GEM Foil Stretching Using a Low-Cost Infrared Heating Array

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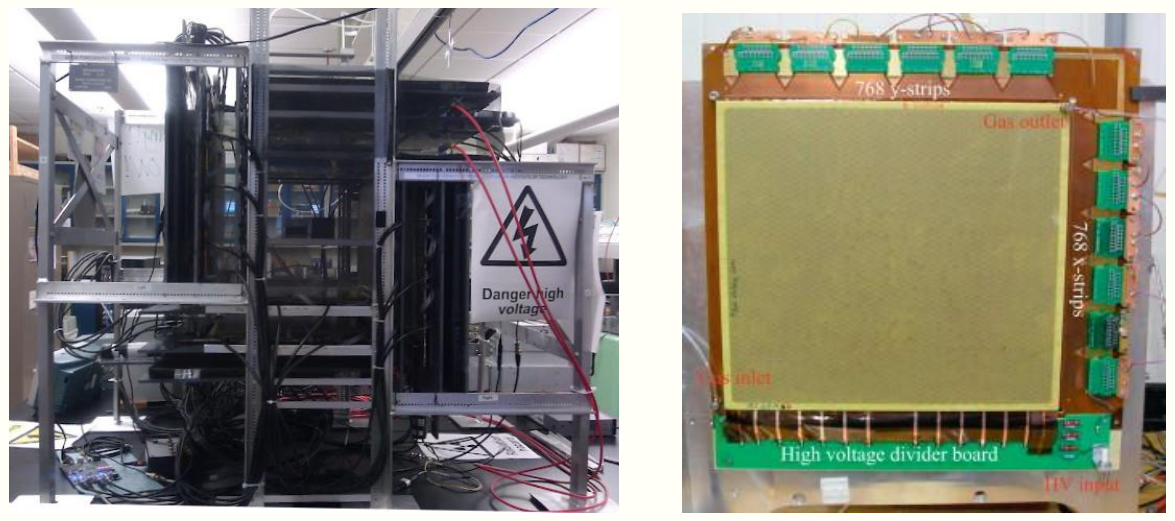
Background

Gas electron multiplier foils, or GEM foils, consist of a 50 μm thick sheet of Kapton foil covered on both sides with a 5 μm thick layer of copper. They are interspersed with 75 μm diameter holes that are spaced 140 μm apart. These foils are a crucial component of the triple-GEM detectors currently used in Florida Institute of Technology's Muon Tomography Station (MTS). The MTS, which employs eight of these detectors, uses naturally-occouring cosmic ray muons striking the detectors to detect high-Z / radioactive materials that may be shielded by lower-Z materials in an attempt to hide and smuggle them into the country. However, in order for the GEM foils to be useable as detector components, they must first be stretched to ensure they are uniform. This is usually accomplished through the use of a clean room oven, which can be a costly process and may not always be readily available.



Figures 1 & 2: The Muon Tomography Station (left), a 30 x 30 cm GEM detector (right)

Method

In order to stretch the GEM foils in a more cost-effective manner than the use of a clean room oven, an array of eight 250 W heat lamp light bulbs was produced using commercially available, off-the-shelf materials. The light bulbs, which are attached to a square aluminum frame that is hung from a hooded table, are connected to dimmer switches in pairs, allowing their intensity, and therefore their temperature, to be controlled. The foils are sandwiched into a custom Plexiglas frame, which is heated by the light bulbs for several hours. The heat from the light bulbs causes the frame to expand, tensioning the foil and providing the necessary stretching.

The first version of this array successfully produced two working 30 x 30 cm detectors. It was then scaled up to be able to heat 100 x 50 cm foils, using sixteen light bulbs instead of eight and a larger, rectangular frame. We then further modified this larger array in several ways. First we machined 1" diameter aluminum rods to support the frame. This provides much greater versatility than the previous design, as the rods can be screwed into any standard optical table and can be easily adjusted as needed.

