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Single Event Effects

Heavy Ions Test Report

Test type	Single Event Latchup
Part Reference	AD7626
Tested function	16-Bit, 10 MSPS, PulSAR Differential ADC
Chip manufacturer	Analog Devices
Test Facility	UCL-HIF, Louvain-La-Neuve Belgium
Test Date	October 2017
Customer	ESA

Call-of order No6 "Radiation testing for Plato and other ESA missions"

BCE 7441

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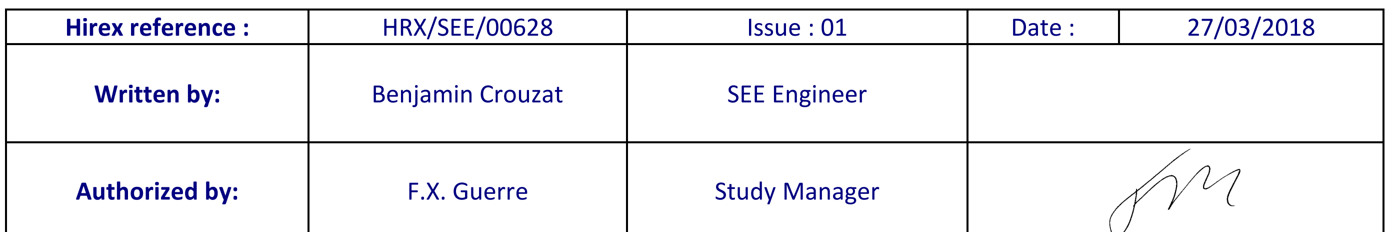
Authorized by:	F.X. Guerre	Study Manager		

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1 Introduction

This report presents results of SEE test campaign for the Analog Devices 16-Bit, 10 MSPS, PulSAR Differential ADC AD7626. The test campaign took place at UCL-HIF, Louvain-La-Neuve Belgium in October 2017. Components were tested for SEL.

2 Applicable and Reference Documents

2.1 Applicable Documents

AD-1 AD7626 datasheet rev. D

AD-2 SEE AD7626 test specification ref. HRX/SEP/00111 issue 1 dated 03/10/2017

2.2 Reference Documents

RD-1. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100

3 Device Information

3.1 Device description

The AD7626, from Analog Devices, is a 16-Bit, 10 MSPS, PulSAR Differential ADC using CMOS technology.

Manufacturer:	Analog Devices
Package:	LFCSP-32
Marking:	AD7626 BCPZ #1702 3725512 KOREA
Part number:	AD7626BCPZ-ND
Technology:	CMOS
Die dimensions:	2036 µm x 2968 µm

3.2 Device and die identification

Figure 1: Package, top.

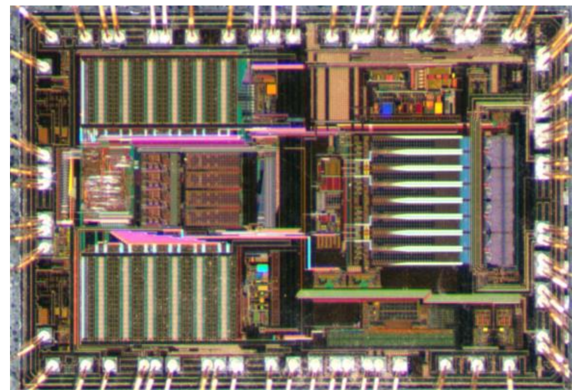


Figure 2: Component die.

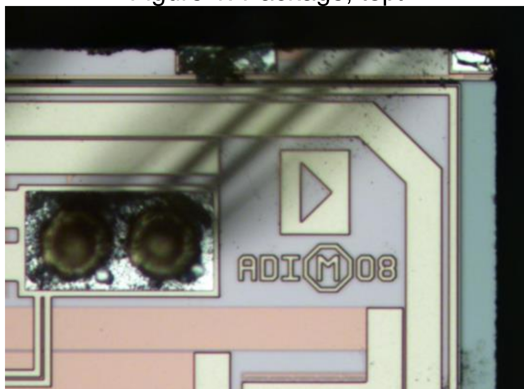


Figure 3: Die marking.

Figure 4: Die mask marking.

3.3 Samples preparation

Three samples have been chemically opened from the top and tested for their functionality before the test campaign.
Three samples are used as Device Under Test (DUT) for SEL test.

Board number	DUT number	Test performed		
		SEU	SET	SEL
1	1	-	-	X
1	2	-	-	X
1	3	-	-	X

Table 1: DUT distribution for the test campaign.

4 Test Setup

4.1 Irradiation board

3 independent DUTs are mounted on the DIB332A daughter board and bias schematic is given in Figure 5.
A photo of the top side of the board is shown in Figure 6.
Bias setup is in accordance with the SEE AD726 test specification (AD-2)

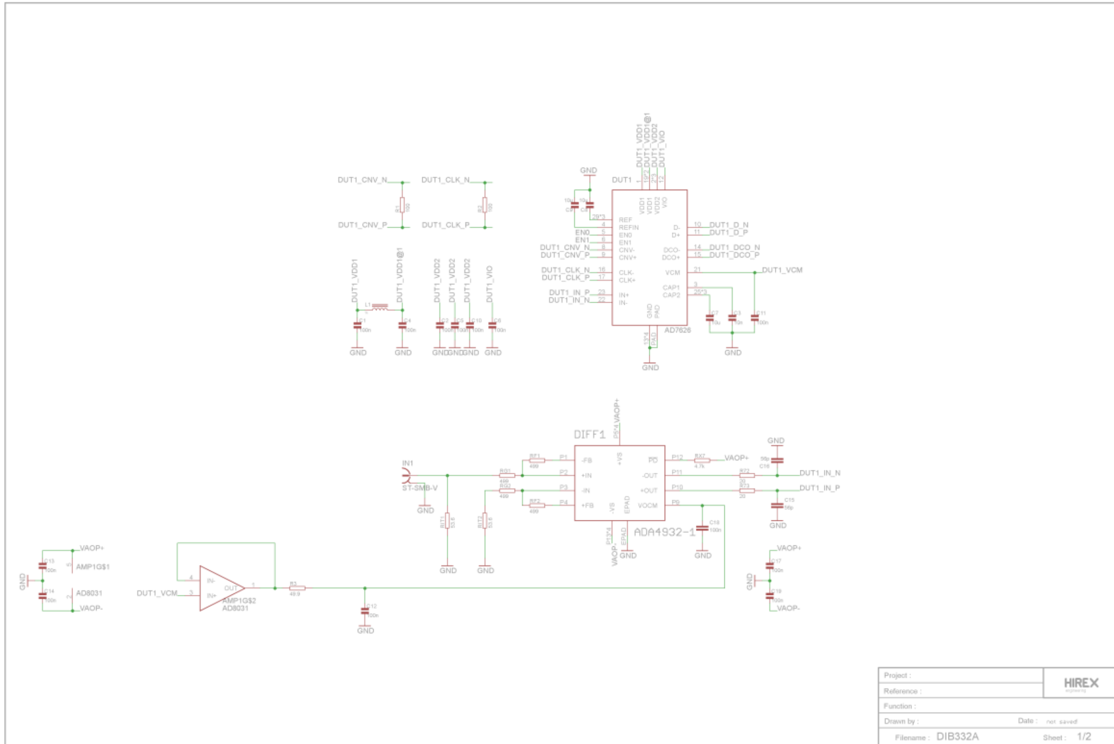


Figure 5: Part biasing.

