



CCL Key comparison K1
Gauge blocks measured by interferometry
Ongoing report on linking the comparisons

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1 Document history

Date / Version	Content	Author(s) and Institute
Oct 2019 Version 1.0	Linking CCL-K1.2011, EURAMET.L-K1.2011 and SIM.L-K1.2007	R. Thalmann, METAS

2 Introduction

At its meeting in October 2017, the CCL WG-MRA decided to report all linking actions in a separate ongoing document for each KC topic, to be updated constantly when new comparison results are available. The DG moderators are responsible for keeping these documents up to date, supported by their DG, TG-L and by the KC pilots.

3 Linking schemes

The TG-L has developed, proposed and applied different methods for linking the results of different comparisons. The application of these methods depend on the scheme of the comparisons, which can be categorized as follows:

- A. Classical, hierarchical scheme, which requires choosing one comparison as a primary to link the results of other (secondary) comparisons to the first one. This is typically the case for CIPM key comparisons considered "primary" and RMO key comparisons considered "secondary".
- B. The comparisons to be linked are treated equally. This is typically the case for the CCL-RMO scheme, where RMO key comparisons are run in parallel with common participants of other RMOs. Also included in this scheme is the case, where within a comparison two loops are run in parallel and need to be linked.

The linking methods identified so far by CCL and considered sufficient for CIPM MRA length comparisons are:

1. Numerical linking: Propagating the key comparison reference value KCRV and its uncertainty from a higher level comparison (e.g. CIPM comparison) to a lower level comparison (e.g. RMO comparison) through the results of laboratories having participated at both levels¹. This requires a hierarchical comparison scheme A and measurands, which do not too much depend on artefact properties, ideally primary realisations of units and national standards.
2. Visual linking: The results are typically represented on a common graph of both comparisons to be linked, showing deviations from the key comparison reference value KCRV and their uncertainty, where the KCRV is determined in each comparison. The comparisons are considered to be linked, when the results of laboratories having participated in both comparisons are consistent with the respective KCRV. It is commonly accepted to have typically two or three common participants. This method may be applied to both comparison schemes A and B, however, in case of scheme A the CIPM and the RMO comparisons are considered on an equal basis in terms of the KCRV.
3. Distributed linking: The results of two simultaneous comparisons or two parallel loops of one comparison are linked by calculating for each comparison a separate reference value, influenced by the results of common participants in both comparisons, i.e. the KCRV in comparison (b) depends on the results of a common participant obtained in comparison (a) and vice versa². This method is only applicable for comparisons schemes B.

¹ Jennifer E Decker, A G Steele and R J Douglas, Measurement science and the linking of CIPM and regional key comparisons, [Metrologia 45 \(2008\) 223–232](#)

² Michael Krystek, Harald Bosse, A Bayesian approach to the linking of key comparisons, <http://arxiv.org/abs/1501.07134>

4.3 Comparison artefacts and quantities suitable for linking

In each comparison, a number of different gauge blocks of different material (steel and ceramic) were circulated. The protocols were separately designed in such a way, that best possible comparability with respect to gauge block length was achieved; the chosen lengths were not necessarily the same. The linking should be performed on gauges of same or similar nominal lengths and of the same material. In the following table the coloured cells suggest the choice of gauge blocks that might be used for linking.

		Gauge block length / mm			
		CCL-K1.2011	EURAMET.L-K1.2011	SIM.L-K1.2007	
Short, steel	0.5	0.5			
		1.15	1.0005		
	3	3			
	5	5	5		
	7	7	7		
			10		
	25	23.5	50		
	80	80	75		
	100	100			
Short, ceramic	0.5	0.5			
		1.15	1.0005		
	3	3			
	5	5	5		
	7	7	7		
	10		10		
		23.5	50		
	80	80	75		
	90	100	100		
Long, steel	152.4	150			
	254	300			
	508	500			

4.4 Common participants suitable for linking

The following table lists the laboratories that participated successfully in more than one comparisons, candidate for linking.

Identifier		Common participants
CCL-K1.2011	EURAMET.L-K1.2011	METAS, MIKES
CCL-K1.2011	SIM.L-K1.2007	INMETRO, NRC, CENAM, NIST
SIM.L-K1.2007	EURAMET.L-K1.2011	CEM ²⁾ , CMI ¹⁾

- 1) Results in EURAMET.L-K1.2011 and in SIM.L-K1.2007 partly not satisfactory
- 2) Results in SIM.L-K1.2007 partly not satisfactory

