BRNO UNIVERSITY OF TECHNOLOGY

FACULTY OF CIVIL ENGINEERING
institute of building testing

ilac-MRA

Z 7008

FINAL REPORT ON THE RESULTS OF PRECISION EXPERIMENT

Proficiency Testing Program
Mechanical Properties of Plastics
ZVP 2023/1

Brno University of Technology
Proficiency testing provider at the SZK FAST
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Czech Republic

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www.ptprovider.cz

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Coordinator of PTP results assessment

Contents

1 Introduction and Important Contacts

In the year 2023, the Proficiency Testing Provider at the SZK FAST (PT Provider) initiated the Proficiency Testing Program (PTP) designated ZVP 2023/1 whose aim was to verify and assess the conformity of test results across laboratories when testing plastics. The assessment of the results of the Proficiency Testing Program was carried out by a committee consisting of the following PT Provider employees:

Head of the PT Provider, PTP coordinator

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Coordinator of PTP result assessment PTP

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The subjects of proficiency testing were the following testing procedures:

1. EN ISO 527-1, 2 (Tensile modulus) [1, 2]
2. EN ISO 527-1, 2 (Stress at yield, Strain at yield) [1, 2]
3. EN ISO 527-1, 2 (Stress at yield) [1, 2]
4. EN ISO 178 (Flexural modulus) [3]
5. EN ISO 178 (Flexural strength, Flexural strain at flexural strength) [3]
6. EN ISO 179-1 (Charpy unnotched impact strength) [4]
7. EN ISO 179-1 (Charpy notched impact strength (note: notch made by distributor)) [4]
8. EN ISO 179-1 (Charpy notched impact strength (note: notch made by laboratory)) [4]
9. EN ISO 868 (Shore hardness D) [5]
10. EN ISO 306 (Vicat softening temperature VST/A/50) [6]
11. EN ISO 306 (Vicat softening temperature VST/B/50) [6]
12. EN ISO 75-1, -2 (Temperature of deflection under load, method A) [7, 8]
13. EN ISO 75-1, -2 (Temperature of deflection under load, method B) [7, 8]
14. EN ISO 1183-1 (Density) [9]
15. EN ISO 11357-1, -3 (Melting temperature T_{m1} ,Enthalpy of fusion ΔH_{m1}) [10, 11]
16. EN ISO 1133-1 (Melt mass-flow rate) [12]
17. EN ISO 1628-1, -5 (Viscosity) [13, 14]
18. EN ISO 11358-1 (Filler content) [15]
19. ISO 3795 (Burning Rate) [16]

Due to lack of interested participants were open following methods only: **No 1, 2, 4, 5 and 14**.

The supplier, UNIPETROL RPA, s.r.o. – POLYMER INSTITUTE BRNO, odštěpný závod, was responsible for the preparation of testing samples for the PTP. The supplier is responsible for homogeneity and stability of testing samples.

The test results from individual PTP participants were compared via a method involving the statistical analysis of all their results in a manner complying with ISO 5725-2 [17], ISO 13528 [18] and EN ISO/IEC 17043 [19]. The outcome is the present final report summarizing the results of the interlaboratory comparison, including statistical evaluation.

8 laboratories took part in PTP. In order to maintain the anonymity of the PTP, each laboratory was given an identification number that will be used henceforth in this document. An integral part of the present final report is a Certificate of Participation in the Proficiency Testing Program. It is unique for each participant and includes the participant's ID used in this report. The following table shows the participation of laboratories in individual parts of the PTP.

Table 1: Participation of individual laboratories in the PTP

ID / Method	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
455613	-	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b1f9a	X	X	-	-	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
689728	X	X	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-
4a8816	-	-	-	X	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
7189e1	X	X	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-
5d42c2	-	-	-	X	X	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b98935	X	X	-	-	-	-	-	-	-	-	-	-	-	X	-	-	-	-	-
2574f1	X	X	-	X	X	-	-	-	-	-	-	-	-	X	-	-	-	-	-

Table 2: List of participants (laboratories)

Laboratory	Address	Accr. No
CENTRO DE CARACTERIZAÇÃO E DESENVOLVIMENTO DE MATERIAIS - UFSCAR	Rodovia Washington Luís, km 23, São Carlos, 13565-905, SP	CRL 0135
Istituto Giordano S.p.A.	Viale Rossini,2, BELLARIA (RN), 47814, ITALY	-
OFI Österreichisches Forschungsinstitut für Chemie und Technik	Franz-Grill-Straße 5, Arsenal Objekt 213, 1030, Österreich	0090
ORLEN Unipetrol RPA, s.r.o.	Záluží, Litvínov 7, 43670, Česká republika	-
ORLEN Unipetrol RPA, s.r.o. - POLYMER INSTITUTE BRNO, odštěpný závod	Tkalcovská 36/2, Brno, 60200, Česká republika	L1380
ORLEN Unipetrol RPA, s.r.o. - POLYMER INSTITUTE BRNO, odštěpný závod - oddělení zkoušení materiálů	Tkalcovská 36/2, Brno, 60200, Česká republika	-
VÚSAPL a.s.	Novozámocká 179, Nitra, 949 05, Slovensko	-
ÉMI Építésügyi Minőségellenőrző Innovációs Nonprofit Kft.	Dózsa György út 26., SZENTENDRE, 2000, Hungary	NAH-1-1011/2018/K

2 Procedures used in the Statistical Analysis of Laboratory Results

The statistical analysis is based on the following steps:

1. Evaluation of intralaboratory variabilities by Cochran's C test: If 5% or 1% critical value is exceeded, the effect of the individual observations is first considered. If the results indicate that high participant variability is caused by a single observation, this value is excluded from the experiment, but the participant is not excluded as outlying. By overcoming 1% of the critical value, the participant's results can be marked as outlying and excluded from the experiment (symbol **X**).
2. The numerical critical evaluation of the test results using Grubbs' test: By overcoming 1% critical value, the participant's results can be marked as outlying and excluded from the experiment (symbol **X**).
3. Graphical determination of the consistency of laboratories (Mandel's statistics): The exceedance of the critical values of Mandel's statistics does not indicate that the results of the laboratories concerned are wrong; it only suggests minor inconsistencies.
4. Evaluation of descriptive statistics and, if possible, taking into account the number of observations, the repeatability and reproducibility.
5. Evaluation of the assigned value.
6. The performance evaluation: The most significant outcome of the PT Program is the so-called z-score and ζ-score (zeta-score). These characteristics assess the performance of individual participants by comparing it with the assigned value and measurement uncertainties. z-score and ζ-score are compared with limit values. The resulting ζ-score values are not taken into account during the final evaluation of the performance of participants as they are to a considerable degree dependent on the values of the measurement uncertainties of the assessed institutions. The following scales are applied for the z-score values:
   - $|z\text{-score}| < 2 \Rightarrow$ shows that the laboratory performance is **satisfactory** and generates no signal – ✓.
   - $2 \leq |z\text{-score}| < 3 \Rightarrow$ shows that the laboratory performance is **questionable** and generates an action signal – **?**.
   - $|z\text{-score}| \geq 3 \Rightarrow$ shows that the laboratory performance is **unsatisfactory** and generates an action signal – **!**.

Procedures used in the statistical analysis of proficiency testing programs can be found here: http://ptprovider.cz/?lang=en.

3 Conclusions of the Statistical Analysis

The present report summarizes the results of the Proficiency Testing Program ZVP 2023/1 (PT Program) organized by the PT Provider at the SZK FAST. 8 participants (laboratories) took part in the PT Program. PT program focused on ordinary standardized testing of plastics. The test results are evaluated separately for each observed test procedure and sample. An evaluation of statistical characteristics is included in the Appendix, as well as test results and graphic presentations. The designation of the test procedures is given in the section 1 of this report.

Table 2: Evaluation of overall performance and outliers.
✓ – satisfactory performance; ? – questionable performance; ! – unsatisfactory performance, X – outlier

ID / Method	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
455613	-	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
2b1f9a	!	✓	-	-	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
689728	✓	✓	-	✓	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-
4a8816	-	-	-	✓	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-
7189e1	✓	✓	-	✓	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-
5d42c2	-	-	-	✓	✓	-	-	-	-	-	-	-	-	-	-	-	-	-	-
b98935	✓	X	-	-	-	-	-	-	-	-	-	-	-	✓	-	-	-	-	-
2574f1	✓	✓	-	✓	✓	-	-	-	-	-	-	-	-	✓	-	-	-	-	-

References

[1] EN ISO 527-1. *Plastics - Determination of tensile properties - Part 1: General principles*. 2019.

[2] EN ISO 527-2. *Plastics - Determination of tensile properties - Part 2: Test conditions for moulding and extrusion plastics*. 2012.

[3] EN ISO 178. *Plastics - Determination of flexural properties*. 2019.

[4] EN ISO 179-1. *Plastics - Determination of Charpy impact properties - Part 1: Non-instrumented impact test*. 2010.

[5] EN ISO 868. *Plastics and ebonite - Determination of indentation hardness by means of a durometer (Shore hardness)*. 2003.

[6] EN ISO 306. *Plastics - Thermoplastic materials - Determination of Vicat softening temperature (VST)*. 2014.

[7] EN ISO 75-1. *Plastics - Determination of temperature of deflection under load - Part 1: General test method*. 2013.

[8] EN ISO 75-2. *Plastics - Determination of temperature of deflection under load - Part 2: Plastics and ebonite*. 2013.

[9] EN ISO 1183-1. *Plastics - Methods for determining the density of non-cellular plastics - Part 1: Immersion method, liquid pyknometer method and titration method*. 2019.

[10] EN ISO 11357-1. *Plastics - Differential scanning calorimetry (DSC) - Part 1: General principles*. 2017.

[11] EN ISO 11357-3. *Plastics - Differential scanning calorimetry (DSC) - Part 3: Determination of temperature and enthalpy of melting and crystallization*. 2018.

[12] EN ISO 1133-1. *Plastics - Determination of the melt mass-flow rate (MFR) and melt volume-flow rate (MVR) of thermoplastics - Part 1: Standard method*. 2012.

[13] EN ISO 1628-1. *Plastics - Determination of the viscosity of polymers in dilute solution using capillary viscometers - Part 1: General principles*. 2009.

[14] EN ISO 1628-5. *Plastics - Determination of the viscosity of polymers in dilute solution using capillary viscometers - Part 5: Thermoplastic polyester (TP) homopolymers and copolymers*. 2015.

[15] EN ISO 11358-1. *Plastics - Thermogravimetry (TG) of polymers - Part 1: General principles*. 2014.

[16] ISO 3795. *Road vehicles and tractors and machinery for agriculture and foresty. Determination of burning behaviour of interior materials*. 1994.

[17] ISO 5725-2. *Accuracy (trueness and precision) of measurement methods and results - Part 2: Basic method for the determination of repeatability and reproducibility of a standard measurement method*. 1997.

[18] ISO 13 528. *Statistical methods for use in proficiency testing by interlaboratory comparisons*. 2005.

[19] EN ISO/IEC 17043. *Conformity assessment - General requirements for proficiency testing*. 2010.

1 Appendix – EN ISO 527-1, 2 (Tensile modulus)

1.1 Sample A

1.1.1 Test results

Table 4: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
2b1f9a	1688	1364	1385	1445	1510	194	1478	130.2	8.81
689728	1867	1684	1859	1792	1694	174	1779	87.2	4.9
7189e1	1830	1952	1960	1902	1912	104	1911	51.8	2.71
2574f1	1984	1855	1879	2019	1834	164	1914	82.2	4.29
b98935	1957	1948	1915	1970	1956	34	1949	20.7	1.06

1.1.2 The Numerical Procedure for Determining Outliers

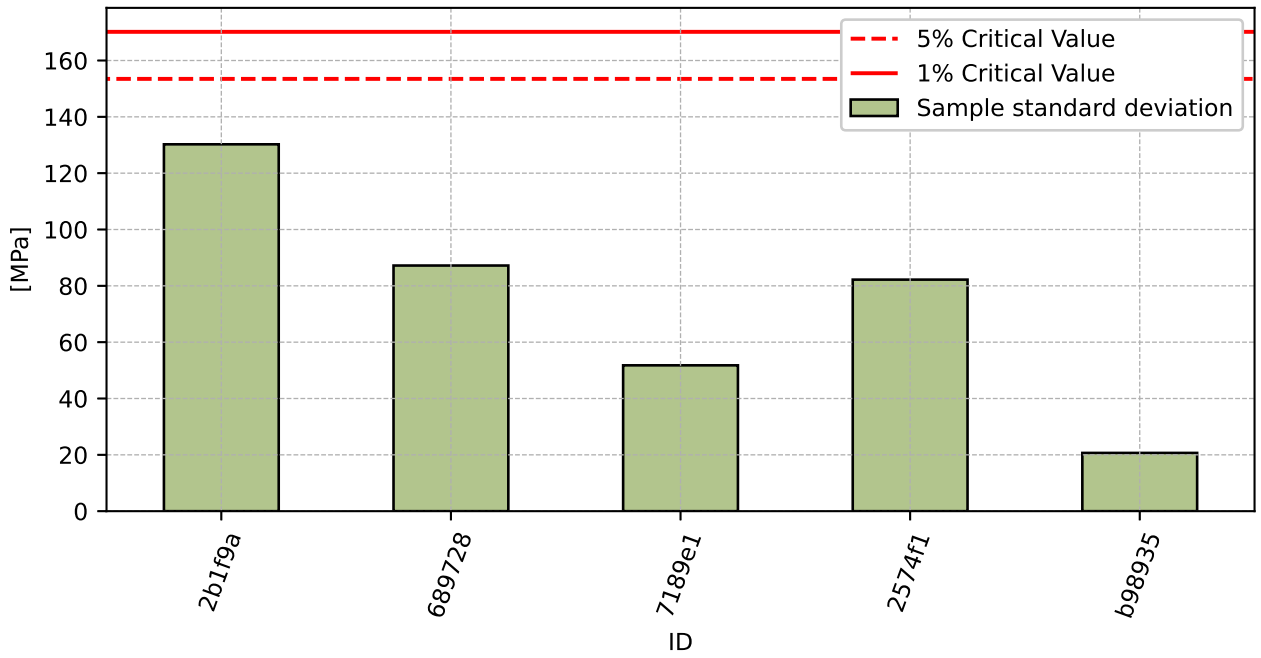

Figure 1: **Cochran's test** - sample standard deviations

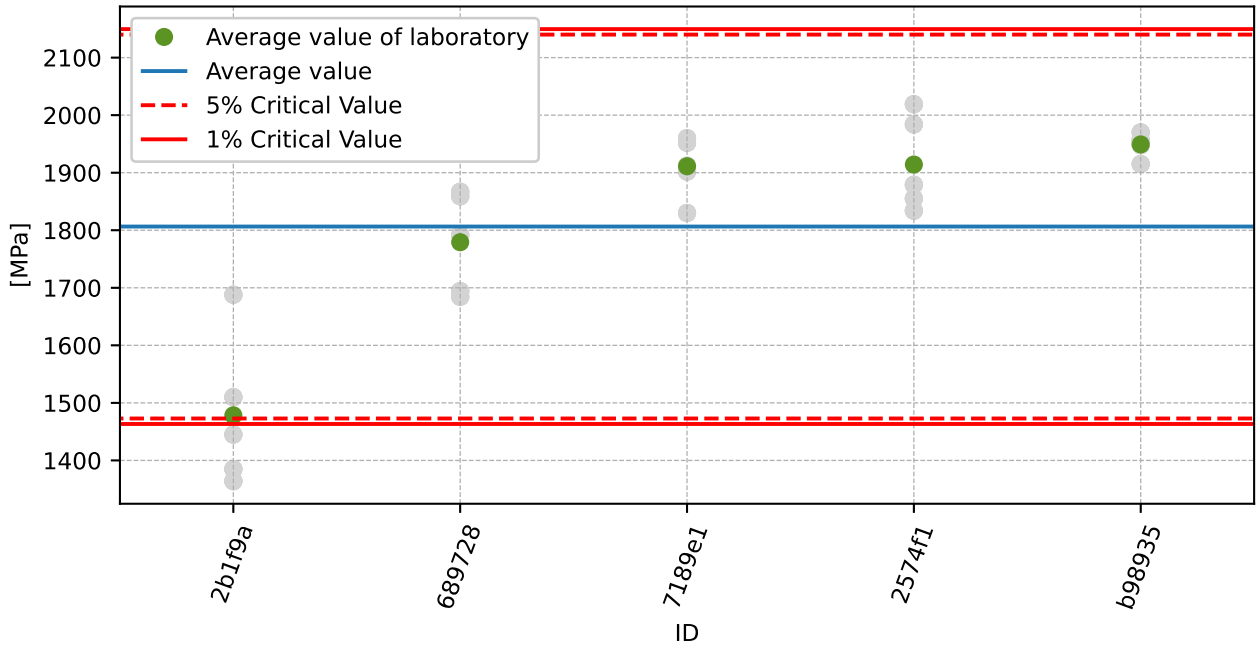

Figure 2: **Grubbs' test** - average values

1.1.3 Mandel's Statistics

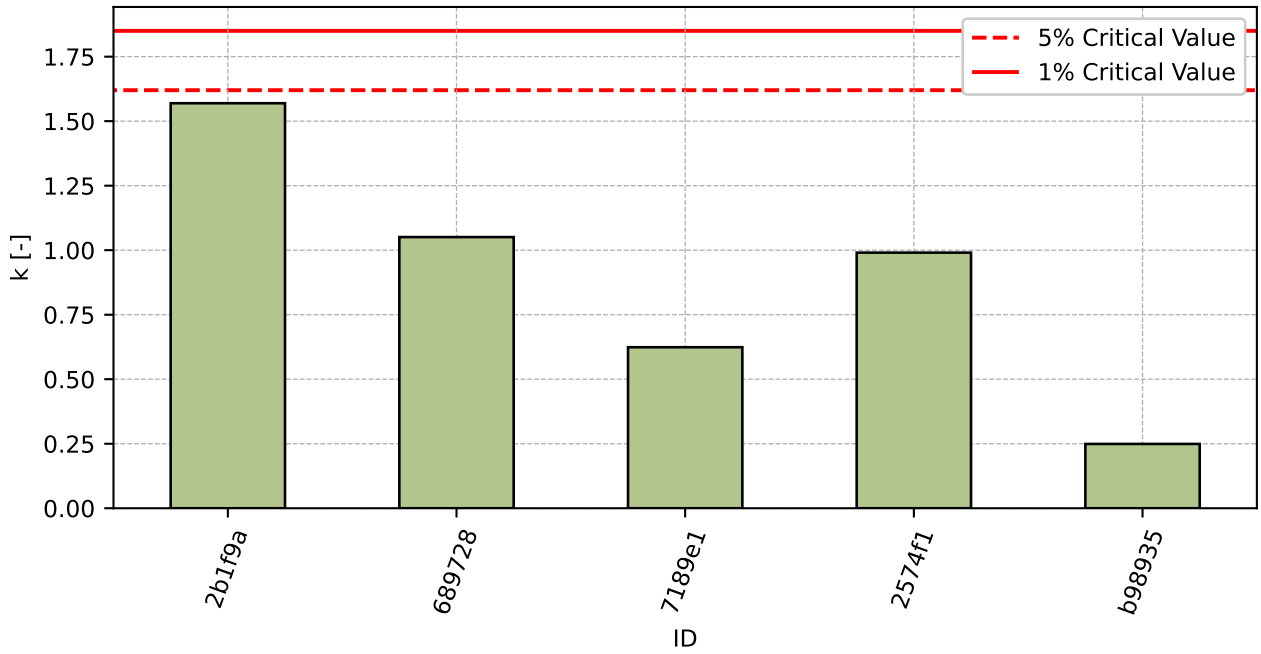

Figure 3: Intralaboratory Consistency Statistic

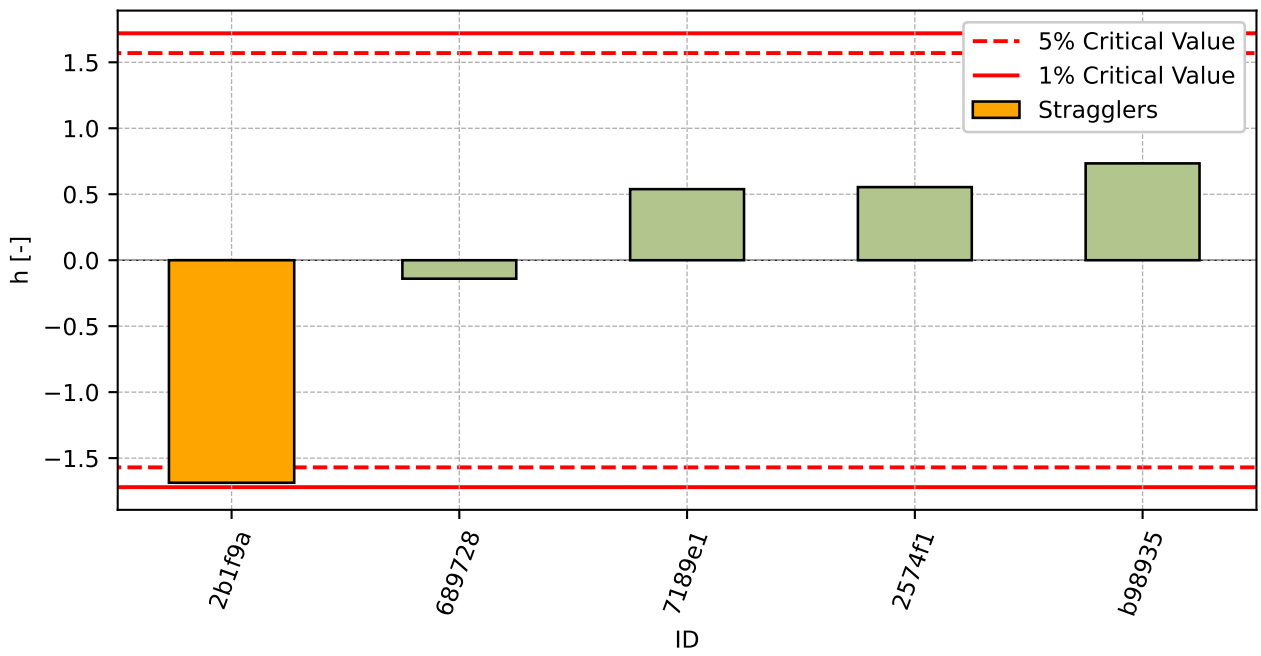

Figure 4: Interlaboratory Consistency Statistic

1.1.4 Descriptive statistics

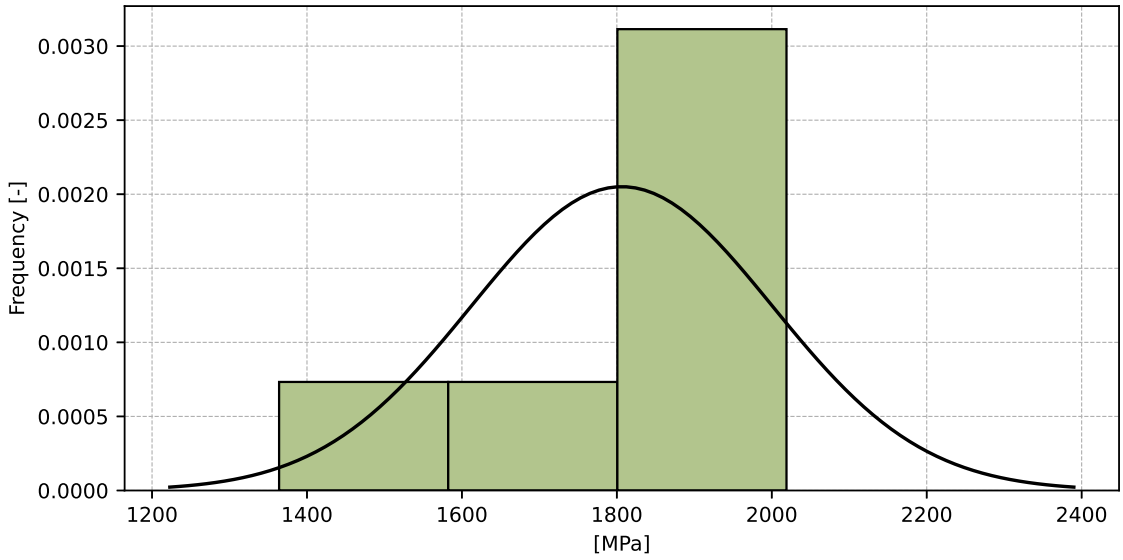

Figure 5: Histogram of all test results

Table 5: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	1806
Sample standard deviation – s	194.5
Asigned value – x^*	1847
Robust standard deviation – s^*	135.0
Measurement uncertainty of asigned value – u_X	1 185.0 Name: horn, dtype: float64
p-value of normality test	0.001 [-]
Interlaboratory standard deviation – s_L	190.9
Repeatability standard deviation – s_r	83.0
Reproducibility standard deviation – s_R	208.2
Repeatability – r	232
Reproducibility – R	583

1.1.5 Evaluation of Performance Statistics

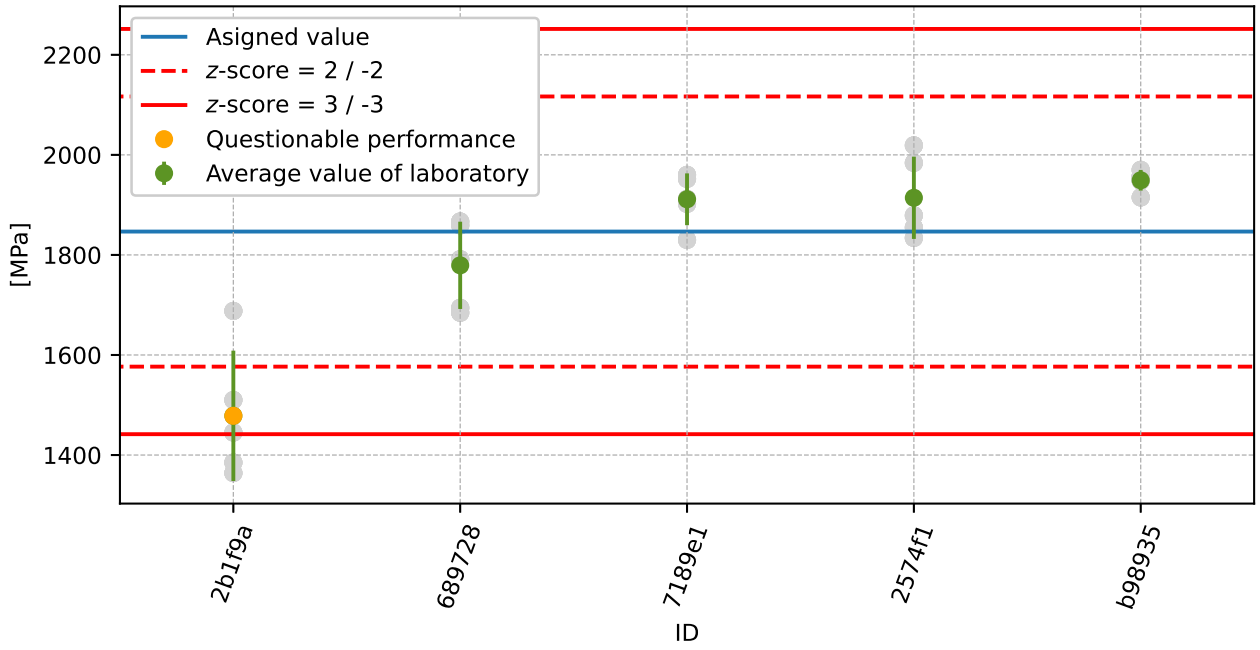

Figure 6: Average values and sample standard deviations

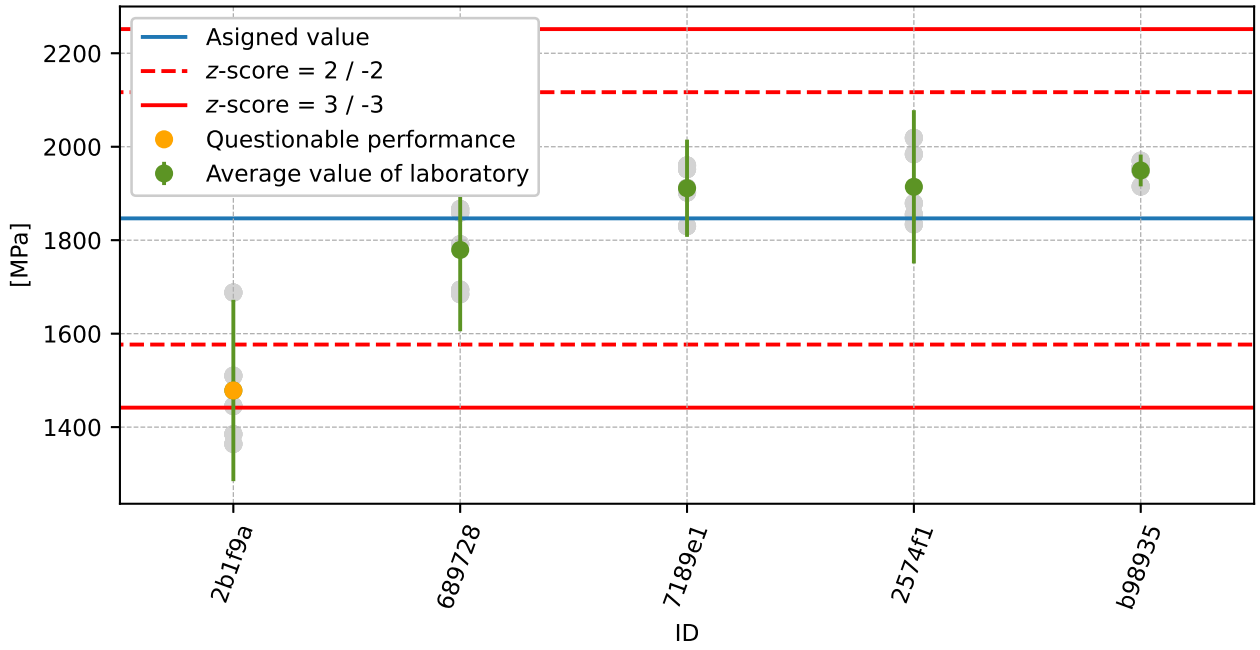

Figure 7: Average values and extended uncertainties of measurement

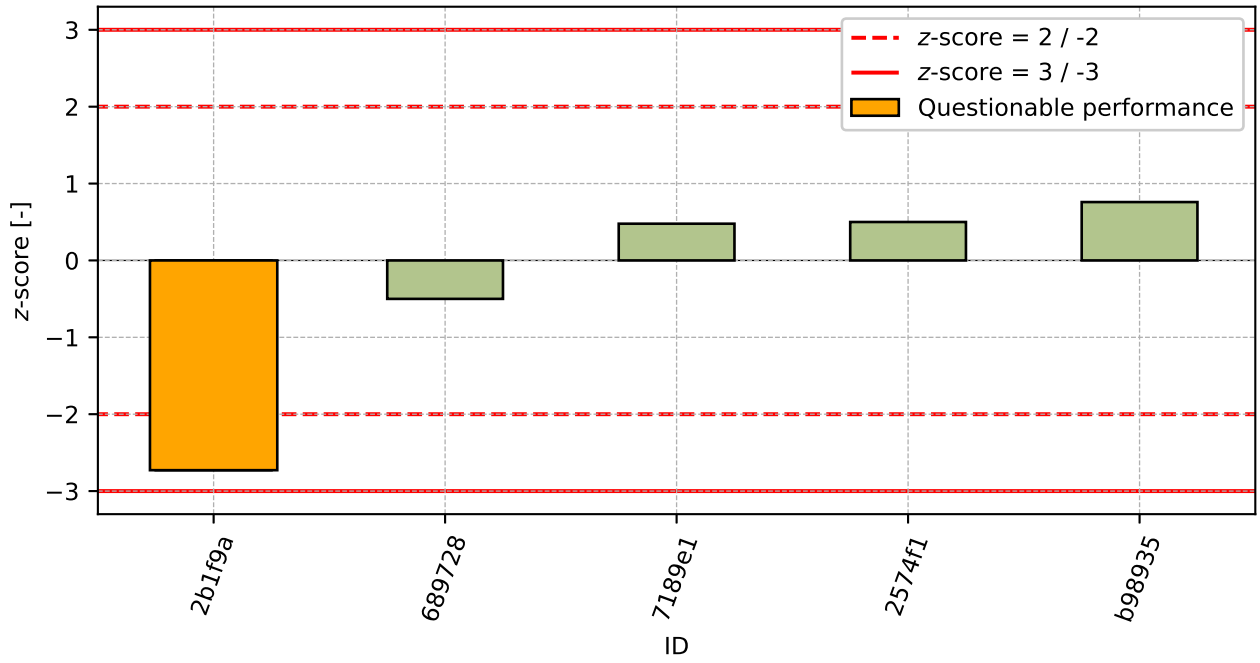

Figure 8: z-score

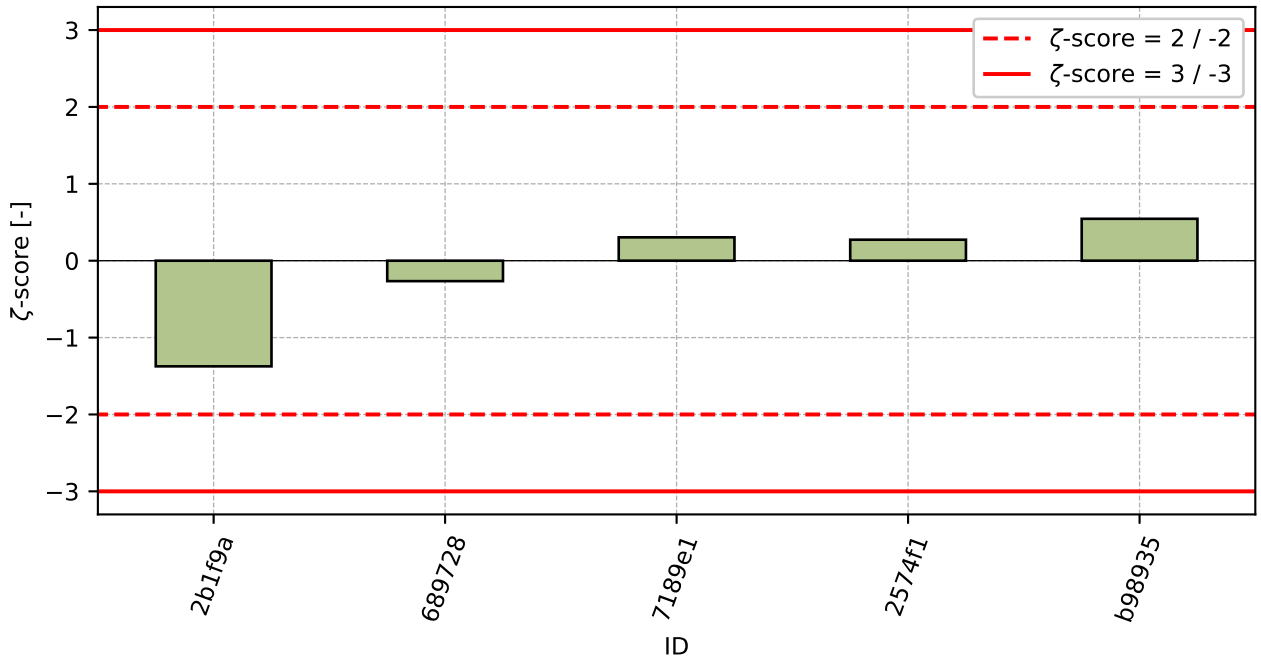

Figure 9: ζ-score

Table 6: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2b1f9a	-2.73	-1.37
689728	-0.5	-0.27
7189e1	0.48	0.3
2574f1	0.5	0.27
b98935	0.76	0.55

1.2 Sample B

1.2.1 Test results

Table 7: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
2b1f9a	810	1103	1239	1070	919	234	1028	166.8	16.22
689728	1354	1334	1560	1484	1344	203	1415	101.6	7.18
b98935	1526	1481	1513	1503	1496	29	1504	17.0	1.13
7189e1	1534	1513	1579	1571	1606	74	1561	37.0	2.37
2574f1	1605	1537	1589	1682	1612	104	1605	52.1	3.25

1.2.2 The Numerical Procedure for Determining Outliers

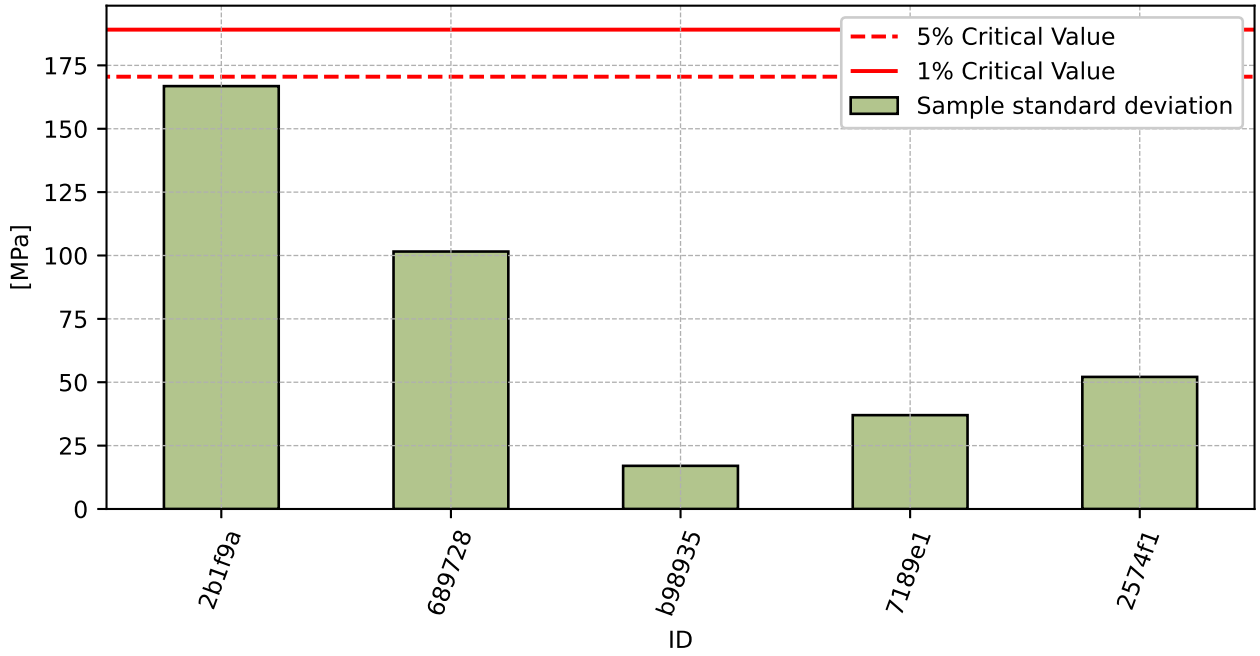

Figure 10: **Cochran's test** - sample standard deviations

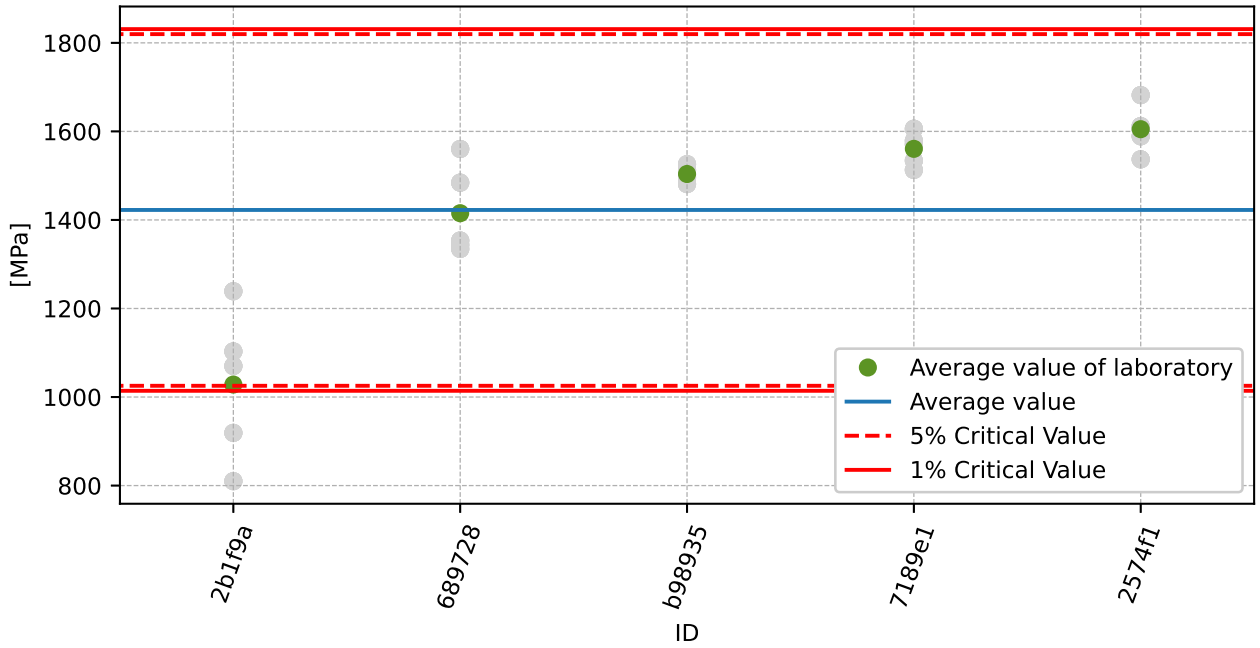

Figure 11: **Grubbs' test** - average values

1.2.3 Mandel's Statistics

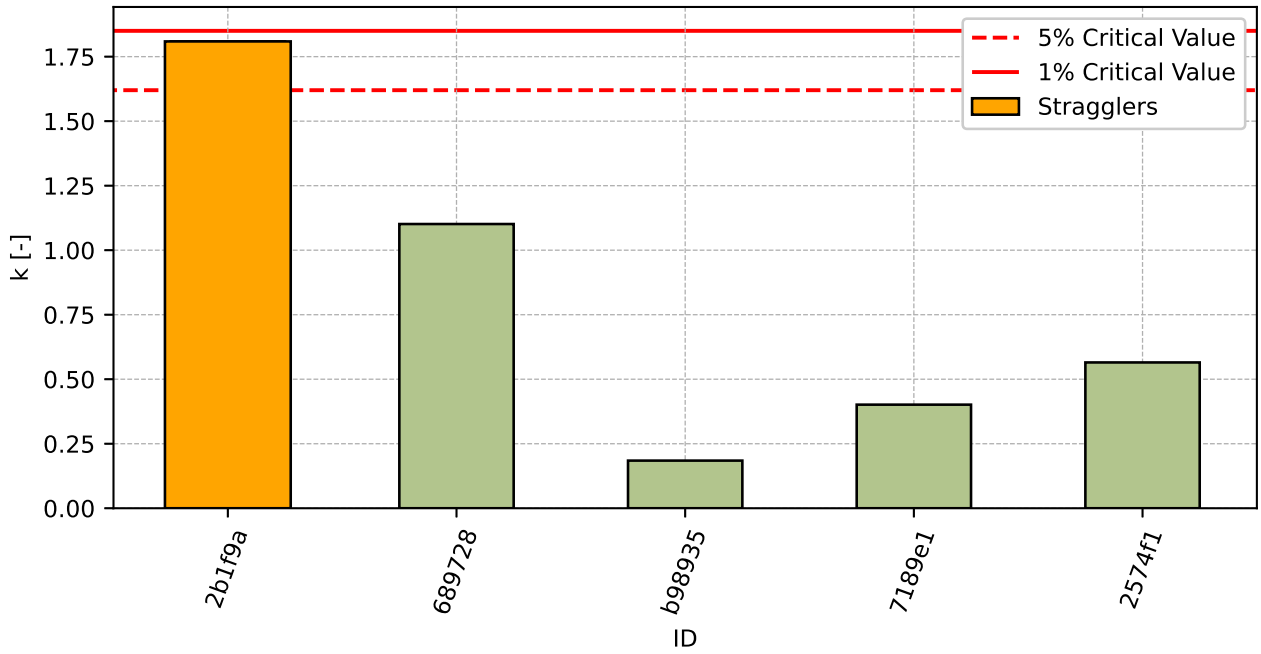

Figure 12: Intralaboratory Consistency Statistic

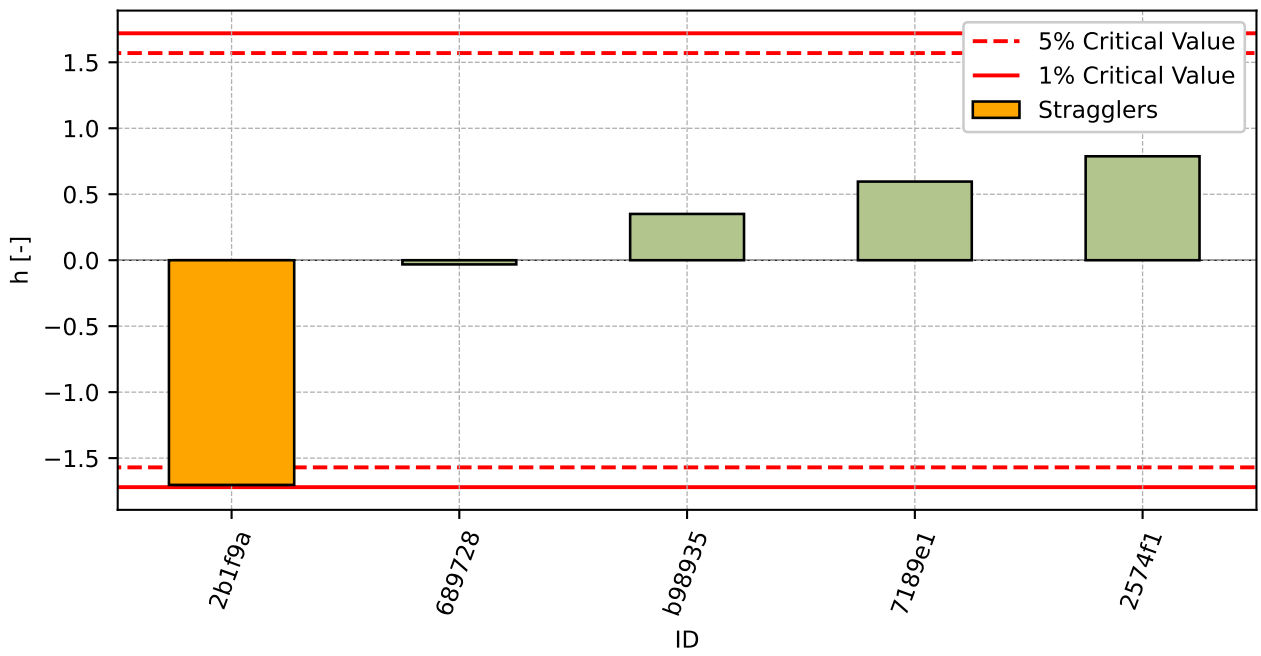

Figure 13: Interlaboratory Consistency Statistic

1.2.4 Descriptive statistics

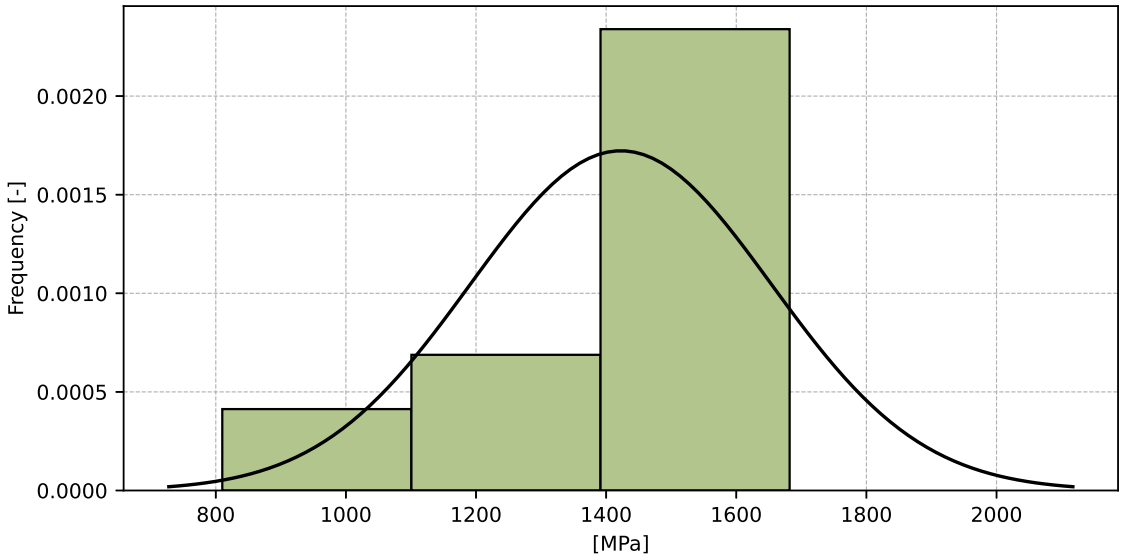

Figure 14: Histogram of all test results

Table 8: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	1423
Sample standard deviation – s	231.6
Asigned value – x^*	1488
Robust standard deviation – s^*	145.4
Measurement uncertainty of asigned value – u_X	199.2
p-value of normality test	0.0 [-]
Interlaboratory standard deviation – s_L	227.9
Repeatability standard deviation – s_r	92.2
Reproducibility standard deviation – s_R	245.8
Repeatability – r	258
Reproducibility – R	688

