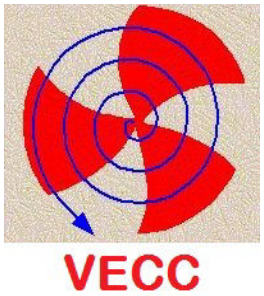


Status of GEM studies for ALICE-TPC upgrade

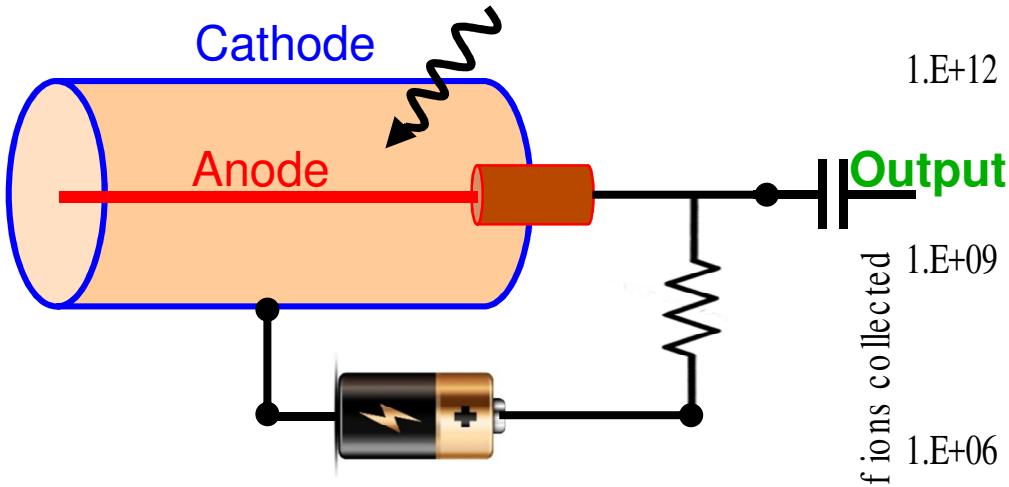
Rajendra Nath Patra

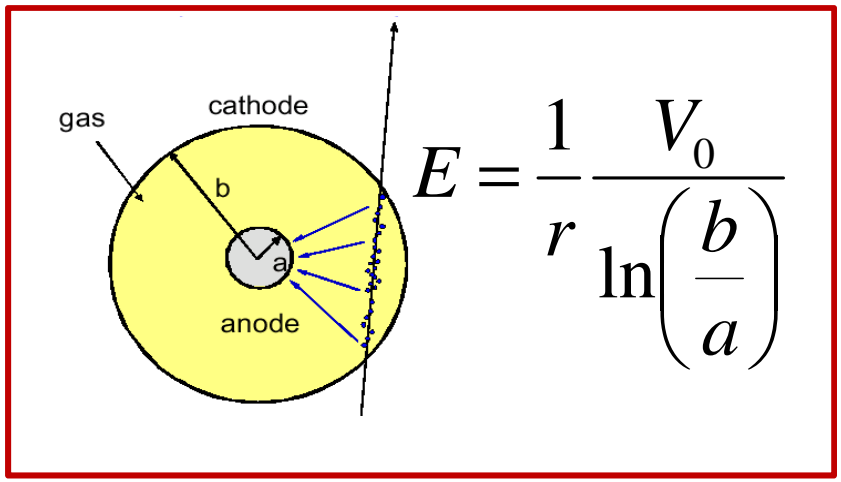
VECC, Kolkata

Work done so far ….

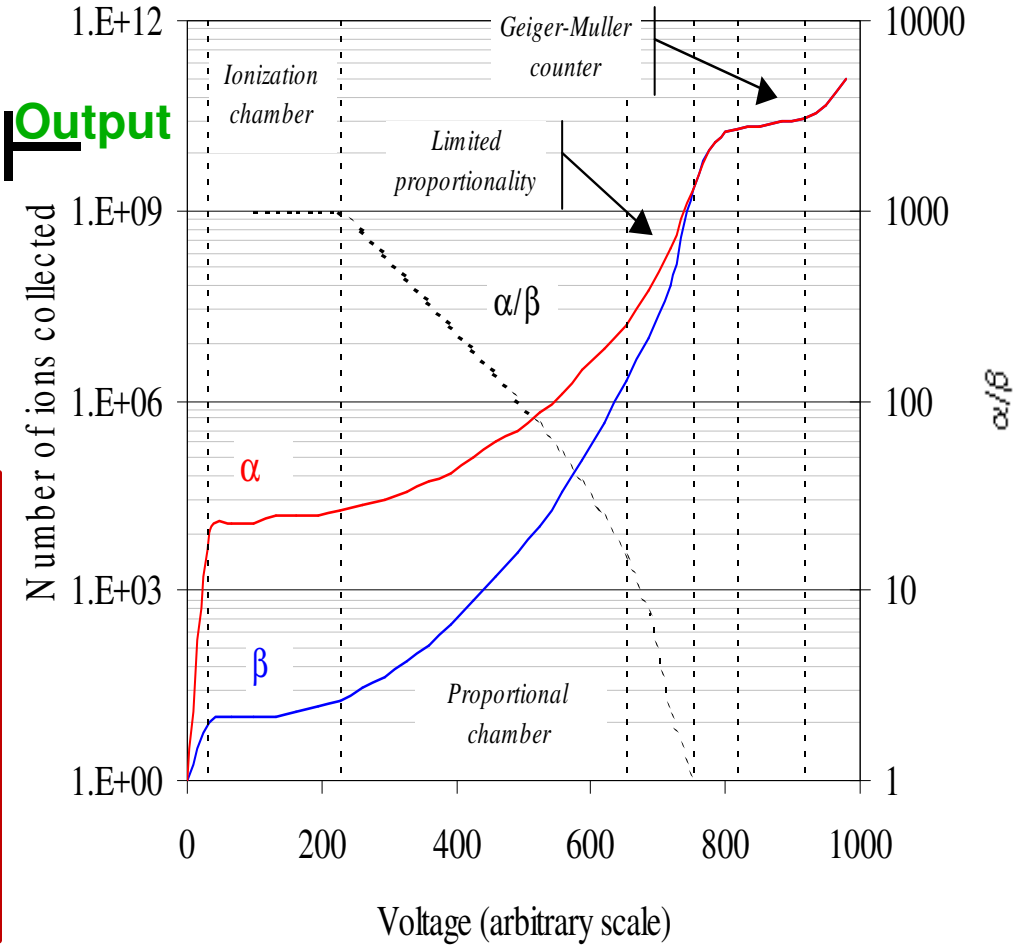
- High Voltage testing of a 10 cm X 10 cm GEM detector
- Characteristic studies of GEM detector with Fe^{55}, Sr^{90} and Ru^{106} sources and cosmic ray
- Gain, efficiency and energy resolution measurements

Gas detector: simple example



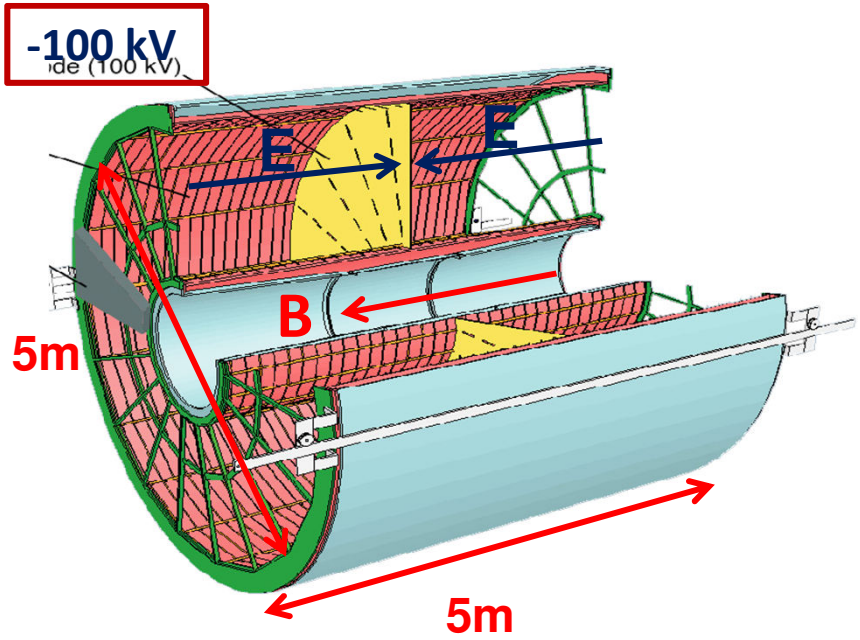


$$E = \frac{1}{r}\frac{V_0}{\ln\left(\frac{b}{a}\right)}$$



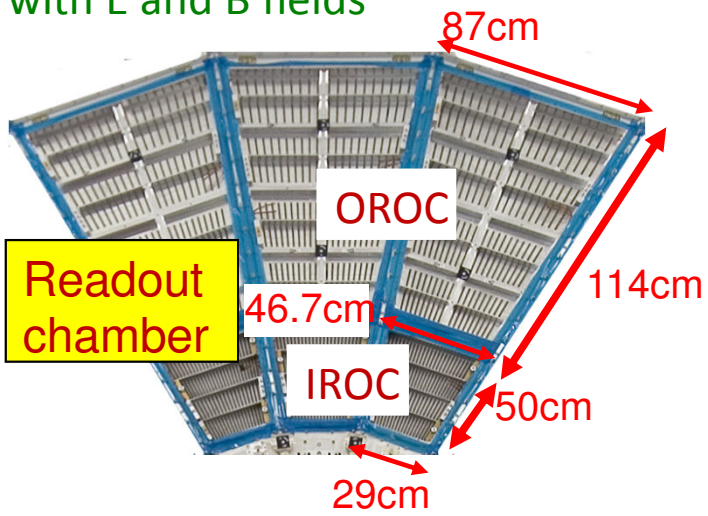
ALICE-TPC

- ALICE-TPC is a large 3D tracking and PID device.
- The projected tracks are registered on the 2D read-out chamber (MWPC, GEM).
- The third coordinate is reconstructed from the drift time of electrons.