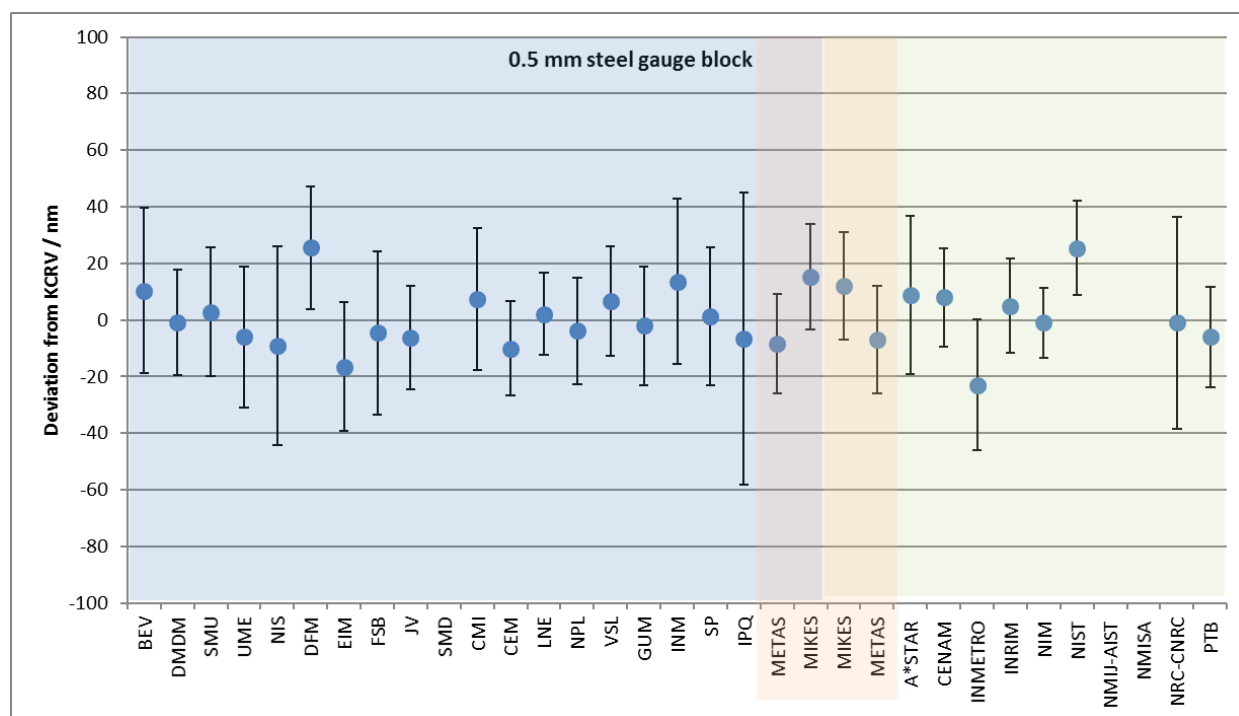
5 Linking of comparisons

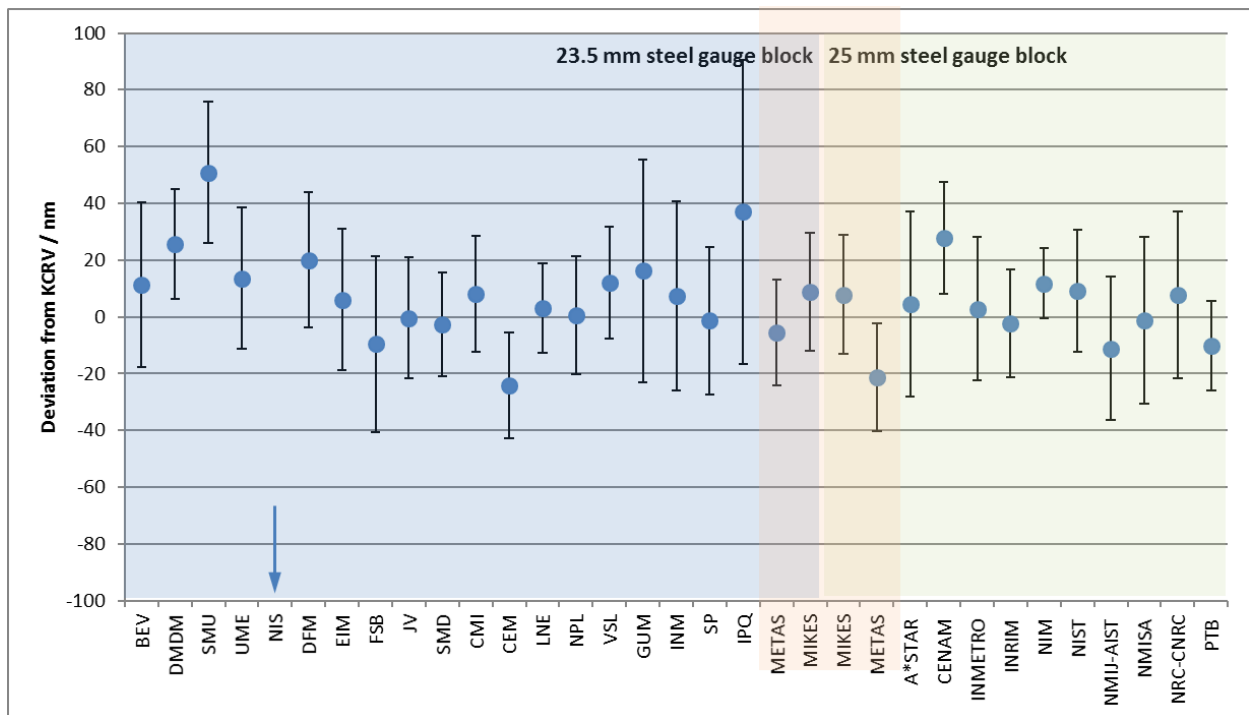
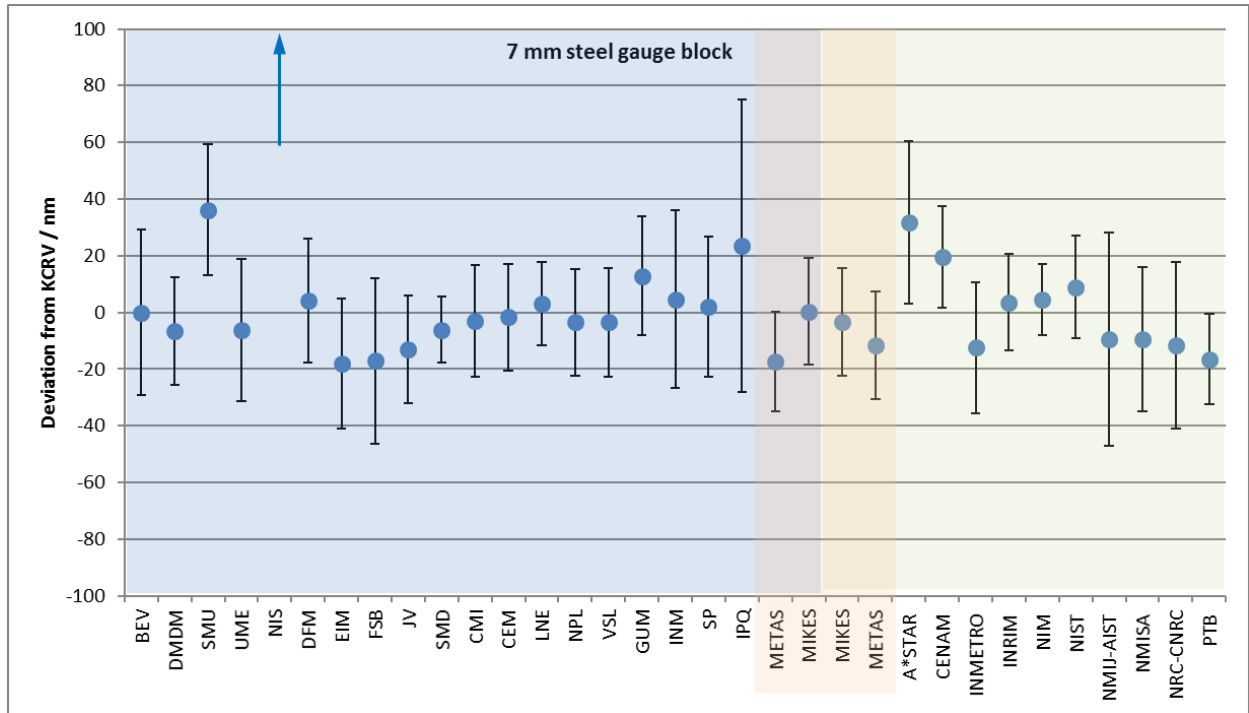
Comparisons shall be linked pairwise by method 2 (common graph) for selected gauge block lengths, as identified in the table of sect. 0. Note that in order to keep the present report short enough, not all possible gauge lengths were considered for linkage, but a representative subset was selected. Due to partially unsatisfactory results of the common participants, the comparisons SIM.L-K1.2007 and EURAMET.L-K1.2011 were not linked to each other.

