Stability study of GEM detector and Performance study of a new RPC prototype

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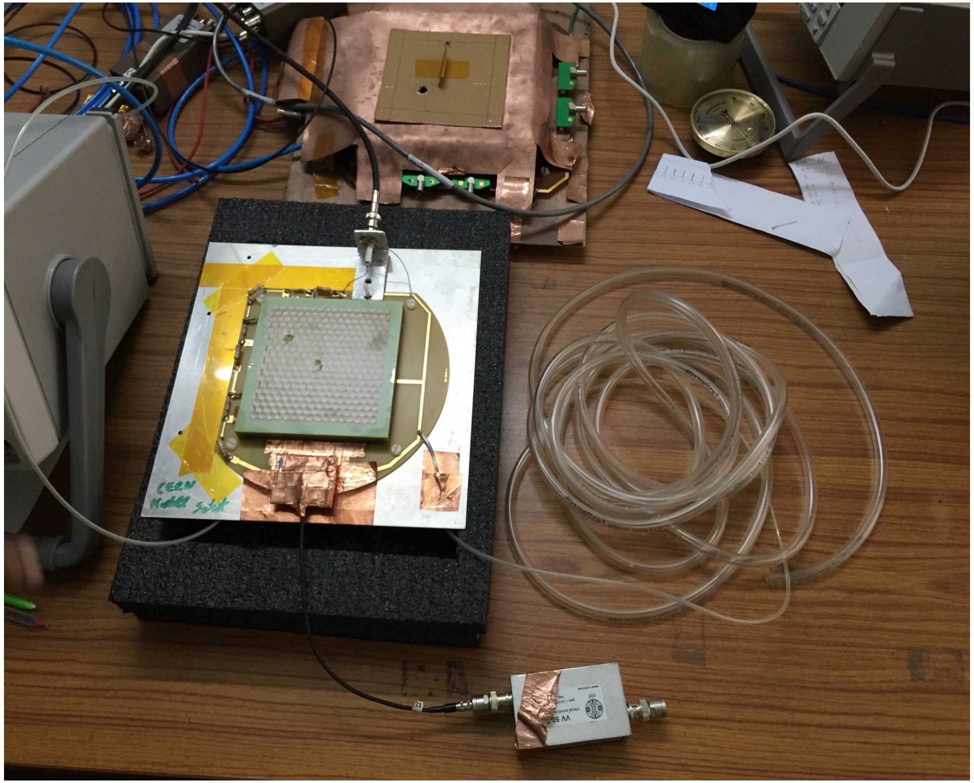
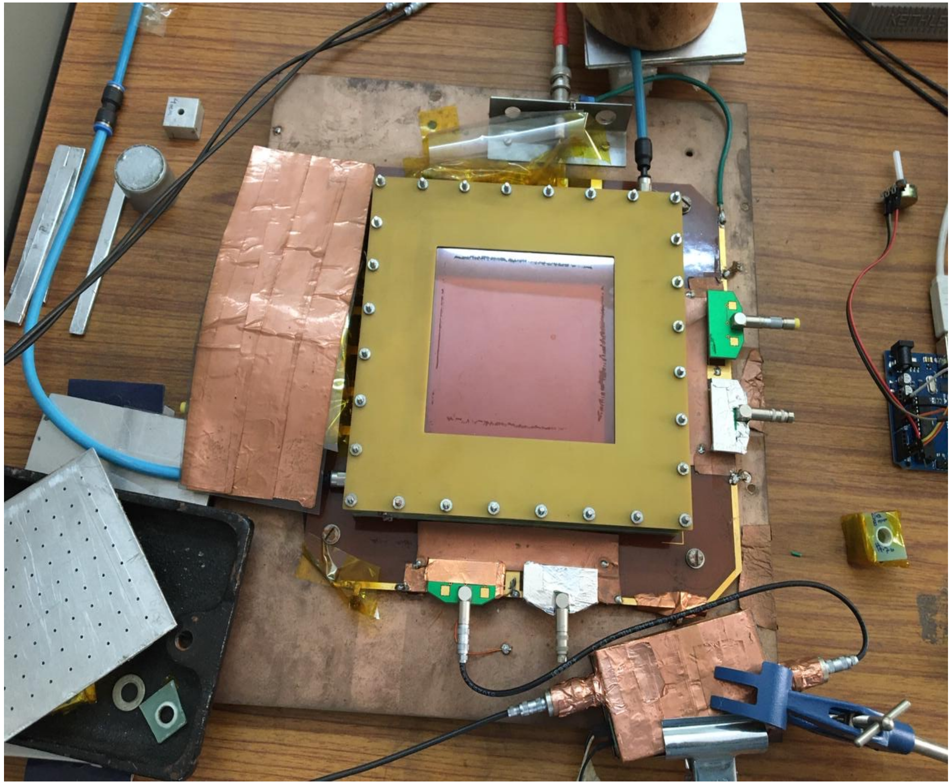
Outline

- Stability study of GEM detector
- Development of Bakelite RPC
  - Study of I-V characteristics
  - Efficiency measurement
  - Time resolution measurement
  - Stability
  - Radiation hardness
  - Charge sharing measurement
- Summary

Triple GEM chambers prototype under testing

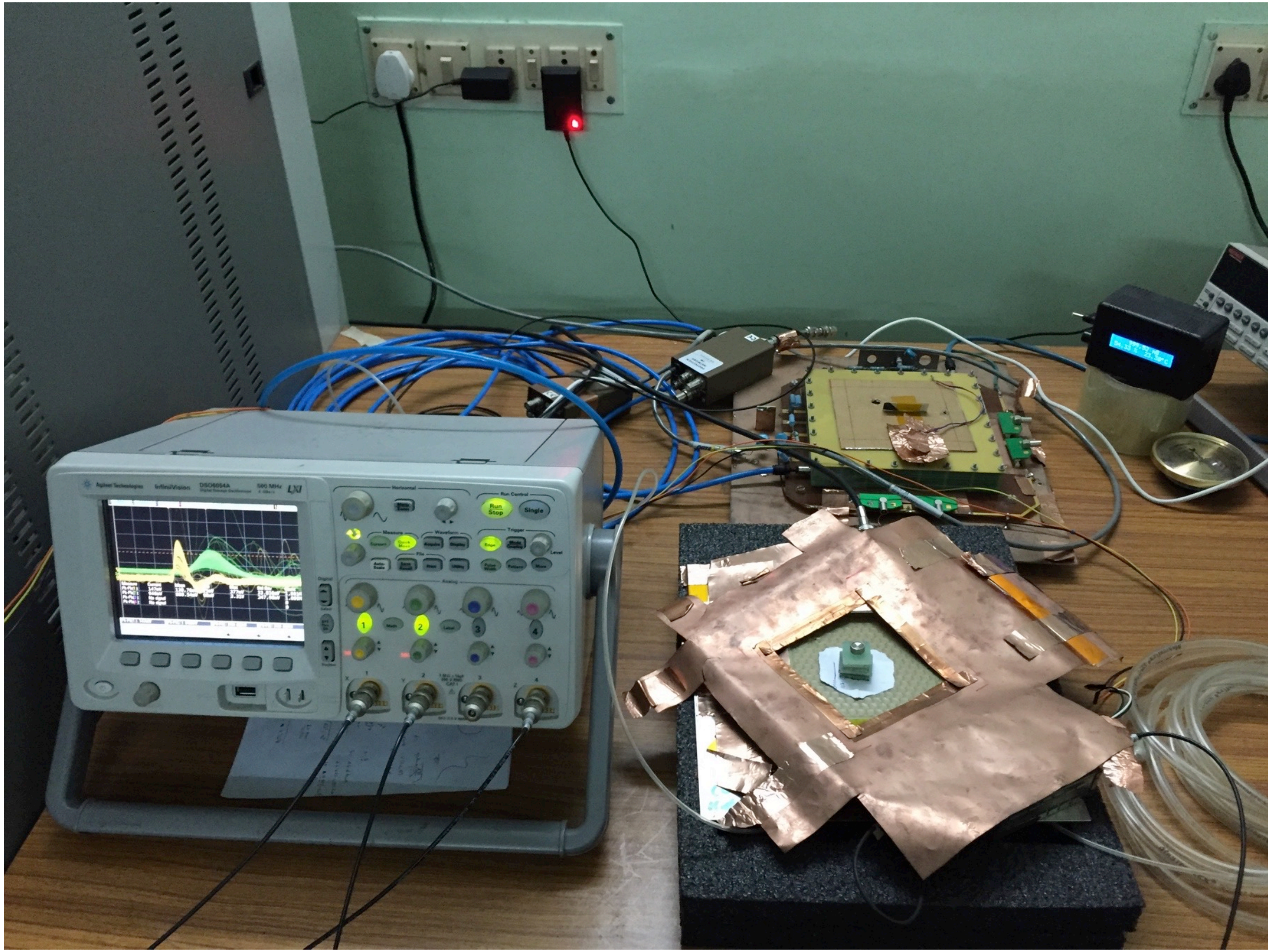


Double Mask (DM) triple GEM chamber



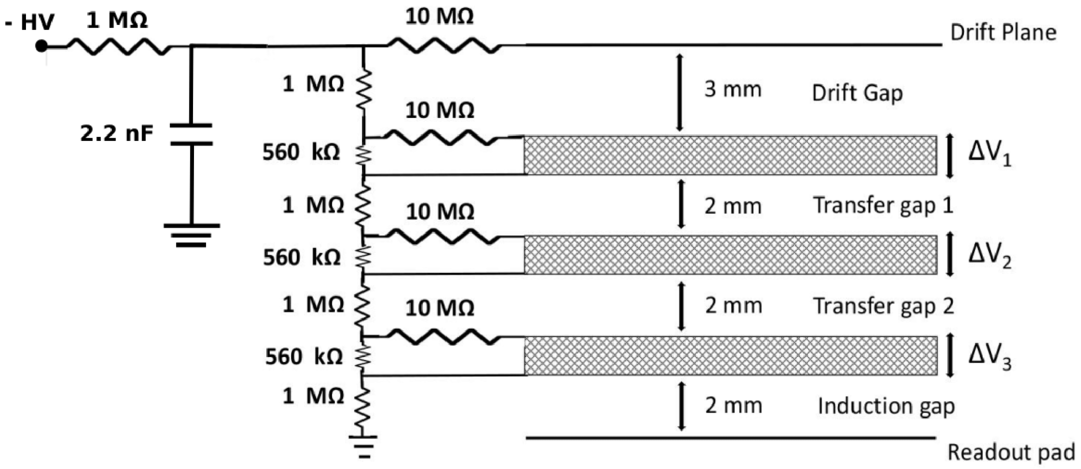
Single Mask (SM) triple GEM chamber

Triple GEM chamber prototype under testing



Characteristics studies of triple GEM prototypes

Characteristics studies



Schematic of the High Voltage distribution of the DM mask triple GEM chamber of dimension 10×10 cm^2

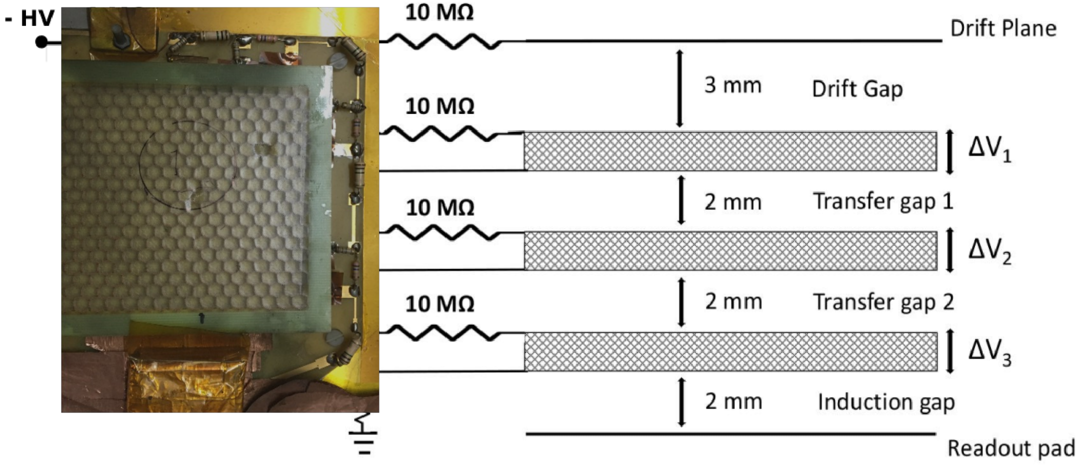
Dimension of the chamber: 10×10 cm^2

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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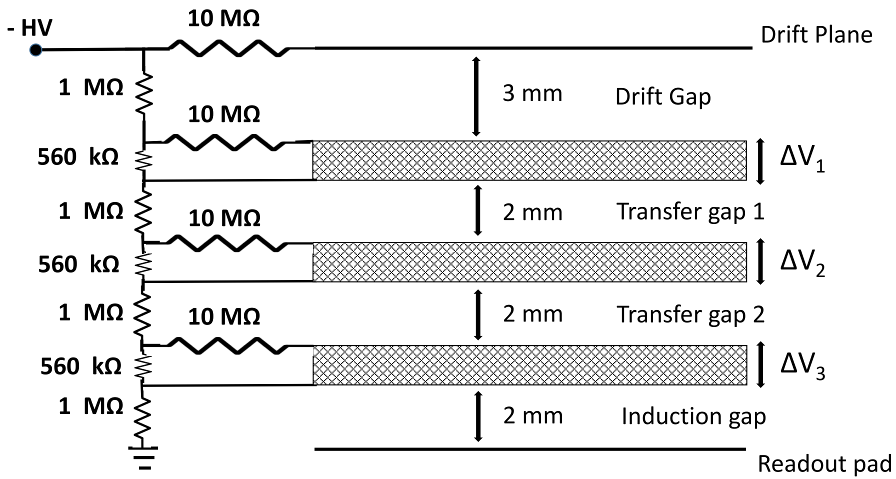

