SINGLE EVENT EFFECTS TEST REPORT

PRODUCT:	ADA4610-2S
DIE TYPE:	ADA4610-2
DATE CODE:	1136
CASE TEMPERATURE:	SEL: 125ºC SET: 25ºC
EFFECTIVE LET:	SEL: (58.8 – 91.4) MeV-cm^2/mg SET: (3.63 – 60) MeV-cm^2/mg
TOTAL EFFECTIVE FLUENCE:	SEL: 1e7 Ions/cm^2 SET: (>2.15E5) ion/cm^2
FACILITIES:	RADEF, University of Jyvaskyla Lawrence Berkeley National Laboratories
TESTED:	January, 2013

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ANALOG DEVICES

SINGLE EVENT EFFECTS
TEST REPORT

Test Type:	Heavy ion
Test facility:	RADEF, University of Jyväskylä, Jyväskylä, Finland
Test Date:	January 2013
Part Type:	ADA4610-2ARZ
Part Description:	Low Noise, Precision, Rail-to-Rail Output, JFET Dual Operational Amplifier
Part Manufacturer:	Analog Devices

Analog Devices contract n° 45399090

Hirex reference :	HRX/SEE/0431	Issue : 01	Date : February 28, 2013
Written by :	Benjamin Crouzat	Design Engineer	
Authorized by:	F.X. Guerre	Study Manager	

RESULTS SUMMARY

Facility

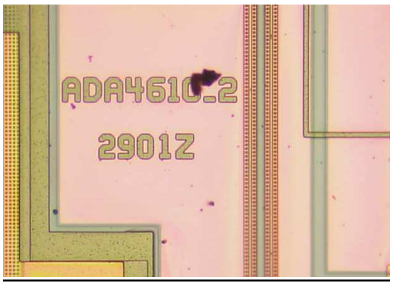
RADEF, University of Jyväskylä, Jyväskylä, Finland
LBNL / BASE, Berkeley, USA

Test date

January 2013
November 2012

Device description

Part type:	ADA4610-2ARZ
Manufacturer:	Analog Devices
Package:	SOIC-08
Top marking:	4610-2 LOGO A#136 .1466
Bottom marking:	#1136 01466 PHIL
Date code:	1136
Die dimensions:	1.64 mm X 1.36 mm



Used test samples :

LBNL/BASE : polyimide removed at hirex :
Date code : 1136
Lot nbr : AH93790.4
Top : 4610-2 LOGO A#136 .1466
Bottom : #1136 01466 PHIL

JYFL/RADEF : samples opened by ADI and with polymide removal :
Date code : 1140
Lot nbr : AH93811.10
no marking

SET Results

RADEF: bias voltage set to ±15 V and room temperature.

Four samples have been exposed over a LET range from 3.63 to 60 MeV/(mg/cm²) for SET testing.
SET events were detected at any tested LET.
Asymptotic SET cross-section / channel is about 1.10^{-02}cm2 while LET threshold is below 3.5 MeV/(mg/cm2).

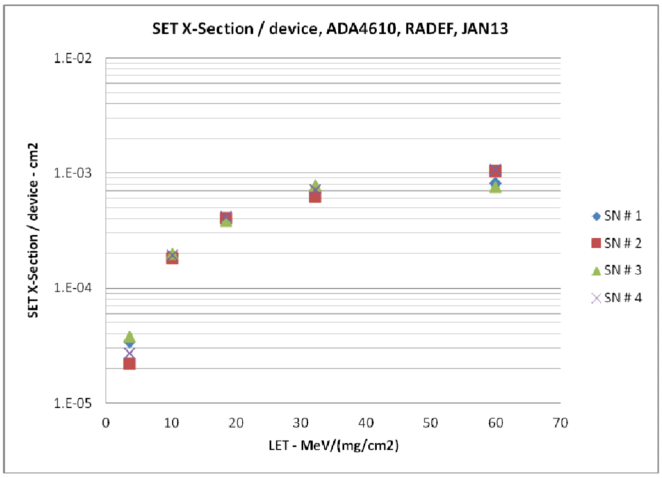


Figure 1: Events Cross-section

SEL Results

BASE: bias voltage set to ±18 V and 125°C.
Four samples have been exposed over a LET of 58.8 MeV/(mg/cm2) and 91.4 MeV/(mg/cm2).
Device is not sensitive to SEL up to a LET of 91.4 MeV/(mg/cm2) under bias voltage set to ±18V.

DOCUMENTATION CHANGE NOTICE

Issue	Date	Page	Change Item	
01	28-Feb-13	All	Original issue	

Contributors to this work:

Benjamin Crouzat	Hirex Engineering

SEE TEST REPORT

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1 Introduction

This report presents the results of Heavy Ions test program carried out on an ADA4610-2ARZ. During January 2013, four samples were used for heavy ions testing at RADEF, University of Jyväskylä, Jyväskylä, Finland, and four samples were used for heavy ions testing at BASE, University of Berkeley, USA during November 2012.
This work was performed for Analog Devices under contract n° 45399090.

2 Applicable and Reference Documents

2.1 Applicable Documents

AD-1. ADA4610-2: Low Noise, Precision, Rail-to-Rail Output, JFET Dual Operational Amplifier Data Sheet (Rev B, 08/2012).

AD-2. Hirex proposal PRO/4032 Issue 02.

2.2 Reference Documents

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

RD-2. The Berkeley Accelerator Space Effects (BASE) Facility, Proceedings of the Space Nuclear Conference 2005, San Diego, California, June 5-9, 2005

3 DEVICE INFORMATION

3.1 Device description

The ADA4610-2ARZ is a Low Noise, Precision, Rail-to-Rail Output, JFET Dual Operational Amplifier.

Part type:	ADA4610-2ARZ
Manufacturer:	Analog Devices
Package:	SOIC-08
Top marking:	4610-2 LOGO A#136 .1466
Bottom marking:	#1136 01466 PHIL
Date code:	1136
Die dimensions:	1.64 mm X 1.36 mm

3.2 Sample identification

ADA4610-2ARZ parts were delivered by Analog Devices. 10 samples were prepared and delidded to be tested to heavy ions. 8 samples were verified fully functional before the test campaign, and 8 were tested under irradiation.

