DAC Scan

Behaviour of pixel- and double column readout DAC settings

Philipp Eller, ETHZ December 2011

1 Introduction

The PSI46 Readout chip (ROC) has in total 28 digital to analog converters (DACs), that have either a 4- or 8-bit structure, thus 16 or 256 different values that can be set, respectively. Two of these DACs are directly associated with the pixel readout and 4 with the double column readout. The settings for these six DACs are studied here. Figure 1 shows a simplified schematic of the pixel and double column periphery. N.B these 6 DACs are global for the entire chip, this means that there is only one value that can be set for all pixel unit cells.

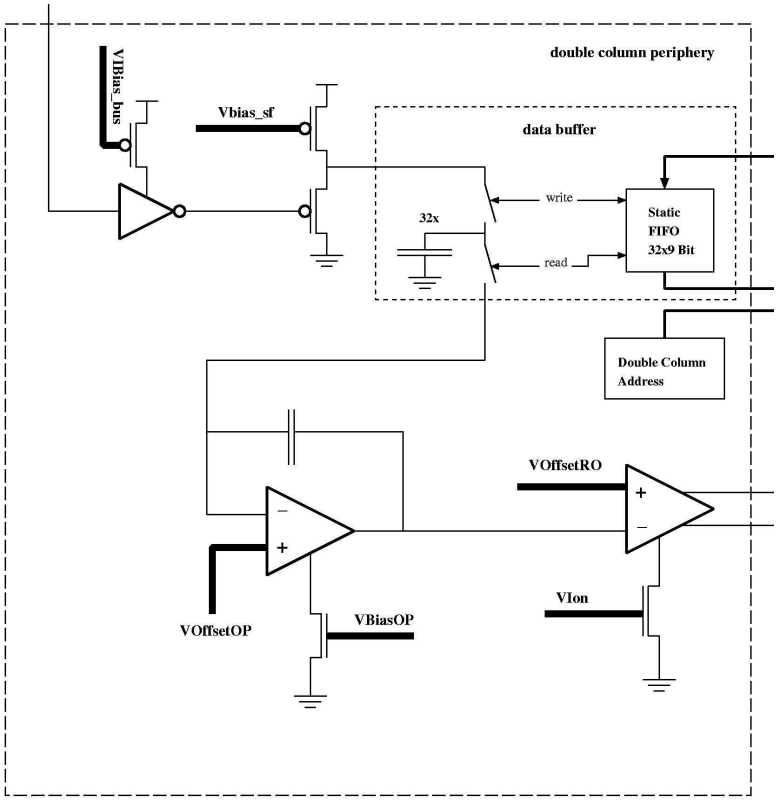

Figure 1: pixel readout and double column periphery

2 Measurement

To evaluate in what range of the DAC settings the ROC is performing best, the following method has been used. Firstly, the DACs have been assumed to be uncorrelated, thus measuring the ranges independently was decided to be sufficient. To quantify the performance under a specific DAC setting, the effective maximal pulse height was used. This is, measuring the resulting pulse height for different calibrate pulses (different Vcal settings), and then taking the maximum in the difference of pulse height. This is illustrated in Figure 2.

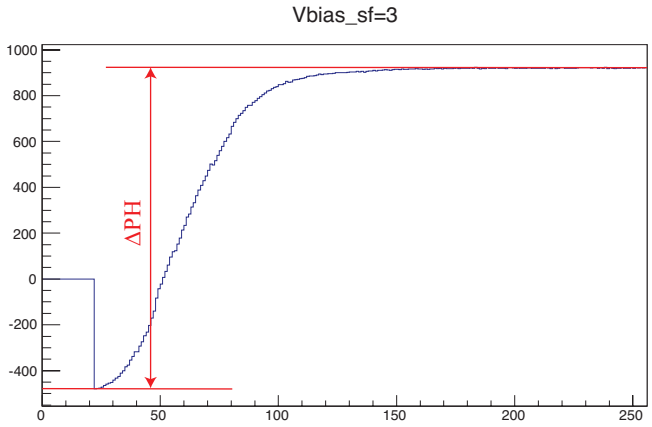

Figure 2: resulting Pulse height for varying Calibrate pulses

This effective maximal pulse height ΔPH was measured for the whole range of all possible DAC settings, every 4 steps for 8-bit DACs (giving 64 data points) and every step for 4-bit DACs (giving 16 data points), respectively.

Having this distribution for a DAC, we decided to define the optimal working range for this DAC to be the ± 10 % range around the maximum.

Since minimizing power consumption is also a crucial point in the design of this ROC, the digital current has been monitored during these measurements.

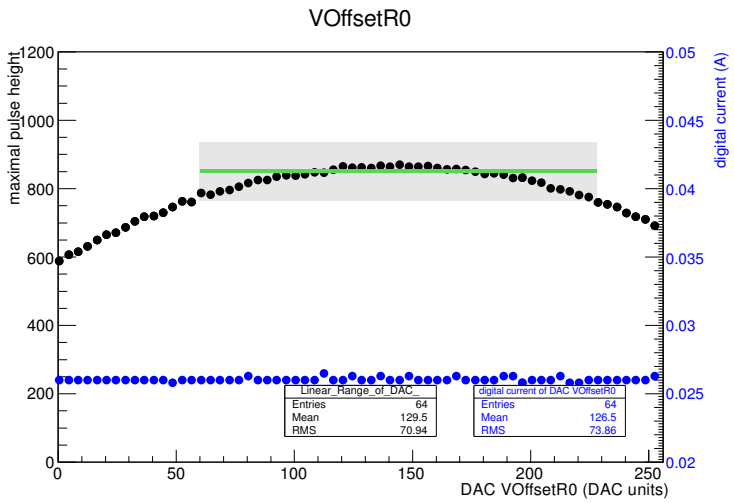

Figure 3: example of Voffset_RO (readout) DAC range measurement for a non-irradiated ROC. The grey shaded area represents the ± 10 % range around the maximum, the green line shows the resulting range. The blue dots show the digital current (here stable).

2.1 Irradiaton effects

To study the effects of irradiation, which is changing the behavior of the ROC, the above described measurements have been done for 6 ROCs without irradiation and 6 ROCs that had been irradiated at 3 different doses: 0.6, 1.2 and 3.0 10^{15} $\frac{\text{p}}{\text{cm}^2}$, for each dose 2 ROCs.

3 Results

3.1 irradiation effects

The first thing, that one can observe is the lowering of ΔPH with more irradiation. This behavior is so far expected. But in addition the area of best performance, i.e. the range, can shift. This can be seen in figures 3-6

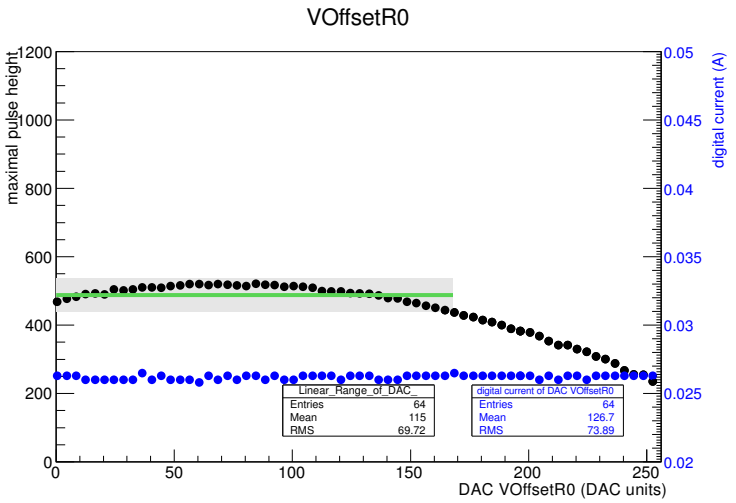

Figure 4: Voffset_RO (readout) DAC range measurement for a ROC irradiated by 0.6 10^{15} $\frac{\text{p}}{\text{cm}^2}$.

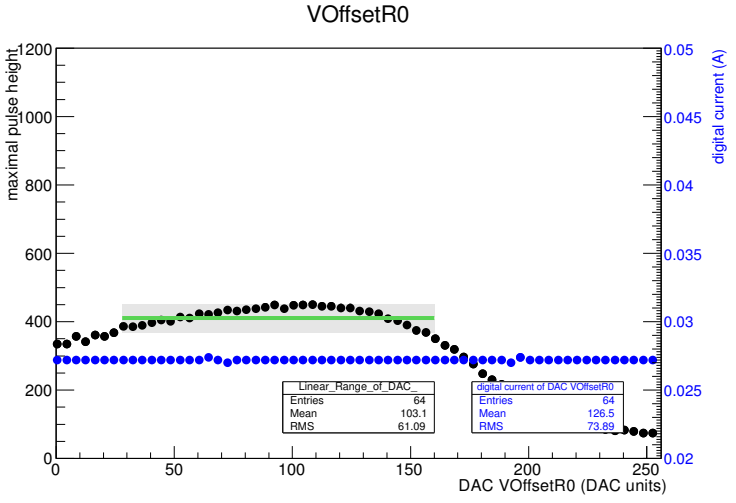

Figure 5: Voffset_RO (readout) DAC range measurement for a ROC irradiated by 1.2 10^{15} $\frac{\text{p}}{\text{cm}^2}$.

For the 12 ROCs that were tested (6 non-iradiated and 6 irradiated), an overview plot showing the resulting 12 ranges for a DAC are shown in the following. Naming convention of the ROC labeling is, that the first two digits correspond to the irradiation dose (00 for non-irradiated, 06, 12 and 30 for the corresponding doses). In the following the individual DACs will be discussed shortly

3.2 Vbias sf

This DAC shows consistent behavior in the ranges for all tested ROCs, the range for DAC settings seems suitable, c.f. figure 7. The recommended value for this DAC from

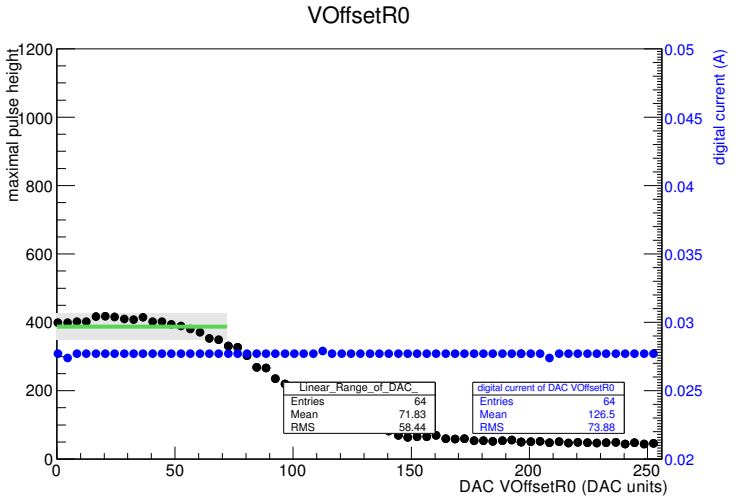

Figure 6: Voffset_RO (readout) DAC range measurement for a ROC irradiated by 3.0 10^{15} $\frac{\text{p}}{\text{cm}^2}$.

the PSI specifications is 6. In the range $[3, 5]$ this DAC shows a little upward fluctuation in ΔPH, thus this region is sometimes excluded in the range and thus the value of 6 might seem on first sight too low, but by looking at the individual plots in the appendix this can be clarified.

