Performance study of Gas Electron Multiplier chamber for future heavy ion experiment

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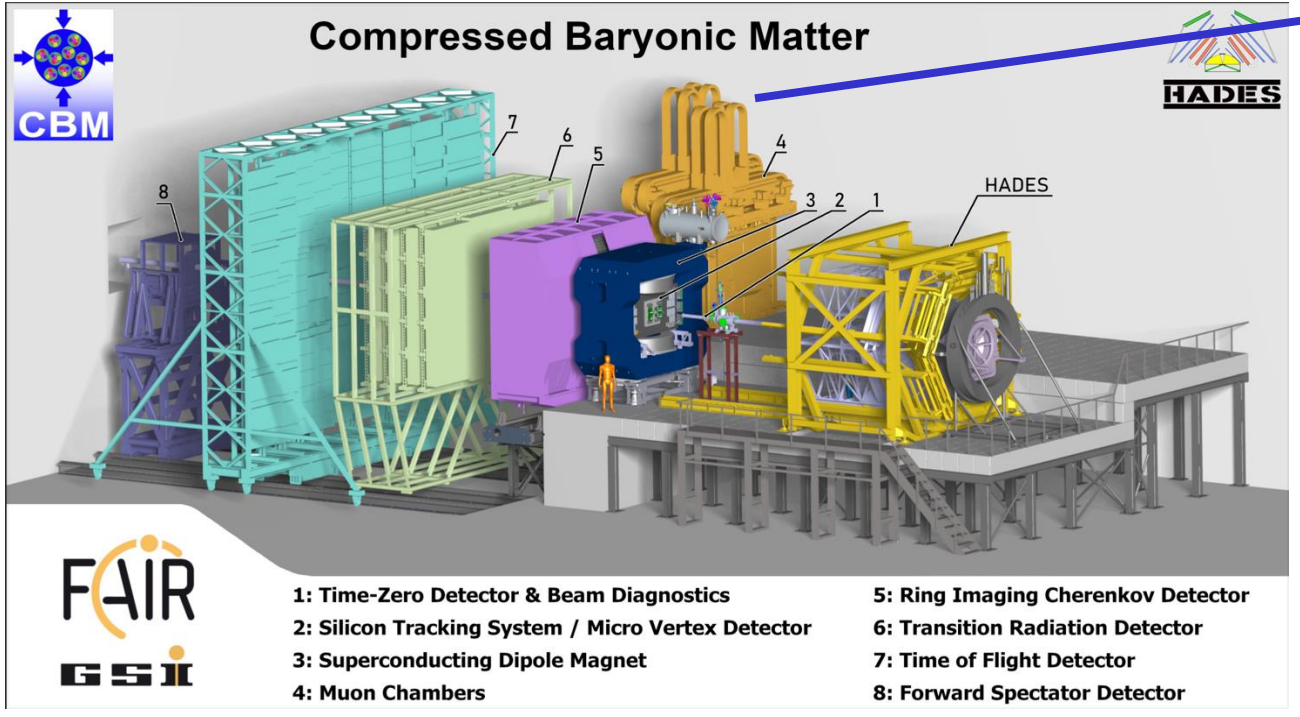
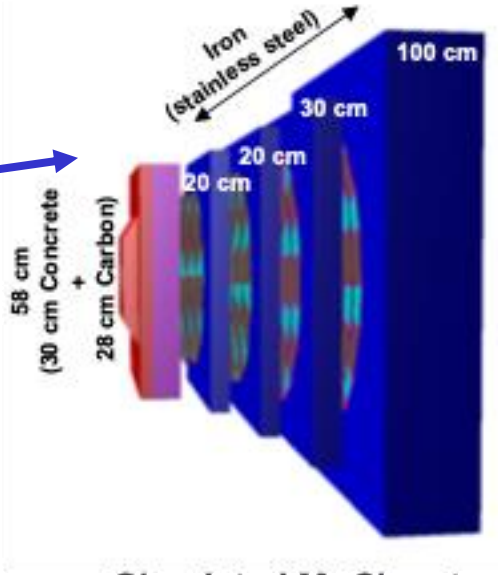
Outline

- Motivation
- Gas Electron Multiplier (GEM) detector
- Performance study of GEM detector
- Summary

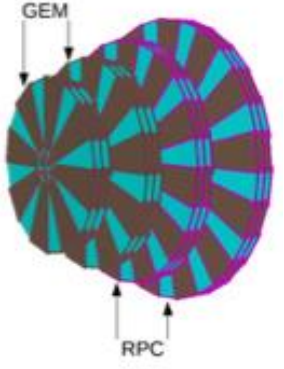
Motivation

Mission: Systematic exploration of the QCD matter at high baryon densities with high precision

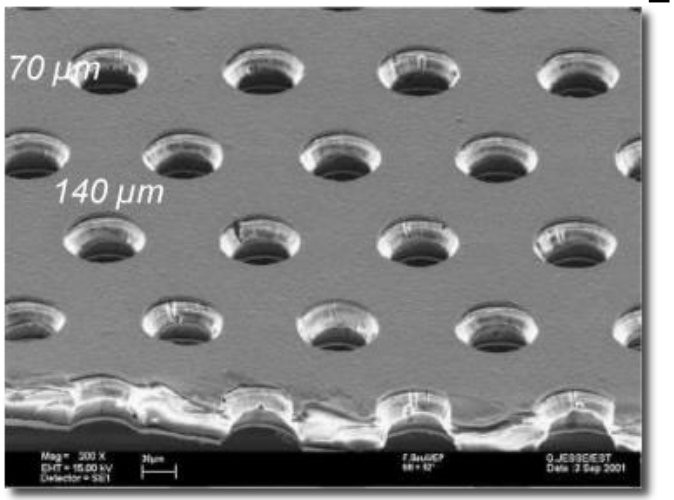




Simulated MuCh setup



Gas Electron Multiplier (GEM)



- GEM foil is made of Copper cladded Kapton foil of thickness 60 µm
- Good rate handling capability (~ 1 MHz/mm^2)
- High efficiency (>95%)
- Can be operated in cascaded mode
- Good spatial resolution (~ 100 µm)
- Operated with non-flammable gas mixtures (conventionally Ar-CO_2)
- Depending on the photolithographic techniques used, the GEM foils are classified as Double Mask (DM) or Single Mask (SM) GEM foils

Reference : F. Sauli, Nucl. Instr. and Meth. A386 (1997) 531, S. Bachmann *et al.*, Nucl. Instr. and Meth. A479 (2002) 294

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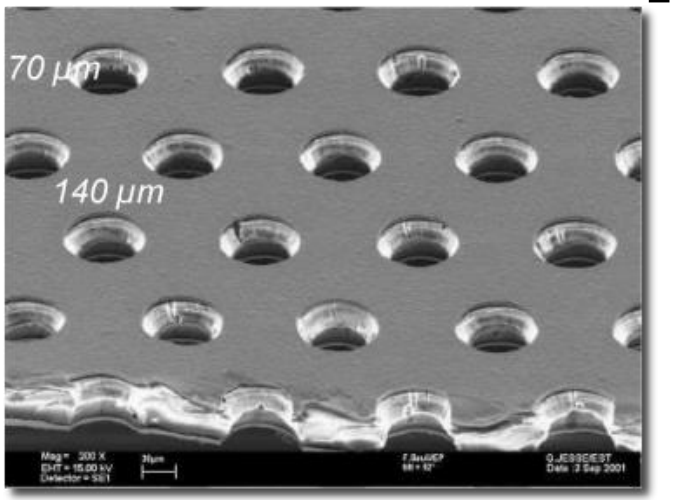

