PHY 4902 Final Report: Resistance and Spurious Signal Measurements of a Low Mass GEM

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Abstract

The IV curve of the Gas Electron Multiplier (GEM) chamber within the straight strip sector of a Low Mass GEM detector was measured. From this curve, it was determined that the resistance of the GEM chamber is 5.75 MΩ and that the chamber is Ohmic as expected. The spurious signal was also measured and plotted against the GEM chamber's monitored current. The detector's spurious signal at operating voltages of 4250 V was found to be 267 Hz when the measurement threshold was set to 300 mV.

1 Introduction

The performance of experimental Gas Electron Multiplier (GEM) particle detectors at Florida Institute of Technology can be characterized by a series of quality control procedures. In particular, this study aims to complete the fourth Quality Control (QC4) measurement for all sectors of the low-mass Triple-GEM (LMG) detector being studied by doctoral candidate student Merrick Lavinsky at Florida Tech. The LMG features 13 readout sectors with three different strip geometries, including traditional straight strips and two types of experimental zigzag strip sectors. The QC4 measurements were completed for the straight strip sector, and the other sectors are to be tested in the future.

The purpose of the QC4 measurements is to determine the resistance and linear ohmic response of the GEM stack and the spurious count rate, or noise, of the detector at a certain threshold. The resistance is found via slowly increasing the applied voltage on the GEM chamber and measuring the slope of the monitored voltage against the monitored current. The resistance can be found in this way since the chamber is Ohmic. The spurious rate is a measurement of how many events are triggered per second above a certain voltage threshold and is measured using a scaler and an oscilloscope.

2 Experimental Setup

The QC4 experiments were conducted with the LMG inside a lead lined X-ray box at the Florida Tech Applied Research Laboratory (ARL).

First a support structure made from 80-20 K-bars was built for the LMG to be hung from with plastic zip ties. The structure needed to be built such that it was able to fit inside the X-ray box with no conductive material in contact with the GEM. After this, large acrylic sheets were cut, drilled into, and tied together to form a shield around the detector. This is vital for safety reasons considering the high voltages (up to 2000 V) induced on the carbon fiber frame of the GEM. The acrylic also helps to act as a barrier to protect the GEM foil from accidental puncturing with sharp tools. This experimental setup can be seen in Figure 1.

Figure 1: LMG detector inside the X-ray box. The LMG is surrounded by acrylic shielding to protect from high voltages. During operation, an additional sheet of acrylic rested over the LMG so that it is completely enclosed. Additionally, it can be seen that the GEM foil is properly inflated.

The LMG was then connected to gas, and CO_2 was flowed into the GEM foil at a rate of 130 mL/min. The LMG was also connected to electrical and its output signal was first sent to a preamplifier, then an amplifier, and finally to a CAEN unit to control the input voltage of the LMG's GEM stack, window, and frame. The GECO control software was used to send commands to the CAEN from a PC and to record the monitored voltages and currents of the LMG.

The high voltages being used require a high voltage filter between the CAEN unit and the GEM, and one was soldered as seen in Figure 2. This low pass filter is necessary for filtering out high frequency noise that results from operating at high voltages.

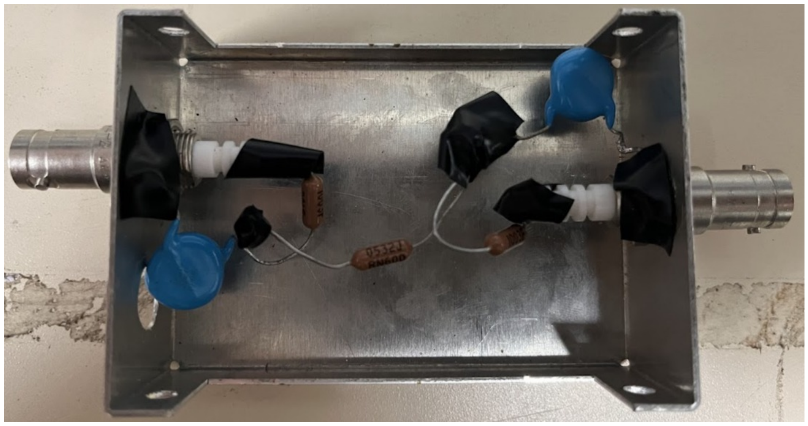

Figure 2: Soldered HV filter. The electrical tape was added for protection against electrical arcing. The resistors in the circuit have a resistance near 100 kΩ and the capacitors a capacitance near 2.2 nF.

On top of this HV filter, extensive grounding with copper sashes and copper tape needed to be applied to the system to further eliminate sources of background noise.

