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Radiation Qualification of the

ELMB

NIKHEF and CERN

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ELMB to be used in ATLAS outside of the calorimeter

- **Total Ionising Dose TID** (charged particles and γ)
- **Non-Ionising Energy Loss NIEL** (neutrons)
- **Single Even Effects SEE** (hadrons with > 20 MeV energy)



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Radiation Tolerance Criteria

according to
the ATLAS POLICY ON RADIATION TOLERANT
ELECTRONICS

ELMB:

- * Will be used in ATLAS MDT
- * Contains CMOS devices, bipolar devices, and optocouplers.
- * Foreseen radiation constraint in **MDT Barrel 1**:

sim x ldr x pre

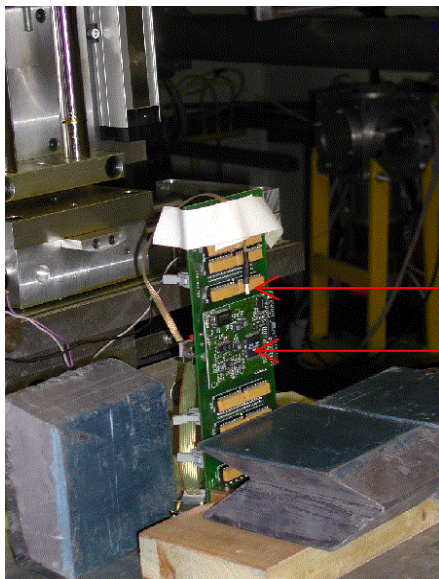
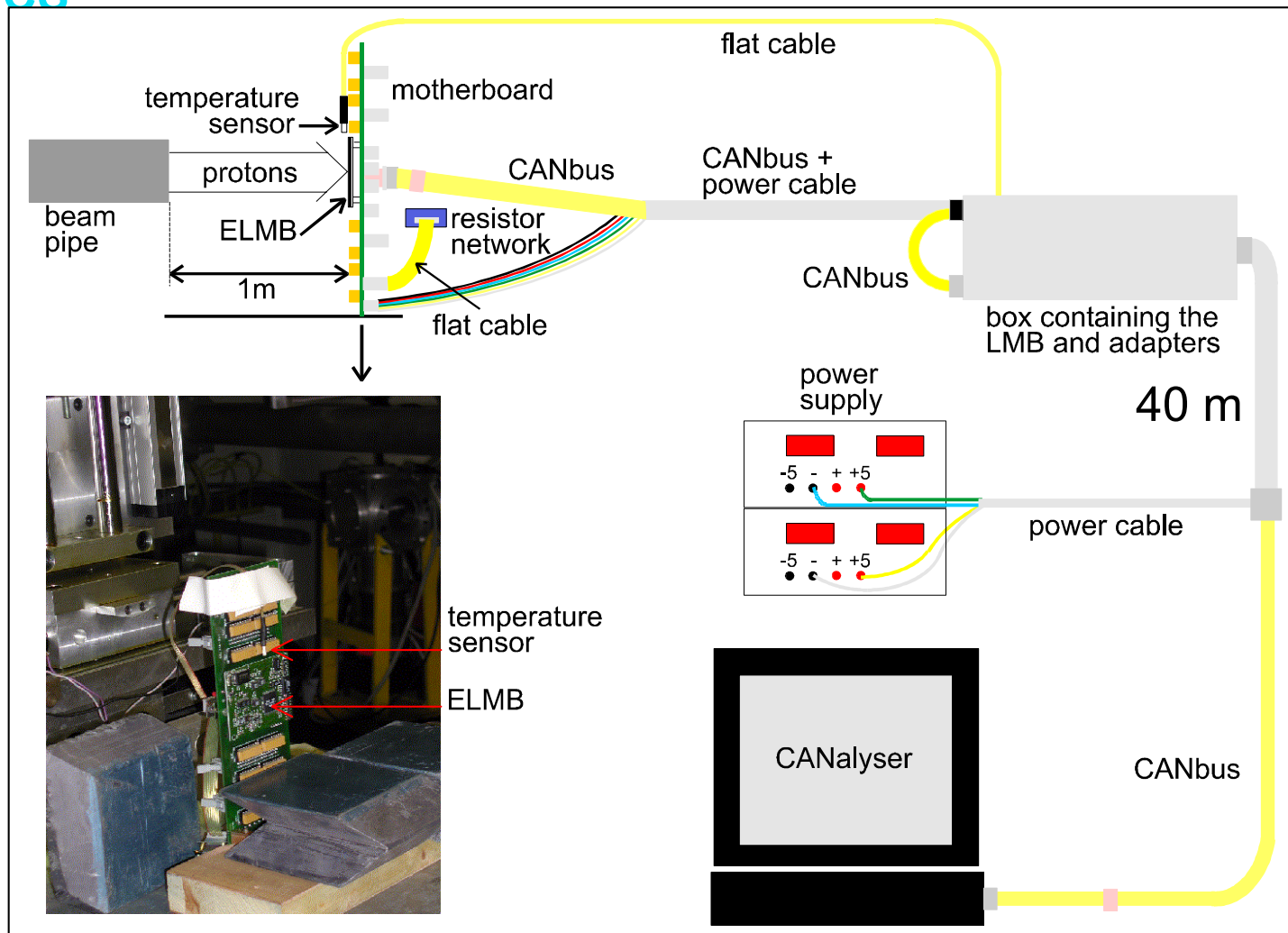
- TID: **4.7 Gy** x 3.5 x 1 x 2 = **33 Gy** 3.3 krad in 10 years;
- NIEL: **3.0E10 n/cm²** x 5 x 1 x 2 = **3.0E11 n/cm²** (1 MeV eq.) in 10 years;
- SEE: **5.4E09 h/cm²** x 5 x 1 x 2 = **5.4E10 h/cm²** (>20 MeV) in 10 years.