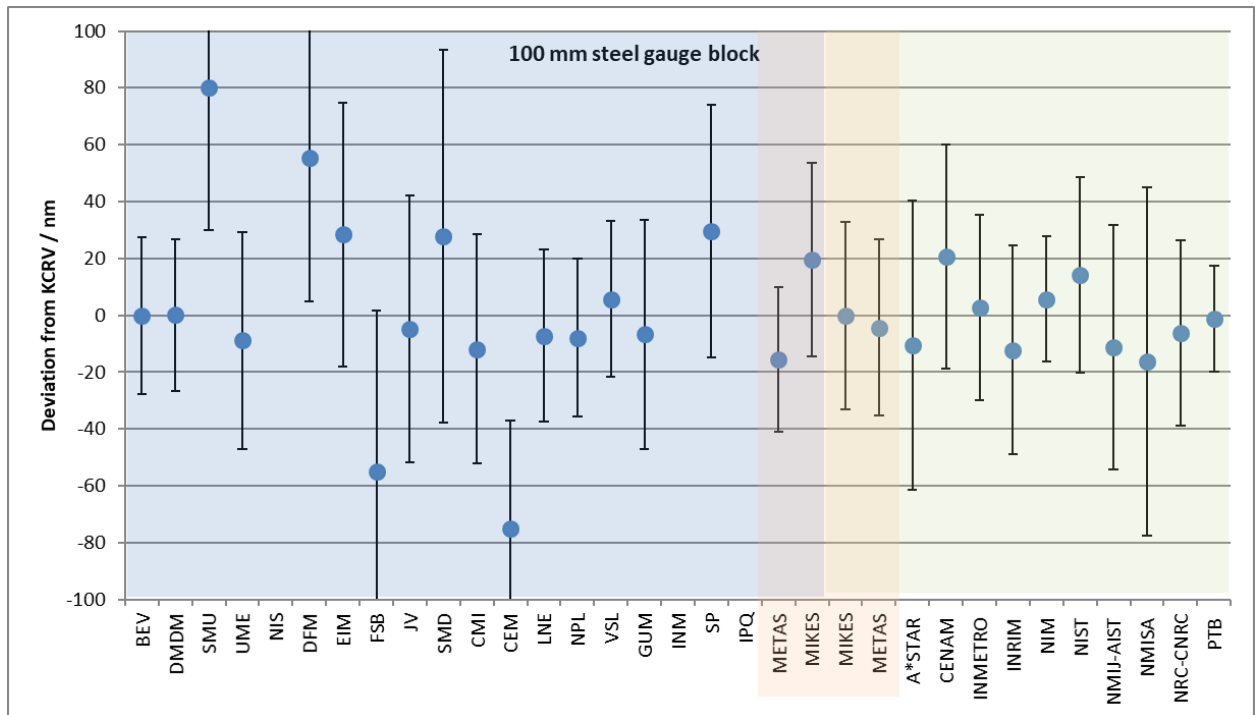
For each comparison pair and for each gauge block length, a plot is drawn in two colours to separate the comparisons. For each laboratory, the difference to the relevant key comparison reference value KCRV and its expanded uncertainty of that difference is plotted (the respective KCRV representing the zero line in each part of the graph). Laboratories establishing the link according to the table in sect. 4.4 are highlighted in orange and placed side by side in the central portion of each plot.

