Gain measurements of Triple Gas Electron Multiplier (GEM) detector with zigzag readout strips

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Outline

- Motivation
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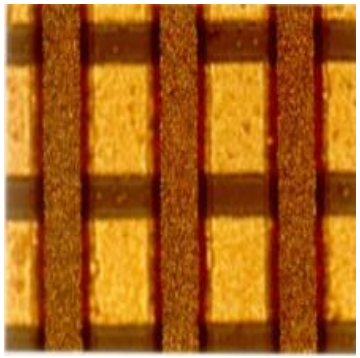
- Experimental Setup
- Energy calibration
- Gain Measurements
- Result
- Conclusion
- Future plans

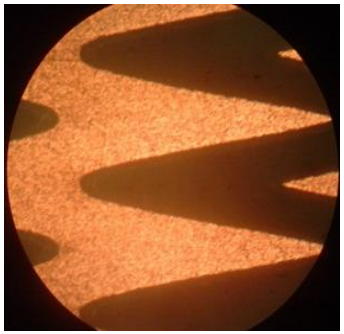
Motivation

- Currently straight readout strips are used in GEM detectors
- We want to replace straight readout strips with zigzag readout strips
- GEM detectors are used in large numbers in big experiments like Compact Muon Solenoid(CMS) at CERN
- Costs associated with electronics of the detector is the biggest issue in CMS GEM upgrade project
- Our solution to this problem is to use zigzag readout system because:

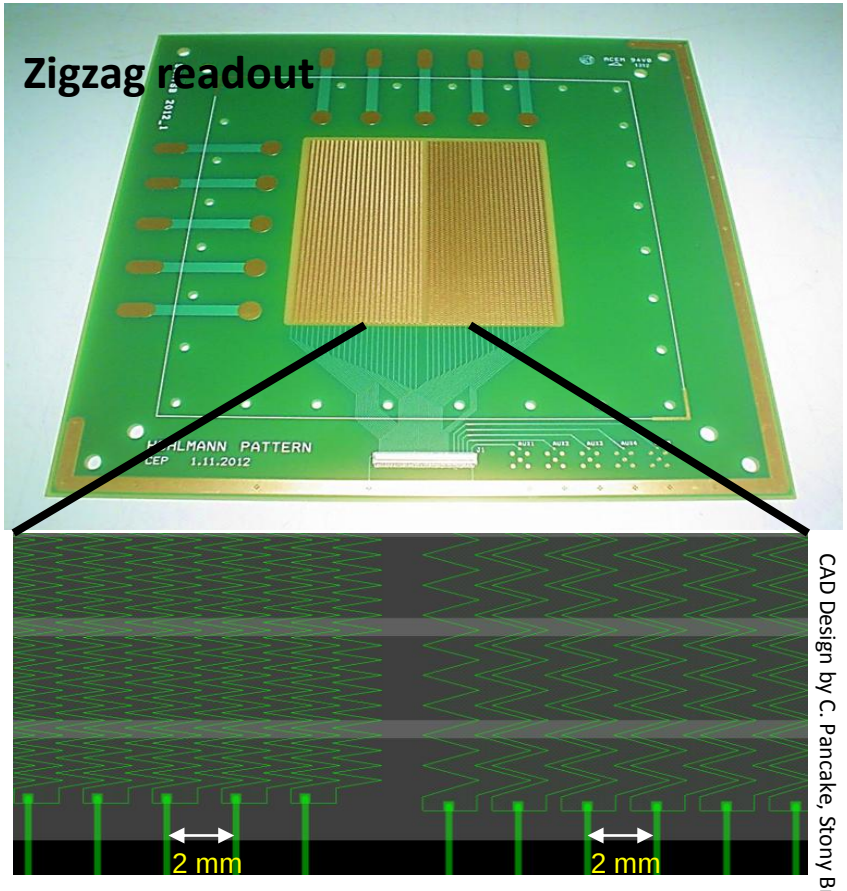
  less no. of readout channel $\longrightarrow$ less cost associated with it
- In the current readout system of the detectors there are 128 straight strips per sector, while in zigzag readout system there are only 48 readout strips