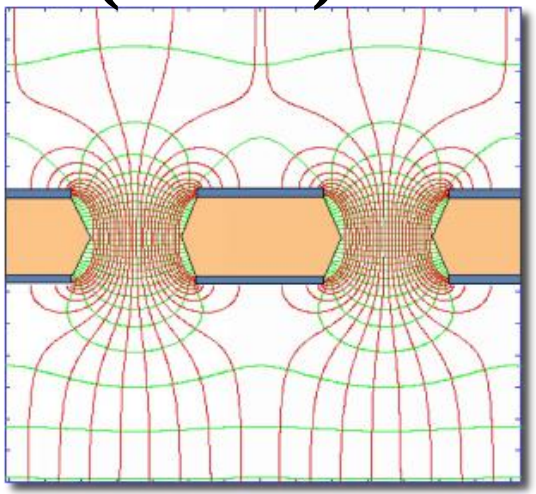

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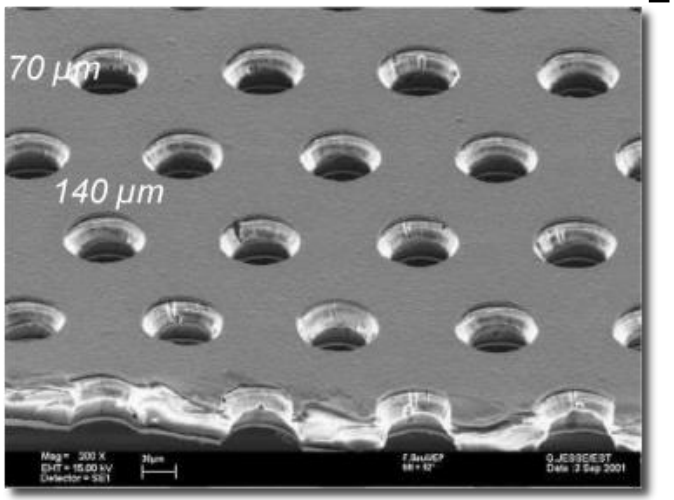

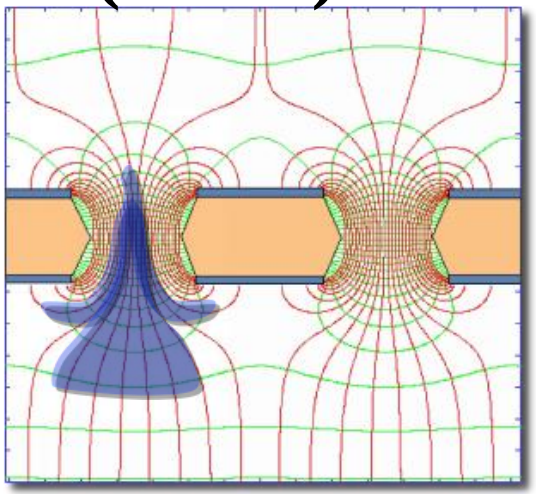

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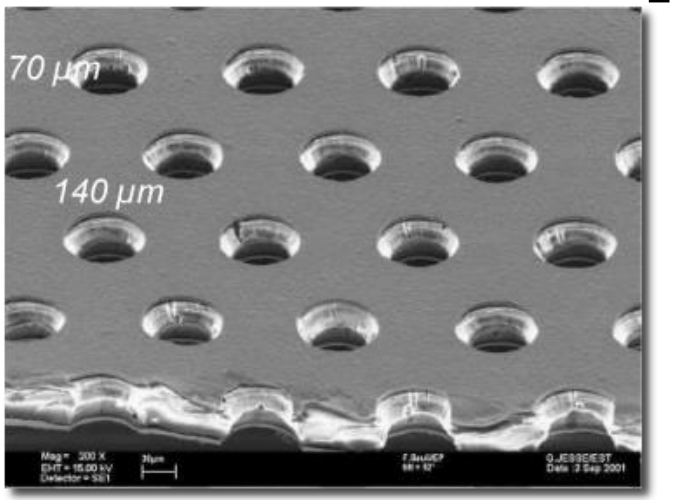

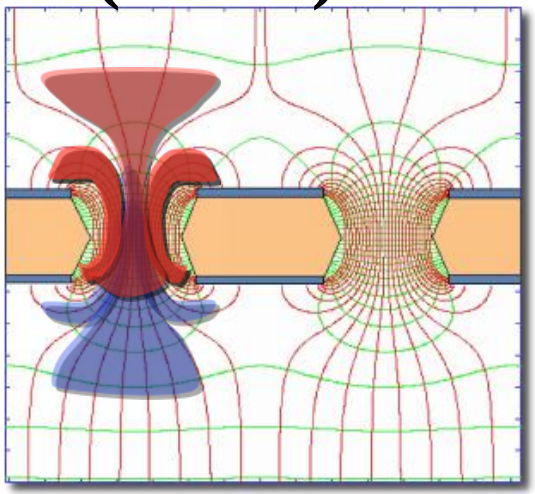

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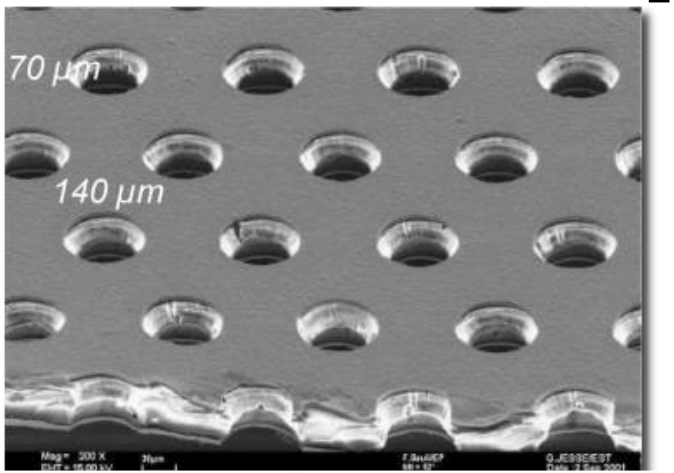

