An update on GEM detector R&D at Bose Institute

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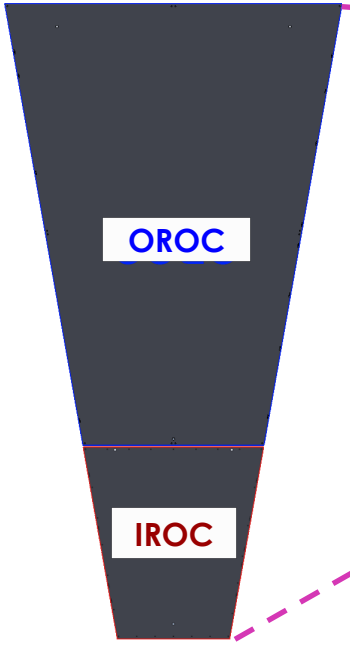
Plan

- Motivation
- ALICE TPC
- GEM detector
- Results
- Future plan

ALICE TPC

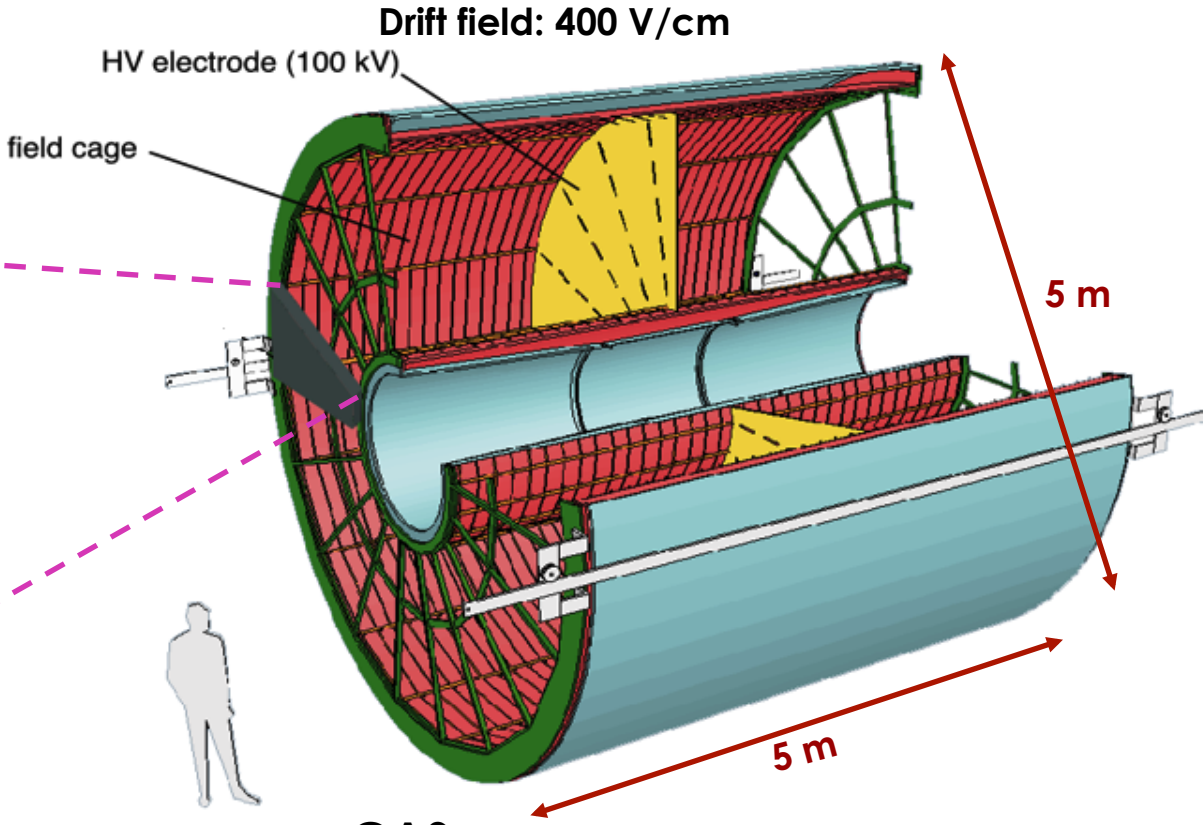
2 x 18
Outer **R**ead **O**ut **C**hambers



2 x 18
Inner **R**ead **O**ut **C**hambers

557568 pads

4 x 7.5 mm^2 (IROC)
6 x 10 mm^2 (OROC)
6 x 15 mm^2 (OROC)

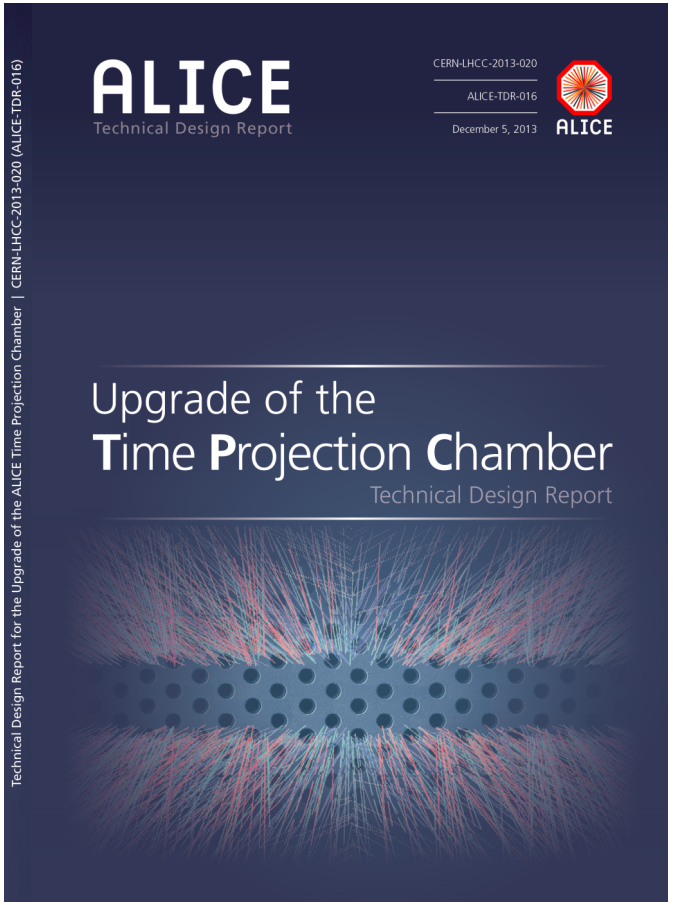


GAS:
~90 m^3
Ne-CO_2 (90-10) in RUN1
v_{drift} = 2.73 cm/μs (@ 400 V/cm)
Maximum drift time: ~92 μs

- Designed for charged-particle tracking and d*E*/dx measurement in Pb-Pb collisions with **$dN_{ch}/d\eta$ =8000, σ(d*E*/dx)/(d*E*/dx)<10%**

- Employs gating grid to block backdrifting ions
- Rate limitations: < 3.5 kHz (in p-p), ~500 Hz (in Pb-Pb)

ALICE TPC upgrade for RUN3



Submitted to LHCC

Operate ALICE at high luminosity
($\mathcal{L}=6\times10^{27}$ cm^{-2}s^{-1})

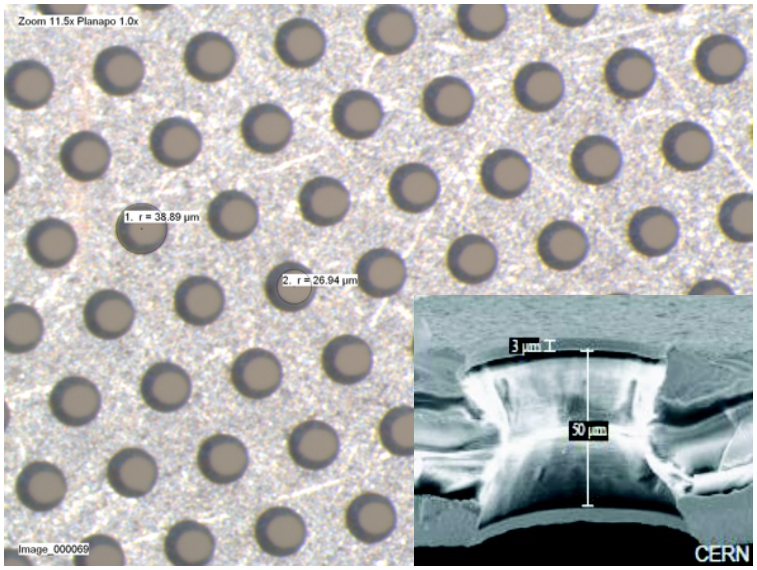
- Record all minimum bias events
  50 kHz Pb-Pb collisions (100× higher than present)
- Event pile-up in TPC: ~5 overlapping events
- **No gating** and **continuous readout** with GEMs

