

Irradiation test with thermal neutrons at LNL on 18/05/99 and 3-4/06/99

Irradiation flux, SEU cross-section and MTBF estimation

Upper side thermal neutron flux at 6.5MeV deuteron energy = 1,28E+06 n/cm²/s/μC
 Lower side thermal neutron flux at 6.5MeV deuteron energy = 4,71E+05 n/cm²/s/μC
 Test beam integrated charge (03-04/06/99)= 0,0194 C

Component	Flux (n/cm ²)	SEU	Φ _{SEU} (cm ² /dev)	MTBF (h/dev)	Total MTBF (h)
LD Regulator type: MICREL 29501-3.3BU year '97	9,1E+09	0	0,00E+00	7,04E+03	4,6905
ASIC TSS type: TOP5 ceramic package	9,1E+09	0	0,00E+00	7,04E+03	7,0358
ASIC MAD#1 (3 channels)	9,1E+09	872	3,18E-08	4,03E+00	0,0001
ASIC MAD#2 (3 channels)	9,1E+09	251	9,16E-09	1,40E+01	0,0002
μP type: MOTOROLA MC68HC16 year '94	2,5E+10	0	0,00E+00	1,91E+04	76,4826
FLASH type: ATMEL AT29C101A-12PC year '96	2,5E+10	0	0,00E+00	1,91E+04	76,4826
SRAM#1 type: SONY CXK581000AM-70LL year '93	2,5E+10	32	1,29E-09	2,94E+02	1,1767
SRAM#2 type: SONY CXK581000AM-70LL year '93	2,5E+10	0	0,00E+00	1,91E+04	76,4826
EPROM type: ATMEL AT27C512R-15JC	2,5E+10	0	0,00E+00	1,91E+04	76,4826
Optical transceiver type: HONEYWELL	2,5E+10	0	0,00E+00	1,91E+04	76,4826
BTIM type: BTIM1 FR4 substrate and BTIs in plastic package	9,1E+09	0	0,00E+00	7,04E+03	0,5629

MTBF is calculated assuming:

Thermal neutron fluence = 5,0E+02 n/cm²/s
 Confidence level = 50%

Irradiation test with thermal neutrons at LNL on 18/05/99 and 3-4/06/99

18/05/99 Estimated neutron flux is $\Phi = 2,30E+06 \text{ n/cm}^2/\mu\text{C}$
 3-4/06/99 Measured neutron flux is $\Phi = 1,28E+06 \text{ n/cm}^2/\mu\text{C}$

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ (n/cm^2)	SEU
18/05/99	18nA	scarica <						