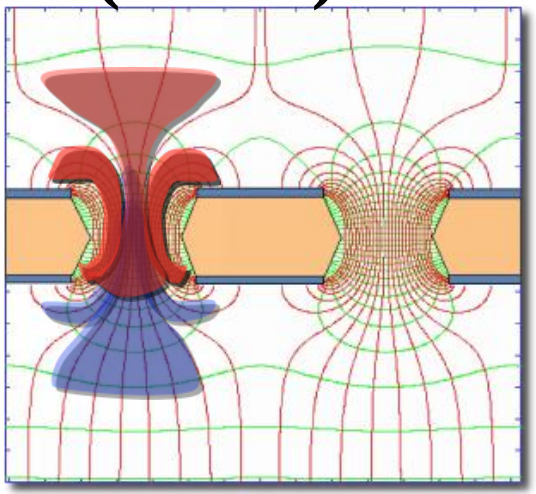

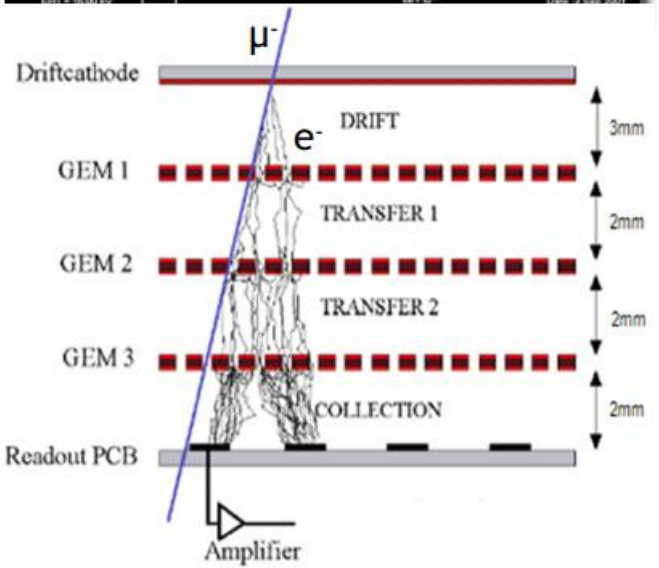

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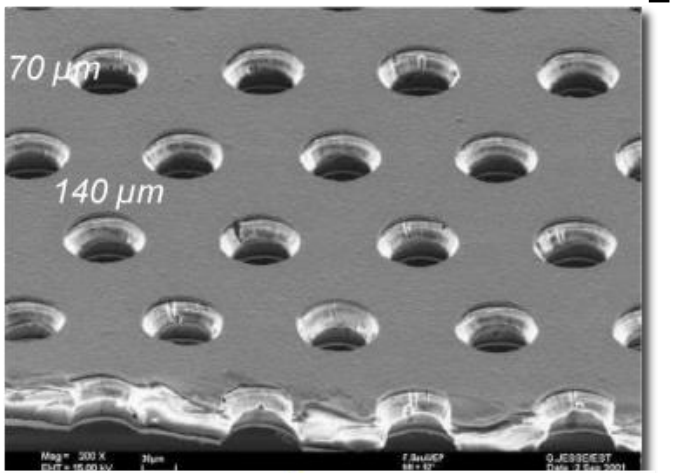