Motivation





Straight strips and zigzag strips under microscope



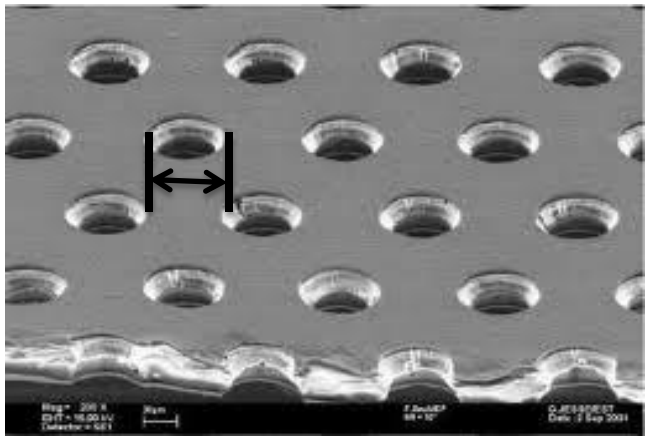
CAD Design by C. Pancake, Stony Brook

Source:CMS_Review_GEM_UpgradeProject_TechnologyChoice_CERN_Feb2013_Hohlmann_FINAL

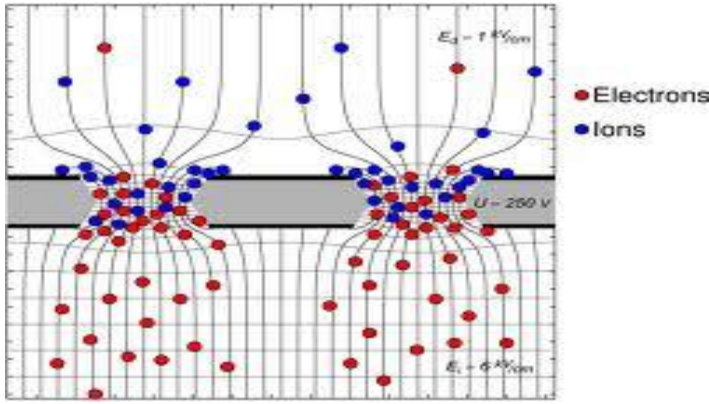
- Before coming to any conclusion , need to verify how detector responds with zigzag readout system.
- The **gain measurement** is one test we are considering to verify the detector's performance.

Gas Electron Multiplier (GEM) Detector

- It is micro pattern gas detector(MPGD)
- Consists of GEM foil that is made up of kapton foil coated with copper on both sides and has array of holes which are equidistant usually 140µm
- High voltage is applied across foils, which creates avalanche of electrons through holes
- Provides good efficiency and spatial resolution



