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DOCUMENT

# RA0616 CO60 TID Test Results on Part Type BFY650B

RA0616

| | |
|---|---|
| **Prepared by** | **Michele Muschitiello TEC-QEC** |
| **Reference** | **RA0616** |
| **Issue** | **1** |
| **Revision** | **1** |
| **Date of Issue** | **25 February 2013** |
| **Status** | **Issued** |
| **Document Type** | **Test Report** |
| **Distribution** | **ESCIES Library** |

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# APPROVAL

| **Title** RA0616 CO60 TID Test Results on Part Type BFY650B | |
|---|---|
| **Issue** 1 | **Revision** 1 |
| **Author** | **Date** |
| **Michele Muschitiello TEC-QEC** | **25 February 2013** |
| **Approved by** | **Date** |
| **Cesar Boatella Polo TEC-QEC** | **25 February 2013** |
| **Authorised by** | **Date** |
| **Christian Poivey TEC-QEC** | **19/04/2013**  |

# CHANGE LOG

| Reason for change | Issue | Revision | Date |
|---|---|---|---|
| Draft release | 1 | 0 | 10 January 2013 |
| Final release | 1 | 1 | 25 February 2013 |
| | | | |

# CHANGE RECORD

| **Issue** 1 | **Revision** 1 | | |
|---|---|---|---|
| **Reason for change** | **Date** | **Pages** | **Paragraph(s)** |
| Statement that tested parts were previously un-screened | 19 February | 4 | 5.2.1 |
| Table 17 and Figure 11 include data on sample s/n 6 | 19 February | 21 | 7 |

**Table of contents:**



# 1 ACRONYMS

TID Total Irradiation Dose

# 2 REFERENCES

REF1 ESA/SCC 22900 “Total Dose Steady-State Irradiation Test Method”, issue 3
REF2 IFX Detail SpecificationA63500-T1580B-D11E
REF3 IFX Detail SpecificationA63500-T580B-D11E
REF4 IFX Detail SpecificationA63500-T1592B-D11E

# 3 PURPOSE

The purpose of this test report is to describe the TID test performed according to REF1 on the devices below specified.

# 4 SCOPE

This documents reports the test results obtained on Silicon-Germanium RF transistors, based on part type BFY650B, manufactured by Infineon.

# 5 TEST DESCRIPTION

## 5.1 Facility and Dosimetry

The ESTEC Co-60 facility comprises of a Nordion Gammabeam 150C irradiator containing a nominal 85.2 TBq (2300 Ci) Co-60 source at the last reload date in October 2011. the irradiation room is monitored for temperature, relative humidity and pressure.

The dosimetry system is based on Farmer type 2571A 0.6 cc air ionisation chambers linked to Farmer 2670 electrometer. The dosimetry system is compensated against temperature and pressure environmental fluctuations.

All irradiations and measurements were performed at room temperature (22.5 ± 3 °C).

## 5.2 Devices Under Test

A total of twenty one devices, were received from Infineon Germany. A test fixture for the DC measurements to be performed, was also received from the manufacturer.

### *5.2.1 Part description*

| | |
|---|---|
| Manufacturer | Infineon - Hirel Discrete & MW Semiconductor |
| Family | RF NPN transistor |
| Group | Silicon-Germanium |
| Package | µX |
| Component Designation | BFY650B Variant 011 |
| Component Specification | ESCC 5611/010 |
| Part Identification Number | BFY650B(SAM) |
| Diffusion Lot | 8575/02 |
| Delivery Lot | 1048.54 |
| Device serial numbers | from 1 to 21 (identified by the individual position in the primary package). |

All received devices were not preliminary submitted to any screening by the manufacturer but just measured before the delivery for the TID test campaign.

The devices from s/n 6 to s/n 10 were irradiated with bias applied according to the schematic in Figure 1 .

The devices from s/n's: 1 to 5 were irradiated with all the pins grounded (un-biased).
The device s/n 11 was retained as control sample and measured at the completion of each irradiation step.

Table 1 summarize the sample usage

**Table 1 received samples and their usage.**

| S/n's | Description |
|---|---|
| **1, 2, 3, 4 and 5** | Unbiased during $^{60}$Co irradiation, anneal and ageing |
| **6, 7, 8, 9 and 10** | Biased during $^{60}$Co irradiation, anneal and ageing |
| **11** | Reference device (not irradiated) - Electrically tested before and after each intermediate measurement run at irradiation step completion. |
| **12, 13, 14, 15, 16, 17, 18, 19, 20** | Nor Irradiated/kept for future use. |

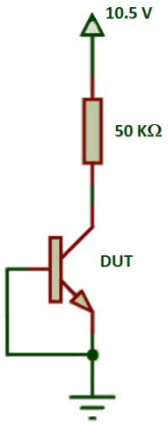


**Figure 1 Biasing circuit**

## 5.3 Radiation Test Plan

The actual radiation test steps are reported in Table 2.

**Table 2 Irradiation Test Plan**

| Step | Step Dose krad (to water) | Total Dose krad (to water) | Dose Rate rad/min (to water) |
|---|---|---|---|
| **(Pre irradiation) 0** | == | | == |
| **Irradiation step # 1** | 47.75 | 47.75 | 6.62 |
| **Irradiation step # 2** | 63.88 | 111.6 | 6.54 |
| **Irradiation step # 3** | 83.54 | 195.2 | 6.53 |
| **Irradiation step # 4** | 166.9 | 362.1 | 6.50 |

At the completion of each of the above irradiation steps, intermediate electrical measurements were carried out according to the next paragraph.

At the end of the final irradiation run, all devices were electrically measured and annealed for 45 hours at room temperature and subsequently aged at 100°C (for 168 hrs in total), maintaining the same bias conditions applied during the TID test.
Table 3 reports the annealing/ageing sequence detail.

**Table 3 Anneal/ageing sequence**

| Step | Temperature | Duration |
|---|---|---|
| **Anneal** | Room temperature | 45 hours |
| **Ageing** | 100 °C | 168 hours |

Again, at the completion of each anneal/ageing step, all devices were electrically tested.

## 5.4 Measurement Set-up

No in-situ measurements were performed during irradiation.
Electrical measurements were performed according to Table 2 of the relevant detail specification.

In the following, the Table 2 from the detail specification is reported.

**Table 4 Measured Parameters, Min-Max Limits and Test conditions**

**BFY640B (Var01-04) and BFY650B (Var11) – DC Parameters from Table 2 of ESCC 5611/010:**

| No. | Characteristic | Symb | Test Fig. | Test Condition | Limits | | Unit |
|---|---|---|---|---|---|---|---|
| | | | | | Min. | Max. | |
| 1 | Collector Cut-off Current, Base shorted (high voltage) | $I_{CESH}$ | 4(a) | $V_{CE}$ = 13 V, $V_{BE}$ = 0 V | - | 10 | µA |
| 2 | Collector Cut-off Current, Base shorted (medium voltage) | $I_{CESM}$ | 4(a) | $V_{CE}$ = 10.5 V, $V_{BE}$ = 0V | - | 5 | µA |
| 3 | Emitter Cut-off Current (high voltage) | $I_{EB0H}$ | 4(a) | $V_{EB}$ = 1.2 V, $I_C$ = 0 mA<br>Variant 01-04:<br>Variant 11: | - | <br>5<br>15 | µA |
| 4 | Collector-Emitter Cut-off Current (high voltage) | $I_{CEXH}$ | 4(a) | $V_{CE}$ = 4 V , $I_B$ = 100 nA<br>(Note 1) | 20 | 100 | µA |

