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EUROPEAN SPACE AGENCY
CONTRACT REPORT
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Survey of Total Ionising Dose Tolerance of Power Bipolar Transistors and Silicon Carbide Devices for JUICE

TN5.2
TID Test Report (LDR / HDR) for

Power Bipolar Transistor

2N7370

Manufacturer:
Microsemi

Date code/Lot code: 1642 CDWR / 88115

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Version history

Table 1: Revision history

Version	Date	Changed by	Changes
1.0	2018-10-16	Steffens	Initial release
2.0	-	-	
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1 Introduction

1.1 Scope

The Fraunhofer Institute for Technological Trend Analysis (INT) carried out a series of Co-60 irradiations on Power Bipolar Transistor 2N7370 from Microsemi for the ESA project "Survey of Total Ionizing Dose Tolerance of Power Bipolar Transistors and Silicon Carbide Devices for JUICE" (ESA-TOPSIDE, AO/1-8148/14/NL/SFe) under contract number 4000113976/15/NL/RA.

Two sets of components were tested at distinct dose rates, one within the standard rate Window 1 of ESCC 22900 [3] labelled "HDR-Test" in this report, and one at or below the low rate Window 2 of ESCC 22900, labelled "LDR-Test".

This reports documents the preparation, execution and the results of these tests.

1.2 Applicable Documents

[AD1] ITT/AO/1-8148/14/NL/SFe "Statement of work: Survey of Total Ionizing Dose Tolerance of Power Bipolar Transistors and Silicon Carbide Devices for JUICE"

[AD2] Proposal for ITT/AO/1-8148/14/NL/SFe, Fraunhofer INT

1.3 Reference Documents

[1] Website of Fraunhofer INT: http://www.int.fraunhofer.de

[2] Guidelines for Evaluating and Expressing the Uncertainty of NIST Measurement Results, B.N. Taylor and C.E. Kuyatt, NIST Technical Note 1297, 1994, http://www.nist.gov/pml/pubs/tn1297/index.cfm.

[3] ESCC Basic Specification No. 22900, issue 5, June 2016

[4] Datasheet of Power Bipolar Transistor 2N7370, "NPN Darlington High Power Silicon Transistor", Microsemi, T4-LDS-0208, Rev. 2, (9/16/13)

[5] TN2.2 "TID Test Plan 2N7370 (HDR+LDR)", Issue 1, 2017-02-02

[6] MIL-STD-883K w/CHANGE 2, Method 1019.9, "Ionizing Radiation (Total Dose) Test Procedure", 2017

2 Summary

Table 2: Summary

Test Report Number	015/2017
Project (INT)	NEO-14-086
Customer	European Space Agency (ESA), contract number 4000113976/15/NL/RA
Contact	Project Coordinator: Stefan Höffgen (INT) ESA Technical Project Officer: Marc Poizat (ESA/ESTEC)
ESA project / contract number	AO/1-8148/14/NL/SFe 4000113976/15/NL/RA
Device under test	2N7370
Family	Power Bipolar Transistor
Technology	NPN high voltage bipolar transistor
Package	TO-254AA
Date code / Wafer lot	1642 CDWR / 88115
SN	Low dose rate (LDR-Test): Biased (5x): # 1, 2, 3, 4, 5 Unbiased (5x): # 6, 7, 8, 9, 10 Reference (1x): # 0 High dose rate (HDR-Test): Biased (5x): # 12, 13, 14, 15, 16 Unbiased (5x): # 17, 18, 19, 20, 21 Reference (1x): # 11
Manufacturer	Microsemi
Irradiation test house	Fraunhofer INT
Radiation source	Co-60
Irradiation facility	LDR: TK100, HDR: TK1000B
Generic specification	ESCC 22900 Iss. 5
Detail specification	ESCC 22900 Iss. 5
Test plan	TN2.2 “TID Test Plan 2N7370 (HDR+LDR)”, Issue 1, 2017-02-02
Max. test level	200 krad(Si)
Dose steps	LDR: Multiple: 11, 19, 32, 50, 100, 150, 202 krad(Si) HDR: Multiple: 10, 20, 30, 50, 100, 150, 200 krad(Si)
Dose rate	LDR: Start @ 33.3 rad(Si)/h – Stop @ 31.1 rad(Si)/h HDR: 10.9 krad(Si)/h

Start of irradiation	LDR: 2017-02-07 16:18, HDR: 2017-08-02 06:14
Stop of irradiation	LDR: 2017-10-30 09:48 HDR: 2017-08-03 12:22
Non-Homogeneity in DUT	LDR: < 2% HDR: 8.3%
Annealing	LDR/HDR: 24h @RT LDR: 168 h @ 100°C HDR: 144h @ 100°C, 18h @RT, 69h @ 100°C (see comments)
Electrical measurements/ Parameters tested	$V_{(Br)CEO}$ (I_C@100V), I_{CEO}, I_{CEX}, I_{EBO},$V_{CE(sat)}$, $V_{BE(sat)}$, $h_{FE}1$, $h_{FE}2$

2.1 Comments

- During the conduction of both test campaigns, some deviations from the requirements of ESCC 22900 occurred:
  - in two instances the time gap between stop of irradiation and the start of the next step was about 4 minutes longer than allowed.
- LDR test:
  - Other tests, e.g. the other bipolar power transistors of the project, were performed simultaneously to the LDR tests at the same facility TK100. Several breaks of the irradiation were necessary to conduct these tests. For the 2N7370 these interruptions were approx. 8 minutes on average and max. 2h (due to maintenance).
  - The dose steps in the HDR test were within timing accuracies at the scheduled total dose levels. To avoid tests on weekends or during the night, the total dose levels in the LDR tests are different than the scheduled levels but deviate less than 10%.
- HDR test:
  - The tests of the 2N7371 were performed simultaneously to the tests of the 2N7370.
  - Due to a furnace malfunction during the high temperature accelerated ageing anneal the DUTs spend approx. 18 h at room temperature. After 144 h at 100°C and 18 h at RT, the DUTs were left at 100°C over the weekend for another 69 h.
- Comparison with respect to ELDRS:
  - A comparison of the tests at high and low dose rate shows no significant difference for any parameter.
  - Calculation of the enhancement factor showed no ELDRS. Detailed analysis of the enhancement factor calculation is thus not included in this report.
  - We would argue that the part is not susceptible to ELDRS.

2.2 Overview of results

Figure 1: LDR: Overview of results

Pass/Fail		Total Dose [krad (Si)]								Annealing	
		0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Vbr_CEO	On										
	Off										
I_Vbr_CEO	On										
	Off										
I_CEO	On										
	Off										
I_EBO	On										
	Off										
V_CE_SAT	On										
	Off										
V_BE_SAT	On										
	Off										
HFE_1	On										
	Off										
HFE_2	On										
	Off										
I_CEX	On										
	Off										

Figure 2: HDR: Overview of results

Pass/Fail		Total Dose [krad (Si)]								Annealing	
		0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Vbr_CEO	On										
	Off										
I_Vbr_CEO	On										
	Off										
I_CEO	On										
	Off										
I_EBO	On										
	Off										
V_CE_SAT	On										
	Off										
V_BE_SAT	On										
	Off										
HFE_1	On										
	Off										
HFE_2	On										
	Off										
I_CEX	On										
	Off										

3 Sample preparations

3.1 Sample shipment

A total of 27 Samples were procured by INT at a commercial supplier (Mouser) for the conduction of these tests for ESA.

Table 3: Sample shipment

Samples ordered	Samples received	Samples sent back
December 2015	November 2016	still at INT

Figure 3: The ESD package with the samples

3.2 Sample identification/ marking

The samples were mounted on an adapter, to ease the exchanging, plugging and storage of the samples.

Figure 4: Sample marking. Top image: LDR-Test, bottom image: HDR-Test. The images are exemplatory as they show the similarly prepared 2N7371 in the identical package.

The samples were colour marked to differentiate the samples between each other and to separate the samples of the different campaigns or types.

3.3 Sample safekeeping

The samples were stored in an Electro-Static Discharge (ESD) box (Figure 4) to handle them safely during the test, the interim storage after the last measurement and the final shipment.

Table 4: Sample marking

Test	Condition	Label	S/N (INT)	Color Code
Low dose rate	Control sample	REF#1	0	
	Biased	ON#1	1	
		ON#2	2	
		ON#3	3	
		ON#4	4	
		ON#5	5	
	Unbiased	OFF#1	6	
		OFF#2	7	
		OFF#3	8	
		OFF#4	9	
		OFF#5	10	
High dose rate	Control sample	REF#1	11	
	Biased	ON#1	12	
		ON#2	13	
		ON#3	14	
		ON#4	15	
		ON#5	16	
	Unbiased	OFF#1	17	
		OFF#2	18	
		OFF#3	19	
		OFF#4	20	
		OFF#5	21	

4 Irradiation conditions

4.1 Irradiation steps

Table 5: LDR: Irradiation steps

	Step [krad(Si)]	Total [krad (Si)]	Startrate [rad(Si)/h]	Start Irr.	Breaks [h:m]	Stop Irr.	Duration [d:h:m:s]	Start Tests	Stop Tests	Dur. [h:m]
0	0.00	0						07. 02.2017 15:05:00	07. 02.2017 15:55:00	0:50
1	10.98	10.98	0.0333	07. 02.2017 16:17:46		21. 02.2017 10:31:02	13d 18:13:16	21. 02.2017 10:38:00	21. 02.2017 11:21:00	0:43
2	7.81	18.79	0.0332	21. 02.2017 11:28:30	03:09	03. 03.2017 10:35:03	9d 23:06:33	03. 03.2017 10:44:00	03. 03.2017 11:35:00	0:51
3	13.34	32.13	0.0331	03. 03.2017 11:41:16		20. 03.2017 08:24:52	16d 20:43:36	20. 03.2017 08:37:00	20. 03.2017 09:06:00	0:29
4	18.20	50.33	0.0329	20. 03.2017 09:14:00		12. 04.2017 13:17:45	23d 04:03:45	12. 04.2017 13:21:00	12. 04.2017 13:49:00	0:28
5	49.88	100.21	0.0326	12. 04.2017 13:56:08	06:43	16. 06.2017 09:22:49	64d 19:26:41	16. 06.2017 09:32:00	16. 06.2017 10:03:00	0:31
6	50.00	150.21	0.0318	16. 06.2017 10:09:33	00:57	21. 08.2017 09:28:56	65d 23:19:23	21. 08.2017 09:32:00	21. 08.2017 09:59:00	0:27
7	51.50	201.71	0.0311	21. 08.2017 10:04:59	01:55	30. 10.2017 09:47:51	69d 23:42:52	30. 10.2017 09:47:51	30. 10.2017 11:47:51	2:00
8	24 h @ RT			30. 10.2017 11:47:51		31. 10.2017 11:47:51		31. 10.2017 11:47:51	31.10.2017 13:47	2:00
9	168 h @100°C			31. 10.2017 13:47:51		07. 11.2017 13:47:51		07. 11.2017 13:47:51	07.11.2017 15:47	2:00

During the conduction of both test campaigns, some deviations from the requirements of ESCC 22900 occurred:

- in two instances the time gap between stop of irradiation and the start of the next step was about 4 minutes longer than allowed.
- due to a furnace malfunction during the high temperature accelerated ageing anneal the DUTs spend approx. 18 h at room temperature. After 144 h at 100°C and 18 h at RT, the DUTs were left at 100°C over the weekend for another 69 h.

Other tests, e.g. the other bipolar power transistors of the project, were performed simulateously to the LDR tests at the same facility TK100. Several breaks of the irradiation were necessary to conduct these tests. For the 2N7370 these interruptions were approx. 9 minutes on average and max. 1h15min.

The dose steps in the HDR test were within timing accuracies at the scheduled total dose levels. To avoid tests on weekends or during the night, the total dose levels of the LDR tests are different than the scheduled levels but deviate less than 10%.

Table 6: HDR irradiation steps

#	Step [krad(Si)]	Total [krad (Si)]	Startrate [rad(Si)/h]	Start Irr.	Stop Irr.	Duration [h:m:s]	Start Tests	Stop Tests	Dur. [h:m]
0	0.00	0					01.08.2017 13:46	01.08.2017 14:18	0:32
1	10.00	10	10.9000	Mi, 02. 08.2017 06:13:37	Mi, 02. 08.2017 07:08:41	0d 00:55:04	02.08.2017 07:17	02.08.2017 08:11	0:54
2	10.00	20	10.8995	Mi, 02. 08.2017 09:02:29	Mi, 02. 08.2017 09:57:34	0d 00:55:05	02.08.2017 10:12	02.08.2017 11:04	0:52
3	10.00	30	10.8990	Mi, 02. 08.2017 12:01:31	Mi, 02. 08.2017 12:56:36	0d 00:55:05	02.08.2017 13:05	02.08.2017 13:45	0:40
4	20.00	50	10.8985	Mi, 02. 08.2017 14:54:45	Mi, 02. 08.2017 16:44:53	0d 01:50:08	02.08.2017 17:43	02.08.2017 18:10	0:27
5	50.00	100	10.8979	Mi, 02. 08.2017 18:49:15	Mi, 02. 08.2017 23:24:32	0d 04:35:17	02.08.2017 23:58	03.08.2017 00:37	0:39
6	50.00	150	10.8969	Do, 03. 08.2017 01:24:08	Do, 03. 08.2017 05:59:27	0d 04:35:19	03.08.2017 06:12	03.08.2017 07:05	0:53
7	50.00	200	10.8960	Do, 03. 08.2017 07:46:38	Do, 03. 08.2017 12:21:55	0d 04:35:17	03.08.2017 12:53	03.08.2017 13:51	0:58
8	24 h @ RT			Do, 03. 08.2017 13:51:00	Fr, 04. 08.2017 15:40:00	1d 01:49	04.08.2017 15:57	04.08.2017 16:37	0:40
	144 h @100°C			Fr, 04. 08.2017 16:45:00	Do, 10. 08.2017 17:00:00	6d 00:15			
	RT			Do, 10. 08.2017 17:00:00	Fr, 11. 08.2017 11:00:00	0d 18:00			
9	69 h @100°C			Fr, 11. 08.2017 11:00:00	Mo, 14. 08.2017 08:00:00	2d 21:00	14.08.2017 08:37	14.08.2017 09:22	0:45

4.2 Sample holder

A custom-build printed-circuit board (Figure 5) was manufactured to

- bias the samples according to the circuit-layout of the irradiation test plan [5] (see also chapter 4.4 Bias conditions)
- fix the samples under the radiation source (see also chapter 4.3 Geometry)
- irradiate the samples homogeneously.

In the LDR tests, the printed circuit boards were fixed to a wooden frame (Figure 6) under the radiation source at a constant distance of 60 cm. Consequently, the dose rate at the DUTs reduced over time due to the Co-60 decay (Table 5).

Figure 5: Bias board

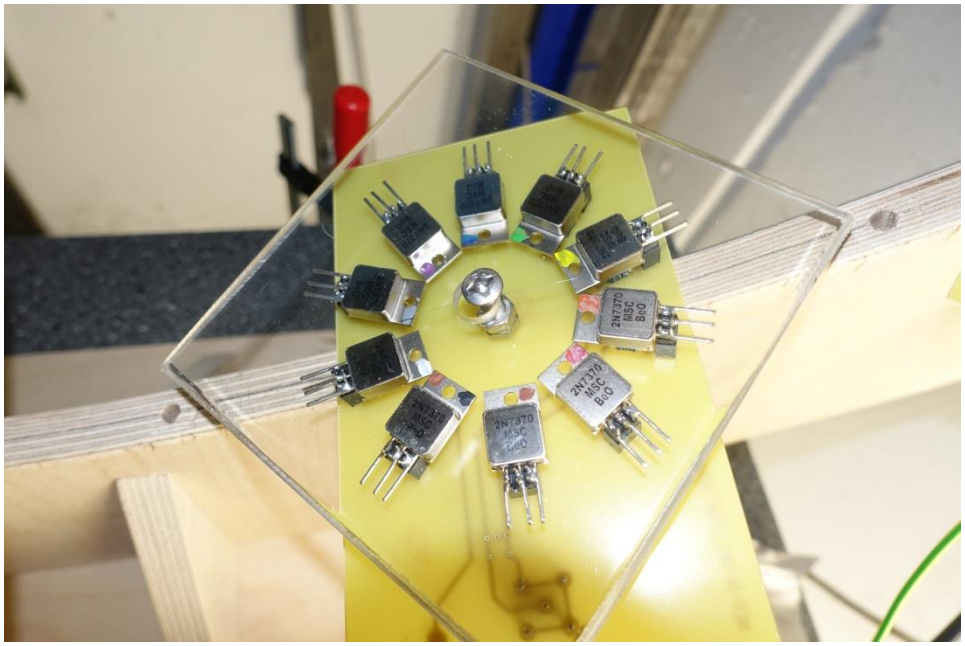


Figure 6: LDR tests: Board fixture at TK100

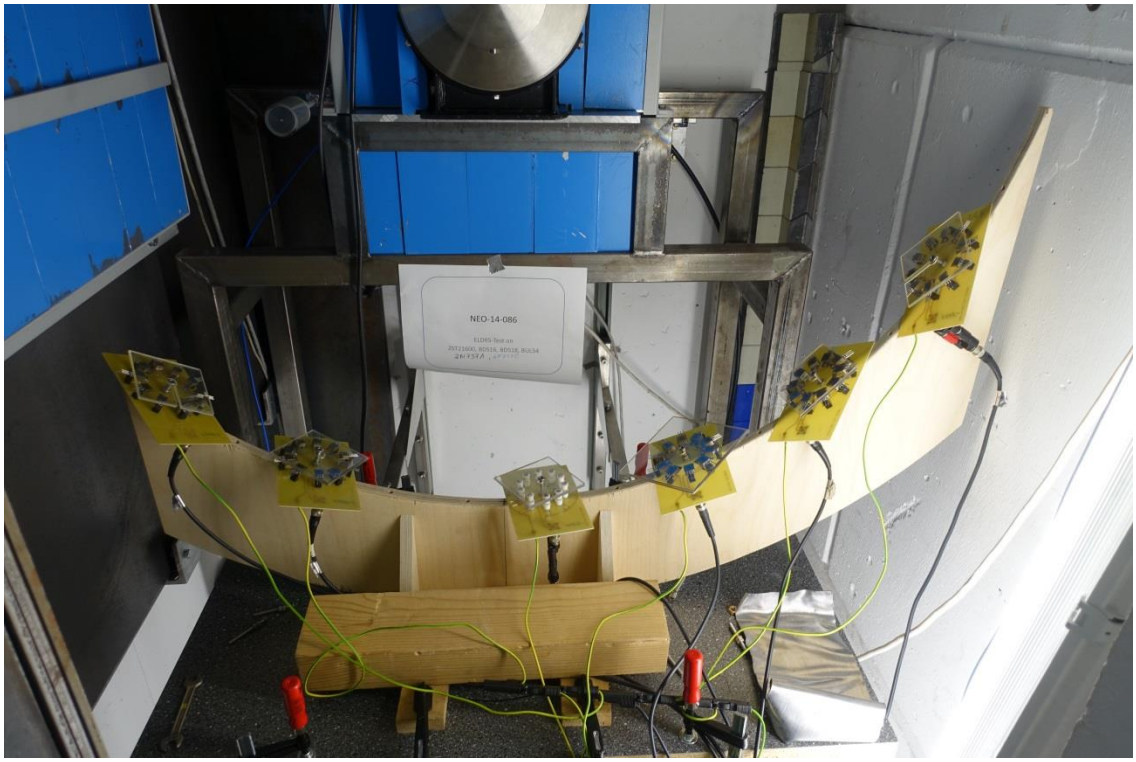
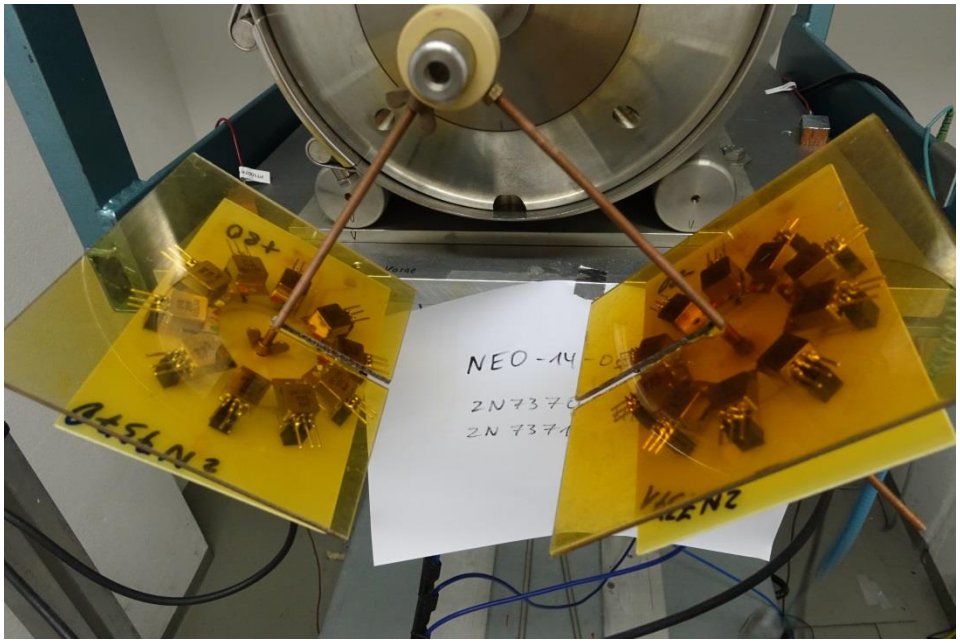


Figure 7: HDR tests: Board fixture at TK1000B



4.3 Geometry

LDR tests: The irradiation parameters correspond to a sample-distance of 60 cm from the source at TK100 (Figure 6) to the object minimum.

HDR tests: The irradiation parameters correspond to a sample-distance of 14 cm from the TK1000B source (Figure 7) to the object minimum.

In each test a PMMA layer of 5 mm was placed over the DUTs to achieve charge equilibrium.

4.4 Bias conditions

During the irradiation and the subsequent annealing the samples were biased or operated according to the circuit-description of the irradiation test plan [5] (see Figure 8).

LDR: A fug HCE 35-125 voltage supply (Eq.Id E-PS1-035) was used for biasing the low dose rate test.

HDR: An EA PS 3150-04B voltage supply (Eq.Id E-PS1-004) was used for biasing the low dose rate test.

Both supplies were not calibrated but the voltage was checked with a calibrated voltmeter.

During transport from the irradiation site to the electrical measurement site and back again all terminals were shorted.

Figure 8: Bias conditions

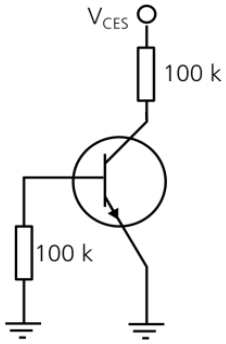
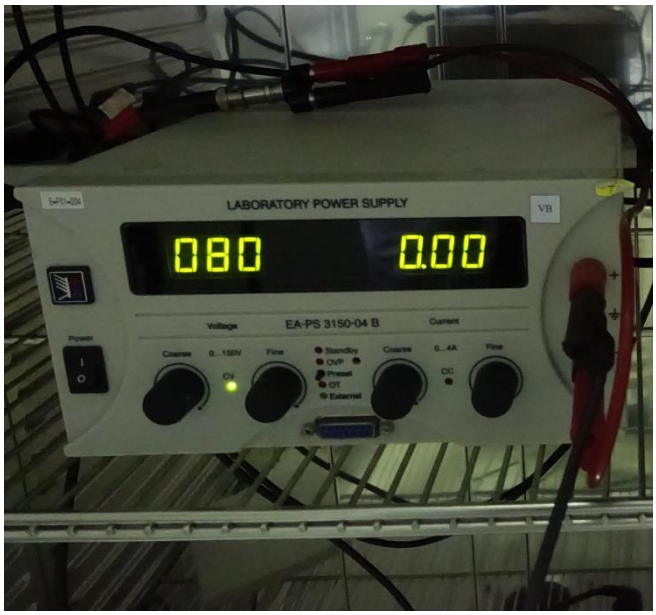
ON-Mode	OFF-Mode
 V_{CES} = 320 V (≥ 80% $V_{(BR)CEO}$)	All pins were short circuited and grounded.

