RAPID2021

Workshop on Advanced Radiation Detector and Instrumentation in Nuclear and Particle Physics (Online)

Charging up studies in thick Gas Electron Multiplier

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Motivation

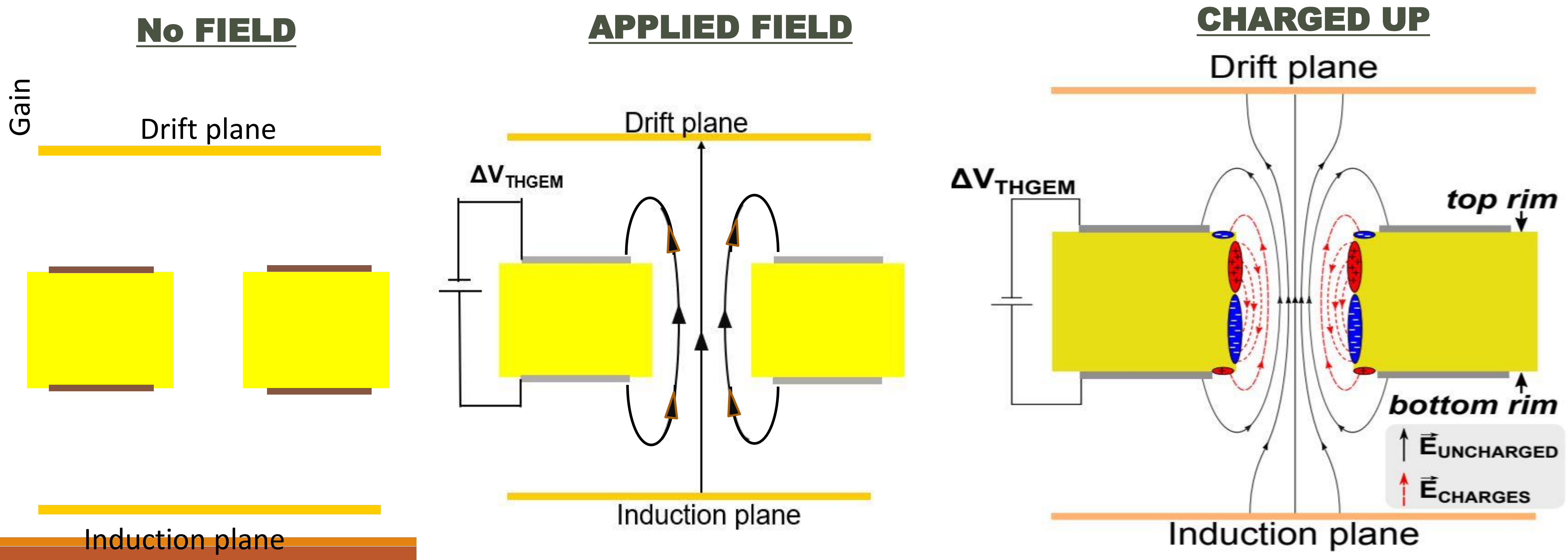
- **The time-dependent variation of avalanche-gain in micro pattern gaseous detectors, is one of the challenging problems in high-rate experiments.**
- **Charging up and charging down are two such phenomena which significantly affect gain-uniformity.**
- **These phenomenon are even more pronounced in THGEM, having thicker dielectric.**
- **Moreover, THGEMs are robust detectors, can be easily fabricated in our country.**

Contents:

- Charging up in THGEMs
- Detector specifications and experimental setup used in lab
- Results and discussion
- Future work and conclusions

Charging up in GEMs

- **Out of all the charges created in the multiplication region, a significant amount of them end up on the exposed dielectric surfaces, leading to charge accumulation during the detector operation.**
- **This accumulation of charge gives rise to an additional electric field, which distorts the originally applied field.**