| NO. | CHARACTERISTIC | SYMB | TEST FIG. | TEST CONDITION | LIMITS | | UNIT |
|---|---|---|---|---|---|---|---|
| 5 | DC Forward Current Transfer Ratio (medium current) | $h_{FE}$ | 4(a) | $V_{CE}$ = 3 V<br>Variant 01-04, $I_C$ = 30 mA:<br>Variant 11, $I_C$ = 80 mA: | <br>135<br>100 | <br>250<br>250 | |
| 6 | Base-Emitter Forward Voltage | $V_{FBE}$ | 4(a) | $I_B$ = 12 mA, $I_C$ = 0<br>(Note 2) | - | 0.96 | V |
| 10 | Collector Cut-off Current, Base shorted (low voltage) | $I_{CESL}$ | 4(a) | $V_{CE}$ = 5 V, $V_{BE}$ = 0 V | - | 2 | µA |
| 11 | Emitter Cut-off Current (low voltage) | $I_{EB0L}$ | 4(a) | $V_{EB}$ = 0.5 V, $I_C$ = 0 mA | - | 100 | nA |
| 12 | DC Forward Current Transfer Ratio (low current) | $h_{FEL}$ | 4(a) | $V_{CE}$ = 3 V, $I_C$ = 20 µA<br>Variant 01-04:<br>Variant 11: | <br>190<br>190 | <br>600<br>530 | |

**NOTES:**

1. Regarding upper limit, this is an alternative method of establishing $V_{(BR)CEO}$ and assures that $V_{(BR)CEO}$ is > 4 V, if the stated base current is not exceeded. Lower limits result from current gain at low Ib.
2. Pulsed measurement: Pulse Duration < 1 second. For the purpose of $V_{FBE}$ measurement, $I_{B,max}$ may be exceeded during a pulsed measurement provided that the pulse length duration < 1 second and $I_C$ = 0 mA.

All the above parameters have been measured by using the following equipment:

DC Source Monitor Unit: Keithley model KE2612A s/n1259457.
Test Jig: Infineon proprietary
Test Program: CLY_inf.vi (Labview© based sw)

## 5.5 Measurement Set-up Calibration

After the test campaign, the DC source monitor was sent out for calibration. According to the calibration certificate (number NL000161 from Fluke Nederland B.V. dated 28 Nov 2012), the current measurements taken on channel A (connected to DUT collector) on ranges:

a) 0.101µA – 1.02µA
b) 1.01µA-10.1 µA

were affected by a systematic error of 15.7nA for $I_C$ values ranging from 0.1µA to 19 µA.

In particular, all the reported collector current measurements falling in the above range, must be corrected by increasing the figures accordingly.

# 6 TEST RESULTS ON BFY650B

All measurement results are reported from Table 5 to Table 13. Test ended with a registered Total Dose of 362.1 krad(water).
At the end of the last irradiation step, electrical measurements were performed. The devices were tested again after 45 hours annealing at room temperature.
After the annealing, the samples went through accelerated ageing, with final measurement performed after 168 hrs at 100°C.
During the entire annealing/ageing, the irradiated devices were biased employing the same test board.

Electrical Measurement uncertainty values, reported in the relevant table header, were estimated by combining the instrument uncertainty for the measured parameter (from the manufacturer specification) and the variations of the same parameter in the reference device (s/n 11), observed during the entire test campaign.

Significant data from tables have also been plotted from Figure 2 to Figure 10.

**Table 5 Collector cut-off current, base shorted (high voltage) - $I_{CESH}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.35 | 0.65 | 0.93 | 1.27 | 1.28 | 0.66 |
| 2 | 0.00 | 0.26 | 0.38 | 0.47 | 0.53 | 0.55 | 0.33 |
| 3 | 0.00 | 0.13 | 0.22 | 0.29 | 0.35 | 0.36 | 0.24 |
| 4 | 0.00 | 0.14 | 0.25 | 0.34 | 0.44 | 0.45 | 0.31 |
| 5 | 0.00 | 0.21 | 0.31 | 0.38 | 0.43 | 0.43 | 0.21 |
| 6 | 0.00 | 1.62 | 3.89 | *(*) > 10.01* | *(*) > 10.00* | *(*) > 10.01* | *(*) > 10.01* |
| 7 | 0.00 | 0.41 | 0.79 | 4.18 | 5.15 | 4.94 | 2.40 |
| 8 | 0.00 | 0.34 | 0.77 | 3.24 | 3.49 | 3.58 | 1.77 |
| 9 | 0.00 | 0.12 | 0.16 | 0.34 | 0.40 | 0.39 | 0.31 |
| 10 | 0.00 | 0.43 | 0.91 | 3.76 | 4.76 | 4.62 | 3.18 |
| 11 | 535.24 pA | 593.11 pA | 592.22 pA | 599.66 pA | 599.81 pA | 599.81 pA | 594.97 pA |

**Part type: BFY650B**

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 10 | uA |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 3.0 | % |

*(*) out of range*

*Note: All values are in µA unless differently noted (in red, values outside spec. limits)*

