PROJECT

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TITLE

Heavy Ion Effects on Bias Conditions in AC/HC logic IC's

EUROPEAN SPACE AGENCY
CONTRACT REPORT

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SUMMARY

This report presents the results of a heavy ion Single Event Effects (SEEs) tests of 54AC/ 54HC logics as a function of three bias voltage conditions (2.5V, 3.3V and 5V).

Tested devices were:
54HC08, 54HC157, 54HC273, 54HC4040, 54HC4053 from ST Microelectronics
54AC08, 54AC153, 54AC257, 54AC244, 54AC273 from ST Microelectronics
54AC08, 54AC153, 54AC257, 54AC244, 54AC273 from National Semiconductor

The selected logic gate devices 54XX08, 54XX157, 54XX244 and 54XX257 are found to be insensitive to heavy ions up to an LET of 110 MeV/mg/cm^2 (see Table 4.1 for details).

The analog multiplexer/demultiplexer 54HC4053 show the same SET sensitivity for all bias voltage levels.

The digital 54AC/HC273 and 54HC4040 logics indicate higher susceptibility to SEU/SET when operated at lower voltages. The relationship observed between threshold-LET and bias voltage level varied between the digital device types. The largest effect of decreasing voltage was observed between 5V and 3.3V.

DOCUMENT CHANGE RECORD

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Issue	Date	Paragraphs affected	Change information
1	2005-05-12	All	New document

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1. ABSTRACT

This report presents the results of a heavy ion evaluation of five types of AC/HC logic IC's from National Semiconductor and ST Microelectronics. Single Event Effects (SEEs) have been studied as a function of bias conditions. The studies have been undertaken during the year 2004 on an ESA contract No. 11409-COO-8/I. All tests were carried at the CYClotron of LOuvain la NEuve (CYCLONE) in Belgium.

2. INTRODUCTION

The growing trend towards lower bias voltage has begun to influence space electronics systems. It is therefore important to assess SEU and SEL vulnerability of CMOS devices at reduced bias voltage levels.
The purpose of these tests was to determine the SEE characteristics of AC/HC logics as a function of the bias voltage conditions. Earlier [1] five types of 54HC logic family from ST Microelectronics (54HC08, 54HC157, 54HC273, 54HC4040, 54HC4053) have been tested at 5Volt bias condition. In the present tests the same five types of 54HC have been selected together with five 54AC types from two manufacturers.
The aim was to select the same types of 54AC logics from ST Microelectronics and National Semiconductor as the selected 54HC types. However, all five types do not exist in 54AC from both manufacturer and therefore, five part types were selected where the AC types from both manufacturer could be compared (54AC08, 54AC153, 54AC257, 54AC244, 54AC273). All types have been tested at 2.5V, 3.3V and 5V bias condition.

2.1 References

[1] H. Constans, C. Tizon, F.X.Guerre, R. Harboe Sorensen,
Heavy ion testing of 54HC from SGS Thomson, Hirex report HRX/97.2770

[2] F. Sturesson, m. Wiktorson, S. Mattsson, S. Larsson, R. Harboe Sorensen
Saab Ericsson Space Test report D-PL-REP-5162-SE /ESA-QCA0202S_C

3. TESTING TECHNIQUES and TEST SAMPLES

Test boards according to drawings for each part type were developed and controlled by a PC computer via GPIB interface. When applicable, two oscilloscopes have been used (Tektronix TDS3054, 500 MHz, 5GS/s) to count the number of events and to store the pulse profile of the events. The test software was developed by use of "Labview software" for the GPIB communication between the computer and the oscilloscopes / test boards. All results were stored as common "Excel-files".

All devices were tested under three bias condition, +5 VDC, +3.3VDC and +2.5VDC. Schematic drawings of the test set-ups are given below.

3.1 Heavy Ion Test Facility

Heavy ion tests were performed at the CYClotron of Louvain la Neuve (CYCLONE) in Belgium. The experiments have been performed in 2004 during three different test campaigns. In each campaign the actual ion cocktail in use have been utilized.
The ions used from the standard (M/Q=5)* and the high energy (M/Q=3.33) cocktail are given in Table 3.9.1 below.

TABLE 3.9.1 HEAVY IONS USED AT LOUVAIN LA NEUVE IN BELGIUM

Element	Energy MeV	Range µm	LET value [MeV/mg/cm^2]
40Ar	372	119	10.1
40Ar*	150	42	14.1
58Ni	500	85	21.9
78Kr	756	92	32.4
78Kr*	316	43	34.0
132Xe*	459	43	55.9

3.2 54AC08 / 54HC08 – Quad 2-Input and Gate

The device type is a logic gate and tested in static conditions with two outputs of the DUT set to "0" and two outputs set to "1". Events on the outputs were captured and counted by two oscilloscopes, one on nominal level=0 and one on nominal level=1, and storing the pulse profile of accumulated events. A test configuration diagram is given in Fig 3.2.1. Details of the test samples are given in Fig 3.2.2 and Table 3.2.1.

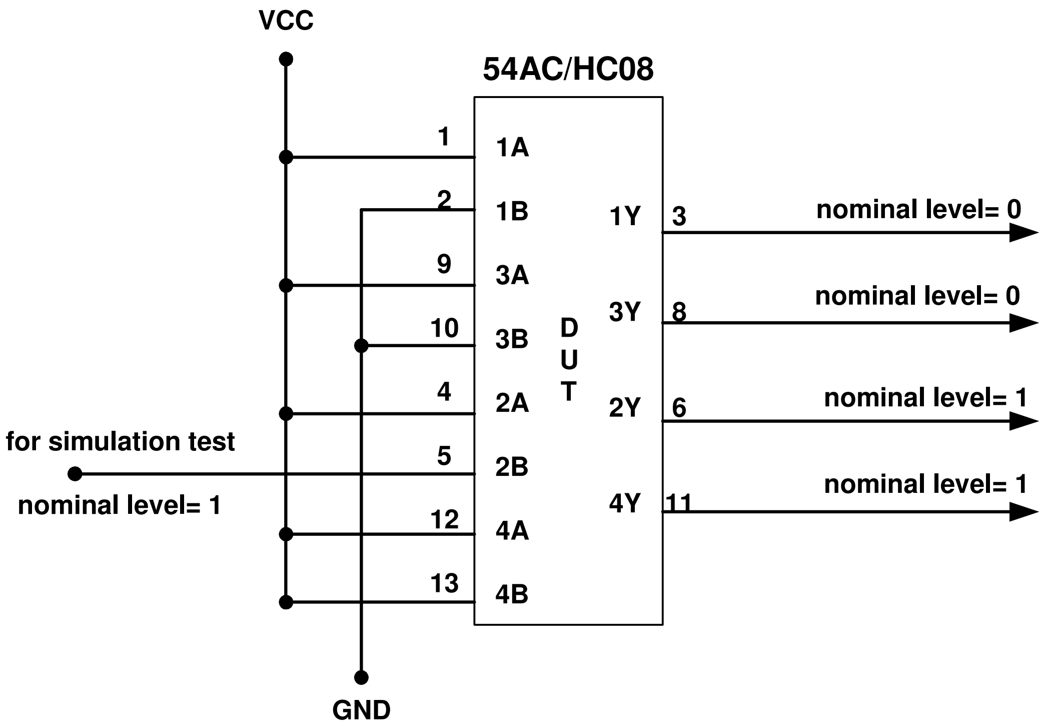

Fig 3.2.1 Test configuration diagram of 54AC08 / 54HC08

Fig 3.2.2 Picture of the top side of the packages for 54HC from STM. 54AC from STM and 54AC from NS