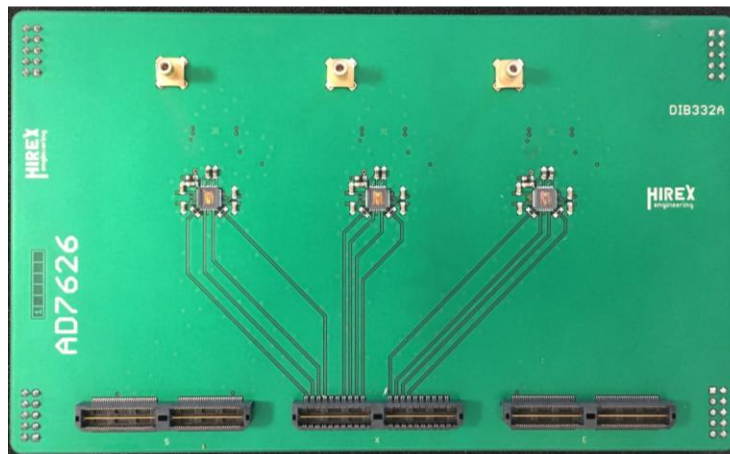


Figure 6: Top side DIB332A photo

4.2 Bias configuration

The input signal feeding the DUT will be a ±4.96V amplitude differential sinus with a frequency of 100 kHz.

The supply voltages will be set to:

Test mode	VDD1	VDD2	VIO
SEL	+6V	+3V	+3V

Clk input signal will be LVDS running at 300MHz.
Cnv input signal will be LVDS running at 10MHz to get an analog to digital conversion rate at 10MSPS.

4.3 Hirex test setup

Figure 7 shows the principle of the single event test system.

The test system is based on a Virtex4 FPGA (Xilinx). It runs at 50 MHz. The test board has 271 I/Os which can be configured using several I/O standards.

The test board includes the voltage/current monitoring and the latch-up management of the DUT power supplies with up to 24 independent channels.

The communication between the test chamber and the controlling computer is done by a 100 Mbit/s Ethernet link which safely enables high speed data transfer.

SEL event is detected when the supply current is over a configurable threshold. Once detected, SEL state is maintained and power supplies are cut off during configurable times. Each power supply under supervision is monitored independently for SEL detection and processing but subsequent cut off is performed on all power supplies.

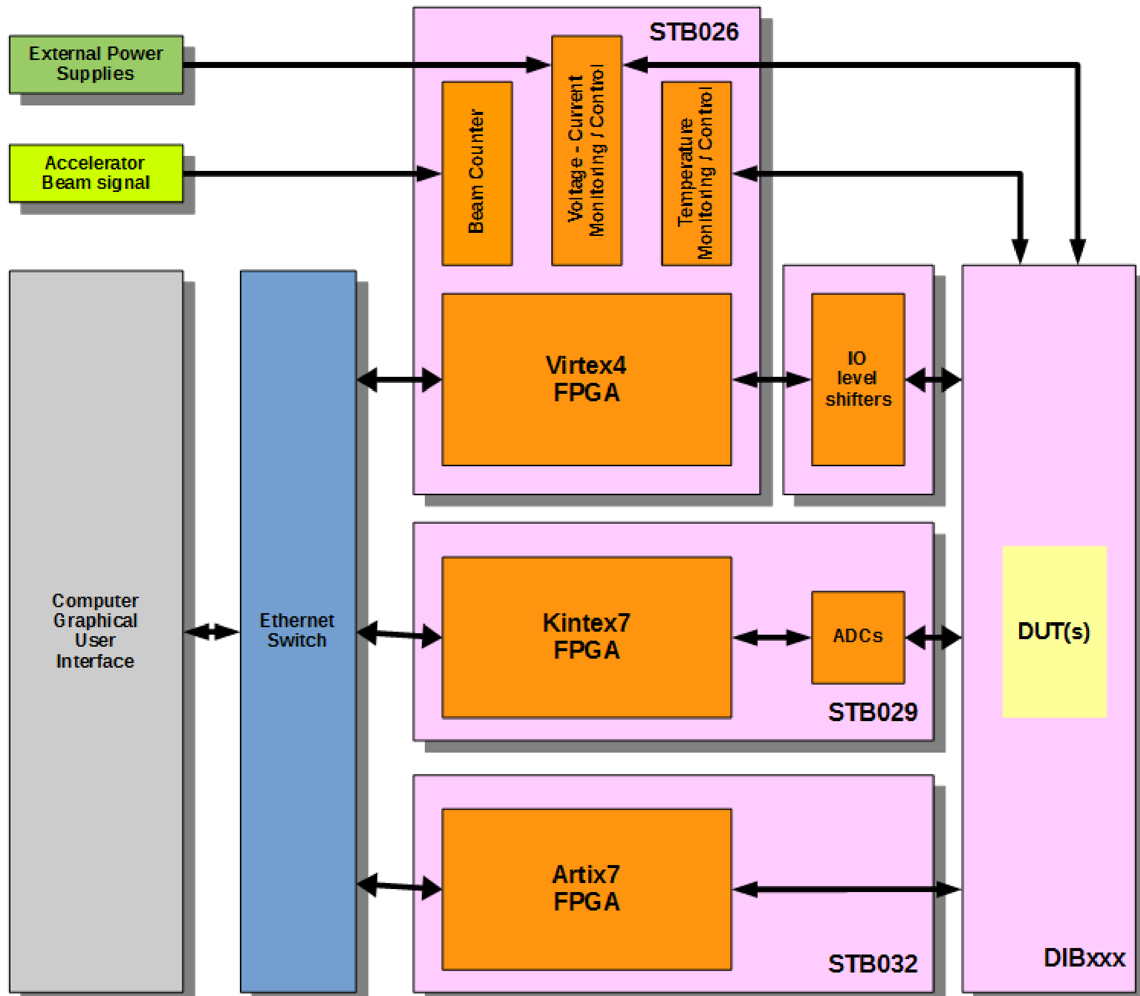


Figure 7: Hirex test setup

5 HIF facility

Test at the cyclotron accelerator was performed at Université Catholique de Louvain (UCL) in Louvain-La-Neuve (Belgium) under HIREX Engineering responsibility.