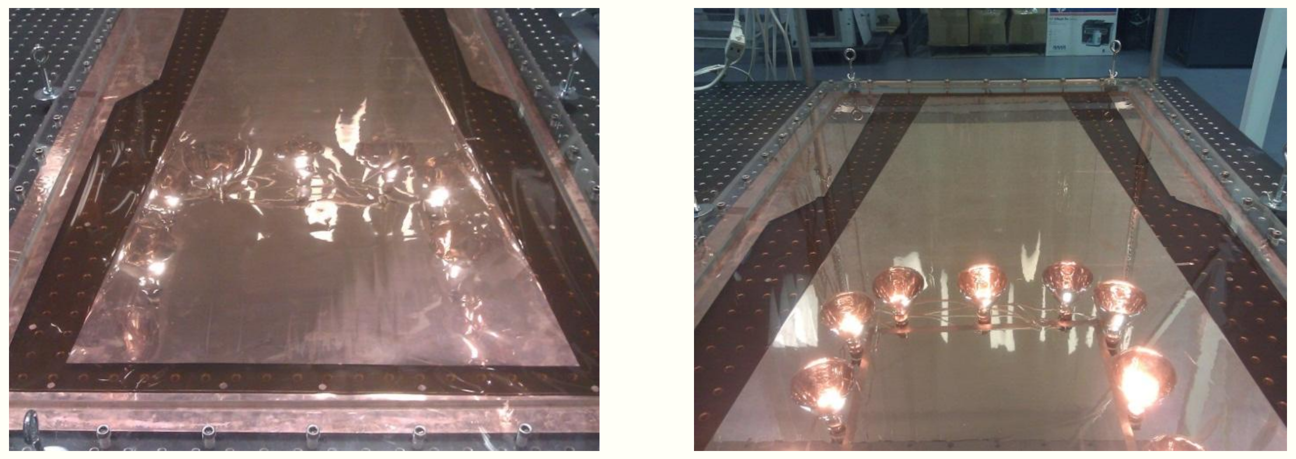
Although the 250 W light bulbs in this configuration produced a fairly even temperature profile between 45ºC and 50ºC, we found that the tension of the foils at this temperature was too high, and

◄ **Figure 3**: The modified infrared stretching array

when the detector framing was attached, the spacer ribs bowed. As such, we aimed for a lower temperature mean, namely 35ºC. This temperature was chosen as one of our aims was to see at how low of a temperature a GEM foil could be acceptably stretched, and it is only slightly lower than the temperature at which CERN currently stretches their GEM foils (37 ºC). However, when we attempted to bring the 250 W light bulbs down to 35ºC, we found that the current through them was not enough to sustain them and they would periodically shut off without warning. This was undesirable as it very clearly affected the long-term temperature stability of the array. In order to rectify this problem, we replaced the 250 W bulbs with 125 W bulbs. These new light bulbs remained in stable operation at the lower currents, allowing us to attain a stable, lower temperature profile.

Results

Using our modified infrared heating array, we were able to obtain a mean temperature of 35.12ºC, with an RMS of 0.1669. All temperature measurements were within 0.6ºC of each other. This is a factor of ten better than results obtained with the unmodified array, which had an RMS of 1.367 and range of 6.1ºC. Any temperature variations that were present did not affect the stretching of the foil, which appeared visibly uniform.



Figures 4 & 5: 100 x 50 cm GEM foil untensioned at 25ºC (left) and tensioned at 35ºC (right).

