HIREX ENGINEERING
A company of ALTER TECHNOLOGY

SINGLE EVENT EFFECTS
TEST REPORT

Test Type:	Heavy ion
Test facility:	RADEF, JYFL, University of Jyvaskyla, Jyvaskyla, Finland
Test Date:	August 2014, November 2014, February2016
Part Type:	ADC128S102
Part Description:	8-Channel, 50 kSPS to 1 MSPS, 12-Bit A/D Converter
Part Manufacturer:	Texas Instruments

ESA contract n° 4000105495/12/NL/SFe dated 27/2/2012

Hirex reference :	HRX/SEE/481	Issue : 02	Date :	March 15, 2016
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DOCUMENTATION CHANGE NOTICE

Issue	Date	Page	Change Item	
01	27/01/2016	All	Original issue	
02	15/03/2016	All	Addition of SEE tests performed at lower LET values.	

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Hirex Engineering

SEE test report

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

1 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.

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 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.

2 Introduction

This report presents the results of Heavy Ions test program carried out on ADC128S102 part type from Texas Instruments. ADC128S102samples were used for heavy ions testing at RADEF, JYFL, University of Jyvaskyla, Jyvaskyla, Finland.
This work was performed for ESA under ESA contract n° 4000105495/12/NL/SFe dated 27/2/2012.
Two test campaigns have been implemented in August 2014 (W35) and in November 2014 (W46).
A third test campaign has been performed in February 2016 with lower LET values (Neon and Argon) so that SET cross-section curve can be plot down to to LET threshold.

3 Applicable and Reference Documents

3.1 Applicable Documents

AD-1. Hirex proposal « Test Methods, Requirements, and Guidelines for Evaluation of Radiation Sensitivity of Analog to Digital Converters (ADC), Digital to Analog Converters (DAC) and Vertical Power MOSFETs» HRX/PRO/3624 Issue 01 /2011/10/12

AD-2. ADC128S102QML, Texas Instruments datasheet, 2011 National Semiconductor Corporation 300181, January 13, 2011

3.2 Reference Documents

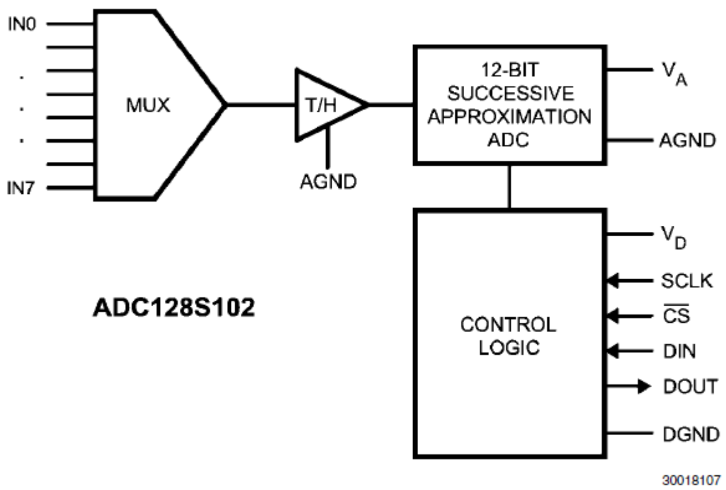
RD-1. Single Event Effects Test method and Guidelines ESA/SCC basic specification No 25100

4 DEVICE INFORMATION

4.1 Device description

ADC128S102 is a 8-Channel, 50 kSPS to 1 MSPS, 12-Bit A/D Converter.

Functional diagram



Part type:	ADC128S102
Component Part No:	ADC128S102WGMPR (flight prototype)
Manufacturer:	(National Semiconductor) Texas Instruments
Manufacturer lot number:	-
Datecode:	1317A
Package:	SOIC-16
Top marking:	logo 1317A 8A ADC128S102WGMPR AS THA
Die dimensions:	1050µ x 1780µ

4.2 Sample preparation

Samples are opened mechanically.

4.3 Sample identification

Photo 1 – Device top view

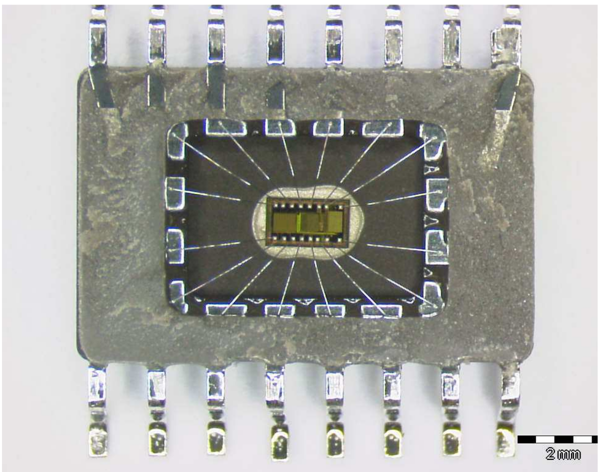


Photo 2 - Device internal cavity

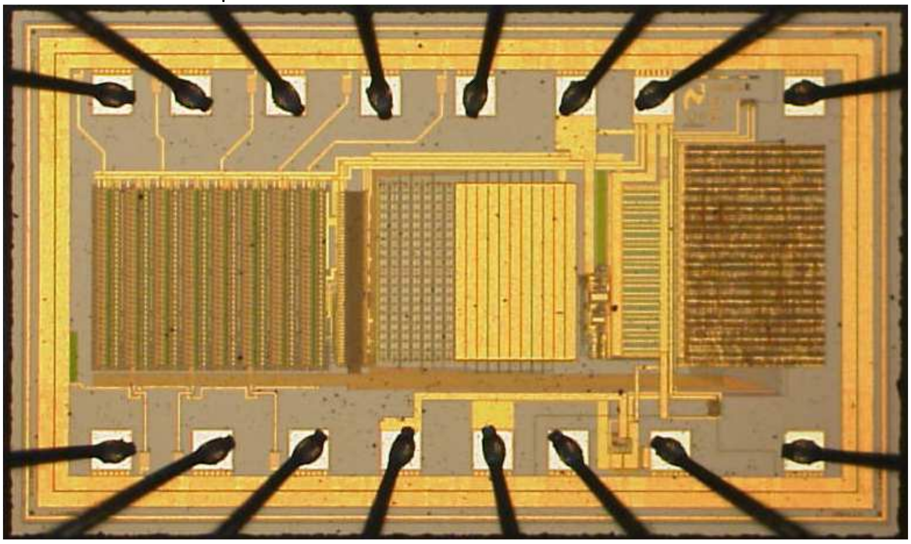


Photo 3 – Die full view

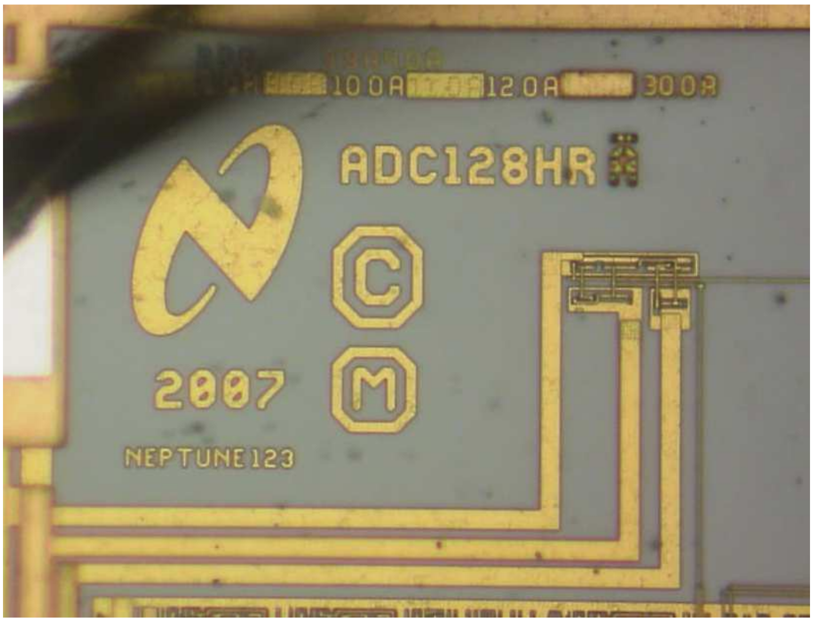


Photo 4 – Die Marking1

Figure 1: ADC128S102 device identification

5 RADEF Facility

Test at the cyclotron accelerator was performed at University of Jyvaskyla (JYFL) (Finland) under HIREX Engineering responsibility.
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 multicusp 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,

$$130\ Q^2/M,$$

where Q is the ion charge state and M is the mass in Atomic Mass Units.

<u>Test chamber</u>

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-throughs 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.

<u>Beam quality control</u>

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.
Two beam wobblers and/or a 0.5 microns diffusion Gold foil can be used to achieve good beam homogeneity. The foil is placed 3 m in front of the chamber. The wobbler-coils vibrate the beam horizontally and vertically, the proper sweeping area being attained with the adjustable coil-currents.

<u>Dosimetry</u>

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 size and shape 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.

Ion	LET^{SRIM} at surface [$MeV.cm^2.mg^{-1}$]	Range [µm]	Beam energy [MeV]
$^{20}Ne^{6+}$	3.63	146	186
$^{40}Ar^{12+}$	10.2	118	372
$^{56}Fe^{15+}$	18.5	97	523
$^{82}Kr^{22+}$	32.1	94	768
$^{131}Xe^{35+}$	60.0	89	1217

SRIM-2003.26

Table 1 – Ion beam setting

6 Test Set-up

Test system Figure 2 shows the principle of the Heavy Ion test system.
The test system is based on a Virtex4 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.

A SEL event is detected when one of the monitored power supply channel current exceeds the corresponding given threshold current within a few microseconds; it is then followed by a device under test power reset after a given off time.

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

Test board has been designed so that 2 samples can be eventually tested at the same time to heavy ions. Two ADC128S102 parts are mounted on the daughter board as shown in Figure 3 and ADC128S102 design schematic is shown in Figure 4.

