TRT ASDBLR
Neutron Irradiation Test

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Abstract

Three ASDBLR boards were tested before and after irradiation. The radiation doses are $3.5 \cdot 10^{14}$, $1 \cdot 10^{14}$ and zero 1 MeV n/cm^2 (NIEL) for board number 7, 8 and 9, respectively.
All channels remain well within operating condition and no additional dead channel are observed. The major radiation effect is the increase in the current flowing into the ASDBLR thresholds (up to a factor of 3) and a slight voltage drop of the threshold values (max 14 %).

Many thanks to Juan Valls for providing major parts of the analysis software.

1 Introduction

ASDBLR [1] boards number 7 and 8 were irradiated with 3.5 and $1{\cdot}10^{14}$ cm^{-2} equiv. neutron fluency, respectively. ASDBLR board number 9 was not irradiated but similarly tested and is used as reference, DTMROC board number 4 is used for all measurements (not irradiated).
The expected integrated dose over 10 years of ATLAS operation is $6.9 \cdot 10^{13}$ cm^{-2} 1 MeV equivalent neutron fluency [2]. The recommended dose for testing is $3.5{\cdot}10^{14}$ cm^{-2}, this includes a safety margin of a factor of 5 for simulation uncertainties which is however expected to be largely over estimated for the ID [3].
During irradiation the chips had no electrical connections (not powered). The arrangement of the ASDBLR boards on the flex board is shown in fig. 1.

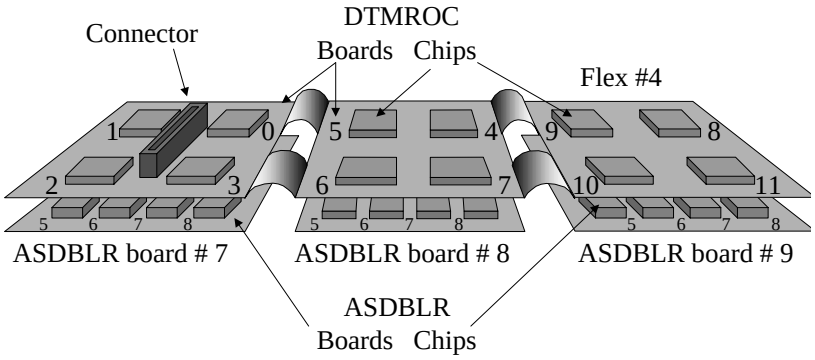


Figure 1: Schematic of the DTMROC flex board and the ASDBLR board arrangement.

BEFORE			AFTER		
V_{EE}	I_{EE}	P_{EE}	V_{EE}	I_{EE}	P_{EE}
-3.01	1.14	3.43	-3.00	1.14	3.42
V_{CC}	I_{CC}	P_{CC}	V_{CC}	I_{CC}	P_{CC}
3.00	1.42	4.26	3.00	1.40	4.20

Table 1: Measured voltages and currents before and after neutron irradiation. Values are given in SI-units (V, A and W).

The following measurements were performed before and after irradiation:

- Power consumption.
- DAC threshold voltages and currents.
- Gain for different test pulses.
- Threshold spread.

2 Measurements

2.1 Power consumption

The measured voltages and currents before and after irradiation are given in table 1. Units are in Volts, Ampere and Watts.

No significant changes are observed. The values are the sum of the three tested boards #7, 8 and 9. The voltages are measured on

the far end (with respect to the connector) DTMROC board at the capacitors.

2.2 Measurement of the threshold parameters

All threshold voltages and the voltage drop across the 1 kΩ resistors were measured before and after irradiation. The average values of all low and high thresholds are given with the standard deviation in table 2.

A consistent increase in current into the ASDBLR threshold is observed with a (corresponding?) voltage drop of the threshold values. Although the increase in current is as high as a factor of 4, the threshold voltages are still well within operating range (minimum threshold voltage measured after irradiation was 1.1 V at DAC=255). This observation is in accordance with the reduction of the β value of irradiated transistors [6].
The average changes are plotted in fig. 2 and fig. 3 for the input current and threshold voltage, respectively.

