GAIN UNIFORMITY OF A QUAD-GEM DETECTOR AT DIFFERENT GAS FLOW RATES

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Advanced Radiation Detector and Instrumentation in Nuclear and Particle Physics
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Plan of the talk

- Introduction
- Experimental method
- Results and discussions
- Conclusion and outlook

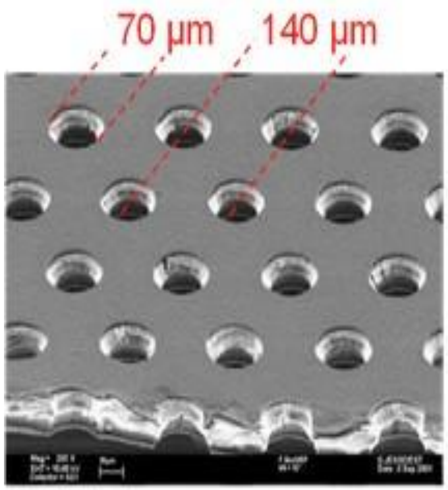
Standard GEM foil

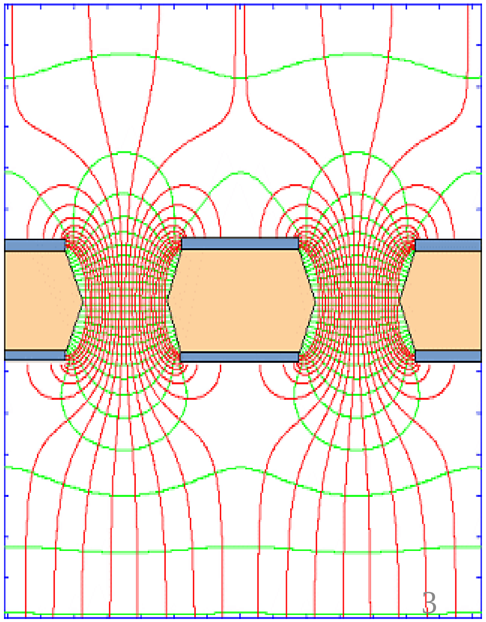
- A GEM foil is a 50 µm thin polymer Kapton plane whose both sides are cladded with copper of 5 µm.

- The bi-conical holes are of inner diameter of 50 µm and outer diameter of 70 µm with a pitch of 140 µm.

- GEM has high density of holes (50−100 /mm^2) made using photolithography method.

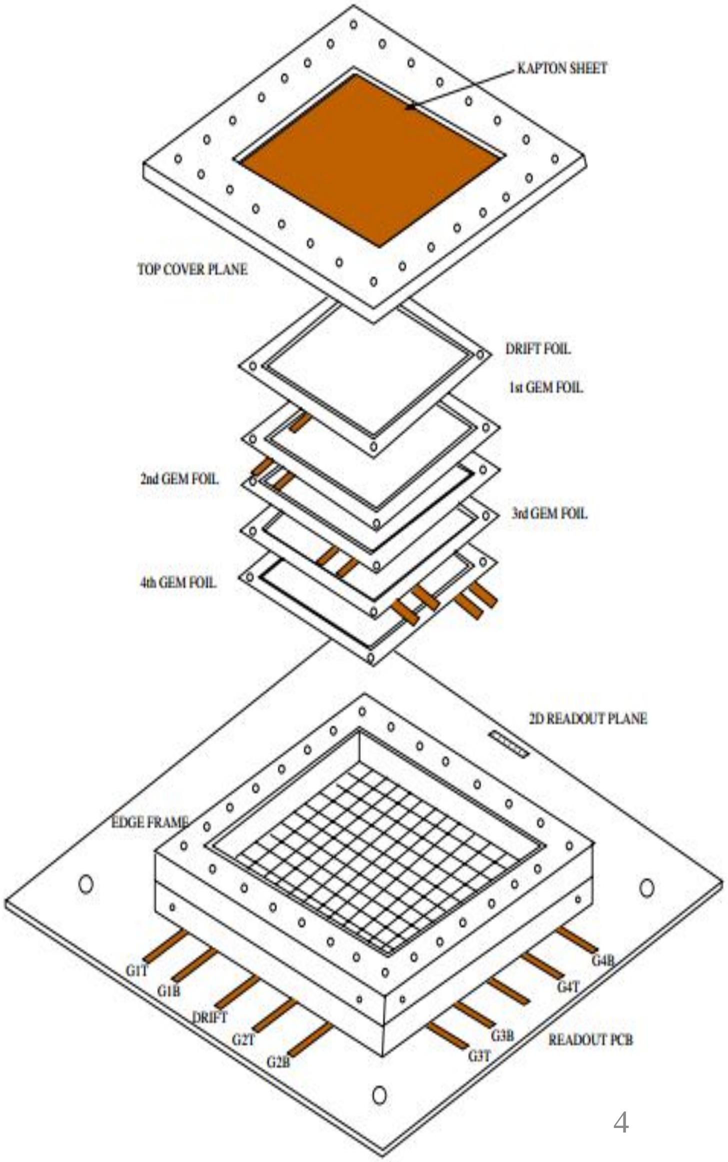
- On application of voltages (~ 360 V) a high field (~ 72 kV/cm) is created inside the holes.





