Final Report on CIPM key comparison of multiples and submultiples of the kilogram (CCM.M-K2)

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1. Introduction

The CCM has agreed, at its 6th meeting in 1996 [1], to perform a key comparison according to [2] with mass standards of the five nominal values:

100 mg
2 g
20 g
500 g
10 kg

These nominal values have been chosen, because they cover the range of weights mostly used in practice and because a box containing these standards can still be transported by hand-carrying.

PTB has accepted the role as pilot laboratory. With the exception of Mexico, the participants are member countries of CCM, in particular:

Laboratory		Country
Physikalisch-Technische Bundesanstalt	PTB	Germany
Commenwealth Scientific and Industrial Research Organization	CSIRO	Australia
Korea Research Institute of Standards and Science	KRISS	Republic of Korea
National Metrology Institute of Japan, National Institute of Advanced Science and Technology	NMIJ/AIST	Japan
National Institute of Metrology	NIM	China
National Physical Laboratory	NPL	United Kingdom

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[12] Slovak Metrological Institute (SMU), 84255 Bratislava, Slovakia
[13] Van Swinden Laboratorium (NMi/VSL), 2600 Delft, Netherlands
[14] National Institute of Metrology (NIM), 100013 Beijing, China

Laboratory		Country
Centro Nacional de Metrologia	CENAM	Mexico
National Research Council of Canada	NRC	Canada
National Institute of Standards and Technology	NIST	USA
Van Swinden Laboratorium	VSL	Netherlands
Slovak Metrological Institute	SMU	Slovakia
Swiss Federal Office of Metrology and Accreditation	METAS	Switzerland
Bureau National de Métrologie/LNE	BNM/LNE	France
Istituto di Metrologia ”G. Colonnetti”	IMGC	Italy

Three sets of mass standards (CA, CB, CC) with the nominal values mentioned above have been circulated amongst four or five participants in parallel. The sets have been under way between May 1998 and January 1999 by hand-carrying. An instruction paper, including data measured at PTB such as density, center of gravity and magnetic suceptibility of the standards, has been attached to the packages after having been prepared by PTB and agreed by the participants. The results have been arrived at PTB – some of them with a delay of several months - until April 1999. No remarkable incident or damage of the travelling standards has been occurred.

2. Description of the devices

The travelling standards are made of non-magnetic stainless steel and have the form and quality recommended by OIML [3] for weights of accuracy class E_1. They had been purchased by PTB in 1997 and observed for their stability during about one year. No significant instability has been found. For transportation, the standards were kept inside a wooden box and fixed in appropriate holes just by being wrapped in low-fluffy paper. The box was carried by a conventional travelling bag.

3. Summary of the results reported by the participants

3.1 Values of mass and combined uncertainty

Table 1 shows the results and combined uncertainties as given by the participants and the pilot laboratory. The number of digits has been restricted to a maximum of three significant ones in the uncertainty and to a minimum giving a tenth of a microgram.

3.2 Stability of the travelling standards

Table 1 shows also the difference between the two PTB measurements before and after circulation. The changes of the travelling standards, in most cases are well below the measurement uncertainties. Only the 2 g and 100 g standards have changed in the order of magnitude of the uncertainties, but not more than the spread of the mass values. Table 2 summarises these changes of the travelling standards.

Table 2. Mass differences Δm of the travelling standards measured at PTB before and after the circulation against the PTB reference standards

m_0	Δm/mg Apr.99 - Apr 98		
	CA	CB	CC
10 kg	0,012	0,038	0,046
500 g	0,0056	0,0039	0,0043
20 g	0,0019	-0,0015	0,0000
2 g	-0,0016	-0,0005	-0,0009
100 mg	-0,0004	0,0001	-0,0007

PTB measured the travelling standards against its reference standards of set 4, which have essentially the same shape and quality. The standards of set 4 have been linked to the national prototype no.52 before and after the circulation by subdivision/multiplication in March 1998 and April 1999. They have been stored under bell jars all the time between the comparisons with the travelling standards.

The differences of their two determinations are shown in Table 3. These changes are mostly less than the changes of the travelling standards. Only the 100 mg standard decreased by a similar amount as the CC 100 mg standard. But, this change could also be caused by possible errors in the subdivision procedure, even though the calculated uncertainty from this calibration is much less (0,17 µg). A significant drift can be excluded for another reason, because the three 100 mg travelling standards don't show corresponding changes (which should have the opposite sign). With the reasonable assumption that the PTB reference standards didn't change significantly during the intercomparison, the same mass values (the average) have been taken for the comparison of the travelling standards before and after the circulation.

Table 3. Mass differences of the PTB reference standards measured by subdivision/multiplication of the 1 kg national prototype before and after the circulation of the travelling standards.

m_0	Δm/mg Apr.99 - Apr 98
10 kg	-0,010
500 g	-0,0037
20 g	-0,0008
2 g	0,0000
100 mg	-0,0008

Table 1. Reported results found for the three sets of travelling standards, CA, CB and CC. m mass and m_0 nominal value of the standard, u_c combined standard uncertainty (k = 1). Δm_{PTB2-1} is the mass difference of the travelling standard measured at PTB before and after the circulation against the PTB reference standard.

		10 kg		**500g**		**20g**		**2g**		**100mg**	
Date	Labora-tory	m-m_0/mg	u_c/mg	m-m_0/mg	u_c/mg	m-m_0/mg	u_c/mg	m-m_0/mg	u_c/mg	m-m_0/mg	u_c/mg
Mar/98	PTB_1	-2,135	0,122	-0,1801	0,0062	-0,0052	0,0023	-0,0002	0,0007	0,0000	0,0003
Jul/98	CSIRO	-2,200	0,340	-0,1820	0,0200	-0,0053	0,0030	-0,0014	0,0006	-0,0005	0,0003
Aug/98	KRISS	-2,296	0,148	-0,1719	0,0073	-0,0029	0,0009	0,0004	0,0004	-0,0011	0,0001
Sep/98	NMIJ/AIST	-1,930	0,280	-0,1490	0,0080	-0,0040	0,0020	0,0004	0,0005	-0,0009	0,0002
Nov/98	NIM	-1,700	0,500	-0,1700	0,0120	-0,0015	0,0020	-0,0008	0,0006	-0,0007	0,0003
Mar/99	PTB_2	-2,123	0,122	-0,1745	0,0062	-0,0033	0,0023	-0,0018	0,0007	-0,0004	0,0003
Δm_{PTB2-1}/mg		0,012		0,0056		0,0019		-0,0016		-0,0004	
Mar/98	PTB_1	-3,071	0,122	-0,2149	0,0062	-0,0035	0,0023	-0,0036	0,0007	-0,0002	0,0003
Aug/98	NPL	-3,200	0,150	-0,2090	0,0074	-0,0008	0,0009	-0,0031	0,0002	-0,0005	0,0004
Sep/98	CENAM	-1,680	0,760	-0,1922	0,0094	-0,0016	0,0021	-0,0032	0,0006	-0,0012	0,0004
Nov/98	NRC	-1,200	0,970	-0,2062	0,0078	-0,0015	0,0037	-0,0004	0,0015	-0,0003	0,0003
Dec/98	NIST	-2,952	0,197	-0,2108	0,0081	-0,0011	0,0010	-0,0025	0,0004	-0,0008	0,0001
Mar/99	PTB_2	-3,032	0,122	-0,2111	0,0062	-0,0049	0,0023	-0,0041	0,0007	-0,0001	0,0003
Δm_{PTB2-1}/mg		0,039		0,0038		-0,0014		-0,0005		0,0001	
Mar/98	PTB_1	-8,542	0,122	-0,5135	0,0062	-0,0024	0,0023	0,0032	0,0007	-0,0007	0,0003
Jun/98	VSL	-8,900	1,100	-0,5600	0,0200	0,0020	0,0040	0,0010	0,0030	-0,0004	0,0008
Aug/98	SMU	-6,870	0,860	-0,5140	0,0220	-0,0119	0,0035	0,0034	0,0020	-0,0002	0,0010
Sep/98	METAS	-8,465	0,251	-0,5010	0,0151	0,0064	0,0026	0,0045	0,0010	-0,0014	0,0003
Oct/98	BNM/LNE	-8,800	0,300	-0,5140	0,0150	0,0037	0,0026	0,0043	0,0010	-0,0019	0,0004
Nov/98	IMGC	-8,760	0,228	-0,4990	0,0076	-0,0039	0,0038	0,0012	0,0018	-0,0019	0,0008
Mar/99	PTB_2	-8,496	0,122	-0,5092	0,0062	-0,0024	0,0023	0,0023	0,0007	-0,0014	0,0003
Δm_{PTB2-1}/mg		0,046		0,0043		0,0000		-0,0009		-0,0007	

4. Mass differences

For comparing the results of the participants related to three different sets of standards, we have to link them to the reference standards of the pilot laboratory. The best way is to calculate the difference between the mass determined by the participant and that determined by the pilot laboratory. The best estimate of the pilot's mass value is the average of the two results before and after the circulation, because we don't know when the change between these two values has occured. This assumption can be made for all data, because there is no sign for a sudden change at some instant or a significant drift (see below, Fig.s 1 to 5). The mass difference between a participant A and the pilot laboratory P is then calculated as follows:

$$\Delta m_{\mathrm{A,P}} = m_{\mathrm{A}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} \qquad (1)$$

The data are shown in Fig.1 to Fig.5. The pilot's data are shown as well and have been calculated similarly, for example:

$$\Delta m_{\mathrm{P1,P}} = m_{\mathrm{P1}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} \qquad (2)$$

The uncertainties given in the mentioned figures are those given by the laboratories, see Table 1. The figures show also a line representing the value of the median.

5. Reference value and assigned uncertainties

The concepts of mean and weighted mean are based on statistical assumptions such as randomness and same population; they would require a positive *t*-test result. In comparisons with different laboratories, the results often do not agree with such requirements. Even though most results of the present comparison are in agreement with the requirements of a statistical treatment on the level of 95% confidence (k = 2), the median will here be chosen as reference value, because its sensitivity to "outliers" is much smaller than that of the mean or the weighted mean. The median, also, does not exclude data as do other procedures, which reject data in order to calculate a mean only from data showing a positive *t*-test.

The mass difference between participant A and the reference value is calculated from:

$$\Delta m_{\mathrm{A,ref}} = m_{\mathrm{A}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} - \left(m_{\mathrm{ref}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} \right) \qquad (3)$$

Or, if we define the reference value as its deviation from the pilot's value, m_{ref}* :

$$\Delta m_{\mathrm{A,ref}} = m_{\mathrm{A}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} - m_{\mathrm{ref}}^{*} \qquad (4)$$

The uncertainties have been evaluated according to an international guide [4]. If we consider a participant's result with respect to a reference value, we have to take into account, that its value is uncertain also due to the instability of the travelling standard, to the uncertainty $u_c(\Delta m_P)$ of the pilot's observation of this instability and to the uncertainty of the reference value. The assumption of a rectangular distribution within the limits of m_{P2} and m_{P1} for the instability of the transfer standards (with an expectation value of zero) is a reasonable approach. We assign therefore to the above mass difference the uncertainty

$$u_a(m_A) = \sqrt{u_c^2(m_A) + u_c^2(\Delta m_P) + \frac{(m_{P2} - m_{P1})^2}{12} + u^2(m_{ref}^*)} \quad (5)$$

The uncertainty of the median, taken as the reference value, $u_{ref}*$, is calculated according to [5].

