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An experimental study to understand the physics behind charging-up of Gas Electron Multiplier (GEM)

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MOTIVATION

- Charging-up is a common phenomenon observed in gaseous ionization detectors with exposed dielectric components.
- Gas Electron Multiplier (GEM) has a large insulating surface exposed to the active gas volume.
- In charging-up process the gain of the detector either increases or decreases due to modification of local field around dielectric.

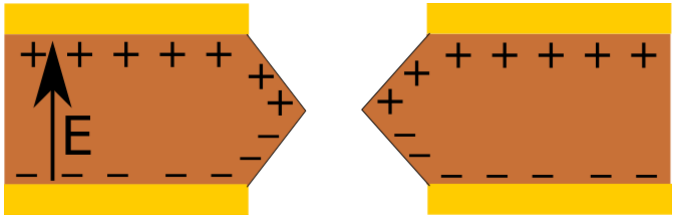
What causes charging-up?

Physics ?

Types of charging-up

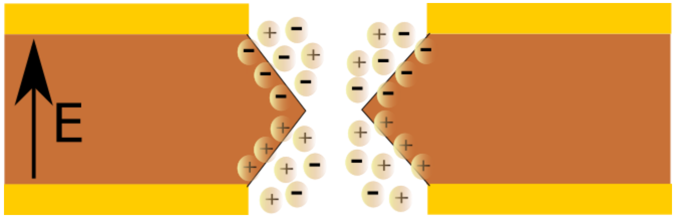
Polarization charging-up

- Space-charge polarization of dielectric
- Very high field across dielectric (~100 kV/cm)
- Modification of local field leading to gain variation



Radiation charging-up

- High density of charges around the dielectric
- Charges get trapped within the dielectric
- Modification of local field leading to gain variation



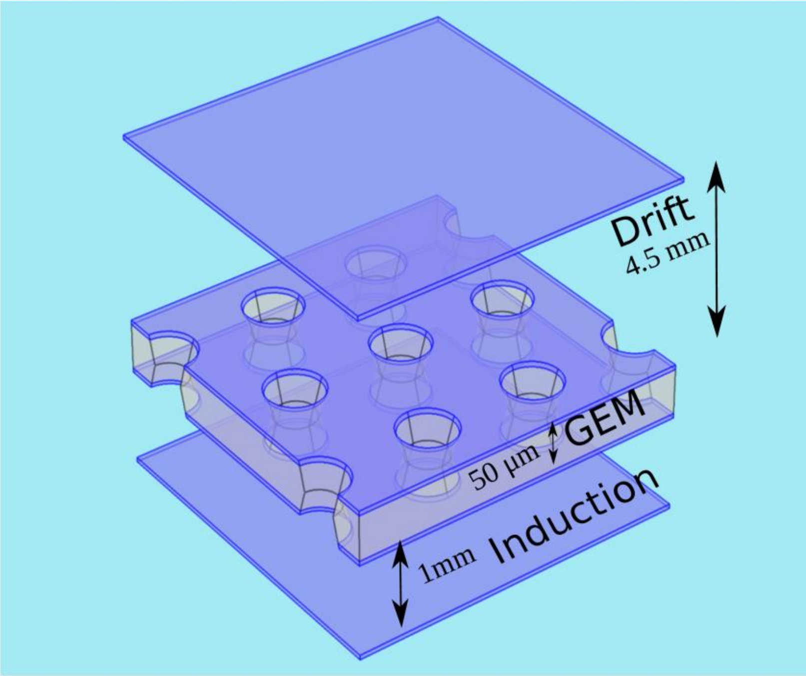
Overview

- Experimental setup
- Gain measurement
- Polarization charging-up
- Radiation charging-up & down
- Conclusions

