

# NIEL Qualification of the ELMB128 Series Production

H. Boterenbrood and B. Hallgren

**Abstract:** 10 Embedded Local Monitor Boards with the ATMEGA128 processor (ELMB128) were irradiated with neutrons to fluence of  $5.3 \cdot 10^{12}$  neutrons/cm<sup>2</sup> equiv. 1 MeV (Si). The results show that all tested ELMB128 boards pass this qualification test.

## 1.0 Introduction

The ELMB [1] will be used by many ATLAS sub-detectors and in other LHC experiments in critical applications in the monitoring and control systems to maintain safe and reliable operation. It is therefore important that the ELMB is thoroughly tested for radiation tolerance. The components for the series production were purchased from the respective manufacturer coming from same production lots. Samples of these components were used to fabricate 30 ELMB128 boards for the two types of radiation qualification tests required by the ATLAS Policy on Radiation Tolerant Electronics. The NIEL qualification tests are described in this report.

Based on pre-selection tests [2], [3], it was decided to make the NIEL qualification tests of ELMB production to a fluence of  $6 \cdot 10^{12}$  neutrons/cm<sup>2</sup>. The tests were performed on 26 November 2003 at the PROSPERO reactor of CEA, Centre de Valduc in France. The ELMB boards were powered during the irradiation and measurements were made on-line in addition to detailed tests at CERN before and after the irradiation. In this way immediate results were available so the production could start without delay.

## 2.0 Experimental test setup

The 10 ELMB boards to be tested were mounted on standard ELMB motherboards which were fixed on 2 PVC panels of the size 40 x 50 cm, see Figure 1. These were placed at 1164 mm distance from the reactor to give  $6 \cdot 10^{12}$  n/cm<sup>2</sup> equiv. to 1 MeV (Si) as shown Figure 2. However the results of 4 dosimeters given by CEA indicates that the mean neutron value fluence actually received by the ELMB board was  $5.3 \pm 0.4 \cdot 10^{12}$  n/cm<sup>2</sup> together with a gamma dose of 6 Gy (Si). Two special adapter boards were connected to each motherboard. In this way each ELMB could measure on itself the power supply voltages, currents and different voltage regulators. Changes of the voltage reference will influence these measurements. All other analog inputs of the ELMB were connected to resistor bias network. The power was supplied via a junction box and a 50m long thick CAN cable. The software used in the ELMB is the standard readout software ELMBio v4.2 for ELMB128 [4]. All CAN-bus messages during the test were logged on two computers in parallel. Throughout the irradiation period a measurement were made every 60 s. While for a 19-hour annealing period after the irradiation a measurement was made every 10 min.

In the same test separate online measurements were also made of 32 optocouplers of the type HCPL-0731. These were mounted on 4 boards, which were fixed on top of the two PVC plates. The currents through the optocouplers were measured by an extra ELMB with motherboard placed 5 m away from the reactor.