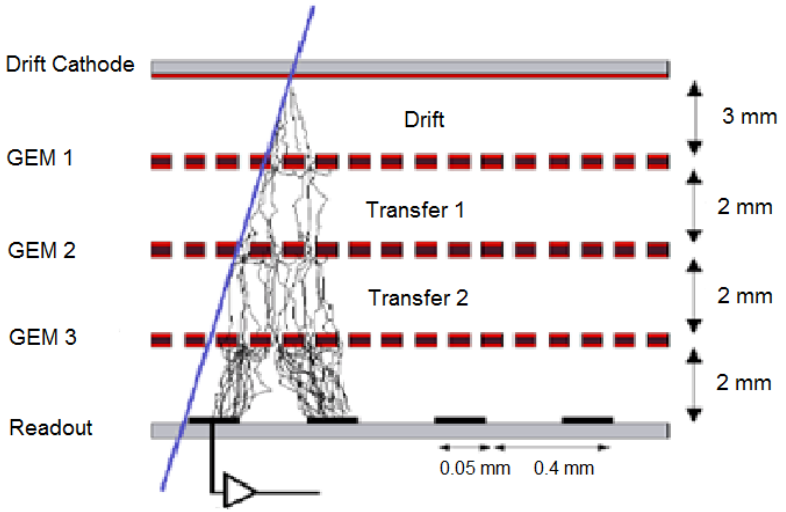
Source: http://gdd.web.cern.ch/GDD/



Source: http://www-flc.desy.de/tpc/basicsgem.php

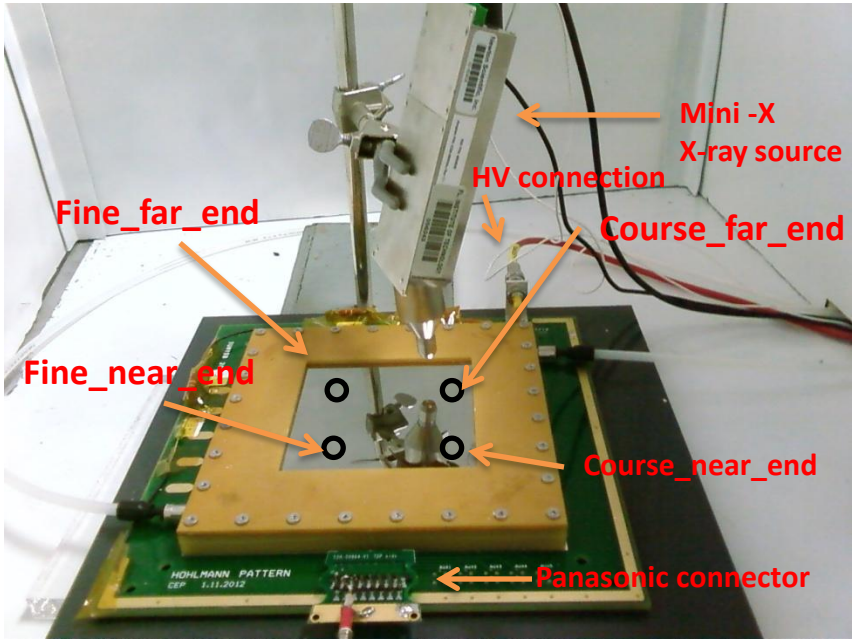
Triple GEM detector

- Most popular and reliable configuration is Triple GEM configuration
- Consists of stack of 3 GEM foils between the drift and readout
- Several experiments use Ar/CO_2 gas mixture in 70:30
- Advantages of using this gas
  - Non flammable
  - Chemically stable
  - Fast electron drift velocity
  - Provides high gain



Murtas, F.: "Development of a gaseous detector based on Gas Electron Multiplier (GEM) Technology

Experimental Setup

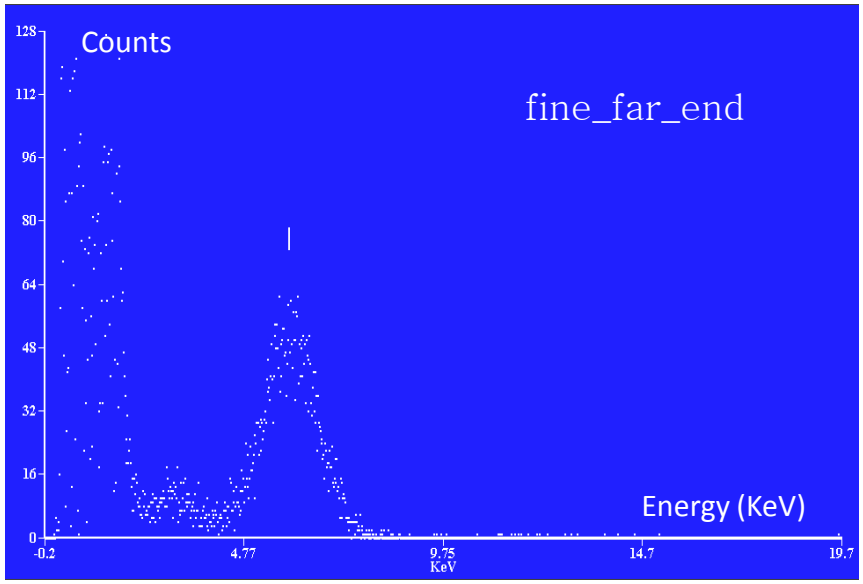


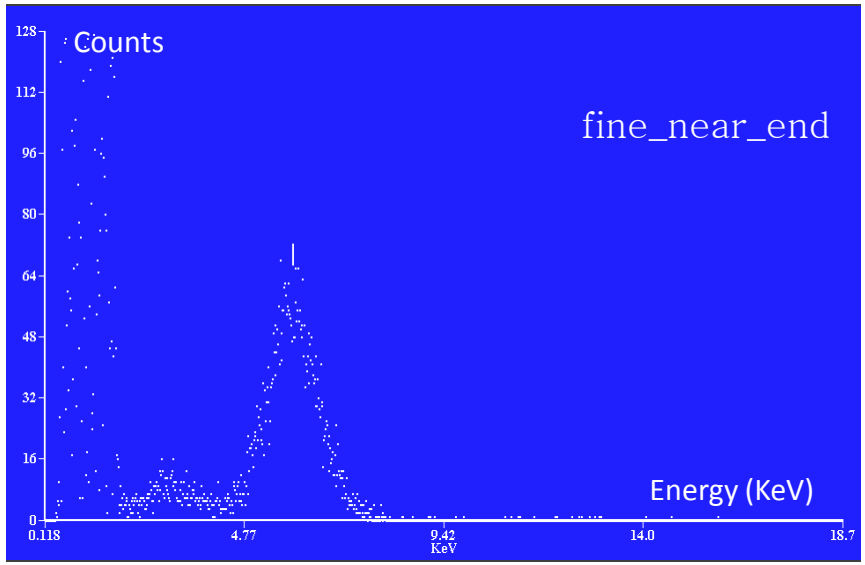
- Detector: Proto type 10×10 Triple GEM detector with zigzag readout
- Gas used in detector: Ar/CO_2 is 70:30
- X- ray source:
  - Mini -X x- ray source with Au source and no filter
  - Settings: 10KV, 5µA

