HIREX ENGINEERING
A company of ALTER TECHNOLOGY

SINGLE EVENT EFFECTS
TEST REPORT

Test Type:	Heavy ion
Test facility:	REF, TAMU, College station, Tx, USA
Test Date:	August 2013, June 2014
Part Type:	STRH100N10
Part Description:	Rad-Hard 100 V, 48 A N-channel Power MOSFET
Part Manufacturer:	STMicroelectronics

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

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SEE TEST REPORT

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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 gate rupture (SEGR), single-event burnout (SEB).

Single-Event Gate rupture (power mosfet) (SEGR): An event in which a single energetic-particle strike results in a breakdown and subsequent conducting path through the gate oxide of a MOSFET.

Sijngle-Event Burnout (SEB): An event in which a single energetic-particle strike induces a localized high-current state in a device, resulting in a catastrophic failure. SEB can be destructive and the use ofa protection limiting current resistor in serie with the drain supply allows for getting non destructive SEB during testing.

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 STRH100N10 part type from STMicroelectronics. STRH100N10 samples were used for heavy ions testing at REF, TAMU, College station, Tx, USA.
This work was performed for ESA under ESA contract n° 4000105495/12/NL/SFe dated 27/2/2012.

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. STRH100N10, STMicroelectronics datasheet, July 2011 Doc ID 17486 Rev 5.

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

STRH100N10 is a Rad-Hard 100 V, 48 A N-channel Power MOSFET.

Part type:	STRH100N10
Manufacturer:	STMicroelectronics
Manufacturer lot number:	-
Datecode:	1305A
Package:	TO-254AA
Top marking:	logo 1305A 520502101F FR BeO .e serial
Die dimensions:	4206µ x 5856µ

4.2 Sample identification

Photo 1 – Device top view

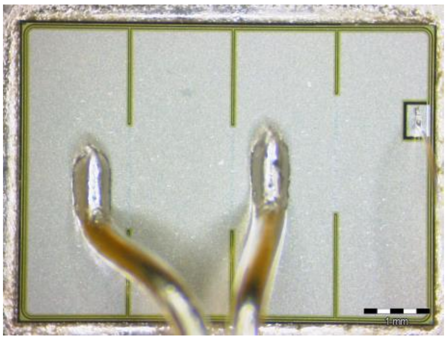

Photo 2 – Die full view

Figure 1: STRH100N10 device identification

4.3 Sample preparation

Samples were opened mechanically.

4.4 Die microsection

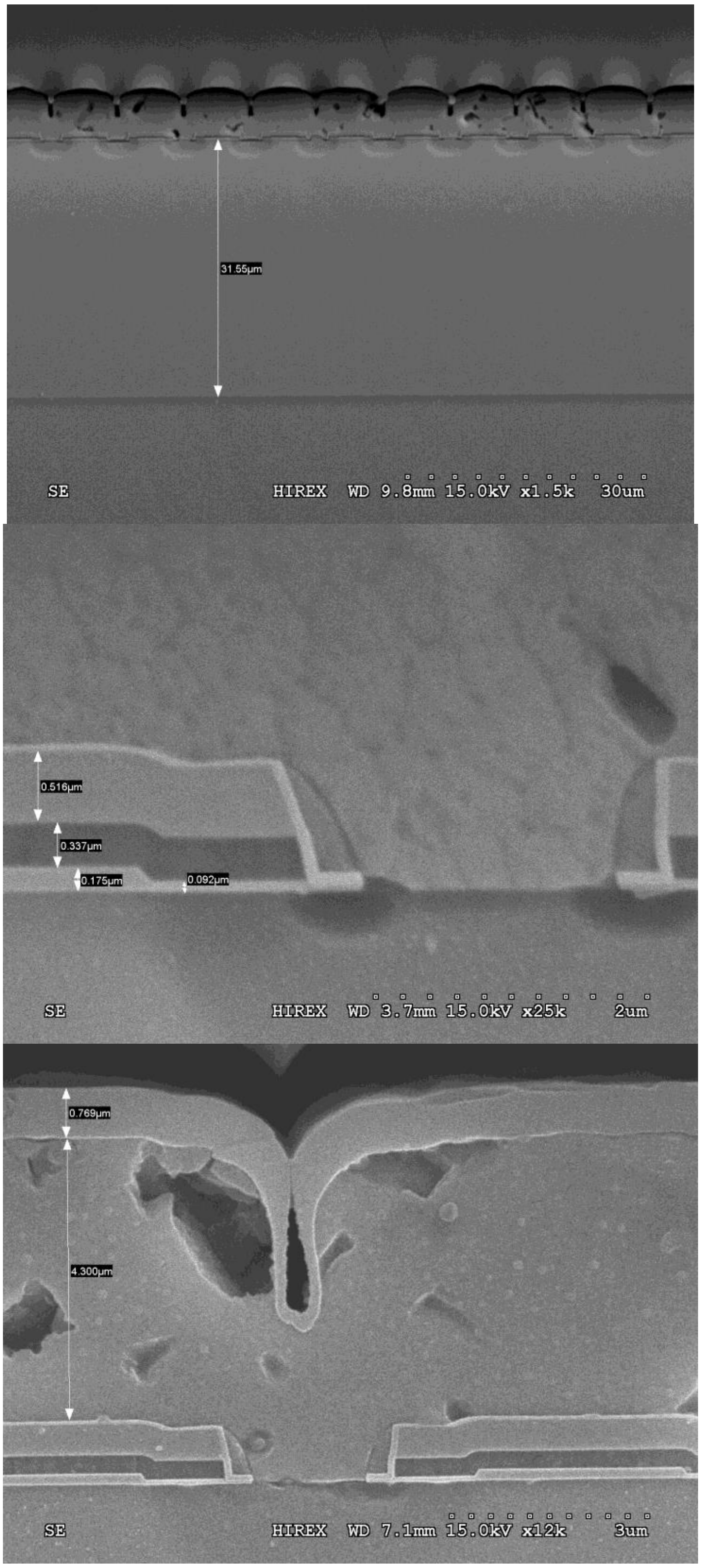

Figure 2 -STRH100N10 die microsection

5 TAMU Facility (REF)

Test at the cyclotron accelerator was performed at Texas A & M in College Station - TX- USA.
This facility includes a special beam line dedicated to irradiation studies of semiconductor components and devices. Testing may be conducted in either 30" diameter vacuum chamber or with in-air positioning system . Both provide precise positioning in x, y, and z as well as rotations up to 60 degrees. Positioning and dosimetry are carried out by custom-made SEUSS software.

In Air Station

The in-air station is located at the end of dedicated beam-line. The station consists of a rotating platform and a removable target mounting fixture. The target positioning assembly allows the motion of the target in four directions: X, Y, Z and Theta. X and Y are the horizontal and the vertical axis in the target plane, respectively. The Z-axis is in the direction of the beam-line, with theta being the clockwise and counter-clockwise rotation about the y-axis. Target position verification is provided by the means of a CCD camera aligned with the beam path and a narrow laser beam that crosses the beam path at the center of the target chamber. The size of the exposed area is controlled by the aperture defined by a pair of remotely adjustable horizontal and vertical slits.