		ATLAS Policy on Radiation Tolerant Electronics			
ATLAS Project Document No. ATC-TE-QA-0001	Revision Document No. EB-00-016	Created 21 July 2001	Revised 21 July 2001	Page 2	1 of 40
ATLAS POLICY ON RADIATION TOLERANT ELECTRONICS					
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Distribution List ATLAS Executive Board members; ATLAS Electronics Co-ordinators; ATLAS Radiation Hardness Assurance Working Group members.					



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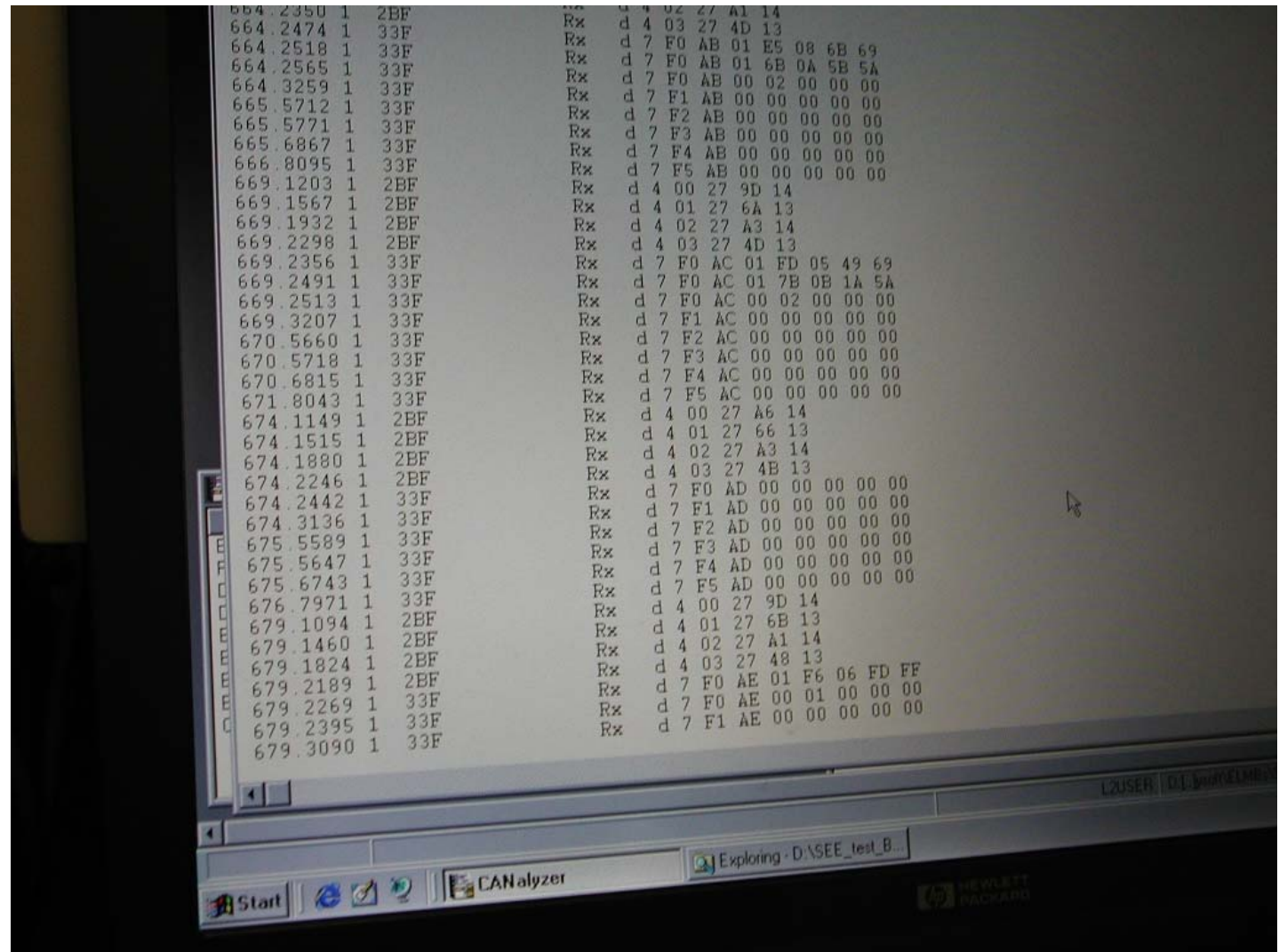
SEE test setup





