EV12DS480AZP – Heavy Ions Test Report

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Scope :	**BUSINESS UNIT BMS**

Last revision approved by :

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1 DOCUMENT AMENDMENT RECORD

Author	Issue	Date	Reason for change
BONNET Olivier	A		Creation
BONNET Olivier	A.1		Curves added, text corrections
BONNET Olivier	A.2		Copyright added

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2 PURPOSE

The present document presents the SEE results of the TELEDYNE e2v EV12DS480AZP DAC device.
The heavy ions test performed at the RADEF, the week 16 of 2019.

3 GLOSSARY

CREME	Cosmic Ray Effects on Micro-Electronics
DAC	Digital-to-Analog Converter
DC	Direct Current
DSP	Digital Signal Processor
DUT	Device Under Test
HF	High Frequency
HIF	Heavy Ions Facility
IUCM	Input Under Clocking Mode
LED	Light-Emitting Diode
LET	Linear Energy Transfer
MTBF	Mean Time Between Failure
MUX	MUltipleXer
NRTZ	Narrow Return To Zero
NRZ	Non Return to Zero
OCDS	Output Clock Division Select Function
OMERE	Modelization tool for extern radiative environment
PSS	Phase Shift Select Function
RADEF	RADiation Effects Facility (Jyväskylä University laboratory, Finland)
RF	Radio Frequency
RTZ	Return To Zero
SEE	Single Event Effect
SEFI	Single Event Functional Interrupt
SEL	Single Event Latchup
SET	Single Event Transient

<u>In Graphs:</u>

- Minimum: Minimum value of each parts (except reference parts)
- Maximum: Maximum value of each parts (except reference parts)
- Mean: Mean value of each parts (except reference parts)
- Median: Median value of each parts (except reference parts), half of the devices are upper this limit, half are under

4 APPLICABLE AND REFERENCE DOCUMENTS

The documents applicable to this work are the following:

Document No.	Rev	Title
MIL-STD-883	J	Test Method Standard Microcircuits
ASTM-F 1192	2011	Standard Guide for the Measurement of Single Event Phenomena (SEP) Induced by Heavy Ion Irradiation of Semiconductor Devices
EIA/ JESD57	Dec. 1996	Test Procedure for the Management of Single-Event Effects in Semiconductor Devices from Heavy Ion Irradiation
DS 60S 217580	A.1	Datasheet EV12DS480AZP Low power 12-bit 8GSps Digital to Analog Converter with 4/2:1 Multiplexer

5 EXECUTIVE SUMMARY

5.1 Lot description

Reference	EV12DS480AZP
Package	FpBGA196
Function	Low power 12bit 8Gsps DAC
Technology	Infineon B7HF200
Diffusion Lot No.	RU516515
Mfr. No.	EV12DS480AMZP-N1
Mask Lot	VN62
Front End Date Code	1527
Manufacturer	Teledyne E2V

5.2 Heavy ions

Teledyne e2v has performed Heavy ions tests on the **EV12DS480AZP** DAC device to evaluate the sensitivity to the Single Event Latch up (SEL) & Single Event Effects (SEU, SEFI, SET) for various clock, 4.5GHz, 6GHz and 8GHz. A special code has been developed to manage automatically the SEFI by re-programming the registers.

Tests were performed at the RADEF, Jyväskylä, Finland, on the 15th, 16th and on the 17th of April 2019.

- No SEL was detected during the irradiation with a LET of 60 MeV.cm²/mg, with no tilt. 3 DUT were tested at Tj=135°C, with maximum power supplies + 10%.
- SET were observed during the irradiation from 3.6 MeV.cm²/mg to 69.3 MeV.cm²/mg, at room temperature and typical power supplies.
- SEFI were observed during the irradiation from 3.6 MeV.cm²/mg to 69.3 MeV.cm²/mg but all these SEFI were successfully managed by software
- There is no significant gap between SET/SEFI cross sections obtained in the different modes.
- There is no significant gap between SET/SEFI cross sections obtained for DACOUT and DSPCLK.
- There is no impact of the clock frequency on the device, the SEFI cross section remains the same whatever is the clock, 4.5GHz, 6GHz or 8GHz

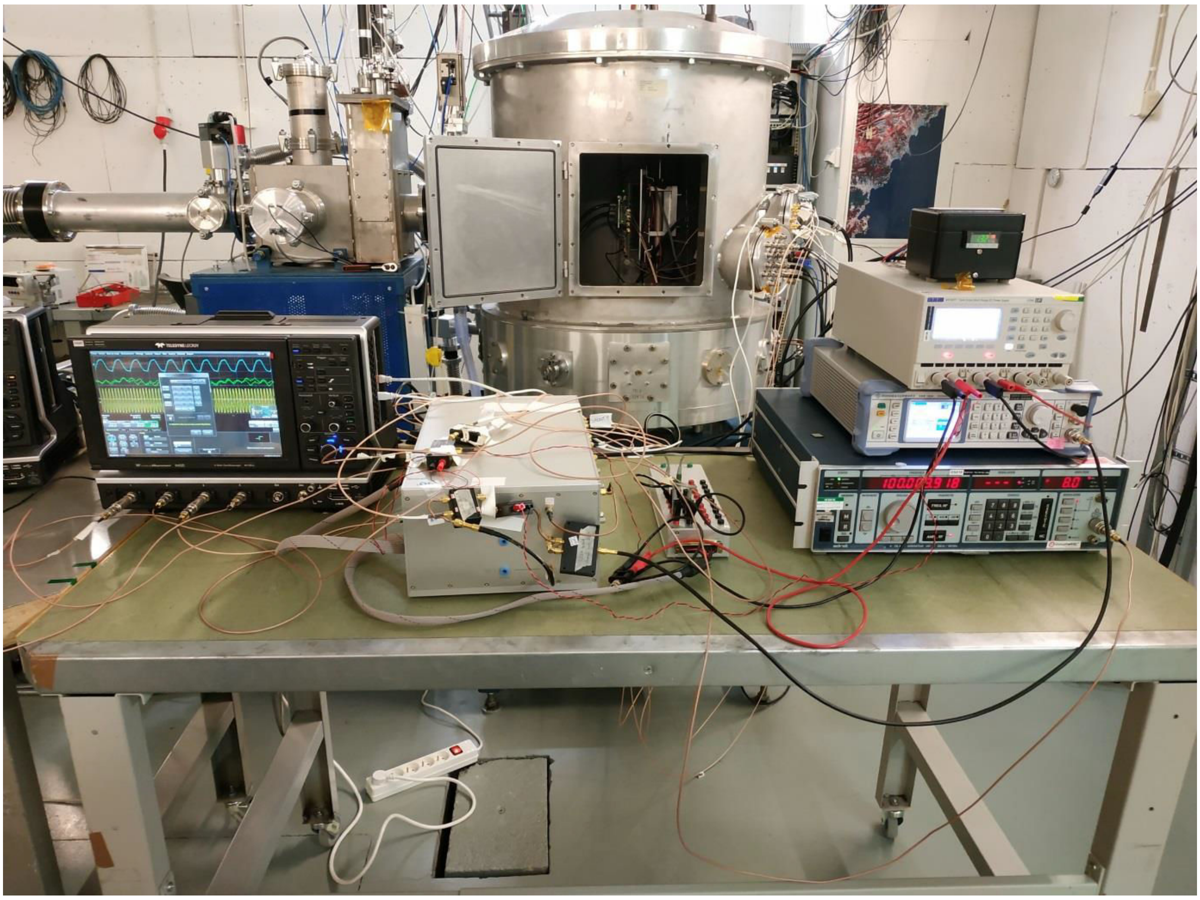
These SEE results show that the EV12DS480 DAC, can be used as a space product.

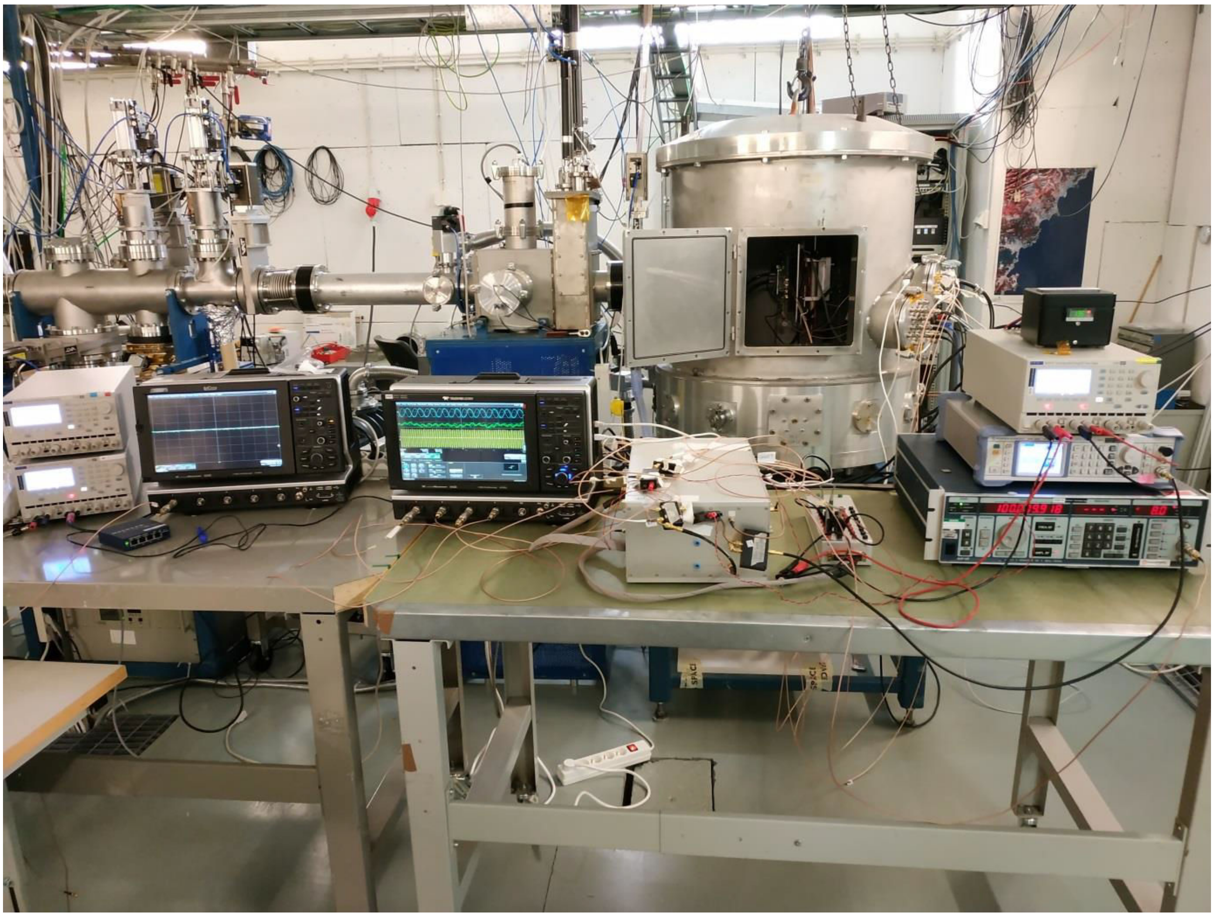
6 HEAVY IONS TEST

6.1 Irradiation facility

An irradiation tests was performed at Jyväskylä (Finland) on the 15th, 16th and on the 17th of April 2019 a maximum LET of **60 MeV.cm²/mg** without tilt, and **69.3 MeV.cm²/mg** with tilt (30°).

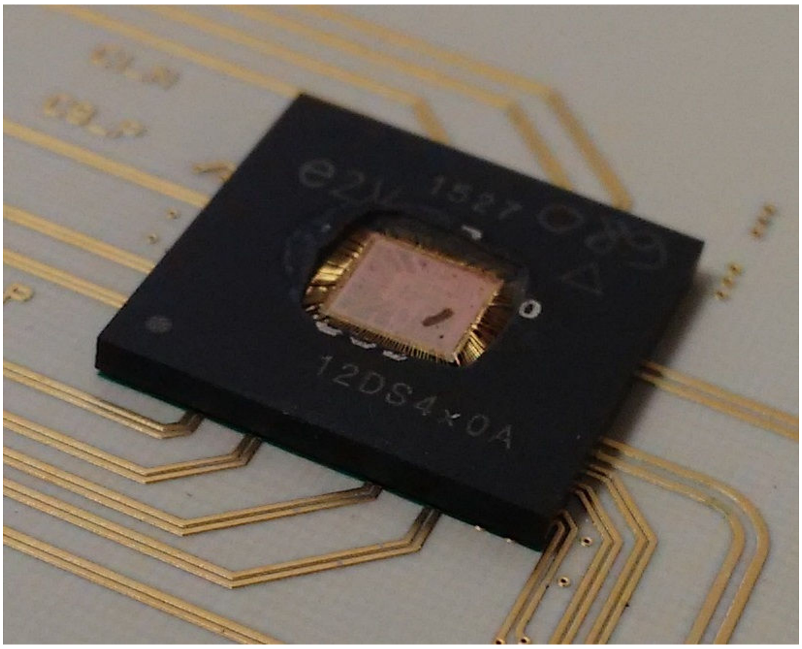
Config	Cocktail A MeV	Ion	Symbol	Tilt	Energy (MeV)	Range (µm(Si))	LET (MeV/mg/cm²) at Surface	LET (MeV/mg/cm²) Bragg peak
1	9.3	Neon	Ne	0°	186	146	3.63	5.9 (@198)
2	9.3	Iron	Fe	0°	523	97	18.5	29.3 (@77)
3	9.3	Krypton	Kr	0°	768	94	32.2	41 (@69)
4	9.3	Xenon	Xe	0°	1217	89	60.0	69.2 (@48)
5	9.3	Xenon	Xe	18°	1217	89	63.1	
6	9.3	Xenon	Xe	30°	1217	89	69.3	
7	16.3	Oxygen	$^{17}O^{6+}$	0°	284	481	1.52	7.17 (@477)
8	16.3	Iron	$^{57}Fe^{20+}$	0°	941	214	13.3	29.3 (@192)
9	16.3	Xenon	$^{126}Xe^{44+}$	0°	2059	157	48.5	69.3 (@119)





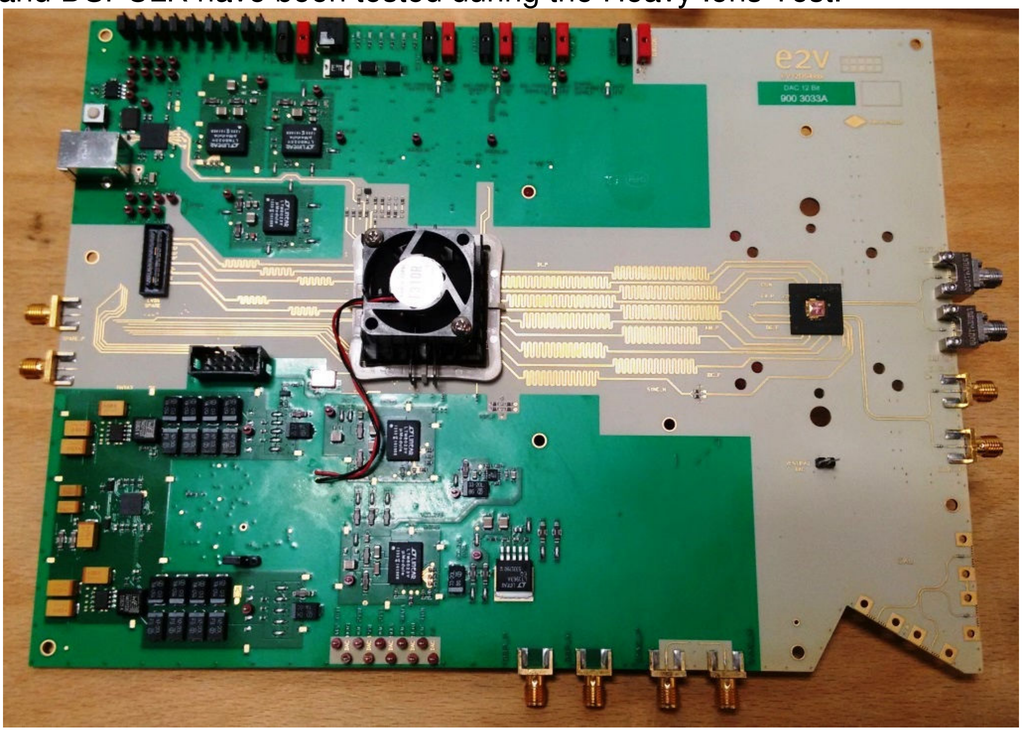
6.2 Components implementation

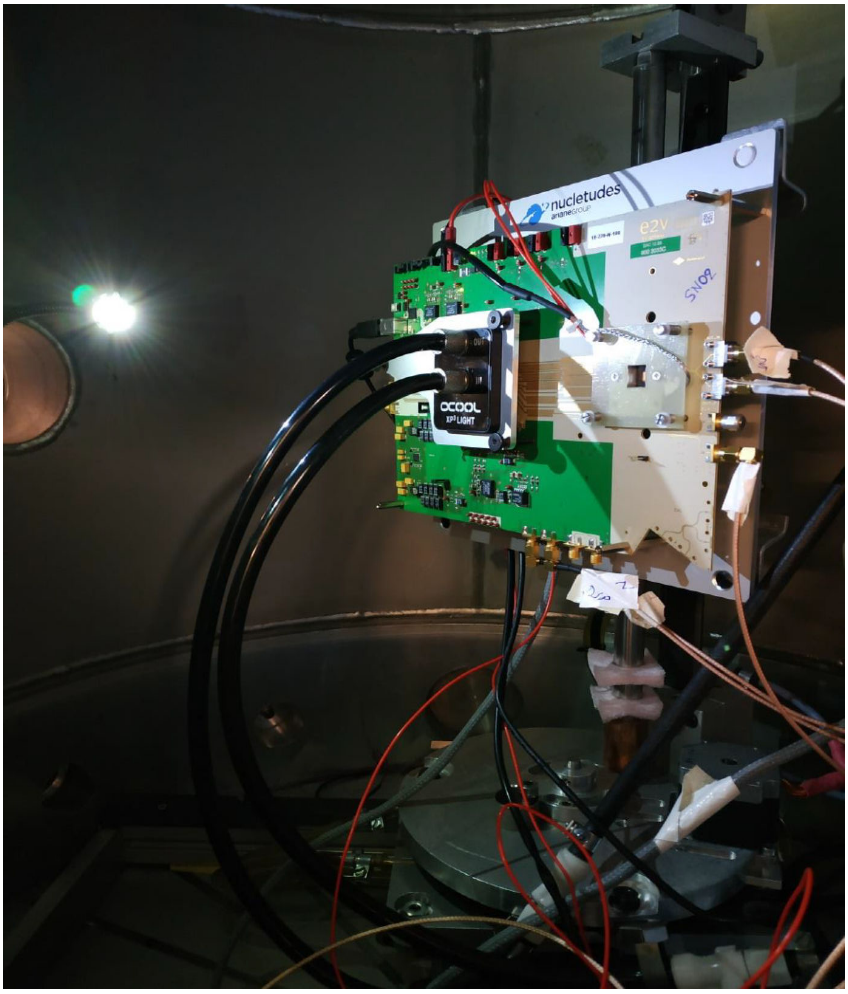
The devices have been decaped by using a chemical process.