TABLE 3.2.1 DETAILS OF TEST SAMPLES 54HC08 / 54AC08

Manufacturer	STM	STM	NS
Part Type	54HC08	54AC08	54AC08FMQB
Package	FP14	FP14	FP14
Quality	Mil Temp	Mil Temp	QMLQ
Date Code	9910	0206	9849A
Tested Sample	#1, #2	#1, #2	#1, #2
Die Marking	R0082	ST, H9001 G008	FAiRCHilD Z008Y
Die Size (mm)	1.30 x 1.20	1.96 x 1.26	1.06 x 0.92

3.3 54AC157 / 54HC157 – Quad 2-Channel Multiplexer

The device type is logic circuit data selector and tested in static conditions in the same way as 54AC08 / 54HC08 with two oscilloscopes, one on nominal level=0 triggering on positive slope and one on nominal level=1 triggering on negative slope. A test configuration diagram is given in Fig 3.3.1. Details of the test samples are given in Fig 3.3.2 and Table 3.3.1

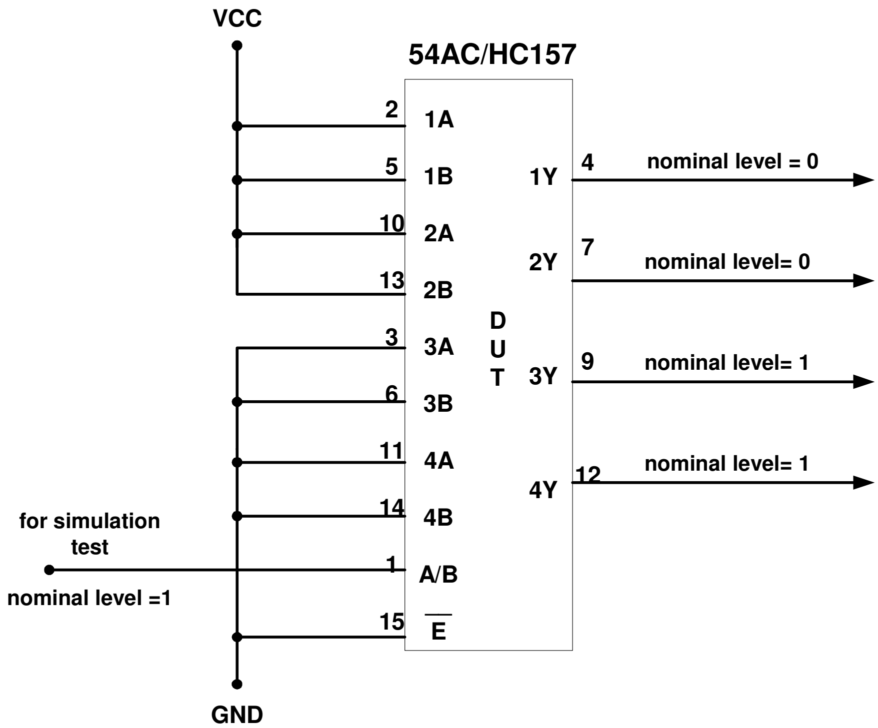

Fig 3.3.1 Test configuration diagram of 54AC157 / 54HC157

Fig 3.3.1 Picture of the top side of the packages for 54HC from STM. 54AC from STM and 54AC from NS

TABLE 3.3.1 DETAILS OF TEST SAMPLES 54HC157 / 54AC157

Manufacturer	STM	STM	NS
Part Type	54HC157	54AC157	54AC157
Package	FP16	FP16	FP16
Quality	Mil Temp	Mil Temp	QMLQ
Date Code	9915	0315A	9718A
Tested Sample	#1, #2	#1, #2	#1, #2
Die Marking	R157	ST G157	FAiRCHilD Z157Y
Die Size (mm)	1.90 x 1.36	1.78 x 1.22	1.16 x 1.16

3.4 54AC244 Octal Buffers with Tri-State Outputs

This device type is tested in static conditions for all three states.
Two modes when the Output Enable is set to truth, 1Y0 & 1Y1 are forced to high and 1Y2 and 1Y3 are forced to low. Two modes when the Output Enable is set to false, i.e. when the output is in the high impedance mode; 2Y0 and 2Y1 are galvanic connected to ground via resistors and will test 0 to 1 false; 2Y1 & 2Y2 will test 1 to 0 false.
Events from the NAND / OR were captured and counted by two oscilloscopes, which also stored the pulse profile of accumulated events. A test configuration diagram is given in Fig 3.4.1. Details of the test samples are given in Fig 3.4.2 and Table 3.4.1.

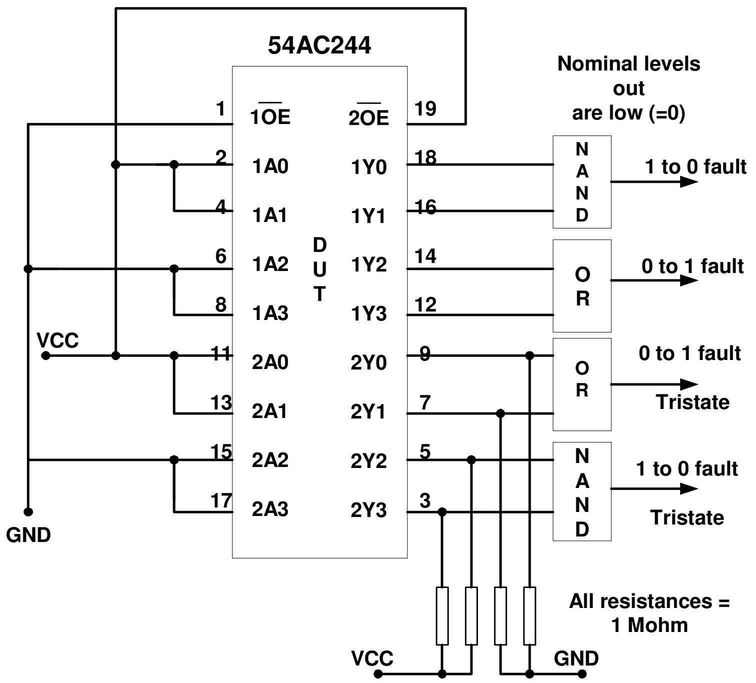

Fig 3.4.1 Test configuration diagram of 54AC244

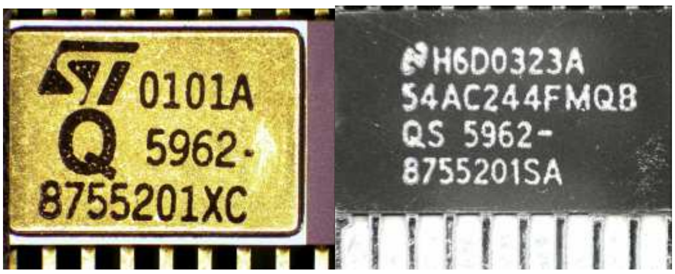

Fig 3.4.2 Picture of the top side of the packages for 54AC from STM and 54AC from NS

TABLE 3.4.1 DETAILS OF 54AC244

Manufacturer	STM	NS
Part Type	54AC244	54AC244
Package	FP20	FP20
Quality	Mil Temp	QMLQ
Date Code	0101A	0323A
Tested Sample	#1, #2	#1, #2
Die Marking	ST, N2403 N244	NSFM, Z244W J240W
Die Size (mm)	1.86 x 1.24	1.48 x 1.36

3.5 54AC257 Quad 2-to-1 Line Selector/Multiplexer

Single Event Transients (SET) pulses were measured using a feeding-and-counting technique[2]. The DUT board was connected to a LVDS driver on the input and a LVDS receiver on the output. Dynamic tests were performed by feeding the driver with accurate known frequency (2.5 MHz) and measuring the response at the receiver side after the frequency train has passed the DUT during irradiation. As the feeding-counting system a Pulse-/Pattern generator (HP81130A 400/660 MHz) were used together with a High Resolution programmable Timer/Counter (Fluke PM6680B). Any difference between fed and measured frequency will be reported as an SET.
A test configuration diagram is given in Fig 3.5.1. Details of the test samples are given in Fig 3.5.2 and Table 3.5.1.

