ASIA – PACIFIC METROLOGY PROGRAMME

Final Report of
APMP Comparison of Mass Standards
APMP.M.M-K5 (Sub-) Multiples Mass Key Comparison

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Final Report : APMP.M.M-K5 Comparison of Mass standards Multiples and Sub-multiples of the Kilogram: 2 kg, 200 g, 50 g, 1 g and 200 mg

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ABSTRACT :

This report describes a key comparison of mass standards APMP.M.M-K5, conducted between nineteen participating members of the Asia-Pacific Metrology Programme (APMP). The APMP.M.M-K5 comparison was launched during the 13th meeting of the Technical Committee for Mass and Related Quantities APMP-TCM (2012).Two sets of stainless steel weights with five nominal mass values: 2 kg, 200 g, 50 g, 1 g, and 200 mg were used as travelling standards. These nominal values were chosen as they followed the nominal values of CCM.M-K5. The aim of the comparison is to verify the consistency of 2 kg, 200 g, 50 g, 1 g and 200 mg stainless steel mass standards among members of APMP-TCM.

The program was piloted by the National Institute of Metrology, P.R.China (NIM). All the participants have provided their support and help to successfully organize and run the comparison.

The nominated nineteen participants have been divided into five petals and the corresponding five sets of transfer standards have been circulated within the groups simultaneously. The pilot laboratory measured the volumes and the magnetic properties of the standards before the circulation and had reported these values to the participants. The pilot laboratory has also verified the stability of all travelling standards for more than one year. The set of five weights was circulated among all the participating laboratories in Aug. 2015 and received back from the last participant in Aug. 2016. Final report of this comparison is being given in this document.

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1. INTRODUCTION

APMP is a grouping of national and territorial measurement laboratories from the Asia-Pacific region helping to develop international recognition for regional measurement competence and, hence, underpin confidence in traded products and services. Some of the successful methods used by APMP to reach its objective are comparisons using artifacts.

The APMP.M.M-K5 comparison was launched during the 13th meeting of the Technical Committee for Mass and Related Quantities APMP-TCM (2012).The results of the participating laboratories have been calculated to give the degrees of equivalence (DoE) with the reference values (RV).

2. PARTICIPANTS

Therefore this report consists of the results from nineteen participants listed in the Table 1. P.R.China, Republic of Korea, Australia, India and Japan had taken part in CCM.M-K5 comparison and acted as linking laboratories). NIM is responsible for organizing this comparison as the pilot laboratory.

Table 1. Details of participating laboratories

Institute of participating laboratory	**Acronym**	**Economy**	**CCM.M-K5 (Y/N)**
National Institute of Metrology (Pilot institute)	NIM	P.R. China	**Y**
National Metrology Laboratory of the Philippines	NML-Phil	Philippines	N
Measurement Standards Laboratory of New Zealand	MSL	New Zealand	N
Mongolia Agency for Standardization and Metrology	MASM	Mongolia	N
Vietnam Metrology Institute	VMI	Vietnam	N
Standard Calibration Laboratory	SCL	Hong Kong	N
Center for Measurement Standards - Industrial Technology Research Institute	ITRI	Taiwan	N
Korea Research Institute of Standards and Science	KRISS	Republic of Korea	**Y**
Research Center for Metrology	RCM LIPI[†]	Indonesia	N
National Measurement Institute, Australia	NMIA	Australia	**Y**
National Institute of Standards and Industrial Technology	NISIT[‡]	Papua New Guinea	N
National Metrology Institute of Malaysia	NMIM	Malaysia	N
National Metrology Center, Agency for Science, Technology and Research	NMC/A-STAR	Singapore	N
Measurement Units, Standards and Services Department	MUSSD	Sri Lanka	N
National Physical Laboratory, India	NPLi	India	**Y**
Egypt National Institute for Standards	NIS	Egypt	N
Bangladesh Standards & Testing Institution	NML-BSTI	Bangladesh	N
National Institute of Metrology Thailand	NIMT	Thailand	N
National Metrology Institute of Japan	NMIJ	Japan	**Y**

[†] Since 2014, the institution has renamed from Calibration, Instrumentation and Metrology LIPI (KIM LIPI) to Research Center for Metrology (RCM LIPI).

[‡] Papua New Guinea is a non-signatory participant of CIPM MRA. According to CIPM MRA-D-05 (Version 1.6). The results for non-signatory participant would be considered as evidence of metrological competence for any future CMC submissions.

3. TRANSFER STANDARDS

3.1 Mass Standards

In November 2012, NIM purchased seven sets of transfer mass standards. Each set contains five pairs of weights for five nominal values of 2 kg, 200 g, 50 g, 1 g, 200 mg. The materials of these weights are stainless steel.

The density, the magnetic susceptibility, and the mass of all standards were determined at NIM (Table 2.1). The stability of the standards has been observed at NIM for about 16 months before the comparison started and found to be small enough for the purpose of this comparison.

Five of the seven sets which were of better characteristics and stability have been delivered to five divided petals of participants which were chosen in consideration of transportation efficiency and CCM linking laboratory. The other two sets remained at NIM for the reference and emergency situation.

Table 2.1 Characteristics of the transfer mass standards used for the comparison.

Nominal value	Marking	shape	Volume* at 20 °C [cm^3]	Density$^+$ at 20 °C [kg/m^3]	Susceptibility
2 kg	J1,J4, J5, J6, J7 P2,P4,P5,P6,P7	OIML	250.54 253.23	7982.7 7898.0	< 0.0004 < 0.07
200 g	J1, J3, J4,J5, J6 P2,P3,P4,P5,P7	OIML	25.060 25.121	7980.8 7961.4	< 0.0004 < 0.02
50 g	J2, J3, J4, J6,J7 P1,P2,P3,P4,P7	OIML	6.2409 6.2825	8011.7 7958.6	< 0.0004 < 0.02
1 g	J1,J2, J3, J5, J7 P2,P3,P4,P5,P6	OIML	0.1247 0.1275	8019.0 7840.7	< 0.0005 < 0.02
200 mg	J2, J3, J5, J6, J7 P1,P2,P3,P5,P6	OIML(Sheet)	0.0249 0.0250	8016.9 8005.4	/

* The cubical thermal expansion coefficient of "Jx" weights is assumed to be 3.5×10^{-5}/℃, and that of "Px" weights is assumed to be 4.5×10^{-5}/℃.

$^+$ The density is average value of Jx or Px;

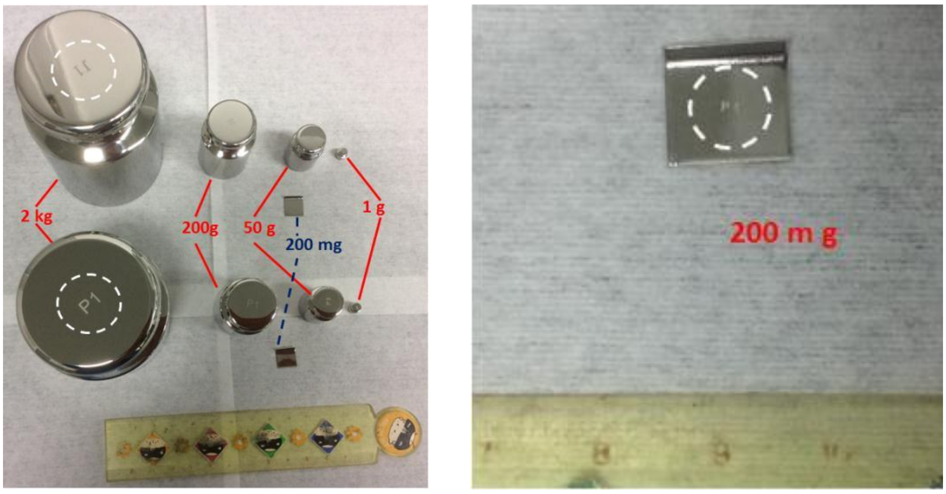

Figure 1. Transfer standards prepared for the APMP.M.M-K5 key comparison.

3.2 Carrying Case

The carrying case can be hermetically sealed and has separated holes to hold the weights tightly. The weights are wrapped in clean optical paper and fixed at their positions by such paper stuffed into the holes. The dimensions of the case are 370 mm width, 260 mm depth, and 135 mm height, the total weight including transfer mass standards are summed up to around 10 kg. The pictures of the carrying cases are shown in the Figure 2.

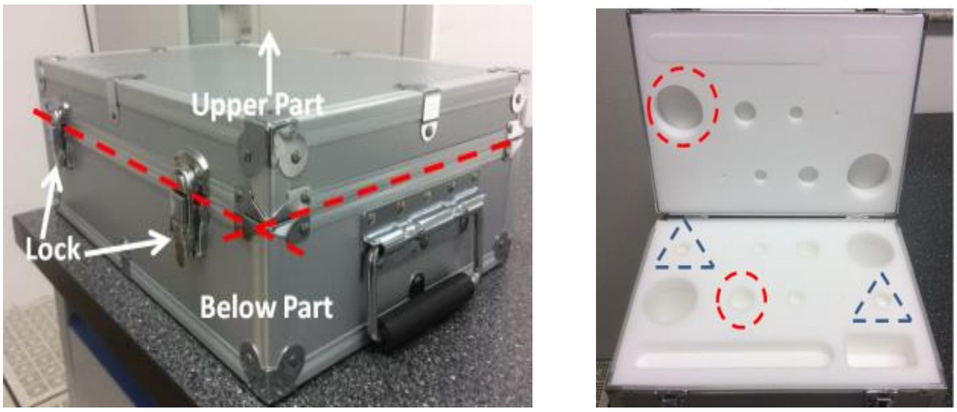

Figure 2. Carrying case of mass traveling standards used for the APMP.M.M-K5 comparison. Right: Carrying case (W: D: H:) and Left: Inside of the case and weight storage place

4. TIME SCHEDULE

The 19 participating laboratories were divided into 5 loops as described below. Each petal may have four or five participants. NIM carried out a comparison among these standards before the comparison and after the conclusion of work within each petal. Four weeks were allowed for the laboratory comparisons and one week for transport between participants. However, there was a problem in the transportation of the artifacts as the A.T.A. Carnet was not used well by some of the custom authorities of the participating countries. This caused a difficulty in custom clearance of the artifacts and delayed the starting date of the laboratory's measurement. The artifacts could not be circulated on schedule and the date of completion of the program was delayed in some petals. The actual arrival date and the departure date are shown in Table 2.2.

Table 2.2 Comparisons and Time Schedule

NMI	Participant	Arrival Date*[1]	Departure Date*[1]	Note	Duration Days*[2]
Petal A					
NIM	China	/	2015/8/17	ATA	/
NML-Phil	Philippines	2015/8/17	2015/9/14	non-ATA, Hand carrying	28
MSL	New Zealand	2015/9/21	2015/10/29	ATA , Posting	38
MASM	Mongolia	2015/11/5	2015/12/7	ATA, Posting	32
NIM	China	2016/1/26	/	ATA	/
Petal B					
NIM	China	/	2015/8/12	ATA	/
VMI	Vietnam	2015/8/12	2015/9/11	non-ATA, Posting	30
SCL	Hong Kong	2015/9/16	2015/10/14	ATA, Posting	28
ITRI	Chinese Taipei	2015/10/30	2015/12/1	non-ATA, Posting	32
KRISS	Republic of Korea	2015/12/5	2016/1/4	ATA, Posting	30
NIM	China	2016/1/21	/	ATA	/
Petal C					
NIM	China	/	2015/8/12	ATA	/
RCM LIPI	Indonesia	2015/8/12	2015/9/15	non-ATA, Posting	34
NMIA	Australia	2015/9/22	2015/10/20	ATA, Posting	28
NISIT	Papua New Guinea	2015/10/29	2015/12/17	non-ATA, Posting	49
NMIM	Malaysia	2015/12/30	2016/1/12	ATA, Posting	13
NIM	China	2016/8/22	/	ATA	/
Petal D					
NIM	China	/	2015/8/12	ATA	/
NMC/A-STAR	Singapore	2015/8/12	2015/9/10	ATA, Posting	29
MUSSD	Sri Lanka	2015/9/21	2015/10/20	ATA, Posting	29
NPLi	India	2015/11/10	2015/12/17	ATA, Posting	37
NIS	Egypt	2016/1/11	2016/6/6	non-ATA, Posting	147
NIM	China	2016/8/22	/	ATA	/
Petal E					
NIM	China	/	2015/8/12	ATA	/
NML-BSTI	Bangladesh	2015/8/12	2015/9/20	non-ATA , Posting	39
NIMT	Thailand	2015/10/1	2015/11/2	ATA, Posting	32
NMIJ	Japan	2015/11/10	2015/12/17	ATA, Posting	37
NIM	China	2015/12/28	/	ATA	/

*[1]Arrival Date and Departure date are approximate date reported by each laboratory.

*[2]Duration Days was to evaluate measurement efficiency in each laboratory.

5. SUMMARY

5.1 Mass Comparator Used by Participants

The mass comparators used by participating laboratories are listed in Tables A.1 to A.5 and instruments used for air density determination reported by participant laboratories (Temperature, Pressure, Humidity and CO_2) are listed in Tables A.6 to A.9 in Annex A.

5.2 Reported Values of Mass and Combined Uncertainty

There are five sets of transfer standards for circulation. Each of these sets were circulated simultaneously within four participant Petals, A, B, C, D and E. Petal A consists of NIM, NML-Phil, MSL and MASM. Petal B consists of VMI, SCL, ITRI and KRISS. Petal C consists of NIM, RCM LIPI, NMIA, NISIT and NMIM. Petal D consists of NIM NMC/A-STAR, MUSSD, NPLi, and NIS. Petal E consists of NIM, NML-BSTI, NIMT and NMIJ/AIST. Table B in Annex B shows the results of reported mass values and their associated combined uncertainties as given by the participants and the pilot laboratory. Corrected results by participants after the first draft were referred to as e.g. “ITRI,c” and “NIS,c”. ITRI reported that the measurement results were calculated with conventional mass due to personnel rearrangement in their lab. NIS changed their results as they were using invalid certificates in the previous calculations. These mistakes were not found out until the pilot laboratory sent out the first draft of the results. After ITRI and NIS reported their mistakes to the pilot laboratory, they sent the revised calculation procedures, modification explanation, and certificates (both wrong and right certificates) to the pilot laboratory.

ITRI changed the mass values of all the samples. Except for the 200 mg, the other standard uncertainties originally reported by ITRI were not changed. NIS updated all the results without the 2 kg results. Except for the 2 kg and 1g results, the other standard uncertainties were modified.

Results under names of NIM of any petal are measured values in the same periods before and after the circulation respectively. These results could be used to make linkage among the five sets of transfer standards.

For each nominal mass value, there are two series of separate group of transfer mass set, Jx and Px.

The results for Jx and Px should be independent but their deviations should show similar characteristics because both should be calibrated with the same standard at each participant laboratory. In the final report of CCM.M-K1, there were methods that examines the average mass for each petal and the average difference between the transfer standards for each petal [1]. The first quantity depends sensitively on traceability to the international prototype (involving an important correction for air buoyancy) but averages over other influences. The second quantity is a good indicator of the mass stability of the travelling standards for the duration of the comparison. This method was also adopted in CCM.M-K4 [2], for it more clearly indicates the relative stability of the travelling standards and the reproducibility of the mass comparator used in the measurement. The difference in mass as obtained by each participant and the pilot laboratory thus serves as a valuable diagnostic tool.

5.3 Consistency of the Analyzed Results

To quantify the discrepancies, tests of equivalence of the measurements were made on the results obtained by the participants corrected by the drift of each travelling standard (Table B.1 to Table B.5). The test is based on a recommended method used for key comparisons [3] based on chi-square statistics.

The criterion for consistency is based on the comparison between $\chi^2(v)$ and χ^2_{obs}. where v is the degree of freedom. If the value of $\chi^2(v) > \chi^2_{\mathrm{obs}}$, then the consistency check pass, or if $\chi^2(v) \leqslant \chi^2_{\mathrm{obs}}$, then the consistency check fail.

In this consistency check, χ^2_{obs} is the observed chi-squared value and $\chi^2(v)$ is from the chi-square test table under the probability of 95% level.

Table 3.1 to 3.5 summarizes the results obtained for the test of consistency among the participants for each travelling standard. It is observed that the results in Petal C/D for 2 kg, Petal C for 200g, Petal A/C/D/E for 50 g, Petal D for 1 g and Petal C/D for 200 mg failed the consistency test. Although individual messages were sent to some related participants in order to resolve these inconsistencies, they were unable to be resolved even after updating the values.

Table 3.1 Tests of consistency on the result reported by the participant laboratories (2 kg)

χ^2 test	**Petal A**		**Petal B**		**Petal C**		**Petal D**		**Petal E**	
	J1	P2	J4	P4	J5	P5	J6	P6	J7	P7
v=N-1	3		4		4		4		3	
Pr{$\chi^2(v) > \chi^2_{\mathrm{obs}}$ }<0.05	Is 7.81 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 7.81 > χ^2_{obs}?	
χ^2_{obs}	0.37	6.93	0.69	1.65	714	6972	6.68	11.50	0.91	0.64
Consistency	Yes	Yes	Yes	Yes	**No**	**No**	Yes	**No**	Yes	Yes

Table 3.2 Tests of consistency on the result reported by the participant laboratories (200 g)

χ^2 test	**Petal A**		**Petal B**		**Petal C**		**Petal D**		**Petal E**	
	J1	P2	J3	P3	J4	P4	J5	P5	J6	P7
v=N-1	3		4		4		4		3	
Pr{$\chi^2(v) > \chi^2_{\mathrm{obs}}$ }<0.05	Is 7.81 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 7.81 > χ^2_{obs}?	
χ^2_{obs}	0.53	3.00	3.12	2.85	22.14	18.24	2.43	1.80	1.67	3.61
Consistency	Yes	Yes	Yes	Yes	**No**	**No**	Yes	Yes	Yes	Yes

Table 3.3 Tests of consistency on the result reported by the participant laboratories (50 g)

χ^2 test	**Petal A**		**Petal B**		**Petal C**		**Petal D**		**Petal E**	
	J2	P1	J3	P2	J4	P3	J6	P4	J7	P7
v=N-1	3		4		4		4		3	
Pr{$\chi^2(v) > \chi^2_{\mathrm{obs}}$ }<0.05	Is 7.81 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 7.81 > χ^2_{obs}?	
χ^2_{obs}	4.59	26.79	5.20	5.95	12.94	12.47	60.0	14.87	8.47	5.63
Consistency	Yes	**No**	Yes	Yes	**No**	**No**	**No**	**No**	**No**	Yes

Table 3.4 Tests of consistency on the result reported by the participant laboratories (1 g)

χ^2 test	**Petal A**		**Petal B**		**Petal C**		**Petal D**		**Petal E**	
	J1	P2	J2	P3	J3	P4	J5	P5	J7	P6
v=N-1	3		4		4		4		3	
Pr{$\chi^2(v) > \chi^2_{\mathrm{obs}}$ }<0.05	Is 7.81 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 7.81 > χ^2_{obs}?	
χ^2_{obs}	0.82	5.16	0.73	0.64	0.88	0.75	0.73	9.02	0.81	0.99
Consistency	Yes	Yes	Yes	Yes	Yes	Yes	Yes	**No**	Yes	Yes

Table 3.5 Tests of consistency on the result reported by the participant laboratories (200 mg)

χ^2 test	**Petal A**		**Petal B**		**Petal C**		**Petal D**		**Petal E**	
	J2	P1	J3	P2	J5	P3	J6	P5	J7	P6
ν=N-1	3		4		4		4		3	
Pr{$\chi^2(\nu) > \chi^2_{obs}$ }<0.05	Is 7.81 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 9.49 > χ^2_{obs}?		Is 7.81 > χ^2_{obs}?	
χ^2_{obs}	1.28	0.29	1.98	2.55	8.42	9.81	3.38	11.64	2.03	5.58
Consistency	Yes	Yes	Yes	Yes	Yes	**No**	Yes	**No**	Yes	Yes

5.4 Interpretation of Comparisons

NIM has two functions as the pilot laboratory. First, it carries out what is essentially a bilateral comparison with each participant. This allows each participant to compare its assigned mass values to those of the NIM. The second function is to allow each participant to compare their assigned mass values to those of the other 18 participating laboratories [1].

In order to link results of participants of all petals, the differences ($diffm_{i,PL}$) between results reported by *i*-th participants (m_i) and pilot laboratory (m_{PL}) were calculated as follows [4]:

$$diffm_{i,\mathrm{PL}} = m_i - m_{\mathrm{PL}} - \varepsilon_{\mathrm{drift}} - \varepsilon_{\mathrm{reprod}} \quad (1)$$

$$m_{\mathrm{PL}} = \frac{m_{\mathrm{PL},i} + m_{\mathrm{PL},i+1}}{2} \quad (2)$$

where,

m_{PL}	is the mean value of the results of the pilot laboratory measurements closest in time to the measurement of participant *i*
$m_{\mathrm{PL},i}$	is value reported by pilot laboratory before the measurement of participant *i*
$m_{\mathrm{PL},i+1}$	is the value reported by pilot laboratory after the measurement of participant *i*
$\varepsilon_{\mathrm{drift}}$	is an error due to the possible drift of the travelling standards
$\varepsilon_{\mathrm{reprod}}$	is an error due to the reproducibility of the pilot laboratory

The error due to the possible drift of the travelling standards $\varepsilon_{\mathrm{drift}}$, was estimated by the difference between the measurements of the pilot laboratory before sending the travelling standard and on its returns. This drift error was considered as centered in zero with a uniform probability density function (PDF) associated to this error.

Table 4.1 Mass changes of the transfer and reference standards during the comparison.

Nominal Value	**Mass change in microgram during the comparison from Aug. 2015 to Sep. 2016**				
	Petal A	**Petal B**	**Petal C**	**Petal D**	**Petal E**
2 kg	**-148**	**-82**	**-116**	**-86**	**22**
200 g	**-1**	**-2**	**7**	**-3**	**-14**
50 g	**-11**	**-7**	**-2**	**-9**	**-8**
1 g	**0.004**	**0.3**	**0.05**	**0.5**	**0.2**
200 mg	**0.2**	**0.2**	**0.3**	**0.5**	**-0.2**

Table 4.2 The standard uncertainty of mass changes of the transfer standards during the comparison.

Nominal Value	The standard uncertainty of mass change (μg)				
	Petal A	**Petal B**	**Petal C**	**Petal D**	**Petal E**
2 kg	**57**	**49**	**49**	**49**	**45**
200 g	**2**	**2**	**2**	**3**	**5**
50 g	**3**	**2**	**2**	**3**	**3**
1 g	**0.4**	**0.4**	**0.4**	**0.4**	**0.4**
200 mg	**0.2**	**0.2**	**0.2**	**0.2**	**0.2**

Besides, for each petal, the value of drift and its standard uncertainty are given in Table 4.1 and 4.2. Here, the error due to the possible drift ($\varepsilon_{\text{drift}}$) of the travelling standards, was estimated by the difference between the measurements of the pilot laboratory before sending the travelling standard and on its returns [4] The expectation and the dispersion for the drift error (of the travelling standards) were assumed as follows:

$$E(\varepsilon_{\text{drift}}) = 0 \tag{3}$$

$$\sigma(\varepsilon_{\text{drift}}) = \frac{m_{\text{PL},i+1} - m_{\text{PL},i}}{\sqrt{12}} \tag{4}$$

On November 2012, NIM purchased 5 sets of mass standards with nominal values of 2 kg, 200 g, 50 g, 1 g, 200 mg. These were choose as the transfer standards which were then monitored to 12th Aug. 2015 at the pilot laboratory and then re-checked for reproducibility after returning to the pilot lab (Aug. 22nd 2016). The standard uncertainty of reproducibility $\varepsilon_{\text{reprod}}$ was estimated in the same way as the drift error, assuming a uniform (rectangular) distribution.

In reference [4], there was also a co-pilot laboratory participating in the comparison. So the error due to the reproducibility associated with the measurements of the pilot laboratory was estimated by the difference between its results and results reported by co-pilot laboratory for each petal. But there was no co-pilot laboratory in APMP.M.M-K5. In reference [5], the uncertainties of difference values were supposed to be comparable with the standard deviation of the mass values that shows reproducibility of the set of transfer standards kept in the pilot laboratory without transportation. Here we followed [5]’s method, and the summary of standard uncertainties due to drift and reproducibility errors $\varepsilon_{\text{reprod}}$ (of the pilot laboratory) are shown in Table 5.

Table 5. The standard uncertainty of drift (u_{drift})and reproducibility(u_{drift}) errors (mg)

Nominal Value	***Max*** u_{drift}	u_{reprod}
2 kg	0.0427	0.0638
200 g	0.0030	0.0018
50 g	0.0030	0.0018
1 g	0.00022	0.00051
200 mg	0.00025	0.00050

Due to the inconsistencies found in the reported data and in order to consider relevant correlations, the pilot laboratory decided to determine the reference value by using the Monte Carlo method (MCM) as recommended by Cox [3].

6. NUMERICAL SIMULATION by MONTE CARLO METHOD

In order to estimate the reference value (RV) for this comparison (m_{RV}), the mass differences (D_i) between participants and RV, and the mass differences ($d_{i,j}$) between any pair of participating laboratories, numerical simulation based on MCM was adopted.

The differences between mass reported by the participant laboratories and the RV was calculated as follows,

$$D_i = diffm_{\mathrm{i,PL}} - m_{\mathrm{RV}} \tag{5}$$

In order to calculate the degree of equivalence (DoE) for any pair of participant laboratories, the mass differences between two laboratories, were calculated as follows,

$$d_{i,j} = diffm_{i,\mathrm{PL}} - diffm_{j,\mathrm{PL}} \tag{6}$$

In reference [4], the MCM algorithm in CCM comparison was first adopted and it was followed by reference [6]. Risk software and LabVIEW software were used respectively. Besides, there are software applications that have been specifically developed for calculating uncertainties based on the MCM method, e.g. @RISK [7] and toolbox in MATLAB [8].

In this paper, we also used Risk software and Excel to evaluate the uncertainty.

6.1 Input Quantities for Monte Carlo Method

The input quantities for the numerical simulation are listed in from Table C.1 to C.5, where $N(\mu,\sigma^2)$ means normal distribution and $U(a,b)$ means uniform distribution, and a and b are lower limit and upper limit respectively.

From the resulting probability density function (PDF) of the numerical simulation, the median values of the four link laboratories (NIM, KRISS, NMIA, NMIJ) were taken as the best estimation for the corresponding estimator of RV. The standard deviations were taken as the standard uncertainty of the quantity, as performed in CCM.M-K6 [4] and CCM.M-K7 [6].

The correlation coefficient between mass measurements done by the same laboratory was estimated as $r(m_{\mathrm{NIM,i}}, m_{\mathrm{NIM,j}}) = 0.3$ for any of the pairs. The correlation coefficient indicated above, was estimated as 0.3 due to the fact that the variance contribution of the type B uncertainty is around 30 % with regard to the variance of the travelling standard estimated by the pilot laboratory [6].

