Studies of charging up in THGEMs

P. Roy [1,2*], V. Kumar[1,2], P. Bhattacharya [3], P. Das[1,2], S. Mukhopadhyay [1,2], N. Majumdar [1,2]

[1] Saha Institute of Nuclear Physics, Kolkata - 700064, India, [2] Homi Bhabha National Institute, Mumbai - 400094, India, [3] Department of Physics, University of Calcutta, Kolkata-700009, India

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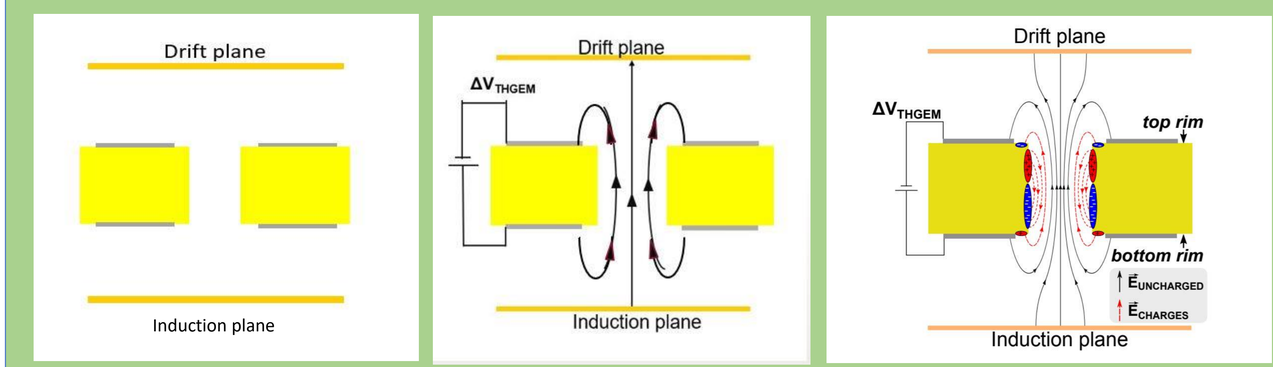
Motivation

- Micro Pattern Gaseous Detectors (MPGDs) are being used widely in particle physics experiments all over the world for their good position resolution, timing resolution and high rate capabilities.
- The time-dependent variation of avalanche-gain in these 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-stabilization and thus the optimum working range.
- These phenomenon are very pronounced in THGEMs, due to thick dielectric (PCB material) used in their construction.
- THGEMs are robust detectors and their manufacturing is cost effective.

Charging Up

- 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.

No FIELD | APPLIED FIELD | CHARGED UP

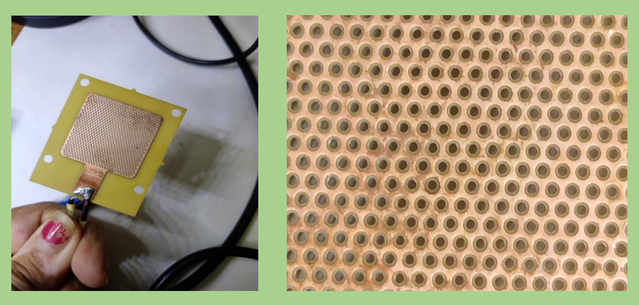


M. Pitt et al, Measurements of charging-up processes in THGEM-based particle detectors, 2018.

Detector used and its specifications

Dielectric thickness : 800μm
Pitch: 1mm
Diameter: 500μm
Rim: 100μm
Gas mixture : Ar-CO_2 in 90:10

