PROTONS SINGLE EVENT TRANSIENTS TEST REPORT

Optocouplers
66193-002 from MICROPAC
OLH7000.001 from ISOLINK
HCPL5431 from AVAGO

TRAD/TP/66193/1120/ESA/PG/1115		Labège, july 23th, 2012
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Issue : 1		
To: Marc POIZAT	Project/Program:	ESA Contract N°4000102571/10/NL/AF-Radiation Characterization of Laplace RH optocouplers, sensors and detectors

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1 INTRODUCTION

This report includes test results of 66193-002 Single Channel Optocoupler from MICROPAC, OLH7000.0010 Hermetic Linear Optocoupler from ISOLINK and HCPL5431 Hermetically Sealed Very High Speed Logic Gate Optocoupler from AVAGO. On January, week 4, 2012, proton induced SET sensitivity of these components was evaluated at the PSI Facility (SWITZERLAND) using their PIF Beam line.
The objective of the test was to detect and characterize the SET sensitivity of these components and the waveform characteristics of the transients (duration, amplitude, polarity) as a function of proton energy.

2 DOCUMENTS

2.1 Applicable Documents

AD	1.	ESA contract	N°4000102571/10/NL/AF-Radiation Characterization of Laplace RH optocouplers, sensors and detectors
AD	2.	Irradiation Test Plan	TRAD_ ITP_TIP_66193_MIC_1124 rev.1, Iss.1, 16/06/11
AD	3.		TRAD_ ITP_TIP_OLH7000_ISO_0721 rev.1, Iss.1, 23/06/11
AD	4.		TRAD_ ITP_TIP_HCPL5431_AVA_1124 rev.1, Iss.1, 16/06/11

2.2 Reference Documents

RD	1.	Datasheet 66193	SINGLE CHANNEL OPTOCOUPLER (Replacement 3C91C) dated 11/01/2008
RD	2.	Datasheet OLH7000	Hermetic Linear Optocoupleur
RD	3.	Datasheet HCPL5431	21/06/2007
RD	4.	Manufacturer's certificate of traceability and conformance dated 25/07/2011	
RD	5.	Manufacturer's certificate of traceability and conformance of 66193 dated 25/07/2011	
RD	6.	Manufacturer's certificate of traceability and conformance of OLH7000 dated 25/07/2011	
RD	7.	Manufacturer's certificate of traceability and conformance of HCPL5431 dated 25/07/2011	
RD	8.	ESCC_25100_ Iss1 October2002_Single events method test and guidelines	

3 DEVICES INFORMATION

3.1 66193 from MICROPAC

3.1.1 Device description

The 66193-002 device is a proton radiation tolerant single channel optocoupler (replacement for 3C91C optocoupler). It contains a proton tolerant 660nm GaAlAs LED optically coupled to a silicon planar phototransistor. It is hermetically sealed in a TO46 metallic package. The internal base connection has been eliminated for improved noise immunity.

Type	66193
Manufacturer	MICROPAC
Function	Optocoupler
Package	TO-46
Date Code	1120
Sample size	4 parts (3 parts + 1 part already tested under neutron irradiation)

3.1.2 Procurement information

75 parts reference 66193 were procured by TRAD and delivered by MICROPAC through its French distributor ISOTOPE ELECTRONICS.
Their quality level defined by the 002 extension number corresponds to a commercial standard operating in the temperature range of -55° to +100°C and temperature tested (hot & cold temperature) by the manufacturer prior to delivery.

3.1.3 External view

Figure 1: package marking

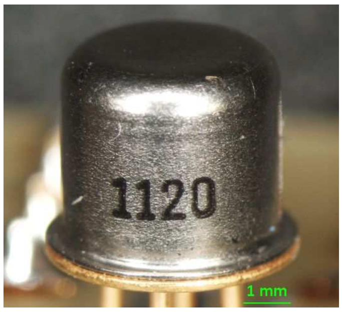

Figure 2: package marking - date code

3.1.4 Internal view

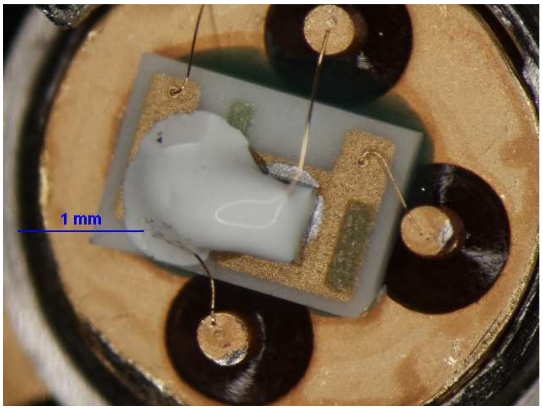

Figure 3: Internal view

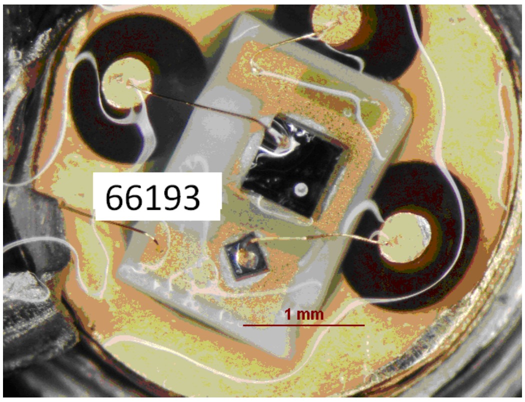

Figure 4: Internal view without potting

3.1.5 Serialization

Each part is serialized to enable pre and post test identification.

	Test samples			
	New Parts			Neutron irradiated Part
Serial Number	1	2	3	2N

The 2N device had been previously subjected to a steady state displacement damage test campaign, using 1MeV neutrons up to a total fluence of 7e12/cm2.

3.2 OLH7000.0010 from ISOLINK

3.2.1 Device description

The OLH7000 is a hermetic linear Optocoupler which consists of two LED in series coupled to two PIN photodiode detectors. The photodiode on the input side acts as a feedback device permitting an external feedback loop to ensure constant LED light output. A similar matching photodiode on the output side is used to drive an output circuit that is electrically isolated from the input. A fixed relationship is thus maintained between input and output. This technique compensates for the LED's nonlinear time and temperature characteristics. Each OLH7000 is mounted and coupled in a hermetic 8-pin ceramic DIP providing 1000 Vdc electrical isolation between input and output.

The OLH7000.0010 is different from the standard OLH7000. As the standard OLH7000's LED cannot withstand displacement damage radiation, the OLH7000.0010 (570587-1) uses a different LED that is more displacement damage tolerant. This LED has higher light output and thus higher Ip1 and Ip2.

Type	OLH7000.0010
Manufacturer	ISOLINK
Function	Hermetic Linear Optocoupler
Package	DIP8
Date Code	0721
Sample size	4 parts (3 parts + 1 parts already tested under neutron irradiation)

3.2.2 Procurement information

75 parts OLH7000-001 were delivered by ISOLINK through the French representative EUROMIP.