Requirements for GEM readout:

- Operate at the gain of 2000 in Ne-CO_2-N_2
- IBF < 1% at Gain = 2000 → ε = 20
- σ_E/E < 12% for ^{55}Fe
- Stable operation under LHC conditions
- + new electronics *(negative polarity, self-triggered)*
- + novel calibration and online reconstruction schemes
  (data compression by factor 20 and space charge distortions)

GEM (Gas Electron Multiplier)

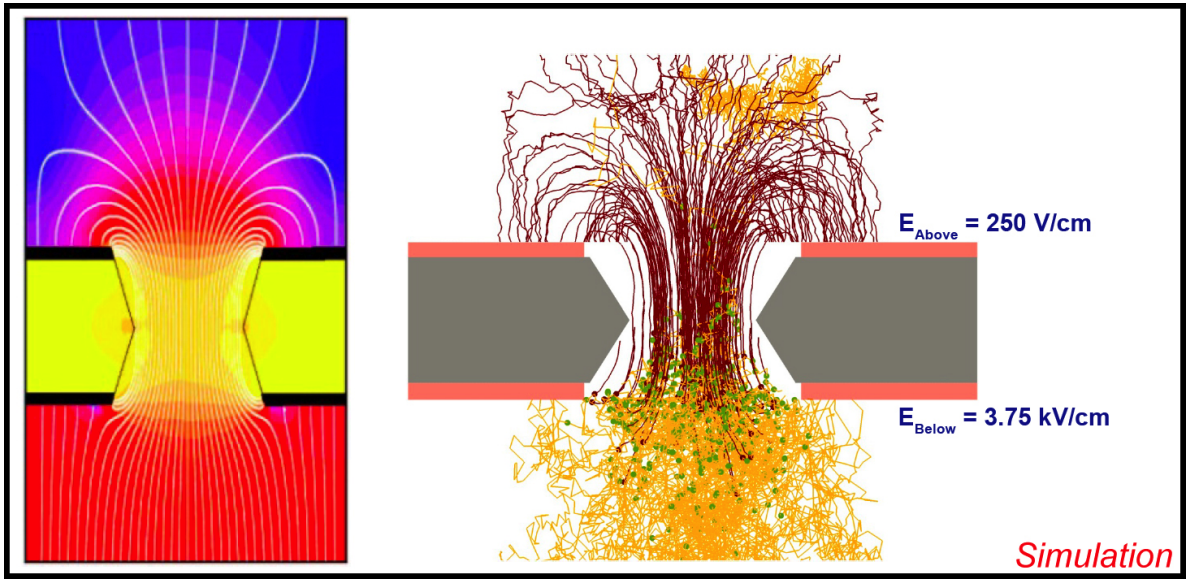
F. Sauli (1996)



- Thin polyimide foil (Kapton®) ~*50* µm
- Cu-clad on both sides ~*5* µm
- Photolithography: ~10^4 holes/cm^2

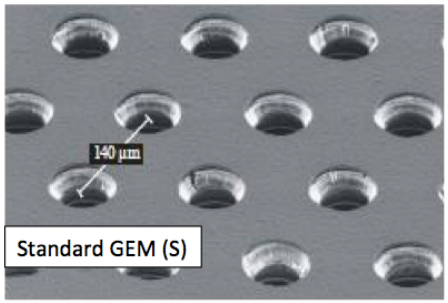
Typical GEM geometry:

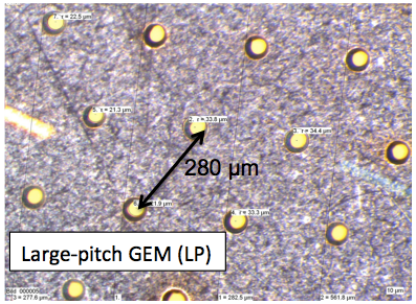
- Inner/Outer hole diameter: 50/70 µm
- **Pitch**: 140 µm

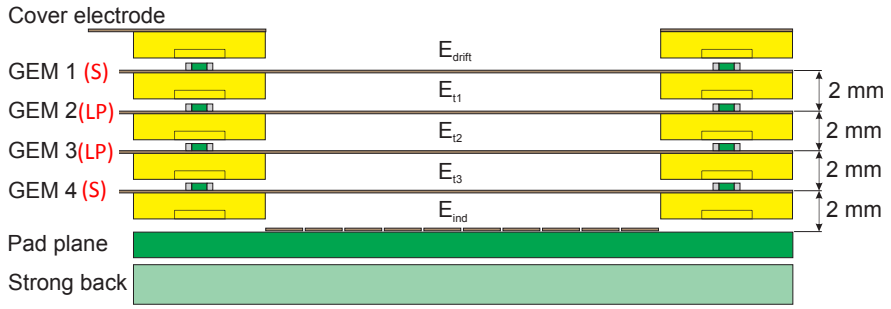


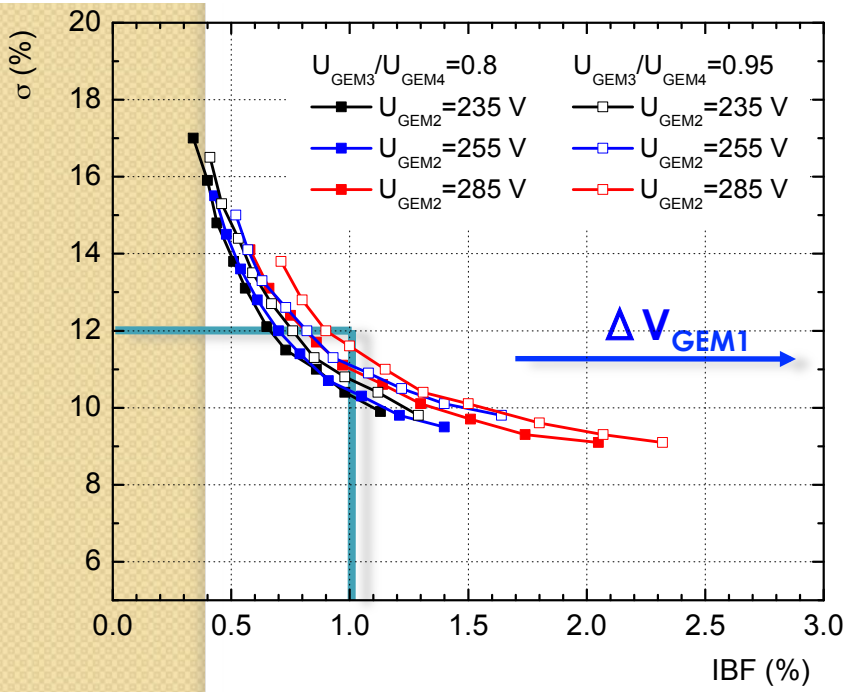
- E_{hole} up to 100 kV/cm with ΔV_{GEM} = 500 V
- $E_{hole} >> E_{above}$
  most of the ions are collected on the top side of GEM
- $E_{below} > E_{above}$
  electron extraction is improved

