INSTITUT FÜR
DATENTECHNIK UND
KOMMUNIKATIONSNETZE

Technische Universität
Braunschweig

TN IDA-MEMRAD 1/2004

M. Brüggemann,
H. Schmidt
Institut für Datentechnik und Kommunikationsnetze
TU Braunschweig, Germany

R. Harboe-Sørensen
European Space Agency / ESTEC
Noordwijk, The Netherlands

SEE Acceptance Test of the Radiation Testbed for Memory Components (RTMC-3).

Performed at the HIF, Université Catholique de Louvain, Louvain la Neuve, Belgium, April 2004.

ESA Reference: ESA_QCA0422S_C

ESA Contract No 11356/95/NL/FM CCN-03

ESTEC Technical Officer: R. Harboe-Sørensen

1. Introduction

This is a summary of the test data collected at UCL in April 2004. Main intention of this test was to verify the handling and performance of the new built test system, RTMC-3. Thus, four of the six DUTs were already tested before. Only two DUTs, AT61 and AT62, are new revisions and are tested for the first time.

2. Devices

Table 1 shows all tested devices with their markings.

Table 1: Tested Devices

Manufacturer	ID	Package	Type	Remarks
Atmel	AT61	FP36 0.5”	AT60142-E	Sample; Rad Hard
Atmel	AT62	FP36 0.5”	AT60142-E	Sample; Rad Hard
MHS	MH41	CerDIP28 0.3”	MMDP65656EV-45	
MHS	MH51	SOJ28 0.4”	MMDP65656FV-55	
White	WH33	SOJ32 0.4”	WMS512K8-70DEM	
White	WH28	SOJ32 0.4”	WMS512K8-45DEM	

The devices AT61 and AT62 from Atmel have a new die revision and are tested here, because during former tests the old die revision showed latch-ups. The devices MH41, MH51 from MHS and WH28, WH33 from White Electronic Designs have been tested already in 1998-99, so previous SEE data is available.

3. Heavy Ion Test Facility

The heavy ion tests were performed at UCL, Université Catholique de Louvain, Louvain la Neuve, Belgium. The HIF beam line with the ion cocktail M/Q=5 was used to irradiate the DUTs. In particular, the following ions and incidence angles have been used:

Table 2: Ions and LETs used for Heavy Ion Tests

Ion	Energy [MeV]	Tilt Angle	Range [µm(Si)]	LET [MeV/mg/cm²]
$^{15}N^{3+}$	62	0°	64	2.97
$^{15}N^{3+}$	62	45°	45.3	4.2
$^{15}N^{3+}$	62	60°	32	5.94
$^{20}Ne^{4+}$	78	0°	45	5.85
$^{20}Ne^{4+}$	78	45°	31.8	8.27
$^{20}Ne^{4+}$	78	60°	22.5	11.7
$^{40}Ar^{8+}$	150	0°	42	14.1
$^{40}Ar^{8+}$	150	45°	29.7	19.94
$^{40}Ar^{8+}$	150	60°	21	28.2
$^{84}Kr^{17+}$	316	0°	43	34
$^{84}Kr^{17+}$	316	45°	30.4	48.08
$^{84}Kr^{17+}$	316	60°	21.5	68
$^{132}Xe^{26+}$	459	45°	30.4	79.05
$^{132}Xe^{26+}$	459	60°	21.5	111.8

Unfortunately, no boron was available at UCL in the test period and therefore no low LET values could be taken.

Fig. 1 shows the range distribution over the LET of the used ions in a diagram.

