Undergraduate Research: Fall 2013
FNAL Beam Test Cross-Talk in CMS'zz

Author: Shreeya Khanal
Florida Institute of Technology
Melbourne, FL, United States

Cross-talk, in electronics, means interference; it is unwanted interference that occurs due to coupling of one channel into the other. When one conducting channel is connected to a source of current, then the adjacent channel automatically shows a current reading even if it is not connected to the current source or the conducting channel. In our Printed Circuit Board (PCB) of a CMS'zz detector, there are total of 127 gold strips, among which just two of the strips were connected to a source of current (a ground source)— 63 and 127. The victim strips (the ones right adjacent to the source strips) were 62, 64 and 126. Once the ADC count of source, victim, and the average ADC noise was extracted from the data, those values were plugged into the cross-talk equation (Equation 1.1), and the cross talk was figured out for that scenario. The most unexpected observation was that APV channel 20 included the highest cross-talk amount, which went high up to approx. 33%. The most charge was shared from source strip 127 to victim strip 126, which ranged mostly from 7% to 10% (a few 12% as well) in all of the APV's for all pedestals. The least amount of cross-talk was observed between victim strips 62 and 64, which shared the common charge from a single source strip 63; they ranged mostly from 2% to 6% for all the pedestals. Hence, the results obtained for victim strips 62 and 64 goes well with the hypothesis of cross-talk being around numbers less than ~5%, but the other results for strip 126 deviates quite much from the ideal cross-talk number. The final average cross-talk were mostly 5%-6% range. The cross-talk coefficient was mostly measured around the values ranging from 0.69 to 0.47 and showed the cross-talk strength in the APV's.

1. Introduction

There are typically three types of cross-talk; specifically, there are three different ways via which coupling within conductors is possible. They are inductive coupling, capacitive coupling, and conductive coupling.

Inductive coupling is when a source containing charge is able to induce charge in the victim right next to it. The conducting gold strips definitely act as ideal inductors when introduced to enough current, because they are capable of inducing charge to the other one.

Capacitance is the ability of a conductor to store a charge; more the area of the conductor, more the capacitance. Higher capacitance means more electric field. Hence, this field could easily be noticed in the a conductor which is right next to it.

Another reason of cross talk is conductive coupling; however, that's not the case with the printed circuit board of the CMS'zz. For conductive coupling to occur, the two or more conducting sources have to be connected to the victims to be able to share charge, but the strips in CMS'zz aren't physically connected to each other. Hence, this reason of cross-talk coupling is ruled out in our case.

Before executing any experiment with the detectors, pedestal experiments are performed at the supply of 2000V in order to measure how much noise is present in the readout boards. Noises are the baseline of electronic signals; any future experiment based on the pedestals would have these noise levels present already acting as an offset signal for the new set of signals. Presence of cross-talk in the conducting strip causes increment in these natural noise levels by creating unwanted noise in them, which would increase the natural offset for future experiments to be performed. Hence, this will have effect on the entire set of data.

2. Materials and Methods

After the pedestals of the FNAL Beam experiments were taken, the data was processed and obtained in the form of pedestal ROOT files. A pedestal file contains two types files—one representing noise and the other representing the offset. For cross-talk analysis, files containing noise data were used. These files are technically histograms that represent how much noise is present in the strips of the APV channel. A histogram contains the ADC (Analogue to Digital Converter) count per strip. A typical noise histogram looks like *figure 1.1*.

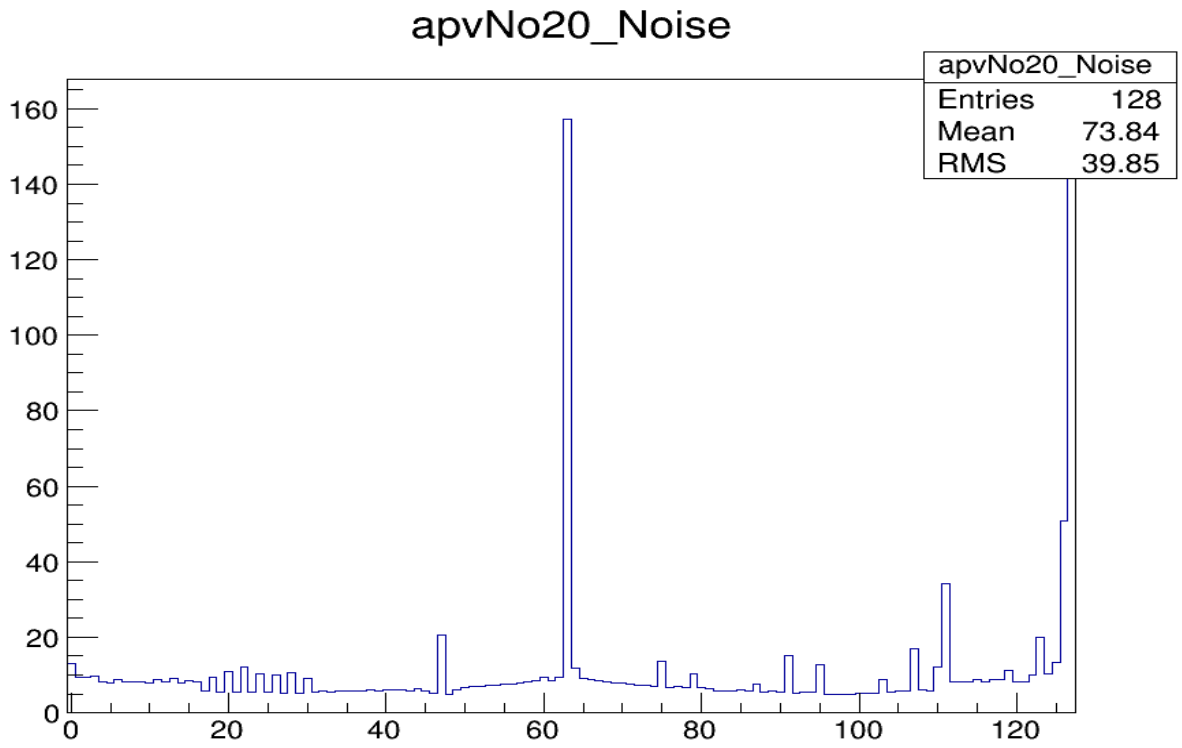


Figure 1.1: A histogram showing noise present in the APV 20 of a pedestal file.

The x-axis in the above histogram represents number of strips, which is 127, and the y-axis is the ADC count. An ADC count is some amount of charge (For example: 1ADC count = $232e^{-}$ = $3.71*10^{-17}$C). If a reading for, say, 12^{th} strip shows an ADC count of 13, then that means that the charge contained in the strip 12 is $4.82*10^{-16}$ C, which is the representation of the amount of noise in the 12^{th} strip.

In the above histogram, the source strips are clearly 63 and 126—they were the only ones to be connected to the ground source; that's why, they have the highest ADC count. To observe charge sharing, one (or more) strips has to be connected to a very high source so that it contains charge that is high enough to be able to induce charge into the adjacent one. Now, to find out the charge shared by these two source strips to the ones right next to them, the following methodology was applied:

- The ADC count of the source strips, 63 and 127 was obtained using a ROOT code for extracting bin content from a histogram. Similarly, the ADC count of victim strips 62, 63 and 126 were obtained.
- The average noise in the strips around 63 and 127 was obtained, again using a ROOT code. The ADC count of strips 40 to 70 (excluding strip 63!) were used to find the average noise around source strip 63, and the ADC count of strips 100 to 126 were used

to find the average noise around source strip 127. Any ADC signal in the victim that was more than the average noise was considered to be due to the cross-talk effect.

- The amount of charge shared by the sources into the victims was calculated by using the following equation:

$$XT = \frac{\sqrt{ADC_{victim}{}^2 - ADC_{avg}{}^2}}{ADC_{source}} * 100 \quad (1.1)$$

For rest of this report, the term 'cross-talk formula' is used to refer to the above equation.

- The calculations were performed three times for each histogram—for finding cross-talk in victim strip 62, 64 and 126. The final cross-talk in each APV was the average value of cross-talk in these three victims. Finally, the values of each APV of the pedestal (except APV 20 due to very high value) were added to obtain a total cross-talk value for that particular pedestal. (Calculations can be referred at the data sheet attached to this report).
- For calculating the standard deviation of the final value of cross-talk, an average value of all the cross-talk in strips 62, 64 and 126 for all 8 APV's were used. That value was taken as a mean value. Then the following formula was applied as standard deviation of mean (SDOM):

$$\sigma_{\bar{x}} = \frac{\sigma_x}{\sqrt{N}}; \sigma_x = \frac{\sqrt{\Sigma(x_i - \bar{x})^2}}{\sqrt{N-1}} \quad (1.2)$$

N represents the number of trials (which was 7 for this analysis).

(Note: instead of 8 APV's, only 7 was used because the cross-talk value of APV 20 was very high; it was omitted for calculating the overall mean cross-talk for each pedestal, and the values for strip 126 was also not included in the final plots.)

The numbers gained after the calculations were the amount of charge (in percentage) that was shared by the source into the victim. In simple words, the cross-talk formula gave a portion of the source charge (in percentage) that would get transferred to the victim.

Note: Only 5 pedestals were taken when CMS'zz detector was installed. That's why, only 5 pedestal files are used for this analysis out of 15 pedestal files obtained. Also, the APV channels from 16 to 23 (total 8 APV's) were connected to the CMS'zz; hence, there were 8 APV noise histograms out of 64 APV histograms that were analyzed for each of those 5 pedestal files.

Another formula used in this research was to measure the cross-talk coefficient, and is mentioned below.

$$\frac{1}{1 + \left(\frac{D}{H}\right)^2}$$

The ‘D’ in previous equation represents the separation between the strips, and ‘H’ is the distance between the strips and the ground plane, which was 3 mm. The values and calculations are shown in the Data Analysis section.

3. Results and Data Analysis

The results include cross-talk quantities for all the APV’s (16-23) of CMS’zz of the 5 pedestal files. After the procedures mentioned in the previous section, the following results were obtained.

3.1 Pedestal 5

Name: newfitRun001_Pedestal_2000V_20131011.root

APV’s	XT on 62 (in %)	XT on 64 (in %)	XT on 126 (in %)	XT_{avg} (in %)
16	0.00	2.33	8.00	3.44
17	5.01	2.43	6.98	4.81
18	0.00	3.51	10.21	4.57
19	2.50	4.42	10.50	5.80
20	2.23	5.31	31.16	12.90
21	4.06	5.75	11.90	7.24
22	3.84	5.51	10.52	6.62
23	3.00	5.27	10.29	6.19

Table 1.1: Pedestal 5 cross-talk in the victim strips 62, 64 and 126 and their averages.

Mean XT: 5.53% ± 0.50 %

The cross-talk values were noted the lowest in the victim strip 62 of both the APV’s 16 and 18 with a value of 0.00%. The reason for this was that the bin content (noise) of strip 62 were lower than the average noise level; so, the cross-talk was recorded as 0.00%. Also, some lowest cross-talk values were recorded in the strip 62 of all the APV channels. On the other hand, the highest value obtained was for strip 126 or APV 20, which was 31.16%. The overall cross-talk in the victim strip 126 was relatively higher than the other victim strips 62 and 64. In the overall averages of each APV, the cross-talk ranged from 3.44%-7.24% except the APV 20 value which counted 12.90%. The victim strips 62 and 64 of APV 21 showed the most cross-talk values among all other APV’s. The overall value of cross-talk across all the APV’s was 5.53% with a standard deviation of 0.50%.

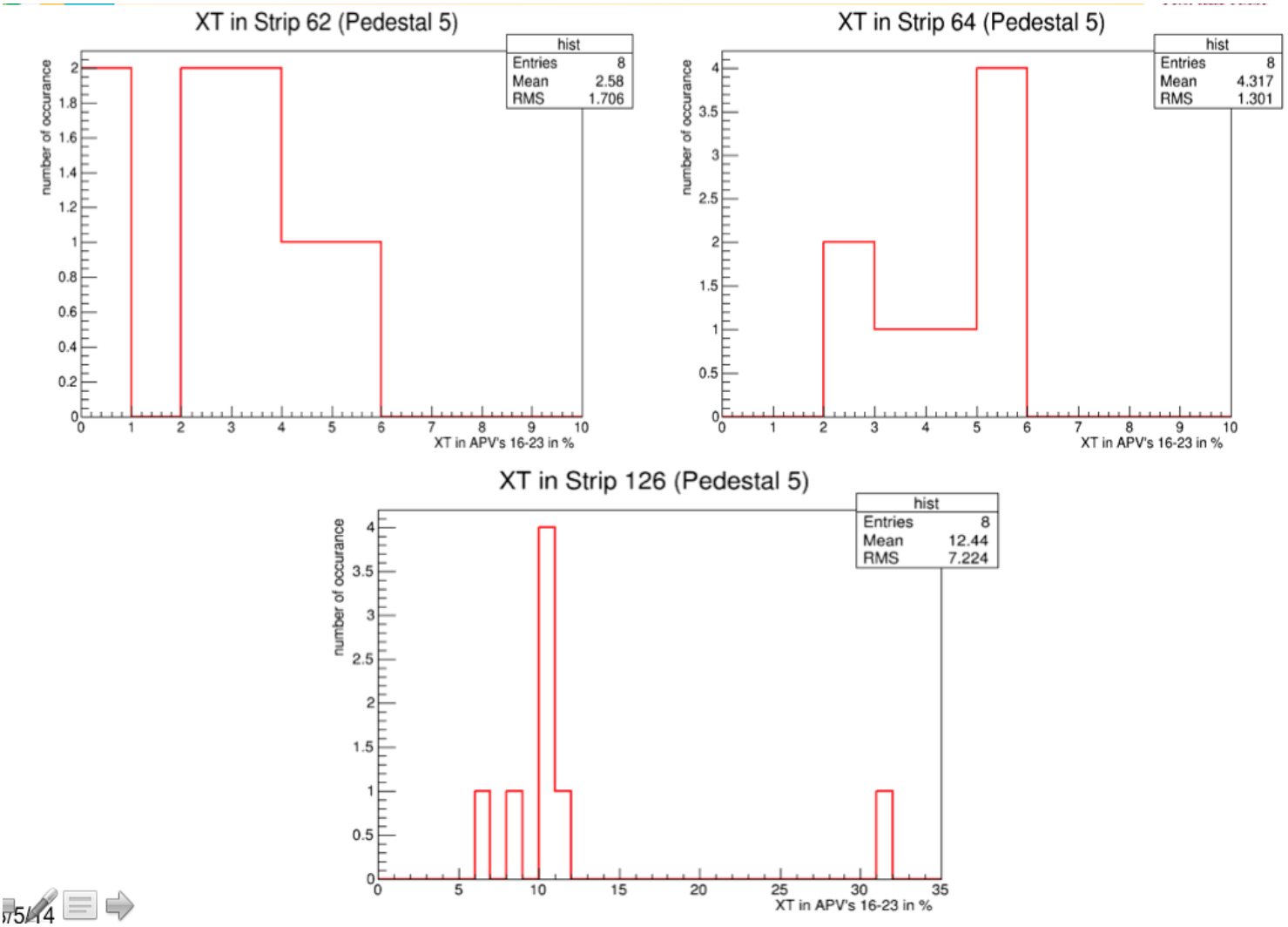


Figure 1.2: Histogram showing cross-talk values for victim strips 62 (top left), 64 (top right), and 126 (bottom) for pedestal 5.

