EIC GEM Detector Prototype - Spring 2020 Progress Report

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Abstract

This paper briefly summarizes the work that was done on the EIC GEM Detector prototype at Florida Institute of Technology in the High Energy Physics laboratory, lead by Dr. Marcus Hohlmann, in the spring 2020 semester. Several major problems in detector construction or performance were identified during this time period and focused upon. The summary here will provide a progress report with respect to the solution of those problems and will inform future collaborators which will engage with work on this prototype. Section (1) provides a brief introduction on the state of the detector as it was at the beginning of the semester. In subsequent sections, we describe the work that was conducted throughout the semester. The report concludes with Section (5), describing anticipated progress on the prototype for the work in the near future.

This work was lead by Brendan Steffens, with substantial hardware contributions coming from Dev Roy in particular, as well as Joey Weatherwax. Additionally, we wish to thank Dr. Hohlmann, as well as both Stephen Butalla and Mehdi Rahmani, for their consistent assistance and guidance throughout the semester.

1 Initial State of Prototype

The initial state of the detector at the beginning of the semester can be seen in Figure 1. Note that the detector is un-closed, the foils are only pre-stretched with green tape (and not tensioned with screws). It is also worth noting that the top foil (the drift foil) exhibits some noticeable wear and tear.

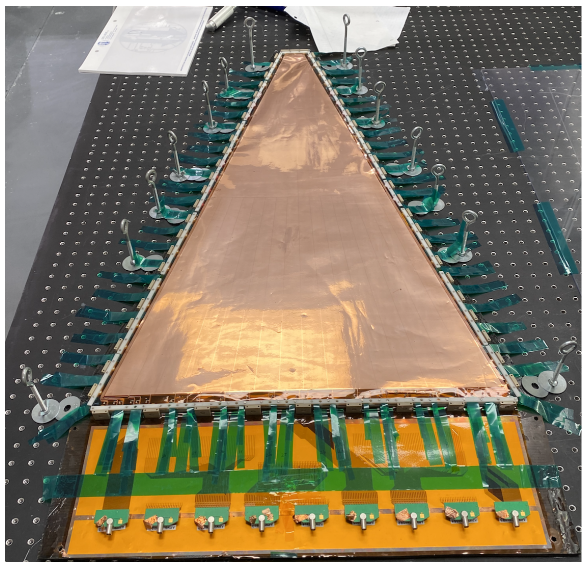

Figure 1: The prototype at the beginning of the semester. Unclosed, foils not tensioned but pre-stretched with green tape.

The initial impedances, measured in mid Janurary, are contained in Figure 2. From these measurements, it can be seen that the detector prototype initially had low impedances for all three GEM foils. Also of immediate concern are the obvious shorts present in both of the transfer gaps, evidenced by the extremely low impedance measurements of order $M\Omega$. Impedances for the induction gap were not measured at this time.

1/13/20				
	50V	100V	250V	
GEM 1	2.37 GΩ	2.17 GΩ	1.78 GΩ	
GEM 2	0.99 GΩ	778 MΩ	750 MΩ	
GEM 3	5.5 GΩ	4.4 GΩ	3.48 GΩ	
GAP D-1	10 GΩ	20 GΩ	50 GΩ	
GAP 1-2	9.96 MΩ	9.8 MΩ	9.3 MΩ	
GAP 2-3	9.89 MΩ	9.71 MΩ	9.22 MΩ	
Temperature	26.1 C	26.3 C	26.3 C	
Pressure	1024.4 hPa	1024.3 hPa	1024.4 hPa	
Humidity	49.00%	49.30%	48.40%	

Figure 2: Impedance measurements for the EIC GEM prototype early in the semester, in mid January. Problems are apparent in both transfer gaps, as well as with several of the GEM foils as well.

The plan developed in response to these measurements was to proceed with tensioning the foils, hoping that in particular, this would solve the shorts in the transfer gaps which were likely being caused by the foils sagging and coming into contact with one another. After tensioning, the plan was to flush the detector with N_2 gas, hoping that this would dry out the GEM foils and increase their individual impedances.

2 Tensioning the Foils

An immediate problem arose while attempting to tension the foils: many of the tensioning screws were somehow not landing in their respective nuts within the pull outs. Without engaging the nuts on the other side of the pull outs, the tensioning screws have no mechanism by which to hold the foils at tension. To solve this problem, we were forced to remove the top layer of internal frames, such that the drift foil could be removed (Figure 3). This exposes the next foil down, as well as the pullouts and nuts, as can be seen in Figure 4.