The radiation effects are reasonably uniform (standard deviation are significantly smaller than the mean values). For the non-irradiated board (#9) the measured threshold voltages also show a change, it is assumed that this is due to a different operating condition (e.g. temperature).
The parameters of the line fits in fig. 2 and fig. 3 are given in table 3.

2.3 Measurement of the gain

Threshold scans were acquired with different input signals allowing the calibration of the boards and the investigation of the spread of the thresholds. The data were acquired with the XTRT [4] software and the analysis was performed in ROOT [5].
The data for this analysis are taken from a fit of an error function to the threshold scan data. The definition used is “any bit set in any of the three time slices is an event”.
The 50 % values and the slope (noise) of the fit to the threshold scan data are histogrammed for the three boards before and after irradiation and given in fig 4.

The main source of errors in the analysis is the fitting of the error function, if the fit does not converge then the corresponding channel is not taken into account. This leads to the different number of entries (Nent) given on each plot.
From these histograms it is concluded that there is no significant change of in the spread of the 50 % values or the noise.

DAC value	ASDBLR board	Threshold voltage	Threshold current
		Before	Before
255	7	1314 ± 137	3.22 ± 0.29
255	8	1371 ± 117	3.28 ± 0.22
255	9	1366 ± 101	3.14 ± 0.18
63	7	326 ± 33	1.619 ± 0.087
63	8	346 ± 29	1.660 ± 0.091
63	9	342 ± 26	1.41 ± 0.55
40	7	208 ± 22	1.331 ± 0.081
40	8	222 ± 19	1.350 ± 0.073
40	9	220 ± 16	1.307 ± 0.062
		After	After
255	7	1249 ± 133	13.12 ± 0.77
255	8	1349 ± 116	5.95 ± 0.30
255	9	1359 ± 101	3.15 ± 0.19
63	7	291 ± 31	7.79 ± 0.27
63	8	335 ± 28	3.29 ± 0.11
63	9	341 ± 24	1.583 ± 0.076
40	7	178 ± 20	7.07 ± 0.23
40	8	212 ± 19	2.96 ± 0.10
40	9	218 ± 16	2.18 ± 0.16
		Difference	Difference
255	7	-64.5± 8.7	9.90± 0.54
255	8	-22.4± 3.7	2.67± 0.18
255	9	-7.5± 2.0	0.005 ± 0.033
64	7	-34.7± 2.0	6.17± 0.24
64	8	-10.8± 1.6	1.630± 0.090
64	9	-2.50± 0.52	-0.026± 0.009
40	7	-30.2± 3.1	5.74± 0.20
40	8	-9.4± 1.1	1.609± 0.071
40	9	-1.81± 0.91	0.87± 0.19

Table 2: Values of the threshold voltage and voltage drop across the 1 kΩ resister. All values are the average over all low and high thresholds.

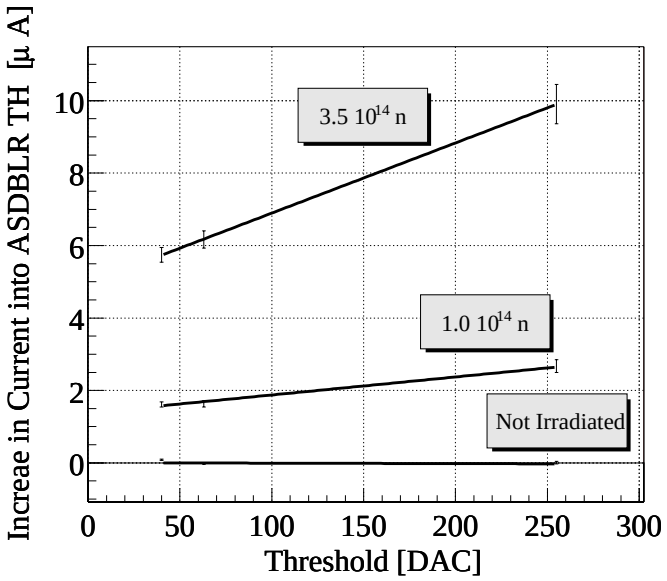


Figure 2: Current into the ASDBLR thresholds before and after irradiation.