LBNL/BASE : polyimide removed at hirex :
Date code : 1136
Lot nbr : AH93790.4
Top : 4610-2 LOGO A#136 .1466
Bottom : #1136 01466 PHIL

JYFL/RADEF : samples opened by ADI and with polymide removal :
Date code : 1140
Lot nbr : AH93811.10
no marking

Photo 1 – Device top view

Photo 2 – Device bottom view

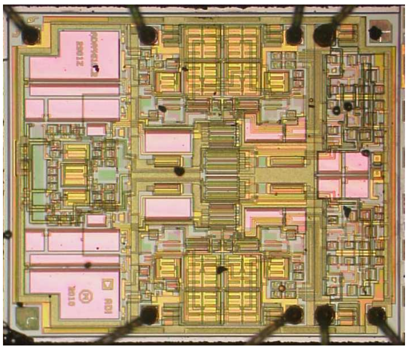


Photo 3 – Device delidded

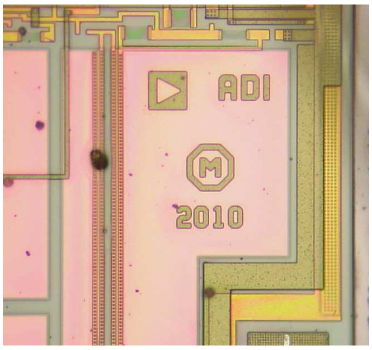


Photo 4 – Die marking #1

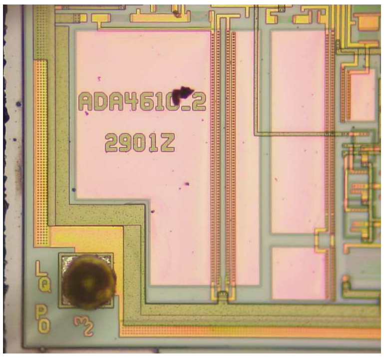


Photo 3 – Die marking #2

Figure 2: ADA4610-2ARZ device identification

4 RADEF Facility

The facility includes a special beam line dedicated to irradiation studies of semiconductor components and devices. It consists of a vacuum chamber including component movement apparatus and the necessary diagnostic equipment required for the beam quality and intensity analysis.

The cyclotron is a versatile, sector-focused accelerator of beams from hydrogen to xenon equipped with three external ion sources: two electron cyclotron resonance (ECR) ion sources designed for high-charge-state heavy ions, and a multi-cusp ion source for intense beams of protons. The ECR's are especially valuable in the study of single event effects (SEE) in semiconductor devices. For heavy ions, the maximum energy attainable can be determined using the formula, 130 Q2/M, where Q is the ion charge state and M is the mass in Atomic Mass Units.

4.1 Test chamber

Irradiation of components is performed in a vacuum chamber with an inside diameter of 75 cm and a height of 81 cm. The vacuum in the chamber is achieved after 15 minutes of pumping, and the inflation takes only a few minutes. The position of the components installed in the linear movement apparatus inside the chamber can be adjusted in the X, Y and Z directions. The possibility of rotation around the Y-axis is provided by a round table. The free movement area reserved for the components is 25 cm x 25 cm, which allows one to perform several consecutive irradiations for several different components without breaking the vacuum.

The assembly is equipped with a standard mounting fixture. The adapters required to accommodate the special board configurations and the vacuum feed-through can also be made in the laboratory’s workshops. The chamber has an entrance door, which allows rapid changing of the circuit board or individual components.

A CCD camera with a magnifying telescope is located at the other end of the beam line to determine accurate positioning of the components. The coordinates are stored in the computer’s memory allowing fast positioning of various targets during the test.

4.2 Beam quality control

For measuring beam uniformity at low intensity, a CsI(Tl) scintillator with a PIN-type photodiode readout is fixed in the mounting fixture. The uniformity is measured automatically before component irradiation and the results can be plotted immediately for more detailed analysis. A set of four collimated PIN-CsI(Tl) detectors is located in front of the beam entrance. The detectors are operated with step motors and are located at 90 degrees with respect to each other. During the irradiation and uniformity scan they are set to the outer edge of the beam in order to monitor the stability of the homogeneity and flux.

4.3 Dosimetry

The flux and intensity dosimeter system contains a Faraday cup, several collimators, a scintillation counter and four PIN-CsI(Tl) detectors. Three collimators of different sizes and shapes are placed 25 cm in front of the device under test. They can be used to limit the beam to the active area to be studied.

At low fluxes a plastic scintillator with a photomultiplier tube is used as an absolute particle counter. It is located behind the vacuum chamber and is used before the irradiation to normalize the count rates of the four PIN-CsI(Tl) detectors.

4.4 Used ions

The following Table 2 summarizes the used ions during the test campaign.

Ion	Beam energy (MeV)	Range (Si) (µm)	LET* (MeV.cm^2/mg)
20 Ne+6	186	146	3.63
40 Ar+12	372	118	10.2
56 Fe+15	523	97	18.5
82 Kr+22	768	94	32.2
131 Xe+35	1217	89	60.0

*: LET at surface SRIM2006

Table 2: Used ions

5 LBNL

A complete description of the facility (BASE) is given in **RD-2.**

5.1 Beam

10 MeV/amu cocktail was used for this experiment. Runs were performed with selected following ions, Ne, Ar, Cu, Kr and Xe and with no tilt angle. All tests were done at room temperature.

5.2 Dosimetry

The current BASE dosimetry system and procedures were used.
Record of the beam count with Hirex hardware was not possible.

5.3 Used ions

The LBNL ions used are listed in the table below (10MeV/nucleon cocktail, see Figure 4).

Ion	Beam energy (MeV)	LET* (MeV.cm^2/mg)	Range (Si) (µm)
Ne	216.28	3.49	174.6
Ar	400	9.74	130.1
Cu	659.19	21.17	108
Kr	906.45	30.23	113.1
Xe	1232.55	58.78	90

Table 3: LBNL ions and features thereof

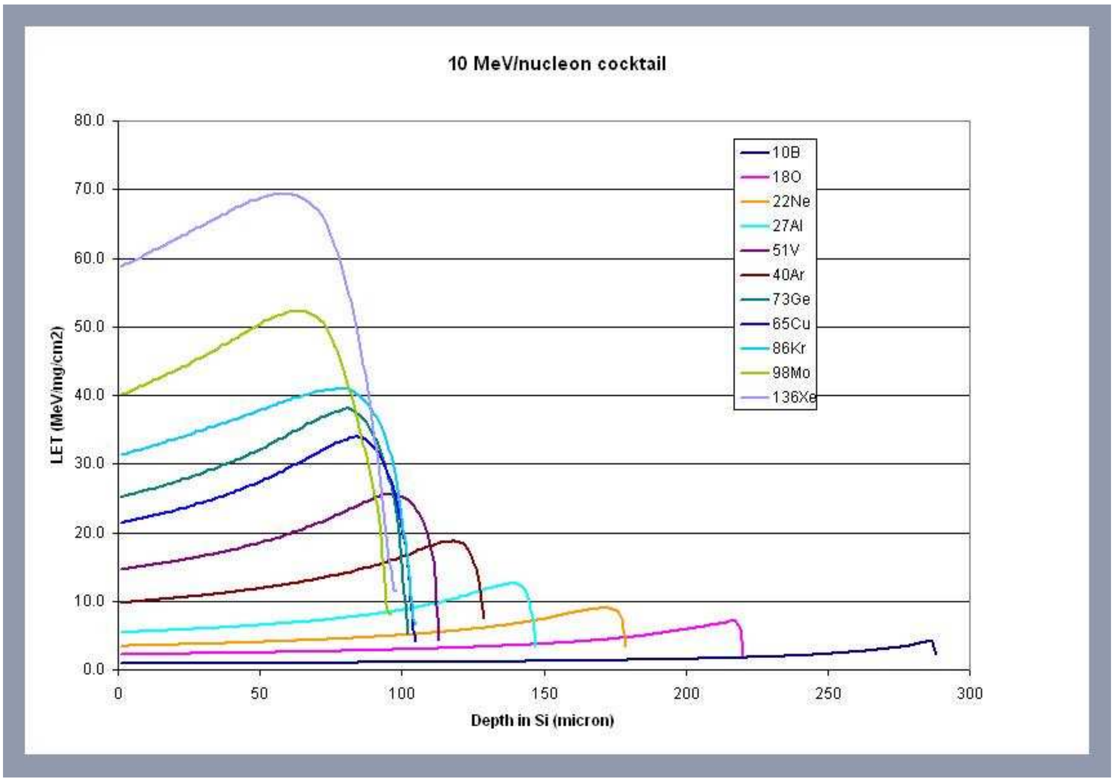


Figure 4: LBNL, 88 inches cyclotron, 10MeV/nucleon cocktail

6 Test Set-up

Test system Figure 5 shows the principle of the Heavy Ion test system.

