Characterization of GEM Detectors for use in the CMS endcap system

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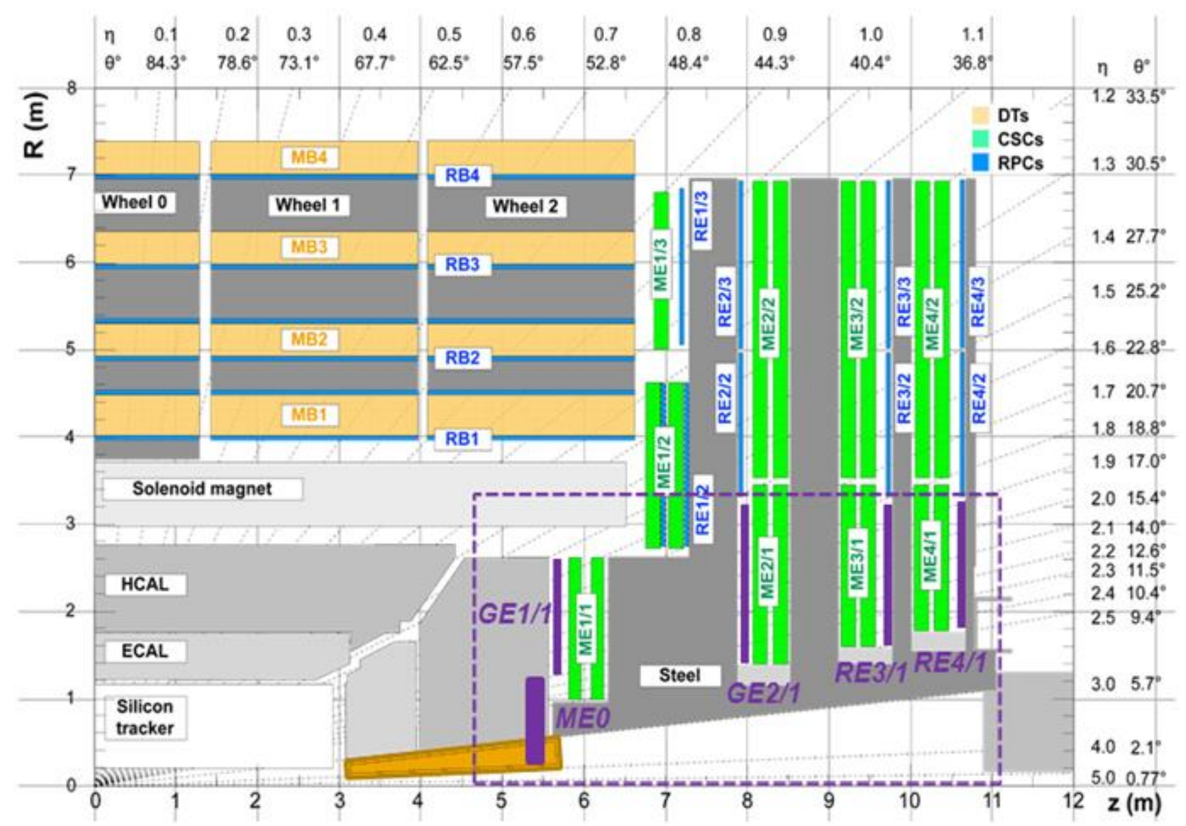
Motivations

