Radiation SEE Evaluation of Candidate Components for New ERC32 SC VME Board Design, Summary Results.

by

[1]R. Harboe-Sørensen, [2]F.-X. Guerre [2]J.-G. Loqut & [2]C. Thizon

[1]European Space Agency/ESTEC - The Netherlands
[2]HIREX Engineering, Toulouse - France

Abstract

Candidate components for the new ERC32 SC VME board design for ISS have been radiation SEE evaluated at the Heavy-ion Irradiation Facility at UCL, Louvain-la-Neuve, Belgium. Radiation SEE summary results covering 2 PAL types, 4 FLASH memory types and 4 SRAM memory types will be presented. Co-60 TID results for two 2Mx8 FLASH memory types will also be presented.

ESTEC - Radiation Effects and Analysis Techniques Section

Objective:

To Radiation Evaluate Candidate Component Types addressing:

- SEE sensitivities to Heavy Ions
- (TID sensitivities to Co-60)

To Have Radiation SEE Data before January 2003 – using expertise from:

- Component selection and procurement;
  Astrium GmbH, Bremen,
- Test House;
  HIREX Engineering, Toulouse
- Test facility;
  Heavy-ion Irradiation Facility (HIF), UCL, Louvain-la-Neuve,
- Technical Management;
  ESA/ESTEC TOS-QCA

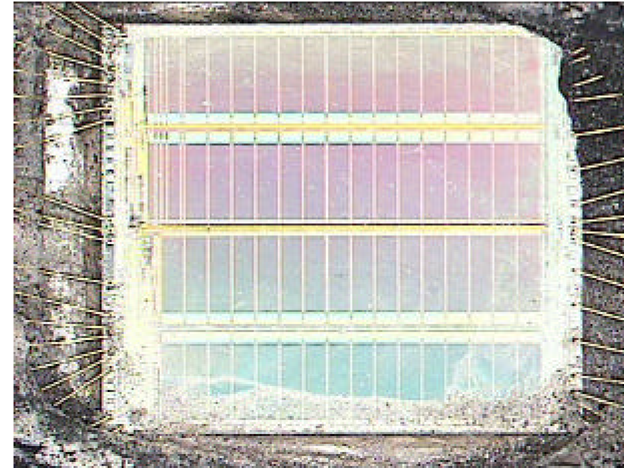
Component Types Tested:

Part Family	Manufacturer	Type	Package
PAL/GAL	ATMEL	ATF22V10C-15JI ATF22V10C-10JI	PLCC28
PAL/GAL	Lattice	GAL22V10D-10LR	LCC28
FLASH2Mx8	AMD	AM29F016D-70E4C	TSOP40
FLASH2Mx8	STM	M29F016B70N1	TSOP40
FLASH4Mx8	AMD	AM29F032B-90EI	TSOP40
FLASH4Mx8	STM	M29F032D70N6	TSOP40
SRAM512kx8	Cypress	CY7C1049B-15VI	SOJ36
SRAM512kx8	Atmel	AT60142E	FP36
SRAM512kx8	Samsung	K6R4008C1D	SOJ36
SRAM2Mx8	Toshiba	TC55V8200FT-12	TSOP II-54

Device Preparation for Heavy ion Testing:

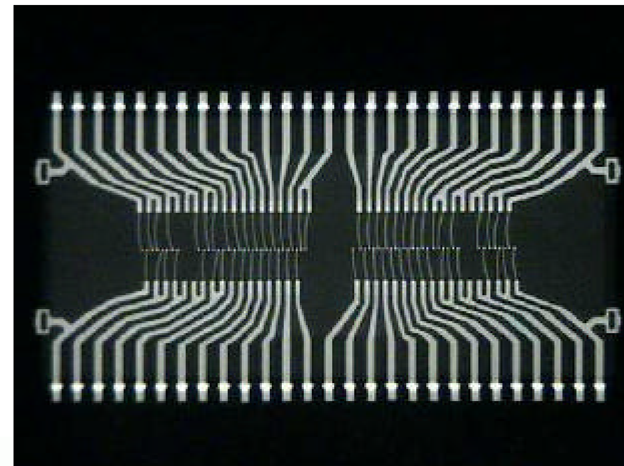
Etching

STM M29F016B s/n 4.1



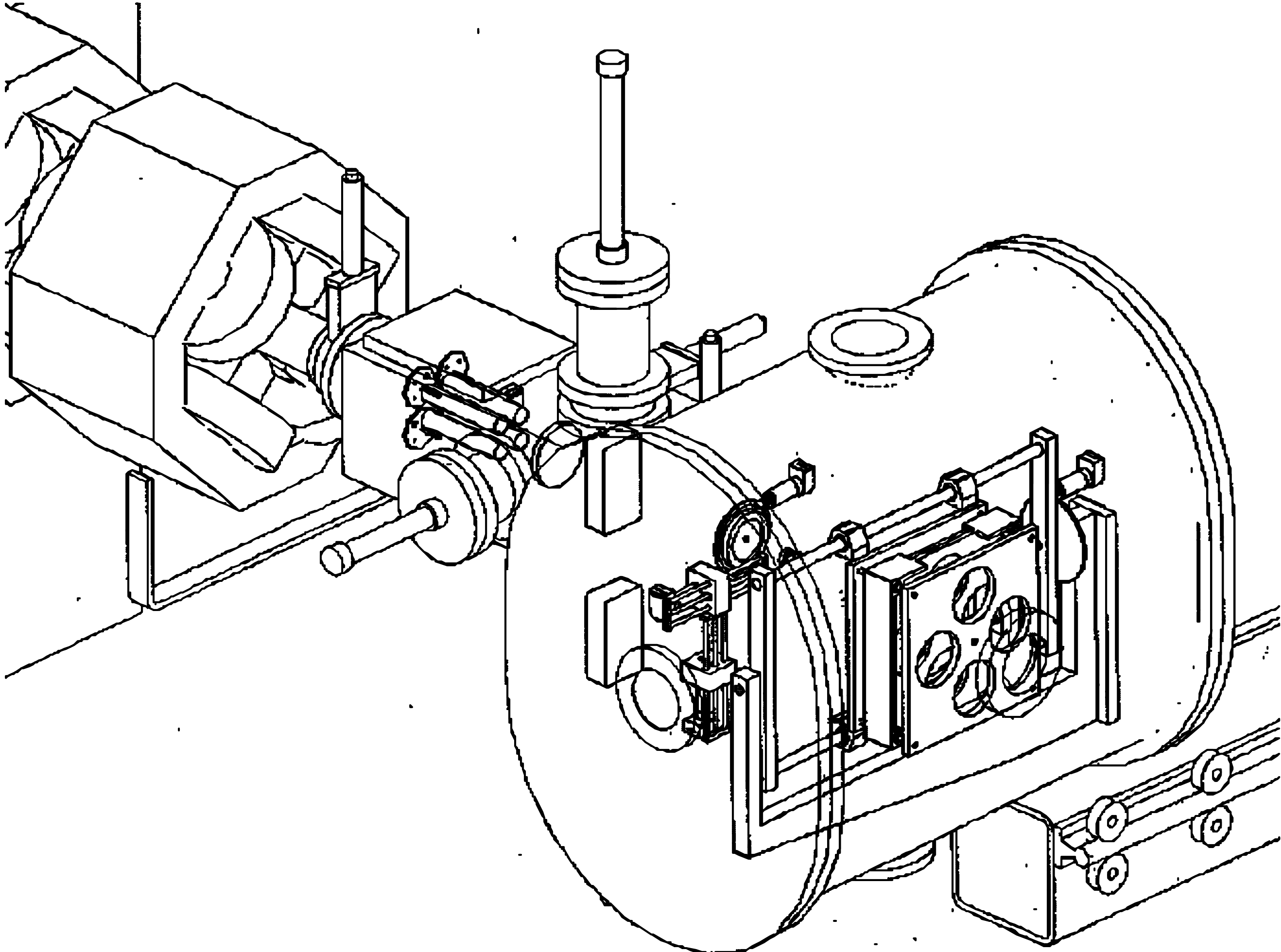
Back Thinning

Toshiba TC55V8200FT
X-Ray -



Heavy Ion Facility - UCL

Heavy Ion Facility - UCL



Accelerator Test Facilities - Heavy Ions used

HIF, UCL, Louvan la Neuve, Belgium

Ion Cocktail M/Q=4.94	Energy MeV	Range µm Si	LET MeV(mg/cm²)
$^{10}B^{2+}$	41	80	1.7
$^{15}N^{3+}$	62	64	2.97
$^{20}Ne^{4+}$	78	45	5.85
$^{40}Ar^{8+}$	150	42	14.1
$^{84}Kr^{17+}$	316	43	34.0
$^{132}Xe^{26+}$	459	43	55.9
UCL – Ion Cocktail #1 produced for ESA			

JYFL, University of Jyvaskyla, Finland

Ion Cocktail M/Q=3.8	Energy MeV	Range µm Si	LET MeV(mg/cm²)
$^{15}N^{4+}$	140	211	2.0
$^{30}Si^{8+}$	280	127	7.0
$^{56}Fe^{15+}$	523	95	18.0
$^{82}Kr^{22+}$	766	93	29.0
JYFL – Ion Cocktail produced for ESA October 2001.			

PAL: Test Set-up & Test Configurations I

Test Set-up

- HIREX Modular rack/Generic memory test board

Test Configurations

1) SET

- Combinatorial logic part
- 5 bit adder - 10 inputs/5 output
- 1 cell used for internal node

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2) SEU

- Flip-Flops
- 4 cells used as 4 bit register
- 50/50 configured by inverters

- Each DUT was programmed prior to testing
- Test cycle time: 10 ms.

