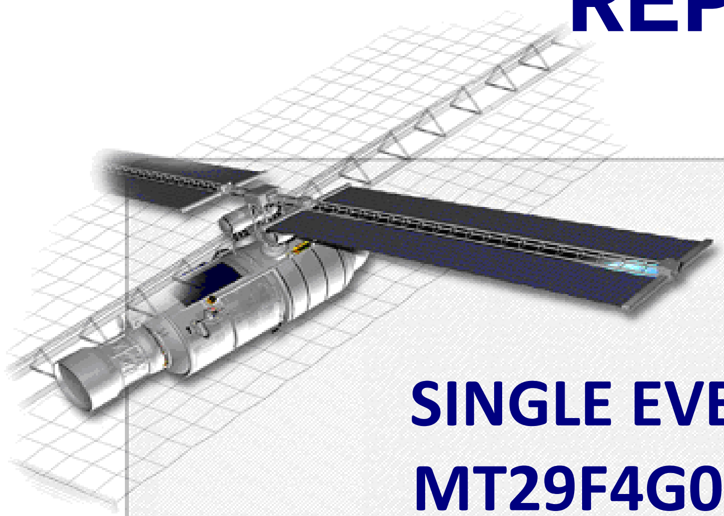
HEAVY IONS TEST REPORT



SINGLE EVENT EFFECTS
MT29F4G08ABADAWP
(DC1350)
4Gb, x8 NAND Flash Memory
From
Micron

TRAD/TI/MT29F4G08ABADAWP/1350/ESA/LG/1409		Labège, 10 September 2015
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Revision: 1		
To: **ESA** **Marc POIZAT**		Project/Program: TID influence on the SEE sensitivity of active EEE components **Ref: ESTEC Contract No.4000111336/14/NL/SW**

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1. Introduction

This report includes the test results of the heavy ions Single Event Effects (SEEs) test sequence carried out on the **MT29F4G08ABADAWP**, a **4Gb, x8 NAND Flash Memory** from **Micron.**

This test was performed for **ESA** at U.C.L (Université Catholique de Louvain, Louvain la Neuve, Belgium) on October 27th and 28th, 2014 and November 26th and 28th, 2014. Ten samples were irradiated.

This test was performed for **ESA** on the **MT29F4G08ABADAWP** susceptible to show Single Event Latchups (SELs), Single Event Upsets (SEUs) and Single Event Functional Interrupts (SEFIs) induced by heavy ions. This test was performed as part of a global study to evaluate the potential synergetic effects of TID on SEE sensitivity. As a result, the development strategy for this test was not the characterization of the MT29F4G08ABADAWP itself, but the evolution of its SEE sensitivity after submission to TID. The results presented in this report were obtained before TID irradiation (0 krad).

2. Documents

2.1. Applicable documents

Financial and technical proposal: TRAD/P/ESA/AO7751/AV/130214 Rev.0
Irradiation test plan: ITP/TRA/TI/MT29F4G08/TSOPI-48/MIC/190814 issue 1 of 15/10/2015

2.2. Reference documents

Data-sheet: Datasheet from Micron N°09005aef83b25735 Rev N of 10/2012

3. Organization of Activities

The relevant company has performed the following tasks during this evaluation:

1	Procurement of Test Samples	TRAD
2	Preparation of Test Samples (delidding)	TRAD
3	Preparation of Test Hardware and Test Program	TRAD
4	Samples Check	TRAD
5	Accelerator Test	TRAD
6	Heavy Ion Test Report	TRAD

Table 1: Organization of activities

4. Parts information

4.1. Device description

Micron NAND Flash devices include an asynchronous data interface for high-performance I/O operations. These devices use a highly multiplexed 8-bit bus (I/Ox) to transfer commands, address, and data. There are five control signals used to implement the asynchronous data interface: CE#, CLE, ALE, WE#, and RE#. Additional signals control hardware write protection and monitor device status (R/B#). This hardware interface creates a low pin-count device with a standard pinout that remains the same from one density to another, enabling future upgrades to higher densities with no board redesign.

4.2. Identification

Type:	MT29F4G08ABADAWP
Manufacturer:	Micron
Function:	4Gb, x8 NAND Flash Memory

4.3. Procurement information

Packaging:	TSOP - 48
Sample size:	10 parts procured by TRAD

4.4. Sample Preparation

All parts were delidded by TRAD.
No samples were damaged during this operation.
A functional test sequence was performed on delidded samples to check that devices were not degraded by the delidding operation.
Among the 10 delidded samples available for the test campaign, all were irradiated.

4.5. Sample pictures

4.5.1. External view

No marking was observed at the bottom of the package.

Figure 1: Package marking

4.5.2. Internal view

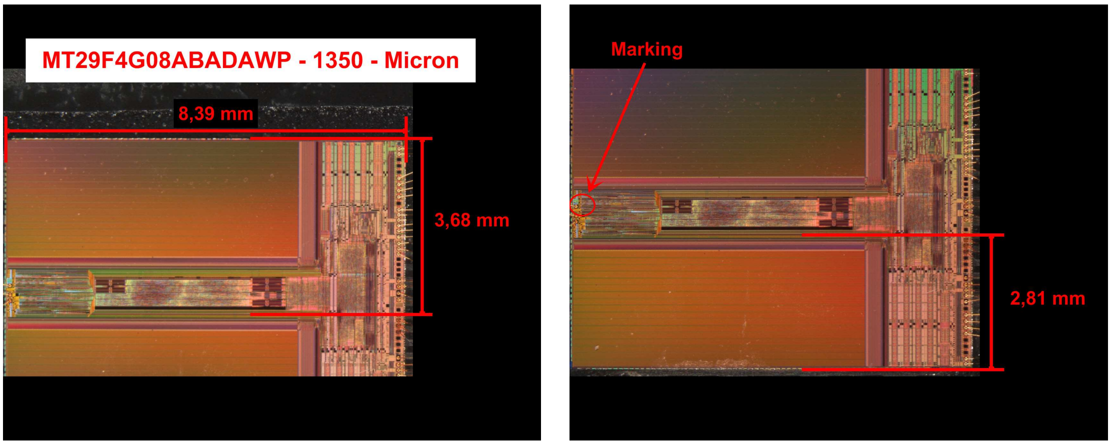


Figure 2: Internal overall view

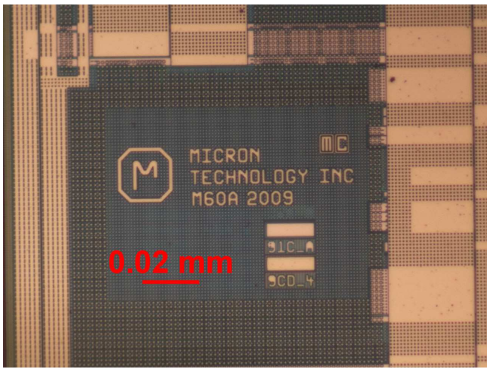


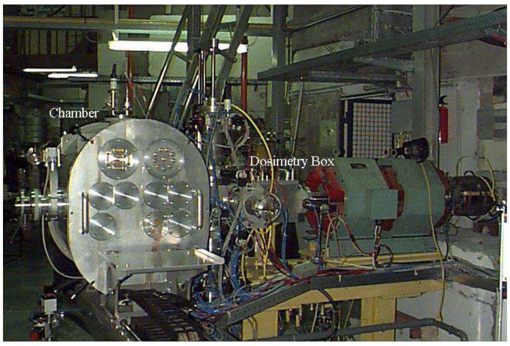
Figure 3: Die marking

5. Dosimetry and Irradiation Facilities

The test performed at U.C.L (Université Catholique de Louvain) on October 27th and 28th, 2014 and November 26th and 28th, 2014. Ten delidded samples were irradiated.

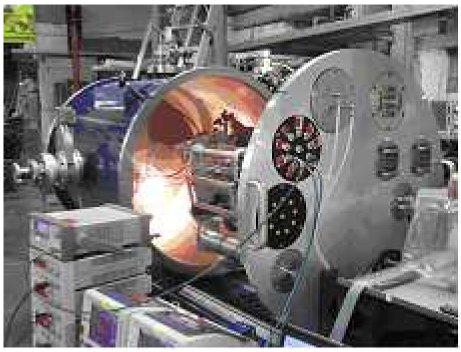
5.1. UCL Heavy Ion Test Facility (Université Catholique de Louvain - Belgique)

The CYClotron of LOuvain la NEuve (CYCLONE) is a multi-particle, variable energy, cyclotron capable of accelerating protons (up to 85 MeV), alpha particles and heavy ions.
For the heavy ions, the covered LET range is between 1.2 MeV.cm².mg^{-1} and 67.7 MeV.cm².mg^{-1}. Heavy ions available are separated in two “Ion Cocktails” named M/Q=5 and M/Q=3.3.