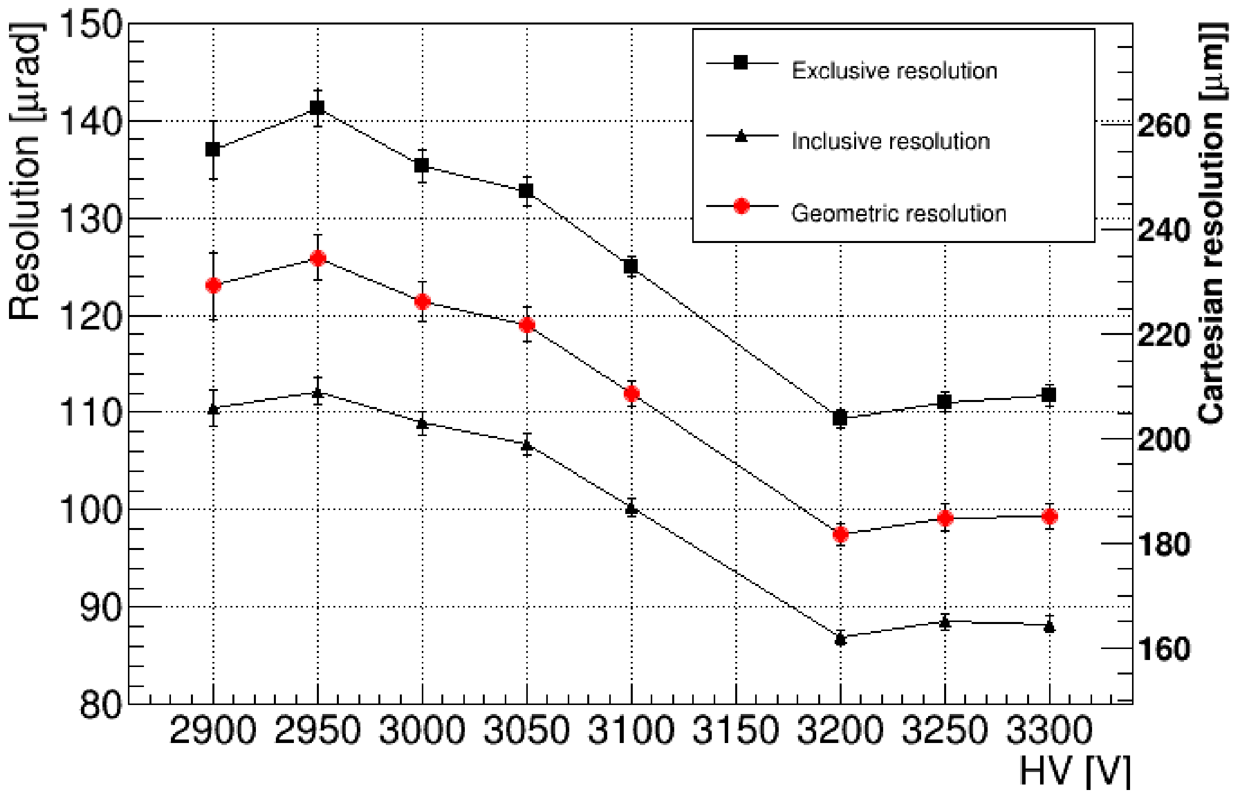
Gas Electron Multiplier (GEM) detectors are being considered for the muon endcap upgrade of CERN's Compact Muon Solenoid (CMS). In order to improve the redundancy of the tracking and triggering systems these detectors are planned to be installed in the GE1/1 sector of the $1.5 < |\eta| < 2.2$ region of the CMS endcaps. Due to the high luminosity experienced at the endcaps the radiation hardness, high spatial resolution, and low dead time of GEM detectors make them an ideal candidate for this upgrade.



