BIPM.EM-K11.b, EUROMET.EM.BIPM-K11, APMP.EM.BIPM-K11.1, EUROMET.EM.BIPM-K11.5, EUROMET.EM.BIPM-K11.6, SIM.EM.BIPM-K11.b, COOMET.EM.BIPM-K11, APMP.EM.BIPM-K11.4 and APMP.EM.BIPM-K11.3

Key comparison BIPM.EM-K11.b **MEASURAND : DC voltage, Zener diode** **NOMINAL VALUE : 10 V**

x $_i$ **: result of measurement carried out by laboratory i expressed as the difference from the BIPM value**
u $_i$ **: combined standard uncertainty of** ***x*** $_i$

Lab *i*	x_i / µV	u_i / µV	Date of measurement
NML(IE)	0.73	2.50	Mar 1997
SPRING Singapore	0.16	0.11	Apr 1998
NML(IE)	-2.5	2.5	Apr 1998
SMU	-0.31	0.32	Aug 1998
NIST	0.26	0.14	Nov 1998
METAS	-0.14	0.14	Apr 1999
NML(IE)	0.3	2.3	Jun 1999
NML(IE)	-1.7	2.4	Apr 2000
CMI	0.77	-1.21	2.7600E+00
NML(IE)	-0.3	2.3	Mar 2001
BEV	-0.04	0.10	Apr 2001
SMU	-0.04	0.86	Apr 2001
GUM	-0.06	0.13	May 2001
NML(IE)	0.37	1.11	Mar 2002
NML(IE)	-0.91	1.03	Mar 2003
NMISA	-0.01	0.33	Nov 2003
NMIA	0.13	0.14	Nov 2003
NML(IE)	-1.86	1.01	Apr 2004
NML(IE)	0.30	1.36	Apr 2005
NML(IE)	0.87	1.40	May 2006
NCM	-0.99	4.00	May 2006

continued…

Lab *i*	x_i / µV	u_i / µV	Date of measurement
NML(IE)	-0.55	1.40	Mar 2007
VNIIM	-0.22	0.34	Sep 2007
KRISS	-0.03	0.10	Feb 2008
NML(IE)	-0.56	1.32	May 2008
NML(IE)	-0.19	1.14	May 2009
INTI	-0.24	0.38	Sep 2009
NSAI NML*	-1.03	1.13	Apr 2010
NSAI NML*	0.16	1.40	Apr 2011
NSAI NML*	0.83	1.35	Mar 2012
NSAI NML*	-0.63	1.31	Feb 2013
NSAI NML*	-0.64	1.35	Mar 2014
NSAI NML*	-0.82	1.35	Fev 2015
NSAI NML*	0.22	1.35	Fev 2016
NSAI NML*	-1.21	1.38	Jun 2018
INM(RO)	-0.43	0.34	Aug 2013
DMDM	0.39	0.12	Feb 2014
NIS	0.22	0.14	Sep 2014
NIMT	-0.03	0.11	Nov 2014
SMD	0.09	0.49	Nov 2014
JV	0.63	0.28	Jan 2015
DEFNAT	0.38	0.10	Feb 2016
NMISA	0.00	0.34	May 2017
KEBS	0.25	1.55	Feb 2018

Laboratories having an independant realization of the volt
by means of a Josephson Array Voltage Standard

* NSAI NML stands for NSAI National Metrology Laboratory from Ireland and is used for the measurement results obtained starting 2010. The acronym NML(IE) is kept for the measurement laboratory results obtained before 2010.

Key comparison EUROMET.EM.BIPM-K11 **Pilot laboratory: NMi-VSL**

MEASURAND : DC voltage, Zener diode **NOMINAL VALUE : 10 V**

$x_{i\text{-EUR}}$: **result of a participant in EUROMET.EM.BIPM-K11 for its voltage measurements on a group of electronic DC voltage standards. This results (designated as Δ_G in the EUROMET.EM.BIPM-K11 Final Report) is calculated as the weighted mean of the voltage differences between the participant's measured values and interpolated values based on the measurements of the Pilot laboratory**

$U'_{i\text{-EUR}}$: **expanded uncertainty (k = 2) in a participant's measurement result for the group of travelling standards (designated as U_{TG} in the EUROMET.EM.BIPM-K11 Final Report)**