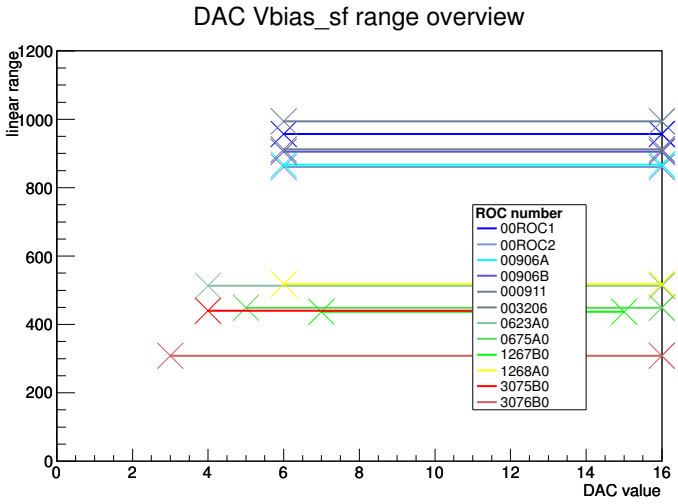

Figure 7: DAC *Vbias sf* range overview for all of the 12 scanned ROCS

3.3 VIBias Bus

For the DAC *VIBias Bus* the suitable DAC range is for all 12 ROCs within about $[0, 175]$ (c.f. figure 9), for higher values, the chip does not produce useable readout anymore. Also a rise in the digital current for higher DAC settings and a step when the readout stops working was found in all tested ROCs. For a representative example consider figure 8. It should be considered to narrow this DAC range in future chips. One of the two most irradiated ROCs shows a bit smaller range, this specific ROC responded slightly different for most tests. It might be a somewhat pathological example or an irradiation damage. The recommended value for this DAC from the PSI specifications is 30.

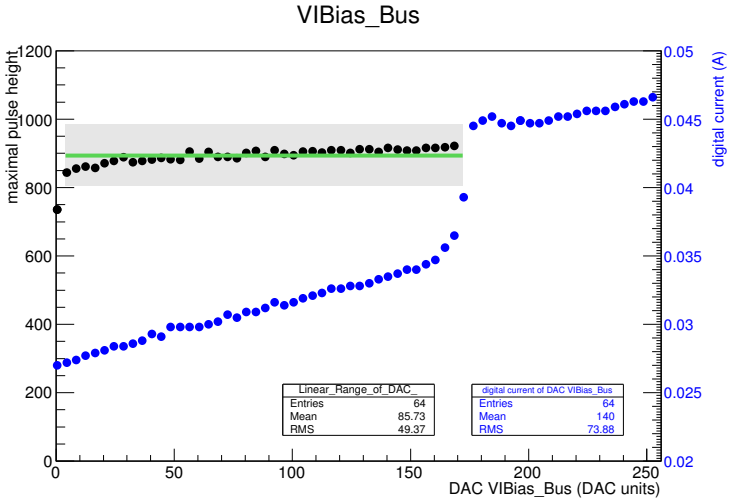

Figure 8: example of *VIBias Bus* DAC range measurement for a non-irradiated ROC.

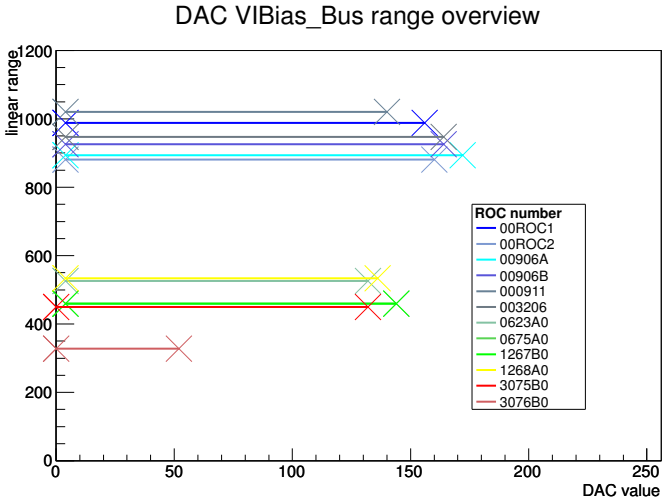

Figure 9: DAC *VIbias bus* range overview for all of the 12 scanned ROCS

3.4 VIBiasOp

This DAC does not show any significant dependence for DAC values greater than 20 (except for highly irradiated ROCs it seems to narrow a bit down from the upper end). One might get rid of this DAC and fix it at a save value around 50, see figure 10. The recommended value for this DAC from the PSI specifications is 115.

3.5 VIon

This DAC shows consistent ranges for 11 DACs and in one of the two most irradiated ones a change in shape of the ΔPH curve is observed, resulting in a different range, c.f. figure 11. The recommended value for this DAC from the PSI specifications is 115.

3.6 VoffsetOp

All ROCs perform best for this DAC value set in a range of roughly $[0, 80]$, it might be considered to change the DACs upper limit in the future accordingly, c.f. figure 12. The recommended value for this DAC from the PSI specifications is 90. This does not seem optimal and a lower value should be set.

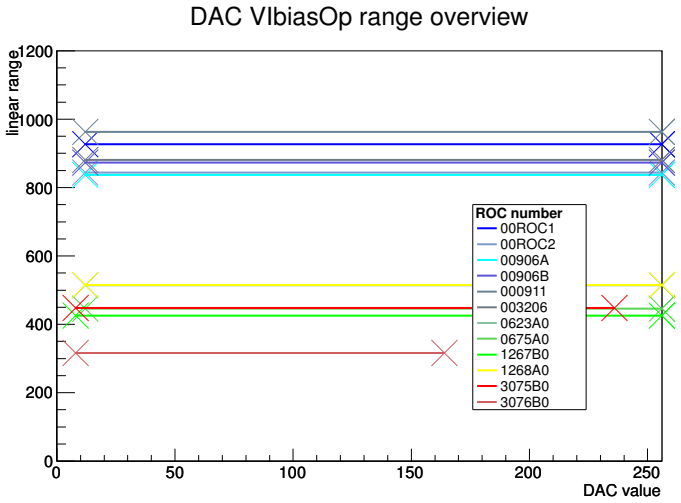

Figure 10: DAC *VIbiasOp* range overview for all of the 12 scanned ROCS

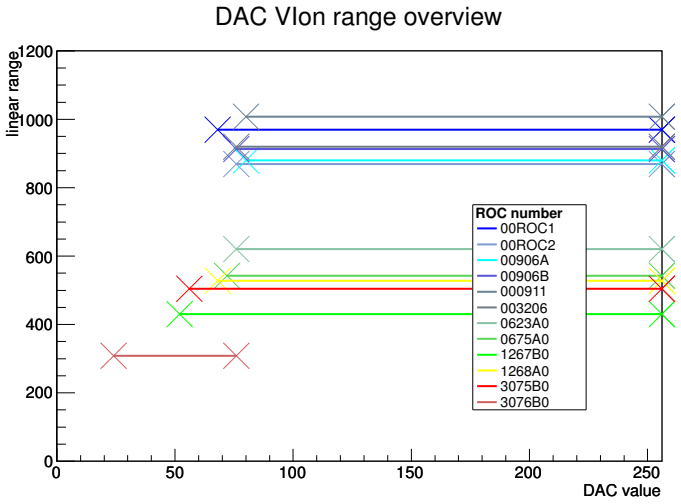

Figure 11: DAC *VIon* range overview for all of the 12 scanned ROCS

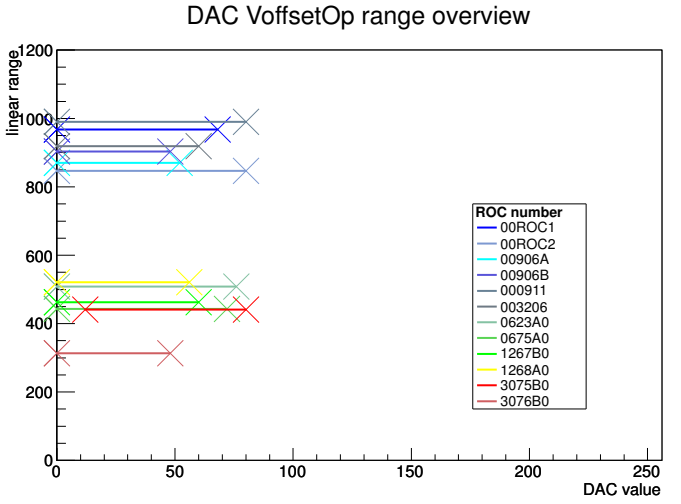

Figure 12: DAC *VoffsetOp* range overview for all of the 12 scanned ROCS

3.7 VOffsetRO

This DAC is needed to be adjusted within irradiation to ensure best performance, as can be seen in the overview plot in figure 13. The recommended value for this DAC from the

PSI specifications is 76.

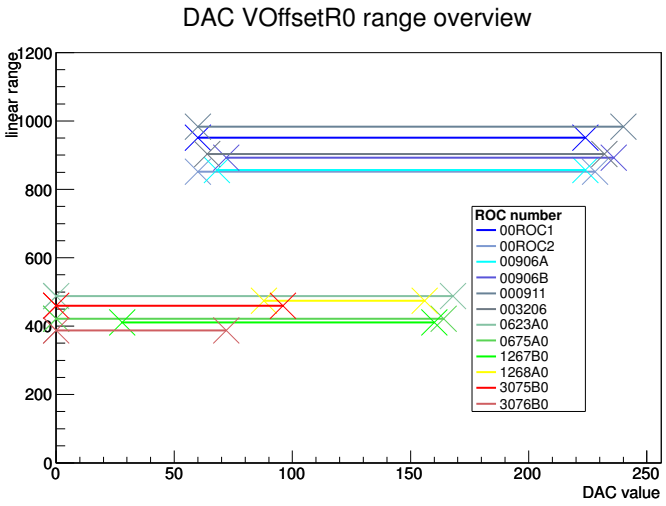

Figure 13: DAC *VOffset RO* range overview for all of the 12 scanned ROCS

3.8 Digital current

The digital current is for all DACs, except the before discussed case of VIBias bus, stable in all 12 tested ROCs.

3.9 Crosschecks

To crosscheck the measurement, the exact same procedure as used before was applied to DACs, that are not influencing the pixel or double column readout. This means that the readout should not depend on the setting of such DACs. This is nicely confirmed with the measured ranges covering the whole DAC setting range for these DACs, c.f. Figures 14 & 15.