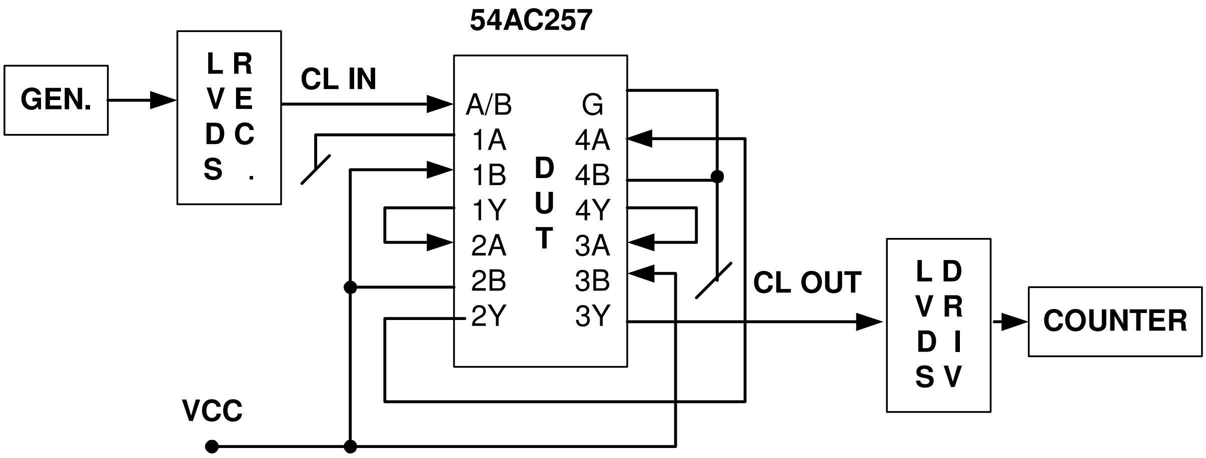

Fig 3.5.1 Test configuration diagram of 54AC257

Fig 3.5.2 Picture of the top side of the packages for 54AC257 from STM and 54AC257 from NS

TABLE 3.5.1 DETAILS OF 54AC257

Manufacturer	STM	NS
Part Type	54AC257	54AC257
Package	FP16	FP16
Quality	MIL Temp	QMLQ
Date Code	9844	9951A
Tested Sample	#1, #2	#1, #2
Die Marking	ST, N257 N257l	FAiRCHilD J157X, Z257X
Die Size (mm)	1.70 x 1.26	1.22 x 1.22

3.6 54AC273 / HC273 – Octal D Type Flip-Flop with Clear

The device is tested continuously during irradiation according to the set-up shown in Fig 3.6.1. Computer generated data patterns are fed thru the device at a frequency of 25 kHz. Details of the test samples are given in Fig 3.6.2 and Table 3.6.1

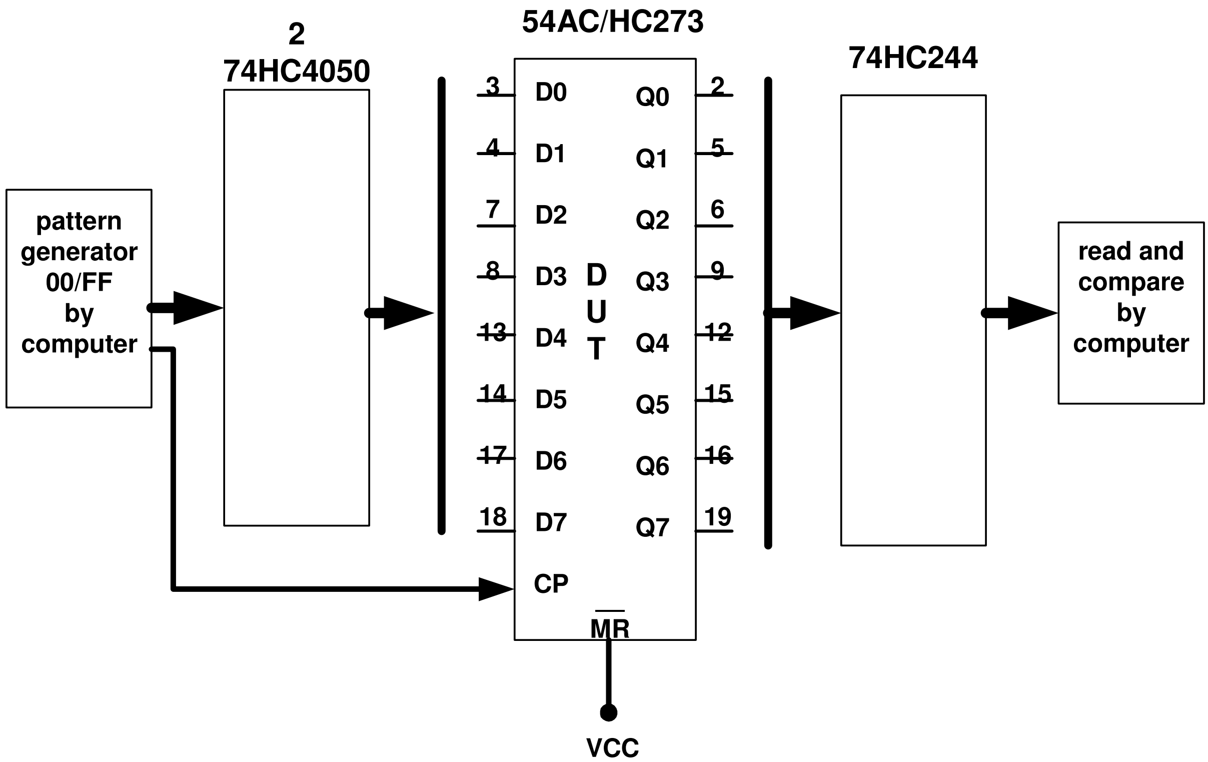

Fig 3.6.1 Test configuration diagram of 54AC273 / 54HC273. Logics at input and output are used for voltage adoption to the various test voltages of the DUT.

Fig 3.6.2 Picture of the top side of the packages for 54HC273 from STM. 54AC273 from STM and 54AC273 from NS

TABLE 3.6.1 DETAILS OF TEST SAMPLES 54HC273 / 54AC273

Manufacturer	STM	STM	NS
Part Type	54HC273	54AC273	54AC273
Package	FP20	FP20	FP20
Quality	Mil Temp	Mil Temp	QMLQ
Date Code	9527	0316A	9548A
Tested Sample	#1, #2	#1, #2	#1, #2
Die Marking	R273 2	ST, N273	FAiRCHilD Z273Z
Die Size (mm)	2.04 x 1.80	2.00 x 1.12	1.66 x 1.46

3.7 54HC4040 – 12 Stage Binary Ripple Counter

The device has been tested in a golden chip configuration. During irradiation the 12-bits output word of the DUT and the golden chip was compared synchronously at each clock period at a rate of 2.5 MHz. Errors were stored on PC. A test configuration diagram is given in Fig 3.7.1. Details of the test samples are given in Fig 3.7.2 and Table 3.7.1

