Characterisation of Thick-GEM detector for imaging applications

RD51 collaboration meeting, Dec 2023
05/12/2023

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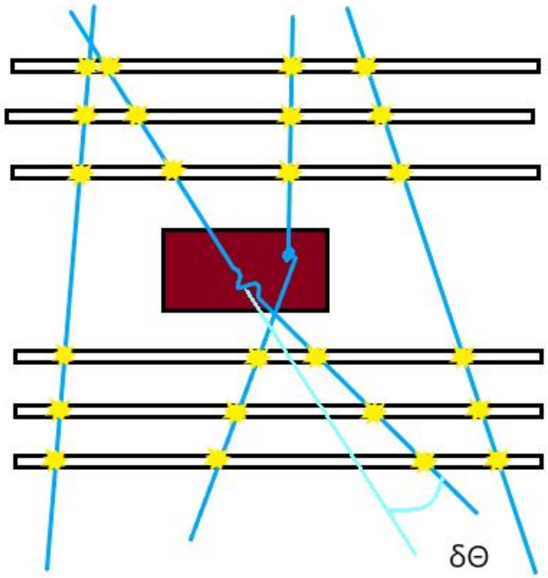
Plan of the talk

- Muon Tomography.
- Current progress.
- COMSOL simulation.
- Design study.
- Practical measurements.
- Detector characterisation.
- Charging up studies.
- Effects of detector conditioning.
- Conclusion and future outlook.

Muon tomography

- EM interaction of muons with the matter such as mcs, ionisation, atomic excitation, Bremsstrahlung.
- Minimum ionizing particle (1-10 GeV) ⟹ Can travel long distance within matter without losing much of its energy.
- Tracks before and after interaction can be interrogated using particle detectors.
- Muon absorption tomography.
  - Depends on matter density
  - Path travelled inside the material
- Muon scattering tomography.
  - Mainly multiple coulomb scattering.
  - Scattering angle follows Gaussian distribution.
  - σ depends on thickness of the material and radiation length.
  - Depends on Z and ρ of the material.

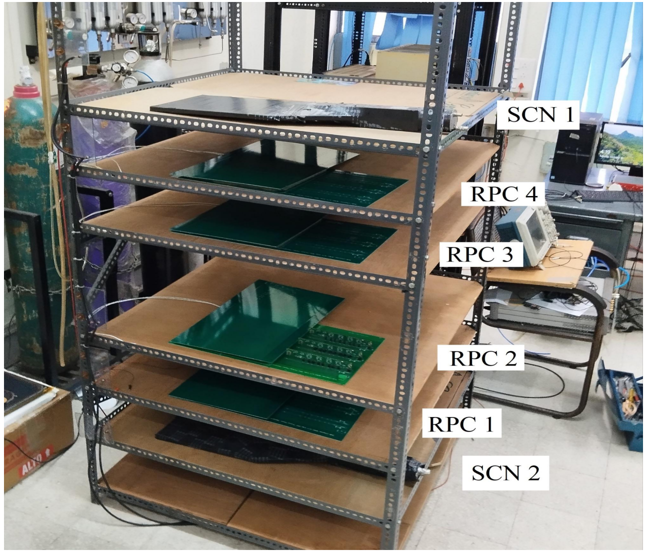


$$\sigma = \frac{13.6MeV}{\beta cp}\sqrt{\frac{L}{X_0}}(1 + 0.038ln\frac{L}{X_0})$$

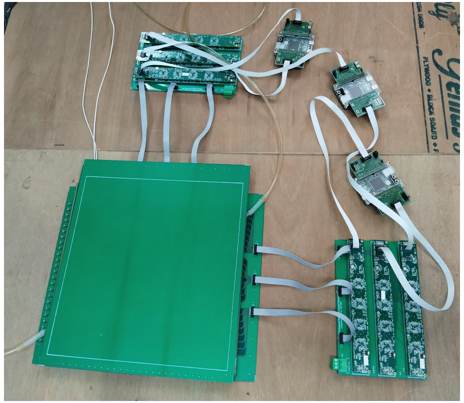
$$X_0 = \frac{716.4(gm/cm^2)}{\rho}\frac{A}{Z(Z+1)ln(\frac{287}{\sqrt{Z}})}$$

Current progress

- RPCs are being used for the tomography setup.
- The whole process of making the detector is done with our own facility at SINP.
- 8-channel NINO boards with MAX10 FPGA is used for DAQ.

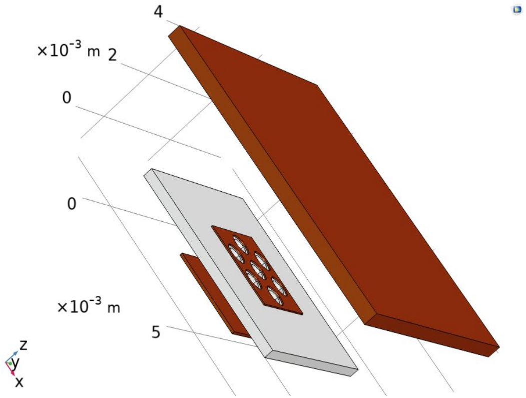


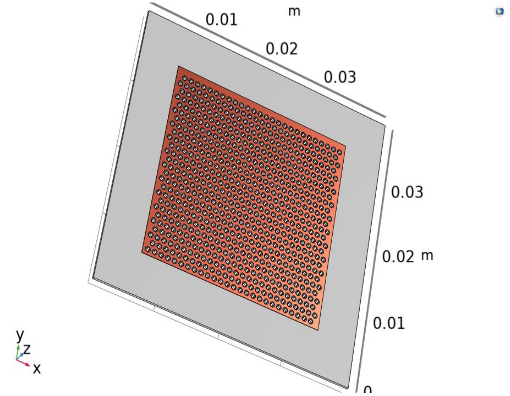
- Good position resolution(~200μm) required for imaging rusted rebers in RCC.
- To use a detector with good spatial resolution, low production cost as well as robust.
- Thick GEM can be used to achieve that level of position resolution with sufficient gain that can be detected with NINO read out system.