M. Pitt et al, Measurements of charging-up processes in THGEM-based particle detectors, 2018.

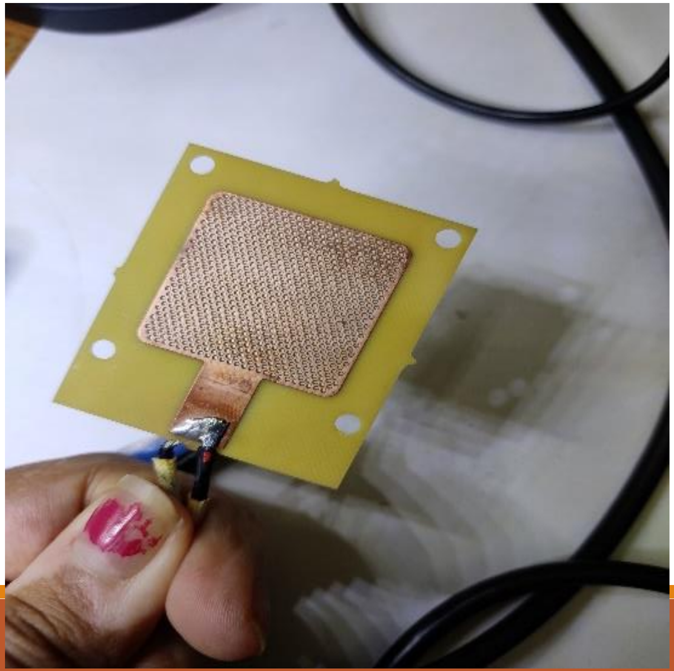
Detector set-up and its specifications

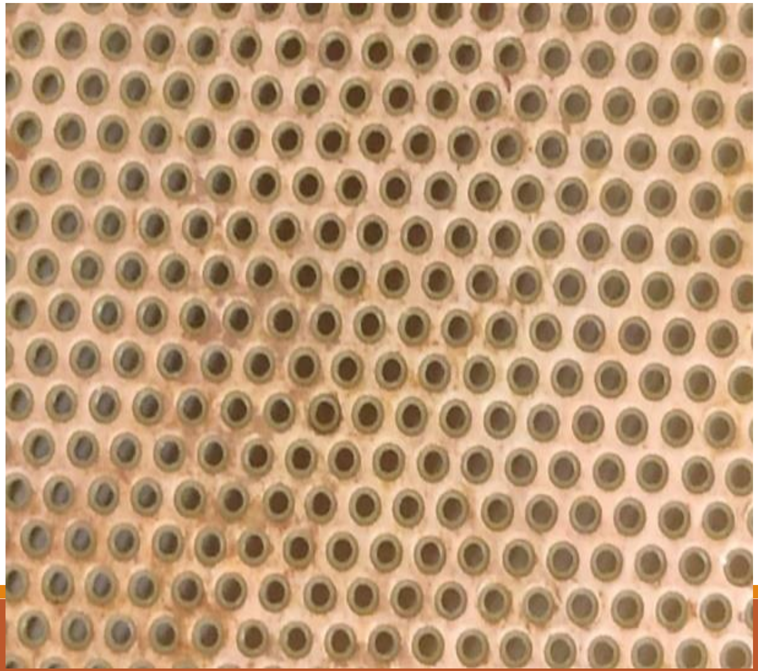
Geometrical specifications:

- GEM hole dia: 0.5mm
- Rim: 0.1 mm
- Pitch: 1mm
- GEM foil thickness: 800µm
- Copper coating : 50µm