Quad-GEM Detector

- Four such foils are cascaded to increase gain at relatively low voltage in a quad-GEM detector.
- Relatively low voltage can be applied for operation, hence discharge probability is reduced.
- The drift gap, transfer gap and the induction gaps are 3 mm, 2 mm, 2 mm respectively.
- Premixed gas: Ar : CO_2 in 70 : 30 ratio.
- When a particle passes through the drift gap, electron-ion pairs are created.
- This electrons create avalanche of electron while passing through the hole.
- Finally electrons are collected at the anode readout plane.



Aim of the experiment

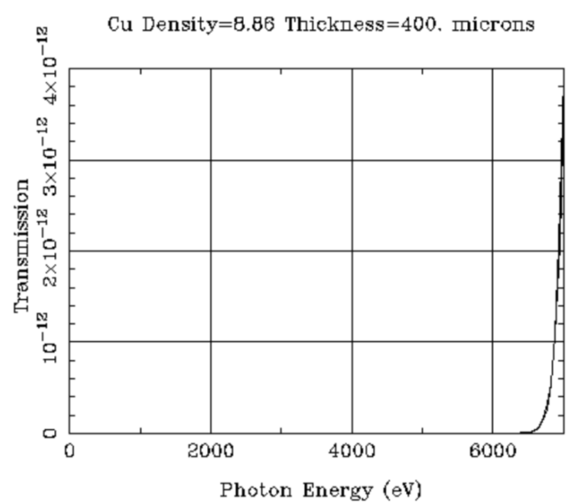
Determination of the gain at different zones of the detector to check it's uniformity at different flowrate

$$Gain = \frac{Output\ charge}{Input\ charge} = \frac{I}{r \times n \times e}$$

Fe ^{55}source

Activity: 23 mCi (27/01/21)

Al-Cu collimator
(2+0.4 mm thick)



CXRO X-ray interactions with matter

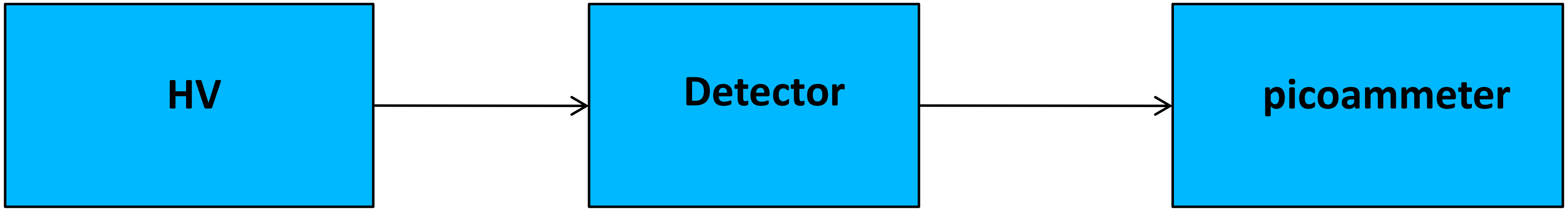
I = Anode current with source –Anode current without source

r = Count rate (~ 8 kHz)

n = Number of primary electron generated for each photon

e = electronic charge

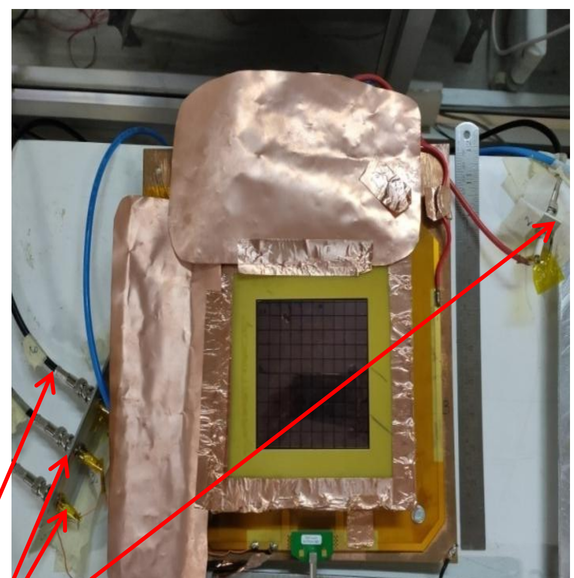
Experimental set-up



4 Channel programmable HV power supply [CAEN (Model N1470)]

quad- GEM detector

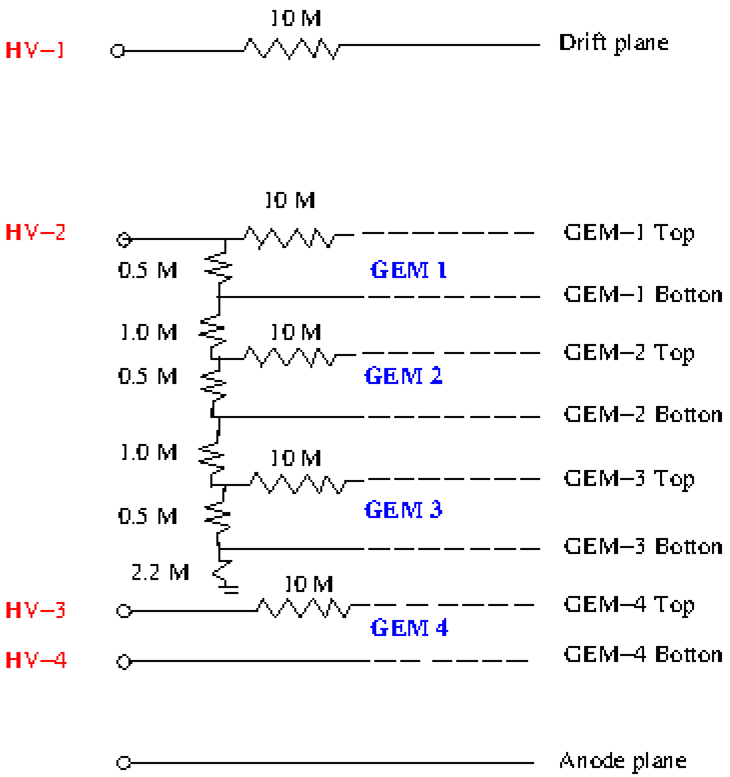
Keithley picoammeter (Model 6485)