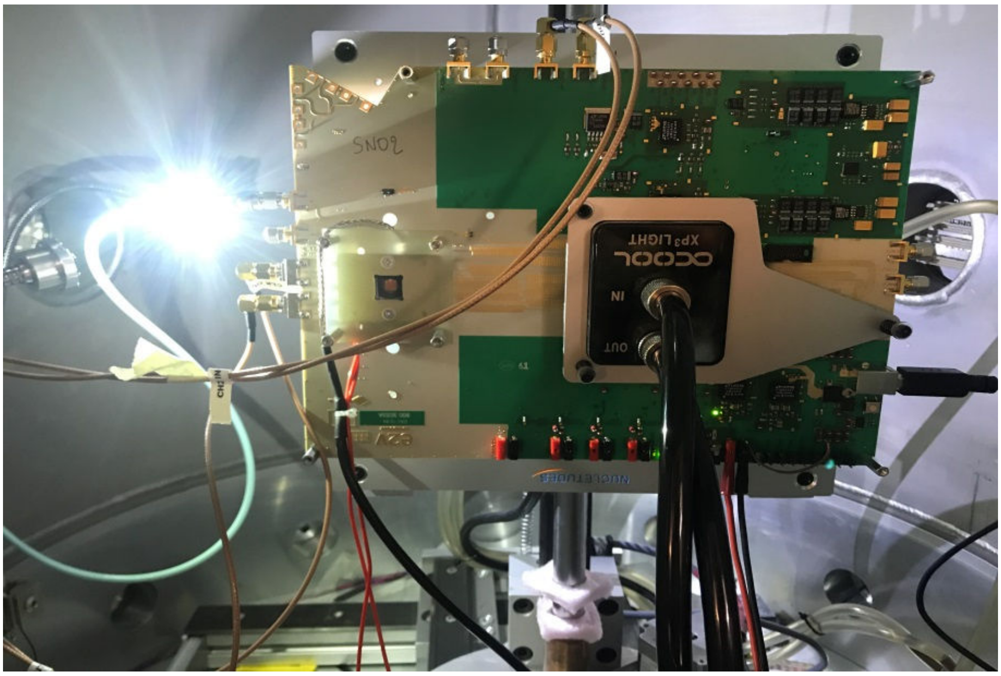


The opened devices have been soldered on Teledyne E2v evaluation boards which have been used to perform the heavy ions tests. These evaluation boards include a FPGA used to generate the pattern to the DAC (DUT).

DACOUT and DSPCLK have been tested during the Heavy Ions Test.




nucletudes
e2v
OCOOL
XP3 LIGHT
SN02


SN02
IN
OUT

6.3 Implementation equipment

The implementation equipment is described in the table below.

6.4 Measurement equipment

Designation	Reference	Identification	Valididty date
Scope	Teledyne Lecroy WR640Zi	ON067	08/04/2021
Scope	Teledyne Lecroy WR620Zi	ON063	31/08/2020
Multimeter	Agilent U1772A	Mu086	Checked before use
Power Supply	Fluke PM2811	QM3549	Checked before use
Syntheyser	Signal generator	QM4217	20/02/2020

6.5 Software used

Designation	Comments
Setup_CaracDAC12_1_3_0	E2V provider Carac DAC 12 bit FW : 1.1.0 FPGA : 2.0 Used for control DAC (Via USB interface)
GenICam 1.1	E2V provider V1.1 Used in order to install necessary drivers.
THIMS - SEFI	E2V provider Used to check SEFI signal from scope (Via USB interface) and to program DAC register (via USB interface) in case of SEFI detection. This soft has been developed with the experience of the SEFI management acquired during the first Heavy Ions run.
TightVnc	Remote controller V2.8.5 Used to perform a remote control of the scope. (Via Ethernet interface)

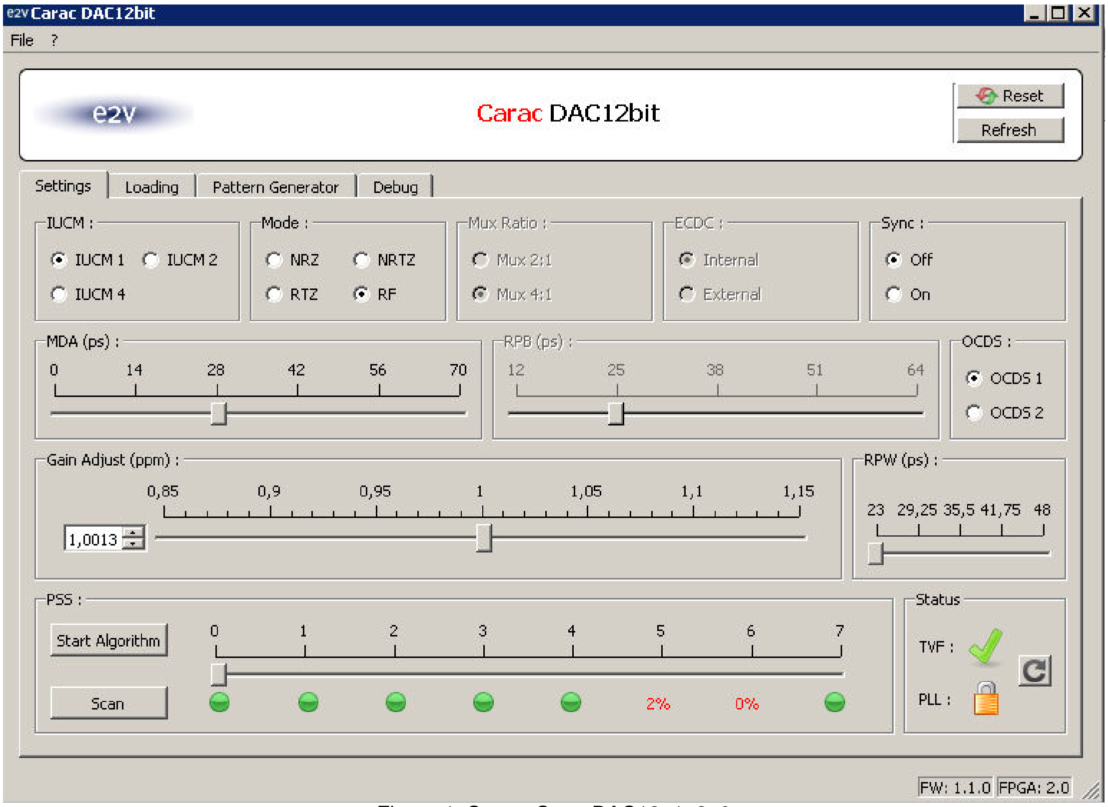


Figure 1: Setup_CaracDAC12_1_3_0

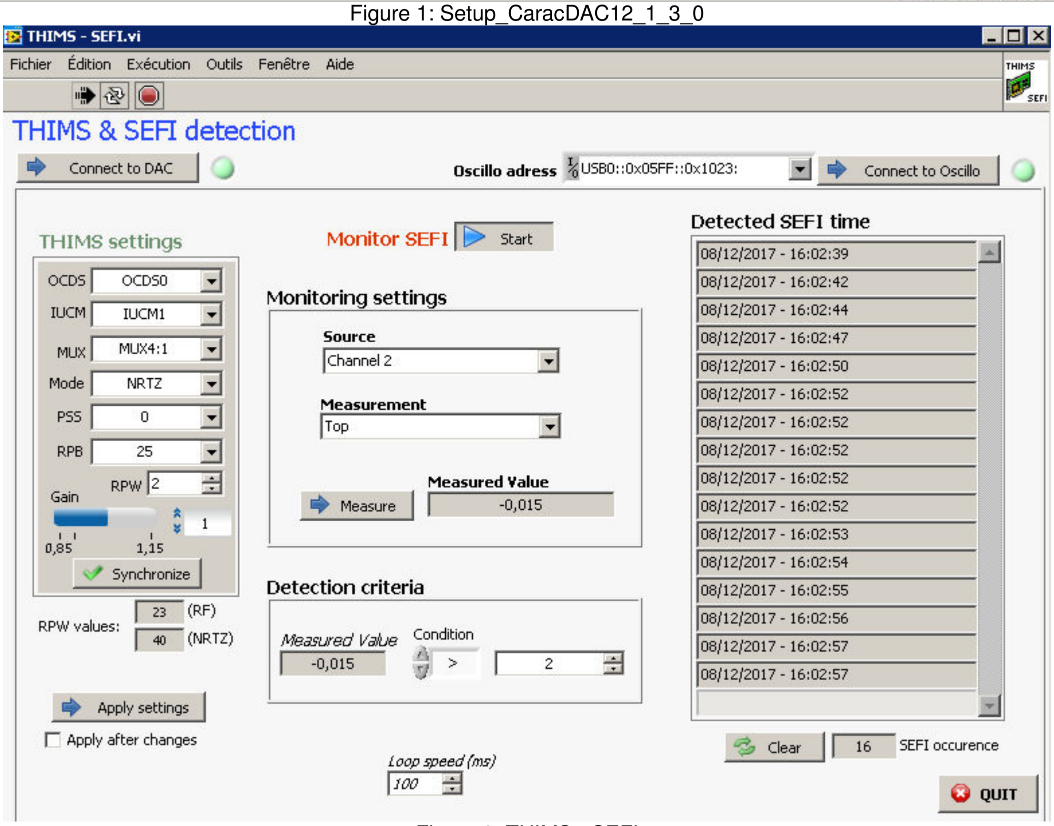


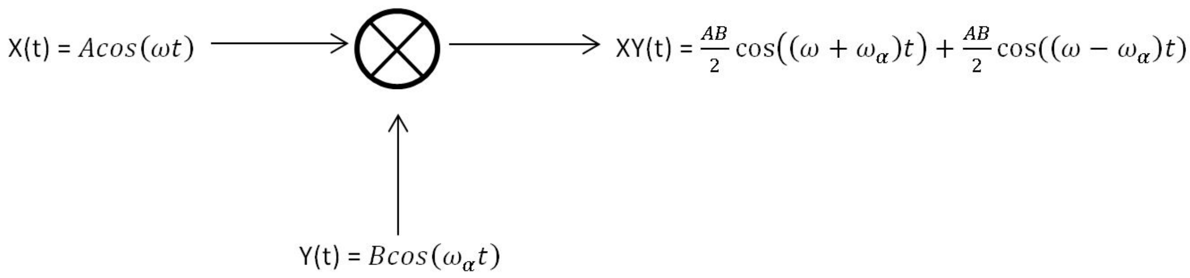
Figure 2: THIMS - SEFI

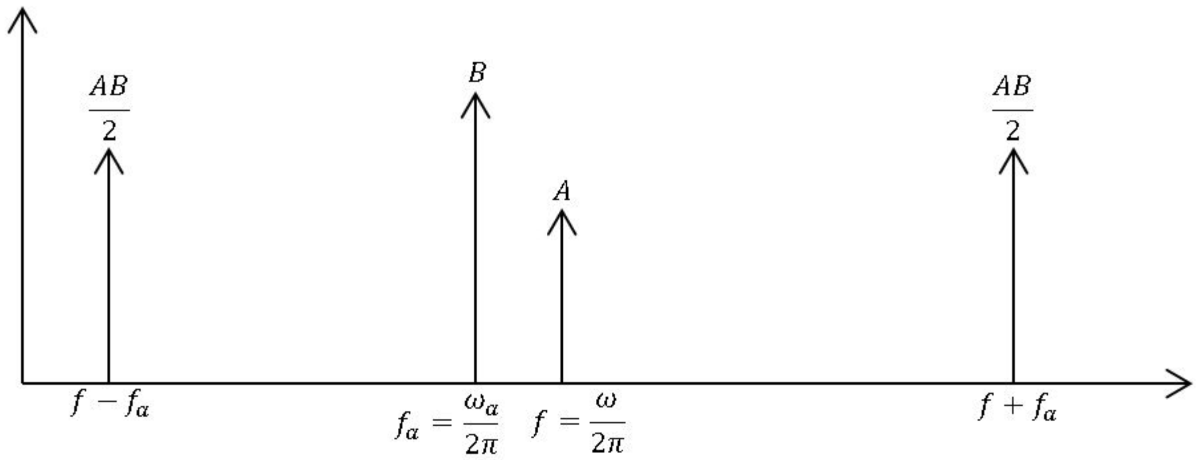
6.6 Implementation and measurement synoptic : Test1

Principle of SEE detection

Detecting SEE on microwave periodical signals implies to remove the periodical component of the output signal, and emphasize the transient component. The resulting signal allows triggering an oscilloscope each time a SEE occurs.

In order to remove the periodical part of a signal coming out of a component under test, a mixer is used. This type of circuit allows frequency transposition, which transposes a signal whose frequency is centered on an initial frequency to another frequency without altering its bandwidth.





The output signal is then filtered in order to keep either its higher frequency or its lower frequency band.

In the present case, the output signal of the DUT is mixed with a signal of same spectral content, in order to get a low pass filtered signal of 0 Hz that is a DC signal. Therefore this signal is composed of all energy other than that of the input signal. In other words it only consists of the transient part, non-sinusoidal part of the signal, coming from the disturbance impacting the DUT during heavy ion experiments.

Setup diagram

The simplified diagram presented below shows the SEL and SET/SEFI setup of the experimentation.

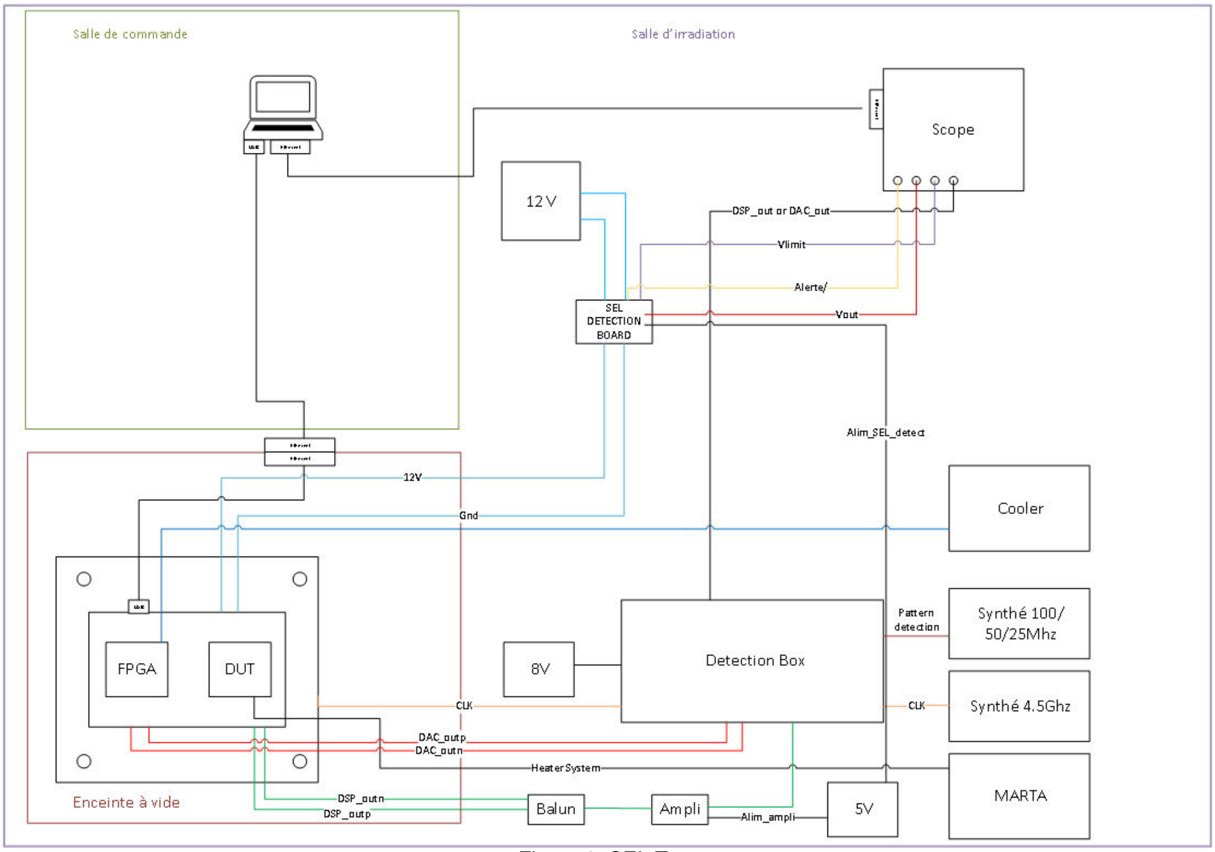


Figure 3: SEL Test

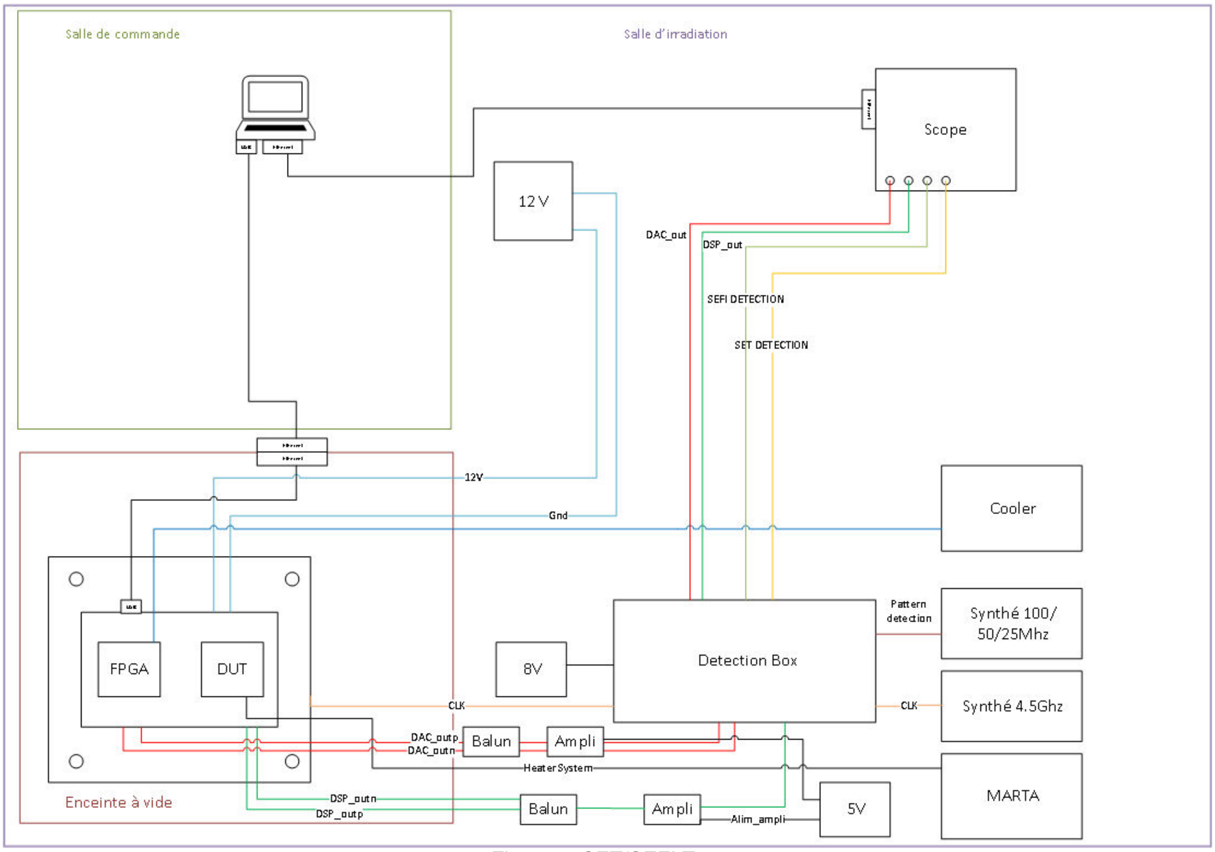


Figure 4: SET/SEFI Test

6.7 Implementation and measurement synoptic : Test2

For this test, both output (DACOUT & DSPCLK) were checked with a scope.