The results $m_{\mathrm{NIM}\text{-}i}$ ($i = 1, 2, \ldots, 10$) are correlated with the correlation matrix:

$$r(m_{\mathrm{NIM},i}, m_{\mathrm{NIM},i}) = \begin{pmatrix} 1 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 1 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 1 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 1 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 1 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 1 & 0.3 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 1 & 0.3 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 1 & 0.3 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 1 & 0.3 \\ 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 0.3 & 1 \end{pmatrix} \qquad (7)$$

6.2 Non-linked RV and DoE

The median of the mass difference *set*, $\{\Delta m_{\mathrm{NIM}}, \Delta m_{\mathrm{KRISS}}, \Delta m_{\mathrm{NMIA}}, \Delta m_{\mathrm{NMIJ}}\}$ was calculated as the best estimator of non-linked RV (NLRV) for this comparison.

The DoE is the degree to which the measured value of a participant is consistent with the NLRV. This is expressed by the deviation D_i from the non-linked RV and the expanded uncertainty of this deviation compared at the 95% level of confidence. The criteria for the equivalence is : if DoE < 1, then the measurement result is equivalent ; if DoE⩾1, then the result is not equivalent.

DoEs were estimated in each step of MCM by the following equation, which can give a normalized value for the DoE.

$$D_i = \mathrm{mean}\{\Delta m_i - \Delta m_{\mathrm{RV}}\} \qquad (8)$$

$$DoE_{\mathrm{i}} = \frac{|D_i|}{2 \cdot u_{D_i}} \qquad (9)$$

where, i is index of participants, u_{D_i} denotes the standard uncertainty of D_i .

Histograms resulting from numerical simulation for DoE between NMIs and NLRV, are listed from Figure D.1 to D.20 and Table D.1 to D.10.

6.3 Simulation Result

The software program @RISK (Palisade Corporation), was add onto Microsoft Excel©. It is easy for us to add Monte Carlo simulation using @RISK in Excel and it has functions in Excel for defining probability distributions and analyzing output results. In this comparison, the numerical simulation was done in @Risk 7.5 for Microsoft Excel 15 with 1×10^5 trials. And the results did not depend greatly on the number of iterations for values larger than 1×10^5.

7. LINKAGE to CCM.M-K5

This analysis combines the APMP.M.M-K5 comparison results with the CCM.M-K5 results of the link laboratories to estimate the DoE for each laboratory relative to the CCM KCRVs, as required by the MRA. The linking method used was that outlined in APMP.M.M-K1 by Dr. Chris Sutton [9].

In CCM.M-K5, there were two KCRVs for the two transfer standards of the same nominal value, all the values are listed in Table 6. In [10], the author used MCM method to process the measurement data of CCM.M-K5 and the unique KCRV was given out for each nominal value as well as the DoE. In this report, after discuss with APMP TCM Chair Sheng-Jui Chen and Former Chair Dr. Shih Mean Lee, we decide to link measurement results to the reference value of Jx and Jy. Here we adopted the method mentioned in APMP.M.M-K6.1[11].

Table.6 KCRV of transfer samples by traditional GUM method in CCM.M-K5

Nominal Value	Marking	CCM.M-K5 report[5]
2 kg	Jx	KCRV=0.051, *U*=0.074
	Jy	KCRV=0.069, *U*=0.096
200 g	Jx	KCRV=0.0116, *U*=0.0100
	Jy	KCRV=0.0137, *U*=0.0078
50 g	Jx	KCRV= -0.0090, *U*=0.0050
	Jy	KCRV=0.0005, *U*=0.0042
1 g	Jx	KCRV=0.0002, *U*=0.0013
	Jy	KCRV=0.0004, *U*=0.0010
200 mg	Jx	KCRV= -0.0001, *U*=0.0009
	Jy	KCRV= -0.0001, *U*=0.0011

NIM, KRISS NMIA and NMIJ have participated in the CCM.M-K5 and are the linking laboratories. Their deviations of each reported mass value of these participants $m_{eq,i}$ and its associated expanded uncertainty $U(m_{eq,i})$ for the *i*-th laboratory in CCM comparison are indicated in Table 7 [5].

Table 7. The deviation of linking labs in CCM.M-K5

Nominal Value (mg) / **NMIs**	**Jx 2kg**		**Jy 2kg**	
	$m_{eq,i}$	$U(m_{eq,i})$	$m_{eq,i}$	$U(m_{eq,i})$
NIM	0.204	0.087	0.075	0.095
KRISS	-0.041	0.089	-0.170	0.088
NMIA	0.239	0.298	0.100	0.300
NMIJ	-0.035	0.123	-0.045	0.128

Nominal Value (mg) NMIs	Jx 200 g		Jy 200 g	
	$m_{eq,i}$	$U(m_{eq,i})$	$m_{eq,i}$	$U(m_{eq,i})$
NIM	0.0056	0.0118	0.0000	0.0121
KRISS	-0.0214	0.0101	-0.0330	0.0105
NMIA	-0.0014	0.0190	-0.0120	0.0193
NMIJ	-0.0098	0.0146	-0.0131	0.0149

Nominal Value (mg) NMIs	Jx 50 g		Jy 50 g	
	$m_{eq,i}$	$U(m_{eq,i})$	$m_{eq,i}$	$U(m_{eq,i})$
NIM	0.0022	0.0087	0.0027	0.0084
KRISS	-0.0028	0.0053	-0.0043	0.0047
NMIA	-0.0008	0.0078	-0.0023	0.0074
NMIJ	0.0046	0.0062	0.0010	0.0058

Nominal Value (μg) NMIs	Jx 1 g		Jy 1 g	
	$m_{eq,i}$	$U(m_{eq,i})$	$m_{eq,i}$	$U(m_{eq,i})$
NIM	0.00	1.65	0.00	1.90
KRISS	0.20	1.05	0.00	1.42
NMIA	0.00	1.18	-0.10	1.52
NMIJ	0.01	1.32	0.61	1.63

Nominal Value (μg) NMIs	Jx 200 mg		Jy 200 mg	
	$m_{eq,i}$	$U(m_{eq,i})$	$m_{eq,i}$	$U(m_{eq,i})$
NIM	-0.42	1.13	-0.21	1.22
KRISS	1.68	0.60	1.89	0.76
NMIA	-0.52	0.79	-0.21	0.92
NMIJ	1.48	0.79	1.83	0.92

The reference values of the current comparison linked to the CCM.M-K5 (Linked Reference Value, LRV) could be calculated by the following equations[11]. Note that, only participants' values with uncertainty bars crossing the reference line are used in equations (10)~(12)[5].

LRV=

$$\frac{w_{\mathrm{NIM}}(diffm_{\mathrm{NIM,PL}} - m_{eq,\mathrm{NIM}}) + w_{\mathrm{KRISS}}(diffm_{\mathrm{KRISS,PL}} - m_{eq,\mathrm{KRISS}}) + w_{\mathrm{NMIA}}(diffm_{\mathrm{NMIA,PL}} - m_{eq,\mathrm{NMIA}}) + w_{\mathrm{NMIJ}}(diffm_{\mathrm{NMIJ,PL}} - m_{eq,\mathrm{NMIJ}})}{w_{\mathrm{NIM}} + w_{\mathrm{KRISS}} + w_{\mathrm{NMIA}} + w_{\mathrm{NMIJ}}} \tag{10}$$

$$w_i = \frac{1}{u_i^2 + U^2(m_{eq,i})/4} \tag{11}$$

and,

$$u_{LRV} = \frac{1}{\sqrt{w_{\mathrm{NIM}} + w_{\mathrm{KRISS}} + w_{\mathrm{NMIA}} + w_{\mathrm{NMIJ}}}} \tag{12}$$

where $diffm_{i,\mathrm{PL}}$ is shown in equation (1).

Then LRV and u_{LRV} could be calculated and listed respectively in Table 8. And these values were simulated also by MCM method. The histograms resulting from numerical simulation for LRV are listed in Figure F.1 to F.20, as well as deviations from LRV (Figure G.1).

Table.8 LRV linked to Jx/Jy KCRV in CCM.M-K5

Nominal Value	LRV	u_{LRV}
Jx 2 kg	-0.045 mg	0.100 mg
Jy 2 kg	-0.075 mg	0.046 mg
Jx 200 g	-0.0022 mg	0.0047 mg
Jy 200 g	0.0035 mg	0.0048 mg
Jx 50 g	-0.0035 mg	0.0021 mg
Jy 50 g	-0.0018 mg	0.0020 mg
Jx 1 g	-0.19 µg	0.56 µg
Jy 1g	-0.25 µg	0.62 µg
Jx 200 mg	0.71 µg	0.45 µg
Jy 200 mg	0.47 µg	0.48 µg

8. COMMENTS and CONCLUSION

8.1 Comments

1) The measurements for the APMP.M.M-K5 comparison were carried out by the participating laboratories over a period of one year. This complicated mass comparison including nineteen participants lasted for a long time due to the different usage and understanding of ATA carnet and choice of posting method.
2) On Dec 2nd 2015, 50 g P1 weight was dropped on the floor. It had some scratches at the bottom of the weight. After that MASM did one more measurement for this 50 g weight and informed the pilot laboratory.
3) During the linking the APMP.M.M-K5 result to the CCM.M-K5, although no reference value is required for the APMP comparison, we also provided the non-linked RV in 6.2, for the reason that the KCRV was not provided in the final report of CCM.M-K5. The LRV for different weights (Jx/Jy) were also listed in Table.7 and simulated by MCM.

8.2 Conclusion

This report summarizes the procedure and the analysis of the APMP.M.M-K5 comparison of 2 kg, 200 g, 50 g, 1 g and 200 mg stainless steel mass standards. Seven sets of standards were prepared, monitored, and five of them were transferred to the participant laboratories. ATA carnet was used in the transportation of the standards but it was overdue in several petals. Other than one weight was dropped in Petal A, there were no other serious problems encountered during the comparison.

All participants reported the results of measurements based on values of their reference standards, but some participants did not send the true mass value at first and some participants did not give feedback to the pilot laboratory on time.

After the consistency check, the median of the mass difference between results reported by linking participant laboratories (KRISS, NMIA, NMIJ) and the pilot laboratory was taken as the RV.

All analyses were done by Monte Carlo simulation method and were evaluated within their expanded uncertainties with a coverage factor of $k = 2$. The result are as shown in Annex E and G. With reference to the NLRV and LRV, it was noted that :

1) NML-Phil, MUSSD, NPLi were not consistent with the NLRV at 2 kg
2) RCM LIPI were not consistent with the NLRV at 200 g
3) RCM LIPI, NPLi , NML-Phil, NIS were not consistent with the NLRV at 50 g
4) NML-Phil, NPLi were not consistent with the LRV at 2 kg
5) RCM LIPI were not consistent with the LRV at 200 g
6) RCM LIPI, NPLi , NML-Phil, NIS were not consistent with the LRV at 50 g

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ANNEX A

Table A.1 Mass Comparators used by participant laboratories (2 kg)

Acronym	Manufacturer	Type	Range	Resolution
NIM	Mettler Toledo	AT10005	10.011 kg	10 µg
NML-Phil	Mettler Toledo	AX10005	10.011 kg	10 µg
MSL	Mettler Toledo	AX10005	10 kg	10 µg
MASM	Sartorius	CCE10000S(manual)	10 kg	100 µg
VMI	Sartorius	CC10000S-L	10.050 kg	100 µg
SCL	Mettler Toledo	AX10005	10 kg	10 µg
ITRI	Sartorius	CCE10000U-L	10.05 kg	10 µg
KRISS	Mettler Toledo	AT10005	10 kg	10 µg
RCM LIPI	Sartorius	CC 10000 UL	10 kg	10 µg
NMIA	Mettler Toledo	AX32004	32 kg	100 µg
NISIT	Mettler Toledo	PR8002	8100 g	10 mg
NMIM	Mettler Toledo	AT10005	10.011 kg	10 µg
NMC/A-STAR	Mettler Toledo	AT10005	10 kg	10 µg
MUSSD	Sartorius	CC3000	3 kg	100 µg
NPLi	Mettler Toledo	AX64004	50 kg (64 kg)	100µg
NIS	Sartorius	CC10000U-L	10 kg	10 µg
NML-BSTI	Mettler Toledo	—	2 kg	100 µg
NIMT	Mettler Toledo	AT10005	10.011 kg	10 µg
NMIJ/AIST	Mettler Toledo	AT10005	10.011 kg	10 µg

Table A.2 Mass Comparators used by participant laboratories (200 g)

Acronym	Manufacturer	Type	Range	Resolution
NIM	Mettler Toledo	m-one	1 kg	0.1 µg
NML-Phil	Mettler Toledo	AX1005	1.109 kg	10 µg
MSL	Mettler Toledo	HK1000	1 kg	0.1 µg / 1.0 µg
MASM	Sartorius	CC1000 automatic	1 kg	2 µg
VMI	Sartorius	CC1000S-L	1 kg	1 µg
SCL	Mettler Toledo	AT1005	1 kg	10 µg
ITRI	Mettler Toledo	AX1006	1.011 kg	1 µg
KRISS	Mettler Toledo	M-one	1 kg	0.1 ug
RCM LIPI	Mettler Toledo	AT1005	1.010 kg	10 µg
NMIA	Mettler Toledo	HK1000MC	1.001 kg	1 µg
NISIT	Mettler Toledo	XP205DR2	220 g	100 µg
NMIM	/	/	/	/
NMC/A-STAR	Mettler Toledo	AT1006	1 kg	1 µg
MUSSD	Mettler Toledo	XP 205	220g	10 µg
NPLi	Mettler Toledo	AX206	200 g	1 µg
NIS	Mettler Toledo	AT1006	1 kg	1 µg
NML-BSTI	Mettler Toledo	/	1 kg	10 µg
NIMT	Mettler Toledo	AT1005	1.109 kg	10 µg
NMIJ/AIST	Mettler Toledo	AT1006	1.011 kg	1 µg

Table A.3 Mass Comparators used by participant laboratories (50 g)

Acronym	Manufacturer	Type	Range	Resolution
NIM	Mettler Toledo	m-one	1 kg	0.1 µg
NML-Phil	Mettler Toledo	AX1005	1109 g	10 µg
MSL	Mettler Toledo	HK1000	1000 g	0.1 µg / 1.0 µg
MASM	Sartorius	CC50 manual	50 g	1 µg
VMI	Mettler Toledo	AX106	111 g	1 µg
SCL	Mettler Toledo	AX106	100 g	1 µg
ITRI	Mettler Toledo	AT106H	111 g	1 µg
KRISS	Mettler Toledo	AT106	100 g	1 ug
RCM LIPI	Mettler Toledo	AT106	110 g	1 µg
NMIA	Sartorius	CC111	111 g	1 µg
NISIT	Mettler Toledo	XP205DR1	80 g	10 µg
NMIM	Mettler Toledo	AT106H	111 g	1 µg
NMC/A-STAR	Mettler Toledo	A100	100 g	1 µg
MUSSD	Mettler Toledo	XP 205	220 g	10 µg
NPLi	Mettler Toledo	AX206	200 g	1 µg
NIS	Mettler Toledo	AT1006	1 kg	1 µg
NML-BSTI	Sartorius	/	100 g	1 µg
NIMT	Mettler Toledo	AT106	111 g	1 µg
NMIJ/AIST	Mettler Toledo	AT107H	111 g	0.1 µg

Table A.4 Mass Comparators used by participant laboratories (1 g)

Acronym	Manufacturer	Type	Range	Resolution
NIM	Mettler Toledo	a5	6.1 g	0.1 ug
NML-Phil	Mettler Toledo	XP6U	6.1 g	0.1 µg
MSL	Mettler Toledo	UMX5	5 g	0.1 µg
MASM	Sartorius	C5S(manual)	5 g	0.1 µg
VMI	Mettler Toledo	UMX5	5.1 g	0.1 µg
SCL	Mettler Toledo	UMX5	5 g	0.1 µg
ITRI	Mettler Toledo	UMX5	5.1 g	0.1 µg
KRISS	Mettler Toledo	a5	5 g	0.1 ug
RCM LIPI	Mettler Toledo	XP6U	5 g	0.1 µg
NMIA	Sartorius	CC111	111 g	1 µg
	Mettler Toledo	UMX5	5 g	0.1 µg
NISIT	Mettler Toledo	XP2U	2.1 g	0.1 µg
NMIM	Mettler Toledo	a5	5.1 g	0.1 µg
NMC/A-STAR	Mettler Toledo	a5	5 g	0.1 µg
MUSSD	Mettler Toledo	UM3	2g	0.1 µg
NPLi	Mettler Toledo	MT5	5 g	1 µg
NIS	Sartorius	CC6	6 g	0.1 µg
NML-BSTI	Sartorius	/	6 g	0.1 µg
NIMT	Mettler Toledo	UMT2	2.1 g	0.1µg
NMIJ/AIST	Mettler Toledo	a5	5.1 g	0.1 µg

Table A.5 Mass Comparators used by participant laboratories (200 mg)

Acronym	**Manufacturer**	**Type**	**Range**	**Resolution**
NIM	Mettler Toledo	a5	6.1 g	0.1 ug
NML-Phil	Mettler Toledo	XP6U	6.1 g	0.1 µg
MSL	Mettler Toledo	UMX5	5 g	0.1 µg
MASM	Sartorius	C5S(manual)	5 g	0.1 µg
VMI	Mettler Toledo	UMX5	5.1 g	0.1 µg
SCL	Mettler Toledo	UMX5	5 g	0.1 µg
ITRI	Mettler Toledo	UMX5	5.1 g	0.1 µg
KRISS	Mettler Toledo	a5	5 g	0.1 ug
RCM LIPI	Mettler Toledo	XP6U	5 g	0.1 µg
NMIA	Mettler Toledo	UMX5	5 g	0.1 µg
NISIT	Mettler Toledo	XP2U	2.1 g	0.1 µg
NMIM	Mettler Toledo	a5	5.1 g	0.1 µg
NMC/A-STAR	Mettler Toledo	a5	5 g	0.1 µg
MUSSD	Mettler Toledo	UM3	2g	0.1 µg
NPLi	Mettler Toledo	MT5	5 g	1 µg
NIS	Sartorius	CC6	6 g	0.1 µg
NML-BSTI	Sartorius	/	6 g	0.1 µg
NIMT	Mettler Toledo	UMT2	2.1 g	0.1 µg
NMIJ/AIST	Mettler Toledo	UMT2	2.1 g	0.1 µg

Table A.6 Instruments used for air density determination reported by participant laboratories (Temperature)

Acronym	Manufacturer	Type	Range	Resolution	Uncertainty(1σ)
NIM	Mettler Toledo (50g, 200g)	Klimet A30V	(15~25)°C	0.001 °C	0.007 °C
	NIM(2 kg,1g,200 mg)	ADMS1011	(-40~60)°C	0.01 ℃	0.2°C
NML-Phil	Technetics	mikromec	(-30 ~ 70)°C	0.01 °C	0.024 °C
MSL	Vaisala	PTU303	(17 ~23)°C	0.001 °C	0.05 °C
	ASL F250 bridge with PRT		(0 ~25)°C	0.0025 °C	0.0035 °C
	Omega iTHX-M microserver with iTHP5 probe		(17 ~23)°C	0.1 °C	0.065 °C
MASM	Vaisala	PTU-200	(0 ~50)°C	0.1 °C	0
VMI	Vaisala	PTU-200	(0 ~50)°C	0.1 °C	0.1 °C
SCL	Extech	SD700	(0 ~50)°C	0.1 °C	0.1 °C
ITRI	Hart Scientific	1560	(0~100) °C	0.0001 °C	0.013 °C
	FLUKE	Meter:1529	(-200 ~ 500) °C	0.001 °C	0.013 °C
KRISS	Vaisala	PTU200	(<0-60) °C	0.01 °C	0.03 °C
RCM LIPI	Pyrosales	Band 5	(0-30) °C	0.001 °C	0.0095 °C
NMIA	Vaisala*(2kg,50g,1 g,200mg)	PT100	(0-50) °C	0.01 °C	0.035 °C
	Pyrosales(200g)	PT100	(0-50) °C	0.01 °C	0.0015 °C
NISIT	PCWI	DewMaster Hygrometer	(0-30) °C	0.1 ˚C	± 0.3 ˚C
NMIM	RUSKA	2456-LEM	(15-35) °C	0.01 °C	0.13 °C
	EXTECH Ins.	SD700	(15-35) °C	0.01 °C	0.15 °C
NMC/A-STAR	Thermometrics	/	(19-23) °C	0.001 °C	0.024 °C
MUSSD	CHINO	HN-CSHT	(-40~ 80) °C	0.1 °C	0.05 °C
NPLi	Lambrecht	Digital	(10~ 70) °C	0.01 °C	0.05 °C
NIS	Fluke	1502A	/	0.001°C	0.004 °C
NML-BSTI	Ahlbron		(18~25)°C	0.01°C	0.20 °C
NIMT	Yokogawa	7563	(0~40) °C	0.01 °C	0.01 °C
NMIJ/AIST	TECHCOL SEVEN	H211	(0~50) ℃	0.1 ℃	0.15 ℃

Table A.7 Instruments used for air density determination reported by participant laboratories (Pressure)

Acronym	Manufacturer	Type	Range	Resolution	Uncertainty(1σ)
NIM	Mettler Toledo (50g, 200g)	Klimet A30V	(35~1060)hPa	0.001 hPa	0.0012 hPa
	NIM(2 kg,1g,200 mg)	ADMS1011	(500～1100) hPa	0.1 hPa	0.15hPa
NML-Phil	Vaisala	PTB110	(600~ 1100)hPa	0.1 hPa	0.003 % of F.S
MSL	Vaisala	PTU303	(900~1050) hPa	0.001 hPa	0.01 hPa
	Druck	DPI 141	(800~1150)hPa	0.01 hPa	0.01 hPa
	Druck	DPI 141	(800~1150)hPa	0.01 hPa	0.01 hPa
MASM	Vaisala	PTU-200	(400~ 1100)hPa	0.1 hPa	0.08 hPa
VMI	Vaisala	PTU200	(500~1100) hPa	0.1 hPa	0.05 hPa
SCL	Extech	SD700	(10~1100)hPa	0.1 hPa	0.2 hPa
ITRI	DHI	Rpm3 A0020b	≤1400 hPa	0.001 hPa	0.045 hPa
	Druck	DPI 140	(800~1150)hPa	0.15 hPa	0.0356 hPa
KRISS	Vaisala	PTU200	(500-1100) hPa	0.1 hPa	0.3 hPa
RCM LIPI	Vaisala	PTB220A	(40~110)hPa	0.01 hPa	0.035 hPa
NMIA	Vaisala	Silicon capacitive	(500~1100)hPa	0.01 hPa	0.015 hPa
NISIT	/	/	/	/	/
NMIM	RUSKA	2456-LEM	(1000~1100)hPa	0.1 hPa	0.1 hPa
	EXTECH Ins.	SD700	(1000~1100)hPa	0.1 hPa	0.1 hPa
NMC/A-STAR	Paroscientific	740-16B	(980~1030)hPa	0.01 hPa	0.17 hPa
MUSSD	LUFFT Mess	8120.11	(300~1300)hPa	0.1 hPa	0.12 hPa
NPLi	/	/	(750 ~1150) hPa	0.01 hPa	$Q(a, b) = \sqrt{(a^2 + b^2)}$ Q(0.03 hPa, 0.01 % of reading)
NIS	Druck	DPI 142	(600~1150)hPa	0.1 Pa	0.243 hPa
NML-BSTI	Ahlbron	/	(700~1050)hPa	0.1 hPa	2 hPa
NIMT	Yokogawa	MT220	(0~1300)hPa	0.01 hPa	0.016 hPa
NMIJ/AIST	Yokogawa	MT110	(0~1300)hPa	0.01 hPa	0.15 hPa

Table A.8 Instruments used for air density determination reported by participant laboratories (Humidity)

Acronym	Manufacturer	Type	Range	Resolution	Uncertainty(1σ)
NIM	Mettler Toledo (50g, 200g)	Klimet A30V	(20~80) %RH	0.01%RH	0.7%RH
	NIM (2 kg, 1g,200 mg)	ADMS1011	(0～100)%RH	0.1 %RH	1.7%RH
NML-Phil	Technetics	mikromec	(0~100) %RH	0.01%RH	0.26 %RH.
MSL	Vaisala	PTU303	(30~80) %RH	0.01%RH	0.3%RH
	Michell 3000 dewpoint meter		/	/	/
	Omega iTHX-M microserver with iTHP5 probe		(30~80) %RH	0.1 %RH	0.75%RH
MASM	Vaisala	PTU-200	(0~100) %RH	%RH	%RH
VMI	Vaisala	PTU200	(0~100) %RH	0.1 %RH	0.6%RH
SCL	Extech	SD700	(10~90) %RH	0.1 %RH	0.4 %RH
ITRI	Rotronic	HygroLab 2	(0~100) %RH	0.1 %RH	0.15%RH
	Rotronic	HYGROPALM	(0~99.9) %RH	0.1 %RH	0.15%RH
KRISS	Vaisala	PTU200	(0.8-100) %RH	0.1 %RH	0.5 %RH
RCM LIPI	CSIRO/Phillips sensor	Capacitive thin film humidity probe	(30-60) %RH	0.1%RH	0.7%RH
NMIA	Vaisala *(for 2kg,50g,1 g,200mg)	Polymer thin film capacitive	(0~100) %RH	0.1 %RH	0.5%RH
	Vaisala *(for 200g)				0.4%RH
NISIT	PCWI	DewMaster Hygrometer	(0~90) %RH	0.1% rh	3.0% RH
NMIM	RUSKA	2456-LEM	(40~70) %RH	0.1 %RH	1.6%RH
	EXTECH Ins.	SD700	(40~70) %RH	0.1 %RH	1.5%RH
NMC/A-STAR	General Eastern	1111H-SR	(6~11) %RH	0.01%RH	0.2%RH
MUSSD	CHINO	HN-CSHT	(0~100) %RH	0.1 %RH	0.55%RH
NPLi	/	/	(10 ~ 95) % RH	0.1 % RH	0.2 % RH
NIS	Love	LC1508-00	/	0.1 %	± 0.7 %
NML-BSTI	Ahlbron	/	(10~74) %RH	0.1%RH	0.5%RH
NIMT	Shinyei	TRH-7X; THP-74	95%RH max without dew condensation	0.1% (PC display 0.01%)	0.6%RH
NMIJ/AIST	TECHCOL SEVEN	H211	(0~99.9) %RH	0.1%RH	1.5%RH

Table A.9 Instruments used for air density determination reported by participant laboratories (CO_2)

Acronym	Manufacturer	Type	Range	Resolution	Uncertainty(1σ)
NIM	Mettler Toledo (50g, 200g)	Klimet A30V	(200~1500) ppm	0.1 ppm	4.5 ppm
	NIM(2 kg,1g,200 mg)	ADMS1011	(0～3000) ppm	0.1 ppm	20 ppm
NML-Phil	/	/	/	/	/
MSL	The CO_2 value was taken as 0.0004				
MASM	/	/	/	/	/
VMI	/	/	/	/	/
SCL	/	/	/	/	/
ITRI	/	/	/	/	/
	meteolabor ag (for 200 g, 50 g, 1 g, 200 mg)	$KLA30VCO_2$	1200 ppm	0.1 ppm	22.3 ppm
KRISS	/	/	/	/	/
RCM LIPI	/	/	/	/	/
NMIA	/	/	/	/	/
NISIT	/	/	/	/	/
NMIM	/	/	/	/	/
NMC/A-STAR	/	/	/	/	/
MUSSD	/	/	/	/	/
NPLi	Agilent	Chromatography	Up to 1000 ppm	/	0.37 ppm
NIS	/	/	/	/	/
NML-BSTI	/	/	/	/	/
NIMT	/	/	/	/	/
NMIJ/AIST	FUJI ELECTRIC	ZRH	(0~500)ppm	0.1 ppm	use as a monitor

ANNEX B

Table B.1 Results of transfer standards, reported from the participants and the pilot. The $\boldsymbol{m}_{\mathrm{A}}$ represents residual value from the nominal mass value, and $\boldsymbol{u}_{\mathrm{c}}$ represents combined standard uncertainty (k = 1) claimed by each participant.