Baseline solution: 4GEM setup









E_{T1} = 2000 V/cm
E_{T2} = 3000 V/cm
E_{T3} = 1000 V/cm
E_{IND} = 4000 V/cm

$\Delta V_{G1} > \Delta V_{G2} \sim \Delta V_{G3} << \Delta V_{G4}$

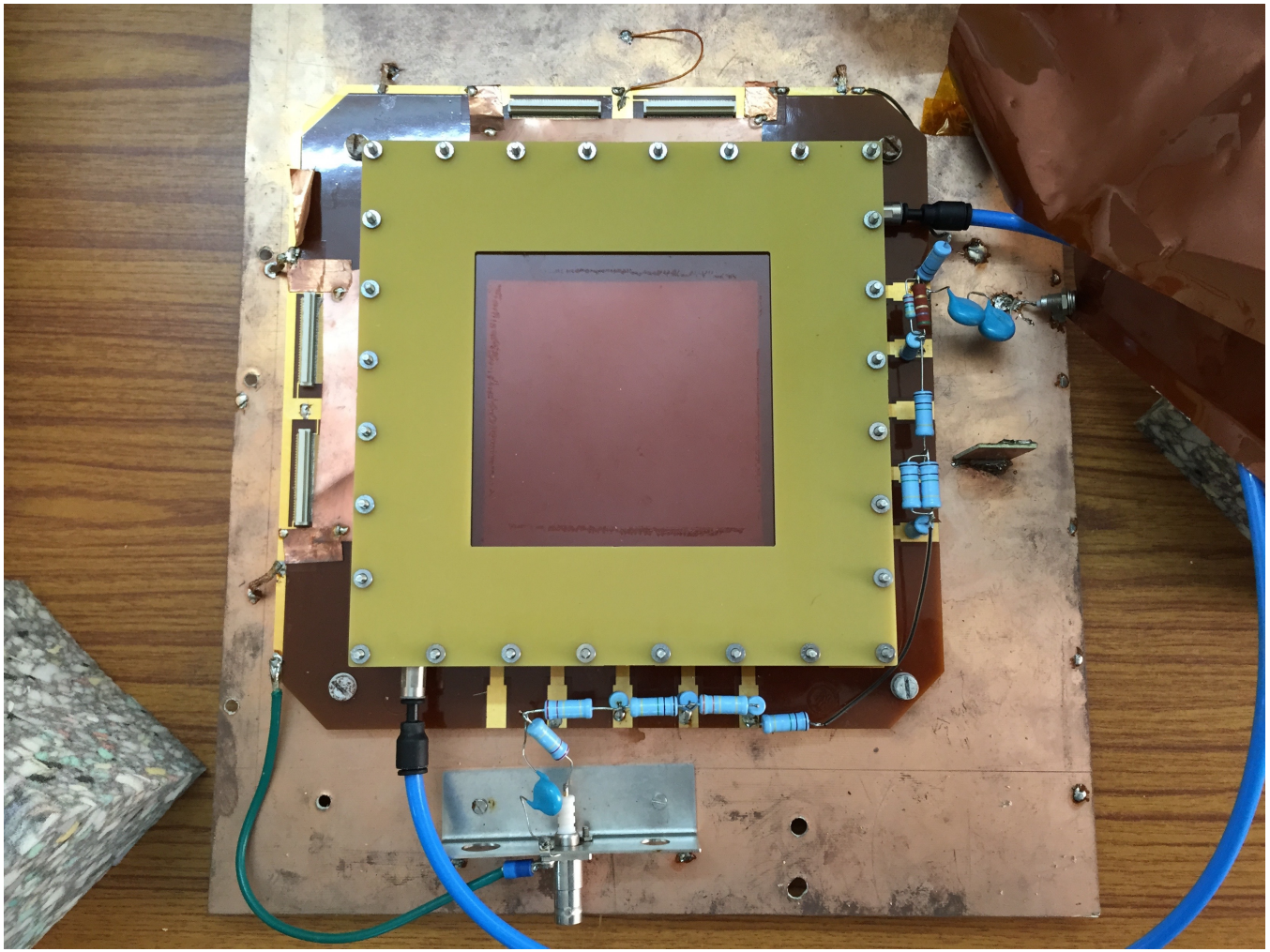
G = 2000

- **Baseline solution performance:**
  - **IBF = 0.6 %**
  - σ_E/E **< 12 %** for 5.9 keV (^{55}Fe)
  - **Sufficient margin for a fine tuning of voltages (e.g. for stability).**
- **R&D continues:**
  - Different aspect ratios
  - Different GEM geometries
  - Gap distances
- **Alternative R&D**
  - COBRA GEMs
  - 2GEM + Micromegas

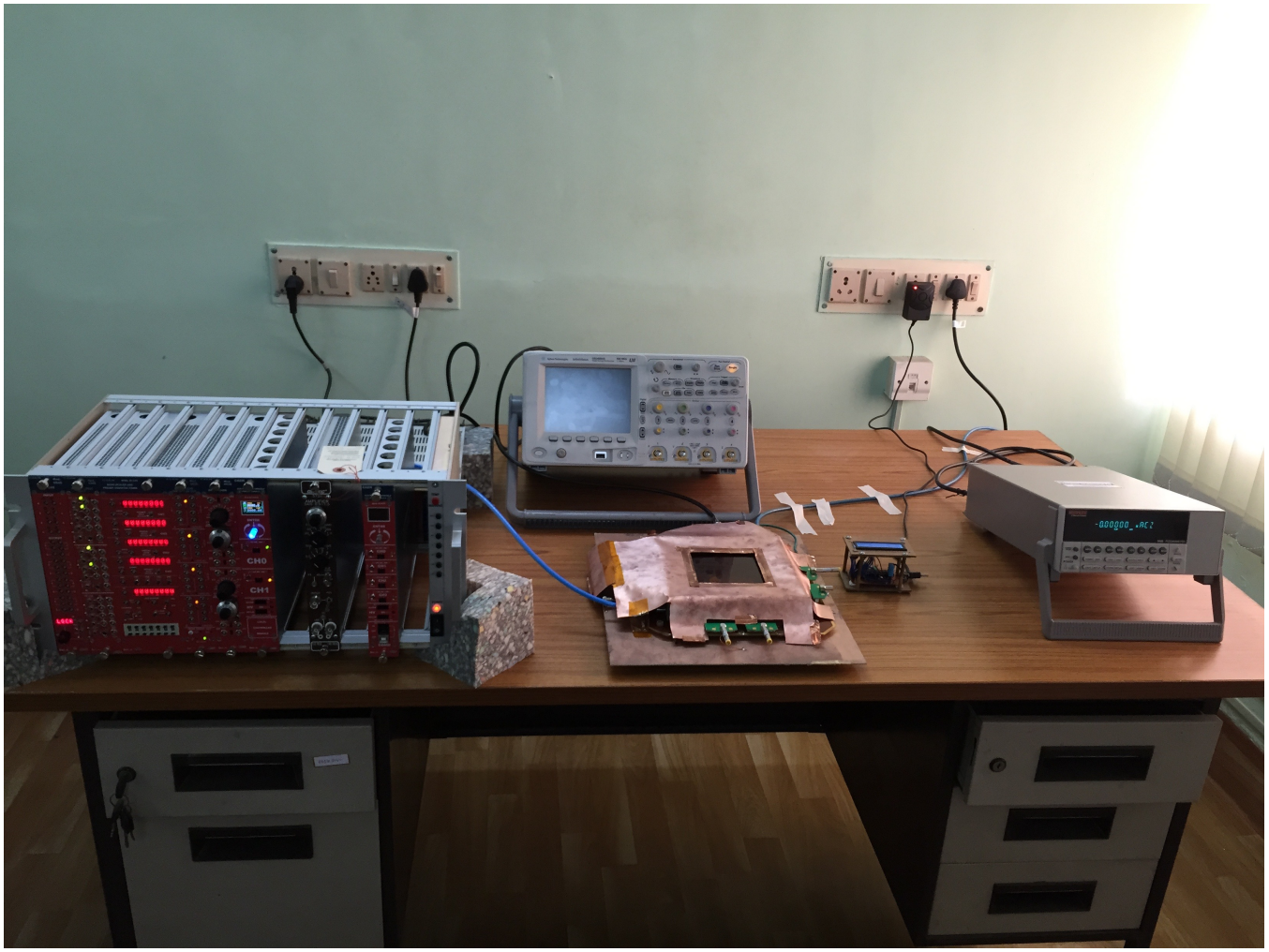
Work done so far ….