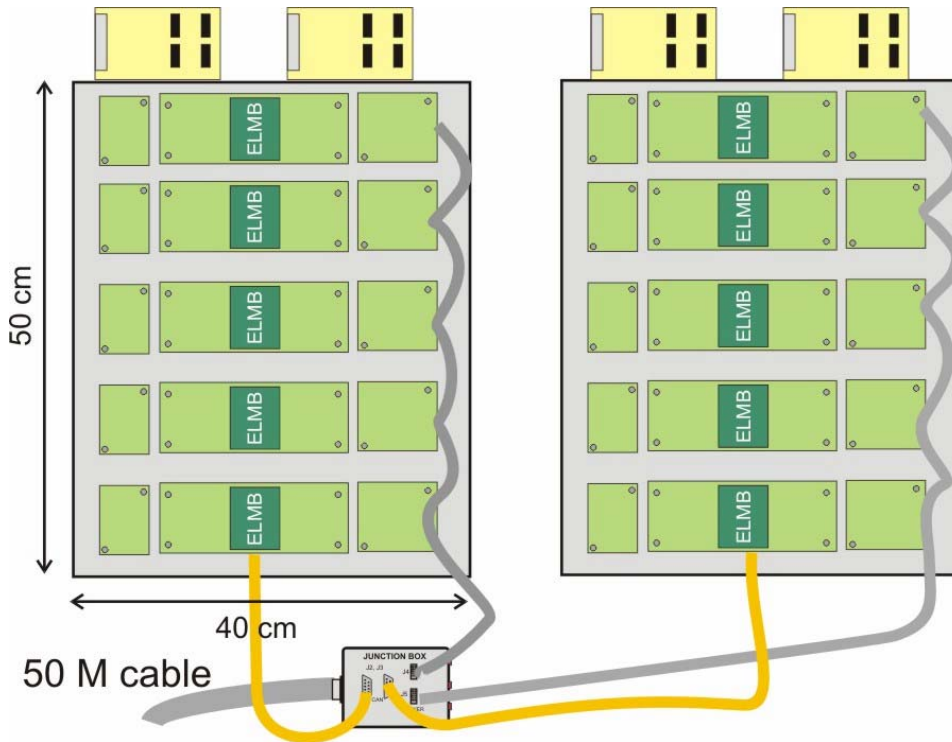


Figure 1 10 ELMB boards mounted on two panels with test circuits and test boards with optocouplers