The differences m_{P2}- m_{P1} are given in Table 2. The uncertainties $u_c(\Delta m_P)$ are shown in Table 4.

A particularity of an intercomparison is that the pilot laboratory's measurement result is not affected by an instability due to travelling and has therefore no uncertainty contribution for it. The average of the two pilot's measurements before and after circulation is considered as a preliminary reference value – also for the pilot laboratory. The uncertainty of the pilot's result – with the assumption of perfect correlation - is therefore:

$$u_a(m_P) = \sqrt{\frac{u_c^2(m_{P1})}{4} + \frac{u_c^2(m_{P2})}{4} + \frac{u_c(m_{P1})u_c(m_{P2})}{2} + u^2(m_{ref}^*)} \quad (6)$$

Table 4. Uncertainties of the mass differences of the travelling standards observed at the pilot laboratory before and after the circulation.

m_0	$u_c(\Delta m_P)$/µg
10 kg	28,3
500 g	1,85
20 g	2,26
2 g	0,61
100 mg	0,30

The results and assigned uncertainties of all participants, including the pilot laboratory, relative to the reference values are shown in Figures 6 to 10; the data are given in Table 11 (Appendix 1).

6. Mass differences and uncertainties among participants

Considering the mass differences among participants - including the pilot laboratory - the reference value will not be accounted. Possible correlations between the reference standards of the laboratories are not expected. It is known that all laboratories dispose of a platinum-iridium prototype of the kilogram and that it took part in the 3rd verification at BIPM 1988-1992 or that it has recently been calibrated at BIPM. Most reports refer to the prototype in the traceability chart or mention the traceability to the international prototype. Tables 5 to 9 give the mass differences and uncertainties for all participants and the five mass standards. We have to distinguish between three cases, as follows.

6.1 Participant A and pilot laboratory P

The mass difference is calculated as given in (1):

$$\Delta m_{\mathrm{A,P}} = m_{\mathrm{A}} - \frac{m_{\mathrm{P1}} + m_{\mathrm{P2}}}{2} \quad (1)$$

The measurements are considered as uncorrelated. The uncertainty of their difference is:

$$u_{\mathrm{a}}\left(\Delta m_{\mathrm{A,P}}\right) = \sqrt{u_{\mathrm{c}}^2\left(m_{\mathrm{A}}\right) + u_{\mathrm{c}}^2\left(m_{\mathrm{P}}\right) + \frac{\left(m_{\mathrm{P2}} - m_{\mathrm{P1}}\right)^2}{12}} \quad (7)$$

6.2 Participants A and B of different loops

The mass difference between A and B of two different loops is calculated by using the pilot's measurements as a link. Because the pilot's reference value is considered to be constant and the average of the initial and final measurements of the travelling standards in a loop are considered as their best estimate, the mass difference between A and B can be considered as to be independent of the measurements of the pilot laboratory.

$$\Delta m_{\mathrm{A,B}} = m_{\mathrm{A}} - m_{\mathrm{B}} \quad (8)$$

The measurements are considered as uncorrelated. The uncertainty of their difference, however, comprises contributions of the drift uncertainties in each loop and contributions of the observations of these drifts by the pilot laboratory (index 1 and 2 for loop comprising A, index 3 and 4 for loop comprising B). It is clear, that -as a worst case - the drift in each of the two loops may add up in the mass difference between A and B and that the uncertainty contributions of the two drifts have to be included in the combined uncertainty.

$$u_{\mathrm{a}}\left(\Delta m_{\mathrm{A,B}}\right) = \sqrt{u_{\mathrm{c}}^2\left(m_{\mathrm{A}}\right) + u_{\mathrm{c}}^2\left(\Delta m_{\mathrm{B}}\right) + 2u_{\mathrm{c}}^2\left(\Delta m_{\mathrm{P}}\right) + \frac{\left(m_{\mathrm{P2}} - m_{\mathrm{P1}}\right)^2}{12} + \frac{\left(m_{\mathrm{P4}} - m_{\mathrm{P3}}\right)^2}{12}} \quad (9)$$

6.3 Participants A and B of the same loop

The mass difference is independent of the measurements of the pilot laboratory.

$$\Delta m_{\mathrm{A,B}} = m_{\mathrm{A}} - m_{\mathrm{B}} \quad (8)$$

Again, the measurements of laboratory A and B are uncorrelated. The drift appears from the two measurements at the pilot laboratory at the beginning and at the end of the loop. Here, we have only one drift contribution to be considered for the mass difference between A and B.

$$u_a\left(\Delta m_{A,B}\right)=\sqrt{u_c^2\left(m_A\right)+u_c^2\left(\Delta m_B\right)+u_c^2\left(\Delta m_P\right)+\frac{\left(m_{P2}-m_{P1}\right)^2}{12}} \qquad (10)$$

7. Coverage factor and effective degrees of freedom

It was agreed, that the uncertainties, to be cited with the degree of equivalence, shall be given as the combined uncertainty multiplied by a coverage factor of 2. It was understood, that such expanded uncertainties refer to results with a level of confidence of about 95%, see also [2]. This assumption, however, is only valid, if the combined uncertainty refers to a nearly infinite degree of freedom, which may be attained, if it is larger than 10.

The participants gave in their reports either the number of repeated measurements or the effective degrees of freedom. For the results, the number of one-to-one comparisons were given, the effective degrees of freedom have been estimated using the Welch-Satterthwaite formula, equ. (G.2b) in [4]. It was assumed that the degrees of freedom for uncertainty contributions other than type A are infinite. For the results, which were obtained by the method of subdivision (or multiplication), the effective degrees of freedom are large, this means by far larger than 10. For the other results they have been found also to be much larger than 10.

The assigned uncertainties, eq.s (5), (7), (9) and (10) have contributions of rectangular distributions, with limits of $\pm\sqrt{3}\ u$. A coverage factor of 2 certainly overestimates the distribution within which values of the determined mass could be expected. The uncertainties concerned are those, where the drift contribution to the combined uncertainty is non-negligible or dominant, that are some of the 2 g and 100 mg results. A way to come over this problem is to apply a coverage factor to these contributions, that covers 95% of the rectangular distribution, as for example for (5):

$$U_a\left(m_A\right)=2\sqrt{u_c^2\left(m_A\right)+u_c^2\left(\Delta m_P\right)+u_c^2\left(m_{ref}^*\right)+\left(\frac{0,95}{2}\right)^2\left(\frac{m_{P2}-m_{P1}}{2}\right)^2} \qquad (11)$$

This procedure is not described in [4]. If however it is agreed, that the expanded uncertainty shall refer to a level of confidence of 95% and if we assume a normal distribution for all uncertainty contributions except the rectangular ones, eq.(11) shows a possible solution and it is applied here in all cases, where the drift contribution to the uncertainty is non-negligible.

8. References

[1] Comité consultatif pour la masse et les grandeurs apparentées, Report of the 6th meeting 1996, BIPM, Sèvres, 1996, G38

[2] Mutual recognition of national measurement standards and of calibration and measurement certificates issued by national metrology institutes, BIPM, Paris, 14 October 1999

[3] Weights of classes E_1, E_2, F_1, F_2, M_1, M_2, M_3, International recommendation OIML R 111, OIML, Paris 1994

[4] Guide to the Expression of Uncertainty in Measurement, International Organization for Standardization, Geneva, Switzerland, 1993

[5] Müller J.W., Possible advantages of a robust evaluation of comparisons, Rapport BIPM-95/2, BIPM, Sèvres 1995

Table 5. Average differences Δm (top) in assigned values between laboratory A (left column) and laboratory B (top row) and expanded uncertainties with a level of confidence of 95 % (bottom) for 10 kg.

Δm/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,07	0,17	-0,20	-0,43	0,15	-1,37	-1,85	-0,10	0,38	-1,65	-0,05	0,28	0,24
CSIRO	-0,07		0,10	-0,27	-0,50	0,08	-1,44	-1,92	-0,17	0,31	-1,72	-0,13	0,21	0,17
KRISS	-0,17	-0,10		-0,37	-0,60	-0,02	-1,54	-2,02	-0,27	0,21	-1,82	-0,22	0,11	0,07
NMIJ/AIST	0,20	0,27	0,37		-0,23	0,35	-1,17	-1,65	0,10	0,58	-1,45	0,15	0,48	0,44
NIM	0,43	0,50	0,60	0,23		0,58	-0,94	-1,42	0,33	0,81	-1,22	0,38	0,71	0,67
NPL	-0,15	-0,08	0,02	-0,35	-0,58		-1,52	-2,00	-0,25	0,23	-1,80	-0,20	0,13	0,09
CENAM	1,37	1,44	1,54	1,17	0,94	1,52		-0,48	1,27	1,75	-0,28	1,32	1,65	1,61
NRC	1,85	1,92	2,02	1,65	1,42	2,00	0,48		1,75	2,23	0,20	1,80	2,13	2,09
NIST	0,10	0,17	0,27	-0,10	-0,33	0,25	-1,27	-1,75		0,48	-1,55	0,05	0,38	0,34
VSL	-0,38	-0,31	-0,21	-0,58	-0,81	-0,23	-1,75	-2,23	-0,48		-2,03	-0,44	-0,10	-0,14
SMU	1,65	1,72	1,82	1,45	1,22	1,80	0,28	-0,20	1,55	2,03		1,60	1,93	1,89
METAS	0,05	0,13	0,22	-0,15	-0,38	0,20	-1,32	-1,80	-0,05	0,44	-1,60		0,34	0,30
BNM/LNE	-0,28	-0,21	-0,11	-0,48	-0,71	-0,13	-1,65	-2,13	-0,38	0,10	-1,93	-0,34		-0,04
IMGC	-0,24	-0,17	-0,07	-0,44	-0,67	-0,09	-1,61	-2,09	-0,34	0,14	-1,89	-0,30	0,04	

U/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,72	0,38	0,61	1,03	0,39	1,54	1,96	0,46	2,21	1,74	0,56	0,65	0,52
CSIRO	0,72		0,74	0,88	1,21	0,75	1,67	2,06	0,79	2,30	1,85	0,85	0,91	0,82
KRISS	0,38	0,74		0,64	1,04	0,43	1,55	1,96	0,50	2,22	1,75	0,59	0,67	0,55
NMIJ/AIST	0,61	0,88	0,64		1,15	0,64	1,62	2,02	0,69	2,27	1,81	0,76	0,83	0,73
NIM	1,03	1,21	1,04	1,15		1,05	1,82	2,18	1,08	2,42	1,99	1,12	1,17	1,10
NPL	0,39	0,75	0,43	0,64	1,05		1,55	1,96	0,50	2,22	1,75	0,59	0,68	0,55
CENAM	1,54	1,67	1,55	1,62	1,82	1,55		2,47	1,57	2,68	2,30	1,60	1,64	1,59
NRC	1,96	2,06	1,96	2,02	2,18	1,96	2,47		1,98	2,93	2,59	2,01	2,03	2,00
NIST	0,46	0,79	0,50	0,69	1,08	0,50	1,57	1,98		2,24	1,77	0,65	0,72	0,61
VSL	2,21	2,30	2,22	2,27	2,42	2,22	2,68	2,93	2,24		2,79	2,26	2,28	2,25
SMU	1,74	1,85	1,75	1,81	1,99	1,75	2,30	2,59	1,77	2,79		1,79	1,82	1,78
METAS	0,56	0,85	0,59	0,76	1,12	0,59	1,60	2,01	0,65	2,26	1,79		0,78	0,68
BNM/LNE	0,65	0,91	0,67	0,83	1,17	0,68	1,64	2,03	0,72	2,28	1,82	0,78		0,76
IMGC	0,52	0,82	0,55	0,73	1,10	0,55	1,59	2,00	0,61	2,25	1,78	0,68	0,76	

Table 6. Average differences Δm (top) in assigned values between laboratory A (left column) and laboratory B (top row) and expanded uncertainties with a level of confidence of 95 % (bottom) for 500 g.

