Final Report

Final Report on EURAMET key comparison (EURAMET.M.M-K4.2 and EURAMET.M.M-K2.2) of 1 kg and submultiples of the kilogram standards in stainless steel (project code: EURAMET 1120)

1 Introduction

This report describes an European regional key comparison of 1 kg standard and submultiples of the kilogram in stainless steel carried out under the auspices of EURAMET and designated Project 1120. This comparison is also a KCDB key comparison, registered as EURAMET.M.M-K4.2 for 1 kg and EURAMET.M.M-K2.2 for the nominal weights of 500 g, 20 g, 2 g and 100 mg. The objectives of the present comparison are to check the measurement possibilities in the field of mass of the participating national laboratories, to facilitate the demonstration of metrological equivalence between the laboratories in Europe, and to check or support the validity of quoted calibration measurement capabilities (CMC).

This comparison is intended to provide a link to the Key Comparison EURAMETM.M-K2, EURAMET M.M-K4 and additional a link to CC M.M-K1 and CCM M.M-K2.

BEV(Austria) was the pilot laboratory and also provided the transfer standards

The participating laboratories are listed in Table 1.

Table 1: List of Participating Laboratories

Laboratory		Country
Bundesamt fur Eich- und Vermessungswesen	BEV	Austria
Hellenic Institute of Metrology	EIM	Greece
Institute of Metrology of Bosnia and Herzegovina	IMBiH	Bosnia and Herzegovina
General Directorate of Metrology, Tirana, Albania	DPM	Albania
Ministry of economy, Bureau of metrology	BOM	Macedonia
Bureau of Metrology	MBM	Montenegro
Kosovo Dept. of Metrology, Kosovo UNSCR 1244/99	MTI	Kosovo UNSCR 1244/99

The time schedule is listed in Table 2

Table 2: Time schedule of the comparison

Beginning: 24. September 2009

Time - start	Time - end	time periode	action
		working days	
24.September 2009	25.September 2009	1 day	Transport to Bosnia Herzegovina, IMBiH
28.September 2009	13.Oktober 2009	12 days	measurements done by Bosnia Herzegovina, IMBiH
14.Oktober 2009	16.Oktober 2009	3 days	Transport to Montenegro, MBM
19.Oktober 2009	3.November 2009	12 days	measurements done by Montenegro, MBM
4.November 2009	6.November 2009	3 days	Transport to Kosovo
9.November 2009	24.November 2009	12 days	measurements done by MIT, Kososvo
25.November 2009	27.November 2009	3 days	Transport to Albania, DPM
30.November 2009	15.Dezember 2009	12 days	measurements done by Albania, DPM
16.Dezember 2009	18.Dezember 2009	3 days	Transport to Macedonia, BOM
21.Dezember 2009	12.Jänner 2010	17 days	measurements done by Macedonia, BOM
13.Jänner 2010	15.Jänner 2010	3 days	Transport to Greece, EIM
18.Jänner 2010	2.Februar 2010	12 days	measurements done by Greece, EIM
3.Februar 2010	5.Februar 2010	3 days	Transport to Austria, BEV
8.Februar 2010	19.Februar 2010	10 days	measurements done by Austria, BEV

List of contact persons for the comparison of the different participants

Table 3: List of contact persons

BOM	Bianka	**Mangutova-Stoilkovska**	**Macedonia**	**signatory of Carnet ATA**	Ministry of economy, Bureau of metrology-Skopje. Macedonia	**Phone: +389 2 24 03 676 Fax: +389 2 24 44 677**	bianka.stoilkovska@bom.gov.mk
DPM	Defrim	**Bulku**	**Albania**	**no Carnet ATA**	General Directorate of Metrology, Tirana, Albania	**Phone: +355 42 233 174 Fax: +355 42 228 244**	defrim.bulku@dpmk.gov.al
M T I	Zijadin	**Isufi**	**Kosovo**	**no Carnet ATA**	MTI-Department of Metrology Kosovo	**Phone: +377 44 413 265 Fax: + 381 38 212 807**	zijadin.Isufi@ks.gov.net
MBM	Tamara	**Boskovic**	**Montenegro**	**signatory of Carnet ATA**	Bureau of Metrology, Montenegro	**Phone: +382 20 643 345 Fax: +382 20 642 159**	tamara_boskovic@yahoo.com
IMBiH	Sejla	**Alisic**	**Bosnia and Herzegovina**	**no Carnet ATA**	Institute of Metrology of Bosnia and Herzegovina, Dolina 6, 71000 Sarajevo	**Phone: +387 (0) 33 565-682 Fax: + 387 (0) 33 714 – 711**	sejla.alisic@met.gov.ba
EIM	Chris	**Mitsas**	**Greece**	**EU and signatory of Carnet ATA**	Hellenic Institute of Metrology (EIM), Greece	**Phone: +30 2310 569 960 Fax: +30 2310 569 996**	chris.mitsas@eim.gr
BEV	Dietmar	**Steindl**	**Austria**	**EU and signatory of Carnet ATA**	Bundesmat für Eich und Vermessungswesen, Arltgasse 35, 1160 Wien	**Phone: +43 1 21110 6362 Fax: +43 1 21110 6000**	dietmar.steindl@bev.gv.at

Description of the transfer standards

One set of five mass standards, of the OIML design, have been used with the following nominal mass values:

Table 4: List of nominal masses

nominal value
1 kg
500 g
20 g
2 g
100 mg

The density and the magnetic susceptibility of each mass standard (except for the 100 mg standards) have been determined by the pilot laboratory.
The density of the mass standards were measured by hydrostatic weighing. The reference standard for the density measurements was a silicon sphere traceable to PTB (Germany).
The susceptibility was measured with as Susceptometer manufactured by the company Sartorius. The Susceptomerter was checked against standard magnets.

Stability of the standards has been monitored at the pilot laboratory.
The drift of the weights can be seen in the figure 1a and figure 1b, page 15 and 16.

The transportation case was a black plastic suitcase with the content described in the Contents List.
It was the responsibility of the laboratory when it had the travelling standards to organize the transport to the next participant - by hand-carrying and ensuring that all necessary customs and importation documents (Carnet, where needed) were in order.




Data for mass standards determined at the pilot laboratory

The BEV determined the density of the weights by hydrostatic weighing, corresponding to method A (hydrostatic comparison, described in B 7.4 OIML R 111-1_2004).

Table 5: Data for mass standards (density and volume)

nominal value	density ρ	uncertainty u_ρ	Volume V	uncertainty u_v
1 kg	7960,64 kgm^{-3}	0,15 kgm^{-3}	125,6181 cm^3	0,001 cm^3
500 g	7961,17 kgm^{-3}	0,15 kgm^{-3}	62,8049 cm^3	0,0007 cm^3
20 g	7945,28kgm^{-3}	0,3 kgm^{-3}	2,5172 cm^3	0,0003cm^3
2 g	8062,23 kgm^{-3}	1,5 kgm^{-3}	0,2481 cm^3	0,0001 cm^3
100 mg *)	8600 kgm^{-3}	85 kgm^{-3}	-	-

*) density assumed

The BEV determined the magnetic susceptibility of the weights by testing the weights with a susceptometer type YSZ 01 C, manufactured by Sartorius corresponding to the susceptometer method B 6.4, OIML R 111-1_2004.

Table 6: Data for mass standards (magnetic susceptibility)

nominal value	magnetic susceptibility χ	uncertainty u_χ
1 kg	≤0,004	0,001
500 g	≤0,004	0,001
20 g	≤0,004	0,001
2 g	≤0,004	0,001
100 mg	-----	-----

3 Summary of results reported by the participants

Values of mass and uncertainty

For each participant the results have been expressed as the difference between the reported mass value (m) and the nominal mass value (m_o) for each of the weights. These results are shown in Table 8, page 14, alongside their corresponding uncertainty (k=2).

Stability of the transfer standards

The transfer standards were returned to the pilot laboratory, BEV, to check their stability. (The stability calibrations were carried out against the BEV stainless steel standards).

The results are given in the figure 1a and figure 1b, page 15 and 16.

Mass differences

In order to compare the values from the participants it is necessary to link them to the initial reference values, calculated from measurements of the pilot laboratory and EIM (Greece).

Calculation of reference value and uncertainty

For the purposes of this comparison, the reference value was taken to be the weighted mean value of the Pilot Laboratory (BEV) and EIM.

The weighted Mean x_w, of the n submitted values x_i is :

$$\bar{x}_w = \frac{\sum_i w_i \cdot x_i}{\sum_i w_i} \quad (1)$$

where the weight *Wi* of each value is given by:

$$w_i = \frac{1}{u^2_{(x_i)}} \quad (2)$$

$$\bar{x}_w = \frac{\sum_i \frac{x_i}{u^2_{(x_i)}}}{\sum_i w_i} \quad (3)$$

The uncertainty of the weighted mean is given by:

$$u_{(\bar{x}_w)} = \frac{1}{\sqrt{\sum_i \frac{1}{u^2_{(x_i)}}}} \quad (4)$$

The calculated weighted mean was set as the reference value for the comparison.

$$\bar{x}_w = x_{ref} \quad (5)$$

$$u_{(\bar{x}_w)} = u_{(x_{ref})} \quad \text{and for k= 2} \quad U_{(\bar{x}_w)} = U_{(x_{ref})} \quad (6)$$

The uncertainty in the reference value has been calculated according to the method described by M.G.Cox [1].

The results for the non corrected reference values (not linked to key comparisons EURAMET M.M-K2 and EURAMET M.M-K4) you can find in Table 7, page 13.