Lab *i*	$x_{i\text{-EUR}}$ / µV	$U'_{i\text{-EUR}}$ / µV	Date of measurement
LNE	0.497	0.529	2 Dec 1998
NPL	-0.217	0.416	16 Jan 1999
NML(IE)	-0.042	4.114	30 Jan 1999
UME	0.097	0.409	06 Mar 1999
DFM	0.134	0.424	24 Apr 1999
SP	0.076	-1.210	2.76
MIKES	0.034	0.450	09 Jun 1999
JV	-0.154	0.438	27 Jun 1999
SMD	-0.055	3.716	05 Sep 1999
CMI	0.867	1.509	23 Oct 1999
BEV	-0.048	0.551	04 Nov 1999
SMU	-0.030	0.411	24 Nov 1999
NMi-VSL	-0.019	0.425	19 Dec 1999
CEM	0.449	0.420	15 Jan 2000
INETI	-2.549	6.515	27 Jan 2000
METAS	0.140	0.415	12 Mar 2000
PTB	0.291	0.410	14 Apr 2000
BIPM	0.125	0.419	30 Apr 2000
EIM	-0.411	0.490	07 Oct 2000
MIRS/SIQ	0.439	6.100	22 Oct 2000
OMH	-0.513	6.484	05 Nov 2000

Laboratories having an independant realization of the volt by means of a Josephson Array Voltage Standard

Key comparison APMP.EM.BIPM-K11.1 — Pilot laboratory: NMIA

MEASURAND : DC voltage, Zener diode
NOMINAL VALUE : 10 V

This is a bilateral key comparison between SCL and NMIA.
Mean date of the period of measurements: 23 June 2002

$x_{\text{SCL-NMIA}}$:	result of measurement carried out by SCL expressed as the difference from the NMIA value	$x_{\text{SCL-NMIA}} = -0.46\ \mu V$
$U_{\text{SCL-NMIA}}$:	expanded uncertainty of $x_{\text{SCL-NMIA}}$ using a coverage factor close to 2.	$U_{\text{SCL-NMIA}} = 0.54\ \mu V$

Key comparison EUROMET.EM.BIPM-K11.5 — Pilot laboratory: DFM

MEASURAND : DC voltage, Zener diode
NOMINAL VALUE : 10 V

This is a bilateral key comparison between VMT/PFI and DFM.
Mean date of the period of measurements: 11 June 2005

$x_{\text{VMT/PFI-DFM}}$:	result of measurement carried out by VMT/PFI expressed as the difference from the DFM value	$x_{\text{VMT/PFI-DFM}} = -0.10\ \mu V$
$U_{\text{VMT/PFI-DFM}}$:	expanded uncertainty of $x_{\text{VMT/PFI-DFM}}$ using a coverage factor equal to 2	$U_{\text{VMT/PFI-DFM}} = 0.30\ \mu V$

Key comparison EUROMET.EM.BIPM-K11.6 — Pilot laboratory: BEV

MEASURAND : DC voltage, Zener diode
NOMINAL VALUE : 10 V

This is a trilateral key comparison between BEV, INM(RO) and UME.
Mean measurement date at INM(RO): 30 June 2005

The difference between the INM(RO) measurement and a calculated expected value at the mean measurement date at INM(RO), together with its uncertainty, is given on page 6 of the EUROMET.EM.BIPM-K11.6 Final Report.

Key comparison SIM.EM.BIPM-K11.b — Pilot laboratory: NIST

MEASURAND : DC voltage, Zener diode
NOMINAL VALUE : 10 V

This is a bilateral key comparison between NIST and CENAM
Period of measurements: 21 to 23 March 2006

$x_{\text{CENAM-NIST}}$:	result of measurement carried out by CENAM and NIST expressed as the difference from the NIST value	$x_{\text{CENAM-NIST}} = -34.7$ nV
$U_{\text{CENAM-NIST}}$:	expanded uncertainty of $x_{\text{CENAM-NIST}}$ using a coverage factor equal to 2	$U_{\text{CENAM-NIST}} = 43.2$ nV

Key comparison COOMET.EM.BIPM-K11 — Pilot laboratory: VNIIM

MEASURAND : DC voltage, Zener diode

NOMINAL VALUE : 10 V

This is a bilateral key comparison between BelGIM and VNIIM.