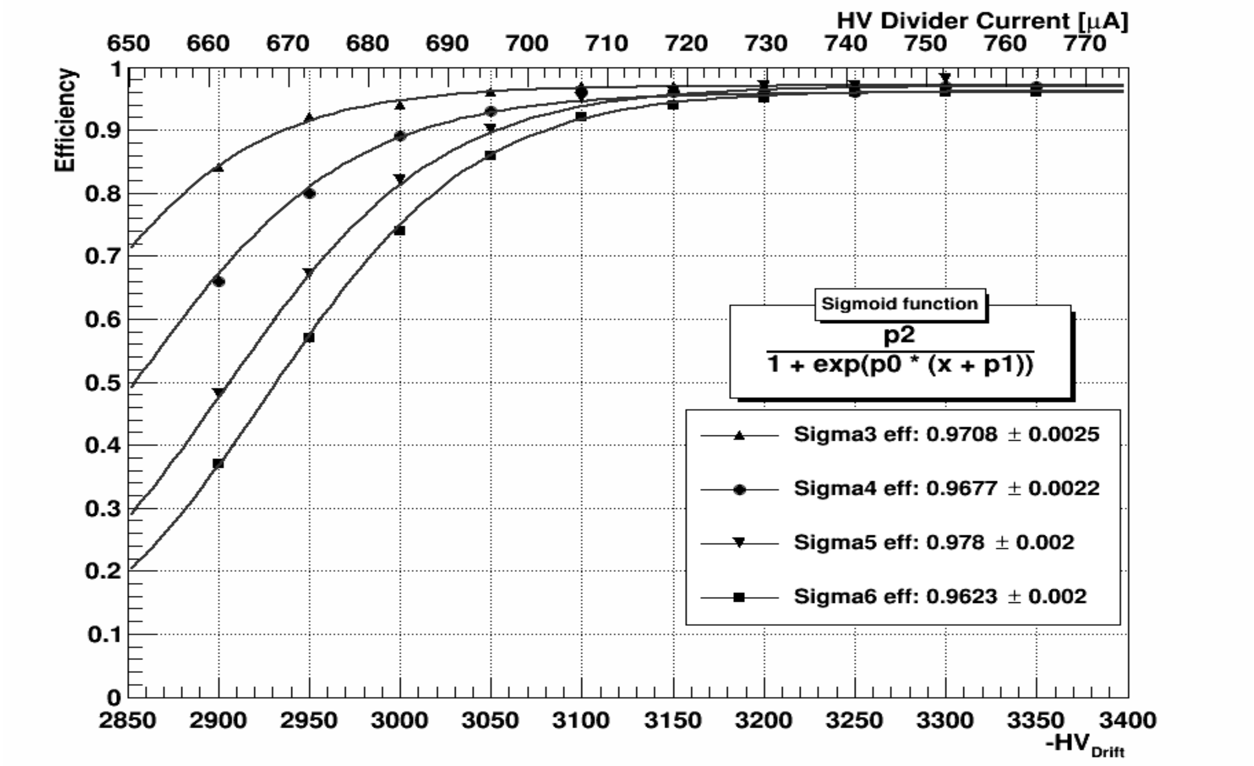
Detector Characterization

During the months leading to the October Beam Test of 2013, we constructed and tested several detectors of various geometries and readout styles using a portable X-ray source within our lead-lined chamber. The Amptek "Mini-X" portable X-ray tube allows us to test our detectors with a source of X-rays ranging from energies of 5 to 40 keV. Most importantly the Mini-X gives the option of variable collimation. When trying to measure the gain uniformity we irradiate as much of the detector's active area as possible, searching for those sections of the readout area that report unusual electron cluster characteristics. Once uniformity was established our detectors were cleared for use in the beam line.

Results

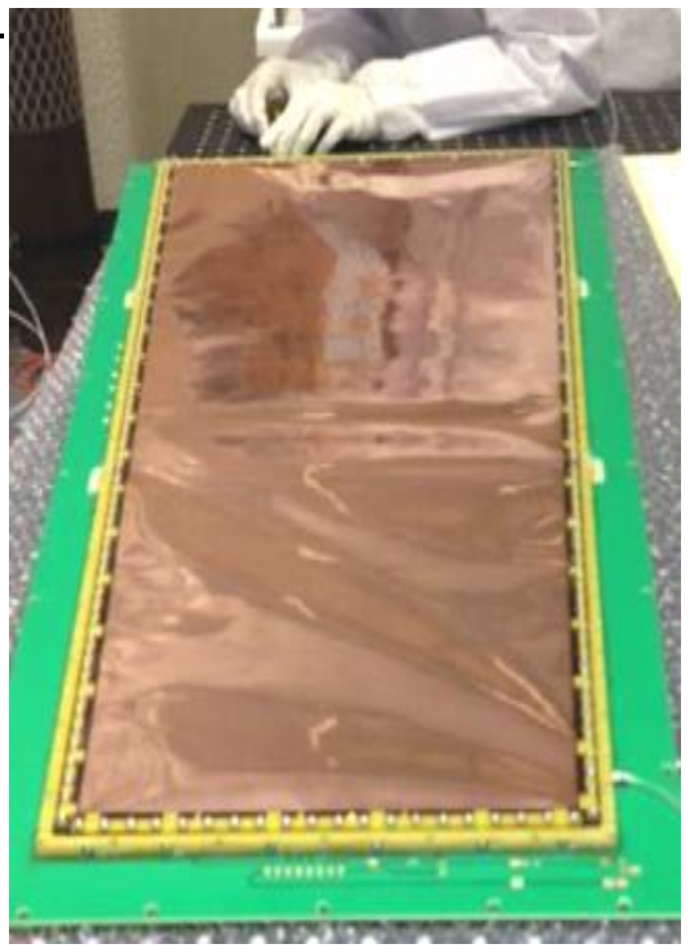


As hoped, we see direct correlation between spatial resolution and detector high voltage. As the operating voltage of the detector is increased the electric field present between neighboring foils strengthens, leading to better amplification of the free electrons created by an incident particle. With better amplification free electron clusters can be more accurately identified; however, it is crucial to understand when this effect reaches saturation. Eventually the detector will reach an efficiency plateau where increases in operating voltage only lead to decreases in spatial resolution.

