AN EXPERIMENTAL STUDY TO UNDERSTAND THE PHYSICS BEHIND CHARGING-UP OF GAS ELECTRON MULTIPLIER (GEM)

Vishal Kumar
Saha Institute of Nuclear Physics, Kolkata & Homi Bhabha National Institute, Mumbai
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?
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

Pre-Amp

Fe-55

R = 120kΩ

Pico Ammeter

X

Y
RATE VARIATION AND CURRENT MEASUREMENT

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

Gaussian fit for repeated current measurement with 4.0 kHz source.
Gain Measurement

\[ G_{eff} = \frac{I \cdot \Delta t}{\sum_i N_i \cdot p_i \cdot e} \]

Where,
- \( I \) is average current from the pico-ammeter,
- \( \Delta t \) 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

\[ G_{eff} = \frac{I \cdot \Delta t}{\sum_i N_i \cdot p_i \cdot e} \]

- 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)

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.
POLARIZATION CHARGING-UP

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

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

- Fixed voltages applied at $t=0$ with $\Delta V_{\text{GEM}} = 508.35$ 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 $\Delta V_{GEM} = 508.35 \text{ V}$
- 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 $\Delta V_{GEM}$ 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 $\Delta V_{GEM}$
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 $\Delta V_{GEM}$ 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
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Thank you
Radiation charging-up
Effect of temperature and pressure
Radiation profile from GEANT4 simulation