In collaboration with the European Space Agency (ESA), the needed equipment for single events studies using heavy ions was built and installed on the HIF beam line in the experimental hall of Louvain-La-Neuve cyclotron.
CYCLONE is a multi-particle, variable energy, cyclotron capable of accelerating protons (up to 75 MeV), alpha particles and heavy ions. For the heavy ions, the covered energy range is between 0.6 MeV/AMU and 27.5 MeV/AMU. For these ions, the maximal energy can be determined by the formula:

$$110\,\frac{Q^2}{M}$$

where Q is the ion charge state, and M is the mass in Atomic Mass Units.
The heavy ions are produced in a double stage Electron Cyclotron Resonance (ECR) source. Such a source allows producing highly charged ions and ion "cocktails". These are composed of ions with the same or very close M/Q ratios. The cocktail ions are injected in the cyclotron, accelerated at the same time and extracted separately by a fine tuning of the magnetic field or a slight changing of the RF frequency. This method is very convenient for a quick change of ion (in a few minutes) which is equivalent to a LET variation.

5.1 Dosimetry

The current UCL Cyclotron dosimetry system and procedures were used.

5.2 Used ions

UCL cocktail ions used for the test campaign are listed in the table below.

M/Q	Ion	DUT energy [MeV]	Range [µm Si]	LET [MeV/mg/cm²]
3.33	$^{40}Ar^{12+}$	379	120.5	10.0
3.31	$^{53}Cr^{16+}$	513	107.6	16.0
3.22	$^{58}Ni^{18+}$	582	100.5	20.4
3.35	$^{84}Kr^{25+}$	769	94.2	32.4
3.32	$^{103}Rh^{31+}$	972	88.7	45.8
3.54	$^{124}Xe^{35+}$	995	73.1	62.5

Table 2: Ion beam setting

6 Results

Overall test results are summarized in Table 3.
DUT Tcase was set to about 70°C so that a die surface temperature of 85°C is measured with an infrared thermometer.
At the end of run001, VDD1 current limit was increased from 100mA to 200mA.
In the course of run004 VDD1 current limit was increased from 100mA to 150mA after the first SEL detected on this UI source.
Most events were detected on VDD1 UI source. SEL cross-section plot is provided in Figure 8.

Facility	dut_medium	run_number	Facility_run_number	board_id	DUT_partnumber	power_config	temperature	Ion	tilt	run_duration	entered_fluence	LET MeV/(mg/cm²)	VDD1 UI channel	VDD2 UI channel	VIO UI channel	VDD1 current limit mA	VDD2 current limit mA	VIO current limit mA	VDD1 SEL	VDD2 SEL	VIO SEL	total	SEL X-section cm²
HIF	vacuum	1	141	1	1	Vmax	85	Kr-769	0	972	1061805	32.4	16	15	17	200	100	100	55	9	0	64	6.03E-05
HIF	vacuum	3	143	1	1	Vmax	85	Ne-238	0	660	1.00E+07	3.3	16	15	17	200	100	100	0	1	0	1	1.00E-07
HIF	vacuum	4	144	1	1	Vmax	85	Ar-379	0	692	1.00E+07	10	16	15	17	200	150	100	2	1	0	3	3.00E-07
HIF	vacuum	2	142	1	2	Vmax	85	Ne-238	0	898	1.00E+07	3.3	19	18	20	100	100	100	0	0	0	0	1.00E-10
HIF	vacuum	5	145	1	2	Vmax	85	Ar-379	0	649	1.00E+07	10	19	18	20	100	100	100	0	0	0	0	1.00E-10
HIF	vacuum	8	148	1	2	Vmax	85	Ni-582	0	505	4.96E+06	20.4	19	18	20	100	100	100	127	0	0	127	2.56E-05
HIF	vacuum	6	146	1	3	Vmax	85	Ar-379	0	645	1.00E+07	10	7	6	5	100	100	100	0	0	0	0	1.00E-10
HIF	vacuum	7	147	1	3	Vmax	85	Ni-582	0	1403	7.75E+06	20.4	7	6	5	100	100	100	108	0	0	108	1.39E-05
HIF	vacuum	9	149	1	3	Vmax	85	Cr-513	0	1356	1.00E+07	16	7	6	5	100	100	100	48	0	0	48	4.80E-06

Table 3: AD7626 results for SEL test runs.

