



**DEUTSCHER SCHRAUBENVERBAND E.V.**  
HERSTELLER MECHANISCHER VERBINDUNGSELEMENTE

Working Group Surface Coating Systems

## **DSV-Round Robin 2023 coefficient of friction**

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## Working Group Surface Coating Systems

### 1 Introduction

Quantitative knowledge of the coefficients of friction is an essential prerequisite for the calculation and reliable assembly of bolted connections in order to ensure a suitable preload force for the application. The friction coefficients are determined using sensors that can measure the preload force  $F$ , tightening torque  $T$ , friction torque in the bearing surface  $T_b$  and / or thread torque  $T_{th}$ . The standard DIN EN ISO 16047 [2] only specifies the test itself, the reference parts and the formulae to be used to calculate the friction coefficients. Quantitative specifications for friction coefficients in practical applications, including repeat assembly, are for example contained in VDA test sheet VDA 235-101 [1].

The standard DIN EN ISO 16047 [2] only sets out basic requirements for the design and function of the sensors used. As a result, a wide range of different test equipment is used in practice today, which is not easy for the comparability of results. The round robin tests carried out in the past in the *working group for surface protection systems* of the German Fastener Association and in the *ISO/TC 2/SC 11 + SC12 Ad hoc Group* (2023, as part of the revision of ISO 16047) show that a satisfactory solution for the correct determination and comparison of friction coefficients has not yet been found.

### 2 Objectives

The 2023 round robin test continued the series of round robin tests to determine the ability of test rigs/sensors to determine the friction coefficients of mechanical fasteners. The aim of the 2023 round robin test was also to record the behaviour of the measuring equipment in the case of multiple tightenings, as well as to assess different nominal thread diameters and thus also sensors with different capacities and to compare them within the nominal thread diameters.

As with the 2014 round robin test, the objectives were to determine the practical suitability of the sensors, based on DIN EN ISO 16047 and VDA 235-101, and to determine their ability to determine friction coefficients.

### 3 Task definition

The tests were carried out on bolts of different dimensions in order to give a larger number of users the opportunity to match their sensors. Whereas in the past the tests were always limited to the nominal thread size M10, this time a smaller thread size (M6) and a larger thread size (M24) were also tested, so that considerably more sensors could be recorded.

The round robin test created a sufficiently large number of test results to test individual sensors on a basic population.



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### 4 Test parts

#### Nominal thread size M6:

Test bolt	
designation:	external hexalobular flange bolt M6 x 40 - 10.9
surface condition:	ZnNi, black + lubrication
Reference nut	
designation:	hexagon nut M6 – 10, DIN EN ISO 4032 [3]
surface condition:	plain, degreased, according to DIN EN ISO 16047 [2]
Reference bearing plate	
designation:	washer, type HH
surface condition:	plain, degreased, according to DIN EN ISO 16047 [2]

#### Nominal thread size M10:

Test bolt	
designation:	hexagon flange bolt M10 x 60 - 10.9
surface condition:	ZnNi, black + lubrication
Reference nut	
designation:	hexagon nut M10 – 10, DIN EN ISO 4032 [3]
surface condition:	plain, degreased according to DIN EN ISO 16047 [2]
Reference bearing plate	(1-step-tightening, 20 rpm / 2-steps-tightening, 200/20 rpm)
designation:	E-coat-bar, to clean with alcohol before test

#### Nominal thread size M24:

Test bolt	
designation:	hexagon bolt M24 x 120 - 10.9
surface condition:	ZnNi, black + lubrication
Reference nut	
designation:	hexagon nut M24 – 10, DIN EN ISO 4032 [3]
surface condition:	ZnNi, black + lubrication
Reference bearing plate	
designation:	washer, type HH
surface condition:	plain, degreased, according to DIN EN ISO 16047 [2]

The cleaning of the reference parts required by DIN EN ISO 16047 [2] was carried out centrally in advance.

After cleaning, the nuts and washers were put into airtight bags.



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### 5 Carrying out the tests

A test series with 25 individual tests (M6 / M10) or 20 individual tests was to be carried out for each sensor. The reference-nuts and –washers were to be fixed against turning during the tightening process. The E-coat reference bar was to be held in a suitable device.

The test was carried out in accordance with the specifications of DIN EN ISO 16047 [2]. Depending on the thread dimension and the property-class of the test screw, the preload force at the switch-off point was set at  $F = 80\% F_p$  and at the evaluation point at  $F = 75\% F_p$ . The corresponding values were taken from the respective evaluation sheet.

A standardized automated evaluation scheme was specified for all measurements, which automatically converted the values to be entered for the preload force  $F$  and the torques into the friction coefficients. The participants were asked to measure the contact pattern diameters themselves and enter them into the evaluation scheme. These values were displayed in a diagram for each measurement in order to document the scattering of the very subjective values to be determined.

For the final evaluation, a fixed value for the friction torque in the bearing surface  $D_b$  was specified for all individual evaluations (of one dimension) in order to achieve comparability of the total friction coefficient  $\mu_{tot}$  and the bearing friction coefficient  $\mu_b$ .

The friction coefficient calculation was based on the following relationships:

$$\mu_{tot} = \frac{\frac{T}{F} - \frac{P}{2\pi}}{0,578 d_2 + 0,5 D_b}$$

$$\mu_b = \frac{2T_b}{D_b F}$$

$$\mu_{th} = \frac{\frac{T_{th}}{F} - \frac{P}{2\pi}}{0,578 d_2}$$

The mean values and standard deviations were calculated for all measurement series. However, results from a sensor whose measured values are outside the calibration range were shown in the diagrams but not taken into account when calculating the mean values and standard deviations.



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### 6 Test results

A comprehensive anonymized presentation of the sensor results is shown below. The numbering of the sensors is arbitrary and does not correlate with the alphabetical order of the participants.

### 7 Summary

A total of 176 sensors with 3 different nominal thread sizes took part in the 2023 round robin test. As there were no decision criteria for the assessment and the test material of the different dimensions came from a single batch, the results were assumed to be normally distributed:

- Practical suitability of the test based on DIN EN ISO 16047 and VDA 235-101 [1]
  - The standard deviations of the tightening torques  $T$  are in most cases significantly lower than those of the partial torques  $T_b$  /  $T_{th}$ .
- Capability of the sensors
  - The sensors were categorized into three quality classes  $C_0$ ,  $C_1$  and  $C_2$  with regard to the friction coefficient window of the VDA 235-101 [1] recommendation.
  - 65 % of the participating sensors whose measured values were within the calibration ranges could be assigned to quality class  $C_0$ . For the remaining 35 %, it is recommended to check / calibrate the sensor.
  - In many cases, the sensors were not categorized in quality class  $C_0$  due to a major deviation in the partial friction coefficients.
  - Compared to the results of the 2014 DSV round robin test (66%), which was carried out exclusively with the M10 thread dimension, a slight deterioration is recognisable (63.5% of the M10 dimension could be assigned to quality class  $C_0$ ). However, there is no perfect comparability with the results of the 2014 round robin test, as there were differences in the coating system, the reference parts and the bearing surface of the bolt head.
  - For the thread size M24, the reference nut was also coated with ZnNi black + lubricant. This resulted in lower scattering of the thread friction coefficients and no assignment to quality class  $C_2$ .
- As with the 2014 round robin test, 2023 also shows that
  - the determination of the effective diameter for the friction torque in the bearing surface  $D_b$  is subject to considerable scatter. There is still great potential for improvement here, as this diameter has a major influence on the calculated friction coefficients, but can currently only be assessed very subjectively.

The organizers would like to thank the DSV members Wilhelm Schumacher GmbH Schraubenfabrik, August Friedberg GmbH, WHW Walter Hillebrand GmbH & Co. KG and Dörken Coatings GmbH & Co. KG for providing the test material, the sample coatings and the cleaning of the reference parts.



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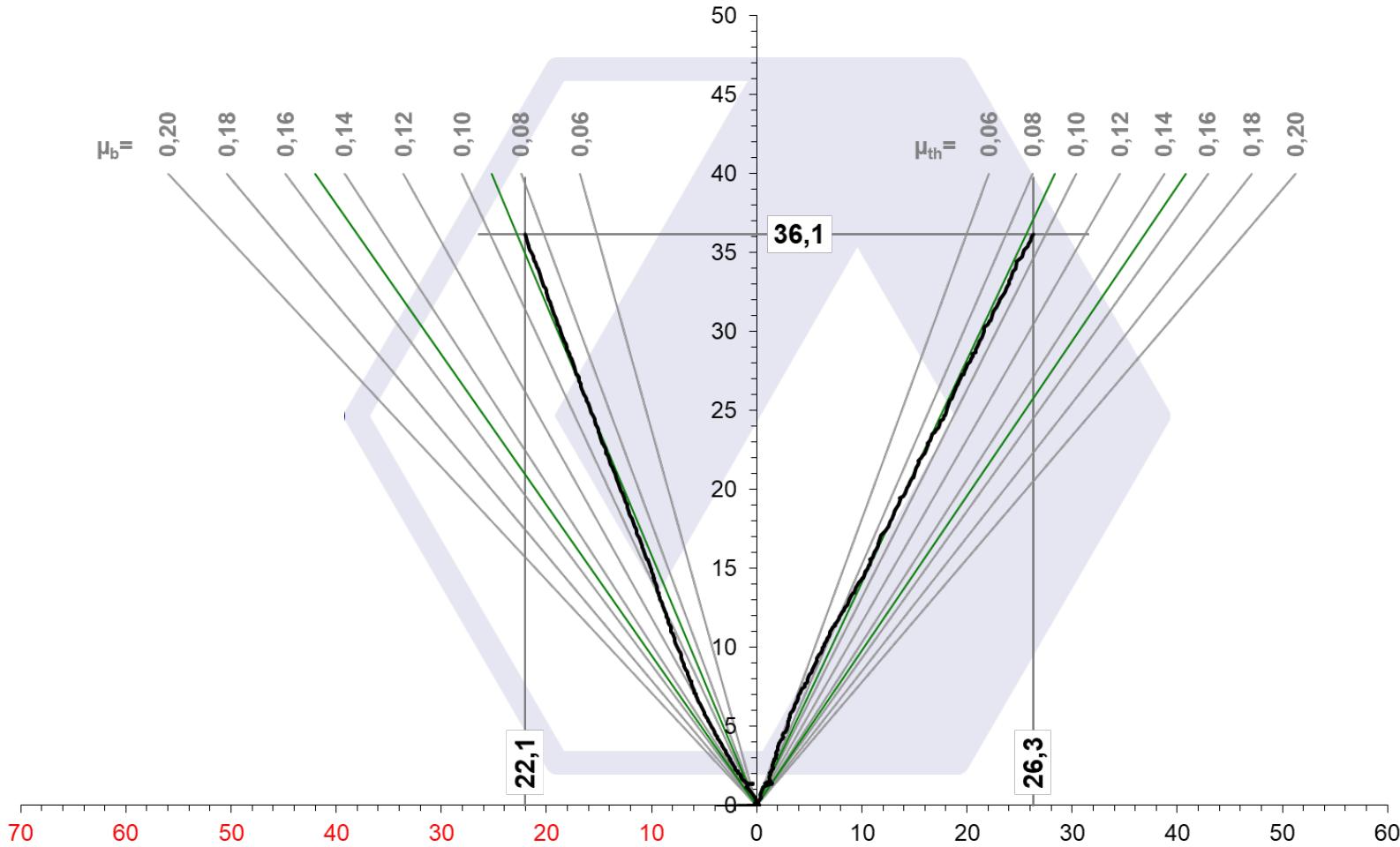
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### Bibliography

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- [1] Verband der Automobilindustrie e. V. (November 2021): VDA 235-101 Ermittlung von Reibungszahlen von mechanischen Verbindungselementen mit metrischem Gewinde, Berlin
  - [2] DIN Deutsches Institut für Normung e. V. (Januar 2013): DIN EN ISO 16047 Verbindungselemente - Drehmoment/Vorspannkraft-Versuch, Berlin
  - [3] DIN Deutsches Institut für Normung e. V. (Dezember 2023): DIN EN ISO 4032 Verbindungselemente Sechskantmuttern (Typ 1), Berlin

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# round robin test 2023 coefficient of friction

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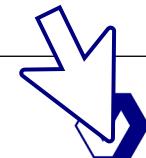


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# round robin test 2023 coefficient of friction

final evaluation



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# round robin test 2023 coefficient of friction



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based on DIN EN ISO 16047

$D_i$	inside diameter of the effective bearing surface	mm
$D_a$	outside diameter of the effective bearing surface	mm
$D_b$	effective diameter for the friction torque at the bolt head or nut bearing area	mm
$F$	clamp force	kN
$T$	tightening torque	Nm
$T_b$	bearing surface friction torque	Nm
$T_{th}$	thread torque	Nm
$\mu_{tot}$	coefficient of total friction	- / -
$\mu_b$	coefficient of friction between bearing surfaces	- / -
$\mu_{th}$	coefficient of friction between threads	- / -

Definition of quality classes

$C_0$	test bench without complaints
$C_1$	test bench where the calibration status and/or sensor function of individual measured variables are likely to be impaired
$C_2$	test bench shows clear indications of malfunctions

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Participants		
M6	66 sensors	34 companies / laboratories
M10 20 rpm	17 sensors	12 companies / laboratories
M10 200 rpm	69 sensors	32 companies / laboratories
M24	24 sensors	20 companies / laboratories
TOTAL	176 sensors	41 companies / laboratories

A series of flags are displayed vertically on the right side of the table, corresponding to the total number of participants:

- Germany (black, red, gold)
- Spain (red, yellow, red)
- France (blue, white, red)
- Netherlands (red, white, blue)
- Czech Republic (blue, white, red)
- China (red, yellow star)
- Slovakia (white, blue, red)
- Italy (green, white, red)
- USA (stars and stripes)
- Switzerland (red, white, red with white cross)



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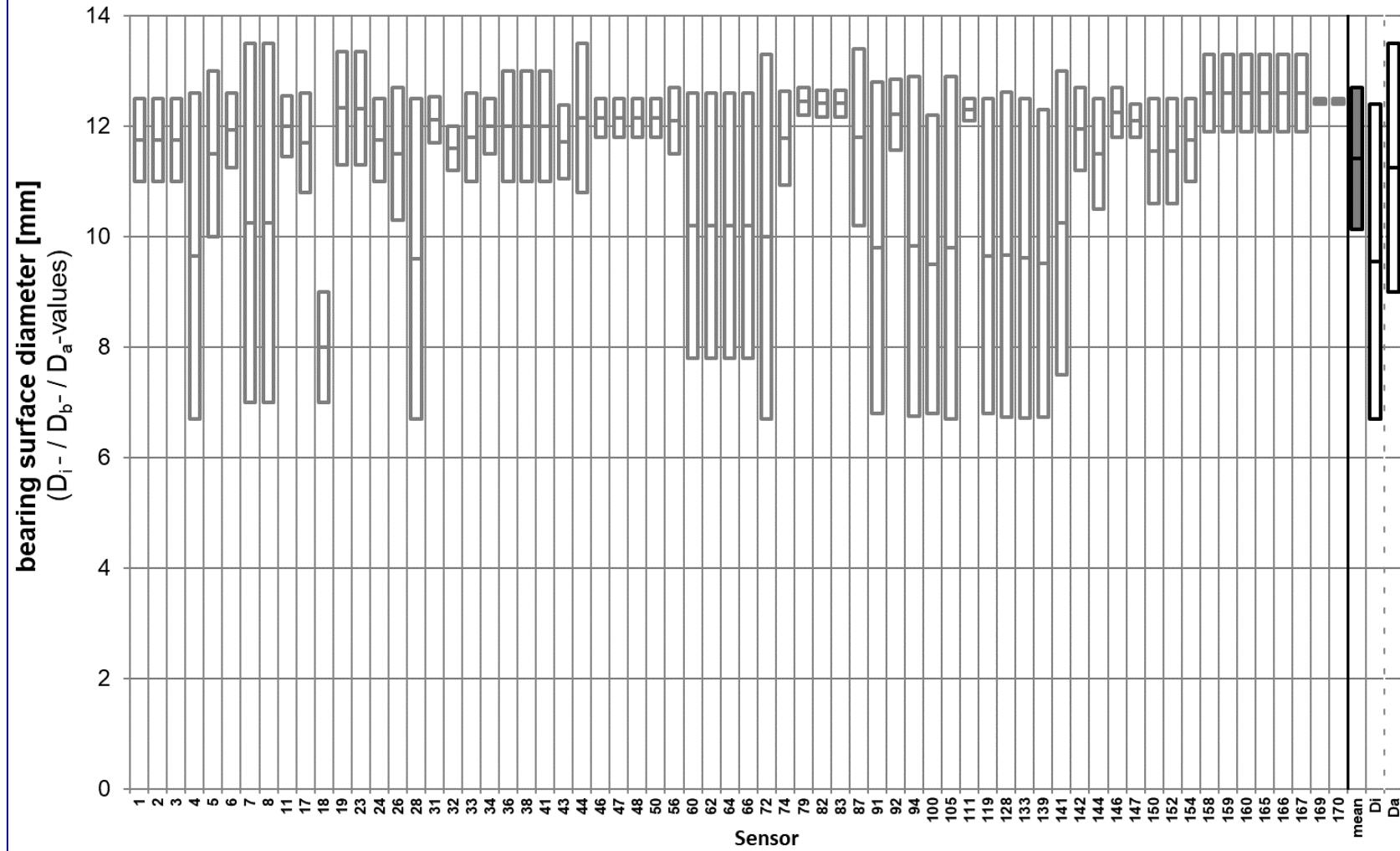
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bearing surface diameter  
M6

effective friction diameter  $D_b = 11,3 \text{ mm}$



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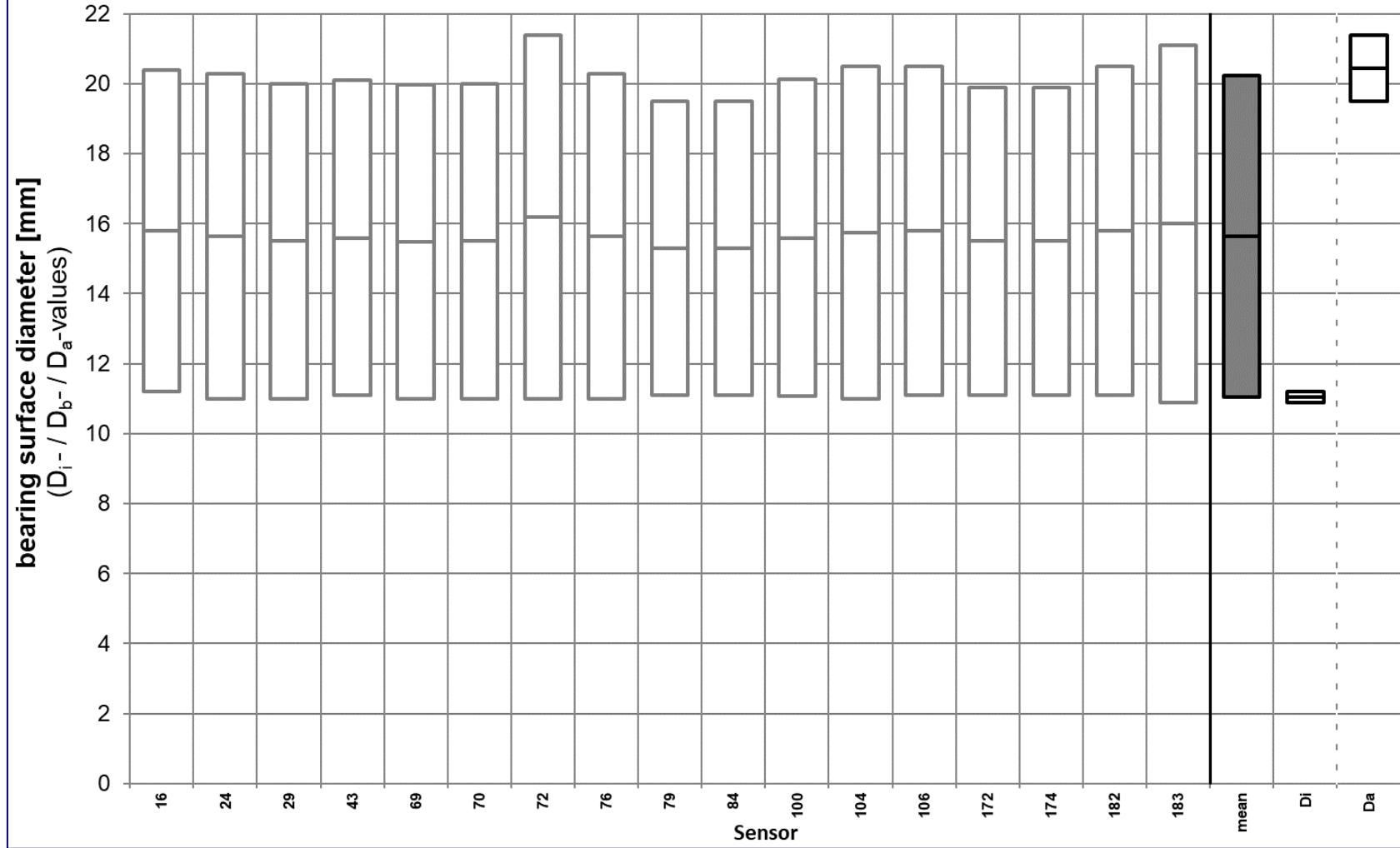
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bearing surface diameter  
M10 - 20 rpm

effective friction diameter  $D_b = 15,7 \text{ mm}$



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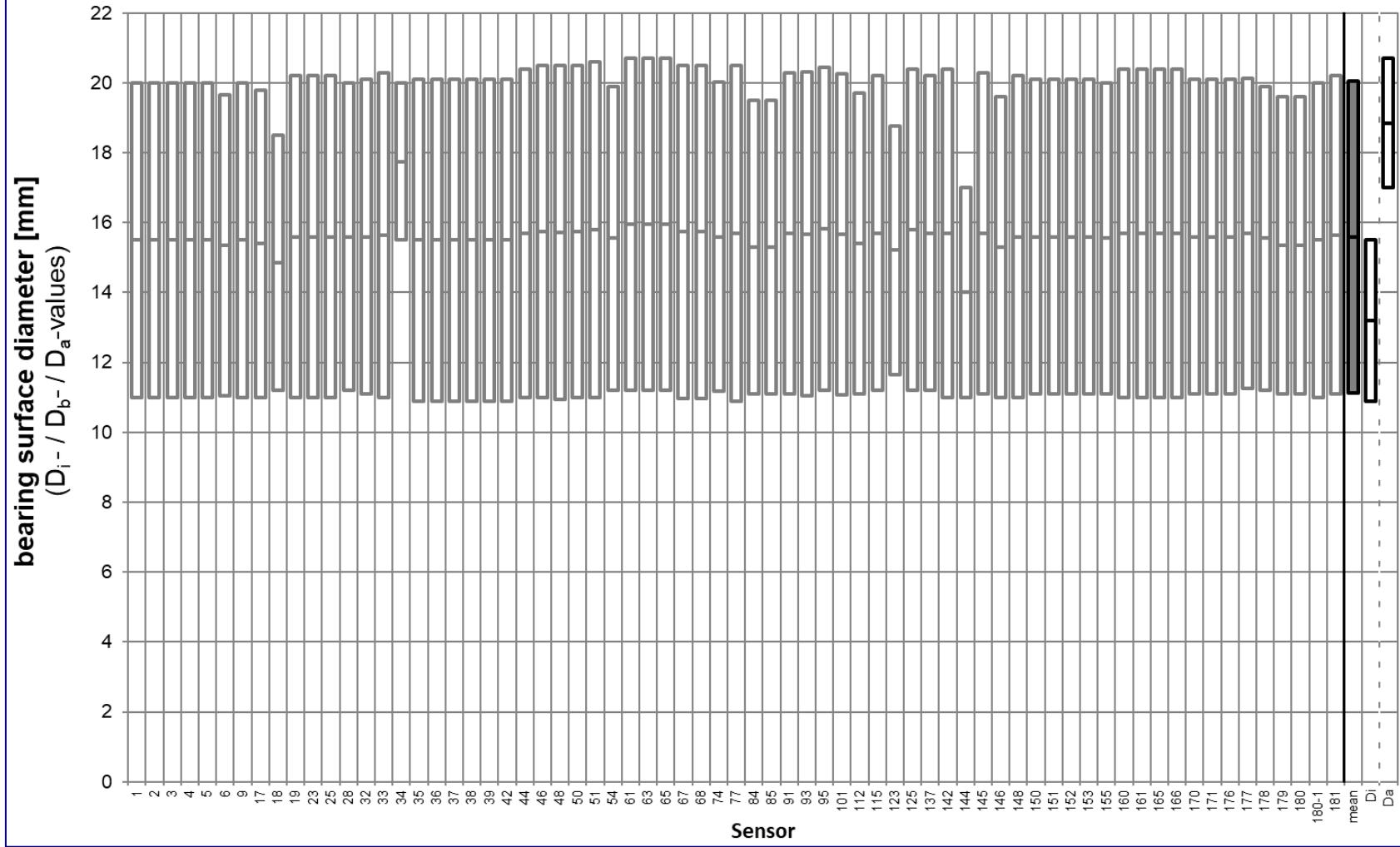
## final evaluation



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bearing surface diameter  
M10 - 200 rpm

effective friction diameter  $D_b = 15,7 \text{ mm}$



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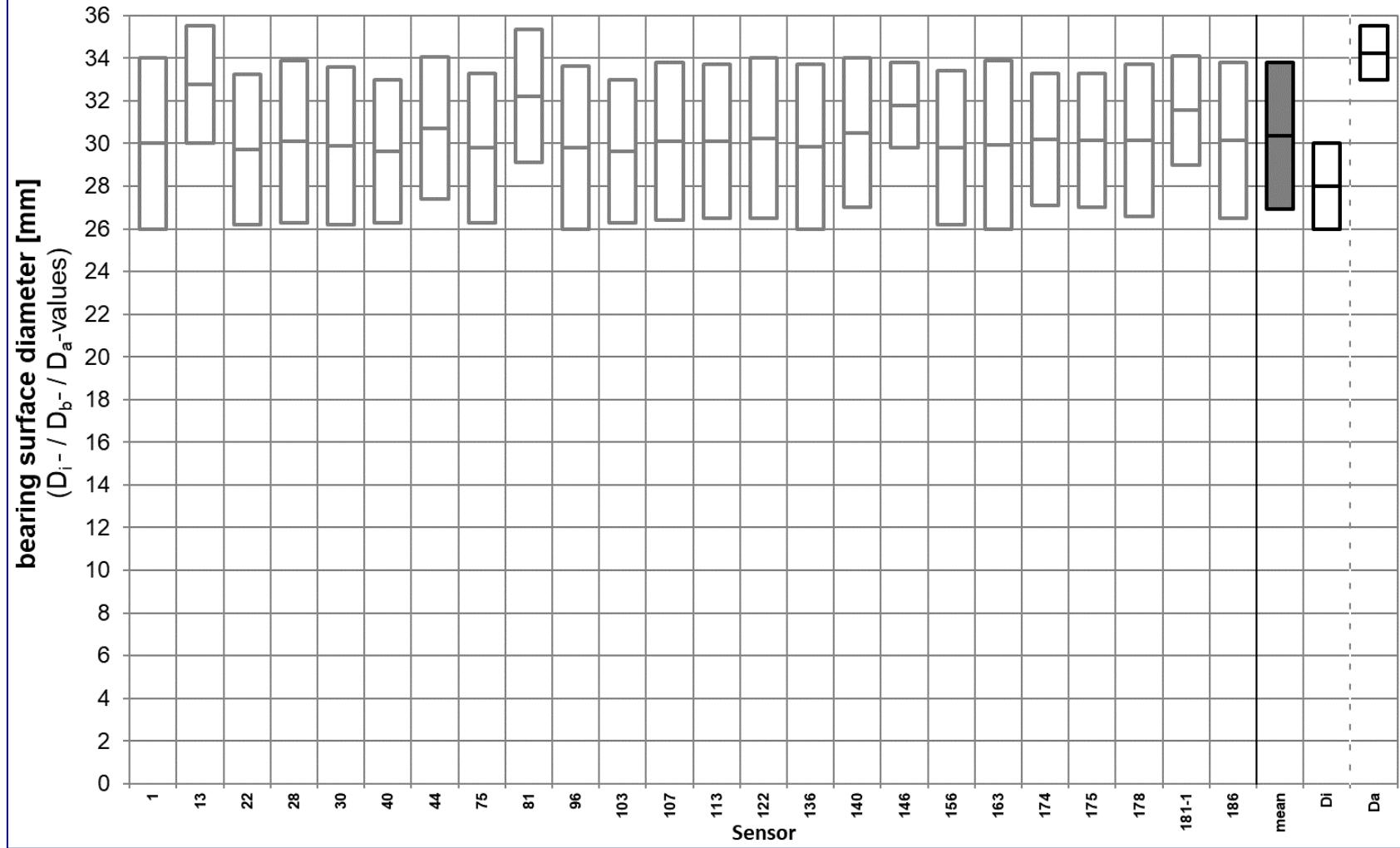
## final evaluation

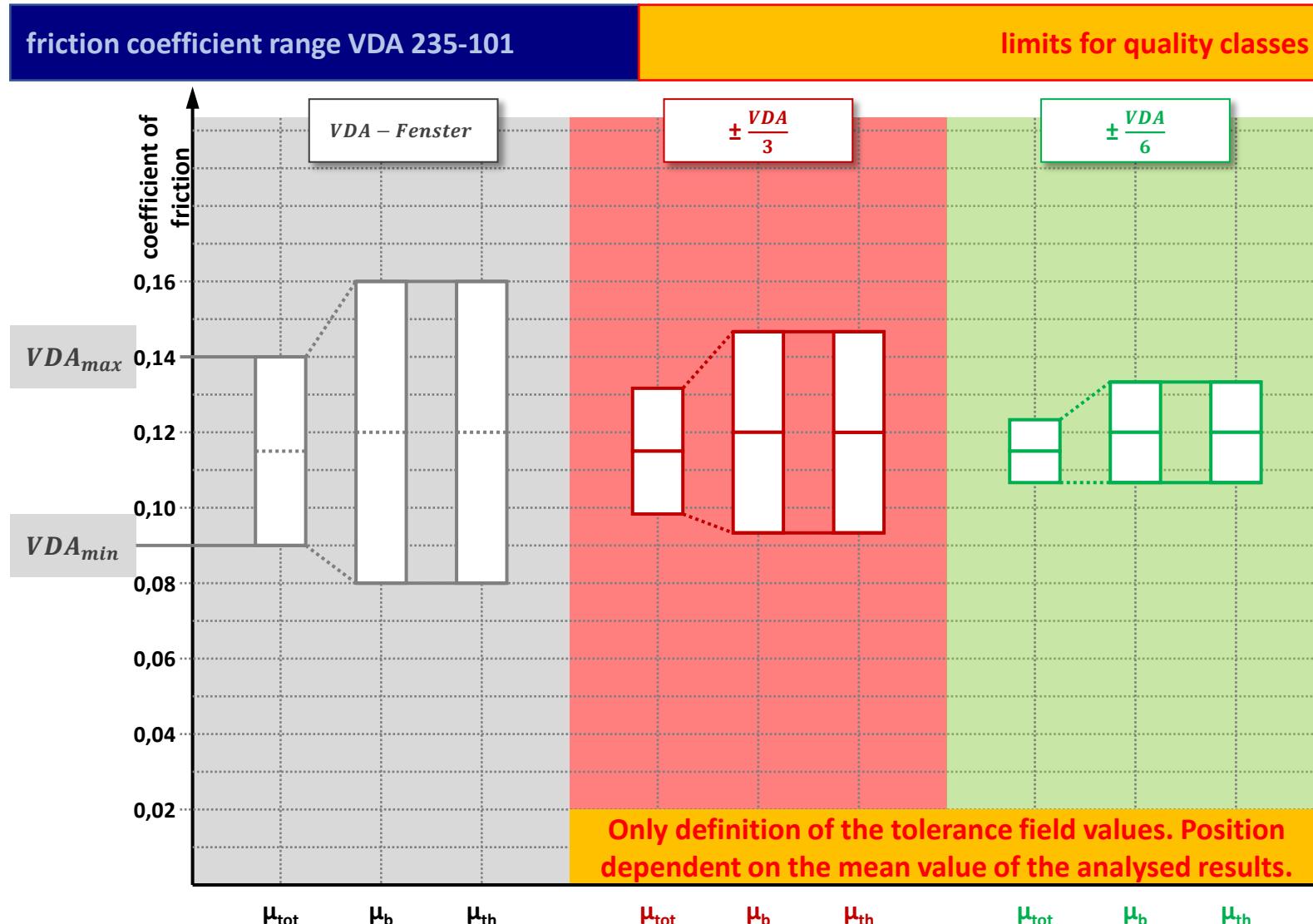


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bearing surface diameter  
M24

effective friction diameter  $D_b = 30,0 \text{ mm}$



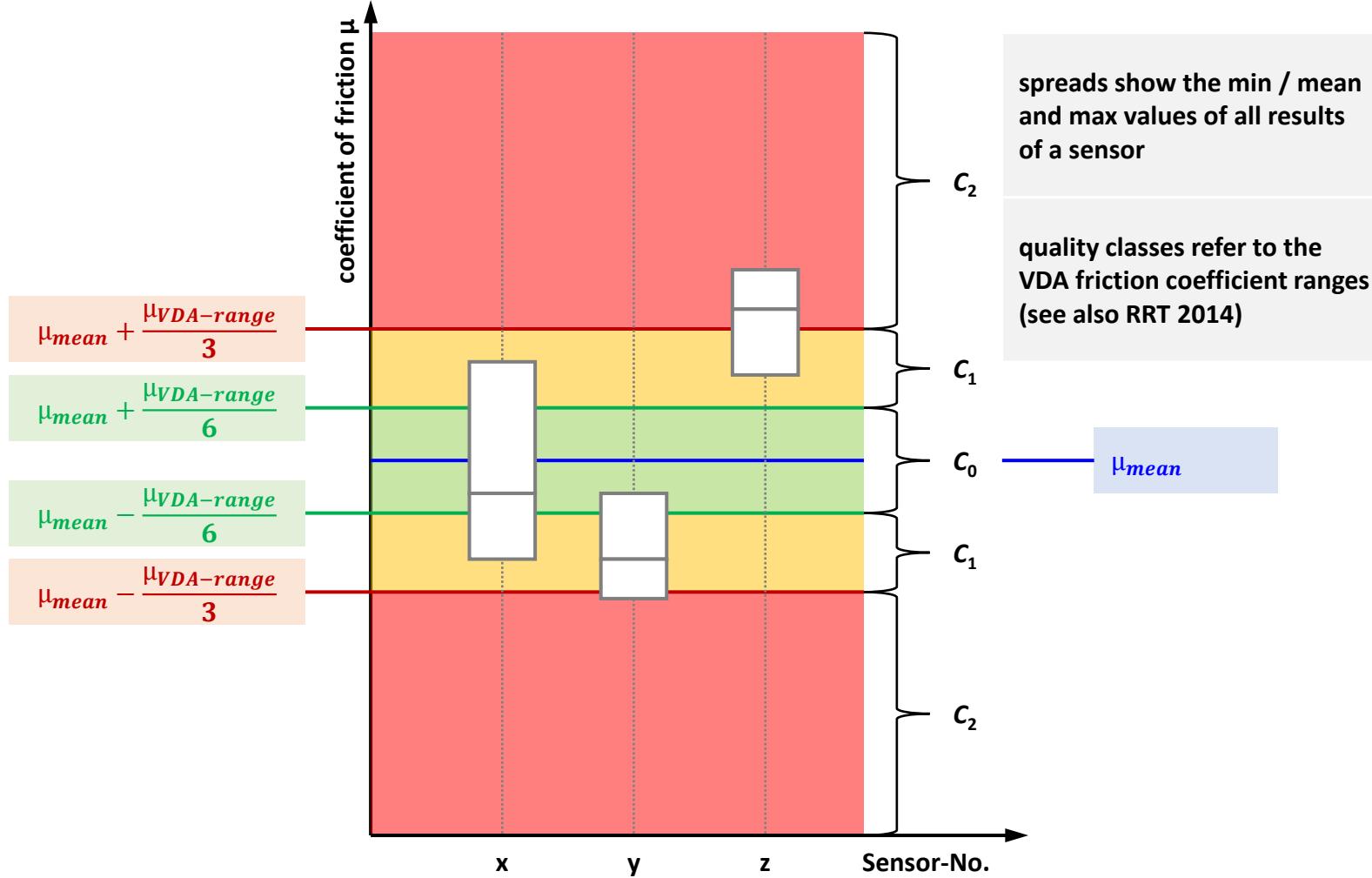


### quality classes of sensors

quality class	description
$C_0$	<p><b>sensor with proper function</b></p> $x_{mean \ of \ all \ sensors} - \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{6}$ $\leq x_{mean \ of \ sensor}$ $\leq x_{mean \ of \ all \ sensors} + \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{6}$
$C_1$	<p><b>sensor with propable adverse effects on the calibrating condition of single measurement values and / or the sensor function</b></p> $x_{mean \ of \ all \ sensors} - \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{3}$ $\leq x_{mean \ of \ sensor}$ $< x_{mean \ of \ all \ sensors} - \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{6}$ $x_{mean \ of \ all \ sensors} + \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{6}$ $< x_{mean \ of \ sensor}$ $\leq x_{mean \ of \ all \ sensors} - \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{3}$
$C_2$	<p><b>sensor with distinct indications of malfunction</b></p> $x_{mean \ of \ sensor} < x_{mean \ of \ all \ sensors} - \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{3}$ $x_{mean \ of \ sensor} > x_{mean \ of \ all \ sensors} + \frac{coefficient \ of \ friction \ range \ according \ to \ VDA \ 235 - 101}{3}$