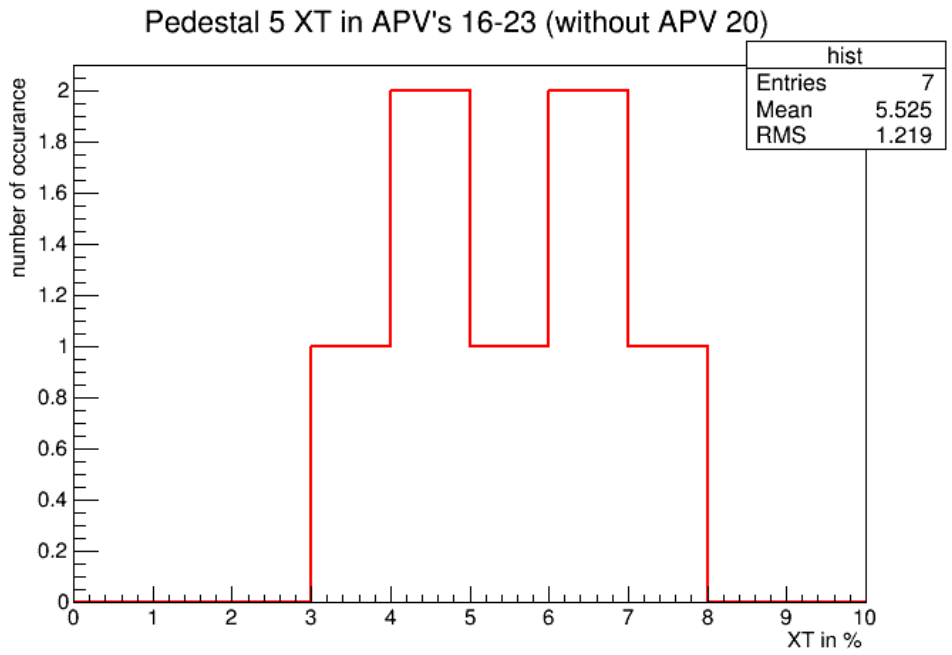


Figure 1.3: Histogram showing the average cross-talk values through all the APV's and their victim strips of pedestal 5 (APV 20 not included).

3.2 Pedestal 6

Name: newfitRun002_Pedestal_2000V_6TW_10cmZZscan_20131011.root

APV's	XT on 62 (in %)	XT on 64 (in %)	XT on 126 (in %)	XT_{avg} (in %)
16	4.83	5.81	8.74	6.46
17	4.75	3.92	7.81	5.49
18	1.60	5.07	10.77	5.81
19	3.84	4.82	9.12	5.93
20	2.75	5.67	33.15	13.86
21	4.39	6.10	11.83	7.44
22	4.38	6.12	11.75	7.42
23	4.07	6.52	12.20	7.60

Table 1.2: Pedestal 6 cross-talk in the victim strips 62, 64 and 126 and their averages.

Mean XT: 6.60% ± 0.33%

In contrast to the previous one, the cross-talk values noted in the victim strip 62 of APV 18 was just 1.60%. The highest value obtained was again for strip 126 or APV 20, which was 33.15%. The overall cross-talk, just like in the previous pedestal, in the victim strip 126 was higher than the other victim strips 62 and 64. The overall averages of each APV were a little higher than the previous one, and they ranged from 5.49%-7.60% except the APV 20 value which counted

13.86%. The overall value of cross-talk across all the APV's was 6.60% with a standard deviation of 0.33%. This was the lowest standard deviation of mean among all pedestals.

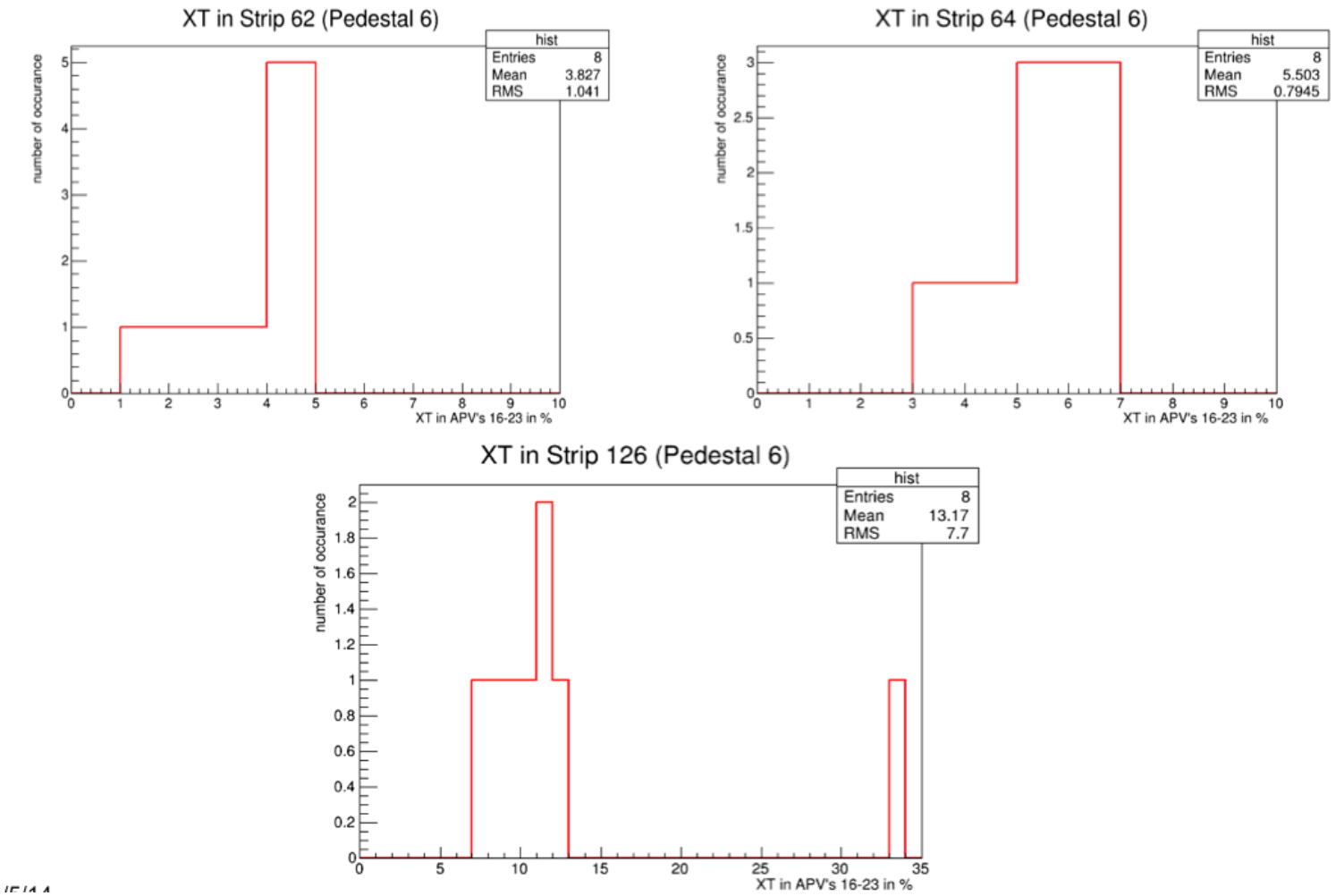


Figure 1.4: Histogram showing cross-talk values for victim strips 62 (top left), 64 (top right), and 126 (bottom) for pedestal 6.

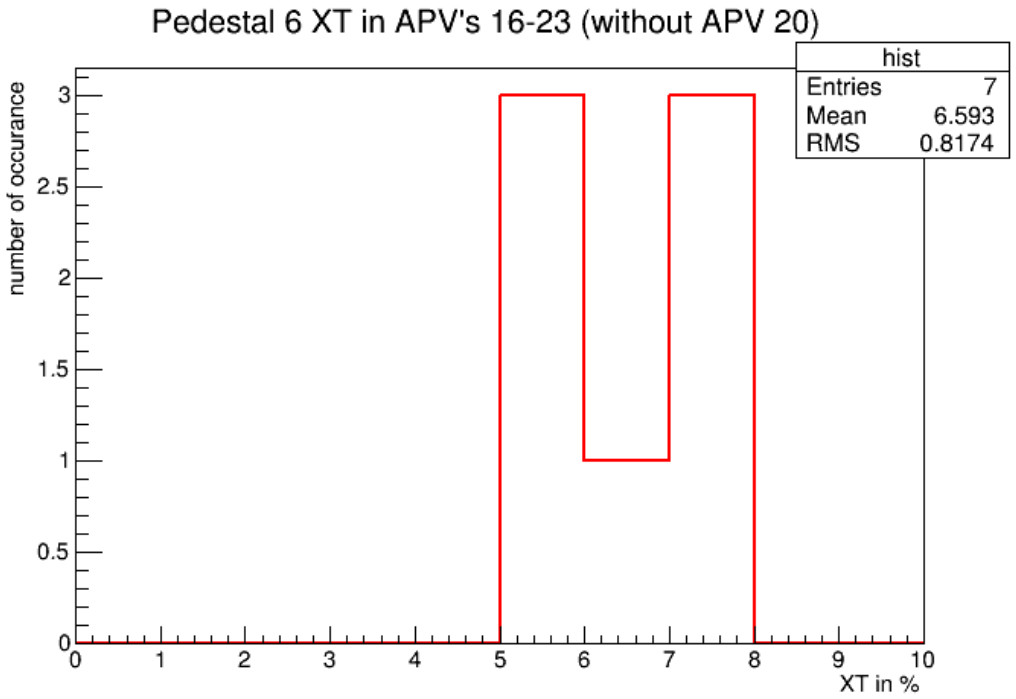


Figure 1.5: Histogram showing the average cross-talk values through all the APV's and their victim strips of pedestal 6 (APV 20 not included).

3.2 Pedestal 7

Name: newfitRun010_Hadron32GeV_CMSzzScan_Pedestal_20131012_1736PM.root

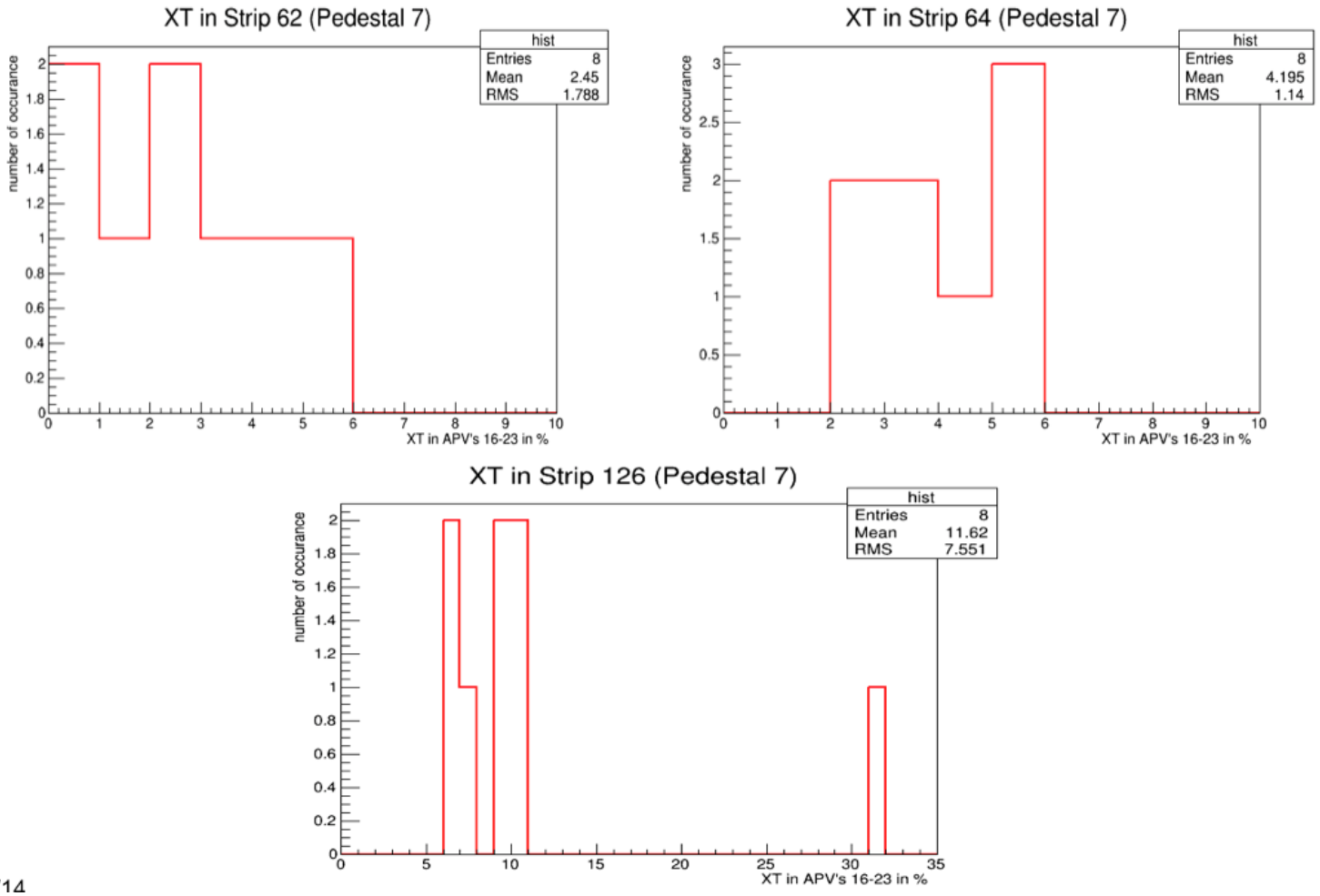
APV's	XT on 62 (in %)	XT on 64 (in %)	XT on 126 (in %)	XT_{avg} (in %)
16	0.00	2.80	7.81	3.54
17	5.46	2.63	6.65	4.91
18	0.00	3.32	9.82	4.38
19	2.04	3.66	6.81	4.17
20	1.76	4.96	31.22	12.65
21	3.49	5.37	9.72	6.19
22	4.09	5.51	10.68	6.76
23	2.76	5.30	10.28	6.11

Table 1.3: Pedestal 7 cross-talk in the victim strips 62, 64 and 126 and their averages.