One of the main advantages of the UCL Heavy Ion Test Facility is the fast changing of ion species. Within the same cocktail, it takes only a few minutes to change from one ion to another.

The chamber has the shape of a barrel stretched vertically; its internal dimensions are 71 cm in height, 54 cm in width and 76 cm in depth. One side flange is used to support the board frame (25 X 25 cm) and user connectors.
The chamber is equipped with a vacuum system.



5.2. Dosimetry

To control and monitor the beam parameters, a dosimetry box is placed in front of the chamber.
It contains a faraday cup, 2 Parallel Plate Avalanche Counters (PPAC).
Two additional surface barrier detectors are placed in the test chamber.
The faraday cup is used during beam preparation at high intensity.
A beam uniformity measurement is performed with a collimated surface barrier detector. This detector is placed on a X and Y movement. The final profile is drawn and the ± 10 % width is calculated. The Homogeneity is ± 10 % on a 25 mm diameter.
During the irradiation, the flux is integrated in order to give the delivered total fluence (particule.cm^{-2}) on the device.

5.3. Beam characteristics

The beam flux is variable between a few particles $s^{-1}cm^{-2}$ and $1.8 \cdot 10^4 s^{-1}cm^{-2}$ depending on the device sensitivity.

Available heavy ion characteristics are listed in the following tables (heavy ions used during the experiment are highlighted in yellow):

Ion	Energy (MeV)	Range (µm(Si))	LET ($MeV.cm^2.mg^{-1}$)
$^{15}N^{3+}$	60	59	3.3
$^{20}Ne^{4+}$	78	45	6.4
$^{40}Ar^{8+}$	151	40	15.9
$^{84}Kr^{17+}$	305	39	40.4
$^{124}Xe^{25+}$	420	37	67.7

Table 2: UCL cocktail M/Q=5

Ion	Energy (MeV)	Range (µm(Si))	LET ($MeV.cm^2.mg^{-1}$)
$^{13}C^{4+}$	131	292	1.1
$^{22}Ne^{7+}$	235	216	3
$^{40}Ar^{12+}$	372	117	10.2
$^{58}Ni^{18+}$	567	100	20.4
$^{83}Kr^{25+}$	756	92	32.6

Table 3: UCL cocktail M/Q=3.3

6. Test Procedure and Setup

6.1. Test procedure

6.1.1. Description of the test method

The test was divided in two parts, with respect to reference or applicable documents:

- Runs were performed up to a fluence of 1.10^7 cm^{-2} with only SEL monitoring. This configuration allowed to verify the latchup sensitivity of the device.
- Runs were performed up to a fluence of 1.10^6 cm^{-2} for the SEU and SEFI detection. A latchup monitoring was used during these tests in order to protect the component. This configuration allowed to verify the SEU and SEFI sensitivity of the device.

The test was terminated when the maximum fluence was reached or when enough events were recorded to be statistically representative of the part behaviour.

6.1.2. SEL Test Principle

The test was performed at nominal operating voltage and ambient temperature.
TRAD has developed a fully integrated test bench to perform Single Event Latchup tests (SEL). The GUARD system (Graphical Universal Autorange Delatcher) allows to easily protect the device under test and perform SEL characterization.
The power supply is applied to the device under test through the GUARD system.
The threshold current of the GUARD system is set according to the nominal current. If the nominal current exceeds the threshold current, the GUARD system is triggered and the event is counted as an SEL. Then, the GUARD system sends a trigger command to the oscilloscope, maintains the power supply during a defined 'Time hold' and cuts it off during a defined 'Time cut'. Then, the power supply is restarted with the nominal current expected consumption.
At the end of each run, the test program reads the oscilloscope's "Local Scope Counter" which represents the total event count and downloads the recorded current waveforms to store them.

Figure 4 shows an example of the SEL detection.

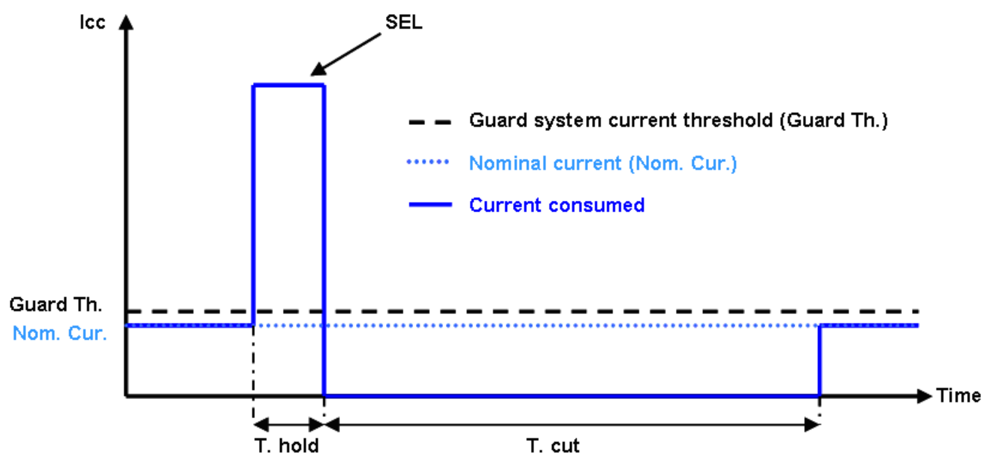


Figure 4: Common SEL characteristic.

During the test, the current consumption has been recorded with an ammeter and plotted for each run. As shown in figure 5, High Current Events (HCE) have been observed. They are defined as an abrupt increase of the UUT supply current, with a self recover within a random duration, typically a few seconds.
That type of event is not a real SEL as it recovers by itself.
With a SEL detection threshold of 50mA, the GUARD system did trigger on this type of events.
Run N°1 on part 1 and run N°3 on part 2 were performed without the GUARD system. All the other runs were performed with the SEL protection. Figure 5 shows an example of recorded HCE.