EXPERIMENTAL SETUP

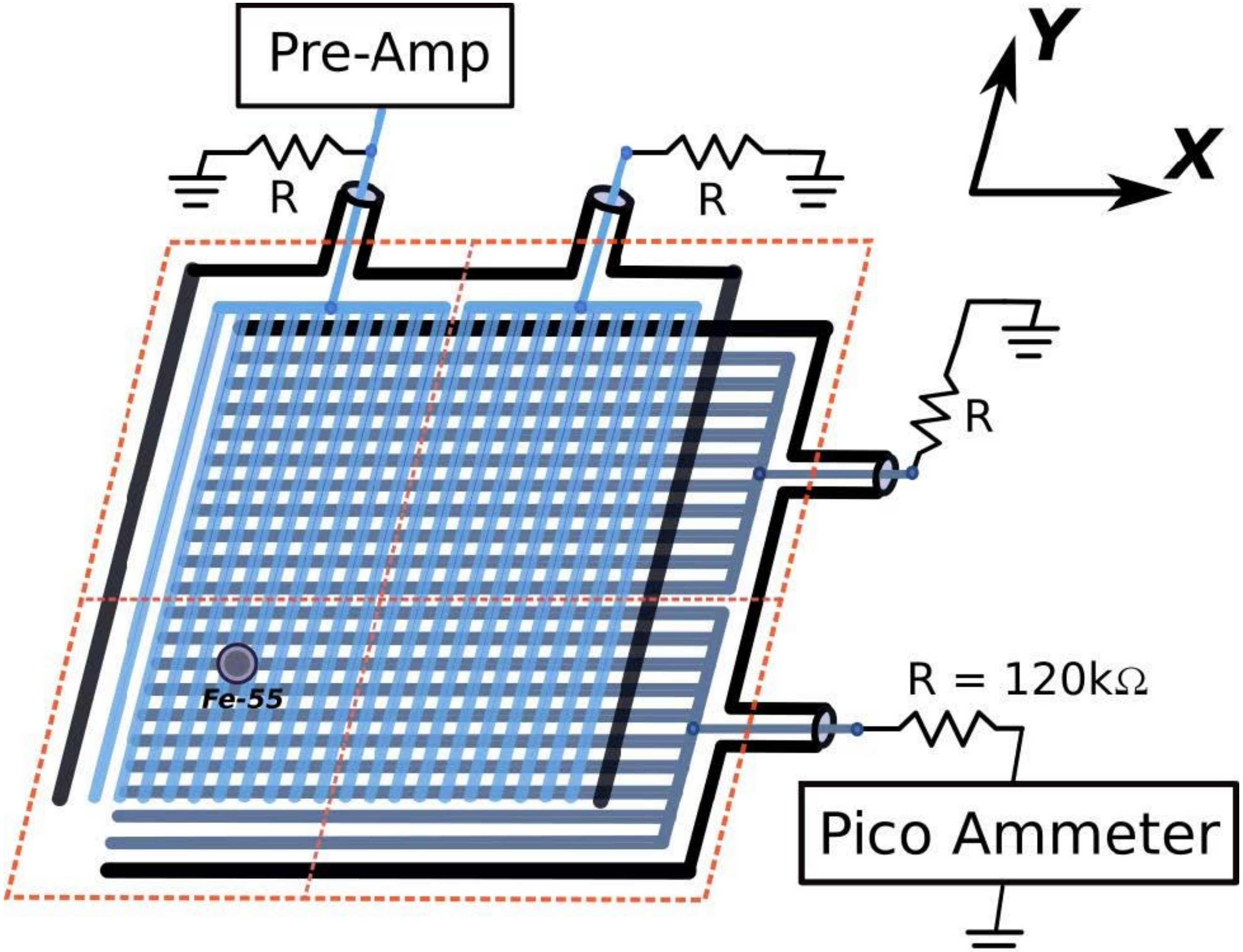
GEM foil

- 50 µm Kapton sheet sandwiched between two copper layers of 5 µm
- Biconical holes of 50 µm and 70 µm inner and outer diameter
- Etched out by chemical lithographic technique in a hexagonal pattern.

