Single Event Effects

Heavy Ions Test Report

Test type	Single Event Latchup, Single Event Transient
Part Reference	AD8021
Tested function	Low Noise, High Speed Amplifier for 16-Bit Systems
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

Hirex reference :	HRX/SEE/00630	Issue : 01	Date :	27/03/2018
Written by:		SEE Engineer		
Authorized by:	F.X. Guerre	Study Manager		

DOCUMENTATION CHANGE NOTICE

Issue	Date	Page	Change Item	
01	06/11/2017	All	Original issue	

Contributors to this work:

Benjamin Crouzat Hirex Engineering

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

1 Introduction

This report presents results of SEE test campaign for the Analog Devices Low Noise, High Speed Amplifier for 16-Bit Systems AD8021. The test campaign took place at UCL-HIF, Louvain-La-Neuve Belgium in October 2017. Components were tested for SET and SEL.

2 Applicable and Reference Documents

2.1 Applicable Documents

AD-1 AD8021datasheet rev. D

AD-2 SEE AD8021test specification ref. HRX/SEP/00113 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 AD8021, from Analog Devices, is a Low Noise, High Speed Amplifier for 16-Bit Systems using CMOS technology.

Manufacturer:	Analog Devices
Package:	SOIC-08
Datecode:	1640
Marking:	8021A logo #1640 . 2877
Mnfr lot number:	6418.7
Part number:	AD8021ARZ-REEL7CT-ND
Technology:	CMOS
Die dimensions:	694 µm x 1045 µm

3.2 Device and die identification

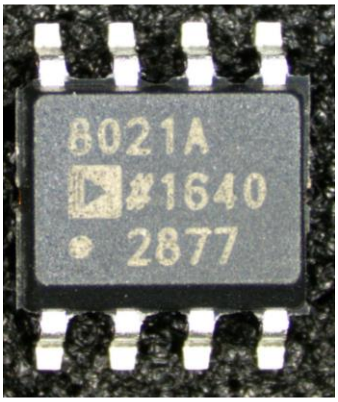


Figure 1: Package, top.

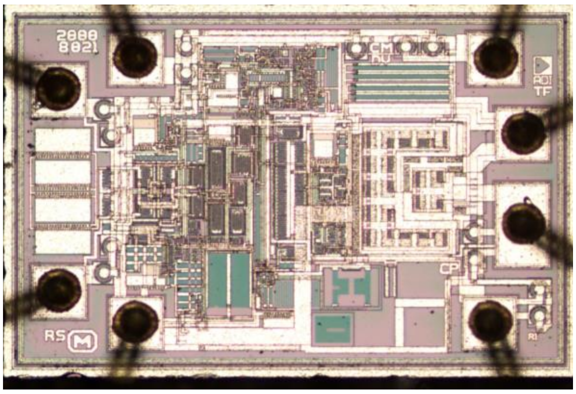


Figure 2: Component die.

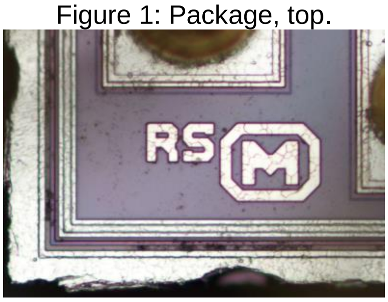


Figure 3: Die marking #1.

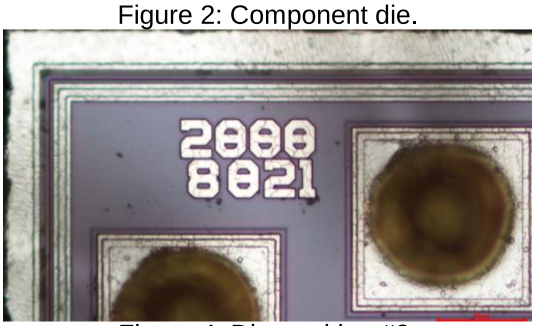


Figure 4: Die marking #2.

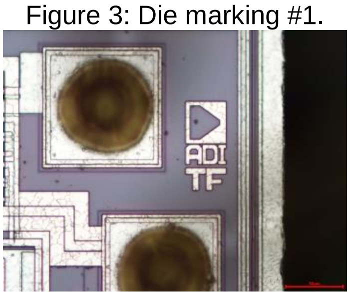


Figure 5: Die marking #3.

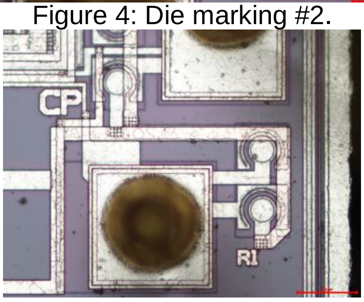


Figure 6: Die mask marking #4.

3.3 Samples preparation

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

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

Table 1: DUT distribution for the test campaign.

4 Test Setup

4.1 Irradiation board

2 independent DUTs are mounted on the DIB330A 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 AD8021 test specification (AD-2)

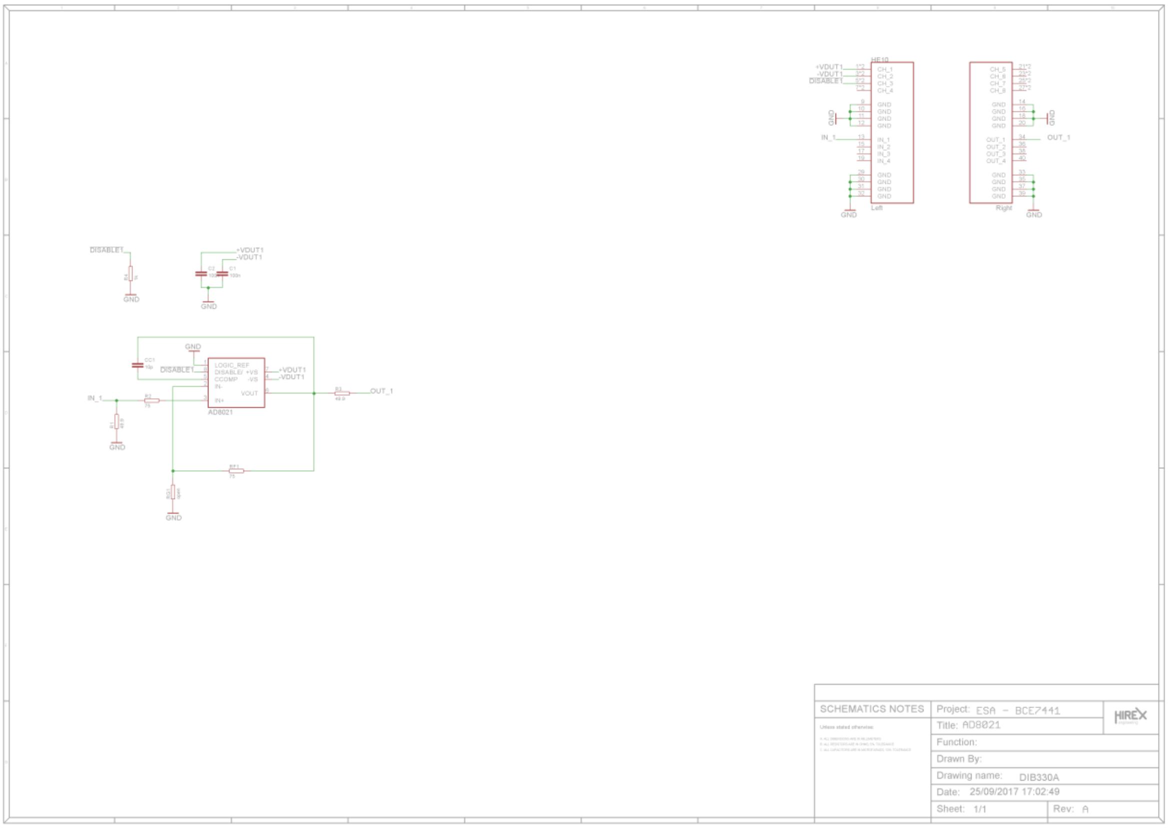


Figure 5: Part biasing.