Mean XT: 5.15% ± 0.46%

Just like in pedestal 5, the cross-talk values were noted the lowest in the victim strip 62 of both the APV's 16 and 18 with a value of 0.00%. The highest value obtained was for strip 126 or APV 20, which was 31.22%, just like previous 2 pedestals. Also, the overall cross-talk in the

victim strip 126 was recorded higher than the other victim strips 62 and 64. In the overall averages of each APV, the cross-talk ranged from 3.54%-6.76% except the APV 20 value which counted 12.65%. The overall value of cross-talk across all the APV's was 5.15% with a standard deviation of 0.46%.



/5/14

Figure 1.6: Histogram showing cross-talk values for victim strips 62 (top left), 64 (top right), and 126 (bottom) for pedestal 7.

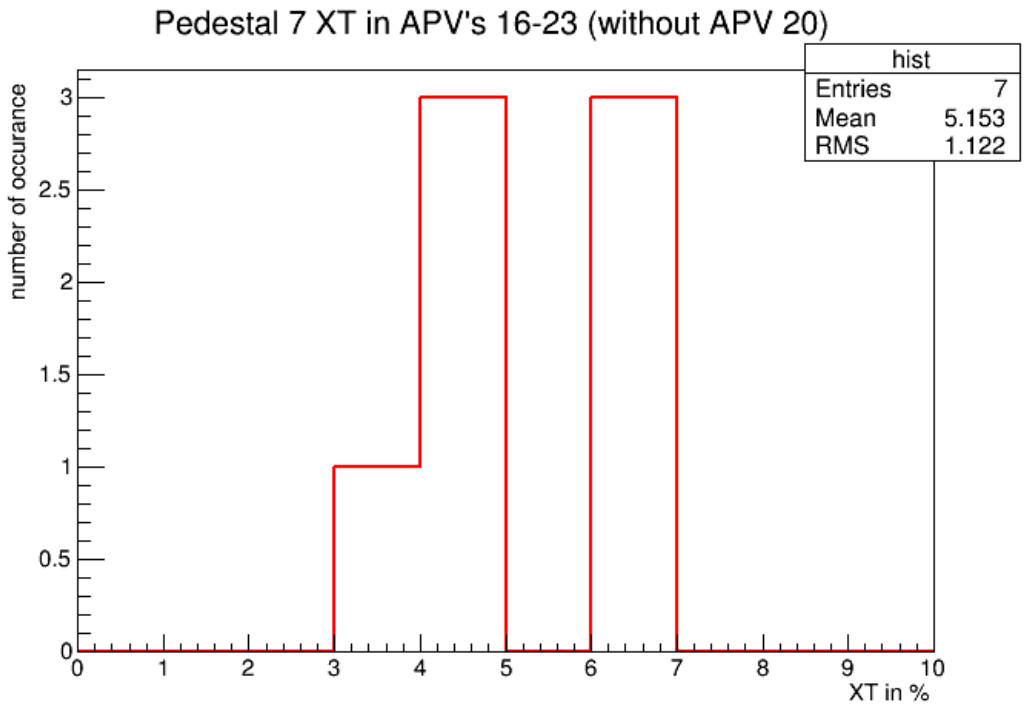


Figure 1.7: Histogram showing the average cross-talk values through all the APV's and their victim strips of pedestal 7 (APV 20 not included).

3.4 Pedestal 8

Name: newfitRun014_20GeV_CMSzzEICScan_Pedestal_20131012_1142pm.root

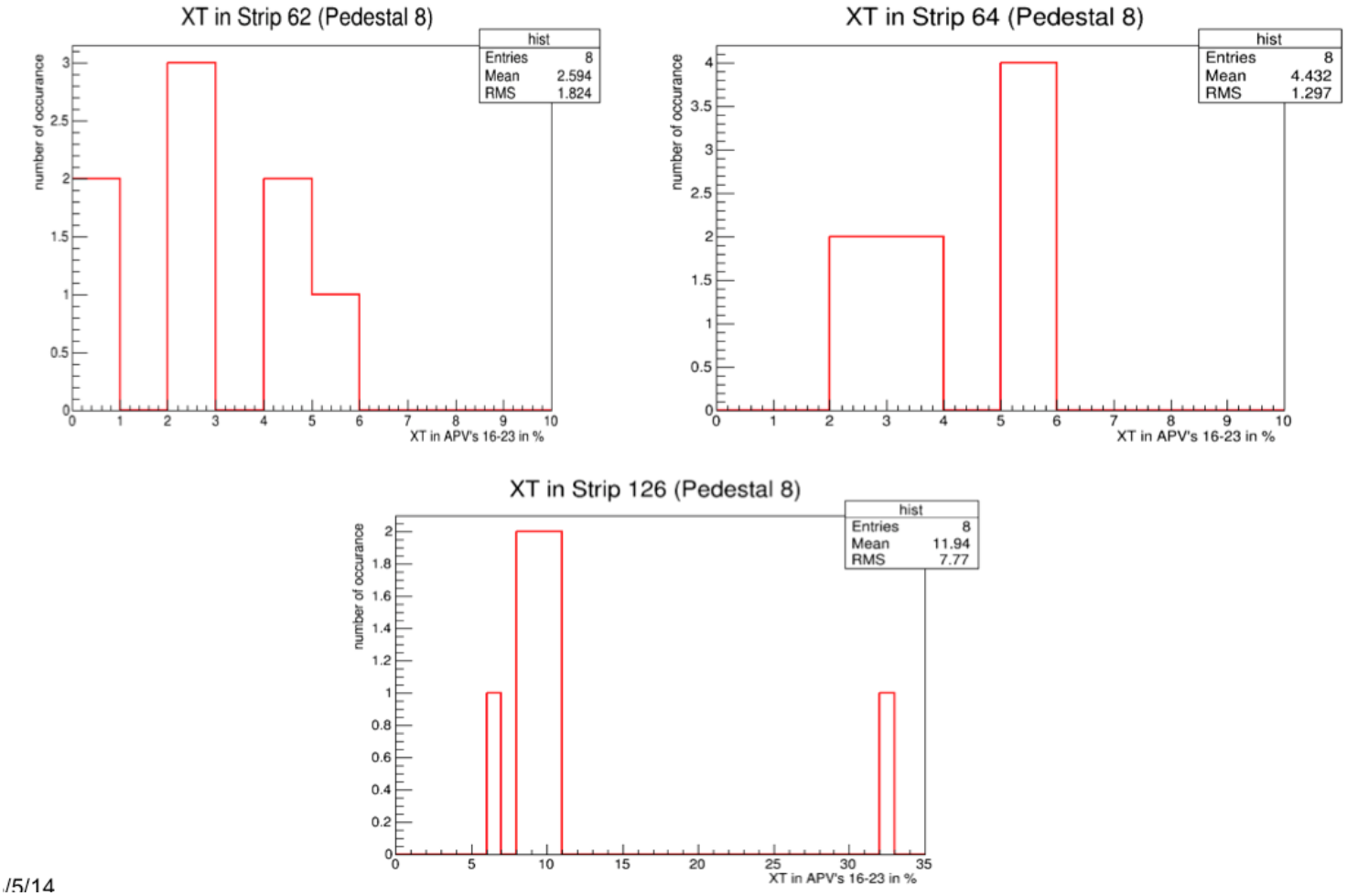
APV's	XT on 62 (in %)	XT on 64 (in %)	XT on 126 (in %)	XT_{avg} (in %)
16	0.00	2.70	8.11	3.60
17	5.33	2.47	6.75	4.85
18	0.00	3.88	9.46	4.45
19	2.30	3.97	8.08	4.78
20	2.22	5.49	32.24	13.31
21	4.11	6.00	10.27	6.79
22	4.36	5.86	10.71	6.98
23	2.44	5.11	9.88	5.81

Table 1.4: Pedestal 8 cross-talk in the victim strips 62, 64 and 126 and their averages.

Mean XT: 5.32% ± 0.47%

The analysis for this pedestal is very much similar to pedestals 5 and 7; the cross-talk values were lowest in the victim strip 62 of both the APV's 16 and 18 with a value of 0.00%. The highest value obtained was for strip 126 or APV 20, which was 32.24%%, just like previous 2 pedestals. In the overall averages of each APV, the cross-talk ranged from 3.60%-6.79% except

the APV 20 value which counted 13.31%. The overall value of cross-talk across all the APV's was 5.32% with a standard deviation of 0.47%, which is very close to pedestal 7.



/5/14

Figure 1.8: Histogram showing cross-talk values for victim strips 62 (top left), 64 (top right), and 126 (bottom) for pedestal 8.

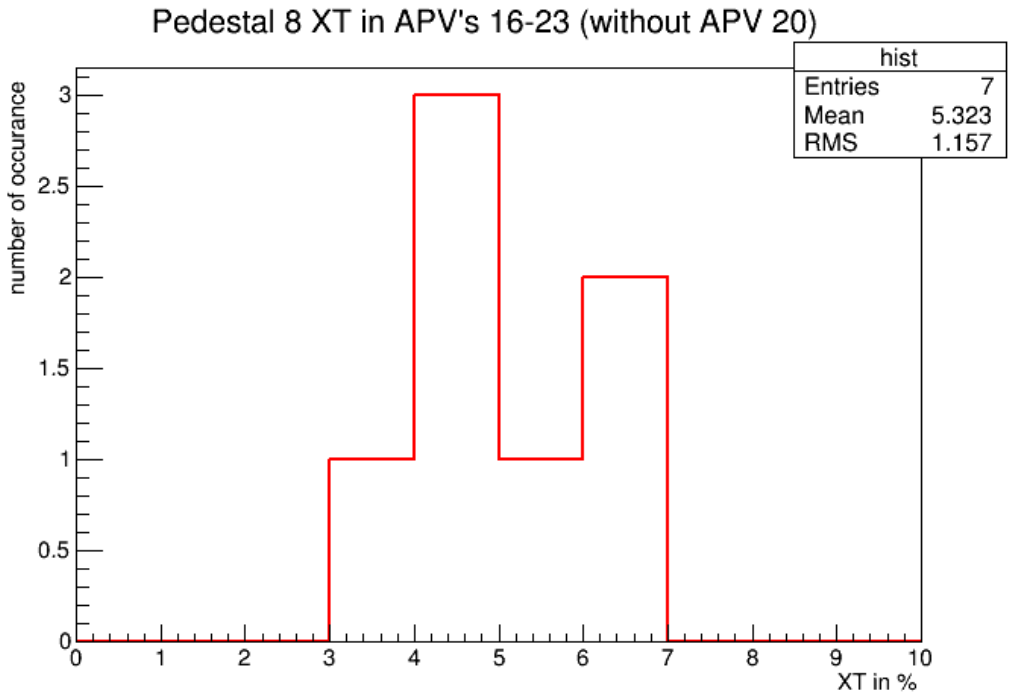


Figure 1.9: Histogram showing the average cross-talk values through all the APV's and their victim strips of pedestal 8 (APV 20 not included).

3.5 Pedestal 9

Name: run010_HVScan_Pedestal_25GeV_20131014_0727am.root

APV's	XT on 62 (in %)	XT on 64 (in %)	XT on 126 (in %)	XT_{avg} (in %)
16	0.00	2.69	8.23	3.64
17	5.62	2.75	6.83	5.07
18	0.00	3.31	9.70	4.34
19	2.70	3.68	2.01	2.80
20	2.24	5.04	31.22	12.83
21	3.77	5.57	9.68	6.34
22	3.37	4.86	9.62	5.95
23	2.81	5.25	10.25	6.10

Table 1.5: Pedestal 9 cross-talk in the victim strips 62, 64 and 126 and their averages.

Mean XT: 4.90% ± 0.51%

Again, like the previous 4 pedestals, the cross-talk values were lowest in the victim strip 62 of both the APV's 16 and 18 with a value of 0.00%. The highest value obtained was for strip 126 or APV 20, which was 31.22. In the overall averages of each APV, the cross-talk ranged from 2.80%-6.34% except the APV 20 value which counted 12.83%. The overall value of cross-talk

across all the APV's was 4.90% with a standard deviation of 0.51%. This pedestal had the lowest averages of cross-talk values, and hence, its overall mean was the lowest. However, it had the highest standard deviation of the mean (very little different among other pedestals, though).

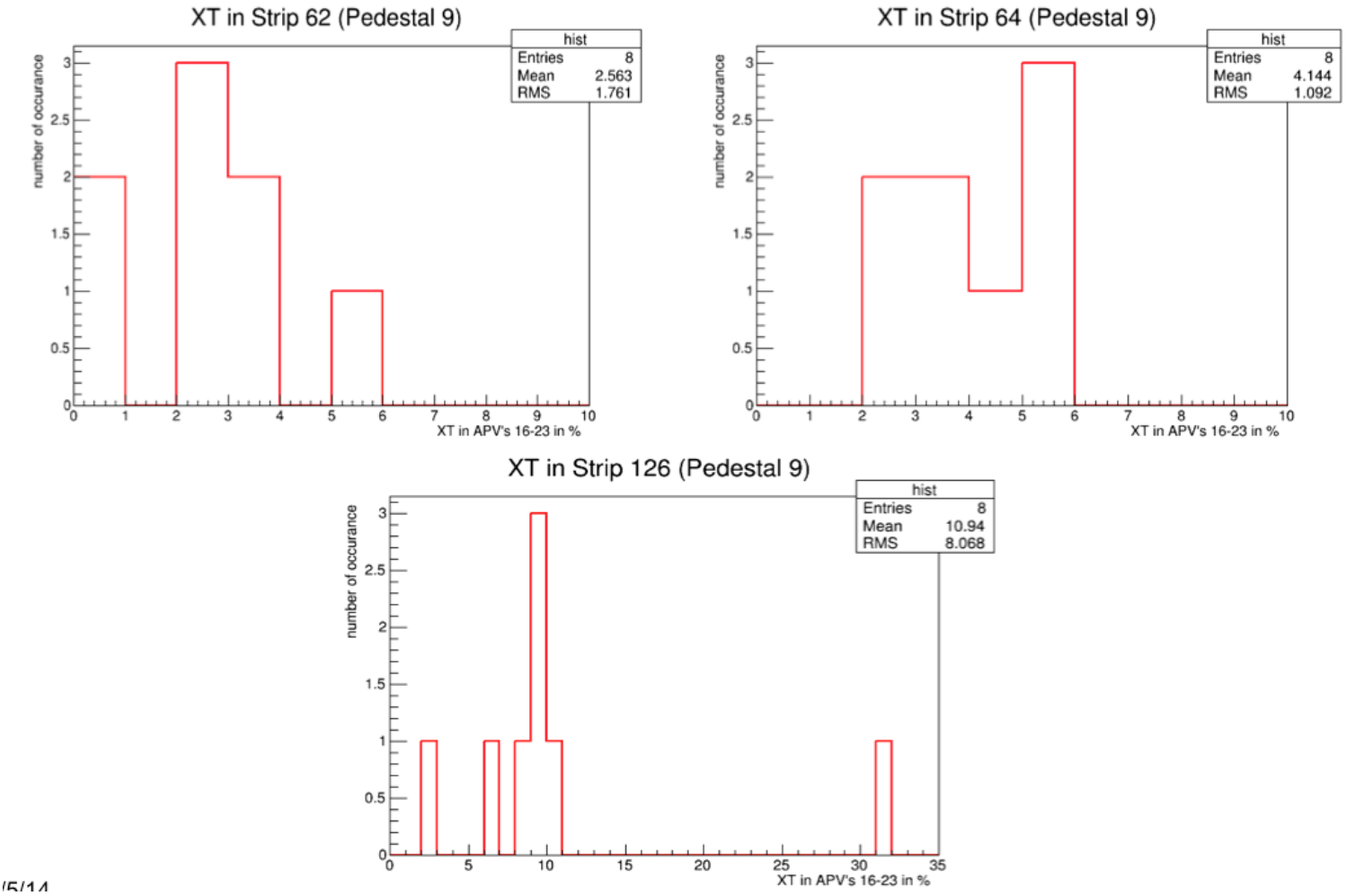


Figure 1.10: Histogram showing cross-talk values for victim strips 62 (top left), 64 (top right), and 126 (bottom) for pedestal 9