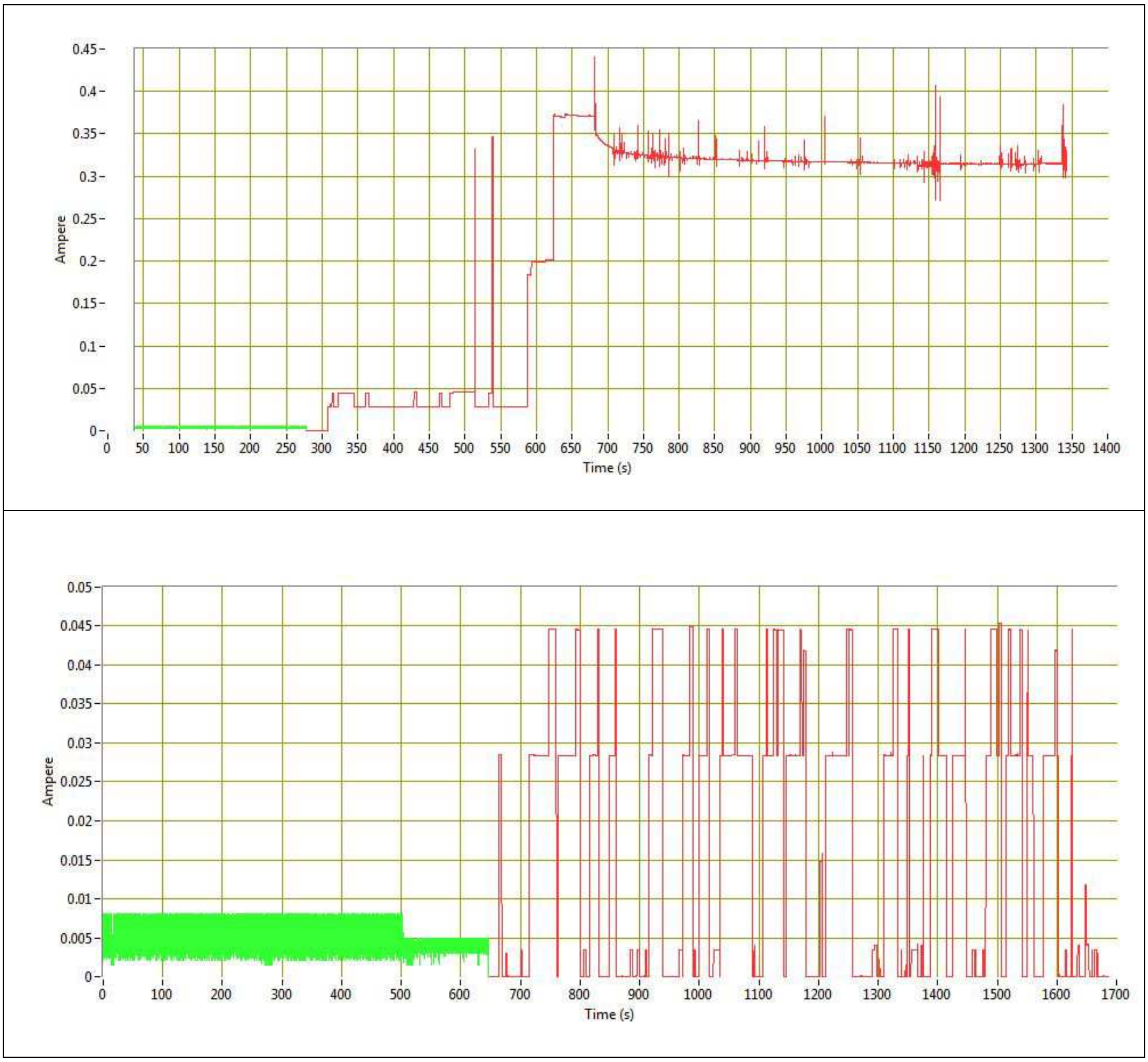


Figure 5: HCE examples.

6.1.3. SEU SEFI Test Principle

These tests are performed at nominal operating voltage and ambient temperature. Each NAND Flash memory tested was checked before the irradiation to evaluate its functionality. The functional test consists of a read/write cycles over the full memory depth. Tests in Retention, Standby and Read only modes were performed up to a fluence of 1.00E+6 #/cm², at ambient temperature.

Retention mode principle:
In Retention mode, the unit under test (UUT) is written with a known pattern and verified before irradiation. Then, the power supply of the memory is turned OFF and the irradiation starts. At the end of the irradiation, the UUT is powered ON and its content is read back in order to observe if events has occurred. SEUs are defined as one or multiple differences between the read and the expected data.

Standby mode principle:
As in Retention mode, the UUT is written and controlled before irradiation. During irradiations, the memory is continuously powered in standby activity. After irradiations, the UUT is read back in order to observe if events have occurred. SEUs are defined as one or multiple differences between the read and the expected data, while a SEFI is defined when at least half page is erroneous.

Read Only mode principle:
Before irradiation the UUT is written and controlled. During irradiations, the part is read continuously block by block. Events are recorded during irradiation. SEUs are defined as one or multiple differences between the read and the expected data, while a SEFI is defined when at least half page is erroneous or if a loss of communication with the UUT occurs. In case of a SEFI event, the UUT is power cycled OFF-ON and the test continues with the next block.

6.2. Test bench description

6.2.1. Preparation of test hardware and program

TRAD has developed a specific test program and a specific motherboard to feed power supply to components.
The test system is driven by a personal computer through a standard IEEE488 communication interface. All signals are delivered and monitored by this equipment and SEE curves are saved in its memory.
At the end of each test run, data is transferred to the hard disk for storage. An overall description of the test system is given in Figure 6.

6.2.2. Test equipment identification

The tests were carried out with evaluation test boards developed by TRAD.

COMPUTER	PO-TE-097
REF. TEST BOARD	TRAD/DEV-SP3/BVLG/1309/Rev1 Irradiation_board/MNEMOS Remote_board/MNEMOS
EQUIPMENT	MI-60, ME-79, SM-92
TEST PROGRAM	TI_MNEMOS_BV-LG_1407_rev5.llb MNEMOS5_FLASH.xise

6.2.3. Test Bench description

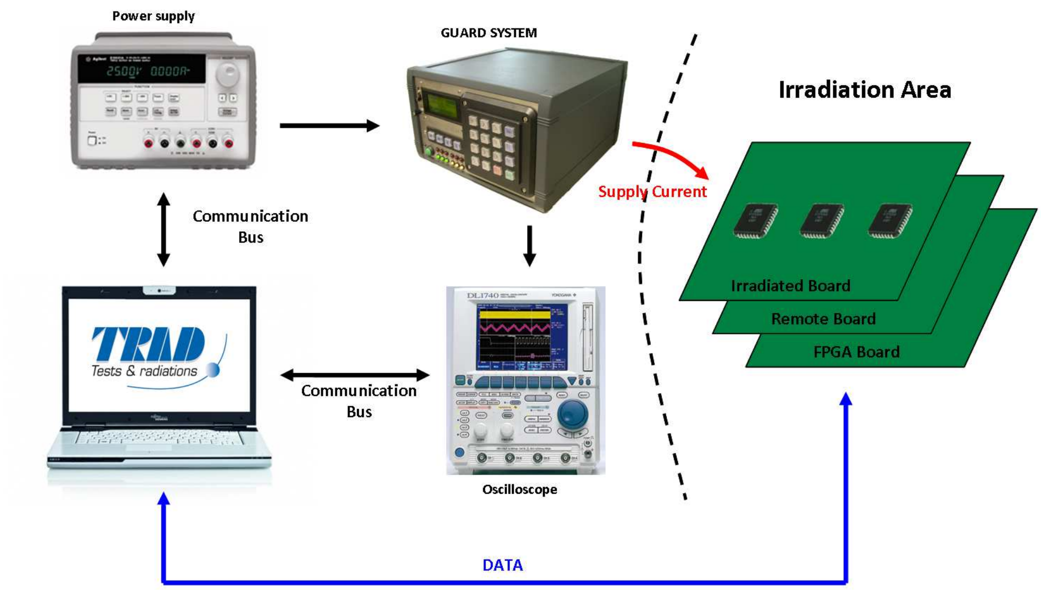


Figure 6: Test system description

6.2.4. Device setup and Test conditions

Trigger threshold for SEL test is defined in the following table:

Power Supply	Vcc
Voltage Value	3.3V
$I_{nominal}$	5mA
$I_{threshold}$	50mA
T_{hold}	1ms
T_{cut}	7ms
Temperature	25°C

Table 4: SEL detection threshold

7. Test Story

Test sequence, test and measurement conditions were nominal.

8. RESULTS

8.1. Summary of runs.

Runs performed during this campaign are summarized in the following table. The “Config” column refers to the different test modes available.
Run N°1 on part 1 and run N°3 on part 2 were performed in “SEL Destructive” configuration. In this mode, the SEL protection is removed.
Functional tests were performed off beam to determine if the part has been damaged during the previous run.
SEU Ro refers to “Read only” test mode.
SEU Ret refers to Retention mode.
SEL/HCE test mode indicates that the run is performed with SEL protection for the characterization of the Latchup/HCE sensibility.
During runs performed in SEU stdby, the UUT is biased and in standby mode during irradiation.

MT29F4G08ABADAWP Vcc = 3.3V T = 25°C												LATCHUP		SEE				Post Run Part Status
Run	Part	Config	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Flux (φ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	Vcc	Cross Section	SEU	Cross Section	SEFI	Cross Section	
High LET M/Q=5																		
1	1	SEL	124Xe 26+	420	37	67.7	7.93E+03	112	8.88E+05	0.962	0.962	-	-	-	-	-	-	Failure
2	1	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Failure
3	2	SEL	124Xe 26+	420	37	67.7	1.00E+04	1000	1.00E+07	10.853	10.853	-	-	-	-	-	-	Failure
4	2	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Failure
5	3	SEU Ro	124Xe 26+	420	37	67.7	9.51E+03	17	1.62E+05	0.175	0.175	0	<6.18E-06	3084	1.91E-02	49	3.03E-04	Functional
6	3	SEL	124Xe 26+	420	37	67.7	9.81E+03	1020	1.00E+07	10.843	11.018	22	2.20E-06	-	-	-	-	Failure
7	3	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Failure
8	4	SEU Ret	124Xe 26+	420	37	67.7	9.09E+03	112	1.02E+06	1.103	1.103	-	-	-	-	-	-	Failure
9	4	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Functional Failure
10	5	SEU Ro	124Xe 26+	420	37	67.7	2.23E+02	497	1.11E+05	0.120	0.120	0	<9.03E-06	4848	4.38E-02	45	4.06E-04	Functional
11	5	SEU Ro	124Xe 26+	420	37	67.7	5.32E+02	411	2.19E+05	0.237	0.357	0	<4.58E-06	11042	5.05E-02	9	4.12E-05	Functional
12	5	SEL	124Xe 26+	420	37	67.7	9.80E+03	1022	1.00E+07	10.852	11.209	21	2.10E-06	-	-	-	-	Failure
13	5	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Failure
14	6	SEU Ro	124Xe 26+	420	37	67.7	4.62E+02	350	1.62E+05	0.175	0.175	0	<6.19E-06	10159	6.28E-02	5	3.09E-05	Failure
15	6	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Failure