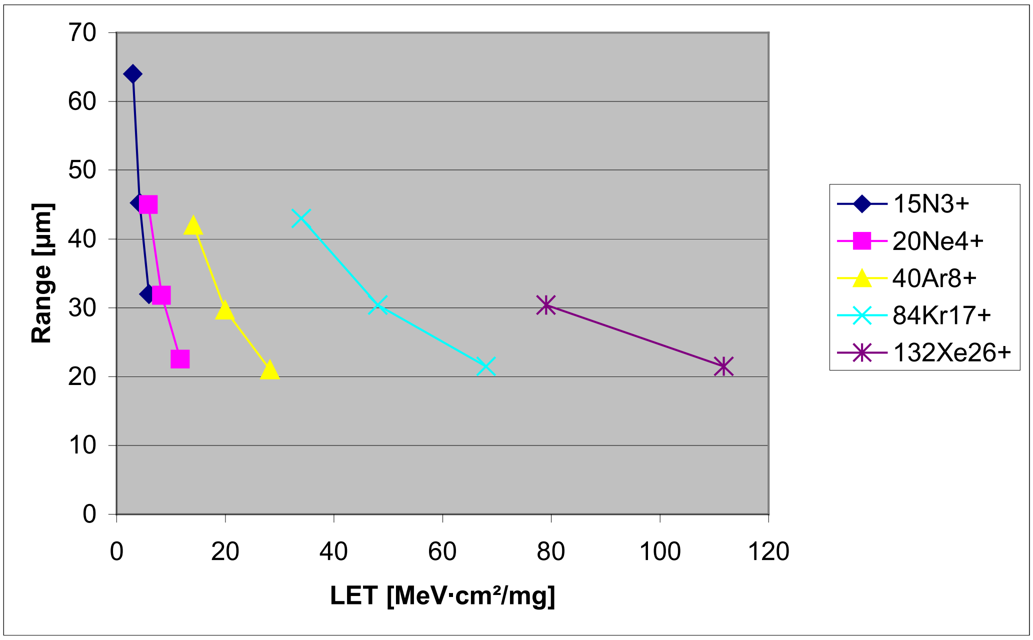

Fig. 1: Range and LET of used Ions

4. Single Event Upsets (SEUs)

No latch-ups occurred during the test.

Fig. 2 to Fig. 7 shows the cross sections of each device over the LET.

During each test run the error distribution over the memory array is displayed and shows some events with errors in multiple cells (physically neighboured) especially at higher LET value and incidence angle. Because this phenomenon produces more than one erroneous cell per event, test data has to be filtered. But for now, the evaluation software isn't capable to do this. If needed, an extra evaluation can be made. This might be useful for future tests because this effect produces an error in cross section of a few percent.