The results of this comparison have been linked to the results of the key comparison CCM.M-K1 and CCM.M-K2 using following formulas:

The results of the laboratories BEV and EIM were corrected with the results of the degree of equivalence between each participants according to the results given in the reports of CCM.M-K1, CCM.M-K2 (reference values (Δm)).

$$x_{ref}^{link} = \frac{\sum_i w_i \cdot (x_i - \Delta m_i)}{\sum_i w_i} \qquad (7)$$

The results for the corrected reference values (linked to key comparisons CCM.M-K1 and CCM.M-K2) you can find in Table 9, page 22.

4 Degree of equivalence, mass difference and uncertainty between participants and reference value

Calculating the degrees of equivalence, d_i:

The degree of equivalence between pairs of national measurement standards is expressed by the difference of their deviations from the reference value and the uncertainty of this difference (at a 95 % level of confidence).

$$d_i = x_i - x_{ref} \qquad (8)$$

$$U(d_i) = 2 \cdot u(d_i) \qquad (9)$$

$$u^2(d_i) = u^2(x_i) - u^2(x_{ref}) \qquad (10)$$

The uncertainties have been calculated in accordance with the international guide [2].

The results of this comparision without the link to the key comparisons CCM.M-K1 and CCM.M-K2 is presented in Table 8, page 14 and from figure 2 to figure 6.

The results for 1 kg of this comparison has been linked to CCM.M-K1 through EUROMET.M.M-K4 using the method that was used to link EUROMET.M.M-K4 to CCM.M-K1, published in NPL Report ENG 4, February 2008 [3].

The results for the weights with the nominal values 500g, 20 g, 2 g and 100 mg of this comparison has been linked to CCM.M-K2 through EUROMET.M.M-K4 using the method that was used to link EUROMET.M.M-K2 to CCM.M-K2, published in NPL Report ENG 13, March 2009 [4].

5 Link to the CCM key comparison

5.1 Results for 1 kg of the Laboratories BEV and EIM according to report of EURAMET.M.M-K4, :

BEV and EIM acted as the linking laboratories. As the basis for the linking for 1 kg to the CCM.M-K1, the degree of equivalence for BEV and EIM given in table 6, NPL Report ENG 4, February 2008 , page 14, ref. [3] was used:

$D_{BEV} = \Delta m_{BEV}$ = -0,021 mg with the uncertainty U_{BEV} = 0,057 mg

$D_{EIM} = \Delta m_{EIM}$ = -0,011 mg with the uncertainty U_{EIM} = 0,096 mg

An Excerpt from EURAMET.M.M-K4, published in NPL Report ENG 4, February 2008 [3] is given below:

Table 6: Degree of equivalence between each participant and the CCM.M-K1 reference value, Δm, and associated k=2 uncertainties, $U_{\Delta m}$

	SMD	NMi VSL	CEM	GUM	CMI	PTB	SMU	NPL	OMH	BEV	INRIM	METAS	JV
Δm/µg	-18	-5	-23	8	-38	4	-1	-7	-9	-21	-5	23	6
$U_{\Delta m}$/µg	48	23	22	56	130	25	30	25	43	57	26	30	46

	DFM	SP	MIKES	METROSERT	LNMC	VMT/VMC	NML	MIRS	EIM	NCM	INM	IPQ
Δm/µg	5	7	-2	13	-7	5	16	26	-11	10	-54	-17
$U_{\Delta m}$/µg	29	38	38	67	152	139	152	149	96	43	47	101

With the above given values for the degree of equivalences D_i the key reference value was corrected according to formula (7).

5. 2 Results for 500 g, 20 g, 2 g and 100 mg of the Laboratories BEV and EIM according to report of EURAMET.M.M-K2, :

BEV and EIM acted also as the linking laboratories for 500 g , 20 g, 2 g and 100 mg . As the basis for the linking for 500 g 20 g 2 g and 100 mg to the CCM.M-K2, the degree of equivalence for BEV and EIM given in table 12, NPL Report ENG 13, March 2009 , page 46, ref. [4] was used:

Weight with nominal mass of 500 g:

$D_{BEV\ (500\ g)} = \Delta m_{BEV\ \ (500\ g)}$ = 0,017 mg with the uncertainty U_{BEV} = 0,043 mg

$D_{EIM\ (500\ g)} = \Delta m_{EIM\ \ (500\ g)}$ = 0,017 mg with the uncertainty U_{EIM} = 0,087 mg

Weight with nominal mass of 20 g:

$D_{BEV\ (20\ g)} = \Delta m_{BEV\ (20\ g)}$ = 0,005 mg with the uncertainty U_{BEV} = 0,007 mg

$D_{EIM\ (20\ g)} = \Delta m_{EIM\ (20\ g)}$ = -0,001 mg with the uncertainty U_{EIM} = 0,011 mg

Weight with nominal mass of 2 g:

$D_{BEV\ (2\ g)} = \Delta m_{BEV\ (2\ g)}$ = 0,001 0 mg with the uncertainty U_{BEV} = 0,0026 mg

$D_{EIM\ (2\ g)} = \Delta m_{EIM\ (2\ g)}$ = -0,001 0 mg with the uncertainty U_{EIM} = 0,0072 mg

Weight with nominal mass of 100 mg:

$D_{BEV\ (100\ mg)} = \Delta m_{BEV\ (100\ mg)}$ = -0,000 1 mg with the uncertainty U_{BEV} = 0,0010 mg

$D_{EIM\ (100\ mg)} = \Delta m_{EIM\ \ (100\ mg)}$ = -0,000 5 mg with the uncertainty U_{EIM} = 0,0021 mg

An Excerpt from EURAMET.M.M-K4, published in NPL Report ENG 13, March 2009 [4] is given below:

Table 12: Differences between participants' results and CCM.M-K2 reference value, Δm, and associated k=2 uncertainties, $U_{\Delta m}$

		IPQ	CEM	SMD	NMi VSL	NML	EIM	UME	INM	NCM	OMH	JV	SP	MIKES
10 kg	Δm/mg		-0.21	-0.40	0.52	1.22	0.06	6.43	0.56	1.43	0.60	0.40	-0.29	-0.04
	$U_{\Delta m}$/mg		1.07	1.24	1.58	2.33	1.91	1.12	0.87	26.01	0.92	1.82	1.56	1.36
500 g	Δm/mg	0.004	0.006	0.019	0.028	0.014	0.017	0.236	0.049	0.018	0.064	-0.088	0.005	-0.011
	$U_{\Delta m}$/mg	0.069	0.034	0.039	0.082	0.128	0.087	0.030	0.047	0.086	0.036	0.070	0.036	0.048
20 g	Δm/mg	0.001	-0.001	0.001	0.005	-0.002	-0.001	0.001	0.007	0.007	0.006	0.002	0.000	-0.004
	$U_{\Delta m}$/mg	0.008	0.007	0.007	0.009	0.012	0.011	0.006	0.007	0.011	0.007	0.008	0.008	0.010
2 g	Δm/mg	-0.002 3	-0.002 1	-0.002 4	-0.001 9	-0.000 8	-0.001 0	-0.000 4	0.001 4	-0.000 1	0.000 2	-0.001 3	0.001 4	-0.000 1
	$U_{\Delta m}$/mg	0.004 2	0.002 1	0.002 3	0.004 3	0.006 3	0.007 2	0.002 0	0.003 5	0.006 5	0.002 0	0.003 7	0.003 0	0.003 3
100 mg	Δm/mg	0.000 2	0.000 1	0.000 3	0.001 0	0.000 2	-0.000 5	-0.000 1	0.000 4	0.001 3	0.001 8	0.000 9	0.001 3	0.000 1
	$U_{\Delta m}$/mg	0.001 7	0.001 1	0.001 2	0.001 6	0.002 2	0.002 1	0.001 2	0.002 1	0.003 6	0.001 2	0.001 7	0.001 4	0.001 4

		METROS	LNMC	DFM	PTB	CMI	GUM	VMC	SMU	BEV	METAS	INRIM	MIRS
10 kg	Δm/mg	-0.80	-0.18	-0.79	-0.03	0.28	1.48	2.18	0.74	-0.05	0.04	-0.27	0.01
	$U_{\Delta m}$/mg	6.45	3.47	1.58	0.30	3.06	2.28	3.26	1.06	1.50	0.51	0.47	1.60
500 g	Δm/mg	0.002	0.003	0.002	0.001	0.045	0.030	-0.003	0.043	0.017	0.020	0.013	0.004
	$U_{\Delta m}$/mg	0.050	0.114	0.020	0.013	0.052	0.042	0.161	0.025	0.043	0.028	0.016	0.078
20 g	Δm/mg	-0.005	-0.002	0.001	-0.002	-0.006	0.005	0.007	0.002	0.005	0.005	0.000	0.001
	$U_{\Delta m}$/mg	0.007	0.010	0.006	0.005	0.013	0.009	0.011	0.008	0.007	0.007	0.006	0.010
2 g	Δm/mg	-0.001 0	-0.003 9	0.000 2	-0.000 3	-0.000 5	0.002 5	0.009 5	0.000 5	0.001 0	0.000 6	0.000 4	0.000 1
	$U_{\Delta m}$/mg	0.002 7	0.005 5	0.002 4	0.001 5	0.006 2	0.002 4	0.018 1	0.003 4	0.002 6	0.002 1	0.002 2	0.004 3
100 mg	Δm/mg	0.000 1	-0.000 4	0.000 7	0.001 0	0.001 5	0.000 0	-0.001 9	-0.002 2	-0.000 1	0.000 1	0.000 3	0.000 2
	$U_{\Delta m}$/mg	0.001 6	0.001 7	0.001 3	0.001 1	0.002 6	0.001 3	0.003 2	0.001 6	0.001 0	0.000 9	0.001 0	0.001 8

With the above given values for the degree of equivalences D_i , Δm_i the key reference values were corrected according to formula (7).