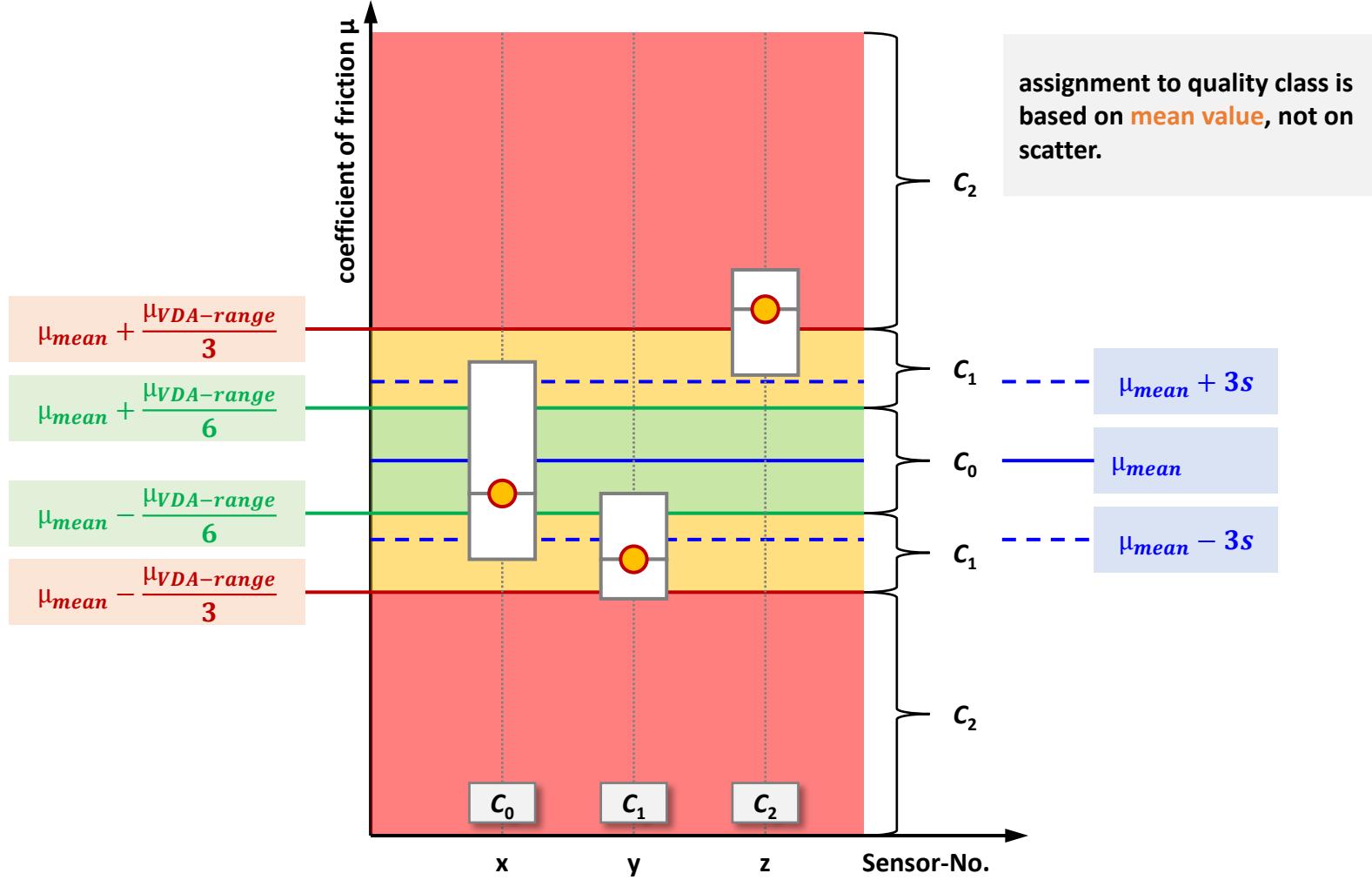
### quality classes

example values with VDA-friction coefficient range!



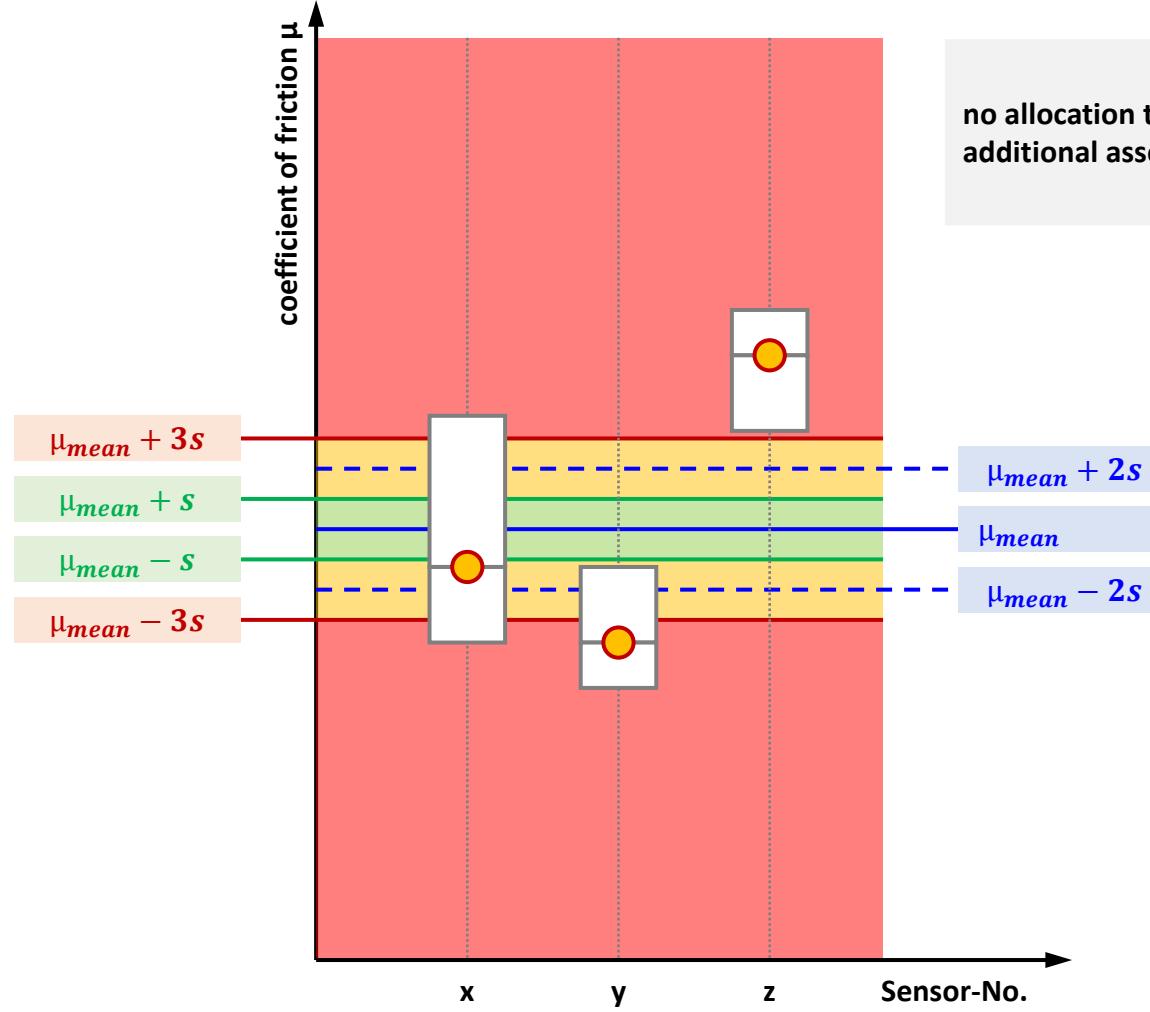
### quality classes

### example values with VDA-friction coefficient range!



### quality classes

example values with standard deviation!



# round robin test 2023 coefficient of friction

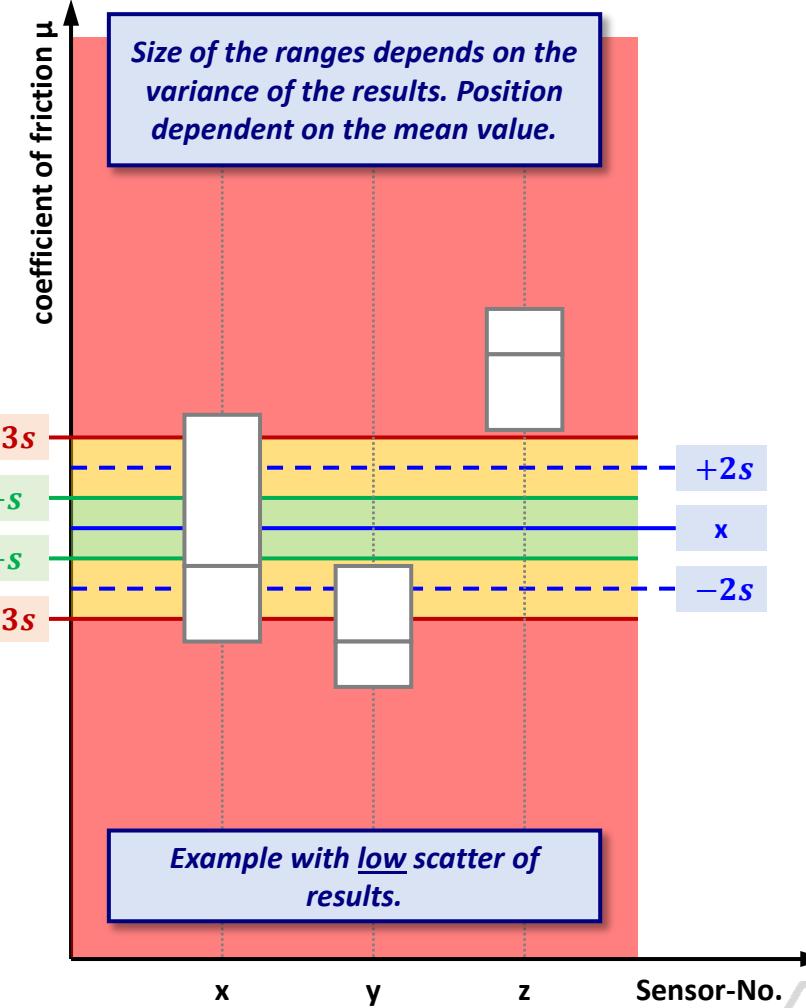
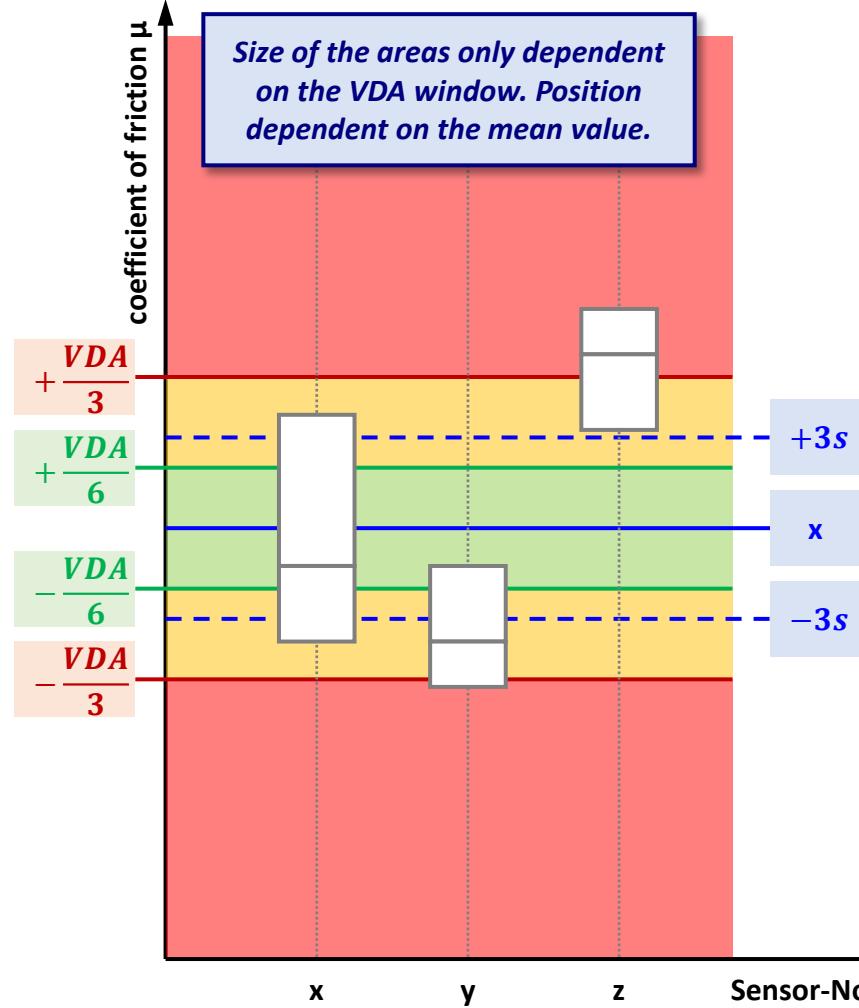
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### basis for assessment

### comparison of VDA-range to standard deviation



# round robin test 2023 coefficient of friction

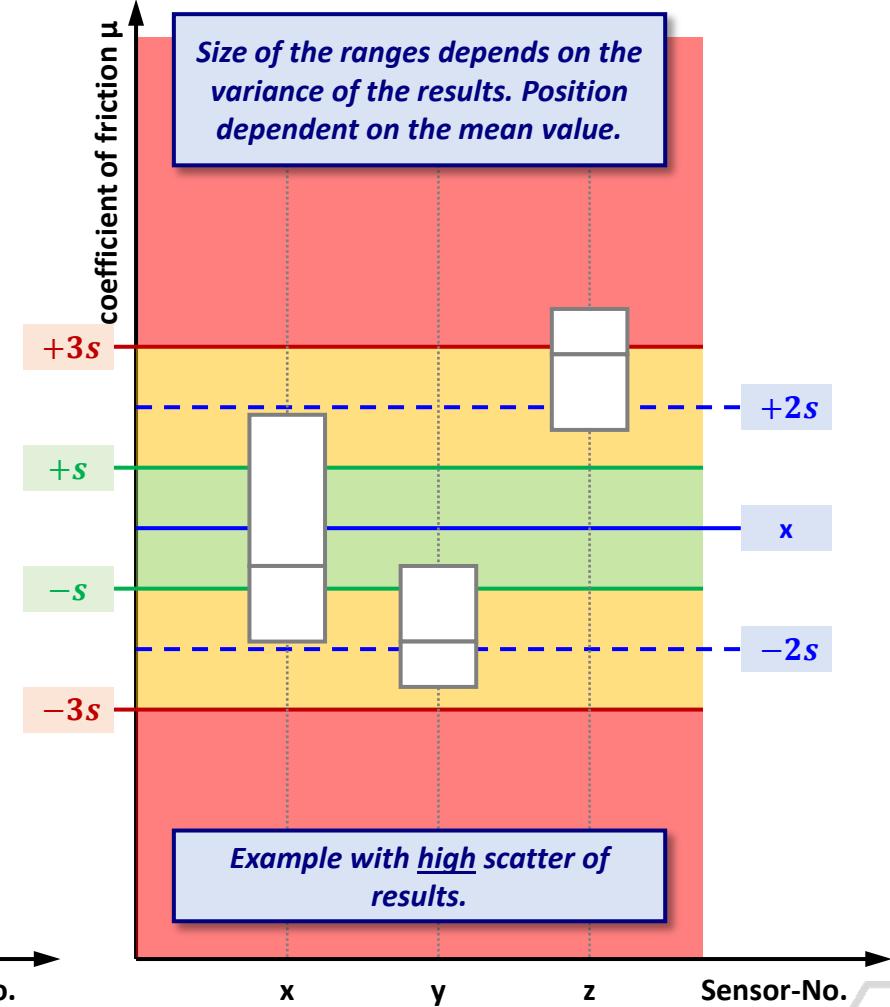
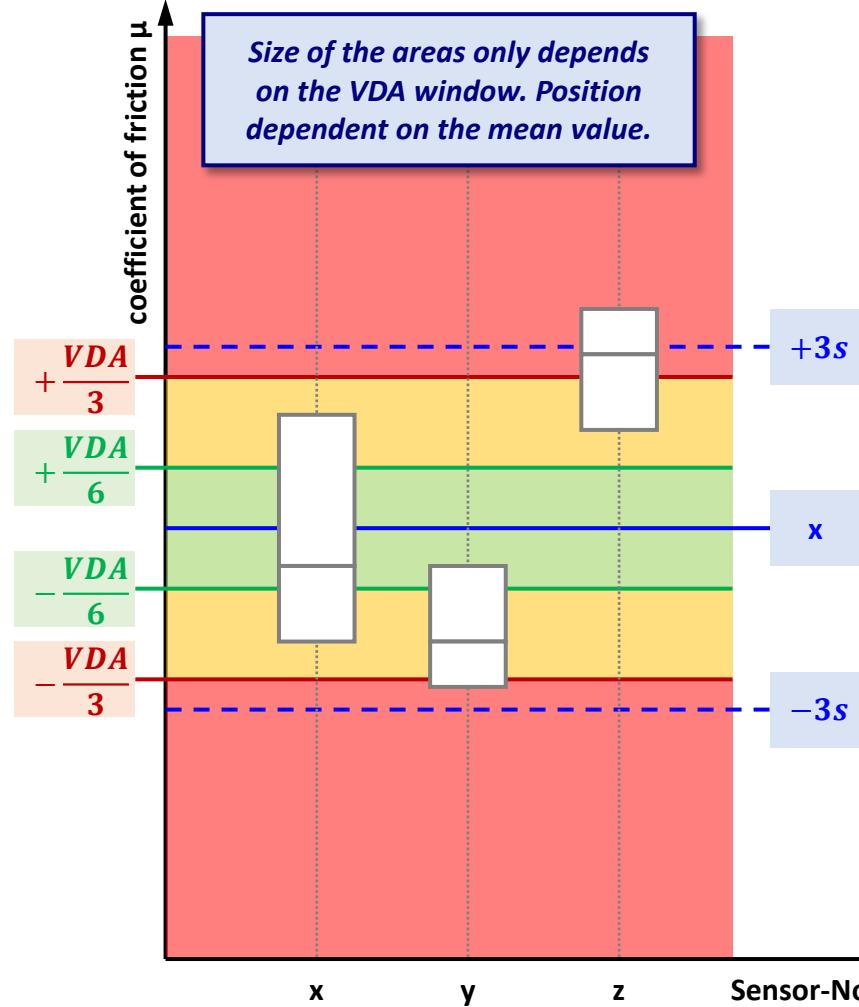
## final evaluation



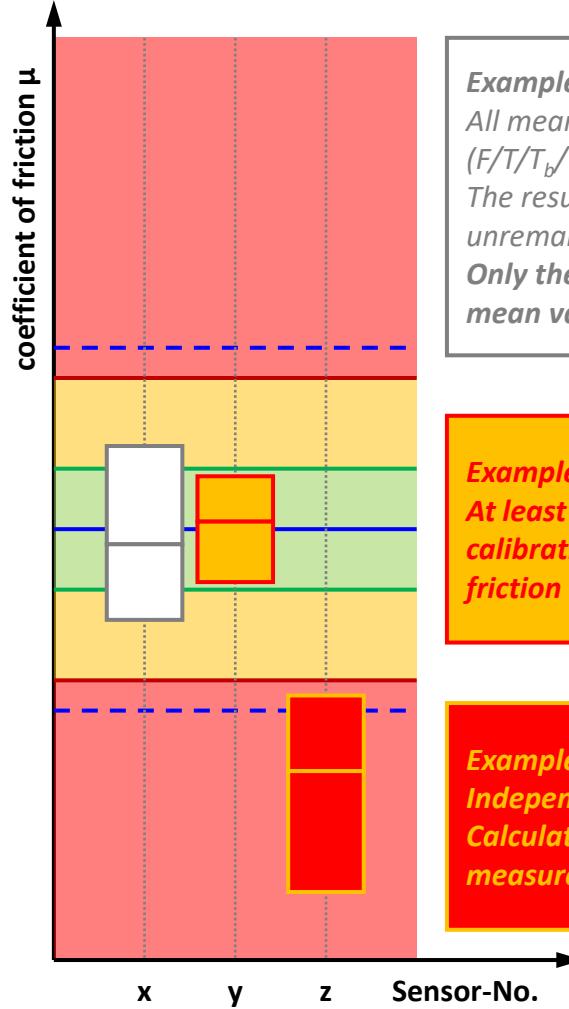
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### basis for assessment

### comparison of VDA-range to standard deviation



### filter for analysis



### explanation of the 3 groups

#### *Example sensor x:*

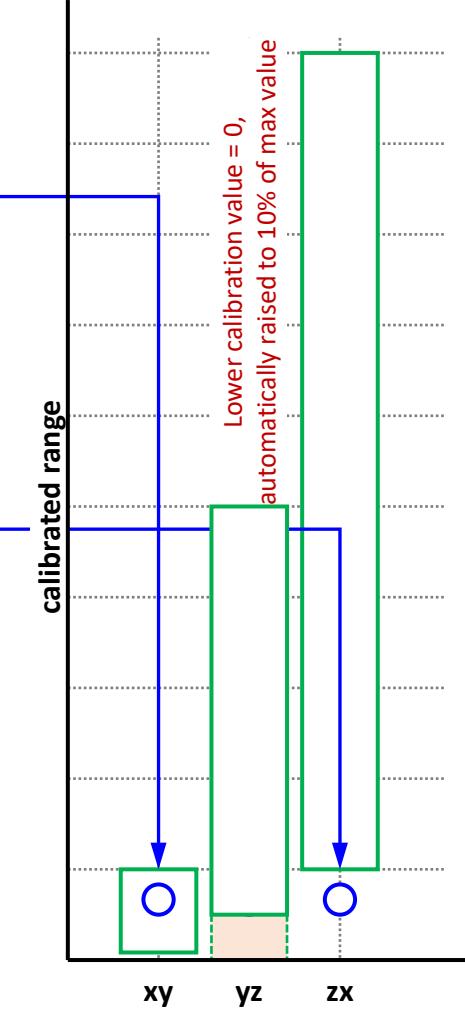
All mean values of the measured values ( $F/T/T_b/T_{th}$ ) are within the calibration range. The result of the calculated friction coefficients is unremarkable.  
Only these values are taken into account for the mean values and the standard deviation!

#### *Example sensor y:*

At least one measured value is outside the calibration range. The result of the calculated friction coefficients may be unremarkable.

#### *Example sensor z:*

Independent of suitable calibration range. Calculated friction coefficients indicate incorrect measurement.



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## final evaluation

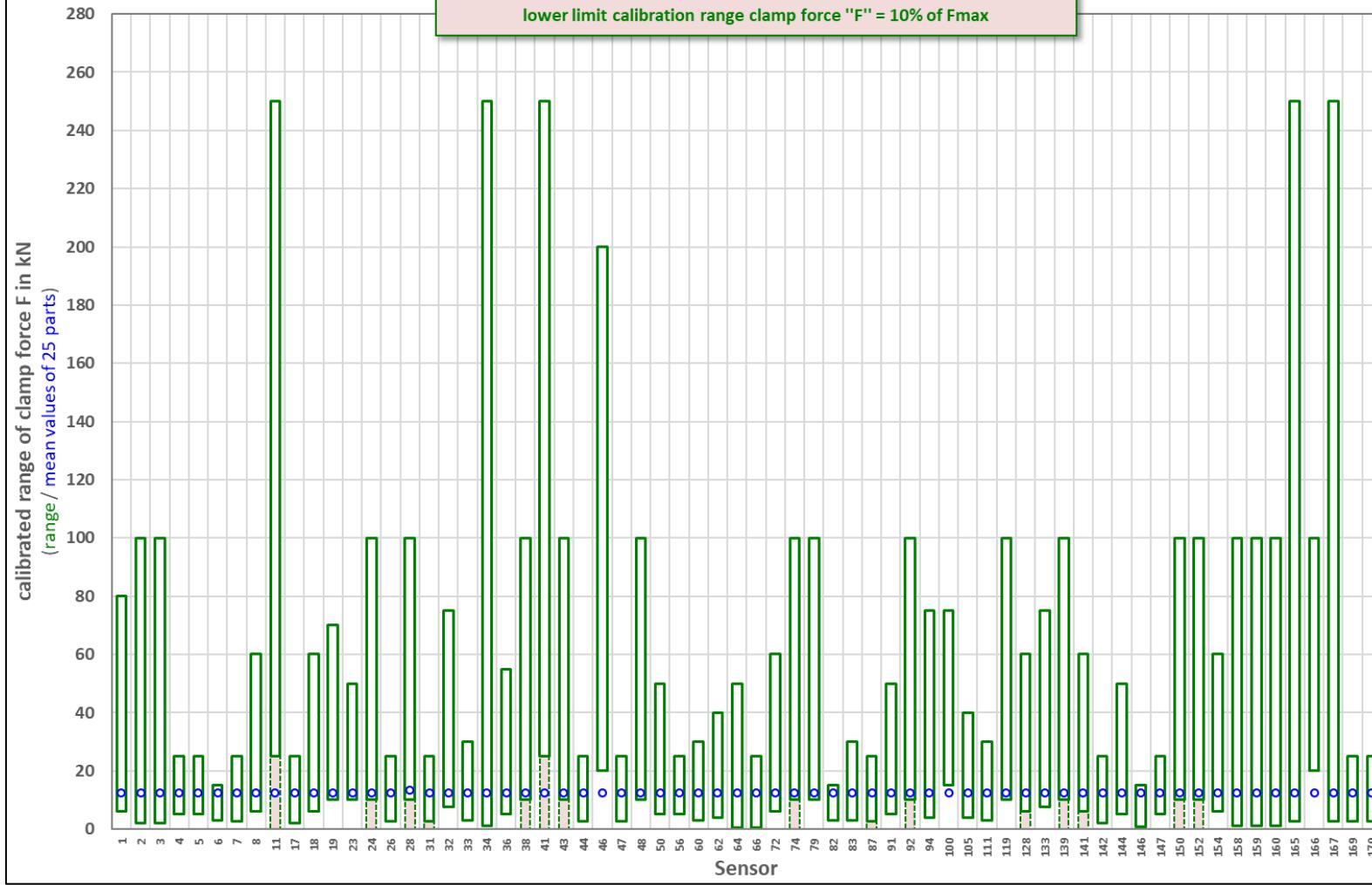


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### calibrated range clamp force F M6

min-value = 0: increase to 10% of the max-value!

lower limit calibration range clamp force "F" = 10% of Fmax



# round robin test 2023 coefficient of friction

## final evaluation

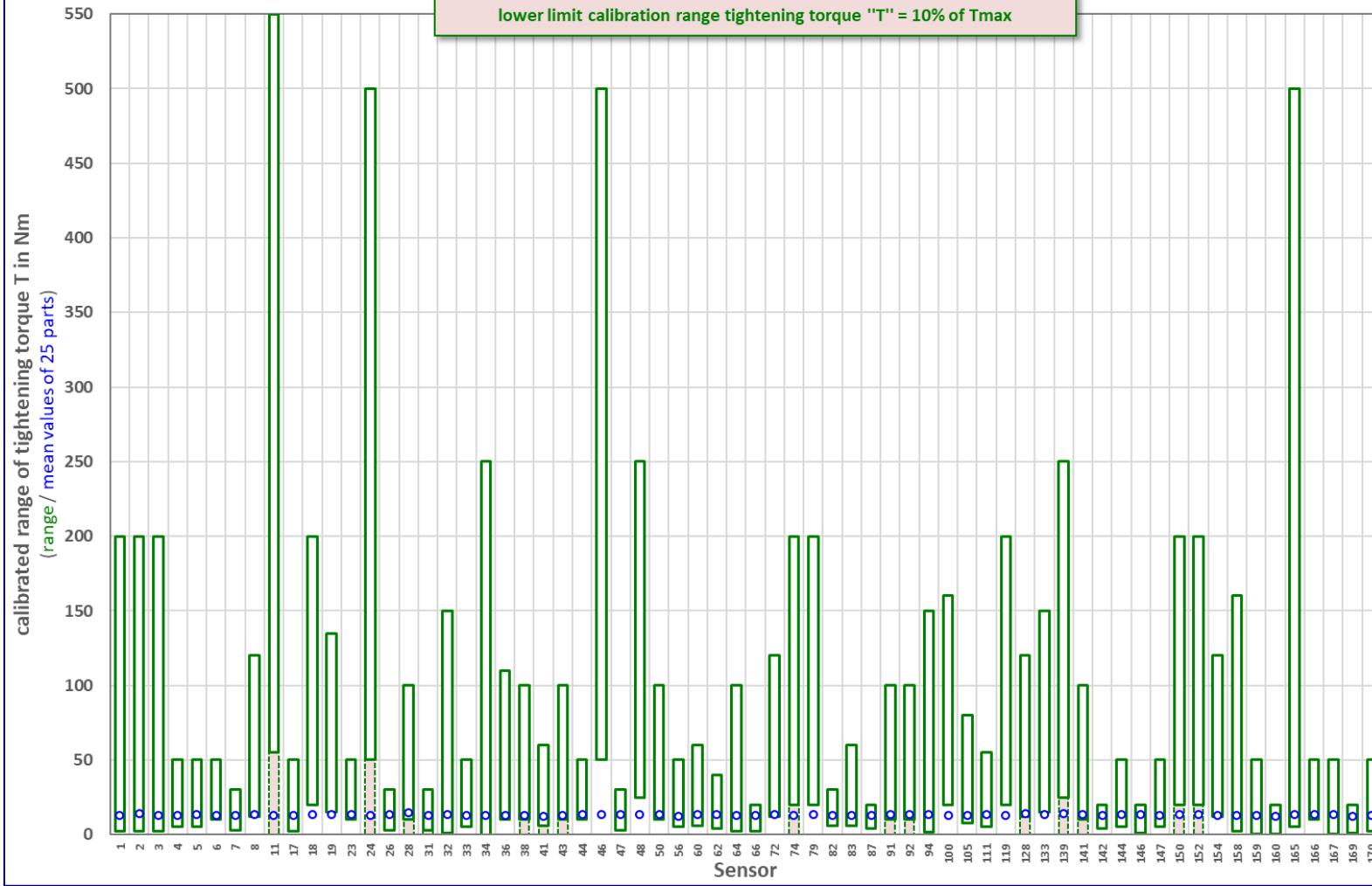


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### calibrated range tightening torque T M6

min-value = 0: increase to 10% of the max-value!