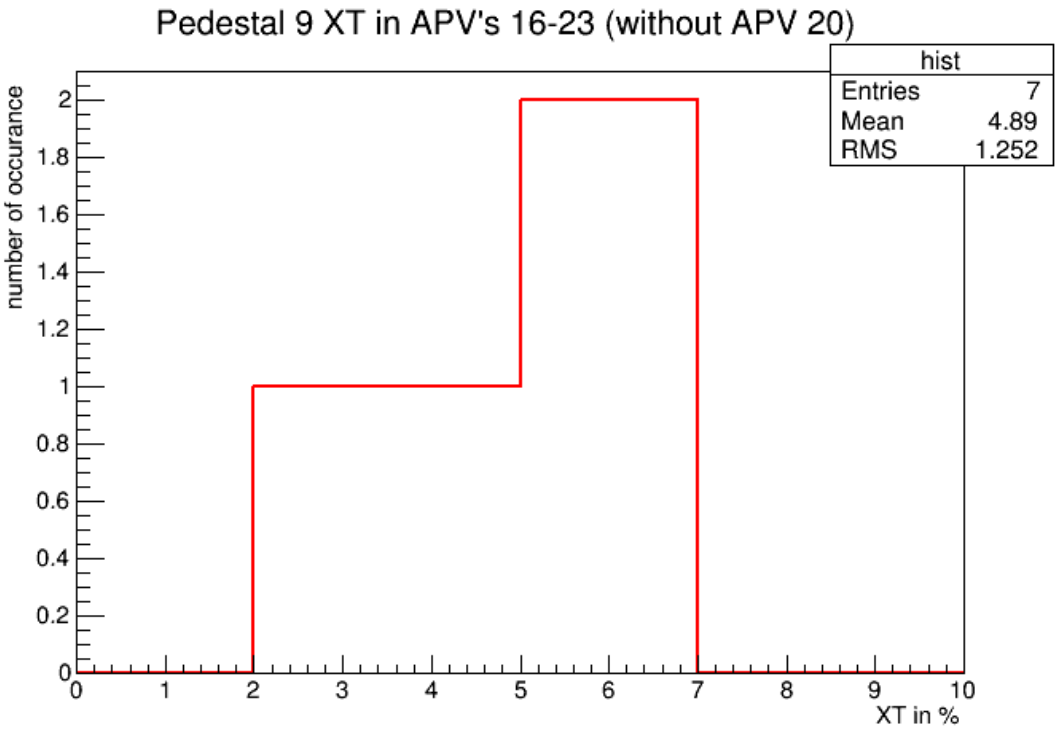


Figure 1.11: Histogram showing the average cross-talk values through all the APV's and their victim strips of pedestal 9 (APV 20 not included).

The histograms are pretty clear representation of the cross-talk within the pedestals which resemble to their corresponding tables.

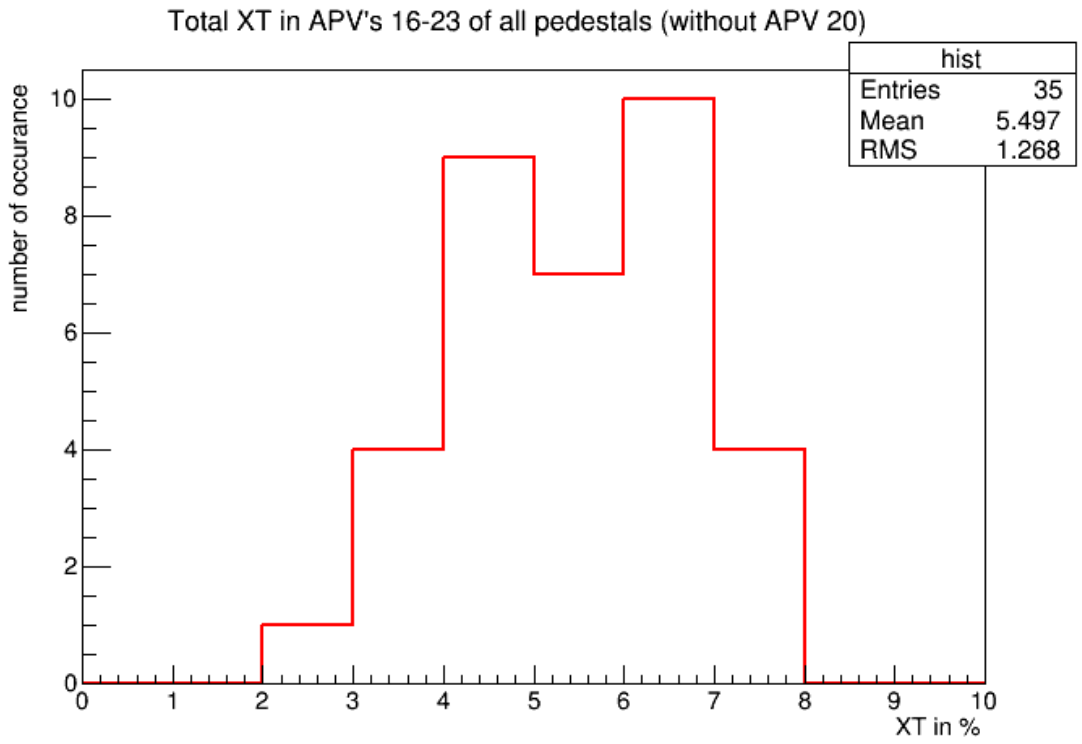


Figure 1.12: Total cross-talk in all pedestals (excluding APV 20 of each).

Figure 1.12 represents an overall distribution of the cross-talk values—the highest amount of cross-talk was noted to be 6%-7% in 10 of the APV's. The next highest was 4%-5% in total 9 APV's. The lowest was noted to be 2%-3% making just 1 APV fall in that range.

The reason that victim strips 62 and 64 had relatively lower amount of charge sharing than strip 126 may be because the source 63 has two victims side by side for sharing the charge (the charge that the source would induce in the victim would get divided into two adjacent victims). But, the source strip 127 just has one adjacent strip, which it could share its charge with (or could induce charge upon it). Hence, strip 126 was the 'alone' victim, literally, and strips 62 and 64 shared charge. The reason for abnormally high sharing on strip 126 of APV 20 is still to be researched; the some of the hypothesis include that it might have been more closely placed to the victim (or the ground), or may be that 126 and 127 are touching each other physically in the APV channel 20. The results of this research will be shared in the next report.

Another method of analysis included comparing the cross-talk in victim strips of the same APV's of different pedestals so that relative differences or similarities in each of them could be studied. Below, in the following tables, the cross-talk values are given for each victim strip of a particular APV for all pedestals. The standard deviation values are also included for any uncertainties.

Note: The following tables represent cross-talk for a particular APV of all pedestal files. The APV is specified in each title. The small tables below the first one show the standard deviation value of each of the victim strips and the standard deviation of the mean. All values including the standard deviations are in percentage %. The histograms represent pretty much the same thing as in previous ones; the difference is that now, the histograms are showing frequency of a cross-talk value in a particular APV of all pedestals.

APV 16

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	0.00	2.33	8.00	3.44
Pedestal 6	4.83	5.81	8.74	6.46
Pedestal 7	0.00	2.80	7.81	3.54
Pedestal 8	0.00	2.70	8.11	3.60
Pedestal 9	0.00	2.69	8.23	3.64
Average	0.97	3.26	8.18	4.14

SD 62	SD 64	SD 126	SD APV 16
2.16	1.43	0.35	1.30
SDOM 62	SDOM 64	SDOM 126	SDOM APV 16
0.97	0.64	0.16	0.58

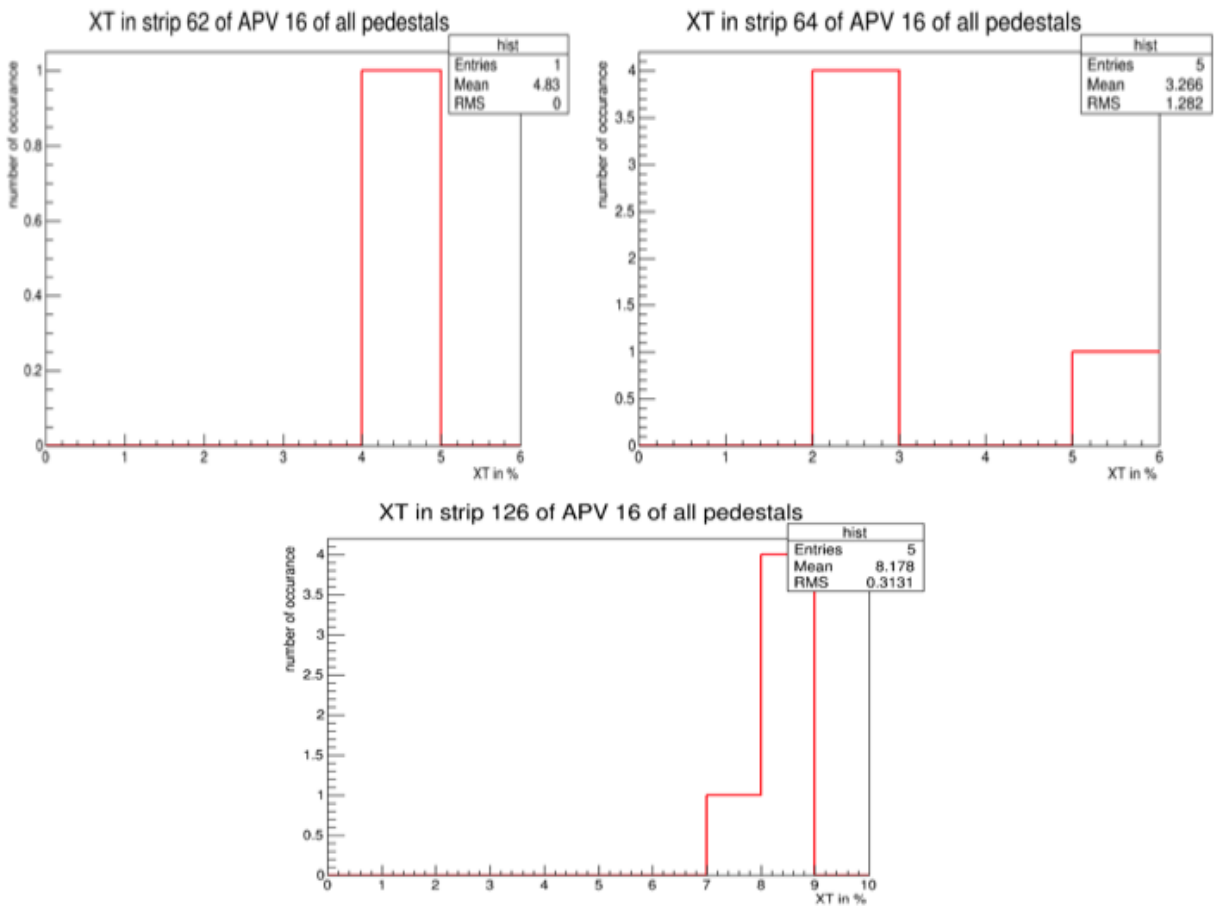


Figure 1.13: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 16 of all pedestals.