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SEE test at CYCLONE

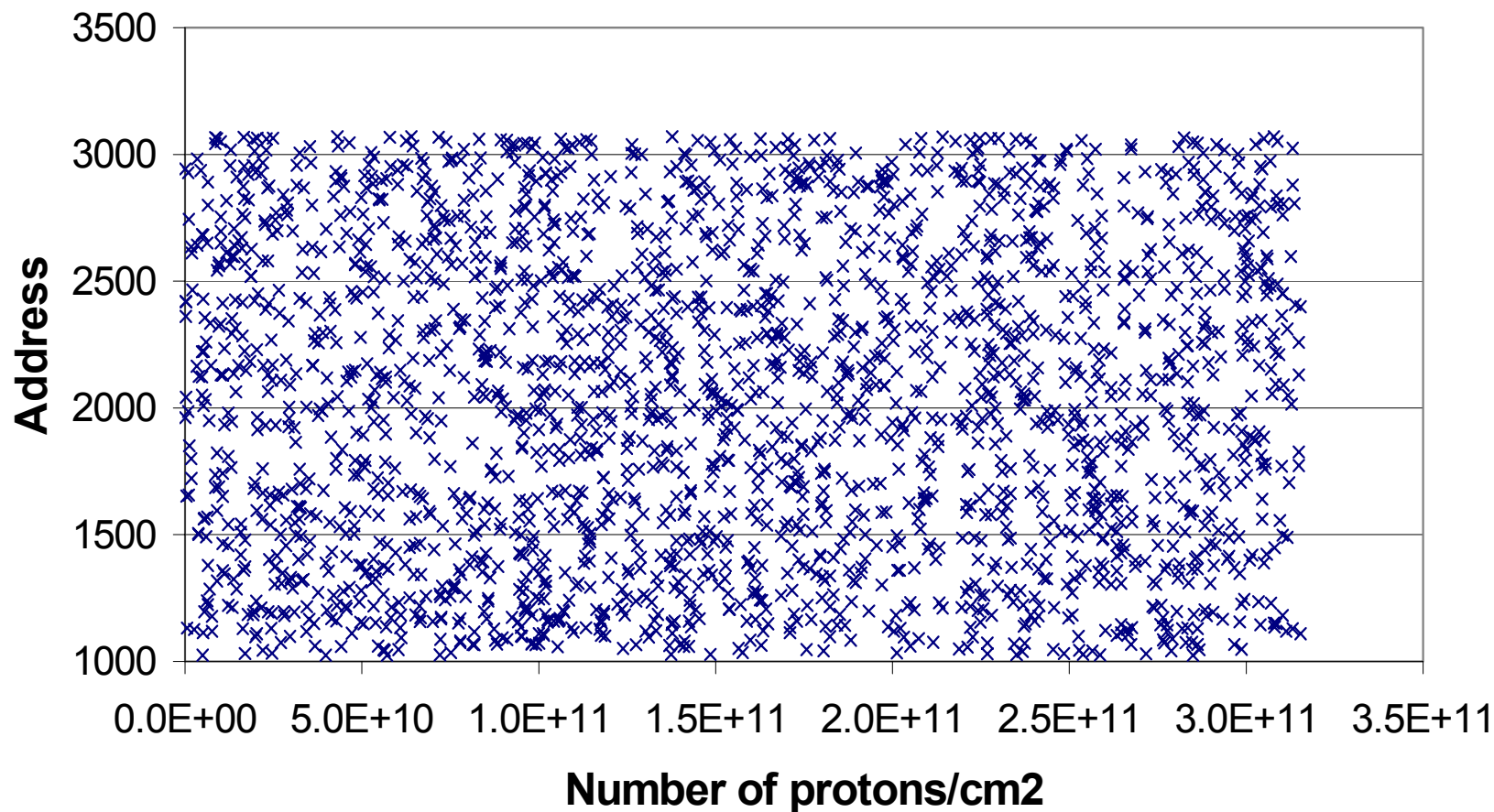




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Systematic tests: SRAM

Addresses where SEE were detected in SRAM

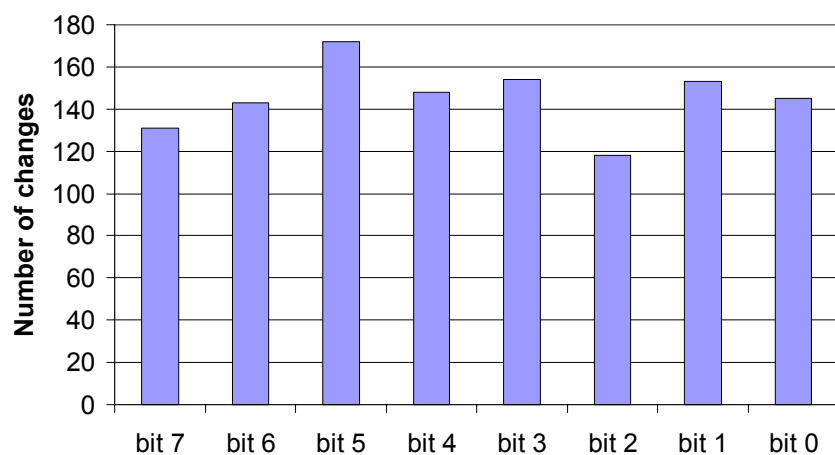




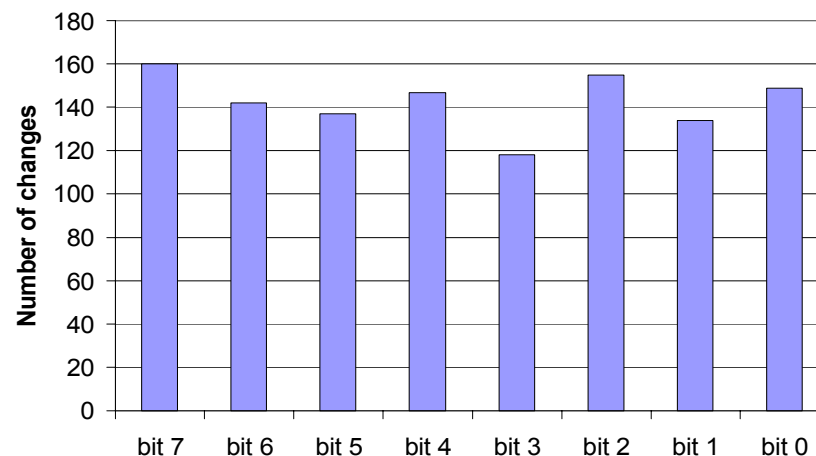
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SRAM SEE test ...

