EV12DS130A : 12-bit 3 Gsps MUX-DAC
Radiation test report
Infineon B7HF200

Revision date :	**07/02/2014**
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Scope :	**HI REL SEMICONDUCTOR DIVISION**

1. DOCUMENT AMENDMENT RECORD

Author	Issue	Date	Reason for change
D. BELLIN	A	06/04/2012	Creation
D. BELLIN	B	02/10/2012	Update following second proton test at UCL facility
D. BELLIN	C	07/02/2014	Chap 7.1.1 & Chap 7.1.2: Correction of an error (inversion) regarding Fclk used during the test

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2. ACRONYMS - DEFINITIONS

- SET: Single Event Transient = Single conversion errors (self recovered)
  Conversion error in only one conversion

- SEFI (recoverable with reset)
  Single Event Functional Interrupt, could be any type of event where the device "hang". One example could be an internal state machine that goes to an unknown state and the data conversion is interrupted.

- Multi conversion errors (self recovered) or long SET
  Conversion error in more than one successive conversion.

3. INTRODUCTION

This document summarizes all radiation tests performed on EV12DS130A 12-bit 3Gsps MUX-DAC designed on Infineon B7HF200 process.

- Total dose tests
- Heavy ion tests
- Proton tests

4. DOCUMENTS

4.1 MUX-DAC Specifications

EV12DS130A-1080	EV12DS130A Datasheet

4.2 Radiation Test Plan

NE 31S 207285	MUX-DAC radiation test plan

4.3 Applicable ESCC specifications

ESCC 22900	Total Dose Steady-State Irradiation Test Method
ESCC 25100	Single Event Effects Test Method and Guidelines

5. EXECUTIVE SUMMARY

5.1 Total dose

It was concluded that the device under test (P/N EV12DS130A) had neither functional failure nor parameter drift up to 110 Krad (Si). Static and Dynamic results are satisfactory for all parameters.
A total of ten devices were tested at 3Gsps Clock frequency.
The total irradiation test program was followed by a 24 hr. annealing process at ambient temperature followed by a 168 hr. annealing at 100°C as per ESCC 22900.
The component is not sensitive to 110 Krad with very low dose rate (36 rad / hr) and it is therefore ELDRS (Enhanced Low Dose Rate Sensitivity) free

5.2 Heavy ions

It was concluded that the devices under test (P/N EV12DS130A) have:

- No SEL (SEL measured at Tj=125°C with maximum power supplies up to a LET of 80 MeV-cm²/mg with a tilt and up to 67.7 MeV-cm²/mg without tilt)
- No SEFI & no permanent error
- Low LET threshold of 0.5 MeV.cm²/mg. From proton test results LET threshold was revised to 0.015 MeV.cm²/mg. Weibull parameters are identical for DSPCLK and DACOUT:
    - LET th = 0.02 MeV.cm²/mg
    - Saturated cross-section = 7.50E-05 cm²
    - W=20 MeV.cm²/mg
    - S=1.2
- Long events on DSPCLK:
    - Maximum duration is 20 ns (which corresponds to ~2 clock periods of the DSPCLK)
- Long events detected on DACOUT:
    - Duration = 20 ns maximum (corresponds to ~55 consecutive data at 2760 Msps) with full-scale amplitude
    - 100 ns maximum (corresponds to ~275 consecutive data at 2760 Msps) with DACOUT amplitude modulation of half of full-scale worst case

5.3 Proton tests

It was concluded that the devices under test (P/N EV12DS130A) have:

- No SEL (up to 200 MeV)
- No SEFI & no permanent error
- Energy threshold is lower than 14 MeV (lowest energy considered for the test)
- Worst case Weibull parameters are therefore considered for both DSPCLK and DACOUT:
    - E th = 1 MeV
    - Saturated cross-section = 3.00E-10 cm²
    - W = 1 MeV
    - S = 1
- An increase of sensitivity is observed at the lower energy tested (10MeV). It is assumed that this effect is due to direct ionization instead of displacement effect. In that case, the electronic LET of protons shall be considered and the heavy ion LET threshold is decreased from 0.5 to 0.015 MeV.cm²/mg.
- Long events on DSPCLK:
        - This corresponds to duty cycle variations on DSPCLK
- Long events detected on DACOUT:
    - Duration: 2 to 3 ns maximum.
        - This corresponds to ~5 to 8 consecutive data on DACOUT at 2770 Msps with full-scale amplitude

5.4 Radiation test results SUMMARY

Parameter	Symbol	Results	Unit	Comments
Radiation total dose	TID	110	Krad	No issue Device is ELDRS free
Latch up free	SEL	> 80	MeV-cm^2/mg	No SEL at 200 MeV with protons
SEFI (Single event Functional Interrupt) - Recoverable with Reset	SEFI	NO SEFI		
HEAVY IONS (DACOUT & DSPCLK)				
LET threshold	LETth	0.015	MeV	Value deduced from proton tests
Saturated cross-section	Xsat	7.50 E-05	Cm^2	
W	W	20	MeV-cm^2/mg	
S	S	1.2		
Worst case long SET duration on DSPCLK	Long SET	< 20	ns	Corresponds to ~2 clock periods at 2760Msps
Worst case long SET duration on DACOUT	Long SET	< 20	ns	Corresponds to ~55 consecutive data at 2760Msps
		< 100	ns	With amplitude modulation by half-full-scale. Corresponds to ~275 consecutive data at 2760Msps
PROTONS (DACOUT & DSPCLK)				
Energy threshold	Eth	1	MeV	Worst case as test was done for Eth > 10 MeV
Saturated cross-section	Xsat	3.00 E-10	Cm^2	
W	W	1	MeV	
S	S	1		
Worst case long SET duration on DSPCLK	Long SET	< 3	ns	Corresponds to duty cycle variations at 2770Msps
Worst case long SET duration on DACOUT	Long SET	< 3	ns	Corresponds to ~8 wrong consecutive data at 2770Msps

6. TOTAL DOSE TESTS

6.1 Parts references

Type:	EV12DS130AGS
Manufacturer:	e2v Grenoble
Function:	12-bit 3Gsps 4:1 MUX-DAC
Technology:	Bipolar SiGeC
Packaging:	Ci-CGA 255
Date Code:	1107
Diffusion number:	RU039535
Number of parts:	10 irradiated (5 biased ON and 5 OFF) + 2 Reference parts

6.2 Dosimetry and irradiation facility

Source:	^{60}Co (36 rad/hr)
Localization:	TRAD/UCL in Louvain La Neuve (Belgium)

6.3 Detailed total dose test report

Refer to document reference NE 31S 207916.

6.4 Total dose results

It was concluded that the device under test (P/N EV12DS130A) had neither functional failure nor parameter drift up to 110 Krad (Si). Static and Dynamic results are satisfactory for all parameters.
A total of ten devices were tested at 3Gsps Clock frequency.
The total irradiation test program was followed by a 24 hr. annealing process at ambient temperature followed by a 168 hr. annealing at 100℃ as per ESCC 22900.
The component is not sensitive to 110 Krad with very low dose rate (36 rad / hr) and it is therefore ELDRS (Enhanced Low Dose Rate Sensitivity) free

7. HEAVY IONS & PROTONS TESTS

7.1 Methods and patterns

E2v evaluation board was used to perform both heavy ions & proton tests. This evaluation board includes a FPGA used to generate the pattern to the MUX-DAC (DUT). Normally the output DSPCLK of the MUX-DAC is used as FPGA input clock.
However for radiation tests, the DSPCLK was not looped back to the FPGA. Indeed, in case of events on the DSPCLK, the FPGA could be desynchronized and the pattern sent to the DAC would be incorrect, leading to the conclusion there is an upset on DACOUT!
In using a dedicated clock synchronized to MUX-DAC Master clock (with a frequency division factor according to MUX Ratio, OCDS and IUCM), it is possible to monitor SET on both DACOUT & DSPCLK independently at the same time.
Note: events were detected on differential output in using a balun.

7.1.1 Static tests

During static tests, the digital inputs were fixed to a constant level so that the DAC outputs a DC static voltage of Full-Scale. Due to the presence of AC capacitors on DAC analog output, the RTZ mode was used during static tests, so that DACOUT becomes a dynamic signal.
The evaluation board has AC capacitors in-line with the differential analogue outputs preventing the measurement of a DC voltage at the bulk-head SMA connectors.
The static tests were performed in 4:1 MUX mode to maximise the internal operation of the DAC's MUX and the DSPCLK clock's dividers. The phase shift select function was preset to 111 to ensure the maximum (worst-case) delay between the sampling clock and the DSPCLK output clock.

Static tests were done with two Fclk frequencies (658 Msps & 2760 Msps).
DSPCLK was also tested against OCDS depending on Fclk:
With OCDS preset to 00 (frequency division by 8) with Fclk = 658 Msps
With OCDS preset to 10 (frequency division by 32) with Fclk = 2760 Msps

7.1.2 Dynamic tests

A dynamic stimulus is selected which fully exercises all the EV12DS130GS' input latches, its MUX and DAC core. OUT P/N dynamically slews across its complete output voltage range at a frequency commensurate with 4:1 MUX operation and is monitored for changes which are recorded as SEEs.

The dynamic tests were performed in 4:1 MUX mode to maximise the internal operation of the DAC's MUX and the DSPCLK clock's dividers. The phase shift select function was preset to 111 to ensure the maximum (worst-case) between the sampling clock and the DSPCLK output clock.