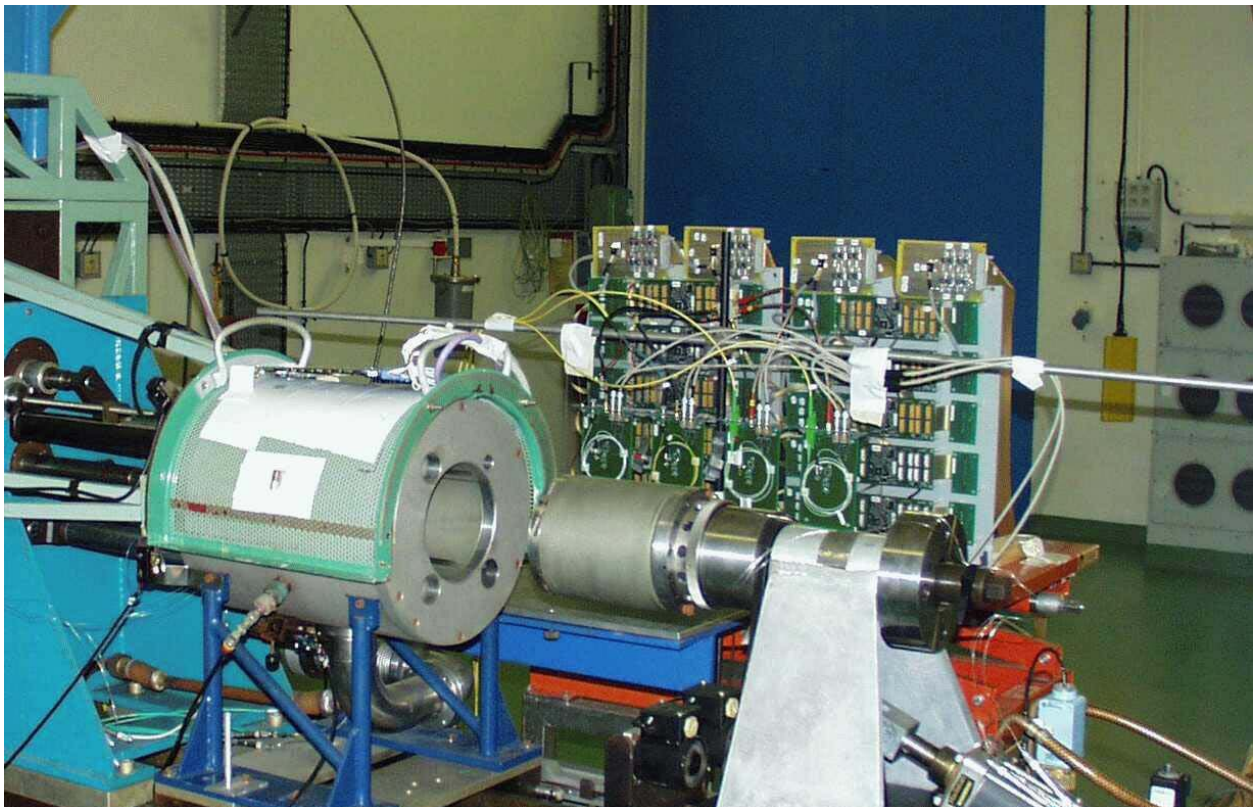


Figure 2 The reactor PROSPERO and the two panels with 10 ELMB boards placed at a distance of 1164 mm.

### 3.0 Detailed tests of the ELMB128

The ELMB128 boards were tested and calibrated just before the PROSPERO test at CERN on 21 November 2003 and again on the 20 January 2004 when they were returned to CERN. All of the boards passed the tests. Table 1 shows the average values of the measured currents. Only the digital current showed a small change of 5.5 %.

**Table 1 Current change for  $5.3 \cdot 10^{12} \text{ n/cm}^2$**

Parameter	Before test (mA)	After test (mA)	Change (%)
Analog Currents	$11.65 \pm 0.14$	$11.64 \pm 0.18$	$-0.1 \pm 0.9$
Digital Currents	$13.32 \pm 0.20$	$14.10 \pm 0.26$	$5.5 \pm 0.9$
CAN Currents	$18.61 \pm 0.17$	$18.42 \pm 0.14$	$-1.0 \pm 0.7$

The Table 2 shows the measured voltages. It is mainly the bipolar voltage regulators MIC5203 which are influenced by the neutron irradiation. Also the output of the bipolar reference is increased by 0.5%.

**Table 2 Changes in Voltages for  $5.3 \cdot 10^{12} \text{ n/cm}^2$**

Parameter	Before test (V)	After test (V)	Change (%)
Reference Voltage (AD680 JR)	$2.506 \pm 0.002$	$2.518 \pm 0.004$	$0.49 \pm 0.15$
Voltage Regulator MIC5203-3.3	$3.258 \pm 0.008$	$3.394 \pm 0.016$	$4.0 \pm 0.5$
Voltage Regulator MIC5203-5.0	$4.961 \pm 0.025$	$5.119 \pm 0.034$	$3.1 \pm 0.4$
Voltage Inverter MAX871	$-V_{in} + 0.048 \pm 0.001$	$-V_{in} + 0.050 \pm 0.001$	$0.04 \pm 0.01$

The accuracy of the irradiated ELMB boards after a new calibration has not changed significantly as shown Figure 3.