Results with the Link to CCM.M-K1 and CCM.M-K2:

The corrected results (corrected value for the reference value and corrected value for the uncertainty of the reference value) with the link to the key comparisons CCM.M-K1 (for 1 kg) and CCM.M-K2 (for 500g, 20 g, 2 g and 100 mg) are shown in Table 10, page 23 and from figure 7 to figure 11.
To the uncertainty of the reference value the uncertainty of the link was added (uncertainty given in the NPL Report ENG 13, March 2009 and NPL Report ENG 4, February 2008).

6. Discussion

The objectives of the present comparison are to check the measurement possibilities in the field of mass of the participating national laboratories, especially the South East European countries, to facilitate the demonstration of metrological equivalence between the laboratories in Europe, and to check or support the validity of quoted calibration measurement capabilities (CMC).

This comparison is intended to provide a link to the Key Comparison EURAMETM.M-K2, EURAMET M.M-K4 and additional a link to CC M.M-K1 and CCM M.M-K2.

The measurement infrastructure and possibilities had been different in some participating counties. Some counties used special E1 weights as reference, some counties used E 2 weights as reference. This is also the reason, that some national metrology Institutes (dpm (Albania) or MBM (Montenegro) have had bigger measurement uncertainty then the others (higher values for the measurement uncertainty given in the calibration certificated for the reference weights).

For an acceptable measurement result in a comparison with a known reference value, the conditions $|E_n| < 1$ or $|d_i| < U(D_i)$ should be fulfilled. The reference values of this comparison was the weighted mean of the laboratories BEV and EIM, which were linked by the results of BEV and EIM, to the CCM Key Comparisons CC M.M-K1 and CCM M.M-K2.

Two participants have not met these conditions for the following weights:

one participant at the nominal weight values: 500 g, 20 g

one participant at the nominal weight values: 1 kg, 500 g, 20 g

All the other five participants fulfilled the conditions for all nominal weight values 1 kg, 500 g, 20 g, 2 g and 100 mg.

After the comparison some national metrology institutes informed the pilot laboratory that the metrological equipment in the mass laboratory had been improved. Some NMI have received new mass standards of higher class, mass standards with smaller values of measurement uncertainty in the calibration certificate, new balances, new laboratory rooms. So the metrology infrastructure has been improved in most of all participating countries from the South East European region in the time from 2010 and 2011.

7. Conclusion

This comparison was specially for the South East European countries (SEE) and was suggested in the 1st Meeting of EURAMET Focus Group on Facilitating national Metrology Infrastructure Development in Skopje, Macedonia, 27-28 November 2008.

The results provided by the participants dpm (Albania), IMBiH (Bosnia and Herzegovina), MBM (Montenegro), EIM (Greece) and BEV (Austria) in this comparison are consistent with each other and also with the key comparisons reference values linked to the key comparisons CCM.M.-K1 through EURAMET.M.M-K4 and CCM.M-K2 through EURAMET.M.M-K2

The results for the weights with nominal values 1 kg, 2 g and 100 mg provided by the participant BOM (Macedonia) are consistent with each other and also with the key comparisons reference values linked to the key comparisons CCM.M.-K1 through EURAMET.M.M-K4 and CCM.M-K2 through EURAMET.M.M-K2

The results for the weights with nominal values 2 g and 100 mg provided by the participant MTI (Kosovo UNSCR 1244/99) are consistent with each other and also with the key comparisons reference values linked to the key comparisons CCM.M.-K1 through EURAMET.M.M-K4 and CCM.M-K2 through EURAMET.M.M-K2

8 References

[1] M.G. Cox, “The evaluation of key comparison data, Metrologia **39** (2002), 589-595

[2] Guide to the Expression of Uncertainty in Measurement, BIPM, IEC, IFCC, ISO, IUPAC, IUPAP, OIML, 1993

[3] Report on EUROMET key comparison of 1 kg standards in stainless steel (EURMET.MM-K4), M. Perkin, NPL Report ENG 4, February 2008

[4] Report on EUROMET key comparison of multiples and submultiples of the kilogram (EURMET.MM-K2), M. Perkin, NPL Report ENG 13, March 2009

[5] M.G. Cox, “The evaluation of key comparison data: determing the largest consistent subset, Metrologia **44** (2007), 187-200

[6] Clemens Elster, Alfred Link and Wolfgang Wöger, “Proposal for linking the results of CIPM and RMO key comparisons, Metrologia **40** (2003), 189-194 187-200

Table 7: Results from the Pilot Lab and EIM and the Reference Value (not linked to the key comparisons CCM.M-K1 and CCM.M-K2)

					ref.Value X_{ref}		degree of equivalence	$U(d_i)$	degree of equivalence	$U(d_i)$
nominal value	BEV-mean	BEV-mean	EIM	EIM	Xw-mean	$U(x_{ref})$	BEV	BEV	EIM	EIM
	nom+	U	nom+	U	nom+		d_i	mg	d_i	mg
	mg	mg	mg	mg	mg	mg	mg		mg	
1 kg	0,235	0,070	0,170	0,120	0,218	0,060	0,016	0,035	-0,048	0,104
500 g	0,081	0,037	0,095	0,060	0,085	0,031	-0,004	0,019	0,010	0,051
20 g	0,045	0,007	0,038	0,006	0,041	0,005	0,004	0,005	-0,003	0,004
2 g	0,005	0,002	0,003	0,003	0,004	0,002	0,000	0,001	-0,001	0,003
100 mg	0,003	0,001	0,003	0,002	0,003	0,001	0,000	0,001	0,000	0,001

$$\bar{x}_w = \frac{\sum_i w_i \cdot x_i}{\sum_i w_i}$$

$$w_i = \frac{1}{u^2_{(x_i)}}$$

$$\bar{x}_w = \frac{\sum_i \frac{x_i}{u^2_{(x_i)}}}{\sum_i w_i}$$

$$u_{(\bar{x}_w)} = \frac{1}{\sqrt{\sum_i \frac{1}{u^2_{(x_i)}}}}$$

$$\bar{x}_w = x_{ref}$$

$$u_{(\bar{x}_w)} = u_{(x_{ref})}$$

$$U_{(\bar{x}_w)} = U_{(x_{ref})}$$

$$d_i = x_i - x_{ref}$$

$$U(d_i) = 2 \cdot u(d_i)$$

$$u^2(d_i) = u^2(x_i) - u^2(x_{ref})$$

Table 8: Reported results, difference between mass, m, and nominal mass, m_0, and expanded uncertainty U (k=2), degree of equivalence d_i between each participant and the reference value and associated uncertainties $U(d_i)$, (k=2).

1 kg	nom+	U	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,235	0,07	0,016	0,035
EIM	0,170	0,12	-0,048	0,104
BOM	0,345	0,165	0,127	0,154
dpm	0,479	1,85	0,261	1,849
M T I	-1,900	0,512	-2,118	0,508
MBM	0,320	2,58	0,102	2,579
IMBiH	0,219	0,152	0,001	0,139

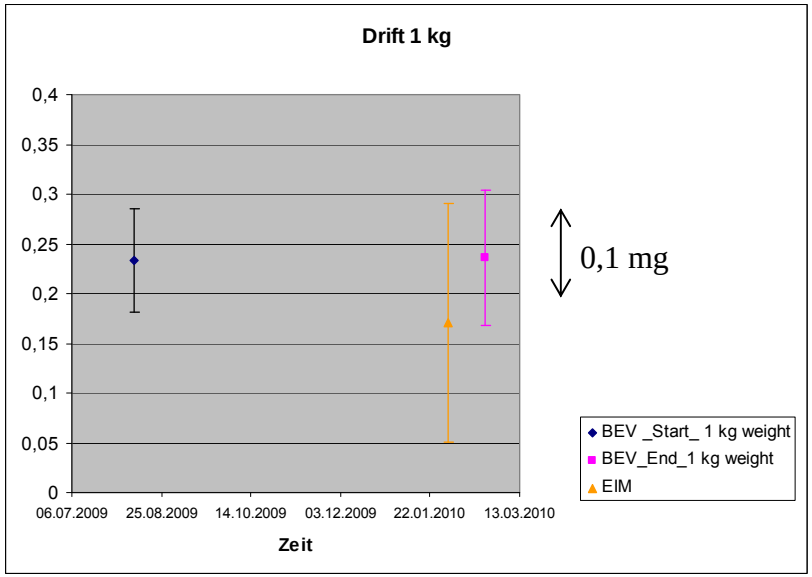
500 g	nom+	U	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,081	0,037	-0,004	0,019
EIM	0,095	0,06	0,010	0,051
BOM	0,232	0,082	0,147	0,076
dpm	0,196	0,92	0,111	0,919
M T I	-0,600	0,309	-0,685	0,307
MBM	0,190	1,28	0,105	1,280
IMBiH	0,066	0,077	-0,019	0,070