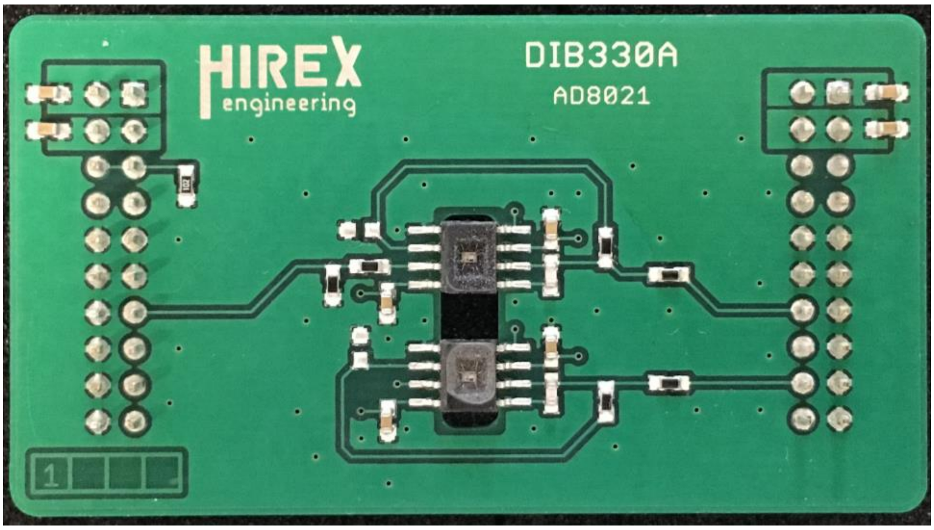


Figure 6: Top side DIB330A photo.

4.2 Bias configuration

The input signal feeding the DUT will be a ±1V amplitude sinus with a frequency of 400 kHz.
The supply voltages will be set to:

Test mode	Vs
SEL	±13.2V
SET	±5V

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.

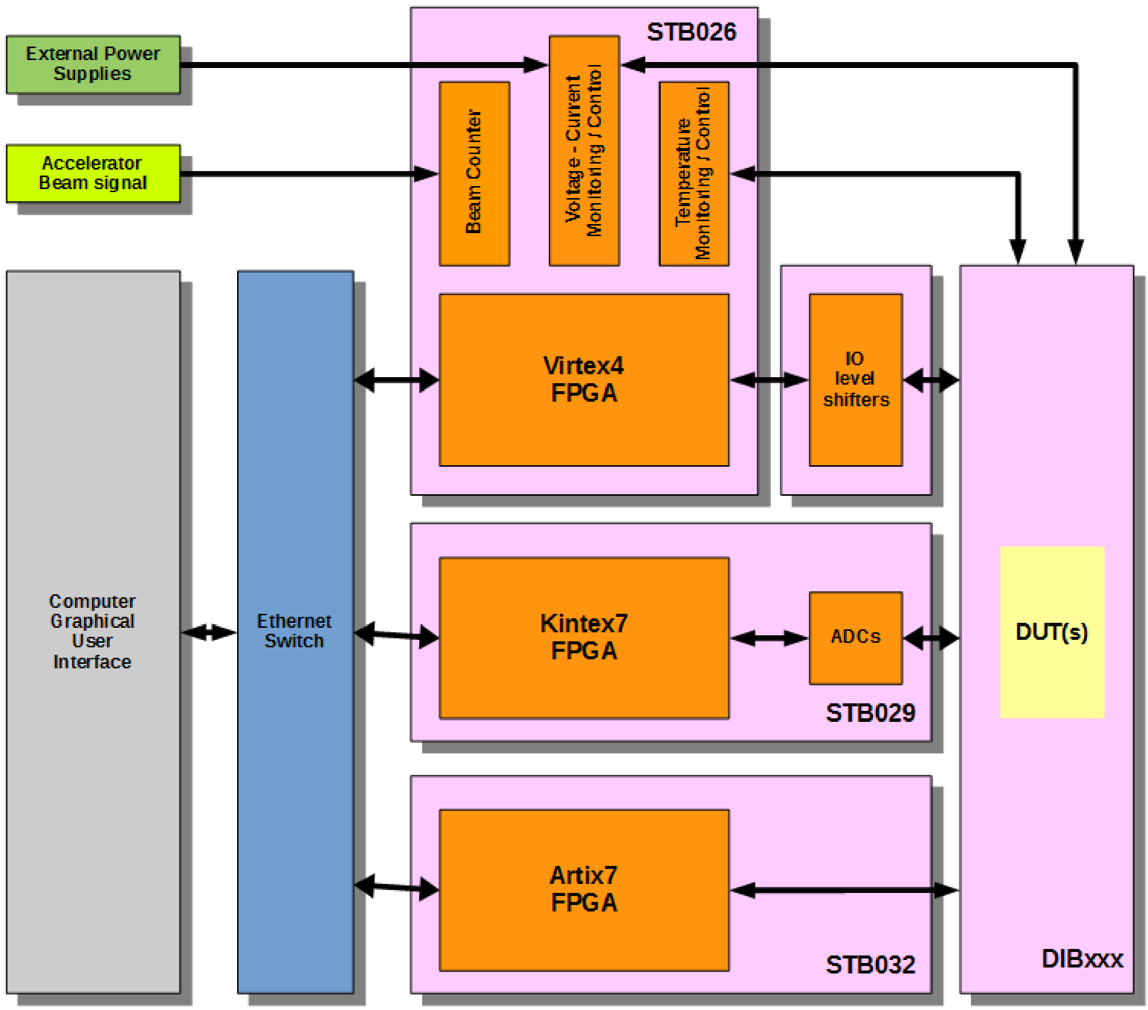


Figure 7: Hirex test setup

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.
DUTs Tcase was set to about 68°C for Board #1 and 50°C for board #2 so that a die surface temperature of 85°C is measured with an infrared thermometer.

No SEL was detected up to an LET of 81.6 MeV/(mg/cm²) and a DUT Tj of 85°C.

A SET run was performed at an LET of 10 MeV/(mg/cm²) with an input sinewave of ±1V and a frequency of 400kHz and the corresponding cross-section is about 3.5 10-6 cm². SET threshold was set to 270mV.