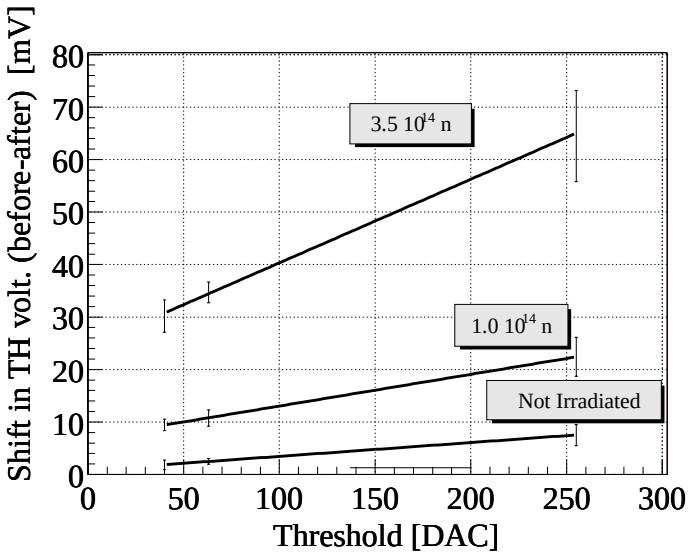
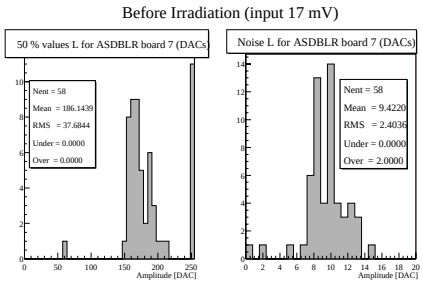
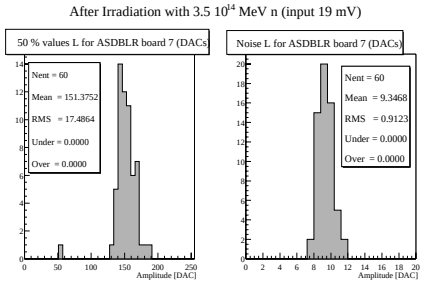


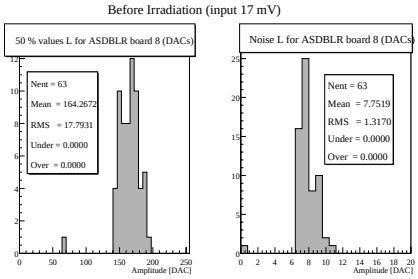
Figure 3: Threshold voltages before and after irradiation.



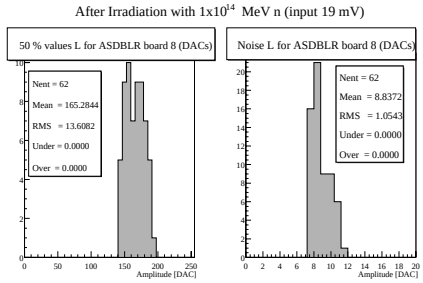
(a) ASDBLR board 7, before irradiation.



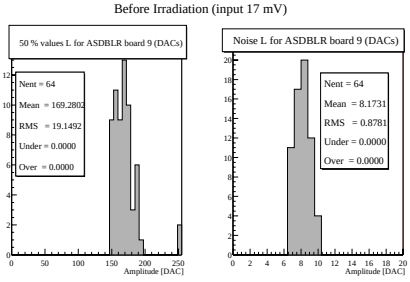
(b) ASDBLR board 7, after irradiation.



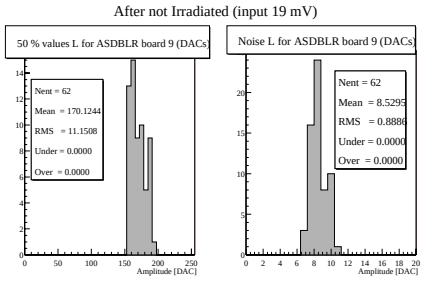
(c) ASDBLR board 8, before irradiation.