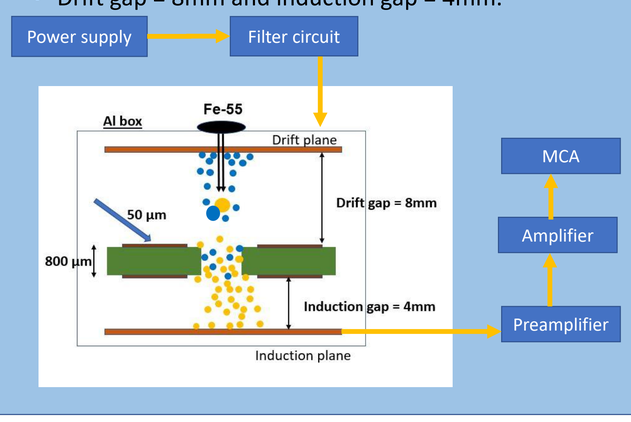
THGEM detector



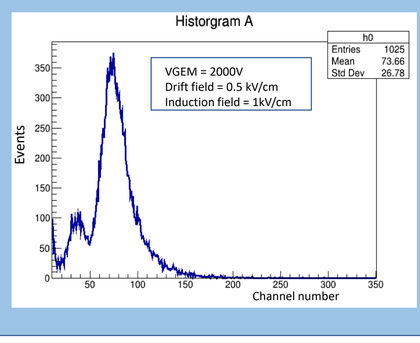
Al box with all the connections

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.
- Entire box was filled with gas Ar:CO_2 = 90:10.
- Drift gap = 8mm and induction gap = 4mm.

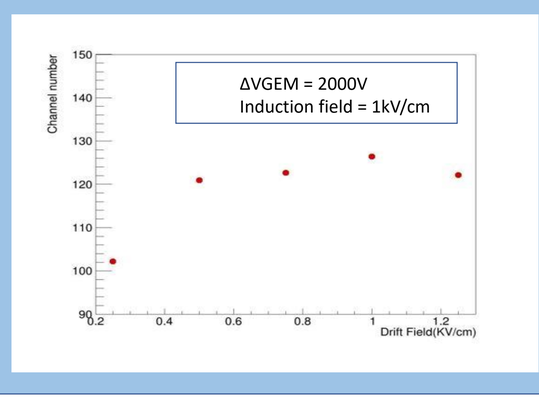


Fe-55 spectrum



Electron transmission study

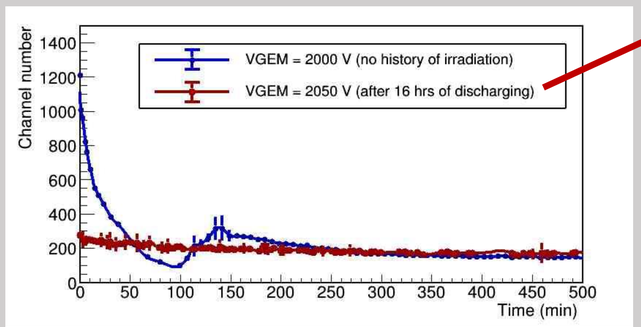
- Electron transfer efficiency (ETE) has been studied varying drift field at constant ΔVGEM and induction field
- ΔVGEM is kept at 2000V and induction field is 1kV/cm

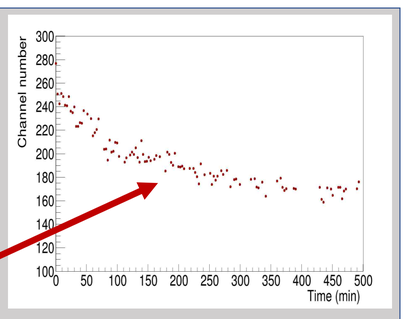


- Electron transfer efficiency is found to increase with drift voltage, attains a maximum value, then it decreases.
- This variation in ETE with drift field can be attributed to the difference in focusing of electrons in a given applied field.
- The electrons lost on the top rim of the holes can charge up the dielectric and introduce a variation in the detector gain along with other factors.