Petal A		NIM		NML-Phil		MSL		MASM		NIM	
Nominal value	Marking	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)
2 kg	J1	2.13	0.19	1.4	1.5	2.071	0.055	2.13	0.19	2.02	0.19
	P2	5.04	0.19	1.1	1.5	5.019	0.055	5.07	0.17	4.85	0.19
200 g	J1	0.1294	0.0084	0.11	0.05	0.1239	0.0056	0.120	0.014	0.1293	0.0084
	P2	0.2391	0.0084	0.16	0.05	0.2297	0.0056	0.229	0.014	0.2182	0.0084
50 g	J2	0.0152	0.0030	-0.003	0.015	0.00933	0.00176	0.0027	0.008	0.0088	0.0030
	P1	0.0688	0.0030	-0.004	0.015	0.06024	0.00176	0.0518	0.008	0.0540	0.0030
1 g	J1	0.0023	0.0014	0.000	0.005	0.00113	0.00052	0.001361	0.0015	0.0027	0.0014
	P2	0.0157	0.0014	0.009	0.005	0.01406	0.00052	0.011562	0.0015	0.0155	0.0014
200 mg	J2	0.0053	0.0007	0.006	0.003	0.00600	0.00031	0.005469	0.0006	0.0060	0.0007
	P1	0.0070	0.0007	0.008	0.003	0.00723	0.00031	0.007378	0.0006	0.0063	0.0007

Table B.2 Results of transfer standards, reported from the participants and the pilot. The $\boldsymbol{m}_{\mathrm{A}}$ represents residual value from the nominal mass value, and $\boldsymbol{u}_{\mathrm{c}}$ represents combined standard uncertainty (k = 1) claimed by each participant.

Petal B		NIM		VMI		SCL		ITRI,c		KRISS		NIM	
Nominal value	Marking	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)
2 kg	J4	1.77	0.19	2.0	0.32	1.9	0.3	1.80	0.43	1.77	0.041	1.76	0.19
	P4	5.18	0.19	5.3	0.32	5.3	0.3	5.14	0.43	5.05	0.041	5.02	0.19
200 g	J3	0.1475	0.0083	0.140	0.022	0.14	0.03	0.119	0.014	0.138	0.0044	0.1379	0.0083
	P3	0.2532	0.0083	0.247	0.022	0.24	0.03	0.226	0.014	0.247	0.0044	0.2451	0.0083
50 g	J3	0.0270	0.0030	0.024	0.012	0.017	0.011	0.0169	0.0034	0.022	0.0023	0.0207	0.0030
	P2	0.0755	0.0030	0.074	0.012	0.069	0.011	0.0648	0.0034	0.069	0.0023	0.0687	0.0030
1 g	J2	0.0018	0.0014	0.0021	0.0015	0.002	0.003	0.0016	0.0013	0.0030	0.0012	0.0024	0.0014
	P3	0.0121	0.0014	0.0134	0.0015	0.012	0.003	0.0121	0.0013	0.0129	0.0012	0.0128	0.0014
200 mg	J3	0.0065	0.0007	0.0081	0.0010	0.0066	0.0015	0.0068	0.0008	0.0065	0.0010	0.0062	0.0007
	P2	0.0070	0.0007	0.0088	0.0010	0.0069	0.0015	0.0073	0.0008	0.0070	0.0010	0.0056	0.0007

Table B.3 Results of transfer standards, reported from the participants and the pilot. The $\boldsymbol{m}_{\mathrm{A}}$ represents residual value from the nominal mass value, and $\boldsymbol{u}_{\mathrm{c}}$ represents combined standard uncertainty (k = 1) claimed by each participant.

Petal C		NIM		RCM LIPI		NMIA		NISIT		NMIM		NIM	
Nominal value	Marking	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)
2 kg	J5	2.00	0.19	1.96	0.073	1.976	0.163	0.5	0.010	2.024	0.1088	1.89	0.19
	P5	5.09	0.19	5.09	0.073	4.956	0.163	0.5	0.010	5.297	0.1088	4.96	0.19
200 g	J4	0.1508	0.0083	0.10	0.009	0.153	0.011	0.06	0.1	0.151	0.031	0.1422	0.0083
	P4	0.2533	0.0083	0.22	0.009	0.259	0.011	-0.04	0.1	0.252	0.031	0.2494	0.0083
50 g	J4	0.0207	0.0030	0.002	0.0043	0.014	0.0042	-0.001	0.031	0.012	0.010	0.0144	0.0030
	P3	0.0728	0.0030	0.057	0.0043	0.064	0.0042	0.014	0.031	0.064	0.010	0.0659	0.0030
1 g	J3	0.0025	0.0014	0.0021	0.00099	0.0013	0.0013	0.0006	0.007	0.003	0.0015	0.0024	0.0014
	P4	0.0141	0.0014	0.0135	0.00099	0.0132	0.0013	0.009	0.007	0.013	0.0015	0.0138	0.0014
200 mg	J5	0.0053	0.0007	0.0063	0.00056	0.0056	0.0007	-0.0056	0.0043	0.00546	0.00100	0.0054	0.0007
	P3	0.0050	0.0007	0.0058	0.00056	0.0057	0.0007	-0.0073	0.0043	0.00523	0.00100	0.0042	0.0007

Table B.4 Results of transfer standards, reported from the participants and the pilot. The $\boldsymbol{m}_\mathrm{A}$ represents residual value from the nominal mass value, and $\boldsymbol{u}_\mathrm{c}$ represents combined standard uncertainty (k = 1) claimed by each participant.

Petal D		NIM		NMC/A-STAR		MUSSD		NPLi		NIS,c		NIM	
Nominal value	Marking	m_A(mg)	u_c(mg)	m_A(mg)	u_c(mg)	m_A(mg)	u_c(mg)	m_A(mg)	u_c(mg)	m_A(mg)	u_c(mg)	m_A(mg)	u_c(mg)
2 kg	J6	1.88	0.19	1.9	0.1	1.50	0.36	1.3	0.24	1.88	0.065	1.81	0.19
	P6	5.51	0.19	5.3	0.1	4.64	0.35	4.8	0.23	5.43	0.087	5.40	0.19
200 g	J5	0.1330	0.0083	0.13	0.01	0.158	0.017	0.146	0.02	0.138	0.015	0.1246	0.0083
	P5	0.2614	0.0083	0.25	0.01	0.296	0.044	0.268	0.02	0.257	0.015	0.2491	0.0083
50 g	J6	0.0250	0.0031	0.020	0.003	0.0081	0.0071	0.003	0.0046	0.084	0.010	0.0129	0.0031
	P4	0.0793	0.0031	0.077	0.003	0.0660	0.0073	0.060	0.0046	0.081	0.010	0.0726	0.0031
1 g	J5	0.0025	0.0014	0.003	0.001	0.0016	0.0015	0.002	0.0014	0.0024	0.0011	0.0026	0.0014
	P5	0.0143	0.0014	0.012	0.001	0.0096	0.0015	0.014	0.0014	0.0142	0.0010	0.0143	0.0014
200 mg	J6	0.0042	0.0007	0.0044	0.0004	0.0039	0.0012	0.006	0.0009	0.0049	0.0012	0.0043	0.0007
	P5	0.0059	0.0007	0.0061	0.0004	0.0097	0.0012	0.008	0.0009	0.0069	0.0012	0.0065	0.0007

Table B.5 Results of transfer standards, reported from the participants and the pilot. The $\boldsymbol{m}_{\mathrm{A}}$ represents residual value from the nominal mass value, and $\boldsymbol{u}_{\mathrm{c}}$ represents combined standard uncertainty (k = 1) claimed by each participant.

Petal E		NIM		NML-BSTI		NIMT		NMIJ		NIM	
Nominal value	Marking	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)	m_{A}(mg)	u_{c}(mg)
2 kg	J7	1.91	0.19	1.60	0.47	1.98	0.10	1.88	0.13	2.01	0.19
	P7	5.11	0.19	4.73	0.47	5.11	0.10	5.04	0.50	5.04	0.19
200 g	J6	0.1586	0.0083	0.122	0.047	0.14	0.02	0.149	0.005	0.1535	0.0083
	P7	0.2517	0.0083	0.254	0.047	0.23	0.02	0.234	0.005	0.2377	0.0083
50 g	J7	0.0232	0.0030	0.0011	0.016	0.013	0.003	0.0134	0.0026	0.0143	0.0030
	P7	0.0618	0.0031	0.0442	0.016	0.053	0.003	0.0542	0.0026	0.0549	0.0031
1 g	J7	0.0022	0.0014	-0.0012	0.0047	0.001	0.001	0.0012	0.0013	0.0015	0.0014
	P6	0.0133	0.0014	0.0093	0.0047	0.012	0.001	0.0122	0.0013	0.0124	0.0014
200 mg	J7	0.0044	0.0007	0.0013	0.0030	0.0051	0.0006	0.0045	0.0008	0.0041	0.0007
	P6	0.0073	0.0007	0.0029	0.0030	0.0087	0.0006	0.0075	0.0008	0.0063	0.0007

ANNEX C

Table C.1 Input quantities for the numerical simulation (2 kg)

Xi	*Distribution*	*Expectation*	*Stand. dev.*	*Expectation*	*Semi-width*
		μ	σ	*(a+b)/2*	*(a-b)/2*
$m_{\mathrm{NIM\text{-}1}}$	$N(\mu,\sigma^2)$	3.5844	0.1368	/	/
$m_{\mathrm{NML\text{-}Phil}}$	$N(\mu,\sigma^2)$	1.2500	1.0621	/	/
m_{MSL}	$N(\mu,\sigma^2)$	3.5450	0.0389	/	/
m_{MASM}	$N(\mu,\sigma^2)$	3.6000	0.1277	/	/
$m_{\mathrm{NIM\text{-}2}}$	$N(\mu,\sigma^2)$	3.4363	0.1369	/	/
$m_{\mathrm{NIM\text{-}3}}$	$N(\mu,\sigma^2)$	3.4735	0.1367	/	/
m_{VMI}	$N(\mu,\sigma^2)$	3.6500	0.2261	/	/
m_{SCL}	$N(\mu,\sigma^2)$	3.6000	0.2122	/	/
m_{ITRI}	$N(\mu,\sigma^2)$	1.1600	0.1277	/	/
m_{KRISS}	$N(\mu,\sigma^2)$	3.4100	0.029	/	/
$m_{\mathrm{NIM\text{-}4}}$	$N(\mu,\sigma^2)$	3.3917	0.1372	/	/
$m_{\mathrm{NIM\text{-}5}}$	$N(\mu,\sigma^2)$	3.5438	0.1364	/	/
$m_{\mathrm{RCM\ LIPI}}$	$N(\mu,\sigma^2)$	3.5250	0.0516	/	/
m_{NMIA}	$N(\mu,\sigma^2)$	3.4660	0.1155	/	/
m_{NISIT}	$N(\mu,\sigma^2)$	0.5000	0.0071	/	/
m_{NMIM}	$N(\mu,\sigma^2)$	3.6605	0.0768	/	/
$m_{\mathrm{NIM\text{-}6}}$	$N(\mu,\sigma^2)$	3.4274	0.1372	/	/
$m_{\mathrm{NIM\text{-}7}}$	$N(\mu,\sigma^2)$	3.6961	0.1375	/	/
$m_{\mathrm{NMC/A\text{-}STAR}}$	$N(\mu,\sigma^2)$	3.6000	0.0705	/	/
m_{MUSSD}	$N(\mu,\sigma^2)$	3.0700	0.2513	/	/
m_{NPLi}	$N(\mu,\sigma^2)$	3.0500	0.1658	/	/
m_{NIS}	$N(\mu,\sigma^2)$	3.6550	0.0543	/	/
$m_{\mathrm{NIM\text{-}8}}$	$N(\mu,\sigma^2)$	3.6093	0.1369	/	/
$m_{\mathrm{NIM\text{-}9}}$	$N(\mu,\sigma^2)$	3.5059	0.1366	/	/
$m_{\mathrm{NML\text{-}BSTI}}$	$N(\mu,\sigma^2)$	3.1650	0.3334	/	/
m_{NIMT}	$N(\mu,\sigma^2)$	3.5450	0.0709	/	/
m_{NMIJ}	$N(\mu,\sigma^2)$	3.4600	0.2586	/	/
$m_{\mathrm{NIM\text{-}10}}$	$N(\mu,\sigma^2)$	3.5277	0.1367	/	/
ε_{drift1}	$U(a,b)$	/	/	0	0.0427
ε_{drift2}	$U(a,b)$	/	/	0	0.0236
ε_{drift3}	$U(a,b)$	/	/	0	0.0336
ε_{drift4}	$U(a,b)$	/	/	0	0.0251
ε_{drift5}	$U(a,b)$	/	/	0	0.0063
$\varepsilon_{reprod1}$	$U(a,b)$	/	/	0	0.0639

Table C.2 Input quantities for the numerical simulation (200 g)

Xi	*Distribution*	*Expectation*	*Stand. dev.*	*Expectation*	*Semi-width*
		μ	σ	*(a+b)/2*	*(a-b)/2*
$m_{\text{NIM-1}}$	$N(\mu,\sigma^2)$	0.1842	0.0059	/	/
$m_{\text{NML-Phil}}$	$N(\mu,\sigma^2)$	0.1350	0.0353	/	/
m_{MSL}	$N(\mu,\sigma^2)$	0.1768	0.0040	/	/
m_{MASM}	$N(\mu,\sigma^2)$	0.1745	0.0099	/	/
$m_{\text{NIM-2}}$	$N(\mu,\sigma^2)$	0.0738	0.0059	/	/
$m_{\text{NIM-3}}$	$N(\mu,\sigma^2)$	0.2004	0.0059	/	/
m_{VMI}	$N(\mu,\sigma^2)$	0.1935	0.0156	/	/
m_{SCL}	$N(\mu,\sigma^2)$	0.1900	0.0212	/	/
m_{ITRI}	$N(\mu,\sigma^2)$	0.1583	0.0044	/	/
m_{KRISS}	$N(\mu,\sigma^2)$	0.1925	0.0031	/	/
$m_{\text{NIM-4}}$	$N(\mu,\sigma^2)$	0.1915	0.0059	/	/
$m_{\text{NIM-5}}$	$N(\mu,\sigma^2)$	0.2020	0.0059	/	/
$m_{\text{RCM LIPI}}$	$N(\mu,\sigma^2)$	0.1600	0.0064	/	/
m_{NMIA}	$N(\mu,\sigma^2)$	0.2060	0.0078	/	/
m_{NISIT}	$N(\mu,\sigma^2)$	0.0100	0.0708	/	/
m_{NMIM}	$N(\mu,\sigma^2)$	0.2015	0.0219	/	/
$m_{\text{NIM-6}}$	$N(\mu,\sigma^2)$	0.1958	0.0059	/	/
$m_{\text{NIM-7}}$	$N(\mu,\sigma^2)$	0.1972	0.0059	/	/
$m_{\text{NMC/A-STAR}}$	$N(\mu,\sigma^2)$	0.1900	0.0071	/	/
m_{MUSSD}	$N(\mu,\sigma^2)$	0.2270	0.0236	/	/
m_{NPLi}	$N(\mu,\sigma^2)$	0.2070	0.0141	/	/
m_{NIS}	$N(\mu,\sigma^2)$	0.1535	0.0038	/	/
$m_{\text{NIM-8}}$	$N(\mu,\sigma^2)$	0.1868	0.0059	/	/
$m_{\text{NIM-9}}$	$N(\mu,\sigma^2)$	0.2052	0.0059	/	/
$m_{\text{NML-BSTI}}$	$N(\mu,\sigma^2)$	0.1880	0.0332	/	/
m_{NIMT}	$N(\mu,\sigma^2)$	0.1850	0.0141	/	/
m_{NMIJ}	$N(\mu,\sigma^2)$	0.1915	0.0035	/	/
$m_{\text{NIM-10}}$	$N(\mu,\sigma^2)$	0.1956	0.0059	/	/
ε_{drift1}	$U(a,b)$	/	/	0	0.0030
ε_{drift2}	$U(a,b)$	/	/	0	0.0026
ε_{drift3}	$U(a,b)$	/	/	0	0.0018
ε_{drift4}	$U(a,b)$	/	/	0	0.0030
ε_{drift5}	$U(a,b)$	/	/	0	0.0028
$\varepsilon_{reprod1}$	$U(a,b)$	/	/	0	0.0018

Table C.3 Input quantities for the numerical simulation (50 g)

Xi	*Distribution*	*Expectation*	*Stand. dev.*	*Expectation*	*Semi-width*
		μ	σ	$(a+b)/2$	$(a-b)/2$
$m_{\text{NIM-1}}$	$N(\mu,\sigma^2)$	0.0420	0.0022	/	/
$m_{\text{NML-Phil}}$	$N(\mu,\sigma^2)$	-0.0035	0.0106	/	/
m_{MSL}	$N(\mu,\sigma^2)$	0.0348	0.0013	/	/
m_{MASM}	$N(\mu,\sigma^2)$	0.0273	0.0057	/	/
$m_{\text{NIM-2}}$	$N(\mu,\sigma^2)$	0.0314	0.0022	/	/
$m_{\text{NIM-3}}$	$N(\mu,\sigma^2)$	0.0513	0.0022	/	/
m_{VMI}	$N(\mu,\sigma^2)$	0.0490	0.0085	/	/
m_{SCL}	$N(\mu,\sigma^2)$	0.0430	0.0078	/	/
m_{ITRI}	$N(\mu,\sigma^2)$	0.0371	0.0019	/	/
m_{KRISS}	$N(\mu,\sigma^2)$	0.0455	0.0016	/	/
$m_{\text{NIM-4}}$	$N(\mu,\sigma^2)$	0.0447	0.0022	/	/
$m_{\text{NIM-5}}$	$N(\mu,\sigma^2)$	0.0468	0.0022	/	/
$m_{\text{RCM LIPI}}$	$N(\mu,\sigma^2)$	0.0295	0.0030	/	/
m_{NMIA}	$N(\mu,\sigma^2)$	0.0390	0.0030	/	/
m_{NISIT}	$N(\mu,\sigma^2)$	0.0065	0.0219	/	/
m_{NMIM}	$N(\mu,\sigma^2)$	0.0380	0.0071	/	/
$m_{\text{NIM-6}}$	$N(\mu,\sigma^2)$	0.0402	0.0022	/	/
$m_{\text{NIM-7}}$	$N(\mu,\sigma^2)$	0.0521	0.0022	/	/
$m_{\text{NMC/A-STAR}}$	$N(\mu,\sigma^2)$	0.0485	0.0021	/	/
m_{MUSSD}	$N(\mu,\sigma^2)$	0.0371	0.0051	/	/
m_{NPLi}	$N(\mu,\sigma^2)$	0.0315	0.0033	/	/
m_{NIS}	$N(\mu,\sigma^2)$	0.0665	0.0021	/	/
$m_{\text{NIM-8}}$	$N(\mu,\sigma^2)$	0.0428	0.0022	/	/
$m_{\text{NIM-9}}$	$N(\mu,\sigma^2)$	0.0425	0.0022	/	/
$m_{\text{NML-BSTI}}$	$N(\mu,\sigma^2)$	0.0227	0.0113	/	/
m_{NIMT}	$N(\mu,\sigma^2)$	0.0330	0.0021	/	/
m_{NMIJ}	$N(\mu,\sigma^2)$	0.0338	0.0018	/	/
$m_{\text{NIM-10}}$	$N(\mu,\sigma^2)$	0.0346	0.0022	/	/
ε_{drift1}	$U(a,b)$	/	/	0	0.0031
ε_{drift2}	$U(a,b)$	/	/	0	0.0019
ε_{drift3}	$U(a,b)$	/	/	0	0.0019
ε_{drift4}	$U(a,b)$	/	/	0	0.0027
ε_{drift5}	$U(a,b)$	/	/	0	0.0023
$\varepsilon_{reprod1}$	$U(a,b)$	/	/	0	0.0018

Table C.4 Input quantities for the numerical simulation (1 g)

Xi	*Distribution*	*Expectation*	*Stand. dev.*	*Expectation*	*Semi-width*
		μ	σ	*(a+b)/2*	*(a-b)/2*
$m_{\mathrm{NIM\text{-}1}}$	$N(\mu,\sigma^2)$	0.0090	0.00097	/	/
$m_{\mathrm{NML\text{-}Phil}}$	$N(\mu,\sigma^2)$	0.0040	0.00353	/	/
m_{MSL}	$N(\mu,\sigma^2)$	0.0076	0.00037	/	/
m_{MASM}	$N(\mu,\sigma^2)$	0.0065	0.00106	/	/
$m_{\mathrm{NIM\text{-}2}}$	$N(\mu,\sigma^2)$	0.0091	0.00097	/	/
$m_{\mathrm{NIM\text{-}3}}$	$N(\mu,\sigma^2)$	0.0070	0.00097	/	/
m_{VMI}	$N(\mu,\sigma^2)$	0.0078	0.00106	/	/
m_{SCL}	$N(\mu,\sigma^2)$	0.0070	0.00212	/	/
m_{ITRI}	$N(\mu,\sigma^2)$	0.0068	0.00085	/	/
m_{KRISS}	$N(\mu,\sigma^2)$	0.0080	0.00085	/	/
$m_{\mathrm{NIM\text{-}4}}$	$N(\mu,\sigma^2)$	0.0076	0.00097	/	/
$m_{\mathrm{NIM\text{-}5}}$	$N(\mu,\sigma^2)$	0.0083	0.00097	/	/
$m_{\mathrm{RCM\ LIPI}}$	$N(\mu,\sigma^2)$	0.0078	0.00070	/	/
m_{NMIA}	$N(\mu,\sigma^2)$	0.0073	0.00092	/	/
m_{NISIT}	$N(\mu,\sigma^2)$	0.0048	0.00495	/	/
m_{NMIM}	$N(\mu,\sigma^2)$	0.0080	0.00106	/	/
$m_{\mathrm{NIM\text{-}6}}$	$N(\mu,\sigma^2)$	0.0081	0.00097	/	/
$m_{\mathrm{NIM\text{-}7}}$	$N(\mu,\sigma^2)$	0.0084	0.00097	/	/
$m_{\mathrm{NMC/A\text{-}STAR}}$	$N(\mu,\sigma^2)$	0.0075	0.00071	/	/
m_{MUSSD}	$N(\mu,\sigma^2)$	0.0056	0.00106	/	/
m_{NPLi}	$N(\mu,\sigma^2)$	0.0080	0.00099	/	/
m_{NIS}	$N(\mu,\sigma^2)$	0.0115	0.00074	/	/
$m_{\mathrm{NIM\text{-}8}}$	$N(\mu,\sigma^2)$	0.0084	0.00097	/	/
$m_{\mathrm{NIM\text{-}9}}$	$N(\mu,\sigma^2)$	0.0077	0.00097	/	/
$m_{\mathrm{NML\text{-}BSTI}}$	$N(\mu,\sigma^2)$	0.0041	0.00333	/	/
m_{NIMT}	$N(\mu,\sigma^2)$	0.0065	0.00071	/	/
m_{NMIJ}	$N(\mu,\sigma^2)$	0.0067	0.00092	/	/
$m_{\mathrm{NIM\text{-}10}}$	$N(\mu,\sigma^2)$	0.0070	0.00097	/	/
ε_{drift1}	$U(a,b)$	/	/	0	0.00005
ε_{drift2}	$U(a,b)$	/	/	0	0.00018
ε_{drift3}	$U(a,b)$	/	/	0	0.00006
ε_{drift4}	$U(a,b)$	/	/	0	0.00001
ε_{drift5}	$U(a,b)$	/	/	0	0.00022
$\varepsilon_{reprod1}$	$U(a,b)$	/	/	0	0.00051

Table C.5 Input quantities for the numerical simulation (200 mg)

Xi	*Distribution*	*Expectation*	*Stand. dev.*	*Expectation*	*Semi-width*
		μ	σ	*(a+b)/2*	*(a-b)/2*
$m_{\text{NIM-1}}$	$N(\mu,\sigma^2)$	0.0061	0.00048	/	/
$m_{\text{NML-Phil}}$	$N(\mu,\sigma^2)$	0.0070	0.00212	/	/
m_{MSL}	$N(\mu,\sigma^2)$	0.0066	0.00022	/	/
m_{MASM}	$N(\mu,\sigma^2)$	0.0064	0.00042	/	/
$m_{\text{NIM-2}}$	$N(\mu,\sigma^2)$	0.0062	0.00048	/	/
$m_{\text{NIM-3}}$	$N(\mu,\sigma^2)$	0.0068	0.00049	/	/
m_{VMI}	$N(\mu,\sigma^2)$	0.0085	0.00071	/	/
m_{SCL}	$N(\mu,\sigma^2)$	0.0068	0.00106	/	/
m_{ITRI}	$N(\mu,\sigma^2)$	0.0070	0.00044	/	/
m_{KRISS}	$N(\mu,\sigma^2)$	0.0068	0.00071	/	/
$m_{\text{NIM-4}}$	$N(\mu,\sigma^2)$	0.0059	0.00049	/	/
$m_{\text{NIM-5}}$	$N(\mu,\sigma^2)$	0.0052	0.00048	/	/
$m_{\text{RCM LIPI}}$	$N(\mu,\sigma^2)$	0.0061	0.00040	/	/
m_{NMIA}	$N(\mu,\sigma^2)$	0.0057	0.00050	/	/
m_{NISIT}	$N(\mu,\sigma^2)$	-0.0065	0.00304	/	/
m_{NMIM}	$N(\mu,\sigma^2)$	0.0054	0.00071	/	/
$m_{\text{NIM-6}}$	$N(\mu,\sigma^2)$	0.0048	0.00048	/	/
$m_{\text{NIM-7}}$	$N(\mu,\sigma^2)$	0.0051	0.00048	/	/
$m_{\text{NMC/A-STAR}}$	$N(\mu,\sigma^2)$	0.0053	0.00028	/	/
m_{MUSSD}	$N(\mu,\sigma^2)$	0.0068	0.00085	/	/
m_{NPLi}	$N(\mu,\sigma^2)$	0.0070	0.00064	/	/
m_{NIS}	$N(\mu,\sigma^2)$	-0.0004	0.00039	/	/
$m_{\text{NIM-8}}$	$N(\mu,\sigma^2)$	0.0054	0.00048	/	/
$m_{\text{NIM-9}}$	$N(\mu,\sigma^2)$	0.0058	0.00048	/	/
$m_{\text{NML-BSTI}}$	$N(\mu,\sigma^2)$	0.0021	0.00212	/	/
m_{NIMT}	$N(\mu,\sigma^2)$	0.0069	0.00042	/	/
m_{NMIJ}	$N(\mu,\sigma^2)$	0.0060	0.00057	/	/
$m_{\text{NIM-10}}$	$N(\mu,\sigma^2)$	0.0052	0.00048	/	/
ε_{drift1}	$U(a,b)$	/	/	0	0.00001
ε_{drift2}	$U(a,b)$	/	/	0	0.00025
ε_{drift3}	$U(a,b)$	/	/	0	0.00011
ε_{drift4}	$U(a,b)$	/	/	0	0.00010
ε_{drift5}	$U(a,b)$	/	/	0	0.00019
$\varepsilon_{reprod1}$	$U(a,b)$	/	/	0	0.00050