(d) ASDBLR board 8, after irradiation.



(e) ASDBLR board 9, before irradiation.



(f) ASDBLR board 9, not irradiated.

Figure 4: Histograms of the 50 % values and the noise for the different ASDBLR boards.

Board #	Slope [mV/DAC]	Offset [mV]
Change in Threshold Voltages		
7	0.159 ± 0.043	24.4 ± 3.2
8	0.060 ± 0.018	7.0 ± 1.4
9	0.026 ± 0.010	0.82 ± 0.81
Change in Voltage across 1 kΩ Resistor		
7	0.0194 ± 0.0027	4.96 ± 0.23
8	0.00497 ± 0.00087	1.377 ± 0.080
9	-0.00012 ± 0.00017	0.004 ± 0.014

Table 3: Parameter values of the fits plotted in fig. 3 and fig. 2.

The mean and RMS in fig. 4 are calculated since the low number of entries does not allow an accurate fit of a Gaussian. Using all channels of the three ASDBLR boards, which have received different doses, yields more accurate histograms and Gaussian distributions were fitted. The data are displayed in fig. 5 and fig. 6.

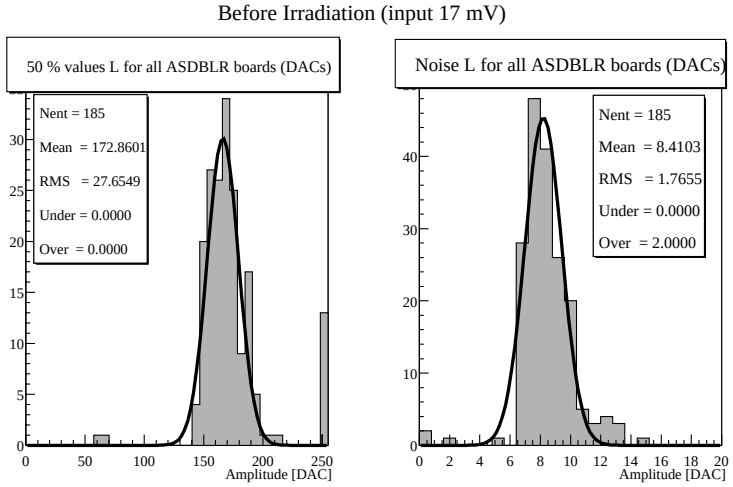


Figure 5: Histograms of the 50 % and noise values with fitted Gaussian before irradiation.

Since the three boards received different doses and in particular number 9 none at all, any effect due to radiation damage would be less evident than in the plots in fig. 4. However any systematic shift due to irradiation would lead to a non-Gaussian distribution and be visible as a change of the parameters of the fitted Gaussian. The parameters extracted from the fit are given in table 4.

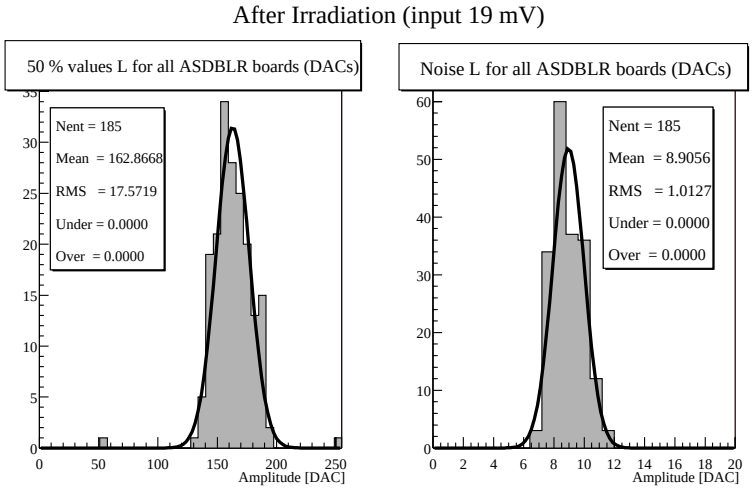


Figure 6: Histograms of the 50 % and noise values with fitted Gaussian after irradiation.