- Characterization of a single mask triple GEM detector
- Long-term stability test of the GEM detector

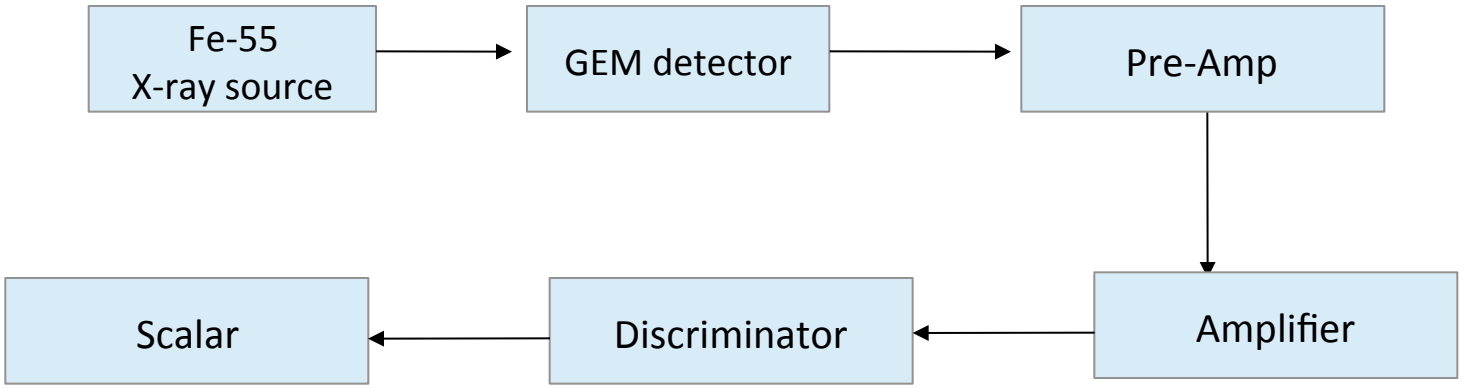
GEM detector



Set-up



Block diagram for count rate measurement

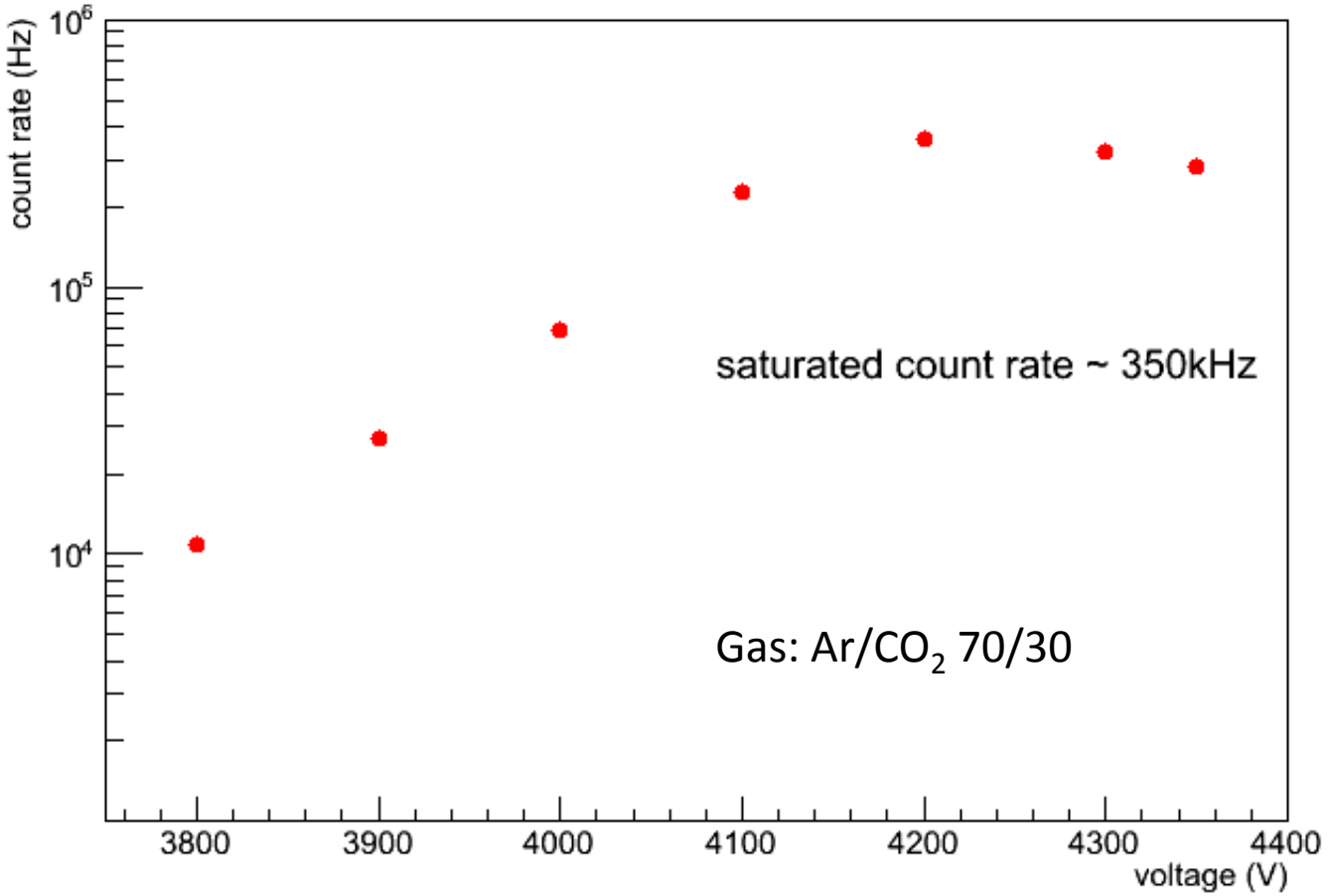


Block diagram for anode current measurement

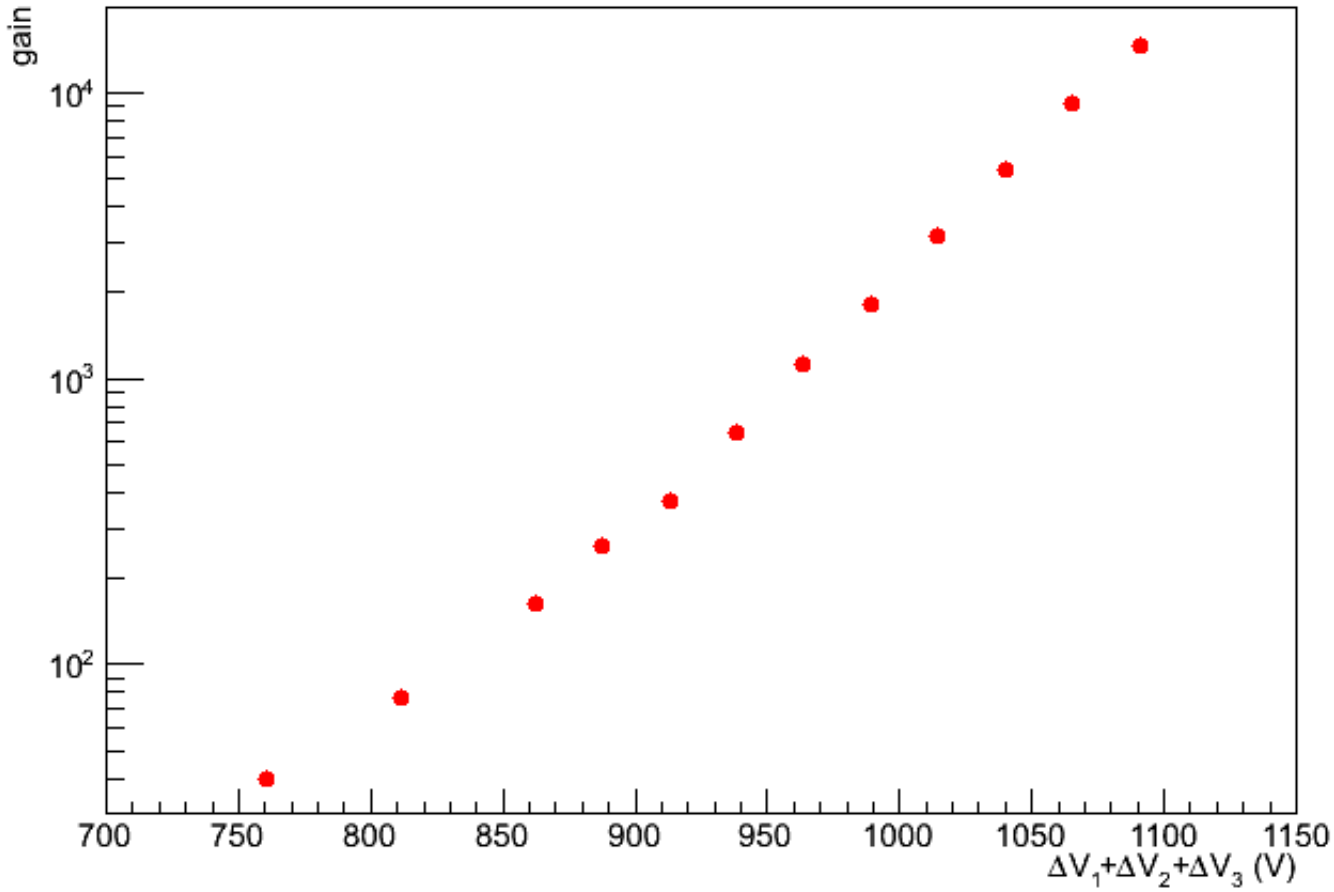
$$Gain = \frac{i_a}{rate \times primary\ no.\ of\ electrons \times e}$$