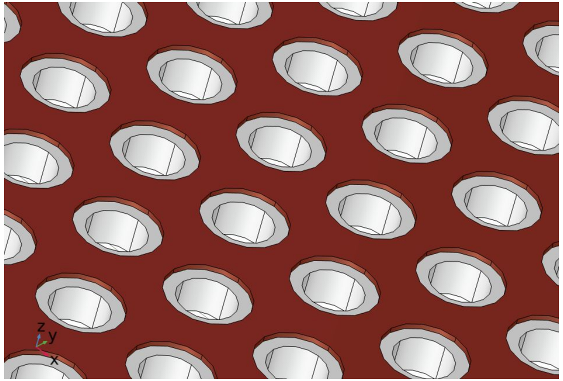


COMSOL simulation of THGEM detctors

- Field calculation in different regions of the detector is necessary to know the transport properties.
- α value thus gain can be predicted.
- COMSOL results are promising for this purpose.
- Finite element analysis, solver and simulation software package.
- Numerically solve partial differential equations.





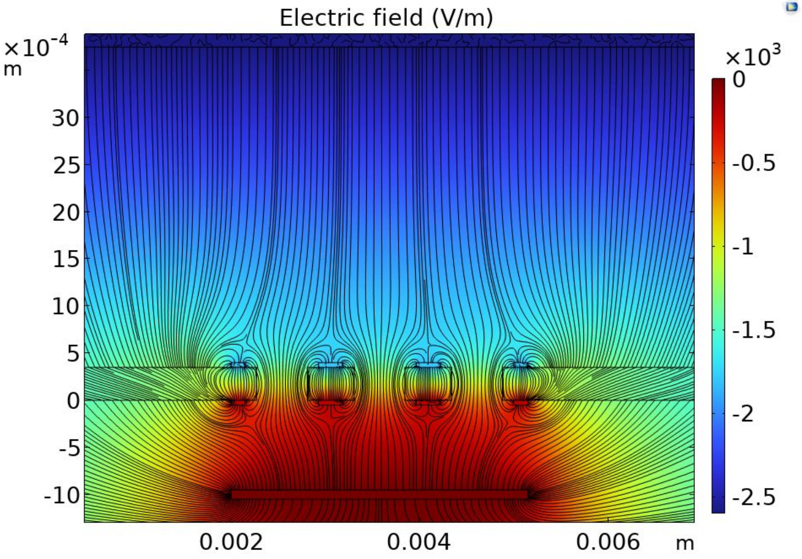


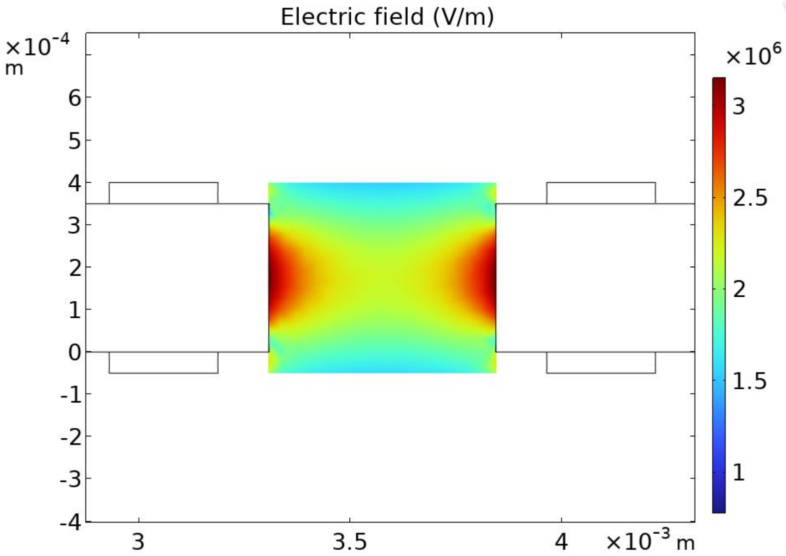
Drift gap = 3.35 mm.
Induction gap = 0.95 mm.
Detector thickness 350 μm.
Copper layer 50 μm.