The test system is based on a Virtex5 FPGA (Xilinx). It runs at 50 MHz. The test board has 168 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 up to 24 independent channels.

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

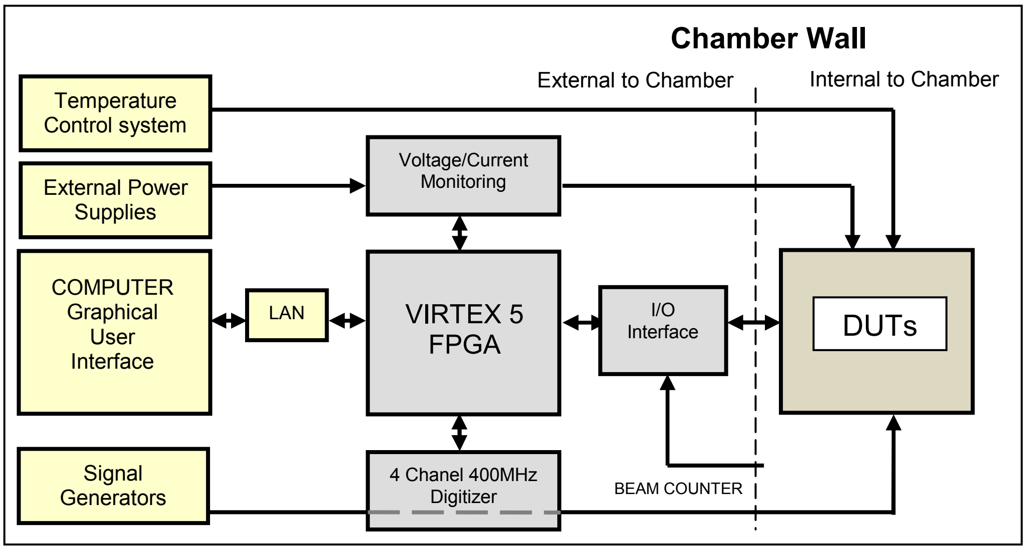


Figure 5: Heavy ion test set-up

6.1 SET

All along the test one signal was applied to the 2 ADA4096 inputs:
- Sine wave -1v/+1V at 100 kHz.

A subtraction operation is executed between each output sample from the present period and equivalent sample from the previous period. If the result of subtraction exceeds 9 LSB (detection threshold), then an error is detected and output recording is triggered.

6.2 SEL

SEL detection is performed by monitoring the DUT supply currents. When a SEL occurs (typically over 100mA during at least 2 milliseconds), then device is switched off during 1 second, and the SEL event is registered in the log file. Input signals are also put in tri-state to avoid feeding the SEL via the inputs.

The SEL threshold can be adjusted during the test, but in general it is adjusted before starting the test. During all irradiation time, the supply currents as well as inputs currents of each DUT are monitored and recorded.

6.3 ADA4610-2ARZ test principle and conditions

In order to test the ADA4610-2ARZ Low Noise, Precision, Rail-to-Rail Output, JFET Dual Operational Amplifier one daughter board was designed. Two DUT sockets were placed on the boards.

The two samples on each board were irradiated in the same time.

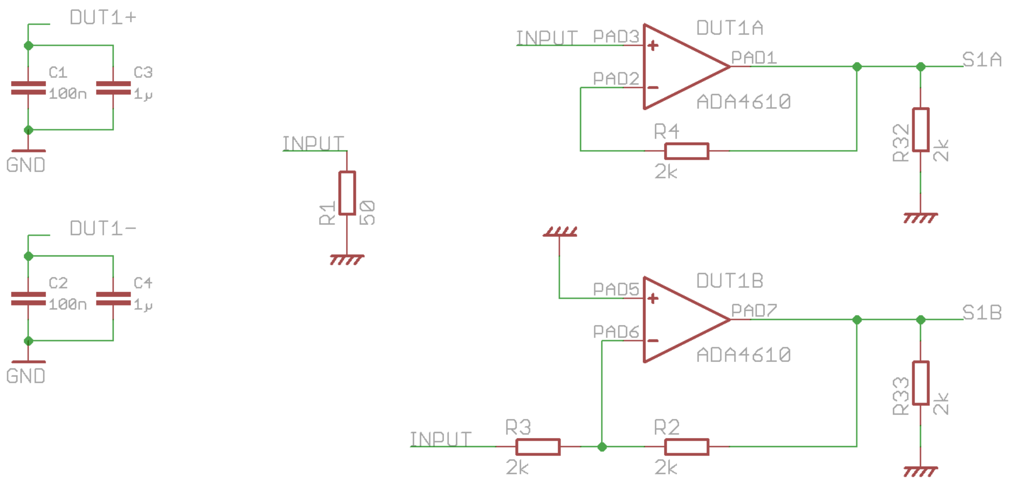


Figure 6: ADA4610-2ARZ Bias conditions

DUT1+ = +18V for SEL testing, -15V otherwise,
DUT1- = -18V for SEL testing, -15V otherwise,
INPUT = ±1V sinus at 100 kHz.

The DUT1A amplifier is a voltage follower and the DUT1B is an inverter amplifier with a gain of G = -1. The amplifiers output is loaded by a 2kΩ resistor.

7 SEE Test Results

Four samples were exposed to 5 different LETs into a range from 3.63 MeV.cm²/mg up to 60 MeV.cm²/mg at ambient temperature for SET characterization, and four other samples to 58.8 MeV.cm²/mg and 91.4 MeV.cm²/mg (Xenon tilted at 50°) at 125 °C for SEL characterization.

The detailed results table is presented in Table 4 and Table 5.

7.1 SEL

No SEL has been observed with the following ions Ne, Ar, Fe, Kr and Xe when supply set to ±15V and test operated at room temperature, and with supply increased to ±18V at 125 °C.

7.2 SET

First event was observed with Neon at LET = 3.63 MeV.cm²/mg.

Minimum event width is below 1ns and for worst case could extend to slightly more than 1.56µs, for voltage spikes between 340mV and 18V.

SET cross-section per device is shown in Figure 7.