Mean date of the period of measurements: 27 July 2011

$x_{\text{BelGIM-VNIIM}}$:	mean of the results of measurement carried out by BelGIM expressed as the difference from the VNIIM value	$x_{\text{BelGIM-VNIIM}} = -0.06$ µV
$u_{\text{BelGIM-VNIIM}}$:	combined standard uncertainty of $x_{i\ \text{BelGIM-VNIM}}$	$u_{\text{BelGIM-VNIIM}} = 0.29$ µV

Key comparison APMP.EM.BIPM-K11.4 — Pilot laboratory: KRISS

MEASURAND : DC voltage, Zener diode

NOMINAL VALUE : 10 V

This is a bilateral key comparison between VMI-STAMEQ and KRISS.

Date of measurement: July 2012.

$x_{\text{VMI-STAMEQ - KRISS}}$:	result of measurement carried out by VMI-STAMEQ expressed as the difference from the KRISS value	$x_{\text{VMI-STAMEQ - KRISS}} = 0.935$ µV
$u_{\text{VMI-STAMEQ - KRISS}}$:	combined standard uncertainty of $x_{\text{VMI-STAMEQ - KRISS}}$	$u_{\text{VMI-STAMEQ - KRISS}} = 0.757$ µV

Key comparison APMP.EM.BIPM-K11.3 **Pilot laboratory: KRISS**

MEASURAND : DC voltage, Zener diode

NOMINAL VALUE : 10 V

This is a key comparison with 10 participants.

Date of measurement: frtom 2009 to 2011

The measurement results are listed in Section 7 (p. 26) of the the APMP.EM.BIPM-K11.3 Final Report.

BIPM.EM-K11.b, EUROMET.EM.BIPM-K11, APMP.EM.BIPM-K11.1, EUROMET.EM.BIPM-K11.5, EUROMET.EM.BIPM-K11.6, SIM.EM.BIPM-K11.b, COOMET.EM.BIPM-K11, APMP.EM.BIPM-K11.4 and APMP.EM.BIPM-K11.3

Key comparison BIPM.EM-K11.b

MEASURAND : DC voltage, Zener diode NOMINAL VALUE : 10 V

The key comparison reference value is the BIPM value, x_R. Its standard uncertainty, u_R, is evaluated to be 0.1 µV and is included in the u_i's values.

The degree of equivalence of laboratory i with respect to the reference value x_R is given by a pair of terms, both expressed in µV: $D_i = x_i$ and its expanded uncertainty ($k = 2$), $U_i = 2u_i$.

When required, the degree of equivalence between two laboratories i and j is given by a pair of terms, both expressed in µV: $D_{ij} = (D_i - D_j) = (x_i - x_j)$ and its expanded uncertainty ($k = 2$) expressed as $U_{ij} = 2[u_i^2 + u_j^2]^{1/2}$.

Key comparison EUROMET.EM.BIPM-K11

MEASURAND : DC voltage, Zener diode NOMINAL VALUE : 10 V

The EUROMET refe -1.21 3
realization of the volt by means of a Josephson Array Voltage Standard. $x_{R\text{-}EUR} = 0.067$ µV with an expanded uncertainty ($k = 2$) $U_{R\text{-}EUR} = 0.113$ µV.

The EUROMET degree of equivalence of each laboratory i participant in EUROMET.EM.BIPM-K11 with respect to the reference value $x_{R\text{-}EUR}$ is given by a pair of terms, both expressed in µV: $D_{i\text{-}EUR} = (x_{i\text{-}EUR} - x_{R\text{-}EUR})$ and its expanded uncertainty $U_{i\text{-}EUR} = (U'^2_{i\text{-}EUR} - U^2_{R\text{-}EUR})^{1/2}$ for independent laboratories, and $U_{i\text{-}EUR} = (U'^2_{i\text{-}EUR} + U^2_{R\text{-}EUR})^{1/2}$ for laboratories which do not have an independent realisation of the volt.

-1.21 1.38 Jun 2018

When required, the degree of equivalence between two laboratories i and j participant in EUROMET.EM.BIPM-K11 is given by a pair of terms, both expressed in µV: $D_{ij\text{-}EUR} = (D_{i\text{-}EUR} - D_{j\text{-}EUR})$ and its expanded uncertainty ($k = 2$), $U_{ij\text{-}EUR} = (U'^2_{i\text{-}EUR} + U'^2_{j\text{-}EUR})^{1/2}$.

Linking EUROMET.EM.BIPM-K11 to BIPM.EM-K11.b

The link is computed using the results of the common participants which have an independent realization of the volt by means of a Josephson Array Voltage Standard: the BIPM, BEV, SMU and METAS.