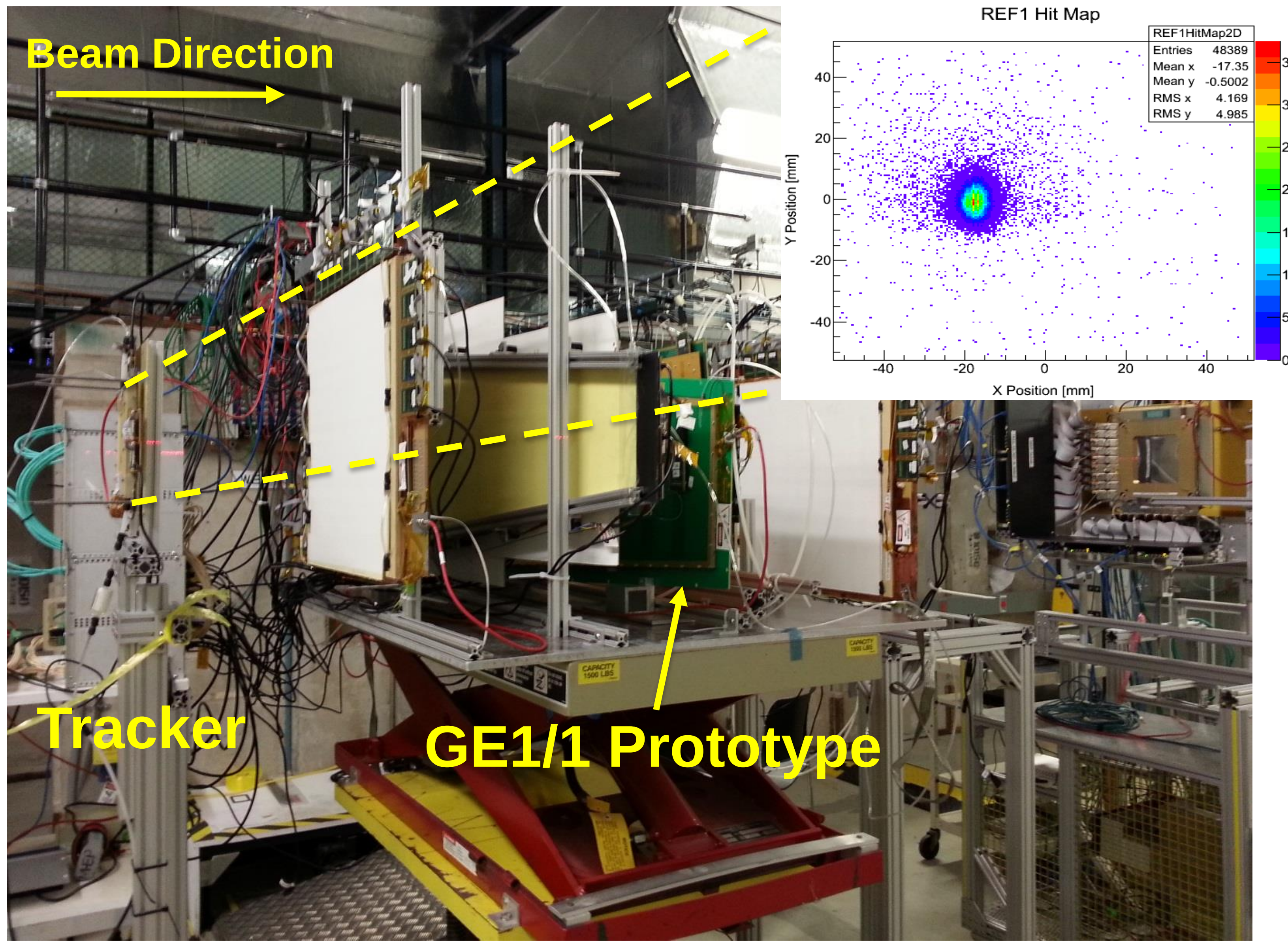


Construction

With previous detector frames GEM foils were held in place using layers of slow-curing epoxy. This feature, as well as the added step of pre-stretching foils under uniform heating, made construction a process measured in days. For the GE1/1 prototype the act of assembly is accomplished with a new self-stretched scheme. In order to reduce the amount of time and labor needed during assembly the GEM foils will be layered, cut to size, and tested separately from the detector's gas frame. When the functioning of each foil is assured they can be placed within the detector for tightening using screws attached to the outer gas frame. These changes allow two people to construct a GE1/1 prototype in as little as two hours.



Beam Test at FNAL



Conclusion

The beam test at FNAL as well the accompanying results prove that we are able to efficiently assemble, characterize, and operate the GE1/1 prototype. We observe a consistent detection efficiency of 97.8% at a cut of five sigma over pedestal noise that begins to plateau at an operating level of 3100 volts. Our results also show a similar charge uniformity response for all detector sections and a spatial resolution that improves with increasing operating voltage.