Dynamic tests were done with two Fclk frequencies (658 Msps & 2760 Msps).
DSPCLK was also tested against OCDS depending on Fclk:
With OCDS preset to 00 (frequency division by 8) with Fclk = 658 MHz
With OCDS preset to 10 (frequency division by 32) with Fclk = 2760 MHz

DSPCLK sensitivity was also checked in IUCM mode (This mode exercise and test the hardness of all of the dividers within the output clock path) with Fclk = 2760 Msps and OCDS preset to 11 (frequency division by 128)

Dynamic tests on DACOUT and DSPCLK were repeated for the 4 DAC output modes (NRZ, NRTZ, RTZ and RF)

7.2 Parts references

Type:	EV12DS130AGS
Manufacturer:	e2v Grenoble
Function:	12-bit 3Gsps MUX-DAC
Technology:	Bipolar SiGeC
Packaging:	Ci-CGA 255 (delidded for heavy ions, not delidded for protons)
Date code front end:	1048
Diffusion number:	RU039535
Number of parts:	2 irradiated + 1 Reference part (spare) for heavy ion tests 1 irradiated + 1 Reference part (spare) for proton tests

The parts used to perform proton tests were different from parts used for heavy ion tests.

7.3 Heavy Ions Tests

7.3.1 Irradiation facility

Tests were performed at U.C.L. (Université Catholique de Louvain) in Belgium in using two cocktails (High LET cocktail and high penetration cocktail)
Tests were subcontracted to ASTRIUM (Elancourt, France).

7.3.2 Test setup and results

Please refer to the document reference ASTR.APX.CP.000130 Issue 00 Rev. 03

7.3.3 Heavy ion test results

7.3.3.1 SEL

No SEL (SEL measured at Tj=125°C with maximum power supplies up to a LET of 80 MeV-cm^2/mg with a tilt and up to 67.7 MeV-cm^2/mg without tilt). The device is therefore SEL free up to at least 80 MeV-cm^2/mg.

7.3.3.2 SEFI

No SEFI detected. The device is therefore SEFI free up to at least 80 MeV-cm^2/mg

7.3.3.3 SET on DSPCLK

The following figures represent the sensitivity curves of DSPCLK in the different modes:

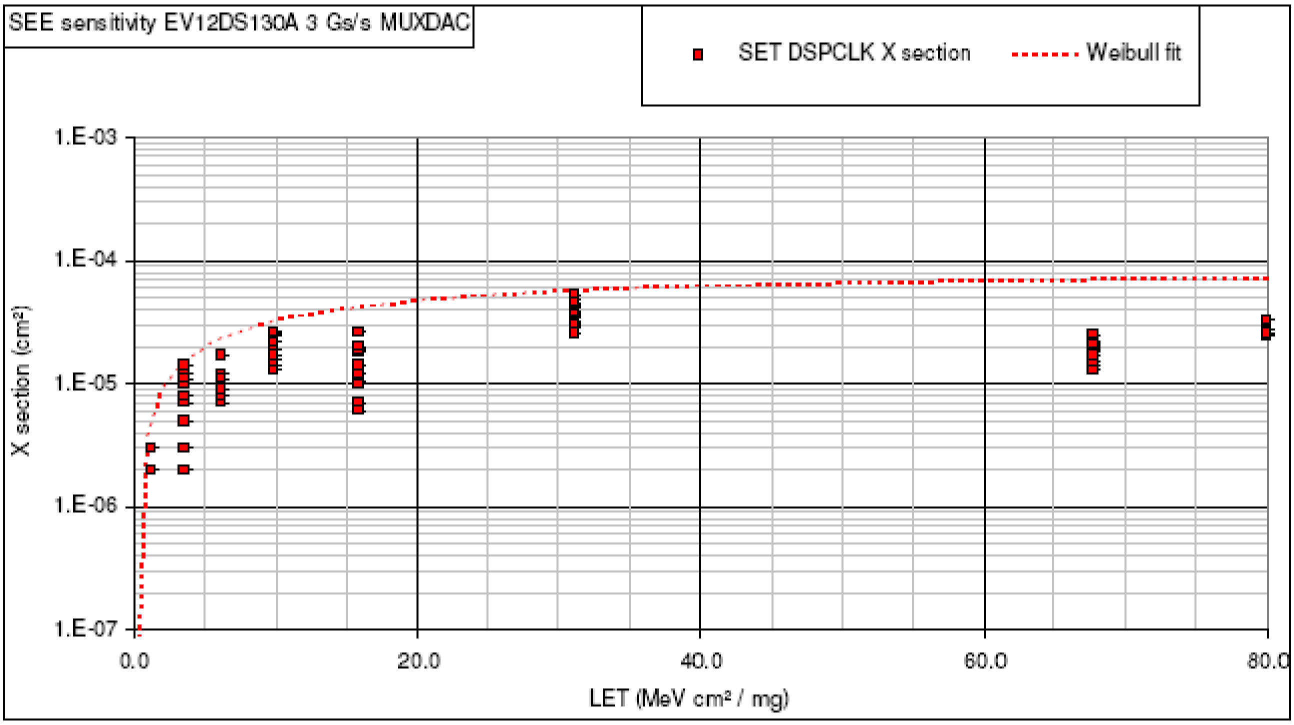

Figure 1 – DSPCLK SET sensitivity (all configurations)

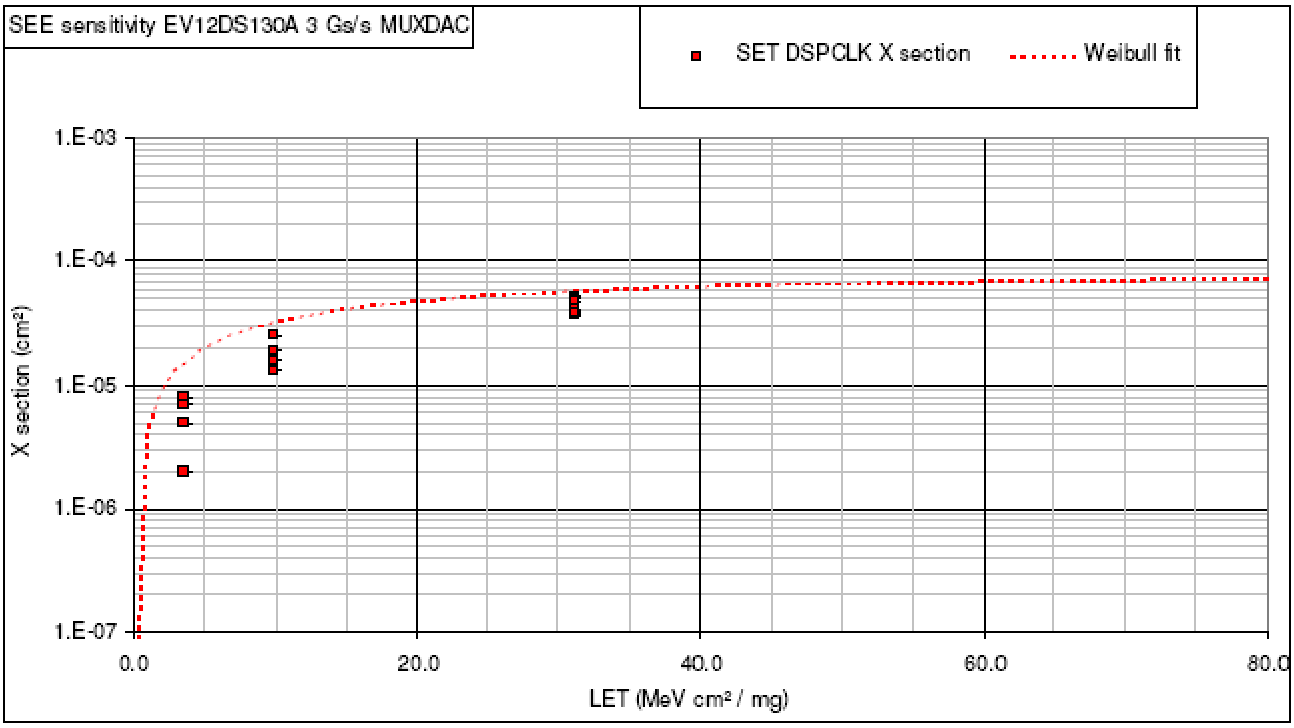

Figure 2 – DSPCLK SET sensitivity (Fclk = 658 MHz)