ANNEX D

D.1 The histograms of non-linked RV and DoE for 2 kg standard

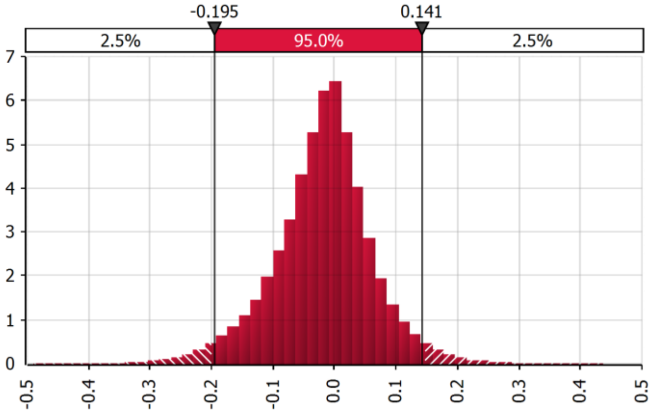


Figure D.1 The histograms of non-linked RV for 2 kg standard

Table D.1 Data of the Median Resulting of Numerical Simulation (mg)

m_{RV}	-0.02
$u(m_{\mathrm{RV}})$	0.09
$U(m_{\mathrm{RV}})$, k=2	0.18
$P[x_1,x_2]$	[-0.19,0.14]

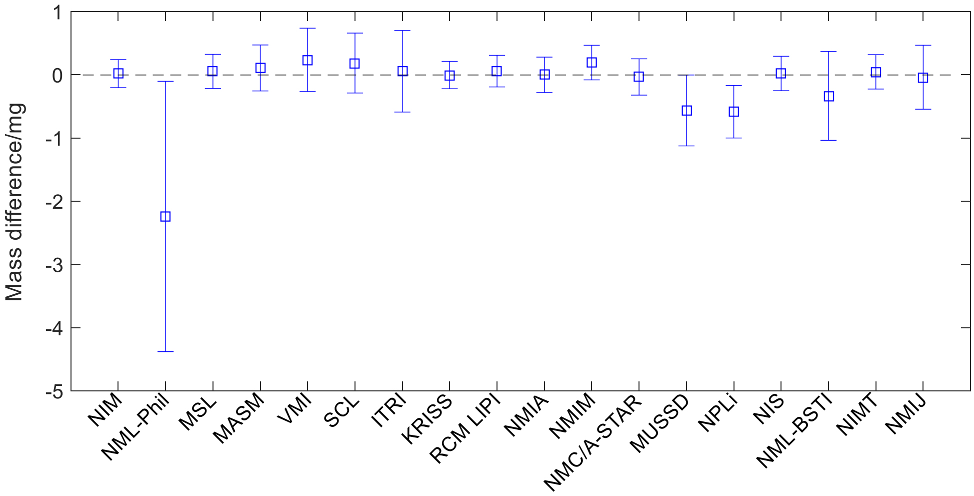


Figure D.2 Deviation D_i and $U(D_i)$ obtained by using the MCM estimation with the travelling standards as the non-linked RV.

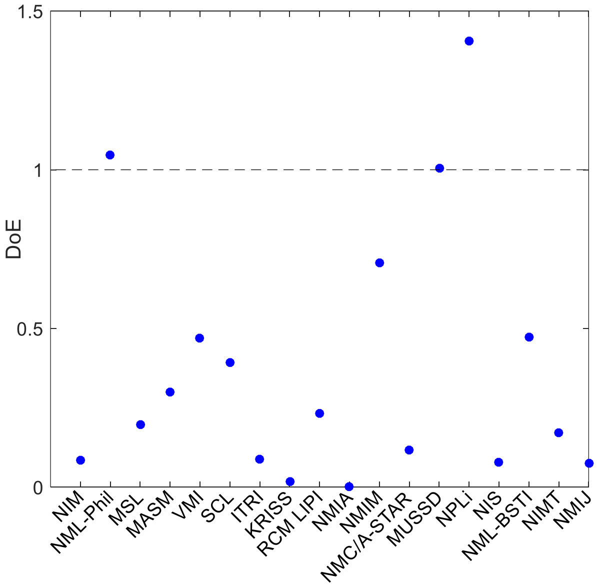
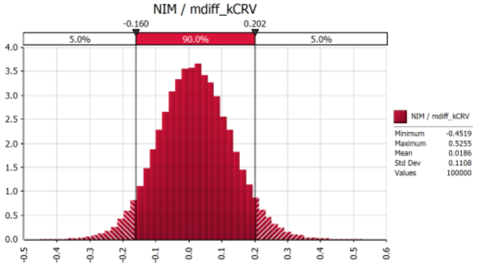
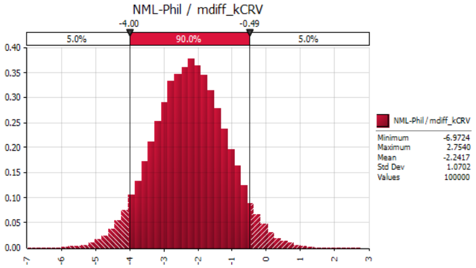


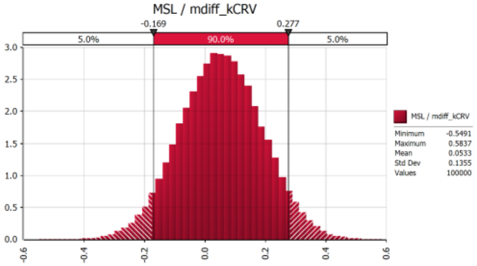
Figure D.3 DoE for 2kg standards

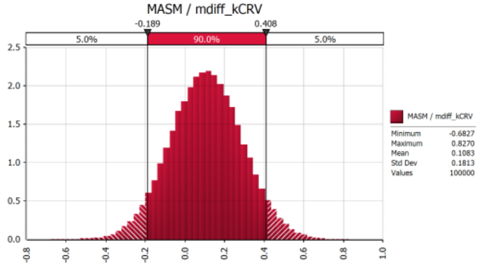
Table D.2 Mass differences between participant laboratories and non-linked RV

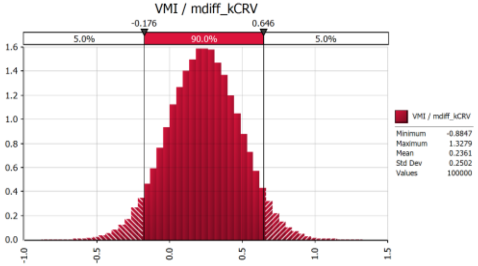
	NIM	NML-Phil	MSL	MASM	VMI	SCL	ITRI	KRISS	RCM LIPI	NMIA	NMIM	NMC/ A-STAR	MUSSD	NPLi	NIS	NML-BSTI	NIMT	NMIJ
D_i ,mg	0.02	-2.24	0.05	0.11	0.24	0.19	0.06	-0.01	0.06	-0.01	0.19	-0.03	-0.56	-0.58	-0.02	-0.33	0.05	-0.04
$u(D_i)$,mg	0.12	1.07	0.14	0.19	0.25	0.24	0.33	0.11	0.13	0.15	0.14	0.15	0.29	0.21	0.14	0.36	0.14	0.26
$U(D_i)$,k=2, mg	0.24	2.14	0.28	0.38	0.50	0.48	0.66	0.22	0.26	0.30	0.28	0.30	0.58	0.42	0.28	0.72	0.28	0.52
$P[x_1,x_2]\approx$ 95%, mg	[-0.19,0.24]	[-4.33,-0.16]	[-0.21,0.32]	[-0.25,0.46]	[-0.26,0.73]	[-0.28,0.65]	[-0.58,0.69]	[-0.22,0.21]	[-0.19,0.30]	[-0.29,0.29]	[-0.07,0.46]	[-0.31,0.25]	[-1.12,-0.02]	[-0.99,-0.18]	[-0.25,0.29]	[-1.02,0.36]	[-0.18,0.28]	[-0.56,0.47]
DoE = | D_i |/$U(D_i)$	0.08	1.05	0.20	0.30	0.47	0.39	0.09	0.02	0.23	0.01	0.71	0.12	1.01	1.41	0.08	0.47	0.17	0.08

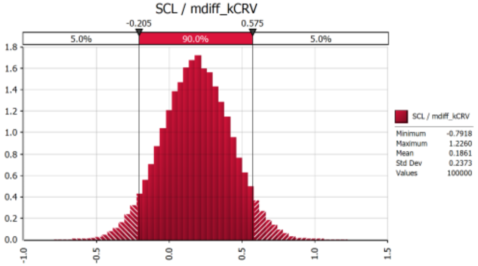


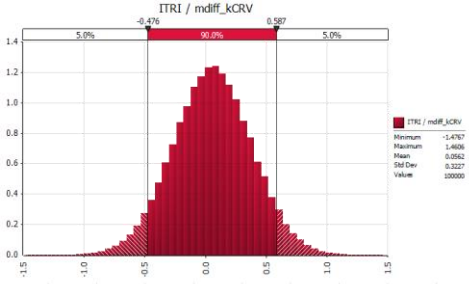


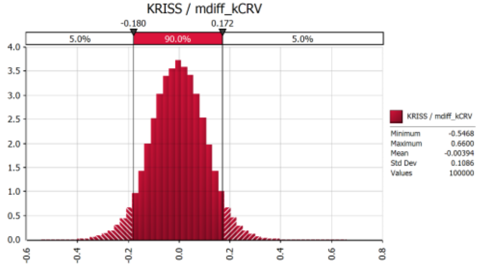












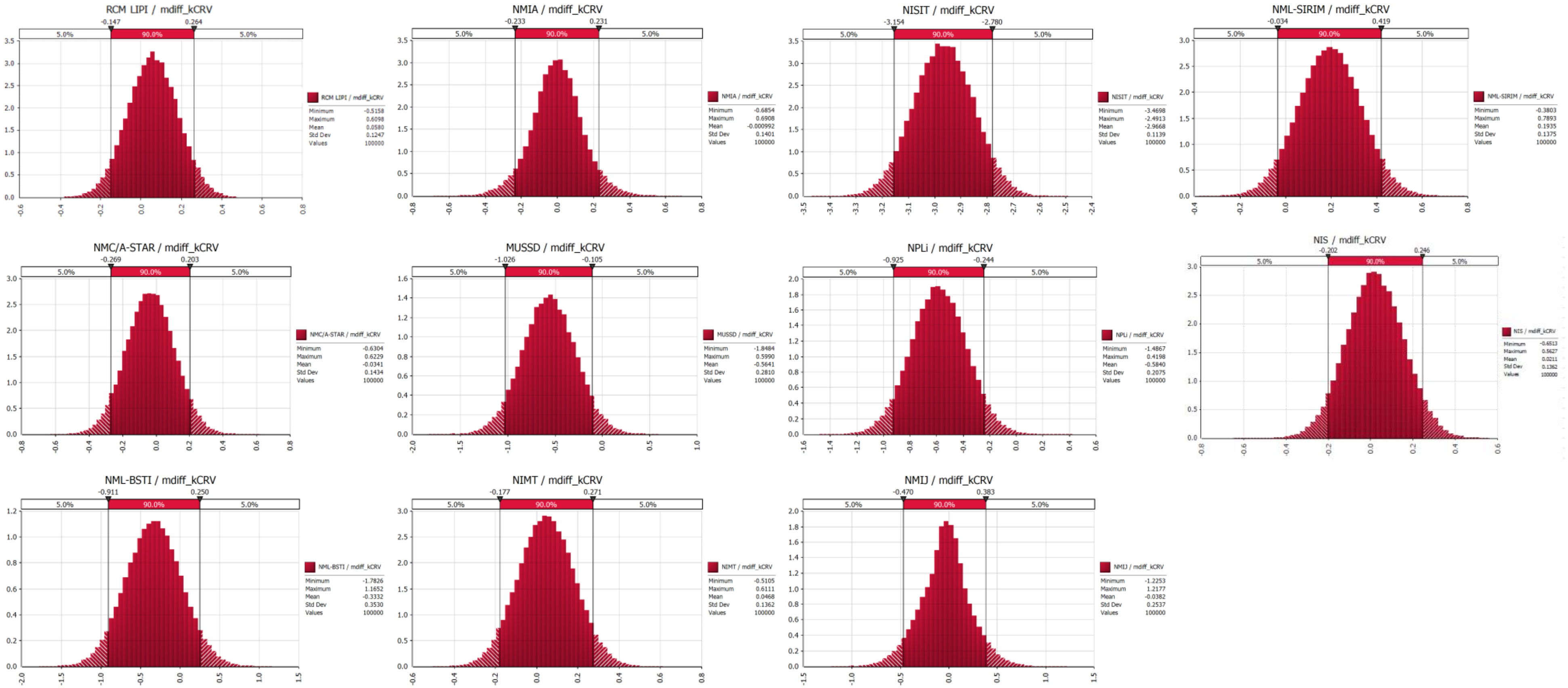


Figure D.4 The histograms of non-linked RV for each participant (2 kg)

D.2 The histograms of non-linked RV and DoE for 200 g standard

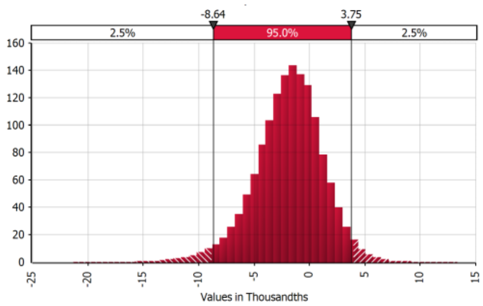


Figure D.5 The histograms of non-linked RV for 200 g standard

Table D.3 Data of the Median Resulting of Numerical Simulation (mg)

m_{RV}	-0.0019
$u(m_{\mathrm{RV}})$	0.0031
$U(m_{\mathrm{RV}})$, k=2	0.0062
$P[x_1,x_2]$	[-0.0086,0.0038]

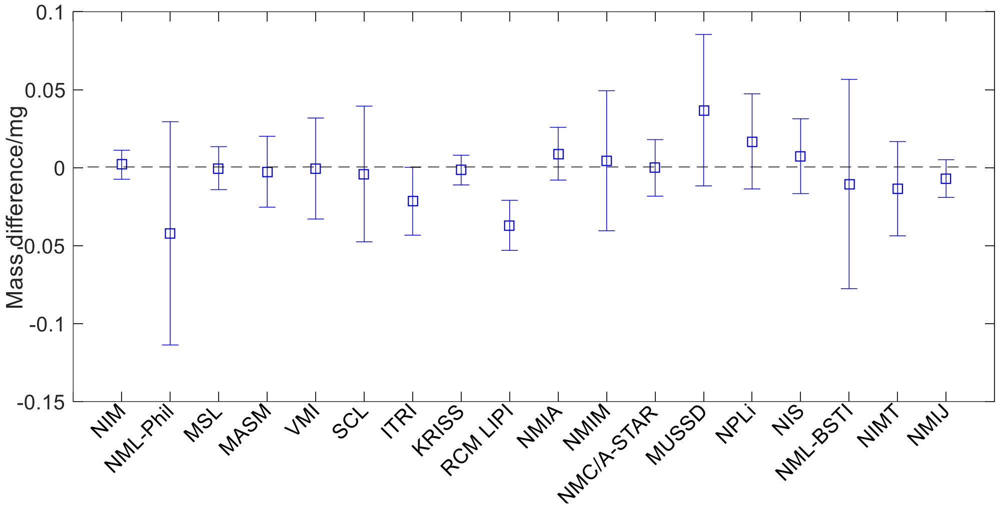


Figure D.6 Deviation D_i and $U(D_i)$ obtained by using the MCM estimation with the travelling standards as the non-linked RV.

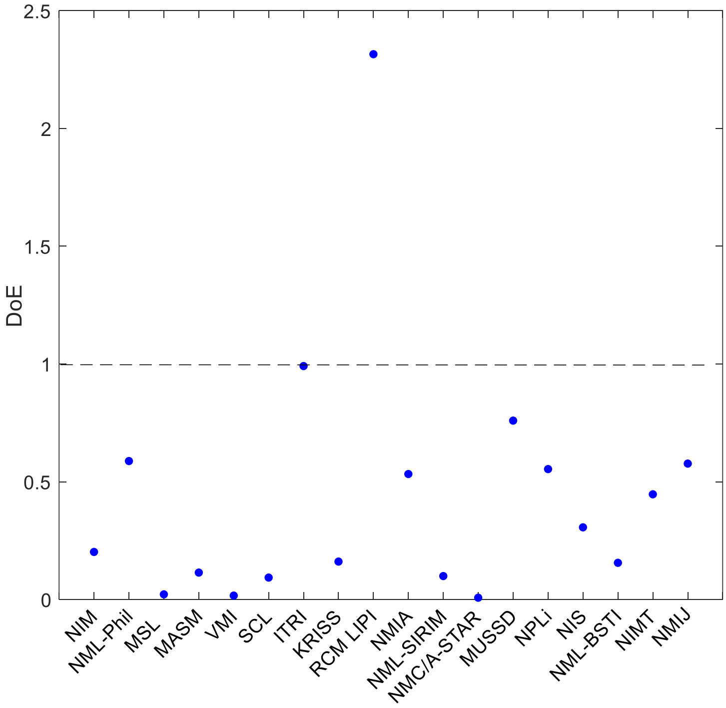
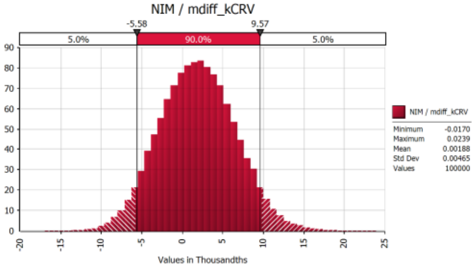
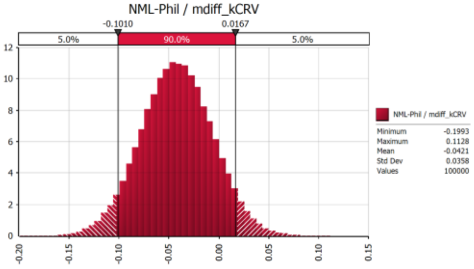


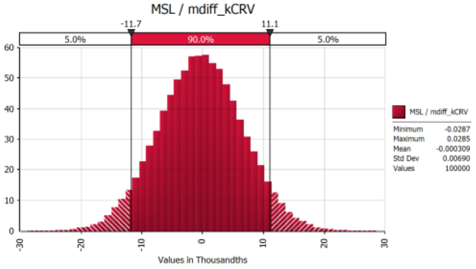
Figure D.7 DoE for 200g standards

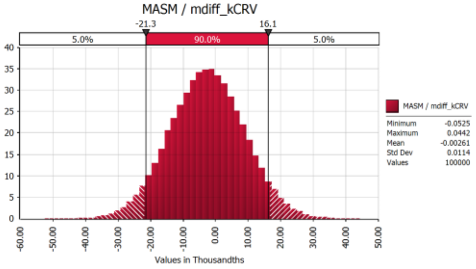
Table D.4 Mass differences between participant laboratories and non-linked RV

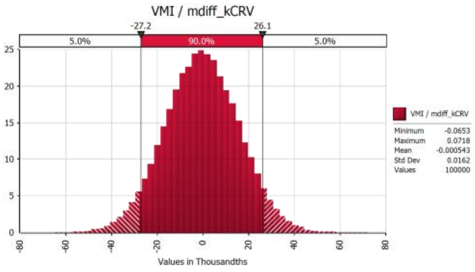
	NIM	NML-Phil	MSL	MASM	VMI	SCL	ITRI	KRISS	RCM LIPI	NMIA	NMIM	NMC/ A-STAR	MUSSD	NPLi	NIS	NML-BSTI	NIMT	NMIJ
D_i ,mg	0.0019	-0.0421	-0.0003	-0.0026	-0.0005	-0.0040	-0.0215	-0.0015	-0.0370	0.0090	0.0045	-0.0001	0.0369	0.0169	0.0074	-0.0105	-0.0135	-0.0070
$u(D_i)$,mg	0.0047	0.0358	0.0070	0.0114	0.0162	0.0217	0.0109	0.0048	0.0080	0.0084	0.0224	0.0090	0.0243	0.0152	0.0120	0.0338	0.0151	0.0061
$U(D_i)$,k=2, mg	0.0094	0.0716	0.0139	0.0229	0.0324	0.0435	0.0218	0.0095	0.0160	0.0169	0.0449	0.0181	0.0486	0.0305	0.0240	0.0676	0.0303	0.0122
$P[x_1,x_2]\approx$ 95%, µg	[-6.9,11.1]	[-112.5,28.1]	[-13.8,13.2]	[-24.9,19.7]	[-32.1,31.2]	[-46.8,38.4]	[-39.4,-3.7]	[-11.1,7.6]	[-52.7,-21.4]	[-5.5,26.5]	[-39.5,48.4]	[-17.8,17.6]	[-10.9,84.3]	[-12.9,47.0]	[-12.4,27.2]	[-76.7,55.8]	[-43.1,16.0]	[-19.5,4.0]
DoE = $\|D_i\|/U(D_i)$	0.20	0.59	0.02	0.11	0.02	0.09	0.99	0.16	2.32	0.53	0.10	0.01	0.76	0.55	0.31	0.16	0.45	0.58

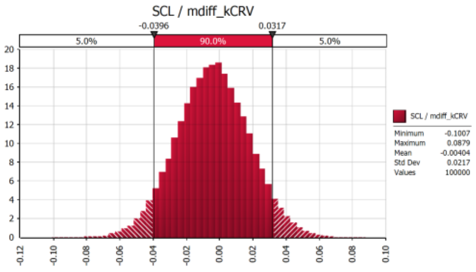


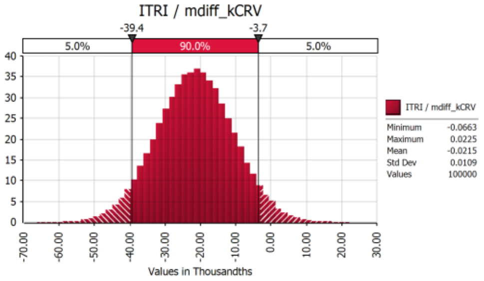


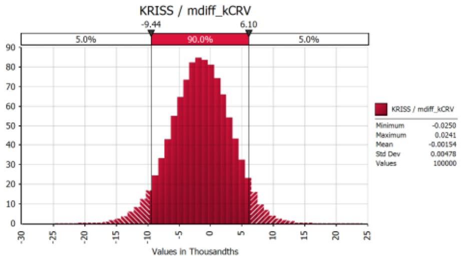












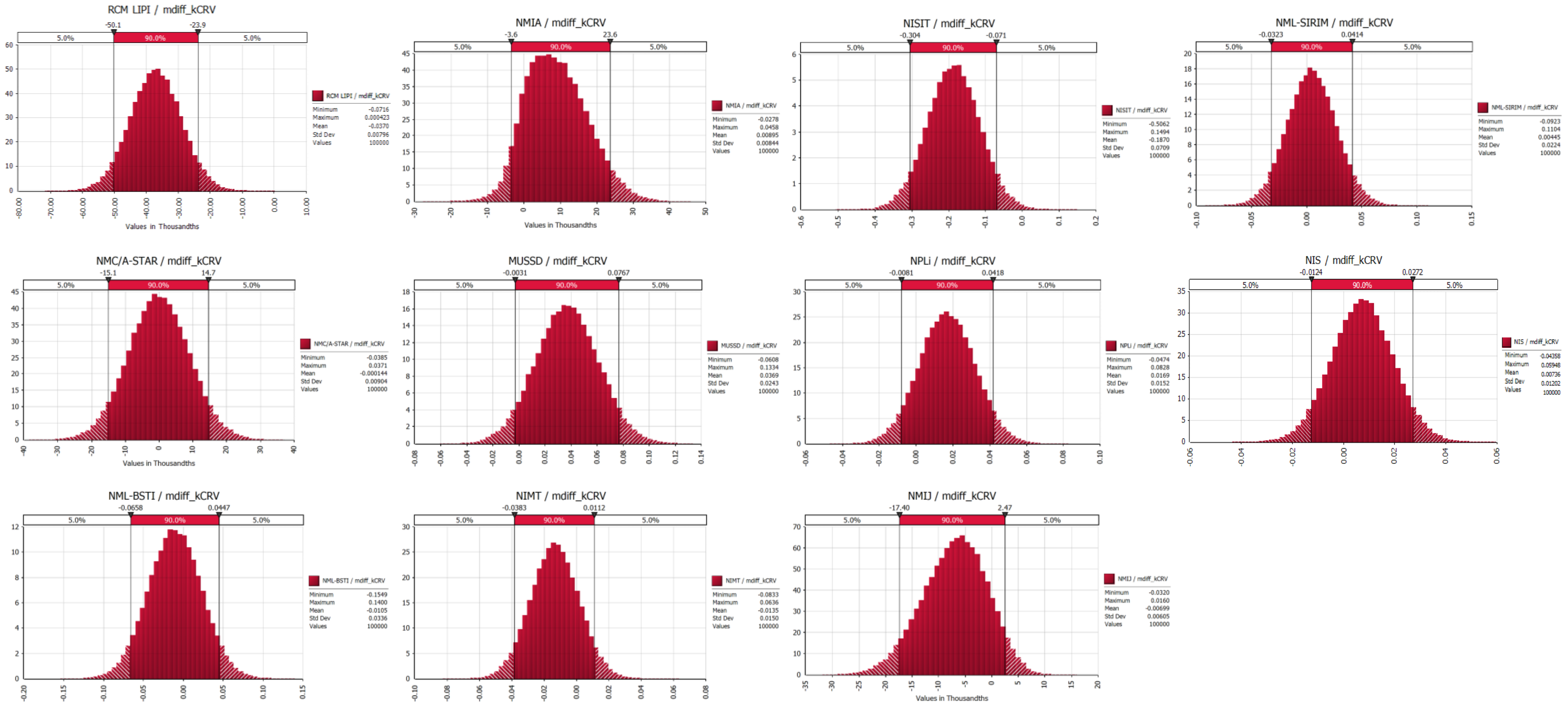


Figure D.8 The histograms of non-linked RV for each participant (200 g)

