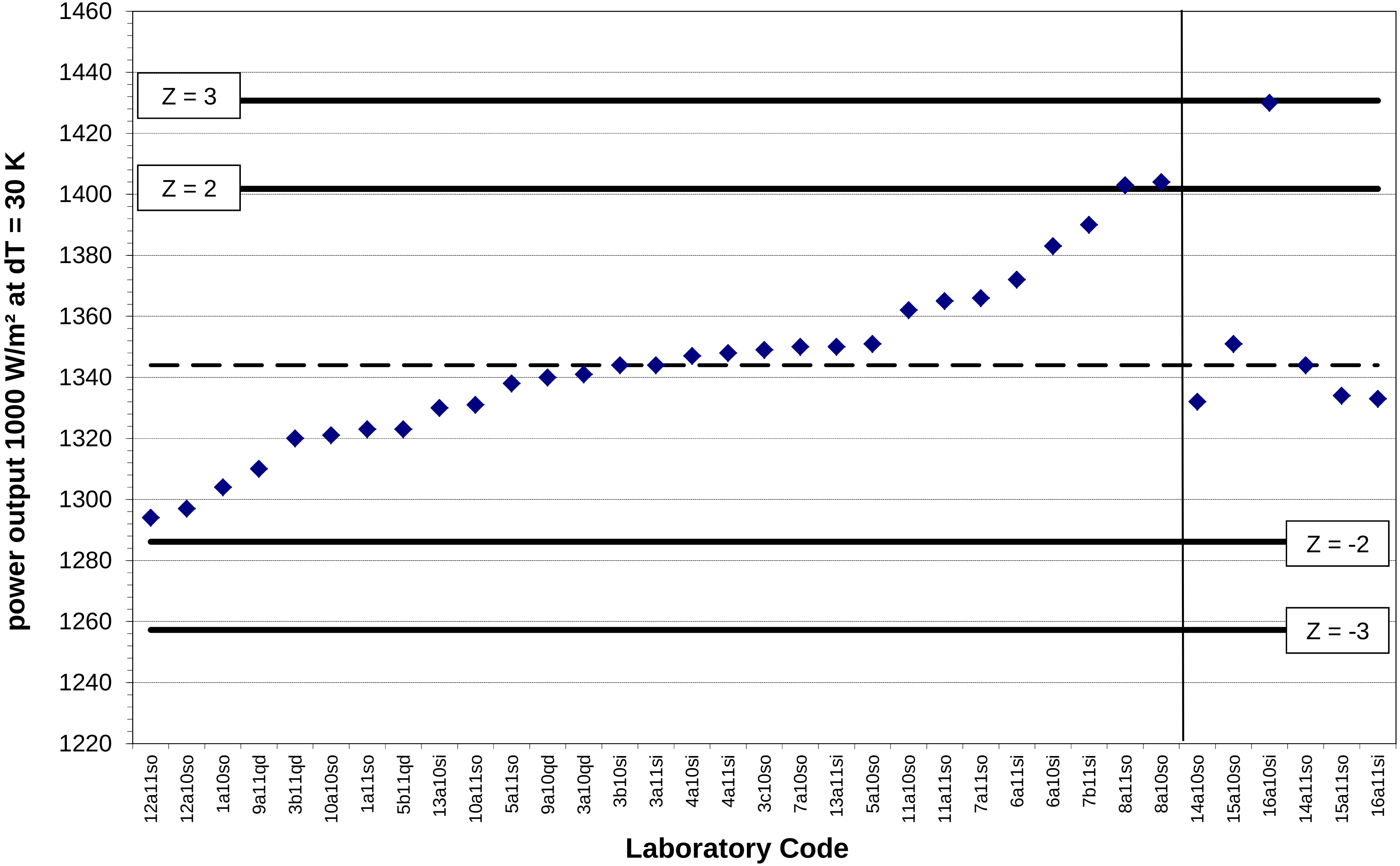

Figure A18: Power output at 1000 W/m² for dT = 30 K; all values.

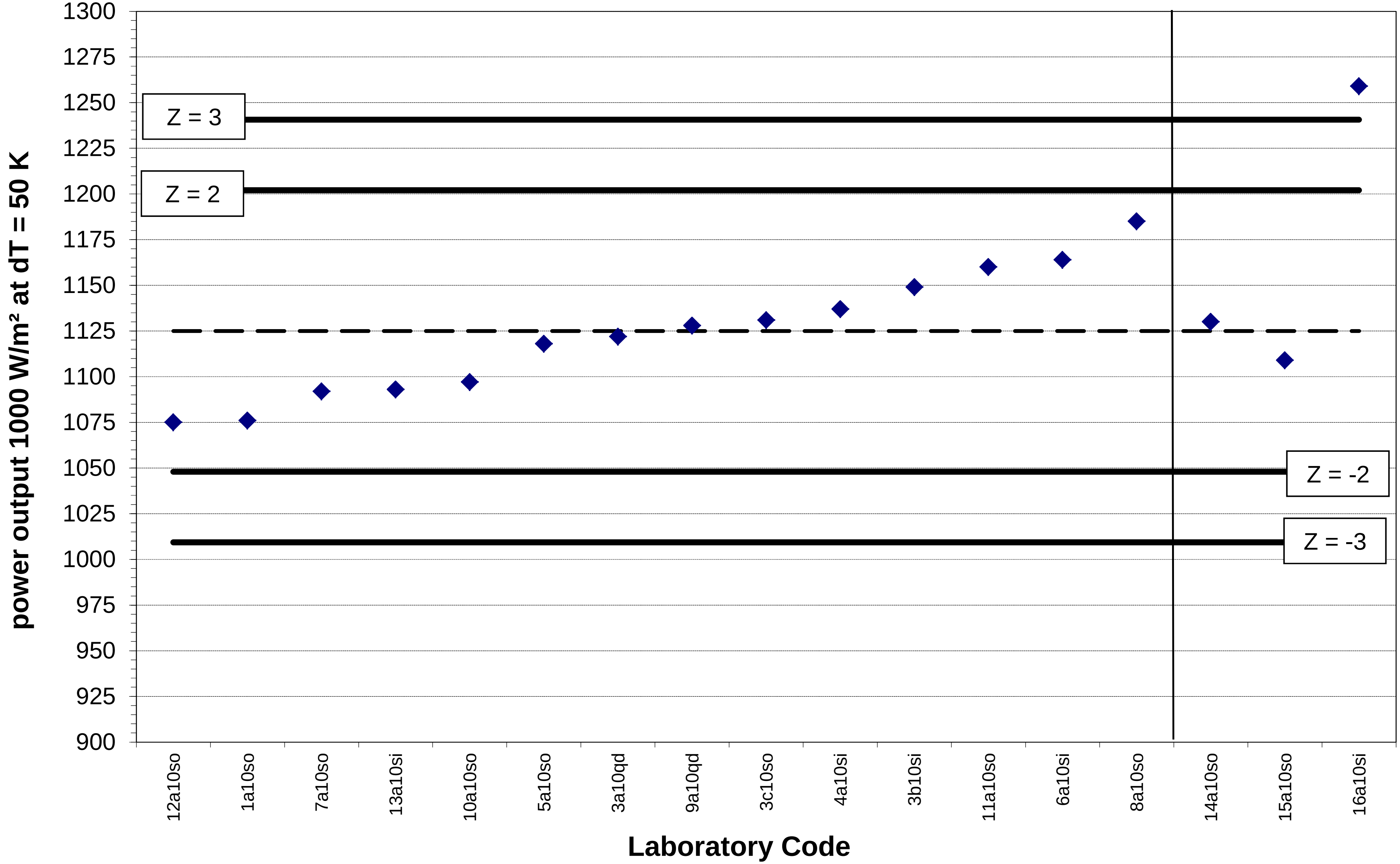

Figure A19: Power output at 1000 W/m² for dT = 50 K; values of 2010.

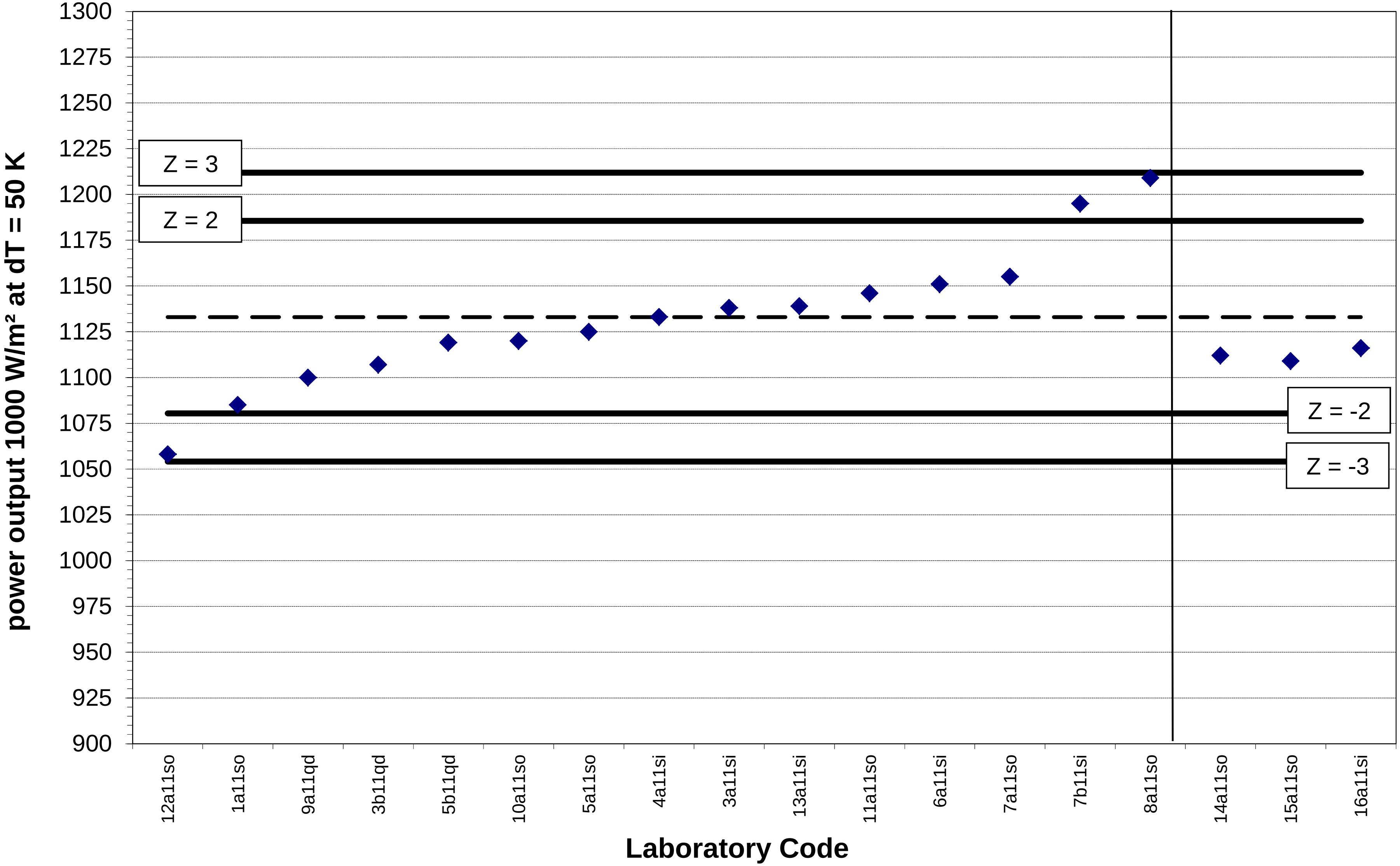

Figure A20: Power output at 1000 W/m² for dT = 50 K; values of 2011.

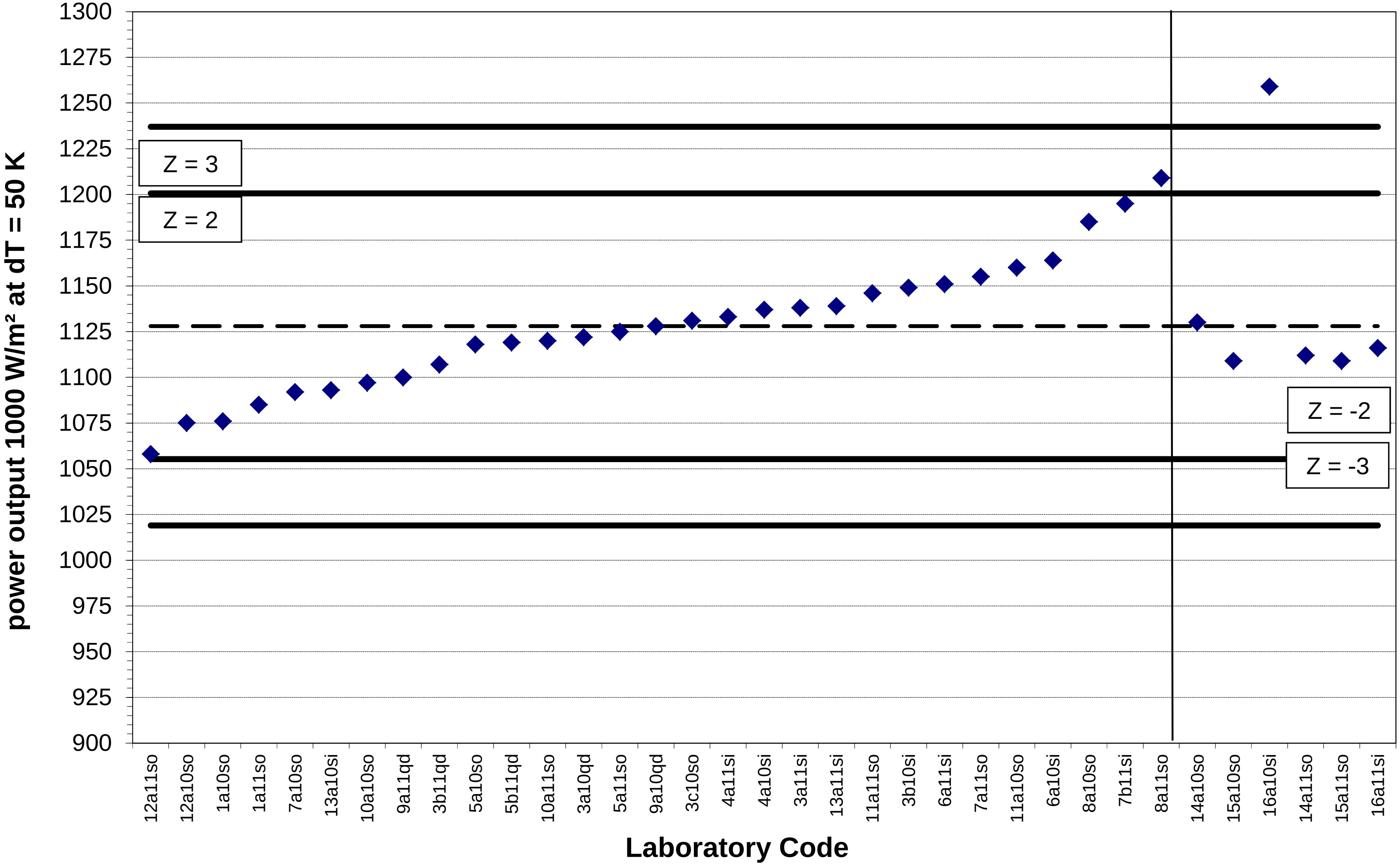

Figure A21: Power output at 1000 W/m² for dT = 50 K; all values.

