



## GREAT<sup>2</sup> 3.1 TID Test Results

26/02/2019



## SUMMARY

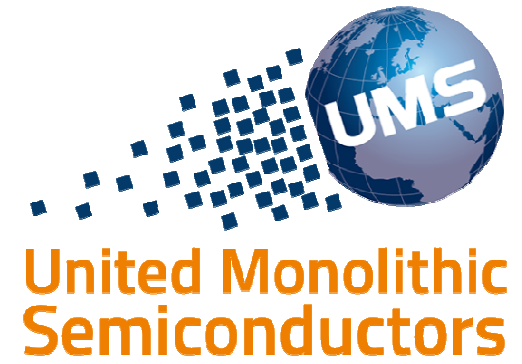


# GREAT<sup>2</sup> 3.1 – TID – CONTEXT



- ESA Project
  - GREAT2 Phase 3.1 - GaN Process Performance Validation and Space Evaluation (GH50\_20)
  - **ESA Contract No. 4000116120/16/NL/BJ**
- Total Ionisation Dose Radiation Test (Co60)
- Hardware
  - Technology: 4GH50-20 GaN Power Bar
    - 100W power bar in Kyocera package
    - Manufacturer: United Monolithic Semiconductor
- 10 devices submitted to Co60 irradiation source, up-to 274Krad (in GaN)
  - 2 units biased at  $V_{gs} = 0V$  /  $V_{ds} = 0V$
  - 3 units biased at  $V_{gs} = -7V$  /  $V_{ds} = 50V$
  - 5 units biased at  $V_{gs} = -7V$  /  $V_{ds} = 80V$
- **All the measurements performed during the radiation period, during intermediate characterization steps, and before/after an annealing period at the end of the radiation period did not exhibit any relevant variation of the electrical characteristics of the devices, whatever their biasing conditions during radiation.**





# TID TEST PLAN

# GREAT<sup>2</sup> 3.1 – TID – TEST PLAN

- Total ionizing dose assessed by submitting devices to a Co60 irradiation source (Estec Co-60 Facility ).
- Devices pinched off during the test.
  - $V_{gs} = 0V$        $V_{ds} = 0V$       => 2 units
  - $V_{gs} = -7V$        $V_{ds} = 50V$       => 3 units
  - $V_{gs} = -7V$        $V_{ds} = 80V$       => 5 units
- Scheduled radiation campaign

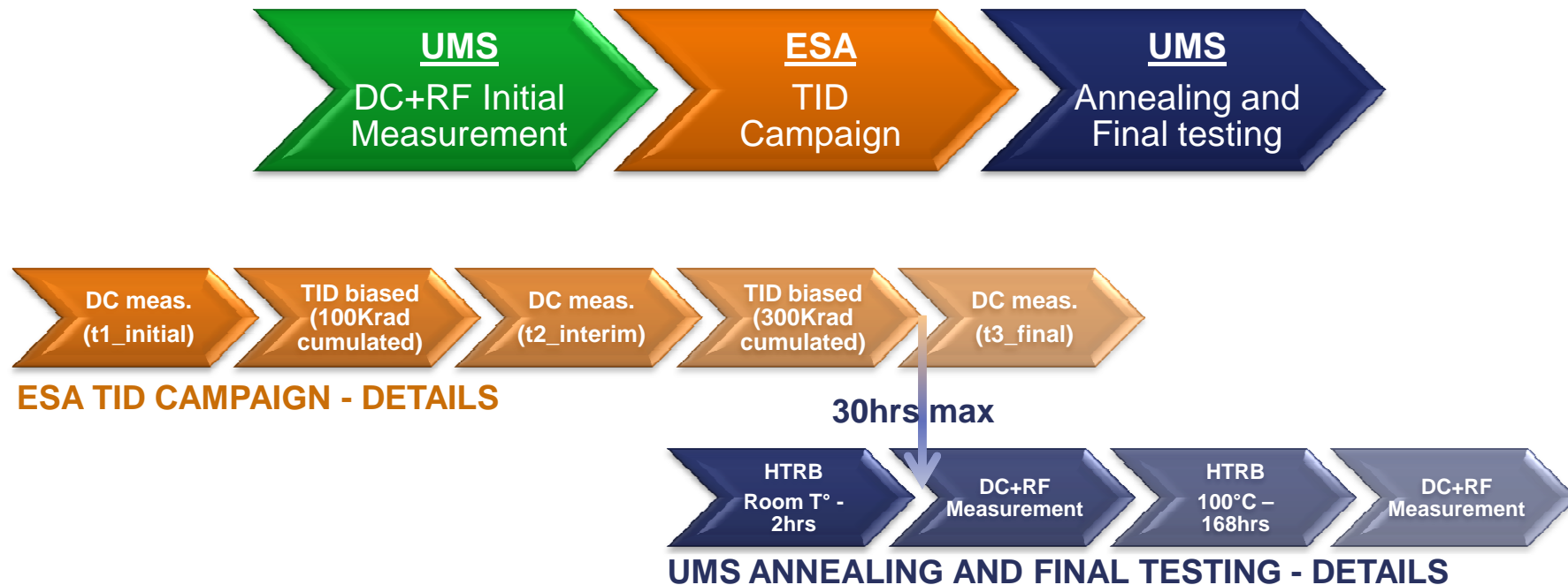
Target Total Dose (*) [rad]	Target Dose Rate (*) [rad/min]	Estimated Distance [m]	length of available irradiation [m]	Irradiation Time [min]	Start [dd-mmm-yyyy hh:mm]	Stop [dd-mmm-yyyy hh:mm]
110,000	27	1.004	0.44	4,074.07	26-Nov-2018 13:30	29-Nov-2018 09:24
300,000	27	1.004	0.44	7,037.04	29-Nov-2018 13:24	04-Dec-2018 10:41

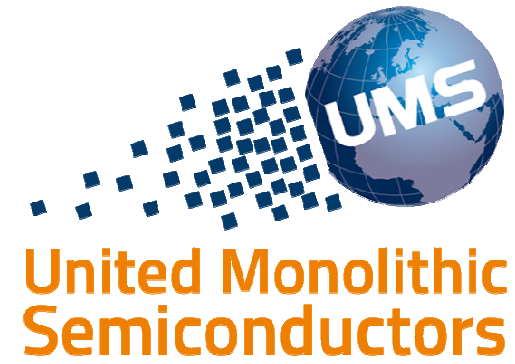
(\*) The figures of dose and dose rate indicated in this document shall be dose to Si.



# GREAT<sup>2</sup> 3.1 - TID – TEST PLAN

## ■ TID Test Sequence





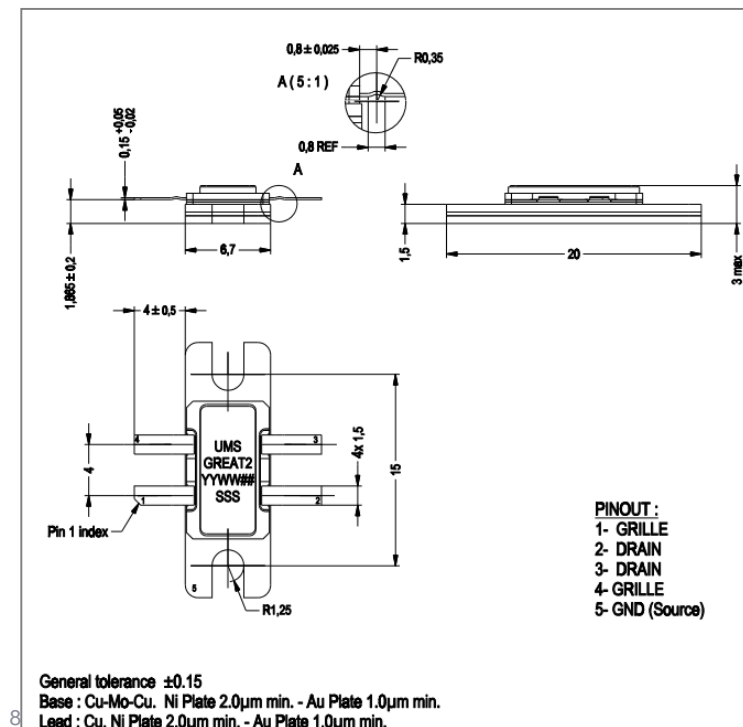
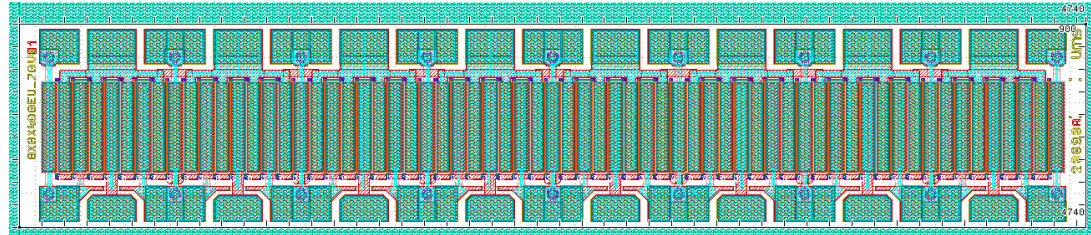
United Monolithic  
Semiconductors