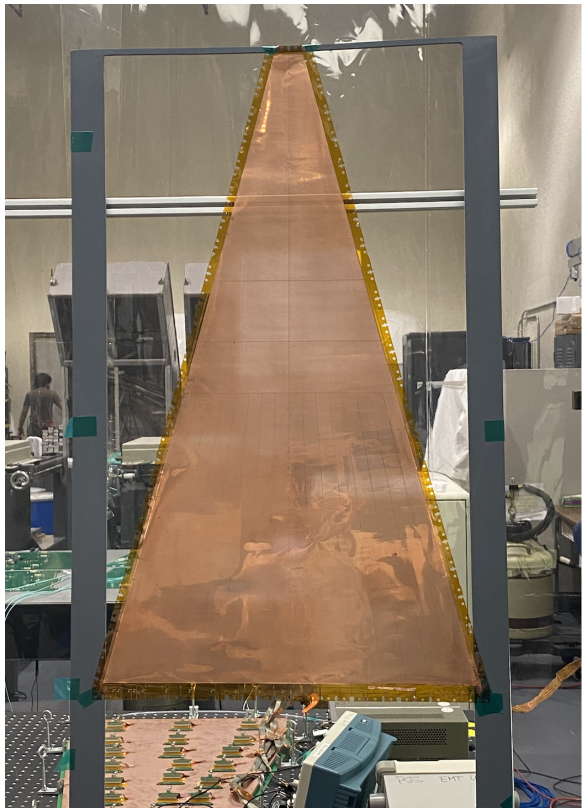

Figure 3: Drift foil removed and hanging on the wall. Unfortunately, an accident occurred at this stage of the work: the drift foil was left hanging on the wall overnight and was found to have come loose from its green tape at the top the following morning. This caused the foil to sag down and bend in half. Fortunately, the bend was gentle and un-creased, causing no additional damage to the foil. It should be noted that the foils need to be extremely well secured when hanging vertically on the wall to prevent this from happening again. Also, leaving foils hanging overnight is to be avoided, if possible.

With the drift foil removed, we were able to see that many of the nuts were sinking too low within the pullouts, causing the screws to land above them. To fix this, we simply held the nuts in place using gloved hands and tweezers, and we got the screws started in them just enough for them to be engaged. We were then able to reapply the drift foil, and screw down the top level of internal frames once again. Before doing so, however, we took this opportunity to re-pre-stretch the exposed GEM foil by removing the original tapes and installing new tapes, applying gentle tension.

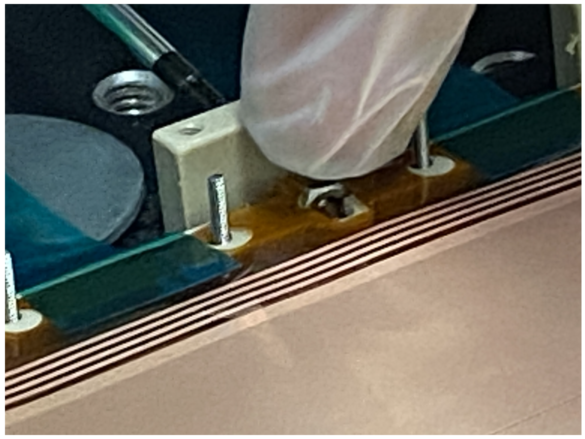

Figure 4: With the drift foil removed and hanging on the wall, the nuts for the pull out screws could be manually held in place with gloved fingers and tweezers, allowing us to get the screws started.

In removing the top layer of frames, it was discovered that loosening the extremely small (2.5 mm) metric nuts that keep these frames in place was extremely difficult using the nut drivers that were available in the high bay at the time, which were not in the best condition. To address this problem, new, precision nut drivers were ordered (Figure 5). These new nut drivers make all the difference when working with the 2.5 mm nuts for the internal frames.

Figure 5: Precision 2.5 mm nut driver. Tip for usage: when removing the 2.5 mm nuts, do not apply too much downward pressure, as this causes the nut to become stuck within the driver. If this occurs, often the nut can be knocked free with a light tap of the driver on the side of the optics bench. Otherwise, you can re-screw the nut down partially, before removing again with even less downward pressure.

After all of this work was completed, we then proceeded to tension the foils, which went smoothly. It should be noted that the torque screwdriver cannot be used in this process, as no adapter seems to exist that allows it to engage metric screws. This causes the tensioning of the EIC GEM prototype foils to be rather haphazard, and may be a problem when it comes to foils being shorted. The uneven tensioning can be seen in Figure 6, which shows the state of the detector after this phase of work.