RATE used in this formula is the maximum count rate at saturation region

Count Rate Vs. Voltage



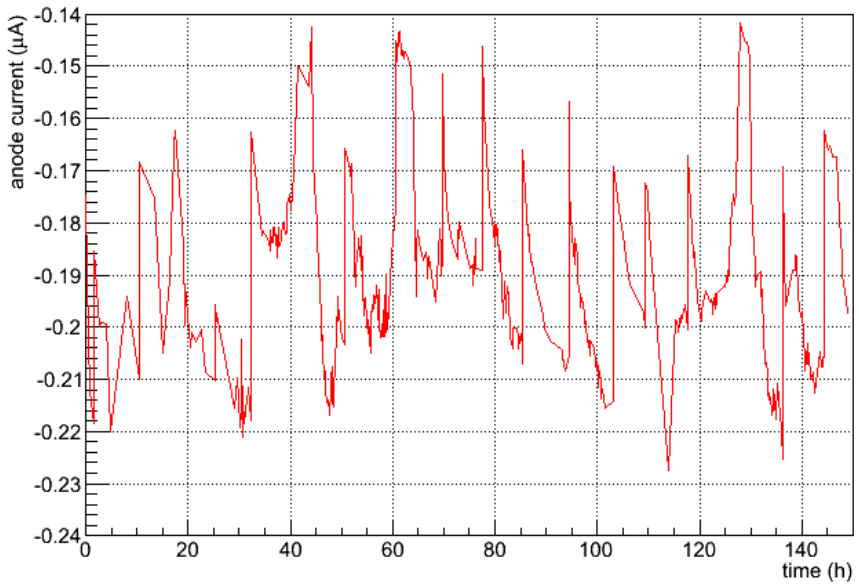
Gain Vs. Global Voltage

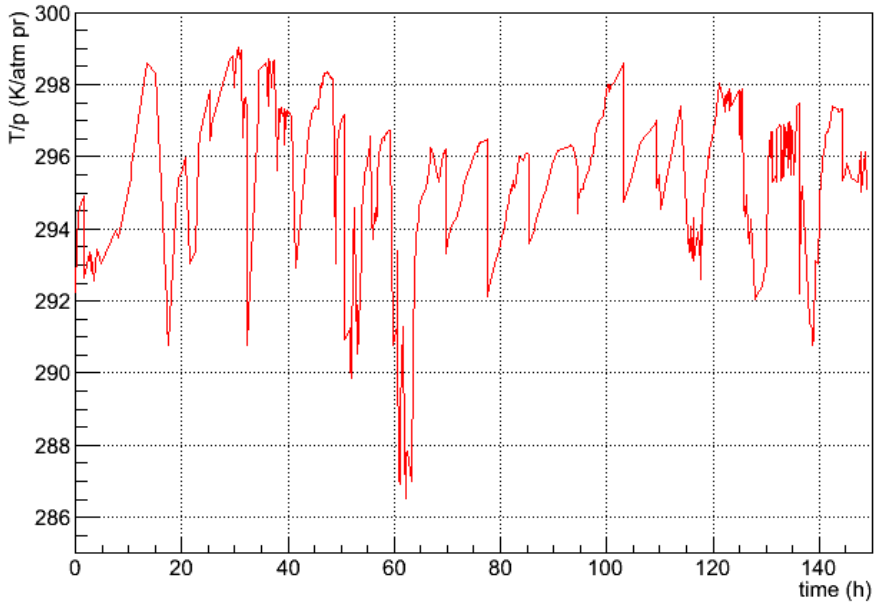


Long term stability test

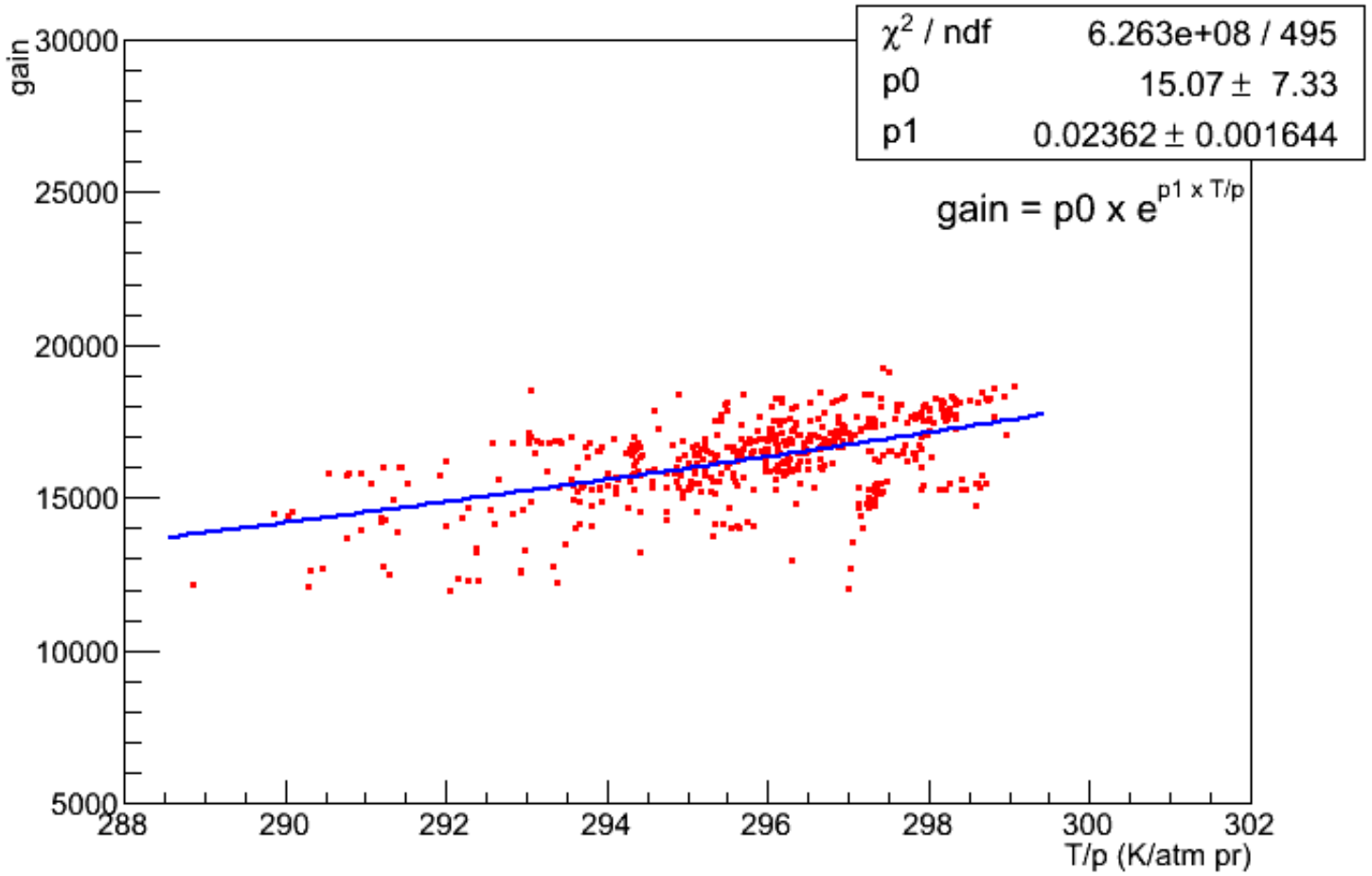
- Long term stability test is done with Fe^{55} source (100 mCi or 3.7 GBq)
- Gas: Ar/CO_2 70/30
- Constant applied voltage to the divider: -4300 V
- Anode current is measured with and without source continuously (using Keithley 6485 Pico-ammeter)
- Temperature, pressure and relative humidity are measured continuously