HARDWARE

# GREAT<sup>2</sup> 3.1 – TID – HARDWARE

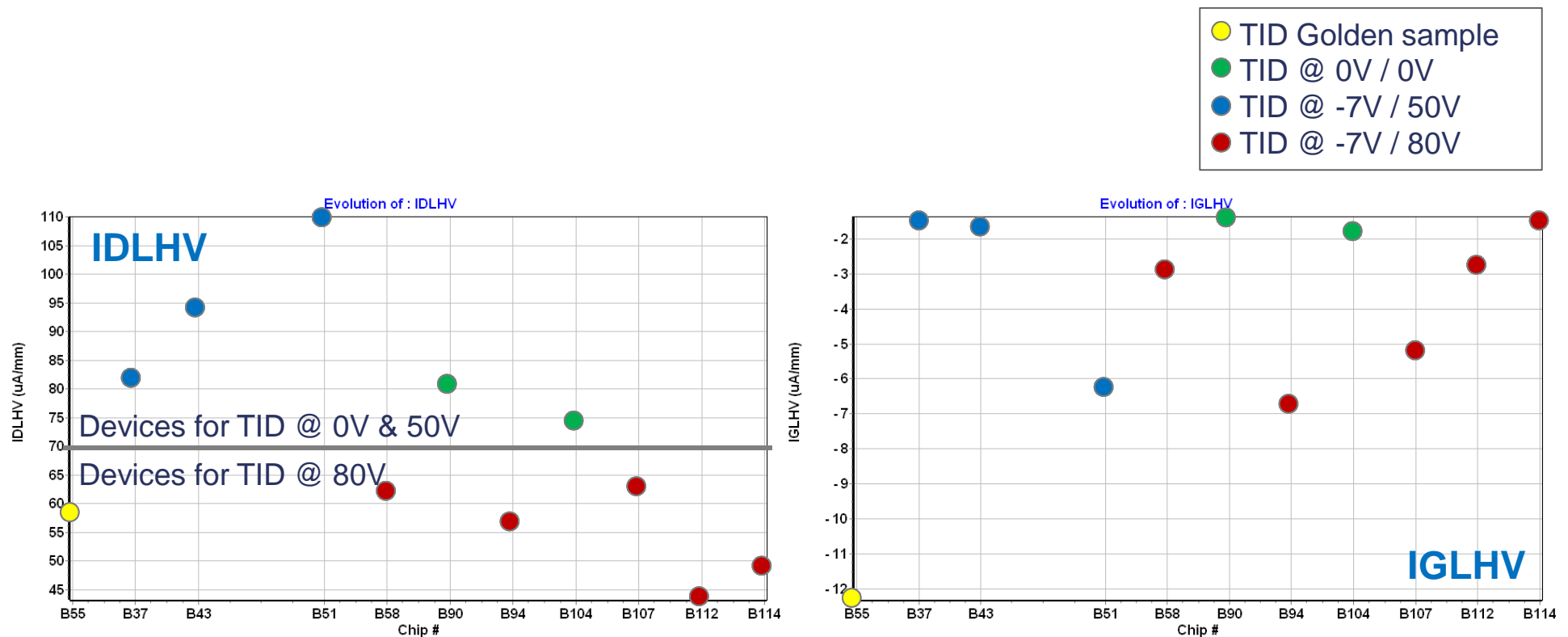
- Technology : GaN 4GH50-20
- Maskset: NOUMEAC
- Design:
  - 23693A
  - 8x8x400EU\_70V1
  - 100W Power Bar
  - Reliability Lot : U460418
- Die soldered with AuSn eutectic into closed Metal Ceramic Package (Kyocera) Package





# GREAT<sup>2</sup> 3.1 – TID – HARDWARE

- Initial Measurements on pre-Selected Devices
  - As TID tests were managed by using common drain biasing and common gate biasing, the 11 devices were specially selected in order to get quite low dispersion on IDLHV and IGLHV

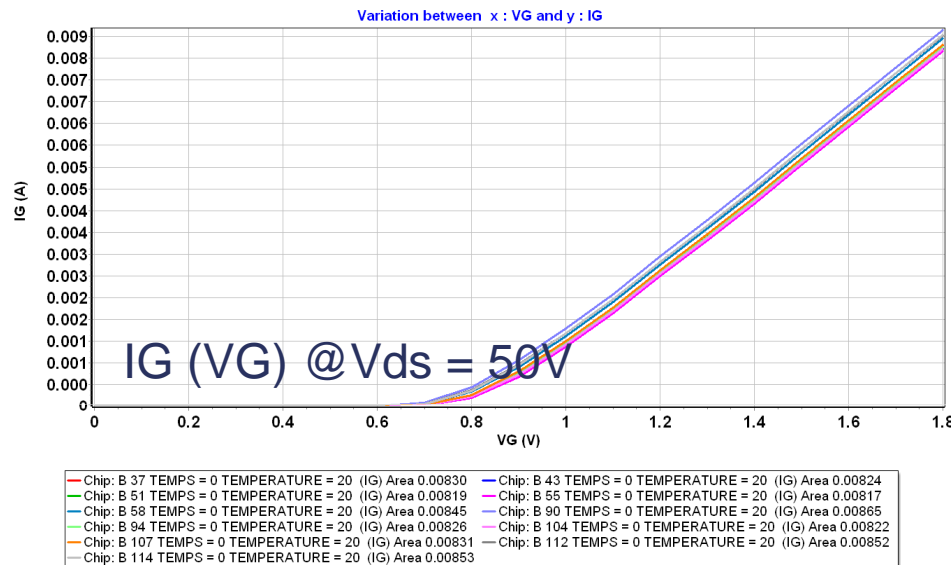


Spec Test = (None)  
HV = 50  
Mask : NOUMEAC, Lot : U460418, Wafer : 1, Device : 23693A  
Test File : U460418\_POW\_R1H  
Test Number : 669366  
Test Type : GANFET, Measure Type : GP04  
IDLHV : Average 70.15595, Standard deviation 20.01115, Area 66.29580  
Printed on 23/01/2019 by UMS

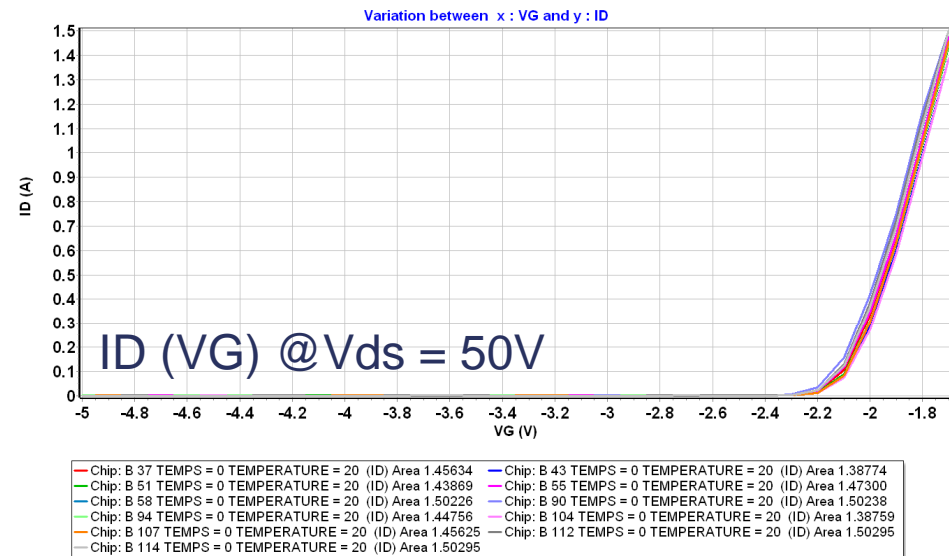
Spec Test = (None)  
HV = 50  
Mask : NOUMEAC, Lot : U460418, Wafer : 1, Device : 23693A  
Test File : U460418\_POW\_R1H  
Test Number : 669366  
Test Type : GANFET, Measure Type : GP04  
IGLHV : Average -3.96788, Standard deviation 3.39599, Area 10.83836  
Printed on 23/01/2019 by UMS

