Indian GEM Foils: R&D and Production Validation

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On behalf of
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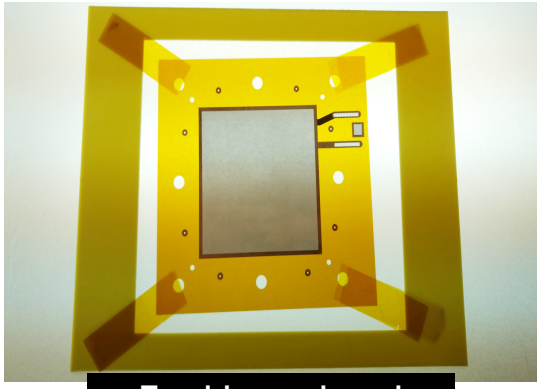
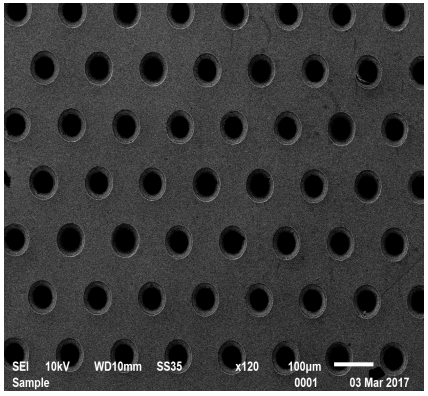
Motivation

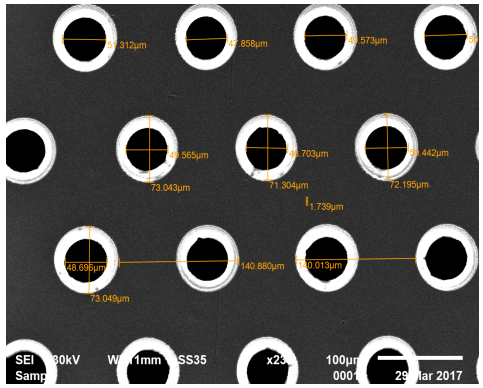
Transfer of Technology, measurements and setups, approval talks, feedback to company

- GEM is the new age of the detector for nuclear and particle physics experiments, which was first developed by CERN.
- From that point onwards only CERN has been the main provider of the GEM foils and it is difficult for CERN to cope up with increasing demand specially when is the case of in-kind contributions.
- India based company Micropack Pvt. Ltd. acquired a license from CERN under ToT to produce GEM foils.
- The University of Delhi (DU) then began collaborating with Micropack to help them establish a consistent manufacturing procedure for GEM foils. The primary focus of producing these foils to use them for the CMS GEM upgrade.
- Micropack after receiving the important feedbacks and from, able to successfully manufacture the 10cm x 10cm, 30cm x 30cm and 45cm x 60cm GEM foils using both double and single mask technique.

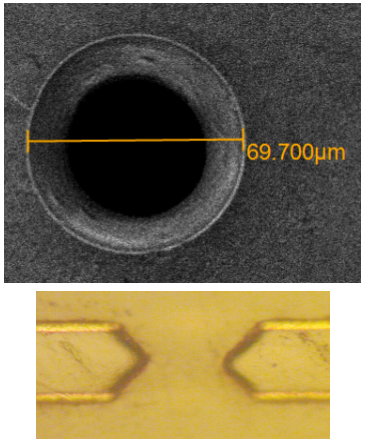


Freshly produced
10 cm x 10 cm GEM foil





SEM images at micron level resolution

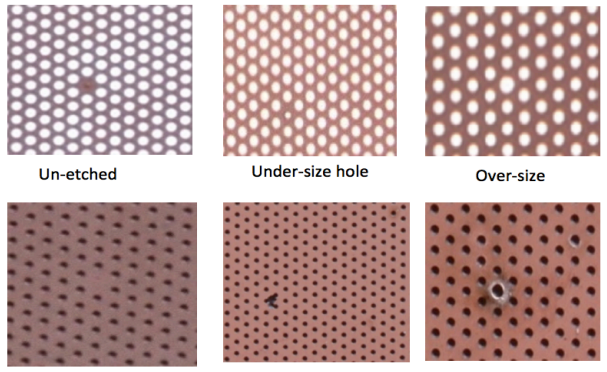


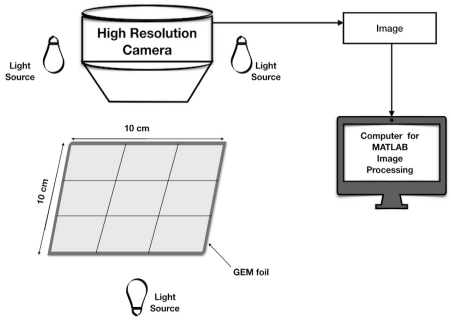
Single-hole structutre

10 cm x 10cm- Optical Inspection

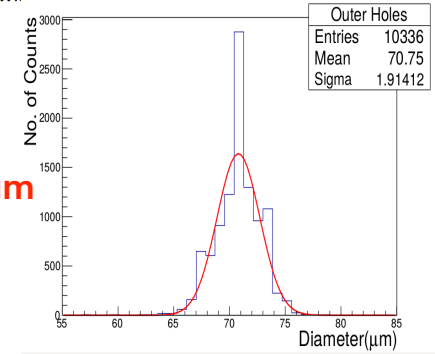
Development, Characterization and Qualification of first GEM foils produced in India, NIM A 892 (2018) 10-17

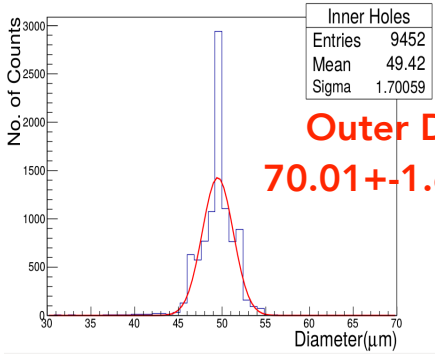
- Hole size and uniformity is very important as it describes the properties of the GEM detectors realized from these foils.
- Foils scanned using Micro lensing technique Imperfections that have been observed are un-etched areas, under-size hole, oversize holes, without hole areas, excess etching, etc
- Images were processed using an Image Processing Toolkit within MATLAB and further processed using ROOT.
- The hole diameters 49.9 μm and 70.01 μm for inner and outer holes.
- Less than 0.15% of defects were observed.