$$\vec{u} = \frac{\mu|\vec{E}|}{(1+\omega^2\tau^2)}\left[\hat{E} + \omega\tau\left(\hat{E}\times\hat{B}\right) + \omega^2\tau^2\left(\hat{E}\cdot\hat{B}\right)\hat{B}\right]$$

Langevin equation for the drift velocity with E and B fields

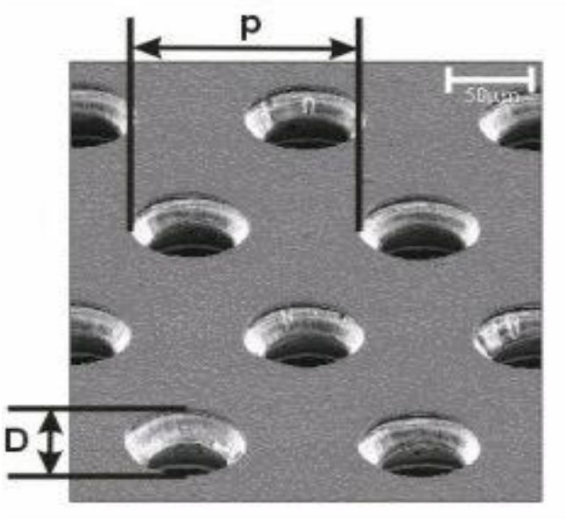


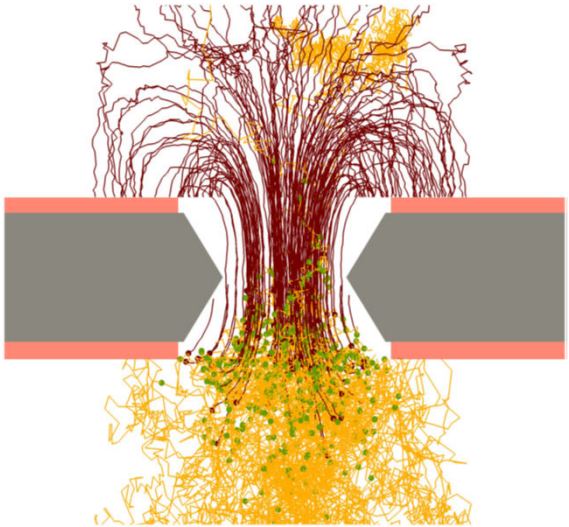
- It's gas volume ~ 92 m^3
- 72 (18x2x2) read-out chamber in present and also for future configuration.
- Drift field : 400 V/cm.
- Total drift time of electron : 92 μs.
- Acceptance : $\Delta\eta<0.9$, $\Delta\phi=2\pi$

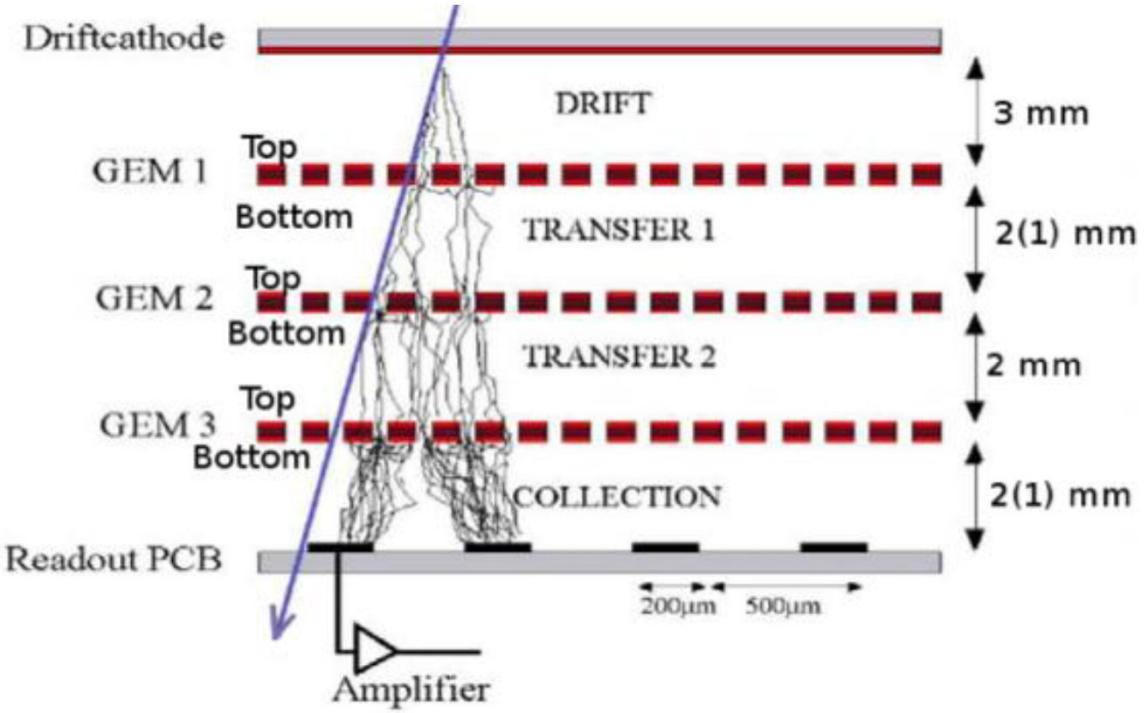
ALICE-TPC towards upgrade

Issues	TPC now	TPC upgrade
•Read-out	•TPC read-out is gating grid + MWPC based.	•TPC read-out will be based on 4-GEM stack.
•Collision rate	•It has collision rate limit 3.5 kHz.	•In run-III rate will increase up to 50 kHz.
•Gas mixture	•Ar-CO_2 (90:10) gas mixture is being used.	•Ne-CO_2-N_2 (90:10:5) gas mixture will be used in future.
•Ion backflow and space charge	• Space charge is an issue at high collision rate.	•Space charge effect is negligible.