The scope was located in the bunker but was controlled from the control room.

DACOUT output was checked by a scope, with a min-max detection for the static pattern and with an envelope detection for the dynamic pattern.

Unfortunately, the scope has saved several time the SET so, for this test, only the SEFI are evaluated in this report.

6.8 Components configuration

Component configuration depends on several parameters, which are listed in the following paragraphs.

Input clock frequency

- Values: 4.5 GHz for Test1, 4.5, 6 and 8GHz for Test2;
- The input clock frequency is generated by a signal generator. It feeds the EV12DS4x0ZPY evaluation board.

Input signal : Test1

- Dynamic pattern: sine wave at 100 MHz frequency;

Input signal : Test2

Two patterns were used for this test:

- Static: Middle code pattern
- Dynamic : Sin pattern

Junction temperature

Junction Temperature	
SEL	SEE/SEFI
135°C	125°C

Power supply

Power supply	
SEL	SEE/SEFI
VCCA5 = 5V + 10%	VCCA5 = 5V
VCCD = 3.3V + 10%	VCCD = 3.3V
VCCA3 = 3.3V + 10%	VCCA3 = 3.3V

Output mode

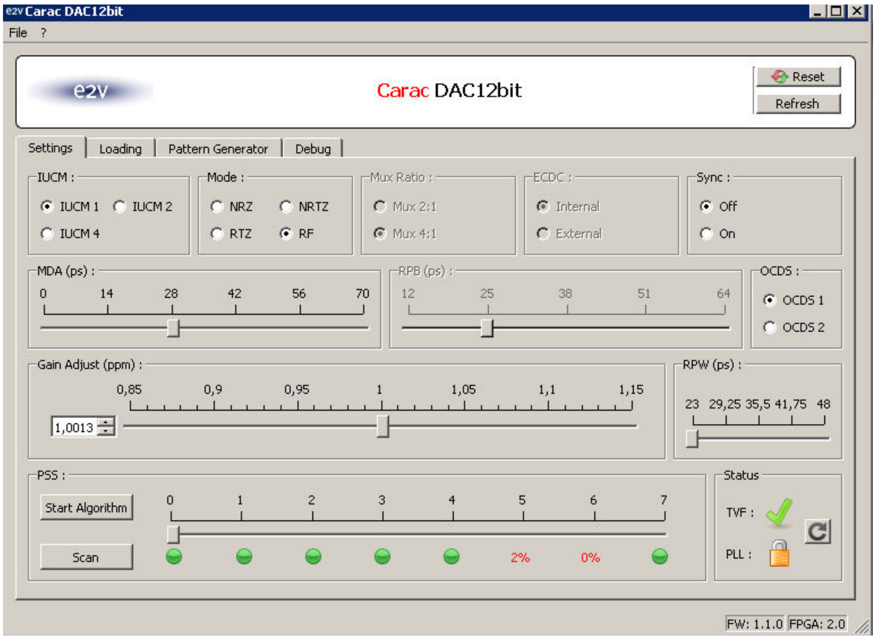
4 modes have been used

Label	Value	Description	Default setting
MODE[1:0]	00	NRZ mode	01 (NRTZ)
	01	Narrow RTZ (a.k.a. NRTZ) mode	
	10	RTZ Mode (50%)	
	11	RF mode	

The mode was set by using the Teledyne e2v software

mode	Mux	OCDS	IUCM	Pss	RPW	RPB	GA
NRZ	4	0	00	111	0	0	200

NRTZ	4	0	00	111	1	1	200
RTZ	4	0	00	111	1	1	200
RF	4	0	00	111	1	1	200



6.9 Test setup

Before each irradiation run, the proper operation of the DUT was checked.

For each run, any detected event causes the recording of all signals listed in the table below.

Signals				
Channel 1	Channel 2	Channel 3	Channel 4	Aux
DSPclk	SEFI trigger	DACout	SET trigger	Not used

SEL

Latchup has been monitored on the following DUT power supplies:

- VCCA5
- VCCD
- VCCA3

Tests have been done at the maximum operating temperature + 10C (135 ℃).

Latchup detection and cut-off board were set to detect an increase of 20% of the nominal current consumption value.

Each time a latchup would occur, the system would switch off the power supply in less than 150 µs after the detection.

SET

SET detection has been performed thanks to a detection board.

The detection board has an attenuation of 14 dB on single-ended channels, and 10 dB on differential channels.

Each detection level is set according to the observed trigger signal in order to be as close as possible to the trigger level.

The conversion of differential signals to single-ended signal is made with baluns, located on the detection board.

The minimum sensitivity of this system was defined experimentally:

Sensitivity of the SET detection system	Time min.	Amplitude min.
DACOUT	≈ 3 ns	40 mV
DSPCLK	≈ 5 ns	100 mV

SEFI

SEFI detection is provided by specific signals (one for DACOUT and one for DSPCLK). If necessary a buzzer could be positioned on the control desk. The buzzer rings when a SEFI occurs.

This detection remained active during all the campaign.

SEFI detection (Alert/ signal) is checked by E2V THIMS software.

SEFI have been classified in term of impact on the device.

SEFI 1	Solved by re-programming the registers
SEFI 2	Solved by using the RESET
SEFI 3	Solved by switching-off the device

TEST LEVEL

For SEL research, the test is stopped when a fluency of 10^7 ions.cm-2 is reached, or when at least 100 events are detected.

For SET research, the test is stopped when a fluency of 10^6 ions.cm-2 is reached, or when at least 100 events are detected.

6.10 Dosimetry

Dosimetry was provided by the RADEF. Fluency, irradiation times and deposited ionizing dose were provided for each run and presented in the following tables.

7 RESULTS

During this campaign, we managed the SEFI with an automatic soft which was programming the registers. Only SEFI 1 were detected during this campaign.

7.1 SEL Results

The SEL test was performed at 135℃ and at maximum supply voltage + 10% with 3 devices.

Description	RUN	Ion	Energy (MeV)	Range (µm (Si))	LET (MeV/mg/cm²)	DUT	Effect	Supply voltage (V)	Tj (°C)	Frequency	Mode	Pattern	Loop	Dose (rad(Si))	Flux (ions/cm²/s)	Time (s)	Fluence (ions/cm²)	SEL Number	SEL Cross section (cm²)	SET Number	SET Cross section (cm²)	SEFI Number	SEFI Cross section (cm²)	SET+SEFI Number	SET+SEFI Cross section (cm²)	Channel 3	Channel 1
TEST SEL Ion Xenon - Board SN01																											
NRZ DACOUT/DSPCLK SEL	01	Xe no tilt	1217	89	60	1	SEL	Max	135°C	4,5 GHz	NRZ	Dynamic	100ms	9.65E+03	4,25E+04	236	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRZ DACOUT/DSPCLK SEL	03	Xe no tilt	1217	89	60	1	SEL	Max	135°C	4,5 GHz	NRZ	Dynamic	100ms	9.62E+03	4,17E+04	249	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RTZ DACOUT/DSPCLK SEL	07	Xe no tilt	1217	89	60	1	SEL	Max	135°C	4,5GHz	RTZ	Dynamic	500ms	9.64E+03	3.2E+04	323	1,0E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRTZ DACOUT/DSPCLK SEL	04	Xe no tilt	1217	89	60	1	SEL	Max	135°C	4,5GHz	NRTZ	Dynamic	500ms	9.64E+03	3.94E+04	262	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	05	Xe no tilt	1217	89	60	1	SEL	Max	135°C	4,5GHz	RF	Dynamic	500ms	9.64E+03	3.5E+04	298	1,0E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	06	Xe tilt 18	1217	89	63.5	1	SEL	Max	135°C	4,5GHz	RF	Dynamic	500ms	1.01E+04	3.3E+04	325	1,0E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	41	Xe no tilt	1217	89	60	2	SEL	Max	135°C	4,5 GHz	RF	Dynamic	100ms	9.65E+03	4.55E+04	219	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RTZ DACOUT/DSPCLK SEL	42	Xe no tilt	1217	89	60	2	SEL	Max	135°C	4,5GHz	RTZ	Dynamic	100ms	9.66E+03	4.57E+04	216	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRTZ DACOUT/DSPCLK SEL	43	Xe no tilt	1217	89	60	2	SEL	Max	135°C	4,5GHz	NRTZ	Dynamic	100ms	9.62E+03	4.56E+04	217	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRZ DACOUT/DSPCLK SEL	44	Xe no tilt	1217	89	60	2	SEL	Max	135°C	4,5GHz	NRZ	Dynamic	100ms	9.62E+03	4.62E+04	215	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	40	Xe tilt 18°	1217	89	63.5	2	SEL	Max	135°C	4,5GHz	RF	Dynamic	100ms	1.01E+04	4.4E+04	230	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	48	Xe no tilt	1217	89	60	3	SEL	Max	135°C	4,5GHz	RF	Dynamic	100ms	9.65E+03	4.76E+04	212	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RTZ DACOUT/DSPCLK SEL	47	Xe no tilt	1217	89	60	3	SEL	Max	135°C	4,5GHz	RTZ	Dynamic	100ms	9.62E+03	4.72E+04	209	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRTZ DACOUT/DSPCLK SEL	46	Xe no tilt	1217	89	60	3	SEL	Max	135°C	4,5GHz	NRTZ	Dynamic	100ms	9.62E+03	4.66E+04	216	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
NRZ DACOUT/DSPCLK SEL	45	Xe no tilt	1217	89	60	3	SEL	Max	135°C	4,5GHz	NRZ	Dynamic	100ms	9.63E+03	4.66E+04	215	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk
RF DACOUT/DSPCLK SEL	49	Xe tilt 18°	1217	89	63.5	3	SEL	Max	135°C	4,5GHz	RF	Dynamic	100ms	1.01E+04	4.51E+04	221	1,00E+07	0	<1e-7	N.A	N.A	N.A	N.A	N.A	N.A	DACout	DSPclk

No Latch-Up were observed during this test under Xenon irradiation with a total fluence equal to 10^7particles.cm^{-2}, with a particle angle of 0° (LET = 60 MeV.cm²/mg) and 18° (LET = 63 MeV.cm²/mg).

7.2 SET/SEFI Results for Test1

NumDescription	RUN	Ion	Energy (MeV)	Range Ion (Si))	LET (MeV/mg/cm²)	DUT	Effect	Supply (V)	Tj (°C)	Freq (GHz)	Mode	Pattern	Loop	Dose (rad(Si))	Flux (ions/cm²/s)	Time (s)	Fluence	SEL Number	SEL Cross section (cm²)	SET Number	SET Cross section (cm²)	SEFI Number	SEFI Cross section (cm²)	SET+SEFI Number	SET+SEFI Cross section (cm²)	SET DAC_OUT Number	SET DAC_OUT Cross section (cm²)	SET DSPCLK Number	SET DSPCLK Cross section (cm²)
TEST SET/SEFI Ion Xenon - Board SN01																													
NRZ DACOUT/DSPCLK SET/SEFI	10	Xe no tilt	1217	89	60	1	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	9,87E+02	2,25E+04	52	1,01E+06	N.A	N.A	86	8,51E-05	30	2,97E-05	116	1,15E-04	47	4,65E-05	33	3,27E-05
NRTZ DACOUT/DSPCLK SET/SEFI	11	Xe no tilt	1217	89	60	1	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	9,75E+02	2,41E+04	46	1,01E+06	N.A	N.A	79	7,82E-05	28	2,77E-05	107	1,06E-04	52	5,15E-05	45	4,46E-05
RTZ DACOUT/DSPCLK SET/SEFI	12	Xe no tilt	1217	89	60	1	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	9,71E+02	2,04E+04	52	1,01E+06	N.A	N.A	118	1,17E-04	41	4,06E-05	159	1,57E-04	73	7,23E-05	60	5,94E-05
RF DACOUT/DSPCLK SET/SEFI	14	Xe no tilt	1217	89	60	1	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	9,74E+02	1,83E+04	57	1,01E+06	N.A	N.A	130	1,29E-04	84	8,32E-05	214	2,12E-04	99	9,80E-05	65	6,44E-05
RTZ DACOUT/DSPCLK SET/SEFI	16	Xe tilt 18°	1217	89	63.5	1	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	1,02E+03	1,7E+04	62	1,01E+06	N.A	N.A	125	1,24E-04	51	5,05E-05	176	1,74E-04	84	8,32E-05	45	4,46E-05
NRTZ DACOUT/DSPCLK SET/SEFI	18	Xe tilt 18°	1217	89	63.5	1	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	1,02E+03	2,1E+03	67	1,01E+06	N.A	N.A	75	7,43E-05	20	1,98E-05	95	9,41E-05	48	4,75E-05	50	4,95E-05
NRZ DACOUT/DSPCLK SET/SEFI	17	Xe tilt 18°	1217	89	63.5	1	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	1,01E+03	1,54E+04	66	1,01E+06	N.A	N.A	111	1,10E-04	34	3,37E-05	145	1,44E-04	73	7,23E-05	57	5,64E-05
RF DACOUT/DSPCLK SET/SEFI	15	Xe tilt 18°	1217	89	63.5	1	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	1,02E+03	1,75E+04	59	1,01E+06	N.A	N.A	147	1,46E-04	85	8,42E-05	232	2,30E-04	117	1,16E-04	71	7,03E-05
TEST SET/SEFI Ion Krypton - Board SN01																													
RF DACOUT/DSPCLK SET/SEFI	20	Kr no tilt	768	94	32,1	1	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	5,16E+02	3,95E+04	26	1,00E+06	N.A	N.A	62	6,20E-05	26	2,60E-05	88	8,80E-05	55	5,50E-05	24	2,40E-05
NRZ DACOUT/DSPCLK SET/SEFI	19	Kr no tilt	768	94	32,1	1	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	5,32E+02	4,00E+04	26	1,03E+06	N.A	N.A	55	5,34E-05	24	2,33E-05	79	7,67E-05	45	4,37E-05	38	3,69E-05
TEST SET/SEFI Ion iron - Board SN01																													
RTZ DACOUT/DSPCLK SET/SEFI	21	Fe no tilt	523	97,4	18,5	1	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	3,02E+02	3,94E+04	27	1,01E+06	N.A	N.A	60	5,94E-05	35	3,47E-05	95	9,41E-05	52	5,15E-05	36	3,56E-05
NRTZ DACOUT/DSPCLK SET/SEFI	22	Fe no tilt	523	97,4	18,5	1	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	2,98E+02	3,82E+04	27	1,00E+06	N.A	N.A	39	3,90E-05	18	1,80E-05	57	5,70E-05	28	2,80E-05	31	3,10E-05
TEST SET/SEFI Ion Neon - Board SN01																													
NRZ DACOUT/DSPCLK SET/SEFI	23	Ne no tilt	186	140	3.6	1	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	5,91E+01	4,1E+04	26	1,03E+06	N.A	N.A	14	1,36E-05	4	3,88E-06	18	1,75E-05	6	5,83E-06	10	9,71E-06
RF DACOUT/DSPCLK SET/SEFI	24	Ne no tilt	186	140	3.6	1	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	5,93E+01	4,15E+04	25	1,03E+06	N.A	N.A	20	1,94E-05	9	8,74E-06	29	2,82E-05	16	1,55E-05	13	1,26E-05