Hole diameter =540μm
Pitch = 1035 μm
Rim = 120μm

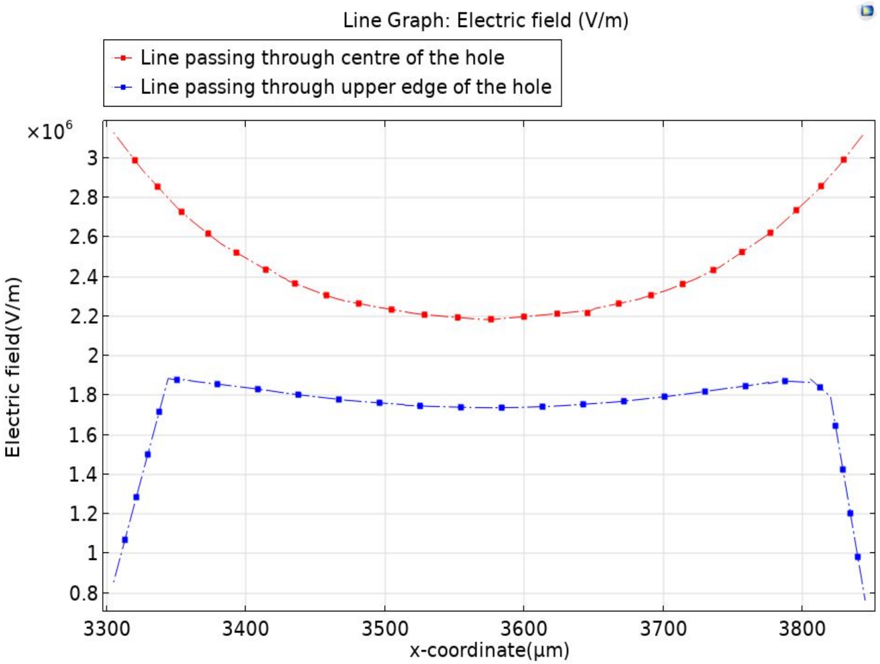
Electric field configuration

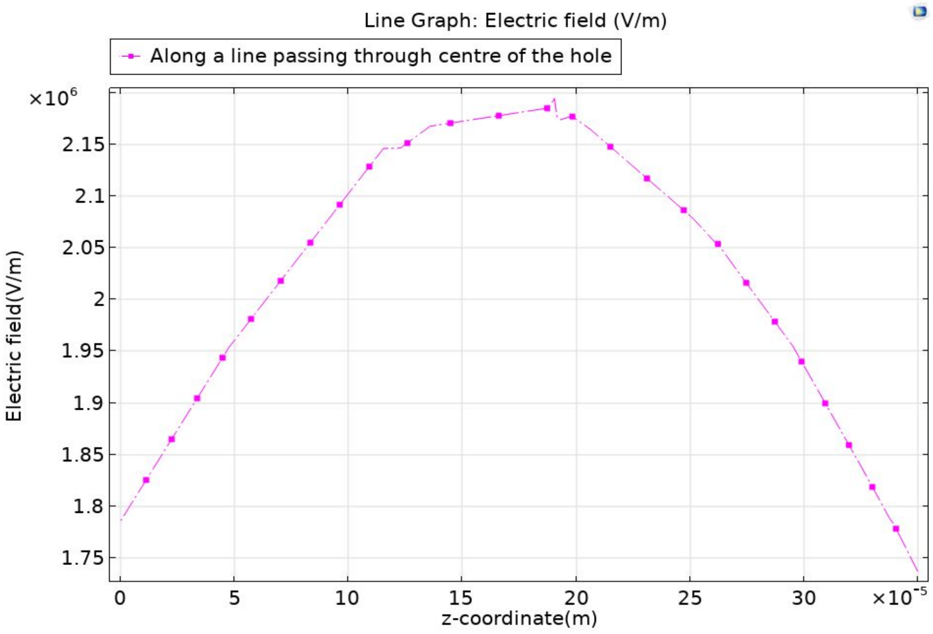
Anode potential = 0V
THGEM bottom potential = -360 V
THGEM top potential = -1800 V
Drift potential = -2600 V



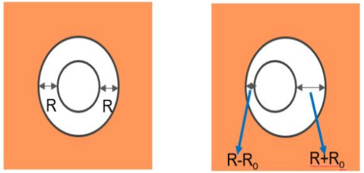


Electric field plots

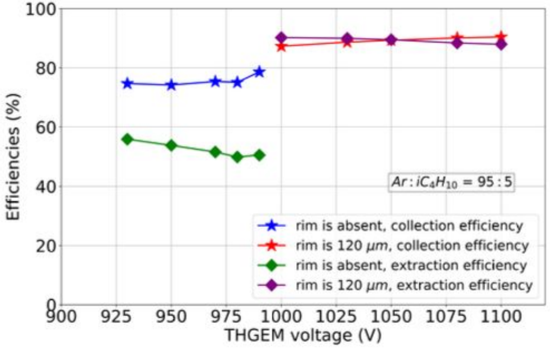


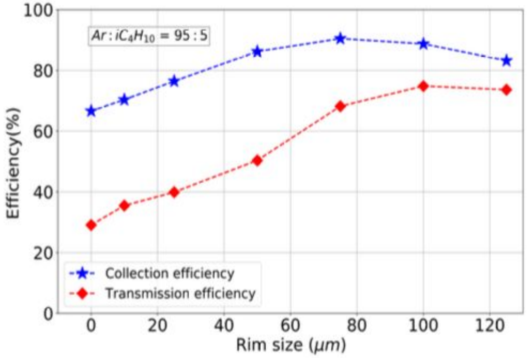


Thick-GEM Design study

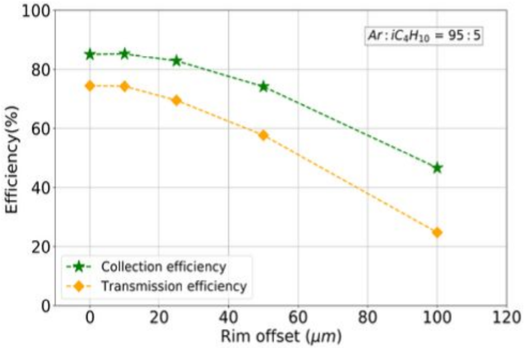


- GARFIELD is used for simulating the detector response.
- It simulates the primary ionization using HEED.
- Electron-ion transport properties using MAGBOLTZ.
- The simulated THGEM has straight cylindrical holes arranged in hexagonal pattern.
- Drift and induction gap 1.5cm and 3mm.
- Argon and isobutane gas mixture in the volumetric ratio of 95:5 has been used.
- Collection efficiency is the ratio of primary electrons and electrons reached to the THGEM holes.
- Transmission efficiency determines the effective gain and is defined as the number of electrons reaching the anode per unit primary electron in the drift gap.