Table 7: Biasing equipment. Left: LDR test, Right: HDR test



4.5 Environmental variables

All irradiation steps were done in air. The samples at TK1000B were irradiated in ambient light. The samples at TK100 were irradiated without ambient light. The parameters of the humidity and the temperature are given in the following tables and figures.

Table 8: LDR: Environmental variables during irradiation

Parameter	Value and Unit	Remarks
Humidity	37.7% ± 7.0%	Non-condensing, during irradiation and first annealing (24 h)
Temperature	25.6 °C ± 1.6 °C	During irradiation and first annealing (24 h)
Temperature	100.0 ± 3.0 °C	During second annealing and normal operation (see comments for malfunction during the HDR campaign)

Figure 9: LDR: Environment variables during irradiation. Several interrupts can be seen in the curves some of which are due to errors in the monitoring system and some due to maintenance.

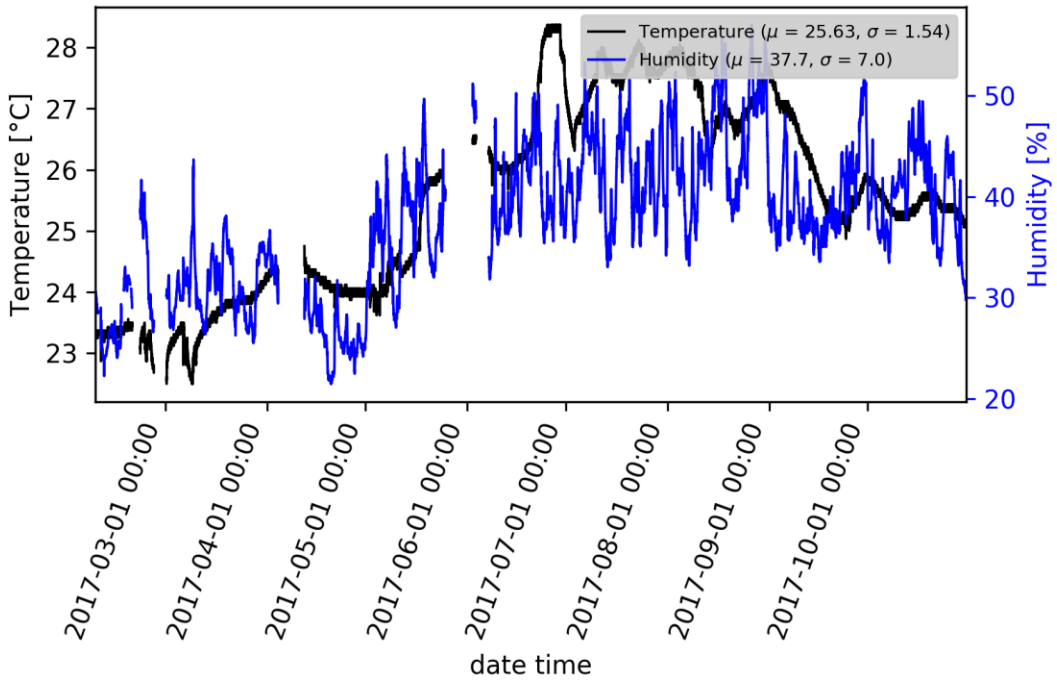
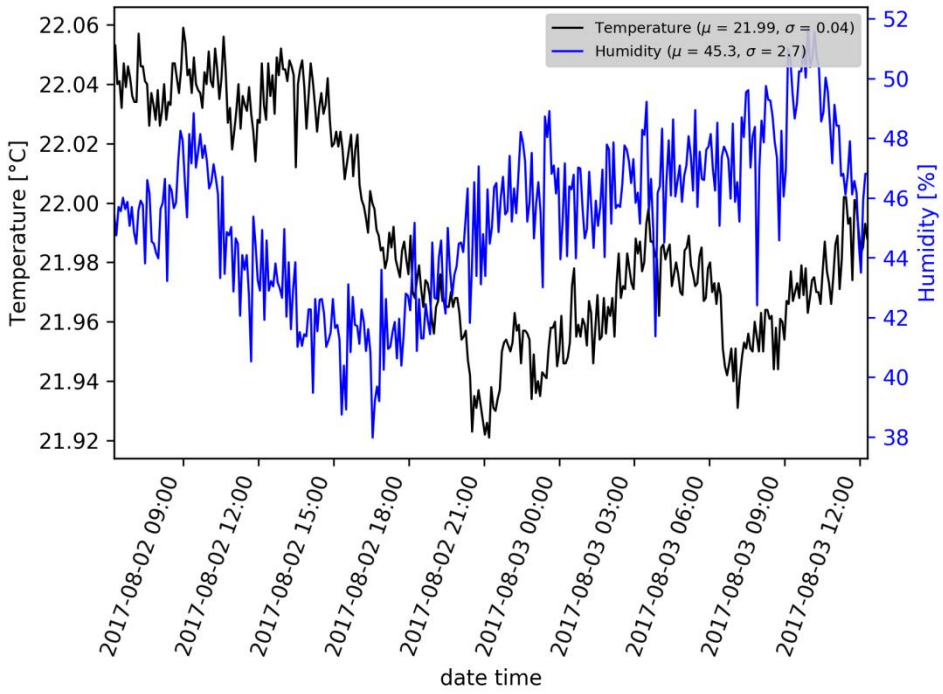


Table 9: HDR: Environmental variables during irradiation

Parameter	Value and Unit	Remarks
Humidity	45.3% ± 2.7%	Non-condensing, during irradiation and first annealing (24 h). Monitoring of the humidity at the source was not running during the tests. Measurements from the next representative sensor in the experimental hall are used.
Temperature	22.0 °C ± 0.1 °C	During irradiation and first annealing (24 h)
Temperature	100.0 ± 3.0 °C	During second annealing (168 h)

Figure 10: HDR: Environment variables during irradiation. Monitoring of the humidity at the source was not running during the tests. Measurements from the next representative sensor in the experimental hall are displayed.



5 Measurement parameters

The measurement of the electrical parameters was done by Fraunhofer INT in accordance with the measurements standards and test methods of ESA, MIL and IEC.

The test plan based on the ESA Basic Specification No. 22900 [3] in general and the irradiation test plan [5] in particular.

Parameters listed in the following Table 10 were measured before and after each irradiation step and each annealing step.

In two cases during the HDR test (see Table 6) the ESCC22900 requirement of 2 hours between stop of radiation and the start of the next step were not fulfilled.

5.1 Measurement parameters

Table 10: Measurement parameters. Based on [4], taken from [5]

No.	Characteristics	Symbol	MIL-STD-750 Test Method	Test Conditions
1	Collector-Emitter Breakdown Voltage	$V_{(BR)CEO}$ I_C@100V	3011, Note 2	I_C = 100 mA, Bias Condition D, Note 1
2	Collector-Emitter Cut-off Current	I_{CEO}	3041	V_{CE} = 50 V, Bias Condition D
3		I_{CEX}		V_{CE} = 100 V, V_{BE} = 1.5 V, Bias Condition A
4	Emitter-Base Cutoff Current	I_{EBO}	3061	V_{EB} = 5 V, Bias Condition D
5	Collector-Emitter Saturation Voltage	$V_{CE(sat)}$	3071	I_C = 12A, I_B = 120 mA, Notes 1
6	Base-Emitter Saturation Voltage	$V_{BE(sat)}$	3066	I_C = 12 A, I_B = 120 mA, Test Condition A, Notes 1
7	Forward Current Transfer Ratio	h_{FE1}	3076	V_{CE} = 3 V, I_C = 6 A, Notes 1
8		h_{FE2}		V_{CE} = 3V, I_C = 12 A, Notes 1

Note 1: As discussed with the technical officer, pulse widths were increased to 1 ms while maintaining < 2% duty cycle

Note 2: The following deviation from Test method 3011 was implemented:

- V_{CE} was increased until either (whatever criteria is met first)
  a) the specified test current is achieved
  or b) the allowed max. rating of V_{CE} (identical with the min. Limit of $V_{(Br)CEO}$) is applied
- If case b) is met then the device is automatically acceptable according to the purpose and acceptance criteria of Test Method 3011, which only gives a lower limit for $V_{(BR)CEO}$.

In this case, I_C @ V_{CE} = 100 V is recorded, which should give some information about parameter drifts.

- If case a) is met, the device fails the test, as the test current is achieved for $V_{CE}<V_{(Br)CEO\ min}$
- The same applies likewise for $V_{BR(CBO)}$ or $V_{BR(EBO)}$

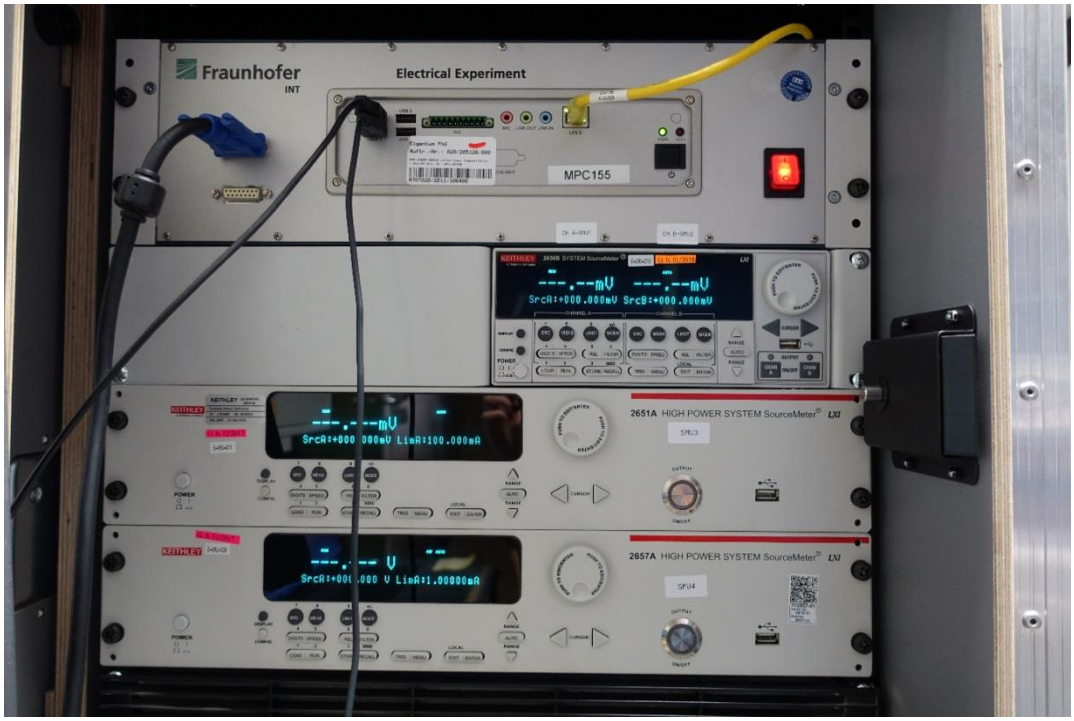
5.2 Measurement equipment

Table 11: Measurement equipment

Equipment	Manufacturer	Model	INT-Code	Calibr. due	Measurement
System Source-Meter	Keithley	2636B	E-SMU-010	01/2018	$V_{(Br)CEO}$, $V_{(BR)CBO}$, $V_{(BR)EBO}$, I_{CBO}, I_{EBO}
High Power System Source-Meter	Keithley	2657A	E-SMU-008	11/2017	$V_{CE(sat)}$, $V_{BE(sat)}$, h_{FE1}, h_{FE2}, h_{FE3}
Test Fixture	Keithley	8010	E-SPAT-004	--	all

Figure 11: Measurement equipment/setup

Figure 12: Test setup: SMUs



5.3 Measurement procedures

Procedures according to the MIL test methods given in Table 10 and Notes 1+2.

Measurements were programmed using the software Keithley ASC Basic allowing timed operation of the SMUs during pulses (e.g. using a fixed delay between pulse rise and parameter readout times).

5.4 Environmental variables

All measurement and annealing steps were done in air. The samples are measured in a lightproof measuring-case. The parameters of the humidity and the temperature during the tests in the ESD area are given in the following table and figure.

Table 12: LDR: Environment variables during measurements

Test cond.	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	168h @ 100°C
Temperature [°C]	22.3	21.7	22.1	22.1	22.0	21.4	22.8	20.0	20.0	20.9
Humidity [%]	41.3	41.2	41.3	42.0	41.4	50.3	47.0	43.4	44.8	41.6

Figure 13: LDR: Environment variables during measurements

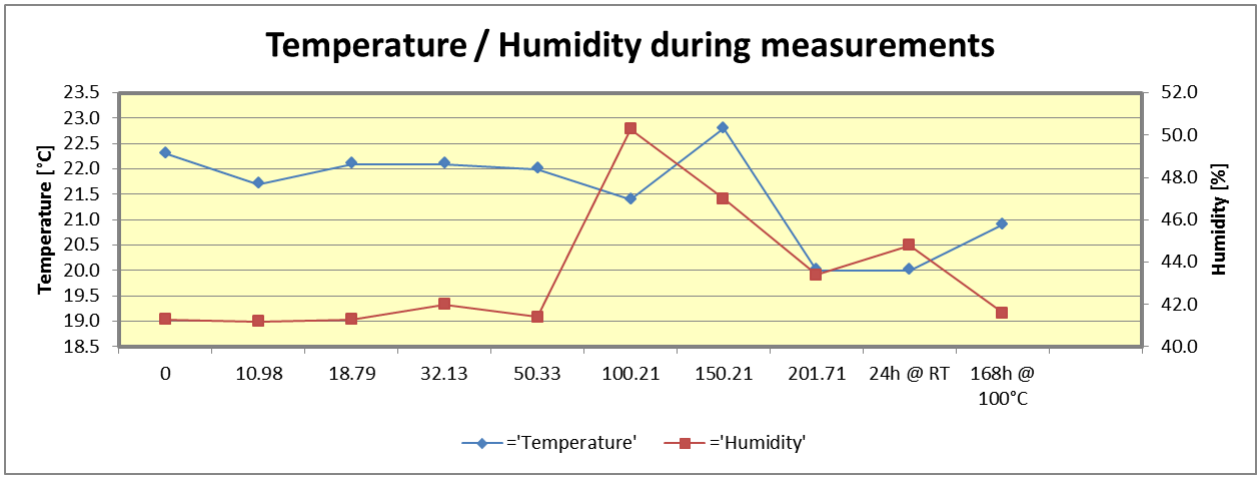
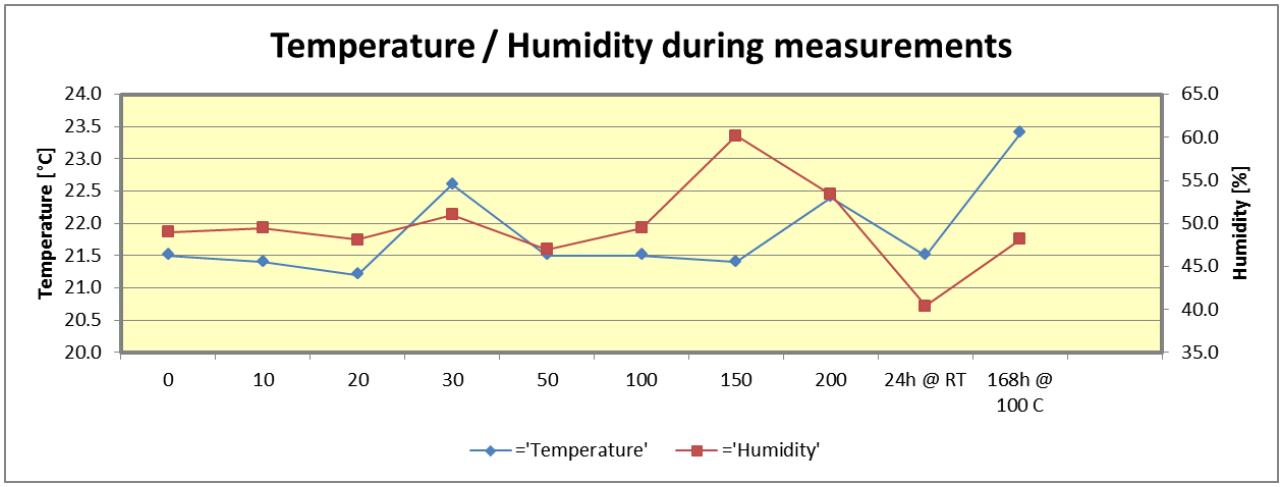


Table 13: HDR: Environment variables during measurements

Test cond.	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	168h @ 100 C
Temperature [°C]	21.5	21.4	21.2	22.6	21.5	21.5	21.4	22.4	21.5	23.4
Humidity [%]	49.0	49.5	48.1	51.0	47.0	49.5	60.2	53.4	40.4	48.2

Figure 14: HDR: Environment variables during measurements



6 Enhancement Factor Calculation

The ELDRS enhancement factor is calculated as the fraction of the parameter shift at low dose rate and at high dose rate with respect to the pre-irradiation values:

$$EF(Dose) = \frac{\Delta\big(para\ (LDR, Dose)\big)}{\Delta\big(para\ (HDR, Dose)\big)}$$

with

$$\Delta(para\ (TEST, Dose)) = para(TEST, Dose) - para(TEST, 0\ krad)$$

This factor is calculated for each individual parameter, dose step and bias mode.

In the recent ESCC 22900 [3], a part is considered ELDRS sensitive if that factor is greater than 1.5 on the median value of the most sensitive measured parameter. According to test method 1019.9 from MIL-STD-883K [6], the calculation of the enhancement factor is only applicable if the respective parameter is beyond the datasheet specifications and changes are not within experimental errors.

When adapting the criteria from MIL-STD-883K, no enhancement satisfying these criteria is found, mostly due to all parameters being within specification.

7 Results LDR

7.1 Overview: Pass/Fail

Pass/Fail		Total Dose [krad (Si)]								Annealing	
		0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Vbr_CEO	On										
	Off										
I_Vbr_CEO	On										
	Off										
I_CEO	On										
	Off										
I_EBO	On										
	Off										
V_CE_SAT	On										
	Off										
V_BE_SAT	On										
	Off										
HFE_1	On										
	Off										
HFE_2	On										
	Off										
I_CEX	On										
	Off										

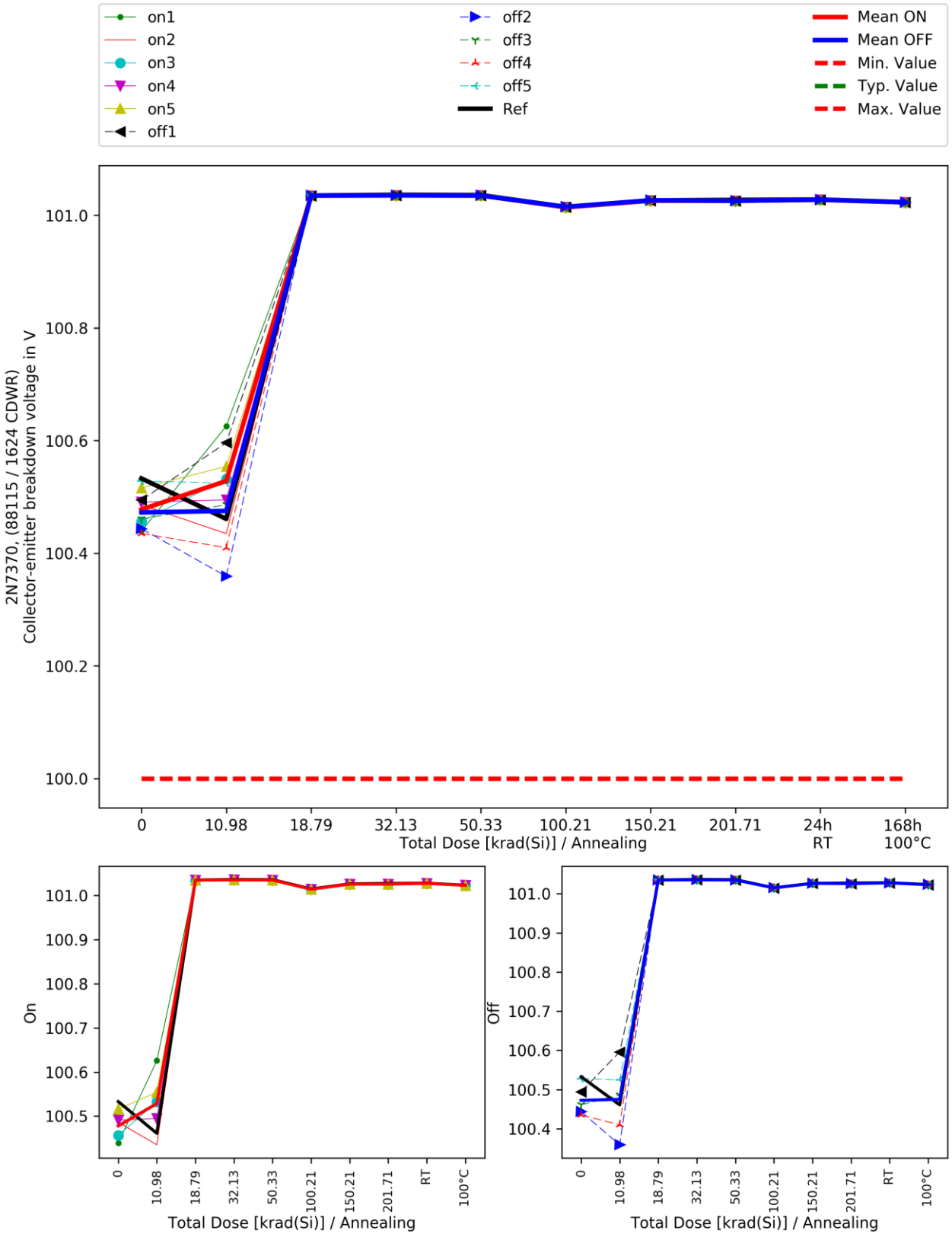
7.2 Collector-emitter breakdown voltage

Collector-emitter breakdown voltage **2N7370**
Vbr_CEO in V Date-/Lotcode: 88115 / 1624 CDWR
Limit: 100.0 < x

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	100.4E+0	100.6E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
on2	100.5E+0	100.4E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
on3	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
on4	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
on5	100.5E+0	100.6E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Radiation-Mean ON	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Standarddeviation	30.1E-3	70.7E-3	554.1E-6	54.8E-6	194.9E-6	167.3E-6	216.8E-6	251.0E-6	288.1E-6	158.1E-6
Mean + kσ	100.6E+0	100.7E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Mean - kσ	100.4E+0	100.3E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	100.5E+0	100.6E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
off2	100.4E+0	100.4E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
off3	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
off4	100.4E+0	100.4E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
off5	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Radiation-Mean OFF	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Standarddeviation	38.5E-3	93.4E-3	260.8E-6	148.3E-6	134.2E-6	311.4E-6	291.5E-6	114.0E-6	70.7E-6	151.7E-6
Mean + kσ	100.6E+0	100.7E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Mean - kσ	100.4E+0	100.2E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	100.5E+0	100.5E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Min. Value	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Collector-emitter breakdown voltage in V
101.0
100.8
100.6
100.4
100.2
100.0
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
On
Off
100.9
100.7
100.5
100.4