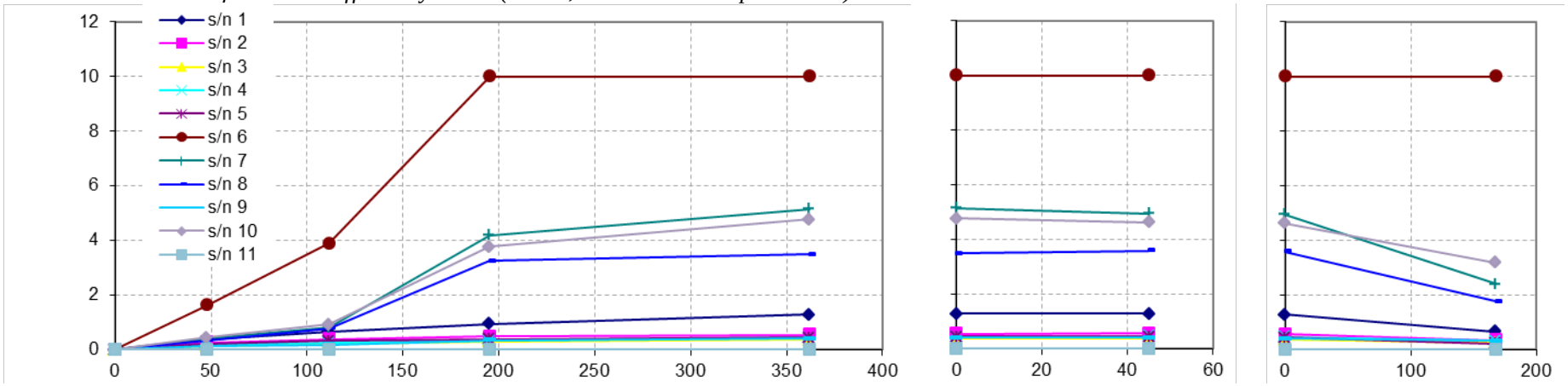


**Figure 2**

**Table 6 Collector Cut-off Current, Base shorted (medium voltage) - $I_{CESM}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.21 | 0.46 | 0.66 | 0.90 | 0.91 | 0.49 |
| 2 | 0.00 | 0.18 | 0.30 | 0.38 | 0.45 | 0.46 | 0.27 |
| 3 | 0.00 | 0.08 | 0.16 | 0.22 | 0.28 | 0.29 | 0.19 |
| 4 | 0.00 | 0.10 | 0.18 | 0.25 | 0.32 | 0.33 | 0.22 |
| 5 | 0.00 | 0.14 | 0.25 | 0.32 | 0.37 | 0.37 | 0.17 |
| 6 | 0.00 | 0.82 | 2.19 | *(*) > 10.00* | *(*) > 10.00* | *(*) > 10.01* | *(*) > 10.00* |
| 7 | 0.00 | 0.26 | 0.55 | 3.21 | 4.02 | 3.85 | 1.85 |
| 8 | 0.00 | 0.20 | 0.48 | 2.62 | 2.86 | 2.96 | 1.44 |
| 9 | 0.00 | 0.08 | 0.13 | 0.30 | 0.35 | 0.34 | 0.27 |
| 10 | 0.00 | 0.23 | 0.61 | 2.92 | 3.71 | 3.60 | 2.44 |
| 11 | 59.59 pA | 71.99 pA | 71.95 pA | 74.85 pA | 73.58 pA | 72.98 pA | 69.50 pA |

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 5 | uA |

Expanded uncertainty (k=2) 5.5 %

*(*) out of range*

*Note: All values are in µA unless differently noted (in red, values outside spec. limits)*

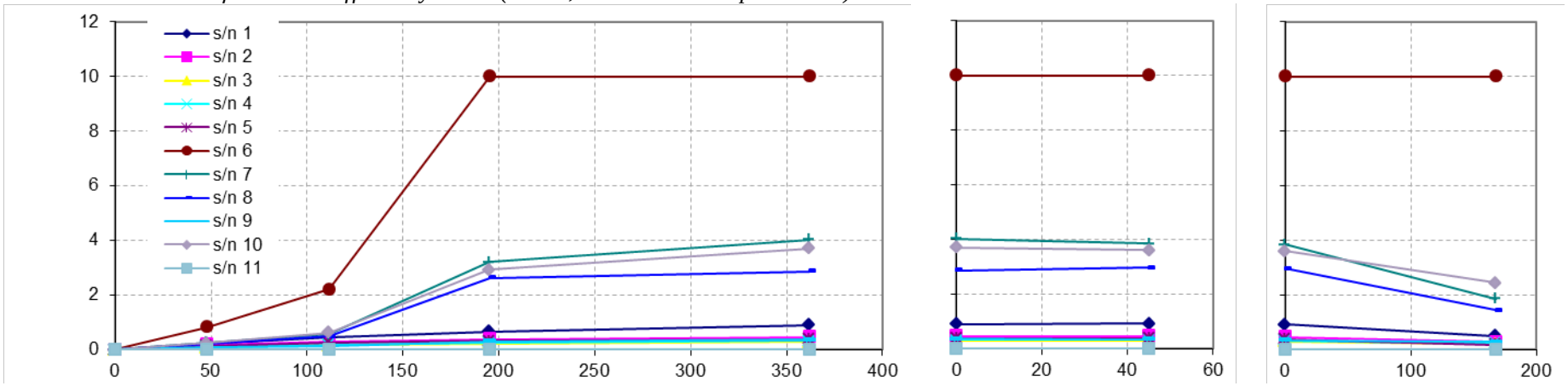


**Figure 3**

**Table 7 Emitter Cut-off Current(high voltage) - $I_{EB0H}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 0.40 | 0.39 | 0.42 | 0.39 | 0.39 | 0.40 | 0.40 |
| 2 | 0.40 | 0.39 | 0.38 | 0.38 | 0.36 | 0.39 | 0.39 |
| 3 | 0.43 | 0.40 | 0.39 | 0.39 | 0.39 | 0.40 | 0.40 |
| 4 | 0.41 | 0.40 | 0.42 | 0.39 | 0.38 | 0.39 | 0.39 |
| 5 | 0.43 | 0.42 | 0.41 | 0.39 | 0.38 | 0.39 | 0.40 |
| 6 | 0.48 | 0.48 | 0.45 | 0.44 | 10.30 | 9.12 | 4.55 |
| 7 | 0.45 | 0.42 | 0.41 | 0.52 | 0.73 | 0.74 | 0.70 |
| 8 | 0.41 | 0.38 | 0.37 | 0.47 | 0.64 | 0.62 | 0.59 |
| 9 | 0.42 | 0.39 | 0.38 | 0.38 | 0.37 | 0.39 | 0.39 |
| 10 | 0.42 | 0.40 | 0.38 | 0.50 | 0.69 | 0.71 | 0.66 |
| 11 | 430.21 pA | 432.22 pA | 429.60 pA | 429.98 pA | 446.93 pA | 444.88 pA | 442.55 pA |

*Note: All values are in nA unless differently noted*

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 15000 | nA |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 1.4 | % |

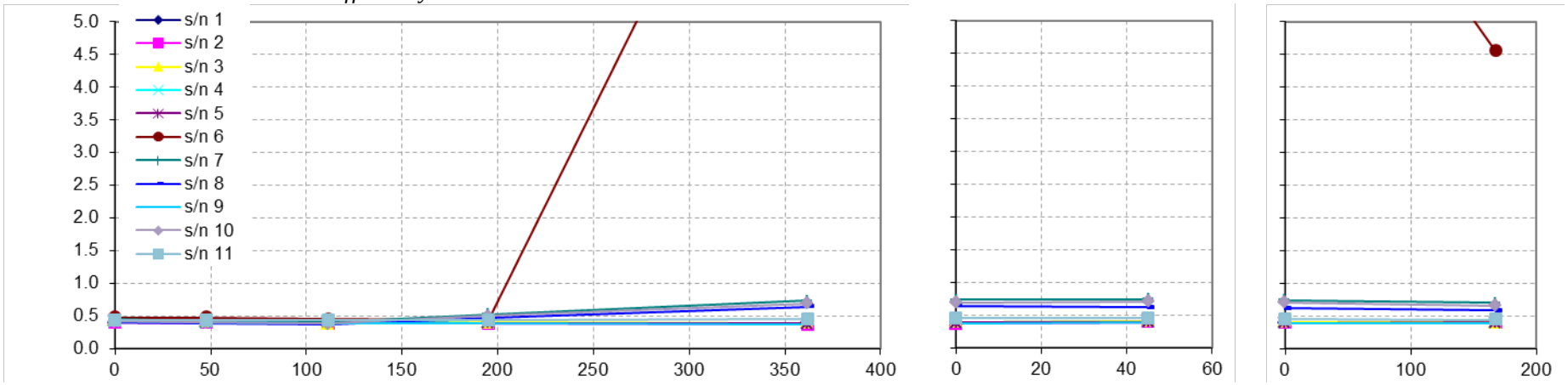


**Figure 4**

**Table 8 Collector-Emitter Cut-off Current (high voltage) - $I_{CEXH}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 42.98 | 33.44 | 26.57 | 22.82 | **17.33** | **18.06** | 20.11 |
| 2 | 43.30 | 33.59 | 26.99 | 22.27 | **17.21** | **17.37** | **19.81** |
| 3 | 43.64 | 35.60 | 29.96 | 24.49 | **18.96** | **19.42** | 21.27 |
| 4 | 43.25 | 36.28 | 30.15 | 27.07 | 21.20 | 21.58 | 21.95 |
| 5 | 44.59 | 33.61 | 26.18 | 21.21 | **16.10** | **16.31** | **19.18** |
| 6 | 42.61 | 33.54 | 28.94 | 35.73 | **13.15** | **13.36** | **11.05** |
| 7 | 43.61 | 34.70 | 27.74 | 24.86 | 20.73 | 22.01 | 23.83 |
| 8 | 43.04 | 34.87 | 28.35 | 25.88 | 21.09 | 22.18 | 23.50 |
| 9 | 43.62 | 35.77 | 29.75 | 26.74 | 20.37 | 20.24 | 20.90 |
| 10 | 43.31 | 36.72 | 32.37 | 29.27 | 23.73 | 24.73 | 26.26 |
| 11 | 42.91 | 42.09 | 42.37 | 42.30 | 41.34 | 41.36 | 41.33 |