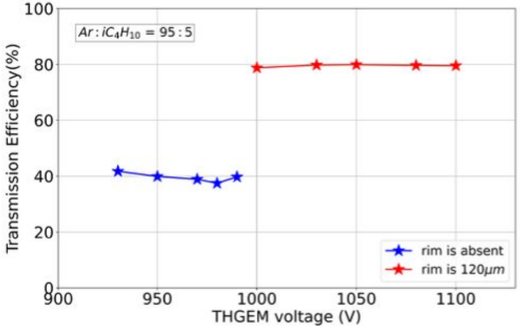




(a) Different sizes of rim

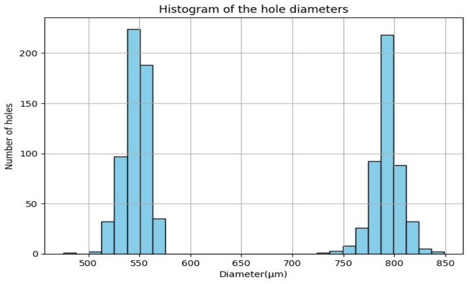


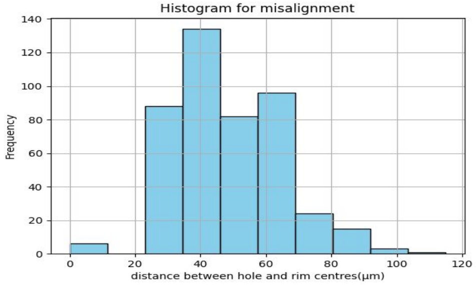
(b) Different offsets in rim



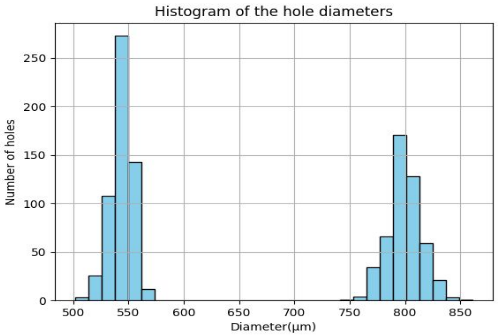
Ref. P. Roy et al.
https://doi.org/10.1016/j.nima.2004.07.138

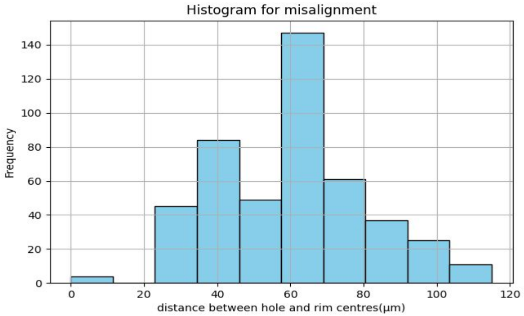
Practical measurements



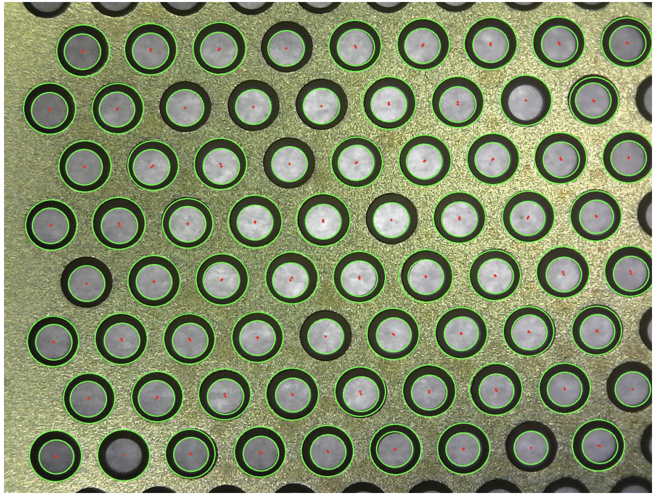


Hole diameter and misalignment measurement for top surface





Hole diameter and misalignment measurement for bottom surface



- Opencv is used for image processing.
- To detect circles Hough Circle Transform has been used.
- Hole-Rim misalignment studies has been done.
- In a single detector misalignment for both the surfaces are not same.

Characterisation of the detector

The steps taken before assembling the detector are

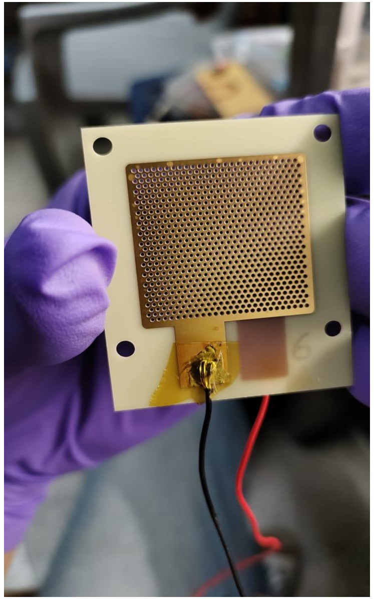
- ➔ Cleaned in alcohol for 12 hrs.
- ➔ Baking in oven at 90℃ for 1 hr to remove the moisture.
- ➔ Soldering with clean and smooth surface.

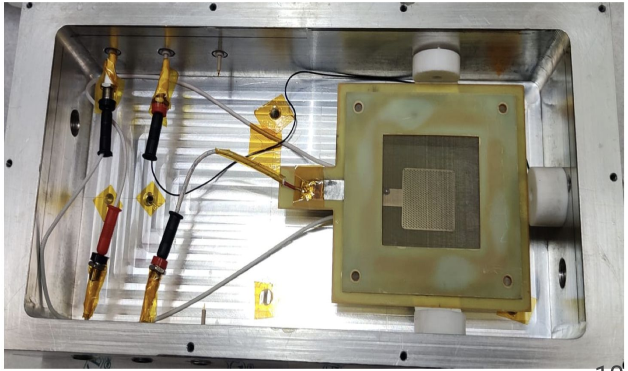
Detector assembled with

- ➔ Drift gap of 1cm.
- ➔ Induction gap of 2.5 mm.

