



# CNES final presentation

Radiation Characterization of various FRAM,  
SRAM and Flash memories

Frédéric LOCHON, Hirex Engineering

CNES contacts:  
Hirex Engineering contact:

David DANGLA, Françoise BEZERRA  
François-Xavier GUERRE

# Tested parts

2/26

Part type	Manufacturer	Package	Function	Testing
<b>R1WV6416RSA</b>	Renesas	TSOP 48	SRAM 4 Mi x 16	SEE
<b>CY7C10612DV33</b>	Cypress	TSOP 44	SRAM 1 Mi x 16	SEE
<b>IDT70V658</b>	IDT	PQFP 208	DPRAM 64 Ki x 36	SEE + TID
<b>FM22L16</b>	Ramtron	TSOP 44	FRAM 256 Ki x 16	SEE + TID
<b>K9WBG08U</b>	Samsung	TSOP 48	Flash 32 Gbit	SEE + TID
<b>MT29F32G08</b>	Micron	TSOP 48	Flash 32 Gbit	SEE + TID
<b>72V2113L10PFI</b>	IDT	TQFP 80	FIFO 256 Ki x 18	SEE
<b>SN74V293-EP</b>	TI	TQFP 80	FIFO 64 Ki x 18	SEE

# SRAM/FRAM/DPRAM testing methodology

3/26

## ⌘ SEL

- ☑ Supply current monitoring
- ☑ Current threshold is about 5 to 10 times the current under dynamic condition
- ☑ Hold time is 1 ms
- ☑ Power off time is 1 s

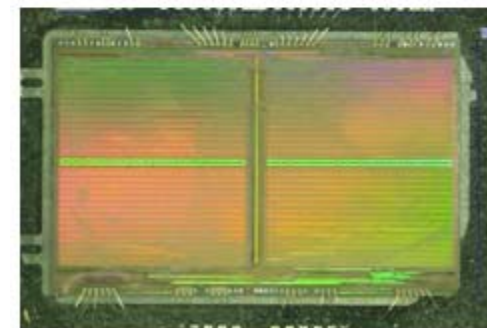
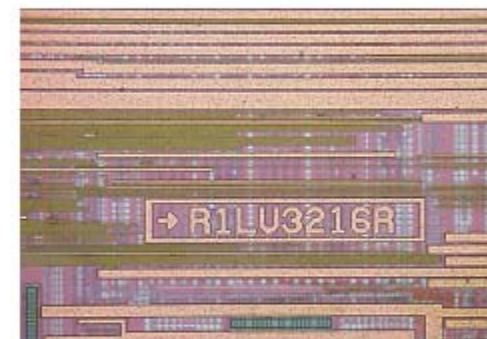
## ⌘ SEU

- ☑ Dynamic access while beam is on
- ☑ Full algorithm to detect and flag error type (read error, upset, stuck bit, write error, ...) over the full memory space
- ☑ No wait time, no lost beam time during the run

## SRAM memory Renesas 4 Mi x 16 (1/2)

4/26

- ⌘ Part type: R1WV6416RSA-5SI
- ⌘ Part description: 64 Mibit static RAM organized as 4,194,304 word x 16 bit - 2 die of 32 Mibit
- ⌘ Manufacturer: Renesas
- ⌘ Package: 48 pin TSOP I
- ⌘ Date code: 0930
- ⌘ Die dimensions: 9750 x 6080  $\mu\text{m}$
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), April 2010\*, 2 parts

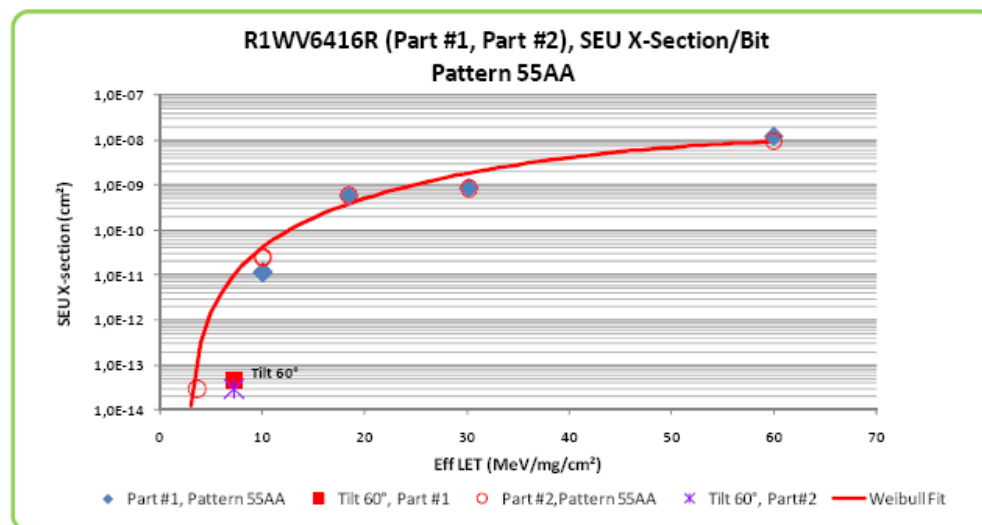


\* no ash cloud inside chamber

## SRAM memory Renesas 4 Mi x 16 (2/2)

5/26

- ⌘ No SEL at Xe and 60° angle (LET of 120 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) up to a fluence of 1E7 part.cm<sup>2</sup>
- ⌘ Some MBU observed (most MBU are 2 bits MBU)
- ⌘ Thanks to descrambling analysis, MCU have been observed (worst case is 9 cells)