Principle of GEM detector







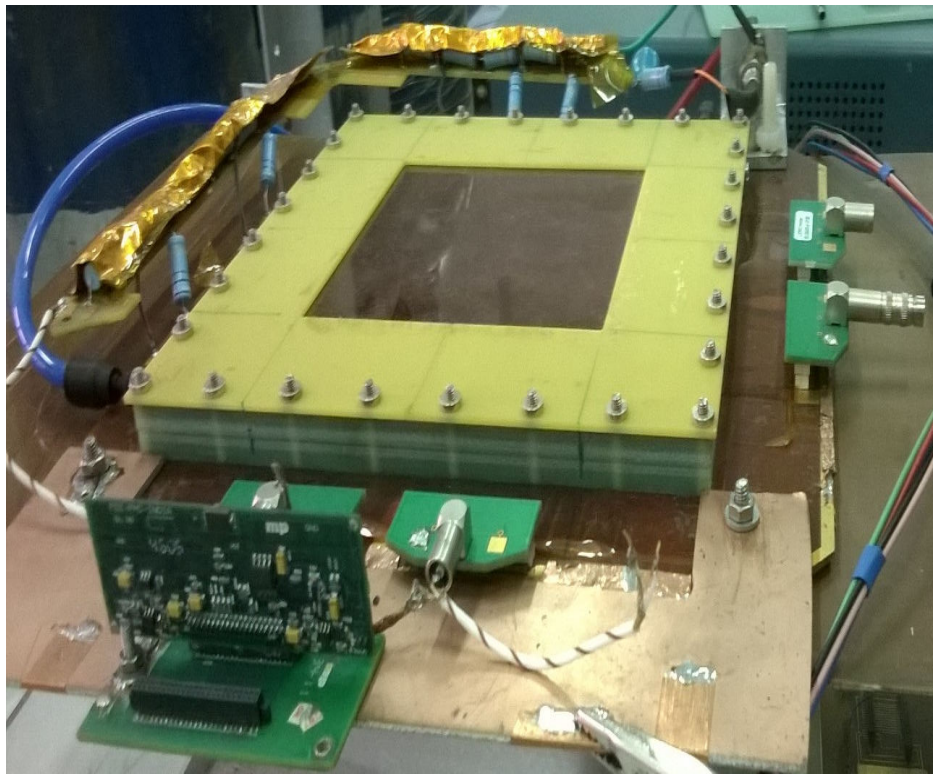
Typical electric field values

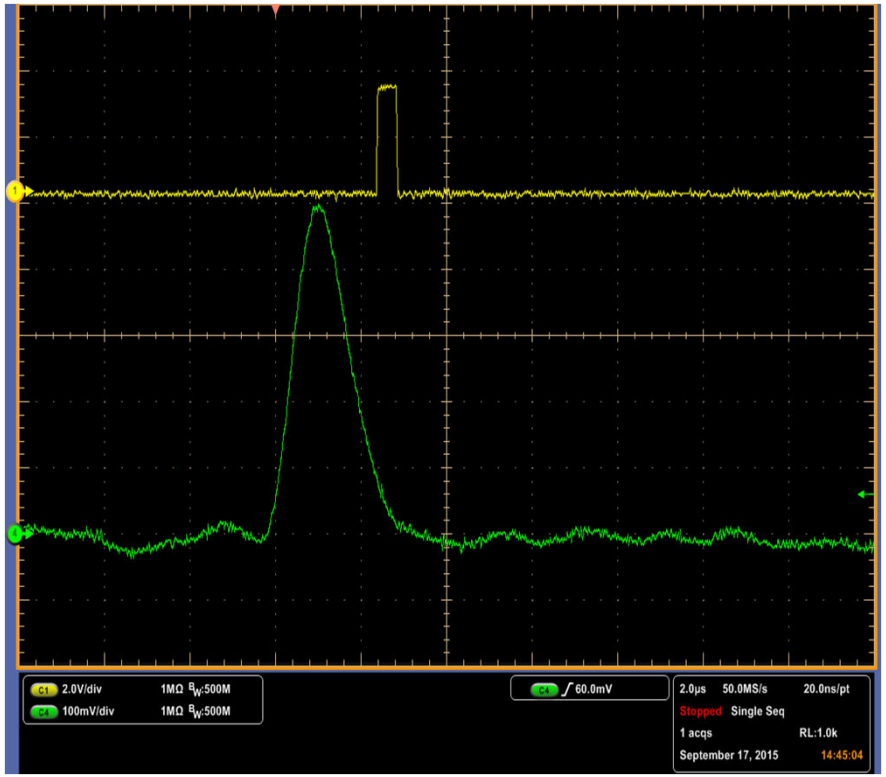
- E_{drift} ~ 2 kV/cm
- $E_{transfe}$ ~ 2 kV/cm
- $E_{induction}$ ~ 3 kV/cm
- E_{GEM} ~ 70 kV/cm

Cu foil - 5 um
Kapton foil - 50 um
Pitch – 140 um
Inner dia. – 50 um
Outer dia. – 70 um

Prototype triple GEM detector and first signal

GEM @ VECC

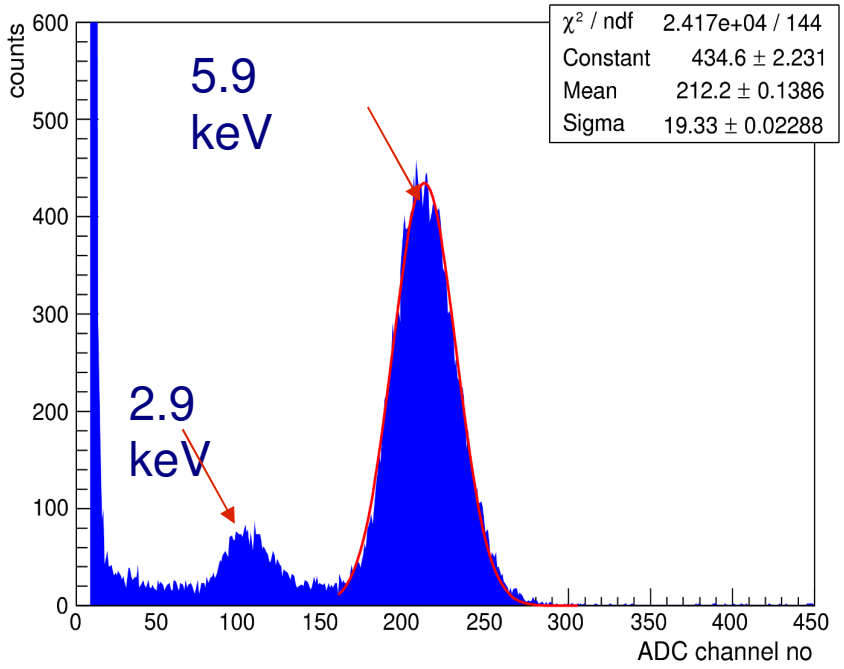




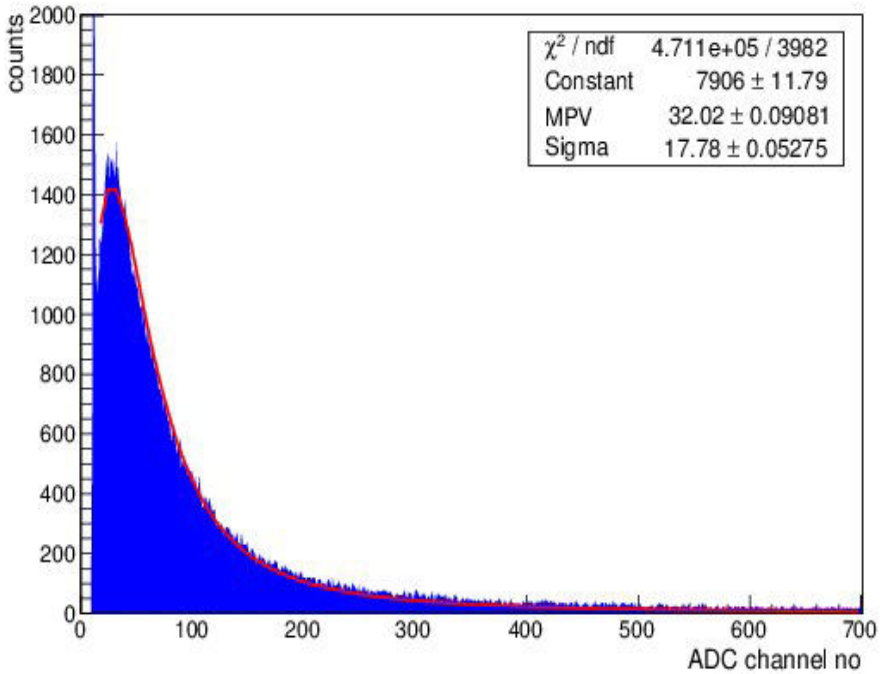
Spectrum of Fe^{55} and Sr^{90}

- Fe^{55} is a 5.9 keV X-ray source. In Argon gas it also shows a 2.9 keV escape peak associate with the full photo peak.
- Sr^{90} is a β^- source with end point energy 546 keV.

Fe^{55} spectrum

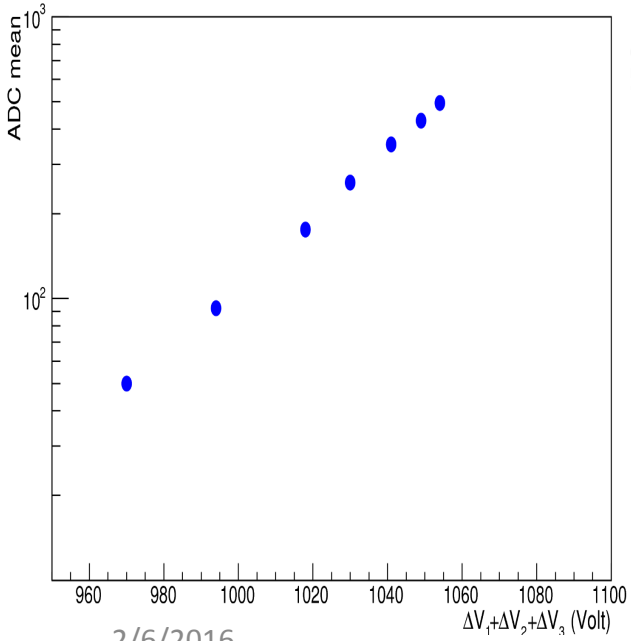


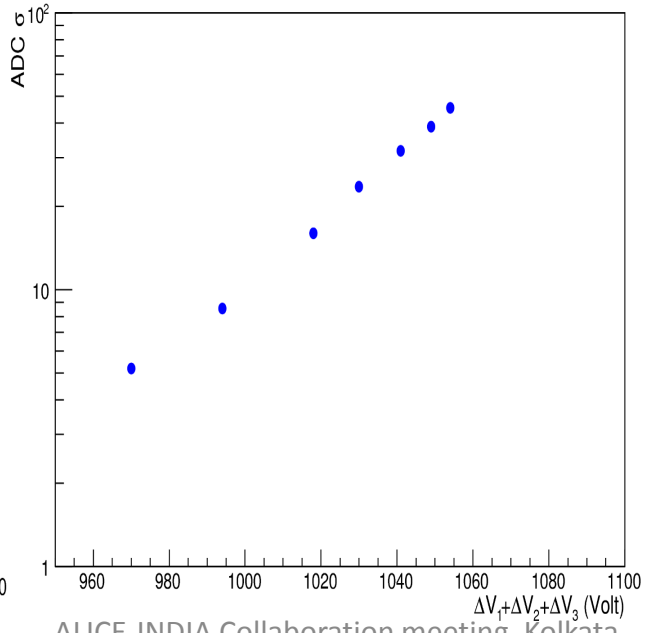
Sr^{90} spectrum

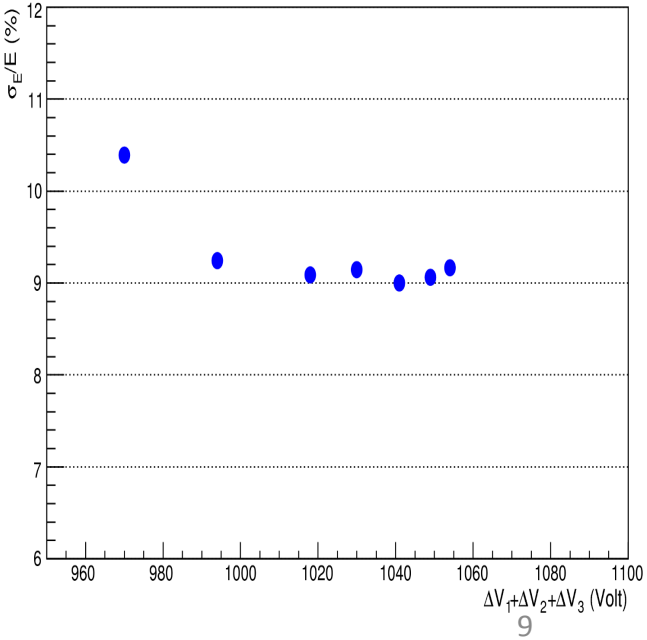


ADC and Energy Resolution (σ_E/E) variation with HV for Fe^{55} X-ray source

- ADC mean and sigma values are from energy spectrums with different HV.
- Energy resolution varies with V_{GEM}
- Resolution is corresponding to 5.9 keV X-ray and the optimum value is reached at ΔV_{GEM} -1050 V