lower limit calibration range tightening torque "T" = 10% of Tmax



# round robin test 2023 coefficient of friction

## final evaluation

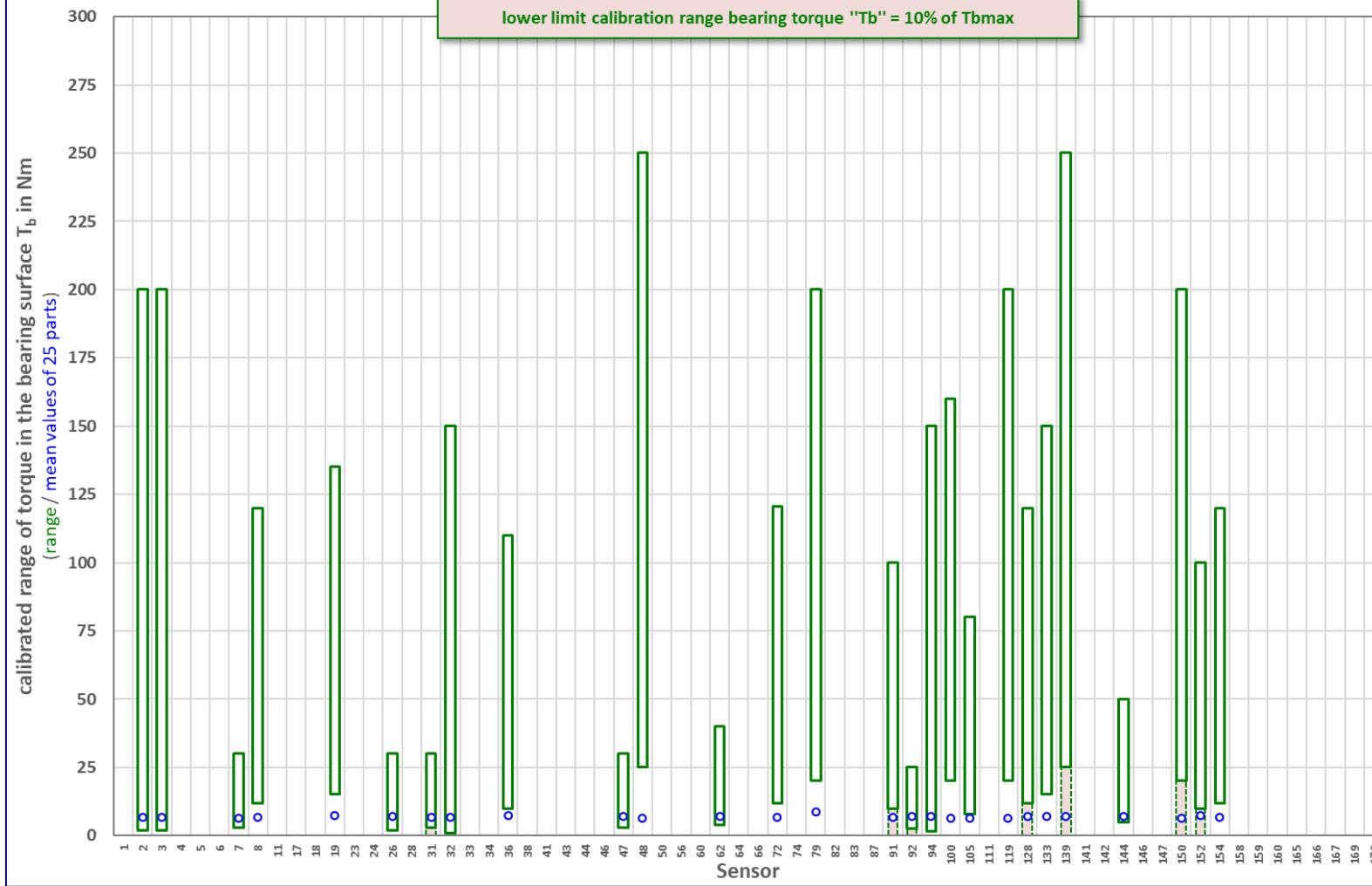


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### calibrated range bearing torque $T_b$ M6

min-value = 0: increase to 10% of the max-value!

lower limit calibration range bearing torque "Tb" = 10% of Tbmax



# round robin test 2023 coefficient of friction

## final evaluation

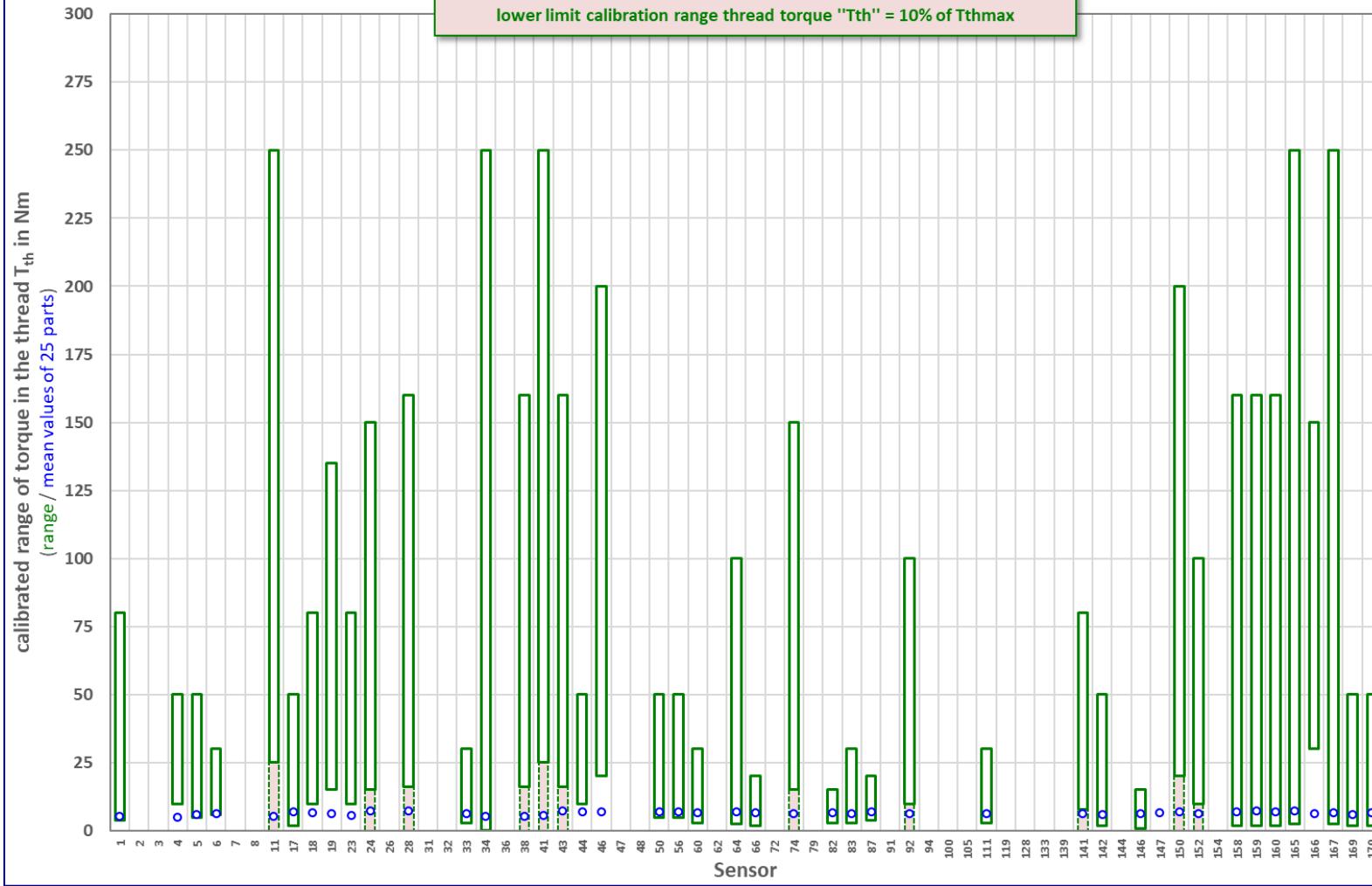


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### calibrated range thread torque $T_{th}$ M6

min-value = 0: increase to 10% of the max-value!

lower limit calibration range thread torque "Tth" = 10% of Tthmax

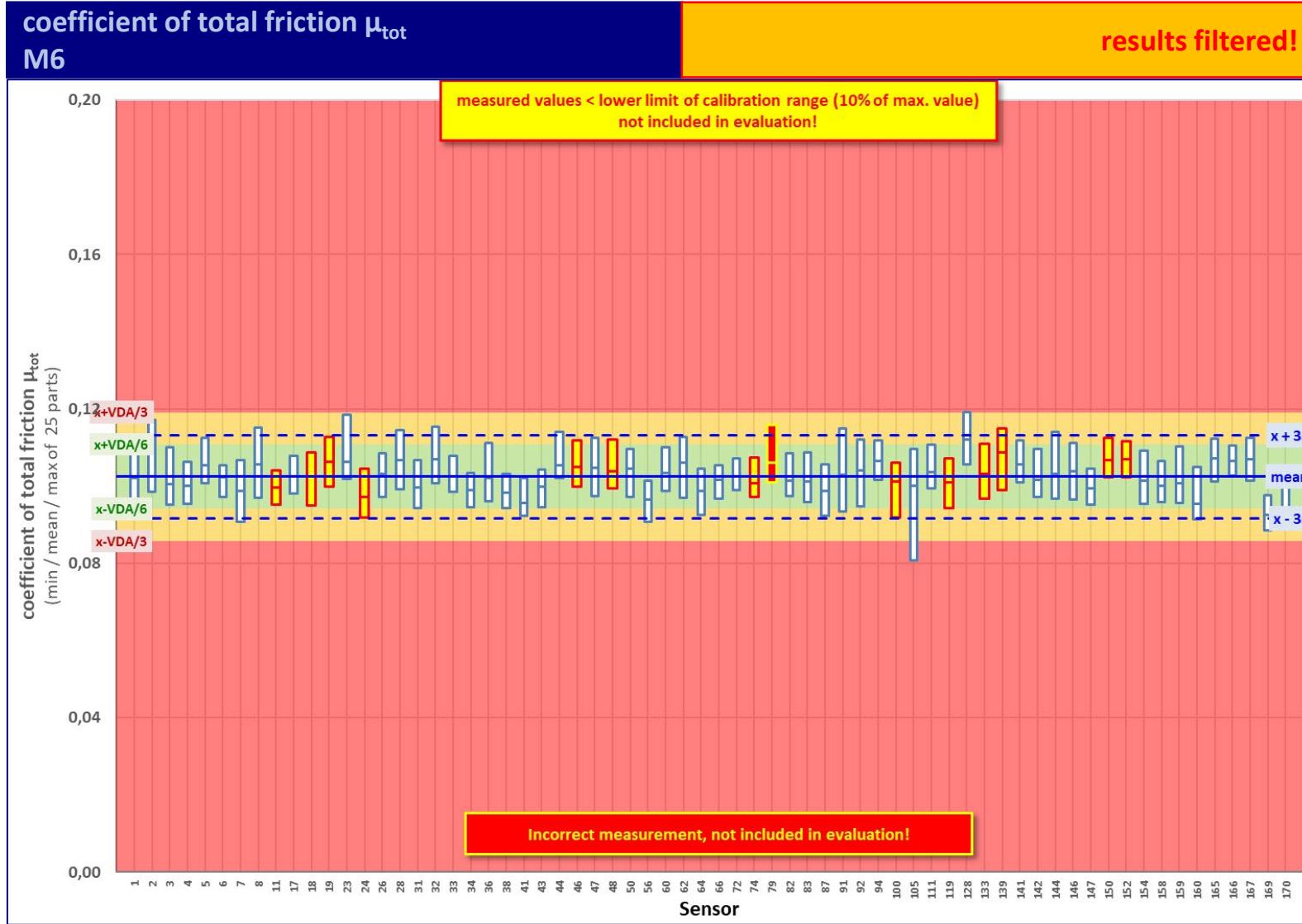


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## final evaluation



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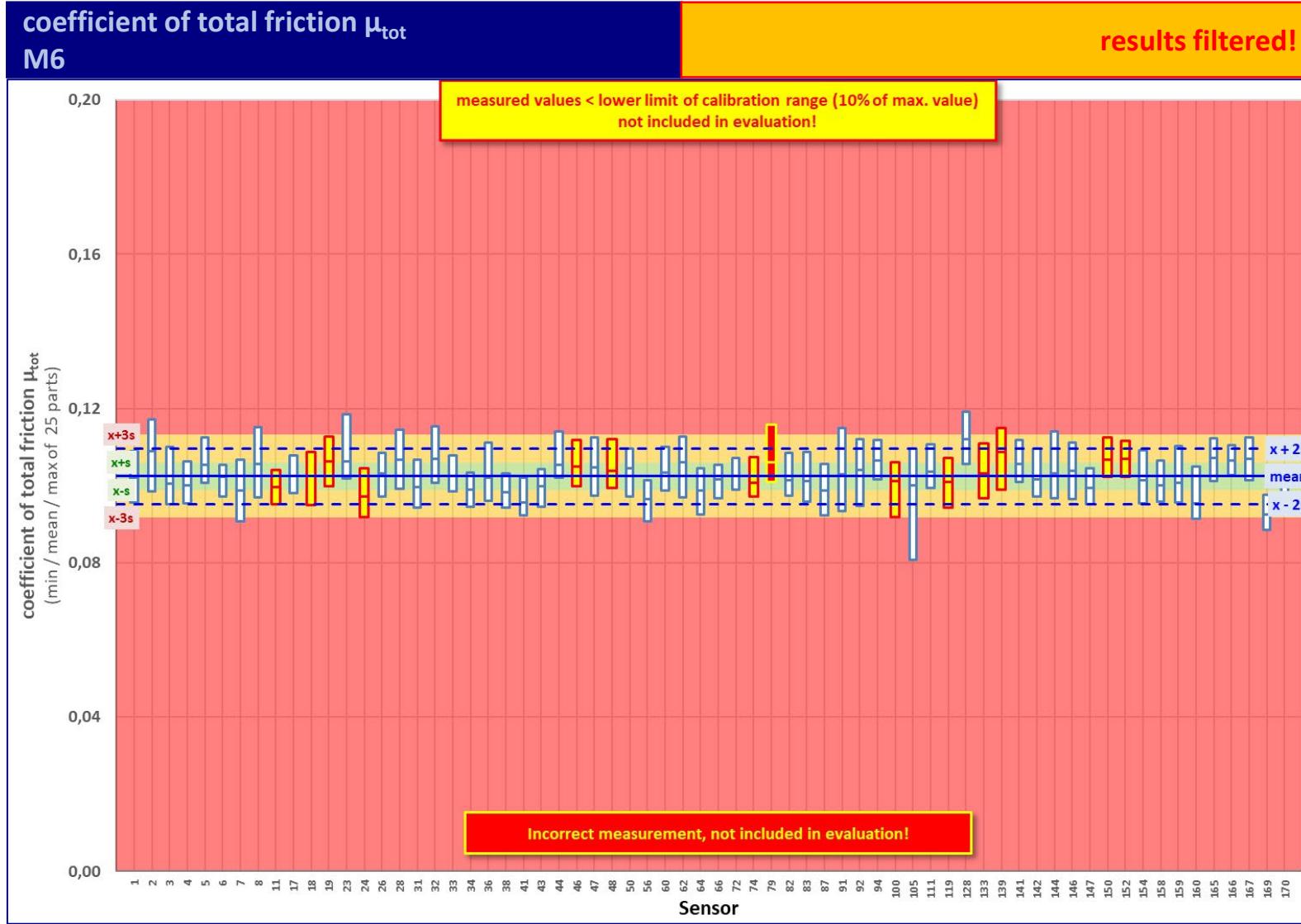


# round robin test 2023 coefficient of friction

## final evaluation



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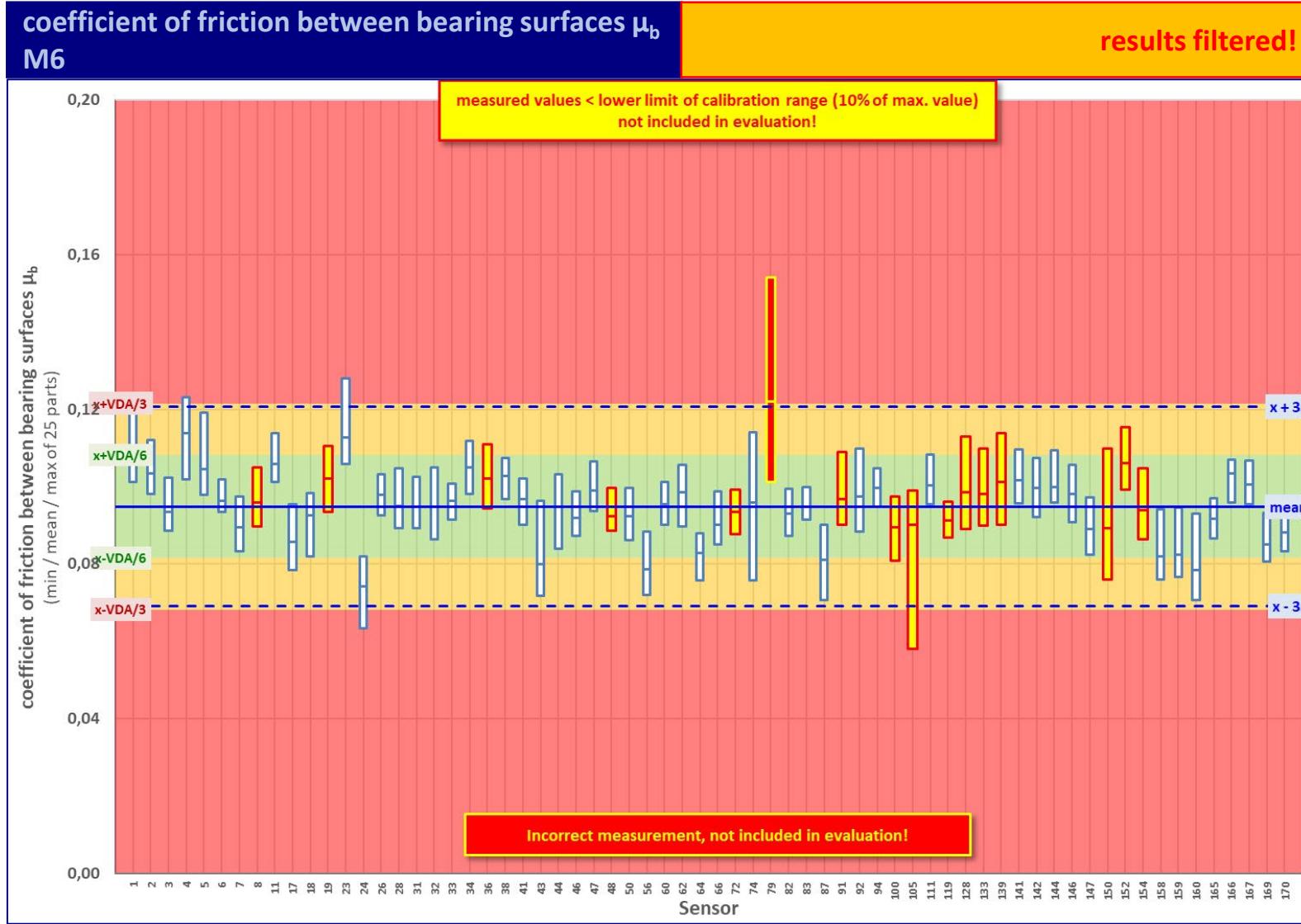


# round robin test 2023 coefficient of friction

## final evaluation



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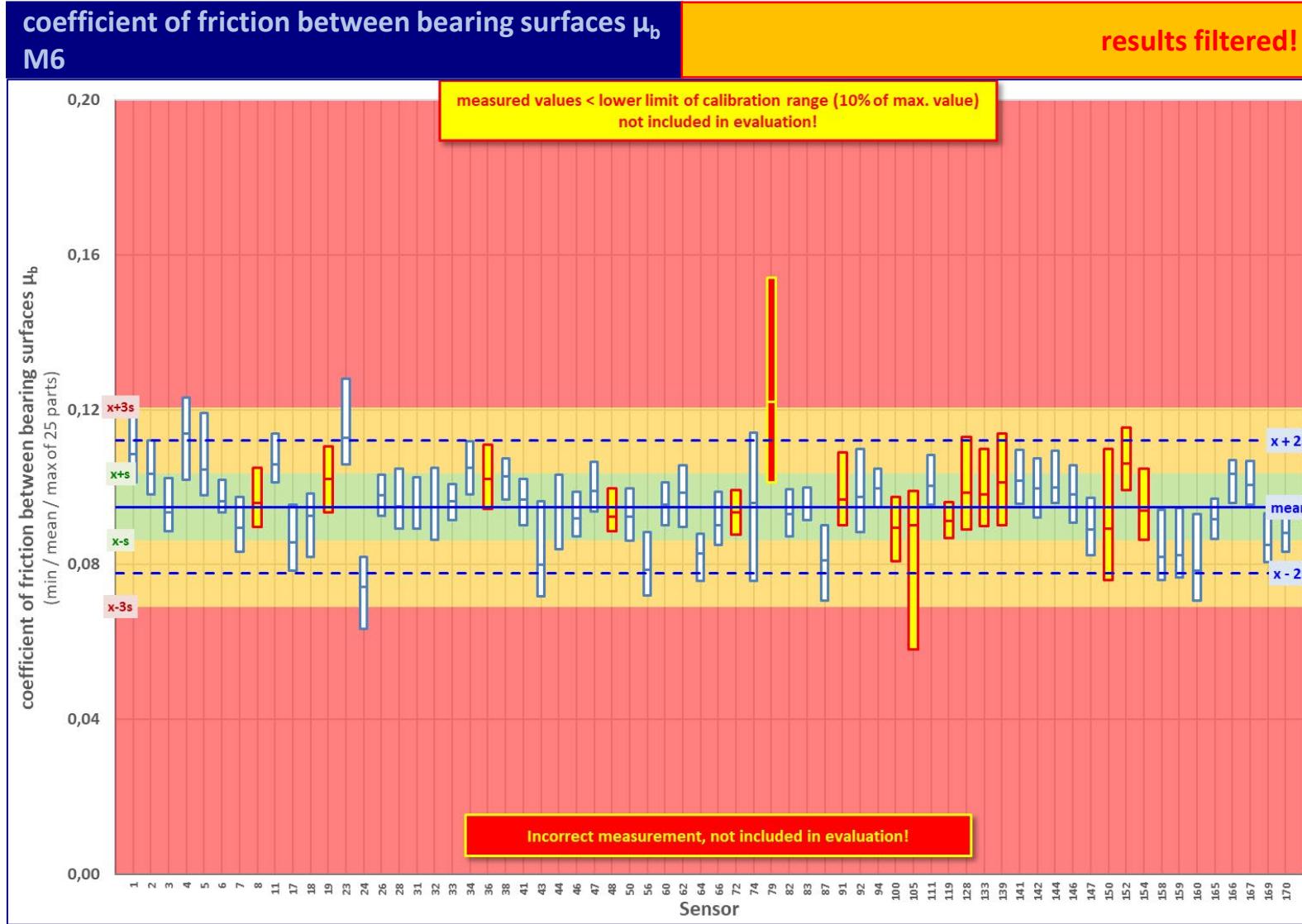


# round robin test 2023 coefficient of friction

## final evaluation



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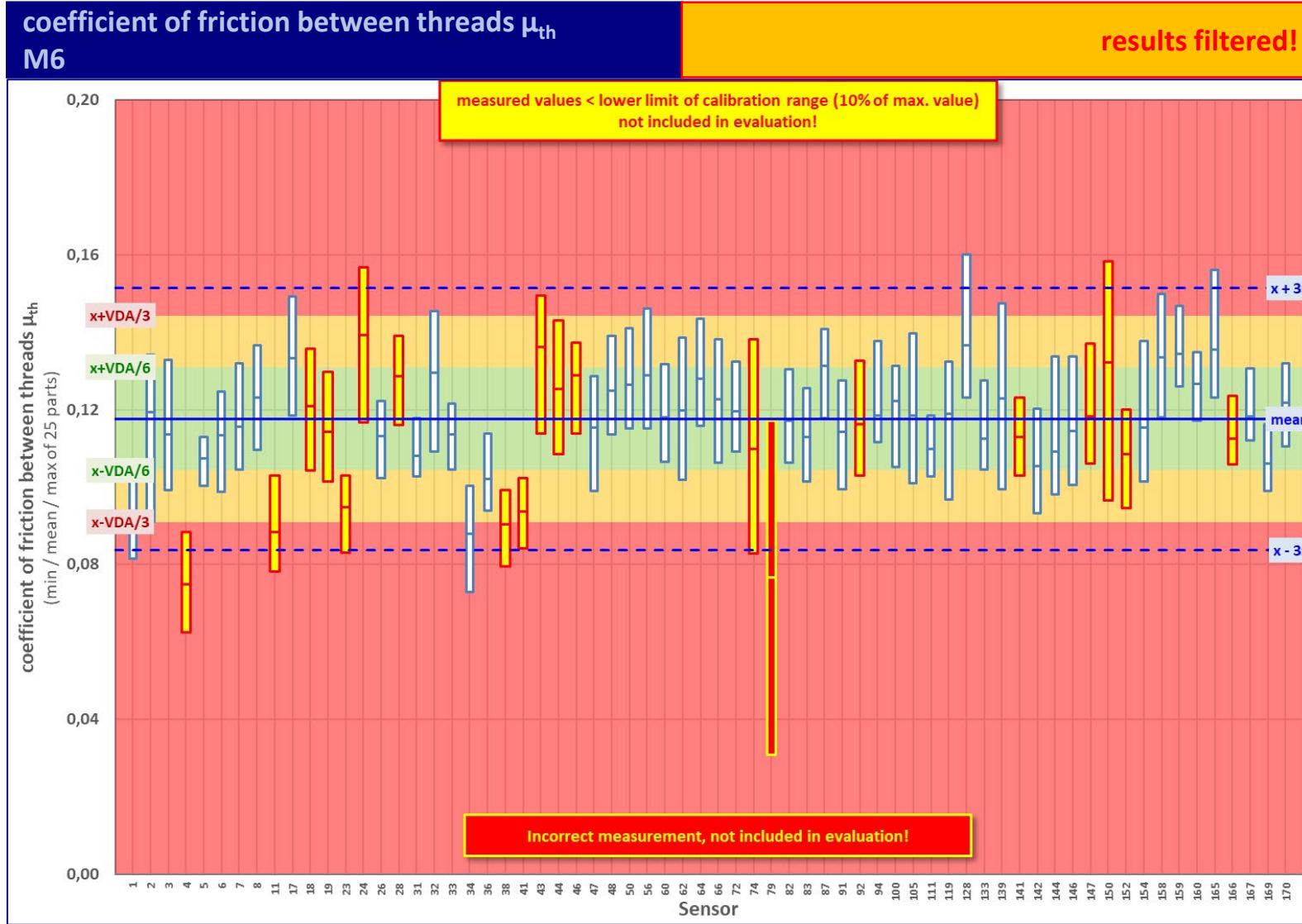


# round robin test 2023 coefficient of friction

## final evaluation



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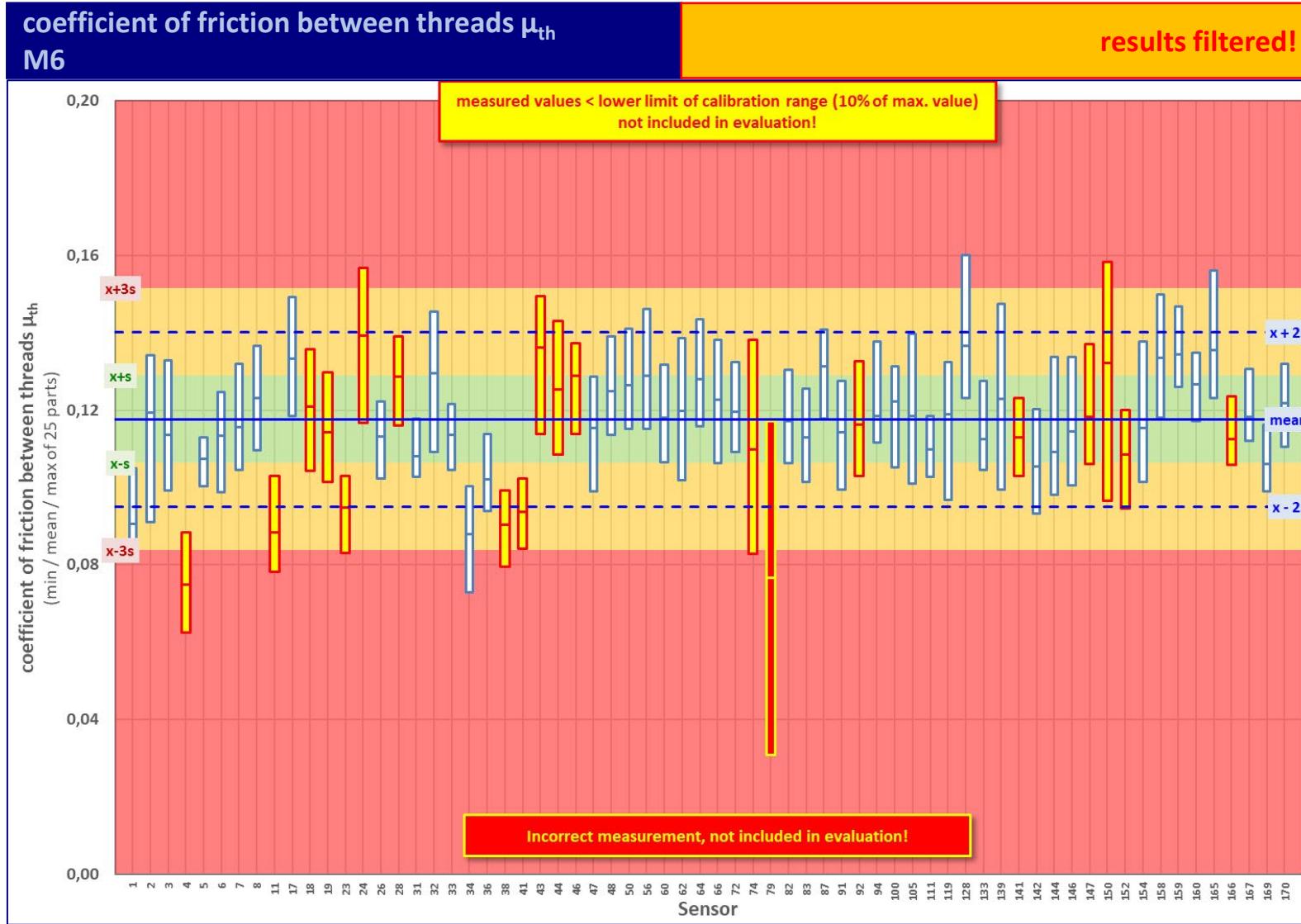


# round robin test 2023 coefficient of friction

## final evaluation



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# round robin test 2023 coefficient of friction

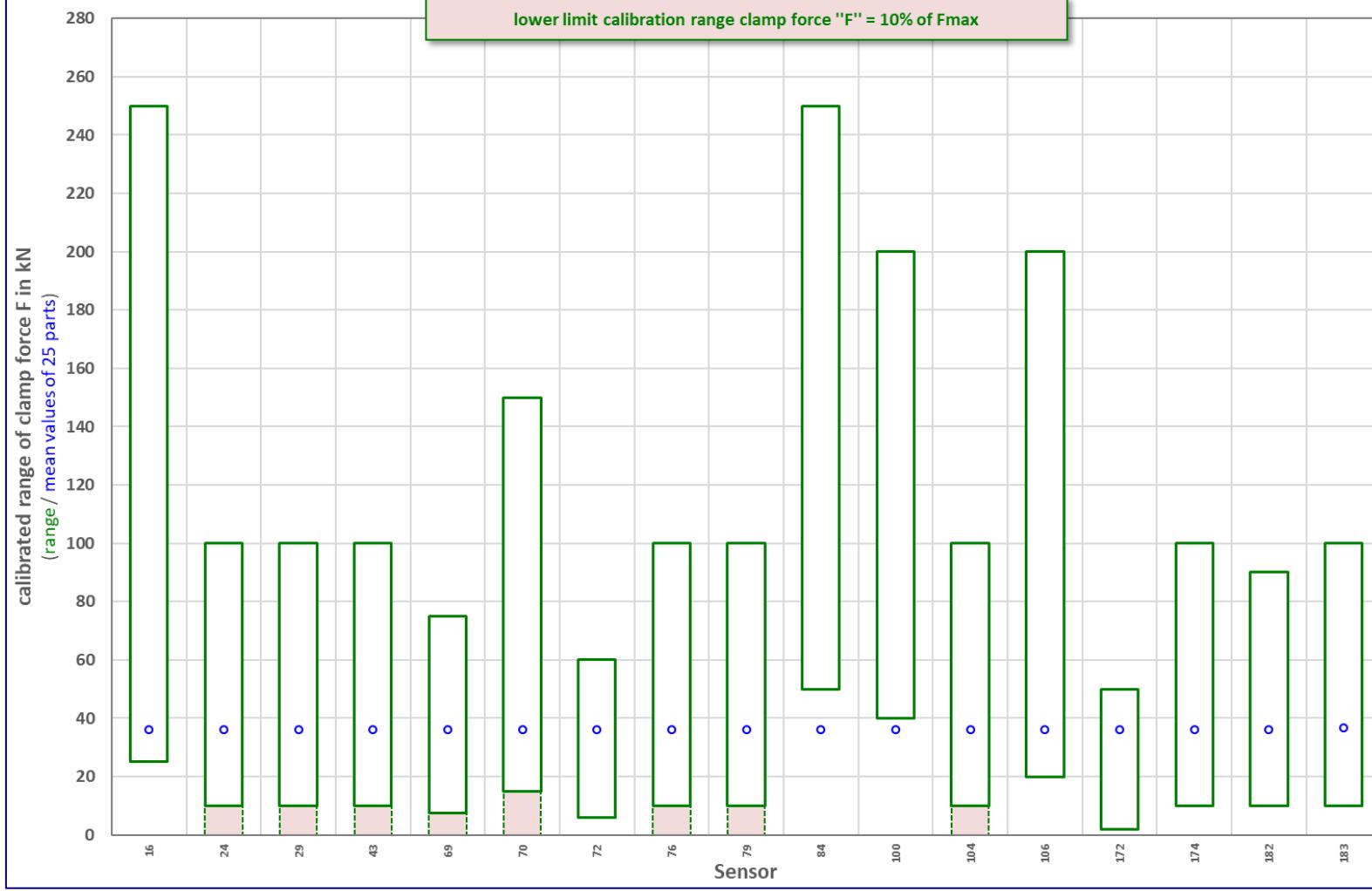
## final evaluation



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calibrated range clamp force F  
M10 - 20 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

