Cross Talk in the ZigZag PCB of world's largest GEM Detector

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1. Causes

There are two ways via which coupling, or cross-talk (XT), within Gas Electron Multiplier's (GEM) Printed Circuit Boards (PCB) is possible. They are:

- **Inductance**

The conducting gold strips in our PCB act as ideal inductors when introduced to enough current; they are capable of inducing charge to the adjacent conductor.

- **Capacitance**.

Higher capacitance means stronger electric field. Hence, this field could easily be noticed in the conductor which is right next to it.

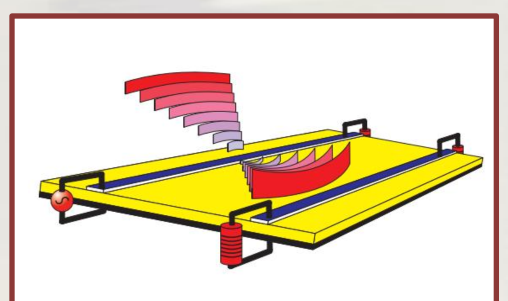

Figure 1: A source strip generating field around it causing cross-talk in the adjacent one (victim).

2. Why is cross-talk important?

Pedestal experiments are performed to measure noise in the detectors by supplying 2000 V. 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 for the new set of signals. Cross-talk in the strips causes increment in these offsets by creating unwanted noise in them i.e. increasing the uncertainty. Hence, this will have effect on the entire set of data. Datas are gained in form of histogram as shown below:

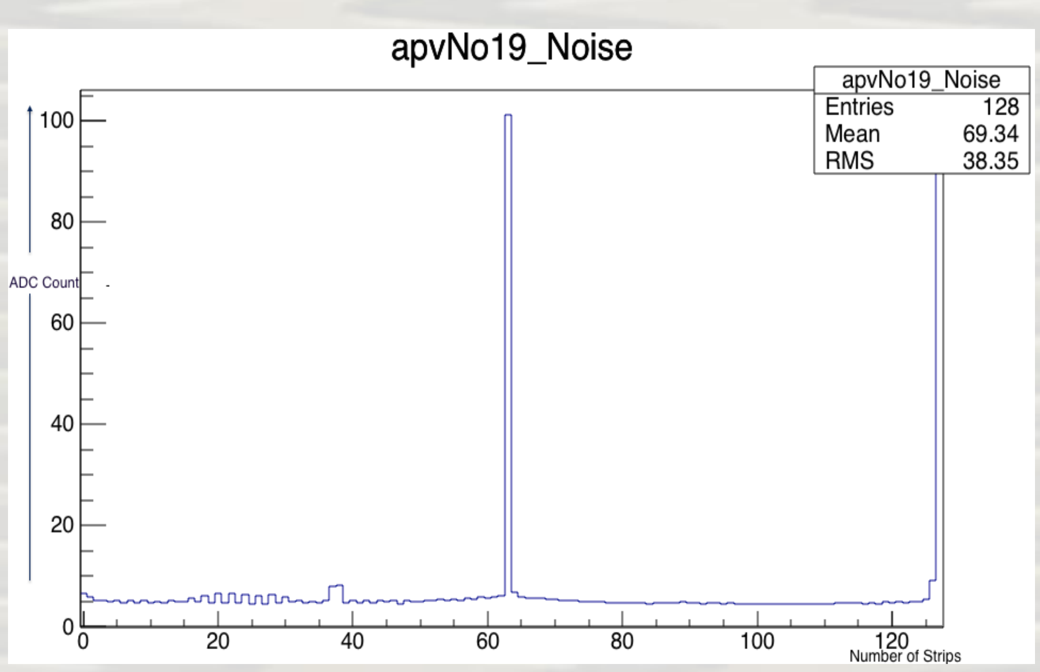

Figure 2: A histogram representing noise in APV 19 of a pedestal file.
An ADC count (y-axis in the histogram) is some amount of charge (For example: 1ADC count = 232e⁻ = 3.71*10^{-17}C).

Figure 3: A readout board of 1m /1m CMS zz.