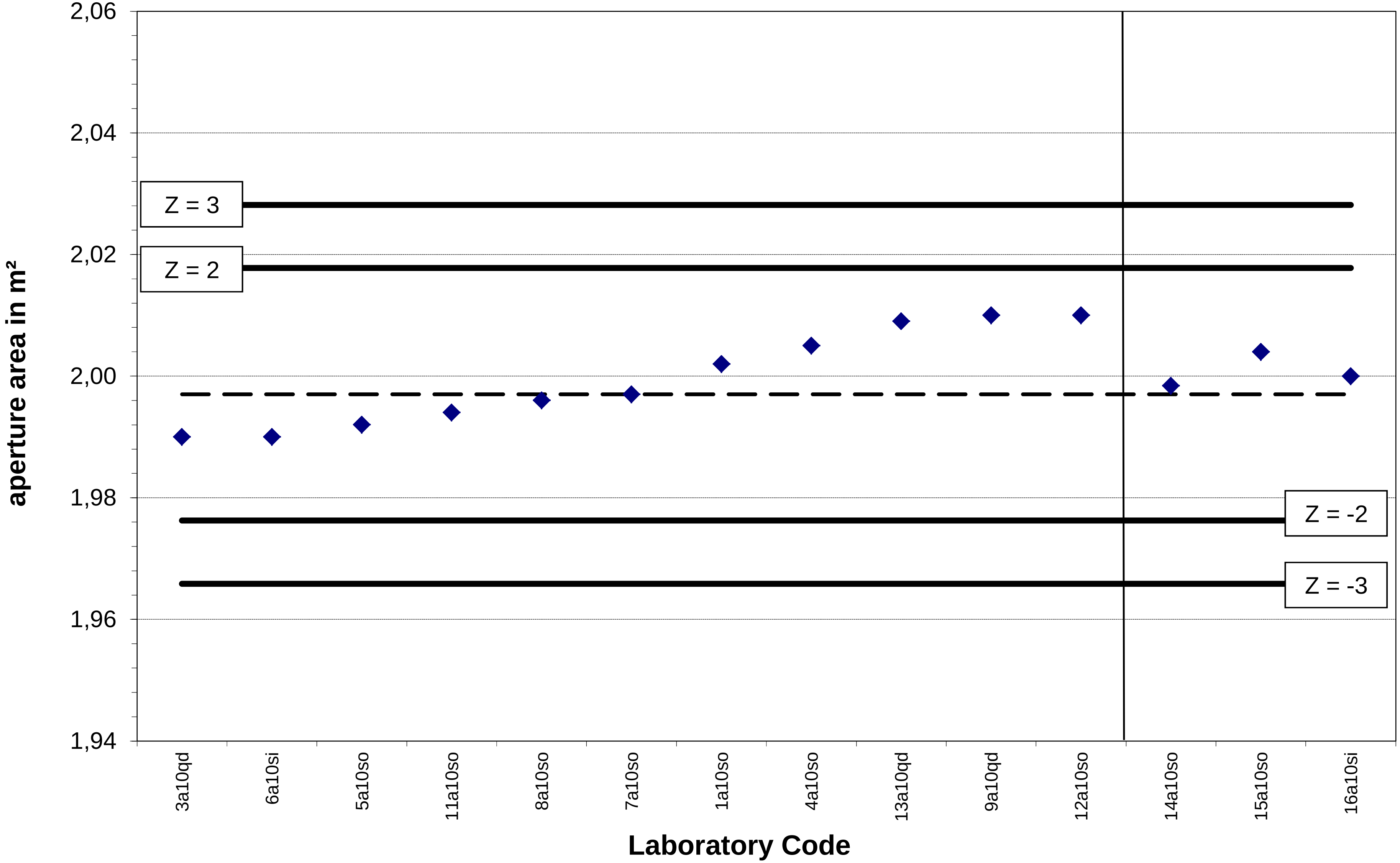

Figure B1: Aperture area; values of 2010

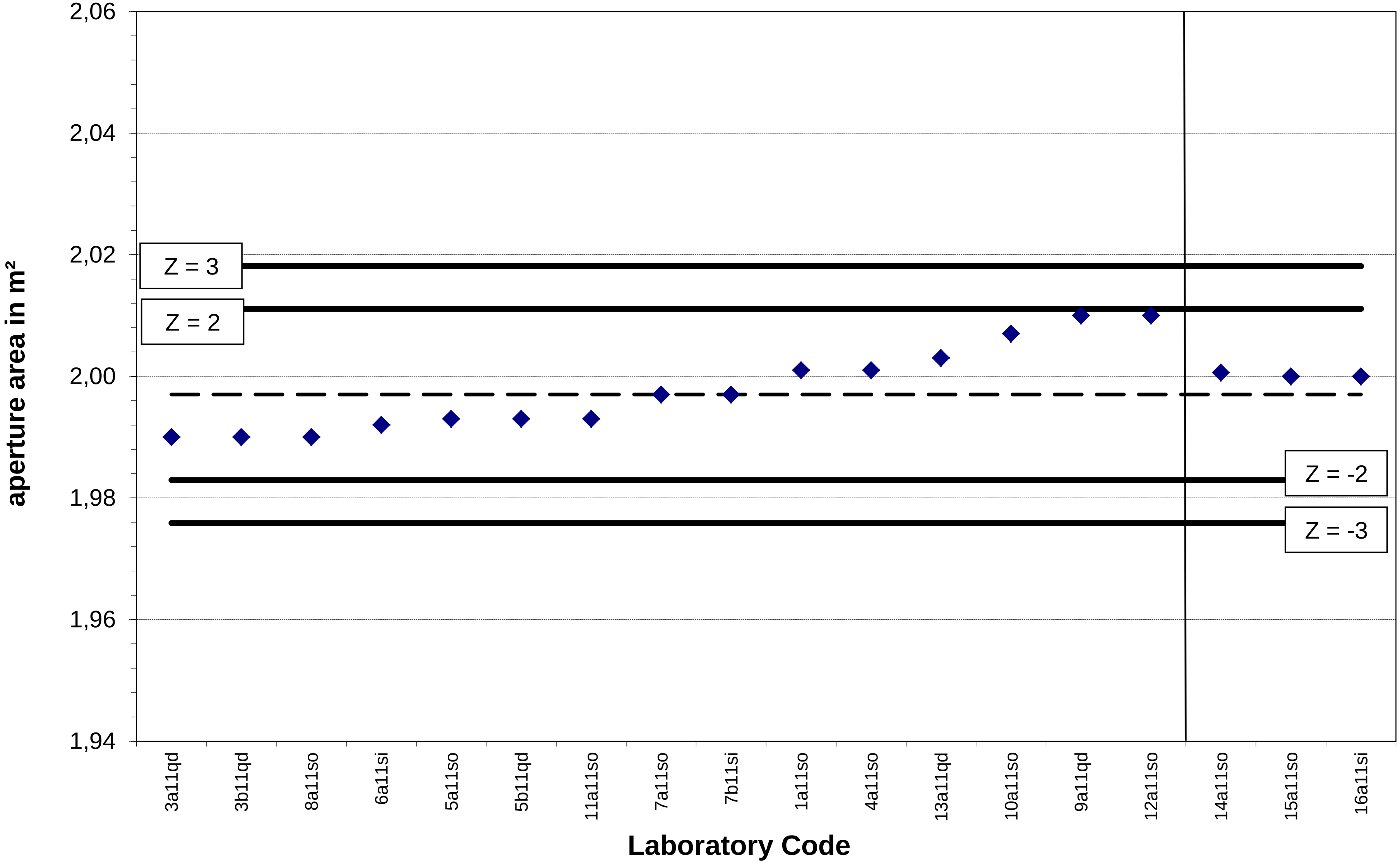

Figure B2: Aperture area; values of 2011

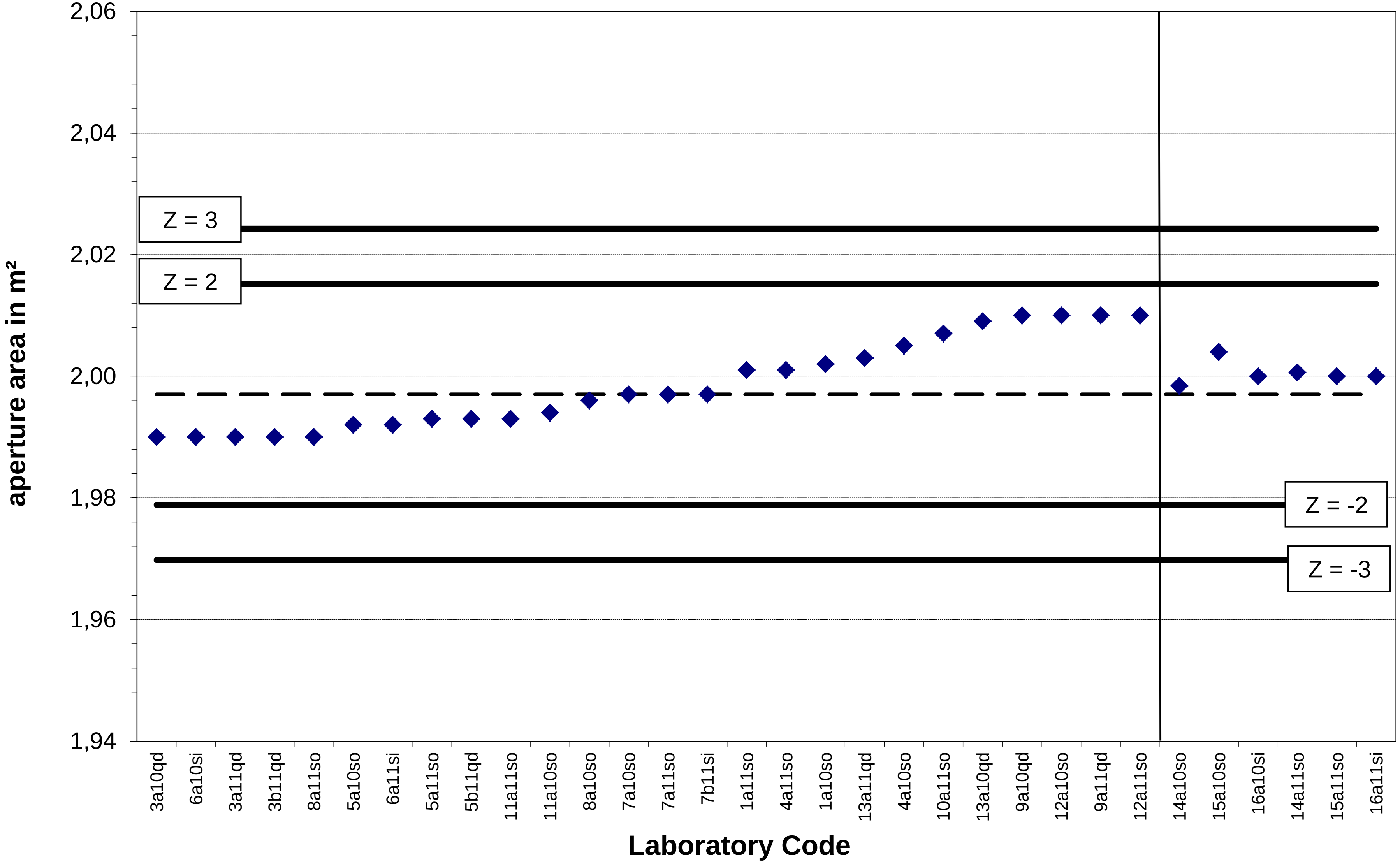

Figure B3: Aperture area; all values

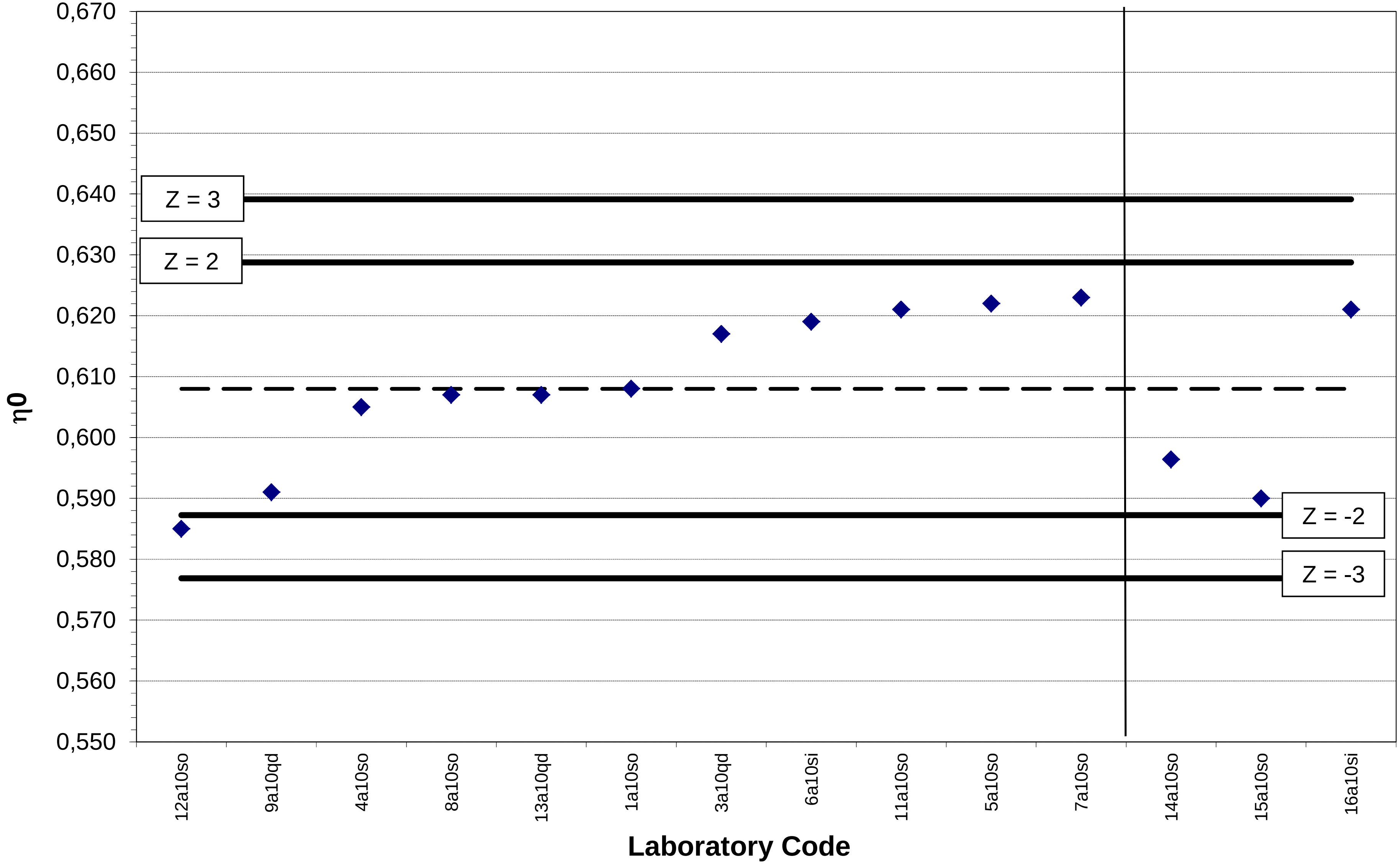

Figure B4: eta (η) 0; values of 2010

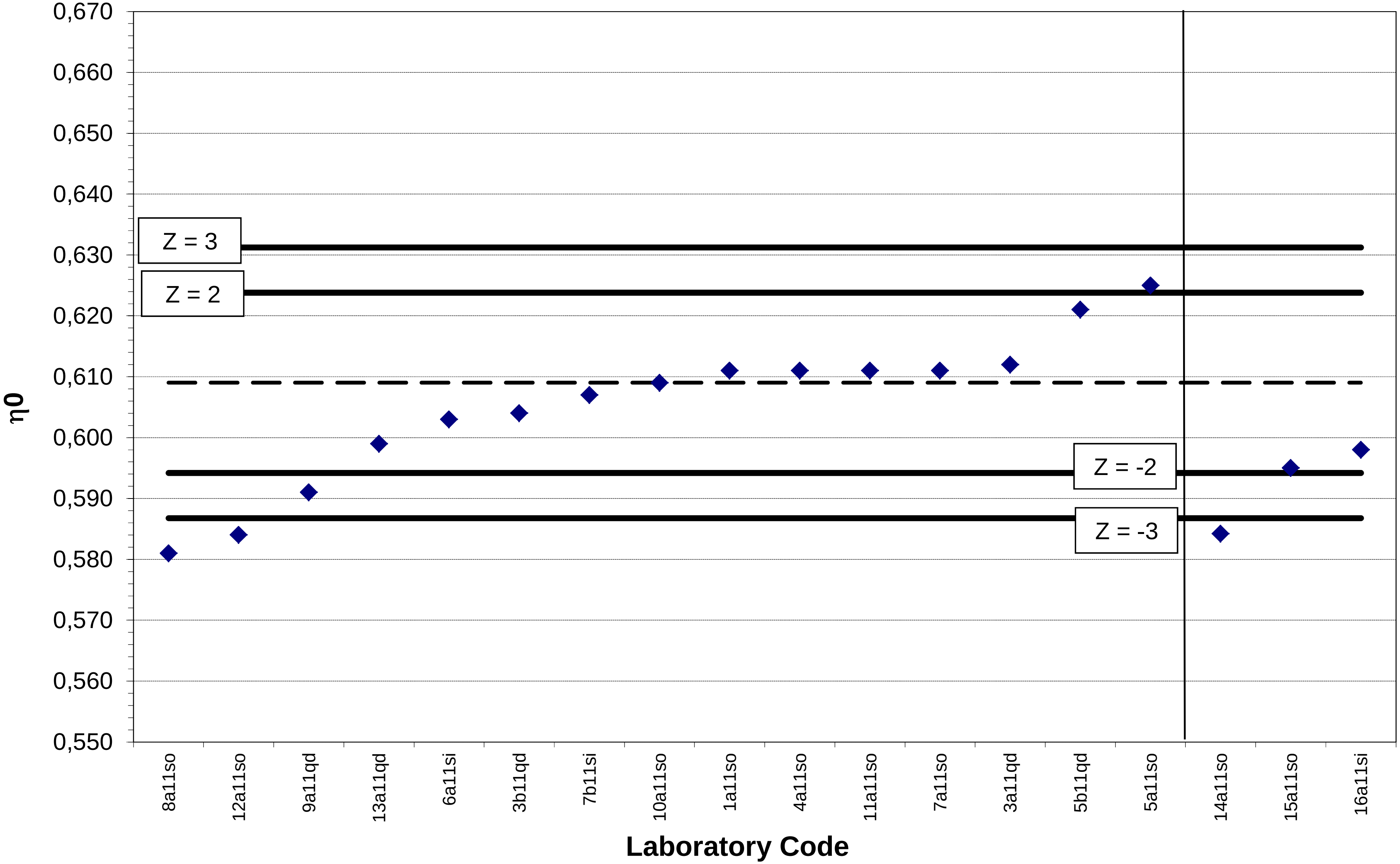

Figure B5: eta (η) 0; values of 2011

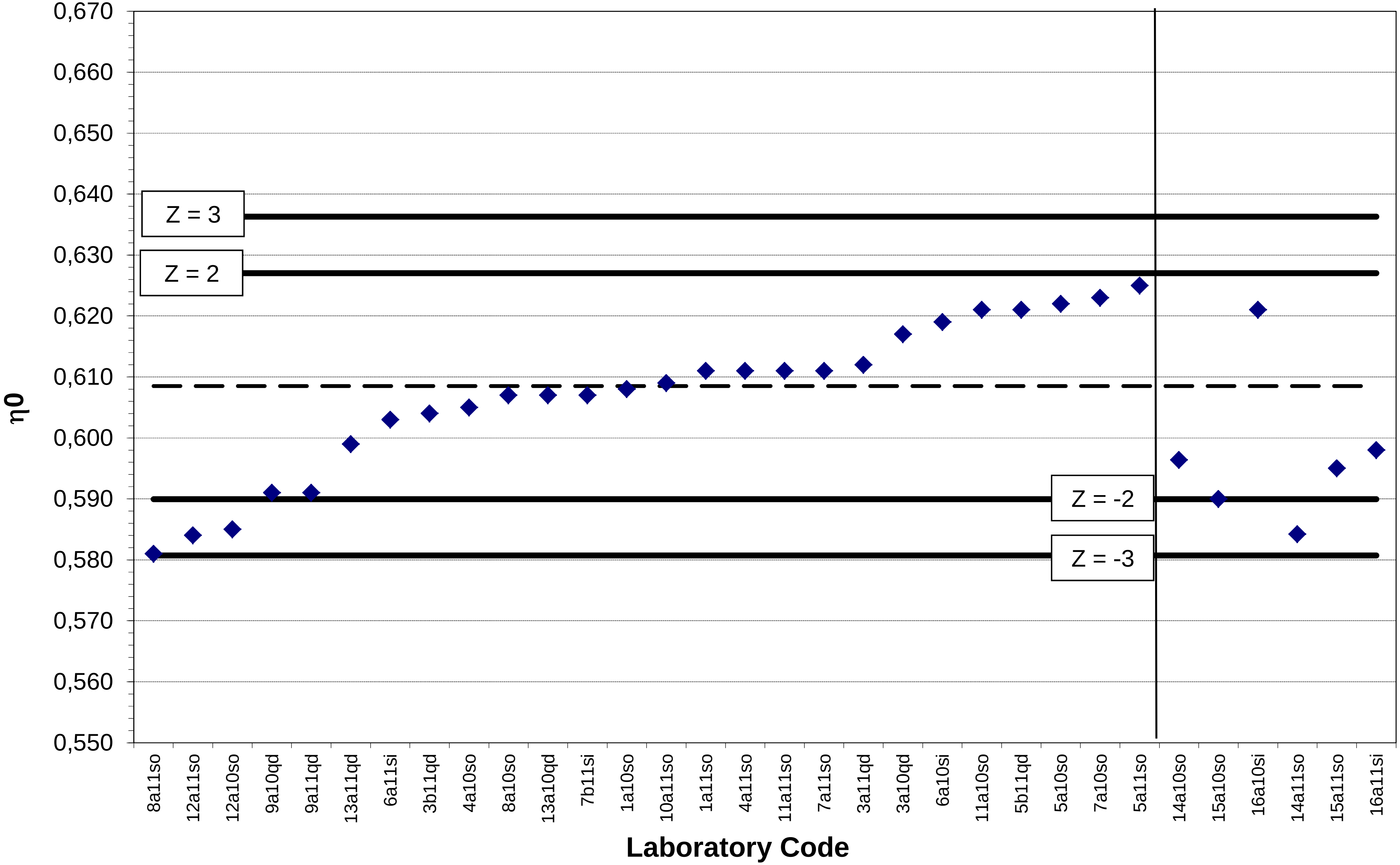

Figure B6: eta (η) 0; all values

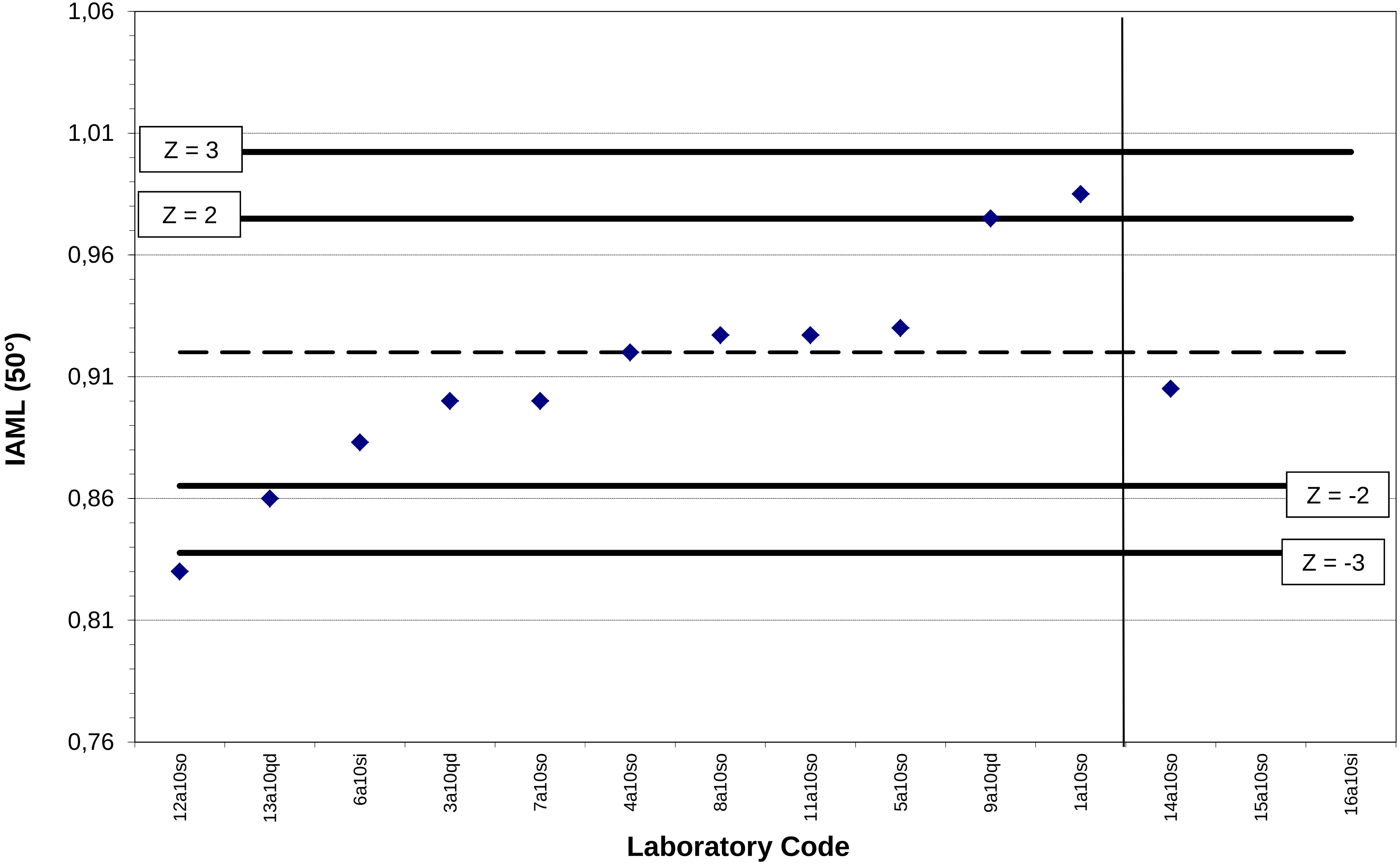

Figure B7: Incidence angle modifier, IAML 50°; values of 2010. Labs w/o data points: not stated

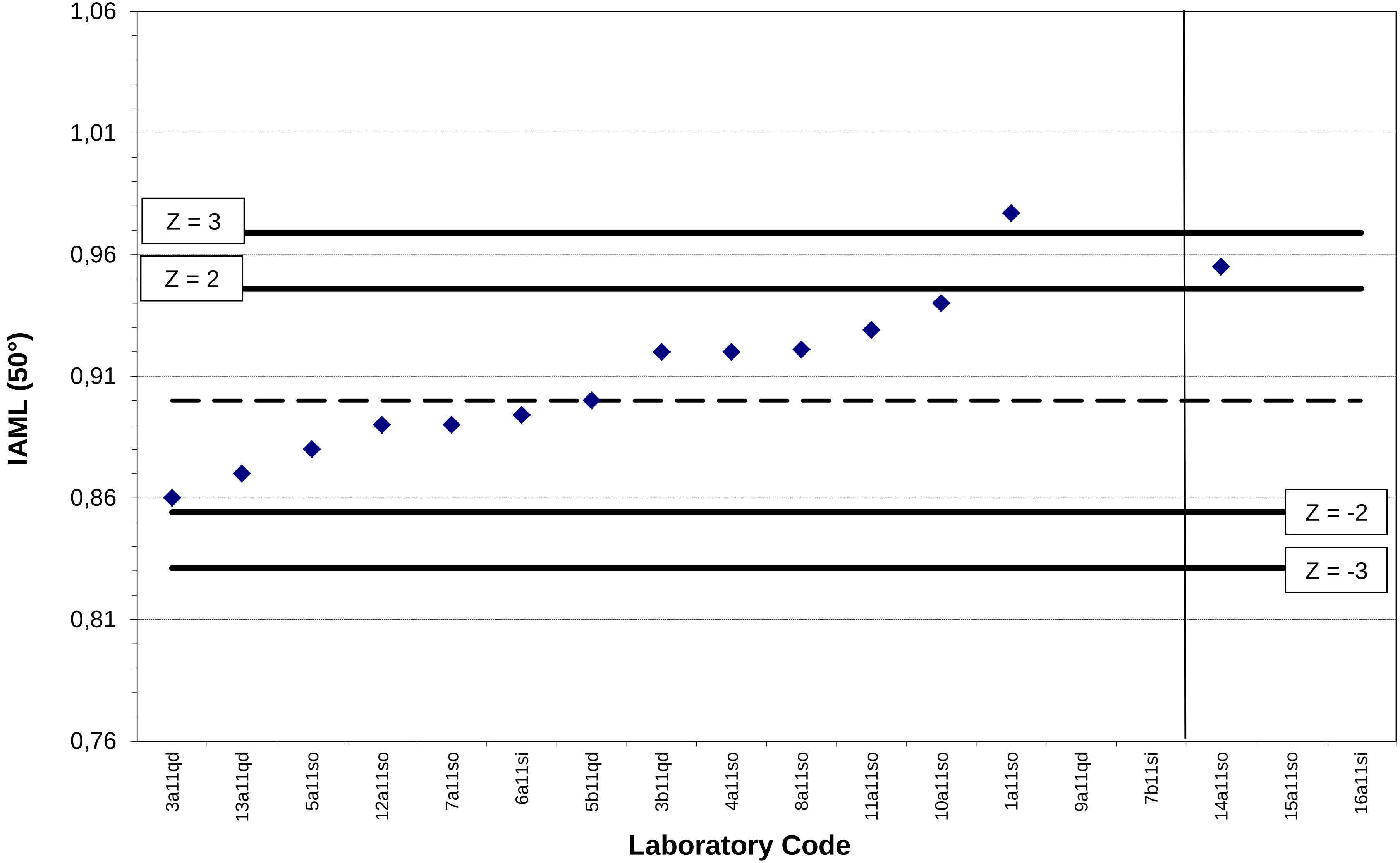

Figure B8: Incidence angle modifier, IAML 50°; values of 2011. Labs w/o data points: not stated

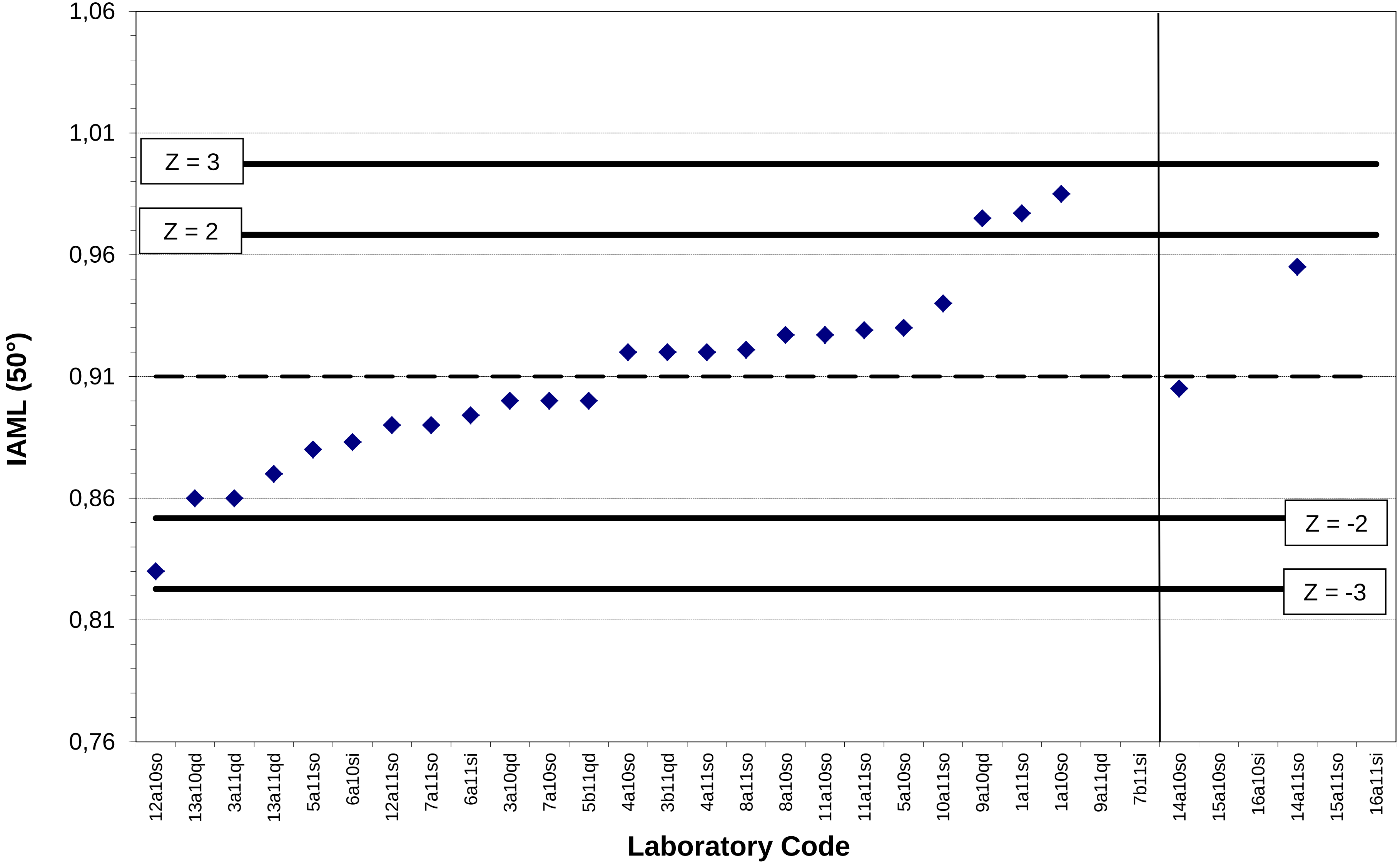

Figure B9: Incidence angle modifier, IAML 50°; all values. Labs w/o data points: not stated

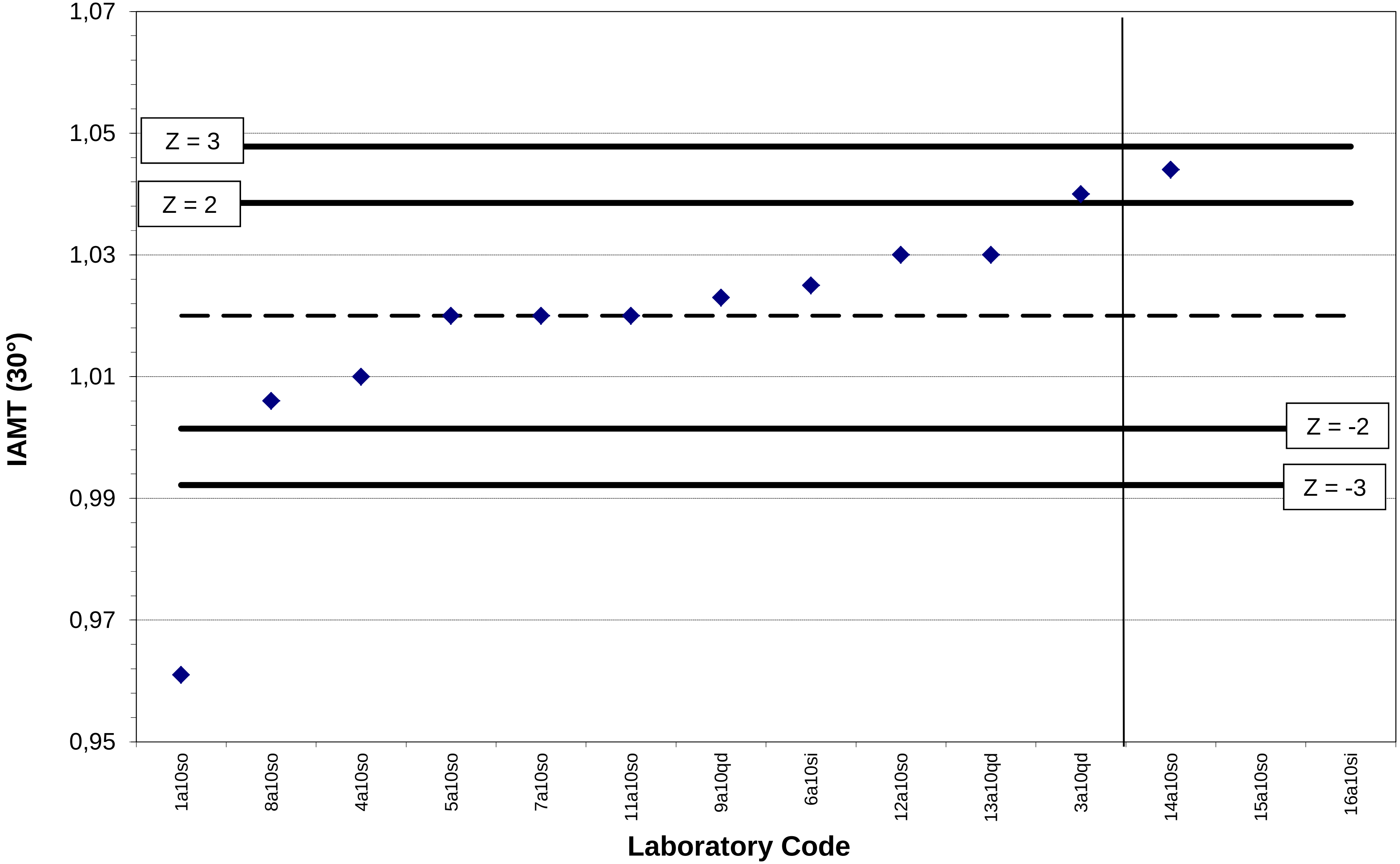

Figure B10: Incidence angle modifier, IAMT 30°; values of 2010. Labs w/o data points: not stated

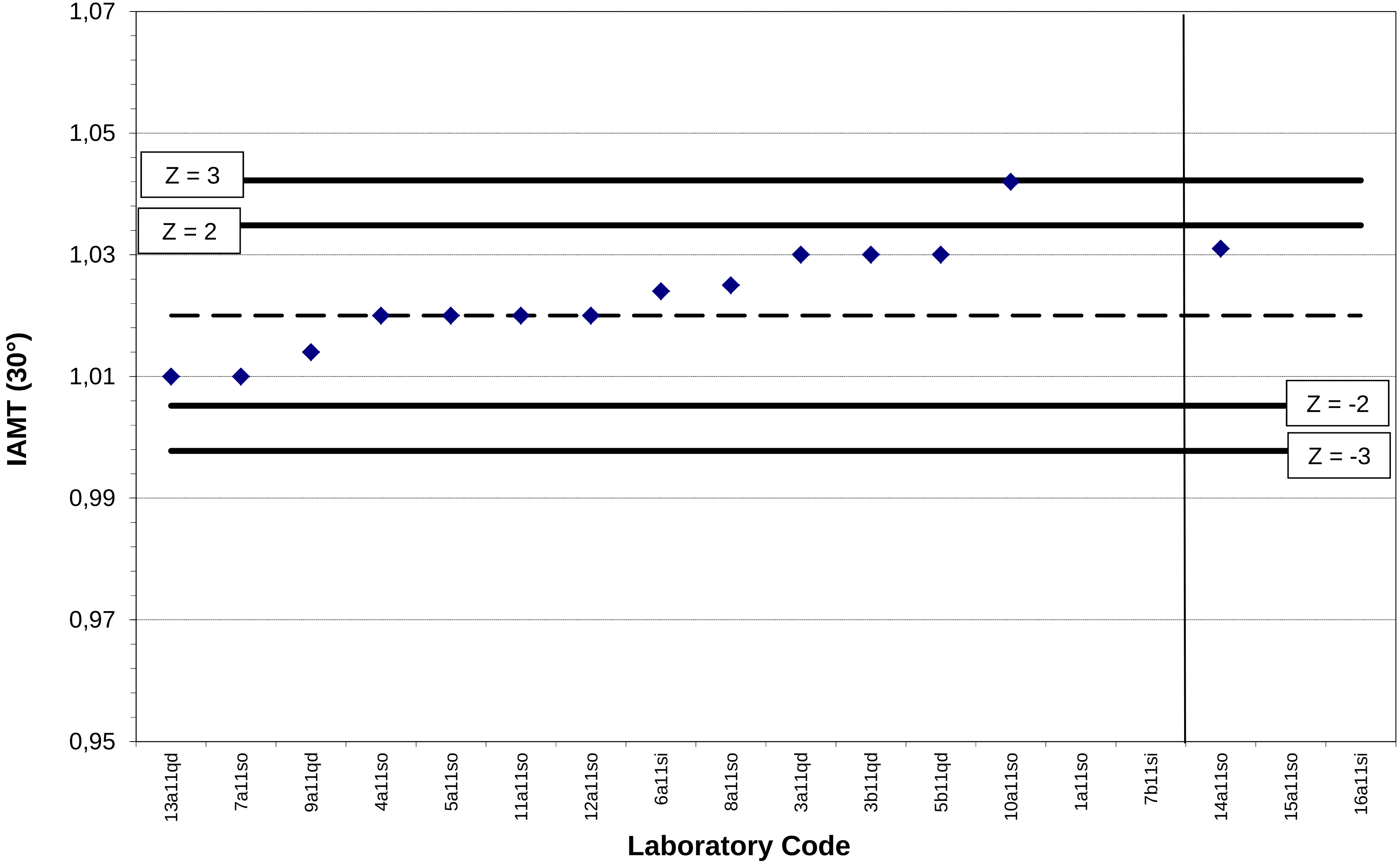

Figure B11: Incidence angle modifier, IAMT 30°; values of 2011. Labs w/o data points: not stated

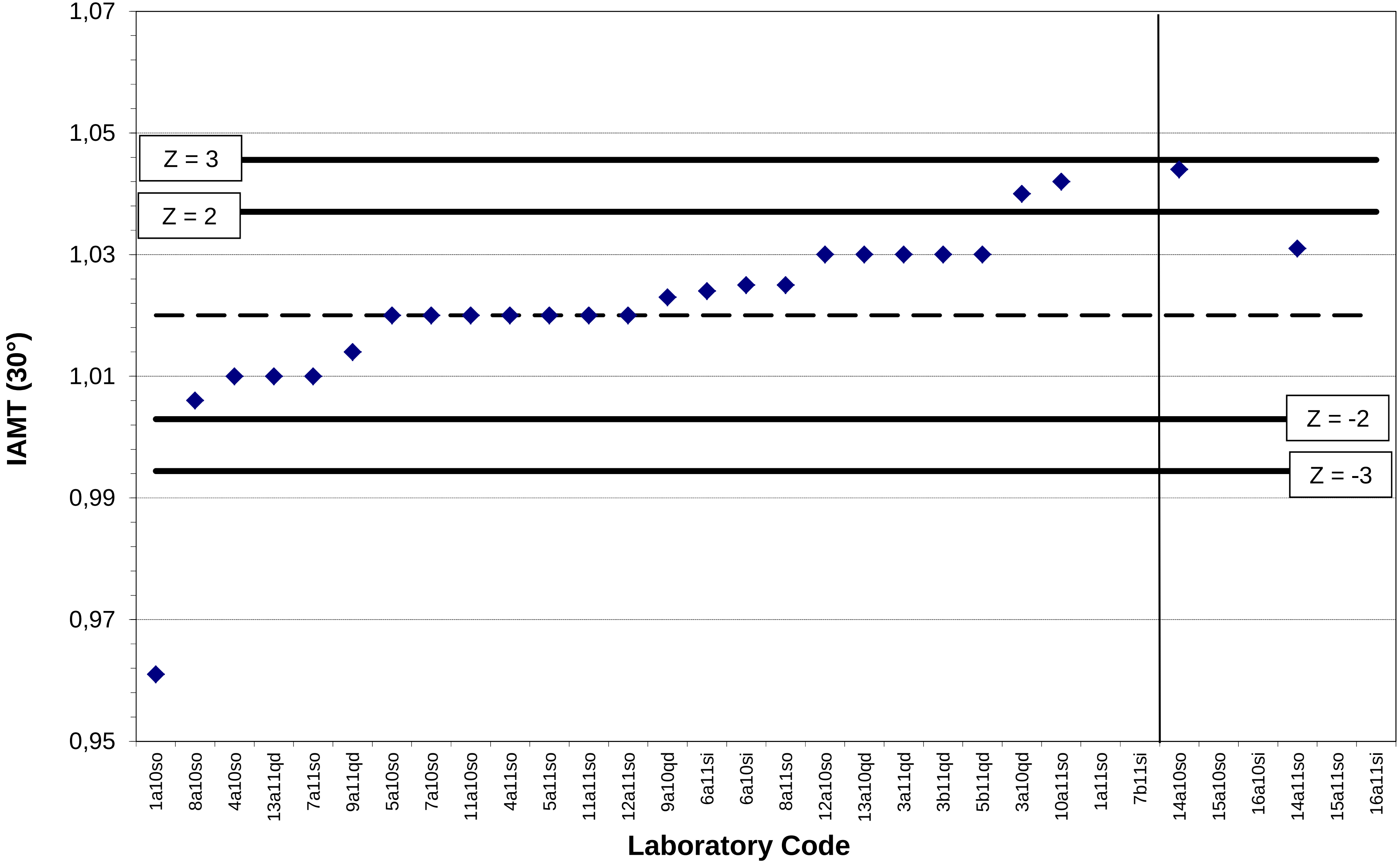

Figure B12: Incidence angle modifier, IAMT 30°; all values. Labs w/o data points: not stated

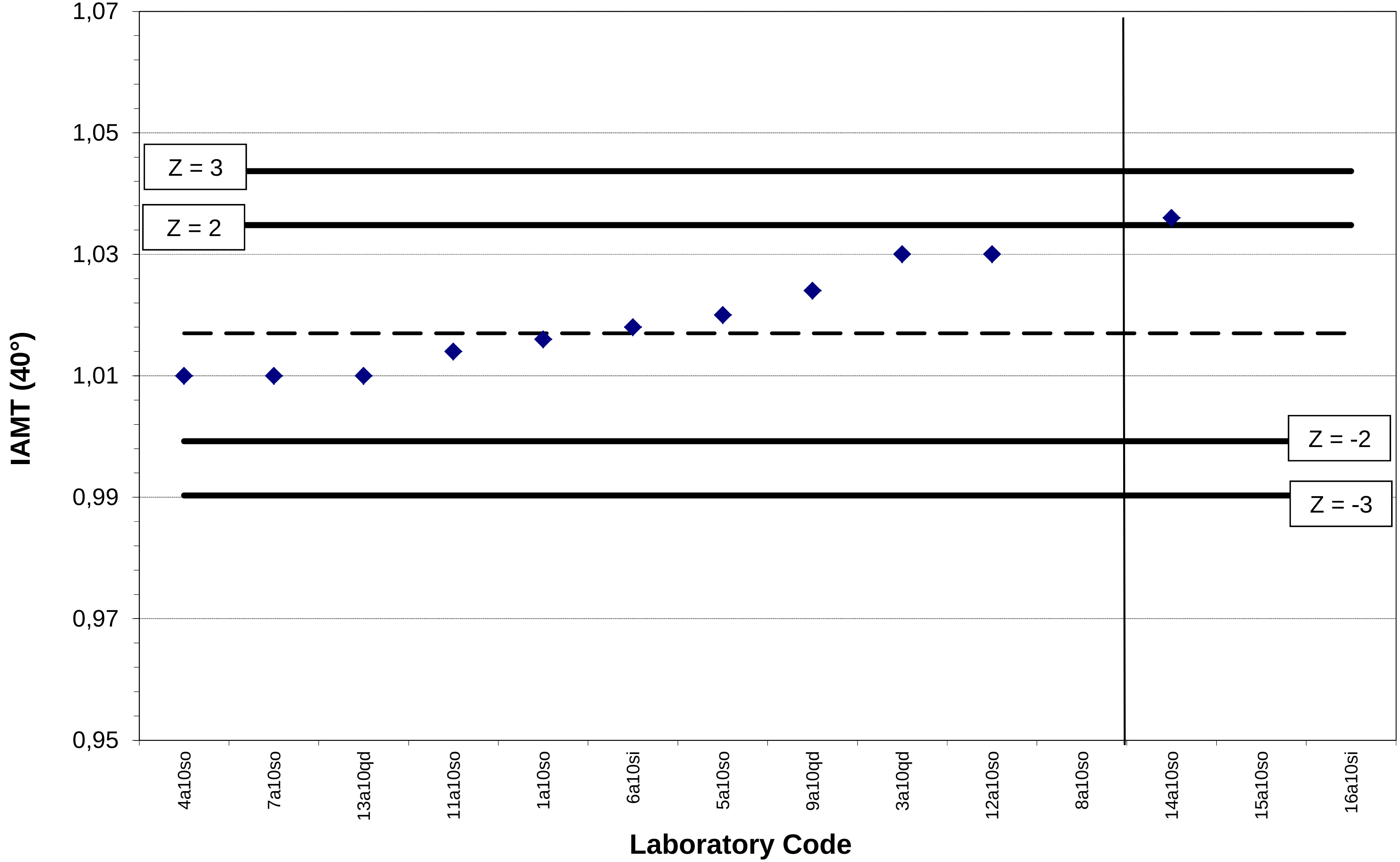

Figure B13: Incidence angle modifier, IAMT 40°; values of 2010. Labs w/o data points: not stated

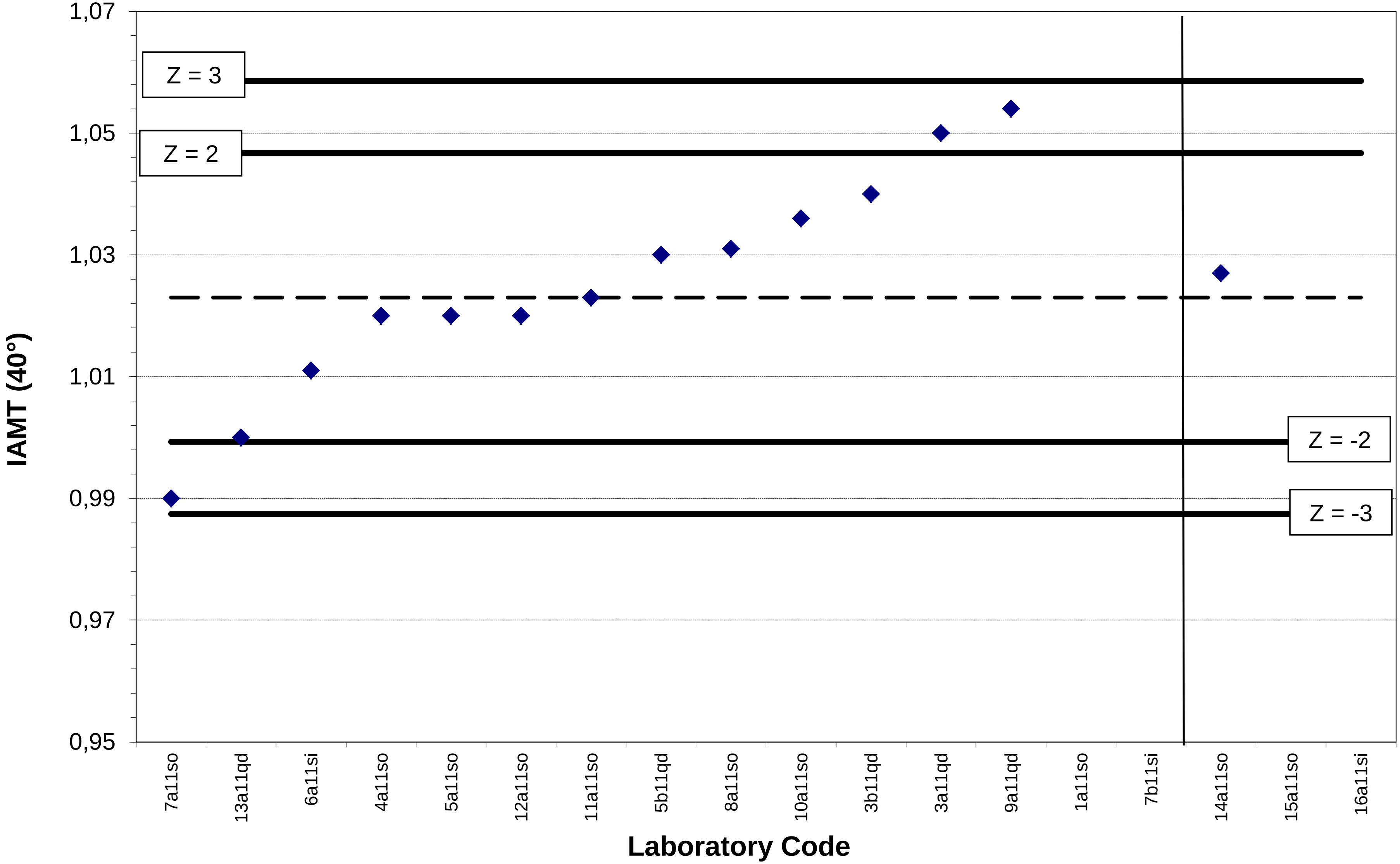

Figure B14: Incidence angle modifier, IAMT 40°; values of 2011. Labs w/o data points: not stated

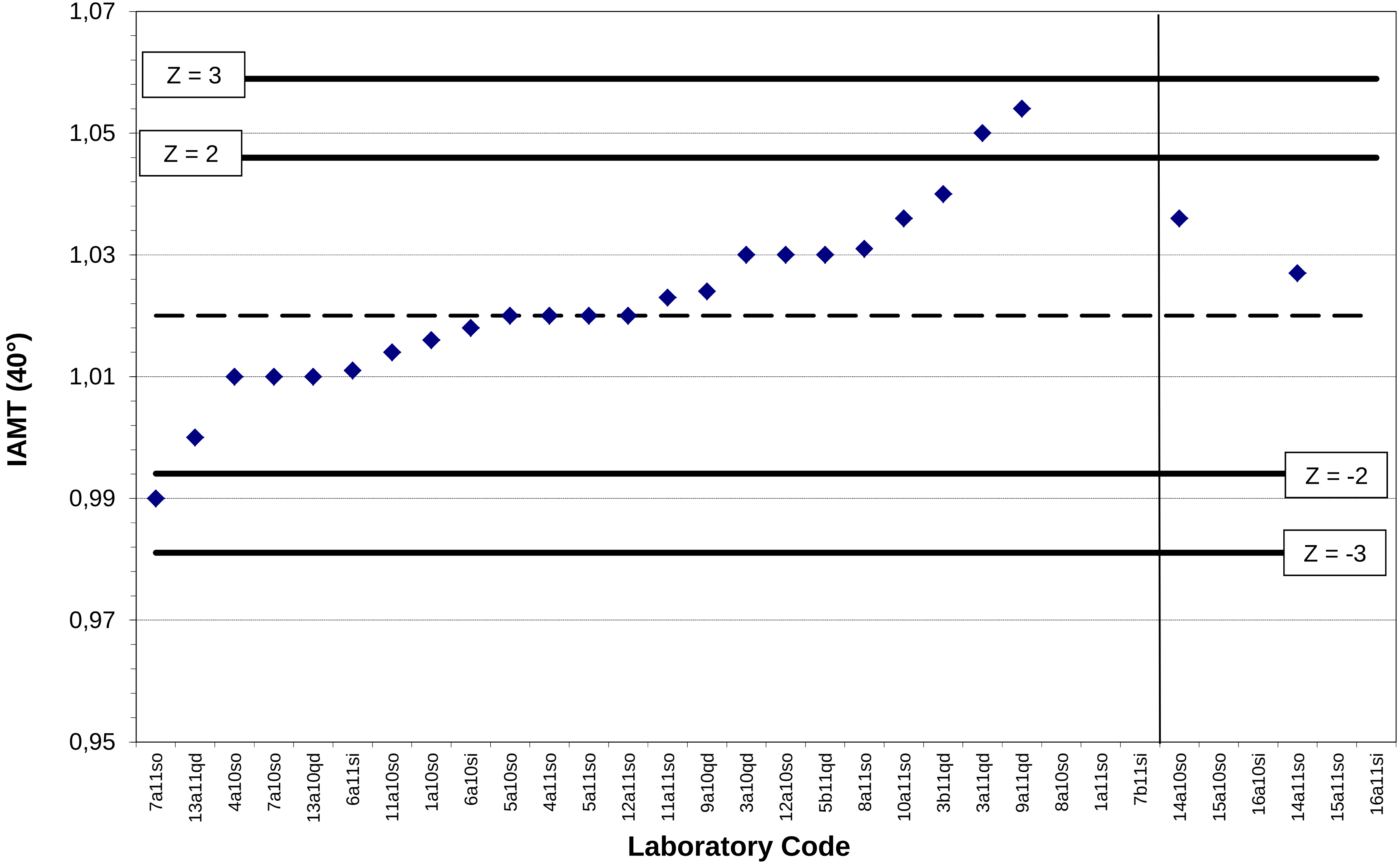

Figure B15: Incidence angle modifier, IAMT 40°; all values. Labs w/o data points: not stated