7.3 ICE @ 100 V

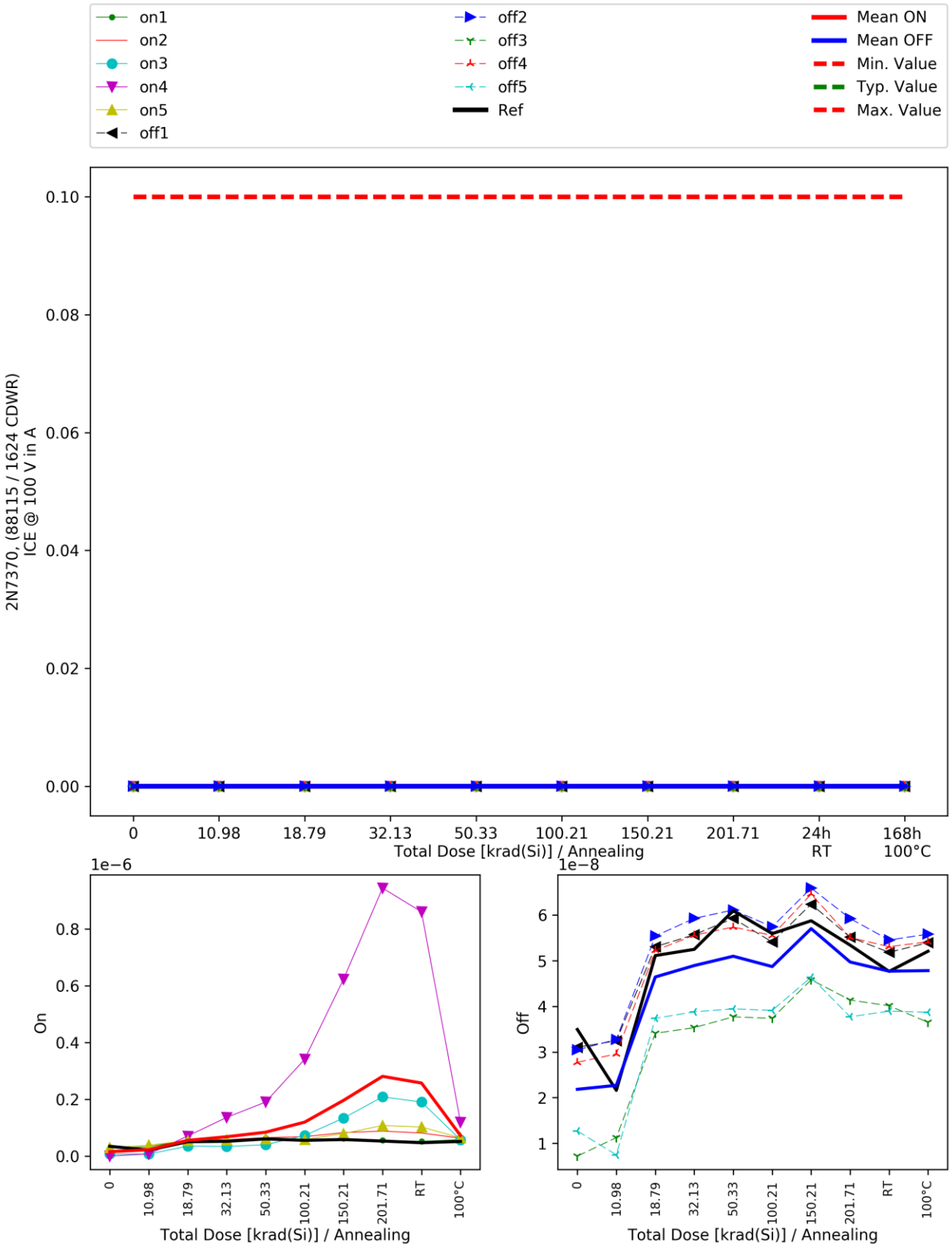
ICE @ 100 V
I_Vbr_CEO in A
Limit: x < 0.1

2N7370
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	28.8E-9	33.2E-9	57.0E-9	55.5E-9	64.1E-9	58.1E-9	62.6E-9	56.2E-9	52.4E-9	58.3E-9
on2	13.6E-9	26.5E-9	59.8E-9	58.4E-9	65.6E-9	68.7E-9	83.3E-9	88.5E-9	81.7E-9	63.6E-9
on3	7.8E-9	7.9E-9	35.5E-9	34.4E-9	40.5E-9	72.8E-9	134.4E-9	208.9E-9	190.7E-9	58.0E-9
on4	611.6E-12	8.1E-9	71.1E-9	136.6E-9	190.7E-9	341.1E-9	623.2E-9	943.5E-9	860.1E-9	120.2E-9
on5	30.2E-9	38.8E-9	55.5E-9	57.9E-9	61.7E-9	58.7E-9	79.9E-9	108.3E-9	103.0E-9	64.8E-9
Radiation-Mean ON	16.2E-9	22.9E-9	55.8E-9	68.6E-9	84.5E-9	119.9E-9	196.7E-9	281.1E-9	257.6E-9	73.0E-9
Standarddeviation	13.0E-9	14.3E-9	12.9E-9	39.3E-9	60.2E-9	123.8E-9	239.9E-9	374.6E-9	340.7E-9	26.6E-9
Mean + kσ	51.8E-9	62.0E-9	91.2E-9	176.4E-9	249.7E-9	459.4E-9	854.6E-9	1.3E-6	1.2E-6	145.8E-9
Mean - kσ	-19.4E-9	-16.2E-9	20.4E-9	-39.3E-9	-80.6E-9	-219.6E-9	-461.2E-9	-746.2E-9	-676.7E-9	160.6E-12

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	31.0E-9	32.4E-9	53.1E-9	55.7E-9	59.3E-9	54.1E-9	62.4E-9	55.1E-9	51.8E-9	54.0E-9
off2	30.5E-9	32.7E-9	55.4E-9	59.3E-9	61.1E-9	57.4E-9	65.9E-9	59.2E-9	54.5E-9	55.8E-9
off3	7.2E-9	11.2E-9	34.1E-9	35.3E-9	37.7E-9	37.4E-9	45.8E-9	41.4E-9	40.1E-9	36.5E-9
off4	27.7E-9	29.6E-9	52.2E-9	55.6E-9	57.4E-9	55.5E-9	64.6E-9	55.1E-9	53.1E-9	54.1E-9
off5	12.7E-9	7.5E-9	37.4E-9	38.8E-9	39.4E-9	39.1E-9	46.4E-9	37.7E-9	38.9E-9	38.7E-9
Radiation-Mean OFF	21.8E-9	22.7E-9	46.4E-9	48.9E-9	51.0E-9	48.7E-9	57.0E-9	49.7E-9	47.7E-9	47.8E-9
Standarddeviation	11.1E-9	12.3E-9	9.9E-9	11.0E-9	11.4E-9	9.6E-9	10.0E-9	9.5E-9	7.5E-9	9.4E-9
Mean + kσ	52.2E-9	56.5E-9	73.6E-9	79.1E-9	82.3E-9	75.1E-9	84.6E-9	75.8E-9	68.3E-9	73.6E-9
Mean - kσ	-8.6E-9	-11.1E-9	19.3E-9	18.8E-9	19.7E-9	22.3E-9	29.5E-9	23.6E-9	27.1E-9	22.1E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	34.9E-9	21.6E-9	51.1E-9	52.5E-9	60.9E-9	55.9E-9	58.7E-9	53.4E-9	47.6E-9	52.1E-9
Max. Value	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
ICE @ 100 V in A
0.10
0.08
0.06
0.04
0.02
0.00
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
1e−6
On
0.8
0.6
0.4
0.2
0.0
1e−8
Off
6
5
4
3
2
1
RT
Total Dose [krad(Si)] / Annealing

7.4 Collector-Emitter cut-off current (VBE = 0)

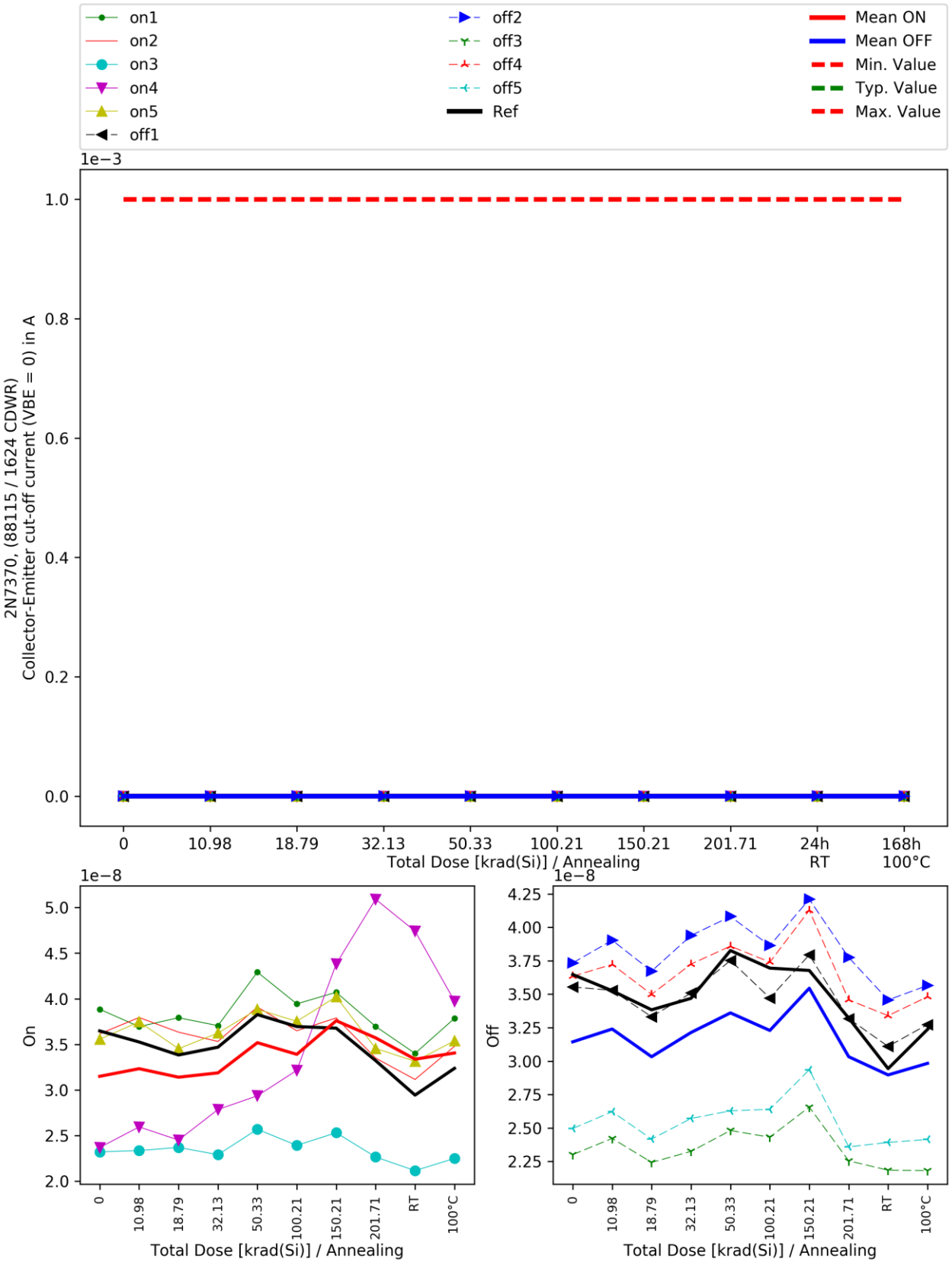
Collector-Emitter cut-off current (VBE = 0) **2N7370**
I_CEO in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 0.001

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	38.8E-9	36.9E-9	37.9E-9	37.1E-9	42.9E-9	39.4E-9	40.7E-9	37.0E-9	34.0E-9	37.8E-9
on2	36.2E-9	37.9E-9	36.3E-9	35.3E-9	39.1E-9	36.5E-9	37.9E-9	33.5E-9	31.2E-9	34.8E-9
on3	23.2E-9	23.4E-9	23.7E-9	22.9E-9	25.7E-9	23.9E-9	25.3E-9	22.7E-9	21.2E-9	22.5E-9
on4	23.7E-9	26.0E-9	24.5E-9	27.9E-9	29.4E-9	32.2E-9	43.8E-9	50.9E-9	47.4E-9	39.7E-9
on5	35.6E-9	37.5E-9	34.5E-9	36.2E-9	38.8E-9	37.5E-9	40.2E-9	34.6E-9	33.1E-9	35.4E-9
Radiation-Mean ON	31.5E-9	32.3E-9	31.4E-9	31.9E-9	35.2E-9	33.9E-9	37.6E-9	35.7E-9	33.4E-9	34.1E-9
Standarddeviation	7.4E-9	7.1E-9	6.8E-9	6.2E-9	7.3E-9	6.2E-9	7.2E-9	10.1E-9	9.4E-9	6.8E-9
Mean + kσ	51.9E-9	51.7E-9	50.0E-9	48.9E-9	55.2E-9	50.9E-9	57.3E-9	63.4E-9	59.1E-9	52.6E-9
Mean - kσ	11.1E-9	12.9E-9	12.8E-9	14.9E-9	15.2E-9	16.9E-9	17.9E-9	8.0E-9	7.7E-9	15.5E-9

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	35.5E-9	35.3E-9	33.3E-9	35.1E-9	37.5E-9	34.7E-9	37.9E-9	33.2E-9	31.1E-9	32.7E-9
off2	37.3E-9	39.0E-9	36.7E-9	39.4E-9	40.8E-9	38.6E-9	42.1E-9	37.7E-9	34.6E-9	35.7E-9
off3	23.0E-9	24.2E-9	22.4E-9	23.2E-9	24.8E-9	24.3E-9	26.6E-9	22.5E-9	21.8E-9	21.8E-9
off4	36.3E-9	37.2E-9	35.0E-9	37.3E-9	38.6E-9	37.4E-9	41.3E-9	34.6E-9	33.4E-9	34.8E-9
off5	25.0E-9	26.2E-9	24.2E-9	25.7E-9	26.3E-9	26.4E-9	29.4E-9	23.6E-9	23.9E-9	24.1E-9
Radiation-Mean OFF	31.4E-9	32.4E-9	30.3E-9	32.1E-9	33.6E-9	32.3E-9	35.4E-9	30.3E-9	29.0E-9	29.8E-9
Standarddeviation	6.9E-9	6.7E-9	6.6E-9	7.2E-9	7.5E-9	6.5E-9	7.1E-9	6.8E-9	5.7E-9	6.4E-9
Mean + kσ	50.3E-9	50.8E-9	48.3E-9	51.9E-9	54.1E-9	50.2E-9	54.9E-9	49.1E-9	44.7E-9	47.4E-9
Mean - kσ	12.6E-9	14.0E-9	12.4E-9	12.4E-9	13.1E-9	14.4E-9	16.0E-9	11.6E-9	13.2E-9	12.3E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	36.5E-9	35.3E-9	33.8E-9	34.7E-9	38.3E-9	37.0E-9	36.8E-9	33.2E-9	29.4E-9	32.4E-9

Max. Value	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−3
2N7370, (88115 / 1624 CDWR)
Collector-Emitter cut-off current (VBE = 0) in A
Total Dose [krad(Si)] / Annealing
1e−8
On
Off
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C

7.5 Emitter-Base cut-off current

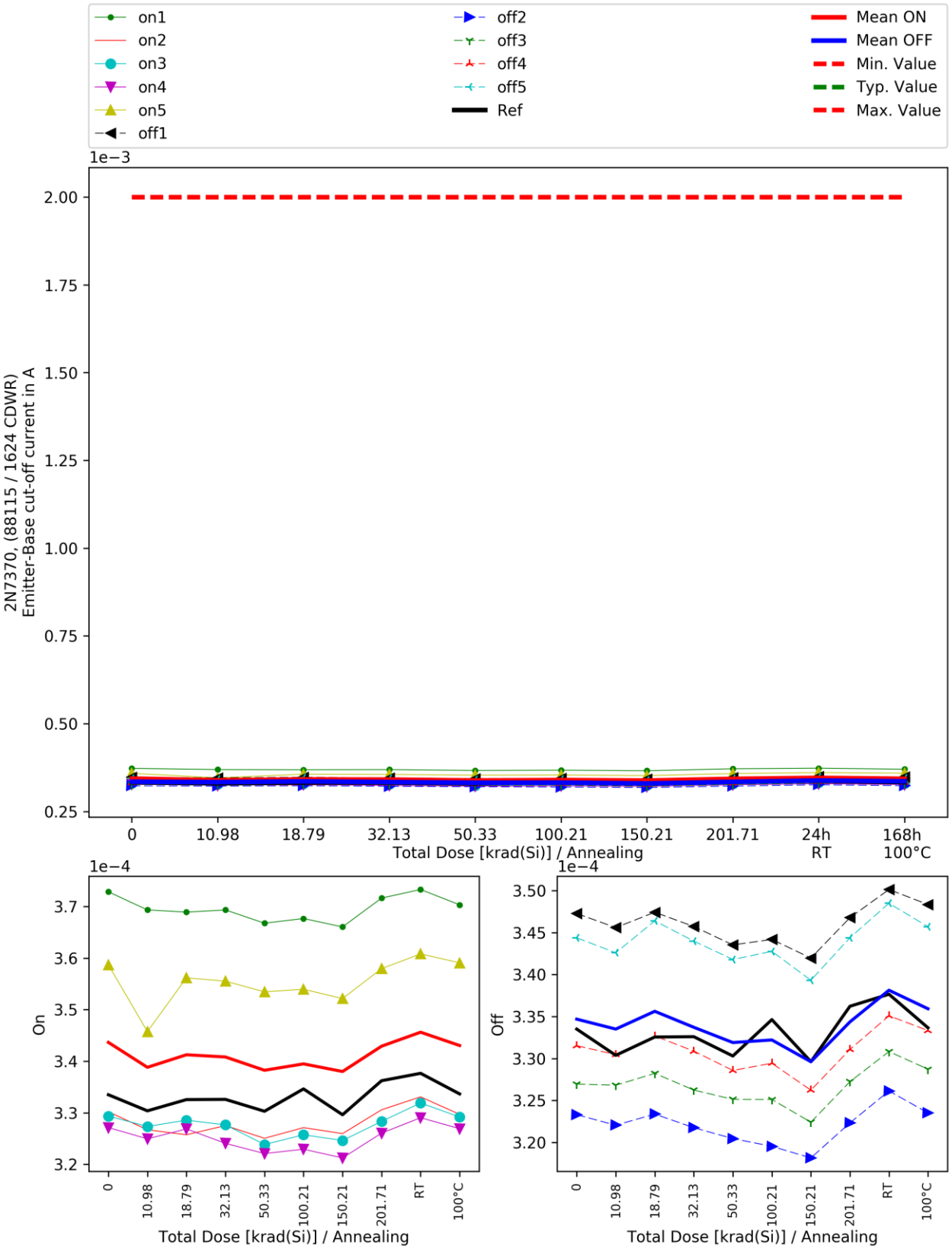
Emitter-Base cut-off current **2N7370**
I_EBO in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 0.002

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	372.9E-6	369.3E-6	368.9E-6	369.3E-6	366.8E-6	367.7E-6	366.0E-6	371.6E-6	373.3E-6	370.3E-6
on2	330.2E-6	326.7E-6	325.7E-6	327.5E-6	325.0E-6	327.1E-6	326.0E-6	330.6E-6	333.1E-6	329.7E-6
on3	329.4E-6	327.3E-6	328.6E-6	327.6E-6	323.8E-6	325.7E-6	324.6E-6	328.3E-6	331.9E-6	329.2E-6
on4	327.1E-6	324.9E-6	326.9E-6	324.1E-6	322.1E-6	322.9E-6	321.2E-6	326.1E-6	329.0E-6	326.9E-6
on5	358.7E-6	345.7E-6	356.2E-6	355.5E-6	353.4E-6	353.9E-6	352.1E-6	357.9E-6	360.8E-6	359.1E-6
Radiation-Mean ON	343.6E-6	338.8E-6	341.2E-6	340.8E-6	338.2E-6	339.5E-6	338.0E-6	342.9E-6	345.6E-6	343.0E-6
Standarddeviation	20.8E-6	19.0E-6	20.0E-6	20.4E-6	20.5E-6	20.1E-6	19.9E-6	20.6E-6	20.1E-6	20.2E-6
Mean + kσ	400.8E-6	391.0E-6	396.0E-6	396.7E-6	394.5E-6	394.7E-6	392.7E-6	399.4E-6	400.7E-6	398.4E-6
Mean - kσ	286.5E-6	286.6E-6	286.5E-6	285.0E-6	281.9E-6	284.3E-6	283.3E-6	286.4E-6	290.5E-6	287.7E-6

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	347.3E-6	345.6E-6	347.4E-6	345.7E-6	343.5E-6	344.2E-6	342.0E-6	346.8E-6	350.1E-6	348.3E-6
off2	323.3E-6	322.0E-6	323.4E-6	321.8E-6	320.5E-6	319.5E-6	318.2E-6	322.3E-6	326.1E-6	323.5E-6
off3	326.9E-6	326.8E-6	328.2E-6	326.2E-6	325.1E-6	325.1E-6	322.4E-6	327.2E-6	330.8E-6	328.7E-6
off4	331.5E-6	330.5E-6	332.7E-6	330.9E-6	328.6E-6	329.4E-6	326.2E-6	331.1E-6	335.1E-6	333.3E-6
off5	344.4E-6	342.6E-6	346.4E-6	344.0E-6	341.8E-6	342.8E-6	339.3E-6	344.4E-6	348.5E-6	345.7E-6
Radiation-Mean OFF	334.7E-6	333.5E-6	335.6E-6	333.7E-6	331.9E-6	332.2E-6	329.6E-6	334.4E-6	338.1E-6	335.9E-6
Standarddeviation	10.6E-6	10.2E-6	10.8E-6	10.7E-6	10.3E-6	10.9E-6	10.5E-6	10.7E-6	10.7E-6	10.7E-6
Mean + kσ	363.8E-6	361.4E-6	365.3E-6	363.0E-6	360.0E-6	362.0E-6	358.4E-6	363.8E-6	367.5E-6	365.4E-6
Mean - kσ	305.6E-6	305.6E-6	306.0E-6	304.4E-6	303.8E-6	302.4E-6	300.8E-6	304.9E-6	308.8E-6	306.5E-6

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	333.5E-6	330.4E-6	332.6E-6	332.6E-6	330.3E-6	334.6E-6	329.6E-6	336.2E-6	337.6E-6	333.7E-6

Max. Value	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−3
2N7370, (88115 / 1624 CDWR)
Emitter-Base cut-off current in A
2.00
1.75
1.50
1.25
1.00
0.75
0.50
0.25
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
1e−4
On
3.7
3.6
3.5
3.4
3.3
3.2
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
RT
100°C
Total Dose [krad(Si)] / Annealing
1e−4
Off
3.50
3.45
3.40
3.35
3.30
3.25
3.20
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
RT
100°C
Total Dose [krad(Si)] / Annealing