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PAL: Test Set-up & Test Configurations II

1) SET errors:

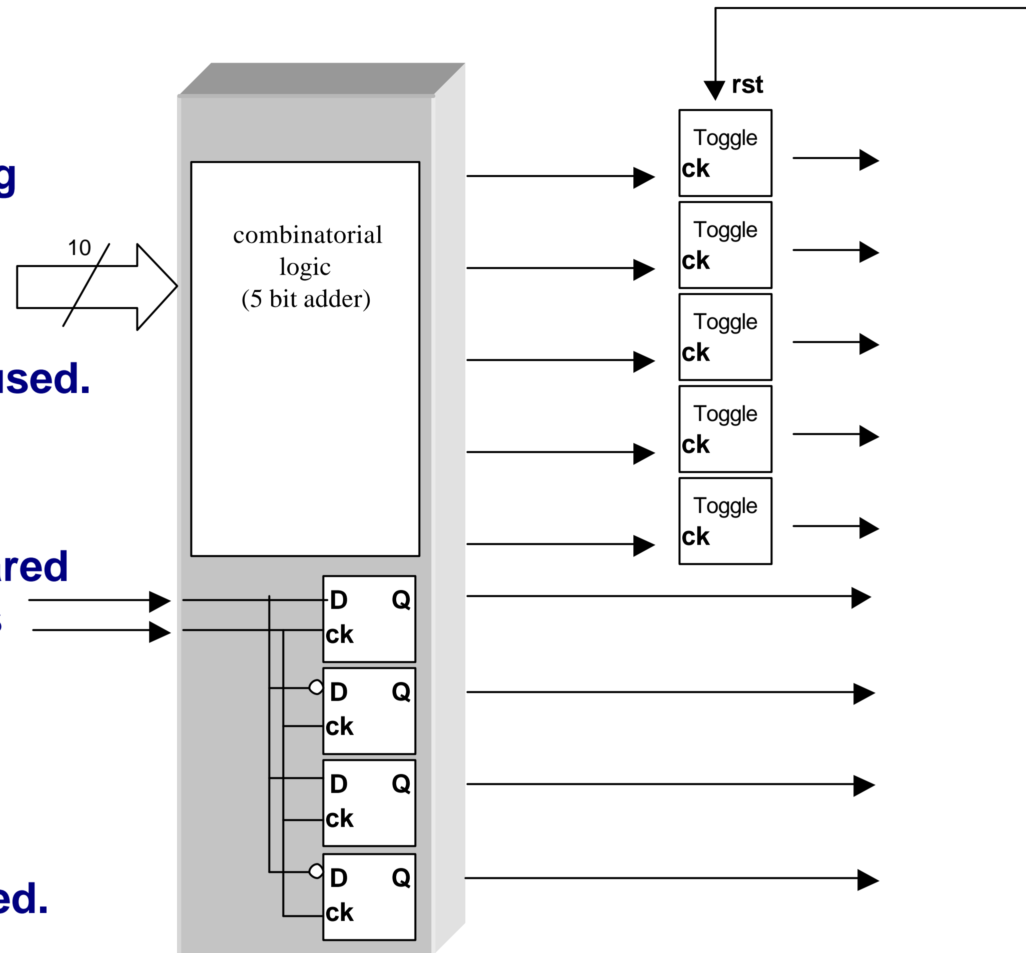
5 toggle latches have triggering active edges in line with the awaited value.
Input data are changed at each new cycle, 10 different words used.

2) SEU errors:

Register output bits are compared with awaited values. Flip-Flops Input data are inverted at each new cycle

3) SEL errors:

Power supply module monitored.



PAL - Atmel ATF22V10C SEE Test Results: I

Run #	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SET	SEU	Permanent error	SEL	SEE cross-section (/cm²)
63	1	Ne	5.85	0	**5.85**	136	1.00E+06	7353	**1**	0		0	1.00E-06
59	1	Ne	5.85	60	**11.70**	91	3.18E+05	3499	1	0	**1**	0	3.14E-06
60	1	Ne	5.85	60	11.70	287	1.00E+06	3484	6	0		0	6.00E-06
56	1	Ar	14.10	0	**14.10**	275	7.11E+05	2584	9	**2**	3	**5**	1.55E-05
57	1	Ar	14.10	45	19.94	475	8.10E+05	1705	34	3	4	10	4.57E-05
58	1	Ar	14.10	60	28.20	606	7.84E+05	1293	61	5	4	35	8.42E-05
62	2	Ne	5.85	0	5.85	127	1.00E+06	7874	0	0		0	<1.00E-06
61	2	Ne	5.85	60	11.70	264	1.00E+06	3788	5	0		0	5.00E-06
54	2	Ar	14.10	0	14.10	33	8.67E+04	2627	2	0	1	0	2.31E-05
53	2	Ar	14.10	45	19.94	549	1.00E+06	1821	40	5	3	22	4.50E-05
52	2	Ar	14.10	60	28.20	604	1.00E+06	1656	63	15	3	44	7.80E-05

Atmel ATF22V10C Heavy ion SEE results per run.

PAL - Atmel ATF22V10C SEE Test Results: II

Summary Results -

- SET observed from a LET of 5.85 MeV/(mg/cm^2)
- SEU observed from a LET of 11.7 MeV/(mg/cm^2)
- SEL observed from a LET of 14.1 MeV/(mg/cm^2)
- Permanent Errors from a LET of 11.7 MeV/(mg/cm^2)

Permanent Errors -

- Occurred both as a permanent SET and SEU requiring a Power-Off/On for resetting.
- These events are linked to the programmed circuit configuration.

Latch-up -

- The difference in some SEL events (impedance associated) could mean that these events may results from internal conflicts linked to changes in the circuit configuration.

PAL - Lettice GAL22V10 SEE Test Results: Ia

Run #	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SET	SEU	SEL	SEE cross-section (/cm²)
67	14	Ne	5.85	0	5.85	117	1.00E+06	8547	0	0	0	0.00E+00
68	14	Ne	5.85	45	**8.27**	162	1.00E+06	6173	**2**	0	0	2.00E-06
64	14	Ne	5.85	60	11.70	227	1.00E+06	4405	5	0	0	5.00E-06
40	14	Ar	14.10	0	14.10	173	2.00E+05	1156	0	0	0	0.00E+00
47	14	Ar	14.10	0	**14.10**	228	1.00E+06	4386	9	**2**	0	1.10E-05
44	14	Ar	14.10	45	19.94	266	1.00E+06	3759	13	1	0	1.40E-05
41	14	Ar	14.10	60	28.20	203	1.00E+05	493	0	0	0	0.00E+00
43	14	Ar	14.10	60	28.20	434	1.00E+06	2304	6	4	0	1.00E-05
114	14	Kr	34.00	0	**34.00**	918	1.00E+06	1089	21	5	**2**	2.60E-05
115	14	Kr	34.00	45	48.08	468	1.00E+06	2137	29	8	13	3.70E-05
116	14	Kr	34.00	60	68.00	581	1.00E+06	1721	57	27	15	8.40E-05

Lerrice GAL22V10 s/n 14, Heavy ion SEE results per run.

PAL - Lettice GAL22V10 SEE Test Results: Ib

Run #	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SET	SEU	SEL	SEE cross-section (/cm²)
66	15	Ne	5.85	0	5.85	113	1.00E+06	8850	0	0	0	0.00E+00
69	15	Ne	5.85	45	8.27	145	1.00E+06	6897	0	0	0	0.00E+00
65	15	Ne	5.85	60	11.70	228	1.00E+06	4386	1	0	0	1.00E-06
46	15	Ar	14.10	0	14.10	237	1.00E+06	4219	8	0	0	8.00E-06
45	15	Ar	14.10	45	19.94	299	1.00E+06	3344	6	1	0	7.00E-06
42	15	Ar	14.10	60	28.20	707	1.00E+06	1414	16	1	0	1.70E-05
119	15	Kr	34.00	0	34.00	263	1.00E+06	3802	29	7	3	3.60E-05
118	15	Kr	34.00	45	48.08	352	1.00E+06	2841	42	6	12	4.80E-05
117	15	Kr	34.00	60	68.00	574	1.00E+06	1742	55	11	23	6.60E-05

Lerrice GAL22V10 s/n 15, Heavy ion SEE results per run.

PAL - Lettice GAL22V10 SEE Test Results: II

Summary Results -

- SET observed from a LET of 8.27 MeV/(mg/cm^2)
- SEU observed from a LET of 14.1 MeV/(mg/cm^2)
- SEL observed from a LET of 34.0 MeV/(mg/cm^2)
- No Permanent Errors observed during these tests

FLASH Memories: Test Set-up & Test Configurations I

Test Set-up

- HIREX Modular rack/Generic memory test board

Test Configurations

1) Static Test

- Device Initialization
- Write test pattern/check for errors (stuck bits)
- Expose DUT to the beam for a given time followed by read operations, new test pattern and h/w reset
- Write test pattern …..

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2) Dynamic Test

- Device Initialization
- Write test pattern/check for errors (stuck bits)
- Expose DUT to the beam and perform continues read operations, new test pattern and h/w reset
- Write test pattern …..

FLASH Memories: STM M29F016B SEE Test Results I

Type of Test	DUT s/n	LET 5.85	LET 11.7	LET 14.1	LET 19.9	LET 28.2	Comments
STM – 2Mx8 FLASH Memory – M29F016B70N1.							
Static Test	4.1		ok	I/F	I	F	SEFI, Program change of data, Power Off-On for reset, High current, Read SEUs
Static Test	4.2			I	I/F/D		
Read Test	4.1		ok	ok	S	S/F	
Read Test	4.2			F			

F = Functional Failure, I = High Current, S = SEU Read & D = Damaged

Summary Results -

- SEU – only a few read events
- High current – I changes from 360 uA up to 25 mA
- Functional Failures from a LET of 14.1 MeV/(mg/cm^2)
- Several Events required a Power-Off/On in order to recover
- Several Events required re-writing of lost data
- DUT goes into programming mode
- One Event caused permanent Damaged

FLASH Memories: STM M29F016B Co-60 TID Results IA

Irradiation Steps	Dose rate	Annealing steps	Temperature
krads	krads/h	hours	°C
0			
5	0,30		25
12	0,30		25
20	0,30		25
		24	25
		168	100

Test Conditions/Results -

- Co-60 Test Facility – CERT/ONERA
- Dose Rate/Steps – see table
- 4 parts Biased – 1 part Control
- Electrical Measurements - Parametric Testing
- Functional Failure lost at the 20 Krad(Si) step.