Al box with all the connections

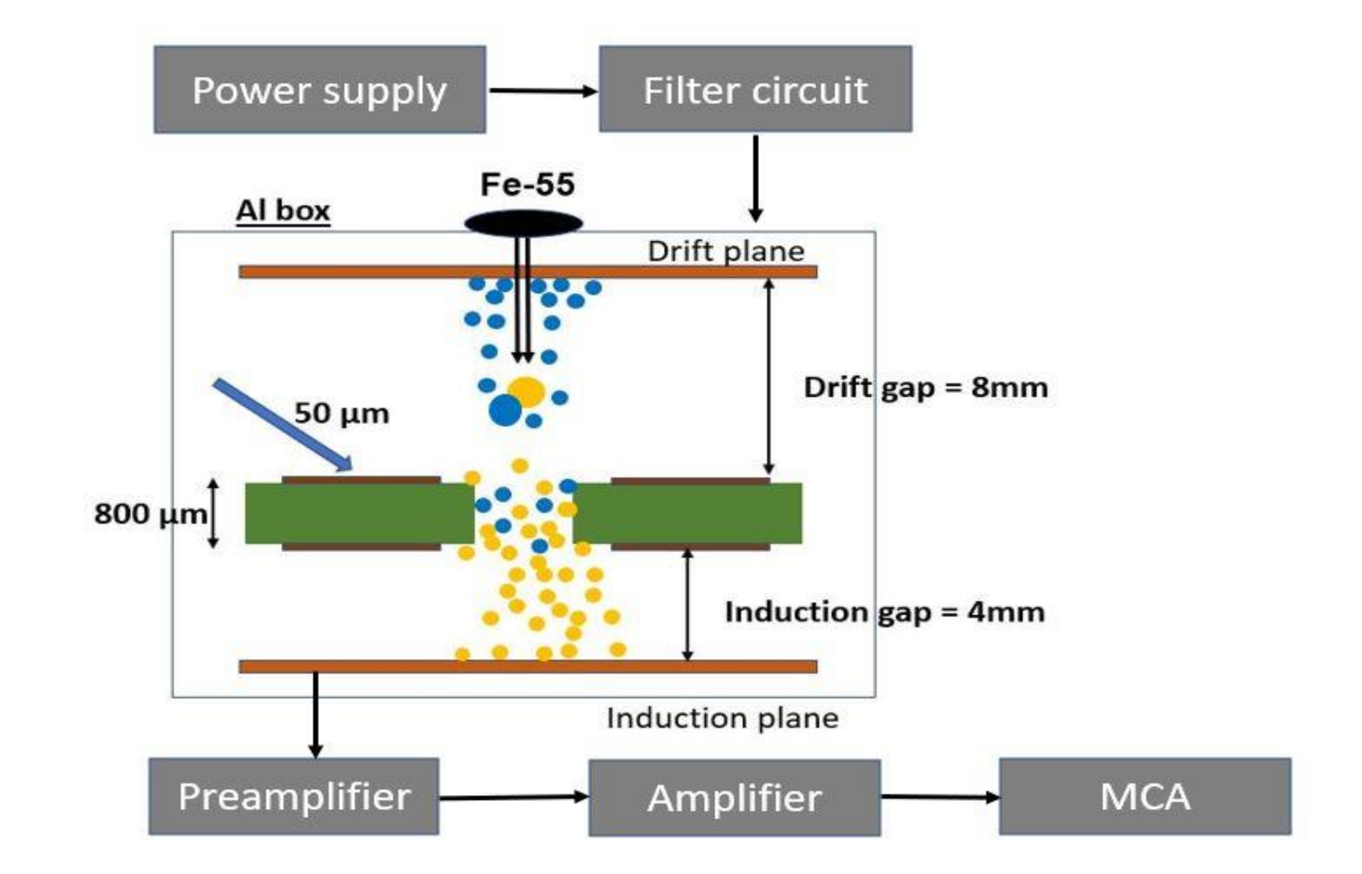
THGEM detector

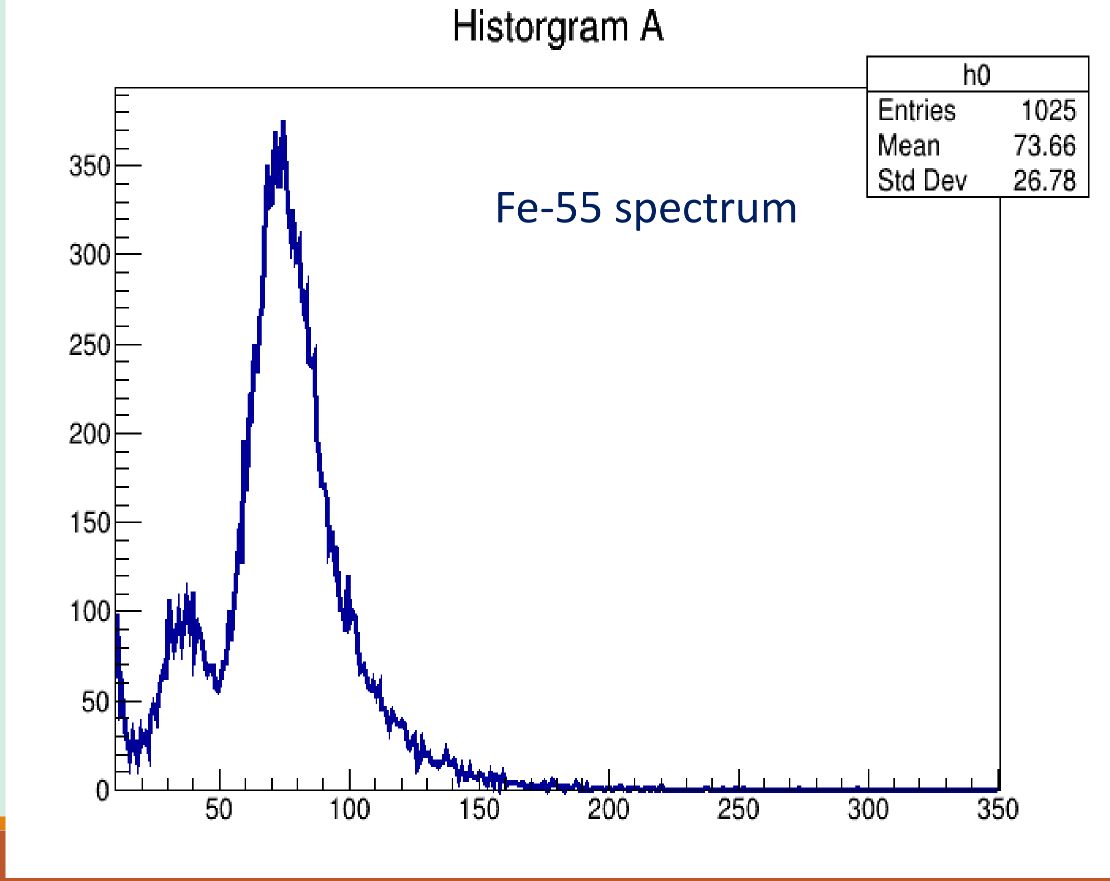




Schematic of experimental setup

- **Detector was placed inside an aluminium box having a hole on the centre of the lid for the placement of the source.**
- **Gas was being flushed into the box.**
- **Chosen drift gap = 8mm and induction gap = 4mm.**