1.2.5 Evaluation of Performance Statistics

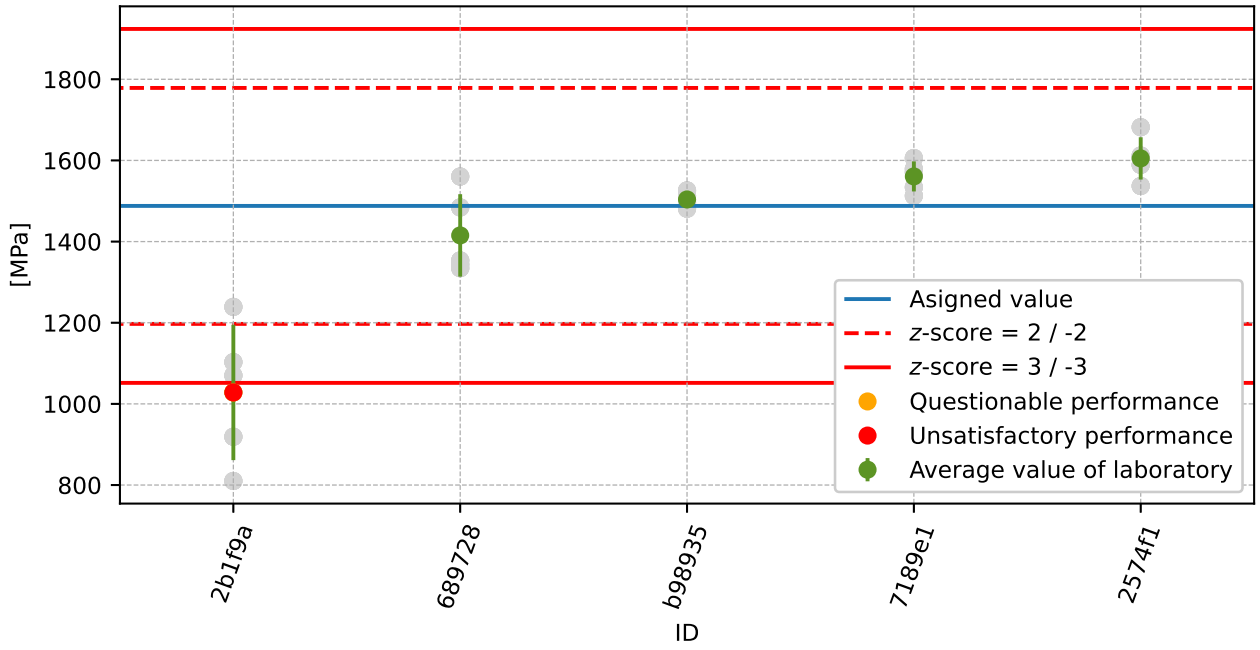

Figure 15: Average values and sample standard deviations

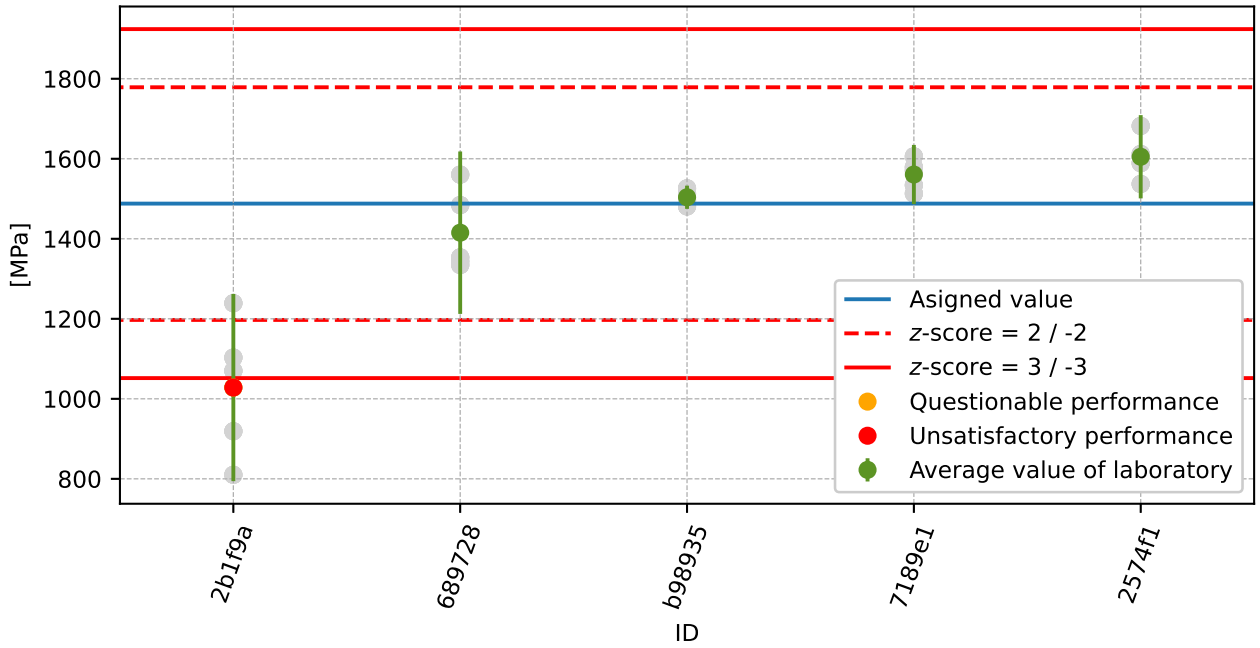

Figure 16: Average values and extended uncertainties of measurement

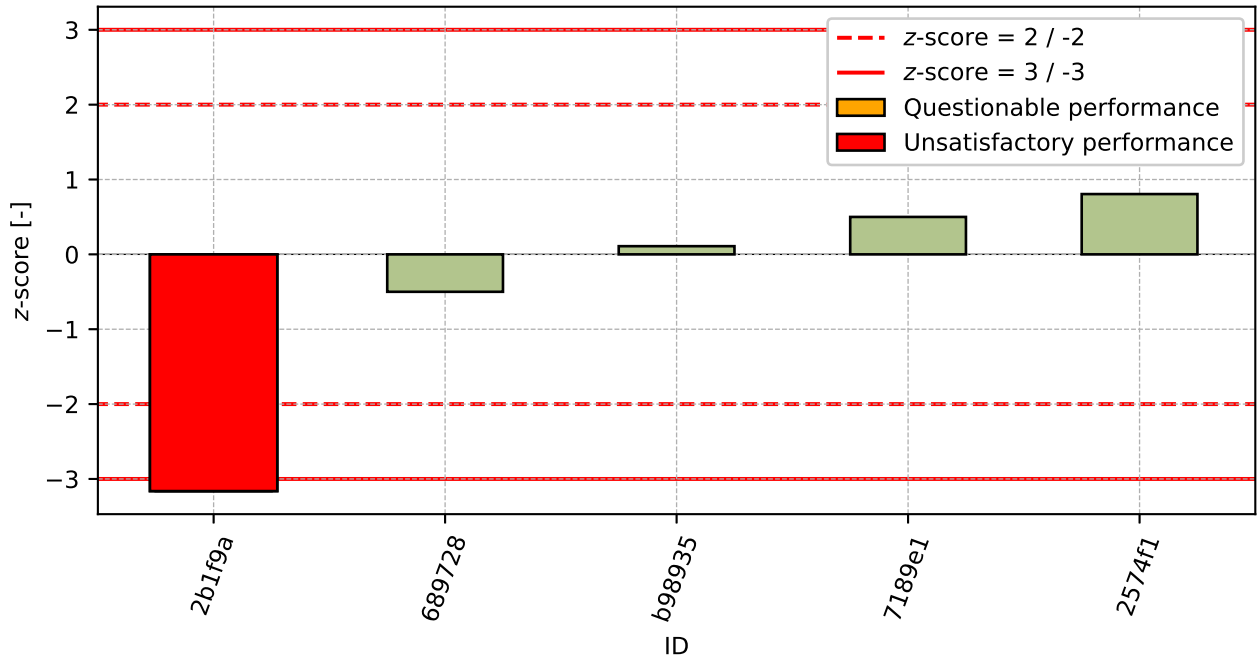

Figure 17: z-score

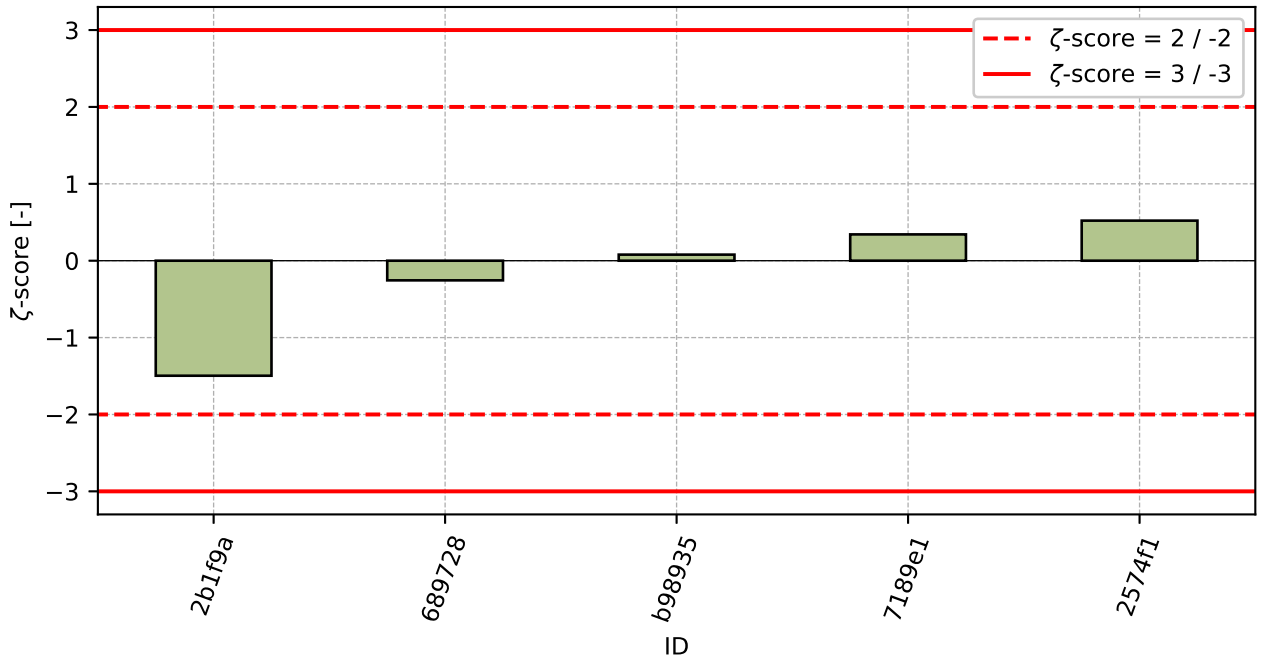

Figure 18: ζ-score

Table 9: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2b1f9a	-3.16	-1.5
689728	-0.5	-0.26
b98935	0.11	0.08
7189e1	0.5	0.34
2574f1	0.81	0.52

2 Appendix – EN ISO 527-1, 2 (Stress at yield, Strain at yield)

2.1 Sample A

2.1.1 Stress at yield

Test results

Table 10: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
689728	39.0	39.1	39.0	39.0	39.1	0.2	39.0	0.05	0.14
2574f1	39.4	39.2	39.6	39.5	39.6	0.4	39.5	0.17	0.42
b98935	39.2	39.7	39.8	39.4	39.3	0.5	39.5	0.26	0.66
7189e1	39.2	39.6	39.5	39.7	39.6	0.5	39.5	0.21	0.53
2b1f9a	41.1	42.6	39.9	39.8	40.4	1.5	40.8	1.15	2.82

The Numerical Procedure for Determining Outliers

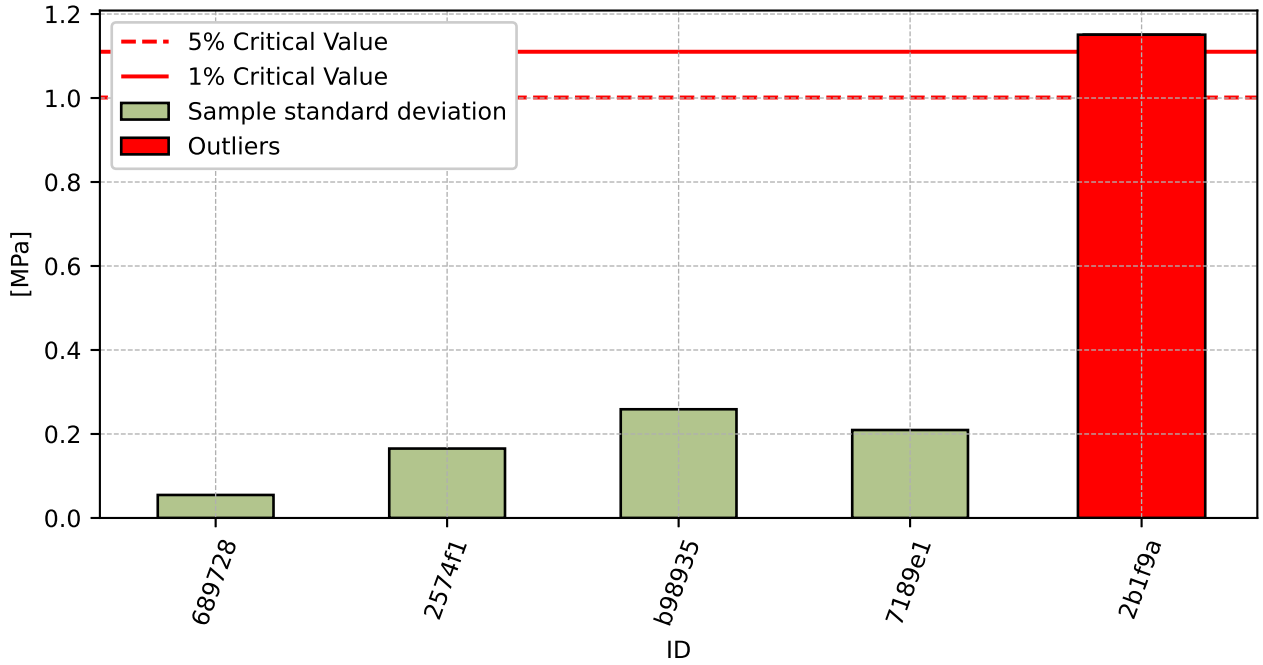

Figure 19: **Cochran's test** - sample standard deviations

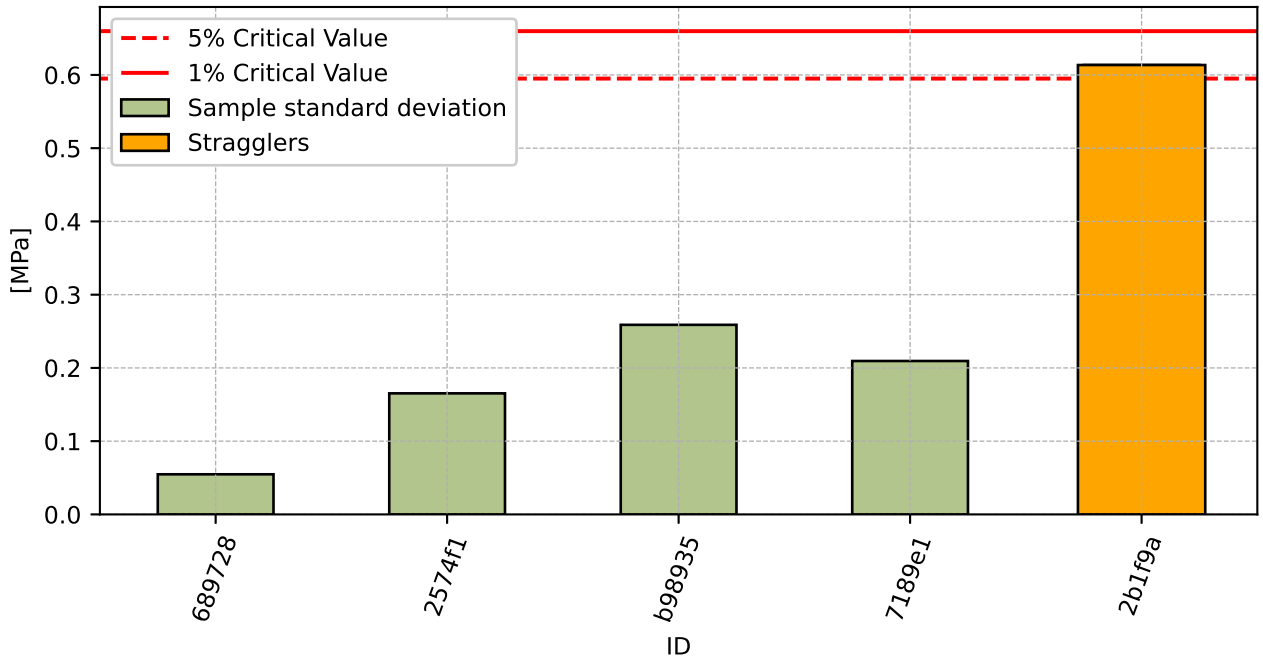

Figure 20: **Cochran's test** - sample standard deviations without outliers

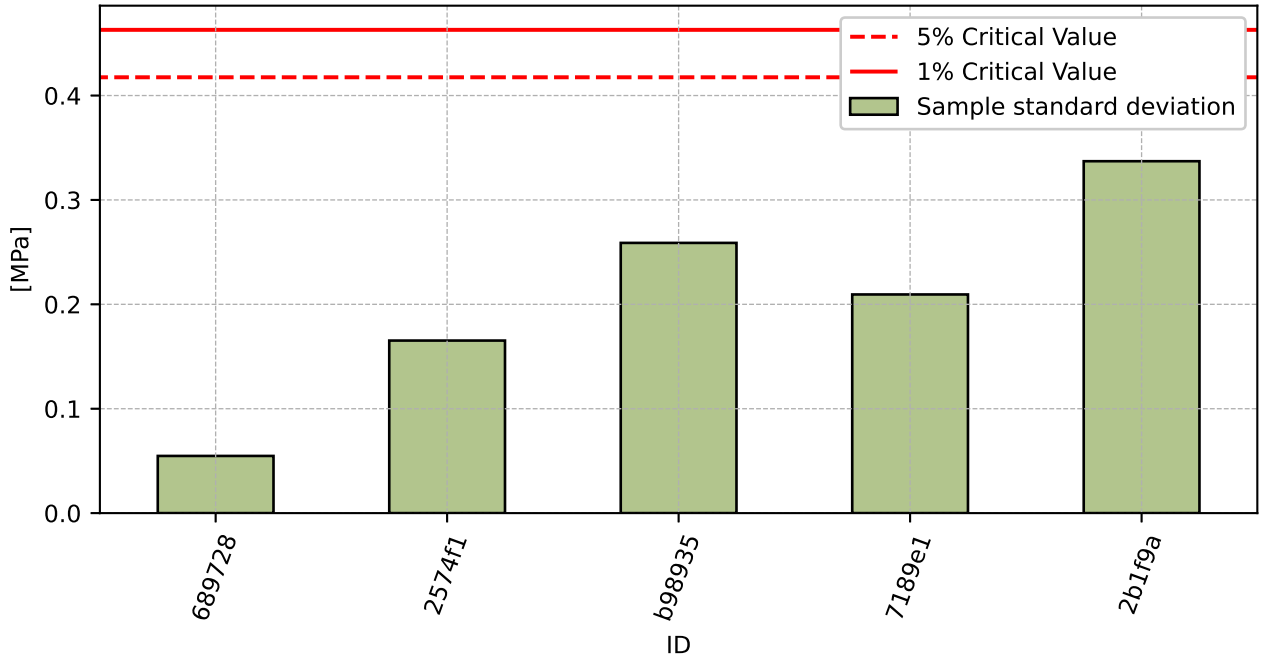

Figure 21: **Cochran's test** - sample standard deviations without outliers

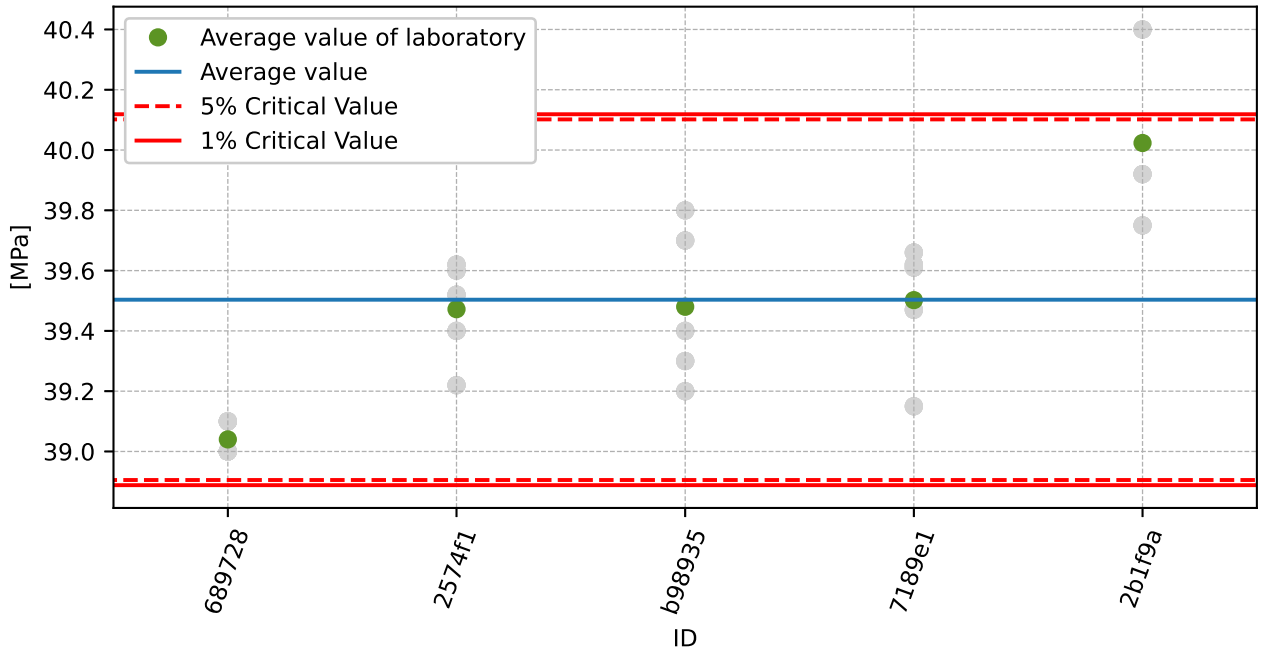

Figure 22: **Grubbs' test** - average values

Mandel's Statistics

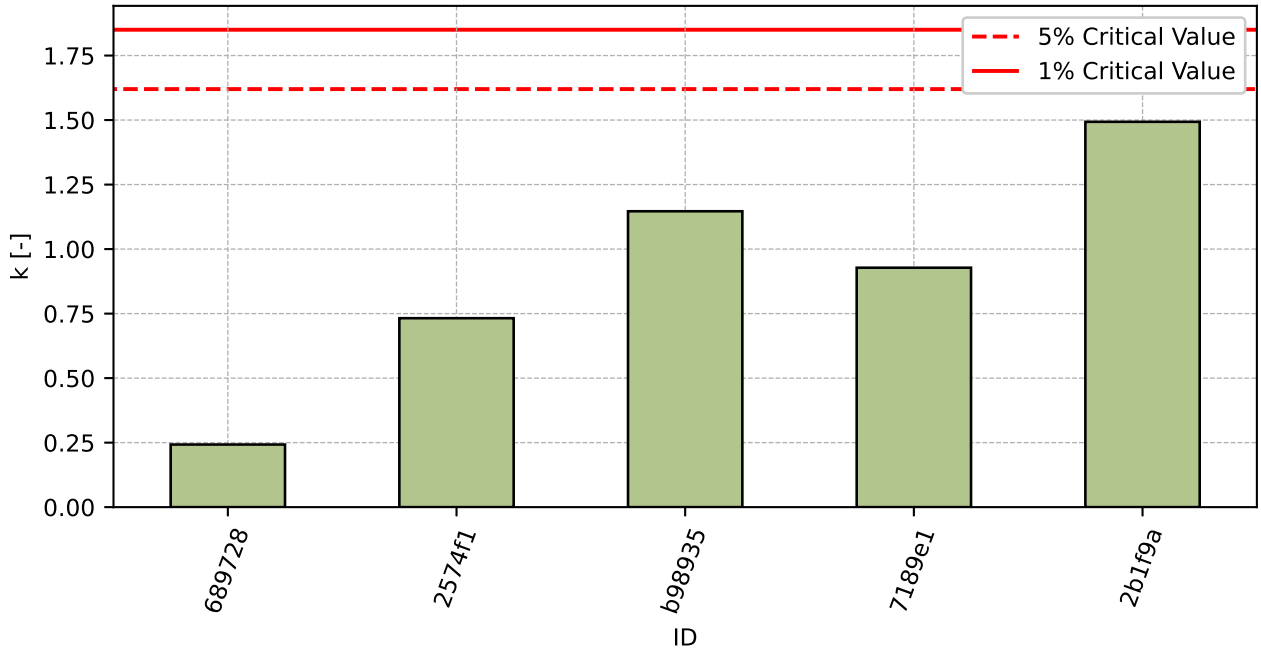

Figure 23: Intralaboratory Consistency Statistic

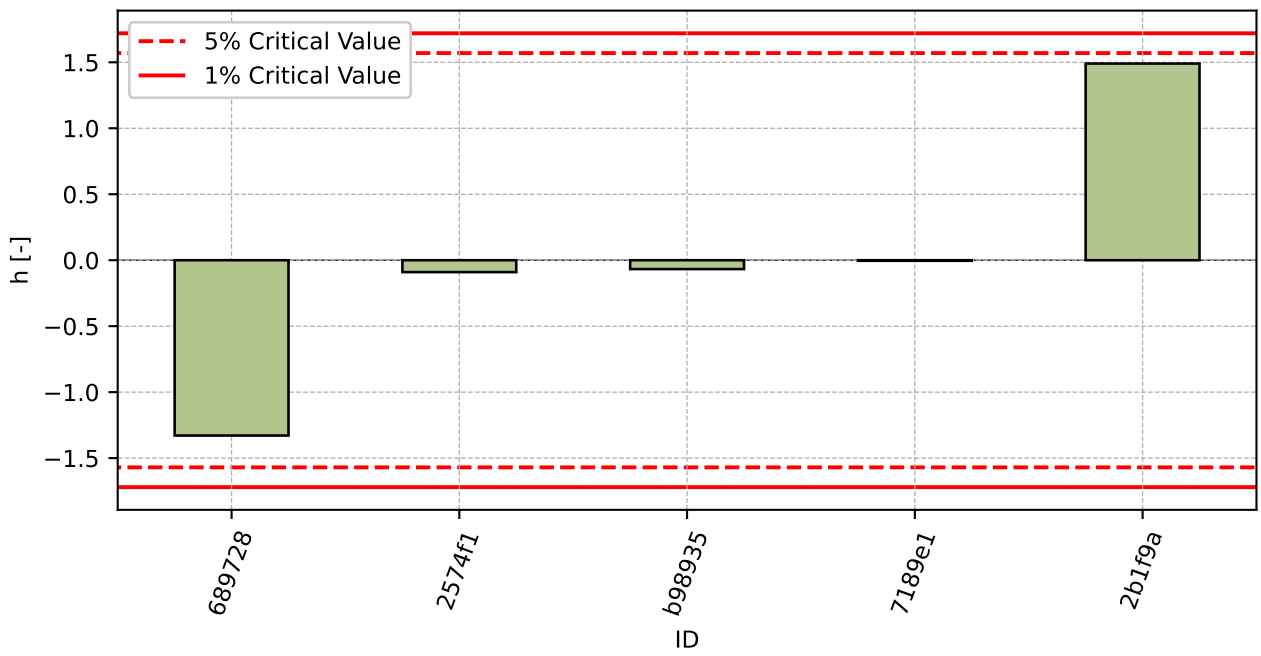

Figure 24: Interlaboratory Consistency Statistic

Descriptive statistics

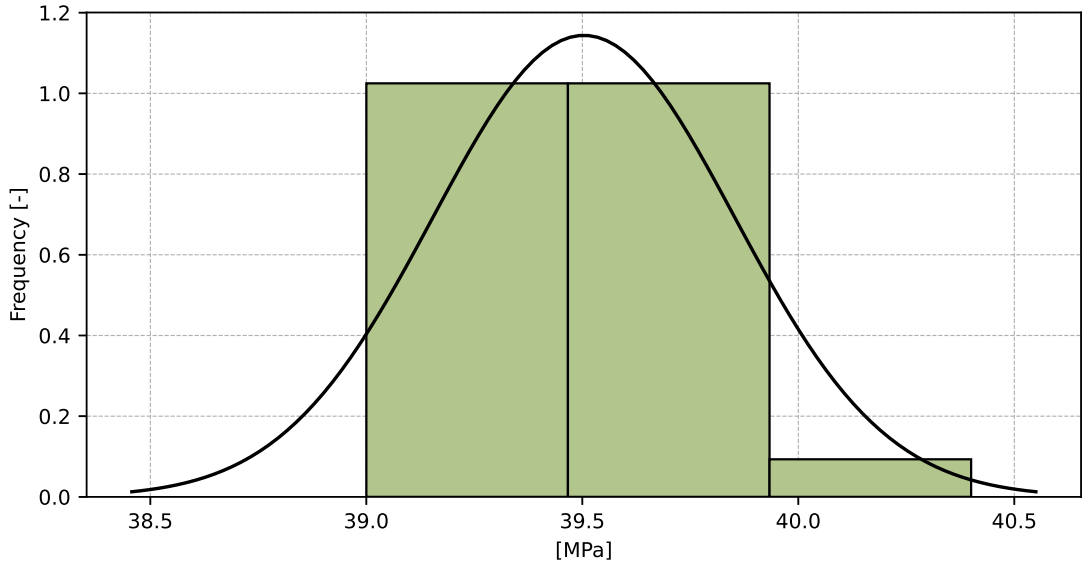

Figure 25: Histogram of all test results

Table 11: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	39.5
Sample standard deviation – s	0.35
Asigned value – x^*	39.5
Robust standard deviation – s^*	0.35
Measurement uncertainty of asigned value – u_X	0.16
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	0.33
Repeatability standard deviation – s_r	0.23
Reproducibility standard deviation – s_R	0.4
Repeatability – r	0.6
Reproducibility – R	1.1

Evaluation of Performance Statistics

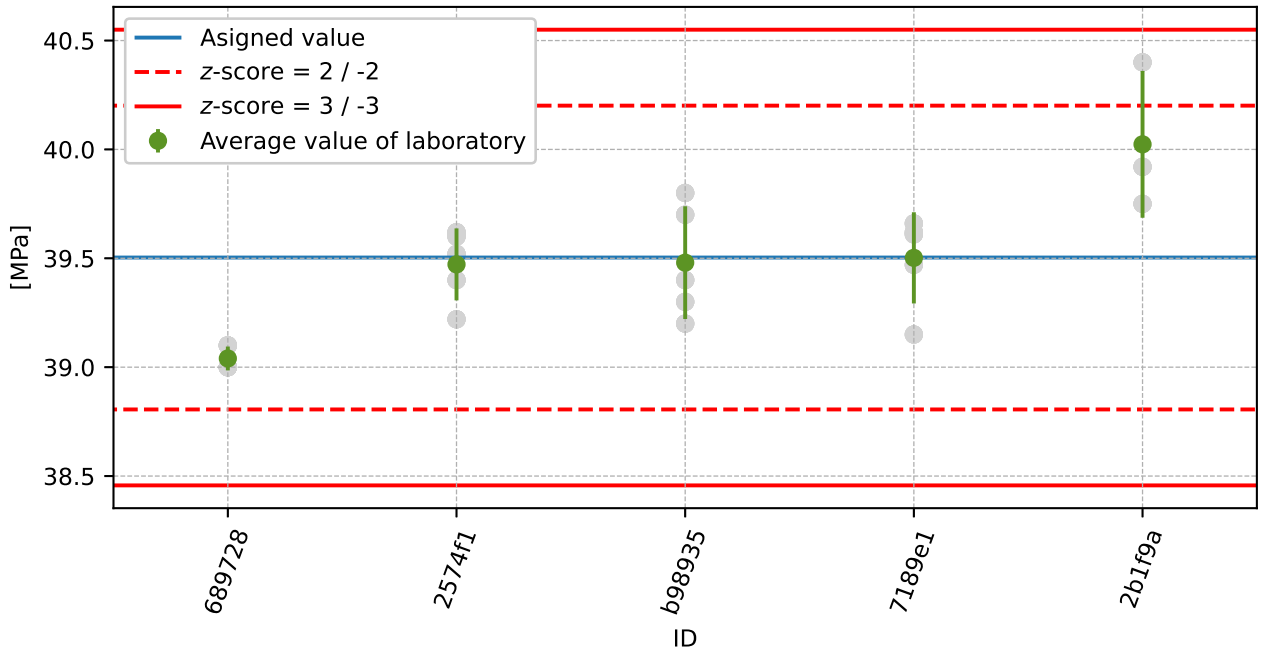

Figure 26: Average values and sample standard deviations

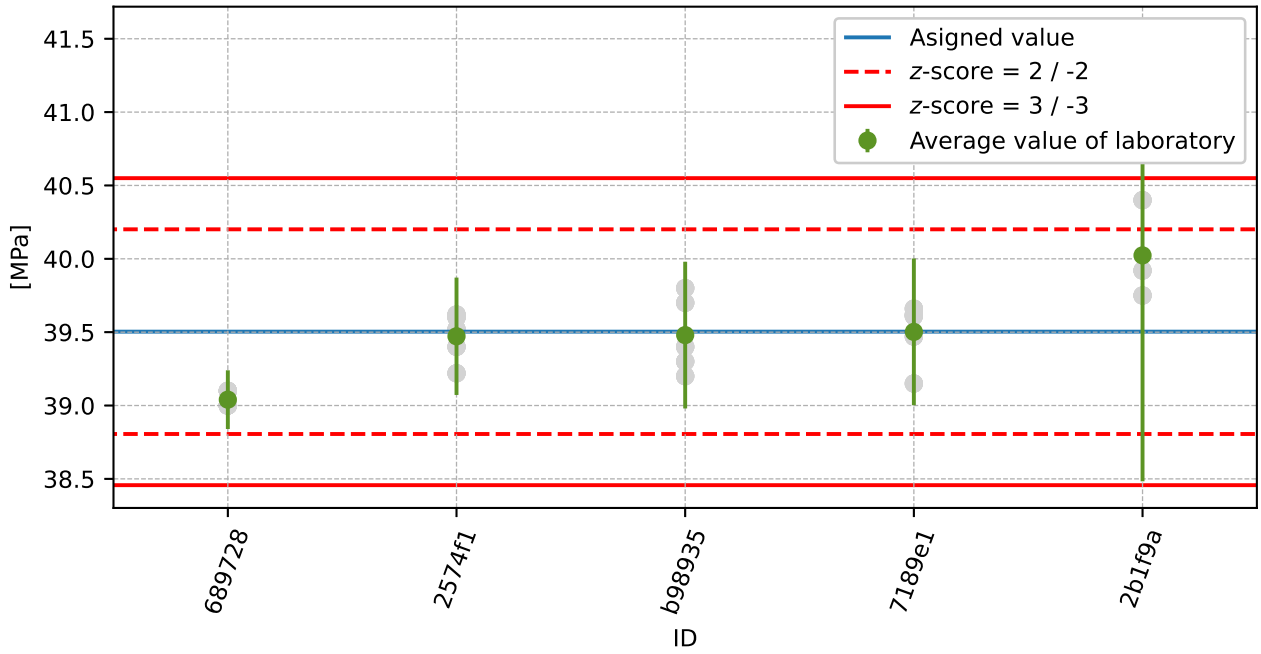

Figure 27: Average values and extended uncertainties of measurement

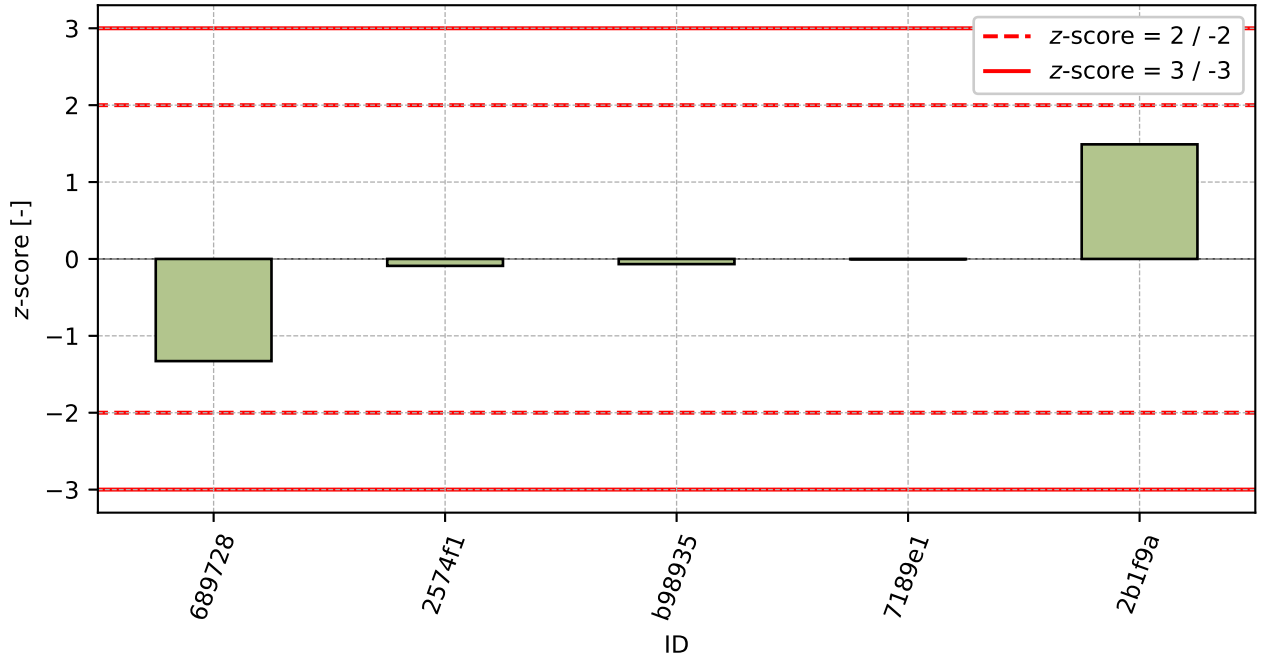

Figure 28: z-score

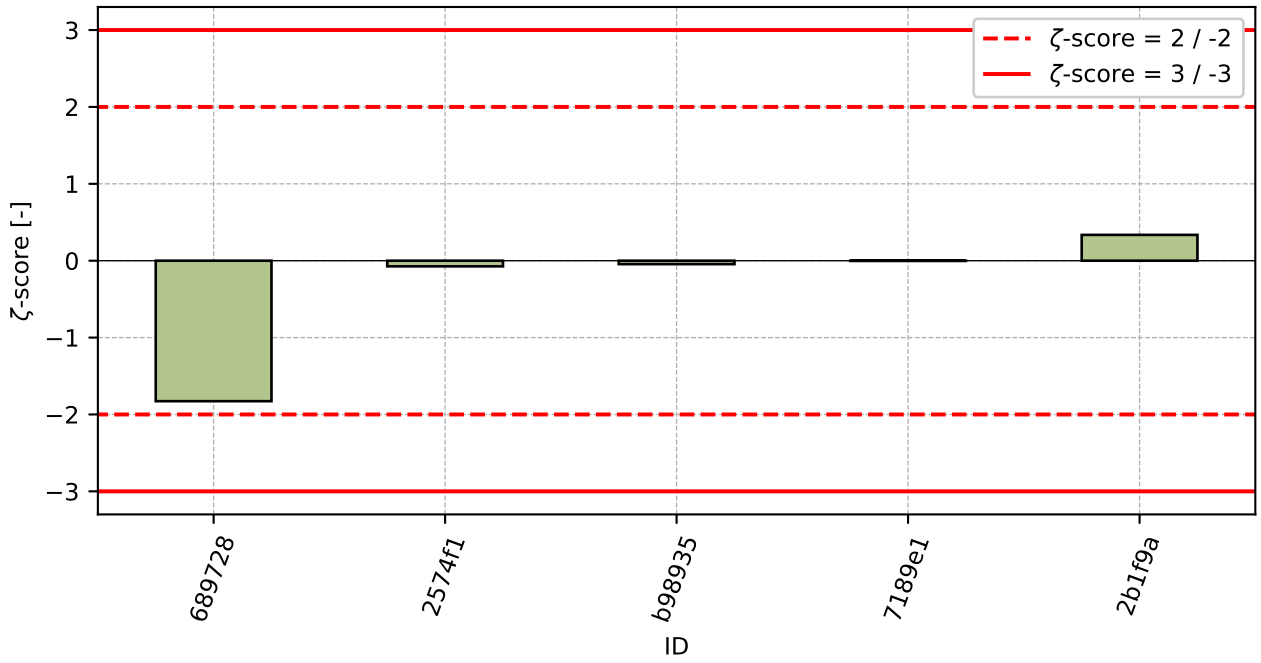

Figure 29: ζ-score

Table 12: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
689728	-1.33	-1.83
2574f1	-0.09	-0.07
b98935	-0.07	-0.04
7189e1	-0.0	-0.0
2b1f9a	1.49	0.34

2.1.2 Strain at yield

Test results

Table 13: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [%]					u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
b98935	6.3	6.3	6.3	6.3	6.3	0.2	6.3	0.0	0.0
2574f1	6.88	6.79	6.74	6.8	6.66	0.2	6.77	0.082	1.22
2b1f9a	6.89	6.96	6.69	6.72	6.76	0.16	6.8	0.116	1.7
7189e1	7.1	6.85	6.74	6.8	6.61	0.36	6.82	0.182	2.67
689728	7.2	6.5	6.6	8.0	6.7	1.24	7.0	0.62	8.86