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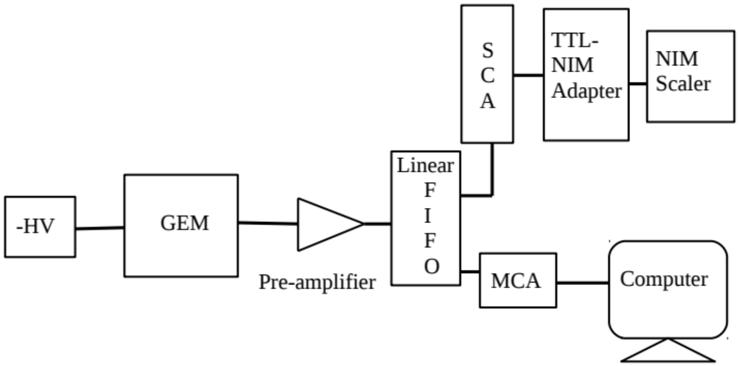

Schematic representation of the electronics setup

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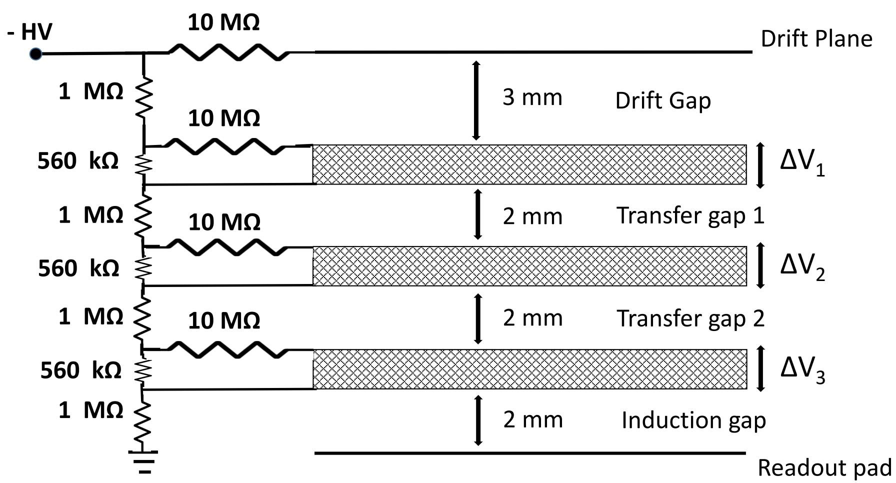

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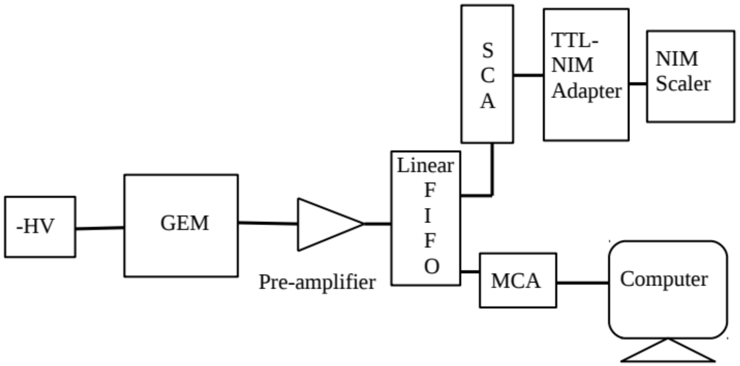

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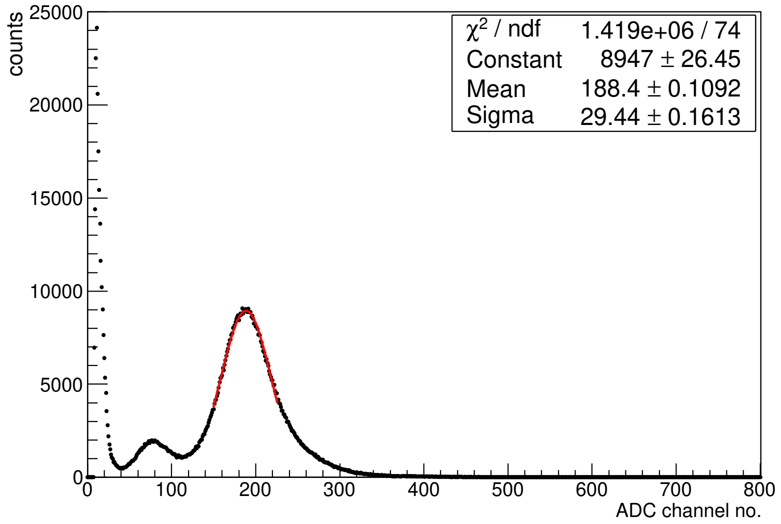
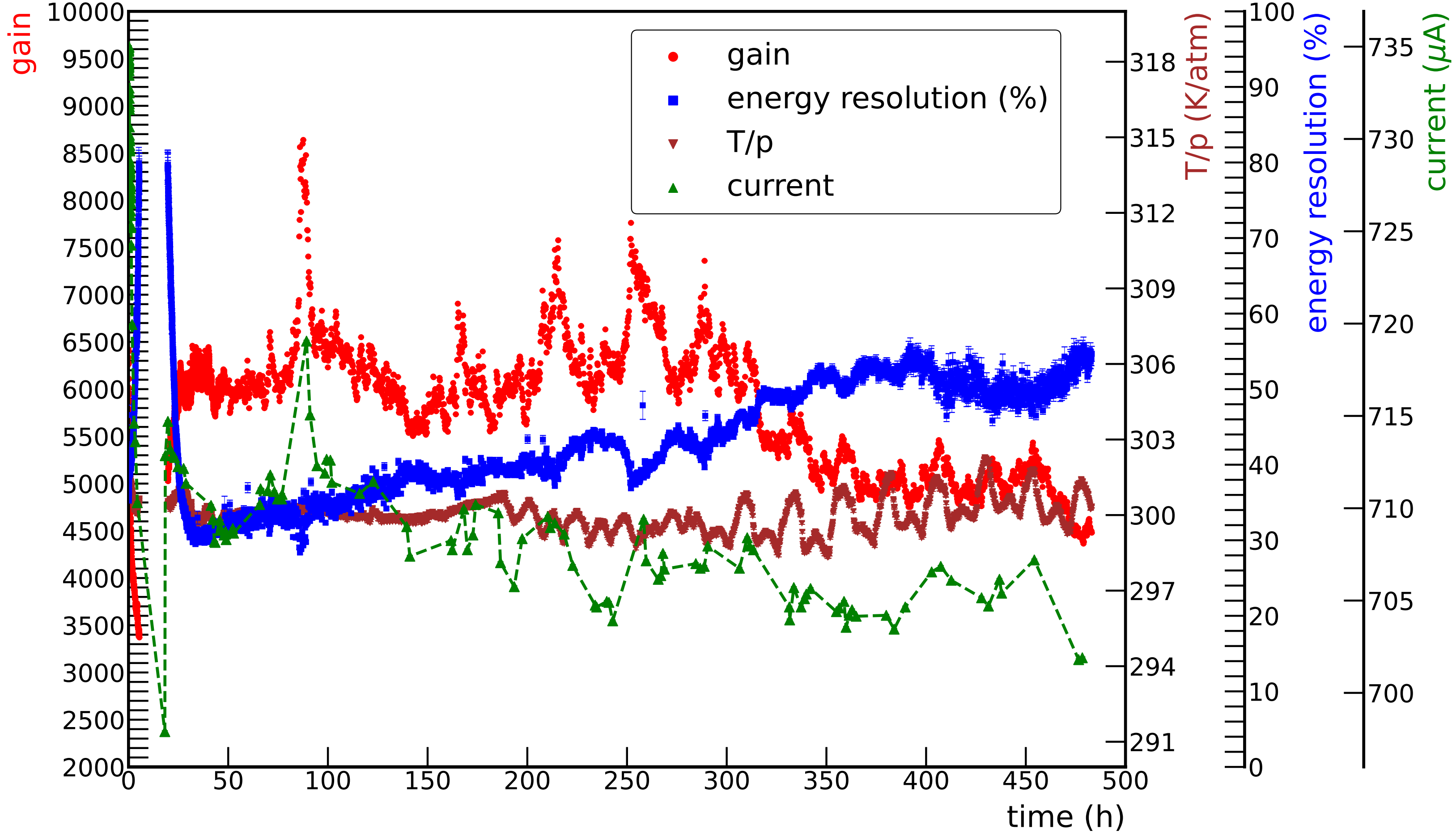


Fe^{55} spectra at ΔV ~ 396 V and with Ar/CO_2 gas mixture at 70/30 volume ratio

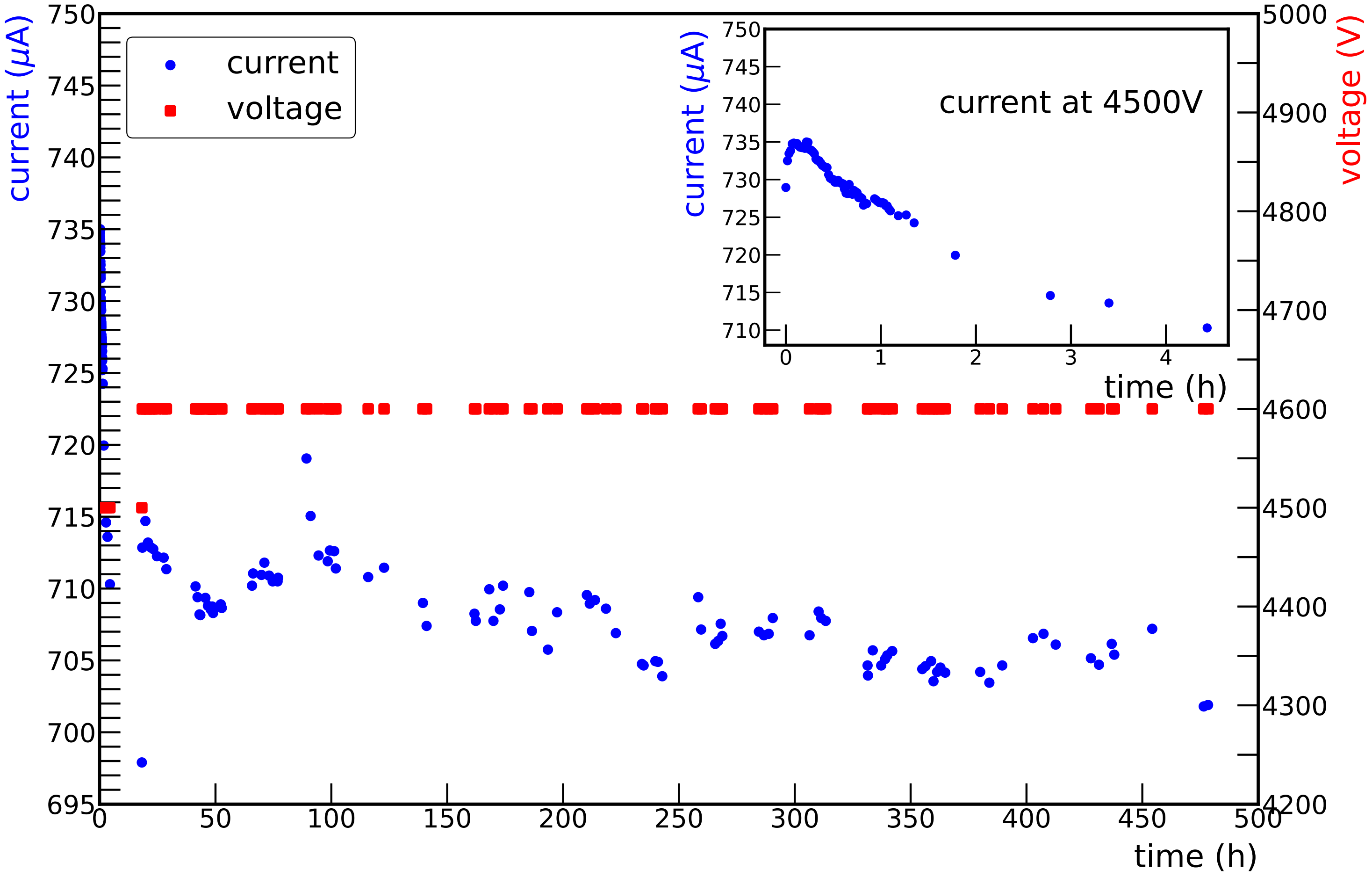
Stability study of SM triple GEM prototypes