NumDescription	RUN	Ion	Energy (MeV)	[illegible] (Si))	LET (MeV/mg/cm²)	DUT	Effect	Supply (V)	Tj (°C)	Freq (GHz)	Mode	Pattern	Loop	Dose (rad(Si))	Flux (ions/cm²/s)	Time (s)	Fluence	SEL Number	SEL Cross section (cm²)	SET Number	SET Cross section (cm²)	SEFI Number	SEFI Cross section (cm²)	SET+SEFI Number	SET+SEFI Cross section (cm²)	SET DAC_OUT Number	SET DAC_OUT Cross section (cm²)	SET DSPCLK Number	SET DSPCLK Cross section (cm²)
TEST SET/SEFI Ion Oxygen - Board SN01 NEW COCKTAIL																													
RF DACCUT/DSPCLK SET/SEFI	69	O^{17} no tilt	284	500	1,5	1	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		3.44E+04	30	1,00E+06	N.A	N.A	8	8,00E-06	3	3,00E-06	11	1,10E-05	1	1,00E-06	8	8,00E-06
RTZ DACCUT/DSPCLK SET/SEFI	68	O^{17} no tilt	284	500	1,5	1	SEE	Typ	+25°C	4,5GHz	RTZ	Dynamic	100ms		3.41E+04	30	1,03E+06	N.A	N.A	7	6,80E-06	3	2,91E-06	10	9,71E-06	7	6,80E-06	5	4,85E-06
NRTZ DACCUT/DSPCLK SET/SEFI	67	O^{17} no tilt	284	500	1,5	1	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		3.54E+04	30	1,03E+06	N.A	N.A	8	7,77E-06	4	3,88E-06	12	1,17E-05	5	4,85E-06	7	6,80E-06
NRZ DACCUT/DSPCLK SET/SEFI	66	O^{17} no tilt	284	500	1,5	1	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		3.52E+04	30	1,01E+06	N.A	N.A	3	2,97E-06	2	1,98E-06	5	4,95E-06	3	2,97E-06	2	1,98E-06
TEST SET/SEFI Ion Iron - Board SN01 NEW COCKTAIL																													
RF DACCUT/DSPCLK SET/SEFI	70	Fe^{57} no tilt	941	190	13	1	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		4.18E+04	24	1,01E+06	N.A	N.A	52	5,15E-05	30	2,97E-05	82	8,12E-05	45	4,46E-05	22	2,18E-05
RTZ DACCUT/DSPCLK SET/SEFI	71	Fe^{57} no tilt	941	190	13	1	SEE	Typ	+25°C	4,5GHz	RTZ	Dynamic	100ms		4.25E+04	25	1,04E+06	N.A	N.A	37	3,56E-05	21	2,02E-05	58	5,58E-05	29	2,79E-05	19	1,83E-05
NRTZ DACCUT/DSPCLK SET/SEFI	72	Fe^{57} no tilt	941	190	13	1	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		4.25E+04	25	1,02E+06	N.A	N.A	38	3,73E-05	16	1,57E-05	54	5,29E-05	29	2,84E-05	27	2,65E-05
NRZ DACCUT/DSPCLK SET/SEFI	73	Fe^{57} no tilt	941	190	13	1	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		4.25E+04	25	1,02E+06	N.A	N.A	41	4,02E-05	21	2,06E-05	62	6,08E-05	34	3,33E-05	30	2,94E-05
TEST SET/SEFI Ion Xenon - Board SN01 NEW COCKTAIL																													
NRZ no tilt DACCUT/DSPCLK SET/SEFI	74	Xe^{129} no tilt	2059	150	50	1	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		4.2E+04	24	1,01E+06	N.A	N.A	62	6,14E-05	22	2,18E-05	84	8,32E-05	45	4,46E-05	41	4,06E-05
NRTZ no tilt DACCUT/DSPCLK SET/SEFI	75	Xe^{129} no tilt	2059	150	50	1	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		4.15E+04	25	1,02E+06	N.A	N.A	60	5,88E-05	27	2,65E-05	87	8,53E-05	53	5,20E-05	41	4,02E-05

NumDescription	RUN	Ion	Energy (MeV)	Range [illegible] (Si))	LET (MeV/mg/cm²)	DUT	Effect	Supply (V)	Tj (°C)	Freq (GHz)	Mode	Pattern	Loop	Dose (rad(Si))	Flux (ions/cm²/s)	Time (s)	Fluence	SEL Number	SEL Cross section (cm²)	SET Number	SET Cross section (cm²)	SEFI Number	SEFI Cross section (cm²)	SET-SEFI Number	SET-SEFI Cross section (cm²)	SET DAC_OUT Number	SET DAC_OUT Cross section (cm²)	SET DSPCLK Number	SET DSPCLK Cross section (cm²)
TEST SET/SEFI Ion Xenon - Board SN02																													
NRZ DACOUT/DSPCLK SET/SEFI	31	Xe no tilt	1217	89	60	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	9.92E+02	4,32E-04	25	1,01E-06	N.A	N.A	65	6,44E-05	25	2,48E-05	90	8,91E-05	54	5,35E-05	41	4,06E-05
NRTZ DACOUT/DSPCLK SET/SEFI	32	Xe no tilt	1217	89	60	2	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	9.71E+02	4,42E-04	24	1,01E-06	N.A	N.A	70	6,93E-05	30	2,97E-05	100	9,90E-05	52	5,15E-05	50	4,95E-05
NRTZ DACOUT/DSPCLK SET/SEFI	33	Xe tilt 18°	1217	89	63,5	2	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	1.05E+03	4,29E-04	24	1,04E-06	N.A	N.A	65	6,25E-05	30	2,88E-05	95	9,13E-05	60	5,77E-05	45	4,33E-05
NRZ DACOUT/DSPCLK SET/SEFI	34	Xe tilt 18°	1217	89	63,5	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	1,05E+03	4,33E-04	24	1,04E-06	N.A	N.A	72	6,92E-05	30	2,88E-05	102	9,81E-05	60	5,77E-05	43	4,13E-05
RTZ DACOUT/DSPCLK SET/SEFI	35	Xe tilt 18°	1217	89	63.5	2	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	1.03E+03	4.25E-04	25	1,02E-06	N.A	N.A	74	7,25E-05	37	3,63E-05	111	1,09E-04	56	5,49E-05	41	4,02E-05
NRTZ DACOUT/DSPCLK SET/SEFI	36	Xe no tilt	1217	89	60	2	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	9.92E+02	4.45E-04	24	1,03E-06	N.A	N.A	78	7,57E-05	44	4,27E-05	122	1,18E-04	73	7,09E-05	44	4,27E-05
RF DACOUT/DSPCLK SET/SEFI	37	Xe tilt 18°	1217	89	63.5	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	1.01E+03	4.19E-04	25	1,00E-06	N.A	N.A	72	7,20E-05	38	3,80E-05	110	1,10E-04	68	6,80E-05	30	3,00E-05
RF DACOUT/DSPCLK SET/SEFI	38	Xe tilt 30°	1217	89	69,3	2	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	1.13E+03	3.81E-04	27	1,01E-06	N.A	N.A	51	5,05E-05	21	2,08E-05	72	7,13E-05	48	4,75E-05	23	2,28E-05
RTZ DACOUT/DSPCLK SET/SEFI	39	Xe tilt 30°	1217	89	69,3	2	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	1.13E+03	3.92E-04	27	1,02E-06	N.A	N.A	47	4,61E-05	19	1,86E-05	66	6,47E-05	39	3,82E-05	28	2,75E-05
TEST SET/SEFI Ion Krypton - Board SN02																													
NRZ DACOUT/DSPCLK SET/SEFI	30	Kr no tilt	768	94	32,1	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	5.26E+02	3.8E-04	28	1,02E-06	N.A	N.A	57	5,59E-05	25	2,45E-05	82	8,04E-05	50	4,90E-05	39	3,82E-05
RF DACOUT/DSPCLK SET/SEFI	29	Kr no tilt	768	94	32,1	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	5.82E+02	3,80E-04	28	1,03E-06	N.A	N.A	90	8,74E-05	43	4,17E-05	133	1,29E-04	83	8,06E-05	34	3,30E-05
TEST SET/SEFI Ion iron - Board SN02																													
RTZ DACOUT/DSPCLK SET/SEFI	28	Fe no tilt	523	97,4	18,5	2	SEE	Typ	+46°C	4,5GHz	RTZ	Dynamic	100ms	3.01E+02	3.47E-04	29	1,01E-06	N.A	N.A	51	5,05E-05	29	2,87E-05	80	7,92E-05	45	4,46E-05	31	3,07E-05
NRTZ DACOUT/DSPCLK SET/SEFI	27	Fe no tilt	523	97,4	18,5	2	SEE	Typ	+46°C	4,5GHz	NRTZ	Dynamic	100ms	2.99E+02	3.44E-04	30	1,01E-06	N.A	N.A	36	3,56E-05	16	1,58E-05	52	5,15E-05	25	2,48E-05	31	3,07E-05
TEST SET/SEFI Ion Neon - Board SN02																													
NRZ DACOUT/DSPCLK SET/SEFI	26	Ne no tilt	186	140	36	2	SEE	Typ	+46°C	4,5GHz	NRZ	Dynamic	100ms	5.87E+01	4.2E-04	24	1,03E-06	N.A	N.A	12	1,17E-05	6	5,83E-06	18	1,75E-05	10	9,71E-06	9	8,74E-06
RF DACOUT/DSPCLK SET/SEFI	25	Ne no tilt	186	140	36	2	SEE	Typ	+46°C	4,5GHz	RF	Dynamic	100ms	6E+01	4.01E-04	26	1,04E-06	N.A	N.A	17	1,63E-05	9	8,65E-06	26	2,50E-05	13	1,25E-05	11	1,06E-05

NumDescription	RUN	Ion	Energy (MeV)	Range Ion (Si))	LET (MeV/mg/cm²)	DUT	Effect	Supply (V)	Tj (°C)	Freq (GHz)	Mode	Pattern	Loop	Dose (rad(Si))	Flux (/s/cm²)	Time (s)	Fluence	SEL Number	SEL Cross section (cm²)	SET Number	SET Cross section (cm²)	SEFI Number	SEFI Cross section (cm²)	SET+SEFI Number	SET+SEFI Cross section (cm²)	SET DAC_OUT Number	SET DAC_OUT Cross section (cm²)	SET DSPCLK Number	SET DSPCLK Cross section (cm²)
TEST SET/SEFI Ion Oxygen - Board SM02 NEW COCKTAIL																													
RF DACOUT/DSPCLK SET/SEFI	51	O^{17} no tilt	284	500	1.5	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		3.6E+04	34	1,00E+06	N.A	N.A	11	1,10E-05	7	7,00E-06	18	1,80E-05	9	9,00E-06	2	2,00E-06
RTZ DACOUT/DSPCLK SET/SEFI	52	O^{17} no tilt	284	500	1.5	2	SEE	Typ	+25°C	4,5GHz	RTZ	Dynamic	100ms		3.15E+04	33	1,00E+06	N.A	N.A	3	3,00E-06	1	1,00E-06	4	4,00E-06	1	1,00E-06	3	3,00E-06
NRTZ DACOUT/DSPCLK SET/SEFI	53	O^{17} no tilt	284	500	1.5	2	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		2.98E+04	35	1,02E+06	N.A	N.A	3	2,94E-06	2	1,96E-06	5	4,90E-06	3	2,94E-06	3	2,94E-06
NRZ DACOUT/DSPCLK SET/SEFI	55	O^{17} no tilt	284	500	1.5	2	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		3.03E+04	34	1,04E+06	N.A	N.A	10	9,62E-06	6	5,77E-06	16	1,54E-05	9	8,65E-06	7	6,73E-06
TEST SET/SEFI Ion Iron - Board SM02 NEW COCKTAIL																													
RF DACOUT/DSPCLK SET/SEFI	59	Fe^{57} no tilt	941	190	13	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		4.40E+04	23	1,04E+06	N.A	N.A	40	3,85E-05	17	1,63E-05	57	5,48E-05	29	2,79E-05	19	1,83E-05
RTZ DACOUT/DSPCLK SET/SEFI	58	Fe^{57} no tilt	941	190	13	2	SEE	Typ	+25°C	4,5GHz	RTZ	Dynamic	100ms		4.41E+04	23	1,01E+06	N.A	N.A	25	2,48E-05	13	1,29E-05	38	3,76E-05	21	2,08E-05	13	1,29E-05
NRTZ DACOUT/DSPCLK SET/SEFI	57	Fe^{57} no tilt	941	190	13	2	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		4.31E+04	24	1,01E+06	N.A	N.A	41	4,06E-05	19	1,88E-05	60	5,94E-05	29	2,87E-05	30	2,97E-05
NRZ DACOUT/DSPCLK SET/SEFI	56	Fe^{57} no tilt	941	190	13	2	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		4.27E+04	25	1,04E+06	N.A	N.A	30	2,88E-05	14	1,35E-05	44	4,23E-05	19	1,83E-05	22	2,12E-05
TEST SET/SEFI Ion Xenon - Board SM02 NEW COCKTAIL																													
RF no tilt DACOUT/DSPCLK SET/SEFI	63	Xe^{126} no tilt	2059	150	50	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		4.06E+04	26	1,02E+06	N.A	N.A	52	5,10E-05	28	2,75E-05	80	7,84E-05	44	4,31E-05	22	2,16E-05
NRZ no tilt DACOUT/DSPCLK SET/SEFI	64	Xe^{126} no tilt	2059	150	50	2	SEE	Typ	+25°C	4,5GHz	NRZ	Dynamic	100ms		3.97E+04	26	1,02E+06	N.A	N.A	41	4,02E-05	18	1,76E-05	59	5,78E-05	35	3,43E-05	28	2,75E-05
NRTZ no tilt DACOUT/DSPCLK SET/SEFI	65	Xe^{126} no tilt	2059	150	50	2	SEE	Typ	+25°C	4,5GHz	NRTZ	Dynamic	100ms		3.82E+04	26	1,03E+06	N.A	N.A	35	3,40E-05	15	1,46E-05	50	4,85E-05	23	2,23E-05	19	1,84E-05
TEST SET/SEFI Ion Xenon - Board SM02 NEW COCKTAIL (KAPTON 100um)																													
RF tilt 30 DACOUT/DSPCLK SET/SEFI	62	Xe^{126} tilt 30°	2059	80	69	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		4,00E+04	26	1,01E+06	N.A	N.A	20	1,98E-05	6	5,94E-06	26	2,57E-05	16	1,58E-05	11	1,09E-05
RF tilt 30 DACOUT/DSPCLK SET/SEFI	61	Xe^{126} tilt 30°	2059	80	69	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		2.05E+03	493	1,04E+06	N.A	N.A	19	1,83E-05	7	6,73E-06	26	2,50E-05	13	1,25E-05	13	1,25E-05
RF no tilt DACOUT/DSPCLK SET/SEFI	60	Xe^{126} no tilt	2059	130	60	2	SEE	Typ	+25°C	4,5GHz	RF	Dynamic	100ms		4.11E+04	26	1,03E+06	N.A	N.A	70	6,80E-05	41	3,98E-05	111	1,08E-04	56	5,44E-05	35	3,40E-05