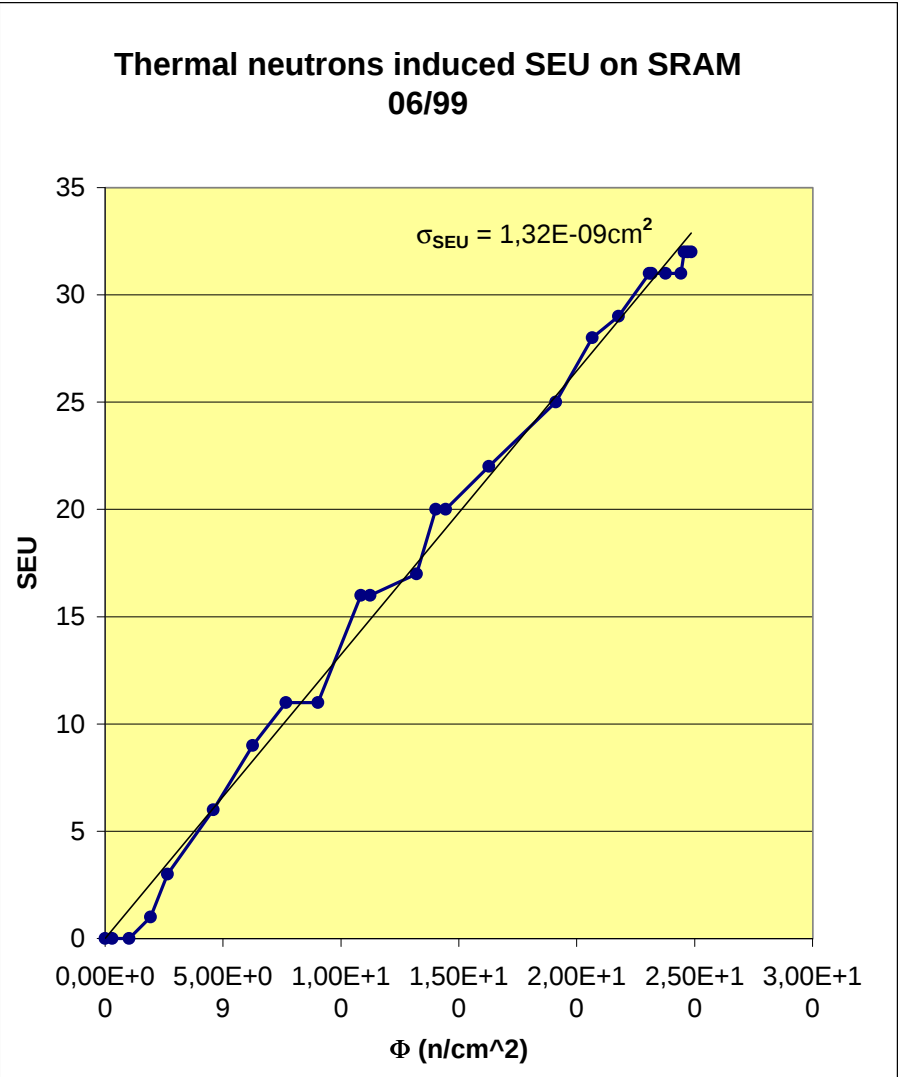
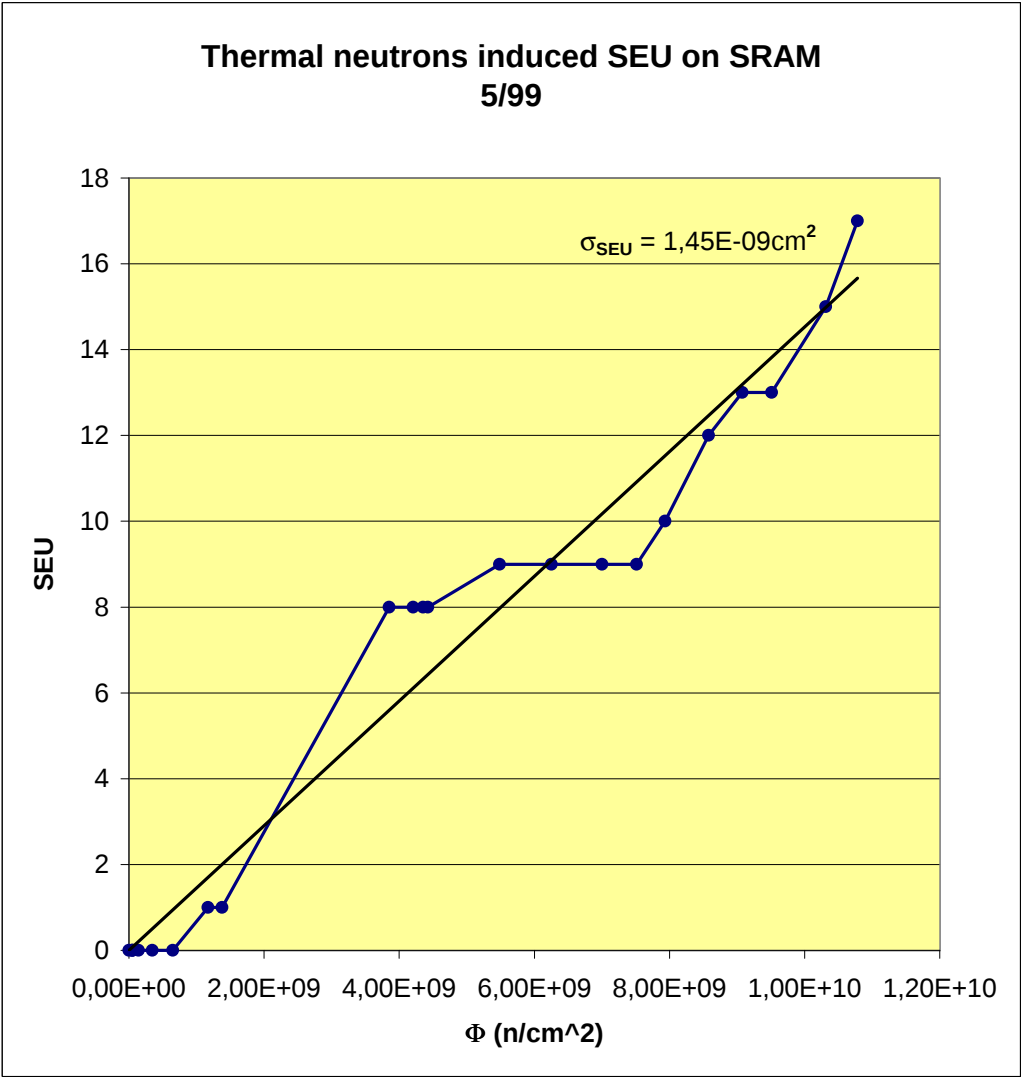
DAY	CHARGE (C)	Φ (n/cm ²)	SEU
18/05/99	0,00E+00	0,00E+00	0
	1,99E-05	4,57E+07	0
	2,22E-05	5,11E+07	0
	2,52E-05	5,80E+07	0
	6,27E-05	1,44E+08	0
	1,50E-04	3,44E+08	0
	2,82E-04	6,48E+08	0
	5,08E-04	1,17E+09	1
	6,00E-04	1,38E+09	1
	1,68E-03	3,85E+09	8
	1,83E-03	4,21E+09	8
	1,89E-03	4,36E+09	8
	1,92E-03	4,42E+09	8
	2,39E-03	5,49E+09	9
	2,72E-03	6,25E+09	9
	3,04E-03	7,00E+09	9
	3,27E-03	7,51E+09	9
	3,45E-03	7,94E+09	10
	3,73E-03	8,58E+09	12
	3,95E-03	9,08E+09	13
	4,14E-03	9,52E+09	13
	4,48E-03	1,03E+10	15
	4,69E-03	1,08E+10	17