Table 5: MT29F4G08ABADAWP test results part 1

MT29F4G08ABADAWP Vcc = 3.3V T = 25°C												LATCHUP		SEE				Post Run Part Status
Run	Part	Config	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Flux (φ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	Vcc	Cross Section	SEU	Cross Section	SEFI	Cross Section	
High Range M/Q=3.3																		
16	7	SEL/HCE	13 C 4+	131	292	1.1	1.02E+04	980	1.00E+07	0.176	0.176	0	<1.00E-07	-	-	-	-	Functional
17	7	SEU Ro	13 C 4+	131	292	1.1	3.59E+03	280	1.00E+06	0.018	0.194	0	<1.00E-06	4	3.98E-06	0	<1.00E-06	Functional
18	8	SEU Ro	13 C 4+	131	292	1.1	5.10E+03	198	1.01E+06	0.018	0.018	0	<1.00E-06	3	2.97E-06	0	<1.00E-06	Functional
19	8	SEU Stdby	13 C 4+	131	292	1.1	9.54E+03	107	1.02E+06	0.018	0.036	0	<1.00E-06	8	7.84E-06	0	<1.00E-06	Functional
20	7	SEU Stdby	13 C 4+	131	292	1.1	9.99E+03	102	1.02E+06	0.018	0.212	0	<1.00E-06	3	2.94E-06	0	<1.00E-06	Functional
21	7	SEU Ret	13 C 4+	131	292	1.1	1.05E+04	96	1.01E+06	0.018	0.230	0	<1.00E-06	4	3.96E-06	-	-	Functional
22	8	SEU Ret	13 C 4+	131	292	1.1	1.05E+04	97	1.02E+06	0.018	0.054	0	<1.00E-06	13	1.27E-05	-	-	Functional
23	8	SEL/HCE	13 C 4+	131	292	1.1	1.09E+04	921	1.00E+07	0.176	0.230	0	<1.00E-07	-	-	-	-	Functional
24	8	SEU Ro	40 Ar 12+	372	117	10.2	1.07E+03	443	4.74E+05	0.077	0.307	0	<2.11E-06	18463	3.90E-02	10	2.11E-05	Functional
25	7	SEU Ro	40 Ar 12+	372	117	10.2	9.89E+02	153	1.51E+05	0.025	0.254	0	<6.61E-06	5194	3.43E-02	4	2.64E-05	Functional
26	7	SEU Stdby	40 Ar 12+	372	117	10.2	1.03E+03	99	1.02E+05	0.017	0.271	0	<1.00E-05	3414	3.35E-02	10	9.80E-05	Functional
27	8	SEU Stdby	40 Ar 12+	372	117	10.2	1.02E+03	100	1.02E+05	0.017	0.324	0	<1.00E-05	4020	3.96E-02	12	1.18E-04	Functional
28	8	SEU Ret	40 Ar 12+	372	117	10.2	1.03E+03	98	1.01E+05	0.017	0.340	0	<1.00E-05	4035	3.98E-02	-	-	Functional
29	7	SEU Ret	40 Ar 12+	372	117	10.2	1.07E+03	95	1.02E+05	0.017	0.288	0	<1.00E-05	3446	3.39E-02	-	-	Functional
30	7	SEL/HCE	40 Ar 12+	372	117	10.2	1.00E+04	1000	1.00E+07	1.634	1.922	3	3.00E-07	-	-	-	-	Functional
31	8	SEL/HCE	40 Ar 12+	372	117	10.2	1.03E+04	972	1.00E+07	1.635	1.976	1	9.98E-08	-	-	-	-	Functional
32	8	SEU Ro	22 Ne 7+	235	216	3	2.88E+03	349	1.00E+06	0.048	2.024	0	<1.00E-06	501	4.99E-04	6	5.97E-06	Functional
33	7	SEU Ro	22 Ne 7+	235	216	3	4.05E+03	249	1.01E+06	0.048	1.970	0	<1.00E-06	268	2.66E-04	6	5.96E-06	Functional
34	7	SEU Stdby	22 Ne 7+	235	216	3	4.02E+03	250	1.00E+06	0.048	2.019	0	<1.00E-06	261	2.60E-04	37	3.68E-05	Functional
35	8	SEU Stdby	22 Ne 7+	235	216	3	4.20E+03	239	1.00E+06	0.048	2.072	0	<1.00E-06	467	4.65E-04	21	2.09E-05	Functional
36	8	SEU Ret	22 Ne 7+	235	216	3	4.05E+03	249	1.01E+06	0.048	2.121	0	<1.00E-06	494	4.90E-04	-	-	Functional
37	7	SEU Ret	22 Ne 7+	235	216	3	4.03E+03	250	1.01E+06	0.048	2.067	0	<1.00E-06	227	2.26E-04	-	-	Functional
38	7	SEL/HCE	22 Ne 7+	235	216	3	9.93E+03	1009	1.00E+07	0.481	2.548	0	<1.00E-07	-	-	-	-	Functional
39	8	SEL/HCE	22 Ne 7+	235	216	3	1.02E+04	980	1.00E+07	0.481	2.601	0	<1.00E-07	-	-	-	-	Functional
40	8	SEL/HCE	83 Kr 25+	756	92	32.6	1.05E+04	955	1.00E+07	5.222	7.823	7	6.99E-07	-	-	-	-	Functional
41	7	SEL/HCE	83 Kr 25+	756	92	32.6	1.02E+04	985	1.00E+07	5.223	7.770	14	1.40E-06	-	-	-	-	Functional

Table 6: MT29F4G08ABADAWP test results part 2

MT29F4G08ABADAWP Vcc = 3.3V T = 25°C												LATCHUP		SEE				Post Run Part Status
Run	Part	Config	Ion	Energy (MeV)	Range (µm)	LET (MeV.cm²/mg)	Flux (φ) ($cm^{-2}.s^{-1}$)	Time (s)	Run Fluence (Φ) (cm^{-2})	Run Dose (krad)	Cumulated Dose (krad)	Vcc	Cross Section	SEU	Cross Section	SEFI	Cross Section	
High Range M/Q=3.3																		
42	9	SEL/HCE	58 Ni 18+	567	100	20.4	1.04E+04	960	1.00E+07	3.271	3.271	0	<1.00E-07	-	-	-	-	Run Canceled
43	9	SEU Ro	58 Ni 18+	567	100	20.4	1.04E+03	76	7.92E+04	0.026	3.296	0	<1.26E-05	581	7.33E-03	28	3.53E-04	Functional
44	9	SEU Ro	58 Ni 18+	567	100	20.4	1.05E+03	302	3.16E+05	0.103	3.400	0	<3.16E-06	20578	6.51E-02	10	3.16E-05	Functional
45	9	SEU Ret	58 Ni 18+	567	100	20.4	9.87E+03	12	1.18E+05	0.039	3.438	0	<8.45E-06	9127	7.71E-02	-	-	Functional
46	9	SEU Stdby	58 Ni 18+	567	100	20.4	1.08E+04	11	1.19E+05	0.039	3.477	0	<8.43E-06	12507	1.05E-01	35	2.95E-04	Functional
47	9	SEL/HCE	58 Ni 18+	567	100	20.4	1.03E+04	974	1.00E+07	3.268	6.745	9	8.99E-07	-	-	-	-	Functional
48	9	Functional Test	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	Functional
49	10	SEL/HCE	58 Ni 18+	567	100	20.4	1.03E+04	976	1.00E+07	3.270	3.270	7	6.99E-07	-	-	-	-	Functional
50	10	SEU Ro	58 Ni 18+	567	100	20.4	1.03E+03	99	1.02E+05	0.033	3.303	0	<9.83E-06	7489	7.36E-02	5	4.92E-05	Functional
51	10	SEU Ret	58 Ni 18+	567	100	20.4	1.00E+04	12	1.20E+05	0.039	3.343	0	<8.33E-06	9730	8.10E-02	-	-	Functional
52	10	SEU Stdby	58 Ni 18+	567	100	20.4	9.89E+03	12	1.19E+05	0.039	3.381	0	<8.43E-06	9077	7.65E-02	30	2.53E-04	Functional
53	10	SEU Ro	83 Kr 25+	756	92	32.6	1.03E+03	70	7.23E+04	0.038	3.419	0	<1.38E-05	9397	1.30E-01	4	5.53E-05	Functional
54	10	SEU Ret	83 Kr 25+	756	92	32.6	9.62E+03	8	7.69E+04	0.040	3.459	0	<1.30E-05	11308	1.47E-01	-	-	Functional
55	10	SEU Stdby	83 Kr 25+	756	92	32.6	9.07E+03	7	6.35E+04	0.033	3.492	0	<1.58E-05	10368	1.63E-01	31	4.88E-04	Functional
56	9	SEU Ro	83 Kr 25+	756	92	32.6	1.05E+03	58	6.12E+04	0.032	6.777	0	<1.63E-05	7570	1.24E-01	3	4.90E-05	Functional
57	9	SEU Ret	83 Kr 25+	756	92	32.6	9.24E+03	7	6.47E+04	0.034	6.810	0	<1.55E-05	9123	1.41E-01	-	-	Functional
58	9	SEU Stdby	83 Kr 25+	756	92	32.6	8.95E+03	7	6.26E+04	0.033	6.843	0	<1.60E-05	9142	1.46E-01	7	1.12E-04	Functional