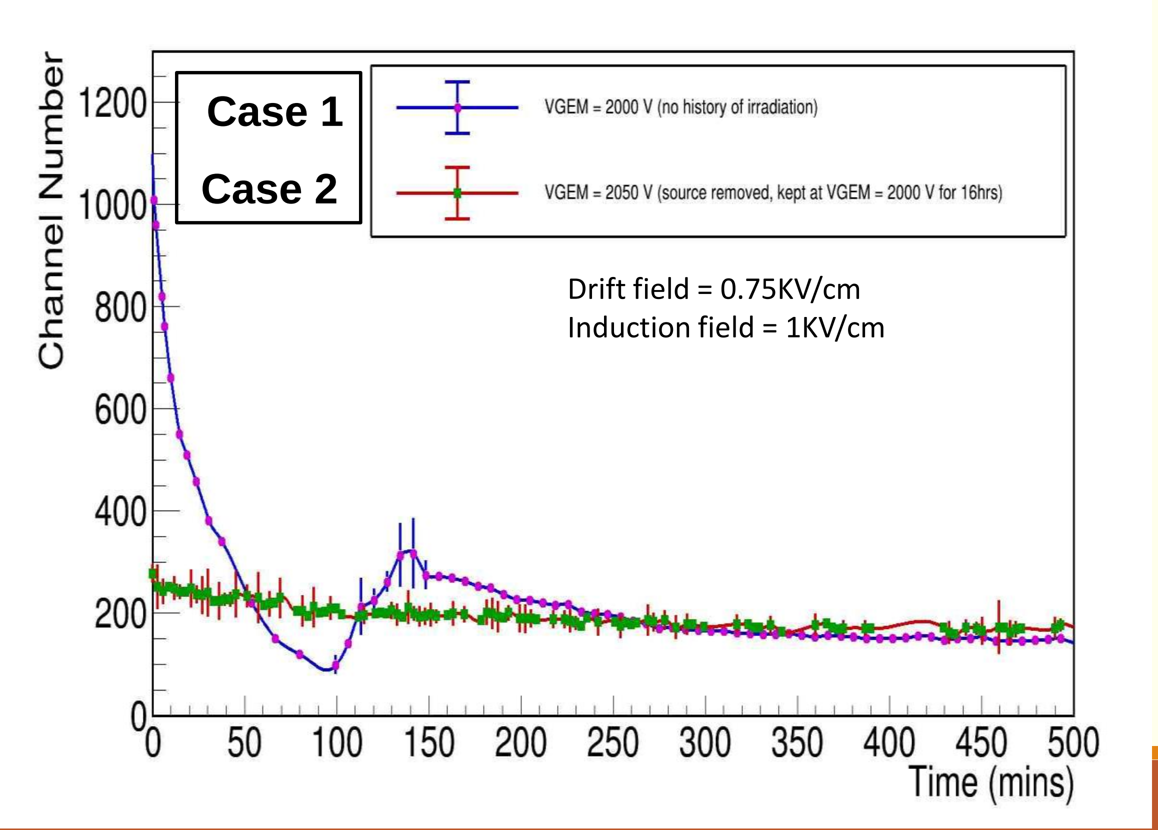


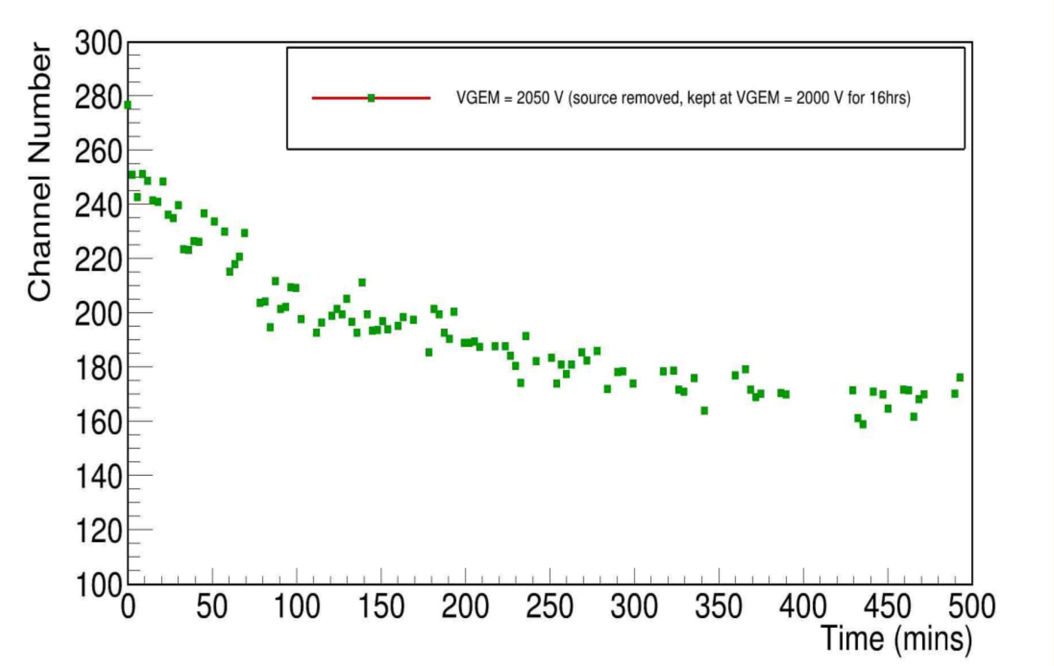


Cleaning the detector

Measurement of charging up processes are strongly affected by the charge history of the electrode:

- Rinsing with solvents (like iso-propyl alcohol), baking at 100 degree centigrade for an hour and flushing with air gun or nitrogen gun.
- Conventional method of nitrogen flushing





Case I :

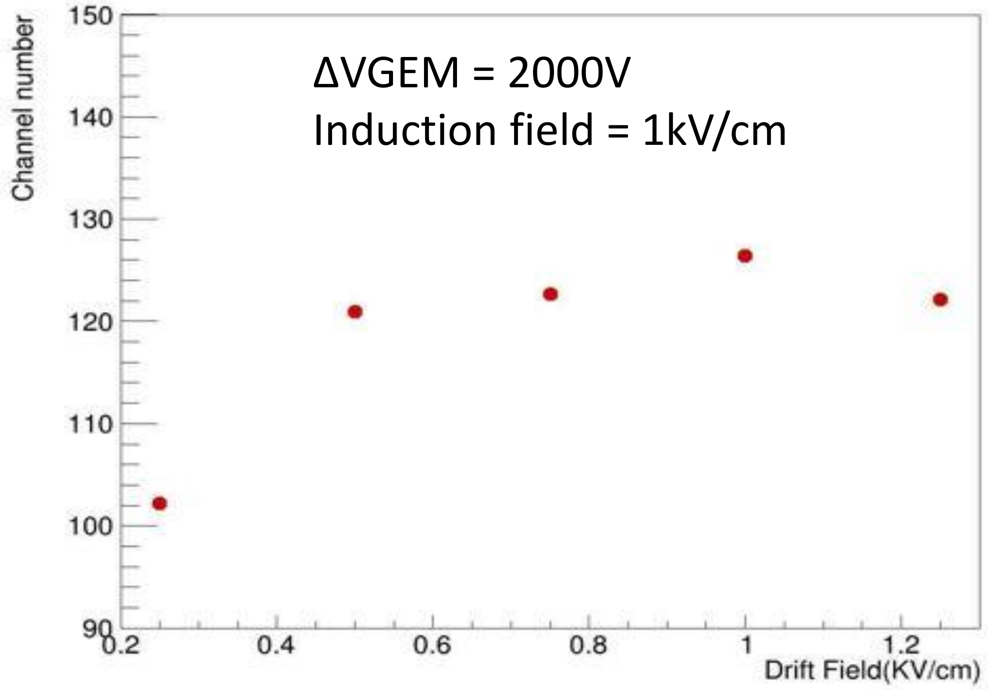
- **Nitrogen flushing for 1 day**
- **Detector was given voltage bias, and Ar:CO_2 = 90:10 was flushed for 1 day.**
- **Irradiated with source (~53 Hz/mm^2)**