*Note: All values are in µA.* ***In dark red values below the min limits***

**Part type: BFY650B**

| limits | | |
|---|---|---|
| min: | max: | unit |
| 20 | 100 | µA |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 1.1 | % |

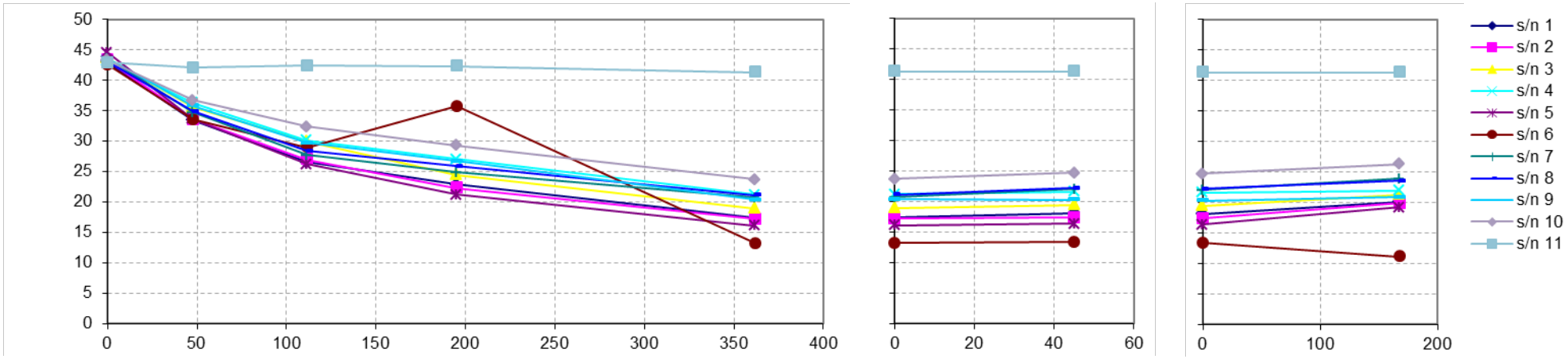


**Figure 5**

**Table 9** **DC Forward Current Transfer Ratio (medium current) - $h_{FE}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 136.7 | 136.3 | 134.4 | 134.5 | 134.9 | 134.7 | 133.4 |
| 2 | 137.2 | 136.8 | 134.4 | 136.3 | 135.6 | 135.1 | 133.7 |
| 3 | 137.9 | 138.2 | 139.3 | 137.4 | 137.1 | 136.9 | 135.4 |
| 4 | 136.8 | 137.0 | 135.4 | 136.4 | 136.1 | 136.1 | 134.5 |
| 5 | 139.1 | 139.0 | 138.9 | 138.6 | 138.3 | 138.5 | 136.5 |
| 6 | 136.8 | 136.3 | 136.7 | 135.6 | 121.7 | 123.6 | 122.5 |
| 7 | 138.1 | 138.3 | 138.2 | 135.3 | 133.0 | 133.4 | 132.2 |
| 8 | 136.3 | 136.4 | 136.0 | 133.2 | 132.0 | 132.3 | 131.3 |
| 9 | 138.1 | 138.3 | 137.5 | 137.6 | 137.6 | 137.5 | 135.8 |
| 10 | 137.2 | 137.7 | 136.3 | 134.3 | 132.5 | 132.7 | 132.0 |
| 11 | 136.0 | 136.1 | 135.6 | 135.9 | 135.6 | 135.6 | 135.5 |

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| 100 | 250 | - |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 0.2 | % |

*Note: none*

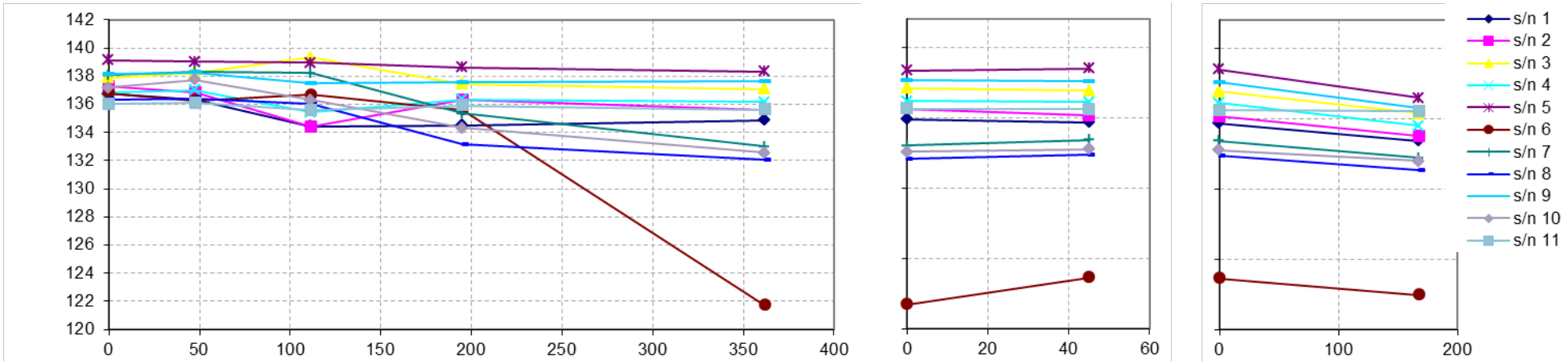


**Figure 6**

**Table 10** **Base-Emitter Forward Voltage - $V_{FBE}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 885.3 | 883.8 | 883.6 | 882.5 | 882.9 | 882.4 | 881.8 |
| 2 | 884.9 | 884.5 | 882.5 | 882.9 | 883.8 | 883.1 | 883.1 |
| 3 | 885.1 | 884.4 | 883.3 | 882.7 | 883.0 | 883.3 | 883.0 |
| 4 | 885.1 | 884.3 | 883.7 | 882.8 | 884.3 | 883.3 | 883.1 |
| 5 | 884.8 | 884.0 | 883.0 | 882.8 | 883.3 | 883.9 | 882.9 |
| 6 | 885.0 | 884.4 | 883.0 | 882.5 | 883.3 | 883.1 | 882.7 |
| 7 | 885.2 | 883.9 | 883.4 | 882.9 | 883.0 | 883.4 | 882.6 |
| 8 | 885.0 | 883.6 | 882.9 | 883.2 | 883.5 | 882.9 | 882.4 |
| 9 | 884.7 | 884.3 | 883.6 | 883.4 | 883.8 | 882.5 | 882.6 |
| 10 | 885.1 | 883.8 | 883.8 | 883.2 | 883.3 | 882.7 | 882.4 |
| 11 | 885.1 | 885.3 | 883.9 | 883.7 | 884.6 | 884.1 | 884.2 |