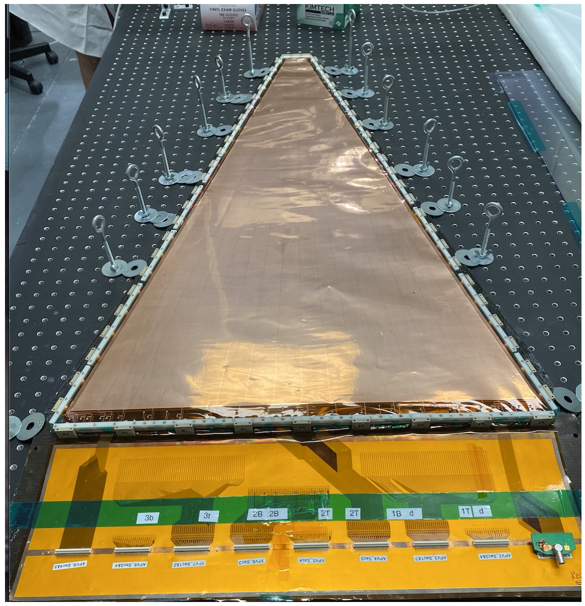

Figure 6: A picture taken of the detector after the tensioning of the foils. The lack of consistent tensioning is clearly evidenced by the ripples that remain in the drift foil.

As can be seen in Figure 6, the pre-stretching tapes were cut after this phase. An accident occurred during this stage of the work: a knife slipped and severed several of the traces leading to right-most readout panasonic. An image of this damage is shown in Figure 7. Currently, the results of this damage, if any, on detector performance, are unknown, and will need to be investigated moving forward. This will be addressed in the final section of this report.

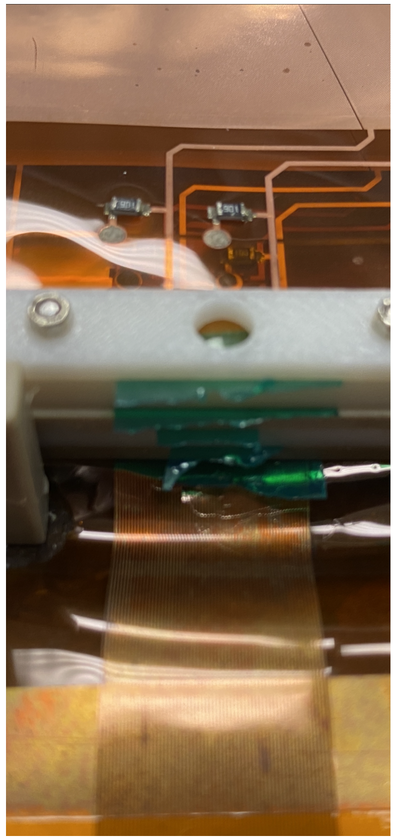

Figure 7: Damage accidentally caused to some of the traces leading to the right-most readout panasonic, labeled "APV1 - Sec 4-5". Several of the traces appear to be severed. At this time, the exact effect of this damage is unknown.

After the tensioning of the foils, the impedances were remeasured. These are contained in Figure 8.

3/02/20 - After tensioning the foils.		
	250V	500V
GEM 1	16 GΩ	>100 GΩ
GEM 2	11.5 GΩ	sparking
GEM 3	1.12 GΩ (very slow)	sparking
GAP 3-D	>50 GΩ	>100 GΩ
GAP 1-2	>50 GΩ	>100 GΩ
GAP 2-3	>50 GΩ	>100 GΩ
APV1	>50 GΩ	>100 GΩ
APV2	>50 GΩ	>100 GΩ
APV3	>50 GΩ	>100 GΩ
APV4	>50 GΩ	>100 GΩ
APV5	>50 GΩ	>100 GΩ
APV6	>50 GΩ	>100 GΩ
APV7	>50 GΩ	>100 GΩ
APV8	>50 GΩ	>100 GΩ
APV9	>50 GΩ	>100 GΩ
Temperature (C)	26.1	26.1
Pressure (hPa)	1020.4	1020.4
Rel. Humidity (%)	43.8	43.8

Figure 8: Impedances measured on March 2nd, 2020, after tensioning the foils. The induction gap impedances are labeled by which APV connector was used in the measurement.

We can see from the impedance measurements that the tensioning of the foils did in fact solve the transfer gap shorts, all of which at this time measured a maximum impedance. It can be seen though that some problems remain concerning the impedance of the individual GEM foils, whose impedances were either low, or caused sparking when measured at $500V$. The plan to address this was to flush the detector with N_2 gas and then remeasure the impedances, hoping that the N_2 gas would dry out the foils and increase their individual impedances.

3 N_2 Gas Flushing

In order to be able to flush the detector with N_2 gas, the detector needed to be closed completely, to achieve gas-tightness. New closing screws were ordered to help in this. The closed detector can be seen in Figure 9.