Vacuum Station

Vacuum station has an inside diameter of 30inch and a height 30inch.Pumping time to an operating pressure in the low 10 -4 Torr range is approximately ten minutes and the chamber vents to gaseous nitrogen in two and half minutes. Target positioning system allows X, Y, Z and Theta moving. Like for in air station, the position is checked with the means of a CCD camera.

Ion Beam

Various ion beams are available for the Radiation Effects Facility. These beams provide for a wide scope of LET with high energies for deep part penetration. Time for beam species changes will vary, but with species that have the same energy per nucleon change times is about one half hour.
Beams can be delivered with a high degree of uniformity over a 1.8" x 1.8" cross sectional area for measurements inside the vacuum chamber and 1" diameter circular cross sectional area for the in-air station. Uniformity is achieved by means of magnetic defocusing.
A degrader foil system makes it possible to set the desired beam LET value at a particular depth inside the target without changing the beam or rotating the target. The beam energy is reduced by means of a degrader system with foils having a suitable thickness and orientation with respect to the incident beam. Each foil can be inserted, withdrawn, and rotated remotely through use of computer controls.
The intensity of any beam is easily regulated over a broad range spanning several orders of magnitude in a matter of seconds. This can be done by the operator on duty at the users request.
The target exposure system is fully automated. Exposure can be set for a certain time, total accumulated fluence, or can be manually stopped at any time.

Beam Quality control

The beam uniformity and flux are determined using an array of five detectors. Each detector is made up with a plastic scintillator coupled to photo-multiplier tubes. Four of the detectors are fixed in position and set up to measure beam particle counting rates continuously at four characteristic points 1.64 inches (4.71 mm) away from the beam axis. The fifth scintillator can be optionally put in to measure the beam particle counting rate right at the beam axis. The sensitive area of each detector is defined by a 0.1 cm^2 aperture, while the intrinsic efficiency is 100% for all practical purposes. The beam uniformity parameter (ranging from 0 to 100%), the axial gain (%), and the beam flux (in particles/cm^2/s) are determined by the control software based on the detector counting rates. The results are displayed and updated once every second.

Dosimetry

The current TAMU Cyclotron dosimetry system and procedures were used.

Figure 3 shows the TAMU facility different beam lines. K500 (88”) cyclotron is used to inject beam in Radiation Effects Facility (REF) cave.

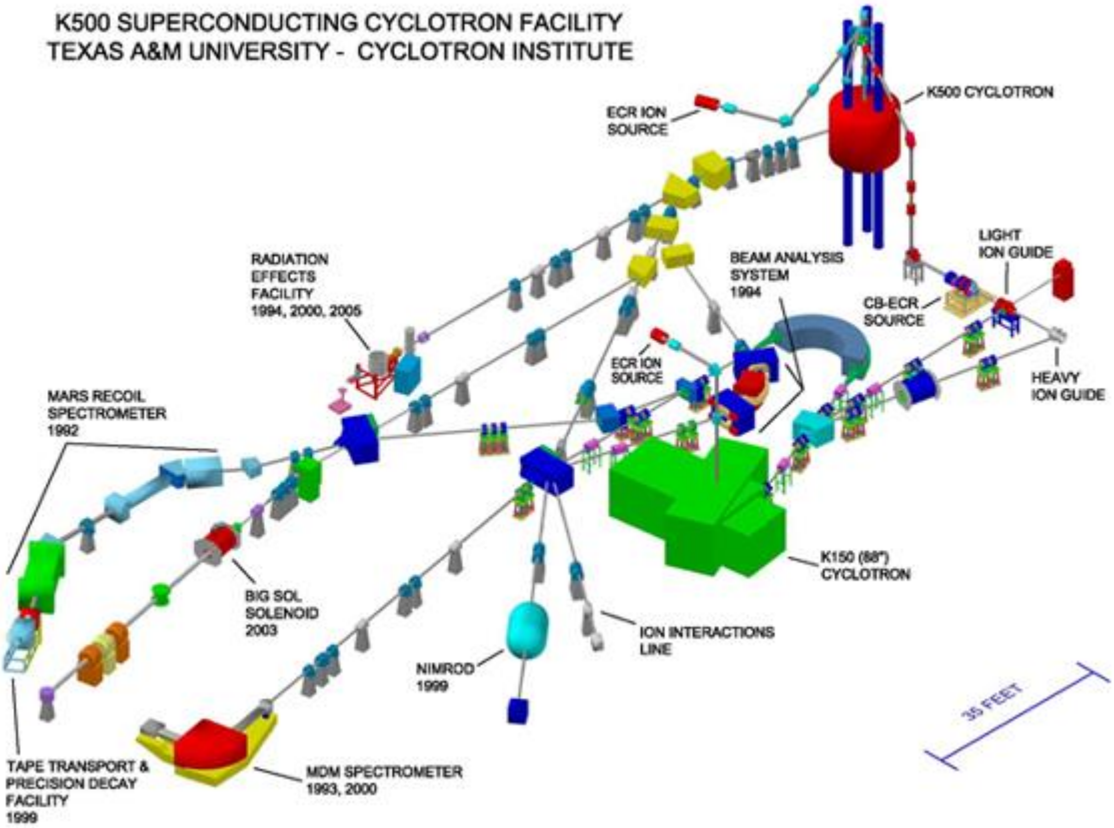

Figure 3 – TAMU facility beam lines (http://cyclotron.tamu.edu/facilities.html)

6 Test Set-up

The test set-up is composed of 4 main parts as shown in the following Figure 4 :

- DUTs board
- Set of Agilent Source Monitor Units (HP4142)
- V5 ASERT test board mounted with a 400 Msps digitizer
- A laptop running a Graphical User Interface

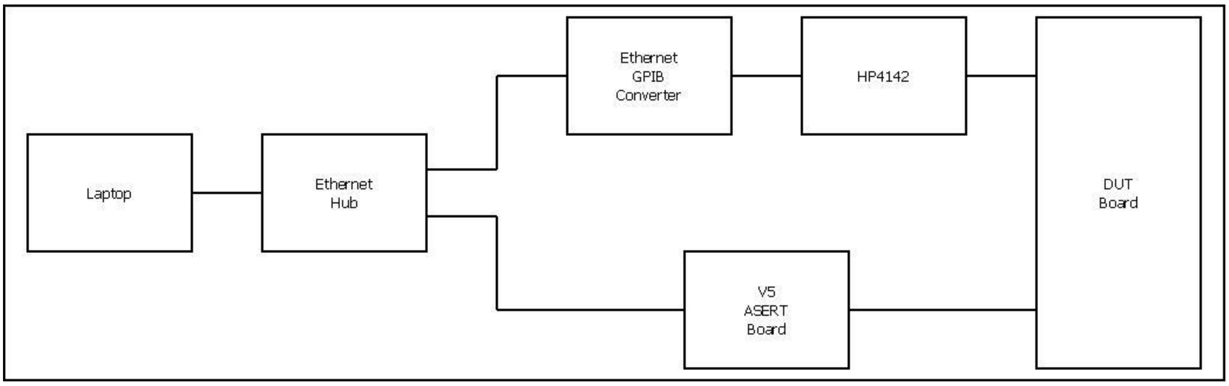

Figure 4 - Test set-up block diagram

6.1 DUTs board:

The DUTs board can hold up to 16 DUTs (2 rows by 8 columns). Each row (or line) as detailed on the Figure 5 is supplied by a set of 2 SMUs (Source Monitor Units) supplying drain and gate supplies. A drain sense is outputted from each line. A relay system allows the dynamic selection of:

- The DUT
- The bias included on the input and output conditioning systems

Input and output conditioning systems as well as DUTs are integrated on daughter boards plugged on the DUTs board.