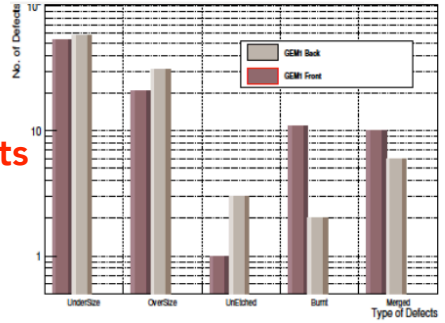
Inner Dia
49.9+-1.6 um

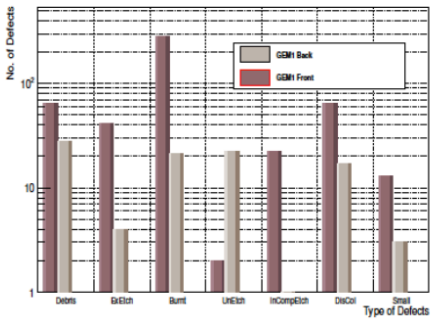




Outer Dia
70.01+-1.6 um

Kapton
&
Copper Defects

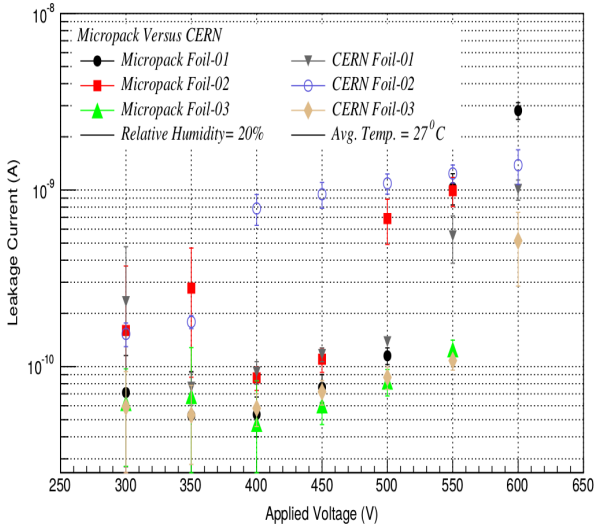


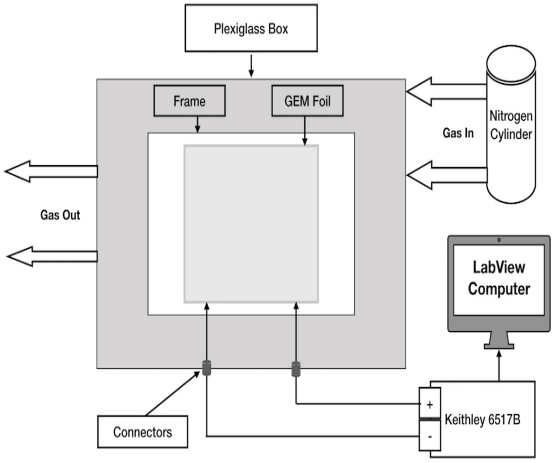


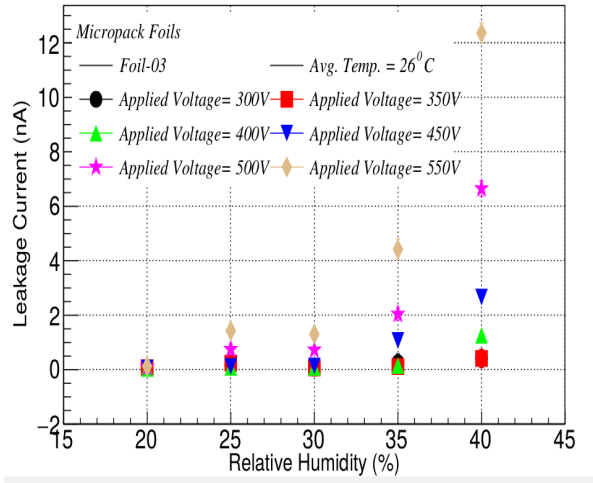
10 cm x 10cm - Electrical Inspection

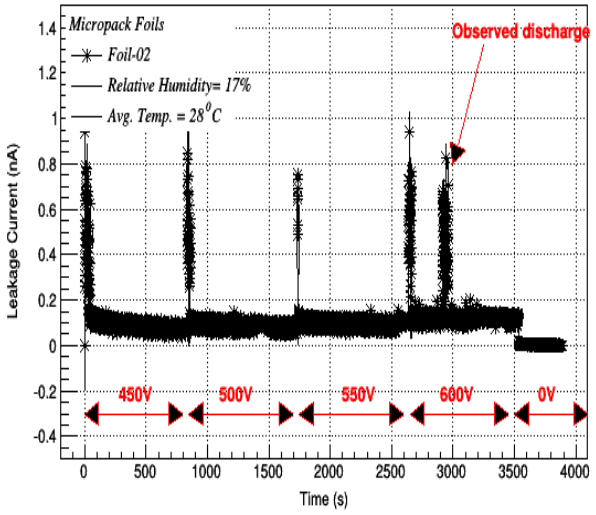
Development, Characterization and Qualification of first GEM foils produced in India, NIM A 892 (2018) 10-17

- Leakage current measurement is very important for a foil to qualify for its use in GEM detectors.
- QC fast method has been done with insulation tester MIT Megger 420.
- Leakage current of < 1 nA observed, and is consistent with CERN foils.
- For the better precision in the current measurement, Keithley Electrometer 6517B has been used.
- No discharges has been observed at 550 V, at the most a single discharge has been observed at 600 V.





