# Studies on charging-up of single Gas Electron Multiplier

RD51 Collaboration Meeting

24th June 2020

*Vishal Kumar*

*Applied Nuclear Physics Division*

*Saha Institute of Nuclear Physics, Kolkata*

&

*Homi Bhabha National Institute, Mumbai*

# 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

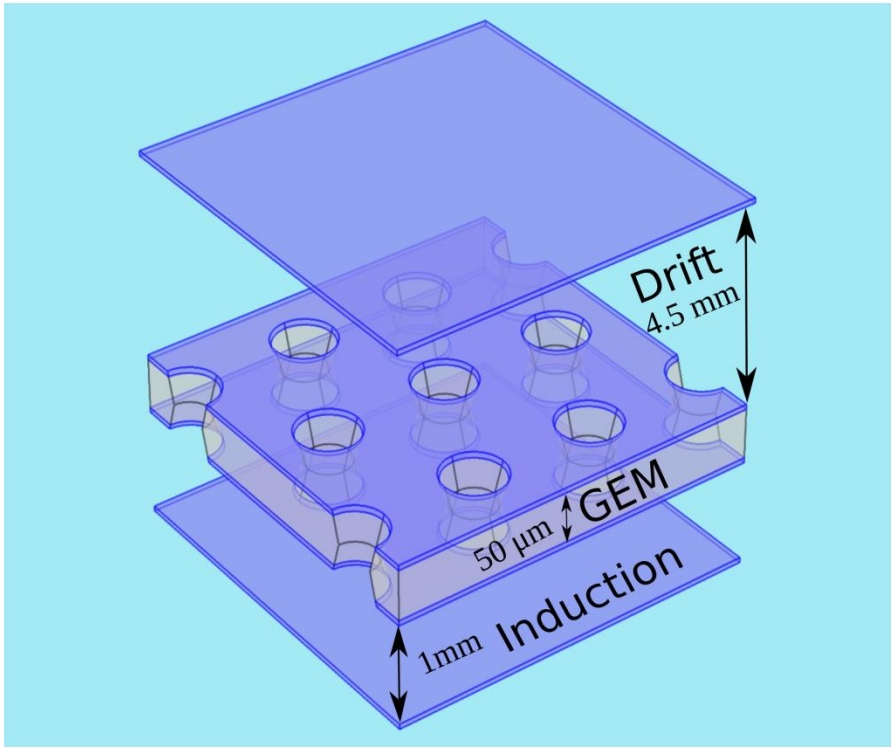