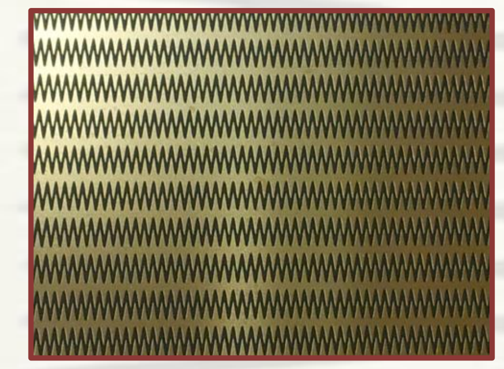

Figure 4: Zoomed in strips

3. Method

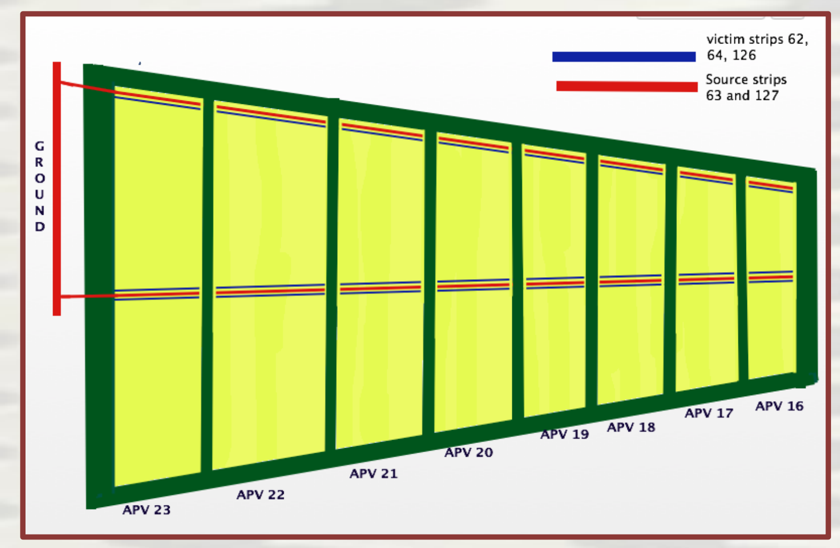

*Figure 5: A simple picture of source (red) and victim (blue) strips. (**Note: the strips are actually zigzag. They are shown straight just for easy visualizing.)***

8 APV channels were connected to the CMS'zz detector (16-23) for each of its sector, so 8 histograms data are gained for each sector. Five pedestal sets were taken for CMS'zz; hence, 8 histograms for 5 pedestal sets left 40 histograms to be analyzed.

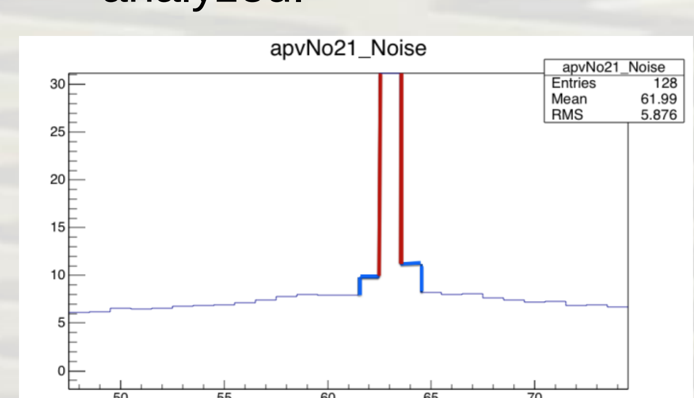

Figure 6: Zoomed in histogram of APV 21 showing cross-talk in victims 62 and 64 by source 63.

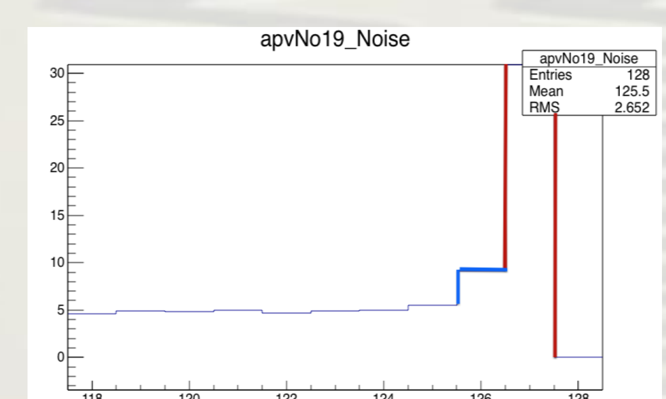

Figure 7: Zoomed in histogram of APV 19 showing cross-talk in victims 126 by source 127.