# GREAT<sup>2</sup> 3.1 – TID – HARDWARE

## Initial Measurements on pre-Selected Devices



Spice Test = (None)  
 Mask - NOLMEAC, Lot - U261818, Water - 1, Device - 23693A  
 Test File - U261818\_FOV\_R0H  
 Test Number - 668919  
 Test Type - GANFET, Measure Type - DIO  
 IG - Average 0.00238, Standard deviation 0.00204, Area 0.00885  
 Printed on 15/02/2019 by LMS



Spice Test = (None)  
 VG = -5, -4.9, -4.8, -4.7, -4.6, -4.5, -4.4, -4.3, -4.2, -4.1, -4, -3.9, -3.8, -3.7, -3.6, -3.5, -3.4, -3.3, -3.2, -3.1, -3, -2.9, -2.8, -2.7, -2.6, -2.5, -2.4, -2.3, -2.2, -2.1, -2, -1.9, -1.8, -1.7  
 Mask - NOLMEAC, Lot - U261818, Water - 1, Device - 23693A  
 Test File - U261818\_FOV\_R0H  
 Test Number - 668919  
 Test Type - GANFET, Measure Type - ID  
 ID - Average 0.10016, Standard deviation 0.31860, Area 1.50345  
 Printed on 15/02/2019 by LMS

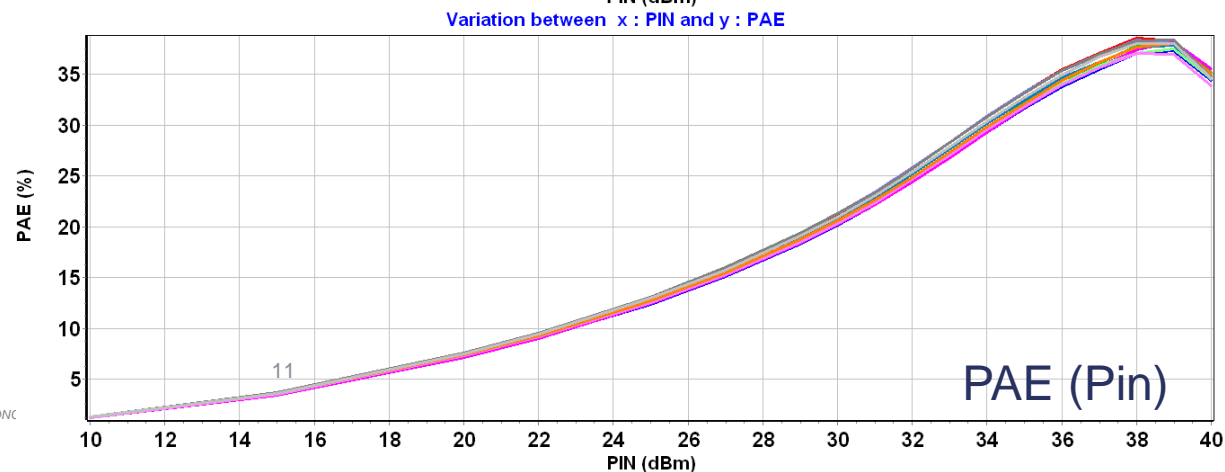
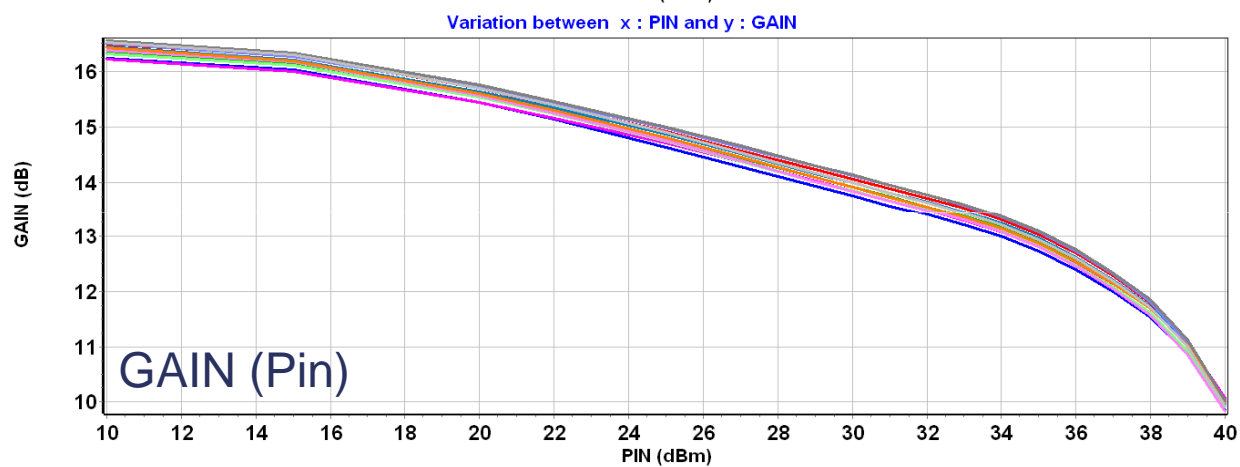
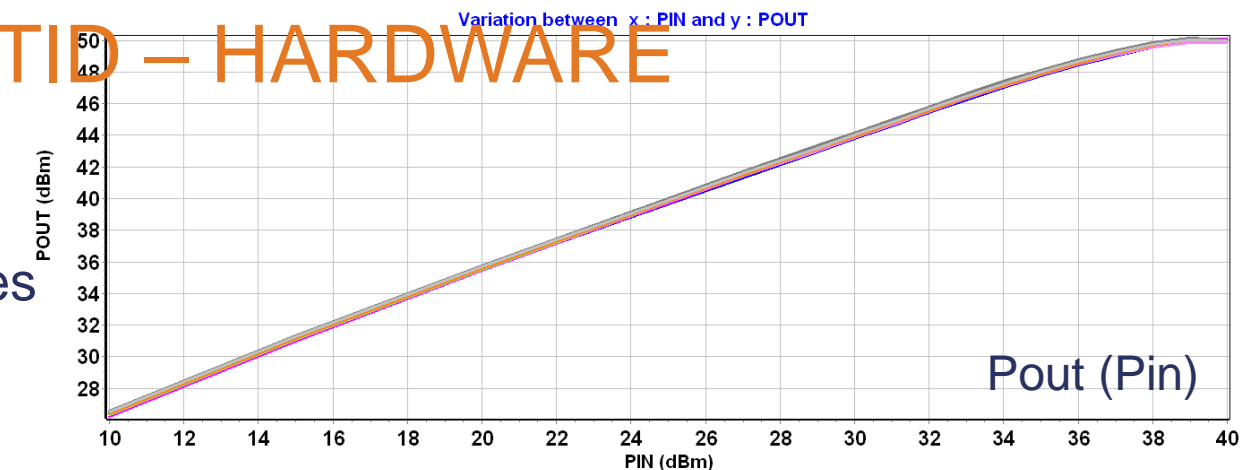
ID test #668919

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# GREAT<sup>2</sup> 3.1 – TID – HARDWARE