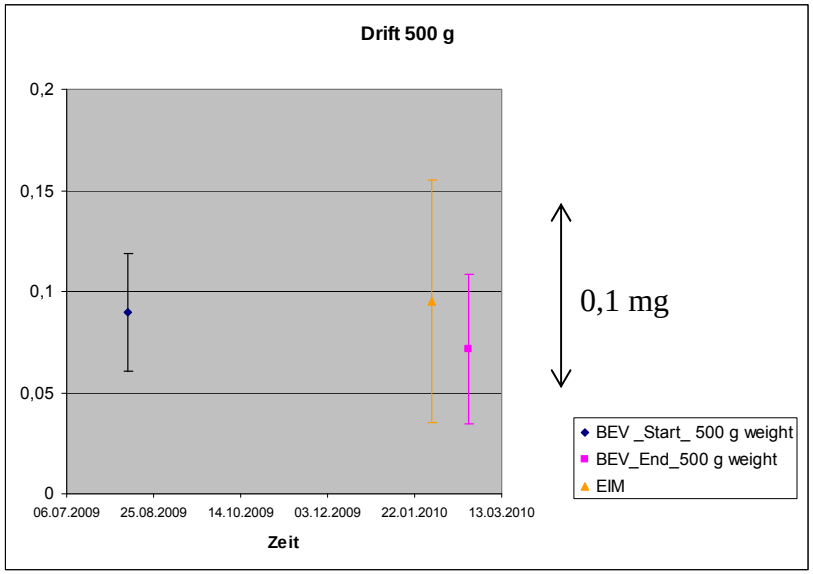
20 g	nom+	U	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,045	0,007	0,004	0,005
EIM	0,038	0,006	-0,003	0,004
BOM	0,07	0,0094	0,029	0,008
dpm	0,077	0,092	0,036	0,092
M T I	0	0,029	-0,041	0,029
MBM	0,049	0,042	0,008	0,042
IMBiH	0,037	0,011	-0,004	0,010

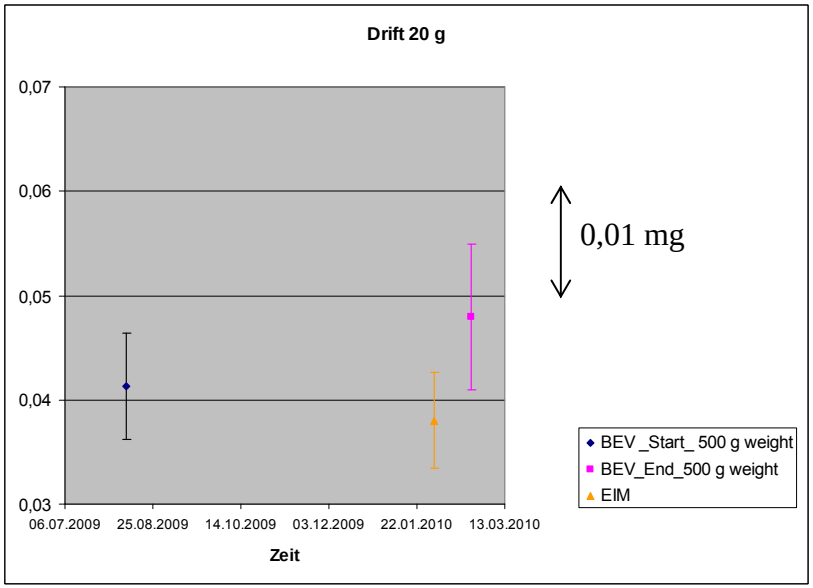
2 g	nom+	U	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,005	0,002	0,0004	0,001
EIM	0,0033	0,0032	-0,0009	0,003
BOM	0,0046	0,0041	0,0004	0,004
dpm	0,0062	0,0462	0,0020	0,046
M T I	0,004	0,012	-0,0002	0,012
MBM	0,005	0,015	0,0008	0,015
IMBiH	-0,0003	0,0045	-0,0045	0,004

100 mg	nom+	U	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,00278333	0,0012	0,0001	0,001
EIM	0,0025	0,0015	-0,0002	0,001
BOM	0,0038	0,0017	0,0011	0,001
dpm	0,007	0,0185	0,0043	0,018
M T I	0,006	0,005	0,0033	0,005
MBM	0,0034	0,0062	0,0007	0,006
IMBiH	0,0024	0,0015	-0,0003	0,001

Figure 1a: Drift of the weights







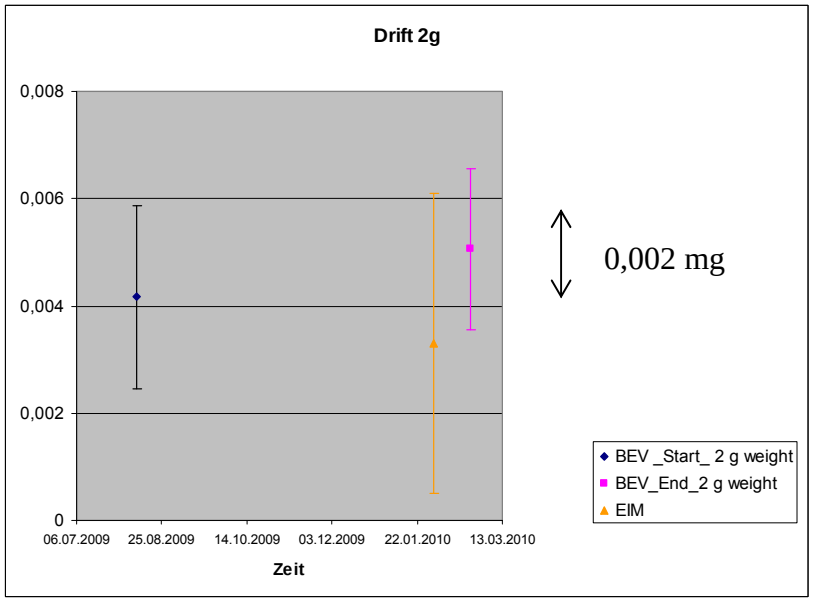


Figure 1b: Drift of the weights

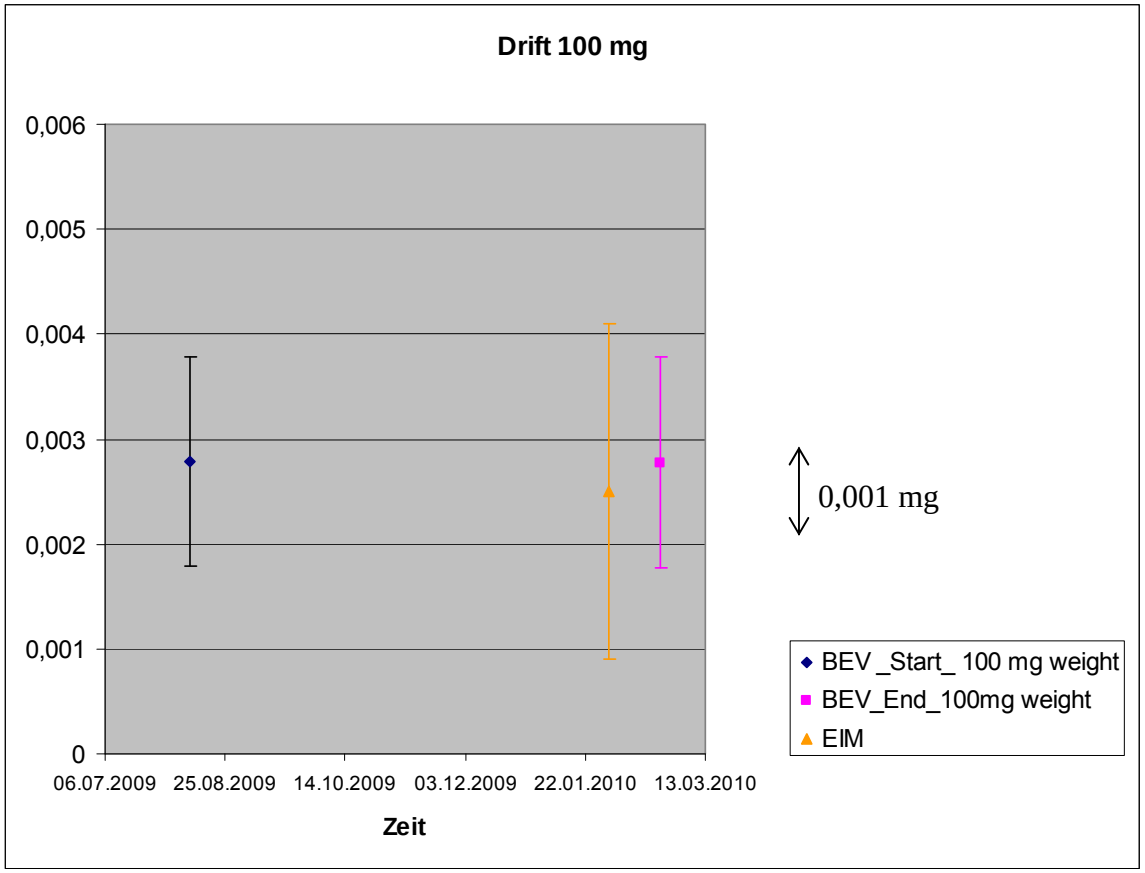


Figure 2: Results for 1 kg, difference between each participant and the reference value without link to CCM.M-K1