FLASH Memories: STM M29F032D SEE Test Results II

Type of Test	DUT s/n	LET 5.85	LET 11.7	LET 14.1	LET 19.9	LET 28.2	Comments
STM – 4Mx8 FLASH Memory – M29F032D70N6.							
Static Test	1.1	ok		F	Tilt?	Tilt?	SEFI, Data to '0', Power Off-On for reset, High current, Read SEUs
Static Test	1.2	ok	F	ok	ok	I	
Read Test	1.1	ok		F	Tilt?	Tilt?	
Read Test	1.2	ok	S	S/F	S/F	F	

F = Functional Failure, I = High Current & S = SEU Read

 # Summary Results -

- **SEU – many different events**
- **High current – I changes from 360 uA to 10.5 mA**
- **Functional Failures from a LET of 11.7 MeV/(mg/cm^2)**
- **Several Events required a Power-Off/On in order to recover**
- **Several Events required re-writing of lost data**
- **DUT goes into programming mode**
- **Tilt – die not fully visible by the beam**

FLASH Memories: AMD AM29F016D SEE Test Results III

Type of Test	DUT s/n	LET 5.85	LET 11.7	LET 14.1	LET 19.9	LET 28.2	Comments
AMD – 2Mx8 FLASH Memory – AM29F016D-70E4C.							
Static Test	3.1	ok	ok	S	ok	ok	SEFI, Data to ‘0’, R/W to reset, Read SEUs
Static Test	3.2		ok	ok	F	F	
Read Test	3.1	ok	S	S	S	F	
Read Test	3.2		ok	S	S	S	

F = Functional Failure & S = SEU Read

Summary Results -

- **SEU – Only a few read events**
- **Stuck bits from a LET of 19.8 MeV/(mg/cm^2)**
- **Reprogramming required to remove stuck-bits**
- **Several Events required a Reset or Power-Off/On in order to recover**
- **Several Events required re-writing of lost data**
- **DUT goes into programming mode**

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FLASH Memories: AMD AM29F016D Co-60 TID Results IIIA

Irradiation Steps	Dose rate	Annealing steps	Temperature
krads	krads/h	hours	°C
0			
5	0,30		25
12	0,30		25
20	0,30		25
		24	25
		168	100

Test Conditions/Results -

- Co-60 Test Facility – CERT/ONERA
- Dose Rate/Steps – see table
- 4 parts Biased – 1 part Control
- Electrical Measurements - Parametric Testing
- Functional Failure lost at the 10 Krad(Si) step.

FLASH Memories: AMD AM29F032B SEE Test Results IV

Type of Test	DUT s/n	LET 5.85	LET 11.7	LET 14.1	LET 19.9	LET 28.2	Comments
AMD – 4Mx8 FLASH Memory – AM29F032B-90E1.							
Static Test	2.1	ok		S/F	Tilt?	Tilt?	SEFI, Stuck bits R/W recovery, Power Off-On for reset
Static Test	2.2	ok	F	ok	ok	F	
Read Test	2.1	ok		F	Tilt?	Tilt?	
Read Test	2.2	ok	ok	F	F	F	

F = Functional Failure & S = SEU Read

 # Summary Results -

- **SEU – Only a few read events**
- **Stuck bits from a LET of 11.7 MeV/(mg/cm^2)**
- **Reprogramming required to remove stuck-bits**
- **Several Events required a Reset or Power-Off/On in order to recover**
- **Several Events required re-writing of lost data**
- **DUT goes into programming mode**
- **Tilt – die not fully visible by the beam**

SRAM Memories: Test Set-up & Test Configurations I

Test Set-up

- HIREX Modular rack/Generic memory test board

Test Configurations

1) Static Test

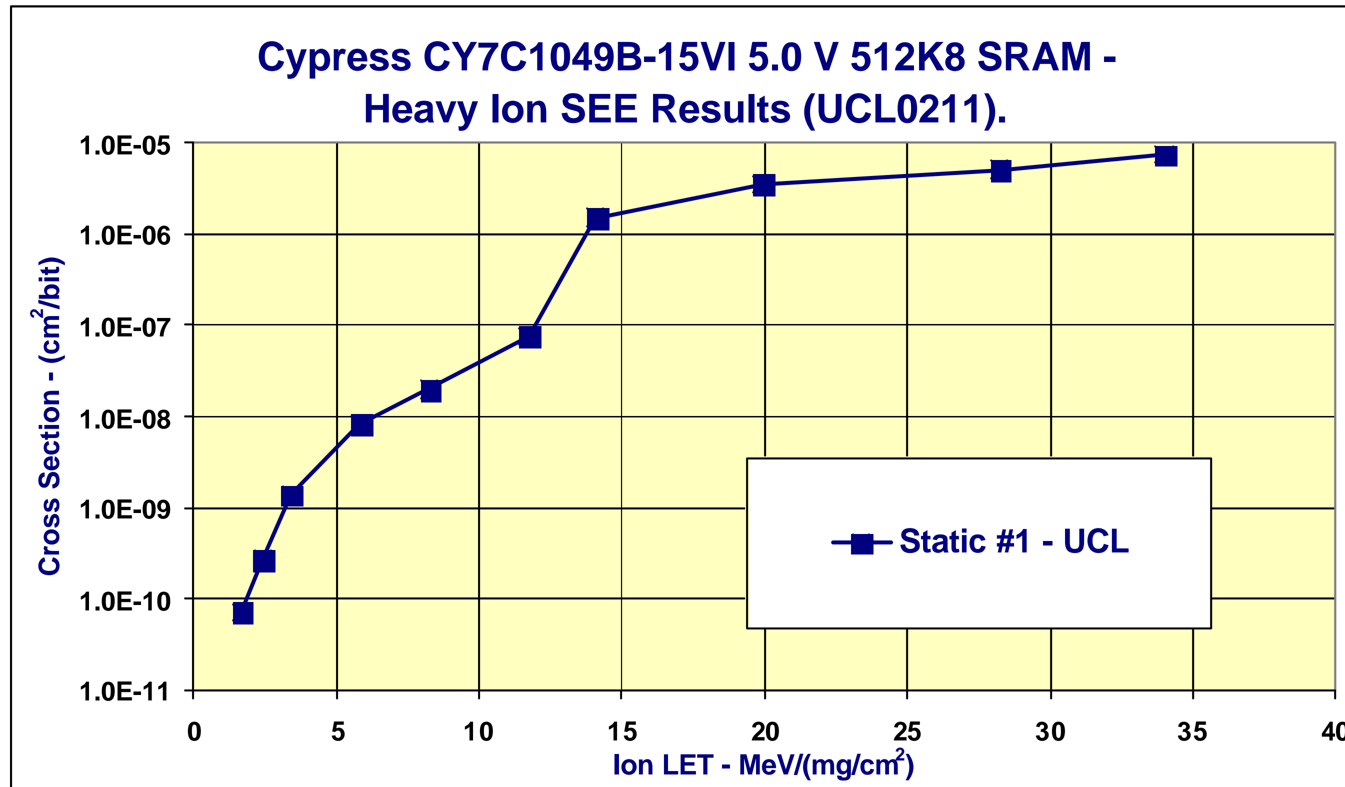
- Device Initialization
- Write test pattern/check for errors (stuck bits)
- Expose DUT to the beam for a given time followed by read operations, new test pattern and h/w reset
- Write test pattern …..

-

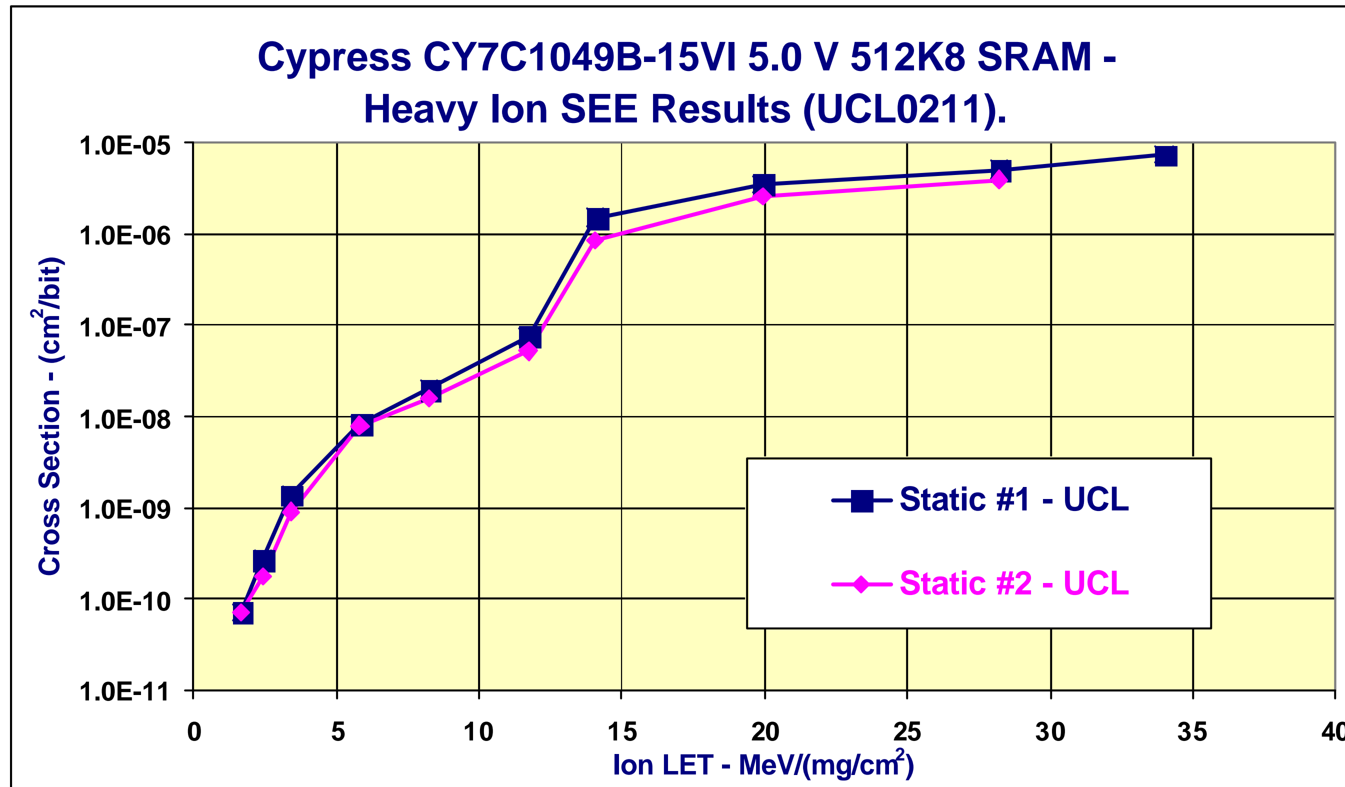
2) Dynamic Test

- Device Initialization
- Write test pattern/check for errors (stuck bits)
- Expose DUT to the beam and perform continues read operations, new test pattern and h/w reset
- Write test pattern …..