For each of these four laboratories, an estimate of $(x_{R\text{-}EUR} - x_R)$ is obtained as $(D_i - D_{i\text{-}EUR})$. Its uncertainty is the root sum square of U_i and $U_{i\text{-}EUR}$. The weighted mean of these four estimates leads to: $(x_{R\text{-}EUR} - x_R) = -0.075$ µV and $U_{LINK} = 0.283$ µV.

The degree of equivalence of each laboratory i participant in EUROMET.EM.BIPM-K11 with respect to the reference value x_R is given by a pair of terms, both expressed in µV: $D_i = (x_{i\text{-}EUR} - x_R) = (x_{i\text{-}EUR} - x_{R\text{-}EUR}) + (x_{R\text{-}EUR} - x_R)$ and its expanded uncertainty $U_i = (U^2_{i\text{-}EUR} + U^2_{LINK})^{1/2}$.

When required, the degree of equivalence between one laboratory participant in EUROMET.EM.BIPM-K11 and one laboratory participant in BIPM.EM-K11.b is given by a pair of terms, both expressed in µV: $D_{ij} = (D_i - D_j)$ and its expanded uncertainty ($k = 2$), $U_{ij} = (U_i^2 + U_j^2)^{1/2}$.

Linking APMP.EM.BIPM-K11.1 to BIPM.EM-K11.b

The degree of equivalence of SCL with respect to the reference value x_R is given by a pair of terms: $D_{SCL} = x_{SCL\text{-}NMIA} + D_{NMIA}$ and its expanded uncertainty (k = 2), $U_{SCL} = (U_{SCL\text{-}NMIA}^2 + U_{NMIA}^2)^{1/2}$, both expressed in μV: D_{SCL} = -0.33 μV and U_{SCL} = 0.60 μV.

Linking EUROMET.EM.BIPM-K11.5 to BIPM.EM-K11.b

The degree of equivalence of VMT/PFI with respect to the reference value x_R is given by a pair of terms: $D_{VMT/PFI} = x_{VMT/PFI\text{-}DFM} + D_{DFM}$ and its expanded uncertainty (k = 2), $U_{VMT/PFI} = (U_{VMT/PFI\text{-}DFM}^2 + U_{DFM}^2)^{1/2}$, both expressed in μV: $D_{VMT/PFI}$ = -0.11 μV and $U_{VMT/PFI}$ = 0.58 μV.

Linking EUROMET.EM.BIPM-K11.6 to BIPM.EM-K11.b

The linkage is computed as explained on pages 8 and 9 of the EUROMET.EM.BIPM-K11.6 Final Report, using the results of BEV which participated in both comparisons, and the results of UME which participated in EUROMET.EM.BIPM-K11.6 and EUROMET.EM.BIPM-K11.

Linking SIM.EM.BIPM-K11.b to BIPM.EM-K11.b

The degree of equivalence of CENAM with respect to the reference value x_R is given by a pair of terms: $D_{CENAM} = x_{CENAM\text{-}NIST} + D_{NIST}$ and its expanded uncertainty (k = 2), $U_{CENAM} = (U_{CENAM\text{-}NIST}^2 + U_{NIST}^2)^{1/2}$, both expressed in μV: D_{CENAM} = 0.23 μV and U_{CENAM} = 0.28 μV.

Linking key comparison COOMET.EM.BIPM-K11 to key comparison BIPM.EM-K11.b

The degree of equivalence of BelGIM participant in COOMET.EM.BIPM-K11 relative to the key comparison reference value is given by a pair of terms: $D_{BelGIM} = x_{BelGIM\text{-}VNIIM} + D_{VNIIM}$ and its expanded uncertainty at a 95% level of confidence, U_{BelGIM}, both expressed in μV. The computation of U_{BelGIM} is explained in page 8 of the COOMET.EM.BIPM-K11 Final Report.

Linking key comparison APMP.EM.BIPM-K11.4 to key comparison BIPM.EM-K11.b

The degree of equivalence of VMI-STAMEQ relative to the key comparison reference value is given by a pair of terms $D_{VMI\text{-}STAMEQ}$, and its expanded uncertainty (k = 2), $U_{VMI\text{-}STAMEQ}$ both expressed in μV. The computation of $D_{VMI\text{-}STAMEQ}$ and $U_{VMI\text{-}STAMEQ}$ is explained in section 7.2 of the APMP.EM.BIPM-K11.4 Final Report.