Δm/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,005	-0,005	-0,028	-0,007	-0,004	-0,021	-0,007	-0,002	0,049	0,003	-0,010	0,003	-0,012
CSIRO	-0,005		-0,010	-0,033	-0,012	-0,009	-0,026	-0,012	-0,007	0,044	-0,002	-0,015	-0,002	-0,017
KRISS	0,005	0,010		-0,023	-0,002	0,001	-0,015	-0,001	0,003	0,054	0,008	-0,005	0,008	-0,007
NMIJ/AIST	0,028	0,033	0,023		0,021	0,024	0,008	0,022	0,026	0,077	0,031	0,018	0,031	0,016
NIM	0,007	0,012	0,002	-0,021		0,003	-0,014	0,000	0,005	0,056	0,010	-0,003	0,010	-0,005
NPL	0,004	0,009	-0,001	-0,024	-0,003		-0,017	-0,003	0,002	0,053	0,007	-0,006	0,007	-0,008
CENAM	0,021	0,026	0,015	-0,008	0,014	0,017		0,014	0,019	0,069	0,023	0,010	0,023	0,008
NRC	0,007	0,012	0,001	-0,022	0,000	0,003	-0,014		0,005	0,055	0,009	-0,004	0,009	-0,006
NIST	0,002	0,007	-0,003	-0,026	-0,005	-0,002	-0,019	-0,005		0,051	0,005	-0,008	0,005	-0,010
VSL	-0,049	-0,044	-0,054	-0,077	-0,056	-0,053	-0,069	-0,055	-0,051		-0,046	-0,059	-0,046	-0,061
SMU	-0,003	0,002	-0,008	-0,031	-0,010	-0,007	-0,023	-0,009	-0,005	0,046		-0,013	0,000	-0,015
METAS	0,010	0,015	0,005	-0,018	0,003	0,006	-0,010	0,004	0,008	0,059	0,013		0,013	-0,002
BNM/LNE	-0,003	0,002	-0,008	-0,031	-0,010	-0,007	-0,023	-0,009	-0,005	0,046	0,000	-0,013		-0,015
IMGC	0,012	0,017	0,007	-0,016	0,005	0,008	-0,008	0,006	0,010	0,061	0,015	0,002	0,015	

U/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,042	0,019	0,020	0,027	0,019	0,023	0,020	0,020	0,042	0,046	0,033	0,033	0,020
CSIRO	0,042		0,043	0,043	0,047	0,043	0,045	0,043	0,044	0,057	0,060	0,051	0,050	0,043
KRISS	0,019	0,043		0,022	0,028	0,022	0,025	0,022	0,023	0,043	0,047	0,034	0,034	0,022
NMIJ/AIST	0,020	0,043	0,022		0,029	0,023	0,025	0,023	0,024	0,044	0,047	0,035	0,035	0,023
NIM	0,027	0,047	0,028	0,029		0,029	0,031	0,029	0,030	0,047	0,051	0,039	0,039	0,029
NPL	0,019	0,043	0,022	0,023	0,029		0,024	0,022	0,022	0,043	0,047	0,034	0,034	0,022
CENAM	0,023	0,045	0,025	0,025	0,031	0,024		0,025	0,025	0,045	0,048	0,036	0,036	0,025
NRC	0,020	0,043	0,022	0,023	0,029	0,022	0,025		0,023	0,043	0,047	0,034	0,034	0,023
NIST	0,020	0,044	0,023	0,024	0,030	0,022	0,025	0,023		0,044	0,047	0,035	0,035	0,023
VSL	0,042	0,057	0,043	0,044	0,047	0,043	0,045	0,043	0,044		0,060	0,050	0,050	0,043
SMU	0,046	0,060	0,047	0,047	0,051	0,047	0,048	0,047	0,047	0,060		0,054	0,053	0,047
METAS	0,033	0,051	0,034	0,035	0,039	0,034	0,036	0,034	0,035	0,050	0,054		0,043	0,034
BNM/LNE	0,033	0,050	0,034	0,035	0,039	0,034	0,036	0,034	0,035	0,050	0,053	0,043		0,034
IMGC	0,020	0,043	0,022	0,023	0,029	0,022	0,025	0,023	0,023	0,043	0,047	0,034	0,034	

Table 7. Average differences Δm (top) in assigned values between laboratory A (left column) and laboratory B (top row) and expanded uncertainties with a level of confidence of 95 % (bottom) for 20 g.

Δm/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0011	-0,0014	-0,0003	-0,0028	-0,0034	-0,0026	-0,0027	-0,0031	-0,0044	0,0095	-0,0088	-0,0061	0,0015
CSIRO	-0,0011		-0,0024	-0,0013	-0,0038	-0,0045	-0,0037	-0,0038	-0,0042	-0,0055	0,0085	-0,0099	-0,0072	0,0005
KRISS	0,0014	0,0024		0,0011	-0,0014	-0,0021	-0,0012	-0,0013	-0,0017	-0,0030	0,0109	-0,0074	-0,0047	0,0029
NMIJ/AIST	0,0003	0,0013	-0,0011		-0,0025	-0,0032	-0,0024	-0,0025	-0,0029	-0,0042	0,0098	-0,0086	-0,0059	0,0018
NIM	0,0028	0,0038	0,0014	0,0025		-0,0007	0,0002	0,0001	-0,0004	-0,0017	0,0123	-0,0061	-0,0034	0,0043
NPL	0,0034	0,0045	0,0021	0,0032	0,0007		0,0008	0,0007	0,0003	-0,0010	0,0129	-0,0054	-0,0027	0,0049
CENAM	0,0026	0,0037	0,0012	0,0024	-0,0002	-0,0008		-0,0001	-0,0005	-0,0018	0,0121	-0,0062	-0,0035	0,0041
NRC	0,0027	0,0038	0,0013	0,0025	-0,0001	-0,0007	0,0001		-0,0004	-0,0017	0,0122	-0,0061	-0,0034	0,0042
NIST	0,0031	0,0042	0,0017	0,0029	0,0004	-0,0003	0,0005	0,0004		-0,0013	0,0126	-0,0057	-0,0030	0,0046
VSL	0,0044	0,0055	0,0030	0,0042	0,0017	0,0010	0,0018	0,0017	0,0013		0,0139	-0,0044	-0,0017	0,0059
SMU	-0,0095	-0,0085	-0,0109	-0,0098	-0,0123	-0,0129	-0,0121	-0,0122	-0,0126	-0,0139		-0,0183	-0,0156	-0,0080
METAS	0,0088	0,0099	0,0074	0,0086	0,0061	0,0054	0,0062	0,0061	0,0057	0,0044	0,0183		0,0027	0,0103
BNM/LNE	0,0061	0,0072	0,0047	0,0059	0,0034	0,0027	0,0035	0,0034	0,0030	0,0017	0,0156	-0,0027		0,0076
IMGC	-0,0015	-0,0005	-0,0029	-0,0018	-0,0043	-0,0049	-0,0041	-0,0042	-0,0046	-0,0059	0,0080	-0,0103	-0,0076	

U/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0076	0,0050	0,0062	0,0062	0,0050	0,0063	0,0088	0,0051	0,0092	0,0084	0,0070	0,0070	0,0089
CSIRO	0,0076		0,0078	0,0086	0,0086	0,0090	0,0098	0,0115	0,0091	0,0119	0,0113	0,0102	0,0102	0,0116
KRISS	0,0050	0,0078		0,0063	0,0063	0,0069	0,0079	0,0100	0,0070	0,0104	0,0097	0,0085	0,0085	0,0101
NMIJ/AIST	0,0062	0,0086	0,0063		0,0073	0,0078	0,0087	0,0106	0,0079	0,0110	0,0103	0,0092	0,0092	0,0107
NIM	0,0062	0,0086	0,0063	0,0073		0,0078	0,0087	0,0106	0,0079	0,0110	0,0103	0,0092	0,0092	0,0107
NPL	0,0050	0,0090	0,0069	0,0078	0,0078		0,0065	0,0089	0,0053	0,0104	0,0097	0,0085	0,0085	0,0101
CENAM	0,0063	0,0098	0,0079	0,0087	0,0087	0,0065		0,0097	0,0065	0,0111	0,0104	0,0093	0,0093	0,0108
NRC	0,0088	0,0115	0,0100	0,0106	0,0106	0,0089	0,0097		0,0089	0,0127	0,0120	0,0111	0,0111	0,0124
NIST	0,0051	0,0091	0,0070	0,0079	0,0079	0,0053	0,0065	0,0089		0,0105	0,0097	0,0085	0,0085	0,0102
VSL	0,0092	0,0119	0,0104	0,0110	0,0110	0,0104	0,0111	0,0127	0,0105		0,0116	0,0106	0,0106	0,0119
SMU	0,0084	0,0113	0,0097	0,0103	0,0103	0,0097	0,0104	0,0120	0,0097	0,0116		0,0098	0,0098	0,0113
METAS	0,0070	0,0102	0,0085	0,0092	0,0092	0,0085	0,0093	0,0111	0,0085	0,0106	0,0098		0,0086	0,0103
BNM/LNE	0,0070	0,0102	0,0085	0,0092	0,0092	0,0085	0,0093	0,0111	0,0085	0,0106	0,0098	0,0086		0,0103
IMGC	0,0089	0,0116	0,0101	0,0107	0,0107	0,0101	0,0108	0,0124	0,0102	0,0119	0,0113	0,0103	0,0103	

Table 8. Average differences Δ*m* (top) in assigned values between laboratory A (left column) and laboratory B (top row) and expanded uncertainties with a level of confidence of 95 % (bottom) for 2 g.

