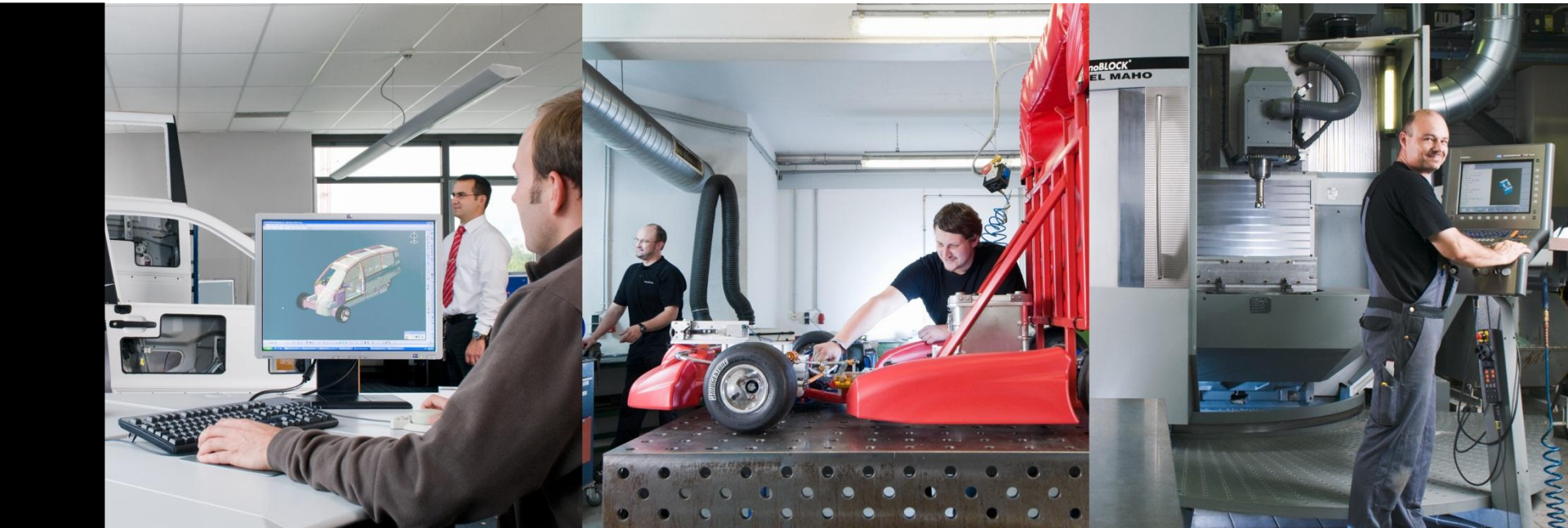
bertrandt

FlexPLI - Round Robin Tests (Update And Additions To Results Presented With Document TF-RUCC-3-05)

Jan Christopher Kolb, Bertrandt
Daniel Folcini, Bertrandt
Thomas Kinsky, GM Europe/Opel (representing the ACEA Task Force Pedestrians)

Ingolstadt, 15.06.2012



Agenda

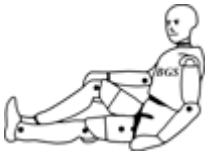
1. **Test Series**
2. Legforms
3. Inverse Certification Test Results
4. Pendulum Certification Test Results
5. Discussion

Test Series

European Automobile Manufacturers Association

- Test series sponsored by ACEA, the European Automobile Manufacturers' Association
- Tests conducted at Bertrandt in Ingolstadt and at BGS Boehme and Gehring in Bergisch Gladbach
- Both labs are considered to be well experienced with FlexPLI testing
- Serial production impactors were tested:
  - 3 inverse certification tests in each lab
  - 3 pendulum certification tests in each lab
- Test scenario according to the scenario proposed for inclusion into gtr No 9 (see document UNECE/TRANS/WP.29/GRSP/2011/13)
- Test results are intended to support the discussion on the possible need to modify the proposed certification corridors
- First results of the test series had been reported to "Task Force Review and Update of (FlexPLI) Certification Corridors" during their audio conference on 25 May 2012
- However, it was wished for to add further data and to perform additional analyses which are presented in this document

bertrandt



Agenda

1. Test Series
2. **Legforms**
3. Inverse Certification Test Results
4. Pendulum Certification Test Results
5. Discussion

Legforms

- All legform impactors used for the test series are FlexPLI version GTR, manufactured by Humanetics
- Legforms are of different build levels:
  - Legform 1 assembled in June 2010 / major repair in May 2011
  - Legform 2 assembled in Sept. 2010 / major repair in Jan. 2012
  - Legform 3 assembled in March 2012
  - Legform 4 assembled in March 2012
- Further tests with additional legforms are planned

Test schedule

- Tests conducted with four legforms

	LAB 1		LAB 2	
	Date	Test	Date	Test
Leg 1	14.03.2012	Pendulum	08.03.2012	Pendulum
Leg 1	14.03.2012	Inverse	08.03.2012	Inverse
Leg 2	15.03.2012	Pendulum	27.02.2012	Pendulum
Leg 2	15.03.2012	Inverse	24.02.2012	Inverse
Leg 3	05.04.2012	Pendulum	02.04.2012	Pendulum
Leg 3	04.04.2012	Inverse	30.03.2012	Inverse
Leg 4	11.06.2012	Pendulum	27.04.2012	Pendulum
Leg 4	11.06.2012	Inverse	11.05.2012	Inverse

Agenda

1. Test Series
2. Legforms
3. **Inverse Certification Test Results**
4. Pendulum Certification Test Results
5. Discussion

Certification Corridors

INVERSE CERTIFICATION TEST CORRIDORS							
Corridors proposed for gtr No 9	Tibia 1 (Nm)	Tibia 2 (Nm)	Tibia 3 (Nm)	Tibia 4 (Nm)	MCL (mm)	ACL (mm)	PCL (mm)
Lower limit	277	269	204	120	23	10.5	6
Upper limit	237	223	176	98	18	8.5	4.5
Corridors proposed by BASt on 18.06.12	Tibia 1 (Nm)	Tibia 2 (Nm)	Tibia 3 (Nm)	Tibia 4 (Nm)	MCL (mm)	ACL (mm)	PCL (mm)
Lower limit	272	252	192	108	21	10	6
Upper limit	230	210	166	93	17	8	4

The information on the new corridors was kindly provided by BASt in preparation of the meeting to already allow this analysis.