Facility	dut_medium	run_number	Facility_run_number	board_id	DUT_partnumber	thermocouple no	Power config	temperature	Ion	LET MeV/(mg/cm²)	tilt	Eff. LET MeV/(mg/cm²)	run_duration	entered_fluence	V+ UI channel	V- UI channel	Disable1/2_n UI channel	V+ current limit mA	V- current limit mA	Disable1/2_n current limit mA	V+ SEL	V- SEL	Disable1/2_n SEL	SET	SET X-section cm²
HIF	vacuum	1	135	1	1	7	±13.2V	85	Kr	32.4	0	32.4	983	1.00E+07	13	14	15	100	120	120	0	0	0	-	-
HIF	vacuum	1	135	1	2	7	±13.2V	85	Kr	32.4	0	32.4	983	1.00E+07	21	22	23	100	120	120	0	0	0	-	-
HIF	vacuum	2	136	2	1	8	±13.2V	85	Kr	32.4	0	32.4	883	1.00E+07	13	14	15	100	120	120	0	0	0	-	-
HIF	vacuum	2	136	2	2	8	±13.2V	85	Kr	32.4	0	32.4	883	1.00E+07	21	22	23	100	120	120	0	0	0	-	-
HIF	vacuum	3	137	2	1	8	±13.2V	85	Xe	62.5	0	62.5	656	1.00E+07	13	14	15	100	120	120	0	0	0	-	-
HIF	vacuum	3	137	2	2	8	±13.2V	85	Xe	62.5	0	62.5	656	1.00E+07	21	22	23	100	120	120	0	0	0	-	-
HIF	vacuum	4	138	1	1	7	±13.2V	85	Xe	62.5	0	62.5	655	1.00E+07	13	14	15	100	120	120	0	0	0	-	-
HIF	vacuum	4	138	1	2	7	±13.2V	85	Xe	62.5	0	62.5	655	1.00E+07	21	22	23	100	120	120	0	0	0	-	-
HIF	vacuum	5	139	1	1	7	±13.2V	85	Xe	62.5	40	81.6	853	1.00E+07	13	14	15	100	120	120	0	0	0	-	-
HIF	vacuum	5	139	1	2	7	±13.2V	85	Xe	62.5	40	81.6	853	1.00E+07	21	22	23	100	120	120	0	0	0	-	-
HIF	vacuum	7	140	1	1	7	±5V		Ar	10	0	10.0	114	1.00E+06	13	14	15	100	120	120	0	0	0	3	3.00E-06
HIF	vacuum	7	140	1	2	7	±5V		Ar	10	0	10.0	114	1.00E+06	21	22	23	100	120	120	0	0	0	4	4.00E-06

Table 3: AD8021 results for test runs.

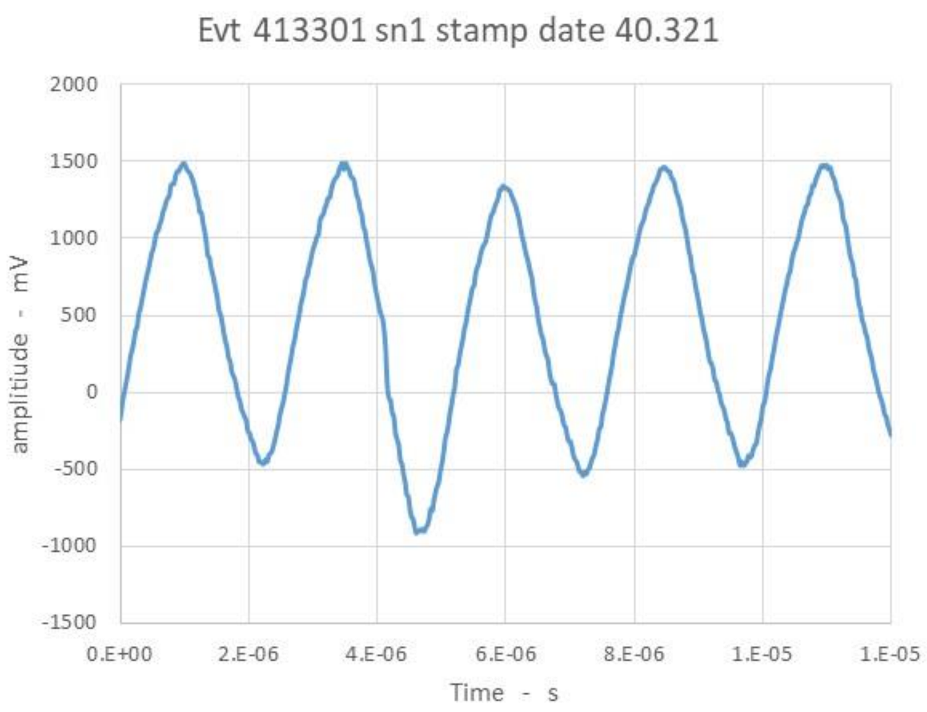
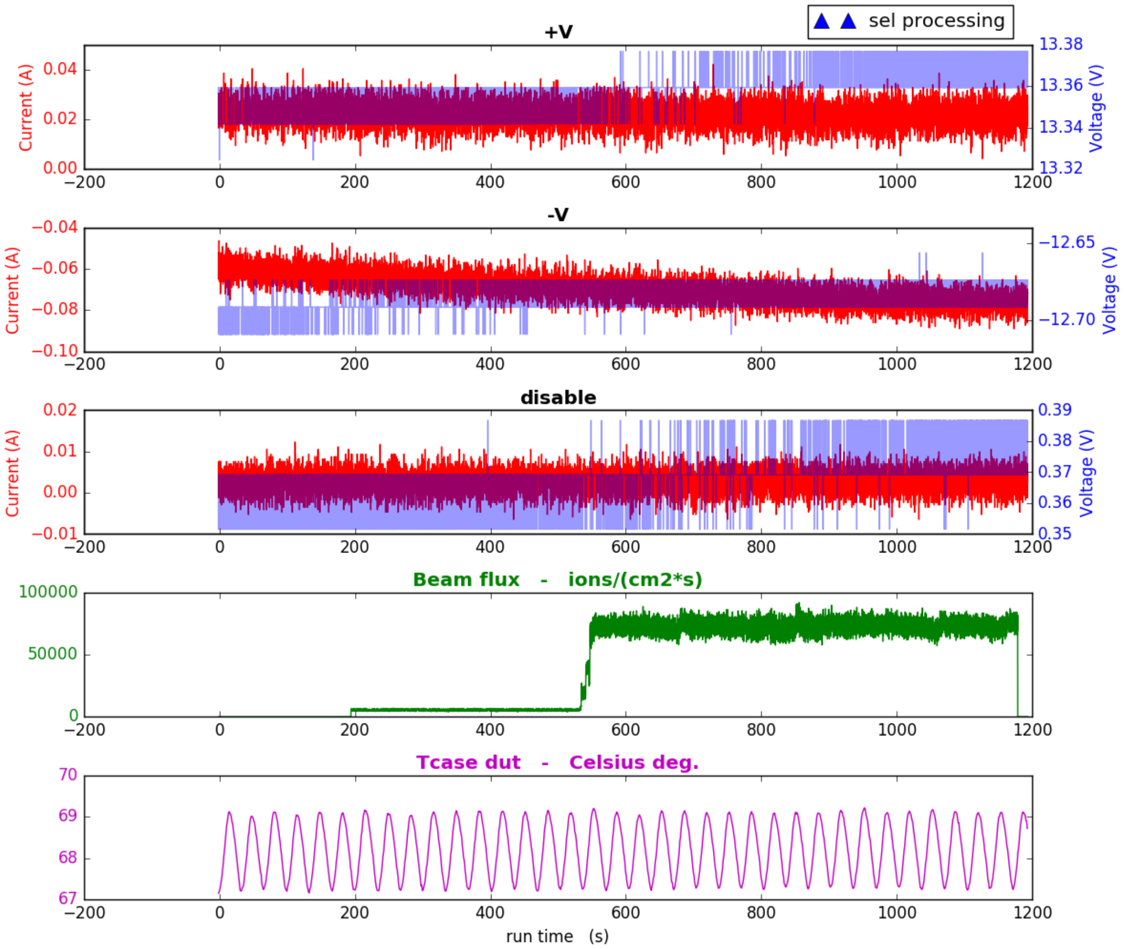
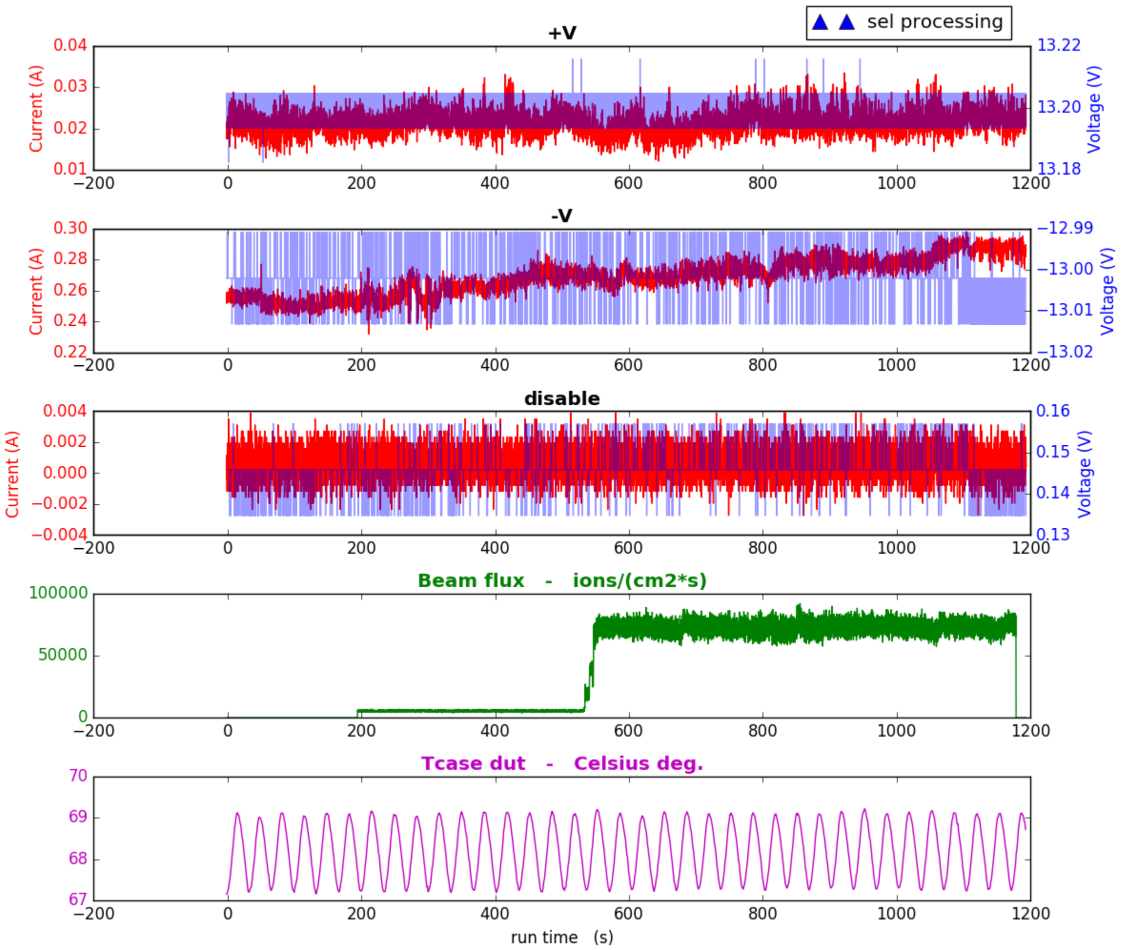


