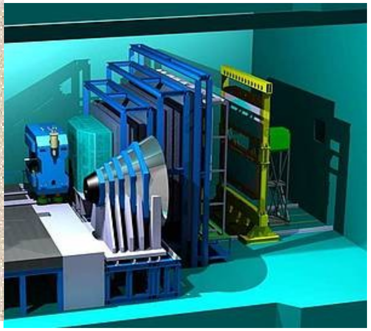
Testing of large size triple GEM detector with Pb+Pb collisions at CERN-SPS and GEM test at VECC



Ajit Kumar

VECC Kolkata

CBM-INDIA Meeting
Feb 15-17, 2018
Falta, West Bengal INDIA

Date : 16/02/2018

Plan of the talk

- CBM experiment
- Motivation of test beam
- Schematic of experimental setup
- Data taking
- Straight line track fitting

GEM detector testing at VECC lab

- GEM detector integration with sts-XYTER
  ---> Preliminary test
- Assembly and Testing of large size (Mv2a/b) with Fe^{55} at VECC lab for mcbm experiment
- Efficiency measurement of 10x10 cm^2 triple GEM detector with beta source (Sr^{90}) at VECC
  ---> Schematic, data analysis and results
- Testing 31x31 cm^2 triple GEM with independent power supply
  ---> Schematic and results

SPS CERN 2016 test beam members

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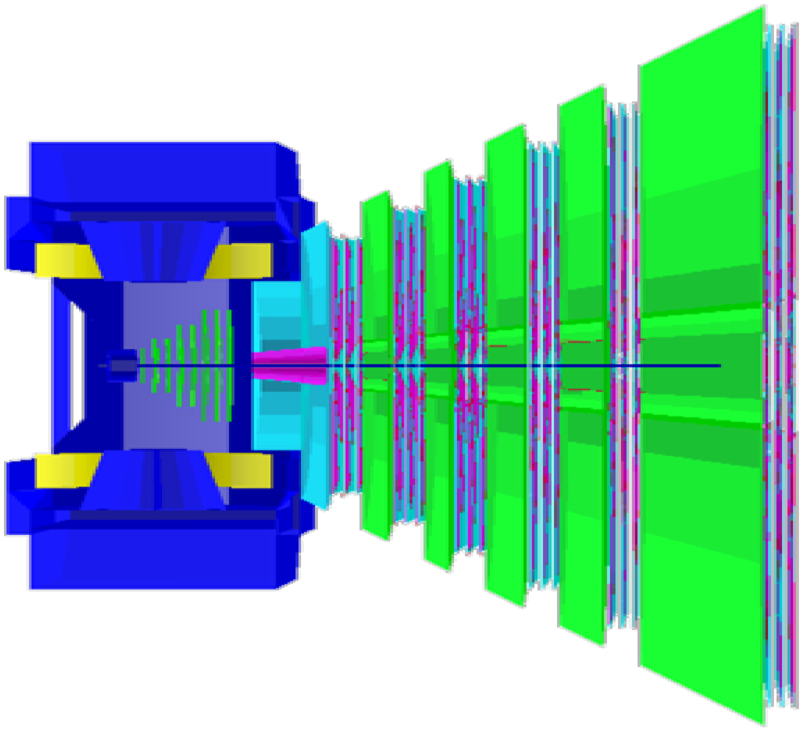
CBM experiment

Compressed Baryonic Matter (CBM) experiment is a fixed target heavy ion experiment

Aim is to measure dimuon arises from:

1. Low mass vector messons and
2. Charmonia



Schematic of CBM-MUCH setup

Trapezoidal shaped triple GEM chambers are being developed for dimuon measurement in CBM experiment.

Motivation

- In all the previous beam tests (before SPS CERN 2016) we tested our detector only with single particle beams where tiny area of the detector is illuminated with particle beam
- In Dec 2016 at SPS CERN, for the first time we tested with spray of particles originitating from the Pb+Pb collisions

Highlights :

1. Testing the large size detectors with full coverage.

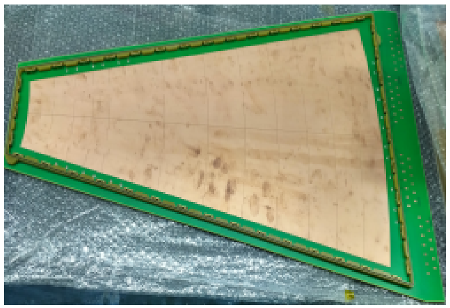
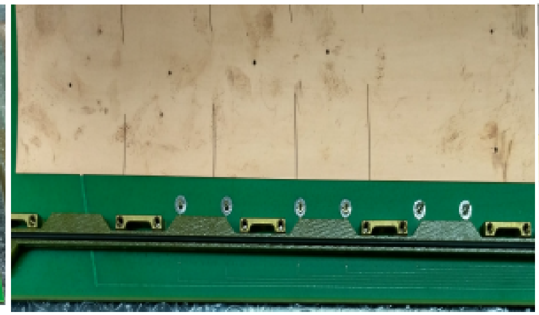
2. New CBM readout chain (including AFCK, FLIB and FLES with new version of electronics (n-XYTER, rev-F).