BASt = Bundesanstalt für Straßenwesen
(German Federal Highway Research Institute)

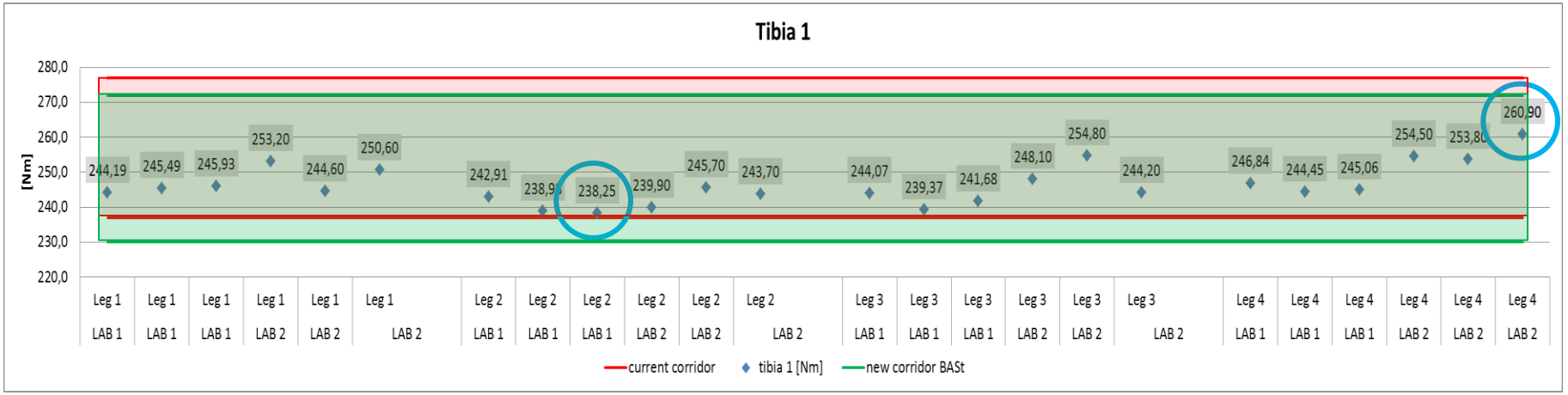
Inverse Certification Test Results – Tibia 1

Corridor proposed for gtr No 9 (237 – 277 Nm)

- All test results are in the corridor proposed for gtr No 9, mainly in the lower part
- Generally, test results in lab 2 are higher and scatter of test results themselves is higher

Corridor proposed by BASt on 18.06.2012 (230 – 272 Nm)

- All test results meet the middle of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	237							
max:	277							
arithmetic mean		247,34	241,57	245,37	250,93	243,10	249,50	246,30
standard deviation		3,36	2,71	4,98	5,97	2,77	5,85	5,58
coefficient of variation		1,36%	1,12%	2,03%	2,38%	1,14%	2,34%	2,27%

○ highest and lowest value

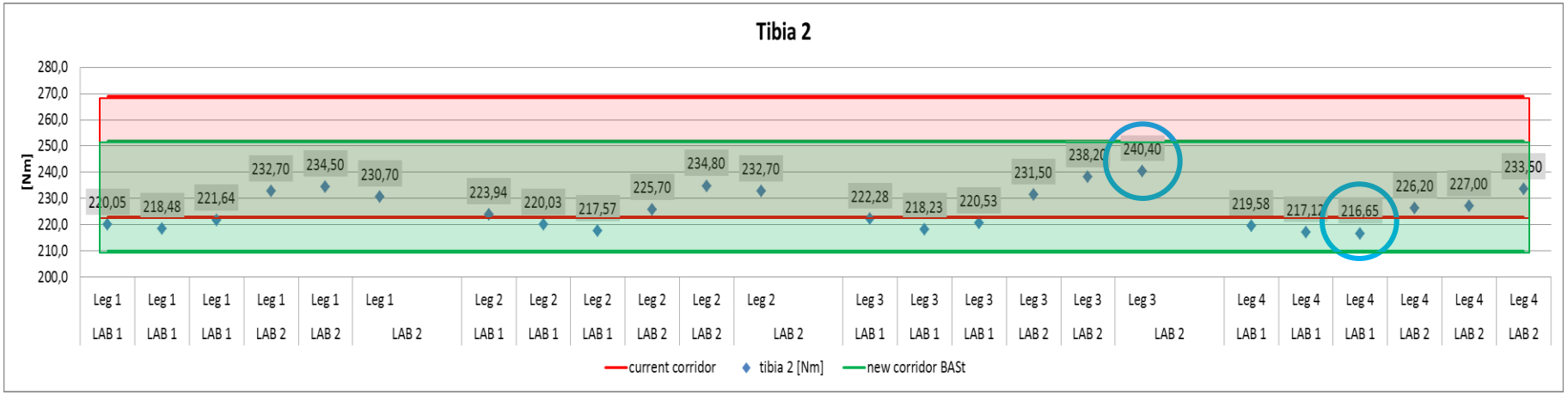
Inverse Certification Test Results – Tibia 2

Corridor proposed for gtr No 9 (223 – 269 Nm)

- In lab 1, most test results are below the lower limit value of the corridor
- In lab 2, test results meet the corridor but all are in the lower half of the corridor
- Again, generally higher test results and higher scatter of results in lab 2

Corridor proposed by BASt on 18.06.2012 (210 – 252 Nm)