Figure 5: package marking

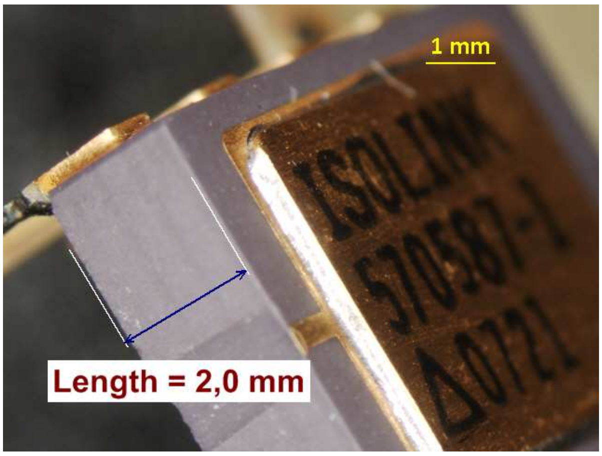

Figure 6: package view

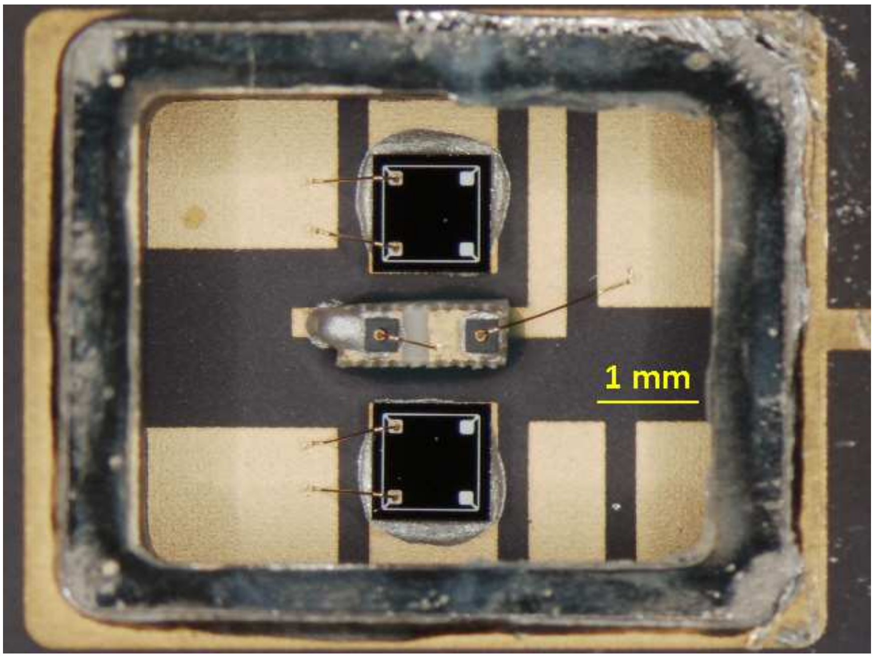

Figure 7: Internal overall view

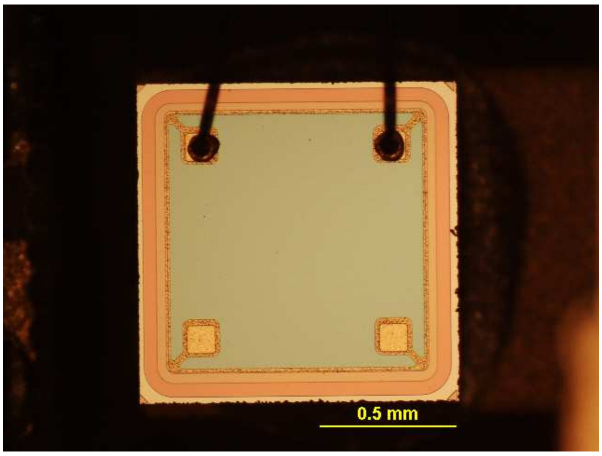

Figure 8: view of photodiode detector

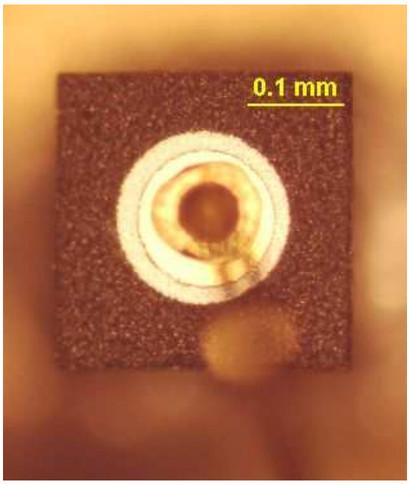

Figure 9: view of LED

3.2.3 Serialization

Each part is serialized to enable pre and post test identification.

	Test samples			
	New Parts			Neutron irradiated Part
Serial Number	1	2	3	2N

The 2N device had been previously subjected to a steady state displacement damage test campaign, using 1MeV neutrons up to a total fluence of 7e12/cm2.

3.2.4 Device description

The HCPL5431 is a hermetically sealed, Very High Speed Logic Gate optocoupler.
It is a two channel optocoupler with an AlGaAs light emitting diode coupled to an integrated high gain photon detector.

Type	HCPL5431
Manufacturer	AVAGO
Function	Hermetically Sealed, Very High Speed, Logic Gate Optocouplers
Packaging :	DIP8
Date Code :	1116
N° Lot :	HS111511
N° LPN :	DS10742242
Sample size	4 parts (3 parts + 1 part already tested under neutron irradiation)

3.3 Procurement information

75 parts HCPL5431 were procured from AVAGO (through ACAL BFI, Germany) with full MIL-PRF-38534 Class Level H testing. Parts were delivered with a certificate of conformance [RD2].
The class H is identifiable by the 1 digit at the end of each reference.

3.4 External view

Figure 10: package marking

Figure 11: back package marking

3.5 Internal view

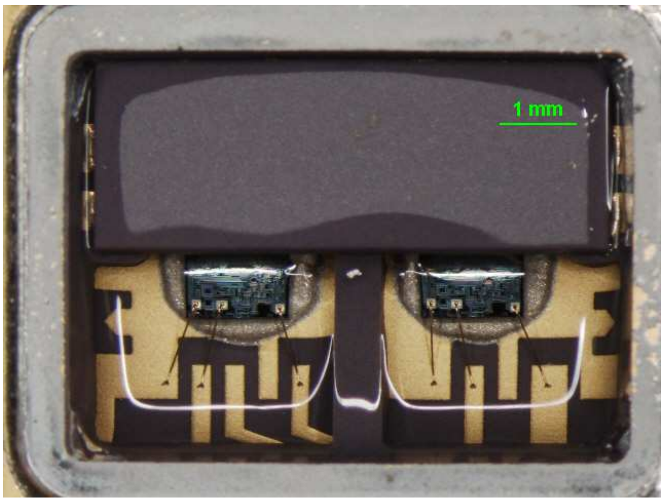

Figure 12: internal general view

Figure 13: AlGaAs light emitting diode

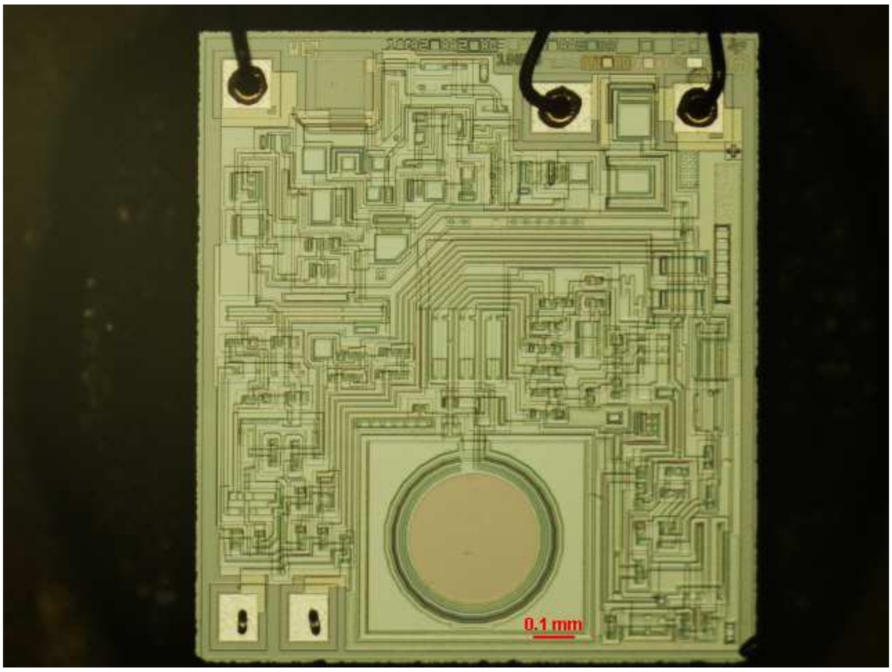

Figure 14: high gain photon detector

3.6 Serialization

Each part is serialized to enable pre and post test identification.

	Test samples			
	New Parts			Neutron irradiated Part
Serial Number	1	2	3	2N

The 2N device had been previously subjected to a steady state displacement damage test campaign, using 1MeV neutrons up to a total fluence of 7e12/cm2.

4 IRRADIATION MEANS AND CONDITIONS

4.1 Proton Irradiation Facility, PIF (SWITZERLAND)

The initial proton beam for PIF is delivered from the PROSCAN accelerator with the help of the primary energy degrader, which allows setting the initial beam energy from 250 MeV down to 30MeV.
The maximum flux at 254 MeV with 10 mA split beam (focused beam) is 2.5E8 protons/sec/cm2.
The PIF experimental set-up consists of the local PIF energy degrader, beam collimating and monitoring devices. Movable XY table with the sample holder enables easy mounting of the user's device under test (DUT) on the beam. This sample mounting frame is 25 x 25 cm2 area. A laser mounted downstream from the XY table allows centering the DUT and controlling its position.
Moreover the maximum diameter of the irradiated area is 9 cm. The beam profiles are either flat or Gaussian-form with minimum FWHM=6 cm.