An oscilloscope was connected to the output of the straight strips sector of the LMG to monitor the background signal being received at the various set voltages. An example signal of the baseline noise with no input voltage is shown in Figure 3. It can be seen that the signal peaks slightly above 200 mV.

Figure 3: Oscilloscope reading of baseline noise in LMG straight strip sector.

To measure the spurious counts, a scaler was also connected to the output of the LMG. The scaler is used for this purpose over the oscilloscope as it is considered to be more reliable at high count rates (high voltages). However, the scaler does not display what the current threshold is set to, while the oscilloscope's threshold can be set to specific mV values. The threshold of the scaler therefore needs to be set by syncing its count rate with that of the oscilloscope at low operating voltages. For the experiment, the threshold was initially set to 220 mV. Later, the entire procedure was repeated at a higher threshold of 300 mV.

To take a spurious rate measurement, the number of counts over a ten second period were recorded and divided by ten seconds to give the counts per second. If it was observed that the count rate fluctuated significantly, multiple trials were taken and averaged.

3 QC4 Results

The QC4 measurements were conducted on the straight strip sector of the LMG, as well as its frame and window. The GEM stack voltage was slowly ramped from 500 V to the operating voltage (4250 V), and the resulting monitored voltages, currents, and spurious count rates are given in Table 1.

Table 1: Monitored voltages and monitored currents for the straight strip sector GEM chamber, the window, and the frame of the LMG. Additionally, the spurious rate (with a threshold of 220 mV) is given with an estimated uncertainty. All voltages have an uncertainty of 0.1 V, and all currents have an uncertainty of 0.05 μA.

GEM[V]	Window[V]	Frame[V]	GEM[μA]	Window[μA]	Frame[μA]	Spurious Rate [Hz]
501.0	500.0	501.0	86.6	0.00	0.05	0.0 $\pm$ 0.0
1001.2	1000.2	1001.0	173.2	0.00	0.05	0.0 $\pm$ 0.0
1501.4	1500.2	1501.0	259.9	0.05	0.05	0.5 $\pm$ 0.2
2001.2	2000.2	1501.0	346.8	0.05	0.05	19.0 $\pm$ 1.4
2501.2	2000.2	1501.2	433.7	0.05	0.05	59.8 $\pm$ 2.4
3001.0	2000.2	1501.2	520.7	0.05	0.05	133.2 $\pm$ 3.6
3251.0	2000.2	1501.2	564.2	0.05	0.05	119.0 $\pm$ 3.4
3501.0	2000.2	1801.0	607.7	0.05	0.05	177.9 $\pm$ 4.2
3800.6	2000.0	1800.8	659.8	0.05	0.05	290.4 $\pm$ 5.4
3900.6	2000.0	2000.8	677.4	0.05	0.05	796.6 $\pm$ 8.9
4000.8	2000.0	2000.8	694.8	0.05	0.05	1200.9 $\pm$ 11.0
4100.6	2000.0	2000.8	712.2	0.05	0.05	2143.3 $\pm$ 14.6
4150.8	2000.2	2000.8	721.0	0.05	0.05	2767.2 $\pm$ 16.6
4200.6	2000.0	2000.8	729.8	0.05	0.05	3397.1 $\pm$ 18.4
4250.8	2000.2	2000.8	738.5	0.05	0.05	4379.7 $\pm$ 20.9

From the data, an IV curve for the GEM chamber as shown in Figure 4 was created. The resulting plot was linear as expected, indicating that the GEM stack was Ohmic for the tested voltages. A linear fit was applied to the IV curve, and the GEM stack resistance is given by the slope as 5.75 MΩ.

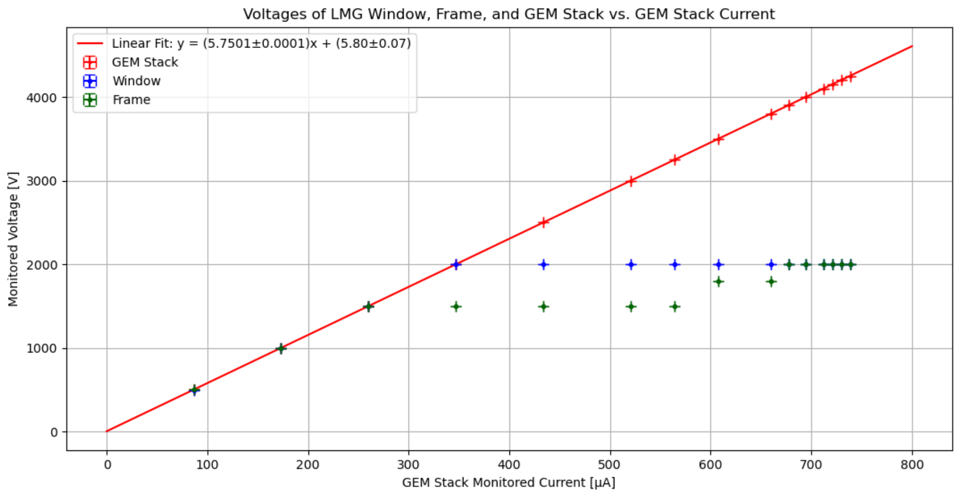

Figure 4: Measured IV curve of the straight strip sector GEM stack filled with CO_2 gas at a rate of 130 mL/min. The uncertainty bars are negligible relative to the data. Also given are the monitored voltages of the window and frame vs. the GEM stack monitored current.