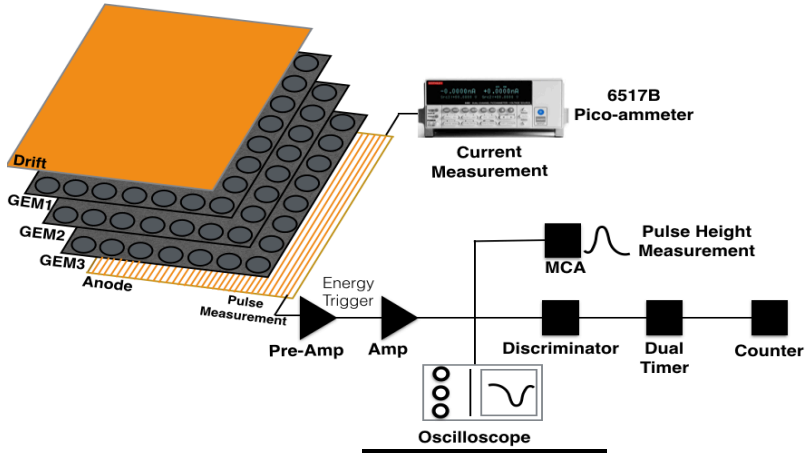


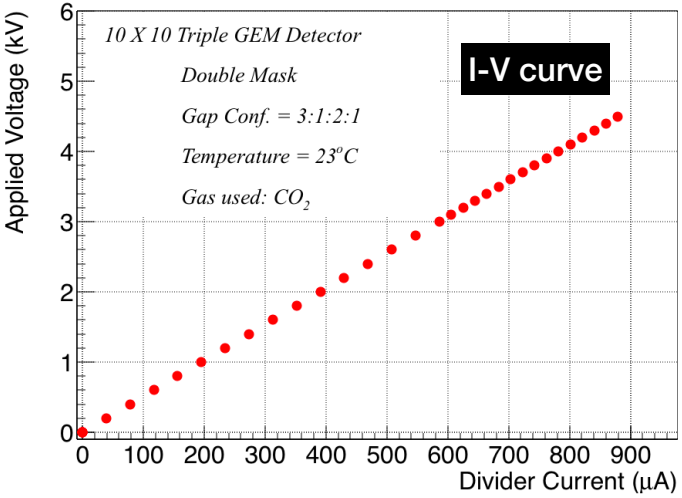


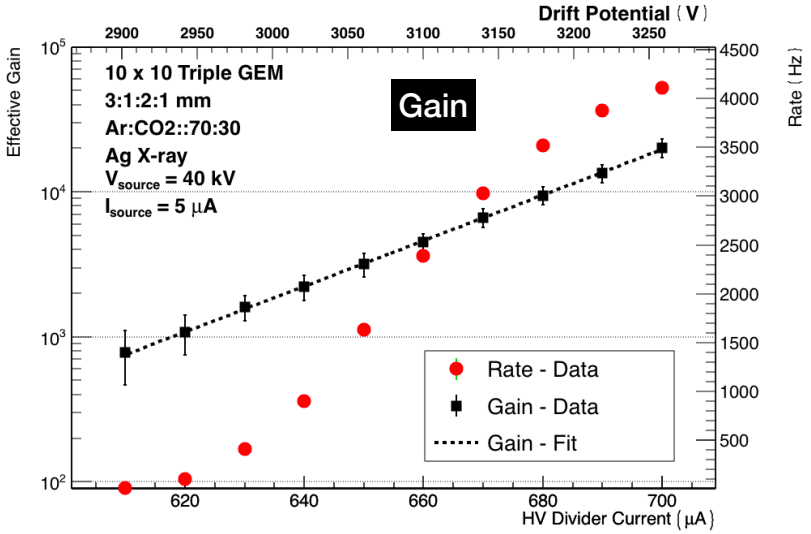
Triple GEM Performance

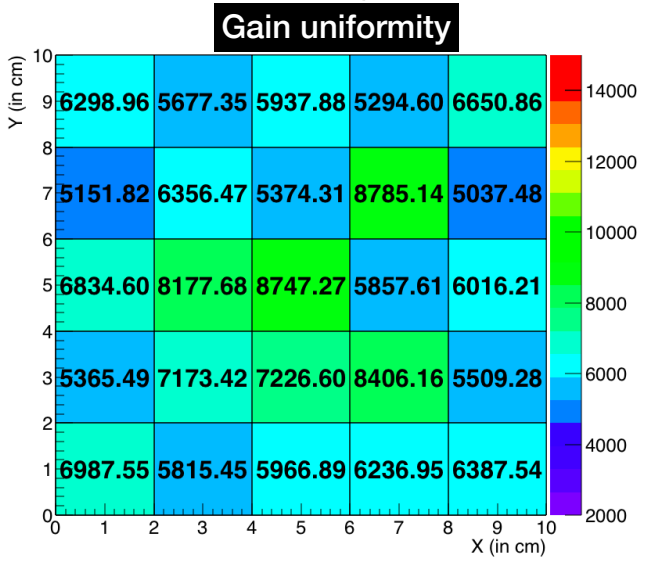
Performance of the triple GEM detector built using commercially manufactured GEM foils in India, NIM A 951 (2019)

- A triple-GEM detector was built using the same gap configuration used by CMS i.e. Drift/transfer1/transfer2/induction gap of 3mm/ 1mm/2mm/1mm.
- 1-D readout board with an active area of 10cm X 10cm used to pick up the signal.
- The Current measurement was performed using a pico-ammeter and pulse measurement was processed using the NIM electronics.