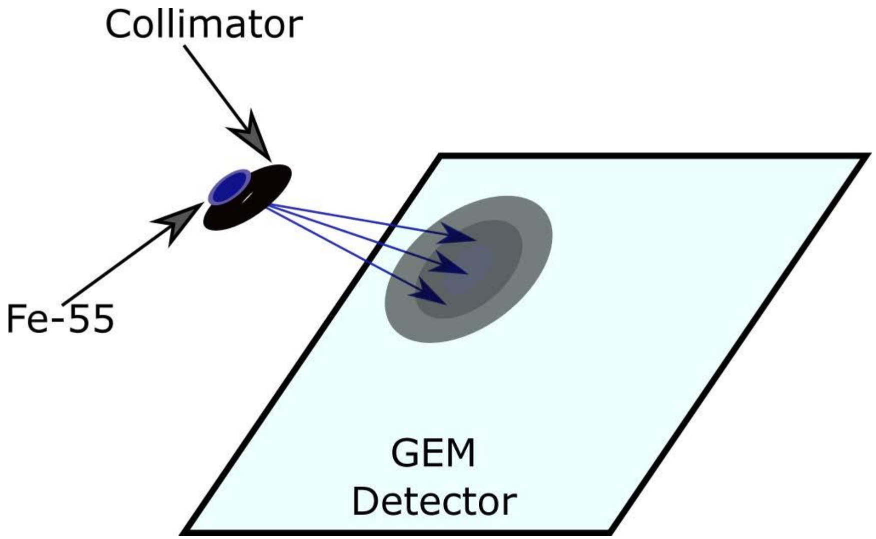


Schematic diagram of single GEM detector.

Readout anode configuration

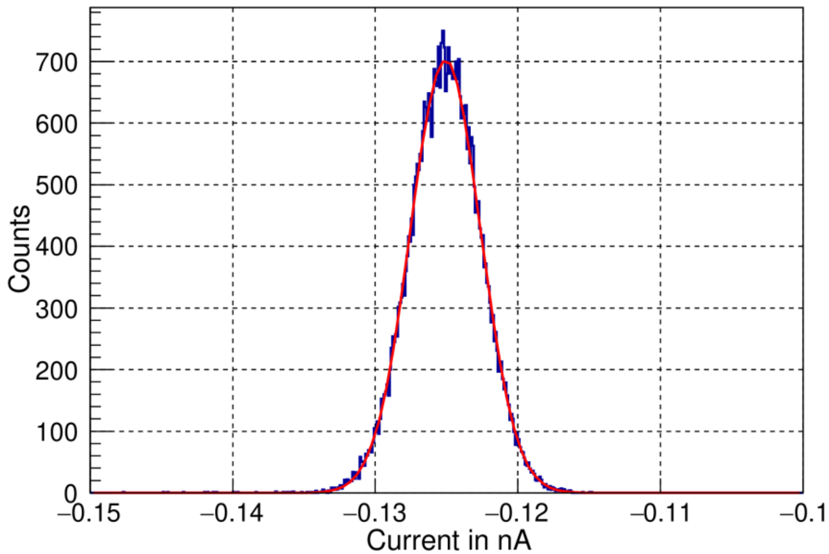


Rate variation and Current measurement



- Aperture of collimator 1-10 mm
- Radiation rate 0.12-25.5 kHz (of 5.9 keV X-ray)

Schematic diagram of irradiation



Gaussian fit for repeated current measurement with 4.0 kHz source.

- Pico-ammeter CAEN AH401D
- Centroid -125.0 pA
- Sigma 2.47 pA

Gain measurement

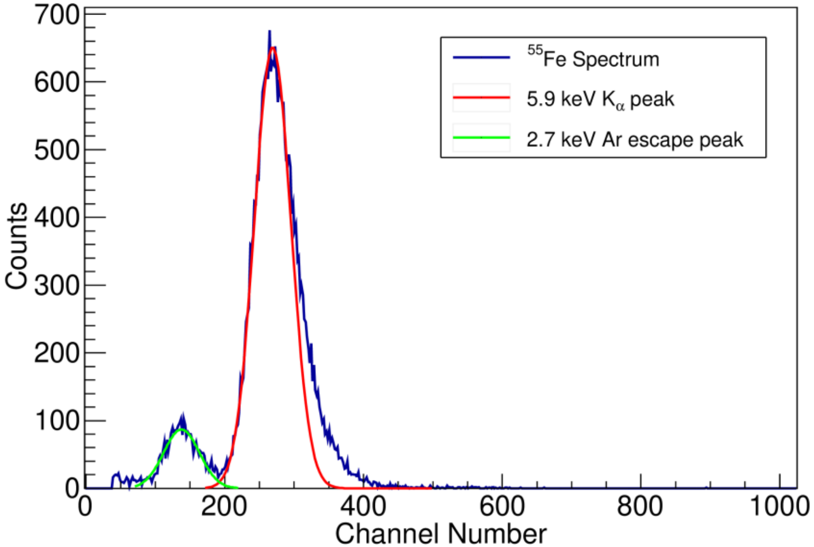
$$G_{eff} = \frac{I.\Delta t}{\sum_i N_i.p_i.e}$$

Total charge collected from readout

Total no. of primaries

Where,

- I is average current from the pico-ammeter,
- Δt is the time interval for energy spectra,
- e is charge of an electron,
- N_i is the number of counts in i^{th} channel, p_i is its corresponding no. of primaries.