Figure 8 – AD8121 SET event example on sn1

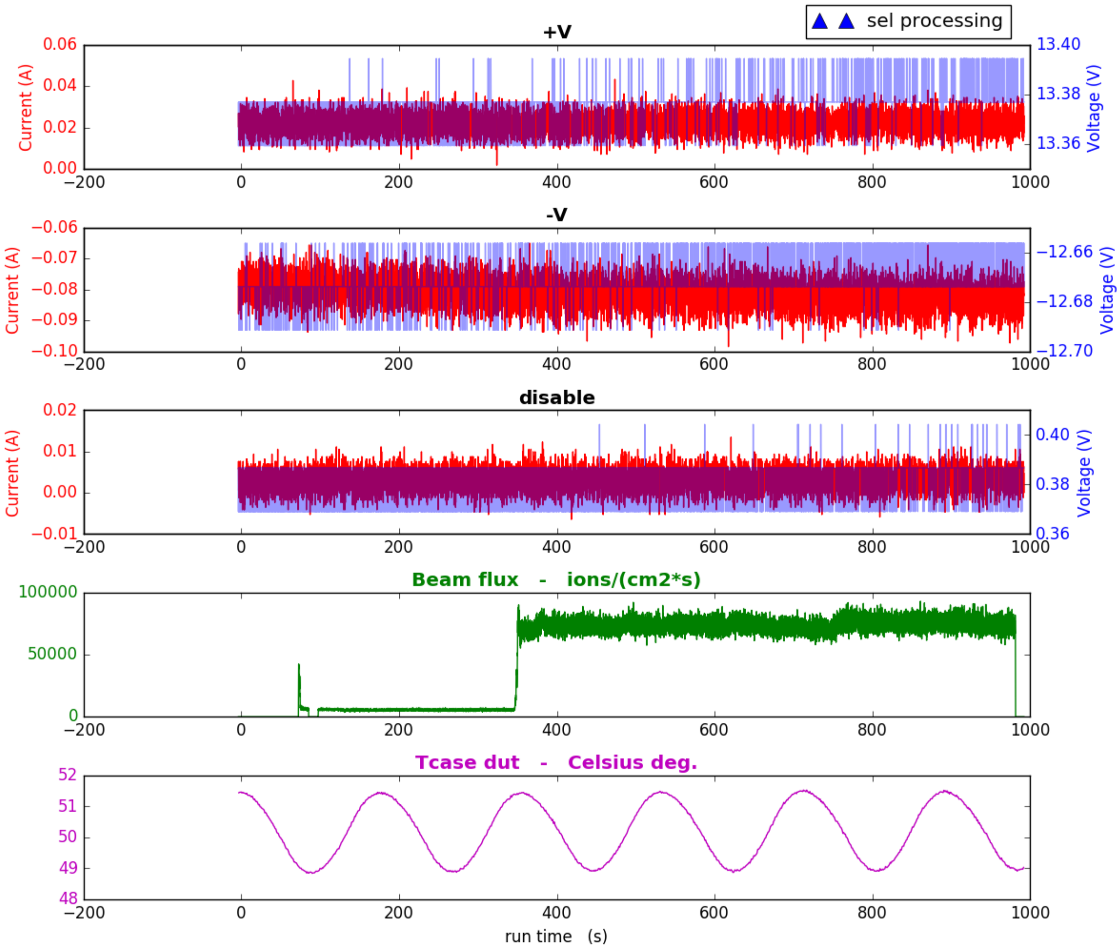
Corresponding runs chronograms are provided in following pages.