Variation of different parameters with time



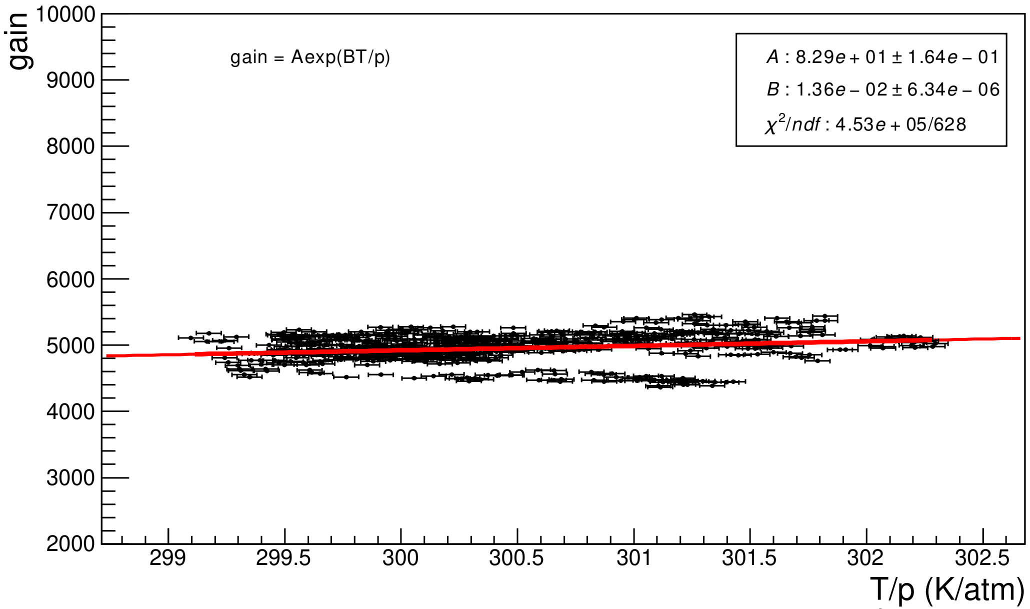
Variation of the measured gain, energy resolution, divider current and T/p as a function of the time

Variation of current with time

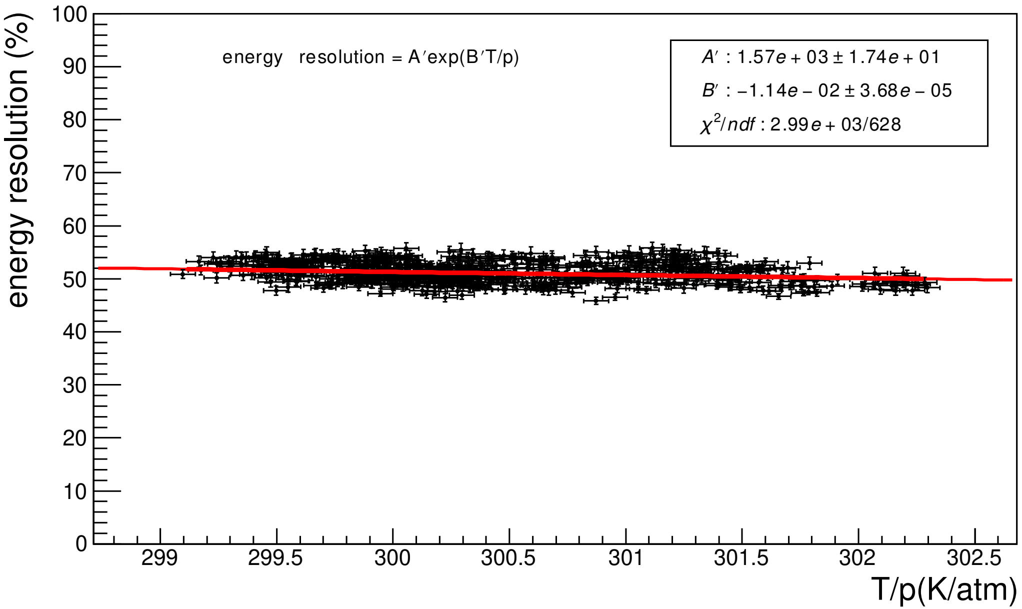


Applied voltage and divider current as a function of time. The current as a function of time for the first 5 hours after applying high voltage is shown in the inset

Variation of gain and energy resolution with T/p



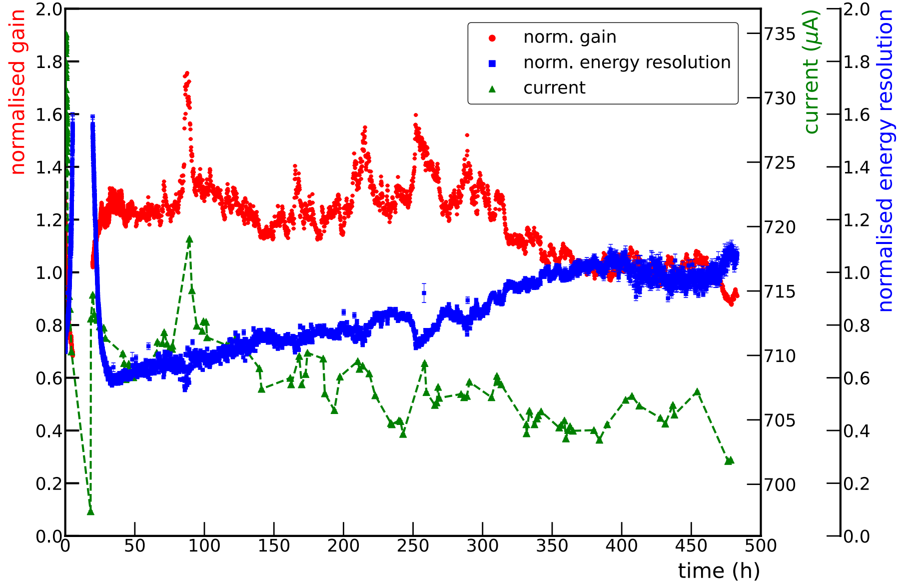
Variation of the gain as a function of T/p

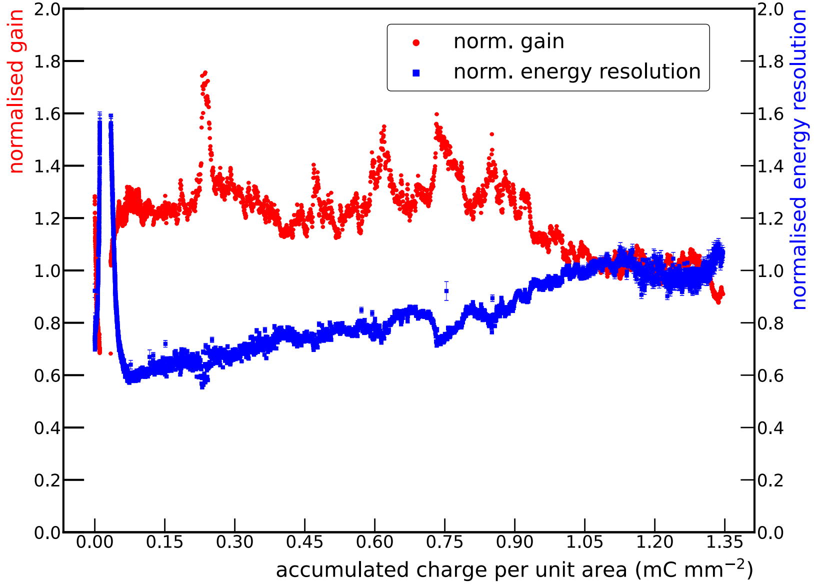


Variation of the energy resolution as a function of T/p

- **Gain of the chamber can be expressed as e^{α}, where α is the first Townsend coefficient**
- **Townsend coefficient $\alpha \propto 1/\rho \propto T/p$; ρ =** mass density**, T =** temperature**, p =** pressure
- **Gain of the chamber depends on the variation of T/p**
- **Gain is normalised using a parameterisation of the form $Ae^{(BT/p)}$**

Normalised gain & energy resolution vs accumulated charge





$$\frac{dq}{dA} = \frac{r \times n \times e \times G \times dt}{dA}$$

r = rate, ***n*** = no of primary electrons, ***dt*** = time
e = electronic charge, ***G*** = gain, ***dA*** = irradiated are

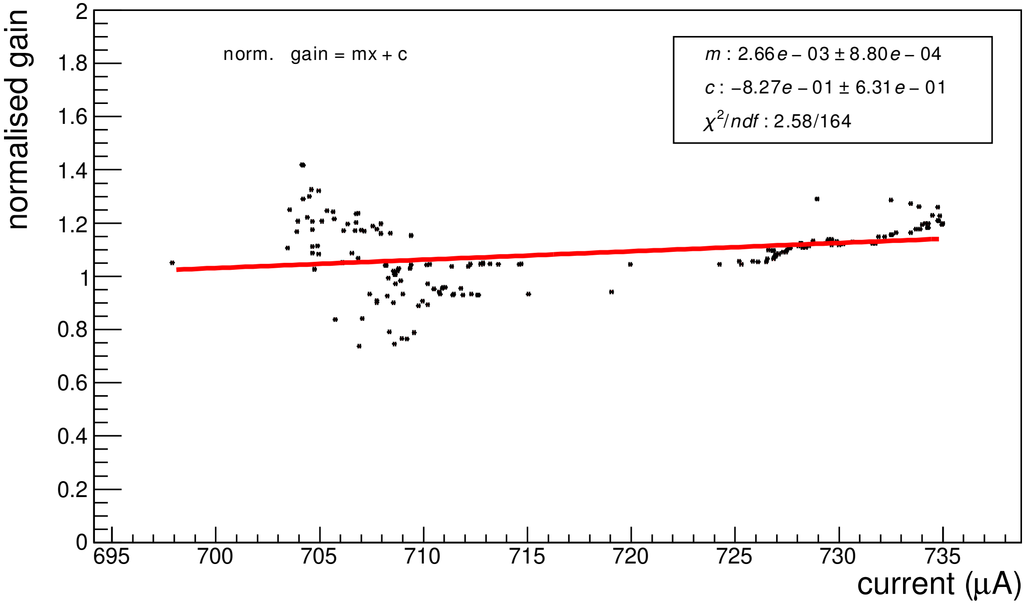
Gain and energy resolution is normalised by T/p ratio to nullify the effects of temperature and pressure variations

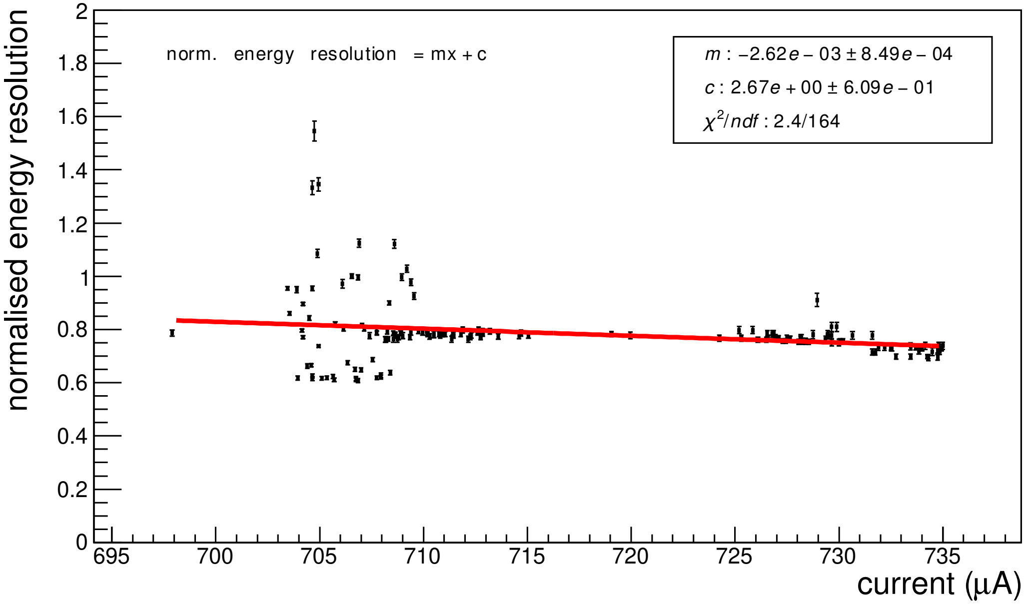
Degradation in the normalised gain and energy resolution is observed due to the change of the biased current