SRAM Memories: Cypress Cy7C1049B SEE Test Results I



SRAM Memories: Cypress Cy7C1049B SEE Test Results I



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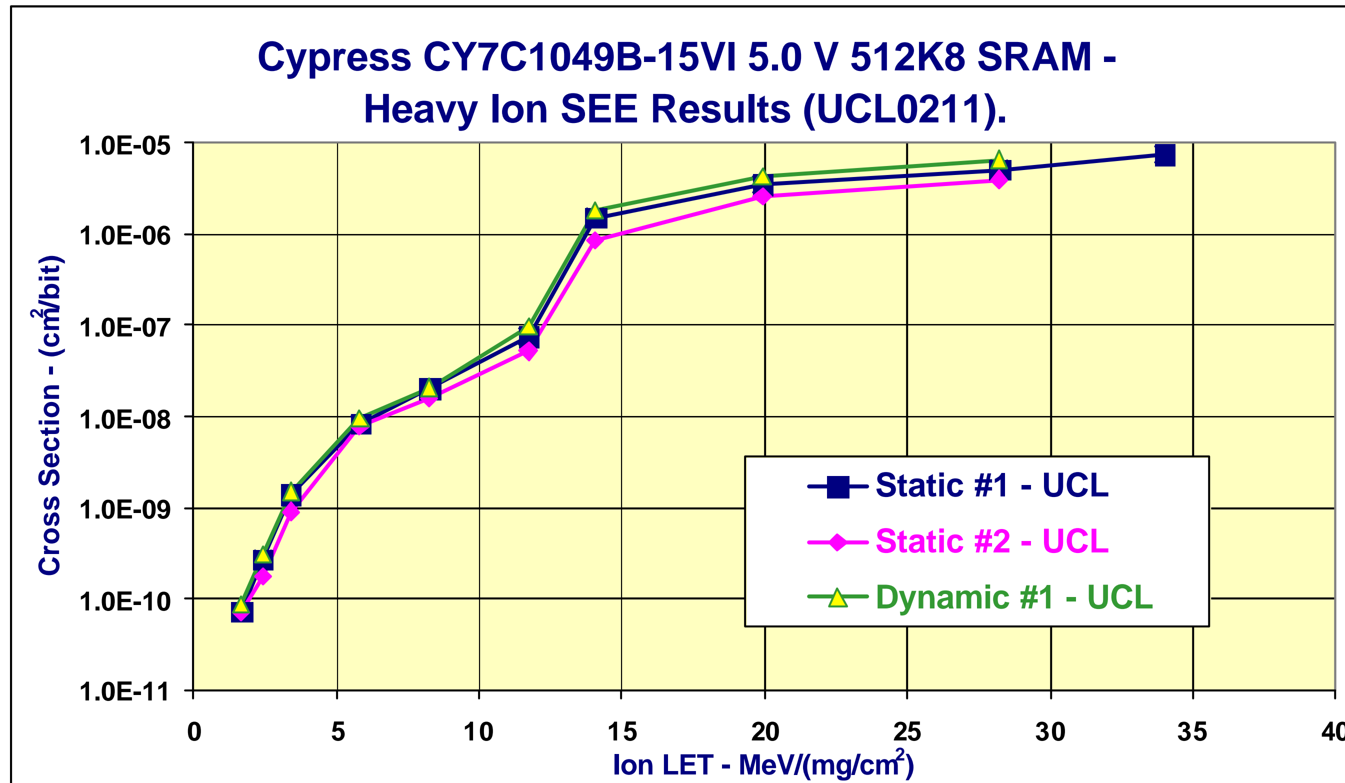
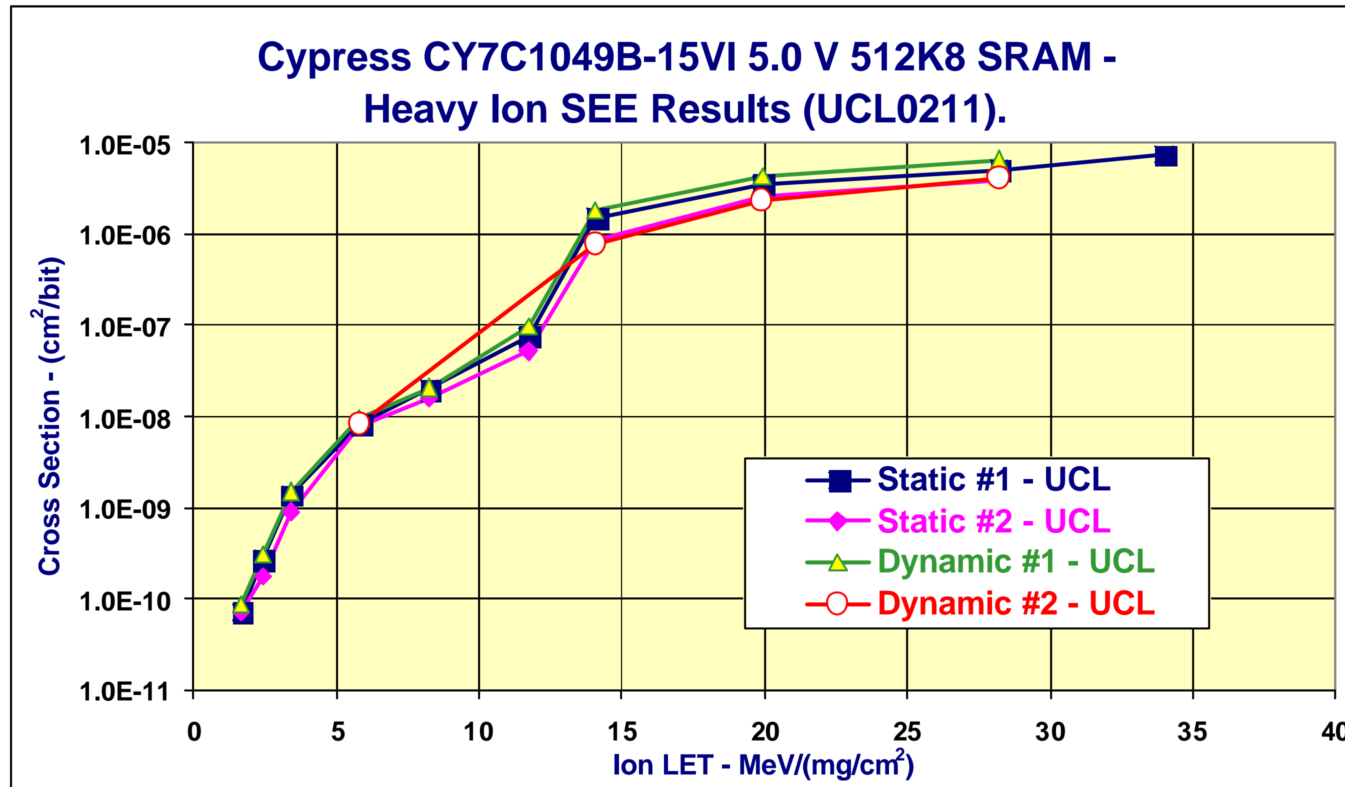
SRAM Memories: Cypress Cy7C1049B SEE Test Results I



SRAM Memories: Cypress Cy7C1049B SEE Test Results I



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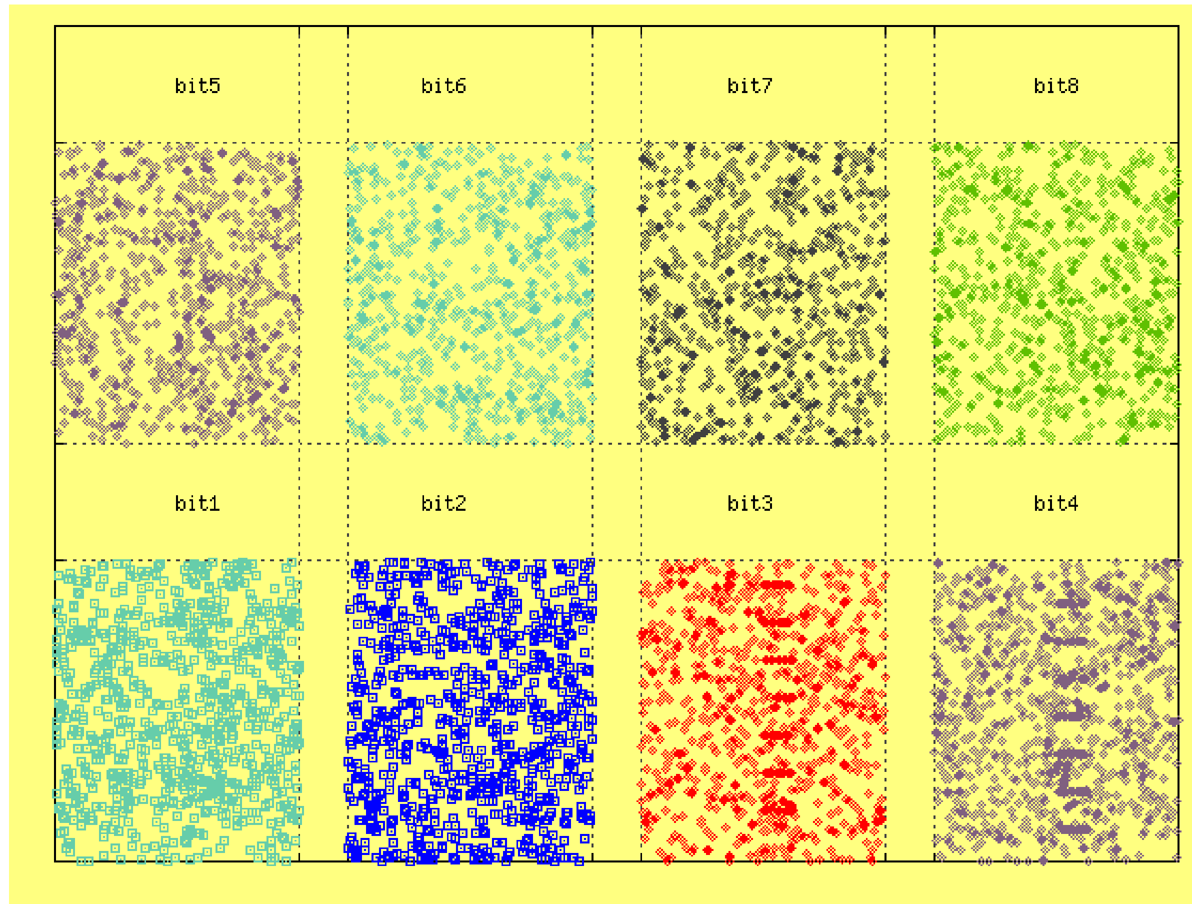
SRAM Memories: Cypress Cy7C1049B SEE Test Results II