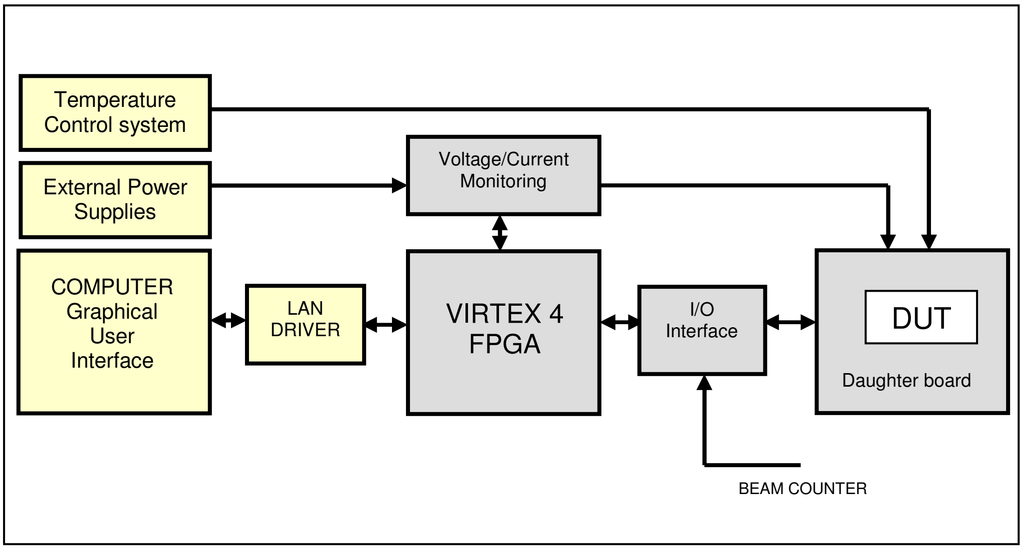


Figure 2: ADC128S102, Heavy ion test set-up

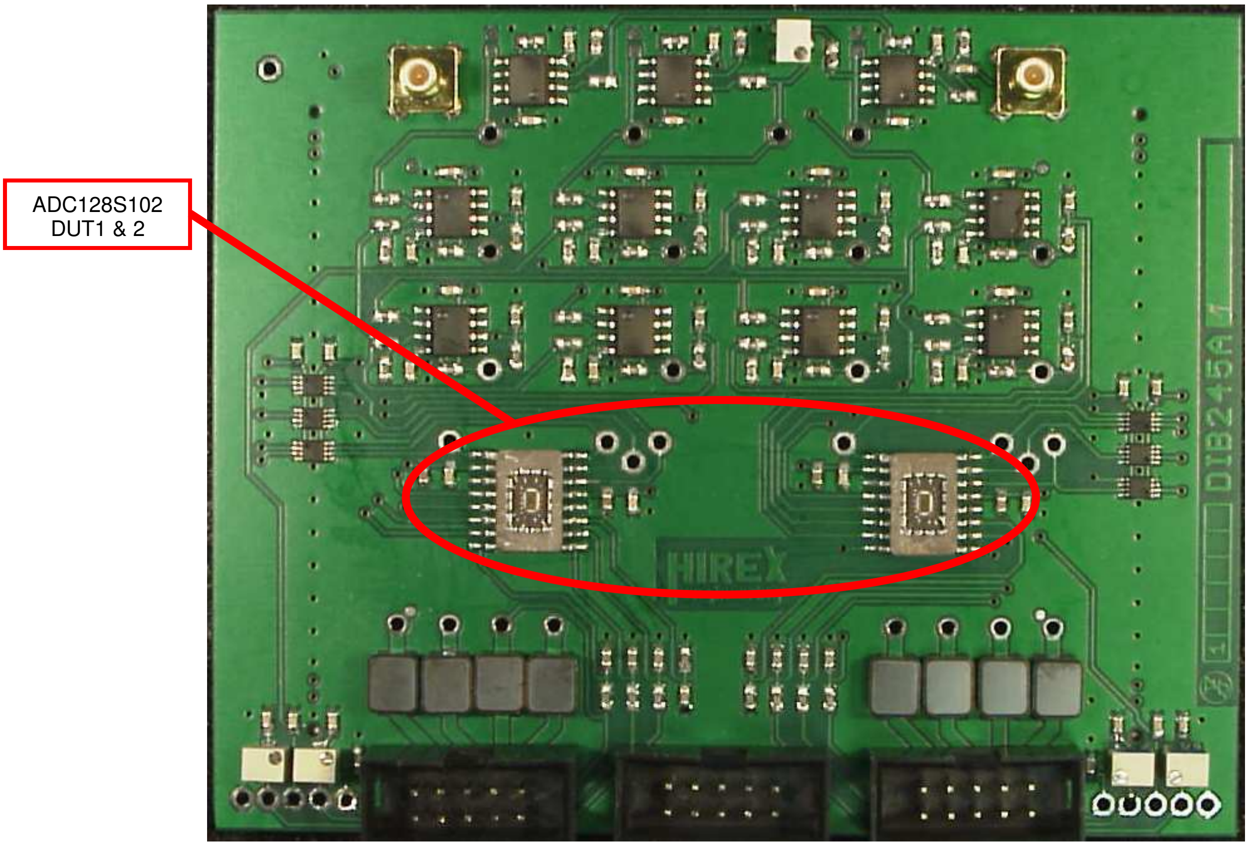


Figure 3: Daughter board (DIB245A) photo

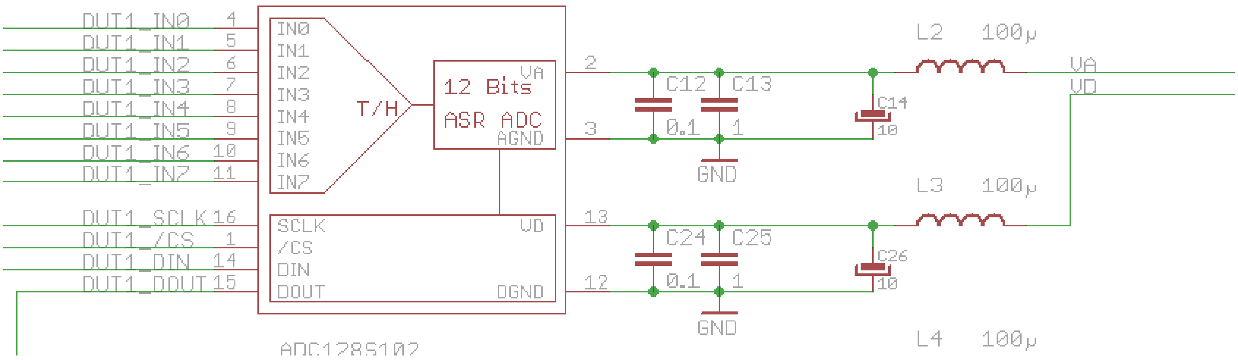


Figure 4: ADC128S102 design schematic

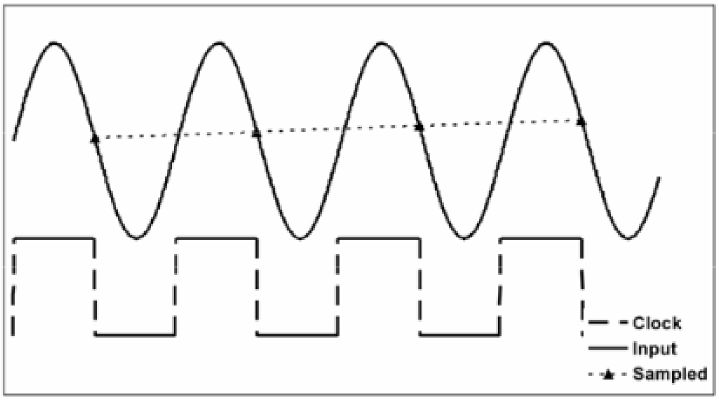
7 Test methods

For this AD converter testing, a sinewave signal is used at ADC128S102 input.
in addition to characterize the SEE behavior of the ADC128S102, the objective of this test was also to compare the efficiency of different test methods based on different sets of sinewave input frequency and DUT sampling frequency. 3 test methods have then been implemented.

- beat frequency: With the input frequency f_{in} set very close to the sampling frequency, the output code of the ADC is a slow moving digital sine wave, changing at a rate of 1 LSB per clock cycle.

  Input sine frequency f_{in} and sampling frequency f_s must repond to:

$$f_{in}-fs=f_s/(2^N*PI) \text{ with } N=12$$



- 4points: DUT sampling frequency being fixed, the selected frequency of the sinewave input is such that only 4 points of the sinewave output are converted continuously.

  Input sinewave frequency f_{in} and sampling frequency f_s must repond to:

$$f_{in}=f_s/4$$

- Hirex method: DUT sampling frequency being fixed, input frequency f_{in} is set to a much lower value than f_s with f_s a multiple of f_{in}, leading to a significant number of points converted by sinewave input period.

  Input sinewave frequency f_{in} and sampling frequency f_s must repond to:

$$f_{in}=f_s/m \text{ with m integer}$$

  In the present test, m was typically set to 1000.

8 Error detection and recording

For beat frequency, detection when the output shifts from the expected value is done by comparing with the previous clock conversion as it should differ only by 1 LSB and trig the data recording.
For 4 points method, this is achieved by comparing the output with the 4 clock times before output (or a multiple of 4).
For Hirex method, as for 4 points, this is achieved by comparing the output with the m clock times before output (or a multiple of m).
2048 conversions values before the detection trig and 2048 after are recorded wich allows for checking the occurrence of successive conversions in error if any. Conversion values before the event trig can then be used for the comparison of the output signal before the event and the event signal and by difference extract the error signal.
SET event amplitude and duration definition used in this report are presented in an example in Figure 5 with a detection threshold of +/- 50LSBs and a time period of 200 points between the output signal before the event (red dots) and the event (blue dots).