Additionally, the monitored voltages on the LMG's window and frame vs. the current in the GEM stack is also provided in Figure 4.

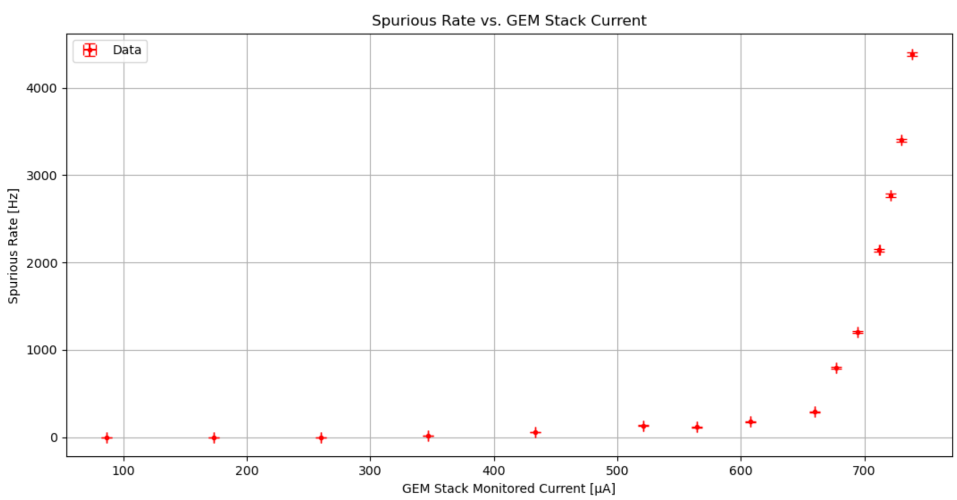

Figure 5: Spurious count rate plotted against monitored current of the GEM stack. The threshold for spurious counts was set to 220 mV.

Finally, the spurious rate at a threshold of 220 mV as a function of the current in the GEM stack is plotted in Figure 5. It can be seen that the spurious rate increases nearly exponentially with the current in the GEM.

3.1 Repeating Spurious Rate Measurement at Higher Threshold

The spurious rate measured at the final operating voltage was much higher than anticipated. A test of the spurious rate for different thresholds was done with the LMG at operating voltage. Four different thresholds were set and the spurious rate was measured for these thresholds with the GEM stack voltage set to 4250 V. A plot of the results from this test can be seen in Figure 6.

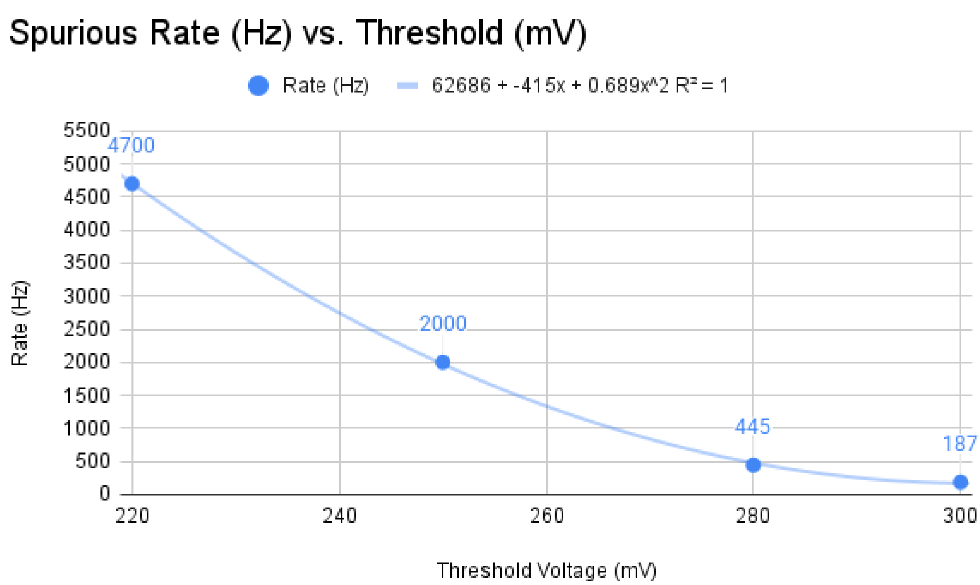

Figure 6: Measured spurious rate at different scaler thresholds with the GEM stack set to 4250 V.