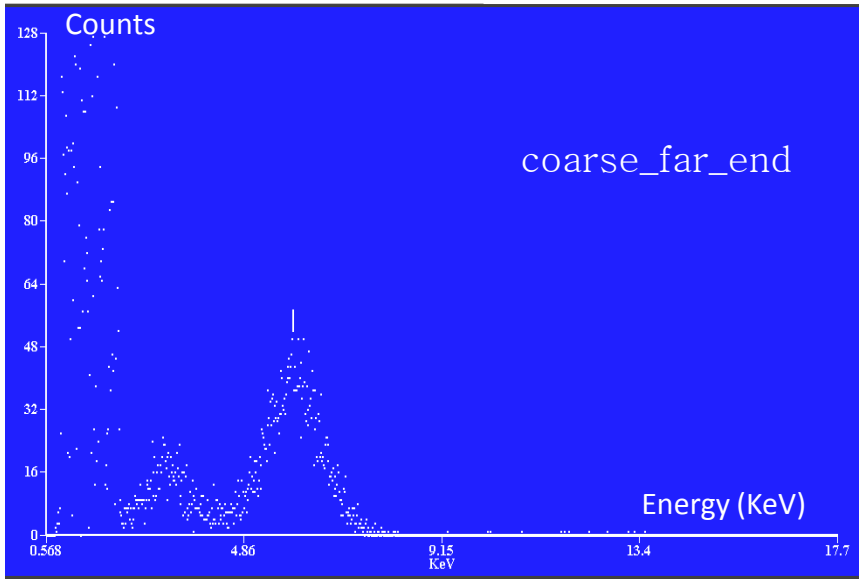
Energy Calibration

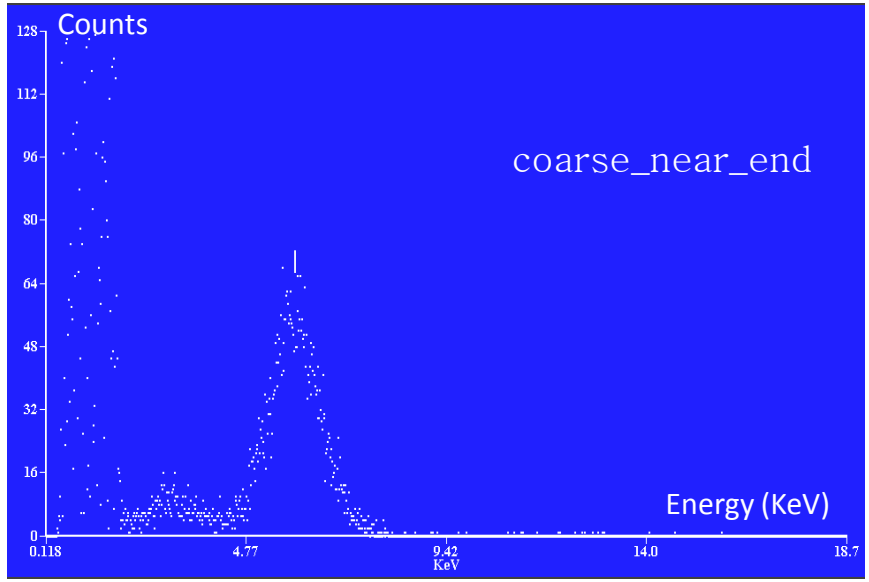
- This step is important in order to calculate the energy of the x-ray source
- Multi channel analyzer is used to obtained the spectrum at four different spot
- Fe^{55} source with known energy 5.9KeV is used for calibration
- Using this calibration, energy of x-rays is obtained individually for four spots