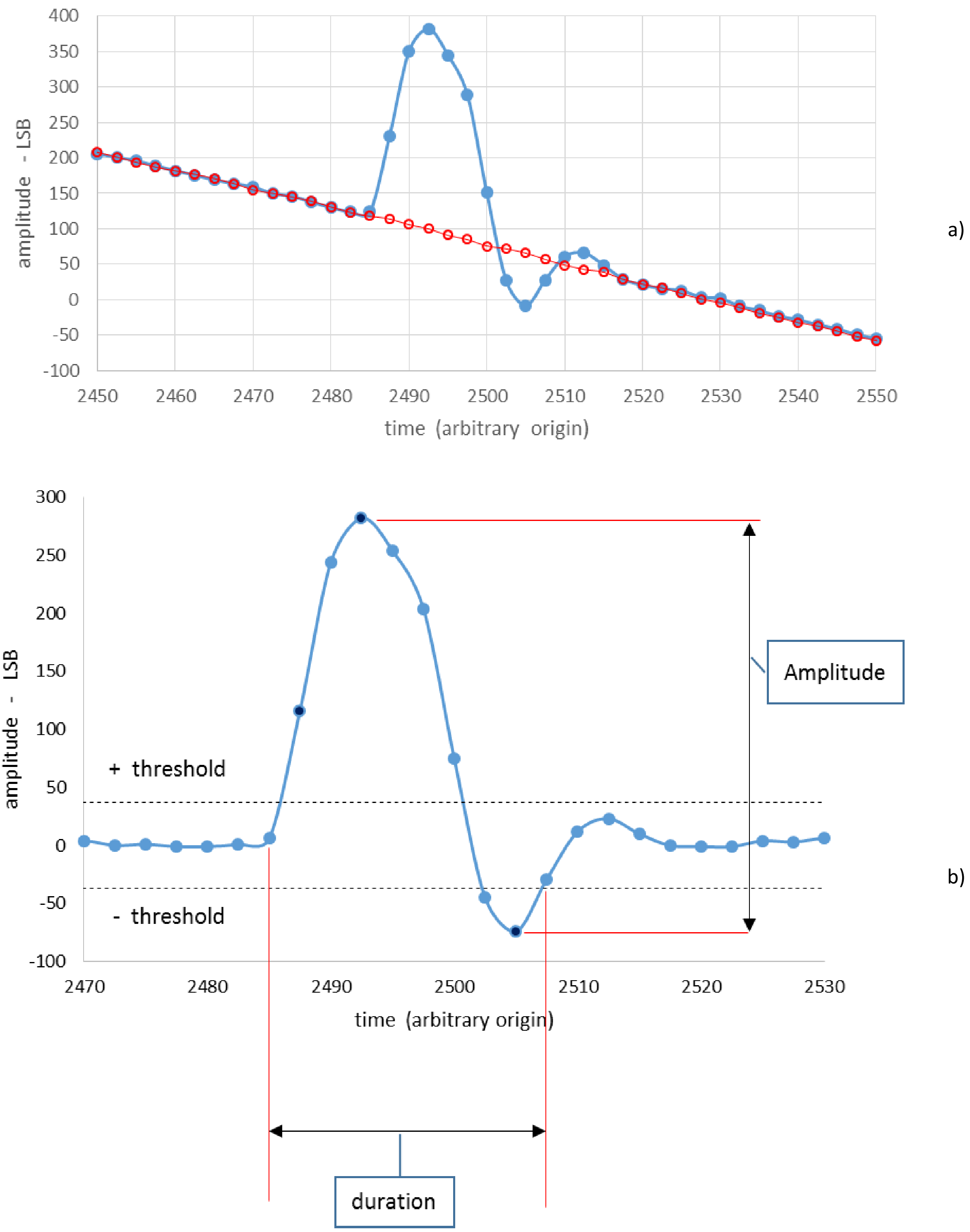


Figure a) shows ADC output (blue dot) for an event trig together with ADC output 200 periods before (red dot).
In figure b) the difference between the 2 curves of figure a) is plot. Event amplitude is defined as the maximum amplitude value minus the minimum value and event duration is the difference in time between the last point before the first conversion above threshold (dotted line) and the first point after the last conversion above threshold.

Figure 5 – SET amplitude and duration

8.1 Wave generation hardware

A specific board has been designed to produce a clock signal of frequency f_S in phase with a sine signal at the desired input frequency f_{in}, so that the three test methods can be implemented easily.
Wave generation board principle is shown in Figure 6.
A single oscillator is used to produce the system's clock. This clock feeds the FPGA's Direct Digital Synthesis (DDS) block on one hand, and the external Digital to Analog Converter (DAC).
The DDS combined to the Signal processing block can produce square and/or sinus waveforms independantly with an accuracy inferior to the millihertz for each signal frequency.
We can also set the amplitude and the offset of these output signals before the analogic conversion.
The waveforms are then converted via the DAC, amplified and symetrised if needed before entering the DUT.
The major benefit of this system is to generate two different waveforms from one single system clock. Then we can create two signals at the exact same frequency with no chance to see any unwanted phase shift.
Moreover the system allows us to set the phase shift between these two signals very precisely if we want some phase shift. This can be usefull for the 4 points testing method : we can choose what are the 4 points on the sinewave we want to observe.

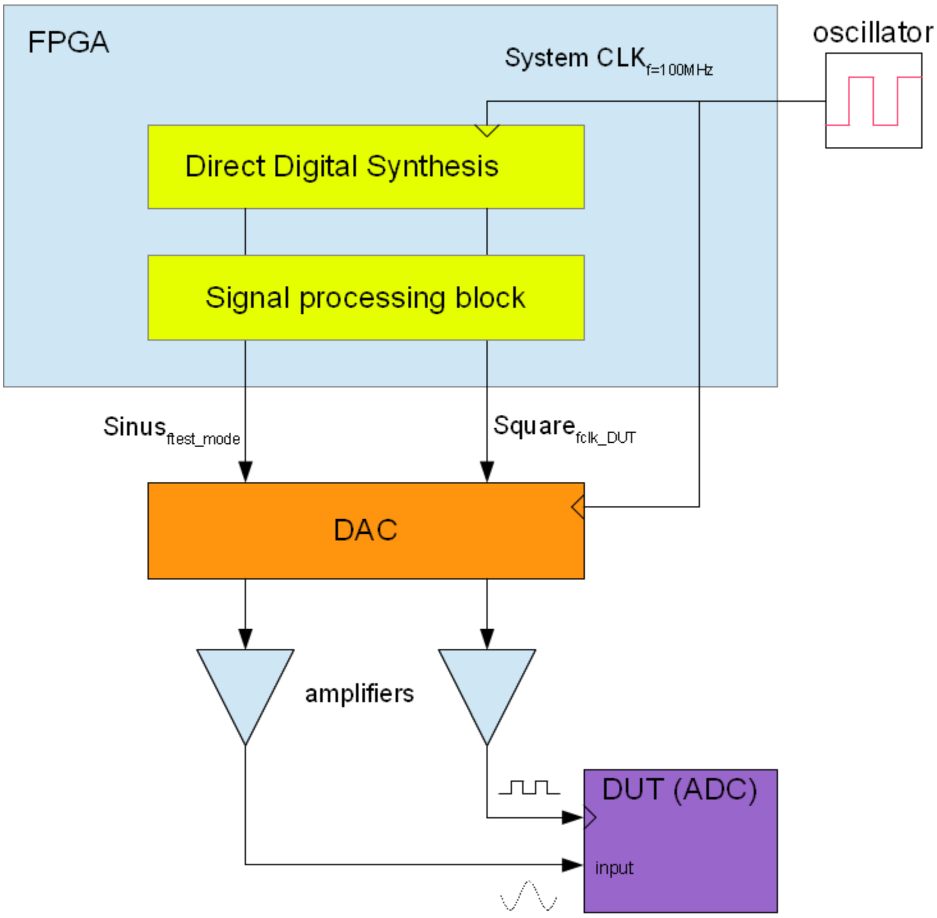


Figure 6 – Wave generation schematic

9 Bias conditions

- VA 5V
- VD 5V
- INmax +5V
- Room temperature
- External reference (VA)

Figure 7 – Bias conditions

10 SEE Test Results

10.1 SEU

Only 1 DUT channel has been selected for all runs as it should not impact the conversion sensitivity.

10.1.1 August 2014 test campaign

1 sample is tested at a time (DUT1 or DUT2) using bias conditions of Figure 7.
The three test methods have been applied with the following sets of frequencies. For the beat frequency and 4 points test methods, the input frequency was adjusted manually from an external AWG unit and not using the board described in paragraph 8.1.

	Input sinus			ADC128S102
	4points	hirex	beat freq	conversion frequency
W35	About 177 778 Hz	711,1 Hz	About 711 055 Hz	711 111 Hz

Input sinewave amplitude was adjusted closed to fullscale. Value of 1 LSB corresponds to 1.221 mV.
Figure 8 show the different digital output waveforms for the three different methods.
The presence of noise at DUT output requires to apply a detection threshold without exposure between 2 and 4 LSBs.
Because of a limitation in test software, the output value is compared to the previous one 2 clocks before instead of 1 clock for beat frequency event detection. Impact on the word output comparison with the previous output value is then 2 LSBs instead of 1.

Run details and results are provided in Table 2.
All runs were performed with normal incidence beam (no tilt).

All SET events were 1 conversion error.

In Table 2 for each run, the detection threshold level in LSBs is noted (column “threshold (LSBs)”) togeteher with the number of events detected (column ‘Nb events above threshold”). As this threshold is not identical for all runs and to ease comparison, we have extracted the number of events which would have been triggered with a threshold of respectively X=2, 3 and 4LSBs: see column “NB events above X LSBs”.
Column ‘period’ refers to the number of clocks to which output value is compared to the current conversion output.
In addition, Table 2 provides the error bar values computed as indicated in §1 in columns named up, low,X-section_up,X_section_low, delta_up and delta_low using a confidence level of 95% and a beam flux uncertainty of +/-10%.

To ease the comparison between the 3 different test methods implemented during this exercise, Figure 9, Figure 10 and Figure 11 show the event cross-section for each test method and with 3 different threshold values. As it can be observed, these methods give similar event cross-section curves.