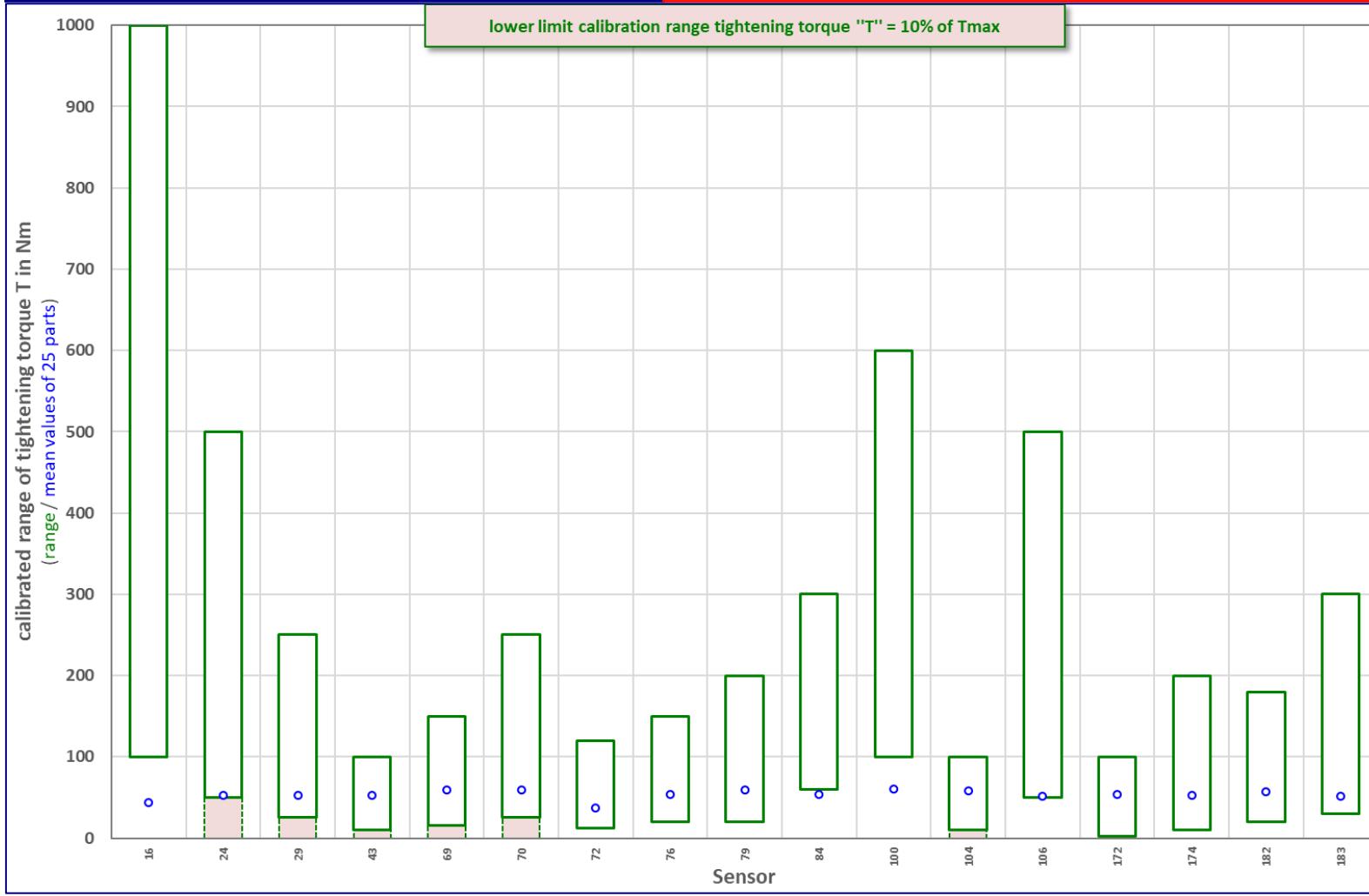
## final evaluation



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### calibrated range tightening torque T M10 - 20 rpm

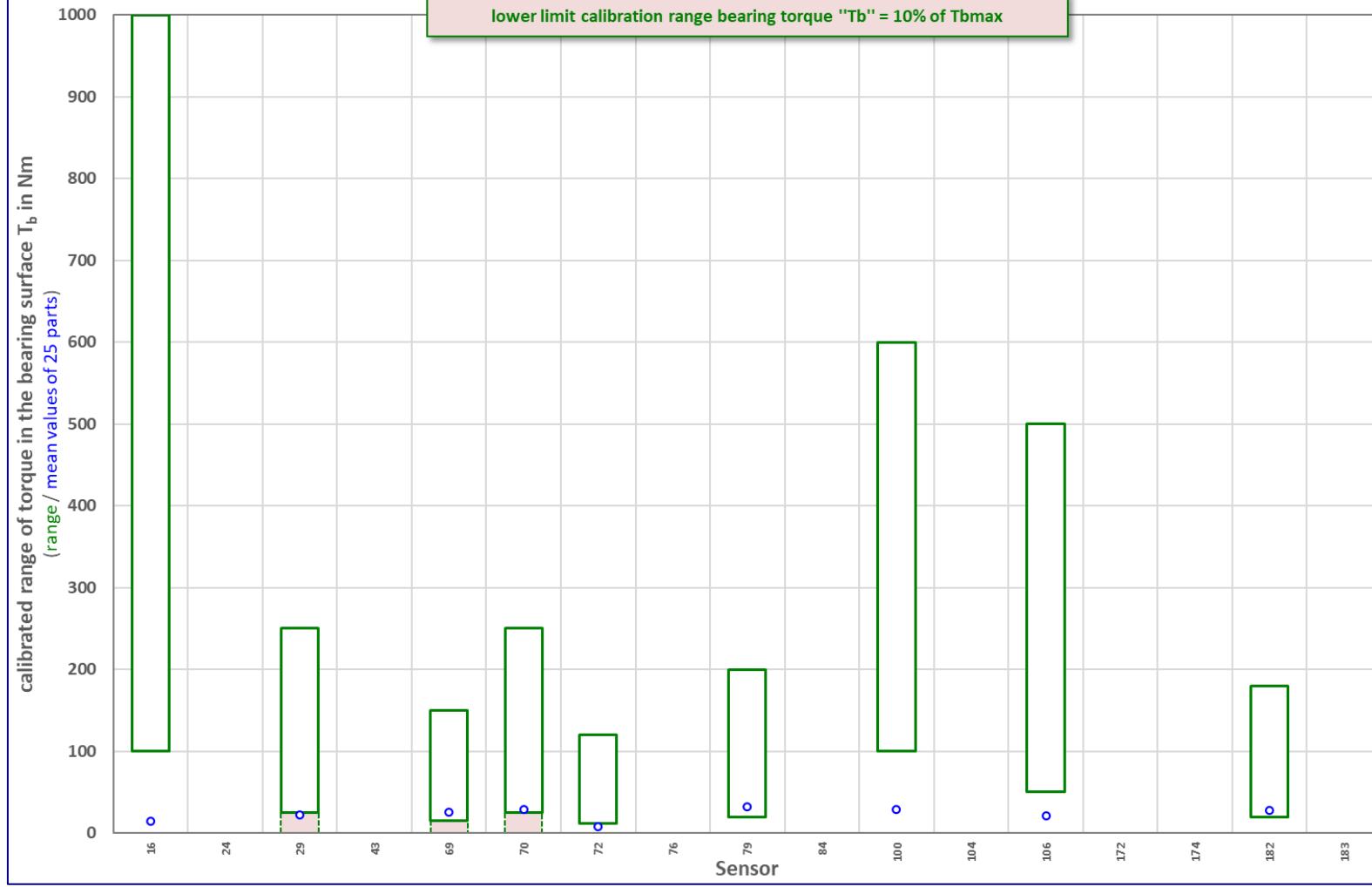
min-value = 0: increase to 10% of the max-value!



### calibrated range bearing torque $T_b$ M10 - 20 rpm

min-value = 0: increase to 10% of the max-value!

lower limit calibration range bearing torque "Tb" = 10% of Tbmax



# round robin test 2023 coefficient of friction

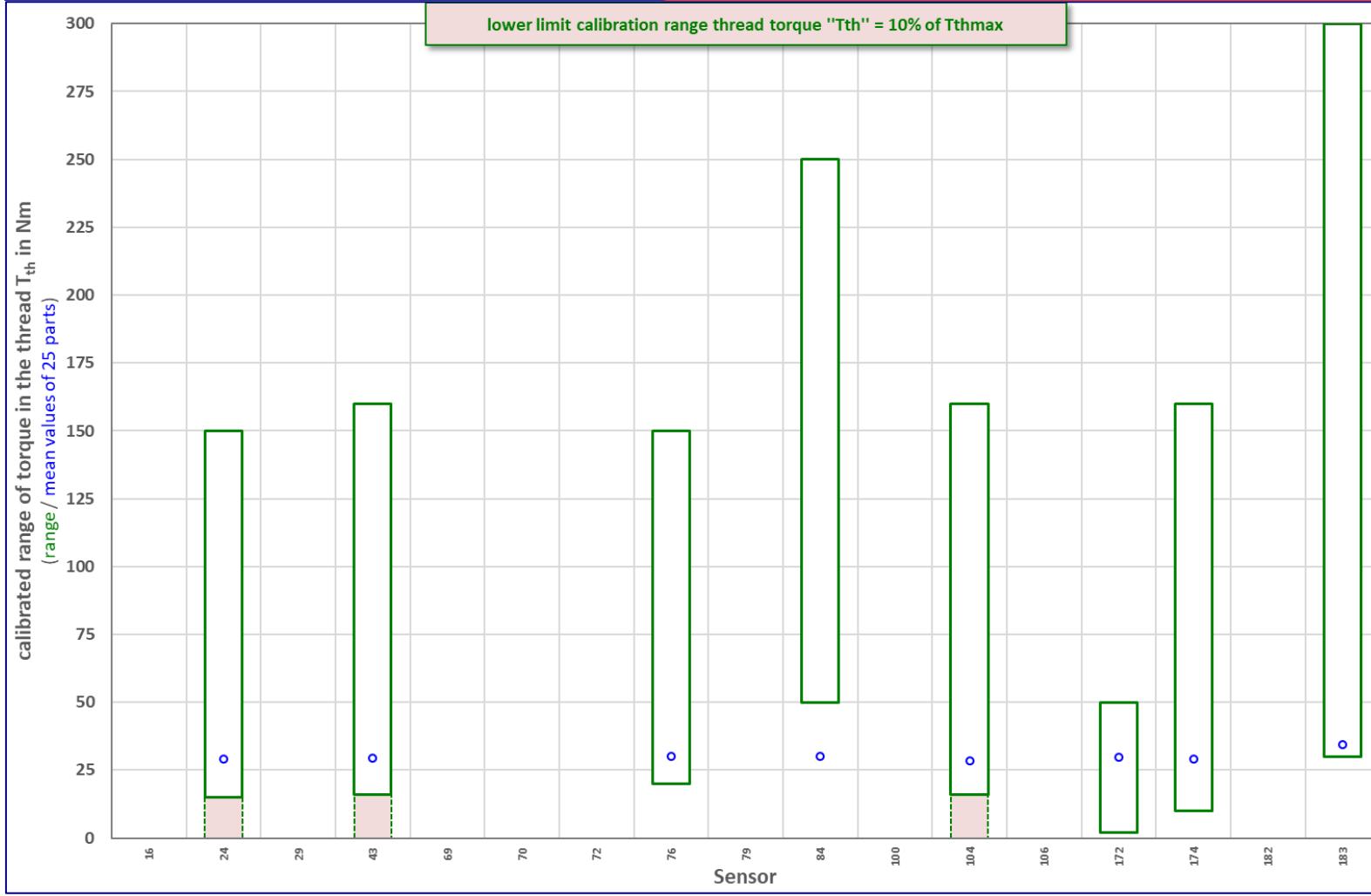
## final evaluation



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calibrated range thread torque  $T_{th}$   
M10 - 20 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

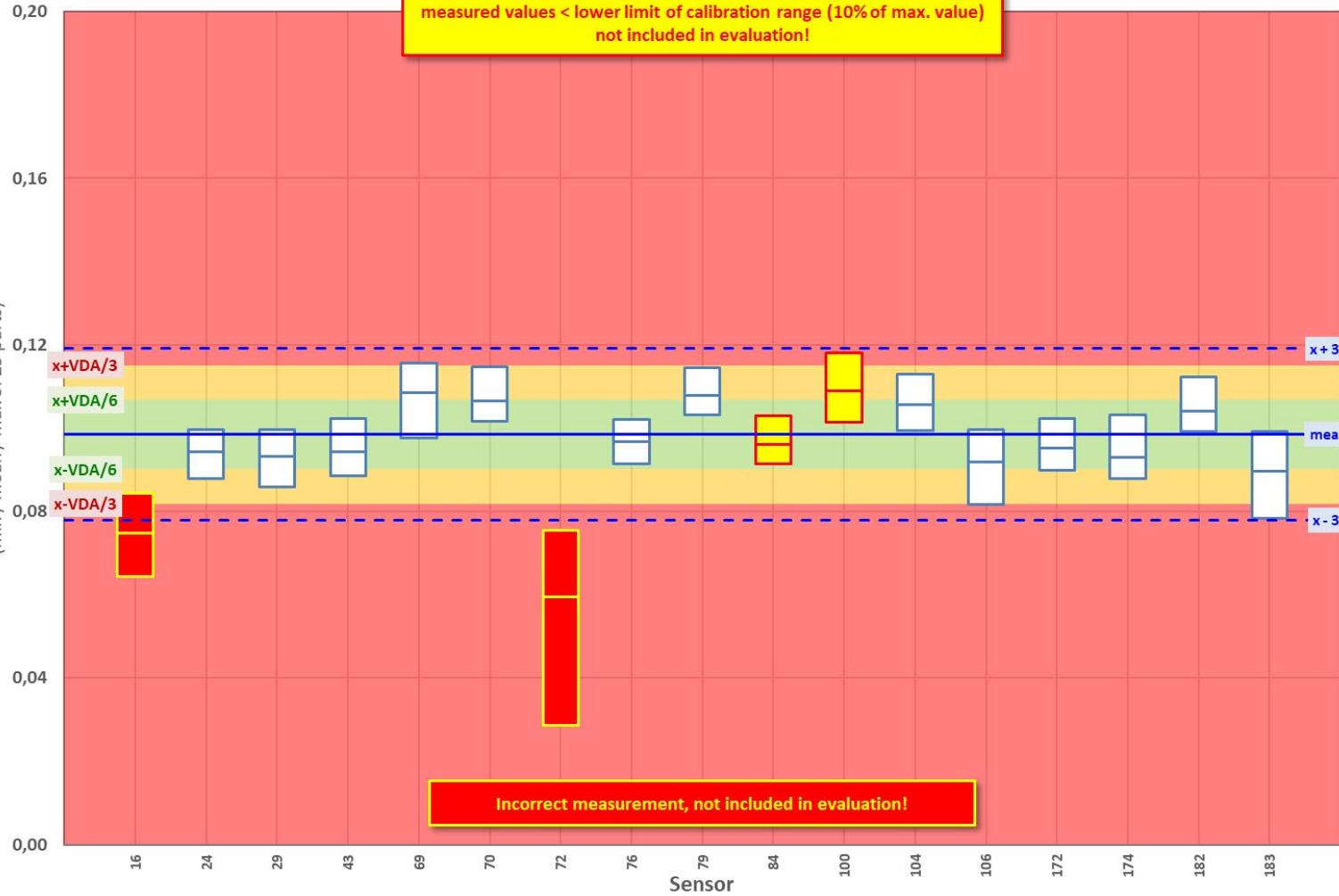
## final evaluation



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coefficient of total friction  $\mu_{\text{tot}}$   
M10 - 20 rpm

results filtered!



# round robin test 2023 coefficient of friction

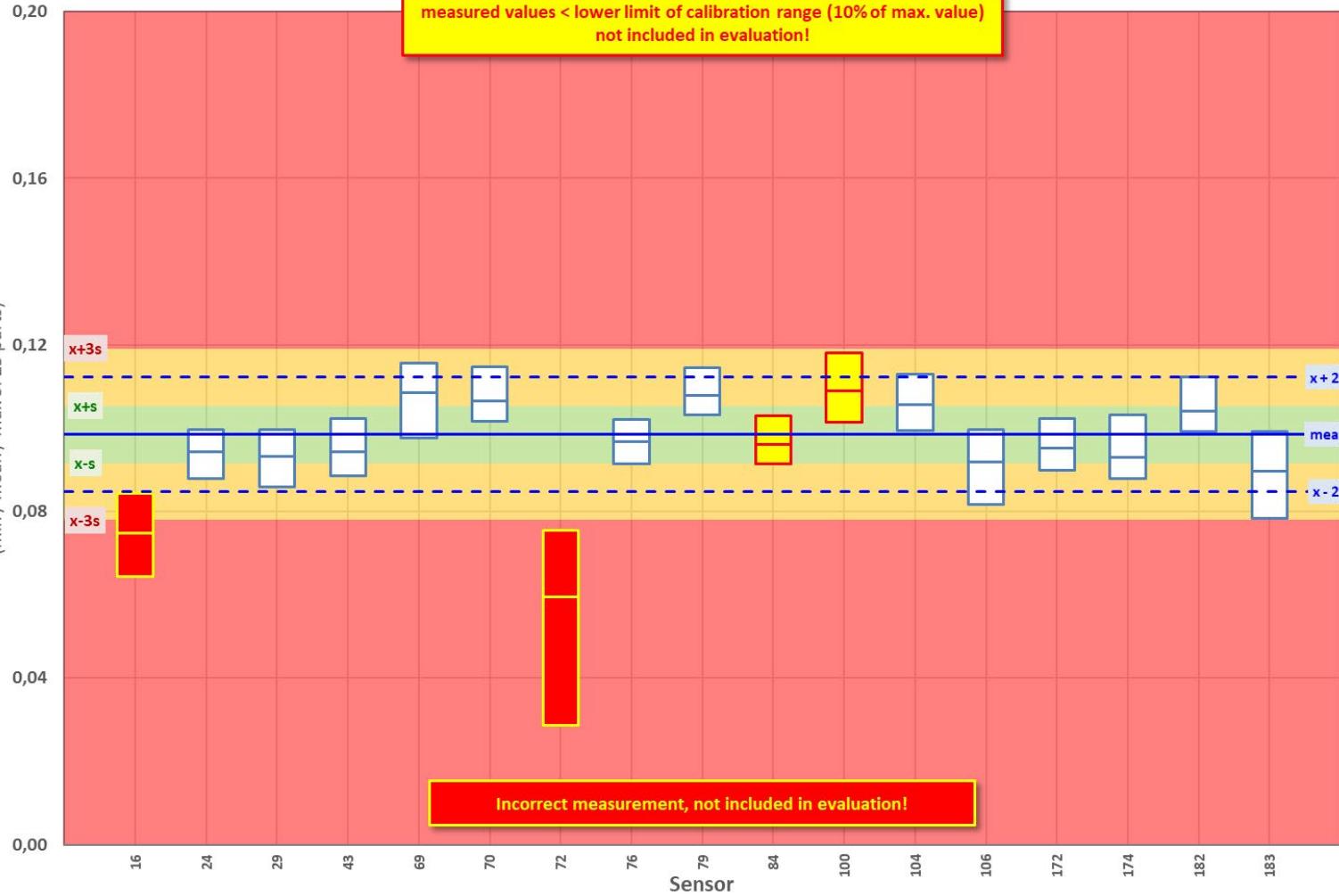
## final evaluation



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coefficient of total friction  $\mu_{\text{tot}}$   
M10 - 20 rpm

results filtered!

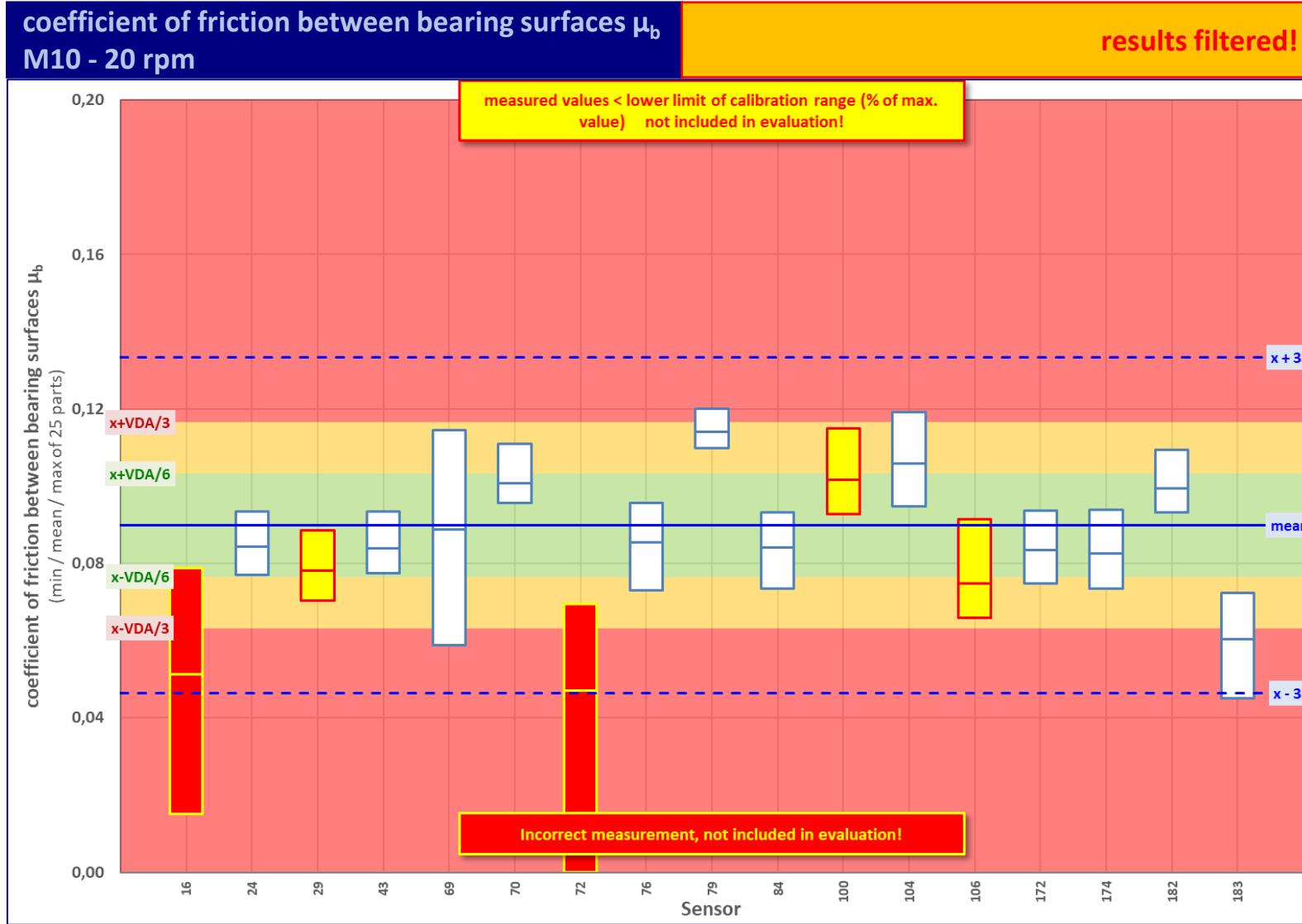


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



# round robin test 2023 coefficient of friction

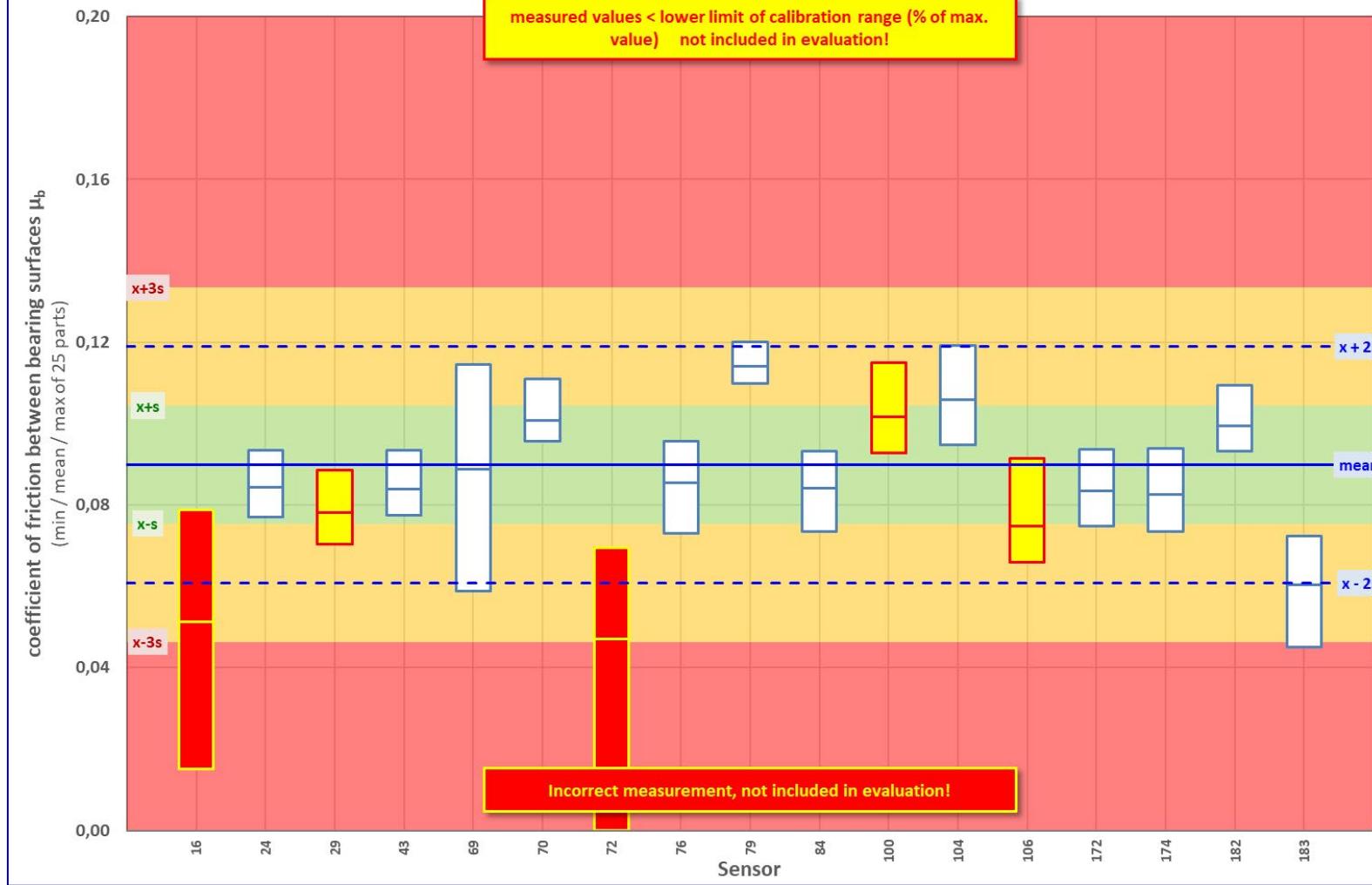
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between bearing surfaces  $\mu_b$   
M10 - 20 rpm

results filtered!

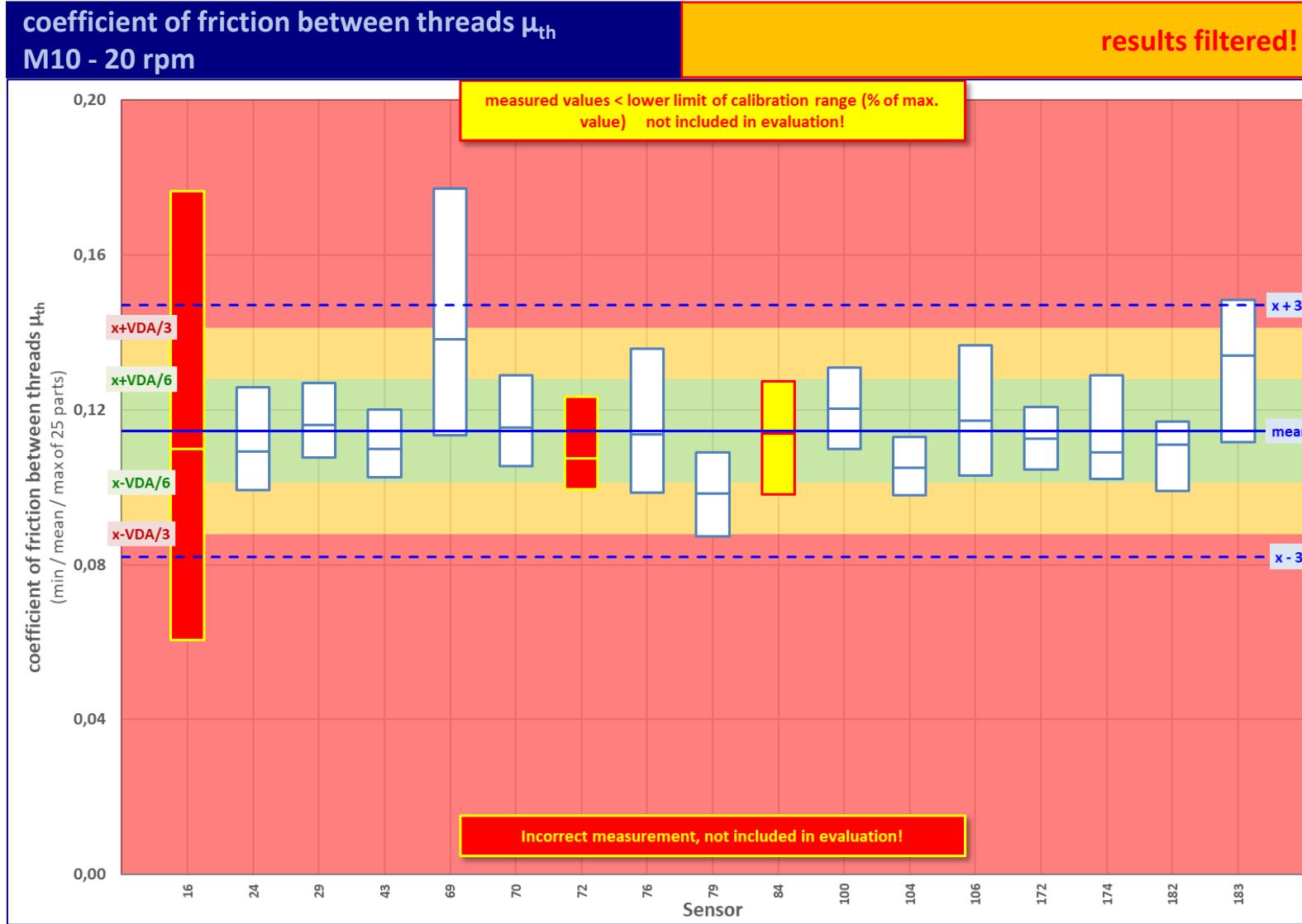


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

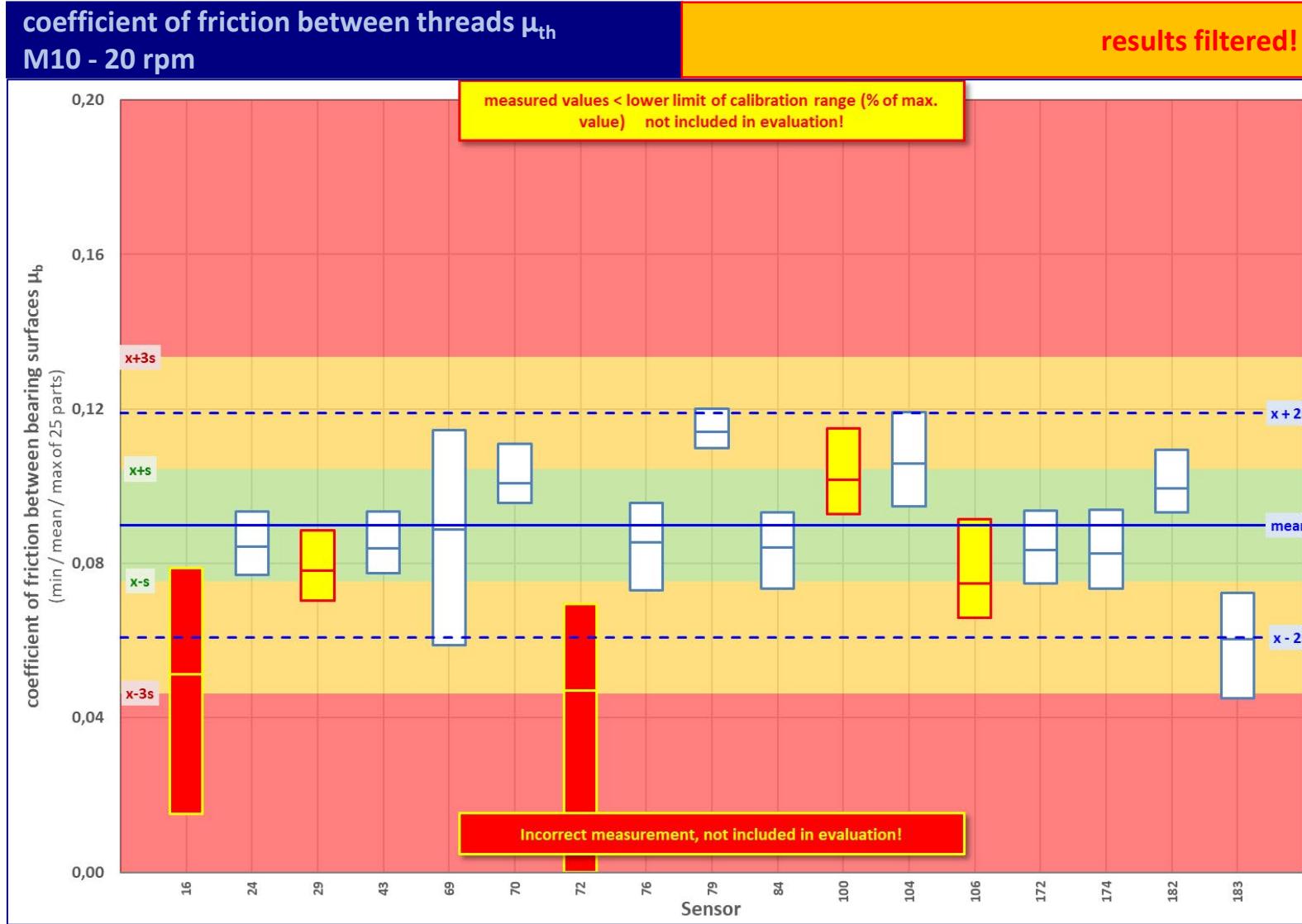


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



# round robin test 2023 coefficient of friction

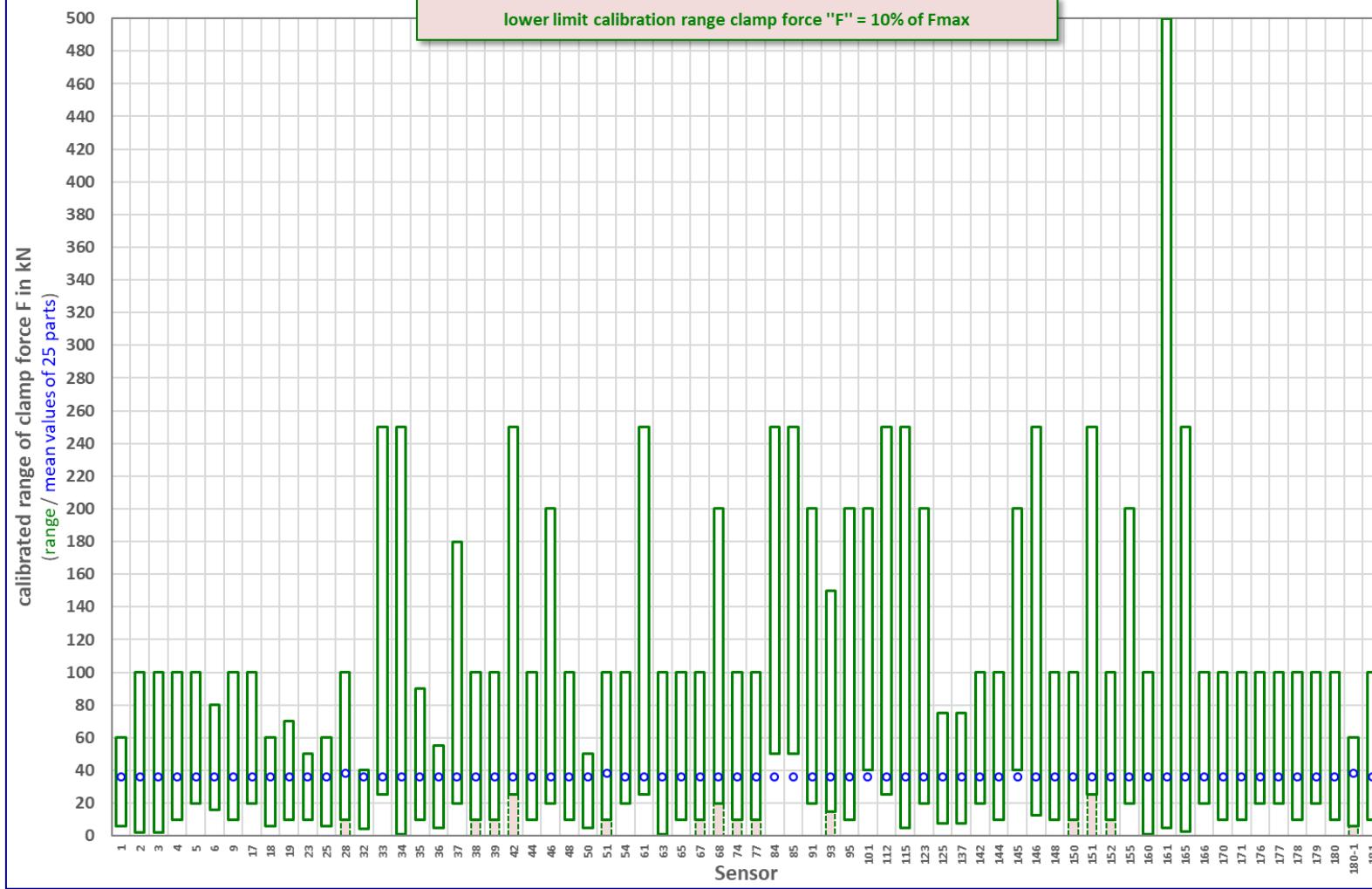
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

calibrated range clamp force F  
M10 - 200 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