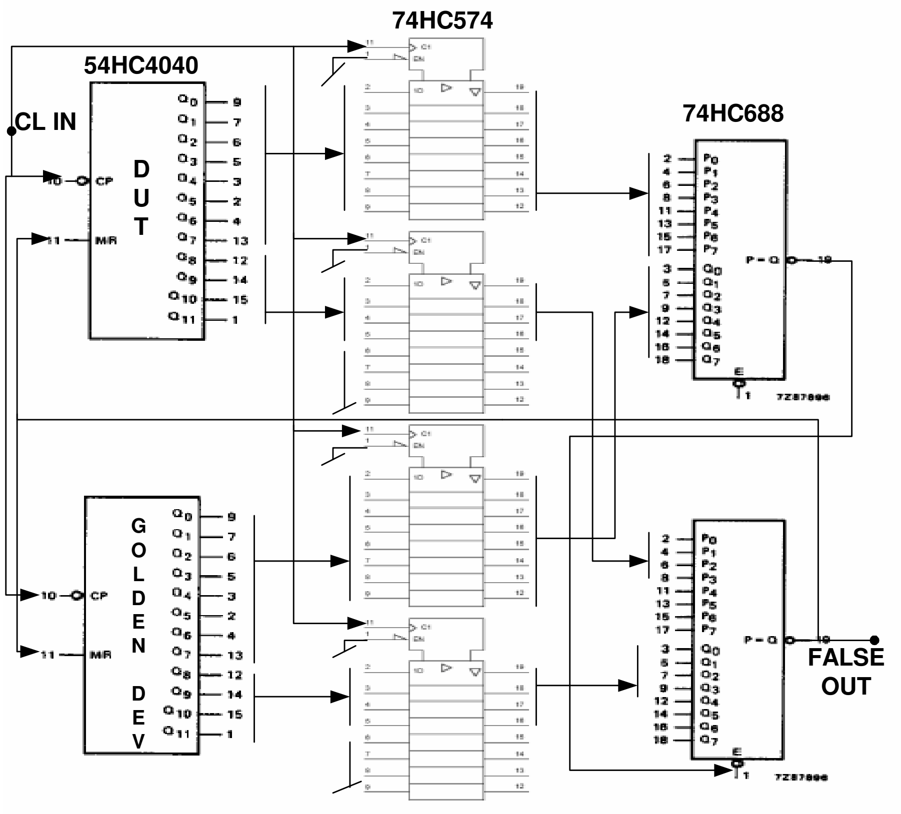

Fig 3.7.1 Test configuration diagram of 54HC4040

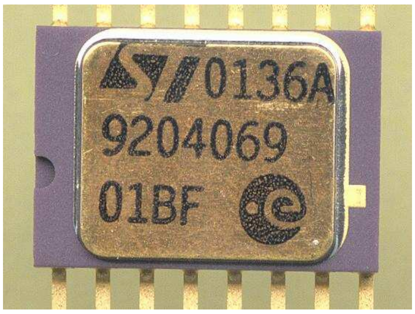

Fig 3.7.2 Picture of the top side of the package for 54HC4040 from STM

TABLE 3.7.1 DETAILS OF 54HC4040

Manufacturer	STM
Part Type	54HC4040
Package	FP16
Quality	Mil Temp
Date Code	0136
Tested Sample	61 & 62
Die Marking	Z440
Die Size (mm)	2.44 x 1.74

3.8 54HC4053 – Analog Mux / Demux, Triple 2 Channel

This device type is tested in static mode with the triple channel connected in a chain. Error was counted with an oscilloscope which also stored the pulse profile of accumulated events.
A test configuration diagram is given in Fig 3.8.1. Details of the test samples are given in Fig 3.8.2 and Table 3.8.1

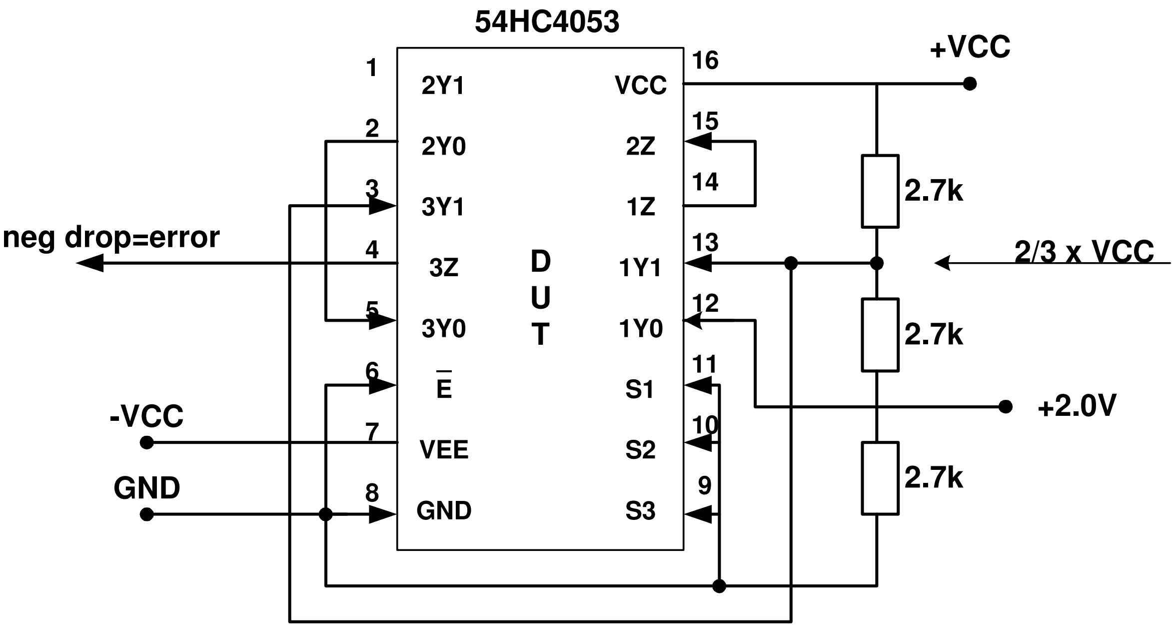

Fig 3.8.1 Test configuration diagram of 54HC4053

Fig 3.8.2 Picture of the top side of the package for 54HC4053 from STM

TABLE 3.8.1 DETAILS OF 54HC4053

Manufacturer	STM
Part Type	54HC40404
Package	DIL300
Quality	Mil Temp
Date Code	0308A
Tested Sample	27 & 28
Die Marking	Z453
Die Size (mm)	2.18 x 1.80

4. RESULTS

4.1 General

All device types have been tested at the three bias conditions +2.5V, +3.3V and +5V. Two samples of each type have been tested. No single event Latch-up was observed. Several of the types were SEU/SET insensitive to heavy ions up to maximum LET value available. The results for these types are only summarized in Table 5.1 for worst case voltage bias condition. Generally, the devices are working down below 2V. Test performed on the specification limits indicated no different results from 2.5V.