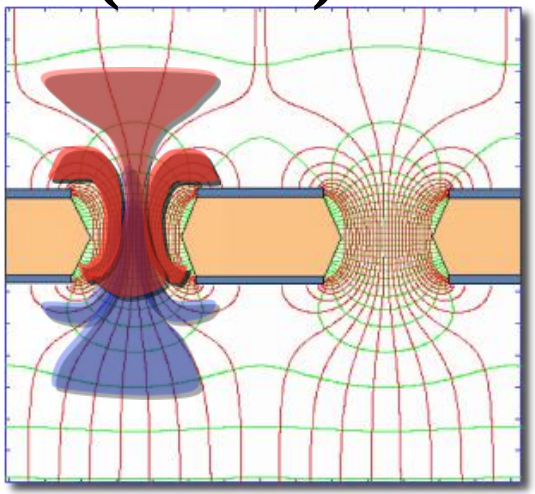

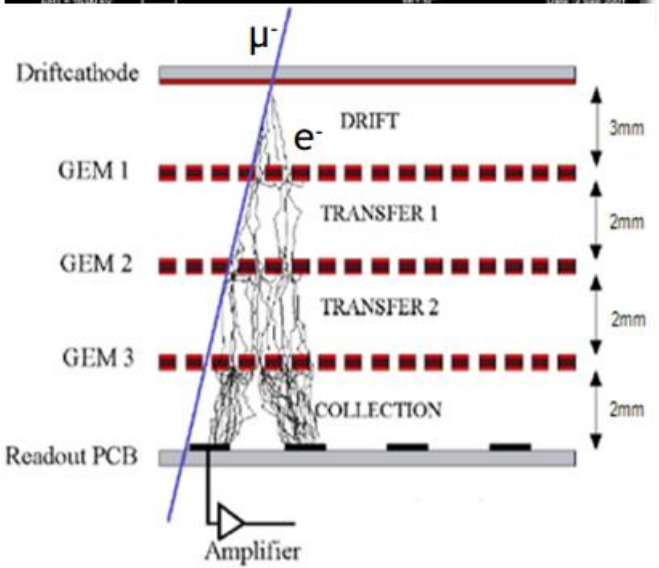

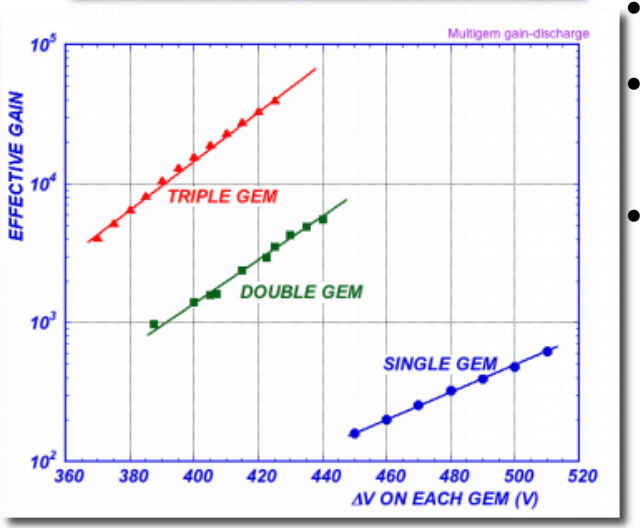

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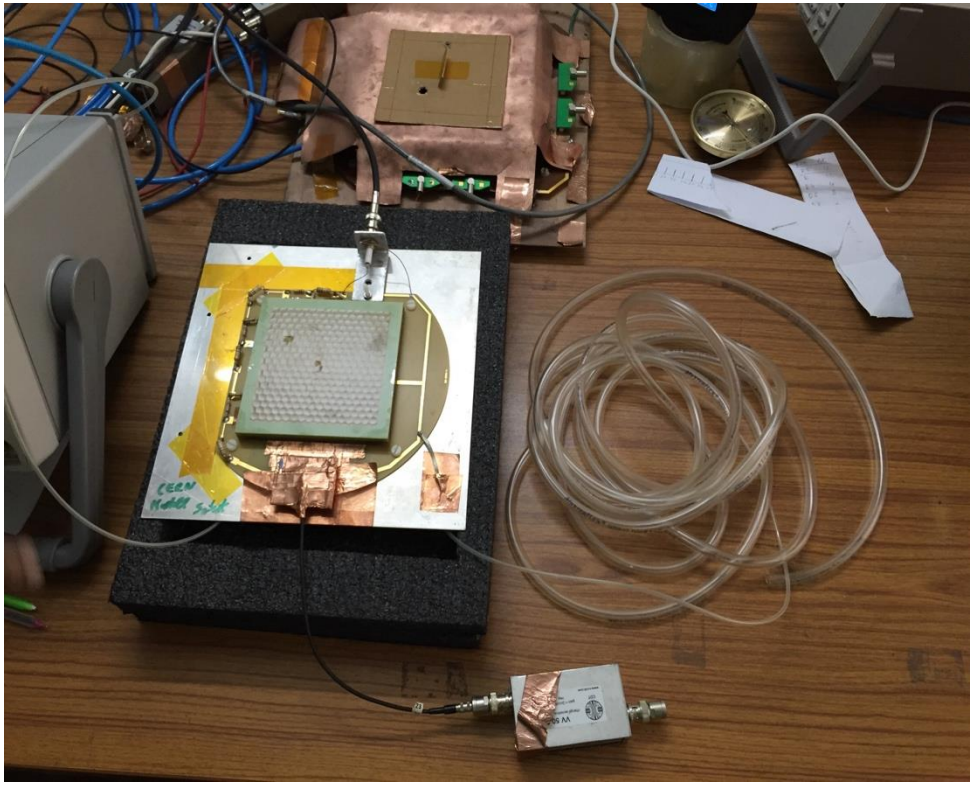
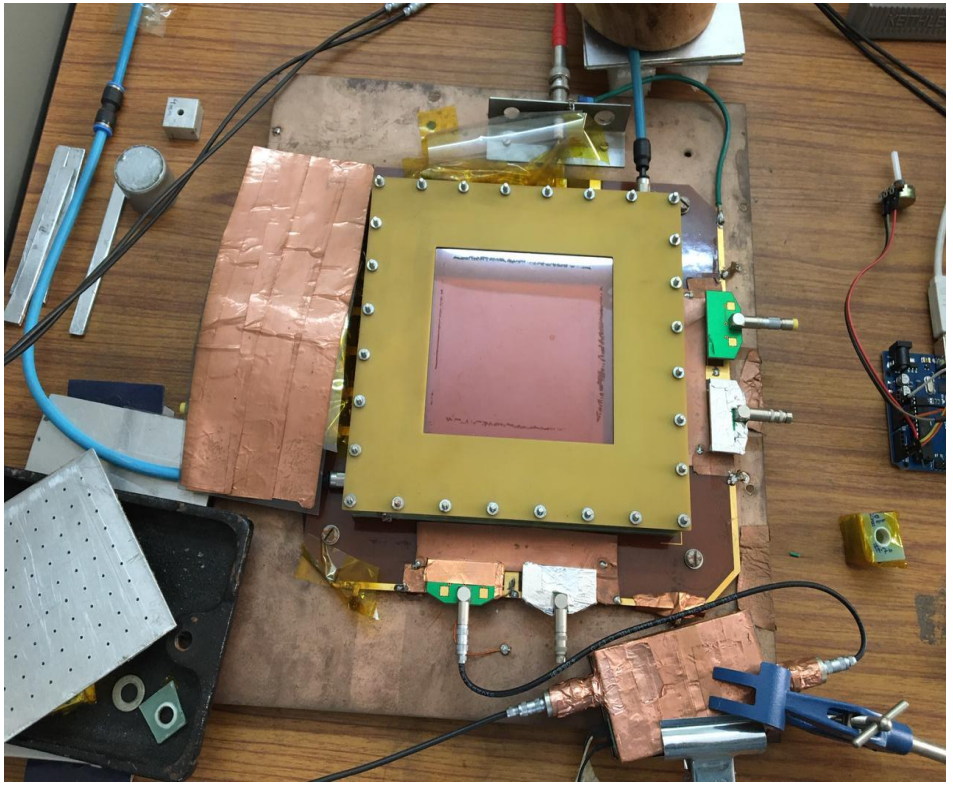
Triple GEM chambers prototype