- Initial Measurements on pre-Selected Devices



ID test #668919

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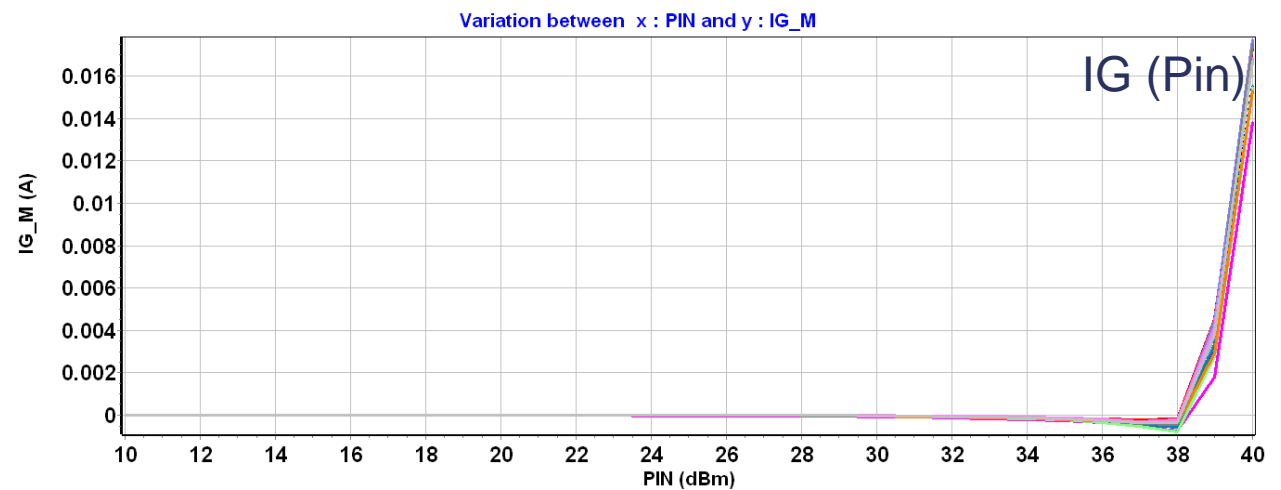
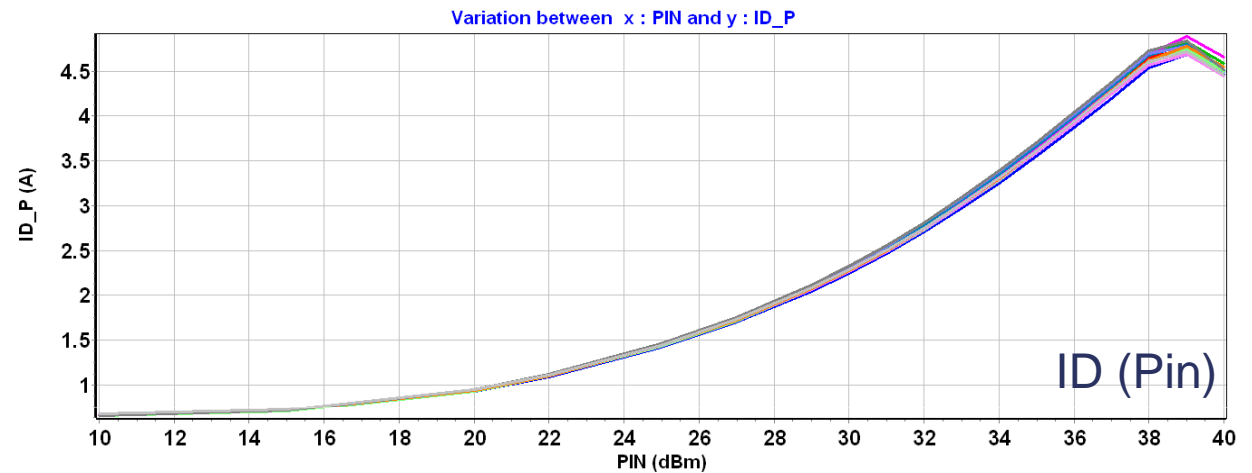
FOR PUBLICATION ON ESCIES



# GREAT<sup>2</sup> 3.1 – TID – HARDWARE

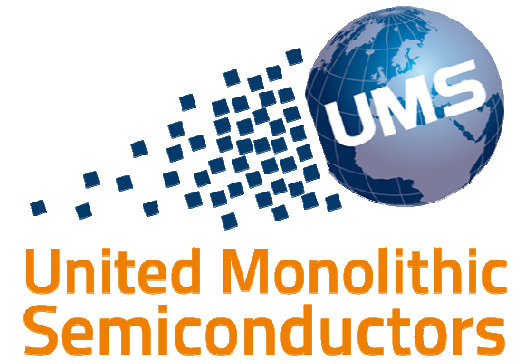


- Hardware
  - Initial measurements on pre-selected devices



ID test #668919

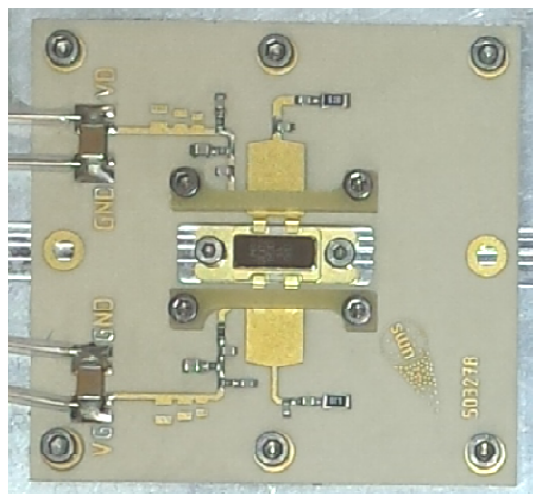
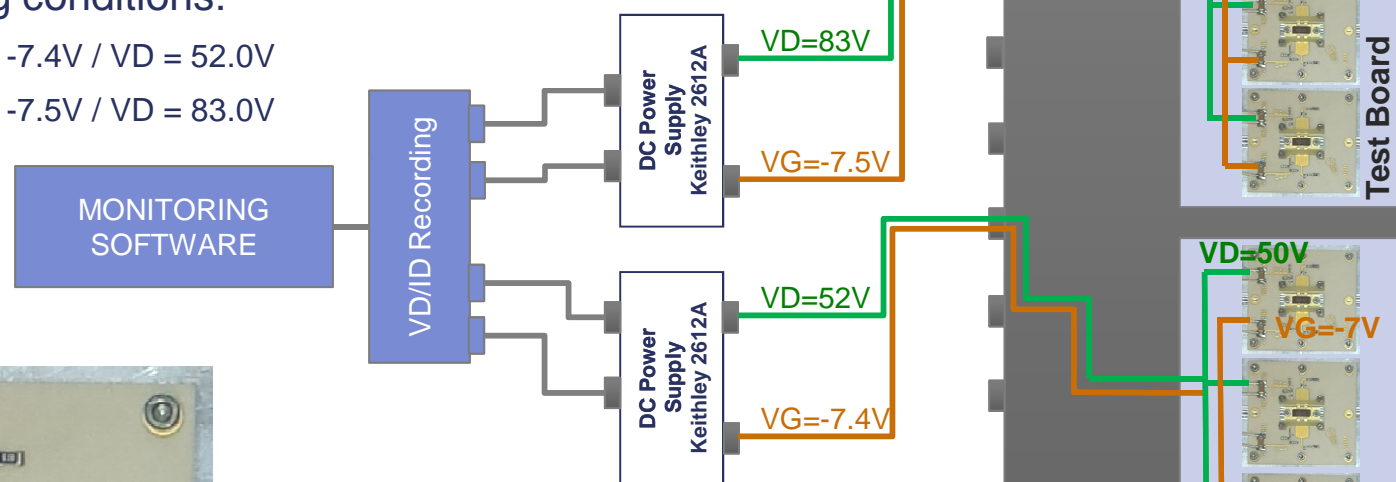