*Note: All values are in mV*

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 960 | mV |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 0.1 | % |

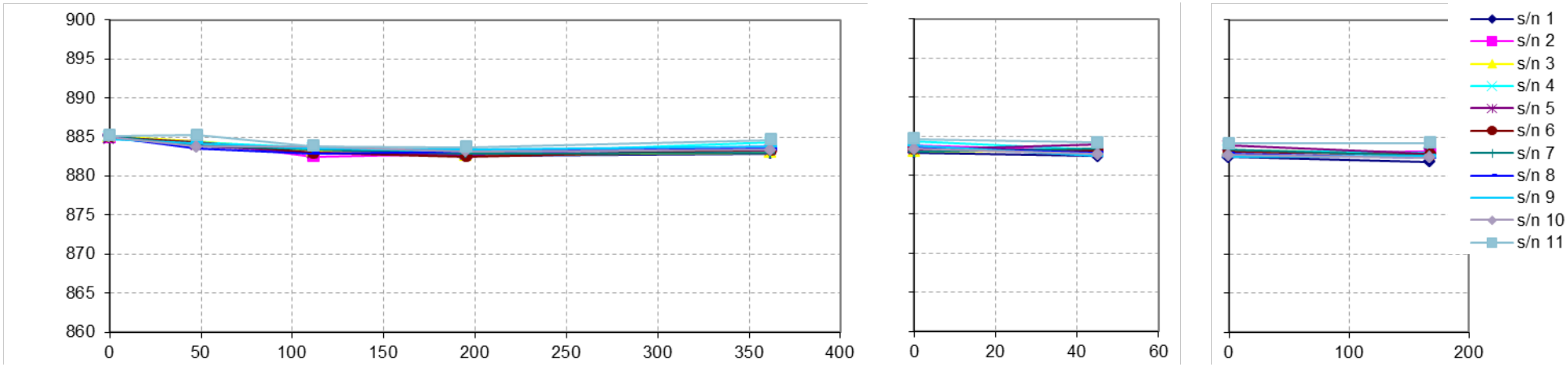


**Figure 7**

**Table 11** **Collector Cut-off Current, Base shorted (low voltage) - $I_{CESL}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 0.0 | 45.8 | 169.7 | 299.1 | 424.6 | 425.9 | 236.4 |
| 2 | 0.0 | 57.7 | 151.4 | 230.8 | 291.6 | 297.9 | 173.6 |
| 3 | 0.0 | 23.5 | 70.0 | 115.4 | 155.1 | 157.6 | 104.6 |
| 4 | 0.0 | 34.4 | 77.6 | 122.0 | 159.9 | 165.3 | 108.5 |
| 5 | 0.0 | 35.3 | 122.6 | 192.4 | 246.5 | 245.0 | 113.3 |
| 6 | 0.0 | 137.9 | 532.1 | *(*) > 9,999.6* | *(*) > 9,999.6* | *(*) > 9,999.6* | 9,248.4 |
| 7 | 0.0 | 54.1 | 219.5 | 1,612.3 | 1,897.6 | 1,841.3 | 978.6 |
| 8 | 0.0 | 45.2 | 166.0 | 1,395.8 | 1,519.7 | 1,569.9 | 797.7 |
| 9 | 0.0 | 32.7 | 71.8 | 225.6 | 247.3 | 245.5 | 199.3 |
| 10 | 0.0 | 45.7 | 180.5 | 1,681.8 | 1,909.1 | 1,913.1 | 1,316.4 |
| 11 | 13.2 pA | 15.0 pA | 15.5 pA | 16.7 pA | 16.9 pA | 15.5 pA | 13.7 pA |

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 2000 | nA |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 6.9 | % |

*(*) out of range*

*Note: All values are in nA unless differently noted (in red, values outside spec. limits)*

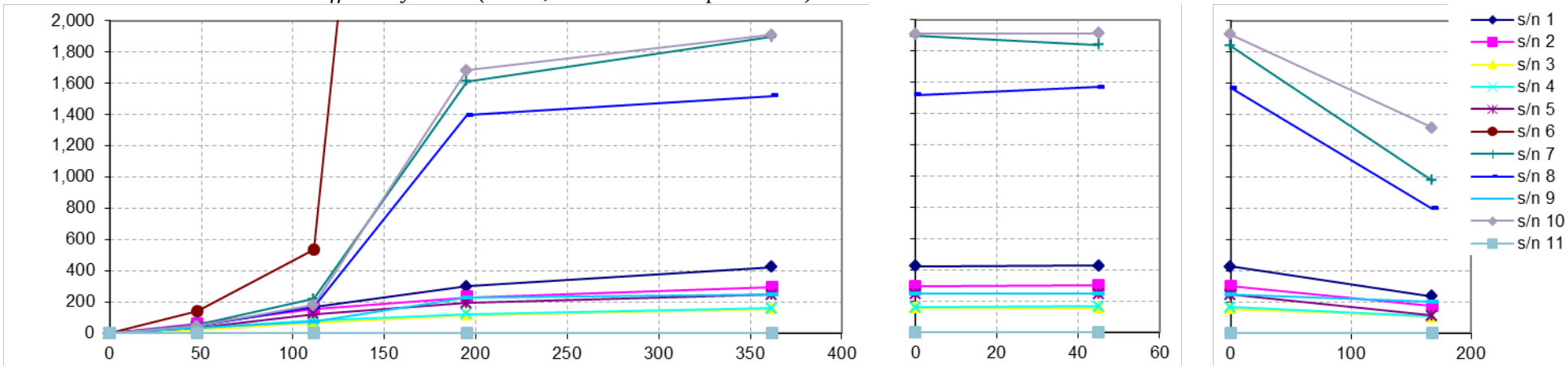


**Figure 8**

**Table 12** **Emitter Cut-off Current (low voltage) - $I_{EB0L}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|---|
| **1** | 2.5 | 2.7 | 2.3 | 2.6 | 2.3 | | 2.2 | 2.0 |
| **2** | 2.7 | 2.8 | 2.8 | 2.7 | 2.3 | | 2.4 | 1.9 |
| **3** | 2.6 | 2.7 | 2.9 | 3.2 | 2.4 | | 2.3 | 2.2 |
| **4** | 2.6 | 2.6 | 2.8 | 2.8 | 2.5 | | 2.2 | 2.2 |
| **5** | 2.5 | 2.7 | 2.7 | 2.6 | 2.5 | | 2.1 | 2.0 |
| **6** | 2.4 | 2.5 | 2.5 | 3.0 | 102.4 | | 98.4 | 51.9 |
| **7** | 2.6 | 3.0 | 2.8 | 2.3 | 1.1 | | 0.7 | 0.9 |
| **8** | 2.8 | 2.8 | 2.8 | 2.5 | 4.4 | | 1.0 | 1.3 |
| **9** | 2.5 | 2.7 | 3.2 | 2.8 | 2.4 | | 2.4 | 2.3 |
| **10** | 2.6 | 3.0 | 3.0 | 2.7 | 1.2 | | 1.1 | 1.1 |
| **11** | 2.8 | 2.6 | 2.5 | 2.8 | 2.5 | | 2.5 | 2.4 |