- All test results meet the corridor but mainly are close to the lower limit



Corridor gtr No.9	relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
	min:	223							
	max:	269							
arithmetic mean			226,35	225,79	228,52	223,34	219,68	232,33	226,00
standard deviation			6,45	6,23	8,68	6,09	2,11	4,33	7,18
coefficient of variation			2,85%	2,76%	3,80%	2,73%	0,96%	1,87%	3,18%

○ highest and lowest value

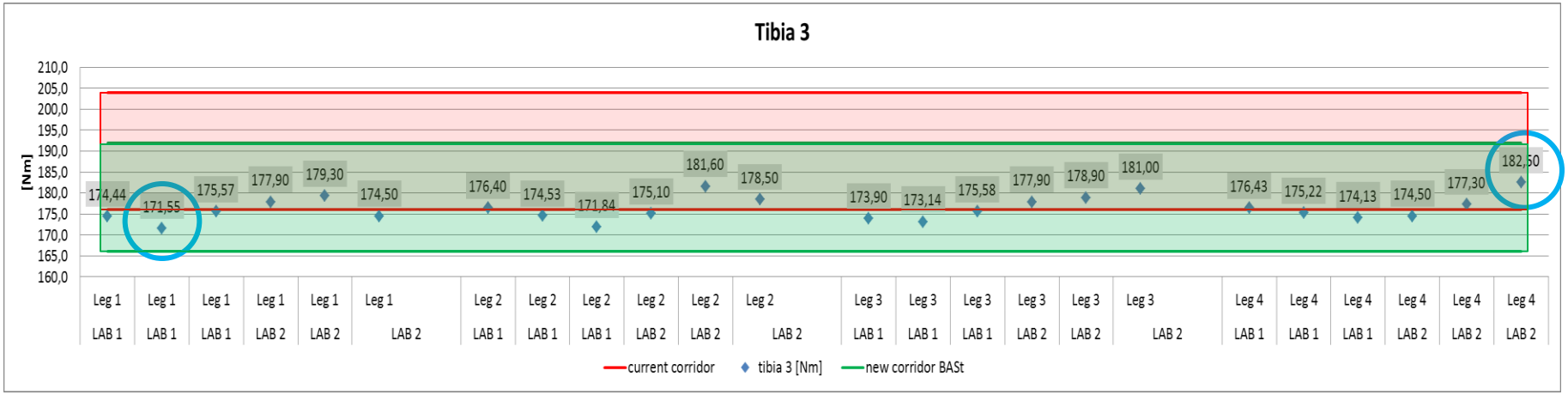
Inverse Certification Test Results – Tibia 3

Corridor proposed for gtr No 9 (176 – 204 Nm)

- All test results are around the lower limit value but regularly miss to meet the corridor

Corridor proposed by BASt on 18.06.2012 (166 – 192 Nm)

- All test results meet the middle of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	176							
max:	204							
arithmetic mean		175,54	176,33	176,74	176,68	174,39	178,25	176,32
standard deviation		2,51	3,09	2,78	2,82	1,53	2,54	2,85
coefficient of variation		1,43%	1,75%	1,58%	1,60%	0,88%	1,43%	1,62%

○ highest and lowest value

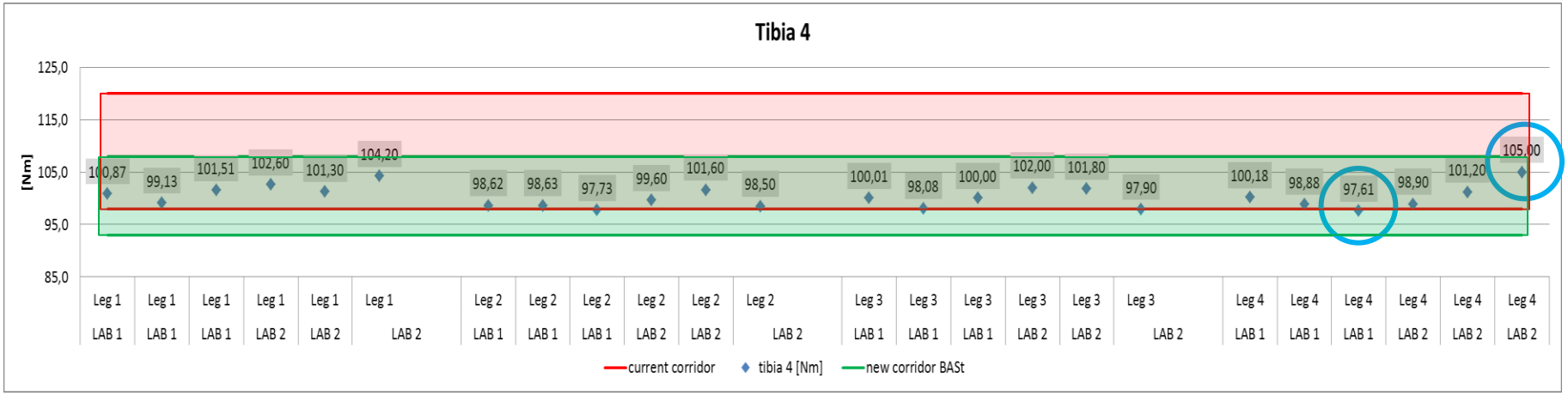
Inverse Certification Test Results – Tibia 4

Corridor proposed for gtr No 9 (98 – 120 Nm)

- Test results are around the lower limit value, nearly all results meet the corridor

Corridor proposed by BASt on 18.06.2012 (93 – 108 Nm)

- All test results well meet the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	98							
max:	120							
arithmetic mean		101,60	99,11	99,97	100,30	99,27	101,22	100,24
standard deviation		1,55	1,24	1,60	2,38	1,19	2,09	1,96
coefficient of variation		1,53%	1,25%	1,60%	2,38%	1,20%	2,07%	1,96%