Case 2:

- **Source was removed**
- **Detector was kept as it is with Voltage bias on, and Ar:CO_2 = 90:10 flowing, for 16hrs**
- **VGEM was increased to 2050 V**
- **Irradiated with source (~53 Hz/mm^2)**

Electron transmission study

• Electron transfer efficiency (ETE) has been studied varying drift field at constant ΔVGEM and induction field
• ΔVGEM is kept at 2000V and induction field is 1kV/cm



➢Electron transfer efficiency is found to increase with drift voltage, attains a maximum value, then it decreases.

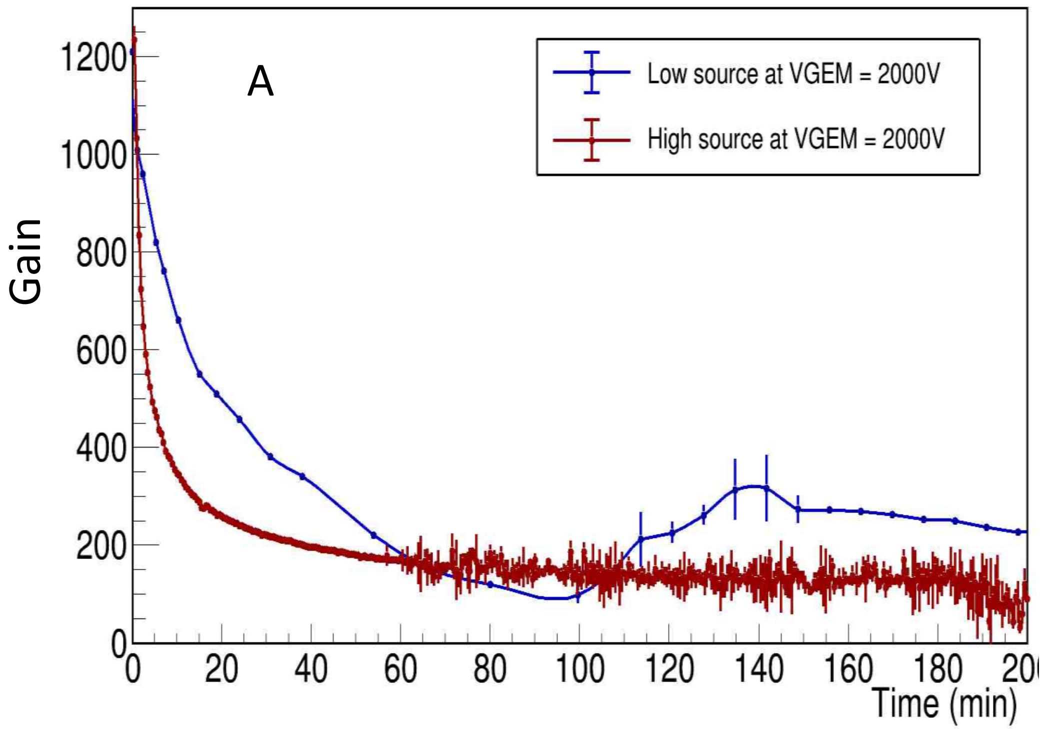
➢ This variation in ETE with drift field can be attributed to the difference in focusing of electrons in a given applied field.

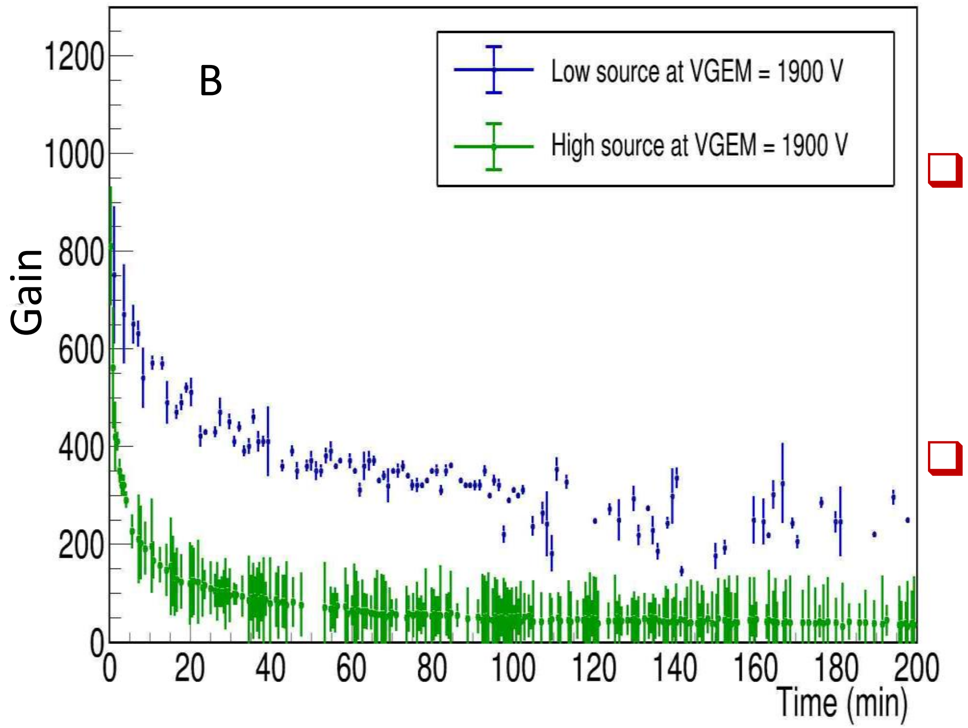
➢The electrons lost on the top rim of the holes can charge up the dielectric and introduce a variation in the detector gain along with other factors.