The 2 lines are fully independent allowing the irradiation of 2 DUTs close by at the same time.

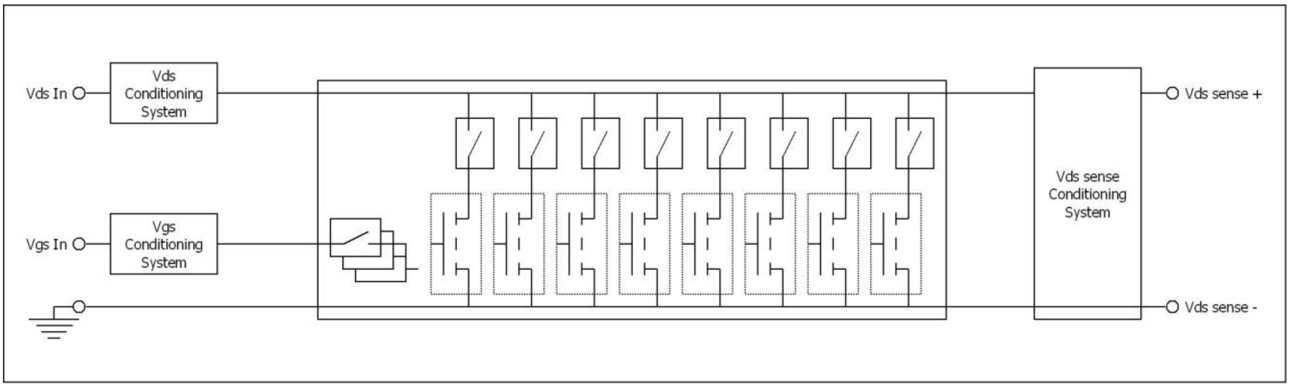

Figure 5 - DUTs board - One line schematic

The used bias is detailed on the following Figure 6.

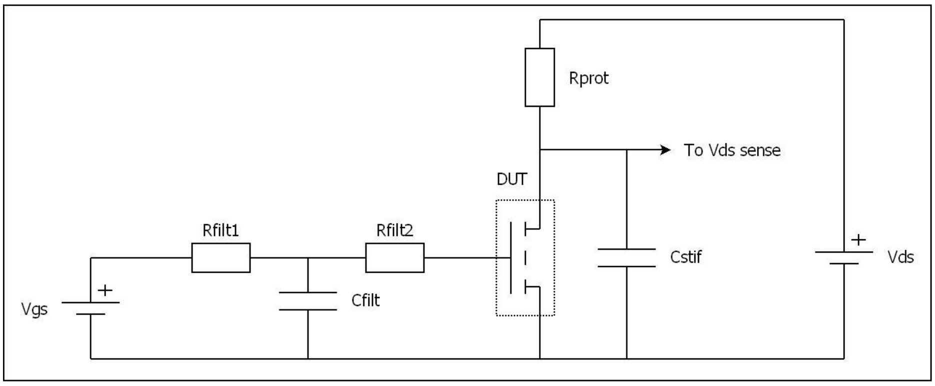

Figure 6 - Bias schematic

6.2 Agilent set of Source Monitor Units

The sourcing and monitoring of the DUT's drain and gate supplies (voltages and currents) are performed using a set of Agilent SMUs (Source Monitor Units) HP4142 featuring the following ranges:

- For the gate: HP41421B: 40µV - 100 V / 20 fA - 100 mA
- For the drain: HP41423A: 2 mV - 1000 V / 2 pA - 2 mA

This set of SMUs is controlled remotely by the Graphical User Interface through an Ethernet/GPIB converter.

6.3 V5 ASERT test board

The V5 ASERT test board is used to:

- Monitor the bias through the relay system.
- Digitize (using a 400Msps digitizer) the drain sense signal. The digitizer is configured to trig on level voltage of both channels (lines). For each test conditions, high and low thresholds are set. All events higher than the high threshold or lower than the low threshold trig the digitizer and data are plotted and recorded on the computer.

6.4 Graphical User Interface

The GUI running on the computer mainly allows the:

- Selection of the DUT
- Control of the bias
- Choice of test conditions
- Monitoring of the SMUs
- Display of currents graphs
- Management of the test sequence

6.5 Test sequence

The basic sequence used to test was the following:

- Pre run test: Initial gate stress
- Pre run test: On / Off test
- Run test: Start off test
- Run test:: exposition
  Run test: Stop off test
- Post run test: Post gate stress (PIGS)

The On / Off test is performed at the beginning of each run before the irradiation. This test is used to verify the functionality of the device.
The Off test is the test achieved during the irradiation.
Gate Stress test is carried out at the beginning and at the end of the each run. This test is used to verify the integrity of the gate. For a selected drain voltage, a voltage cycle (between the upper and lower absolute maximum ratings) is applied on the gate.

7 SEE Test Results

7.1 Ions selection

The selection of the different ions and energies was performed in compliance with the following requirements:

The device type shall be tested with at least four ion types. Two of the ion types shall have an atomic number 25 < Z < 37 (group 1). The two other ion types shall have an atomic number 45< Z < 55 (group 2). At least three energies shall be used for one ion type of each group: worst-case energy (corresponding to maximum deposited charge in sensitive volume), one energy that satisfies ion range requirements of Table 3 in [RD11] and a high energy (≥40 MeV/u). The second ion type of each group shall be tested at one energy such as the mean LET in EPI layer is similar to the mean LET in EPI corresponding to one of the selected energies with the first ion.
Calculation of worst case energy shall be detailed in the test plan. For each irradiation condition at least 2 devices shall be tested to SEGR according to [AD3]. **SEGR test shall be performed with Vgsoff=10V in order to have SEGR failures during irradiation.** Vds bias shall incremented up to the first value Vdsth for which SEGRs or degradations are observed. When only degradation are observed, Vds shall be incremented another time and another irradiation run shall be performed with this bias condition outside SOA. **Test fluences for SEGR tests shall be 3E5 ions/cm2.**
After each irradiation run a PIGS testshall be performed. Degraded parts shall be replaced by non-irradiated parts for the following irradiation run.
Degradations are defined as follows : Igss reaches the value of 100 nA during irradiation, or the part fails during PIGS test, or the part is degraded after PIGS test (Igss > 100 nA).
SEGR cross-section shall be measured. Gate current measurements during irradiation shall be recorded.