○ highest and lowest value

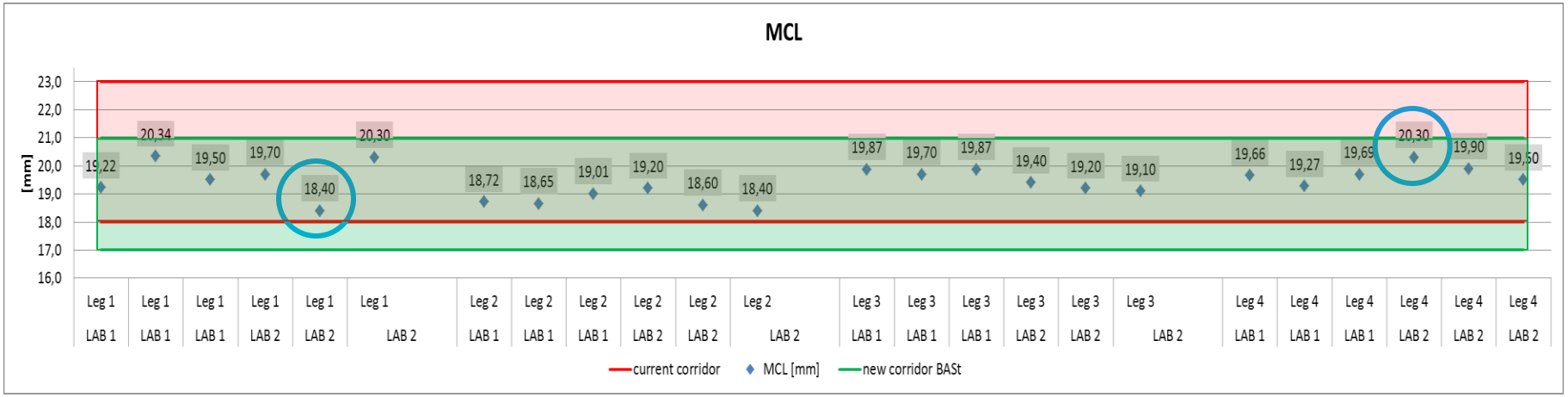
Inverse Certification Test Results – MCL

Corridor proposed for gtr No 9 (18 – 23 mm)

- All test results meet the corridor
- For legform 1, test results significantly scatter in both labs as well as in total

Corridor proposed by BASt on 18.06.2012 (17 – 21 mm)

- Test results are mainly in the upper half of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	18							
max:	23							
arithmetic mean		19,58	18,76	19,52	19,72	19,46	19,33	12,38
standard deviation		0,66	0,13	0,31	0,32	0,48	0,63	0,56
coefficient of variation		3,39%	0,68%	1,58%	1,64%	2,47%	3,25%	4,54%

○ highest and lowest value

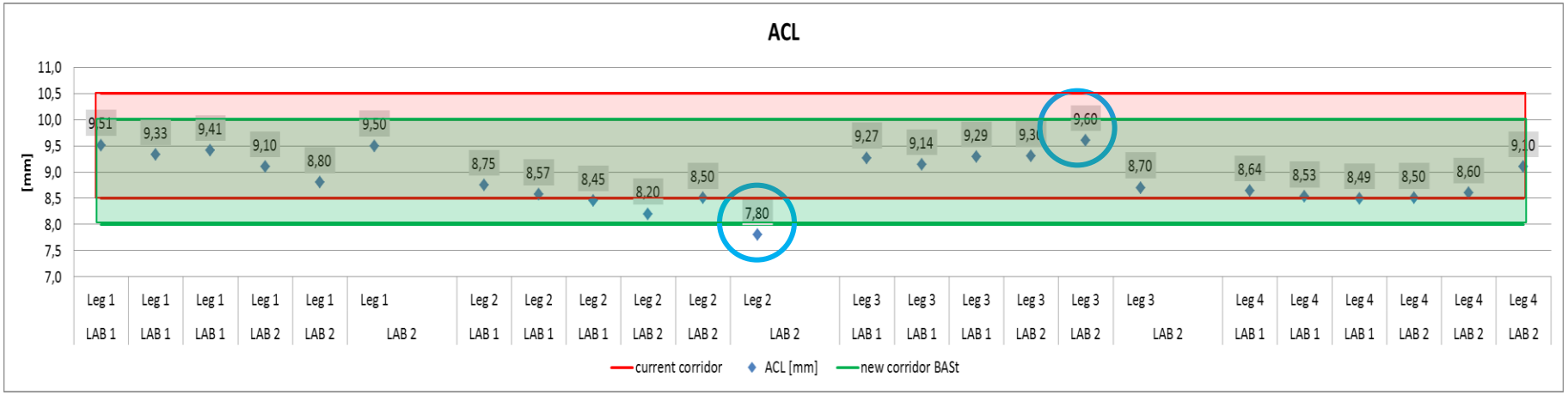
Inverse Certification Test Results – ACL

Corridor proposed for gtr No 9 (8.5 – 10.5 mm)

- For legforms 1 and 3, test results are in the middle of the corridor
- For legforms 2 and 4, test results are around the lower limit value but do not all meet the corridor
- Test results of legforms 1, 2 and 3 significantly scatter during tests in lab 2

Corridor proposed by BASt on 18.06.2012 (8 – 10 mm)

- All test results meet the corridor except one for legform 2 in lab 2 (outlier?)