Anode current and T/p Vs. time



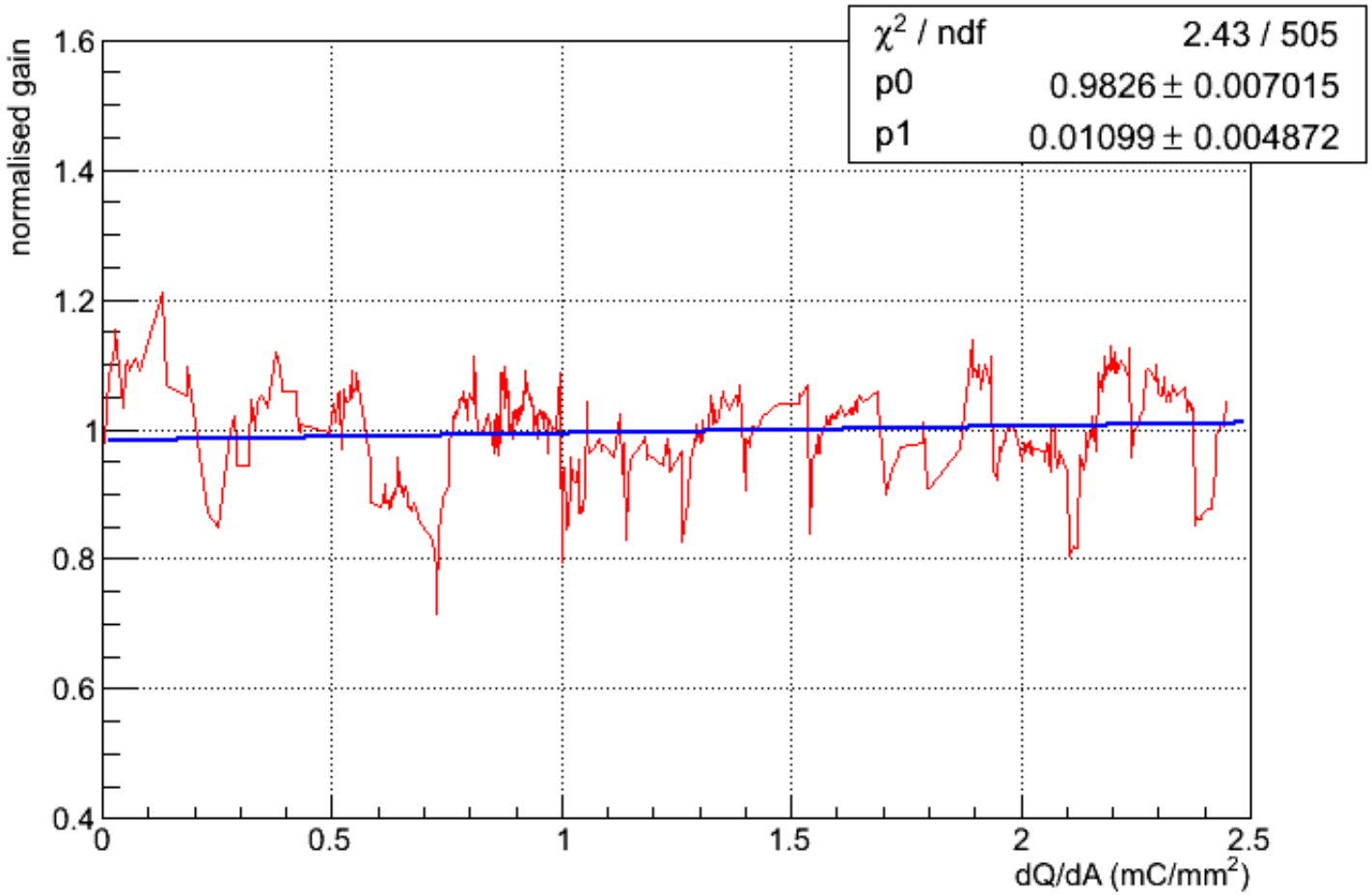


Gain Vs. T/p

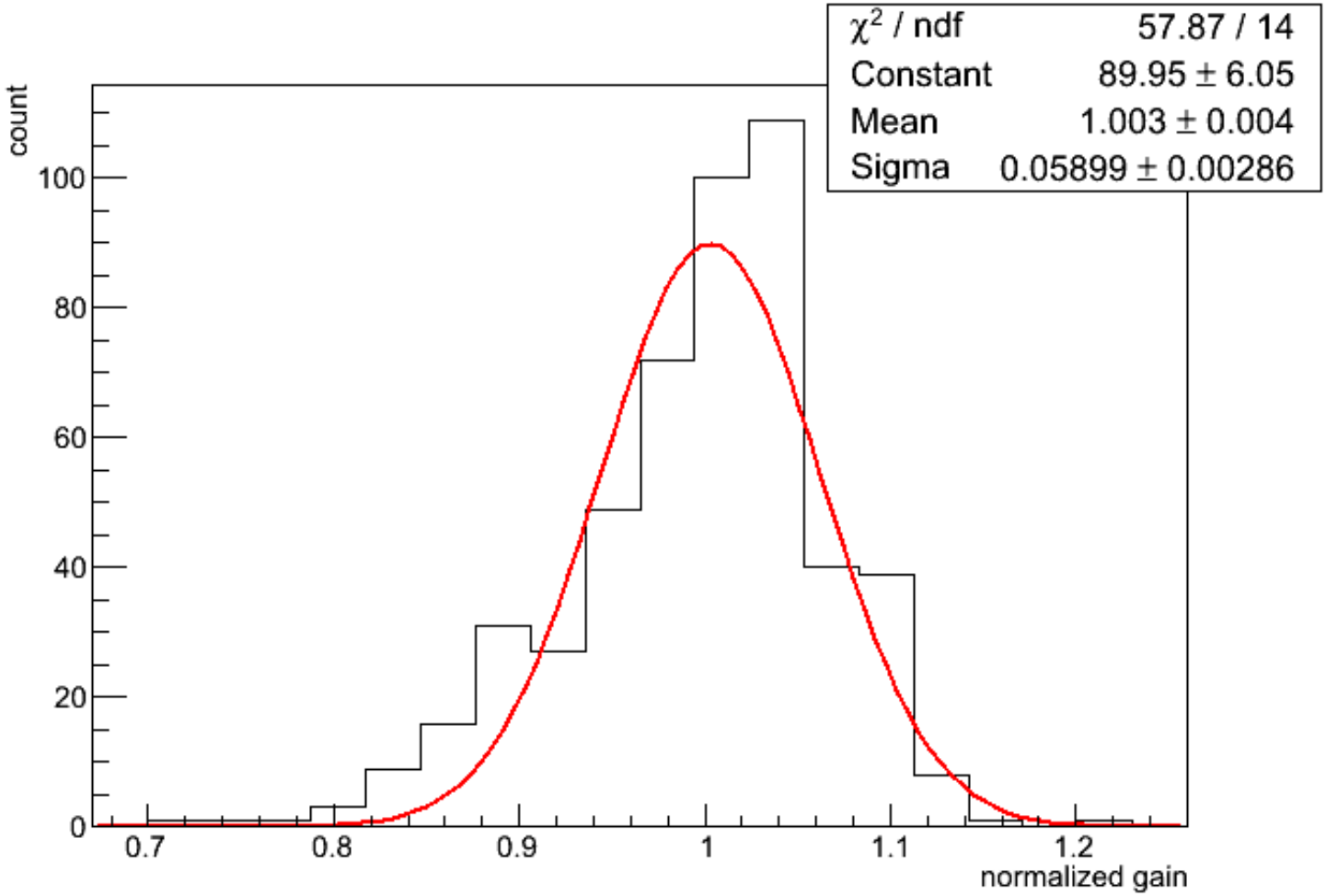

gain
30000
25000
20000
15000
10000
5000
288
290
292
294
296
298
300
302
T/p (K/atm pr)
χ² / ndf 6.263e+08 / 495
p0 15.07 ± 7.33
p1 0.02362 ± 0.001644
gain = p0 x e^(p1 x T/p)