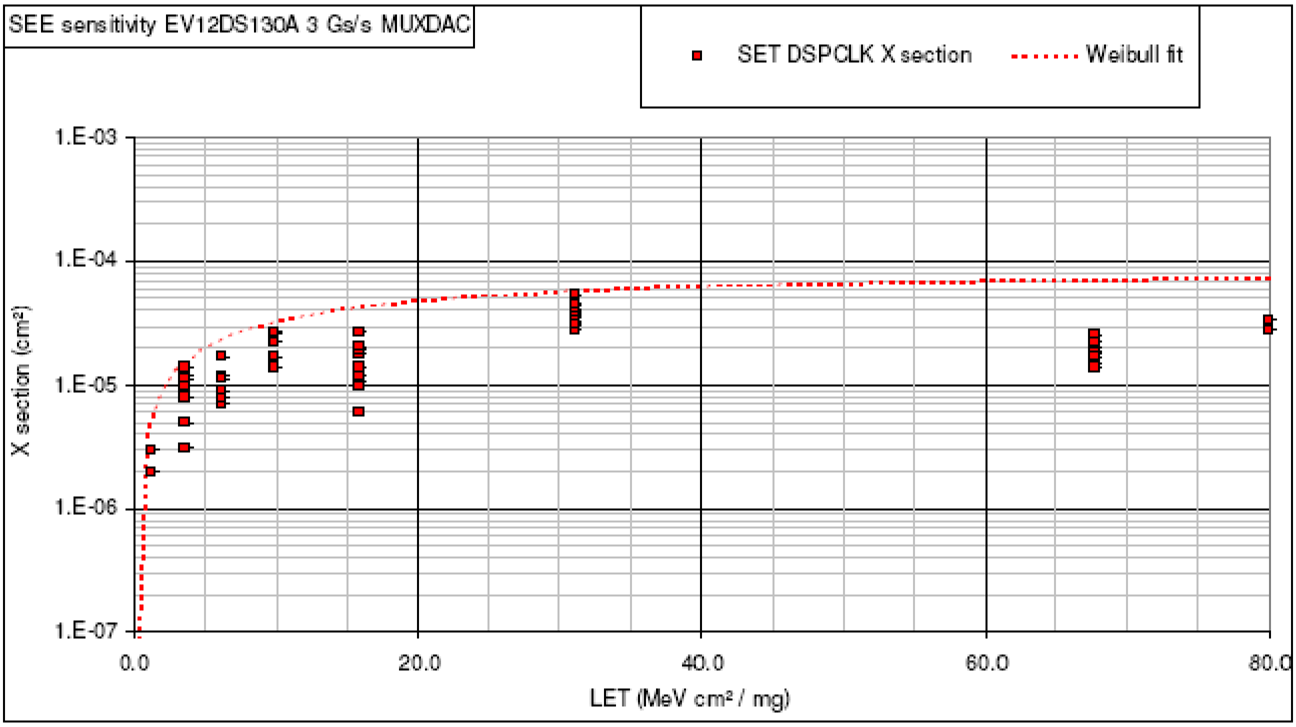

Figure 3 – DSPCLK SET sensitivity (Fclk = 2760 MHz)

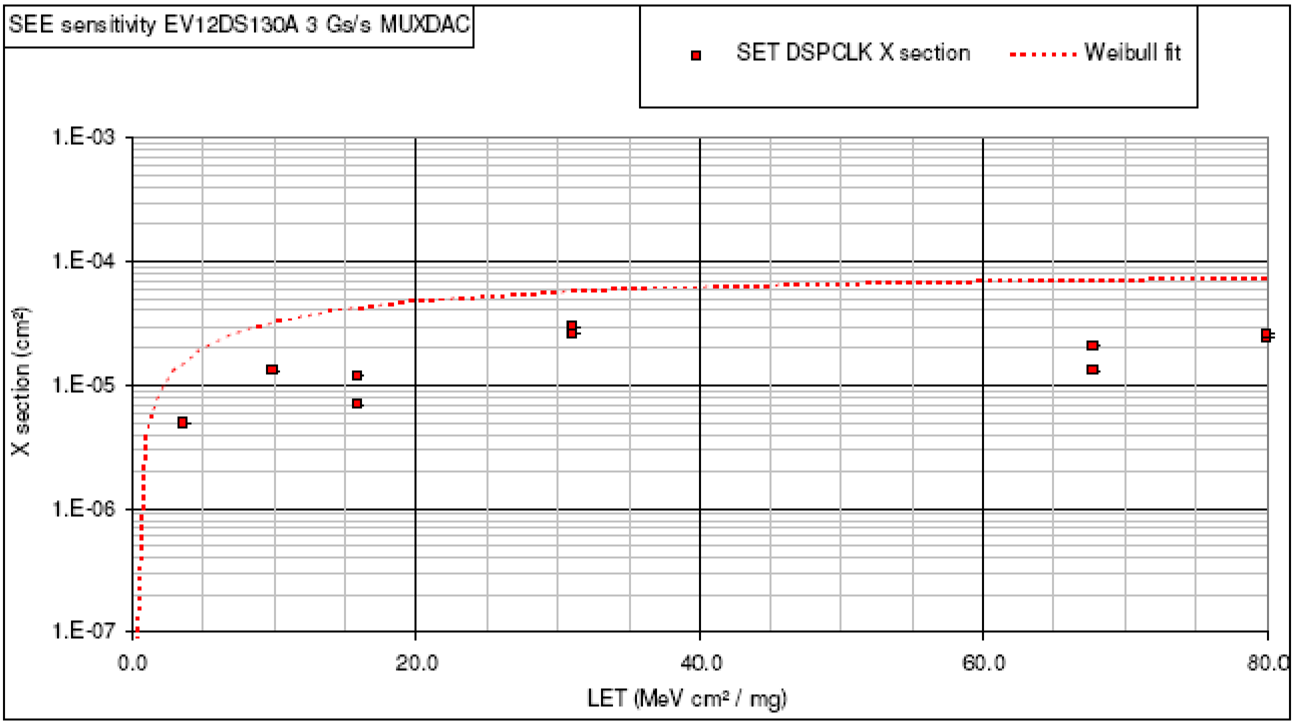

Figure 4 – DSPCLK SET sensitivity (IUCM mode)

There is no major difference depending on the working frequency, the WEIBULL fit can be used in both cases.

In the case IUCM mode is enabled (Figure 4), it clearly appears that sensitivity is 2 to 3 times lower.

Only short duration transients (~20 ns) have been seen in all configurations. This corresponds to ~2 clock periods of the DSPCLK.
A typical example of SET observed on DSPCLK is represented in Figure 5 :

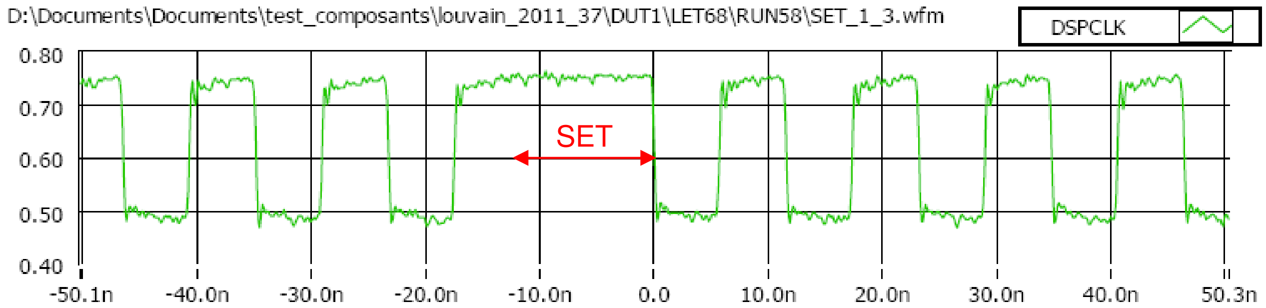

Figure 5 – DSPCLK SET example

The Table 1 provides worst case Weibull fit parameters for DSPCLK

	Worst case, all runs (LET th issued from proton test (1))
σ sat (cm²)	7.50E-05
LET th (MeV.cm²/mg)	0.015 (1)
S	1.2
W (MeV.cm²/mg)	20

Table 1 – Worst case Weibull fit for DSPCLK

Note 1:
From heavy ion tests, it appears that the device was still sensitive under a LET of 1.2 MeV.cm²/mg and the threshold was then estimated around 0.5 MeV.cm²/mg. However, the proton test showed an increase in cross section at lowest energy tested. Thus it can be assumed that this effect is due to direct ionization instead of displacement effect.
From the graph given in appendix A, it appears that the LET threshold needs to be revised to 0.015 MeV.cm²/mg

7.3.3.4 SET on DACOUT

The following figures represent the sensitivity curves of DACOUT in the different modes:

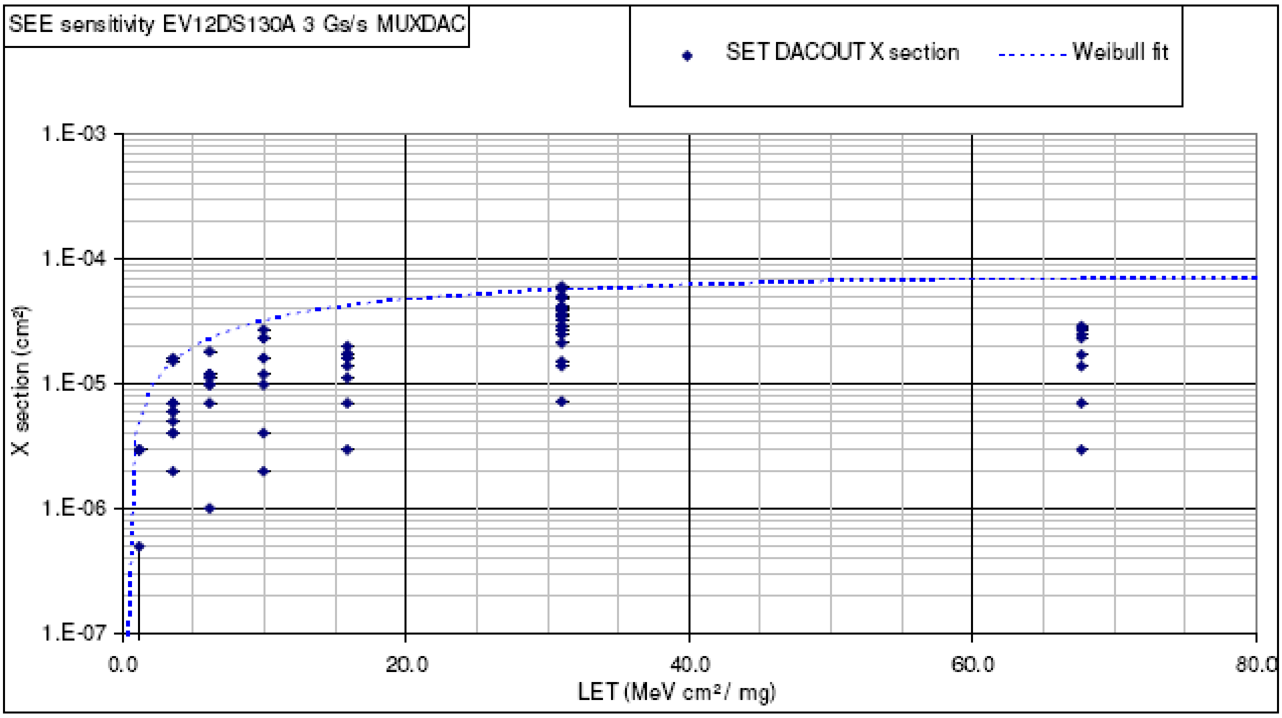

Figure 6 – DACOUT SET sensitivity (all configurations)