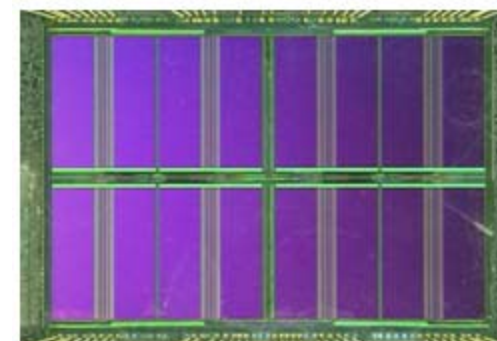


- ⌘ SEU saturation cross-section
  - ⌘ 1.2E-8 cm<sup>2</sup>.bit<sup>-1</sup>
- ⌘ LET threshold
  - ⌘ 2.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>

## SRAM memory Cypress 1 Mi x 16 (1/2)

6/26

- ⌘ Part type: CY7C10612DV33-10ZSXI
- ⌘ Part description: 1 Mi x 16 bit static RAM
- ⌘ Manufacturer: Cypress Semiconductor
- ⌘ Package: 54 pin TSOP II
- ⌘ Date code: 1001
- ⌘ Die dimensions: 6.4 x 4.6 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), April 2010\*, 2 parts



\* no ash cloud inside chamber

March, 28<sup>th</sup> 2010

CNES final presentation

## SRAM memory Cypress 1 Mi x 16 (2/2)

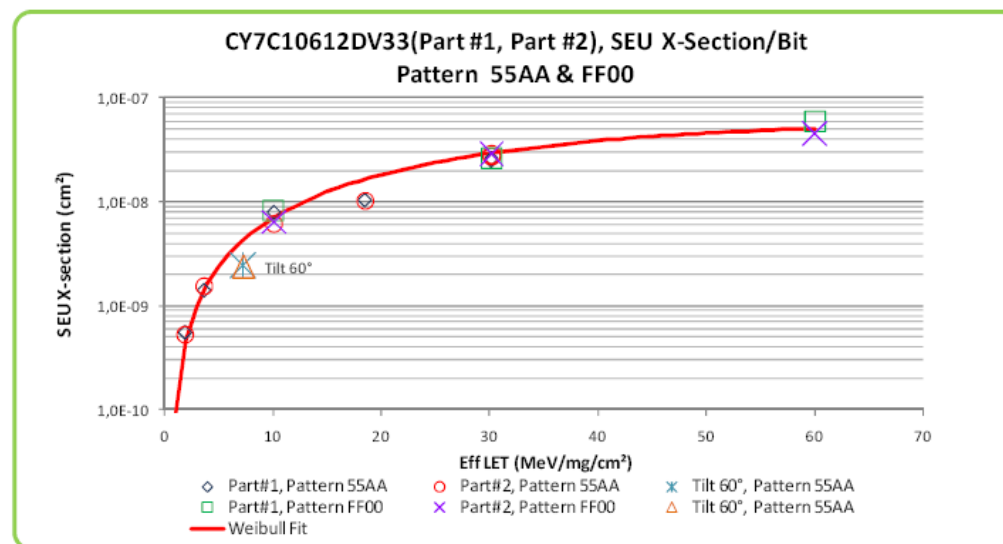
7/26

⌘ Few SEL at Xe and 60° angle  
(LET of 120 MeV.cm<sup>2</sup>.mg<sup>-1</sup>)

⌘ Cross-section: 3E-7 cm<sup>2</sup>

⌘ Some MBU observed (most MBU are 2 bits MBU)

⌘ MCU have been observed  
(worst case is 15 cells wide)



⌘ SEU saturation cross-section

⌘ 5.9E-8 cm<sup>2</sup>.bit<sup>-1</sup>

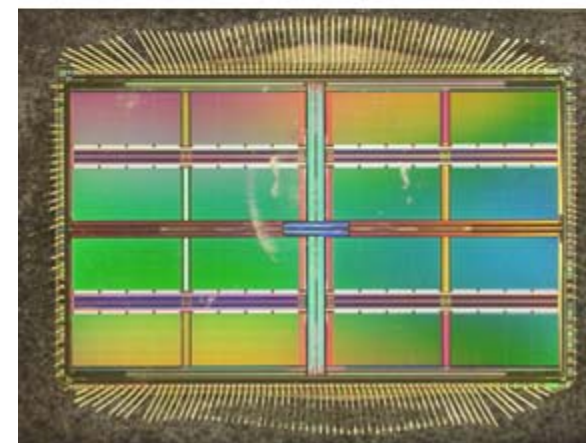
⌘ LET threshold

⌘ 0.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>

## DPRAM memory IDT 64Ki x 36 (1/3)

8/26

- ⌘ Part type: IDT70V658
- ⌘ Part description: Asynchronous dual-port static RAM, organized as 64Ki x 36 bits
- ⌘ Manufacturer: IDT
- ⌘ Package: 208 pin PQFP
- ⌘ Date code: 0930
- ⌘ Die dimensions: 10.843 x 6.885 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), July and November 2009, 2 parts
- ⌘ TID Testing: ENEA-Calliope (Rome), 5 parts ON, 3 parts OFF, 1 Ref.