SEU data on 18/05/99

DAY	CHARGE (C)	Φ (n/cm ²)	SEU
03/06/99	0,00E+00	0,00E+00	0
	2,30E-04	2,94E+08	0
	8,00E-04	1,02E+09	0
	1,51E-03	1,93E+09	1
	2,07E-03	2,65E+09	3
	3,59E-03	4,59E+09	6
	4,89E-03	6,26E+09	9
	5,99E-03	7,66E+09	11
	7,05E-03	9,02E+09	11
	8,48E-03	1,09E+10	16
	8,78E-03	1,12E+10	16
	1,03E-02	1,32E+10	17
	1,10E-02	1,40E+10	20
	1,13E-02	1,44E+10	20
	1,27E-02	1,63E+10	22
	1,49E-02	1,91E+10	25
	1,61E-02	2,07E+10	28
	1,70E-02	2,18E+10	29
	1,80E-02	2,31E+10	31
	1,81E-02	2,32E+10	31
	1,86E-02	2,38E+10	31
	1,91E-02	2,44E+10	31
	1,92E-02	2,46E+10	32
	1,93E-02	2,47E+10	32
	1,94E-02	2,48E+10	32

SEU data on 03-04/06/99

BEAM Deuterium nominal beam current
 TIME Day time of CHARGE measurement
 Δt Differential day time
 t Irradiation time
 CHARGE Beam current integrated on target
 Φ Estimated neutron flux on DUT
 SEU Total number of SEU