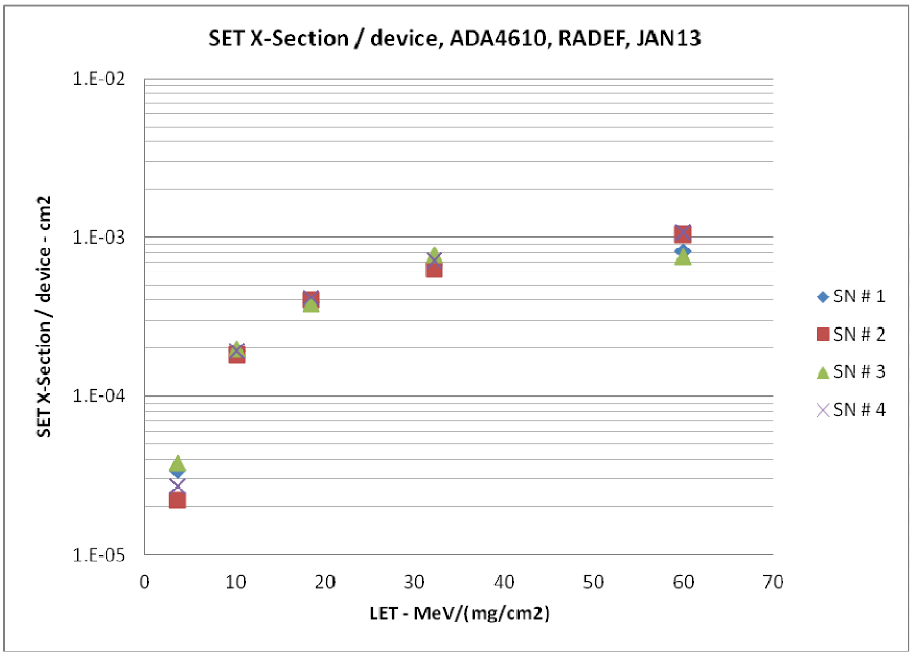


Figure 7: SET Cross-section

To calculate each event specifications (amplitude, length, type) it was decided to subtract the observed output sinus with the expected sinus.

Due to this way of calculation, observed events can be classified into 3 different types:

- Positive events,
- Negative events,
- Positive_Negative events.

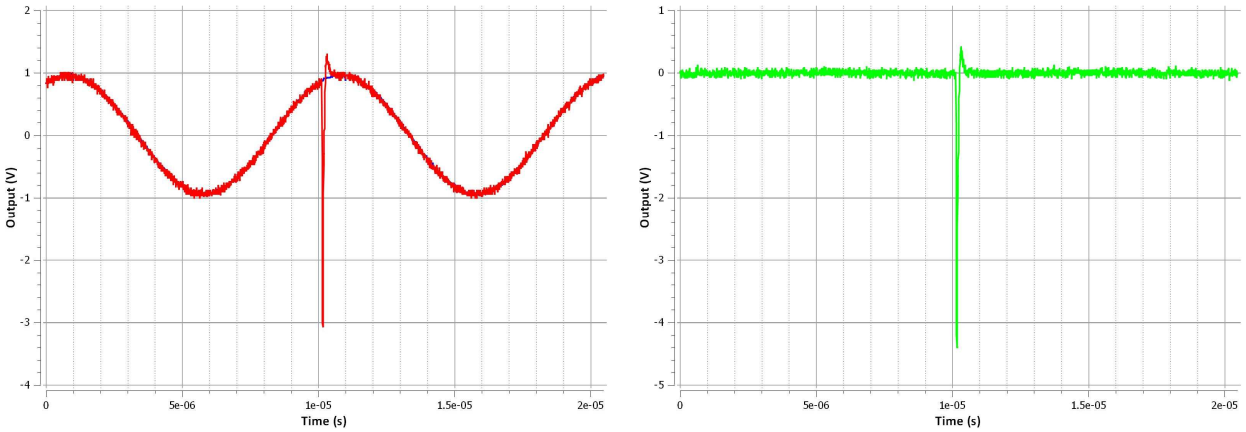


Figure 8: Event example, RUN17, LET = 18.5 MeV / (mg / cm²)

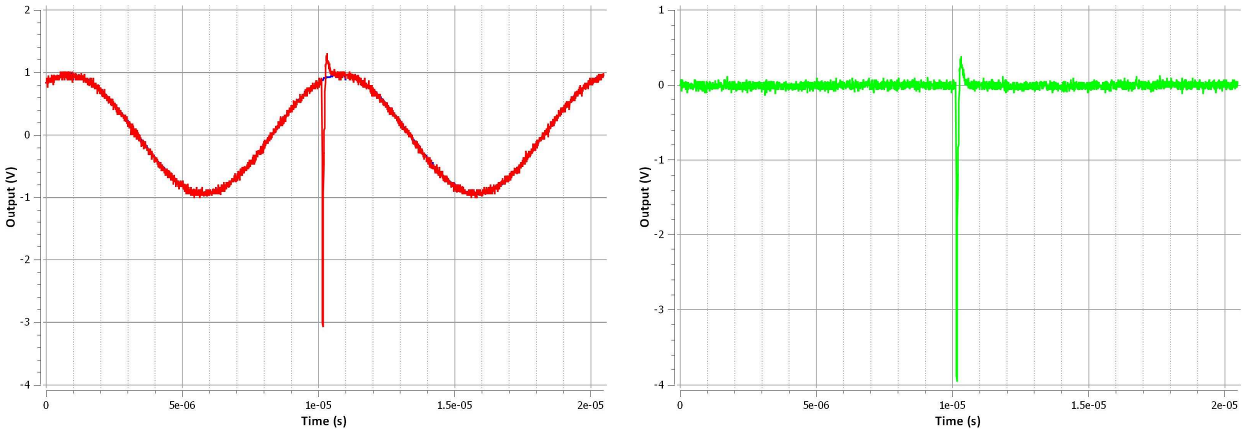


Figure 9: Event example, RUN18, LET =18.5 MeV / (mg / cm²)