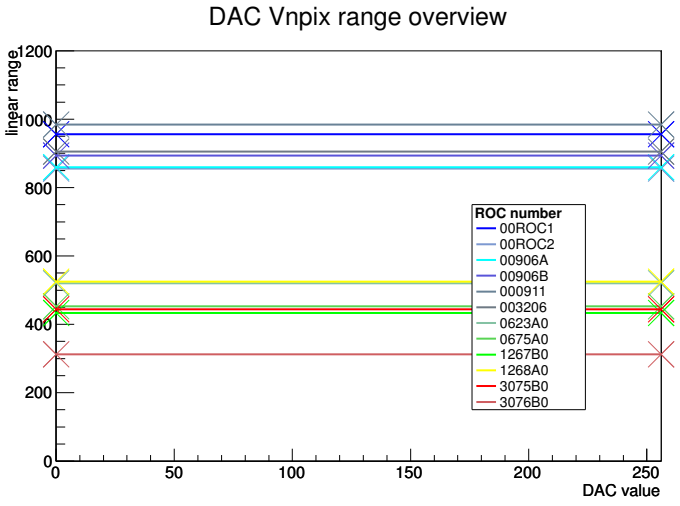

Figure 14: DAC *Vnpix* range overview for all of the 12 scanned ROCS

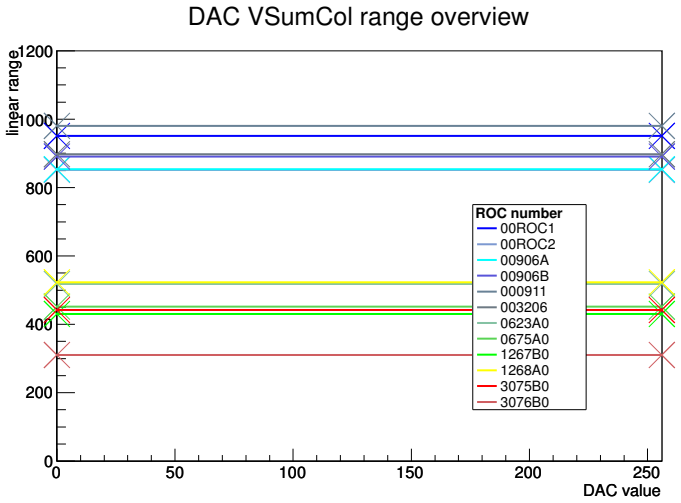

Figure 15: DAC *VSumCol* range overview for all of the 12 scanned ROCS

4 Summary / Conclusion

In this short study the necessity of the 6 readout DACs has been analyzed and one DAC identified to possibly be removed in the future. Also the ranges in which a DAC can be set was looked at and for two DACs a narrowing would be conceivable. Irradiation effects are shown and the necessity to be able to change DAC settings since the shape of the ΔPH, and thus the position of the maximum, can change. The outcome of this measurements for actions that should be considered can be summarized as follows:

- narrow down the DAC range of *VIBias_bus*
- narrow down the DAC range of *VOffsetOp*
- replace the DAC *VIBiasOp* by a fixed value
- reconsider the recommended value of DAC *VOffsetOp*

5 Appendix

Here all the individual plots for each DAC and each ROC are shown. The grey shaded area represents the ± 10 % range around the maximum, the green line shows the resulting range. The blue dots show the digital current.

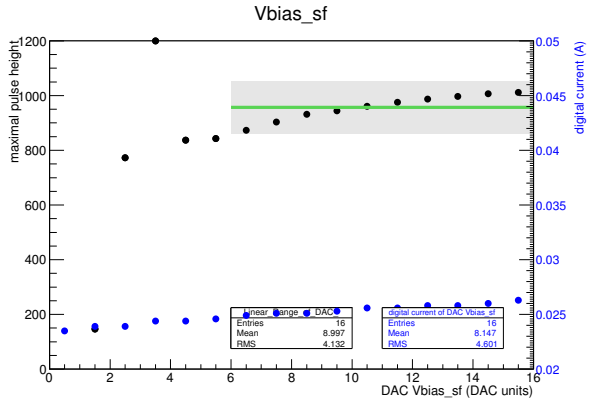

Figure 16: *Vbias_sf* DAC range measurement for ROC 00ROC1.

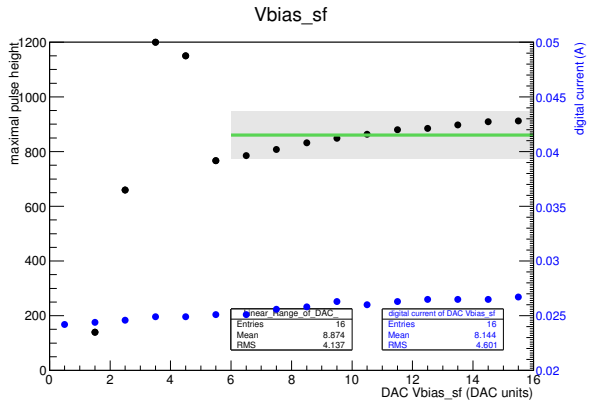

Figure 17: *Vbias_sf* DAC range measurement for ROC 00ROC2.

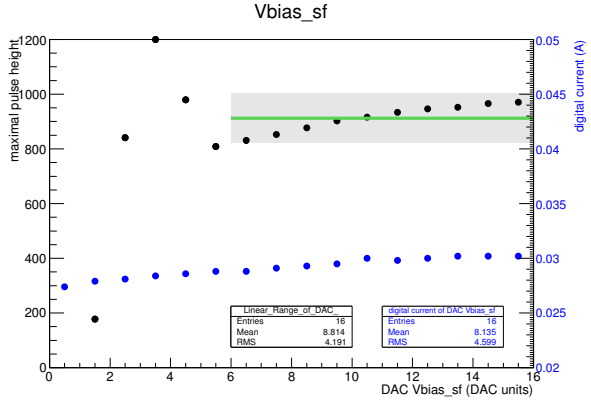

Figure 18: *Vbias_sf* DAC range measurement for ROC 003206.

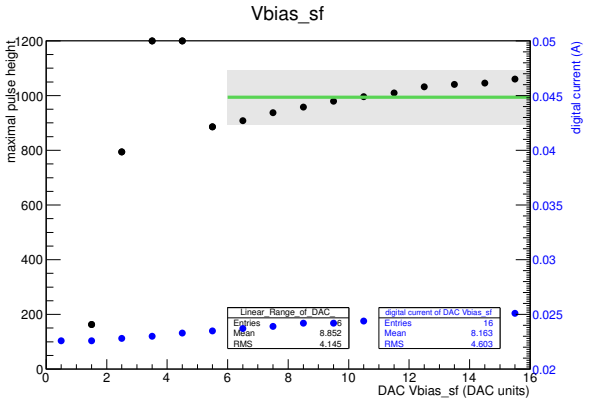

Figure 19: *Vbias_sf* DAC range measurement for ROC 000911.

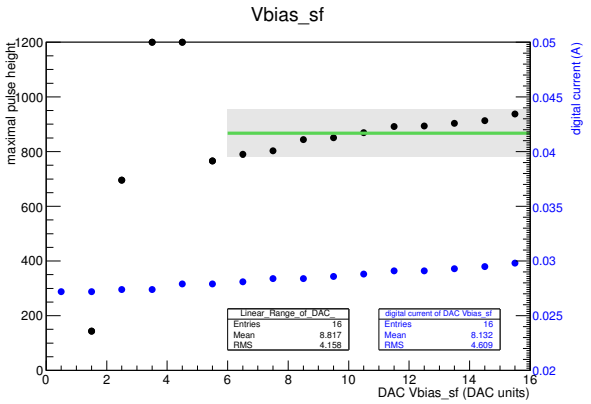

Figure 20: *Vbias_sf* DAC range measurement for ROC 00906A.

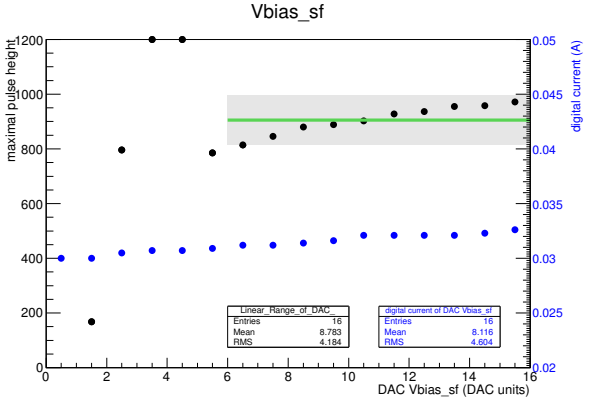

Figure 21: *Vbias_sf* DAC range measurement for ROC 00906B.

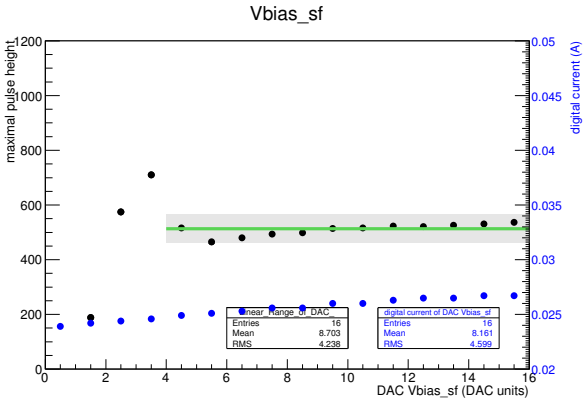

Figure 22: *Vbias_sf* DAC range measurement for ROC 0623A0.

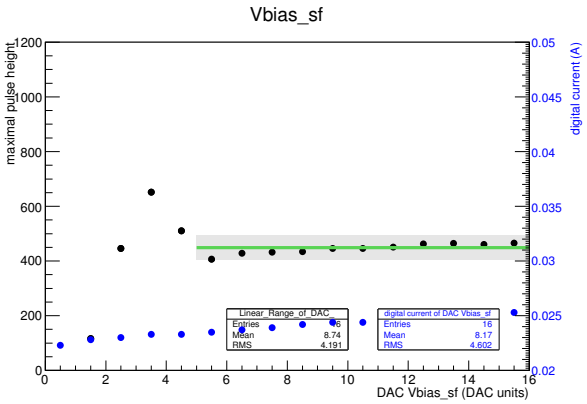

Figure 23: *Vbias_sf* DAC range measurement for ROC 0675A0.

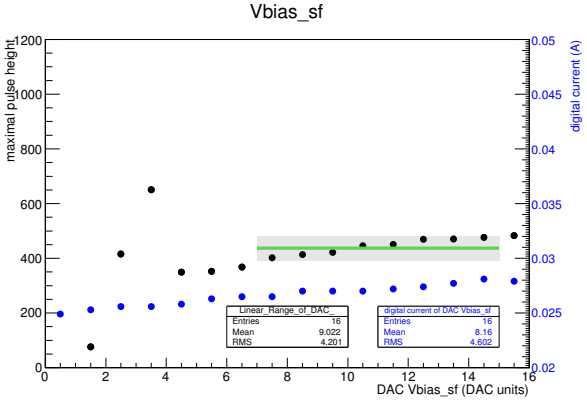

Figure 24: *Vbias_sf* DAC range measurement for ROC 1267B0.