Fe^{55} spectra at 4 points

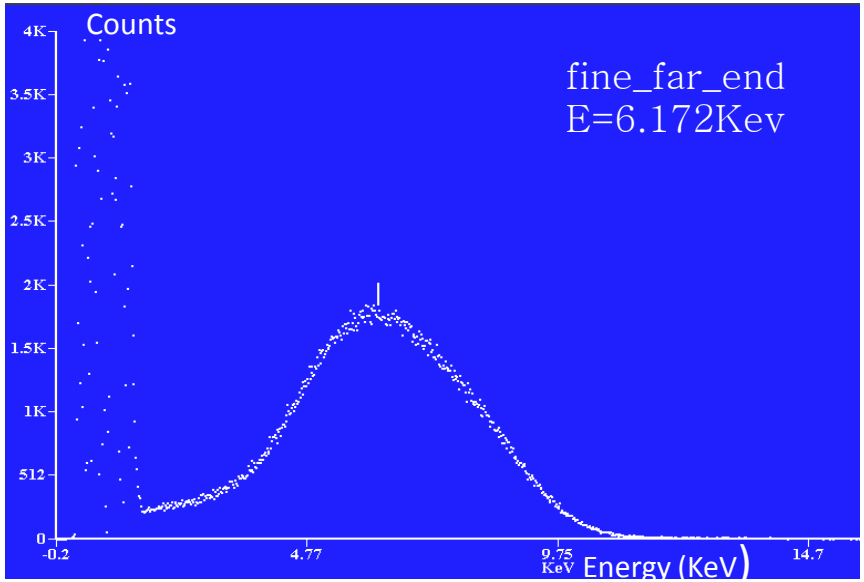


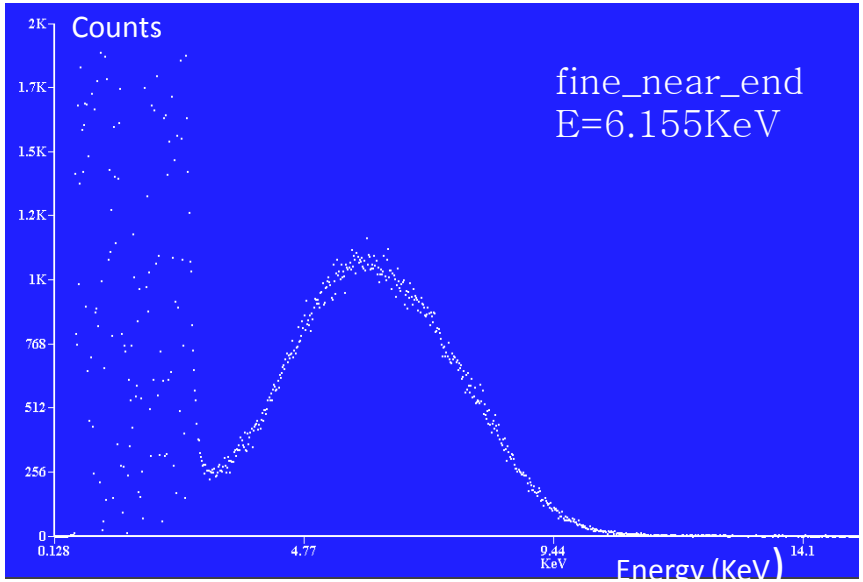


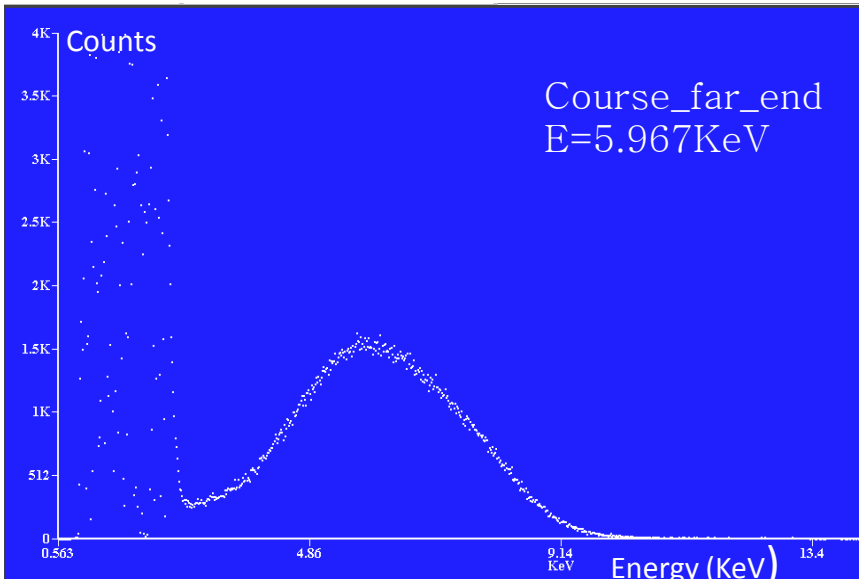


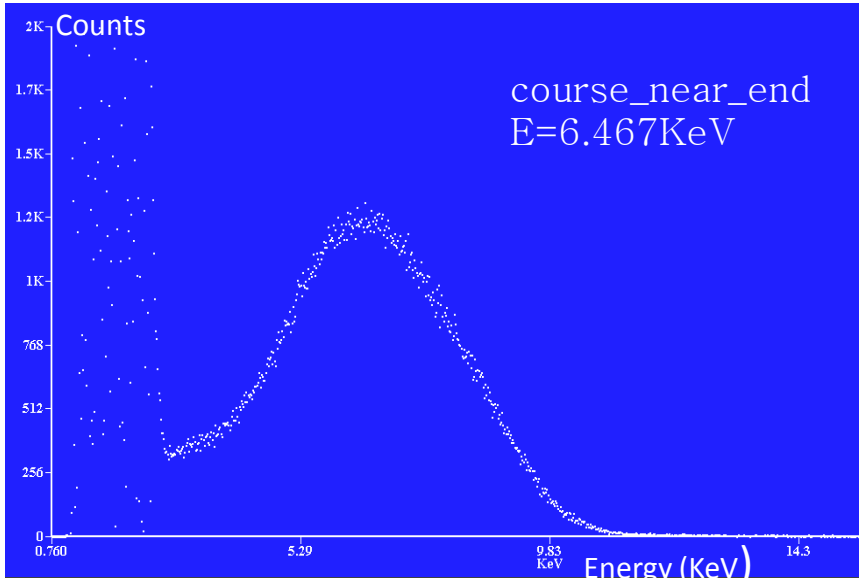


X-ray with spectra at 4 points (no filter)