D.3 The histograms of non-linked RV and DoE for 50 g standard

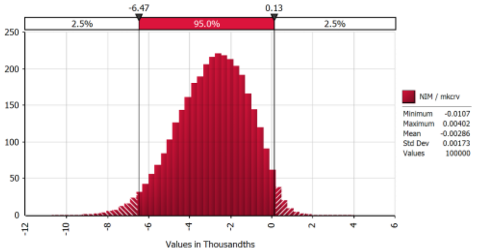


Figure D.9 The histograms of non-linked RV for 50 g standard

Table D.5 Data of the Median Resulting of Numerical Simulation (mg)

m_{RV}	-0.0029
$u(m_{\mathrm{RV}})$	0.0017
$U(m_{\mathrm{RV}})$, k=2	0.0035
$P[x_1,x_2]$	[-0.0065,0.0001]

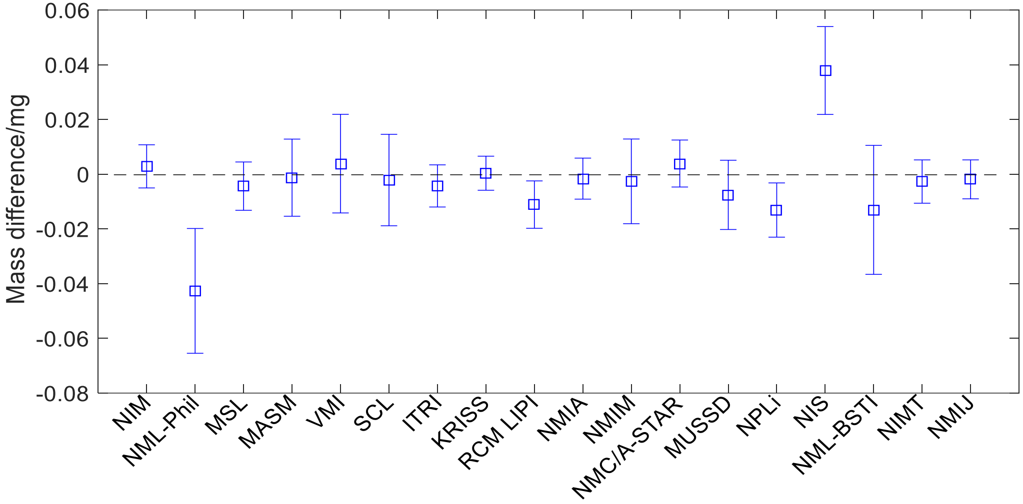


Figure D.10 Deviation D_i and $U(D_i)$ obtained by using the MCM estimation with the travelling standards as the non-linked RV

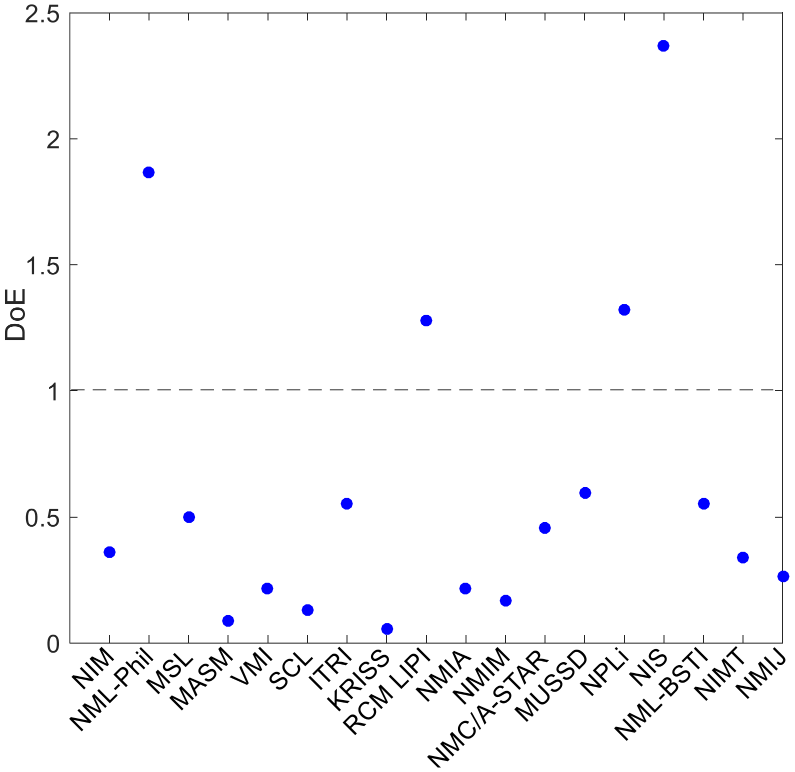
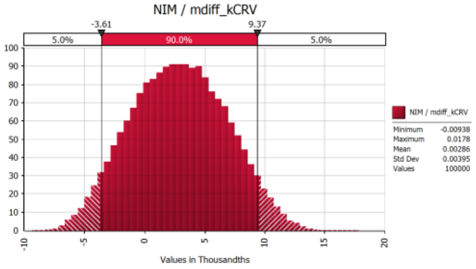
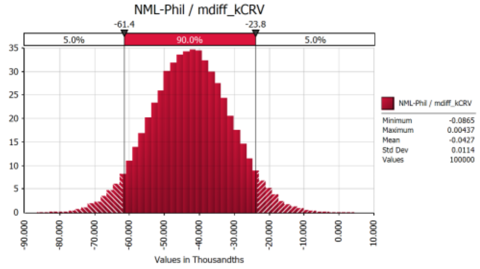


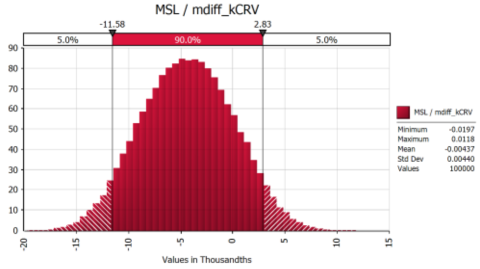
Figure D.11 DoE for 50 g standards

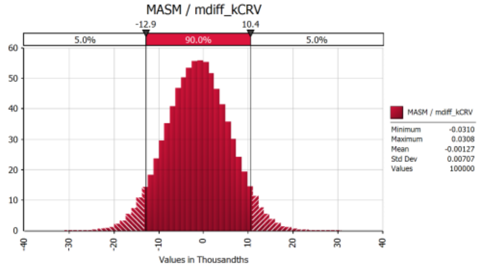
Table D.6 Mass differences between participant laboratories and non-linked RV

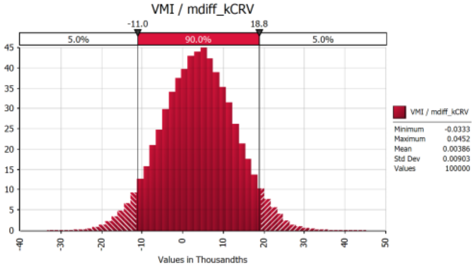
	NIM	NML-Phil	MSL	MASM	VMI	SCL	ITRI	KRISS	RCM LIPI	NMIA	NMIM	NMC/ A-STAR	MUSSD	NPLi	NIS	NML-BSTI	NIMT	NMIJ
D_i ,mg	0.0029	-0.0427	-0.0044	-0.0013	0.0039	-0.0021	-0.0043	0.0004	-0.0111	-0.0016	-0.0026	0.0039	-0.0076	-0.0131	0.0379	-0.0130	-0.0027	-0.0019
$u(D_i)$,mg	0.0039	0.0114	0.0044	0.0070	0.0090	0.0083	0.0039	0.0031	0.0043	0.0037	0.0077	0.0043	0.0063	0.0050	0.0080	0.0118	0.0039	0.0036
$U(D_i)$,k=2, mg	0.0079	0.0228	0.0088	0.0141	0.0180	0.0167	0.0078	0.0063	0.0087	0.0075	0.0155	0.0087	0.0127	0.0100	0.0160	0.0236	0.0079	0.0072
$P[x_1,x_2]\approx$ 95%, µg	[-4.6,10.4]	[-64.9,-20.3]	[-12.8,4.1]	[-15.0,12.5]	[-10.9,18.7]	[-18.5,14.2]	[-11.8,3.24]	[-5.6,6.3]	[-19.6,-2.6]	[-9.3,5.3]	[-17.7,12.5]	[-4.5,12.2]	[-19.9,4.9]	[-22.7,-3.4]	[22.1,53.6]	[-36.0,10.0]	[-10.4,5.0]	[-9,4.79.0]
DoE = | D_i |/$U(D_i)$	0.36	1.87	0.50	0.09	0.21	0.13	0.56	0.06	1.28	0.22	0.17	0.45	0.60	1.32	2.37	0.55	0.34	0.26

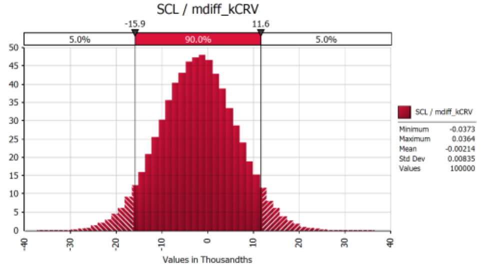


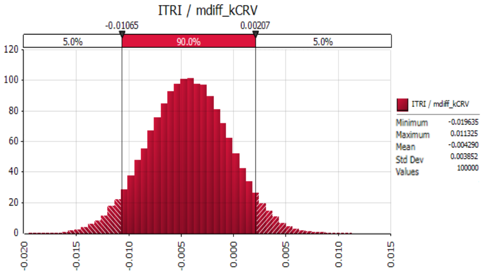


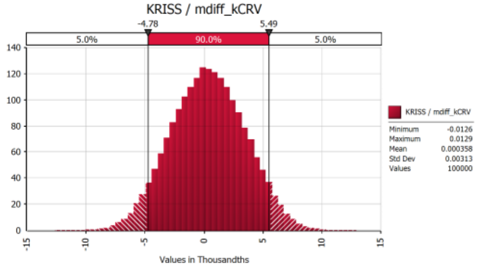












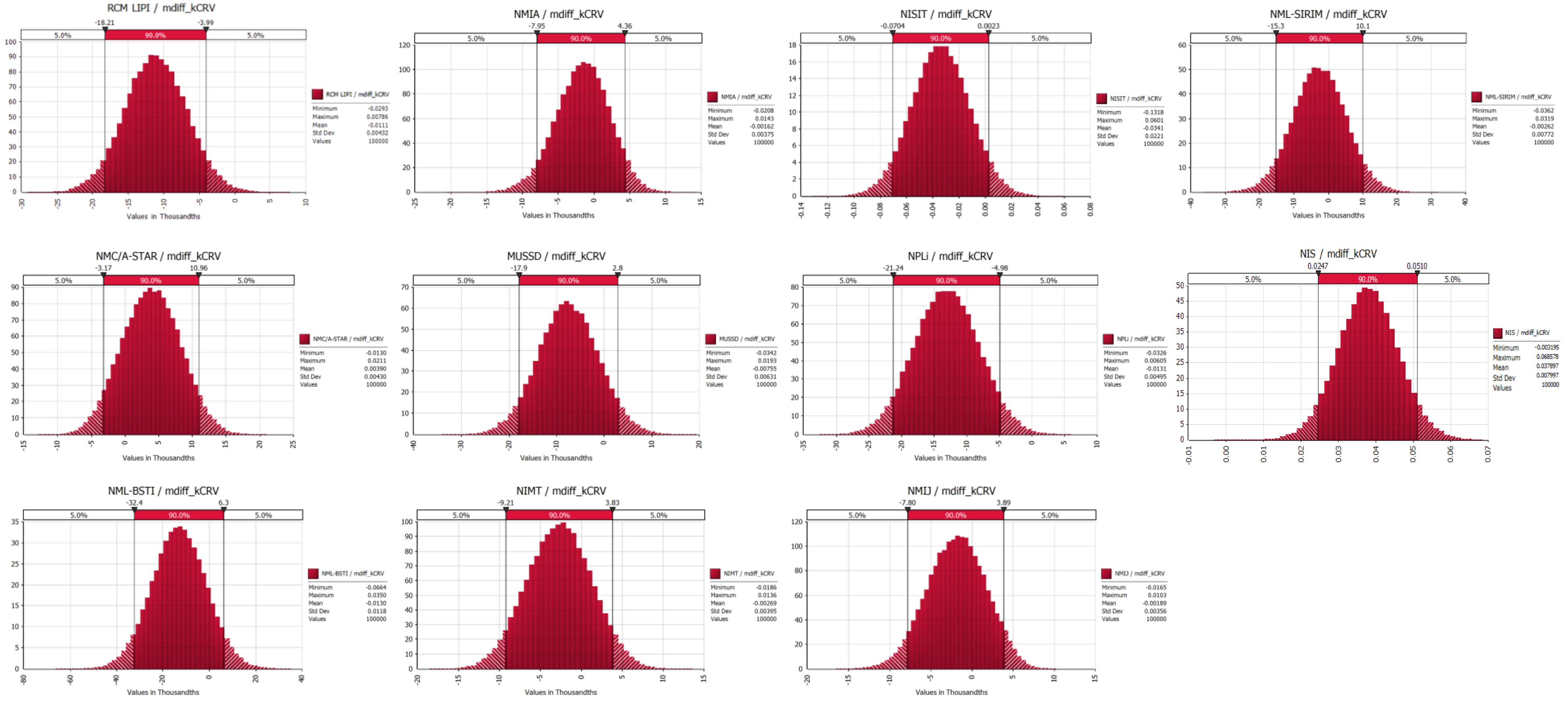


Figure D.12 The histograms of non-linked RV for each participant (50 g)

D.4 The histograms of non-linked RV and DoE for 1 g standard

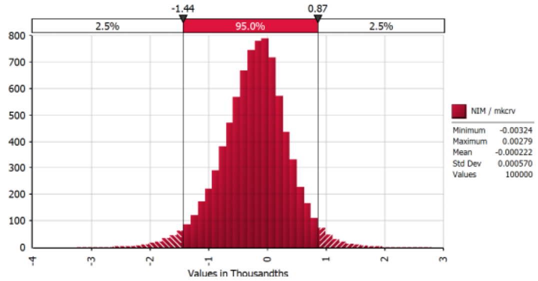


Figure D.13 The histograms of non-linked RV for 1 g standard

Table D.7 Data of the Median Resulting of Numerical Simulation (mg)

m_{RV}	-0.0002
$u(m_{\mathrm{RV}})$	0.0006
$U(m_{\mathrm{RV}})$, k=2	0.0012
$P[x_1,x_2]$	[-0.0014,0.0009]

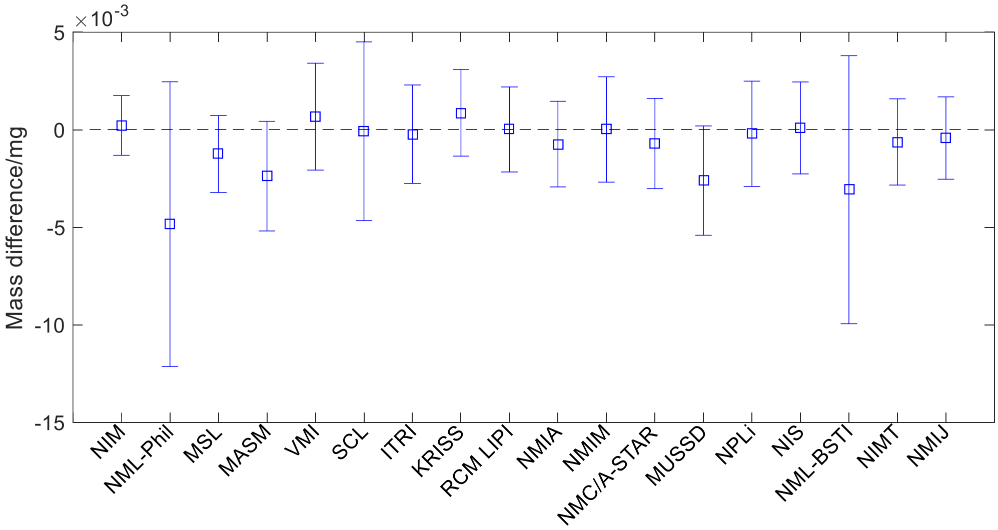


Figure D.14 Deviation D_{i} and $U(D_i)$ obtained by using the MCM estimation with the travelling standards as the non-linked RV.

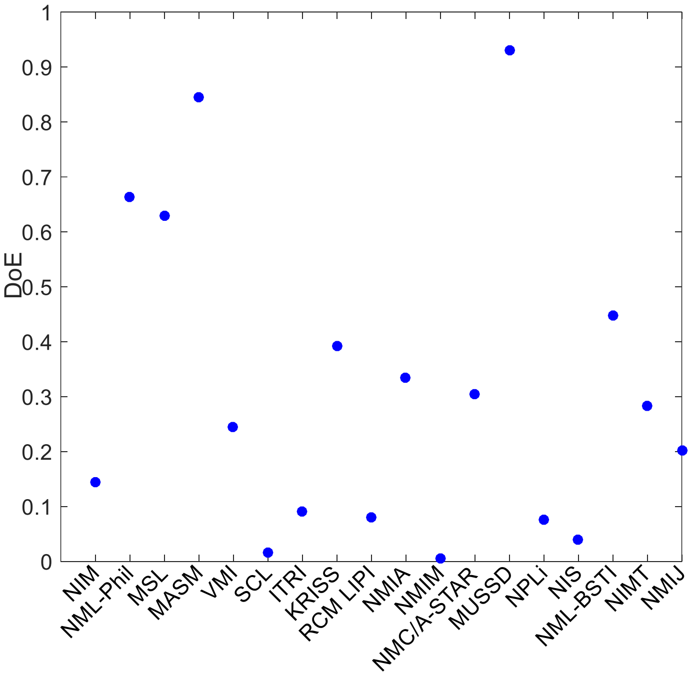
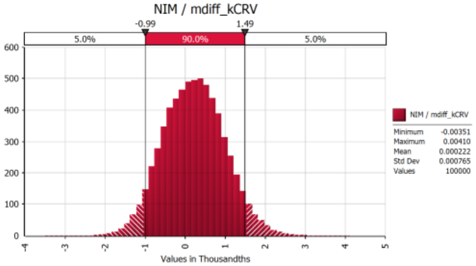
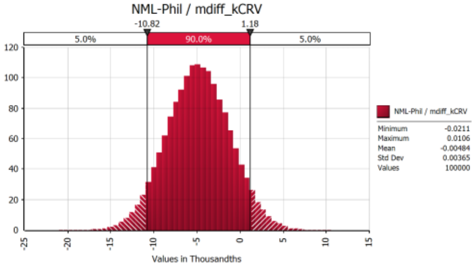


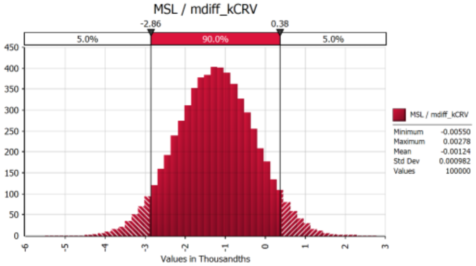
Figure D.15 DoE for 1 g standards

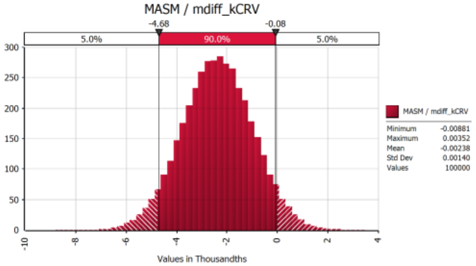
Table D.8 Mass differences between participant laboratories and non-linked RV

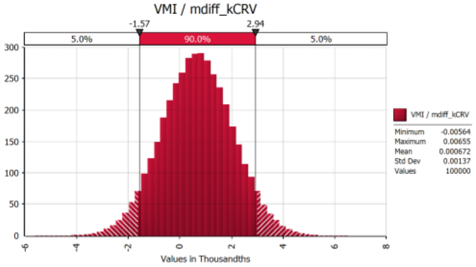
	NIM	NML-Phil	MSL	MASM	VMI	SCL	ITRI	KRISS	RCM LIPI	NMIA	NMIM	NMC/ A-STAR	MUSSD	NPLi	NIS	NML-BSTI	NIMT	NMIJ
D_i ,µg	0.2	-4.8	-1.2	-2.4	0.7	-0.1	-0.2	0.9	-0.2	-0.7	0.1	-0.7	-2.6	-0.2	0.1	-3.1	-0.6	-0.4
$u(D_i)$, µg	0.8	3.7	1.0	1.5	1.4	2.3	1.3	1.2	1.1	1.1	1.4	1.2	1.4	1.4	1.2	3.5	1.1	1.1
$U(D_i)$,k=2, µg	1.6	7.4	2.0	3.0	2.8	4.6	2.6	2.4	2.2	2.2	2.8	2.4	2.8	2.8	2.4	7.0	2.2	2.2
$P[x_1,x_2]\approx$ 95%, µg	[-1.2,1.7]	[-12.0,2.3]	[-3.2,0.7]	[-5.1,0.4]	[-2.0,3.4]	[-4.5,4.4]	[-2.7,2.3]	[-1.1,3.2]	[-2.3,2.0]	[-3.1,1.2]	[-2.6,2.7]	[-3.0,1.6]	[-5.3,0.2]	[-2.9,2.4]	[-2.2,2.4]	[-9.8,3.6]	[-2.8,1.5]	[-2.7,1.6]
DoE = | D_i |/$U(D_i)$	0.15	0.67	0.63	0.85	0.25	0.02	0.09	0.39	0.08	0.33	0.01	0.31	0.93	0.08	0.04	0.45	0.28	0.20

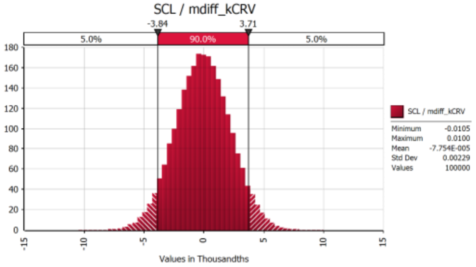


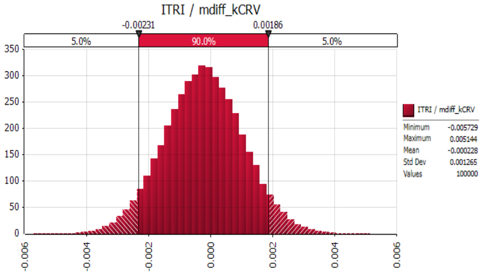


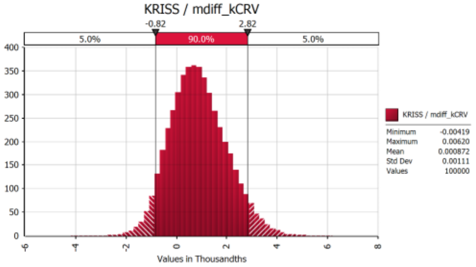












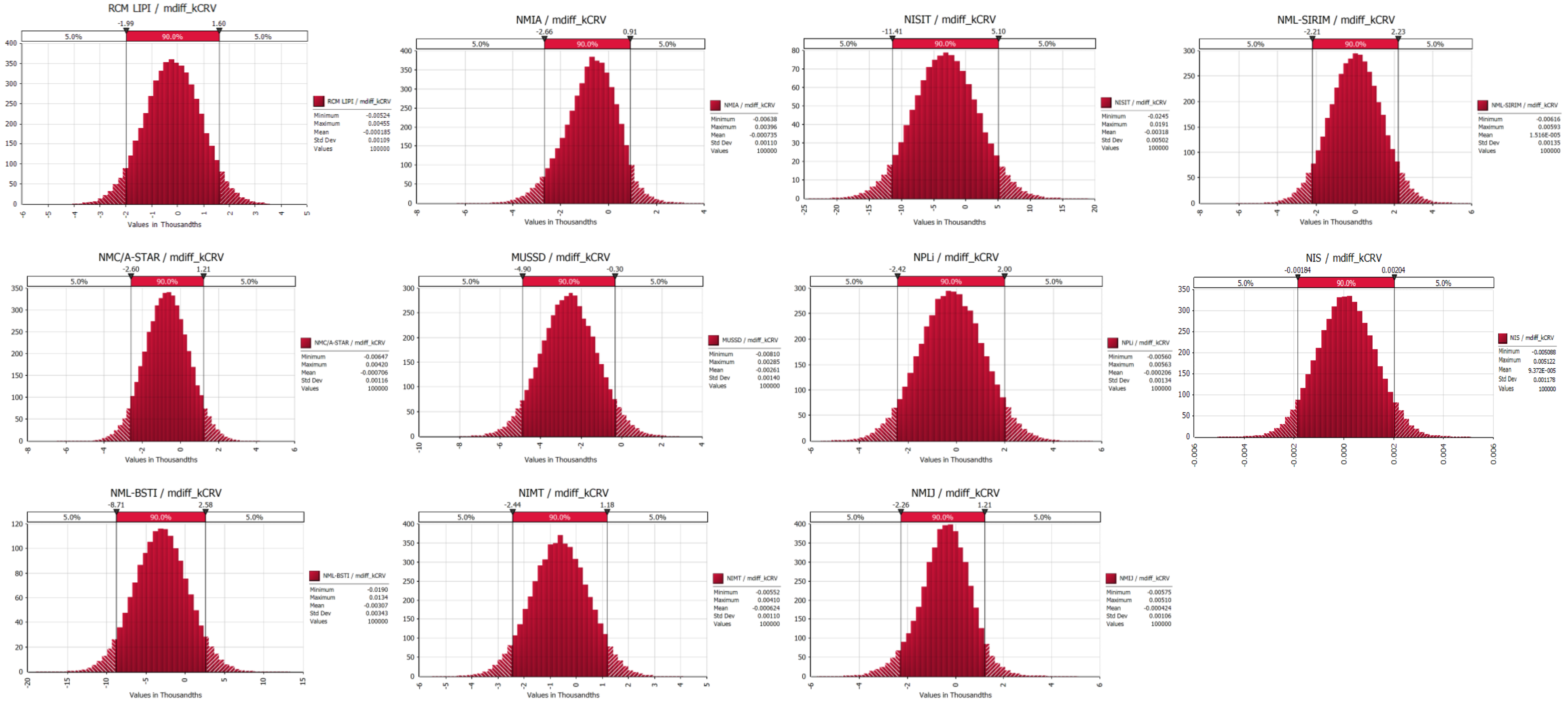


Figure D.16 The histograms of non-linked RV for each participant (1 g)