Typical accumulated charge for 10 CBM years is ~ 0.8 mC/mm^2 at the gain of 10^3

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

Normalised gain & energy resolution vs bias current

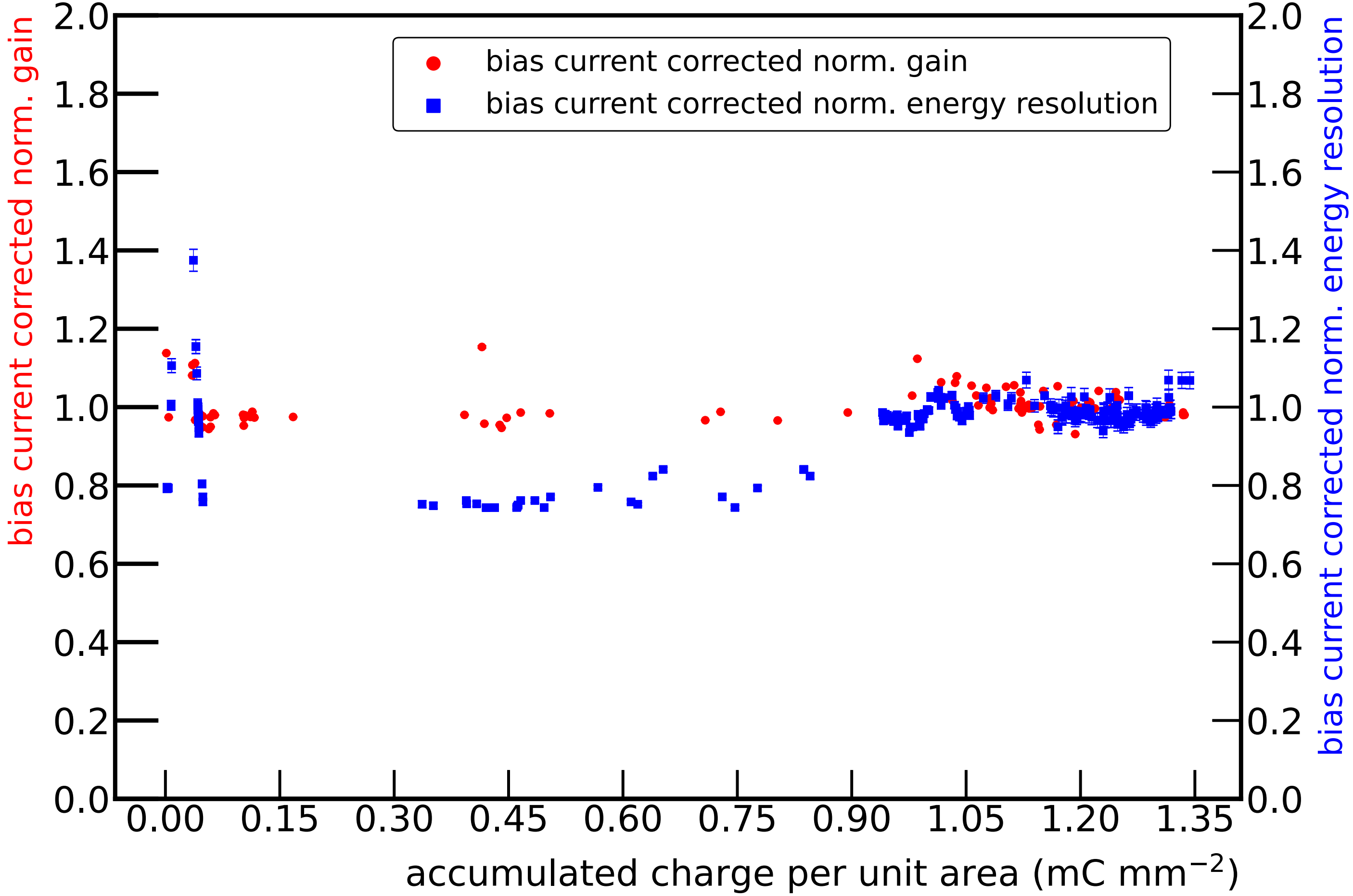




Variation of normalised gain and normalised energy resolution as a function of bias current

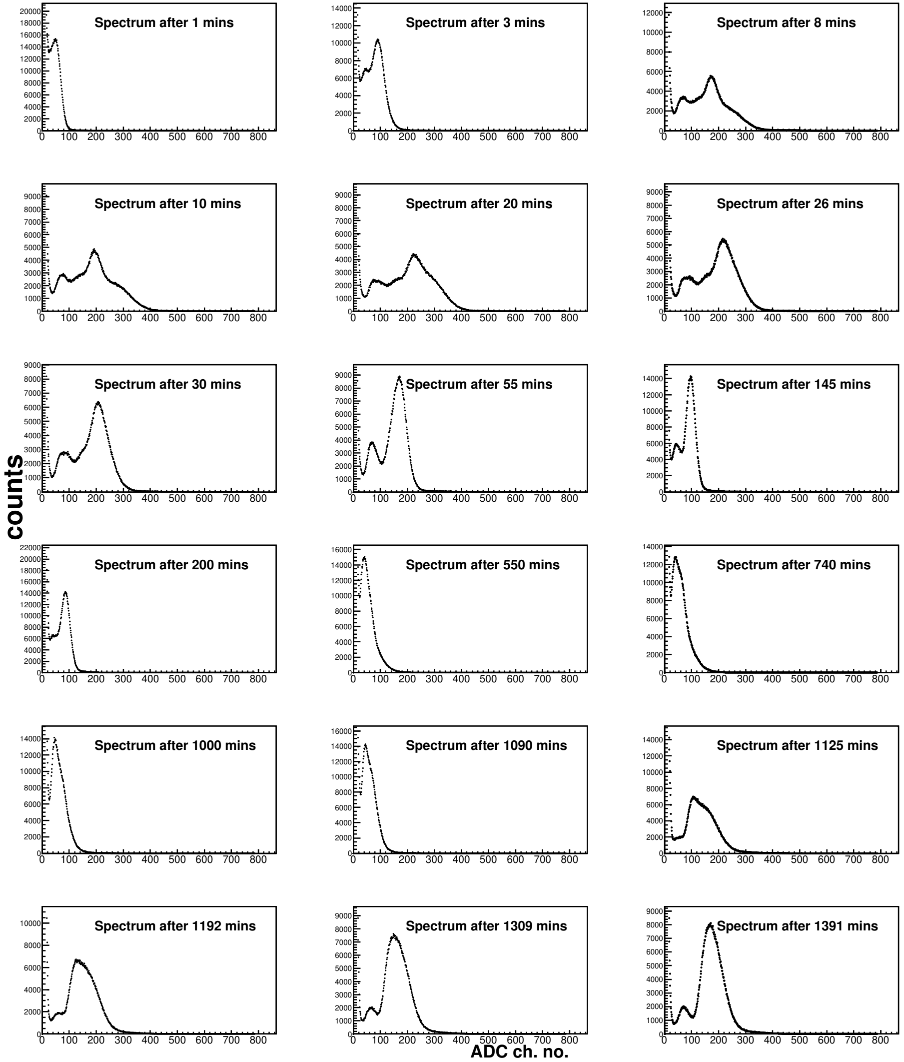
Reference : S. Mandal *et al.*, NIM, A 1064 (2024) 169389

Bias current corrected norm. gain and norm. energy reso.



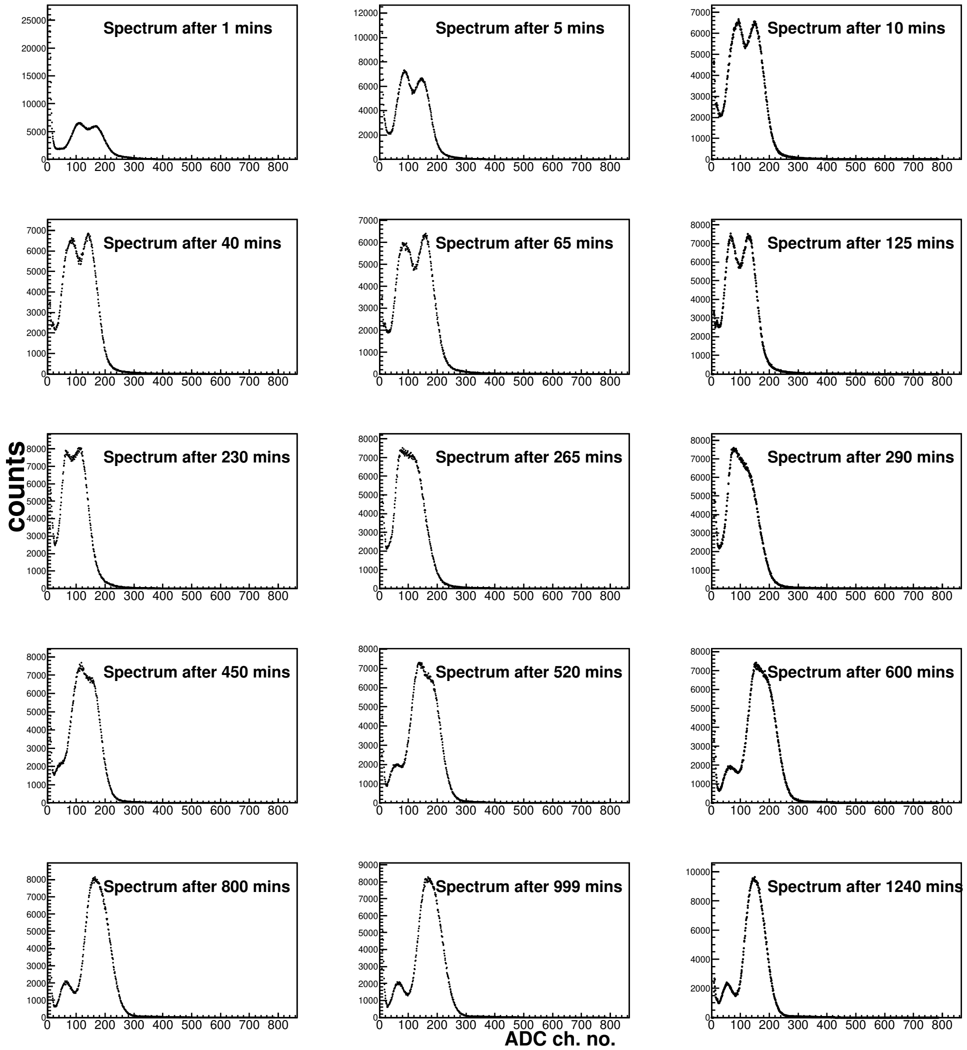
No significant degradation is observed

Abnormality in the initial spectra



The shape of ^{55}Fe X-ray spectra at different times after the application of HV.

Abnormality in the initial spectra



Variation of the shape of ^{55}Fe X-ray spectra after different time from the application of HV. Appearance of an abnormal double peak at the beginning

Summary

- **Stability studies of a SM triple GEM chamber**
  - ❖ The T/p normalised gain decreases with time after initial charging up phase
  - ❖ The probable reason: The bias current started decreasing gradually. As a result, the ΔV across the GEM foils decrease which in turn reduce the gain of the detector
  - ❖ The decrease in the normalised gain is directly proportional to the decrease in the bias current
  - ❖ Long term stability study doesn't show any significant degradation in the performance in terms of gain and energy resolution of the chamber after correction for the bias current

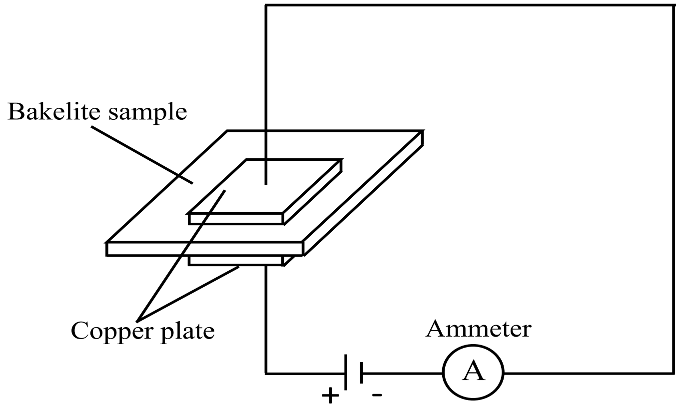
Bakelite based RPCs have been developed using indigenous material