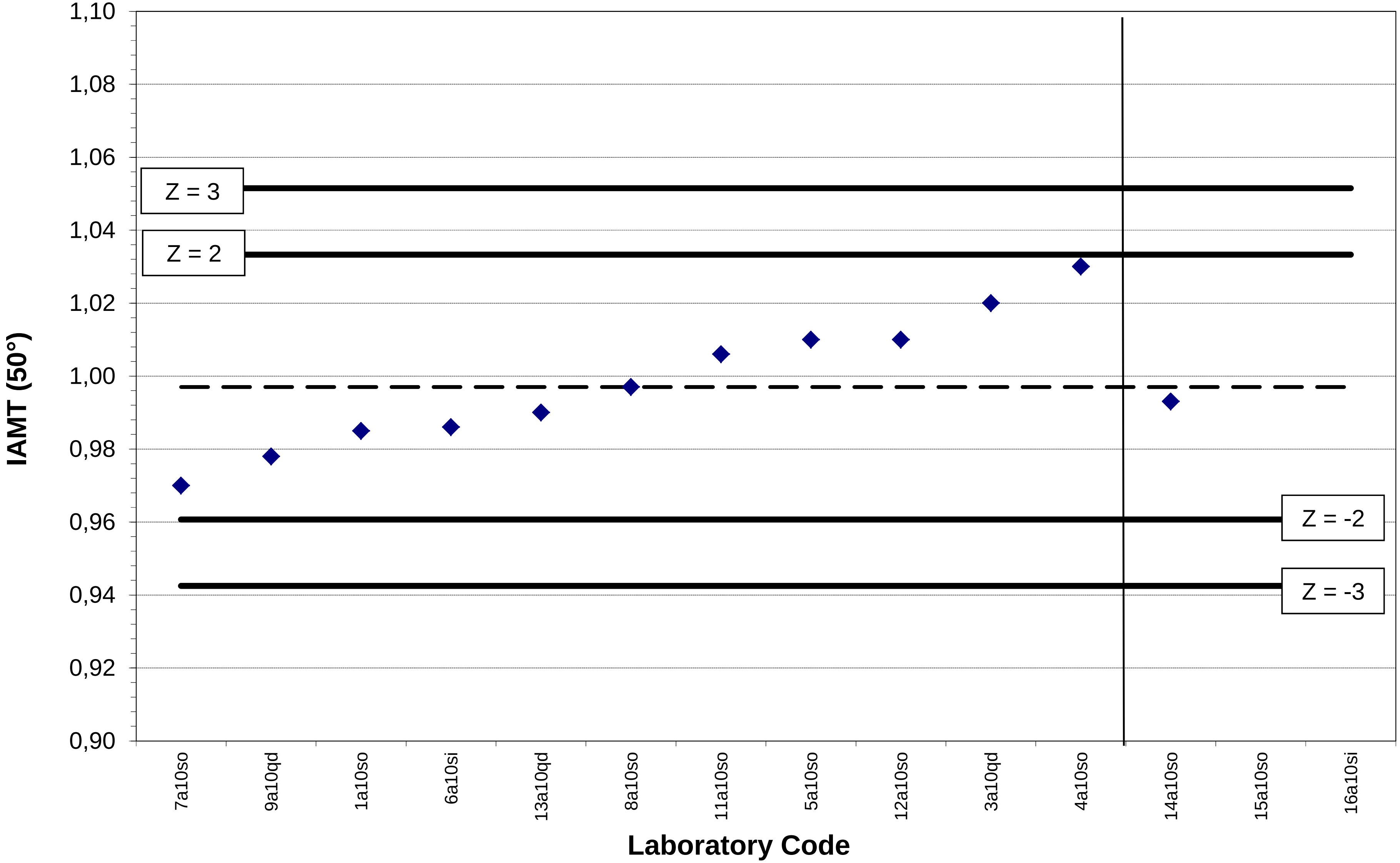

Figure B16: Incidence angle modifier, IAMT 50°; values of 2010. Labs w/o data points: not stated

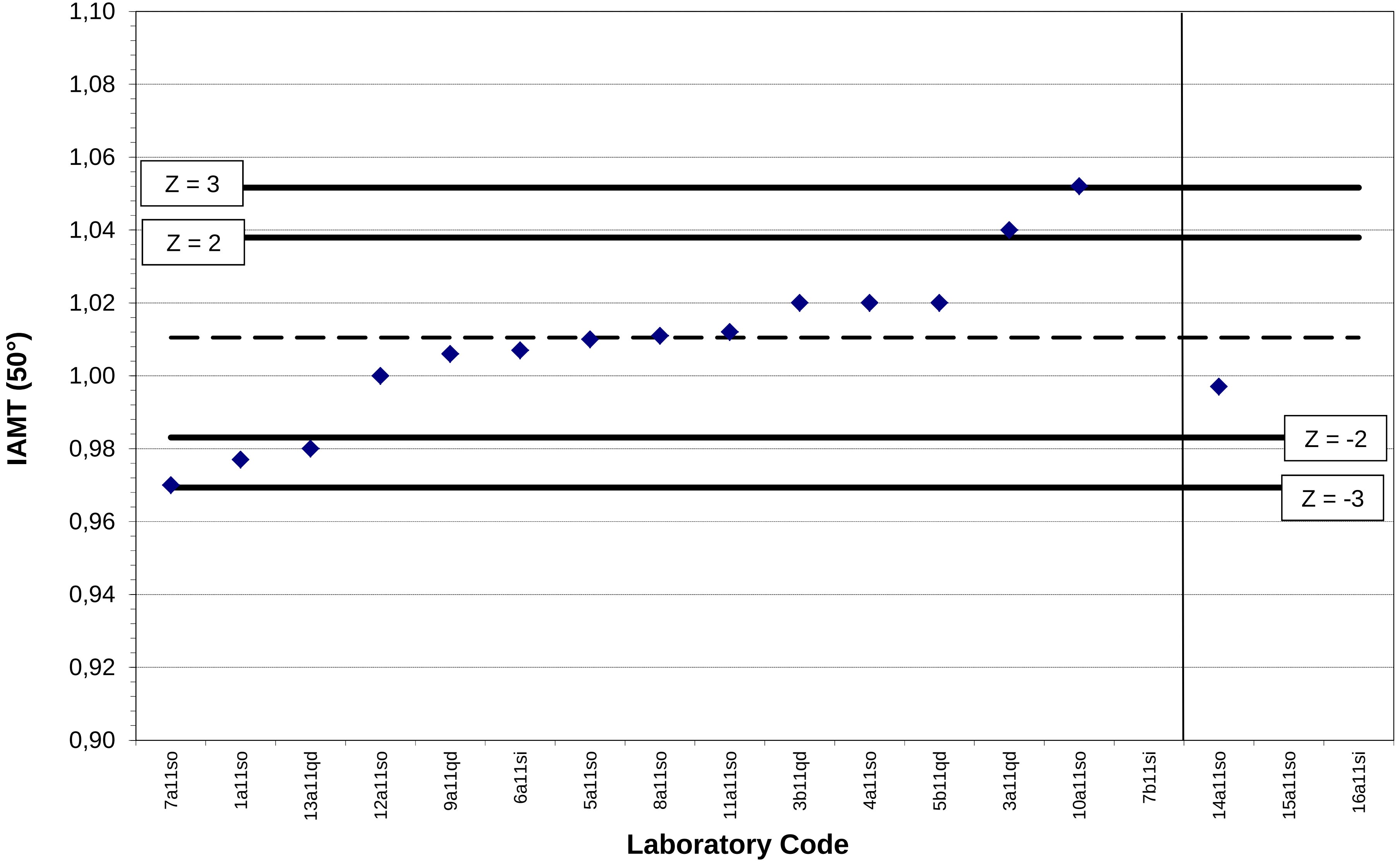

Figure B17: Incidence angle modifier, IAMT 50°; values of 2011. Labs w/o data points: not stated

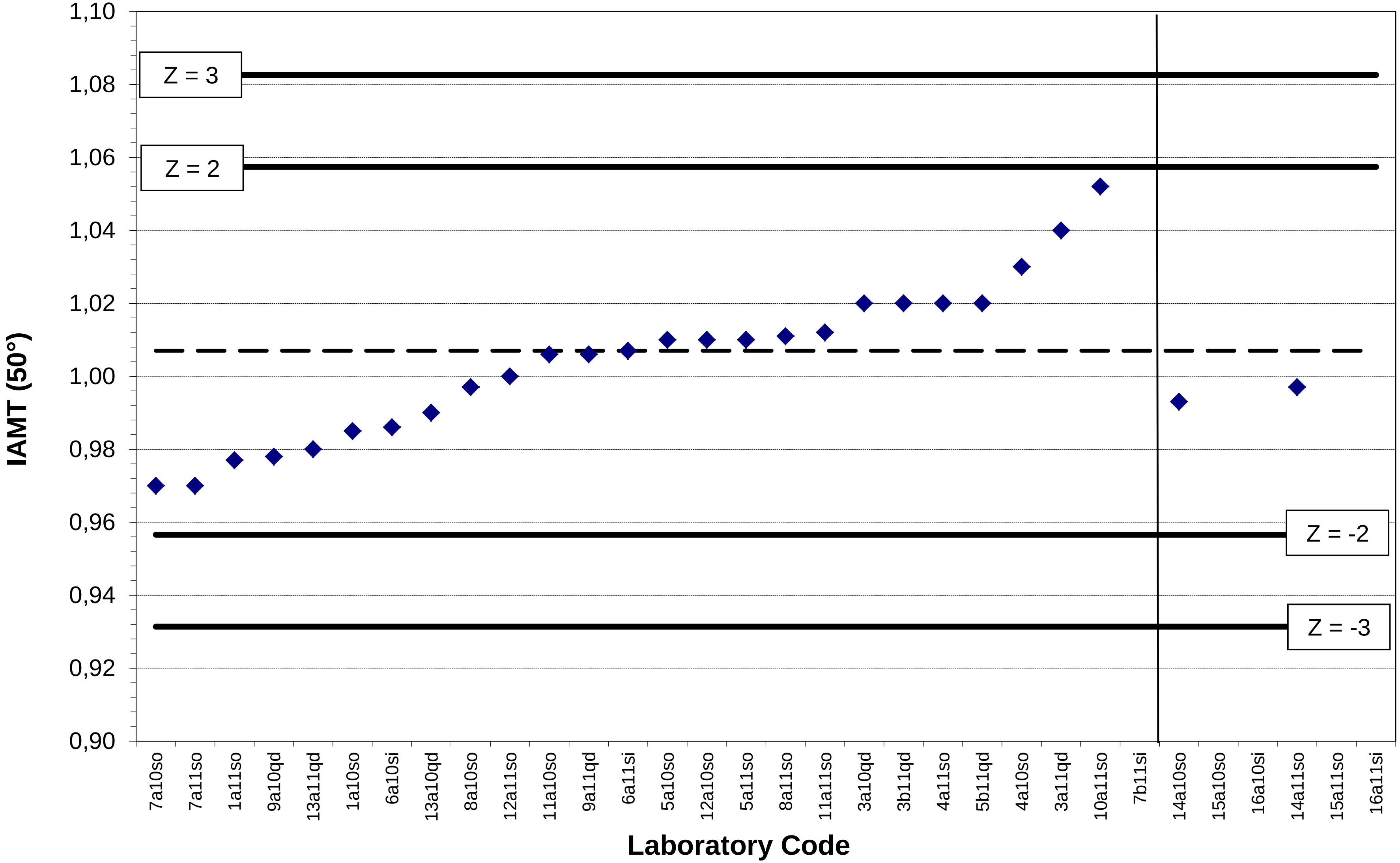

Figure B18: Incidence angle modifier, IAMT 50°; all values. Labs w/o data points: not stated

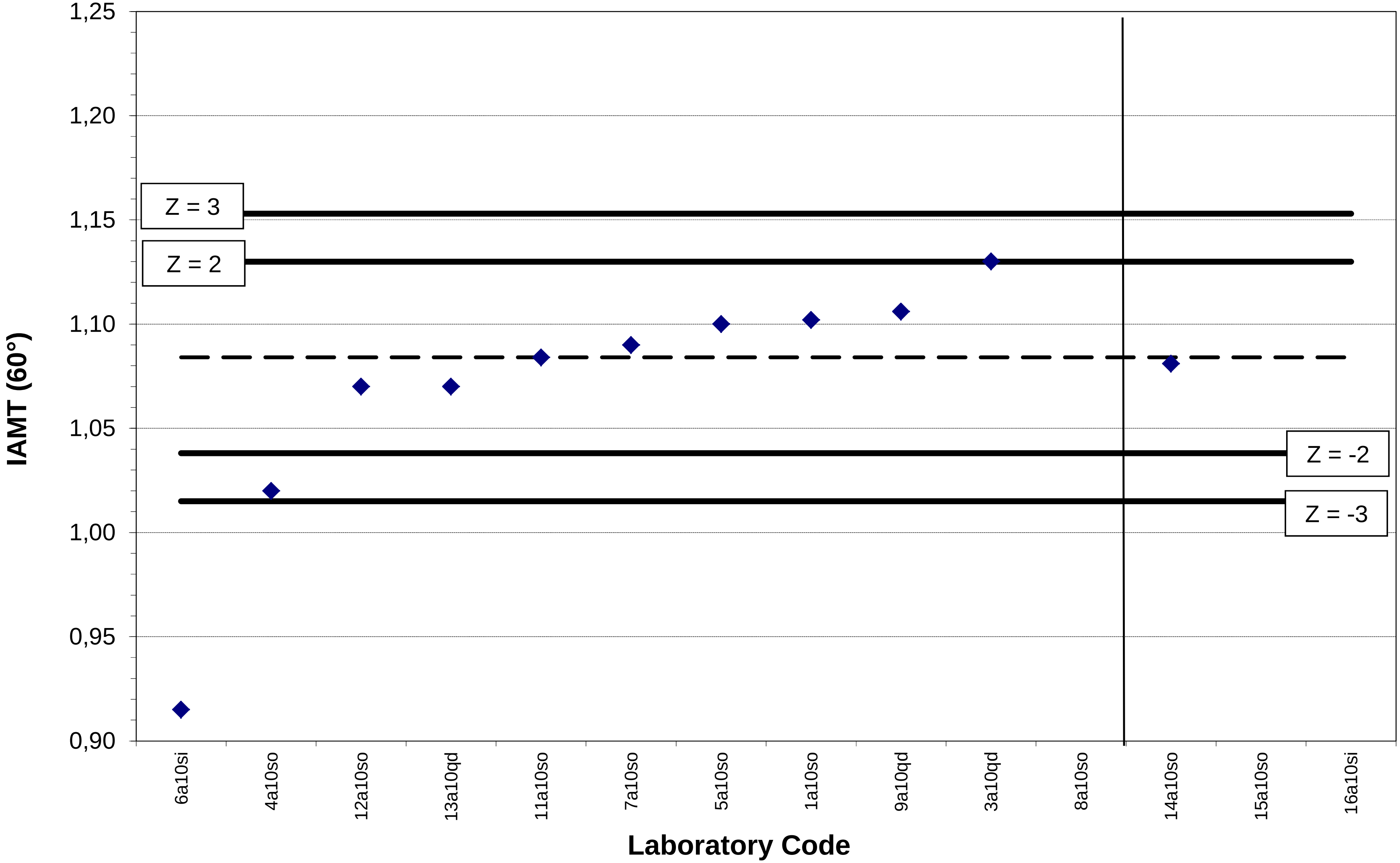

Figure B19: Incidence angle modifier, IAMT 60°; values of 2010. Labs w/o data points: not stated

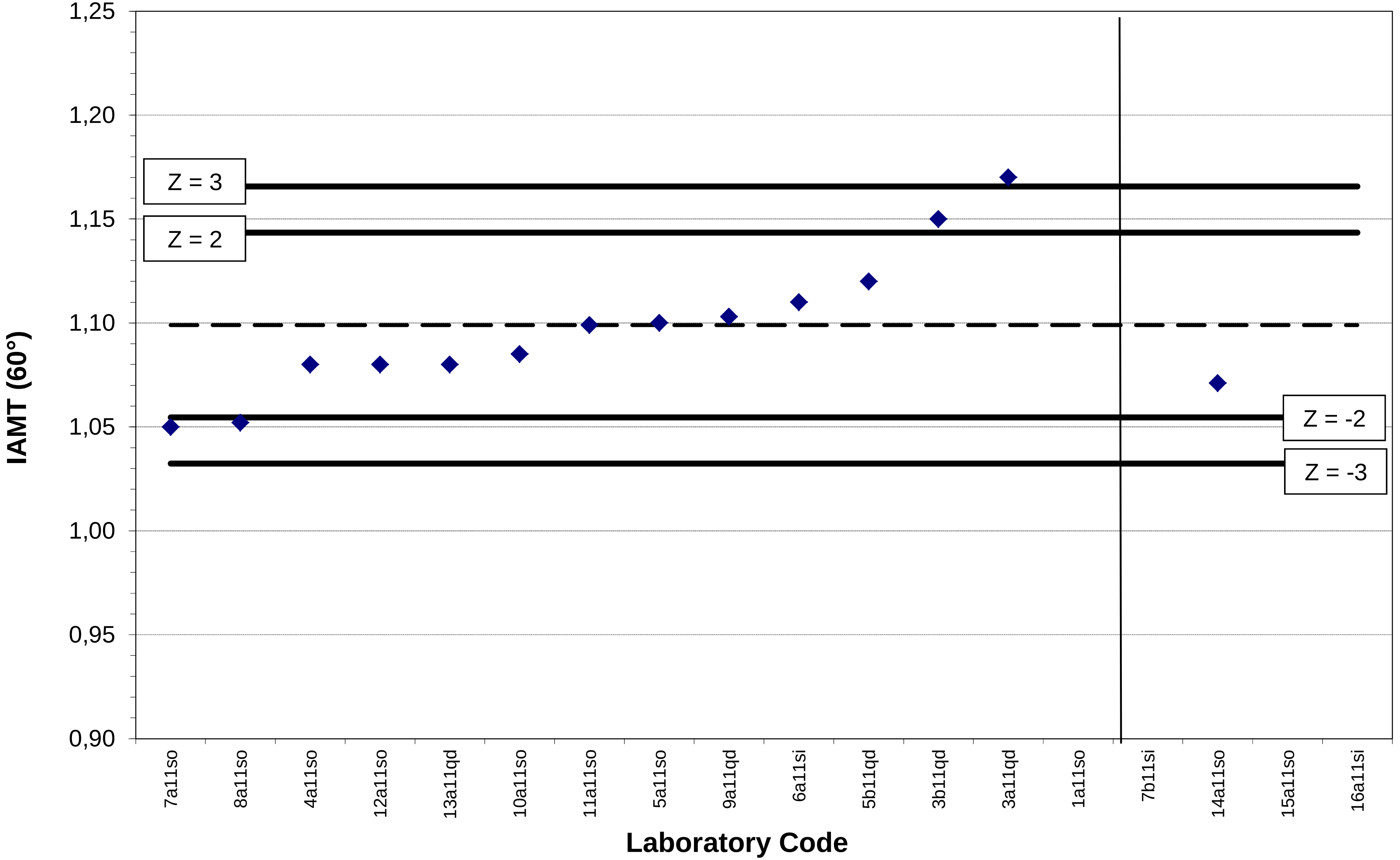

Figure B20: Incidence angle modifier, IAMT 60°; values of 2011. Labs w/o data points: not stated

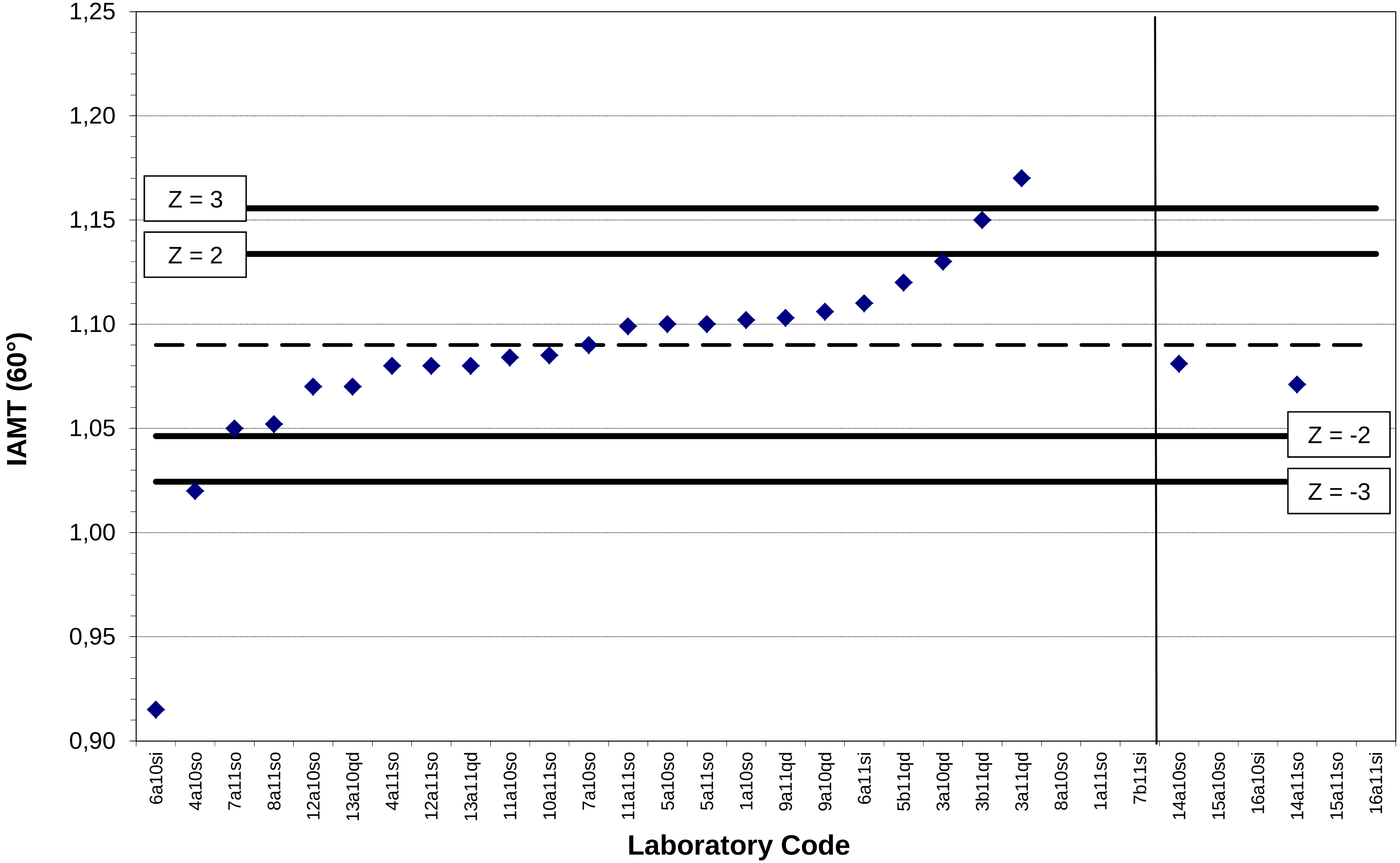

Figure B21: Incidence angle modifier, IAMT 60°; all values. Labs w/o data points: not stated

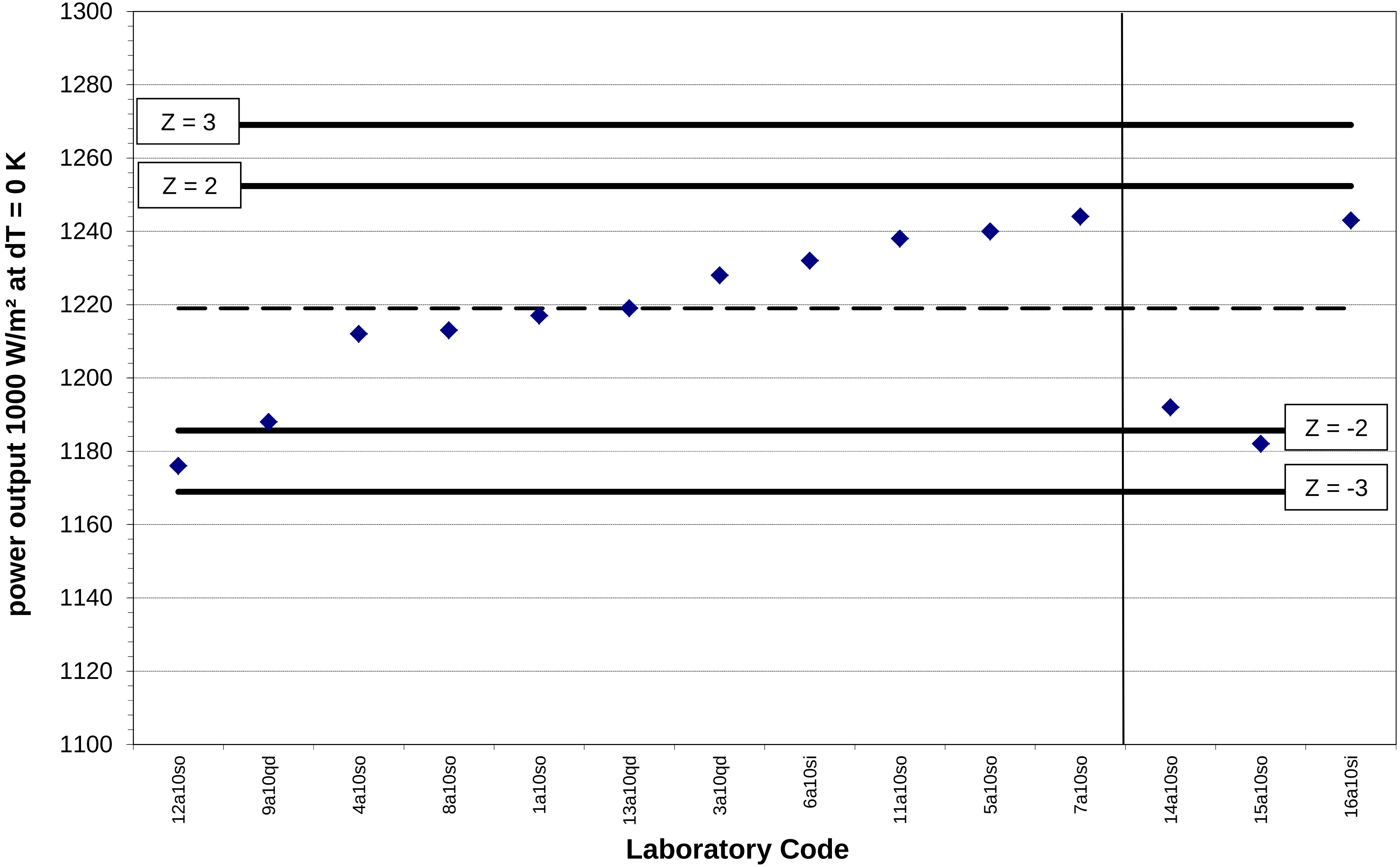

Figure B22: Power output at 1000 W/m² for dT = 0 K; values of 2010.

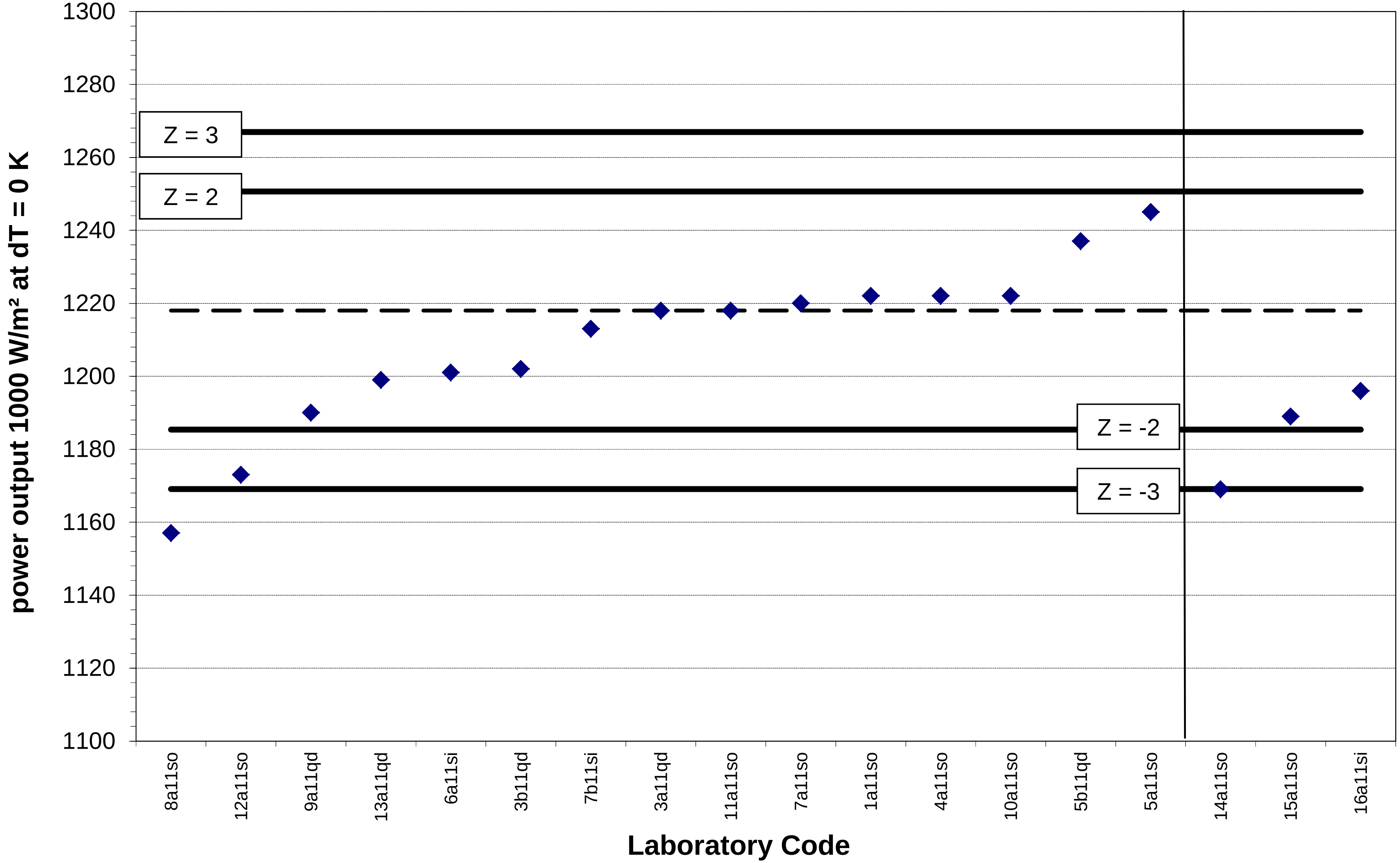

Figure B23: Power output at 1000 W/m² for dT = 0 K; values of 2011.

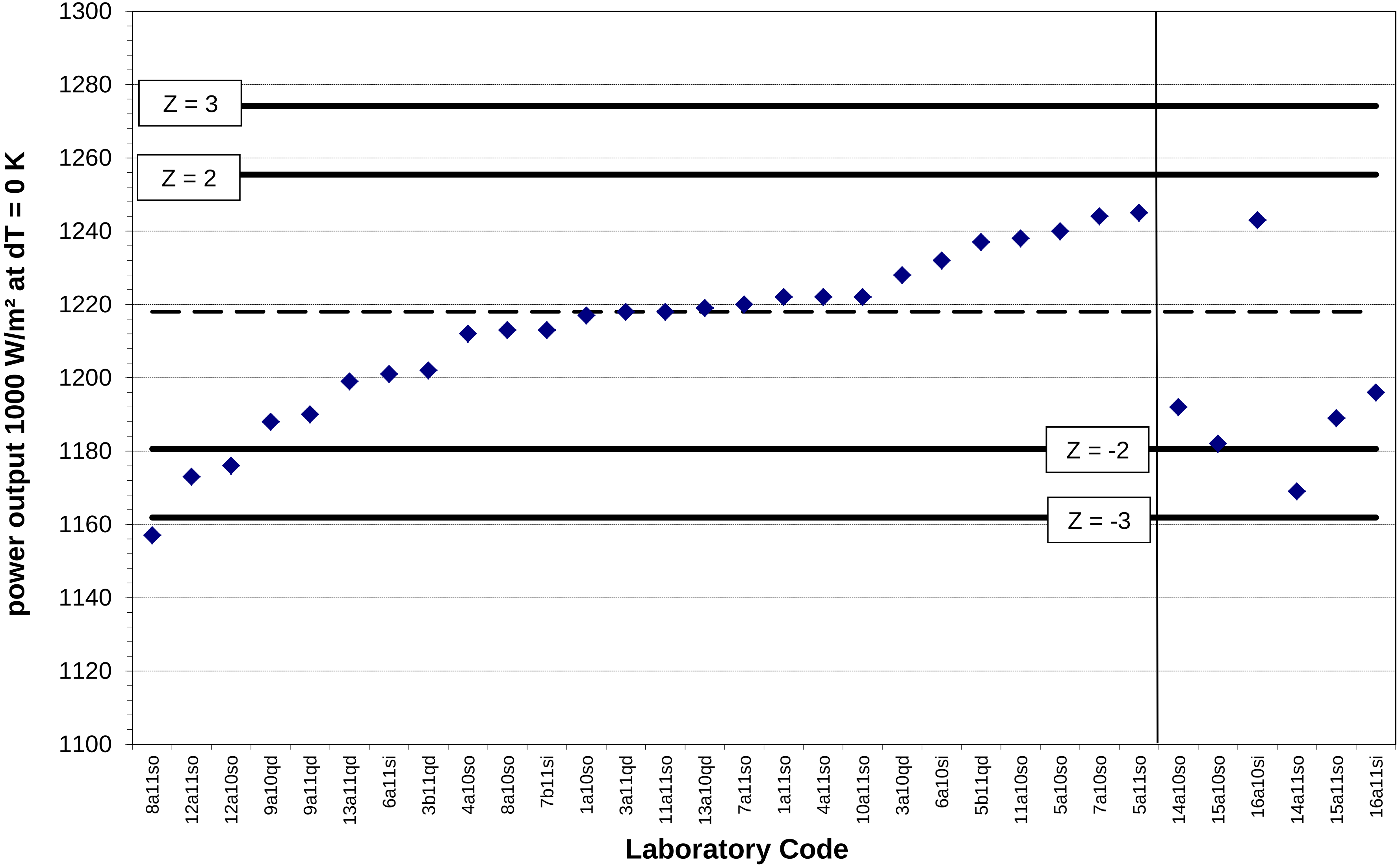

Figure B24: Power output at 1000 W/m² for dT = 0 K; all values.