## TEST SET-UP

# GREAT<sup>2</sup> 3.1 – TID – TEST SET-UP

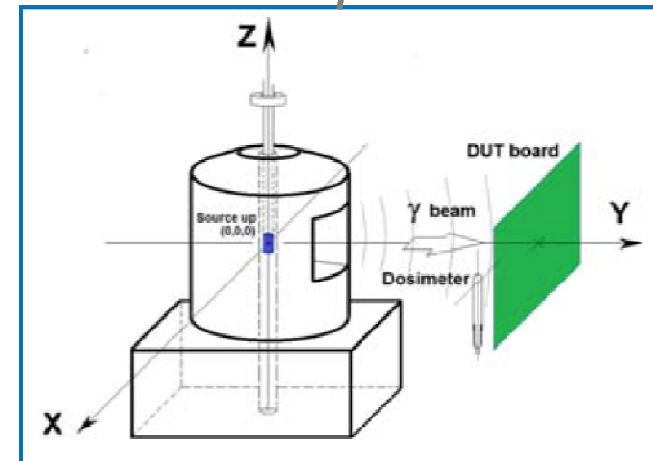
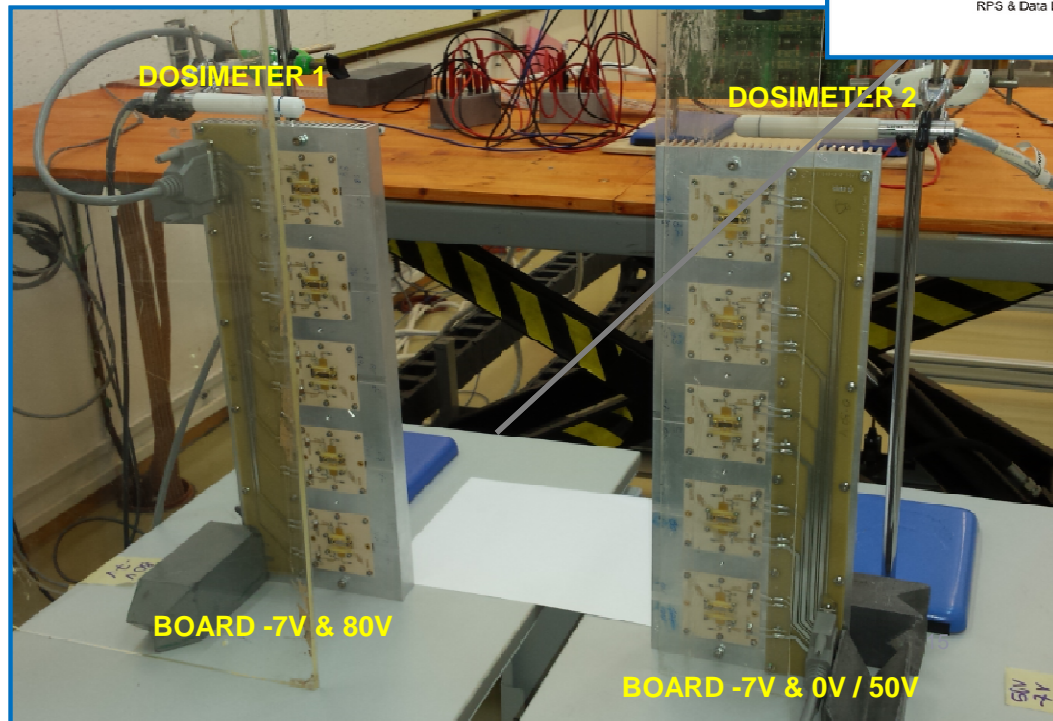
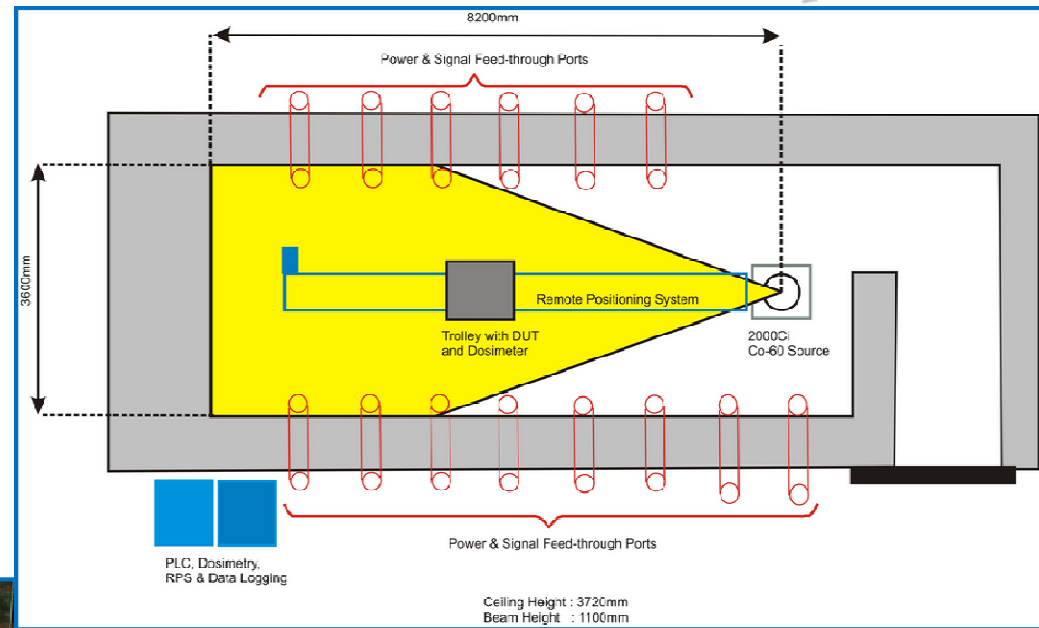
- Electrical set-up
  - Test performed at common biasing for VG and VD
    - To compensate voltage losses across the long cable from power supply to the test board in the irradiation chamber, power supplies were set at the following biasing conditions:
      - VG = -7.4V / VD = 52.0V
      - VG = -7.5V / VD = 83.0V

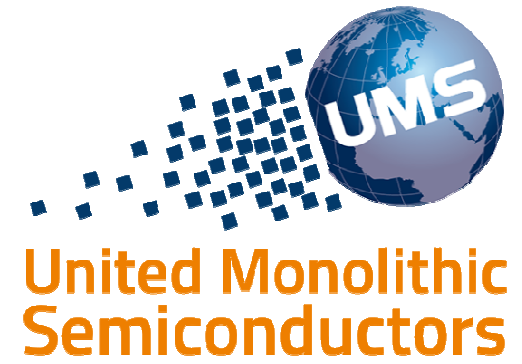


Focus on individual  
test circuit

# GREAT<sup>2</sup> 3.1 - TID – TEST SET-UP

## ■ TID Radiation Room Configuration





## TEST RESULTS



# GREAT<sup>2</sup> 3.1 – TID – TEST SET-UP

## ■ Data Monitoring

- Power Supplies were set at
  - VG = -7.4V / VD = 52.0V
  - VG = -7.5V / VD = 83.0V
- Individual device biasing were recording on the board before and after at each TID step
  - No specific changes occurred all along the test

	BEFORE FIRST RADIATION STEP		AFTER FIRST RADIATION STEP		BEFORE SECOND RADIATION STEP		AFTER SECOND RADIATION STEP	
<b>BOARD 80V</b>	<b>t=0h (26/11/2018 15:30)</b>		<b>t=100kRads (29/11/2018 11:00)</b>		<b>t=100kRads (29/11/2018 18:00)</b>		<b>t=300Krad (04/12/2018 10:10)</b>	
<b>DUT</b>	VD_MEAS;	VG_meas.	VD_meas.	VG_meas.	VD_meas.	VG_meas.	VD_meas.	VG_meas.
<b>B58</b>	81.3 V	-7.2 V	82.1 V	-7.3 V	81.9 V	-7.2 V	82.2 V	-7.3 V
<b>B94</b>	79.8 V	-7.0 V	81.4 V	-7.1 V	80.8 V	-7.0 V	81.6 V	-7.2 V
<b>B107</b>	80.6 V	-7.0 V	81.9 V	-7.3 V	81.5 V	-7.2 V	82.0 V	-7.3 V
<b>B112</b>	81.6 V	-7.2 V	82.2 V	-7.3 V	81.9 V	-7.3 V	82.3 V	-7.3 V
<b>B114</b>	82.0 V	7.3 V	82.4 V	7.4 V	82.2 V	7.3 V	82.4 V	7.4 V

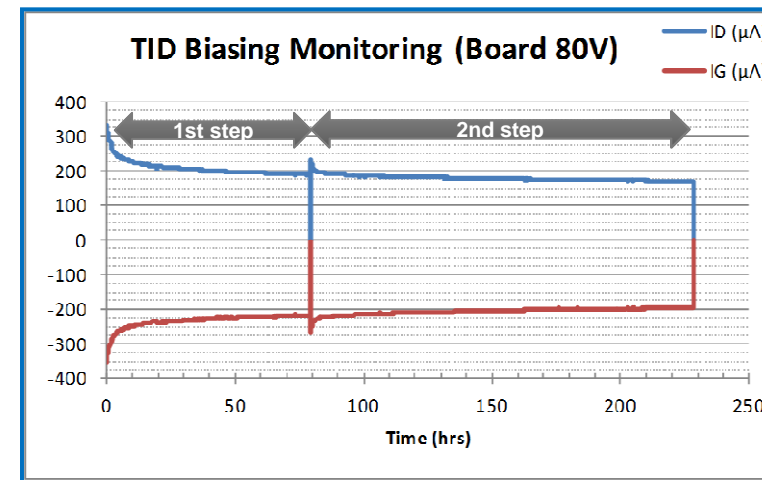
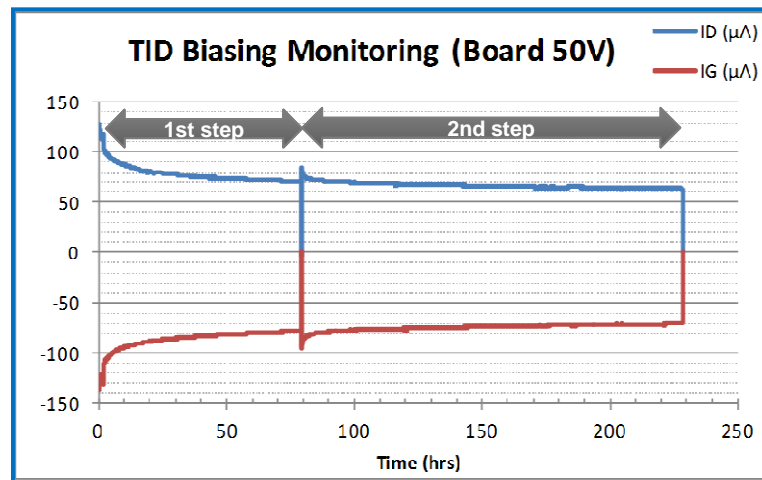
	BEFORE FIRST RADIATION STEP		AFTER FIRST RADIATION STEP		BEFORE SECOND RADIATION STEP		AFTER SECOND RADIATION STEP	
<b>BOARD 50V</b>	<b>t=0h (26/11/2018 15:30)</b>		<b>t=100kRads (29/11/2018 11:00)</b>		<b>t=100kRads (29/11/2018 18:00)</b>		<b>t=300Krad (04/12/2018 10:10)</b>	
<b>DUT</b>	VD_meas.	VG_meas.	VD_meas.	VG_meas.	VD_meas.	VG_meas.	VD_meas.	VG_meas.
<b>B37</b>	51.3V	-7.3V	51.6 V	-7.3 V	51.5 V	-7.3 V	51.6 V	-7.3 V
<b>B43</b>	51.2V	-7.2V	51.6 V	-7.3 V	51.5 V	-7.3 V	51.6 V	-7.3 V
<b>B51</b>	49.8V	-6.9V	50.9 V	-7.2 V	50.6 V	-7.1 V	51.0 V	-7.2 V
<b>B90</b>	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V
<b>B104</b>	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V	0.0V