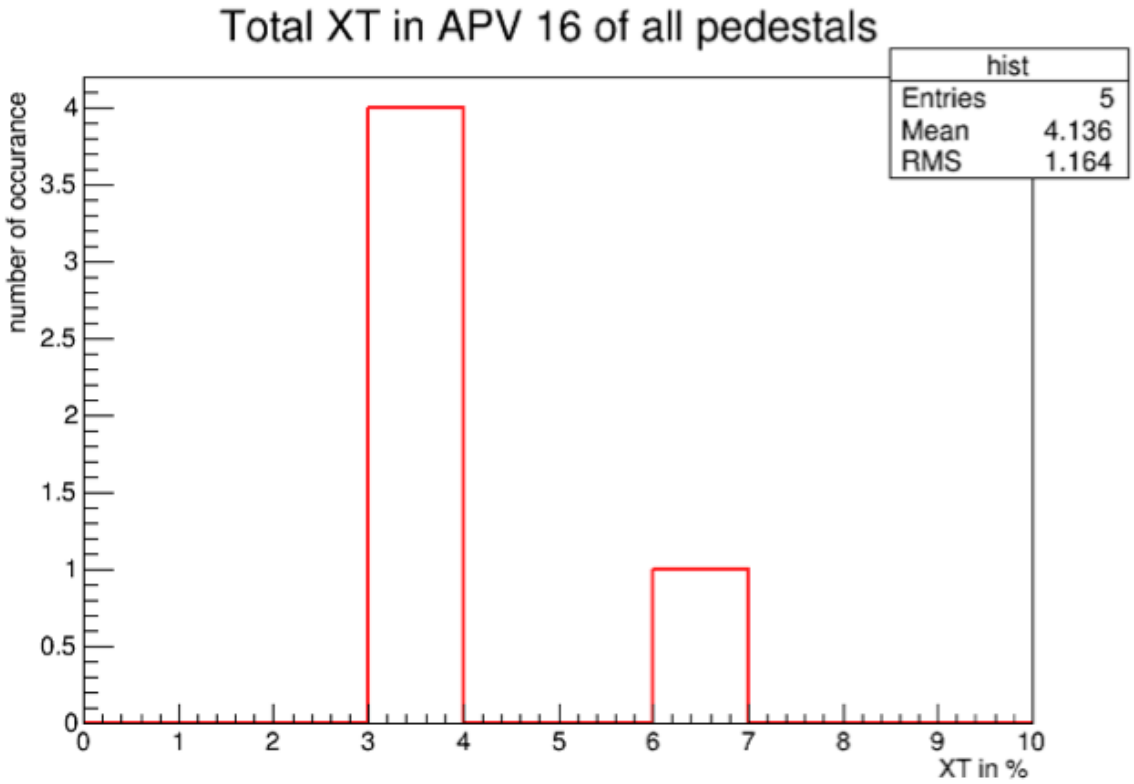
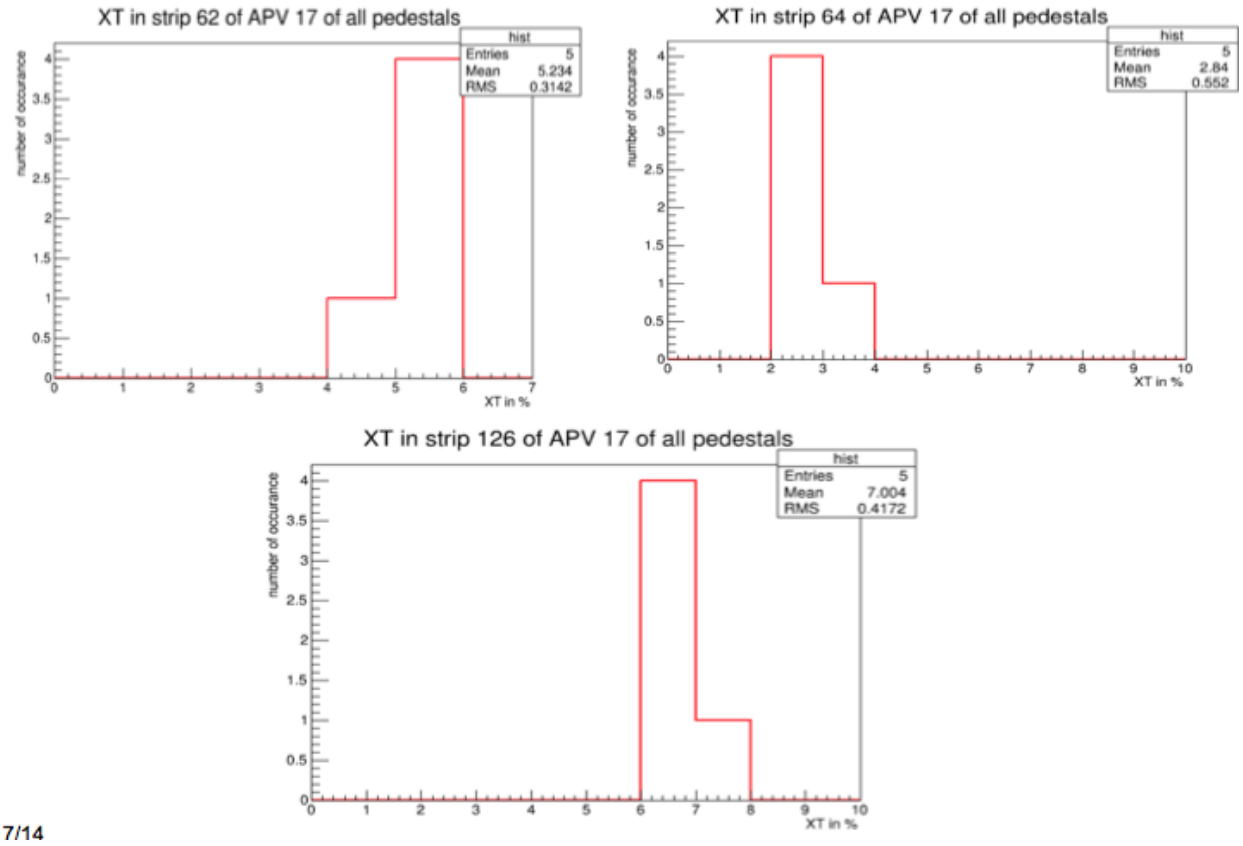


Figure 1.14: Total XT in APV 16 of all pedestals.

APV 17

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	5.01	2.43	6.98	4.81
Pedestal 6	4.75	3.92	7.81	5.49
Pedestal 7	5.46	2.63	6.65	4.91
Pedestal 8	5.33	2.47	6.75	4.85
Pedestal 9	5.62	2.75	6.83	5.07
Average	5.23	2.84	7.00	5.03

SD 62	SD 64	SD 126	SD APV 17
0.35	0.62	0.46	0.28
SDOM 62	SDOM 64	SDOM 126	SDOM APV 17
0.16	0.28	0.21	0.12



17/14

Figure 1.15: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 17 of all pedestals.

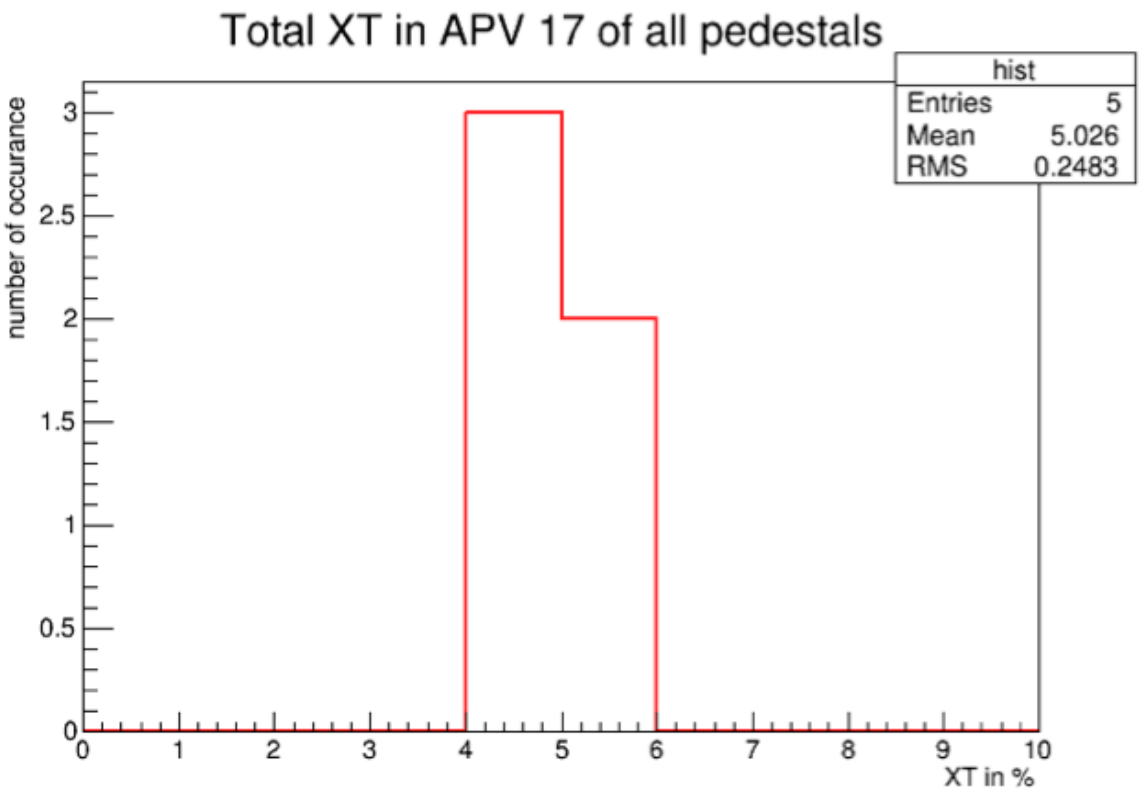
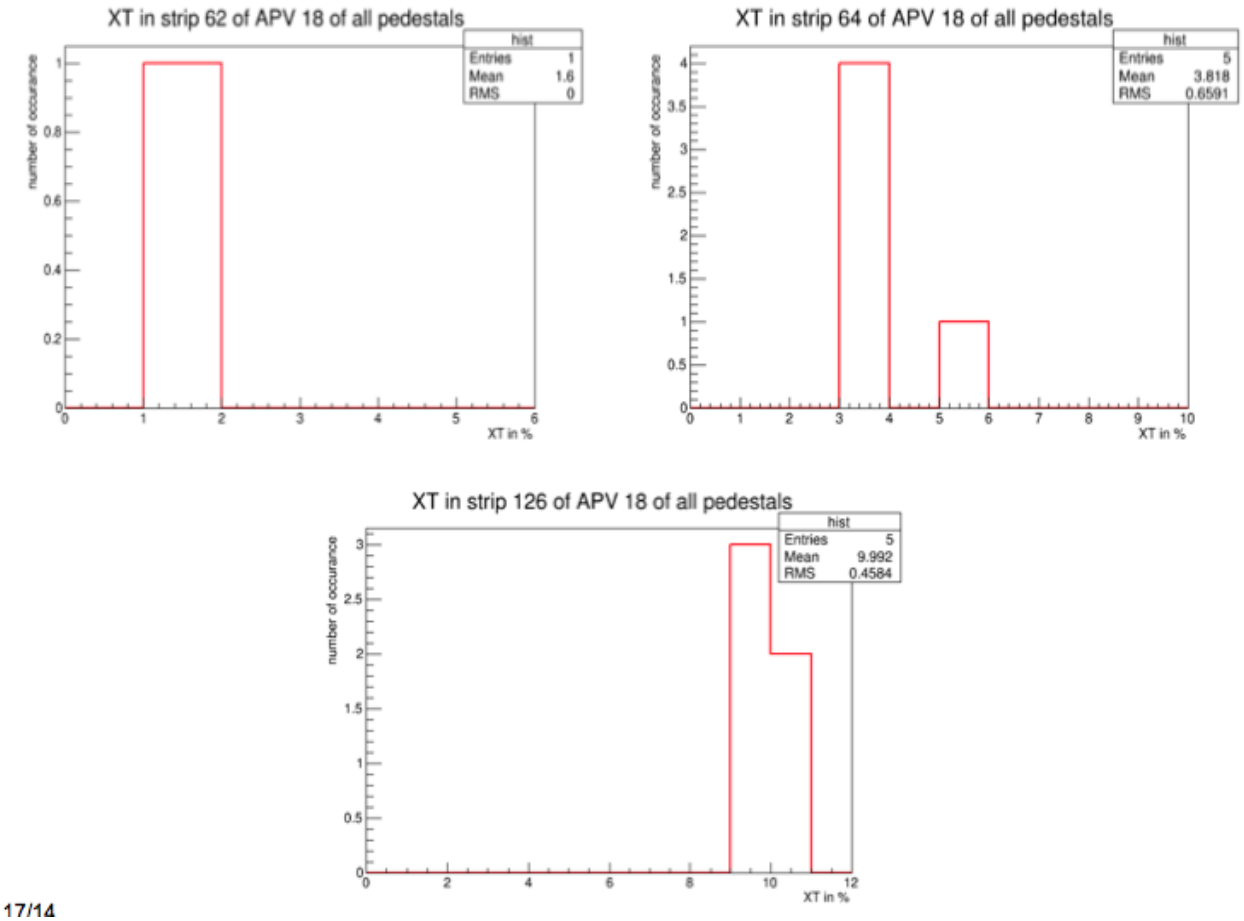


Figure 1.16: Total XT in APV 17 of all pedestals.

APV 18

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	0.00	3.51	10.21	4.57
Pedestal 6	1.60	5.07	10.77	5.81
Pedestal 7	0.00	3.32	9.82	4.38
Pedestal 8	0.00	3.88	9.46	4.45
Pedestal 9	0.00	3.31	9.70	4.34
Average	0.32	3.82	9.99	4.71

SD 62	SD 64	SD 126	SD APV 18
0.72	0.74	0.51	0.62
SDOM 62	SDOM 64	SDOM 126	SDOM APV 18
0.32	0.33	0.23	0.28



17/14

Figure 1.17: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 18 of all pedestals.

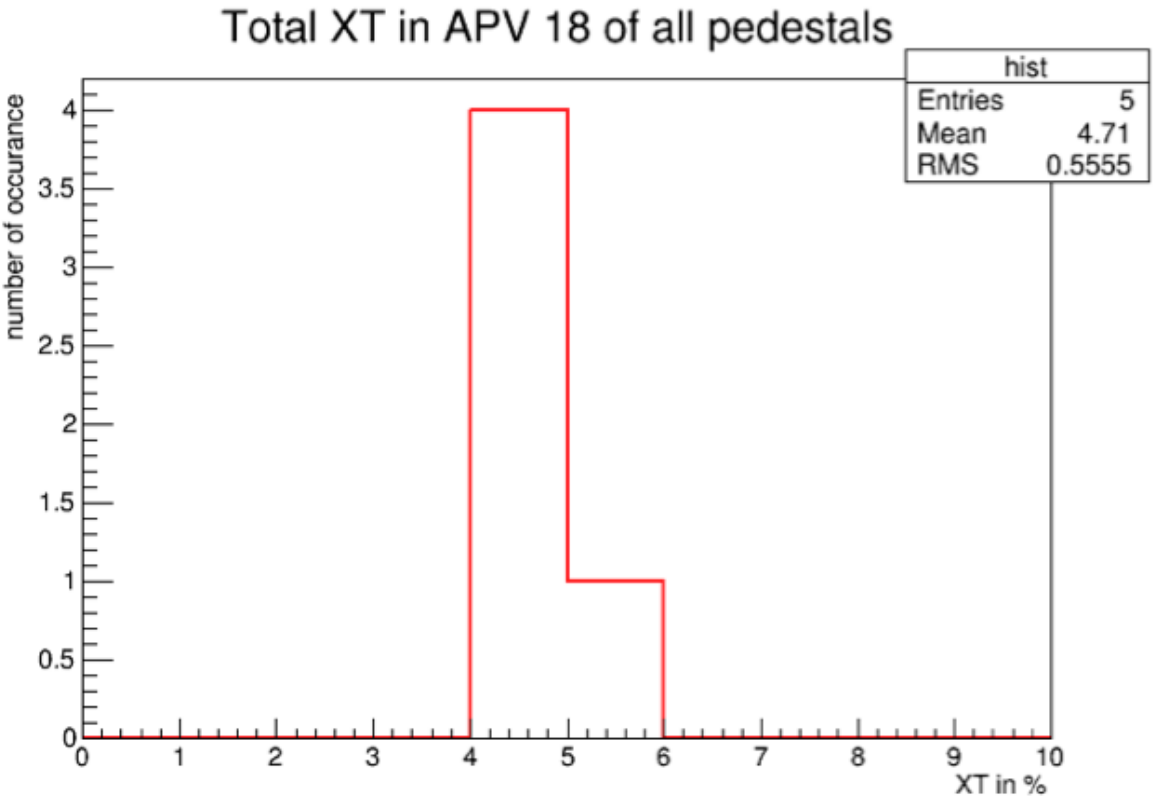
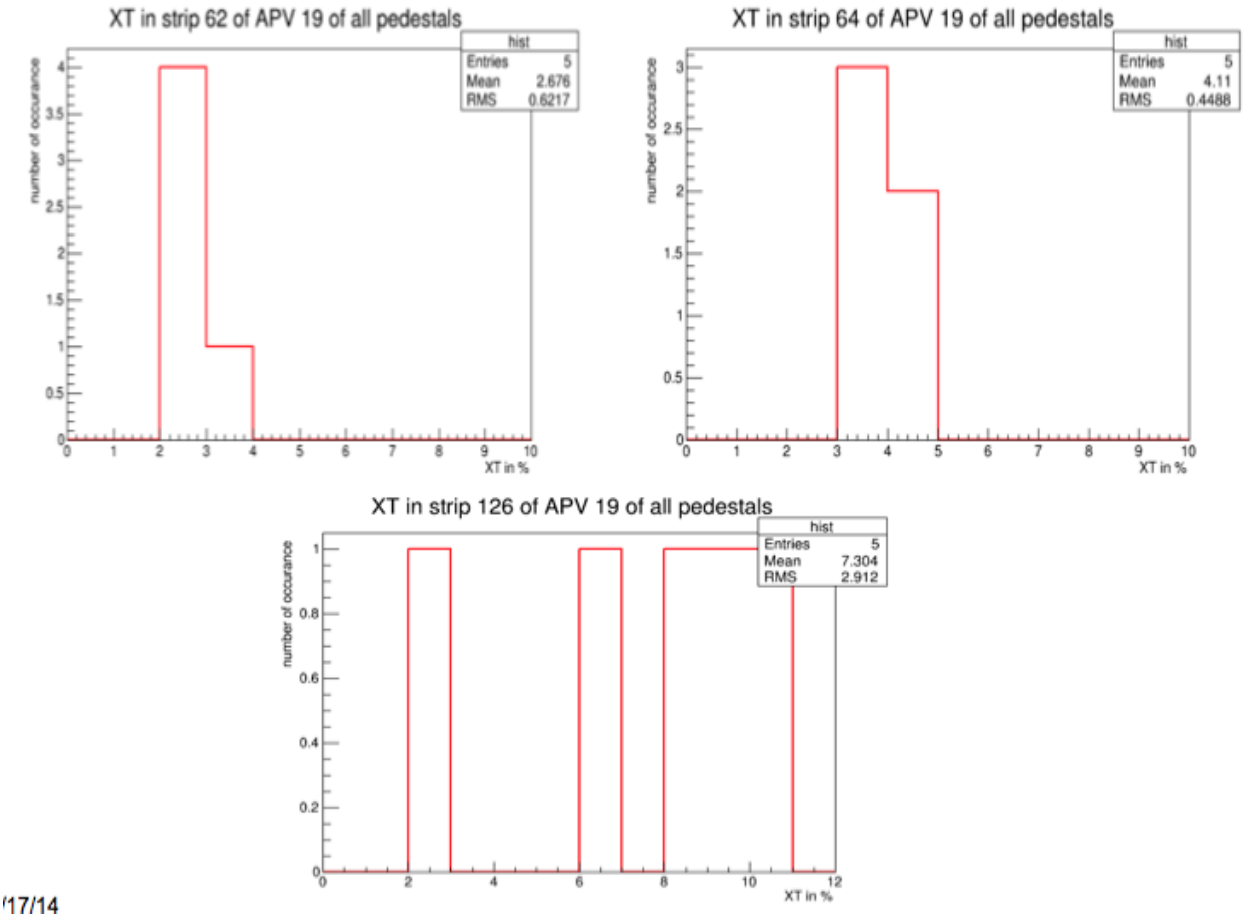