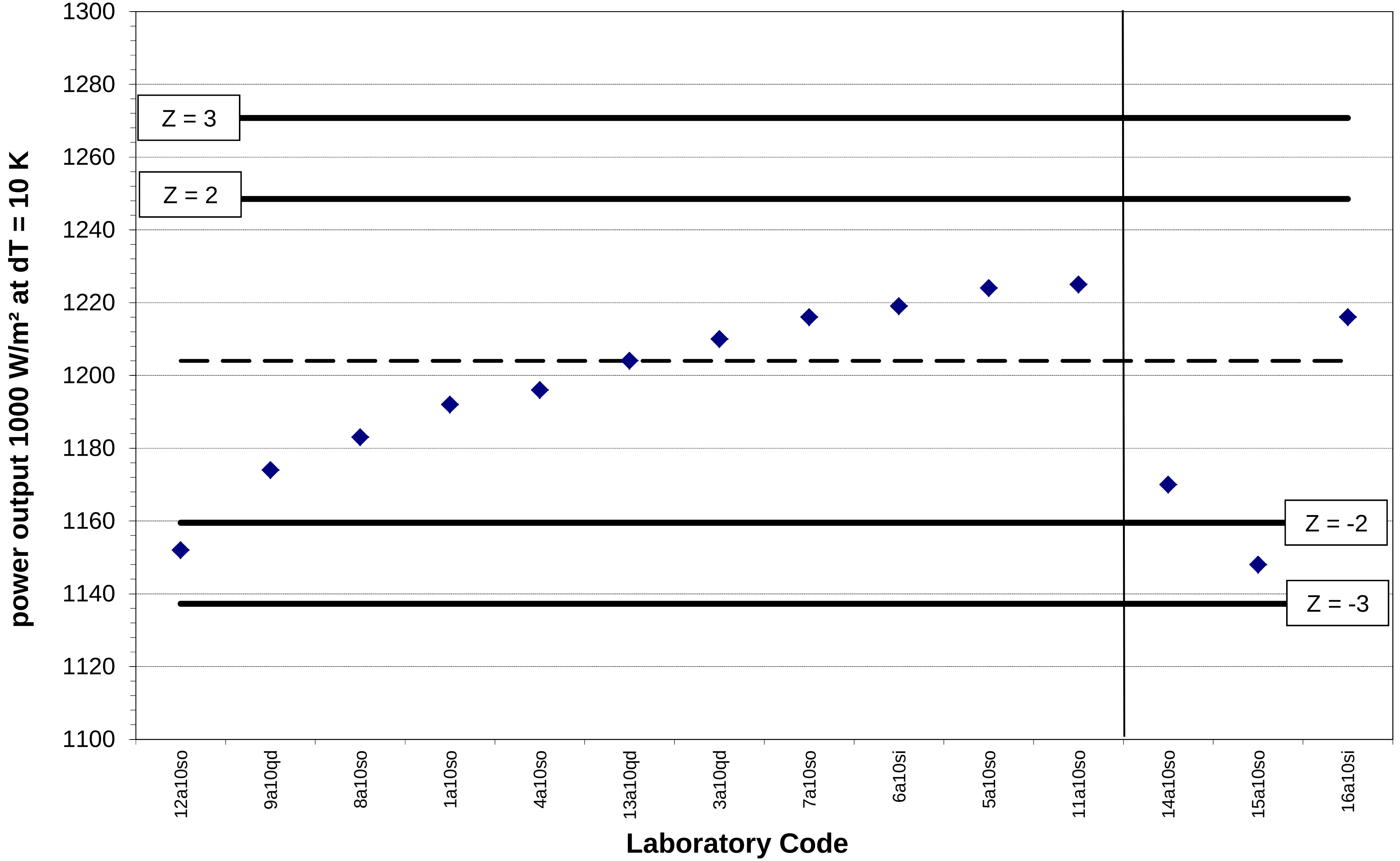

Figure B25: Power output at 1000 W/m² for dT = 10 K; values of 2010.

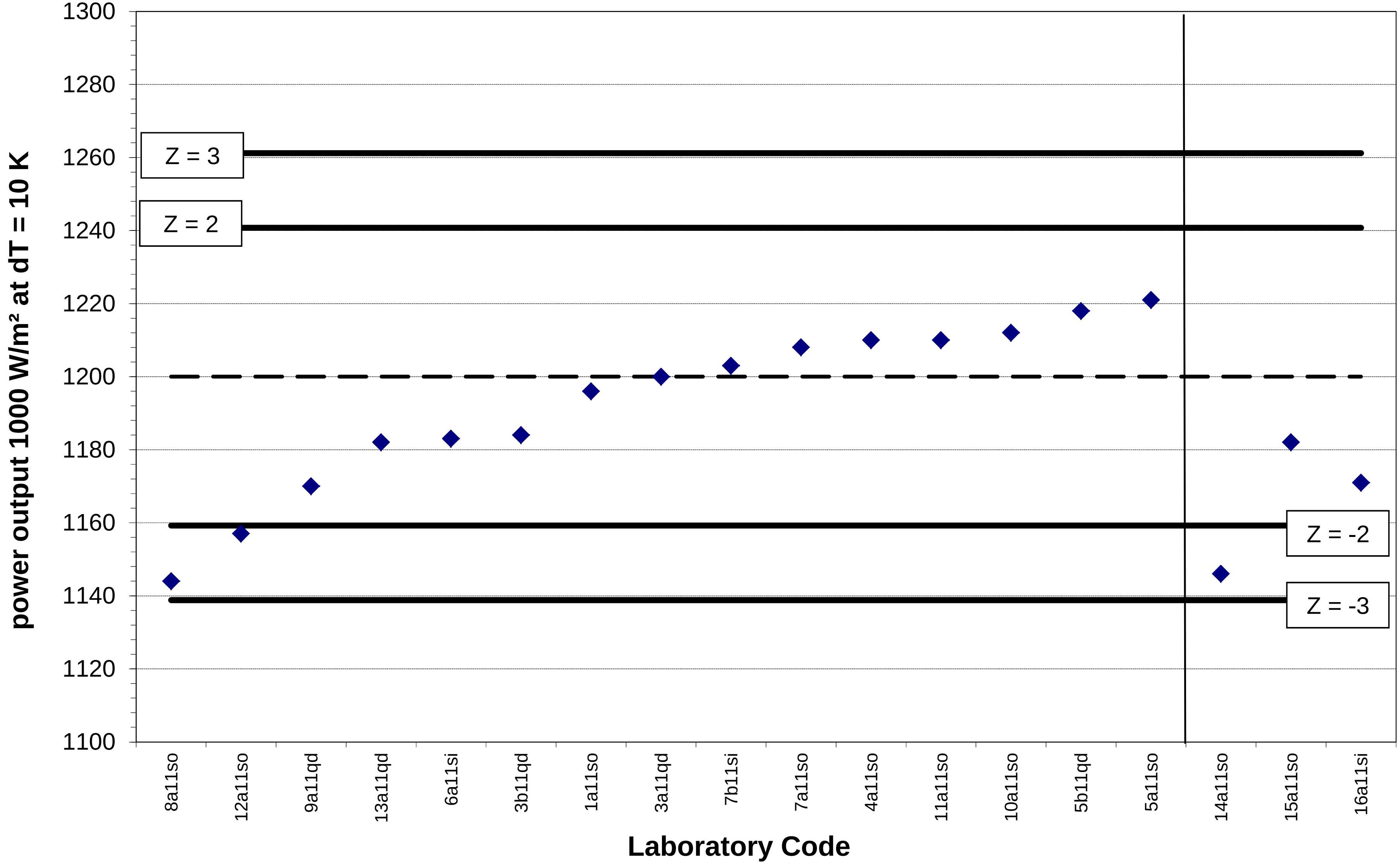

Figure B26: Power output at 1000 W/m² for dT = 10 K; values of 2011.

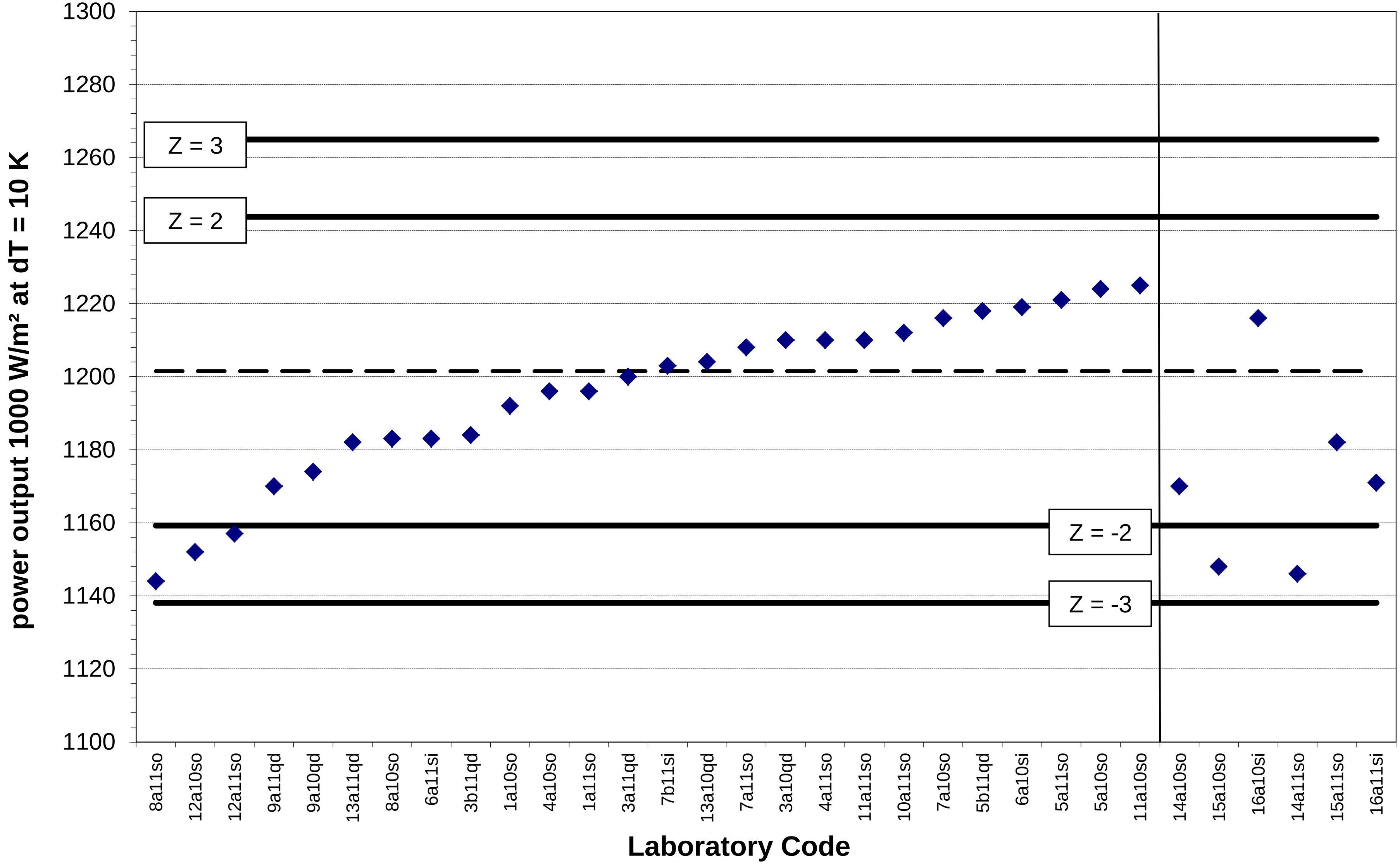

Figure B27: Power output at 1000 W/m² for dT = 10 K; all values.

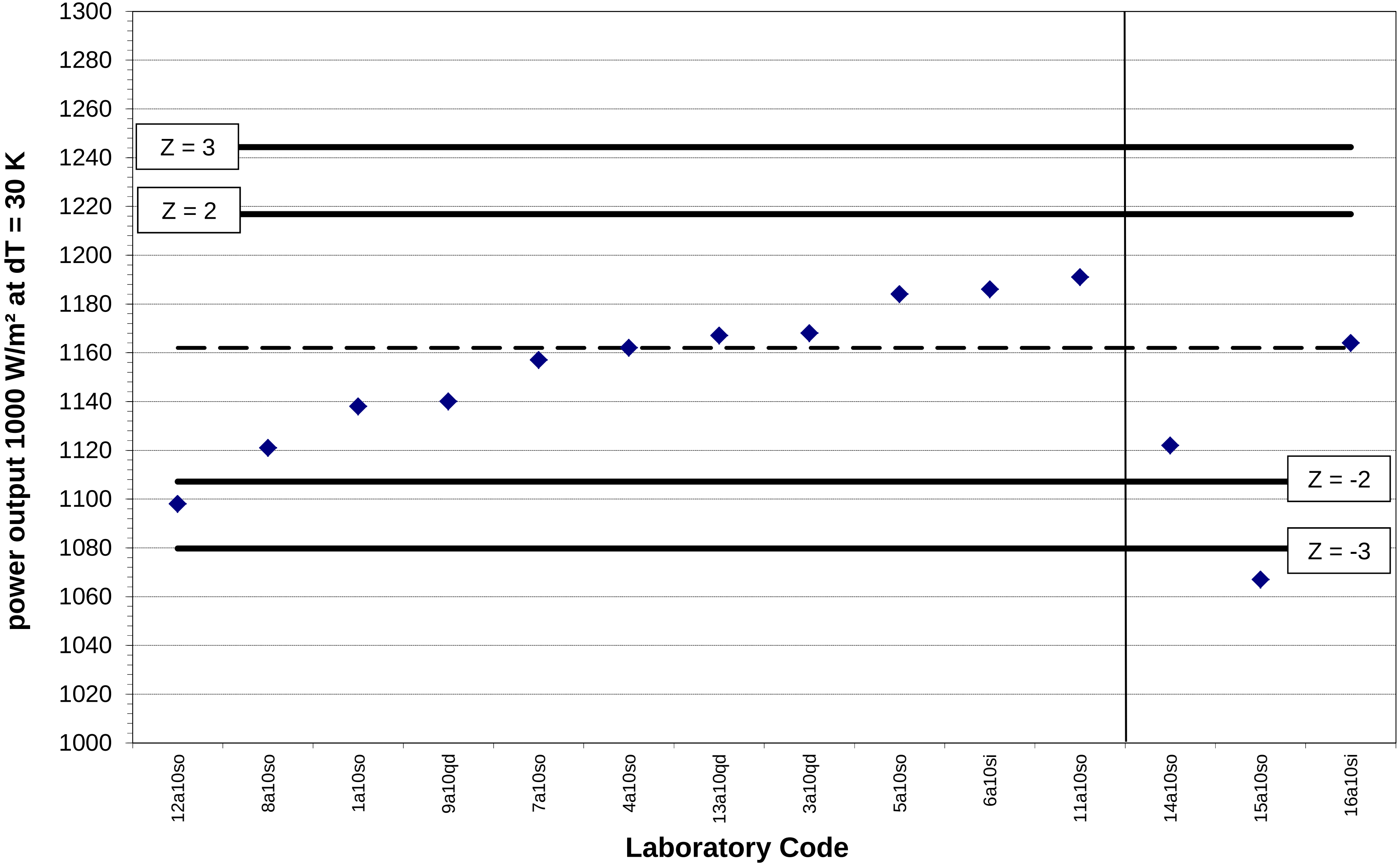

Figure B28: Power output at 1000 W/m² for dT = 30 K; values of 2010.

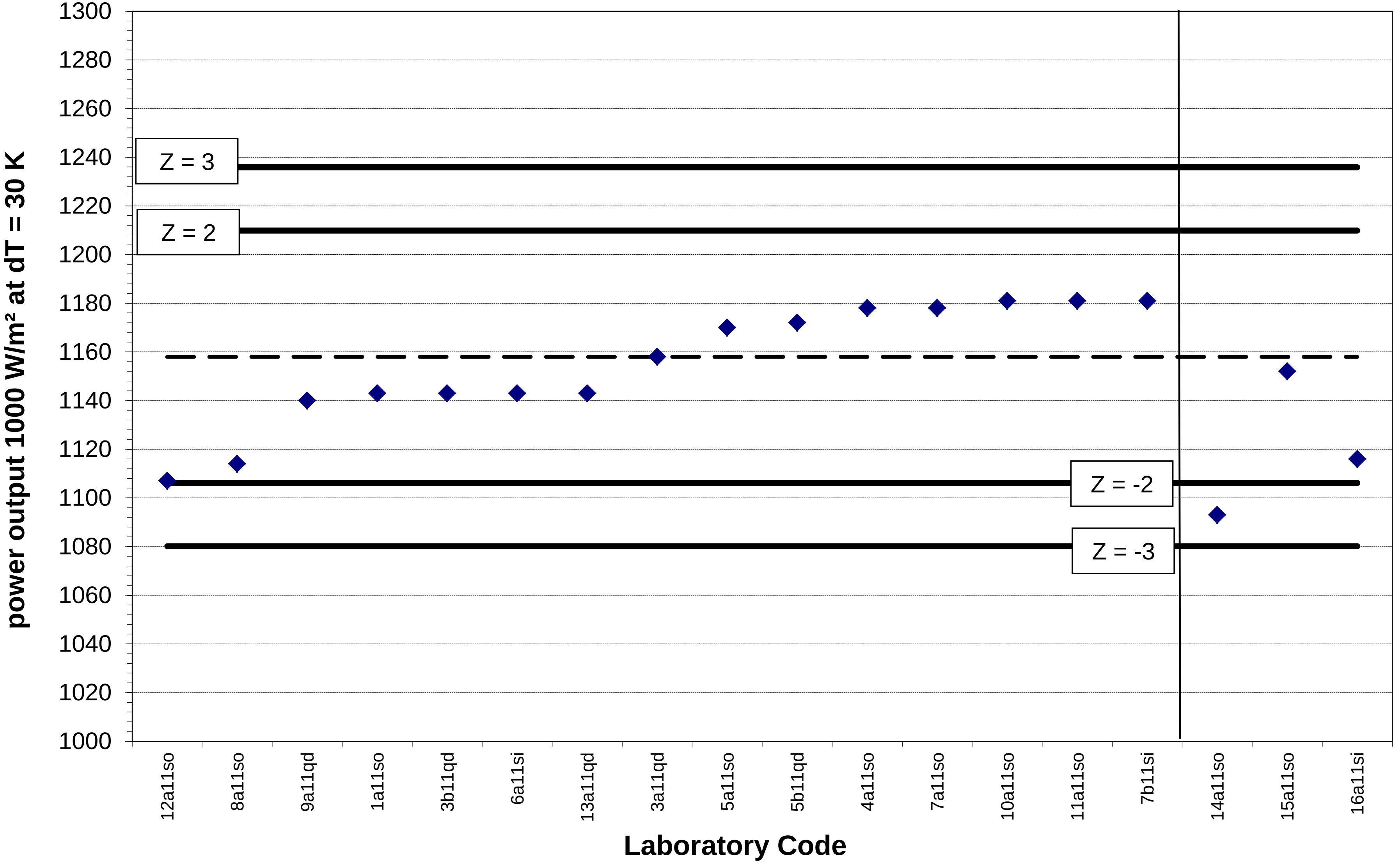

Figure B29: Power output at 1000 W/m² for dT = 30 K; values of 2011.

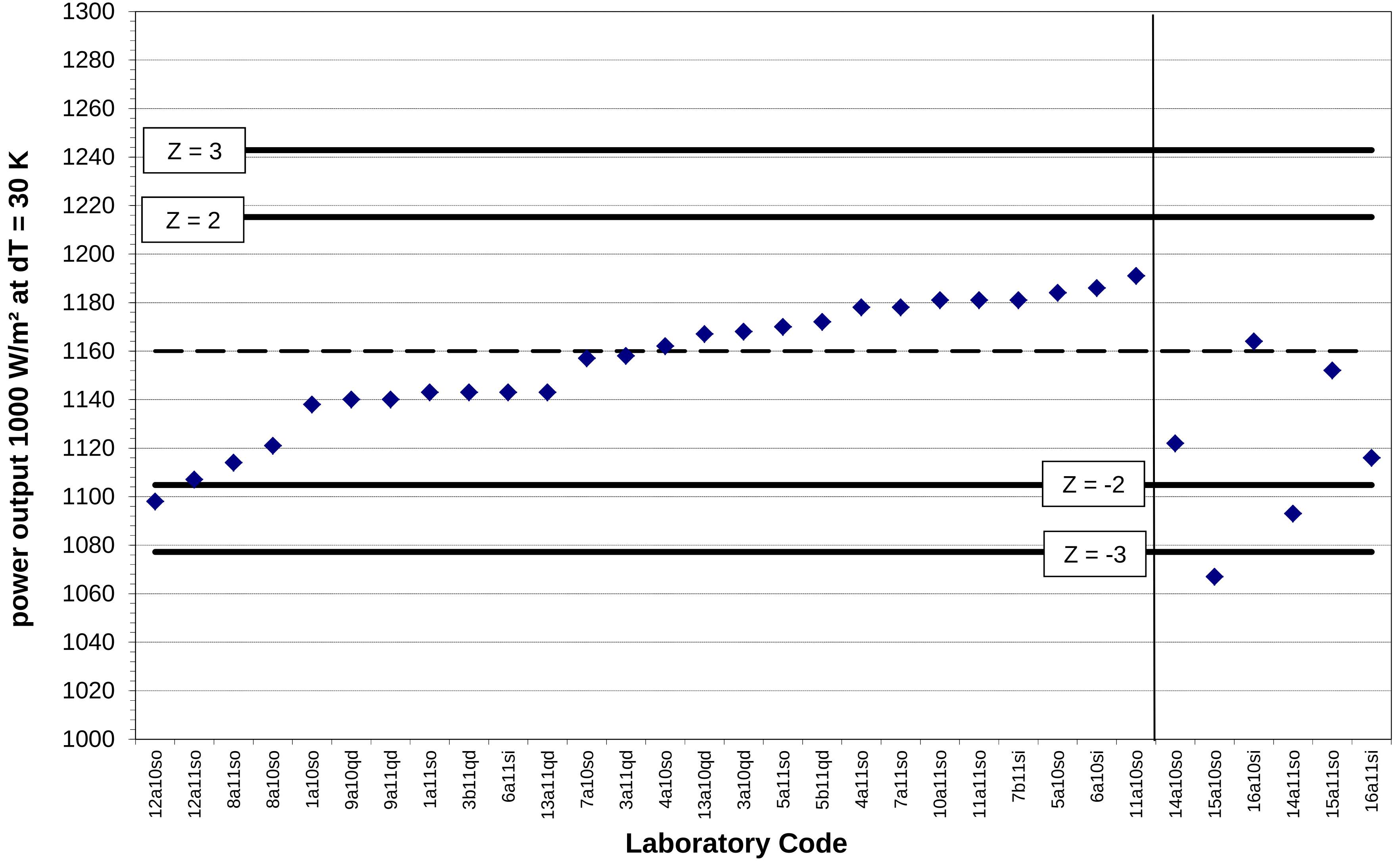

Figure B30: Power output at 1000 W/m² for dT = 30 K; all values.

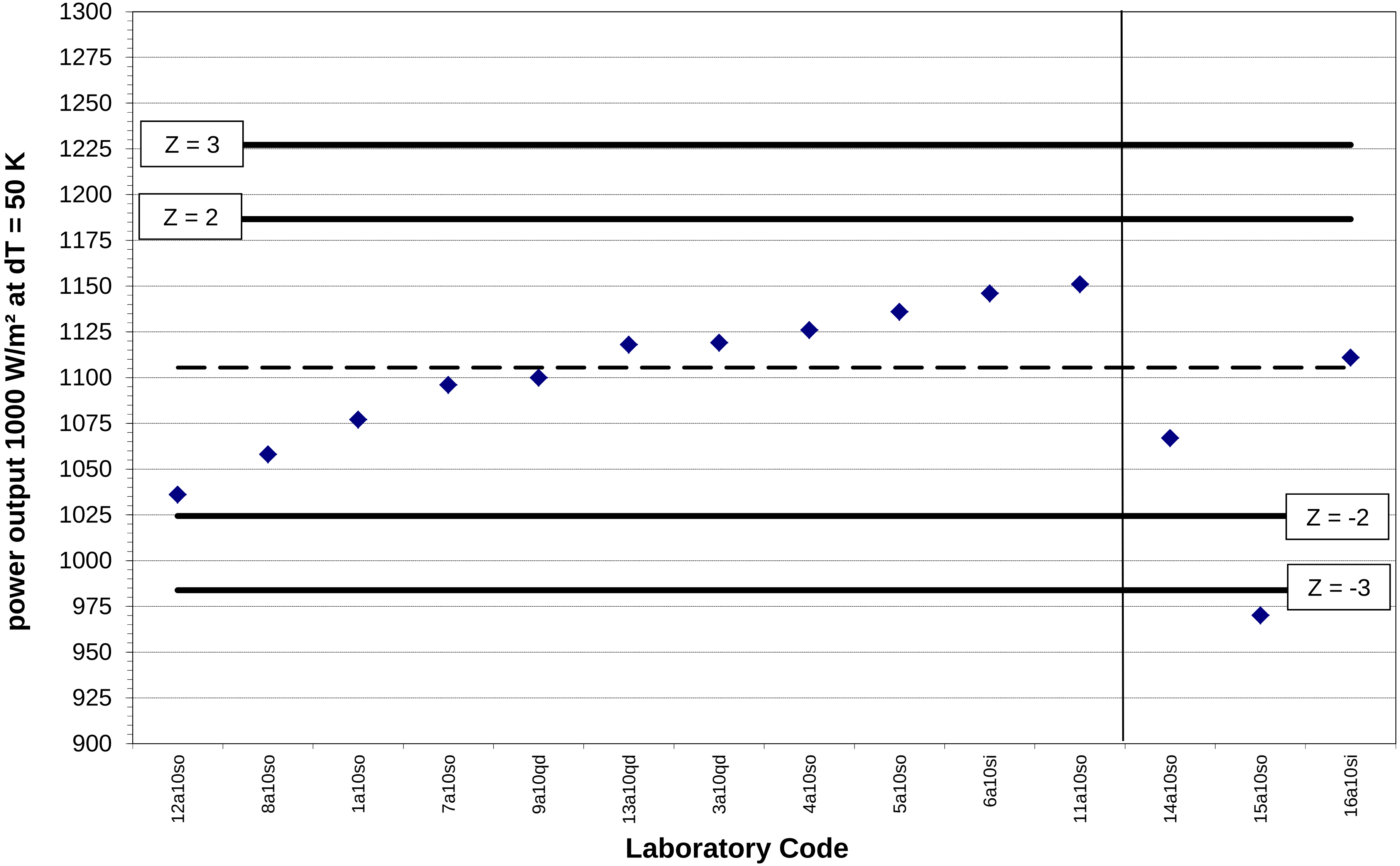

Figure B31: Power output at 1000 W/m² for dT = 50 K; values of 2010.

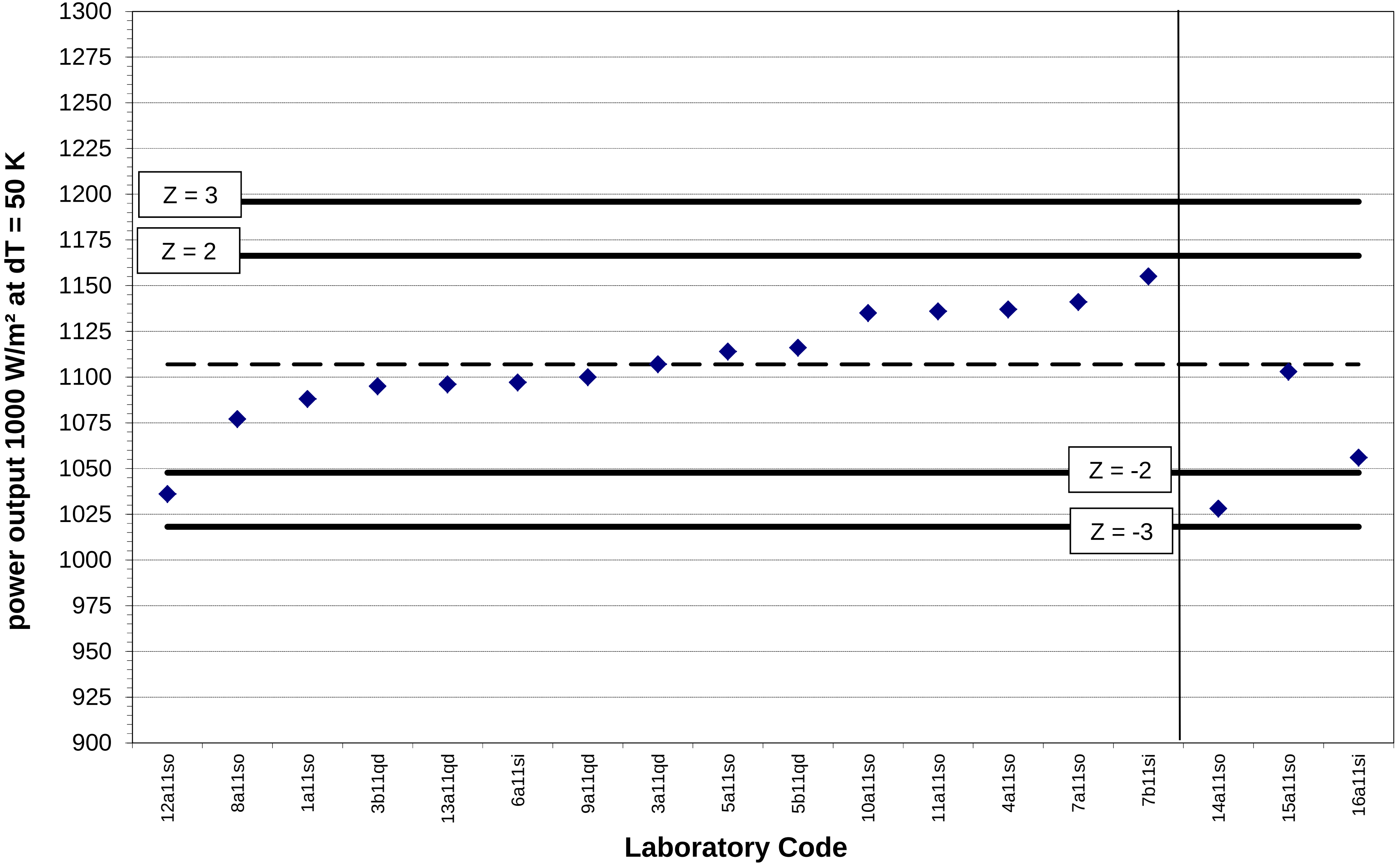

Figure B32: Power output at 1000 W/m² for dT = 50 K; values of 2011.

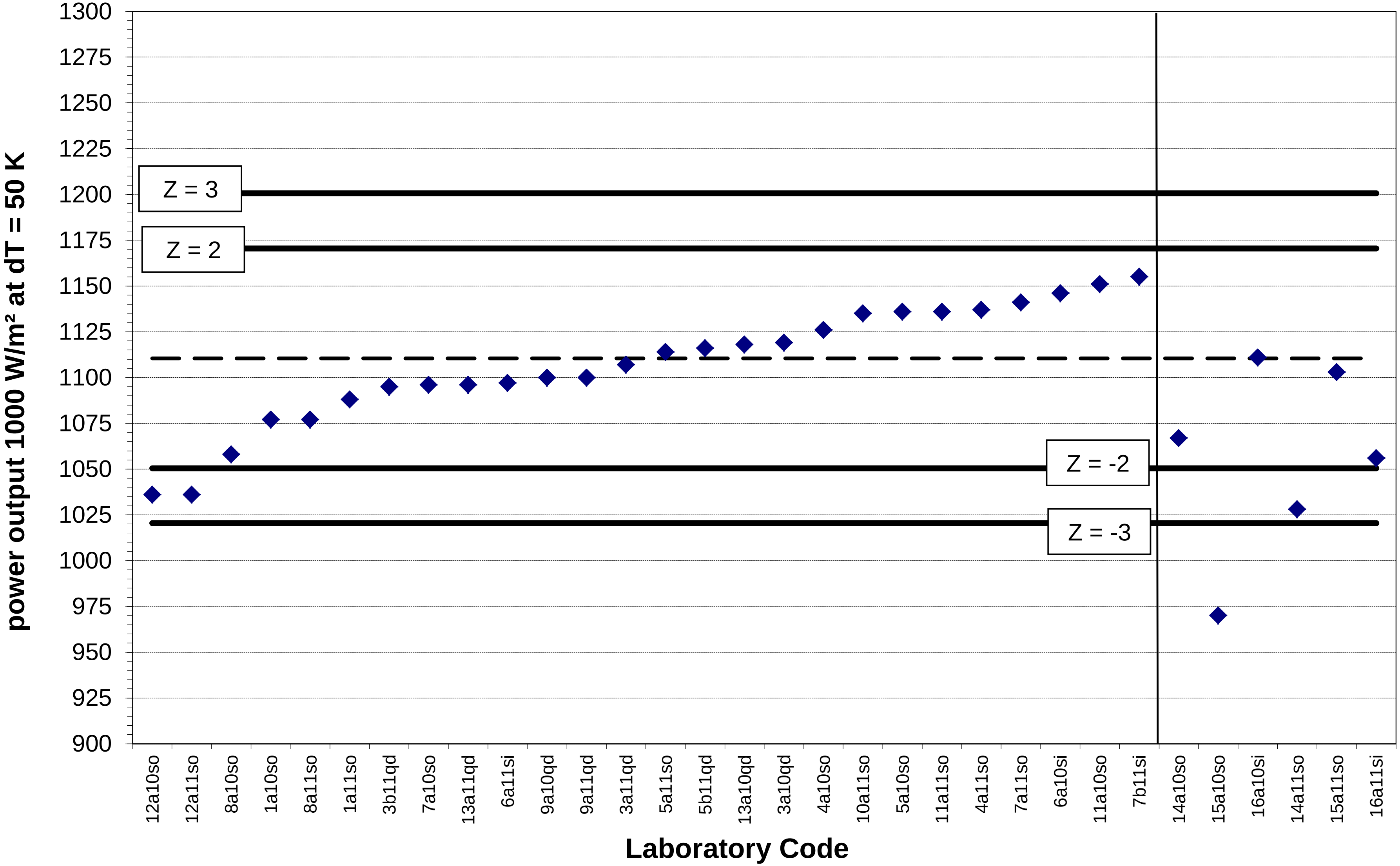

Figure B33: Power output at 1000 W/m² for dT = 50 K; all values.