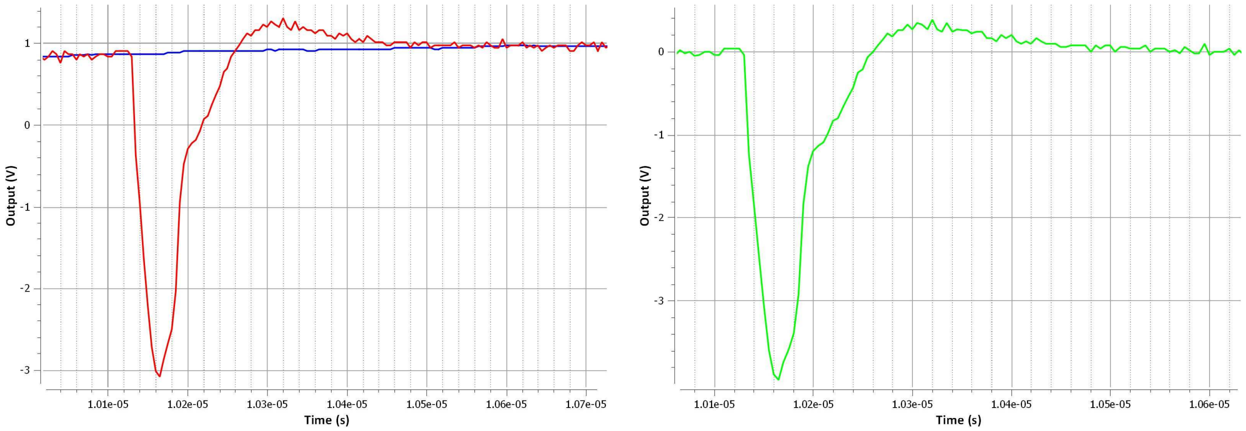
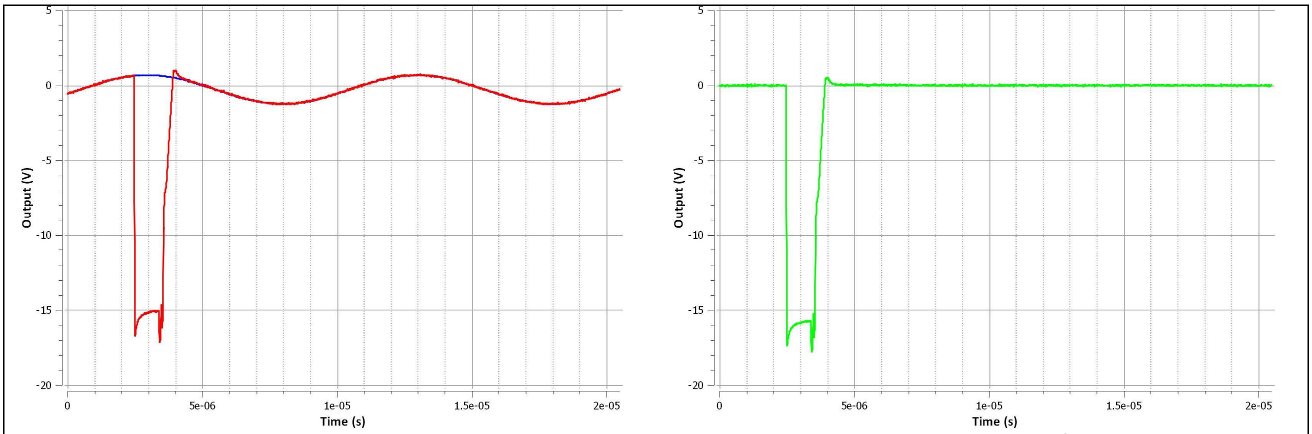
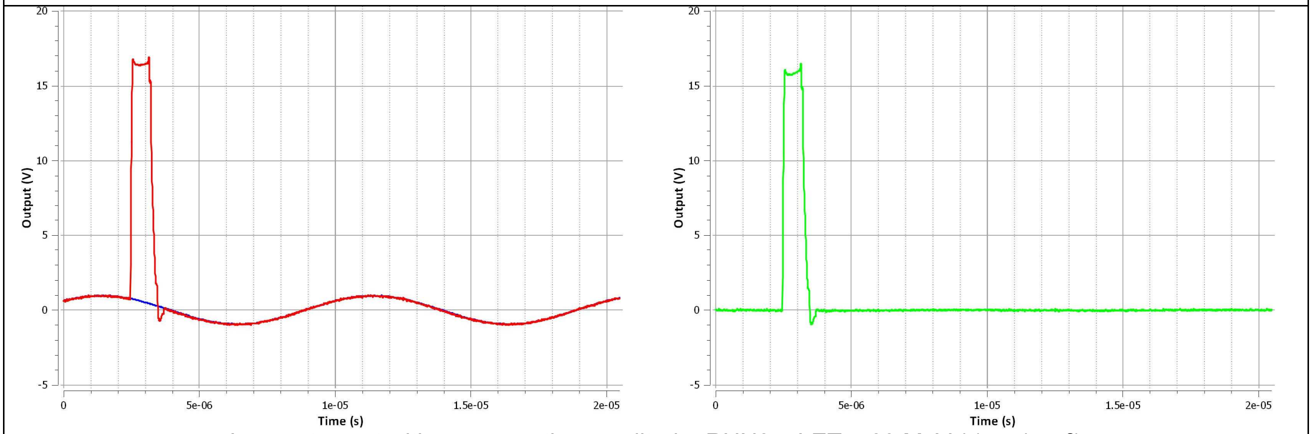


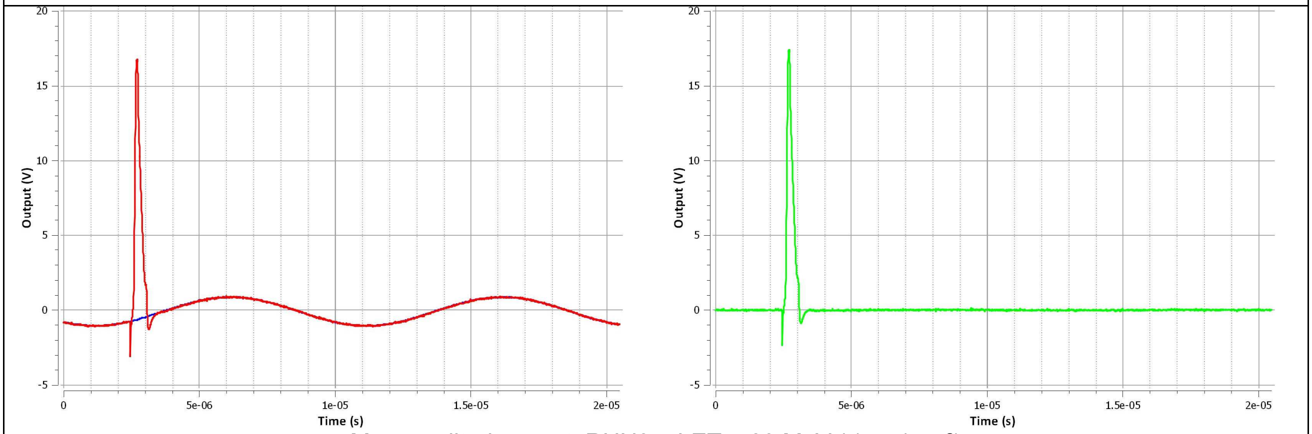
Figure 10: Zoom on event example Figure 9



Longest event with max positive amplitude, RUN37, LET = 60 MeV / (mg / cm²)