TABLE 4.1 SUMMARY OF DATA FOR DEVICE TYPES WHERE NO ERROR WAS OBSERVED TO THE MAXIMUM LET-VALUE AVAILABLE. THE RESULTS ARE ONLY GIVEN FOR 2.5V, WHICH IS CONSIDERED TO BE WORST CASE BIAS CONDITION

Type	Manufacturer	LET Effective	Fluence	SEU/ SET 2,5V	Cross Section (MeVx cm^2/mg)	Comments
54HC08	STM	111.8	1e6	0	<1e-6	
54AC08	STM	111.8	1e6	0	<1e-6	
54AC08	NS	111.8	2e6	0	<5e-7	
54HC157	STM	111.8	1e6	0	<1e-6	
54AC157	STM	111.8	1e6	0	<1e-6	
54AC157	NS	111.8	4e6	0	<2.5e-7	
54AC244	STM	64.8	2e6	1	<5e-7	Tristate 1-0 *
54AC244	NS	64.8	1e6	0	<1e-6	High penetration ions
45AC257	STM	111.8	1e6	0	<1e-6	
54AC257	NS	111.8	2e6	0	<5e-7	

** This error appeared immediately at beam-on and could not be repeated by new test runs or more statistics. The error may be induced by other means than heavy ions.*

4.2 Logic Circuits

The D flip/flop logic circuits represented by 54AC273 and 54HC273 indicated increased cross section and lower threshold values with decreasing voltage. The results are shown in Figs 4.2.1 to 4.2.3. The largest effect of decreasing voltage was observed between 5V and 3.3V. The SEU difference between 3.3V and 2.5 were marginal in all cases. The STM 54AC part indicated lower cross section and high threshold than corresponding NS part. The 54HC part has significantly higher cross section than the 54AC parts, while the 54AC parts have lower threshold than the 54HC273.
The two device types 54HC273 and 54HC4040 indicated the same increase in heavy ion sensitivity for lower bias levels, while 54HC4040 show significantly higher threshold than 45HC273. The results for 54HC4040 are given in Fig 4.2.4.
The change in threshold value between 5V and 3.3V is generally lager than shown in the figures due to the limited statistics. There is usually only one error in 1E6 ions/cm^2 at the lowest measured LET values.

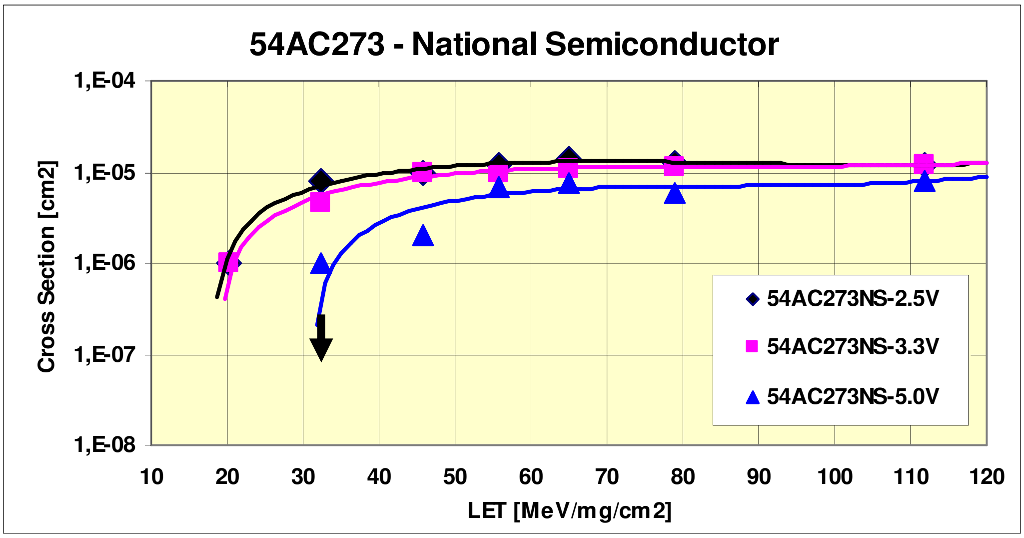

Figure 4.2.1 . Cross Section versus LET value for 54AC273 from National Semiconductor. The graph shows the average results of two tested devices. The arrow at 1E-7 MeV/mg/cm^2 indicates zero measured SEU.

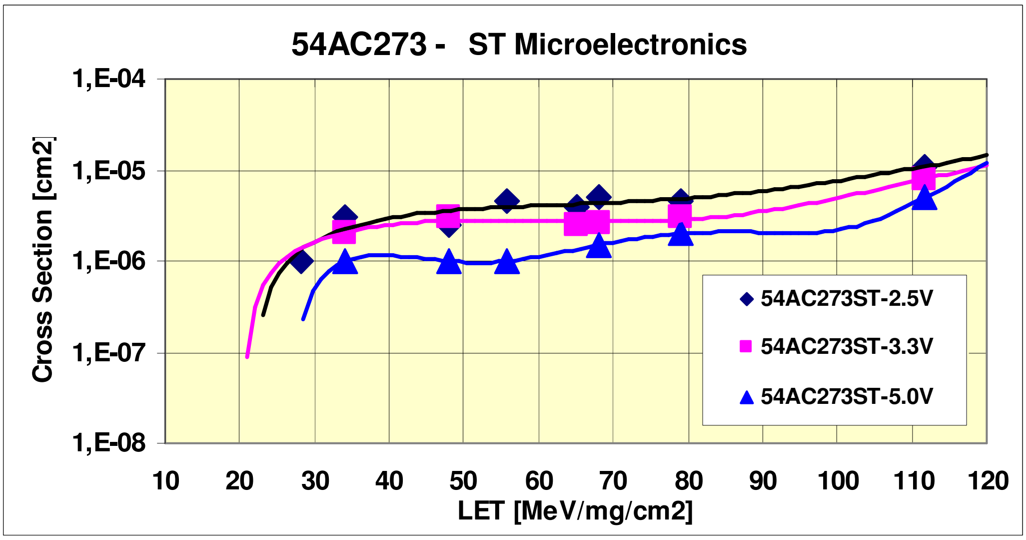

Figure 4.2.2 . Cross Section versus LET value for 54AC273 from ST Microelectronics. The graph shows the average results of two tested devices.

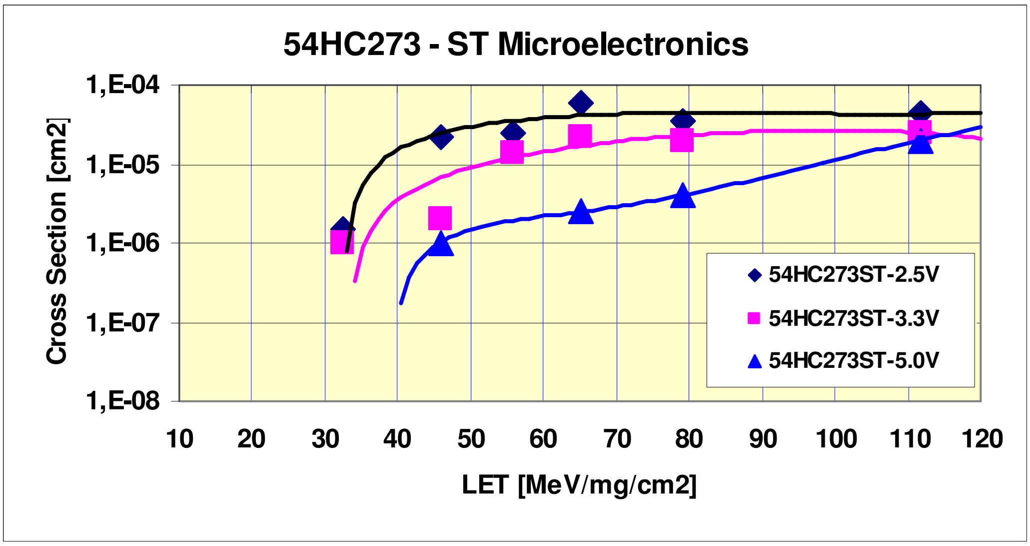

Figure 4.2.3 . Cross Section versus LET value for 54AC273 from ST Microelectronics. The graph shows the average results of two tested devices.

