CCM

CCM.M-K8.2019
First CCM key comparison of kg realizations

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Key comparison of realizations of the kilogram

Objectives	- test the consistency of realizations based on different realization experiments (Kibble balances, joule balance, XRCD method) - contribute to the first consensus value for coordinated dissemination	
Pilot laboratory	BIPM	
Conditions for participation	- $u(m)$ < 200 µg at 1 kg (2×10^{-7}) - peer reviewed publication incl. detailed uncertainty budget	
Participants	Kibble balances:	BIPM, KRISS, NIST, NRC
	Joule balance:	NIM
	XRCD method:	NMIJ, PTB
Timeline	Technical protocol	21 October 2019
	BIPM measurements	Nov 2019 – Feb 2020
	last NMI results	29 May 2020
	Draft A-1	20 July 2020
	Draft B	12 October 2020
	Final Report	16 October 2020 (delay of 4 months due to covid-19)

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CCM.M-K8.2019: organization of comparison

- **Each participants selected 1 or 2 travelling 1 kg standards:**

  - 1 Pt-Ir standard
  - 1 optional standard (Pt-Ir, stainless steel, Si-sphere, none)

  for calibration under vacuum using realization experiment (Kibble balance, joule balance, Avo sphere),

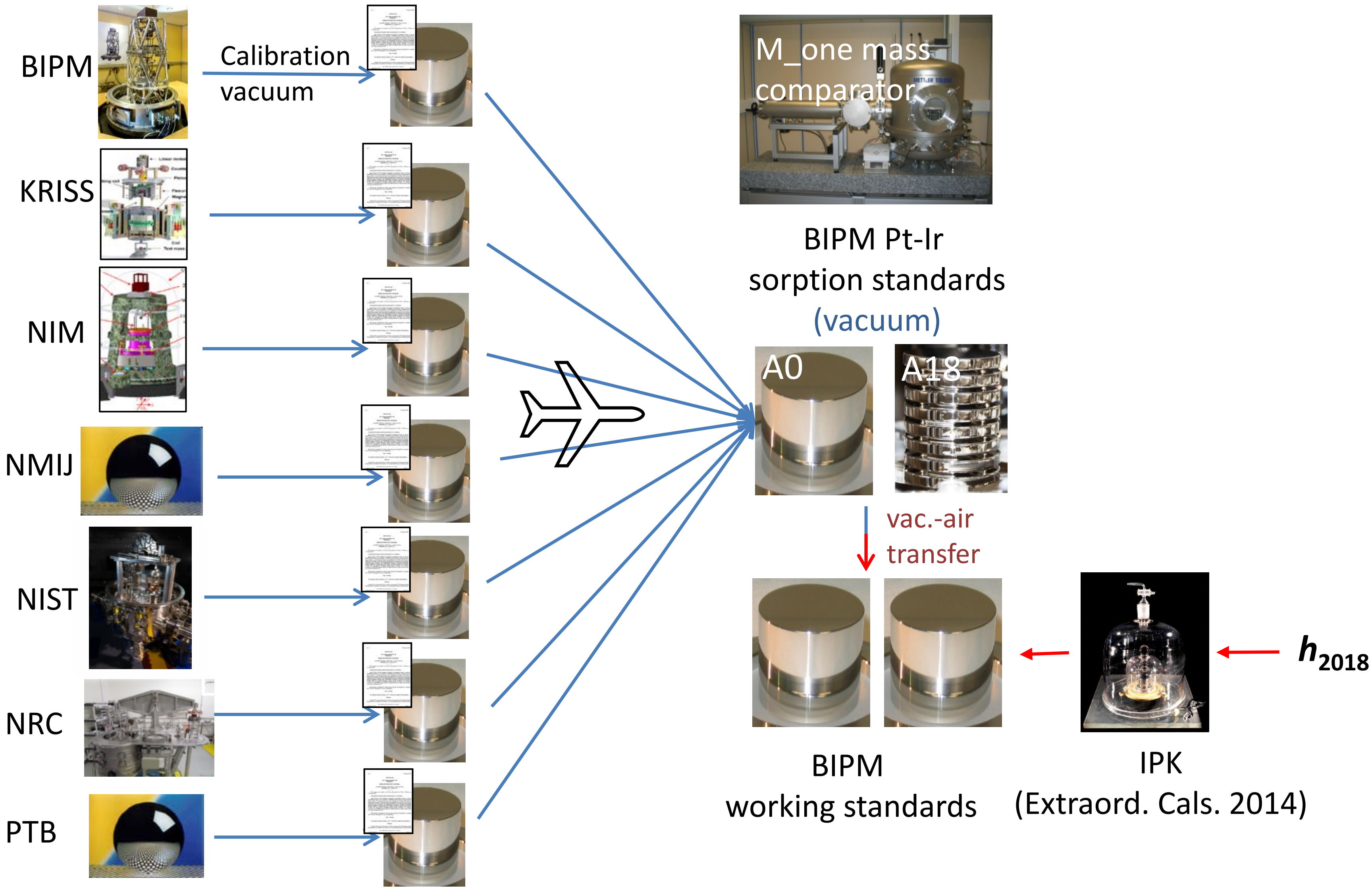
  based on : $h = 6.626\ 070\ 15 \times 10^{-34}$ **Js (revised SI)**