Δ*m*/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0004	-0,0014	-0,0014	-0,0002	-0,0008	-0,0007	-0,0035	-0,0013	0,0018	-0,0007	-0,0018	-0,0016	0,0016
CSIRO	-0,0004		-0,0018	-0,0018	-0,0006	-0,0012	-0,0011	-0,0039	-0,0017	0,0014	-0,0011	-0,0022	-0,0020	0,0012
KRISS	0,0014	0,0018		0,0000	0,0012	0,0006	0,0007	-0,0021	0,0000	0,0031	0,0007	-0,0004	-0,0002	0,0029
NMIJ/AIST	0,0014	0,0018	0,0000		0,0012	0,0007	0,0008	-0,0021	0,0001	0,0032	0,0008	-0,0004	-0,0002	0,0030
NIM	0,0002	0,0006	-0,0012	-0,0012		-0,0006	-0,0005	-0,0033	-0,0011	0,0020	-0,0005	-0,0016	-0,0014	0,0018
NPL	0,0008	0,0012	-0,0006	-0,0007	0,0006		0,0001	-0,0027	-0,0006	0,0025	0,0001	-0,0010	-0,0008	0,0023
CENAM	0,0007	0,0011	-0,0007	-0,0008	0,0005	-0,0001		-0,0028	-0,0007	0,0024	0,0000	-0,0011	-0,0009	0,0022
NRC	0,0035	0,0039	0,0021	0,0021	0,0033	0,0027	0,0028		0,0021	0,0052	0,0028	0,0017	0,0019	0,0050
NIST	0,0013	0,0017	0,0000	-0,0001	0,0011	0,0006	0,0007	-0,0021		0,0031	0,0007	-0,0004	-0,0002	0,0029
VSL	-0,0018	-0,0014	-0,0031	-0,0032	-0,0020	-0,0025	-0,0024	-0,0052	-0,0031		-0,0024	-0,0035	-0,0033	-0,0002
SMU	0,0007	0,0011	-0,0007	-0,0008	0,0005	-0,0001	0,0000	-0,0028	-0,0007	0,0024		-0,0011	-0,0009	0,0022
METAS	0,0018	0,0022	0,0004	0,0004	0,0016	0,0010	0,0011	-0,0017	0,0004	0,0035	0,0011		0,0002	0,0033
BNM/LNE	0,0016	0,0020	0,0002	0,0002	0,0014	0,0008	0,0009	-0,0019	0,0002	0,0033	0,0009	-0,0002		0,0031
IMGC	-0,0016	-0,0012	-0,0029	-0,0030	-0,0018	-0,0023	-0,0022	-0,0050	-0,0029	0,0002	-0,0022	-0,0033	-0,0031	

U/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0020	0,0018	0,0019	0,0020	0,0015	0,0019	0,0033	0,0016	0,0062	0,0043	0,0024	0,0025	0,0039
CSIRO	0,0020		0,0020	0,0021	0,0022	0,0023	0,0026	0,0038	0,0024	0,0064	0,0046	0,0030	0,0030	0,0043
KRISS	0,0018	0,0020		0,0019	0,0020	0,0021	0,0024	0,0036	0,0022	0,0063	0,0045	0,0028	0,0029	0,0041
NMIJ/AIST	0,0019	0,0021	0,0019		0,0021	0,0022	0,0025	0,0037	0,0023	0,0064	0,0046	0,0029	0,0030	0,0042
NIM	0,0020	0,0022	0,0020	0,0021		0,0023	0,0025	0,0037	0,0024	0,0064	0,0046	0,0030	0,0030	0,0043
NPL	0,0015	0,0023	0,0021	0,0022	0,0023		0,0018	0,0033	0,0015	0,0063	0,0044	0,0027	0,0027	0,0041
CENAM	0,0019	0,0026	0,0024	0,0025	0,0025	0,0018		0,0035	0,0019	0,0064	0,0045	0,0029	0,0029	0,0042
NRC	0,0033	0,0038	0,0036	0,0037	0,0037	0,0033	0,0035		0,0033	0,0069	0,0053	0,0040	0,0040	0,0050
NIST	0,0016	0,0024	0,0022	0,0023	0,0024	0,0015	0,0019	0,0033		0,0063	0,0044	0,0027	0,0028	0,0041
VSL	0,0062	0,0064	0,0063	0,0064	0,0064	0,0063	0,0064	0,0069	0,0063		0,0073	0,0064	0,0065	0,0071
SMU	0,0043	0,0046	0,0045	0,0046	0,0046	0,0044	0,0045	0,0053	0,0044	0,0073		0,0046	0,0047	0,0055
METAS	0,0024	0,0030	0,0028	0,0029	0,0030	0,0027	0,0029	0,0040	0,0027	0,0064	0,0046		0,0031	0,0043
BNM/LNE	0,0025	0,0030	0,0029	0,0030	0,0030	0,0027	0,0029	0,0040	0,0028	0,0065	0,0047	0,0031		0,0043
IMGC	0,0039	0,0043	0,0041	0,0042	0,0043	0,0041	0,0042	0,0050	0,0041	0,0071	0,0055	0,0043	0,0043	

Table 9. Average differences Δm (top) in assigned values between laboratory A (left column) and laboratory B (top row) and expanded uncertainties with a level of confidence of 95 % (bottom) for 100 mg.

Δm/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0003	0,0009	0,0007	0,0005	0,0004	0,0011	0,0002	0,0006	-0,0007	-0,0009	0,0004	0,0008	0,0009
CSIRO	-0,0003		0,0006	0,0004	0,0002	0,0001	0,0008	-0,0002	0,0003	-0,0010	-0,0012	0,0001	0,0005	0,0006
KRISS	-0,0009	-0,0006		-0,0002	-0,0004	-0,0005	0,0002	-0,0007	-0,0002	-0,0015	-0,0017	-0,0005	0,0000	0,0000
NMIJ/AIST	-0,0007	-0,0004	0,0002		-0,0002	-0,0004	0,0004	-0,0006	-0,0001	-0,0014	-0,0016	-0,0004	0,0001	0,0002
NIM	-0,0005	-0,0002	0,0004	0,0002		-0,0002	0,0006	-0,0004	0,0001	-0,0012	-0,0014	-0,0002	0,0003	0,0004
NPL	-0,0004	-0,0001	0,0005	0,0004	0,0002		0,0007	-0,0002	0,0003	-0,0010	-0,0012	0,0000	0,0005	0,0005
CENAM	-0,0011	-0,0008	-0,0002	-0,0004	-0,0006	-0,0007		-0,0009	-0,0004	-0,0017	-0,0019	-0,0007	-0,0002	-0,0002
NRC	-0,0002	0,0002	0,0007	0,0006	0,0004	0,0002	0,0009		0,0005	-0,0008	-0,0010	0,0002	0,0007	0,0007
NIST	-0,0006	-0,0003	0,0002	0,0001	-0,0001	-0,0003	0,0004	-0,0005		-0,0013	-0,0015	-0,0003	0,0002	0,0002
VSL	0,0007	0,0010	0,0015	0,0014	0,0012	0,0010	0,0017	0,0008	0,0013		-0,0002	0,0010	0,0015	0,0015
SMU	0,0009	0,0012	0,0017	0,0016	0,0014	0,0012	0,0019	0,0010	0,0015	0,0002		0,0012	0,0017	0,0017
METAS	-0,0004	-0,0001	0,0005	0,0004	0,0002	0,0000	0,0007	-0,0002	0,0003	-0,0010	-0,0012		0,0005	0,0005
BNM/LNE	-0,0008	-0,0005	0,0000	-0,0001	-0,0003	-0,0005	0,0002	-0,0007	-0,0002	-0,0015	-0,0017	-0,0005		0,0000
IMGC	-0,0009	-0,0006	0,0000	-0,0002	-0,0004	-0,0005	0,0002	-0,0007	-0,0002	-0,0015	-0,0017	-0,0005	0,0000	

U/mg	PTB	CSIRO	KRISS	NMIJ/AIST	NIM	NPL	CENAM	NRC	NIST	VSL	SMU	METAS	BNM/LNE	IMGC
PTB		0,0009	0,0007	0,0008	0,0009	0,0010	0,0010	0,0009	0,0007	0,0018	0,0021	0,0009	0,0011	0,0017
CSIRO	0,0009		0,0009	0,0010	0,0011	0,0013	0,0013	0,0012	0,0011	0,0020	0,0023	0,0013	0,0014	0,0019
KRISS	0,0007	0,0009		0,0008	0,0009	0,0012	0,0012	0,0011	0,0009	0,0019	0,0022	0,0011	0,0013	0,0018
NMIJ/AIST	0,0008	0,0010	0,0008		0,0010	0,0012	0,0012	0,0011	0,0010	0,0019	0,0022	0,0011	0,0013	0,0018
NIM	0,0009	0,0011	0,0009	0,0010		0,0013	0,0013	0,0012	0,0011	0,0019	0,0023	0,0012	0,0014	0,0019
NPL	0,0010	0,0013	0,0012	0,0012	0,0013		0,0013	0,0012	0,0010	0,0020	0,0023	0,0013	0,0015	0,0019
CENAM	0,0010	0,0013	0,0012	0,0012	0,0013	0,0013		0,0012	0,0010	0,0020	0,0023	0,0013	0,0015	0,0019
NRC	0,0009	0,0012	0,0011	0,0011	0,0012	0,0012	0,0012		0,0009	0,0019	0,0023	0,0012	0,0014	0,0019
NIST	0,0007	0,0011	0,0009	0,0010	0,0011	0,0010	0,0010	0,0009		0,0018	0,0022	0,0011	0,0013	0,0018
VSL	0,0018	0,0020	0,0019	0,0019	0,0019	0,0020	0,0020	0,0019	0,0018		0,0027	0,0018	0,0020	0,0023
SMU	0,0021	0,0023	0,0022	0,0022	0,0023	0,0023	0,0023	0,0023	0,0022	0,0027		0,0022	0,0023	0,0026
METAS	0,0009	0,0013	0,0011	0,0011	0,0012	0,0013	0,0013	0,0012	0,0011	0,0018	0,0022		0,0012	0,0018
BNM/LNE	0,0011	0,0014	0,0013	0,0013	0,0014	0,0015	0,0015	0,0014	0,0013	0,0020	0,0023	0,0012		0,0019
IMGC	0,0017	0,0019	0,0018	0,0018	0,0019	0,0019	0,0019	0,0019	0,0018	0,0023	0,0026	0,0018	0,0019	

Figure captions

Fig. 1 Results of the three 10 kg standards CA, CB and CC. Shown are the differences between the participant's results and the average of the two PTB results, before and after the circulation of the standards – including these two PTB results. The uncertainties (k =1) are those given by the participants. The horizontal broken line represents the median.

Fig.2 Results of the 500 g standards as in Fig.1

Fig.3 Results of the 20 g standards as in Fig.1

Fig.4 Results of the 2 g standards as in Fig.1

Fig.5 Results of the 100 mg standards as in Fig.1

Fig.6 Results of the 10 kg standards as differences between the participant's results and the reference value, the median (average of the two values marked by large rhombs). The expanded uncertainties with a level of confidence of 95 % are composed of the combined uncertainties given by the participants, the contributions of the instability of the standards, the uncertainty of the instability observation by the pilot laboratory and the uncertainty of the reference standard.