D.5 The histograms of non-linked RV and DoE for 200 mg standard

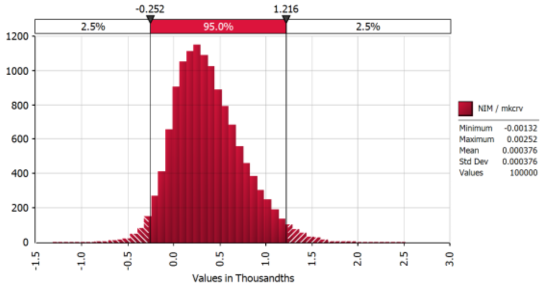


Figure D.17 The histograms of non-linked RV for 200 mg standard

Table D.9 Data of the Median Resulting of Numerical Simulation (mg)

m_{RV}	0.0004
$u(m_{\mathrm{RV}})$	0.0004
$U(m_{\mathrm{RV}})$, k=2	0.0008
$P[x_1,x_2]$	[-0.0003,0.0012]

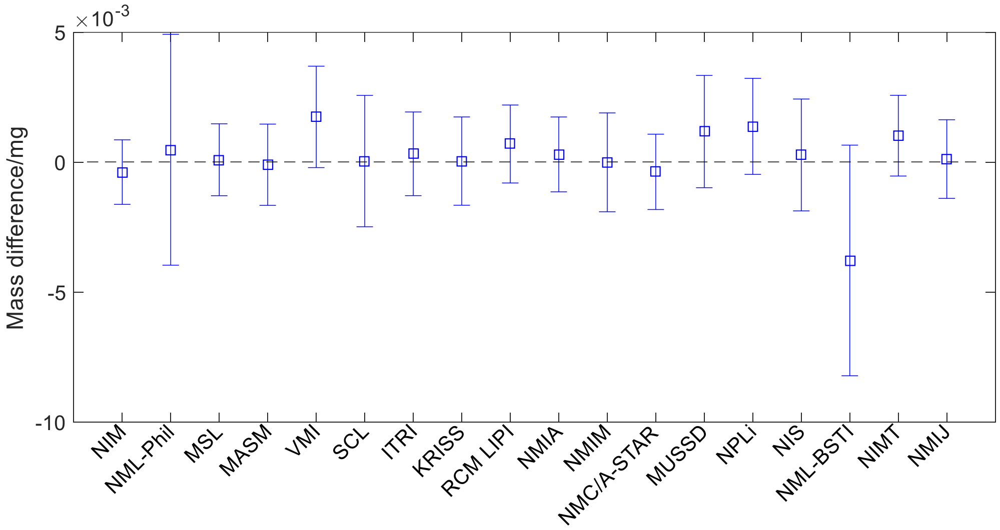


Figure D.18 Deviation D_{i} and $U(D_i)$ obtained by using the MCM estimation with the travelling standards as the non-linked RV

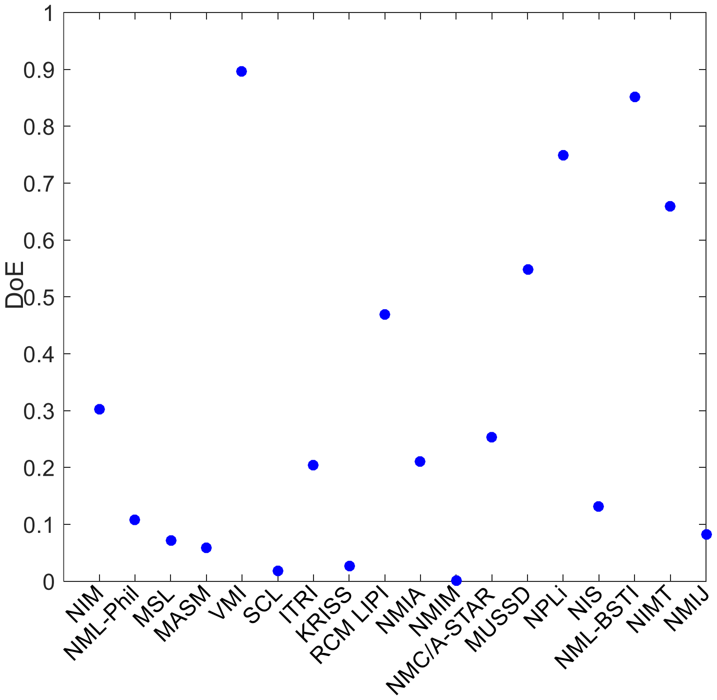
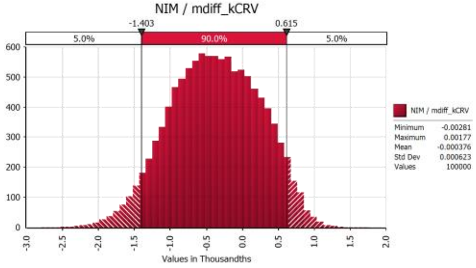
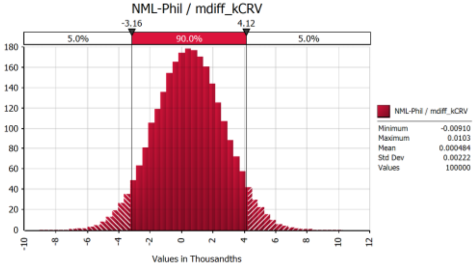


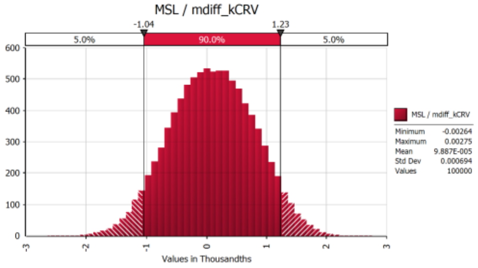
Figure D.19 DoE for 200 mg standards

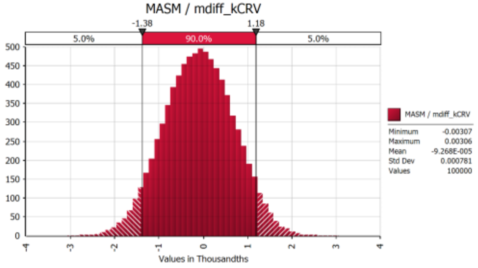
Table D.10 Mass differences between participant laboratories and non-linked RV

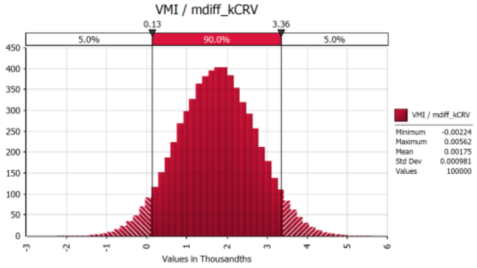
	NIM	NML-Phil	MSL	MASM	VMI	SCL	ITRI	KRISS	RCM LIPI	NMIA	NMIM	NMC/ A-STAR	MUSSD	NPLi	NIS	NML-BSTI	NIMT	NMIJ
D_i ,μg	-0.4	0.5	0.1	-0.1	1.7	0.1	0.3	0.1	0.7	0.3	0.1	-0.4	1.2	1.4	2.9	-3.8	1.0	0.1
$u(D_i)$, μg	0.7	2.3	0.7	0.8	1.0	1.3	0.9	0.9	0.8	0.8	1.0	0.8	1.1	1.0	1.1	2.3	0.8	0.8
$U(D_i)$,k=2, μg	1.4	4.6	1.4	1.6	2.0	2.6	1.8	1.8	1.6	1.6	2.0	1.6	2.2	2.0	2.2	4.6	1.6	1.6
$P[x_1,x_2]\approx$ 95%, μg	[-1.6,0.7]	[-3.9,4.9]	[-1.2,1.4]	[-1.6,1.4]	[-0.2,3.7]	[-2.4,2.5]	[-1.2,1.9]	[-1.6,1.7]	[-0.7,2.2]	[-1.0,1.8]	[-1.9,1.9]	[-1.8,1.0]	[-1.0,3.3]	[-0.4,3.2]	[-1.8,2.4]	[-8.1,0.6]	[-0.5,2.5]	[-1.3,1.6]
DoE = | D_i |/$U(D_i)$	0.30	0.11	0.07	0.06	0.89	0.02	0.20	0.03	0.47	0.21	0.01	0.25	0.55	0.75	0.13	0.85	0.66	0.08

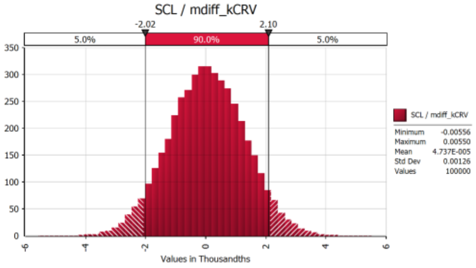


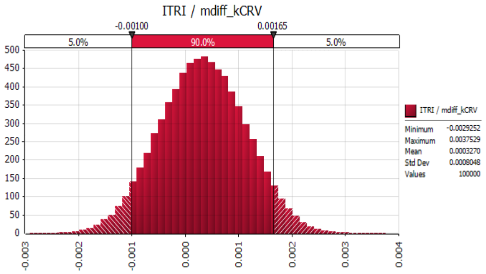


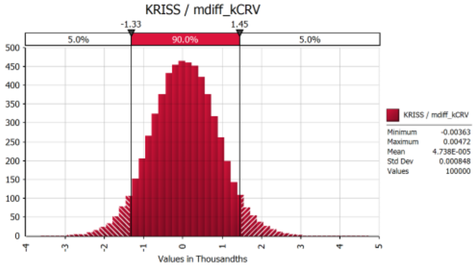












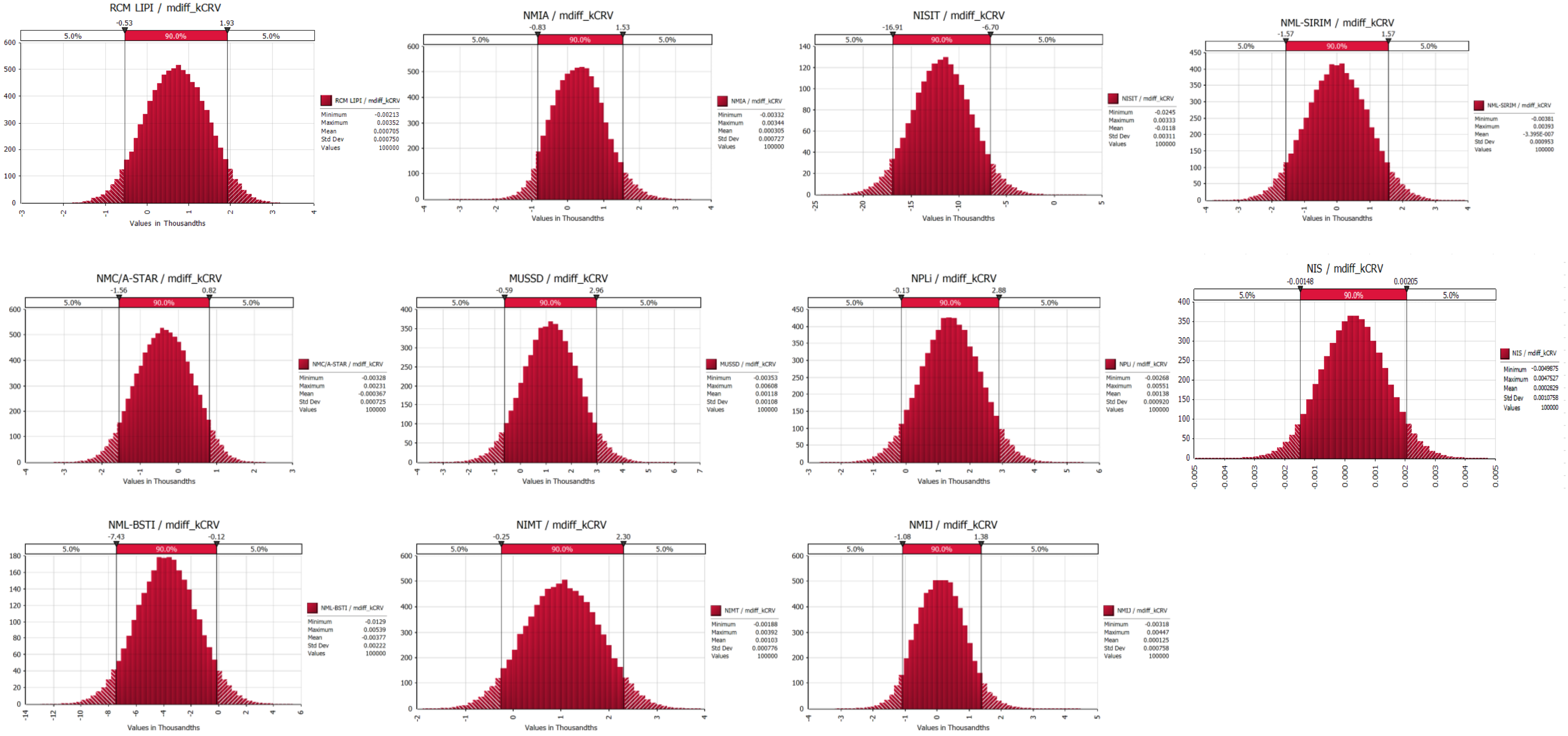


Figure D.20 The histograms of non-linked RV for each participant (200 mg)

ANNEX E

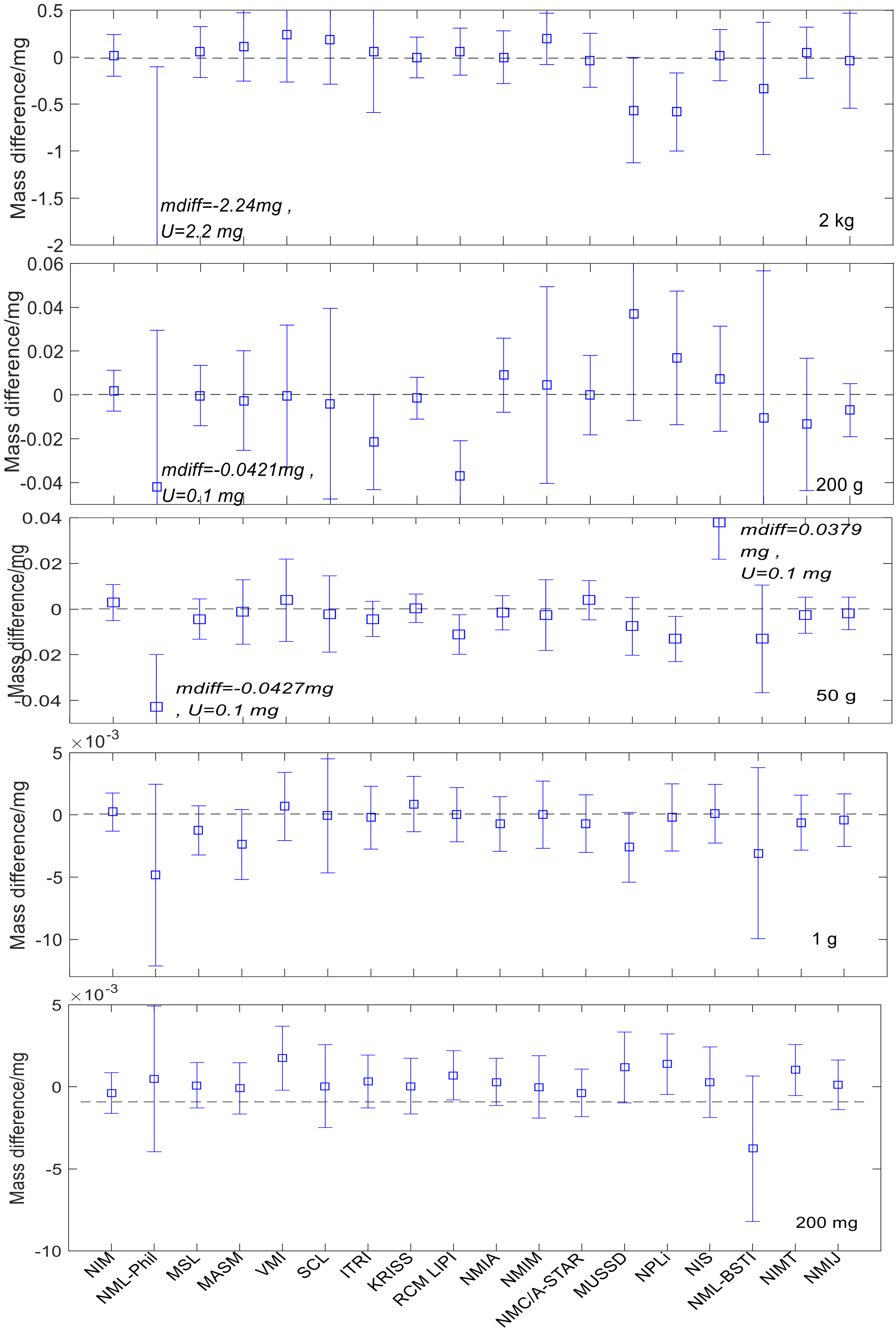


Figure E.1 Deviation D_i and $U(D_i)$ for 2 kg, 200 g, 50 g, 1 g, and 200 mg travelling standards