HV module

HV connector

Experimental set-up (contd..)



Voltage divider circuit

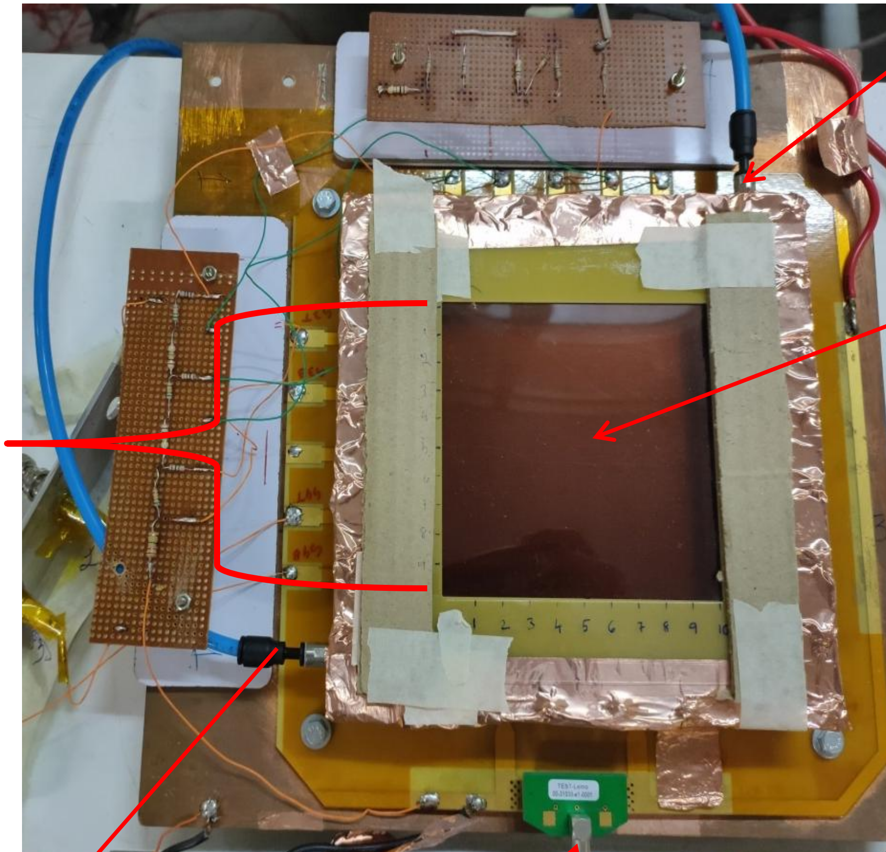
Region	Gap width (mm)	Voltage difference ΔV (V)	Electric field (kV/cm)
Drift	3	120	0.4
Transfer	2	720	3.6
Induction	2	800	4