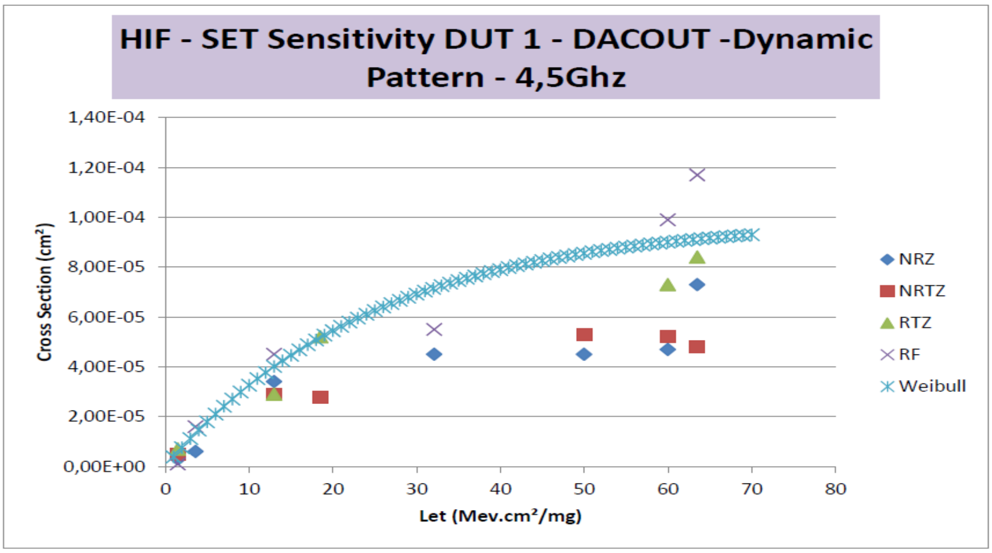


Figure 5 : SET Cross-section Vs LET for DACOUT, DUT1, Dynamic pattern

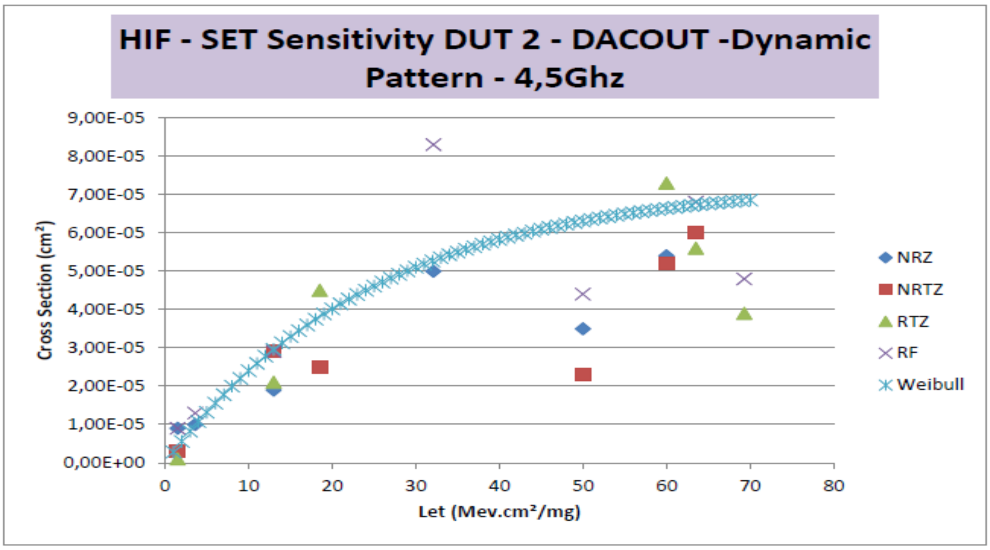


Figure 6 : SET Cross-section Vs LET for DACOUT, DUT2, Dynamic pattern

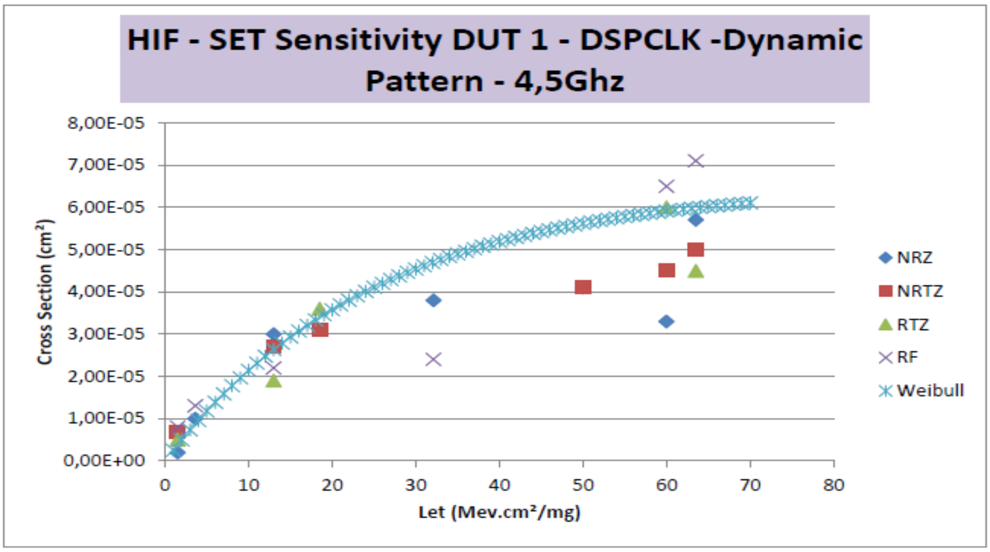


Figure 7 : SET Cross-section Vs LET for DSPCLK, DUT1, Dynamic pattern

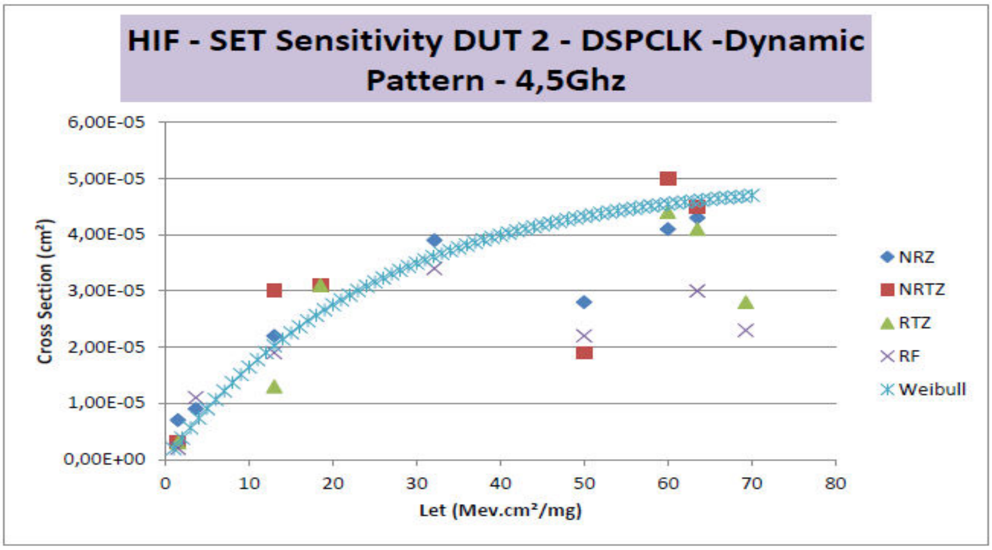


Figure 8 : SET Cross-section Vs LET for DSPCLK, DUT2, Dynamic pattern

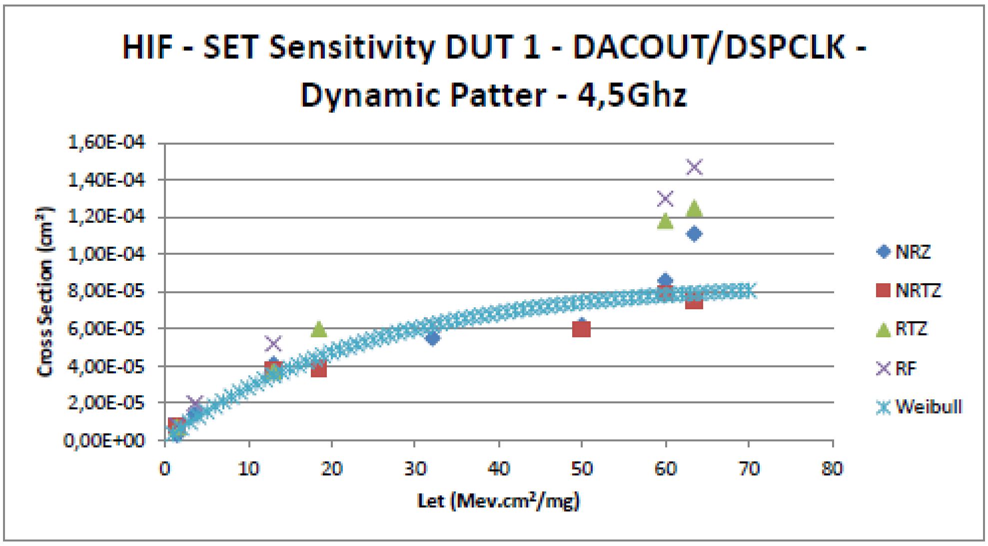


Figure 9 : SET Cross-section vs. LET for DACOUT/DSPCLK signals DUT 1: dynamic pattern in NRZ, NRTZ, RTZ and RF modes.

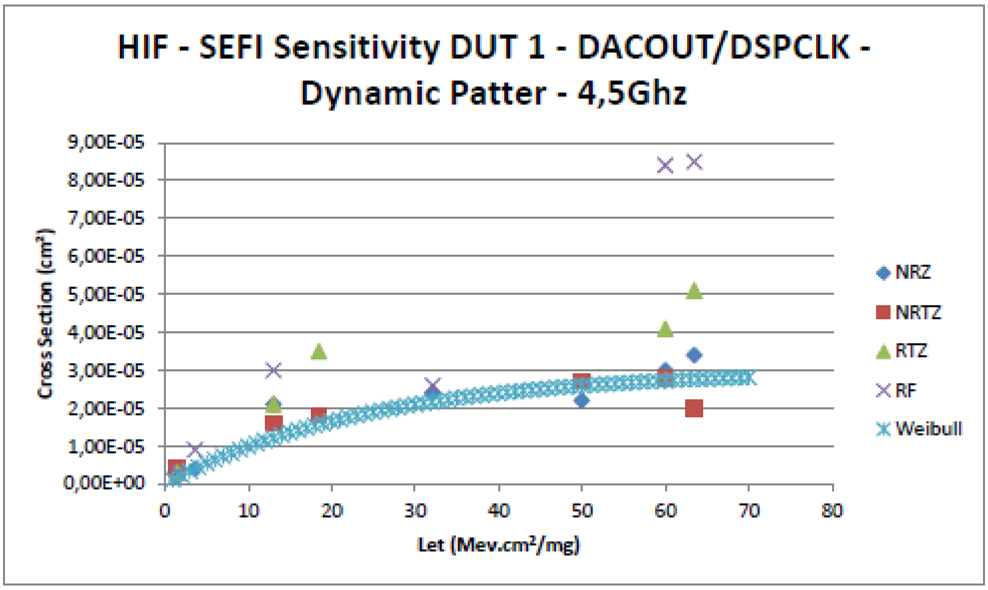


Figure 10 : SEFI Cross-section vs. LET for DACOUT/DSPCLK signals DUT1: dynamic pattern in NRZ, NRTZ, RTZ and RF modes

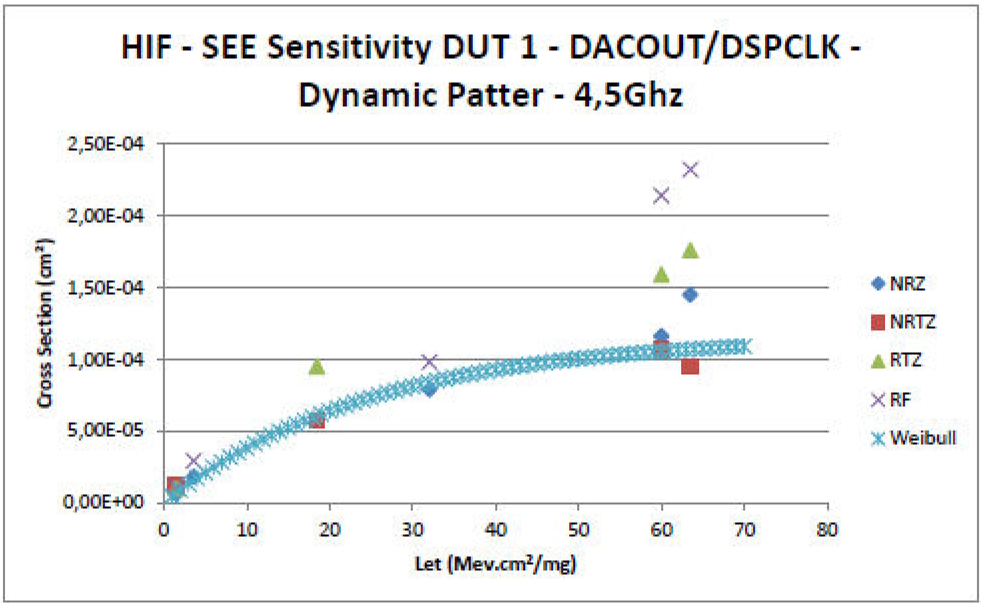


Figure 11 : SEE Cross-section vs. LET for DACOUT/DSPCLK signals DUT1: dynamic pattern in NRZ, NRTZ, RTZ and RF modes

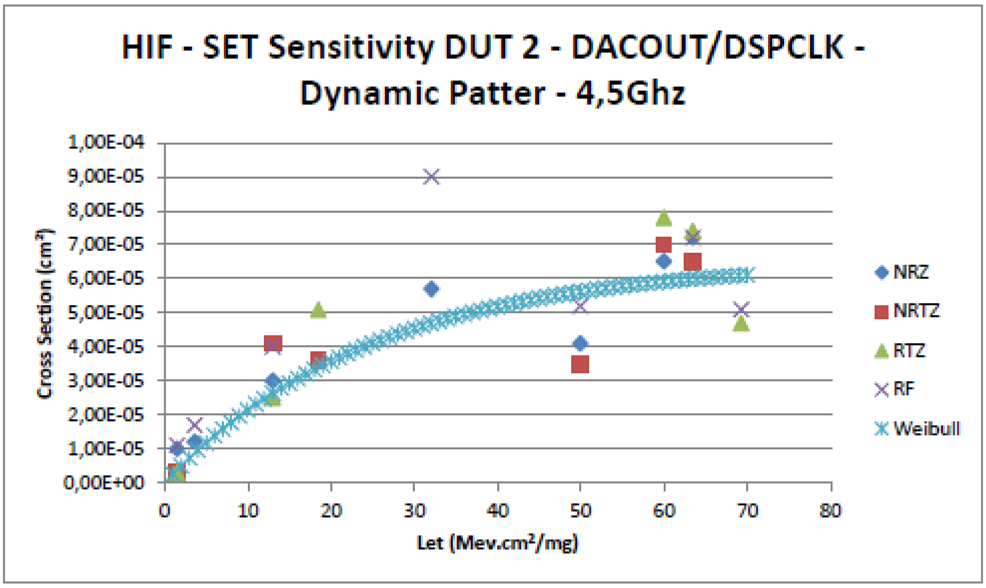


Figure 12 : SET Cross-section vs. LET for DACOUT/DSPCLK signals DUT2: dynamic pattern in NRZ, NRTZ, RTZ and RF modes

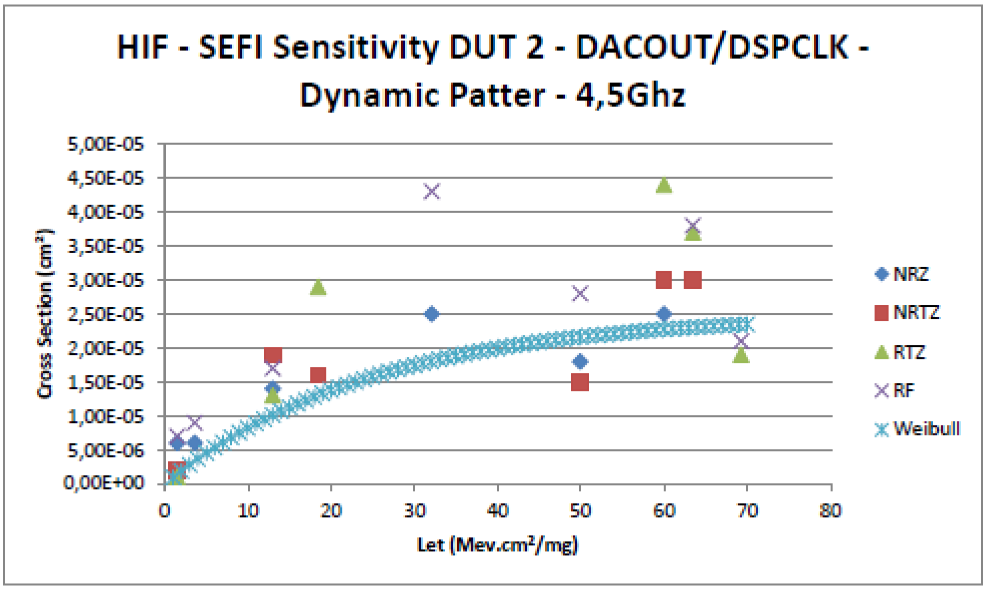


Figure 13 : SEFI Cross-section vs. LET for DACOUT/DSPCLK signals DUT2: dynamic pattern in NRZ, NRTZ, RTZ and RF modes

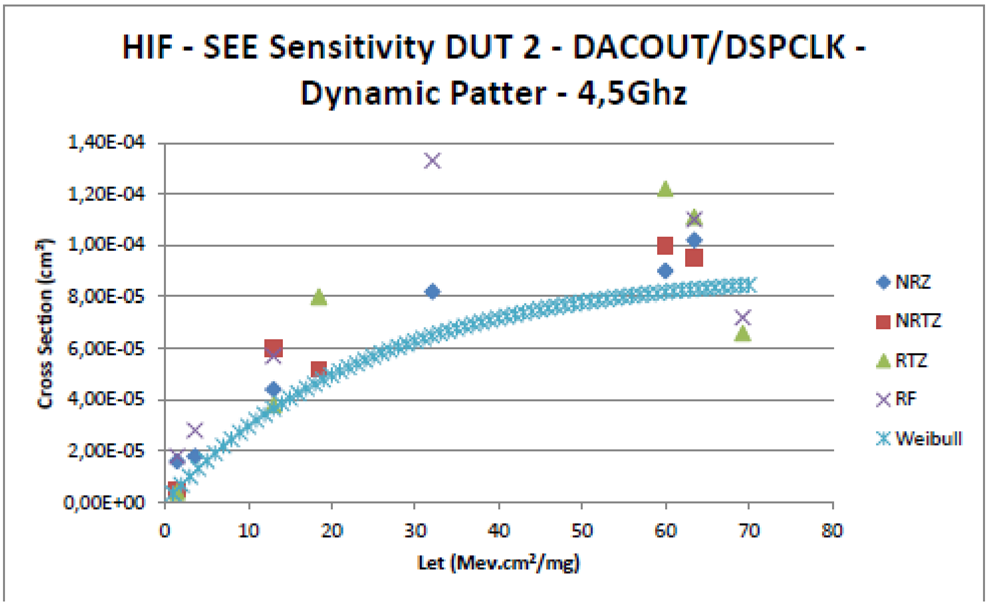


Figure 14 : SEE Cross-section vs. LET for DACOUT/DSPCLK signals DUT2: dynamic pattern in NRZ, NRTZ, RTZ and RF modes

All the SEFI are **SEFI 1**, which means that they have been solved using the software, by writing into the registers (no reset, no reboot, no power down/up).

7.3 SEFI Results for Test2

Run Number	DUT	Flux	Fluence	Ion	LET	Dose	Fclock	Pattern	IUCM	Mode	SEFI	Commentaire
1-->7	4		4,72E+06	Xe	60	4,25E+00	4,5	Mil	1	NRTZ		Setup with the static pattern
8	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	4,5	Mil	1	NRZ	29	
9	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	4,5	Mil	1	NRTZ	38	
10	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	4,5	Mil	1	RTZ	34	
11	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	4,5	Mil	1	RF	14	
12	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	6	Mil	1	NRZ	20	
13	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	6	Mil	1	NRTZ	19	
14	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	6	Mil	1	RTZ	20	
15	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	6	Mil	1	RF	25	
16	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	8	Mil	2	NRZ	34	
17	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	8	Mil	2	NRTZ	24	
18	4	2,00E+03	4,20E+05	Xe	60	3,78E-01	8	Mil	2	NRZ		Wrong Mode
19	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	8	Mil	2	RTZ	34	
20	4	2,00E+03	1,00E+06		60	9,00E-01	8	Mil	2	RF	30	
21-->22	4	2,00E+03	2,11E+05	Xe	60	1,90E-01						Setup with the Sin pattern
23	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	4,5	Sin	1	NRZ	43	
24	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	6	Sin	1		55	
25	4	2,00E+03	1,00E+06	Xe	60	9,00E-01	8	Sin	2		51	

All the SEFI are **SEFI 1**, which means that they have been solved using the software, by writing into the registers (no reset, no reboot, no power down/up).