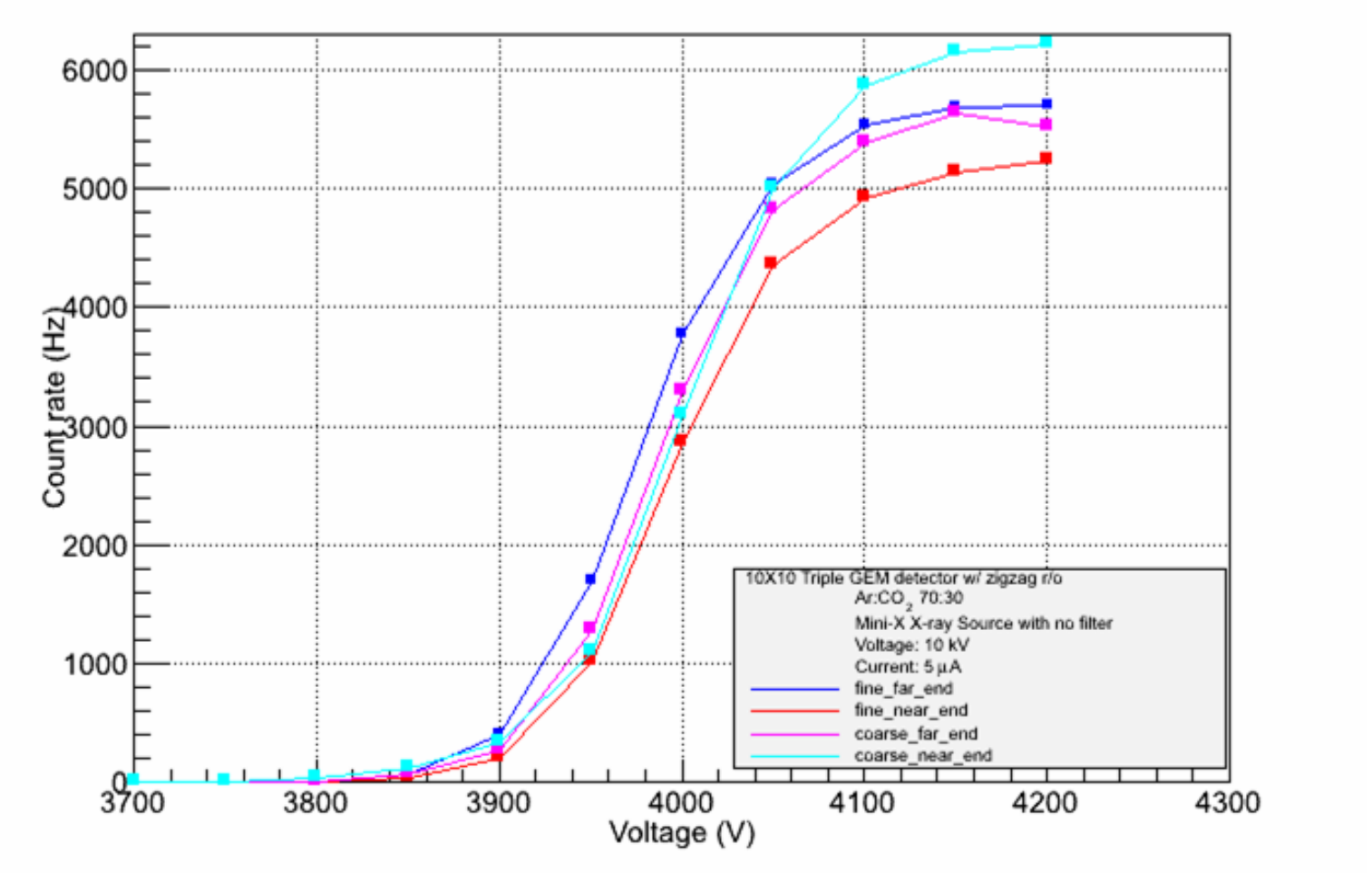








Rate Plateau



Gain Measurements

The gain of the detector is defined as the ratio of the primary charges to the charges detected by the readout board.