	Before 17 mV	After 19 mV
	50 % values	
Mean:	166.3 ± 1.2	163.0 ± 1.2
Sigma:	13.2 ± 1.1	14.03 ± 0.82
	Noise	
Mean:	8.20 ± 0.11	8.957 ± 0.091
Sigma:	1.222 ± 0.077	1.041 ± 0.061

Table 4: Parameters of the fits to the histograms of the 50 % values and the noise.

These parameters do not indicate any change due to irradiation. Four input pulse height were scan before and after irradiation and allow a calibration of the systems. The 50 % values obtained from the fit of the error function are plotted vs. the input pulse amplitude. A line fit to these data give the gain and offset. These are histogrammed for each board, the data are displayed in fig. 7, 8 and 9.

A constant shift of the offset is observed before and after irradiation. Since this shift is similar for all boards regardless of the dose they received, it is concluded that it is not due to irradiation effects. The gains (slope of line) do not show significant changes before and after irradiation.

2.4 Threshold Spread

Each ASDBLR chip receives 4 threshold levels, 2 high and 2 low. Of the 16 channels on an ASDBLR 8 are associated with one low and one high threshold level. Therefore the accuracy at which the threshold can be set depends on the spread in gain and offset between the 8 channels which share the same threshold.
The RMS (normalised) is calculated for every 8 channels sharing the same low threshold value before and after irradiation. Fig. 10 shows the RMS values for all 24 low thresholds of the flex board.

The sum of the differences between the RMS before and after irradiation is 7.74 DACs. Not included is threshold number 18 because of evaluation problems (value of 0 after irradiation). This indicates a slight increase in threshold spread due to irradiation. Dead channels and possible fitting problems have been taken into account (a cut is applied to the 50 % values). The RMS is therefore not always calculated from 8 channels but in some cases from less.

2.5 Conclusion

Over all the radiation damage of the ASDBLR boards and chips is not observed to affect the operational functionality.
The only strong change is the increase in current flowing into the ASDBLR thresholds (lowering of the β values of the input transistors). A increase in threshold spread is observable.

References

[1] M. Newcomer et al., "Implementation of the ASDBLR ATLAS TRT Straw Tube Readout ASIC in the DMILL Technology", Nuclear Science Symposium, Lyon France, Oct 2000.