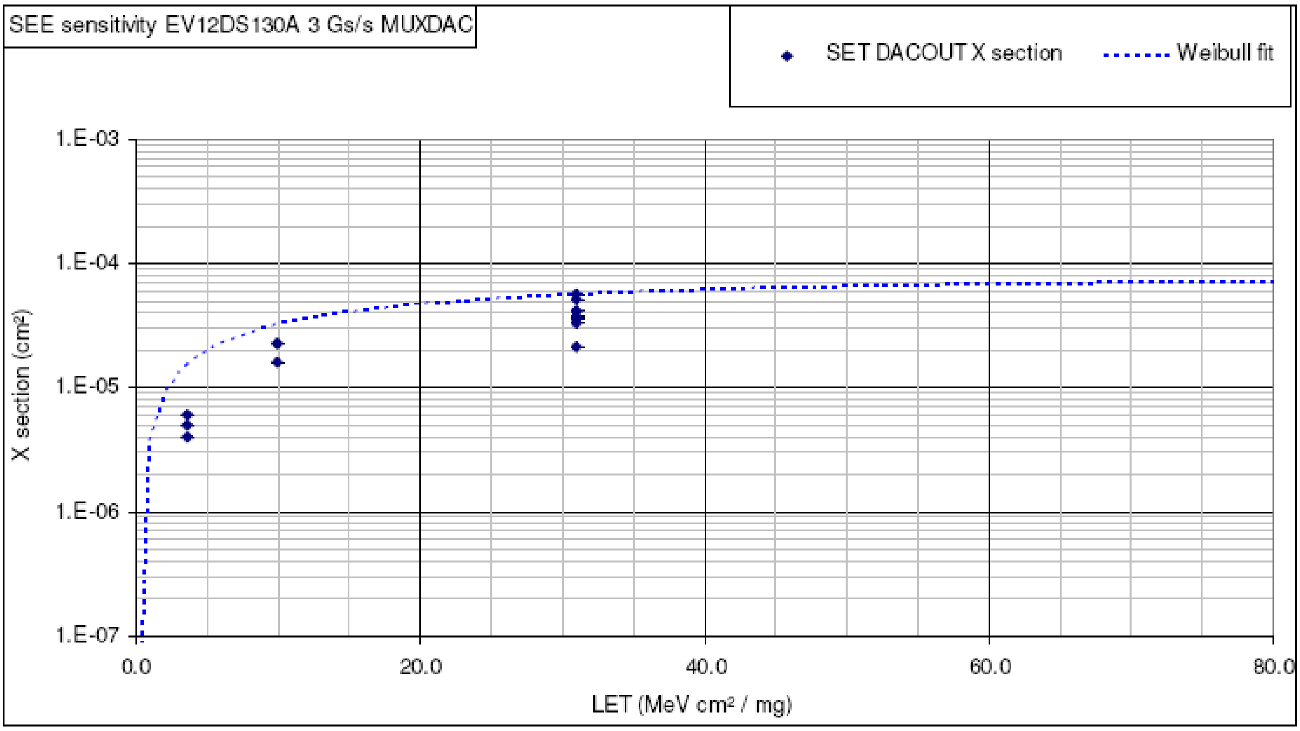

Figure 7 – DACOUT SET sensitivity (Fclk = 658 MHz all modes)

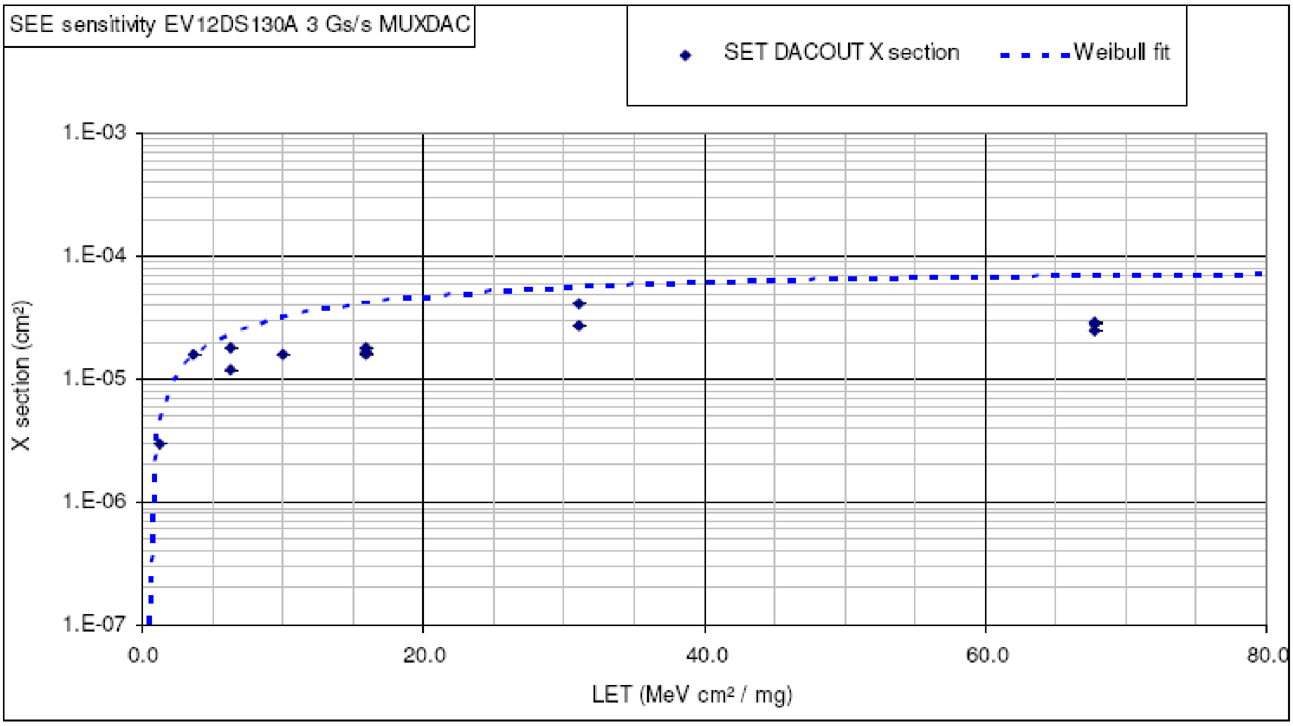

Figure 8 – DACOUT SET sensitivity (Fclk = 2760 MHz NRZ mode)

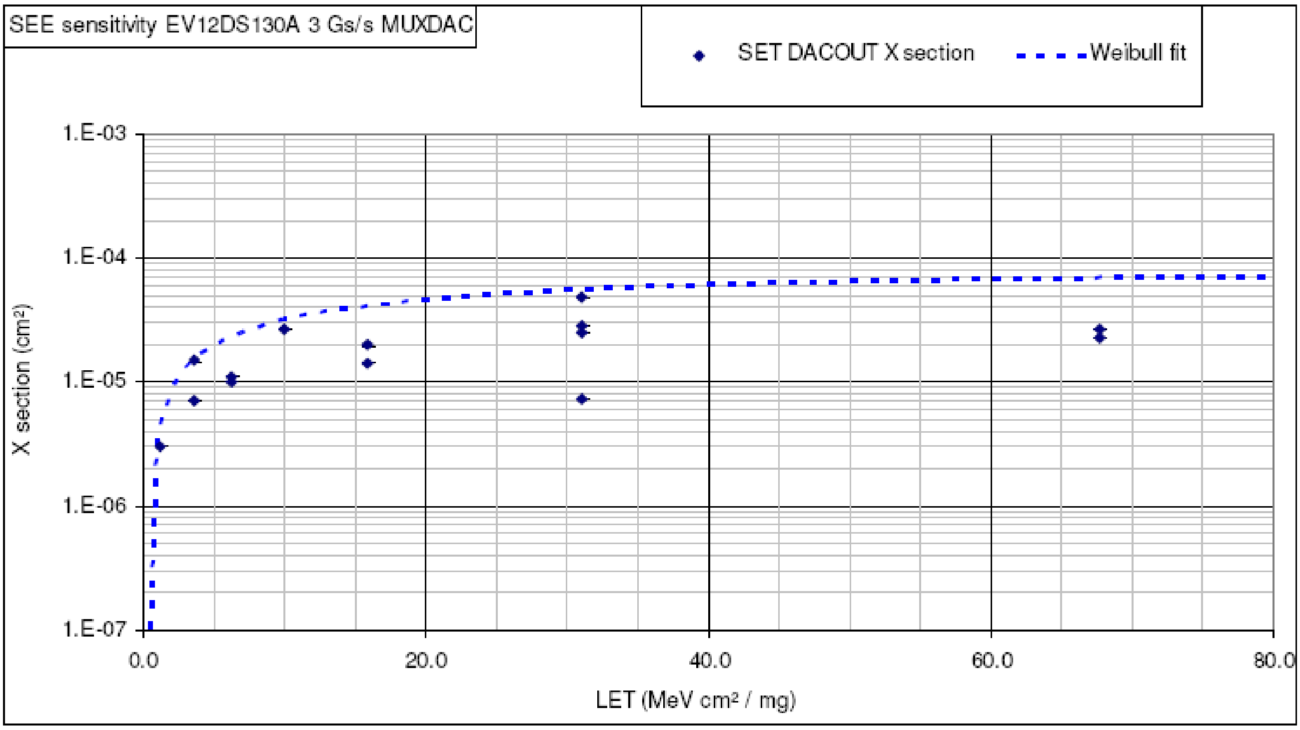

Figure 9 – DACOUT SET sensitivity (Fclk = 2760 Msps NRTZ mode)