The Numerical Procedure for Determining Outliers

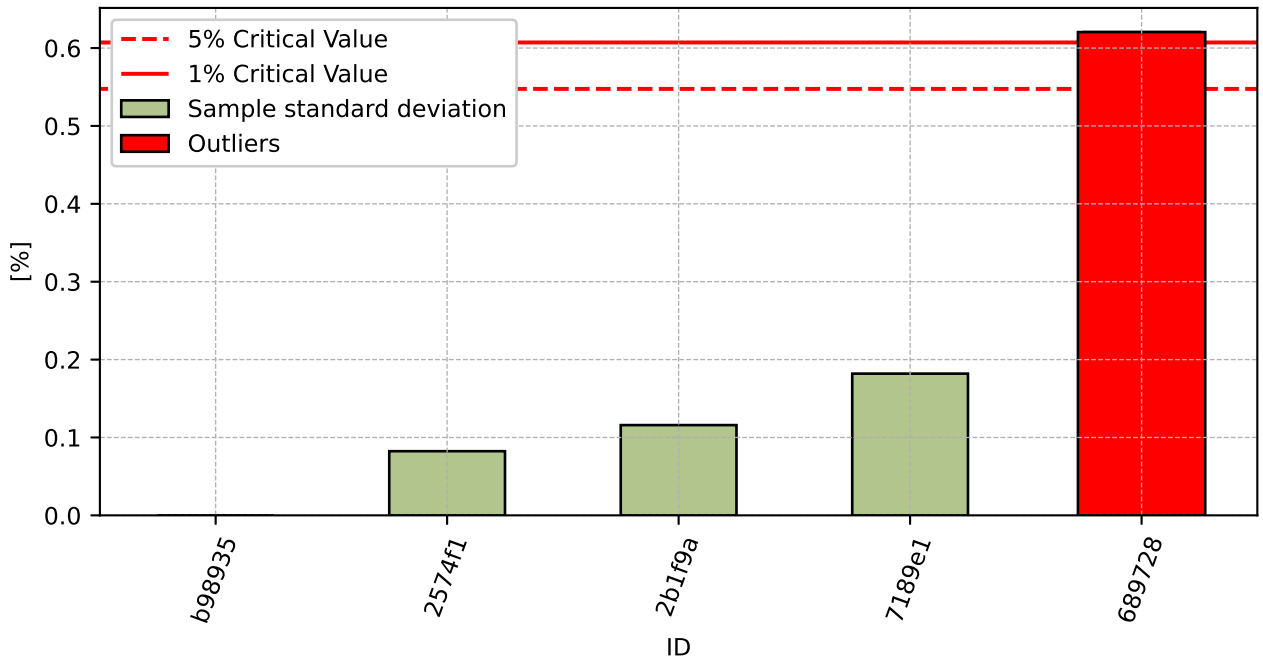

Figure 30: **Cochran's test** - sample standard deviations

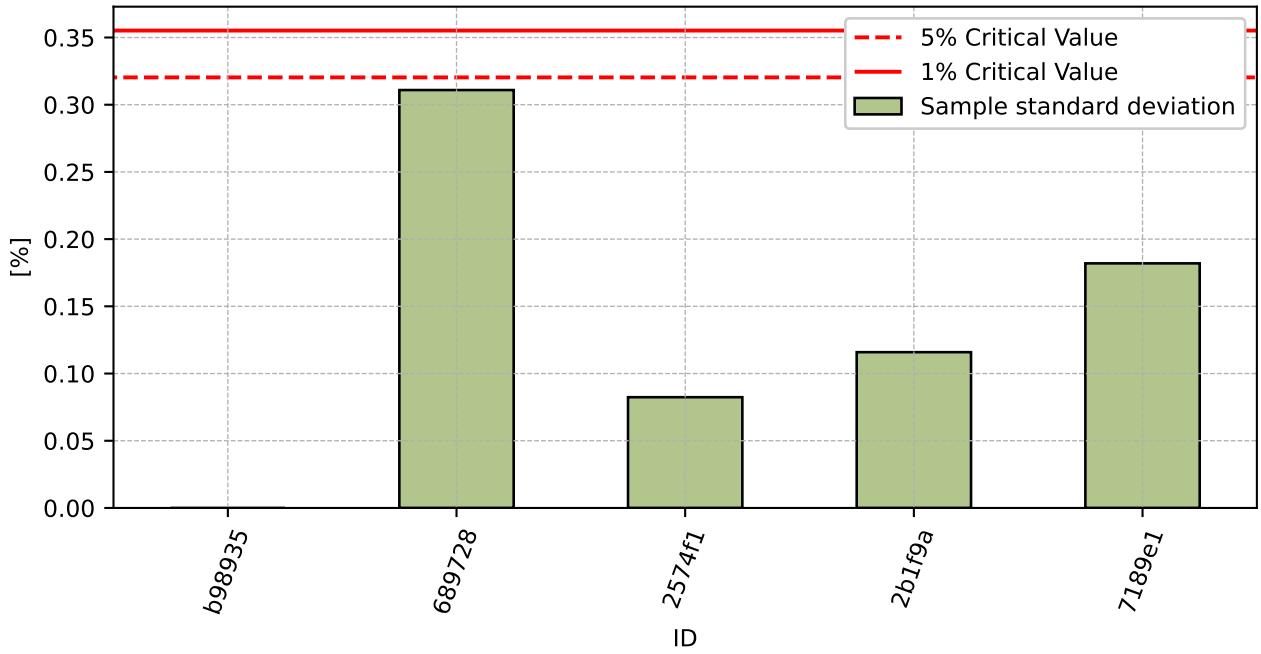

Figure 31: **Cochran's test** - sample standard deviations without outliers

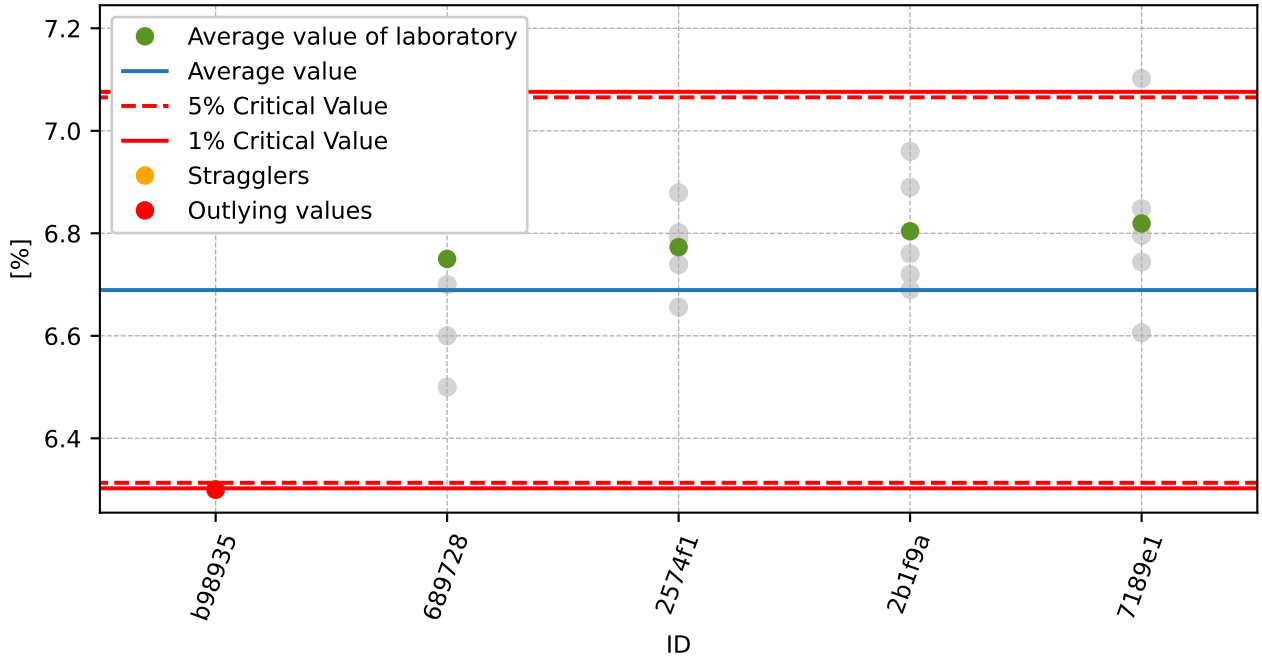

Figure 32: **Grubbs' test** - average values

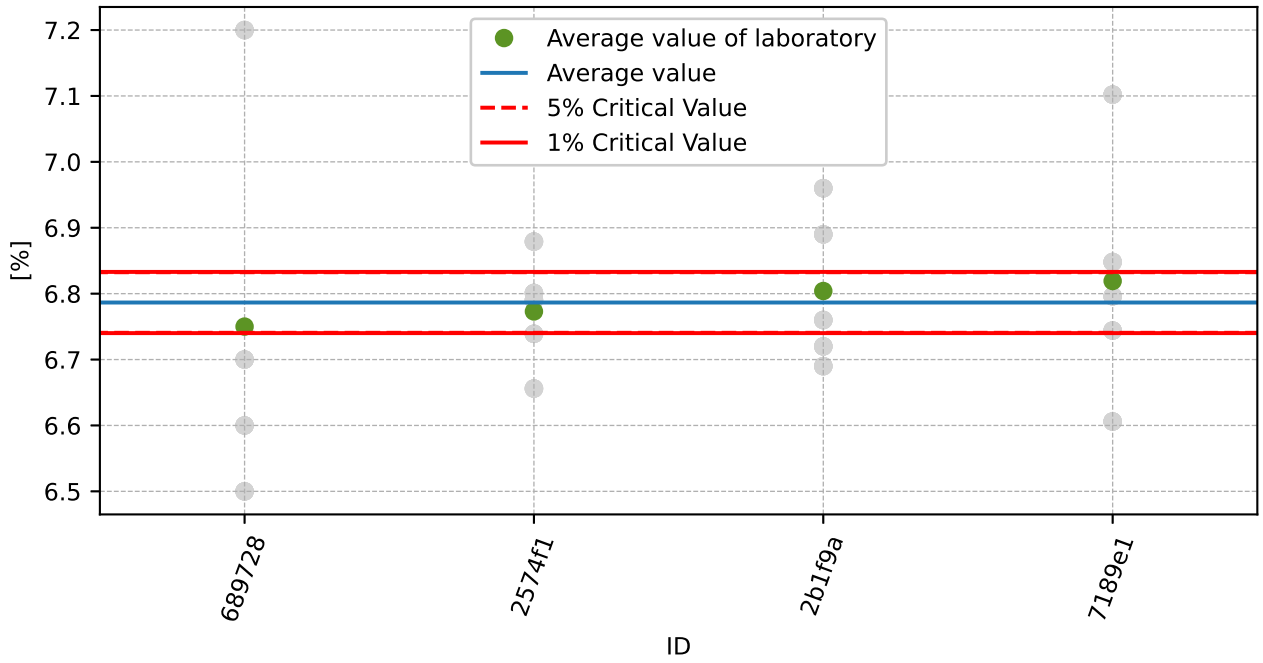

Figure 33: **Grubbs' test** - average values without outliers

Mandel's Statistics

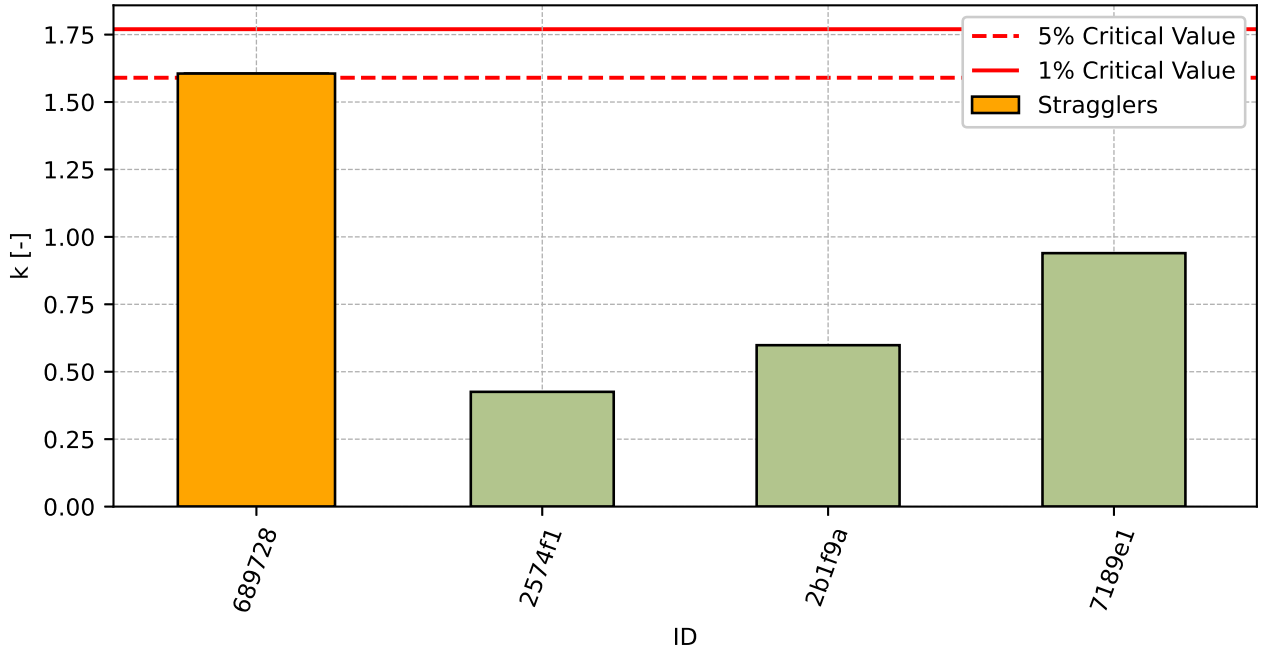

Figure 34: Intralaboratory Consistency Statistic

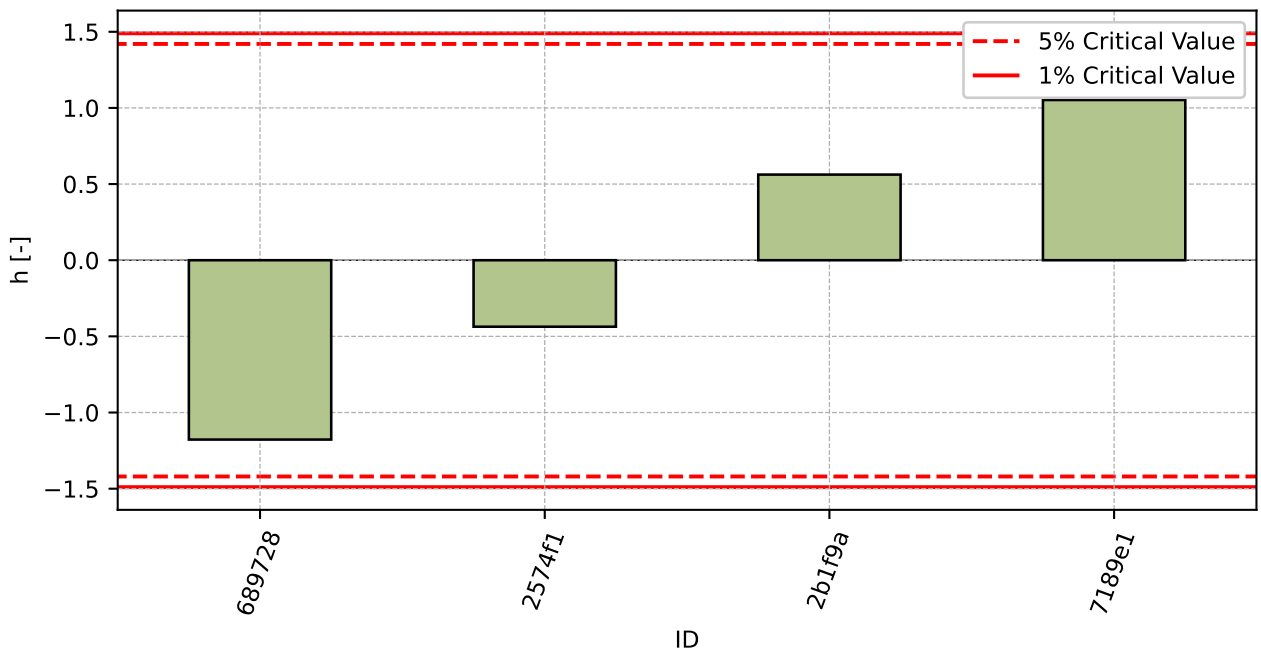

Figure 35: Interlaboratory Consistency Statistic

Descriptive statistics

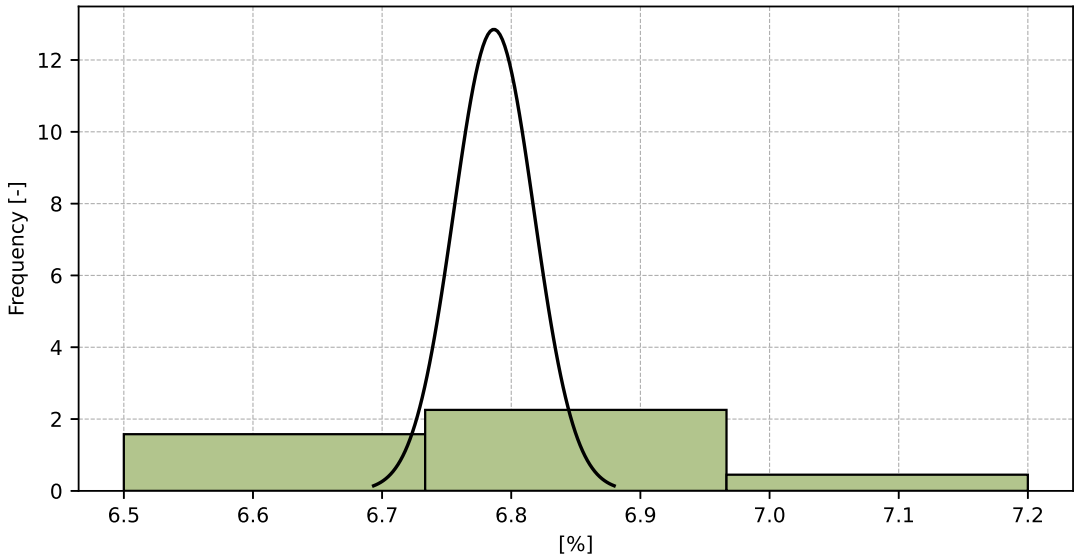

Figure 36: Histogram of all test results

Table 14: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	6.79
Sample standard deviation – s	0.031
Asigned value – x^*	6.78
Robust standard deviation – s^*	0.069
Measurement uncertainty of asigned value – u_X	0.038
p-value of normality test	1.0 [-]
Repeatability standard deviation – s_r	0.194
Repeatability – r	0.54

Evaluation of Performance Statistics

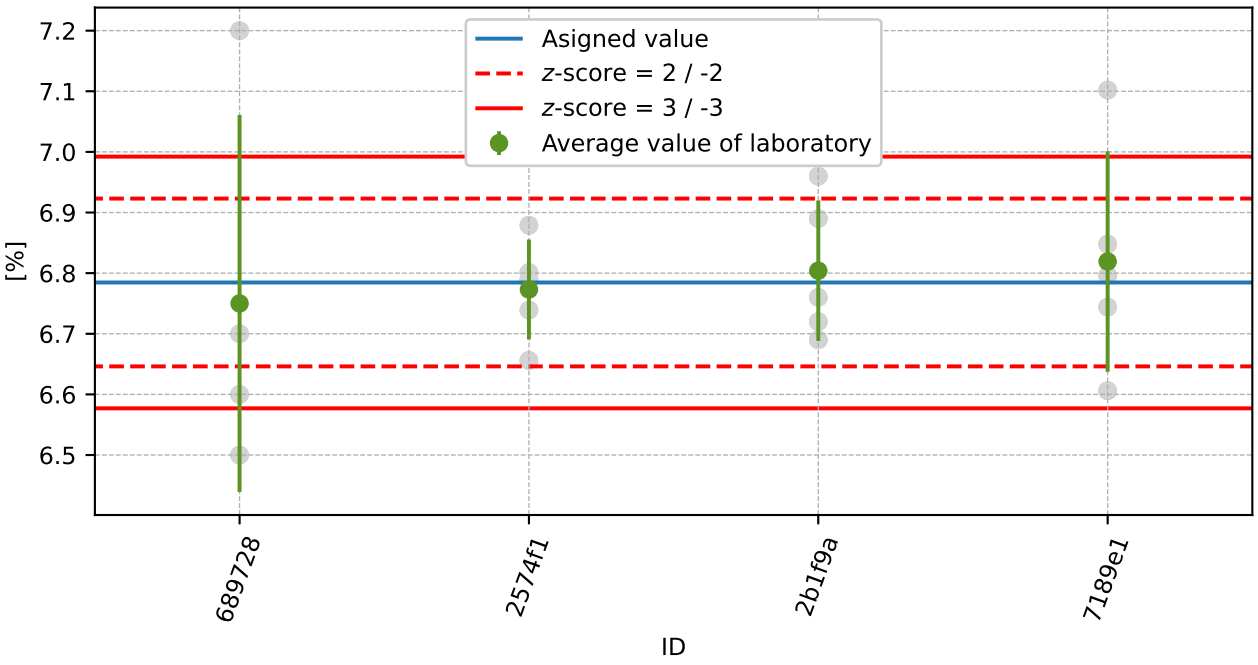

Figure 37: Average values and sample standard deviations

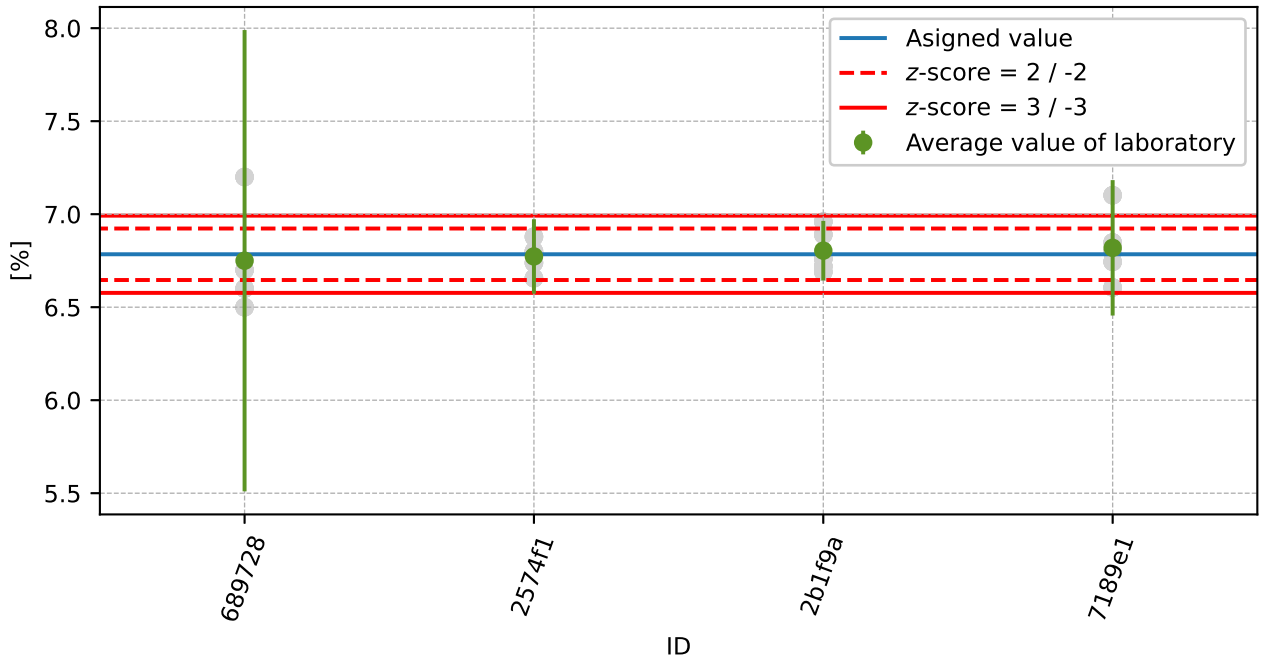

Figure 38: Average values and extended uncertainties of measurement

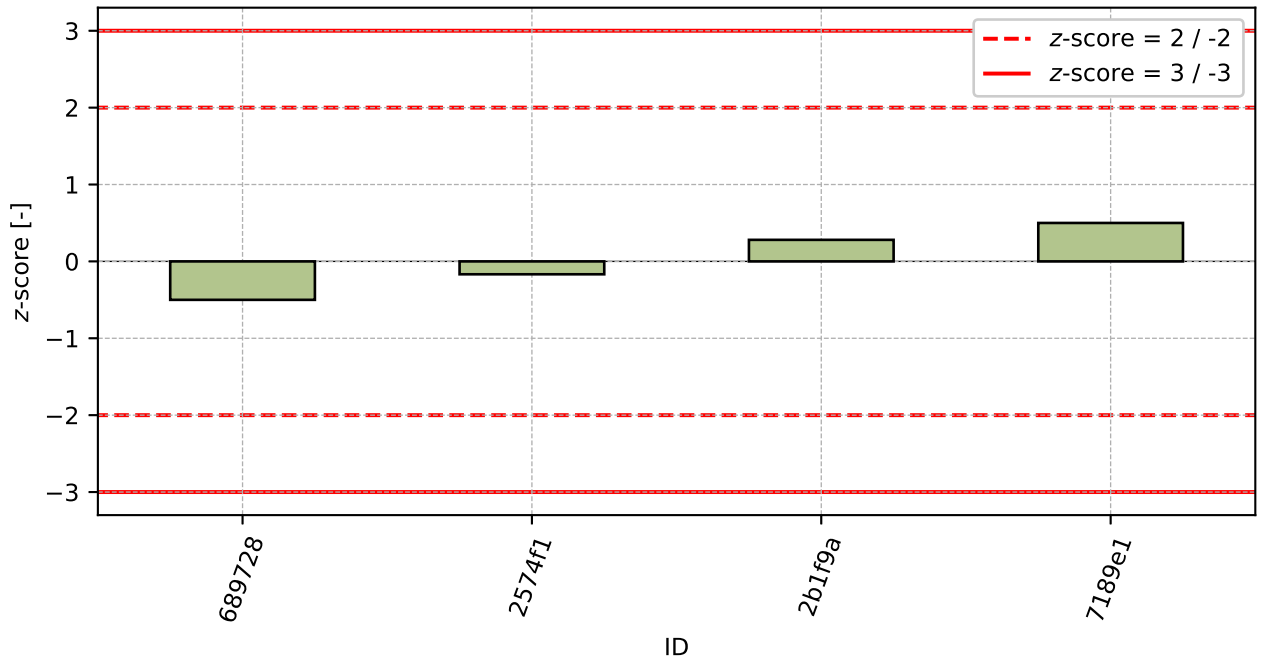

Figure 39: z-score

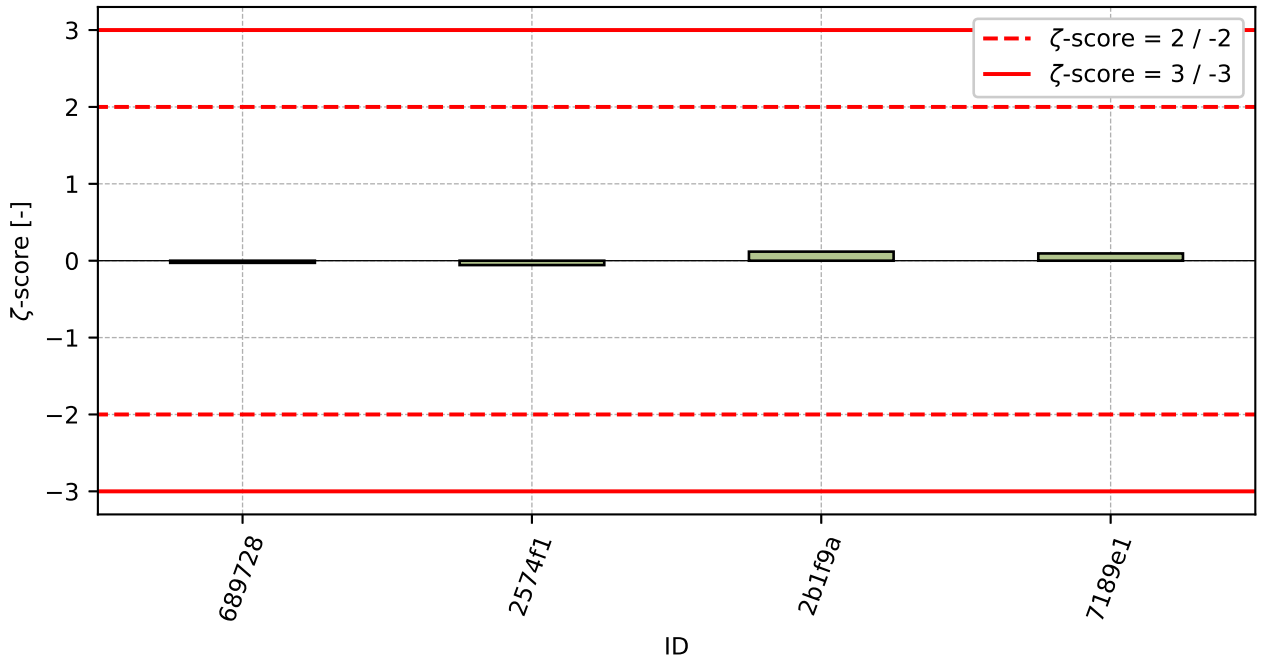

Figure 40: ζ-score

Table 15: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
689728	-0.5	-0.03
2574f1	-0.17	-0.06
2b1f9a	0.28	0.12
7189e1	0.5	0.09

2.2 Sample B

2.2.1 Stress at yield

Test results

Table 16: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
689728	28.5	28.5	28.4	28.6	28.0	0.5	28.4	0.23	0.83
b98935	28.8	28.8	28.7	28.8	29.0	0.3	28.8	0.11	0.38
7189e1	28.9	29.0	28.8	28.9	28.9	0.1	28.9	0.05	0.18
2574f1	29.0	28.9	29.0	29.0	29.0	0.1	29.0	0.02	0.08
2b1f9a	30.1	30.9	30.2	31.0	30.0	0.6	30.4	0.47	1.53

The Numerical Procedure for Determining Outliers

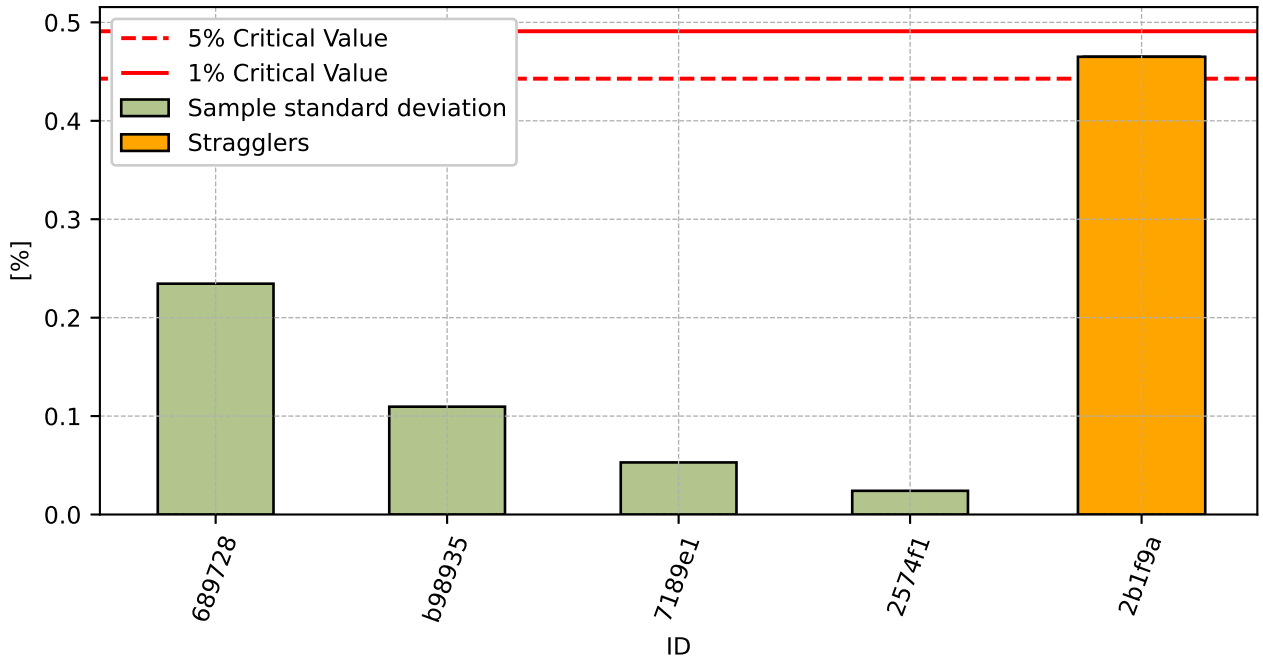

Figure 41: **Cochran's test** - sample standard deviations

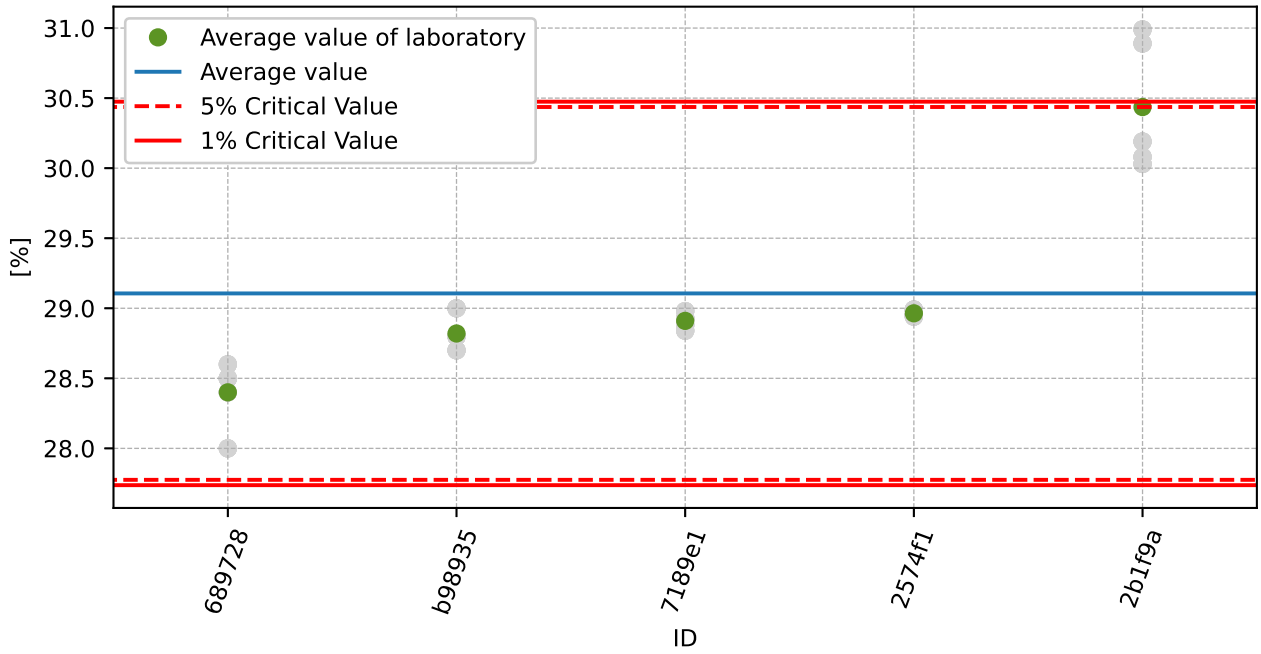

Figure 42: **Grubbs' test** - average values

Mandel's Statistics

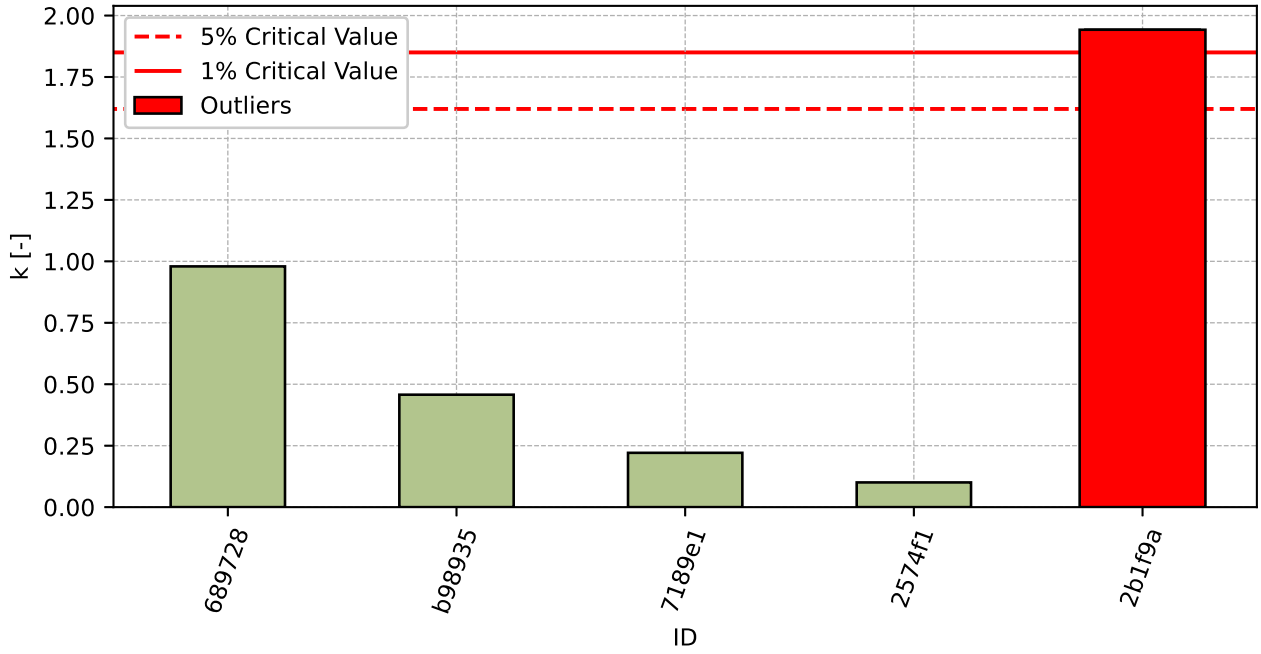

Figure 43: Intralaboratory Consistency Statistic

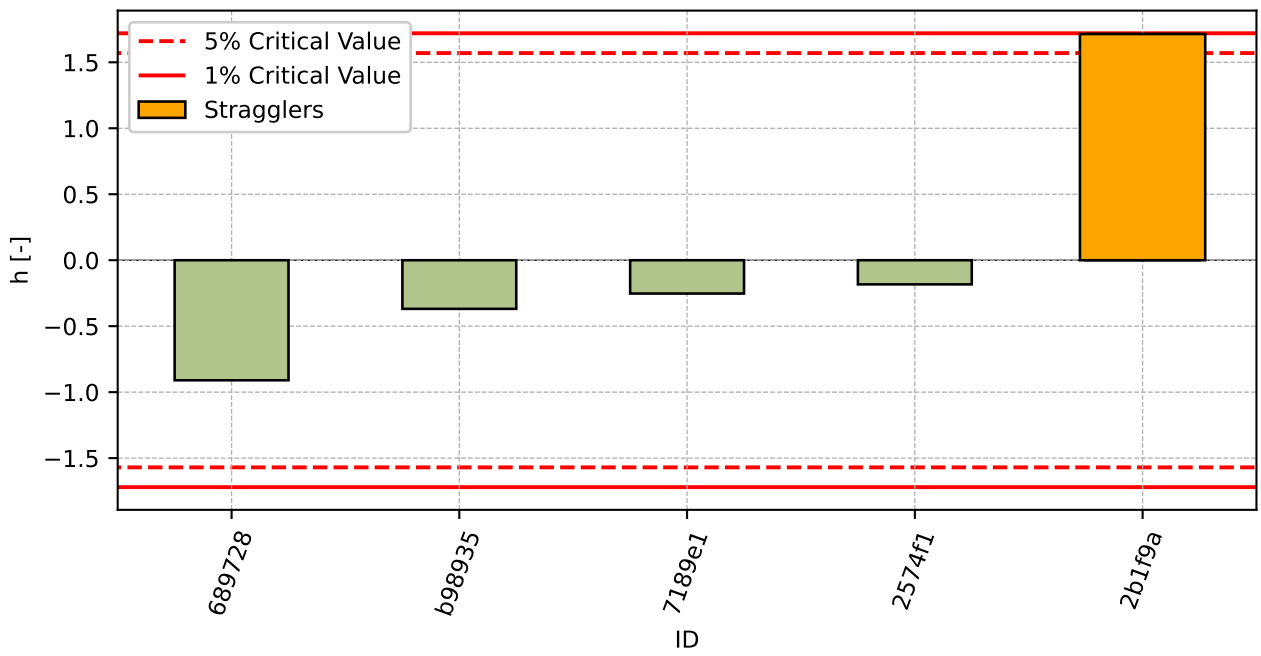

Figure 44: Interlaboratory Consistency Statistic

Descriptive statistics

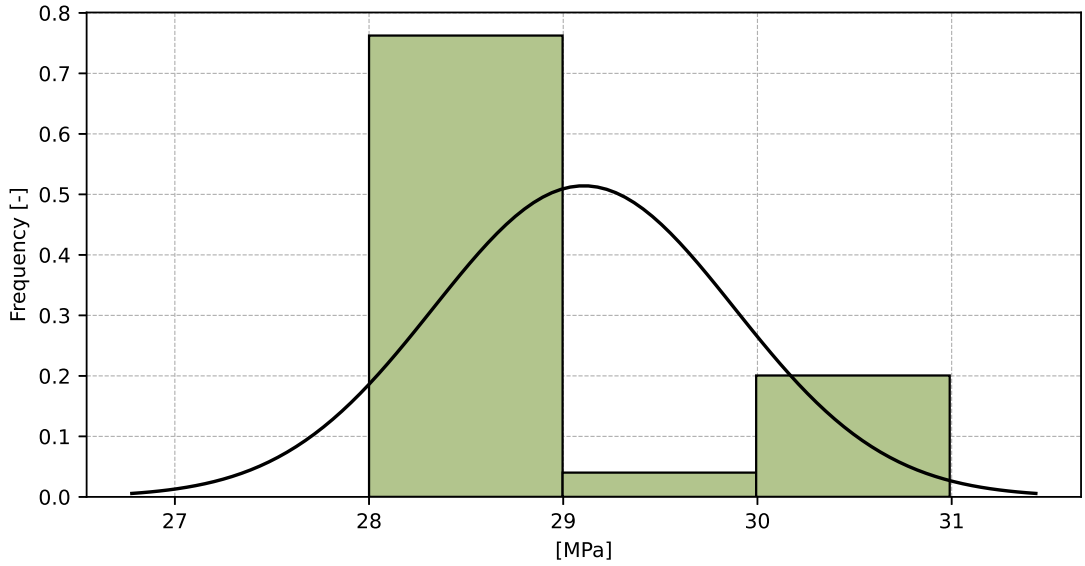

Figure 45: Histogram of all test results

Table 17: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	29.1
Sample standard deviation – s	0.78
Asigned value – x^*	29.2
Robust standard deviation – s^*	0.73
Measurement uncertainty of asigned value – u_X	0.41
p-value of normality test	0.0 [-]
Interlaboratory standard deviation – s_L	0.77
Repeatability standard deviation – s_r	0.24
Reproducibility standard deviation – s_R	0.8
Repeatability – r	0.7
Reproducibility – R	2.3

Evaluation of Performance Statistics

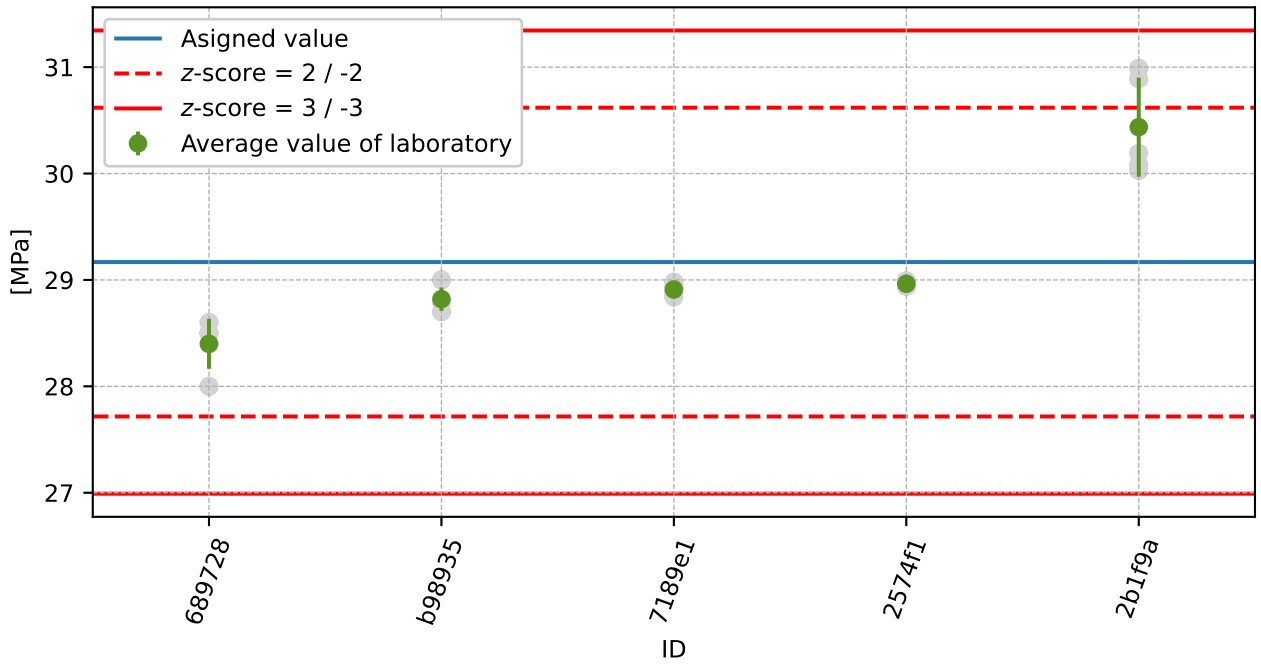

Figure 46: Average values and sample standard deviations

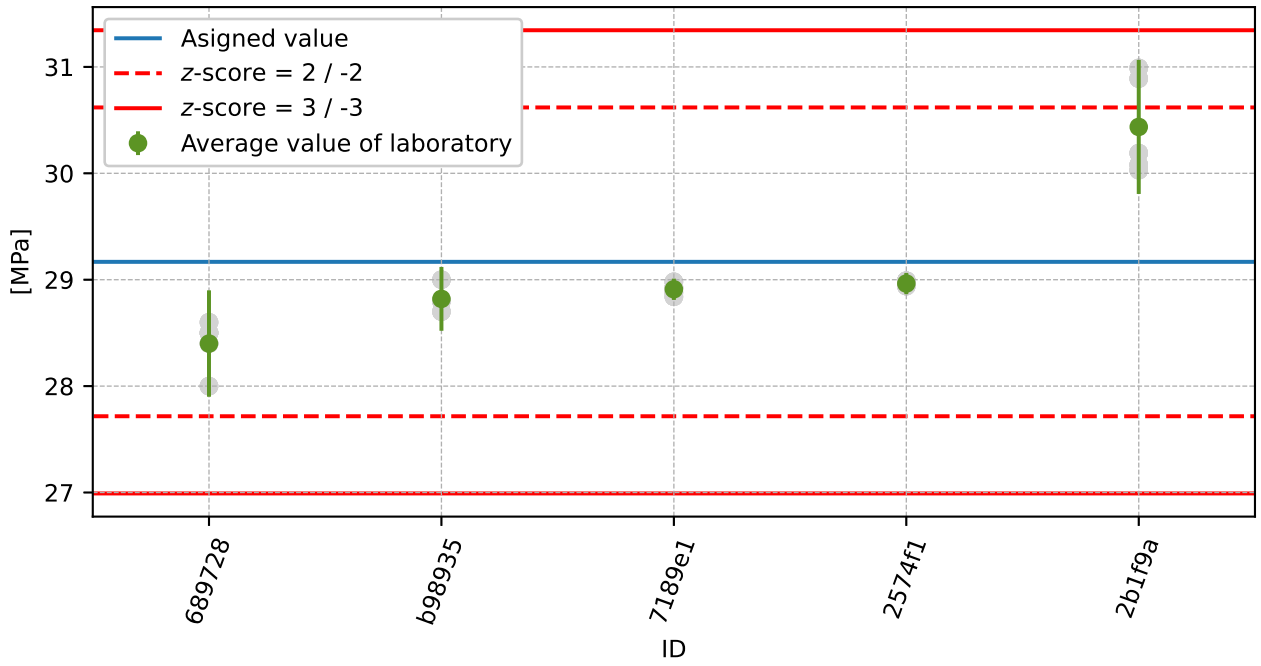

Figure 47: Average values and extended uncertainties of measurement

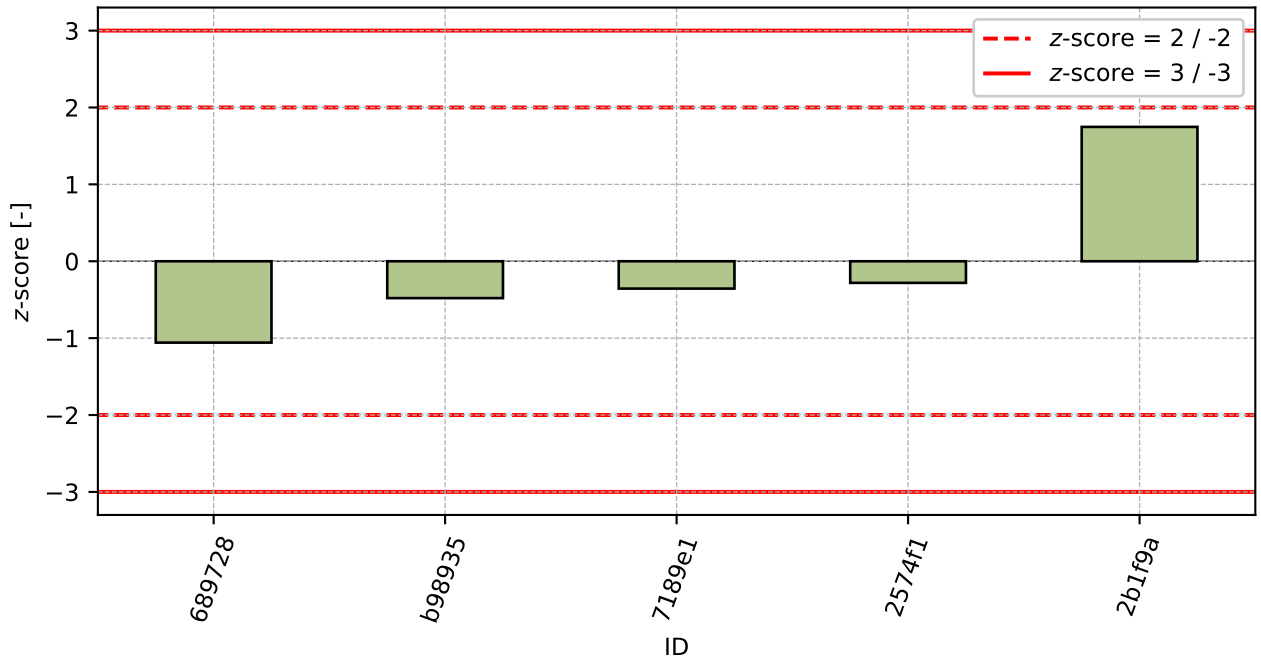

Figure 48: z-score

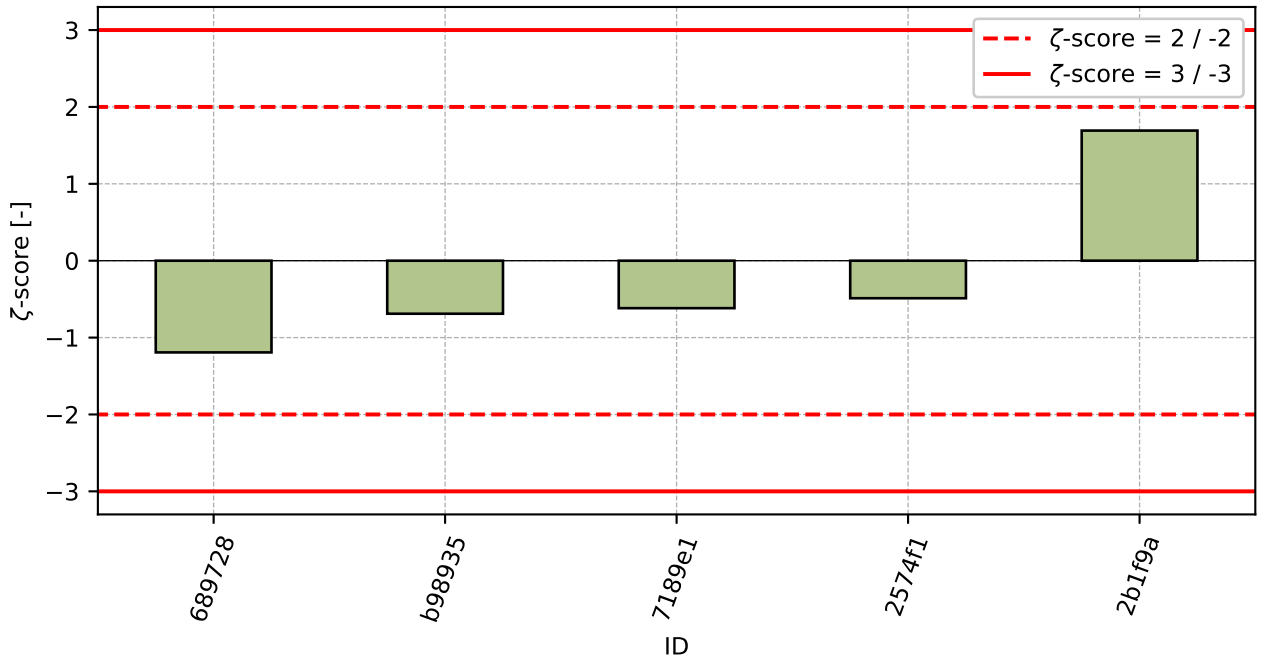

Figure 49: ζ-score

Table 18: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
689728	-1.06	-1.19
b98935	-0.48	-0.69
7189e1	-0.36	-0.62
2574f1	-0.28	-0.49
2b1f9a	1.75	1.69