5.1 EURAMET.L-K1.2011 vs. CCL-K1.2011, short steel gauge blocks

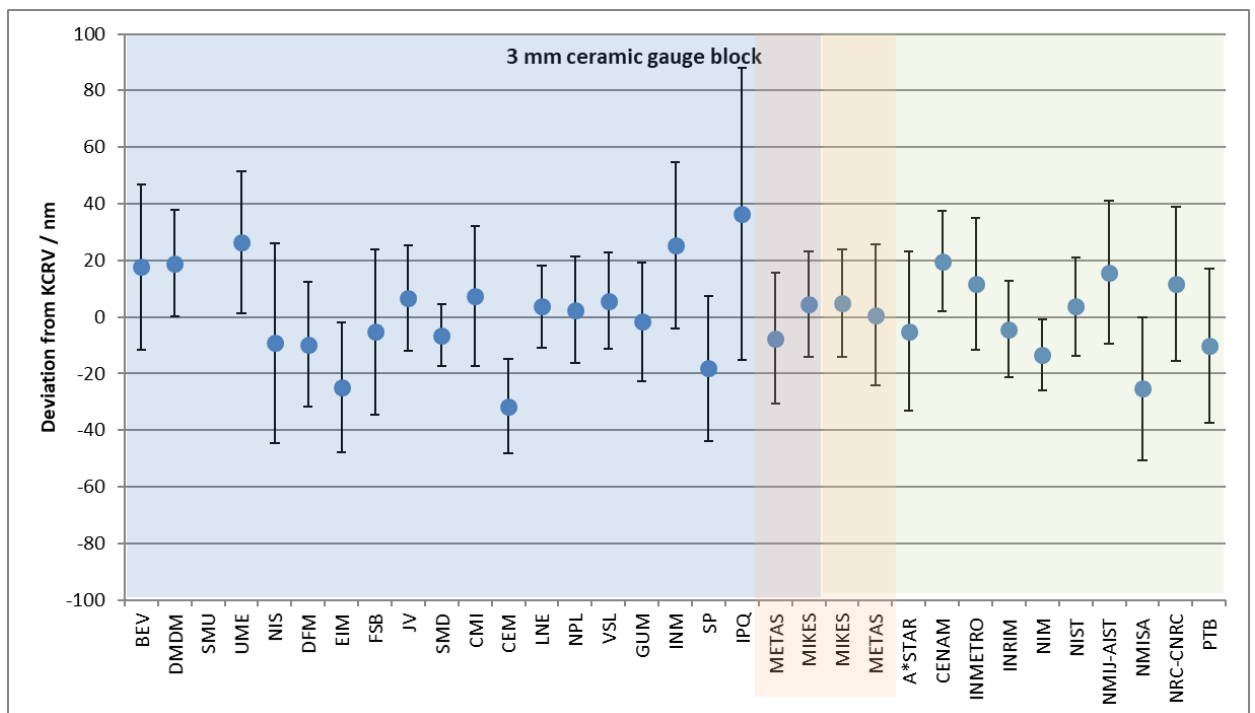
EURAMET.L-K1.2011 consisted of two loops. METAS, MIKES and BEV participated in both loops to provide the link between the two loops. The average of their results was taken for the following graphs.

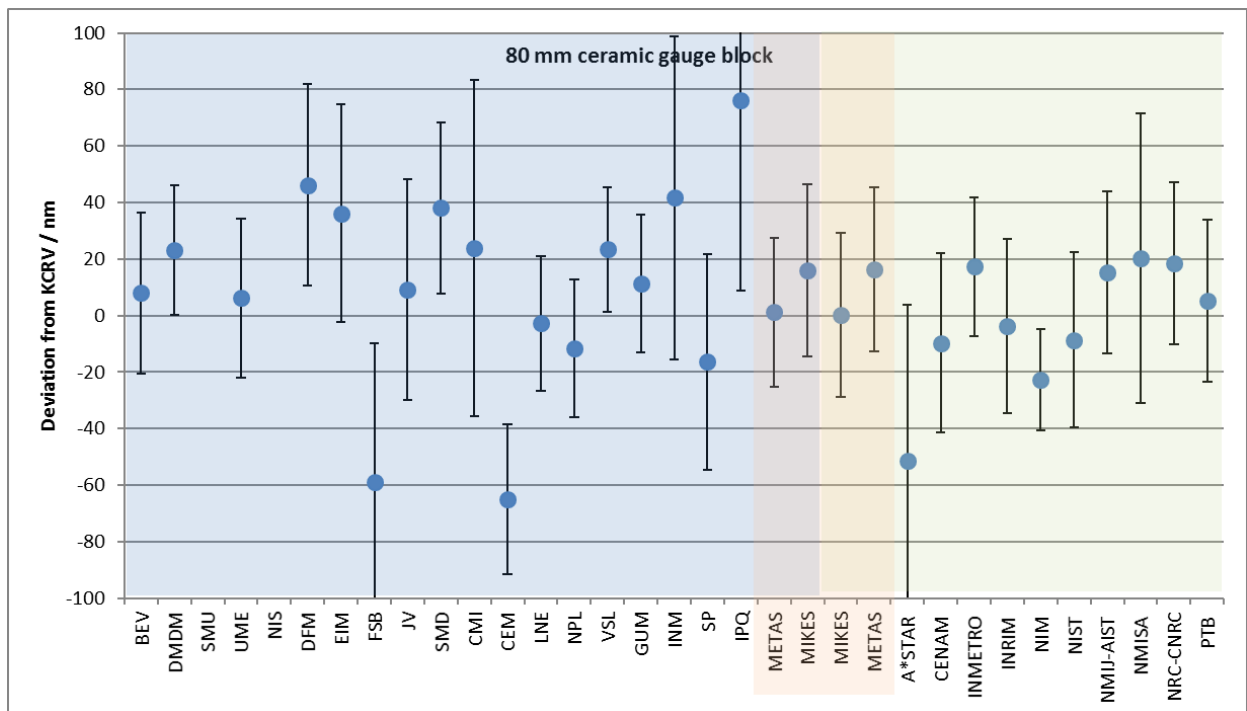
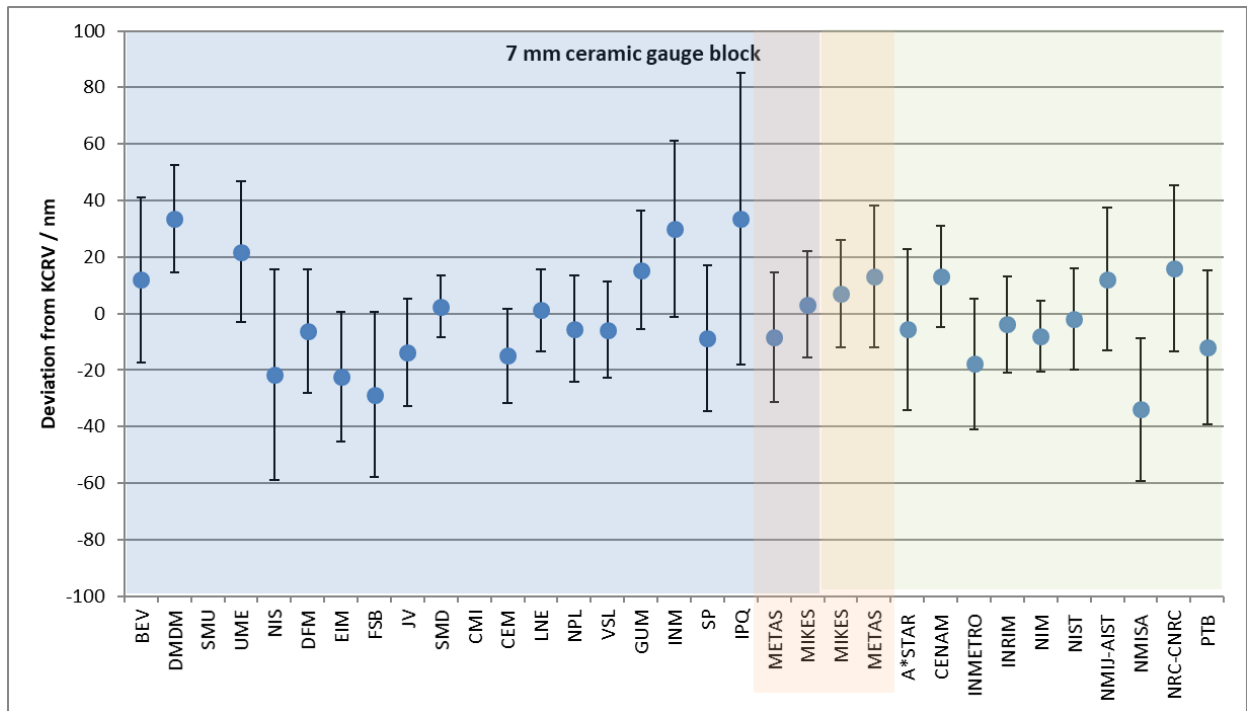