## DPRAM memory IDT 64Ki x 36 (2/3)

9/26

⌘ No SEL observed up to LET of  $60 \text{ MeV.cm}^2.\text{mg}^{-1}$  with a fluence of  $1\text{E}7 \text{ part.cm}^{-2}$

⌘ SEU results:

⌘ equivalent sensitivity for 0 to 1 and 1 to 0 upsets

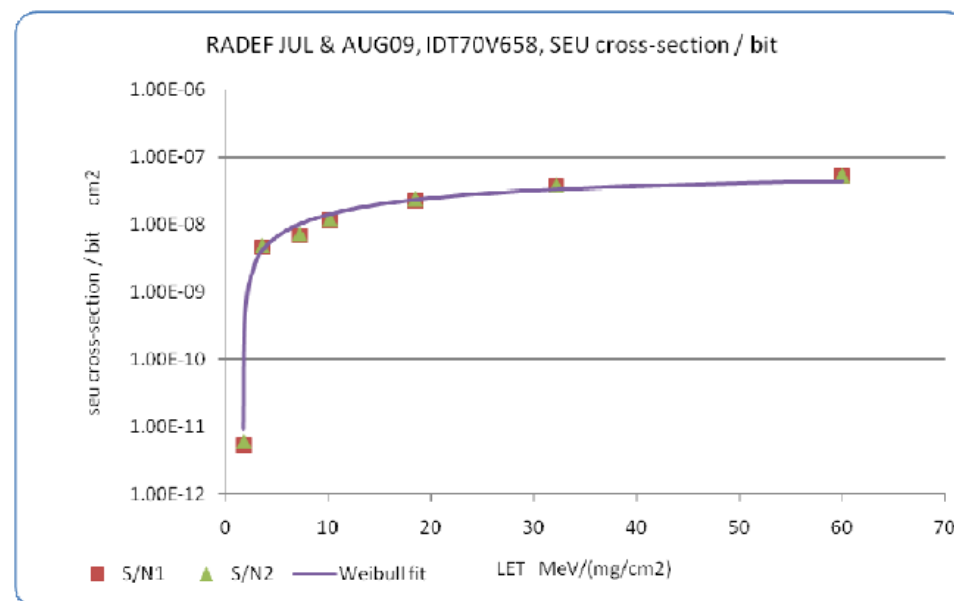
⌘ No MBU observed

⌘ LET threshold

⌘  $1.8 \text{ MeV.cm}^2.\text{mg}^{-1}$

⌘ Cross-section saturation

⌘  $3.5\text{E-}8\text{cm}^2$



## DPRAM memory IDT 64Ki x 36 (3/3)

10/26

⌘ TID: dose rate 200 rad(Si).h<sup>-1</sup>

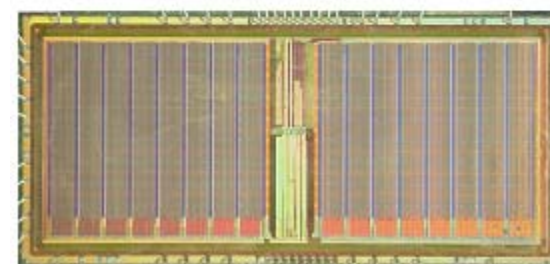
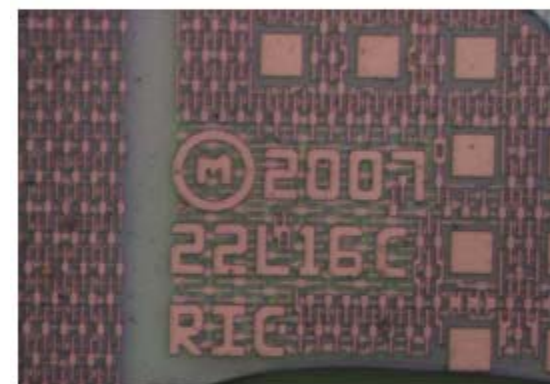
⌘ No significant drift observed up to 100 krad(Si)

<b>Irradiation Steps</b>	<b>Dose rate</b>	<b>Annealing steps</b>	<b>Temperature</b>
<b>krads</b>	<b>krads/h</b>	<b>Hours</b>	<b>°C</b>
0			
4.6	0.2		Room
8.6	0.2		Room
12.5	0.2		Room
16.7	0.2		Room
49.7	0.2		Room
67.6	0.2		Room
100.6	0.2		Room
		24	Room
		168	100

## FRAM memory Ramtron 4 Mibit (1/3)

11/26

- ⌘ Part type: FM22L16-55TG
- ⌘ Part description: 256 Ki x 16 non-volatile ferroelectric RAM
- ⌘ Manufacturer: Ramtron
- ⌘ Package: 44 pin TSOP II
- ⌘ Date code: 0849
- ⌘ Die dimensions: 6.3 x 2.9 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), April 2010\*, 2 parts
- ⌘ TID Testing: ENEA-Calliope, Rome, 5 parts ON, 5 parts OFF, 1 Ref.