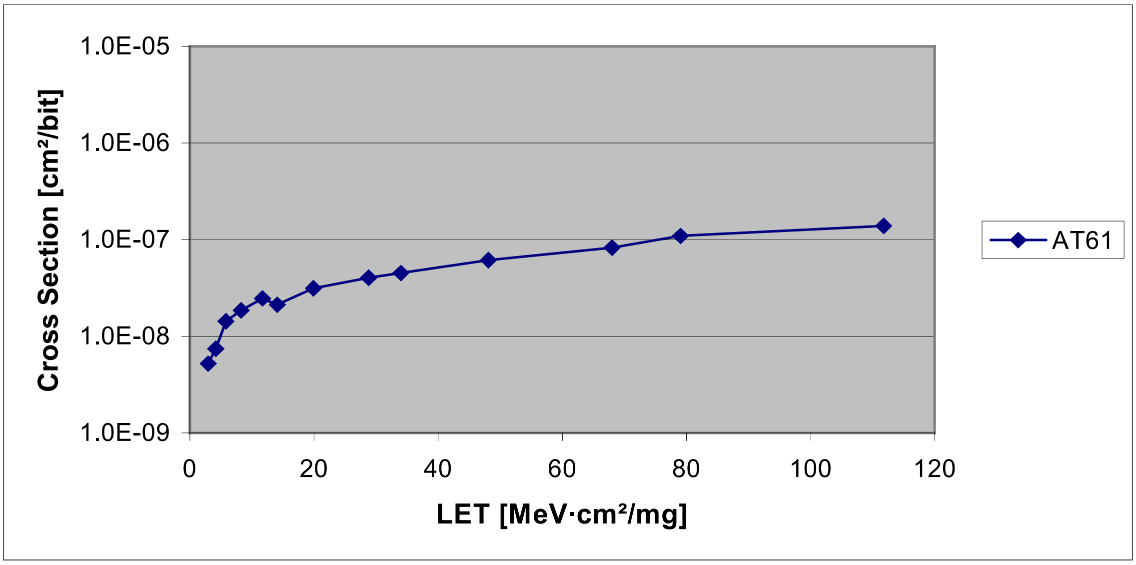

Fig. 2: Cross section for AT61

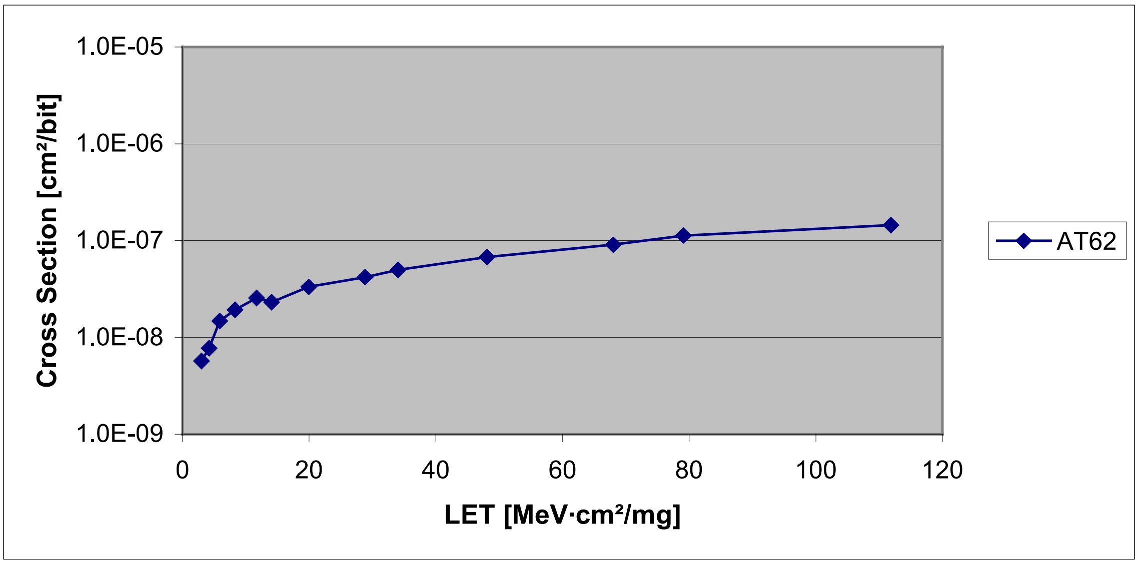

Fig. 3: Cross section for AT62

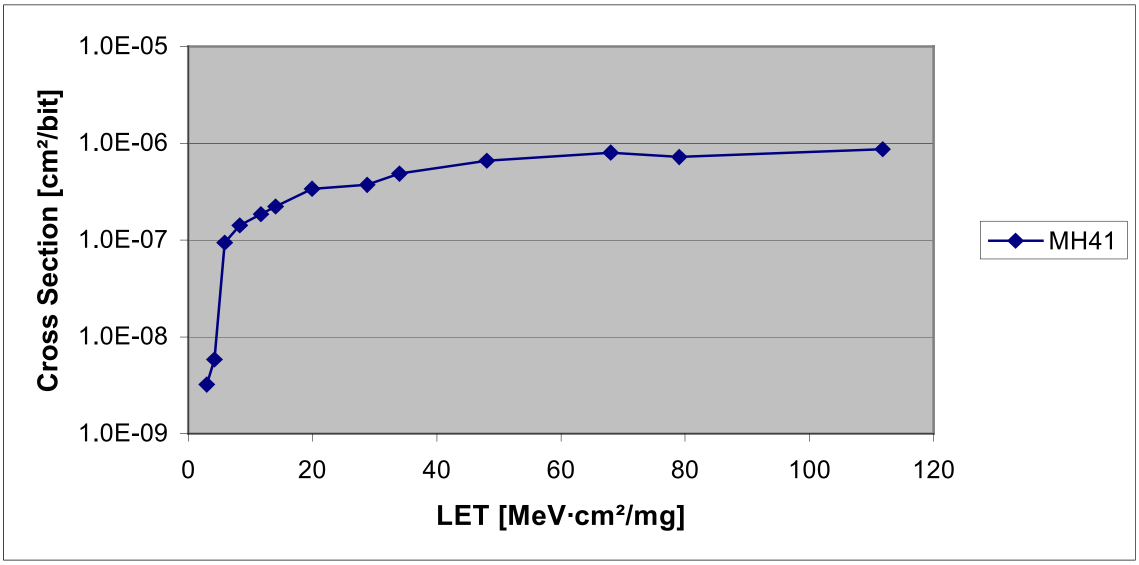

Fig. 4: Cross section for MH41

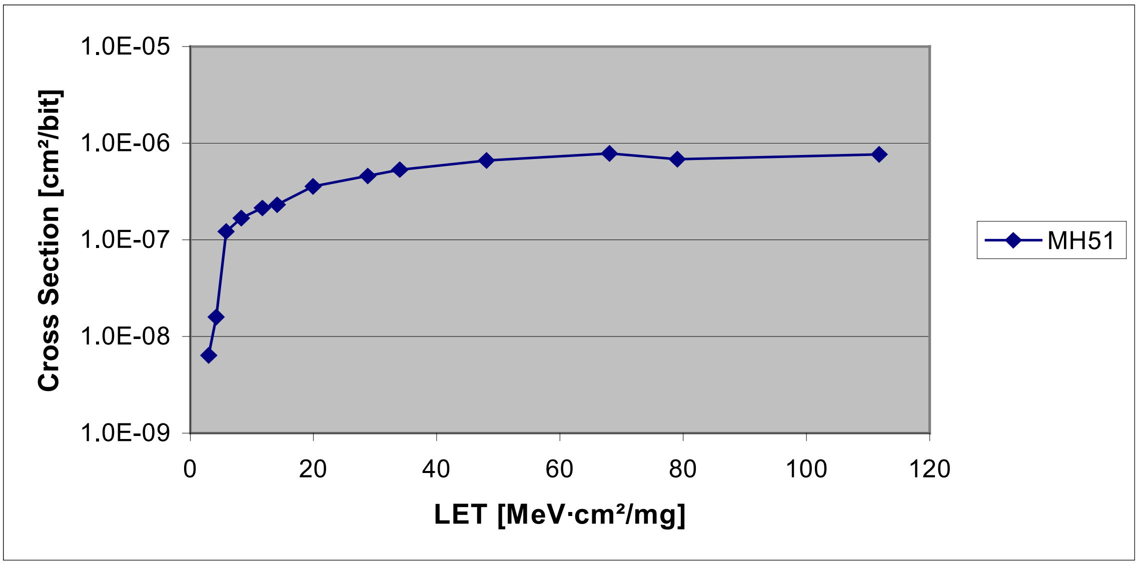

Fig. 5: Cross section for MH51

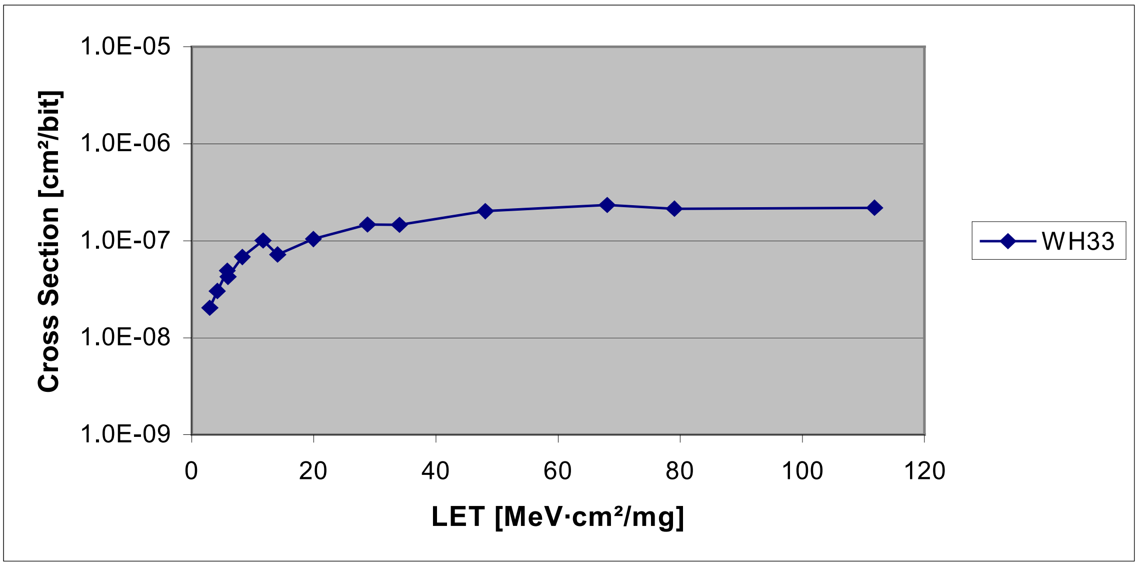

Fig. 6: Cross section for WH33

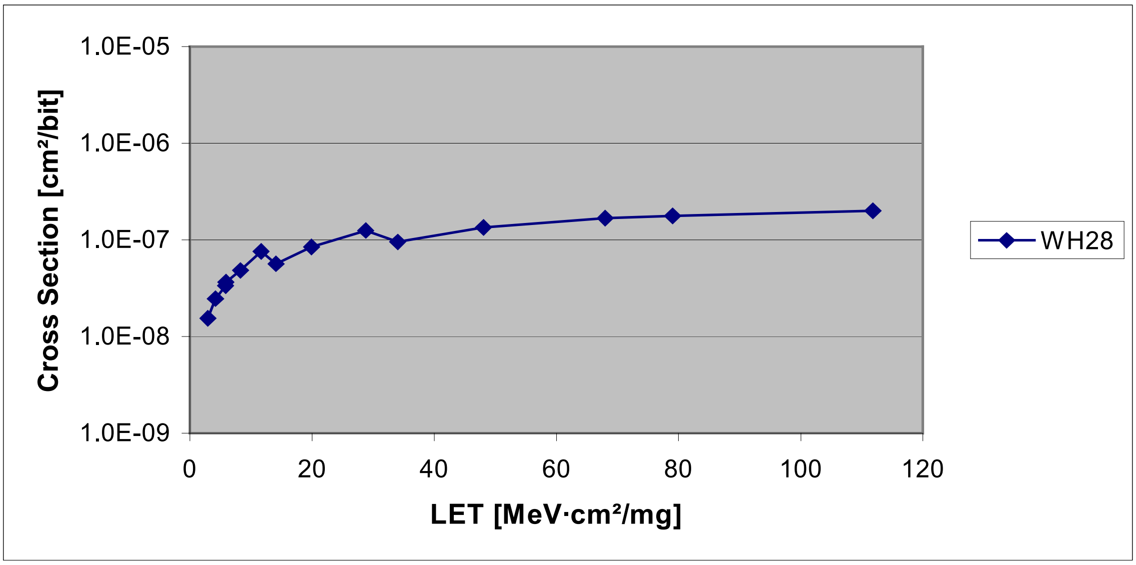

Fig. 7: Cross section for WH28

Table 3 shows the occurrence of 8-bit errors (the full output word is wrong) in the various tests. This type of error can be attributed to events hitting the address decoder or read/write control. Remarkable is the fact that this type of error occurs only at low (< 6) LET or at high (> 34) LET. This leads to an assumption that in fact two different mechanisms causing this effect. Further analysis of the test data could show which type of the above described error mechanisms are responsible.

Table 3: Full Word Errors

LET	AT61	AT62	MH41	MH51	WH33	WH28
2.97	6	4	0	7	8	2
4.20	2	4	0	0	19	0
5.85	0	0	0	0	0	0
5.94					18	2
8.27	0	0	0	0	0	0
11.70	0	0	0	0	0	0
14.10	0	0	0	0	0	0
19.94	0	0	0	0	0	0
28.80	0	0	0	0	0	0
34.00	0	2	0	0	0	0
48.08	0	0	0	0	0	1
68.00	0	0	0	0	0	0
79.05	0	0	4	0	4	0