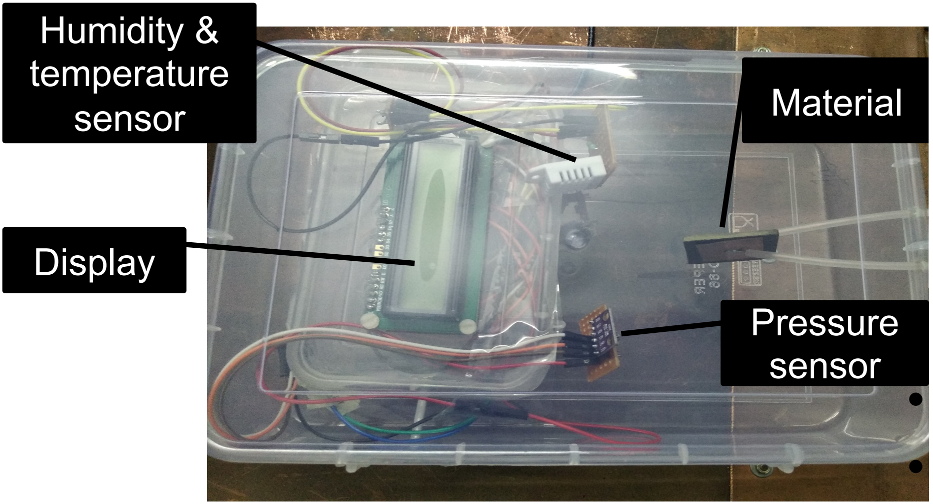
and

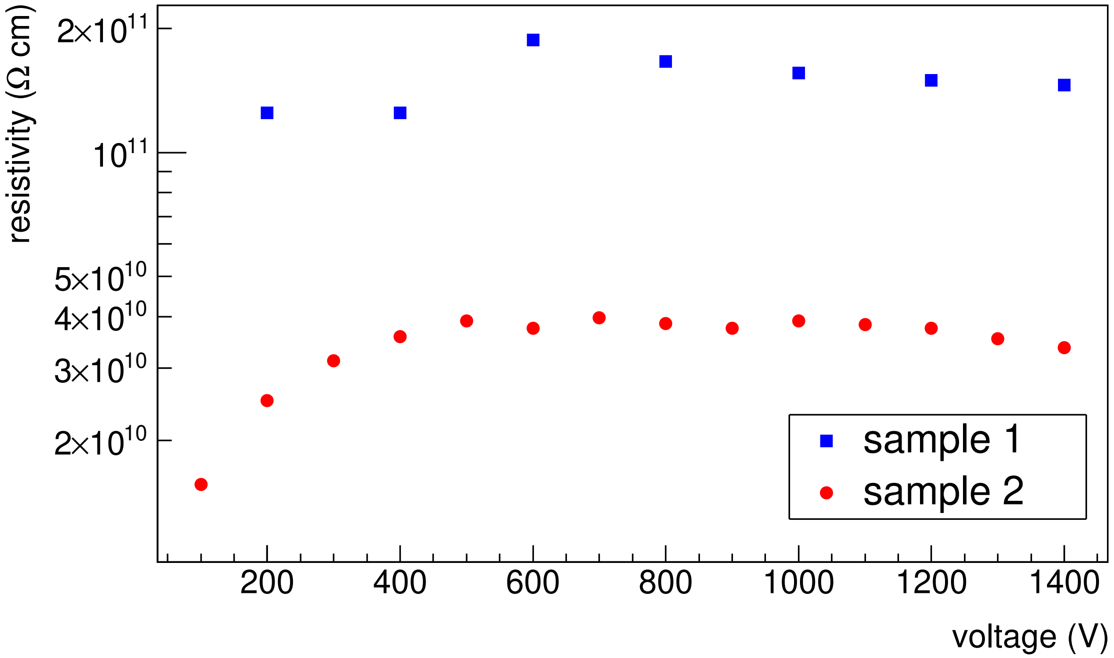
characterized in the Avalanche mode

1. A. Sen *et al.*, Nucl. Instrum. Methods. A 1045 (2023) 167572
2. A. Sen *et al.*, Nucl. Instrum. Methods. A 1024 (2022) 166095
3. A. Sen *et al.*, 2020 JINST 15 C06055
4. A. Sen *et al.*, CBM Progress report 2021, 106
5. A. Sen *et al.*, Proc. of the DAE-BRNS Symp. on Nucl. Phys. Vol. 64 (2019), 996

Measurement of bulk resistivity



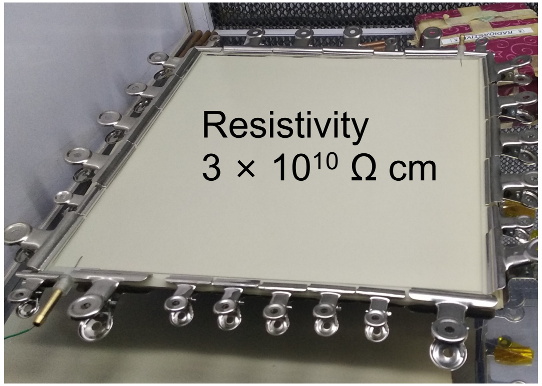




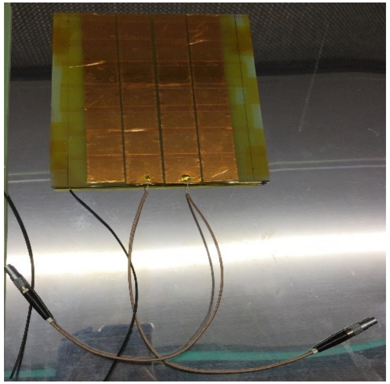
- Bakelite Sample 1: Bulk resistivity 2×10^{11} Ω cm
- Bakelite Sample 2: Bulk resistivity 3×10^{10} Ω cm

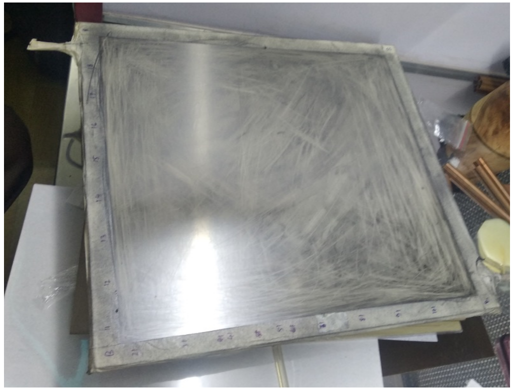
@ Temp: 22 °C and RH: 60 %

Fabrication of the first prototype

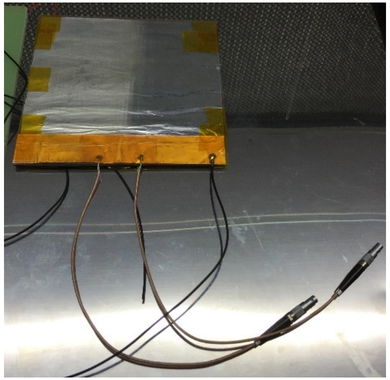


Assembling of Components

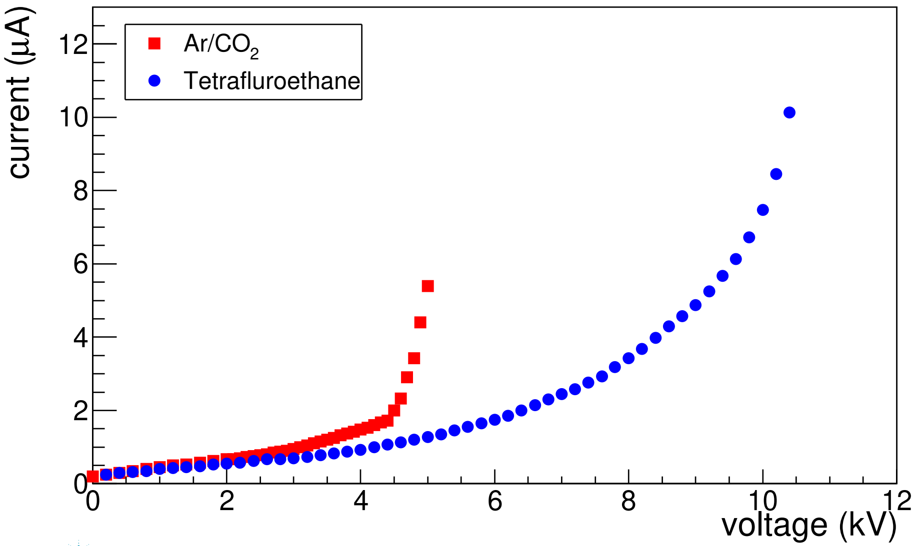


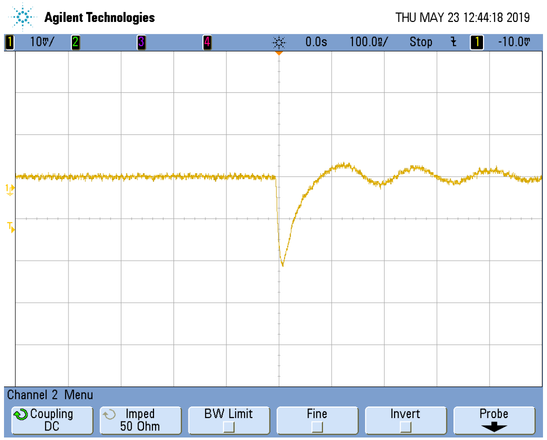


Complete RPC



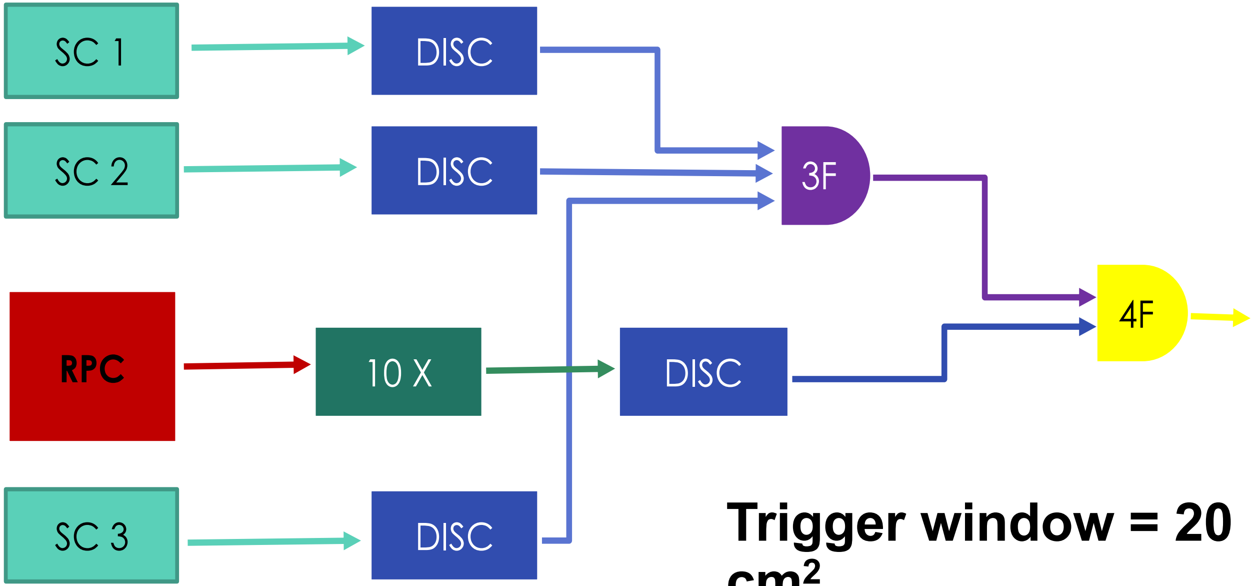
Pick-up strips





Typical induced pulse on a pick-up strip observed in oscilloscope with 10 mV/div, 100 ns/div and 50 Ω termination

Efficiency measurement



Trigger window = 20 cm^2

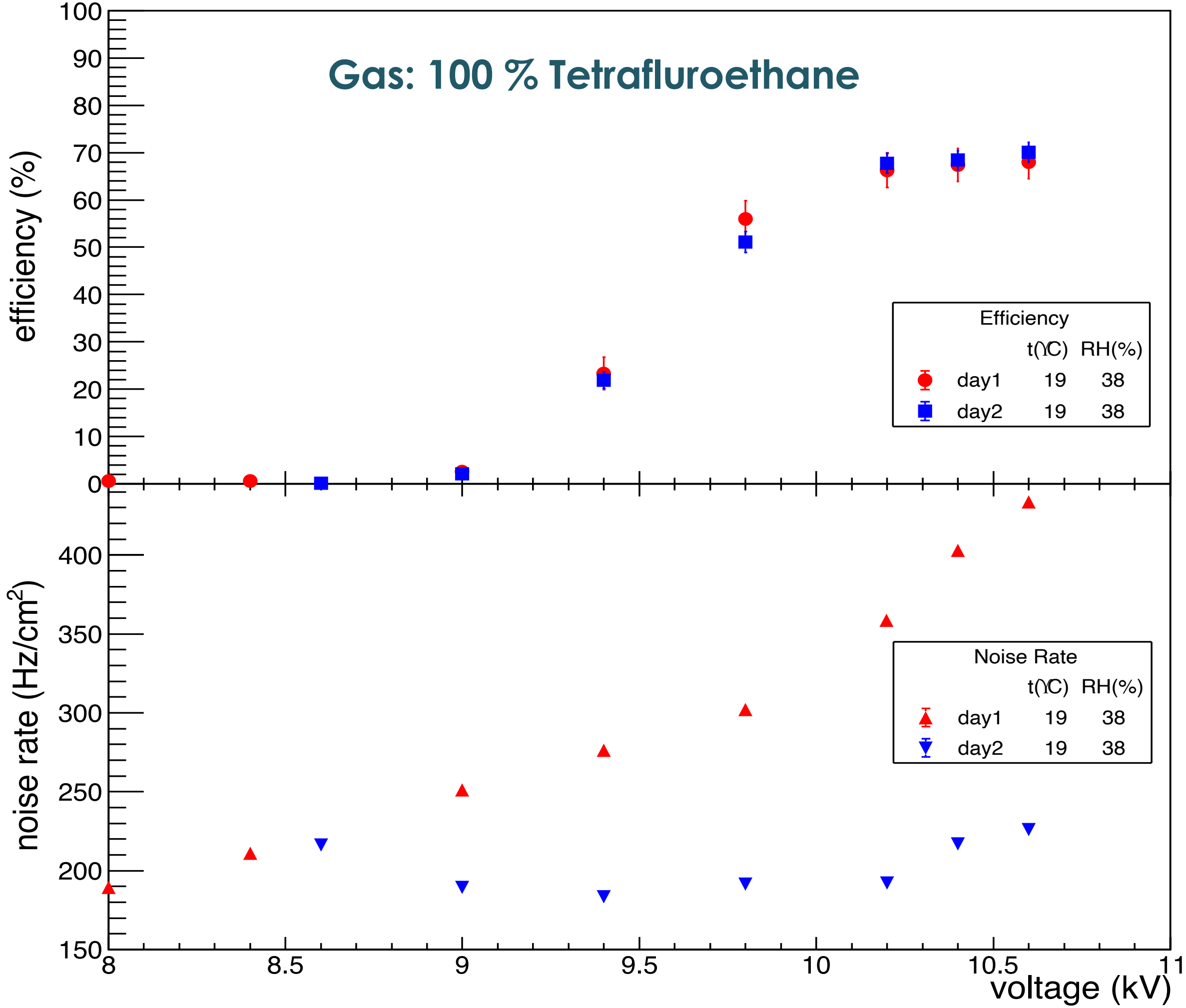
Trigger = SC1 .AND. SC2 .AND. SC3

Efficiency = $\frac{\text{RPC signal in coincidence with trigger (4F)}}{\text{Trigger (3F)}}$