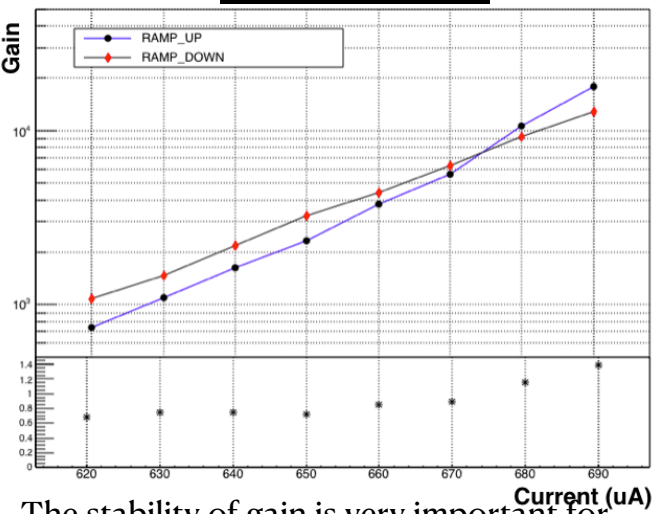




Advanced Studies

Stability test performed on the triple GEM detector built using commercially manufactured GEM foils in India, 2019 JINST 14 P08004

Hysteresis Effect



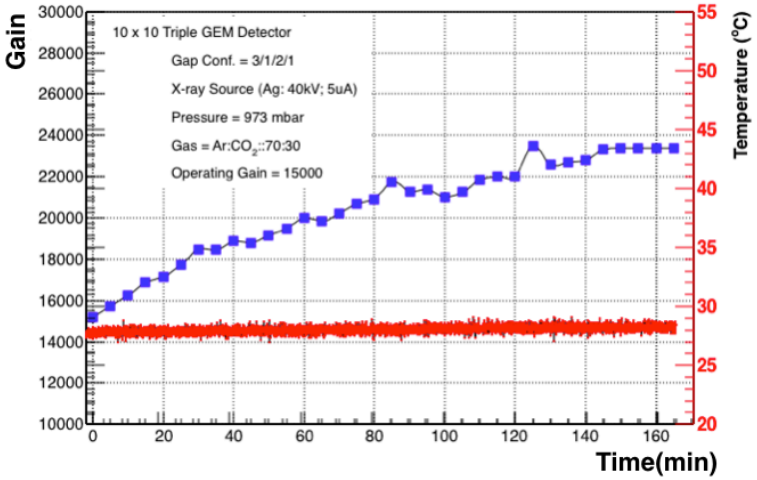
The stability of gain is very important for gaseous detector any un-wanted variation in gain can cause the loss of efficiency.

Effective gain was measured while ramping up and down the voltage across the detector.

Two curves shows the different slope on the log scale and this is the clear manifestation of the hysteresis effect.

This can be due to the polarisation within the caption layer.

Polarisation Effect

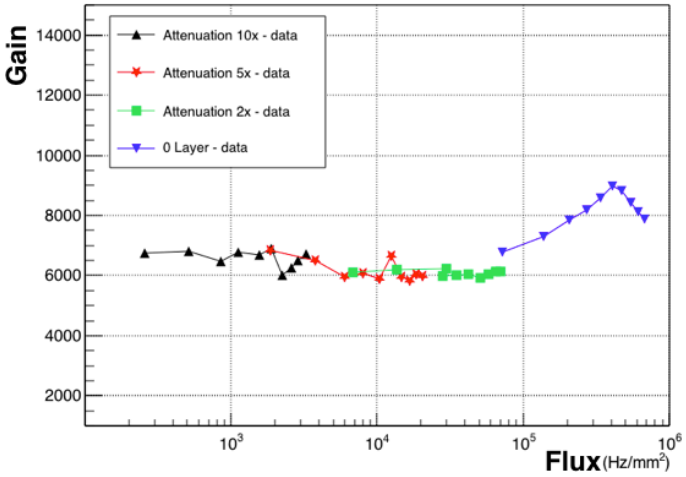


The stability of gain is mainly affected by two phenomena namely charging up or polarisation.

Charging up effect is due to the trapping of the charge inside the hole, and polarisation is due to the movement of the charge inside the polyamide.

To estimate the variation in gain due to the polarisation a series of measurement performed for several hours and gain amplitude w.r.t time was measured.

Rate Capability



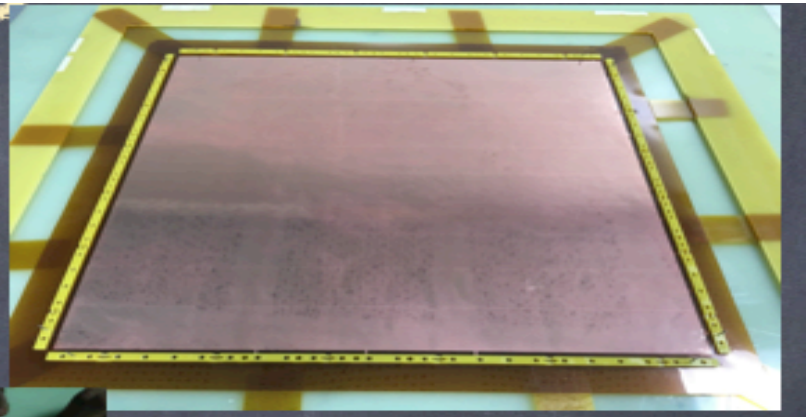
The MPGD technology were mainly introduced in response to the limited rate capability of MWPC.

By reducing the size of the amplifying to microscopic scale, the time necessary to evacuate the avalanche ions reduced to sub-microsecond, hence reduced the effect of space-charge and shows the stability in gain.

GEM detectors are known for the stable operation even at very high incoming flux. And three possible regions can be distinguished depending upon the incoming flux.