2.2.2 Strain at yield

Test results

Table 19: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [%]					u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
b98935	4.9	4.8	4.9	4.9	4.8	0.3	4.86	0.055	1.13
689728	5.2	5.2	5.2	5.5	5.4	0.3	5.3	0.141	2.67
2574f1	5.39	5.31	5.36	5.39	5.34	0.1	5.36	0.035	0.66
7189e1	5.39	5.41	5.3	5.38	5.35	0.1	5.37	0.044	0.82
2b1f9a	5.65	5.61	5.51	5.67	5.72	0.11	5.63	0.079	1.4

The Numerical Procedure for Determining Outliers

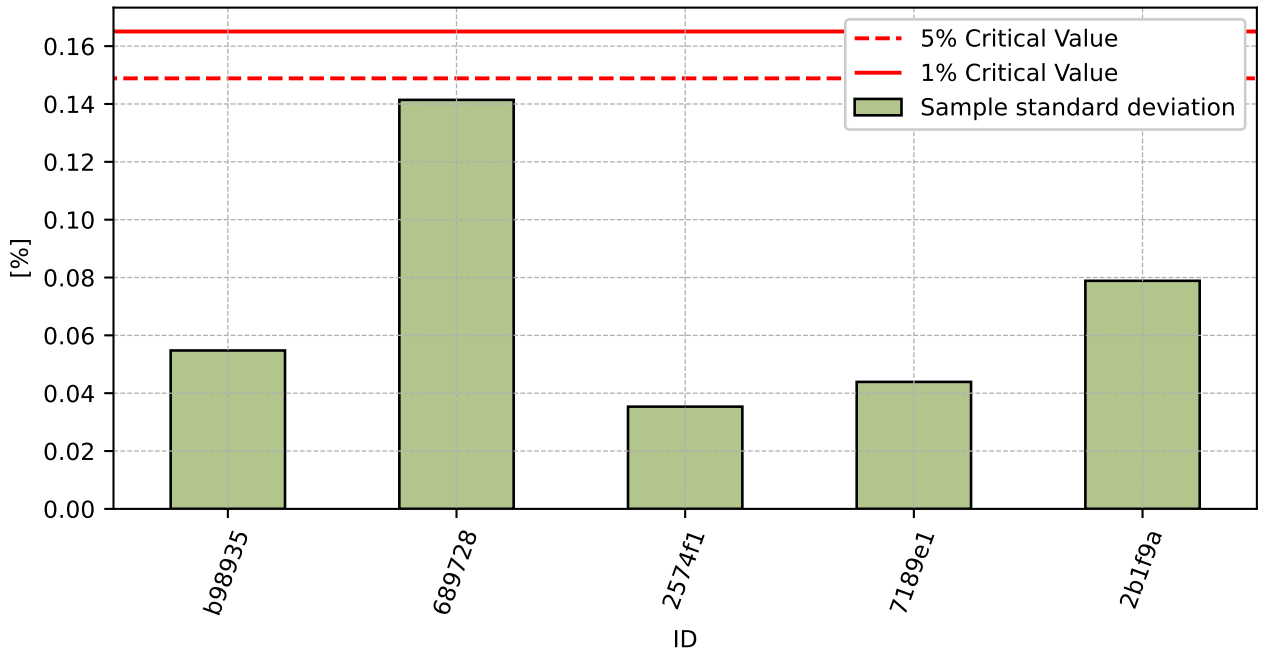

Figure 50: **Cochran's test** - sample standard deviations

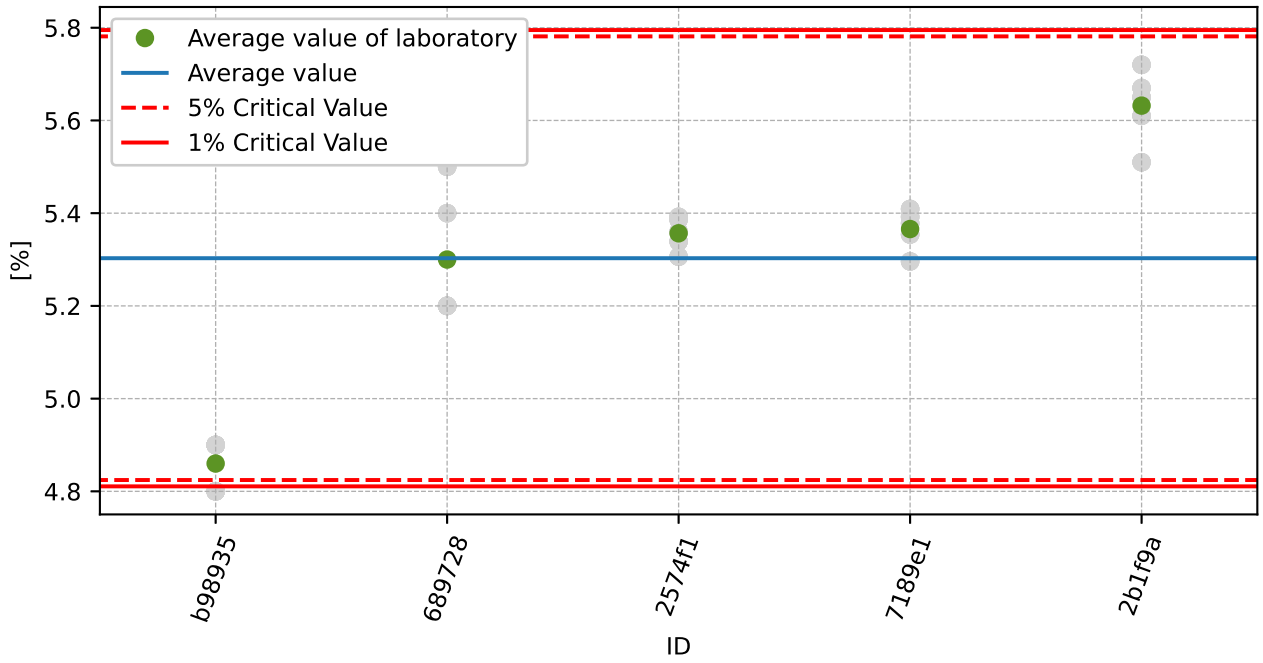

Figure 51: **Grubbs' test** - average values

Mandel's Statistics

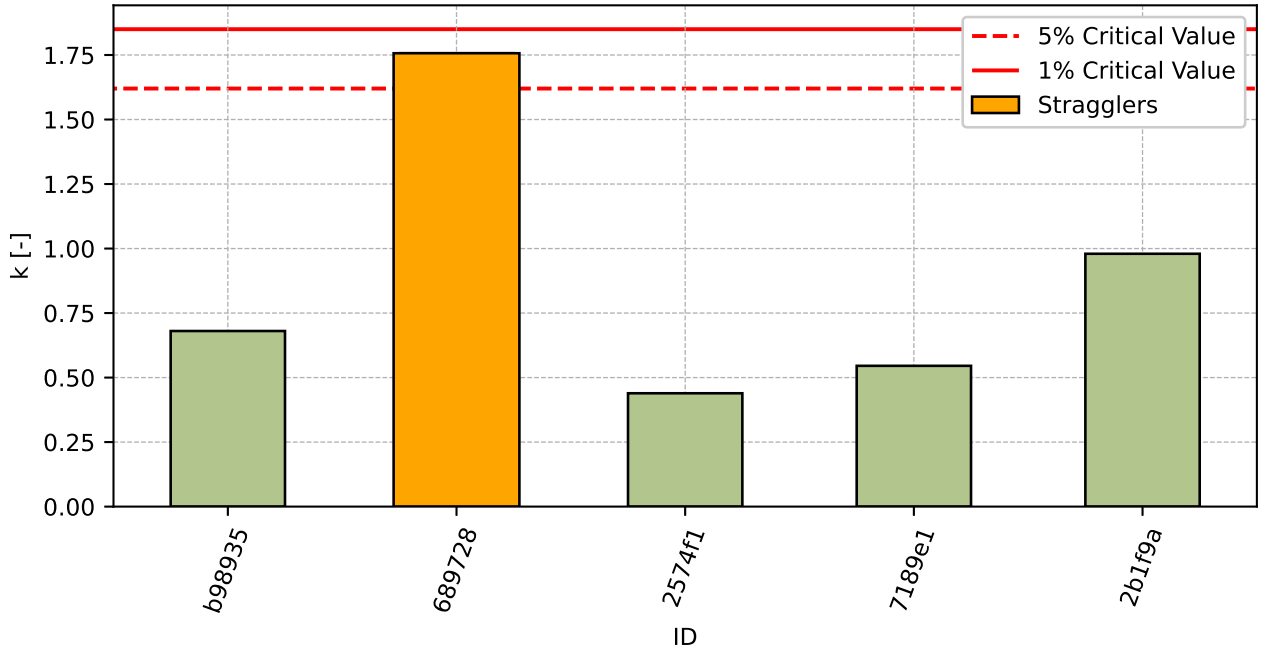

Figure 52: Intralaboratory Consistency Statistic

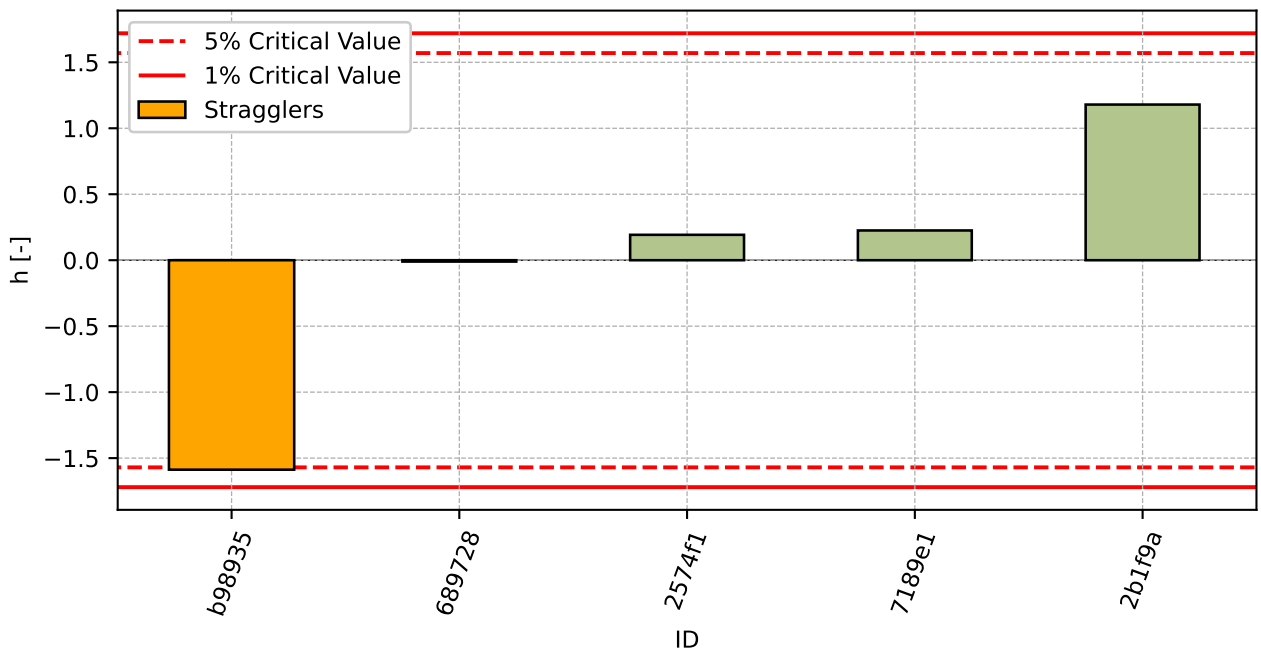

Figure 53: Interlaboratory Consistency Statistic

Descriptive statistics

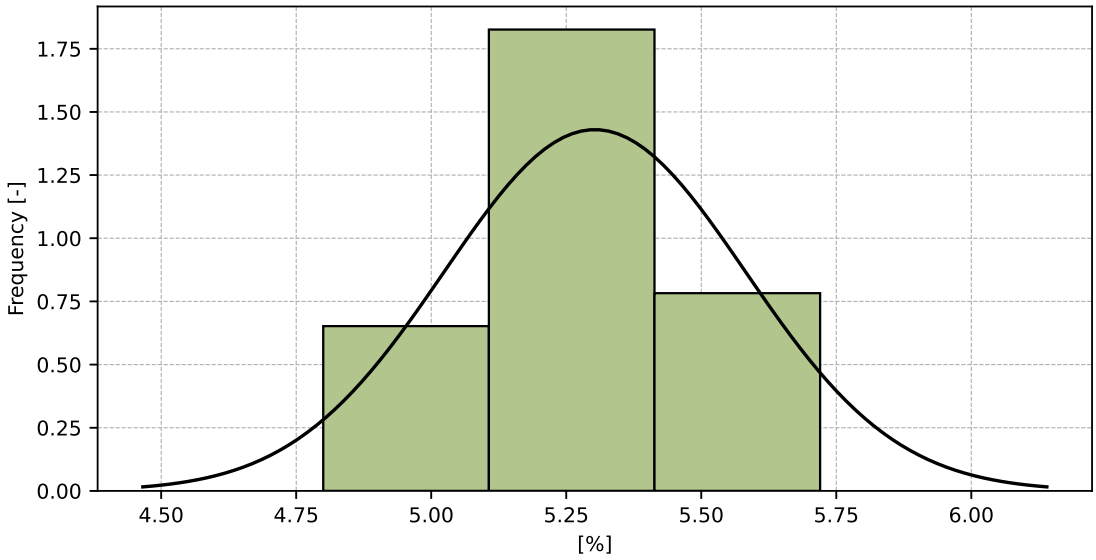

Figure 54: Histogram of all test results

Table 20: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	5.3
Sample standard deviation – s	0.279
Asigned value – x^*	5.3
Robust standard deviation – s^*	0.279
Measurement uncertainty of asigned value – u_X	0.125
p-value of normality test	0.037 [-]
Interlaboratory standard deviation – s_L	0.277
Repeatability standard deviation – s_r	0.08
Reproducibility standard deviation – s_R	0.288
Repeatability – r	0.23
Reproducibility – R	0.81

Evaluation of Performance Statistics

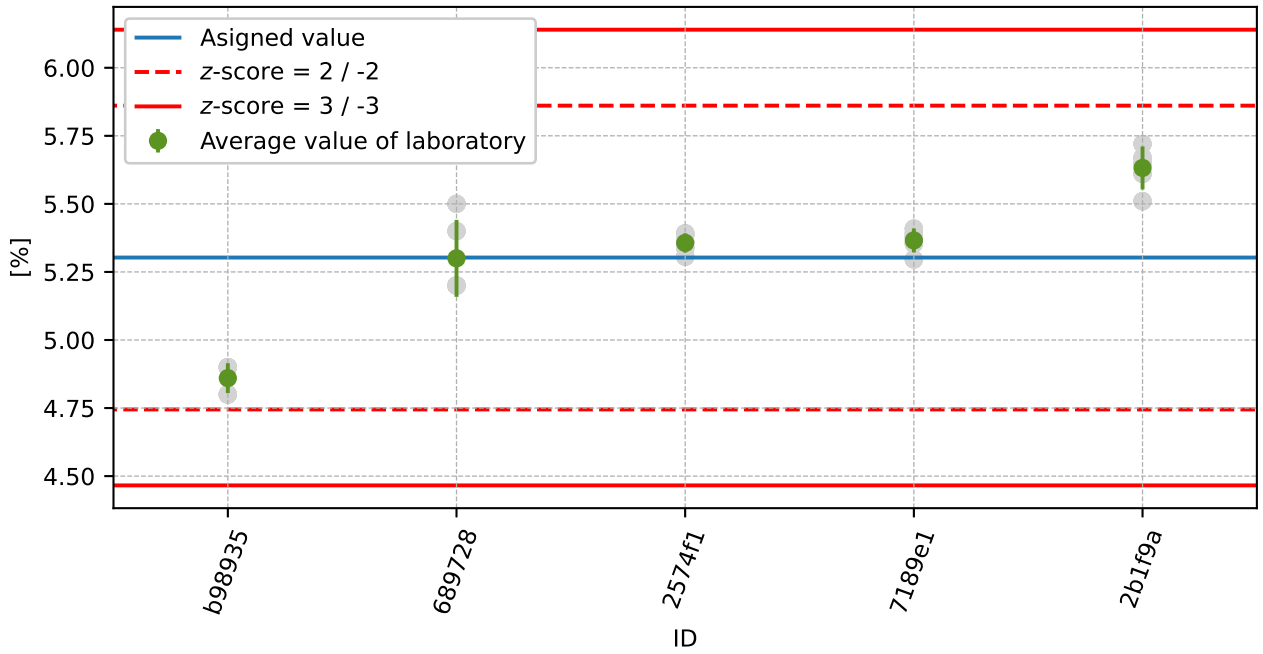

Figure 55: Average values and sample standard deviations

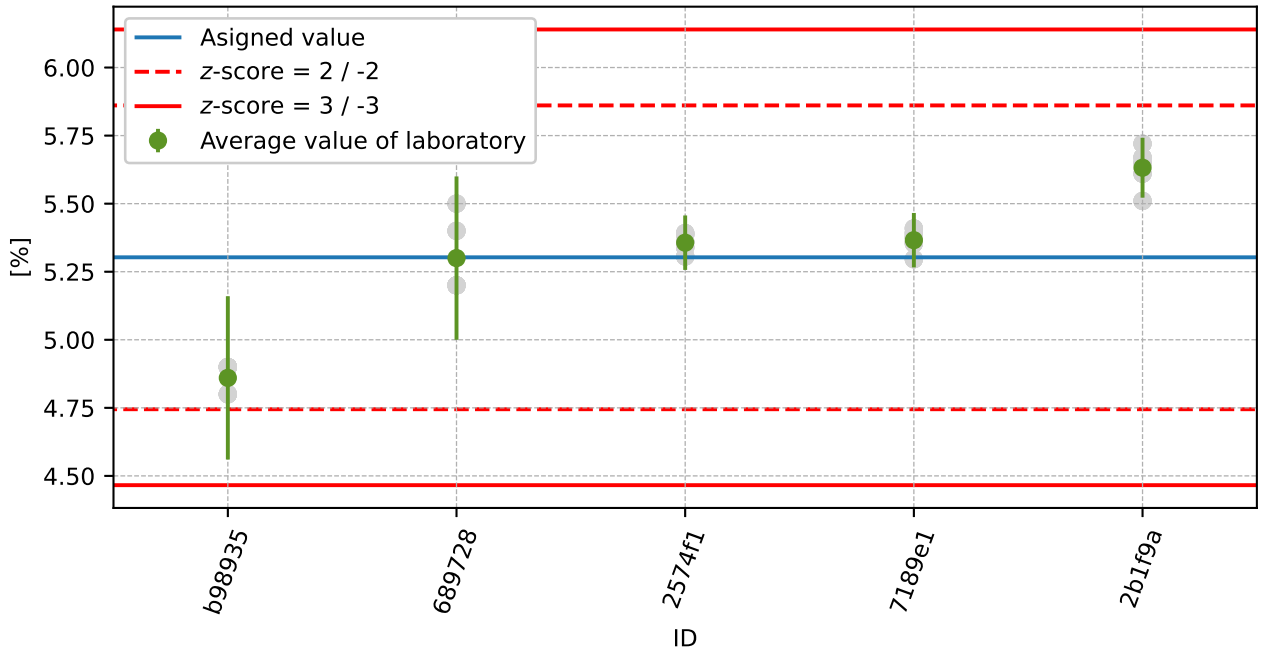

Figure 56: Average values and extended uncertainties of measurement

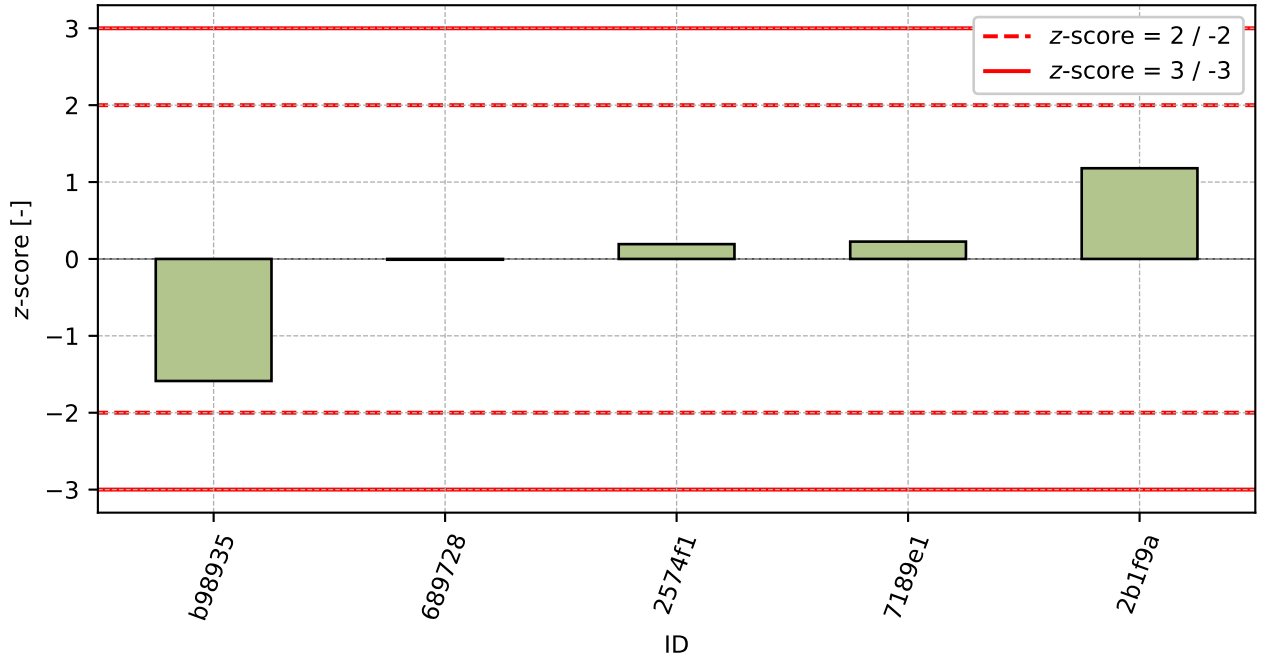

Figure 57: z-score

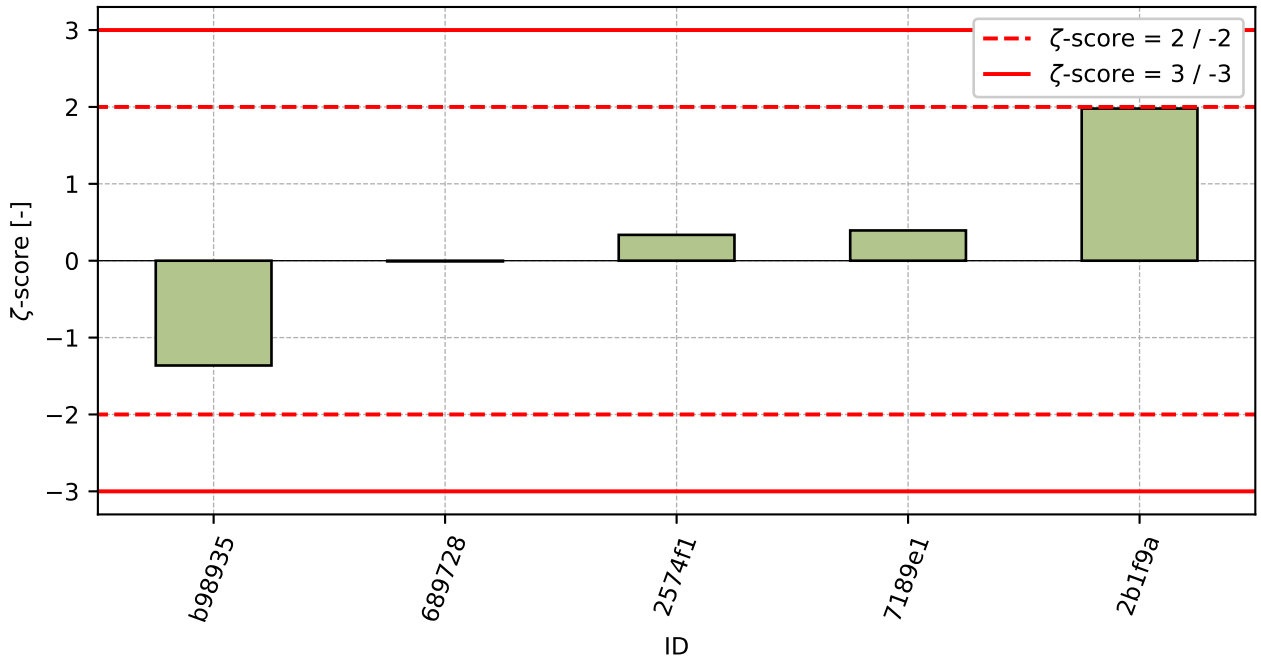

Figure 58: ζ-score

Table 21: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
b98935	-1.59	-1.36
689728	-0.01	-0.01
2574f1	0.19	0.34
7189e1	0.23	0.39
2b1f9a	1.18	1.98

3 Appendix – EN ISO 527-1, 2 (Stress at yield)

The test method was not opened due to the low number of participants.

4 Appendix – EN ISO 178 (Flexural modulus)

4.1 Sample A

4.1.1 Test results

Table 22: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
7189e1	1930	1940	1950	1920	1940	20	1936	11.4	0.59
2574f1	1950	1940	1940	1920	1950	22	1940	12.2	0.63
689728	1949	1938	1991	1920	1978	58	1955	28.9	1.48
5d42c2	2053	2023	2050	2054	2034	7	2043	13.7	0.67
4a8816	2093	2097	2094	2102	2096	4	2096	3.5	0.17
455613	2236	2279	2320	2281	2267	30	2277	30.2	1.33

4.1.2 The Numerical Procedure for Determining Outliers

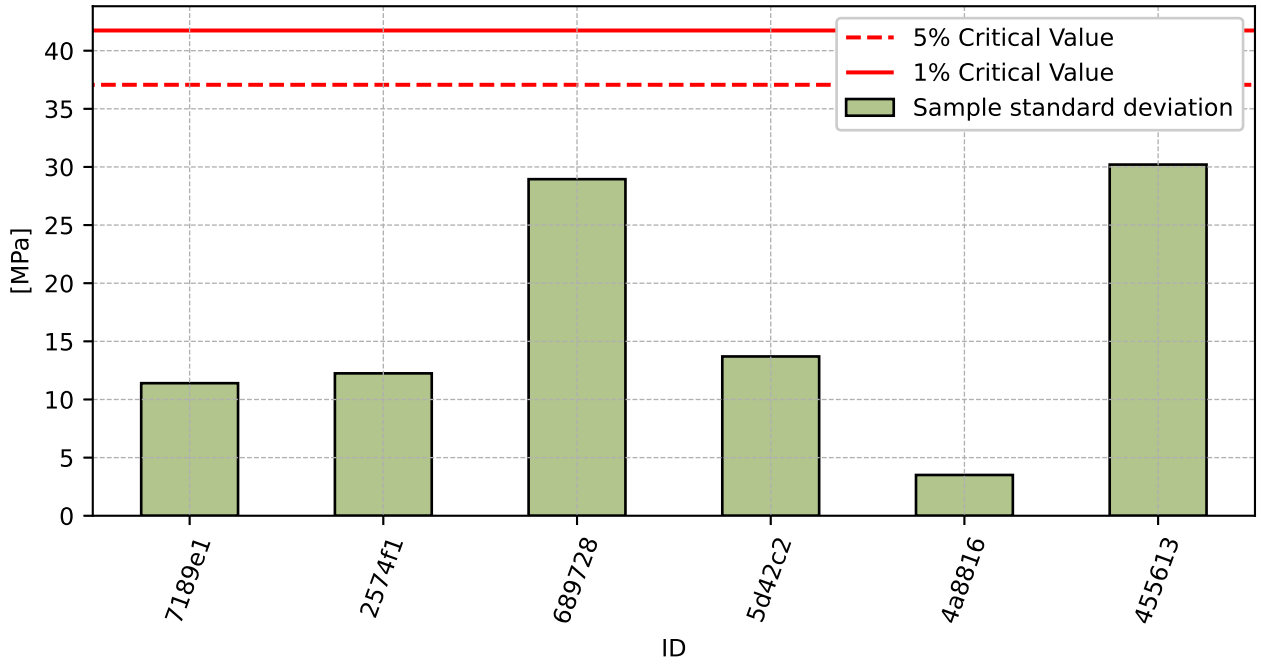

Figure 59: **Cochran's test** - sample standard deviations

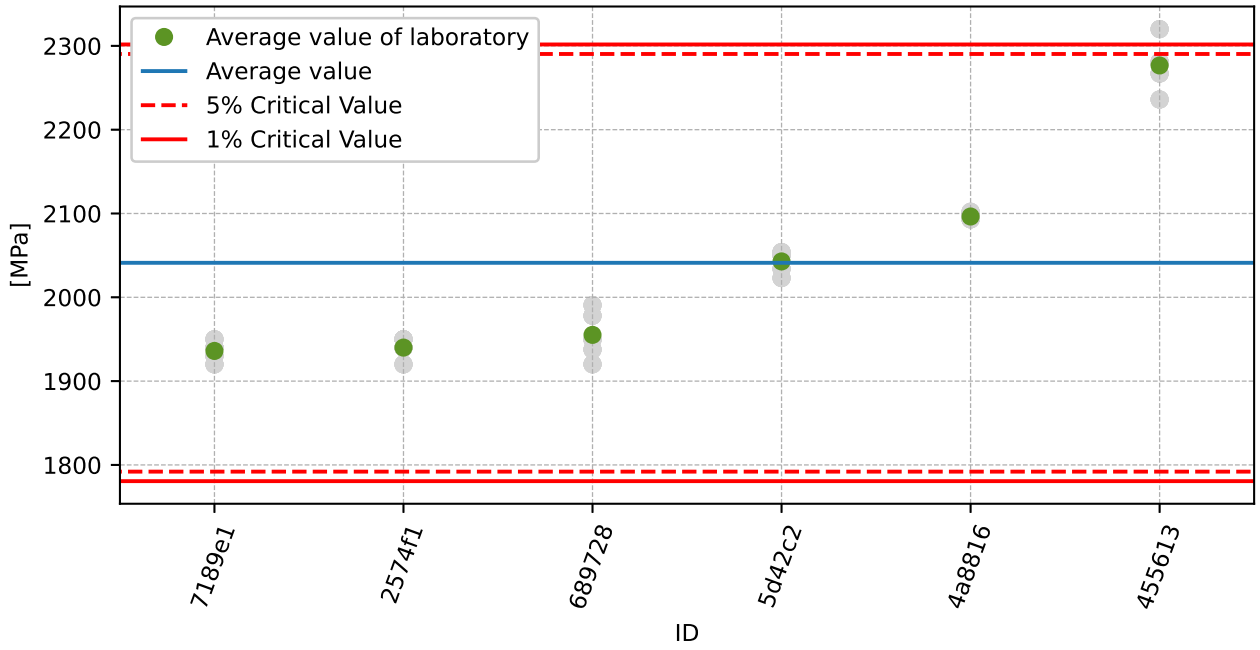

Figure 60: **Grubbs' test** - average values

4.1.3 Mandel's Statistics

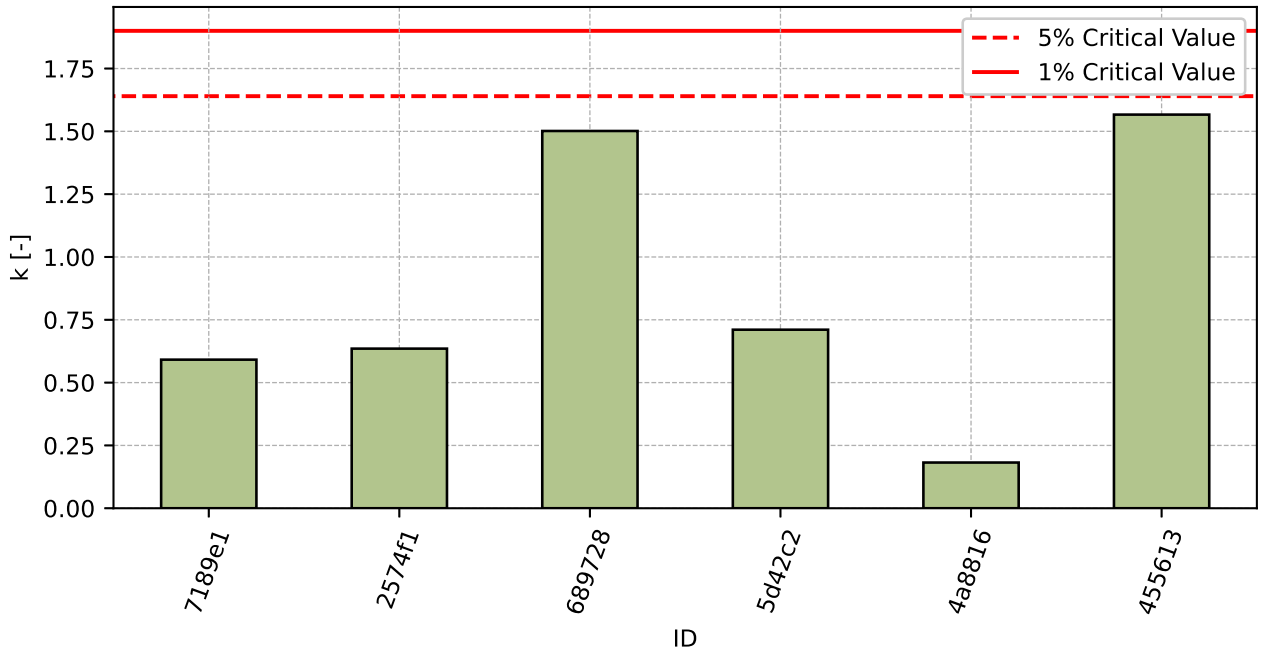

Figure 61: Intralaboratory Consistency Statistic

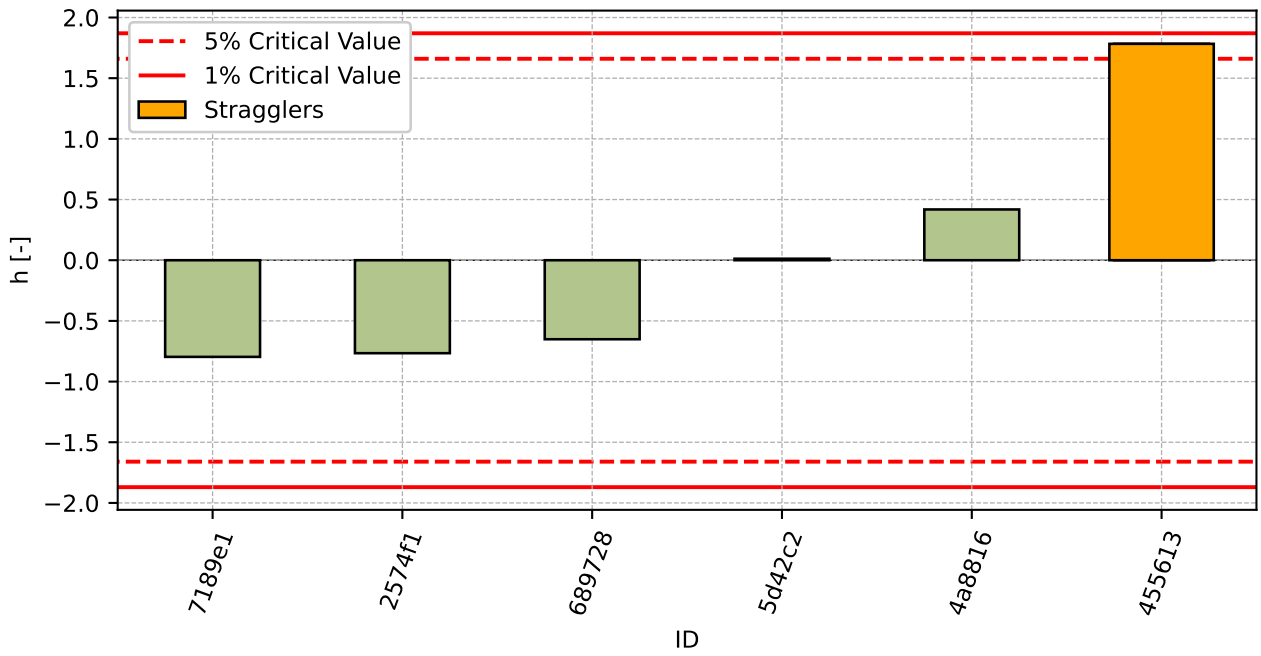

Figure 62: Interlaboratory Consistency Statistic

4.1.4 Descriptive statistics

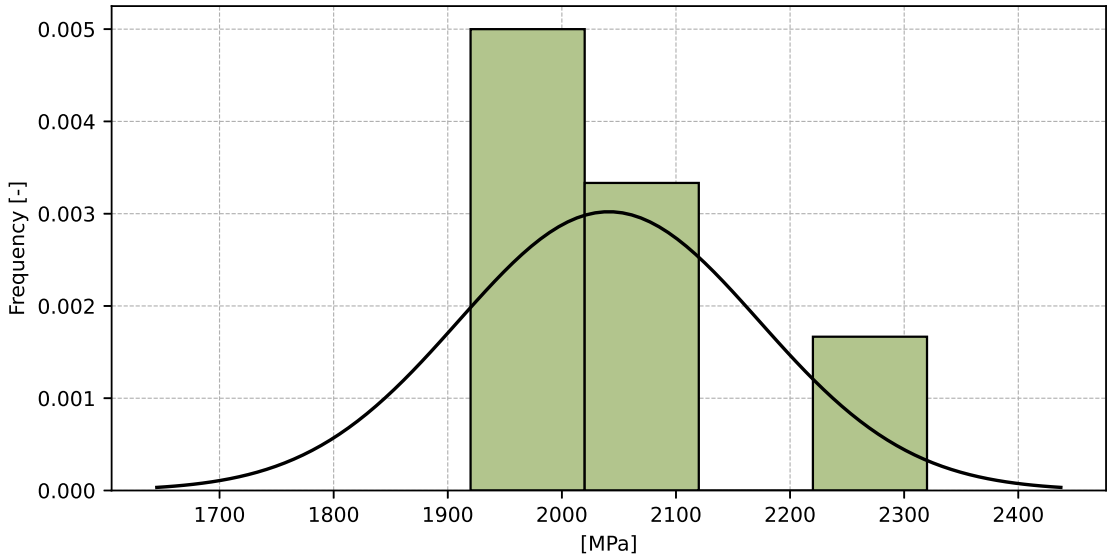

Figure 63: Histogram of all test results

Table 23: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	2041
Sample standard deviation – s	132.0
Asigned value – x^*	2041
Robust standard deviation – s^*	136.7
Measurement uncertainty of asigned value – u_X	69.8
p-value of normality test	0.0 [-]
Interlaboratory standard deviation – s_L	131.8
Repeatability standard deviation – s_r	19.3
Reproducibility standard deviation – s_R	133.2
Repeatability – r	54
Reproducibility – R	373