Gain measurement using Fe^{55} X-ray source

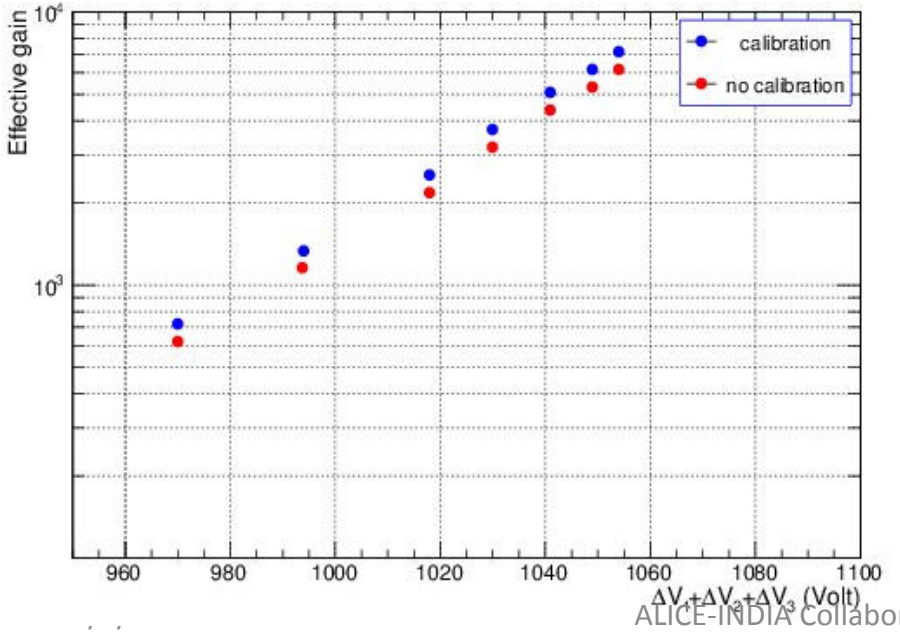
Gain increases exponentially as a function of ΔV_{GEM}

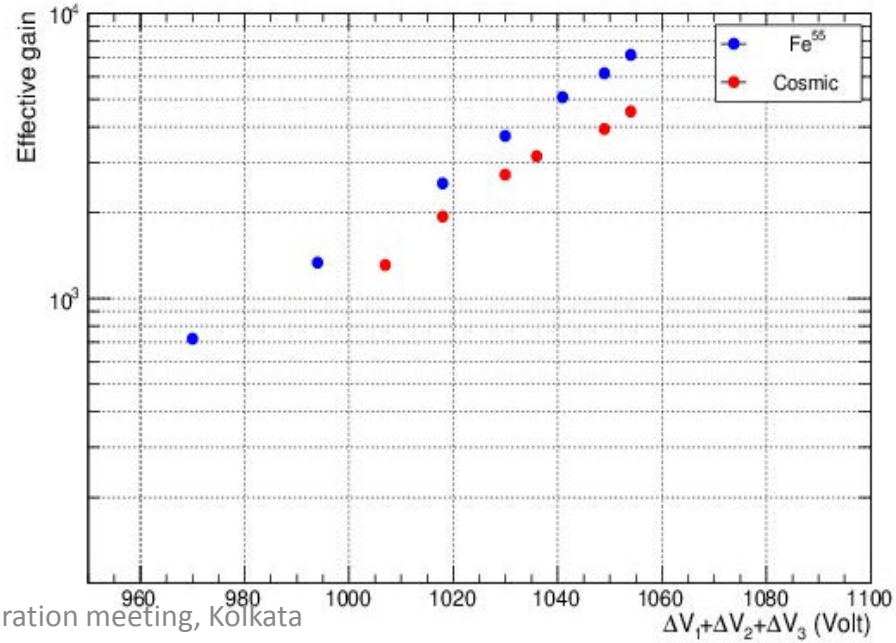
$$G_{eff} = \frac{Q}{N_p q_e}$$

Where,

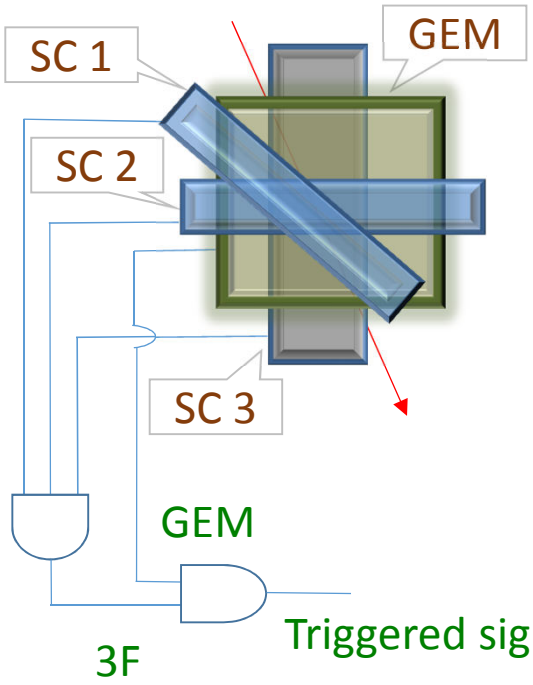
$$Q = \frac{V_{amp}}{G_{pre-amp} G_{amp}}$$

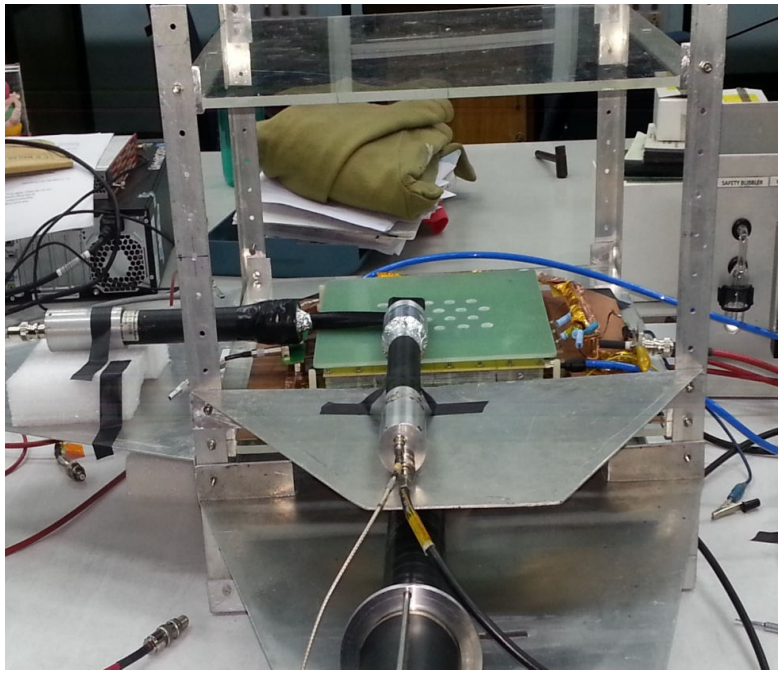
- Q – measured charge
- N_p – no. of primary ionization
- [N_p = 200, for Ar/CO2 (70:30)]
- q_e – electron charge





Cosmic ray setup and Efficiency measurement





- SC 1 and SC 2 were dimension of 2.5 X 2.5 cm^2.
- SC 3 was 7 X 5 cm^2.
- Read-Out area of GEM was 10 X 5 cm^2.

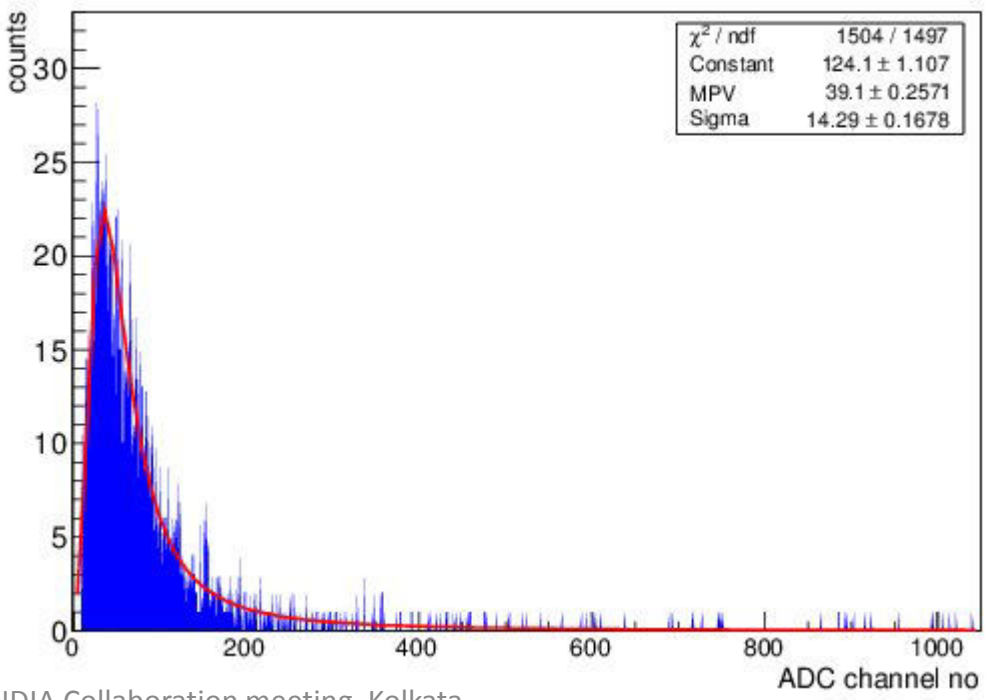
- Because of very small overlap zone at the middle of the read-out probability of false trigger was negligible.
- Triggered count rate was very low (~1/min).