Fig.7 Results of the 500 g standards as in Fig.6

Fig.8 Results of the 20 g standards as in Fig.6

Fig.9 Results of the 2 g standards as in Fig.6

Fig.10 Results of the 100 mg standards as in Fig.6

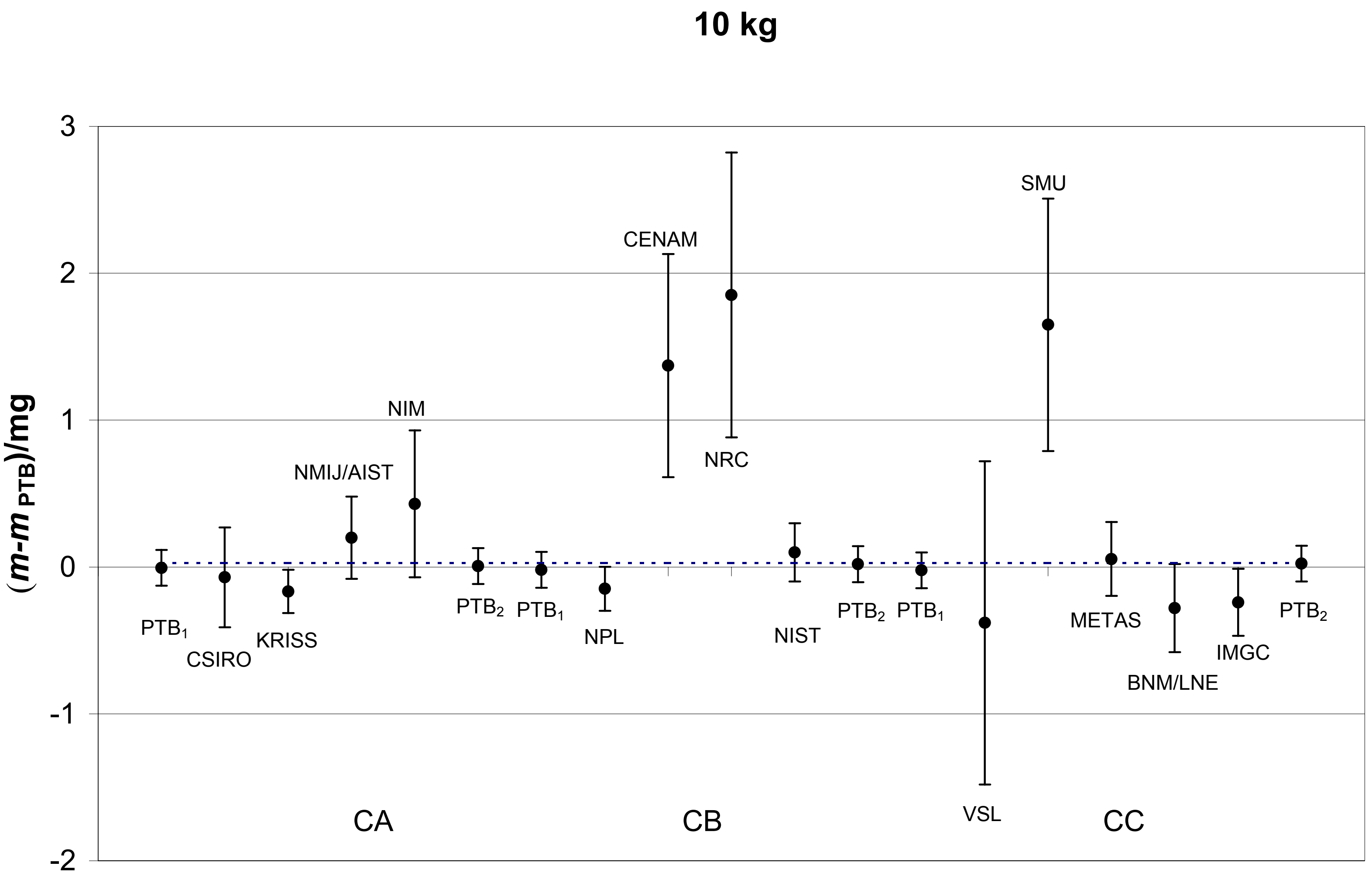
10 kg
(m-m PTB)/mg
3
2
1
0
-1
-2
CENAM
SMU
NIM
NMIJ/AIST
NRC
PTB1
CSIRO
KRISS
PTB2
PTB1
NPL
NIST
PTB2
PTB1
METAS
BNM/LNE
IMGC
PTB2
VSL
CA
CB
CC

Figure 1

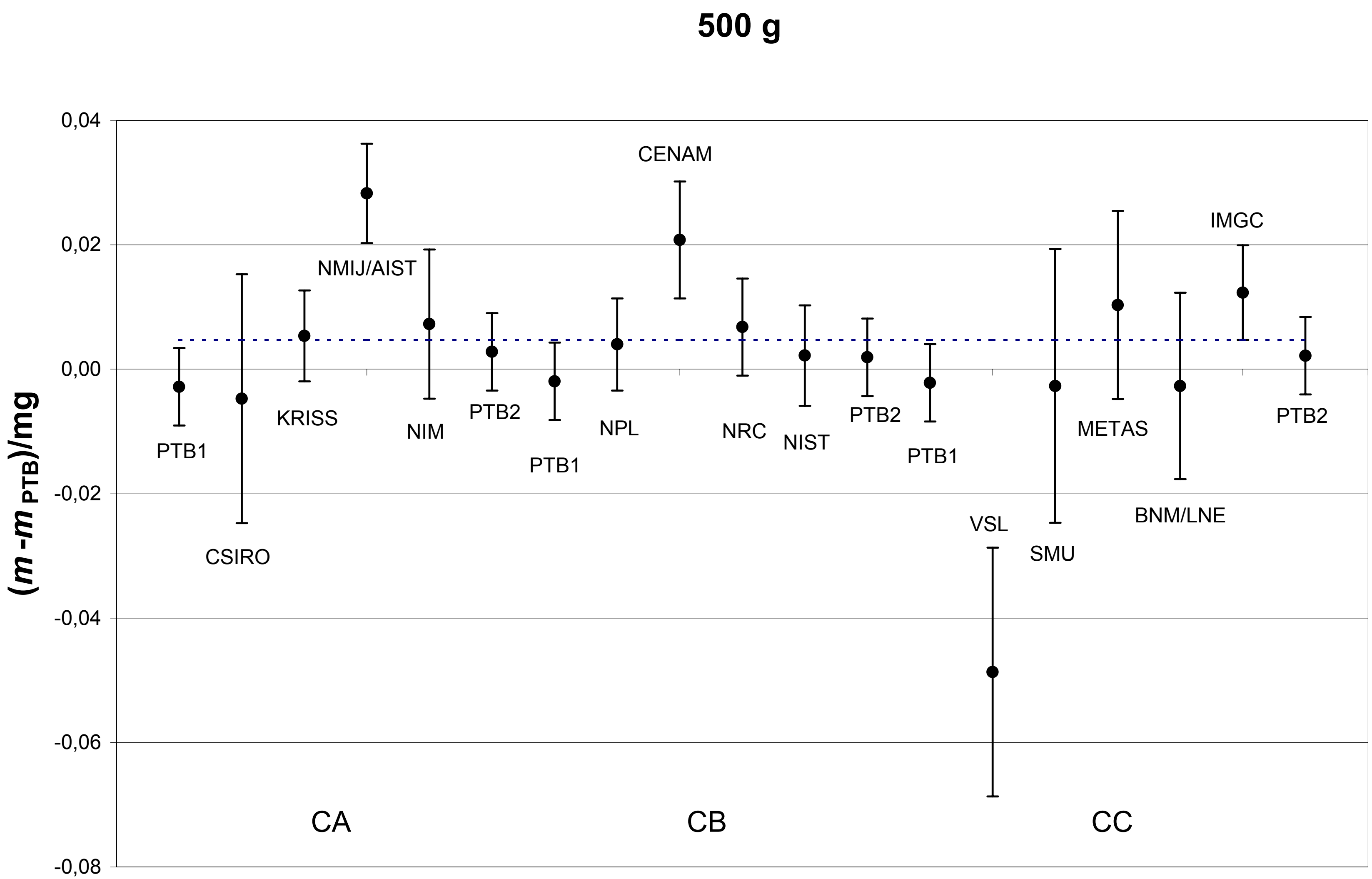
500 g
0,04
0,02
0,00
-0,02
-0,04
-0,06
-0,08
(m -m PTB)/mg
PTB1
CSIRO
KRISS
NMIJ/AIST
NIM
PTB2
PTB1
NPL
CENAM
NRC
NIST
PTB2
PTB1
VSL
SMU
METAS
BNM/LNE
IMGC
PTB2
CA
CB
CC

Figure 2

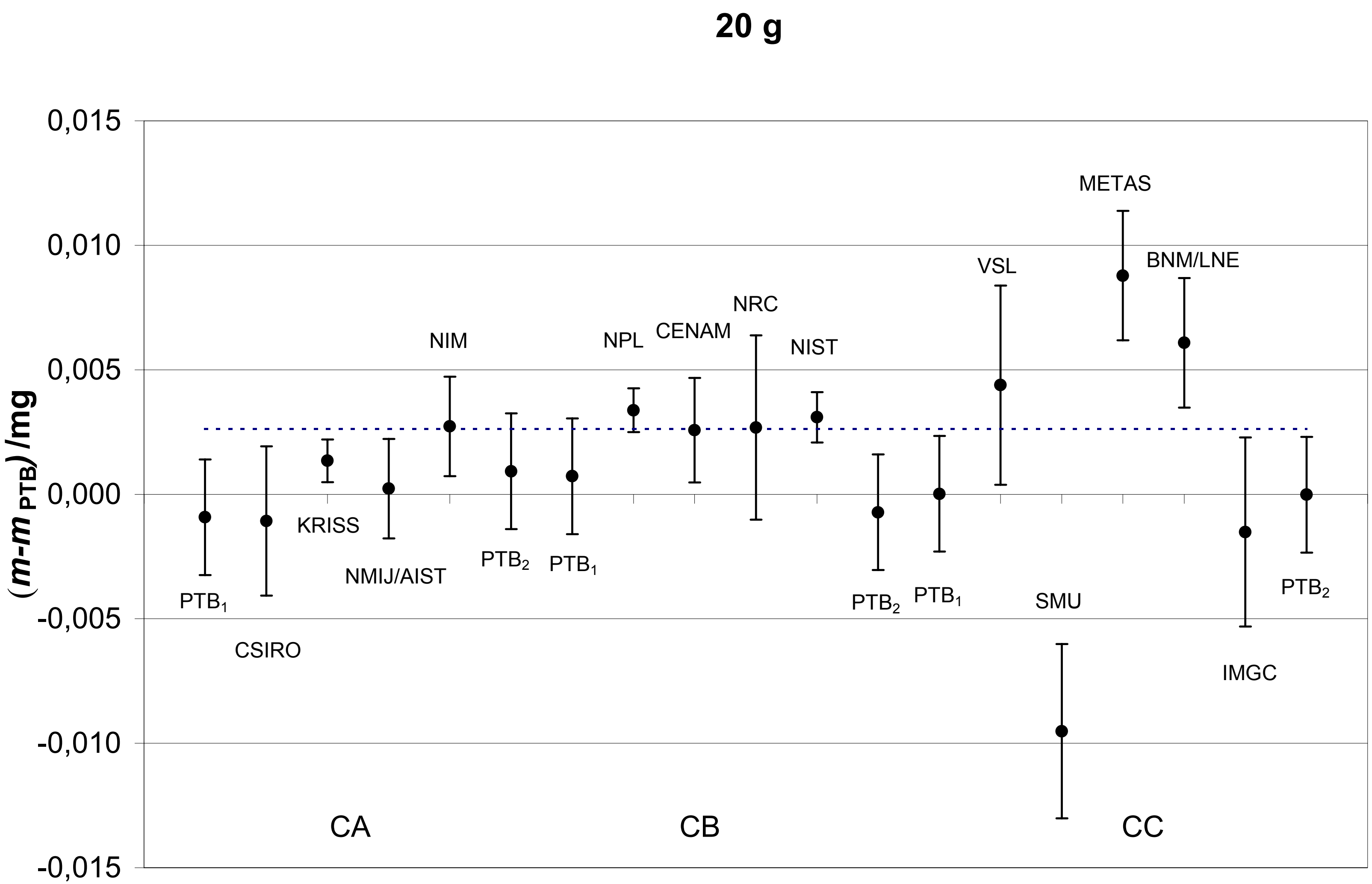
20 g
0,015
0,010
0,005
0,000
-0,005
-0,010
-0,015
(m-m PTB) /mg
PTB1
CSIRO
KRISS
NMIJ/AIST
NIM
PTB2
PTB1
NPL
CENAM
NRC
NIST
PTB2
PTB1
VSL
SMU
METAS
BNM/LNE
IMGC
PTB2
CA
CB
CC