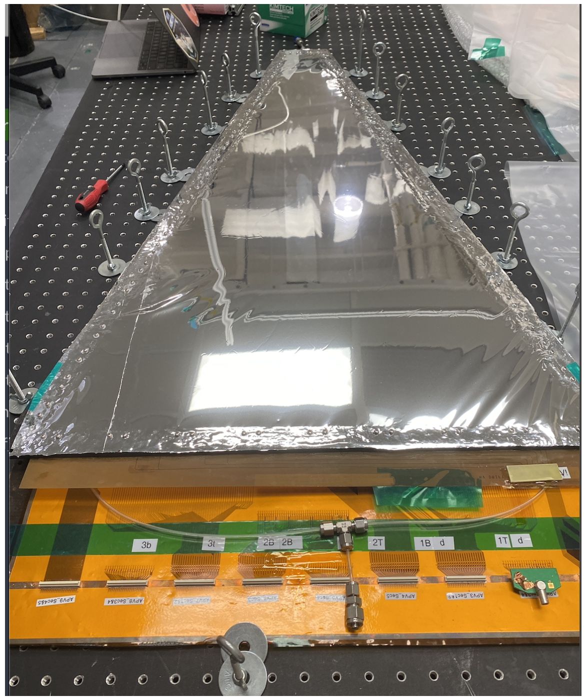

Figure 9: The detector has been closed using brand new $14mm$ closing screws and nylon/plastic washers 'borrowed' from the CMS GEM construction.

Even at max flow of N_2 gas, no outflow of gas was detected coming out of the other side of the detector. This is taken to be an indication of the lack of gas-tightness of the prototype. This is something that could be addressed in future work on the prototype.

After flushing with N_2 gas for 24 hours, the impedances were remeasured. Unfortunately, the new measurements showed a brand new short in the transfer gap between GEMS 2 and 3. Additionally, a short persists in the induction gap to $APV2$, which connects to Sectors 3 and 4.

4 State of Detector at End of Semester

The main problems with the detector presently at the end of the semester are a short in the transfer gap between GEMS 2 and 3, and a short in the induction gap to APV2. We will address possibilities as to what to do about these problems in the last section of this report.

5 Moving Forward

It seems that a lot of the problems with the detector, in particular shorts in the transfer gaps, could be solved or mitigated by more consistent tensioning of the foils. As mentioned earlier, the torque screwdriver cannot be used with the metric screws that tension the foils, and for this reason, the tensioning process for the EIC prototype is rather haphazard, and probably results in uneven or asymmetric tensioning of the GEM foils. Obviously, this can lead to shorts, as we have observed.

I spent a fair bit of time looking into adapter pieces that could allow either of our two torque screwdrivers to be used with the metric screws, but I was unable to find anything, unfortunately. Thus, I think the only solution here is to manufacture an adapter either via machining or via 3D printing. 3D printing would probably be the easiest and most time-effective approach. I would recommend printing the adapter on the highest resolution available, as the adapter needs to be able to sustain substantial torque without deforming.

Another immediate problem that should be addressed moving forward is the damage to the HV traces on the readout, mentioned previously, and shown in Figure 7. Presently, it is unknown what effect, if any, this damage will have on detector performance in the future. This should be investigated by the next HEP member working on the EIC prototype. The short exists with respect to Sectors 4 and 5. The significance of these labels can be seen in the schematic provided in Figure 10.

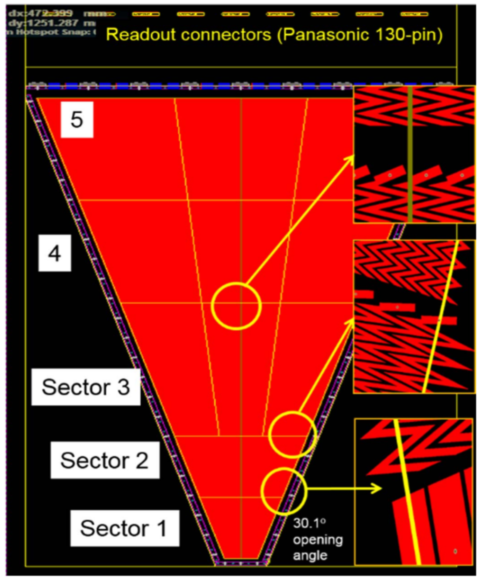

Figure 10: The layout of the EIC GEM prototype. Figure adapted from Hohlmann et. al: "A Low-mass GEM Detector with Radial Zigzag Readout Strips for Forward Tracking at the EIC".

Lastly, the apparent lack of gas-tightness of the prototype (even when fully and properly closed) needs to be addressed. We conclude by itemizing the main tasks that should be addressed moving forward:

- Develop 3D-printed or machined adapter which allows the torque screwdrivers to be used with the metric tensioning screws for the prototype.
- Investigate the damage caused to the HV traces on the readout.
- Develop plan for increasing the gas tightness of the prototype.