Cosmic ray muon spectrum study

High energy cosmic particles which are passing through earth surface are mostly muon (μ).

Since cosmic muons (μ) are high energy charged particle their interaction show a MIP spectrum when they passes through the medium.

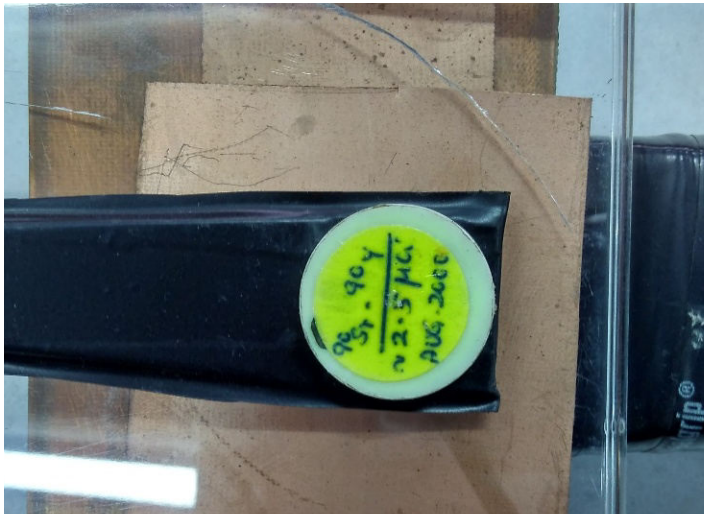
- Global voltage = -1050 V
- Three Scintillator detectors were used to get a trigger.

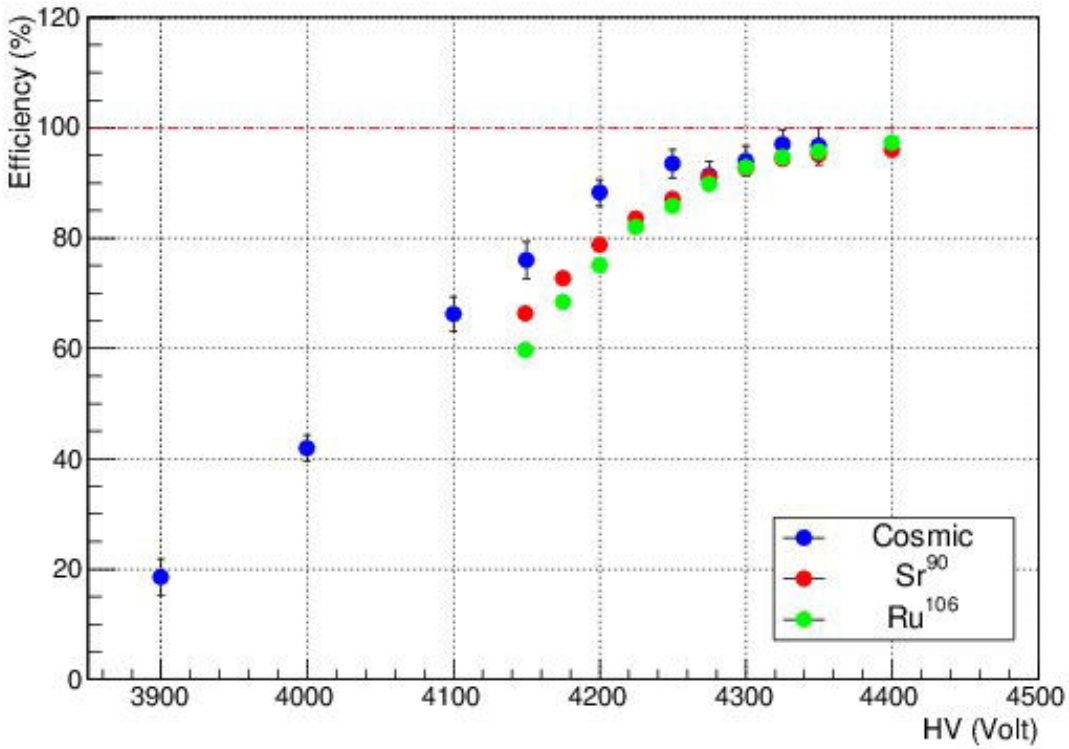


Efficiency measurements

- N_{GEM} - no of GEM counts w.r.t. trigger.
- $N_{trigger}$ - no of counts with trigger.
- For source 2-fold trigger is used
- Efficiency plateau ~ 96%
- Efficiency study with sources is much faster lab based method
- trigger rate Sr^{90} 2Hz and for Ru^{106} 10Hz

$$Efficiency = \frac{N_{GEM}}{N_{trigger}}$$





Summary

- GEM related activity is started for the ALICE-TPC upgrade
- Tests done with prototype GEM detector
  - ADC spectrum studied with Fe^{55} and Sr^{90} sources with different HV settings
  - Using Fe^{55} spectrum **gain** and **energy resolution** are calculated as a function of HV
  - Tested with cosmic ray muon and **efficiency** is measured

Publication:

1. ***"Characterisations of GEM detector prototype",***
   Rajendra Nath Patra, Amit Nanda, Sharmili Rudra, P. Bhattacharya, Sumanya Sekhar Sahoo, S. Biswas, B. Mohanty, T.K. Nayak, P.K. Sahu, S. Sahu

   Nuclear Instrumentations and Methods A
   http://www.sciencedirect.com/science/article/pii/S0168900215014618)

Conference and Symposium presentation and participation:

1. *"Studies of characteristics of triple GEM detector for the ALICE-TPC upgrade".*
   Oral presentation at DAE-BRNS Symposium 2015, Dec 11, 2015, Puttapati.

2. *"Development of a triple GEM detector prototype"* at 7th International Conference on Physics and Astrophysics of Quark Gluon Plasma, February 2015, Kolkata, India. Poster presentation

3. Oral presentations on ALICE-INDIA collaboration meetings.

Future plans

- Plan for GEM R&D in our Lab:
  - Direct current measurement from readout strips and gain calculation
  - Mobility measurement of ions
  - Assembling a 4 layer GEM detector and tests

- TPC-GEM Assembly and Testing at GSI, Darmstadt

- Garfield simulation studies for ion mobility measurements

Thank you

Ionization of gas detector

- Ionisation in medium is statistical nature.

In a gas mixture, $W = \sum w_i \, . \, W_i$

Average no of electron-ion pairs from all mechanism are created for ΔE energy loss,

$$N = \frac{\Delta E}{W}$$

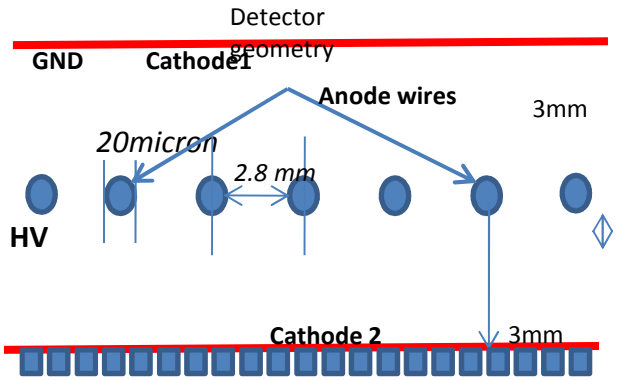
in Ar/CO_2(70:30) mixture 5.9 keV X-ray will produce ~**212** electron-ion pairs and for cosmic ray ~**100**/cm.

Gas	I [eV]	W [eV]
Ar	15.8	26
He_2	24.6	41
H_2	15.4	37
N_2	15.5	35
O_2	12.2	31
Air		33.8
CO_2	13.7	33
CH_4	13.1	28

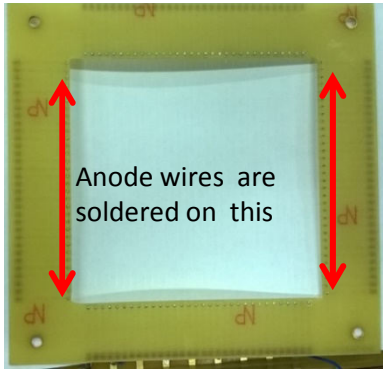
I-first ionization potential
W-average energy for electron-ion pair production