4.1.5 Evaluation of Performance Statistics

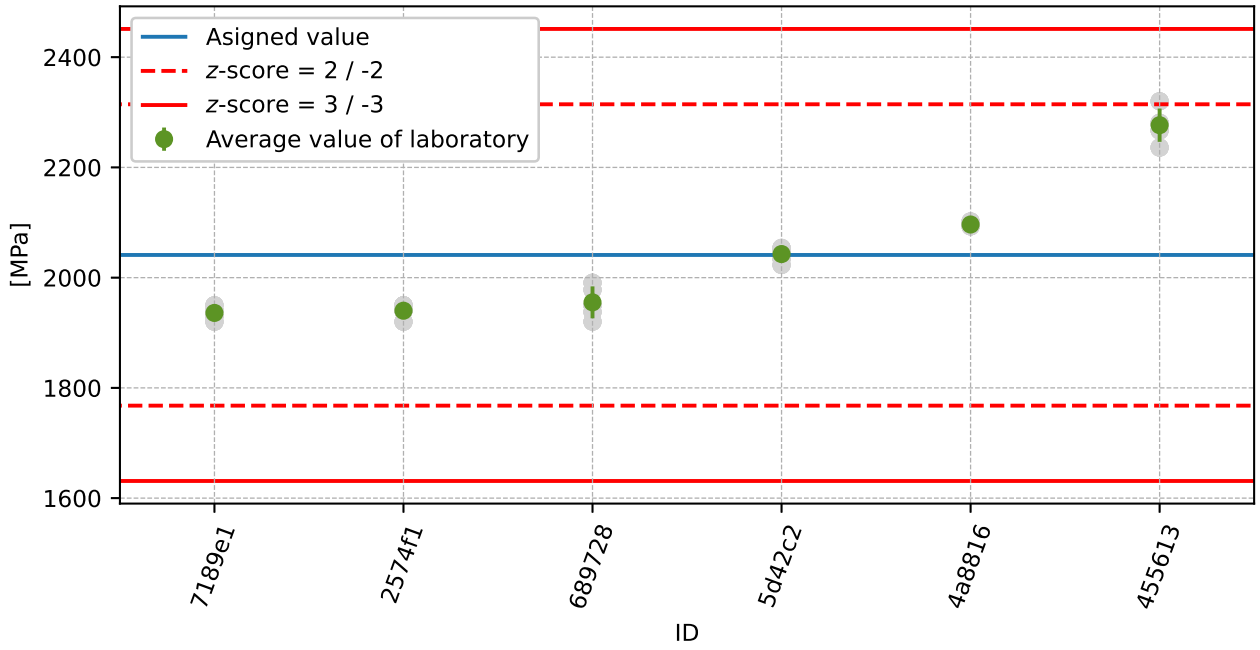

Figure 64: Average values and sample standard deviations

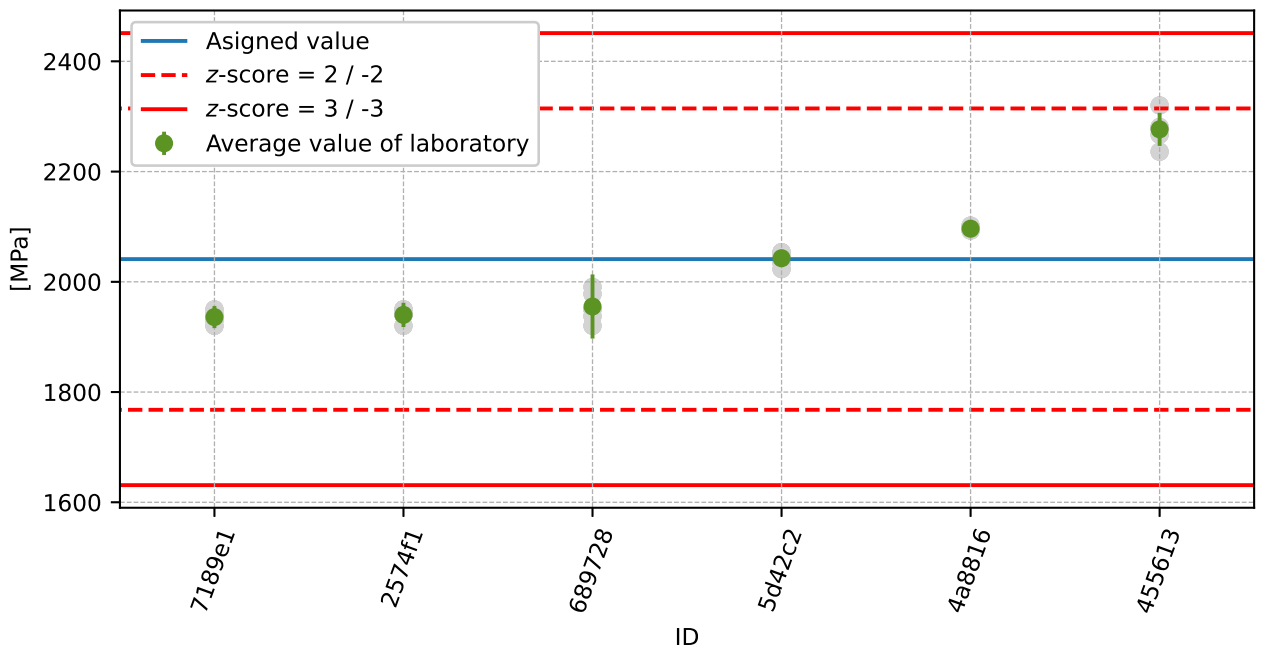

Figure 65: Average values and extended uncertainties of measurement

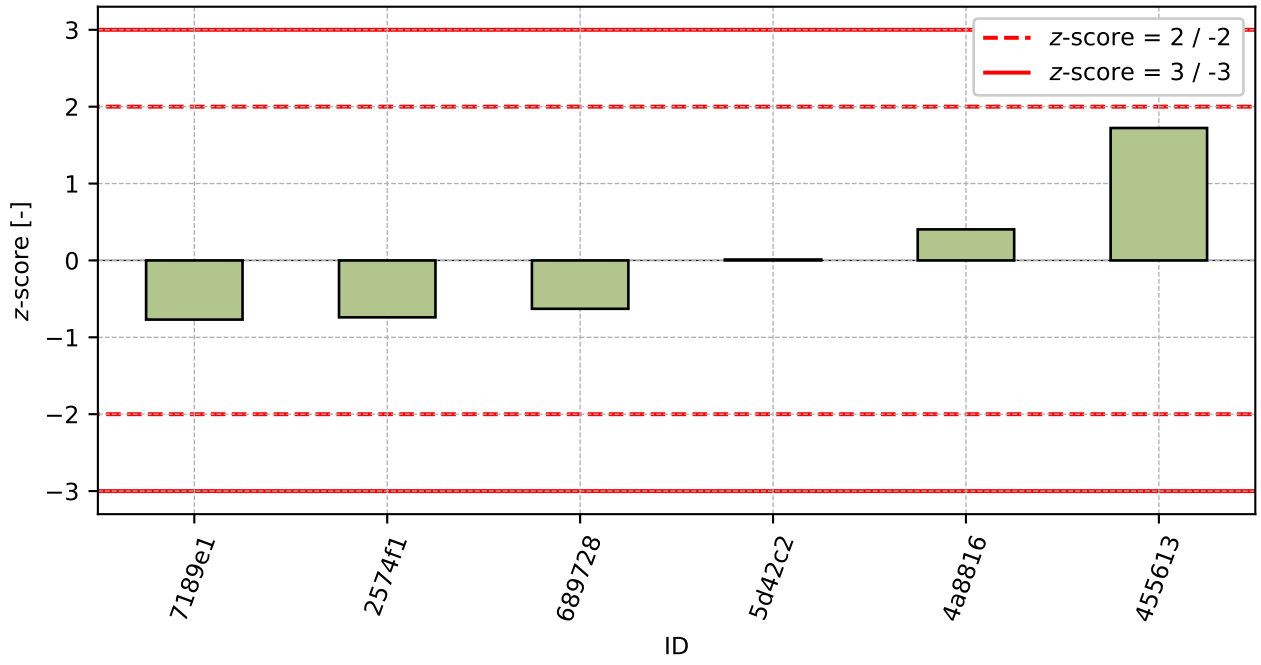

Figure 66: z-score

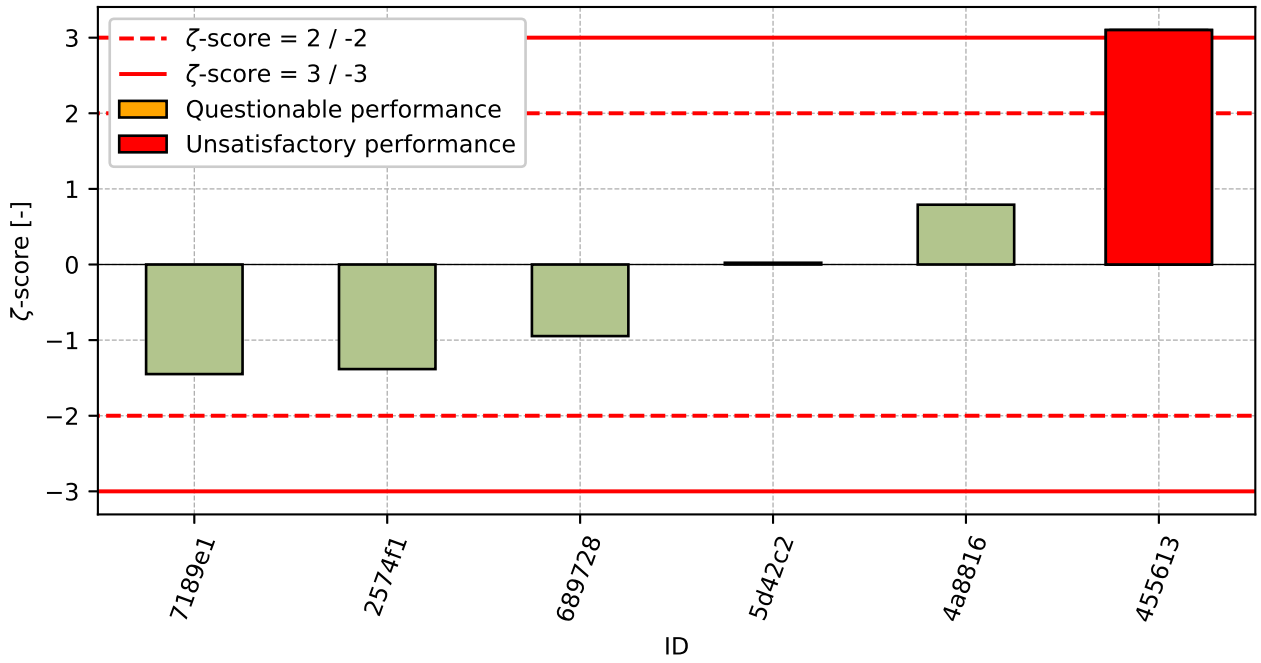

Figure 67: ζ-score

Table 24: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
7189e1	-0.77	-1.45
2574f1	-0.74	-1.38
689728	-0.63	-0.95
5d42c2	0.01	0.02
4a8816	0.4	0.79
455613	1.72	3.1

4.2 Sample B

4.2.1 Test results

Table 25: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
7189e1	1430	1430	1430	1430	1430	5	1430	0.0	0.0
2574f1	1440	1430	1430	1430	1440	8	1434	5.5	0.38
689728	1458	1459	1468	1504	1430	53	1464	26.6	1.82
5d42c2	1494	1525	1513	1531	1526	7	1518	14.9	0.98
4a8816	1549	1560	1547	1559	1556	6	1554	5.9	0.38
455613	1622	1540	1634	1567	1698	62	1612	61.6	3.82

4.2.2 The Numerical Procedure for Determining Outliers

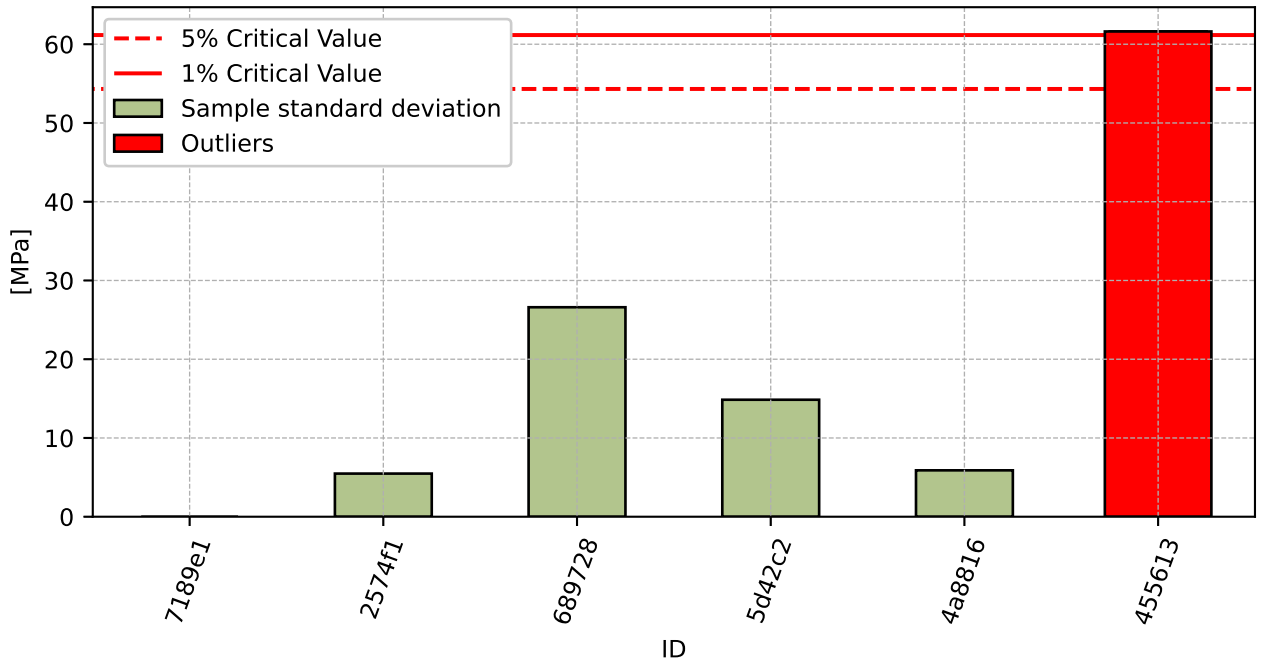

Figure 68: **Cochran's test** - sample standard deviations

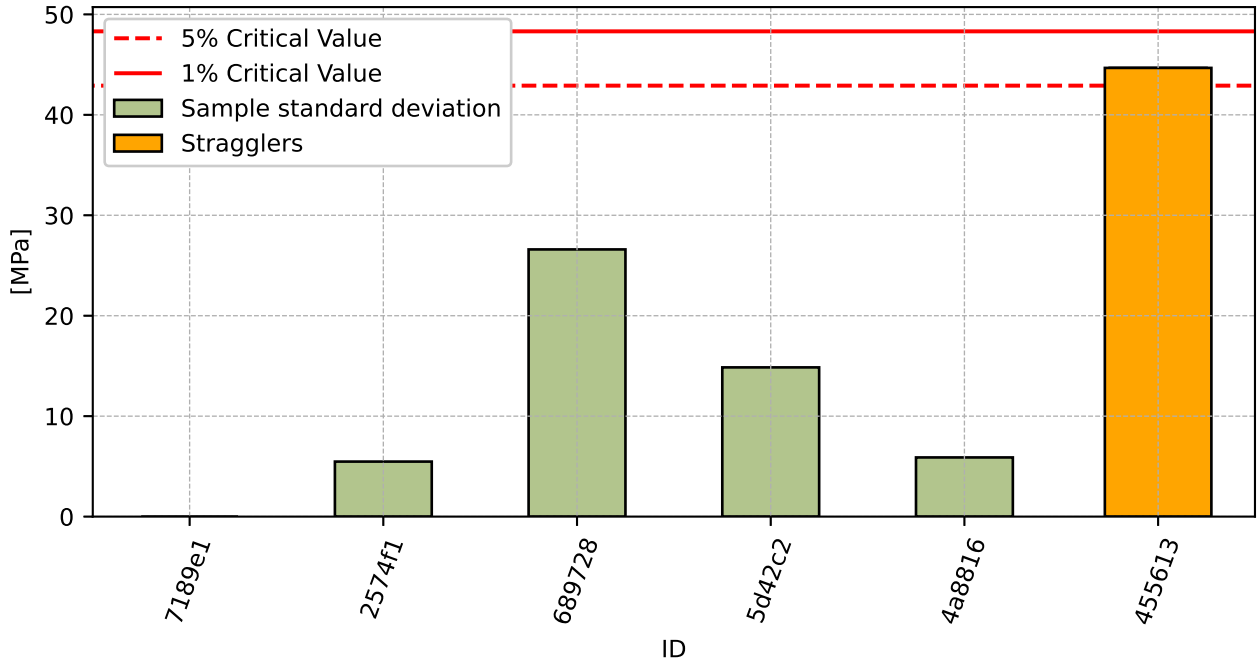

Figure 69: **Cochran's test** - sample standard deviations without outliers

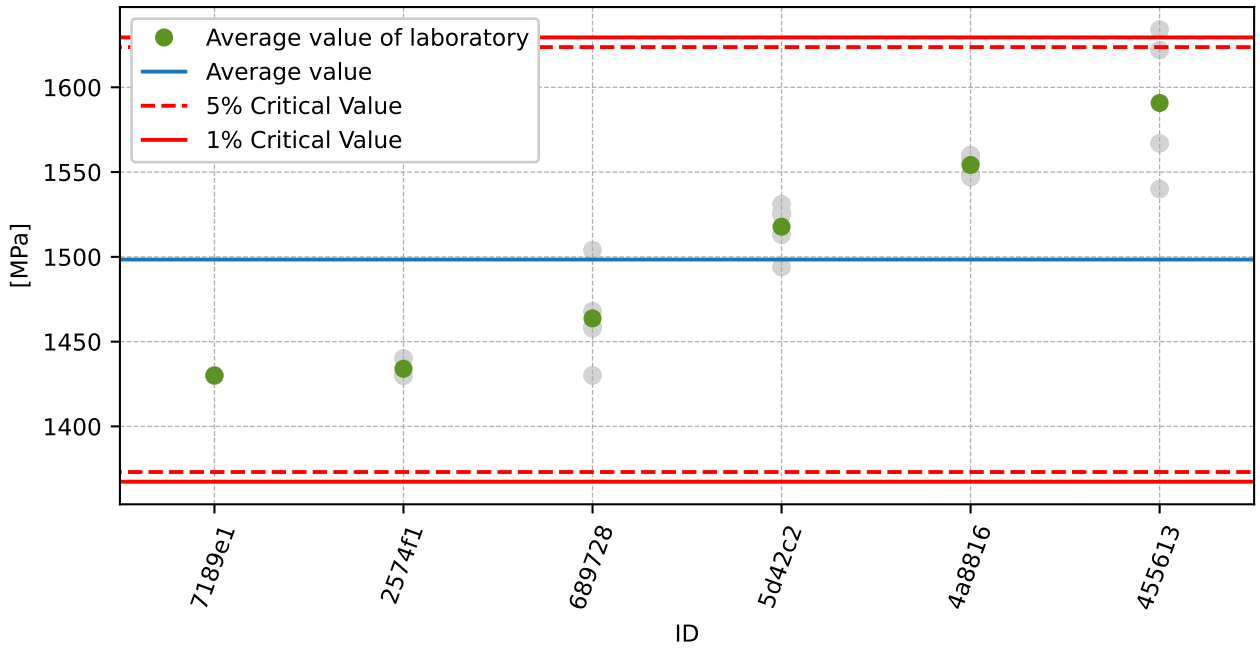

Figure 70: **Grubbs' test** - average values

4.2.3 Mandel's Statistics

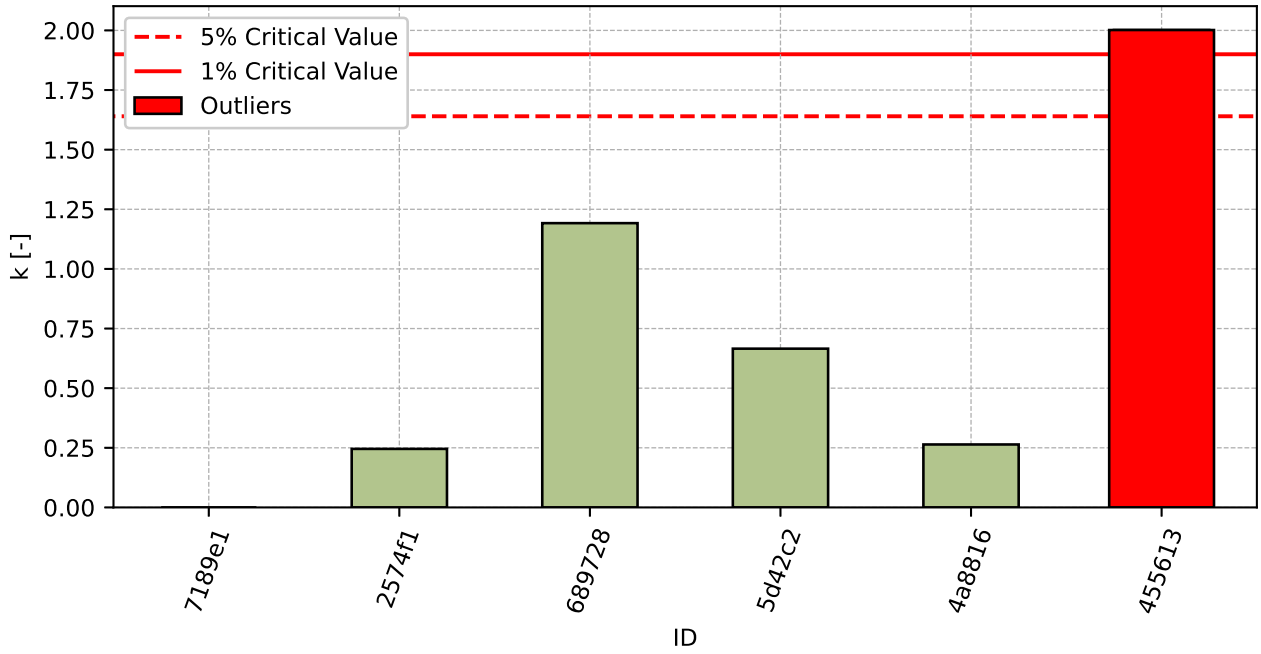

Figure 71: Intralaboratory Consistency Statistic

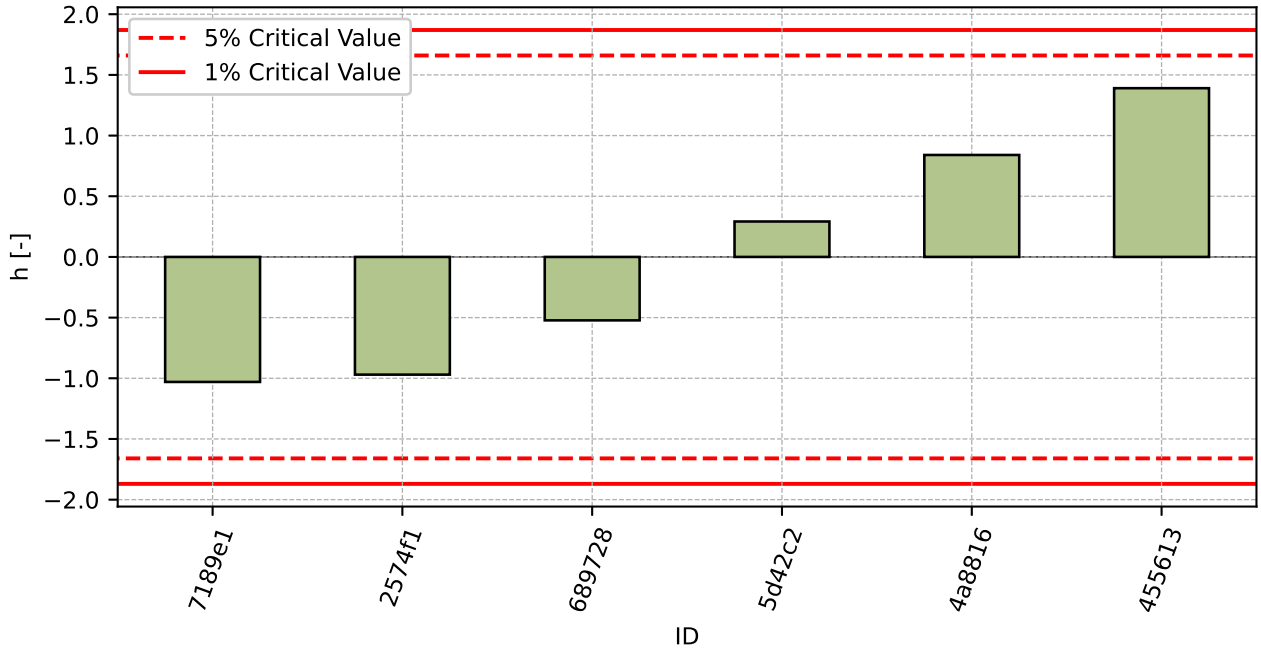

Figure 72: Interlaboratory Consistency Statistic

4.2.4 Descriptive statistics

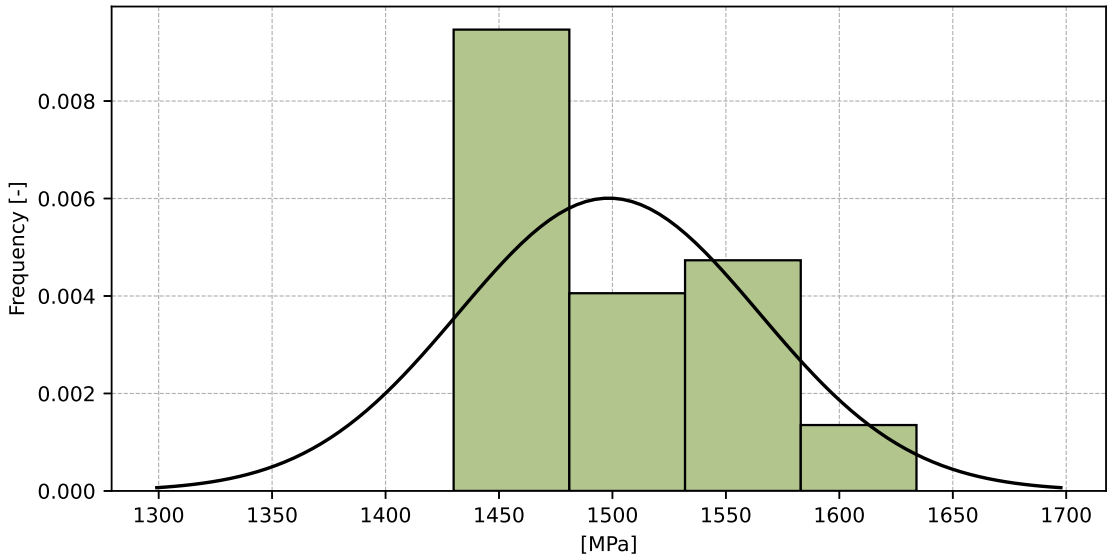

Figure 73: Histogram of all test results

Table 26: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	1498
Sample standard deviation – s	66.4
Asigned value – x^*	1498
Robust standard deviation – s^*	68.7
Measurement uncertainty of asigned value – u_X	35.1
p-value of normality test	1.0 [-]
Interlaboratory standard deviation – s_L	65.7
Repeatability standard deviation – s_r	22.3
Reproducibility standard deviation – s_R	69.3
Repeatability – r	62
Reproducibility – R	194

4.2.5 Evaluation of Performance Statistics

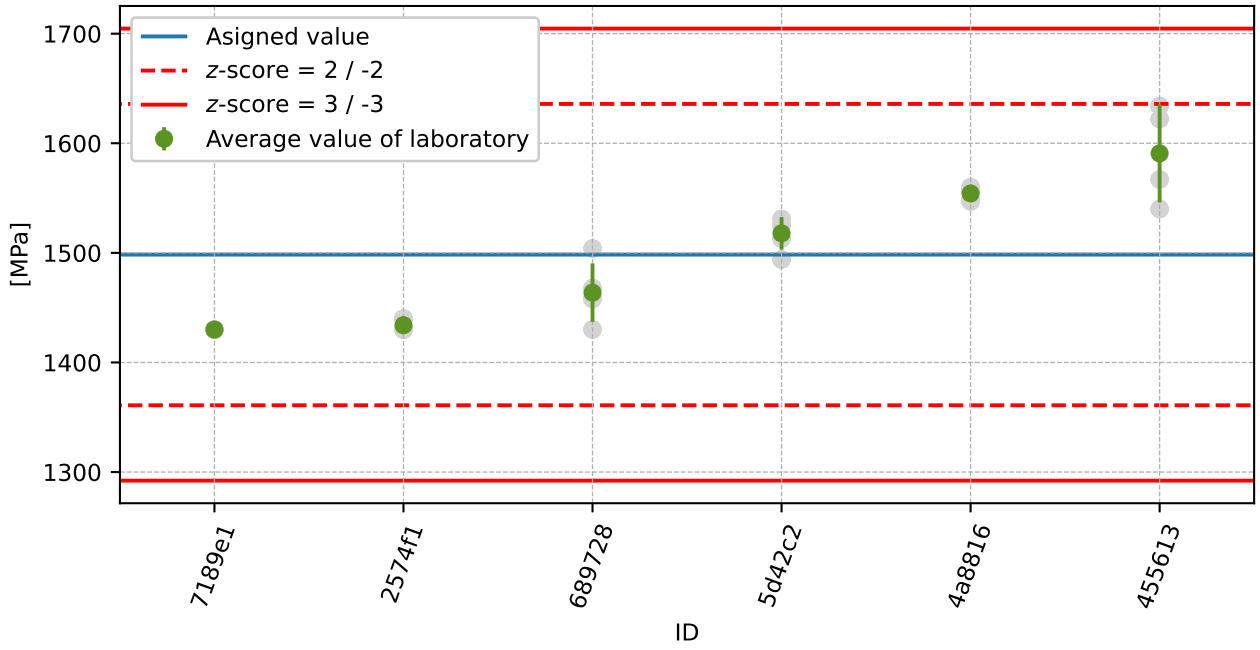

Figure 74: Average values and sample standard deviations

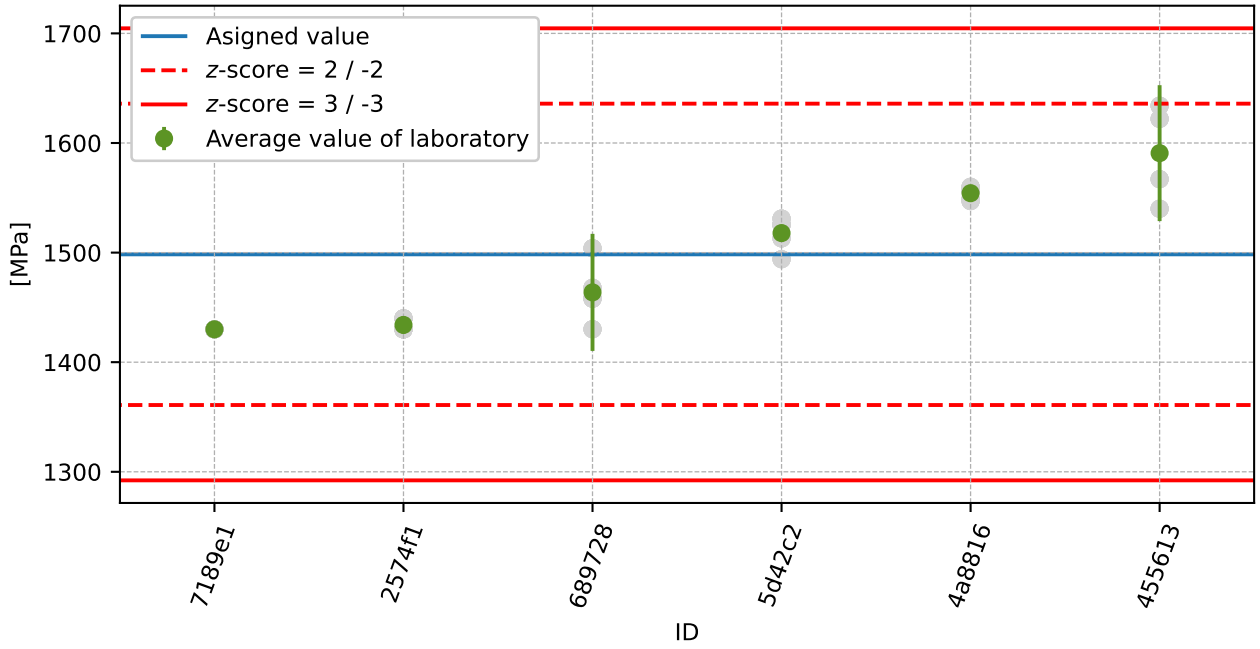

Figure 75: Average values and extended uncertainties of measurement

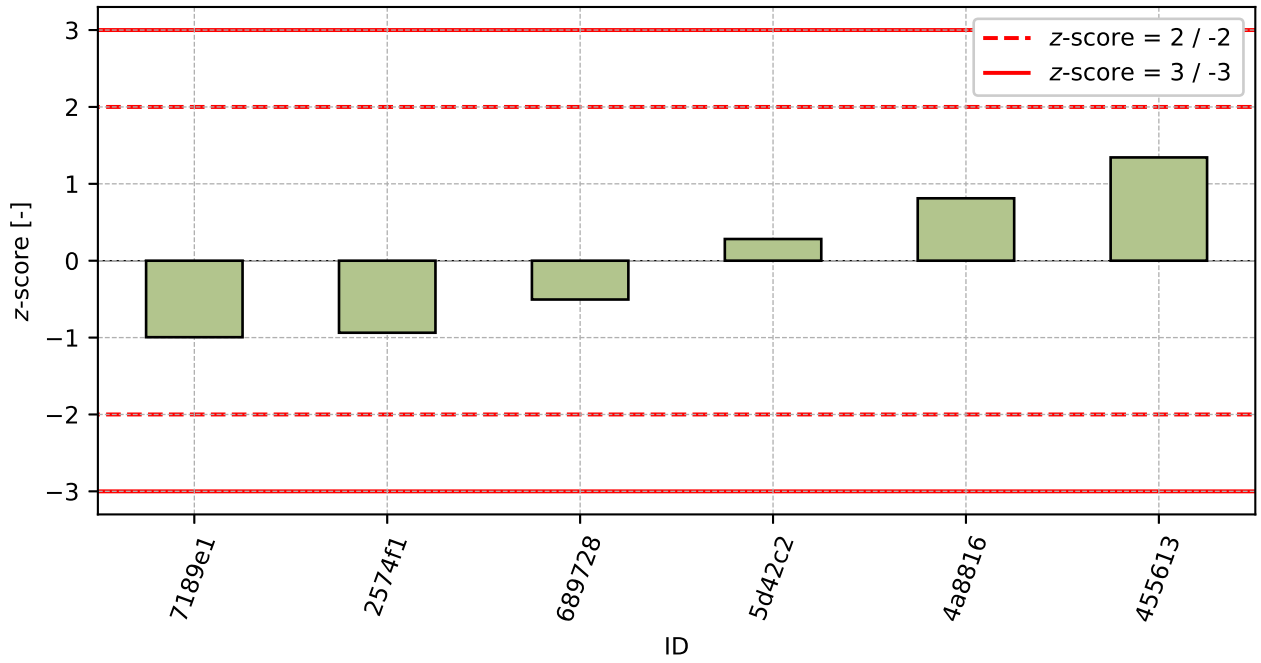

Figure 76: z-score

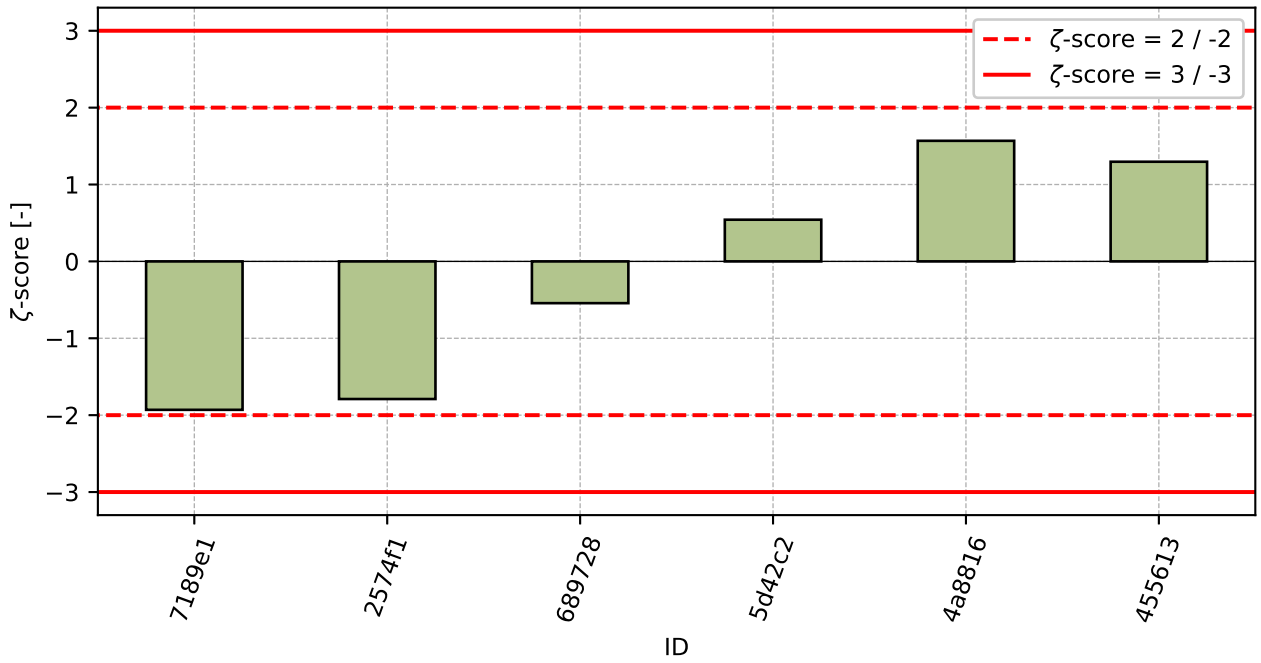

Figure 77: ζ-score

Table 27: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
7189e1	-1.0	-1.93
2574f1	-0.94	-1.79
689728	-0.5	-0.54
5d42c2	0.28	0.54
4a8816	0.81	1.57
455613	1.34	1.3

5 Appendix – EN ISO 178 (Flexural strength, Flexural strain at flexural strength)

5.1 Flexural strain at flexural strength

5.1.1 Sample A

Test results

Table 28: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [%]					u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
2b1f9a	6.5	6.6	6.7	6.5	6.5	0.1	6.6	0.07	1.09
2574f1	6.8	6.8	6.7	6.6	6.6	0.2	6.7	0.1	1.49
7189e1	6.7	6.7	6.8	6.7	6.7	0.1	6.7	0.04	0.67
689728	6.8	6.6	7.0	7.0	7.0	0.4	6.9	0.18	2.6
5d42c2	7.0	7.1	6.9	7.0	7.2	0.0	7.0	0.11	1.57

The Numerical Procedure for Determining Outliers

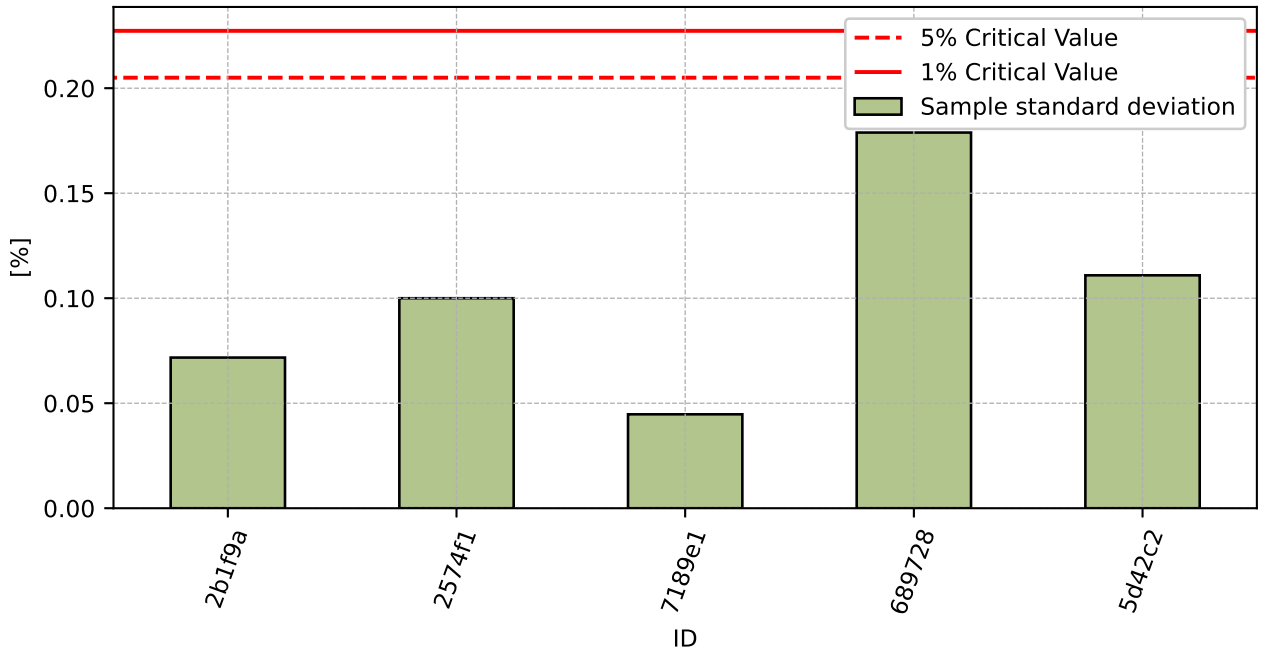

Figure 78: **Cochran's test** - sample standard deviations

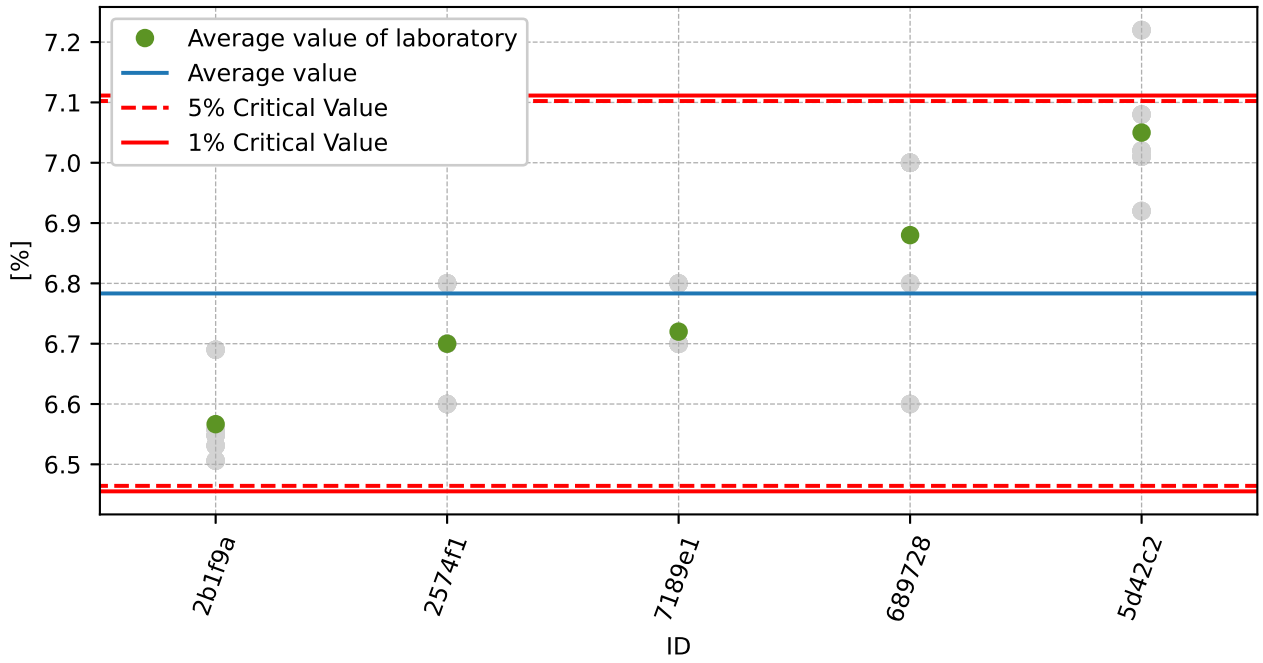

Figure 79: **Grubbs' test** - average values

Mandel's Statistics

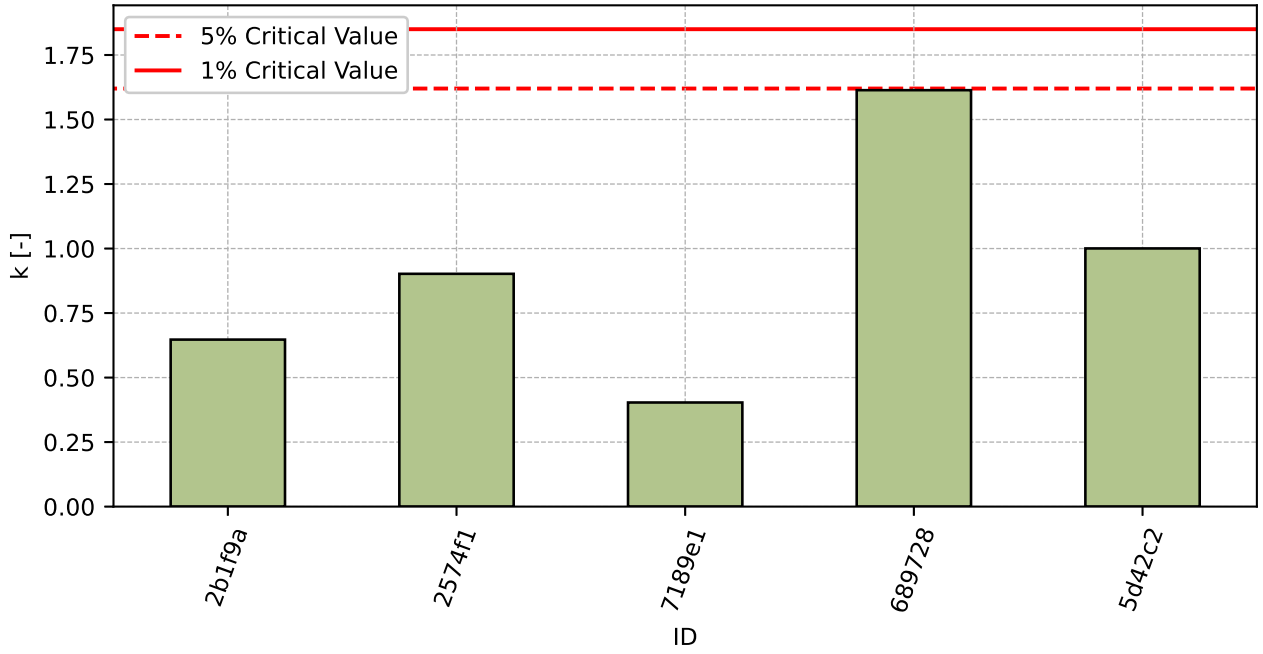

Figure 80: Intralaboratory Consistency Statistic

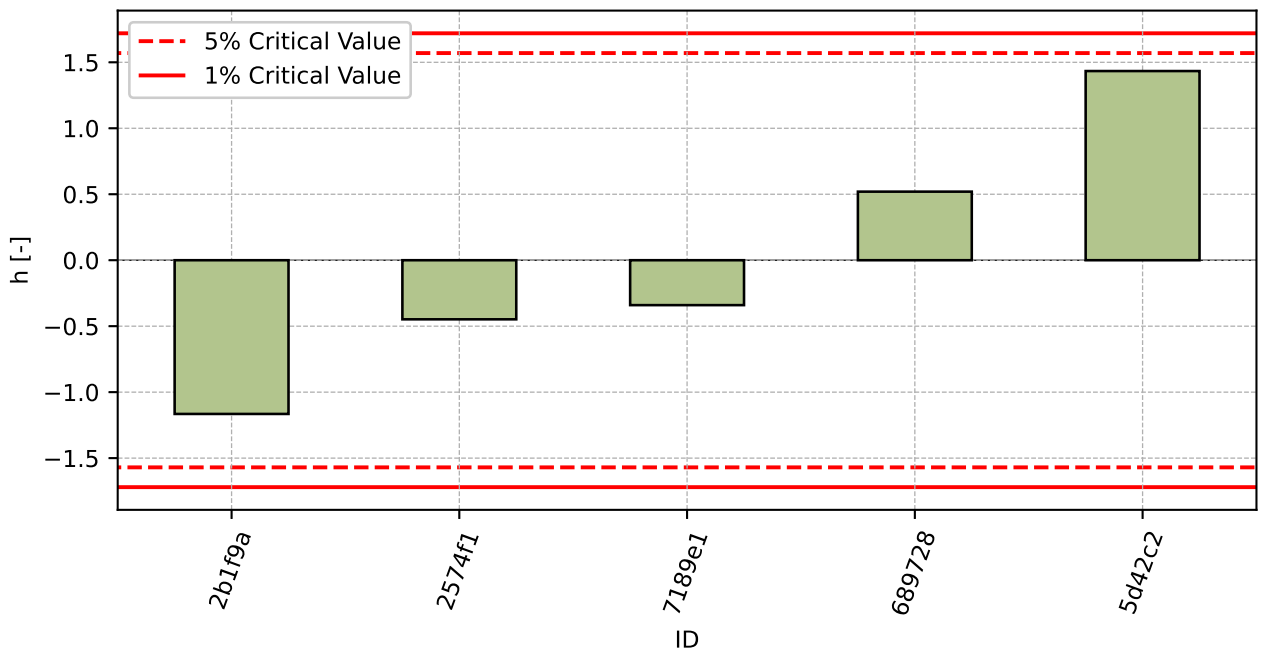

Figure 81: Interlaboratory Consistency Statistic

Descriptive statistics

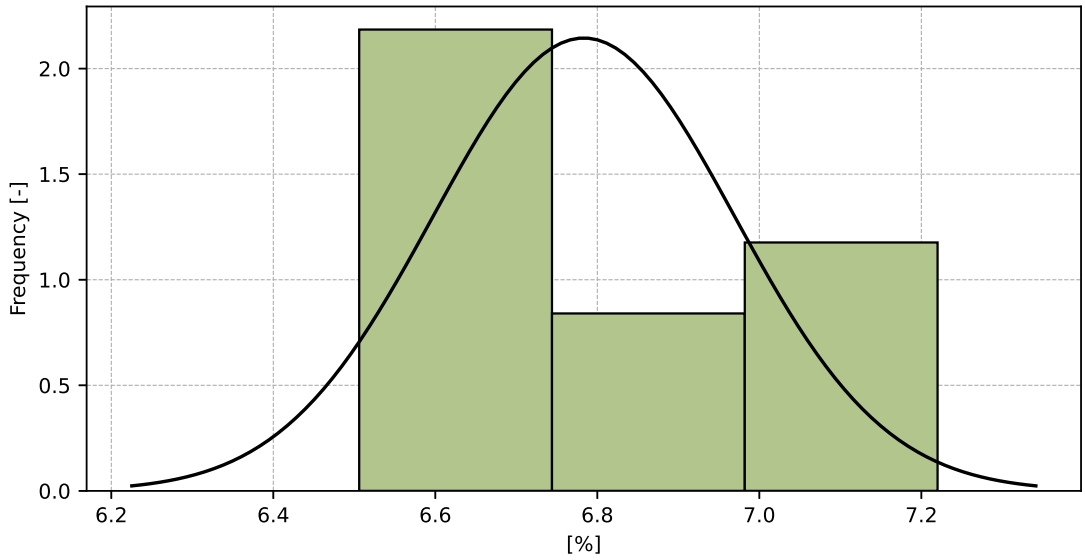

Figure 82: Histogram of all test results

Table 29: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	6.8
Sample standard deviation – s	0.19
Asigned value – x^*	6.8
Robust standard deviation – s^*	0.19
Measurement uncertainty of asigned value – u_X	0.11
p-value of normality test	0.089 [-]
Interlaboratory standard deviation – s_L	0.18
Repeatability standard deviation – s_r	0.11
Reproducibility standard deviation – s_R	0.21
Repeatability – r	0.3
Reproducibility – R	0.6