*Note: All values are in pA*

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| - | 100 | nA |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 4.7 | % |

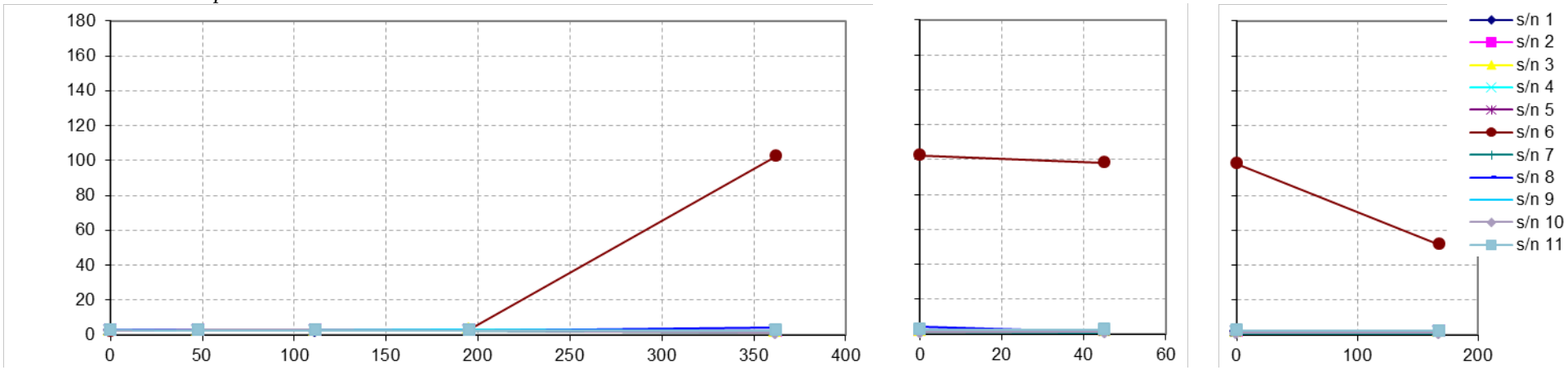


**Figure 9**

**Table 13** **DC Forward Current Transfer Ratio (low current) - $h_{FEL}$**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| 1 | 295.6 | 247.6 | 211.3 | **184.1** | **154.9** | **156.4** | **161.9** |
| 2 | 297.6 | 248.0 | 210.1 | **180.9** | **150.4** | **153.2** | **160.0** |
| 3 | 299.4 | 256.4 | 222.2 | 192.1 | **161.2** | **163.5** | **166.6** |
| 4 | 298.4 | 260.5 | 230.3 | 204.5 | **172.7** | **174.2** | **170.7** |
| 5 | 305.3 | 249.8 | 206.2 | **175.5** | **145.0** | **146.8** | **155.0** |
| 6 | 293.4 | 247.4 | 217.1 | 267.9 | **80.3** | **83.9** | **91.3** |
| 7 | 300.0 | 251.2 | 211.1 | 200.5 | **177.6** | **180.4** | **186.3** |
| 8 | 297.3 | 252.7 | 215.7 | 203.3 | **176.8** | **178.5** | **183.1** |
| 9 | 300.8 | 256.7 | 221.2 | 195.6 | **163.1** | **164.0** | **161.4** |
| 10 | 298.2 | 261.2 | 233.9 | 221.2 | 192.0 | 194.1 | 198.3 |
| 11 | 296.9 | 290.7 | 291.4 | 291.1 | 286.2 | 286.0 | 286.1 |

## Part type: BFY650B

| limits | | |
|---|---|---|
| min: | max: | unit |
| 190 | 530 | - |

| | | |
|---|---|---|
| Expanded uncertainty (k=2) | 1.1 | % |

*This parameter is the most sensitive to TID*

*Note: -*

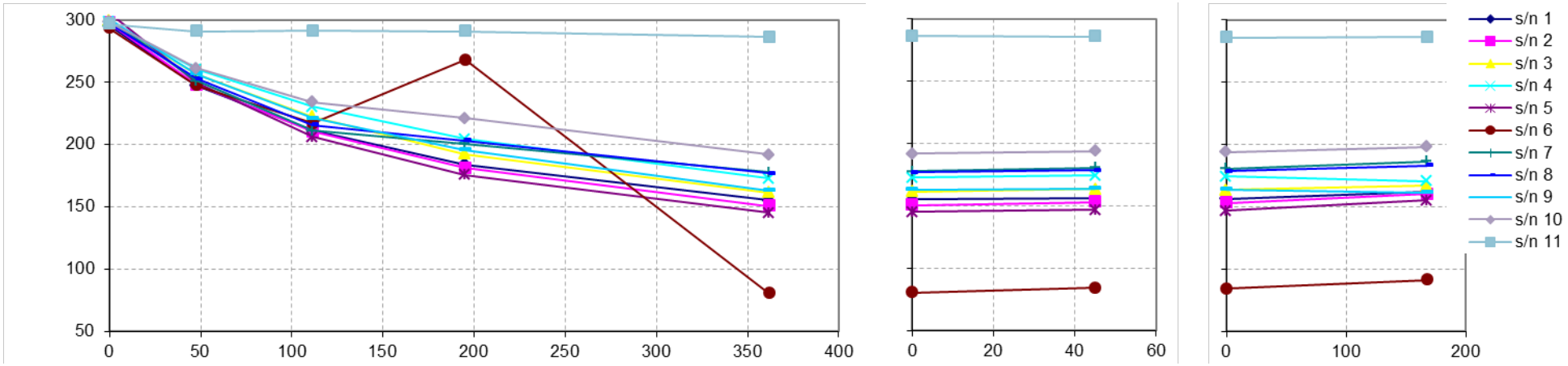


**Figure 10**

# 7 SUMMARY OF RESULT AND CONCLUSION ON BFY650B

No catastrophic failures were observed during the entire test.
Device s/n 6 showed the higher variability on all measured parameters together with anomalous degradation trends compared with the remaining parts .
The parameter degradations induced by gamma radiation is summarized in: Table 14, Table 15 and Table 16.
Table 14 reports the total doses, recorded before and after the parameter *out of limit* per applied bias condition.

**Table 14** TID levels, in [krad(H2O)], before and after the parameter out of limit, per different BIAS conditions

| nr. | Parameter | Unbiased | | Biased | |
|---|---|---|---|---|---|
| | | *pass* | *fail* | *Pass* | *fail* |
| (*) 1 | $I_{CESH}$ | 362 | - | 111.6 | 195.2 |
| (*) 2 | $I_{CESM}$ | 362 | - | 111.6 | 195.2 |
| (**) 3 | $I_{EB0H}$ | 362 | - | 362 | - |
| 4 | $I_{CEXH}$ | 195.2 | 362 | 195.2 | 362 |
| (**) 5 | $h_{FE}$ | 362 | - | 362 | - |
| 6 | $V_{FBE}$ | 362 | - | 362 | - |
| (**) 7 | $I_{CESL}$ | 362 | - | 111.6 | 195.2 |
| (**) 8 | $I_{EB0L}$ | 362 | - | 362 | - |
| 9 | $h_{FEL}$ | 111.6 | 195.2 | 195.2 | 362.1 |

(*) s/n 6 only failed before the end of irradiation, at 111.6 krad(H2O)
(**) s/n 6 parameter trend differs significantly with respect to the remaining parts