No. of primaries for 5.9 and 2.7 keV are generated by Garfield++ using HEED for Ar-CO_2 (74-26%) gas mixture and used to calibrate p_i values.

Gain measurement continuation

$$G_{eff} = \frac{I.\Delta t}{\sum_i N_i.p_i.e}$$

optimized to be large enough to get the energy spectrum for the Gaussian fitting and small enough to capture the changes caused by charging-up with time.

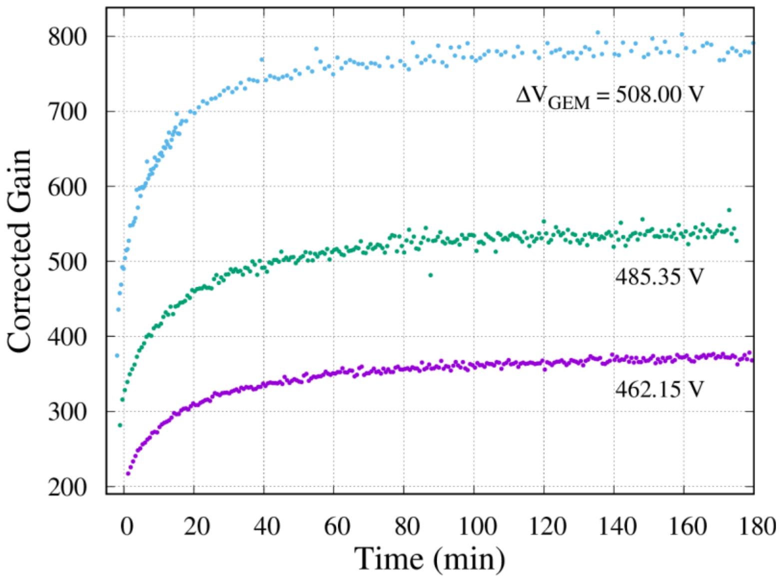
- Channel number $\Rightarrow$ Energy values

  (using two peak calibration from Gaussian fit)

- Energy values $\Rightarrow$ p_i values

  (using two point calibration since no. of primaries are known for 5.9 & 2.7 keV, numerically)

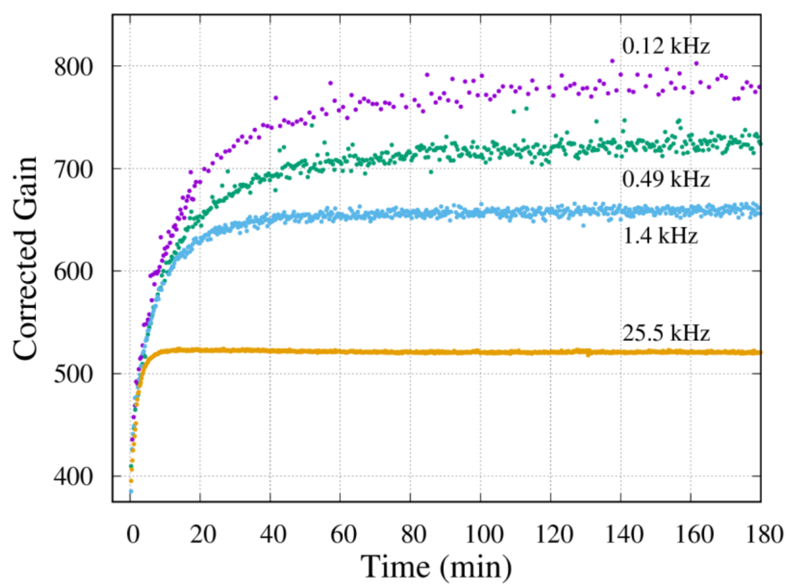
POLARIZATION CHARGING-UP



The detector has been kept without bias and radiation for few days before performing the experiment.