- **NMIs sent travelling standards to BIPM**

- **At BIPM, all travelling standards were compared under vacuum with a BIPM reference standard**

- **The mass of the reference standard under vacuum is known in terms of BIPM as-maintained mass unit (traceable to *h* via the IPK)**

CCM.M-K8.2019: principle of the comparison



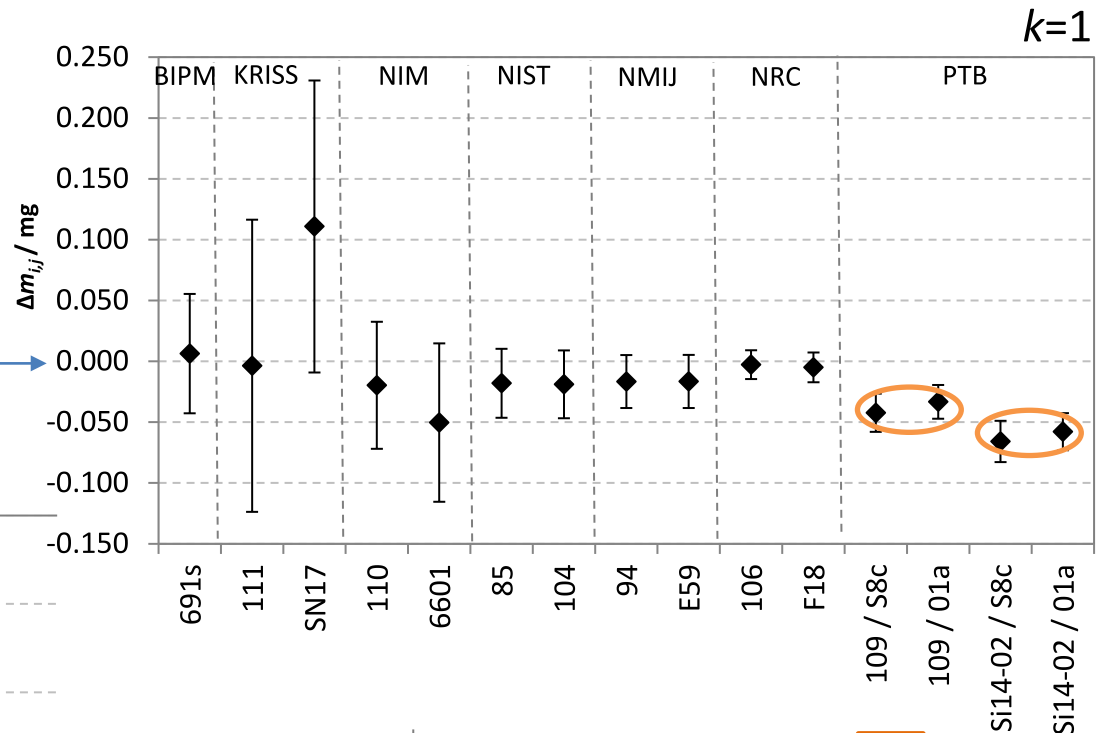
CCM.M-K8.2019: travelling standards

Institute	Identification of standard	Manufacturer	Type	Estimated air-vacuum surface sorption / µg	Magnetic susceptibility	Magnetic polarization / µT
BIPM	691s	BIPM	Pt-Ir standard with small Pt wire	4	24×10^{-5}	<0.02
KRISS	111	BIPM	Pt-Ir prototype		24×10^{-5}	< 0.02