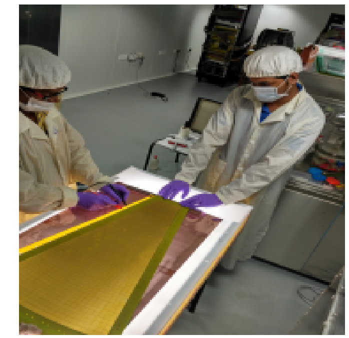
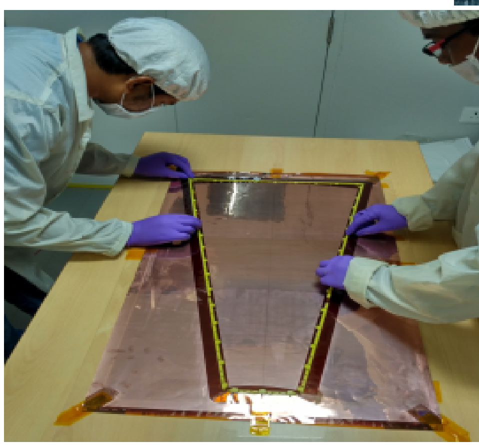
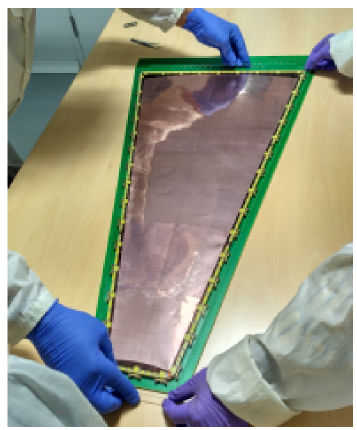
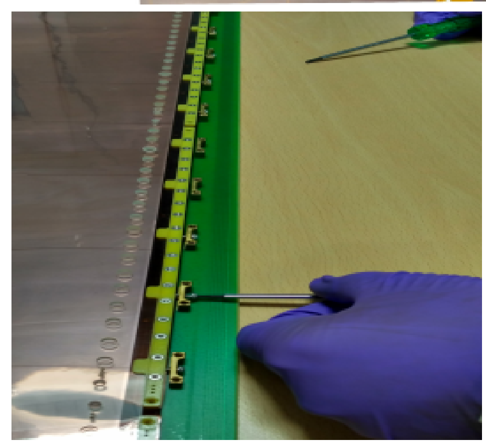
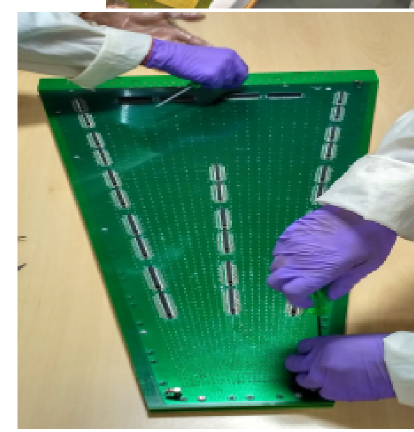
3. Use of water cooling system for the first time

4. Tracking using hits in different GEM planes.

Two large size (Mv1C and Mv1V) and one small size (10 cm x 10 cm) detector were tested ...
--- one assembled at RD51 lab CERN
--- second one assembled at VECC(Thanks to CPDA lab)

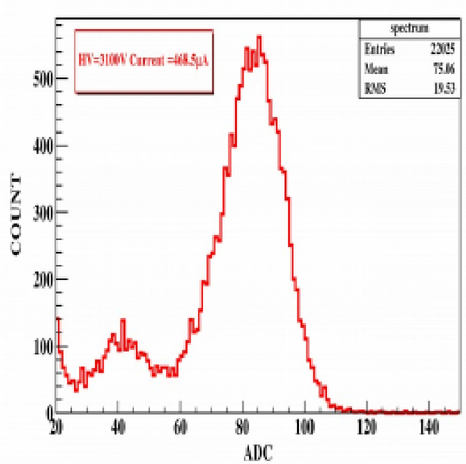
Building first real size trapezoidal shaped triple GEM chamber at VECC (clean room of CPDA lab)