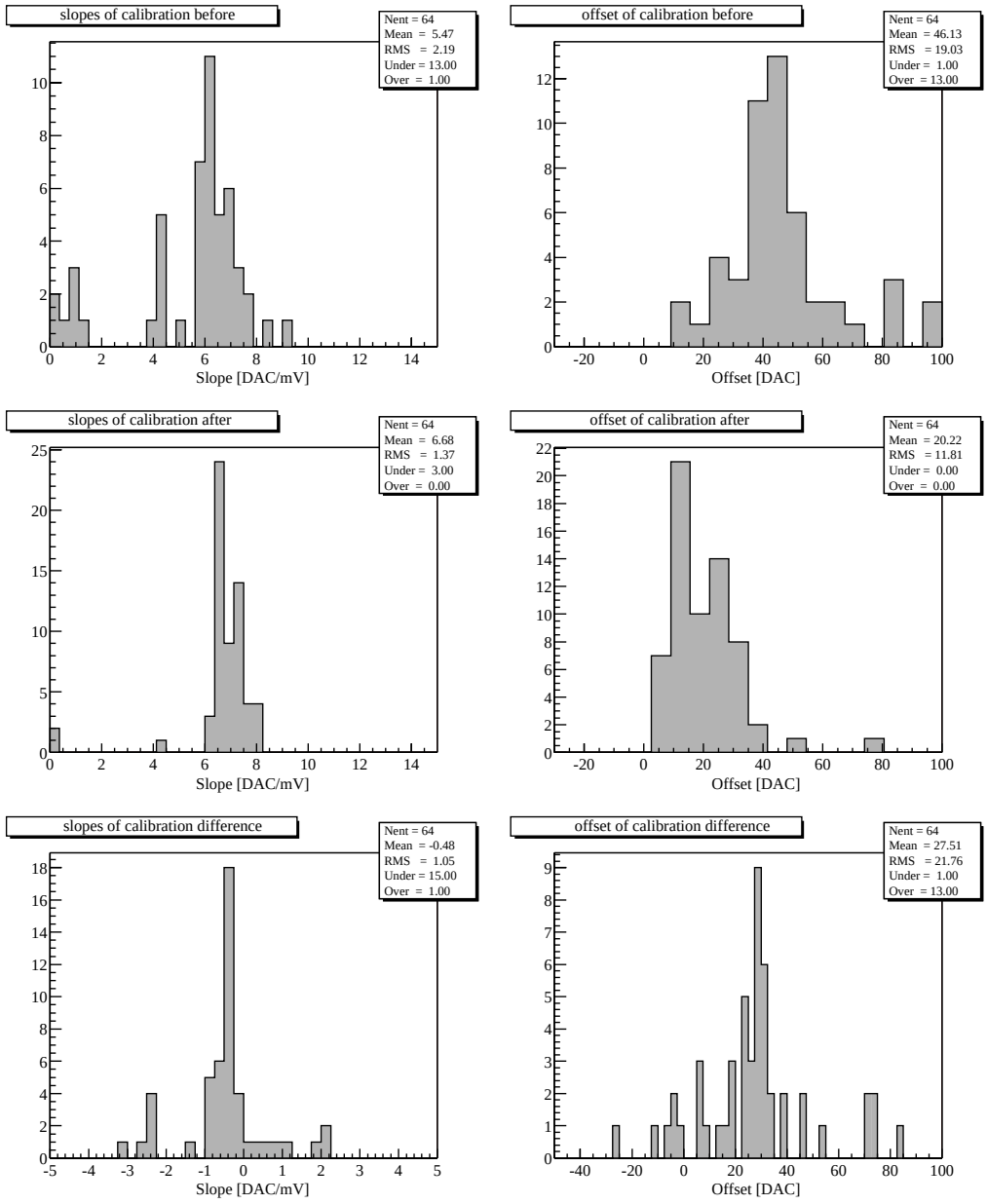


Figure 7: Histograms of the gains and offsets for ASDBLR board 7.