# Outlook

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

# Experimental setup

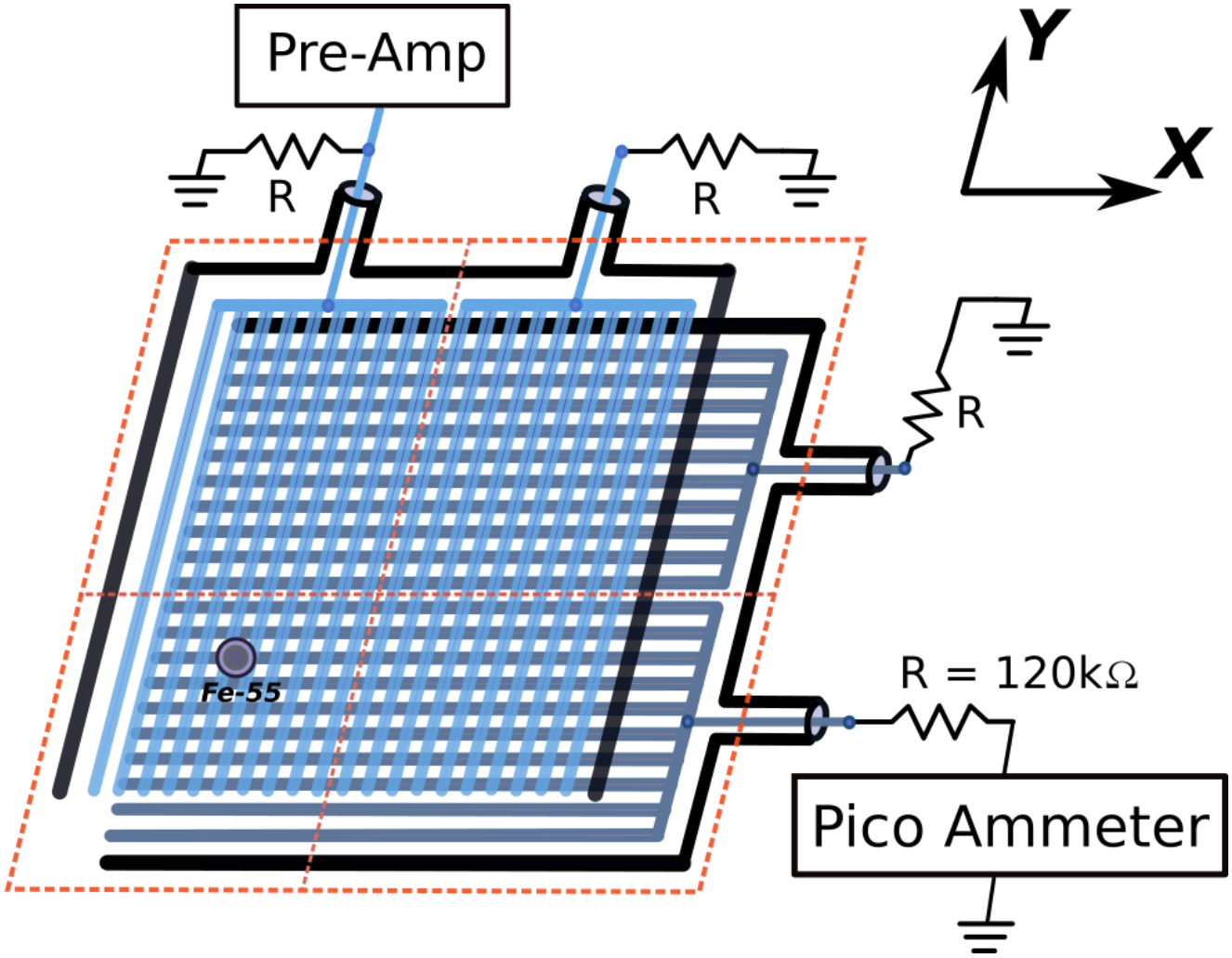
GEM foil

- 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.

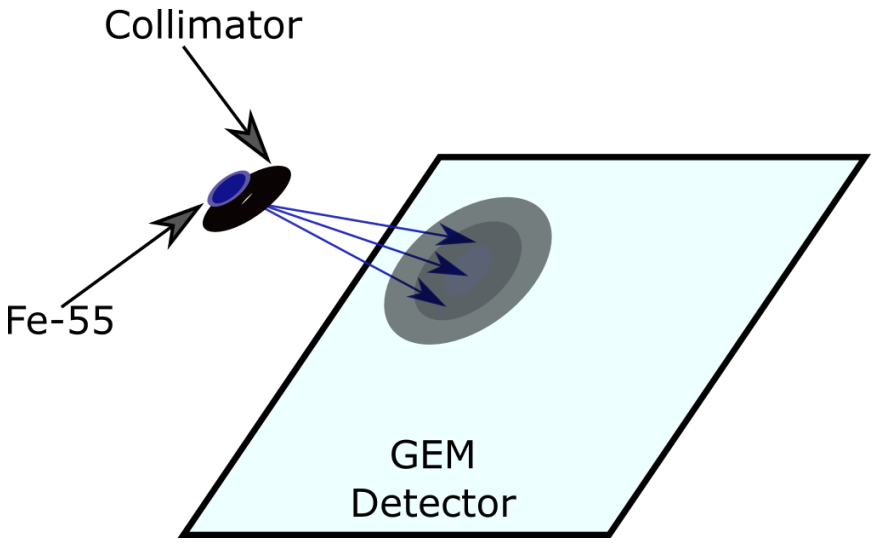



Schematic diagram of single GEM detector.