1164 'bitflips' 0 into 1



1142 'bitflips' 1 into 0





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Systematic SEE test

	No of bits tested	No of errors	Cross-section cm ² /bit
SRAM	16384	2320	$4.3 \cdot 10^{-13}$
EEPROM	28672	<1	$<1.1 \cdot 10^{-16}$
FLASH	1048576	<1	$<2.9 \cdot 10^{-18}$
CAN reg.	320	23	$2.2 \cdot 10^{-13}$
ADC reg.	264	22	$2.5 \cdot 10^{-13}$

No errors found in Flash memory and EEPROM!

ELMB Requirements

SEE category / Symptoms	Error recovery	Maximum allowed rate
Soft SEE/ Data readout errors	Automatic	1 per 10 min per CAN branch
Soft SEE / CAN node hangs	Software reset	1 per 24 h per CAN node
Soft SEE / CAN branch hangs	Power cycling	1 per 24 h per CAN branch
Hard SEE / Permanent error	Replace ELMB	1 per months for 3000 ELMBs
Destructive SEE / Damage	Power limitation	Not allowed



ELMB Functional SEE results

Category

Requirements

ELMB Result

for $5.4 \cdot 10^{10}$ h/cm²

SEE upsets for $3.3 \cdot 10^{11}$ h/cm²

Soft SEE

automatic recovery	2604	21
software reset	1152	5
requiring power off-on	18	4

Hard SEE

0.03

0



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Coping with SEE in the DCS system

**Monitoring of the status of each node using the CANopen
node guarding protocol and SCADA**

- **reset and restart node(s) automatically**
- **reset of all nodes on a CAN branch with power cycling**
- **monitor of the current consumption for Single Event Latch-ups**

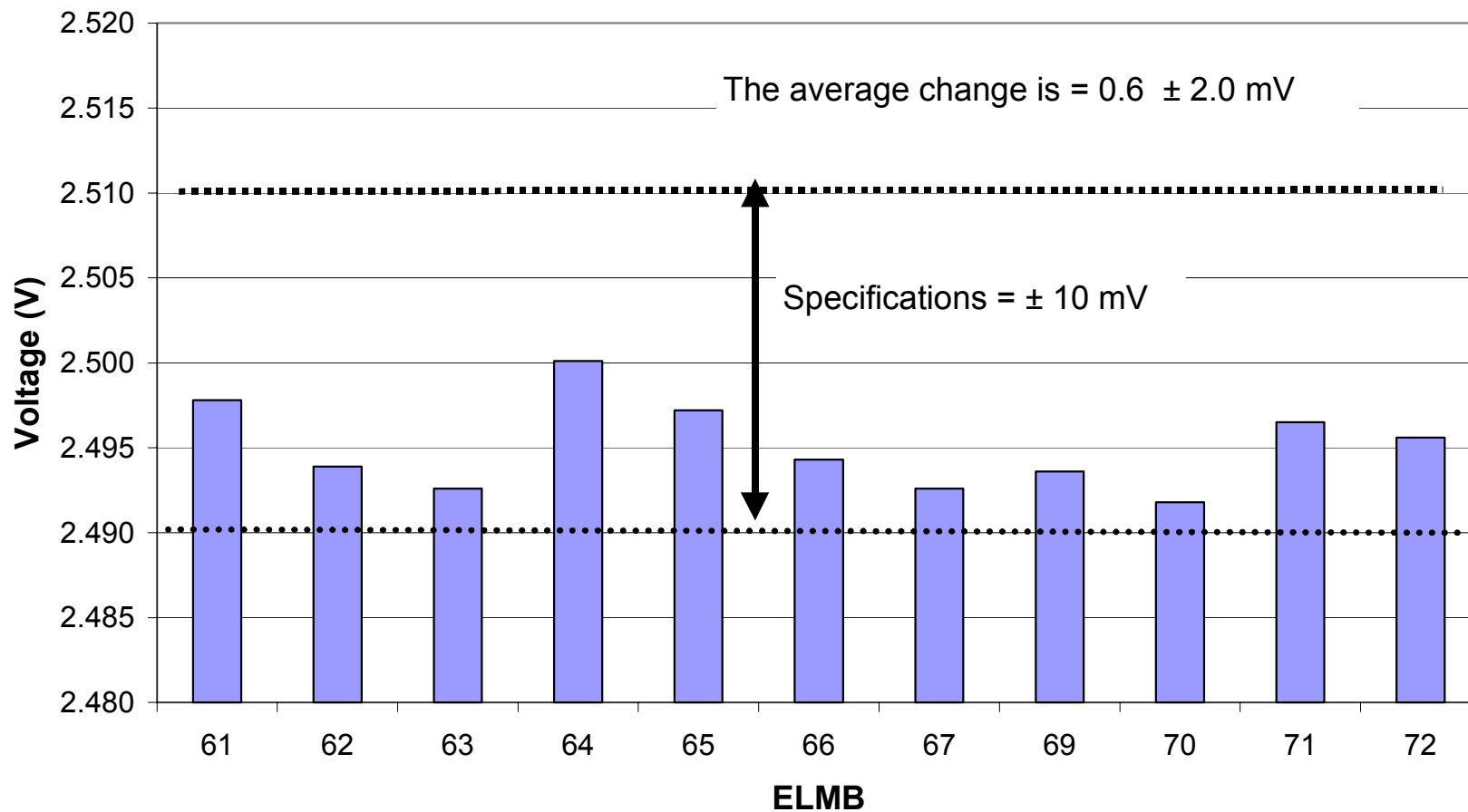
This needs to be tested in the TCC2 radiation test ASAP