Evaluation of Performance Statistics

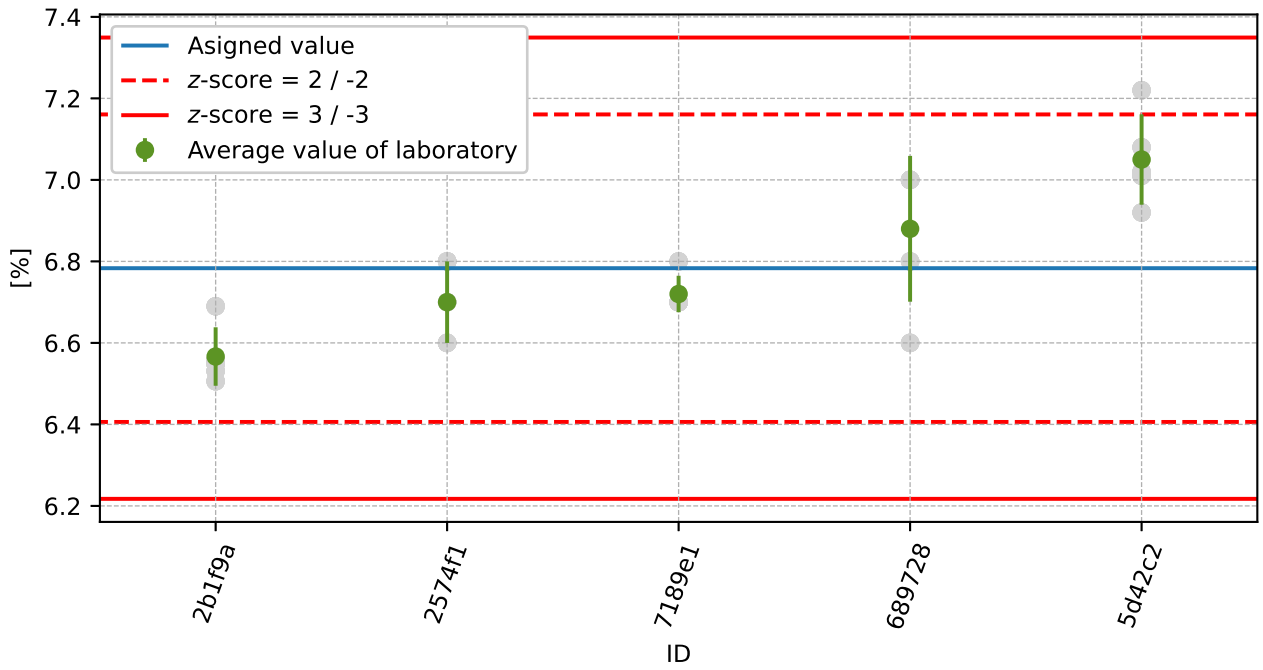

Figure 83: Average values and sample standard deviations

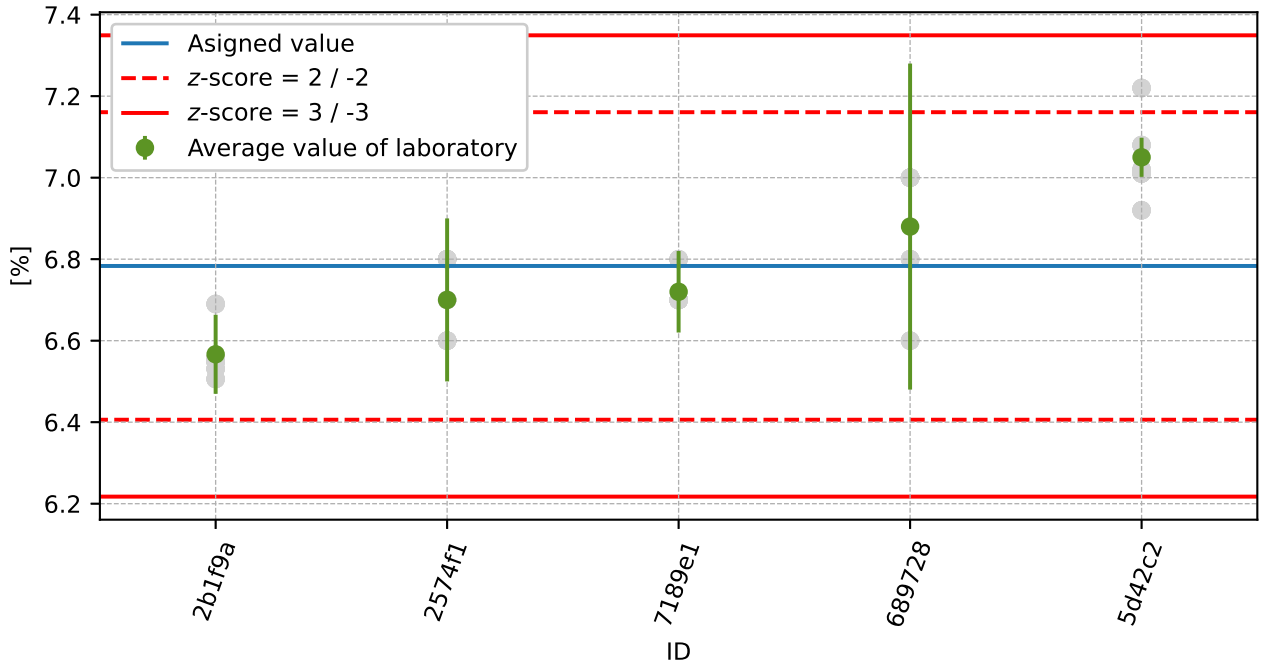

Figure 84: Average values and extended uncertainties of measurement

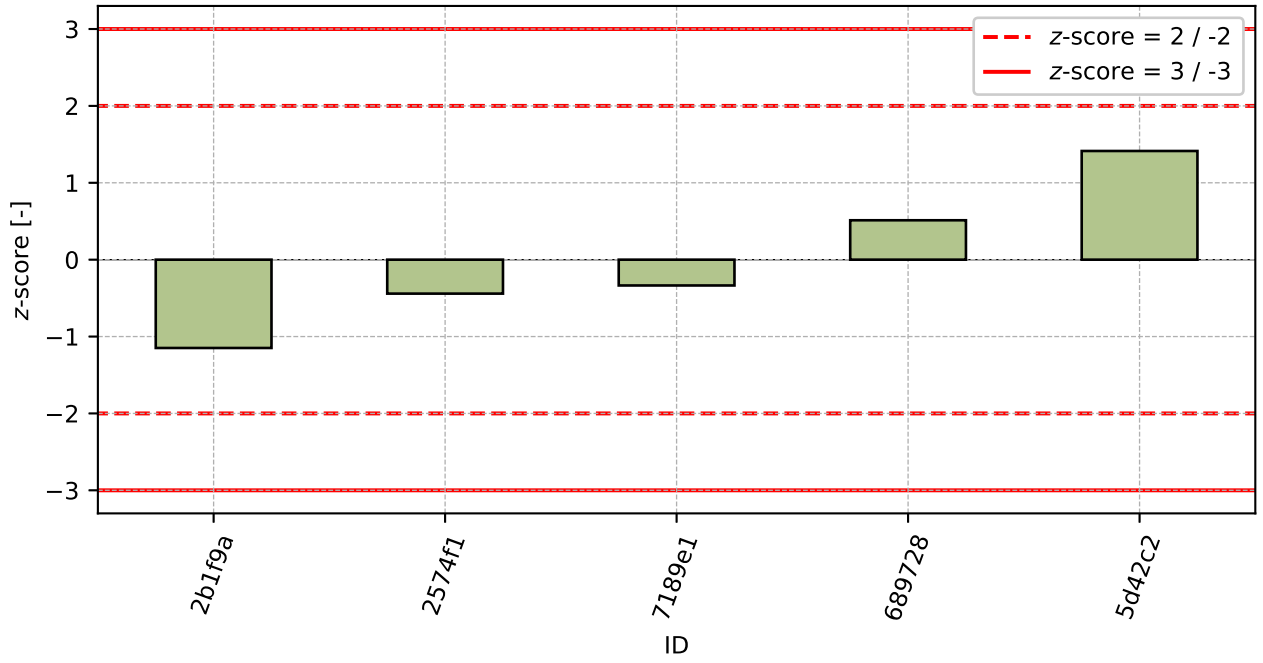

Figure 85: z-score

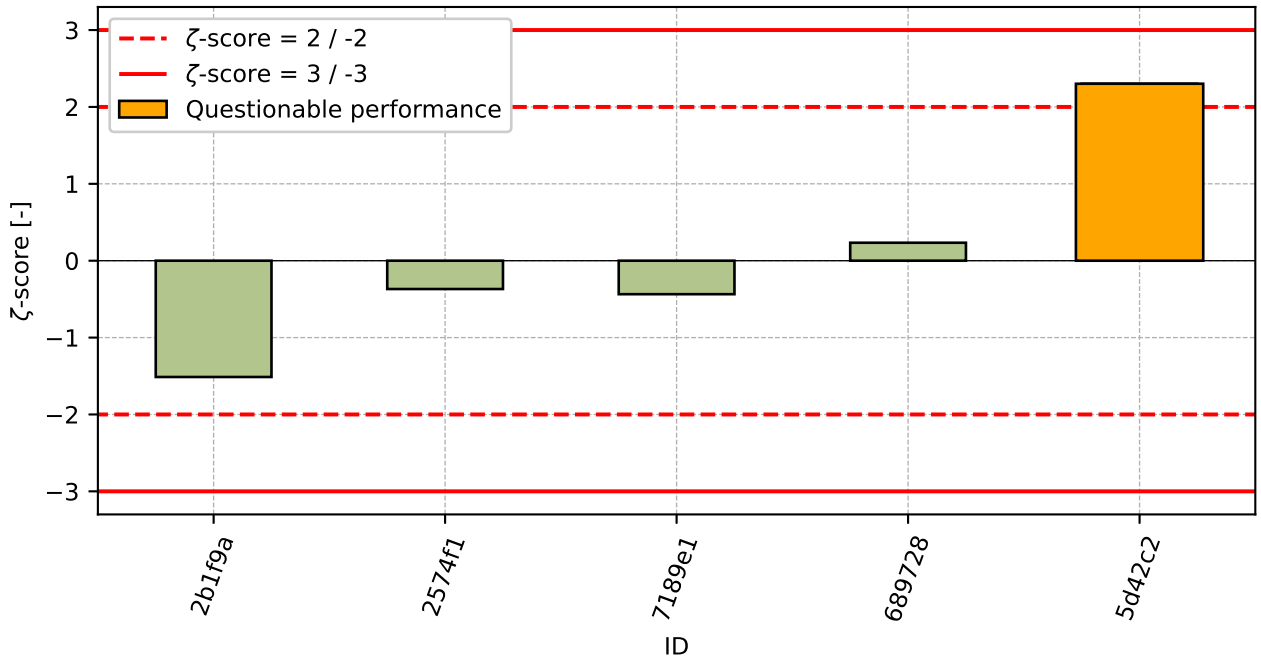

Figure 86: ζ-score

Table 30: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2b1f9a	-1.15	-1.51
2574f1	-0.44	-0.37
7189e1	-0.34	-0.44
689728	0.51	0.23
5d42c2	1.41	2.3

5.1.2 Sample B

Test results

Table 31: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [%]					u_X [%]	$\bar{x}$ [%]	s_0 [%]	V_X [%]
2b1f9a	6.3	6.3	6.4	6.3	6.4	0.1	6.4	0.06	0.88
7189e1	6.1	6.1	6.5	6.6	6.6	0.6	6.4	0.26	4.06
689728	6.4	6.6	6.6	6.4	6.3	0.3	6.5	0.13	2.08
5d42c2	6.8	6.5	6.6	6.5	6.8	0.0	6.6	0.14	2.05
2574f1	6.6	6.7	6.7	6.8	6.7	0.2	6.7	0.07	1.06

The Numerical Procedure for Determining Outliers

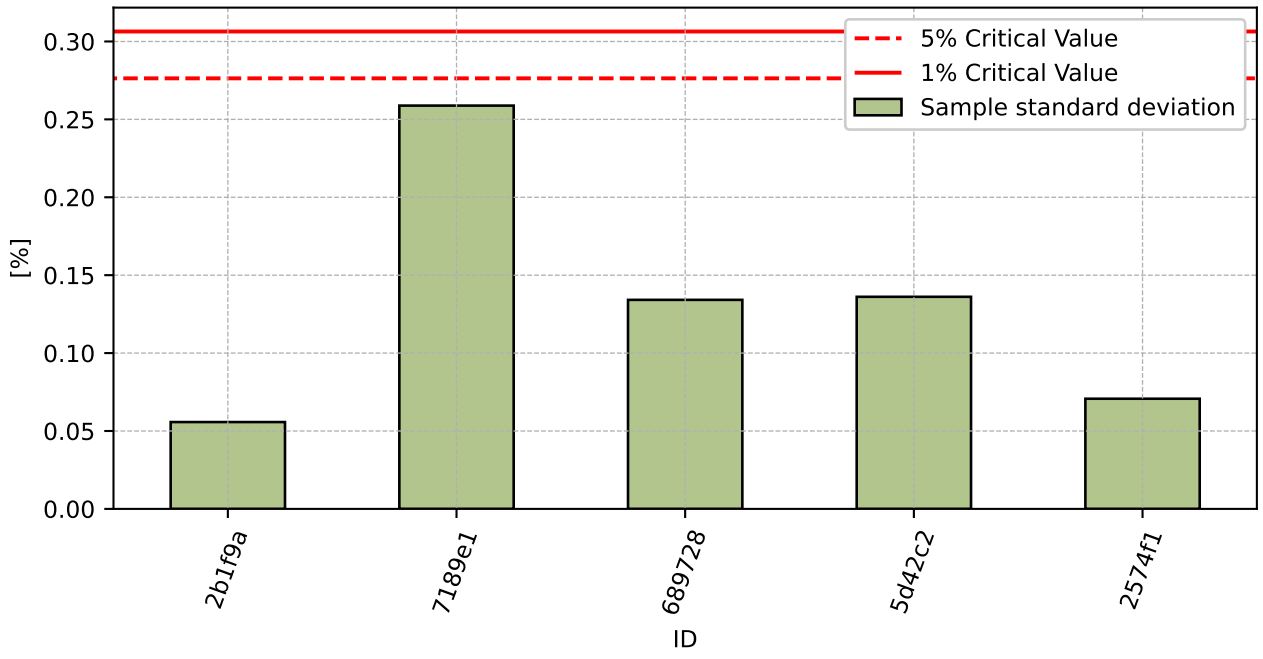

Figure 87: **Cochran's test** - sample standard deviations

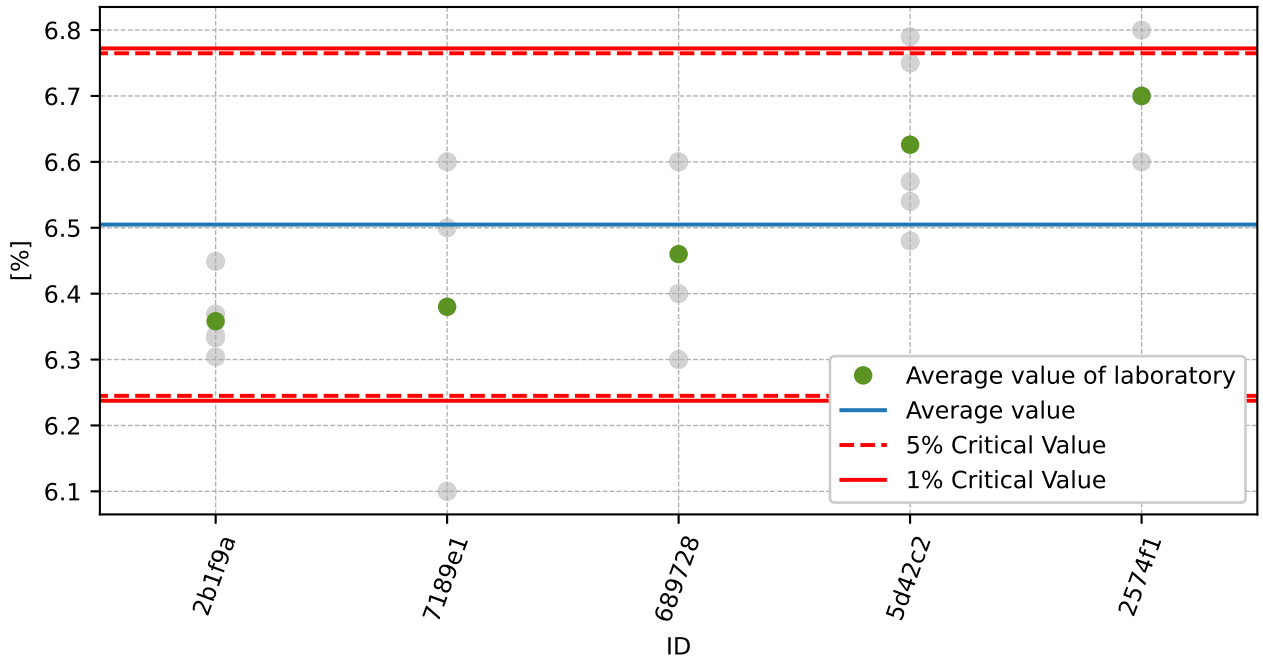

Figure 88: **Grubbs' test** - average values

Mandel's Statistics

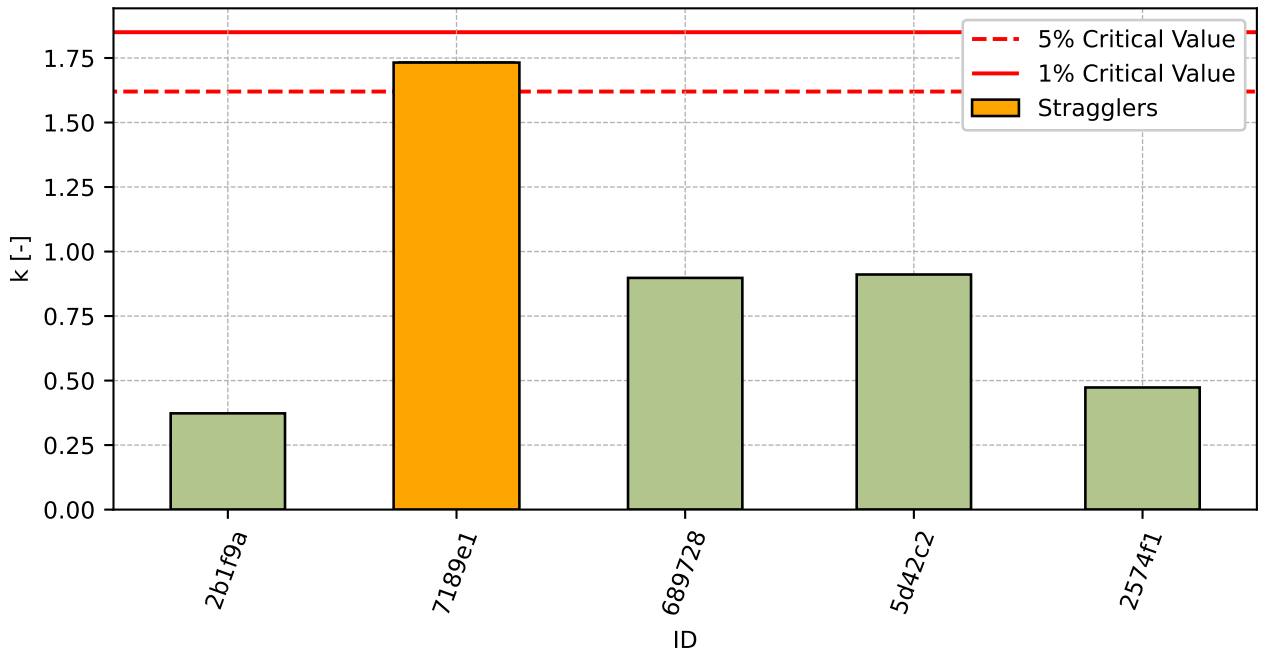

Figure 89: Intralaboratory Consistency Statistic

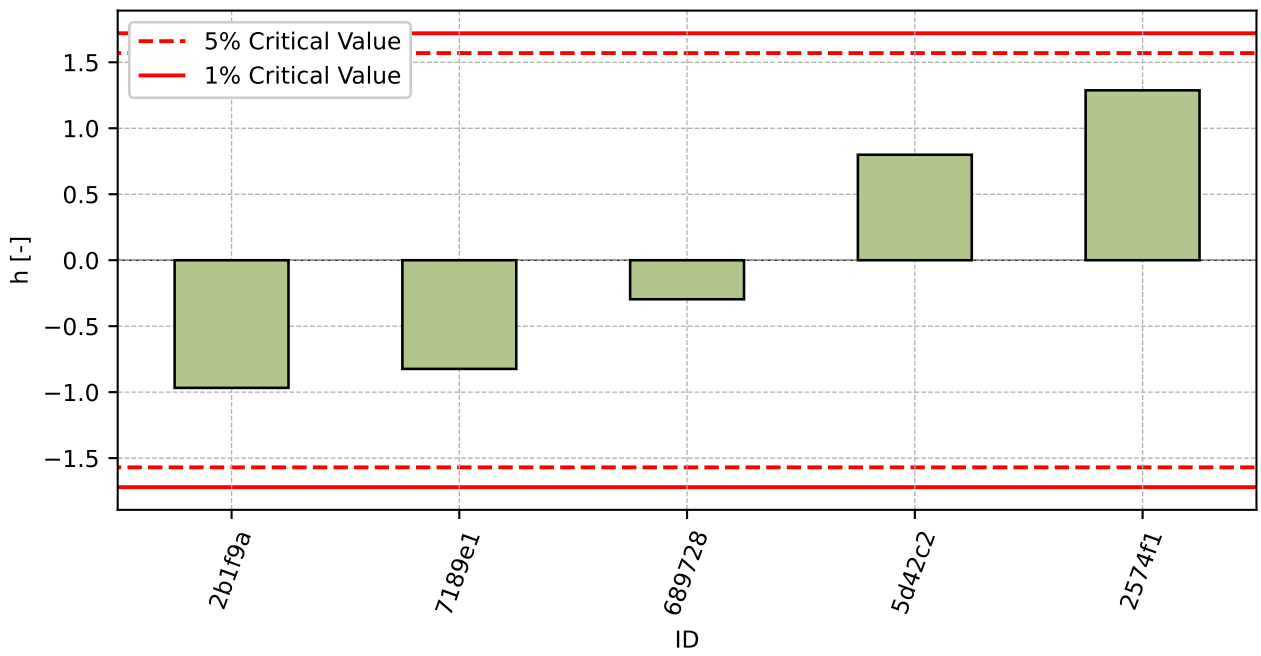

Figure 90: Interlaboratory Consistency Statistic

Descriptive statistics

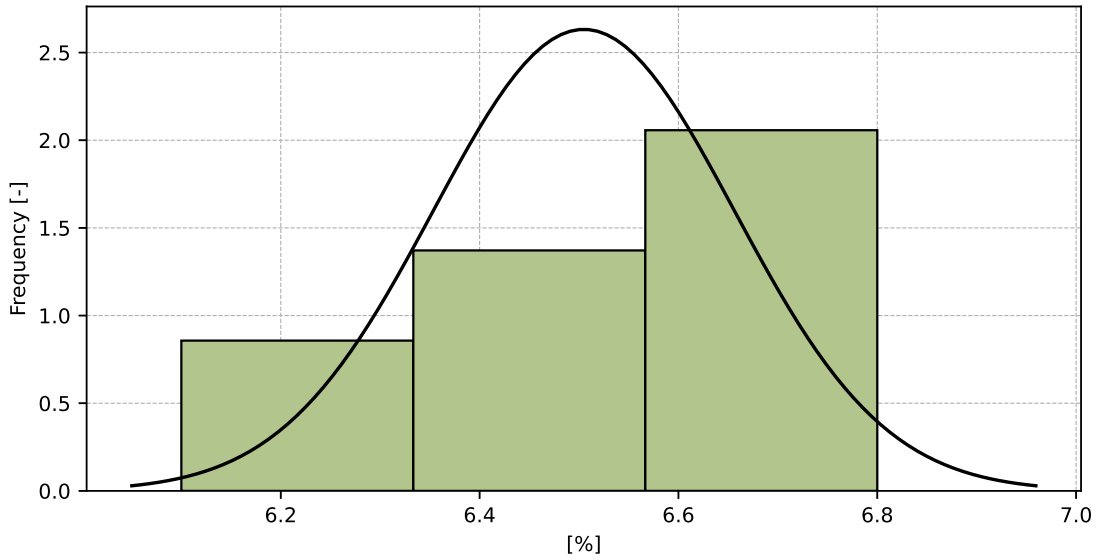

Figure 91: Histogram of all test results

Table 32: Descriptive statistics

Characteristics	[%]
Average value – $\bar{x}$	6.5
Sample standard deviation – s	0.15
Asigned value – x^*	6.5
Robust standard deviation – s^*	0.15
Measurement uncertainty of asigned value – u_X	0.09
p-value of normality test	0.294 [-]
Interlaboratory standard deviation – s_L	0.14
Repeatability standard deviation – s_r	0.15
Reproducibility standard deviation – s_R	0.2
Repeatability – r	0.4
Reproducibility – R	0.6

Evaluation of Performance Statistics

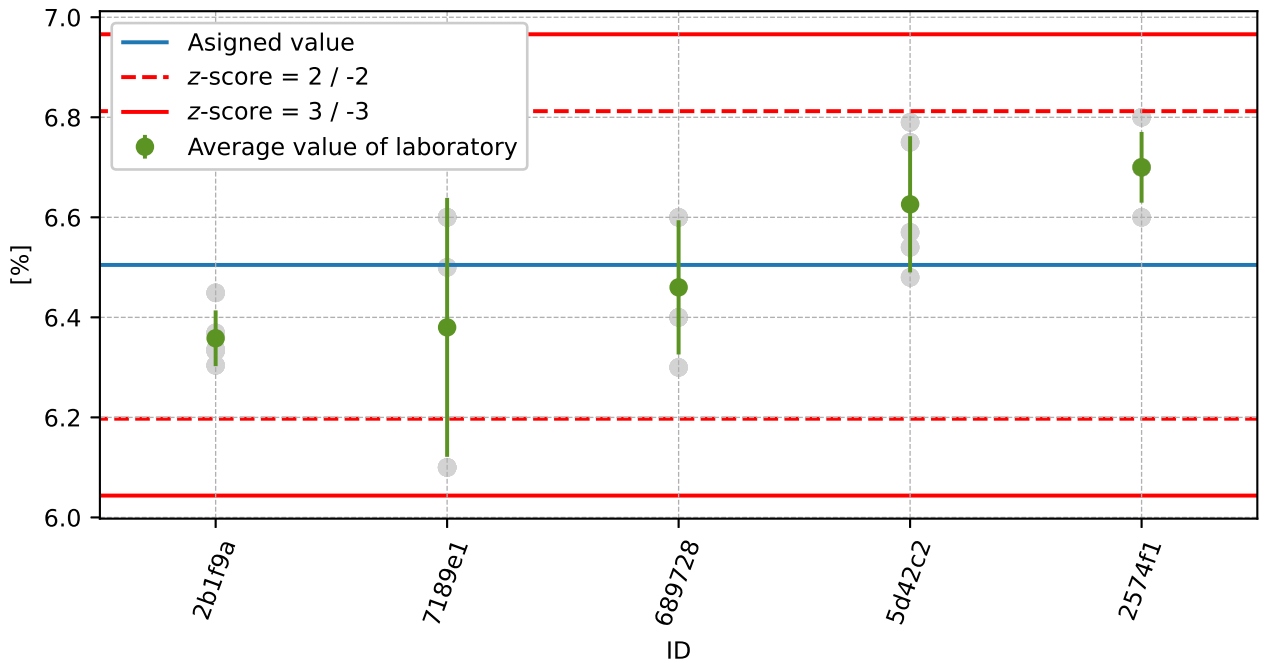

Figure 92: Average values and sample standard deviations

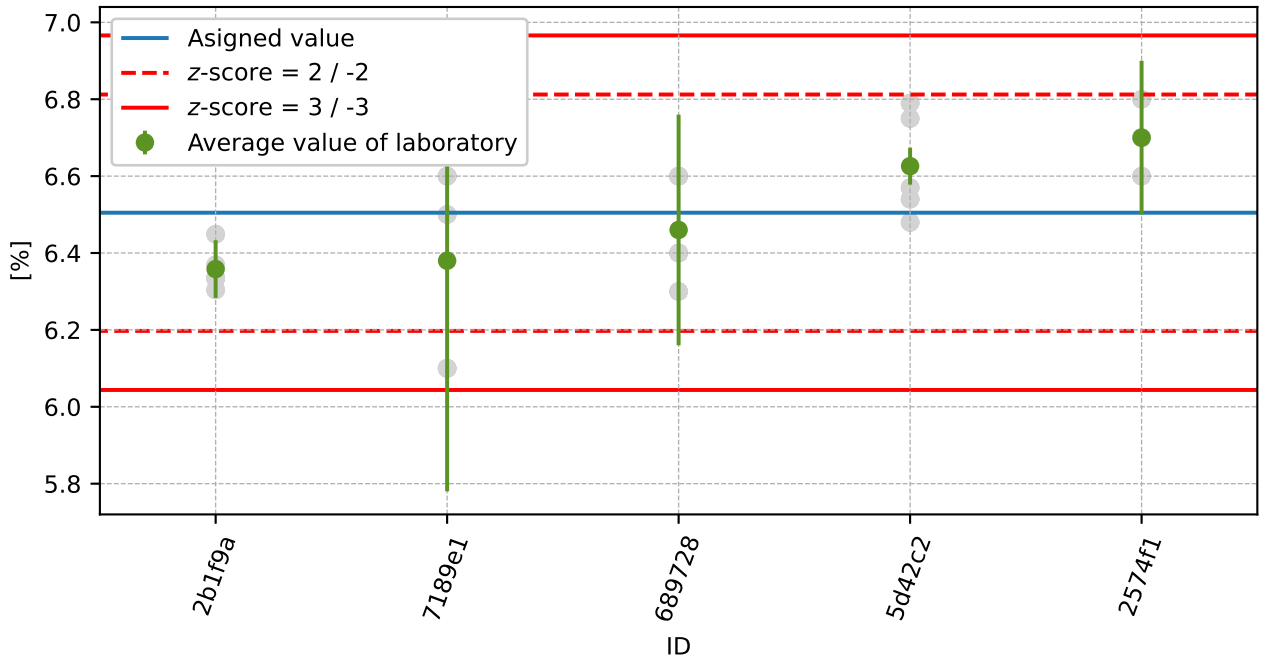

Figure 93: Average values and extended uncertainties of measurement

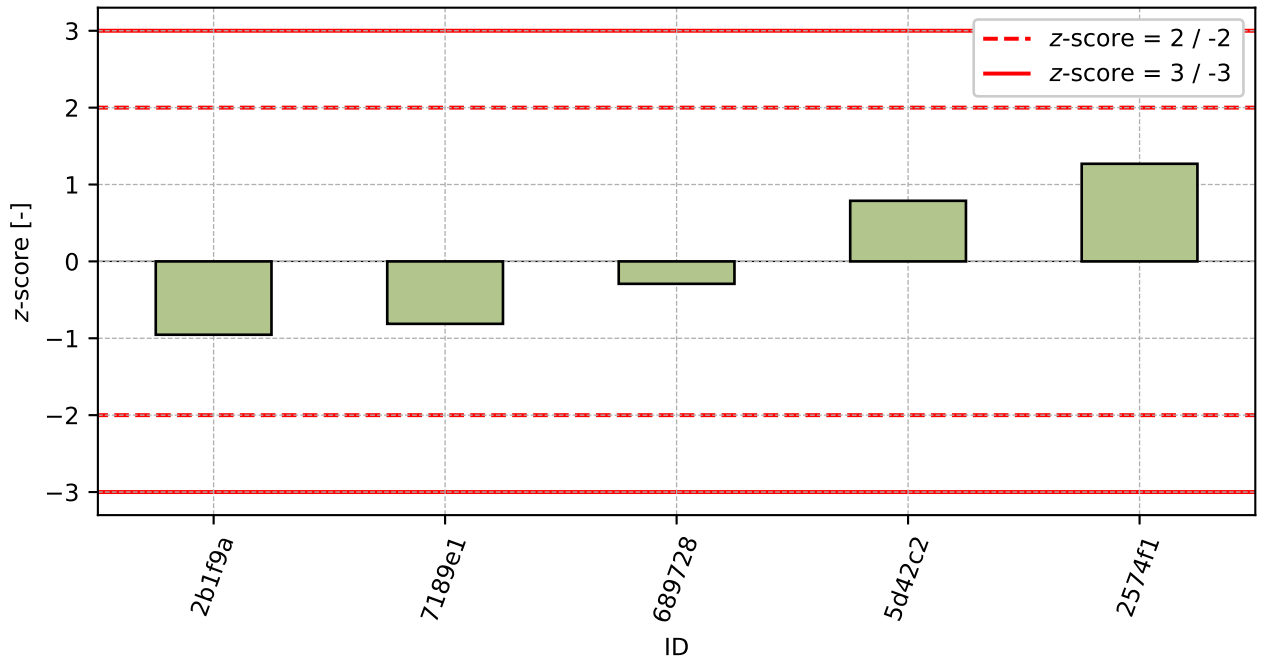

Figure 94: z-score

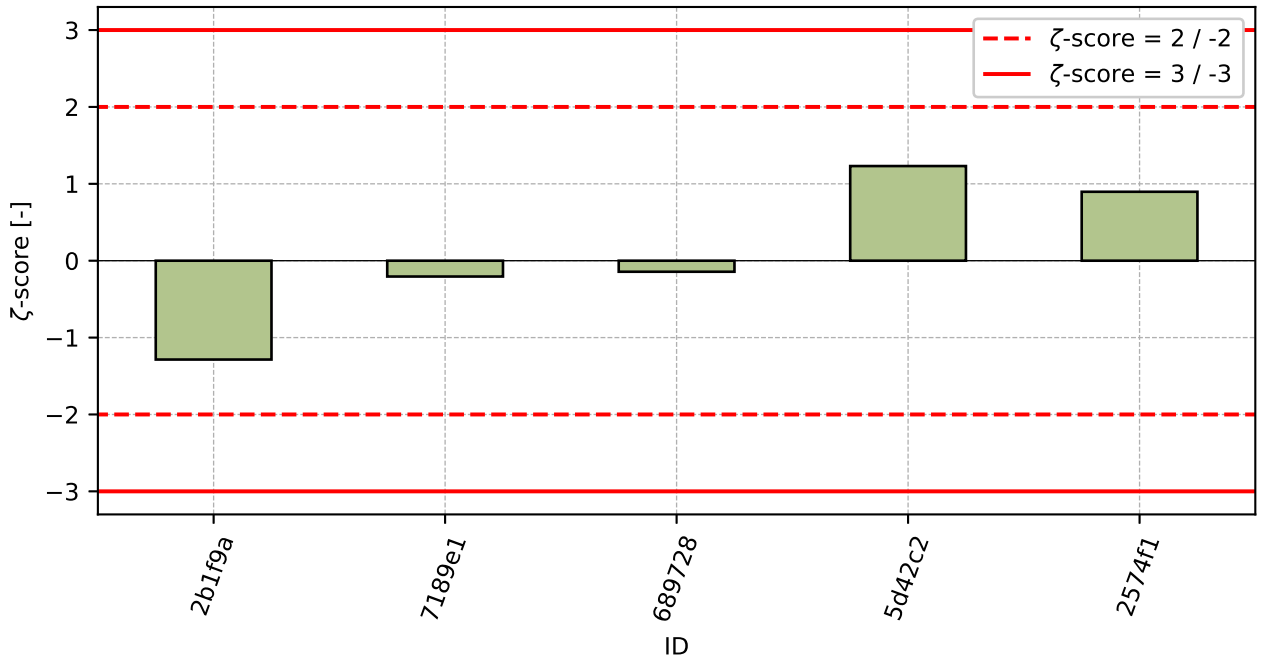

Figure 95: ζ-score

Table 33: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2b1f9a	-0.95	-1.29
7189e1	-0.81	-0.21
689728	-0.29	-0.14
5d42c2	0.79	1.23
2574f1	1.27	0.9

5.2 Flexural strength

5.2.1 Sample A

Test results

Table 34: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
2574f1	48.4	48.5	48.6	48.3	48.6	0.2	48.5	0.13	0.27
7189e1	49.8	49.1	48.9	48.9	48.9	1.0	49.1	0.39	0.79
689728	49.6	50.6	50.9	50.5	49.6	1.2	50.2	0.6	1.2
2b1f9a	54.8	55.6	55.5	54.5	55.0	0.6	55.1	0.46	0.83
5d42c2	56.9	56.9	56.8	57.1	56.5	1.4	56.8	0.21	0.37

The Numerical Procedure for Determining Outliers

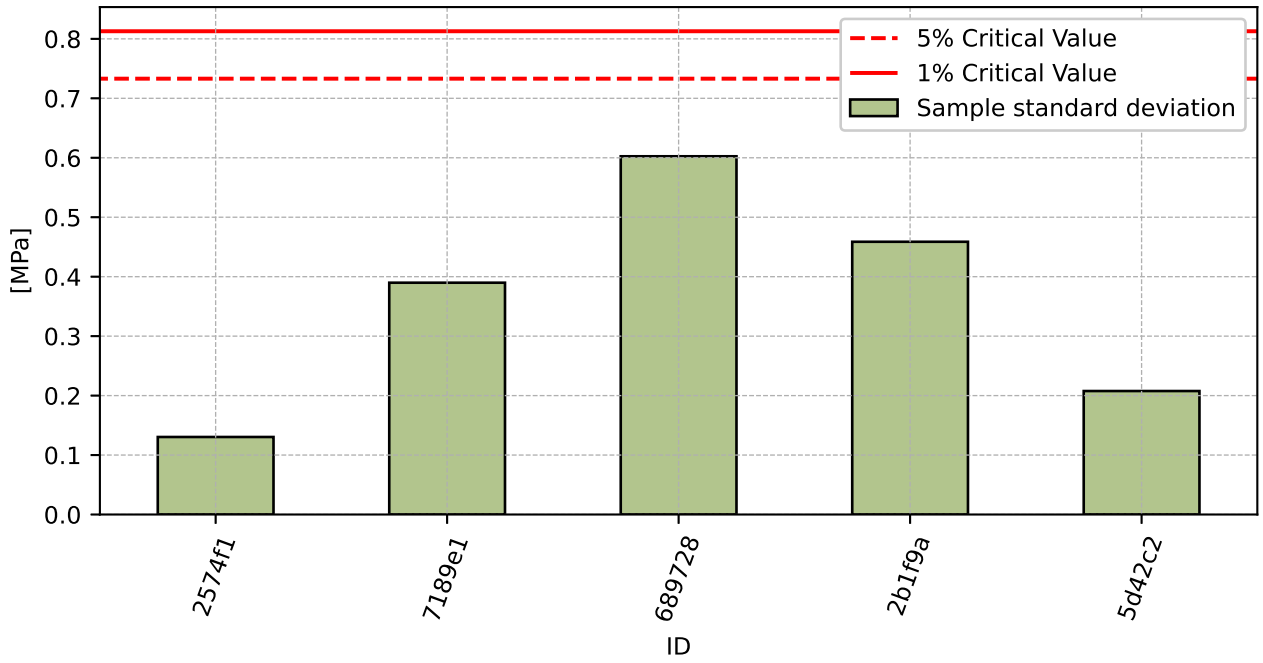

Figure 96: **Cochran's test** - sample standard deviations

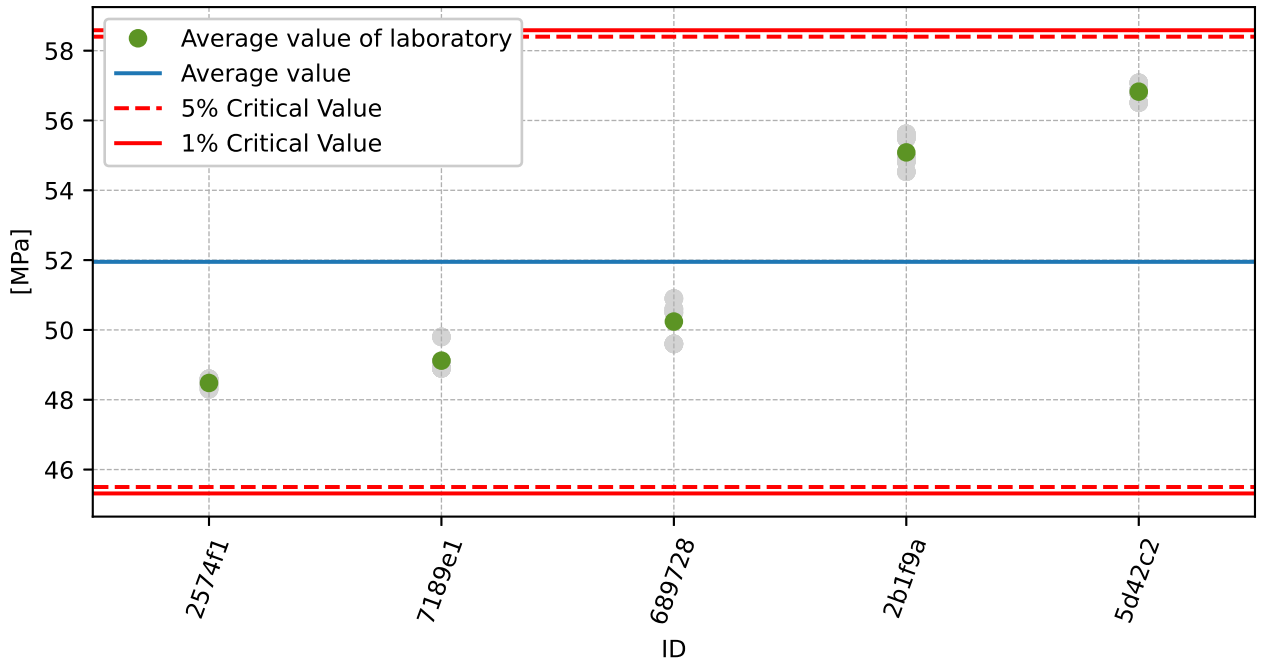

Figure 97: **Grubbs' test** - average values

Mandel's Statistics

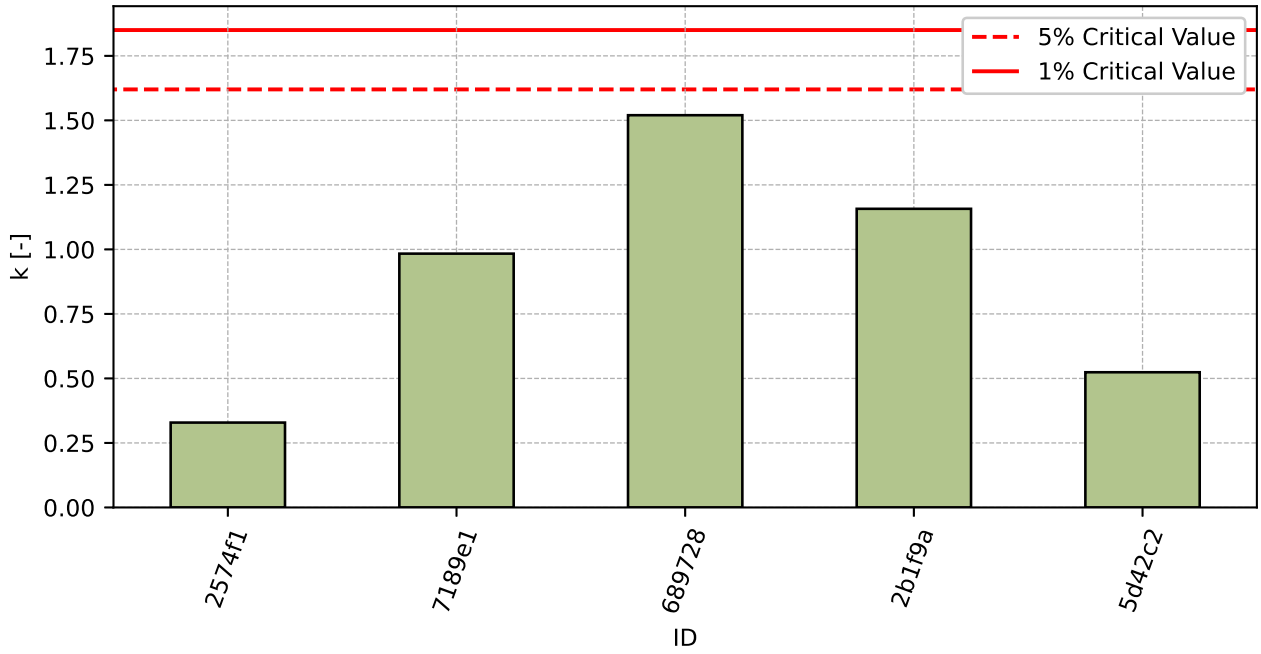

Figure 98: Intralaboratory Consistency Statistic

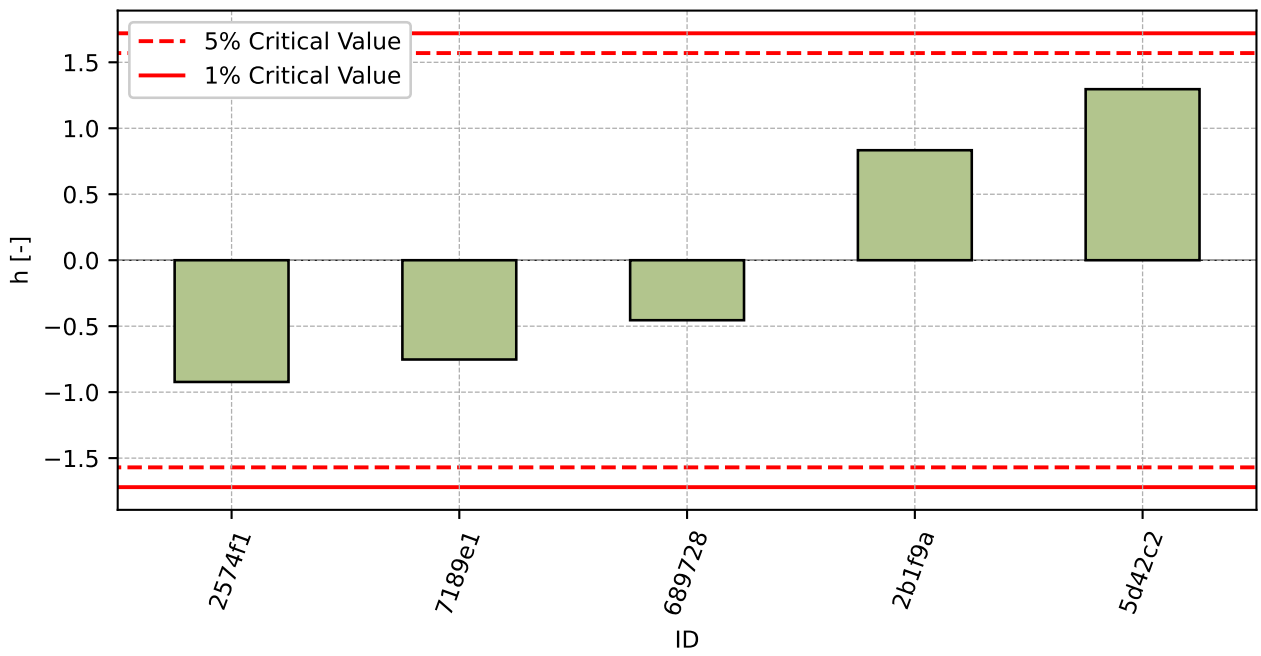

Figure 99: Interlaboratory Consistency Statistic

Descriptive statistics

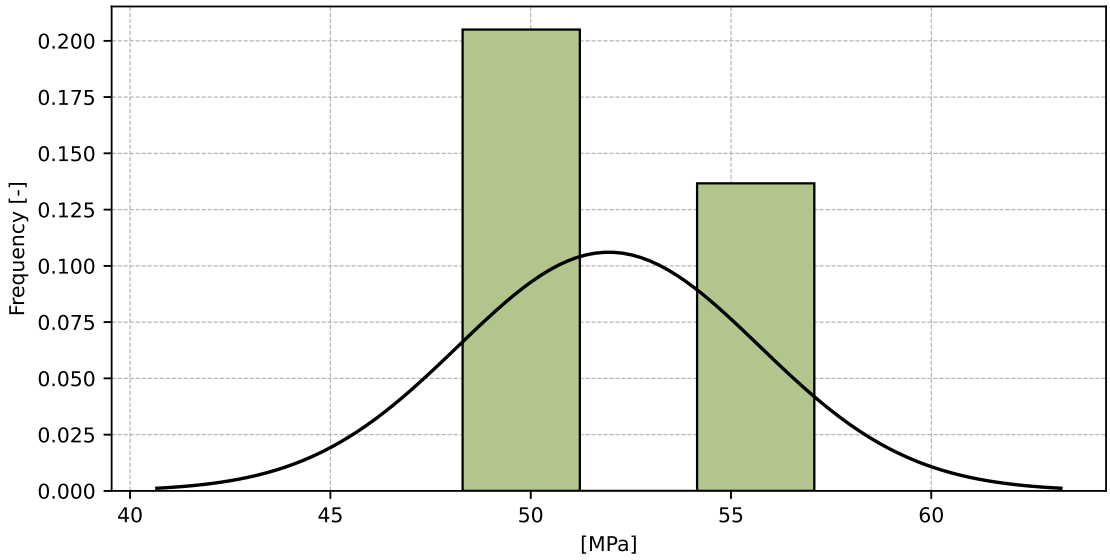

Figure 100: Histogram of all test results

Table 35: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	52.0
Sample standard deviation – s	3.76
Asigned value – x^*	51.8
Robust standard deviation – s^*	3.64
Measurement uncertainty of asigned value – u_X	2.03
p-value of normality test	0.0 [-]
Interlaboratory standard deviation – s_L	3.76
Repeatability standard deviation – s_r	0.4
Reproducibility standard deviation – s_R	3.78
Repeatability – r	1.1
Reproducibility – R	10.6