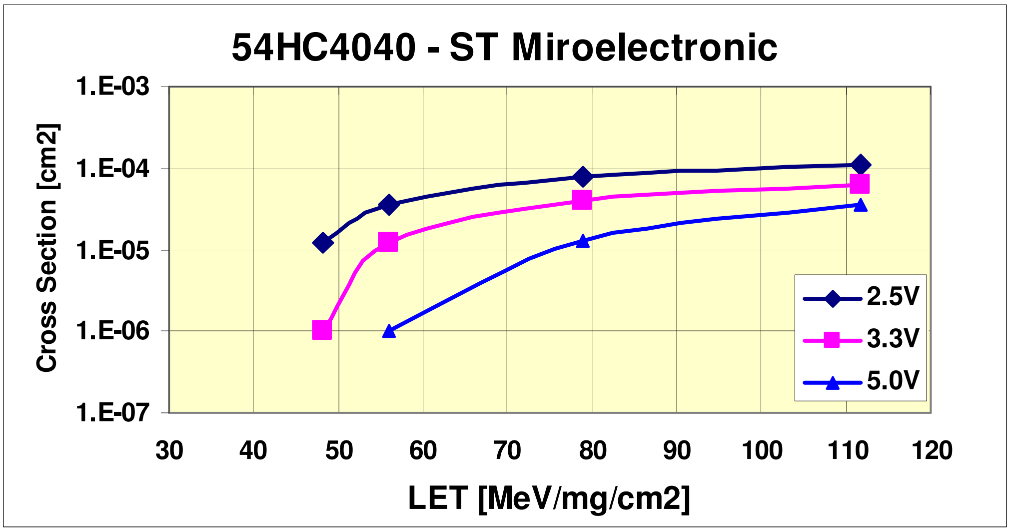

Figure 4.2.4 Cross Section versus LET value for 54HC4040 from ST Microelectronics. The graph shows the average results of two tested devices. The test results for 5V was zero at LET=48.1 MeV/mg/cm^2 and zero for 2.5V at LET=34 MeV/mg/cm^2.

4.3 Analog Circuits

The analog multiplexer/demultiplexer has been tested at the three bias condition 2.5V, 3.3V and 5V using the same analog input signal at 2V. The analog device 54HC4053 indicates opposite to the digital logics the same SET sensitivity independent of bias conditions. The cross sections for the various bias conditions are shown in Fig 4.3.1. The SET pulse shapes for different bias conditions and different LET-values were very similar. One example of SET pulse shape is given in Fig 4.3.2. Maximum measured pulse width was around 200 ns.

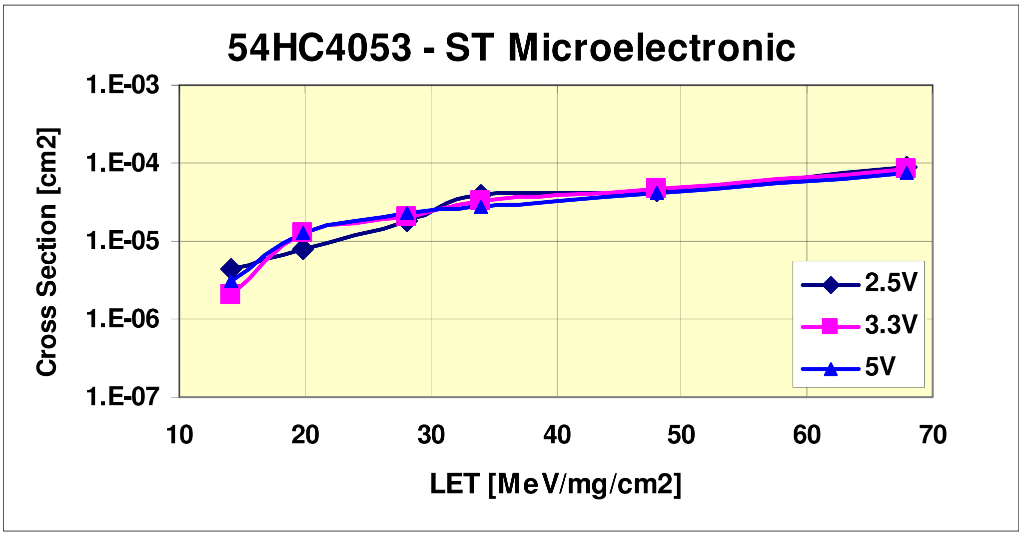

Figure 4.3.1 . Cross Section versus LET value for 54HC4053 from ST Microelectronics. The graph shows the average results of two tested devices.

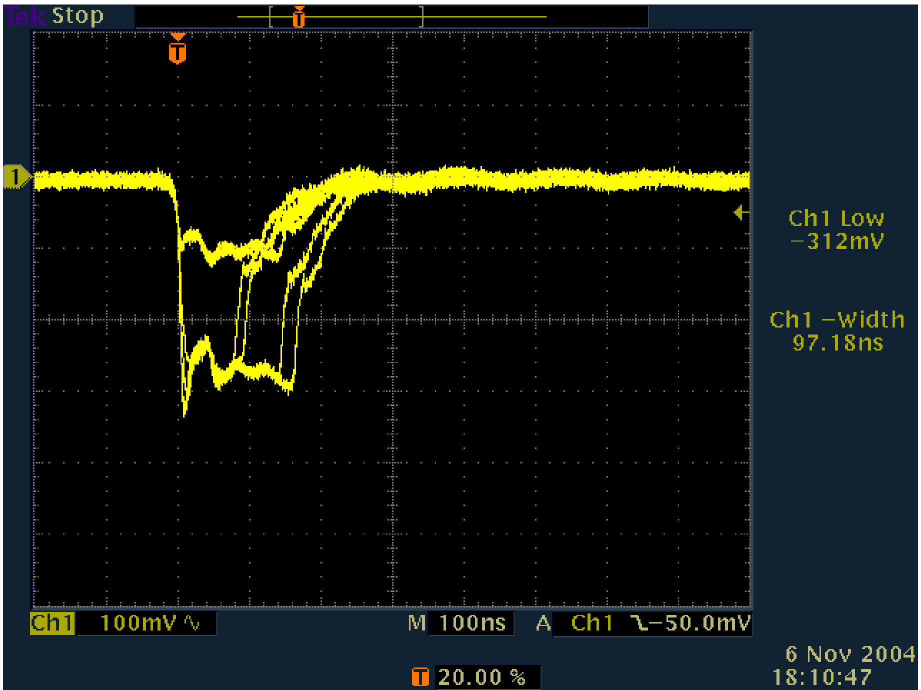

Figure 4.3.2 SET pulse shape for 54HC4053, LET=14 MeV/mg/cm^2, Vcc=5V

5. CONCLUSION

Present data for the selected 54HC devices show very similar 5V SEU/SET behaviour as reported in earlier tests [1] for almost 10 years ago.
The selected 54AC/54HC logic gate devices are found to be insensitive to heavy ions up to an LET of 110 $MeV/mg/cm^2$ (see Table 4.1 for details).

For Analog logics the SET sensitivity is not affected by the voltage level at all.

For Digital AC/HC logics, present data indicate higher susceptibility to SEU/SET when operated at lower voltages. The relationship observed between threshold-LET and bias voltage level varied between the digital device types. For some types the threshold increased smoothly with increased bias, whereas others indicated more abrupt increases. Because of these irregularities, SEU results obtained at 5V cannot safely be extrapolated to lower voltages.