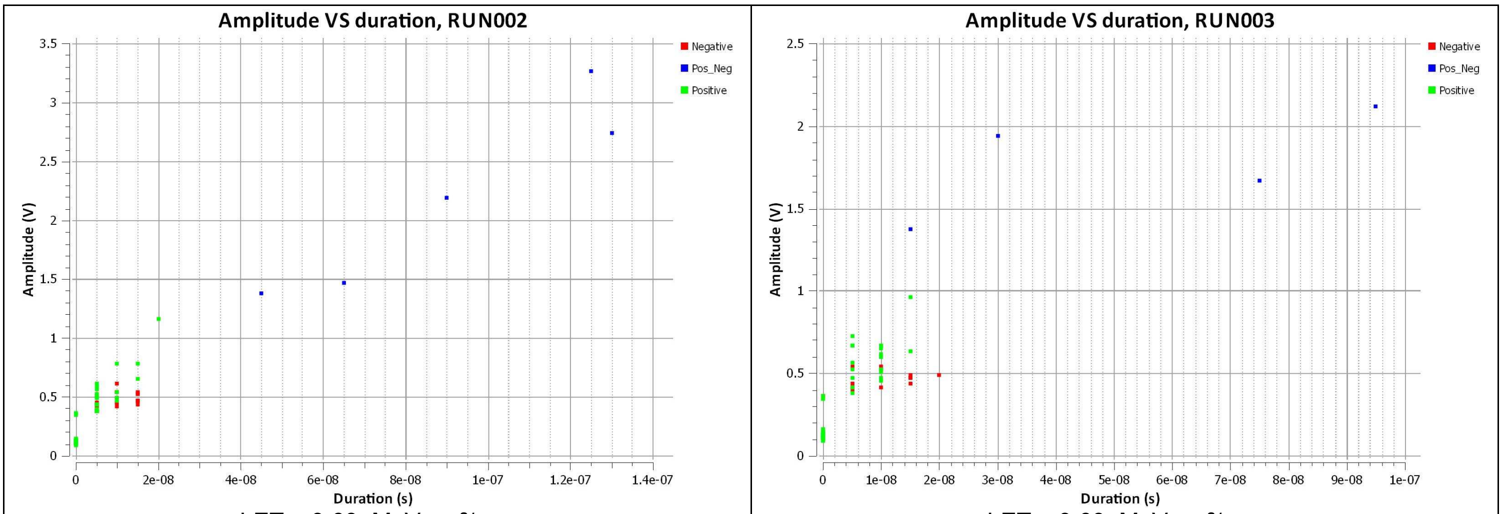


Longest event with max negative amplitude, RUN37, LET = 60 MeV / (mg / cm²)



Max amplitude event, RUN37, LET = 60 MeV / (mg / cm²)

Figure 11: Worst case Events

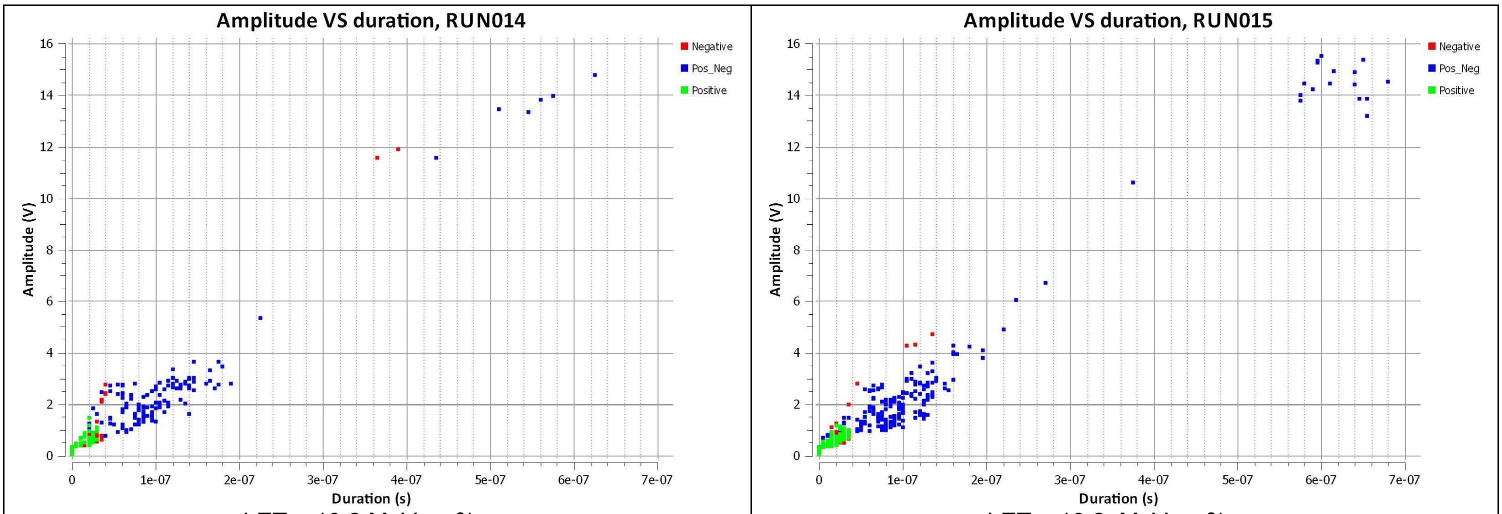


Amplitude VS duration, RUN002

Amplitude VS duration, RUN003

LET = 3.63 MeV.cm²/mg.

LET = 3.63 MeV.cm²/mg.

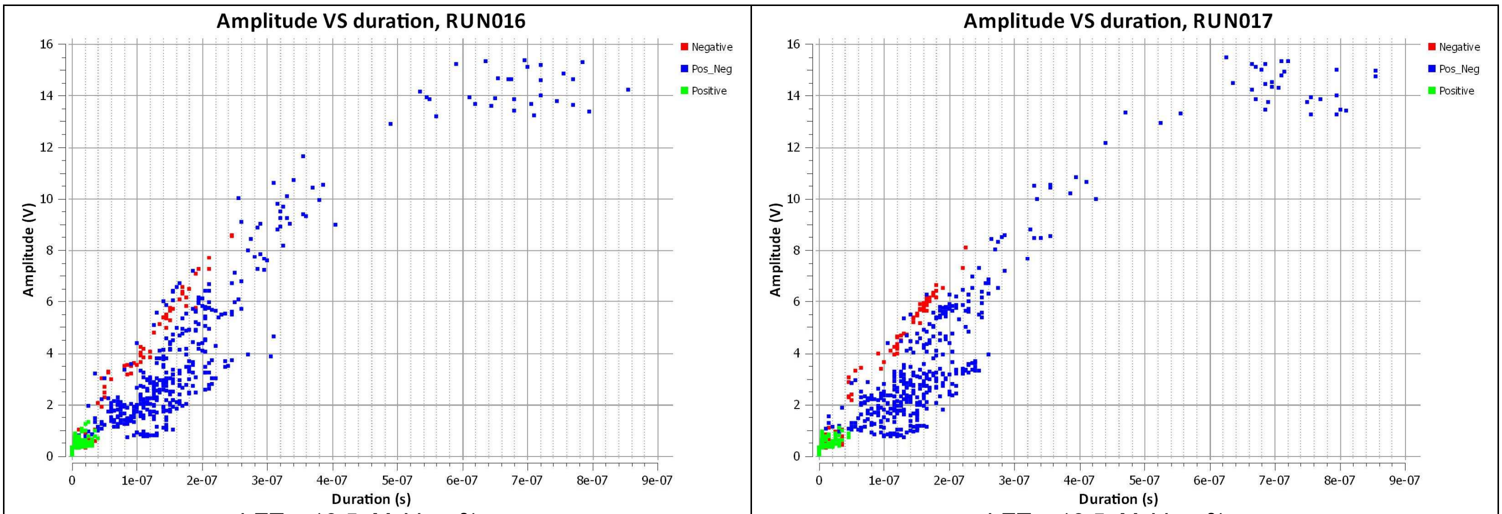


Amplitude VS duration, RUN014

Amplitude VS duration, RUN015

LET = 10.2 MeV.cm²/mg.

LET = 10.2 MeV.cm²/mg.