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	8,5							
max:	10,5							
arithmetic mean		9,28	8,38	9,22	8,64	8,95	8,81	8,88
standard deviation		0,25	0,31	0,27	0,21	0,39	0,51	0,46
coefficient of variation		2,73%	3,65%	2,92%	2,44%	4,38%	5,82%	5,20%

○ highest and lowest value

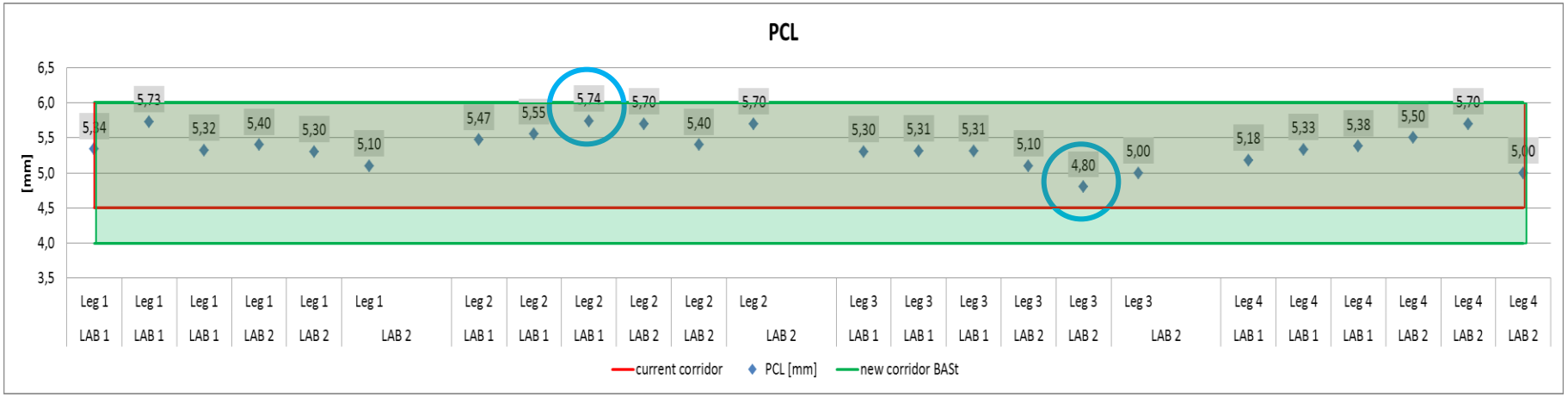
Inverse Certification Test Results – PCL

Corridor proposed for gtr No 9 (4.5 – 6 mm)

- All test results are around the middle or in the upper half of the corridor

Corridor proposed by BASt on 18.06.2012 (4 – 6 mm)

- All test results are in the upper half of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	4,5							
max:	6							
arithmetic mean		5,37	5,59	5,14	5,35	5,41	5,31	5,36
standard deviation		0,19	0,13	0,19	0,22	0,17	0,30	0,25
coefficient of variation		3,50%	2,29%	3,73%	4,16%	3,11%	5,57%	4,59%

○ highest and lowest value

Agenda

1. Test Series
2. Legforms
3. Inverse Certification Test Results
4. **Pendulum Certification Test Results**
5. Discussion

Certification Corridors

PENDULUM CERTIFICATION TEST CORRIDORS							
Corridors proposed for gtr No 9	Tibia 1 (Nm)	Tibia 2 (Nm)	Tibia 3 (Nm)	Tibia 4 (Nm)	MCL (mm)	ACL (mm)	PCL (mm)
Lower limit	272	211	160	108	26	11	5.4
Upper limit	235	185	135	94	23	9	4
Corridors proposed by BASt on 18.06.12	Tibia 1 (Nm)	Tibia 2 (Nm)	Tibia 3 (Nm)	Tibia 4 (Nm)	MCL (mm)	ACL (mm)	PCL (mm)
Lower limit	272	219	166	111	24	10.5	5
Upper limit	235	187	139	90	20.5	8	3.5

The information on the new corridors was kindly provided by BASt in preparation of the meeting to already allow this analysis.

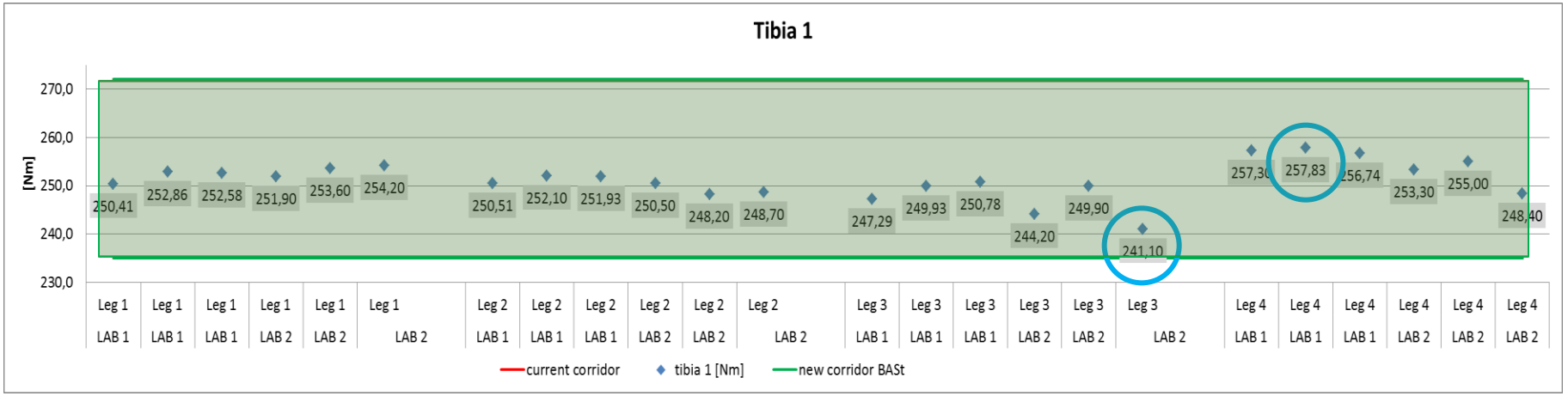
Pendulum Certification Test Results – Tibia 1

Corridor proposed for gtr No 9 (235 – 272 Nm)

- All test results meet the corridor, most test results are in the lower half
- For tests of legforms 3 and 4 tested in lab 2, test results significantly scatter

Corridor proposed by BASt on 18.06.2012 (235 – 272 Nm)

- (No shifting of the corridor was proposed)



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	235							
max:	272							
arithmetic mean		252,59	250,32	247,20	254,76	252,52	249,92	251,22
standard deviation		1,22	1,47	3,51	3,23	3,10	3,99	3,80
coefficient of variation		0,48%	0,59%	1,42%	1,27%	1,23%	1,59%	1,51%