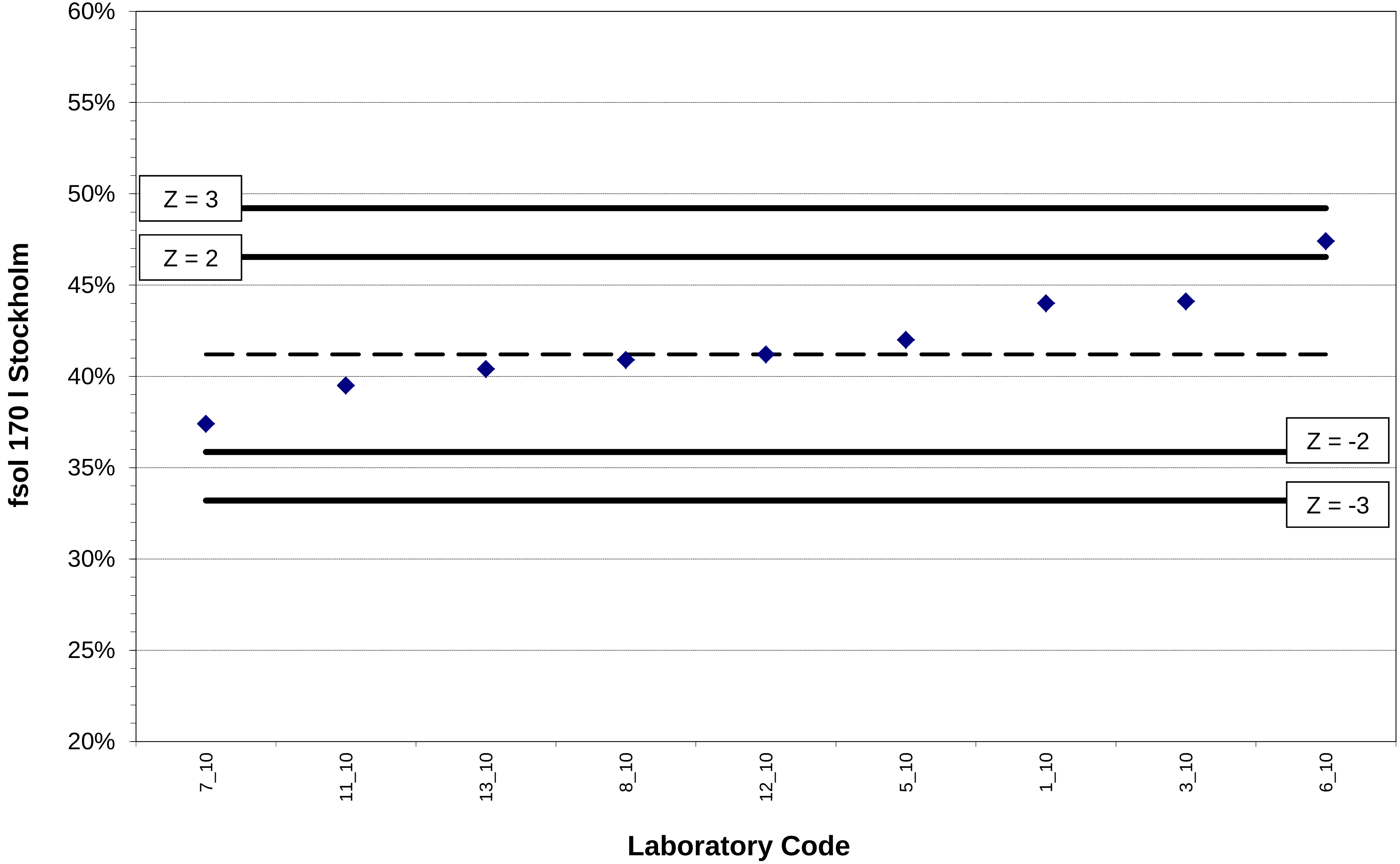

Figure C1: Stockholm, fsol for 170 l/day, values of 2010. Labs w/o data points: not stated

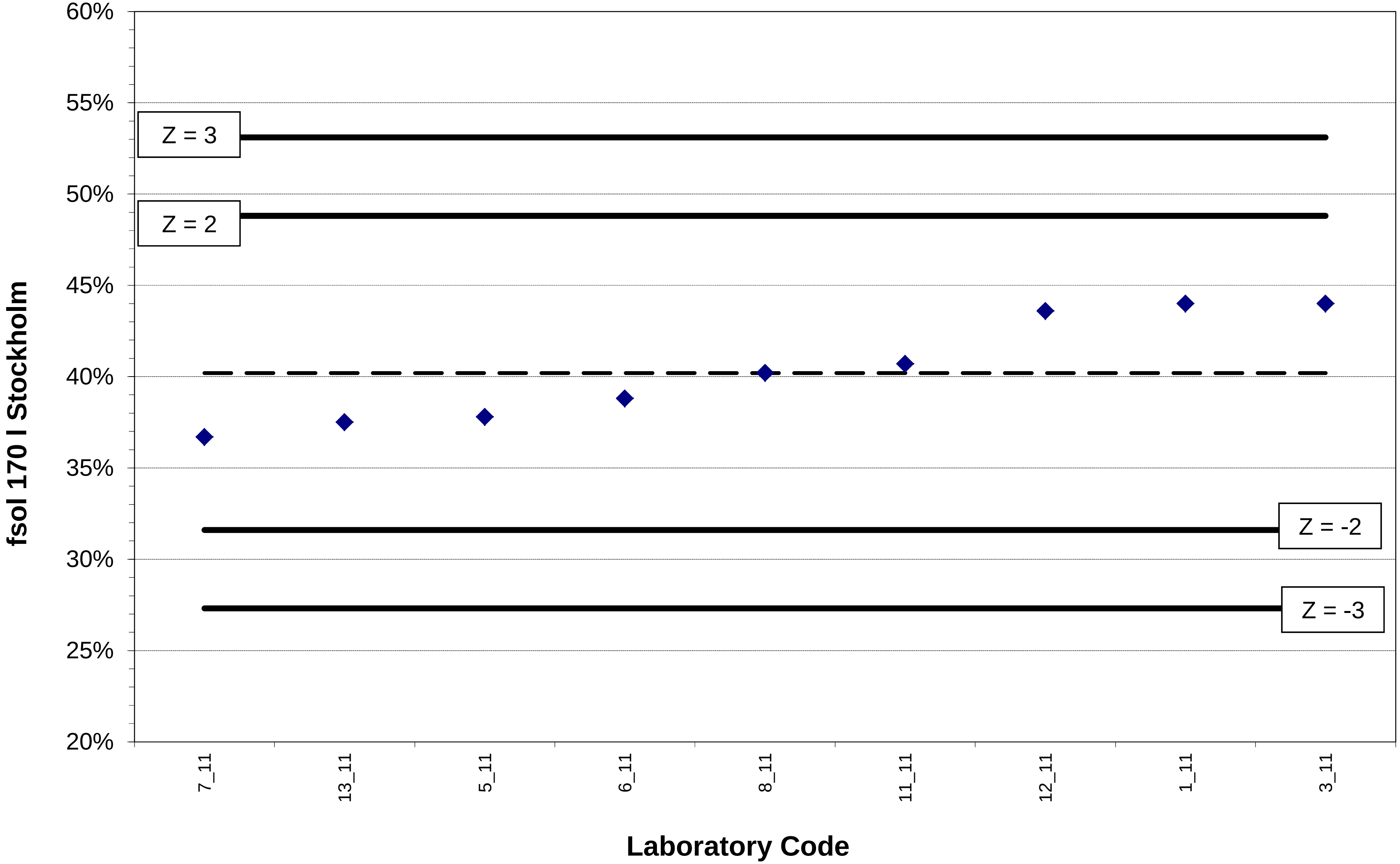

Figure C2: Stockholm, fsol for 170 l/day, values of 2011. Labs w/o data points: not stated

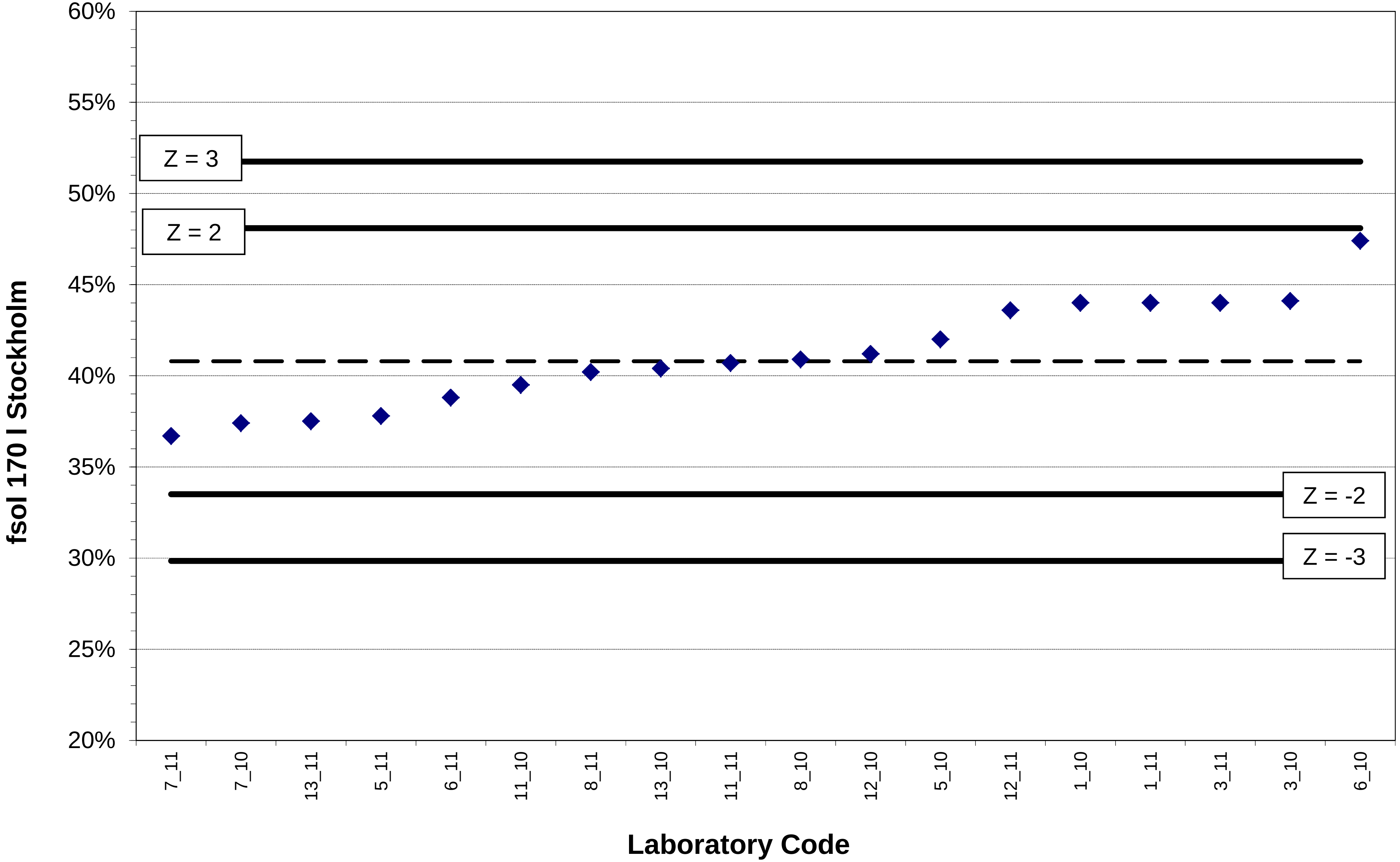

Figure C3: Stockholm, fsol for 170 l/day, all values. Labs w/o data points: not stated

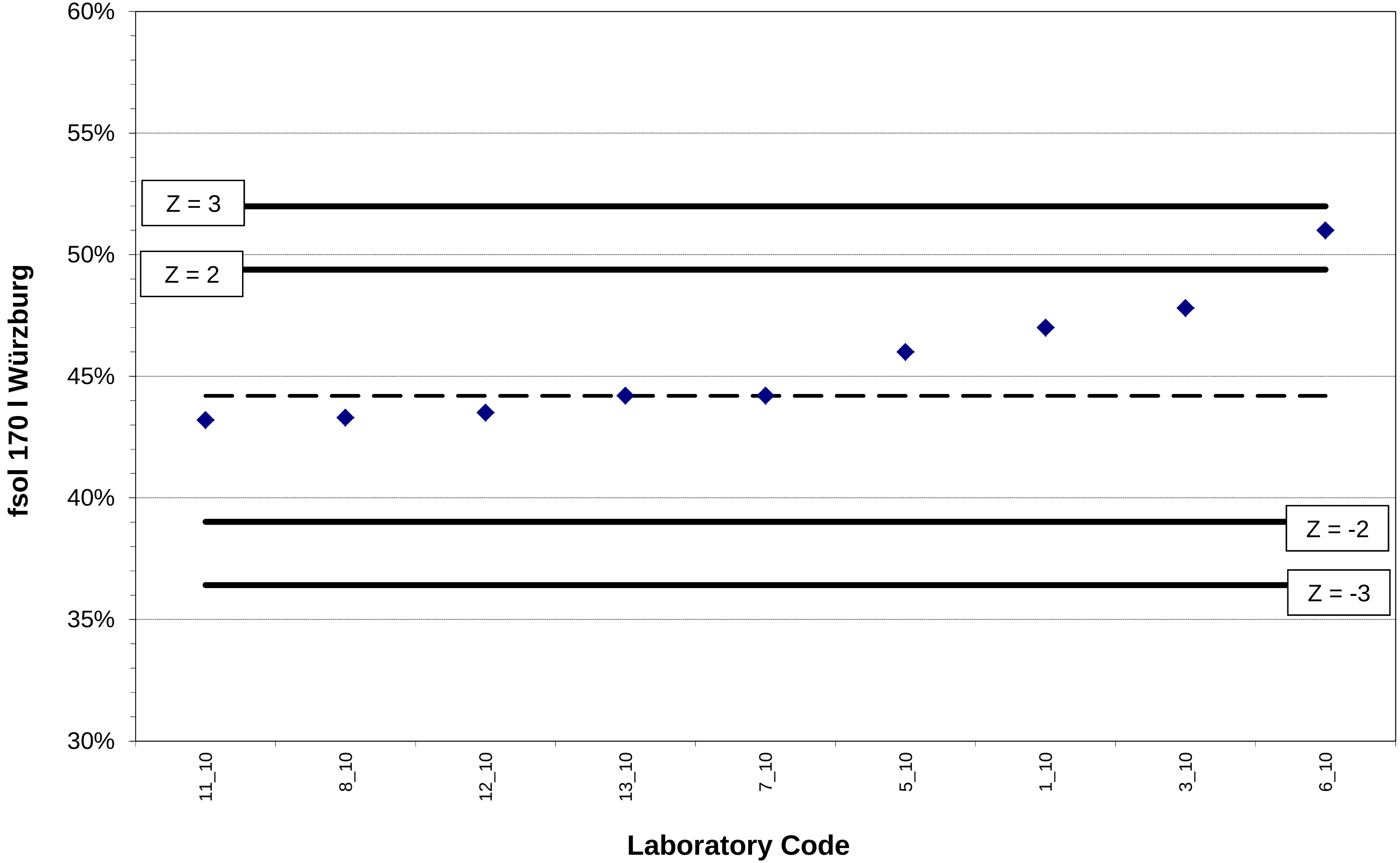

Figure C4: Würzburg, fsol for 170 l/day, values of 2010. Labs w/o data points: not stated

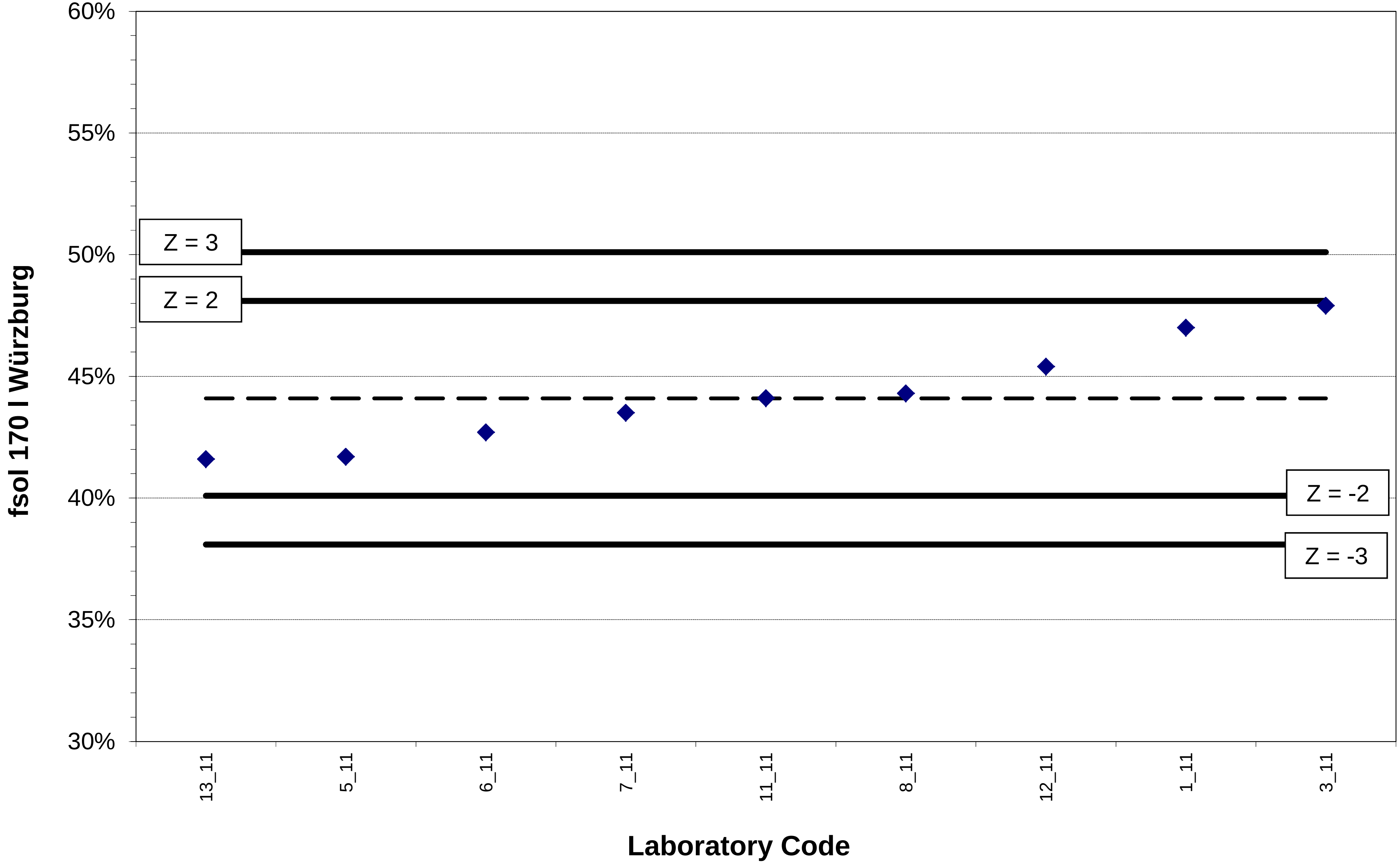

Figure C5: Würzburg, fsol for 170 l/day, values of 2011. Labs w/o data points: not stated

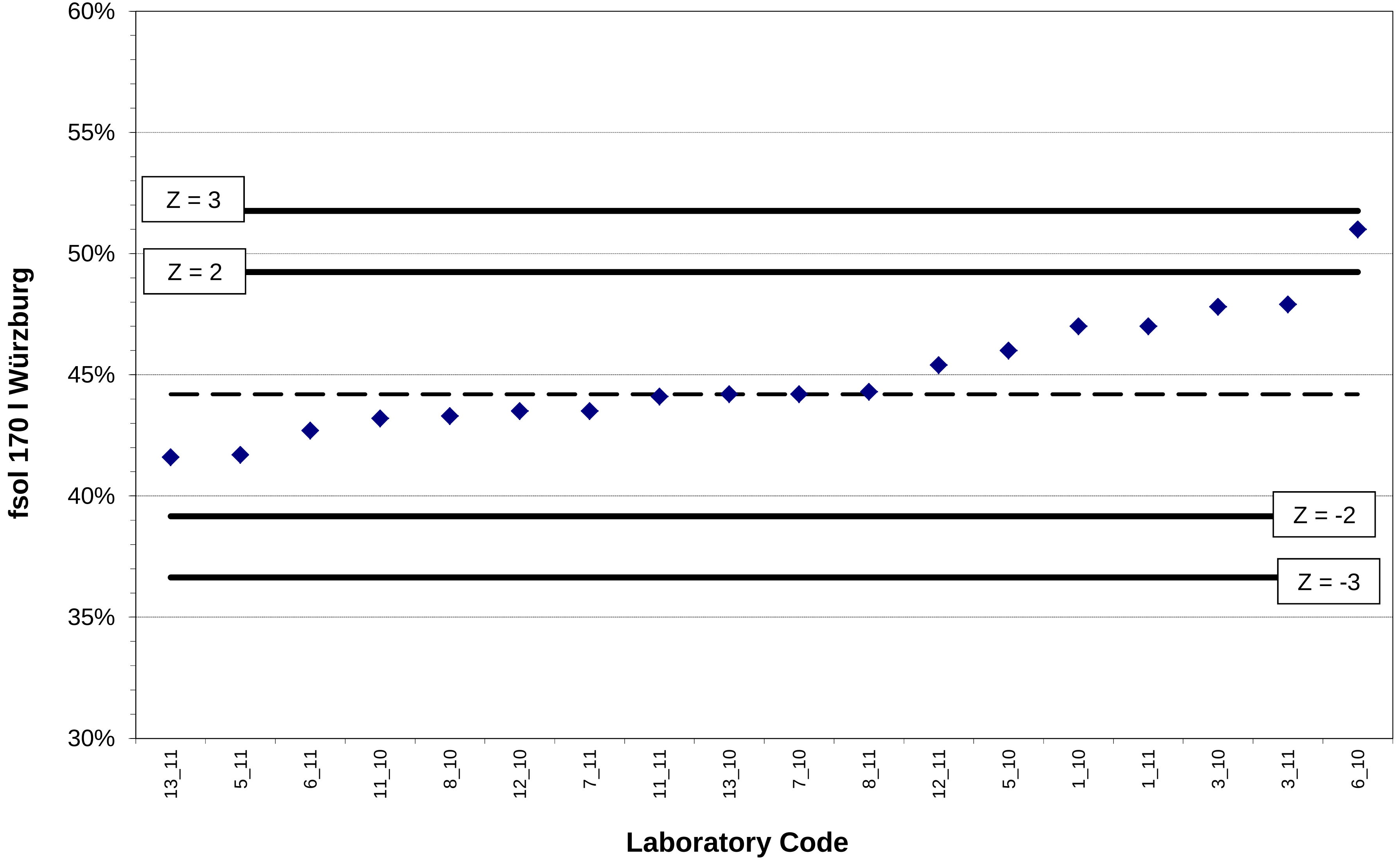

Figure C6: Würzburg, fsol for 170 l/day, all values. Labs w/o data points: not stated

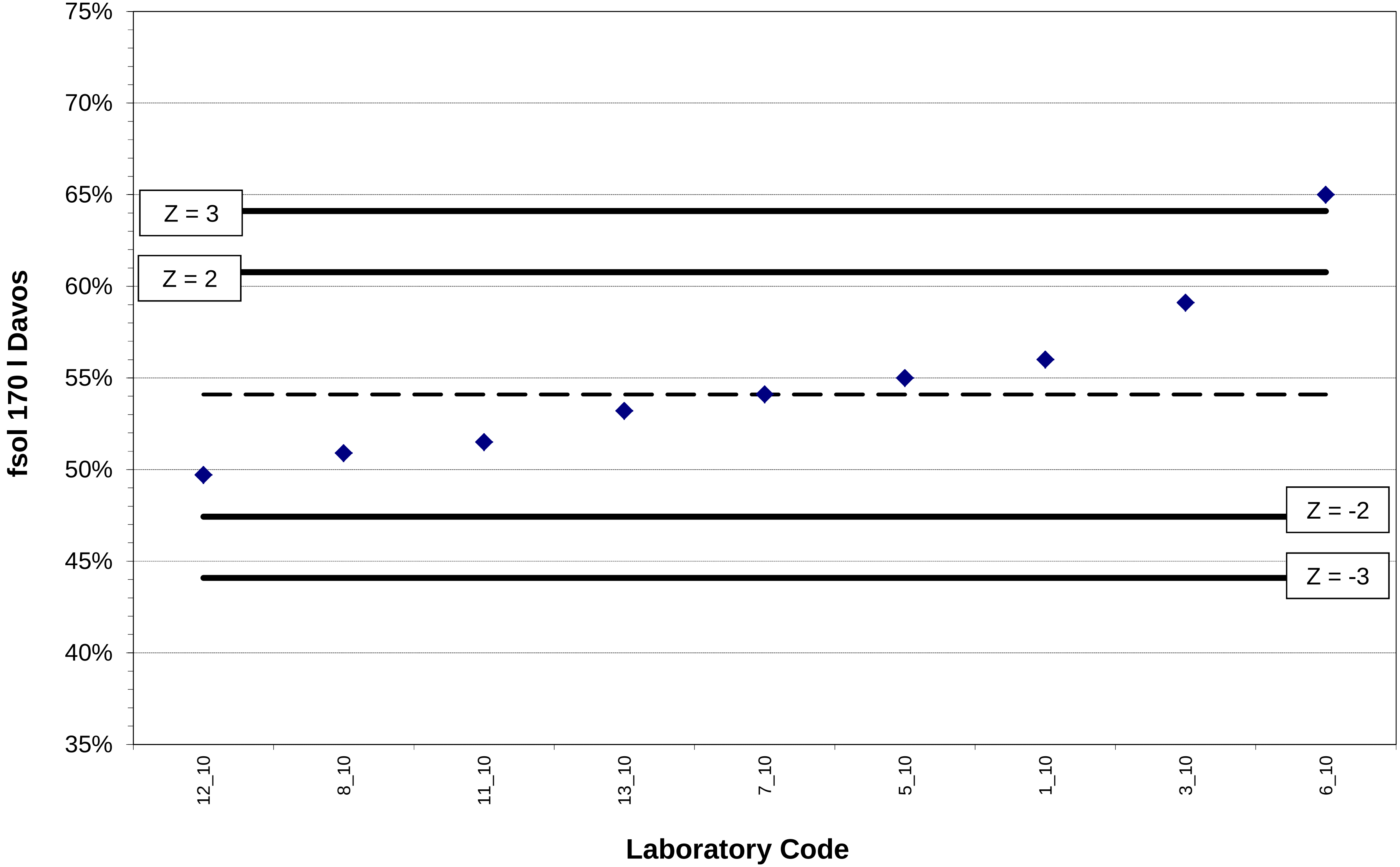

Figure C7: Davos, fsol for 170 l/day, values of 2010. Labs w/o data points: not stated

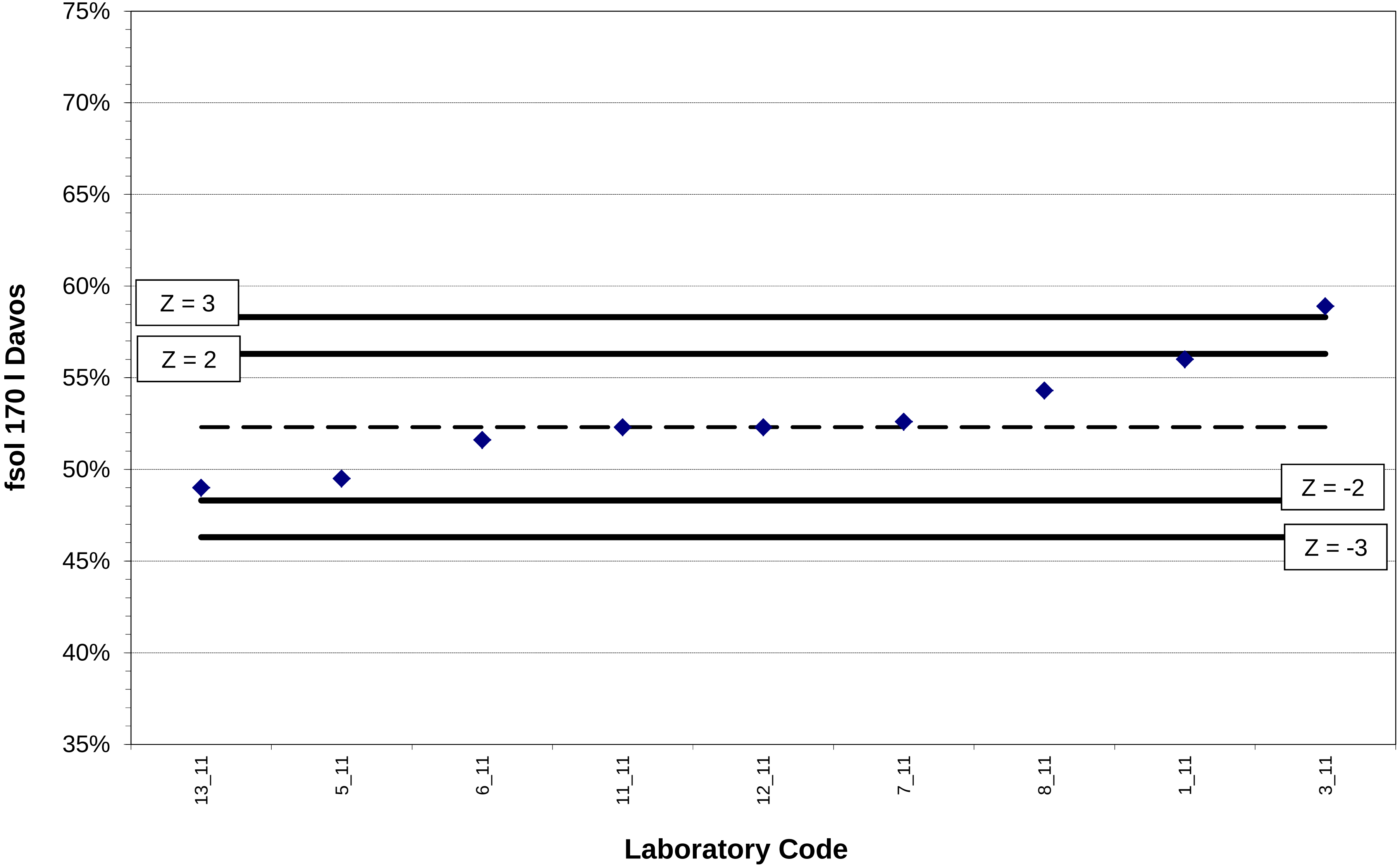

Figure C8: Davos, fsol for 170 l/day, values of 2011. Labs w/o data points: not stated

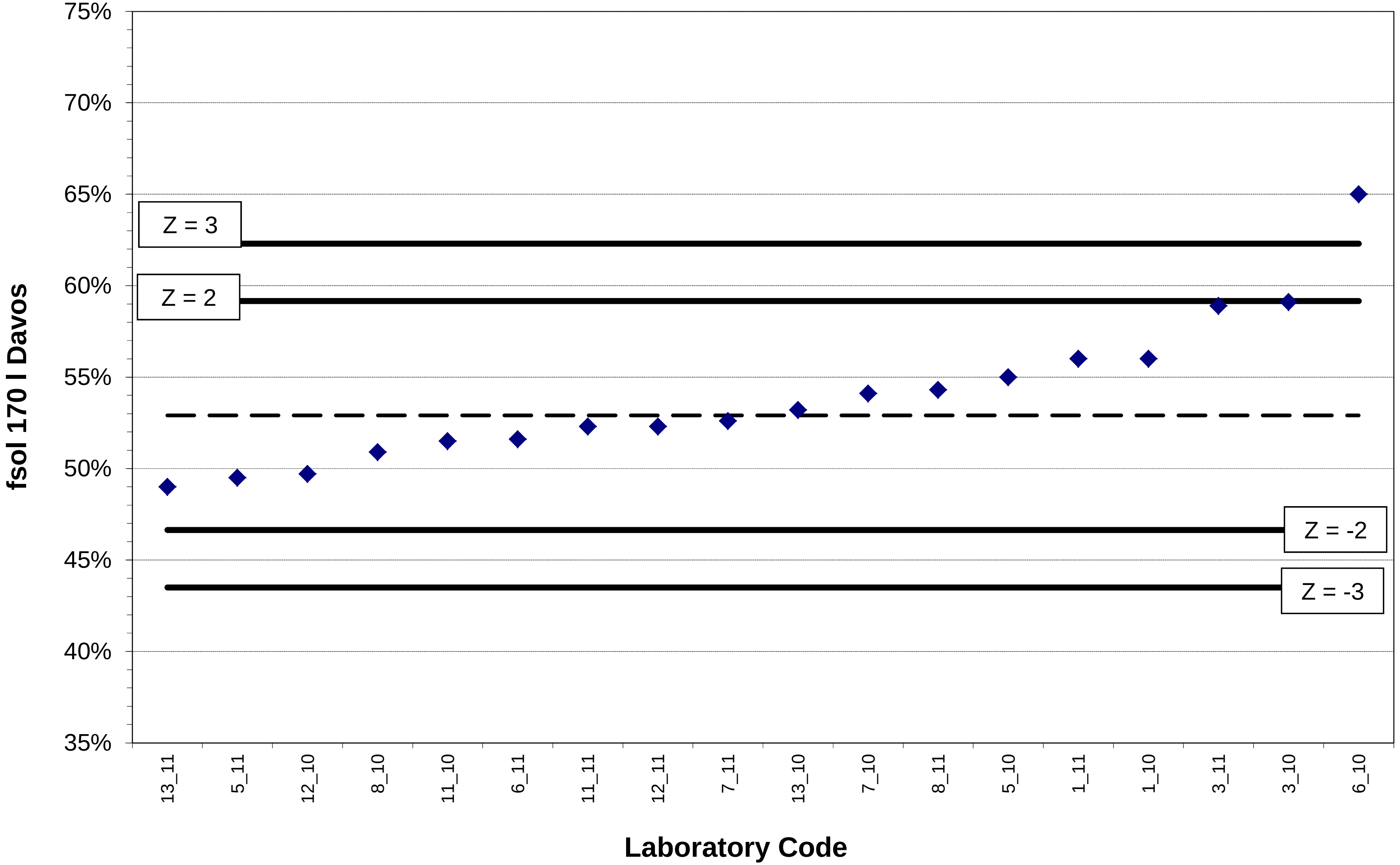

Figure C9: Davos, fsol for 170 l/day, all values. Labs w/o data points: not stated

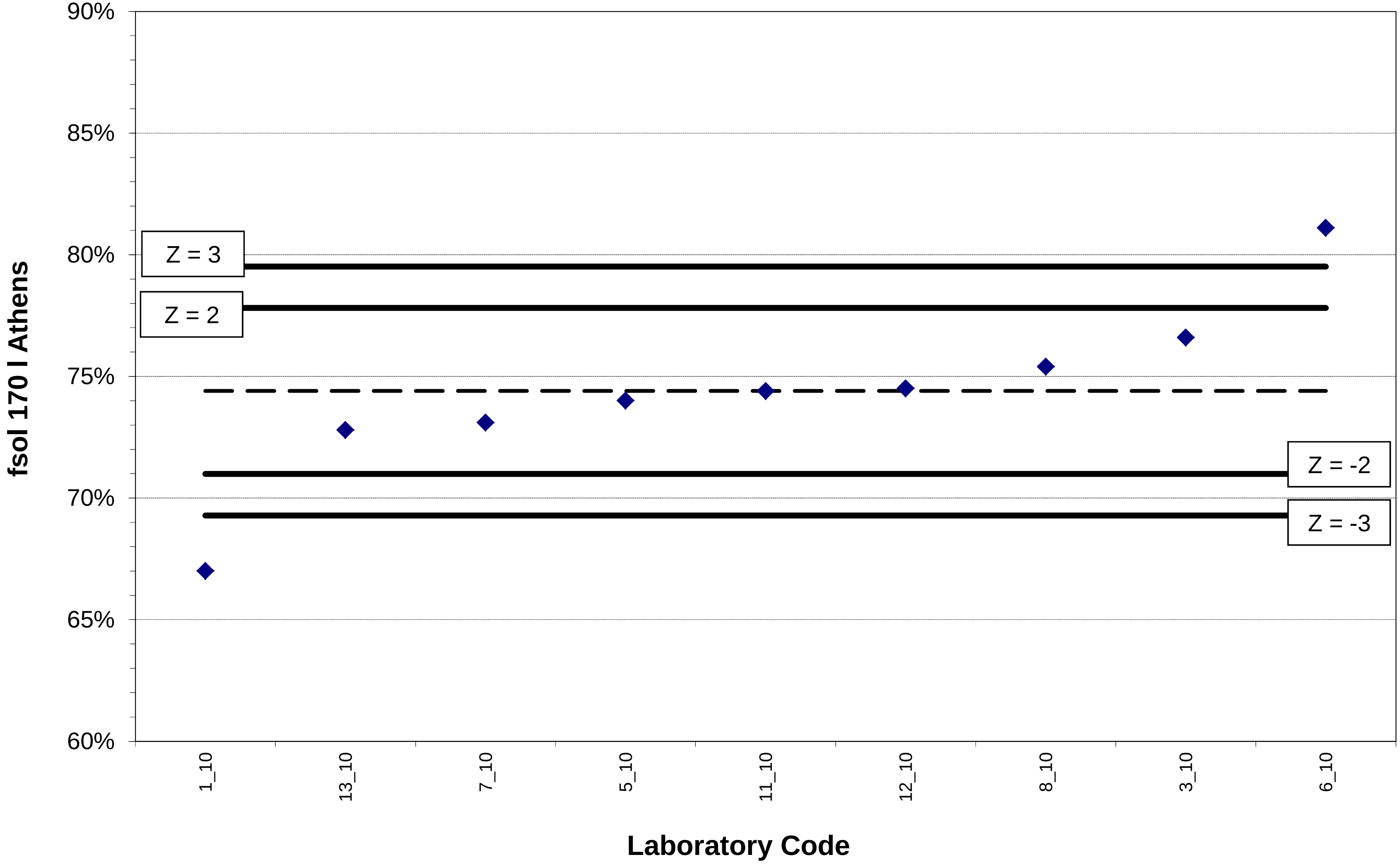

Figure C10: Athens, fsol for 170 l/day, values of 2010. Labs w/o data points: not stated