Linking key comparison APMP.EM.BIPM-K11.3 to key comparison BIPM.EM-K11.b

The linking of APMP.EM.BIPM-K11.3 to the BIPM.EM-K11.a is made via the BIPM, KRISS and NMIA who participated in both comparisons. The lining procedure is described in Section 8 (p. 33) of the APMP.EM.BIPM-K11.3 Final Report.

BIPM.EM-K11.b, EUROMET.EM.BIPM-K11, APMP.EM.BIPM-K11.1, EUROMET.EM.BIPM-K11.5, EUROMET.EM.BIPM-K11.6, SIM.EM.BIPM-K11.b, COOMET.EM.BIPM-K11, APMP.EM.BIPM-K11.4 and APMP.EM.BIPM-K11.3

Degrees of equivalence relative to the key comparison reference Degrees of equivalence relative to the key comparison reference value

BIPM.EM-K11.b

Lab *i* ⇩	D_i / µV	U_i / µV
BIPM	0.00	0.20
SPRING Singapore	0.16	0.22
NIST	0.26	0.28
METAS	-0.14	0.28
CMI	0.77	1.46
BEV	-0.04	0.20
SMU	-0.04	1.72
GUM	-0.06	0.26
NMISA	-0.01	0.66
NMIA	0.13	0.28
NCM	-0.99	8.00
VNIIM	-0.22	0.68
KRISS	-0.03	0.20
INTI	-0.24	0.76
INM(RO)	-0.43	0.68
DMDM	0.39	0.24
NIS	0.22	0.28
NIMT	-0.03	0.22
SMD	0.09	0.98
JV	0.63	0.56
DEFNAT	0.38	0.20
NMISA	0.00	0.68
KEBS	0.25	3.10
NSAI NML*	-1.21	2.76

EUROMET.EM.BIPM-K11

Lab *i* ⇩	D_i / µV	U_i / µV
LNE	0.35	0.59
NPL	-0.36	0.49
NML(IE)	-0.18	4.13
UME	-0.05	0.48
DFM	-0.01	0.50
SP	-0.07	0.50
MIKES	-0.11	0.52
JV	-0.30	0.51
SMD	-0.20	3.73
CMI	0.73	1.54
BEV	-0.19	0.61
SMU	-0.17	0.49
NMi-VSL	-0.16	0.50
CEM	0.31	0.49
INETI	-2.69	6.52
METAS	0.00	0.49
PTB	0.15	0.49
BIPM	-0.02	0.49
EIM	-0.55	0.56
MIRS/SIQ	0.30	6.11
OMH	-0.65	6.49