All SET events were 1 conversion error.
Figure 12 shows the amplitude distribution in % for thr three methods (all runs cumulated)

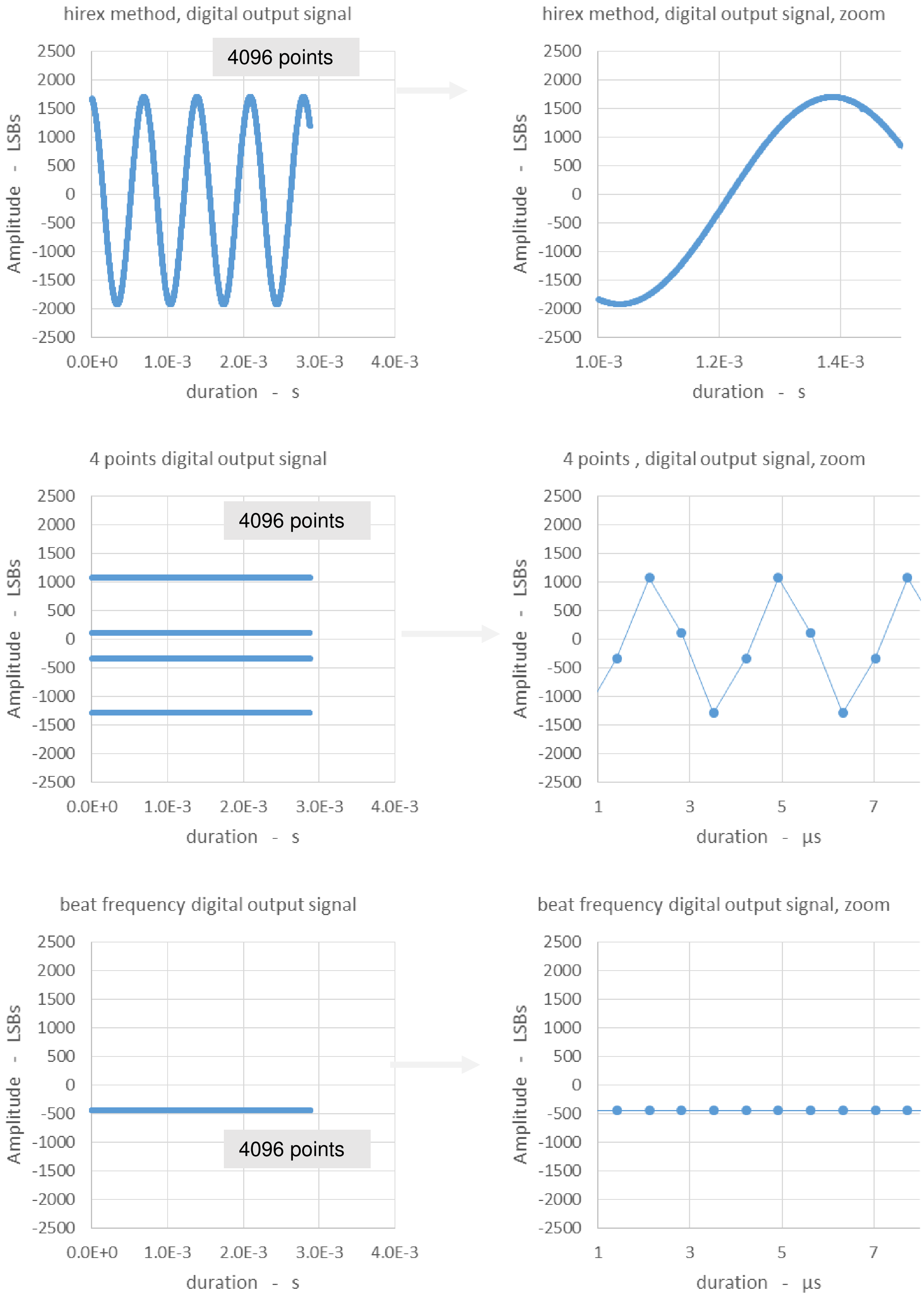


Figure 8 – Digital output waveform with the 3 different methods

															SET			SET cross-sections			error bars (threshold : 4 LSBs)			
Facility	medium	hrx_run_number	site_run_number	DUT_part_id	temperature	test_mode	PERIOD	Ion	roll	tilt	LET	fluence	run_duration	Threshold ' LSBs	Nb events above threshold 2 LSBs	Nb events above threshold 3 LSBs	Nb events above threshold 4 LSBs	Event cross-section above threshold 2 LSBs	Event cross-section above threshold 3 LSBs	Event cross-section above threshold 4 LSBs	error bar up	error bar down	delta up	delta down
RADEF	vacuum	8	176	1	Room	4 points	4	Fe	0	0	18.5	1.00E+07	205	2	55	36	18	5.50E-06	3.60E-06	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
RADEF	vacuum	11	179	1	Room	4 points	4	Kr	0	0	32.2	1.00E+07	207	2	101	77	58	1.01E-05	7.70E-06	5.80E-06	7.59E-06	4.29E-06	1.8E-06	1.5E-06
RADEF	vacuum	21	187	1	Room	4 points	4	Xe	0	0	60	4.24E+06	201	2	116	90	78	2.74E-05	2.12E-05	1.84E-05	2.33E-05	1.41E-05	4.9E-06	4.3E-06
RADEF	vacuum	9	177	2	Room	4 points	4	Fe	0	0	18.5	1.00E+07	217	2	49	31	20	4.90E-06	3.10E-06	2.00E-06	3.11E-06	1.20E-06	1.1E-06	8.0E-07
RADEF	vacuum	10	178	2	Room	4 points	4	Kr	0	0	32.2	1.00E+07	313	2	114	84	63	1.14E-05	8.40E-06	6.30E-06	8.17E-06	4.71E-06	1.9E-06	1.6E-06
RADEF	vacuum	20	186	2	Room	4 points	4	Xe	0	0	60	5.96E+06	255	2	127	95	70	2.13E-05	1.59E-05	1.17E-05	1.51E-05	8.90E-06	3.3E-06	2.8E-06
RADEF	vacuum	7	175	1	Room	Beat frequency	2	Fe	0	0	18.5	1.00E+07	192	3		34	25		3.40E-06	2.50E-06	3.72E-06	1.58E-06	1.2E-06	9.2E-07
RADEF	vacuum	12	180	1	Room	Beat frequency	2	Kr	0	0	32.2	1.00E+07	190	2	115	76	56	1.15E-05	7.60E-06	5.60E-06	7.36E-06	4.12E-06	1.8E-06	1.5E-06
RADEF	vacuum	6	174	2	Room	Beat frequency	2	Fe	0	0	18.5	1.00E+07	191	3		26	18		2.60E-06	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
RADEF	vacuum	13	181	2	Room	Beat frequency	2	Kr	0	0	32.2	1.00E+07	182	2	96	65	45	9.60E-06	6.50E-06	4.50E-06	6.09E-06	3.20E-06	1.6E-06	1.3E-06
RADEF	vacuum	22	188	1	Room	Hirex's classic	1000	Xe	0	0	60	5.53E+06	234	3		103	83		1.86E-05	1.50E-05	1.89E-05	1.16E-05	3.9E-06	3.4E-06
RADEF	vacuum	17	183	1	Room	Hirex's classic	1000	Kr	0	0	32.2	1.00E+07	184	3		96	67		9.60E-06	6.70E-06	8.63E-06	5.05E-06	1.9E-06	1.6E-06
RADEF	vacuum	18	184	1	Room	Hirex's classic	1000	Xe	0	0	60	4.10E+06	236	3		107	80		2.61E-05	1.95E-05	2.47E-05	1.50E-05	5.2E-06	4.5E-06
RADEF	vacuum	23	189	2	Room	Hirex's classic	1000	Xe	0	0	60	5.29E+06	264	3		100	79		1.89E-05	1.49E-05	1.89E-05	1.15E-05	4.0E-06	3.5E-06
RADEF	vacuum	4	173	2	Room	Hirex's classic	1000	Fe	0	0	18.5	1.00E+07	228	2	30	29	18	3.00E-06	2.90E-06	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
RADEF	vacuum	15	182	2	Room	Hirex's classic	1000	Kr	0	0	32.2	1.01E+07	185	4			81			8.02E-06	1.01E-05	6.18E-06	2.1E-06	1.8E-06
RADEF	vacuum	19	185	2	Room	Hirex's classic	1000	Xe	0	0	60	5.57E+06	281	4			113			2.03E-05	2.49E-05	1.62E-05	4.6E-06	4.1E-06