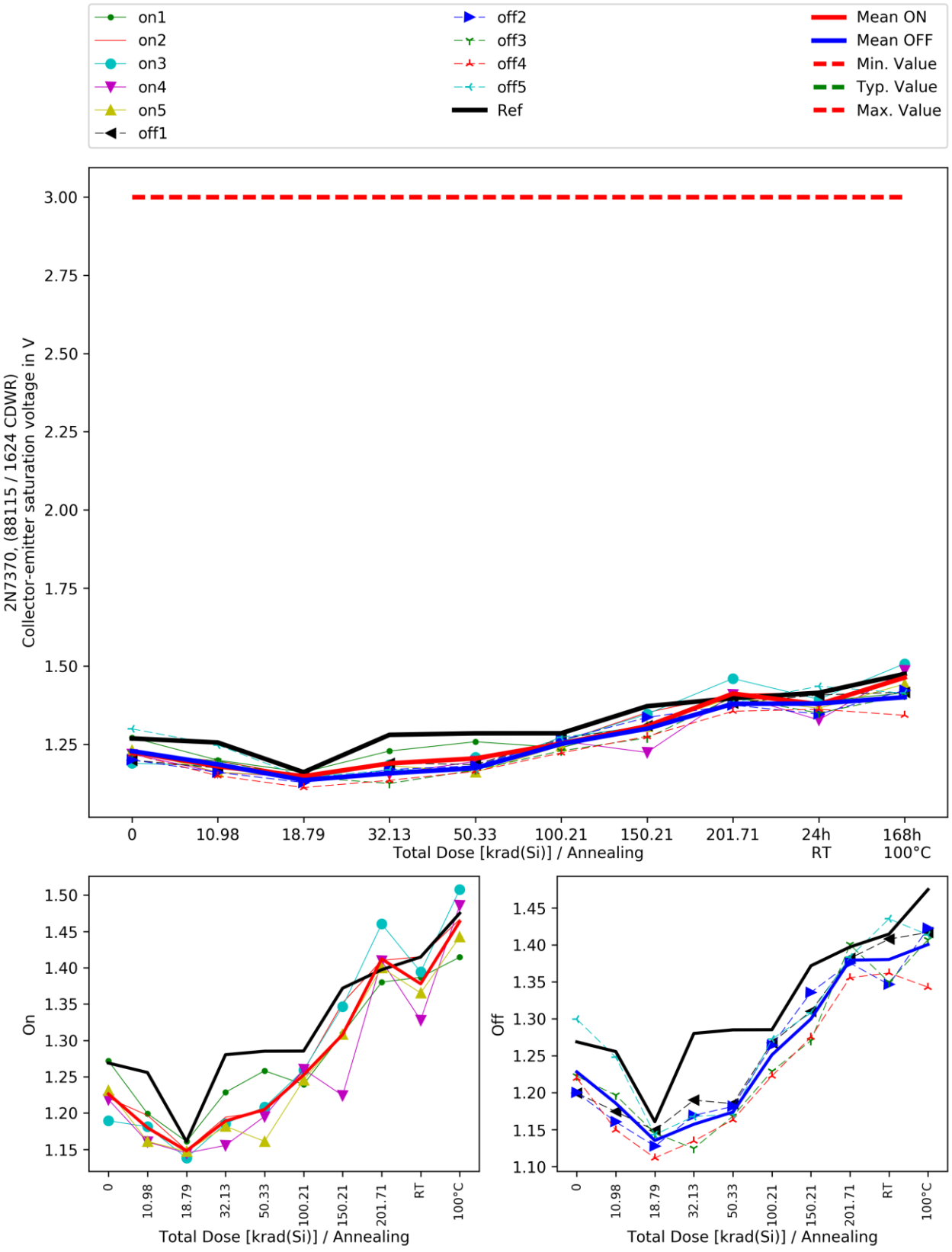
7.6 Collector-emitter saturation voltage

Collector-emitter saturation voltage **2N7370**
V_CE_SAT in V Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 3.0

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	1.3E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0
on2	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0	1.5E+0
on3	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.5E+0	1.4E+0	1.5E+0
on4	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.4E+0	1.3E+0	1.5E+0
on5	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0
Radiation-Mean ON	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0	1.5E+0
Standarddeviation	29.8E-3	18.8E-3	8.2E-3	26.4E-3	34.9E-3	9.4E-3	51.1E-3	29.6E-3	33.1E-3	36.4E-3
Mean + kσ	1.3E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.3E+0	1.4E+0	1.5E+0	1.5E+0	1.6E+0
Mean - kσ	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0
off2	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.3E+0	1.4E+0
off3	1.2E+0	1.2E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.3E+0	1.4E+0
off4	1.2E+0	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.3E+0
off5	1.3E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0
Radiation-Mean OFF	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0
Standarddeviation	41.3E-3	38.9E-3	15.5E-3	27.0E-3	9.2E-3	23.4E-3	27.1E-3	16.1E-3	39.4E-3	32.8E-3
Mean + kσ	1.3E+0	1.3E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.5E+0	1.5E+0
Mean - kσ	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.3E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	1.3E+0	1.3E+0	1.2E+0	1.3E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0	1.4E+0	1.5E+0
Max. Value	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Collector-emitter saturation voltage in V
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
On
Off
Total Dose [krad(Si)] / Annealing
Total Dose [krad(Si)] / Annealing

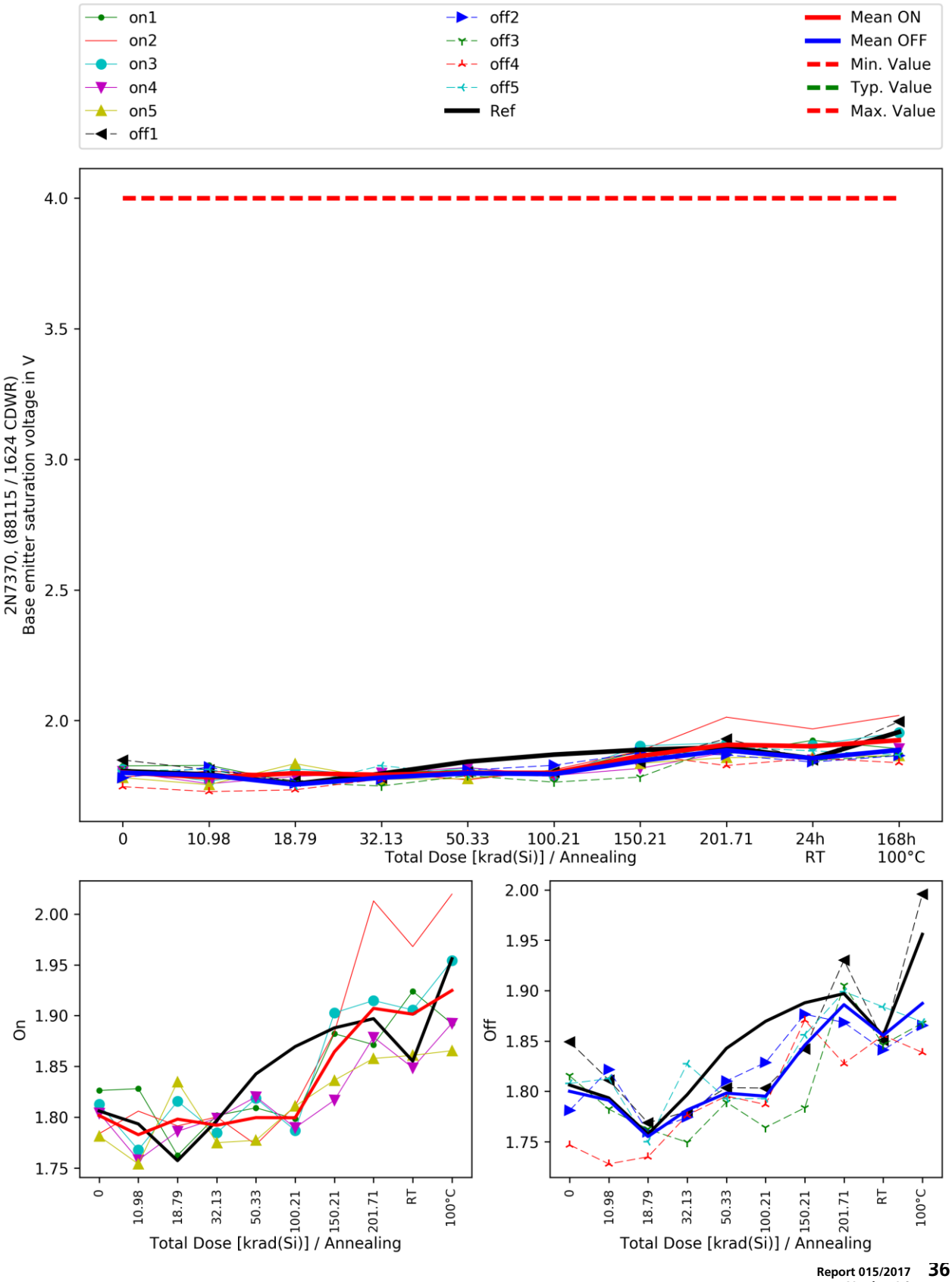
7.7 Base emitter saturation voltage

Base emitter saturation voltage **2N7370**
V_BE_SAT in V Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 4.0

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0
on2	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	2.0E+0	2.0E+0	2.0E+0
on3	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	2.0E+0
on4	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.9E+0
on5	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0
Radiation-Mean ON	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0
Standarddeviation	19.1E-3	32.6E-3	27.9E-3	11.8E-3	22.8E-3	11.4E-3	36.1E-3	62.7E-3	48.4E-3	62.2E-3
Mean + kσ	1.9E+0	1.9E+0	1.9E+0	1.8E+0	1.9E+0	1.8E+0	2.0E+0	2.1E+0	2.0E+0	2.1E+0
Mean - kσ	1.7E+0	1.7E+0	1.7E+0	1.8E+0	1.7E+0	1.8E+0	1.8E+0	1.7E+0	1.8E+0	1.8E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	2.0E+0
off2	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.8E+0	1.9E+0
off3	1.8E+0	1.8E+0	1.8E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.9E+0
off4	1.7E+0	1.7E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.9E+0	1.8E+0
off5	1.8E+0	1.8E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0
Radiation-Mean OFF	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0
Standarddeviation	38.5E-3	38.3E-3	13.2E-3	28.4E-3	8.6E-3	23.6E-3	37.2E-3	39.5E-3	16.8E-3	62.0E-3
Mean + kσ	1.9E+0	1.9E+0	1.8E+0	1.9E+0	1.8E+0	1.9E+0	1.9E+0	2.0E+0	1.9E+0	2.1E+0
Mean - kσ	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.8E+0	1.7E+0	1.7E+0	1.8E+0	1.8E+0	1.7E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0	2.0E+0
Max. Value	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Base emitter saturation voltage in V
4.0
3.5
3.0
2.5
2.0
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
On
2.00
1.95
1.90
1.85
1.80
1.75
Off
2.00
1.95
1.90
1.85
1.80
1.75
Total Dose [krad(Si)] / Annealing
Total Dose [krad(Si)] / Annealing

7.8 DC current gain (1)

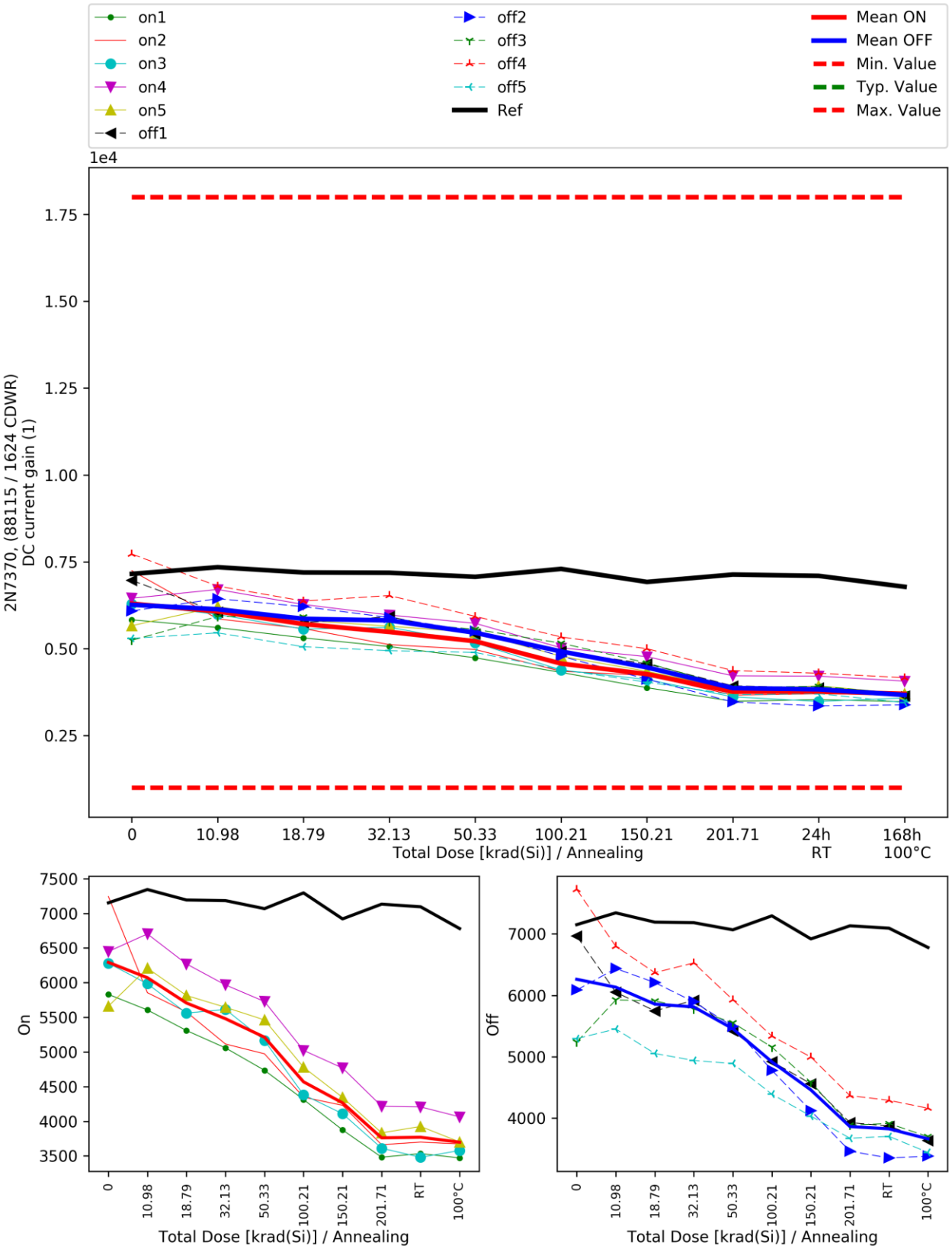
DC current gain (1)
HFE_1
Limit: 1000.0 < x < 18000.0

2N7370
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	5.8E+3	5.6E+3	5.3E+3	5.1E+3	4.7E+3	4.3E+3	3.9E+3	3.5E+3	3.5E+3	3.5E+3
on2	7.2E+3	5.9E+3	5.6E+3	5.1E+3	5.0E+3	4.3E+3	4.2E+3	3.7E+3	3.7E+3	3.7E+3
on3	6.3E+3	6.0E+3	5.6E+3	5.6E+3	5.2E+3	4.4E+3	4.1E+3	3.6E+3	3.5E+3	3.6E+3
on4	6.4E+3	6.7E+3	6.3E+3	6.0E+3	5.7E+3	5.0E+3	4.8E+3	4.2E+3	4.2E+3	4.1E+3
on5	5.7E+3	6.2E+3	5.8E+3	5.6E+3	5.5E+3	4.8E+3	4.3E+3	3.8E+3	3.9E+3	3.7E+3
Radiation-Mean ON	6.3E+3	6.1E+3	5.7E+3	5.5E+3	5.2E+3	4.6E+3	4.3E+3	3.8E+3	3.8E+3	3.7E+3
Standarddeviation	620.9E+0	415.0E+0	362.2E+0	385.2E+0	392.1E+0	316.0E+0	330.5E+0	284.6E+0	299.9E+0	223.8E+0
Mean + kσ	8.0E+3	7.2E+3	6.7E+3	6.5E+3	6.3E+3	5.4E+3	5.2E+3	4.5E+3	4.6E+3	4.3E+3
Mean - kσ	4.6E+3	4.9E+3	4.7E+3	4.4E+3	4.1E+3	3.7E+3	3.4E+3	3.0E+3	2.9E+3	3.1E+3

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	7.0E+3	6.1E+3	5.7E+3	5.9E+3	5.4E+3	4.9E+3	4.6E+3	3.9E+3	3.9E+3	3.6E+3
off2	6.1E+3	6.4E+3	6.2E+3	5.9E+3	5.5E+3	4.8E+3	4.1E+3	3.5E+3	3.4E+3	3.4E+3
off3	5.2E+3	5.9E+3	5.9E+3	5.8E+3	5.6E+3	5.2E+3	4.6E+3	3.9E+3	3.9E+3	3.7E+3
off4	7.7E+3	6.8E+3	6.4E+3	6.5E+3	5.9E+3	5.3E+3	5.0E+3	4.4E+3	4.3E+3	4.2E+3
off5	5.3E+3	5.5E+3	5.1E+3	4.9E+3	4.9E+3	4.4E+3	4.0E+3	3.7E+3	3.7E+3	3.4E+3
Radiation-Mean OFF	6.3E+3	6.1E+3	5.9E+3	5.8E+3	5.5E+3	4.9E+3	4.5E+3	3.9E+3	3.8E+3	3.7E+3
Standarddeviation	1.1E+3	512.2E+0	511.5E+0	568.5E+0	372.9E+0	363.4E+0	390.7E+0	337.5E+0	340.9E+0	307.7E+0
Mean + kσ	9.2E+3	7.5E+3	7.3E+3	7.4E+3	6.5E+3	5.9E+3	5.5E+3	4.8E+3	4.8E+3	4.5E+3
Mean - kσ	3.3E+3	4.7E+3	4.5E+3	4.3E+3	4.4E+3	3.9E+3	3.4E+3	2.9E+3	2.9E+3	2.8E+3

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	7.2E+3	7.3E+3	7.2E+3	7.2E+3	7.1E+3	7.3E+3	6.9E+3	7.1E+3	7.1E+3	6.8E+3
Min. Value	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3
Max. Value	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e4
1.75
1.50
1.25
1.00
0.75
0.50
0.25
2N7370, (88115 / 1624 CDWR)
DC current gain (1)
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing
On
Off
7500
7000
6500
6000
5500
5000
4500
4000
3500
RT
100°C

7.9 DC current gain (2)

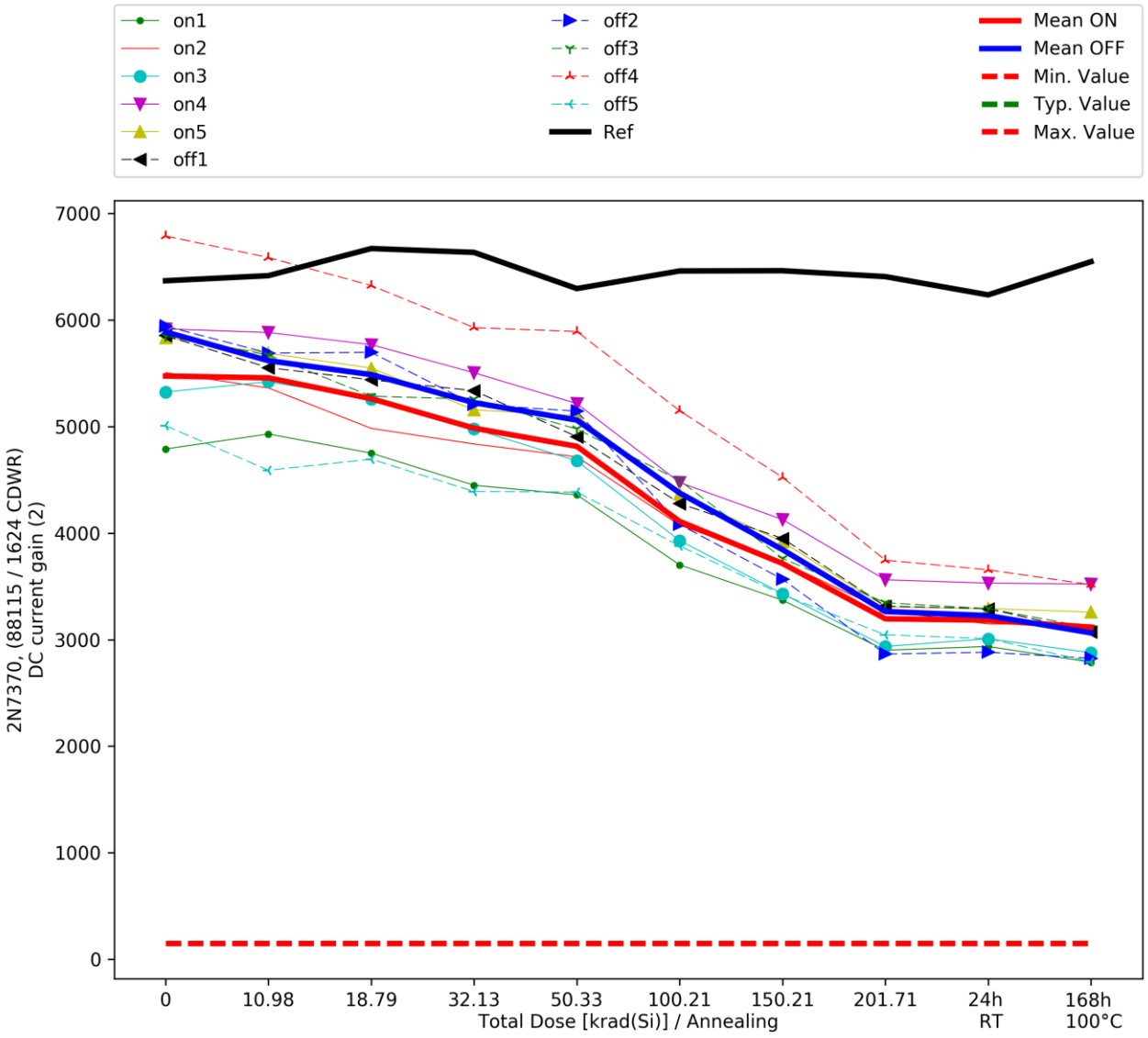
DC current gain (2)
HFE_2
Limit: 150.0 < x

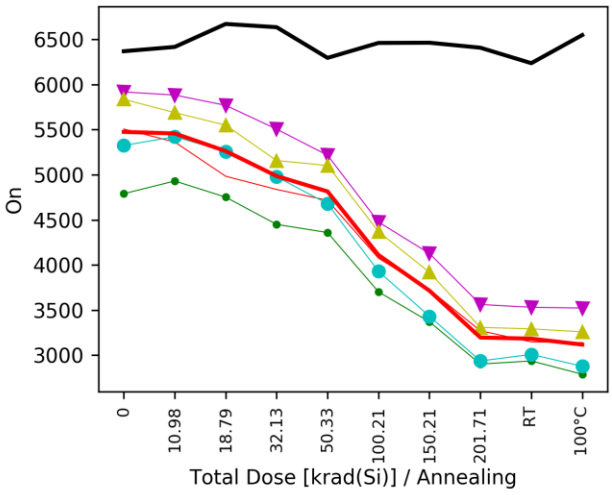
2N7370
Date-/Lotcode: 88115 / 1624 CDWR

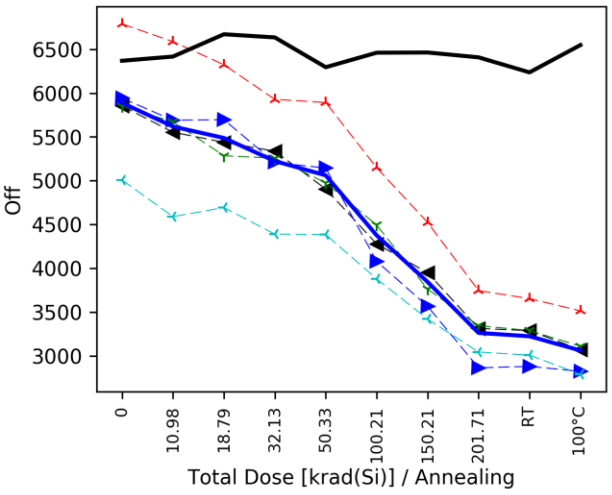
ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	4.8E+3	4.9E+3	4.8E+3	4.4E+3	4.4E+3	3.7E+3	3.4E+3	2.9E+3	2.9E+3	2.8E+3
on2	5.5E+3	5.4E+3	5.0E+3	4.8E+3	4.7E+3	4.1E+3	3.7E+3	3.3E+3	3.1E+3	3.1E+3
on3	5.3E+3	5.4E+3	5.3E+3	5.0E+3	4.7E+3	3.9E+3	3.4E+3	2.9E+3	3.0E+3	2.9E+3
on4	5.9E+3	5.9E+3	5.8E+3	5.5E+3	5.2E+3	4.5E+3	4.1E+3	3.6E+3	3.5E+3	3.5E+3
on5	5.8E+3	5.7E+3	5.5E+3	5.2E+3	5.1E+3	4.4E+3	3.9E+3	3.3E+3	3.3E+3	3.3E+3
Radiation-Mean ON	5.5E+3	5.5E+3	5.3E+3	5.0E+3	4.8E+3	4.1E+3	3.7E+3	3.2E+3	3.2E+3	3.1E+3
Standarddeviation	452.5E+0	361.4E+0	411.8E+0	390.2E+0	346.4E+0	316.7E+0	320.4E+0	276.9E+0	237.5E+0	295.8E+0
Mean + kσ	6.7E+3	6.4E+3	6.4E+3	6.1E+3	5.8E+3	5.0E+3	4.6E+3	4.0E+3	3.8E+3	3.9E+3
Mean - kσ	4.2E+3	4.5E+3	4.1E+3	3.9E+3	3.9E+3	3.2E+3	2.8E+3	2.4E+3	2.5E+3	2.3E+3