111.80	0	0	10	2	6	0

5. Multiple Event Upsets (MEUs)

Table 4 shows the amount of two single bit errors in the same output word and the statistically expected amount of each device and run. This type of error is normally caused by two independent events hitting the geometrically distant bit planes. Most of these figures are within their expected value, values marked in green are slightly above the expectancy. There are two remarkable outliers coloured in yellow and red at device MH51 with an LET of 79.05 and 111.8, which cannot be explained. The recorded data sets from these two runs look quite normal and do not differ from other runs.

No three or more bit error occurred during the test.

Table 4: Double Bit Upsets

	AT61		AT62		MH41		MH51		WH33		WH28	
LET	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.	Read	Exp.
2.97	4	5.51	1	4.81	0	0.01	0	0.03	5	11.5	0	6.76
4.20	3	6.52	3	8.32	0	0.02	0	0.19	5	10.2	3	7.32
5.85	0	2.18	1	5.7	**4**	**3.74**	**4**	**3.29**	12	25.4	8	22.4
5.94									7	10.1	4	8.32
8.27	3	2.58	1	4.45	2	2.94	0	3.06	23	33.6	8	23.1
11.70	1	3.75	3	4.03	0	3.19	1	3.58	18	40.5	9	22.2
14.40	4	4.94	2	3.95	0	1.82	1	1.01	5	7.55	0	2.37
19.94	3	4.48	0	3.7	1	2.53	1	2.92	4	8.88	4	4.8