TABLE III
MINIMUM AND MAXIMUM ION RANGE AS A FUNCTION OF RATED V_{DS} FOR SEB TESTING OF VERTICAL POWER MOSFETS

Max rated Vds (V)	Minimum ion range (µm)	Maximum ion range (µm)
Up to 100	60	120
101 to 200	90	180
201 to 400	150	300
401 to 1000	200	400

(Table III Charge Collection in Power MOSFETs for SEB Characterisation—Evidence of Energy Effects, V. Ferlet-Cavrois *et al., IEEE TNS, VOL. 57, NO. 6, DECEMBER 2010)*

Table 1 – Ion range requirements

Copper and Kryptons ions, Cu (Z=29), Kr (Z=36), have been selected for the group 1 while Silver and Xenon, Ag(Z=47), Xe (Z=54) have been selected for the group 2.
SRIM 2013 was used to compute the critical charge deposited,energy deposited, the average LET value.
A dead layer equivalent to 6µm of Aluminum (noted 4(1) in detailed run results in Table 4.
 was used during the first test campaign (y13w35), for the second slot, a sandwich of 0.84 µm Silicon dioxde, 4.3 µm of Aluminum, 0.77 µm of silicon dioxyde noted 6(3) in detailed run results inTable 4.
Epitaxy depth was set to 32µm according to the die microsection results (see § 4.4).
The different ion beams selected are detailed in Table 2 where R correspond to the silicon surface level below the dead layer. TAMU interface is based on SRIM 2005 computations and then some minor differences have been observed with SRIM 2013 computations. Table 2 identifies also the beam selected during the three different test slots.

SRIM 2013 computation						TAMU beam selection					
Ion	Q	R	LET at R	E at R	Mean_LET	Cocktail	Energy	degrader	Eff. LET	y13w353	y14w26
	pC	µm	MeV/ (mg/cm²)	MeV	MeV/ (mg/cm²)		MeV		MeV/ (mg/cm²)		
Cu	10.5248	48	28.83	317.8	31.9	15MeV	318	3.052	27.6	y	
Kr_wc	13.21	50	38.7	405.5	40.04	15MeV	406	2.938	37.2	y	
Kr high	5.015	568	15.01	2999.7	15.2	40MeV	2996	0	14.6	y	y
Kr_0	10.6407	32	40.76	238.8	32.26	15MeV	239	3.572	40.4	y	
Kr	10.5226	114	30.11	912.5	31.9	25MeV	914	6.305	29.3	y	y
Ag	19.1227	53	56.56	591.6	57.97	15MeV	592	2.248	51.1	y	
Xe_wc	22.5263	59	66.72	777	68.28	15MeV	777	1.979	59.5	y	
Xe	19.1145	116	55.17	1579.6	57.94	25MeV	1581	4.334	50.8	y	

Table 2 – Ion beam setting

7.2 Run tests

All tests were performed in air and at room temperature.
Resistor protection was set to 10kOms.
The detailed list of runs performed at TAMU during the three test campains is provided in Table 4.
One or two samples can be tested at the same time with same or different test biasing conditions
Figure 7 shows Example of the data recorded for each dut under test and each test run.
In this figure, one can observe the initial get stress followed by on/off condition then under off condition, beam is started until the desired fluence, then when run is stopped, a post gate stress is performed.
Actual final beam fluence value is listed in Table 4 while in this figure the computed flux is based on the recorded data from one scintillator only instead of the four scintillator detectors used by the accelerator interface.
Please note that Igs current plot can exhibit a scale factor (1e-8 in the present case)
All data recorded for the different runs and duts are provided in a companion document ref. HRX/SEE/472-appendix issue1.
This allows for a quick overview of each sample behavior for each test run.
When a SEGR occurs as for instance shown in Figure 8 on dutA run029, a zoom on both Vds and Igs supplies during beam exposure only allows for quantifying the sample degradation as shown in Figure 9.

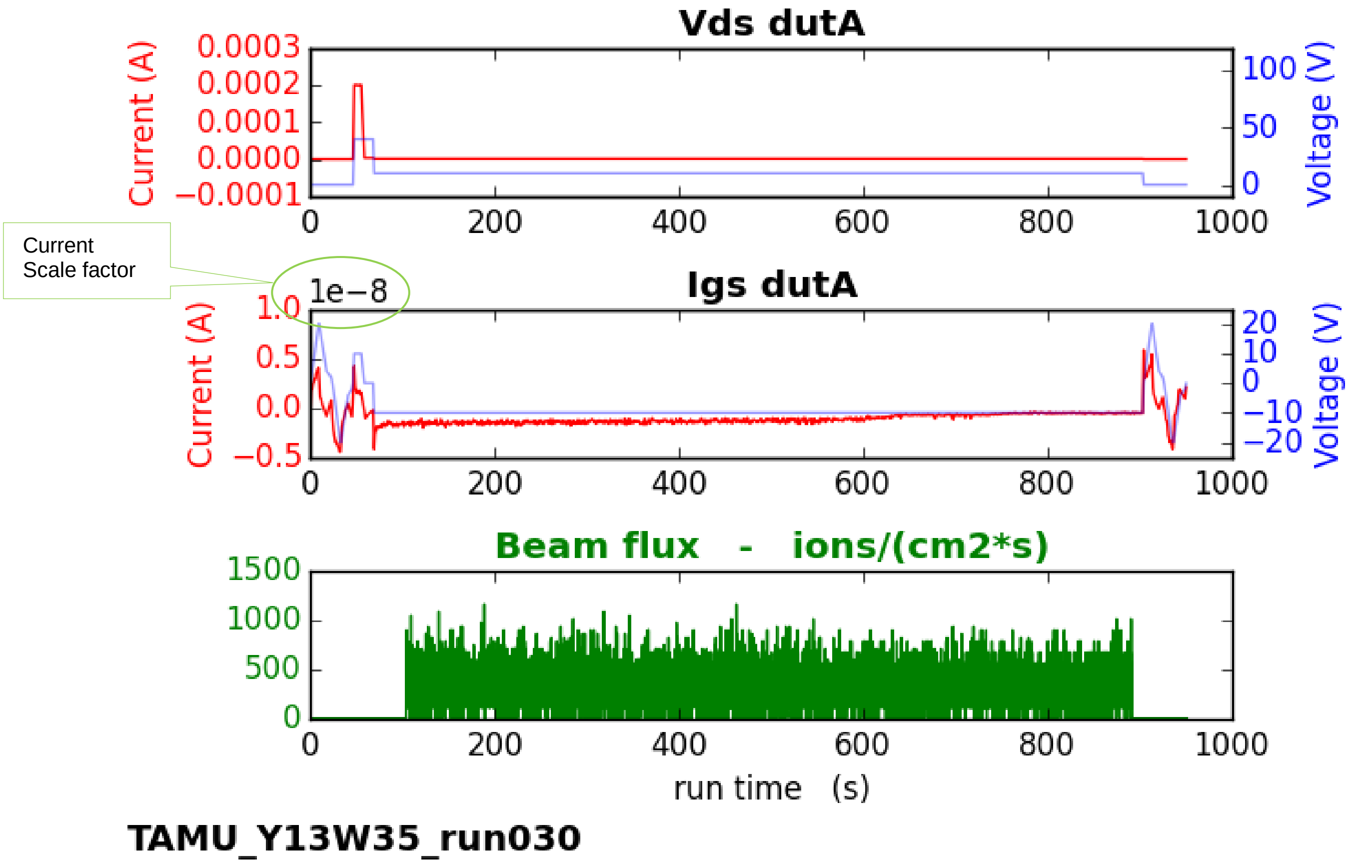

Figure 7 – Example of the data recorded for each dut under test and each test run.