Run 99, B-ions at LET = 3.4 MeV/(mg/cm2) – row/column distributions of 6265 SEU

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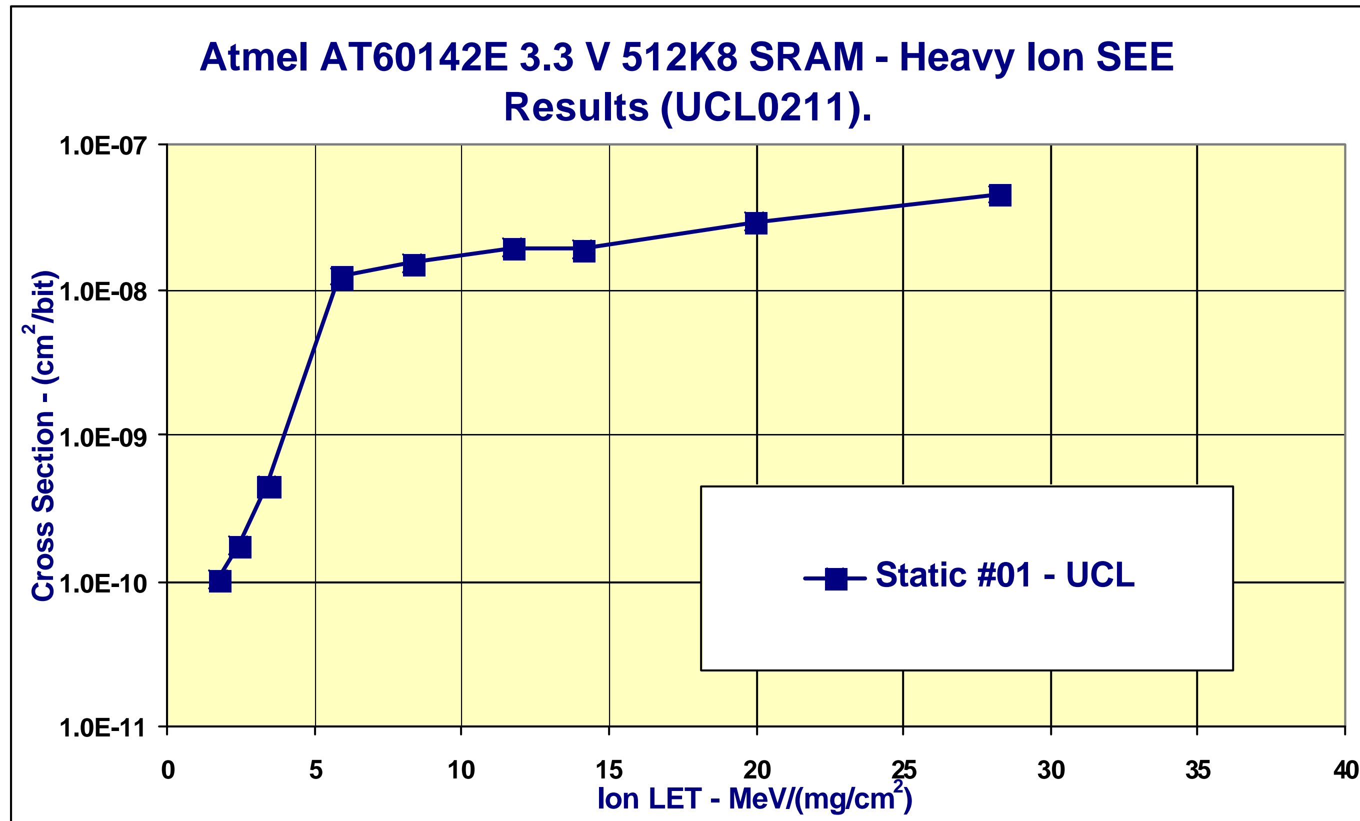
SRAM Memories: Cypress Cy7C1049B SEE Test Results III

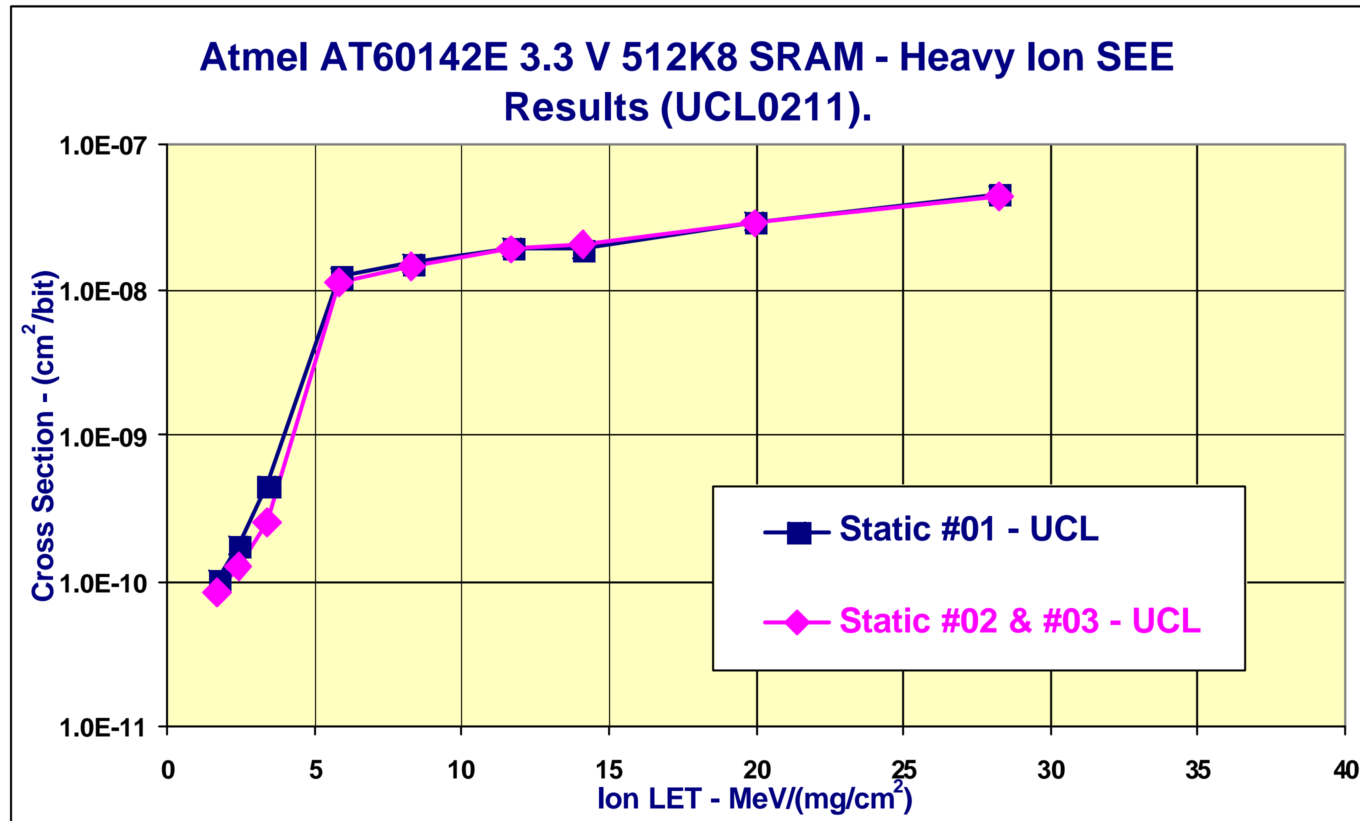
Summary Results -

- SEU – very sensitive device type
  - LET Threshold < 1.7 MeV/(mg/cm^2)
  - Asymptotic cross-section about 1.0E-5 cm^2/per bit
- SEL – no events
- Functional Errors – 2 large events at LET of 14.1 MeV/(mg/cm^2)
  - Every bit reset to '0'
  - Only observed in s/n #01