30 cm x 30 cm

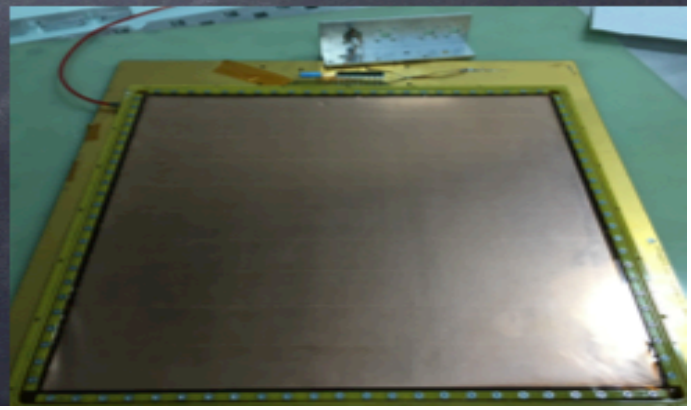
Plexiglass



GEM on Alignment pins

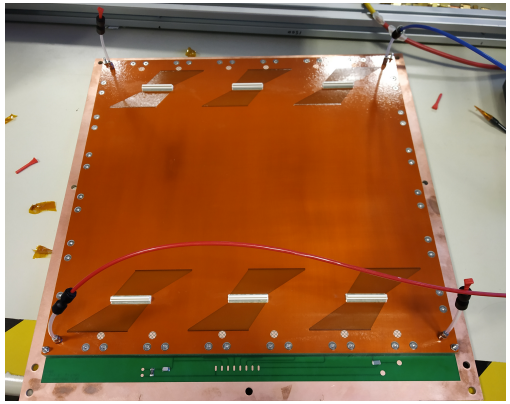
Cutting HV pads

Chambers closing

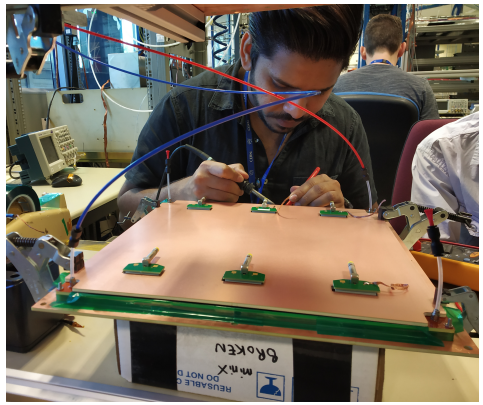


Measurements

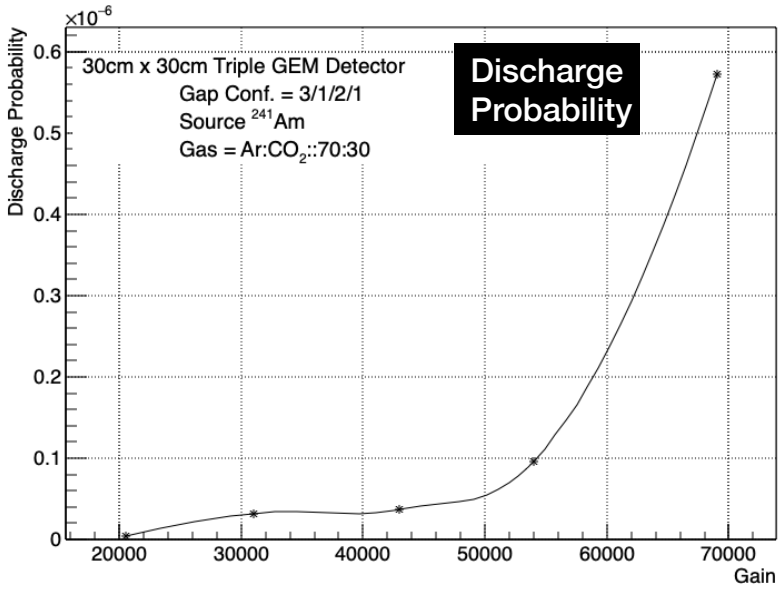
Development and qualification of triple-GEM detector built with large size single mask foils produced in India, JINST 15 P02003

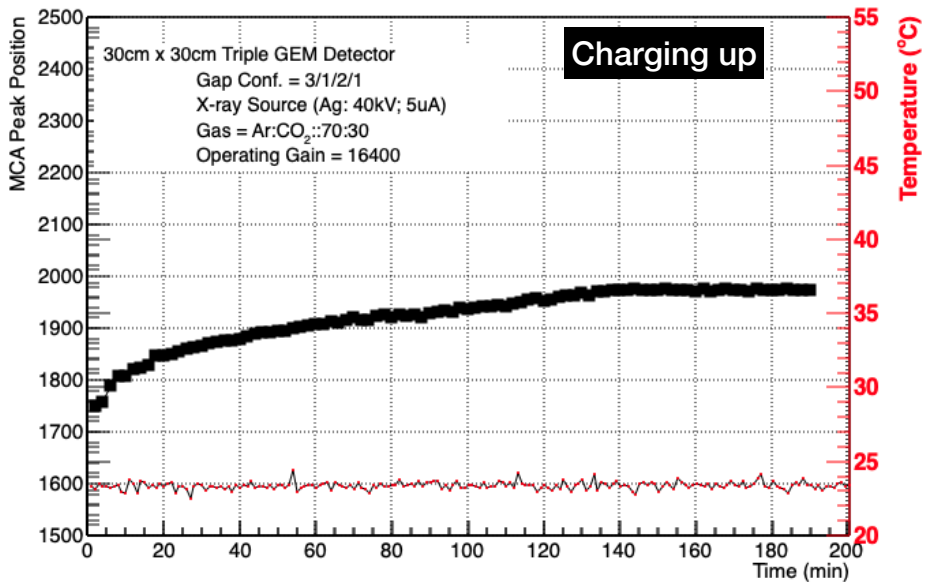


- Post assembly the detector was tested of gas leak and found to be 3 mbar/hr.
- Also, detector shows the ohmic behaviour up to 4.9 kV with any spark or strange behaviour.
- Performed effective gain measurement and Gain Uniformity.