**Table 15 Detail of Failures**

| nr. | Parameter | Bias conditions | Remarks | Ref. to |
|---|---|---|---|---|
| 1 | $I_{CESH}$ | biased | S/n 06 pass up to 111.6krad($H_2O$) and failed at 195.2 krad($H_2O$). Failure not recovered after 168 hrs H.T. ageing. | Table 5 |
| 2 | $I_{CESM}$ | biased | S/n 06 pass up to 111.6krad($H_2O$) and failed at 195.2 krad($H_2O$). Failure not recovered after 168 hrs H.T. ageing. | Table 6 |
| 4 | $I_{CEXH}$ | unbiased | s/n's 01,02,03 and 05 failed at 362.1 krad($H_2O$). S/n 03 failure only recovered after168 hrs H.T. ageing. | Table 8 |
| | | biased | S/n 06 failed at 362.1 krad($H_2O$). Failure not recovered after 168 hrs H.T. ageing. | |
| 7 | $I_{CESL}$ | biased | S/n 06 pass up to 111.6krad($H_2O$) and failed at 195.2 krad($H_2O$). Failure not recovered after 168 hrs H.T. ageing. | Table 11 |
| 9 | $h_{FEL}$ | unbiased | s/n's 01,02 and 05 failed at 195.2 and s/n's 03 and 04 failed at 362.1 krad($H_2O$). All failures did not recover after168 hrs H.T. ageing. | Table 13 |
| | | biased | s/n's 06, 07, 08 and 09 failed at 362.1 krad($H_2O$). All failures did not recover significantly after168 hrs H.T. ageing. | |

**Table 16 Summary of TID test results**

| nr. | Parameter | Remarks | Ref. to |
|---|---|---|---|
| 1 | $I_{CESH}$ | More sensitive to TID when biased. | Table 5 |
| 2 | $I_{CESM}$ | More sensitive to TID when biased. | Table 6 |
| (**) 3 | $I_{EB0H}$ | Almost not sensitive to TID up to 300krad ($H_2O$) with slightly evidence of bias dependence except for device s/n 06 (biased). | Table 7 |
| 4 | $I_{CEXH}$ | Sensitive to TID. No evidence of bias dependence. | Table 8 |
| (**) 5 | $h_{FE}$ | Not significantly sensitive to TID up to 300krad ($H_2O$). No evidence of bias dependence. Slightly worsening after High Temperature ageing. | Table 9 |
| 6 | $V_{FBE}$ | Not significantly sensitive to TID up to 300krad ($H_2O$). No evidence of bias dependence. | Table 10 |
| (**) 7 | $I_{CESL}$ | More sensitive to TID when biased. This parameter has been selected for the worst case estimation together with $h_{FEL}$ (see below). | Table 11 |
| (**) 8 | $I_{EB0L}$ | Not significantly sensitive to TID up to 300krad ($H_2O$). No evidence of bias dependence. | Table 12 |
| 9 | $h_{FEL}$ | Sensitive to TID. No evidence of bias dependence. Most critical parameter showing the earliest out of spec condition. Also selected for worst case estimation | Table 13 |

(**) s/n 6 parameter trend differs significantly with respect to the remaining parts.

The worse performances were observed on biased devices. Biased devices showed also significant parameter spreads versus TID. The parameters $I_{CESL}$ and $h_{FEL}$ have been selected as representatives of worst case parameter performances as shown in **Table 17** and **Table 18**.

**NOTE that the remarks on the test equipment calibration status, (see chapter 5.5) did not substantially change the TID test report results.**

**Table 17** **Collector Cut-off Current, Base shorted (low voltage) - $I_{CESL}$ - STATISTICS**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| Unbiased devices | | | | | | | |
| avg | 0.0 | 39.3 | 118.3 | 191.9 | 255.5 | 258.3 | 147.3 |
| min | 0.0 | 23.5 | 70.0 | 115.4 | 155.1 | 157.6 | 104.6 |
| max | 0.0 | 57.7 | 169.7 | 299.1 | 424.6 | 425.9 | 236.4 |
| σ | 0.0 | 13.0 | 44.0 | 77.1 | 110.9 | 110.3 | 57.2 |
| Biased devices | | | | | | | |
| avg | 0.0 | 44.4 | 159.4 | 1,228.9 | 1,393.4 | 1,392.5 | 823.0 |
| min | 0.0 | 32.7 | 71.8 | 225.6 | 247.3 | 245.5 | 199.3 |
| max | 0.0 | 54.1 | 219.5 | 1,681.8 | 1,909.1 | 1,913.1 | 1,316.4 |
| σ | 0.0 | 8.8 | 62.6 | 679.9 | 785.2 | 778.8 | 468.1 |

**Part type: BFY650B**

| limits | | |
|---|---|---|
| min: | max: | unit |
| | 2000 | - |

**$I_{CESL}$ Statistical data on biased devices include data from device s/n 6, showing a behaviour significantly different from the remaining biased devices, and affected by out of range current errors.**

*Note: all values are in nA. Error bars -> ±2 σ(362.1krad)*

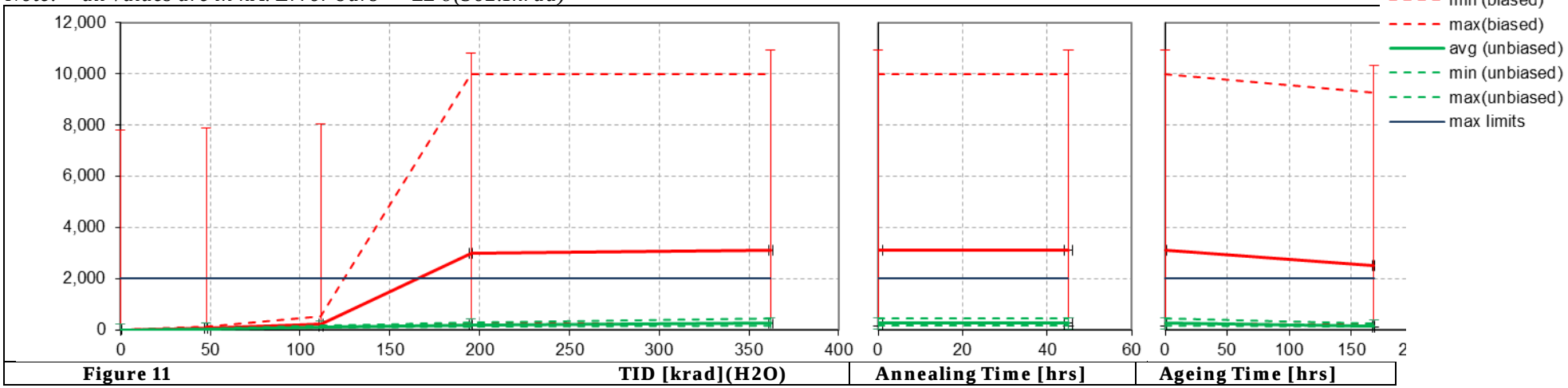


**Figure 11** **TID [krad](H2O)** **Annealing Time [hrs]** **Ageing Time [hrs]**

**Table 18** **DC Forward Current Transfer Ratio (low current) - $h_{FEL}$ - STATISTICS**

| | Pre-irradiation | 47.5 [krad] | 111.6 [krad] | 195.2 [krad] | 362.1 [krad] | Anneal @R.T. 45 h | Ageing @100'C 168 h |
|---|---|---|---|---|---|---|---|
| Unbiased devices | | | | | | | |
| avg | 299.2 | 252.4 | 216.0 | 187.4 | 156.9 | 158.8 | 162.8 |
| min | 295.6 | 247.6 | 206.2 | 175.5 | 145.0 | 146.8 | 155.0 |
| max | 305.3 | 260.5 | 230.3 | 204.5 | 172.7 | 174.2 | 170.7 |
| σ | 3.7 | 5.7 | 9.9 | 11.3 | 10.7 | 10.5 | 6.0 |
| Biased devices | | | | | | | |
| avg | 297.9 | 253.8 | 219.8 | 217.7 | 158.0 | 160.2 | 164.1 |
| min | 293.4 | 247.4 | 211.1 | 195.6 | 80.3 | 83.9 | 91.3 |
| max | 300.8 | 261.2 | 233.9 | 267.9 | 192.0 | 194.1 | 198.3 |
| σ | 2.9 | 5.3 | 8.7 | 29.7 | 44.6 | 43.9 | 42.8 |