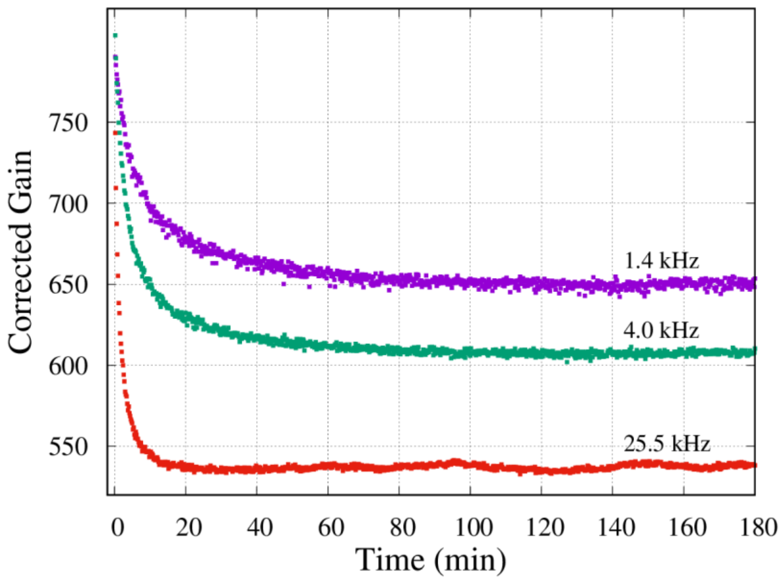
- Fixed voltage ΔV_{GEM}, V_{Ind} and V_{Drift} applied at t=0
- Radiation rate 120 Hz
- Repeated by varying ΔV_{GEM}

- Fixed voltages applied at t=0 with ΔV_{GEM} = 508.35 V
- Repeated by varying radiation rate



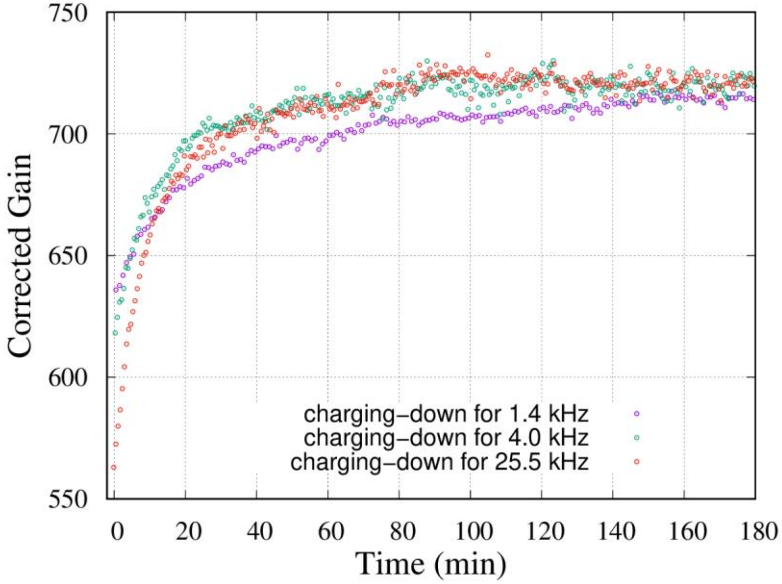
Radiation charging-up & down

The detector has been kept at its respective potential values for days before irradiation.

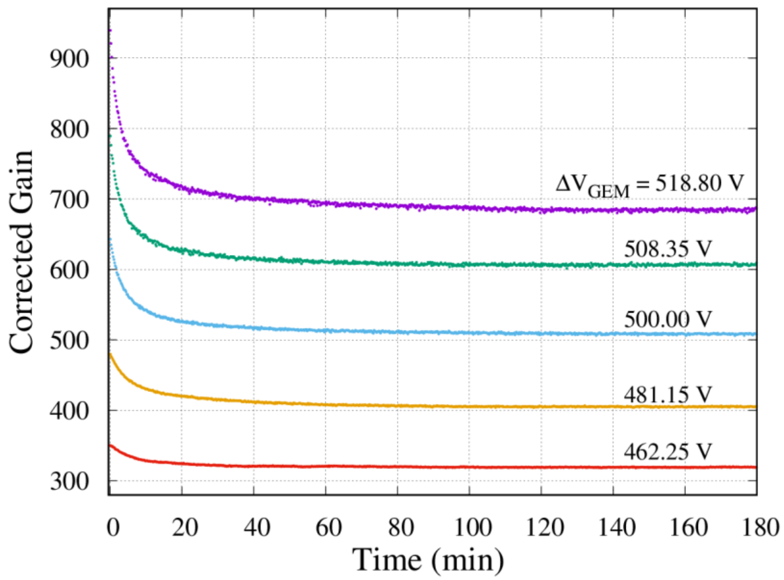


- Fixed voltages with ΔV_{GEM} = 508.35 V
- Repeated by varying radiation rate

- After charging-up with high rate
- High rate source is replaced by test probe (0.49 kHz)