The average noise of neighboring strips around 63 and 127 was obtained**; any ADC signal in the victim strips that was more than the average noise of the surrounding strips was considered to be due to the cross-talk effect**, as shown in figures 6 and 7. The portion of charge shared by the sources into their victims was calculated by using the following equation:

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

Formula Derivation: The derivation of the cross-talk equation was done by the approach to percent difference formula. Apart from this, the values were calculated in quadrature the cross-talk represents uncertainty.

The calculations were performed three times for each of the 40 histograms—for finding cross-talk in victim strip 62, 64 and 126. A final value was achieved by calculating the mean of all 40 histograms. For example, mean cross-talk for victim 62 was the average of all the cross-talk values of strips 62 of the 40 histograms. Same goes for the other two.

4. Conclusion

The important conclusion could be taken as the most occurring ranges of cross-talk were 4%-5% and 6%-7%. Total of 6 APV's had this amount of cross-talk out of 8. The lowest occurrence were 5%-6% and 13%-14%. The range of cross-talk would have changed if the cross-talk values for APV 20 wasn't as high; because of the very high value in strip 126 (until 14%!), it raised the overall average of cross-talk for APV 20 . Further research is to be done on why was victim strip 126 of APV 20 the most affected one. The summary of results can be seen in *Figure 1.4.*

Future work also includes further research on the variables affecting cross-talk such as material and distance between the source and the victim conductors.

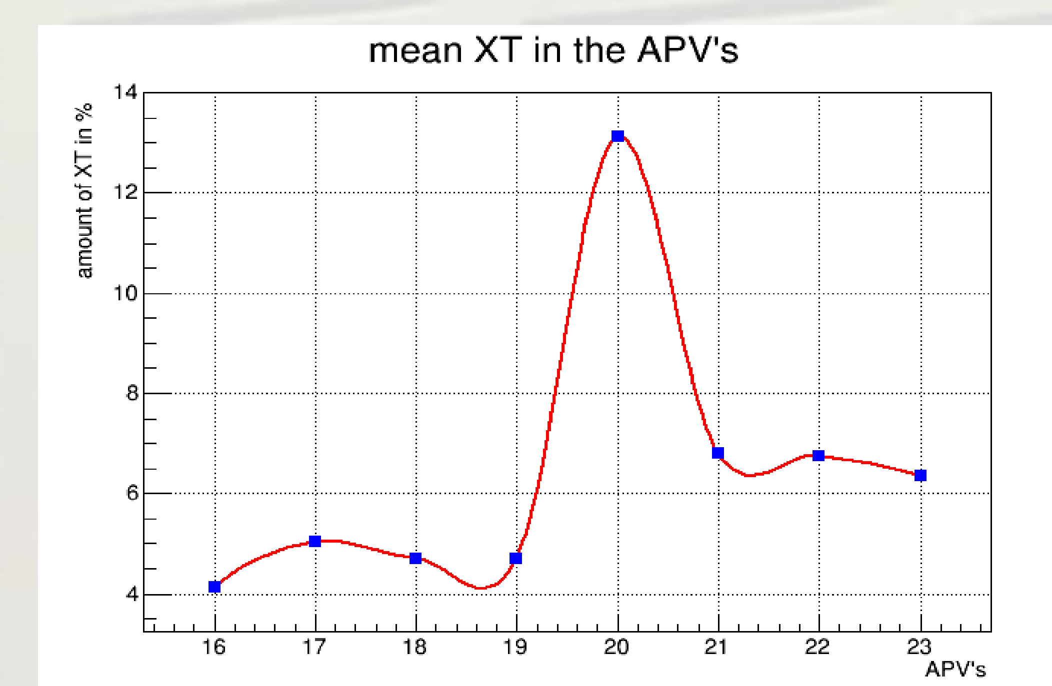

Figure 8: Plot representing the mean cross-talk in each APV.

5. Reference

- **Analysis of Multi-conductor Transmission Lines** by Clayton R. Paul