	SN17	Mettler Toledo	stainless steel cylinder	6.3	<0.002	<0.2
NIM	110	BIPM	Pt-Ir prototype		24×10^{-5}	0
	6601	Changzhou Accurate Weight Co., China	stainless steel cylindrical	5.5	5.16×10^{-4}	0.01
NIST	85	BIPM	Pt-Ir prototype	7.2	24×10^{-5}	<0.02
	104	BIPM	Pt-Ir prototype	3.5	24×10^{-5}	<0.02
NMIJ	94	BIPM	Pt-Ir prototype	5.7(3.3)	3×10^{-4}	< 0.02
	E59	Stanton Instruments	Pt-Ir standard	11.6(3.3)	2×10^{-4}	< 0.02
NRC	106	BIPM	Pt-Ir prototype	3.4	24×10^{-5}	<0.02
	F18	BIPM	Stack of 8 Pt-Ir disks	12.2	24×10^{-5}	<0.02
PTB	109	BIPM	Pt-Ir prototype	2	< 0.001	< 0.1
	Si14-02	PTB	Si sphere	20	-2.6×10^{-7}	0

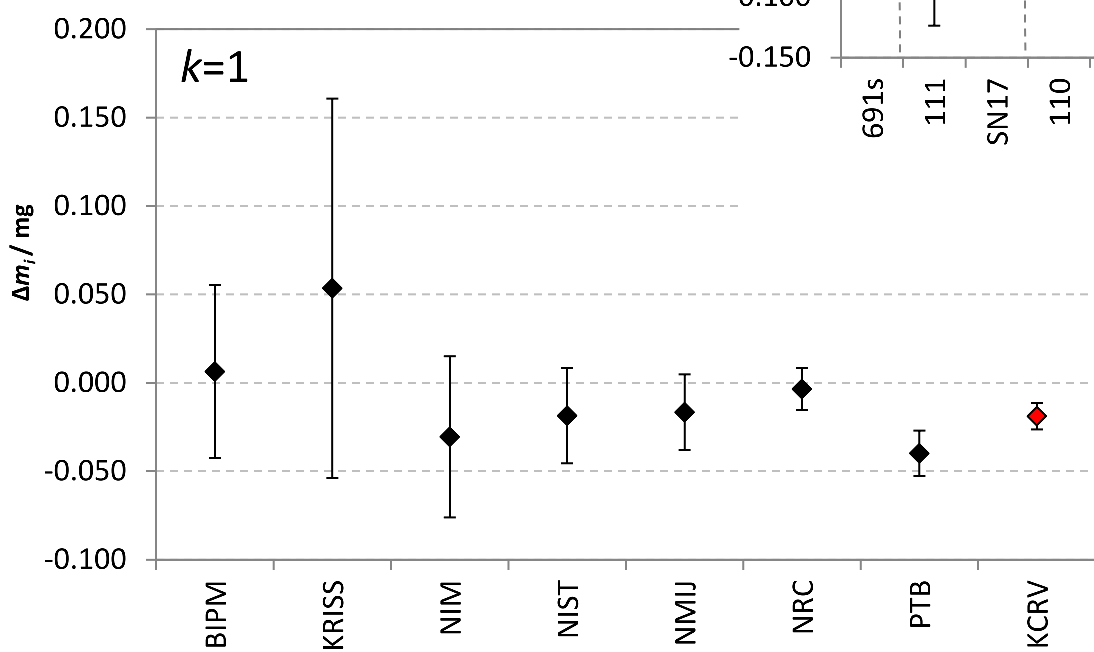
9 Pt-Ir prototypes
1 Pt-Ir stack
2 stainless steel standards
1 Si sphere