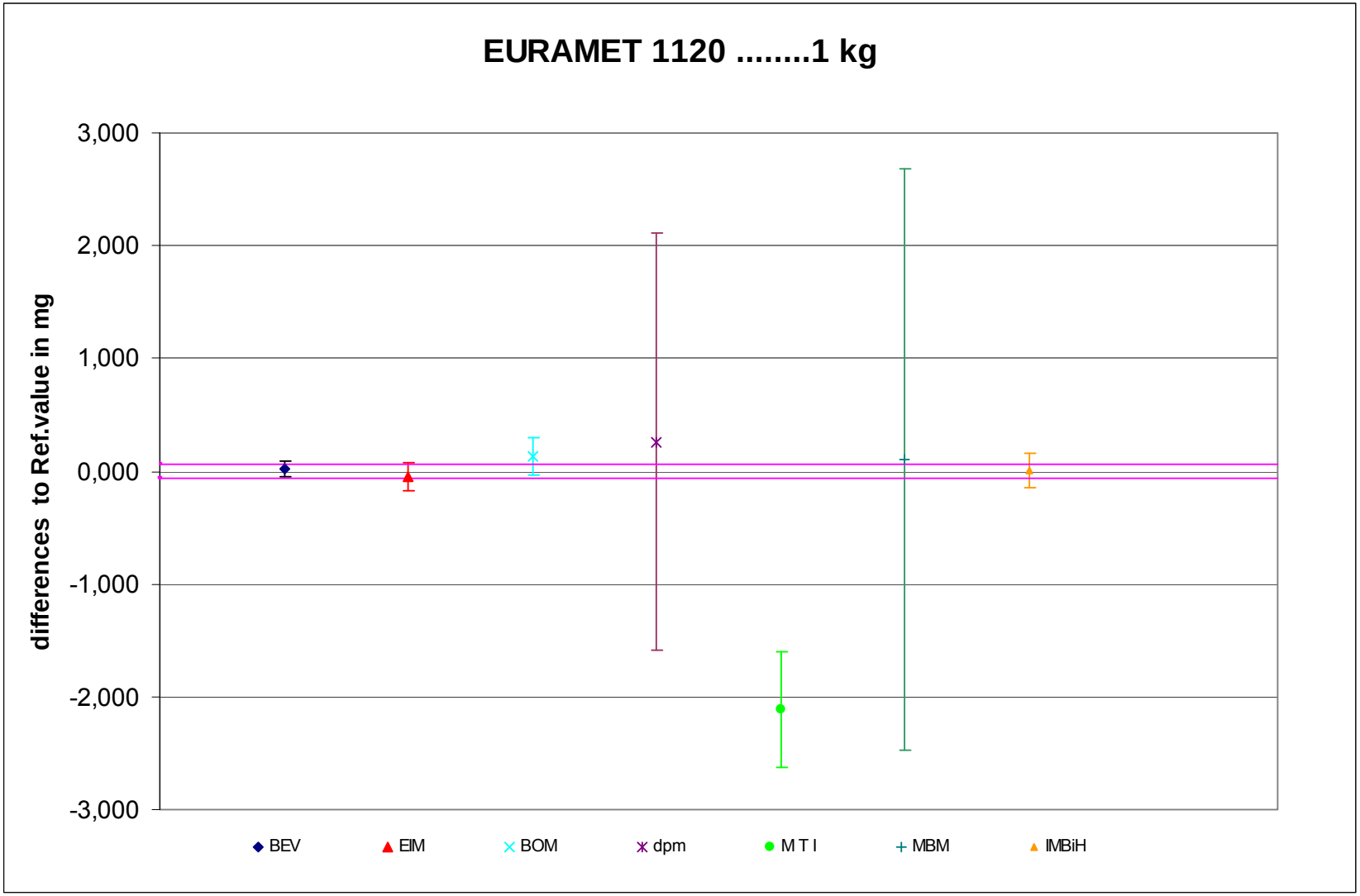


Figure 3: Results for 500 g, difference between each participant and the reference value without link to CCM.M-K2

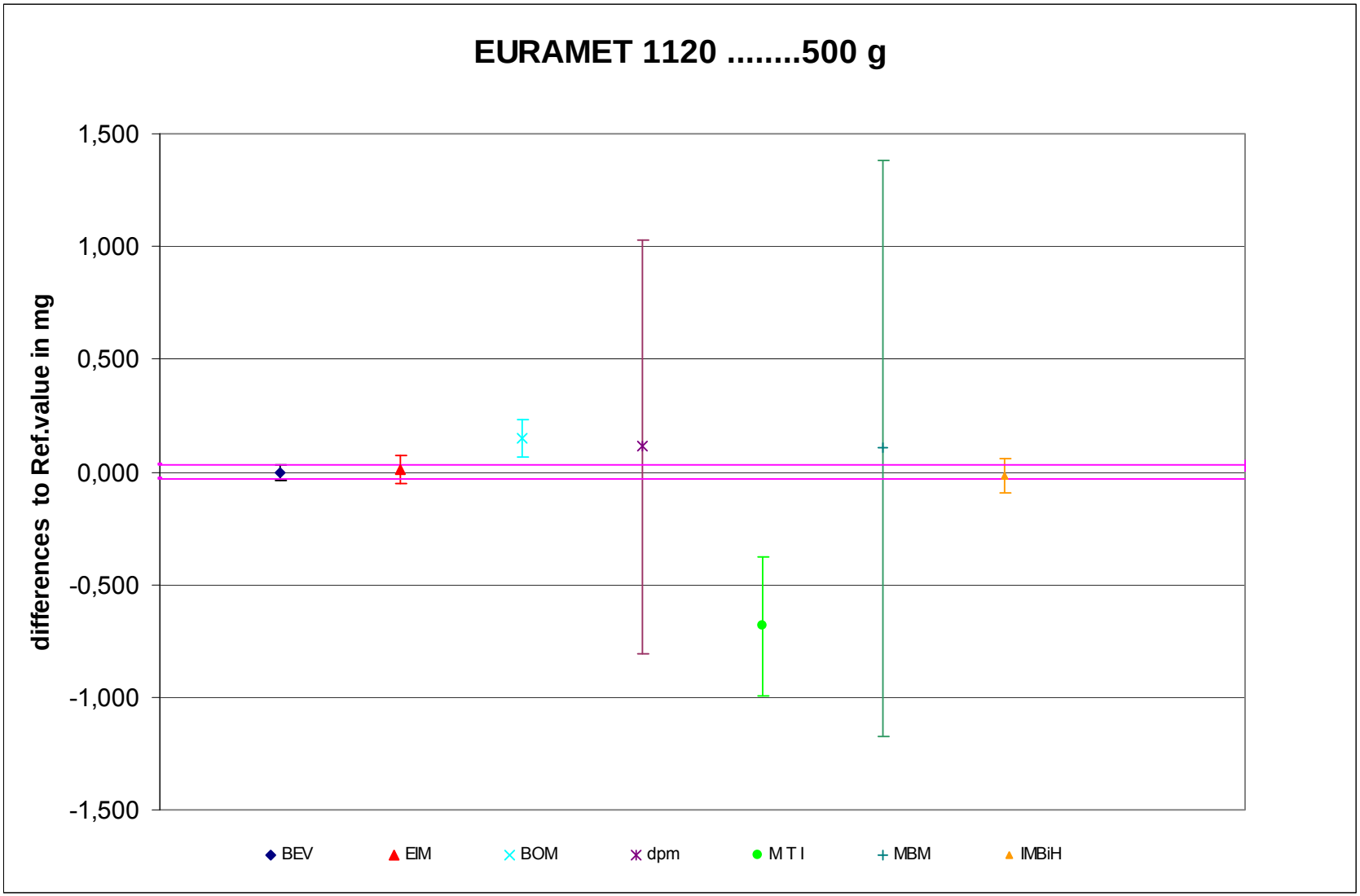


Figure 4: Results for 20 g, difference between each participant and the reference value without link to CCM.M-K2

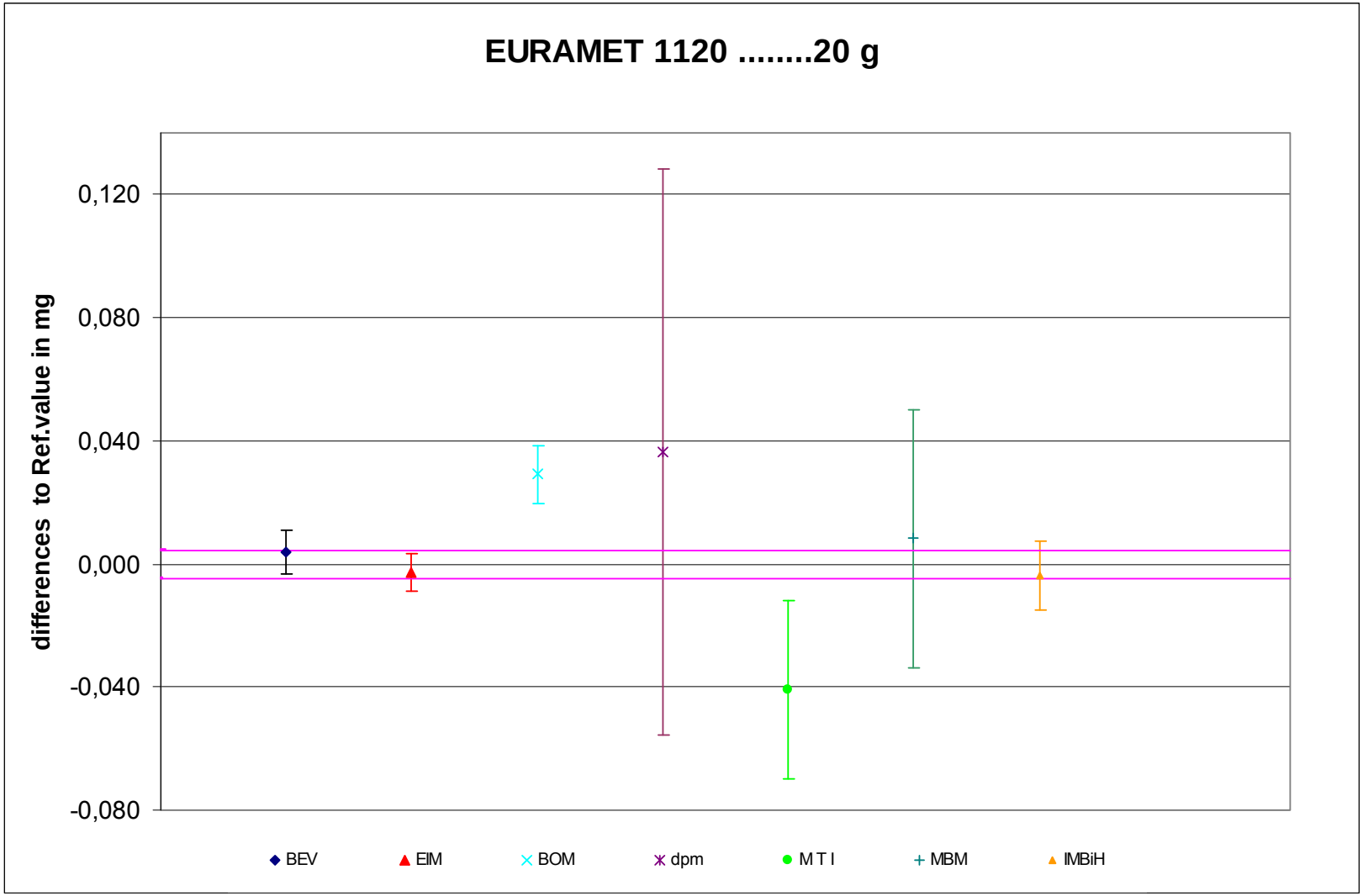


Figure 5: Results for 2 g, difference between each participant and the reference value without link to CCM.M-K2