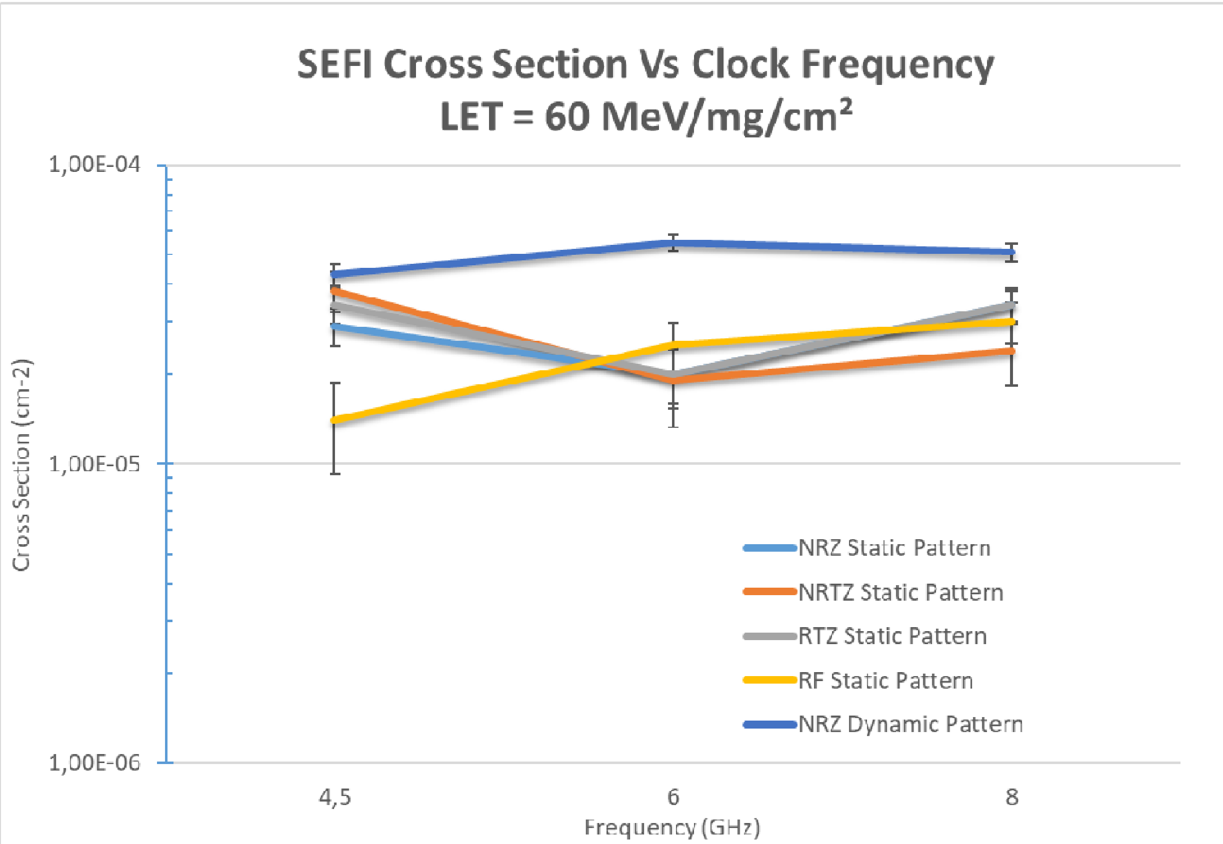


Figure 15: SEFI Cross Section Vs Clock Frequency with a LET = 60 Mev/mg/cm²

Total ionizing dose received by each component in the campaign:

DUT 1 (Board SN01) : 68 Krad(Si).
DUT 2 (Board SN02) : 59.8 Krad(Si).
DUT 3 (Board SN04) : 48.6 Krad(Si).
DUT 4 (Borad SN03) : 18.3 Krad(Si)

The Weibull fit equation is given by the following formula:

$$\sum_{IL}(\leq L) = \Sigma_0 . \left[1 - e^{-\left(\frac{L-L_0}{W}\right)^S}\right]$$

The table below summarizes the worst case Weibull fit parameters for DACOUT and DSPCLK, for both dynamic and static pattern. Both SEE rate and MTBF calculations were performed with OMERE software from parameters detailed in the table hereafter.

Test Conditions			Weibull Fit Parameters				SEE Rate Calculation		
FClock (GHz)	Output	Pattern	W (MeV.cm²/mg)	S	LET threshold L0 (MeV.cm²/mg)	Cross-Section Sat (cm²)	Mission (GEO)	Rate/Day	MTBF (Days)
4.5	DACOUT (SET)	Dynamic	40	1.6	1.50E-2	3.25E-5	M3 15 years	1.58E-4	6329
							M8 16 Days	6.26e-2	16
4.5	DSPCLK (SET)	Dynamic	40	1.6	1.50E-2	2E-5	M3 15 years	9.62e-5	10395
							M8 16 Days	3.45e-2	30
4.5	DACOUT (SEE)	Dynamic	40	1.6	1.50E-2	5.68E-5	M3 15 years	2.80e-4	3571
							M8 16 Days	1.23e-1	8.1
4.5	DSPCLK (SEE)	Dynamic	40	1.6	1.50E-2	2.21E-5	M3 15 years	1.07e-4	9346
							M8 16 Days	3.92e-2	25.51
4.5	DACOUT (SEFI)	Dynamic	40	1.6	1.50E-2	2.44E-5	M3 15 years	1.18e-4	8474
							M8 16 Days	4.41e-2	22.7
4.5	DSPCLK (SEFI)	Dynamic	40	1.6	1.50E-2	1.35E-5	M3 15 years	6.43e-5	15552
							M8 16 Days	2.11e-2	47.4

Figure 16: Heavy ion SEE Rate Calculation with OMERE

Orbit	GEO (35870 km)	
Radiative Environment	CREME 86 – M3 – Cosmic Rays Solar Min	CREME 86 – M8 – Solar Eruption – Worst-Case Flux
Mission Duration	15 years	16 days
Magnetospheric Cut-Off	Without	
Shielding	1 $g.cm^{-2}$	
Number of Cells	12	
Cell Depth	6 µm	

Figure 17: Calculation parameters with OMERE

7.4 SET Duration

The following graphs plot the events depending on their amplitude and duration.

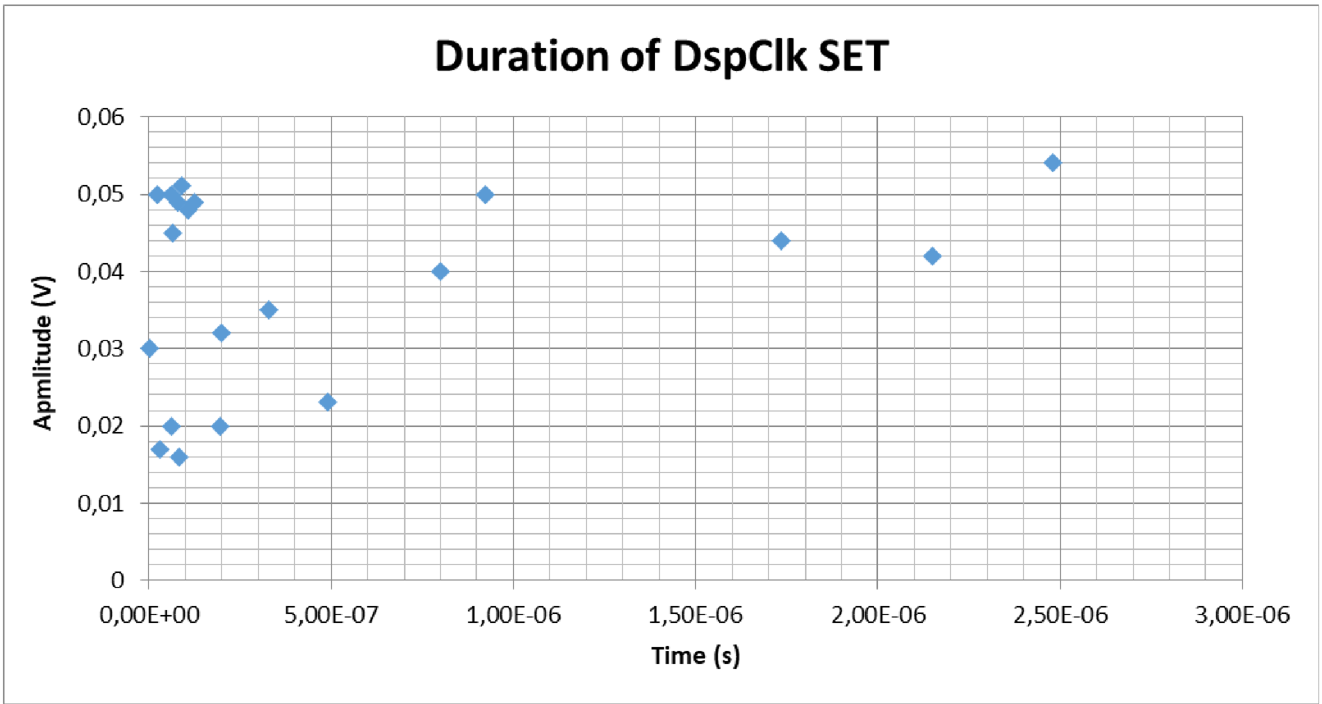


Figure 18 : Maximum amplitude Vs maximum duration for DSPCLK events @ 4.5GHz

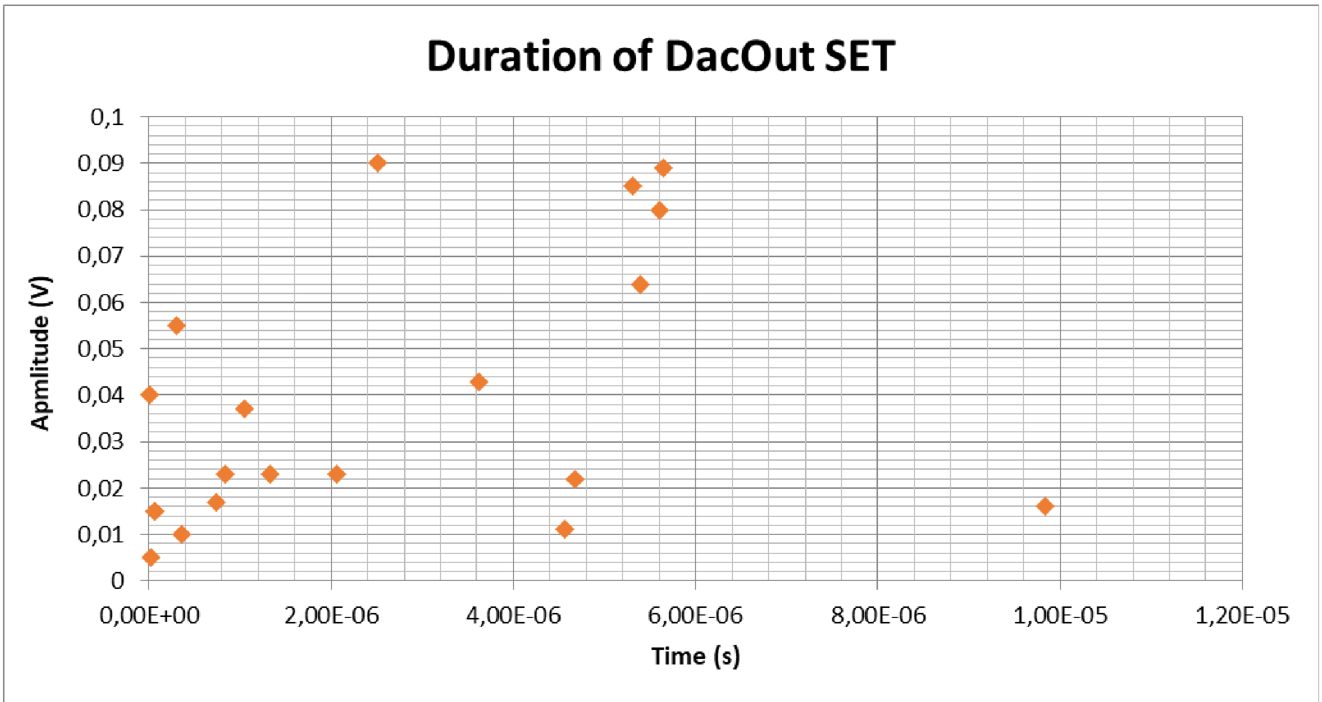


Figure 19 : Maximum amplitude Vs maximum duration for DACOUT events @ 4.5GHz

Some examples of events are presented on the following pages. The attenuation on DACOUT induced by the detection system is 10 dB, the attenuation on DSPCLK is 11 dB. These examples show a lot of possible waveforms in case of SET induced certainly by DAC registers failures.

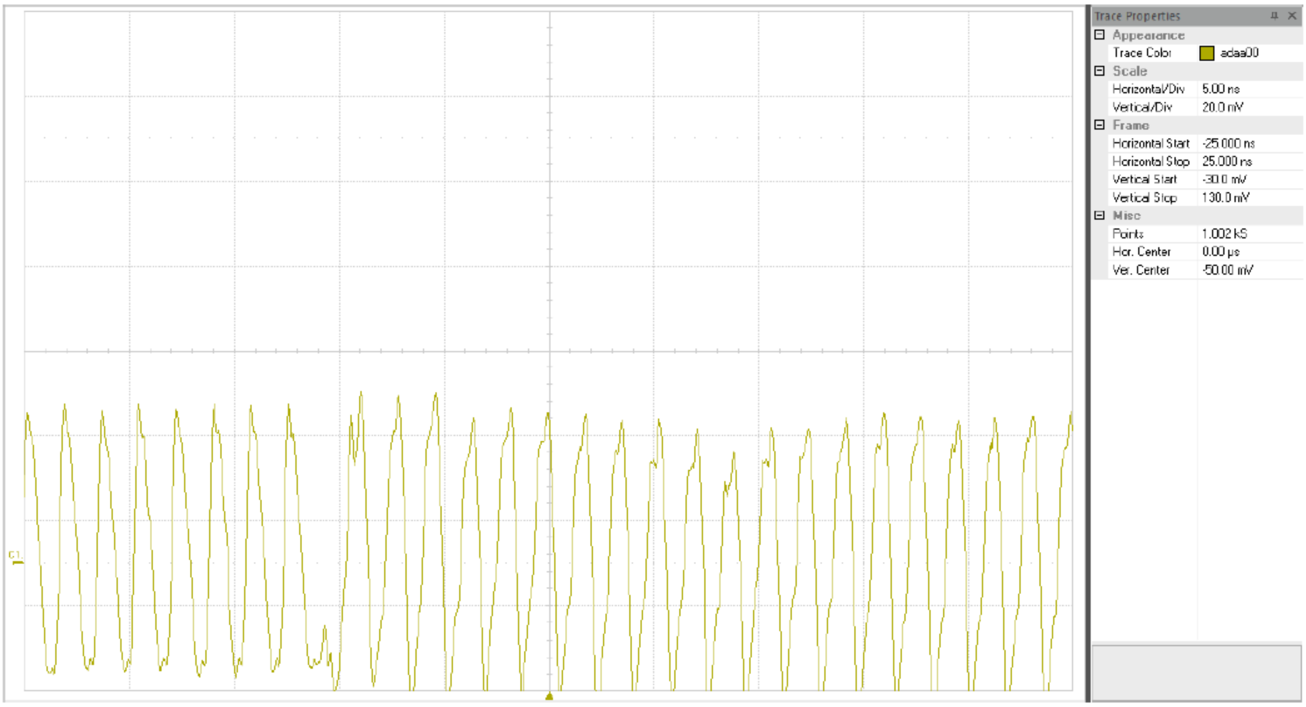


Figure 20 : DSPCLK SET example Run 10 (NRZ mode, LET 60 MeV/mg/cm2)

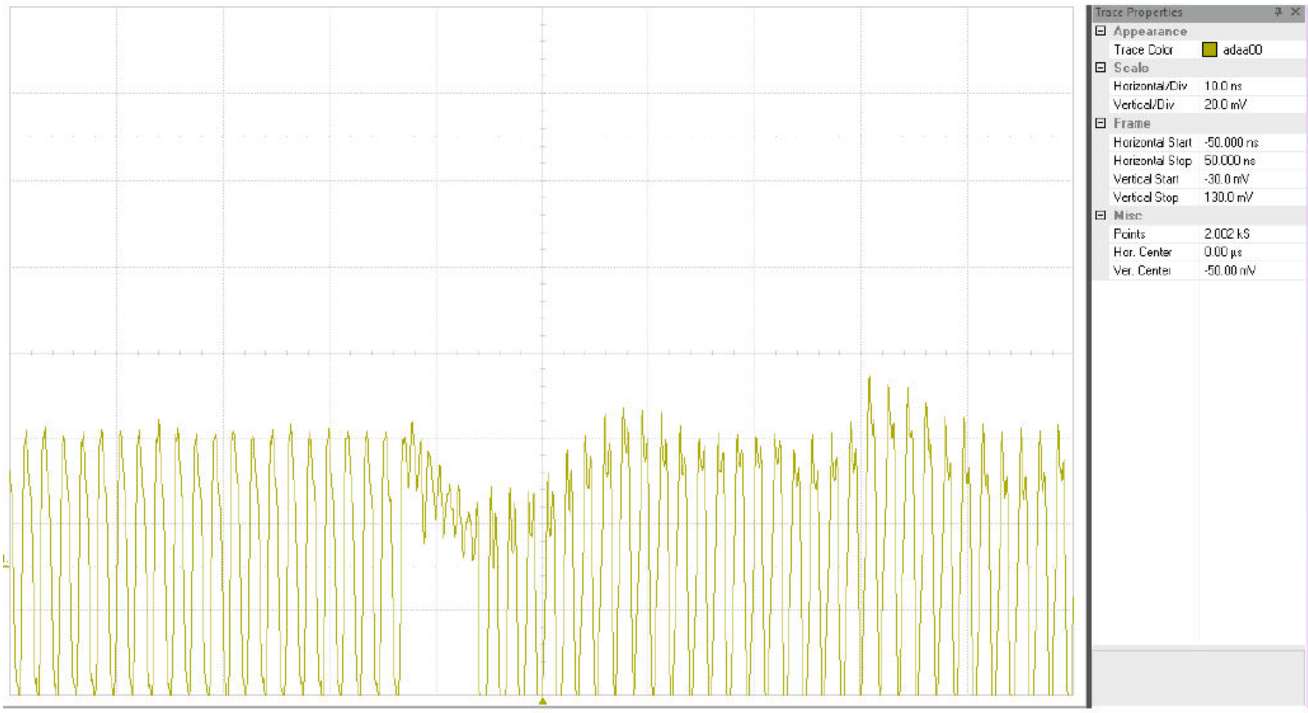


Figure 21 : DSPCLK SET example Run 18 (NRTZ mode, LET 63.5 MeV/mg/cm2, tilt 18°)