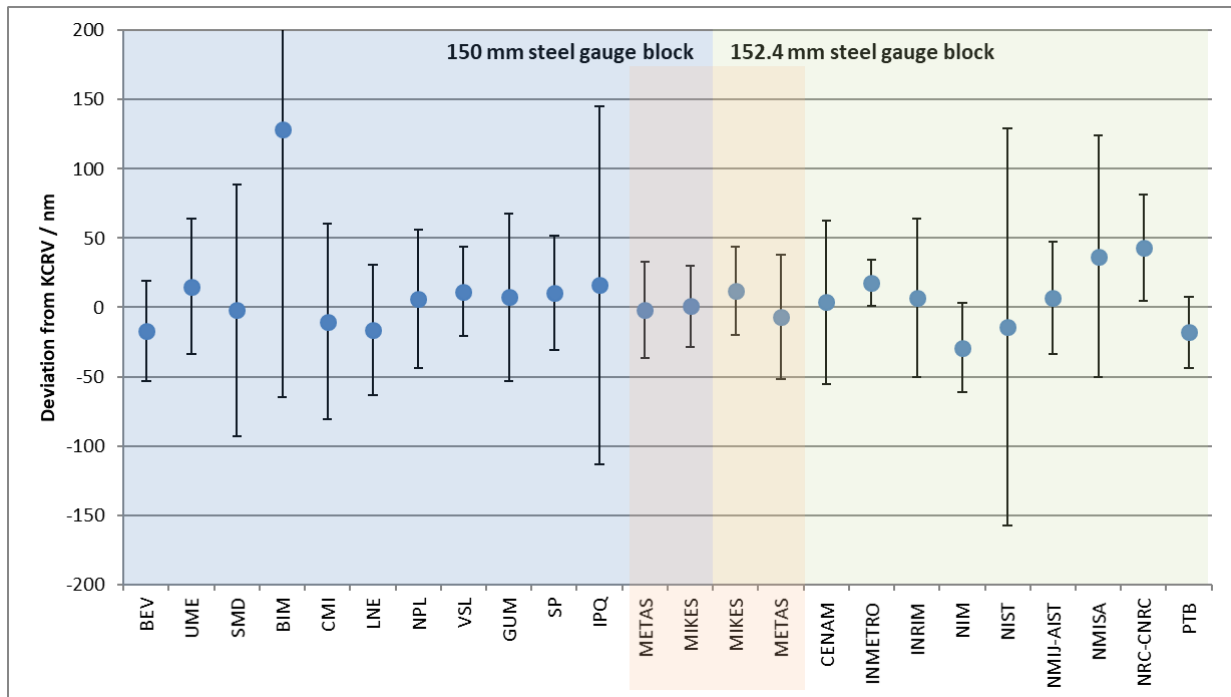
5.2 EURAMET.L-K1.2011 vs. CCL-K1.2011, short ceramic gauge blocks