Gain evolution

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

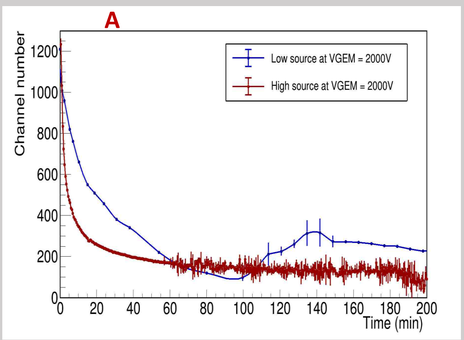


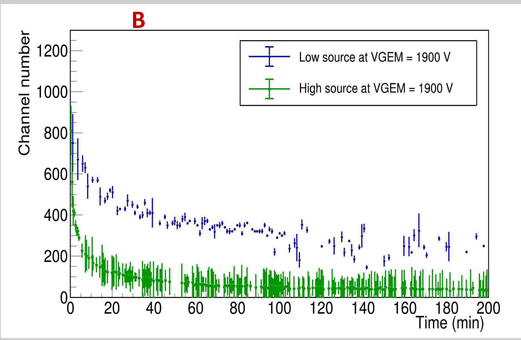


Case 2:
- Source was removed
- Detector was kept as it is with Voltage bias on, and Ar:CO_2 = 90:10 flowing, for 16hrs
- VGEM was increased to 2050 V
- Irradiated with source (~53 Hz/mm^2)

Gain evolution with irradiation rate

- Two different irradiation rates were used to study the evolution of gain.
- Low rate source: **52.77 Hz/mm^2**
- High rate source: **686 Hz/mm^2**
- Drift field was 0.5 kV/cm and induction field was 1kV/cm



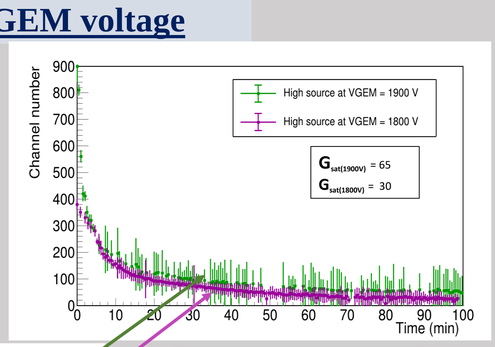


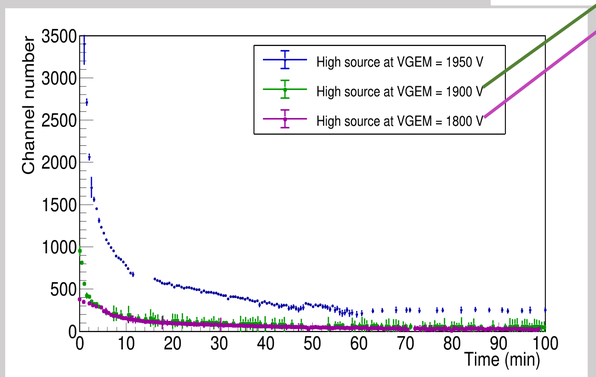
Note:
- Result A has been obtained in September 2020 with approximate temperature 25.0 °C and humidity more than 50%.
- Result B has been obtained in April 2021 with nearly same temperature 25.0 °C but less humidity 30%.

- 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.

Gain evolution with applied THGEM voltage

- 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/mm^2)** was used .





- Maximum gain (the initial value) increases sharply with increasing THGEM voltage.
- For instance, maximum gain
  - $G_{max(1800V)}$ = 380
  - $G_{max(1900V)}$ = 899
  - $G_{max(1950V)}$ = 3450
- Also ΔG is higher for higher ΔVGEM.

Results and discussions

- 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.

References:
- M. Pitt et al, Measurements of charging-up processes in THGEM-based particle detectors, 2018.
- He Zhan-Ying et al, Experimental studies of THGEM in different Ar/CO2 mixtures, 2014.
- P.M.M. Correia, A dynamic method for charging-up calculations: the case of GEM, 2014.

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