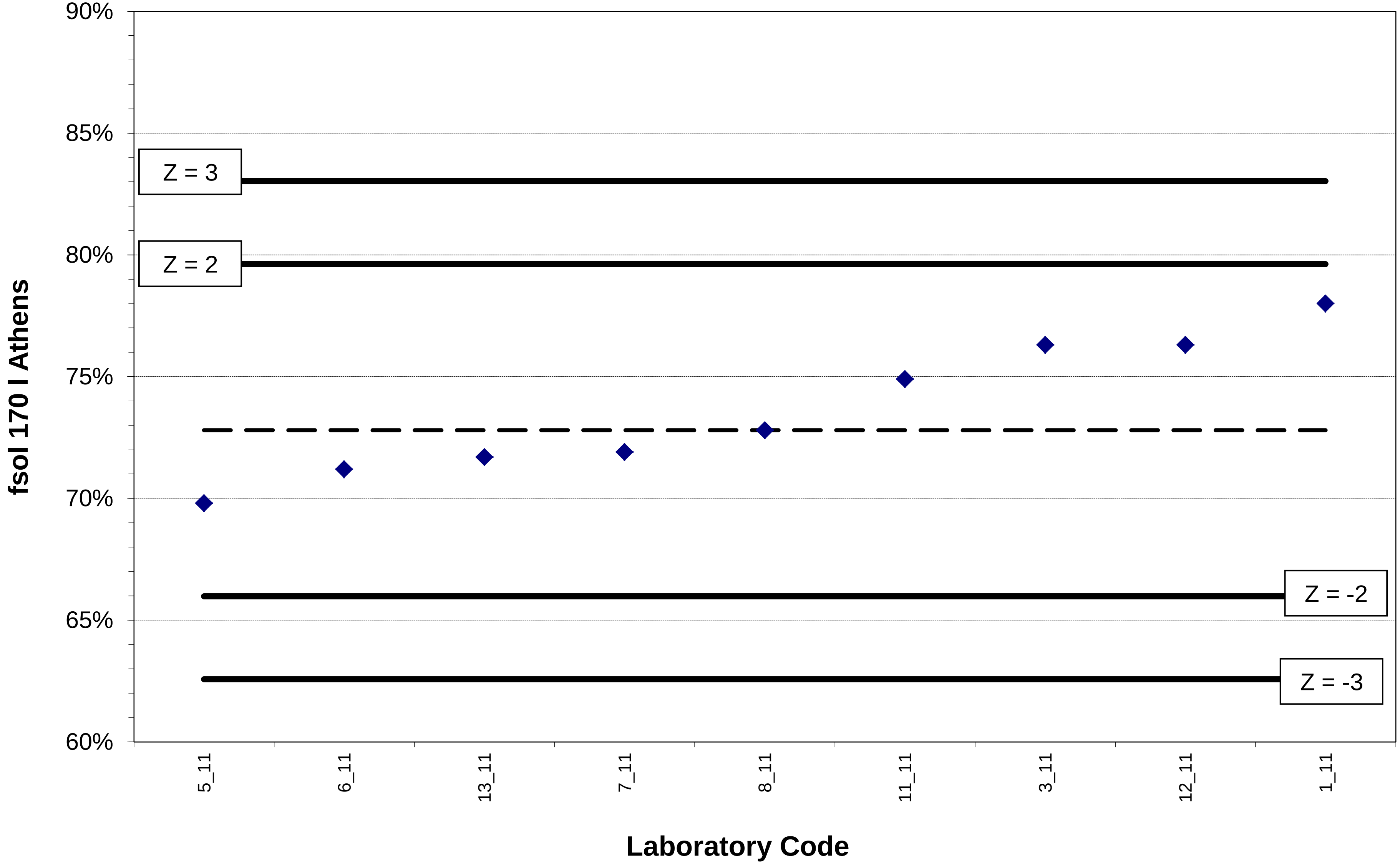

Figure C11: Athens, fsol for 170 l/day, values of 2011. Labs w/o data points: not stated

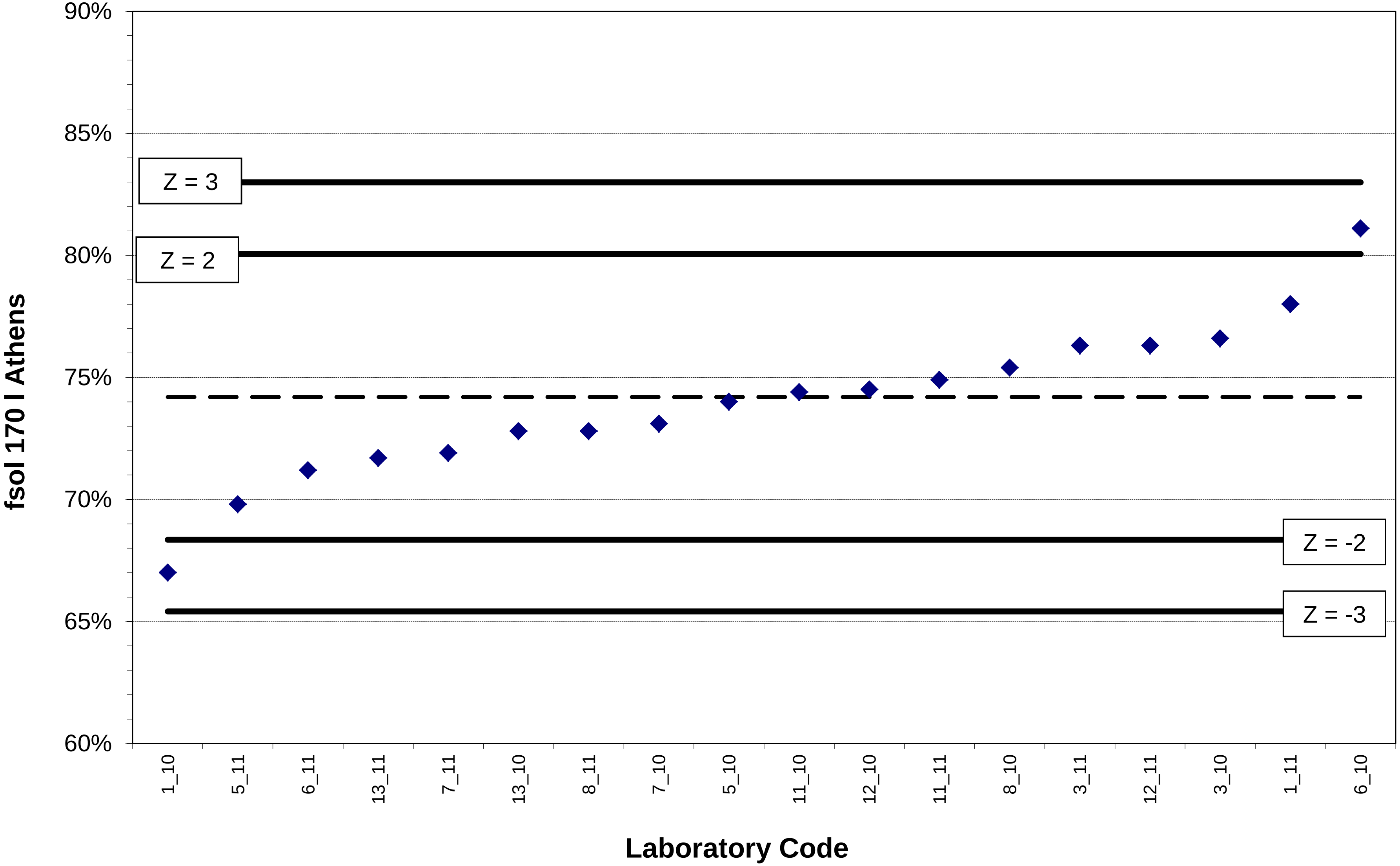

Figure C12: Athens, fsol for 170 l/day, all values. Labs w/o data points: not stated

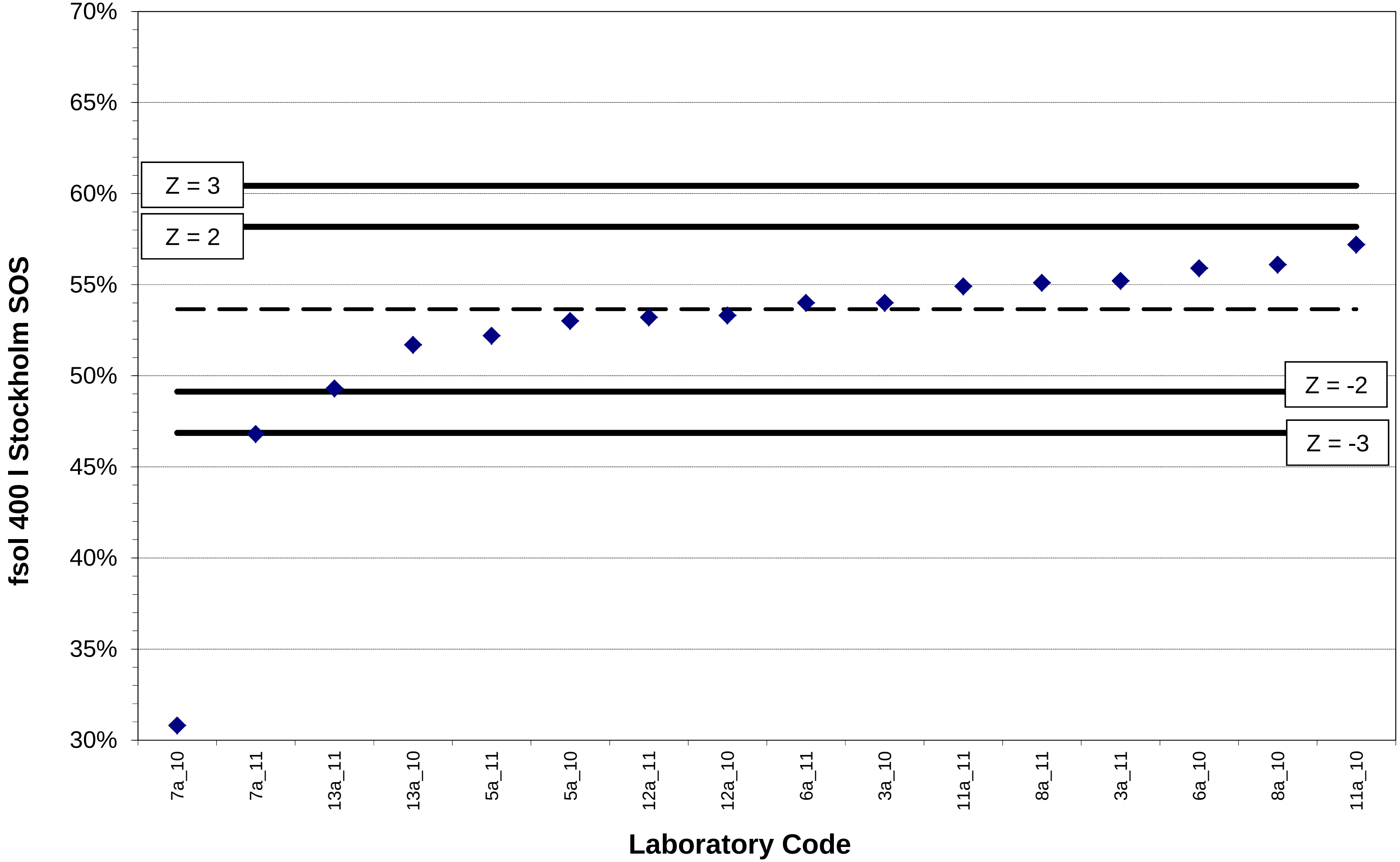

Figure D1: Stockholm, fsol for 400 l/day, SOS. Labs w/o data points: not stated

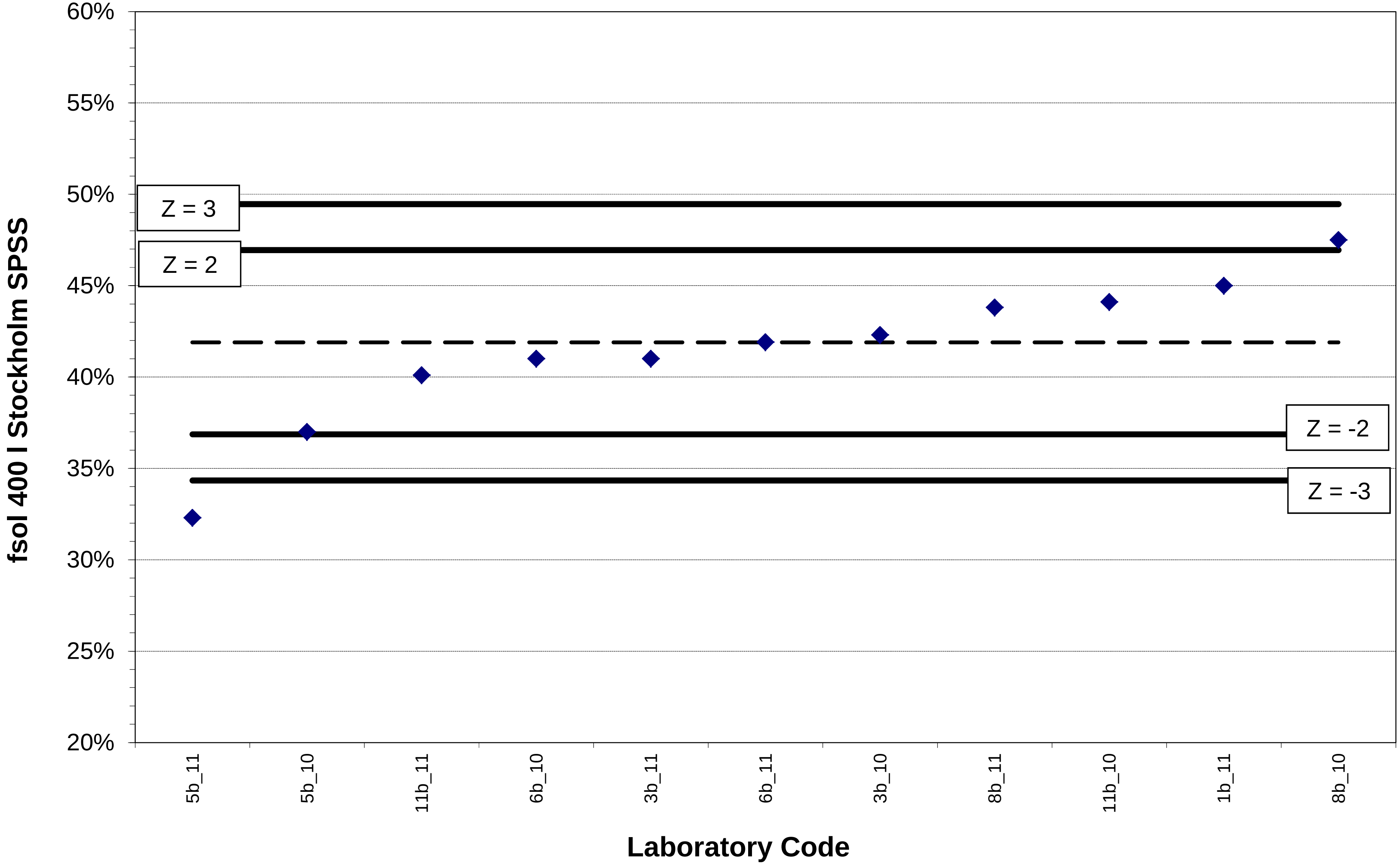

Figure D2: Stockholm, fsol for 400 l/day, SPSS. Labs w/o data points: not stated

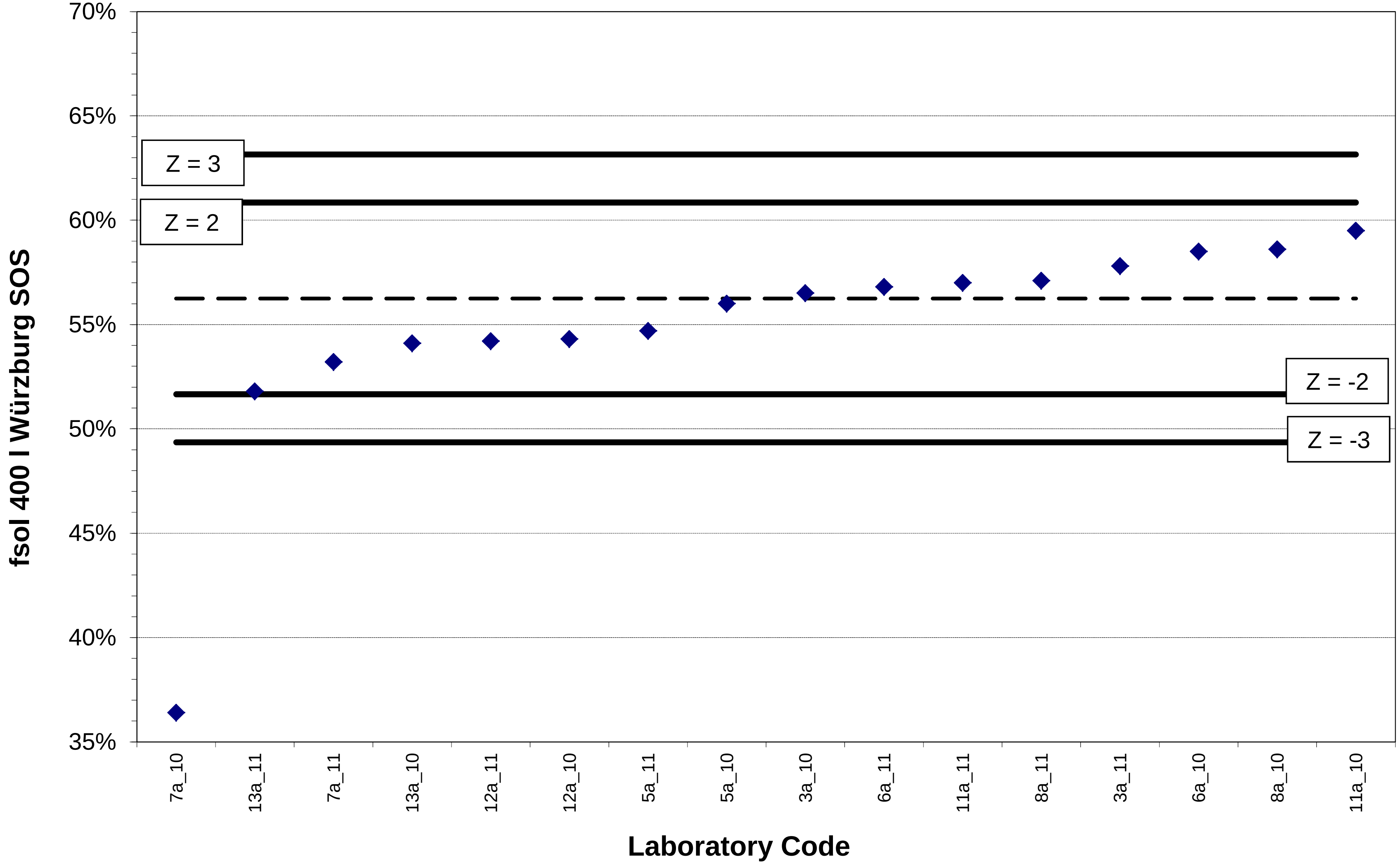

Figure D3: Würzburg, fsol for 400 l/day, SOS. Labs w/o data points: not stated

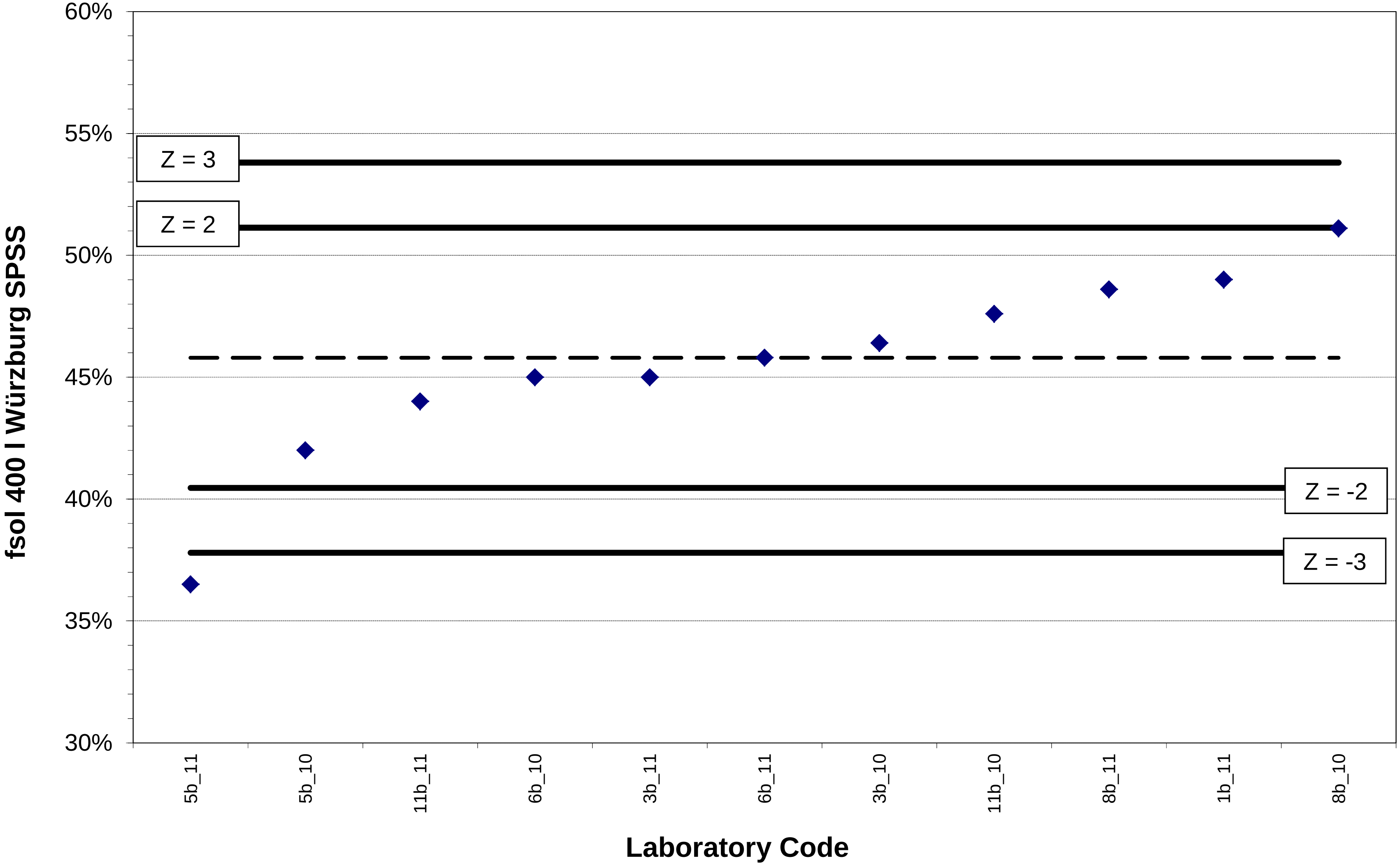

Figure D4: Würzburg, fsol for 400 l/day, SPSS. Labs w/o data points: not stated

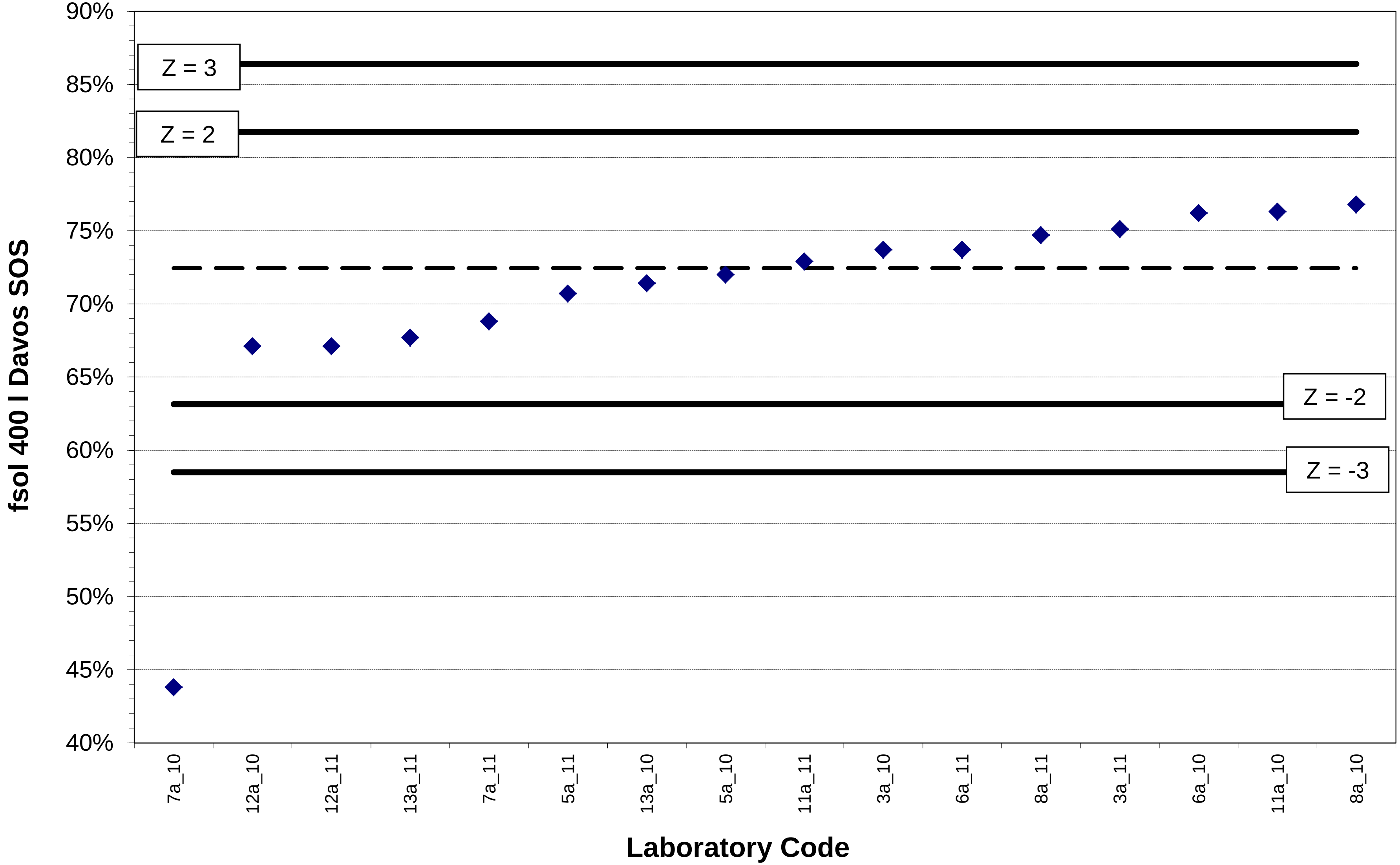

Figure D5: Davos, fsol for 400 l/day, SOS. Labs w/o data points: not stated

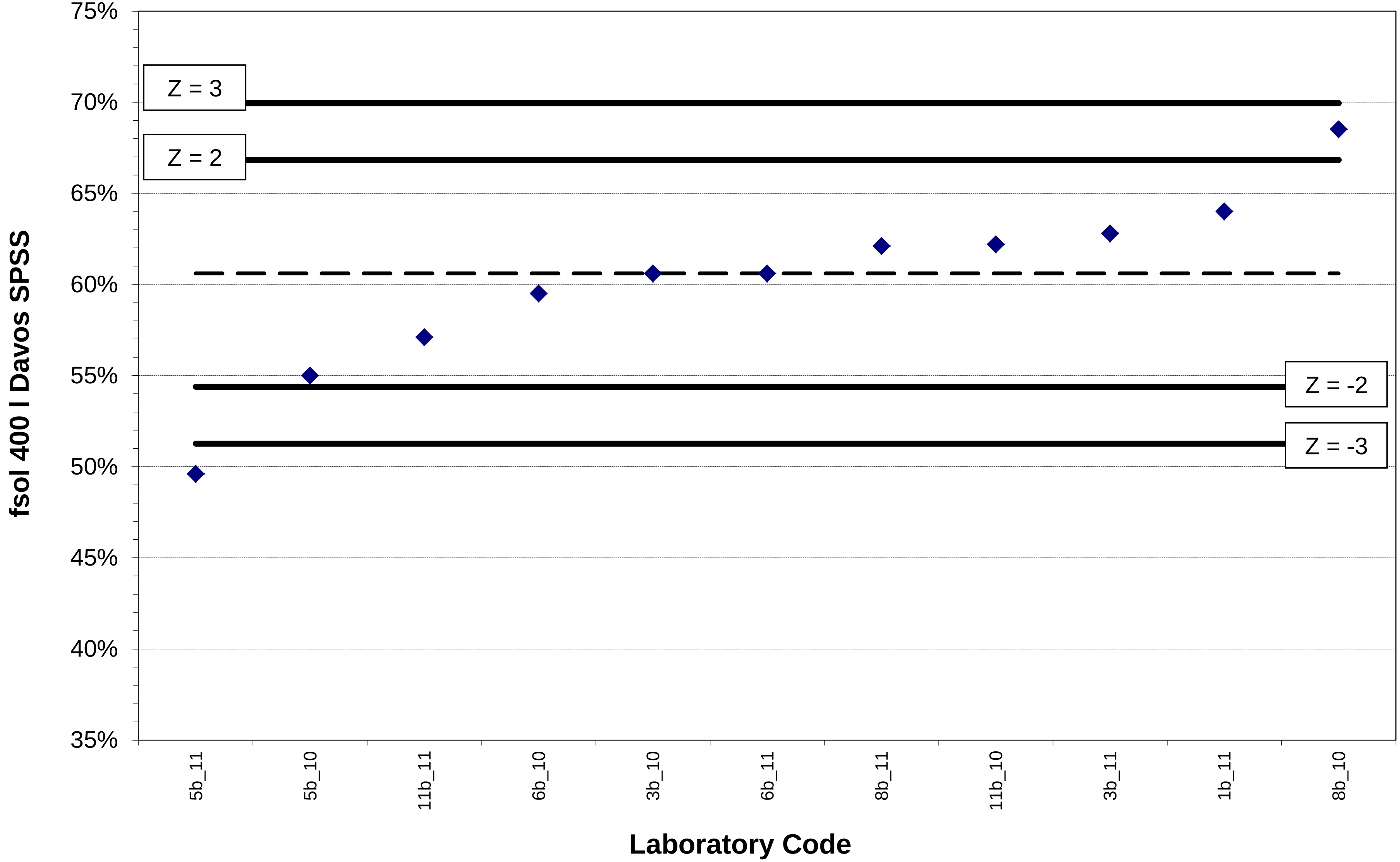

Figure D6: Davos, fsol for 400 l/day, SPSS. Labs w/o data points: not stated

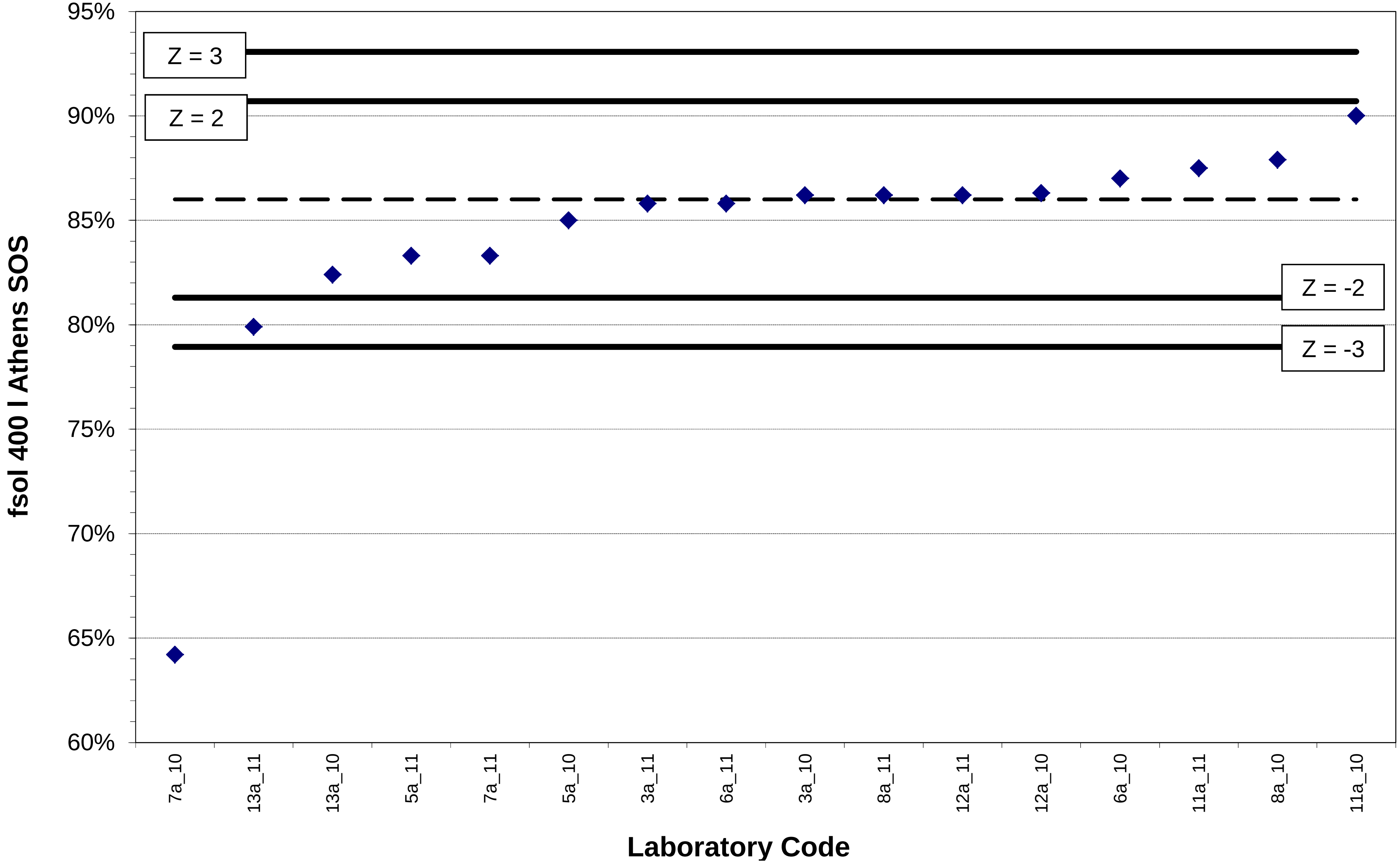

Figure D7: Figure D5: Athens, fsol for 400 l/day, SOS. Labs w/o data points: not stated