ANNEX F

F.1 The histograms of linked RV and DoE for 2 kg standard

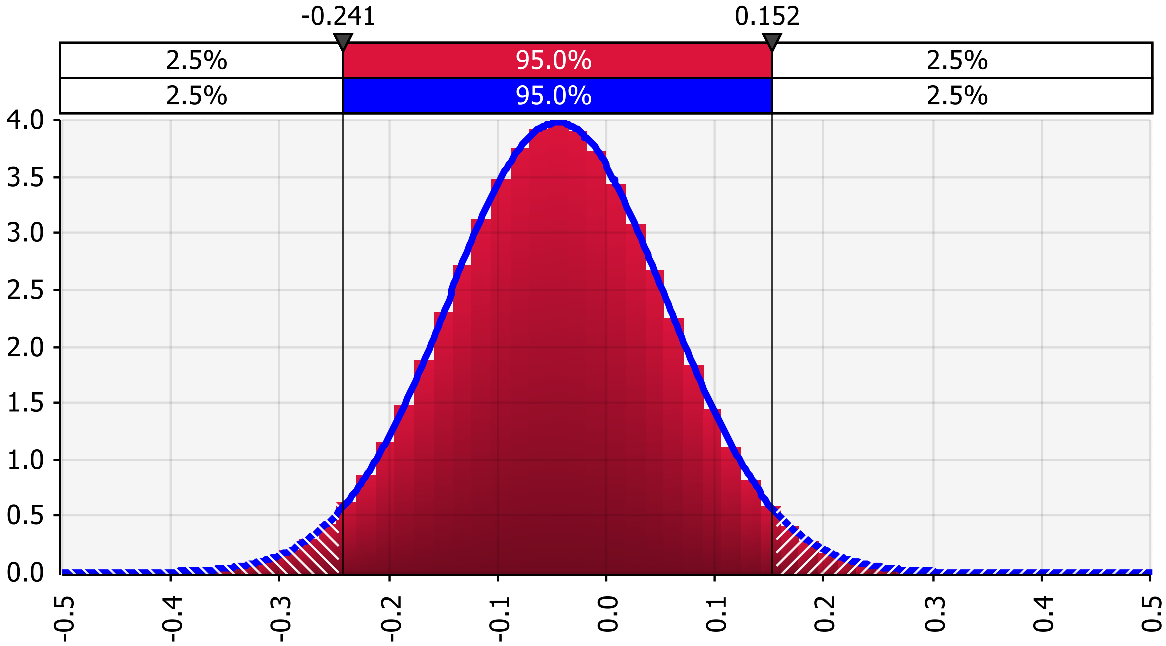


Figure F.1 The Numerical Simulation Result of Linked RV to Jx 2 kg

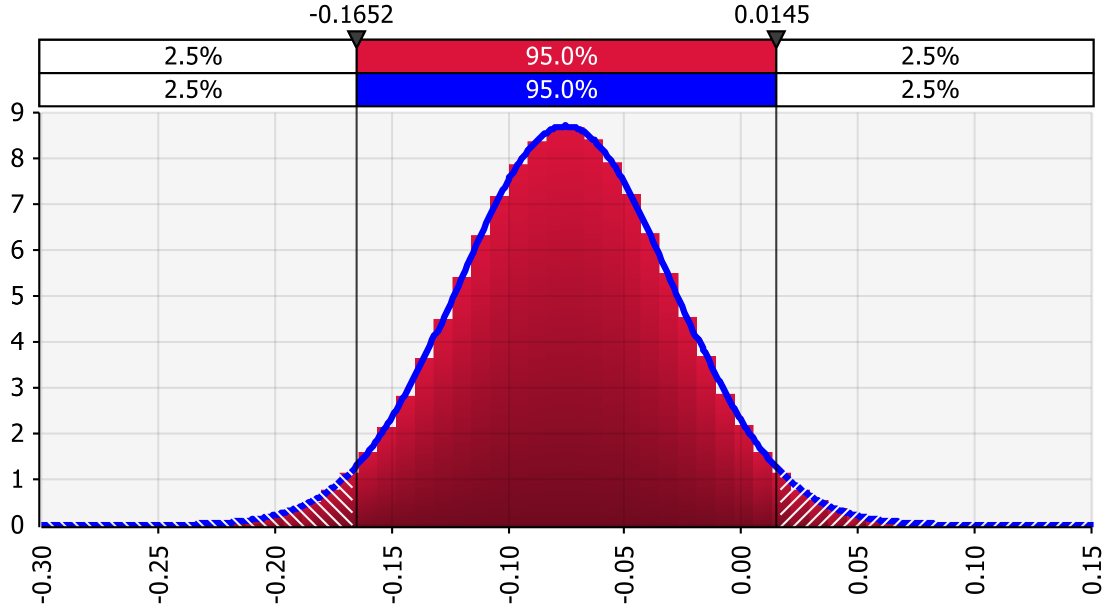


Figure F.2 The Numerical Simulation Result of Linked RV to Jy 2 kg

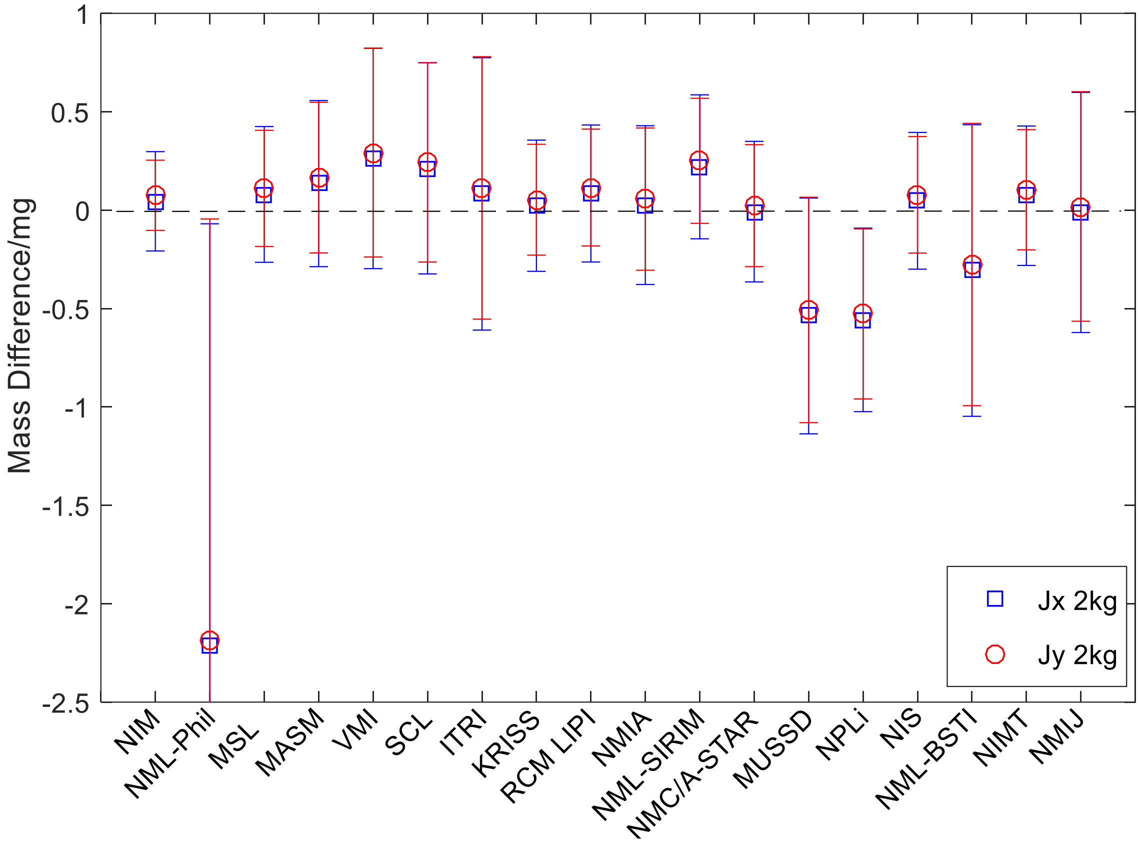


Figure F.3 Deviation D_i and $U(D_i)$ obtained by linking to KCRV of Jx/Jy 2kg

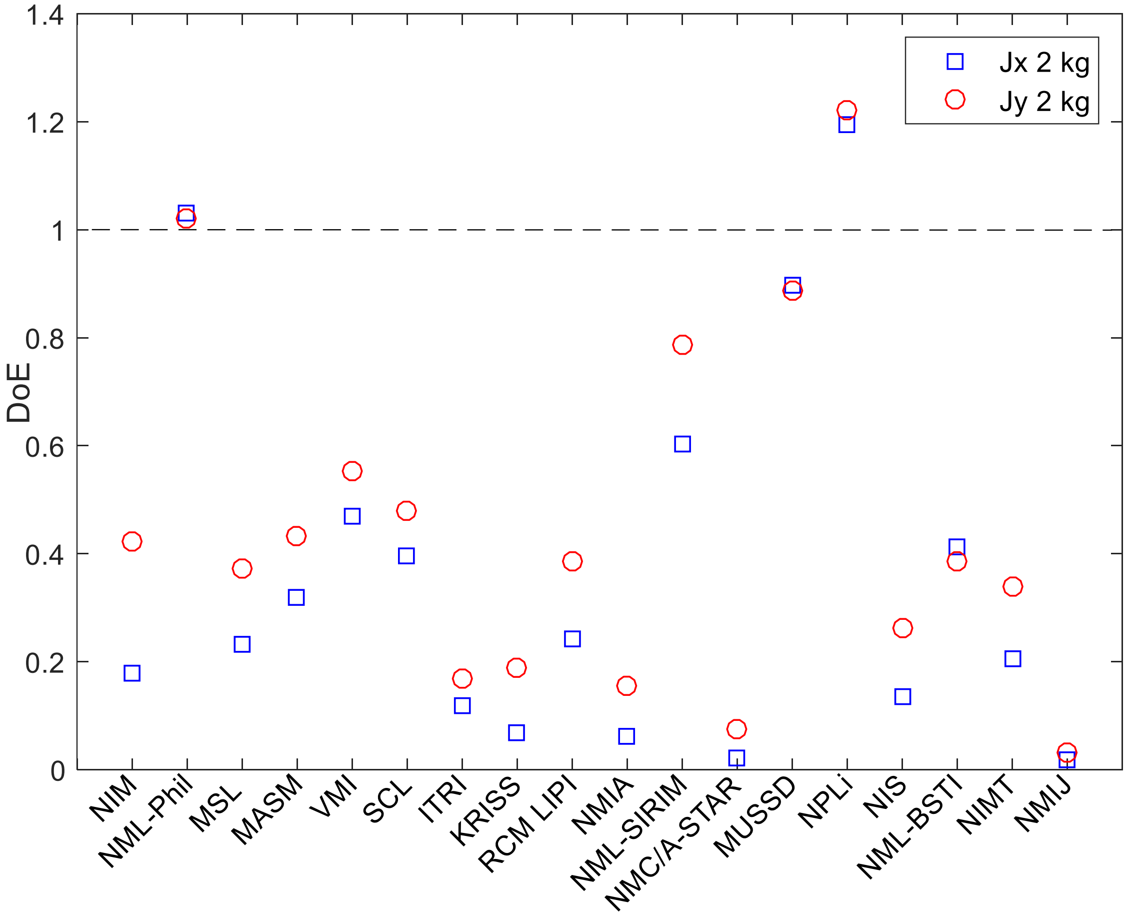


Figure F.4 DoE for linking to KCRV of Jx/Jy 2kg

F.2 The histograms of linked RV and DoE for 200 g standard

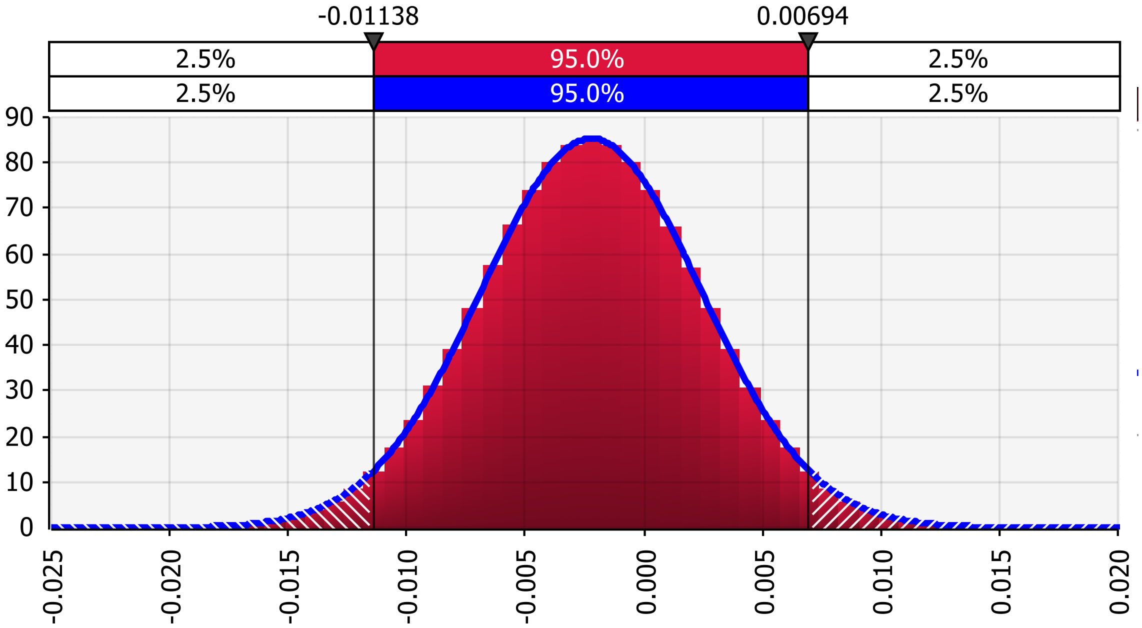


Figure F.5 The Numerical Simulation Result of Linked RV to Jx 200 g

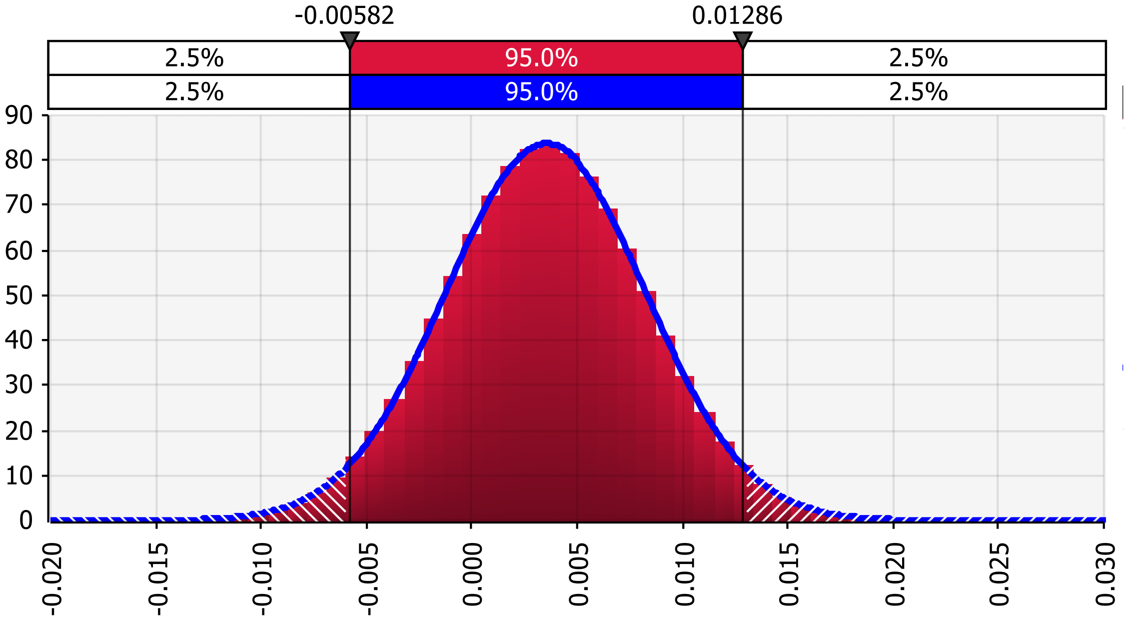


Figure F.6 The Numerical Simulation Result of Linked RV to Jy 200 g

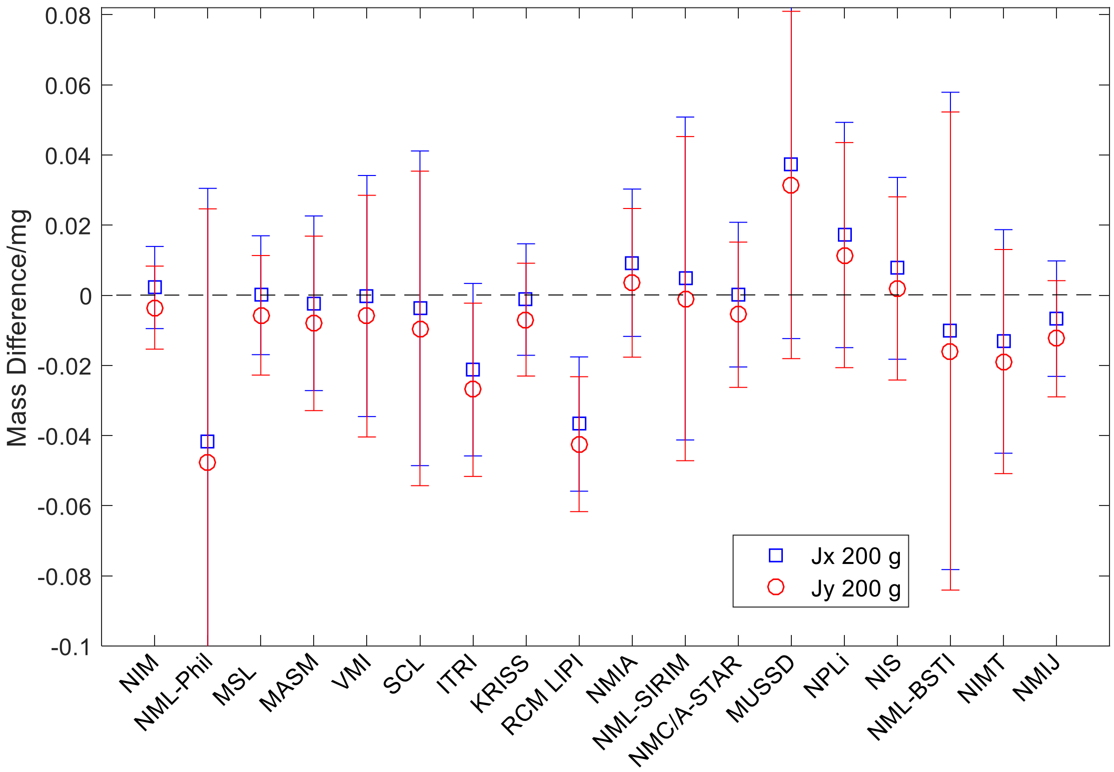


Figure F.7 Deviation D_i and $U(D_i)$ obtained by linking to KCRV of Jx/Jy 200 g

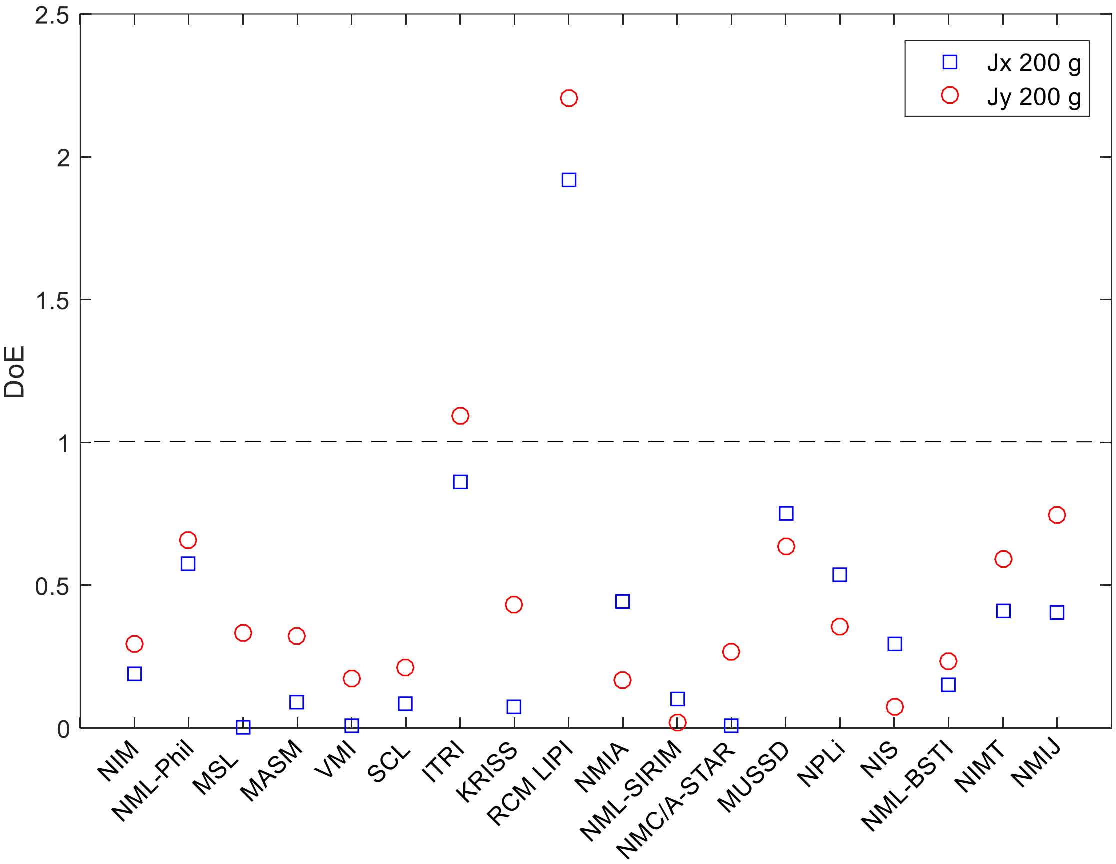


Figure F.8 DoE for linking to KCRV of Jx/Jy 200 g

F.3 The histograms of linked RV and DoE for 50 g standard

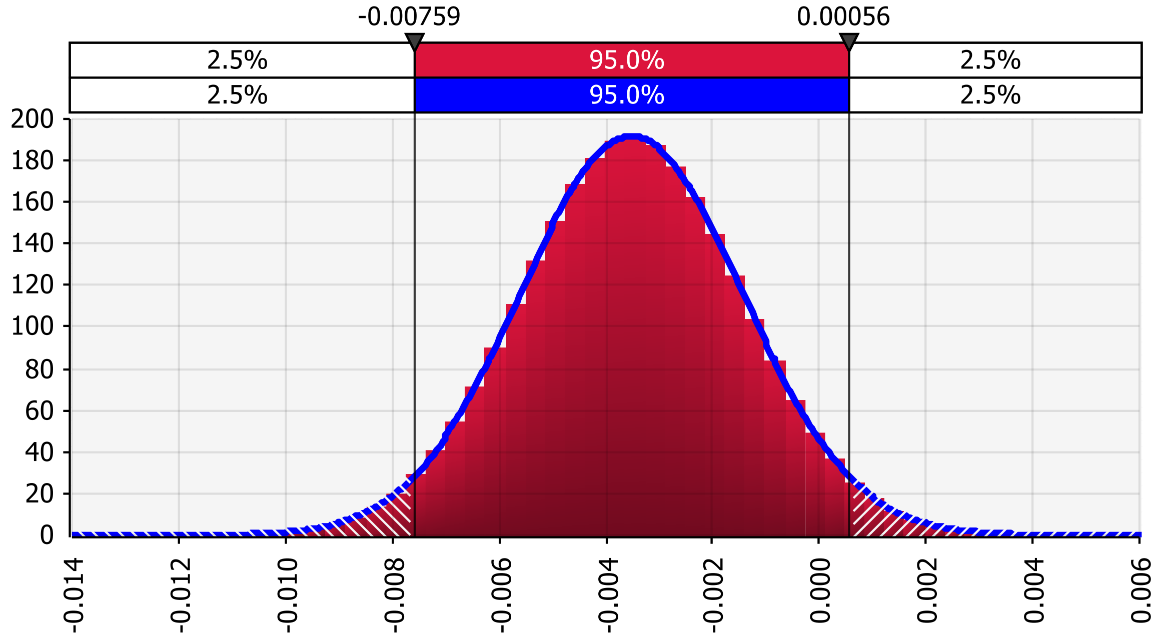


Figure F.9 The Numerical Simulation Result of Linked RV to Jx 50 g

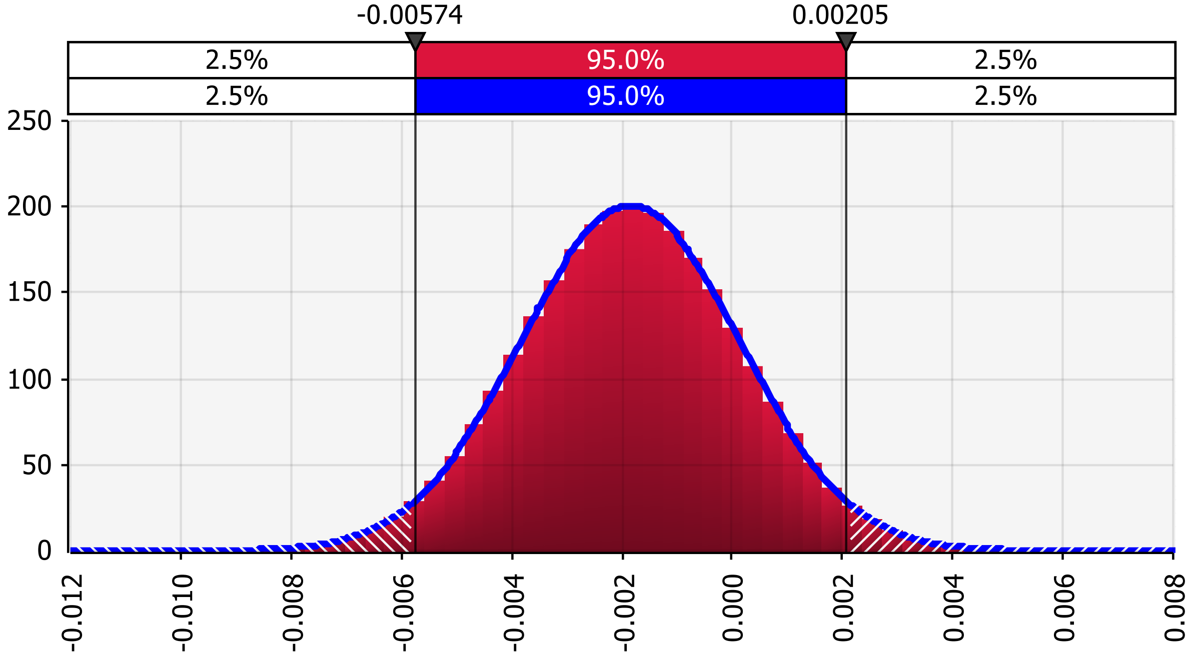


Figure F.10 The Numerical Simulation Result of Linked RV to Jy 50g

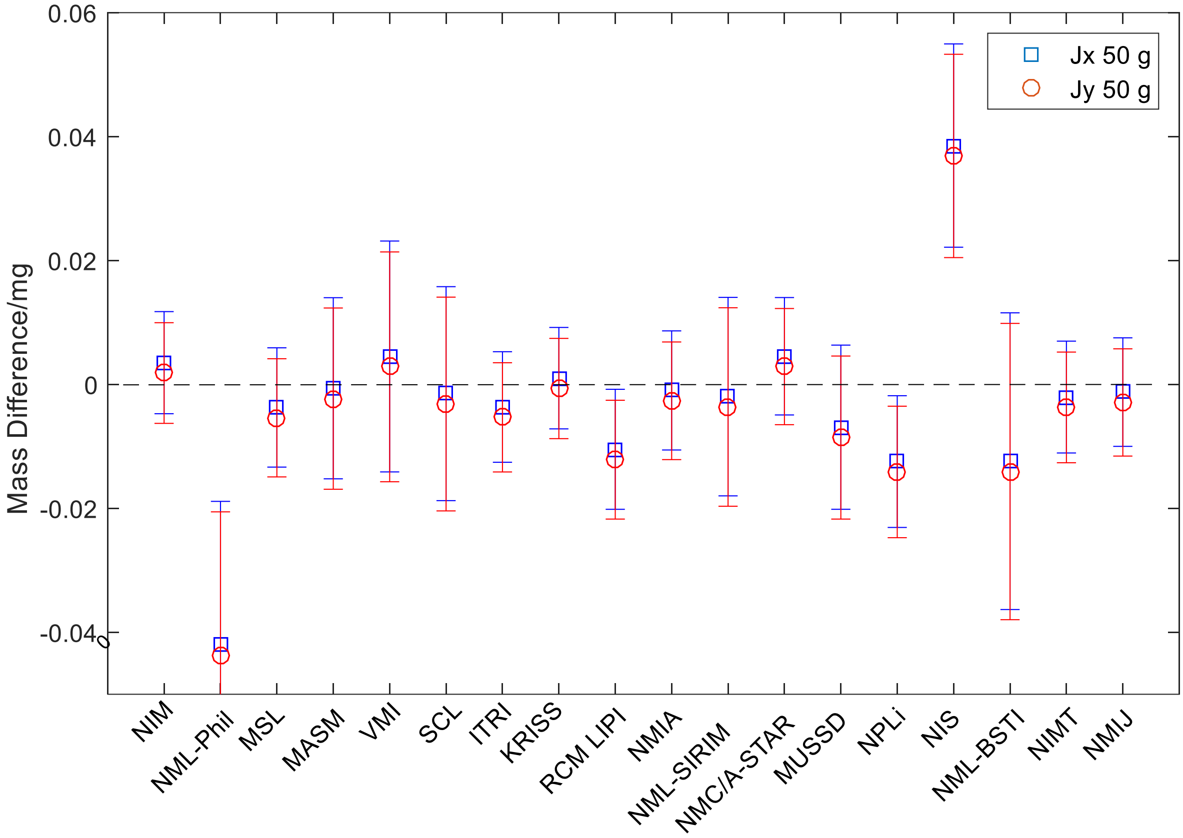


Figure F.11 Deviation D_i and $U(D_i)$ obtained by linking to KCRV of Jx/Jy 50 g

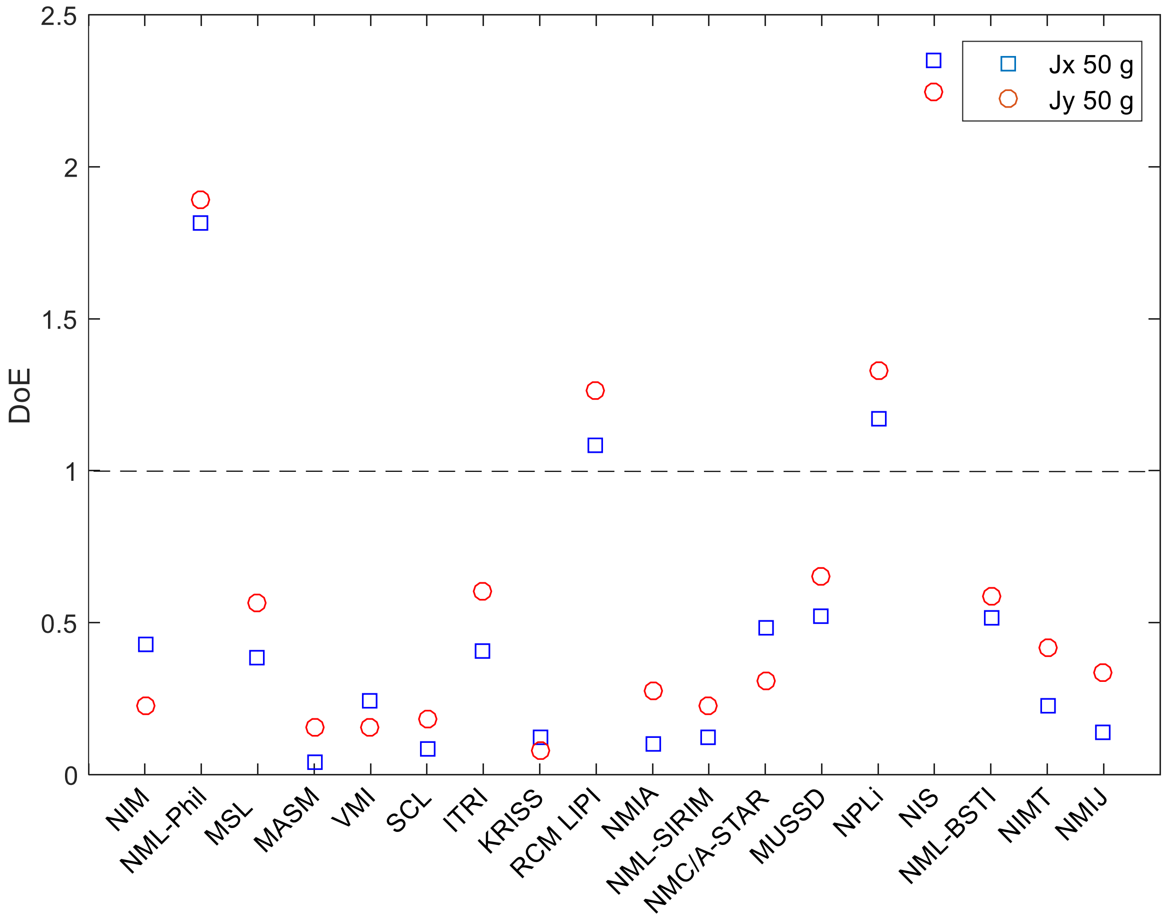


Figure F.12 DoE for linking to KCRV of Jx/Jy 50 g

F.4 The histograms of linked RV and DoE for 1 g standard

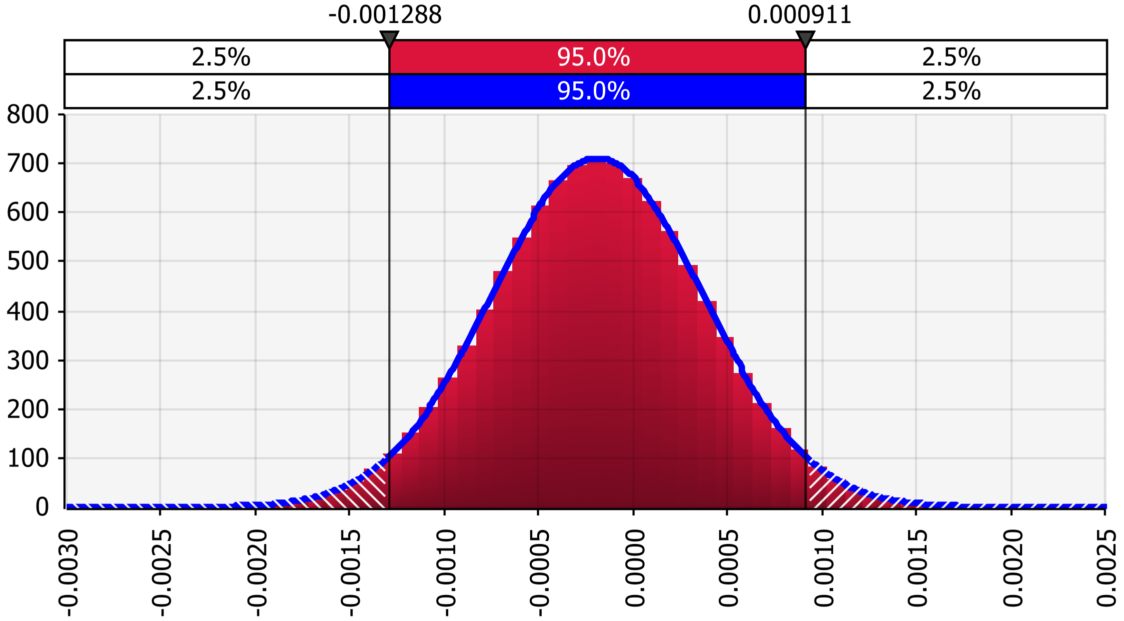


Figure F.13 The Numerical Simulation Result of Linked RV to Jx 1 g

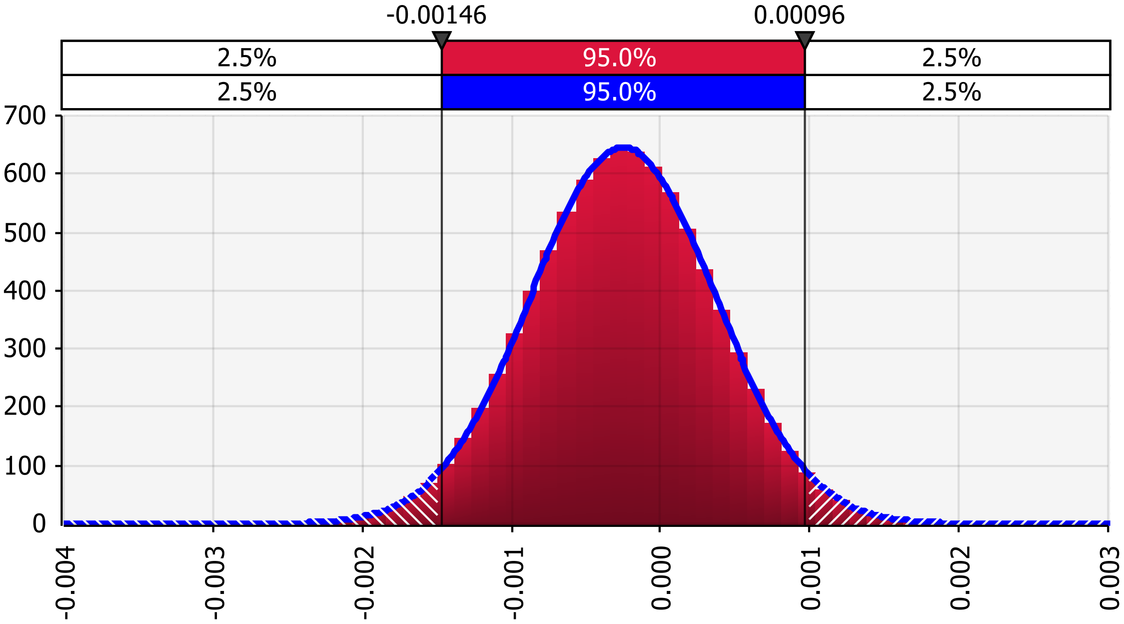


Figure F.14 The Numerical Simulation Result of Linked RV to Jy 1 g

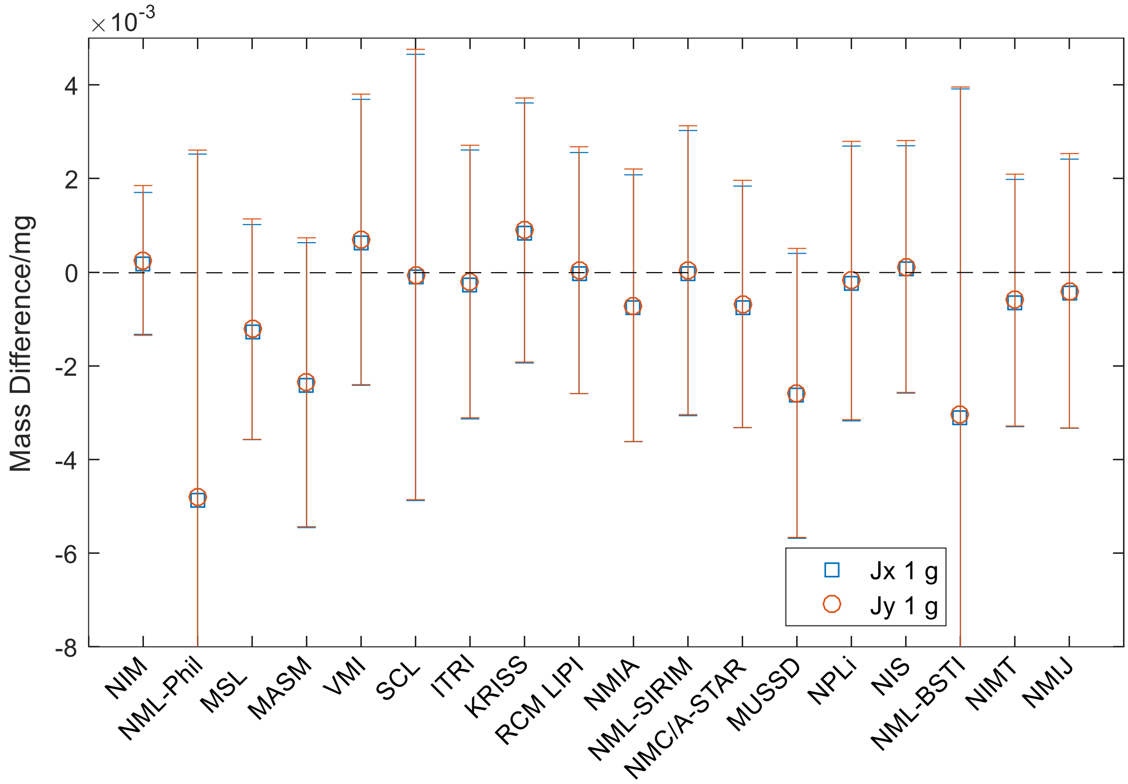


Figure F.15 Deviation D_i and $U(D_i)$ obtained by linking to KCRV of Jx/Jy 1 g

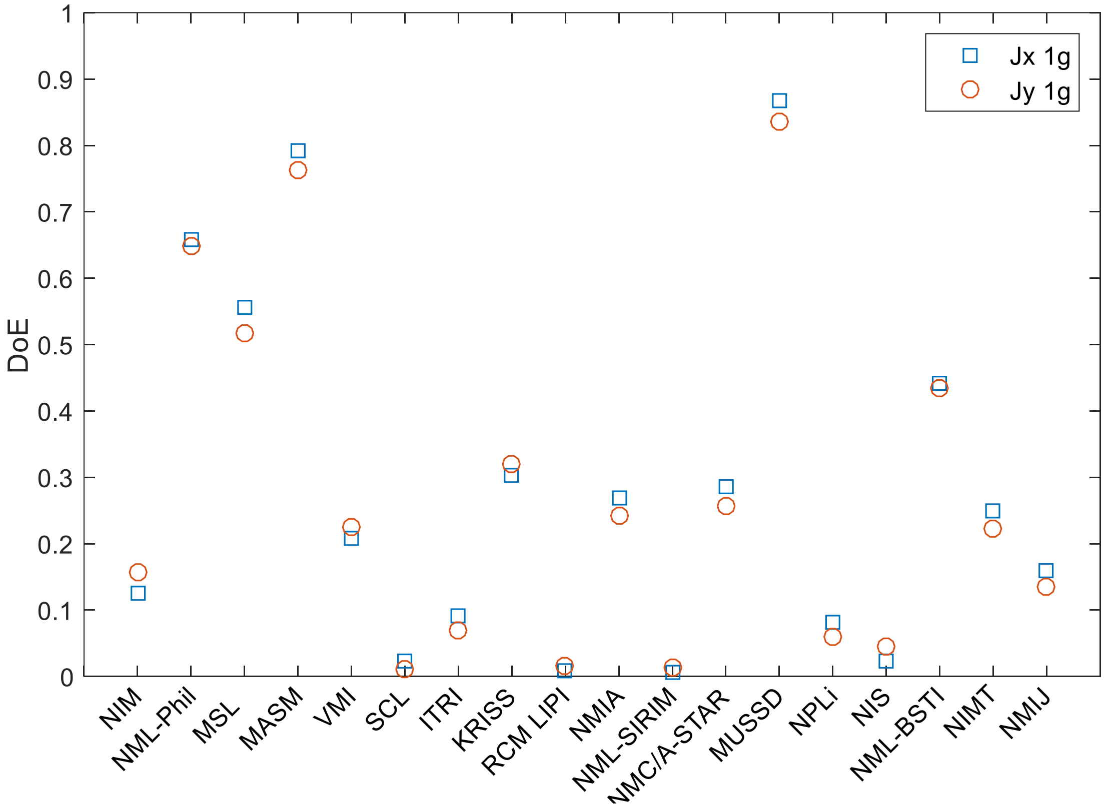


Figure F.16 DoE for linking to KCRV of Jx/Jy 1 g

F.5 The histograms of linked RV and DoE for 200 mg standard

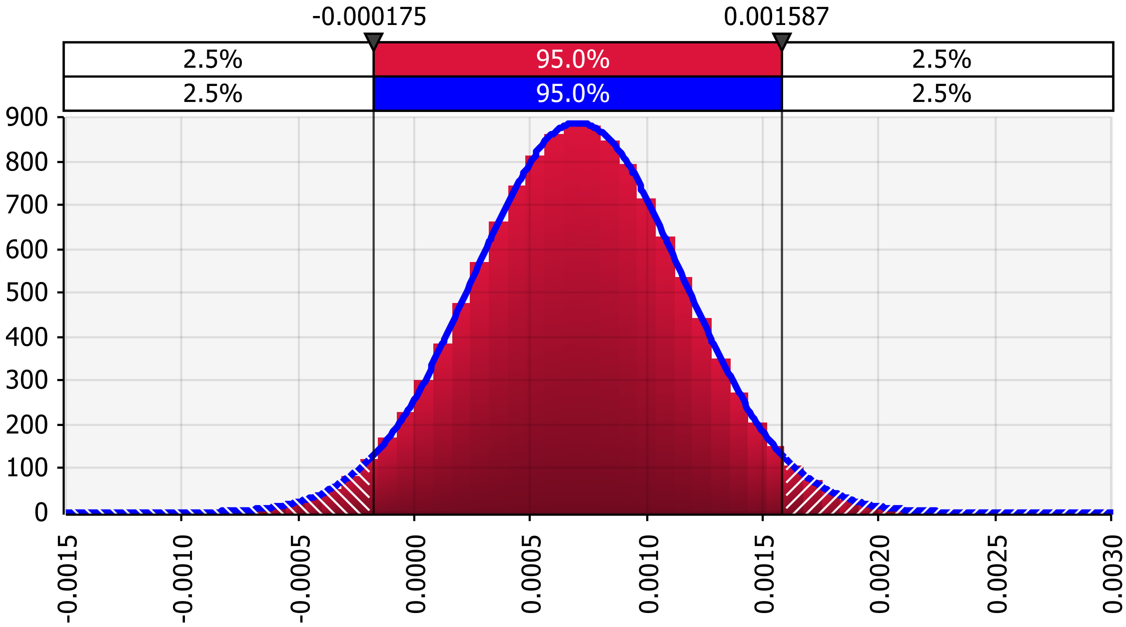


Figure F.17 The Numerical Simulation Result of Linked RV to Jx 200 mg

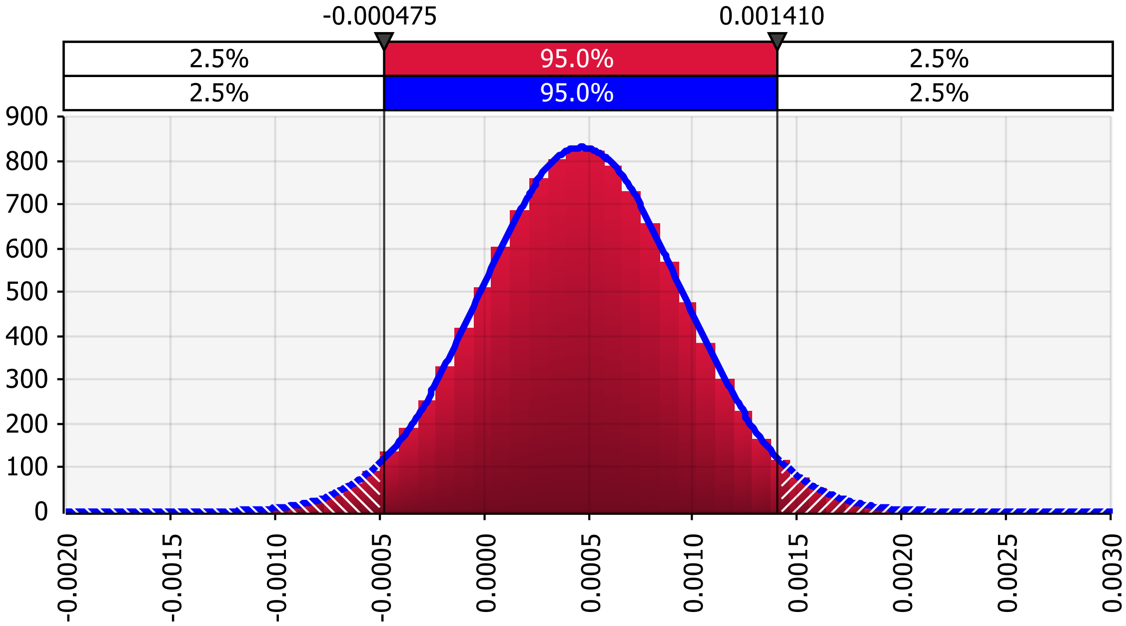


Figure F.18 The Numerical Simulation Result of Linked RV to Jy 200 mg

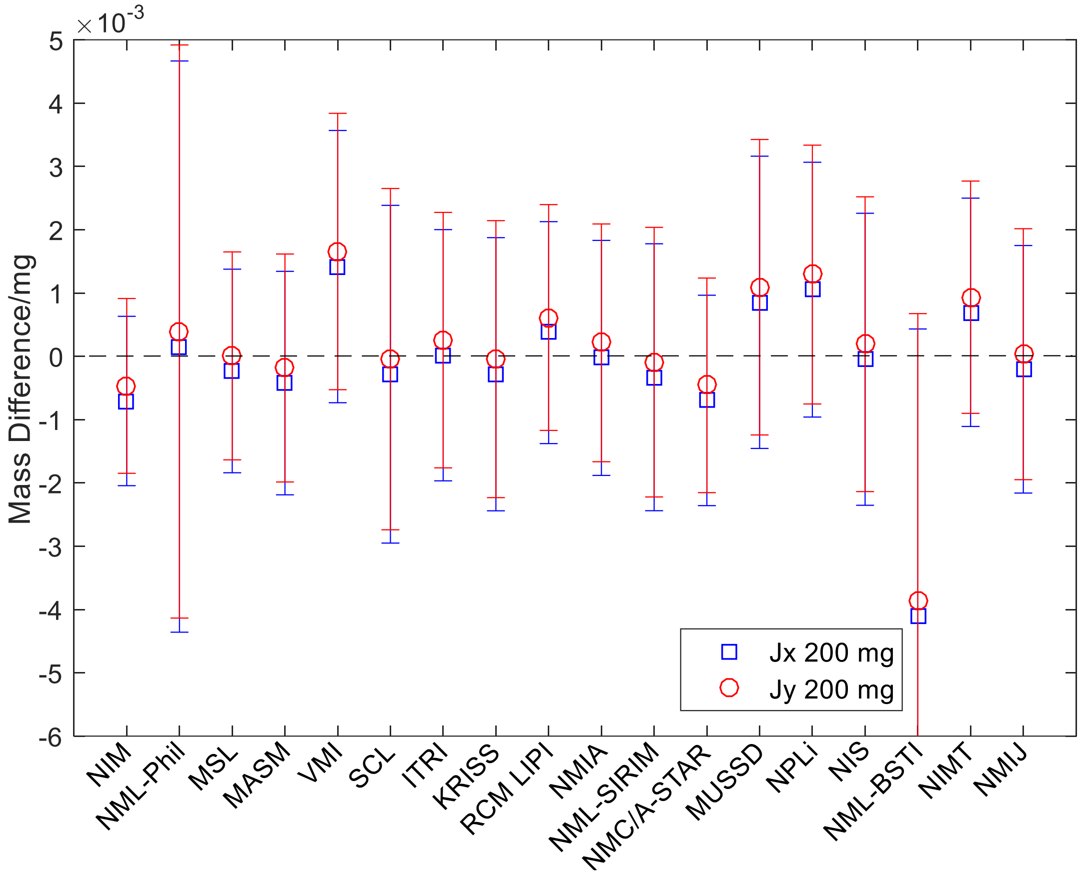


Figure F.19 Deviation D_i and $U(D_i)$ obtained by linking to KCRV of Jx/Jy 200 mg

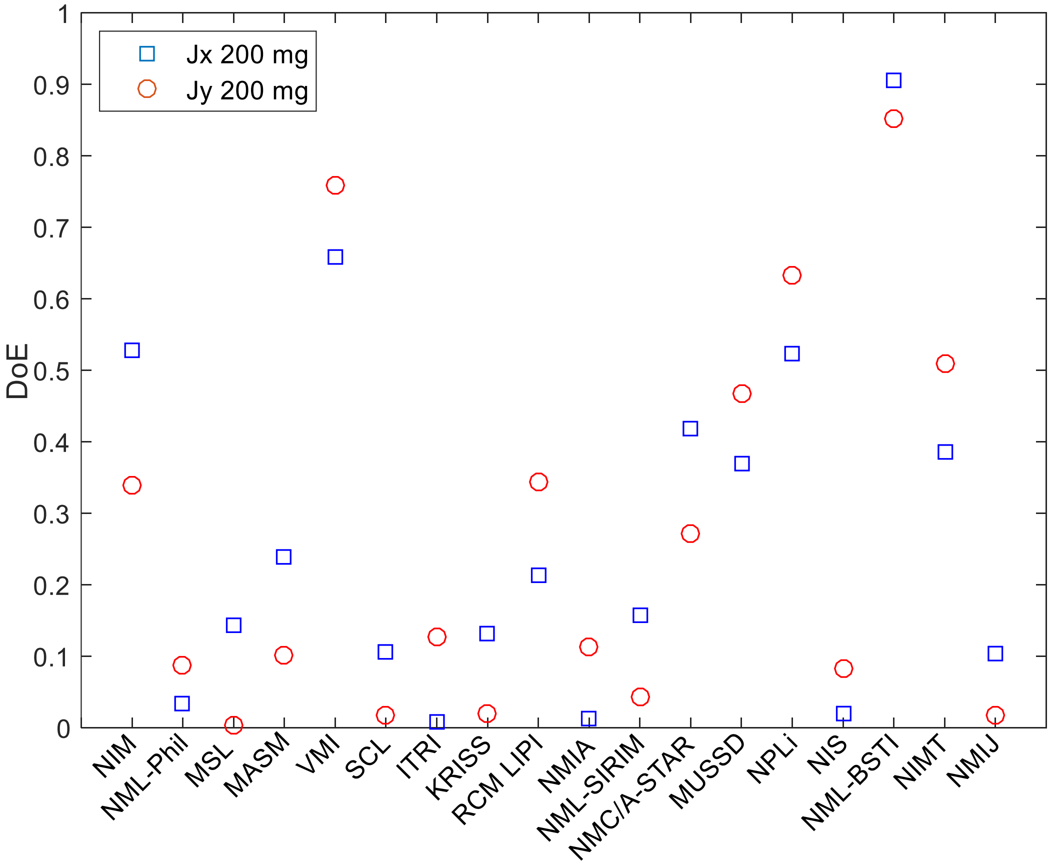
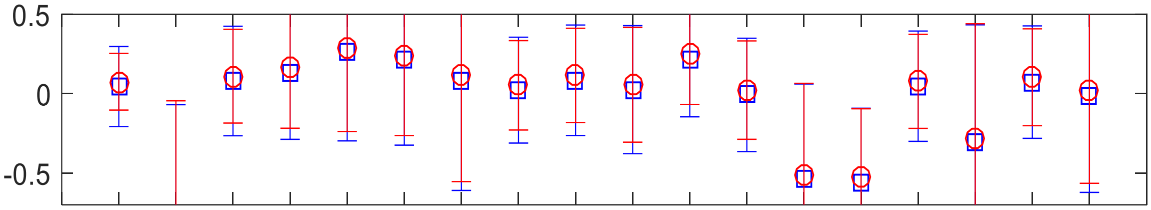
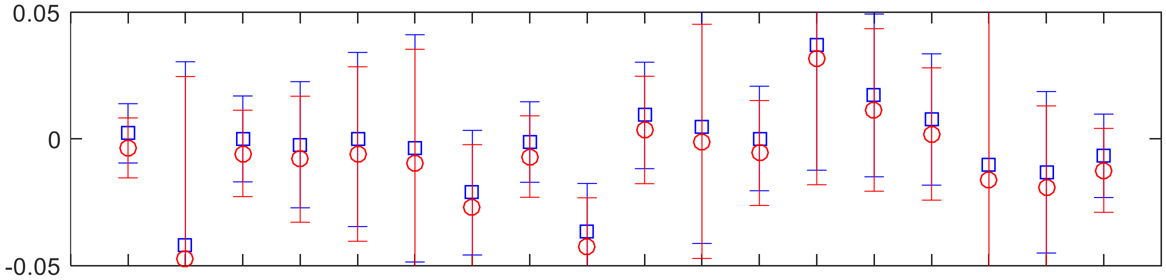


Figure F.20 DoE for linking to KCRV of Jx/Jy 200 mg

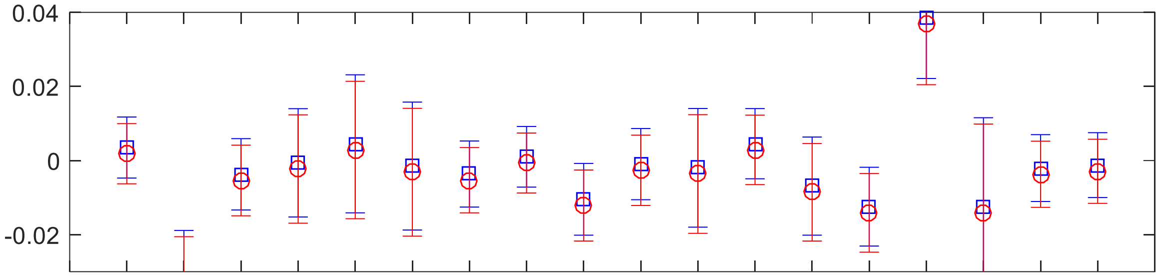
ANNEX G



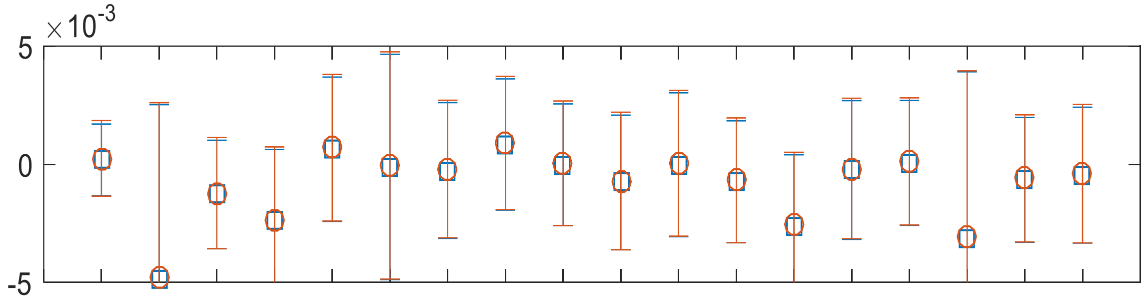
Jx/Jy 2 kg



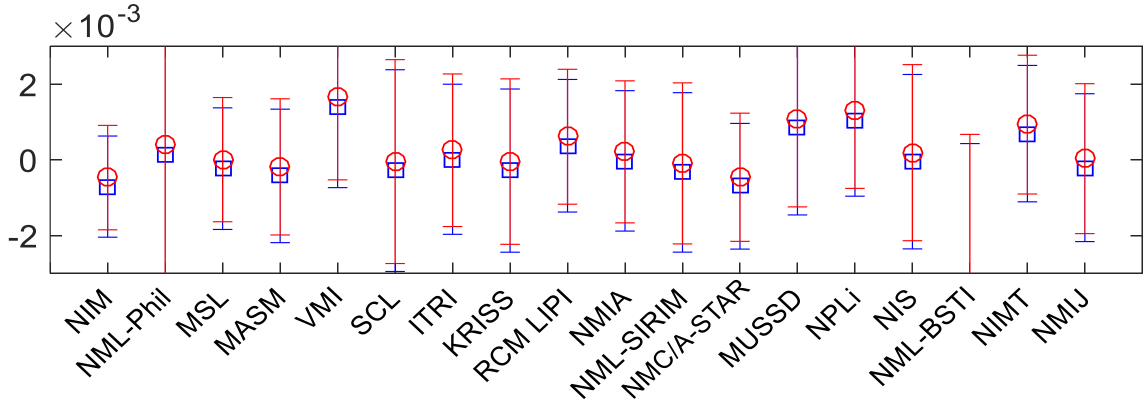
Jx/Jy 200 g



Jx/Jy 50 g



Jx/Jy 1 g



Jx/Jy 200 mg

Figure G.1 Deviation D_i and $U(D_i)$ for 2 kg, 200 g, 50 g, 1 g, and 200 mg linking to CCM.M-K5 (☐: Jx ; O: Jy)

ANNEX H

According to the CCM Guidelines for approval and publication of the final reports of key and supplementary comparisons, it is mandatory that all participants confirm to the pilot laboratory that they have reviewed their published CMCs in respect of the results of the comparison.