○ highest and lowest value

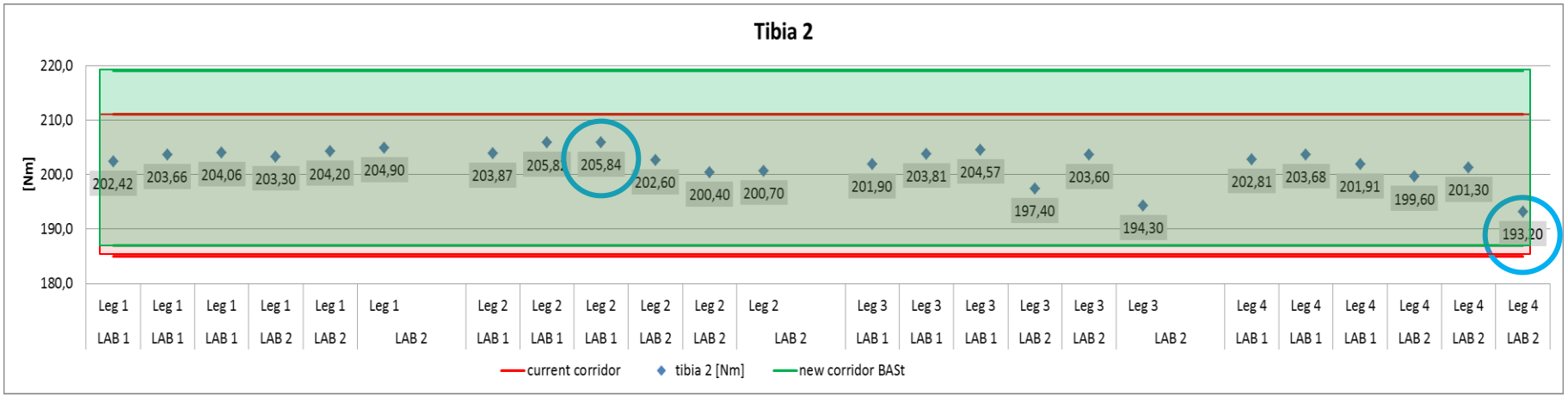
Pendulum Certification Test Results – Tibia 2

Corridor proposed for gtr No 9 (185 – 211 Nm)

- All test results meet the corridor, most test results are in the upper half
- Again, for legforms 3 and 4 test results significantly scatter during tests in lab 2

Corridor proposed by BASt on 18.06.2012 (187 – 219 Nm)

- All test results meet the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	185							
max:	211							
arithmetic mean		203,76	203,21	200,93	200,42	203,70	200,46	202,08
standard deviation		0,77	2,19	3,79	3,47	1,25	3,63	3,16
coefficient of variation		0,38%	1,08%	1,88%	1,73%	0,62%	1,81%	1,56%

○ highest and lowest value

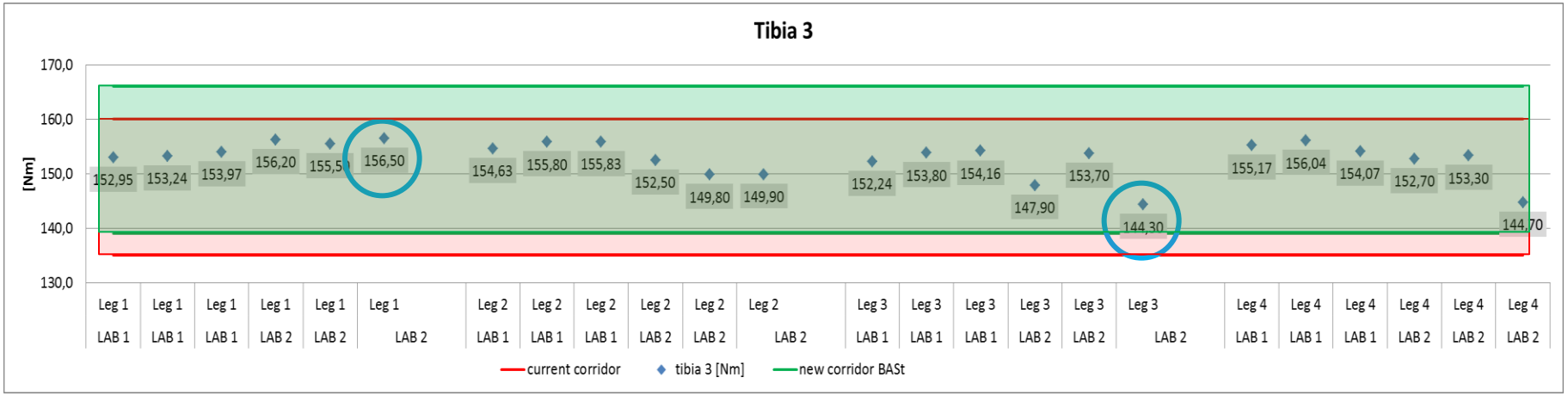
Pendulum Certification Test Results – Tibia 3

Corridor proposed for gtr No 9 (135 – 160 Nm)

- Most test results are in the upper half of the corridor
- Again, for legforms 3 and 4 test results significantly scatter during tests in lab 2

Corridor proposed by BASt on 18.06.2012 (139 – 166 Nm)

- All test results meet the middle of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	135							
max:	160							
arithmetic mean		154,73	153,08	151,02	152,66	154,33	151,42	152,87
standard deviation		1,41	2,54	3,68	3,73	1,16	3,98	3,27
coefficient of variation		0,91%	1,66%	2,44%	2,44%	0,75%	2,63%	2,14%