$$I \propto \text{Rate} \times n_{prime} \times e \qquad \text{Gain} = \left\{ \frac{I}{(R \times n_{prim} \times e)} \right\}$$

Where, I -> current

R -> count rate at 4150V

Ex:

$$n_{prime} = \frac{E_{x-ray}}{w_i} = 227.12$$

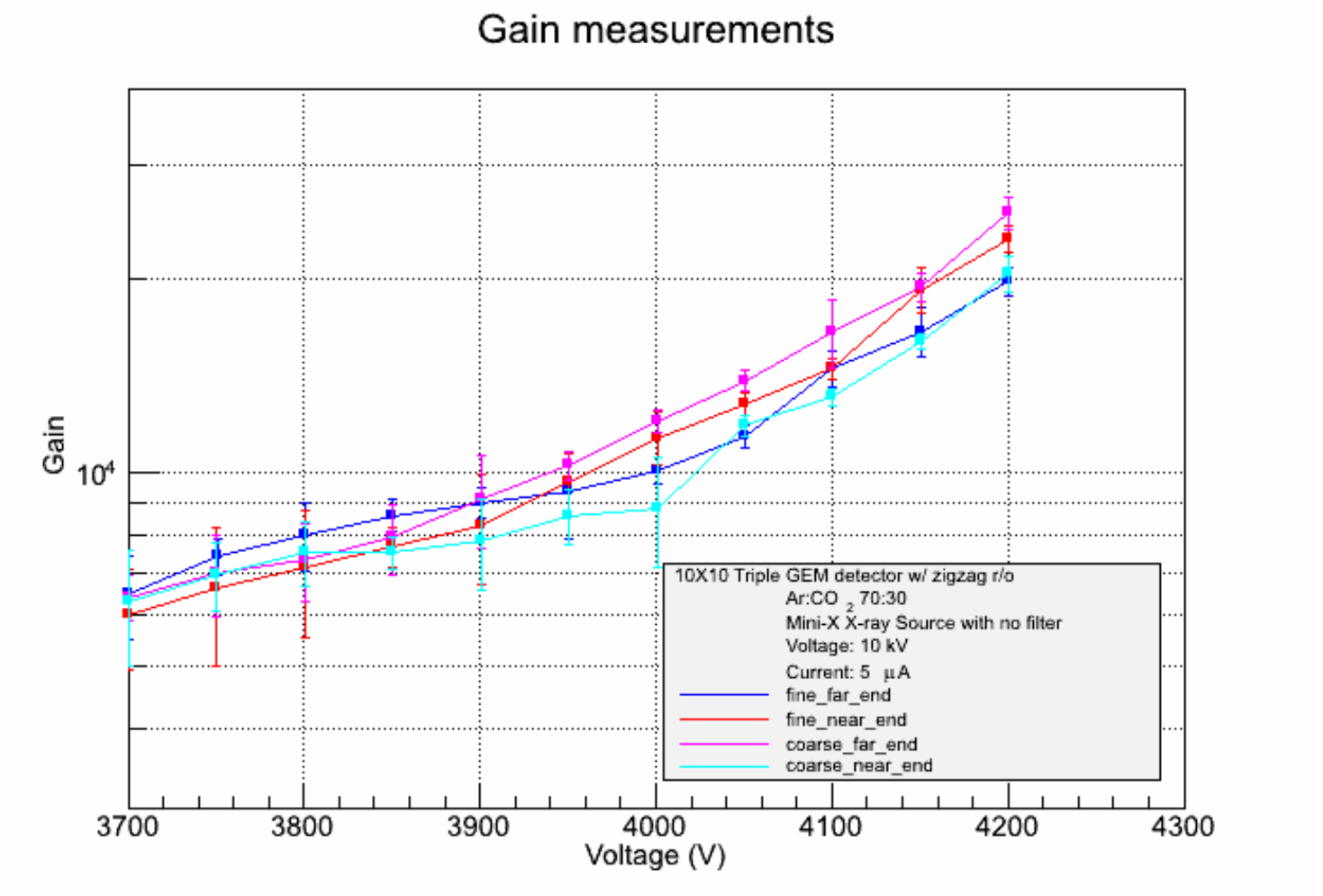
Where, $E_{x\text{-}ray}$ = 6.172keV

(avg energy of the X-ray spectrum for fine_far_end)