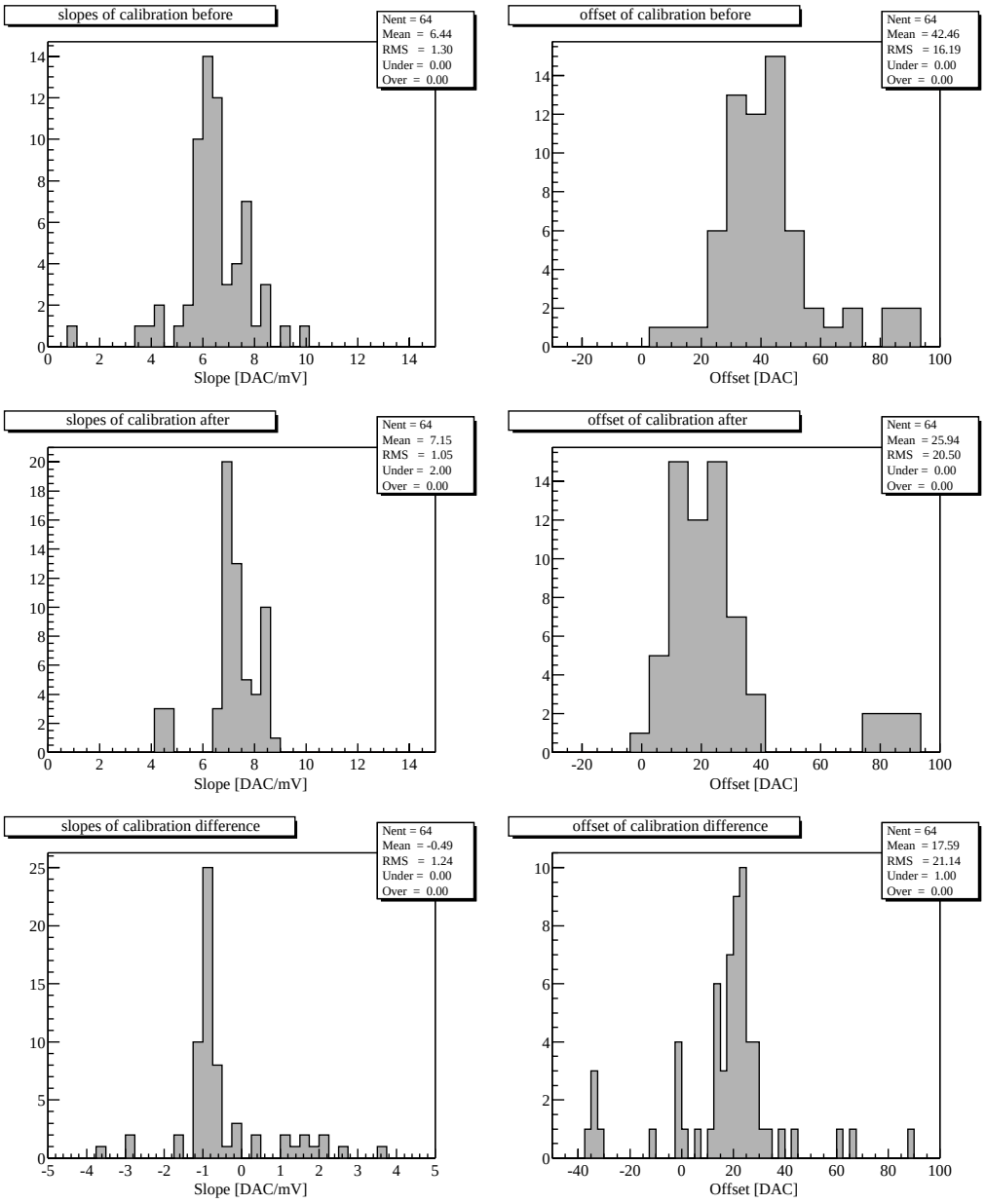


Figure 8: Histograms of the gains and offsets for ASDBLR board 8.