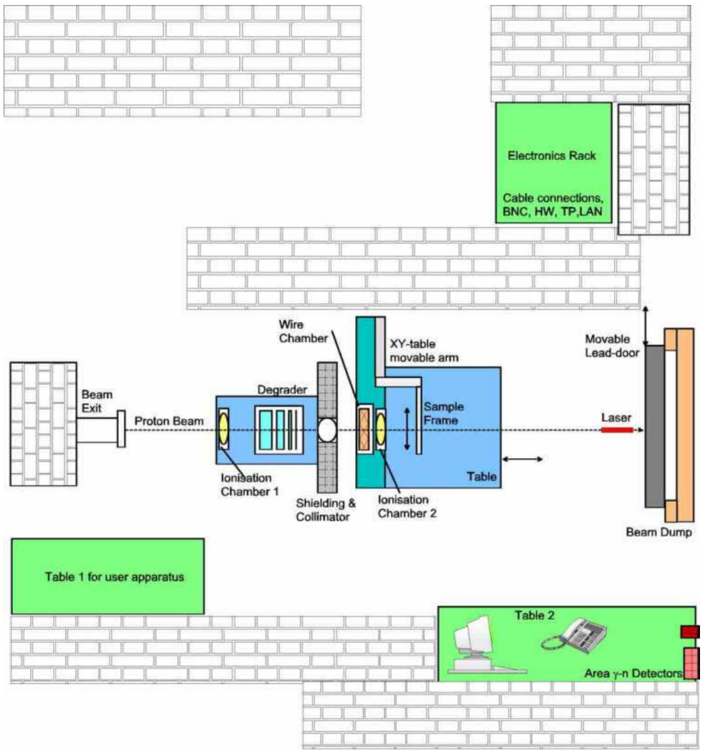

Figure 15: PIF-NA3 Experimental site

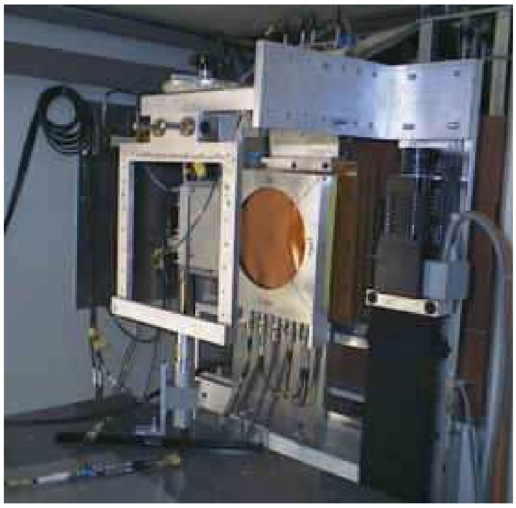

Figure 16: view of the XY-table with movable arm and sample holder

4.2 Dosimetry

Depending on the experiment conducted and the user's requirements, the monitor detectors are selected for each experiment individually: ionization chambers, Si-detectors, plastic scintillators.
The accuracy of the flux and dose determination is 5% and neutron background is less than 10^{-4} neutrons/proton/cm2.

4.3 Experimental conditions

The parts were tested at normal incidence.
An Equivalent total fluence of 5e10 proton/cm² of 230 MeV protons is applied.
Fluxes used range from 1e4 to 1e8 protons/sec/cm^2 depending on device sensitivity.

5 TESTS PROCEDURE

5.1 Description of the test method

Runs are performed up to a total fluence to 5 e10 protons/cm^2 for the SET detection.
A device is considered as insensitive at a given energy if no SET is detected up to a fluence of 5E+10.
If the component is insensitive at a given energy, then the test is carried out until 100SETs are detected or when a fluence of 5e10 is reached, whichever comes first.
For each device, the test starts at the highest energy specified in the test plan
If SETs are detected at the highest energy, additional tests are performed with decreasing energies beam down to the energy threshold.

5.2 SET Test description

Single Event Transient is an event described by a voltage amplitude and a timing parameter.
SET can be positive or negative as shown in Figure 17.
To detect these events, the output voltage component is monitored.
Two trigger thresholds (positive and negative) are used to detect the amplitude voltage due to SET.
An SET is detected when the output device voltage becomes higher or lower than the positive trigger threshold or the negative trigger threshold respectively. During the test, the oscilloscope internal counter is incremented at each detected SET and the waveform of each transient is stored.

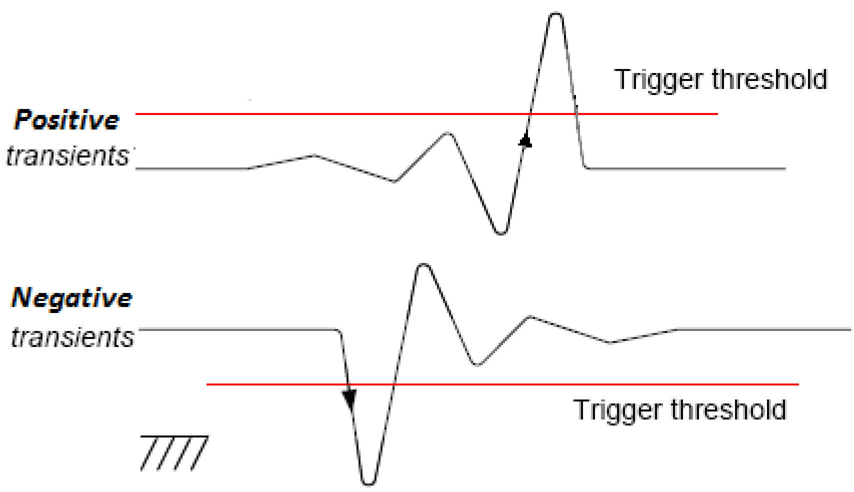

Figure 17 : positive and negative SET detection

5.3 Test set-up

Each SET is detected and stored using an oscilloscope with an adapted bandwidth. The trigger is done on the falling edge or the rising edge to ensure that the whole transient is recorded. the overall event with a correct time base. Some trials were performed to adjust the time base of oscilloscope.

All shape events are recorded on a scope during runs and then transferred to a PC for storage.

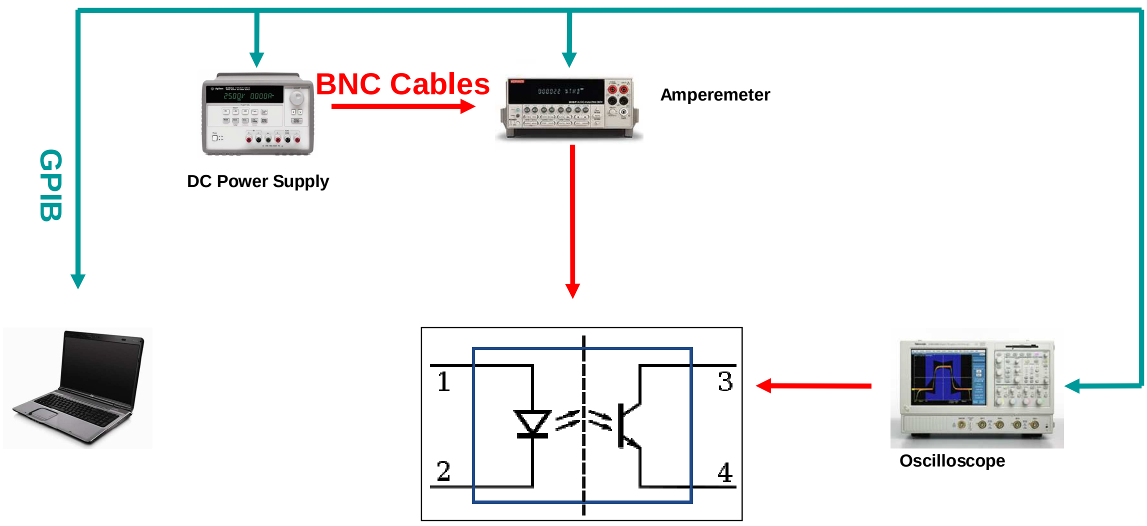

Figure 18: test set-up

5.4 Test configuration

5.4.1 66193 SET test configuration

TEST BOARD	TRAD/CT1/P/66193/ZIP14/BR/1201
TEST PROGRAM	66193_TP_XXX1_BP_V10.spf

As shown in Figure 19, the input diode is connected to ground to have a high level on the output.