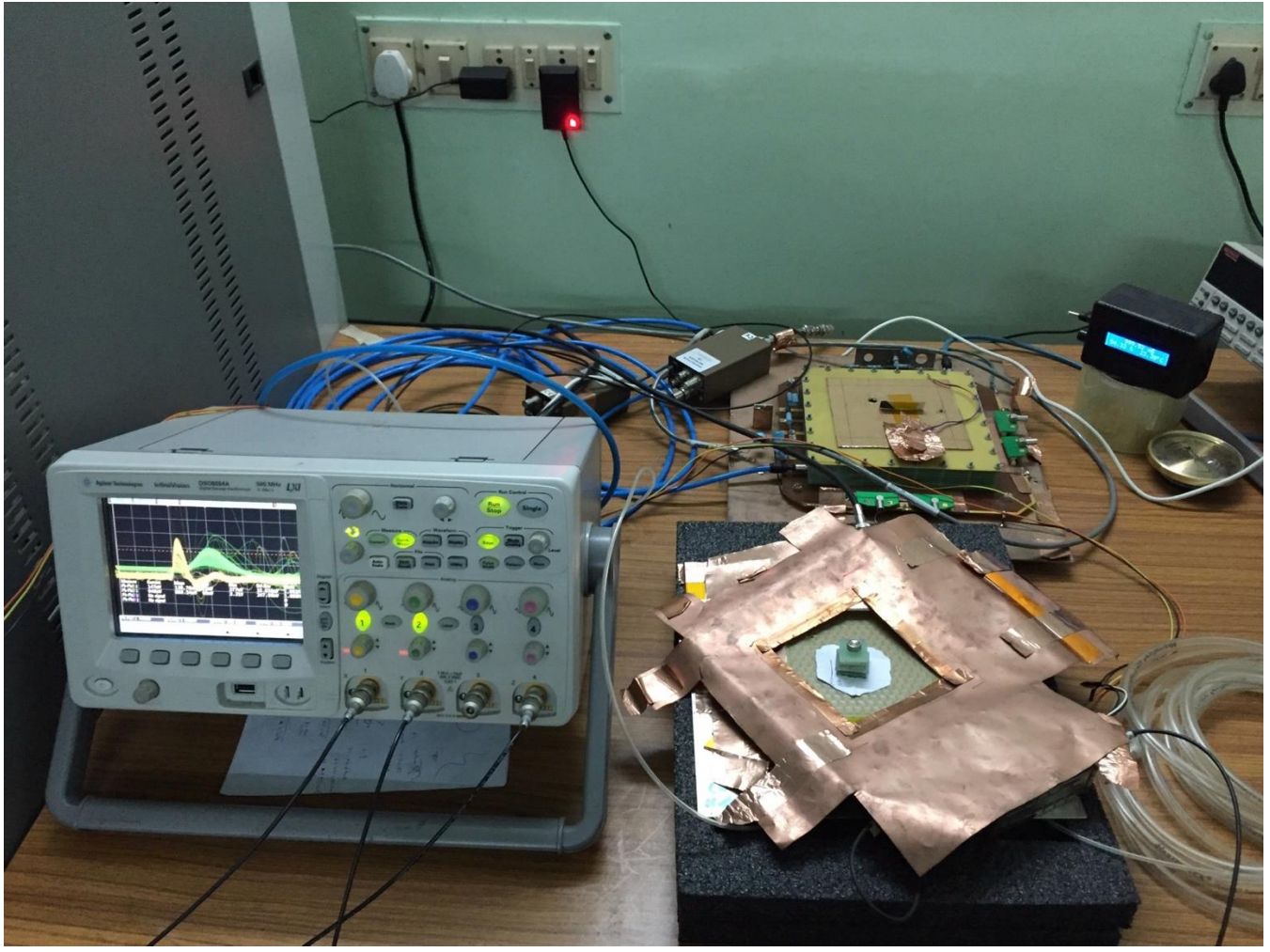


Double Mask (DM) triple GEM chamber



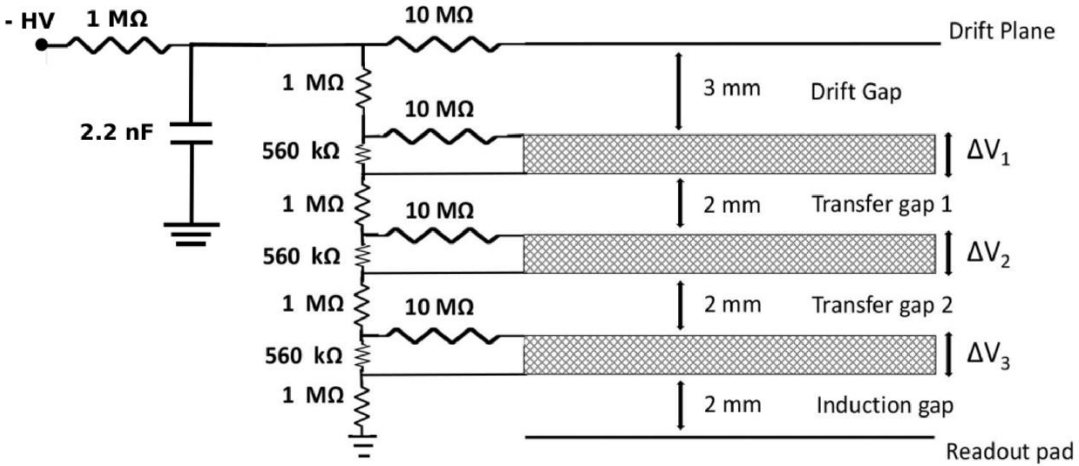
Single Mask (SM) triple GEM chamber

Triple GEM chamber prototype under testing at Bose Institute



Characteristics studies of triple GEM prototypes at Bose Institute

Characteristics studies



Schematic of the High Voltage distribution of the SM mask triple GEM chamber of dimension 10×10 cm²

Dimension of the chamber: 10×10 cm^2

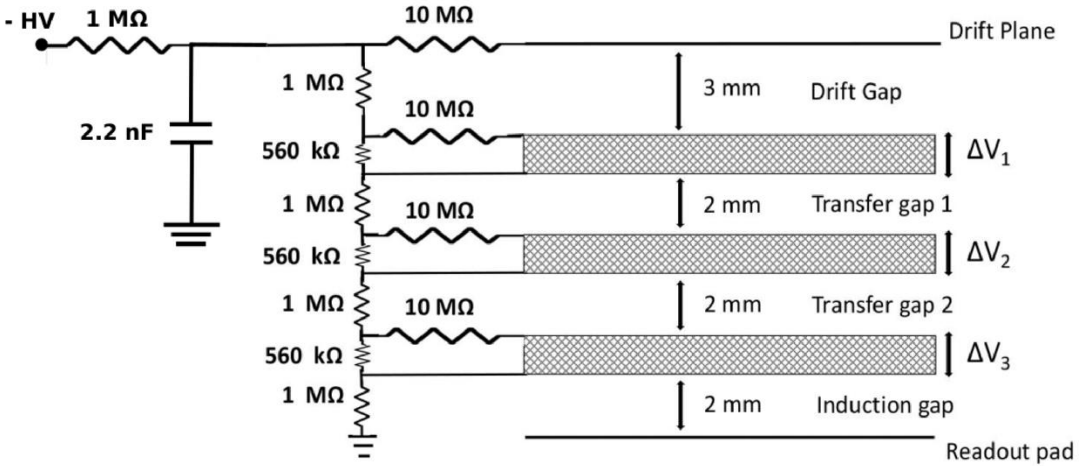
GEM: SM & DM triple GEM chamber

Source: Same Fe^{55} X-ray (5.9 keV) source is used for irradiation and monitoring the spectrum

Gas mixture: Ar/CO_2 (Continuous flow mode)

Preamplifier gain: 2 mV/fC (charge sensitive)

Characteristics studies



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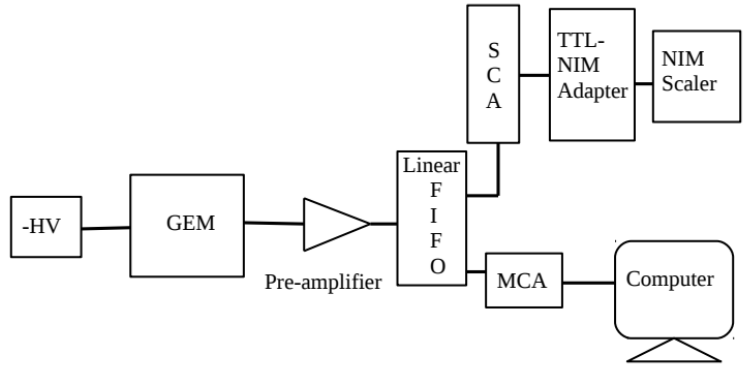

Schematic representation of the electronics setup

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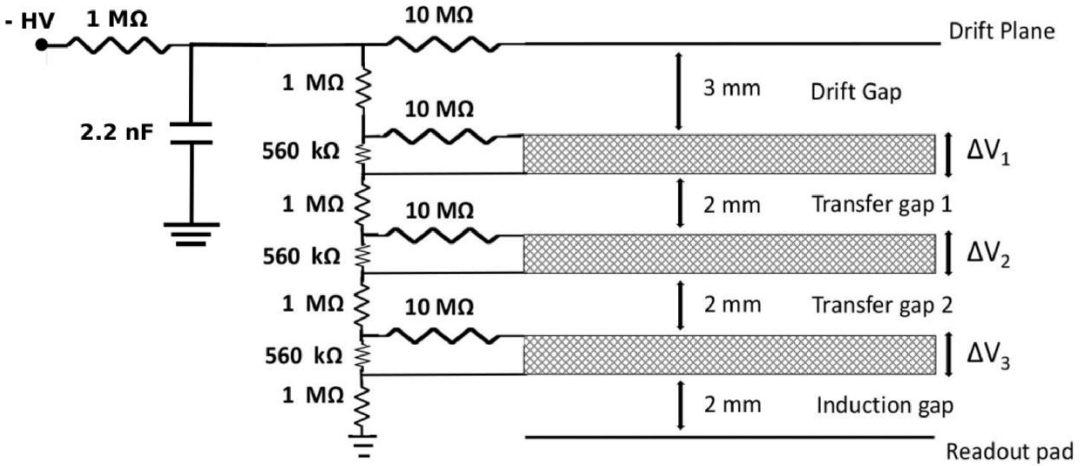