MWPC: Characteristics study

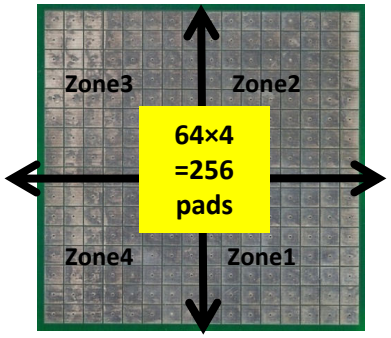
Geometry and assembly of MWPC

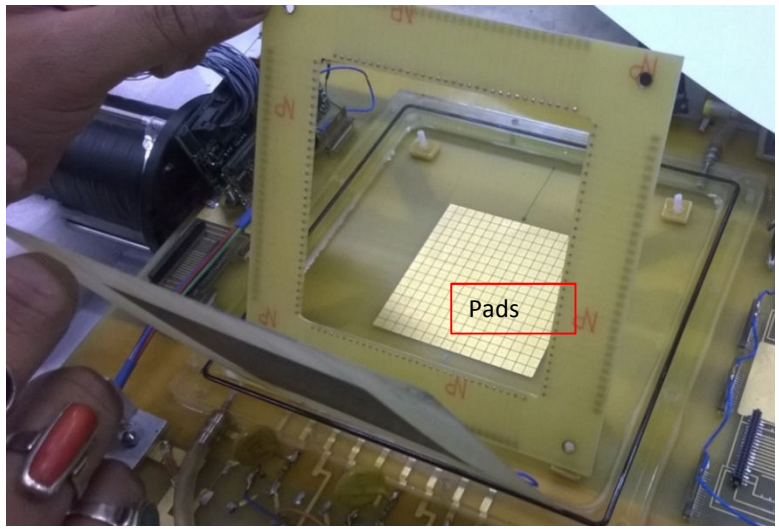


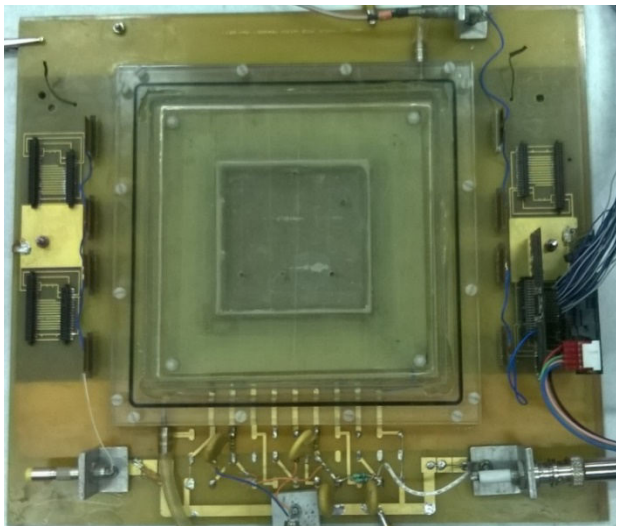
Anode wire PCB



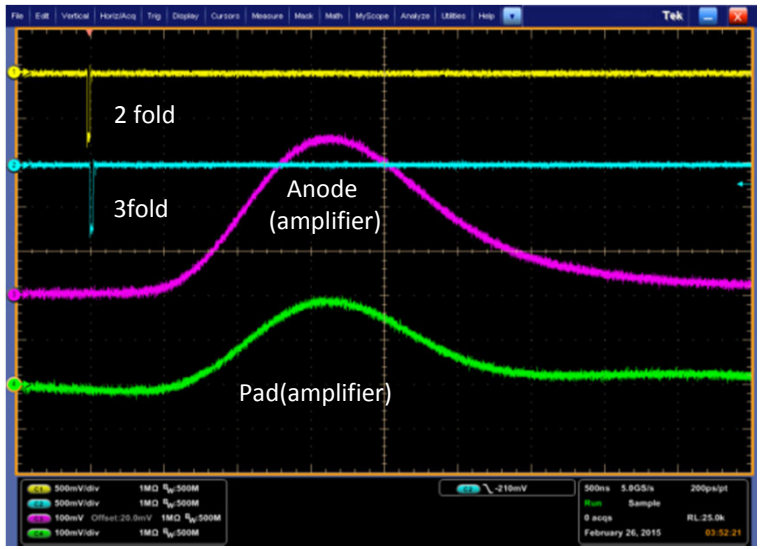
Readout PCB with 4 sq mm pads

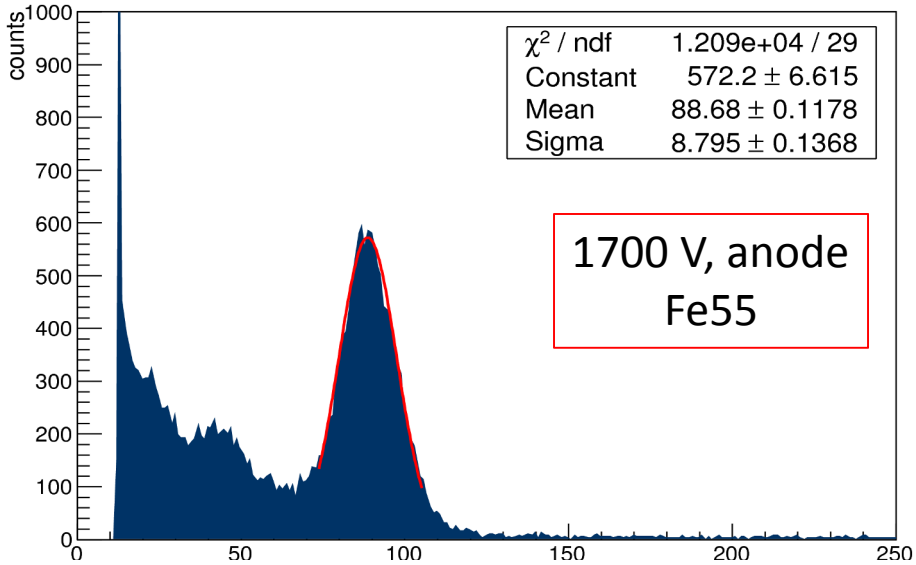


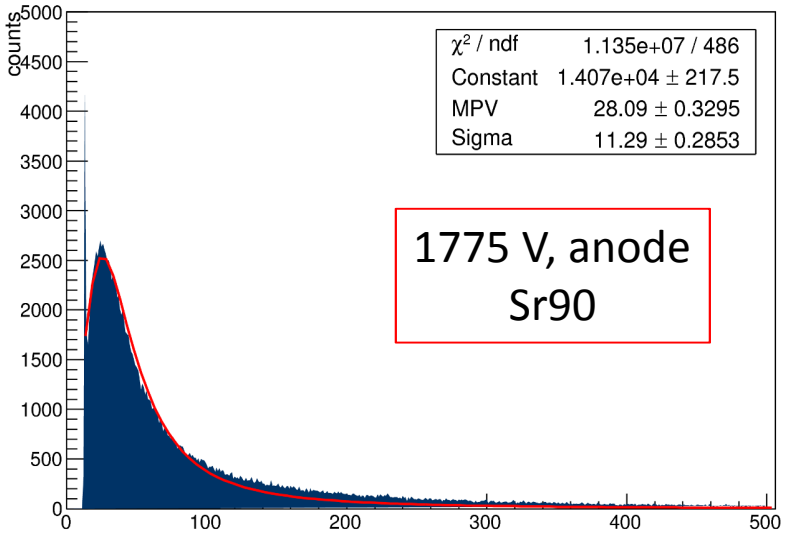


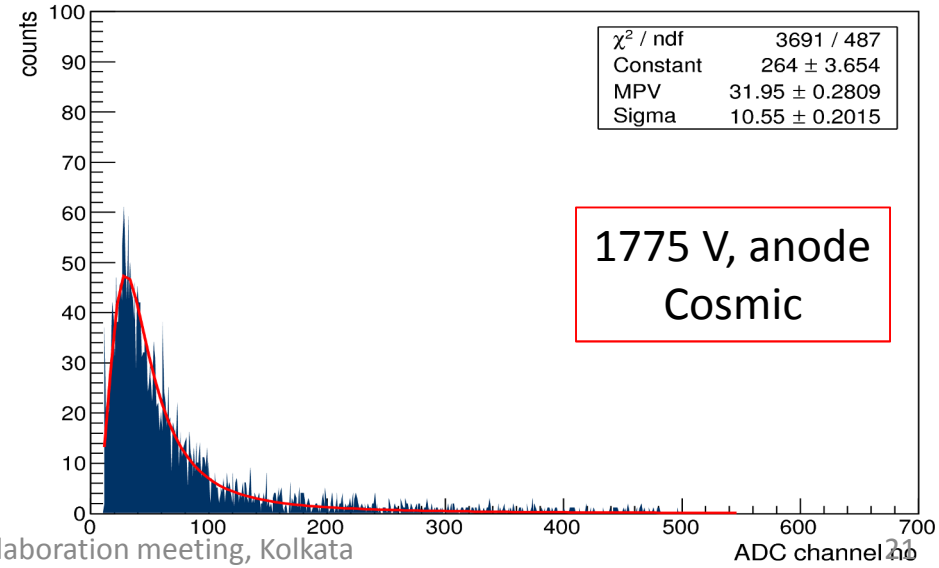


Results with NIM electronics

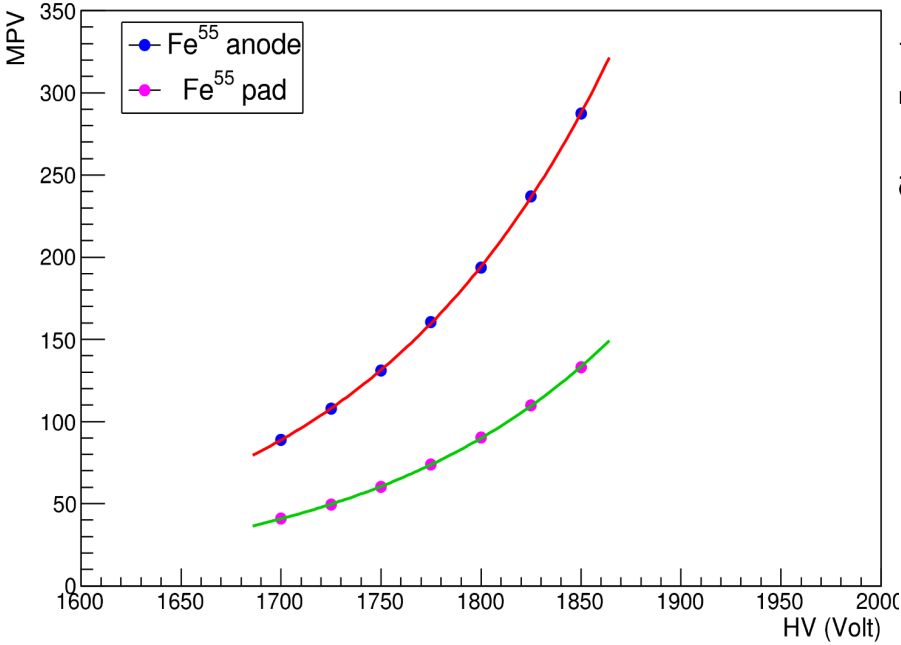


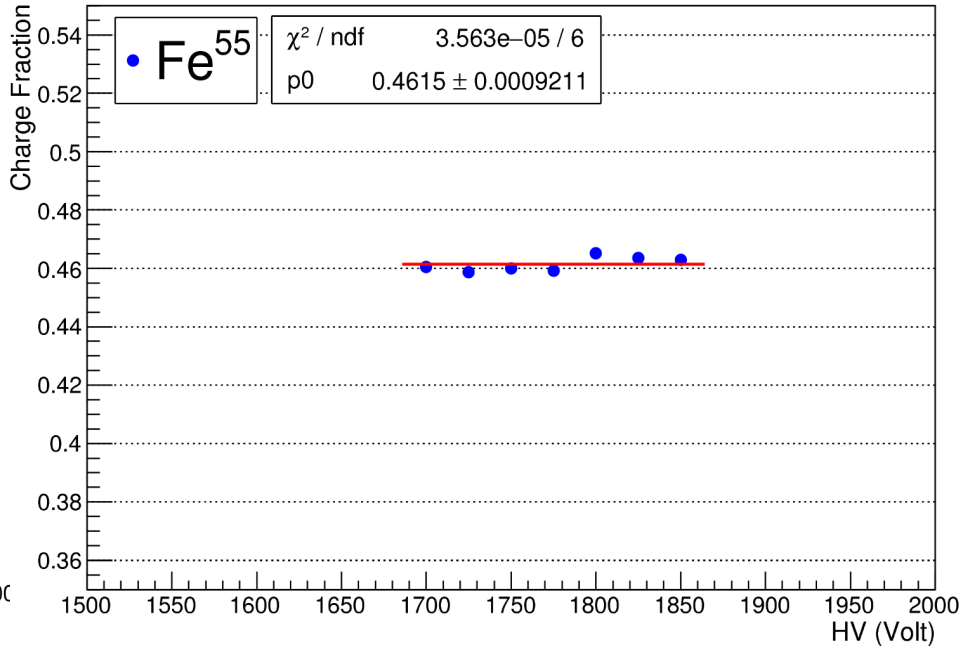






ADC and Charge fraction variations With NIM readout

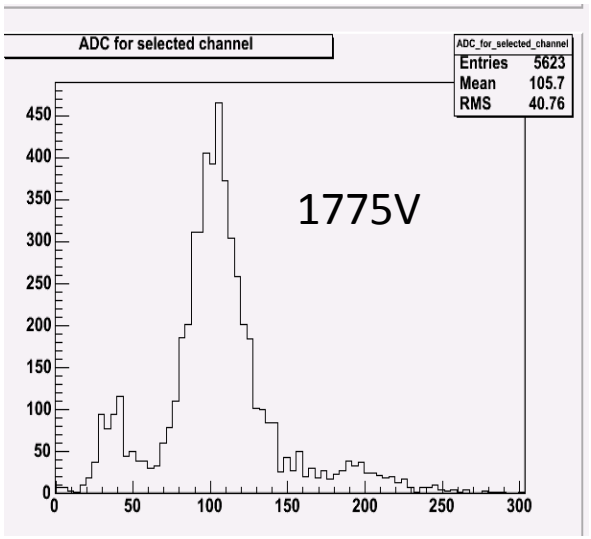