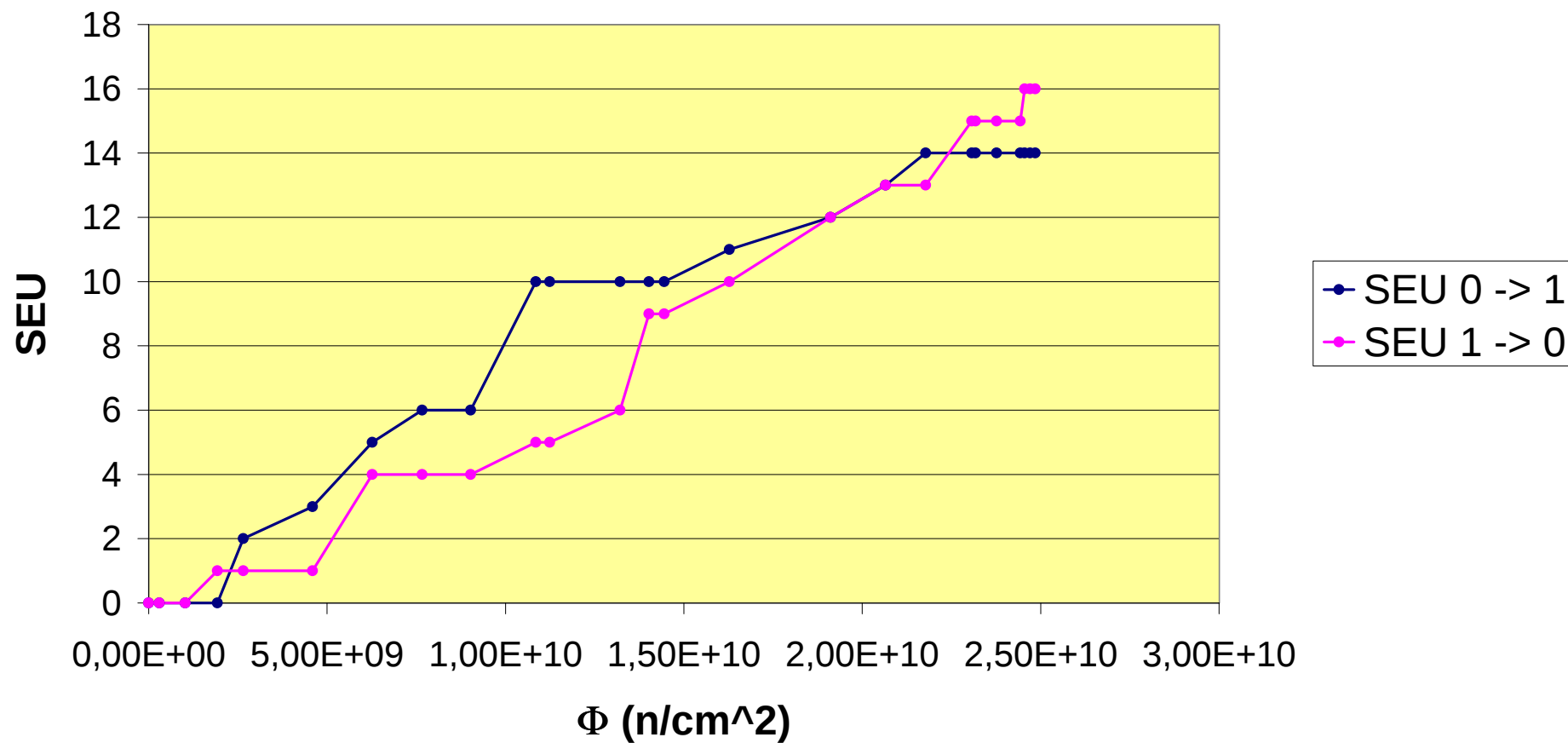


SRAM SEU distinguishing 0-to-1 from 1-to-0 upsets
1Mbit SRAM type SONY CXK581000AM-70LL (SN. 445J93E S) package SOIC-32

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ (n/cm^2)	SEU 0 -> 1	SEU 1 -> 0
03/06/99	300nA	start	10.36	0	0	0,00E+00	0,00E+00	0	0
			10.48	0.12	720	2,30E-04	2,94E+08	0	0
			11.18	0.30	2520	8,00E-04	1,02E+09	0	0
			11.52	0.34	4560	1,51E-03	1,93E+09	0	1
			12.21	0.29	6300	2,07E-03	2,65E+09	2	1
			13.33	1.12	10620	3,59E-03	4,59E+09	3	1
			14.31	0.58	14100	4,89E-03	6,26E+09	5	4
			15.26	0.55	17400	5,99E-03	7,66E+09	6	4
			16.18	0.52	20520	7,05E-03	9,02E+09	6	4
			17.15	0.57	23940	8,48E-03	1,09E+10	10	5
			17.28	0.13	24720	8,78E-03	1,12E+10	10	5
04/06/99	300nA	start 9.18	10.29	1.11	28980	1,03E-02	1,32E+10	10	6
			10.54	0.25	30480	1,10E-02	1,40E+10	10	9
			11.08	0.14	31320	1,13E-02	1,44E+10	10	9
			12.07	0.59	34860	1,27E-02	1,63E+10	11	10
			13.38	1.31	40320	1,49E-02	1,91E+10	12	12
			14.32	0.54	43560	1,61E-02	2,07E+10	13	13
			15.15	0.43	46140	1,70E-02	2,18E+10	14	13
			16.06	0.51	49200	1,80E-02	2,31E+10	14	15
			16.12	0.06	49560	1,81E-02	2,32E+10	14	15
			16.37	0.25	51060	1,86E-02	2,38E+10	14	15
			17.00	0.23	52440	1,91E-02	2,44E+10	14	15
			17.05	0.05	52740	1,92E-02	2,46E+10	14	16
			17.10	0.05	53040	1,93E-02	2,47E+10	14	16
			17.15	0.05	53340	1,94E-02	2,48E+10	14	16

BEAM Deuterium nominal beam current
TIME Day time of CHARGE measurement
 Δt Differential day time
t Irradiation time
CHARGE Beam current integrated on target
 Φ Estimated neutron flux on DUT
SEU Total number of SEU