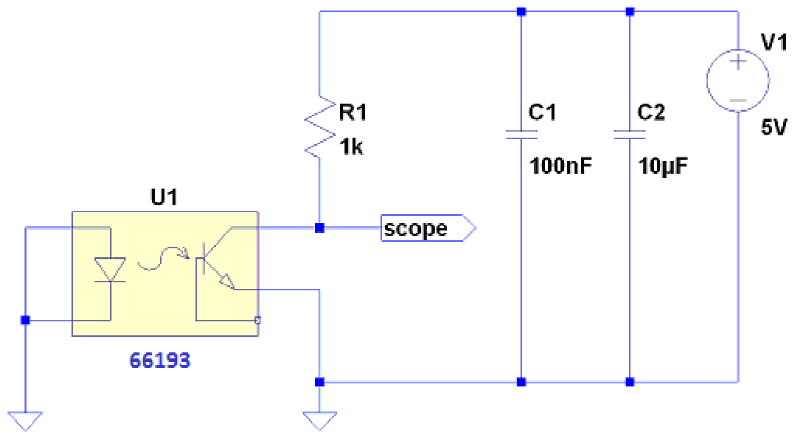

Figure 19 : 66193 test polarization configuration

Trigger thresholds for SET test are defined in the following table:

VCC	4.97V
Positive Trigger threshold	5V
Negative Trigger threshold	4.95V

5.4.2 OHL7000.0010 SET test configuration

TEST BOARD	TRAD/CT1/P/OLH7000/ZIP14/BR/1201
TEST PROGRAM	OLH7000_TP_XXX1_BP_V10.spf

As shown in Figure 20, the input LED and the feedback photodiode are connected to ground to have a high level on the output.

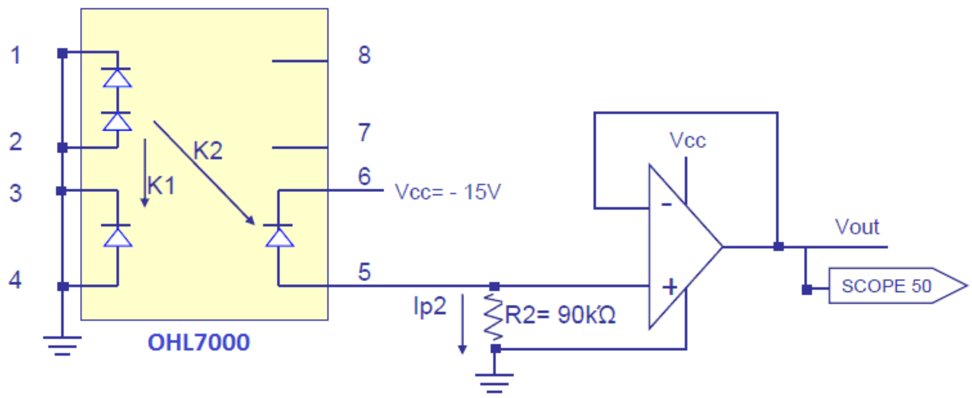

Figure 20: OHL7000 test polarization configuration

Trigger thresholds for SET test are defined in the following table:

VCC	4.97V
Positive Trigger threshold	5V
Negative Trigger threshold	4.95V

5.4.3 HCPL5431 SET test configuration

TEST BOARD	TRAD/CT1/P/HCPL5431/ZIP14/BR/1201
TEST PROGRAM	HCPL5431_TP_XXX1_BP_V10.spf

As shown in Figure 21, the input diode is connected to ground to have a high level on the output.

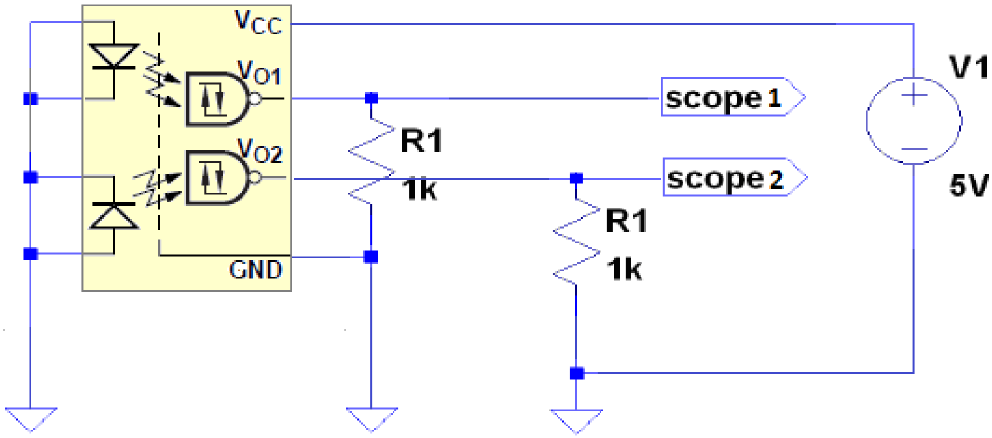

Figure 21: HCPL5431 test polarization configuration

Trigger thresholds for SET test are defined in the following table:

VCC	5.3V
VO1	3.5V
Positive Trigger threshold 1	3.7V
Negative Trigger threshold 1	3.3V
VO2	3.5V
Positive Trigger threshold 2	3.7V
Negative Trigger threshold 2	3.3V

6 TEST STORY

No incident during the test was noticed.

7 SUMMARY RESULTS

7.1 66193 SUMMARY RESULTS

No SET was observed during the proton irradiation.

7.2 OLH7000 SUMMARY RESULTS

No SET was observed during the proton irradiation.

7.3 HCPL5431 SUMMARY RESULTS

No positive SET was observed but negative SETs were observed at each energy step.
Next figure shows voltage amplitude versus time duration of all SETs observed.
As shown in Figure 22, most of SETs have time duration between 0 and 6 ns and voltage amplitude between 0.3V and 4.4V.
However, SETs occurred on Part N°1 have also time duration more important, between 7 and 15 ns, and between 30 and 55ns as shown in Figure23.

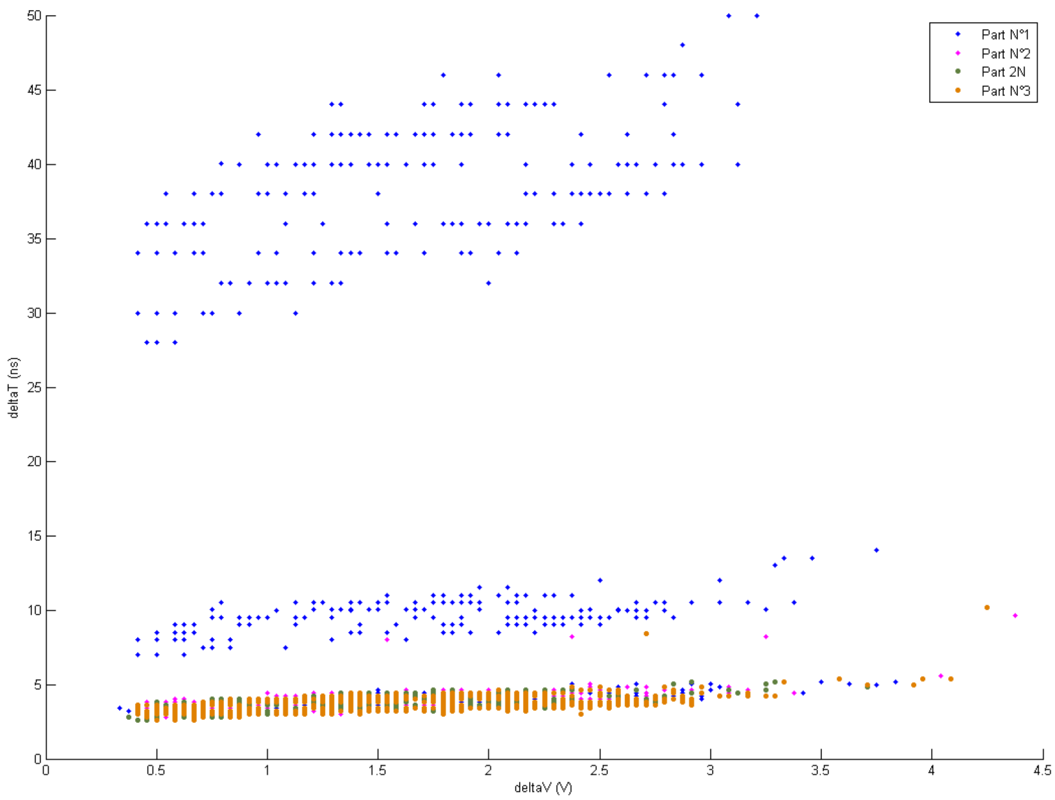

Figure 22 : SETs voltage amplitude versus time duration

The scattering of SETs time duration is explained by different time bases used during the first four runs. Run N°2 and N°3 were performed with a time base of 100ns. Run N°4 and N°5 were performed with a time base of 50ns. All following runs (N°6 to N°32) were performed with the same time base of 20ns.