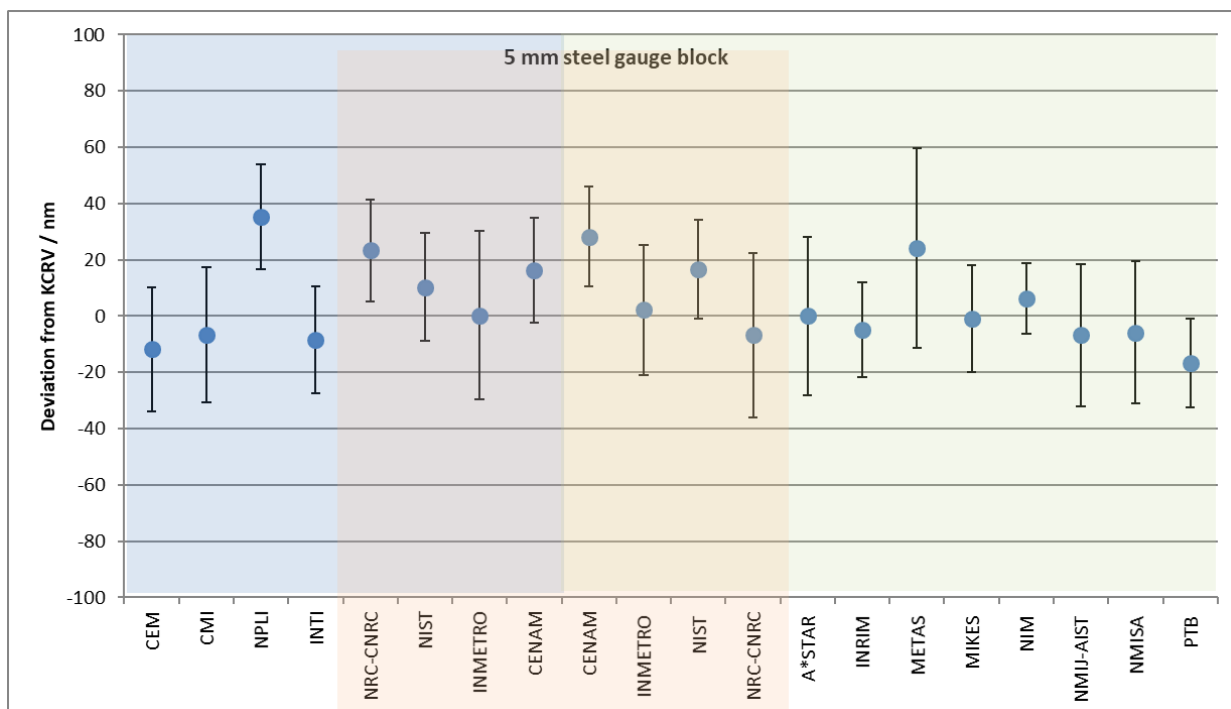


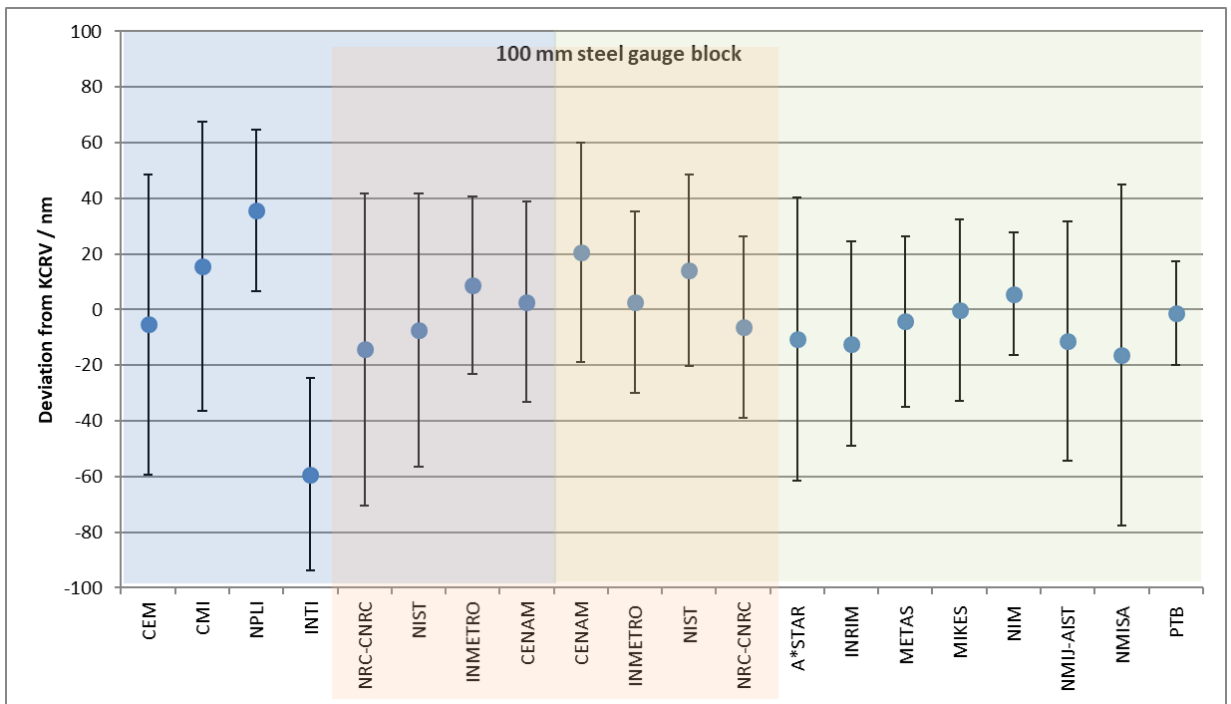
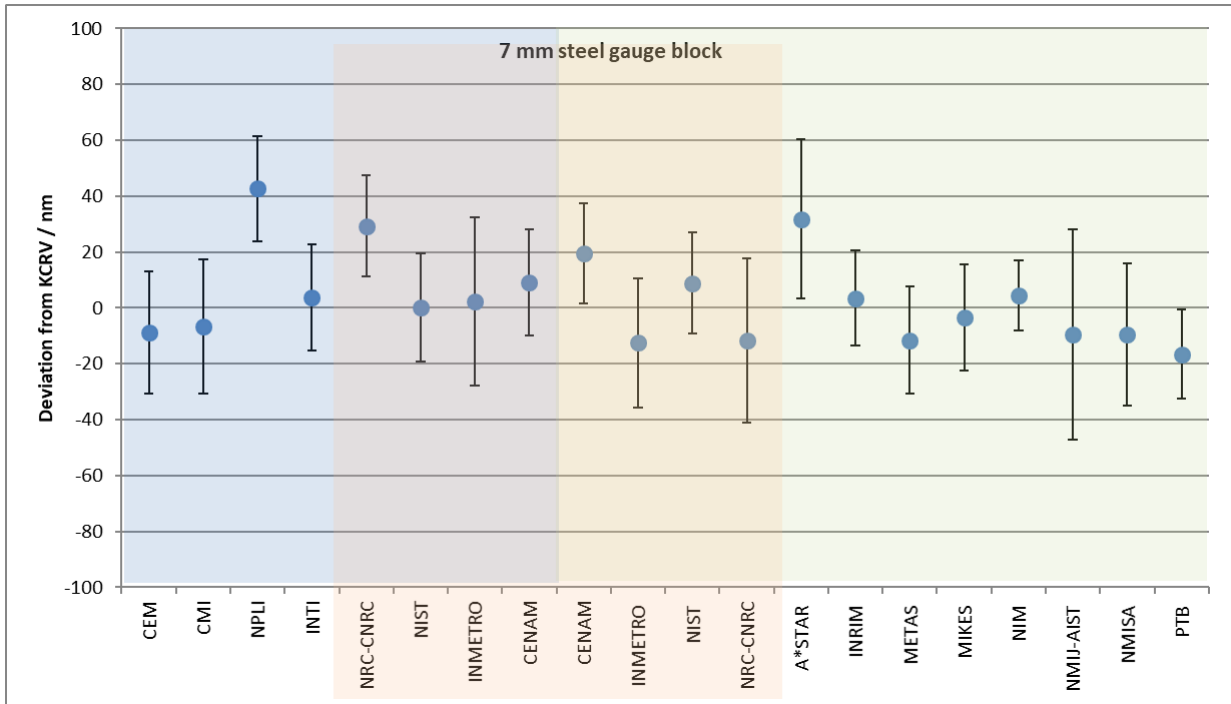
5.3 EURAMET.L-K1.2011 vs. CCL-K1.2011, long steel gauge blocks