Discharge probability of 3.6 X 10^{-9} at the gain of 2 x 10^{4}

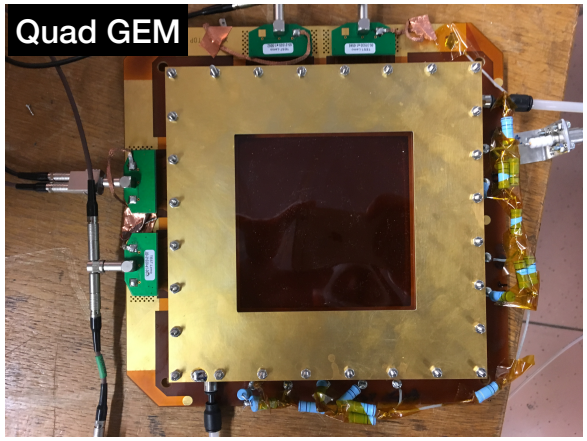


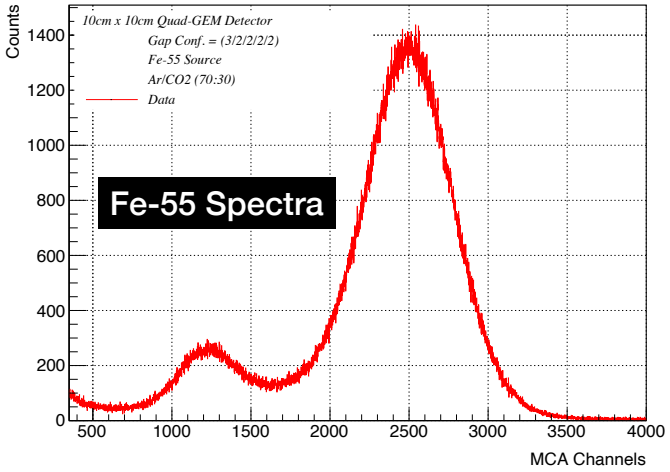


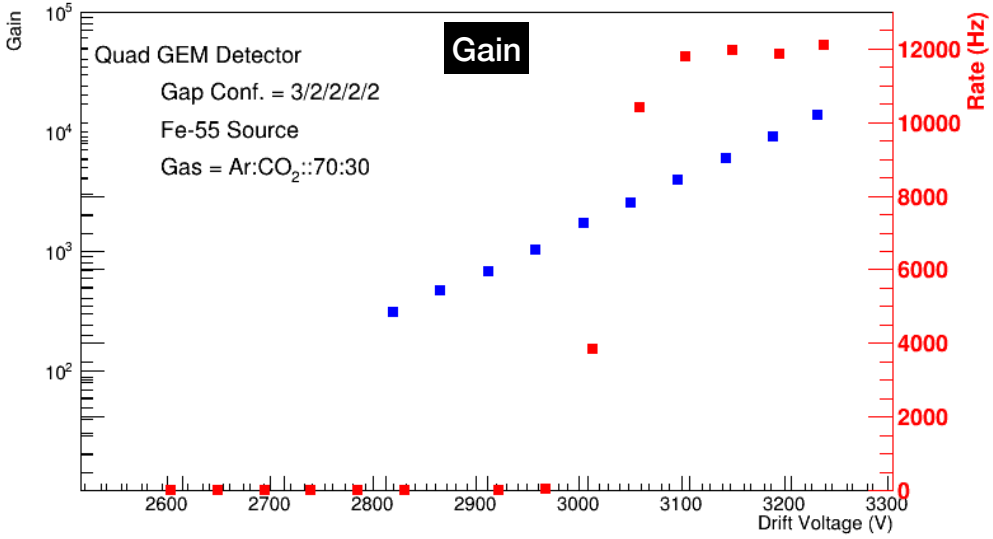
Quadruple GEM

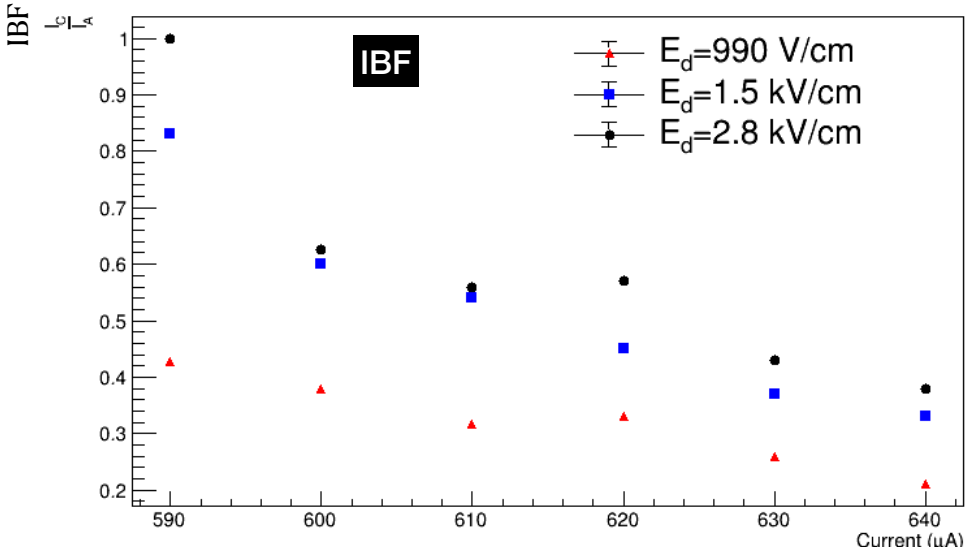
Ion feedback and electron transparency measurement for a quadruple GEM detector, to be submitted soon

- A four-GEM detector was built using the same gap configuration used by CMS i.e. Drift/ transfer1/transfer2/induction gap of 3mm/ 1mm/2mm/1mm/2mm.
- 1-D readout board with an active area of 10cm X 10cm used to pick up the signal.
- The Current measurement was performed using a pico-ammeter and pulse measurement was processed using the NIM electronics.