28.80	3	4.46	**5**	**3.96**	0	1.83	0	1.95	1	6.66	1	5.37
34.00	4	8.06	5	6.61	8	12.1	10	11	41	61.7	5	8.73
48.08	2	6.82	1	4.08	7	9.29	5	7.85	3	12.6	2	6.9
68.00	1	6.34	2	9.3	**8**	**6.89**	4	7.97	4	9.94	5	6.73
79.05	4	7.19	2	10.2	0	5.07	**17**	**2.04**	3	5.69	0	5.57
111.80	2	6.07	4	7.33	2	4.75	**6**	**3.77**	2	3.94	1	4.12

6. Conclusion

During the SEE test, the radiation testbed runs stable and reliable. It is capable to record and display the DUT data even at higher fluxes. The resulting cross section diagrams are very similar to those measured earlier. One big advantage over the old test system is the in-situ evaluation and visualisation of the test data during the irradiation. Additionally, an advantage is the offline playback of the recorded test data to do a deeper analysis. Working with the new radiation testbed revealed a few things that had to be improved:

- The black background colour of the error map display is chosen unfavourable: Blue dots showing single errors are poorly visible. The background colour is now changed to light grey, so error dots are clearly shown.
- Operating the test system turned out to be very intricate and error-prone. Improvements in the test software have been made to get a safer user interface.