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	5.9E+3	5.6E+3	5.4E+3	5.3E+3	4.9E+3	4.3E+3	4.0E+3	3.3E+3	3.3E+3	3.1E+3
off2	5.9E+3	5.7E+3	5.7E+3	5.2E+3	5.1E+3	4.1E+3	3.6E+3	2.9E+3	2.9E+3	2.8E+3
off3	5.8E+3	5.7E+3	5.3E+3	5.3E+3	5.0E+3	4.5E+3	3.8E+3	3.3E+3	3.3E+3	3.1E+3
off4	6.8E+3	6.6E+3	6.3E+3	5.9E+3	5.9E+3	5.1E+3	4.5E+3	3.7E+3	3.7E+3	3.5E+3
off5	5.0E+3	4.6E+3	4.7E+3	4.4E+3	4.4E+3	3.9E+3	3.4E+3	3.0E+3	3.0E+3	2.8E+3
Radiation-Mean OFF	5.9E+3	5.6E+3	5.5E+3	5.2E+3	5.1E+3	4.4E+3	3.8E+3	3.3E+3	3.2E+3	3.1E+3
Standarddeviation	630.5E+0	708.4E+0	595.0E+0	548.6E+0	544.4E+0	488.2E+0	428.5E+0	335.0E+0	299.2E+0	290.5E+0
Mean + kσ	7.6E+3	7.6E+3	7.1E+3	6.7E+3	6.6E+3	5.7E+3	5.0E+3	4.2E+3	4.0E+3	3.9E+3
Mean - kσ	4.2E+3	3.7E+3	3.9E+3	3.7E+3	3.6E+3	3.0E+3	2.7E+3	2.3E+3	2.4E+3	2.3E+3

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	6.4E+3	6.4E+3	6.7E+3	6.6E+3	6.3E+3	6.5E+3	6.5E+3	6.4E+3	6.2E+3	6.5E+3
Min. Value	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
DC current gain (2)
7000
6000
5000
4000
3000
2000
1000
0
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
Total Dose [krad(Si)] / Annealing


On
6500
6000
5500
5000
4500
4000
3500
3000
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
RT
100°C
Total Dose [krad(Si)] / Annealing


Off
6500
6000
5500
5000
4500
4000
3500
3000
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
RT
100°C
Total Dose [krad(Si)] / Annealing

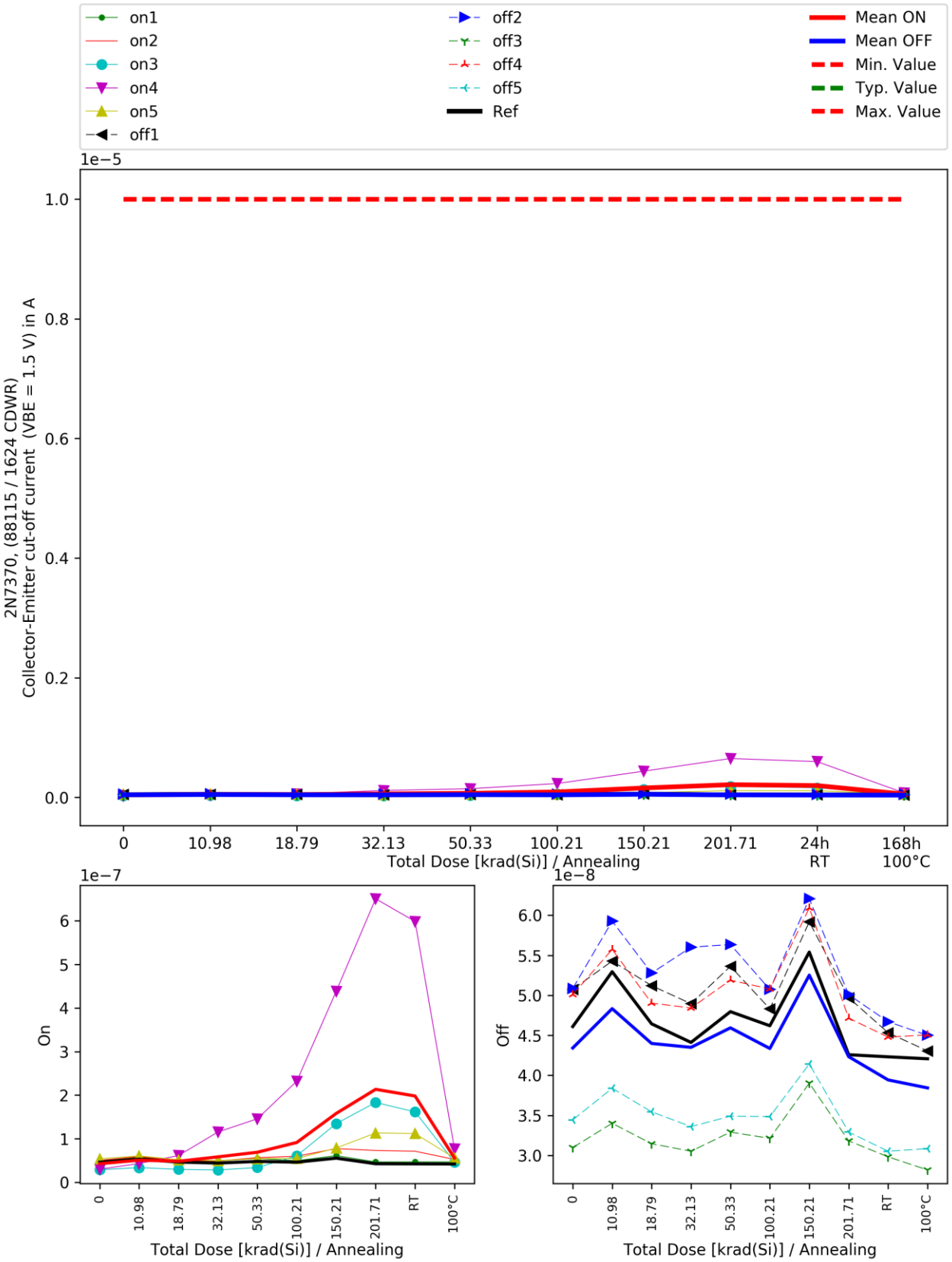
7.10 Collector-Emitter cut-off current (VBE = 1.5 V)

Collector-Emitter cut-off current (VBE = 1.5 V) **2N7370**
I_CEX in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 1e-05

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
on1	50.1E-9	57.4E-9	49.0E-9	49.2E-9	54.6E-9	49.5E-9	61.3E-9	46.7E-9	46.8E-9	46.8E-9
on2	50.5E-9	58.9E-9	49.7E-9	49.0E-9	56.5E-9	59.9E-9	77.3E-9	73.1E-9	71.3E-9	52.5E-9
on3	28.7E-9	33.7E-9	29.7E-9	28.3E-9	33.8E-9	60.9E-9	134.6E-9	183.3E-9	161.6E-9	46.4E-9
on4	29.9E-9	43.1E-9	61.5E-9	115.5E-9	145.9E-9	232.1E-9	438.5E-9	650.7E-9	598.8E-9	76.9E-9
on5	54.0E-9	60.6E-9	51.7E-9	49.7E-9	54.3E-9	54.5E-9	78.7E-9	113.2E-9	111.9E-9	55.9E-9
Radiation-Mean ON	42.6E-9	50.8E-9	48.3E-9	58.3E-9	69.0E-9	91.4E-9	158.1E-9	213.4E-9	198.1E-9	55.7E-9
Standarddeviation	12.3E-9	11.8E-9	11.6E-9	33.2E-9	43.9E-9	78.8E-9	159.2E-9	249.8E-9	228.2E-9	12.5E-9
Mean + kσ	76.3E-9	83.1E-9	80.0E-9	149.4E-9	189.5E-9	307.5E-9	594.6E-9	898.4E-9	823.8E-9	90.0E-9
Mean - kσ	9.0E-9	18.4E-9	16.6E-9	-32.7E-9	-51.5E-9	-124.7E-9	-278.4E-9	-471.6E-9	-427.6E-9	21.4E-9

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
off1	50.8E-9	54.3E-9	51.2E-9	49.0E-9	53.6E-9	48.3E-9	59.2E-9	49.7E-9	45.3E-9	43.1E-9
off2	50.8E-9	59.3E-9	52.8E-9	56.0E-9	56.4E-9	50.7E-9	62.1E-9	50.1E-9	46.7E-9	45.0E-9
off3	31.0E-9	34.0E-9	31.5E-9	30.5E-9	32.9E-9	32.1E-9	39.0E-9	31.8E-9	29.8E-9	28.2E-9
off4	50.1E-9	55.7E-9	49.0E-9	48.4E-9	51.9E-9	50.8E-9	60.9E-9	47.2E-9	44.8E-9	45.1E-9
off5	34.4E-9	38.4E-9	35.4E-9	33.6E-9	34.9E-9	34.8E-9	41.4E-9	32.9E-9	30.5E-9	30.9E-9
Radiation-Mean OFF	43.4E-9	48.3E-9	44.0E-9	43.5E-9	45.9E-9	43.4E-9	52.5E-9	42.3E-9	39.4E-9	38.4E-9
Standarddeviation	9.9E-9	11.3E-9	9.8E-9	10.9E-9	11.1E-9	9.1E-9	11.3E-9	9.2E-9	8.5E-9	8.2E-9
Mean + kσ	70.5E-9	79.4E-9	70.9E-9	73.4E-9	76.4E-9	68.4E-9	83.5E-9	67.5E-9	62.7E-9	61.0E-9
Mean - kσ	16.4E-9	17.3E-9	17.1E-9	13.6E-9	15.4E-9	18.4E-9	21.5E-9	17.2E-9	16.2E-9	15.9E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10.98	18.79	32.13	50.33	100.21	150.21	201.71	24h @ RT	68h @ 100°C
Ref1	46.1E-9	53.0E-9	46.4E-9	44.1E-9	48.0E-9	46.2E-9	55.4E-9	42.6E-9	42.3E-9	42.1E-9
Max. Value	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6


on1
on2
on3
on4
on5
off1
off2
off3
off4
off5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−5
2N7370, (88115 / 1624 CDWR)
Collector-Emitter cut-off current (VBE = 1.5 V) in A
Total Dose [krad(Si)] / Annealing
0
10.98
18.79
32.13
50.33
100.21
150.21
201.71
24h
RT
168h
100°C
1e−7
On
1e−8
Off

8 Results HDR

8.1 Overview: Pass/Fail

Pass/Fail		Total Dose [krad (Si)]								Annealing	
		0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Vbr_CEO	On										
	Off										
I_Vbr_CEO	On										
	Off										
I_CEO	On										
	Off										
I_EBO	On										
	Off										
V_CE_SAT	On										
	Off										
V_BE_SAT	On										
	Off										
HFE_1	On										
	Off										
HFE_2	On										
	Off										
I_CEX	On										
	Off										

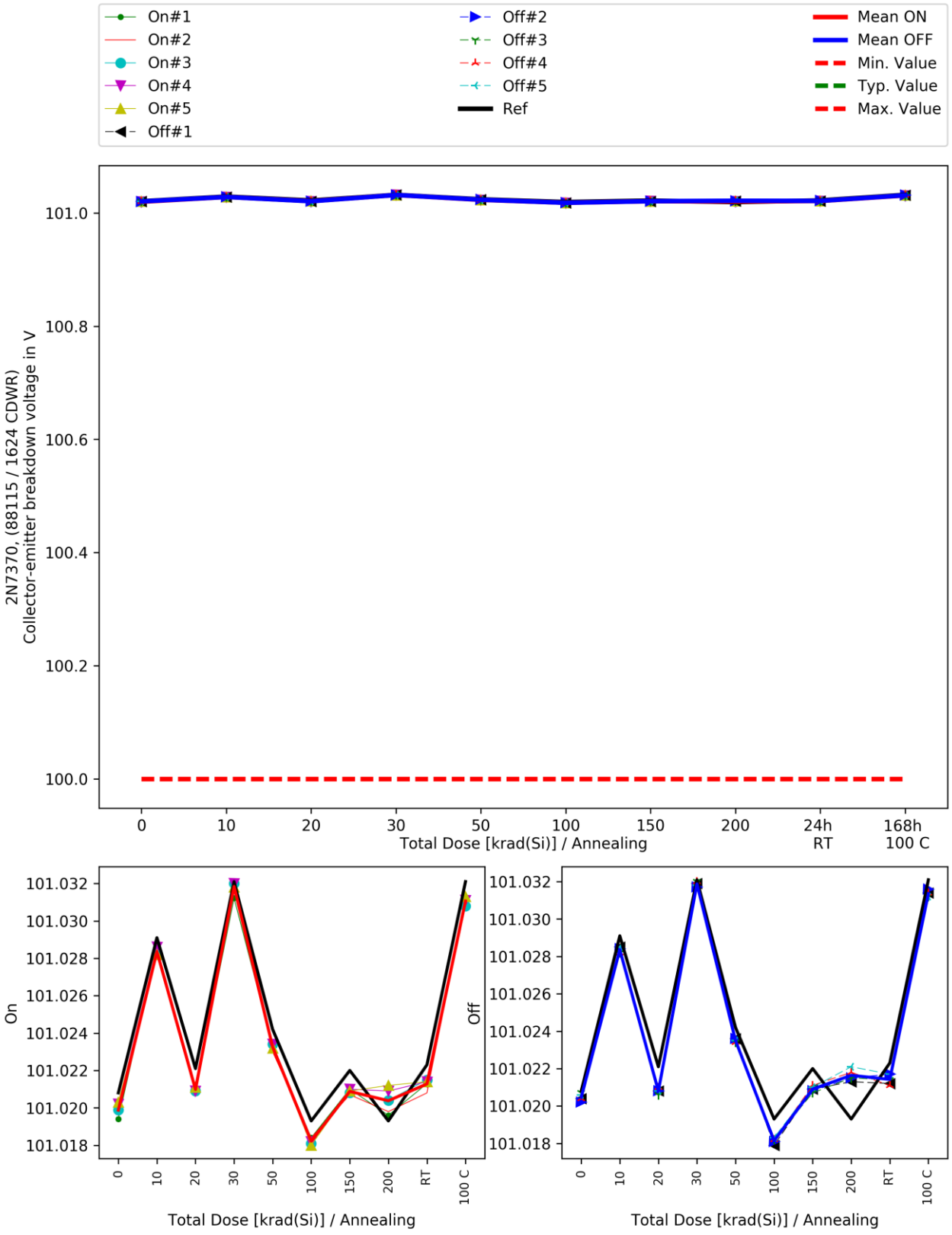
8.2 Collector-emitter breakdown voltage

Collector-emitter breakdown voltage **2N7370**
Vbr_CEO in V Date-/Lotcode: 88115 / 1624 CDWR
Limit: 100.0 < x

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
On#2	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
On#3	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
On#4	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
On#5	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Radiation-Mean ON	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Standarddeviation	383.4E-6	181.7E-6	83.7E-6	376.4E-6	167.3E-6	178.9E-6	130.4E-6	687.0E-6	277.5E-6	181.7E-6
Mean + kσ	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Mean - kσ	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Off#2	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Off#3	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Off#4	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Off#5	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Radiation-Mean OFF	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Standarddeviation	194.9E-6	151.7E-6	141.4E-6	130.4E-6	100.0E-6	151.7E-6	158.1E-6	313.0E-6	277.5E-6	167.3E-6
Mean + kσ	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Mean - kσ	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0	101.0E+0
Min. Value	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0	100.0E+0


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Collector-emitter breakdown voltage in V
101.0
100.8
100.6
100.4
100.2
100.0
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
Total Dose [krad(Si)] / Annealing
On
Off
101.032
101.030
101.028
101.026
101.024
101.022
101.020
101.018
RT
Total Dose [krad(Si)] / Annealing

8.3 ICE @ 100 V

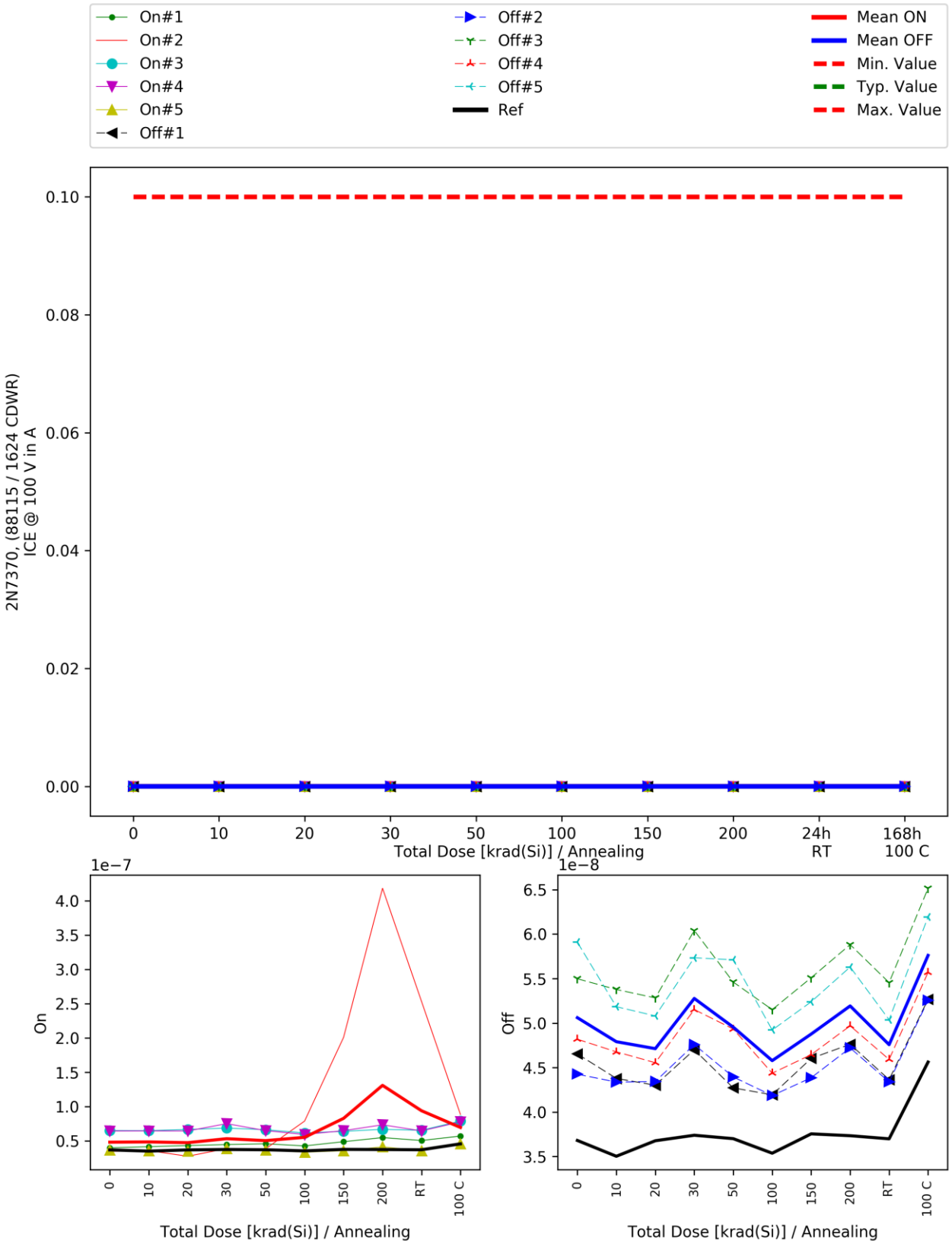
ICE @ 100 V
I_Vbr_CEO in A
Limit: x < 0.1

2N7370
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	39.8E-9	41.5E-9	43.1E-9	44.6E-9	45.7E-9	42.6E-9	48.8E-9	54.8E-9	50.5E-9	57.0E-9
On#2	34.6E-9	35.8E-9	27.5E-9	38.7E-9	38.4E-9	78.8E-9	200.9E-9	418.3E-9	253.4E-9	88.4E-9
On#3	65.1E-9	64.9E-9	66.6E-9	68.6E-9	66.3E-9	61.5E-9	63.8E-9	66.8E-9	65.4E-9	78.9E-9
On#4	64.4E-9	64.5E-9	64.4E-9	75.1E-9	64.9E-9	59.3E-9	64.8E-9	73.4E-9	64.5E-9	77.7E-9
On#5	36.5E-9	35.5E-9	35.1E-9	38.7E-9	36.3E-9	33.4E-9	35.6E-9	41.3E-9	35.6E-9	45.5E-9
Radiation-Mean ON	48.1E-9	48.4E-9	47.3E-9	53.1E-9	50.3E-9	55.1E-9	82.8E-9	130.9E-9	93.9E-9	69.5E-9
Standarddeviation	15.3E-9	15.0E-9	17.5E-9	17.4E-9	14.4E-9	17.7E-9	67.1E-9	161.1E-9	90.0E-9	17.6E-9
Mean + kσ	90.1E-9	89.7E-9	95.3E-9	100.8E-9	89.7E-9	103.5E-9	266.8E-9	572.7E-9	340.7E-9	117.8E-9
Mean - kσ	6.0E-9	7.2E-9	-647.6E-12	5.4E-9	10.9E-9	6.7E-9	-101.2E-9	-310.9E-9	-152.9E-9	21.1E-9

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	46.5E-9	43.8E-9	43.0E-9	47.0E-9	42.7E-9	41.9E-9	46.0E-9	47.6E-9	43.6E-9	52.7E-9
Off#2	44.3E-9	43.4E-9	43.4E-9	47.6E-9	43.9E-9	41.9E-9	43.9E-9	47.2E-9	43.4E-9	52.6E-9
Off#3	55.0E-9	53.8E-9	52.8E-9	60.4E-9	54.6E-9	51.5E-9	55.1E-9	58.8E-9	54.5E-9	65.1E-9
Off#4	48.2E-9	46.8E-9	45.5E-9	51.5E-9	49.3E-9	44.4E-9	46.4E-9	49.7E-9	45.9E-9	55.7E-9
Off#5	59.1E-9	51.8E-9	50.8E-9	57.3E-9	57.1E-9	49.2E-9	52.4E-9	56.3E-9	50.4E-9	61.9E-9
Radiation-Mean OFF	50.6E-9	47.9E-9	47.1E-9	52.8E-9	49.5E-9	45.8E-9	48.8E-9	51.9E-9	47.6E-9	57.6E-9
Standarddeviation	6.2E-9	4.7E-9	4.4E-9	5.9E-9	6.3E-9	4.4E-9	4.7E-9	5.3E-9	4.8E-9	5.7E-9
Mean + kσ	67.6E-9	60.8E-9	59.3E-9	69.0E-9	66.9E-9	57.8E-9	61.8E-9	66.5E-9	60.7E-9	73.2E-9
Mean - kσ	33.6E-9	35.0E-9	34.9E-9	36.5E-9	32.2E-9	33.8E-9	35.7E-9	37.4E-9	34.4E-9	42.0E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	36.8E-9	35.0E-9	36.8E-9	37.4E-9	37.0E-9	35.4E-9	37.5E-9	37.3E-9	37.0E-9	45.6E-9
Max. Value	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3	100.0E-3


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
ICE @ 100 V in A
0.10
0.08
0.06
0.04
0.02
0.00
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
Total Dose [krad(Si)] / Annealing
1e−7
On
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5
Total Dose [krad(Si)] / Annealing
1e−8
Off
6.5
6.0
5.5
5.0
4.5
4.0
3.5
Total Dose [krad(Si)] / Annealing