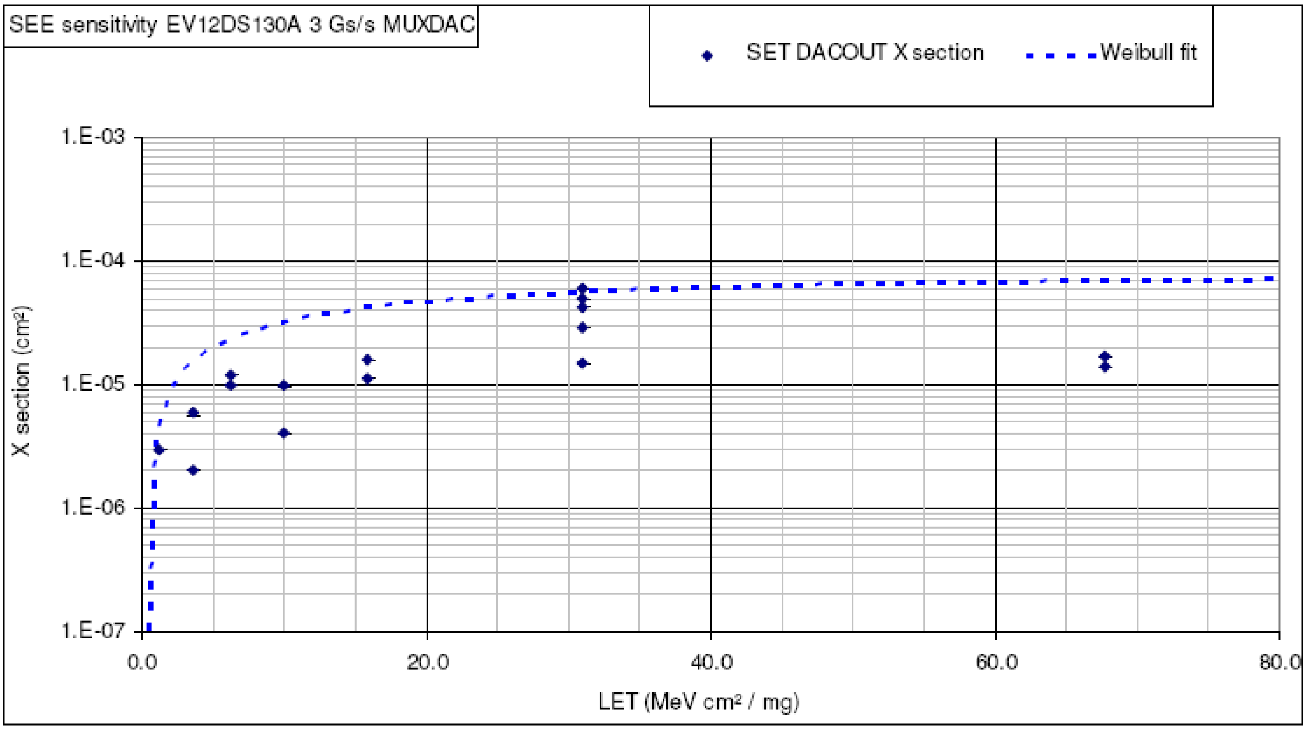

Figure 10 – DACOUT SET sensitivity (Fclk = 2760 Msps RTZ mode)

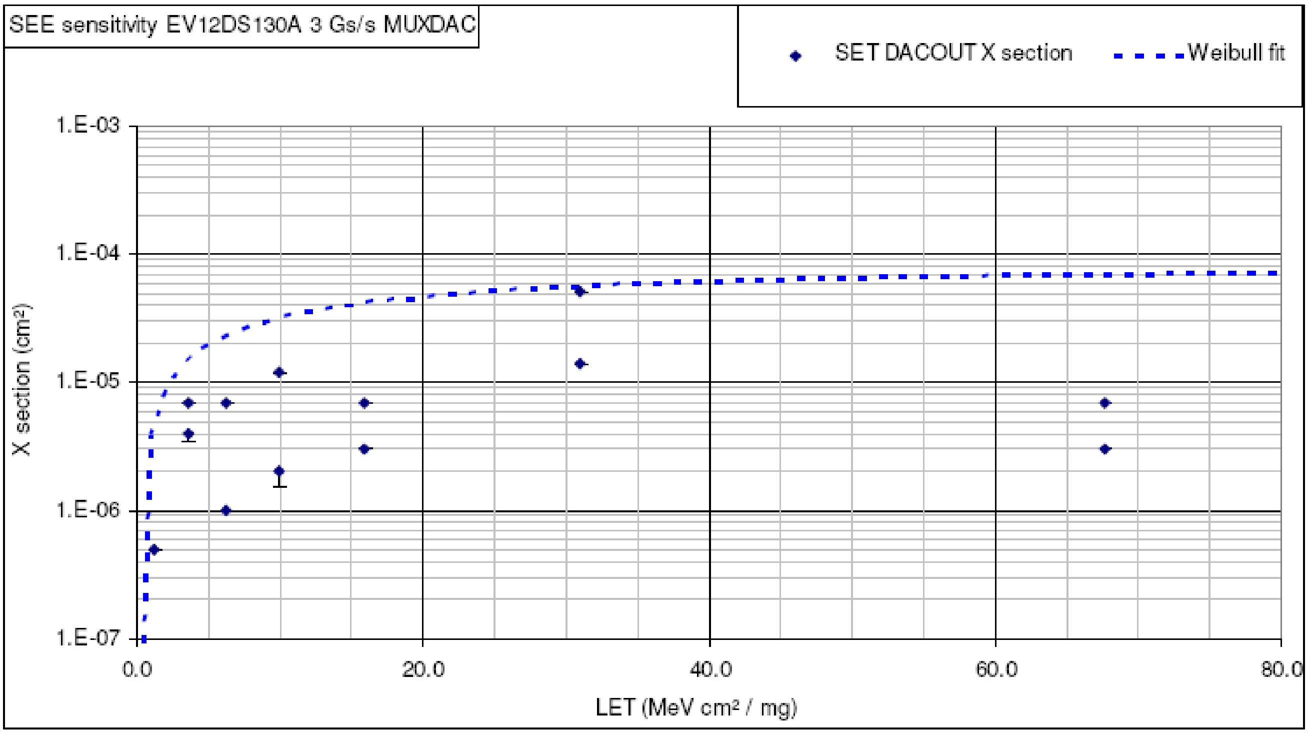

Figure 11 – DACOUT SET sensitivity (Fclk = 2760 Msps RF mode)

There are small differences on sensitivity curves depending on clock frequency and DAC output modes.
Among all events detected on DACOUT we can distinguish:

- Temporary timing change (See example in Figure 12)
- Temporary mode change (See example in Figure 13 – Example of temporary mode change on DACOUT at 2760MHz, in NRTZ mode, LET = 31 MeV.cm²/mg)
- DACOUT Amplitude perturbation (See example in Figure 14)
  (Amplitude modulation is half of DACOUT full-scale worst case)

- Timing perturbation (See example in Figure 15)

From all the transients reviewed on DACOUT, two main families were identified:

- Short duration transients with a worst case duration perturbation estimated to last 20ns maximum, whenever the amplitude is limited to the output max span of the DAC.
  20 ns corresponds to ~55 consecutive data at 2760 Msps.
- Longer duration transients for which timing is not affected, but only smooth variation on the envelope amplitude is visible. Transients duration is estimated to be around 100ns. These transients are only seen for LET higher or equal to 31 MeV.cm²/mg and above, and represent 25% of events in static mode, while it decreases to 10% in dynamic mode.
  100 ns corresponds to ~275 consecutive data at 2760 Msps

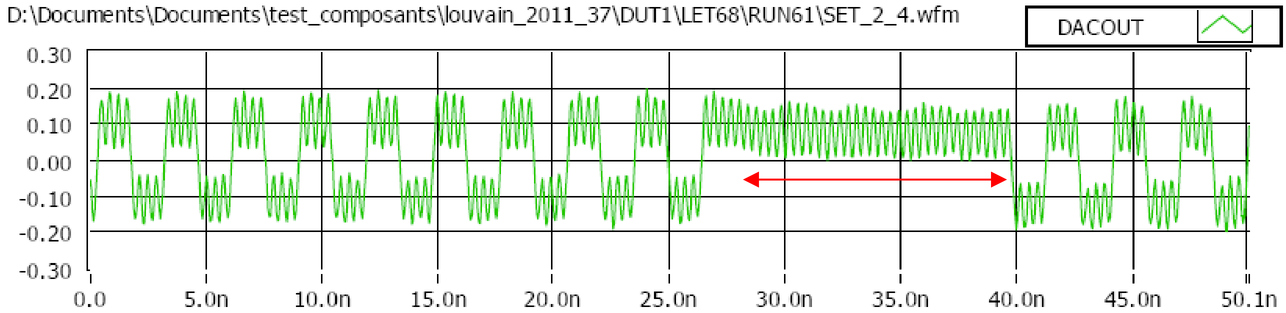

Figure 12 – Example of temporary timing change on DACOUT at 2760MHz, in RTZ mode, LET = 68 MeV.cm²/mg