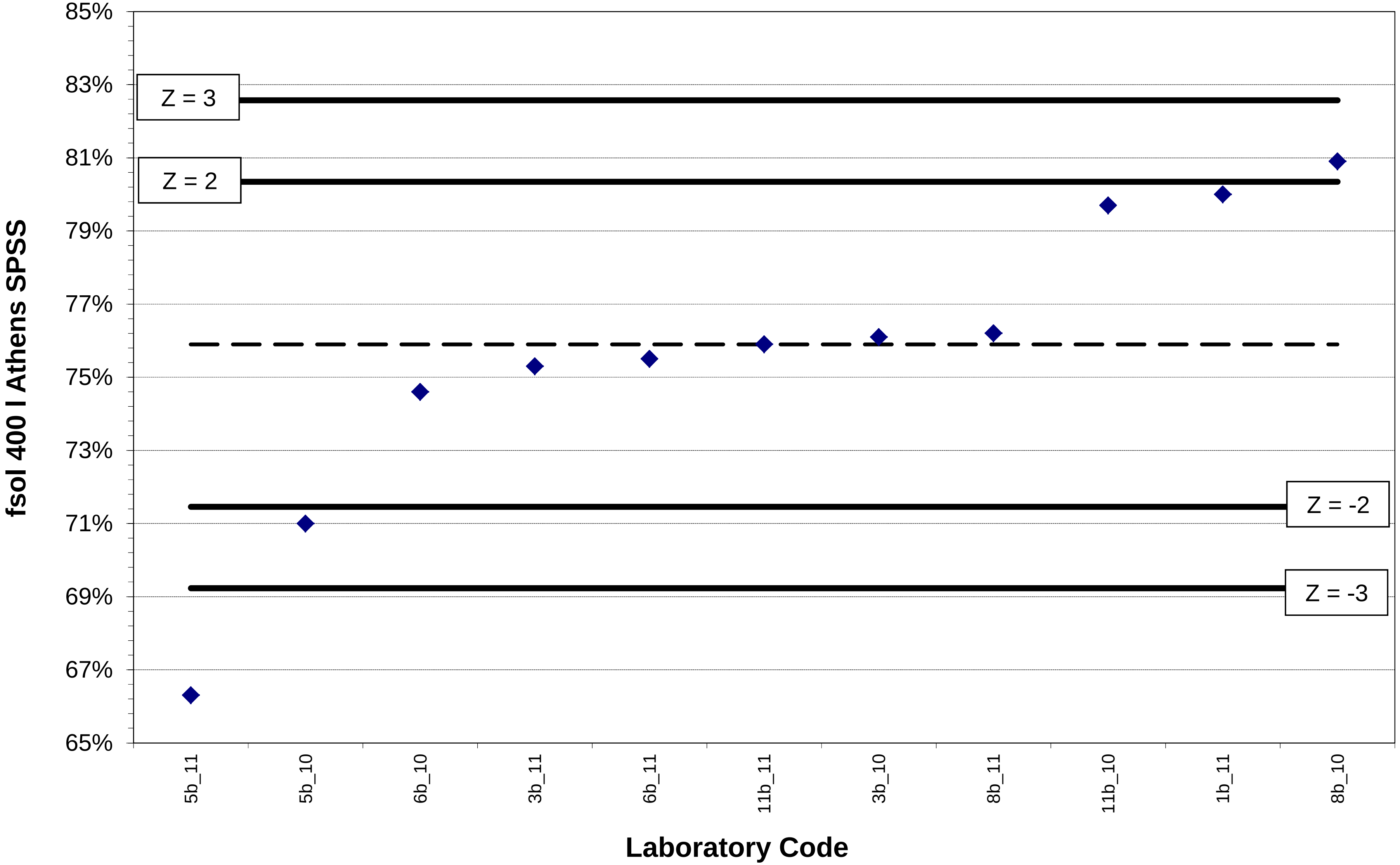

Figure D8: Athens, fsol for 400 l/day, SPSS. Labs w/o data points: not stated

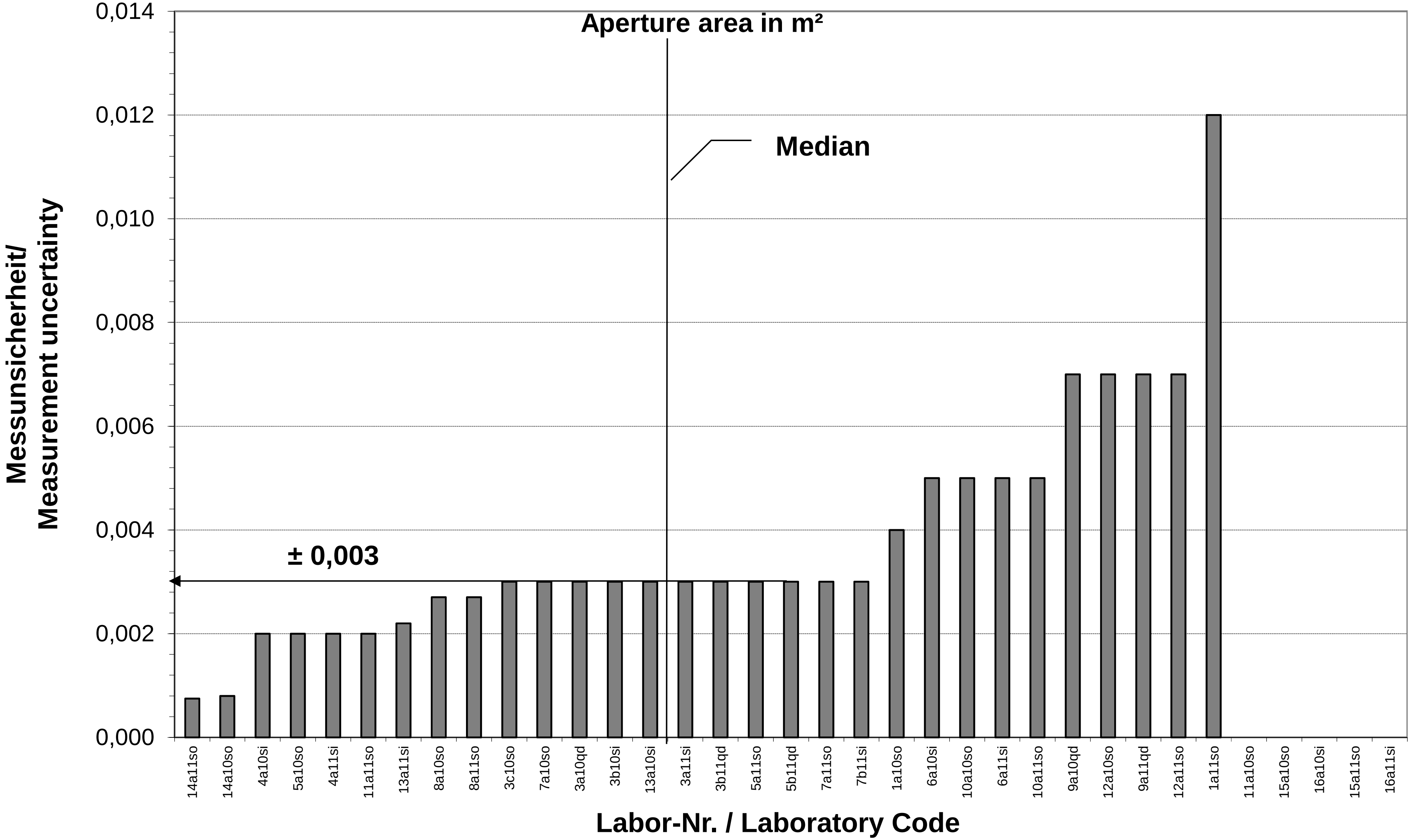

Figure E1: FPC, aperture area; Measurement uncertainty statement by the participants. Labs w/o data points: not stated

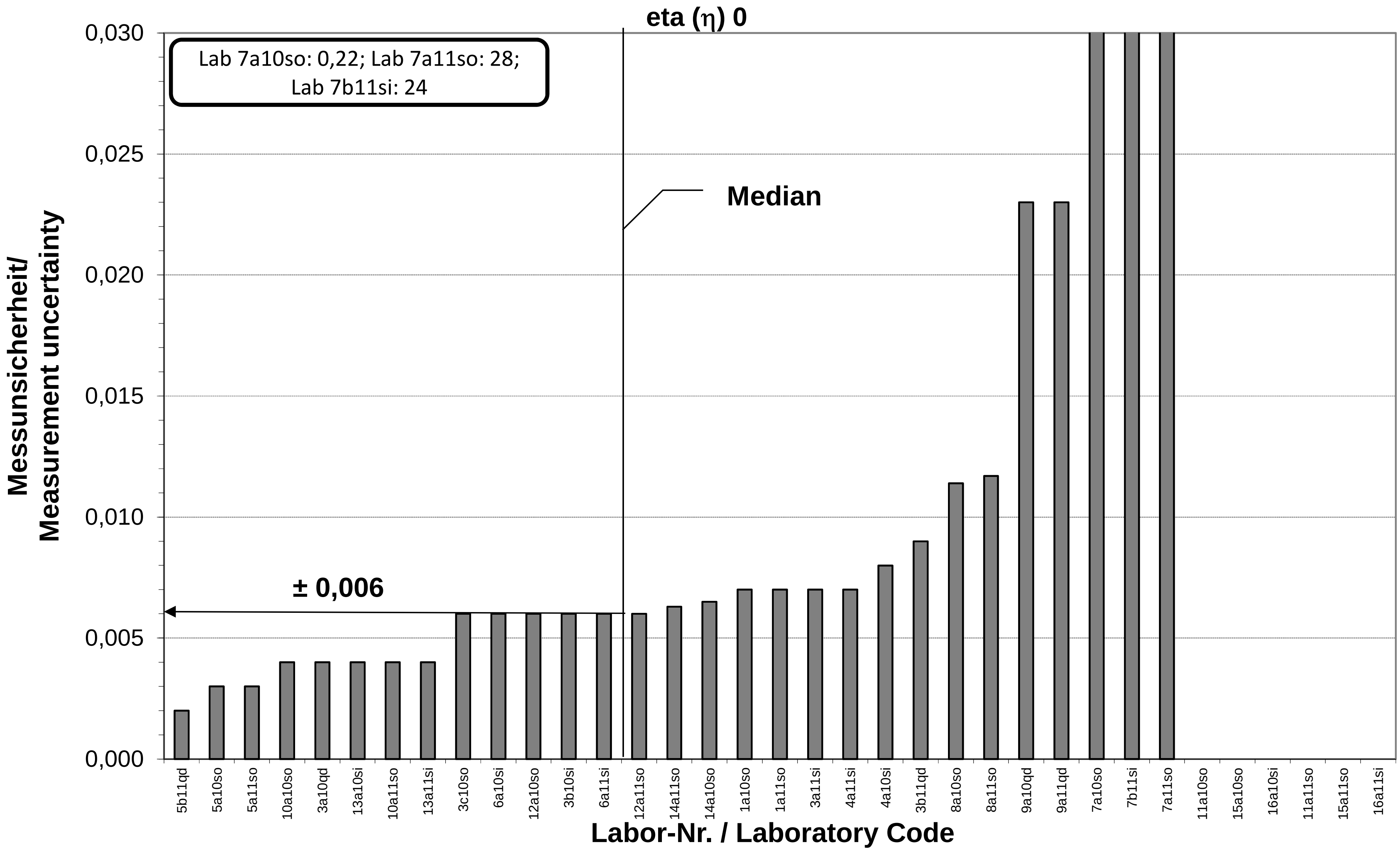

Figure E2: FPC, eta (η) 0; Measurement uncertainty statement by the participants. Labs w/o data points: not stated

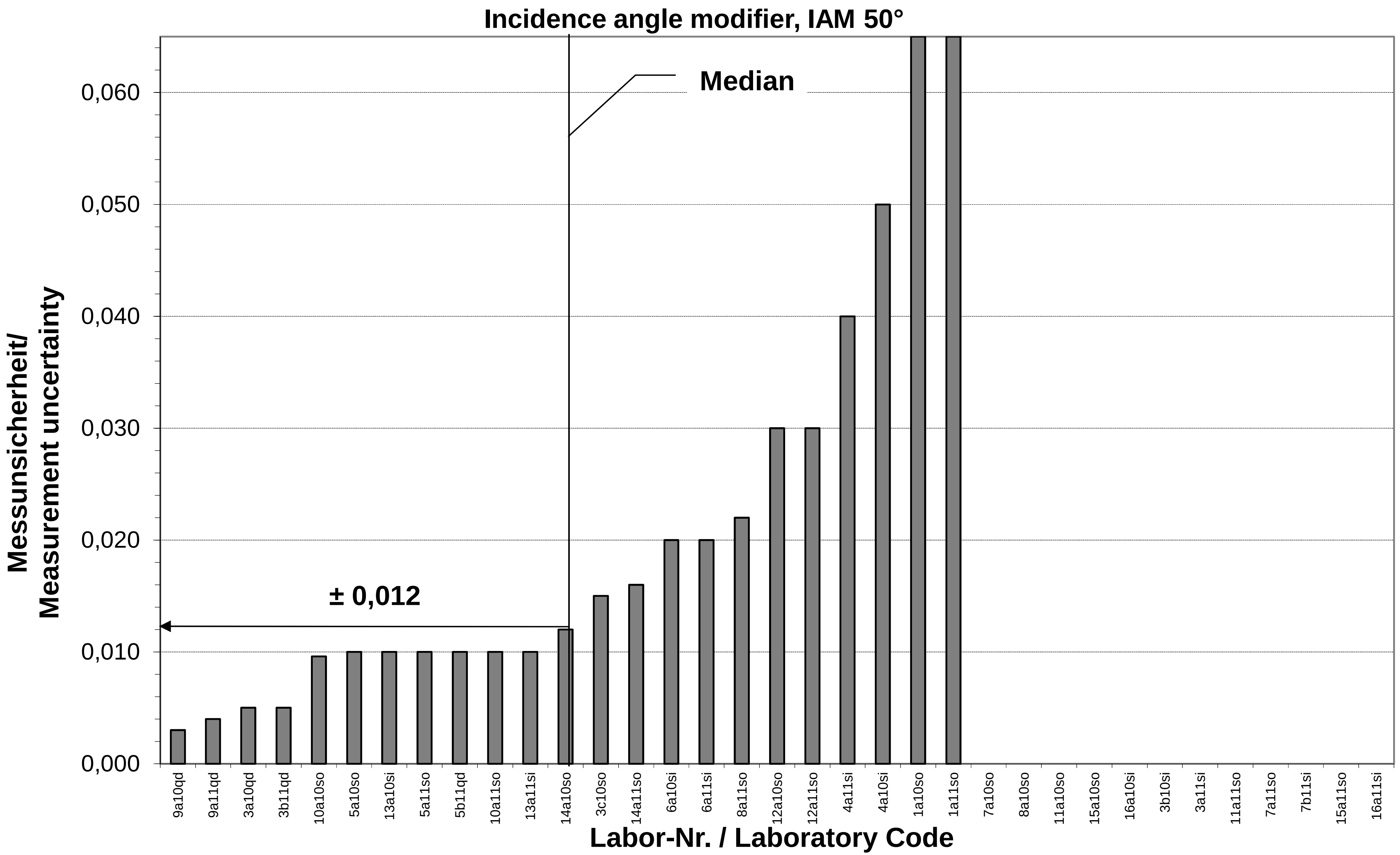

Figure E3: FPC, Incidence angle modifier, IAM 50°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

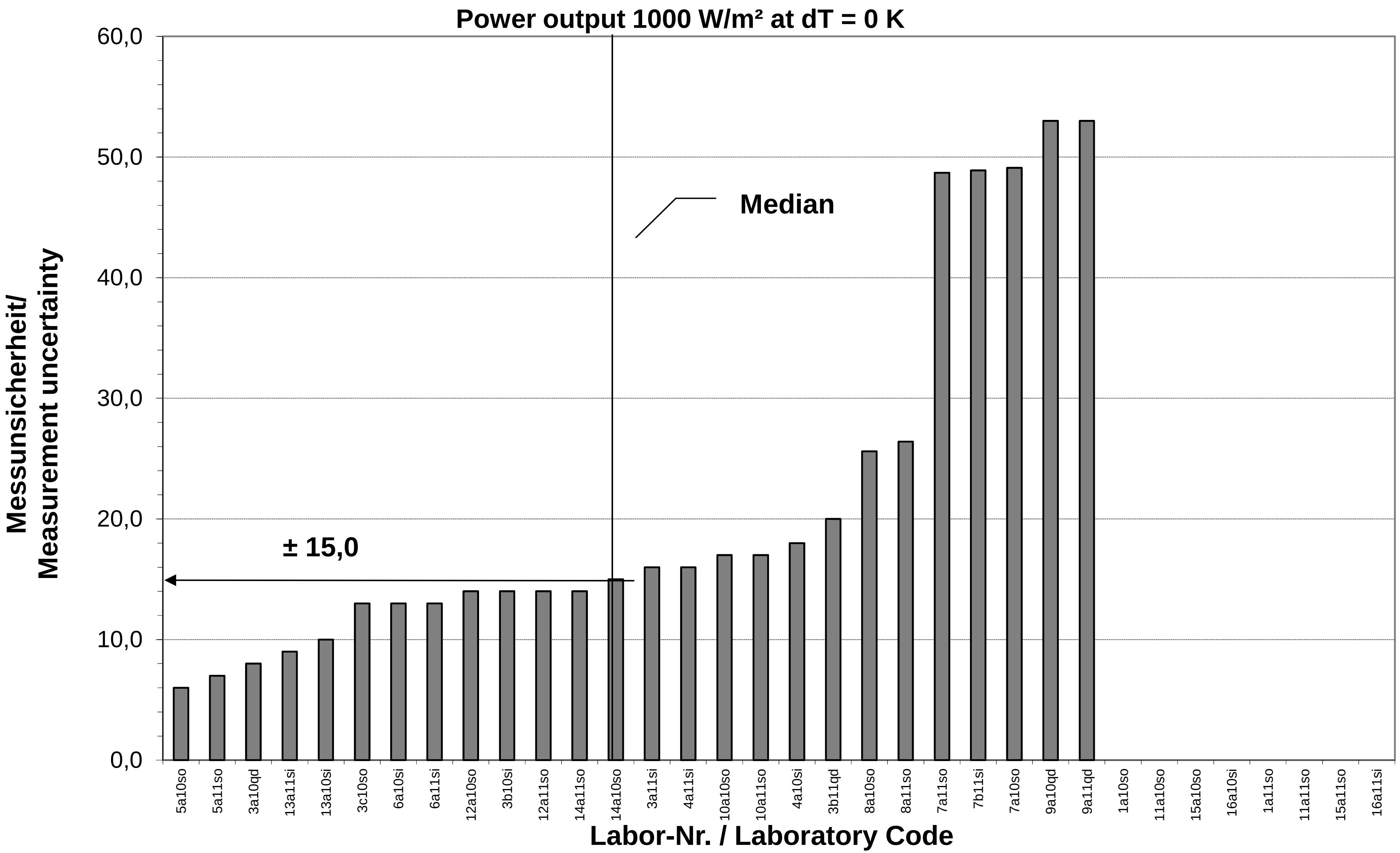

Figure E4: FPC, Power output at 1000 W/m² for dT = 0 K; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated.

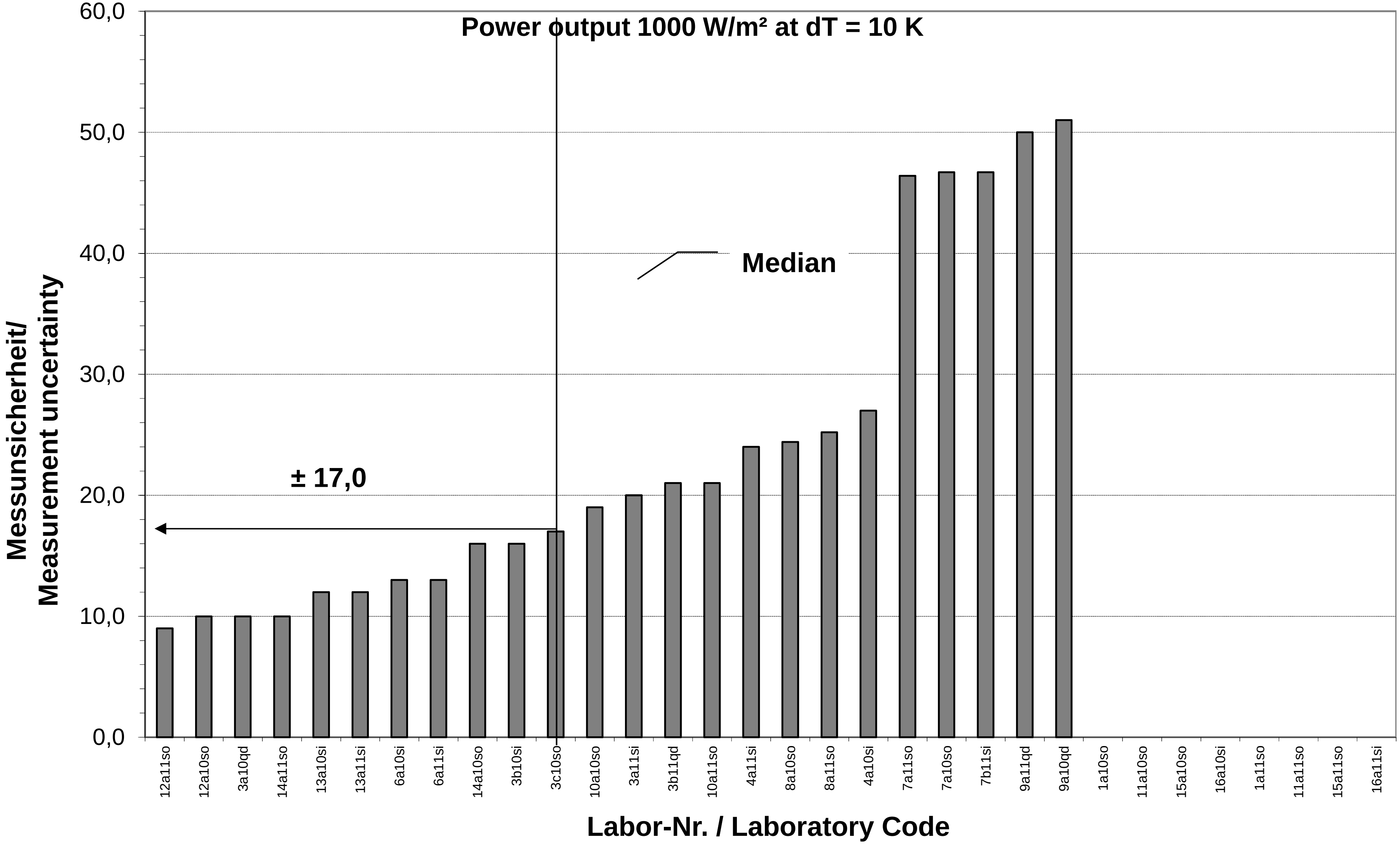

Figure E5: FPC, Power output at 1000 W/m² for dT = 10 K; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated.

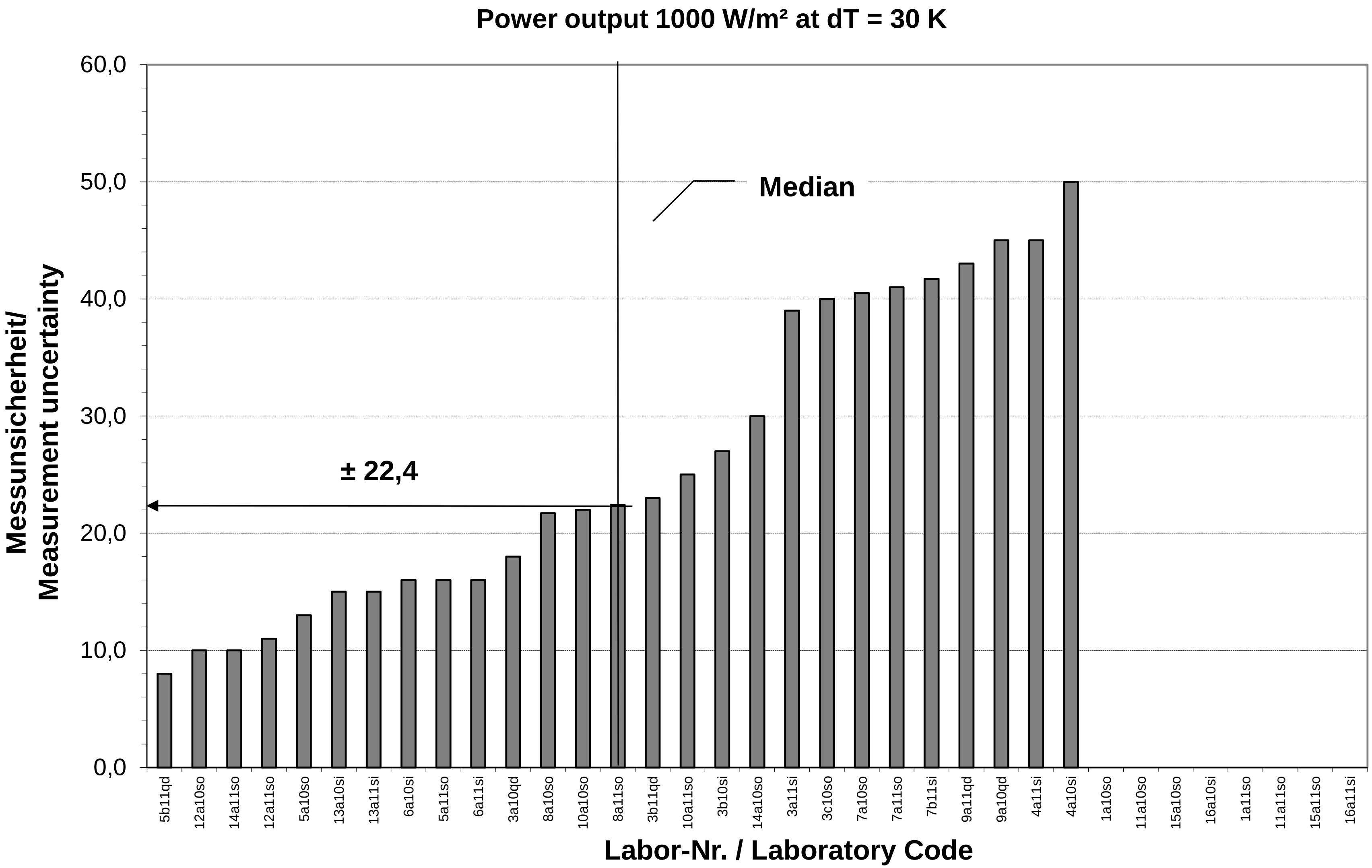

Figure E6: FPC, Power output at 1000 W/m² for dT = 30 K; Measurement uncertainty statement by the participants. Labs w/o data points: not stated.

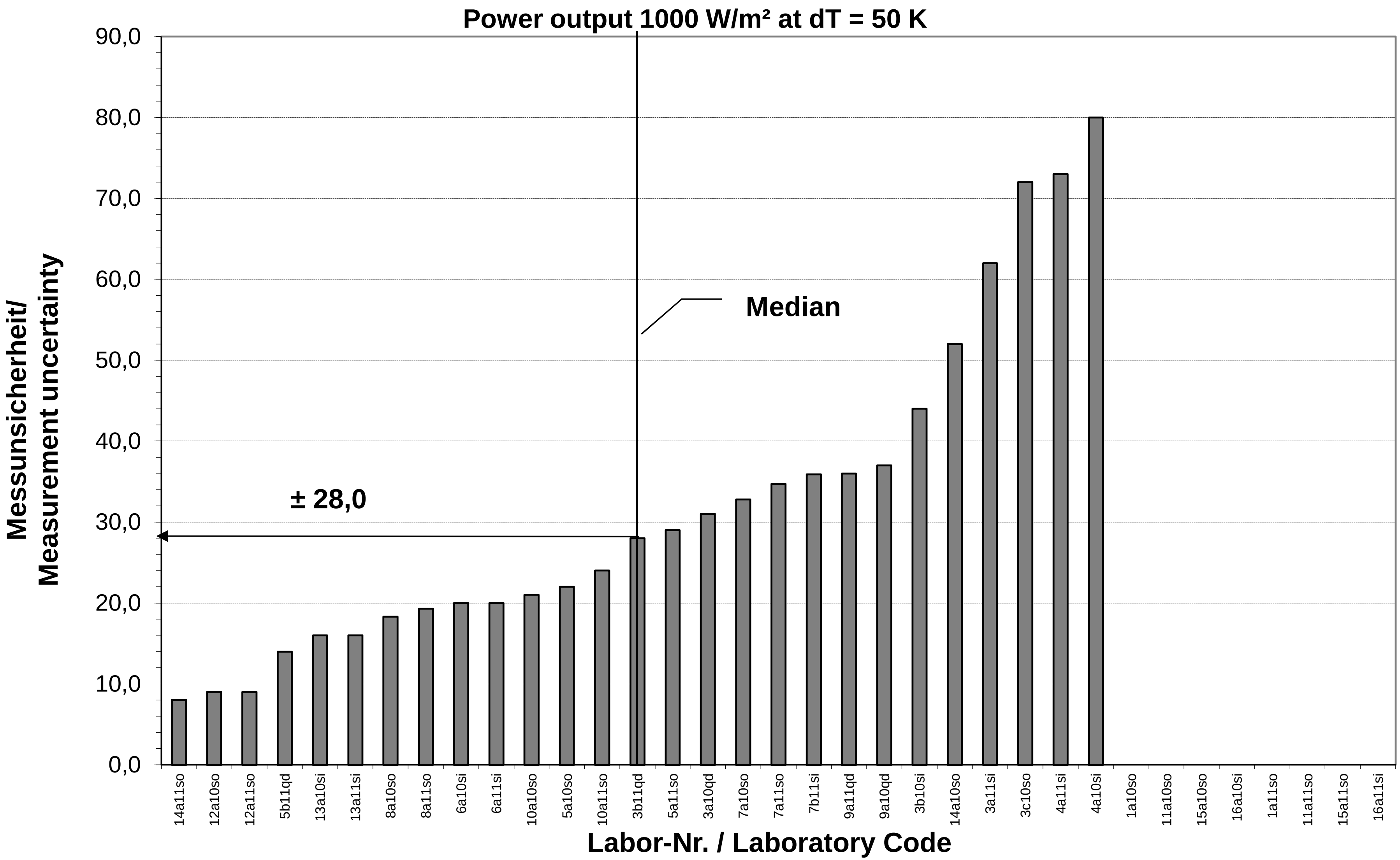

Figure E7: FPC, Power output at 1000 W/m² for dT = 50 K; Measurement uncertainty statement by the participants. Labs w/o data points: not stated.

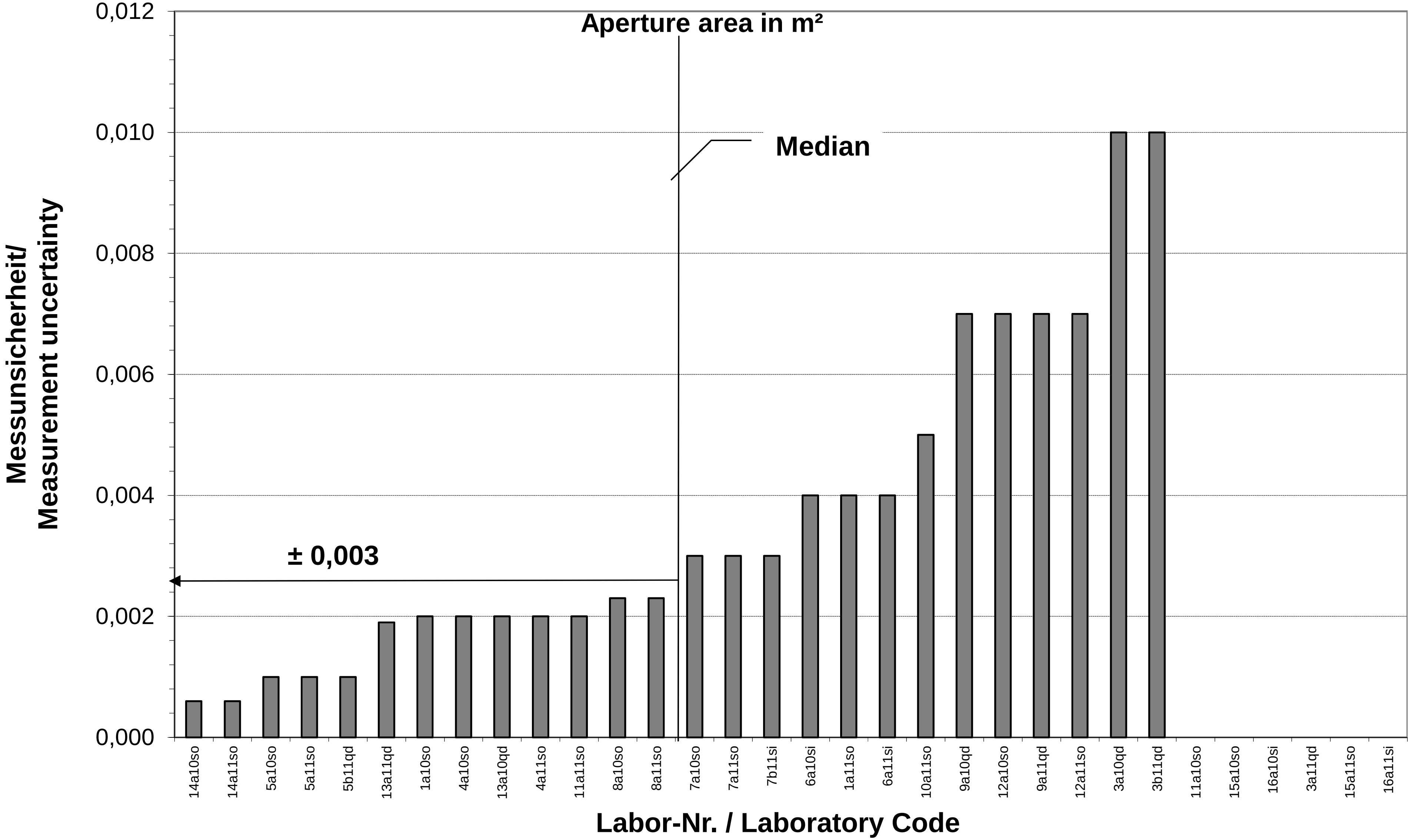

Figure E8: ETC, aperture area; Measurement uncertainty statement by the participants. Labs w/o data points: not stated

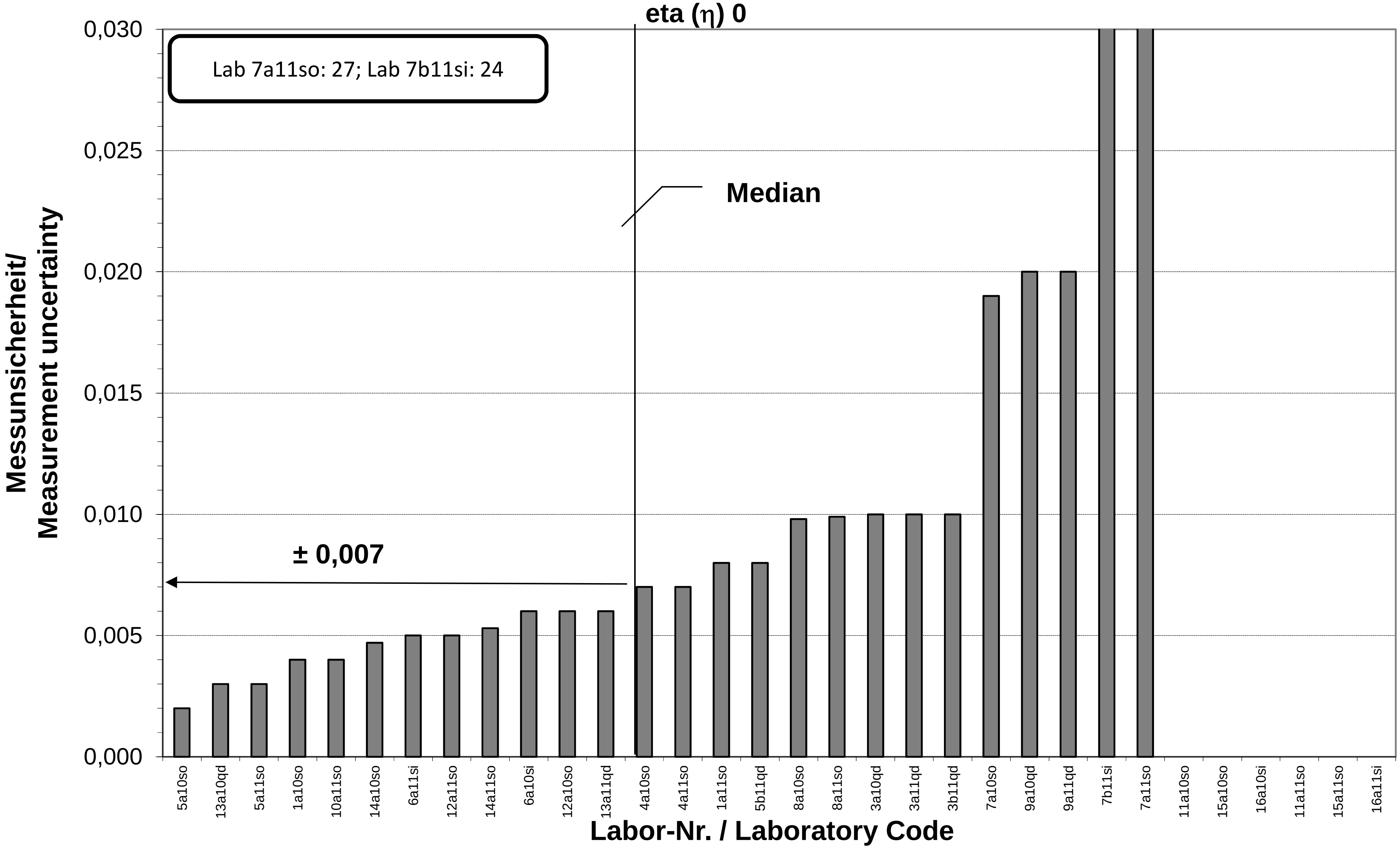

Figure E9: ETC, eta (η) 0; Measurement uncertainty statement by the participants. Labs w/o data points: not stated