Thermal neutrons induced SEU on SRAM 06/99

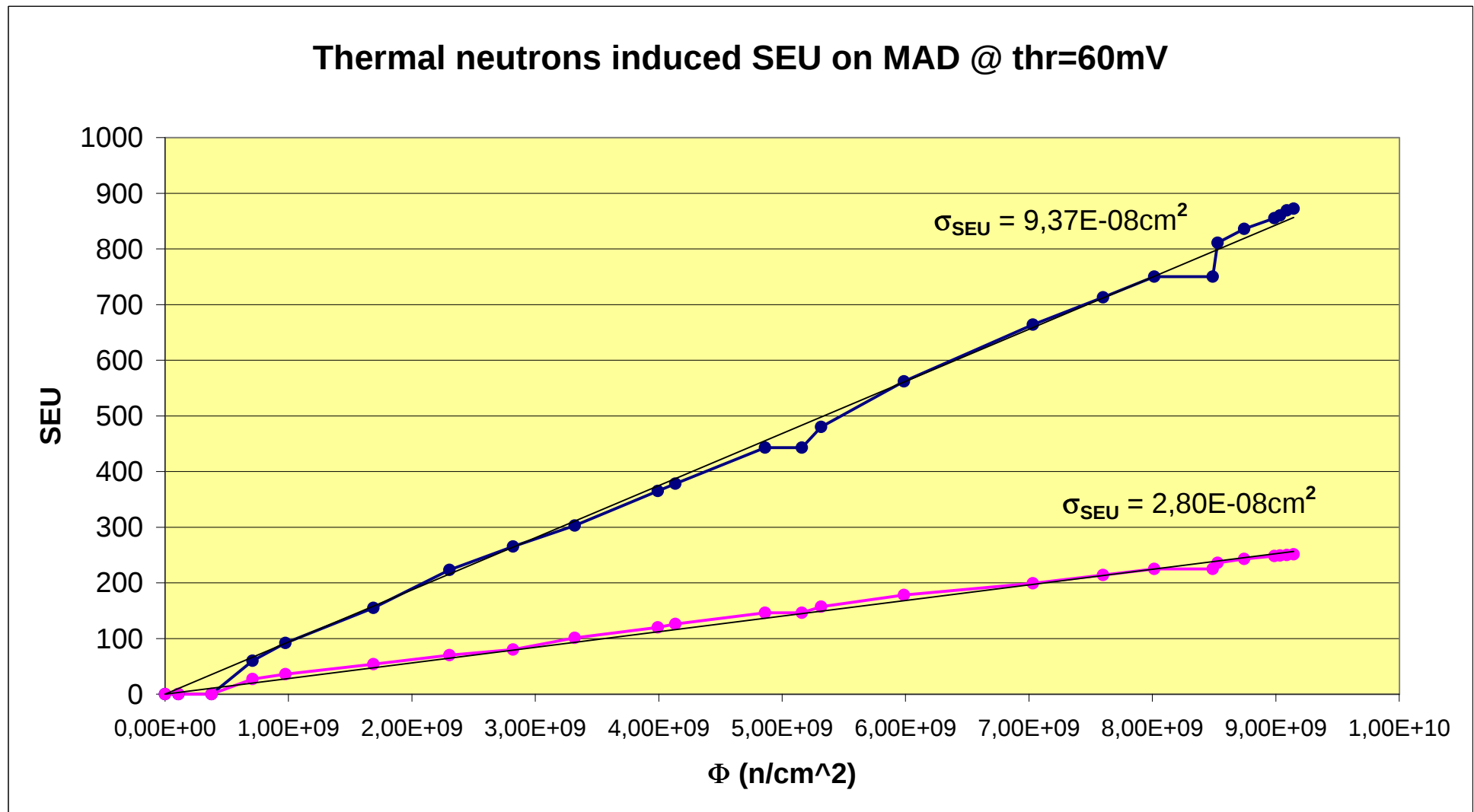


Irradiation test with thermal neutrons at LNL on 18/05/99 and 3-4/06/99

3-4/06/99 Measured neutron flux is $\Phi = 4,71\text{E}+05 \text{ n/cm}^2/\mu\text{C}$