- Threshold to the Sc: - 15 mV
- Threshold to RPC: - 15 mV

Reference : A. Sen *et al.*, 2020 JINST 15 C06055

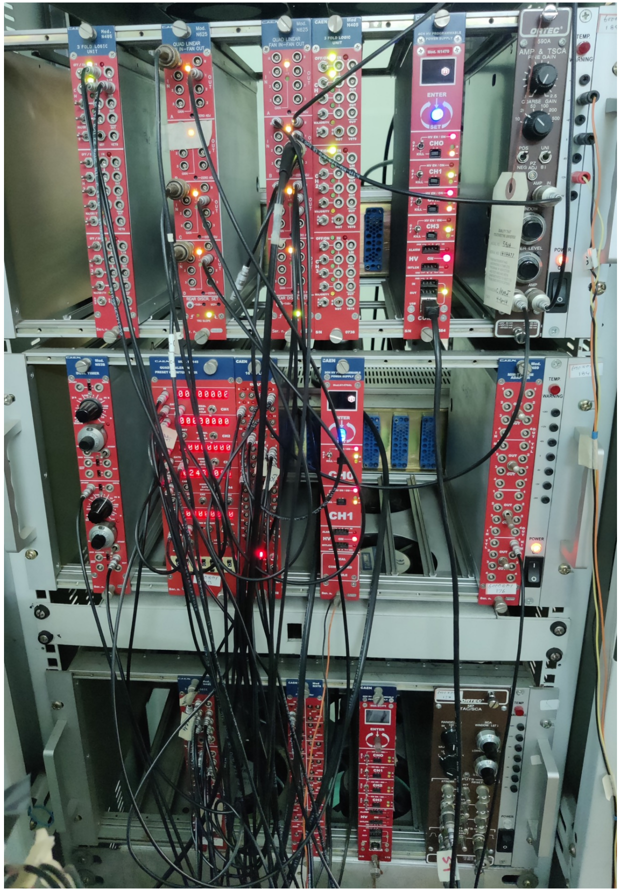
Efficiency vs voltage

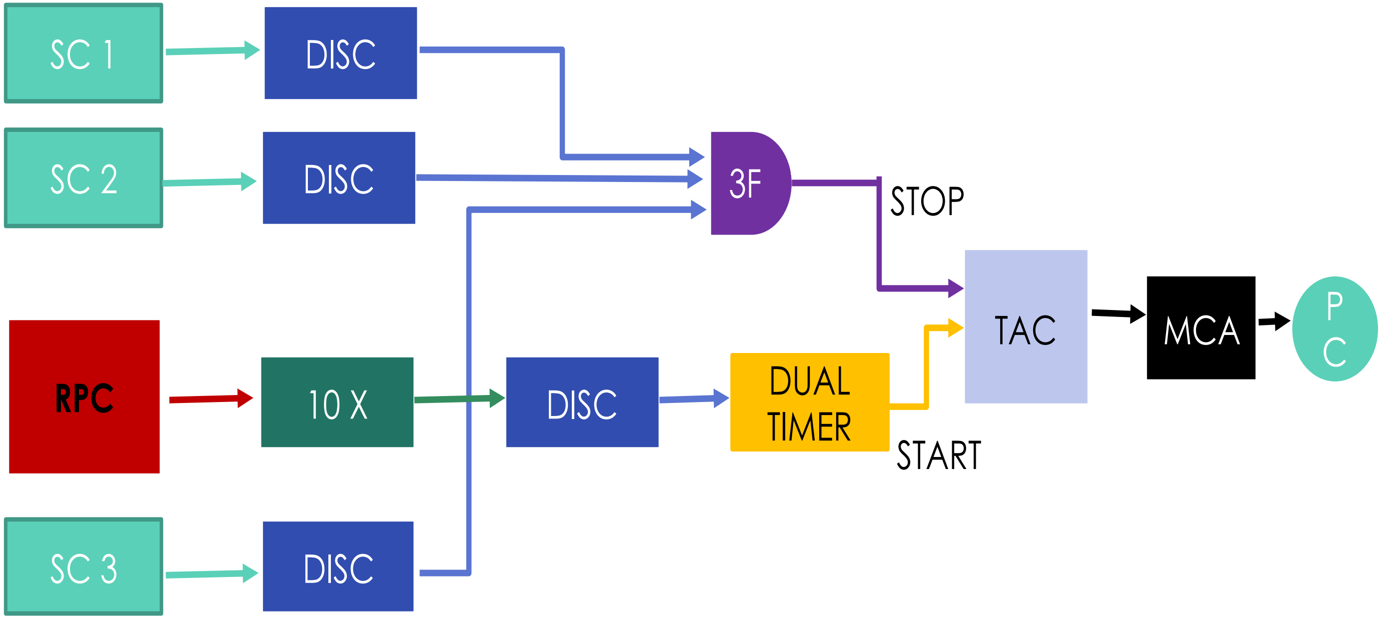


Efficiency ~70±3%

Reference : A. Sen *et al.*, 2020 JINST 15 C06055

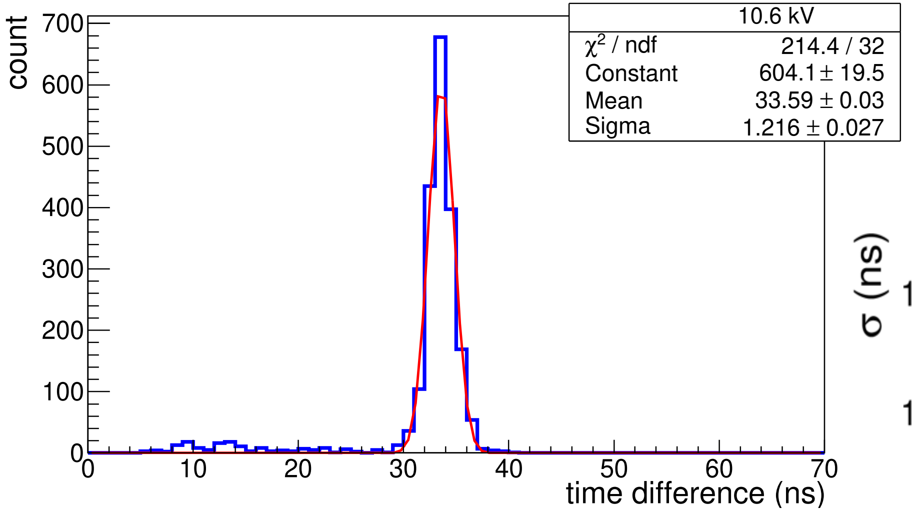
Time resolution measurement





Reference : A. Sen *et al.*, 2020 JINST 15 C06055

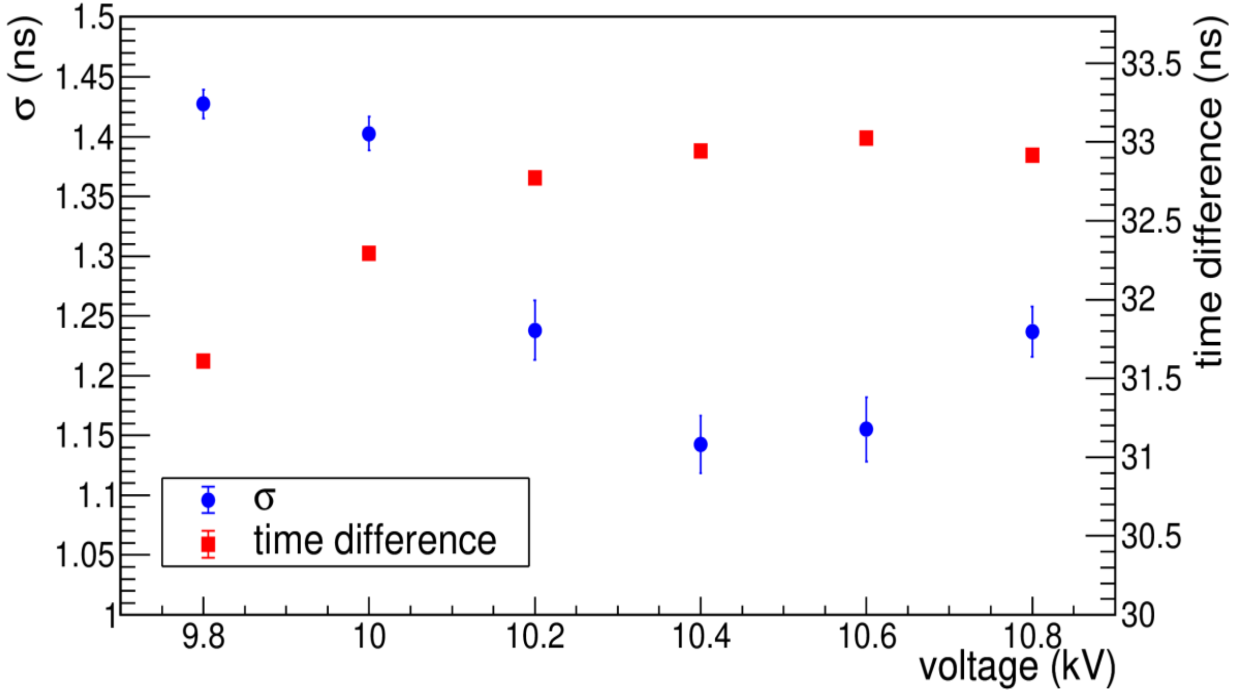
Time resolution vs voltage



Timing Spectrum

Time resolution ~1.2±0.03 ns (σ)

Gas: 100 % Tetrafluroethane



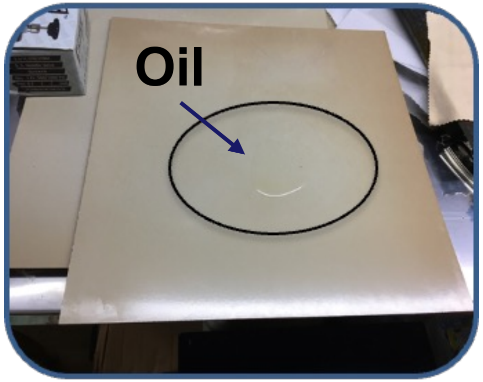
Reference : A. Sen *et al.*, 2020 JINST 15 C06055

New technique of linseed oil coating

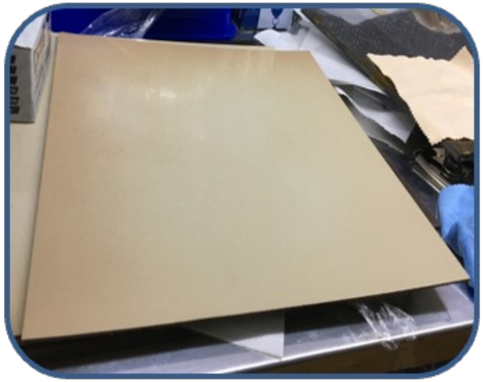
- In the present work the linseed oil coating is done on bakelite plate before making the gas gap.
- We take about 2g of linseed oil is applied over the 27 cm × 27 cm area of each plate.
- The linseed oil is distributed over the surfaces and both the plates are left for 15 days in a sealed box for curing.
- The advantage of this procedure is that after linseed oil coating it can be checked visually whether the curing is properly done or any uncured droplet of linseed oil is present.