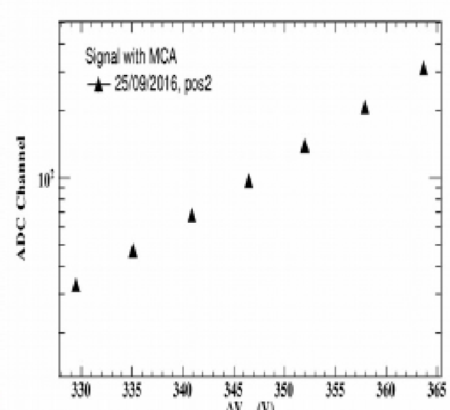






Fe-55

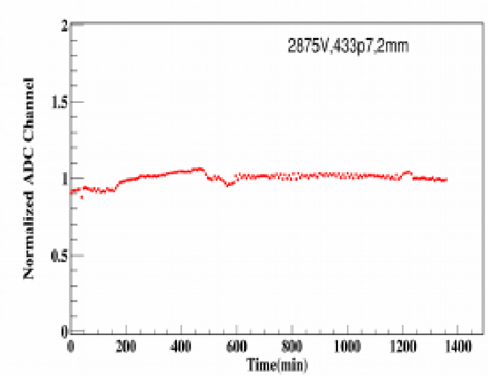
Pulse height spectra of Fe-55 source



Gain variation at different delta V of GEM.



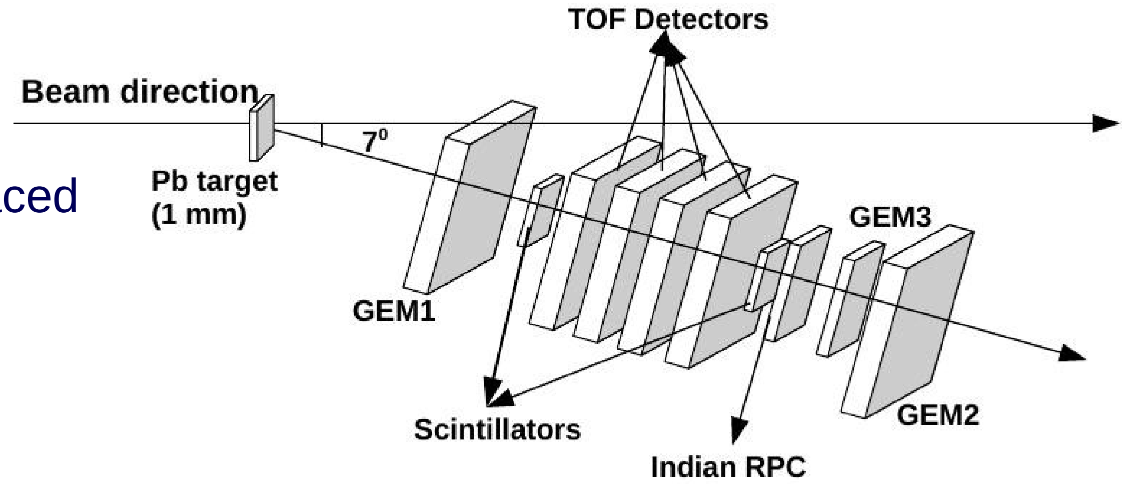
Variation of normalized ADC channel with Time(min).