\* no ash cloud inside chamber

## FRAM memory Ramtron 4 Mibit (2/3)

12/26

⌘ No SEL at LET of 120 MeV.cm<sup>2</sup>.mg<sup>-1</sup> up to a fluence of 1E7 part.cm<sup>-2</sup>

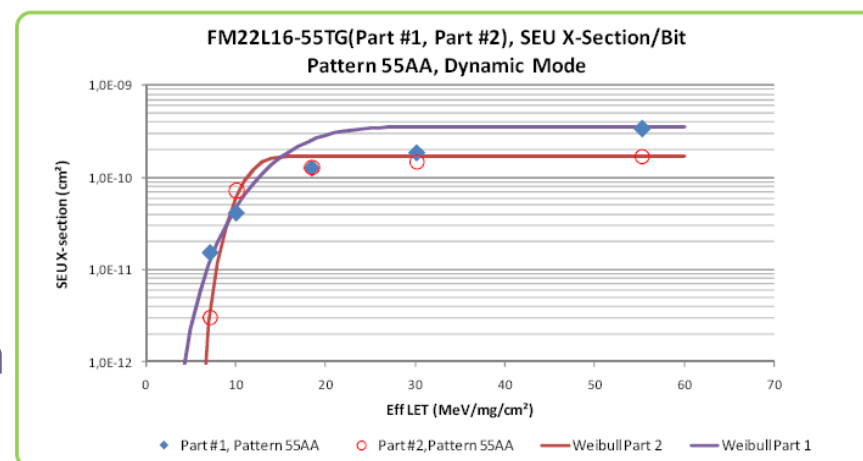
⌘ Under static condition, only few errors observed at Xe

⌘ With dynamic condition, errors from Ne up to Xe

⌘ 0 to 1 upsets are more common

⌘ Some SEFI have been observed from Ar to Xe

⌘ 11 SEFI, for a cumulated fluence of 5.07E7 part.cm<sup>-2</sup>



⌘ SEU saturation cross-section

⌘ 5.9E-8 cm<sup>2</sup>.bit<sup>-1</sup>

⌘ LET threshold

⌘ 0.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>

## FRAM memory Ramtron 4 Mibit (3/3)

13/26

- ⌘ TID dose rate about 212 rad(Si).h<sup>-1</sup>
- ⌘ Sleep mode current failed for ON components between 72.2 and 96.6 krad(Si)
- ⌘ Complete healing after annealing
- ⌘ Other parameters OK up to 96.6 krad(Si)

<b>Irradiation Steps</b>	<b>Dose rate</b>	<b>Annealing steps</b>	<b>Temperature</b>
<b>krads</b>	<b>krads/h</b>	<b>Hours</b>	<b>°C</b>
0			
6	0.212		Room
9.6	0.212		Room
14	0.212		Room
18.5	0.212		Room
32.5	0.212		Room
52.3	0.212		Room
72.2	0.212		Room
96.6	0.212		Room
		24	Room
		168	100

# FIFO testing methodology

14/26

## ⌘ SEL

- ☑ Supply current monitoring
- ☑ Current threshold is about 5 to 10 times the current under dynamic condition
- ☑ Hold time is 1 ms
- ☑ Power off time is 1 s

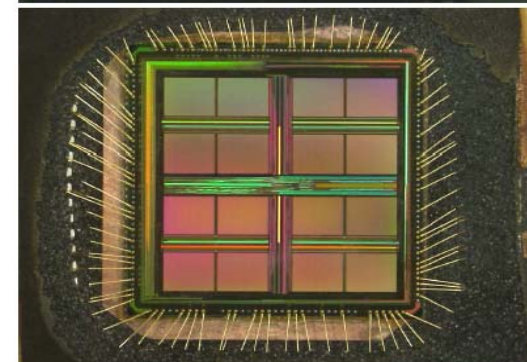
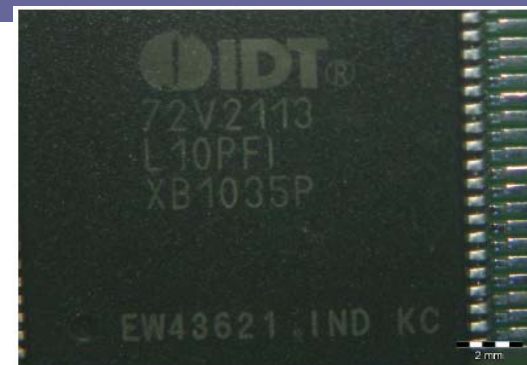
## ⌘ SEU

- ☑ The memory is fully filled, then fully emptied after a wait period
- ☑ During read and write operations, the flags are monitored
- ☑ Any flag or data error is time stamped and recorded