CCM.M-K8.2019: Results

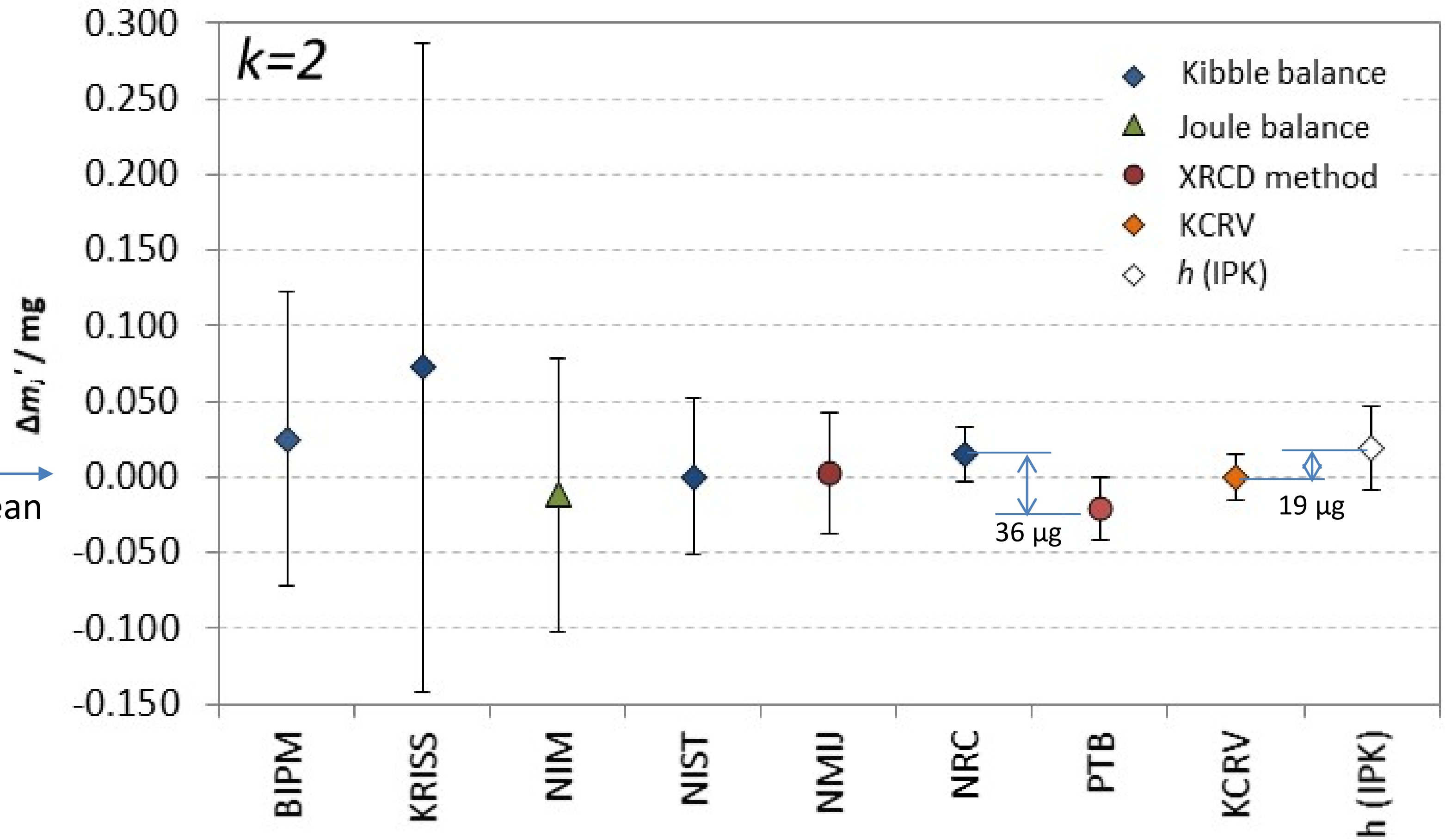
BIPM as-maintained mass unit



Calculating weighted mean of both standards, taking into account correlations



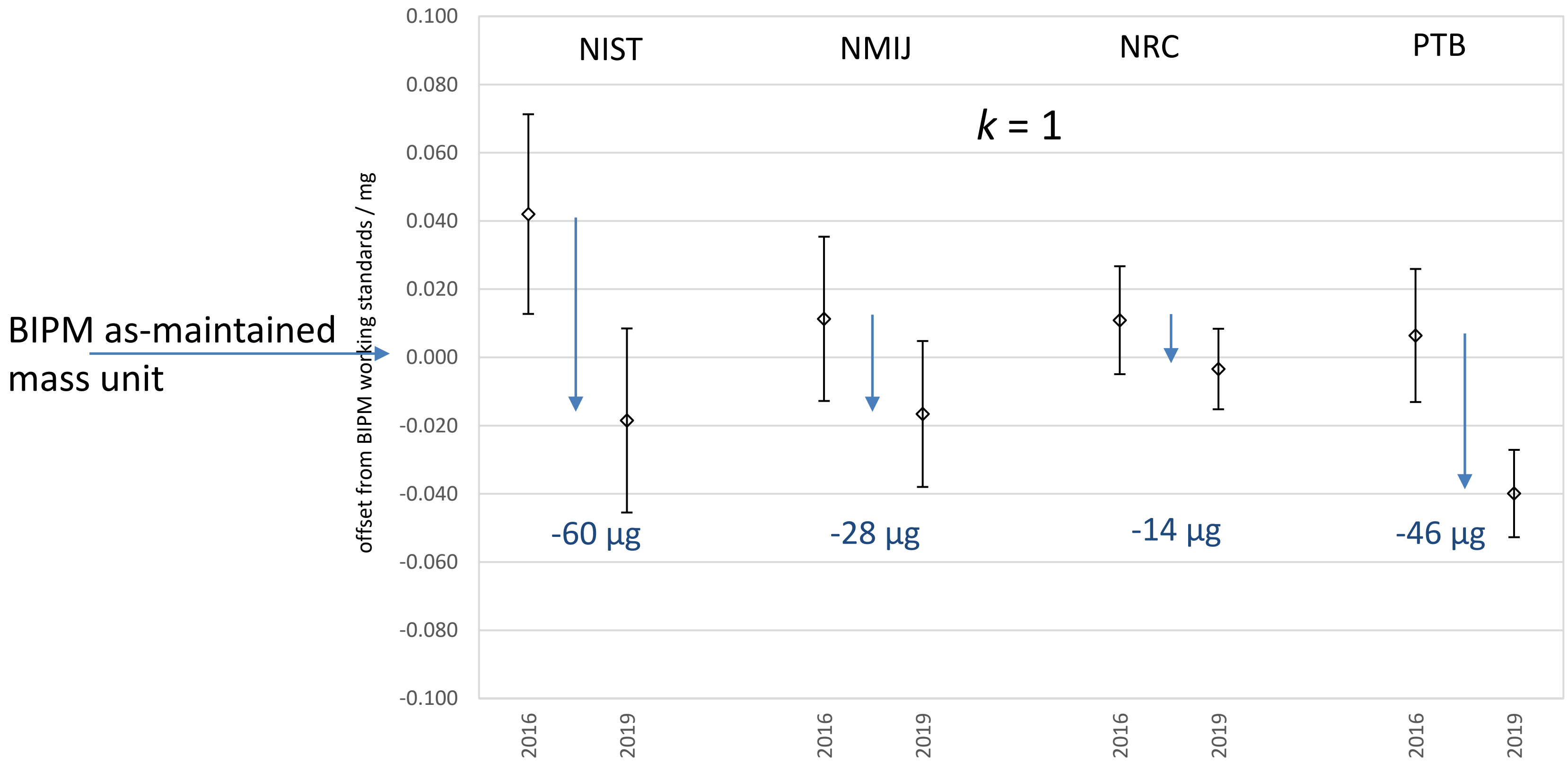
CCM.M-K8.2019: Results



KCRV weighted mean

standard uncertainty of weighted mean: 7.5 µg

CCM.R-kg-P1 (2016) compared to CCM.M-K.2019



kg realizations have changed with respect to BIPM mass unit from -14 µg to -60 µg.