6. APPENDIX

UCL 2004 April 21-22								
Run#	Ion	Tilt (º)	LET	Flux	Fluence	Bias (V)	Data	Part_dev_#
5	Xe	0	55.9	3000	1.E+06	2.5	0	AC08_NS-1
7	Xe	60	111.8	3000	1.E+06	2.5	0	AC08_NS-1
8	Xe	60	111.8	3000	1.E+06	2.5	0	AC08_NS-1
9	Xe	60	111.8	3000	1.E+06	5.0	0	AC08_NS-2
10	Xe	60	111.8	3000	1.E+06	5.0	0	AC08_ST-1
11	Xe	60	111.8	3000	1.E+06	2.5	0	AC08_ST-1
12	Xe	60	111.8	3000	3.E+05	2.5	0	AC157_NS-1
13	Xe	60	111.8	3000	1.E+06	2.5	0	AC157_NS-1
14	Xe	60	111.8	3000	1.E+06	5.0	0	AC157_NS-1
15	Xe	60	111.8	3000	1.E+06	5.0	0	AC157_ST-1
16	Xe	60	111.8	3000	1.E+06	2.5	0	AC157_ST-1
17	Xe	60	111.8	3000	1.E+06	2.5	0	HC157_ST-1
18	Xe	60	111.8	3000	1.E+06	5.0	0	HC157_ST-1
19	Xe	60	111.8	3000	1.E+06	5.0	0	HC08_ST-1
20	Xe	60	111.8	3000	1.E+06	2.5	0	HC08_ST-1
21	Xe	0	55.9	4500	1.E+06	5.0	14	AC273_NS-1
23	Xe	45	79.0	4500	1.E+06	5.0	12	AC273_NS-1
24	Xe	60	111.8	3000	1.E+06	5.0	16	AC273_NS-1
25	Xe	60	111.8	3000	1.E+06	3.3	24	AC273_NS-1
26	Xe	45	79.0	4500	1.E+06	3.3	23	AC273_NS-1
27	Xe	0	55.9	6000	1.E+06	3.3	20	AC273_NS-1
28	Xe	0	55.9	5300	1.E+06	2.5	24	AC273_NS-1
29	Xe	45	79.0	5300	1.E+06	2.5	25	AC273_NS-1
30	Xe	60	111.8	5300	1.E+06	2.5	24	AC273_NS-1
40	Xe	60	111.8	3500	1.E+06	5.0	33	AC273_ST-2
41	Xe	60	111.8	3500	1.E+06	3.3	32	AC273_ST-2
42	Xe	60	111.8	3600	1.E+06	2.5	44	AC273_ST-2
43	Xe	60	111.8	4000	1.E+06	2.5	87	HC273_ST-1
44	Xe	60	111.8	4000	1.E+06	3.3	50	HC273_ST-1
45	Xe	60	111.8	4000	1.E+06	5.0	20	HC273_ST-1
46	Xe	45	79.0	4000	1.E+06	5.0	4	HC273_ST-1
47	Xe	45	79.0	3700	1.E+06	3.3	40	HC273_ST-1
48	Xe	45	79.0	4500	1.E+06	2.5	72	HC273_ST-1
49	Xe	0	55.9	6500	1.E+06	2.5	49	HC273_ST-1
50	Xe	0	55.9	6500	1.E+06	3.3	27	HC273_ST-1
51	Xe	0	55.9	6500	1.E+06	5.0	0	HC273_ST-1

UCL 2004 Aug. 27								
Run#	Ion	Tilt (º)	LET	Flux	Fluence	Bias (V)	Data	Part_dev_#
101	Kr	45	45.8	5000	1.E+06	2.5	21	HC273_ST-1
102	Kr	45	45.8	5000	1.E+06	3.3	2	HC273_ST-1
103	Kr	0	32.4	5000	1.E+06	3.3	0	HC273_ST-1
104	Kr	0	32.4	5000	1.E+06	2.5	2	HC273_ST-1
105	Kr	60	64.8	5000	1.E+06	2.5	70	HC273_ST-1
108	Kr	60	64.8	5000	1.E+06	3.3	12	AC273_NS-1
109	Kr	60	64.8	5000	1.E+06	5.0	7	AC273_NS-1
111	Kr	45	45.8	5000	1.E+06	2.5	10	AC273_NS-1
112	Kr	45	45.8	5000	1.E+06	3.3	14	AC273_NS-1
113	Kr	45	45.8	5000	1.E+06	5.0	2	AC273_NS-1
114	Kr	0	32.4	5000	1.E+06	5.0	0	AC273_NS-1
115	Kr	0	32.4	5000	1.E+06	3.3	4	AC273_NS-1
116	Kr	0	32.4	5000	1.E+06	2.5	7	AC273_NS-1
117	Kr	60	64.8	5000	1.E+06	3.3	27	HC273_ST-1
118	Kr	60	64.8	5000	1.E+06	5.0	2	HC273_ST-1
119	Kr	60	64.8	5000	1.E+06	5.0	0	AC273_ST-1
120	Kr	60	64.8	5000	1.E+06	2.5	4	AC273_ST-1
121	Kr	60	64.8	5000	1.E+06	3.3	5	AC273_ST-1
122	Kr	45	45.8	5000	1.E+06	3.3	1	AC273_ST-1
123	Kr	45	45.8	5000	1.E+06	2.5	2	AC273_ST-1
134	Kr	0	32.4	8000	1.E+06	5.0	0	HC273_ST-2
135	Kr	0	32.4	8000	1.E+06	2.5	1	HC273_ST-2
136	Kr	45	45.8	8000	1.E+06	2.5	22	HC273_ST-2
137	Kr	45	45.8	8000	1.E+06	3.3	2	HC273_ST-2
138	Kr	60	64.8	8000	1.E+06	3.3	16	HC273_ST-2
139	Kr	60	64.8	8000	1.E+06	2.5	50	HC273_ST-2
140	Kr	60	64.8	8000	1.E+06	5.0	3	HC273_ST-2
141	Kr	60	64.8	8000	1.E+06	5.0	8	AC273_NS-2
142	Kr	60	64.8	8000	1.E+06	3.3	10	AC273_NS-2
143	Kr	60	64.8	8000	1.E+06	2.5	12	AC273_NS-2
144	Kr	45	45.8	8000	1.E+06	2.5	10	AC273_NS-2
145	Kr	45	45.8	8000	1.E+06	3.3	6	AC273_NS-2
146	Kr	45	45.8	8000	1.E+06	5.0	2	AC273_NS-2
147	Kr	0	32.4	8000	1.E+06	2.5	9	AC273_NS-2
148	Kr	0	32.4	8000	1.E+06	3.3	5	AC273_NS-2
149	Kr	0	32.4	8000	1.E+06	5.0	0	AC273_NS-2
162	Ar	60	20.2	8000	1.E+06	2.5	0	AC273_NS-2
163	Ar	60	20.2	8000	1.E+06	3.3	0	AC273_NS-2
169	Kr	60	64.8	8000	1.E+06	2.5	0	AC244_ST-1*
170	Kr	60	64.8	8000	1.E+06	2.5	1	AC244_ST-1**
171	Kr	60	64.8	8000	1.E+06	2.5	0	AC244_ST-1**
172	Kr	60	64.8	8000	1.E+06	2.5	0	AC244_NS-1**
173	Kr	60	64.8	8000	1.E+06	2.5	0	AC244_NS-1*

* Static output tested (low and high)