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# GREAT<sup>2</sup> 3.1 – TID – TEST SET-UP

- Data Monitoring
  - IG and ID were in-situ monitored during the radiation test
    - No specific changes occurred all along the test



# GREAT<sup>2</sup> 3.1 – TID – TEST RESULTS

## ■ Data Monitoring

### ■ Co60 dose rate was monitored all along the test

- It is to be noticed that the initial target of 300 Krad was not reached due to external constraints that obliged to reduce the dose rate to ~22 rad/min, leading to a total cumulated dose of 274 Krad (in GaN). This value remains far from the standard dose of 100Krad.

Beam Step	Start Date & Time (CET)		End Date & Time (CET)		Total Ionising Dose ( GaN )	Dose Rate ( GaN )
1	26-11-2018	15:43	27-11-2018	10:23	24 082 rad	21.49 rad/min
2	27-11-2018	10:38	27-11-2018	12:14	2 163 rad	22.52 rad/min
3	27-11-2018	12:40	28-11-2018	10:13	28 965 rad	22.40 rad/min
4	28-11-2018	10:49	28-11-2018	12:19	2 019 rad	22.40 rad/min
5	28-11-2018	12:29	29-11-2018	10:33	29 677 rad	22.41 rad/min
6	29-11-2018	10:50	29-11-2018	15:56	6 860 rad	22.41 rad/min
<b>First step</b>					<b>93 766 rad</b>	
7	29-11-2018	18:15	30-11-2018	11:09	22 806 rad	22.48 rad/min
8	30-11-2018	11:35	30-11-2018	13:14	2 240 rad	22.48 rad/min
9	30-11-2018	13:24	30-11-2018	18:35	6 996 rad	22.51 rad/min
10	30-11-2018	18:54	03-12-2018	10:02	85 154 rad	22.47 rad/min
11	03-12-2018	10:12	03-12-2018	14:04	5 208 rad	22.50 rad/min
12	03-12-2018	14:10	03-12-2018	16:45	3 487 rad	22.47 rad/min
13	03-12-2018	17:09	04-12-2018	10:37	23 550 rad	22.48 rad/min
14	04-12-2018	10:43	04-12-2018	12:38	2 588 rad	22.47 rad/min
15	04-12-2018	12:45	05-12-2018	9:59	28 630 rad	22.48 rad/min
<b>Second step</b>					<b>180 659 rad</b>	
<b>Gran Total</b>					<b>274 424 rad</b>	



# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS

DC meas.  
(t1\_initial)

TID biased  
(100Krad  
cumulated)

DC meas.  
(t2\_interim)

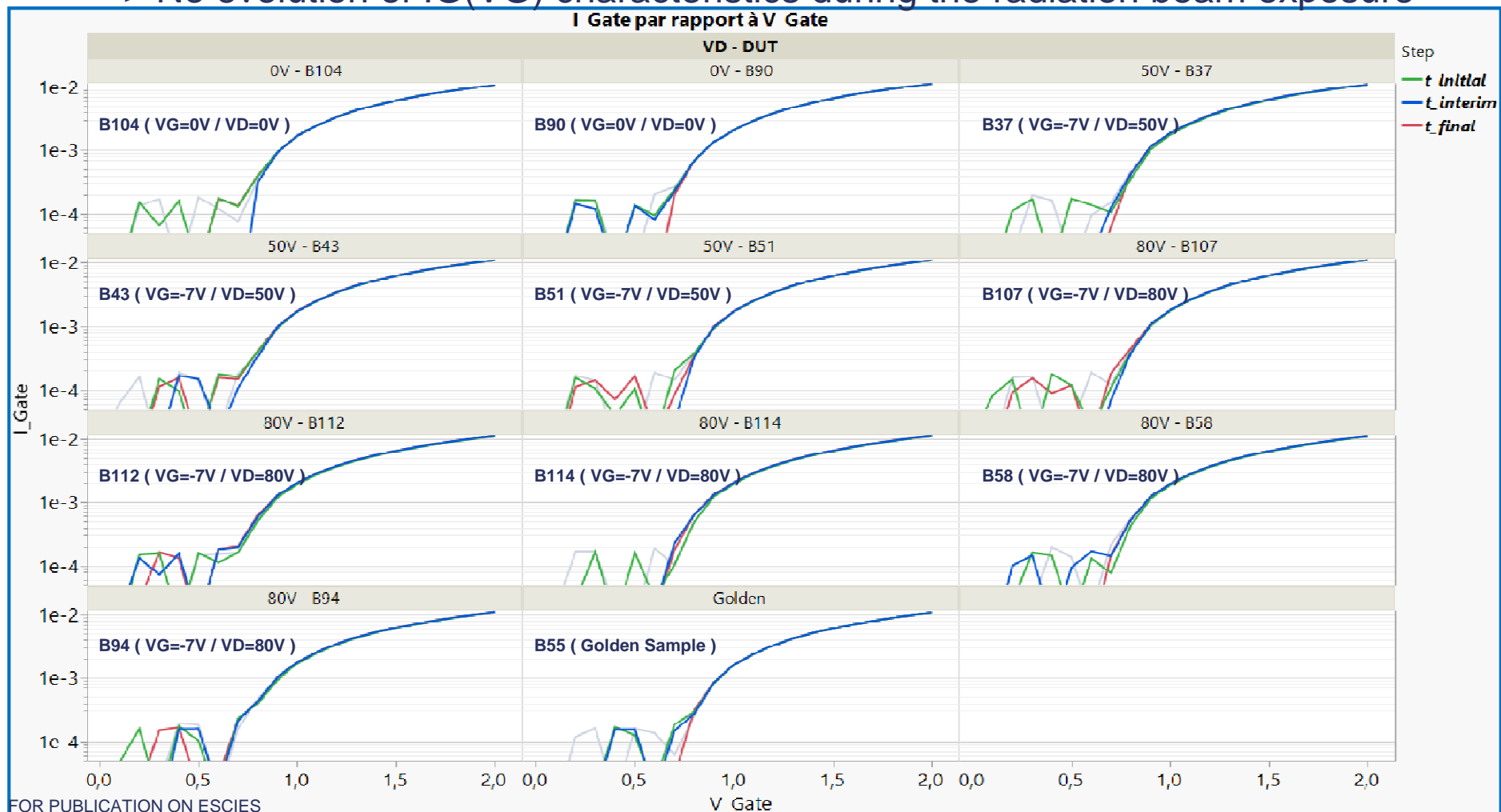
TID biased  
(300Krad  
cumulated)

DC meas.  
(t3\_final)

## ■ Interim Measurements Data Analysis

### ■ Forward IG(VG) characteristics

=> No evolution of IG(VG) characteristics during the radiation beam exposure



# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS

DC meas.  
(t1\_initial)

TID biased  
(100Krad  
cumulated)

DC meas.  
(t2\_interim)