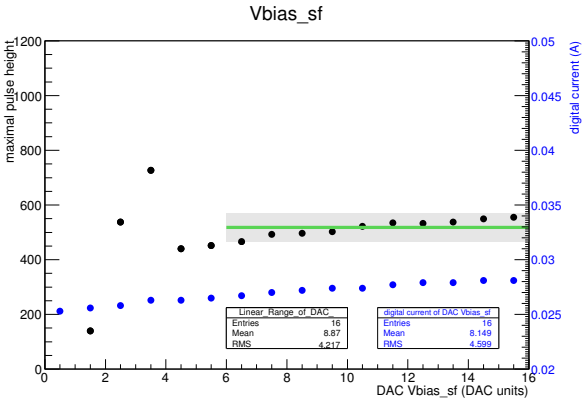

Figure 25: *Vbias_sf* DAC range measurement for ROC 1268A0.

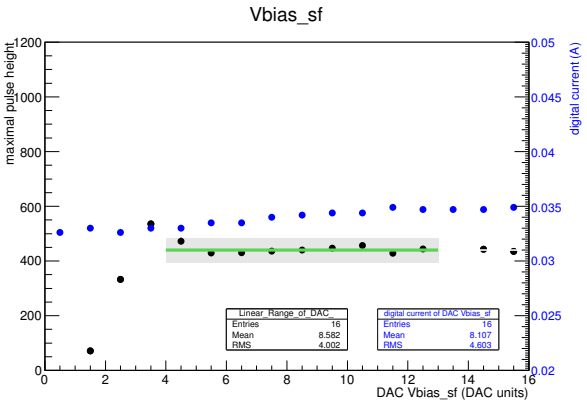

Figure 26: *Vbias_sf* DAC range measurement for ROC 3075B0.

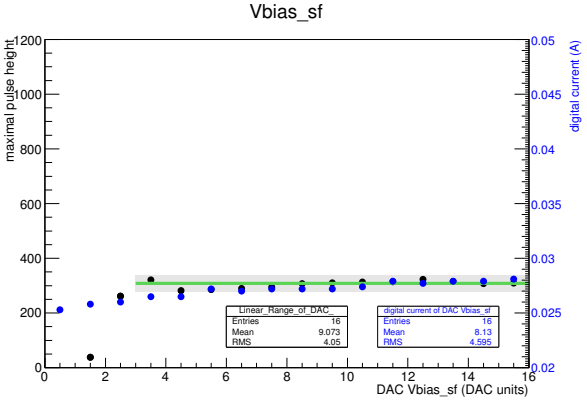

Figure 27: *Vbias_sf* DAC range measurement for ROC 3076B0.

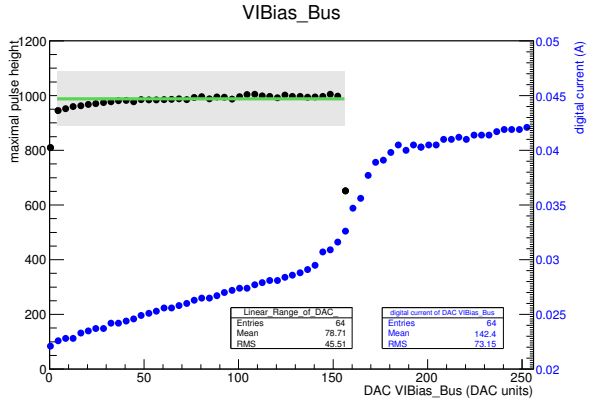

Figure 28: *VIBias_bus* DAC range measurement for ROC 00ROC1.

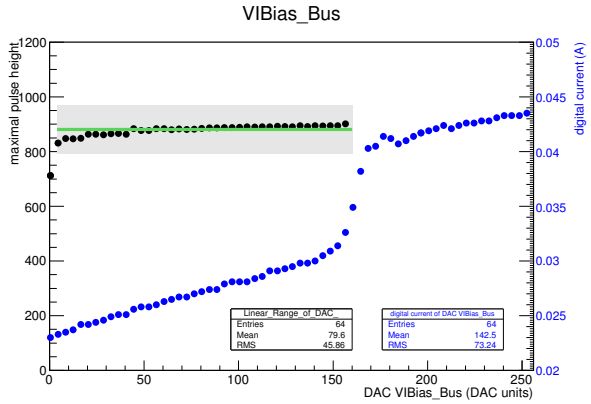

Figure 29: *VIBias_bus* DAC range measurement for ROC 00ROC2.

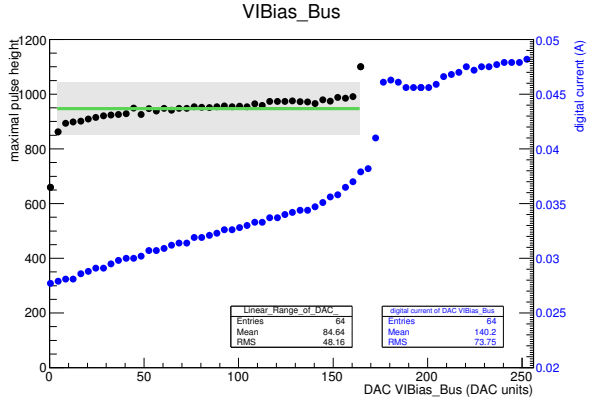

Figure 30: *VIBias_bus* DAC range measurement for ROC 003206.

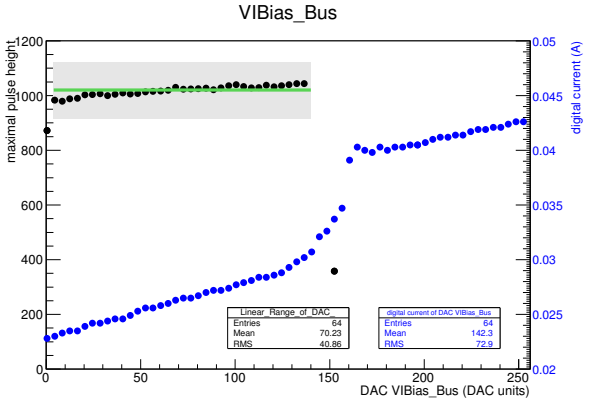

Figure 31: *VIBias_bus* DAC range measurement for ROC 000911.

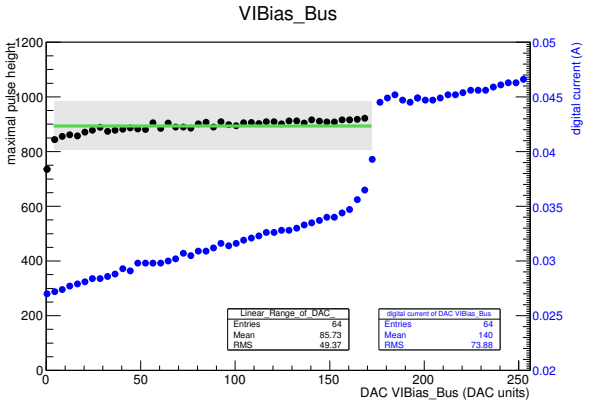

Figure 32: *VIBias_bus* DAC range measurement for ROC 00906A.

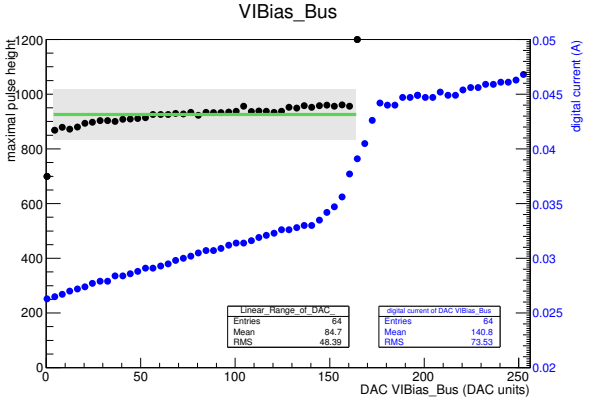

Figure 33: *VIBias_bus* DAC range measurement for ROC 00906B.

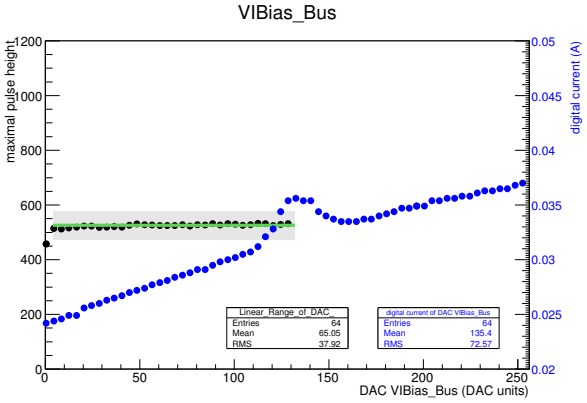

Figure 34: *VIBias_bus* DAC range measurement for ROC 0623A0.

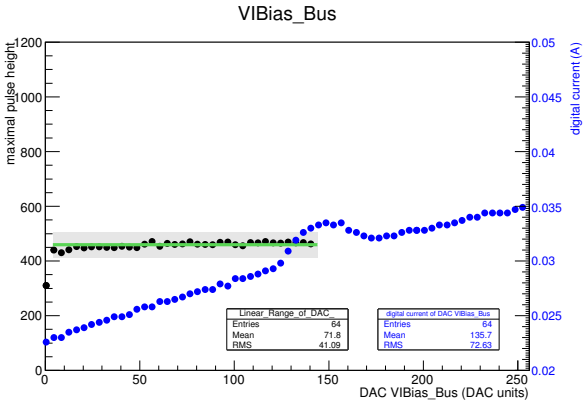

Figure 35: *VIBias_bus* DAC range measurement for ROC 0675A0.

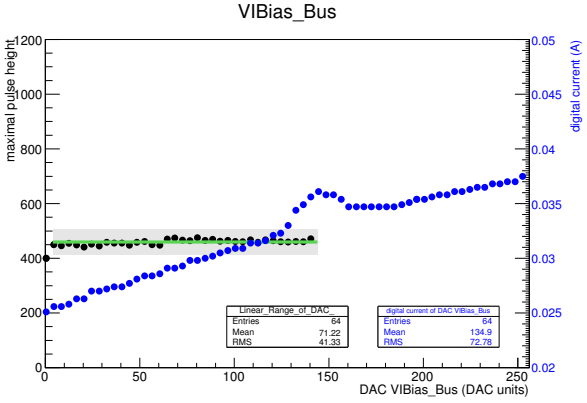

Figure 36: *VIBias_bus* DAC range measurement for ROC 1267B0.