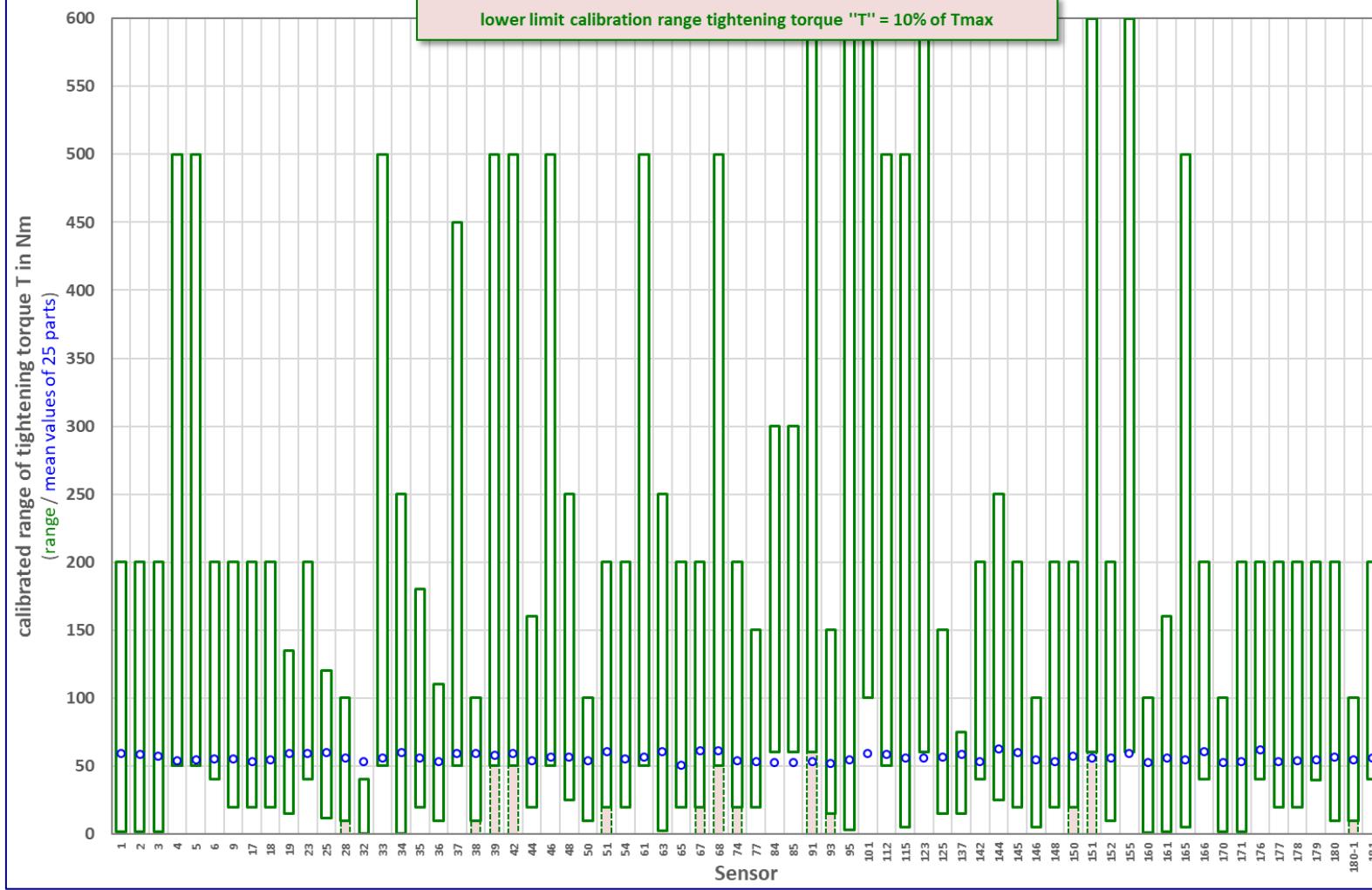
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

calibrated range tightening torque T  
M10 - 200 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

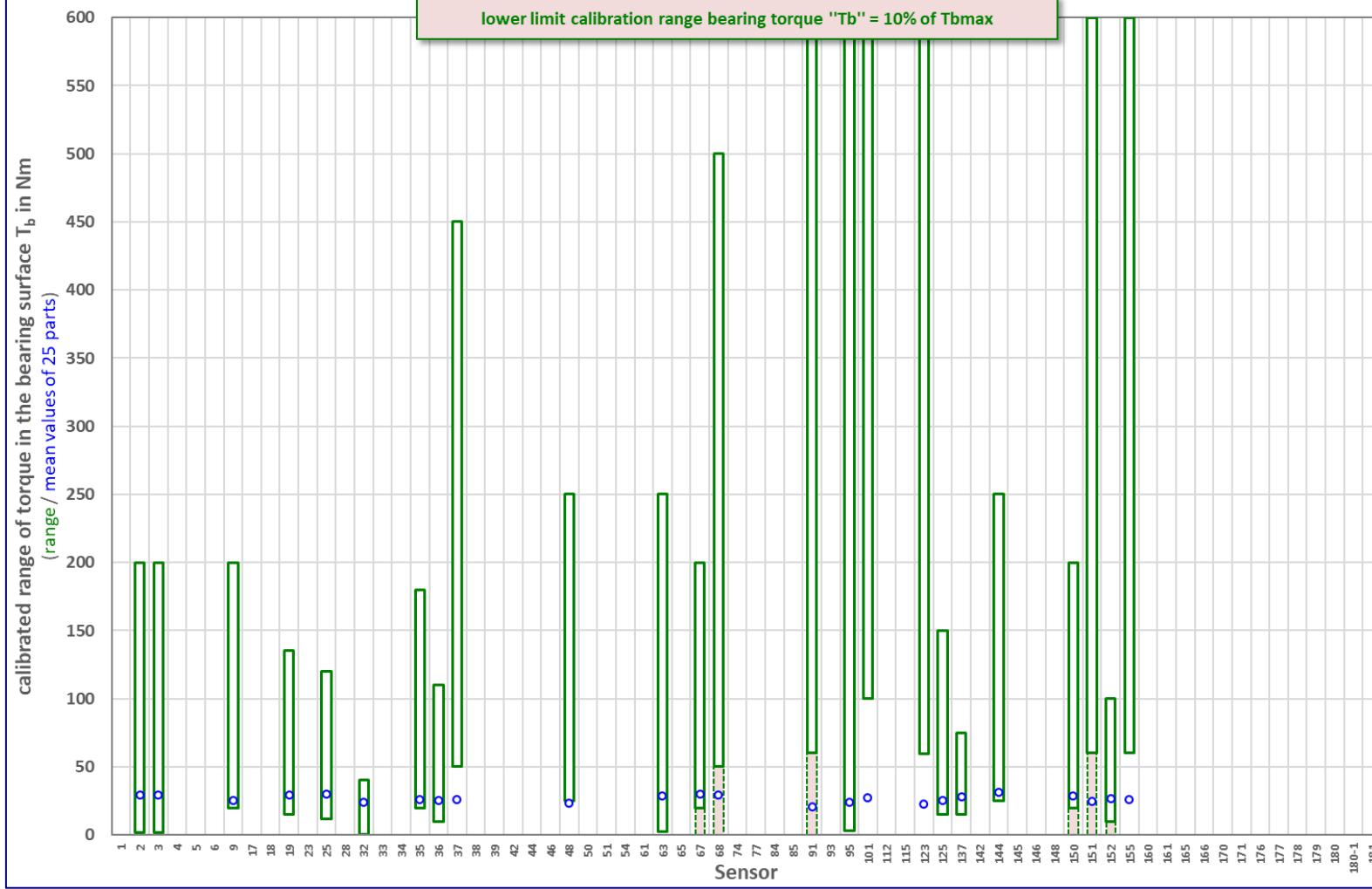
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

calibrated range bearing torque  $T_b$   
M10 - 200 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

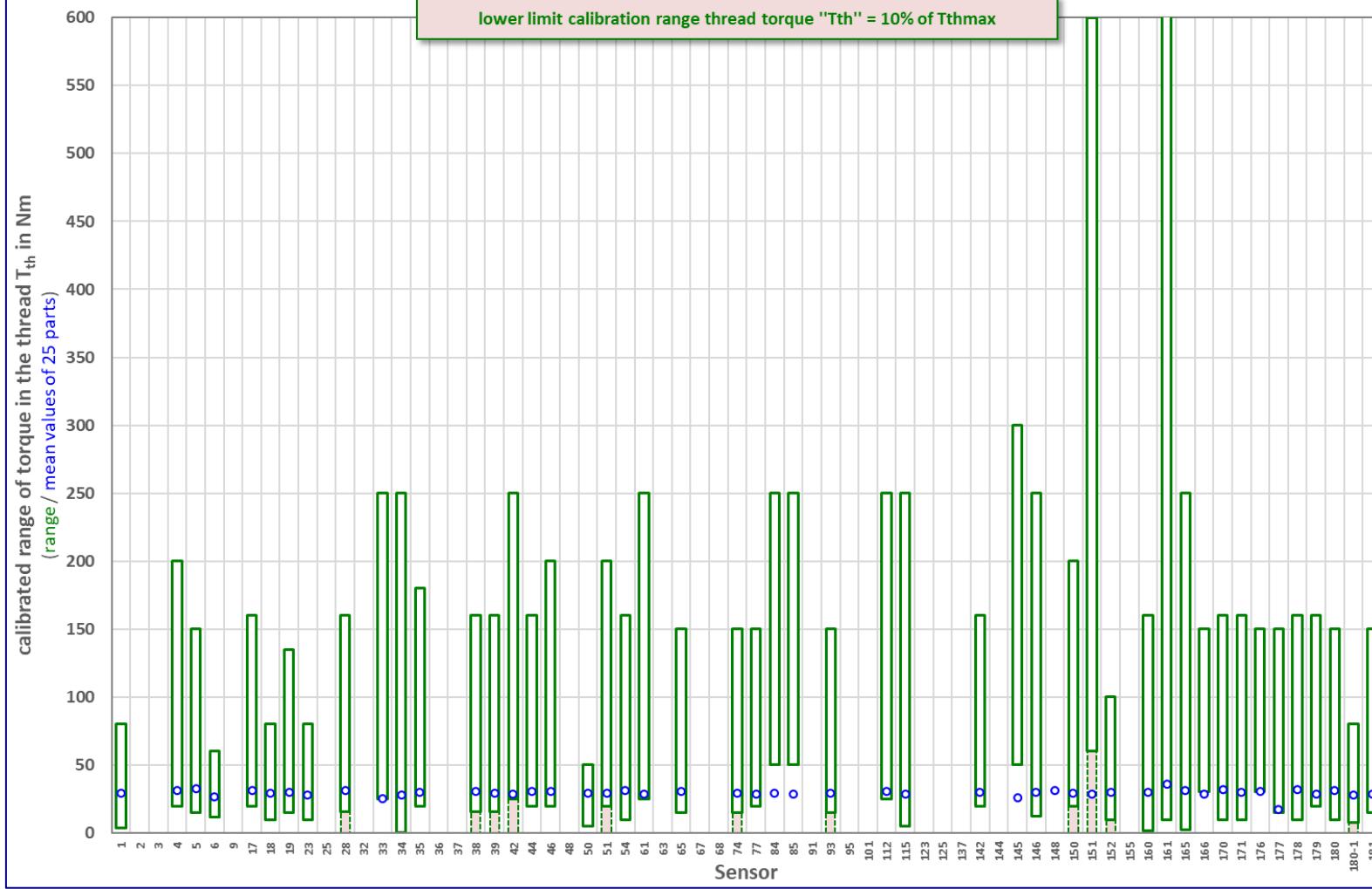
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

calibrated range thread torque  $T_{th}$   
M10 - 200 rpm

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

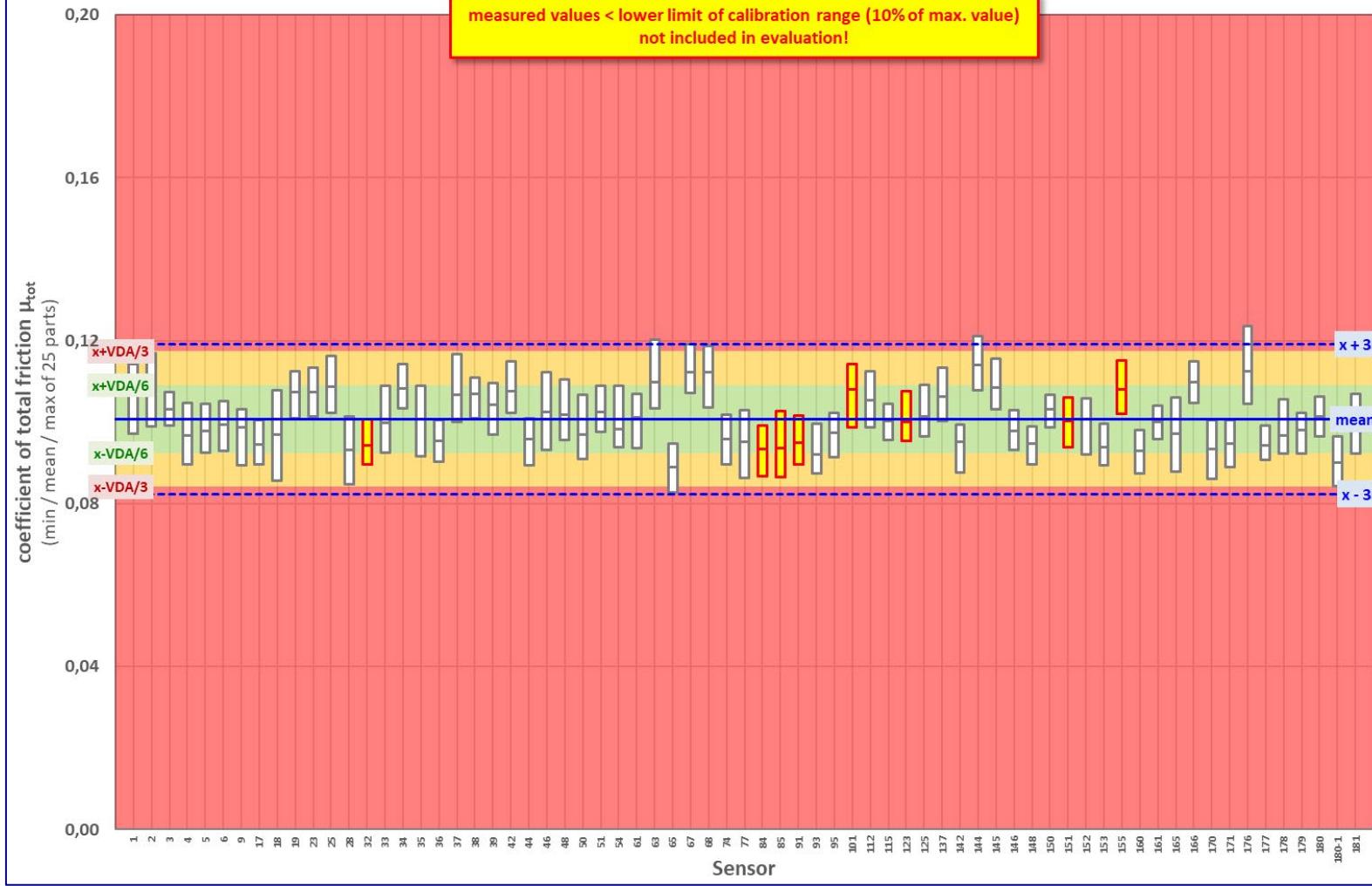
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of total friction  $\mu_{\text{tot}}$   
M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

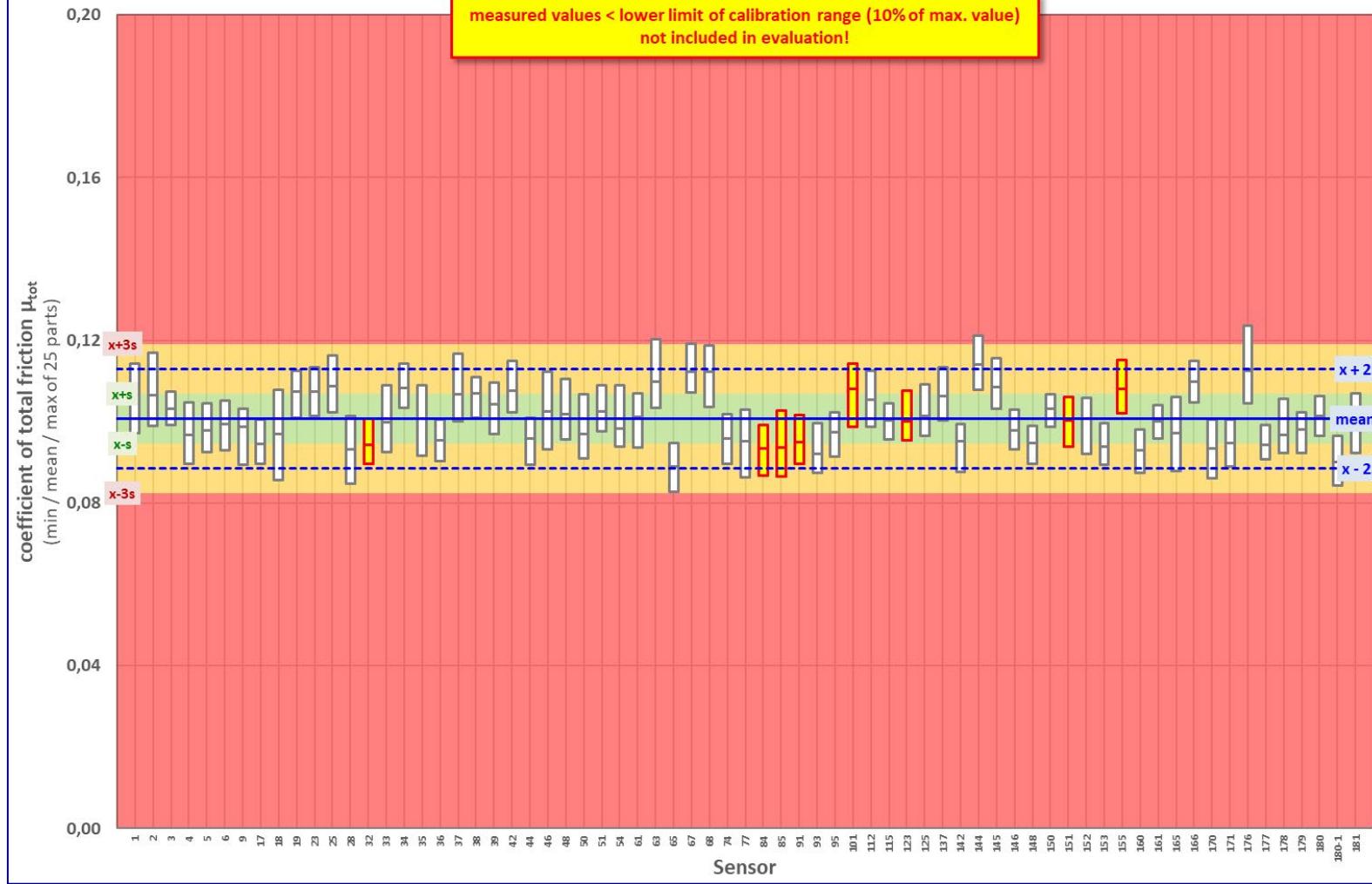
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of total friction  $\mu_{\text{tot}}$   
M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

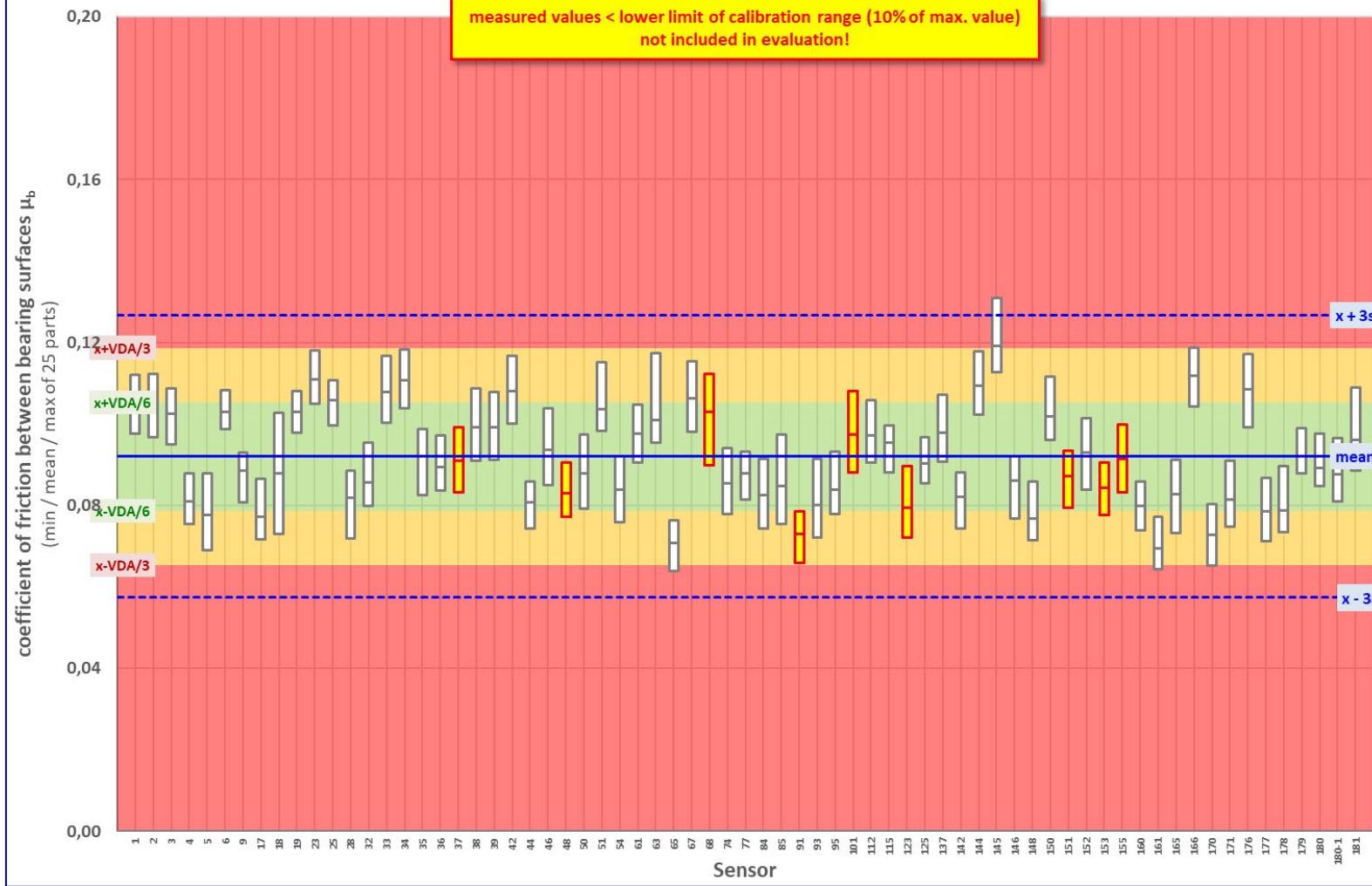
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between bearing surfaces  $\mu_b$   
M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

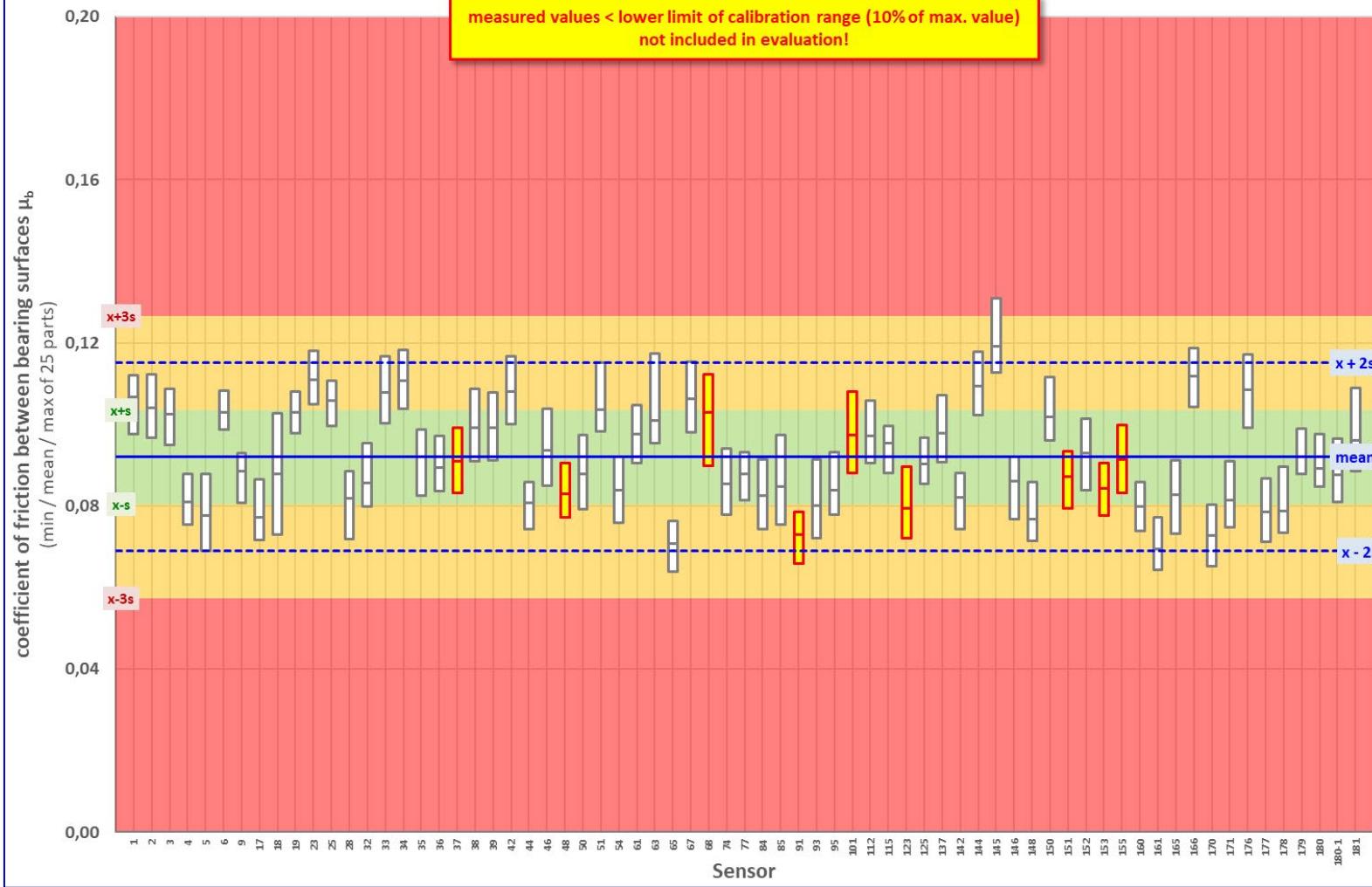
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of friction between bearing surfaces $\mu_b$ M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

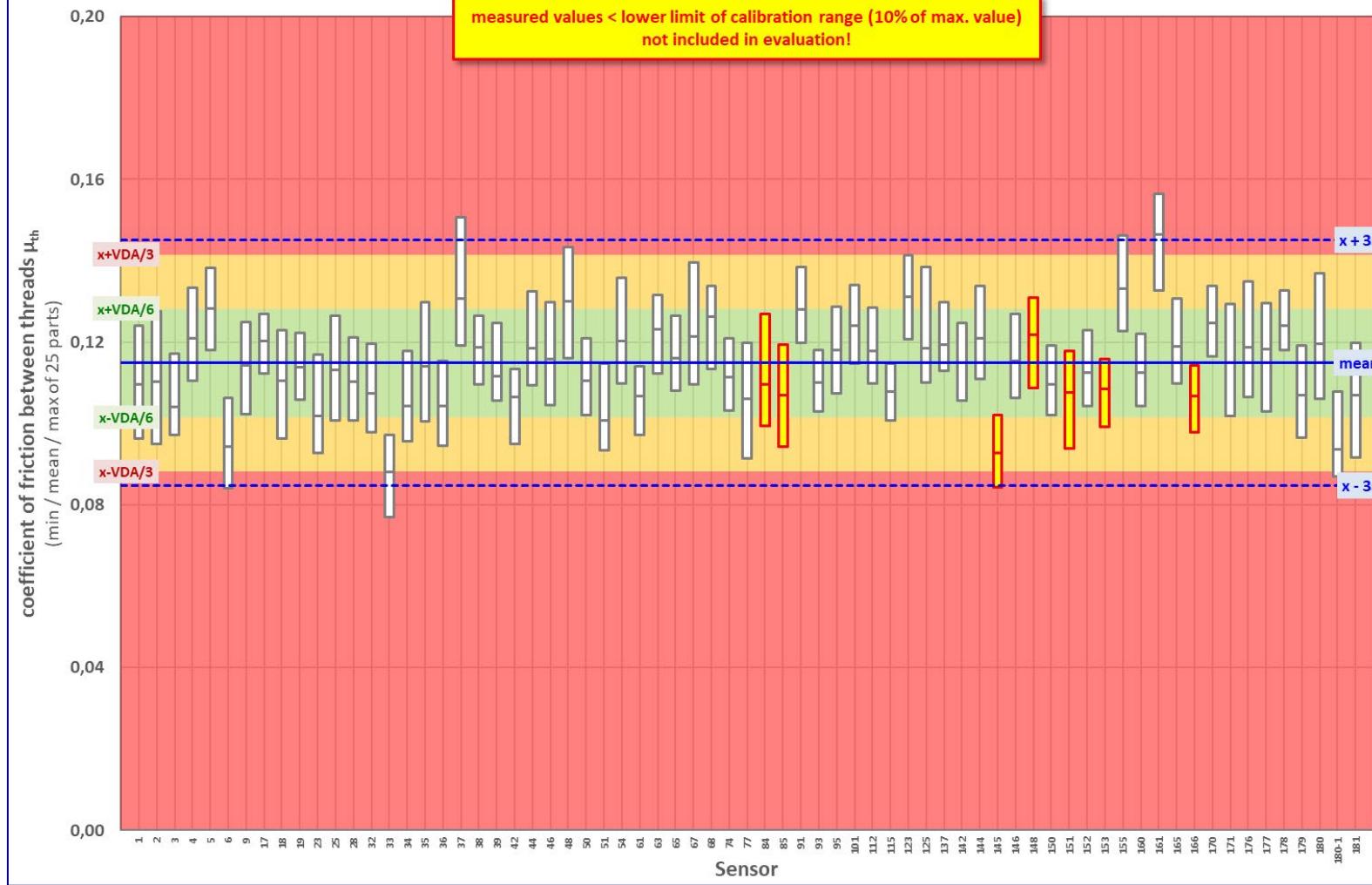
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between threads  $\mu_{th}$   
M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