It was observed that the data fit to a quadratic curve well, and from the curve it can be observed that increasing the threshold any further than 300 mV results in an insignificant decrease in spurious rate. Therefore, the spurious rate measurements were redone at a threshold of 300 mV.

The QC4 procedure was repeated for this new threshold, and the new resulting plot of spurious counts is given in Figure 7. For all new spurious measurements, four trials of measuring counts for 10 seconds were taken and averaged as the spurious rate. The IV curve of the GEM stack did not significantly change and therefore does not need to be replotted.

The new spurious count rate at operating voltage was measured as 267 Hz when the GEM stack was at operating voltage.

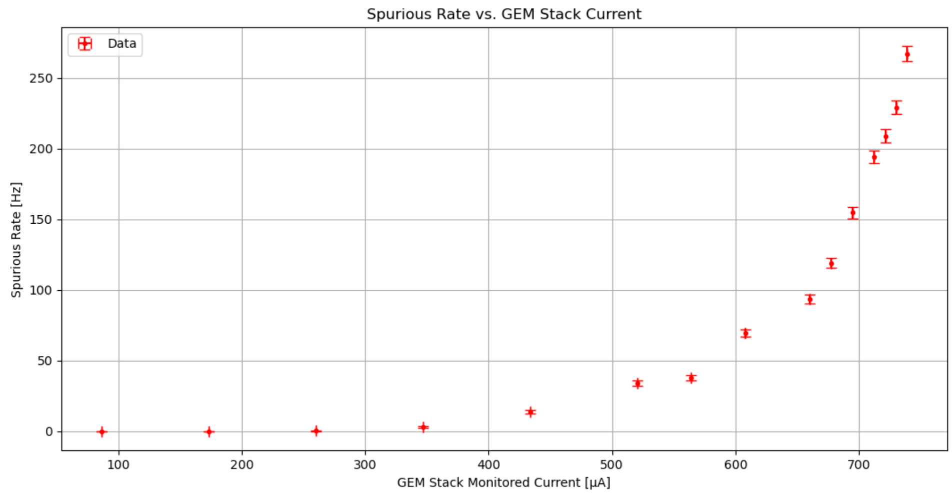

Figure 7: New spurious count rate measurements plotted against monitored current of the GEM stack. The threshold for the spurious counts was now set to 300 mV.

4 Experimental Difficulties

The main experimental hurdle was eliminating a source of periodic noise that was detected while operating near 1500 V and grew in amplitude with increasing voltage. The signal can be seen in Figure 8.

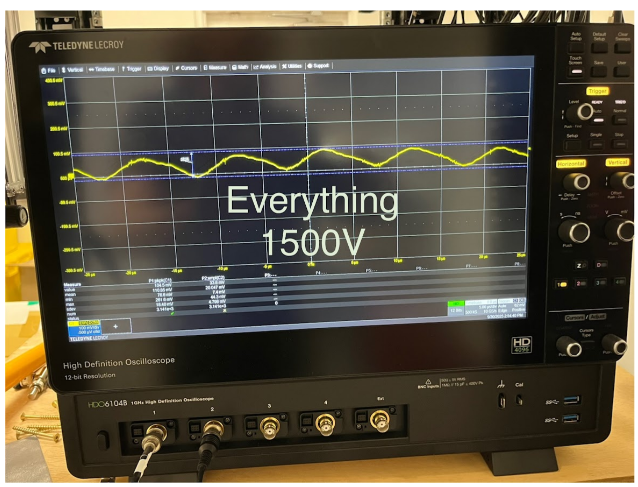

Figure 8: Periodic noise encountered while the LMG was operating at 1500 V or higher.

Much time was spent troubleshooting this problem. Some of the attempted solutions included adding more HV filters, swapping out the CAEN unit and the preamplifier, or changing the connections being used on the CAEN. Eventually the problem was solved by applying even more grounding to the system until the signal disappeared.

5 Conclusions

It was determined that the resistance of the GEM chamber for the straight strip sector of the LMG was 5.75 MΩ and the spurious rate at operating voltage of 4250 V was near 4380 Hz at a threshold of 220 mV and near 267 Hz at a threshold of 300 mV. The threshold used to find the spurious rate is somewhat higher than desired, but it is still an acceptable result.

The next steps for the characterization of the LMG are to complete the QC4 measurements for the other sectors in the same manner as was done for the straight strips. Once this is done, QC5 can be performed to measure the effective gain and gain uniformity.