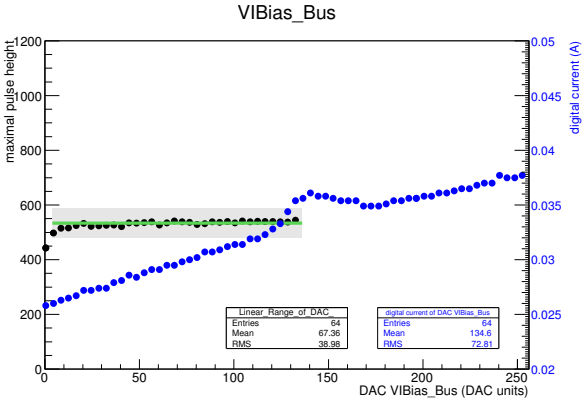

Figure 37: *VIBias_bus* DAC range measurement for ROC 1268A0.

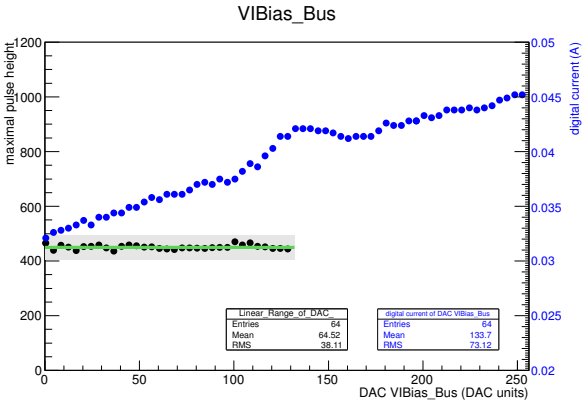

Figure 38: *VIBias_bus* DAC range measurement for ROC 3075B0.

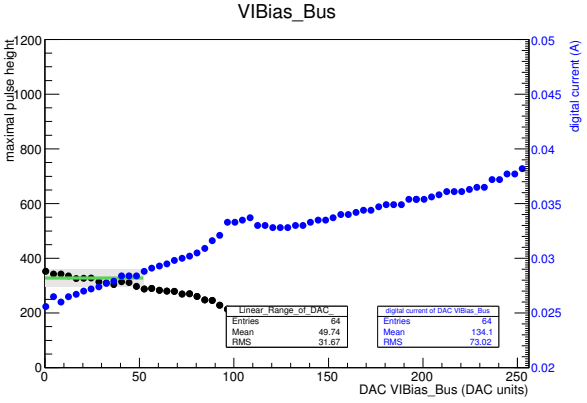

Figure 39: *VIBias_bus* DAC range measurement for ROC 3076B0.

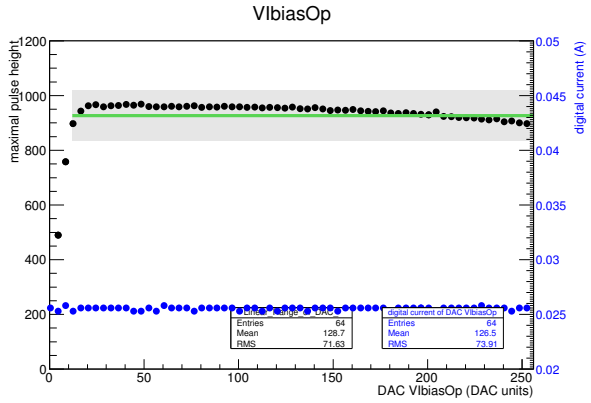

Figure 40: *VIBiasOp* DAC range measurement for ROC 00ROC1.

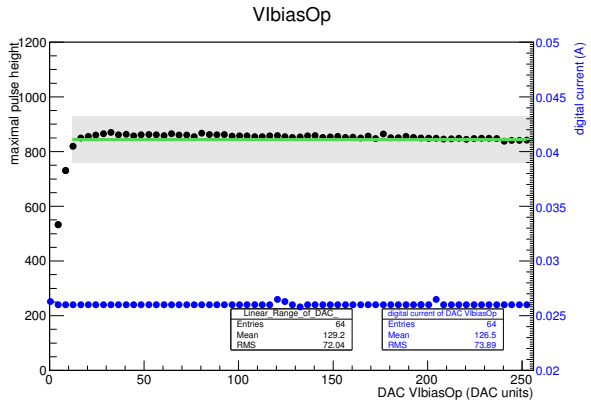

Figure 41: *VIBiasOp* DAC range measurement for ROC 00ROC2.

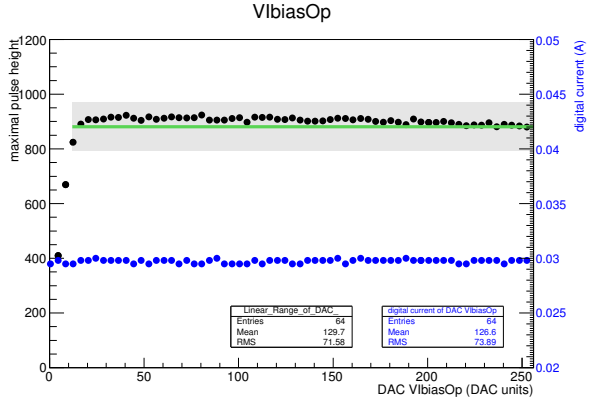

Figure 42: *VIBiasOp* DAC range measurement for ROC 003206.

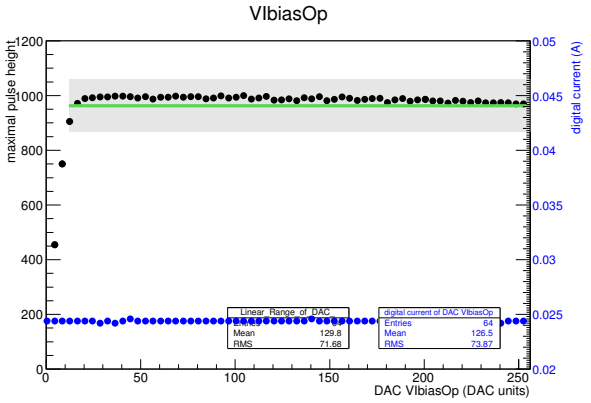

Figure 43: *VIBiasOp* DAC range measurement for ROC 000911.

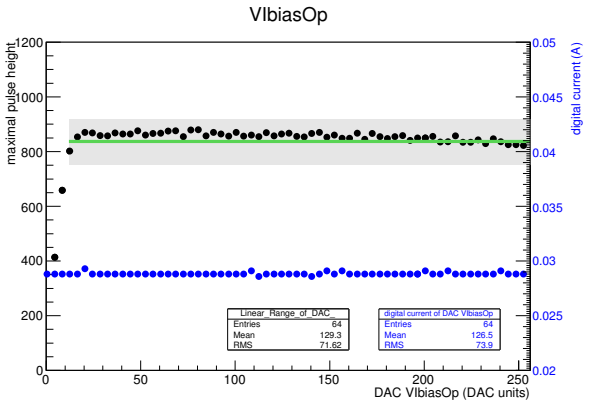

Figure 44: *VIBiasOp* DAC range measurement for ROC 00906A.

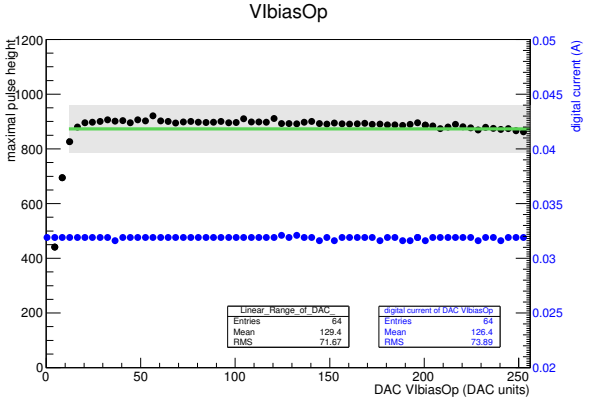

Figure 45: *VIBiasOp* DAC range measurement for ROC 00906B.

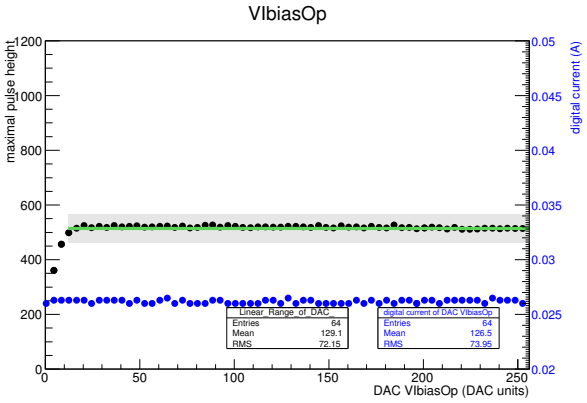

Figure 46: *VIBiasOp* DAC range measurement for ROC 0623A0.

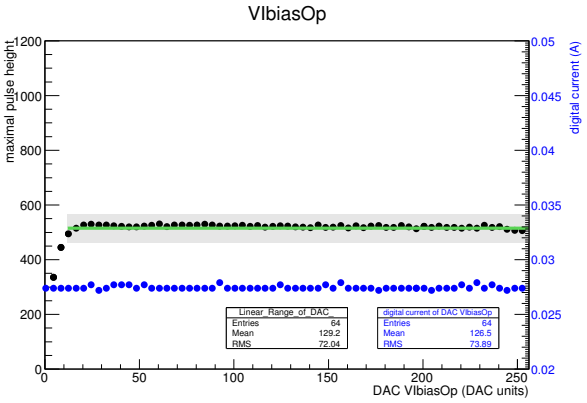

Figure 49: *VIBiasOp* DAC range measurement for ROC 1268A0.

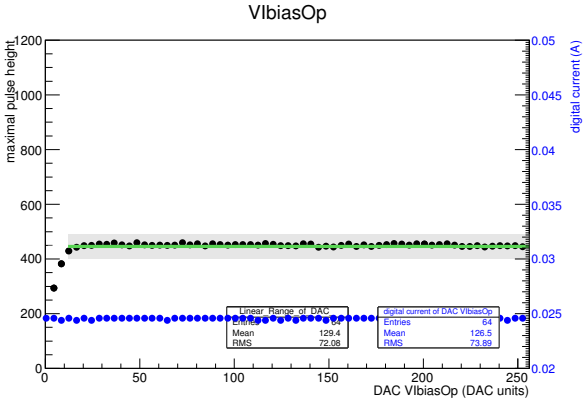

Figure 47: *VIBiasOp* DAC range measurement for ROC 0675A0.

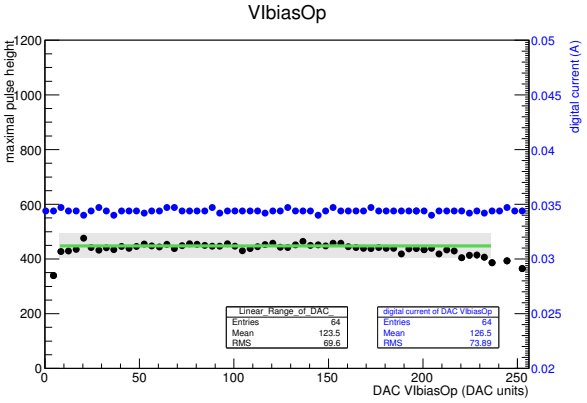

Figure 50: *VIBiasOp* DAC range measurement for ROC 3075B0.