Figure 3

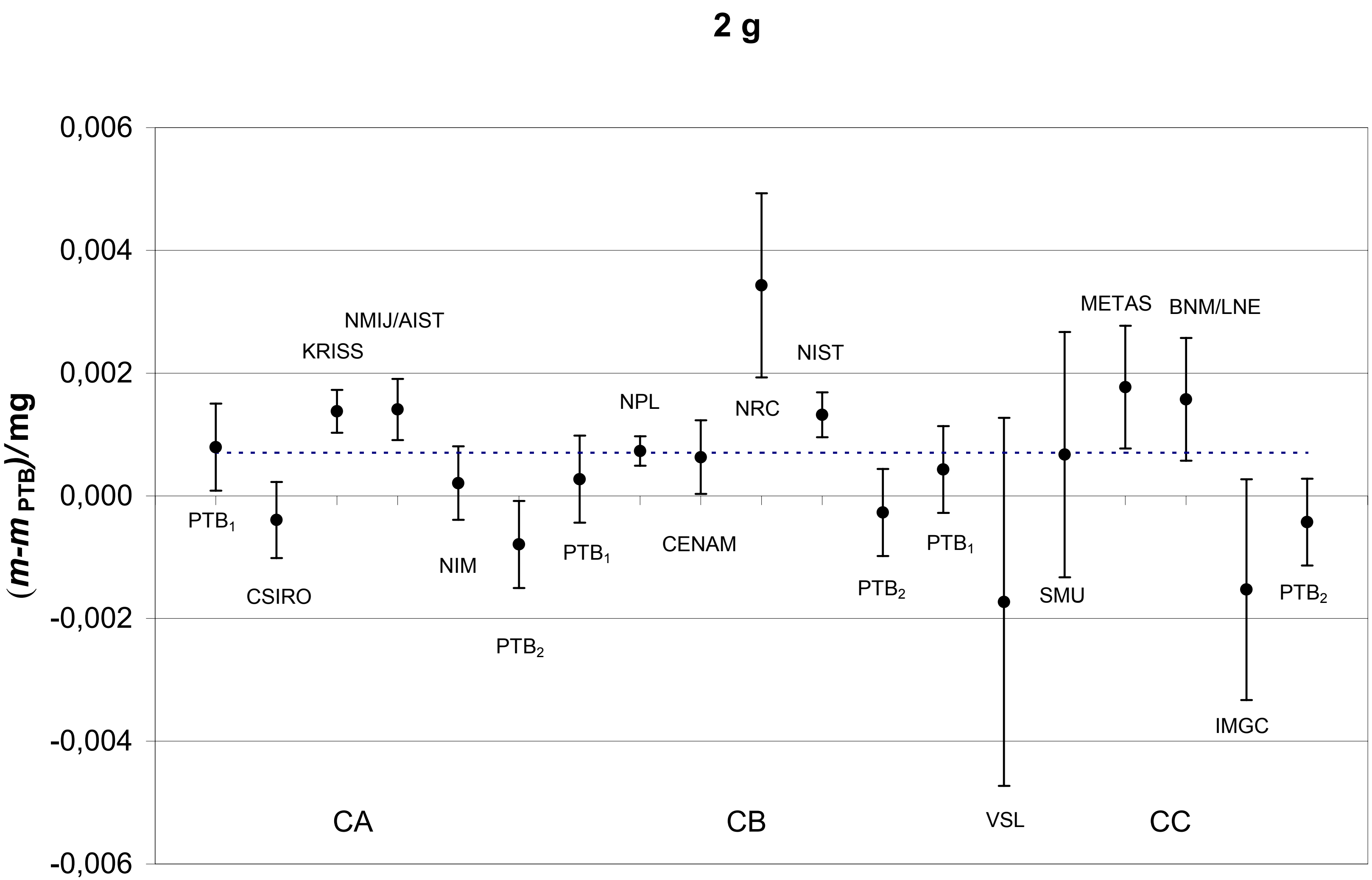
2 g
0,006
0,004
0,002
0,000
-0,002
-0,004
-0,006
(m-m PTB)/mg
NMIJ/AIST
KRISS
PTB1
CSIRO
NIM
PTB2
PTB1
NPL
CENAM
NRC
NIST
PTB2
PTB1
VSL
SMU
METAS
BNM/LNE
IMGC
PTB2
CA
CB
CC

Figure 4

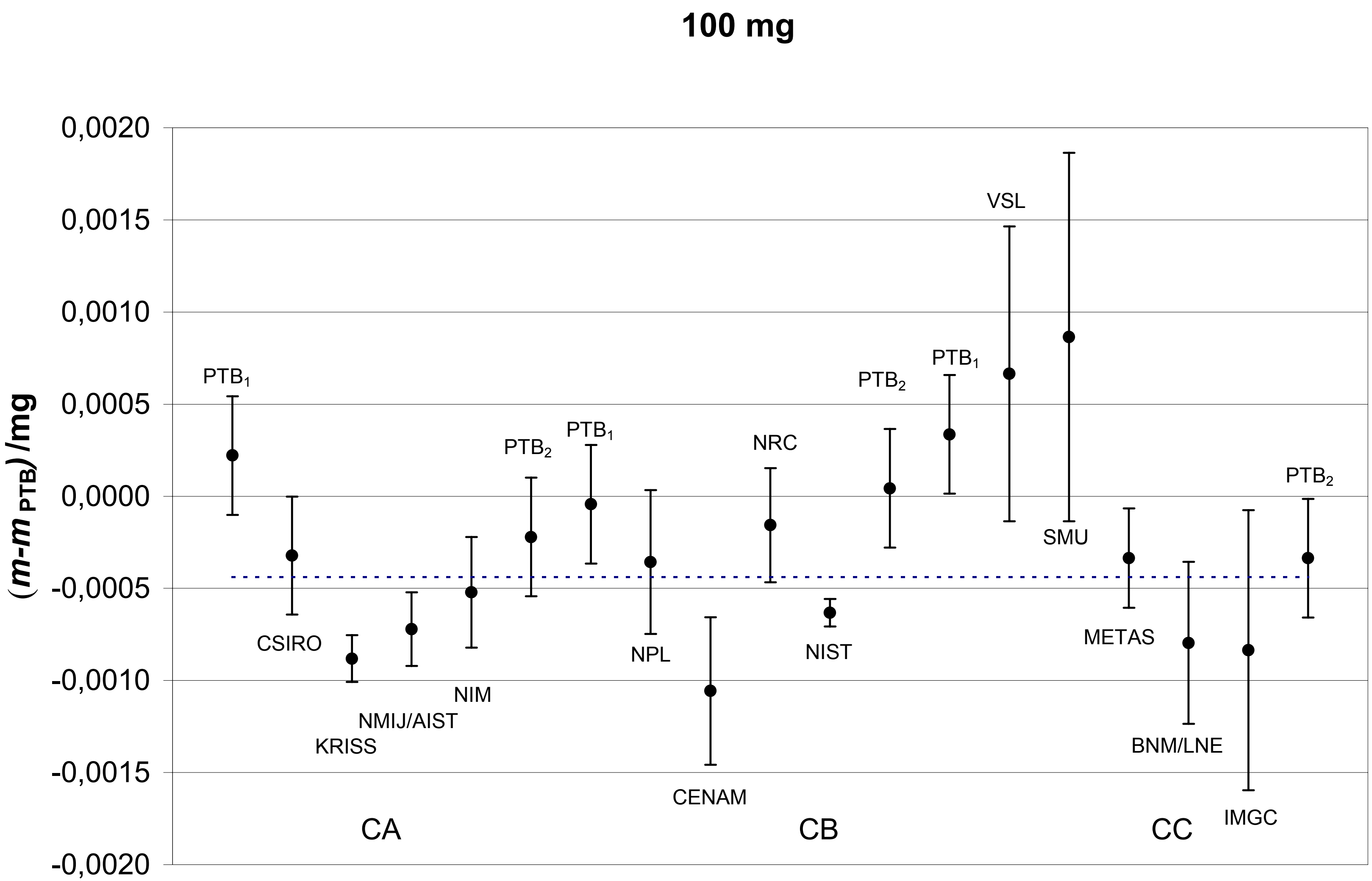
100 mg
0,0020
0,0015
0,0010
0,0005
0,0000
-0,0005
-0,0010
-0,0015
-0,0020
(m-m PTB) /mg
PTB1
CSIRO
KRISS
NMIJ/AIST
NIM
PTB2
PTB1
NPL
CENAM
NRC
NIST
PTB2
PTB1
VSL
SMU
METAS
BNM/LNE
IMGC
PTB2
CA
CB
CC