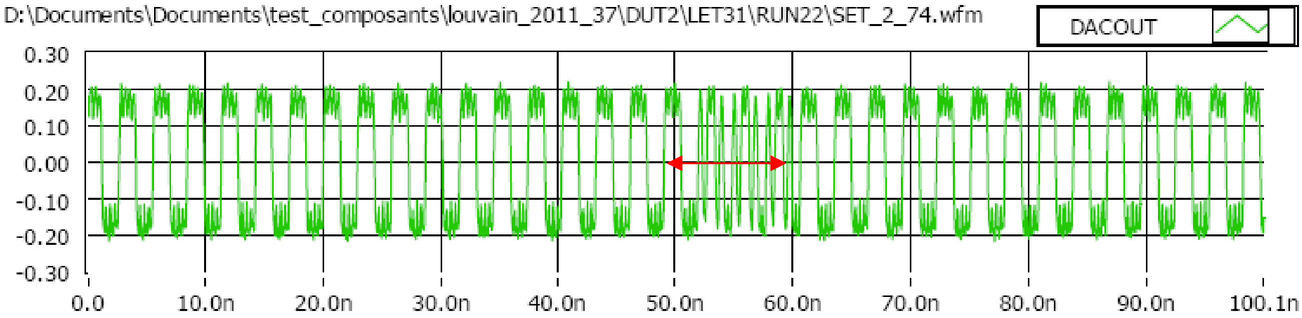

Figure 13 – Example of temporary mode change on DACOUT at 2760MHz, in NRTZ mode, LET = 31 MeV.cm²/mg

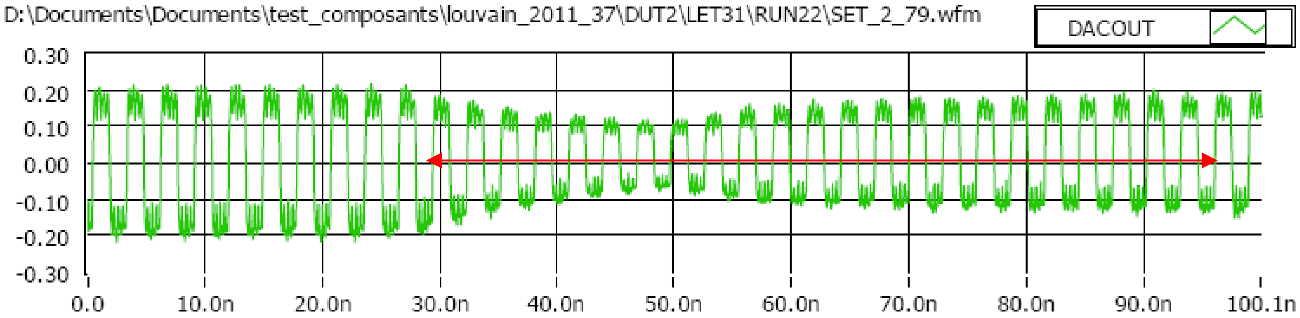

Figure 14 – Example of DACOUT Amplitude modulation at 2760MHz, in NRTZ mode, LET = 31 MeV.cm²/mg

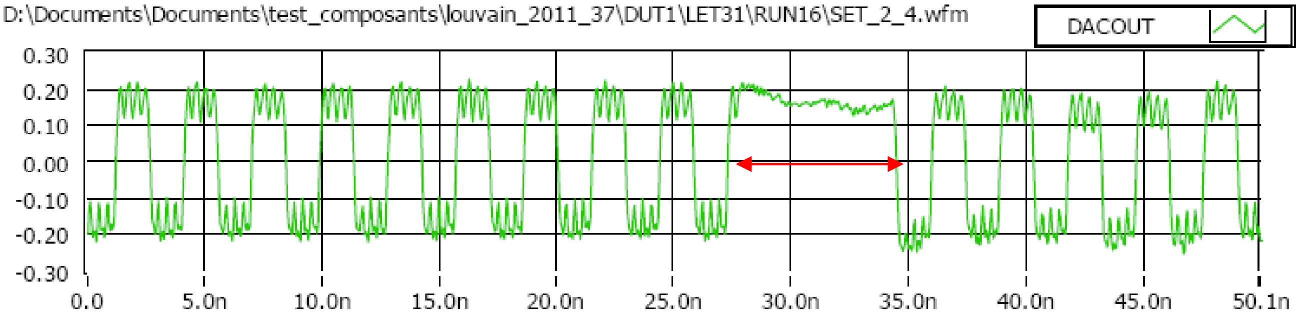

Figure 15 – Example of timing perturbations at 2760MHz, in NRTZ mode, LET = 31 MeV.cm²/mg

The Table 2 provides worst case Weibull fit parameters for DACOUT

	Worst case, all runs (LET th issued from proton test (1))
σ sat (cm²)	7.50E-05
LET th (MeV.cm²/mg)	0.015 (1)
S	1.2
W (MeV.cm²/mg)	20

Table 2 – Worst case Weibull fit for DACOUT (raw value from heavy ion tests)

Note 1:
From heavy ion tests, it appears that the device was still sensitive under a LET of 1.2 MeV.cm²/mg and the threshold was then estimated around 0.5 MeV.cm²/mg. However, the proton test showed an increase in cross section at lowest energy tested. Thus it can be assumed that this effect is due to direct ionization instead of displacement effect.
From the graph given in appendix A, it appears that the LET threshold needs to be revised to 0.015 MeV.cm²/mg

7.3.3.5 Conclusion on DACOUT & DSPCLK sensitivity

DACOUT and DSPCLK have the same sensitivity. No significant variation was noticed depending on the different modes tested.

7.4 Protons Tests

7.4.1 Irradiation facility

Tests were subcontracted to ASTRIUM (Elancourt, France).
A first test was performed at P.S.I. (Paul Scherrer Institute) in Switzerland. Only one part was tested at P.S.I. facility due to a failure of a generator.
A second test was performed at LIF UCL facility (Louvain La Neuve, Belgium), on two devices.

7.4.2 Test setup and results

Please refer to the document reference ASTR.APX.CP.000160 Issue 00 Rev. 04

7.4.3 Proton test results

Note: For the proton test, only the worst case conditions issued from Heavy Ions were considered (No static test / only dynamic tests at 2740 Msps)

7.4.3.1 SEL

The device is SEL free up to at least 200 MeV.

7.4.3.2 SEFI

The device is therefore SEFI free up to at least 200 MeV.

7.4.3.3 SET on DSPCLK

The following figures represent the sensitivity curves of DSPCLK in the different modes:

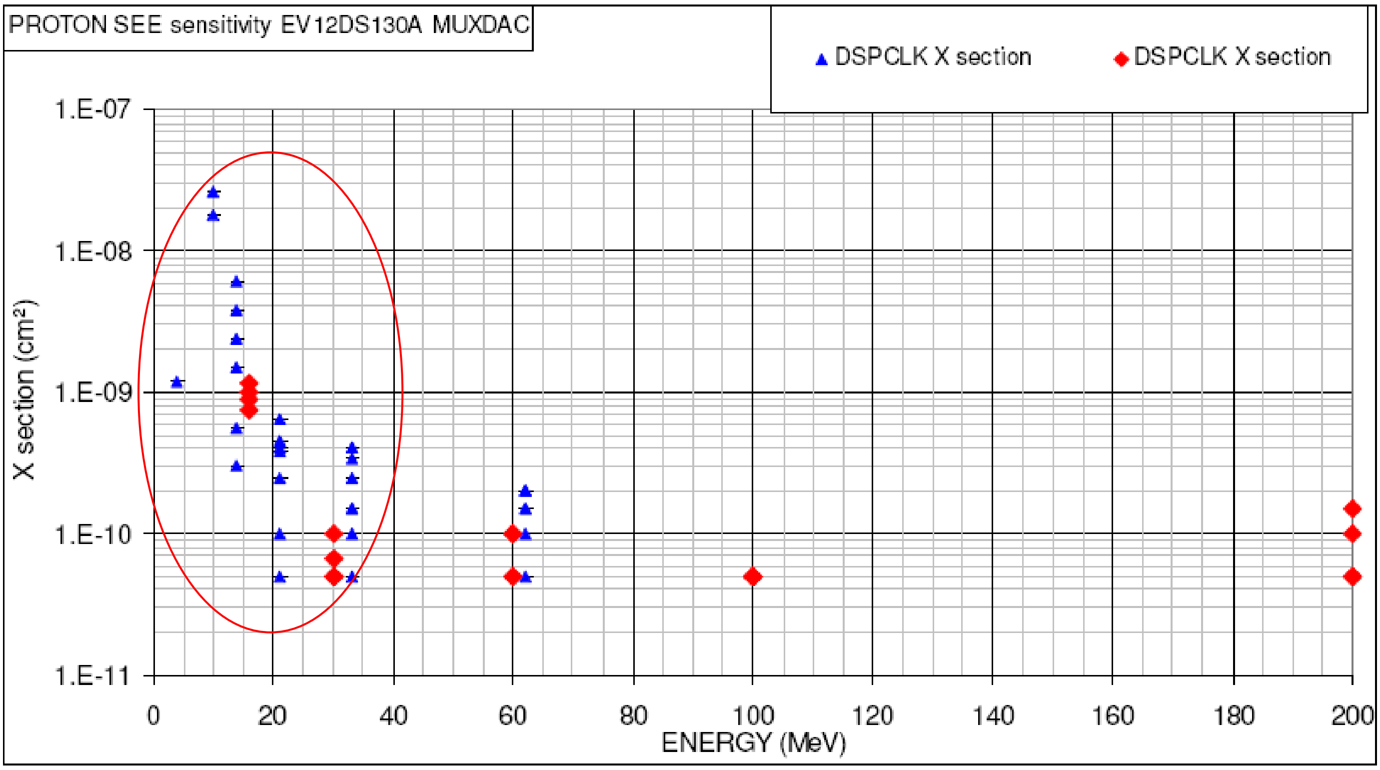

Figure 16 – DSPCLK SET sensitivity (all configurations)
Red dots represents data from PSI-PIF. Blue points represent data from LIF-UCL

The results of PSI-PIF facility and LIF-UCL facility are in accordance.