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ (n/cm ²)	MAD Ch1	MAD Ch2	CHARGE (C)	Φ (n/cm ²)	MAD Ch1	MAD Ch2
03/06/99	300nA	Illegal Instruction -> Reboot System crash	10.36	0	0	0,00E+00	0,00E+00	0	0	0,00E+00	0,00E+00	0	0
			10.48	0.12	720	2,30E-04	1,08E+08	0	0	2,30E-04	1,08E+08	0	0
			11.18	0.30	2520	8,00E-04	3,77E+08	0	0	8,00E-04	3,77E+08	0	0
			11.52	0.34	4560	1,51E-03	7,09E+08	60	27	1,51E-03	7,09E+08	60	27
			12.21	0.29	6300	2,07E-03	9,75E+08	92	36	2,07E-03	9,75E+08	92	36
			13.33	1.12	10620	3,59E-03	1,69E+09	155	54	3,59E-03	1,69E+09	155	54
			14.31	0.58	14100	4,89E-03	2,31E+09	223	70	4,89E-03	2,31E+09	223	70
			15.26	0.55	17400	5,99E-03	2,82E+09	265	80	5,99E-03	2,82E+09	265	80
			16.18	0.52	20520	7,05E-03	3,32E+09	303	101	7,05E-03	3,32E+09	303	101
			17.15	0.57	23940	8,48E-03	3,99E+09	365	120	8,48E-03	3,99E+09	365	120
			17.28	0.13	24720	8,78E-03	4,14E+09	378	126	8,78E-03	4,14E+09	378	126
			9.18	0.00	0	0,00E+00	0,00E+00	0	0	1,03E-02	4,86E+09	443	146
			10.29	1.11	4260	1,54E-03	7,27E+08	65	20	1,10E-02	5,16E+09	443	146
04/06/99	300nA	Execution Error -> Reboot	10.54	0.25	5760	2,17E-03	1,02E+09	65	20	1,13E-02	5,32E+09	480	157
			11.08	0.14	6600	2,51E-03	1,18E+09	102	31	1,27E-02	5,99E+09	562	178
			12.07	0.59	10140	3,93E-03	1,85E+09	184	52	1,49E-02	7,03E+09	664	199
			13.38	1.31	15600	6,15E-03	2,90E+09	286	73	1,61E-02	7,60E+09	713	214
			14.32	0.54	18840	7,36E-03	3,46E+09	335	88	1,70E-02	8,01E+09	750	225
			15.15	0.43	21420	8,24E-03	3,88E+09	372	99	1,80E-02	8,49E+09	750	225
			16.06	0.51	24480	9,24E-03	4,35E+09	372	99	1,81E-02	8,53E+09	811	236
			16.12	0.06	24840	9,33E-03	4,39E+09	433	110	1,86E-02	8,74E+09	836	243
			16.37	0.25	26340	9,79E-03	4,61E+09	458	117	1,91E-02	8,99E+09	855	248
			17.00	0.23	27720	1,03E-02	4,85E+09	477	122	1,92E-02	9,03E+09	860	249
			17.05	0.05	28020	1,04E-02	4,90E+09	482	123	1,93E-02	9,09E+09	869	250
			17.10	0.05	28320	1,05E-02	4,95E+09	491	124	1,94E-02	9,14E+09	872	251
			17.15	0.05	28620	1,06E-02	5,01E+09	494	125				

BEAM Deuterium nominal beam current
 CHARGE Beam current integrated on target
 Φ Estimated neutron flux on DUT
 MAD MAD board channels SEU
 TIME Day time of CHARGE measurement
 Δt Differential day time
 t Irradiation time



Irradiation test with fast neutrons at LNL on 16/06/99

Map of irradiation fluxes

Neutron flux from target at 6.5MeV deuteron energy = 1,60E+10 n/μA
 Test beam integrated charge = 1,02E-02 C

Component	Surface (cm ²)	Fraction (%)	Fraction/cm ² (%)	Fluence (n/cm ² /μA)	Flux (n/cm ²)
LD Regulator type: MICREL 29501-3.3BU year '97	0,608	0,018	0,0293	4,7E+06	4,8E+10
ASIC TSS type: TOP5 ceramic package	6,760	0,324	0,0480	7,7E+06	7,8E+10
ASIC MAD#1	1,082	0,026	0,0245	3,9E+06	4,0E+10
ASIC MAD#2	1,082	0,042	0,0388	6,2E+06	6,3E+10
μP type: MOTOROLA MC68HC16 year '94	4,326	0,266	0,0614	9,8E+06	1,0E+11
FLASH type: ATMEL AT29C101A-12PC year '96	5,408	0,404	0,0746	1,2E+07	1,2E+11
SRAM#1 type: SONY CXK581000AM-70LL year '93	1,622	0,116	0,0712	1,1E+07	1,2E+11
SRAM#2 type: SONY CXK581000AM-70LL year '93	1,622	0,114	0,0705	1,1E+07	1,2E+11
EPROM type: ATMEL AT27C512R-15JC	1,082	0,081	0,0744	1,2E+07	1,2E+11
Optical transceiver type: HONEYWELL	5,273	0,208	0,0395	6,3E+06	6,4E+10
BTIM type: BTIM1 FR4 substrate and BTIs in plastic package	6,760	0,336	0,0497	7,9E+06	8,1E+10

Component	Flux (n/cm ²)	SEU	SEU Φ (cm ² /dev)	MTBF (h/dev)	Total MTBF (h)
LD Regulator type: MICREL 29501-3.3BU year '97	4,8E+10	0	1,0E-11	3,7E+04	24,561
ASIC TSS type: TOP5 ceramic package	7,8E+10	0	6,4E-12	6,0E+04	60,285
ASIC MAD#1	4,0E+10	72	1,8E-09	2,1E+02	0,003
ASIC MAD#2	6,3E+10	28	4,5E-10	8,6E+02	0,013
μP type: MOTOROLA MC68HC16 year '94	1,0E+11	0	5,0E-12	7,7E+04	308,641
FLASH type: ATMEL AT29C101A-12PC year '96	1,2E+11	0	4,1E-12	9,4E+04	375,180
SRAM#1 type: SONY CXK581000AM-70LL year '93	1,2E+11	9	8,2E-11	4,7E+03	18,846
SRAM#2 type: SONY CXK581000AM-70LL year '93	1,2E+11	0	4,3E-12	8,9E+04	354,514
EPROM type: ATMEL AT27C512R-15JC	1,2E+11	0	4,1E-12	9,4E+04	374,111
Optical transceiver type: HONEYWELL	6,4E+10	0	7,8E-12	5,0E+04	198,429
BTIM type: BTIM1 FR4 substrate and BTIs in plastic package	8,1E+10	0	6,2E-12	6,2E+04	4,994