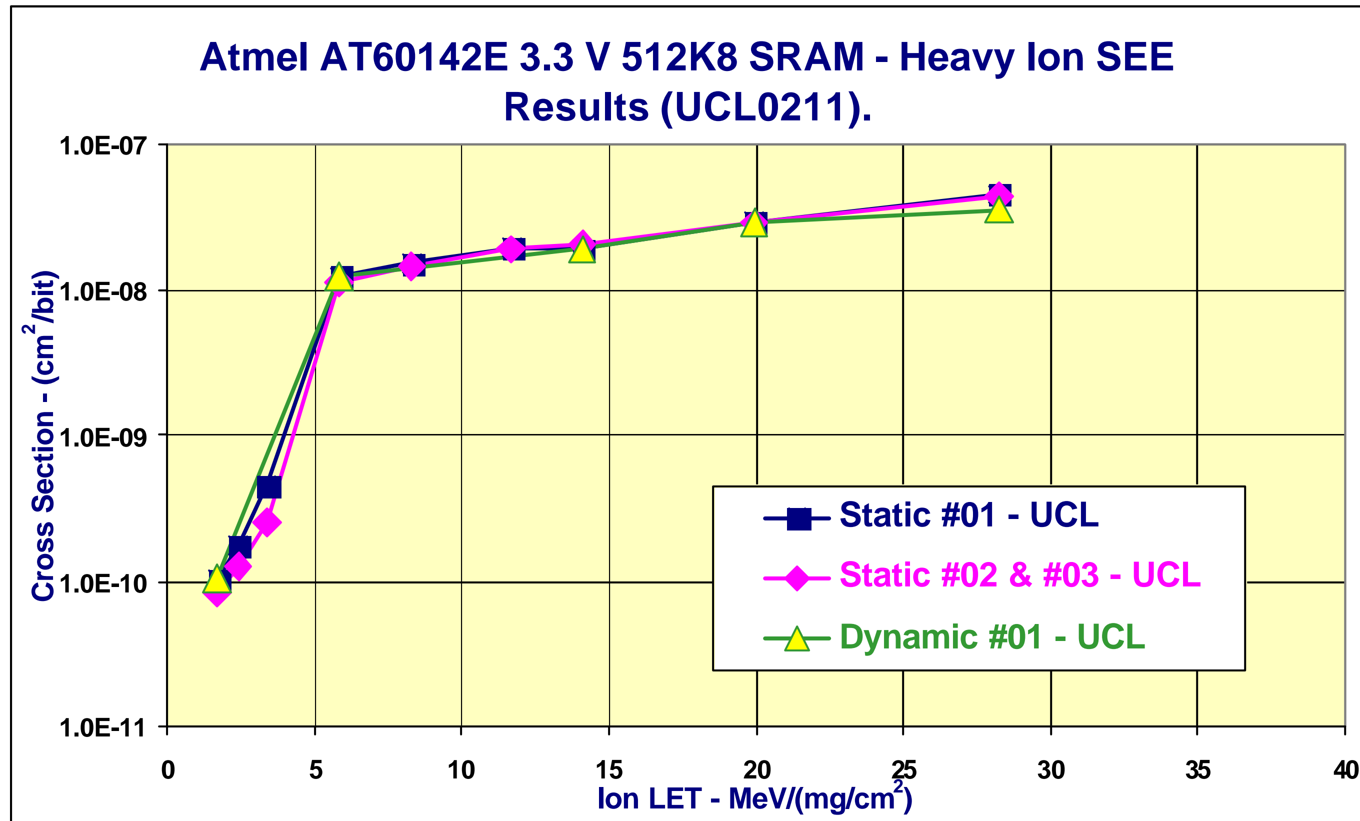
SRAM Memories: Atmel AT60142E SEE Test Results I



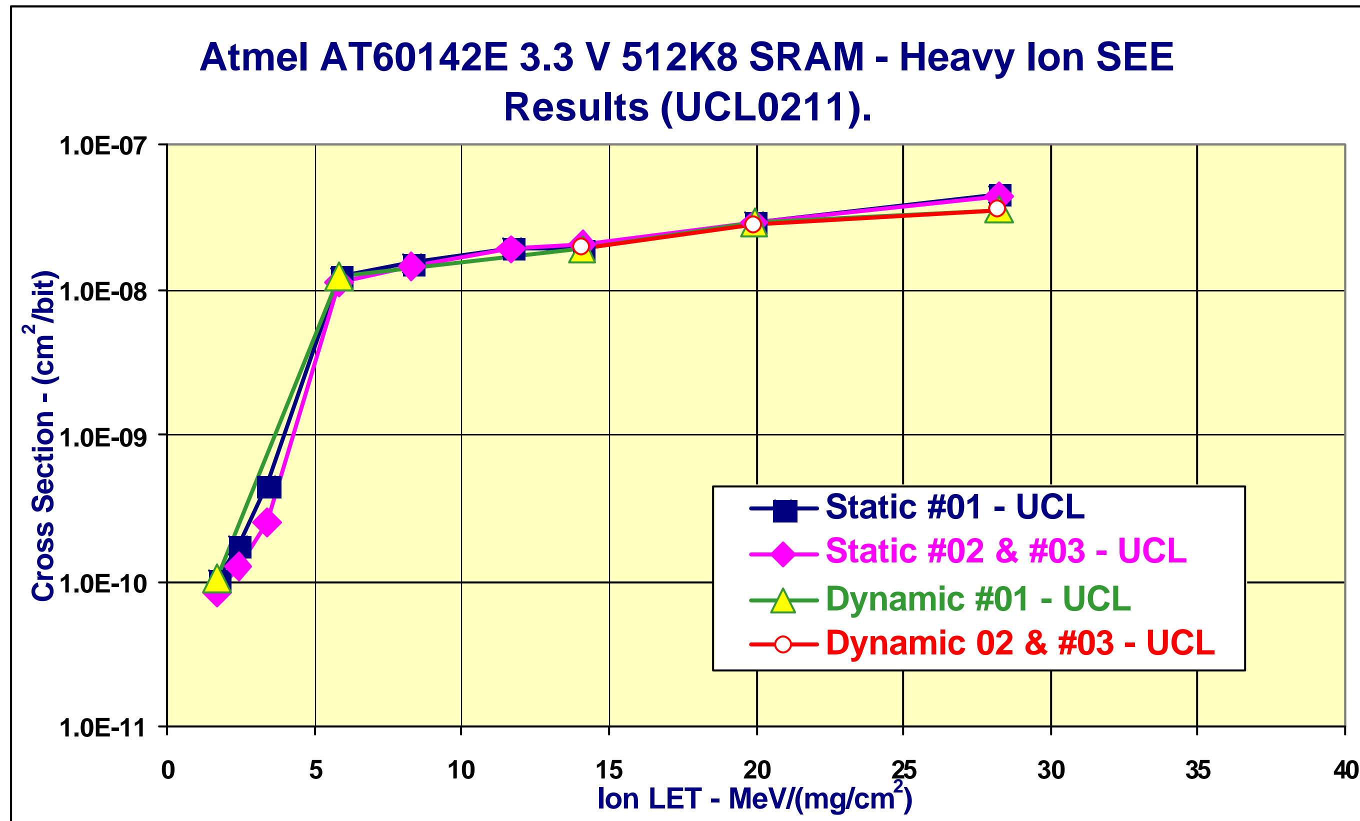
SRAM Memories: Atmel AT60142E SEE Test Results I



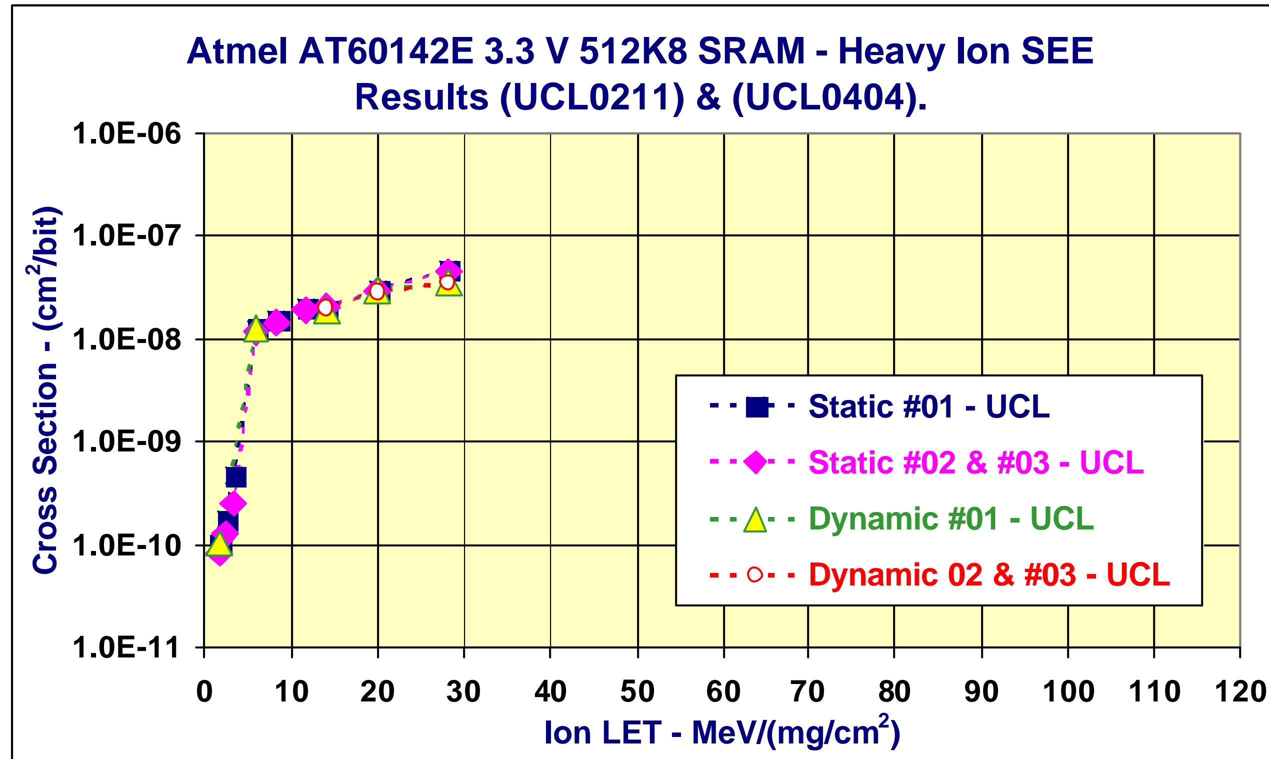
SRAM Memories: Atmel AT60142E SEE Test Results I