The replies from all participants are compiled in the following table:

Laboratory	Status	Date	Further Plan
NIM	Consistent with published CMCs.	Reply on 2019 July 8th	No action is required.
NML-Phil	Consistent with published CMCs.	Reply on 2021 November 11th	No action is required.
MSL	Consistent with published CMCs.	Reply on 2019 July 8th	No action is required.
MASM	Consistent with published CMCs.	Reply on 2019 July 8th	No action is required.
VMI	Consistent with published CMCs.	Reply on 2022 November 12th	No action is required.
SCL	Inconsistencies at nominal value 200 mg, 1 g, 50 g and 200 g	Reply on 11 Nov. 2021 and 30 Nov. 2022	An extra uncertainty components equal to 10 % of the maximum permissible error of the standard mass was added to the uncertainty model during the re-evaluation of our Mass Prototype No. 75 in BIPM in 2014. Disregard the extra components and using the actual uncertainty from BIPM, our uncertainties would be consistent with the published CMCs.
ITRI	Consistent with published CMCs.	Reply on 2019 July 2nd	No action is required.
KRISS	Consistent with published CMCs.	Reply on 2021 November 15	No action is required.
RCM LIPI	Inconsistencies at nominal value 50 g and 200 g.	Reply on 2019 July 3rd	They required change the result after draft B. PL has refused this.
NMIA	Consistent with published CMCs	Kitty resent their reply to NIM in 2019 on 2020 November 11	The NMIA’s claimed uncertainties in CCM.M-K5 support our CMC and we are one of the link labs for the APMP.M.M-K5. NMIA’s claimed uncertainties in APMP.M.M-K5 were larger than our CMC due to the properties of the transfer standards. Therefore I can say that our claimed unc. are consistent with our CMC.
NISIT	NISIT is not a participant to CIPM MRA, and has no published mass CMCs		No action is required
NMIM	Consistent with published CMCs.	Reply on 2019 July 9th	No action is required.

NMC/A-STAR	Smaller than the published CMC	Reply on 2019 June 11th	No action is required.
MUSSD	MUSSD currently has no published mass CMCs.	Reply on 2020 November 13 by e-mail	No action is required, MUSSD has no CMC related to this KC
NPLI	Consistent for all values except at nominal value 50 g and 2 kg	Reply sent to NIM, China, on 2019 July 4th; Copy of the mail attached	Following actions are required: 2 kg: Slightly discrepant result due to environmental stability problem. As per the options given in the email of Dr. Ren in 2019 we would like to expand the CMC from ±0.58 mg to ±0.6 mg at k=2 which would bring the DoE within 1. 50 g: Discrepancy due to environmental stability problem. Plan to participate in new inter-lab comparison.
NIS	Consistent with published CMCs except at nominal value 50 g	Reply on 2021 November, 11th	NIS will take the appropriate corrective action
NML-BSTI	Consistent with published CMCs.	Reply on 2019 July 7th	No action is required.
NIMT	Smaller than the published CMC	Reply on 2019 July 3rd	No action is required. Apply the new CMCs.
NMIJ	Consistent with published CMCs.	Reply on 2020 July 6th	No action is required.