# FIFO memory IDT 256 Ki x 18 (1/2)

15/26

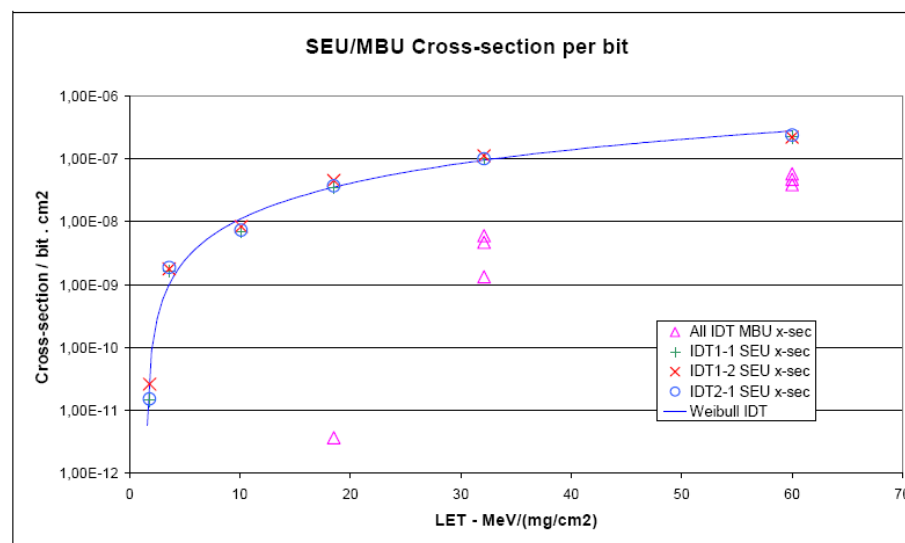
- ⌘ Part type: IDT72V2113
- ⌘ Part description: 4Mbit FIFO organized as 256Ki x 18 bits
- ⌘ Manufacturer: IDT
- ⌘ Package: 80 pin TQFP
- ⌘ Date code: 1035
- ⌘ Die dimensions: 7.6 x 7.6 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), December 2010, 2 parts



## FIFO memory IDT 256 Ki x 18 (2/2)

16/26

- ⌘ SEL have been observed at Xe (LET of 60.0 MeV.cm<sup>2</sup>.mg<sup>-1</sup>)
  - ☑ Cross-section: 1E-5 cm<sup>2</sup>
- ⌘ No SEL have been observed at Kr (LET of 32.1 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) up to a fluence of 1.2E5 part.cm<sup>-2</sup>
- ⌘ MBU at Fe (LET of 18.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) and above
  - ☑ Worst case MBU is 6 bits
- ⌘ MCU most likely occurred
- ⌘ PAF and PAF registers are sensitive
- ⌘ SEFI at Xe. Master reset not OK.



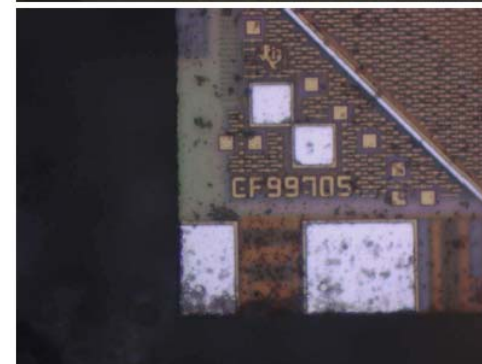
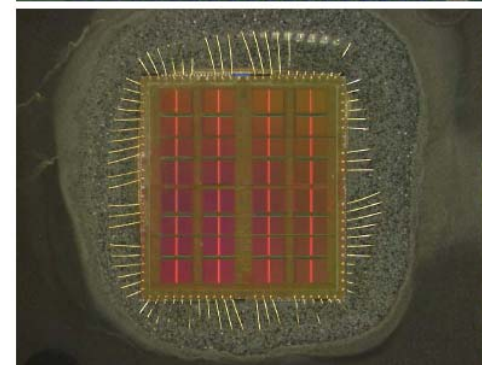
- ⌘ SEU saturation cross-section
  - ☑ 2.4E-7 cm<sup>2</sup>.bit<sup>-1</sup>
- ⌘ LET threshold
  - ☑ 1.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>



## FIFO memory TI 64 Ki x 18 (1/2)

17/26

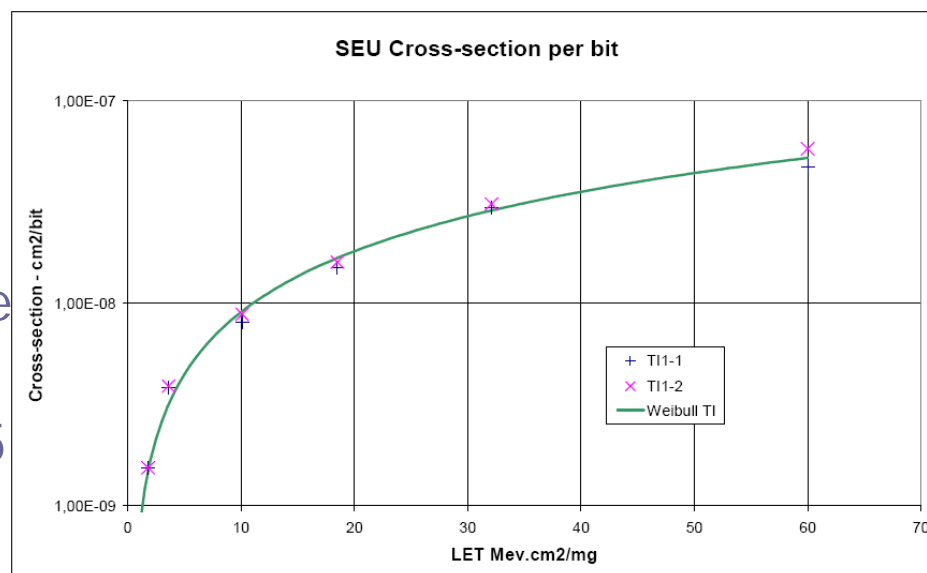
- ⌘ Part type: SN74V293-EP
- ⌘ Part description: 64Ki x 18 FIFO
- ⌘ Manufacturer: Texas Instruments
- ⌘ Package: 80 pin TQFP
- ⌘ Date code: 1035
- ⌘ Die dimensions: 5.7x 6.4 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland),  
December 2010, 2 parts