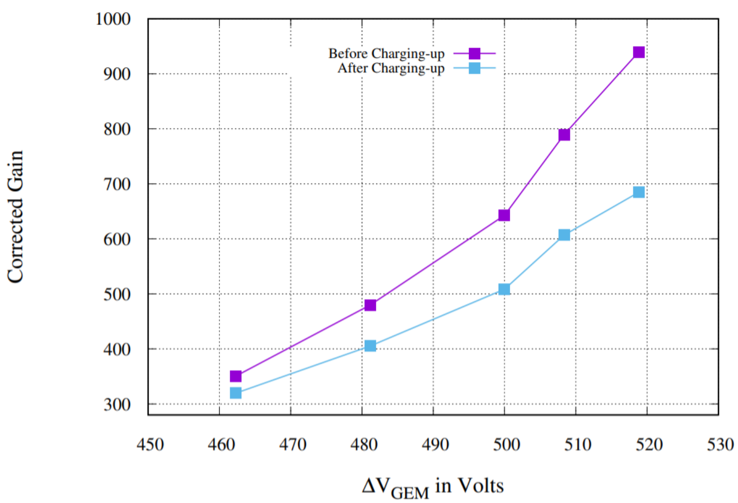


Radiation charging-up continuation



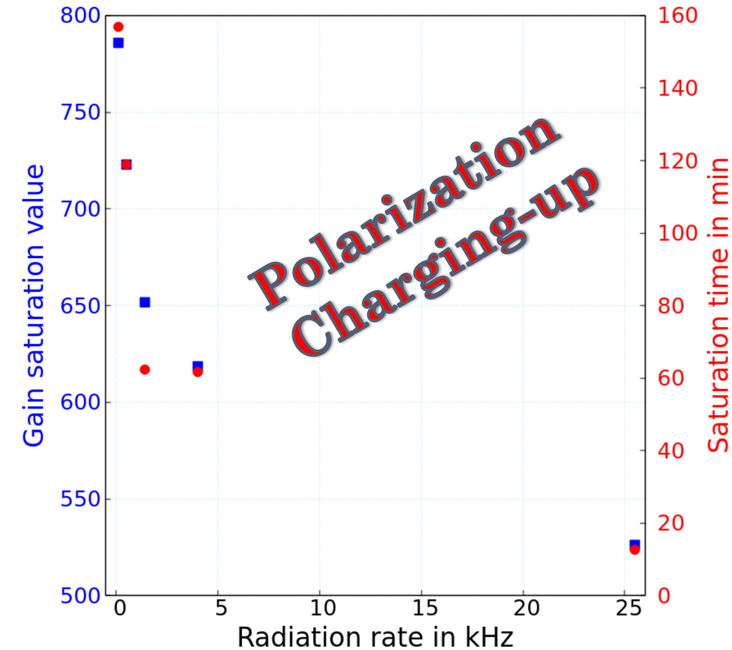
- Radiation rate 4.0 kHz
- Fixed voltages for a curve
- Repeated by varying ΔV_{GEM} while keeping the drift and induction field fixed.

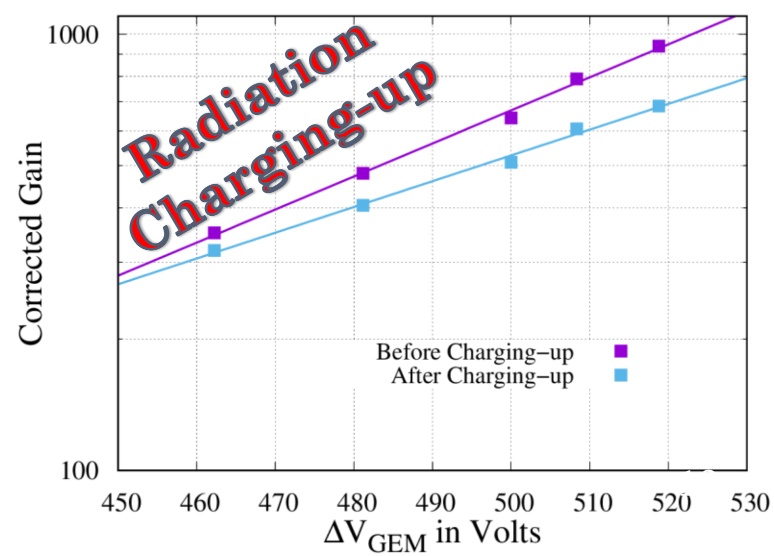
- Charging-up has significant effect on gain
- Gain saturates within an hour or two.
- Effect of charging up increases with increasing ΔV_{GEM}