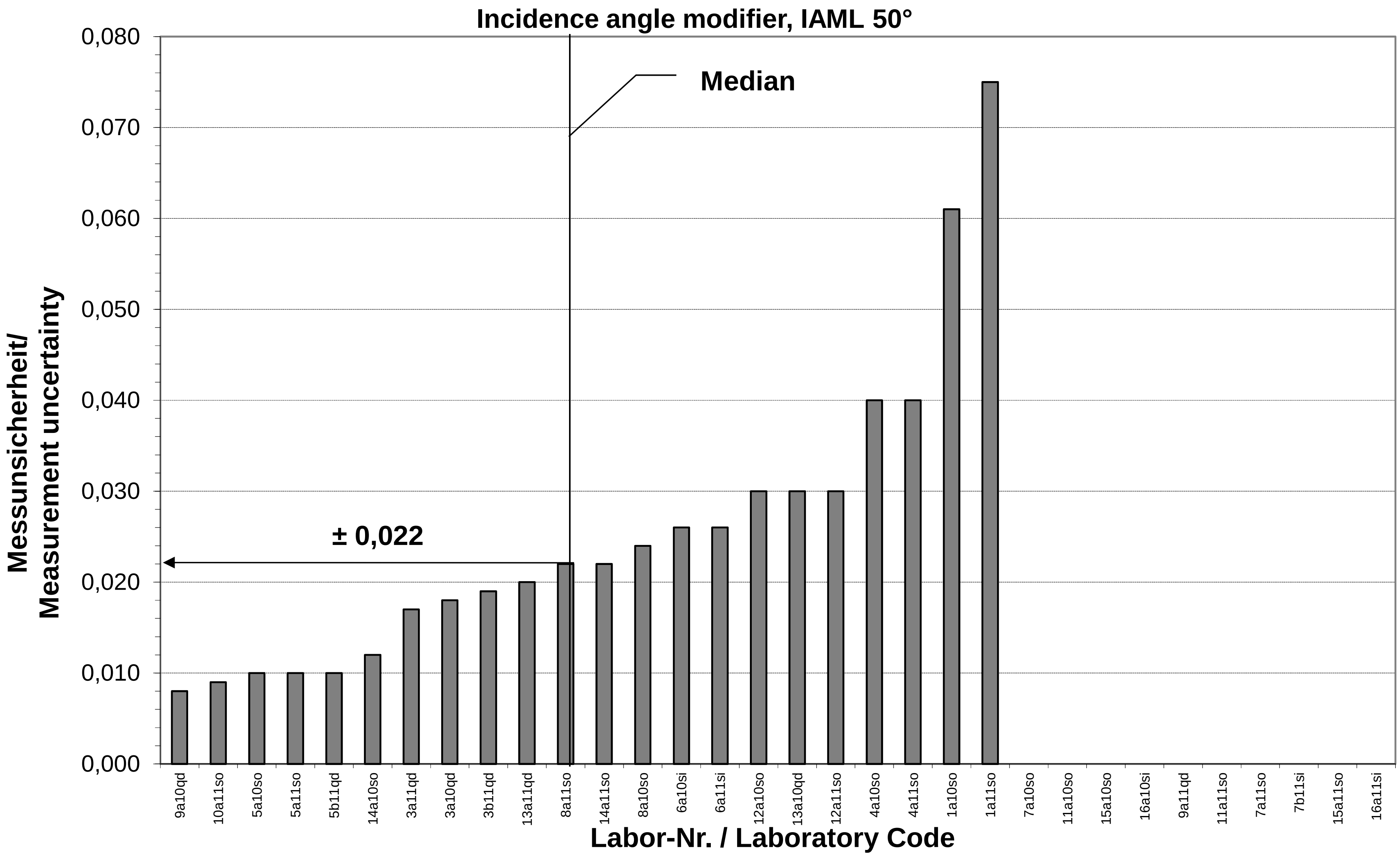

Figure E10: ETC, Incidence angle modifier, IAML 50°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

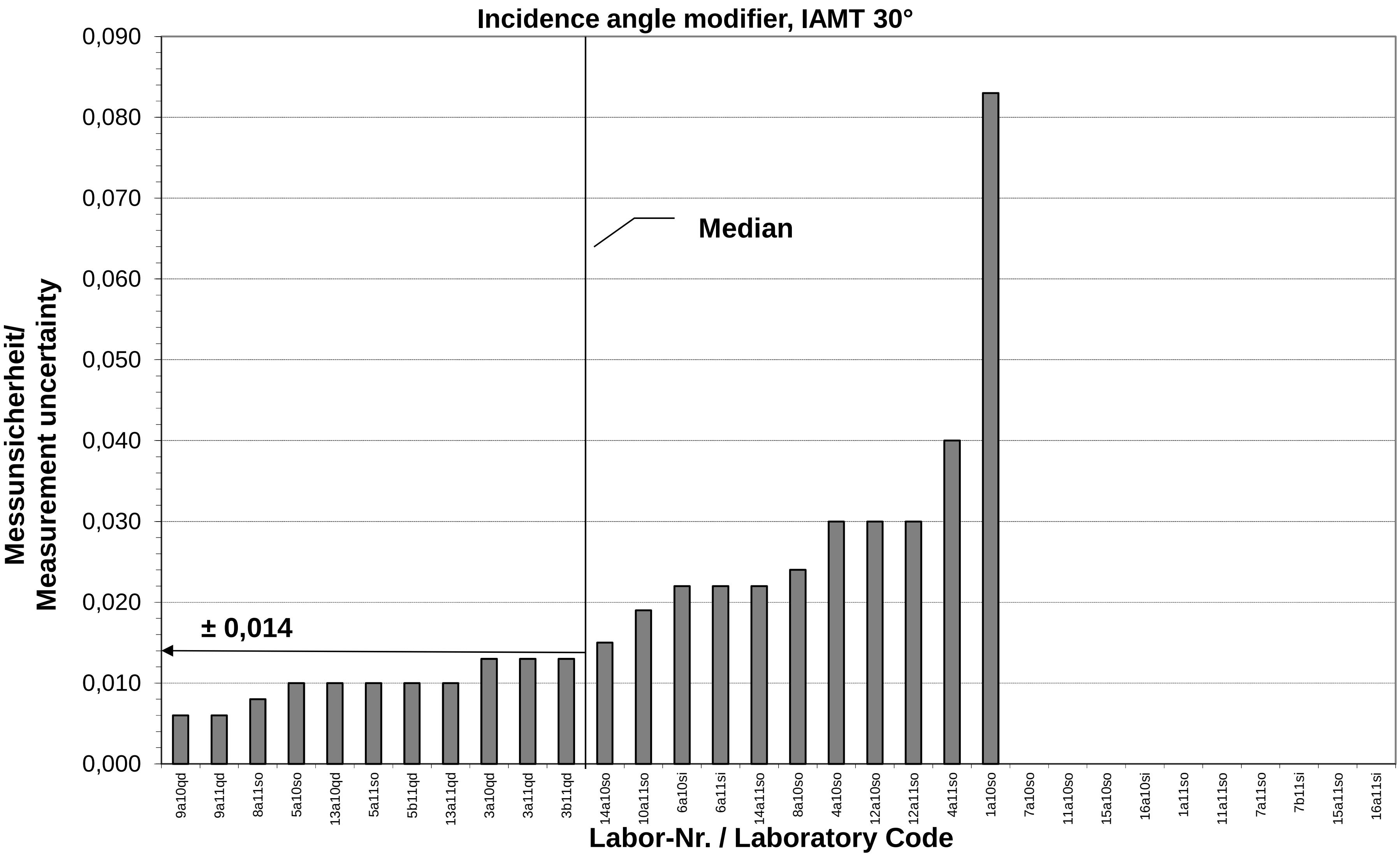

Figure E11: ETC, Incidence angle modifier, IAMT 30°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

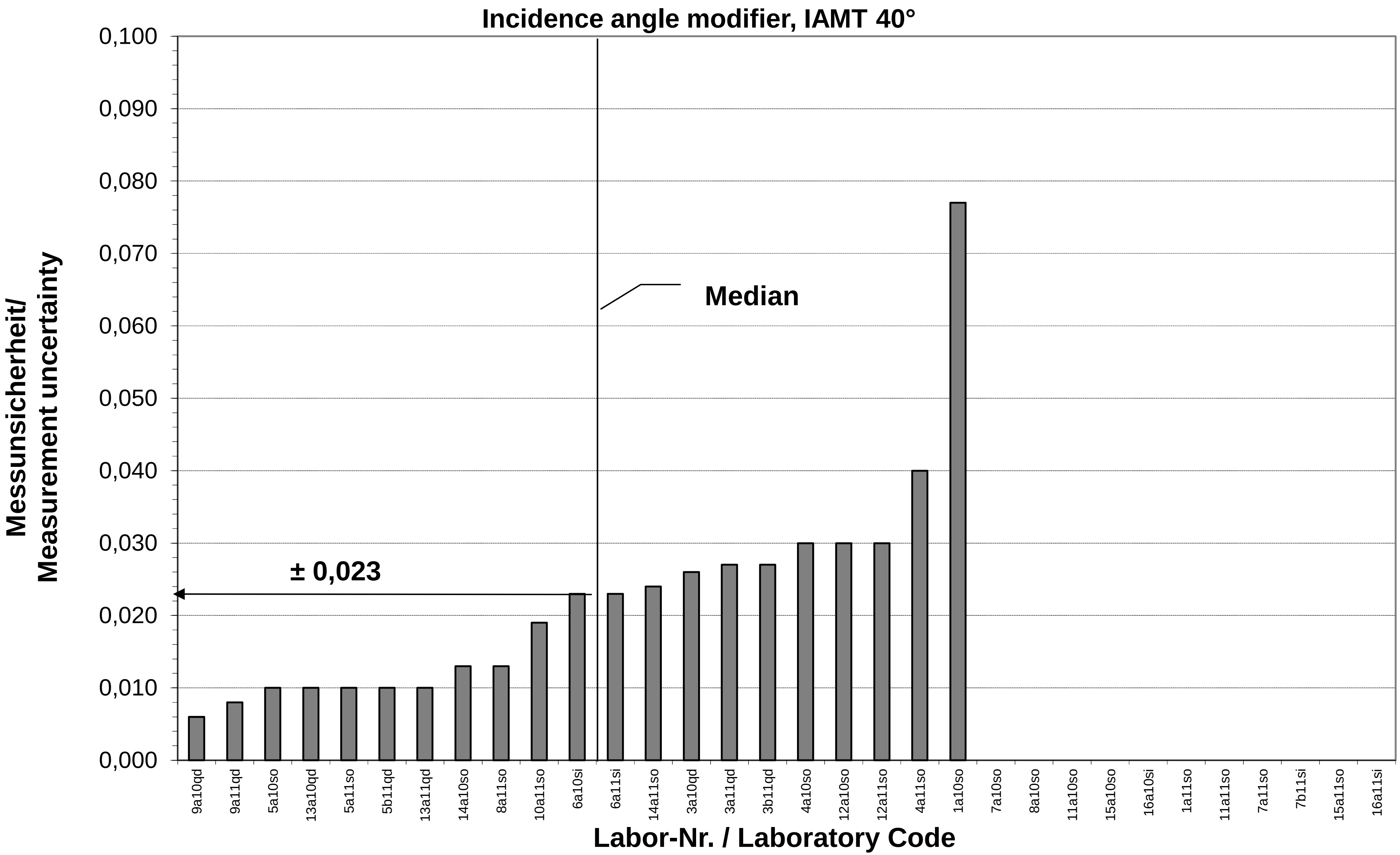

Figure E12: ETC, Incidence angle modifier, IAMT 40°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

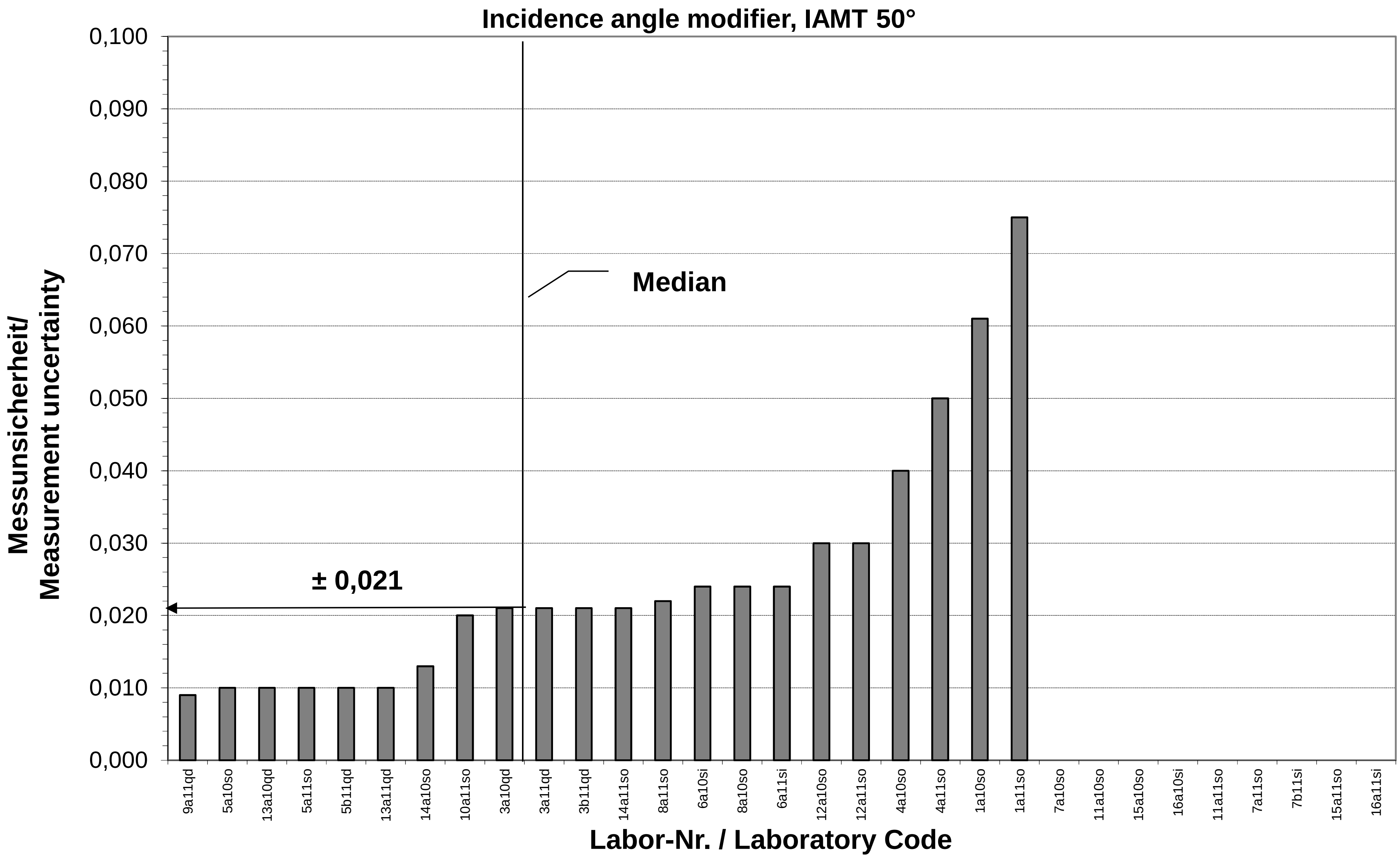

Figure E13: ETC, Incidence angle modifier, IAMT 50°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

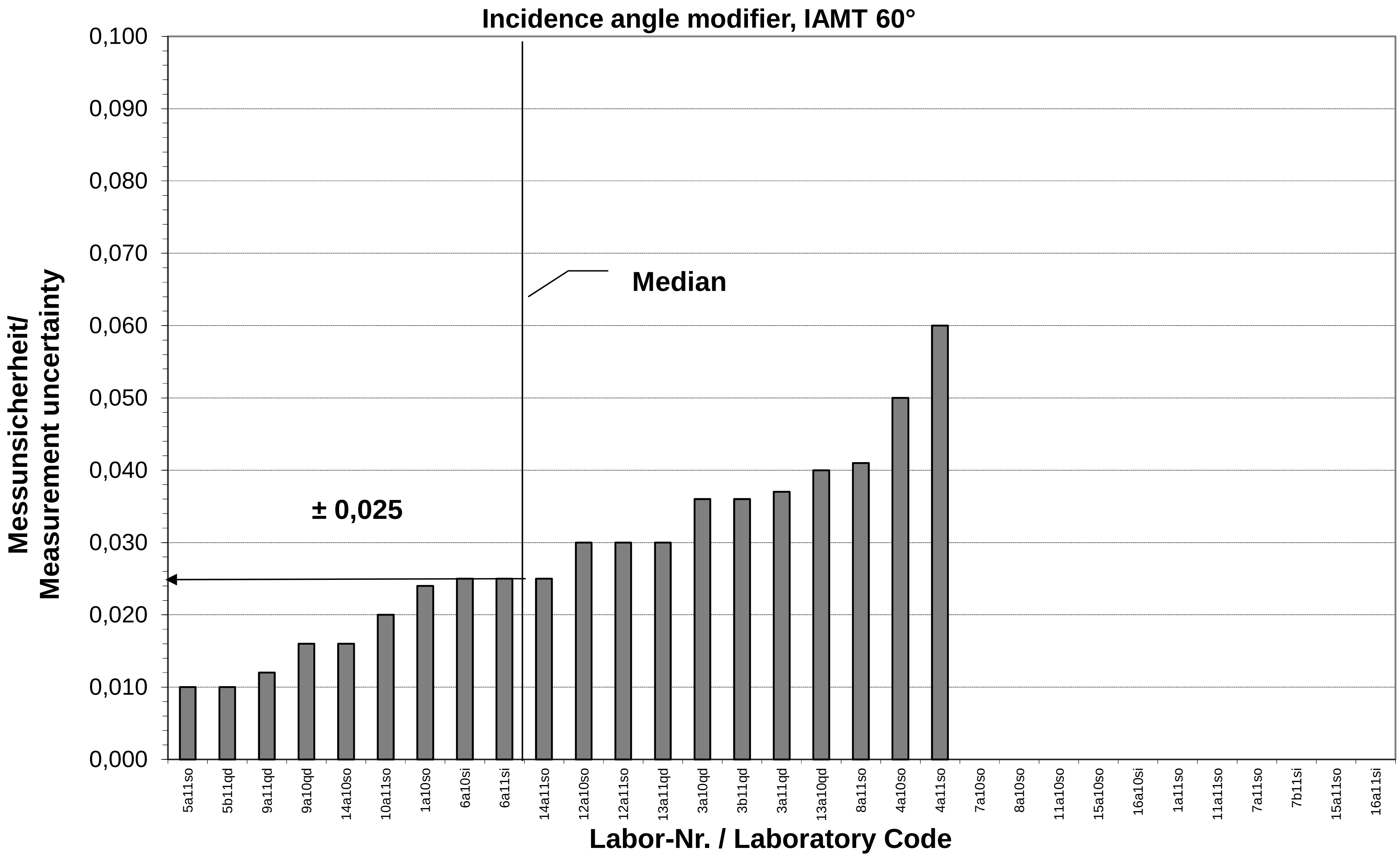

Figure E14: ETC, Incidence angle modifier, IAMT 50°; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated

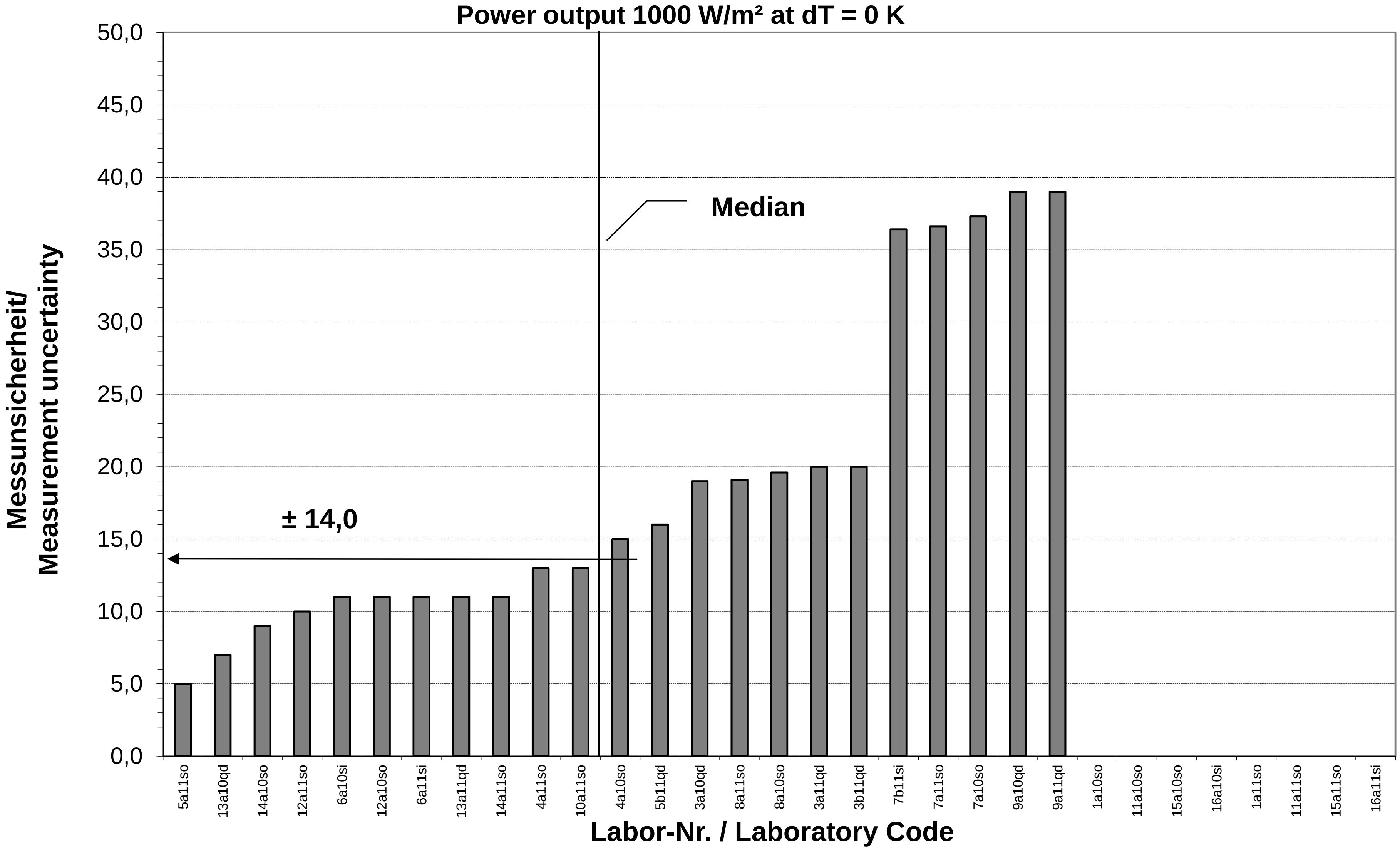

Figure E15: ETC, Power output at 1000 W/m² for dT = 0 K; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated.

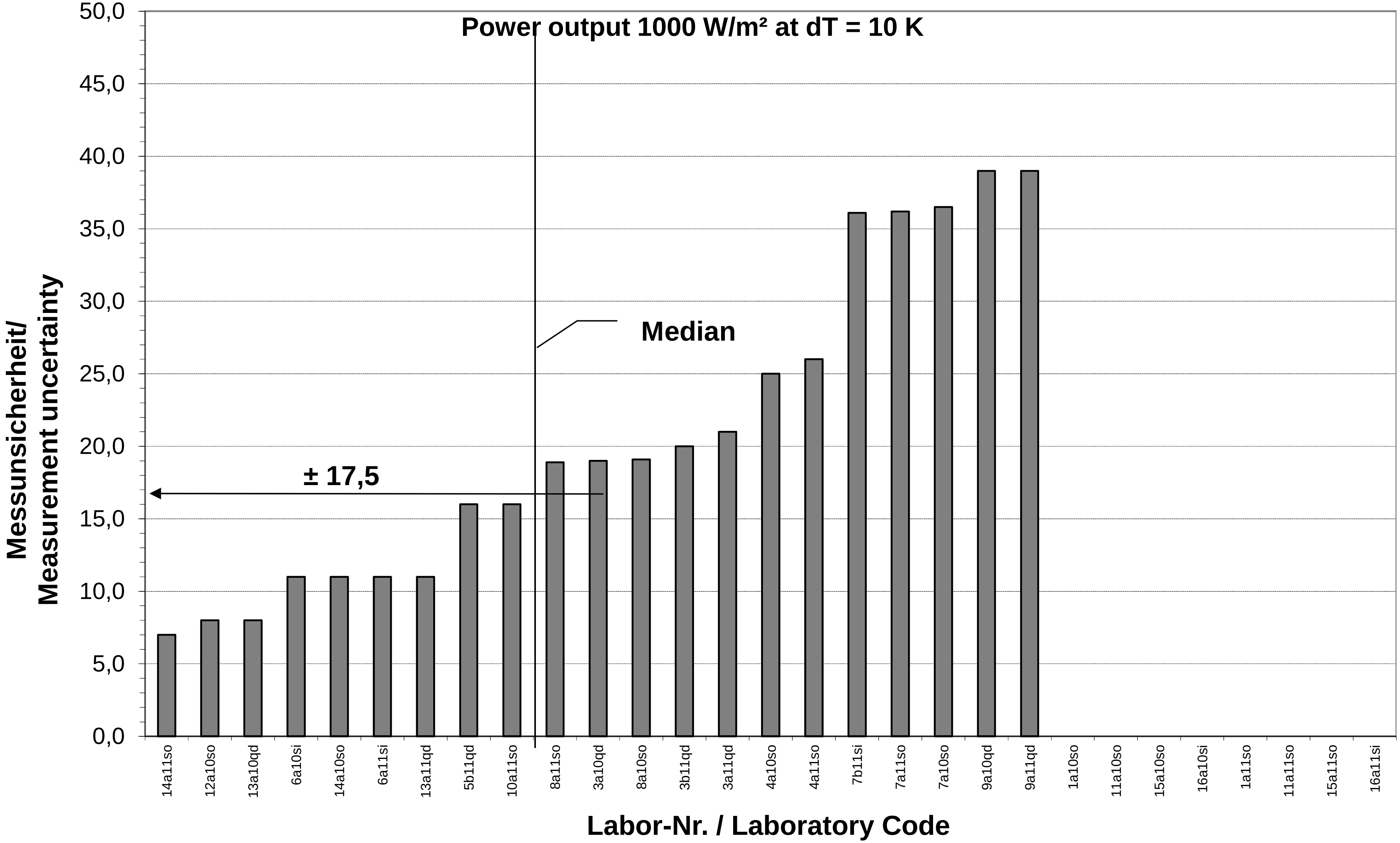

Figure E16: ETC, Power output at 1000 W/m² for dT = 10 K; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated.

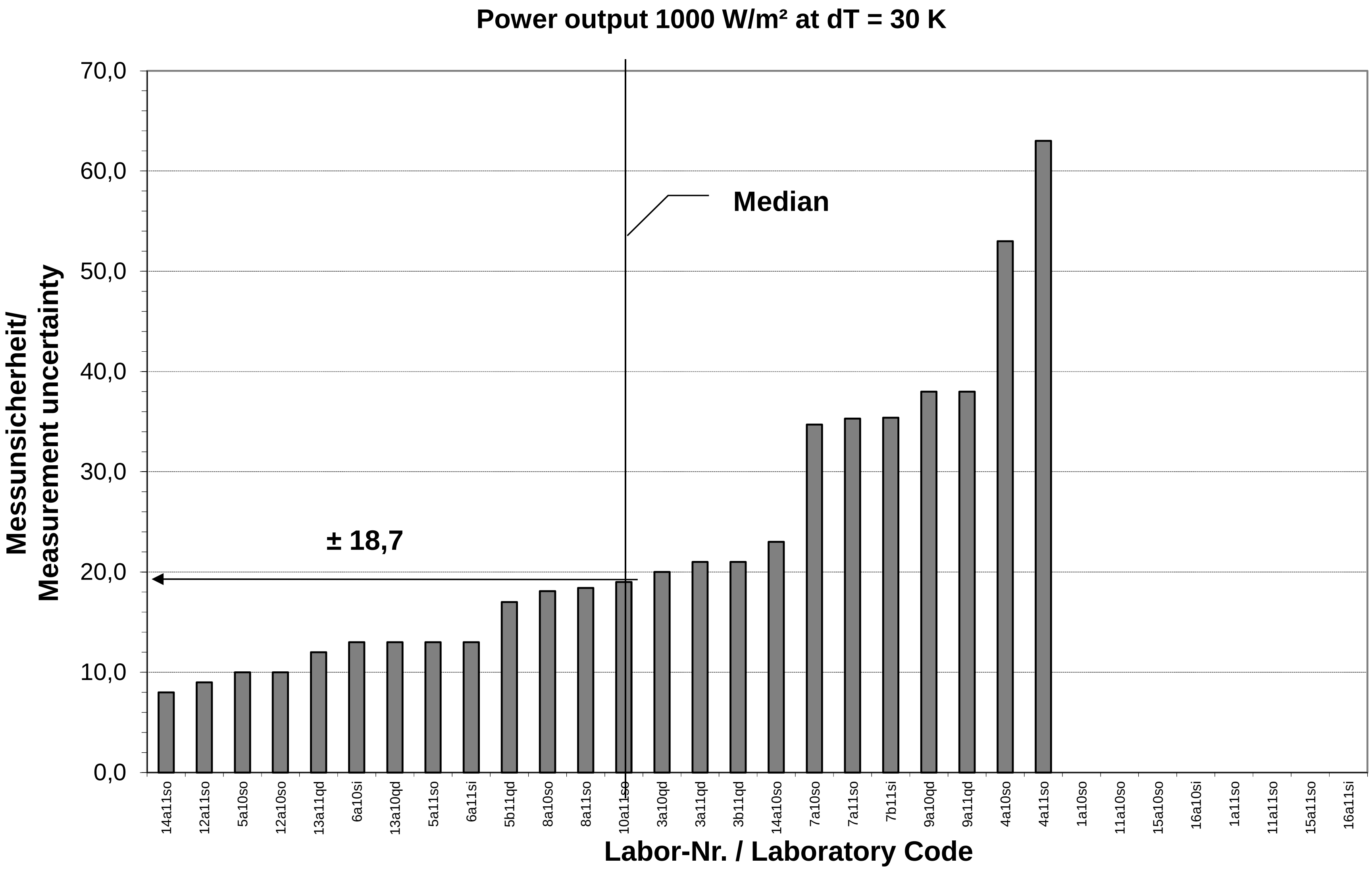

Figure E17: ETC, Power output at 1000 W/m² for dT = 30 K; Measurement uncertainty statement by the participants. Labs w/o data points: not stated.

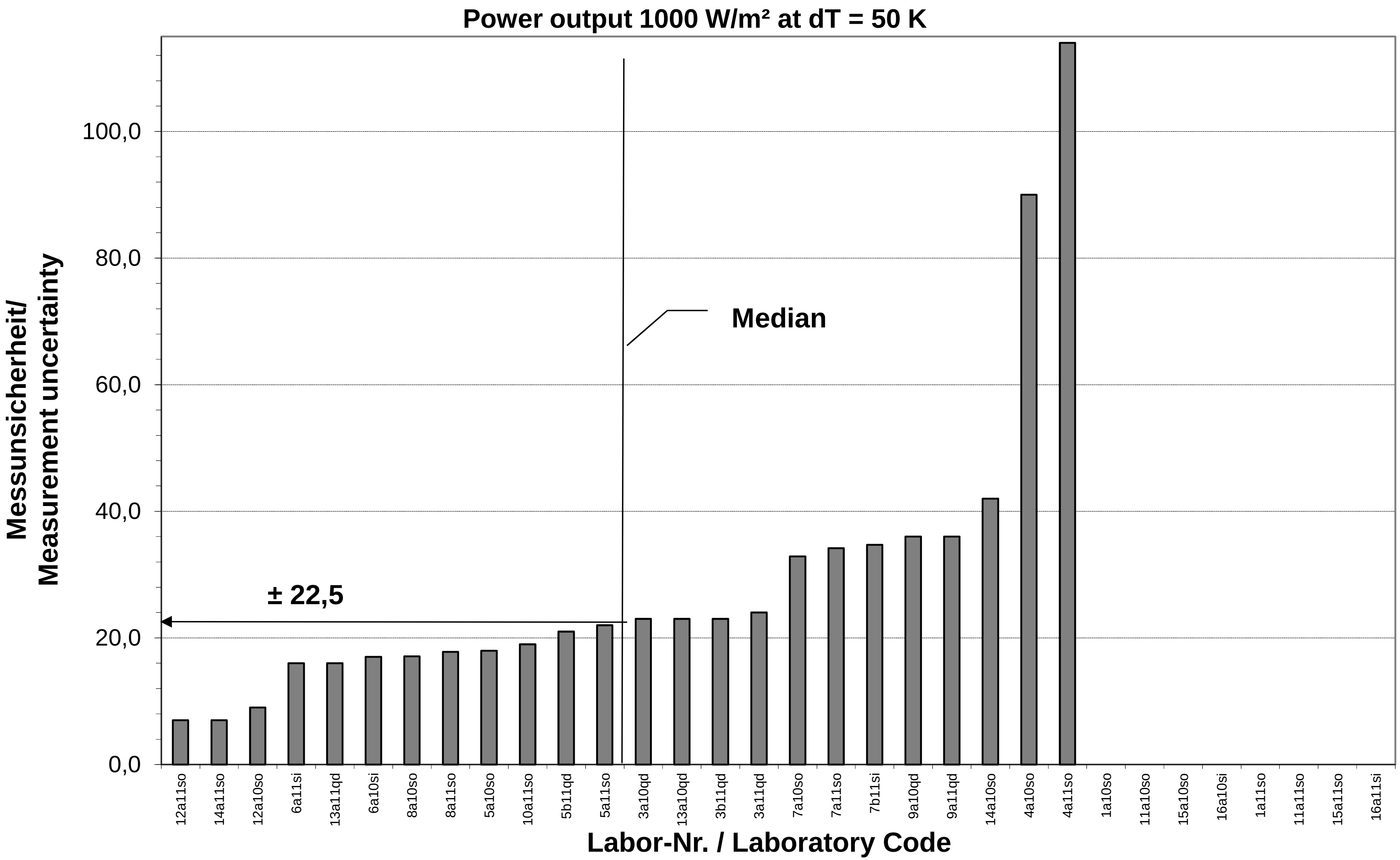

Figure E18: ETC, Power output at 1000 W/m² for dT = 30 K; Measurement uncertainty statement by the participants.
Labs w/o data points: not stated.

End of report