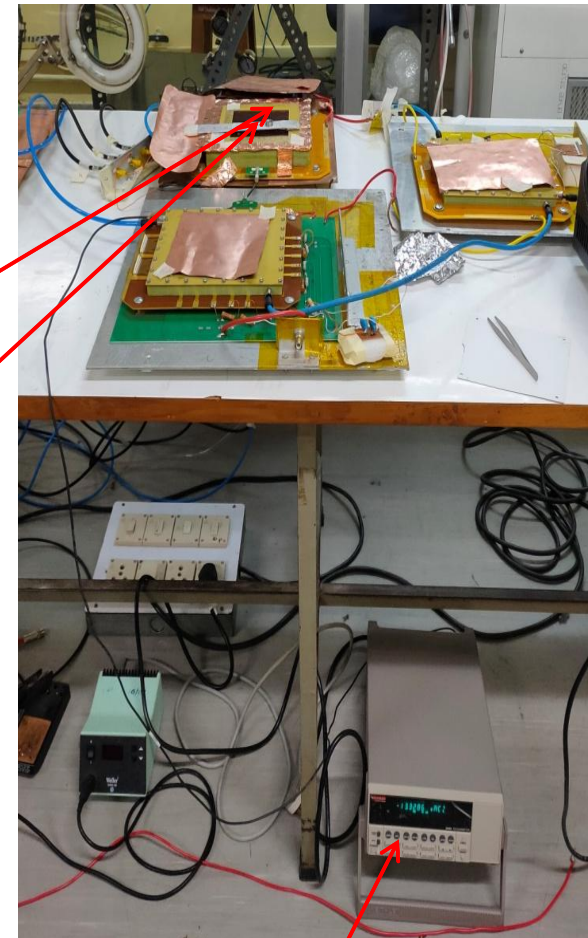
Pre-mixed gas mixture:- Ar:CO_2 = 70:30

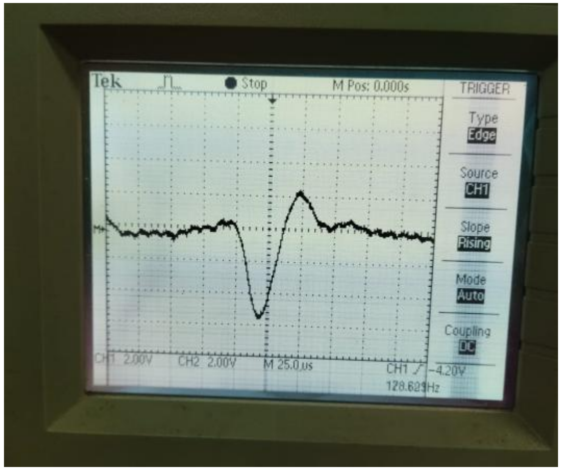
ΔV_{GEM} = 360 V

Flow rate varies from 4 – 26 SCCM

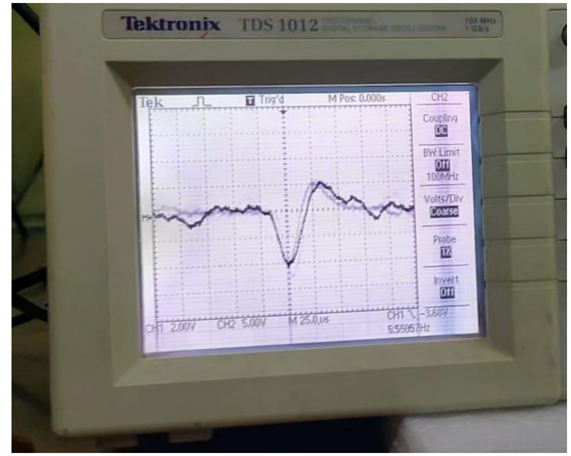
Experimental set-up (contd..)







Cosmic muon signal on quad-GEM



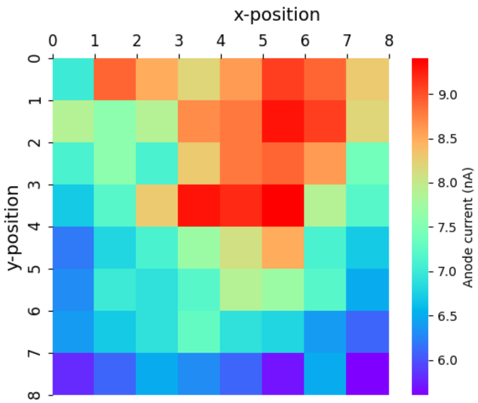
Fe^{55} signal on quad-GEM

Temperature sensor (DS18B20),
Pressure sensor (BMP180)
Humidity sensor(DHT11)
Airflow sensor (AWM2100V)

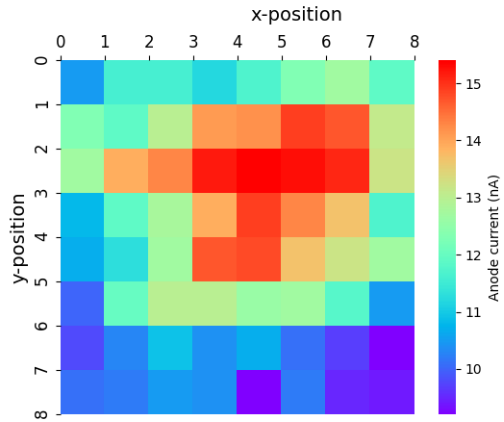
Instrument to monitor ambient parameter and flow rate
(built in-house)