CONCLUSION

- Both polarization and radiation charging-up have significant impacts on the gain.
- Polarization charging-up increases the gain whereas radiation charging-up reduces it.
- On increasing ΔV_{GEM} the effect of both the charging-up processes increases.
- Increase in radiation rate decreases the gain saturation time in both the processes.
- These effects are temporary and the detector comes back to its normal state once the biasing and radiation source are removed.





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Collaborators

- ❑ Sridhar Tripathy
- ❑ Supratik Mukhopadhyay
- ❑ Nayana Majumdar
- ❑ Sandip Sarkar

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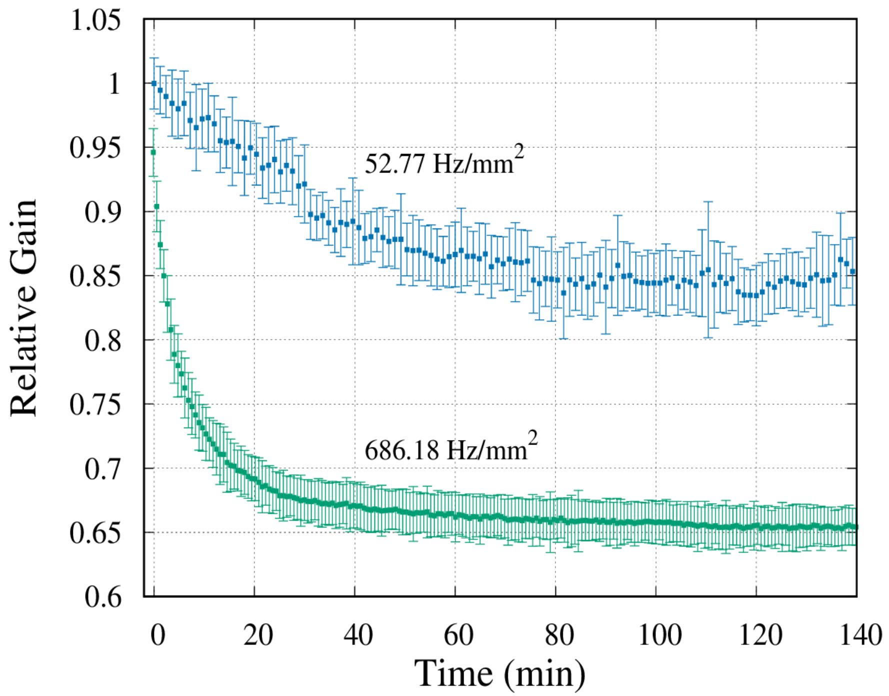
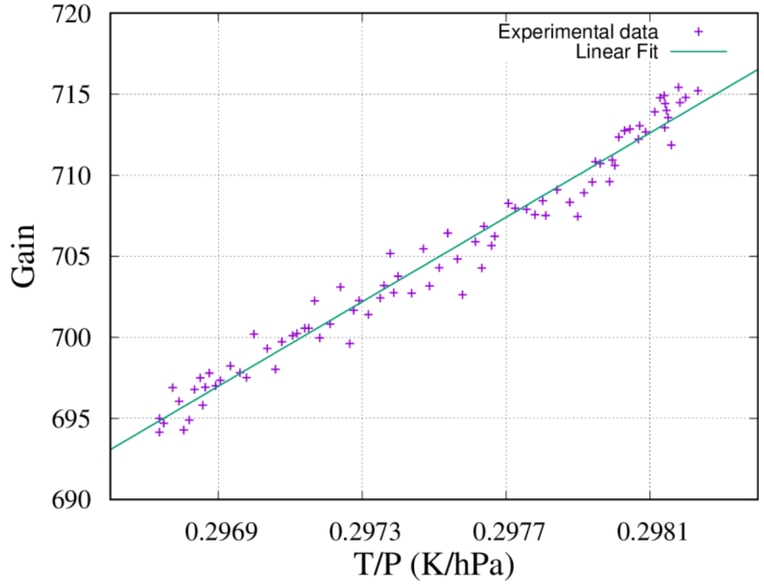
Thank you