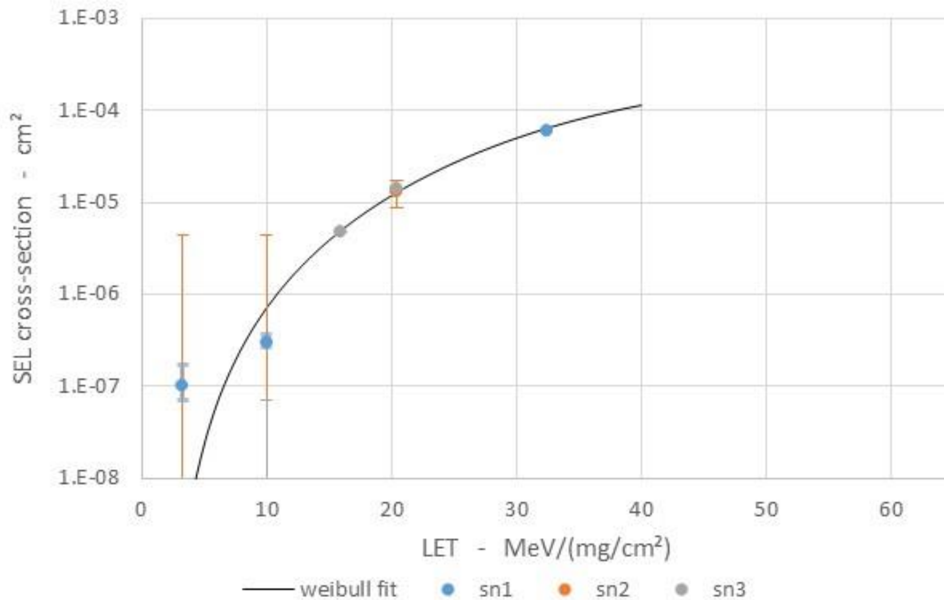
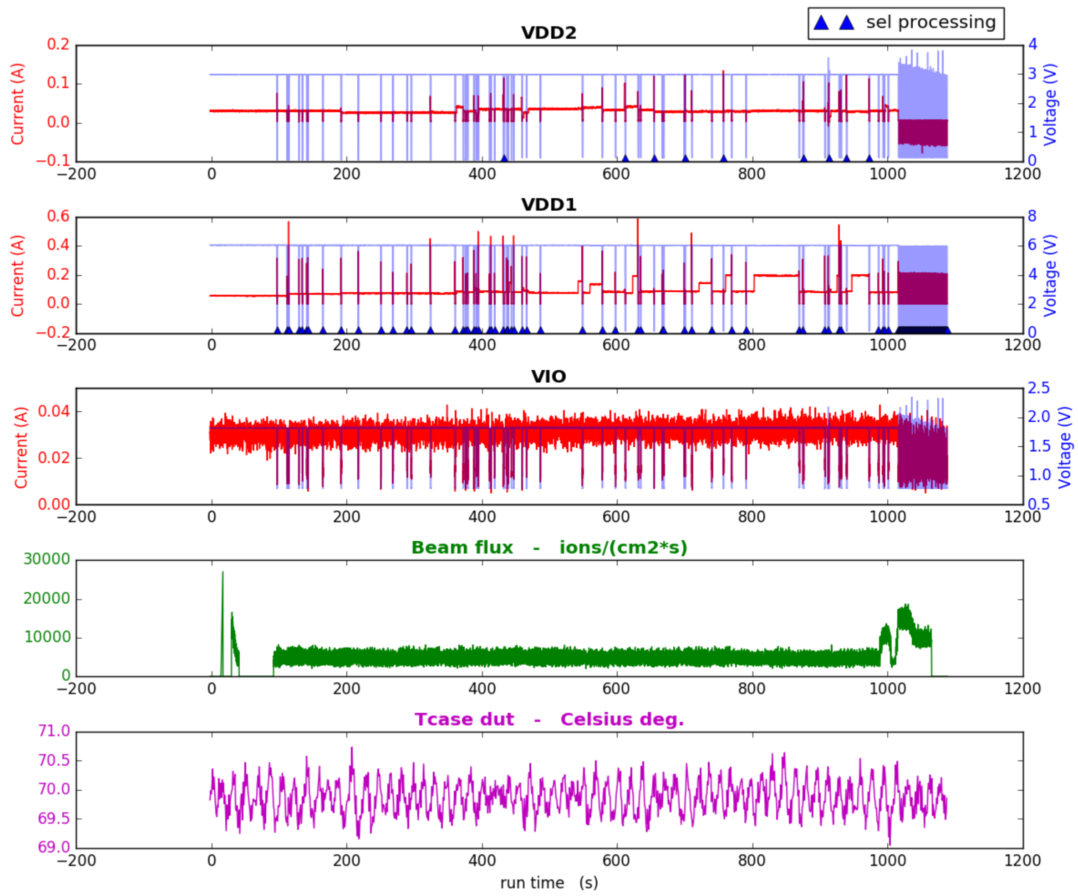


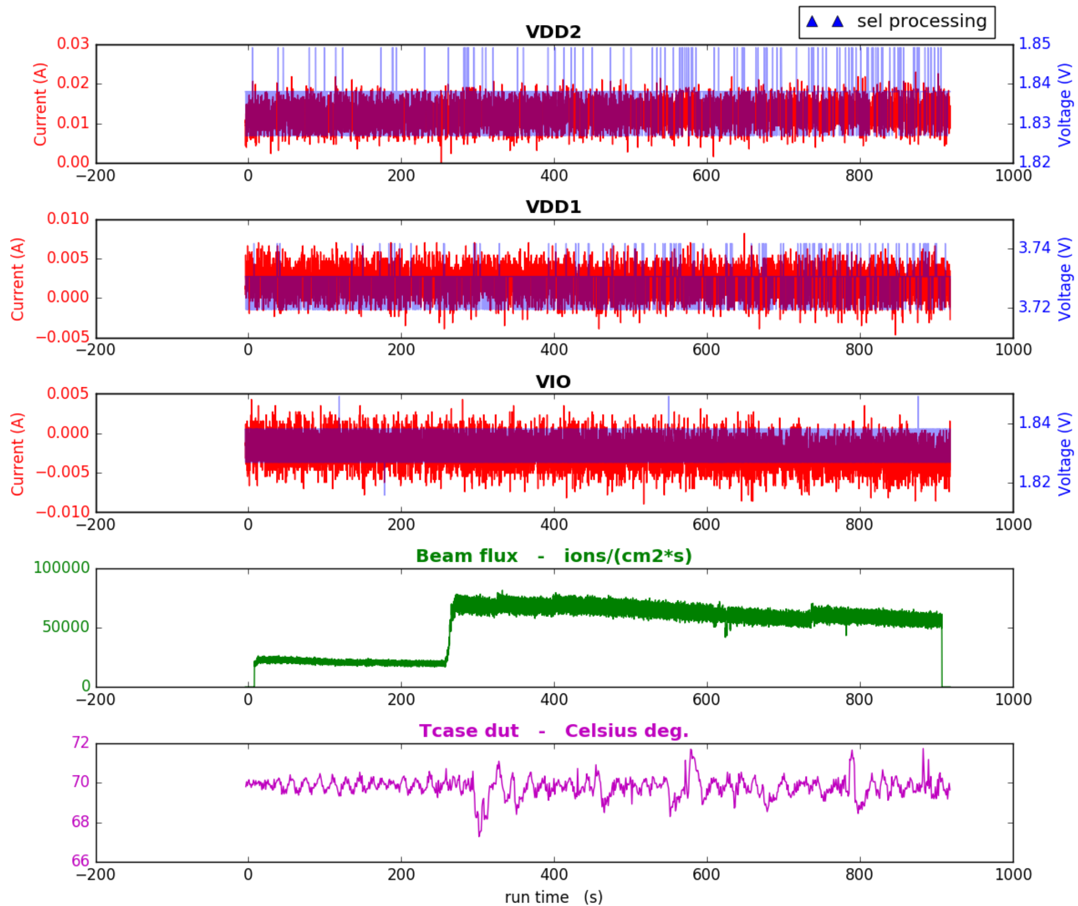
Figure 8 – UCL October 2017, AD7626 SEL cross-section plot

Corresponding runs chronograms are provided in following pages.
Current steps on both VDD1 and VDD2 UI sources can be observed and distinction between SEL events and high current steps may be difficult.