Results

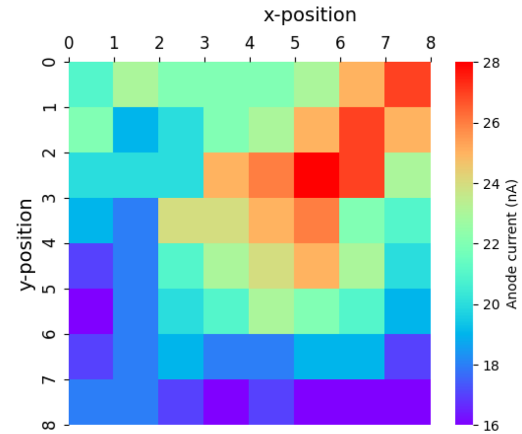
Δ V = 360 V



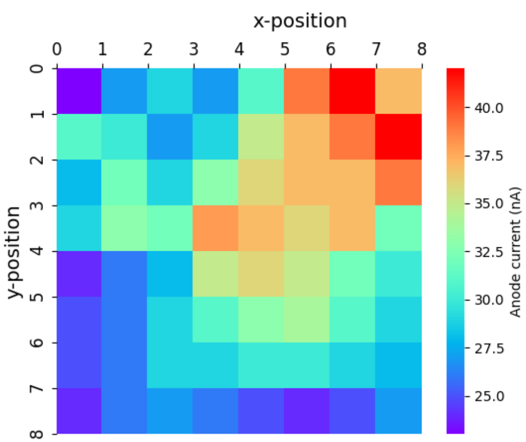
4.23 SCCM



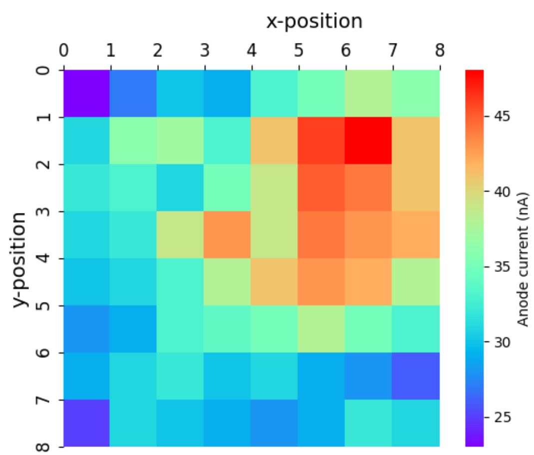
7.01 SCCM



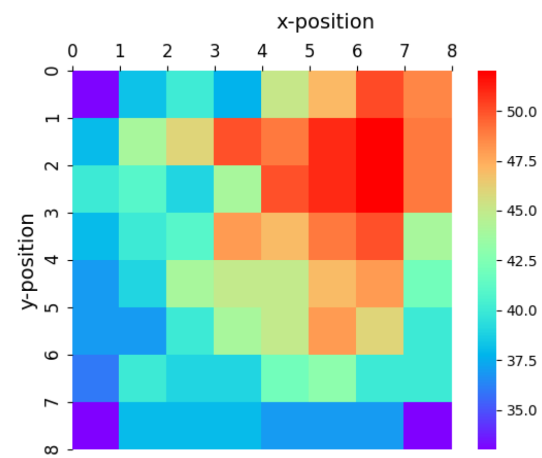
10.18 SCCM



15.05 SCCM



21.71 SCCM

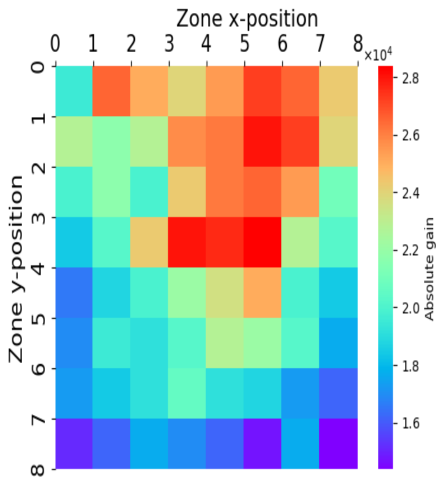


26.57 SCCM

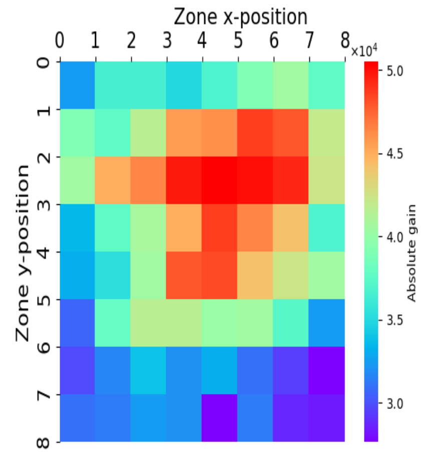