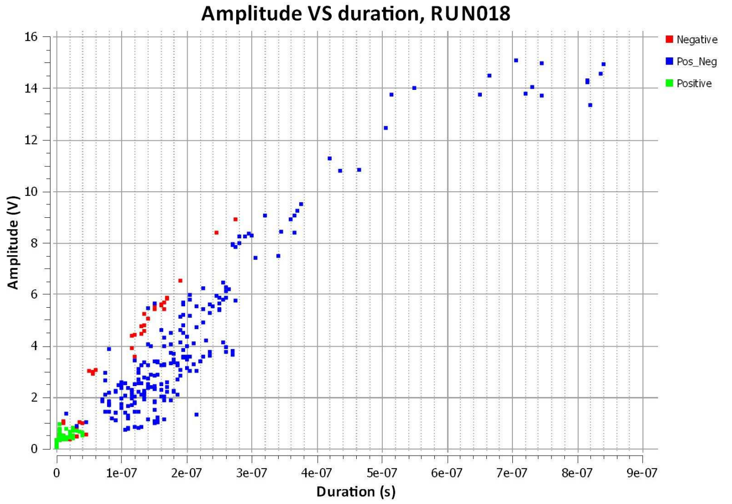
Amplitude VS duration, RUN016

Amplitude VS duration, RUN017

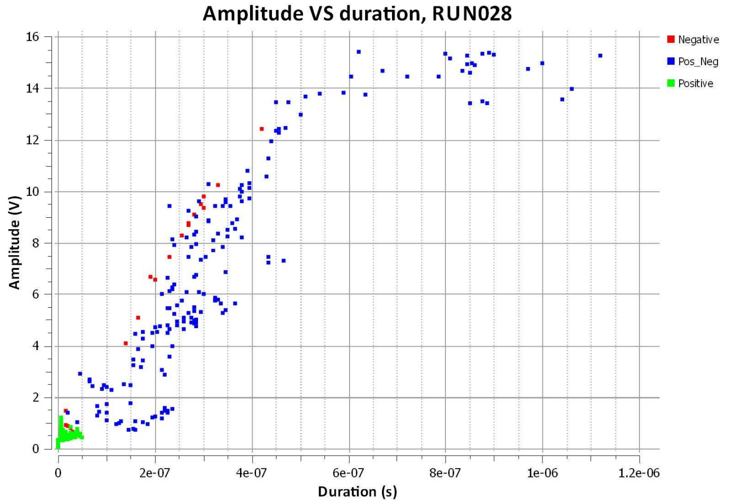
LET = 18.5 MeV.cm²/mg.

LET = 18.5 MeV.cm²/mg.

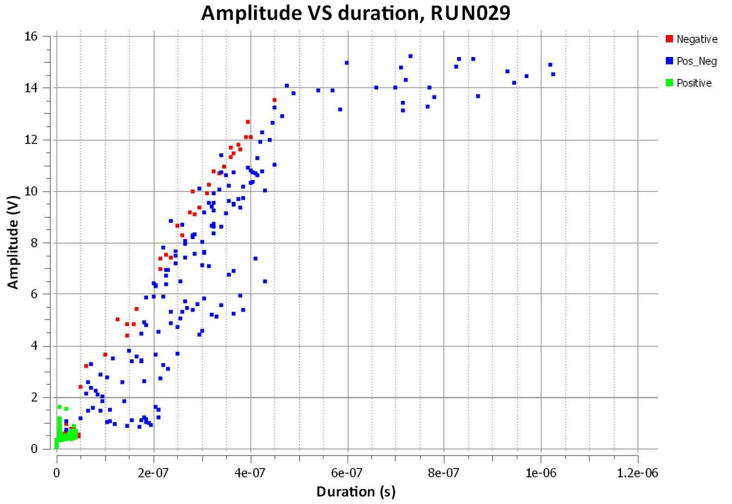
Figure 12: Events amplitude VS duration plots for each RUN (part 1)



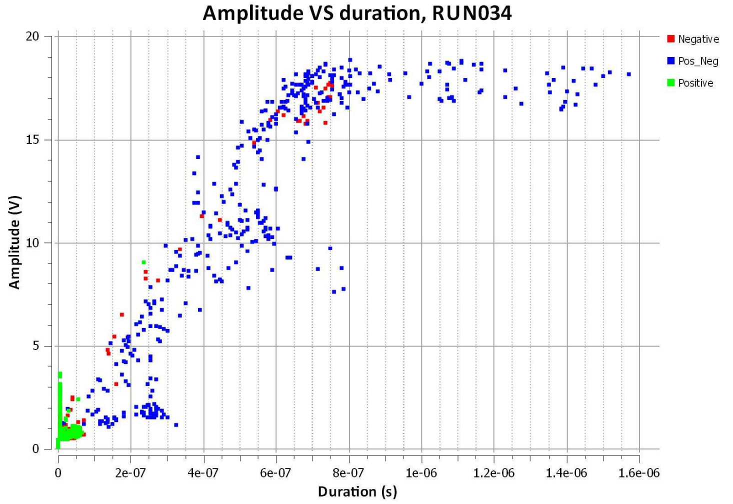
LET = 18.5 MeV.cm²/mg.



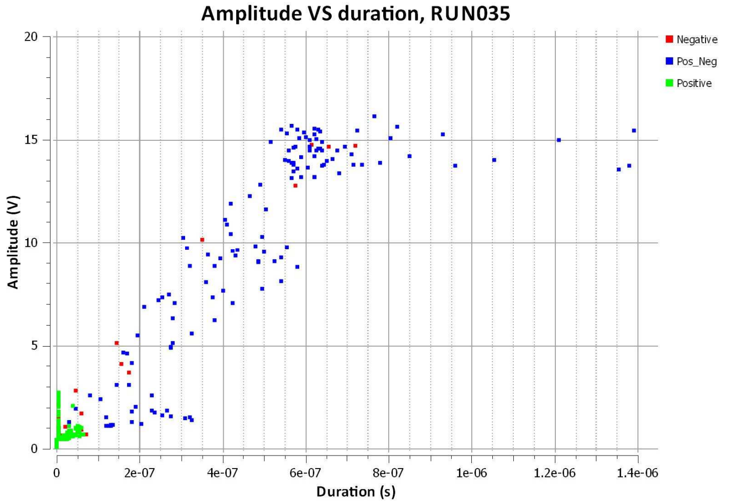
LET = 32.2 MeV.cm²/mg.



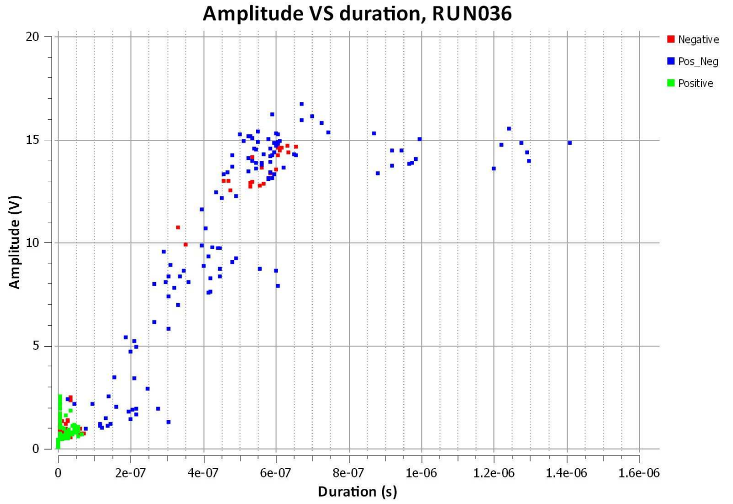
LET = 32.2 MeV.cm²/mg.