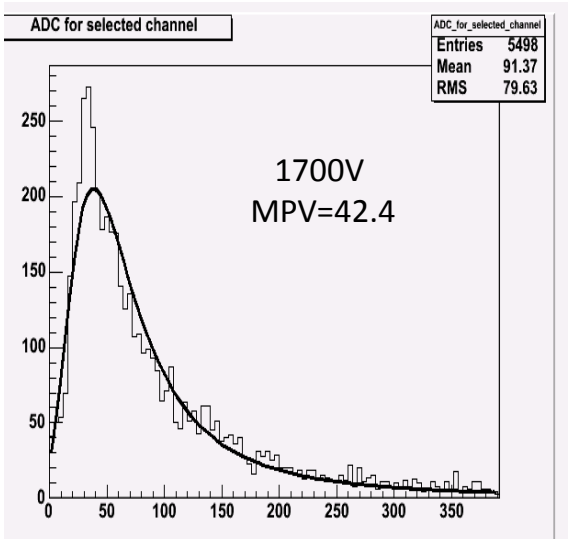
- ✓ADC Of both anode and Pad changes with exponentially.
- ✓Pad ADC is less than corresponding anode ADC.
- ✓The ratio (charge fraction) of pad to ADC to anode ADC is almost uniform.
- ✓This ratio is about is s about 46%.

Spectrum of Fe^{55}, Sr^{90} and cosmic with MANAS readout

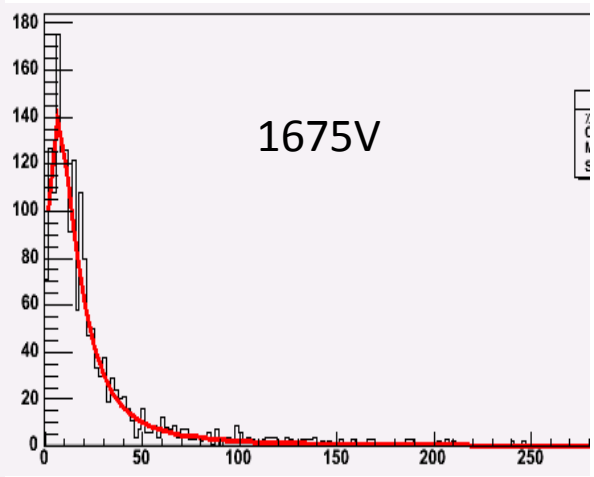
Fe^{55}



Sr^{90}



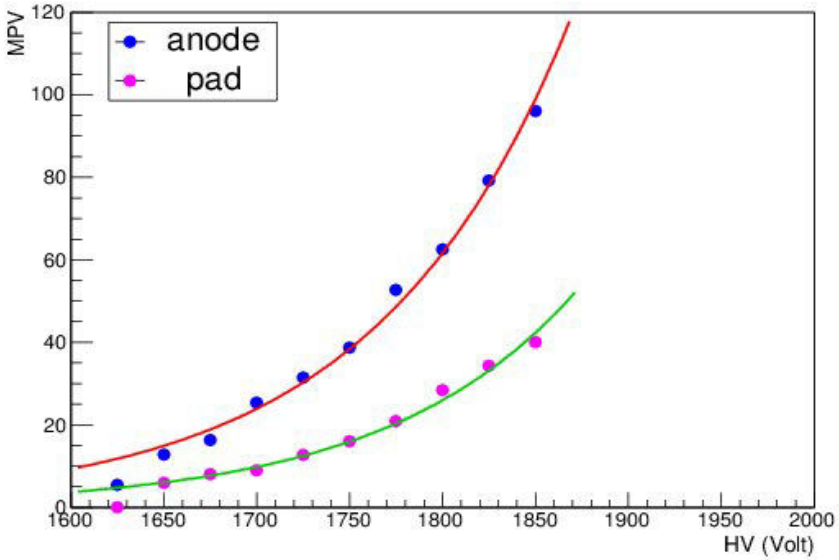
Cosmic



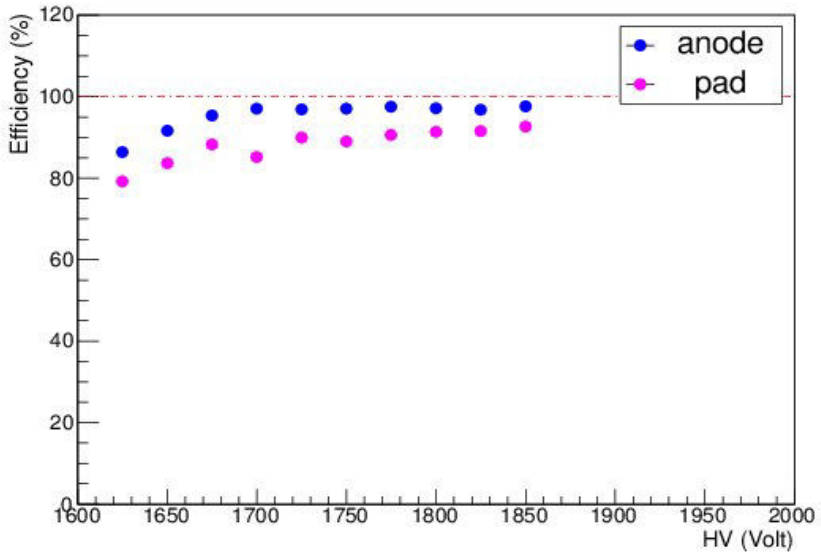
- Fe^{55} and Sr^{90} signals are from read-out pad with anode trigger.
- Cosmic signal is taken from both anode and pad with 3F external trigger.