Anode current at different flow rates

Results

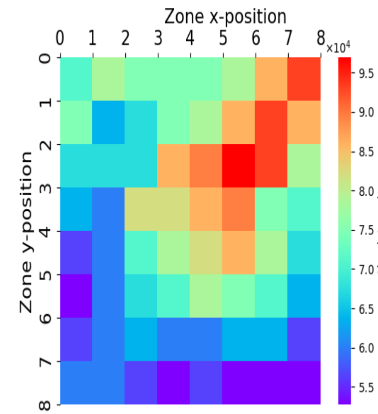
Δ V = 360 V



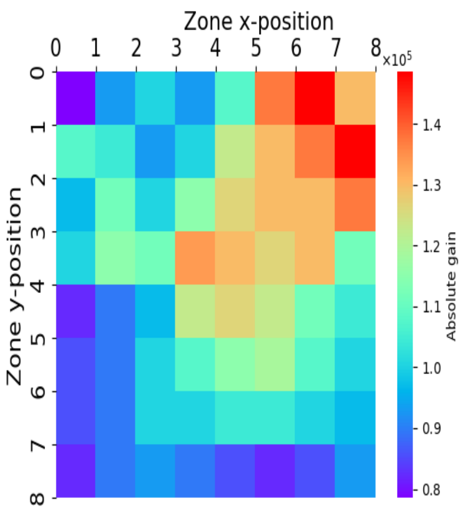
4.23 SCCM



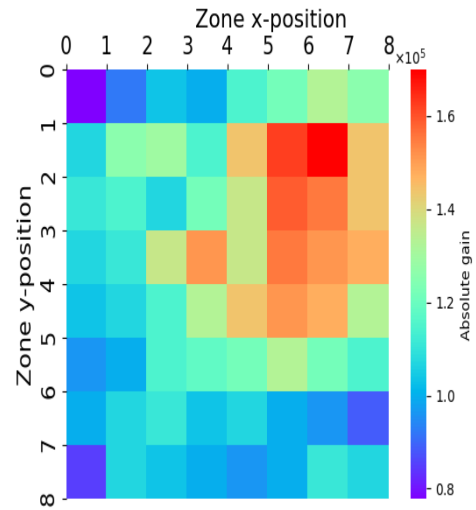
7.01 SCCM



10.18 SCCM



15.05 SCCM



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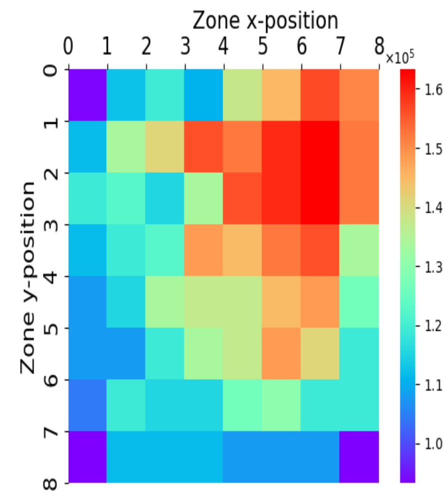
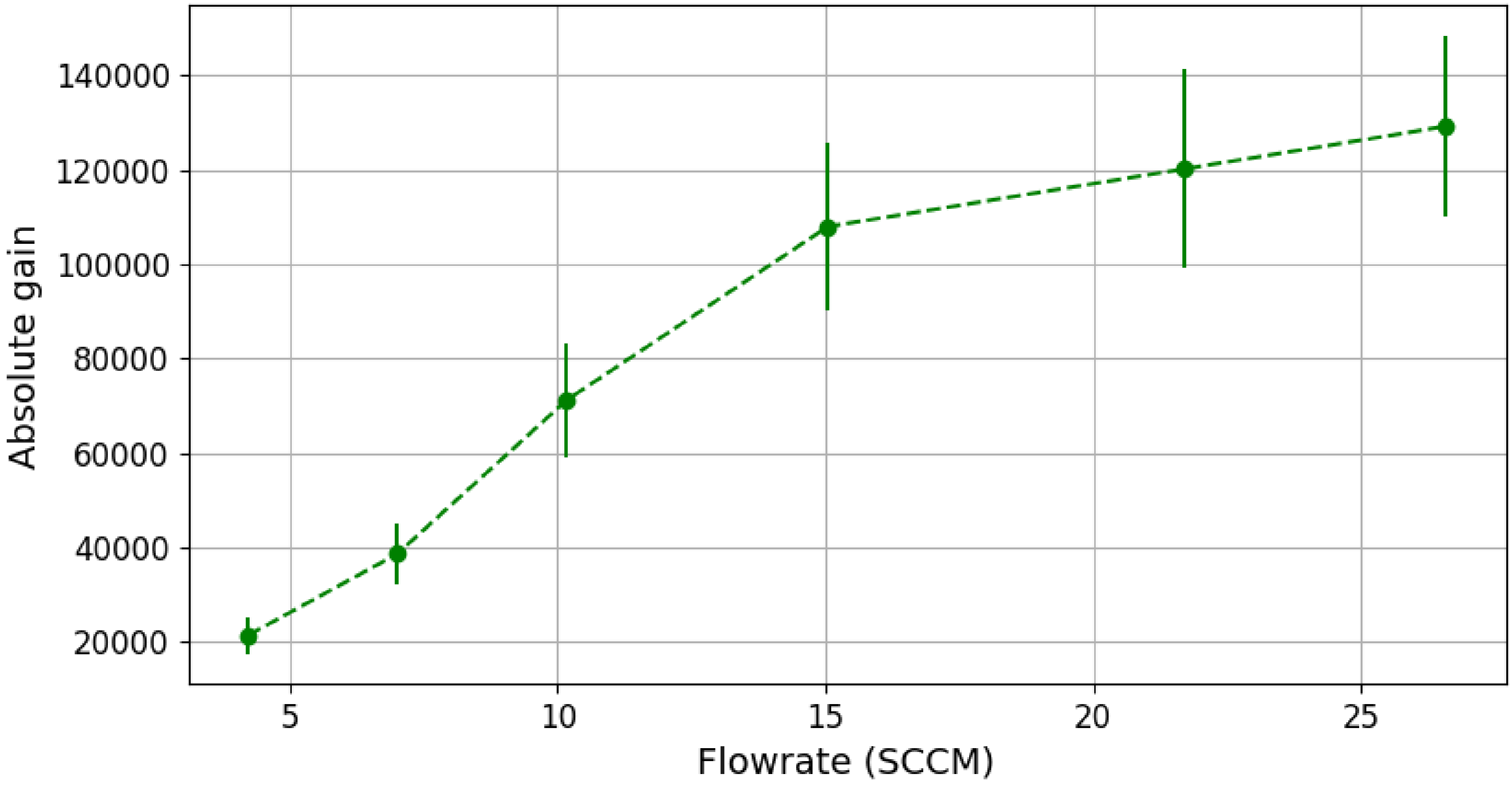