Table 2 – RADEF, August 2014(W35), ADC128S102, run table

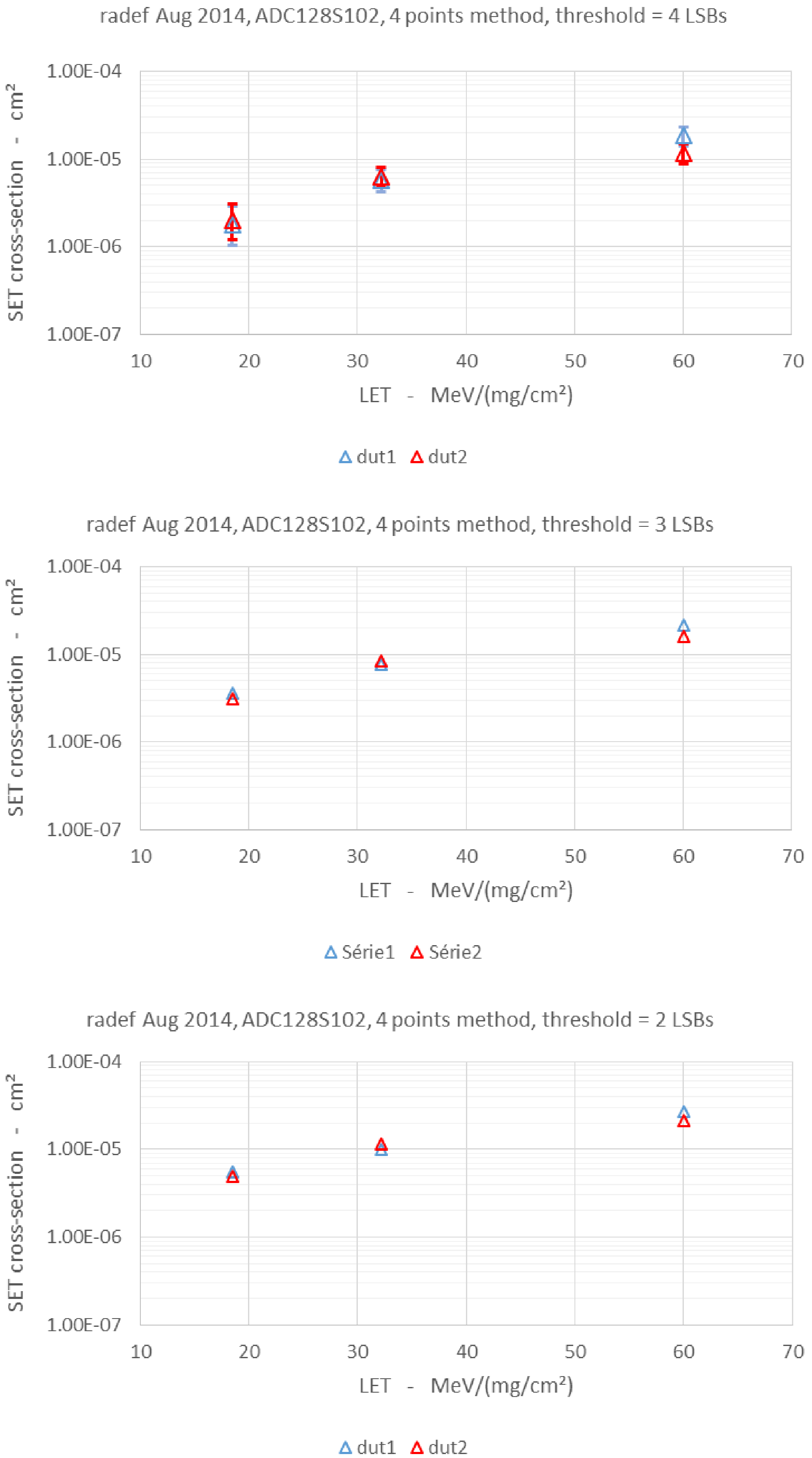


Figure 9 – SET event cross-section for the 4points test method with 3 different thresholds

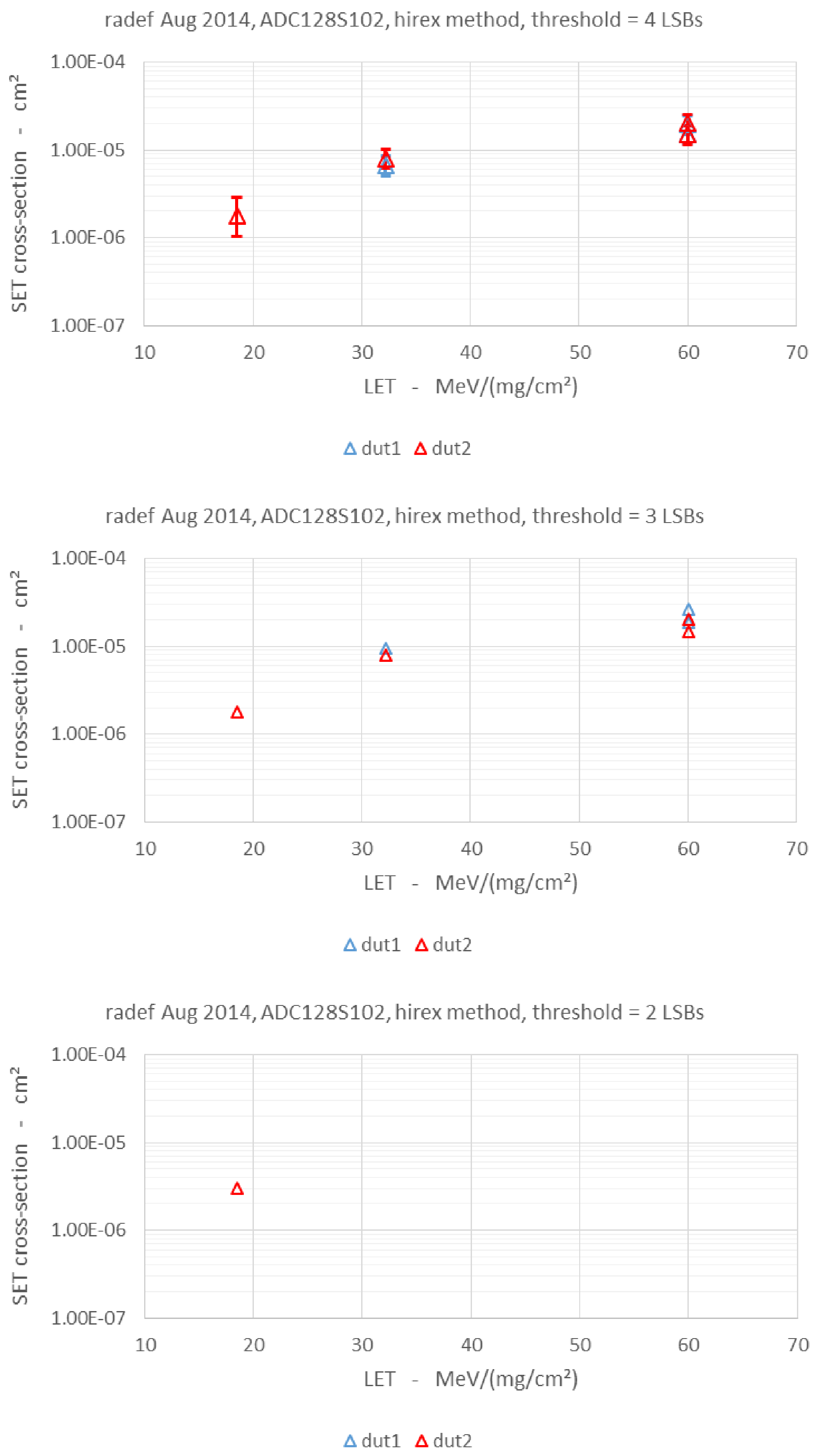


Figure 10 – SET event cross-section for the hrx test method with 3 different thresholds

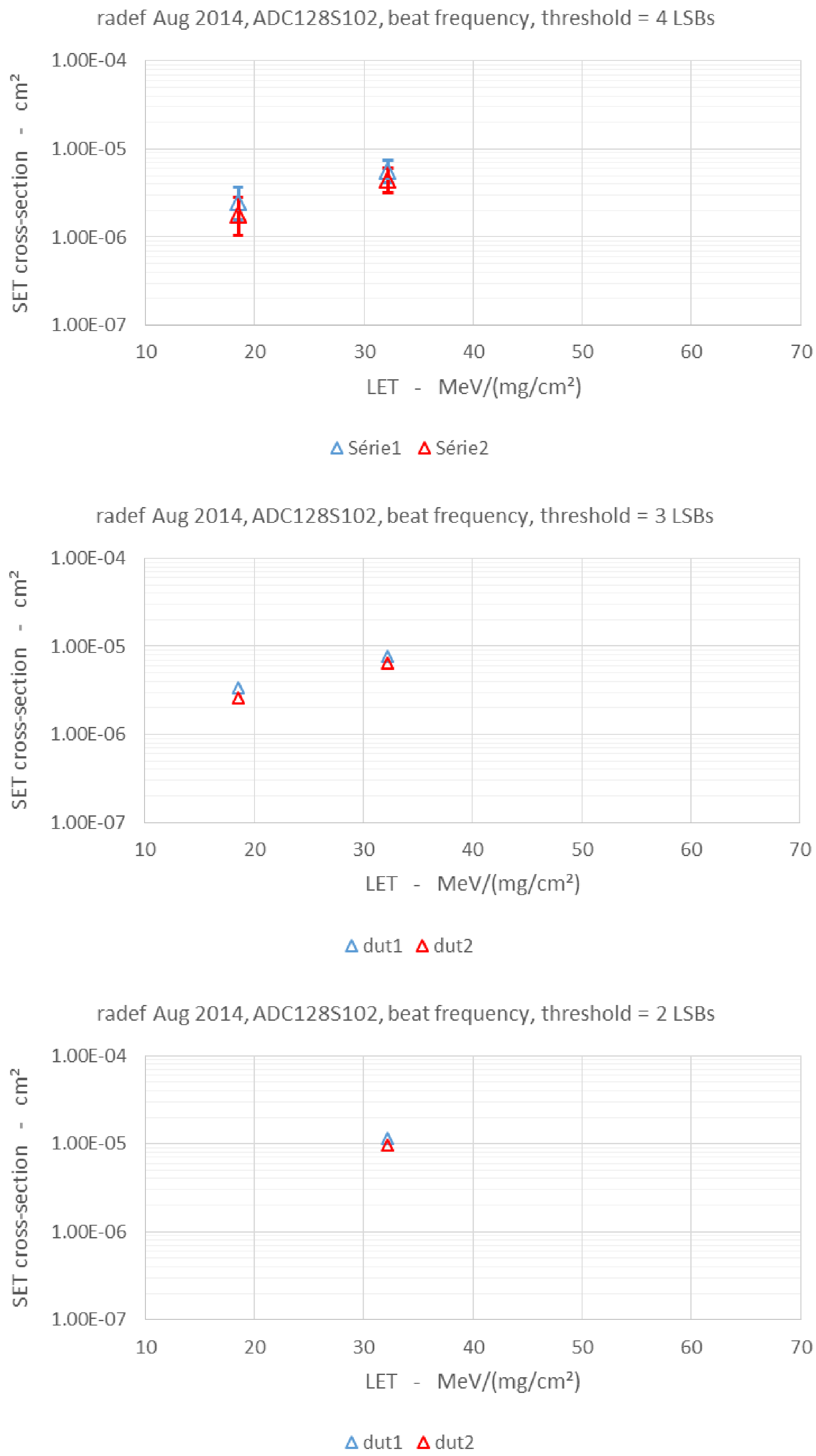


Figure 11 – SET event cross-section for the beat frequency test method with 3 different thresholds

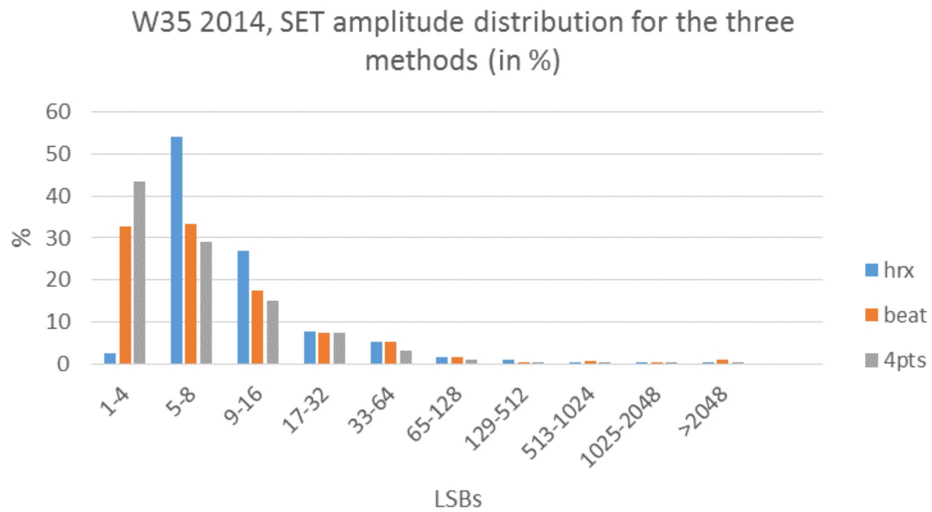


Figure 12 – radef August 2014, SET amplitude distribution in % for the three methods

10.2 November 2014 test campaign

1 sample is tested at a time (DUT1 or DUT2) using bias conditions of Figure 7.