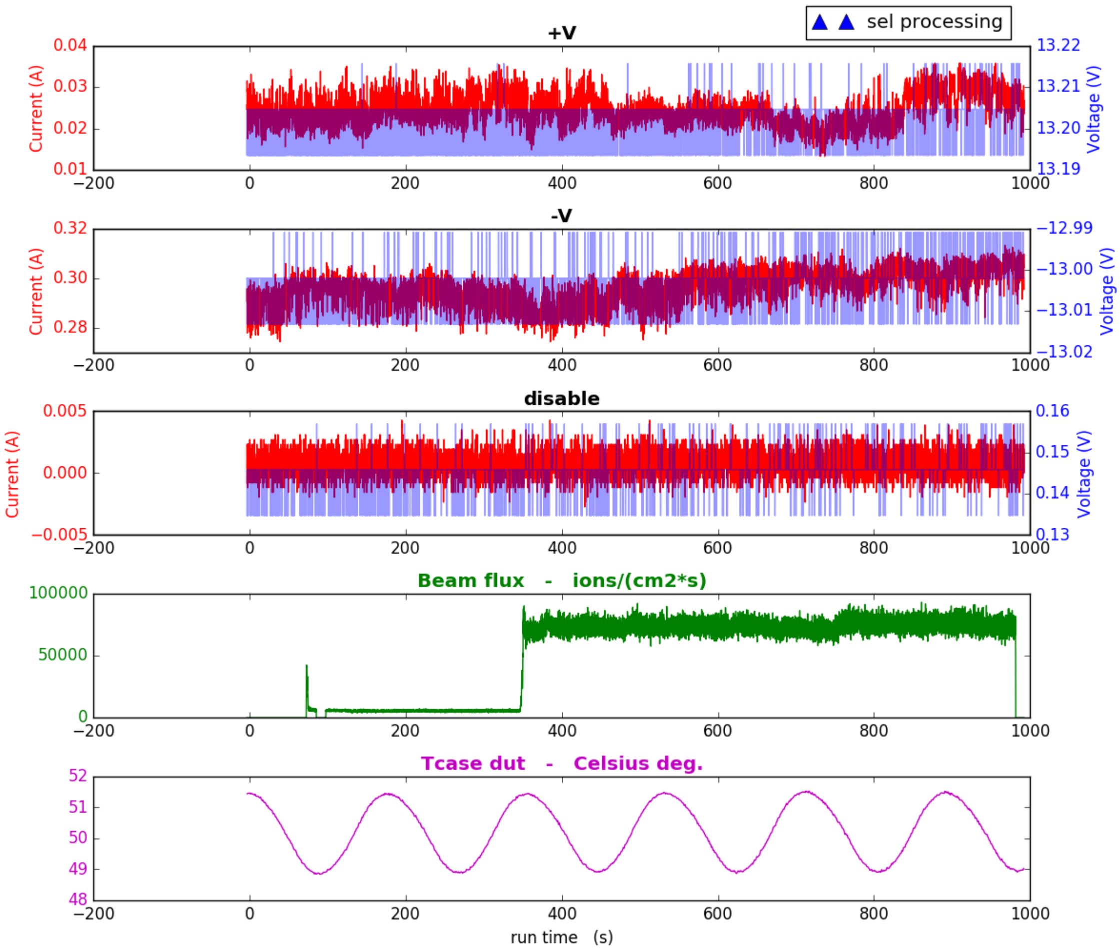
RUN001 sn1



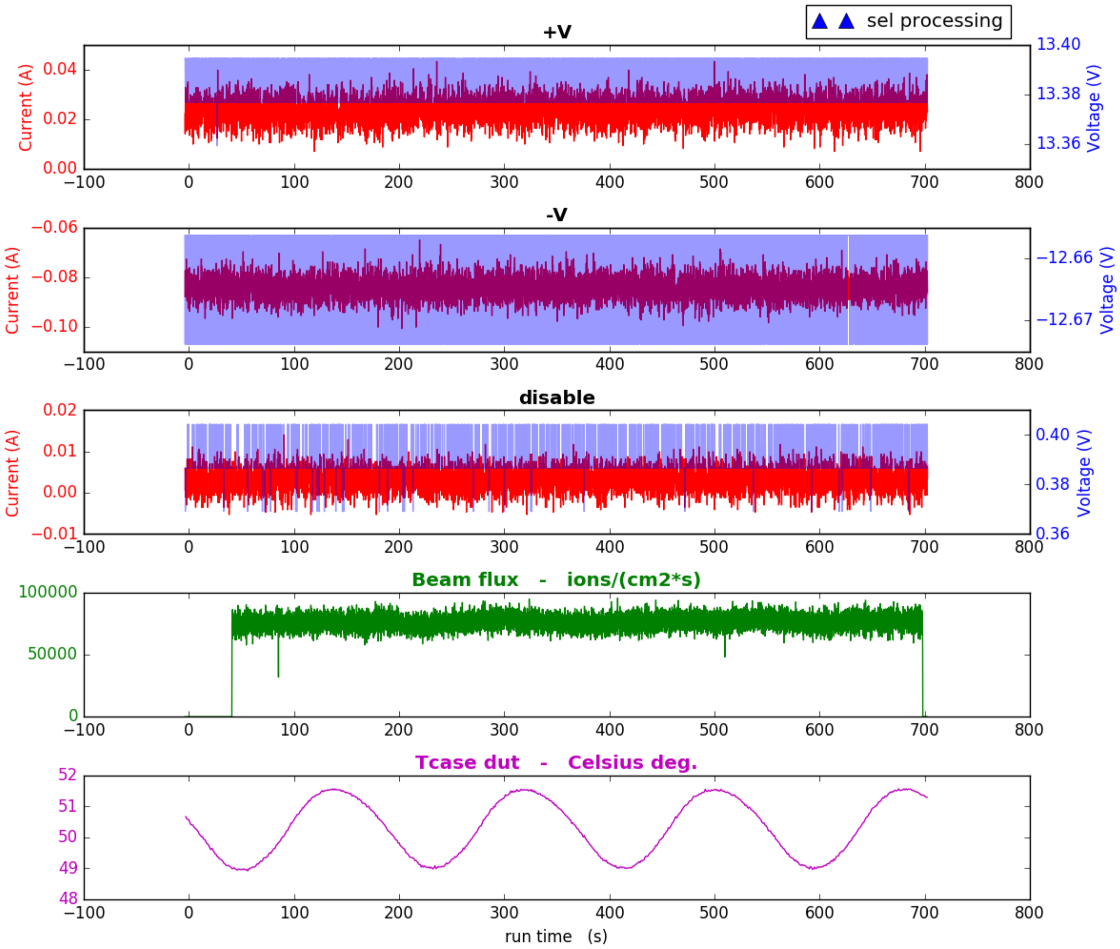
RUN001 sn2



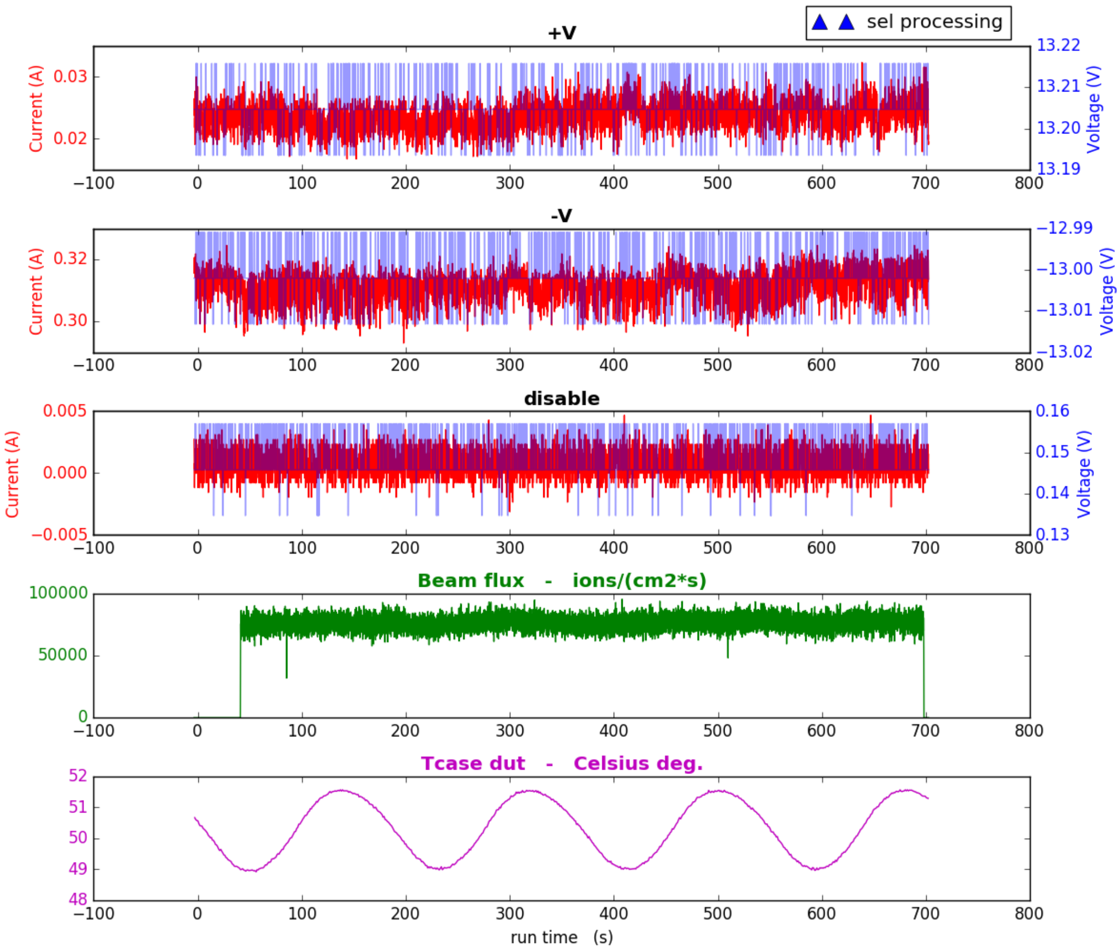