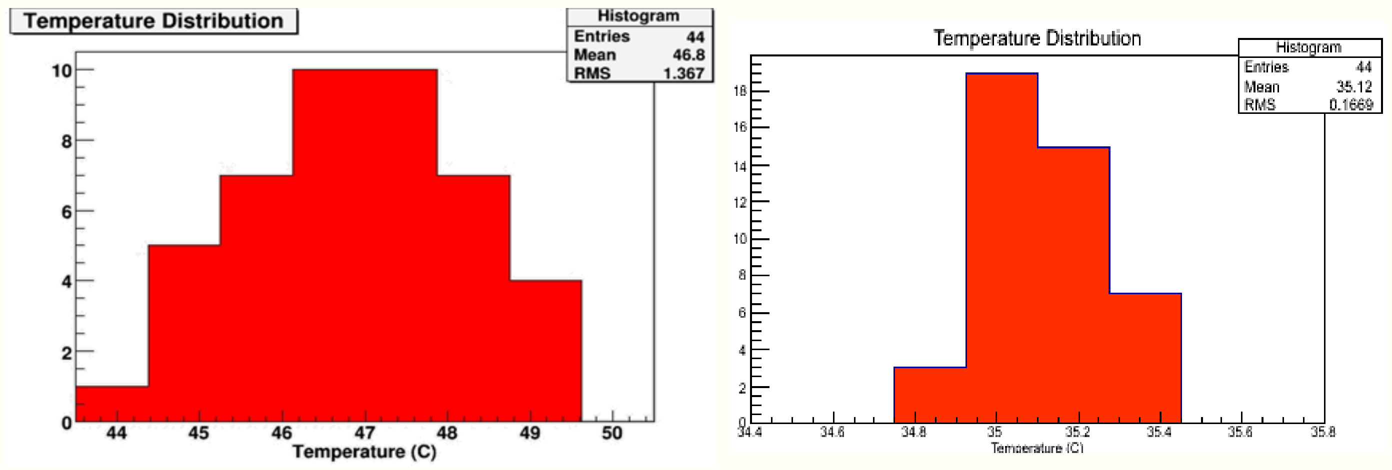


Figure 6: A histogram of previous results (left) and of current results (right)

Temperature Profile

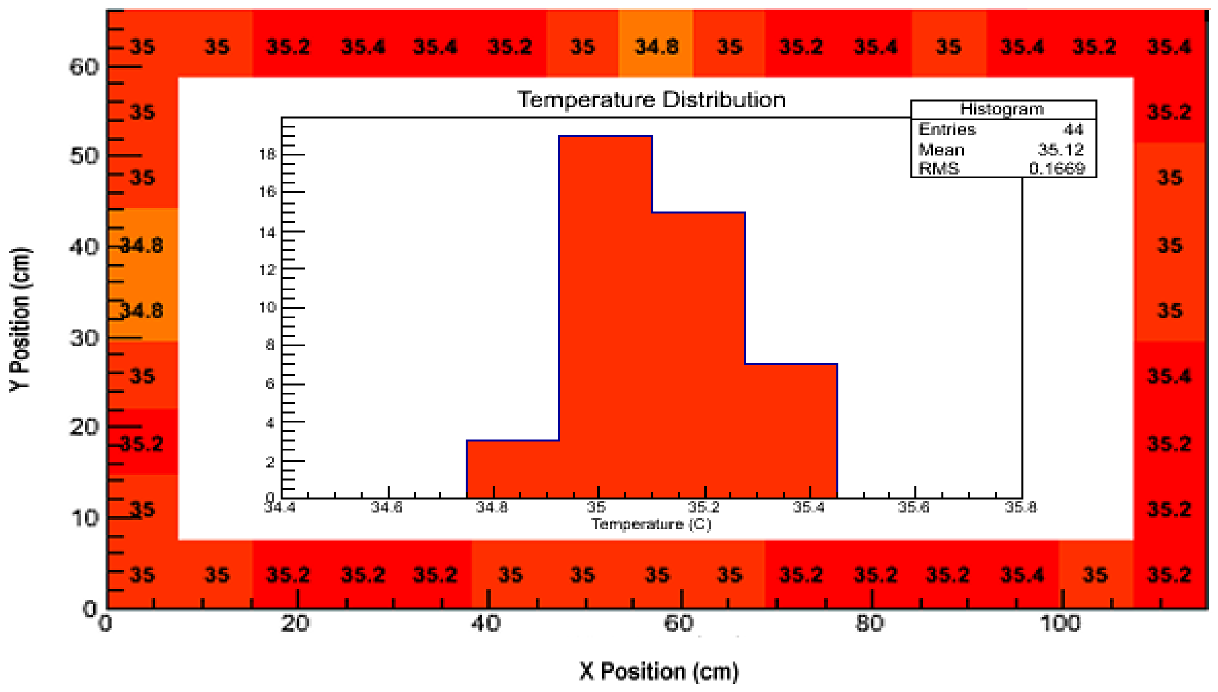


Figure 7: Temperature profile of the frame once a stable peak has been reached (outer), histogram of all 44 temperature measurements (inner).