Results of cosmic tests with MANAS

ADC vs HV



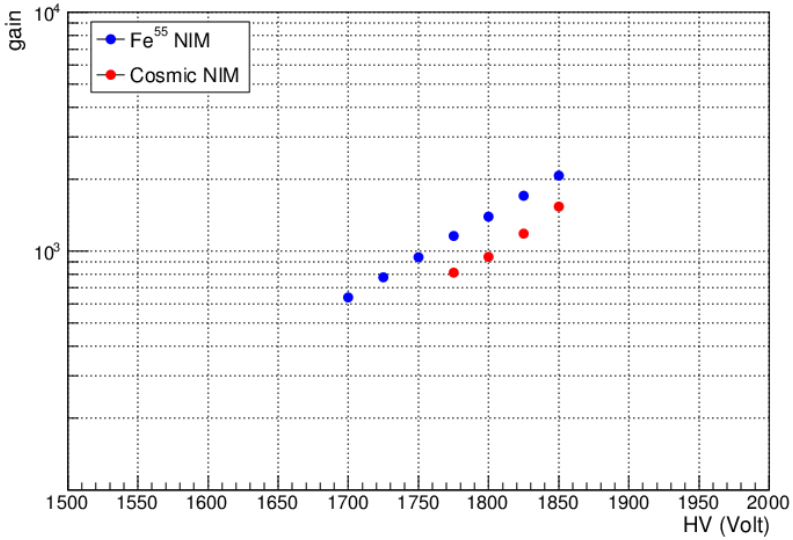
Efficiency vs HV

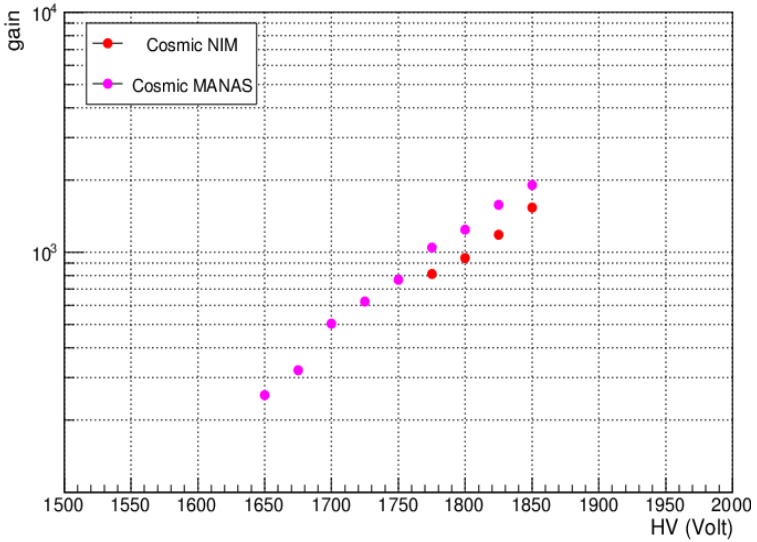


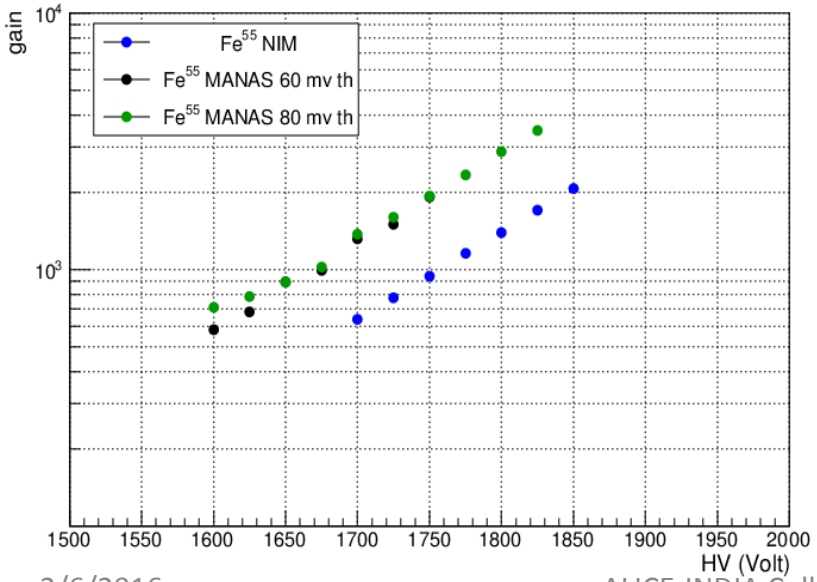
With 3fold from PMTs as trigger for cosmic test with MANAS ;

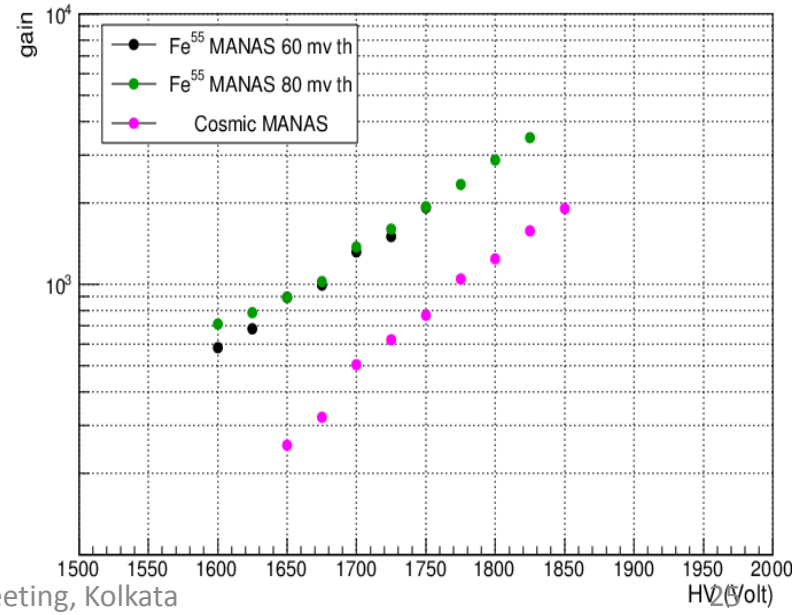
- ADC of anode is higher than ADC of Pad.
- Efficiency of Anode(>95%) is higher than efficiency of pad w.r.t 3F is 92-93%.

Gain comparison of different methods

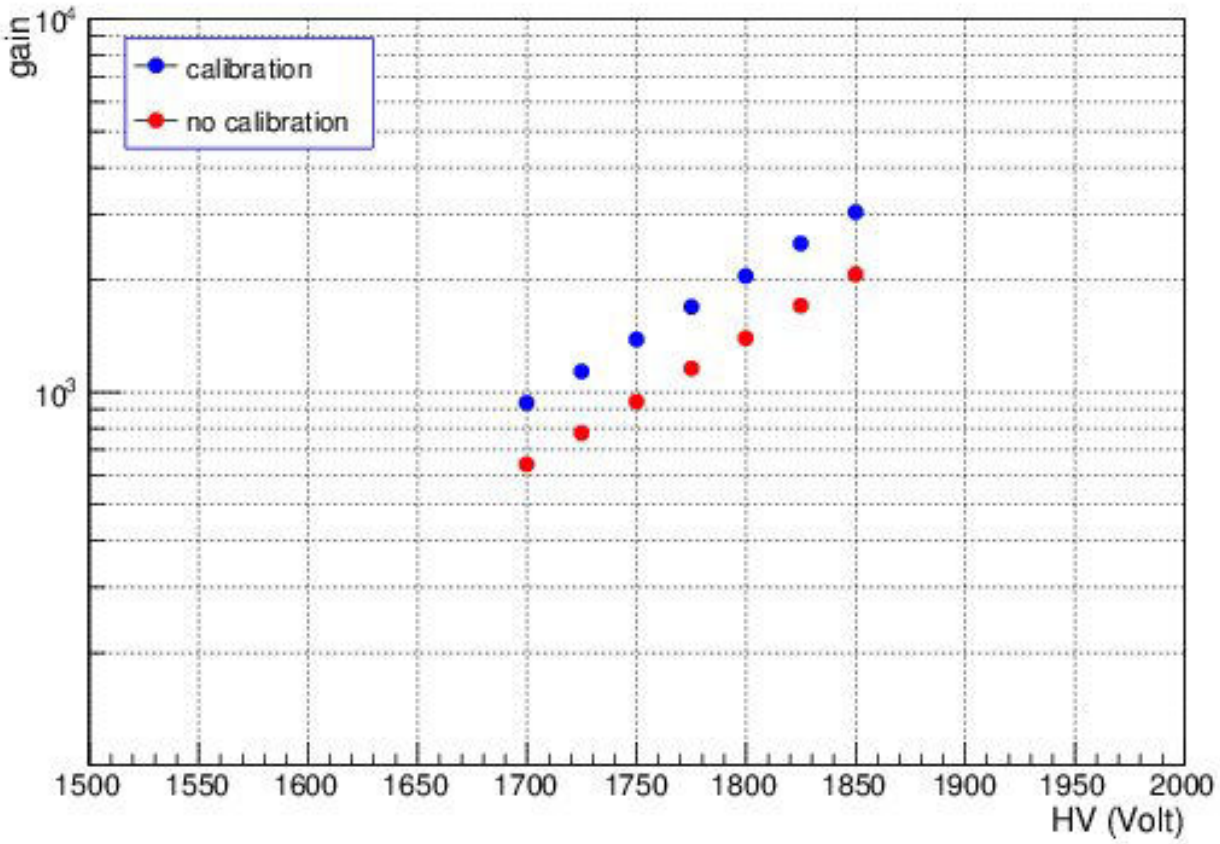








Calibration with Fe^{55}



Calibrated gain