Note that the 254 / 300 mm and the 508 / 500 mm gauge blocks could not yet been linked, since in CCL-K1.2011 a linear drift correction had to be applied for the 245 mm and the 508 mm gauge block, and the numerical data were not available from the final report.

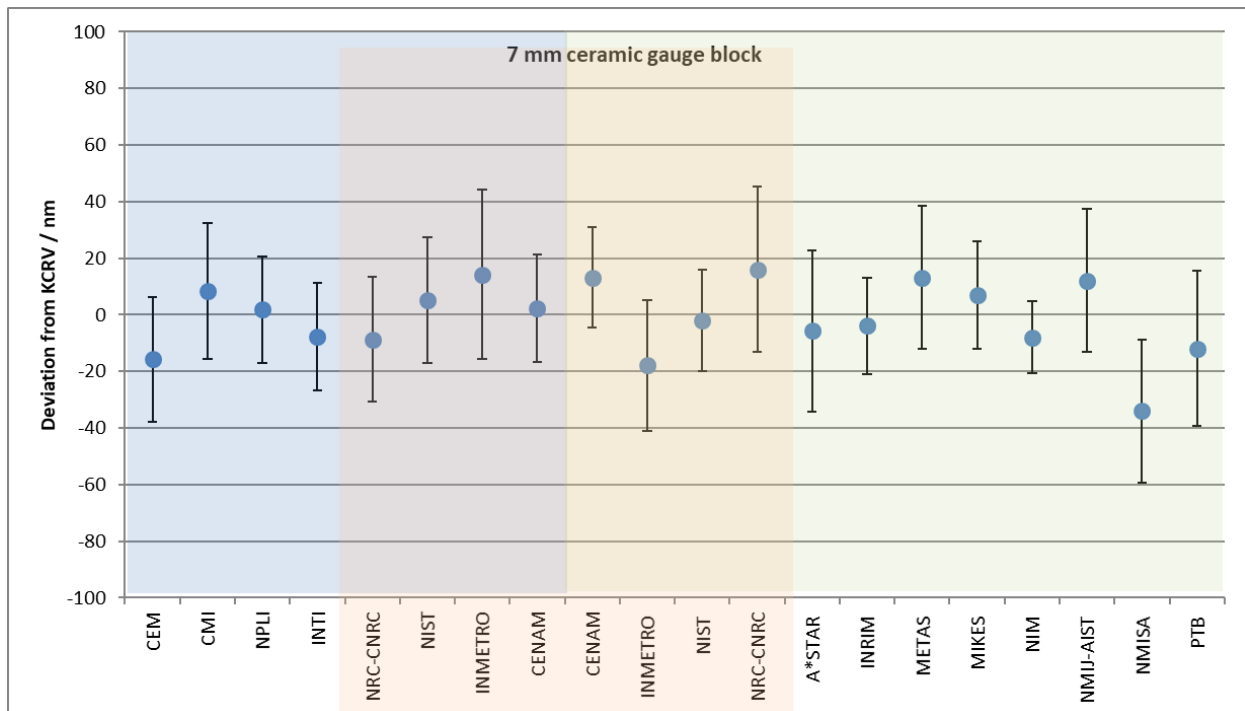
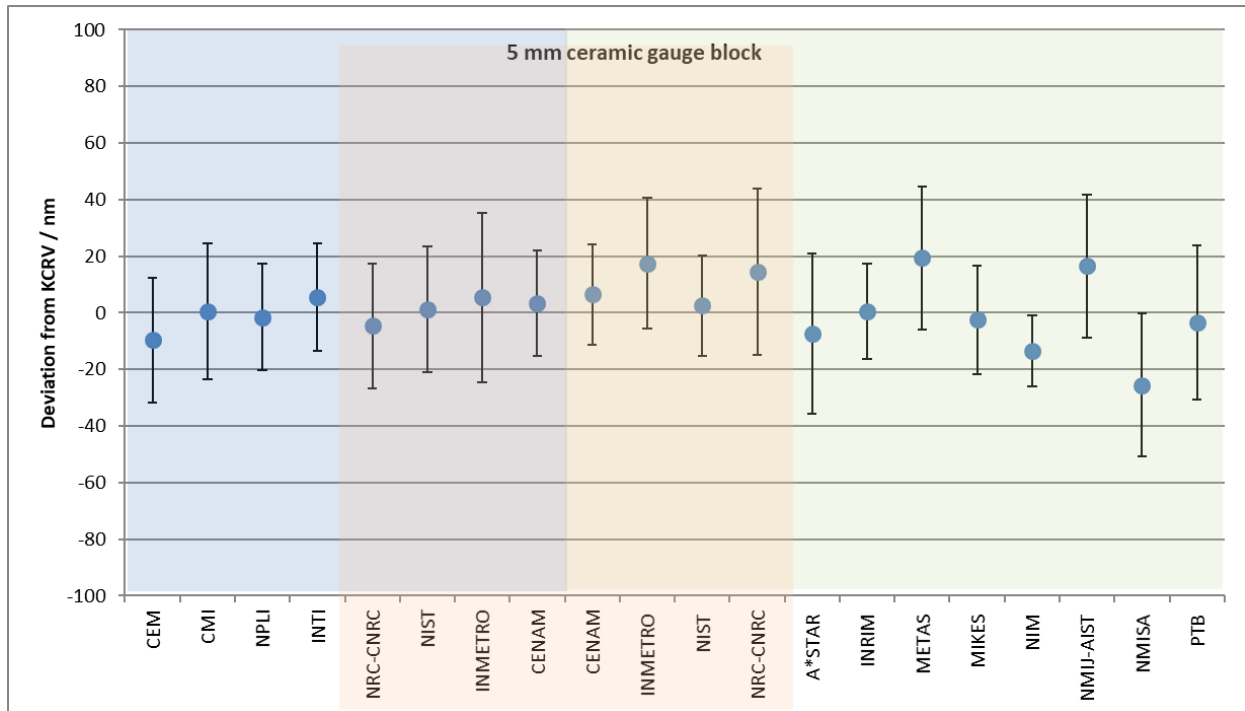