We started flowing nitrogen gas in a closed chamber

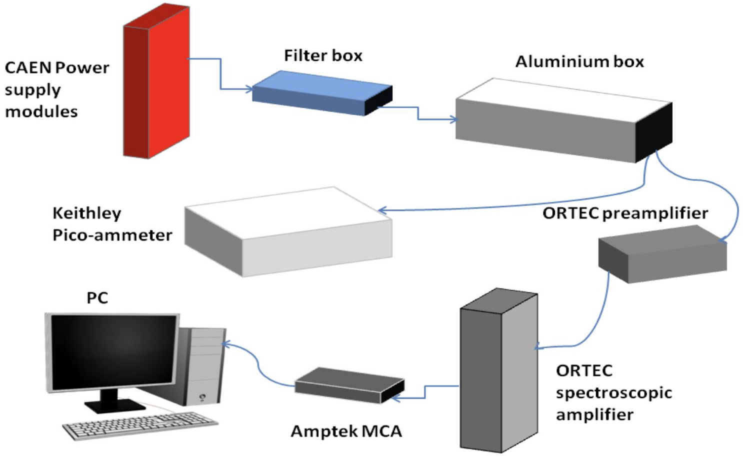
- ➔ Flow rate is 5 sccm.
- ➔ Flushed the box at least 5 times before applying voltage.
- ➔ Voltage applied to the top plane.
- ➔ Bottom plane grounded through pico ammeter.
- ➔ At N_2 gas Paschen limit for parallel plate with 350 μm gap is 2150V.

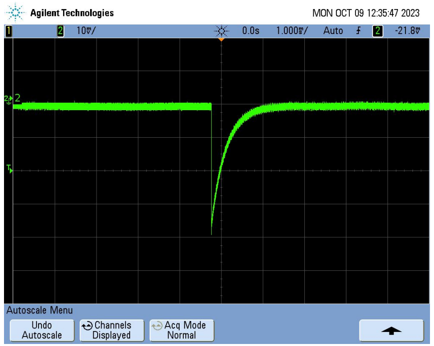


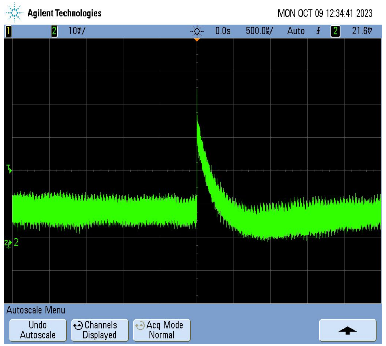


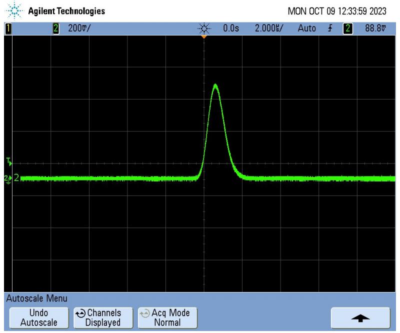
Electronics

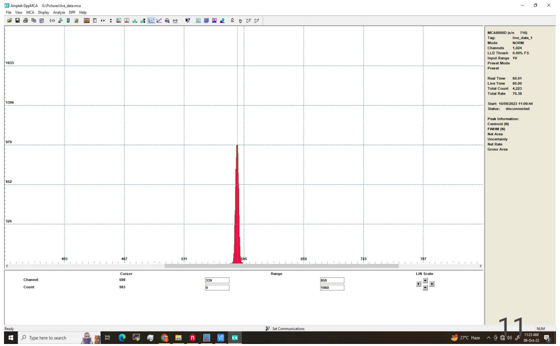
- CAEN SY4527 module with A1527N HV board has been used for powering the detector.
- CAEN A1422A charge sensitive preamplifier has been used.
- That signal is fed to ORTEC 672 spectroscopy amplifier.
- Amplified signal is then fed to Amptek MCA8000D multi channel analyzer.
- MCA is connected to desktop for data acquisition.





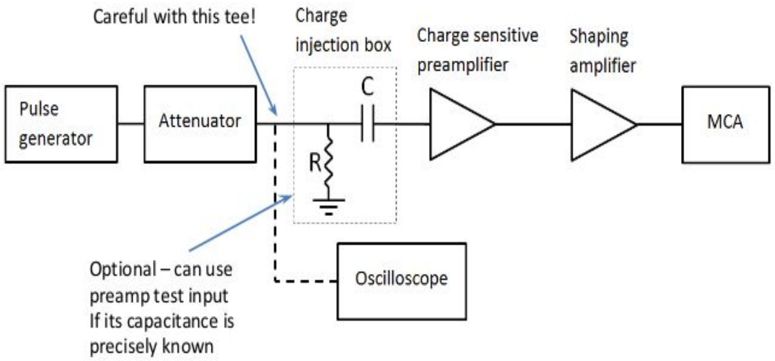


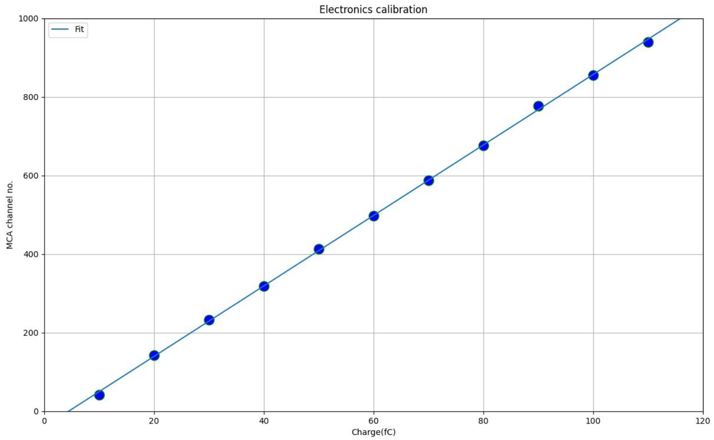




Charge calibration

➔ To measure the energy deposited in the detector by incoming radiation from MCA spectrum.
➔ MCA channel number has been converted to total charge deposited in the detector.
➔ Detector has been replaced by ORTEC 419 precision pulse generator and a charge injection box.