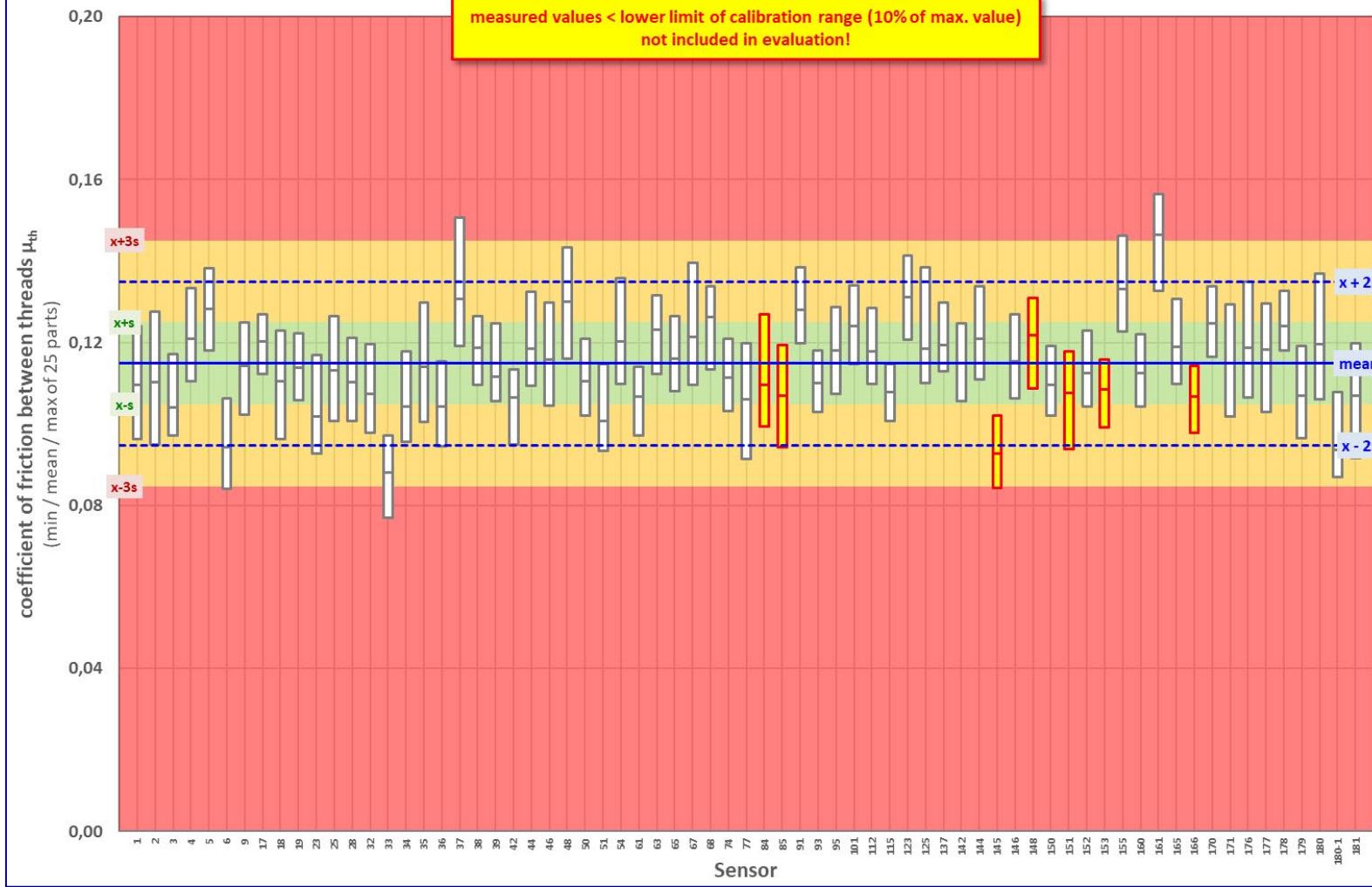
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between threads  $\mu_{th}$   
M10, 1. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

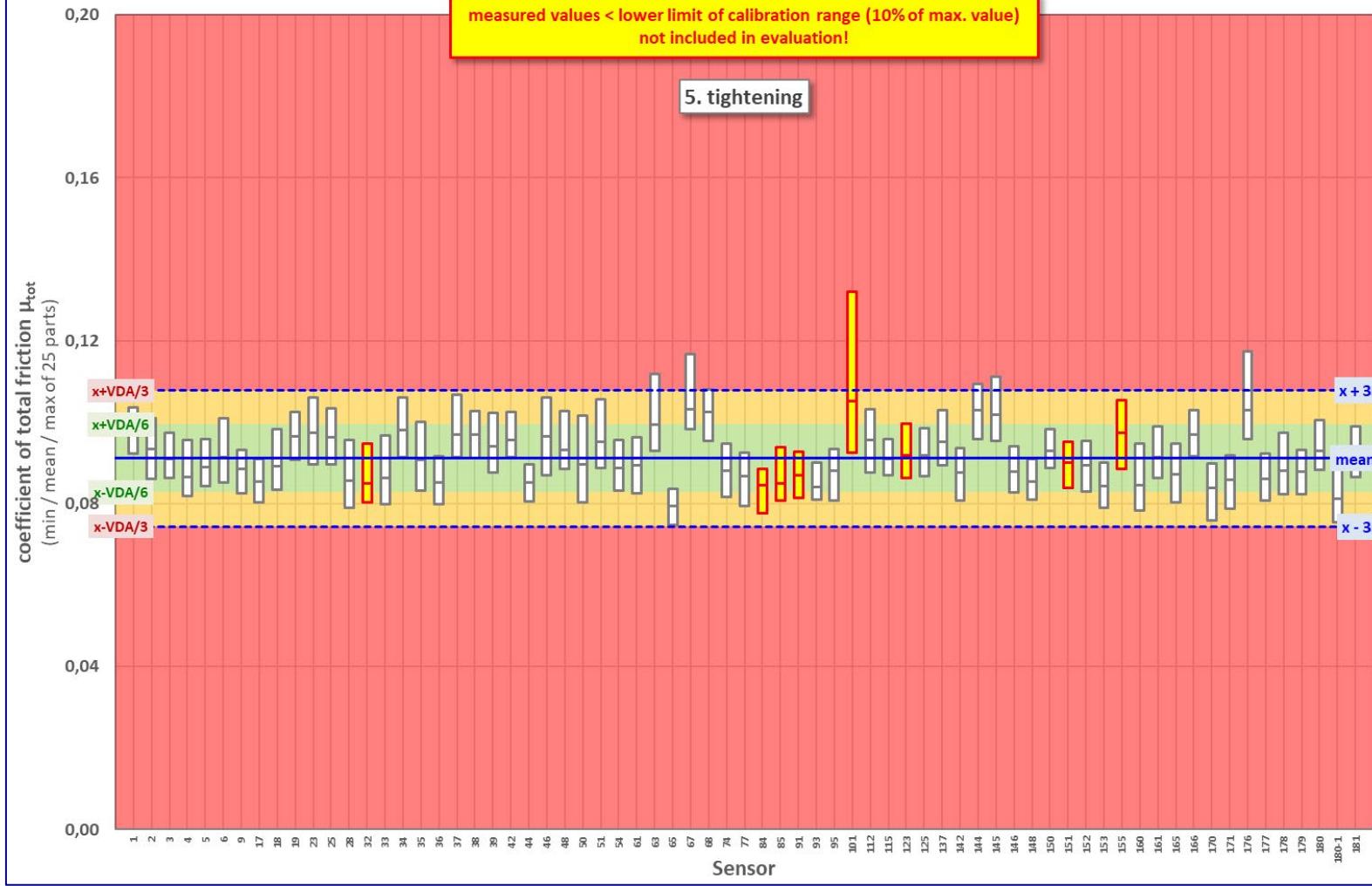
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of total friction  $\mu_{\text{tot}}$   
M10, 5. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

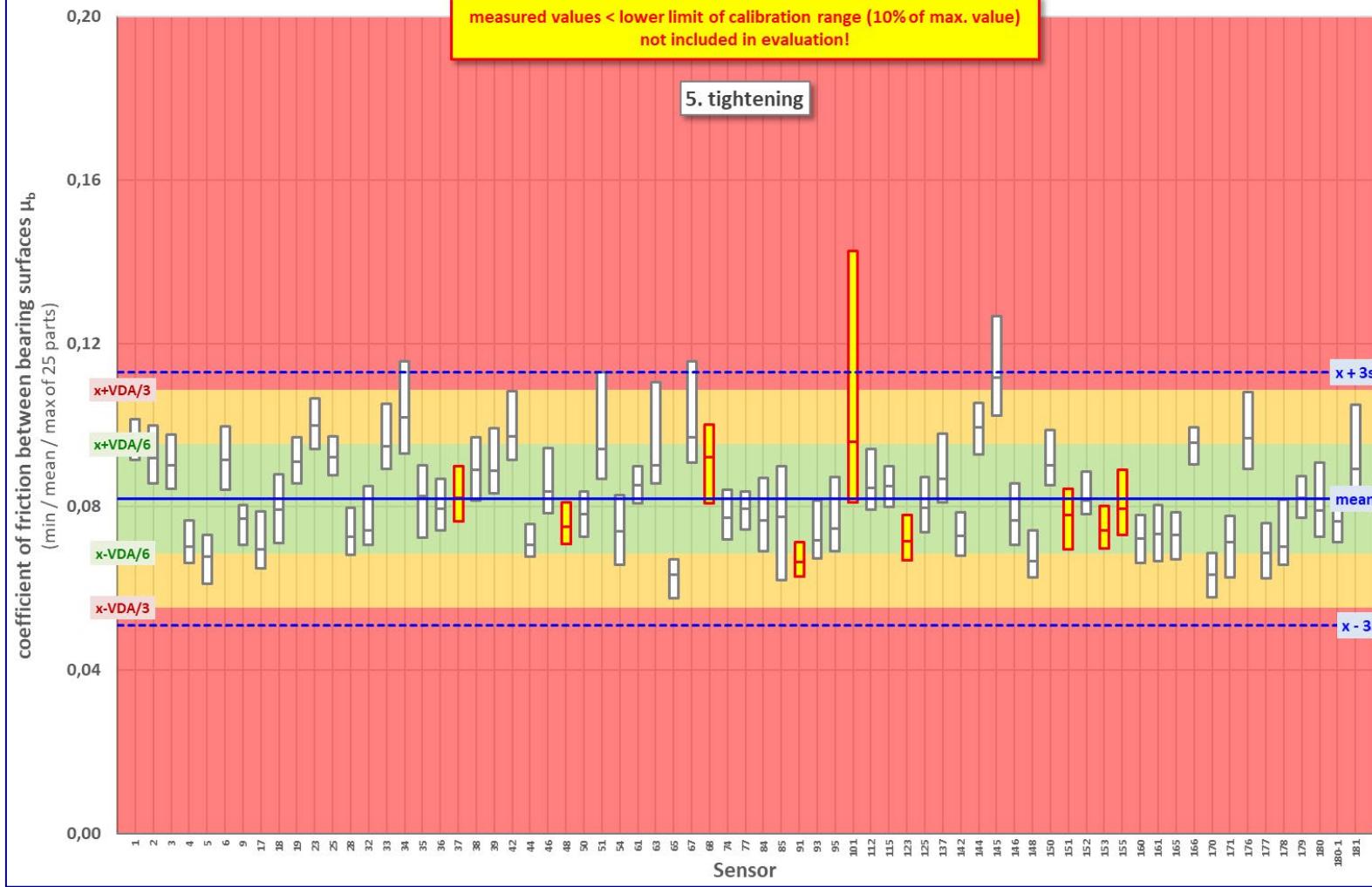
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between bearing surfaces  $\mu_b$   
M10, 5. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

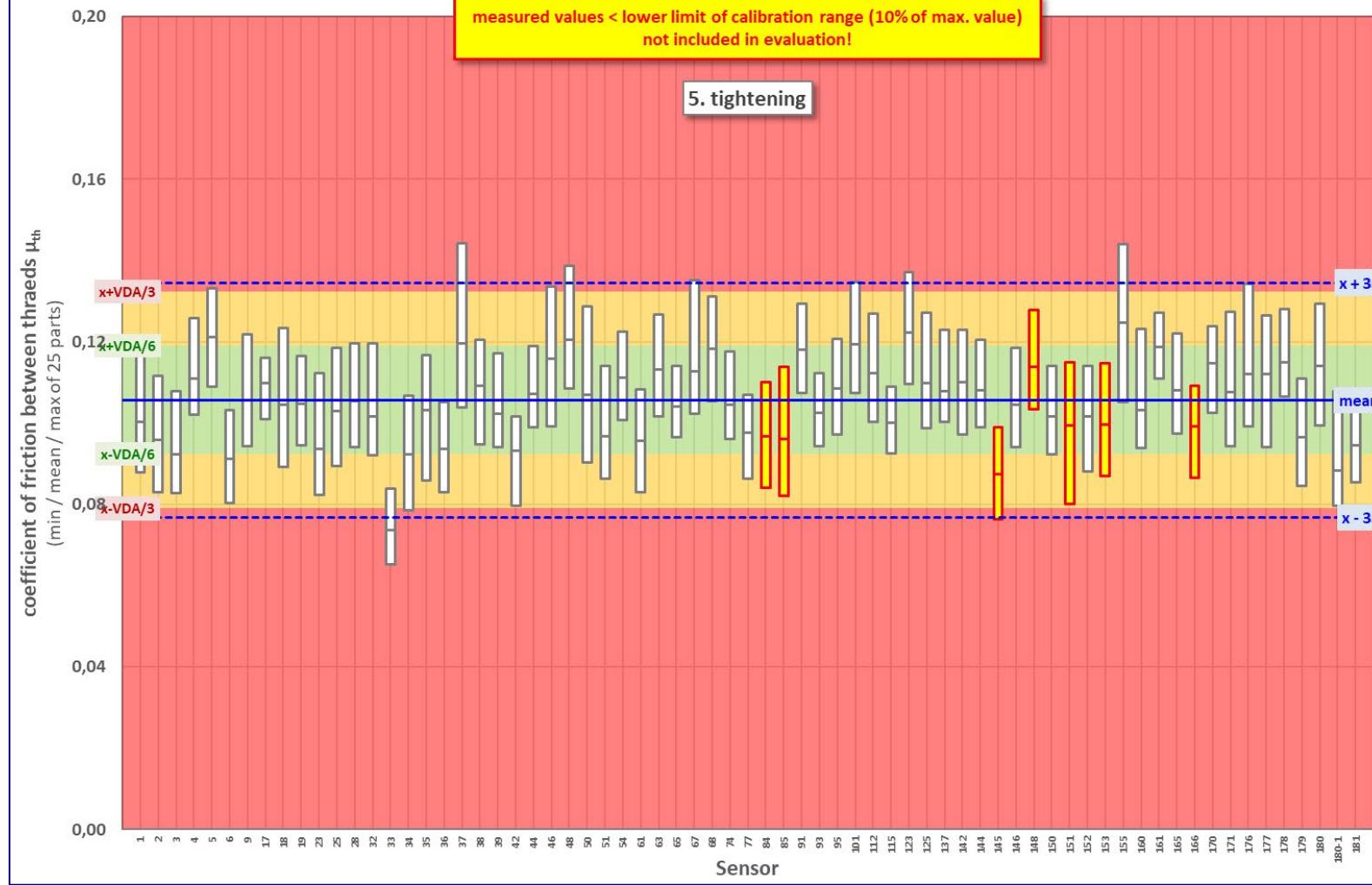
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between threads  $\mu_{th}$   
M10, 5. tightening, 200 rpm

results filtered!



# round robin test 2023 coefficient of friction

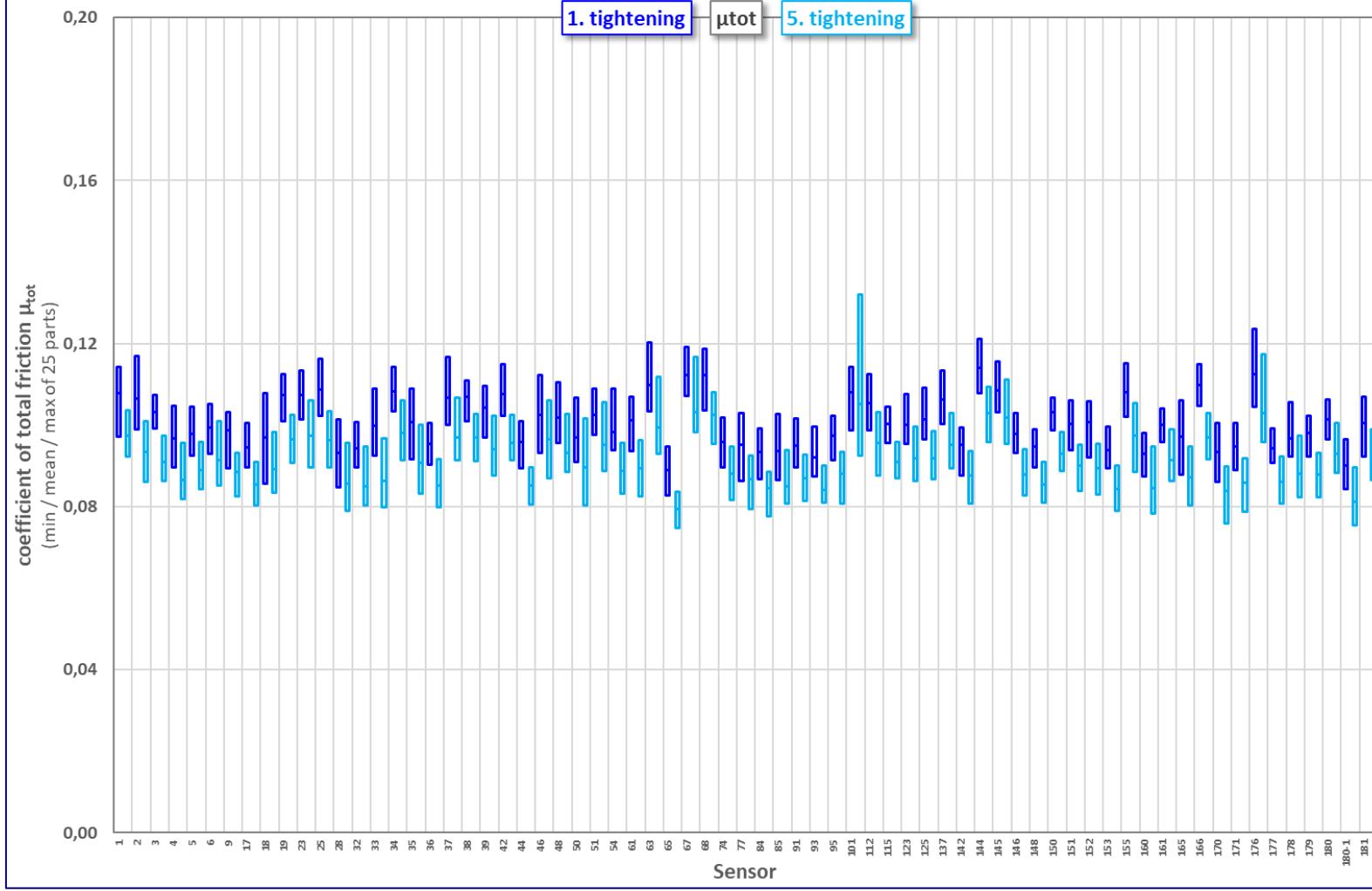
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of total friction  $\mu_{\text{tot}}$   
1. + 5. tightening, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

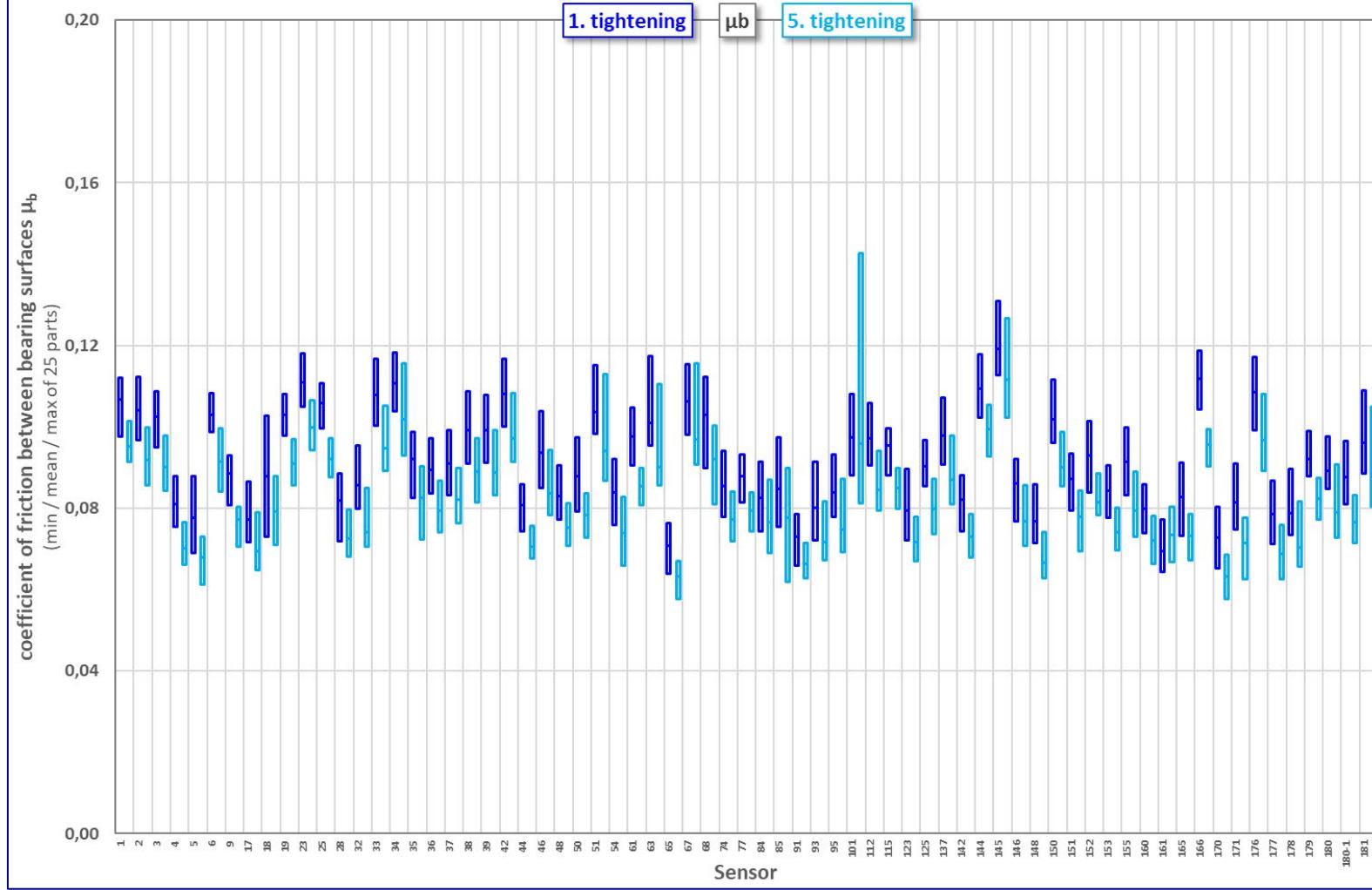
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between bearing surfaces  $\mu_b$   
1. + 5. tightening, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

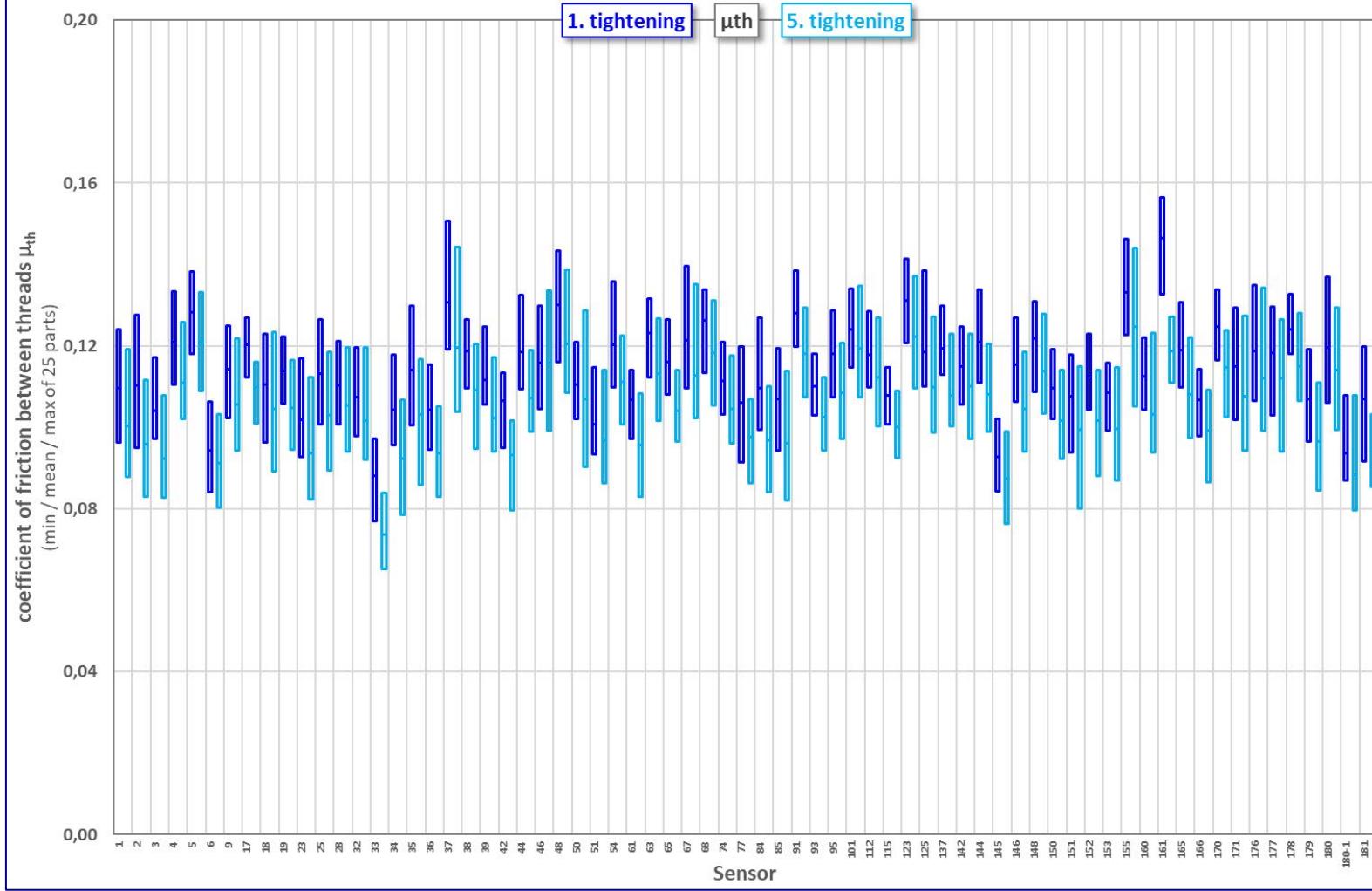
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between threads  $\mu_{th}$   
1. + 5. tightening, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

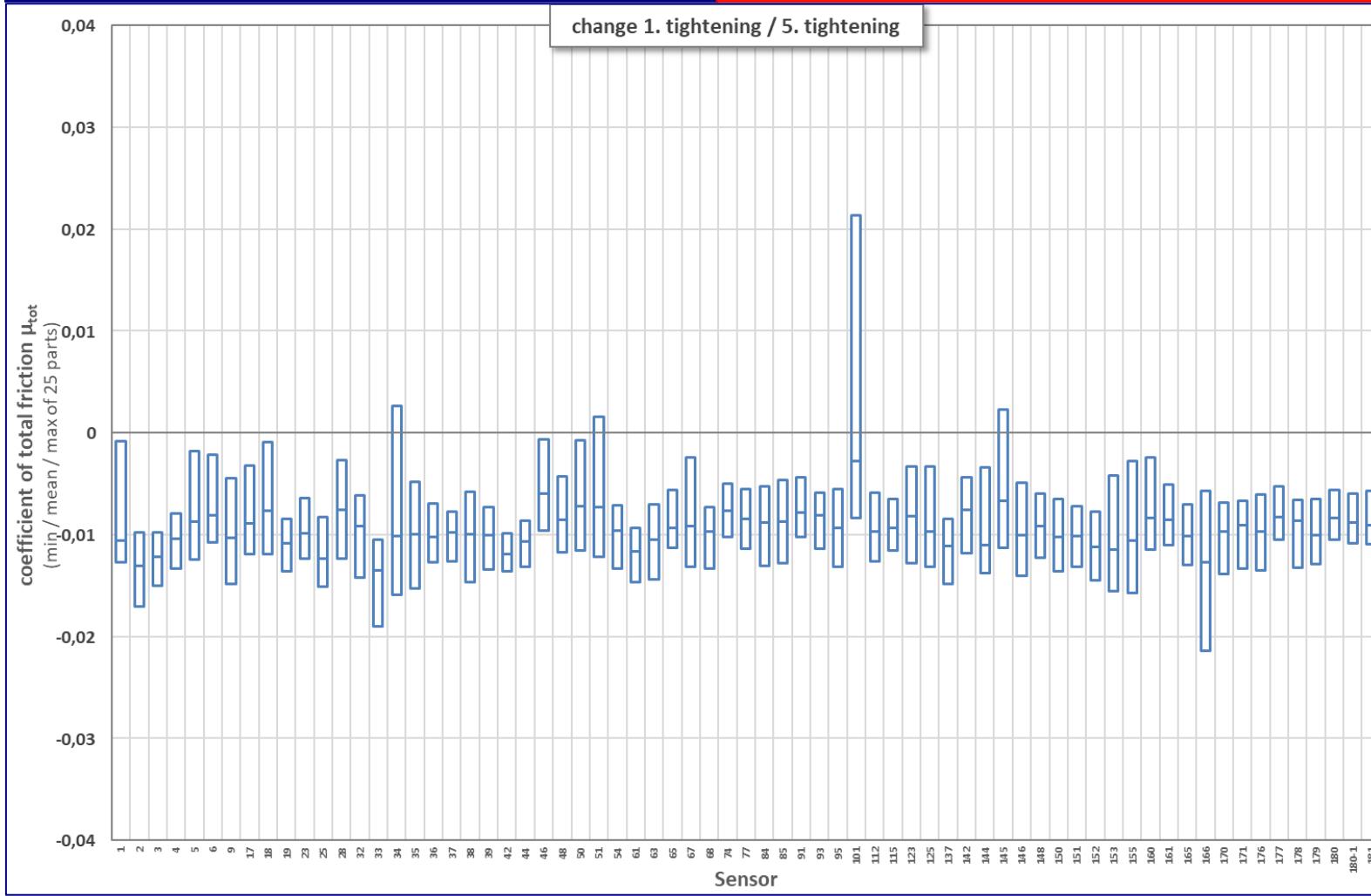
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of total friction  $\mu_{\text{tot}}$   
changes, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