**Part type: BFY650B**

| limits | | |
|---|---|---|
| min: | max: | unit |
| 190 | 530 | - |

**ICESL Statistical data on biased devices include data from device s/n 6, showing a behaviour significantly different from the remaining biased devices .**

*Note: Error bars -> ±2 σ(362.1krad)*

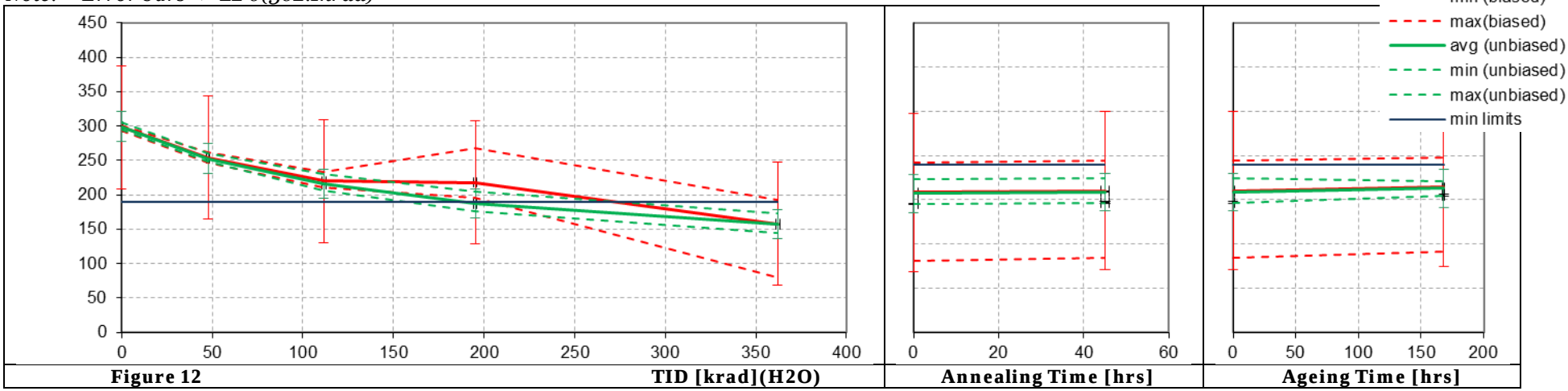


**Figure 12**

# APPENDIX A RADIATION SUMMARY

**ESTEC $^{60}$Co Facility**

Keplerlaan, 1 2200AG Noordwijk Zh (NL)

## RADIATION TEST SUMMARY

*Irradiation Test Report Number :* **20184** *Date :* **04-10-2012**

| | | |
|---|---|---|
| *Test Requester :* | *Name* | Infineon Technologies AG<br>Am Campeon 1-12 |
| | *Address* | 85579 Neubiberg<br>Germany |
| | *Personnel present :* | M Muschitiello, B Nickson |
| *Project/Cost Code :* | | ECI |
| *Devices/Components irradiated :* | | SiGe Transistors |
| *Device/Component details :* (conditions and identification) | | BFY650B, BFY640B, BFY640 & BFY740B |
| *Dosimetry Chain used :* | | C |
| *Dosimeter :* | | Farmer model 2680 – s/n 491 |
| *Gas Ionisation Chamber :* | | NE Type 2571 – s/n 3611 |
| *Measured Dosimetry :* | | Total Ionising Dose in [Gy] (water) |
| *Dosimetry Procedure :* | | ESCC 22900 section 4.1.1<br>TEC-QEC/PR001 - Appendix D<br>***(Total Ionising Dose accredited by RvA according to ISO/IEC 17025.2005 Certificate No. L517)*** |

*(With the exception of the above specified dosimetry equipment, ESTEC $^{60}$Co Facility does not assume any liability for the calibration status of any other equipment lent to the requester )*

## Irradiation Test Campaign Details

*Source Activity :* 75.3 TBq *on date :* 26-07-2012

| | units | *Min.* | *Max.* | Time-weighted Average |
|---|---|---|---|---|
| *Temperature* | °C | *25.2* | *26.0* | 25.74 |
| *Pressure* | mbar | *1000.7* | *1027.5* | 1014.22 |
| *Relative Humidity* | % | *33.7* | *45.4* | 41.02 |

| Dosimeter position relative to $^{60}$Co source | | |
|---|---|---|
| X | cm | -28.0 |
| Y | cm | 225.0 |
| Z | cm | 5.0 |

| *Run* | *Start Date & Time (CET)* | *End Date & Time (CET)* | *Total Ionising Dose [Gy] (water)* | *Dose Rate [Gy/h] (water)* |
|---|---|---|---|---|
| 1 | 26/07/2012 13:32 | 31/07/2012 13:41 | 477.49 | 3.97 |
| 2 | 31/07/2012 16:31 | 06/08/2012 09:16 | 536.83 | 3.93 |
| 3 | 06/08/2012 10:56 | 07/08/2012 12:53 | 101.92 | 3.93 |
| 4 | 07/08/2012 15:54 | 16/08/2012 13:01 | 835.39 | 3.92 |

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## ESTEC $^{60}$Co Facility

Keplerlaan, 1 2200AG Noordwijk Zh (NL)

| Run | Start Date & Time (CET) | End Date & Time (CET) | Total Ionising Dose [Gy] (water) | Dose Rate [Gy/h] (water) |
|---|---|---|---|---|
| 5 | 16/08/2012 15:49 | 17/08/2012 10:21 | 70.97 | 3.91 |
| 6 | 17/08/2012 10:36 | 22/08/2012 10:48 | 467.44 | 3.89 |
| 7 | 22/08/2012 10:53 | 22/08/2012 14:48 | 15.29 | 3.90 |
| 8 | 22/08/2012 14:52 | 24/08/2012 14:11 | 184.42 | 3.90 |
| 9 | 24/08/2012 14:16 | 03/09/2012 12:59 | 931.41 | 3.90 |

Note: *The uncertainty budgets (according to TEC-QEC/PR001 section 12) are: 4.2 % (k=2) for absorbed dose to water and 4.4% (k=2) for absorbed dose rate to water*

Notes: no remarks.

Bob Nickson/Michele Muschitiello
*(TEC-QEC Radiation Test Engineer)*

Ali Zadeh
*(TEC-QEC Section Head)*

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