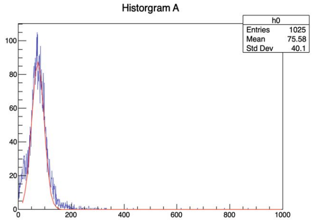


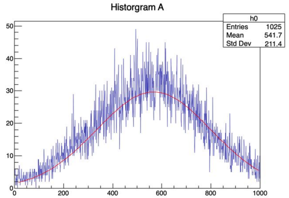


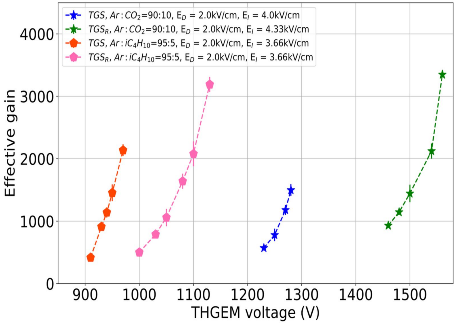
Study of Gain

Gain of the detector is defined as $= \frac{Total\ no\ of\ electrons\ collected\ after\ avalanche}{No.\ of\ primaries}$

- Each histogram is fitted with gaussian fit.
- Mean value of the Gaussian is converted to total no. of electrons.
- Number of primaries for Ar-CO_2 90:10 mixture is 212.
- Paschen limit for parallel plate configuration is 1150 V.





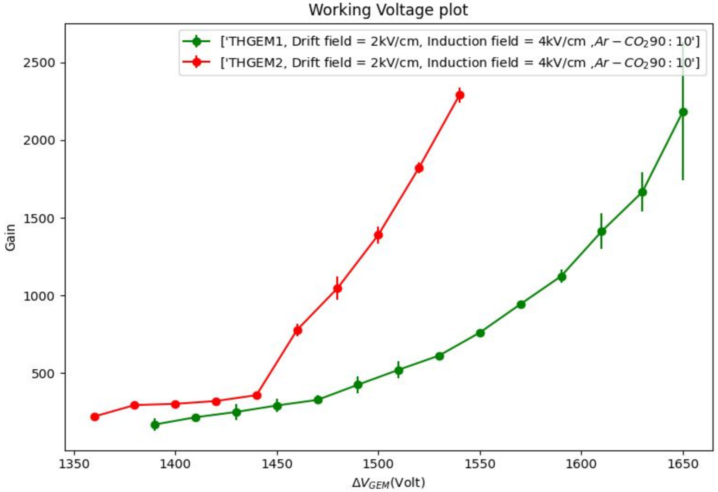


THGEM1

- ➔ Thickness 350 μm.
- ➔ Hole inner diameter 540 μm.
- ➔ Concentric rim 125 μm.

THGEM2

- ➔ Thickness 360 μm.
- ➔ Hole inner diameter 535 μm.
- ➔ Concentric rim 125 μm.

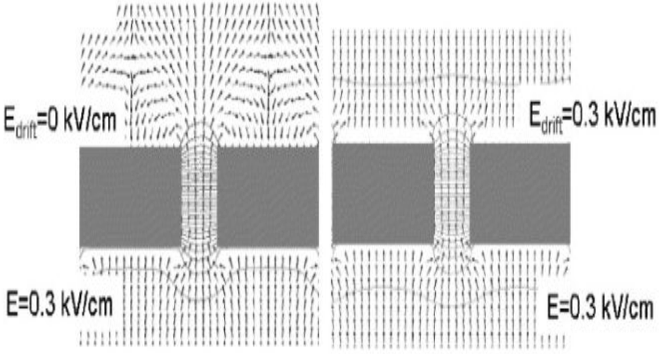


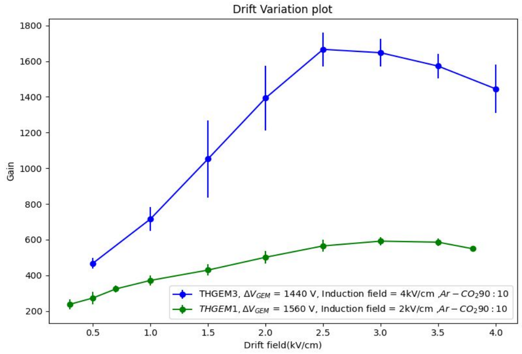
Ref. P. Roy et al.
https://doi.org/10.48550/arXiv.2210.10721

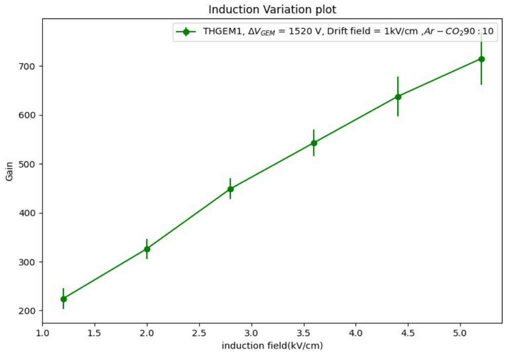
Gain variation with drift and induction field

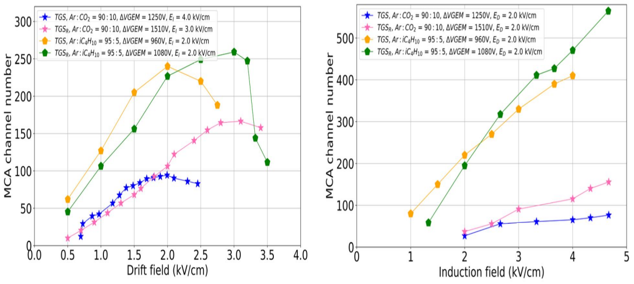
To find the optimised working voltage of the detector variation of the gain with different configuration of fields should be observed.