Finally, Fig. 8 shows an example of cross section results obtained using two different test systems but using the same ion species and the same Atmel (MHS) memory type. As shown below, good correlation can be reported between the Testbed SEU data and earlier obtained results. Further correlation results as well as a Testbed summary presentation can be found on ESA's www pages detailing the 6th QCA presentation day, May 11th, 2004.

https://escies.org/public/radiation/esa/database/qcaday6data/Presentations/VME_BOARD_QCADAY.pdf (correlation data pages 33-35)
https://escies.org/public/radiation/esa/database/qcaday6data/Presentations/Rad_Days_Presentation_IDA.pdf (Testbed presentation)

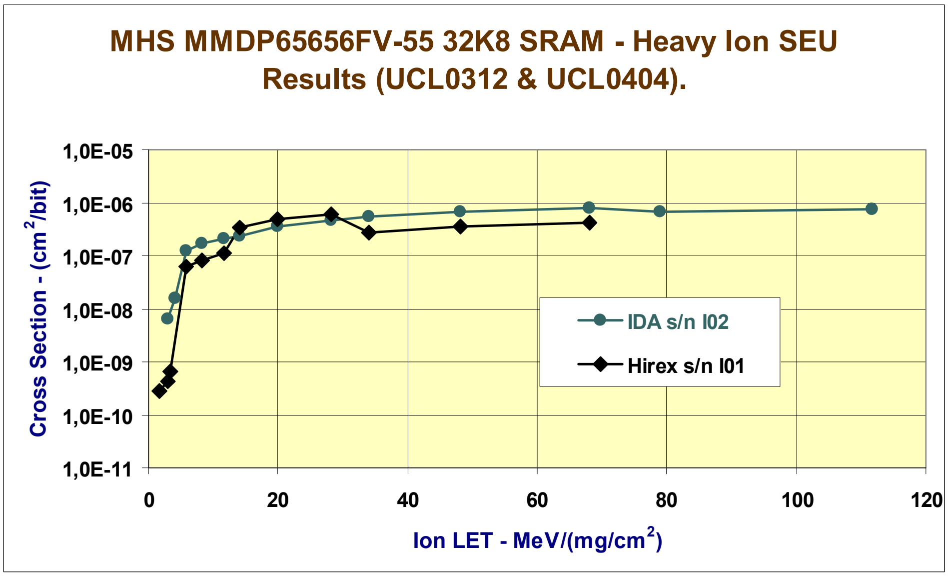

Fig. 8: Comparison of test results for MH51

Appendix: Detailed Results of Each Run

Run	Ion	Tilt [°]	LET [MeV·cm²/mg]	DUT	Capacity	Time [s]	Fluence [/cm²]	Errors	Single Bit	Double Bit	Triple Bit	8 bit	Exp. Double	Exp. Triple	Xsection [/cm²]
52	N-15	0	2.97	AT61	4194304	100	1.00E+06	21940	21884	4	0	6	5.51	0.00119	5.23E-09
51	N-15	45	4.2	AT61	4194304	169	1.00E+06	31275	31253	3	0	2	6.52	0.00117	7.46E-09
20	Ne-20	0	5.85	AT61	4194304	184	307000	18440	18440	0	0	0	2.18	0.000221	1.43E-08
21	Ne-20	45	8.27	AT61	4194304	186	259500	20237	20231	3	0	0	2.58	0.000281	1.86E-08
22	Ne-20	60	11.7	AT61	4194304	163	225000	23326	23324	1	0	0	3.75	0.000517	2.47E-08
19	Ar-40	0	14.1	AT61	4194304	163	293400	26217	26209	4	0	0	4.94	0.000798	2.13E-08
18	Ar-40	45	19.94	AT61	4194304	134	172200	22768	22762	3	0	0	4.48	0.000756	3.15E-08
17	Ar-40	60	28.8	AT61	4194304	181	154900	26223	26217	3	0	0	4.46	0.000651	4.04E-08
58	Kr-84	0	34	AT61	4194304	84	128300	24286	24278	4	0	0	8.06	0.0023	4.51E-08
57	Kr-84	45	48.08	AT61	4194304	87	88100	22780	22776	2	0	0	6.82	0.00175	6.16E-08
56	Kr-84	60	68	AT61	4194304	93	65300	22651	22649	1	0	0	6.34	0.00152	8.27E-08
82	Xe-132	45	79.05	AT61	4194304	72	46200	21284	21276	4	0	0	7.19	0.00209	1.10E-07
81	Xe-132	60	111.8	AT61	4194304	60	34150	19914	19910	2	0	0	6.07	0.00159	1.39E-07
49	N-15	0	2.97	AT62	4194304	138	1.00E+06	23992	23958	1	0	4	4.81	0.000829	5.72E-09
50	N-15	45	4.2	AT62	4194304	148	1.00E+06	32546	32508	3	0	4	8.32	0.00182	7.76E-09
25	Ne-20	0	5.85	AT62	4194304	137	415056	25866	25864	1	0	0	5.7	0.00108	1.49E-08
24	Ne-20	45	8.27	AT62	4194304	134	280554	22636	22634	1	0	0	4.45	0.000751	1.92E-08
23	Ne-20	60	11.7	AT62	4194304	151	212200	22740	22734	3	0	0	4.03	0.000612	2.55E-08
13	Ar-40	0	14.1	AT62	4194304	124	212200	20518	20514	2	0	0	3.95	0.00065	2.31E-08
14	Ar-40	45	19.94	AT62	4194304	106	137200	19071	19071	0	0	0	3.7	0.000616	3.31E-08
16	Ar-40	60	28.8	AT62	4194304	152	129500	22755	22745	5	0	0	3.96	0.000591	4.19E-08
53	Kr-84	0	34	AT62	4194304	90	108600	22805	22779	5	0	2	6.61	0.00164	5.01E-08
54	Kr-84	45	48.08	AT62	4194304	110	93000	26434	26432	1	0	0	4.08	0.000539	6.78E-08
55	Kr-84	60	68	AT62	4194304	99	76600	29199	29195	2	0	0	9.3	0.00254	9.09E-08
79	Xe-132	45	79.05	AT62	4194304	63	50600	23868	23864	2	0	0	10.2	0.00375	1.12E-07
80	Xe-132	60	111.8	AT62	4194304	81	37800	22868	22860	4	0	0	7.33	0.00201	1.44E-07