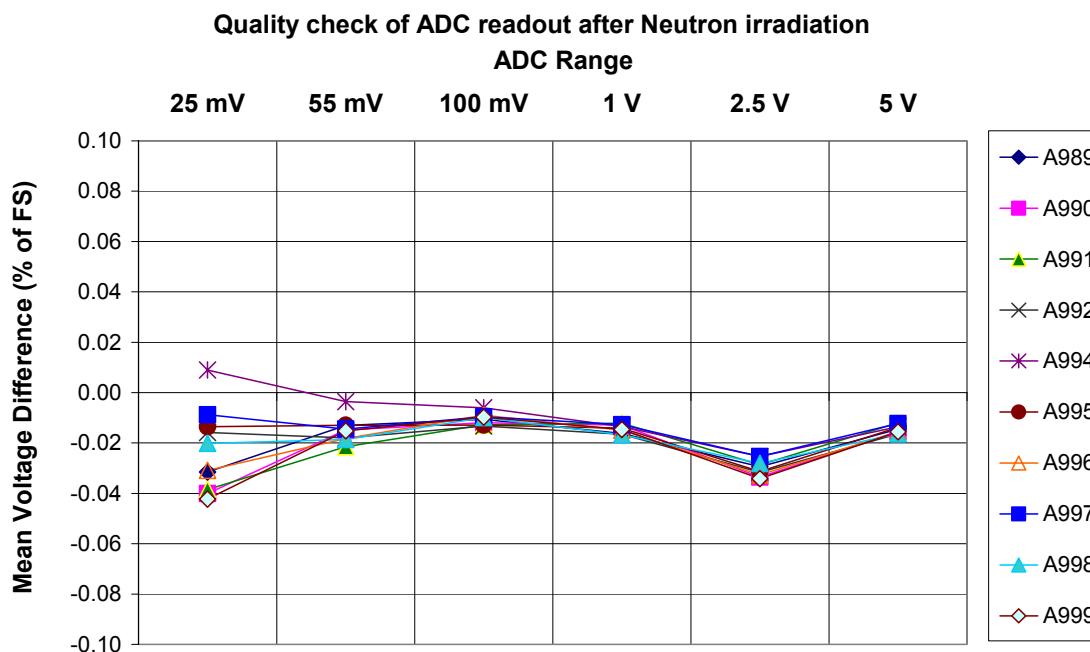


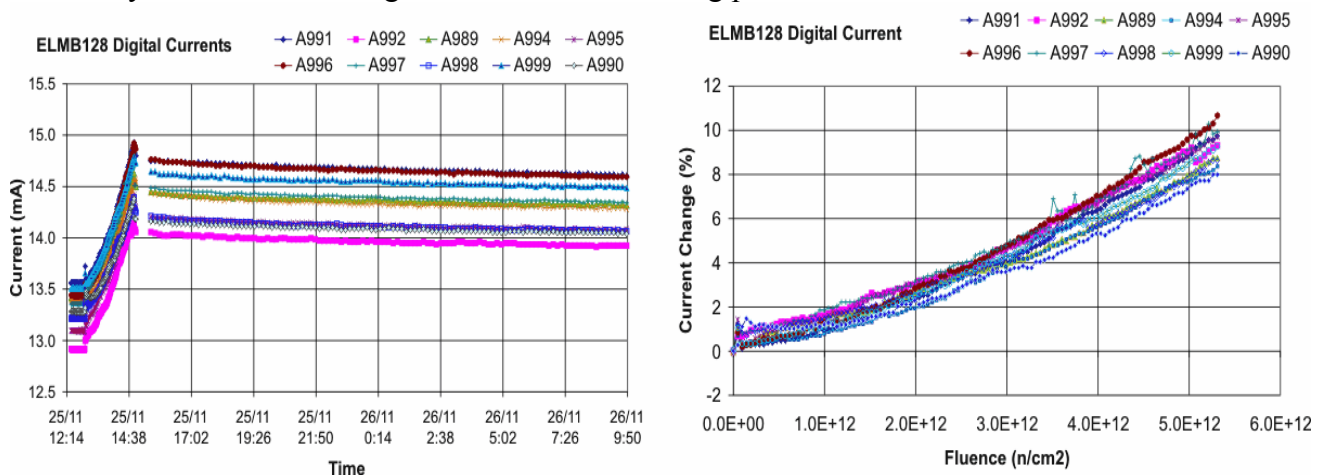
Figure 3 Performance test of the irradiated ELMB after calibration

## 4.0 Online measurements

Measurements of the 10 ELMB128 boards begun 30 minutes before the turn-on of the reactor and was continued for an annealing period of 19 hours after the end of the irradiation. The data acquisition was stopped for about 30-min after the reactor was turned off in order to back-up the measurements files. This shows up as a gap in the curves. Power was applied to the tested devices during the whole measurement period. Only the parameters which show any significant changes are described. These are the digital currents, the voltage regulators MIC5203 and the optocouplers.