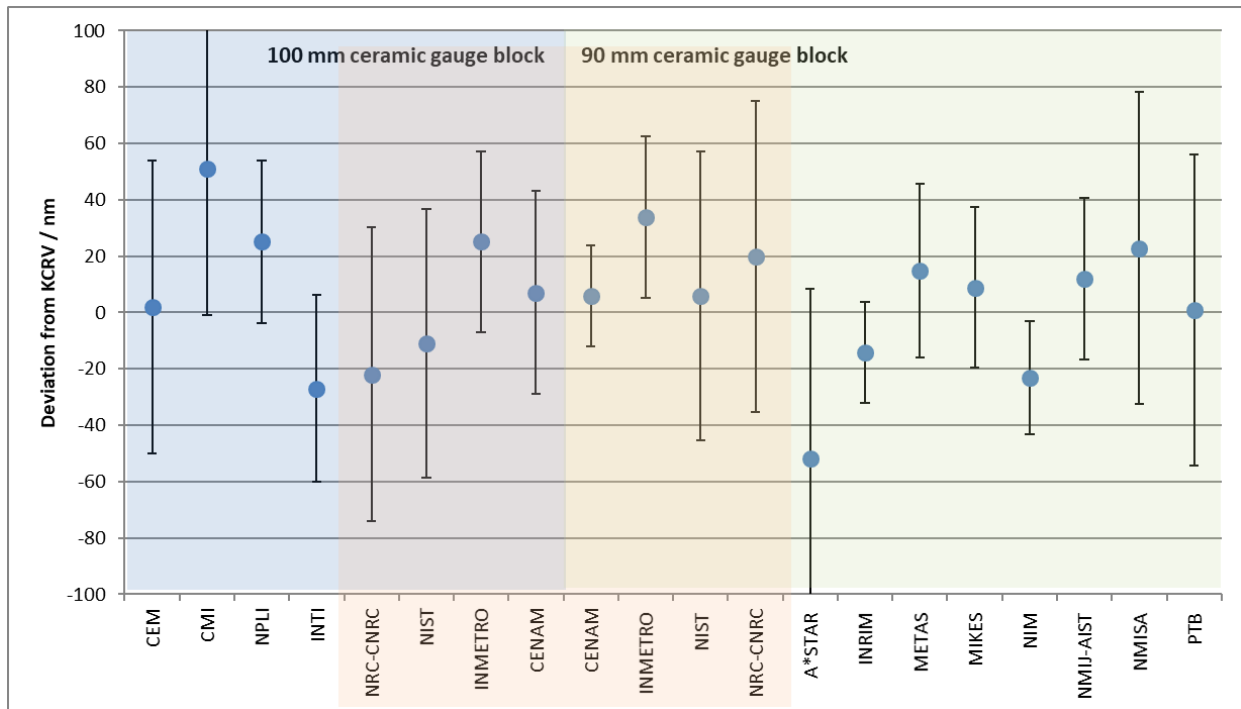
5.4 SIM.L-K1.2007 vs. CCL-K1.2011, steel gauge blocks





5.5 SIM.L-K1.2007 vs. CCL-K1.2011, ceramic gauge blocks





6 Conclusions

- Linkage is proven between all three comparisons (CCL-K1.2011, EURAMET.L-K1.2011 and SIM.L-K1.2007), i.e. the performance of the linking laboratories allowed extending the consistency of results across different comparisons.
- The present report does provide only the linking of comparisons, i.e. the information, whether two comparison can be considered consistent and equivalent to each other. The consistency of the results of a particular laboratory is analysed in the final and executive reports of each comparison.
- In principle, the degrees of equivalence of NMI pairs could be evaluated based on the available information. However, this has never been done for CCL comparisons and is not in the spirit of the SI, where traceability of measurement results to the SI is required rather than consistency between measurements carried out in different economies, the latter being a consequence of the former.