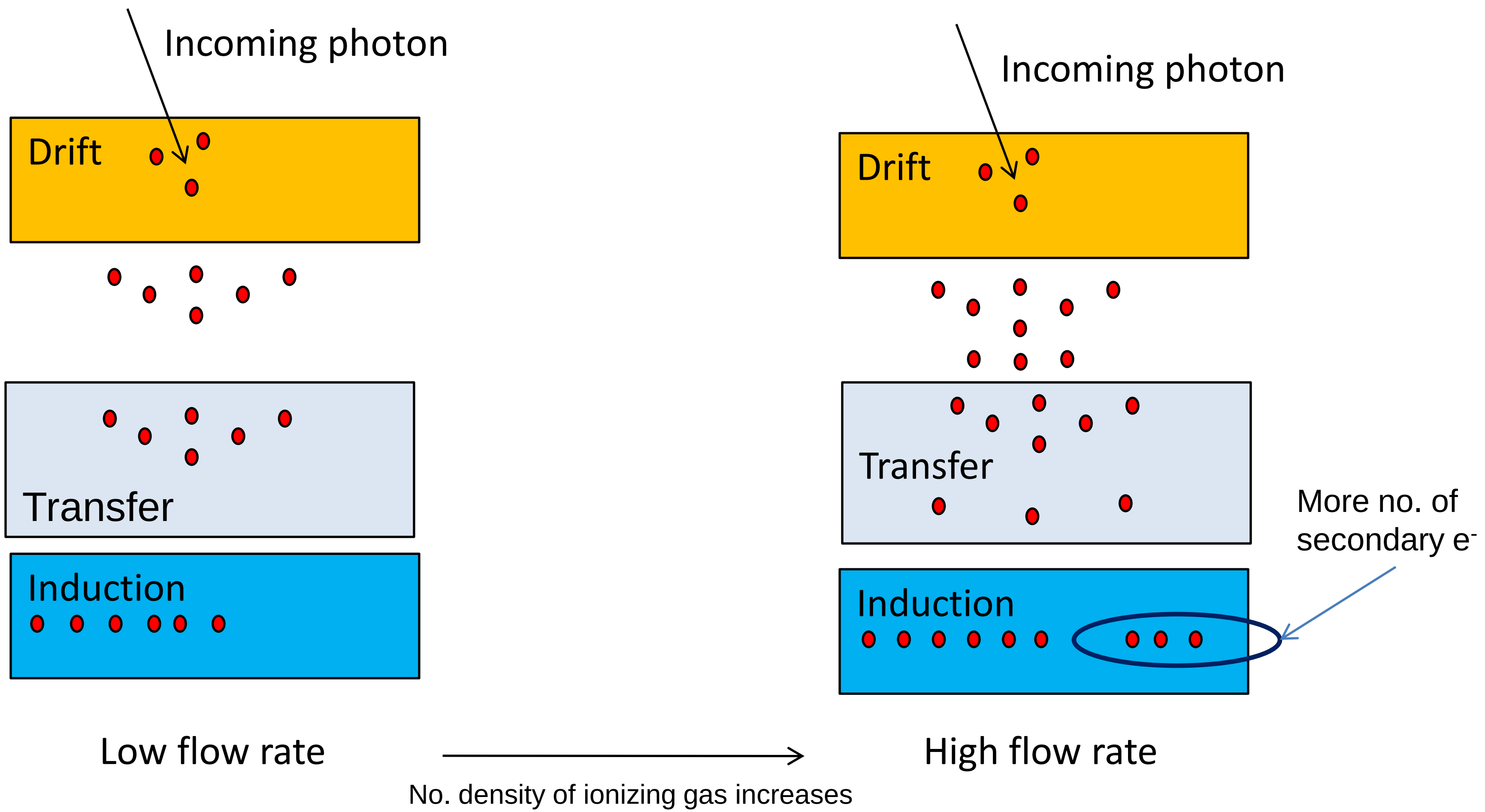
26.57 SCCM

Gain at different flow rates

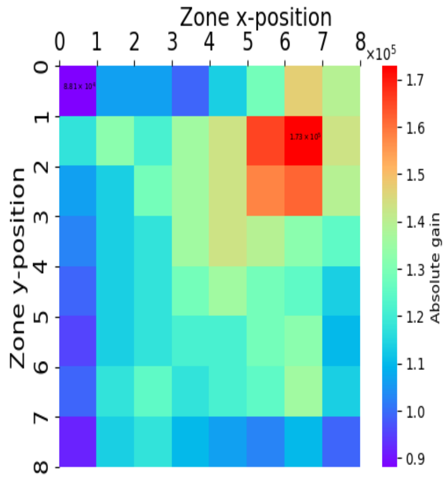
Absolute gain vs. flow rate at Δ V = 360 V