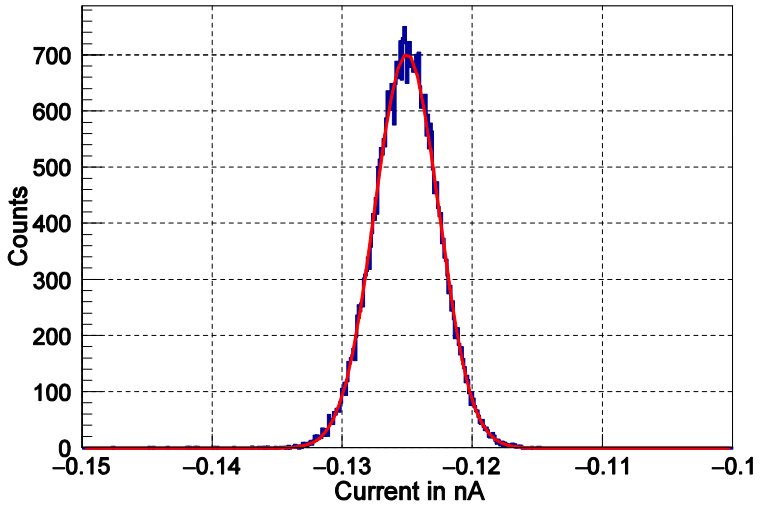
# Readout anode configuration



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




Schematic diagram of irradiation



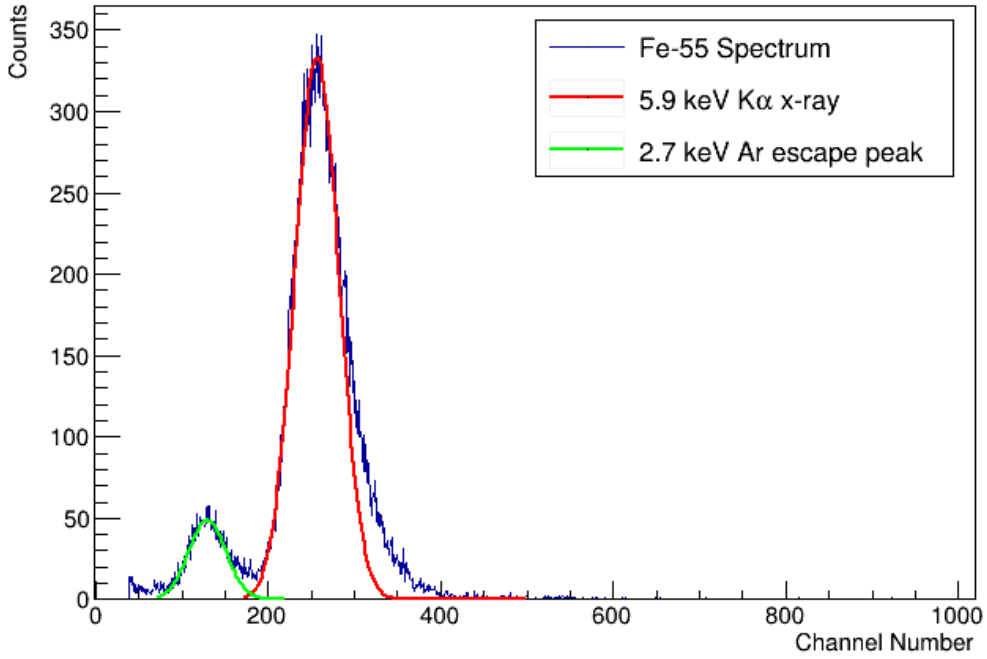

Gaussian fit for repeated current measurement with 4.0 kHz source to get the accuracy in the current.

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

# Gain measurement

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

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

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

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.