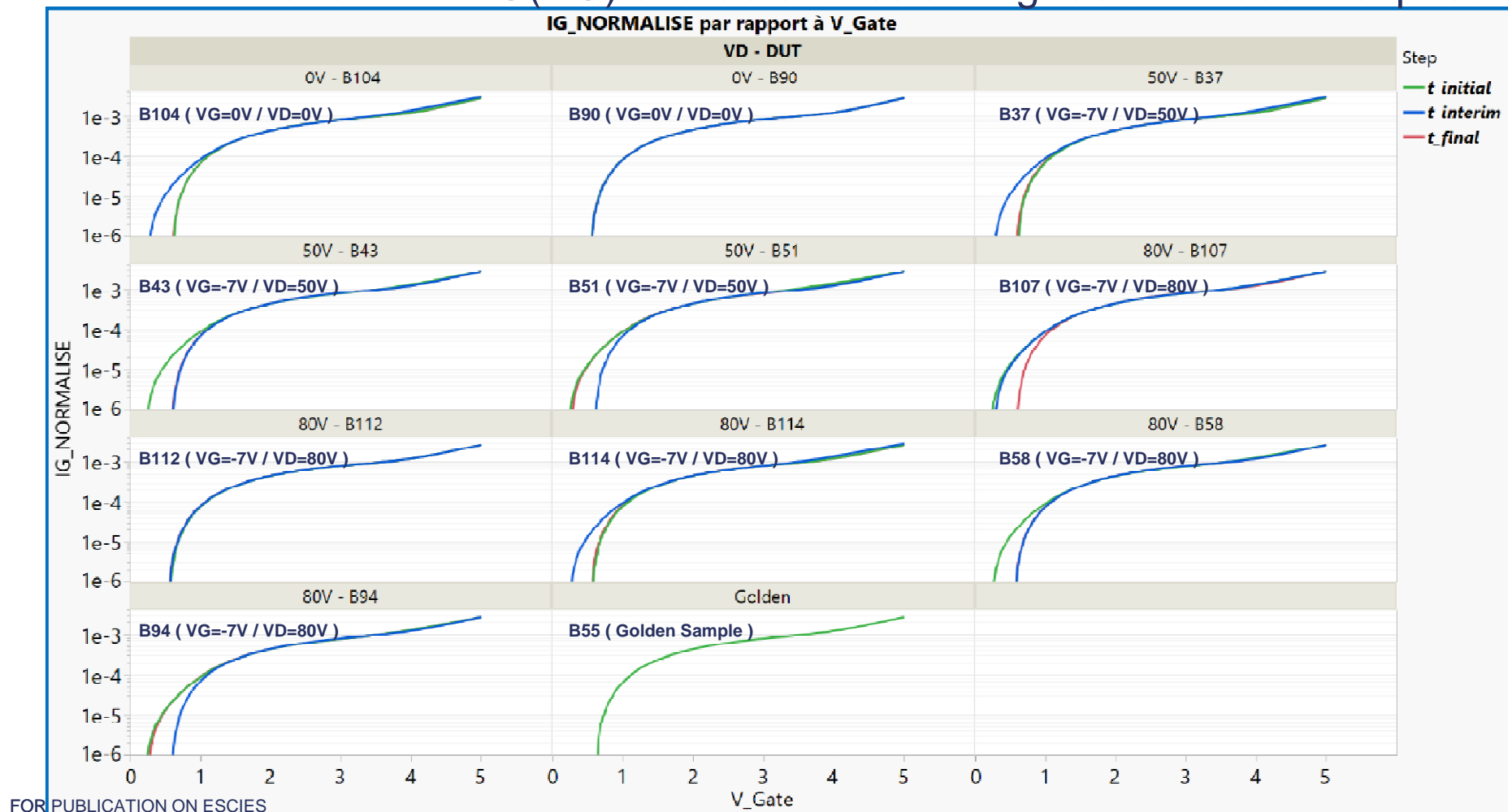
TID biased  
(300Krad  
cumulated)

DC meas.  
(t3\_final)

## ■ Interim Measurements Data Analysis

### ■ Reverse IG(VG) characteristics

=> Low variation of IG(VG) characteristics during radiation beam exposure



# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS

DC meas.  
(t1\_initial)

TID biased  
(100Krad  
cumulated)

DC meas.  
(t2\_interim)

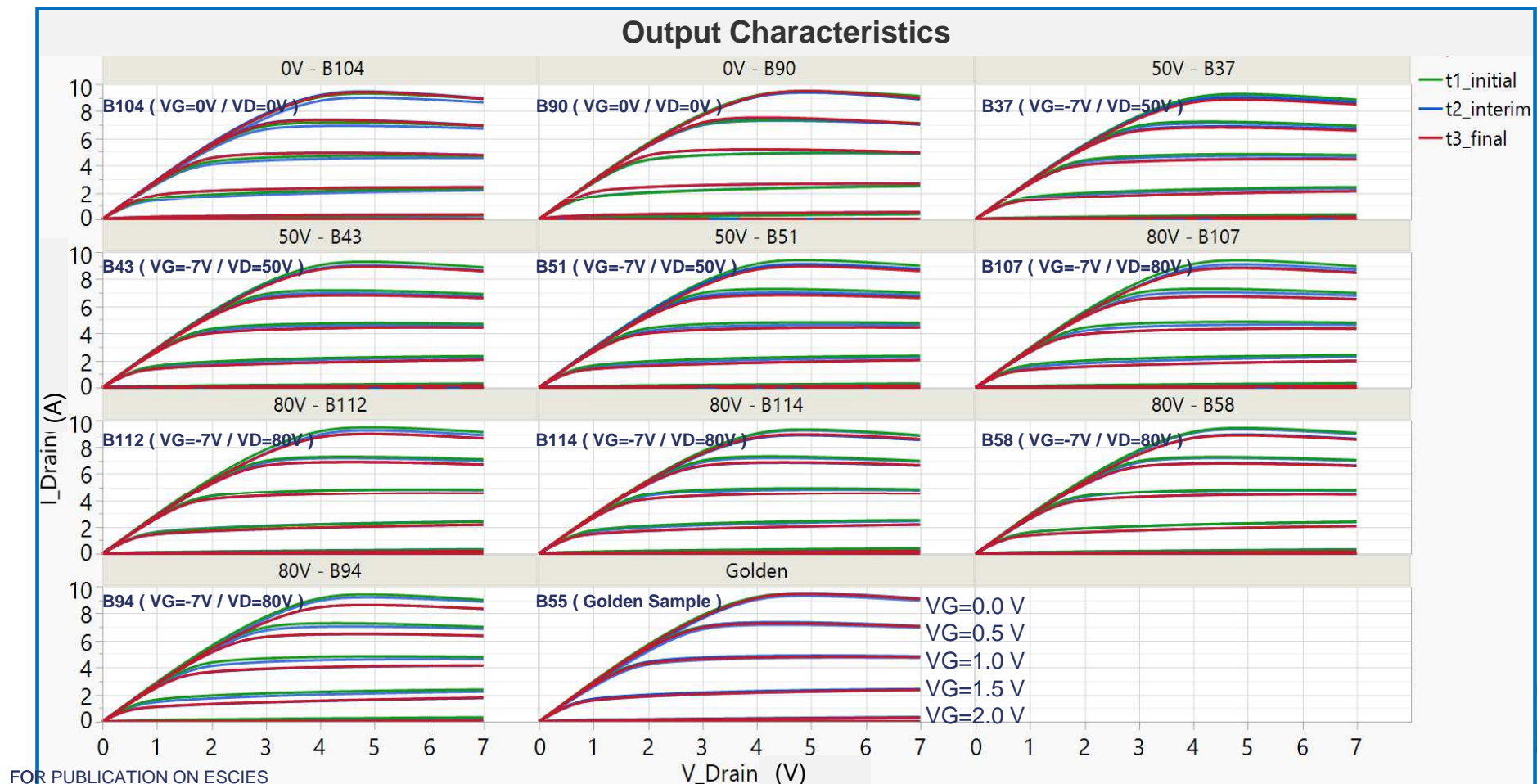
TID biased  
(300Krad  
cumulated)

DC meas.  
(t3\_final)