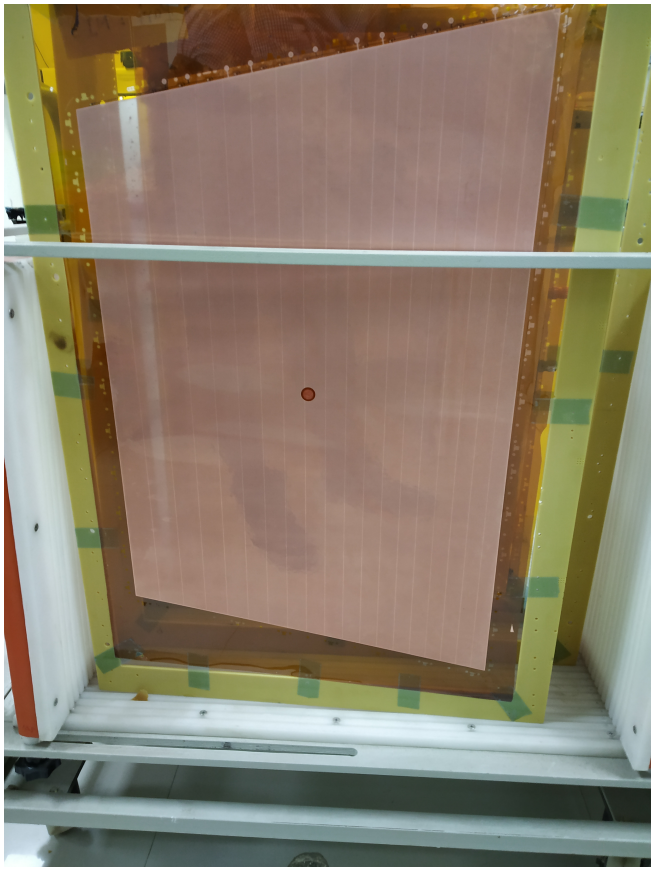








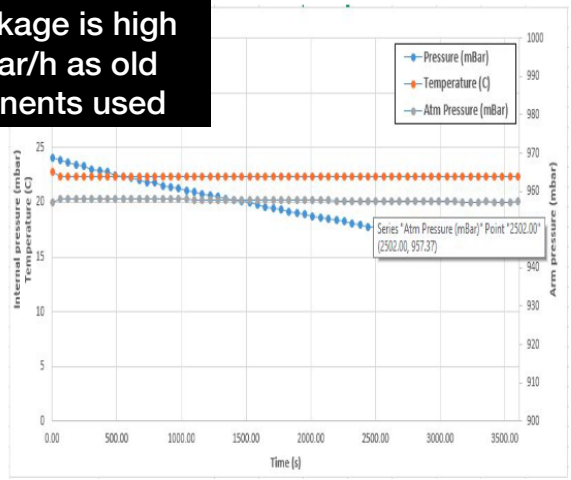
45 cm x 60 cm: Inspection at Micropack

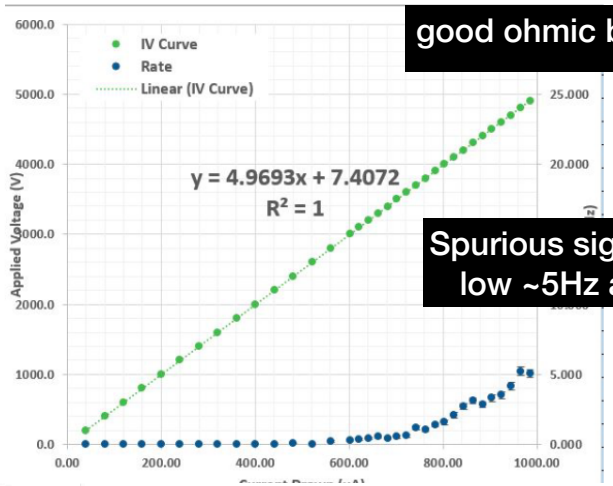


CMS GE2/1 chamber with 45 cm x 60 cm

Gas leak Test(QC3) & HV Test (QC4)

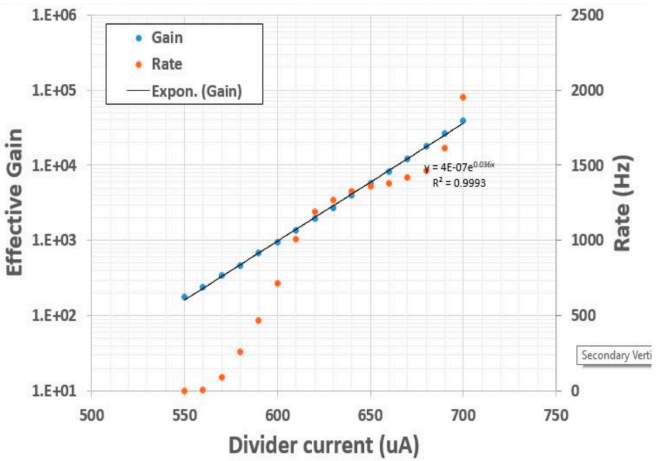
Gas leakage is high ~8 mbar/h as old components used