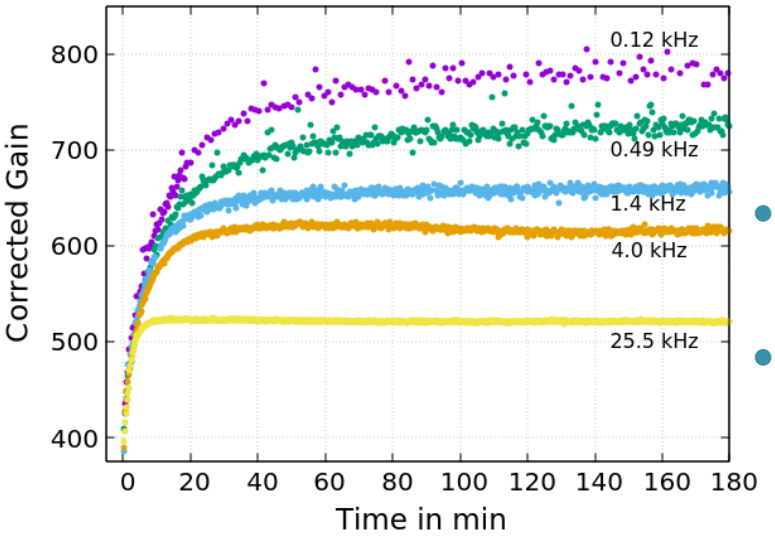
- Channel number ⟹ Energy values

  (using two peak calibration from Gaussian fit)