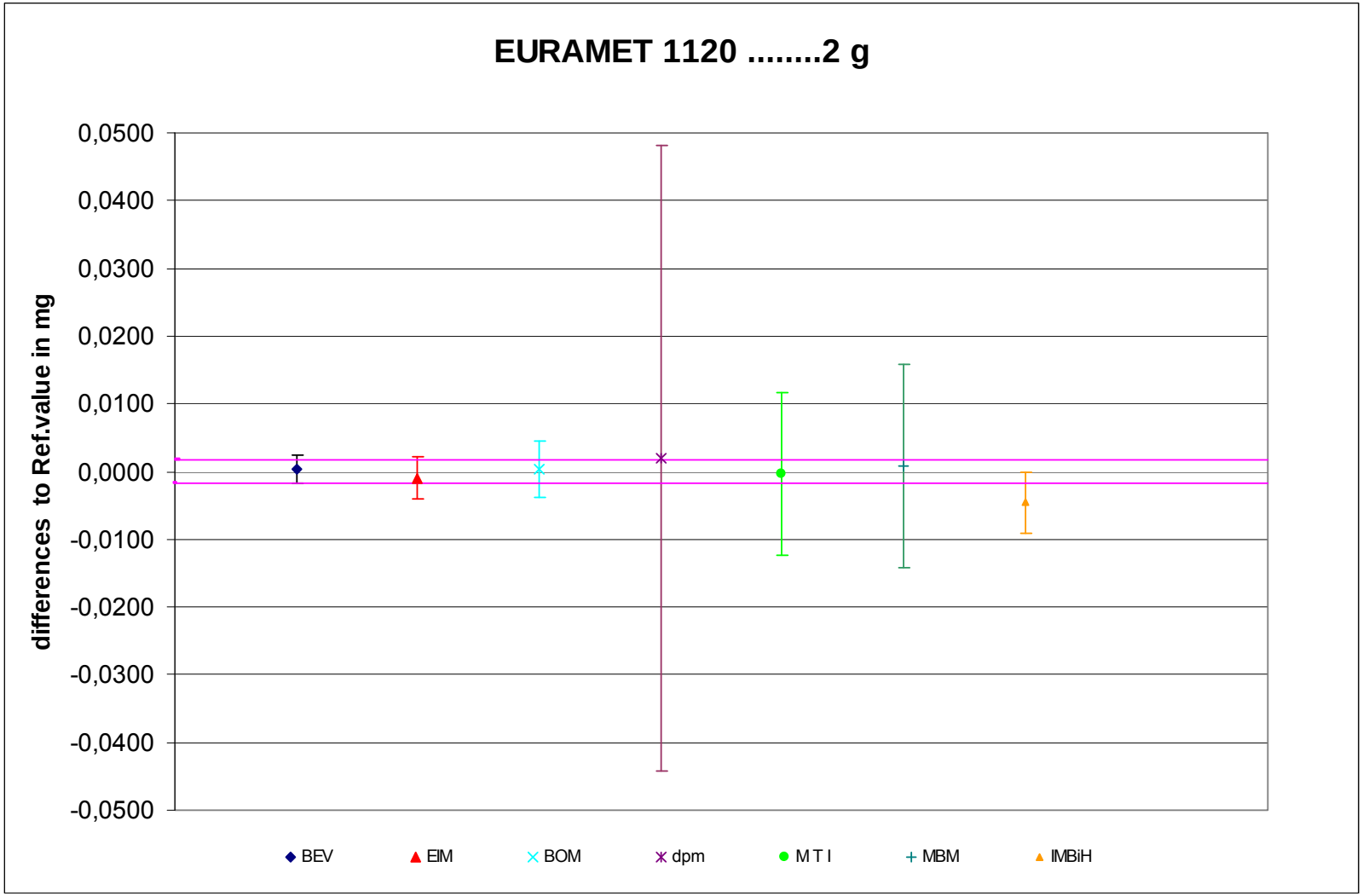


Figure 6: Results for 100 mg, difference between each participant and the reference value without link to CCM.M-K2

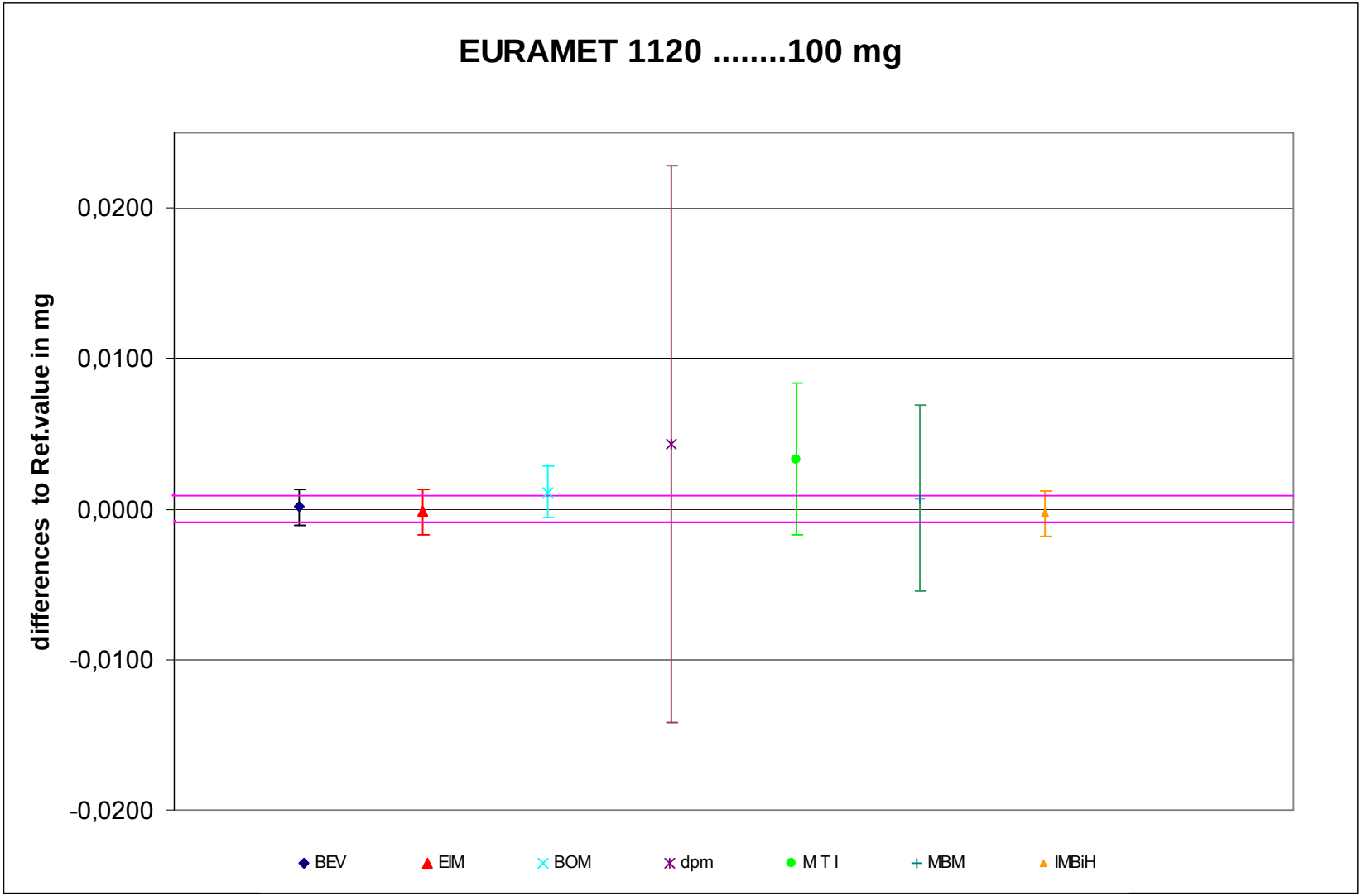


Table 9: Results for the Pilot Lab and EIM and the Reference Value corrected and linked to the key comparisons CCM.M-K1 (for 1 kg) and CCM.M-K2 (for 500, 20 g, 2 g, 100 mg)

					ref.Value	Uncertainty ref. Value	degree of equivalence	$U(d_i)$	degree of equivalence	$U(d_i)$
nominal value	BEV-mean	BEV-mean	EIM	EIM	x_{ref}	$U(x_{ref})$	BEV	BEV	EIM	EIM
	nom+	*U*	*nom+*	*U*	*nom+*	k=2	D	mg	D	mg
	mg	mg	mg	mg	mg	mg	mg		mg	
1 kg	0,256	0,090	0,181	0,154	0,236	0,078	0,019	0,046	-0,055	0,133
500 g	0,064	0,057	0,078	0,106	0,067	0,050	-0,003	0,027	0,011	0,093
20 g	0,040	0,010	0,039	0,013	0,039	0,008	0,000	0,006	0,000	0,010
2 g	0,004	0,003	0,004	0,008	0,004	0,003	0,000	0,001	0,001	0,007
100 mg	0,003	0,002	0,003	0,003	0,003	0,001	0,000	0,001	0,000	0,002

$$x_{ref}^{link} = \frac{\sum_i w_i \cdot (x_i - \Delta m_i)}{\sum_i w_i}$$

$$w_i = \frac{1}{u_{(x_i)}^2}$$

$$d_i = x_i - x_{ref}$$

$$U(d_i) = 2 \cdot u(d_i)$$

$$u^2(d_i) = u^2(x_i) - u^2(x_{ref})$$

Table 10: Reported results, difference between mass, *m*, and nominal mass, m_0, and expanded uncertainty U (*k*=2), degree of equivalence between each participant and the reference value and associated the uncertainties (k=2); (reference value linked to the key comparison CCM.M-K1 and CCM.M-K2)