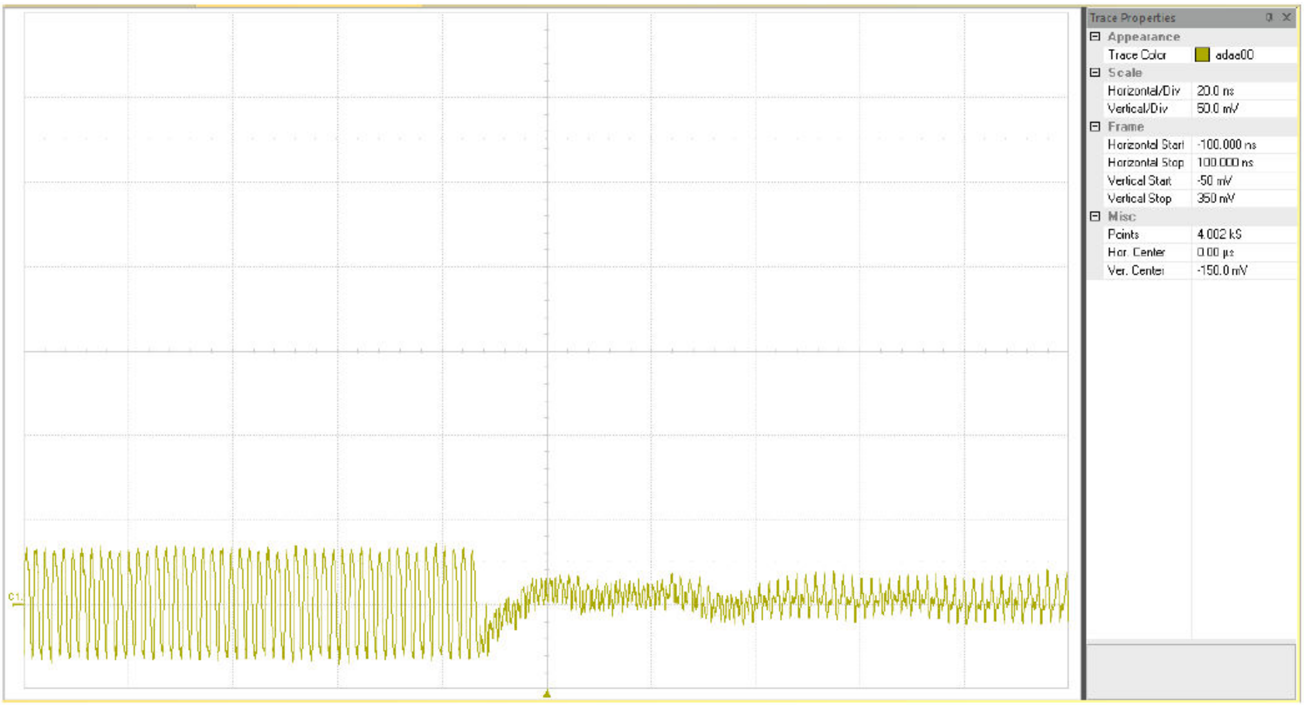


Figure 22 : DSPCLK SET example Run 20 (Mode RF, LET 32.1 MeV/mg/cm2)

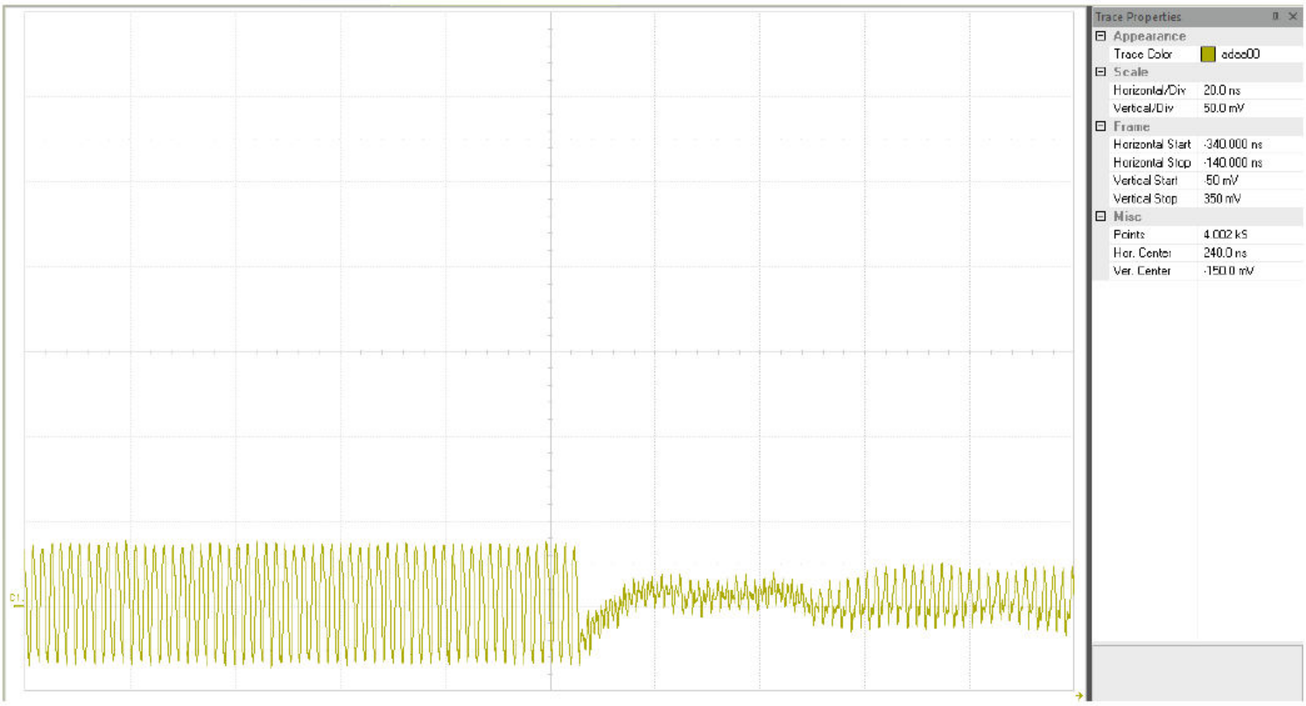


Figure 23 : DSPCLK SET example Run 22 (Mode NRTZ, LET 18.5 MeV/mg/cm2)

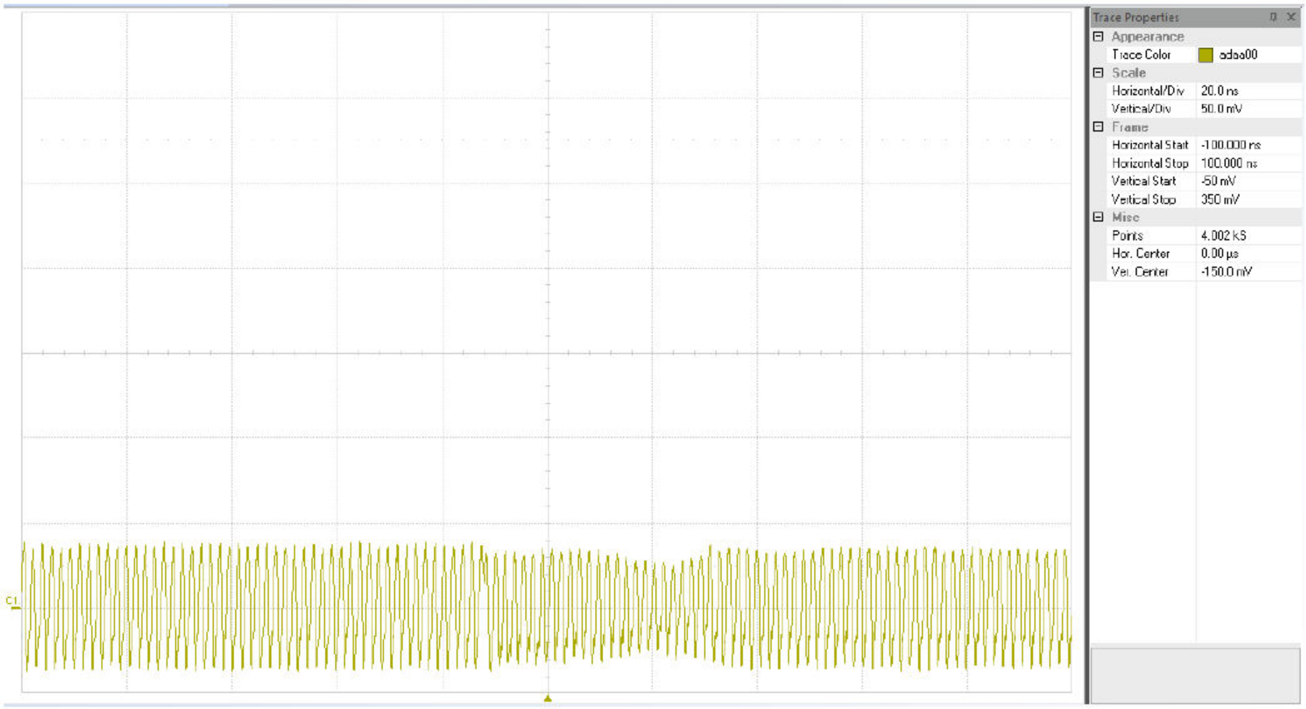


Figure 24 : DSPCLK SET example Run 23 (Mode NRZ, LET 3.6 MeV/mg/cm2)

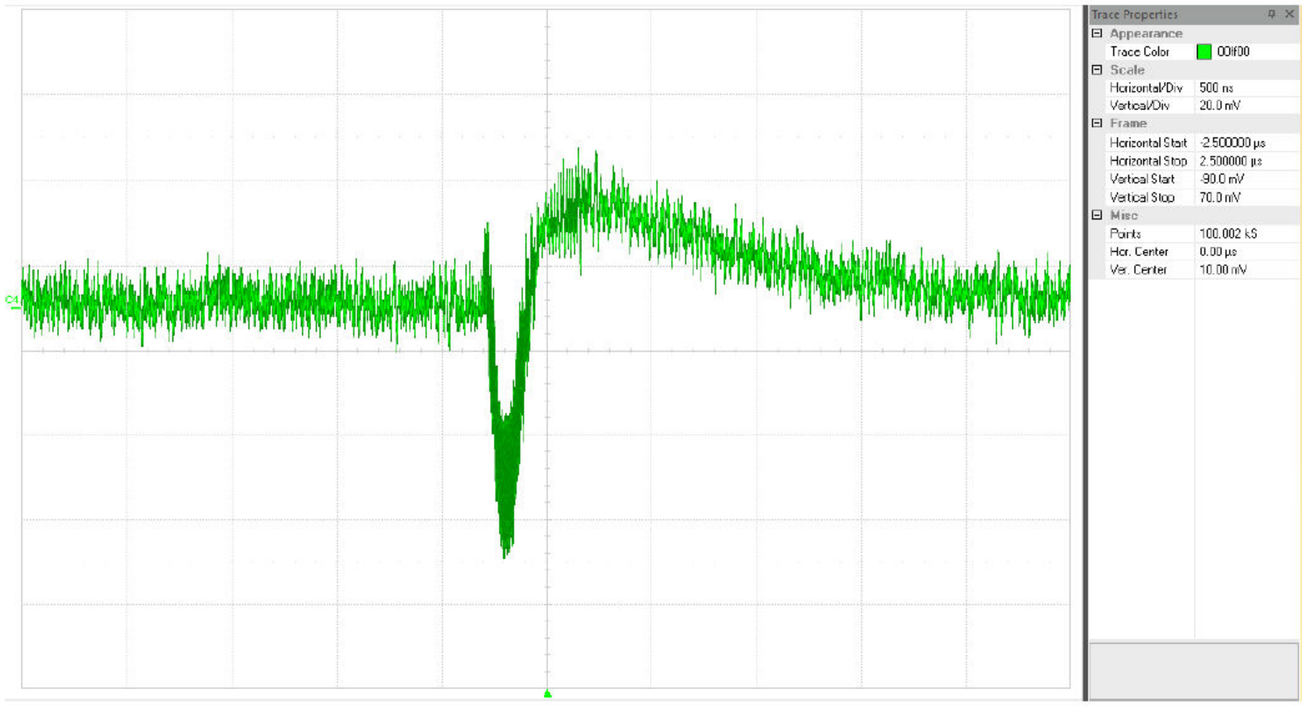


Figure 25 : DACOUT SET example Run 10 (NRZ mode, LET 60 MeV/mg/cm2)

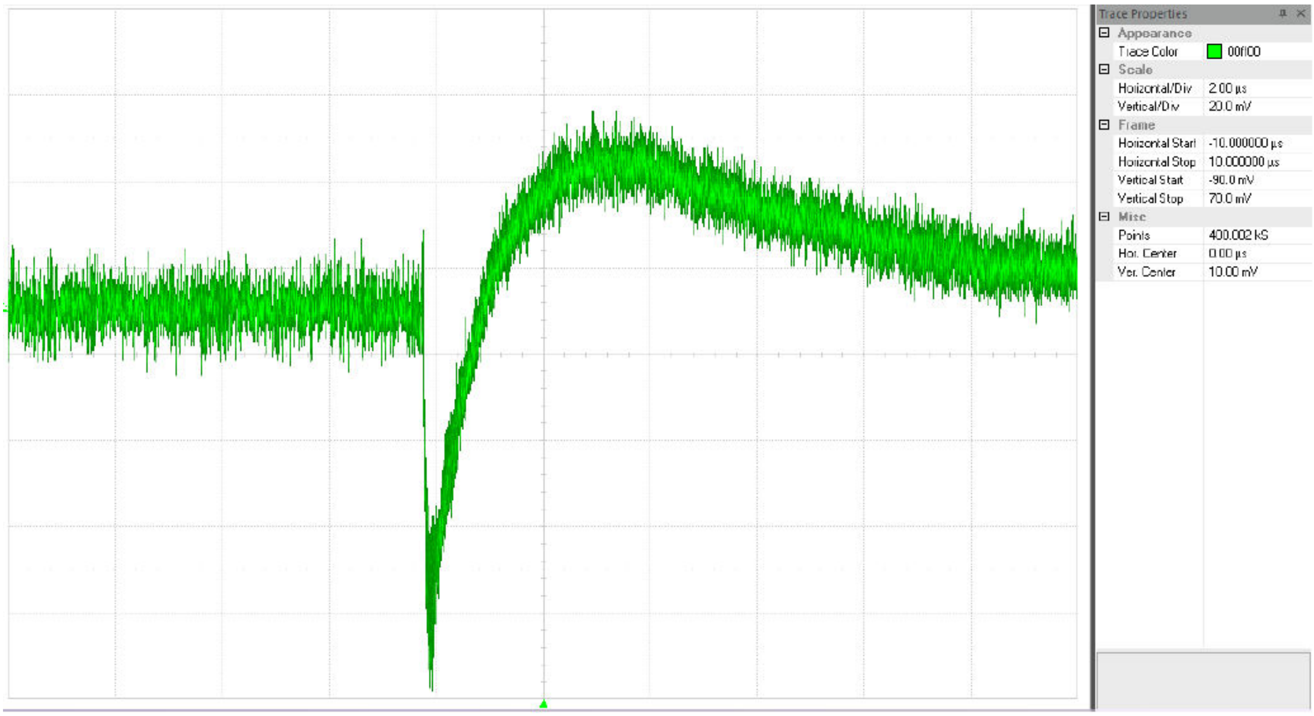


Figure 26 : DACOUT SET example Run 18 (NRTZ, LET 63.5 MeV/mg/cm2, tilt 18°)

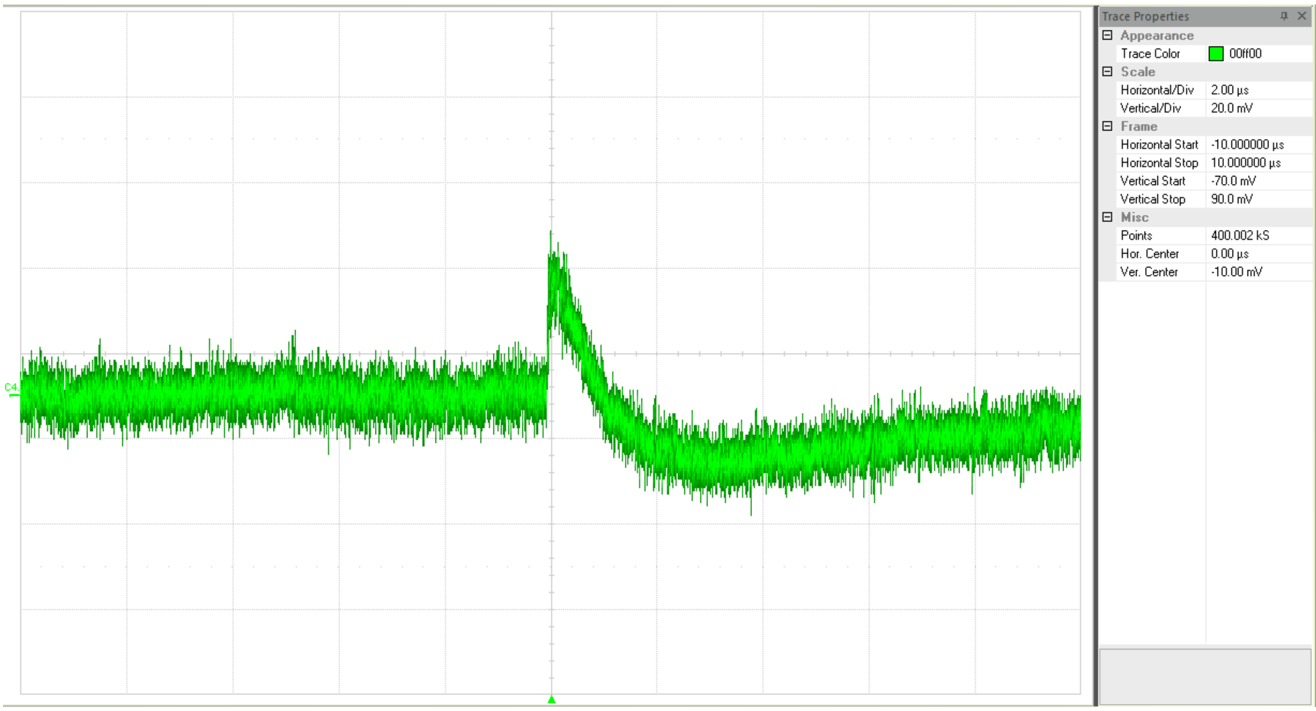


Figure 27 : DACOUT SET example Run 20 (Mode RF, LET 32.1 MeV/mg/cm2)