RUN002 sn1



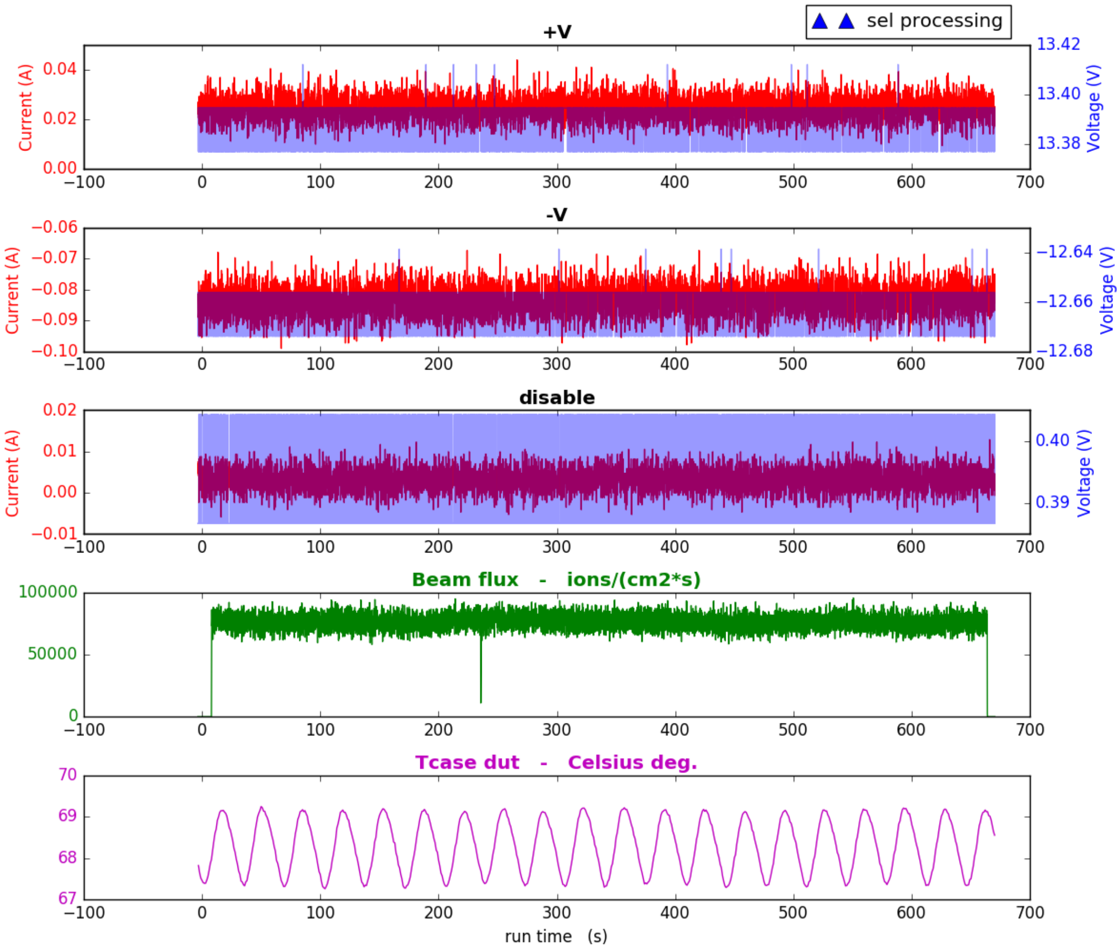
RUN002 sn2



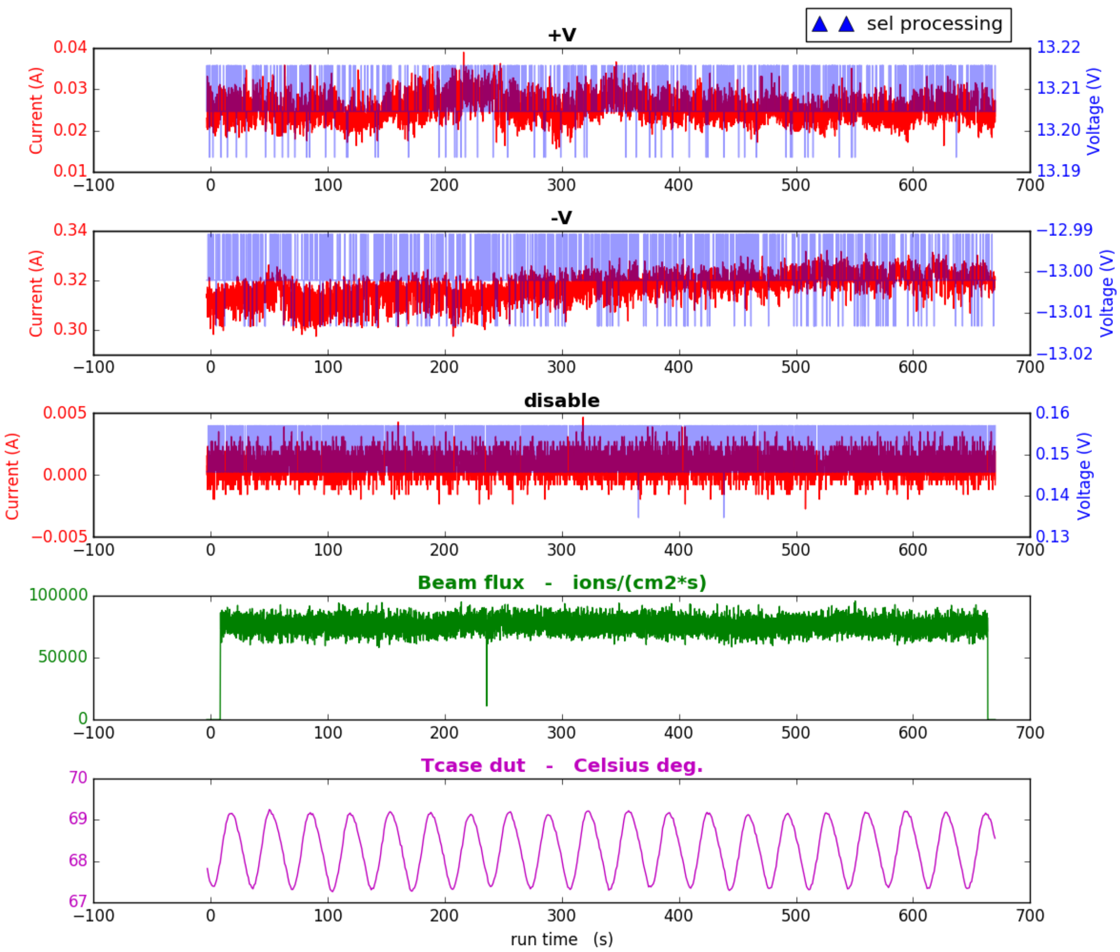
RUN003 sn1