Long-term measurements were also taken to ensure that the temperature profile was stable over the period of time that would be required to stretch and frame a GEM foil. The results of this long-term measurement are shown below.

Long-Term Temperature Variation

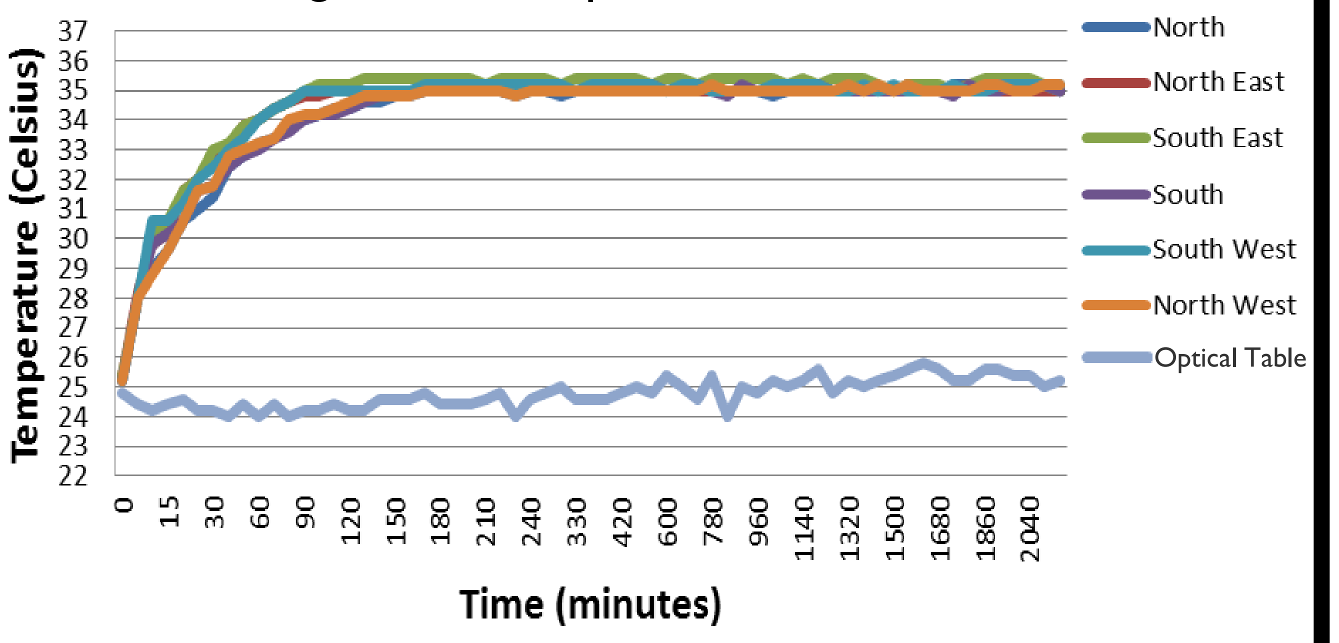


Figure 8: Periodic temperature measurements over a 36-hour period at six locations around the Plexiglas frame, including a 7th, ambient temperature measurement on the optical table

Conclusions and Future Work

The modifications to the previous stretching array were successful. The 125 W light bulbs provided desirable stability at temperatures of ~35ºC, and any temperature variations present did not affect the operation of the array. Foils stretched with our array appeared to be uniform. We obtained an RMS of 0.1669, compared to the previous value of 1.367.

In the future, we plan to upgrade the dimmer switches to provide more precise temperature control. We also plan to build several more identical stations, to be installed side-by-side for more efficient stretching. Ultimately, foils stretched using this array will be used in a future upgrade of the MTS.