Table 7: MT29F4G08ABADAWP test results part 3

8.2. SEL & HCE test results.

During the test campaign, several runs have been performed on 6 NAND Flash devices using the Xenon ion corresponding to the highest available LET (67.7 MeV.cm²/mg).
These runs have been performed in order to evaluate the SEL and SEU sensitivity at high LET.
The results table summarizes all those runs and post run part status. As shown in this table most of the devices were detected non functional after the SEE test with the Xenon ion. These parts are shown with the status “failure” in Table 5. When such failure was detected the test was stopped. Following this failure a test has been performed again to evaluate the functionally of the device after a power ON/OFF. Indeed, at the beginning of each SEE test, a functional test has been performed on the NAND Flash memories.
All the 4096 blocks are written with the pattern AA55 and read again. If an error is detected the block is defined as a Bad Block and is not used during the following SEE test. If more than 25% of the 4096 blocks are detected as Bad Block, the device is then considered as not functional anymore. The status “failure” is then applied.
If the number of blocks is sufficient for test, an SEE test is then performed. However, if an atypical behavior is observed, like out of beam errors, then this device is considered as not functional anymore and the status “failure” is also applied.

These results seem to show that heavy ion tests increase the number of Bad Blocks.
This tendency is observed for various fluences (from 1.65E5 p/cm² to 1E7 p/cm²) and by consequence for various cumulated doses due to heavy ions.

The next figure presents the number of functional blocks before SEE test, after SEE test using the Xenon ion, after 36 hours of annealing at room temperature and after 128 hours of annealing at room temperature.

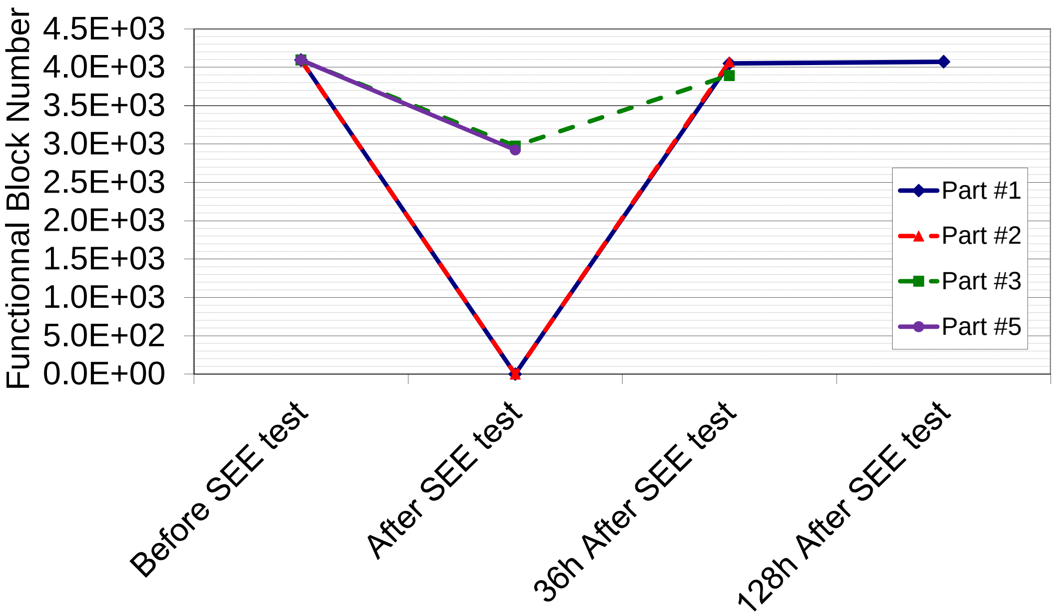


Figure 7 : MT29F4G08AAC Number of functional blocks before and after SEE test using the Xenon ion

The next table shows the number of functional Blocks at each step of test.

	Part 1	Part 2	Part 3	Part 5
Before SEE test	4095	4095	4095	4095
After SEE test	0	0	2972	2924
36h After SEE test	4050	4073	3893	Not mesured
128h After SEE test	4071	Not mesured	Not mesured	Not mesured

TABLE 8 : MT29F4G08AAC Number of functional blocks before and after SEE test using the Xenon ion

Parts 1 and 2 were tested without the Guard system, in order to measure the complete High Current Event (HCE) signature. After the heavy ion test, both of them show the entire block in error.
Parts 3 and 5 were tested using the Guard system with a threshold at 50mA. As shown in the previous figure, many blocks are detected as bad blocks after heavy ion test.
Therefore components irradiated without the Guard system, and by consequence subject to HCE with high current, show a more important degradation compared to those protected against SEL.
Moreover, it appears that this effect is not permanent. After 36 hours of annealing at room temperature the measured devices are almost totally functional. Only some Blocks are always “not functional” and this number decreases again after 128 hours.

This observation has not been detected using other ions. For example, all devices remain functional after runs using the Krypton ion (LET = 32.6 MeV.cm²/mg) up to a dose level of 6.77 krad(Si) (corresponding to a total fluence of 6.12E4 p/cm²). The dose level is then probably not the origin of the non-functionality.

This effect could potentially be induced by High Current Event (HCE) and leads to temporary functional failure at LET of 67.7 MeV.cm²/mg but not at lower LETs.
The following figures present the current spectrum measured during runs using the Xenon and Krypton ions. Current spectrums are almost identical: three thresholds are observed at 5 mA, 30 mA and 50 mA.

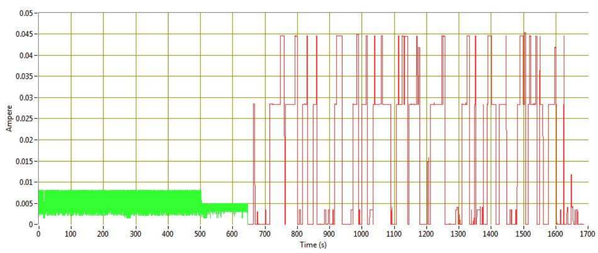


Figure 8: Current spectrum for MT29F4G08AAC. Data is taken with ^{124}Xe ion at LET 67.7 MeV.cm²/mg at the UCL facility

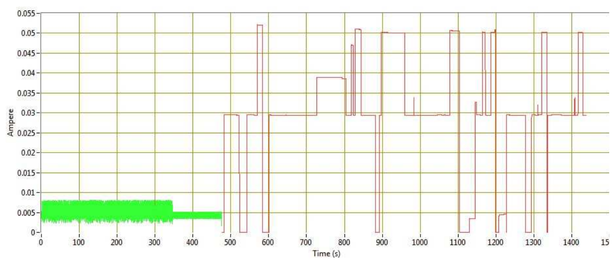


Figure 9: Current spectrum for MT29F4G08AAC. Data is taken with ^{83}Kr ion at LET 32.6 MeV.cm²/mg at the UCL facility

The SEL & HCE test has been performed at 25°C.