1 kg	nom+	*U*	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	mg
BEV	0,256	0,090	0,019	0,046
EIM	0,181	0,154	-0,055	0,133
BOM	0,345	0,165	0,109	0,145
dpm	0,479	1,850	0,243	1,848
M T I	-1,900	0,512	-2,136	0,506
MBM	0,320	2,580	0,084	2,579
IMBiH	0,219	0,152	-0,017	0,131

500 g	nom+	*U*	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	
BEV	0,064	0,057	-0,003	0,027
EIM	0,078	0,106	0,011	0,093
BOM	0,232	0,082	0,165	0,065
dpm	0,196	0,920	0,129	0,919
M T I	-0,600	0,309	-0,667	0,305
MBM	0,190	1,280	0,123	1,279
IMBiH	0,066	0,077	-0,001	0,059

20 g	nom+	*U*	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	
BEV	0,040	0,010	0,000	0,006
EIM	0,039	0,013	0,000	0,010
BOM	0,070	0,009	0,031	0,005
dpm	0,077	0,092	0,038	0,092
M T I	0,000	0,029	-0,039	0,028
MBM	0,049	0,042	0,010	0,041
IMBiH	0,037	0,011	-0,002	0,008

2 g	nom+	*U*	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	
BEV	0,0036	0,003	-0,0001	0,001
EIM	0,0043	0,008	0,0006	0,007
BOM	0,0046	0,004	0,0009	0,003
dpm	0,0062	0,046	0,0025	0,046
M T I	0,0040	0,012	0,0003	0,012
MBM	0,0050	0,015	0,0013	0,015
IMBiH	-0,0003	0,005	-0,0040	0,003

100 mg	nom+	*U*	degree of equivalence d_i	$U(d_i)$
	mg	mg	mg	
BEV	0,0029	0,002	0,0000	0,001
EIM	0,0030	0,003	0,0001	0,002
BOM	0,0038	0,002	0,0009	0,001
dpm	0,0070	0,019	0,0041	0,018
M T I	0,0060	0,005	0,0031	0,005
MBM	0,0034	0,006	0,0005	0,006
IMBiH	0,0024	0,002	-0,0005	0,001

Figure 7: Results for 1 kg, difference between each participant and the reference value, linked to CCM.M-K1

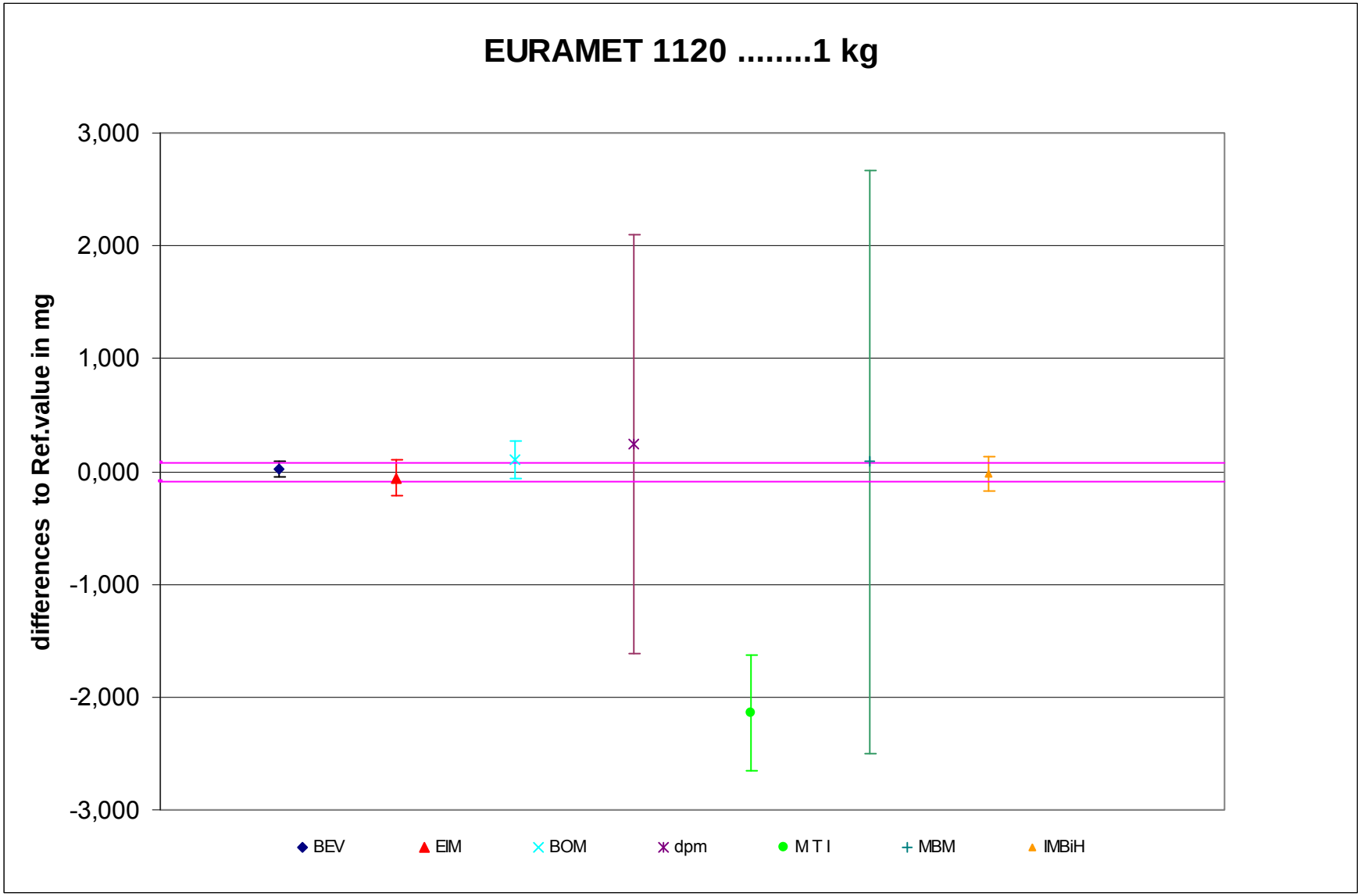


Figure 8: Results for 500 g, difference between each participant and the reference value, linked to CCM.M-K2