Figure 1.18: Total XT in APV 18 of all pedestals.

APV 19

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	2.50	4.42	10.50	5.80
Pedestal 6	3.84	4.82	9.12	5.93
Pedestal 7	2.04	3.66	6.81	4.17
Pedestal 8	2.30	3.97	8.08	4.78
Pedestal 9	2.70	3.68	2.01	2.80
Average	2.68	4.11	7.31	4.70

SD 62	SD 64	SD 126	SD APV 19
0.70	0.50	3.25	1.29
SDOM 62	SDOM 64	SDOM 126	SDOM APV 19
0.31	0.22	1.46	0.58



'17/14

Figure 1.19: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 19 of all pedestals.

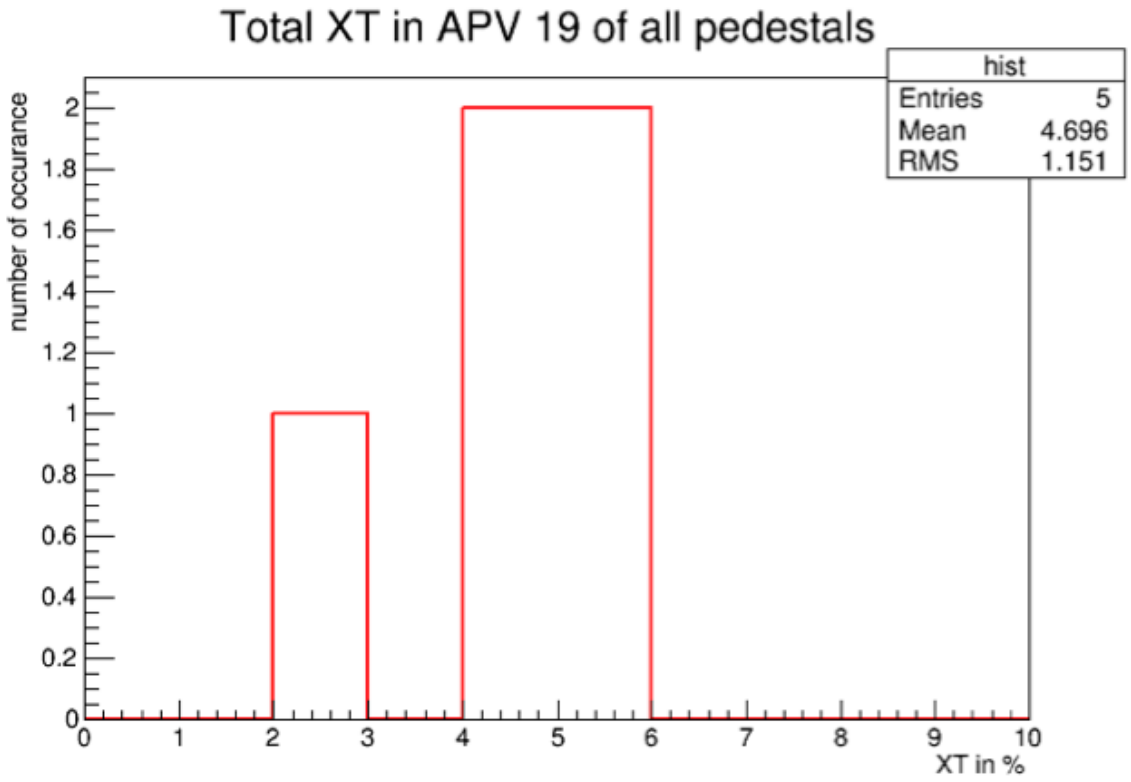
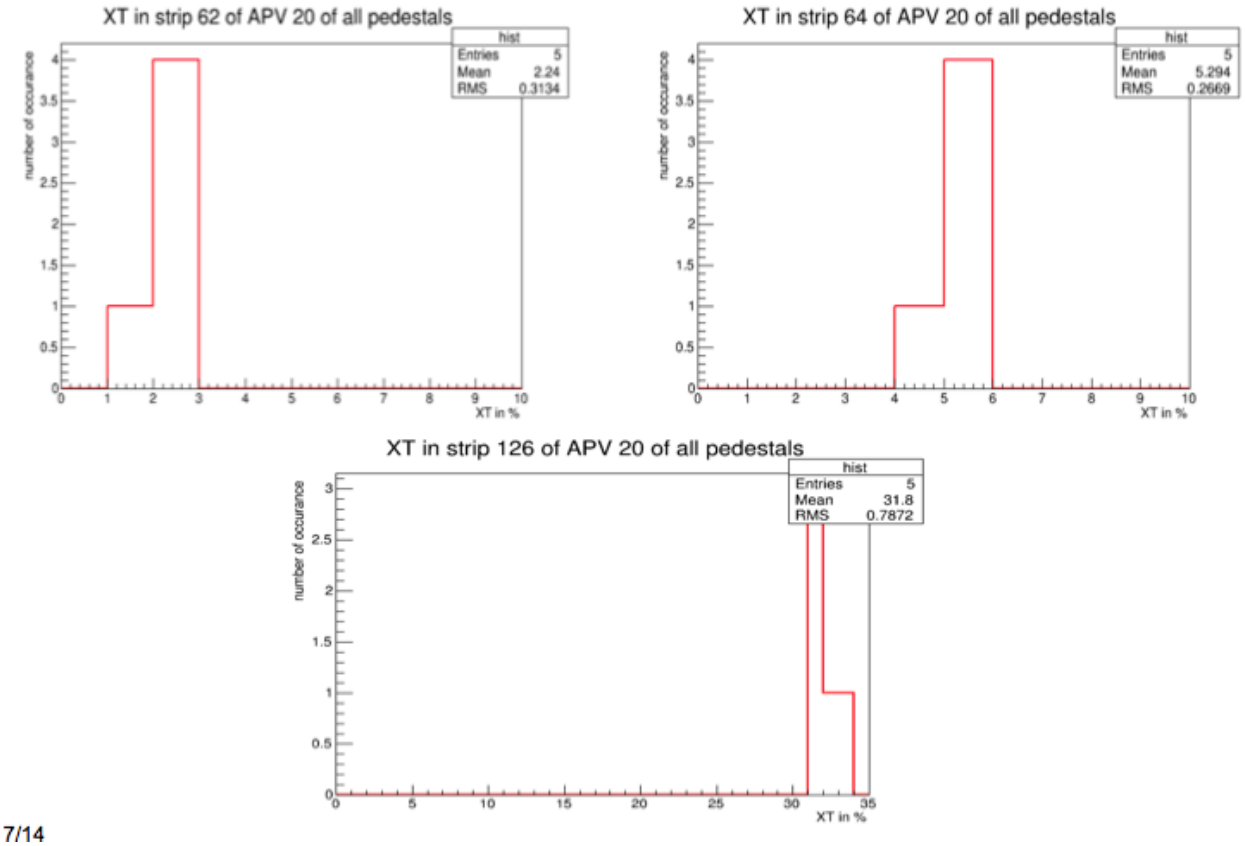


Figure 1.20: Total XT in APV 19 of all pedestals.

APV 20

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	2.23	5.31	31.16	12.90
Pedestal 6	2.75	5.67	33.15	13.86
Pedestal 7	1.76	4.96	31.22	12.65
Pedestal 8	2.22	5.49	32.24	13.31
Pedestal 9	2.24	5.04	31.22	12.83
Average	2.24	5.29	31.80	13.11

SD 62	SD 64	SD 126	SD APV 20
0.35	0.30	0.88	0.48
SDOM 62	SDOM 64	SDOM 126	SDOM APV 20
0.16	0.13	0.39	0.22



7/14

Figure 1.21: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 20 of all pedestals.

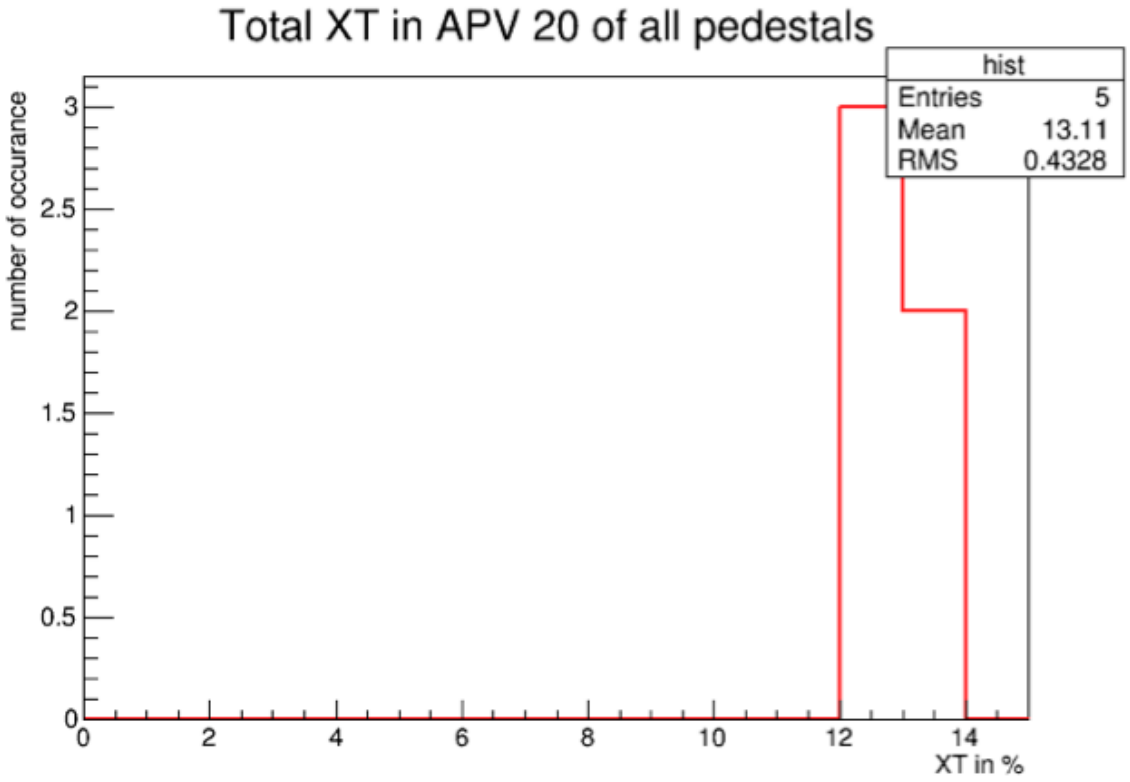
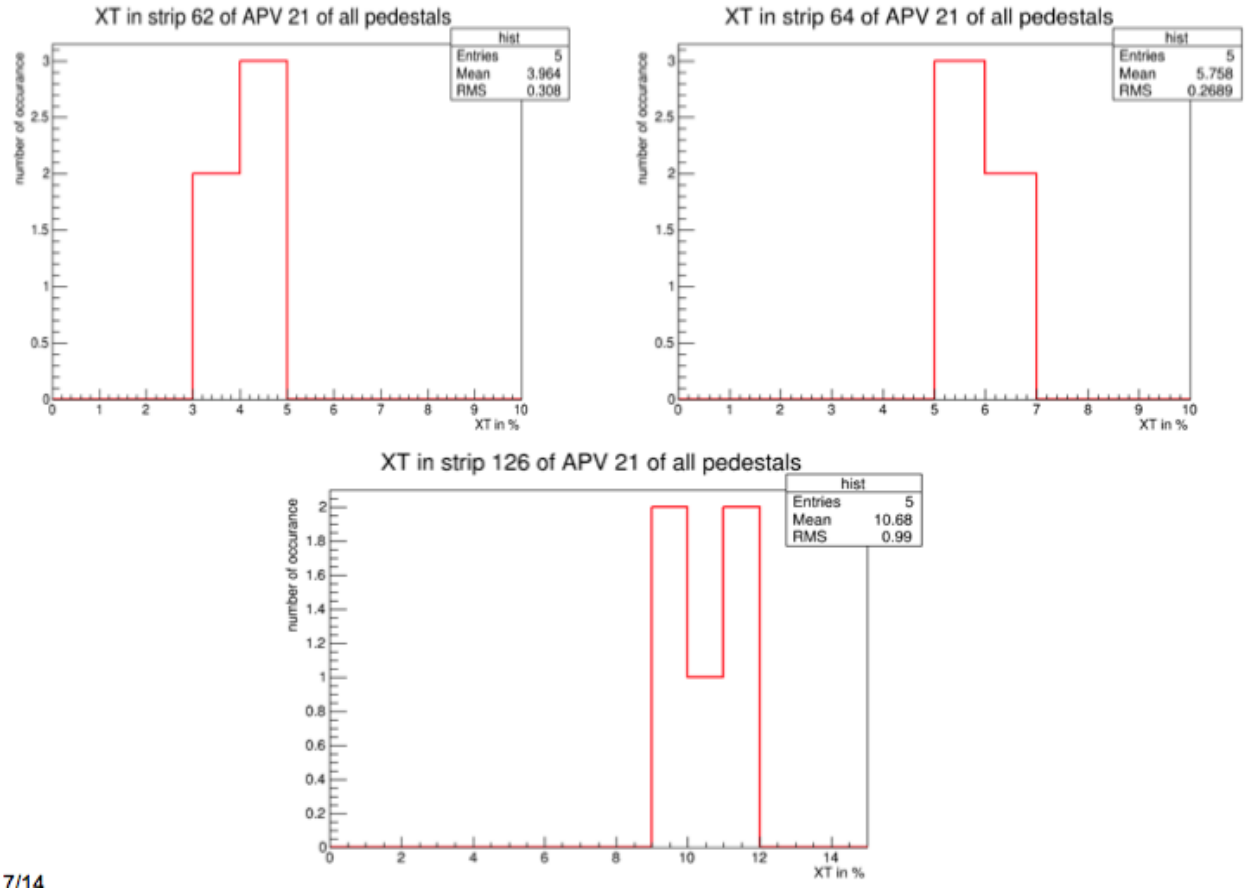


Figure 1.22: Total XT in APV 20 of all pedestals.