HCE were observed during the irradiation with minimum LET equal to 10.2 MeV.cm²/mg (Argon).
After a destructive SEL test (without the GUARD System), the two tested parts showed functional failure. The functionality of the device recovered a few days after the irradiation. These parts are also considered as not sensitive to SEL under Xenon Heavy Ion (LET = 67.7 MeV.cm²/mg). In the following, all events recorded with the GUARD are also counted as HCE.

No HCE was observed with the Neon Heavy Ion (LET = 3 MeV.cm²/mg).

8.2.1. SEL Cross section

MT29F4G08ABADAWP HCE Cross Section (cm²)						
LET Eff (MeV.cm².mg⁻¹)	SEL					
	N° 3	N° 5	N° 7	N° 8	N° 9	N° 10
67.7	2.20E-06	2.10E-06	-	-	-	-
32.6	-	-	1.40E-06	6.99E-07	-	-
20.4	-	-	-	-	8.99E-07	6.99E-07
10.2	-	-	3.00E-07	9.98E-08	-	-
3	-	-	<1.00E-07	<1.00E-07	-	-

Table 9: MT29F4G08ABADAWP SEL cross section results

The following figure presents the cross section of the HCE events on the MT29F4G08ABADAWP part. Points represented by an arrow pointing down indicate that no events were observed at the corresponding LET. The evaluated cross section is then lower than 1.10^{-7}cm^{-2}, value corresponding to one event at maximum fluence.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

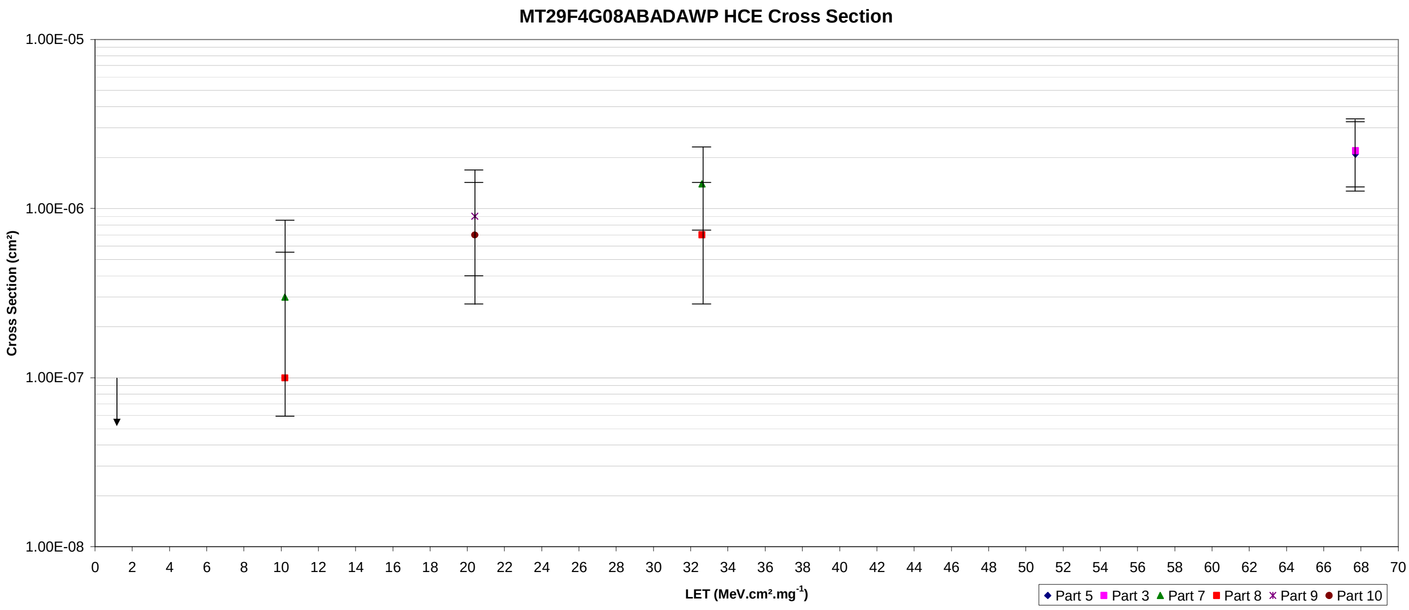


Figure 10: HCE cross section curve for MT29F4G08ABADAWP

8.3. Retention Mode test results

The SEE test was performed at 25°C.

SEUs were observed during the irradiation with the Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).

8.3.1. Retention Mode SEU Cross section

MT29F4G08ABADAWP Retention Mode SEU Cross Section (cm^2)				
LET Eff (MeV.cm².mg^{-1})	SEU Retention mode			
	N° 7	N° 8	N° 9	N° 10
32.6	-	-	1.41E-01	1.47E-01
10.2	3.39E-02	3.98E-02	-	-
3	2.26E-04	4.90E-04	-	-

Table 10: MT29F4G08ABADAWP Retention Mode SEU cross section results

The following figure presents the cross section of the Retention Mode SEU event on the MT29F4G08ABADAWP part.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

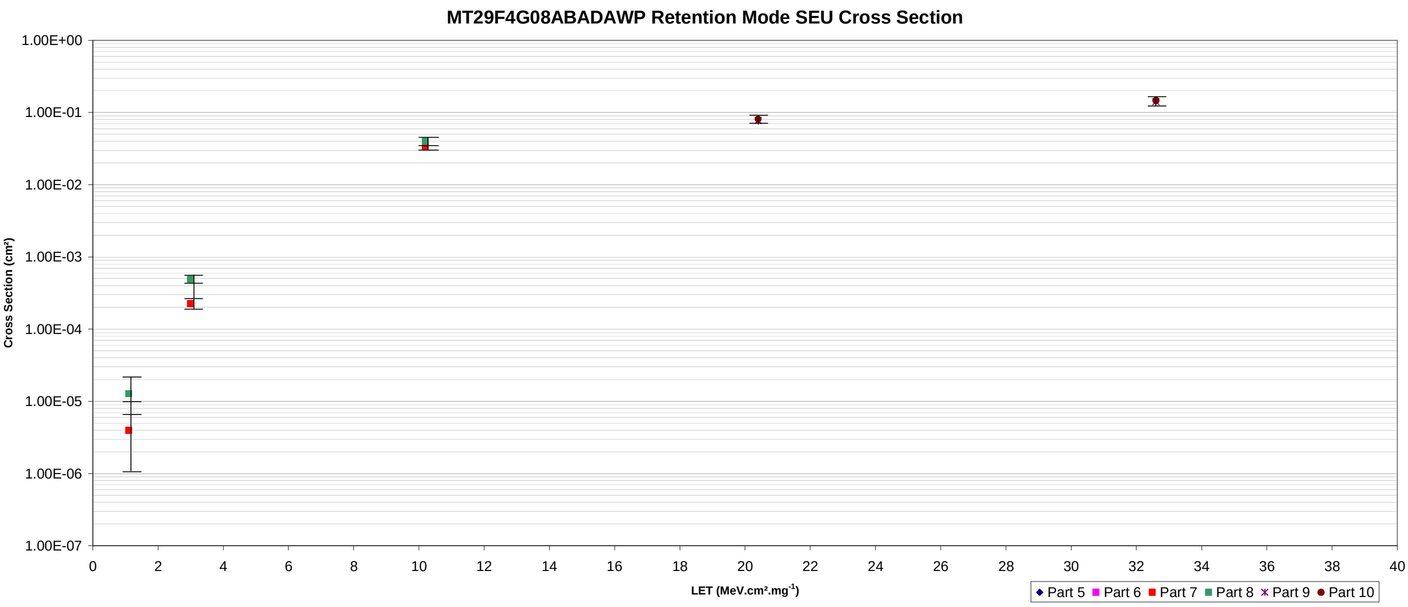


Figure 11: Retention Mode SEU cross section curve for MT29F4G08ABADAWP

8.4. Standby Mode test results

The SEE test was performed at 25°C.

SEUs were observed during the irradiation with the Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).

SEFIs were observed during the irradiation with minimum LET = 3 MeV.cm²/mg (Neon).
No SEFI was observed for the Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).