** Tristate output tested

UCL 2004 Nov. 6-7								
Run#	Ion	Tilt (º)	LET	Flux	Fluence	Bias (V)	Data	Part_dev_#
173	Xe	0	55.9	3000	5.E+05	2.5	8	HC4040_ST-61
174	Xe	0	55.9	4000	5.E+05	3.3	6	HC4040_ST-61
175	Xe	0	55.9	4000	5.E+05	5.0	1	HC4040_ST-61
176	Xe	45	79.0	3500	5.E+05	5.0	6	HC4040_ST-61
177	Xe	45	79.0	3500	5.E+05	3.3	19	HC4040_ST-61
178	Xe	45	79.0	3500	5.E+05	2.5	39	HC4040_ST-61
179	Xe	60	111.8	2500	5.E+05	2.5	58	HC4040_ST-61
180	Xe	60	111.8	2500	5.E+05	3.3	33	HC4040_ST-61
181	Xe	60	111.8	2500	5.E+05	5.0	21	HC4040_ST-61
182	Xe	60	111.8	4000	5.E+05	3.3	28	HC4040_ST-62
183	Xe	60	111.8	4000	5.E+05	2.5	54	HC4040_ST-62
184	Xe	60	111.8	4000	5.E+05	5.0	14	HC4040_ST-62
185	Xe	45	79.0	6000	5.E+05	5.0	7	HC4040_ST-62
186	Xe	45	79.0	6000	5.E+05	3.3	21	HC4040_ST-62
187	Xe	45	79.0	6000	5.E+05	2.5	40	HC4040_ST-62
188	Xe	0	55.9	8000	5.E+05	2.5	21	HC4040_ST-62
189	Xe	0	55.9	8000	5.E+05	3.3	6	HC4040_ST-62
190	Xe	0	55.9	8000	5.E+05	5.0	0	HC4040_ST-62
194	Xe	0	55.9	6000	5.E+05	2.5	19	HC4040_ST-62
199	Kr	45	48.1	6000	5.E+05	2.5	8	HC4040_ST-61
200	Kr	45	48.1	6000	1.E+06	2.5	11	HC4040_ST-61
201	Kr	45	48.1	6000	1.E+06	3.3	1	HC4040_ST-61
202	Kr	45	48.1	6000	1.E+06	5.0	0	HC4040_ST-61
203	Kr	0	34.0	10000	1.E+06	2.5	0	HC4040_ST-61
204	Kr	0	34.0	10000	1.E+06	2.5	0	HC4040_ST-62
205	Kr	45	48.1	10000	1.E+06	2.5	11	HC4040_ST-62
206	Kr	45	48.1	10000	1.E+06	3.3	1	HC4040_ST-62
207	Kr	45	48.1	10000	1.E+06	5.0	0	HC4040_ST-62
213	Kr	0	34.0	8000	1.E+06	5.0	34	HC4053_ST-27
214	Kr	0	34.0	8000	1.E+06	3.3	31	HC4053_ST-27
215	Kr	0	34.0	8000	1.E+06	2.5	34	HC4053_ST-27
216	Kr	45	48.1	8000	1.E+06	2.5	37	HC4053_ST-27
217	Kr	45	48.1	8000	1.E+06	3.3	47	HC4053_ST-27
220	Kr	45	48.1	8000	1.E+06	5.0	34	HC4053_ST-27
222	Kr	45	48.1	8000	1.E+06	5.0	47	HC4053_ST-28
223	Kr	45	48.1	7500	1.E+06	3.3	48	HC4053_ST-28
225	Kr	0	34.0	8000	1.E+06	2.5	45	HC4053_ST-28
226	Kr	0	34.0	8000	1.E+06	3.3	33	HC4053_ST-28
227	Kr	0	34.0	8000	1.E+06	5.0	22	HC4053_ST-28
228	Kr	60	68.0	8000	1.E+06	5.0	72	HC4053_ST-28
229	Kr	60	68.0	8000	1.E+06	3.3	82	HC4053_ST-28
230	Kr	60	68.0	8000	1.E+06	2.5	79	HC4053_ST-28
235	Kr	60	68.0	8000	1.E+06	2.5	94	HC4053_ST-27
236	Kr	60	68.0	8000	1.E+06	3.3	82	HC4053_ST-27

237	Kr	60	68.0	8000	1.E+06	5.0	80	HC4053_ST-27
239	Ar	60	28.0	8000	1.E+06	5.0	22	HC4053_ST-27
240	Ar	60	28.0	8000	1.E+06	3.3	22	HC4053_ST-27
241	Ar	60	28.0	8000	1.E+06	2.5	18	HC4053_ST-27
242	Ar	45	19.8	8000	1.E+06	2.5	7	HC4053_ST-27
244	Ar	45	19.8	8000	1.E+06	3.3	13	HC4053_ST-27
245	Ar	45	19.8	8000	1.E+06	5.0	14	HC4053_ST-27
246	Ar	0	14.0	8000	1.E+06	5.0	3	HC4053_ST-27
248	Ar	0	14.0	8000	1.E+06	3.3	0	HC4053_ST-27
249	Ar	0	14.0	8000	1.E+06	2.5	2	HC4053_ST-27
251	Ar	0	14.0	8000	1.E+06	2.5	7	HC4053_ST-28
252	Ar	0	14.0	8000	1.E+06	3.3	4	HC4053_ST-28
253	Ar	0	14.0	8000	1.E+06	5.0	3	HC4053_ST-28
254	Ar	45	19.8	8000	1.E+06	5.0	12	HC4053_ST-28
255	Ar	45	19.8	8000	1.E+06	3.3	12	HC4053_ST-28
256	Ar	45	19.8	8000	1.E+06	2.5	9	HC4053_ST-28
257	Ar	60	28.0	8000	1.E+06	2.5	18	HC4053_ST-28
258	Ar	60	28.0	8000	1.E+06	3.3	18	HC4053_ST-28
259	Ar	60	28.0	8000	1.E+06	5.0	24	HC4053_ST-28
260	Ar	60	28.0	4000	1.E+06	2.5	0	AC273_ST-3
261	Ar	60	28.0	6000	1.E+06	2.5	0	AC273_ST-4
264	Kr	60	68.0	6000	1.E+06	2.5	5	AC273_ST-4
265	Kr	60	68.0	8000	1.E+06	3.3	3	AC273_ST-4
266	Kr	60	68.0	8000	1.E+06	5.0	2	AC273_ST-4
268	Kr	45	48.1	7000	1.E+06	5.0	0	AC273_ST-4
269	Kr	45	48.1	7000	1.E+06	3.3	5	AC273_ST-4
270	Kr	45	48.1	7000	1.E+06	2.5	4	AC273_ST-4
271	Kr	0	34.0	10000	1.E+06	2.5	3	AC273_ST-4
272	Kr	0	34.0	10000	1.E+06	3.3	2	AC273_ST-4
273	Kr	0	34.0	10000	1.E+06	3.3	2	AC273_ST-3
274	Kr	0	34.0	10000	1.E+06	2.5	3	AC273_ST-3
291	Xe	0	55.9	10000	1.E+06	2.5	4	AC273_ST-4
292	Xe	45	79.0	10000	1.E+06	2.5	5	AC273_ST-4
293	Xe	45	79.0	10000	1.E+06	3.3	3	AC273_ST-4
294	Xe	45	79.0	10000	1.E+06	5.0	2	AC273_ST-4
296	Xe	60	111.8	10000	1.E+06	3.3	7	AC273_ST-4
297	Xe	60	111.8	10000	1.E+06	2.5	11	AC273_ST-4
299	Xe	0	55.9	5000	1.E+06	2.5	0	AC257_ST-1
300	Xe	60	111.8	5000	1.E+06	2.5	0	AC257_ST-1
301	Xe	60	111.8	5000	1.E+06	2.5	0	AC257_NS-1
302	Xe	60	111.8	7500	1.E+06	2.5	0	AC257_ST-3
303	Xe	0	55.9	5000	1.E+06	2.5	0	AC257_ST-3
304	Xe	0	55.9	5000	1.E+06	2.5	0	AC257_NS-1
305	Xe	0	55.9	5000	1.E+06	5.0	0	AC257_NS-2
306	Xe	60	111.8	4000	1.E+06	5.0	0	AC257_NS-2
307	Xe	60	111.8	4000	1.E+06	5.0	0	AC257_NS-4
308	Xe	60	111.8	4000	1.E+06	5.0	0	AC257_ST-2
309	Xe	60	111.8	4000	1.E+06	5.0	0	AC257_ST-4
310	Xe	60	111.8	4000	1.E+06	2.2	0	AC257_NS-1