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TID effects

Voltage reference AD680JR after Proton irradiation 3.3E10 / 39 Gy

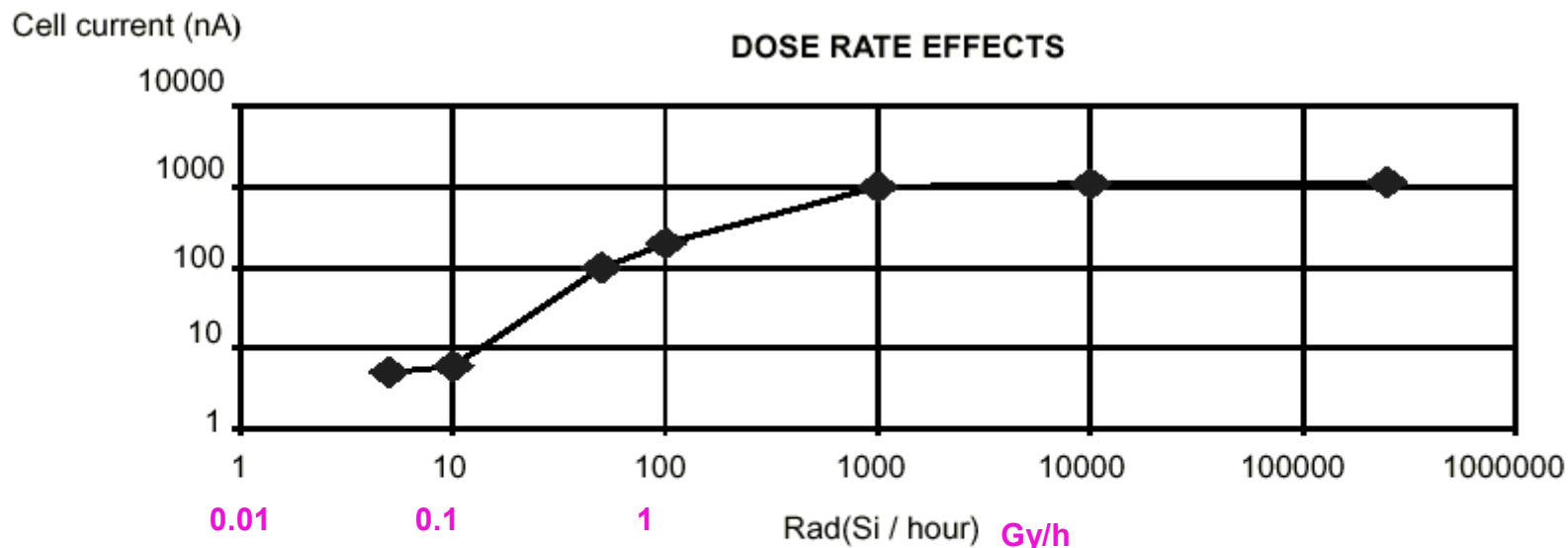




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Low dose rate effects ?

<http://www.atmel-wm.com/upload/doc3b8a15ead3abe.pdf>



Atmel and the French space agency (CNES) have conducted a dose rate study on Atmel parts. This clearly demonstrates negative effects induced by high dose rates on sensitive FG_Leftmeters such as leakage currents. For instance, after irradiation up to 40Krad(Si), a standard memory cell leaks 1 μ A @ 100Krad(Si)/hour and 5nA @ 10 rad(Si)/hour dose rate!