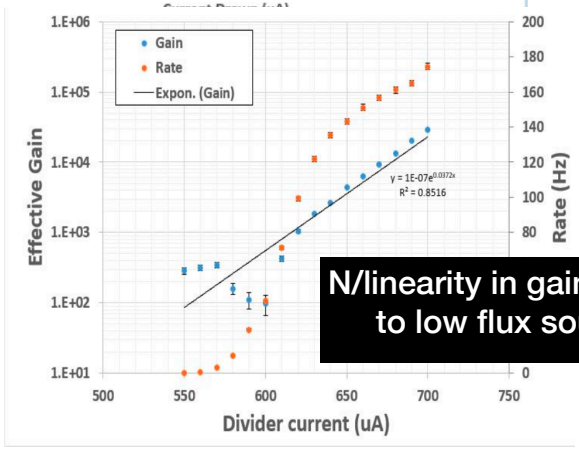




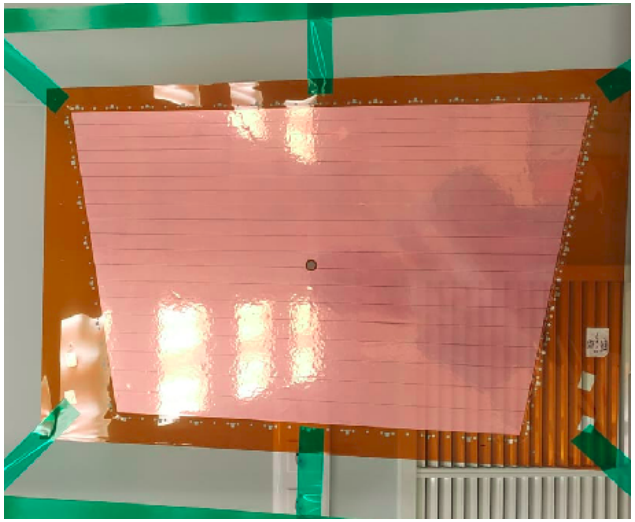
good ohmic behaviour

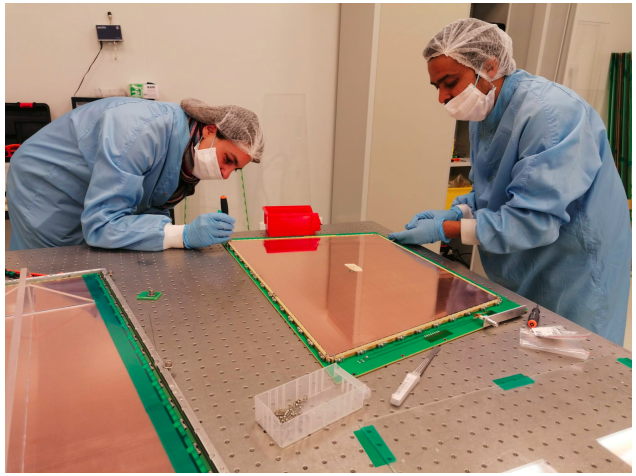
Spurious signal is very low ~5Hz at 4.9 kV





N/linearity in gain is due to low flux source





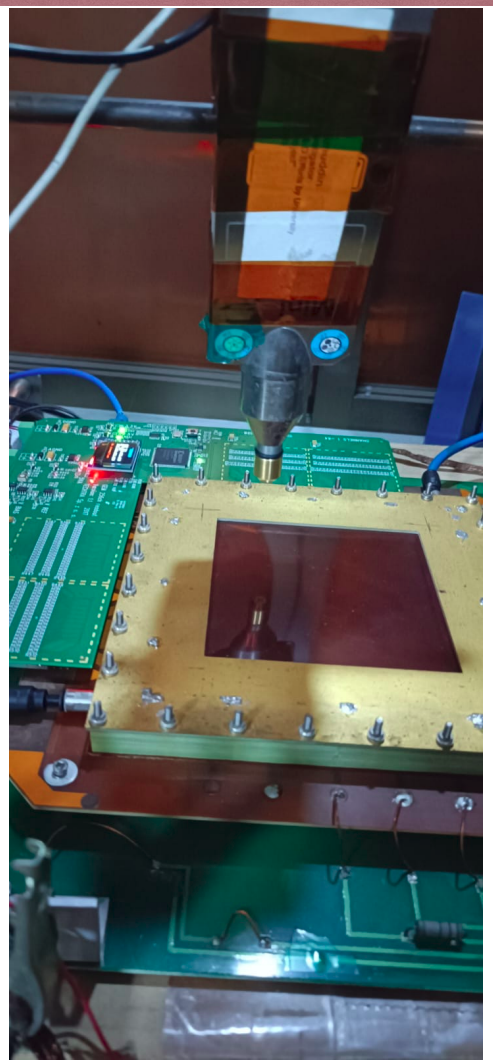
With XRay gun: 40kV, 5uA

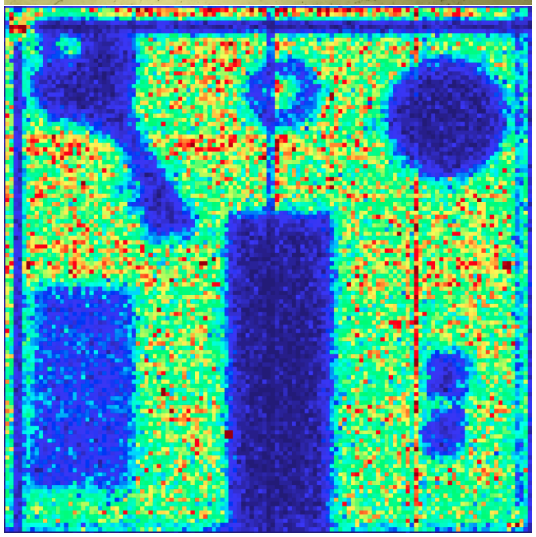
Source: Cd109

Imaging with X-ray

The qualification of GEM detector and its application to imaging, JINST 17 P04002 (2022)

- Excellent detector performance: Highly uniform and stable gain.
- 2D readout with 256X256 channels to take data.
- Electronic board with four 64 channel 20 bit ADC (DDC24)
- Stores charge information per strip at 6k samples/s
- Xilinx Spartan-3 FPGA to control various electronics components.
- Ar:CO2 :: 70:30 & ~10^4 gain
- Algorithm finds clusters and Gaussian fit mean is taken as hit position
- Image is reconstructed for cluster size < 6 and energy (a.u) < 0.4





Summary

- Micropack successfully built GEM foils, with active area of 10 cm x 10 cm, 30 cm x 30 cm, and 45 cm x 60 cm using single as well as double mask etching technique.
- The needed tests are conducted and seems are of excellent quality.
- The gain performance after assembly of the triple layer detector is also superb.
- We also tested the foils for Imaging application and now building a full and large system.
- RD51 community and interested collaborators can also be benefited for their scientific and societal applications.
- Many thanks to Rui and RD51 for their continuous support.