An increase of sensitivity is visible at the lowest energy tested. It can be assumed that this effect is due to direct ionization instead of displacement effect.
Weibull fit for proton is done by considering the higher cross section for energy > 30 MeV.

In term of kind of events, there is mainly slight variation of one DSPCLK period or some sort of glitches. Worst case duration of events is in the range of 2 to 3 ns. Typical examples of SET observed on DSPCLK are represented in Figure 17 and Figure 18:

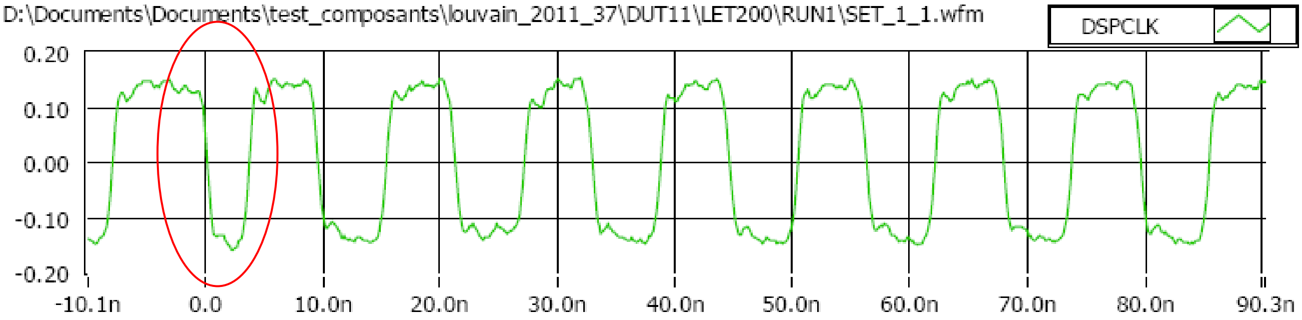

Figure 17 – DSPCLK SET example: slight variation of period

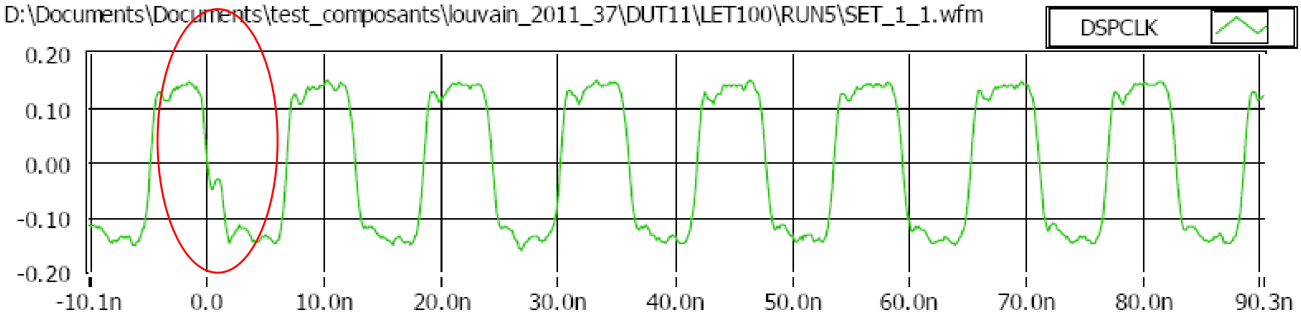

Figure 18 – DSPCLK SET example: sort of glitches

The table below provides worst case Weibull fit parameters for DSPCLK.
As proton test has been done with the minimum energy available at PSI & UCL and as the device was found sensitive at this lowest energy, the worst case is considered (Eth = 1 MeV, W=1, S=1, and highest cross-section found for E>30MeV). It means that all the spectrum available in space is considered.

	Worst case, all runs
σ sat (cm²)	3.00E-10
E th (MeV)	1
S	1
W (MeV)	1

Table 3 – Worst case Weibull fit for DSPCLK

7.4.3.4 SET on DACOUT

The following figures represent the sensitivity curves of DACOUT in the different modes:

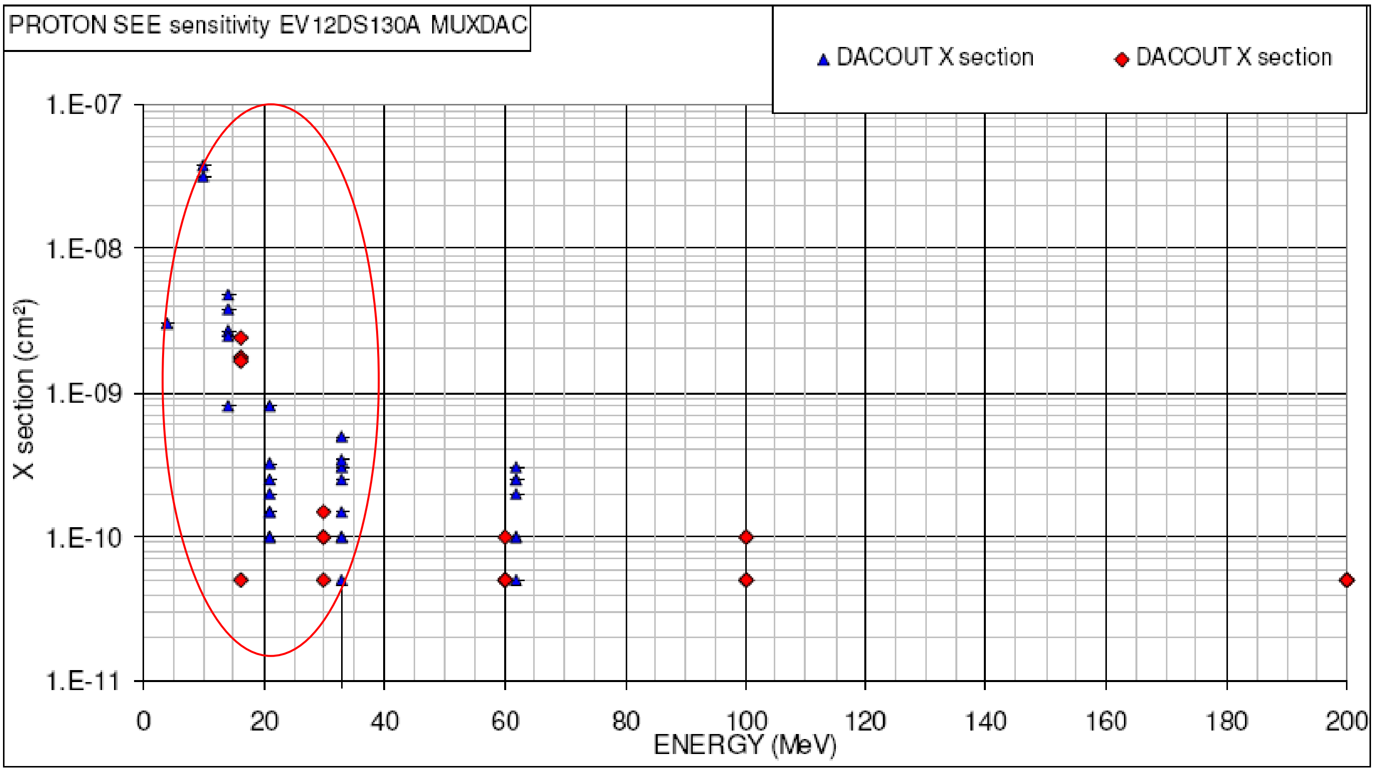

Figure 19 – DACOUT SET sensitivity (all configurations)
Red dots represents data from PSI-PIF. Blue points represent data from LIF-UCL

The results of PSI-PIF facility and LIF-UCL facility are in accordance.

An increase of sensitivity is visible at the lowest energy tested. It can be assumed that this effect is due to direct ionization instead of displacement effect.
Weibull fit for proton is done by considering the higher cross section for energy > 30 MeV.

Among all events detected on DACOUT we mainly observed short transient. The transient duration is less than 5 ns for longest duration. No change of mode neither amplitude modulation have been seen during the proton test.