$$\text{MDT} < 10\text{Gy} / 10^8\text{s} = 3.6 \cdot 10^{-4} \text{ Gy/h}$$



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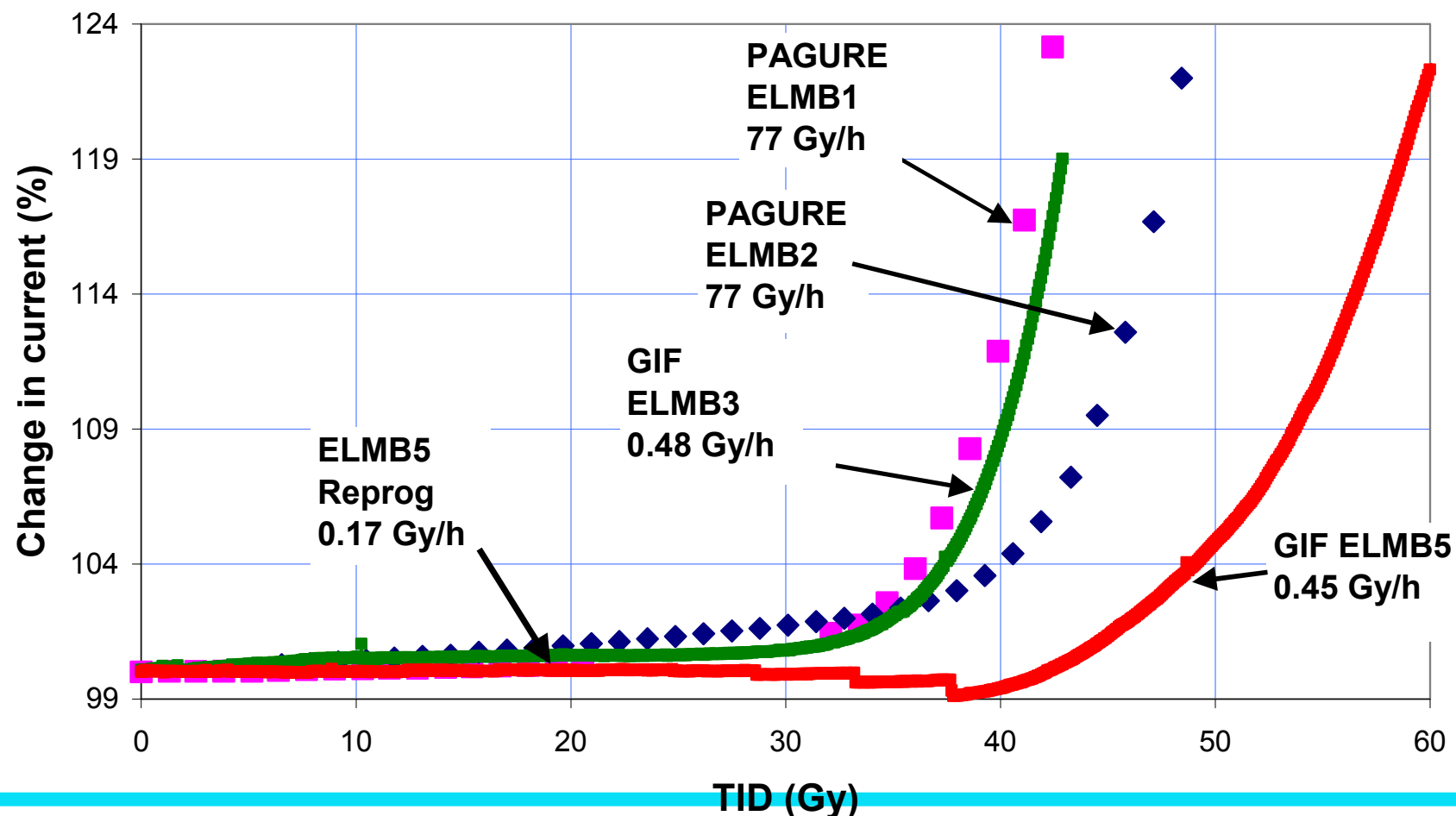
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TID tests