- Energy values ⟹ $p_i$ values

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

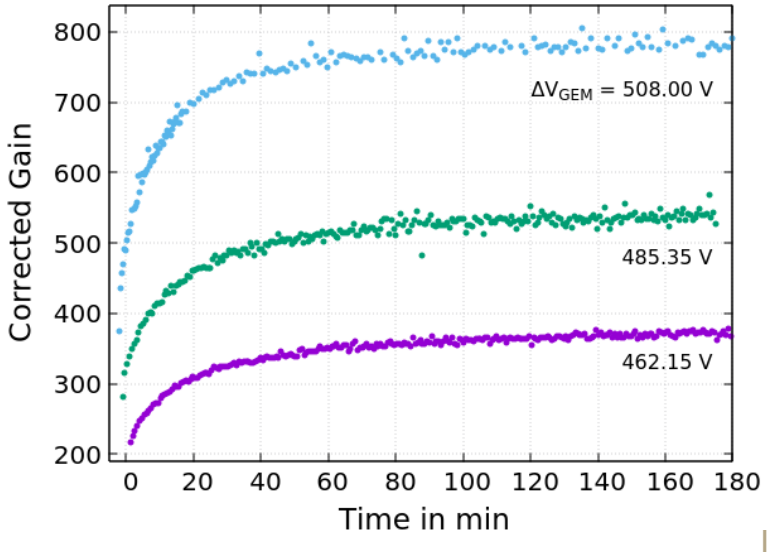
# Polarization charging-up



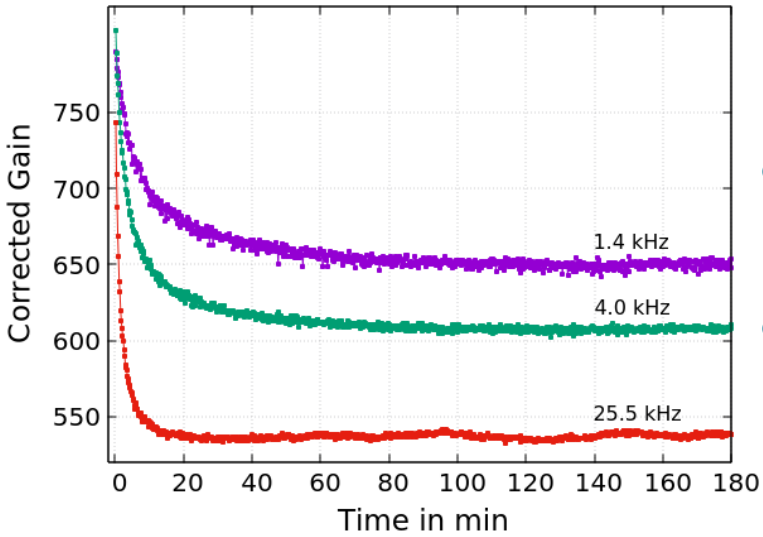

**The detector has been kept without bias and radiation for few days before performing the experiment.**

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

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



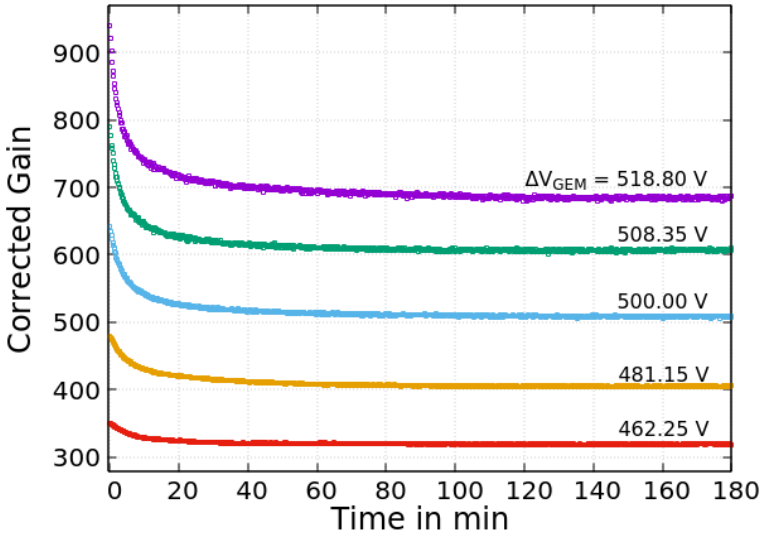
# Radiation charging-up




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

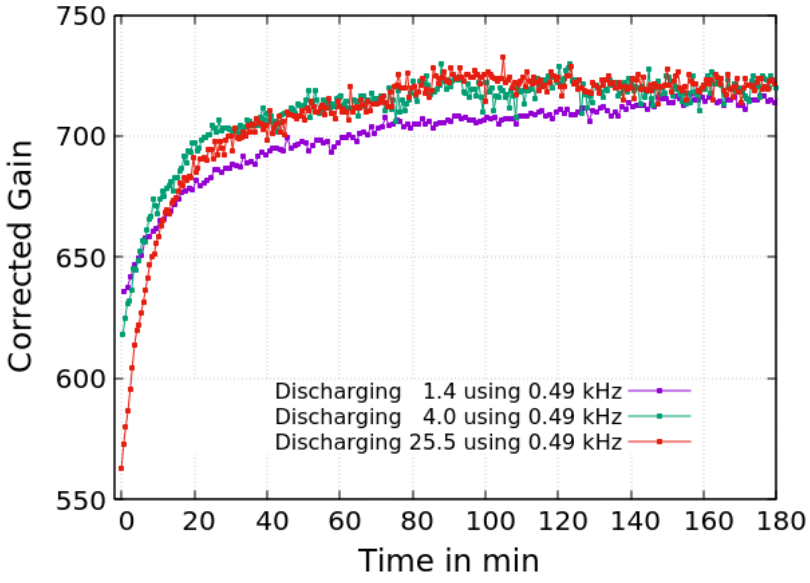
- Fixed $\Delta V_{GEM}$, and $V_{Drift}$ with $\Delta V_{GEM}$ = 508.35 V
- Repeated by varying radiation rate