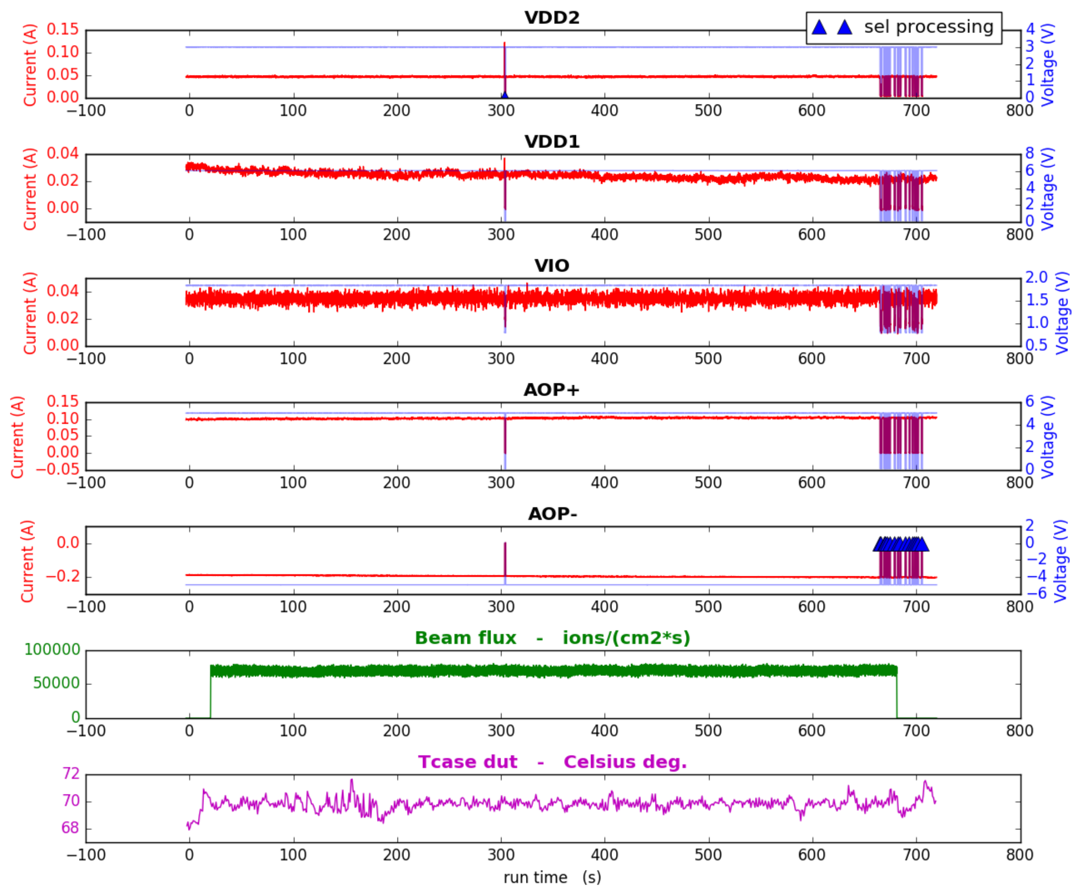


RUN001

At the end of the run001, VDD1 current limit was increased from 100mA to 200mA

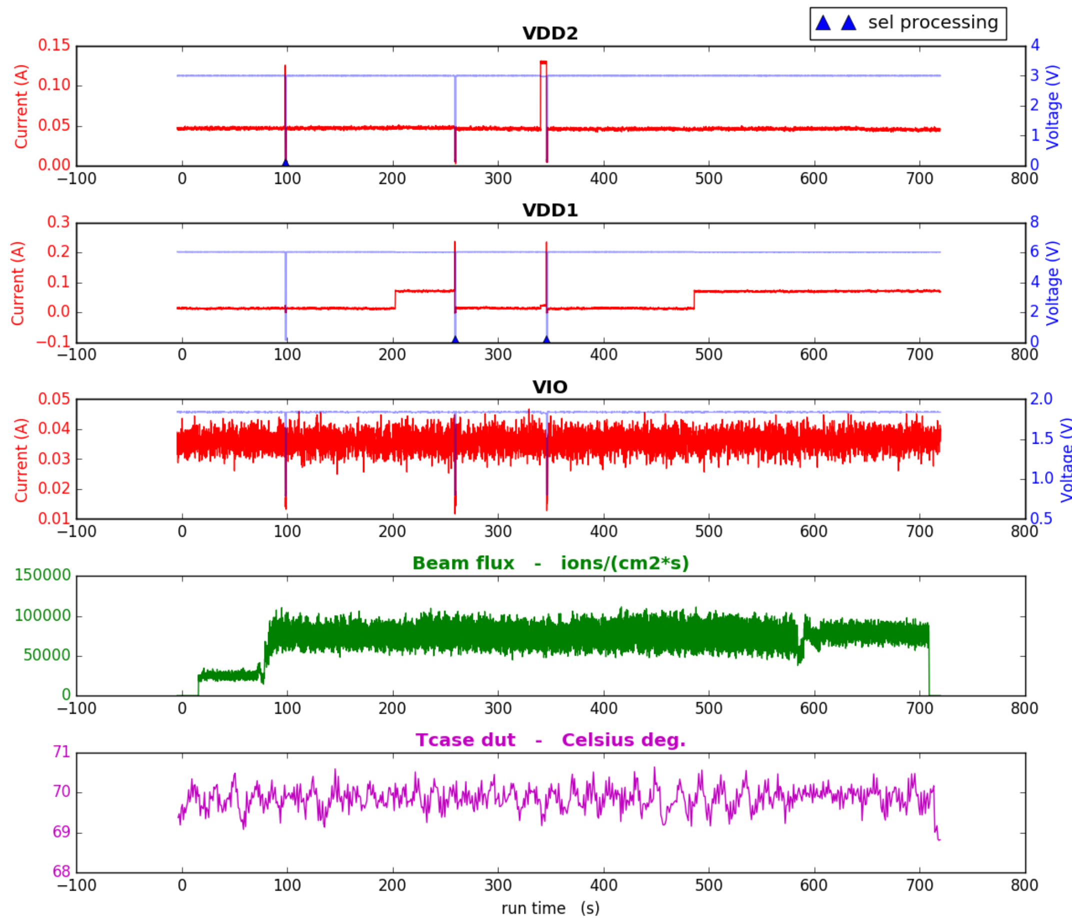


RUN002



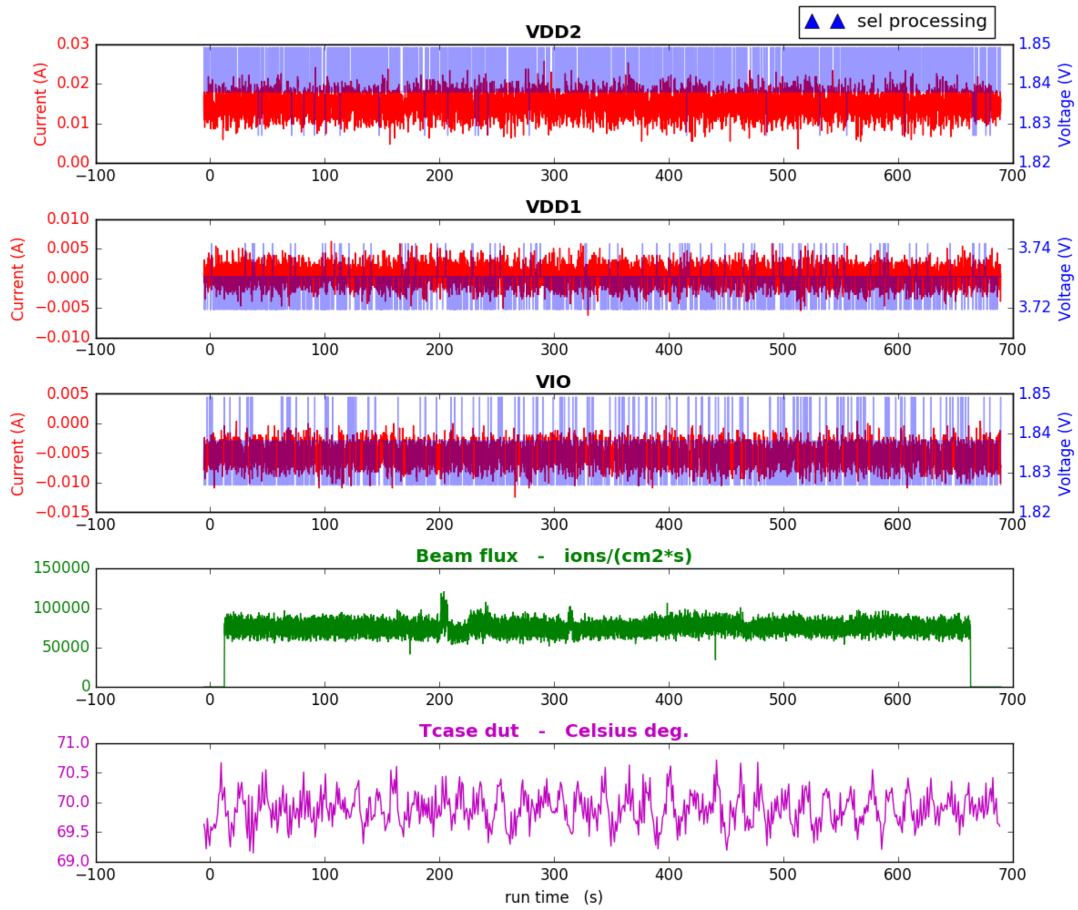
RUN003

Toward the end of the run003, Differential amplifier used in the bias setup exceeded continuously the current limit set for this part but it is not related in any case to the DUT behaviour.