The figures below provide some example of typical transients observed on DACOUT:

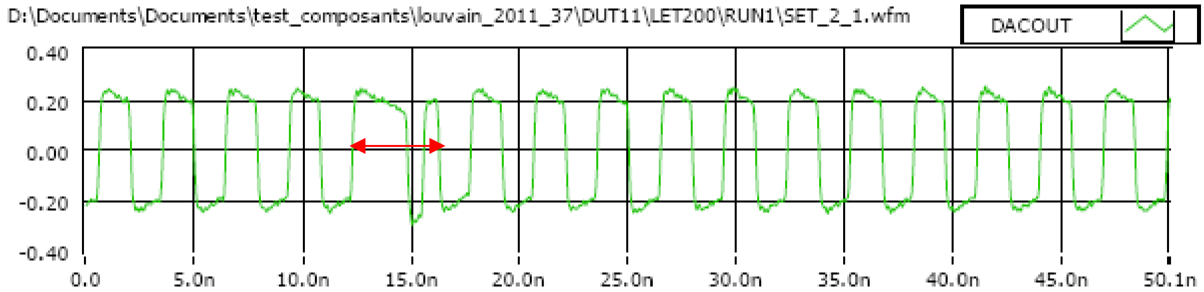

Figure 20 – Example of temporary timing change on DACOUT at 2740MHz, in NRZ mode, E = 200 MeV

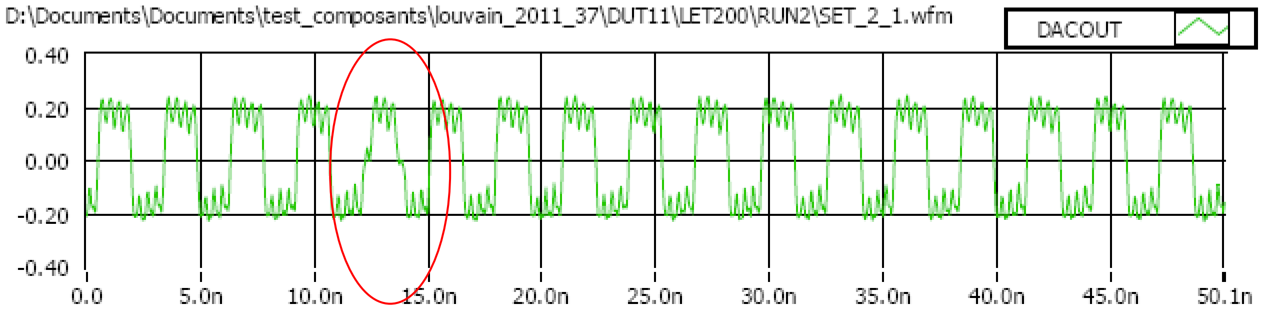

Figure 21 – Example of temporary mode change on DACOUT at 2740MHz, in NRTZ mode, E = 200 MeV

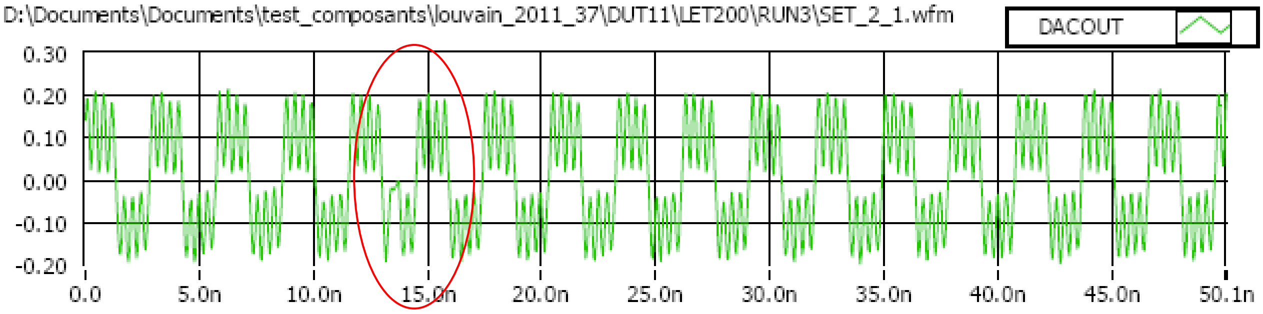

Figure 22 – Example of DACOUT Amplitude modulation at 270MHz, in RTZ mode, E = 200 MeV

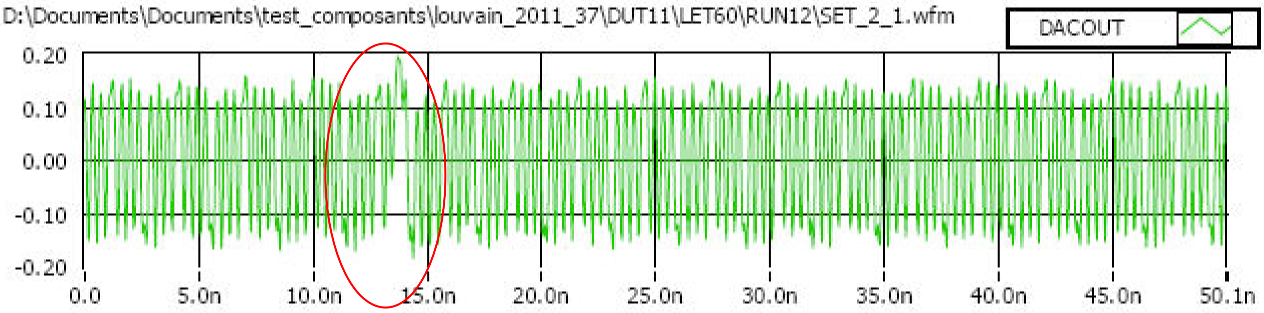

Figure 23 – Example of timing perturbations at 2740MHz, in RF mode, LET = 60 MeV

The table below provides worst case Weibull fit parameters for DACOUT.
As proton test has been done with the minimum energy available at PSI & UCL and as the device was found sensitive at this lowest energy, the worst case is considered (Eth = 1 MeV, W=1, S=1, and highest cross-section found for E>30MeV). It means that all the spectrum available in space is considered.

	Worst case, all runs
σ sat (cm²)	3.00E-10
E th (MeV)	1
S	1
W (MeV)	1

Table 4 – Worst case Weibull fit for DACOUT

7.4.3.5 Conclusion on DACOUT & DSPCLK sensitivity

DACOUT and DSPCLK have the same sensitivity. No significant variation was noticed depending on the different modes tested.

APPENDIX A

Device behaviour with protons of low energy

From heavy ion tests, it appears that the device was still sensitive under a LET of 1.2 MeV.cm²/mg and the threshold was then estimated around 0.5 MeV.cm²/mg. However, the proton test showed an increase in cross section at lowest energy tested. Thus it can be assumed that this effect is due to direct ionization instead of displacement effect.
In that case, the LET of proton shall be considered and the heavy ion LET threshold is decrease to 0.015 instead of 0.5 MeV.cm²/mg as shown on Figure 24.

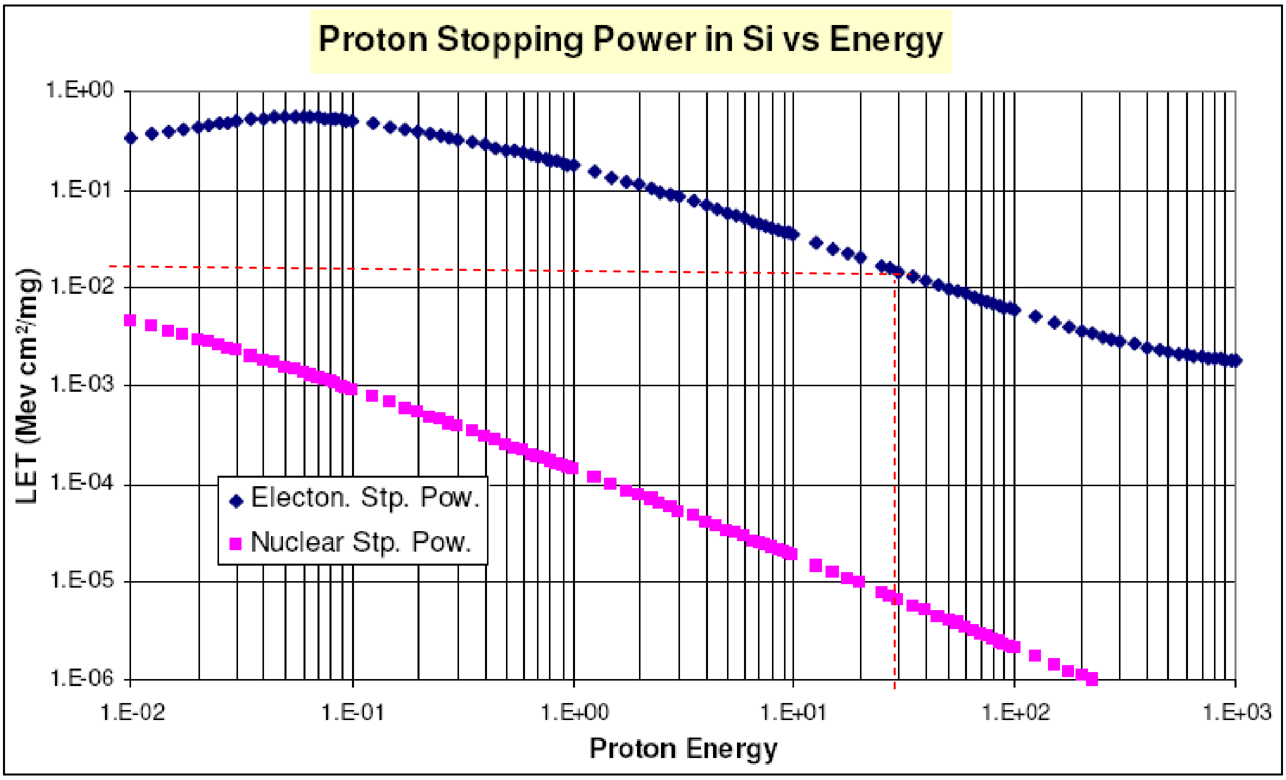

Figure 24 – Proton stopping power vs. energy