➢Top rim gets negatively charged due to primary electrons whereas bottom rim gets positively charged due to accumulation of ions in the vicinity of hole bottom.

Evolution of gain with different irradiation rates

- **Two different irradiation rates were used to study the evolution of gain.**
- **Low rate source: 52.77 Hz/mm²**
- **High rate source: 686 Hz/mm²**





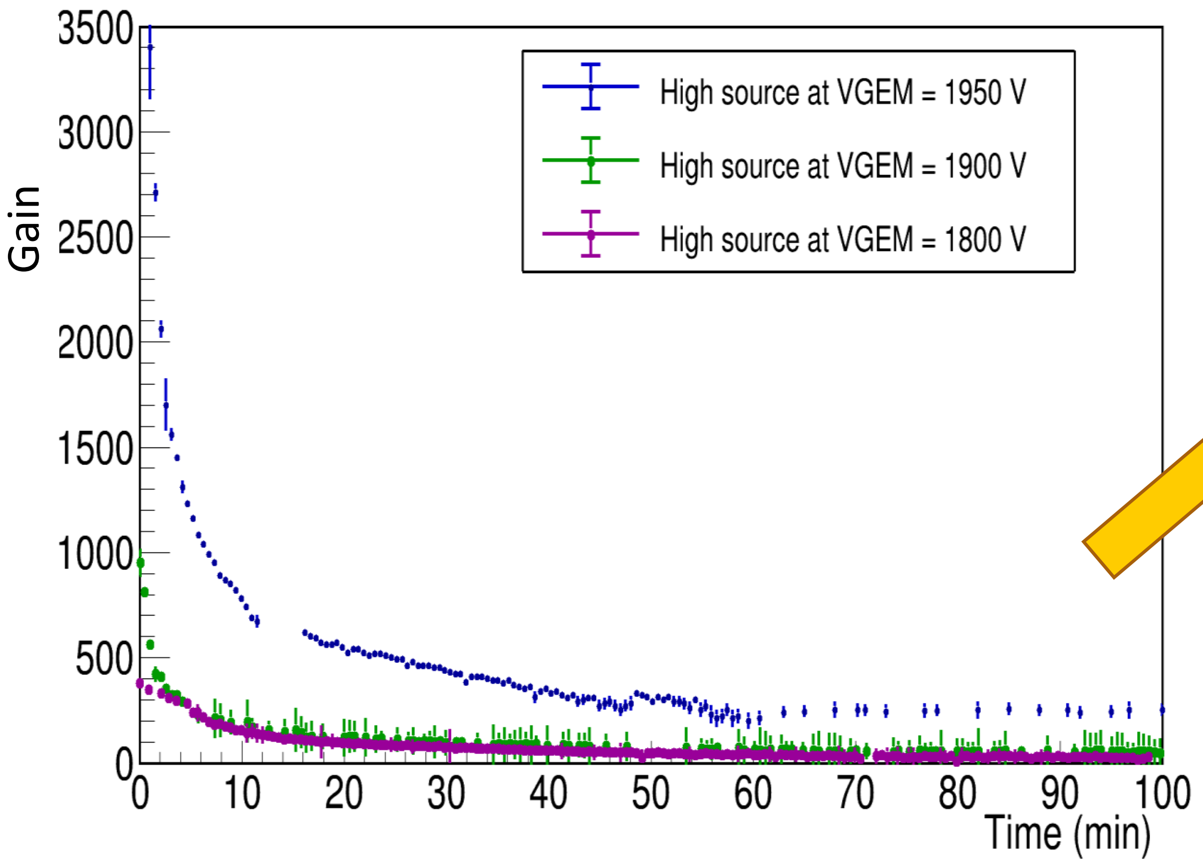
- ❑ **Gain for high rate source falls sharply, stabilizes faster as compared to gain for low rate source.**
- ❑ **Also, $\Delta G_{high} > \Delta G_{low}$ where ΔG is the total change in gain.**