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



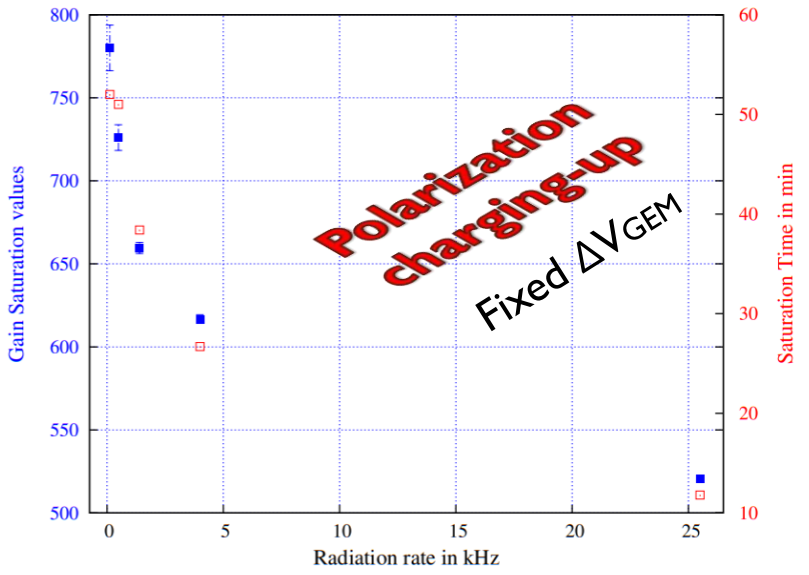
# Radiation charging-down

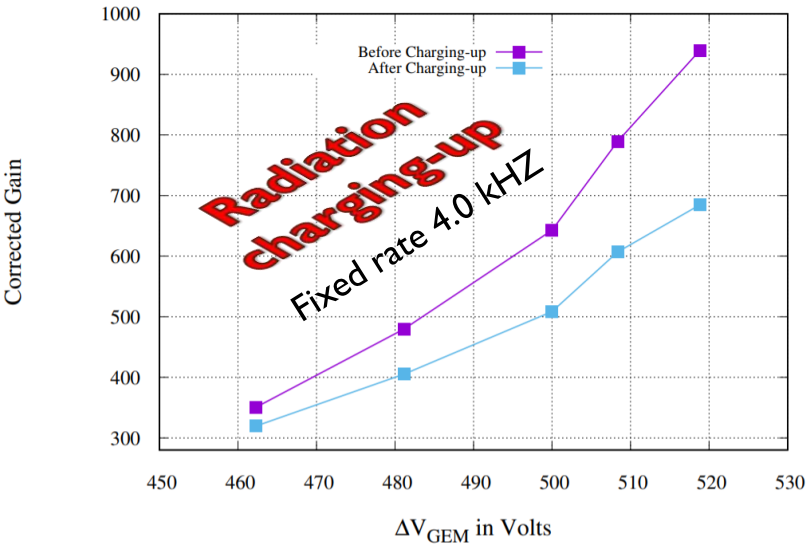
- After charging-up with high rate
- High rate source is replaced by test probe
- Test probe radiation rate = 0.49 kHz
- Fixed $\Delta V_{GEM}$ and $V_{drift}$ with $\Delta V_{GEM}$ = 508.35 V



# 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 $\Delta V_{GEM}$ 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

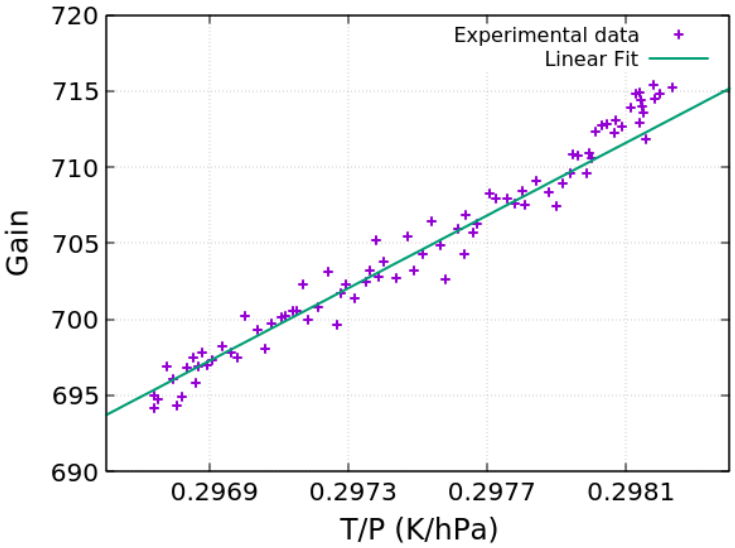
- Prof. Supratik Mukhopadhyay
- Prof. Nayana Majumdar
- Prof. Sandip Sarkar

# 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.

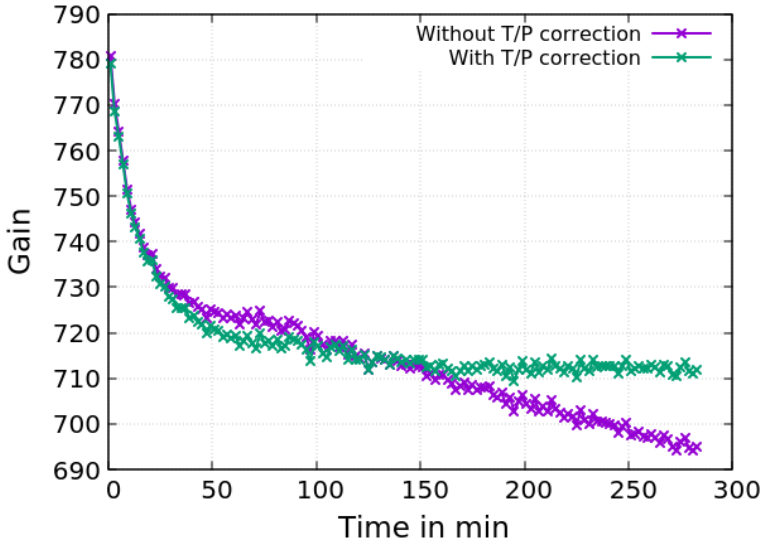
## Thank you for listening

# Backup 1




- 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.