- ➔ With increasing drift field primary electron collection efficiency increases.
- ➔ After reaching a maximum value electrons can not follow the field lines to the hole.
- ➔ With increasing induction field more numbers of electron can reach the anode plate.





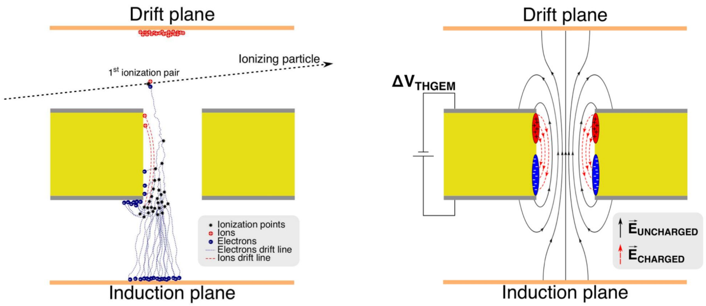


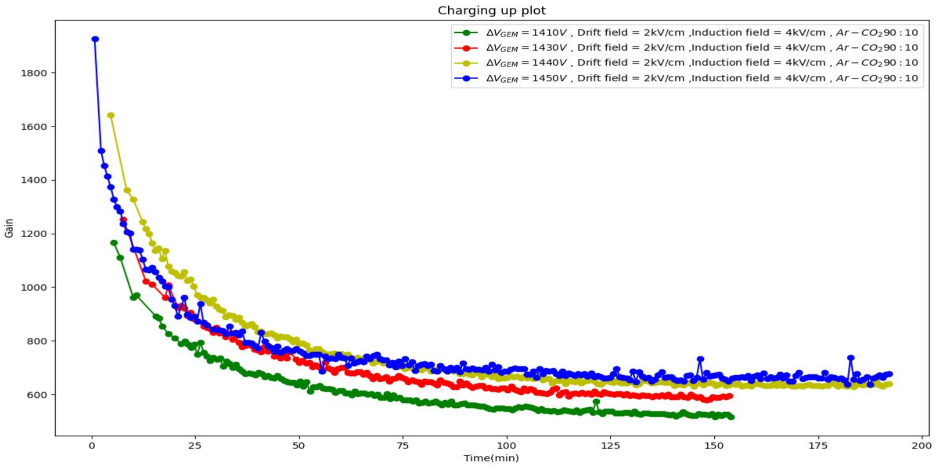


Ref. P. Roy et al. https://doi.org/10.1016/j.nima.2004.07.138

Radiation charging up effect

- Exposed dielectric within gas volume.
- Existence of impurity, material imperfections can lead to charge adherence.
- Field value decreases within the hole.

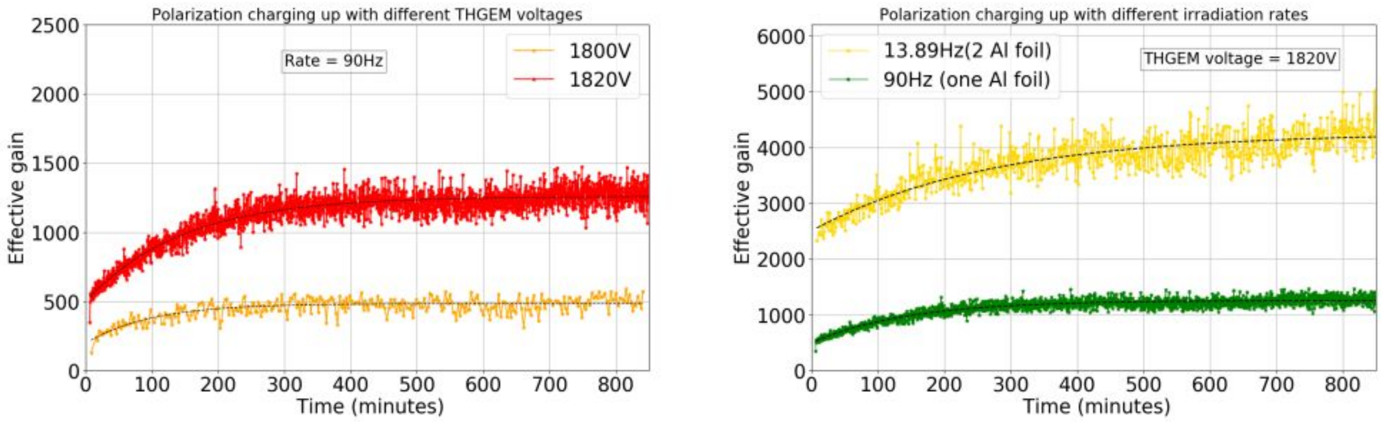




- With increasing source rate charging up becomes faster.
- After removing the source with time attached charges are removed.
- Comes back to its original state.

Polarization charging up effect

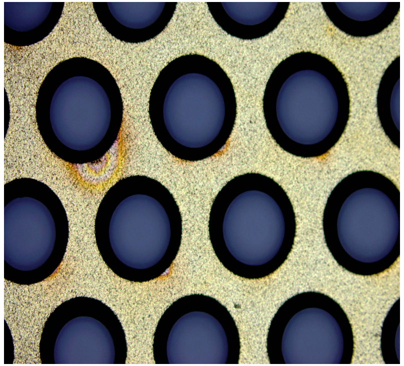
- Space charge polarization can take time from minutes to several hours .
- It increases the gain and saturates over time.
- With sufficiently low rate source effect of radiation charging up can be neglected.