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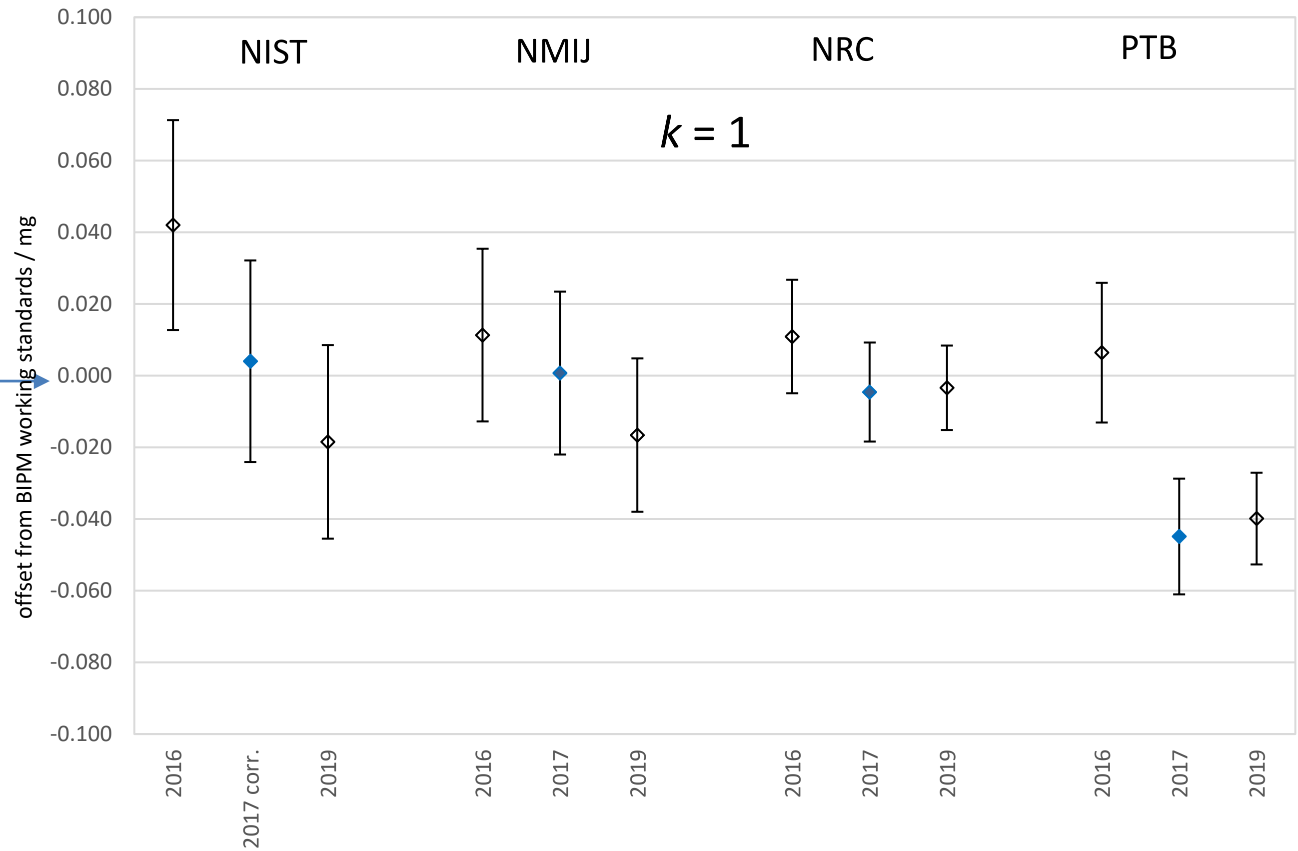
Pilot Study CCM.R-kg-P1 (2016) compared to CCM.M-K.2019

BIPM as-maintained mass unit



blue points: recalculated from Pilot Study 2016 and change of NMI's value for *h* or N_A from 2016 (Pilot Study) to 2017 (CODATA fundamental constants adjustment

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Summary and Conclusions

- All except two results agree within their standard uncertainties.
- The two results with the smallest uncertainties do not agree.
- The weighted mean of the seven results has an uncertainty of 7.5 µg.
- The weighted mean of the independent realizations agrees within the expanded uncertainty with the BIPM as-maintained mass unit, traceable to the IPK.
- Some of the independant kg realizations have changed significantly since 2016.
- Not all travelling standards could be returned due to the travel restrictions. Those who were returned showed mass changes between +2 µg and -8 µg (for a standard with bad surface): mass stability in general not an issue.

Recommendations for future key comparisons

- Follow same approach as for CCM.M-K8.2019
- Slightly less tight schedule
- Conditions for participation: u < 200 µg, peer-reviewed publication
- Travel restriction might make it difficult to use Pt-Ir prototypes, which are in general hand-carried. Use only stainless steel and Si-spheres?
- Keep the travelling standards at the BIPM until the NMI measurement report is available so that possible inconsistencies can be investigated
- The time for sending the NMI measurement report was in some cases very long (up to 6 months), it would be desirable that the reports are sent within 2 months.

Proposed timescale for CCM.M-K8.2021

June 2021	Call for participation
June/July 2021	Agreement on technical protocol (similar to K8.2019)
September – December 2021	Measurement of travelling standards at NMIs
January – March 2022	Comparison measurements at BIPM
April-May 2022	Stability checks at NMIs after return of standards
June 2022	Draft A
September 2022	Final report

Thank you for your attention !