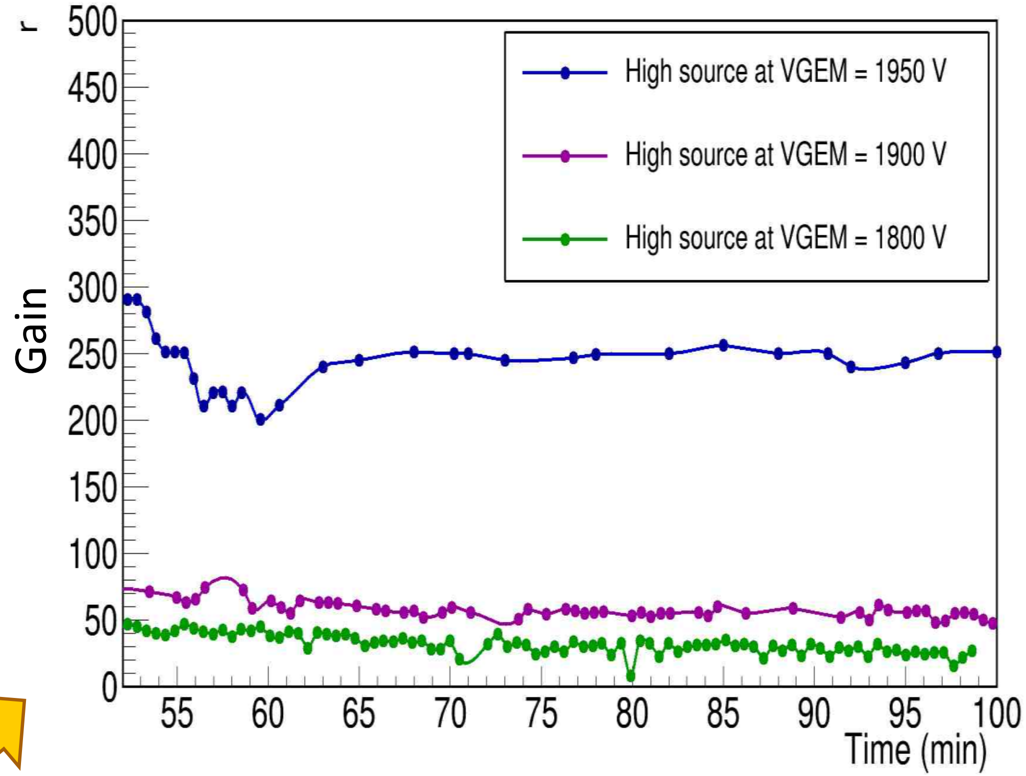
Note:

- **Result A has been obtained with approximate temperature 25.0 °C and humidity 60%.**
- **Result B has been obtained with nearly same temperature 25.0 °C but less humidity 30%.**

Evolution of gain with different THGEM voltages

- **Voltage across the dielectric is changed to get the gain evolution curve**
- **Drift field was again 0.5 kV/cm and induction field was 1kV/cm .**
- **High rate source (686 Hz/mm2)was used .**





- ❑ **Maximum gain (the initial value) increases sharply with increasing THGEM voltage.**
- ❑ **Also ΔG is higher for higher ΔVGEM**

Results and discussion

- Experimentally, we could get Fe-55 spectrum and signal for thick GEM using gas Ar:CO2 = 90:10.

- Charging up of THGEM dielectric decreases its gain which is found to depend on irradiation rate, drift field/ electron transmission and applied voltage across the dielectric.

- Discharging the dielectric to take it back to its pristine form takes a minimum of 2-3 days if done conventionally.

- High rate source charges up the dielectric faster than the low-rate source, which results in faster reduction in gain. Also, the gain with high-rate source stabilizes at lower value than that with low-rate source.

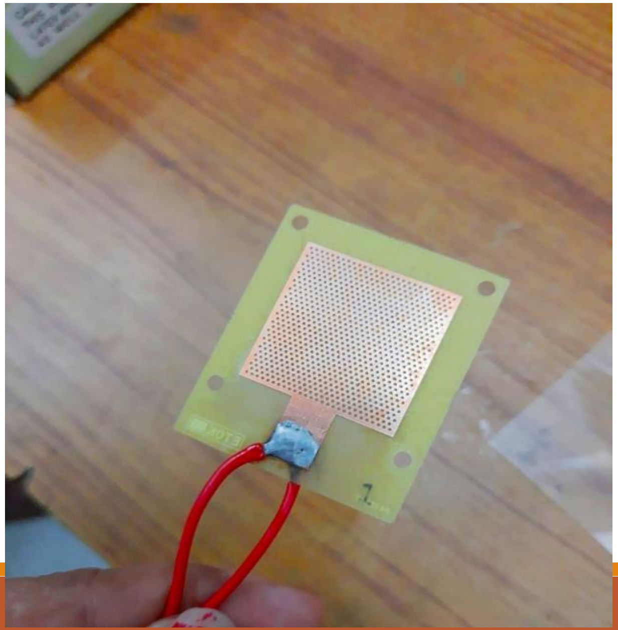
- Maximum gain as well as stabilized gain increases with increase in voltage across dielectric.