most recent value retained

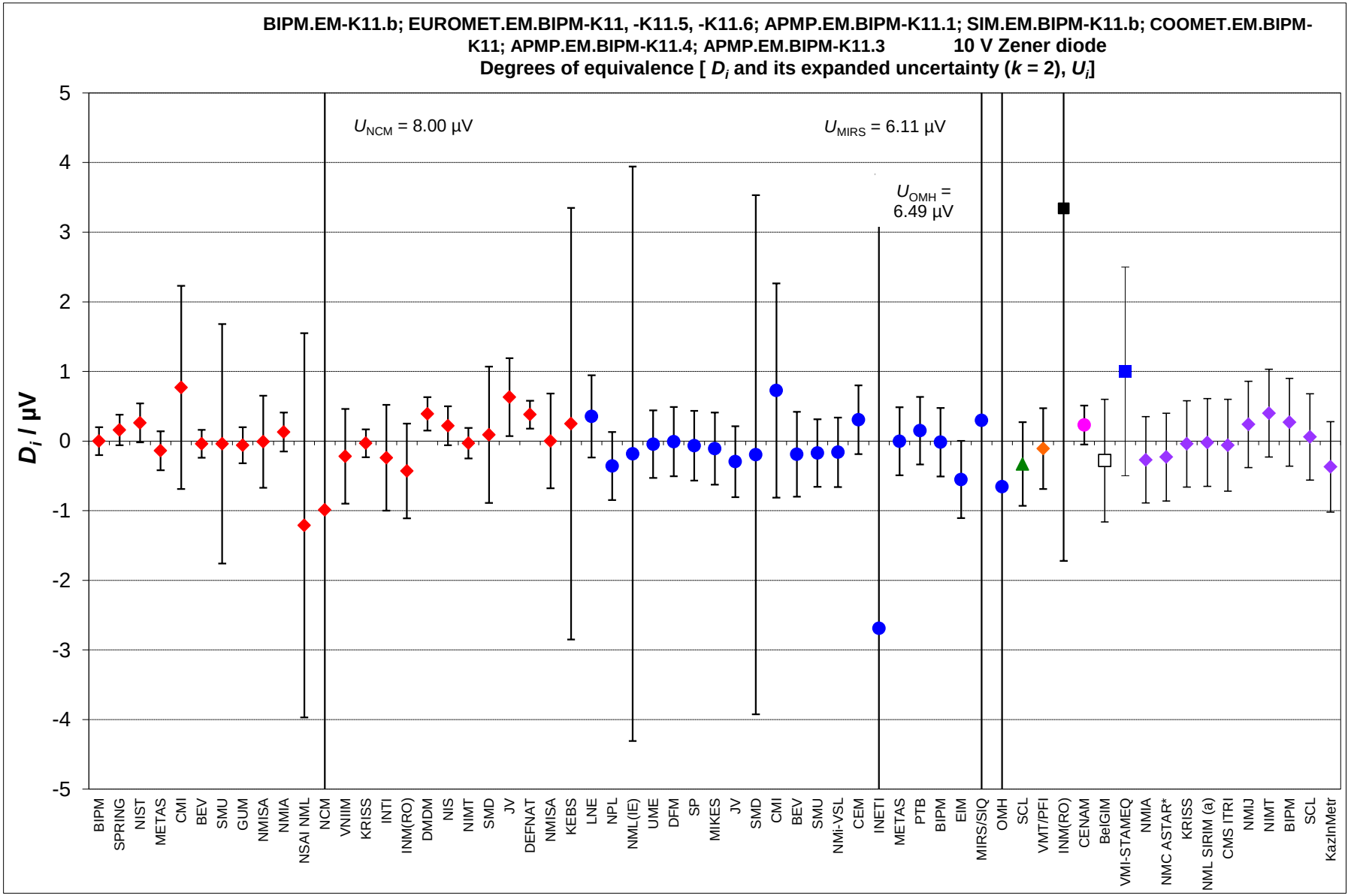
*NSAI NML stands for NSAI National Metrology Laboratory from Ireland and is used for the measurement results obtained starting 2010.

BIPM.EM-K11.b, EUROMET.EM.BIPM-K11, APMP.EM.BIPM-K11.1, EUROMET.EM.BIPM-K11.5, EUROMET.EM.BIPM-K11.6, SIM.EM.BIPM-K11.b, COOMET.EM.BIPM-K11, APMP.EM.BIPM-K11.4 and APMP.EM.BIPM-K11.3

Degrees of equivalence relative to the key comparison reference value **Degrees of equivalence relative to the key comparison reference value**

	Lab *i* ⇩	D_i / µV	U_i / µV
APMP.EM-K11.1	SCL	-0.33	0.60
EUROMET.EM-K11.5	VMT/PFI	-0.11	0.58
EUROMET.EM-K11.6	INM(RO)	3.34	5.06
SIM.EM-K11.b	CENAM	0.23	0.28
COOMET.EM-K11	BelGIM	-0.28	0.88
APMP.EM-K11.4	VMI-STAMEQ	-1.2	2.8
APMP.EM-K11.3	NMIA	-0.27	0.62
	NMC ASTAR*	-0.23	0.63
	KRISS	-0.04	0.62
	NML SIRIM (a)	-0.02	0.63
	CMS ITRI	-0.06	0.66
	NMIJ	0.24	0.62
	NIMT	0.40	0.63
	BIPM	0.27	0.63
	SCL	0.06	0.62
	KazInMetr	-0.37	0.65

(a) Now NMIM



Red diamonds: participants in BIPM.EM-K11.b

Blue circles: participants in EUROMET.EM.BIPM-K11

Black square: participant in EUROMET.EM.BIPM-K11.6

Green triangle: participant in APMP.EM.BIPM-K11.1

Orange square: participant in EUROMET.EM.BIPM-K11.5

Pink circle: participant in SIM.EM.BIPM-K11.b

White square: participant in COOMET.EM.BIPM-K11

Blue square: participant in APMP.EM.BIPM-K11.4

Violet diamonds: participants in APMP.EM.BIPM-K11.3