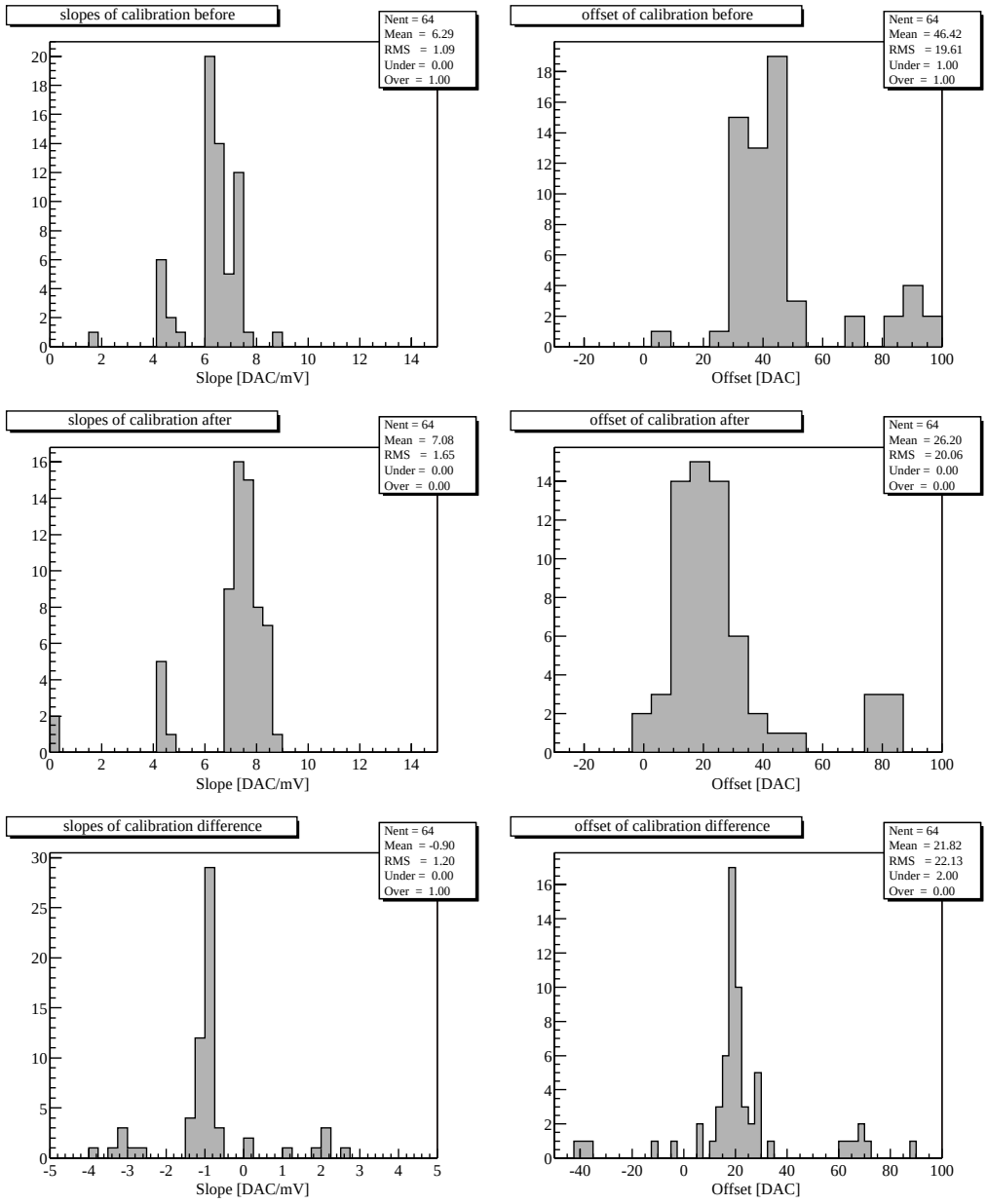


Figure 9: Histograms of the gains and offsets for ASDBLR board 9.

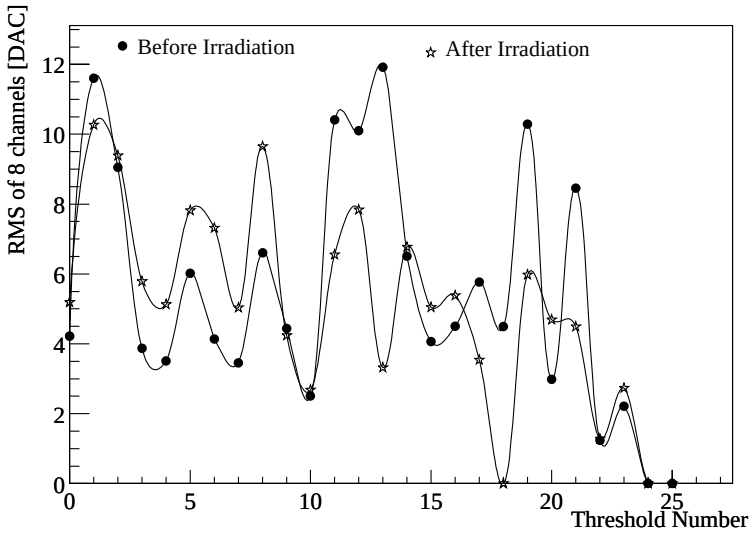


Figure 10: RMS values before and after irradiation for all 24 low thresholds of the flex board.

[2] ATLAS Policy on Radiation Tolerant Electronics, ATC-TE-QA-0001, Jul 2001.

[3] Ph. Farthouat, "Irradiation tests of the ASDBLR and DTMROC", ATLAS internal note, Aug 2001.

[4] J. Valls, "XTRT A program for TRT system test", http://valls.home.cern.ch/valls/xtrt.htm, accessed 29.10.01.

[5] ROOT version 3.01/05, "http://root.cern.ch/root", accessed 29.10.01.

[6] M. Dentan, "Radiation effects on electronic components and circuits", CERN Training, Apr 2000.