MTBF is calculated assuming:

Fast neutron fluence = 5,0E+02 n/cm²/s

Confidence level = 50%

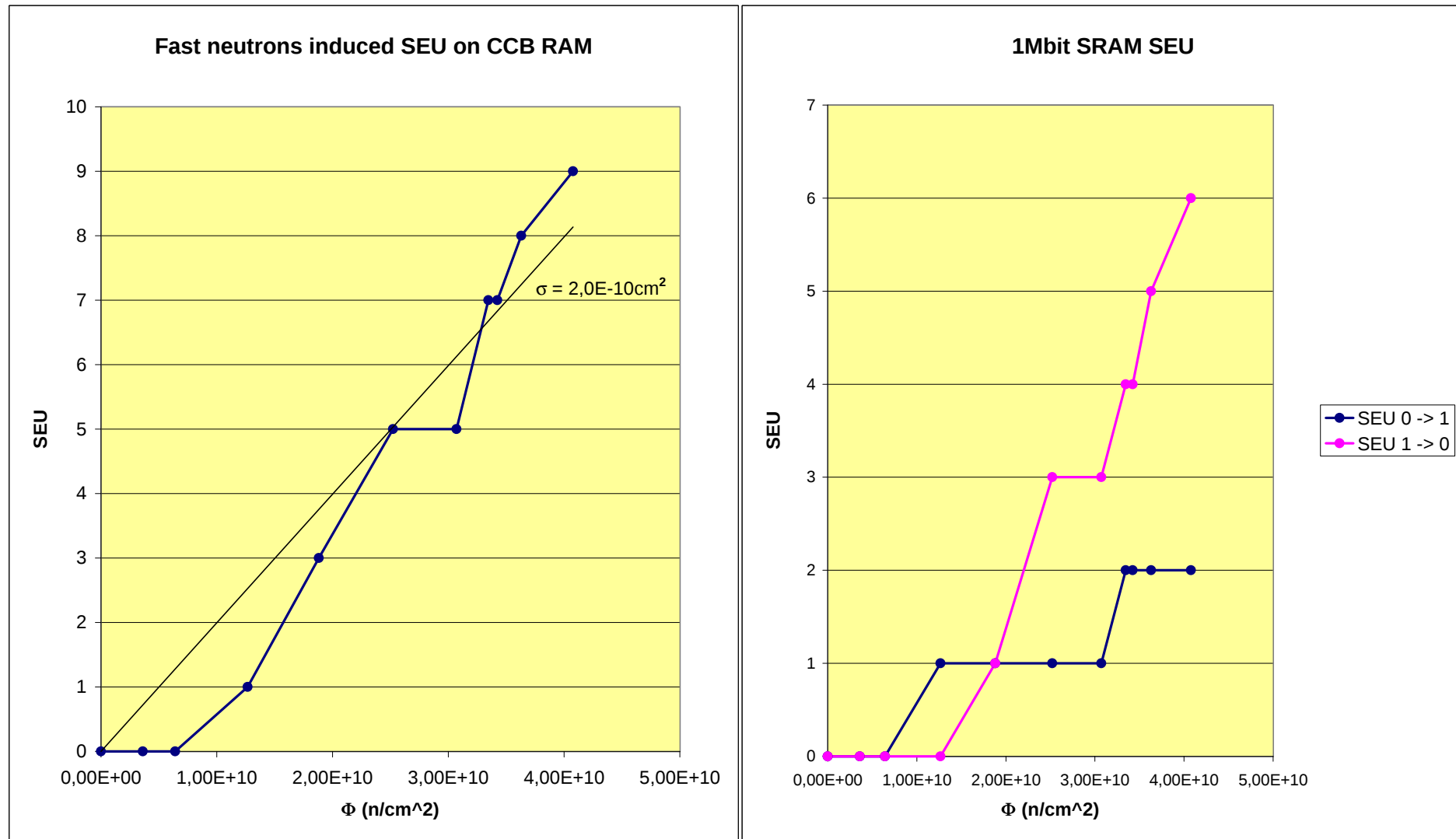
Irradiation test with fast neutrons at LNL on 16/06/99
Estimated mean neutron flux is $\Phi=4\times10^6$ n/cm²/μC