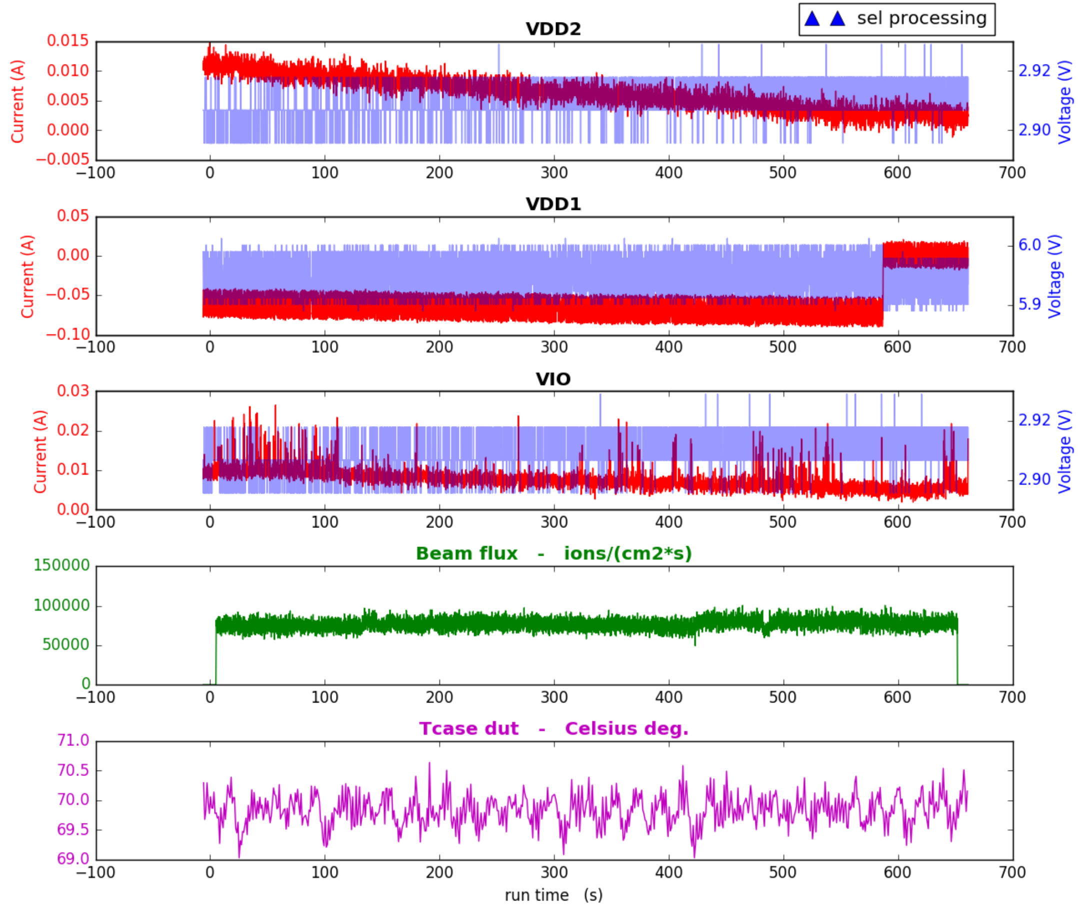


RUN004

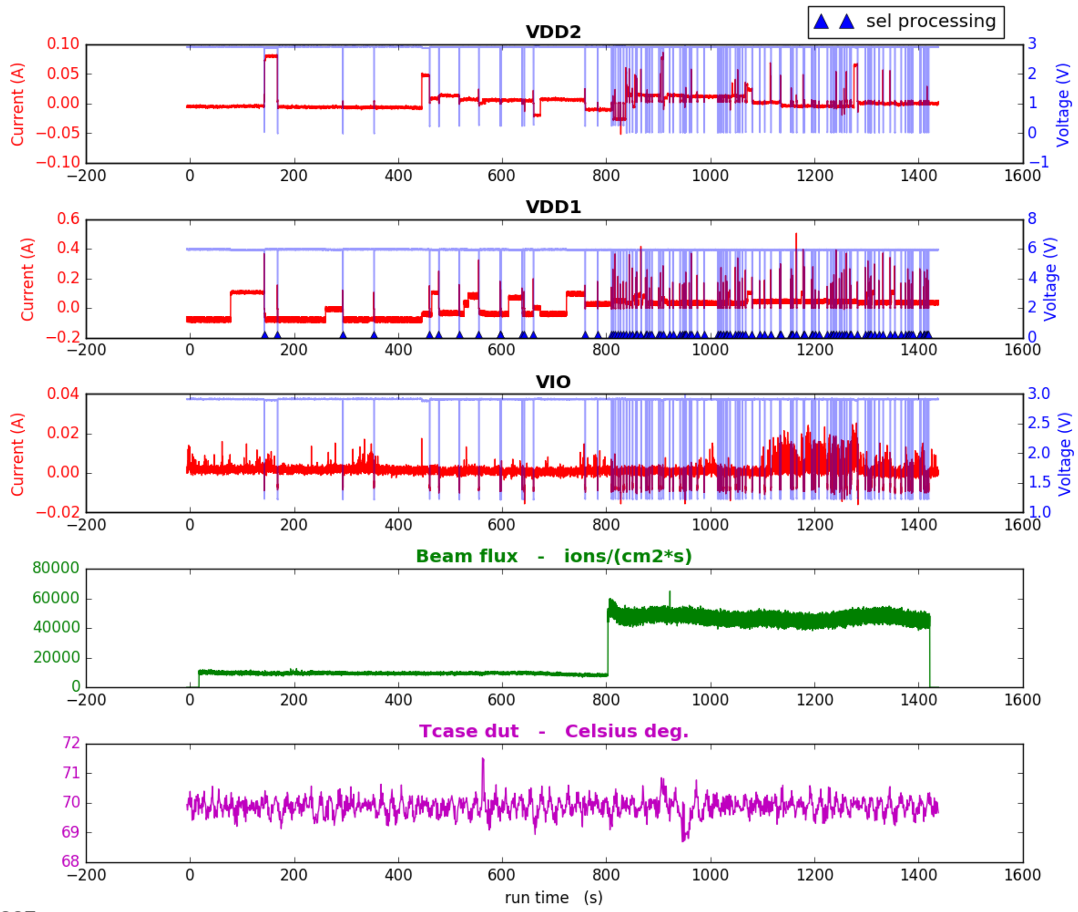
In the course of run004 and after the first SEL event detected on VDD1 UI source, current limit was increased from 100mA to 150mA