○ highest and lowest value

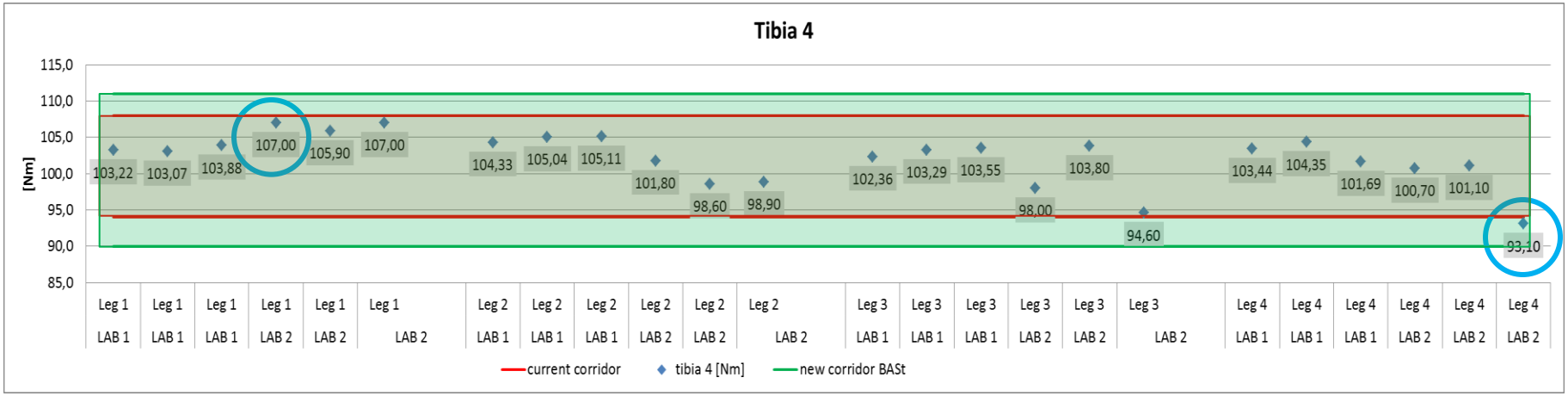
Pendulum Certification Test Results – Tibia 4

Corridor proposed for gtr No 9 (94 – 108 Nm)

- For all legforms, significant differences of test results when tested in different labs can be noted
- Again, for legforms 3 and 4 test results significantly scatter during tests in lab 2

Corridor proposed by BASt on 18.06.2012 (90 – 111 Nm)

- All test results well meet the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	94							
max:	108							
arithmetic mean		105,01	102,30	100,93	100,73	103,61	100,88	102,24
standard deviation		1,68	2,74	3,45	3,65	0,97	4,35	3,43
coefficient of variation		1,60%	2,68%	3,42%	3,62%	0,93%	4,31%	3,36%

○ highest and lowest value

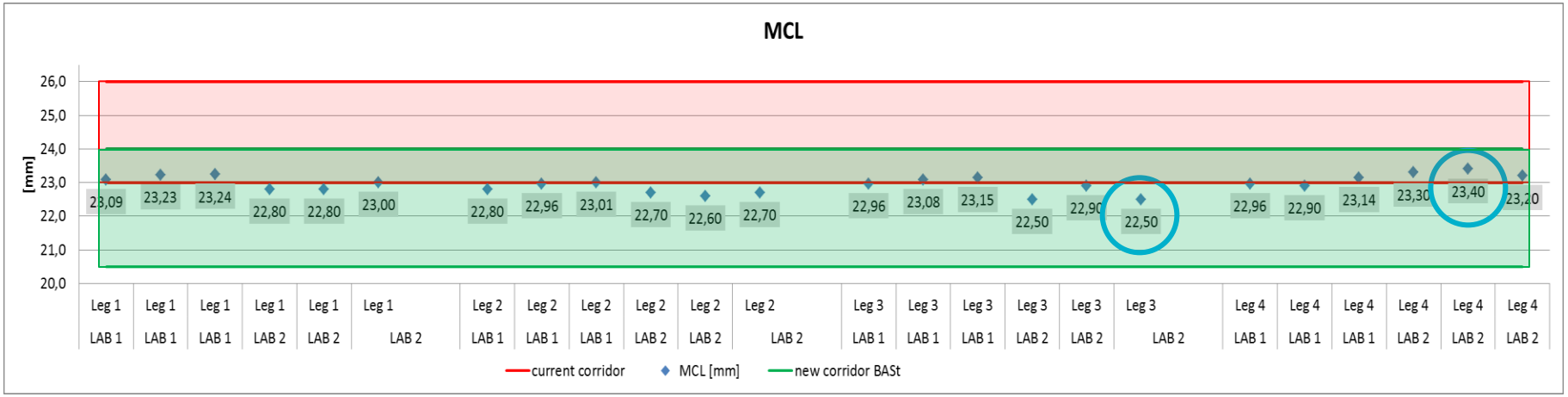
Pendulum Certification Test Results – MCL

Corridor proposed for gtr No 9 (23 – 26 mm)

- All test results are around the lower limit value but regularly miss to meet the corridor

Corridor proposed by BASt on 18.06.2012 (20.5 – 24 mm)

- All test results are in the upper half of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	23							
max:	26							
arithmetic mean		23,03	22,80	22,85	23,15	23,04	22,87	22,96
standard deviation		0,18	0,15	0,26	0,18	0,13	0,29	0,24
coefficient of variation		0,78%	0,64%	1,13%	0,76%	0,56%	1,27%	1,05%