## FIFO memory TI 64 Ki x 18 (2/2)

18/26

- ⌘ SEL observed at Xe (LET of 60.0 MeV.cm<sup>2</sup>.mg<sup>-1</sup>), cross-section is about 5.3E-6 cm<sup>2</sup>
- ⌘ No SEL observed at Kr (LET of 32.1 MeV.cm<sup>2</sup>.mg<sup>-1</sup>), with fluence up to 5E5 part.cm<sup>-2</sup>
- ⌘ MBU observed at Fe (LET of 18.5 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) and above
  - ☑ Biggest MBU: 2 bits
- ⌘ One flag error associated to a possible upset in PAE register
- ⌘ One upset in read pointer ?
- ⌘ SEFI at Fe. Partial reset OK



- ⌘ LET threshold
  - ☑ 1 MeV.cm<sup>2</sup>.mg<sup>-1</sup>
- ⌘ Saturation cross-section
  - ☑ 5.8E-8 cm<sup>2</sup>.bit<sup>-1</sup>

# Flash testing methodology

19/26

## ⌘ SEL

- ☑ Supply current monitoring
- ☑ Current threshold is about 5 to 10 times the current under dynamic condition
- ☑ Hold time is 1 ms
- ☑ Power off time is 1 s

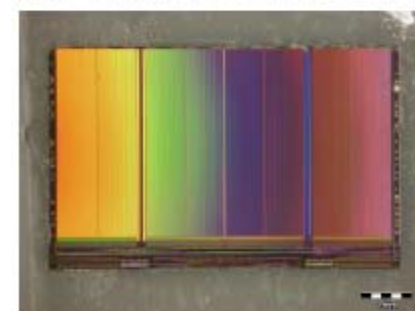
## ⌘ SEU

- ☑ Different test sequences may be used to get statistics on read/write/erase operations
- ☑ Few commands used (Read Page, Page program, Block erase, Read Status)

## Flash memory Samsung 32 Gbit (1/3)

20/26

- ⌘ Part type: K9WBF08U1M
- ⌘ Part description: SLC 4 die stack 32Gbit NAND Flash, organized as 4 die x 4096 blocks x 64 pages x (4096+128) words x 8 bits
- ⌘ Manufacturer: Samsung
- ⌘ Package: 48 pin TSOP I
- ⌘ Date code: 0816
- ⌘ Die dimensions: 15.17 x 9.59 mm
- ⌘ SEE Testing: UCL (Belgium), June 2009, 3 parts
- ⌘ TID Testing: ENEA-Calliope (Rome), 5 parts ON, 3 parts OFF, 1 Ref



# Flash memory Samsung 32 Gbit (2/3)

21/26

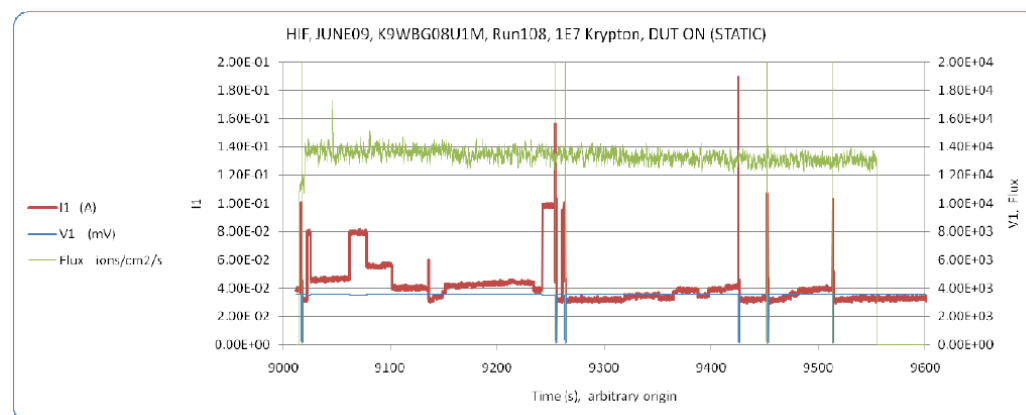
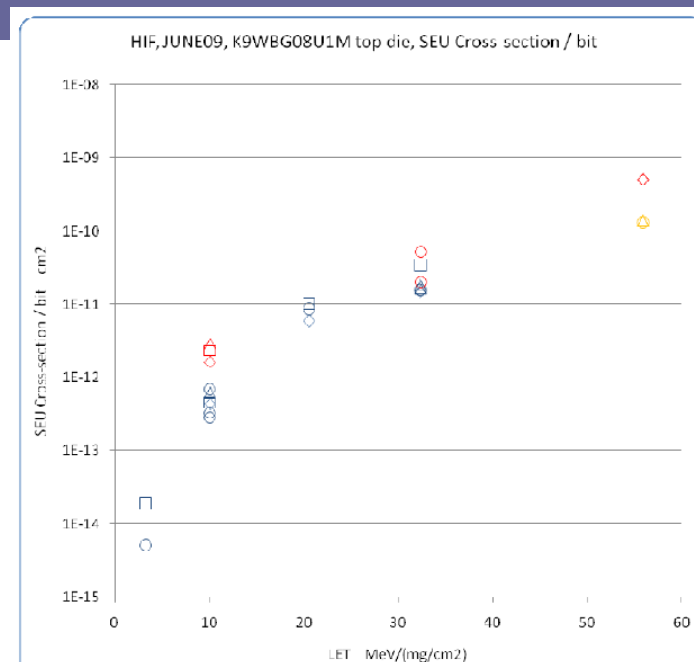
- ⌘ Most likely, SEL have not occurred or have been hidden by current steps.
- ⌘ “block erase” and “page program” errors have been reported by the DUT (via “read status” command)
  - ☑ No such events on S/N1
  - ☑ S/N 2 and 3 got more events along the runs up to device failure