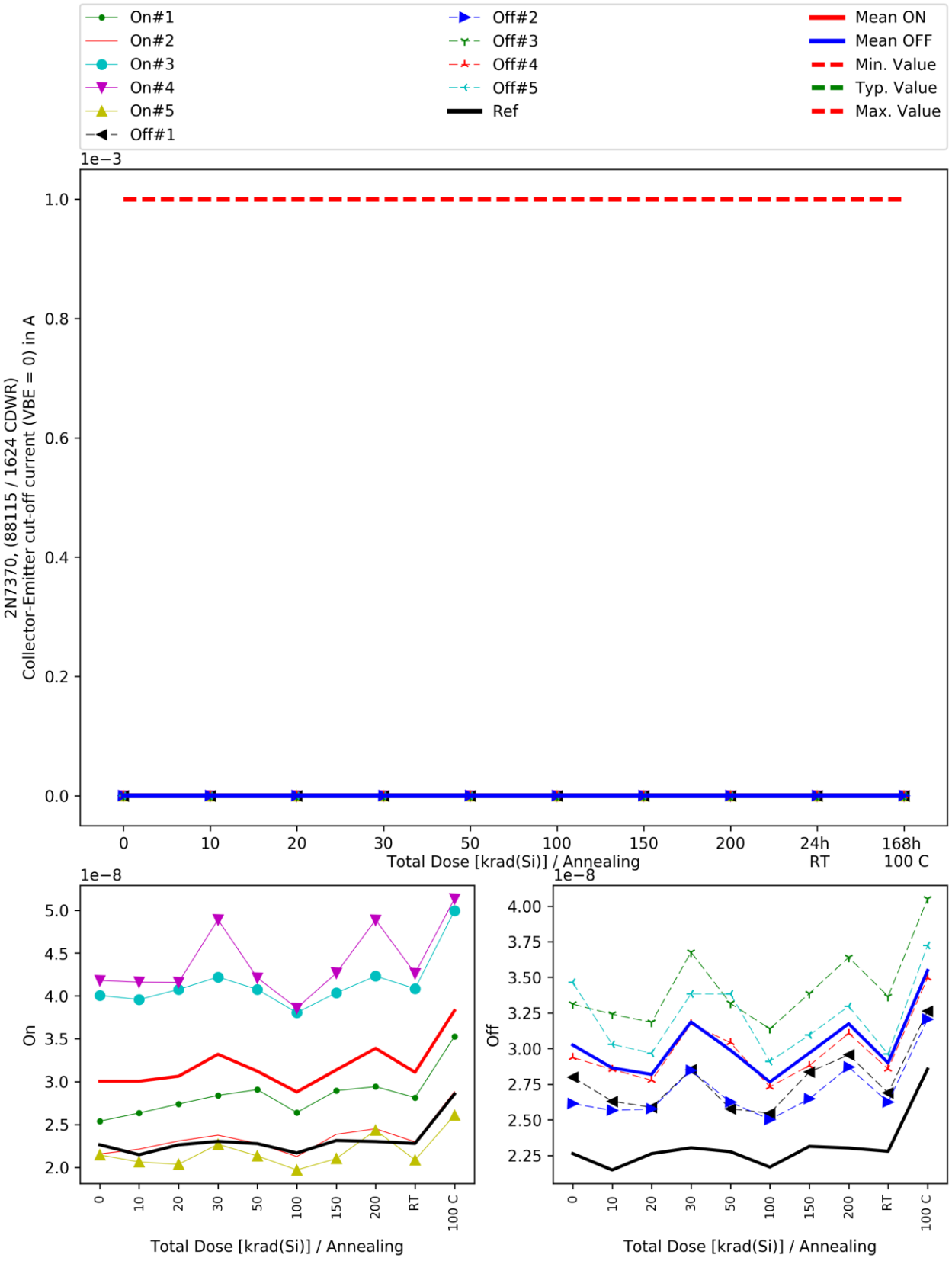
8.4 Collector-Emitter cut-off current (VBE = 0)

Collector-Emitter cut-off current (VBE = 0) **2N7370**
I_CEO in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 0.001

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	25.4E-9	26.3E-9	27.4E-9	28.4E-9	29.1E-9	26.4E-9	28.9E-9	29.4E-9	28.1E-9	35.3E-9
On#2	21.6E-9	22.1E-9	23.1E-9	23.8E-9	22.8E-9	21.3E-9	23.9E-9	24.5E-9	23.0E-9	28.8E-9
On#3	40.1E-9	39.6E-9	40.8E-9	42.2E-9	40.8E-9	38.1E-9	40.4E-9	42.3E-9	40.9E-9	49.9E-9
On#4	41.8E-9	41.6E-9	41.6E-9	48.9E-9	42.1E-9	38.6E-9	42.6E-9	48.9E-9	42.6E-9	51.3E-9
On#5	21.5E-9	20.6E-9	20.4E-9	22.7E-9	21.3E-9	19.7E-9	21.0E-9	24.3E-9	20.9E-9	26.1E-9
Radiation-Mean ON	30.1E-9	30.1E-9	30.6E-9	33.2E-9	31.2E-9	28.8E-9	31.4E-9	33.9E-9	31.1E-9	38.3E-9
Standarddeviation	10.1E-9	9.9E-9	9.9E-9	11.7E-9	9.8E-9	9.0E-9	9.7E-9	11.1E-9	10.1E-9	11.8E-9
Mean + kσ	57.7E-9	57.1E-9	57.9E-9	65.3E-9	58.0E-9	53.6E-9	58.0E-9	64.4E-9	58.8E-9	70.5E-9
Mean - kσ	2.4E-9	3.0E-9	3.4E-9	1.0E-9	4.4E-9	4.0E-9	4.7E-9	3.4E-9	3.4E-9	6.0E-9

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	28.0E-9	26.3E-9	25.9E-9	28.5E-9	25.8E-9	25.5E-9	28.3E-9	29.6E-9	26.9E-9	32.6E-9
Off#2	26.1E-9	25.7E-9	25.8E-9	28.5E-9	26.2E-9	25.0E-9	26.5E-9	28.7E-9	26.2E-9	32.1E-9
Off#3	33.1E-9	32.4E-9	31.8E-9	36.8E-9	33.2E-9	31.4E-9	33.9E-9	36.4E-9	33.7E-9	40.5E-9
Off#4	29.4E-9	28.5E-9	27.8E-9	31.7E-9	30.4E-9	27.3E-9	28.8E-9	31.1E-9	28.6E-9	35.0E-9
Off#5	34.6E-9	30.3E-9	29.7E-9	33.8E-9	33.8E-9	29.1E-9	30.9E-9	33.0E-9	29.6E-9	37.2E-9
Radiation-Mean OFF	30.3E-9	28.6E-9	28.2E-9	31.9E-9	29.9E-9	27.7E-9	29.7E-9	31.7E-9	29.0E-9	35.5E-9
Standarddeviation	3.5E-9	2.8E-9	2.6E-9	3.6E-9	3.8E-9	2.6E-9	2.8E-9	3.1E-9	2.9E-9	3.5E-9
Mean + kσ	40.0E-9	36.3E-9	35.3E-9	41.6E-9	40.2E-9	34.9E-9	37.4E-9	40.2E-9	37.0E-9	45.0E-9
Mean - kσ	20.5E-9	21.0E-9	21.1E-9	22.1E-9	19.6E-9	20.4E-9	21.9E-9	23.3E-9	21.0E-9	25.9E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	22.6E-9	21.5E-9	22.6E-9	23.0E-9	22.8E-9	21.7E-9	23.1E-9	23.0E-9	22.8E-9	28.6E-9
Max. Value	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3	1.0E-3


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−3
2N7370, (88115 / 1624 CDWR)
Collector-Emitter cut-off current (VBE = 0) in A
Total Dose [krad(Si)] / Annealing
1e−8
On
Total Dose [krad(Si)] / Annealing
1e−8
Off
Total Dose [krad(Si)] / Annealing

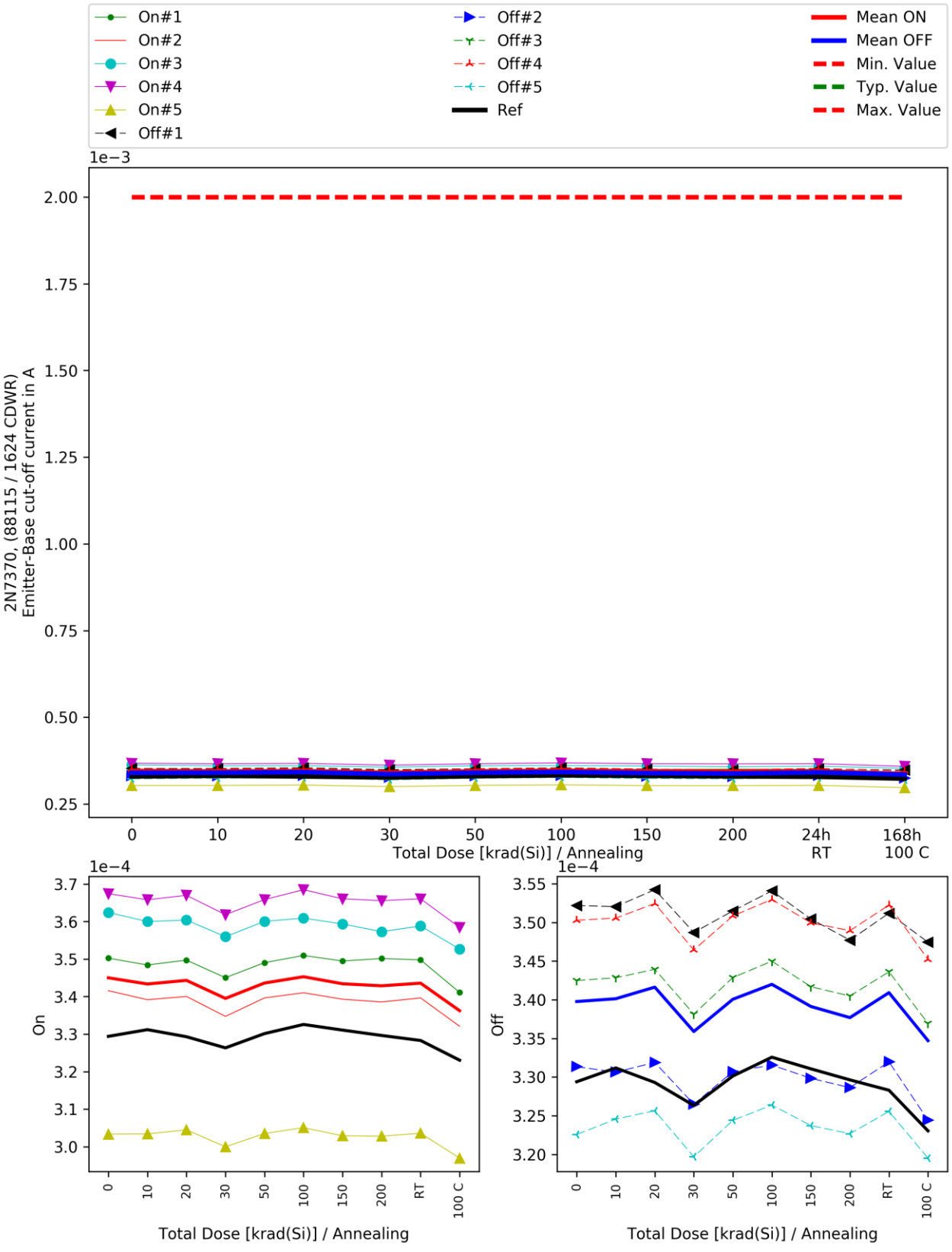
8.5 Emitter-Base cut-off current

Emitter-Base cut-off current **2N7370**
I_EBO in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 0.002

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	350.2E-6	348.4E-6	349.7E-6	345.0E-6	349.0E-6	351.0E-6	349.5E-6	350.2E-6	349.8E-6	341.1E-6
On#2	341.6E-6	339.2E-6	340.0E-6	334.7E-6	339.6E-6	341.0E-6	339.3E-6	338.6E-6	339.6E-6	332.1E-6
On#3	362.4E-6	360.0E-6	360.4E-6	356.0E-6	360.1E-6	360.9E-6	359.4E-6	357.3E-6	358.8E-6	352.7E-6
On#4	367.5E-6	365.8E-6	367.0E-6	361.8E-6	365.9E-6	368.5E-6	366.1E-6	365.6E-6	366.1E-6	358.4E-6
On#5	303.3E-6	303.4E-6	304.5E-6	300.0E-6	303.5E-6	305.1E-6	302.9E-6	302.8E-6	303.6E-6	296.9E-6
Radiation-Mean ON	345.0E-6	343.4E-6	344.3E-6	339.5E-6	343.6E-6	345.3E-6	343.4E-6	342.9E-6	343.6E-6	336.2E-6
Standarddeviation	25.4E-6	24.6E-6	24.5E-6	24.4E-6	24.6E-6	24.8E-6	24.8E-6	24.5E-6	24.5E-6	24.2E-6
Mean + kσ	414.7E-6	410.8E-6	411.6E-6	406.5E-6	411.1E-6	413.2E-6	411.5E-6	410.1E-6	410.6E-6	402.7E-6
Mean - kσ	275.3E-6	275.9E-6	277.0E-6	272.5E-6	276.2E-6	277.4E-6	275.4E-6	275.7E-6	276.5E-6	269.8E-6

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	352.2E-6	352.1E-6	354.2E-6	348.7E-6	351.5E-6	354.1E-6	350.5E-6	347.7E-6	351.2E-6	347.4E-6
Off#2	331.3E-6	330.6E-6	331.9E-6	326.5E-6	330.7E-6	331.6E-6	329.8E-6	328.6E-6	332.0E-6	324.4E-6
Off#3	342.5E-6	342.8E-6	343.9E-6	338.1E-6	342.9E-6	345.0E-6	341.7E-6	340.5E-6	343.6E-6	336.9E-6
Off#4	350.3E-6	350.6E-6	352.4E-6	346.4E-6	350.8E-6	353.0E-6	350.0E-6	348.9E-6	352.2E-6	345.2E-6
Off#5	322.6E-6	324.6E-6	325.6E-6	319.7E-6	324.4E-6	326.4E-6	323.7E-6	322.7E-6	325.6E-6	319.5E-6
Radiation-Mean OFF	339.8E-6	340.1E-6	341.6E-6	335.9E-6	340.1E-6	342.0E-6	339.1E-6	337.7E-6	340.9E-6	334.7E-6
Standarddeviation	12.6E-6	12.2E-6	12.6E-6	12.6E-6	12.1E-6	12.5E-6	12.0E-6	11.6E-6	11.8E-6	12.4E-6
Mean + kσ	374.4E-6	373.5E-6	376.1E-6	370.4E-6	373.3E-6	376.4E-6	372.0E-6	369.6E-6	373.3E-6	368.7E-6
Mean - kσ	305.1E-6	306.8E-6	307.2E-6	301.4E-6	306.8E-6	307.6E-6	306.2E-6	305.8E-6	308.5E-6	300.7E-6

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	329.4E-6	331.2E-6	329.3E-6	326.3E-6	330.1E-6	332.6E-6	331.1E-6	329.6E-6	328.3E-6	323.0E-6
Max. Value	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3	2.0E-3


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−3
2N7370, (88115 / 1624 CDWR)
Emitter-Base cut-off current in A
Total Dose [krad(Si)] / Annealing
1e−4
On
Off
0
10
20
30
50
100
150
200
24h
RT
168h
100 C

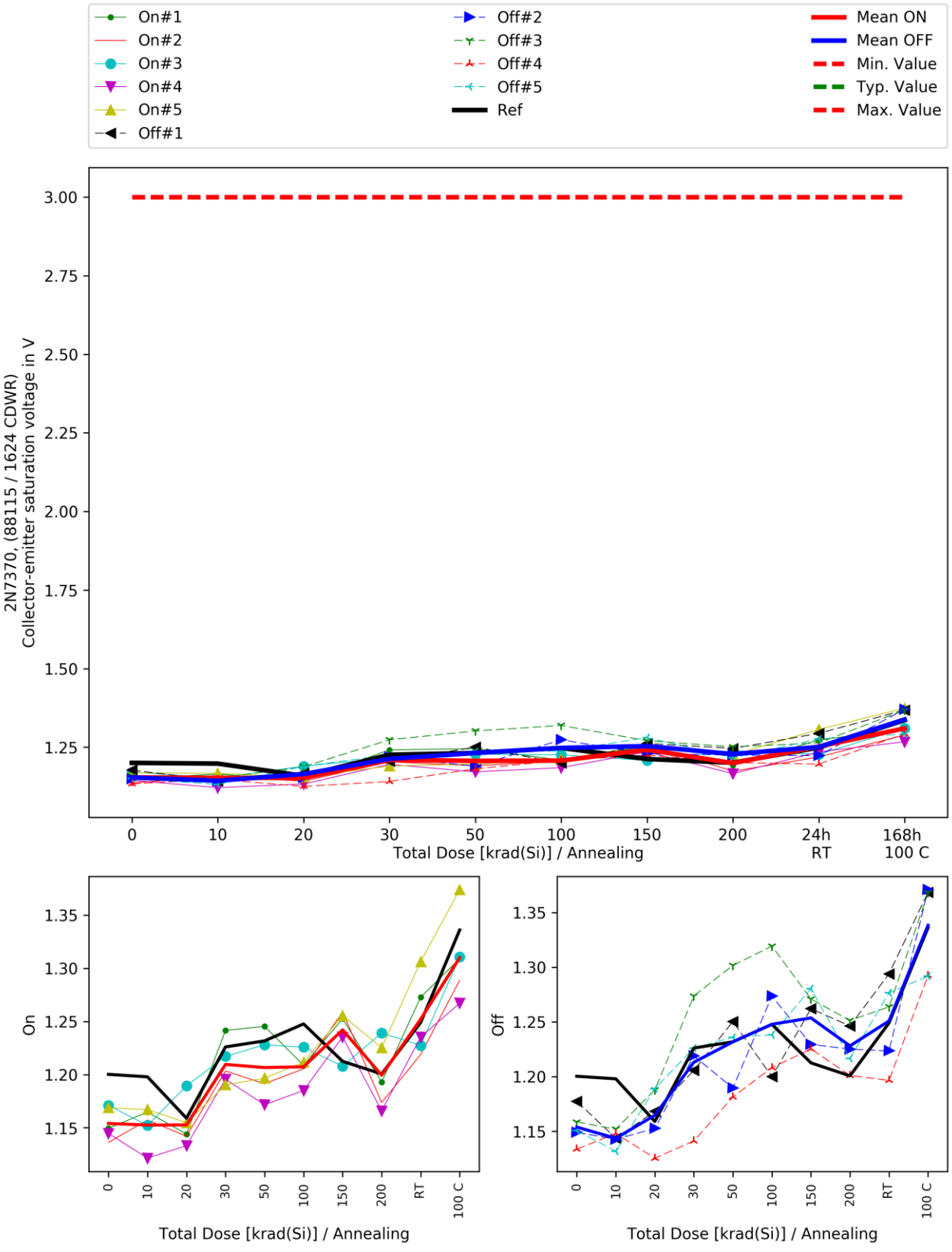
8.6 Collector-emitter saturation voltage

Collector-emitter saturation voltage **2N7370**
V_CE_SAT in V Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 3.0

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	1.1E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.3E+0
On#2	1.1E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.2E+0	1.3E+0
On#3	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0
On#4	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0
On#5	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.4E+0
Radiation-Mean ON	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0
Standarddeviation	15.3E-3	18.4E-3	21.9E-3	20.5E-3	29.7E-3	14.7E-3	21.2E-3	31.9E-3	36.7E-3	39.9E-3
Mean + kσ	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.2E+0	1.3E+0	1.3E+0	1.4E+0	1.4E+0
Mean - kσ	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.1E+0	1.2E+0	1.2E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.4E+0
Off#2	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.2E+0	1.2E+0	1.4E+0
Off#3	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.3E+0	1.3E+0	1.3E+0	1.3E+0	1.3E+0	1.4E+0
Off#4	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0
Off#5	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.3E+0
Radiation-Mean OFF	1.2E+0	1.1E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.2E+0	1.3E+0	1.3E+0
Standarddeviation	15.9E-3	7.6E-3	26.6E-3	47.7E-3	49.0E-3	49.3E-3	24.9E-3	20.9E-3	40.0E-3	42.2E-3
Mean + kσ	1.2E+0	1.2E+0	1.2E+0	1.3E+0	1.4E+0	1.4E+0	1.3E+0	1.3E+0	1.4E+0	1.5E+0
Mean - kσ	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.1E+0	1.2E+0	1.2E+0	1.1E+0	1.2E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.2E+0	1.3E+0
Max. Value	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0	3.0E+0


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Collector-emitter saturation voltage in V
3.00
2.75
2.50
2.25
2.00
1.75
1.50
1.25
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
Total Dose [krad(Si)] / Annealing
On
Off
1.35
1.30
1.25
1.20
1.15
Total Dose [krad(Si)] / Annealing
Total Dose [krad(Si)] / Annealing

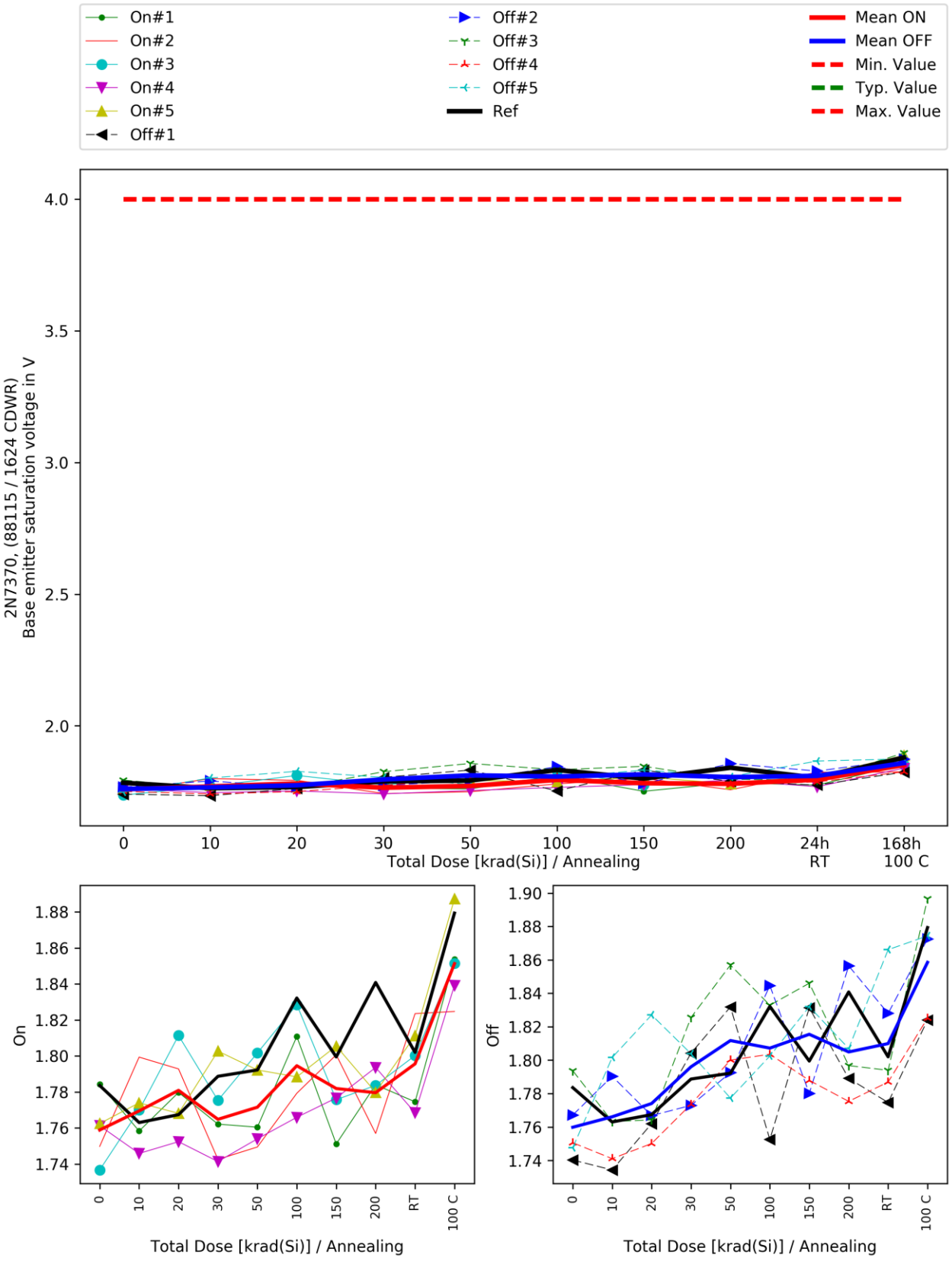
8.7 Base emitter saturation voltage

Base emitter saturation voltage **2N7370**
V_BE_SAT in V
Limit: x < 4.0
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
On#2	1.7E+0	1.8E+0	1.8E+0	1.7E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0
On#3	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
On#4	1.8E+0	1.7E+0	1.8E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0
On#5	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
Radiation-Mean ON	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
Standarddeviation	17.6E-3	20.0E-3	22.6E-3	25.5E-3	23.7E-3	25.0E-3	21.9E-3	13.6E-3	23.6E-3	23.2E-3
Mean + kσ	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0
Mean - kσ	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.8E+0