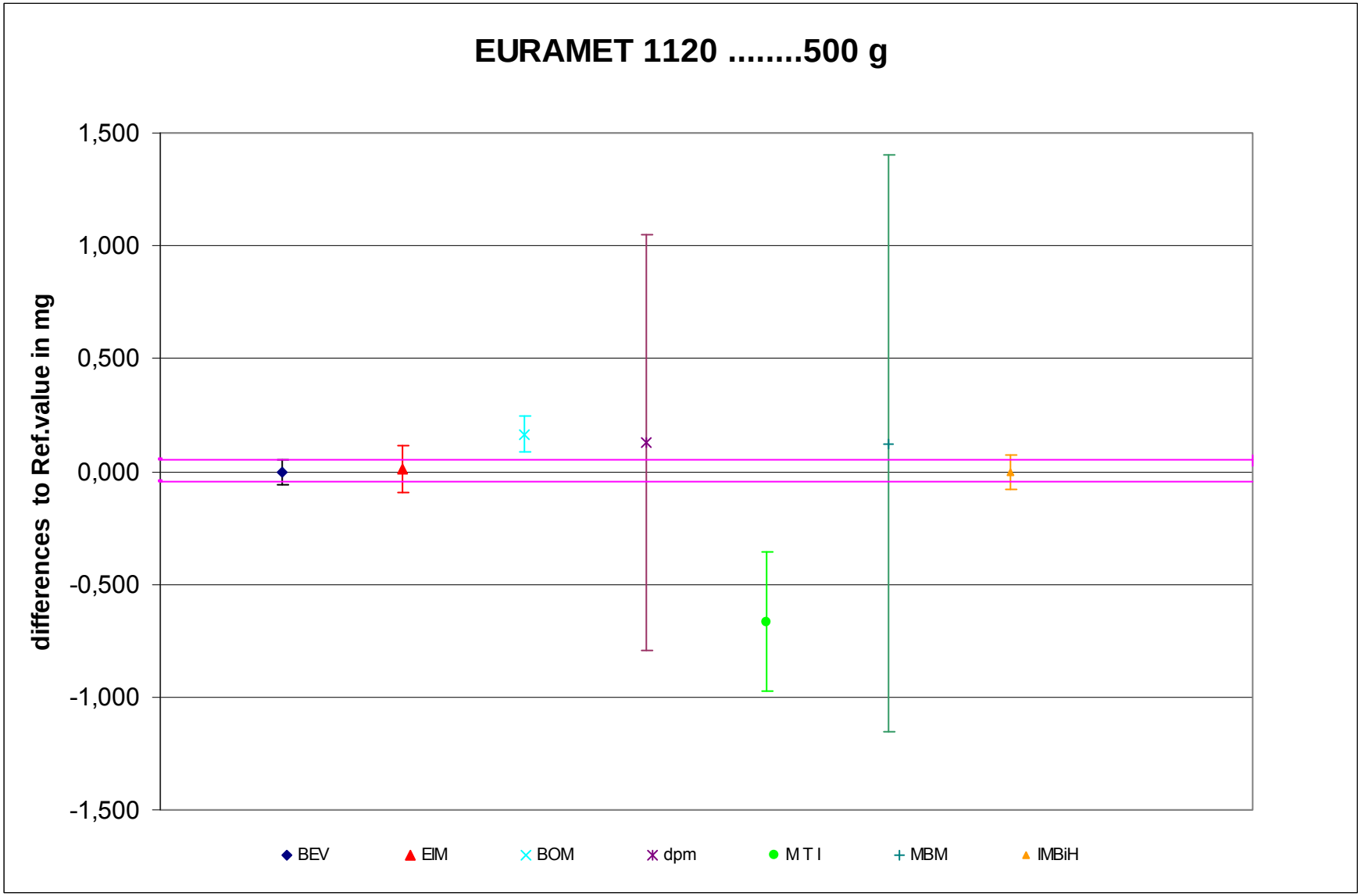


Figure 9: Results for 20 g, difference between each participant and the reference value, linked to CCM.M-K2

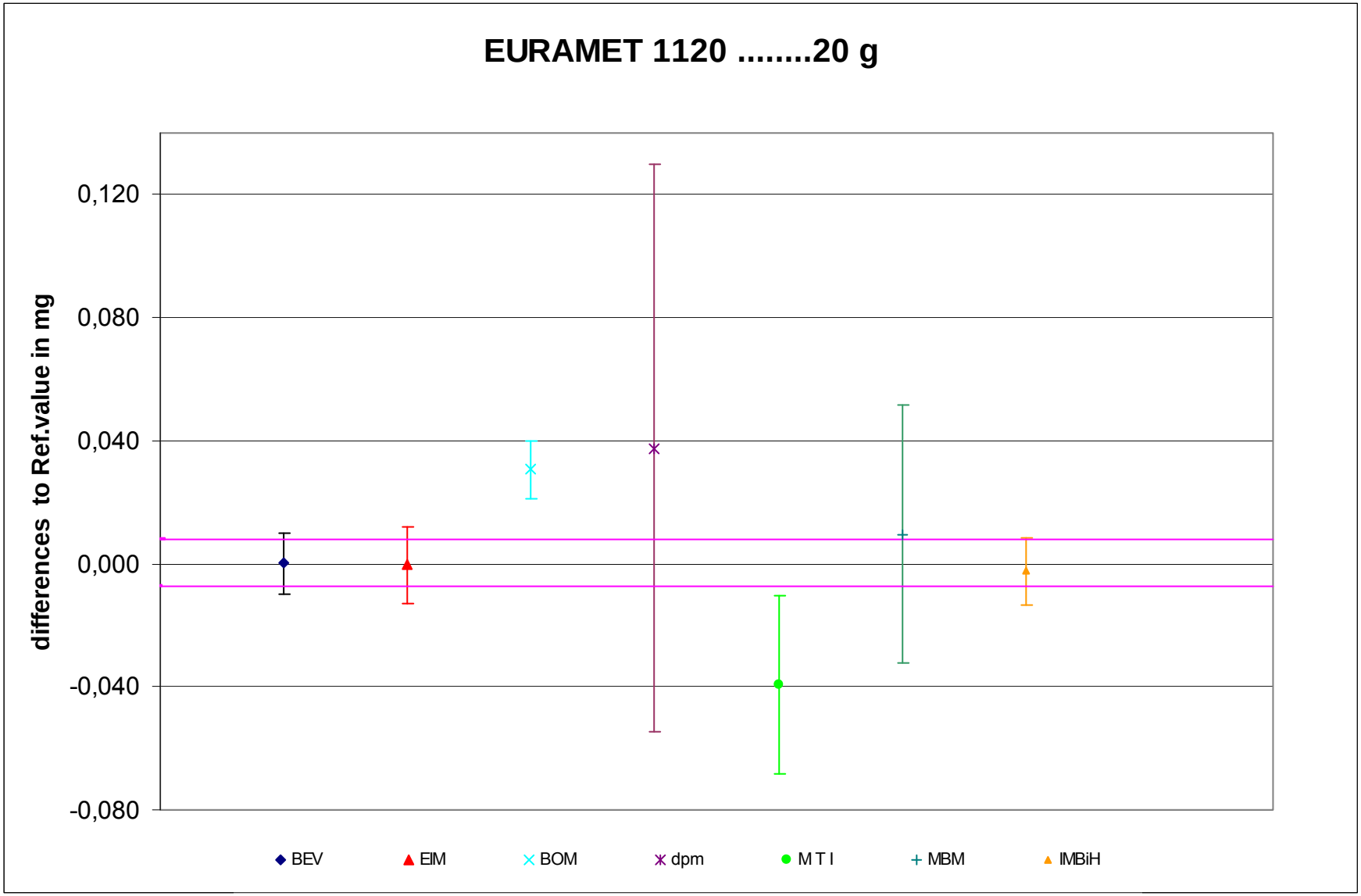


Figure 10: Results for 2 g, difference between each participant and the reference value, linked to CCM.M-K2

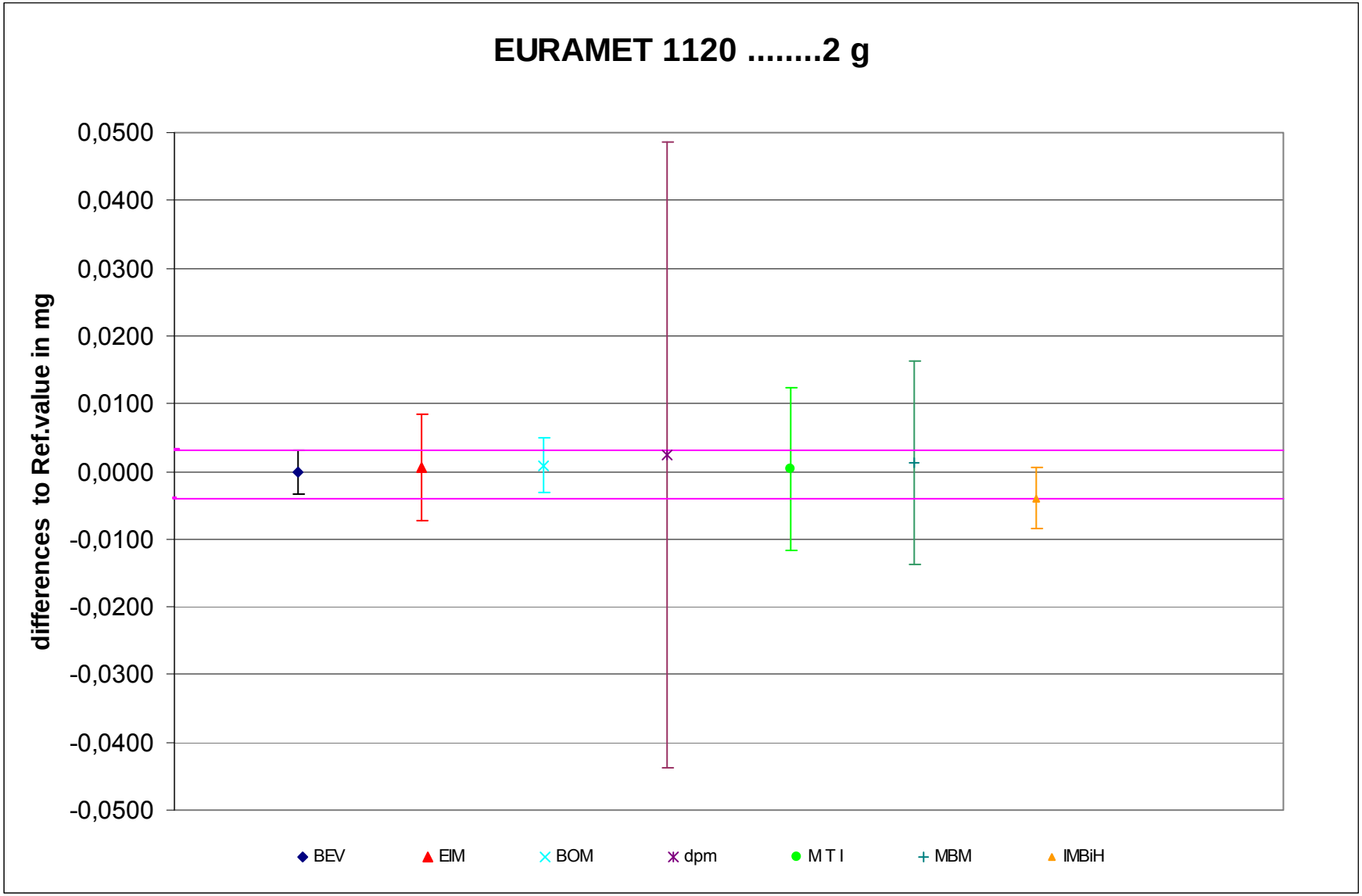


Figure 11: Results for 100 mg, difference between each participant and the reference value, linked to CCM.M-K2