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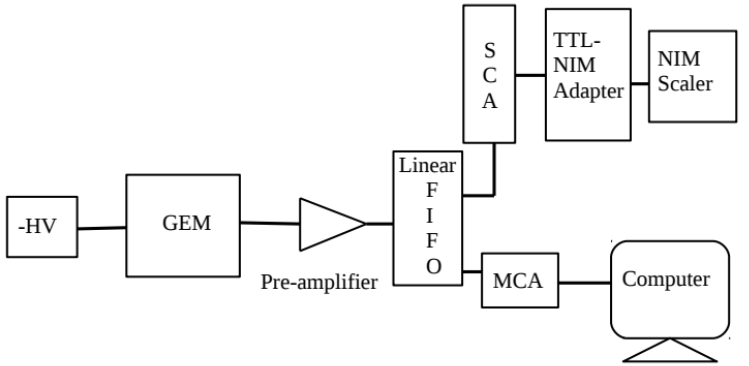

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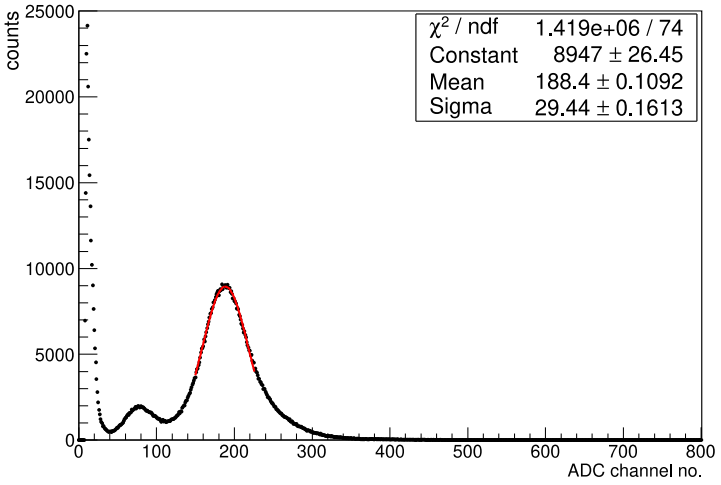
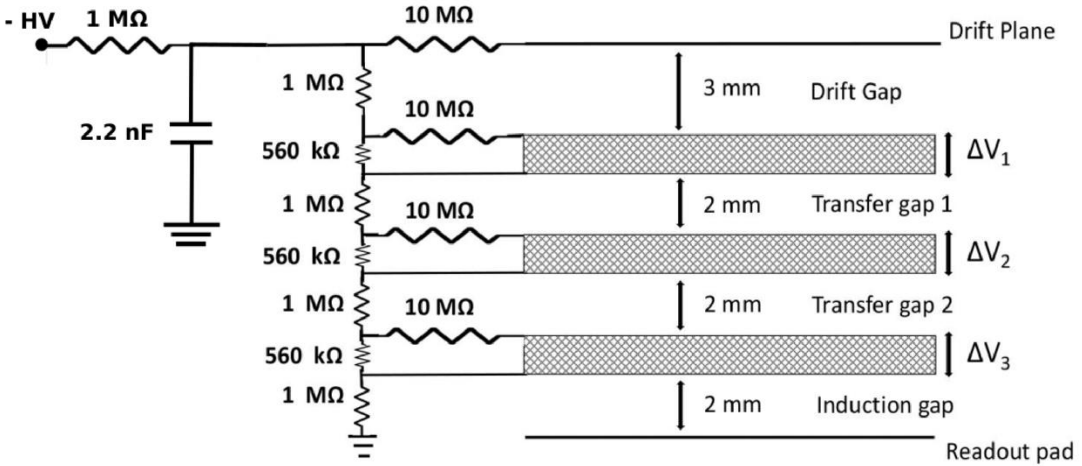


Fe^{55} spectra at ΔV ~ 400 V and with Ar/CO_2 gas mixture at 70/30 volume ratio

Characteristics studies



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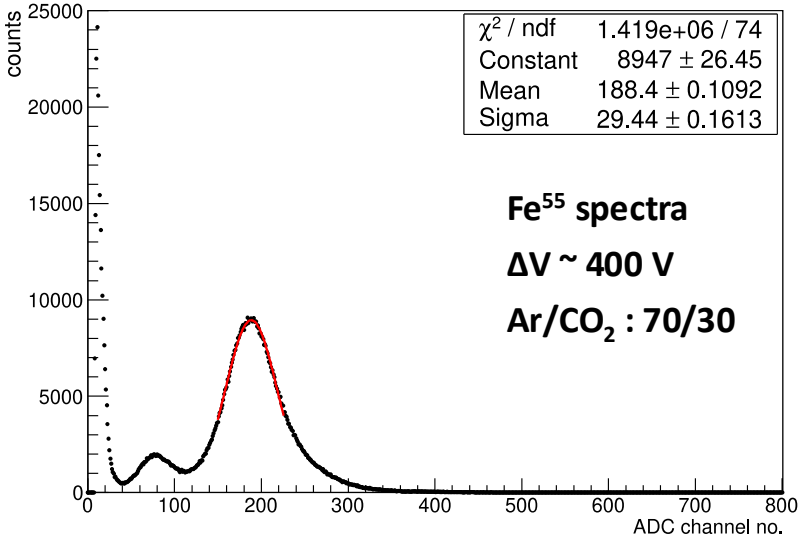

$$\text{Gain} = \frac{\text{Output charge}}{\text{Input charge}} = \frac{\text{(Mean pulse height/ 2 mV) fC}}{\text{No of primary electrons} \times e\ \text{C}}$$

$$\text{Energy resolution} = \frac{\text{Sigma} \times 2.355}{\text{Mean}} \times 100\ \%$$

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Preamplifier gain: 2 mV/fC (charge sensitive)

Number of primary electrons (n)

$$n = E_{gamma}\left(\frac{\%\ \text{of Ar}}{W_{Ar}} + \frac{\%\ \text{of } CO_2}{W_{CO2}}\right)$$

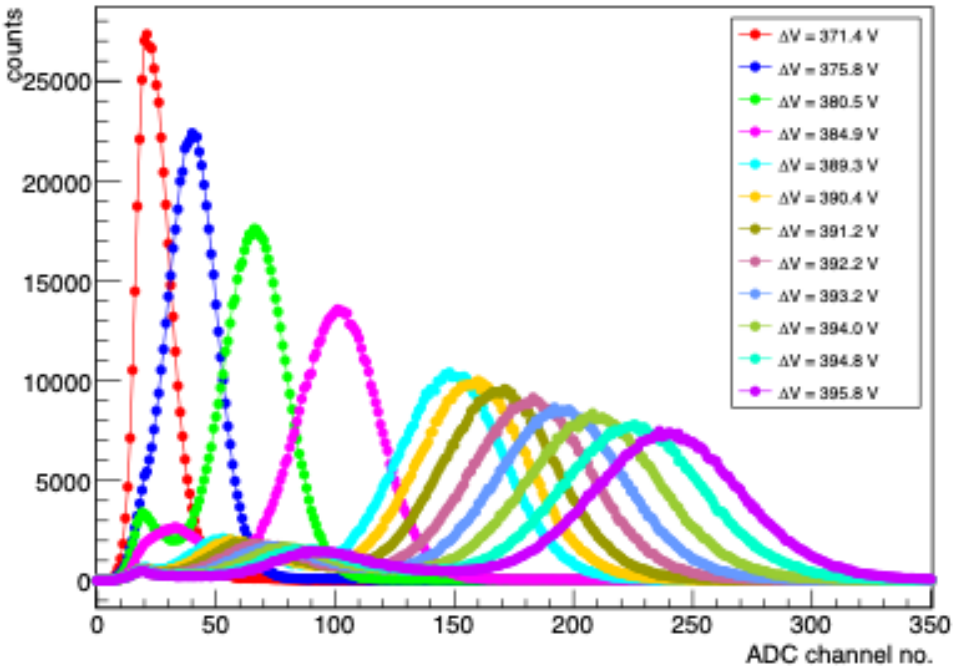
For Ar/CO_2 in 70/30 volume ratio, the average number of the primary electrons is 212 with the 5.9 keV X-ray source