APV 21

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	4.06	5.75	11.90	7.24
Pedestal 6	4.39	6.10	11.83	7.44
Pedestal 7	3.49	5.37	9.72	6.19
Pedestal 8	4.11	6.00	10.27	6.79
Pedestal 9	3.77	5.57	9.68	6.34
Average	3.96	5.76	10.68	6.80

SD 62	SD 64	SD 126	SD APV 21
0.34	0.30	1.11	0.54
SDOM 62	SDOM 64	SDOM 126	SDOM APV 21
0.15	0.13	0.49	0.24



7/14

Figure 1.23: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 21 of all pedestals.

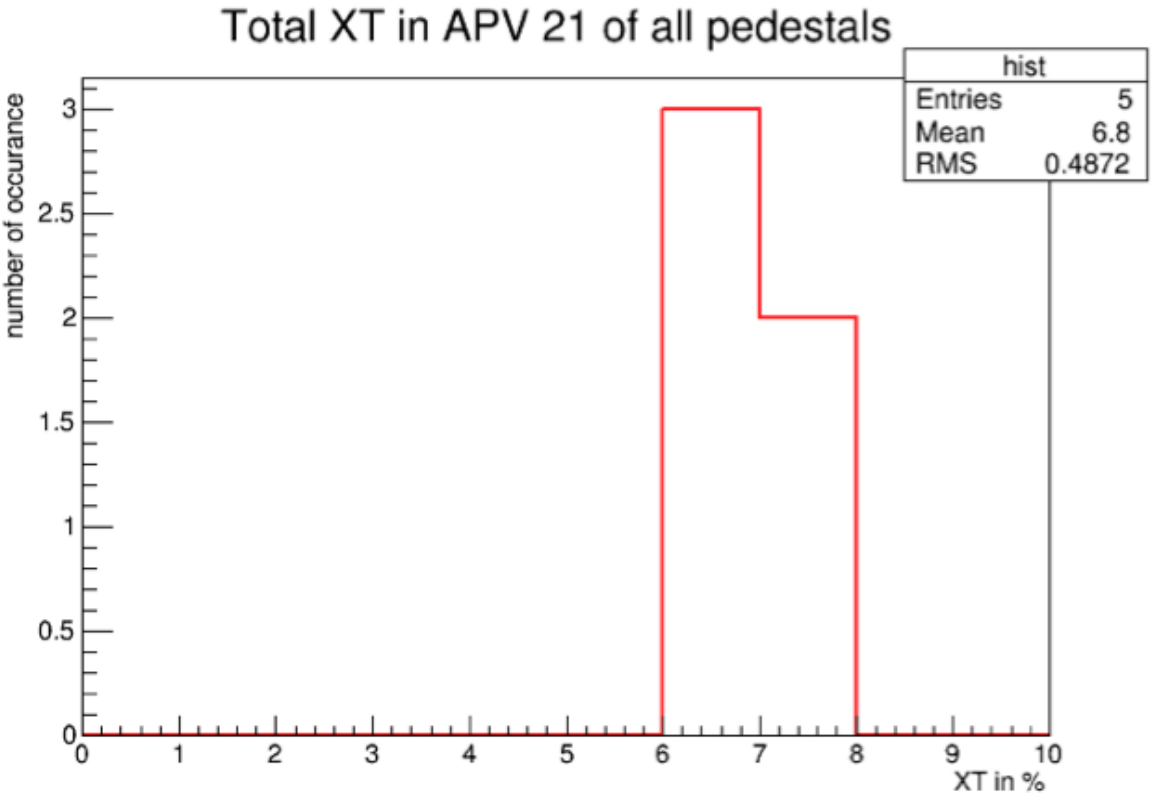


Figure 1.24: Total XT in APV 21 of all pedestals.

APV 22

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	3.84	5.51	10.52	6.62
Pedestal 6	4.38	6.12	11.75	7.42
Pedestal 7	4.09	5.51	10.68	6.76
Pedestal 8	4.36	5.86	10.71	6.98
Pedestal 9	3.37	4.86	9.62	5.95
Average	4.01	5.57	10.66	6.75

SD 62	SD 64	SD 126	SD APV 22
0.42	0.47	0.76	0.54
SDOM 62	SDOM 64	SDOM 126	SDOM APV 22
0.19	0.21	0.34	0.24

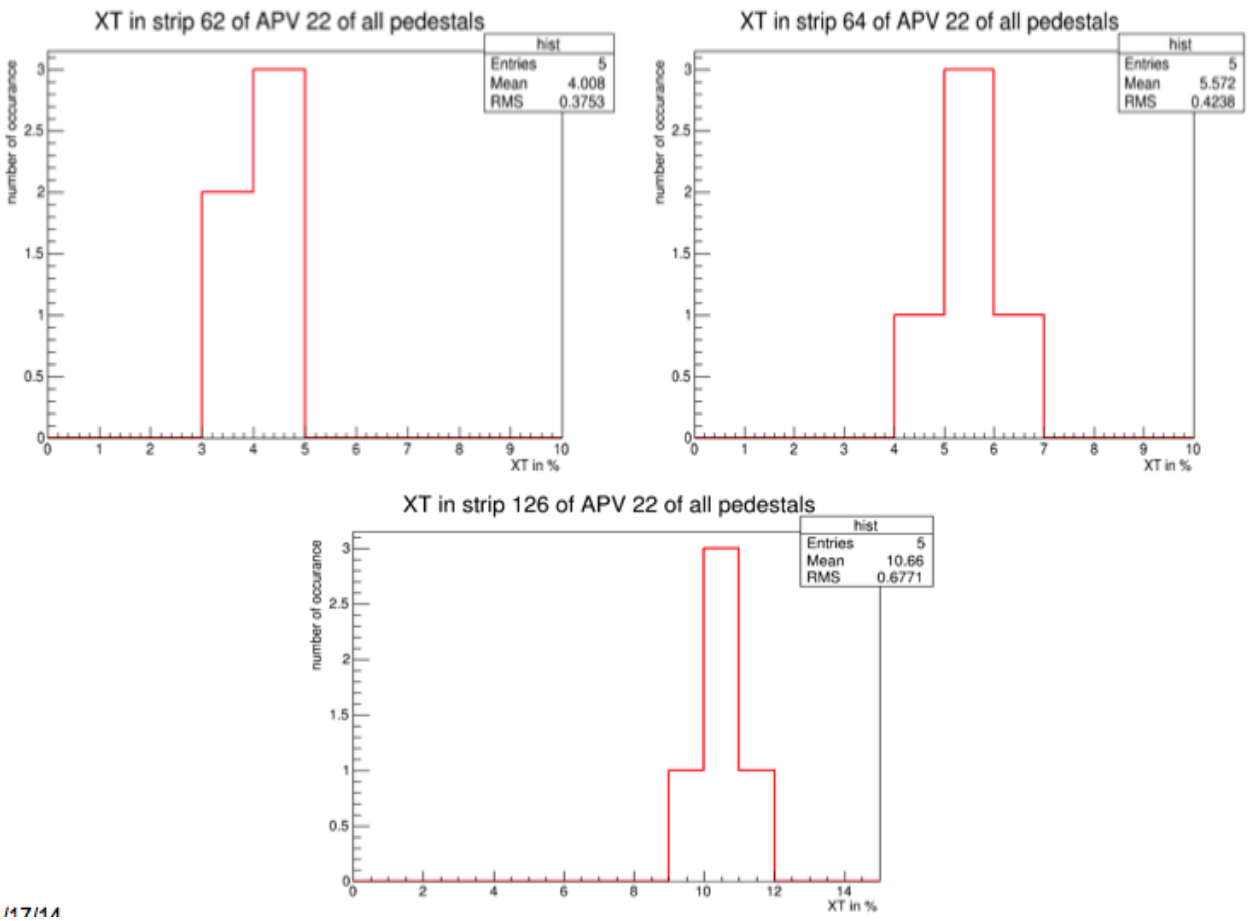


Figure 1.25: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 22 of all pedestals.

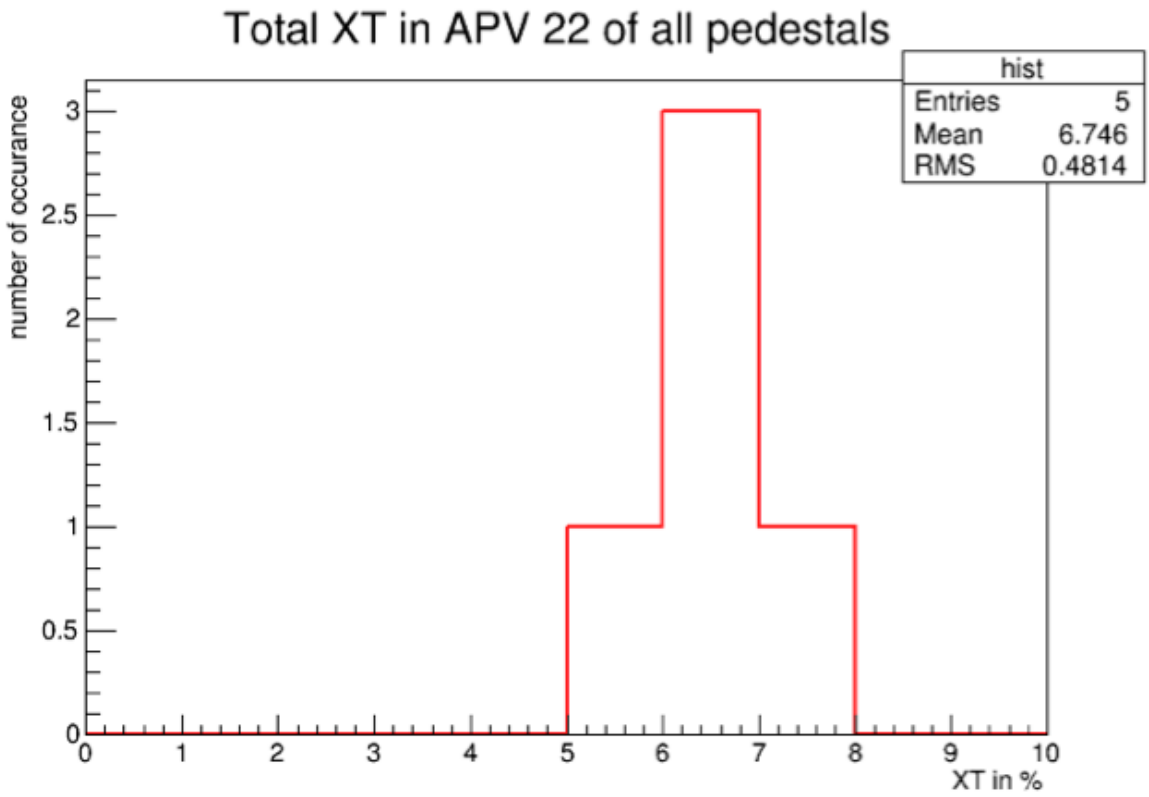


Figure 1.26: Total XT in APV 22 of all pedestals.