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	1.7E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0
Off#2	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.9E+0
Off#3	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
Off#4	1.8E+0	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0
Off#5	1.7E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0	1.9E+0
Radiation-Mean OFF	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
Standarddeviation	21.3E-3	29.6E-3	30.3E-3	22.5E-3	32.2E-3	35.6E-3	29.5E-3	31.0E-3	37.1E-3	32.4E-3
Mean + kσ	1.8E+0	1.8E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0	1.9E+0
Mean - kσ	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.7E+0	1.8E+0

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.8E+0	1.9E+0
Max. Value	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0	4.0E+0


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
Base emitter saturation voltage in V
4.0
3.5
3.0
2.5
2.0
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
Total Dose [krad(Si)] / Annealing
On
1.88
1.86
1.84
1.82
1.80
1.78
1.76
1.74
Total Dose [krad(Si)] / Annealing
Off
1.90
1.88
1.86
1.84
1.82
1.80
1.78
1.76
1.74
Total Dose [krad(Si)] / Annealing

8.8 DC current gain (1)

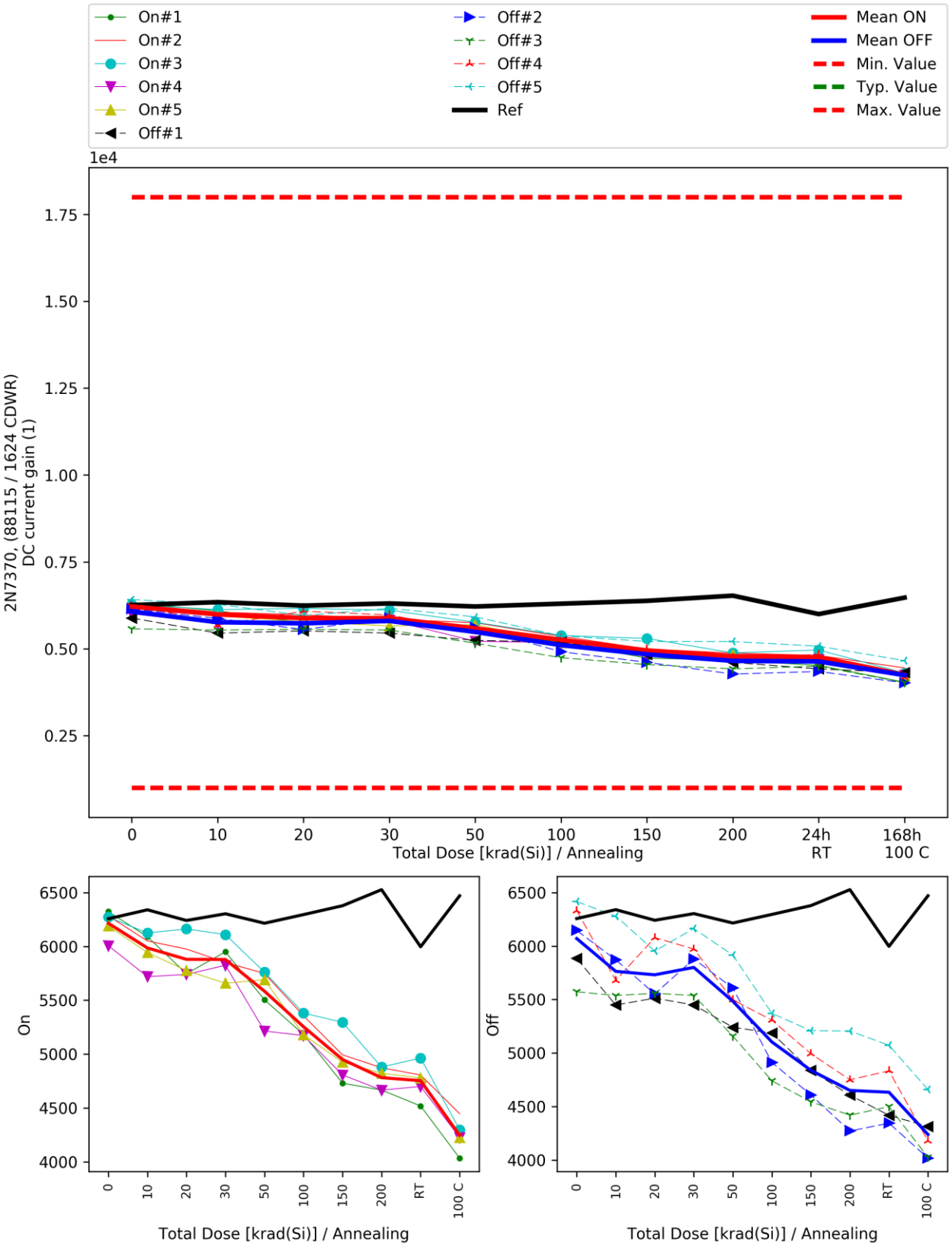
DC current gain (1)
HFE_1
Limit: 1000.0 < x < 18000.0

2N7370
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	6.3E+3	6.1E+3	5.7E+3	5.9E+3	5.5E+3	5.2E+3	4.7E+3	4.7E+3	4.5E+3	4.0E+3
On#2	6.3E+3	6.1E+3	6.0E+3	5.9E+3	5.7E+3	5.4E+3	5.0E+3	4.9E+3	4.8E+3	4.4E+3
On#3	6.3E+3	6.1E+3	6.2E+3	6.1E+3	5.8E+3	5.4E+3	5.3E+3	4.9E+3	5.0E+3	4.3E+3
On#4	6.0E+3	5.7E+3	5.7E+3	5.8E+3	5.2E+3	5.2E+3	4.8E+3	4.7E+3	4.7E+3	4.2E+3
On#5	6.2E+3	5.9E+3	5.8E+3	5.7E+3	5.7E+3	5.2E+3	4.9E+3	4.8E+3	4.8E+3	4.2E+3
Radiation-Mean ON	6.2E+3	6.0E+3	5.9E+3	5.9E+3	5.6E+3	5.3E+3	4.9E+3	4.8E+3	4.8E+3	4.2E+3
Standarddeviation	126.1E+0	163.8E+0	185.2E+0	166.5E+0	230.6E+0	104.4E+0	218.2E+0	107.9E+0	162.4E+0	148.9E+0
Mean + kσ	6.6E+3	6.4E+3	6.4E+3	6.3E+3	6.2E+3	5.5E+3	5.5E+3	5.1E+3	5.2E+3	4.7E+3
Mean - kσ	5.9E+3	5.5E+3	5.4E+3	5.4E+3	5.0E+3	5.0E+3	4.4E+3	4.5E+3	4.3E+3	3.8E+3

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	5.9E+3	5.4E+3	5.5E+3	5.4E+3	5.2E+3	5.2E+3	4.8E+3	4.6E+3	4.4E+3	4.3E+3
Off#2	6.1E+3	5.9E+3	5.6E+3	5.9E+3	5.6E+3	4.9E+3	4.6E+3	4.3E+3	4.3E+3	4.0E+3
Off#3	5.6E+3	5.5E+3	5.6E+3	5.5E+3	5.2E+3	4.7E+3	4.5E+3	4.4E+3	4.5E+3	4.0E+3
Off#4	6.3E+3	5.7E+3	6.1E+3	6.0E+3	5.5E+3	5.3E+3	5.0E+3	4.7E+3	4.8E+3	4.2E+3
Off#5	6.4E+3	6.3E+3	6.0E+3	6.2E+3	5.9E+3	5.4E+3	5.2E+3	5.2E+3	5.1E+3	4.7E+3
Radiation-Mean OFF	6.1E+3	5.8E+3	5.7E+3	5.8E+3	5.5E+3	5.1E+3	4.8E+3	4.6E+3	4.6E+3	4.2E+3
Standarddeviation	345.0E+0	330.1E+0	264.6E+0	300.1E+0	302.8E+0	268.6E+0	274.2E+0	360.0E+0	308.7E+0	264.2E+0
Mean + kσ	7.0E+3	6.7E+3	6.5E+3	6.6E+3	6.3E+3	5.8E+3	5.6E+3	5.6E+3	5.5E+3	5.0E+3
Mean - kσ	5.1E+3	4.9E+3	5.0E+3	5.0E+3	4.7E+3	4.4E+3	4.1E+3	3.7E+3	3.8E+3	3.5E+3

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	6.3E+3	6.3E+3	6.2E+3	6.3E+3	6.2E+3	6.3E+3	6.4E+3	6.5E+3	6.0E+3	6.5E+3
Min. Value	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3	1.0E+3
Max. Value	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3	18.0E+3


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e4
1.75
1.50
1.25
1.00
0.75
0.50
0.25
2N7370, (88115 / 1624 CDWR)
DC current gain (1)
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
Total Dose [krad(Si)] / Annealing
6500
6000
5500
5000
4500
4000
On
Off
Total Dose [krad(Si)] / Annealing
Total Dose [krad(Si)] / Annealing

8.9 DC current gain (2)

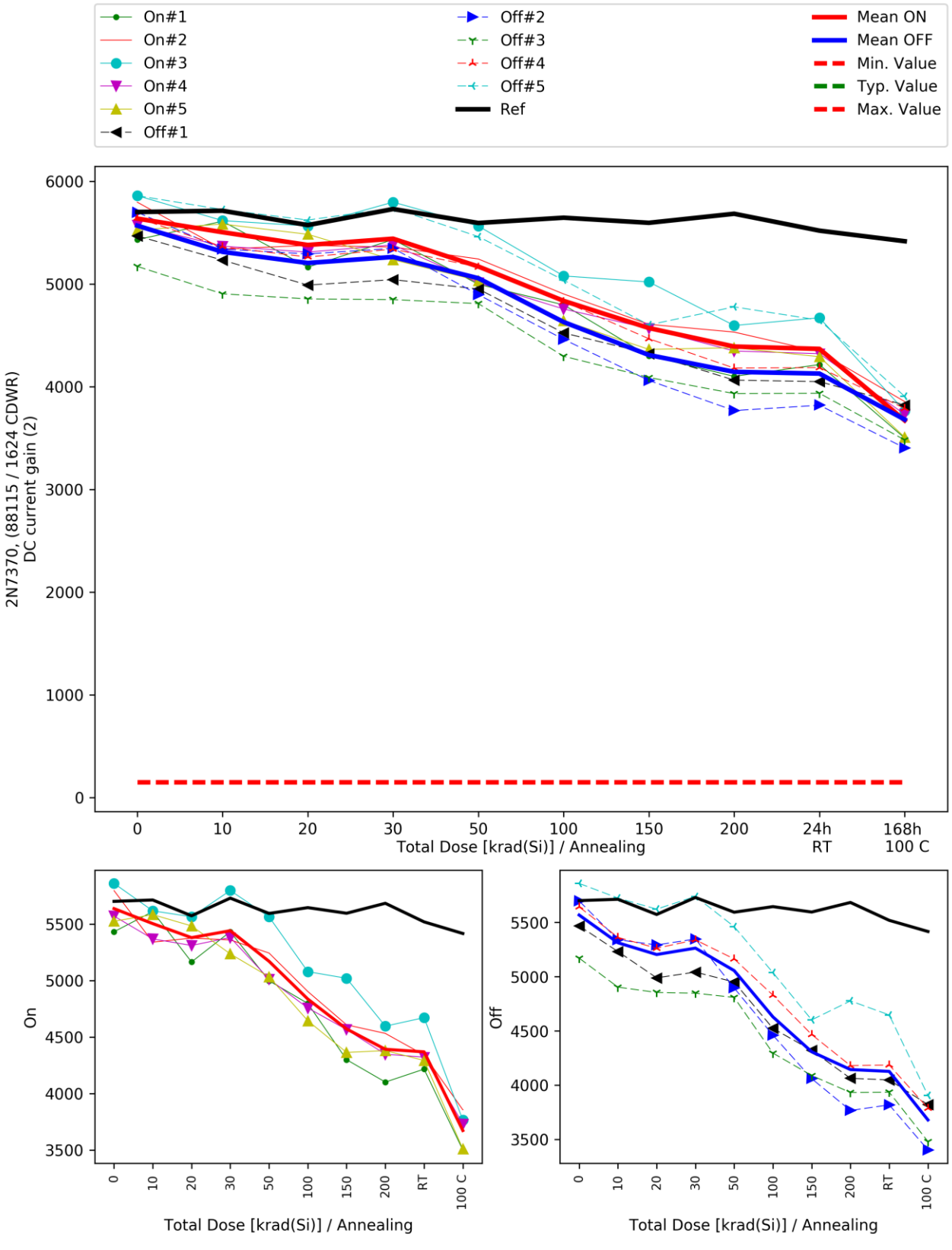
DC current gain (2)
HFE_2
Limit: 150.0 < x

2N7370
Date-/Lotcode: 88115 / 1624 CDWR

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	5.4E+3	5.6E+3	5.2E+3	5.4E+3	5.0E+3	4.8E+3	4.3E+3	4.1E+3	4.2E+3	3.5E+3
On#2	5.8E+3	5.3E+3	5.4E+3	5.4E+3	5.2E+3	4.9E+3	4.6E+3	4.5E+3	4.3E+3	3.9E+3
On#3	5.9E+3	5.6E+3	5.6E+3	5.8E+3	5.6E+3	5.1E+3	5.0E+3	4.6E+3	4.7E+3	3.8E+3
On#4	5.6E+3	5.4E+3	5.3E+3	5.4E+3	5.0E+3	4.8E+3	4.6E+3	4.3E+3	4.3E+3	3.7E+3
On#5	5.5E+3	5.6E+3	5.5E+3	5.2E+3	5.0E+3	4.6E+3	4.4E+3	4.4E+3	4.3E+3	3.5E+3
Radiation-Mean ON	5.6E+3	5.5E+3	5.4E+3	5.4E+3	5.2E+3	4.8E+3	4.6E+3	4.4E+3	4.4E+3	3.7E+3
Standarddeviation	183.3E+0	137.6E+0	155.2E+0	211.7E+0	241.9E+0	164.4E+0	282.8E+0	192.4E+0	176.0E+0	159.7E+0
Mean + kσ	6.1E+3	5.9E+3	5.8E+3	6.0E+3	5.8E+3	5.3E+3	5.3E+3	4.9E+3	4.9E+3	4.1E+3
Mean - kσ	5.1E+3	5.1E+3	5.0E+3	4.9E+3	4.5E+3	4.4E+3	3.8E+3	3.9E+3	3.9E+3	3.2E+3

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	5.5E+3	5.2E+3	5.0E+3	5.0E+3	5.0E+3	4.5E+3	4.3E+3	4.1E+3	4.0E+3	3.8E+3
Off#2	5.7E+3	5.3E+3	5.3E+3	5.3E+3	4.9E+3	4.5E+3	4.1E+3	3.8E+3	3.8E+3	3.4E+3
Off#3	5.2E+3	4.9E+3	4.9E+3	4.8E+3	4.8E+3	4.3E+3	4.1E+3	3.9E+3	3.9E+3	3.5E+3
Off#4	5.6E+3	5.4E+3	5.3E+3	5.3E+3	5.2E+3	4.8E+3	4.5E+3	4.2E+3	4.2E+3	3.8E+3
Off#5	5.9E+3	5.7E+3	5.6E+3	5.7E+3	5.5E+3	5.0E+3	4.6E+3	4.8E+3	4.6E+3	3.9E+3
Radiation-Mean OFF	5.6E+3	5.3E+3	5.2E+3	5.3E+3	5.1E+3	4.6E+3	4.3E+3	4.1E+3	4.1E+3	3.7E+3
Standarddeviation	262.2E+0	294.3E+0	297.7E+0	339.5E+0	261.5E+0	298.7E+0	234.8E+0	385.7E+0	320.9E+0	222.7E+0
Mean + kσ	6.3E+3	6.1E+3	6.0E+3	6.2E+3	5.8E+3	5.4E+3	5.0E+3	5.2E+3	5.0E+3	4.3E+3
Mean - kσ	4.8E+3	4.5E+3	4.4E+3	4.3E+3	4.3E+3	3.8E+3	3.7E+3	3.1E+3	3.2E+3	3.1E+3

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	5.7E+3	5.7E+3	5.6E+3	5.7E+3	5.6E+3	5.6E+3	5.6E+3	5.7E+3	5.5E+3	5.4E+3
Min. Value	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0	150.0E+0


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
2N7370, (88115 / 1624 CDWR)
DC current gain (2)
Total Dose [krad(Si)] / Annealing
0
10
20
30
50
100
150
200
24h
RT
168h
100 C
On
Off

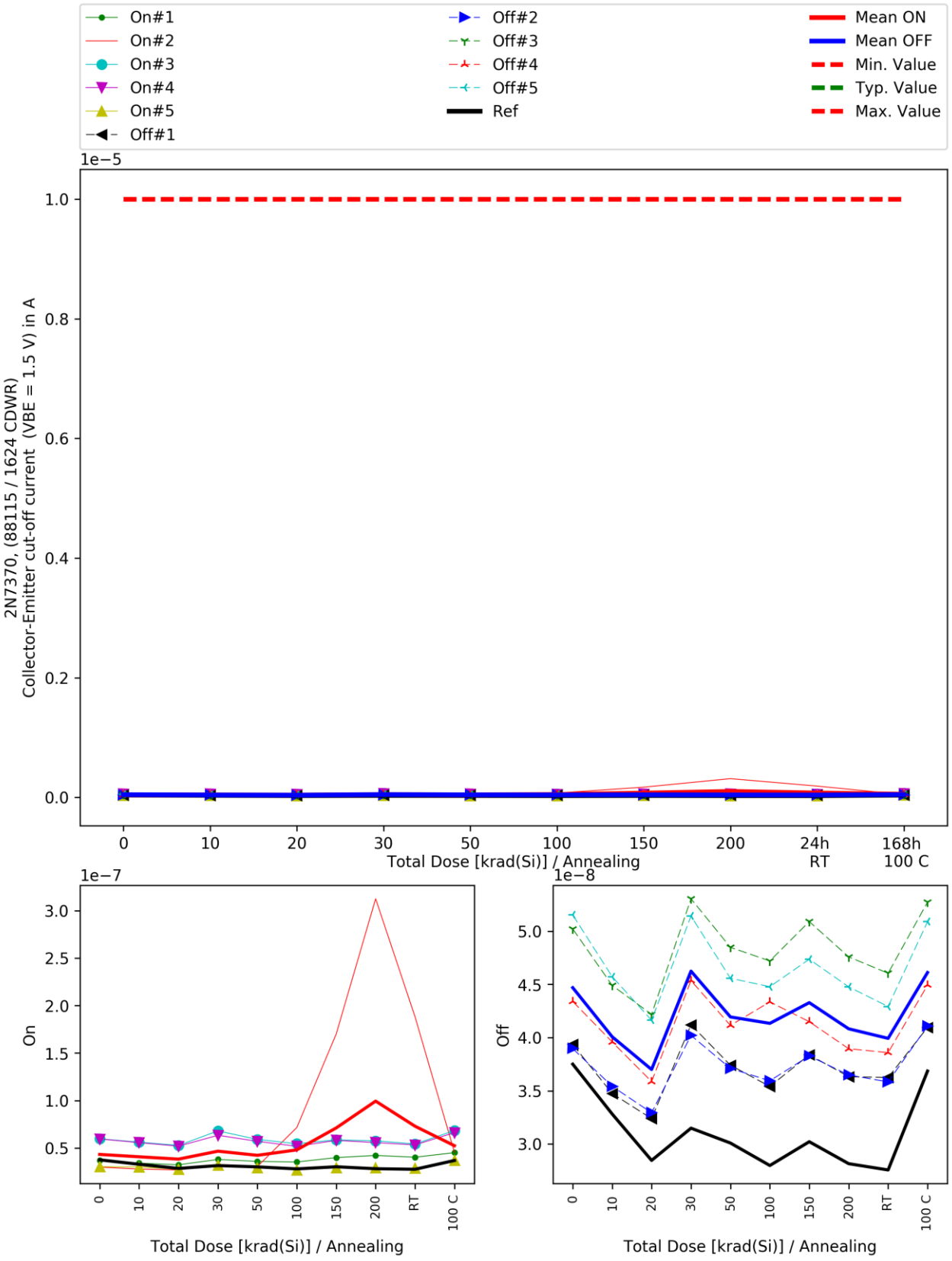
8.10 Collector-Emitter cut-off current (VBE = 1.5 V)

Collector-Emitter cut-off current (VBE = 1.5 V) **2N7370**
I_CEX in A Date-/Lotcode: 88115 / 1624 CDWR
Limit: x < 1e-05

ON-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
On#1	36.8E-9	34.0E-9	32.3E-9	37.9E-9	35.9E-9	35.3E-9	39.9E-9	42.2E-9	40.3E-9	45.1E-9
On#2	29.9E-9	27.8E-9	26.8E-9	32.1E-9	30.5E-9	71.6E-9	170.1E-9	312.6E-9	188.2E-9	45.4E-9
On#3	59.7E-9	56.1E-9	52.7E-9	68.0E-9	59.0E-9	54.5E-9	58.6E-9	57.6E-9	54.3E-9	68.3E-9
On#4	59.5E-9	55.7E-9	51.9E-9	63.4E-9	57.0E-9	51.8E-9	58.0E-9	55.7E-9	53.3E-9	66.2E-9
On#5	30.3E-9	30.0E-9	27.6E-9	31.8E-9	29.0E-9	26.9E-9	29.1E-9	29.0E-9	28.6E-9	37.1E-9
Radiation-Mean ON	43.2E-9	40.7E-9	38.3E-9	46.6E-9	42.3E-9	48.0E-9	71.1E-9	99.4E-9	72.9E-9	52.4E-9
Standarddeviation	15.2E-9	14.0E-9	13.0E-9	17.6E-9	14.6E-9	17.5E-9	56.7E-9	119.7E-9	65.3E-9	14.0E-9
Mean + kσ	84.9E-9	79.2E-9	73.9E-9	95.0E-9	82.4E-9	95.9E-9	226.7E-9	427.7E-9	251.9E-9	90.7E-9
Mean - kσ	1.6E-9	2.3E-9	2.6E-9	-1.7E-9	2.2E-9	143.5E-12	-84.4E-9	-228.9E-9	-106.1E-9	14.1E-9

OFF-Mode	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Off#1	39.4E-9	34.7E-9	32.4E-9	41.2E-9	37.4E-9	35.4E-9	38.4E-9	36.3E-9	36.2E-9	41.0E-9
Off#2	39.0E-9	35.4E-9	32.9E-9	40.2E-9	37.1E-9	35.9E-9	38.3E-9	36.5E-9	35.8E-9	41.1E-9
Off#3	50.2E-9	44.9E-9	42.2E-9	53.0E-9	48.5E-9	47.2E-9	50.9E-9	47.6E-9	46.0E-9	52.7E-9
Off#4	43.4E-9	39.6E-9	35.9E-9	45.4E-9	41.1E-9	43.4E-9	41.5E-9	39.0E-9	38.6E-9	44.9E-9
Off#5	51.5E-9	45.7E-9	41.6E-9	51.4E-9	45.6E-9	44.8E-9	47.4E-9	44.8E-9	42.9E-9	50.9E-9
Radiation-Mean OFF	44.7E-9	40.1E-9	37.0E-9	46.2E-9	41.9E-9	41.3E-9	43.3E-9	40.8E-9	39.9E-9	46.1E-9
Standarddeviation	5.9E-9	5.1E-9	4.7E-9	5.8E-9	5.0E-9	5.4E-9	5.6E-9	5.1E-9	4.4E-9	5.5E-9
Mean + kσ	60.9E-9	54.2E-9	49.8E-9	62.2E-9	55.7E-9	56.0E-9	58.7E-9	54.8E-9	52.1E-9	61.1E-9
Mean - kσ	28.5E-9	26.0E-9	24.2E-9	30.3E-9	28.2E-9	26.7E-9	27.8E-9	26.9E-9	27.8E-9	31.1E-9

Reference	Total Dose [krad (Si)]								Annealing	
	0	10	20	30	50	100	150	200	24h @ RT	68h @ 100 C
Ref1	37.5E-9	32.8E-9	28.5E-9	31.5E-9	30.1E-9	28.0E-9	30.2E-9	28.2E-9	27.6E-9	36.9E-9
Max. Value	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6	10.0E-6


On#1
On#2
On#3
On#4
On#5
Off#1
Off#2
Off#3
Off#4
Off#5
Ref
Mean ON
Mean OFF
Min. Value
Typ. Value
Max. Value
1e−5
2N7370, (88115 / 1624 CDWR)
Collector-Emitter cut-off current (VBE = 1.5 V) in A
Total Dose [krad(Si)] / Annealing
1e−7
On
1e−8
Off
0
10
20
30
50
100
150
200
RT
100 C
24h
168h

9 Results of Enhancement Calculation

9.1 Overview of Enhanced low dose rate sensitivity

No.	Characteristics	Values out of specs during irradiation?	Enhancement factor applicable (ELDRS?)	max. Calculated enhancement factor	Comment
1	Collector-Emitter Breakdown Voltage	no	no	--	--
2	Collector-Emitter Cut-off Current	no	no	--	--
3		no	no	--	--
4	Emitter-Base Cutoff Current	no	no	--	--
5	Collector-Emitter Saturation Voltage	no	no	--	--
6	Base-Emitter Saturation Voltage	no	no	--	--
7	Forward Current Transfer Ratio	no	no	--	--
8		no	no	--	--

- All parameters are within specifications and as there is no parameters (especially the HFEs) which do not show an enhanced sensitivity, we would argue that the part is not susceptible to ELDRS.