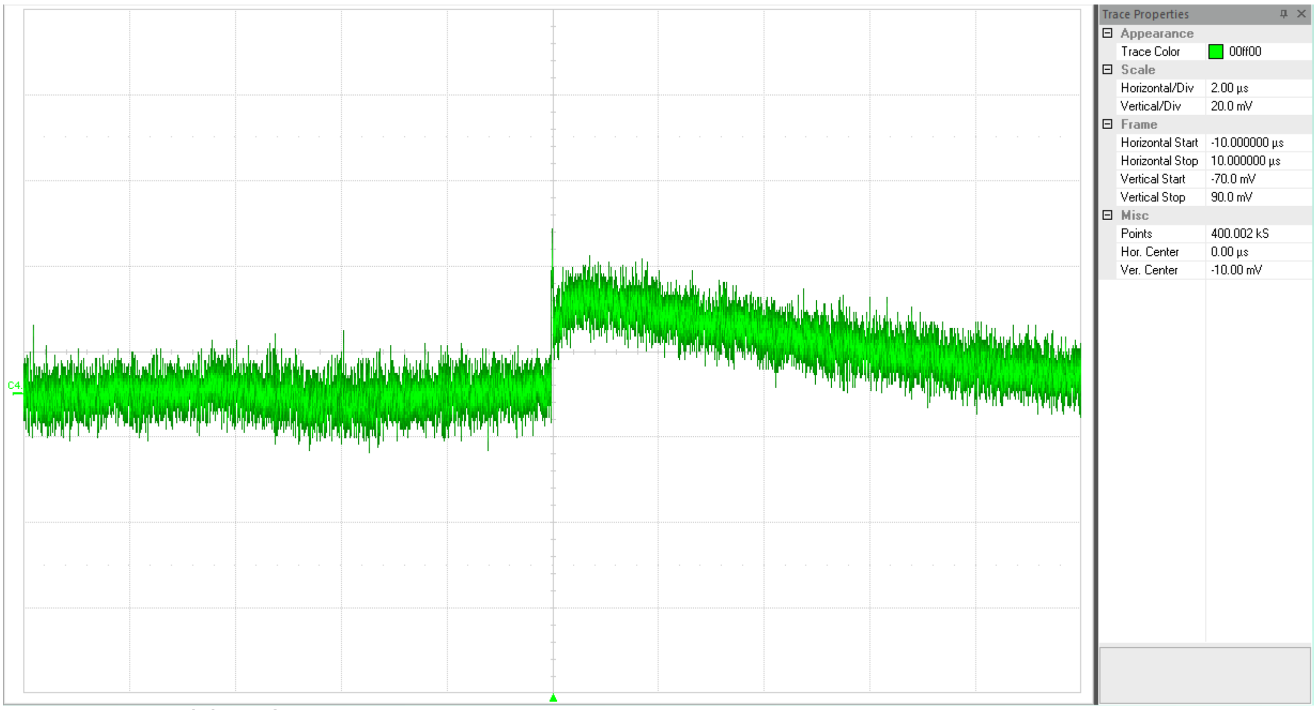


Figure 28 : DACOUT SET example Run 22 (LET 18.5 MeV/mg/cm2)

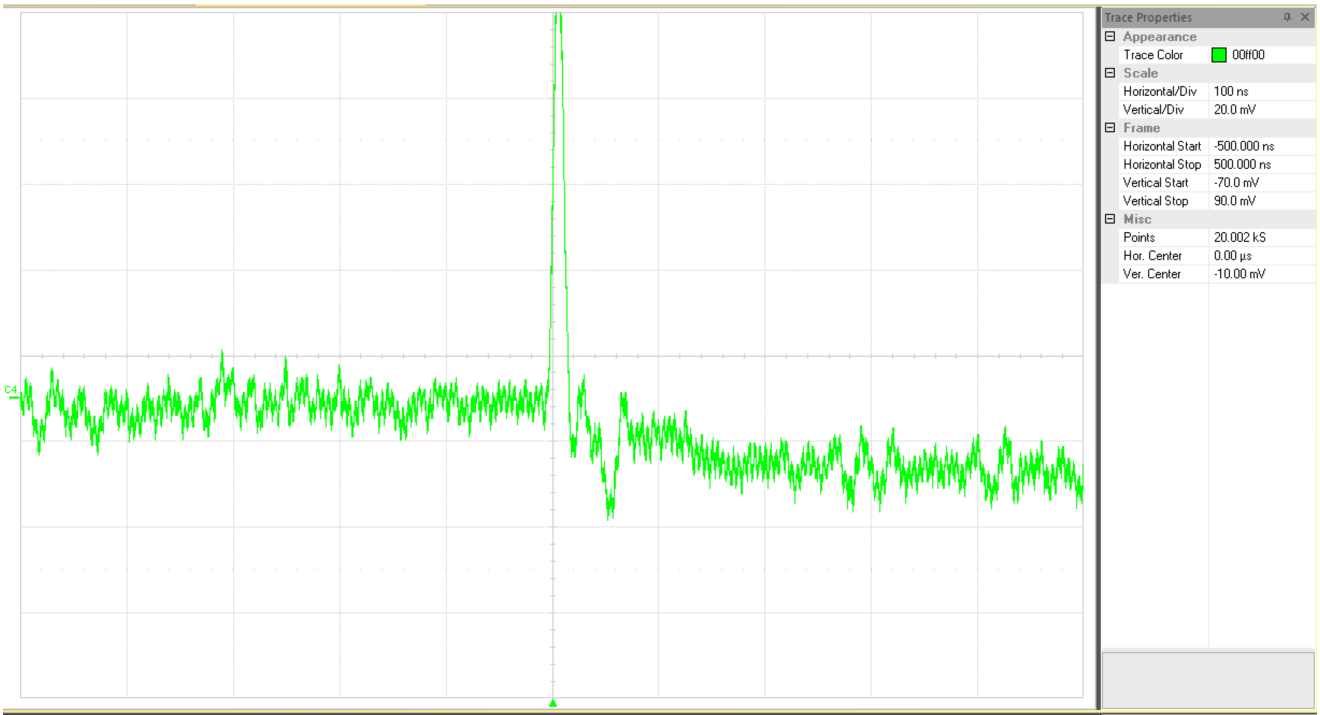


Figure 29 : DACOUT SET example Run 23 (Mode NRZ, LET 3.6 MeV/mg/cm2)

8 SEE CONCLUSION

Teledyne e2v has performed a Heavy ions tests on the **EV12DS480AZP** DAC device to evaluate the sensitivity to the Single Event Latch up (SEL) & Single Event Effects (SEU, SEFI, SET) for various clock, 4.5GHz, 6GHz and 8GHz. A special code has been developed to manage automatically the SEFI by re-programming the registers.

Tests were performed at the RADEF, Jyväskylä, Finland, on the 15^{th}, 16th and on the 17th of April 2019.

- No SEL was detected during the irradiation with a LET of 60 MeV.cm²/mg, with no tilt. 3 DUT were tested at Tj=135°C, with maximum power supplies + 10%.
- SET were observed during the irradiation from 3.6 MeV.cm²/mg to 69.3 MeV.cm²/mg, at room temperature and typical power supplies.
- SEFI were observed during the irradiation from 3.6 MeV.cm²/mg to 69.3 MeV.cm²/mg but all these SEFI were successfully managed by software
- There is no significant gap between SET/SEFI cross sections obtained in the different modes.
- There is no significant gap between SET/SEFI cross sections obtained for DACOUT and DSPCLK.
- There is no impact of the clock frequency on the device, the SEFI cross section remains the same whatever is the clock, 4.5GHz, 6GHz or 8GHz

These SEE results show that the EV12DS480 DAC, can be used as a space product.

9 APPENDIX

9.1 Details of equipment used for the measurements

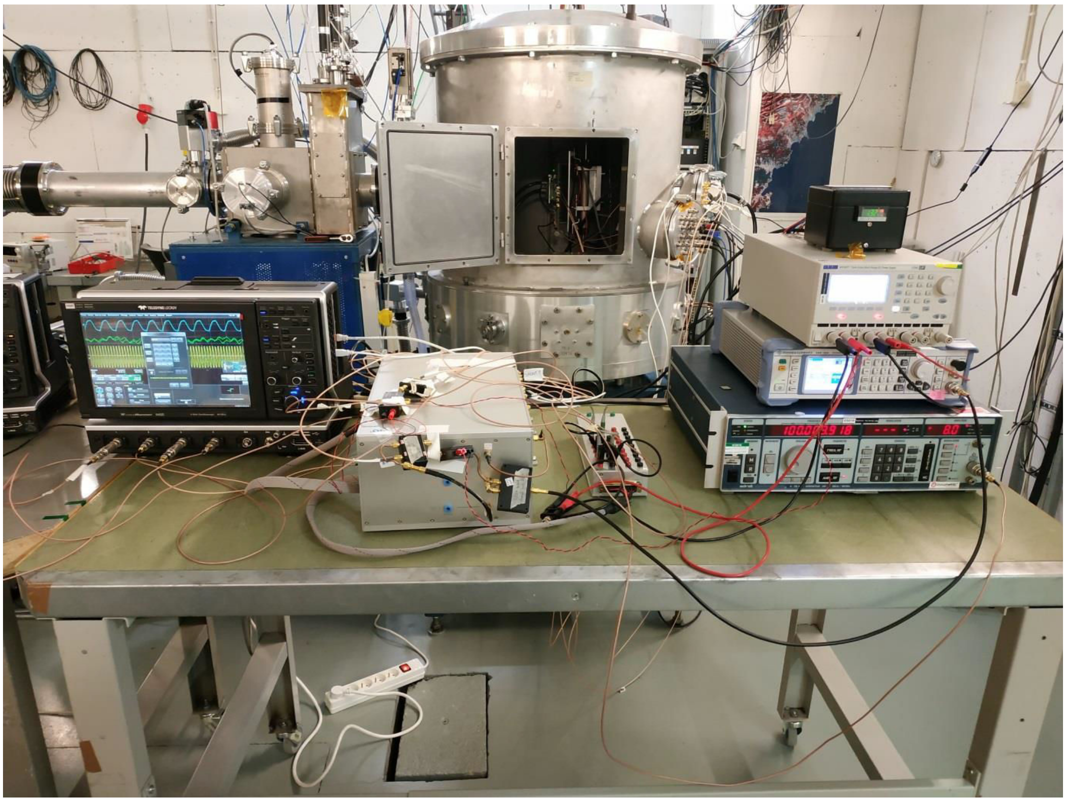


Figure 30 : Test Instrumentation (1)

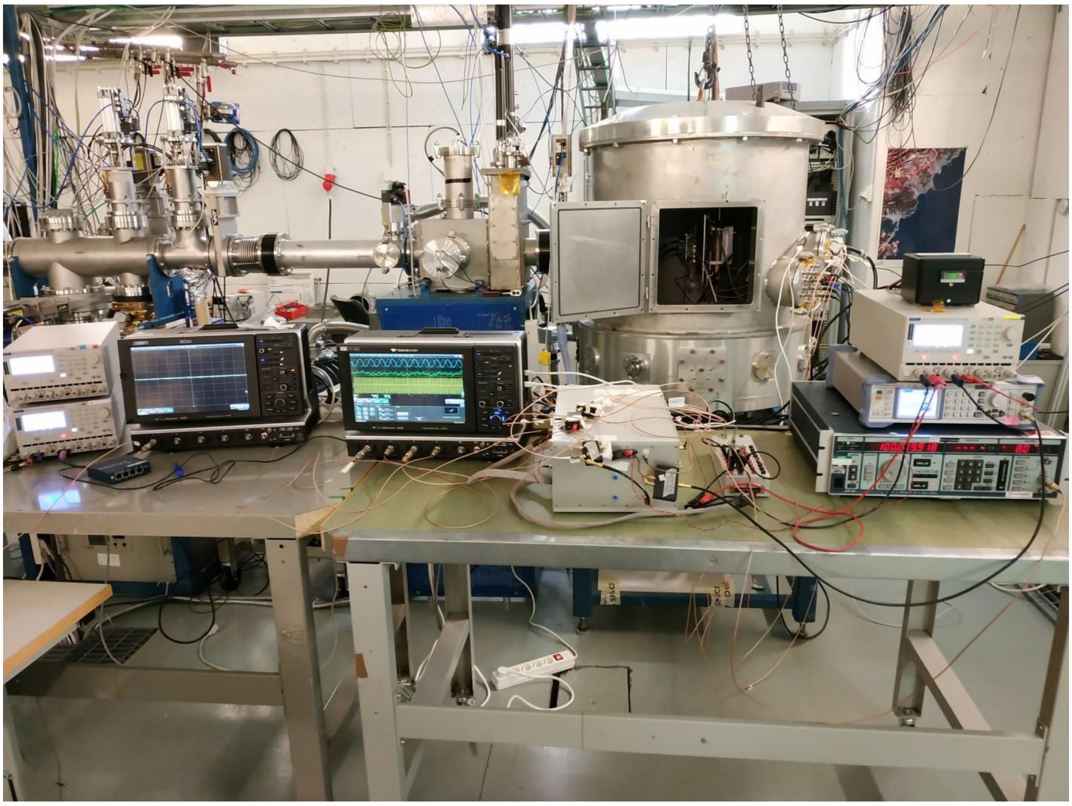


Figure 31 : Test Instrumentation (2)

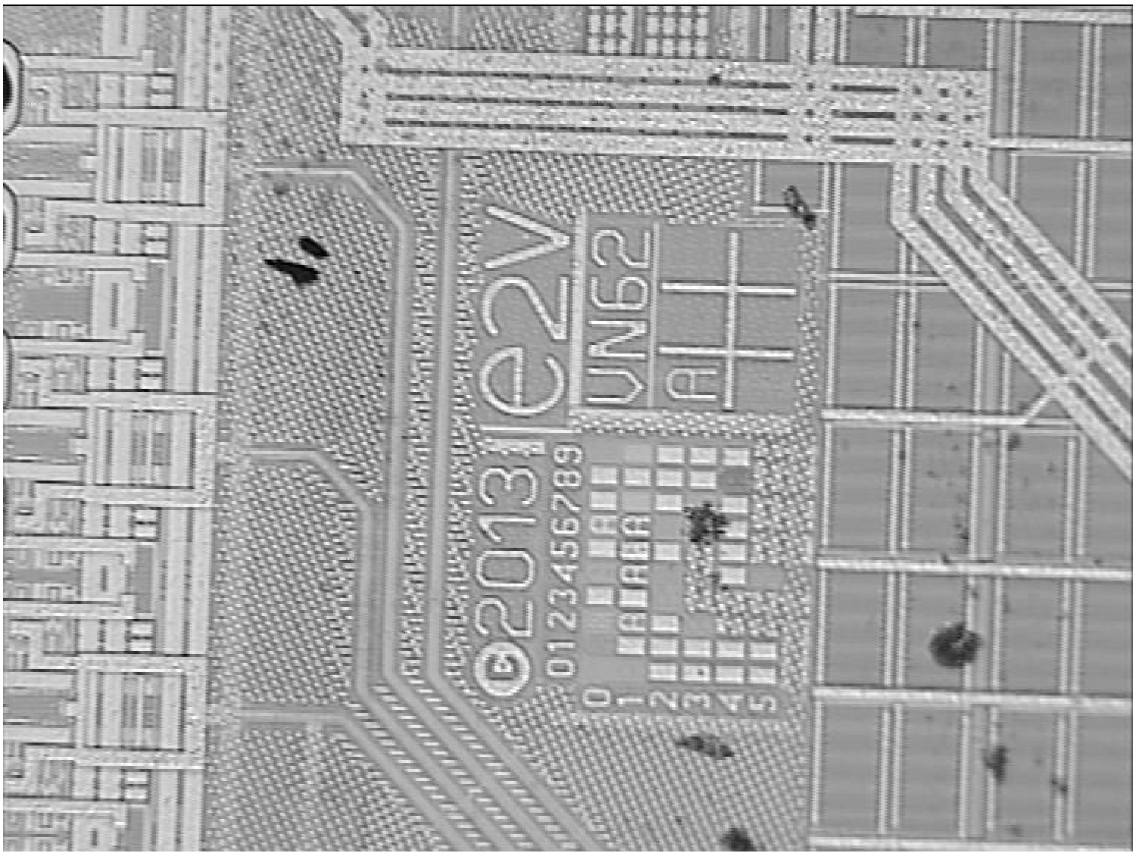


Figure 32 : Die Marking DUT1

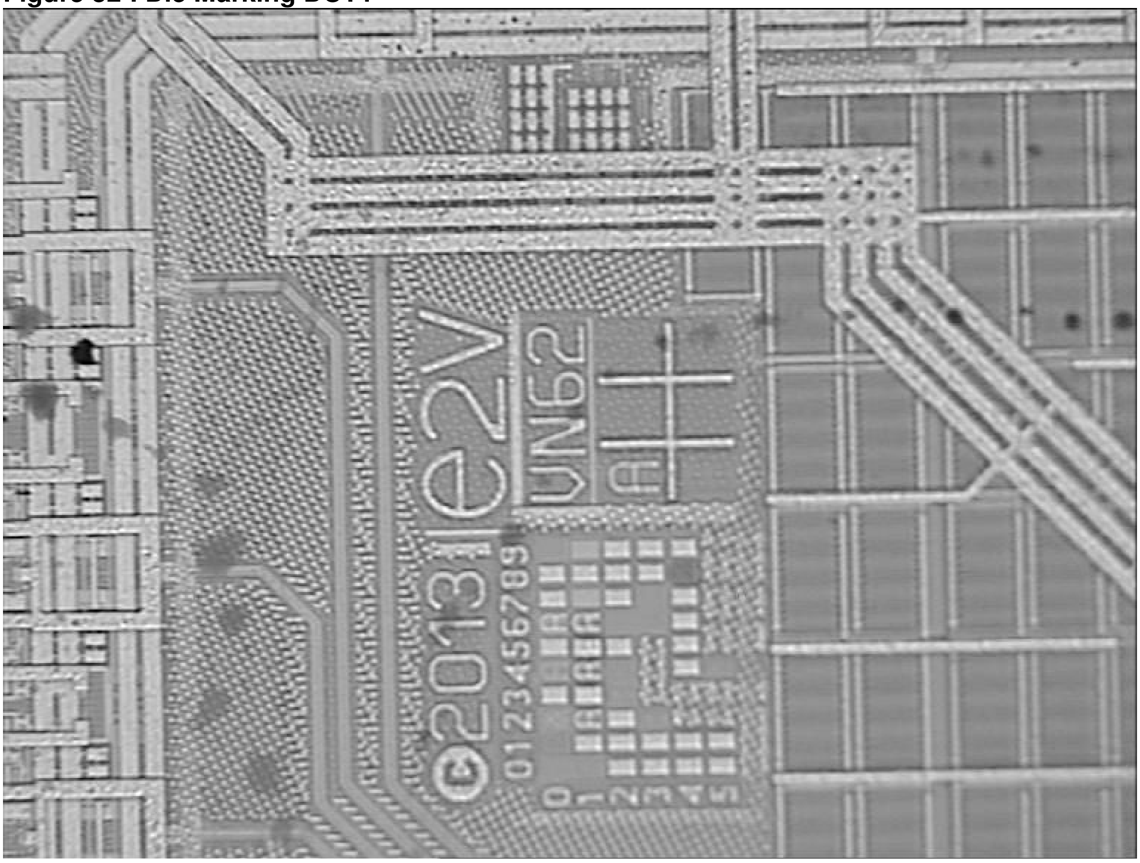


Figure 33 : Die Marking DUT2

Figure 34 : 135°C mini-MARTA view