# Backup 2

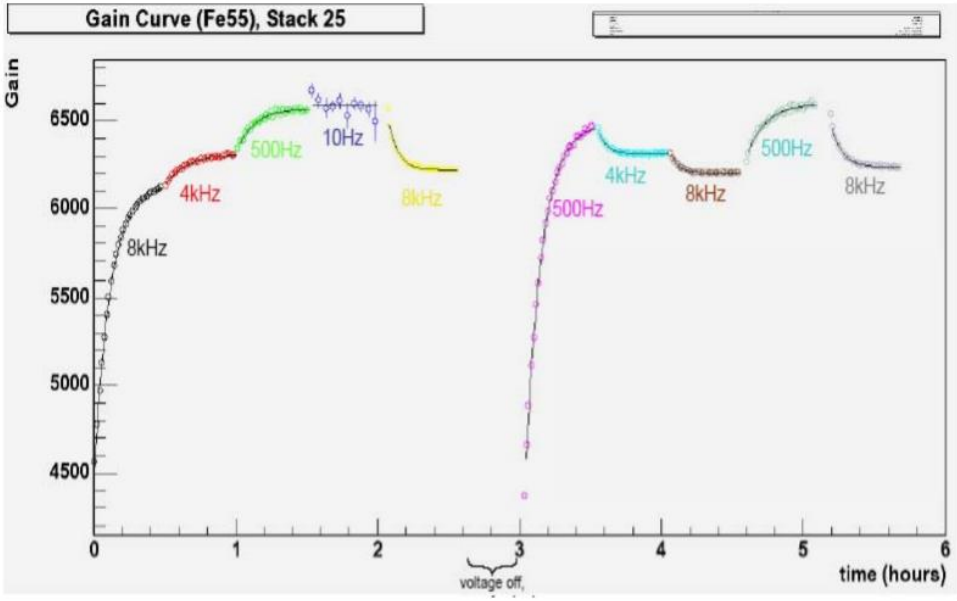
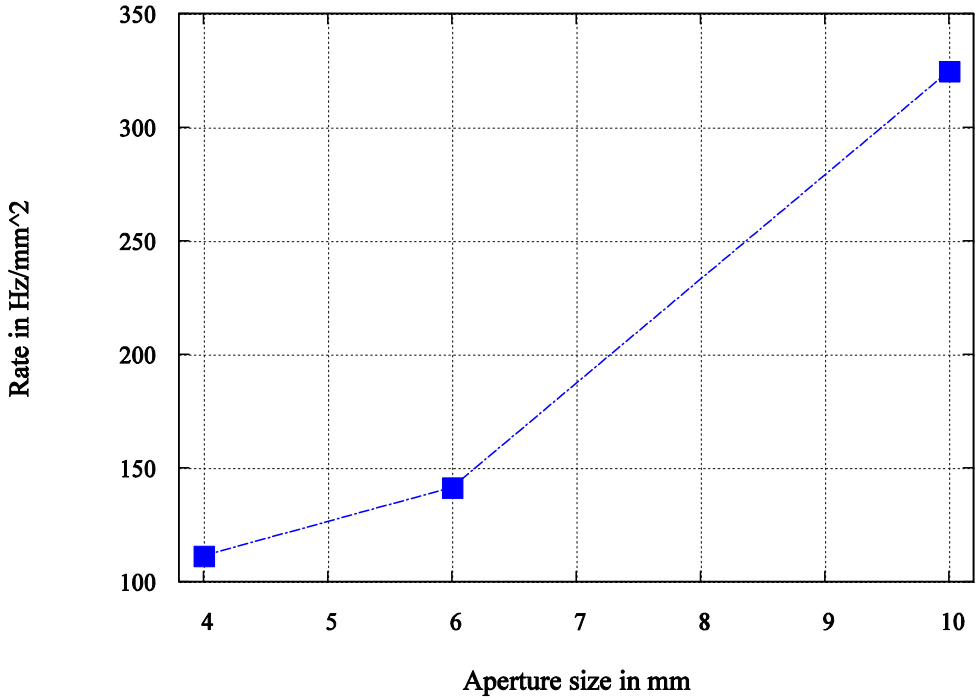