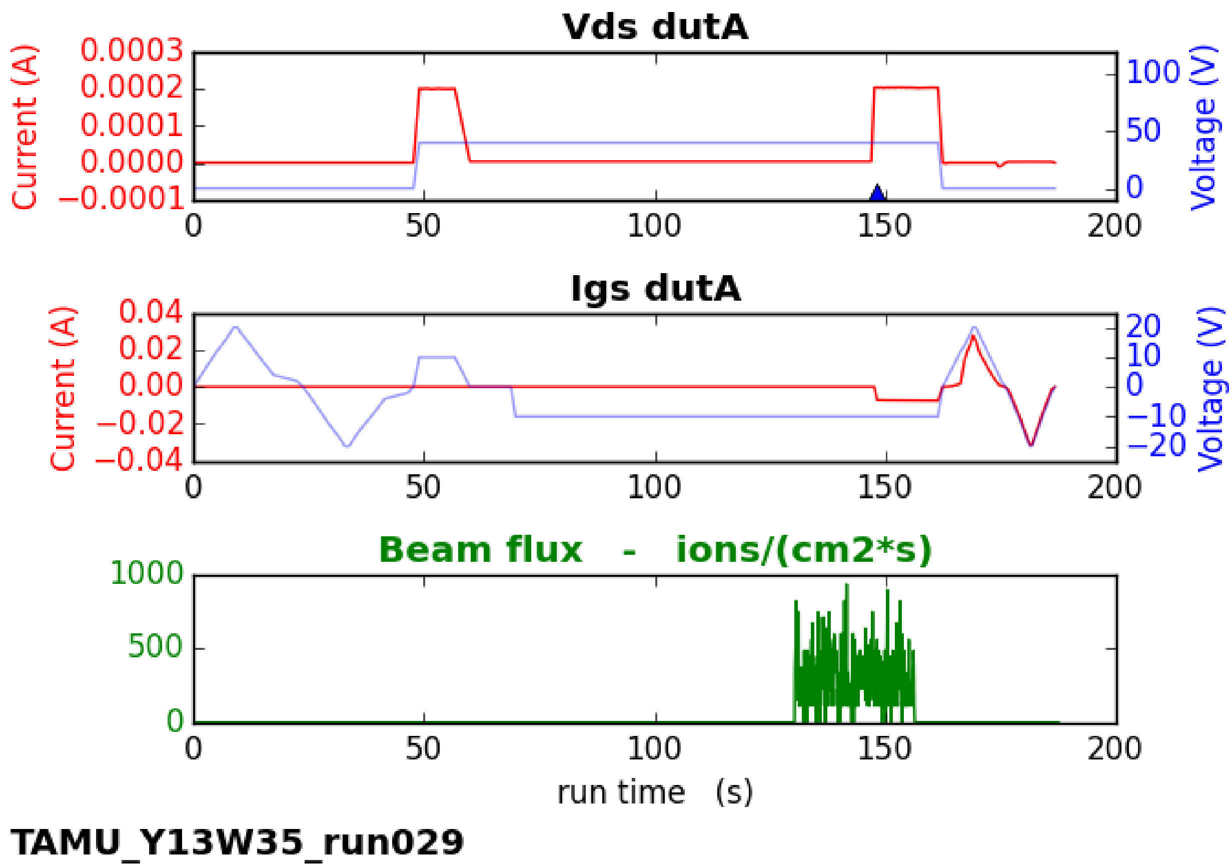

Figure 8 – run029, example of the data recorded with SEGR occurrence during exposure.

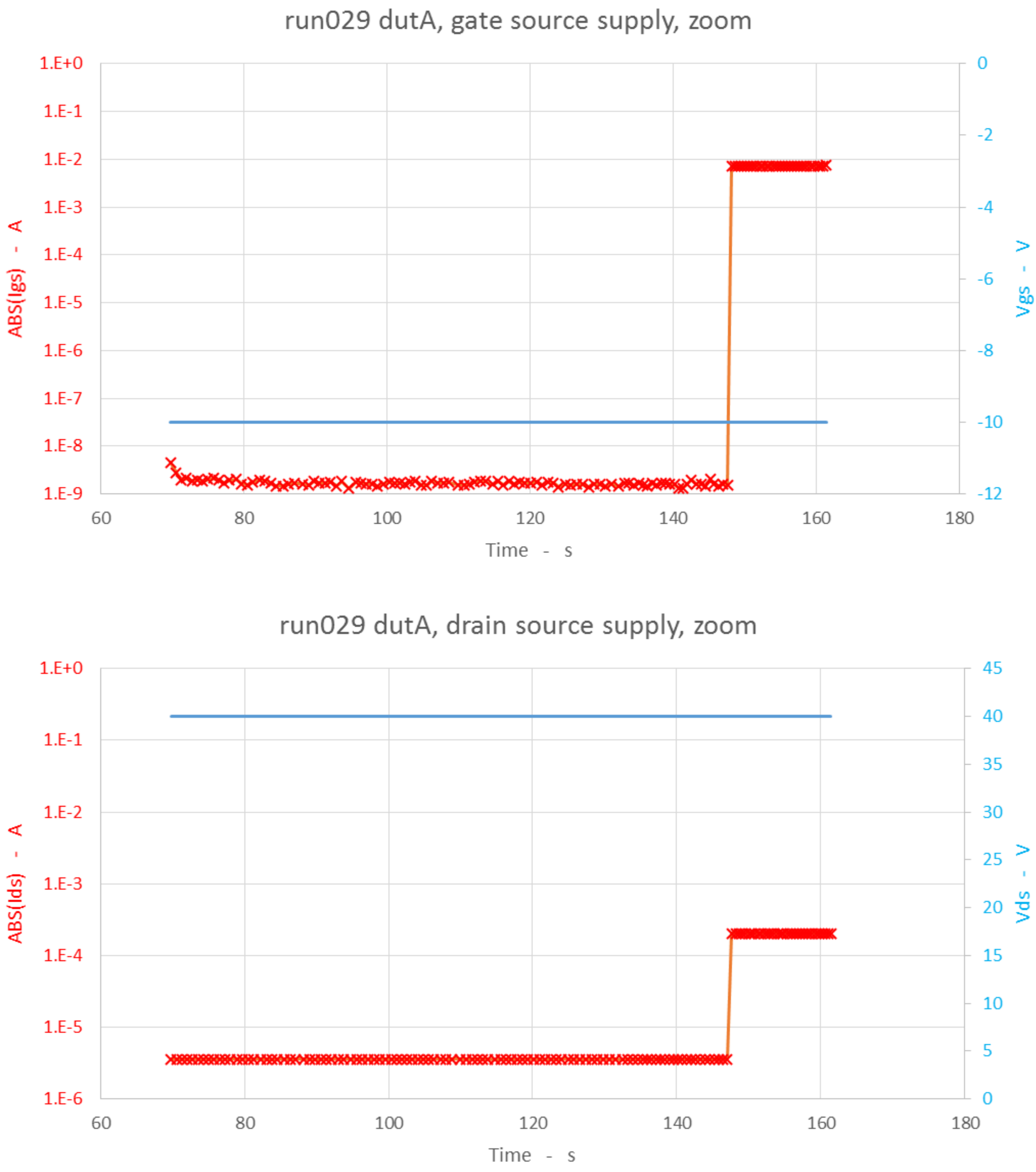

Figure 9 – run029, Igs and Ids source supplies zoom on SEGR occurrence and part degradation.