Figure 5

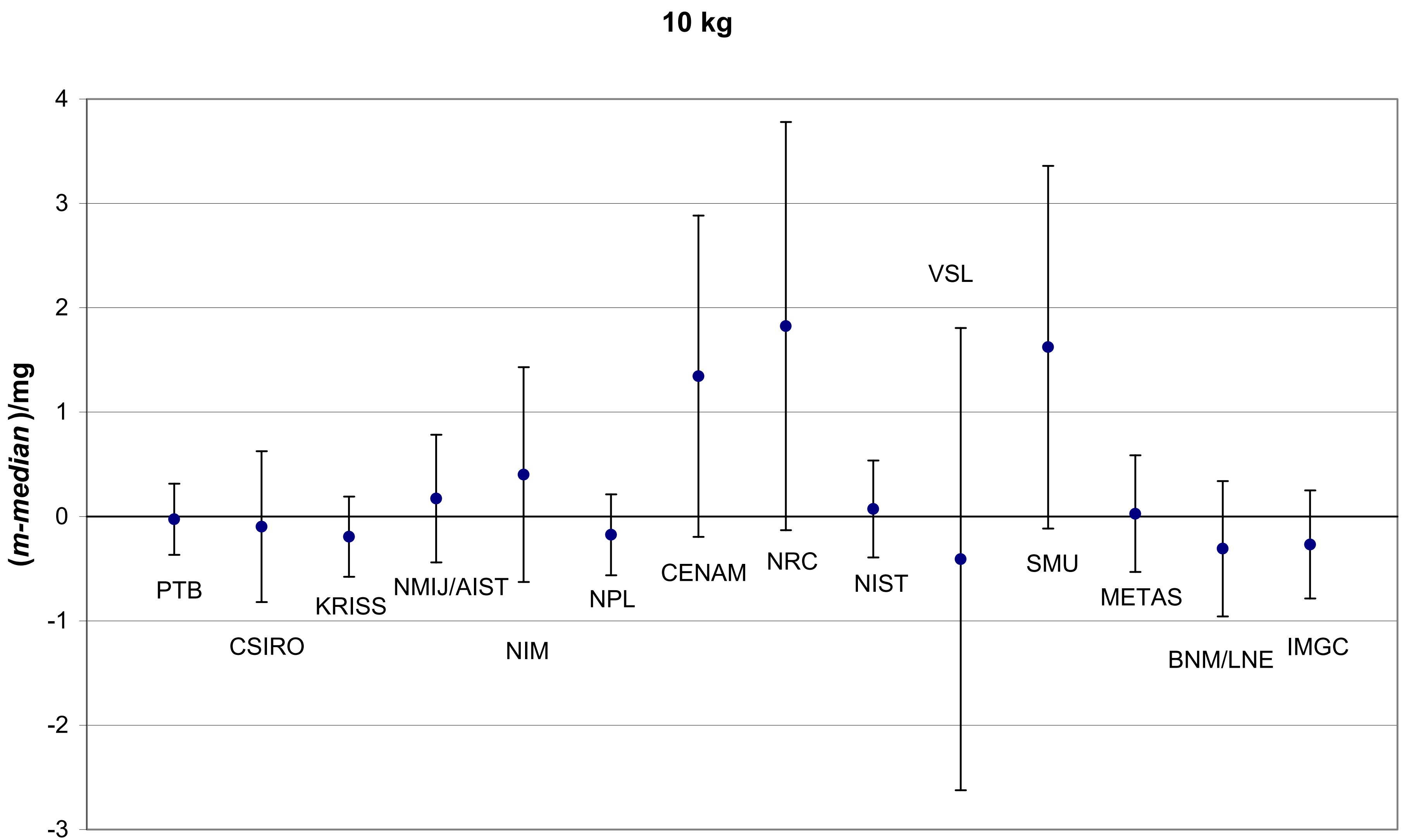
10 kg
4
3
2
1
0
-1
-2
-3
(m-median)/mg
PTB
CSIRO
KRISS
NMIJ/AIST
NIM
NPL
CENAM
NRC
NIST
VSL
SMU
METAS
BNM/LNE
IMGC

Figure 6

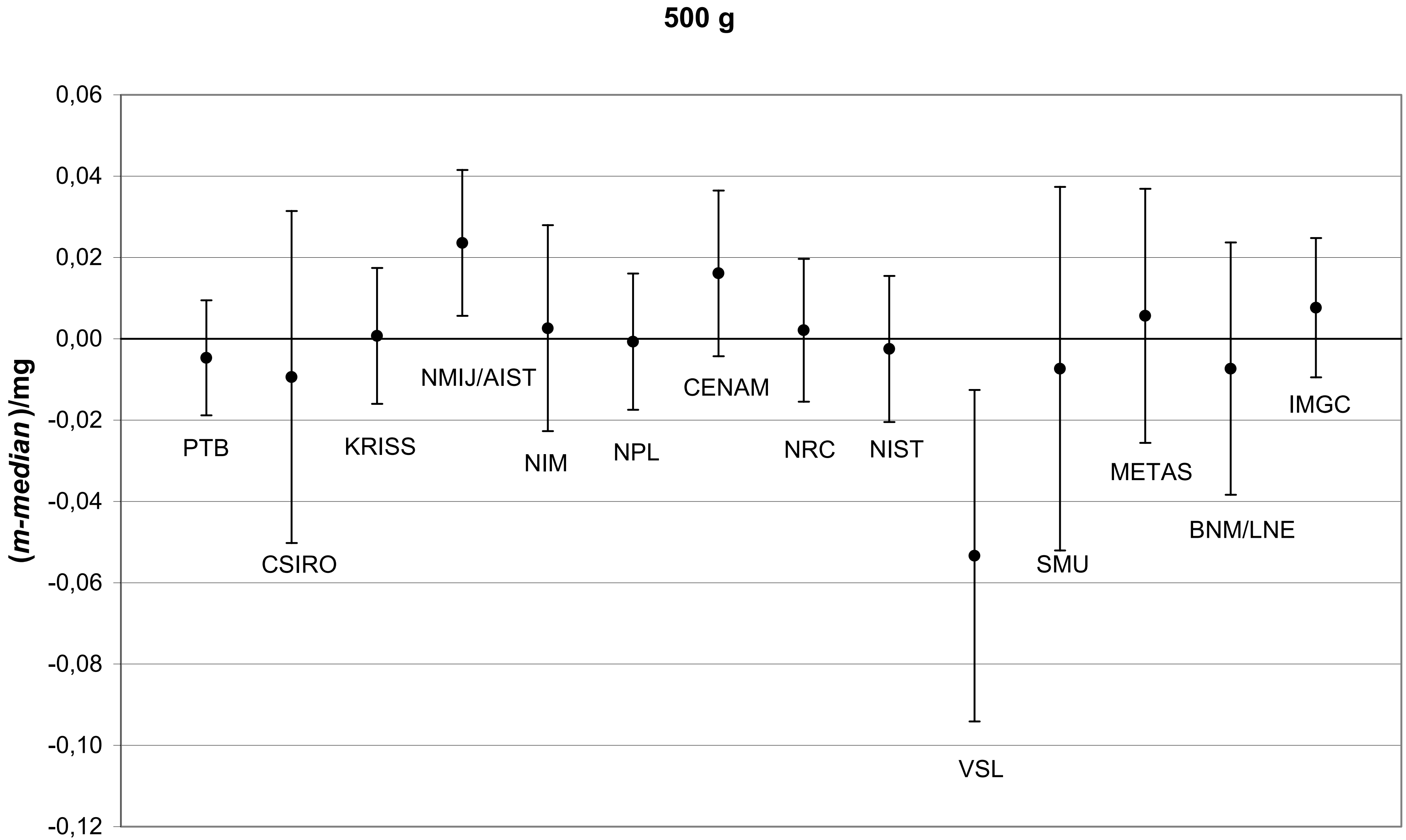
500 g
0,06
0,04
0,02
0,00
-0,02
-0,04
-0,06
-0,08
-0,10
-0,12
(m-median)/mg
PTB
CSIRO
KRISS
NMIJ/AIST
NIM
NPL
CENAM
NRC
NIST
VSL
SMU
METAS
BNM/LNE
IMGC

Figure 7

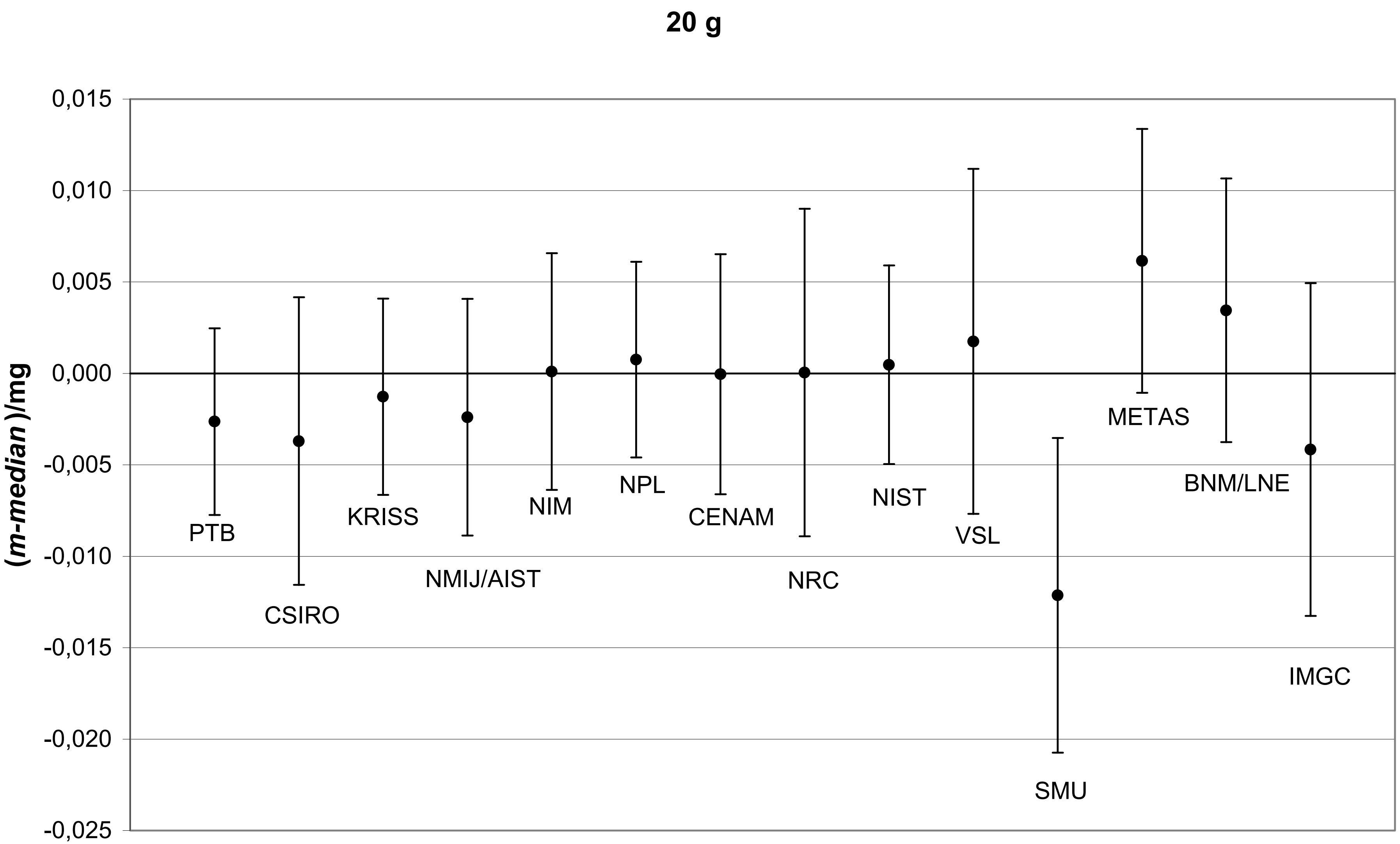
20 g
0,015
0,010
0,005
0,000
-0,005
-0,010
-0,015
-0,020
-0,025
(m-median)/mg
PTB
CSIRO
KRISS
NMIJ/AIST
NIM
NPL
CENAM
NRC
NIST
VSL
SMU
METAS
BNM/LNE
IMGC