### 4.1 Digital currents

The digital current increases during the irradiation to about 10% as shown in Figure 4. There was a recovery of about 2% during the 19-hour of annealing period after the irradiation.



a) Overall behaviour

b) Change during the irradiation

Figure 4 Behaviour of the digital current for an irradiation of  $5.3 \cdot 10^{12}$  n/cm<sup>2</sup>

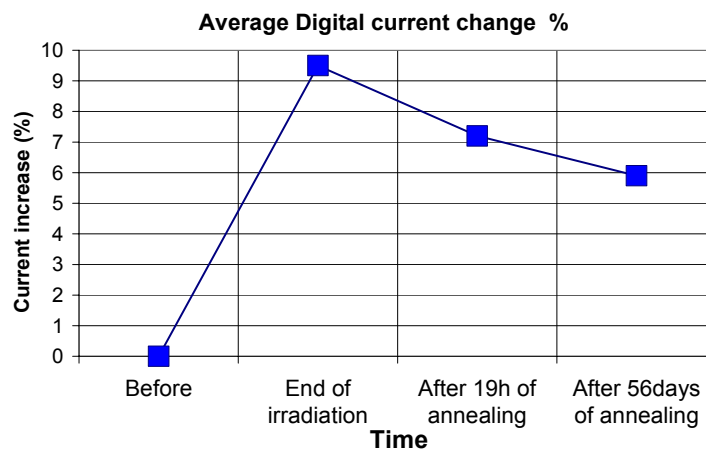
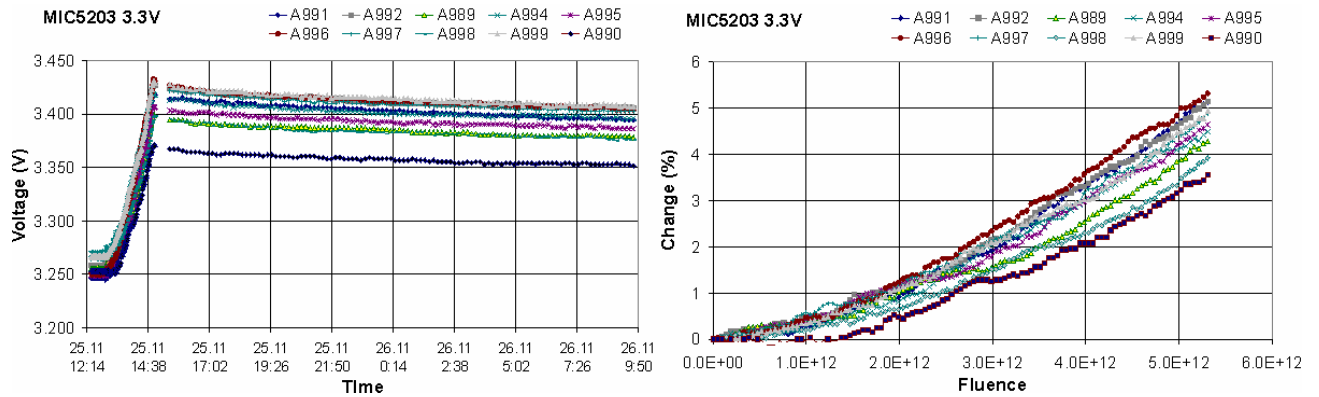


Figure 5 The average digital current change during the irradiation and after a period of annealing

The 10 ELMB128 boards show an average digital current increase of 6% after about a period 2 months as shown in Figure 5. This increase in the digital current of the ELMB128 is negligible compared to the dynamic change of the current during normal operations and have no influence on the performance of the ELMB.