7.3 Discussion

Vgs value at -10V was needed to get SEGR before nominal Vds voltage. This has been verified for copper and 0V and -10V Vgs values.
SEGR occurred at 2 different votages depending on the ion group, around 30 to 45V for Group1 and around 20 to 25 for group2. This is illustrated in Figure 10 and in Table 3 below (threshold is the lowest Vds voltage for which an SEB has been detected).

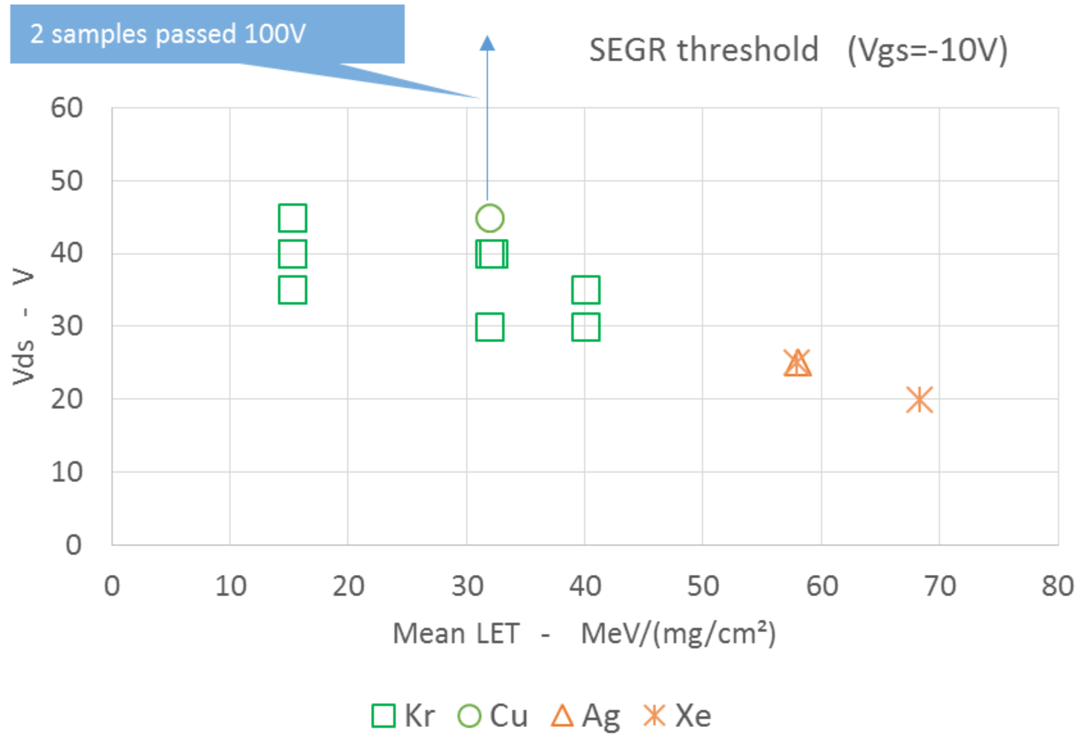

Figure 10 – SEGR threshold for the 4 ions selected as a function of LET value

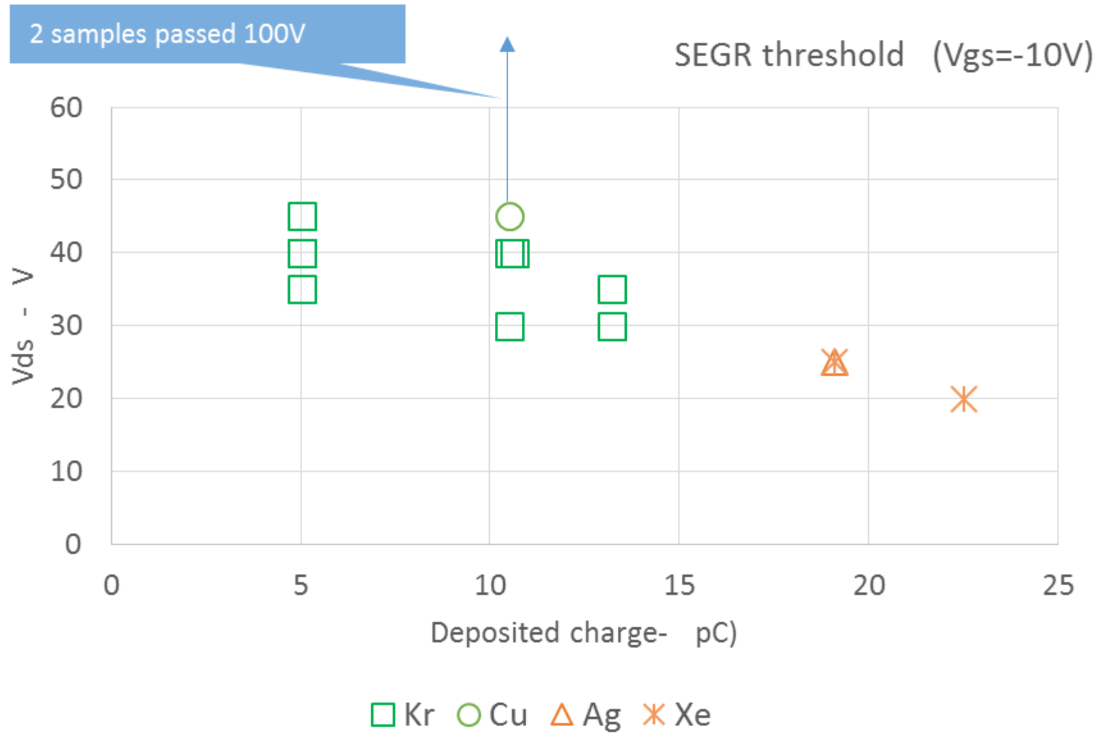

Figure 11 – SEGR threshold for the 4 ions selected as a function of deposited charge

All SGRs were true SEGR but one. For y13w35 run035 dutB, a small step current occurred at exposure start and device was destroyed during post gate stress test, see Figure 12 below.