LET = 60 MeV.cm²/mg.

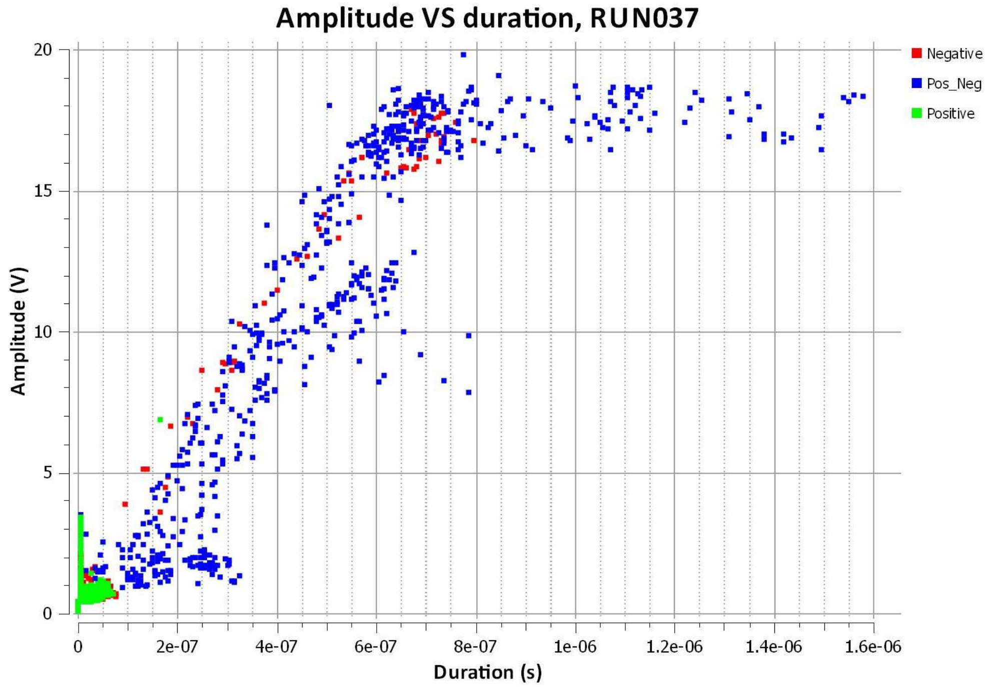


LET = 60 MeV.cm²/mg.



LET = 60 MeV.cm²/mg.

Figure 13: Events amplitude VS duration plots for each RUN (part 2)



LET = 60 MeV.cm²/mg.

Figure 14: Events amplitude VS duration plots for each RUN (part 3)

8 Detailed result table

HIREX RUN	FACILITY RUN	Ion	Energy [MeV]	Range [µm]	Base LET[MeV/(mg*cm²)	Fluence	Beam Time (s)	Flux (p/s)	SET 1	SET 1 Empty	SET 2	SET 2 Empty	x-section 1	x-section 2	Bias config	Temperature	Tilt	Roll	Total SEL component 0	Total SEL component 1	Board ID	DUT Part ID
2	2	20Ne+6	186	146	3.7	1.00E+06	535	1.87E+03	38	0	27	0	3.79E-05	2.69E-05	±15V	Room	0	0	0	0	2	4610
3	3	20Ne+6	186	146	3.7	1.00E+06	512	1.95E+03	34	0	22	4	3.39E-05	2.19E-05	±15V	Room	0	0	0	0	1	4610
14	14	40Ar+12	372	118	10.1	7.01E+05	358	1.96E+03	139	2	135	0	1.98E-04	1.92E-04	±15V	Room	0	0	0	0	2	4610
15	16	40Ar+12	372	118	10.1	1.00E+06	501	2.00E+03	192	6	182	2	1.91E-04	1.81E-04	±15V	Room	0	0	0	0	1	4610
16	68	56Fe+15	523	97	18.8	1.00E+06	314	3.18E+03	382	13	415	8	3.81E-04	4.14E-04	±15V	Room	0	0	0	0	2	4610
17	69	56Fe+15	523	97	18.8	1.01E+06	260	3.88E+03	404	51	414	21	4.01E-04	4.11E-04	±15V	Room	0	0	0	0	1	4610
18	70	56Fe+15	523	97	18.8	5.20E+05	314	1.66E+03	201	5	211	0	3.87E-04	4.07E-04	±15V	Room	0	0	0	0	1	4610
28	80	82Kr+22	768	94	30.4	3.28E+05	284	1.15E+03	220	15	205	4	6.71E-04	6.26E-04	±15V	Room	0	0	0	0	1	4610
29	81	82Kr+22	768	94	30.4	3.60E+05	275	1.31E+03	279	2	257	8	7.77E-04	7.15E-04	±15V	Room	0	0	0	0	2	4610
34	86	131Xe+35	1217	89	55	8.21E+06	742	1.11E+04							±18V	Room	0	0	0	0	1	4610
35	87	131Xe+35	1217	89	55	2.15E+05	157	1.37E+03	173	8	221	18	8.11E-04	1.04E-03	±15V	Room	0	0	0	0	1	4610
36	88	131Xe+35	1217	89	55	2.47E+05	249	9.92E+02	188	2	266	6	7.60E-04	1.08E-03	±15V	Room	0	0	0	0	2	4610
37	89	131Xe+35	1217	89	55	1.00E+07	472	2.12E+04							±18V	Room	0	0	0	0	2	4610

Table 4: Result run table for the ADA4610-2ARZ, RADEF January 2013

HRX Run #	Facility Run #	Cocktail (MeV/nuc)	Ion specie	LET surface (MeV.cm^2/mg)	Tilt (Degree)	Eff. LET surface (MeV.cm^2/mg)	Fluence (p/cm^2)	Time (s)	Mean Flux (p/(cm^2.s))	Device	Board	Vcc (V)	Vccin (V)	Temp (°C)	SEL
26	49	10	Xe	58.78	0	58.8	1.00E+07	417	2.40E+04	ADA4610	1	±18	±1	125°	0
27	50	10	Xe	58.78	50	91.4	1.00E+07	610	1.64E+04	ADA4610	1	±18	±1	125°	0
28	51	10	Xe	58.78	50	91.4	1.00E+07	610	1.64E+04	ADA4610	2	±18	±1	125°	0

Table 5: Result run table for the ADA4610-2ARZ, LBNL November 2012

9 Glossary

Most of the definitions here below are from JEDEC standard JESD89A

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.

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 Transient (SET): A soft error caused by the 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 Latch-up (SEL) cross-section: the number of events per unit fluence. For chip SEL cross-section, the dimensions are cm2 per chip.

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 Function: $F(x) = A (1- \exp\{-[(x-x0)/W]s\})$

x = effective LET in MeV-cm2 /milligram;
F(x) = SEE cross-section in square-cm2/bit;
A = limiting or plateau cross-section;
x0 = onset parameter, such that F(x) = 0 for x < x0;
W = width parameter;
s = a dimensionless exponent.