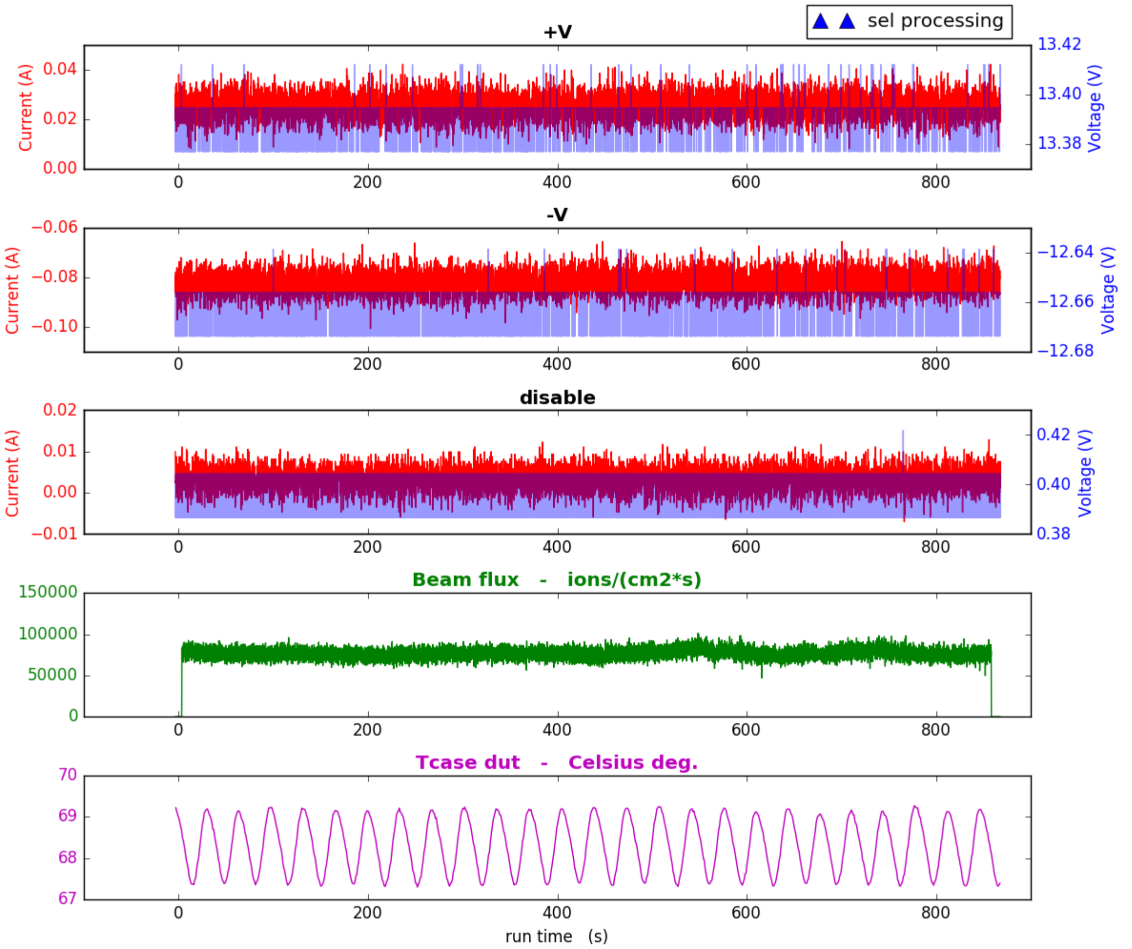
RUN003 sn2



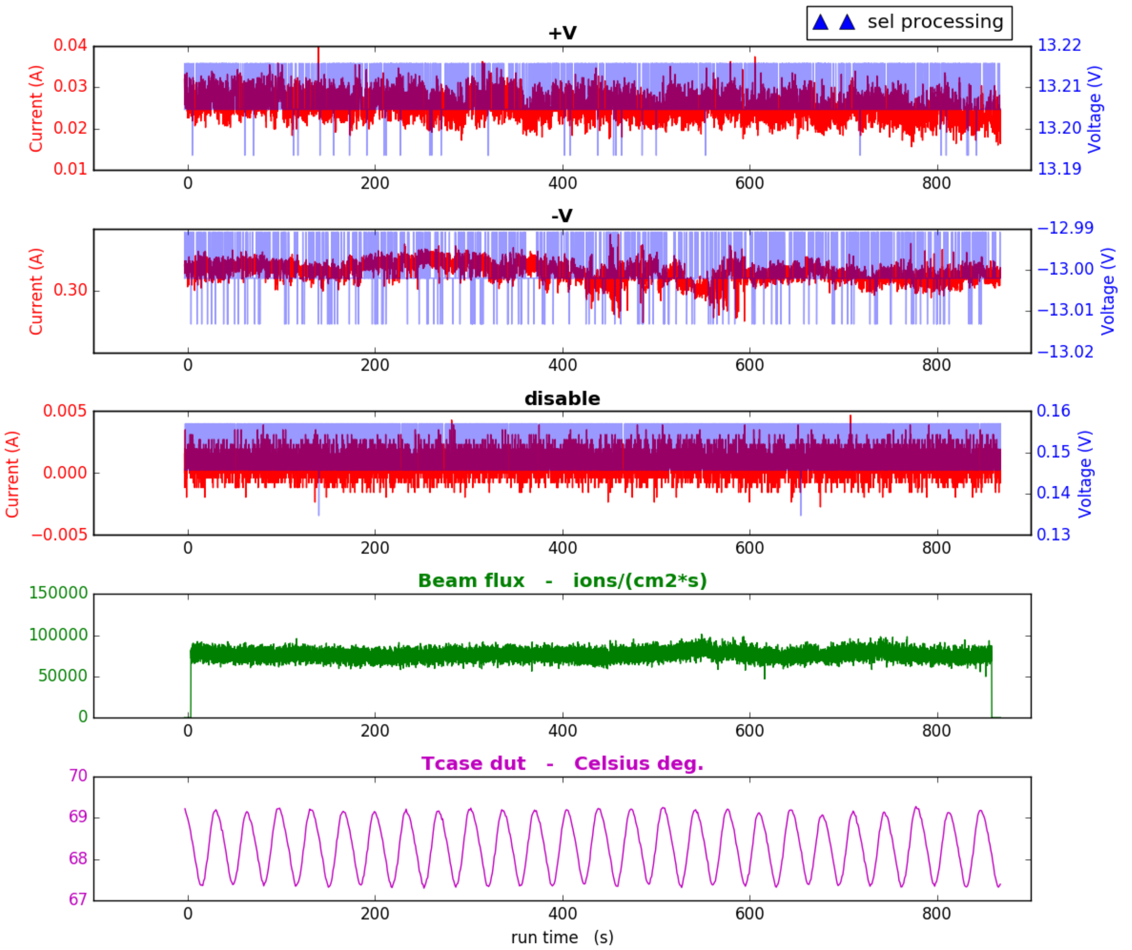
RUN004 sn1



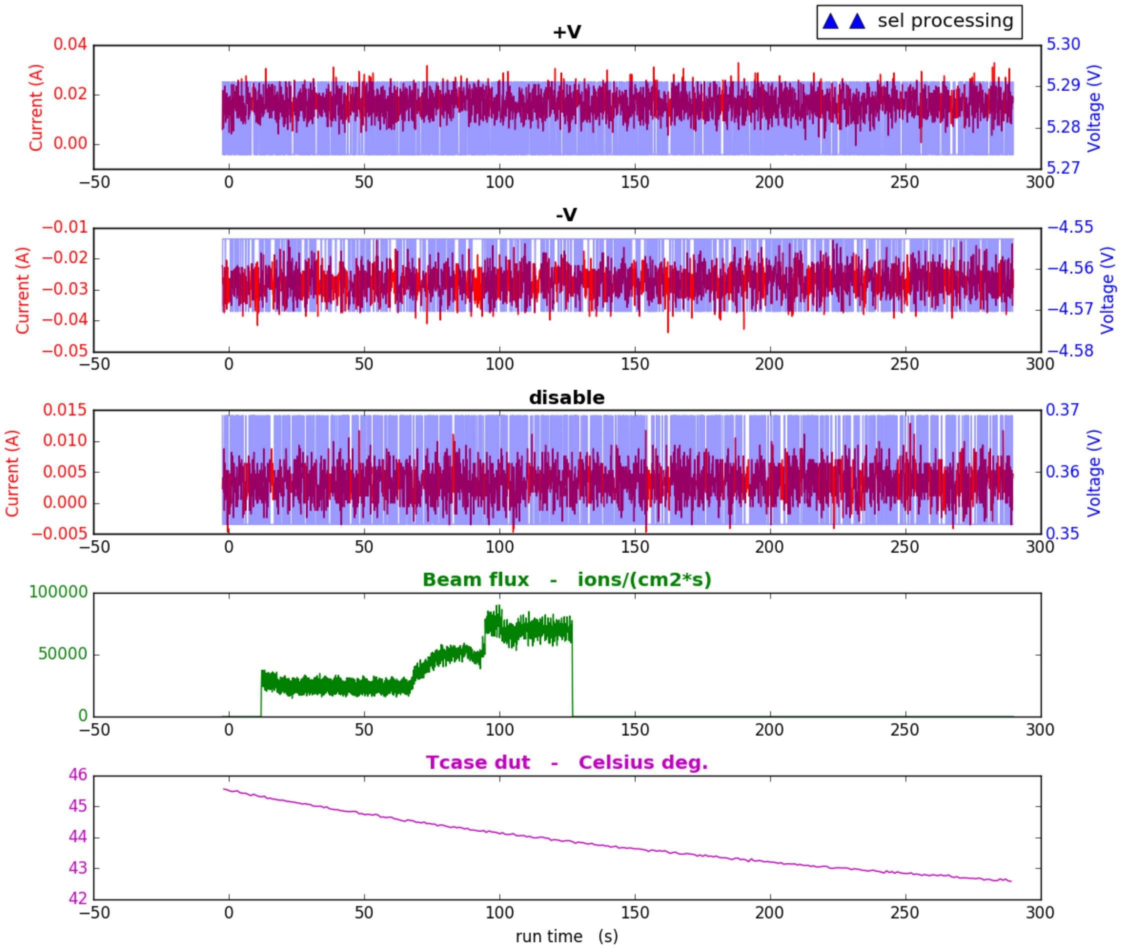
RUN004 sn2