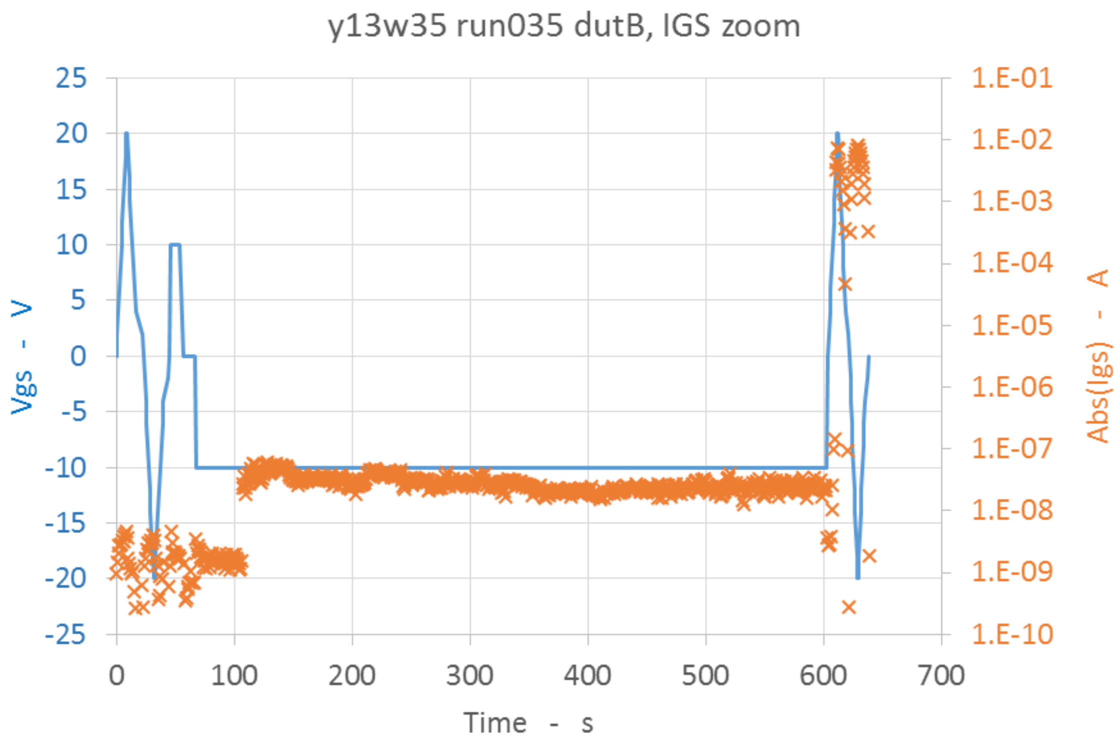

Figure 12 – device failure during post gate stress test (y13w35 run035 dutB)

Ion group	Ion	Q (pC)	Ion, LET	Test slot	SEGR
Group1	Kr high	5.015	Kr, 14.6	y13w35	samples passed Vgs=-0V and Vds=30-40V 6 samples failed Vgs=-10V and Vds=35-40V
				y14w26	1 sample out of 2 failed (SEGR) at Vgs=-10V and Vds=45V
	Kr	10.5	Kr, 29.3	y13w35	1 sample failed (SEGR) at Vgs=-10V and Vds=30V 2 samples failed (SEGR) at Vgs=-10V and Vds=40V
	Kr_wc	13.2	Kr, 40.4	y13w35	SEGR on the 2 DUTs, Vgs=-10V, Vds=40V
			Kr, 37.2	y13w35	SEGR on the 2 DUTs, Vgs=-10V, Vds=30-35V
	Cu	10.5	Cu, 27.6	y13w35	Vgs=-10V, 1 SEGR at Vds=45V out of 2 samples Vgs=-10V, 1 second SEGR at Vds=55V but on 1 sample out of 2 that passed Vds=100V
				y14w26	4 samples passed Vgs=0V and Vds=100V
Group2	Ag	19.1	Ag, 51.1	y13w35	2 samples failed (SEGR) at Vgs=-10V and Vds=25V
	Xe	19.1	Xe, 50.8	y13w35	2 samples failed (SEGR) at Vgs=-10V and Vds=25V
	Xe_wc	22.5	Xe, 59.5	y13w35	2 samples failed (SEGR) at Vgs=-10V and Vds=20V

Table 3 – Summary of SEGR results for the different ions and energies.

test campaign	medium	run_number	Facility_run_number	board_name	dut_part_id	Selected_beam	Ion	LET	roll	tilt	Al_thickness(mil)	Number_of_layers(file)	Beam_energy(MeV)	Eff._LET(MeVcm2/mg)	Eff._range(um)	Eff._fluence(ions/cm2)	Dose(rad)	run_duration live_time	Aver._flux(ions/(cm2s))	VgsA	vdsA	dutA	SEGR	VgsB	vdsB	dutB	SEGR	comment
y13w35	air	29	52		1, 2	15	Kr		0	0	3.572	4(1)	239	40.4	30.8	8630	5.59	25.2333	342	-10	40	0	1	-10	40	0	1	
y13w35	air	30	53		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	300000	179	786.65	381	-10	10	0	√	-10	10	0	√	
y13w35	air	31	54		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	300000	179	577.433	519	-10	15	0	√	-10	15	0	√	
y13w35	air	32	55		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	300000	179	580.967	517	-10	20	0	√	-10	20	0	√	
y13w35	air	33	56		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	300000	179	610.383	492	-10	25	0	√	-10	25	0	√	
y13w35	air	34	57		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	300000	179	614.45	488	-10	30	0	√	-10	30	0	1	
y13w35	air	35	58		3, 4	15	Kr		0	0	2.938	4(1)	406	37.2	49.3	71800	42.8	153.75	467	-10	35	0	1	-10	35	0		dutB dead previous run
y13w35	air	36	59		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	774.967	387	-10	20	0	√	-10	20	0	√	
y13w35	air	37	61		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	1166.17	257	-10	25	0	√	-10	25	0	√	
y13w35	air	38	62		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	1271.42	236	-10	30	0	√	-10	30	0	√	
y13w35	air	39	63		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	546.65	549	-10	35	0	√	-10	35	0	√	
y13w35	air	40	64		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	484.483	619	-10	40	0	√	-10	40	0	√	
y13w35	air	41	65		5, 6	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	486.817	616	-10	45	0	√	-10	45	0	1	
y13w35	air	42	66		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	450.033	667	-10	50	0	√	-10	50	0	√	
y13w35	air	43	67		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	372.6	805	-10	55	0	√	-10	55	0	√	
y13w35	air	44	68		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	406.933	737	-10	60	0	√	-10	60	0	√	
y13w35	air	45	69		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	397.983	754	-10	65	0	√	-10	65	0	√	
y13w35	air	46	70		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	426.333	703	-10	70	0	√	-10	70	0	√	
y13w35	air	47	71		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	397.95	754	-10	75	0	√	-10	75	0	√	
y13w35	air	48	72		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	345.9	867	-10	80	0	√	-10	80	0	√	
y13w35	air	49	74		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	382.283	784	-10	90	0	√	-10	90	0	√	
y13w35	air	50	75		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	299000	132	398.583	750	-10	100	0	√	-10	100	0	√	
y13w35	air	51	76		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	435.65	689	-10	50	0	√	-10	50	0	√	
y13w35	air	52	77		7, 8	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	447.467	670	-10	55	0	√	-10	55	0	1	
y13w35	air	53	78		9, 10	15	Cu		0	0	3.052	4(1)	318	27.6	47.6	300000	133	460.533	652	-10	55	0	1	-10	55	0	√	
y13w35	air	54	79		11, 12	15	Ag		0	0	2.248	4(1)	592	51.1	54.3	300000	246	495.633	606	-10	10	0	√	-10	10	0	√	
y13w35	air	55	80		11, 12	15	Ag		0	0	2.248	4(1)	592	51.1	54.3	300000	246	499.783	600	-10	15	0	√	-10	15	0	√	