SRAM Memories: Atmel AT60142E SEE Test Results I



SRAM Memories: Atmel AT60142E SEE Test Results II



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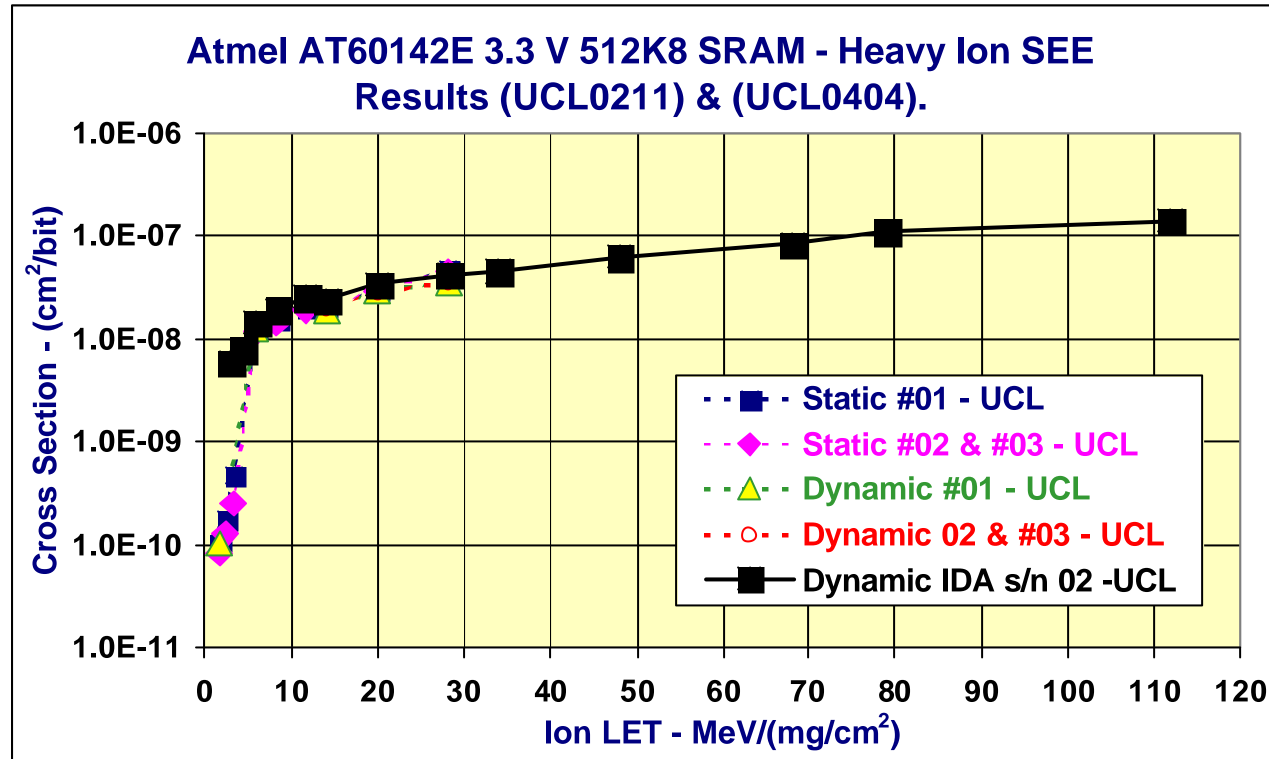
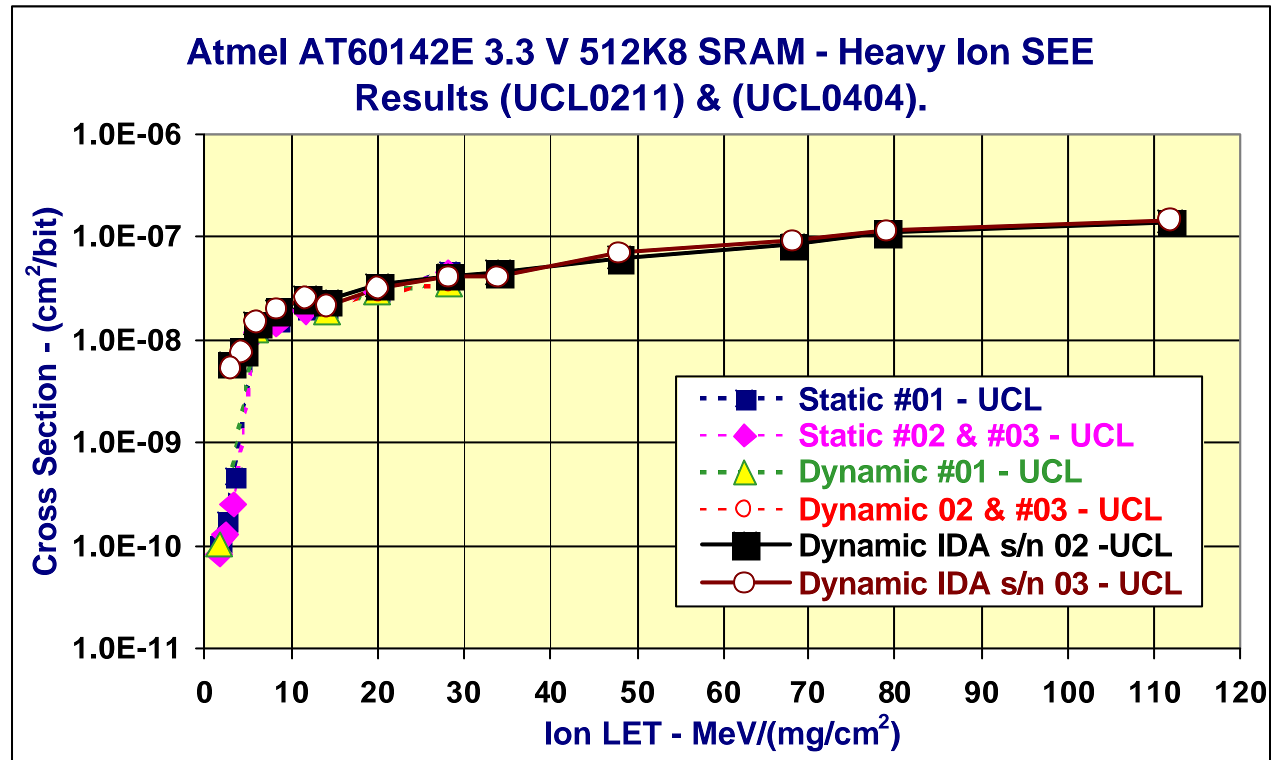
SRAM Memories: Atmel AT60142E SEE Test Results II



SRAM Memories: Atmel AT60142E SEE Test Results II



SRAM Memories: Atmel AT60142E SEE Test Results II

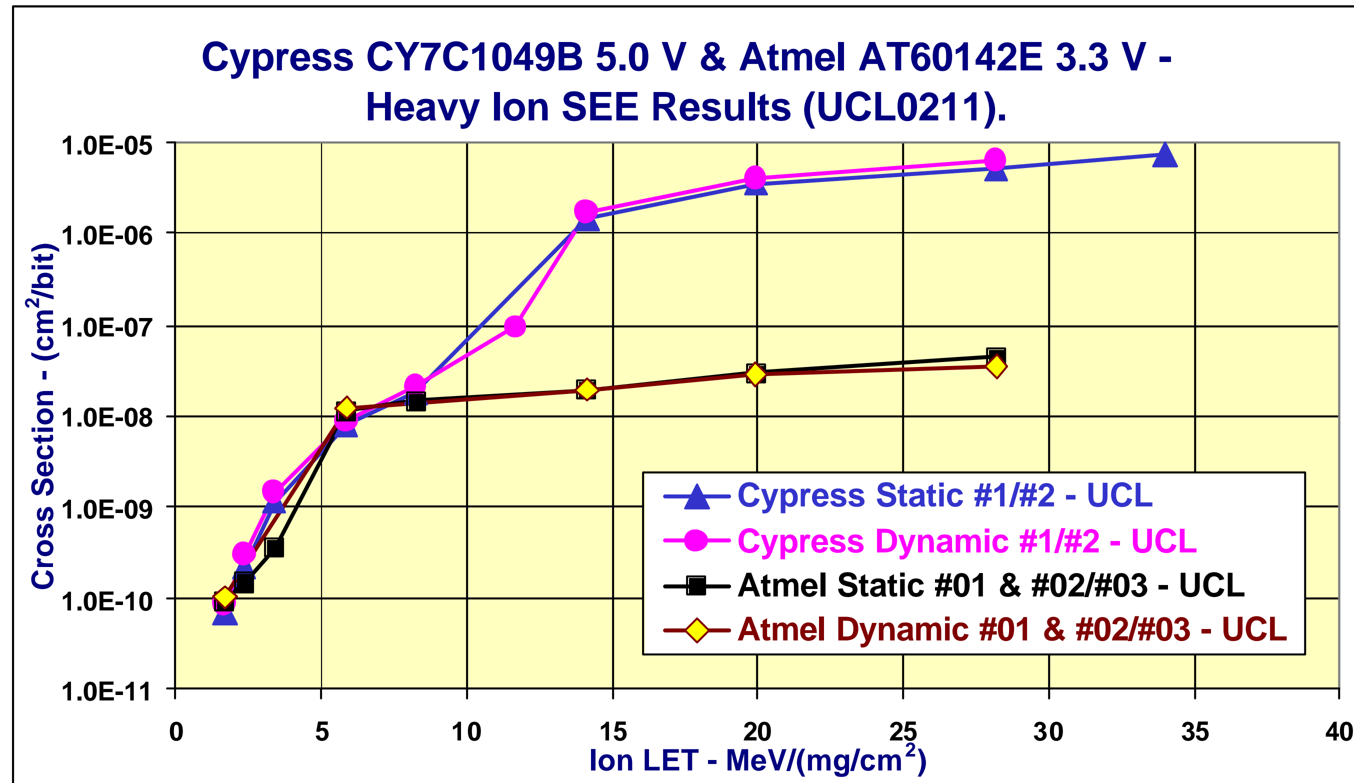
Summary Results – Old Version

- SEU – sensitive device type
  - LET Threshold < 1.7 MeV/(mg/cm^2)
  - Asymptotic cross-section about 3.0E-8 cm^2/per bit
- SEL – occurred at LET of 28.2 MeV/(mg/cm^2)
- Functional Errors – none
- Large Errors - 3 events at LET of 28.2 MeV/(mg/cm^2)
  - Observed in s/n #01 & s/n #03

Summary Results – New Version

- SEU – similar
- SEL – No events up to a LET of 111.8 MeV/(mg/cm^2)