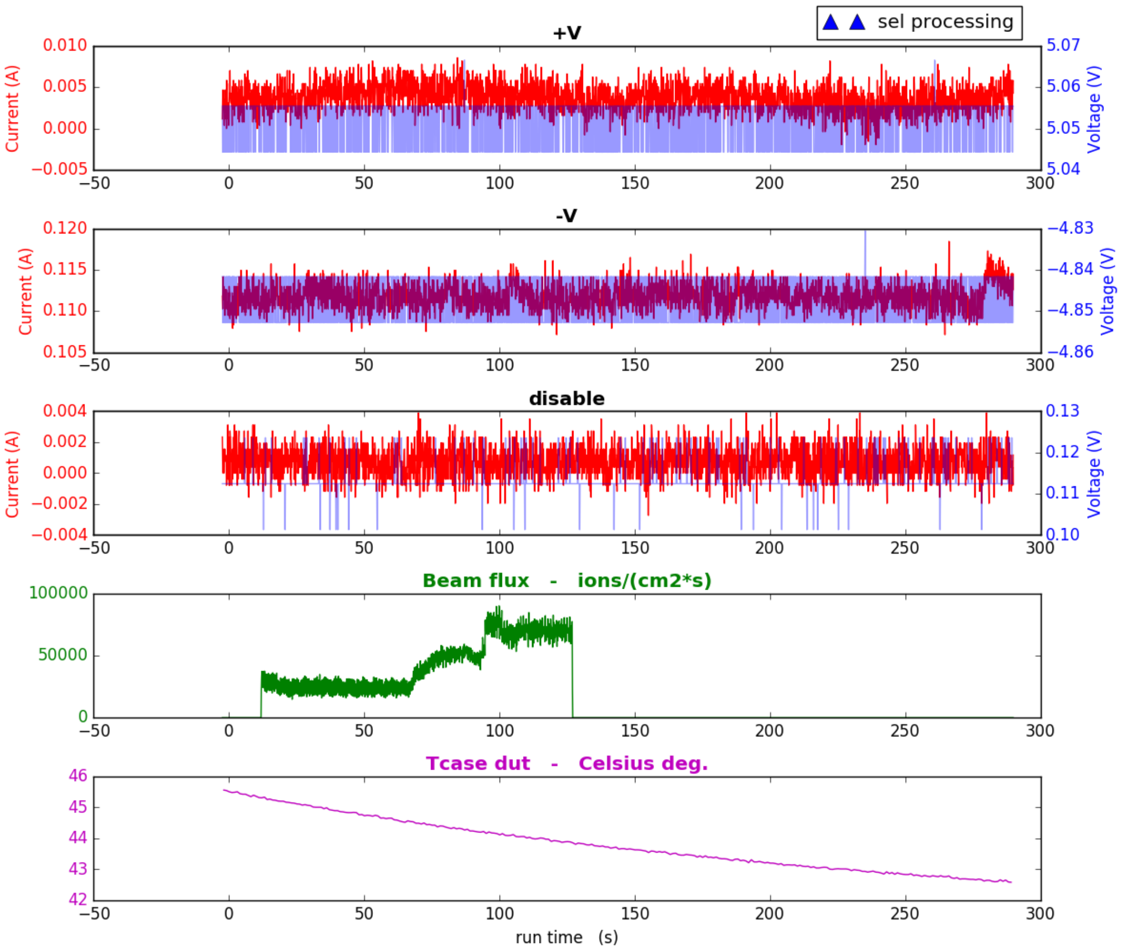
RUN005 sn1



RUN005 sn2



RUN007 sn1



RUN007 sn2

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.