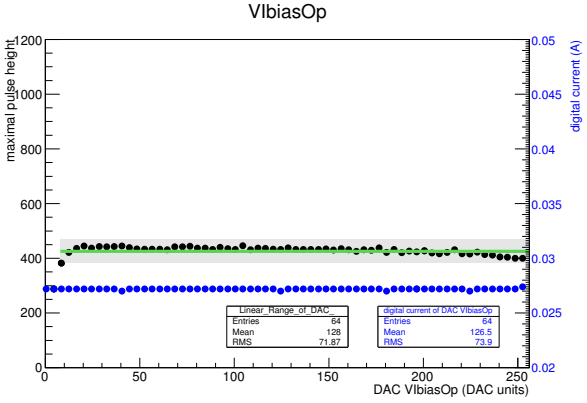

Figure 48: *VIBiasOp* DAC range measurement for ROC 1267B0.

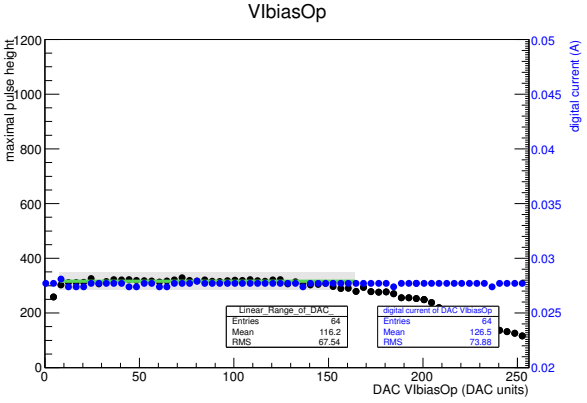

Figure 51: *VIBiasOp* DAC range measurement for ROC 3076B0.

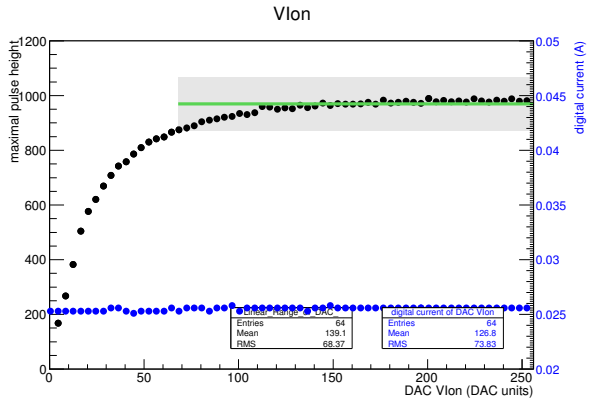

Figure 52: *VIon* DAC range measurement for ROC 00ROC1.

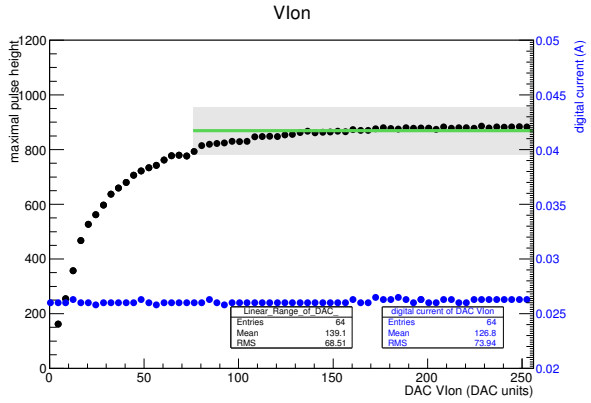

Figure 53: *VIon* DAC range measurement for ROC 00ROC2.

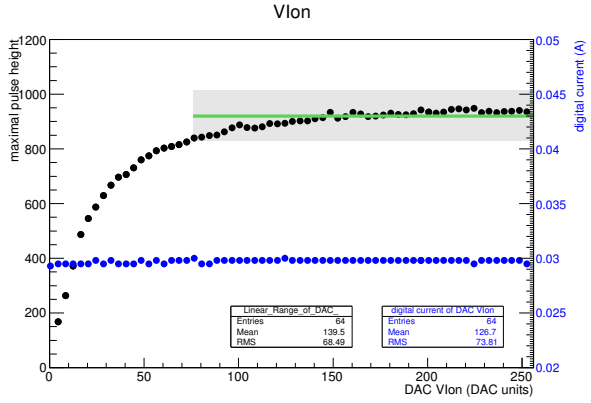

Figure 54: *VIon* DAC range measurement for ROC 003206.

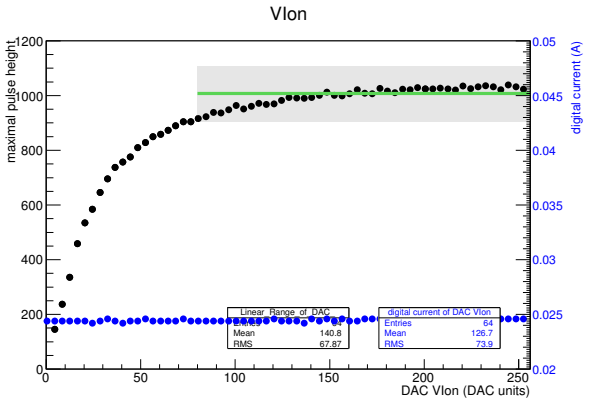

Figure 55: *VIon* DAC range measurement for ROC 000911.

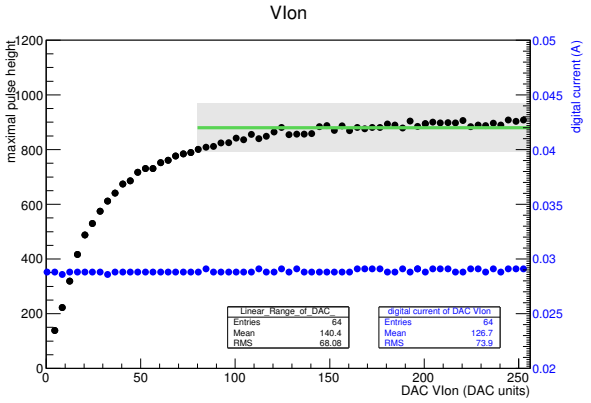

Figure 56: *VIon* DAC range measurement for ROC 00906A.

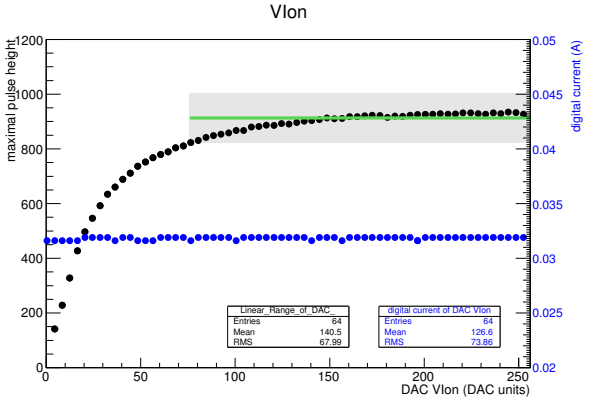

Figure 57: *VIon* DAC range measurement for ROC 00906B.

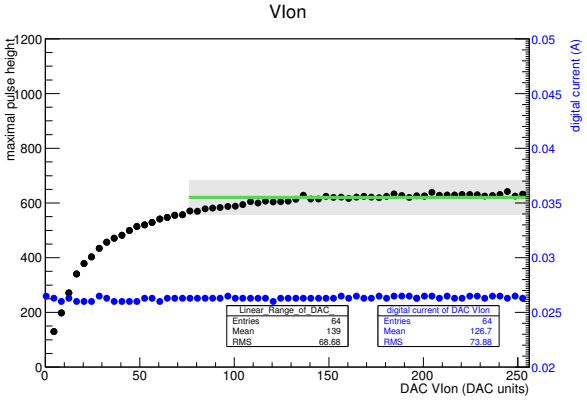

Figure 58: *VIon* DAC range measurement for ROC 0623A0.

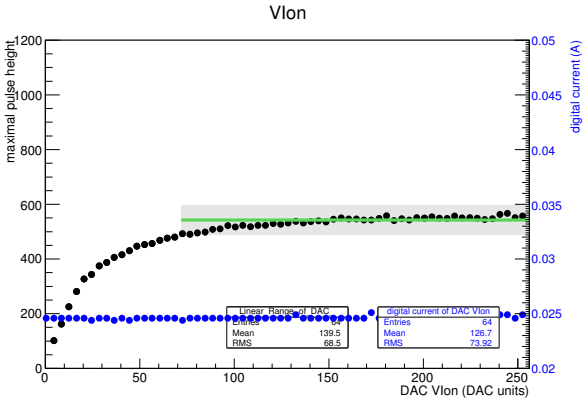

Figure 59: *VIon* DAC range measurement for ROC 0675A0.

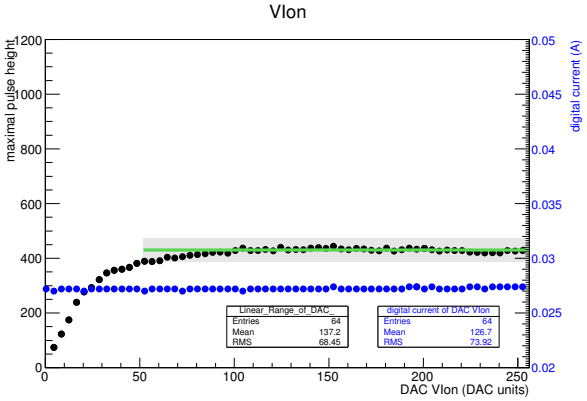

Figure 60: *VIon* DAC range measurement for ROC 1267B0.

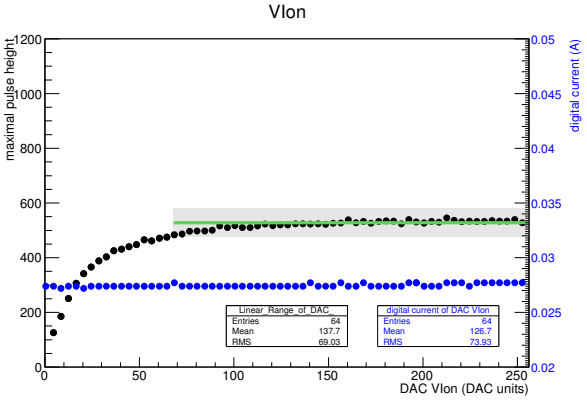

Figure 61: *VIon* DAC range measurement for ROC 1268A0.