SRAM Memories: Cypress/Atmel SEE Test Results I



SRAM Memories: Samsung K6R4008C1D SEE Test Results I

Run #	Test mode (*)	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SEE	SEL	SEE cross-section (/cm²)	Comment
1	S	1	Ar	14.10	0	14.10							SEL as soon as beam is on
3	D	1	Ar	14.10	0	14.10							SEL as soon as beam is on
70	S	1	Ne	5.85	0	5.85							SEL as soon as beam is on
71	S	2	Ne	5.85	0	5.85							SEL as soon as beam is on
103	S	1	B	1.70	0	1.70	140	1.00E+06	7143	3075	0	3.08E-03	
104	S	1	B	1.70	0	1.70	140	1.00E+06	7143	2981	0	2.98E-03	
105	S	1	B	1.70	60	3.40							SEL as soon as beam is on
106	S	1	B	1.70	45	2.40	205	1.00E+06	4878	4287	3	4.29E-03	

Summary Results -

- **SEU – only data available at a LET of 1.7 MeV/(mg/cm²)**
- **SEL – occurred at a LET of 2.4 MeV/(mg/cm²)**

SRAM Memories: Toshiba TC55V8200FT SEE Test Results I

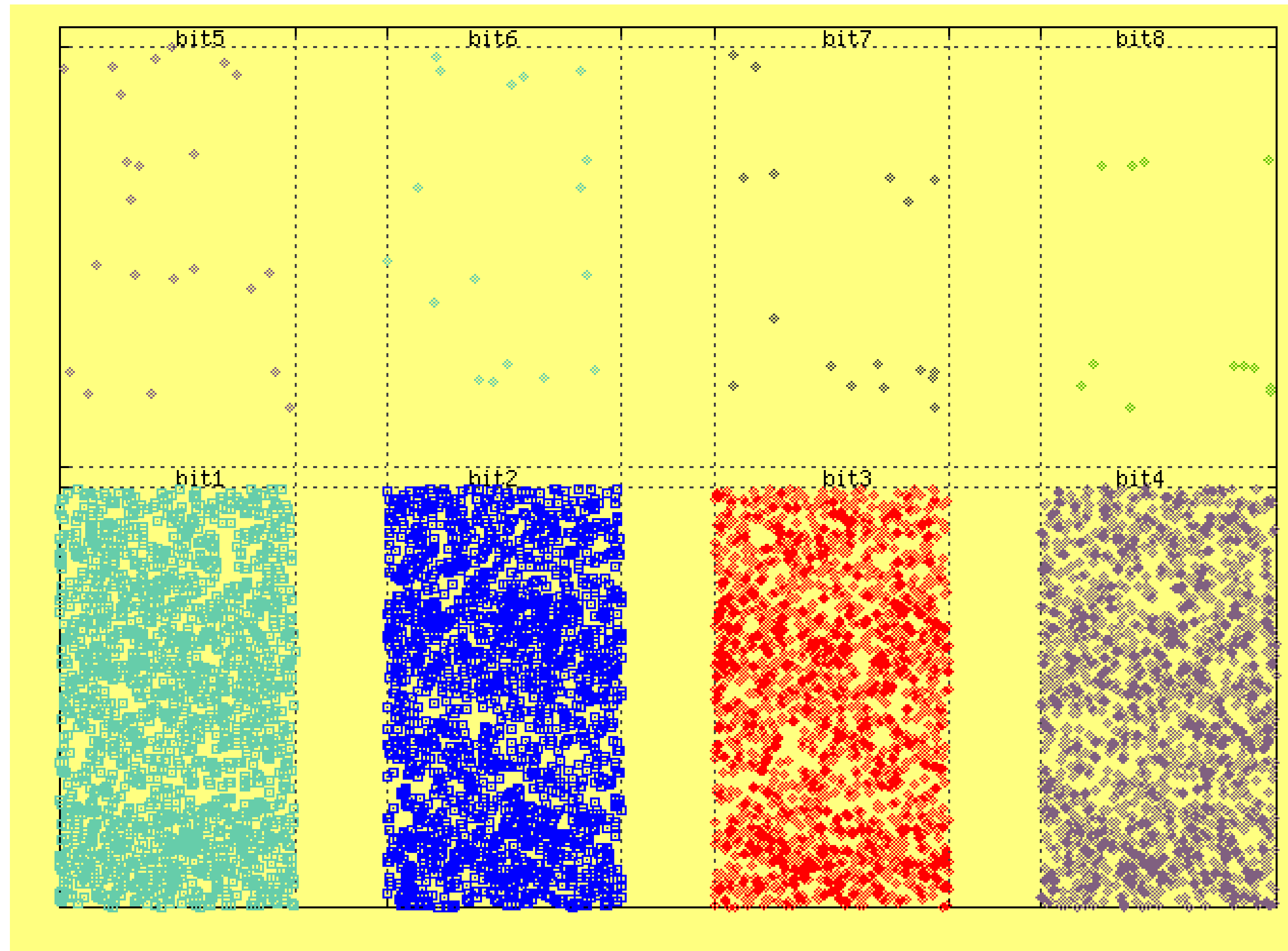
Run #	Test mode	S/N	Ion	LET (MeV.cm²/mg)	Angle (°)	Eff LET (MeV.cm²/mg)	Time (s)	Fluence (/cm²)	Flux (/cm²/s)	SEE	SEE cross-section (/cm²)
38	S	2	Ar	14.10	0	14.10	299	215149	720	0	0.00E+00
39	D	2	Ar	14.10	0	14.10	296	249588	843	0	0.00E+00
89	S	2	Ne	5.85	0	5.85	193	301076	1560	6	1.99E-05
90	D	2	Ne	5.85	0	5.85	177	301221	1702	17	5.64E-05
91	S	2	B	1.70	0	1.70	57	304921	5349	7083	2.32E-02
92	D	2	B	1.70	0	1.70	59	303116	5138	7136	2.35E-02
93	S	2	B	1.70	45	2.40	108	504726	4673	458	9.07E-04

 # Summary Results -

- **This device was improperly tested due to ion beam penetration limitations as earlier highlighted.**

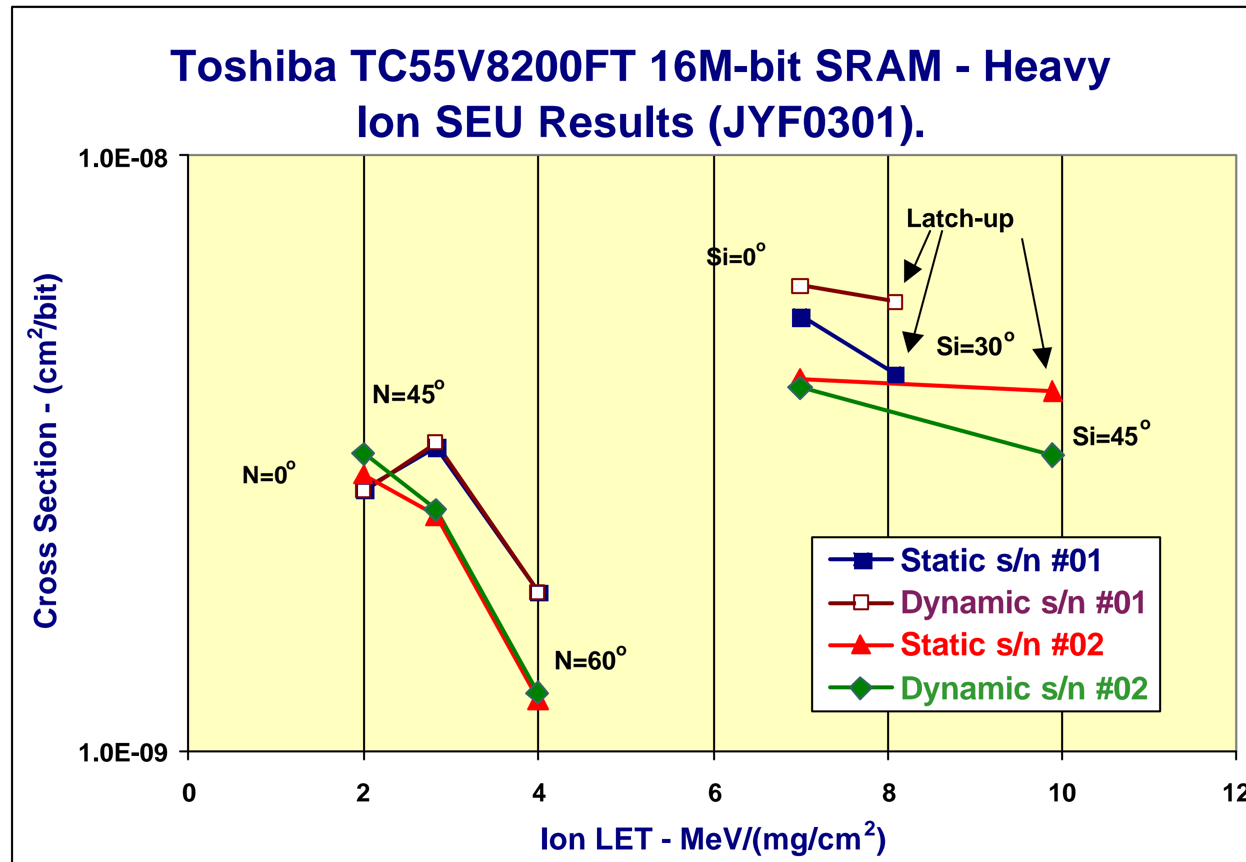
- **Note 0 SEU at the highest LET –**

SRAM Memories: Toshiba TC55V8200FT SEE Test Results II



Toshiba back-side irradiated results – row/column distributions of SEU

SRAM Memories: Toshiba TC55V8200FT SEE Results I - JYFL



Component Types Tested: Candidate for VME design ?

Part Family	Manufacturer	Type	Candidate
PAL/GAL	ATMEL	ATF22V10C-15JI ATF22V10C-10JI	No
PAL/GAL	Lattice	GAL22V10D-10LR	Yes
FLASH2Mx8	AMD	AM29F016D-70E4C	?
FLASH2Mx8	STM	M29F016B70N1	No
FLASH4Mx8	AMD	AM29F032B-90EI	No
FLASH4Mx8	STM	M29F032D70N6	No
SRAM512kx8	Cypress	CY7C1049B-15VI	No
SRAM512kx8	Atmel	AT60142E	Yes
SRAM512kx8	Samsung	K6R4008C1D	No
SRAM2Mx8	Toshiba	TC55V8200FT-12	No