8.4.1. Stanby Mode SEU Cross section

MT29F4G08ABADAWP Standby Mode SEU Cross Section (cm^2)				
LET Eff (MeV.cm².mg^{-1})	SEU Standby Mode			
	N° 7	N° 8	N° 9	N° 10
32.6	-	-	1.46E-01	1.63E-01
20.4	-	-	1.05E-01	7.65E-02
10.2	3.35E-02	3.96E-02	-	-
3	2.60E-04	4.65E-04	-	-
1.1	2.94E-06	7.84E-06	-	-

Table 11: MT29F4G08ABADAWP Standby Mode SEU cross section results

The following figure presents the cross section of the Standby Mode SEU event on the MT29F4G08ABADAWP part.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

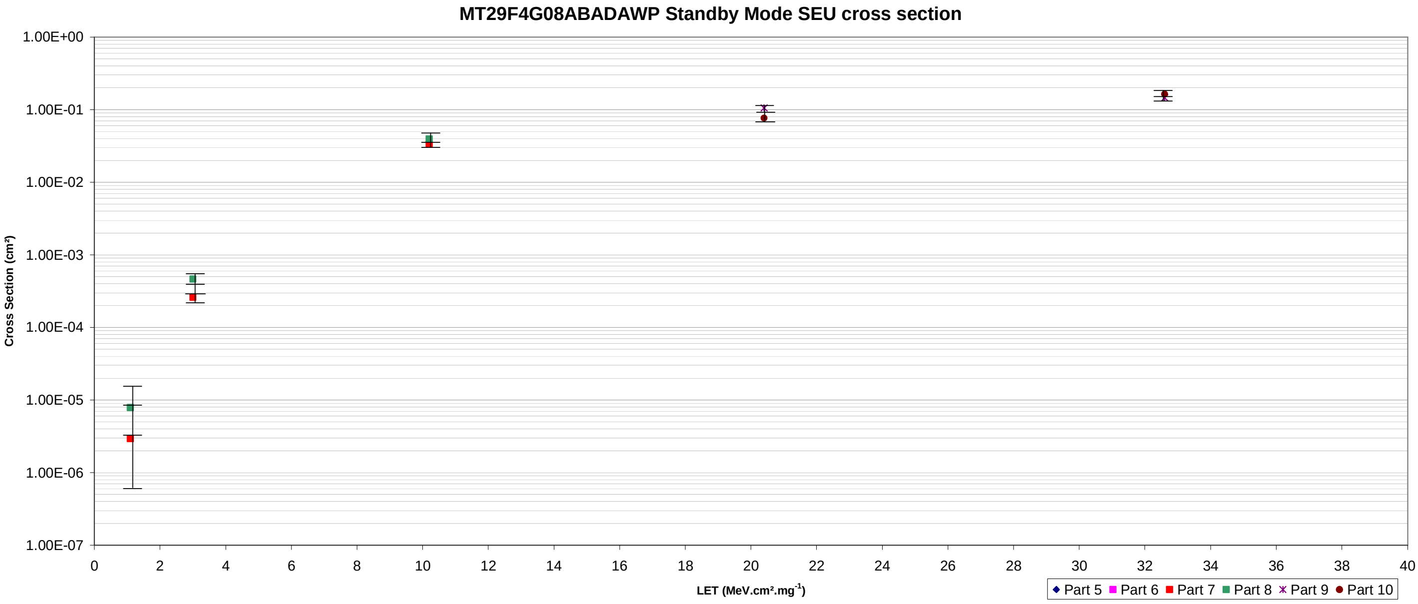


Figure 12: Standby Mode SEU cross section curve for MT29F4G08ABADAWP

8.4.2. Standby Mode SEFI Cross section

MT29F4G08ABADAWP Standby Mode SEFI Cross Section (cm^2)				
LET Eff ($MeV.cm^2.mg^{-1}$)	SEFI Standby Mode			
	N° 7	N° 8	N° 9	N° 10
32.6	-	-	1.12E-04	4.88E-04
20.4	-	-	2.95E-04	2.53E-04
10.2	9.80E-05	1.18E-04	-	-
3	3.68E-05	2.09E-05	-	-
1.1	<1E-06	<1E-06	-	-

Table 12: MT29F4G08ABADAWP Standby Mode SEFI cross section results

The following figure presents the cross section of the Standby Mode SEFI event on the MT29F4G08ABADAWP part. Points represented by an arrow pointing down indicate that no events were observed at the corresponding LET. The evaluated cross section is then lower than 1.00 $10^{-6}cm^{-2}$, value corresponding to one event at maximum fluence.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

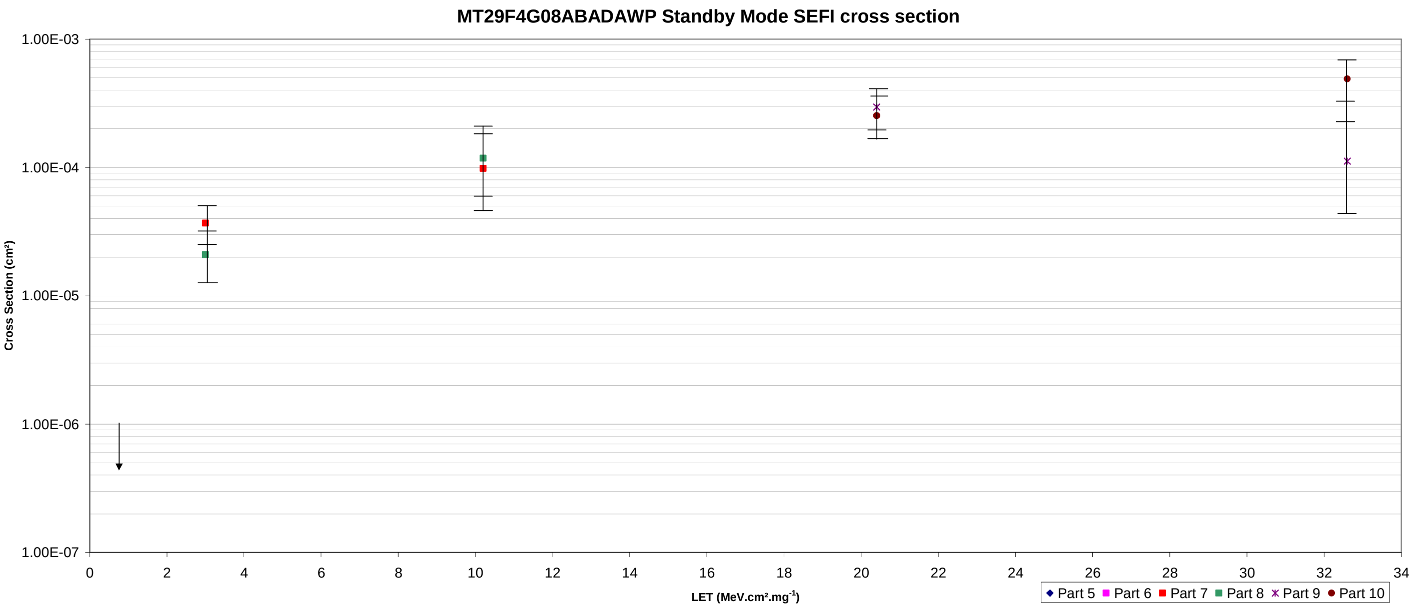


Figure 13: Standby Mode SEFI cross section curve for MT29F4G08ABADAWP

8.5. Read Only Mode test results

The SEE test was performed at 25°C.

SEUs were observed during the irradiation with the Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).

SEFIs were observed during the irradiation with minimum LET = 3 MeV.cm²/mg (Neon). No SEFI was observed with the Carbon Heavy Ion (LET = 1.1 MeV.cm²/mg).