Evaluation of Performance Statistics

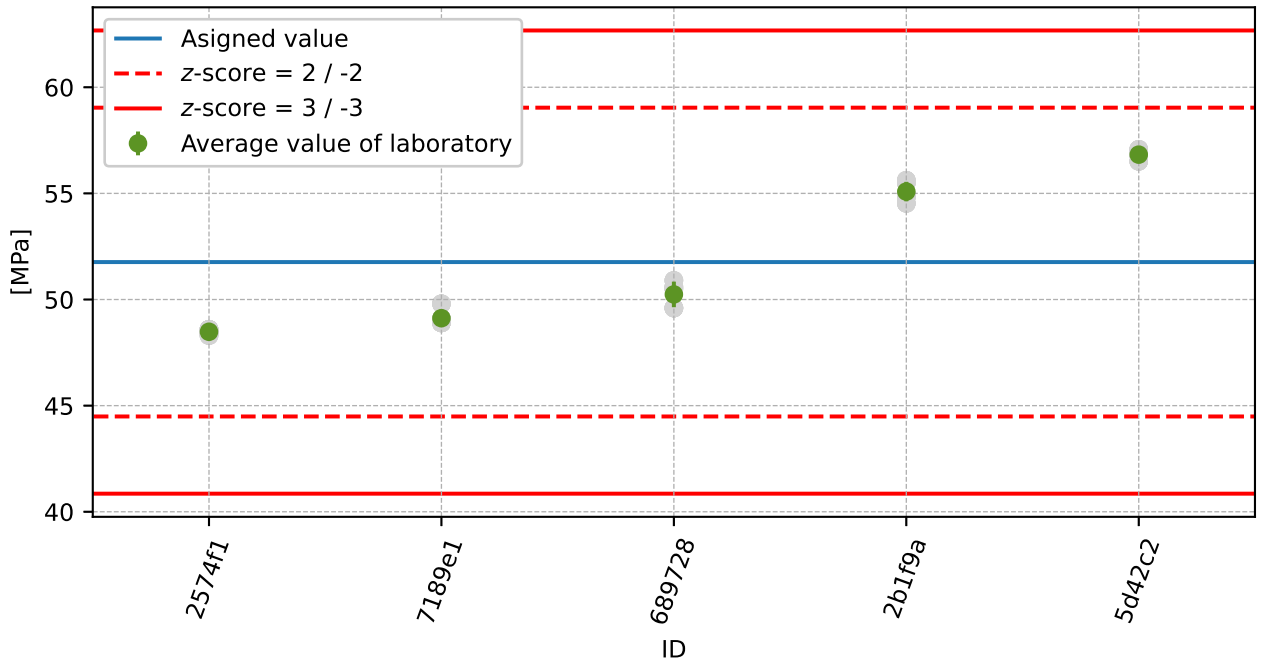

Figure 101: Average values and sample standard deviations

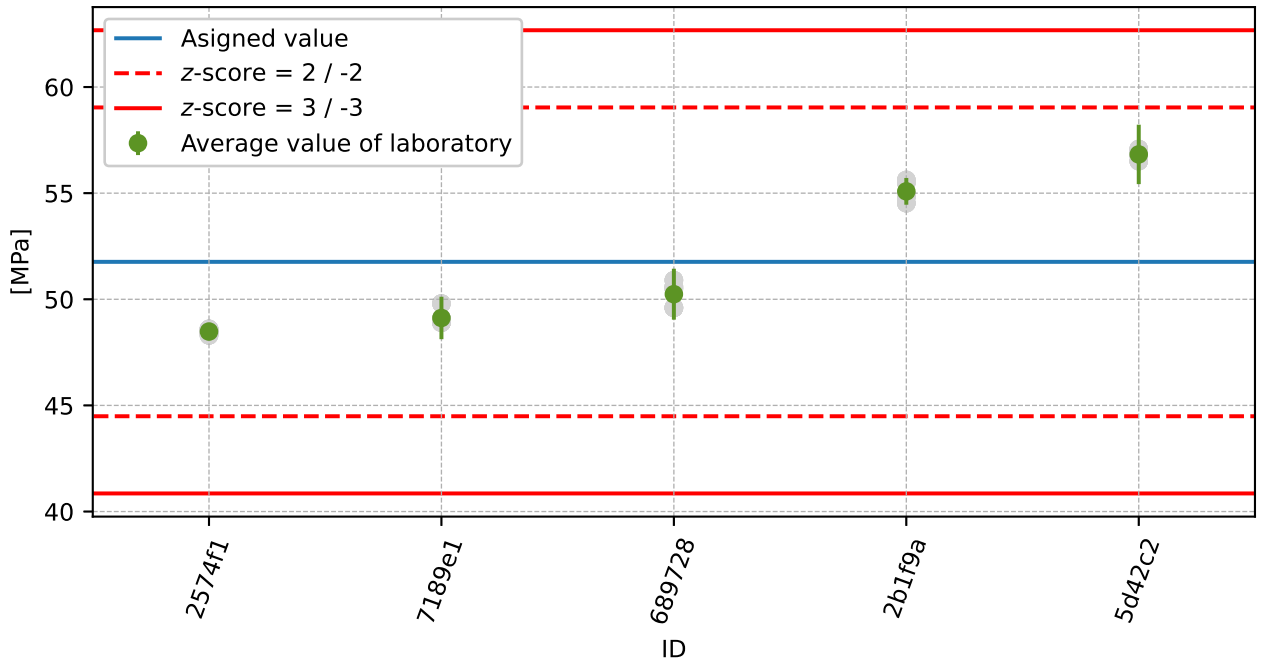

Figure 102: Average values and extended uncertainties of measurement

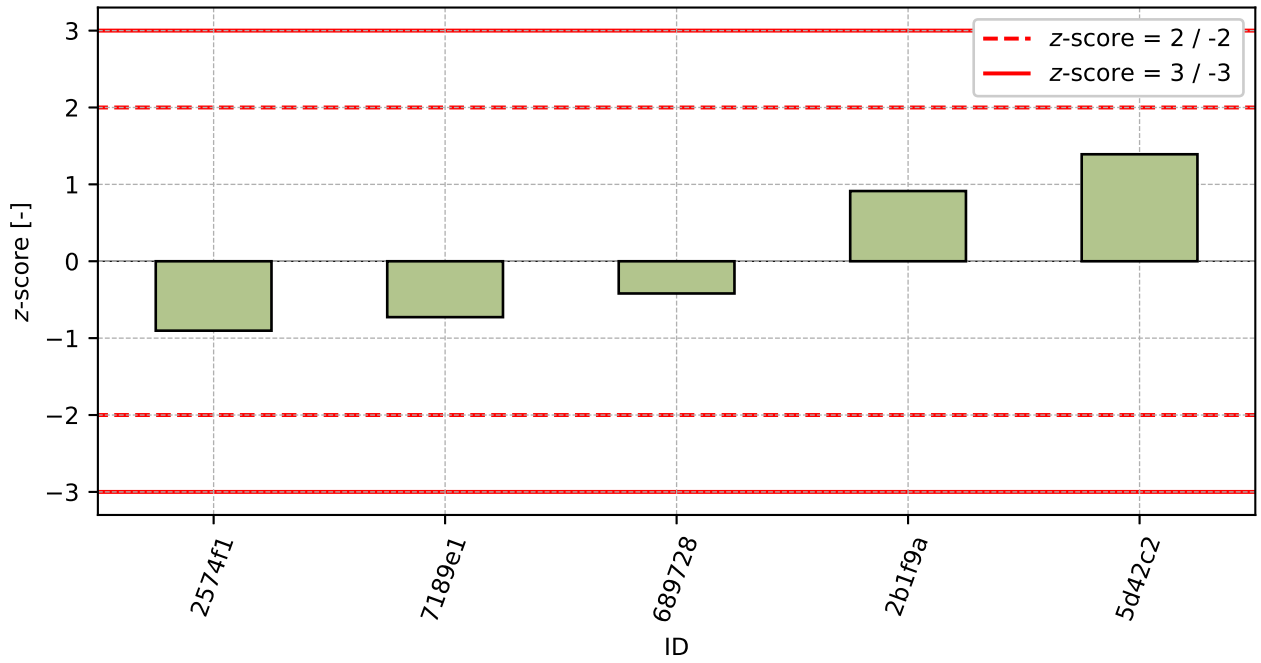

Figure 103: z-score

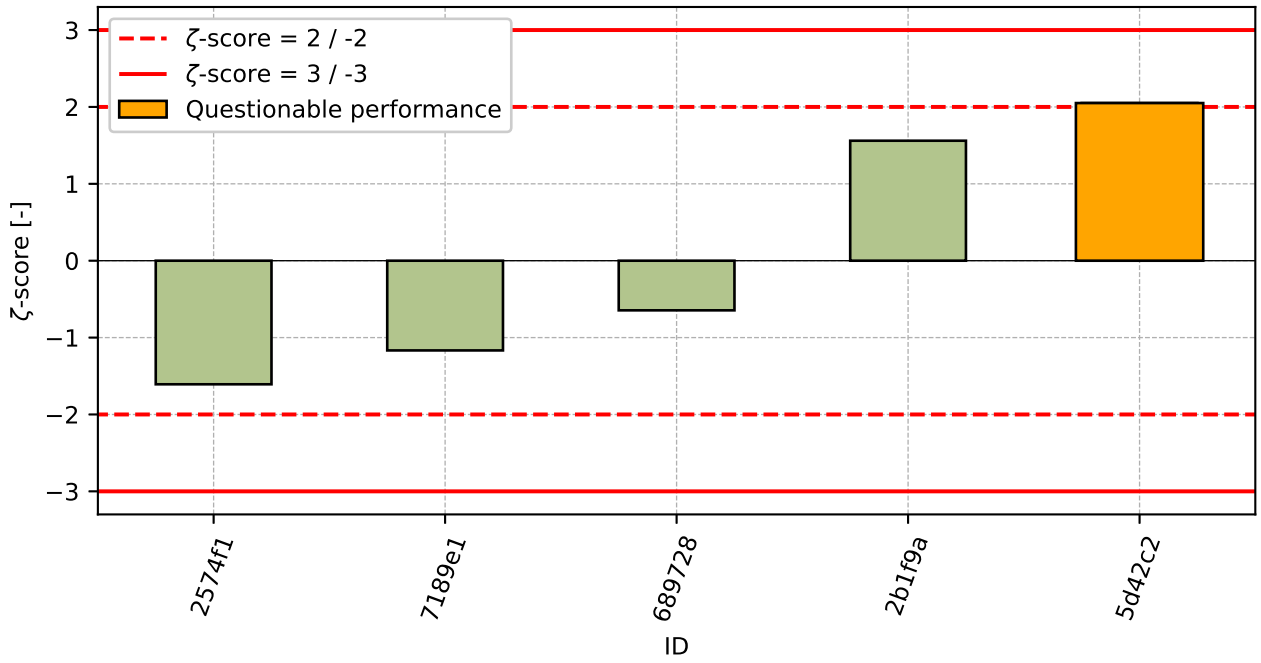

Figure 104: ζ-score

Table 36: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2574f1	-0.9	-1.61
7189e1	-0.73	-1.17
689728	-0.42	-0.65
2b1f9a	0.91	1.56
5d42c2	1.39	2.05

5.2.2 Sample B

Test results

Table 37: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [MPa]					u_X [MPa]	$\bar{x}$ [MPa]	s_0 [MPa]	V_X [%]
2574f1	34.8	35.0	35.2	34.9	35.0	0.4	35.0	0.15	0.42
7189e1	35.3	35.4	35.4	35.4	35.2	0.2	35.3	0.09	0.25
689728	38.6	38.2	37.6	38.0	38.1	0.7	38.1	0.36	0.95
2b1f9a	39.5	39.5	39.5	39.5	39.4	0.1	39.5	0.06	0.16
5d42c2	40.8	40.7	40.6	40.7	40.7	1.4	40.7	0.11	0.27

The Numerical Procedure for Determining Outliers

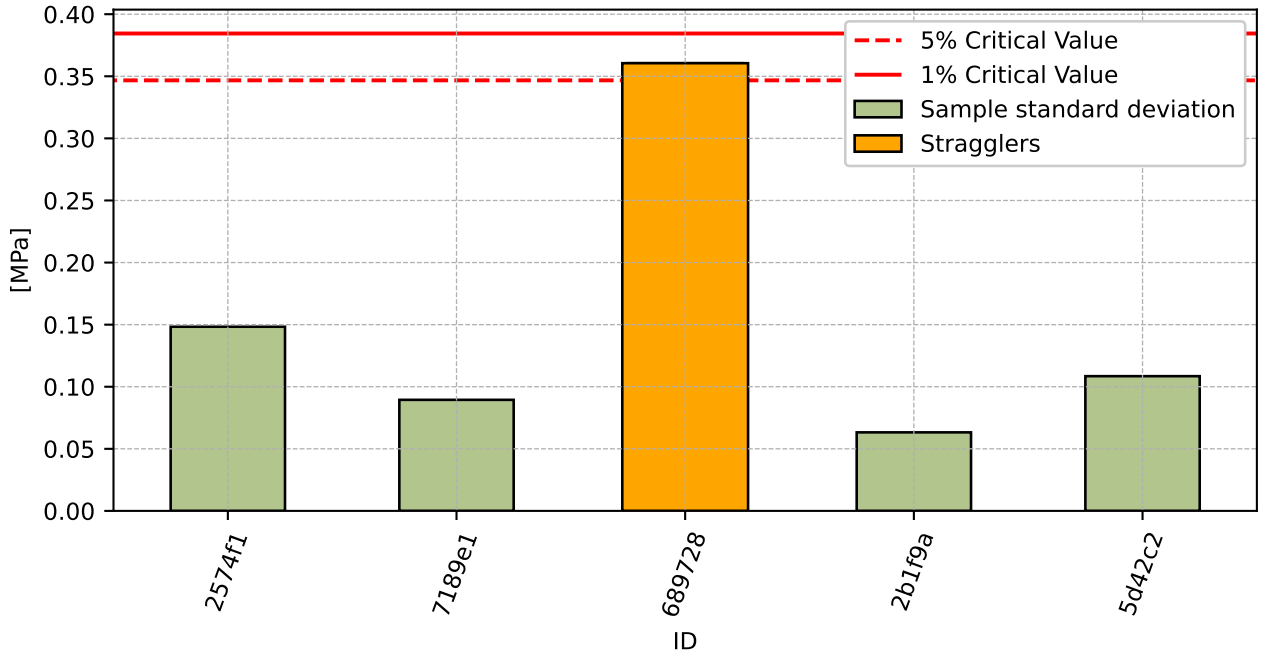

Figure 105: **Cochran's test** - sample standard deviations

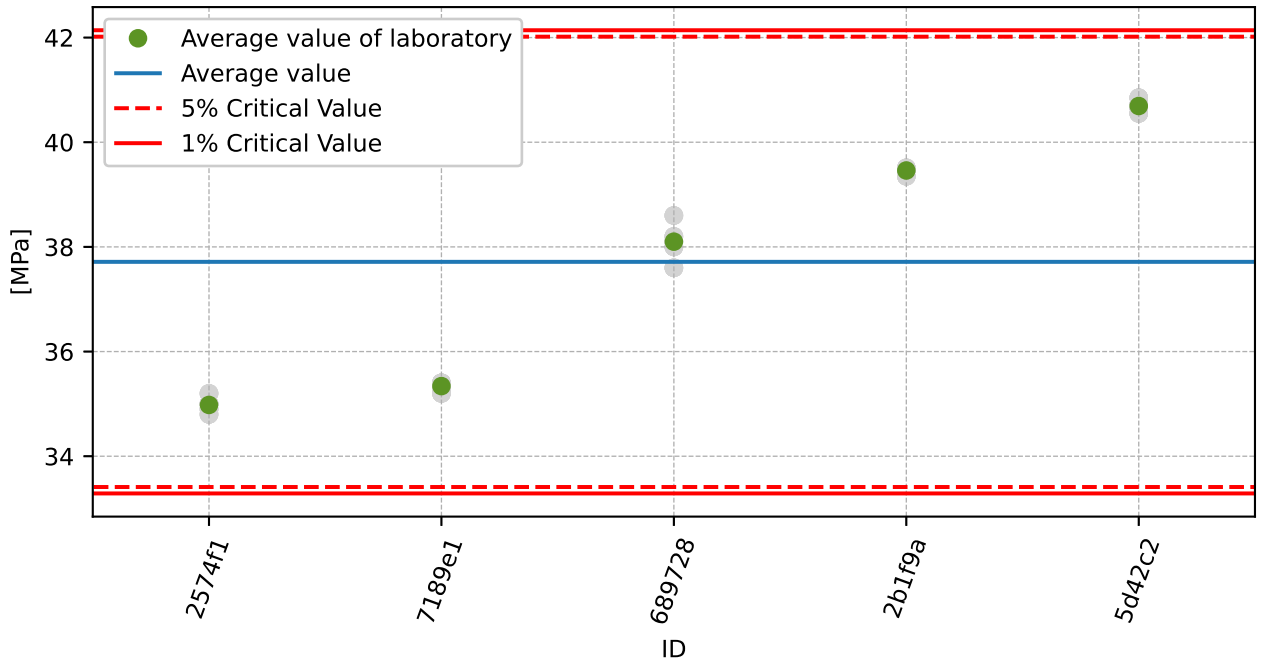

Figure 106: **Grubbs' test** - average values

Mandel's Statistics

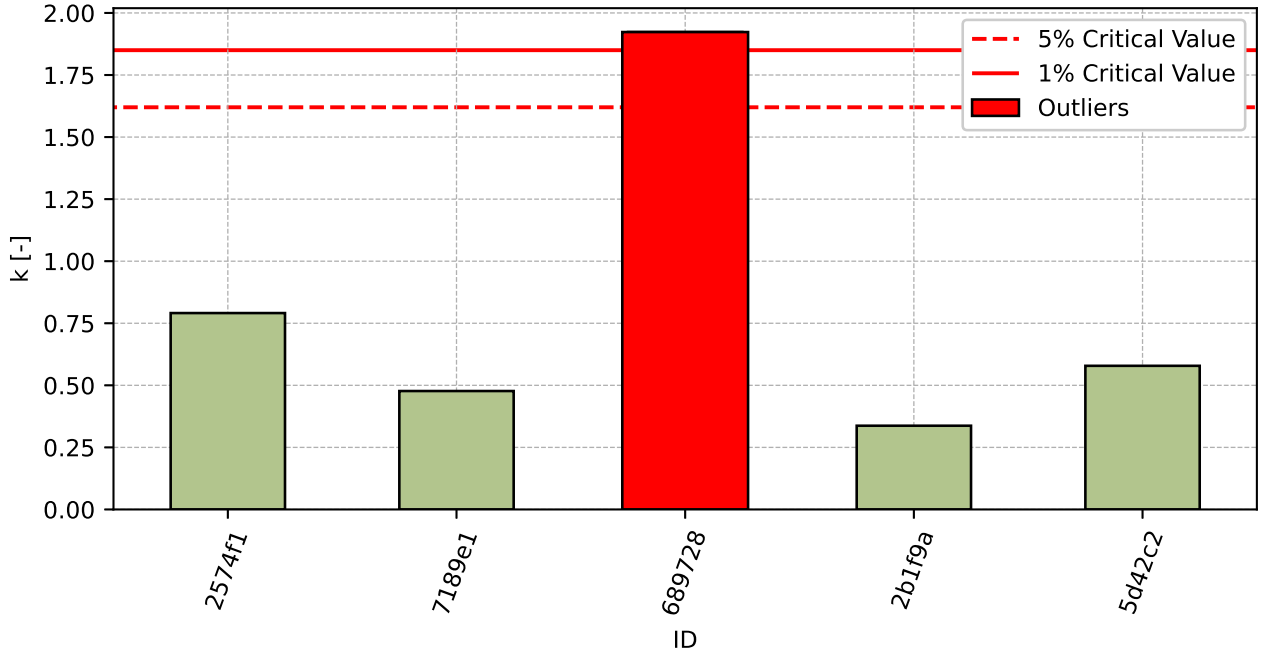

Figure 107: Intralaboratory Consistency Statistic

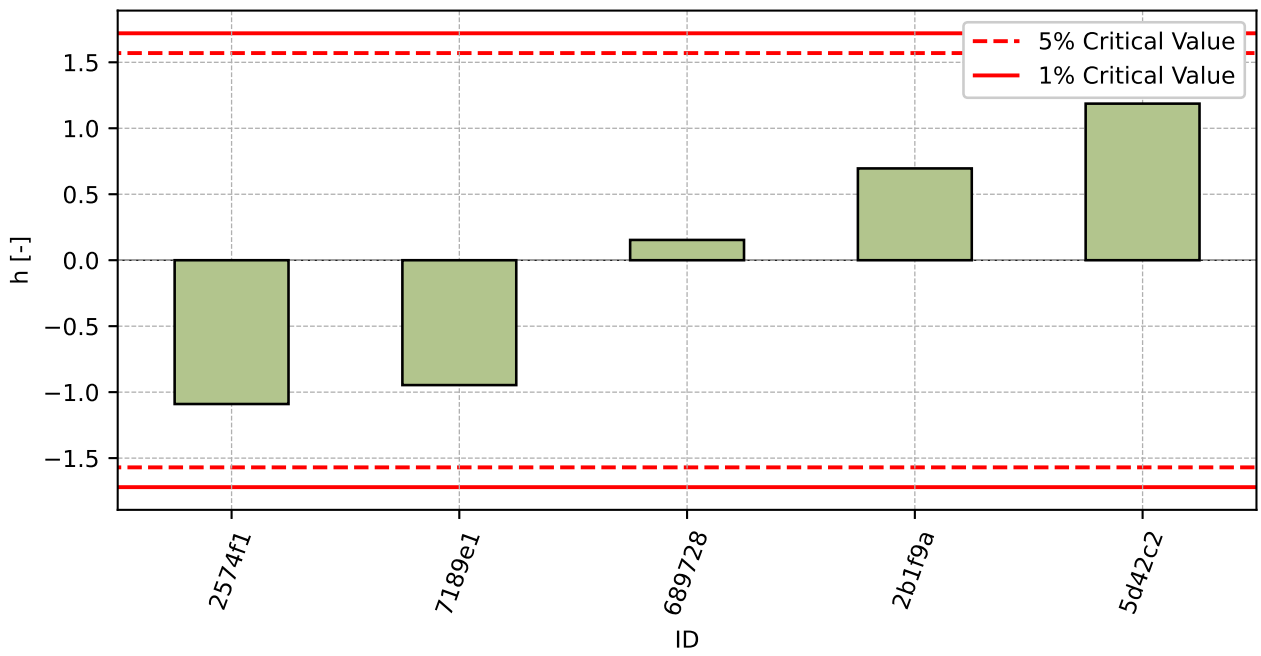

Figure 108: Interlaboratory Consistency Statistic

Descriptive statistics

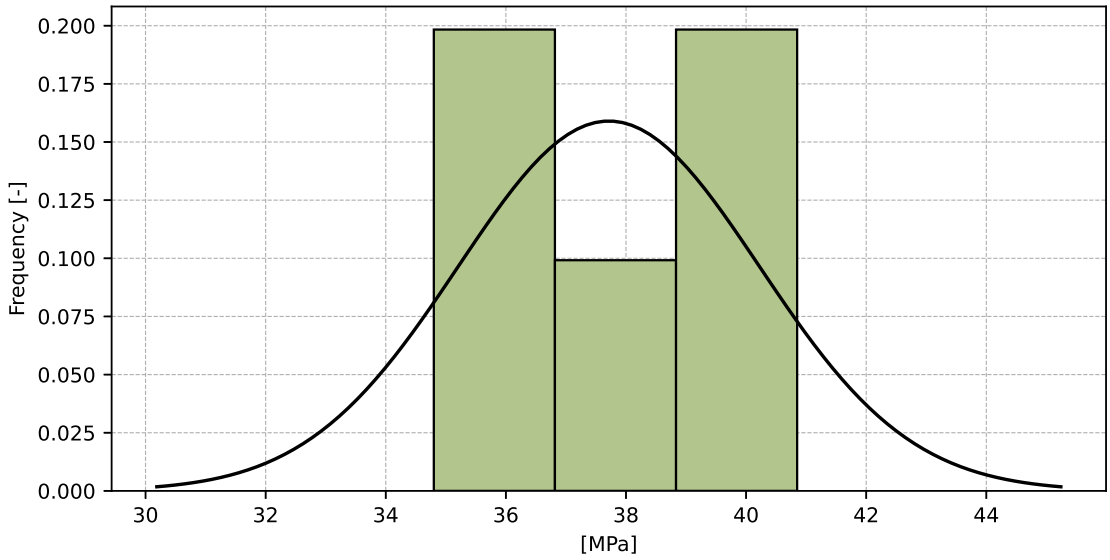

Figure 109: Histogram of all test results

Table 38: Descriptive statistics

Characteristics	[MPa]
Average value – $\bar{x}$	37.7
Sample standard deviation – s	2.51
Asigned value – x^*	37.7
Robust standard deviation – s^*	2.54
Measurement uncertainty of asigned value – u_X	1.42
p-value of normality test	0.002 [-]
Interlaboratory standard deviation – s_L	2.51
Repeatability standard deviation – s_r	0.19
Reproducibility standard deviation – s_R	2.51
Repeatability – r	0.5
Reproducibility – R	7.0

Evaluation of Performance Statistics

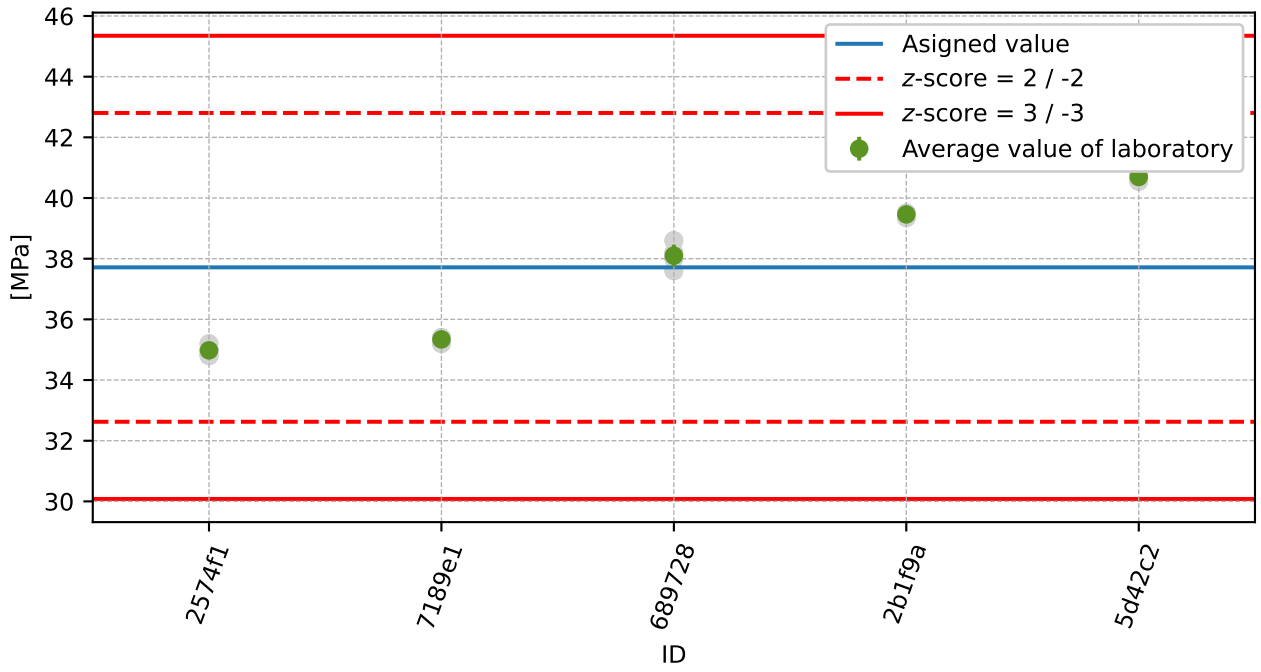

Figure 110: Average values and sample standard deviations

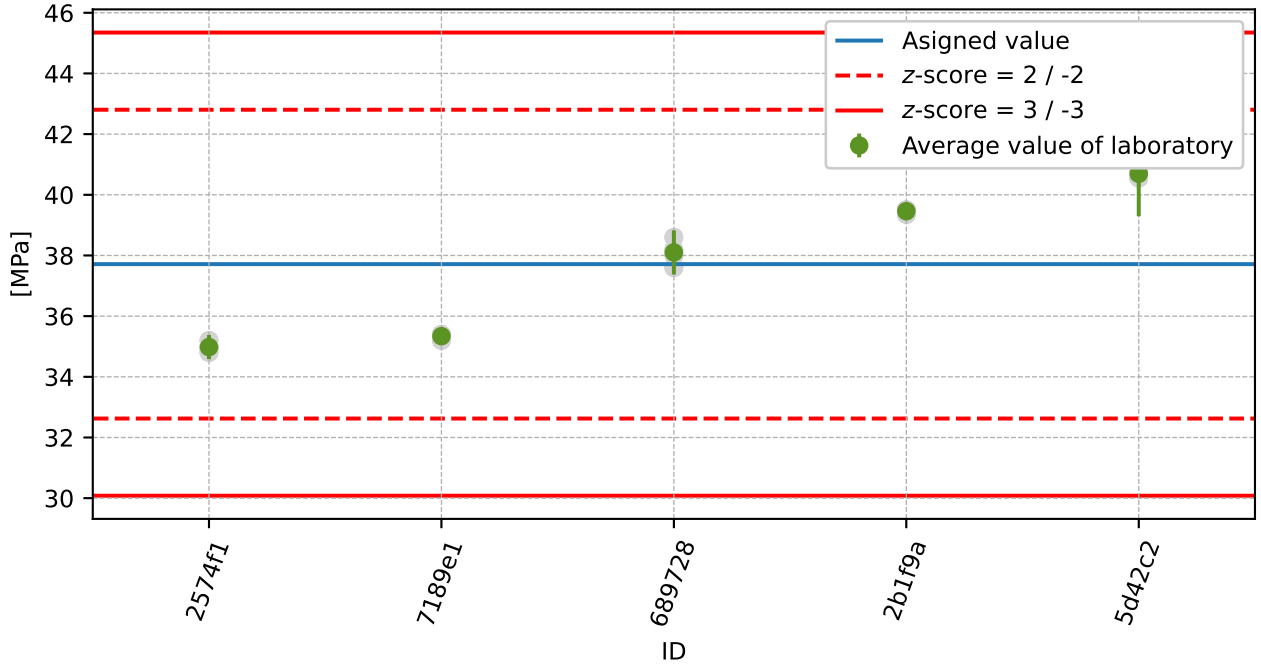

Figure 111: Average values and extended uncertainties of measurement

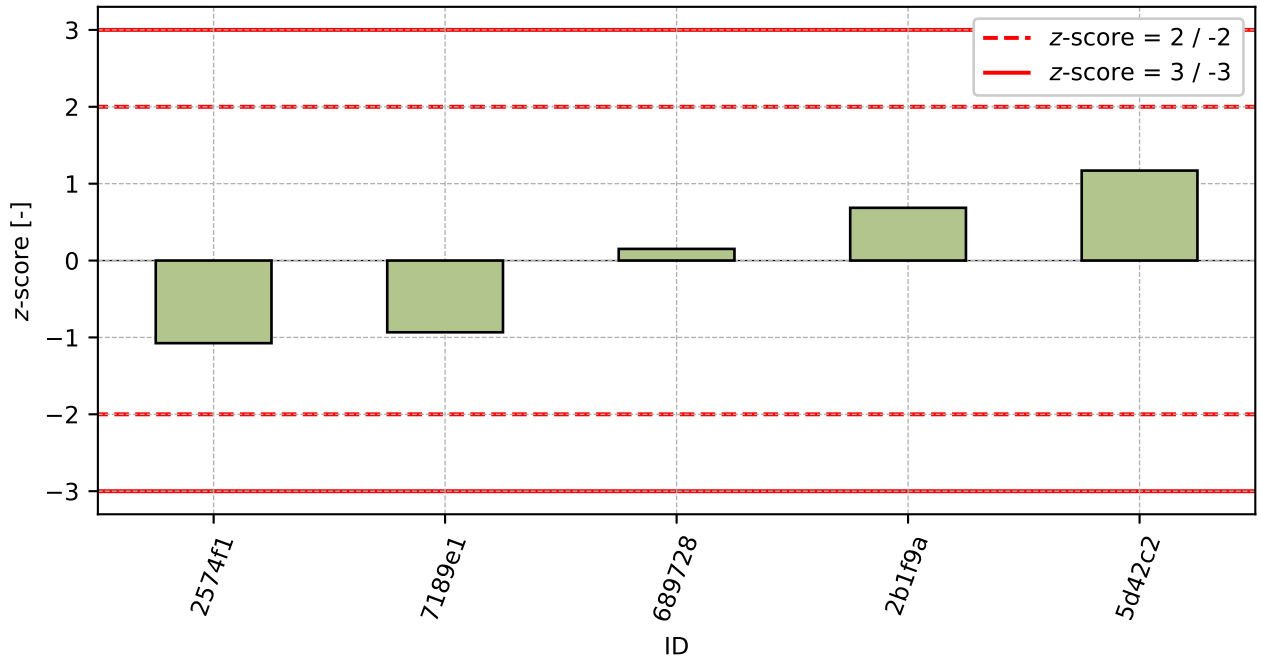

Figure 112: z-score

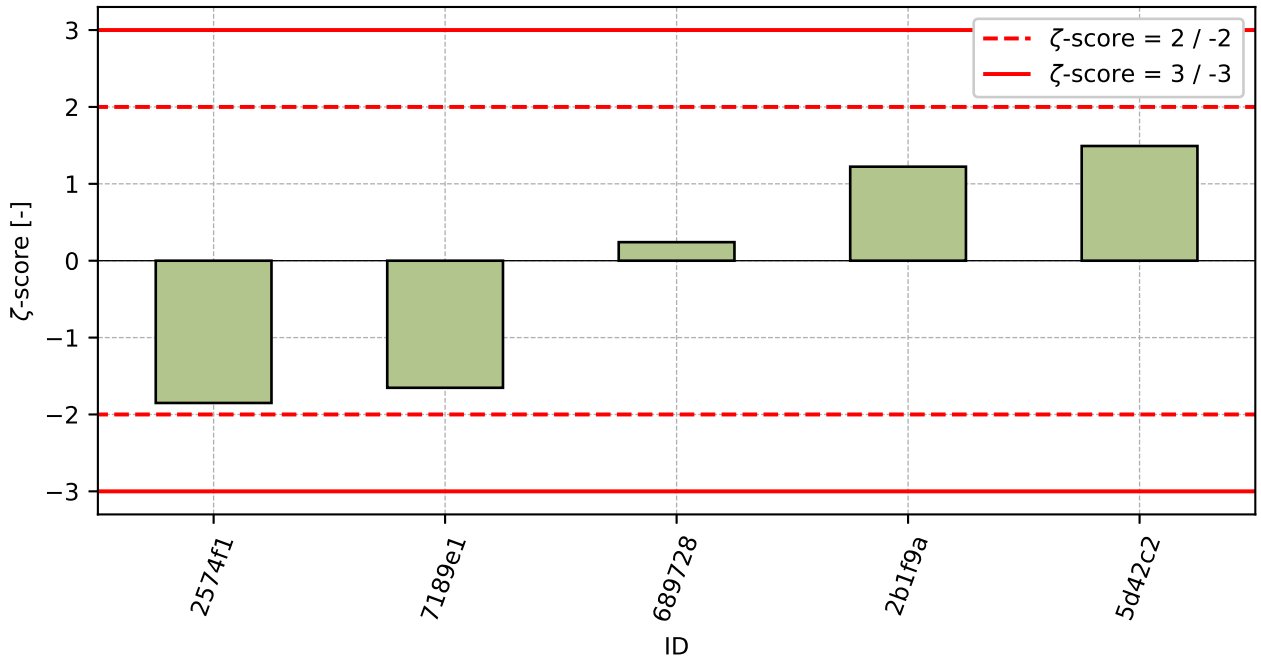

Figure 113: ζ-score

Table 39: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2574f1	-1.07	-1.85
7189e1	-0.93	-1.65
689728	0.15	0.24
2b1f9a	0.69	1.22
5d42c2	1.17	1.49

6 Appendix – EN ISO 179-1 (Charpy unnotched impact strength)

The test method was not opened due to the low number of participants.

7 Appendix – EN ISO 179-1 (Charpy notched impact strength (note: notch made by distributor))

The test method was not opened due to the low number of participants.

8 Appendix – EN ISO 179-1 (Charpy notched impact strength (note: notch made by laboratory))

The test method was not opened due to the low number of participants.

9 Appendix – EN ISO 868 (Shore hardness D)

The test method was not opened due to the low number of participants.

10 Appendix – EN ISO 306 (Vicat softening temperature VST/A/50)

The test method was not opened due to the low number of participants.

11 Appendix – EN ISO 306 (Vicat softening temperature VST/B/50)

The test method was not opened due to the low number of participants.

12 Appendix – EN ISO 75-1, -2 (Temperature of deflection under load, method A)

The test method was not opened due to the low number of participants.

13 Appendix – EN ISO 75-1, -2 (Temperature of deflection under load, method B)

The test method was not opened due to the low number of participants.

14 Appendix – EN ISO 1183-1 (Density)

The test method was not opened due to the low number of participants.