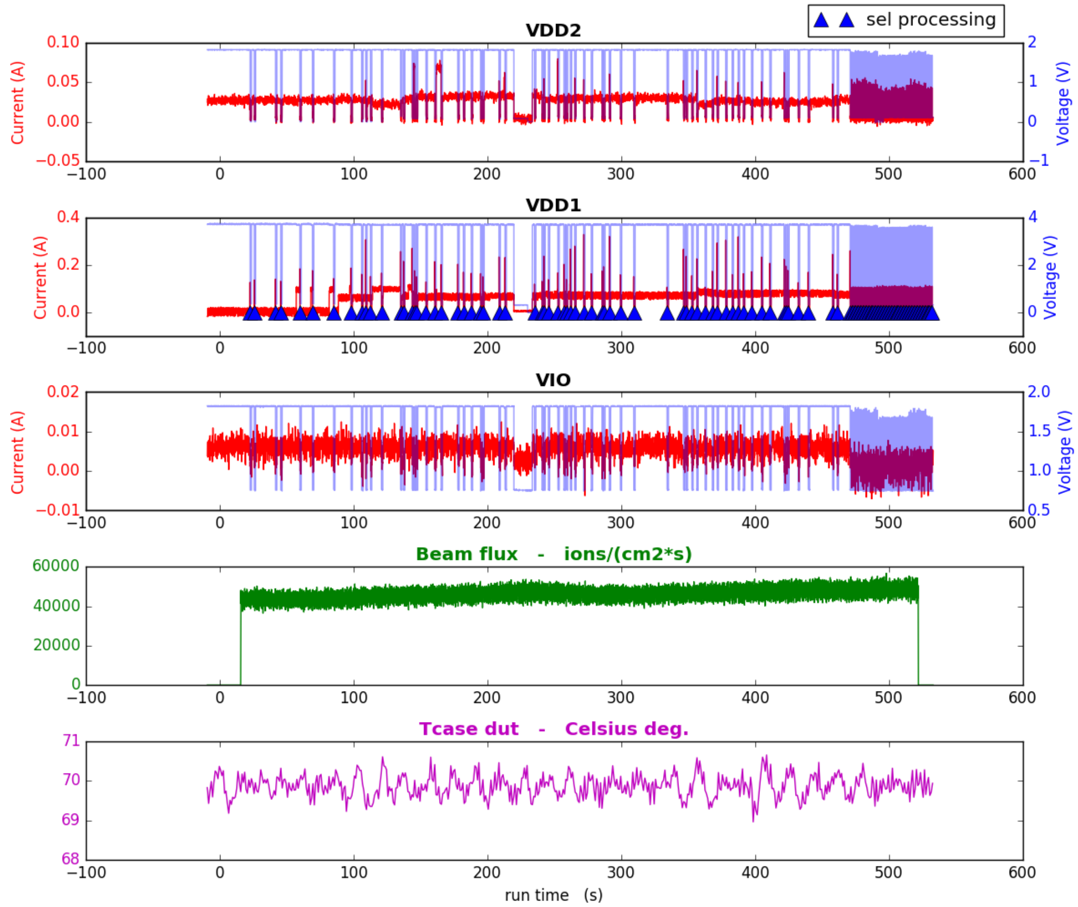
RUN005



RUN006

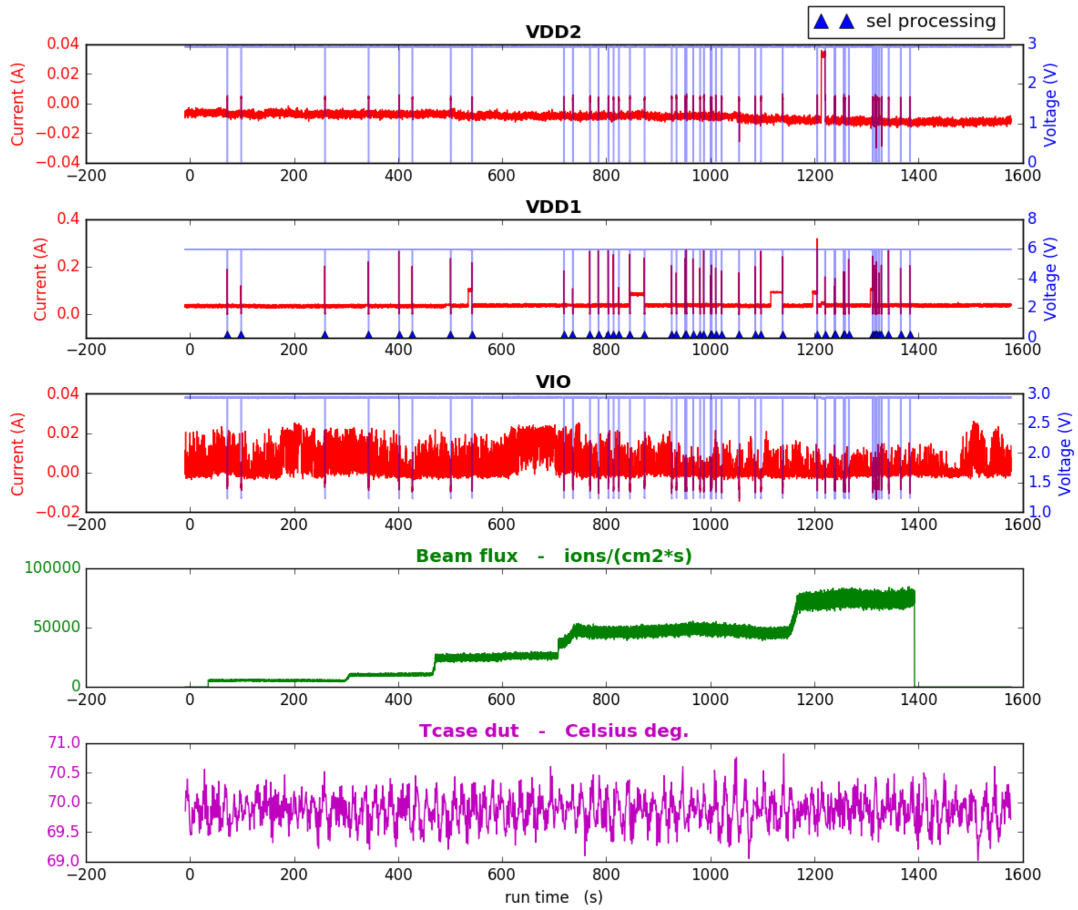


RUN007



RUN008

At the end of the run008, VDD1 current limit was continuously exceeded and then corresponding events have been removed from the SEL count.



RUN009

7 Glossary

DUT: Device under test.

Fluence (of particle radiation incident on a surface): The total amount of particle radiant energy incident on a surface in a given period of time, divided by the area of the surface.
In this document, Fluence is expressed in ions per cm².

Flux: The time rate of flow of particle radiant energy incident on a surface, divided by the area of that surface.
In this document, Flux is expressed in ions per cm².s.

Linear Energy Transfer (LET): Amount of energy lost by an ion inside its path in the absorber medium when colliding with atomic electron. In this document, LET is divided by the mass density of the absorber medium and is expressed in MeV.cm²/mg.

Single-Event Effect (SEE): Any measurable or observable change in state or performance of a microelectronic device, component, subsystem, or system (digital or analog) resulting from a single energetic particle strike.
Single-event effects include single-event upset (SEU), multiple-bit upset (MBU), multiple-cell upset (MCU), single-event functional interrupt (SEFI), single-event latch-up (SEL).

Single Event Gate Rupture (SEGR) **/ Single Event Dielectric Rupture (**SEDR**):** Destructive rupture of the gate oxide layer or dielectric layer by a single ion strike. This leads to leakage currents under bias and can be observed as stuck bits in digitals devices

Single-Event Upset (SEU)**:** A soft error caused by the transient signal induced by a single energetic particle strike.

Single-Event Transient (SET): A transient signal induced by a single energetic particle strike.

Single-Event Latch-up (SEL): An abnormal high-current state in a device caused by the passage of a single energetic particle through sensitive regions of the device structure and resulting in the loss of device functionality.
SEL may cause permanent damage to the device. If the device is not permanently damaged, power cycling of the device (off and back on) is necessary to restore normal operation.
An example of SEL in a CMOS device is when the passage of a single particle induces the creation of parasitic bipolar (p-n-p-n) shorting of power to ground.

Single-Event Functional Interrupt (SEFI): A soft error that causes the component to reset, lock-up, or otherwise malfunction in a detectable way, but does not require power cycling of the device (off and back on) to restore operability, unlike single-event latch-up (SEL), or result in permanent damage as in single-event burnout (SEB).
A SEFI is often associated with an upset in a control bit or register.

Error cross-section: the number of errors per unit fluence. For device error cross-section, the dimensions are cm² per device. For bit error cross-section, the dimensions are cm² per bit.

Tilt angle: tilt angle, rotation axis of the DUT board is perpendicular to the beam axis; roll angle, board rotation axis is parallel to the beam axis

Weibull fit: $F(x) = A\,(1-\exp\{-[(x-x_0)/W]^s\})$ with:

x = effective LET in MeV/(mg/cm^2);
$F(x)$ = SEE cross-section in cm^2;
A = limiting or plateau cross-section;
x_0 = onset parameter, such that $F(x) = 0$ for $x < x_0$;
W = width parameter;
s = a dimensionless exponent.

Error bars: error bars are computed using a confidence level of 95% and a beam flux uncertainty of +/- 10% as recommended by Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100.