8.5.1. Read Only Mode SEU Cross section

MT29F4G08ABADAWP Read Only Mode SEU Cross Section (cm^2)						
LET Eff ($MeV.cm^2.mg^{-1}$)	SEU Read Only Mode					
	N° 5	N° 6	N° 7	N° 8	N° 9	N° 10
67.7	5.05E-02	6.28E-02	-	-	-	-
20.4	-	-	-	-	6.51E-02	7.36E-02
10.2	-	-	3.43E-02	3.90E-02	-	-
1.1	-	-	3.98E-06	2.97E-06	-	-

Table 13: MT29F4G08ABADAWP Read Only Mode SEU cross section results

The following figure presents the cross section of the Read Only Mode SEU event on the MT29F4G08ABADAWP part.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

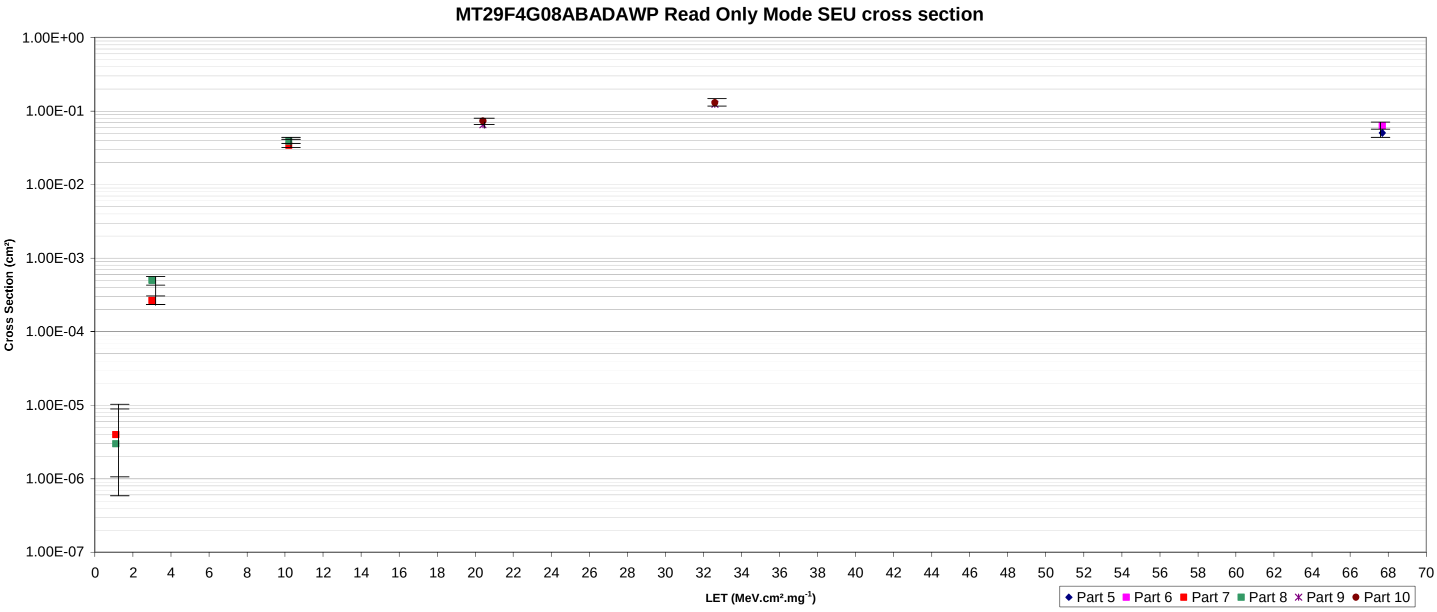


Figure 14: Read Only Mode SEU cross section curve for MT29F4G08ABADAWP

8.5.2. Read Only Mode SEFI Cross section

MT29F4G08ABADAWP Read Only Mode SEFI Cross Section (cm^2)						
LET Eff ($MeV.cm^2.mg^{-1}$)	SEFI Read Only Mode					
	N° 5	N° 6	N° 7	N° 8	N° 9	N° 10
67.7	4.12E-05	3.09E-05	-	-	-	-
20.4	-	-	-	-	3.16E-05	4.92E-05
10.2	-	-	2.64E-05	2.11E-05	-	-
1.1	-	-	<1.00E-06	<1.00E-06	-	-

Table 14: MT29F4G08ABADAWP Read Only Mode SEFI cross section results

The following figure presents the cross section of the Read Only Mode SEFI event on the MT29F4G08ABADAWP part. Points represented by an arrow pointing down indicate that no events were observed at the corresponding LET. The evaluated cross section is then lower than 1.00 $10^{-6}cm^{-2}$, value corresponding to one event at maximum fluence.
Error bars are calculated as described in the ESCC25100, using 95% confidence level and 10% fluence uncertainty.

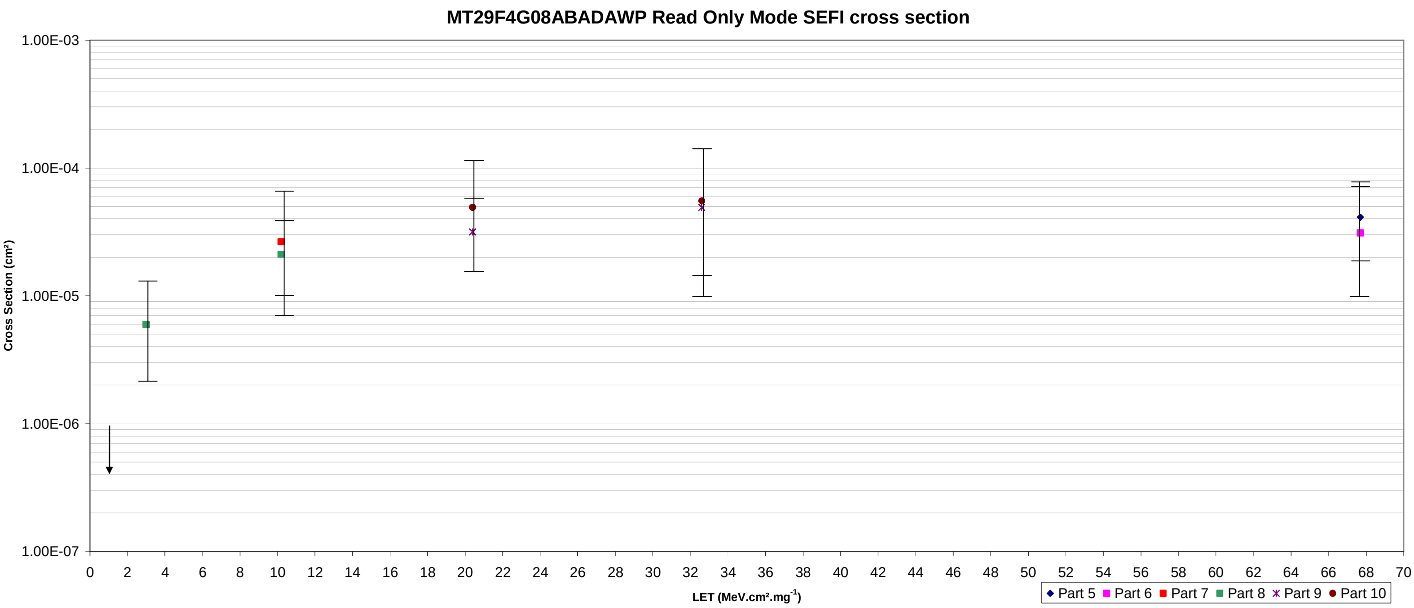


Figure 15: Read Only Mode SEFI cross section curve for MT29F4G08ABADAWP

9. Conclusion

Heavy ion tests were performed on the MT29F4G08ABADAWP. The aim of the test was to evaluate the sensitivity of the device versus SEL, HCE, SEU and SEFI. This test was performed as part of a global study to evaluate the potential synergetic effects of TID on SEE sensitivity. As a result, the development strategy for this test was not the characterization of the MT29F4G08ABADAWP itself, but the evolution of its SEE sensitivity after submission to TID. The results presented in this report were obtained before TID irradiation (0 krad).

No SEL was observed at LET = 67.7MeV.cm²/mg (Xenon Heavy Ion).
HCEs were observed on the MT29F4G08ABADAWP with a minimum LET of 10.2MeV.cm²/mg (Argon heavy ion). No HCE was observed at LET = 3MeV.cm²/mg (Neon Heavy Ion).

Retention Mode:
SEUs were observed on the MT29F4G08ABADAWP with a minimum LET of 1.1 MeV.cm²/mg (Carbon heavy ion).

Standby Mode:
SEUs were observed on the MT29F4G08ABADAWP with a minimum LET of 1.1 MeV.cm²/mg (Carbon heavy ion).
SEFIs were observed on the MT29F4G08ABADAWP with a minimum LET of 3 MeV.cm²/mg (Neon heavy ion). No SEFI was observed at LET =1.1 MeV.cm²/mg (Carbon Heavy Ion).

Read Only Mode:
SEUs were observed on the MT29F4G08ABADAWP with a minimum LET of 1.1MeV.cm²/mg (Carbon heavy ion).
SEFIs were observed on the MT29F4G08ABADAWP with a minimum LET of 3MeV.cm²/mg (Neon heavy ion). No SEFI was observed at LET = 1.1MeV.cm²/mg (Carbon Heavy Ion).