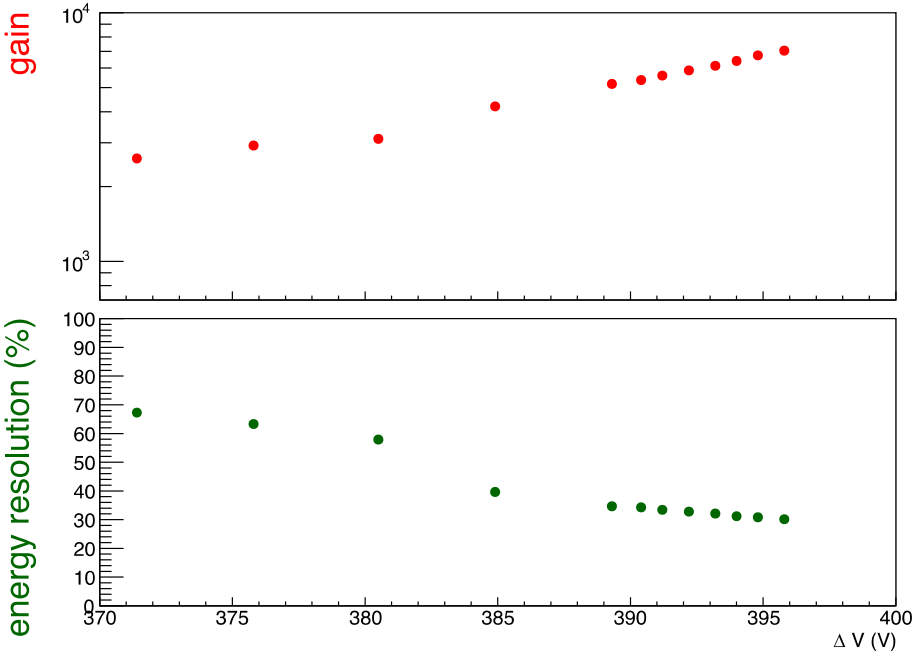
Studies so far at Bose Institute…

Study	Result so far	
Stability	Single Mask	Double Mask
	750 h; ~12.0 mC/mm²; Gain fluctuation 8.6%; No ageing (Measuring Anode Current) 350 h; ~0.85 mC/mm²; Gain and energy resolution fluctuation ~5%; No ageing (From Fe^{55} spectra)	1200 h; ~6.5 mC/mm²; Gain fluctuation 12%; Energy resolution fluctuation 18%; No ageing (From Fe^{55} spectra)
Spark probability	~10^{-9} at gain 5000-8000 with 150 GeV/c pion beam	~10^{-8} at gain 5000-8000 with 150 GeV/c pion beam (** earlier result)
Charging up effect	0.2-1.0 hours *(*depends on gain and irradiation rate etc.)*	1.4-2.4 hours
Uniformity	Gain ~10%, energy resolution ~13%, count rate ~10%	Gain ~10%, energy resolution ~20%, count rate ~20%

S. Chatterjee *et al.* NIM A 977 (2020) 164334, 2020 JINST 15 T09011, NIM A 1014 (2021) 165749, NIM A 1049 (2023) 168110, S. Biswas *et al.* NIM A 800 (2015) 93