Next figures show voltage amplitude versus time duration of all SETs observed without Run N°2 and N°3 (Figure 23) and without Run N°2 to N°5 (Figure 24).
As shown in Figure 24, when Runs N°2 to N°5 are not taken into account, there is no scattering in SET time duration between the four tested parts.

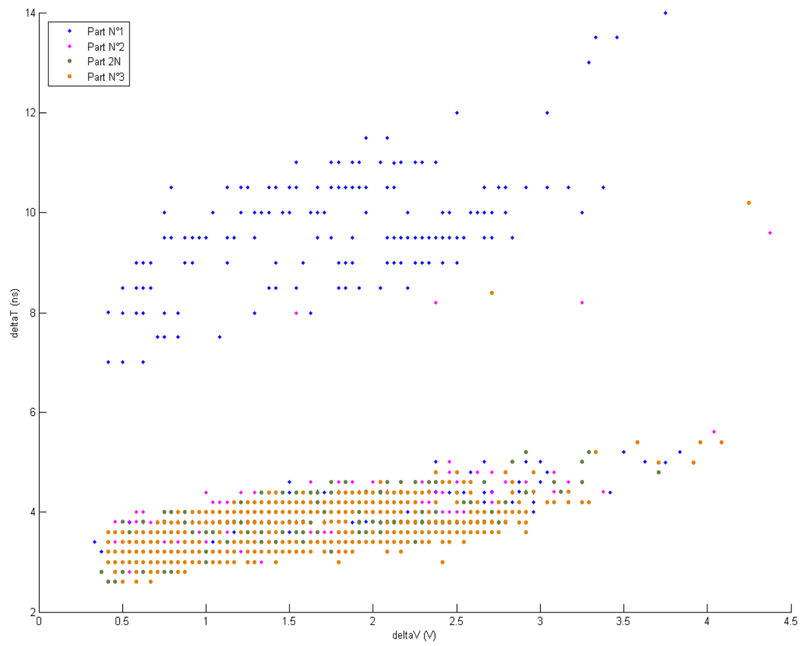

Figure 23: SETs voltage amplitude versus time duration, without Run N°2 & N°3

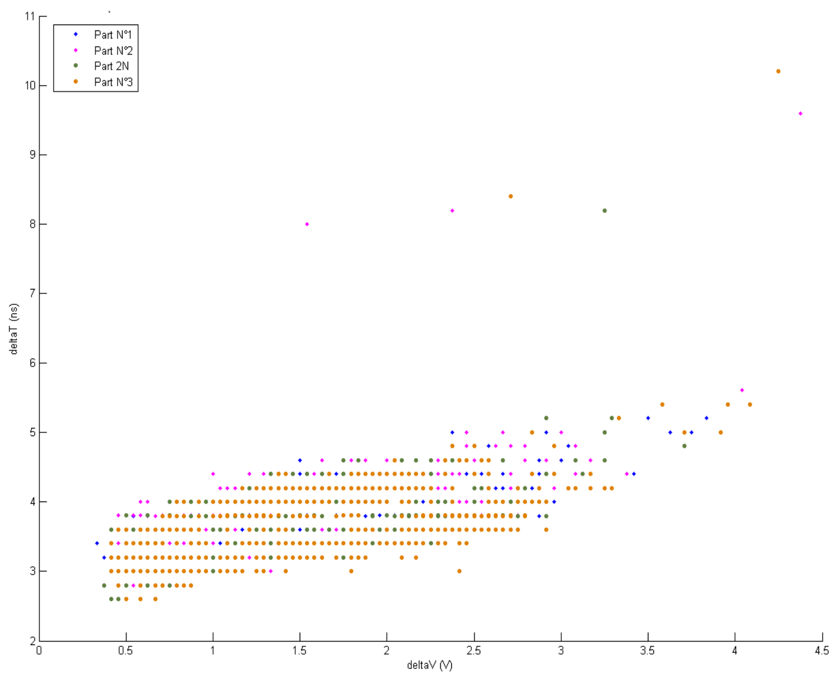

Figure 24: SETs voltage amplitude versus time duration, without Run N°2 to N°5

Runs N°6 to N°34 are then taken into account in the following charts.