The three test methods presented in paragraph 7 have been applied with the following sets of frequencies.

	Input sinus			ADC128S102
	4points	hirex	beat freq	conversion frequency
W35	177 778 Hz	711,1 Hz	711 055 Hz	711 111 Hz

Input sinewave amplitude was adjusted closed to fullscale. Value of 1 LSB value corresponds to 1.221 mV.

The presence of noise at DUT output requires to apply a detection threshold without exposure of 2 LSBs.

Because of a limitation in test software, the output value is compared to the previous one 2 clocks before instead of 1 clock for beat frequency event detection. Impact on the word output comparison with the previous output value is then 2 LSBs instead of 1.

Run details and results are provided inTable 3.
All runs were performed with normal incidence beam (no tilt).
In Table 3 for each run, the detection threshold level in LSBs is noted (column “threshold (LSBs)”) togeteher with the number of events detected (column ‘Nb events above threshold”). To compare with August 2014 test camapaign, we have extracted the number of events which would have been triggered with a threshold of 3 LSBs: see column “NB events above 3LSBs” and with a threshold of 4 LSBs.
Column ‘period’ refers to the number of clocks to which output value is compared to the current conversion output.
In addition, Table 3 provides the error bar values computed as indicated in §1 in columns named up, low,X-section_up,X_section_low, delta_up and delta_low low using a confidence level of 95% and a beam flux uncertainty of +/-10%.

All SET events were 1 conversion error.
Figure 12 shows the amplitude distribution in % for thr three methods (all runs cumulated)

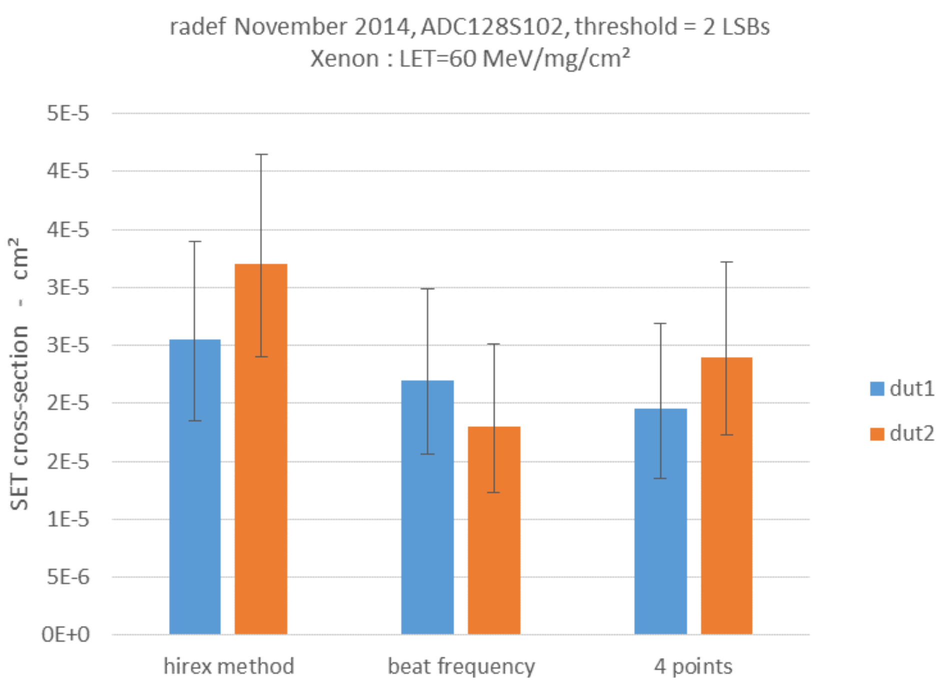


Figure 13 – Nov 2014, SET event cross-section, LET = 60 MeV/(mg/cm²) and SET threshold = 2LSBs

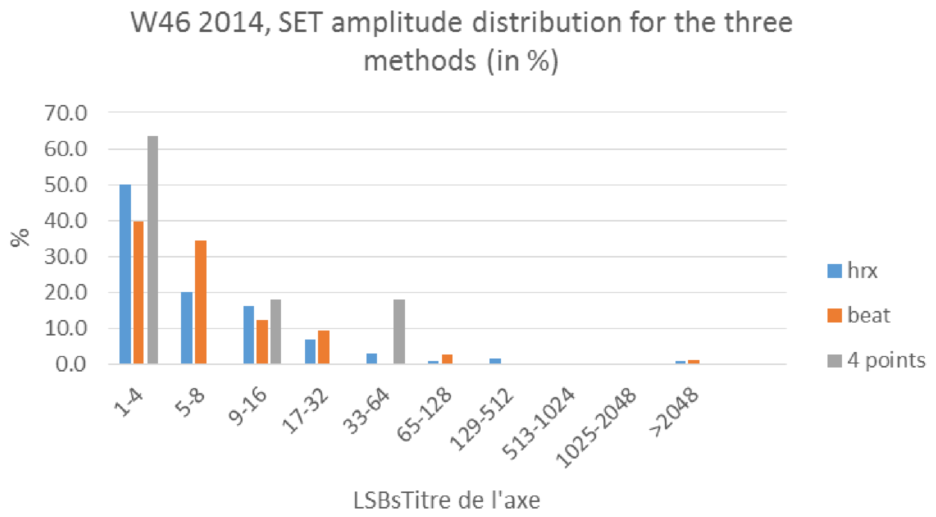


Figure 14 – radef November2014, SET amplitude distribution in % for the three methods

															SET			SET cross-sections			error bars (threshold : 2 LSBs)			
Facility	medium	hrx_run_number	site_run_number	DUT_under_beam	power_config	test_mode	Ion	roll	tilt	LET	run_duration	fluence	PERIOD	Threshold ' LSBs	Nb events above threshold 2 LSBs	Nb events above threshold 3 LSBs	Nb events above threshold 4 LSBs	Event cross-section above threshold 2 LSBs	Event cross-section above threshold 3 LSBs	Event cross-section above threshold 4 LSBs	error bar up	error bar down	delta up	delta down
RADEF	vacuum	2	25	1	5V	hirex method	Xe	0	0	60	411	2.00E+06	1000	2	51	24	20	2.55E-05	1.20E-05	1.00E-05	3.39E-05	1.85E-05	8.4E-06	7.0E-06
RADEF	vacuum	3	26	1	5V	beat frequency	Xe	0	0	60	450	2.00E+06	2	2	44	29	20	2.20E-05	1.45E-05	1.00E-05	2.98E-05	1.56E-05	7.8E-06	6.4E-06
RADEF	vacuum	6	29	1	5V	4 points	Xe	0	0	60	416	2.00E+06	4	2	39	32	24	1.95E-05	1.60E-05	1.20E-05	2.69E-05	1.35E-05	7.4E-06	6.0E-06
RADEF	vacuum	1	24	2	5V	hirex method	Xe	0	0	60	436	2.00E+06	1000	2	64	41	33	3.20E-05	2.05E-05	1.65E-05	4.14E-05	2.40E-05	9.4E-06	8.0E-06
RADEF	vacuum	4	27	2	5V	beat frequency	Xe	0	0	60	423	2.00E+06	2	2	36	28	20	1.80E-05	1.40E-05	1.00E-05	2.51E-05	1.23E-05	7.1E-06	5.7E-06
RADEF	vacuum	5	28	2	5V	4 points	Xe	0	0	60	412	2.00E+06	4	2	48	33	28	2.40E-05	1.65E-05	1.40E-05	3.22E-05	1.73E-05	8.2E-06	6.7E-06

Table 3 – RADEF, November 2014(W46), ADC128S102, run table with corresponding event cross-sections

10.2.1 February 2016 test campaign

1 sample is tested at a time (DUT1 or DUT2) using bias conditions of Figure 7.

The three test methods presented in paragraph 7 have been applied with the following sets of frequencies.

	Input sinus			ADC128S102
	4points	hirex	beat freq	conversion frequency
W07 2016	177 778 Hz	711,1 Hz	711 055 Hz	711 111 Hz

Input sinewave amplitude was adjusted closed to fullscale. Value of 1 LSB value corresponds to 1.221 mV.

The presence of noise at DUT output requires to apply a detection threshold without exposure of 3 LSBs minimum.

Because of a limitation in test software, the output value is compared to the previous one 2 clocks before instead of 1 clock for beat frequency event detection. Impact on the word output comparison with the previous output value is then 2 LSBs instead of 1.

Run details and results are provided inTable 4.
All runs were performed with normal incidence beam (no tilt).