Run	Ion	Tilt [°]	LET [MeV·cm²/mg]	DUT	Capacity	Time [s]	Fluence [/cm²]	Errors	Single Bit	Double Bit	Triple Bit	8 bit	Exp. Double	Exp. Triple	Xsection [/cm²]
48	N-15	0	2.97	MH41	262144	111	1.00E+06	845	845	0	0	0	0.0104	1.10E-07	3.22E-09
47	N-15	45	4.2	MH41	262144	166	1.00E+06	1533	1533	0	0	0	0.0233	3.03E-07	5.85E-09
26	Ne-20	0	5.85	MH41	262144	190	843500	20799	20791	4	0	0	3.74	0.000576	9.41E-08
27	Ne-20	45	8.27	MH41	262144	178	508800	18920	18916	2	0	0	2.94	0.000391	1.42E-07
28	Ne-20	60	11.7	MH41	262144	155	356500	17398	17398	0	0	0	3.19	0.000503	1.86E-07
12	Ar-40	0	14.1	MH41	262144	123	206800	12073	12073	0	0	0	1.82	0.000235	2.23E-07
11	Ar-40	45	19.94	MH41	262144	155	178000	15863	15861	1	0	0	2.53	0.000347	3.40E-07
10	Ar-40	60	28.8	MH41	262144	144	140400	13717	13717	0	0	0	1.83	0.00021	3.73E-07
59	Kr-84	0	34	MH41	262144	137	256200	32716	32700	8	0	0	12.1	0.00382	4.87E-07
60	Kr-84	45	48.08	MH41	262144	115	148200	25668	25654	7	0	0	9.29	0.00288	6.61E-07
61	Kr-84	60	68	MH41	262144	97	104400	21907	21891	8	0	0	6.89	0.00186	8.00E-07
78	Xe-132	45	79.05	MH41	262144	109	100900	19113	19081	0	0	4	5.07	0.00116	7.23E-07
77	Xe-132	60	111.8	MH41	262144	128	87500	19948	19864	2	0	10	4.75	0.000973	8.70E-07
45	N-15	0	2.97	MH51	262144	130	1.00E+06	1680	1624	0	0	7	0.0331	5.79E-07	6.41E-09
46	N-15	45	4.2	MH51	262144	152	1.00E+06	4190	4190	0	0	0	0.189	7.32E-06	1.60E-08
31	Ne-20	0	5.85	MH51	262144	145	531200	17067	17059	4	0	0	3.29	0.000545	1.23E-07
30	Ne-20	45	8.27	MH51	262144	153	392000	17294	17294	0	0	0	3.06	0.000463	1.68E-07
29	Ne-20	60	11.7	MH51	262144	142	331800	18586	18584	1	0	0	3.58	0.00059	2.14E-07
7	Ar-40	0	14.1	MH51	262144	178	176500	10714	10712	1	0	0	1.01	8.20E-05	2.32E-07
8	Ar-40	45	19.94	MH51	262144	132	163400	15391	15389	1	0	0	2.92	0.000476	3.59E-07
9	Ar-40	60	28.8	MH51	262144	121	100400	12049	12049	0	0	0	1.95	0.00027	4.58E-07
64	Kr-84	0	34	MH51	262144	80	174000	24456	24436	10	0	0	11	0.00426	5.36E-07
63	Kr-84	45	48.08	MH51	262144	81	123000	21513	21503	5	0	0	7.85	0.00246	6.67E-07
62	Kr-84	60	68	MH51	262144	130	129600	26665	26657	4	0	0	7.97	0.00204	7.85E-07
75	Xe-132	45	79.05	MH51	262144	295	106800	19131	19097	17	0	0	2.04	0.000187	6.83E-07
76	Xe-132	60	111.8	MH51	262144	170	98400	19775	19747	6	0	2	3.77	0.000618	7.67E-07
44	N-15	0	2.97	WH33	4194304	57	284700	24256	24182	5	0	8	11.5	0.00467	2.03E-08