Comparison GIF versus PAGURE

ELMB1
ELMB3

ELMB2
ELMB5

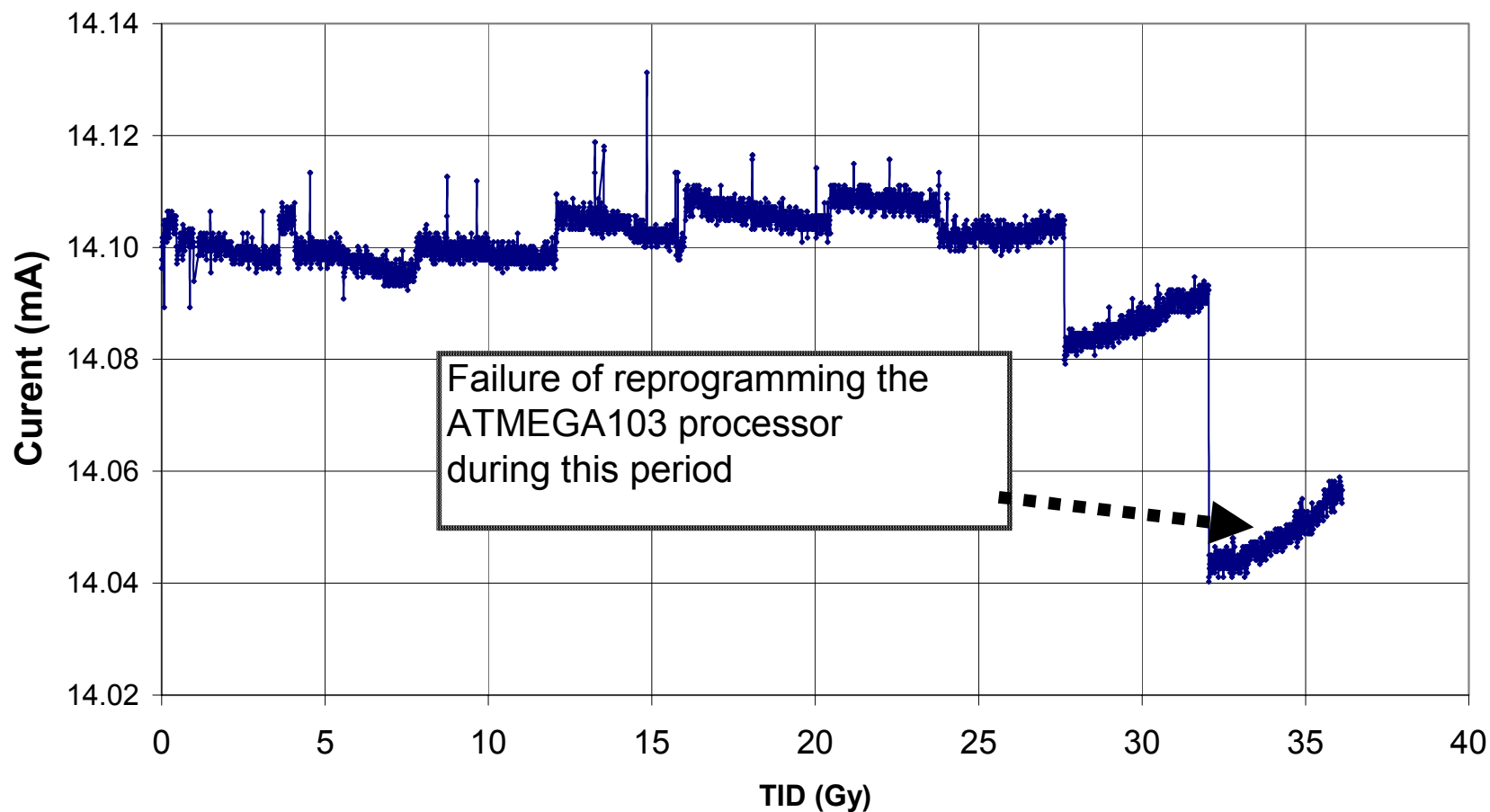




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TID at GIF 2nd test

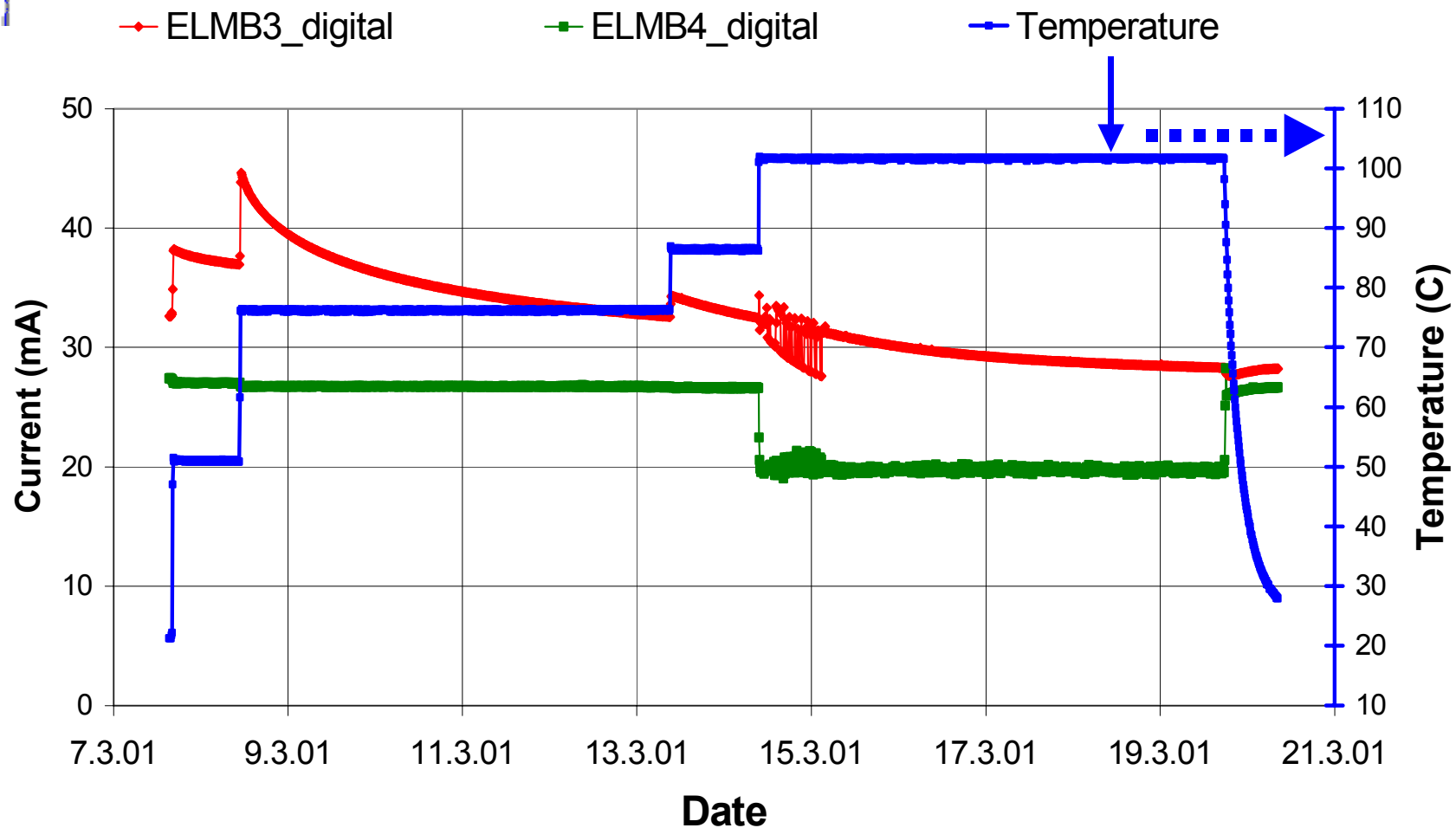
Digital Current





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Accelerated ageing test





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Tests performed

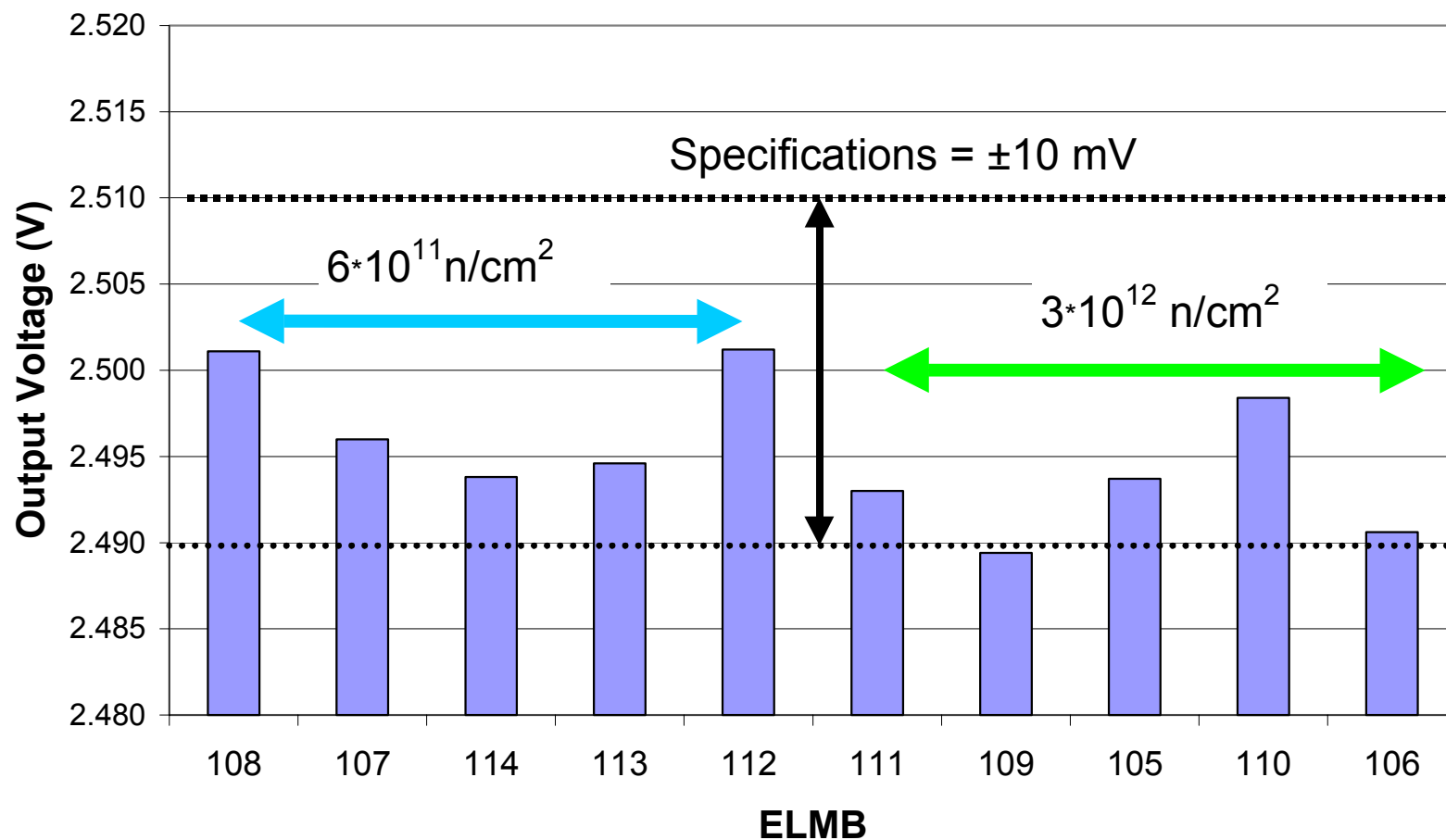
Quant	Component	Techn.	TID (Gy)	NIEL (n/cm ²)	SEE
1	ATMEGA103-6AC	CMOS	39		3.3*10 ¹¹
1	AT90S2313-10SC	CMOS	39		
1	SAE81C91	CMOS	39		3.3*10 ¹¹
1	CS5523-AS	CMOS			3.3*10 ¹¹
1	AD680JR	Bipolar		3*10 ¹²	
1	PCA 82C250T	Bipolar		3*10 ¹²	
3	MIC5203	Bipolar		3*10 ¹²	
3	HCPL-0731	Opto		3*10 ¹²	
2	HCPL-0601	Opto		3*10 ¹²	3.3*10 ¹¹
1	74HC1G66GW	CMOS			
16	MAX4582CEE	CMOS			
1	MIC2754MBM5TS	CMOS			
1	ADP3607AR	CMOS			
1	MAX871EUK	CMOS			
1	NC74S14M5 P	CMOS			
1	74HC74ADT	CMOS			
4	NC7SZ00P5	CMOS			
5	BAV70W diode	Bipolar		3*10 ¹²	
4	BAT54W diode	Bipolar		3*10 ¹²	



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NIEL test Prospero

AD680JR Voltage Reference after Neutron test





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Summary

- ◆ **Low cost but still radiation tolerant**
 - ◆ **SEE = very good**
 - ◆ **NIEL = very good**
 - ◆ **TID = OK**
-
- ◆ 300 have been produced
 - ◆ Available to all experiments via the CERN pool (CERN EP-ESS)