Figure 8

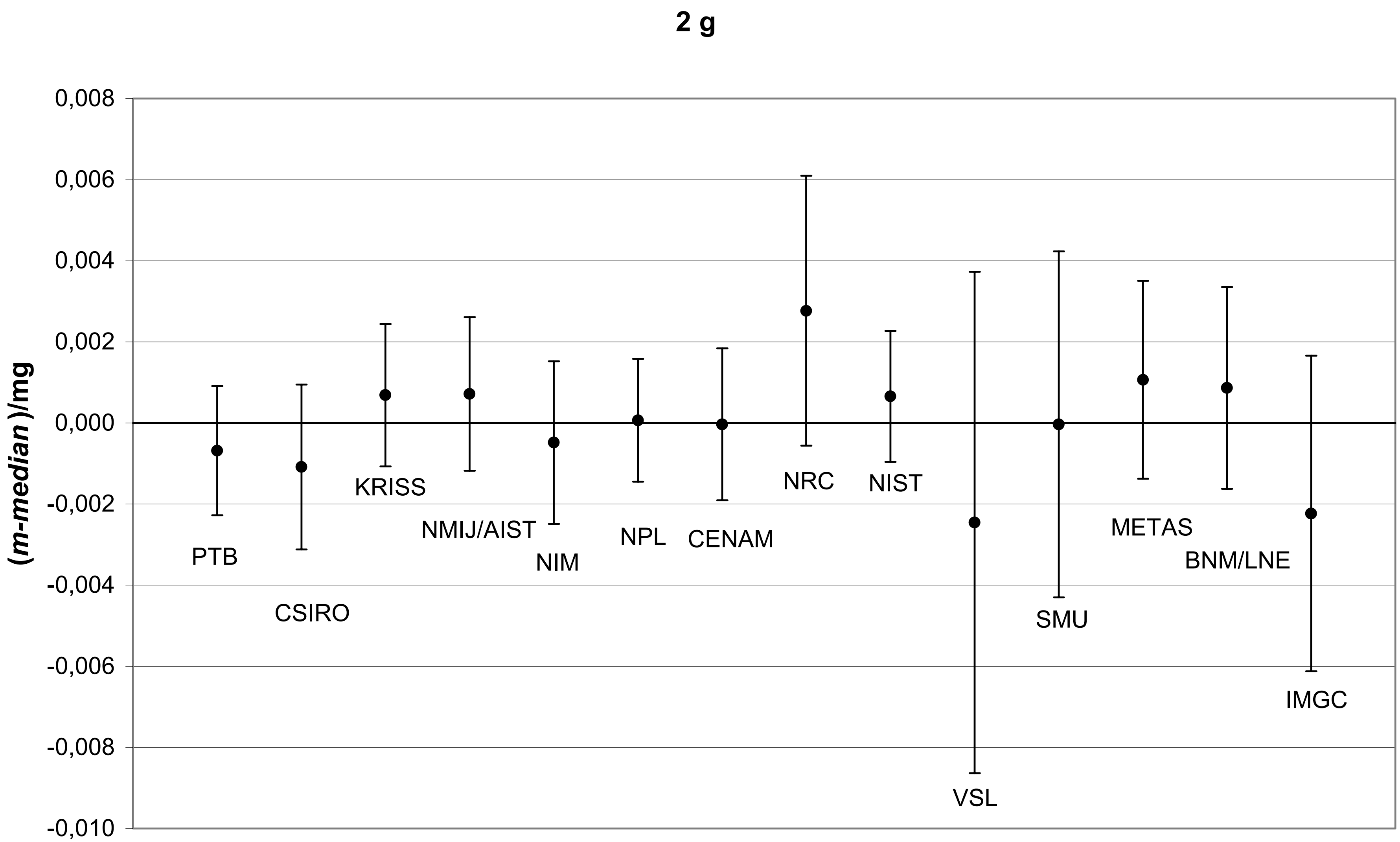
2 g
(m-median)/mg
0,008
0,006
0,004
0,002
0,000
-0,002
-0,004
-0,006
-0,008
-0,010
PTB
CSIRO
KRISS
NMIJ/AIST
NIM
NPL
CENAM
NRC
NIST
VSL
SMU
METAS
BNM/LNE
IMGC

Figure 9

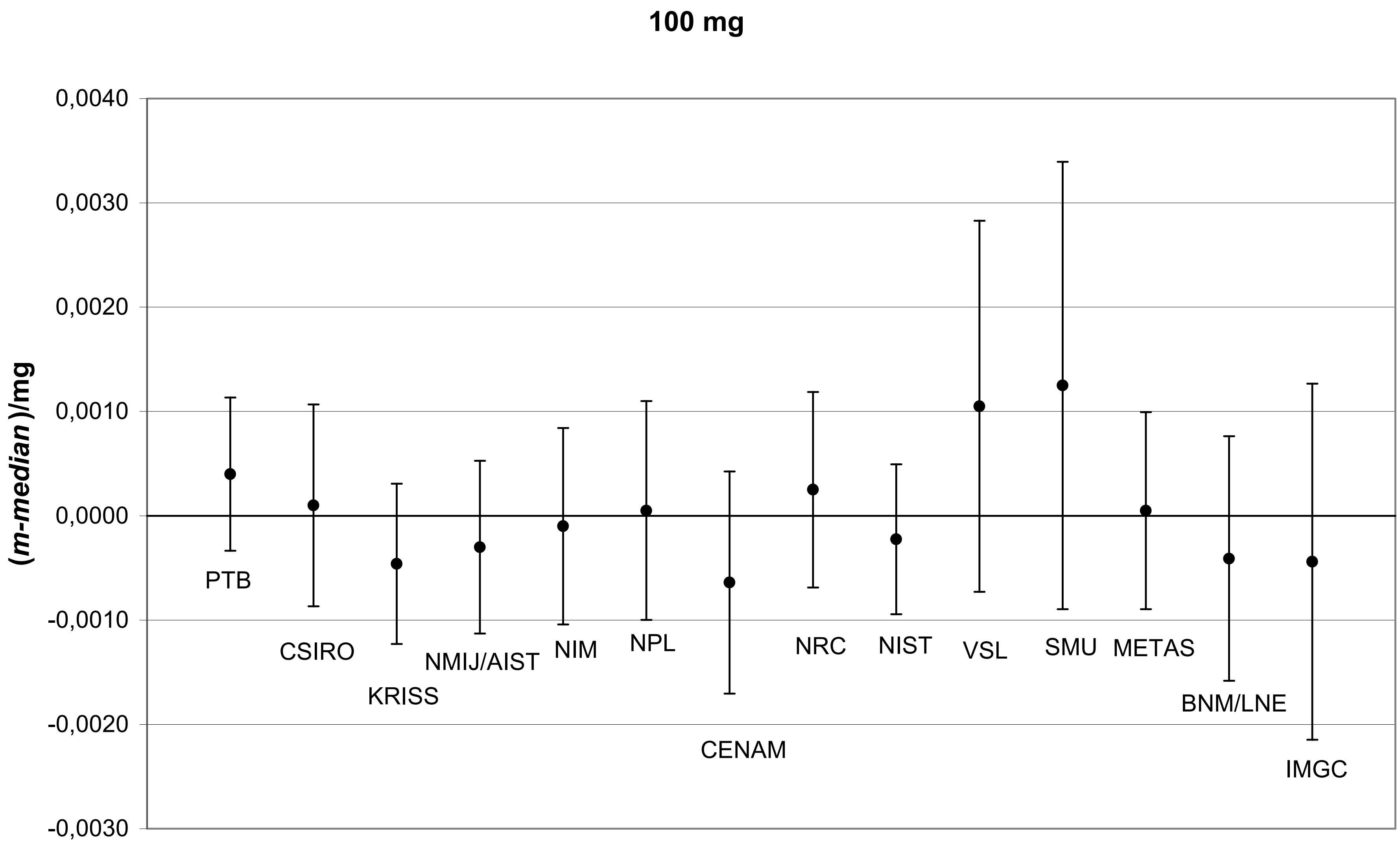
100 mg
(m-median)/mg
0,0040
0,0030
0,0020
0,0010
0,0000
-0,0010
-0,0020
-0,0030
PTB
CSIRO
KRISS
NMIJ/AIST
NIM
NPL
CENAM
NRC
NIST
VSL
SMU
METAS
BNM/LNE
IMGC

Figure 10

Appendix 1 Reference value and degree of equivalence

The participants of this comparison agreed for taking the median as reference value. The reasons for this decision are given in ch.5. The values of the pilot laboratory (PTB) have been taken as provisional reference values, and after having evaluated the median values of the travelling standards, the differences between the median values and PTB's values have been calculated, see Table 10. Because three sets of standards have been circulated, there are 15 reference values in total. Their absolute values can be obtained from the PTB values in Table 1 and the differences given in Table 10. The uncertainties of the reference values have been evaluated from [5].

Table 10. Differences of the reference values from the pilot laboratory's ones and the uncertainty of the reference value (k =1).

	m(ref)-*m*(PTB)	*u*(ref)
10 kg	0,03	0,12
500 g	0,005	0,004
20 g	0,0027	0,0011
2g	0,0007	0,0004
100 mg	-0,0004	0,0002

The degree of equivalence is defined [2] by the two quantities: 1. the difference between the value obtained by the laboratory and the reference value and 2. the uncertainty of this difference at a level of 95 % confindence. These values are given in Table 11 for each participating laboratory.

Table 11. Differences m-m_{ref} between the participant's results and the reference values and assigned expanded uncertainties U with a level of confidence of 95 %.

	10 kg		500 g		20 g		2 g		100 mg	
Laboratory	$(m-m_{ref})$/mg	U/mg	$(m-m_{ref})$/mg	U/mg	$(m-m_{ref})$/mg	U/mg	$(m-m_{ref})$/mg	U/mg	$(m-m_{ref})$/mg	U/mg
PTB	-0,03	0,34	-0,005	0,014	-0,0026	0,0051	-0,0007	0,0016	0,0004	0,0007
CSIRO	-0,10	0,72	-0,009	0,041	-0,0037	0,0079	-0,0011	0,0020	0,0001	0,0010
KRISS	-0,19	0,38	0,001	0,017	-0,0013	0,0054	0,0007	0,0018	-0,0005	0,0008
NMIJ/AIST	0,17	0,61	0,024	0,018	-0,0024	0,0065	0,0007	0,0019	-0,0003	0,0008
NIM	0,40	1,03	0,003	0,025	0,0001	0,0065	-0,0005	0,0020	-0,0001	0,0009
NPL	-0,18	0,39	-0,001	0,017	0,0008	0,0053	0,0001	0,0015	0,0001	0,0010
CENAM	1,34	1,54	0,016	0,020	0,0000	0,0066	0,0000	0,0019	-0,0006	0,0011
NRC	1,82	1,96	0,002	0,018	0,0001	0,0090	0,0028	0,0033	0,0003	0,0009
NIST	0,07	0,46	-0,002	0,018	0,0005	0,0054	0,0007	0,0016	-0,0002	0,0007
VSL	-0,41	2,21	-0,053	0,041	0,0018	0,0094	-0,0025	0,0062	0,0011	0,0018
SMU	1,62	1,74	-0,007	0,045	-0,0121	0,0086	0,0000	0,0043	0,0013	0,0021
METAS	0,03	0,56	0,006	0,031	0,0062	0,0072	0,0011	0,0024	0,0001	0,0009
BNM/LNE	-0,31	0,65	-0,007	0,031	0,0035	0,0072	0,0009	0,0025	-0,0004	0,0012
IMGC	-0,27	0,52	0,008	0,017	-0,0041	0,0091	-0,0022	0,0039	-0,0004	0,0017