## ⌘ SEU saturation cross-section

☑  $2\text{E-}10 \text{ cm}^2.\text{bit}^{-1}$

## ⌘ LET threshold

☑  $3 \text{ MeV.cm}^2.\text{mg}^{-1}$



## Flash memory Samsung 32 Gbit (3/3)

22/26

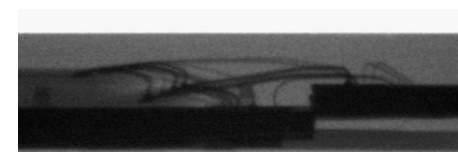
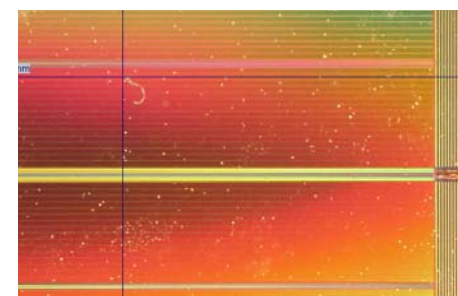
- ⌘ Stand-by current failed between 20 and 53 krad(Si), complete healing after annealing
- ⌘ Others parameters OK up to 100 krad(Si)

<b>Irradiation Steps</b>	<b>Dose rate</b>	<b>Annealing steps</b>	<b>Temperature</b>
<b>krads</b>	<b>rads/h</b>	<b>Hours</b>	<b>°C</b>
0			
5.6	200		Room
9.6	200		Room
14.8	200		Room
20	200		Room
53.6	200		Room
68.7	200		Room
96.1	200		Room
		24	Room
		168	100

## Flash memory Micron 32 Gbit (1/3)

23/26

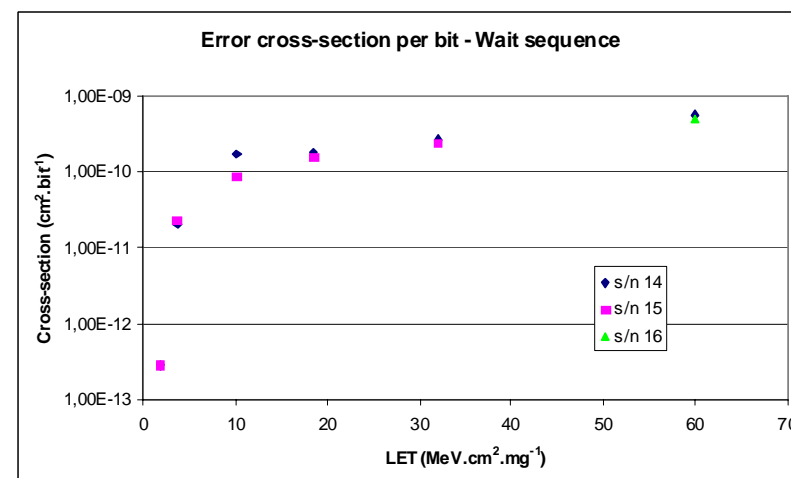
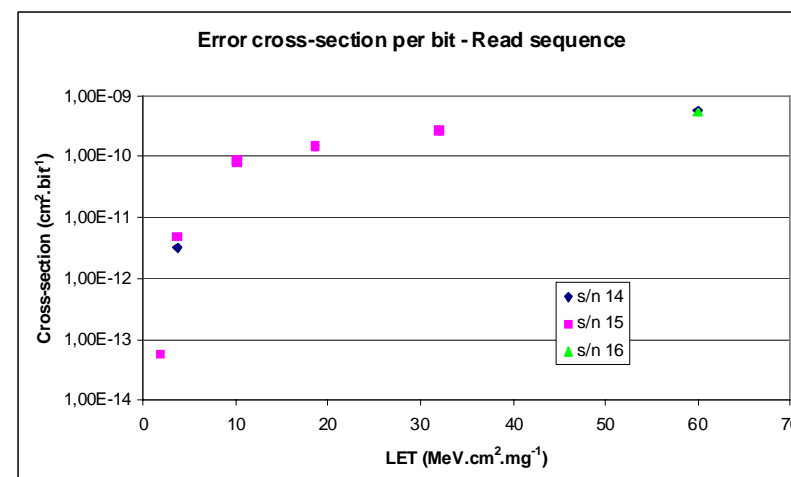
- ⌘ Part type: MT29F32G08
- ⌘ Part description: 3.3V 32 Gbit Flash memory, organized as 2 die x 4096 blocks x 128 pages x (4096+224) words x 8 bits
- ⌘ Manufacturer: Micron technology
- ⌘ Package: 48 pin TSOP
- ⌘ Date code: 1006
- ⌘ Die dimensions: 10.7 x 12.8 mm
- ⌘ SEE Testing: RADEF (Jyväskylä / Finland), August 2010, 3 parts
- ⌘ TID Testing: UCL (Belgium), 5 parts ON, 5 parts OFF, 1 Ref.