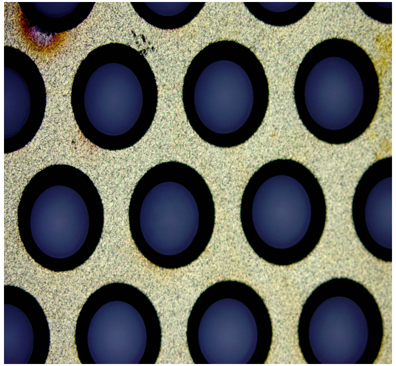


(a) With different voltages (b) With different irradiation rates

Ref. P. Roy et al.
https://doi.org/10.1016/j.nima.2004.07.138

Effects of detector conditioning

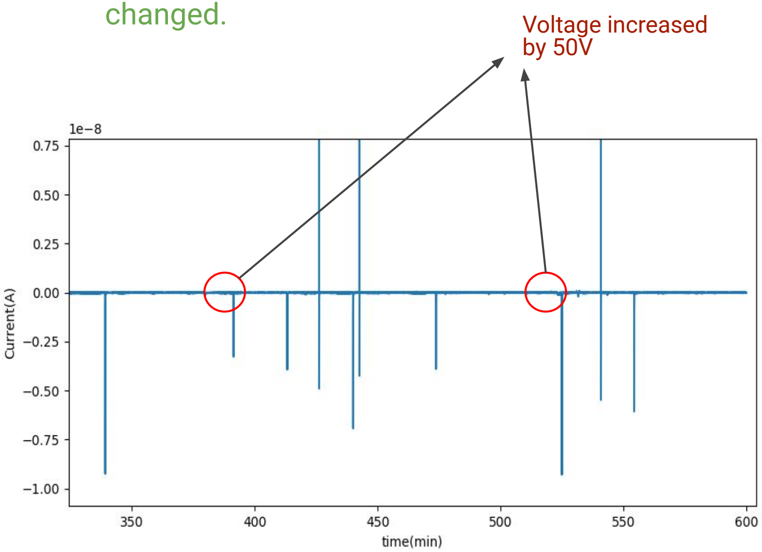


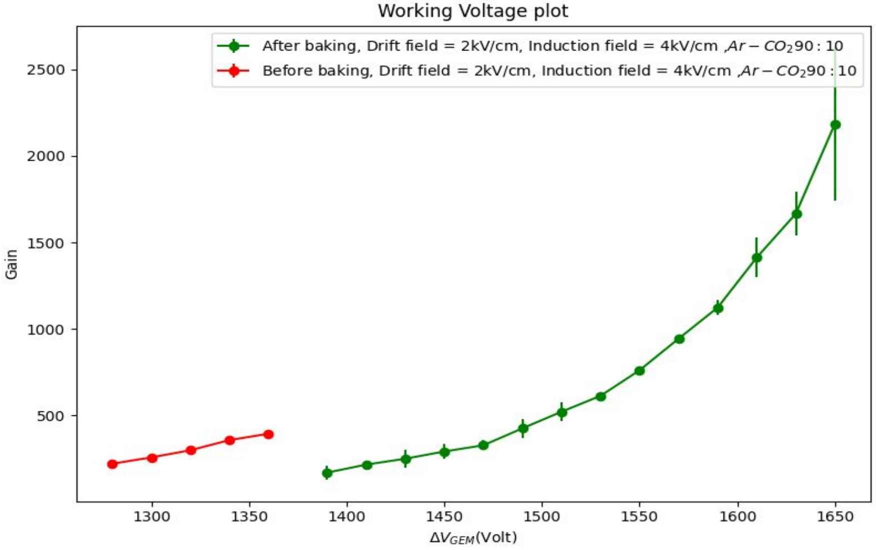


Due to atmospheric humidity, roughness on the surface of holes and sharp edges causes frequent discharges to happen.

➔ To remove absorbed moisture the detector is baked in oven at 90°C for 1 hr before gas flow.

➔ Discharge limit increases and working range also changed.



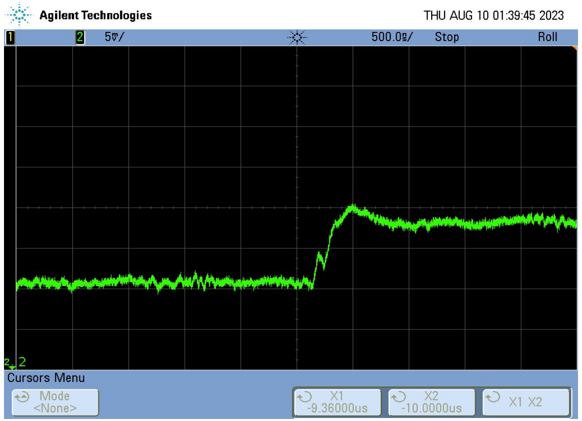


Conclusion and future outlook

- For a single thick GEM all the characterization studies have been done.
- Three of the five tested detectors are behaving as expected.
- Other detectors are either damaged due to sparks or prone to frequent discharges.
- To minimize discharge probability and increase gain we have to use two-three layers of the detector. A multi THGEM structure.
- These detectors have not been tested for muon detection.
- A coincidence set up is to be build for this purpose.
- Also the position resolution should also be checked.
- Our future goal is to use NINO boards for double THGEM data acquisition system.
- And if possible to make a whole tomography system with THGEM detectors.

Thank You !

Back up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