○ highest and lowest value

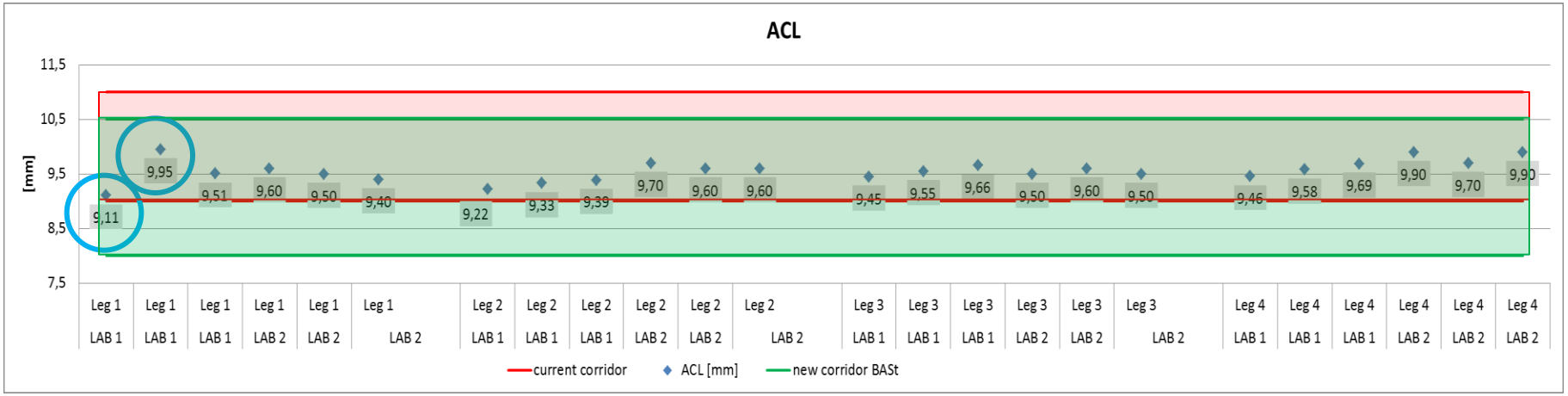
Pendulum Certification Test Results – ACL

Corridor proposed for gtr No 9 (9 – 11 mm)

- All test results are in the lower half of the corridor

Corridor proposed by BASt on 18.06.2012 (8 – 10.5 mm)

- Test results are mainly around the middle of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	9							
max:	11							
arithmetic mean		9,51	9,47	9,54	9,71	9,49	9,63	9,56
standard deviation		0,25	0,17	0,07	0,16	0,21	0,15	0,20
coefficient of variation		2,62%	1,80%	0,73%	1,64%	2,25%	1,54%	2,05%

○ highest and lowest value

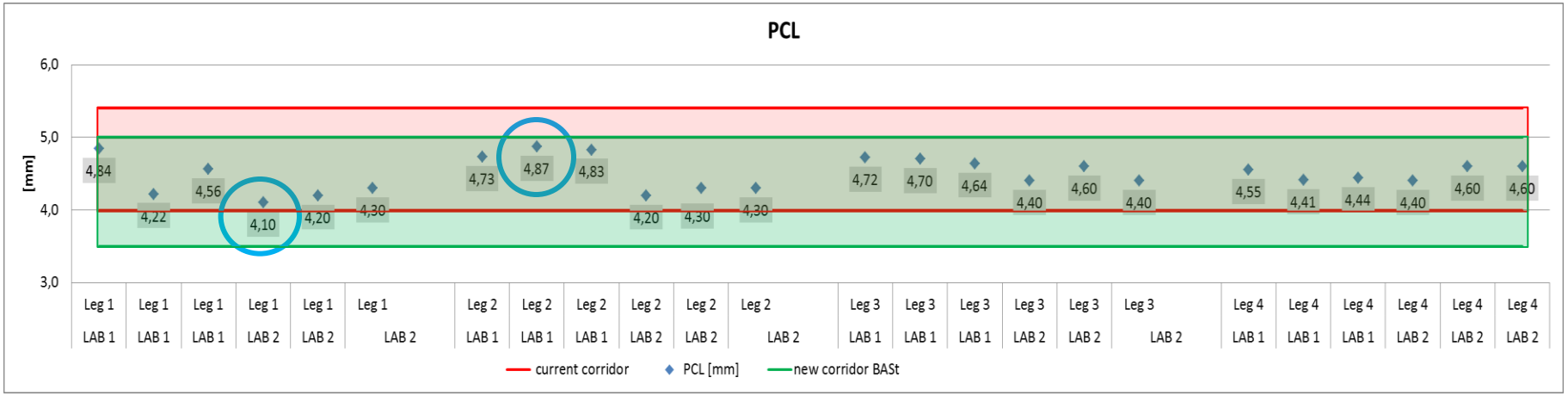
Pendulum Certification Test Results – PCL

Corridor proposed for gtr No 9 (4 – 5.4 mm)

- All test results are in the corridor but show significant scatter

Corridor proposed by BASt on 18.06.2012 (3.5 – 5 mm)

- Test results are in the corridor, being better distributed to the middle of the corridor



Corridor gtr No.9

relevant limits		Leg 1	Leg 2	Leg 3	Leg 4	LAB 1	LAB 2	Overall
min:	4							
max:	5,4							
arithmetic mean		4,37	4,54	4,58	4,50	4,63	4,37	4,50
standard deviation		0,25	0,28	0,13	0,09	0,19	0,16	0,22
coefficient of variation		5,81%	6,10%	2,86%	1,91%	3,00%	3,66%	4,84%

○ highest and lowest value

Agenda

1. Test Series
2. Legforms
3. Inverse Certification Test Results
4. Pendulum Certification Test Results
5. **Discussion**

Discussion

- Test results remain promising, as well as test results presented in document TF-RUCC-3-05: Still, meeting the corridors for both certification tests with one single impactor in principle is possible
- The newly proposed corridors improve the location of the test results within the corridors: Out of 168 inverse test results just one result fails to meet the respective corridor, out of 168 pendulum tests results all meet the corridor
- The redefinitions of the corridors are based on the test results with the three “master legforms” but it is unclear whether the sensor capabilities (allowed scatter of single sensors) also were (and need to be) considered
- Also, new corridors are expected to be proposed after finalization of the tests with the three “master legforms” prepared for the TF-RUCC activities
- Further tests to confirm the test results and to assess the long time performance of impactors still are wished for
- Lack of clarity remains for the root causes for the scatter of different legforms, for the question of what can be done if a legform constantly fails meeting the corridors and how a fine tuning of the respective legforms could be done

Thanks.