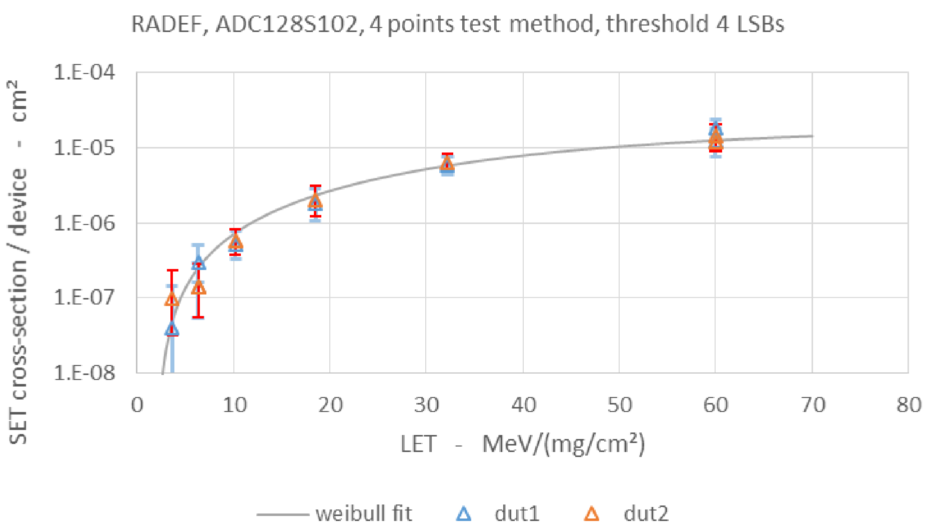
In Table 4 for each run, the detection threshold level in LSBs is noted (column “threshold (LSBs)”) togeteher with the number of events detected (column ‘Nb events above threshold”). To compare with August 2014 test campaign, we have extracted the number of events which would have been triggered with a threshold of 4 LSBs: see column “NB events above 4LSBs”.
Column ‘period’ refers to the number of clocks to which output value is compared to the current conversion output.
In addition, Table 4 provides the error bar values computed as indicated in §1 in columns named up, low,X-section_up,X_section_low, delta_up and delta_low low using a confidence level of 95% and a beam flux uncertainty of +/-10%.

All SET events were 1 conversion error.

Figure 15 show the SET cross-section / device for the 3 different test methods and with the results of the 3 test campaigns and a threshold of 4 LSBs presented in Table 5.
One may note that the point at let =6.33MeV/(mg/cm²) is slightly below the Weibull fit. One assumption is because of the use of a tilt angle of 55 deg.

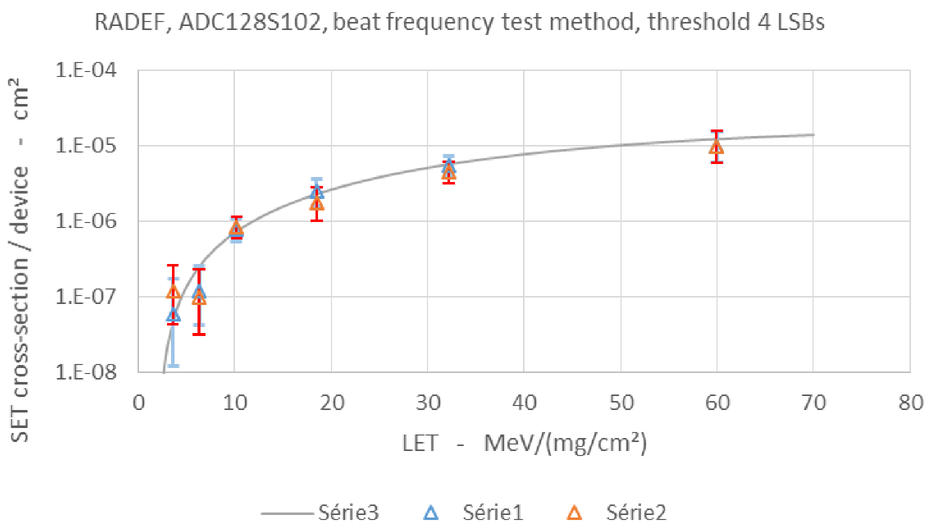
	Facility	medium	hrx_run_number	site_run_number	DUT_part_id	temperature	test_mode	PERIOD	Ion	roll	tilt	LET	fluence	run_duration	Threshold - LSBs	Nb events above threshold 2 LSBs	Nb events above threshold 3 LSBs	Nb events above threshold 4 LSBs	Event cross-section above threshold 2 LSBs	Event cross-section above threshold 3 LSBs	Event cross-section above threshold 4 LSBs	error bar up	error bar down	delta up	delta down
W07 2016	RADEF	vacuum	1	1	2	room	4 points	4	Ne	0	0	3.63	5E+07	902	4			5			9.98E-08	2.33E-07	3.17E-08	1.3E-07	6.8E-08
W07 2016	RADEF	vacuum	2	2	1	room	4 points	4	Ne	0	0	3.63	5E+07	643	4			2			3.98E-08	1.44E-07	4.60E-09	1.0E-07	3.5E-08
W07 2016	RADEF	vacuum	3	3	1	room	4 points	4	Ne	0	55	6.33	5E+07	678	4			15			2.99E-07	4.96E-07	1.64E-07	2.0E-07	1.4E-07
W07 2016	RADEF	vacuum	4	4	1	room	4 points	4	Ne	0	55	6.33	5E+07	442	4			7			1.40E-07	2.88E-07	5.50E-08	1.5E-07	8.5E-08
W07 2016	RADEF	vacuum	10	9	2	room	4 points	4	Ne	0	55	6.33	5E+07	402	4			7			1.40E-07	2.88E-07	5.49E-08	1.5E-07	8.5E-08
W07 2016	RADEF	vacuum	11	10	2	room	4 points	4	Ne	0	55	6.33	5E+07	436	4			7			1.40E-07	2.89E-07	5.51E-08	1.5E-07	8.5E-08
W07 2016	RADEF	vacuum	22	20	2	room	4 points	4	Ar	0	0	10.20	5E+07	241	4			29			5.77E-07	8.35E-07	3.78E-07	2.6E-07	2.0E-07
W07 2016	RADEF	vacuum	23	21	1	room	4 points	4	Ar	0	0	10.20	5E+07	248	3		38	26		7.57E-07	5.18E-07	7.65E-07	3.31E-07	2.5E-07	1.9E-07
W07 2016	RADEF	vacuum	13	11	2	room	beat frequency	2	Ne	0	55	6.33	5E+07	392	3		9	5		1.80E-07	9.97E-08	2.33E-07	3.16E-08	1.3E-07	6.8E-08
W07 2016	RADEF	vacuum	14	12	1	room	beat frequency	2	Ne	0	55	6.33	5E+07	432	3		13	6		2.59E-07	1.20E-07	2.61E-07	4.29E-08	1.4E-07	7.7E-08
W07 2016	RADEF	vacuum	15	13	1	room	beat frequency	2	Ne	0	0	3.63	5E+07	238	3		4	3		7.97E-08	5.98E-08	1.75E-07	1.20E-08	1.2E-07	4.8E-08
W07 2016	RADEF	vacuum	16	14	2	room	beat frequency	2	Ne	0	0	3.63	5E+07	244	3		6	6		1.19E-07	1.19E-07	2.60E-07	4.29E-08	1.4E-07	7.7E-08
W07 2016	RADEF	vacuum	24	22	1	room	beat frequency	2	Ar	0	0	10.20	5E+07	239	4			39			7.75E-07	1.07E-06	5.38E-07	2.9E-07	2.4E-07
W07 2016	RADEF	vacuum	25	23	2	room	beat frequency	2	Ar	0	0	10.20	5E+07	29	3		63	43		1.25E-06	8.57E-07	1.17E-06	6.05E-07	3.1E-07	2.5E-07
W07 2016	RADEF	vacuum	5	5	1	room	Hirex	1000	Ne	0	55	6.33	5E+07	409	3		12			2.39E-07					
W07 2016	RADEF	vacuum	7	7	1	room	Hirex	1000	Ne	0	55	6.33	5E+07	411	3		9	4		1.80E-07	7.98E-08	2.05E-07	2.12E-08	1.2E-07	5.9E-08
W07 2016	RADEF	vacuum	8	8	2	room	Hirex	1000	Ne	0	55	6.33	5E+07	431	4			7			1.40E-07	2.89E-07	5.51E-08	1.5E-07	8.5E-08
W07 2016	RADEF	vacuum	17	15	2	room	Hirex	1000	Ne	402	0	3.63	5E+07	228	4			5			9.96E-08	2.33E-07	3.16E-08	1.3E-07	6.8E-08
W07 2016	RADEF	vacuum	18	16	1	room	Hirex	1000	Ne	402	0	3.63	5E+07	251	3		3	2		5.96E-08	3.98E-08	1.44E-07	4.59E-09	1.0E-07	3.5E-08
W07 2016	RADEF	vacuum	20	17	1	room	Hirex	1000	Ar	402	0	10.20	5E+07	248	3		42	37		8.35E-07	7.36E-07	1.02E-06	5.06E-07	2.9E-07	2.3E-07
W07 2016	RADEF	vacuum	21	19	2	room	Hirex	1000	Ar	402	0	10.20	5E+07	242	4			28			5.59E-07	8.14E-07	3.63E-07	2.5E-07	2.0E-07

Table 4 – RADEF, February 2016(W07), ADC128S102, run table with corresponding event cross-sections



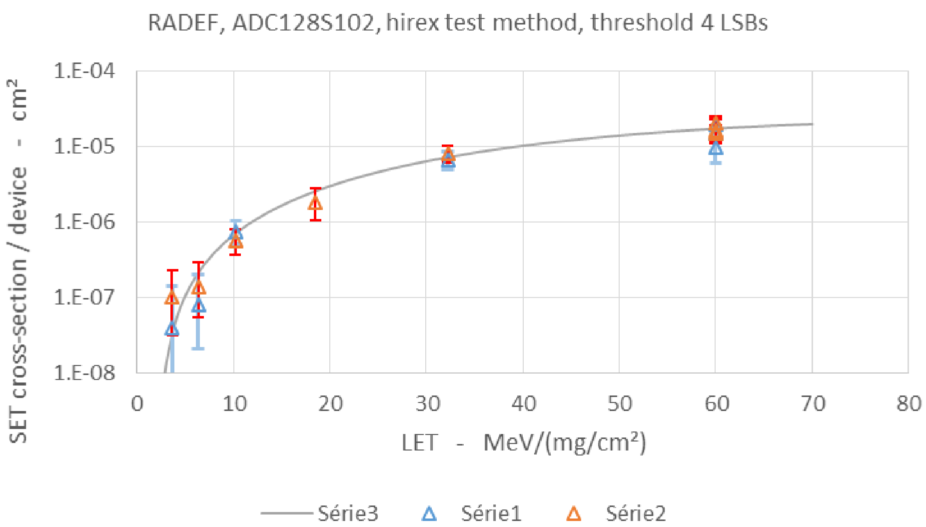
W	53
xo	2
s	1.7
A	1.80E-05

Weibull parameters



W	53
xo	2
s	1.7
A	1.80E-05

Weibull parameters



W	53
xo	2
s	1.9
A	2.50E-05

Weibull parameters

Figure 15 – SET event cross-section for the 3 different test methods (threshold = 4LSBs)