APV 23

Pedestals	XT in 62 In %	XT in 64 In %	XT in 126 In %	total XT In apv 16 In %
Pedestal 5	3.00	5.27	10.29	6.19
Pedestal 6	4.07	6.52	12.20	7.60
Pedestal 7	2.76	5.30	10.28	6.11
Pedestal 8	2.44	5.11	9.88	5.81
Pedestal 9	2.81	5.25	10.25	6.10
Average	3.02	5.49	10.58	6.36

SD 62	SD 64	SD 126	SD APV 23
0.62	0.58	0.92	0.70
SDOM 62	SDOM 64	SDOM 126	SDOM APV 23
0.28	0.26	0.41	0.32

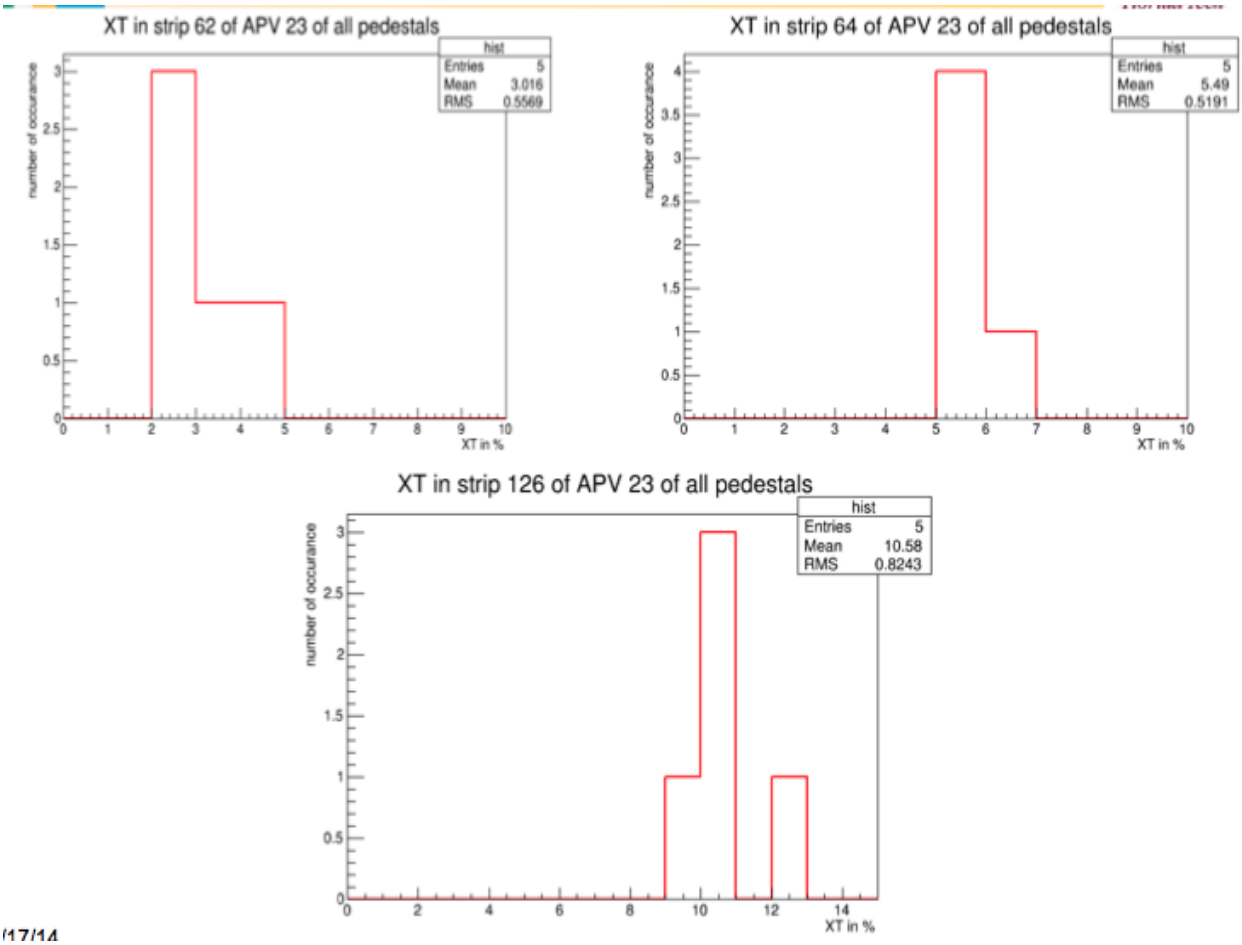


Figure 1.27: Histogram showing the XT values and their frequency in the victim strips 62, 64 and 126 for just APV 23 of all pedestals.

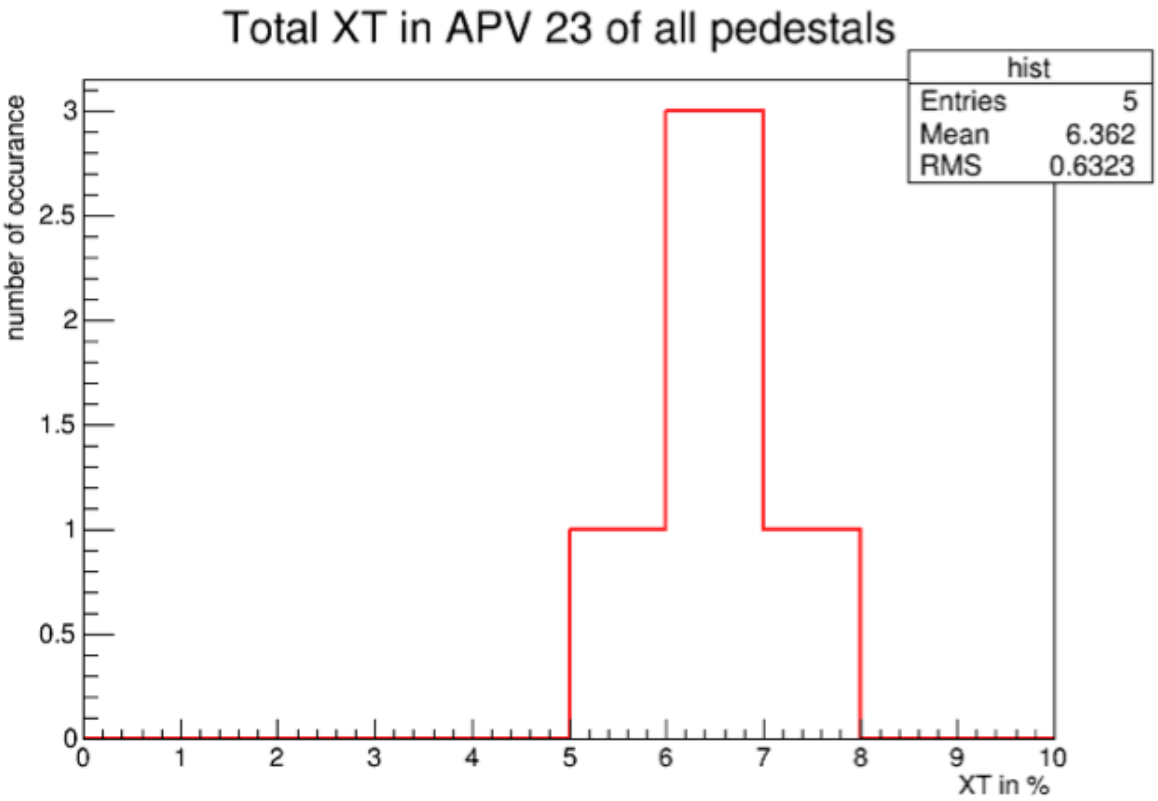


Figure 1.28: Total XT in APV 23 of all pedestals.

XT coefficients

CMS_ZZ	connected to:	pitch in mm	XT coefficient using eq 1
Eta1	APV 16	2.02	0.69
Eta2	APV 17	2.16	0.66
Eta3	APV 18	2.30	0.63
Eta4	APV 19	2.45	0.60
Eta5	APV 20	2.61	0.57
Eta6	APV 21	2.78	0.54
Eta7	APV 22	2.97	0.50
Eta8	APV 23	3.18	0.47

Summary

Following is the summary of the mean cross-talk. One table represents mean cross-talk comparing each pedestals. The other one shows mean cross-talk comparing each APV.

Pedestals	XT ± SDOM (in %)
pedestal 5	5.53 ± 0.50
pedestal 6	6.6 ± 0.33
pedestal 7	5.15 ± 0.46
pedestal 8	5.32 ± 0.47
pedestal 9	4.9 ± 0.51

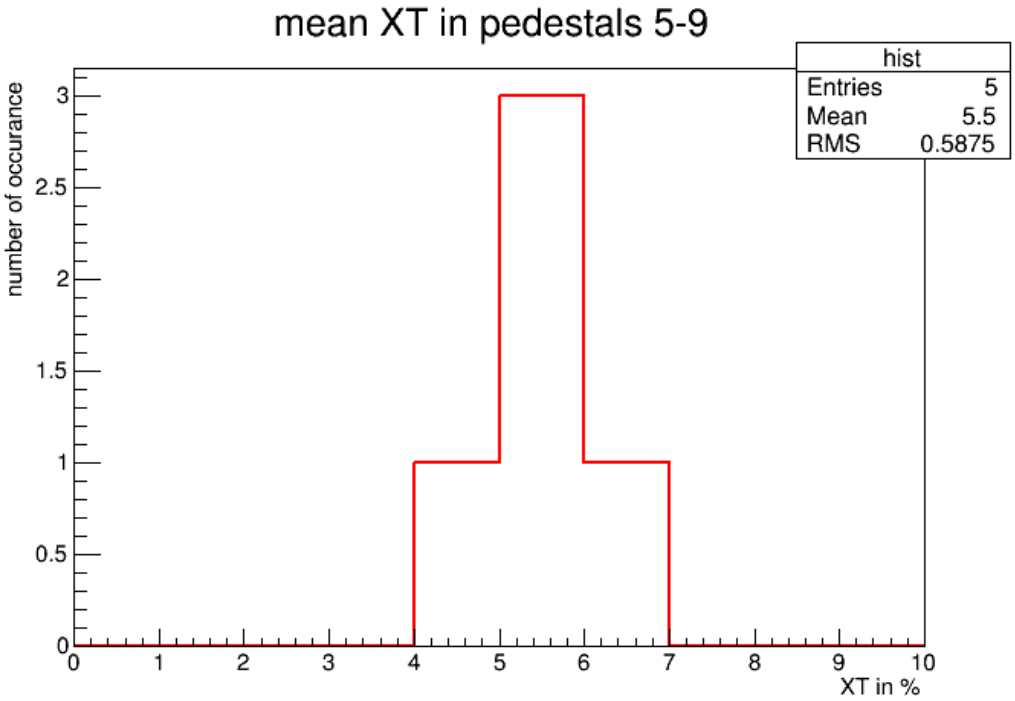


Figure 1.29: mean XT in pedestals 5-9

APV's	XT ± SDOM (in %)
APV 16	4.14 ± 0.58
APV 17	5.03 ± 0.12
APV 18	4.71 ± 0.28
APV 19	4.7 ± 0.58
APV 20	13.11 ± 0.22
APV 21	6.8 ± 0.24
APV 22	6.75 ± 0.24
APV 23	6.36 ± 0.32

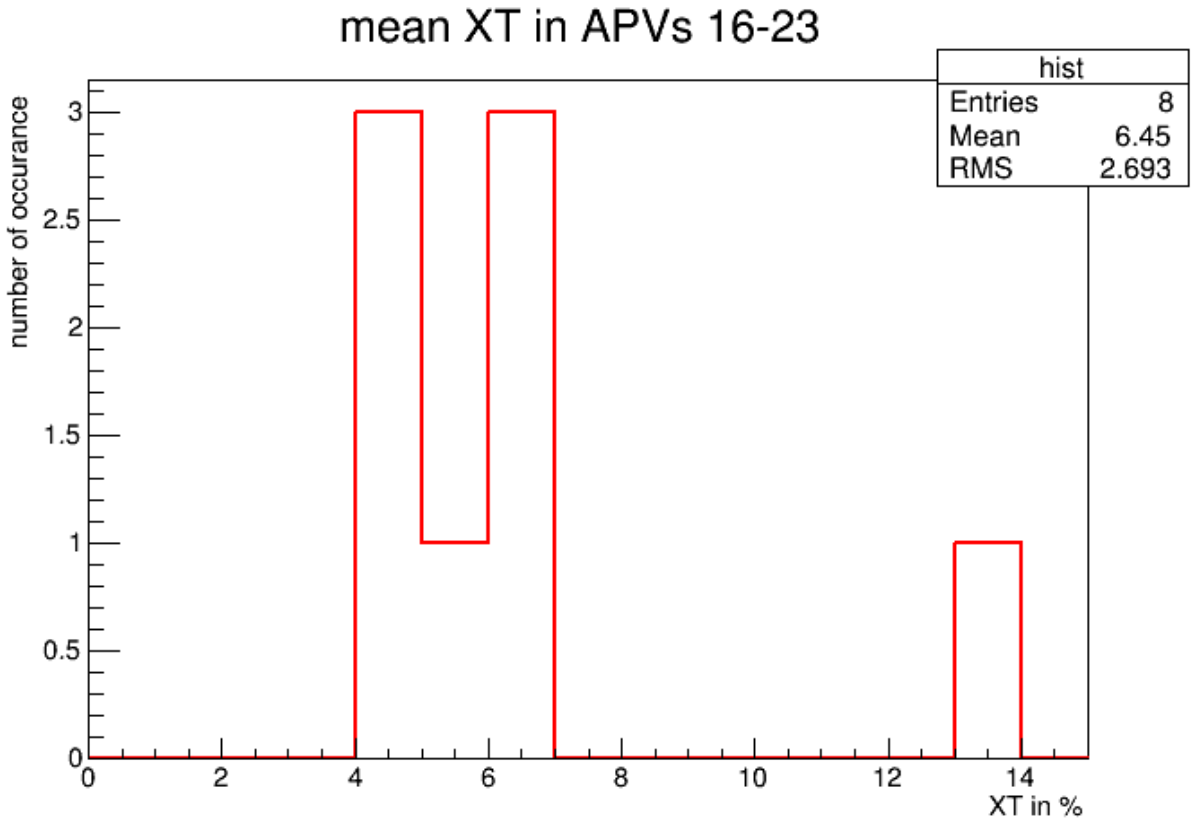


Figure 1.30: mean XT in APV's 16-23.

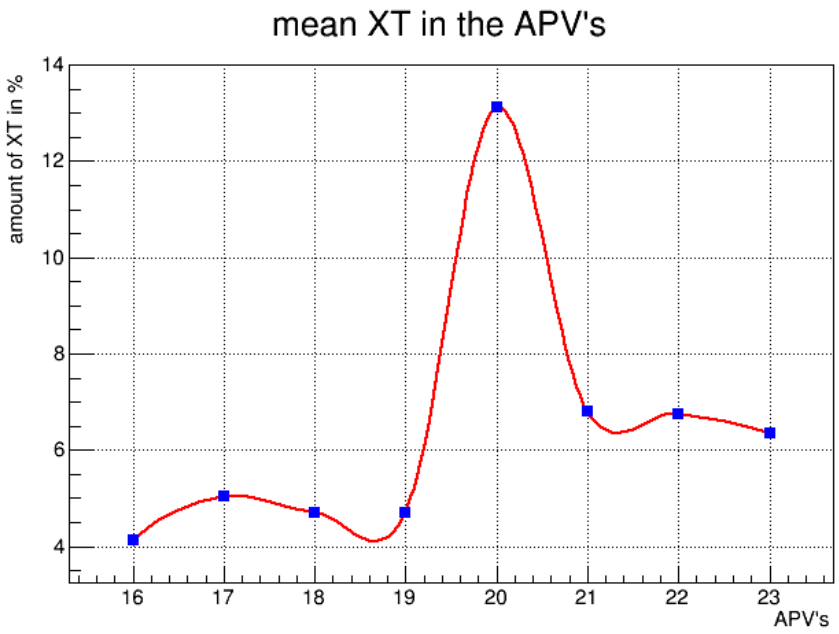


Figure 2.0: Figure showing the amount of mean XT in each APV, on average.

4. Conclusion

The tables and the histograms gave a clear idea of the cross-talk ranges in the APV's of the pedestals. The important conclusion could be taken as the highest and the lowest set of ranges which were 6%-7% and 2%-3% respectively. The ranges 6%-7% and 4%-5% occurred in more than half the APV's (10 and 9 made 19 APV's out of 35). The overall range was from 2%-8% without including the APV 20 in the mean cross-talk value. The range of cross-talk would have changed or increased significantly if the cross-talk values for APV 20 was included because of the very high value in strip 126 (until 13%!); hence, it was excluded. Further research will be continued on why was victim strip 126 of APV 20 the most affected one due to cross-talk effect. The strength of the cross talk coefficient mostly resulted in the values ranged from 0.69 to 0.47. This meant that the cross-talk strength decreased as the pitch size increased. It made sense that more the distance separation, less the cross-talk effect! Future work also includes further research on the variables affecting cross-talk such as material and distance between the source and the victim conductors.