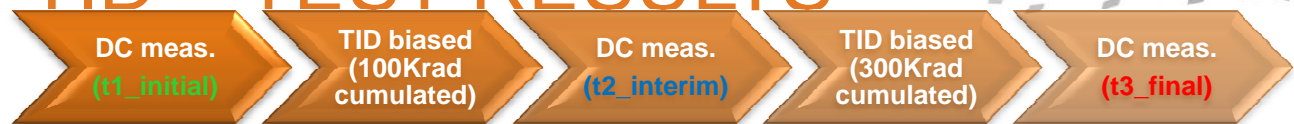
## ■ Interim Measurements Data Analysis

### ■ ID(VD) characteristics

=> Low variations of ID(VD) characteristics during the radiation beam exposure



# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS



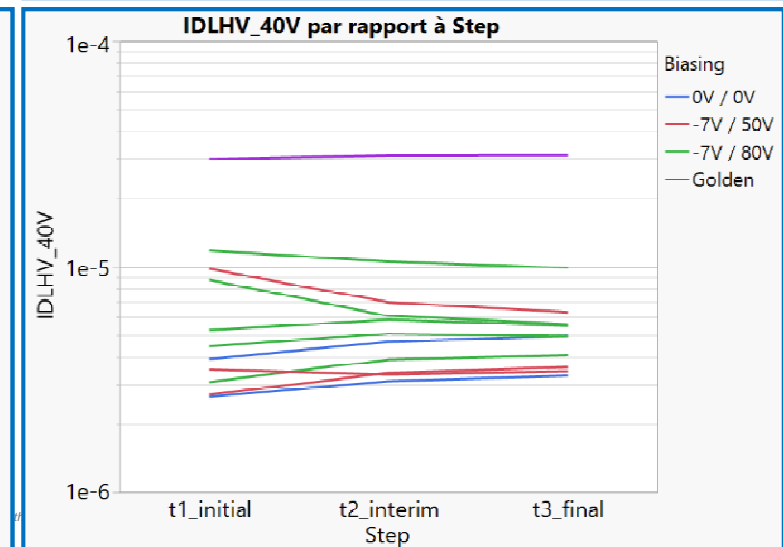
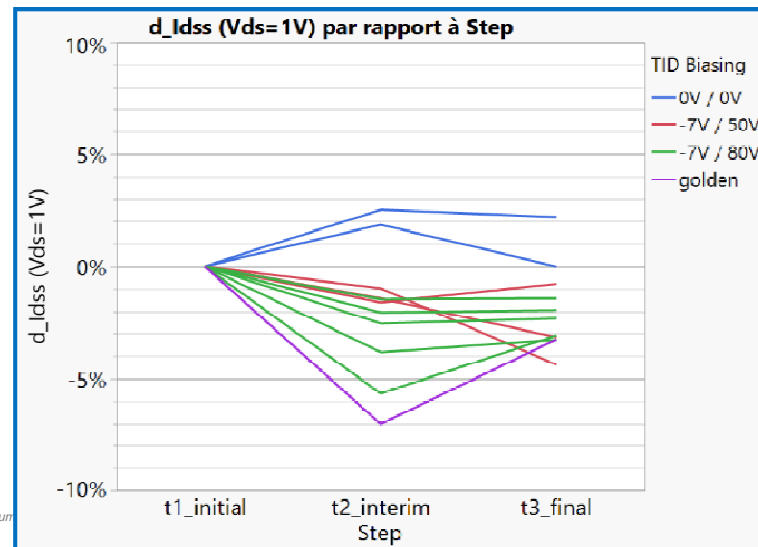
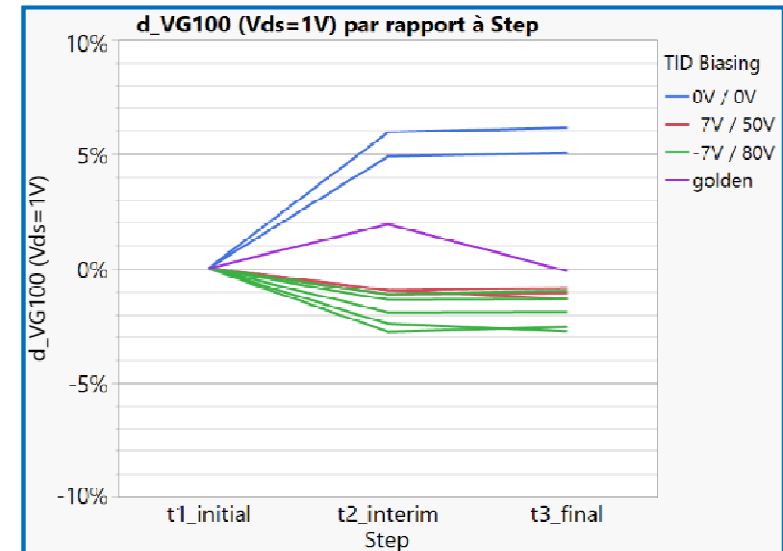
## ■ Interim Measurements Data Analysis

### ■ DC parameters

- Idss, VG100, IDLHV (40V) variations

=> Low impact of radiations on DC characteristics.

- VG100 : Main variations observed on grounded units
- Idss : Correlation is observed between drain Voltage and Idss decrease after first step, but lower discrimination at the end of radiation campaign

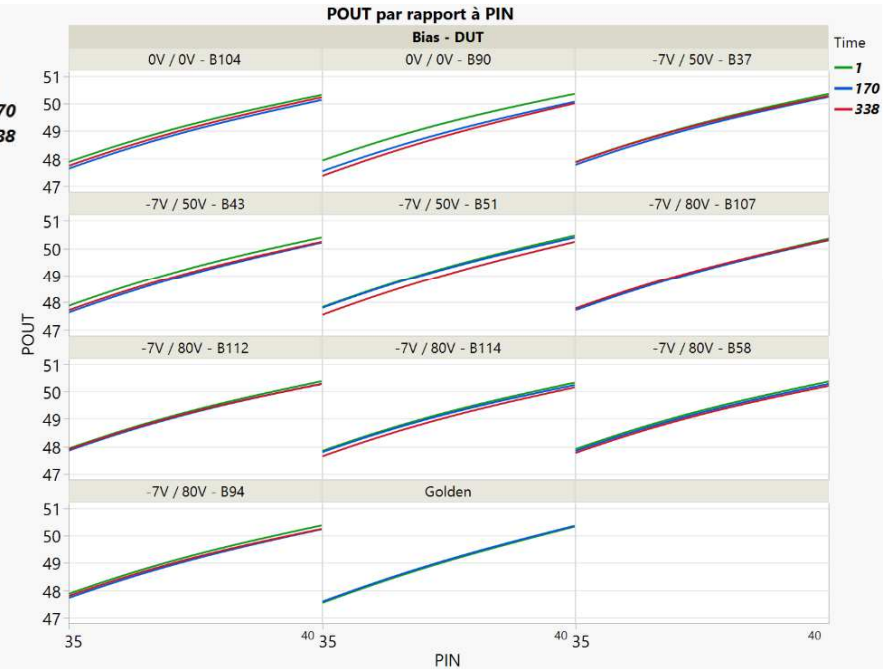
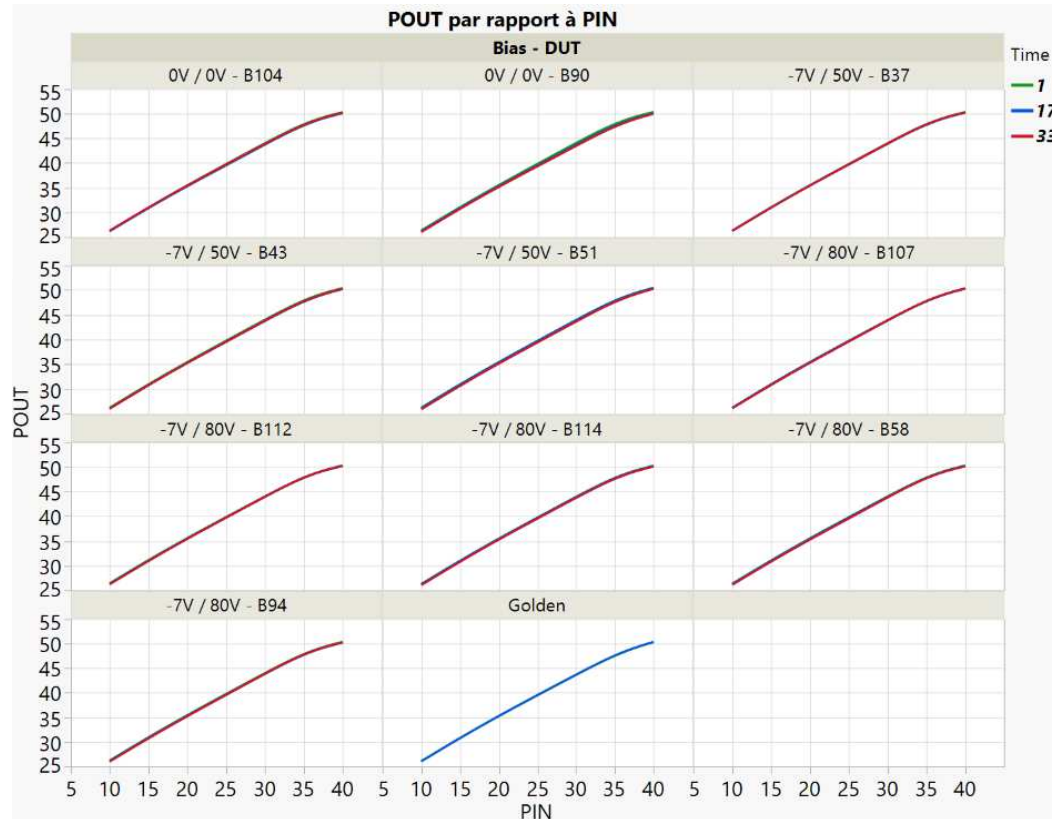


All information contained in this document



# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS

- TID Test + Annealing Step
  - RF characteristics
- => Low impact of radiations on DC



Focus on High Power Range





# GREAT<sup>2</sup> 3.1 - TID – TEST RESULTS

## ■ TID Test + Annealing Step

### ■ RF characteristics

=> No significant variation on RF power high level, and on gate current leakage

Note: reference device failed during last sequence of RF measurement