Fabrication steps

Resistivity= $3 \times 10^{10}\ \Omega$ cm

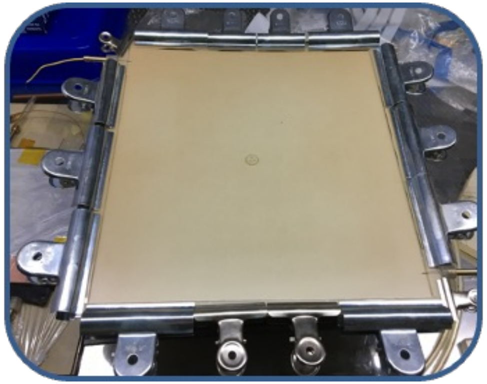


Application of linseed oil on the bakelite surface

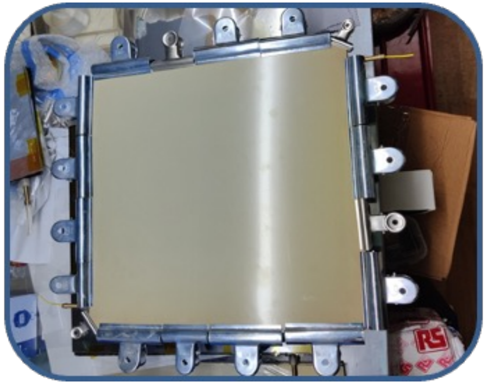


Cured linseed oil coated bakelite surface

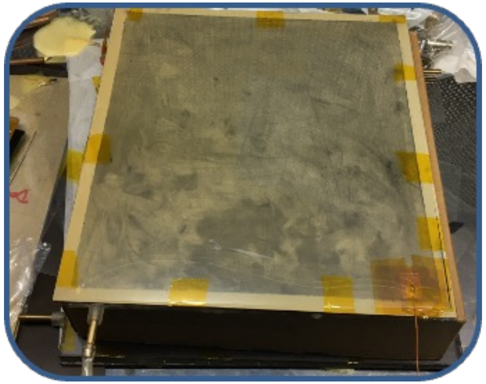
Gas nozzles and spacers



Gluing of spacers and nozzles

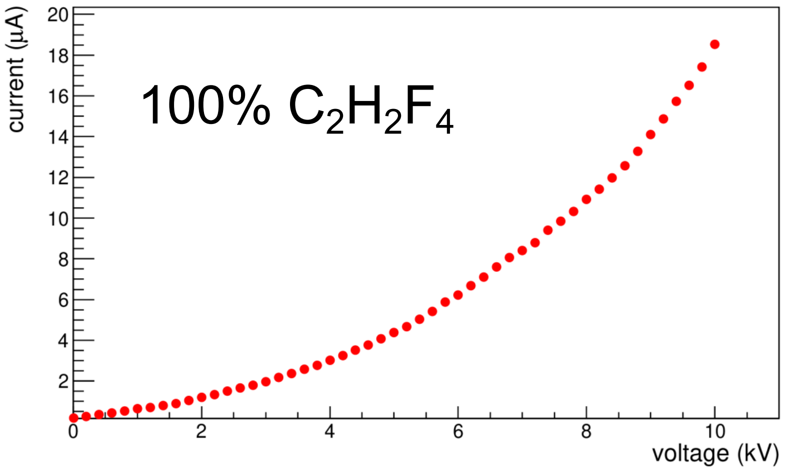


Making of gas gap

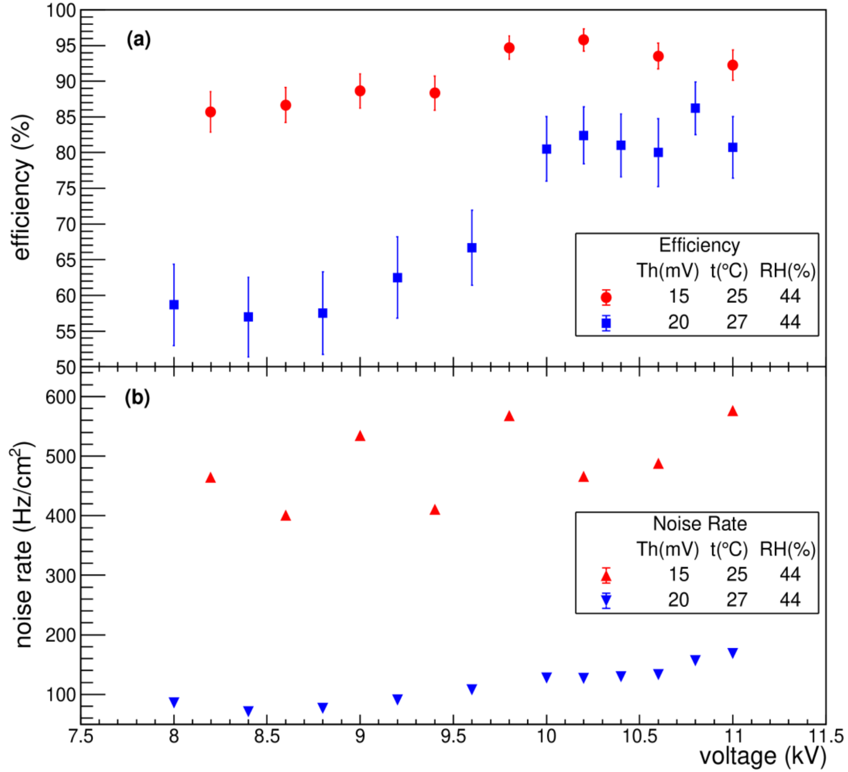


Complete RPC module after graphite coating

Results



Leakage current as a function of the applied voltage



(a) The efficiency vs the applied voltage
(b) Noise rate as a function of the applied voltage

@ -15 mV threshold

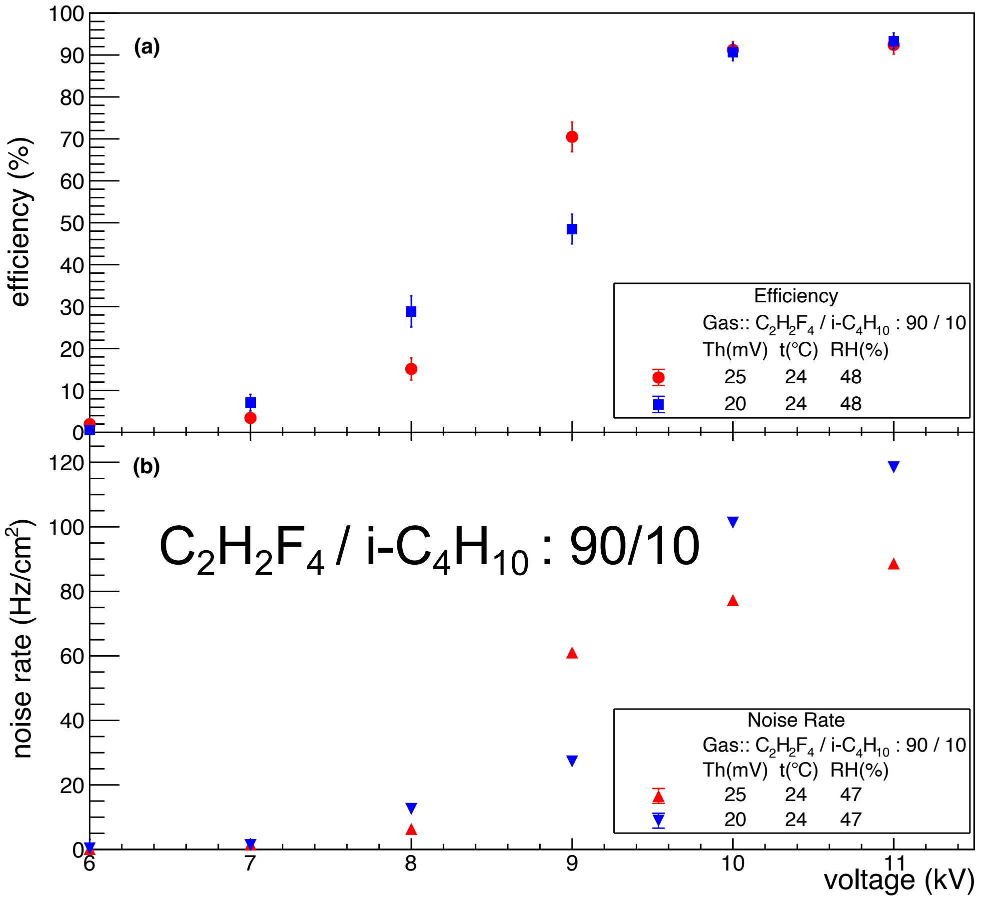
- **Efficiency: ~ 95±1% from 9.4 kV onwards**
- **Noise rate ~ 500 Hz/cm^2**

@-20 mV threshold

- **Efficiency: ~ 85±5% from 10.1 kV onwards**
- **Noise rate ~ 200 Hz/cm^2**

Reference : A. Sen *et al.*, NIM A 1024 (2022) 166095

Results



@ -20 mV threshold

- **Efficiency: ~ 95±2% from 10 kV onwards**
- **Noise rate ~ 120 Hz/cm^2**

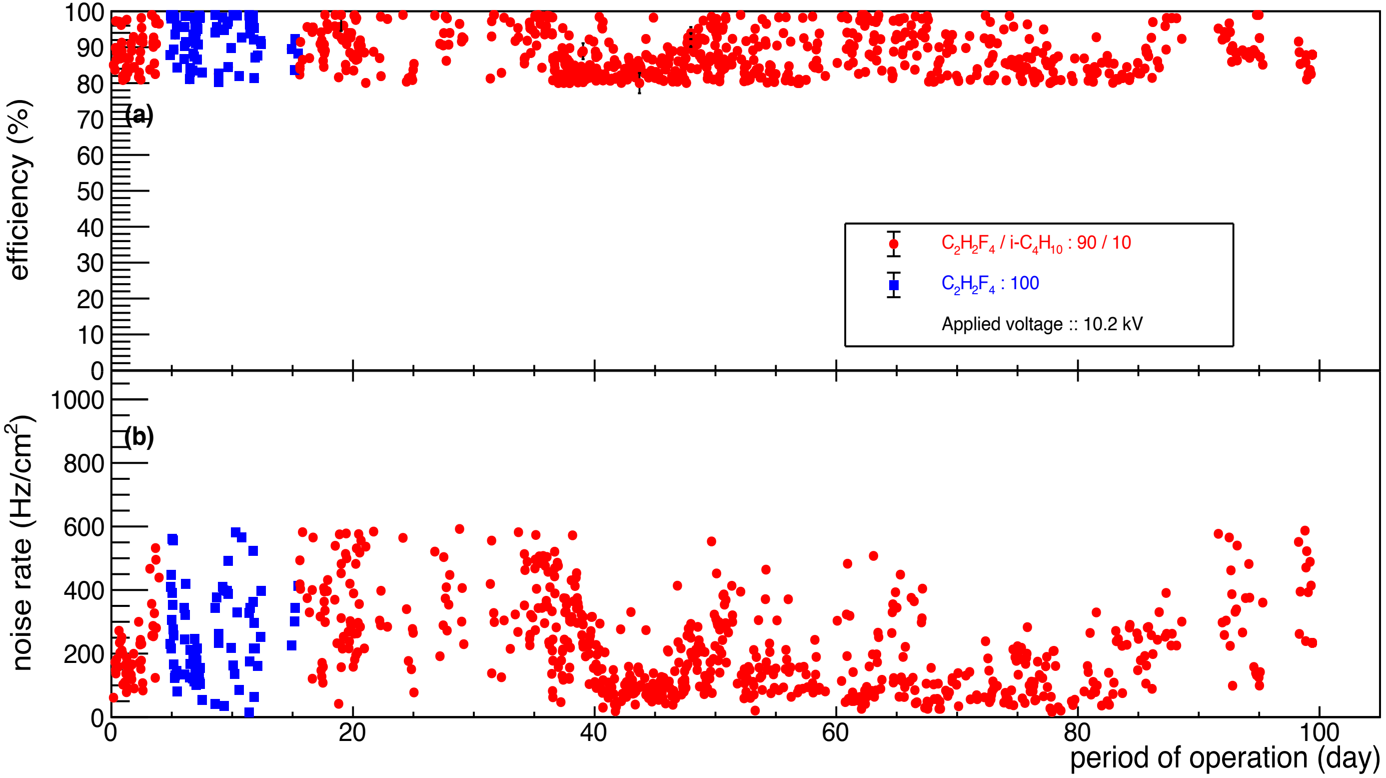
@-25 mV threshold

- **Efficiency: ~ 95±2% from 10 kV onwards**
- **Noise rate ~ 80 Hz/cm^2**

(a) The efficiency vs the applied voltage
(b) Noise rate as a function of the applied voltage

Reference : A. Sen *et al.*, NIM A 1045 (2023) 167572

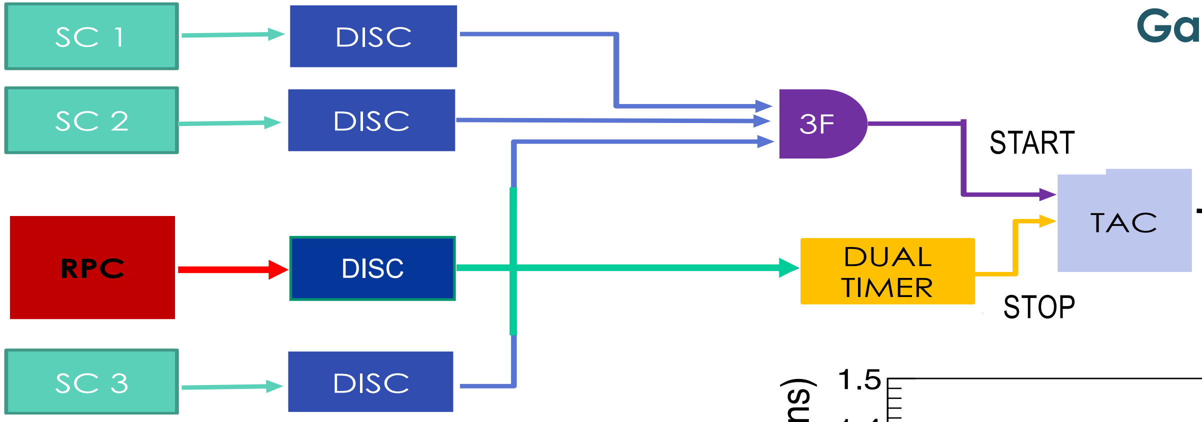
Stability test result



@ 10.2 kV applied voltage

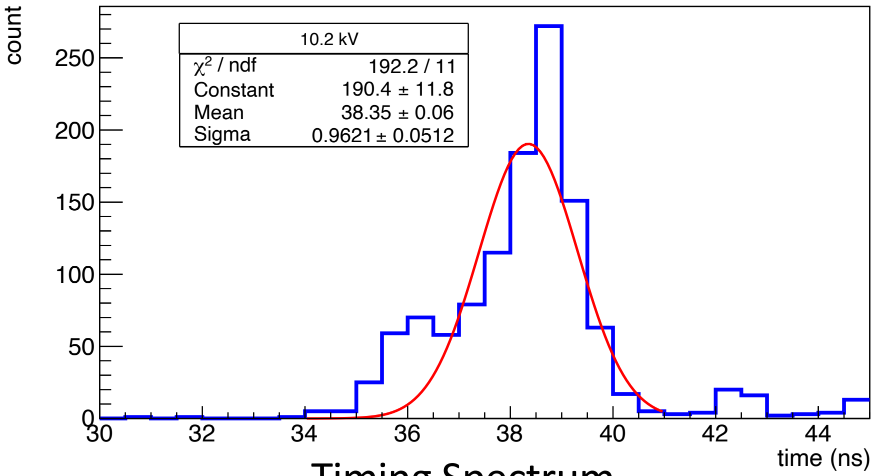
- **Efficiency: 88±6% from Noise rate ~ 189 Hz/cm^2 for $C_2H_2F_4$ / i-C_4H_{10} : 90/10**
- **Efficiency: 93±6% from Noise rate ~ 207 Hz/cm^2 for $C_2H_2F_4$: 100%**