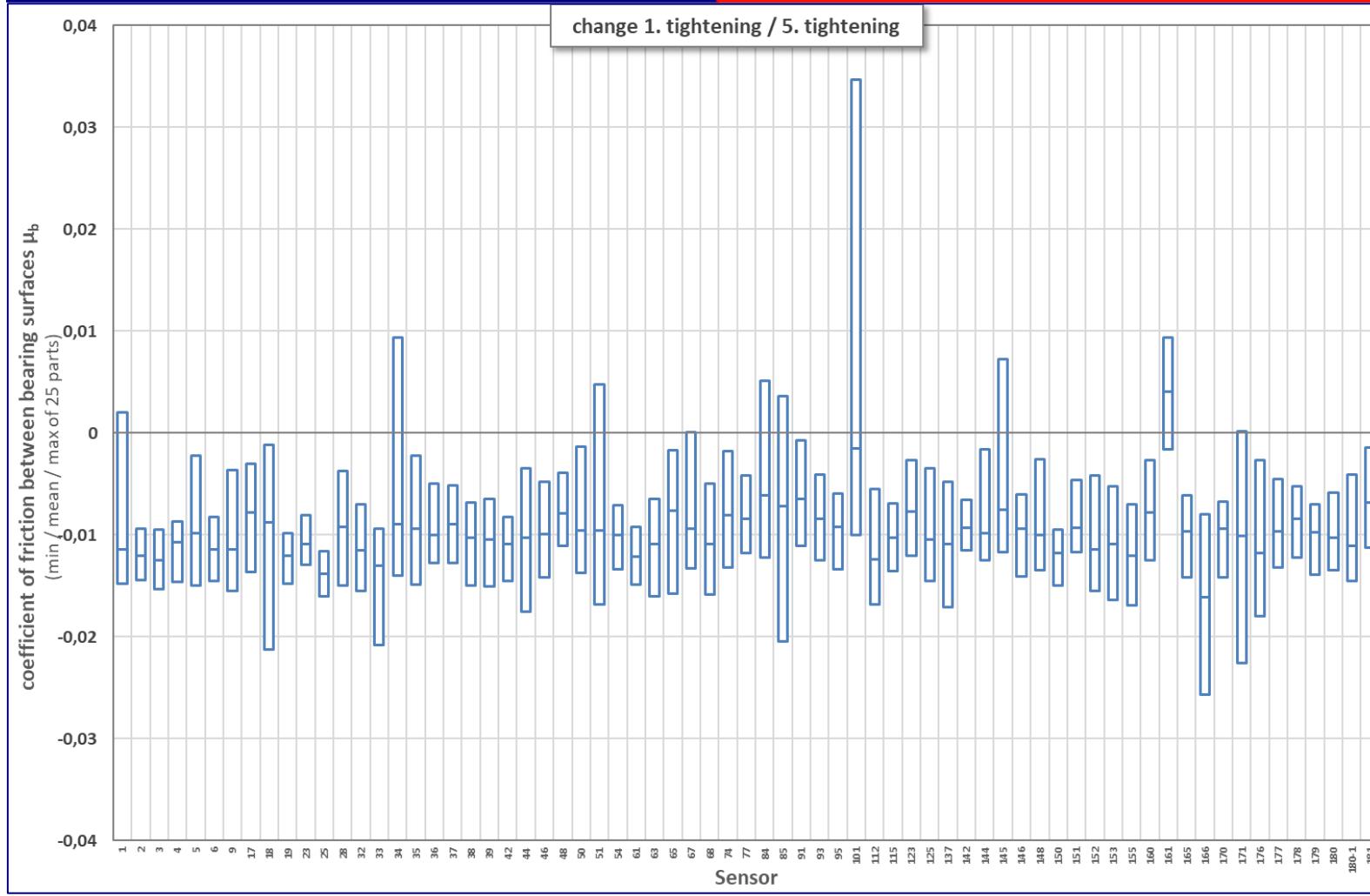
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between bearing surfaces  $\mu_b$   
changes, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

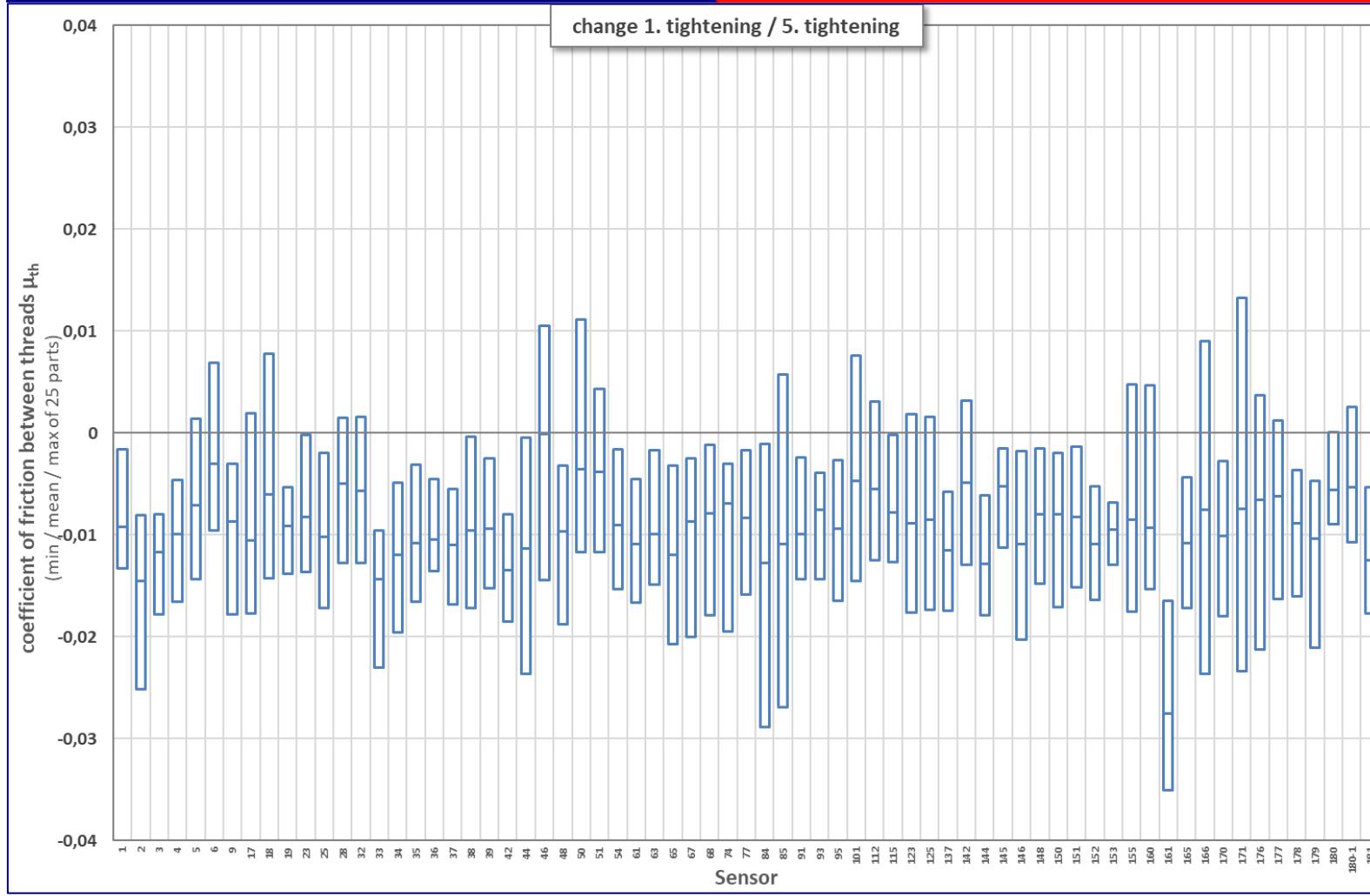
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

coefficient of friction between threads  $\mu_{th}$   
changes, M10 - 200 rpm

all available results without filters!



# round robin test 2023 coefficient of friction

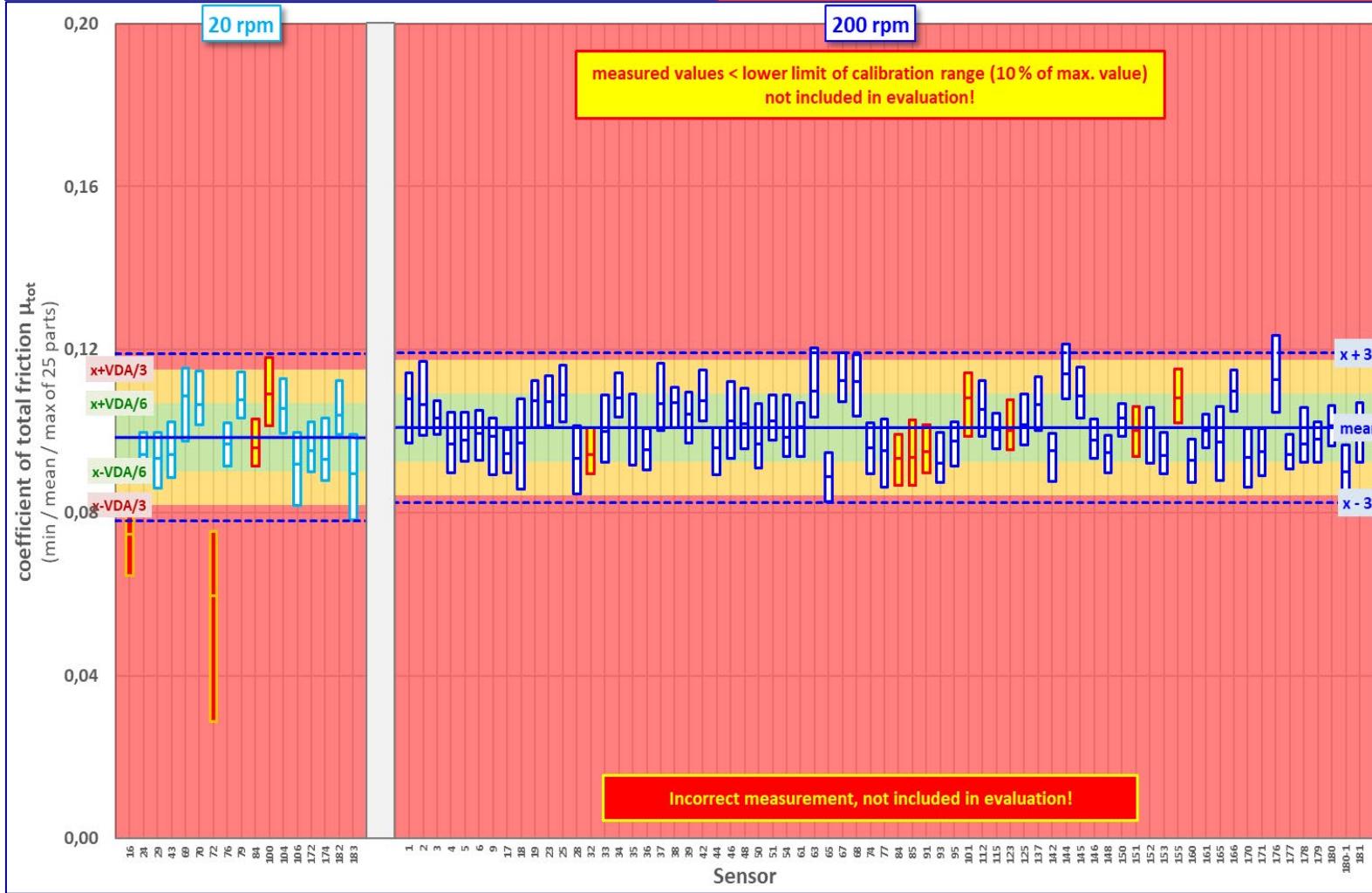
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of total friction $\mu_{\text{tot}}$ comparison tightening 1- / 2-steps

results filtered!



# round robin test 2023 coefficient of friction

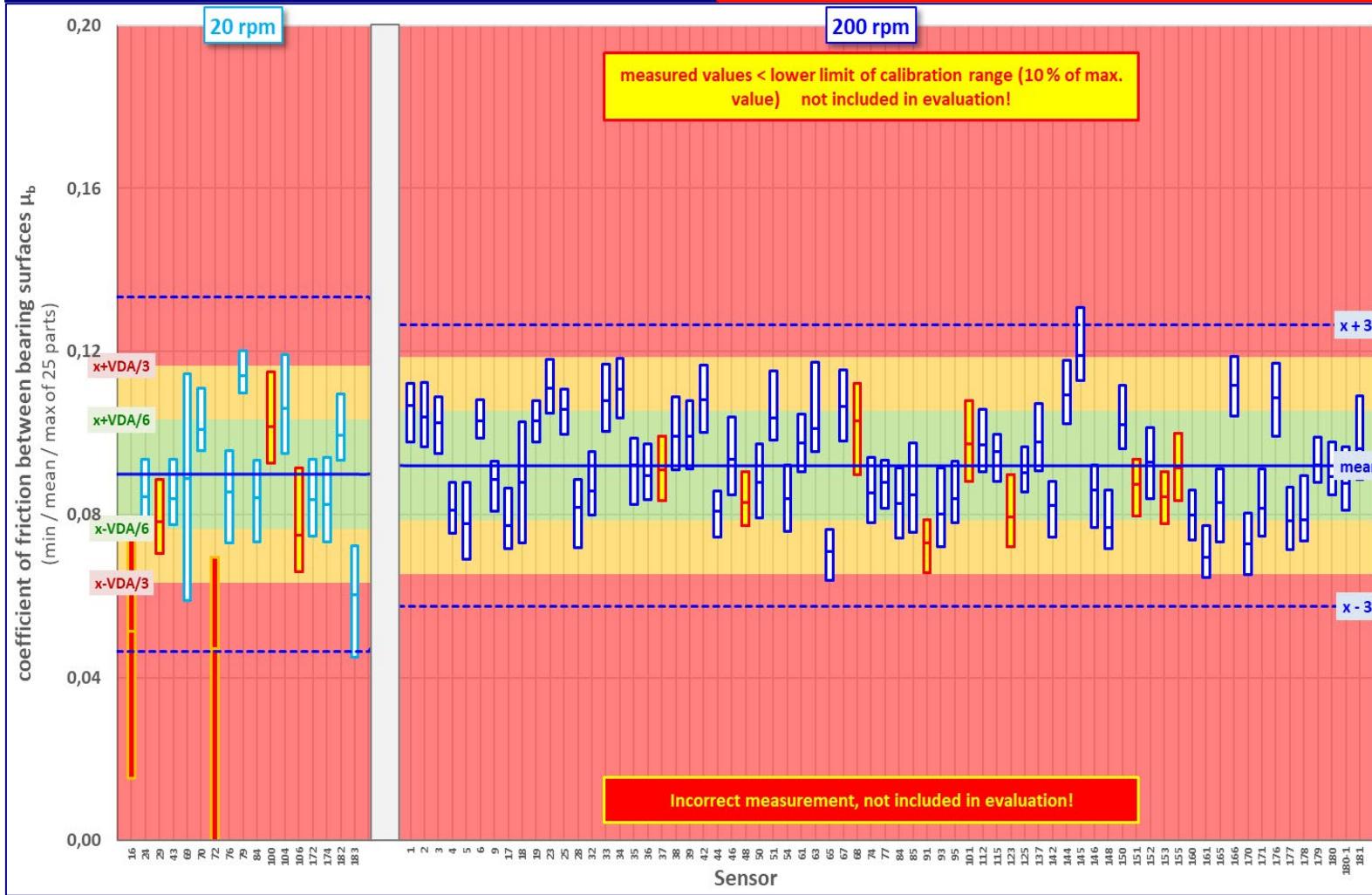
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of friction between bearing surfaces $\mu_b$ comparison tightening 1- / 2-steps

results filtered!



# round robin test 2023 coefficient of friction

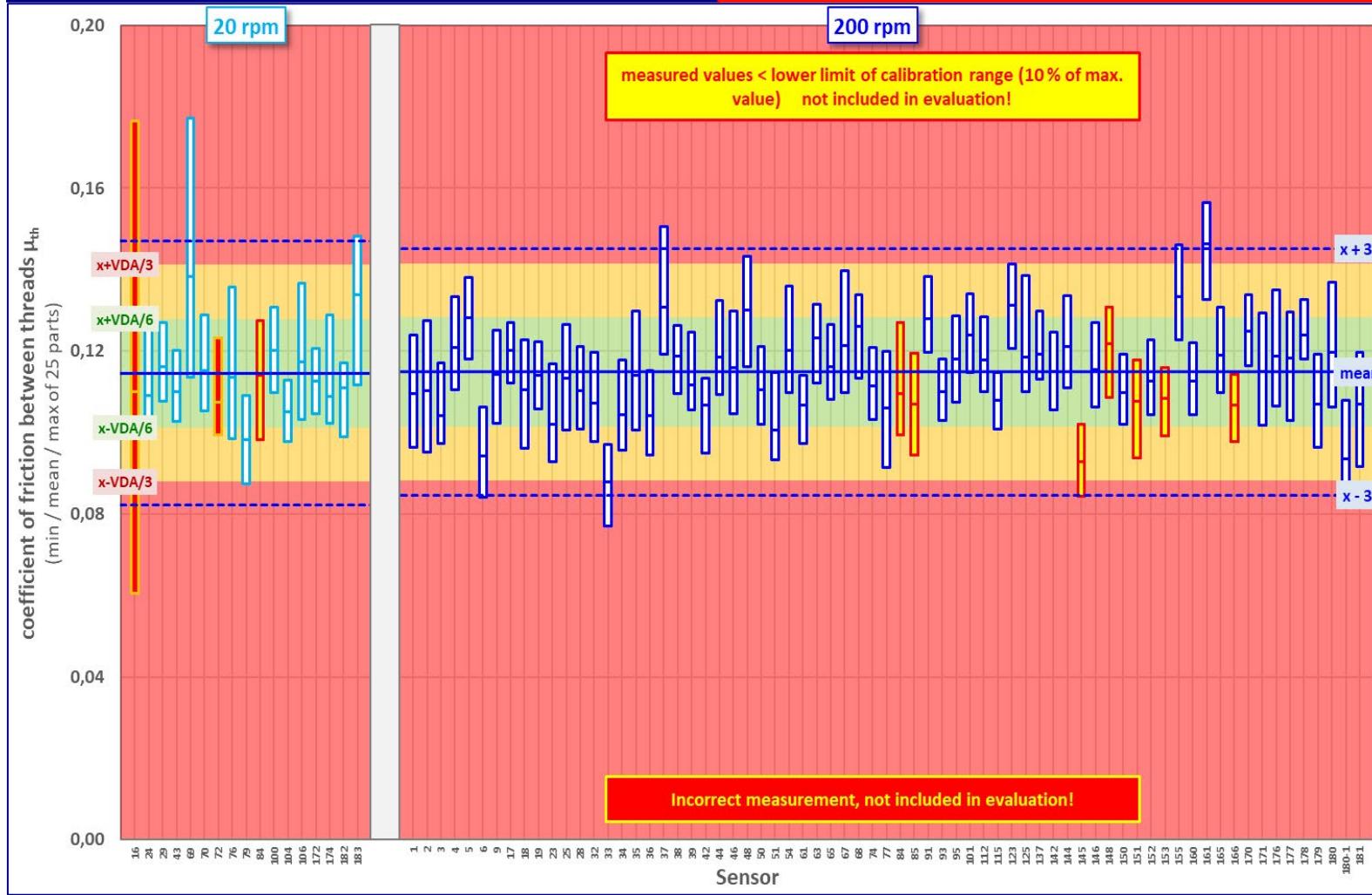
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of friction between threads $\mu_{th}$ comparison tightening 1- / 2-steps

results filtered!



# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

stop point  
with 2steps-tightening

69 sensors, 11x no data (stop point)  
2x uniform values, 9x no mode of drive



# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

stop point  
with 2steps-tightening

69 sensors, 11x no data (stop point)  
2x uniform values, 9x no mode of drive

### round robin 2023 coefficients of friction

test procedure M10, 200 rpm



DEUTSCHER SCHRAUBENVERBAND E.V.

program of first tightening step to  
 $0,3 \times 0,8 \times F_p = 11,5 \text{ kN}$  (documentation of  $F_{vmax\_real} !$ ).  
tightening with  $n = 200 \text{ rpm}$

#### remarks:

the test stand must meet the boundary conditions of DIN EN ISO 16047.

see point 5 - point 8 of this flow chart.

use of new test and reference parts.

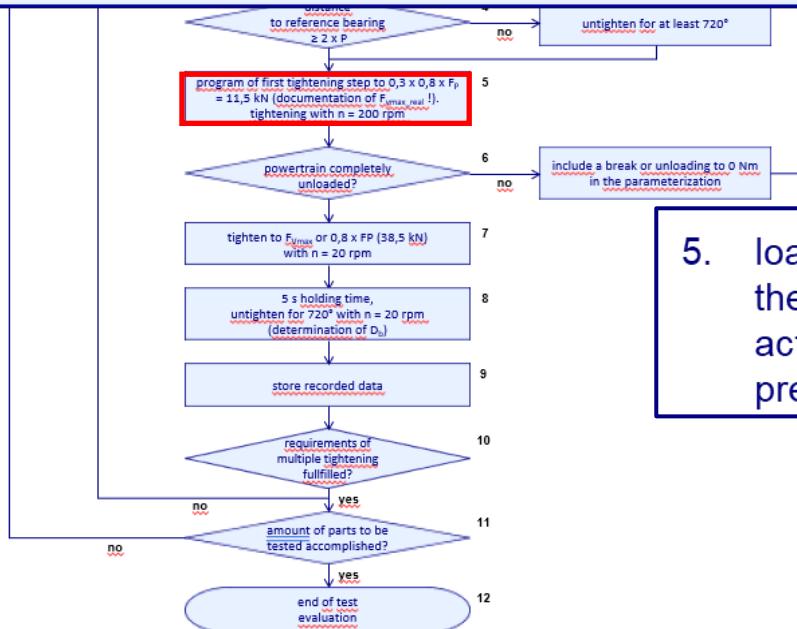
an angle of min.  $720^\circ$  or  $2 \times P$  as distance from the test part to the bearing surface is required so that the spindle has sufficient time to accelerate.

5. load at the shift point is programmed to 30 % of the maximum force of  $0.8 \times F_p$  (11.5 kN). The actually achieved max. force value of the fast pretightening must be documented
6. simulation of the static friction at the transition of the tightening steps by a short break (1 s). The tightening torque must be relieved to zero during the break.

5. load at the shift point is programmed to 30 % of the maximum force of  $0.8 \times F_p$  (11.5 kN). The actually achieved max. force value of the fast pretightening must be documented

for each test part before re-tightening, it must be ensured that the test piece has cooled down. Accordingly, a waiting time of 5 s is also required here.

11. The determination of the friction coefficients is to be carried out on 25 test parts.
12. Evaluation at 75% of the test force  $F_p$  (36.1 kN).



2023-06

# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

stop point  
with 2steps-tightening

69 sensors, 11x no data (stop point)  
2x uniform values, 9x no mode of drive

thread torque	Switch point	cof total	cof bearing surfaces	cof threads	clamp force	tightening torque	bearing torque	thread torque	Switch point
T <sub>th1</sub> in Nm		μ <sub>tot1</sub>	μ <sub>b1</sub>	μ <sub>th1</sub>	F <sub>s</sub> in kN	T <sub>s</sub> in Nm	T <sub>bs</sub> in Nm	T <sub>th5</sub> in Nm	
	x	x	x						
x	x				x	x		x	x
31,65	10,95	0,097	0,081	0,122	36,13	51,26	20,44	30,83	10,95
30,55	10,95	0,095	0,081	0,117	36,12	48,34	20,31	28,03	10,95
29,29	10,95	0,088	0,073	0,110	36,11	46,47	19,04	27,43	10,95
30,38	10,95	0,097	0,084	0,116	36,13	50,38	21,74	28,64	10,95

Standardised switching point, but no indication of the maximum preload force values. Value of 10.95 kN not comprehensible. Possibly selected in order to have actually switched at 11.5 kN?



stop point with 2steps-tightening	69 sensors, 11x no data (stop point) 2x uniform values, 9x no mode of drive
Type of machine:	Kistler
Drive unit:	200 rpm
Date of last calibration:	01.06.2023

Term 'drive' not clear? The max. speed or sensor capacity is often mentioned.

# round robin test 2023 coefficient of friction

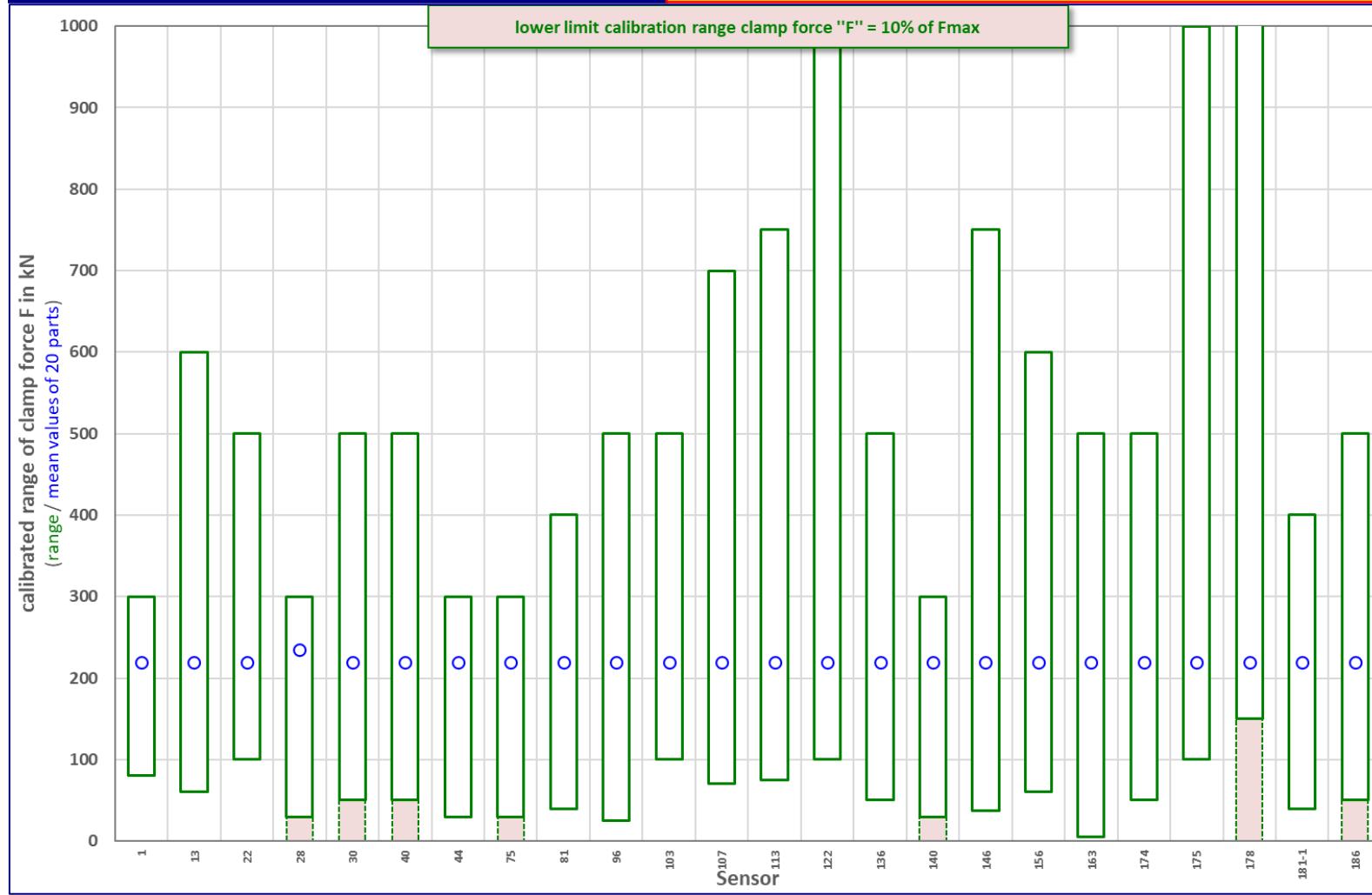
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### calibrated range clamp force F M24

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

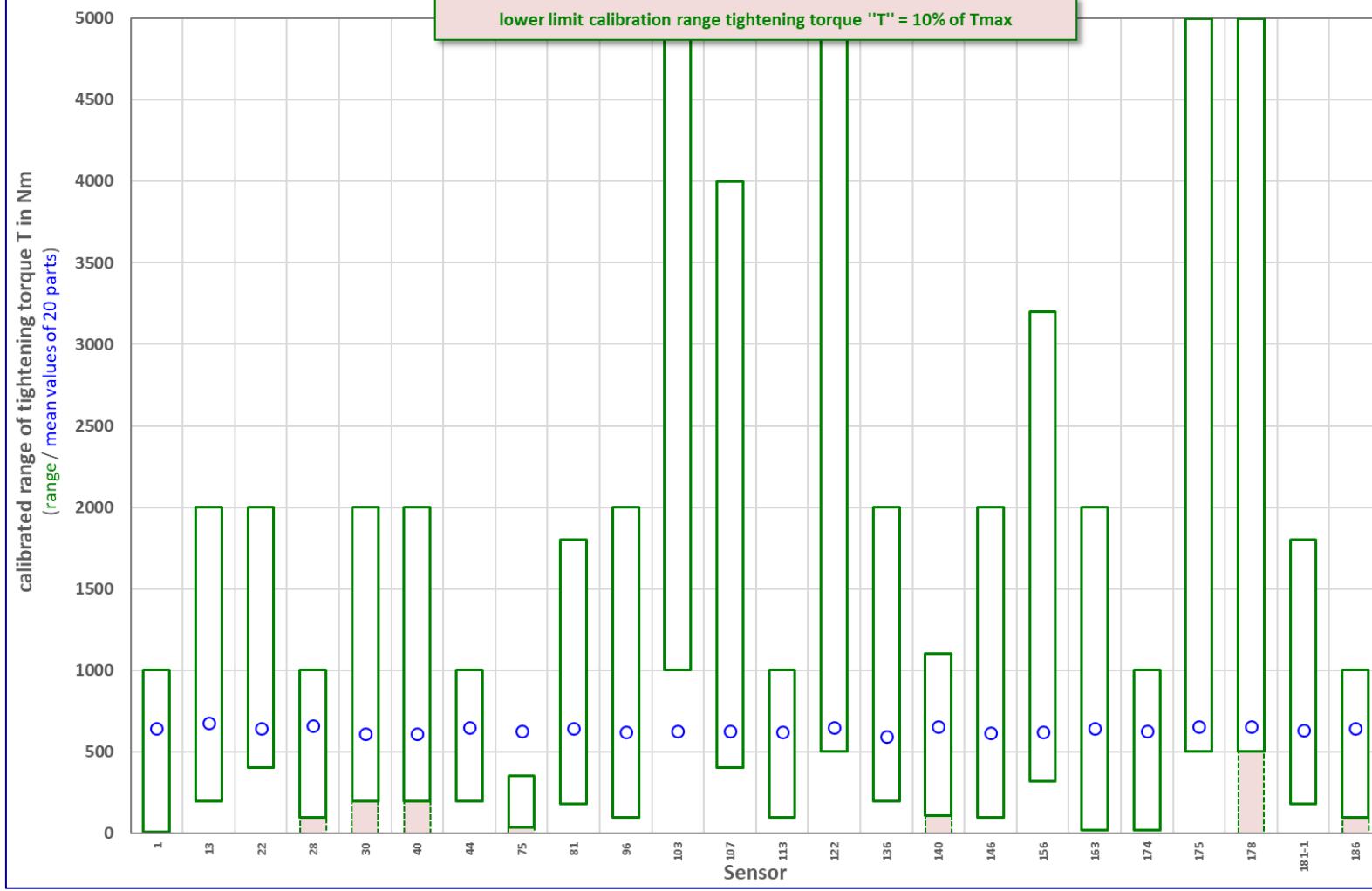
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### calibrated range tightening torque T M24

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

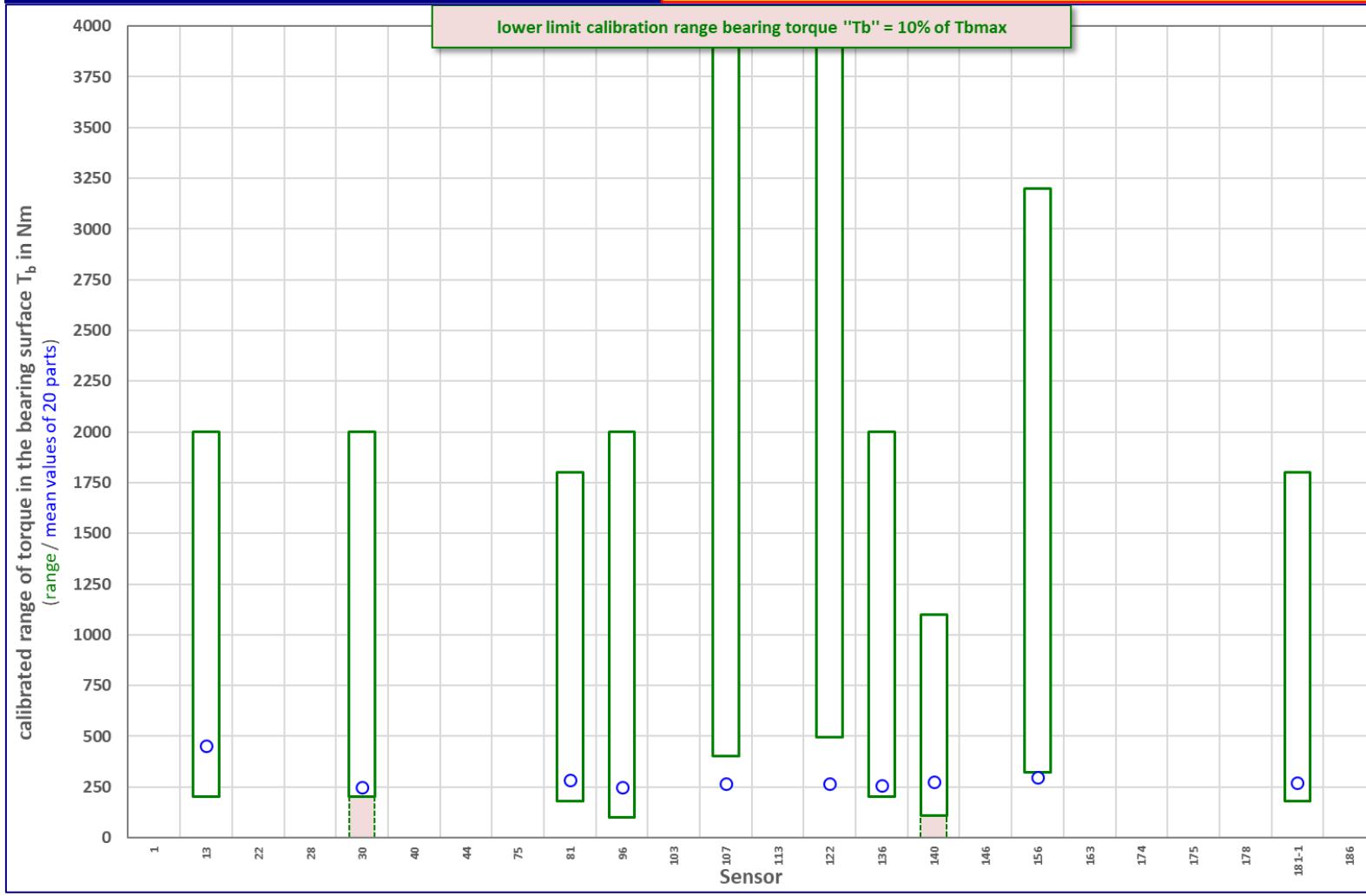
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### calibrated range bearing torque $T_b$ M24

min-value = 0: increase to 10% of the max-value!