Normalized gain Vs. $\frac{dQ}{dA}$

Normalized gain = measured gain/$p_0 \exp(p_1 T/p)$



Distribution of Normalized gain

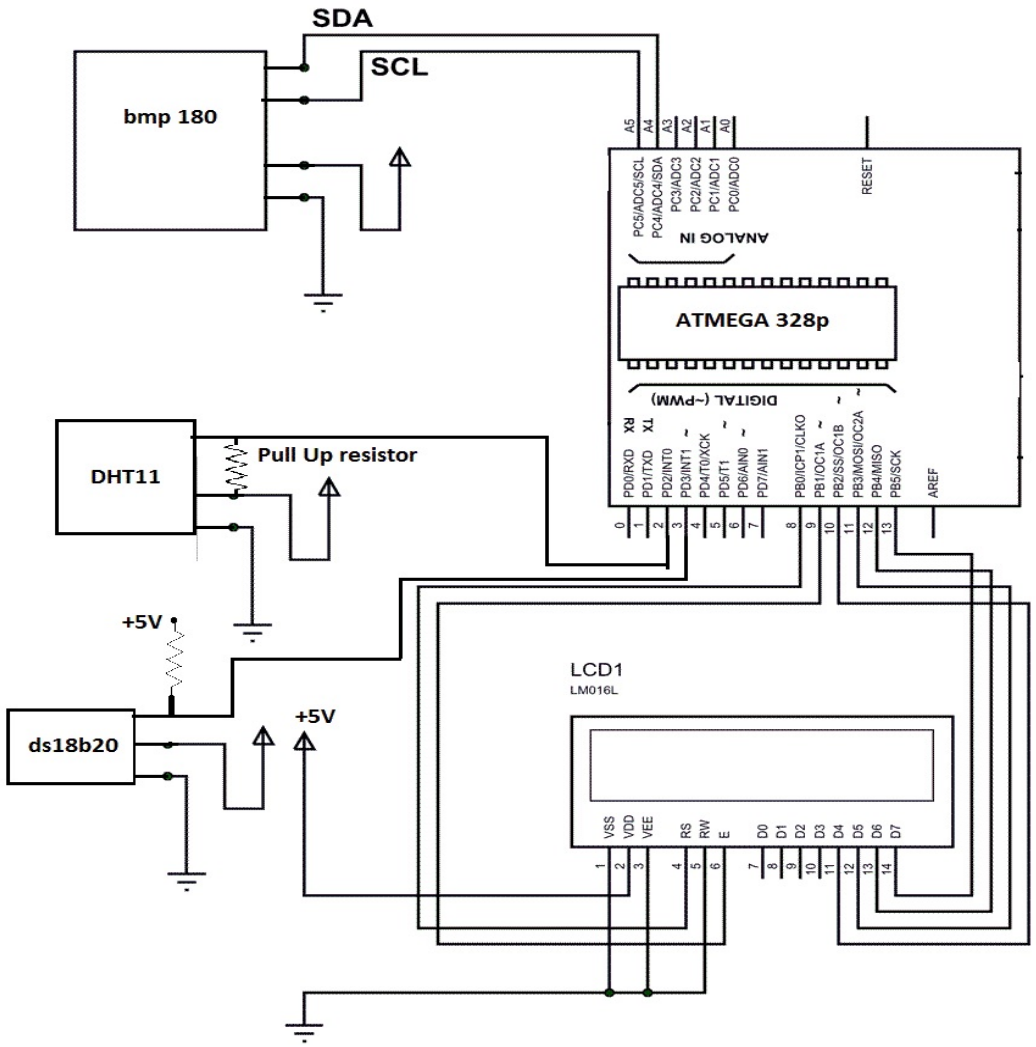


Temperature, Pressure and Relative Humidity measurement

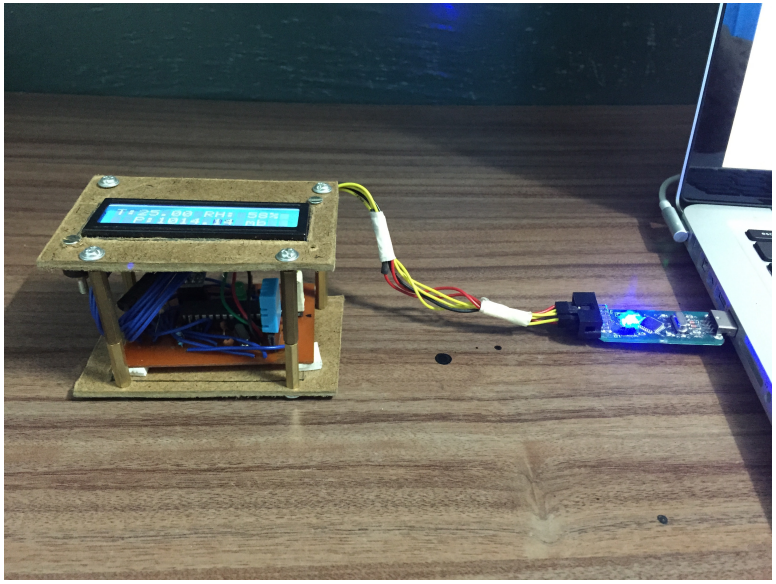
- Temperature sensor – ds18b20 One Wire digital Thermometer (Accuracy: ±0. 5°C)
- Pressure Sensor – BMP180 Atmospheric Sensor (Accuracy: 0.02 hPa)
- Relative Humidity Sensor – DHT11 (Accuracy: ± 5%)
- Microcontroller – Atmega 328p

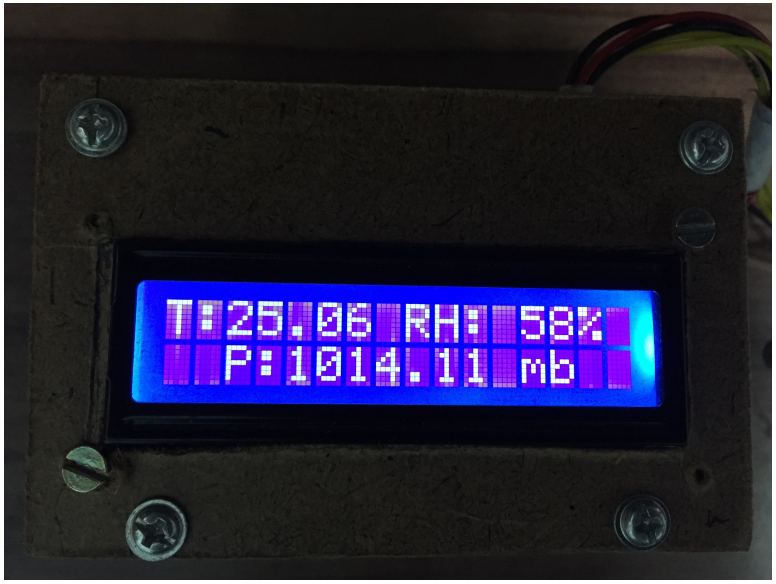
- The Microcontroller takes the data from the sensors and displays on the Output 16 X 2 character LCD. The device operates on 5V DC supply.
- Programme is written in C and uploaded via ISP programmer.
- The microcontroller is a 8bit microcontroller running at 16MHz .
- Circuit Diagram follows-

