Studies on charging-up of single Gas Electron Multiplier

RD51 Collaboration Meeting
24th June 2020

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Motivation

- In general, charging-up is a common phenomenon seen in gaseous ionization detectors with exposed dielectric components.
- Gas Electron Multiplier (GEM) has a large amount of insulating material exposed to the active gas volume.
- Charging-up process includes two sub-processes (polarization of dielectric and accumulation of charges on the dielectric)
- We have tried to identify the effects of these two processes on the effective gain stability, separately, as well as in combination.
Types of charging-up

Polarization charging-up
- Very high field across dielectric (up to 104 kV/cm)
- Polarization of dielectric
- Modification of local field leading to gain variation

Radiation charging-up
- High density of charges around the dielectric
- Charges gets trapped within the dielectric
- Modification of local field leading to gain variation
Outlook

- Experimental setup
- Gain measurement
- Polarization charging-up
- Radiation charging-up
- Radiation charging-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
• Aperture of collimator 1-10 mm
• Radiation rate 0.12-25.5 kHz (of 5.9 keV X-ray)

Pico-ammeter CEAN AH401D
• Centroid -125.0 pA
• Sigma 2.47 pA

Gaussian fit for repeated current measurement with 4.0 kHz source to get the accuracy in the current.
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-CO2 (74-26\%) gas mixture and used to calibrate \( p_i \) values.
Gain measurement

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

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 and 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 $\Delta V_{\text{GEM}}$ and $V_{\text{Drift}}$ applied at $t=0$ with $\Delta V_{\text{GEM}} = 508.35$ V
- Repeated by varying radiation rate

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

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

- Fixed $\Delta V_{\text{GEM}}$, and $V_{\text{Drift}}$ with $\Delta V_{\text{GEM}} = 508.35$ V
- Repeated by varying radiation rate

- Radiation rate 4.0 kHz
- Fixed $V_{\text{Ind}}$ and $\Delta V_{\text{GEM}}$
- Repeated by varying $\Delta V_{\text{GEM}}$
Radiation charging-down

- After charging-up with high rate
- High rate source is replaced by test probe
- Test probe radiation rate = 0.49 kHz
- Fixed $\Delta V_{GEM}$ and $V_{drift}$ with $\Delta V_{GEM} = 508.35$ V
Conclusions

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

- Prof. Supratik Mukhopadhyay
- Prof. Nayana Majumdar
- Prof. Sandip Sarkar

Acknowledgment

I would like to thank the technical staffs Shaibal Saha, Pradipta K. Das and lab colleagues Anil Kumar, Prasant K. Rout, Promita Roy and Subhendu Das.

Thank you for listening
• **Linear dependence of GEM gain with T/P, with slope 13029.8 hPa/K at 490 Hz.**

• **Temperature and pressure correction of radiation charging-up data using collimator with a rate of 490 Hz.**
Fig. 5 Gain variation of a triple GEM module consisting of three 23x27 cm$^2$ CERN foils used in the PHENIX HBD detector [11]. Rates given are over an area of ~ 5.24 cm$^3$. The source intensity was lowered with the high voltage on and then increased. Measurements were then repeated starting at a lower rate.

B.Azmoun et al., A Study of Gain Stability and Charging Effects in GEM Foils, IEEE Nuclear Science Symposium Conference Record (2006) 3847–3851.
Backup 3

- Increase in radiation rate with aperture size
Backup 4

- Incident photon (5.9 keV)
  - L shell Ionized: 10.5% BE=0.3 keV
    - K shell Ionized: 89.5% BE=3.2 keV
      - 15% Auger
      - Fluorescence: hv=2.9 keV
      - Reabsorption
      - Escape

| 5.6 keV | 5.9 keV | 5.3 keV | 2.7 keV |
|---------|---------|---------|---------|

X-ray detection in Ar atom

X-ray emission by Fe-55

Kα = 5.898 keV
Kβ = 6.490 keV