# round robin test 2023 coefficient of friction

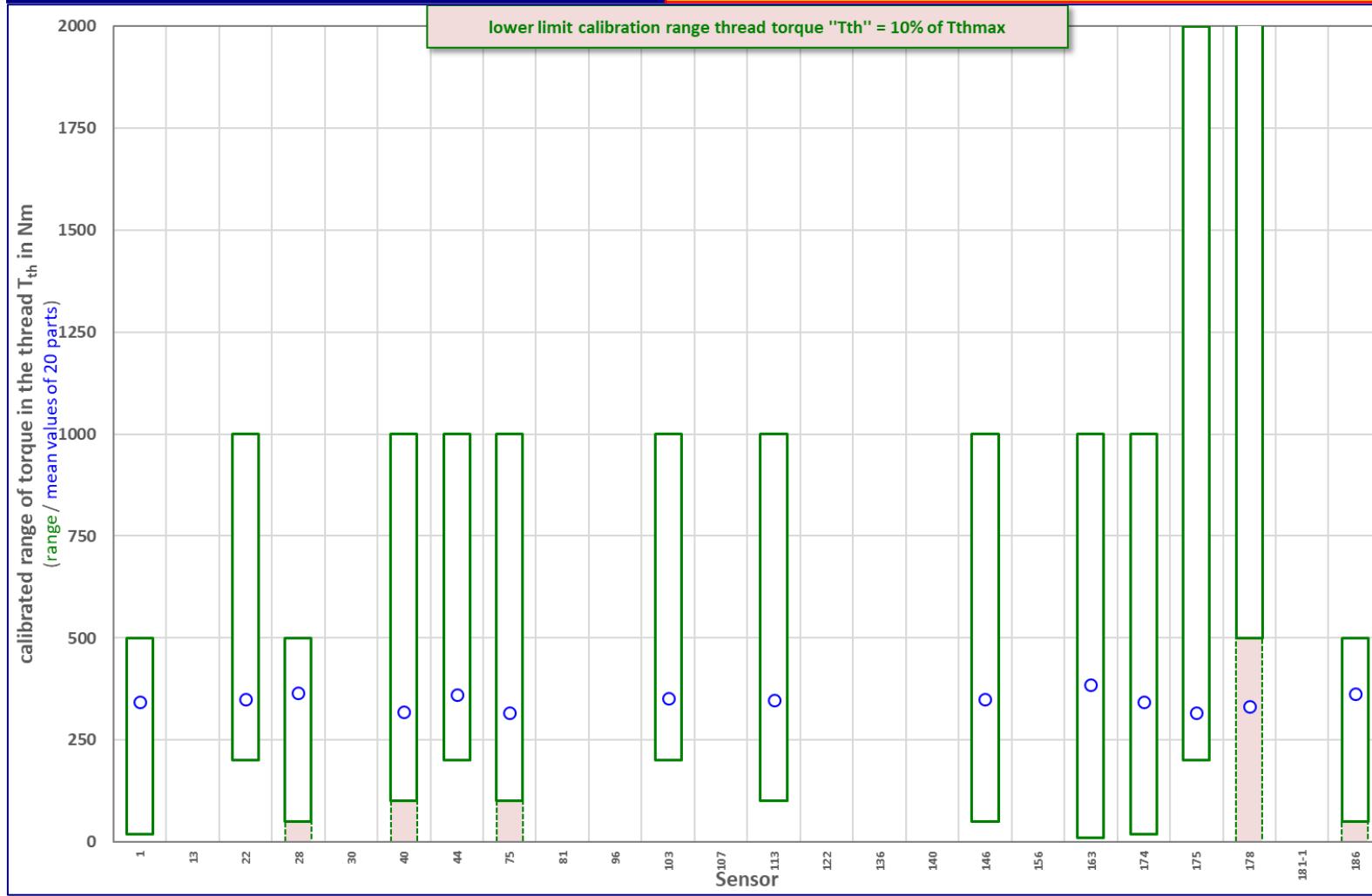
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### calibrated range thread torque $T_{th}$ M24

min-value = 0: increase to 10% of the max-value!

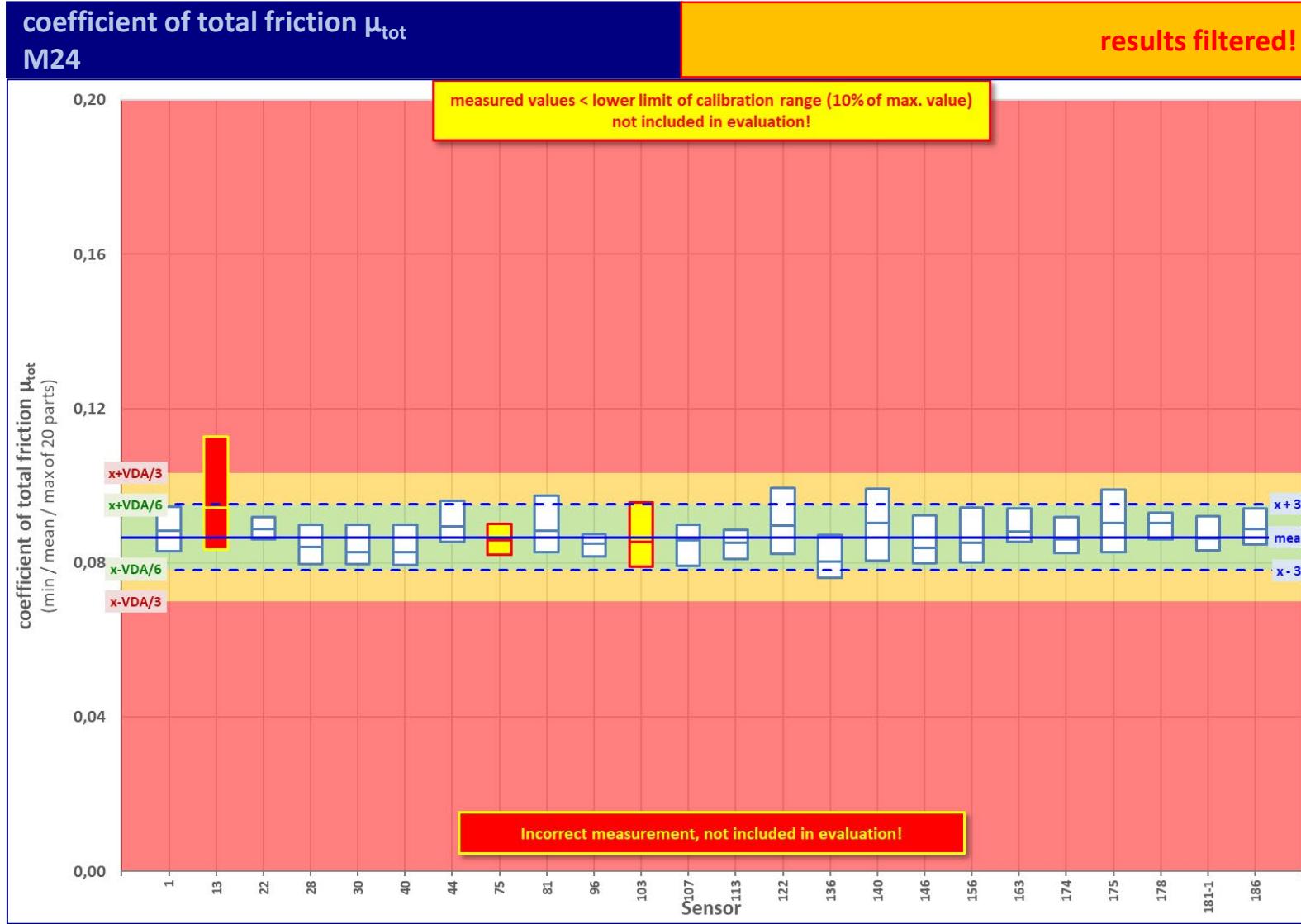


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

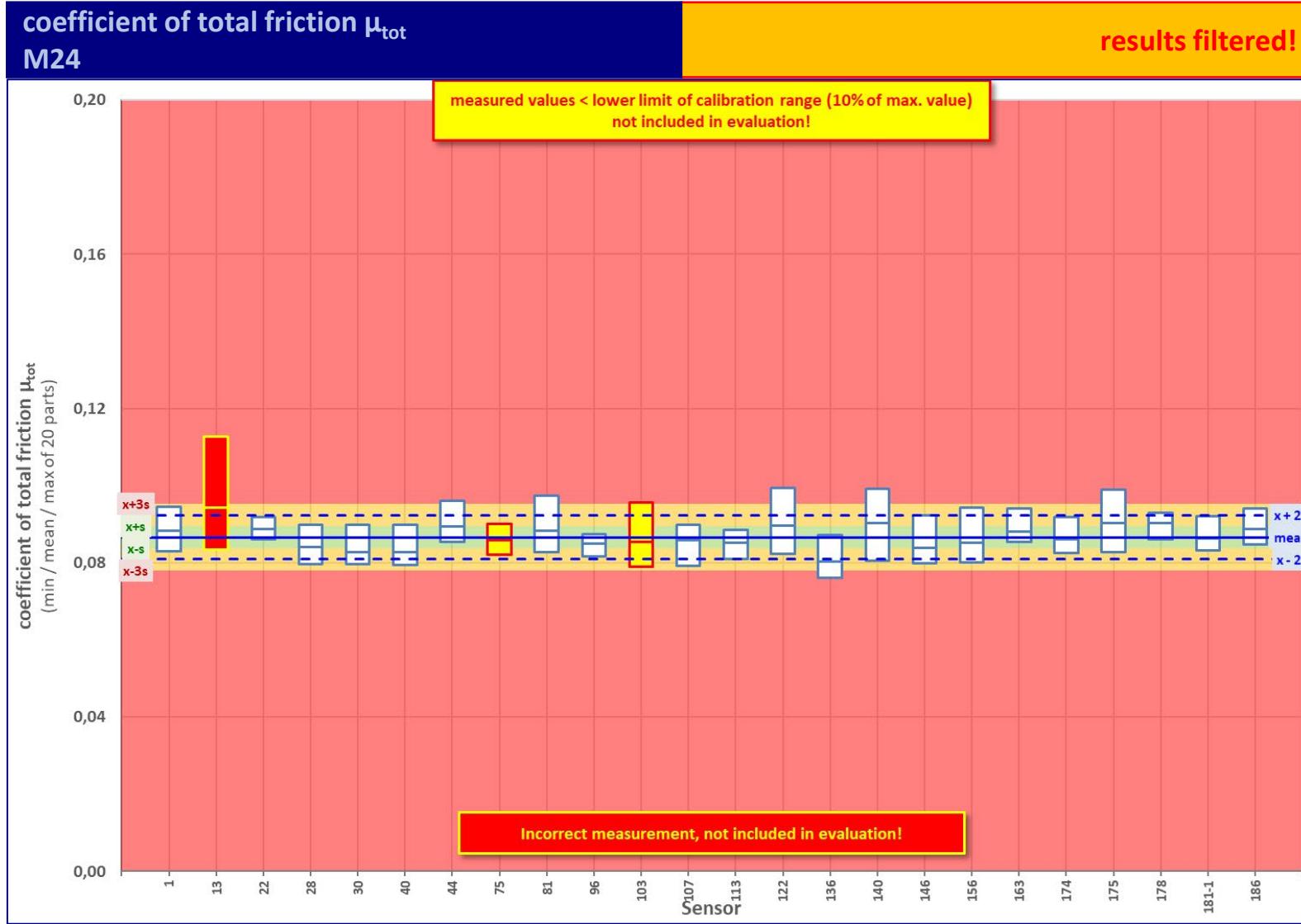


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



# round robin test 2023 coefficient of friction

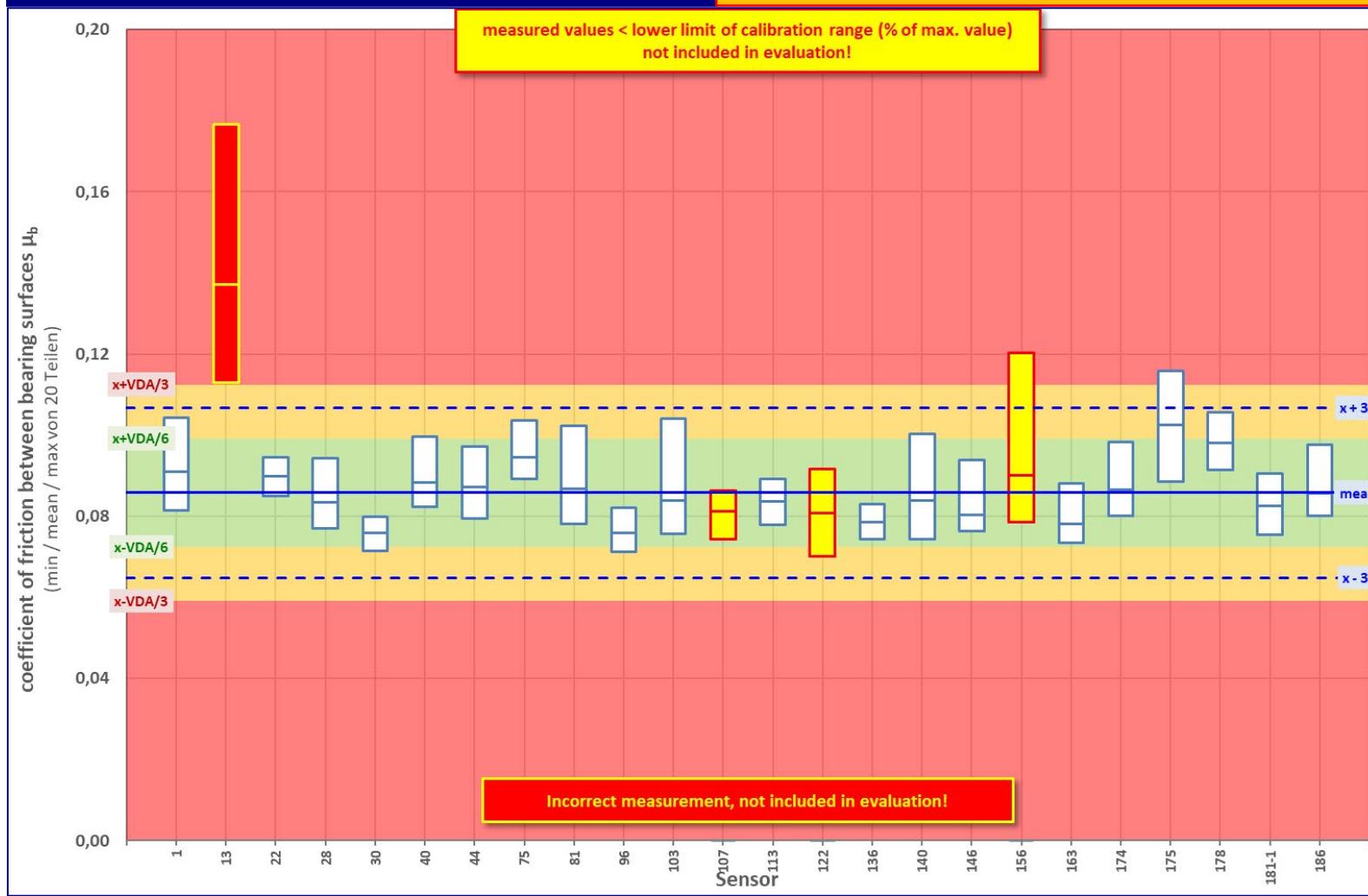
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of friction between bearing surfaces $\mu_b$ M24

results filtered!



# round robin test 2023 coefficient of friction

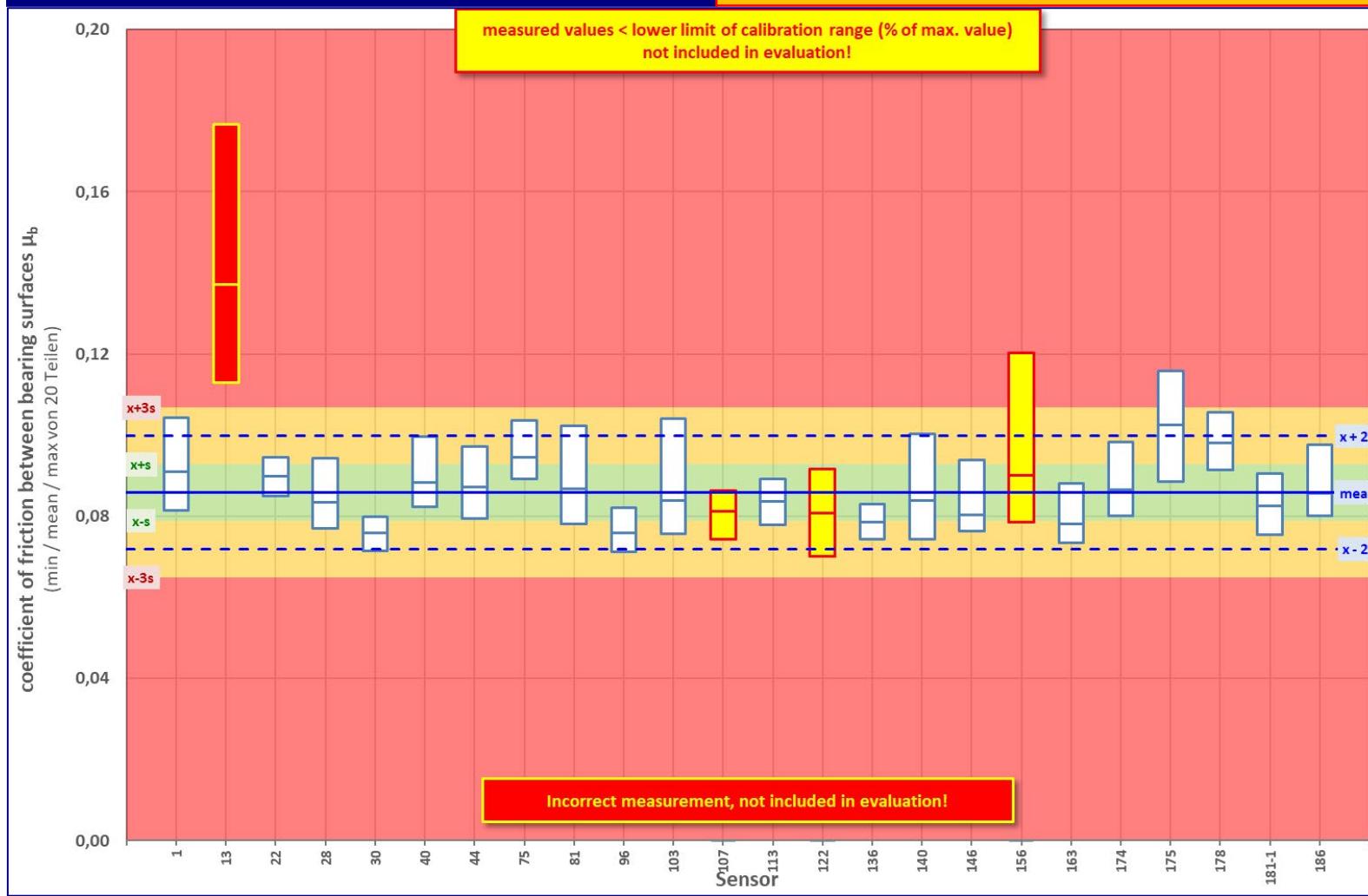
## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

### coefficient of friction between bearing surfaces $\mu_b$ M24

results filtered!

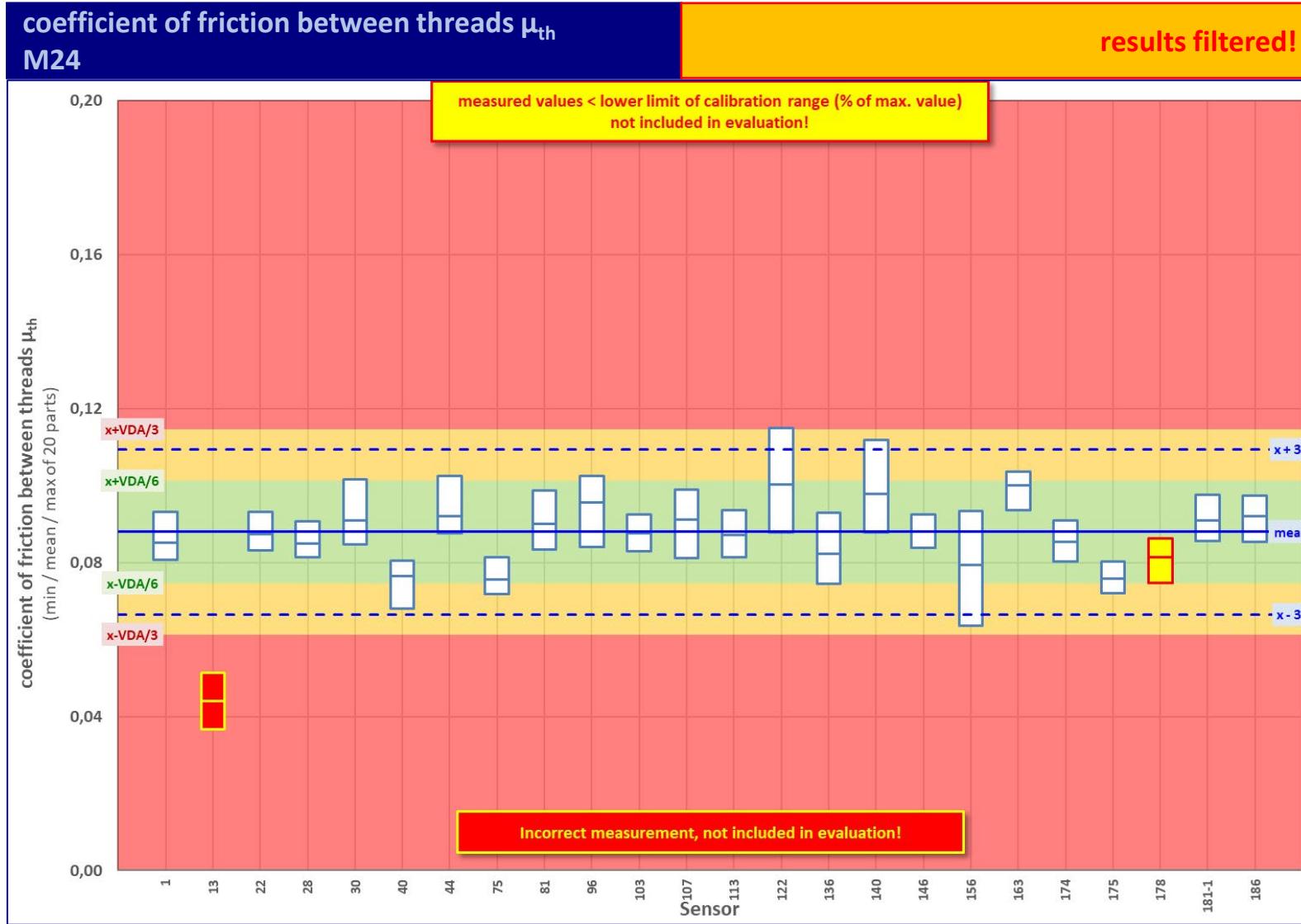


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

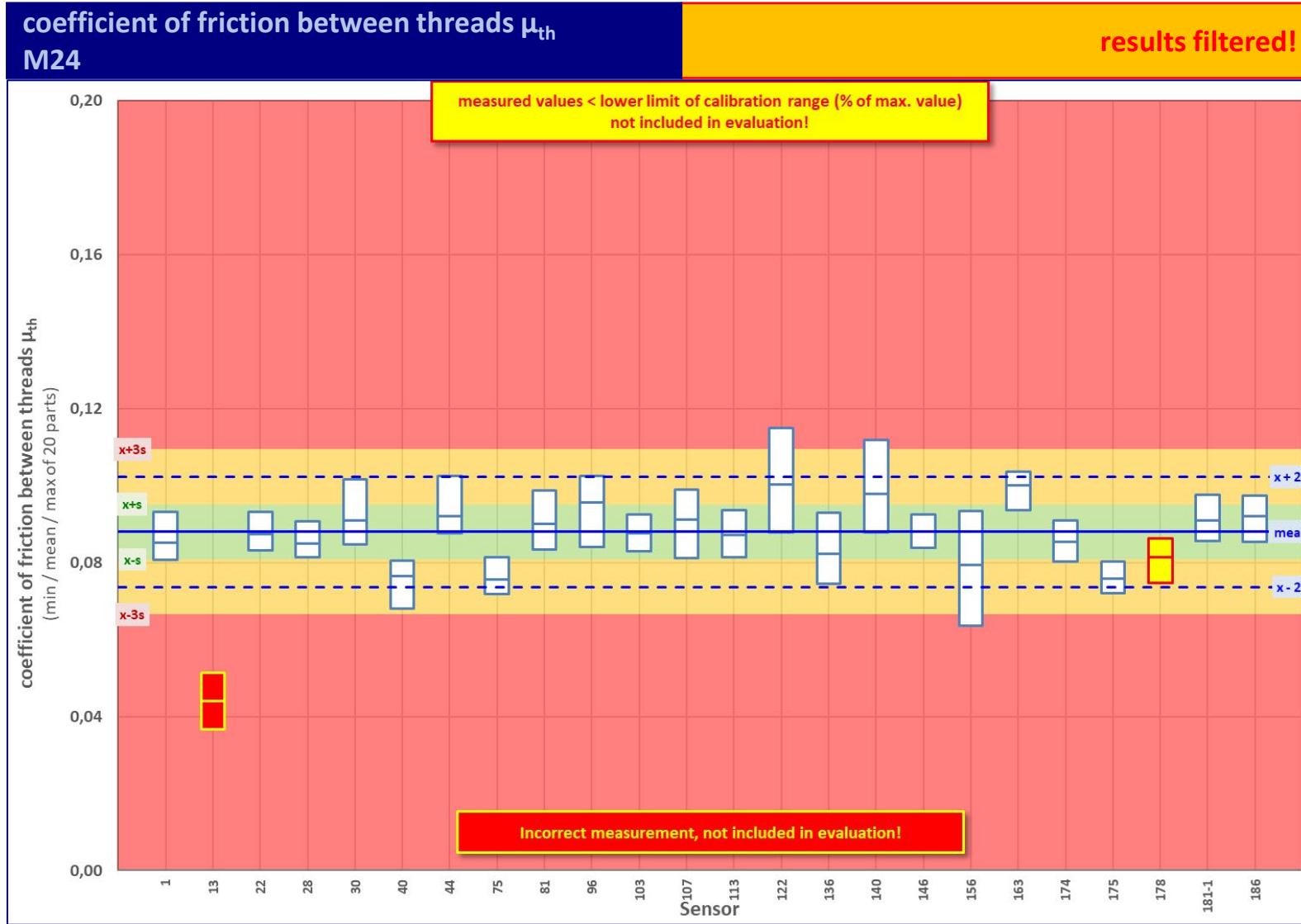


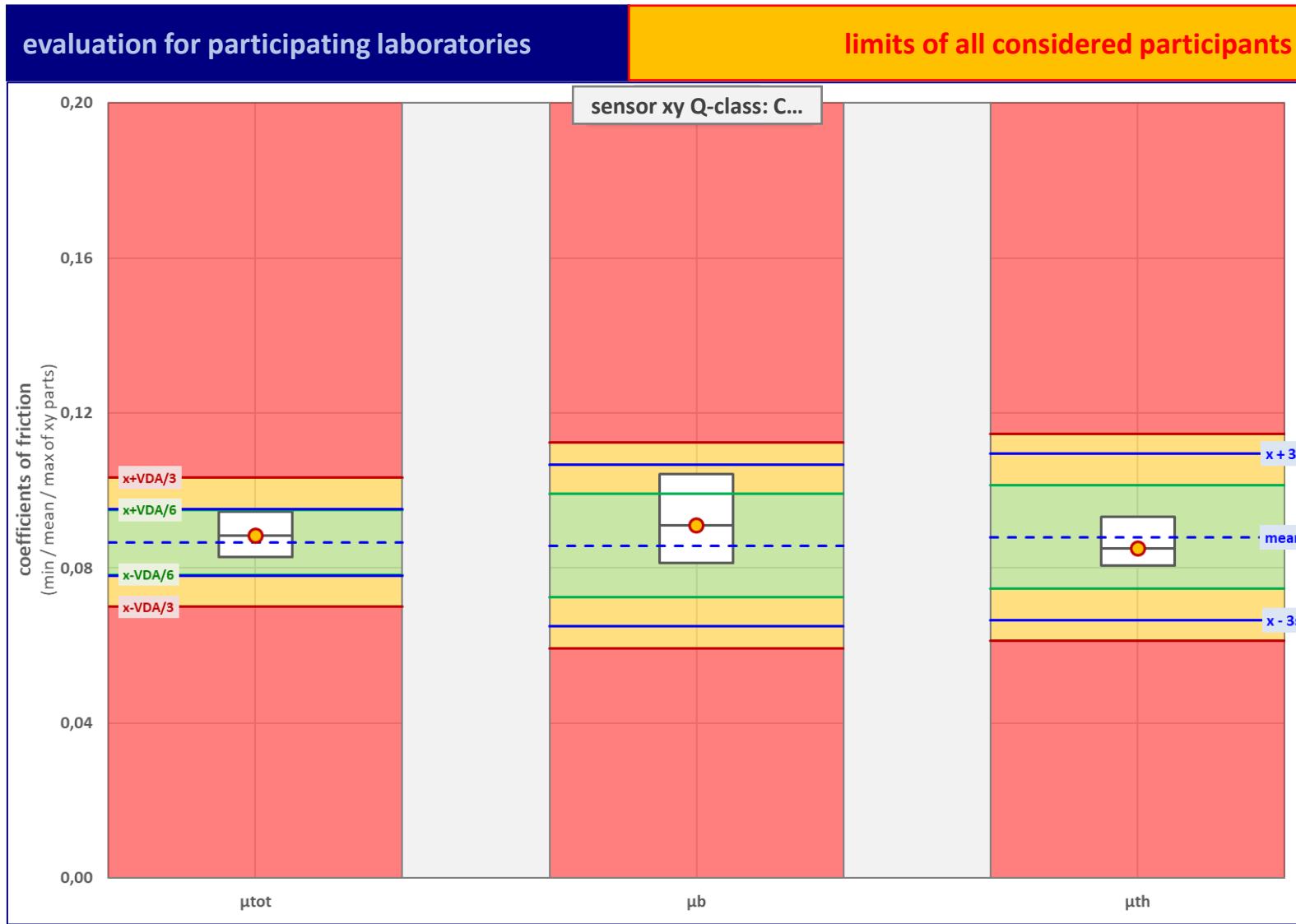
# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



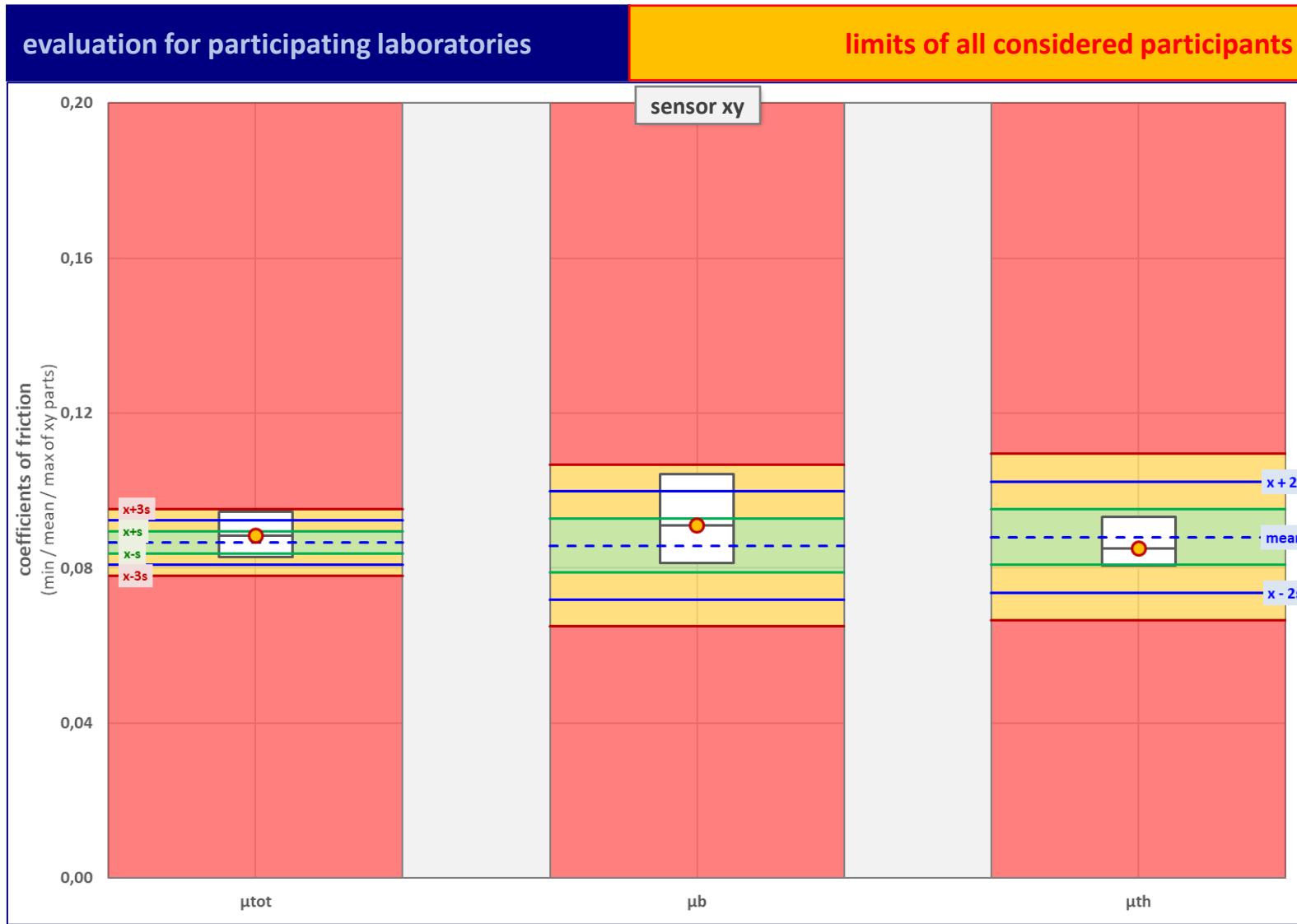


# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.



# round robin test 2023 coefficient of friction

## final evaluation



DEUTSCHER SCHRAUBENVERBAND E.V.