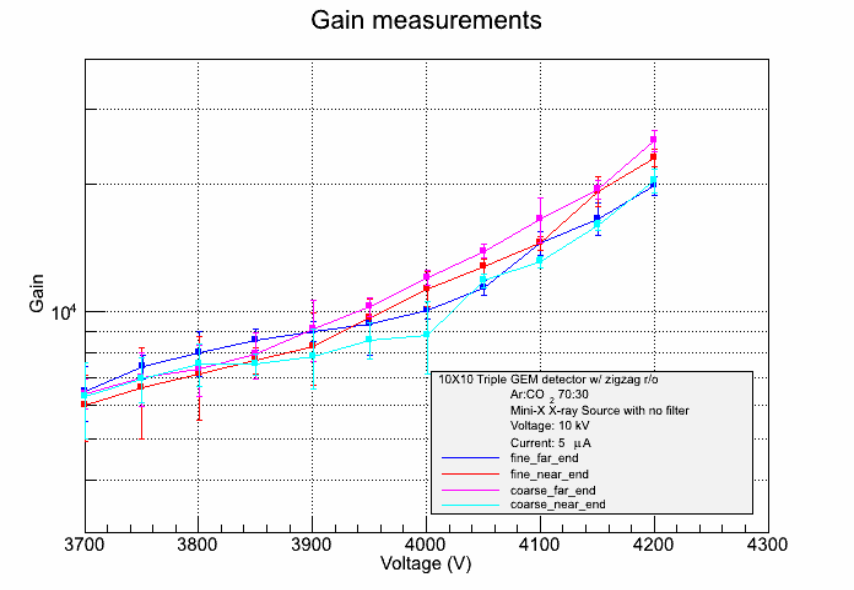
W_i is the effective average energy to produce one ion-electron pair

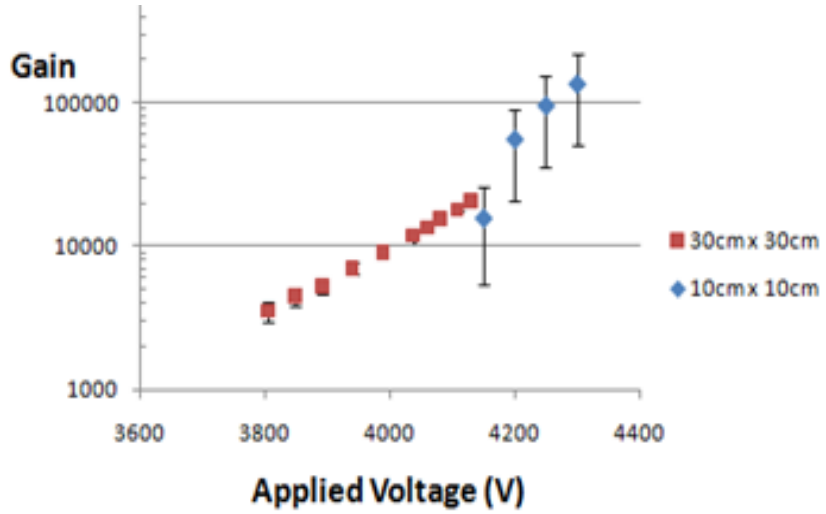
To calculate the gain we consider the rate against voltage from the plateau region. In calculation, we used the rate against the 4150V

Gain Plots


Gain measurements
Gain
10^4
3700
3800
3900
4000
4100
4200
4300
Voltage (V)
10X10 Triple GEM detector w/ zigzag r/o
Ar:CO $_2$ 70:30
Mini-X X-ray Source with no filter
Voltage: 10 kV
Current: 5 μA
fine_far_end
fine_near_end
coarse_far_end
coarse_near_end

Gain Plots





Source: Amilkar Alejandro Quintero Segovia (FIT) Master's Thesis

- Gain of the detector with zigzag readout strips is on the order of 10^4-10^5 (same with straight readout strips)

Conclusion

- From our gain calculation, it is clear that the gain doesn't change by changing the readout out system.
- In addition to the gain, zigzag readout strips provide better resolution almost by factor of 3-4
- Finally less number of readout strips and hence, less is the cost associated with it. Therefore, by considering the detector's performance and cost associated with it, we can say that the replacement of straight strip readout board with zigzag readout is beneficial!

Future Plan

- After having success with proto type 10×10 triple GEM detector, we are planning to build zigzag readout system for our 30×30 detector
- Currently undergraduate students in our research group are working on its designing part.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Thank you!