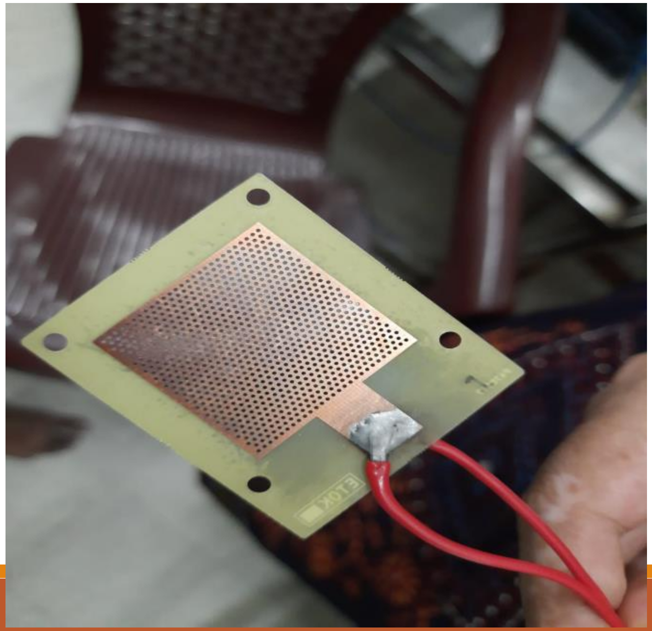
Future studies

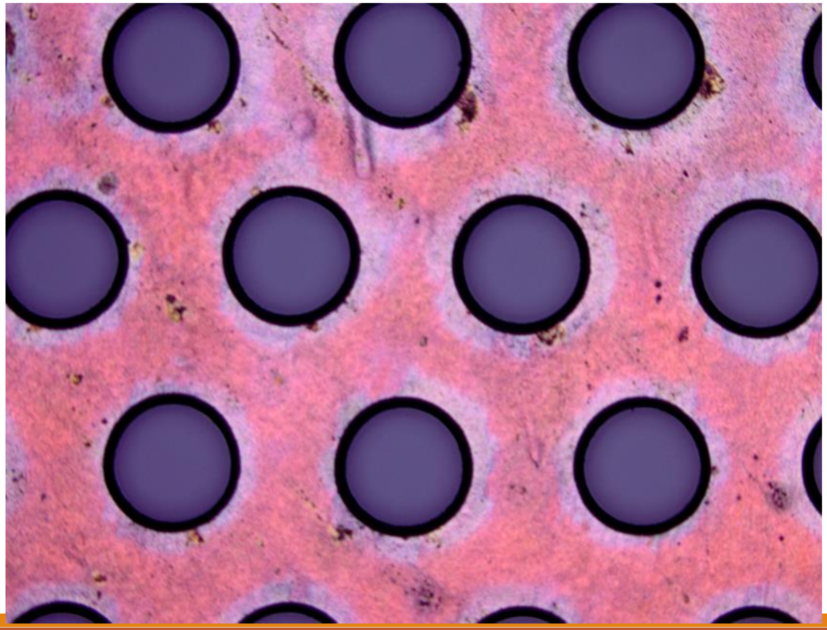
- Numerical and experimental study of effect of “Rim” on gain evolution with different irradiation rates and rim sizes.
- Use of other gas mixtures in experiments, and get an optimum working range.

- Study micro-discharges and see whether charging up is the driving factor.

- New thick GEMs have been procured from a local manufacturer in KOLKATA, which have been tested under the microscope and they appear reasonably good. Study the charging up phenomena with these new thick GEMs and do the numerical calculations as well.







Microscopic view

Acknowlegdement

- **Collaborators**
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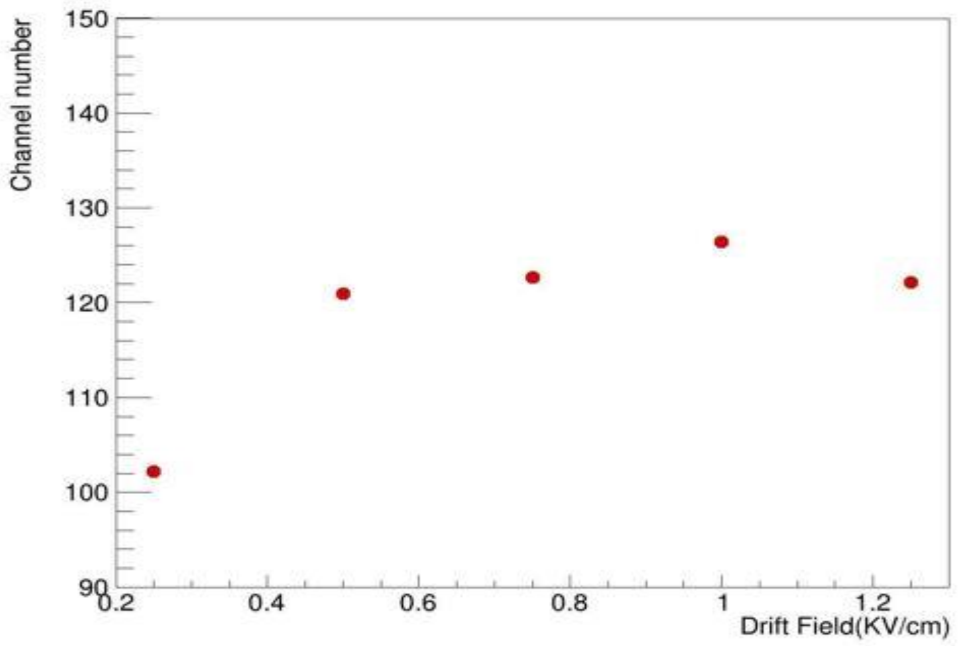
THANK YOU

Back up

Top and bottom rim charging up

- Charging up of top rim depends on the initial number of primary electrons.
- Charging up of holes and bottom rim depends on detector's gain.
- Top rim ⟹ negatively charged and
- Bottom rim ⟹ positively charged due to ions created in the vicinity of bottom GEM electrode.

Steady state gain variation with drift voltage



Effect of bottom rim:

- Rate of charge accumulation on hole walls is greater than rate of ion accumulation on bottom rim.
- As a result, the combined effect of charging up of holes and bottom rim ↓ the gain.

Effect of top rim:

- Charging up of top rim ↑ the gain and introduces long-term stabilization (long time scale of charging up by primary electrons.
- However, this long term stabilization is affected by drift field which governs the ETE (electron transfer efficiency).
- At higher drift fields, ETE decreases ⟹ top rim gets heavily charged ⟹ long-term characteristic time increases