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ (n/cm ²)	SEU
16/06/99	400nA	Chip TO su targhetta	10.23	0.00	0	0,00E+00	0,00E+00	0
			10.54	0.31	1860	9,01E-04	3,60E+09	0
			11.23	0.29	3600	1,60E-03	6,42E+09	0
			12.23	1.00	7200	3,17E-03	1,27E+10	1
			13.23	1.00	10800	4,71E-03	1,88E+10	3
			14.32	1.09	14940	6,30E-03	2,52E+10	5
			15.27	0.55	18240	7,68E-03	3,07E+10	5
			16.02	0.35	20340	8,37E-03	3,35E+10	7
			16.21	0.19	21480	8,56E-03	3,42E+10	7
		tolto chip TO da targhetta	16.46	0.25	22980	9,07E-03	3,63E+10	8
			17.30	0.44	25620	1,02E-02	4,08E+10	9

SRAM SEUs distinguishing 0-to-1 from 1-to-0 upsets.
1Mbit SRAM type SONY CXK581000AM-70LL (SN. 445J93E S) package SOIC-32

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ (n/cm ²)	SEU 0 -> 1	SEU 1 -> 0
16/06/99	400nA	Chip TO su targhetta	10.23	0.00	0	0,00E+00	0,00E+00	0	0
			10.54	0.31	1860	9,01E-04	3,60E+09	0	0
			11.23	0.29	3600	1,60E-03	6,42E+09	0	0
			12.23	1.00	7200	3,17E-03	1,27E+10	1	0
			13.23	1.00	10800	4,71E-03	1,88E+10	1	1
			14.32	1.09	14940	6,30E-03	2,52E+10	1	3
			15.27	0.55	18240	7,68E-03	3,07E+10	1	3
			16.02	0.35	20340	8,37E-03	3,35E+10	2	4
			16.21	0.19	21480	8,56E-03	3,42E+10	2	4
		tolto chip TO da targhetta	16.46	0.25	22980	9,07E-03	3,63E+10	2	5
			17.30	0.44	25620	1,02E-02	4,08E+10	2	6

BEAM Deuterium nominal beam current
TIME Day time of CHARGE measurement
Δt Differential day time
t Irradiation time
CHARGE Beam current integrated on target
Φ Estimated neutron flux on DUT
SEU Total number of SEU



σ SRAM SEU cross section
 Neutron flux is calculated using the nominal yield of $4 \times 10^6 \text{ n/cm}^2/\text{m C}$

Irradiation test with fast neutrons at LNL on 16/06/99

DAY	BEAM	Threshold (mV)	CHARGE (C)	Φ CH1 (n/cm ²)	Φ CH2 (n/cm ²)	MAD Ch1	MAD Ch2	σ Ch1 (cm ²)	σ Ch2 (cm ²)
16/06/99	400nA	30	2,52E-03	9,86E+09	1,56E+10	72	28	7,30E-09	1,79E-09
		40	1,37E-03	5,37E+09	8,52E+09	25	13	4,66E-09	1,53E-09
		50	1,60E-03	6,26E+09	9,93E+09	25	12	4,00E-09	1,21E-09
		60	1,60E-03	6,28E+09	9,96E+09	15	4	2,39E-09	4,02E-10
		90	1,54E-03	6,02E+09	9,56E+09	10	5	1,66E-09	5,23E-10
		120	1,56E-03	6,11E+09	9,70E+09	4	3	6,54E-10	3,09E-10

DAY	BEAM	NOTES	TIME	Δt (hh.mm)	t (s)	CHARGE (C)	Φ CH1 (n/cm ²)	Φ CH2 (n/cm ²)	MAD Ch1	MAD Ch2
16/06/99	400nA	Threshold 30mV	15.27	0.00	0	0,00E+00	0,00E+00	0,00E+00	0	0
			16.02	0.35	2100	6,89E-04	2,70E+09	4,28E+09	26	4
			16.17	0.15	3000	8,16E-04	3,19E+09	5,06E+09	30	5
		tolto chip TO da targhetta	16.21	0.04	3240	8,81E-04	3,45E+09	5,47E+09	39	5
			16.46	0.25	4740	1,40E-03	5,47E+09	8,68E+09	51	14
			17.30	0.44	7380	2,52E-03	9,86E+09	1,56E+10	72	28

BEAM Deuterium nominal beam current
 THRESHOLD MAD chip threshold
 CHARGE Beam current integrated on target
 Φ Estimated neutron flux on DUT
 MAD MAD board channels SEU
 σ MAD board channels cross section
 TIME Day time of CHARGE measurement
 Δt Differential day time
 t Irradiation time