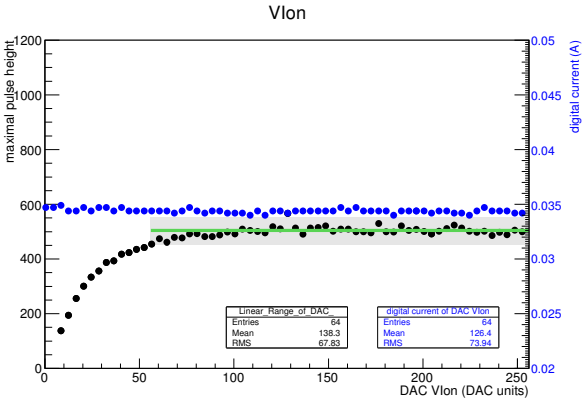

Figure 62: *VIon* DAC range measurement for ROC 3075B0.

Figure 63: *VIon* DAC range measurement for ROC 3076B0.

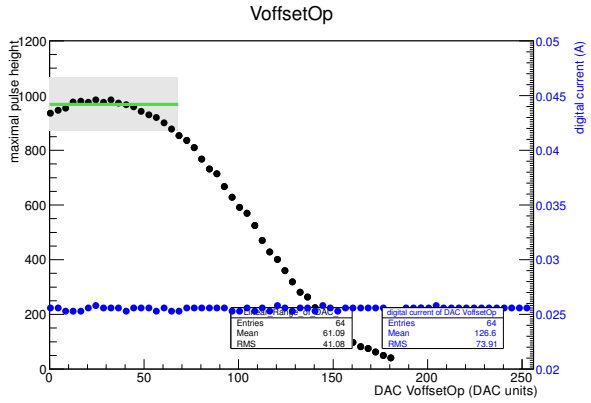

Figure 64: *Voffset_Op* DAC range measurement for ROC 00ROC1.

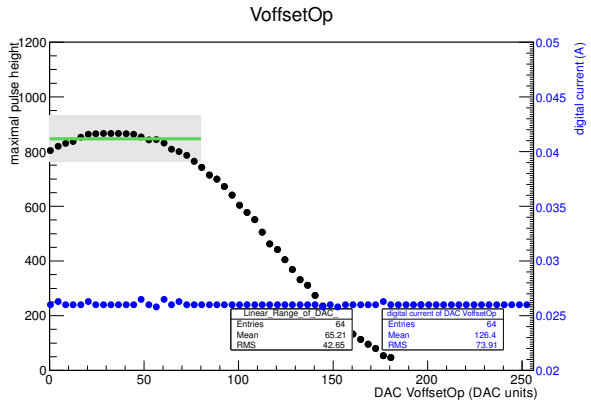

Figure 65: *Voffset_Op* DAC range measurement for ROC 00ROC2.

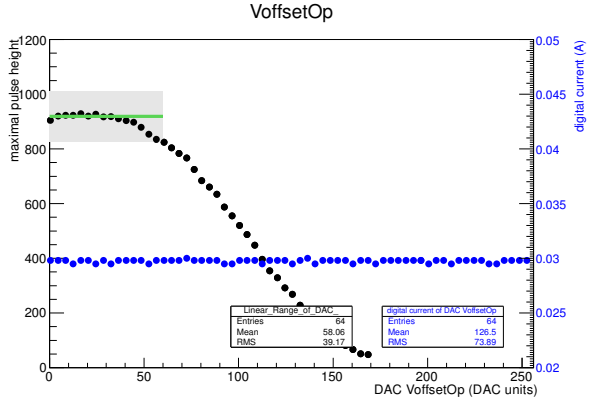

Figure 66: *Voffset_Op* DAC range measurement for ROC 003206.

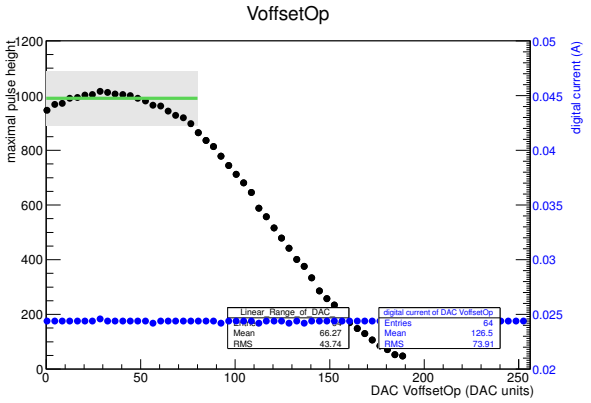

Figure 67: *Voffset_Op* DAC range measurement for ROC 000911.

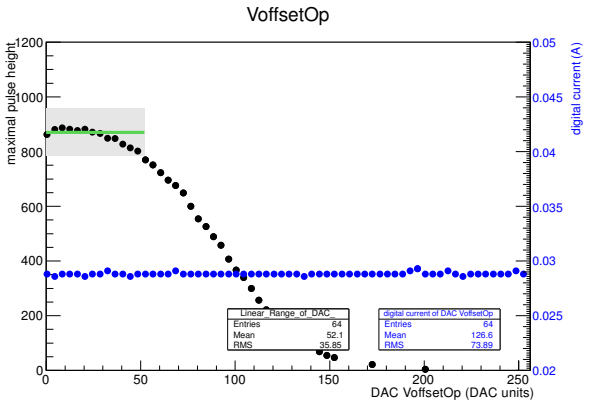

Figure 68: *Voffset_Op* DAC range measurement for ROC 00906A.

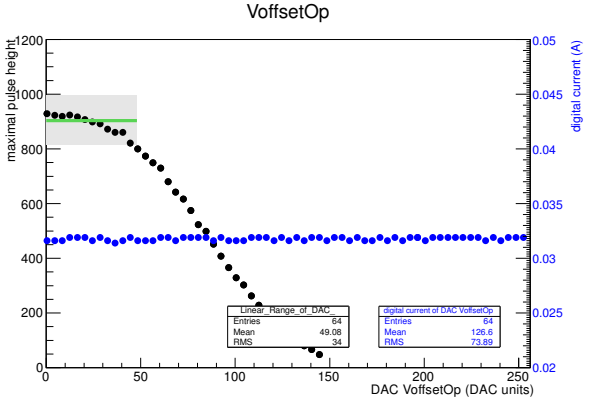

Figure 69: *Voffset_Op* DAC range measurement for ROC 00906B.

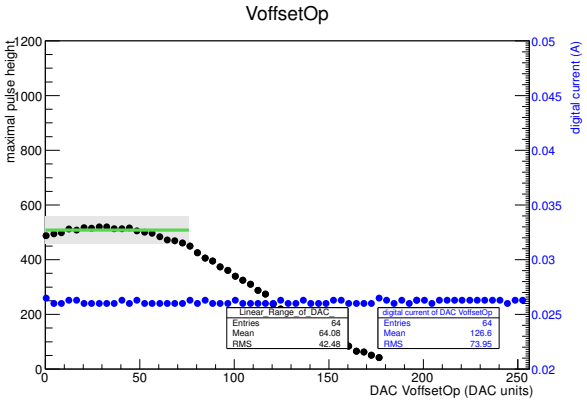

Figure 70: *Voffset_Op* DAC range measurement for ROC 0623A0.

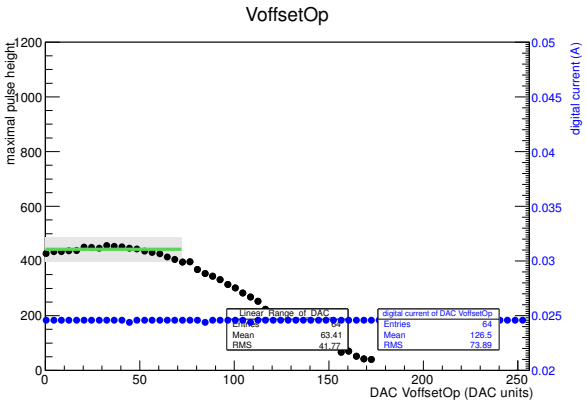

Figure 71: *Voffset_Op* DAC range measurement for ROC 0675A0.

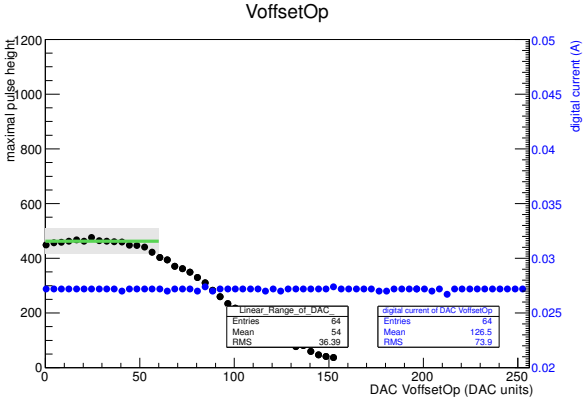

Figure 72: *Voffset_Op* DAC range measurement for ROC 1267B0.

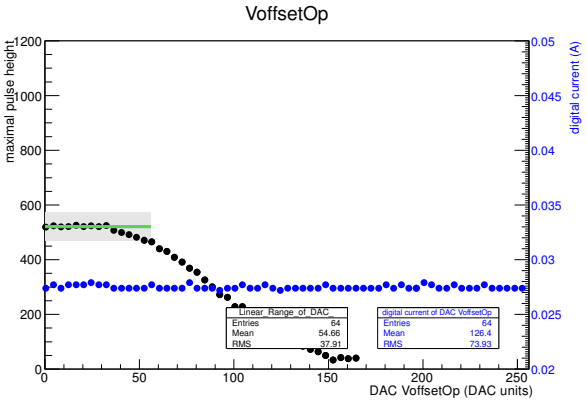

Figure 73: *Voffset_Op* DAC range measurement for ROC 1268A0.

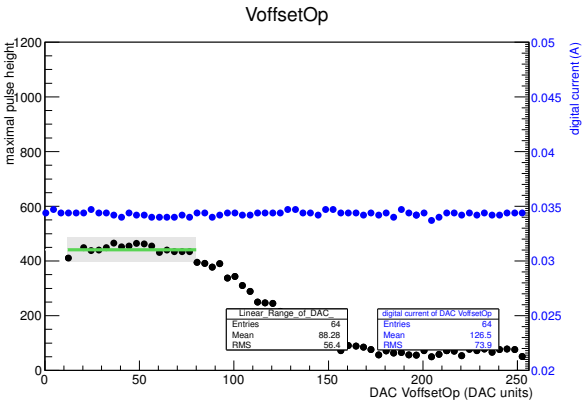

Figure 74: *Voffset_Op* DAC range measurement for ROC 3075B0.

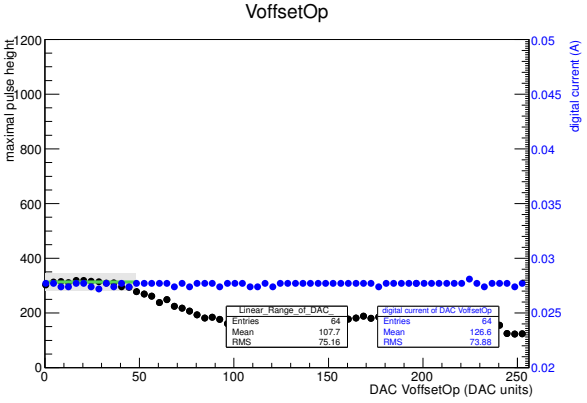

Figure 75: *Voffset_Op* DAC range measurement for ROC 3076B0.