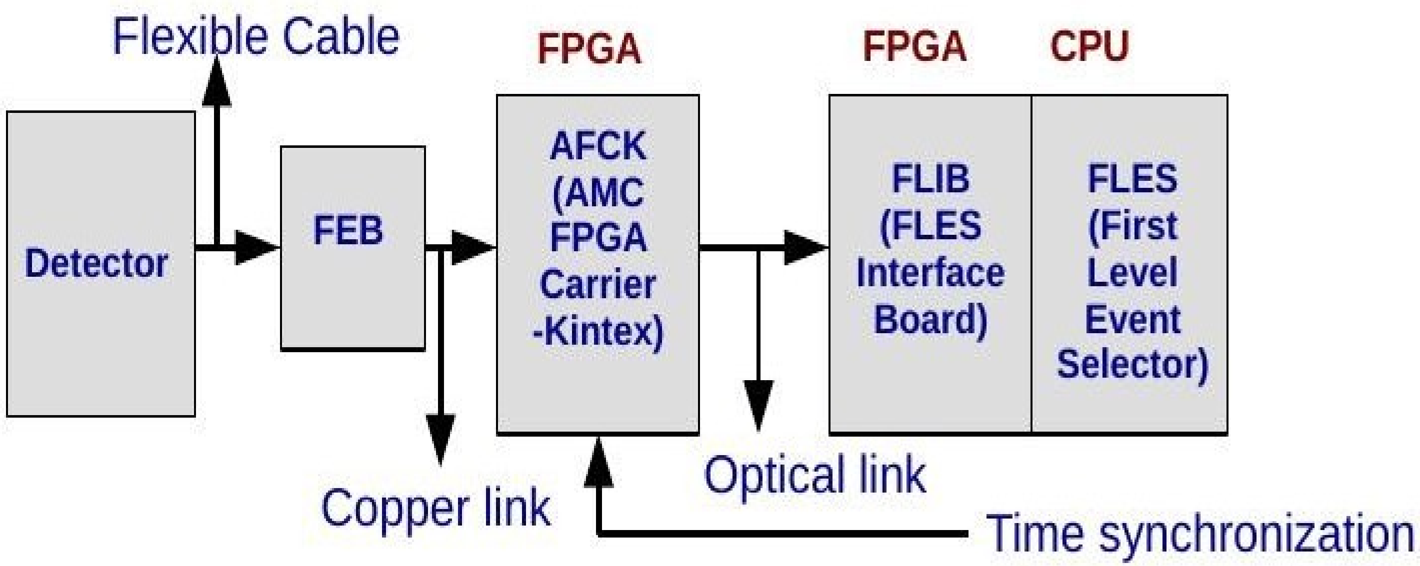
Experimental Setup at CERN SPS

1. Detector setup:

A diamond detector was placed just before the target.



2. Daq setup:



Data taking

Data Taking : Data were taken in 3 phases

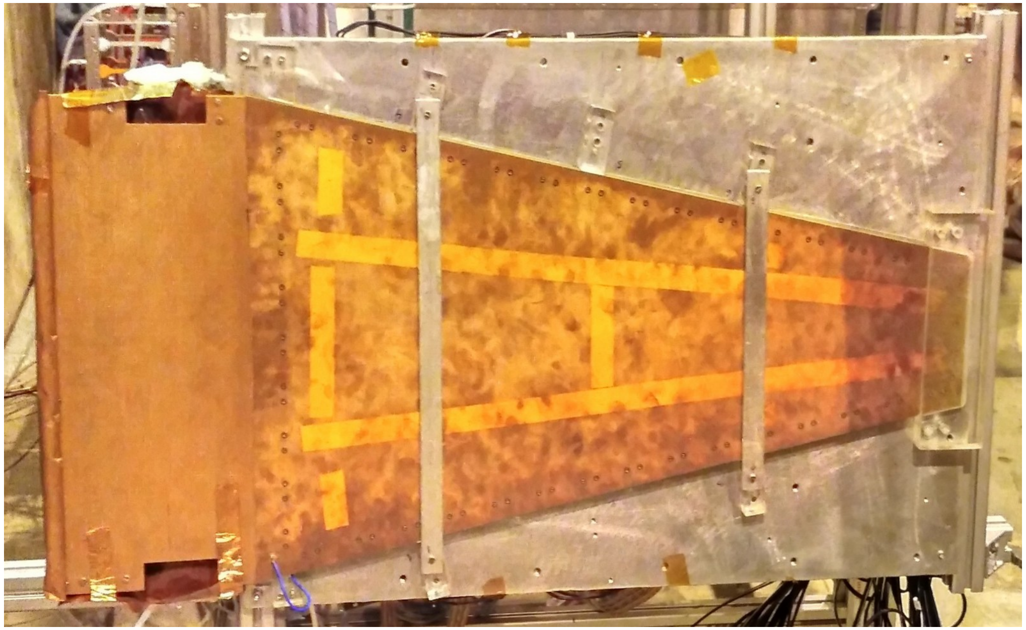
Phase1 : 13 AGeV/c, Pb beam , 1mm thickness Pb target-- Only one large size detector