A Fraunhofer INT

A.1. About the institute

The Fraunhofer Institute for Technological Trend Analysis INT provides scientifically sound assessments and counselling on the entire spectrum of technological developments. On this basis, the Institute conducts Technology Forecasting, making possible a long-term approach to strategic research planning. Fraunhofer INT constantly applies this competence in projects tailor-made for our clients.

Over and above these skills, we run our own experimental and theoretical research on the effects of ionizing and electromagnetic radiation on electronic components, as well as on radiation detection systems. To this end, INT is equipped with the latest measurement technology. Our main laboratory and large-scale appliances are radiation sources, electromagnetic simulation facilities and detector systems that cannot be found in this combination in any other civilian body in Germany.

For more than 40 years, INT has been a reliable partner for the Federal German Ministry of Defence, which it advises in close cooperation and for which it carries out research in technology analysis and strategic planning as well as radiation effects. INT also successfully advises and conducts research for domestic and international civilian clients: both public bodies and industry, from SMEs to DAX 30 companies.

Further information can be found on the website [1].

A.2. Business unit Nuclear Effects in Electronics and Optics

The Business Unit „Nuclear Effects in Electronic and Optics (NEO)“ at Fraunhofer INT investigates the effects of ionizing radiation on electronic, optoelectronic, and photonic components and systems. Its work is based on more than 40 years of experience in that field.

NEO performs irradiation tests based on international standards and advises companies regarding radiation qualification and hardening of components and systems. The knowledge obtained in years of radiation testing is also used for the development of new radiation sensor systems. These activities are performed either at irradiation facilities installed at INT or at partner institutions to which our scientists have regular access.

A multitude of modern equipment to measure electrical and optical parameters is available. Furthermore our institute runs a precision mechanical workshop and an electronic laboratory. This enables us to conduct most of the irradiation tests without help or equipment of the customer.

The activities within NEO are:

- Investigations of the effects in all kinds of radiation environments
- Performance, analysis, and evaluation of irradiation tests done at Fraunhofer INT and external facilities

- Ensuring the operability of components and systems in typical radiation environments, such as space, nuclear facilities, medicine, or accelerators
- Consulting users and manufacturers on the use of products in radiation environments by selecting, optimizing and hardening
- Measurement of the radiation effects on optical fibers and fiber Bragg gratings (FBG)
- Development of radiation sensors based on optical fibers, FBGs, oscillating crystals, UV-EPROMs, and SRAMs
- Participation in the development of international test procedures for IEC, IEEE, NATO, and IAEA
- Since 2013 all services of the business unit are certified according to ISO 9001

A.3. Irradiation facilities

Fraunhofer INT operates several irradiation facilities on site that are dedicated to perform irradiation tests. For that purpose the design and operation characteristics are highly optimised from many decades of experience and to comply with all relevant standards and test procedures.

Furthermore Fraunhofer INT accesses regularly external facilities, partly with dedicated irradiation spots for exclusive use to Fraunhofer INT.

These irradiation facilities are:

- Co-60 irradiation sources on site to simulate the effect of total dose
- Neutron generators on site to simulate the displacement damage of heavy particles
- 450 keV X-ray irradiation facility on site
- Laser induced single event test system on site
- Dedicated proton irradiation spot at the injector cyclotron of FZ Jülich to simulate the effects of solar and trapped protons
- External Co-60 irradiation sources for high dose and high dose rate irradiations

The facilities used in the context of this work will be described in detail in the following sections.

A.4. QM-Certificate

DNV·GL

MANAGEMENT SYSTEM CERTIFICATE

Certificate No: 126306-2012-AQ-GER-DAkkS | Initial certification date: 13. February 2013 | Valid: 29. March 2018 - 12. February 2019

This is to certify that the management system of

Fraunhofer INT

Fraunhofer-Institut für Naturwissenschaftlich-Technische Trendanalysen INT
Appelsgarten 2, 53879 Euskirchen, Germany

has been found to conform to the Quality Management System standard:

ISO 9001:2015

This certificate is valid for the following scope:

Scientific research on the effects of nuclear and electromagnetic radiation as well as application and development of methods for their characterization

Place and date:
Essen, 29. March 2018

DAkkS Deutsche Akkreditierungsstelle D-ZM-18453-01-00

For the issuing office:
DNV GL - Business Assurance
Schnieringshof 14, 45329 Essen, Germany

Thomas Beck
Technical Manager

Lack of fulfilment of conditions as set out in the Certification Agreement may render this Certificate invalid.
ACCREDITED UNIT: DNV GL Business Assurance Zertifizierung und Umweltgutachter GmbH, Schnieringshof 14, 45329 Essen, Germany.
TEL: +49 201 7296-222. www.dnvgl.de/assurance

B Irradiation details LDR

B.1. Irradiation facility TK100

The TK100 is a Co-60 gamma irradiator manufactured by Sauerwein Isotopentechnik, Germany. Inside the shielding container is a small radioactive pellet with a diameter of 2 mm and a length of 3 mm. The activity decreases with a physical half-life of 5.27 years. The current used radioactive pellet was installed in the irradiator at 2015-12-17. The activity at that time was 485 GBq.

In deactivated state the radioactive pellet is stored inside the shielding container allowing the operator to install the samples and conduct measurements without getting exposed to ionizing radiation. On activation, the radioactive source is pushed into the source guiding tube in less than a second irradiating the surrounding volume.

The certificate of the radioactive source can be found in Appendix B.4.

Figure 15: TK100 irradiation facility

B.2. Radiation properties of TK100

The samples are irradiated with Co-60 gamma radiation. The radioactive Co 60 isotope decays by emitting beta radiation (i.e. electrons) into a highly excited Ni-60 isotope which emits two gamma photons to reach the stable ground state. The gamma radiation has two energy levels of 1.172 MeV and 1.332 MeV.

The gamma radiation of around 1 MeV is a penetrating radiation, so the samples are irradiated completely. The shielding of the sample holder and other surrounding material between the source and the sample is negligible.

The radiation is emitted from a point-like source. Thus the dose rate $\dot{D}$ falls off with $1/r^2$ where r is the distance from the source.

$$\dot{D}(r) = \dot{D}_0 \cdot \frac{r_0^2}{r^2}$$

B.3. Dosimetry at TK100

The dosimetry is done regularly with calibrated and ionization chambers manufactured by IBA, Germany, and PTW Freiburg, Germany.

The dose rates obtained at varying distances between 2 cm and 50 cm and in different directions relative to the source are used to develop a model of the dose rate distribution around the source as a function of distance and direction. The dose rate of an individual measurement is scaled to a reference date taking the half-life of the radioactive isotope into account. This model is constantly checked and improved with each additional measurement of dose rates.

As a result a reliable description of the dose rates inside a specific volume arranged in a given geometry in the vicinity of the irradiation source is available.

The uncertainties of the reported dose rates are given by an uncertainty evaluation according to [2] and mainly result from the uncertainties of the dosimetry and positioning of the samples.

The uncertainty evaluation for this irradiation can be found in Appendix C.

B.4. Certificate of TK100 irradiation source

IT-Service Leipzig

Ingenieur-Technischer Geräte- und Produktservice für Werkstoffprüfung und Medizintechnik

Qualitätszertifikat

für umschlossene Strahlenquelle

Prüfungszeugnis - Nr.:	15805
Kunde:	Fraunhofer Institut
Strahler/HRQ Ident. Nr.:	**RU002**
Kapsel Typ:	G6
ISO Code:	ISO/99/C 64545
AFNOR Code:	NF/99/C 64545 ic (i:Feuertest, c:Korrosionstest)
Zertifikat Nr.:	B/012/S-96 (Rev. 10)
Radionuklid:	**Co-60**
Physikalische Form:	**fest, umschlossen**
Chemische Form:	**Element, metallisch**
Brennfleck in mm x mm:	4,2x2,6 mm
Herstellungsaktivität:	1563,99 GBq (42,27 Ci)
Herstellungsdatum:	19.01.2007

Dichtheitsbescheinigung

Oberflächenkontaminationstest:		ohne Beanstandung
Datum:	19.01.2007	Ergebnis: < 185 Bq
Lecktest:		ohne Beanstandung
Datum:	19.01.2007	Ergebnis: dicht

Die Qualitätskontrolle wurde vom Hersteller in unserem Namen durchgeführt.
Es wird bescheinigt, daß die umschlossene radioaktive Strahlenquelle den Anforderungen nach NF / ISO 9978 (1992), ISO 2919 (1999) und NF M61002 (1984) entspricht.

Der oben genannte Strahler wurde in einem neuen bzw. entsprechend DIN 54115 Teil 6 überprüften und zugelassenen Strahlerhalter Nr.: **7221** eingebaut.

Datum: 17.12.2015 Signum IT-Service:

IT-Service Leipzig GmbH, BS Haan, Bergische Straße 16, 42781 Haan Tel.: 02129 / 377595 Fax: 02129 / 378794

C Irradiation Documentation LDR

Irradiation Test Documentation

Fraunhofer INT

Irradiation Source	TK100 (2015)	Date	13.05.2016
Responsible Employee	MS		
Project Description	ESA-PowerBipolar ELDRS		

Reference Data for Dose Rate Calculation

Reference Activity	0.44 TBq ± *10.0%*	Standard uncertainty[1)]
Reference Dose Rate	0.1187 Gy/s ± *2.5%*	Standard uncertainty[1)]
Reference Distance	10 cm ± *0.5%*	Standard uncertainty[1)]
Reference Date	01.01.1990	

Geometry of Irradiated Object (As defined or measured):

Inner Diameter	4.50 cm ± *0.05* cm	Standard uncertainty[1)]
Outer Diameter	5.50 cm ± *0.05* cm	Standard uncertainty[1)]
Height	0.50 cm ± *0.05* cm	Standard uncertainty[1)]

Distances of Point Source:

Surface of Object	60.00 cm ± *0.05* cm	Standard uncertainty[1)]
Object Minimum	60.04 cm ± 0.05 cm	Standard uncertainty[2)]
Object Maximum	60.56 cm ± 0.07 cm	Standard uncertainty[2)]
Mean Distance	**60.30 cm ± 0.11 cm**	*Expanded uncertainty*[3)]

Dose Rates in Object

Minimum	0.0001 Gy/s ± 2.7%	Standard uncertainty[2)]
Mean	**0.0001 Gy/s ± 2.7%**	Standard uncertainty[2)]
Maximum	0.0001 Gy/s ± 2.7%	Standard uncertainty[2)]

Irradiation Time	**20342698 s ± *1* s**	Standard uncertainty[1)]
in MM DD HH:MM:SS	08 22 10:44:58 ± *1* s	Standard uncertainty[1)]

Dose in Object

Minimum	1983 Gy ± 2.7%	Standard uncertainty[2)]
Maximum	2017 Gy ± 2.7%	Standard uncertainty[2)]
Mean	**2000 Gy ± 5.4%**	*Expanded uncertainty*[3)]
Homogeneity	1.7%	

[1)] Experience or statistics based estimation of standard uncertainty with a coverage factor k=1
[2)] Combined standard uncertainty with a coverage factor k=1
[3)] Determined from a combined standard uncertainty (i.e., estimated standard deviations of values above) and a coverage factor k = 2. Since it can be assumed that the possible estimated values of the dose are approximately normally distributed with approximate standard deviation, the unknown value of the dose is believed to lie in the interval given with a level of confidence of approximately 95 %.

Standard Irradiation Test Documentation Sheet, 2015-12-18

For the LDR campaign this only serves to document the geometry and field homogeneity. Timing calculation does not account for Co60 decay.

D Irradiation details HDR

D.1. Irradiation facility TK1000B

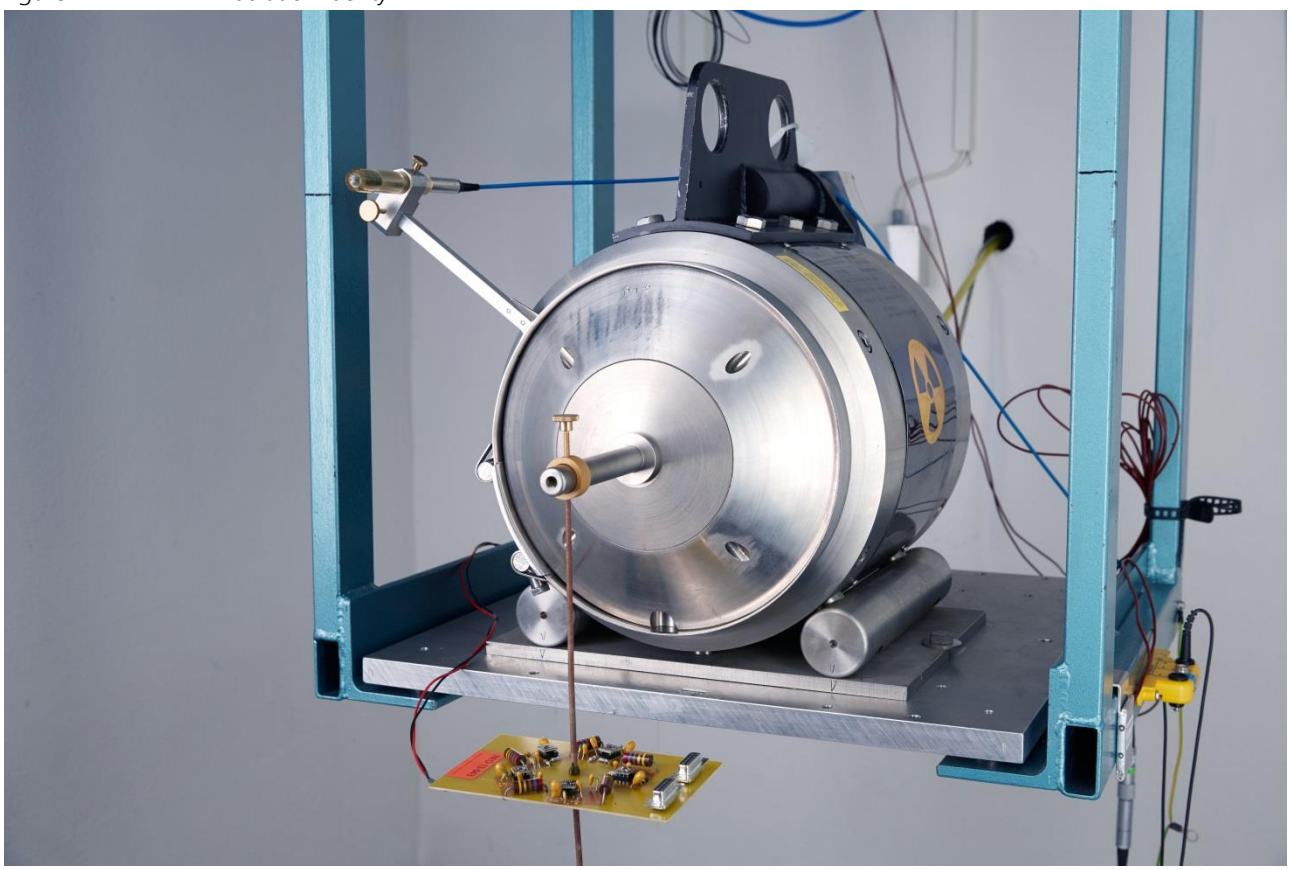
The TK1000B is a Co-60 gamma irradiator manufactured by Sauerwein Isotopentechnik, Germany. Inside the shielding container is a small radioactive pellet with a diameter of 7 mm and a length of 10.4 mm. The activity decreases with a physical half-life of 5.27 years. The current radioactive pellet was installed in the irradiator at 2012-01-25. The activity at that time was 16526 GBq.

In deactivated state the radioactive pellet is stored inside the shielding container allowing the operator to install the samples and conduct measurements without getting exposed to ionizing radiation.

On activation, the radioactive source is pushed into the source guiding tube in less than a second irradiating the surrounding volume.

The certificate of the radioactive source can be found in Appendix D.4.

Figure 16: TK1000B irradiation facility



D.2. Radiation properties of TK1000B

The samples are irradiated with Co-60 gamma radiation. The radioactive Co 60 isotope decays by emitting beta radiation (i.e. electrons) into a highly excited Ni-60 isotope which emits two gamma photons to reach the stable ground state. The gamma radiation has two energy levels of 1.172 MeV and 1.332 MeV.

The gamma radiation of around 1 MeV is a penetrating radiation, so the samples are irradiated completely. The shielding of the sample holder and other surrounding material between the source and the sample is negligible.

The radiation is emitted from a point-like source. Thus the dose rate $\dot{D}$ falls off with $1/r^2$ where r is the distance from the source.

$$\dot{D}(r) = \dot{D}_0 \cdot \frac{r_0^2}{r^2}$$

D.3. Dosimetry at TK1000B

The dosimetry is done regularly with calibrated ionisation chambers manufactured by IBA, Germany, and PTW Freiburg, Germany.

The dose rates obtained at varying distances between 2 cm and 50 cm and in different directions relative to the source are used to develop a model of the dose rate distribution around the source as a function of distance and direction. The dose rate of an individual measurement is scaled to a reference date taking the half-life of the radioactive isotope into account. This model is constantly checked and improved with each additional measurement of dose rates.

As a result a reliable description of the dose rates inside a specific volume arranged in a given geometry in the vicinity of the irradiation source is available.

The uncertainties of the reported dose rates are given by an uncertainty evaluation according to [2] and mainly result from the uncertainties of the dosimetry and positioning of the samples.

The uncertainty evaluation for this irradiation can be found in Appendix E.

D.4. Certificate of TK1000B irradiation source

IT-Service Leipzig

Ingenieur-Technischer
Geräte- und
Produktservice für
Werkstoffprüfung
und Medizintechnik

Qualitätszertifikat
für umschlossene Strahlenquelle

TK 1000 B

Prüfungszeugnis - Nr.:	12061
Kunde:	Frauenhofer Institut
Strahler/HRQ Ident. Nr.:	**001-2010(GK60R01**
Kapsel Typ:	GK60R01
ISO Code:	ISO/99/E 65546
AFNOR Code:	NF/99/E 65546
Zertifikat Nr.:	RUS/5614/S-96 (Rev. 0)
Radionuklid:	**Co-60**
Physikalische Form:	**fest, umschlossen**
Chemische Form:	**metallisch**
Brennfleck in mm x mm:	7,0x10,4 mm
Herstellungsaktivität:	20102,1 GBq (543,3 Ci)
Herstellungsdatum:	30.07.2010

Dichtheitsbescheinigung

Oberflächenkontaminationstest:		ohne Beanstandung
Datum:	30.07.2010	Ergebnis: < 185 Bq
Lecktest:		ohne Beanstandung
Datum:	30.07.2010	Ergebnis: dicht

Die Qualitätskontrolle wurde vom Hersteller in unserem Namen durchgeführt.
Es wird bescheinigt, daß die umschlossene radioaktive Strahlenquelle den Anforderungen nach NF / ISO 9978 (1992), ISO 2919 (1999) und NF M61002 (1984) entspricht.

Der oben genannte Strahler wurde in einem neuen bzw. entsprechend DIN 54115 Teil 6 überprüften und zugelassenen Strahlerhalter Nr.: eingebaut.

Datum: 25.01.2012 Signum IT-Service:

IT-Service Leipzig GmbH, BS Haan, Bergische Straße 16, 42781 Haan Tel.: 02129 / 377595 Fax: 02129 / 378794

E Irradiation documentation HDR

Irradiation Test Documentation

Fraunhofer INT

Irradiation Source	TK1000B (2012)	Date	13.05.2016
Responsible Employee	MS		
Project Description	NEO-14-086 HDR(3 - 2N7370/2N7371)		

Reference Data for Dose Rate Calculation

Reference Activity	8.00 TBq ± *10.0%*	Standard uncertainty[1)]
Reference Dose Rate	2.35 Gy/s ± *2.5%*	Standard uncertainty[1)]
Reference Distance	10 cm ± *0.5%*	Standard uncertainty[1)]
Reference Date	01.01.1990	

Geometry of Irradiated Object (As defined or measured):

Inner Diameter	4.50 cm ± *0.05* cm	Standard uncertainty[1)]
Outer Diameter	5.50 cm ± *0.05* cm	Standard uncertainty[1)]
Height	0.50 cm ± *0.05* cm	Standard uncertainty[1)]

Distances of Point Source:

Surface of Object	13.95 cm ± *0.05* cm	Standard uncertainty[1)]
Object Minimum	14.12 cm ± 0.05 cm	Standard uncertainty[2)]
Object Maximum	14.72 cm ± 0.07 cm	Standard uncertainty[2)]
Mean Distance	**14.42 cm ± 0.11 cm**	*Expanded uncertainty*[3)]

Dose Rates in Object

Minimum	0.0291 Gy/s ± 2.9%	Standard uncertainty[2)]
Mean	**0.0303 Gy/s ± 2.8%**	Standard uncertainty[2)]
Maximum	0.0316 Gy/s ± 2.8%	Standard uncertainty[2)]

Irradiation Time	**65943 s ± *1* s**	Standard uncertainty[1)]
in DD HH:MM:SS	00 18:19:03 ± *1* s	Standard uncertainty[1)]

Dose in Object

Minimum	1919 Gy ± 2.9%	Standard uncertainty[2)]
Maximum	2086 Gy ± 2.8%	Standard uncertainty[2)]
Mean	**2000 Gy ± 5.6%**	*Expanded uncertainty*[3)]
Homogeneity	8.3%	

[1)] Experience or statistics based estimation of standard uncertainty with a coverage factor k=1
[2)] Combined standard uncertainty with a coverage factor k=1
[3)] Determined from a combined standard uncertainty (i.e., estimated standard deviations of values above) and a coverage factor k = 2. Since it can be assumed that the possible estimated values of the dose are approximately normally distributed with approximate standard deviation, the unknown value of the dose is believed to lie in the interval given with a level of confidence of approximately 95 %.

Standard Irradiation Test Documentation Sheet, 2015-12-18