14.1 Sample A

14.1.1 Test results

Table 40: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [kg/m^3]			u_X [kg/m^3]	$\bar{x}$ [kg/m^3]	s_0 [kg/m^3]	V_X [%]
2574f1	907.8	907.8	907.7	0.8	907.8	0.06	0.01
7189e1	908.0	908.1	908.0	0.8	908.0	0.06	0.01
b98935	908.2	908.0	907.9	0.4	908.0	0.15	0.02
4a8816	908.8	908.9	908.9	0.1	908.9	0.05	0.01
689728	909.0	909.0	909.0	0.0	909.0	0.0	0.0

14.1.2 The Numerical Procedure for Determining Outliers

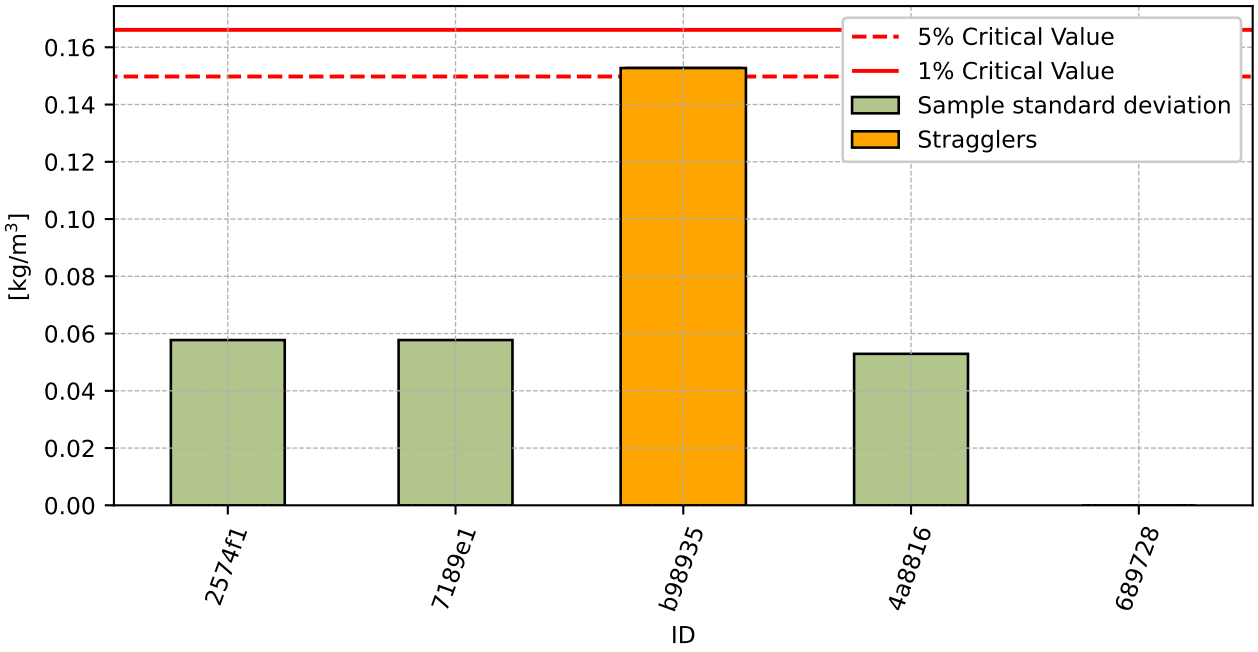

Figure 114: **Cochran's test** - sample standard deviations

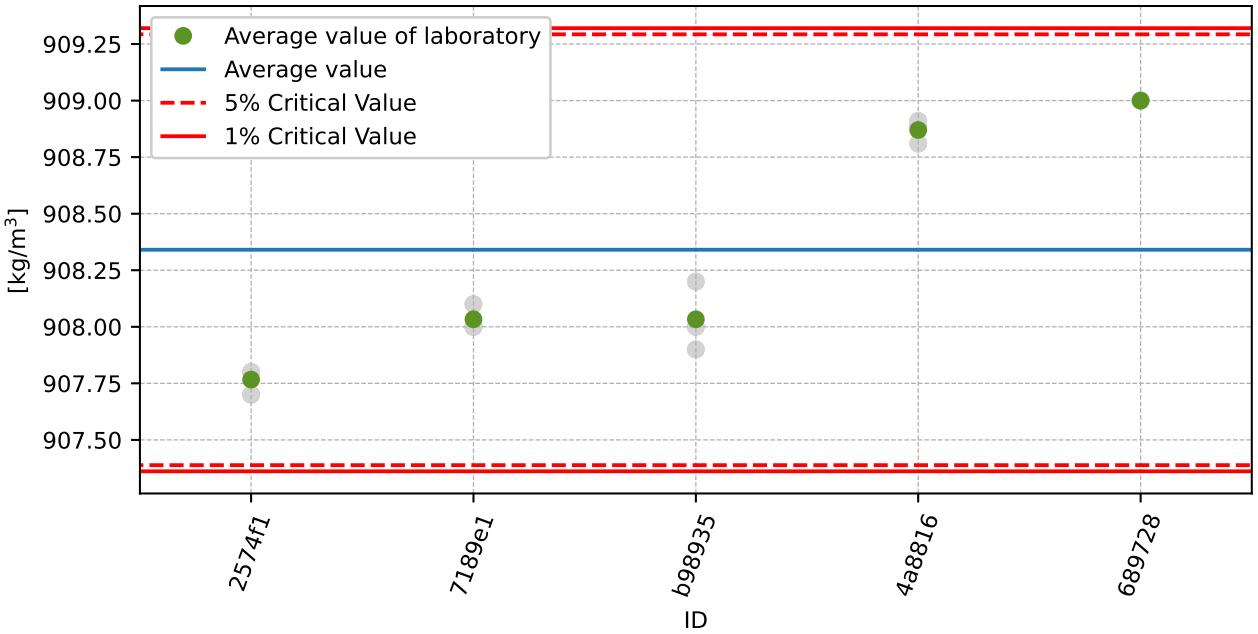

Figure 115: **Grubbs' test** - average values

14.1.3 Mandel's Statistics

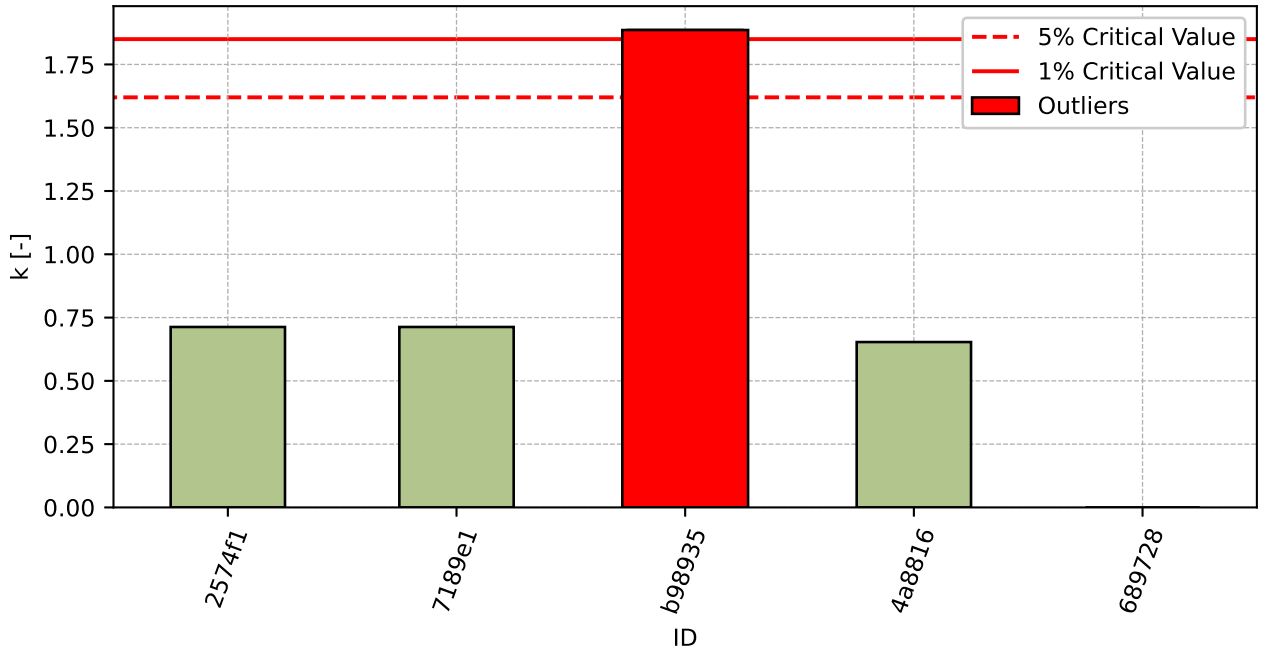

Figure 116: Intralaboratory Consistency Statistic

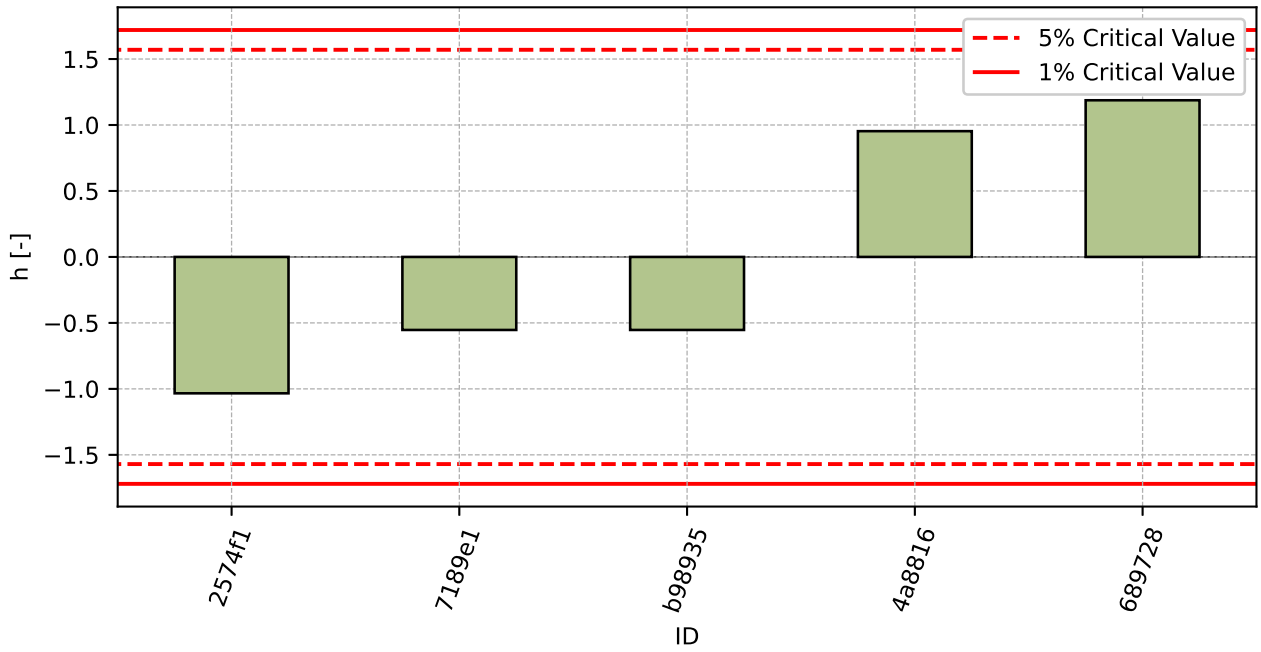

Figure 117: Interlaboratory Consistency Statistic

14.1.4 Descriptive statistics

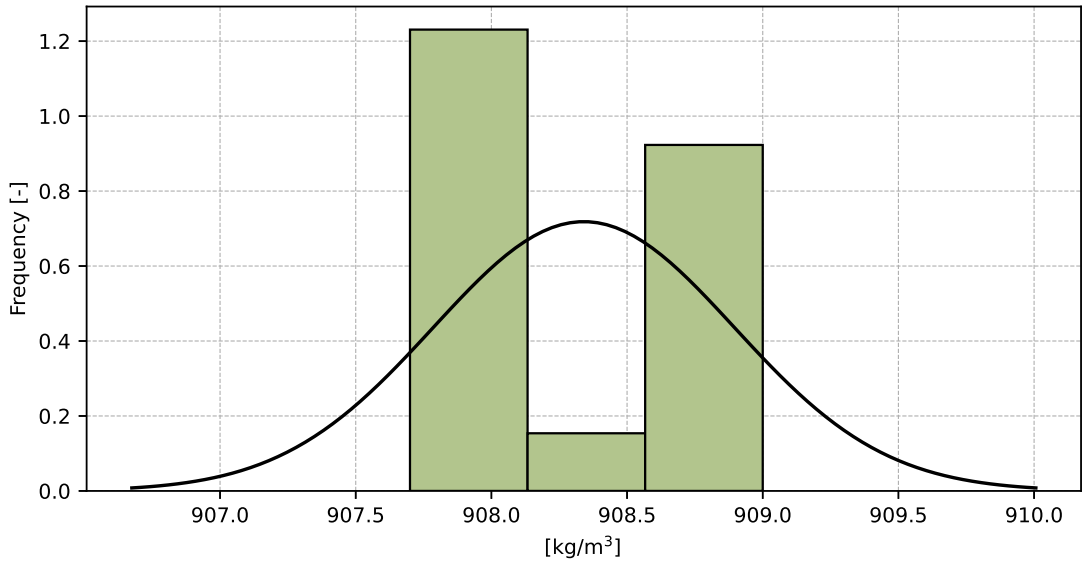

Figure 118: Histogram of all test results

Table 41: Descriptive statistics

Characteristics	[kg/m³]
Average value – $\bar{x}$	908.3
Sample standard deviation – s	0.56
Asigned value – x^*	908.3
Robust standard deviation – s^*	0.51
Measurement uncertainty of asigned value – u_X	0.29
p-value of normality test	0.006 [-]
Interlaboratory standard deviation – s_L	0.55
Repeatability standard deviation – s_r	0.08
Reproducibility standard deviation – s_R	0.56
Repeatability – r	0.2
Reproducibility – R	1.6

14.1.5 Evaluation of Performance Statistics

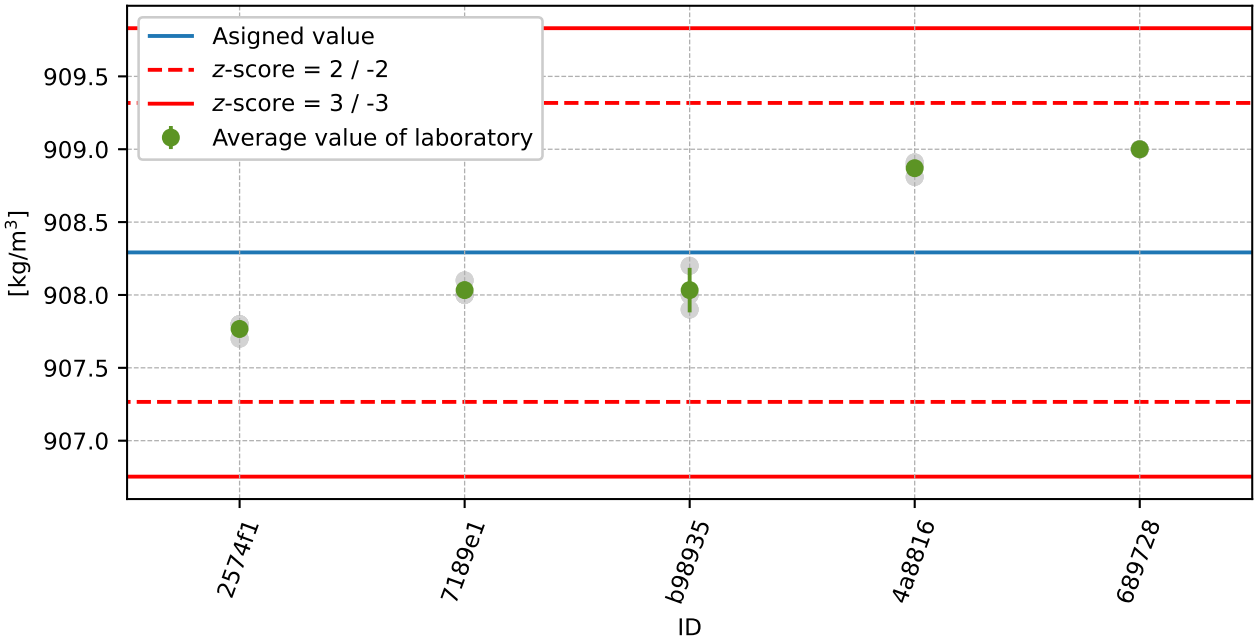

Figure 119: Average values and sample standard deviations

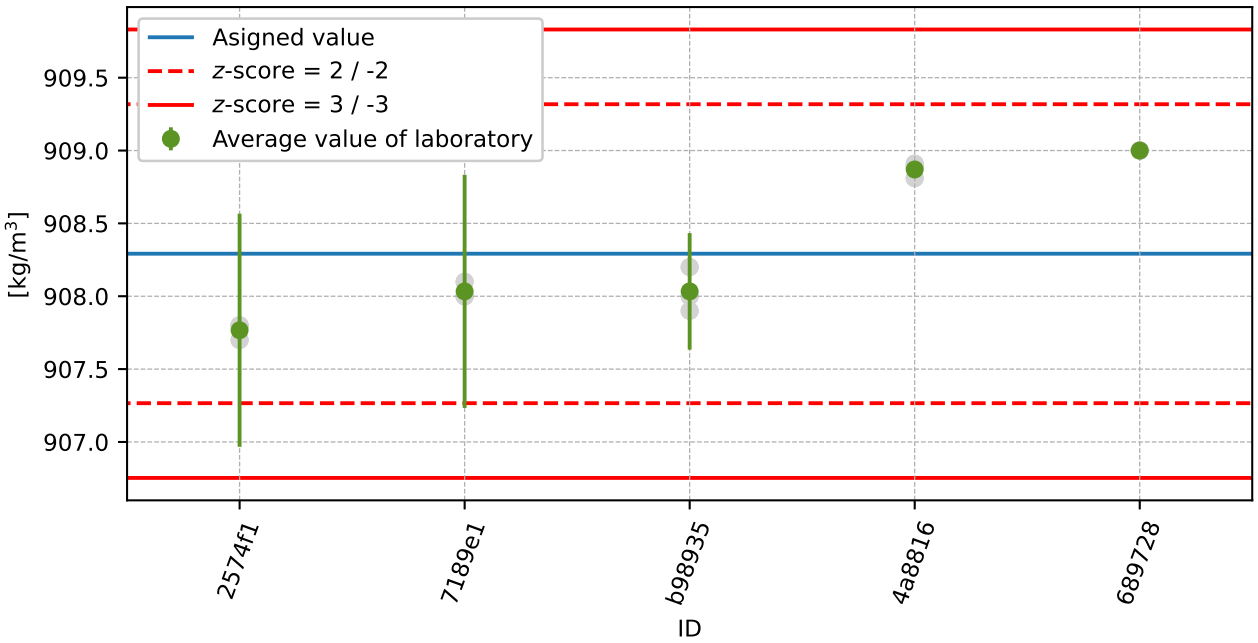

Figure 120: Average values and extended uncertainties of measurement

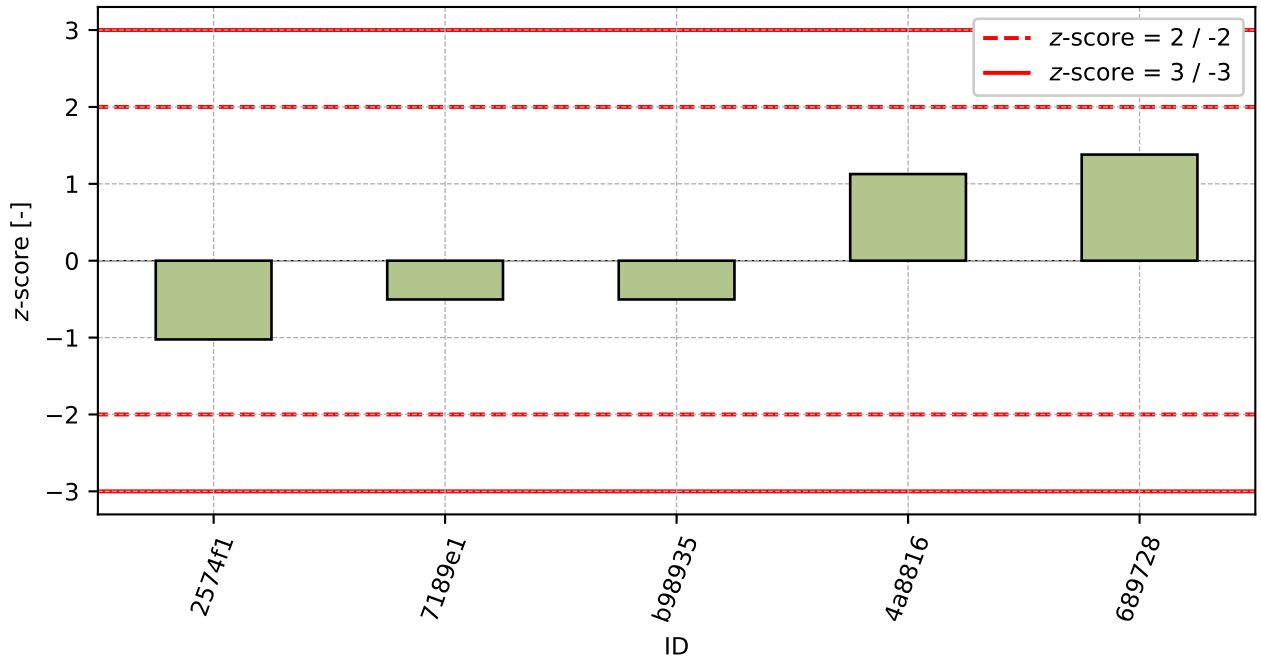

Figure 121: z-score

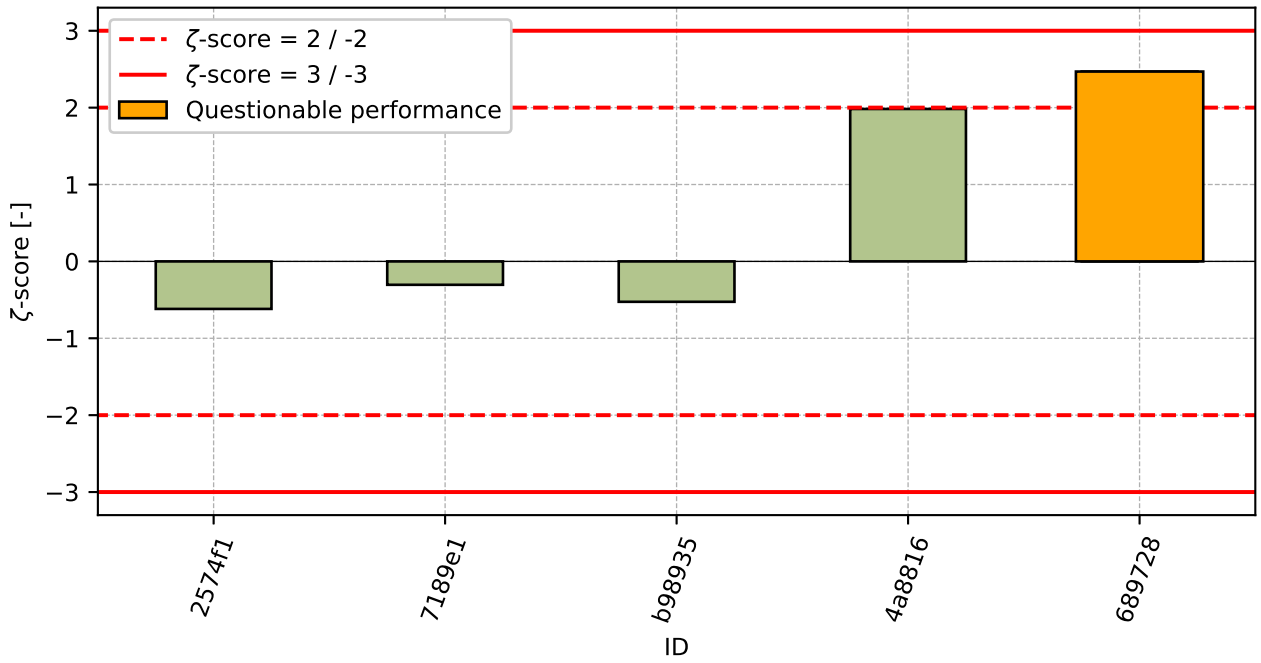

Figure 122: ζ-score

Table 42: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2574f1	-1.02	-0.62
7189e1	-0.5	-0.3
b98935	-0.5	-0.53
4a8816	1.13	1.98
689728	1.38	2.47

14.2 Sample B

14.2.1 Test results

Table 43: Test results - ordered by average value. Outliers are marked by red color. u_X - extended uncertainty of measurement; $\bar{x}$ - average value; s_0 - sample standard deviation; V_X - variation coefficient

ID	Test results [kg/m³]			u_X [kg/m³]	$\bar{x}$ [kg/m³]	s_0 [kg/m³]	V_X [%]
2574f1	902.1	902.1	902.0	0.8	902.1	0.06	0.01
7189e1	902.3	902.3	902.3	0.8	902.3	0.0	0.0
b98935	902.3	902.4	902.2	0.4	902.3	0.1	0.01
689728	903.0	903.0	903.0	0.0	903.0	0.0	0.0
4a8816	903.1	903.1	903.2	0.0	903.1	0.04	0.0

14.2.2 The Numerical Procedure for Determining Outliers

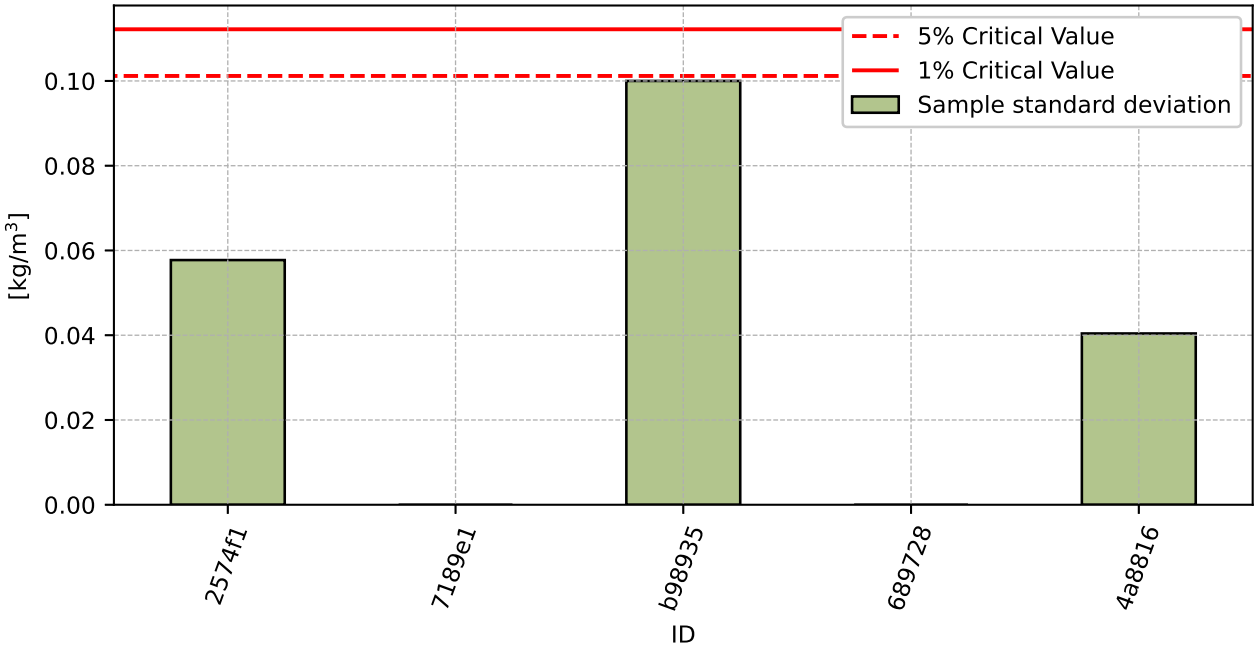

Figure 123: **Cochran's test** - sample standard deviations

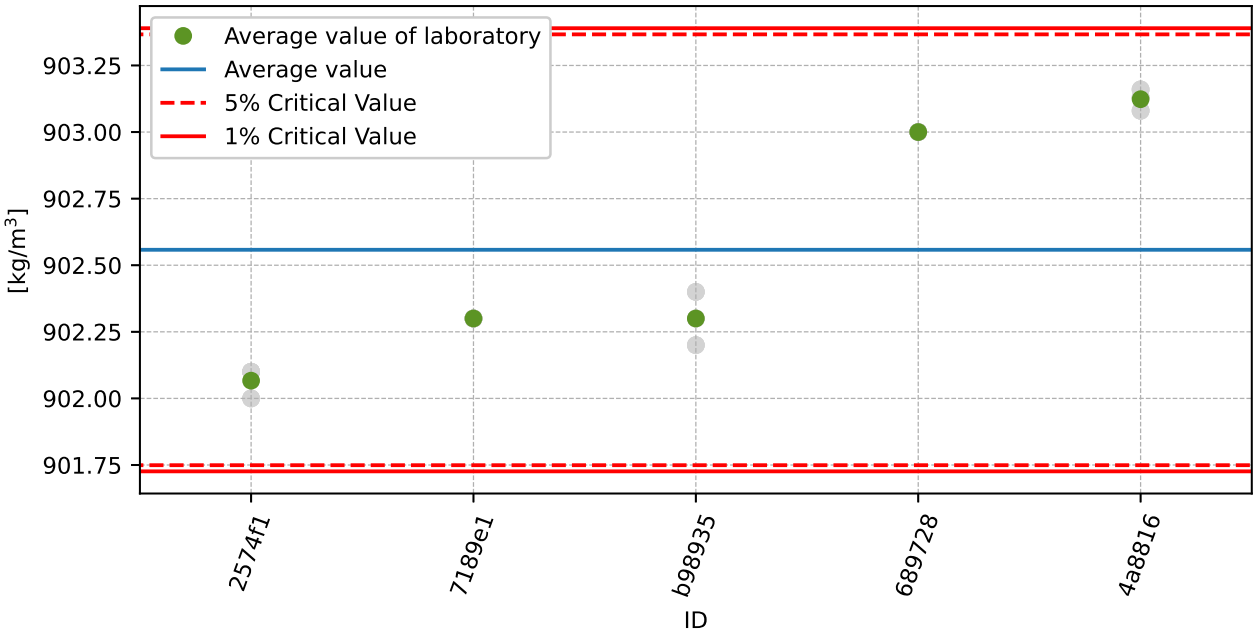

Figure 124: **Grubbs' test** - average values

14.2.3 Mandel's Statistics

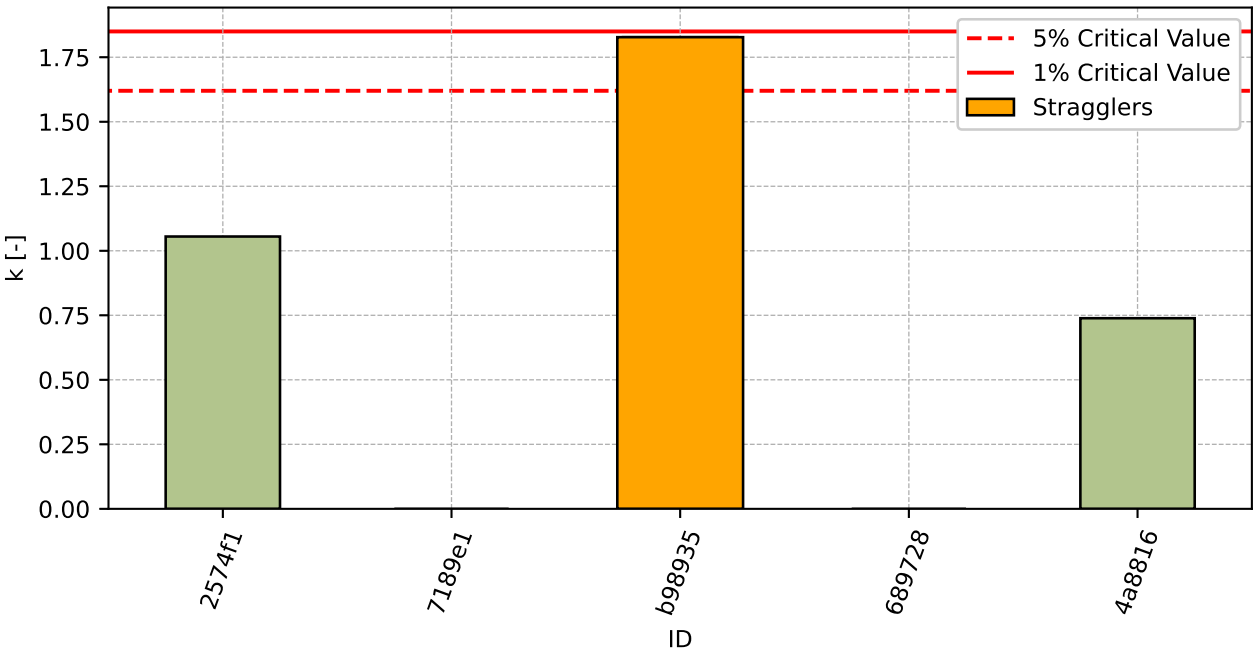

Figure 125: Intralaboratory Consistency Statistic

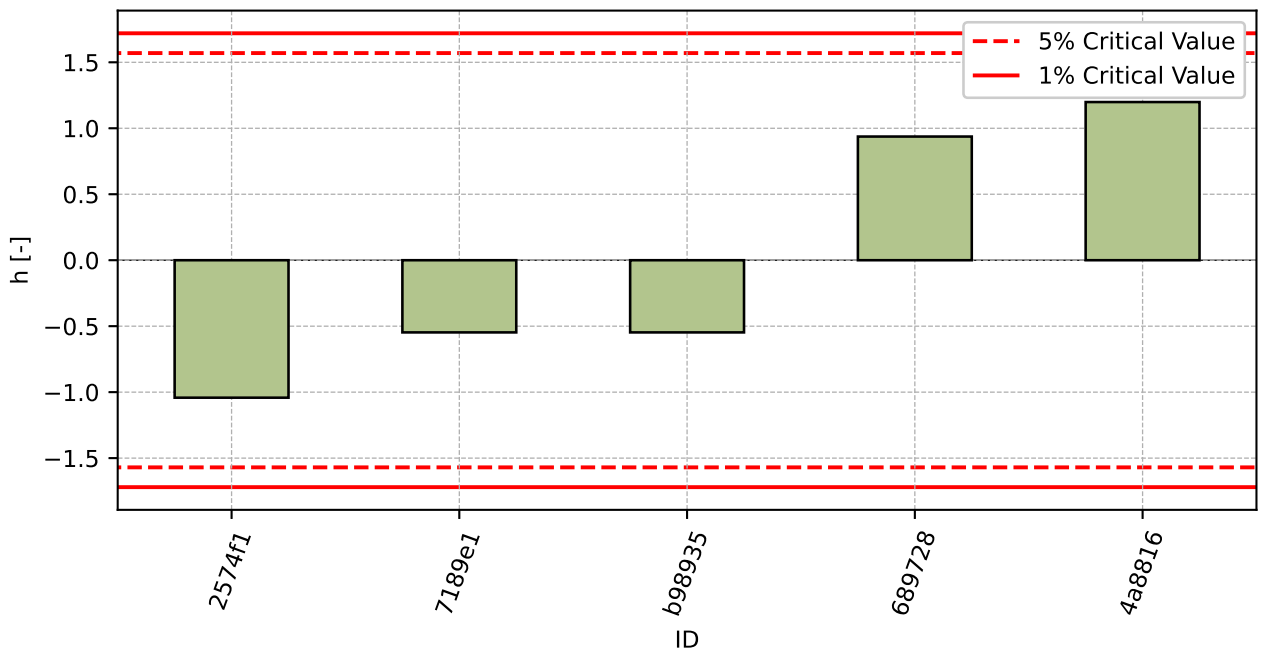

Figure 126: Interlaboratory Consistency Statistic

14.2.4 Descriptive statistics

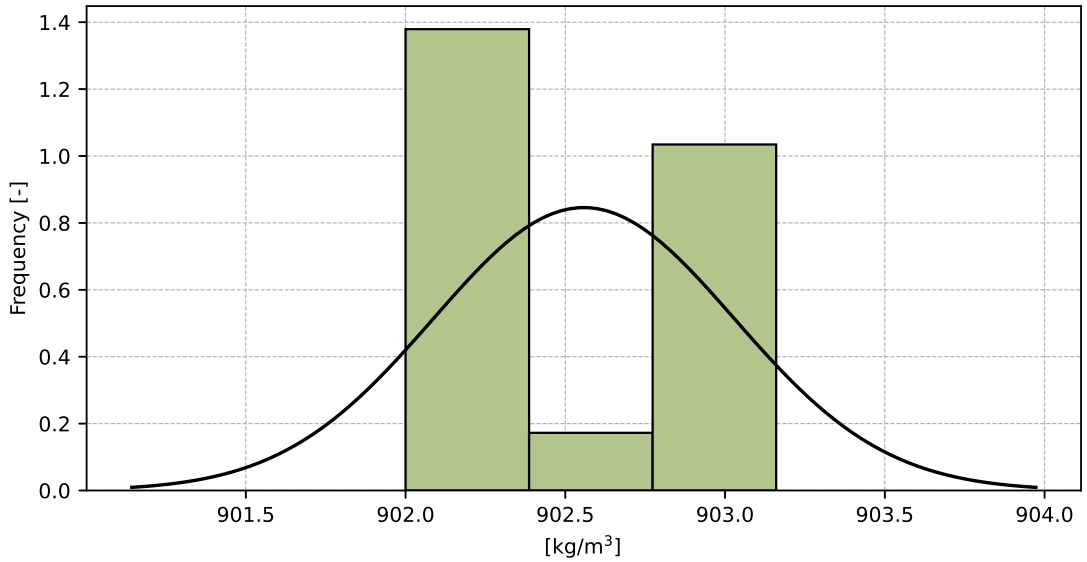

Figure 127: Histogram of all test results

Table 44: Descriptive statistics

Characteristics	[kg/m³]
Average value – $\bar{x}$	902.6
Sample standard deviation – s	0.47
Asigned value – x^*	902.5
Robust standard deviation – s^*	0.44
Measurement uncertainty of asigned value – u_X	0.25
p-value of normality test	0.008 [-]
Interlaboratory standard deviation – s_L	0.47
Repeatability standard deviation – s_r	0.05
Reproducibility standard deviation – s_R	0.47
Repeatability – r	0.2
Reproducibility – R	1.3

14.2.5 Evaluation of Performance Statistics

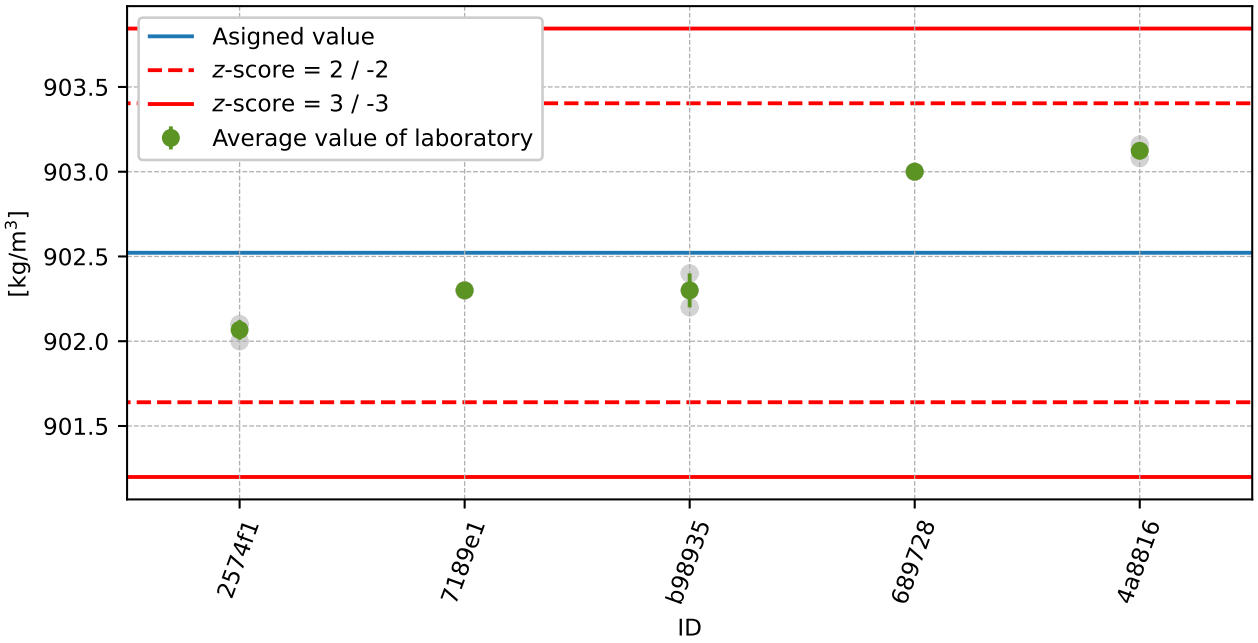

Figure 128: Average values and sample standard deviations

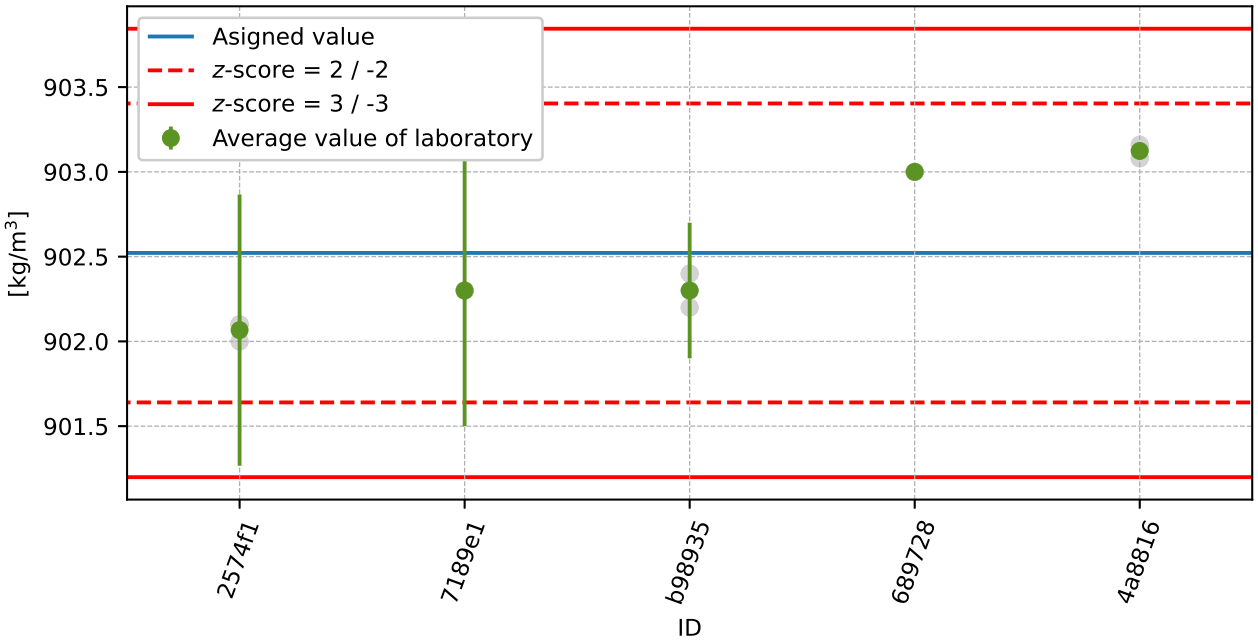

Figure 129: Average values and extended uncertainties of measurement

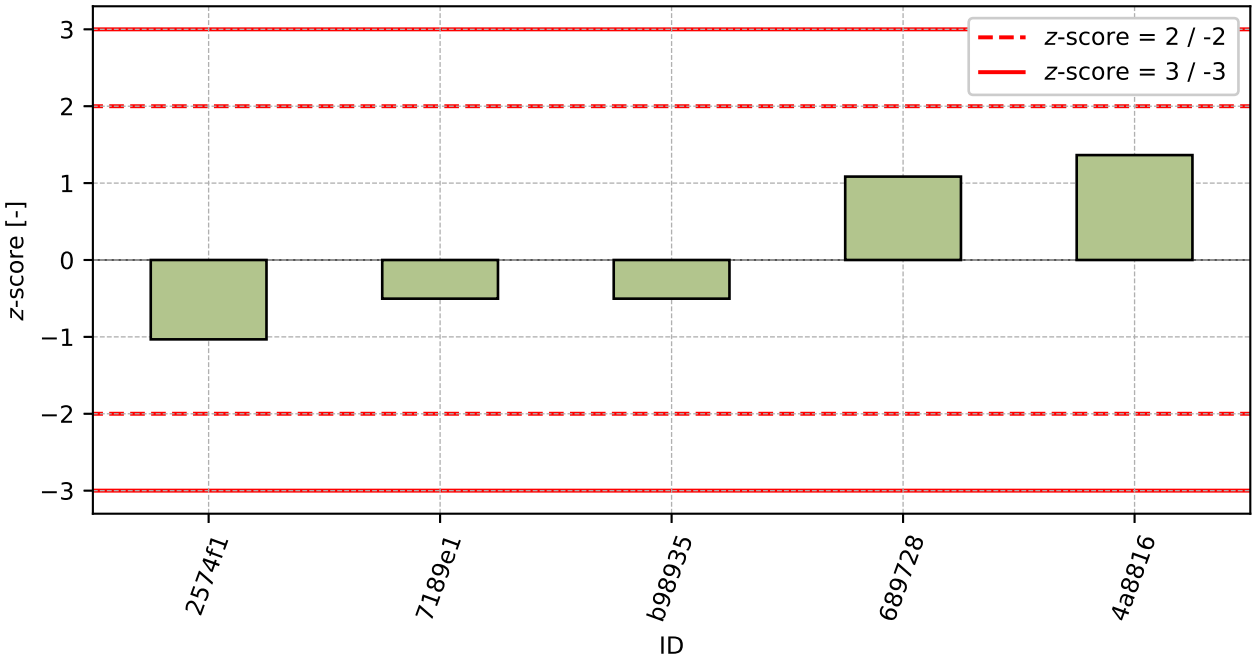

Figure 130: z-score

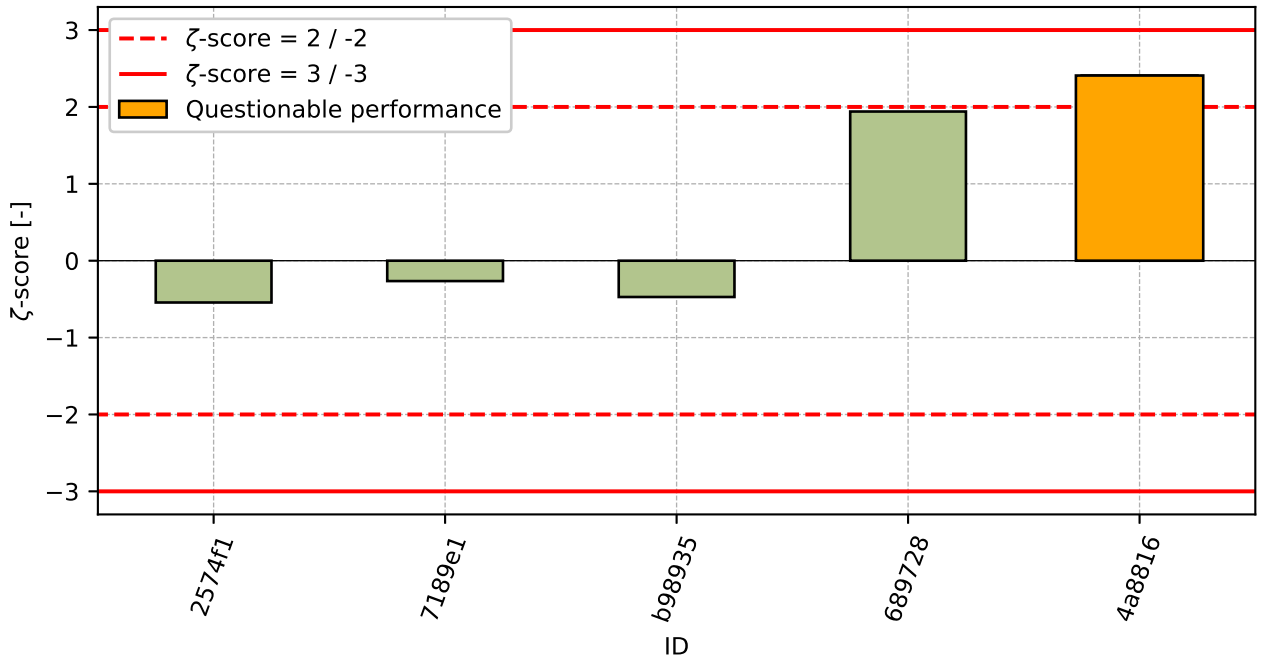

Figure 131: ζ-score

Table 45: z-score and ζ-score

ID	z-score [-]	ζ-score [-]
2574f1	-1.03	-0.54
7189e1	-0.5	-0.26
b98935	-0.5	-0.47
689728	1.08	1.94
4a8816	1.36	2.41

15 Appendix – EN ISO 11357-1, -3 (Melting temperature T_{m1}, Enthalpy of fusion ΔH_{m1})

The test method was not opened due to the low number of participants.

16 Appendix – EN ISO 1133-1 (Melt mass-flow rate)

The test method was not opened due to the low number of participants.

17 Appendix – EN ISO 1628-1, -5 (Viscosity)

The test method was not opened due to the low number of participants.

18 Appendix – EN ISO 11358-1 (Filler content)

The test method was not opened due to the low number of participants.

19 Appendix – ISO 3795 (Burning Rate)

The test method was not opened due to the low number of participants.