Circuit Diagram of the Temperature, Pressure and Humidity sensor

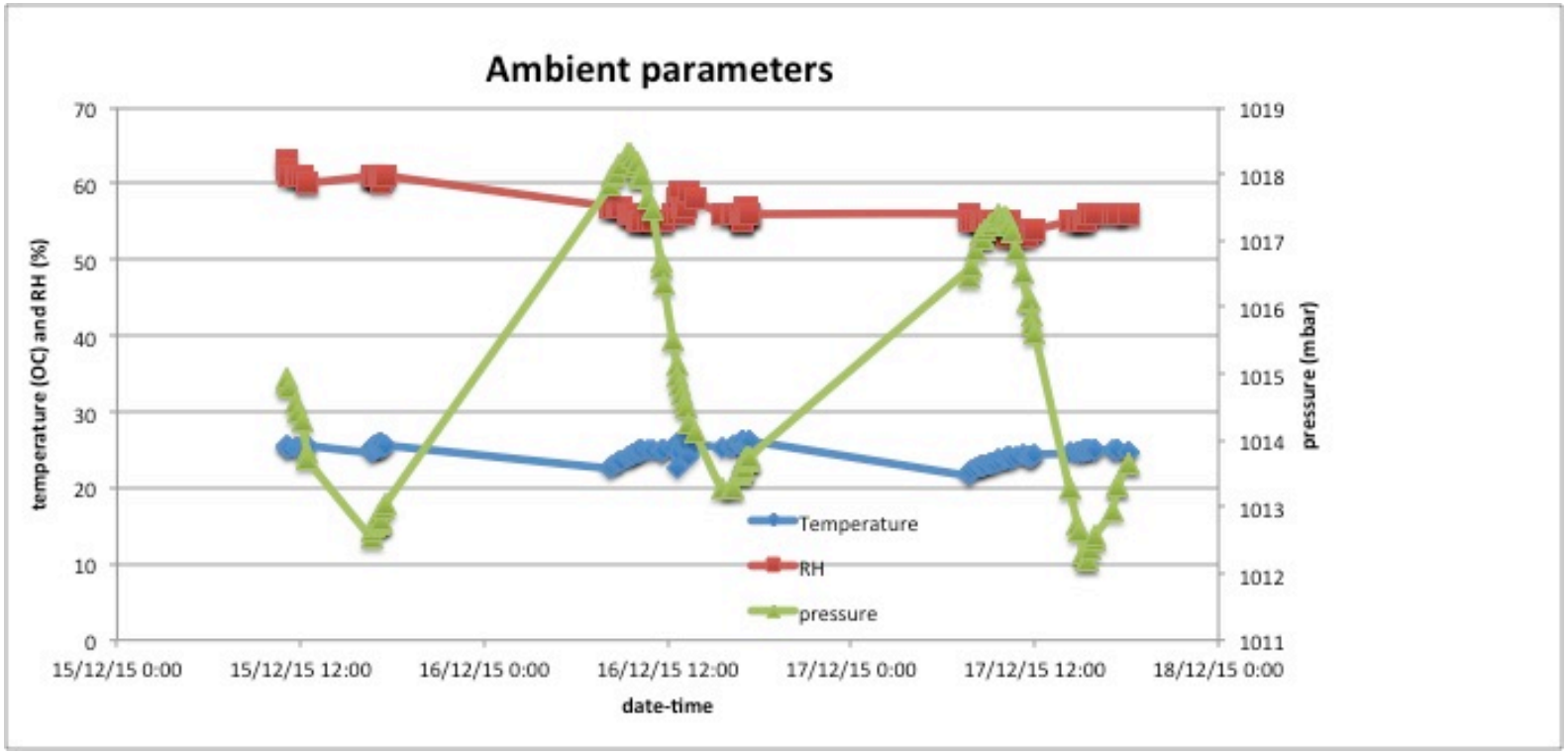


The data logger





Preliminary results



Summary

- ~2.5 mC/mm^2 charge is accumulated in ~150 hours of operation
- No ageing is observed
- One instrument is built to measure the ambient parameters

Future plan

- To build 4-GEM detector prototype
- Long-term test of 4-GEM detector

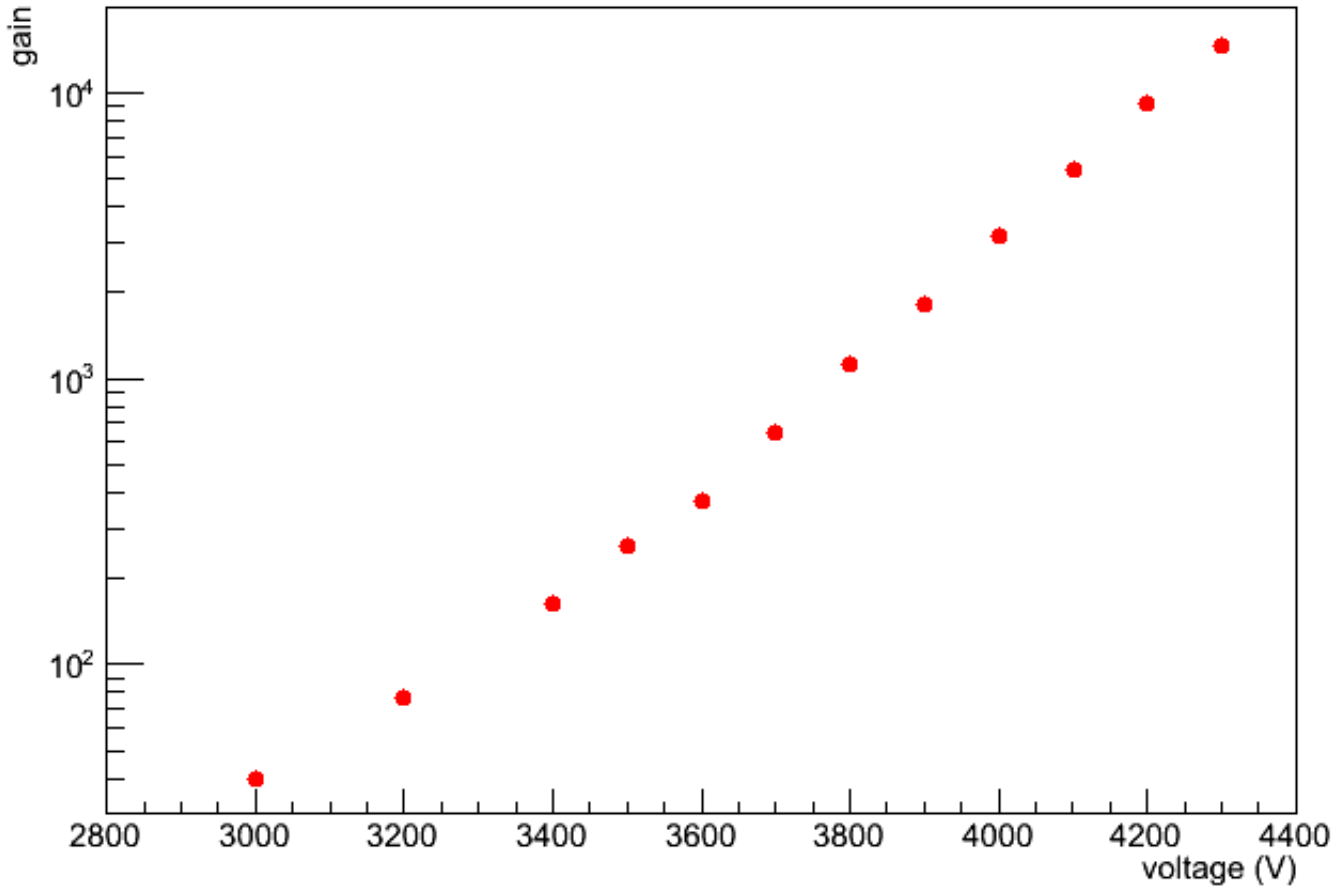
Acknowledgement

Rama Prasad Adak and Subhojit Roy

Thank you

Back up slides

Gain Vs. Applied Voltage



Normalized gain = measured gain/$p_0 \exp(p_1 T/p)$