Time resolution measurement

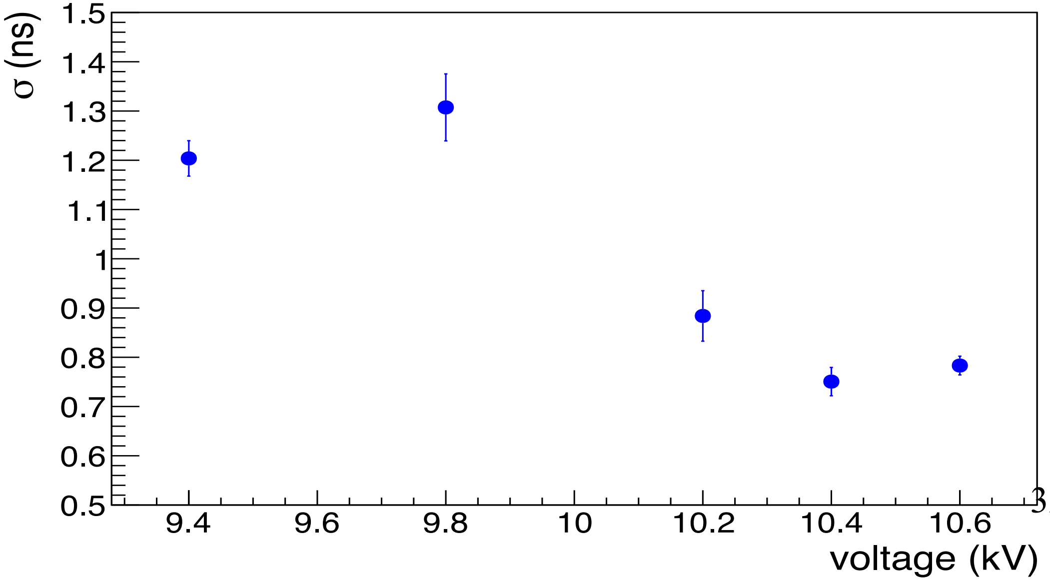


Gas: 100 % Tetrafluroethane

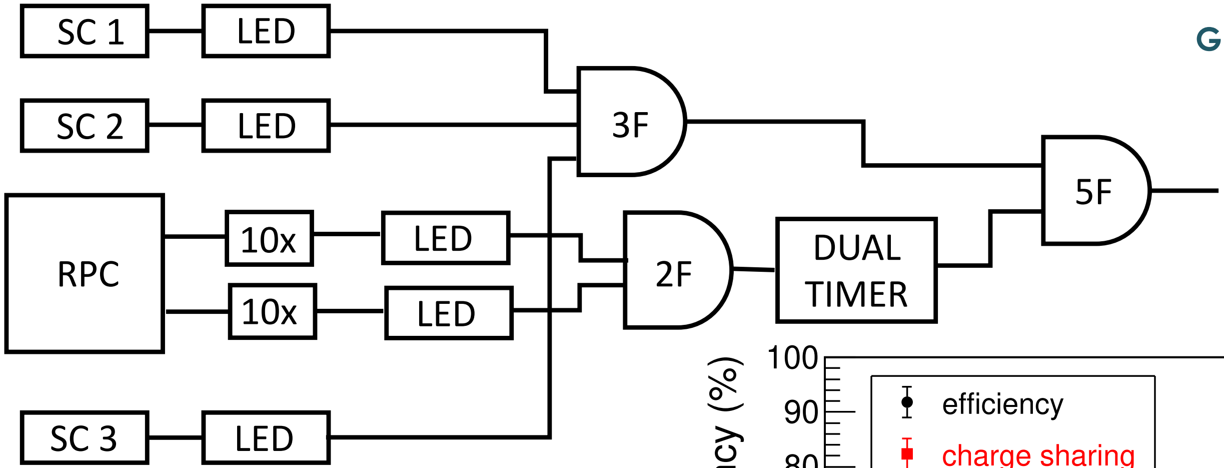
Time resolution ~0.8±0.06 ns (σ)



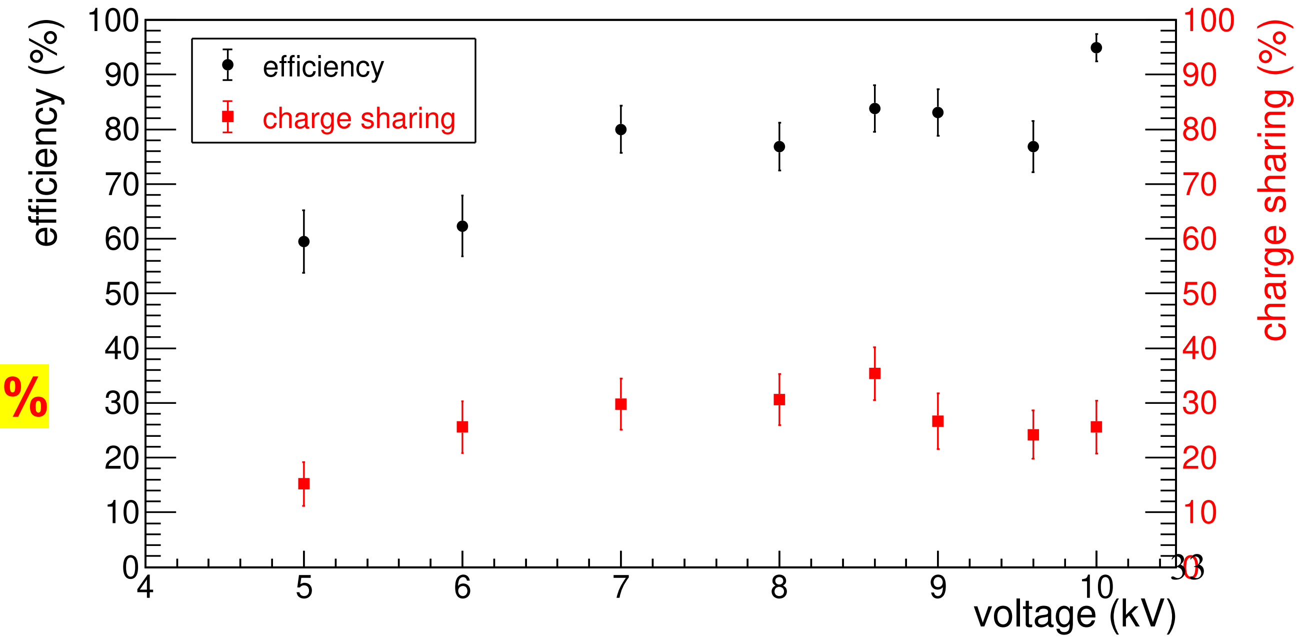
Timing Spectrum



Charge sharing measurement

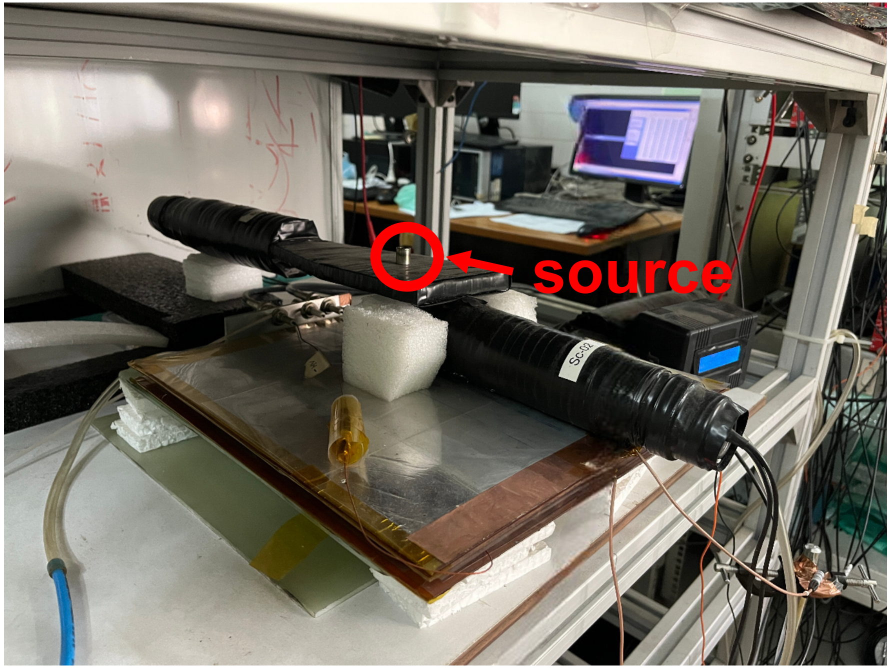


Gas: 90 % $C_2H_2F_4$ + 10 % i-C_4H_{10}

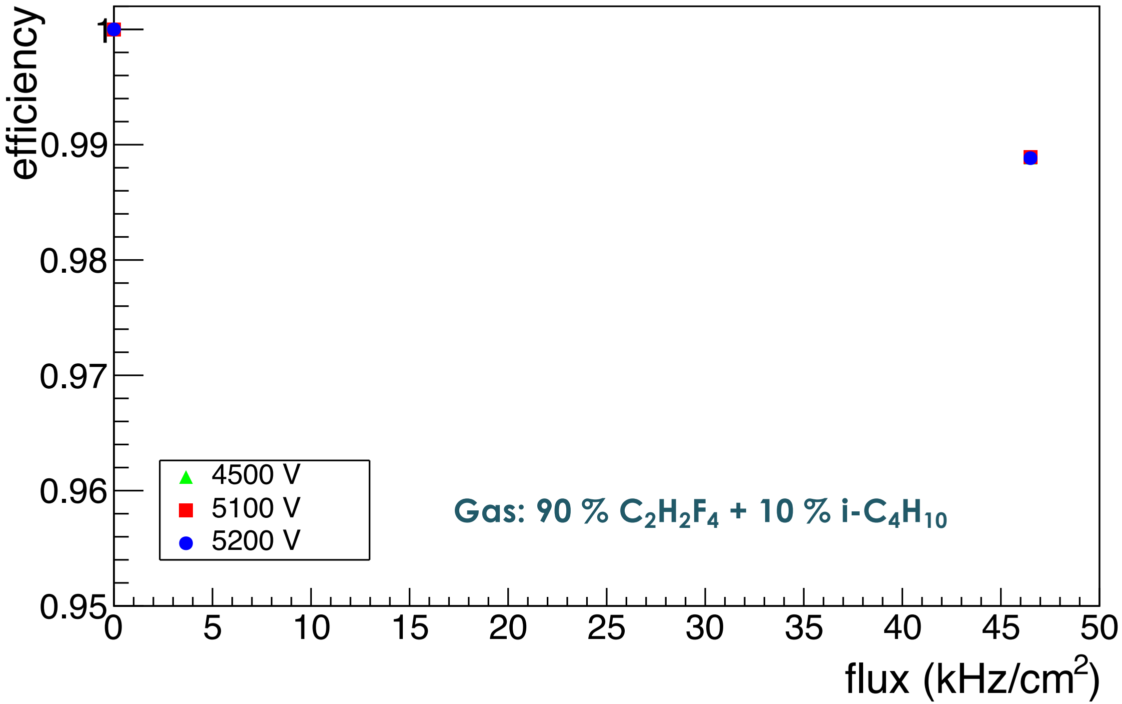


Shared charge between strips ~ 30%

Efficiency measurement in Gamma ray background



Source: Cs^{137}
Activity: 0.6 GBq



High efficiency even with ~46 kHz/cm² gamma flux

Summary

- Several RPC modules are built with locally available bakelite material
- Resistivity measurement set-up and cosmic ray test set-up is currently operational
- One bakelite RPC is fabricated with resistivity ∽ 3×10^{10} Ω cm
- With 100% tetrafluroethane ($C_2H_2F_4$) gas, an efficiency ∽70±3% is obtained in cosmic ray test
- The time resolution of the chamber is found to be ∽ 1.2±0.03 ns (σ)
- **A new technique is introduced for linseed oil coating in bakelite RPC**
- With linseed oil coated electrode an efficiency ~ 95±1% for -15 mV threshold efficiency ~ 85±5% for -20 mV threshold for 100% $C_2H_2F_4$ gas
- The time resolution of the chamber is found to be ∽ 0.8±0.06 ns (σ)
- For $C_2H_2F_4$ / i-C_4H_{10} : 90/10 gas composition an efficiency ~ 95% for both -20 mV and -25 mV threshold
- Charge sharing is found to be ~ 30%
- High efficiency obtained even with gamma ray background of ~46 kHz/cm^2

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Thank You