Run	Ion	Tilt [°]	LET [MeV·cm²/mg]	DUT	Capacity	Time [s]	Fluence [/cm²]	Errors	Single Bit	Double Bit	Triple Bit	8 bit	Exp. Double	Exp. Triple	Xsection [/cm²]
43	N-15	45	4.2	WH33	4194304	60	184300	23474	23312	5	0	19	10.2	0.00382	3.04E-08
32	Ne-20	0	5.85	WH33	4194304	39	148200	30486	30462	12	0	0	25.4	0.0181	4.90E-08
42	N-15	60	5.94	WH33	4194304	53	131000	23369	23211	7	0	18	10.1	0.00377	4.25E-08
33	Ne-20	45	8.27	WH33	4194304	55	142900	40679	40633	23	0	0	33.6	0.0238	6.79E-08
34	Ne-20	60	11.7	WH33	4194304	53	104000	43825	43789	18	0	0	40.5	0.0321	1.00E-07
6	Ar-40	0	14.1	WH33	4194304	93	81600	24720	24710	5	0	0	7.55	0.00198	7.22E-08
5	Ar-40	45	19.94	WH33	4194304	82	58000	25386	25378	4	0	0	8.88	0.00266	1.04E-07
4	Ar-40	60	28.8	WH33	4194304	89	38143	23556	23554	1	0	0	6.66	0.00161	1.47E-07
65	Kr-84	0	34	WH33	4194304	50	86000	52753	52671	41	0	0	61.7	0.062	1.46E-07
66	Kr-84	45	48.08	WH33	4194304	54	29100	24597	24591	3	0	0	12.6	0.00555	2.02E-07
67	Kr-84	60	68	WH33	4194304	78	26500	26060	26052	4	0	0	9.94	0.00325	2.34E-07
74	Xe-132	45	79.05	WH33	4194304	85	23000	20599	20561	3	0	4	5.69	0.00135	2.14E-07
73	Xe-132	60	111.8	WH33	4194304	130	21500	19661	19609	2	0	6	3.94	0.000677	2.18E-07
39	N-15	0	2.97	WH28	4194304	104	380304	24670	24654	0	0	2	6.76	0.00159	1.55E-08
40	N-15	45	4.2	WH28	4194304	74	209000	21771	21765	3	0	0	7.32	0.00211	2.48E-08
38	Ne-20	0	5.85	WH28	4194304	53	244200	34596	34580	8	0	0	22.4	0.0125	3.38E-08
41	N-15	60	5.94	WH28	4194304	73	151500	23225	23201	4	0	2	8.32	0.00256	3.65E-08
36	Ne-20	45	8.27	WH28	4194304	70	185600	37772	37756	8	0	0	23.1	0.0121	4.85E-08
35	Ne-20	60	11.7	WH28	4194304	52	101200	32440	32422	9	0	0	22.2	0.013	7.64E-08
1	Ar-40	0	14.1	WH28	4194304	140	70900	16898	16898	0	0	0	2.37	0.000285	5.68E-08
2	Ar-40	45	19.94	WH28	4194304	200	80600	28591	28583	4	0	0	4.8	0.000691	8.46E-08
3	Ar-40	60	28.8	WH28	4194304	108	42700	22486	22484	1	0	0	5.37	0.0011	1.26E-07
70	Kr-84	0	34	WH28	4194304	75	62700	25071	25061	5	0	0	8.73	0.00261	9.53E-08
69	Kr-84	45	48.08	WH28	4194304	82	39200	22285	22273	2	0	1	6.9	0.00183	1.36E-07
68	Kr-84	60	68	WH28	4194304	79	31900	22559	22549	5	0	0	6.73	0.00172	1.69E-07
71	Xe-132	45	79.05	WH28	4194304	98	29200	21769	21769	0	0	0	5.57	0.00122	1.78E-07
72	Xe-132	60	111.8	WH28	4194304	115	24100	20255	20253	1	0	0	4.12	0.00072	2.00E-07