## 4.2 Voltage regulators MIC5203

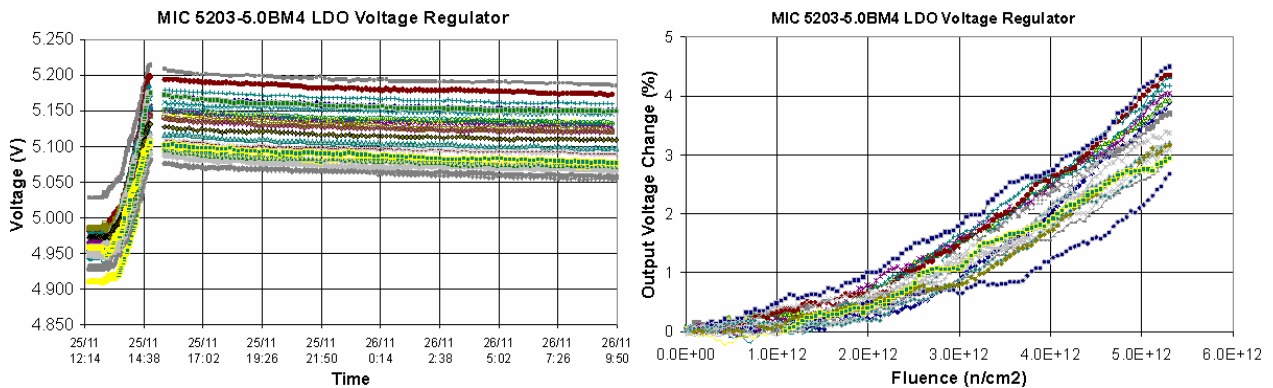


a) Overall time behaviour

b) Change during the irradiation

Figure 7 The MIC 5203 3.3V change during the irradiation and 19 h period of annealing

The behaviour of the voltage regulators version 3.3V is shown in Figure 7 respectively for the 5V in Figure 8. The datasheet specifies a maximum  $\pm 4\%$  tolerance in the output voltage tolerance for these devices, which has been reached as shown in figures at about  $4 \cdot 10^{12}$  n/cm<sup>2</sup>. An earlier test [2], [3] shows that the MIC5203 fails for a fluence of  $8 \cdot 10^{12}$  n/cm<sup>2</sup> and this by a decrease in the output voltage by 40 to 70%. Figure 9 shows that there is no recovery of the voltage regulator MIC5203 due to annealing.



a) Overall time behaviour

b) Change during the irradiation

Figure 8 The MIC 5203 5V change during the irradiation period and 19h period of annealing

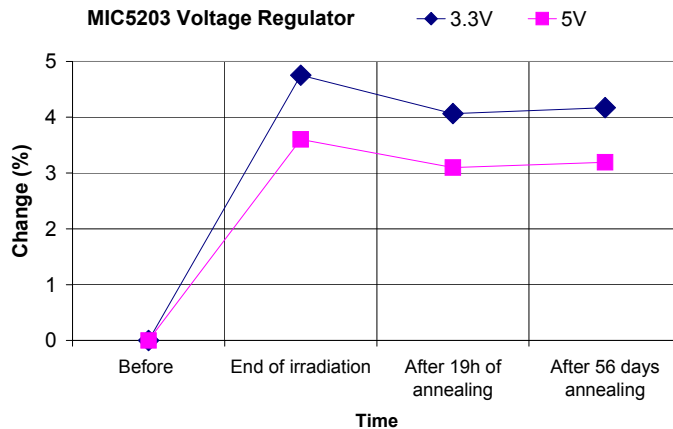


Figure 9 Voltage regulator MIC5203 average changes for  $5.3 \cdot 10^{12}$  n/cm<sup>2</sup> and after annealing