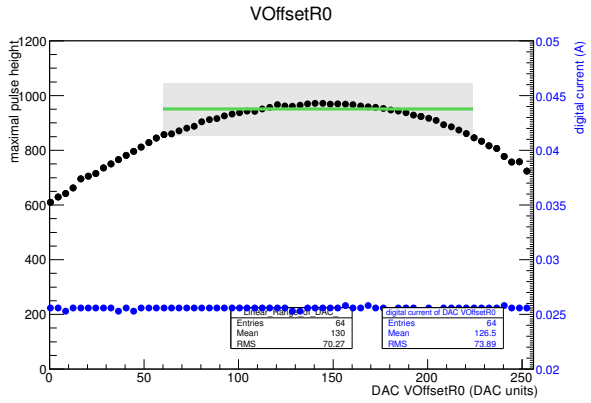

Figure 76: *Voffset_RO* DAC range measurement for ROC 00ROC1.

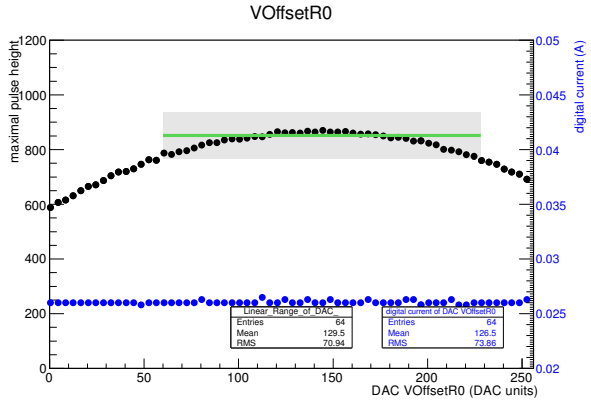

Figure 77: *Voffset_RO* DAC range measurement for ROC 00ROC2.

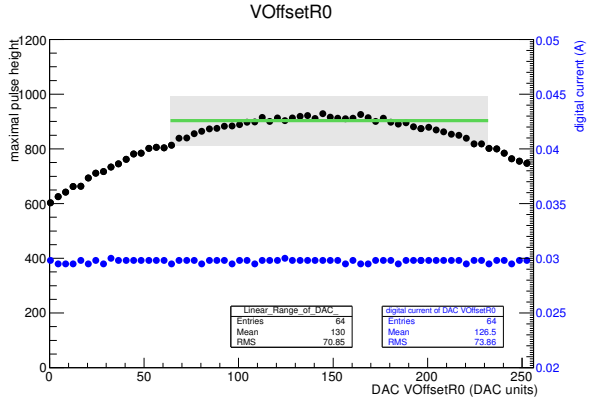

Figure 78: *Voffset_RO* DAC range measurement for ROC 003206.

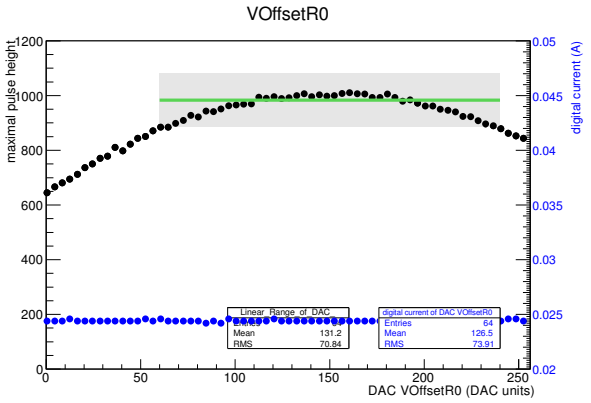

Figure 79: *Voffset_RO* DAC range measurement for ROC 000911.

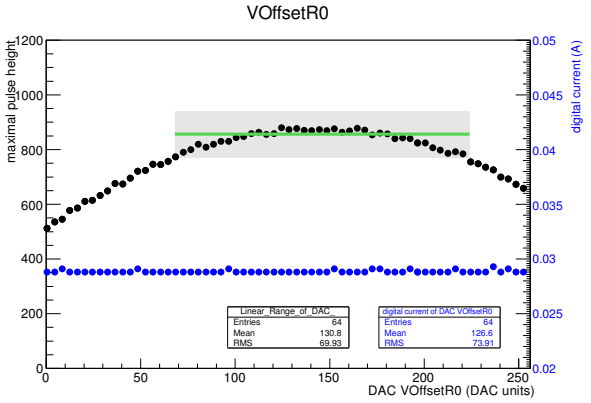

Figure 80: *Voffset_RO* DAC range measurement for ROC 00906A.

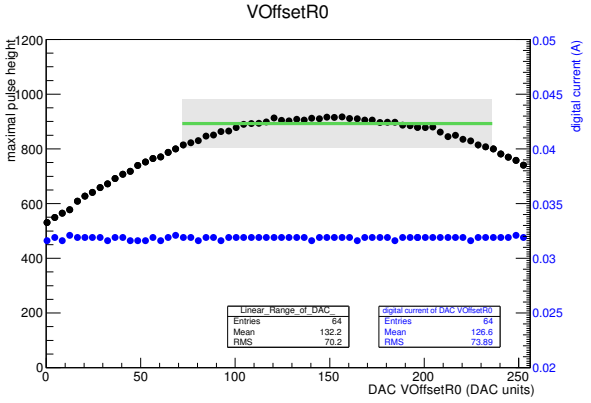

Figure 81: *Voffset_RO* DAC range measurement for ROC 00906B.

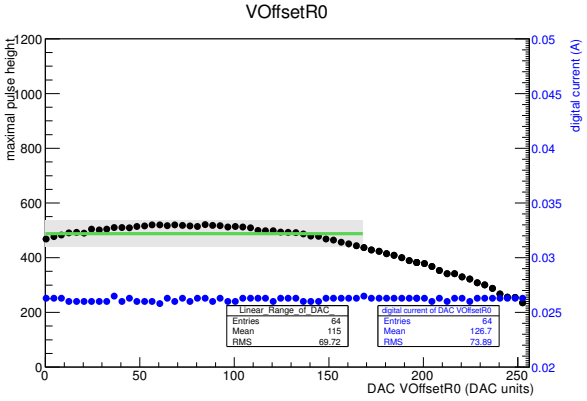

Figure 82: *Voffset_RO* DAC range measurement for ROC 0623A0.

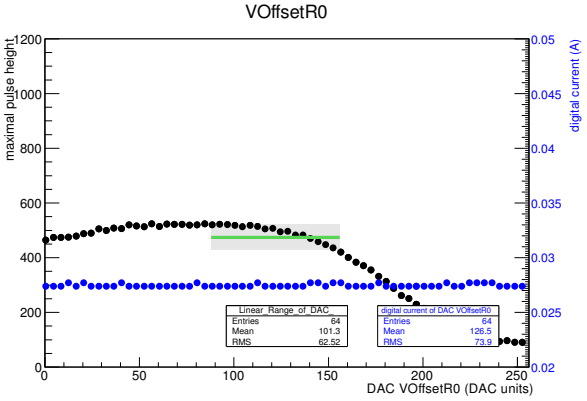

Figure 85: *Voffset_RO* DAC range measurement for ROC 1268A0.

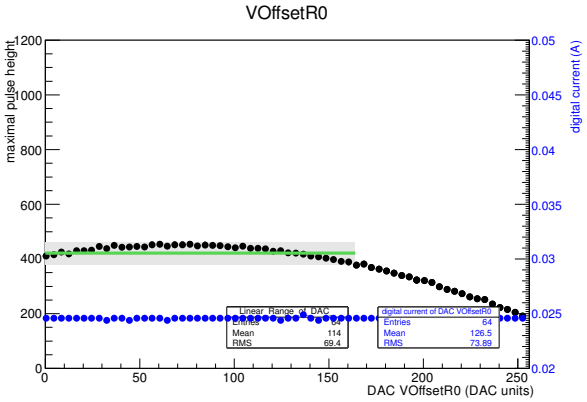

Figure 83: *Voffset_RO* DAC range measurement for ROC 0675A0.

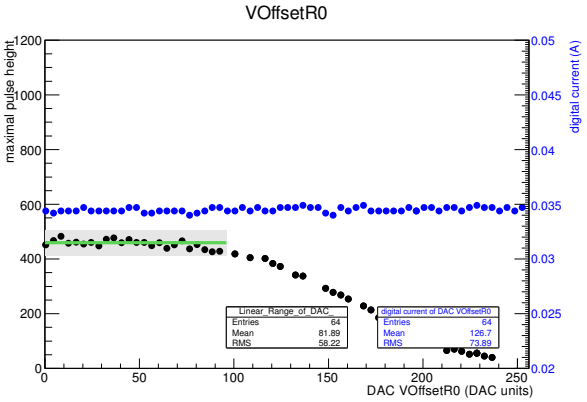

Figure 86: *Voffset_RO* DAC range measurement for ROC 3075B0.

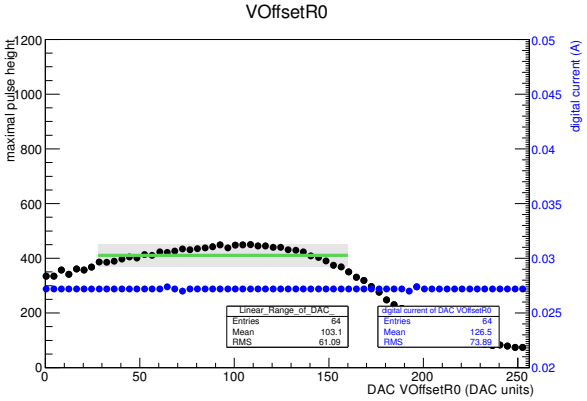

Figure 84: *Voffset_RO* DAC range measurement for ROC 1267B0.

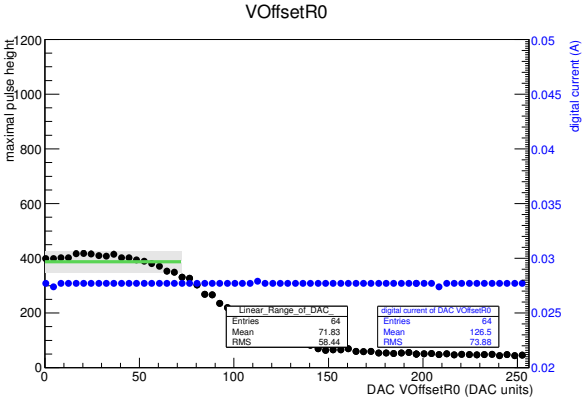

Figure 87: *Voffset_RO* DAC range measurement for ROC 3076B0.