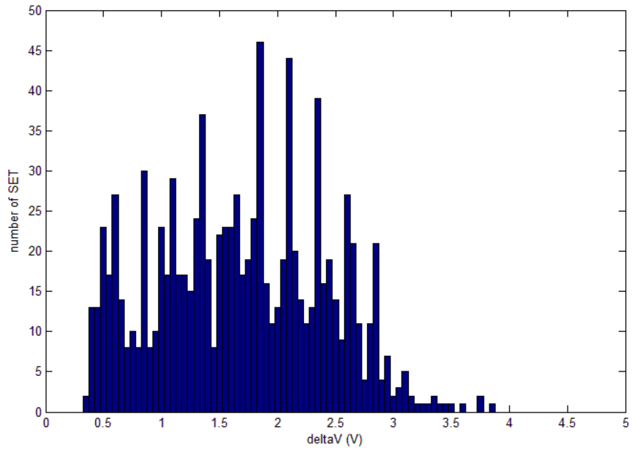

Figure 25: PART N°1
Number of SET as function of amplitude voltage

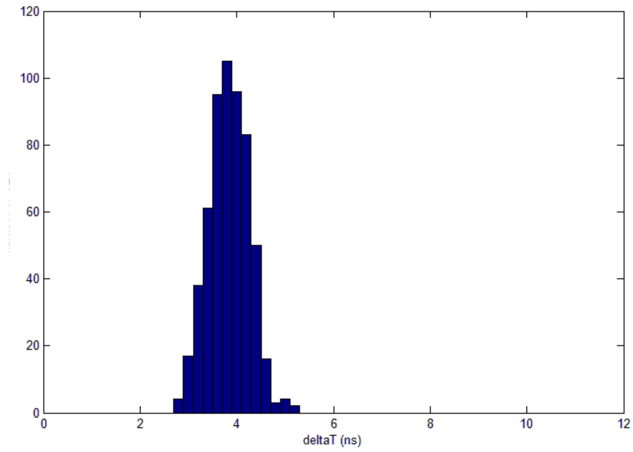

Figure 26: PART N°1
Number of SET as function of time duration

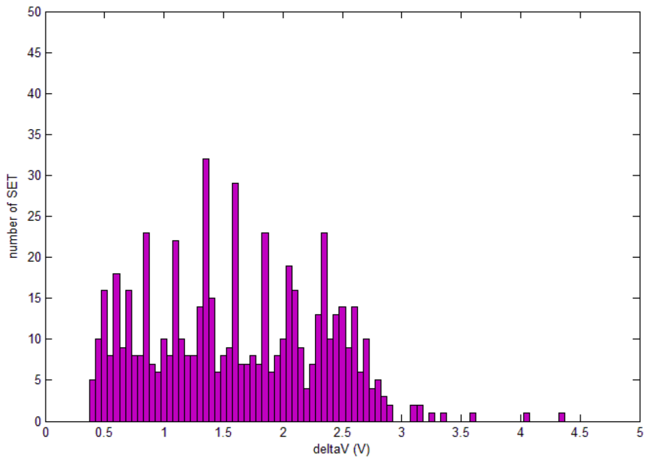

Figure 27: PART N°2
Number of SET as function of amplitude voltage

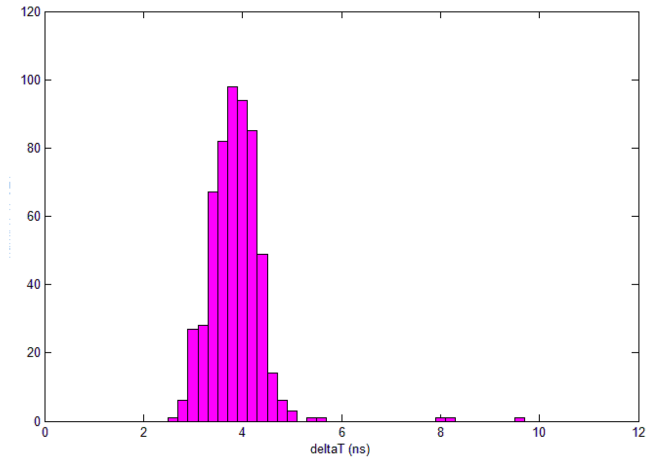

Figure 28: PART N°2
Number of SET as function of time duration

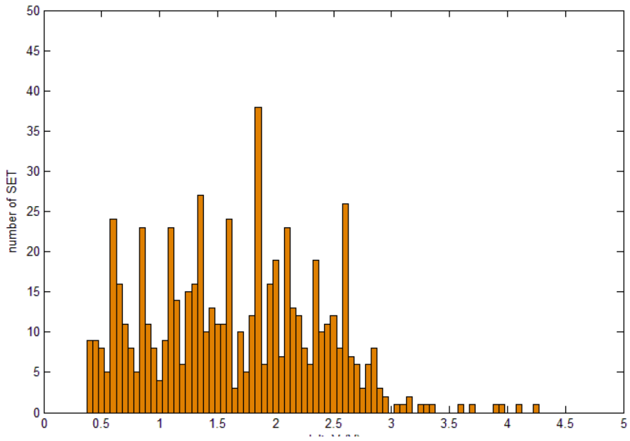

Figure 29: PART N°3
Number of SET as function of amplitude voltage

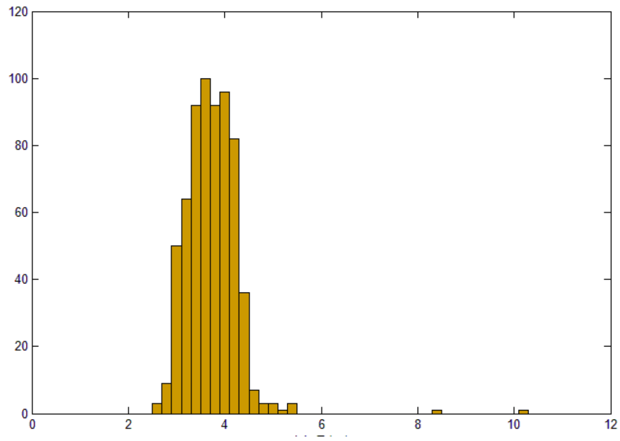

Figure 30: PART N°3
Number of SET as function of time duration

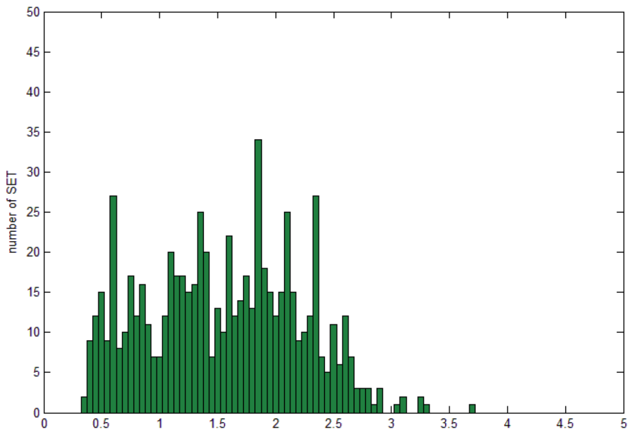

Figure 31: PART N°2N
Number of SET as function of amplitude voltage

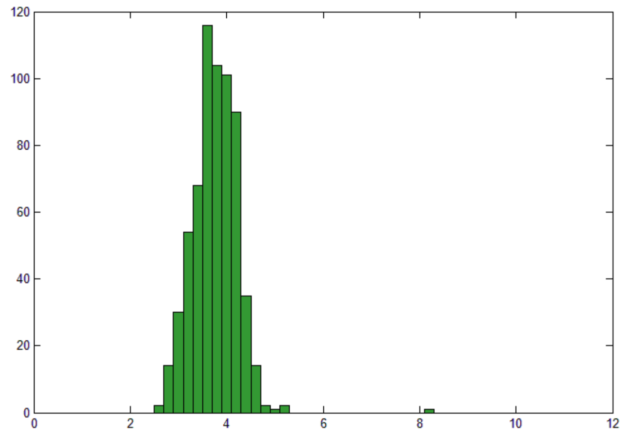

Figure 32: PART N°2N
Number of SET as function of time duration

A worst time duration case occurs on Part N°3 (step 29) with duration of 10.4ns. See figure 33.
Worst voltage amplitude case occurs on Part N°2 (step 15) with an amplitude of 4.375V as shown in figure 34.