### 4.3 HCPL0731 Optocouplers

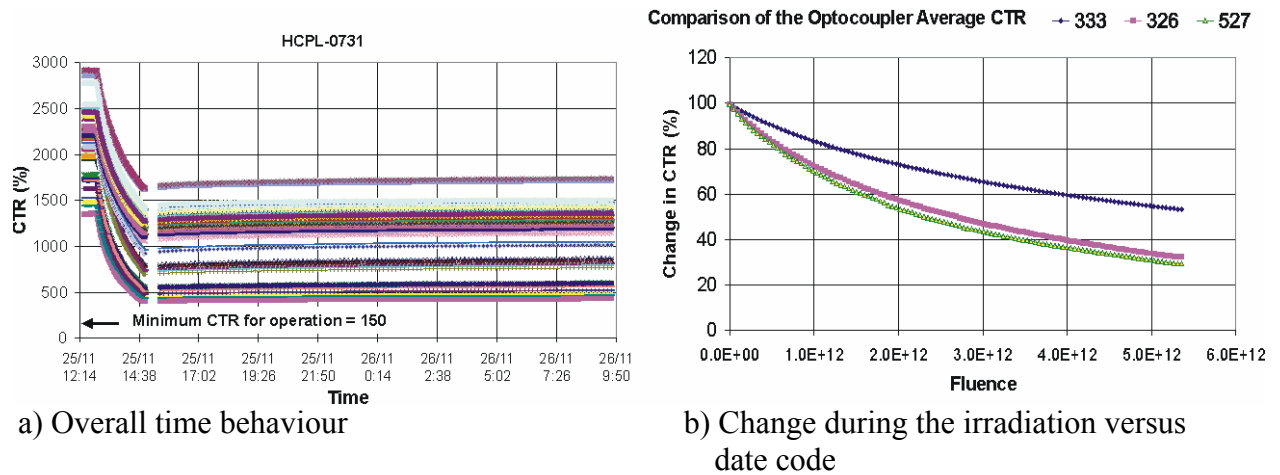


Figure 10 The change in current transfer ratio of the optocouplers HCPL0731.

Figure 10 shows the CTR of the HCPL0731 optocouplers has decrease by 30 to 50% for a fluence of  $5.3 \times 10^{12} \text{ n/cm}^2$  depending on the data code. However the minimum CTR is 150 % which nonetheless gives a margin for operation of a factor 3. It is interesting to note that the change in CTR seems most pronounced for low values of the fluence in contrast to the voltage regulator MIC5203.

The HCPL0731 is used in the SPI bus interface of the ADC on the ELMB board. The clock period of this interface can be set under software control. A test was made before the irradiation and repeated immediately after in order to determine the change of the minimum length of the clock period necessary to operate the SPI interface, due to irradiation. As shown Figure 11 the speed improves with  $19 \pm 15 \mu\text{sec}$  for the tested ELMB boards.

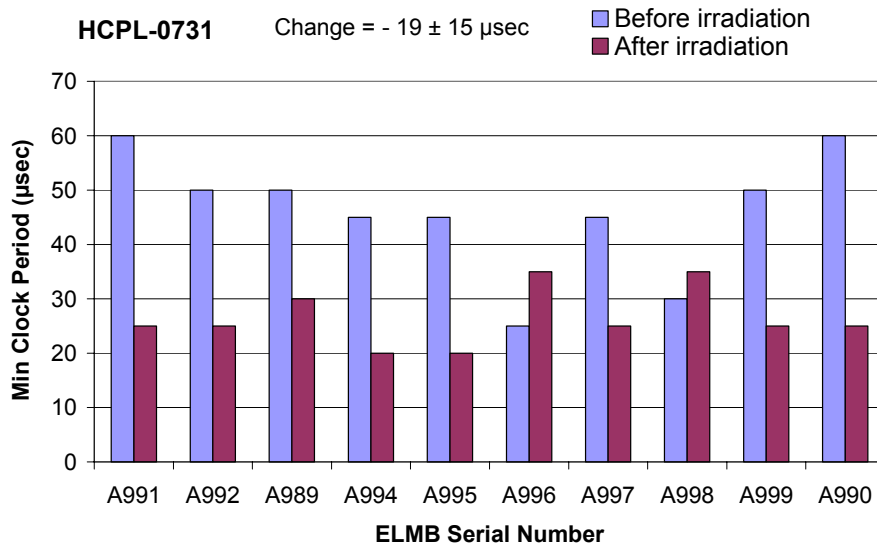


Figure 11 Change in overall speed of the HCPL0731 for a fluence of  $5.3 \times 10^{12} \text{ n/cm}^2$