Possible explanation of increase in gain at higher flowrate



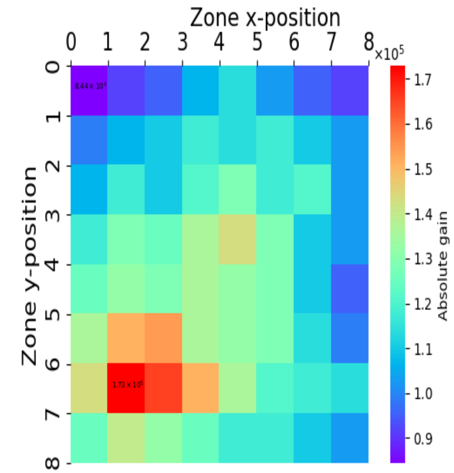
Reversing the flow



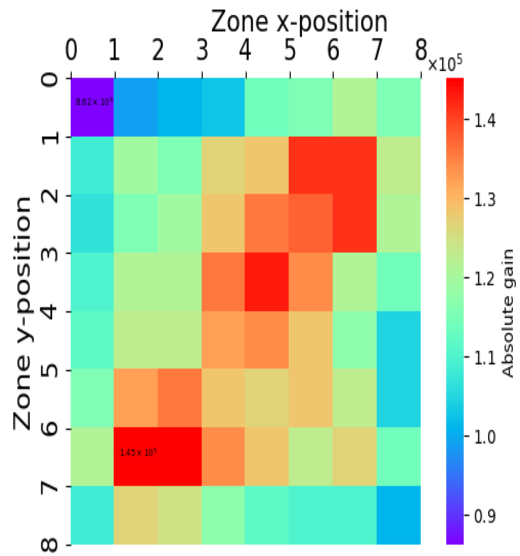
Gas flow direction:
Top-Right to Bottom-Left

$\Delta V = 360$ V

Flow rate = 24.12 SCCM



Gas flow direction:
Bottom-Left to Top-Right



Average over each zone

Conclusion: Presence of dead/noisy zone discarded

Possible explanation of non uniformity

Pressure difference across the detector

Continuity equation

$$A_1 v_1 = A_2 v_2$$

A_1 = cross-sectional area of region 1

v_1 = flow velocity in region 1

A_2 = cross-sectional area of region 2

v_2 = flow velocity in region 2

High velocity near the inlet

Bernoulli's equation

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g h_2$$

ρ = fluid density

g = acceleration due to gravity

P_1 = pressure at elevation 1

v_1 = velocity at elevation 1

h_1 = height of elevation 1

P_2 = pressure at elevation 2

v_2 = velocity at elevation 2

h_2 = height at elevation 2

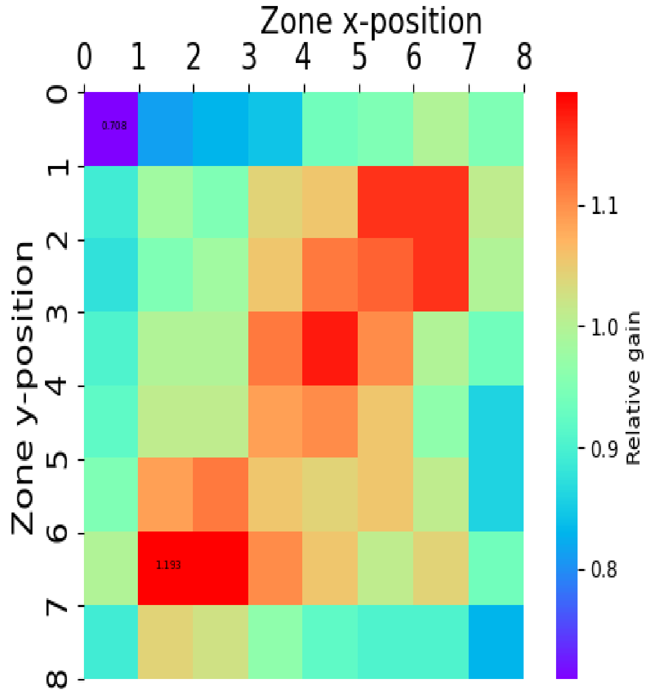
Low pressure near the inlet

Gain dependence on T/P

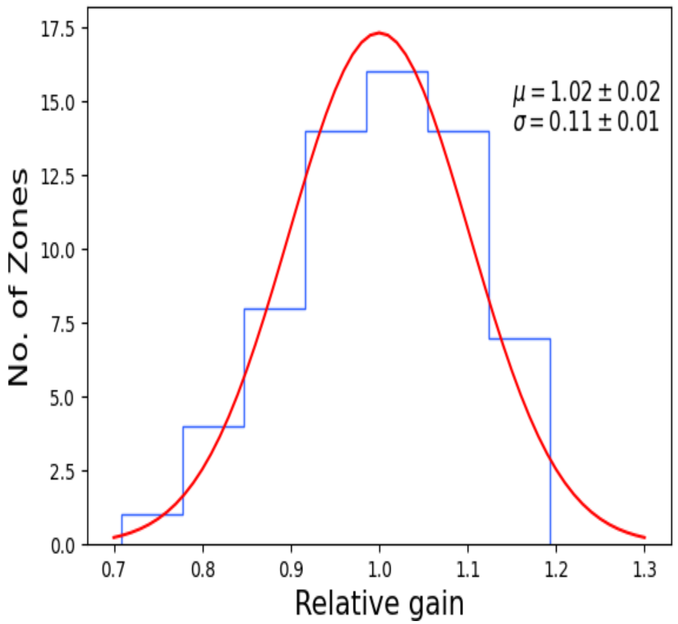
$$Gain(T/P) = A\, e^{B\frac{T}{P}}$$

High gain near the inlet

Gain uniformity of a quad-GEM detector at Δ V = 360 V and flow rate = 24.12 SCCM



2D distribution of relative gain over 64 zones



1D distribution of relative gain

Conclusion and outlook

- Gain of the detector increases rapidly with flowrates at relatively lower flow rates
- Gain tends to saturate after flow rate ~20 SCCM (1.2 l/h)
- ~10% non-uniformity of gain is observed around the mean value at

  Δ V = 360 V and flow rate = 24.12 SCCM
- No noisy/dead region is found in the prototype quad-GEM detector

THANK YOU