## Flash memory Micron 32 Gbit (2/3)

24/26

- ⌘ No SEL at Xe (LET: 60 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) up to a fluence of 9.6E6 cm<sup>-2</sup>
- ⌘ SEU have been observed from N (LET: 1.8 MeV.cm<sup>2</sup>.mg<sup>-1</sup>) to Xe
- ⌘ SEU may only be temporary
- ⌘ MBU have been observed, biggest MBU is 5 bits
- ⌘ Failure modes may concern addresses, pages, blocks or iterations as soon as Ne (LET of 3.6 MeV.cm<sup>2</sup>.mg<sup>-1</sup>)
- ⌘ “block erase” failures observed only when Fluencerun > 4E5 cm<sup>-2</sup>

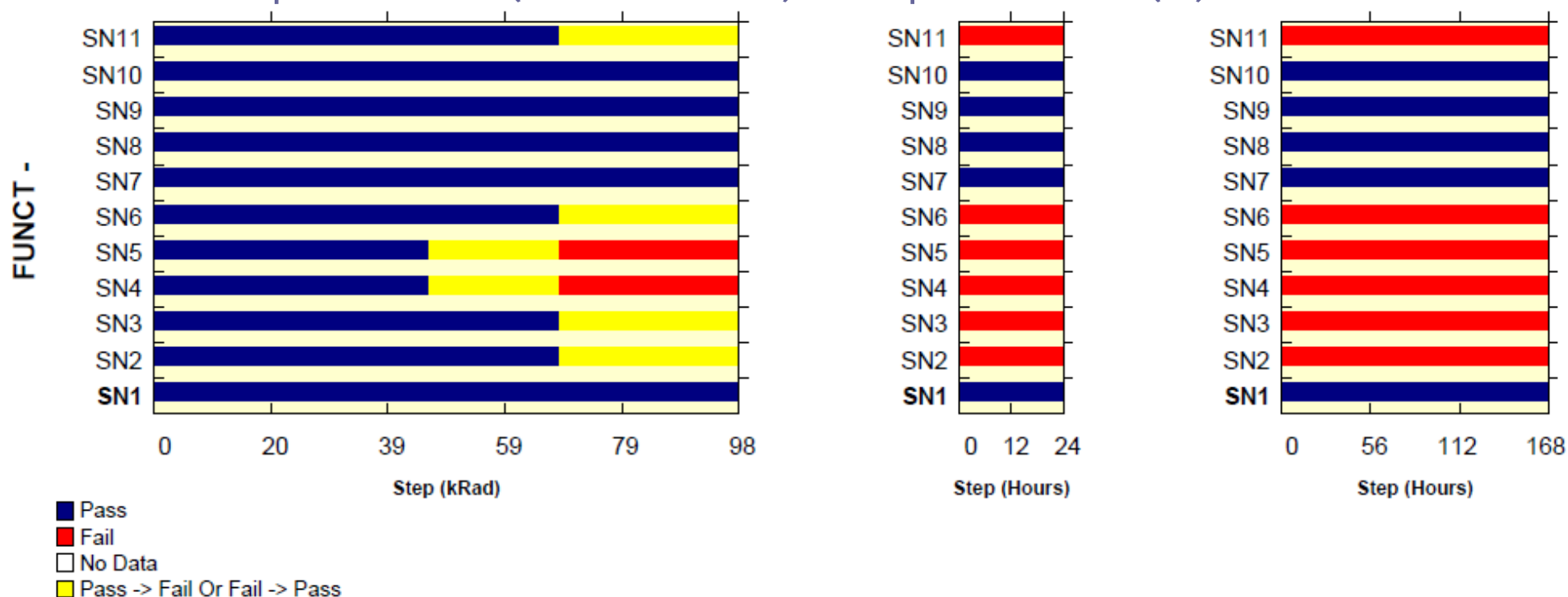




## Flash memory Micron 32 Gbit (3/3)

25/26

- ⌘ ON devices failed "stand by current" above 46 krad(Si)
- ⌘ Failed parameters after 68 krad(Si): VOH, VIL/VIH, tPROG, tBERS, tWP, tWH, tAR, tCLR, tRP, tREH, tWW, tADL and functionality
- ⌘ Other parameters (more than 20) OK up to 98 krad(Si)





# Radiation Characterization of various FRAM, SRAM and Flash memories

Thank you !