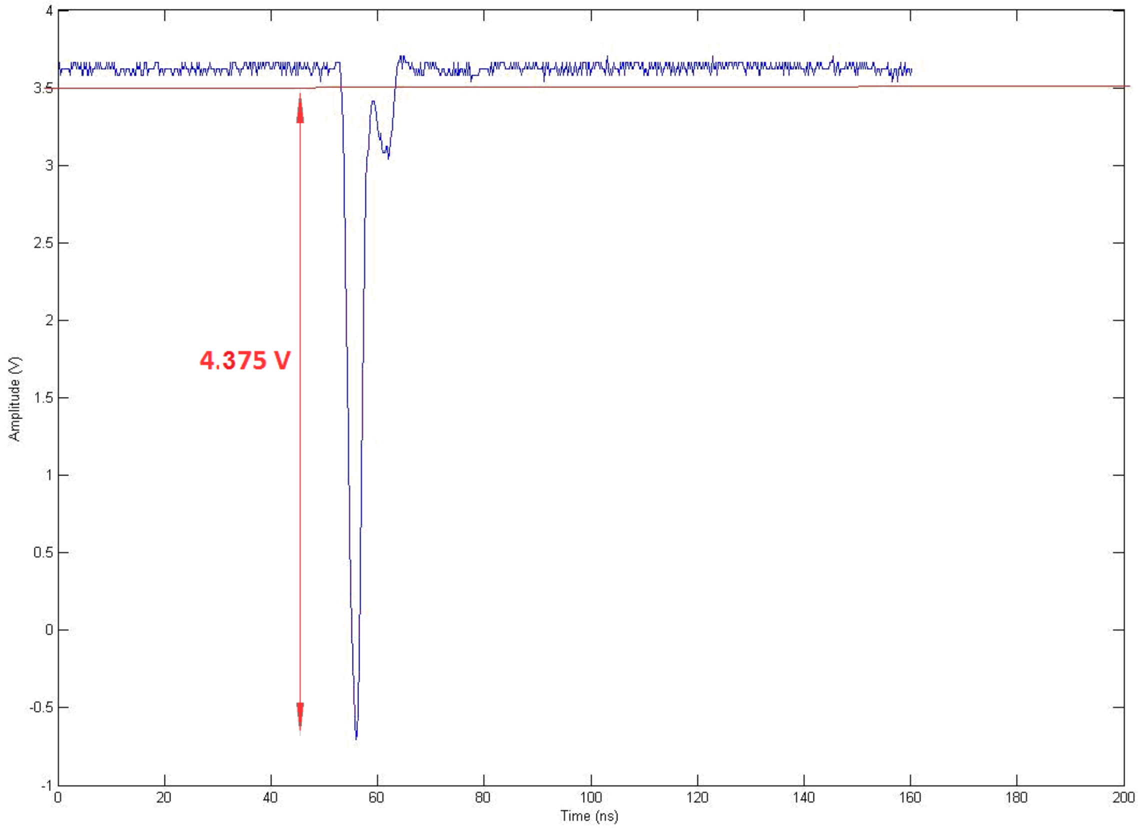

Figure 33: Worst amplitude 4.375V

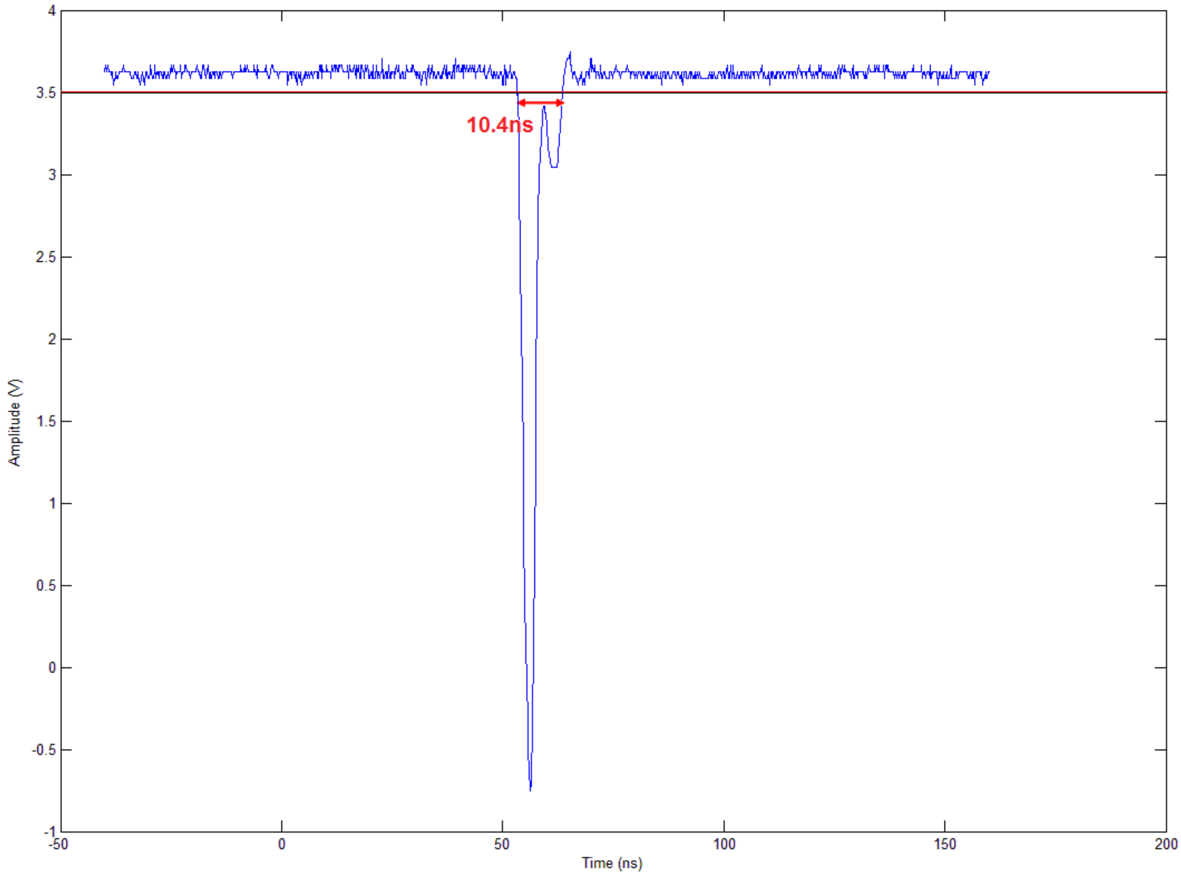

Figure 34: Worst duration 10.4ns

8 SUMMARY OF RUNS

As described in the test plans [AD2, AD3 and AD4], three proton energies were selected: 150MeV, 175MeV and 250MeV.
However because of the irradiation facilities performance, the maximum achievable energy was 230MeV instead of 250MeV.

8.1 66193 / SUMMARY of runs

Table 1: 66193 SUMMARY of runs

66193 SEE Test performed under Proton beam, PSI (2012, January).								SEE	
Run	Part	Energy (MeV)	Flux (ϕ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SET	Cross Section (cm^2/device)
1	1	230	1.010E+08	495	5.00E+10	2.685	2.685	0	<2.00E-11
2	2	230	1.014E+08	493	5.00E+10	2.668	2.668	0	<2.00E-11
3	3	230	1.014E+08	493	5.00E+10	2.670	2.670	0	<2.00E-11
4	2N	230	1.014E+08	493	5.00E+10	2.667	2.667	0	<2.00E-11

8.2 OHL7000.0010 / SUMMARY of runs

Because of the insensitivity of the first three components, the last one (N°3) was not tested.

Table 2: OHL7000.0010 SUMMARY of runs

OLH7000 SEE Test performed under Proton beam, PSI (2012, January).								SEE	
Run	Part	Energy (MeV)	Flux (ϕ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SET	Cross Section (cm^2/device)
5	1	230	1.01E+08	495	5.00E+10	2.685	2.685	0	<2.00E-11
6	2	230	1.01E+08	494	5.00E+10	2.668	2.668	0	<2.00E-11
7	2N	230	1.01E+08	494	5.00E+10	2.670	2.670	0	<2.00E-11

8.3 HCPL5431 / SUMMARY of run

Table 3: HCPL5431 SUMMARY of runs

HCPL5431 SEE Test performed under Proton beam, PSI (2012, january).												SEE		LATCHUP	
Run	Part	Energy (MeV)	Flux (ϕ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SET OUT1	Cross Section	SET OUT2	Cross Section	SET total	Cross Section	VCC	Cross Section
1	1	230	101 340 206	97	9.83E+09	0.525	0.525					1492	1.52E-07	0	<1.02E-10
2	1	230	72 666 667	12	8.72E+08	0.047	0.572	53	6.08E-08	65	7.45E-08	118	1.35E-07	0	<1.15E-09
3	1	230	17 857 143	28	5.00E+08	0.027	0.599	44	8.80E-08	36	7.20E-08	80	1.60E-07	0	<2.00E-09
4	1	230	16 666 667	30	5.00E+08	0.027	0.625	26	5.20E-08	28	5.60E-08	54	1.08E-07	0	<2.00E-09
5	1	230	17 241 379	58	1.00E+09	0.053	0.679	65	6.50E-08	60	6.00E-08	125	1.25E-07	0	<1.00E-09
6	1	176	13 888 889	72	1.00E+09	0.063	0.742								
7	1	176	24 328 358	67	1.63E+09	0.103	0.845	92	5.64E-08	107	6.56E-08	199	1.22E-07	0	<6.13E-10
8	1	139.5	11 235 955	89	1.00E+09	0.074	0.919	53	5.30E-08	68	6.80E-08	121	1.21E-07	0	<1.00E-09
9	1	101.4	9 803 922	102	1.00E+09	0.094	1.013	63	6.30E-08	70	7.00E-08	133	1.33E-07	0	<1.00E-09
10	1	50.9	7 246 377	138	1.00E+09	0.158	1.171	58	5.80E-08	63	6.30E-08	121	1.21E-07	0	<1.00E-09
11	1	29.41	12 345 679	81	1.00E+09	0.236	1.407	15	1.50E-08	13	1.30E-08	28	2.80E-08	0	<1.00E-09
12	2	230	18 518 519	27	5.00E+08	0.027	0.027	25	5.00E-08	19	3.80E-08	44	8.80E-08	0	<2.00E-09
13	2	230	18 518 519	27	5.00E+08	0.027	0.053	26	5.20E-08	32	6.40E-08	58	1.16E-07	0	<2.00E-09
14	2	176	12 987 013	77	1.00E+09	0.063	0.117	40	4.00E-08	53	5.30E-08	93	9.30E-08	0	<1.00E-09
15	2	139.5	11 363 636	88	1.00E+09	0.074	0.191	44	4.40E-08	50	5.00E-08	94	9.40E-08	0	<1.00E-09
16	2	101.4	11 111 111	90	1.00E+09	0.094	0.284	50	5.00E-08	66	6.60E-08	116	1.16E-07	0	<1.00E-09
17	2	50.9	6 944 444	144	1.00E+09	0.158	0.443	44	4.40E-08	57	5.70E-08	101	1.01E-07	0	<1.00E-09
18	2	29.41	12 345 679	81	1.00E+09	0.236	0.679	17	1.70E-08	14	1.40E-08	31	3.10E-08	0	<1.00E-09
19	2	29.41	12 500 000	80	1.00E+09	0.236	0.915	27	2.70E-08	15	1.50E-08	42	4.20E-08	0	<1.00E-09
20	2N	230	17 857 143	28	5.00E+08	0.027	0.027	22	4.40E-08	38	7.60E-08	60	1.20E-07	0	<2.00E-09
21	2N	230	17 241 379	29	5.00E+08	0.027	0.053	29	5.80E-08	40	8.00E-08	69	1.38E-07	0	<2.00E-09
22	2N	176	13 888 889	72	1.00E+09	0.063	0.117	53	5.30E-08	63	6.30E-08	116	1.16E-07	0	<1.00E-09
23	2N	139.5	11 235 955	89	1.00E+09	0.074	0.191	56	5.60E-08	52	5.20E-08	108	1.08E-07	0	<1.00E-09
24	2N	101.4	10 101 010	99	1.00E+09	0.094	0.284	55	5.50E-08	62	6.20E-08	117	1.17E-07	0	<1.00E-09