Fig. 5 Gain variation of a triple GEM module consisting of three 23x27 $cm^2$ CERN foils used in the PHENIX HBD detector [11]. Rates given are over an area of ~ 5.24 $cm^2$. The source intensity was lowered with the high voltage on and then increased. Measurements were then repeated starting at a lower rate.

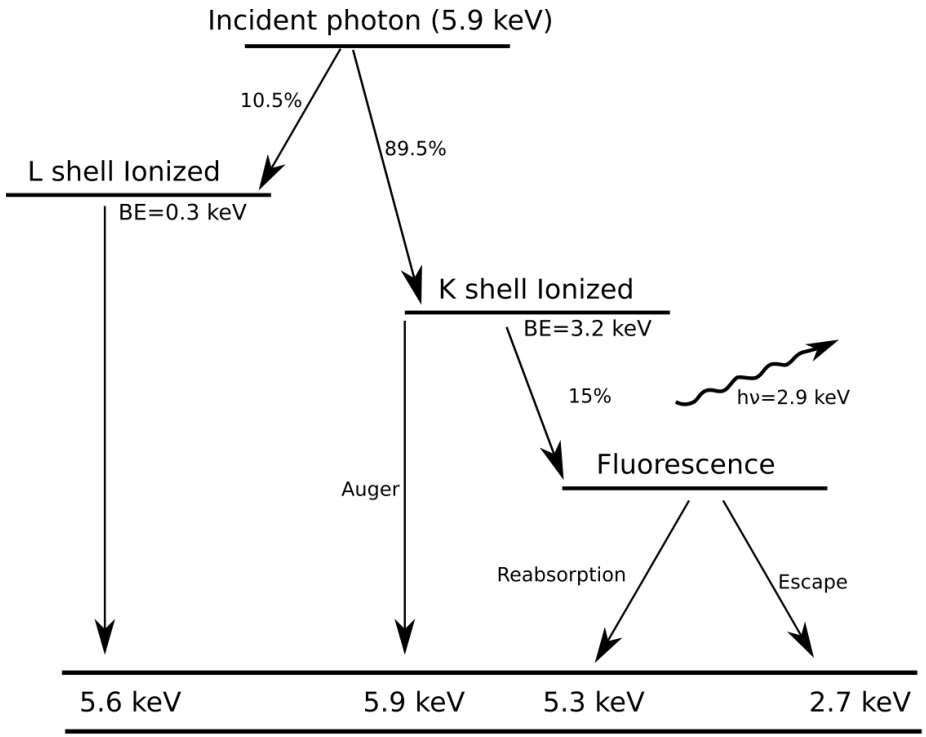
*B. Azmoun et al., A Study of Gain Stability and Charging Effects in GEM Foils, IEEE Nuclear Science Symposium Conference Record (2006) 3847–3851.*

# Backup 3

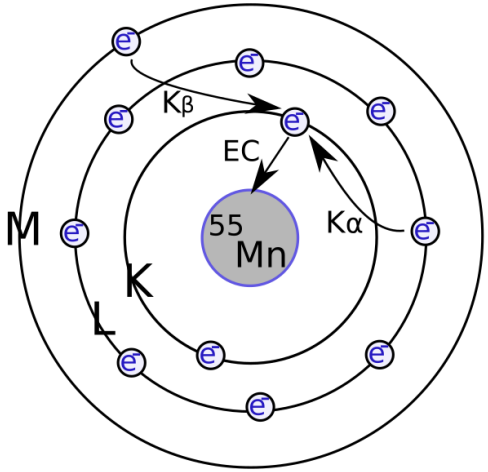
- Increase in radiation rate with aperture size



# Backup 4




X-ray detection in Ar atom




$K_\alpha$= 5.898 keV
$K_\beta$= 6.490 keV

X-ray emission by Fe-55