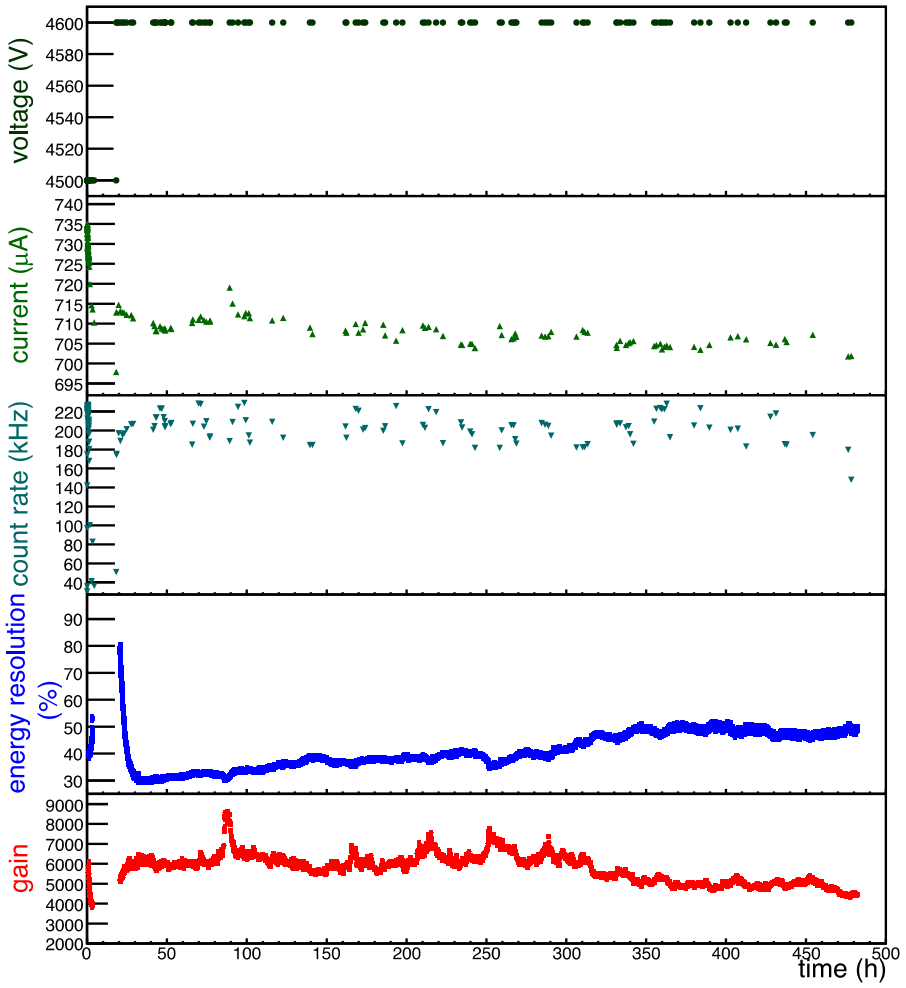
Voltage scan

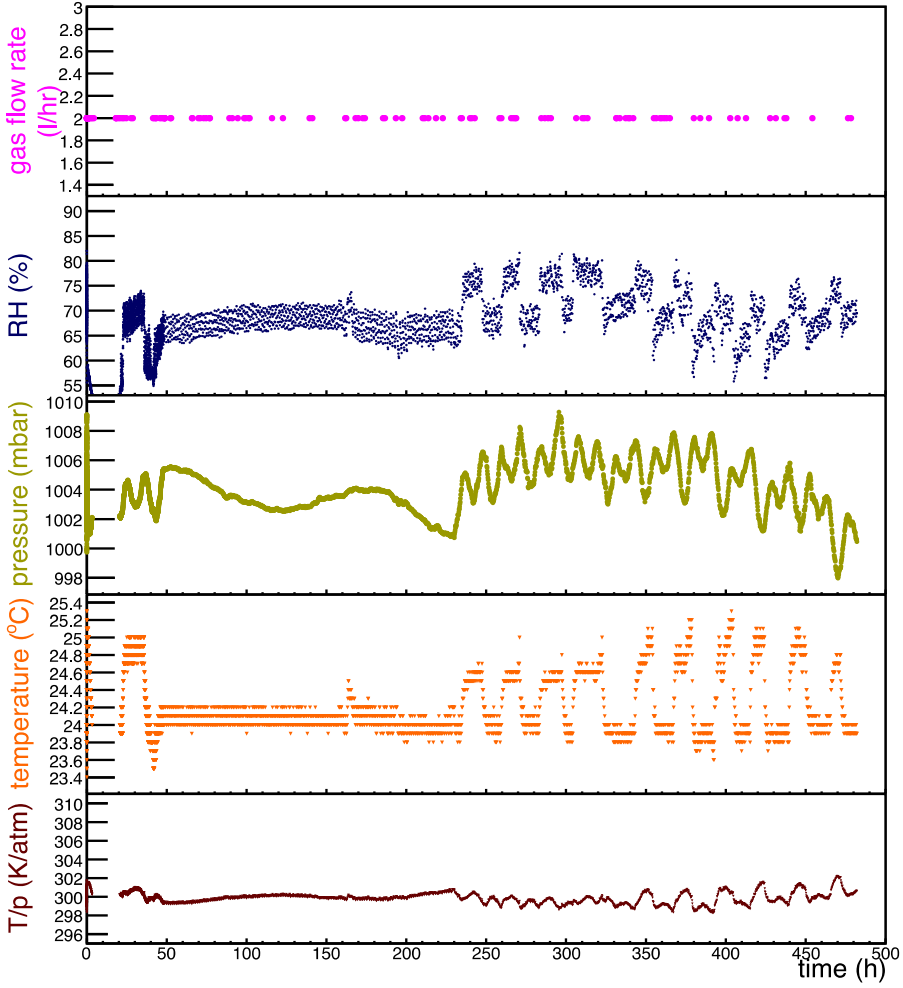




- Gain increases with T/p
- Recently during stability study, it was observed that the gain is slowly decreasing even after correction for the T/p effect -> anomalous behavior

Stability study Ar/CO_2 : 70/30





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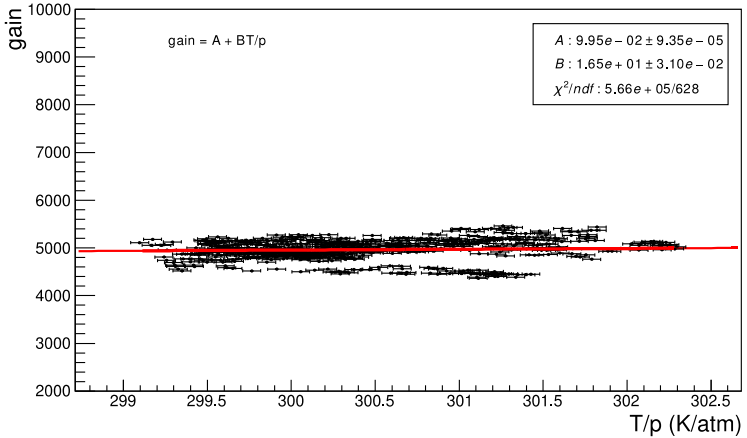

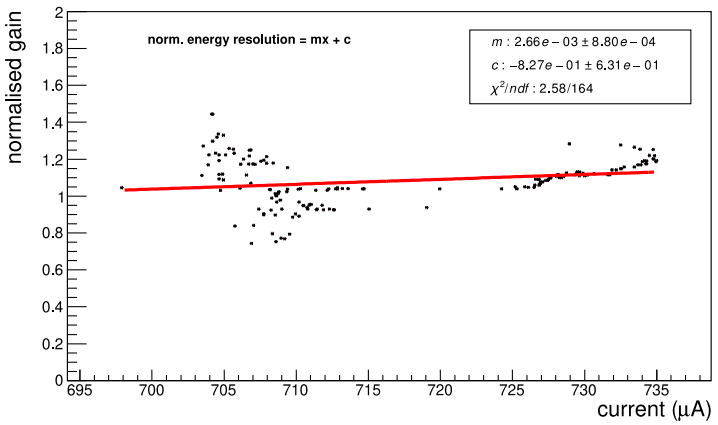

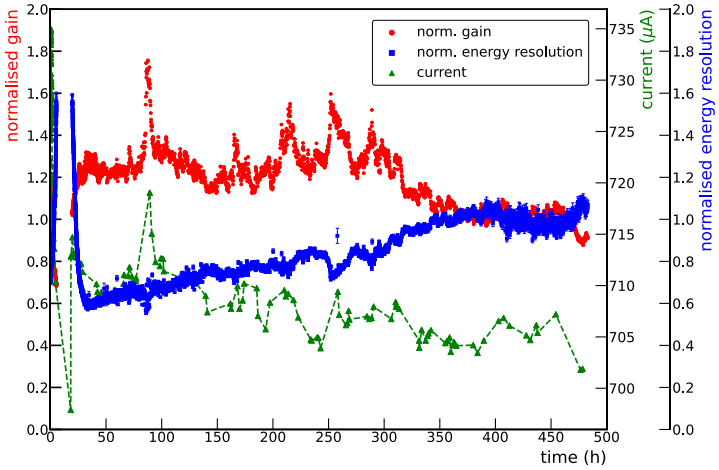

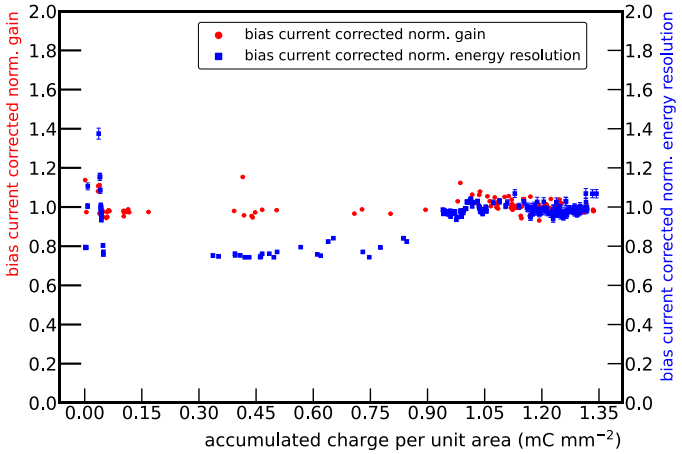

S. Mandal *et al.*, NIM, A 1064 (2024) 169389

Summary

- No ageing observed for GEM chamber
- GEM is a good detector for future high-rate experiment

Thank you for your attention!!!