HCPL5431 SEE Test performed under Proton beam, PSI (2012, january).												SEE		LATCHUP	
Run	Part	Energy (MeV)	Flux (ϕ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	SET OUT1	Cross Section	SET OUT2	Cross Section	SET total	Cross Section	VCC	Cross Section
25	2N	50.9	7 352 941	136	1.00E+09	0.158	0.443	55	5.50E-08	67	6.70E-08	122	1.22E-07	0	<1.00E-09
26	2N	29.41	12 738 854	157	2.00E+09	0.472	0.915	43	2.15E-08	37	1.85E-08	80	4.00E-08	0	<5.00E-10
27	3	230	17 543 860	57	1.00E+09	0.053	0.053	64	6.50E-08	58	5.90E-08	122	1.23E-07	0	<1.00E-09
28	3	176	13 888 889	72	1.00E+09	0.063	0.117	55	5.50E-08	58	5.80E-08	113	1.13E-07	0	<1.00E-09
29	3	139.5	11 494 253	87	1.00E+09	0.074	0.191	45	4.50E-08	42	4.20E-08	87	8.70E-08	0	<1.00E-09
30	3	101.4	10 101 010	99	1.00E+09	0.094	0.284	58	5.80E-08	64	6.40E-08	122	1.22E-07	0	<1.00E-09
31	3	50.9	7 407 407	135	1.00E+09	0.158	0.443	50	5.00E-08	69	6.90E-08	119	1.19E-07	0	<1.00E-09
32	3	29.41	12 820 513	156	2.00E+09	0.472	0.915	33	1.65E-08	36	1.80E-08	69	3.45E-08	0	<5.00E-10

During Run N°6, no data acquisition was performed.

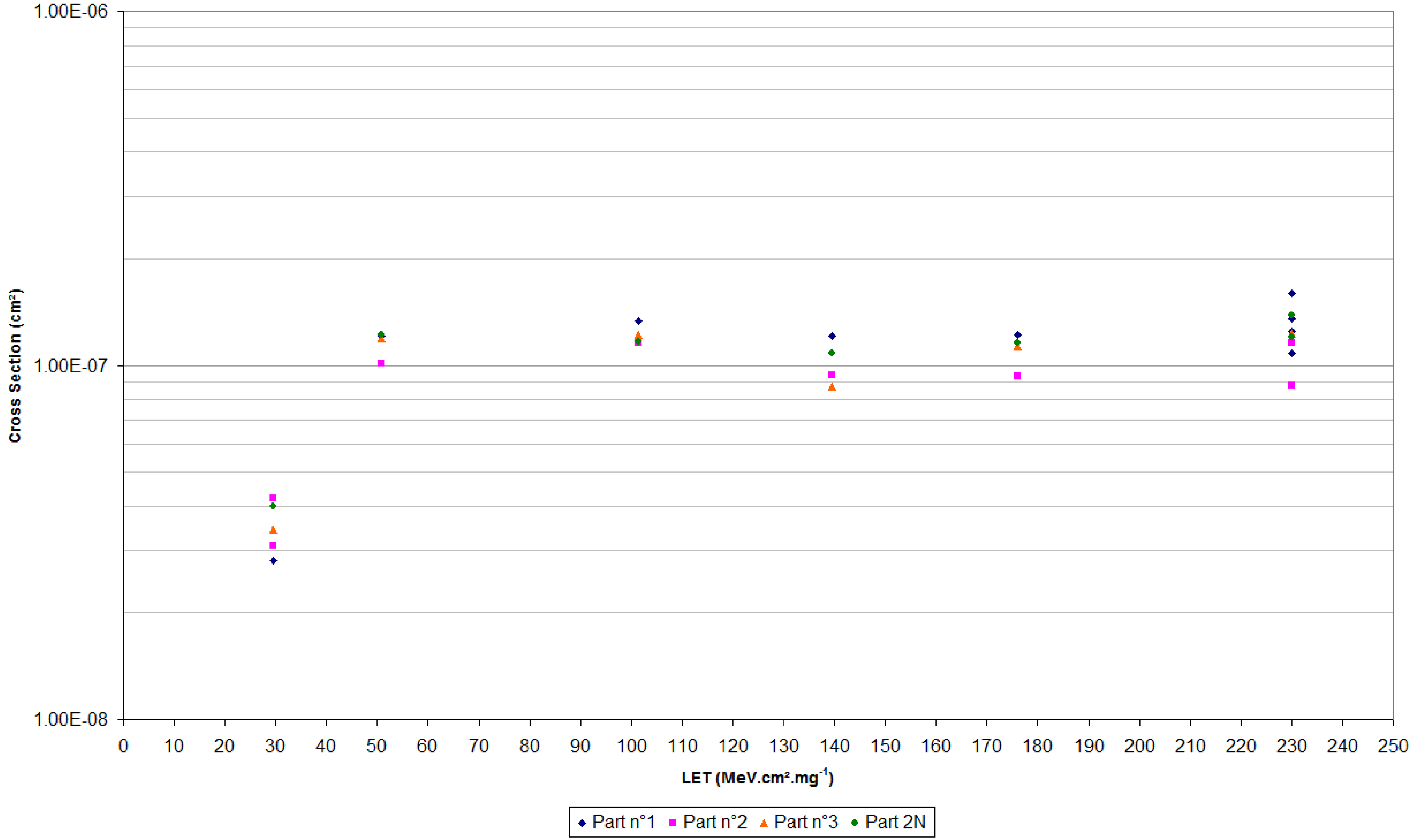

Figure 35 : HCPL5431 SET cross section

9 CONCLUSION

Four **66193-002** devices**,** Single Channel Optocouplers from **MICROPAC** were tested under proton beam up to 5E+10 protons/cm² with an energy of 230 MeV.
One of the four devices under test was previously irradiated with 1MeV neutron up to a total fluence of 7E+12neutrons/cm².
As shown in the previous Table 1, no SET was detected during test sequence even with the previously neutron irradiated part.
In conclusion, **66193-002,** Single Channel Optocoupler from **MICROPAC** can be considered insensitive to SET effect under 230MeV proton energy.
No sensitivity difference is identified between previously neutron irradiated device and new parts.

Four devices **OHL7000.0010,** a Hermetic Linear Optocoupler from **ISOLINK** were tested under proton beam up to 5E+10 protons/cm² with an energy of 230 MeV.
One of the four devices tested was previously irradiated with 1MeV neutron up to a total fluence of 7E+12neutrons/cm².
As shown in the previous Table 2, no SETs were detected in the four devices tested during proton irradiation.
In conclusion, **OHL7000.0010,** Hermetic Linear Optocoupler from **ISOLINK** is insensitive to SET effect under 230MeV proton energy.
No susceptibility difference is detected between previously neutron irradiated device and new parts.

Four devices **HCPL5431,** Hermetically Sealed Very High Speed Logic Gate Optocoupler from **AVAGO** were tested under proton beam up to 5E+10 protons/cm² with an energy of 230 MeV.
One of the four devices tested was previously irradiated with 1MeV neutron up to a total fluence of 7E+12neutrons/cm².
In conclusion, as shown in the previous Table 3 and Figure 35, for each proton energy used, negative SETs were detected during proton irradiation of the four parts.
No susceptibility difference is detected between previously neutron irradiated device and new parts.
Observed SET have:

- a duration between 2.6ns to 10.4ns
- an amplitude between 0.33V to 4.375V