test campaign	medium	run_number	Facility_run_number	board_name	dut_part_id	Selected_beam	Ion	LET	roll	tilt	Al_thickness(mil)	Number_of_layers(file)	Beam_energy(MeV)	Eff._LET(MeVcm2/mg)	Eff._range(um)	Eff._fluence(ions/cm2)	Dose(rad)	run_duration live_time	Aver._flux(ions/(cm2s))	VgsA	vdsA	dutA	SEGR	VgsB	vdsB	dutB	SEGR	comment
y13w35	air	56	81		11, 12	15	Ag		0	0	2.248	4(1)	592	51.1	54.3	300000	245	689.8	435	-10	20	0	√	-10	20	0	√	
y13w35	air	57	82		11, 12	15	Ag		0	0	2.248	4(1)	592	51.1	54.3	23200	18.9	58.6333	395	-10	25	0	1	-10	25	0	1	
y13w35	air	58	83		13, 14	15	Xe		0	0	1.979	4(1)	777	59.5	62.4	300000	286	534.383	562	-10	10	0	√	-10	10	0	√	
y13w35	air	59	84		13, 14	15	Xe		0	0	1.979	4(1)	777	59.5	62.4	300000	286	514.267	583	-10	15	0	√	-10	15	0	√	
y13w35	air	60	85		13, 14	15	Xe		0	0	1.979	4(1)	777	59.5	62.4	40500	38.6	69.5667	582	-10	20	0	1	-10	20	0	1	
y13w35	air	61	86		18, 19	25	Kr		0	0	6.305	4(1)	914	29.3	116.2	300000	141	630.4	476	-10	20	0	√	-10	20	0	√	
y13w35	air	62	87		18, 19	25	Kr		0	0	6.305	4(1)	914	29.3	116.2	300000	141	598.85	501	-10	30	0	√	-10	30	0	1	
y13w35	air	63	88		20, 21	25	Kr		0	0	6.305	4(1)	914	29.3	116.2	300000	141	669.55	448	-10	30	0	√	-10	30	0	√	
y13w35	air	64	89		20, 21	25	Kr		0	0	6.305	4(1)	914	29.3	116.2	300000	141	684.533	438	-10	35	0	√	-10	35	0	√	
y13w35	air	65	90		20, 21	25	Kr		0	0	6.305	4(1)	914	29.3	116.2	264000	124	588.5	449	-10	40	0	1	-10	40	0	1	
y13w35	air	67	92		22, 23	25	Xe		0	0	4.334	4(1)	1581	50.8	125.5	300000	244	684.45	439	-10	10	0	√	-10	10	0	√	dutB correctly biased?
y13w35	air	68	93		22, 23	25	Xe		0	0	4.334	4(1)	1581	50.8	125.5	300000	244	858.617	350	-10	10	0	√	-10	10	0	√	
y13w35	air	69	94		22, 23	25	Xe		0	0	4.334	4(1)	1581	50.8	125.5	300000	244	711.467	422	-10	15	0	√	-10	15	0	√	
y13w35	air	70	95		22, 23	25	Xe		0	0	4.334	4(1)	1581	50.8	125.5	300000	244	493.367	609	-10	20	0	√	-10	20	0	√	
y13w35	air	71	96		22, 23	25	Xe		0	0	4.334	4(1)	1581	50.8	125.5	76100	61.9	130.167	585	-10	25	0	1	-10	25	0	1	
y13w35	air	124	136		24, 25	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.2	689.45	435	0	30	0	√	0	30	0	√	charge amplifier
y13w35	air	125	137		24, 25	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.3	702.267	427	-10	35	0	√	-10	35	0	1	charge amplifier
y13w35	air	126	138		26, 27	40	Kr		0	0	0	4(1)	2996	14.6	584.6	108000	25.3	283.717	380	-10	40	0	1	-10	40	0	1	charge amplifier
y13w35	air	127	139		28, 29	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.3	625.917	479	0	30	0	√	0	30	0	√	charge amplifier
y13w35	air	128	140		28, 29	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.2	650.6	461	0	40	0	√	0	40	0	√	charge amplifier
y13w35	air	129	141		28, 29	40	Kr		0	0	0	4(1)	2996	14.6	584.6	118000	27.7	270.417	437	-10	40	0	1	-10	40	0	1	charge amplifier
y13w35	air	131	142		15, 16	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.2	589.783	508	-	-	-	-	0	30	0	√	charge amplifier
y13w35	air	132	143		15, 16	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.2	619.05	484	-	-	-	-	-10	40	0	√	charge amplifier
y13w35	air	133	144		17, -	40	Kr		0	0	0	4(1)	2996	14.6	584.6	300000	70.2	511.633	586	0	30	0	√	-	-	-	-	charge amplifier
y13w35	air	134	145		17, -	40	Kr		0	0	0	4(1)	2996	14.6	584.6	292000	68.5	433.05	675	-10	40	0	1	-	-	-	-	charge amplifier
y14w26	air	37	34	A	A&B	40	Kr		0	0	0	6(2)	2997	14.6	584.8	300000	70.2	542.633	552	-10	35	0	√	-10	35	0	√	
y14w26	air	38	35	A	A&B	40	Kr		0	0	0	6(2)	2997	14.6	584.8	300000	70.2	573.633	523	-10	40	0	√	-10	40	0	√	

test campaign	medium	run_number	Facility_run_number	board_name	dut_part_id	Selected_beam	Ion	LET	roll	tilt	Al_thickness(mil)	Number_of_layers(file)	Beam_energy(MeV)	Eff._LET(MeVcm2/mg)	Eff._range(um)	Eff._fluence(ions/cm2)	Dose(rad)	run_duration live_time	Aver._flux(ions/(cm2s))	VgsA	vdsA	dutA	SEGR	VgsB	vdsB	dutB	SEGR	comment
y14w26	air	39	36	A	A&B	40	Kr		0	0	0	6(2)	2997	14.6	584.8	355000	83	671.65	528	-10	45	0	1	-10	45	0	√	
y14w26	air	114	105	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	263.983	1140	0	40	0	√	0	40	0	√	
y14w26	air	115	106	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	273.5	1100	0	45	0	√	0	45	0	√	
y14w26	air	116	107	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	301000	133	294.967	1020	0	50	0	√	0	50	0	√	
y14w26	air	117	108	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	311.733	961	0	55	0	√	0	55	0	√	
y14w26	air	118	109	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	315.717	950	0	60	0	√	0	60	0	√	
y14w26	air	119	110	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	316.317	949	0	65	0	√	0	65	0	√	
y14w26	air	120	111	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	301000	133	331.167	907	0	70	0	√	0	70	0	√	
y14w26	air	121	112	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	278.35	1080	0	75	0	√	0	75	0	√	
y14w26	air	122	113	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	333.983	900	0	80	0	√	0	80	0	√	
y14w26	air	123	114	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	371.317	808	0	85	0	√	0	85	0	√	
y14w26	air	124	115	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	369.683	812	0	90	0	√	0	90	0	√	
y14w26	air	125	116	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	370.517	810	0	95	0	√	0	95	0	√	
y14w26	air	126	117	E	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	374.533	801	0	100	0	√	0	100	0	√	
y14w26	air	127	118	F	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	374.133	803	0	100	0	√	-	-	-	-	
y14w26	air	128	119	F	A&B	15	Cu		0	0	3.058	6(2)	318	27.7	47.6	300000	133	389.517	770	-	-	-	-	0	100	0	√	

Table 4 – REF, August 2013 (y13w35) and June 2014 (y14w26), STRH100N10, run table