	Facility	medium	hrx_run_number	site_run_number	DUT_part_id	temperature	test_mode	PERIOD	Ion	roll	tilt	LET	fluence	run_duration	Threshold ' LSBs	Nb events above threshold 4 LSBs	Event cross-section above threshold 4 LSBs	error bar up	error bar down	delta up	delta down
W35	RADEF	vacuum	8	176	1	Room	4 points	4	Fe	0	0	18.5	1.00E+07	205	2	18	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
W35	RADEF	vacuum	11	179	1	Room	4 points	4	Kr	0	0	32.2	1.00E+07	207	2	58	5.80E-06	7.59E-06	4.29E-06	1.8E-06	1.5E-06
W35	RADEF	vacuum	21	187	1	Room	4 points	4	Xe	0	0	60	4.24E+06	201	2	78	1.84E-05	2.33E-05	1.41E-05	4.9E-06	4.3E-06
W07	RADEF	vacuum	2	2	1	room	4 points	4	Ne	0	0	3.63	50189305	643	4	2	3.98E-08	1.44E-07	4.60E-09	1.0E-07	3.5E-08
W07	RADEF	vacuum	3	3	1	room	4 points	4	Ne	0	55	6.33	50125488	678	4	15	2.99E-07	4.96E-07	1.64E-07	2.0E-07	1.4E-07
W07	RADEF	vacuum	4	4	1	room	4 points	4	Ne	0	55	6.33	50107440	442	4	7	1.40E-07	2.88E-07	5.50E-08	1.5E-07	8.5E-08
W07	RADEF	vacuum	23	21	1	room	4 points	4	Ar	0	0	10.20	50185583	248	3	26	5.18E-07	7.65E-07	3.31E-07	2.5E-07	1.9E-07
W46	RADEF	vacuum	6	29	1	room	4 points	4	Xe	0	0	60	2.00E+06	416	2	24	1.20E-05	1.80E-05	7.52E-06	6.0E-06	4.5E-06
W35	RADEF	vacuum	9	177	2	Room	4 points	4	Fe	0	0	18.5	1.00E+07	217	2	20	2.00E-06	3.11E-06	1.20E-06	1.1E-06	8.0E-07
W35	RADEF	vacuum	10	178	2	Room	4 points	4	Kr	0	0	32.2	1.00E+07	313	2	63	6.30E-06	8.17E-06	4.71E-06	1.9E-06	1.6E-06
W35	RADEF	vacuum	20	186	2	Room	4 points	4	Xe	0	0	60	5.96E+06	255	2	70	1.17E-05	1.51E-05	8.90E-06	3.3E-06	2.8E-06
W07	RADEF	vacuum	1	1	2	room	4 points	4	Ne	0	0	3.63	50085573	902	4	5	9.98E-08	2.33E-07	3.17E-08	1.3E-07	6.8E-08
W07	RADEF	vacuum	10	9	2	room	4 points	4	Ne	0	55	6.33	50169915	402	4	7	1.40E-07	2.88E-07	5.49E-08	1.5E-07	8.5E-08
W07	RADEF	vacuum	11	10	2	room	4 points	4	Ne	0	55	6.33	50040900	436	4	7	1.40E-07	2.89E-07	5.51E-08	1.5E-07	8.5E-08
W07	RADEF	vacuum	22	20	2	room	4 points	4	Ar	0	0	10.20	50270670	241	4	29	5.77E-07	8.35E-07	3.78E-07	2.6E-07	2.0E-07
W46	RADEF	vacuum	5	28	2	room	4 points	4	Xe	0	0	60	2.00E+06	412	2	28	1.40E-05	2.04E-05	9.10E-06	6.4E-06	4.9E-06
W07	RADEF	vacuum	14	12	1	room	beat	2	Ne	0	55	6.33	50183198	432	3	6	1.20E-07	2.61E-07	4.29E-08	1.4E-07	7.7E-08
W07	RADEF	vacuum	15	13	1	room	beat	2	Ne	0	0	3.63	50183422	238	3	3	5.98E-08	1.75E-07	1.20E-08	1.2E-07	4.8E-08
W07	RADEF	vacuum	24	22	1	room	beat	2	Ar	0	0	10.20	50299484	239	4	39	7.75E-07	1.07E-06	5.38E-07	2.9E-07	2.4E-07
W35	RADEF	vacuum	7	175	1	Room	beat	2	Fe	0	0	18.5	1.00E+07	192	3	25	2.50E-06	3.72E-06	1.58E-06	1.2E-06	9.2E-07
W35	RADEF	vacuum	12	180	1	Room	beat	2	Kr	0	0	32.2	1.00E+07	190	2	56	5.60E-06	7.36E-06	4.12E-06	1.8E-06	1.5E-06
W46	RADEF	vacuum	3	26	1	Room	beat	2	Xe	0	0	60	2.00E+06	450	2	20	1.00E-05	1.55E-05	5.98E-06	5.5E-06	4.0E-06
W07	RADEF	vacuum	13	11	2	room	beat	2	Ne	0	55	6.33	50139031	392	3	5	9.97E-08	2.33E-07	3.16E-08	1.3E-07	6.8E-08
W07	RADEF	vacuum	16	14	2	room	beat	2	Ne	0	0	3.63	50243715	244	3	6	1.19E-07	2.60E-07	4.29E-08	1.4E-07	7.7E-08
W07	RADEF	vacuum	25	23	2	room	beat	2	Ar	0	0	10.20	50202789	29	3	43	8.57E-07	1.17E-06	6.05E-07	3.1E-07	2.5E-07
W35	RADEF	vacuum	6	174	2	Room	beat	2	Fe	0	0	18.5	1.00E+07	191	3	18	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
W35	RADEF	vacuum	13	181	2	Room	beat	2	Kr	0	0	32.2	1.00E+07	182	2	45	4.50E-06	6.09E-06	3.20E-06	1.6E-06	1.3E-06
W46	RADEF	vacuum	4	27	2	Room	beat	2	Xe	0	0	60	2.00E+06	423	2	20	1.00E-05	1.55E-05	5.98E-06	5.5E-06	4.0E-06
W07	RADEF	vacuum	5	5	1	room	hirex	1000	Ne	0	55	6.33	50147522	409	3						
W07	RADEF	vacuum	7	7	1	room	hirex	1000	Ne	0	55	6.33	50113221	411	3	4	7.98E-08	2.05E-07	2.12E-08	1.2E-07	5.9E-08
W07	RADEF	vacuum	18	16	1	room	hirex	1000	Ne	0	0	3.63	50301420	251	3	2	3.98E-08	1.44E-07	4.59E-09	1.0E-07	3.5E-08
W07	RADEF	vacuum	20	17	1	room	hirex	1000	Ar	0	0	10.20	50274941	248	3	37	7.36E-07	1.02E-06	5.06E-07	2.9E-07	2.3E-07
W35	RADEF	vacuum	22	188	1	Room	hirex	1000	Xe	0	0	60	5.53E+06	234	3	83	1.50E-05	1.89E-05	1.16E-05	3.9E-06	3.4E-06
W35	RADEF	vacuum	17	183	1	Room	hirex	1000	Kr	0	0	32.2	1.00E+07	184	3	67	6.70E-06	8.63E-06	5.05E-06	1.9E-06	1.6E-06
W35	RADEF	vacuum	18	184	1	Room	hirex	1000	Xe	0	0	60	4.10E+06	236	3	80	1.95E-05	2.47E-05	1.50E-05	5.2E-06	4.5E-06
W46	RADEF	vacuum	2	25	1	Room	hirex	1000	Xe	0	0	60	2.00E+06	411	2	20	1.00E-05	1.55E-05	5.98E-06	5.5E-06	4.0E-06
W07	RADEF	vacuum	8	8	2	room	hirex	1000	Ne	0	55	6.33	50022371	431	4	7	1.40E-07	2.89E-07	5.51E-08	1.5E-07	8.5E-08
W07	RADEF	vacuum	17	15	2	room	hirex	1000	Ne	0	0	3.63	50190857	228	4	5	9.96E-08	2.33E-07	3.16E-08	1.3E-07	6.8E-08
W07	RADEF	vacuum	21	19	2	room	hirex	1000	Ar	0	0	10.20	50126775	242	4	28	5.59E-07	8.14E-07	3.63E-07	2.5E-07	2.0E-07
W35	RADEF	vacuum	23	189	2	Room	hirex	1000	Xe	0	0	60	5.29E+06	264	3	79	1.49E-05	1.89E-05	1.15E-05	4.0E-06	3.5E-06
W35	RADEF	vacuum	4	173	2	Room	hirex	1000	Fe	0	0	18.5	1.00E+07	228	2	18	1.80E-06	2.86E-06	1.05E-06	1.1E-06	7.5E-07
W35	RADEF	vacuum	15	182	2	Room	hirex	1000	Kr	0	0	32.2	1.01E+07	185	4	81	8.02E-06	1.01E-05	6.18E-06	2.1E-06	1.8E-06
W35	RADEF	vacuum	19	185	2	Room	hirex	1000	Xe	0	0	60	5.57E+06	281	4	113	2.03E-05	2.49E-05	1.62E-05	4.6E-06	4.1E-06
W46	RADEF	vacuum	1	24	2	Room	hirex	1000	Xe	0	0	60	2.00E+06	436	2	33	1.65E-05	2.34E-05	1.11E-05	6.9E-06	5.4E-06

Table 5 – RADEF, ADC128S102, run table with corresponding event cross-sections (4 LSBs threshold)

10.3 SEL

During the 3 test campaigns, no latchup has been detected for any run with LETs up to 60MeV/(mg/cm²)

10.4 Conclusion

No SEL was detected up to a LET of 60MeV/(mg/cm²)

All set were 1 conversion error only.

Three test methods, hirex method, 4 points method and beat frequency method have been implemented and give similar results in term of event detection and event SET cross-section curve as a function of LET.