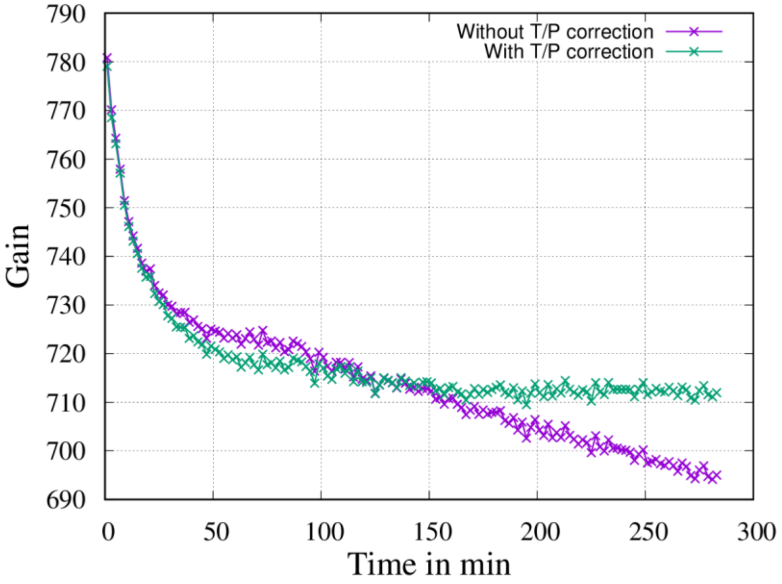
BACKUP 1



Radiation charging-up

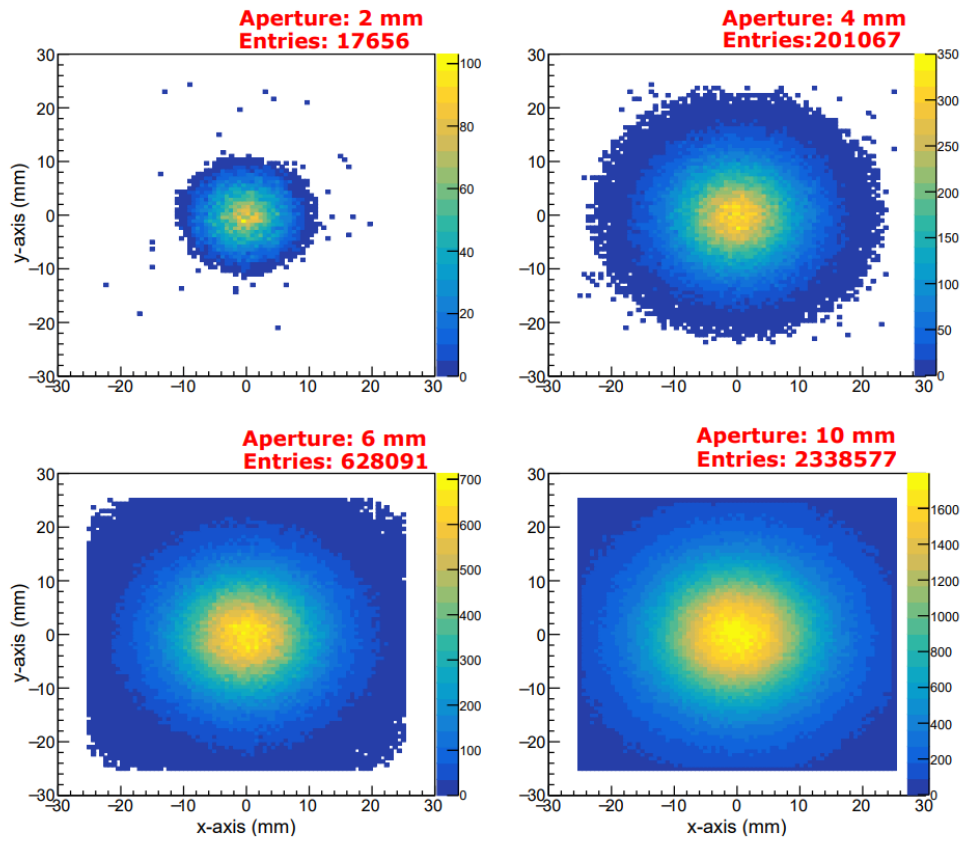
Backup 2





Effect of temperature and pressure

Backup 3



Radiation profile from GEANT4 simulation