Phase2 : 30 AGeV/c, Pb beam , 1mm thickness Pb target-- Two large size detector

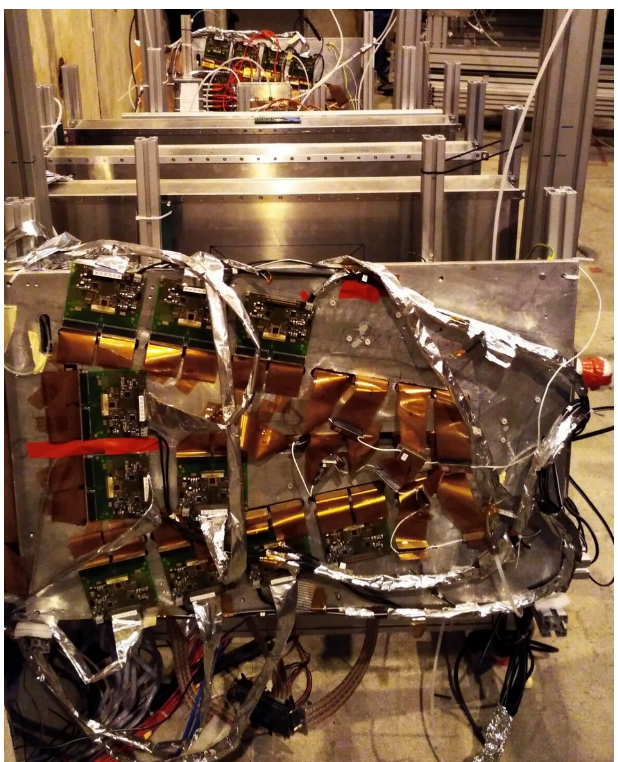
Phase3 : 150 AGeV/c, Pb beam , 1mm thickness Pb target + extra Fe block were used as target to increase the ineraction rate -- Two large size detector + one small (10 cm x 10 cm)

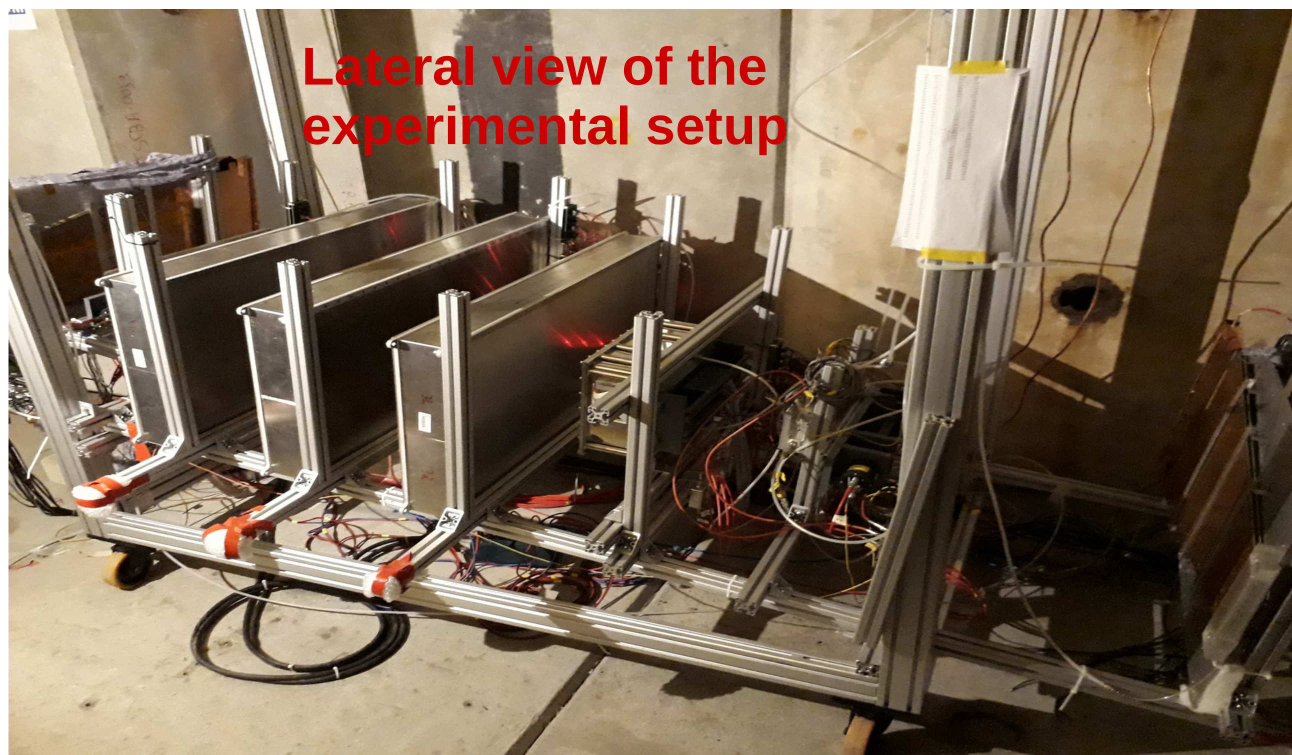
-- we have used two large size triple GEM detectors and one 10 cm x 10 cm detector.

Drift side



Connector side

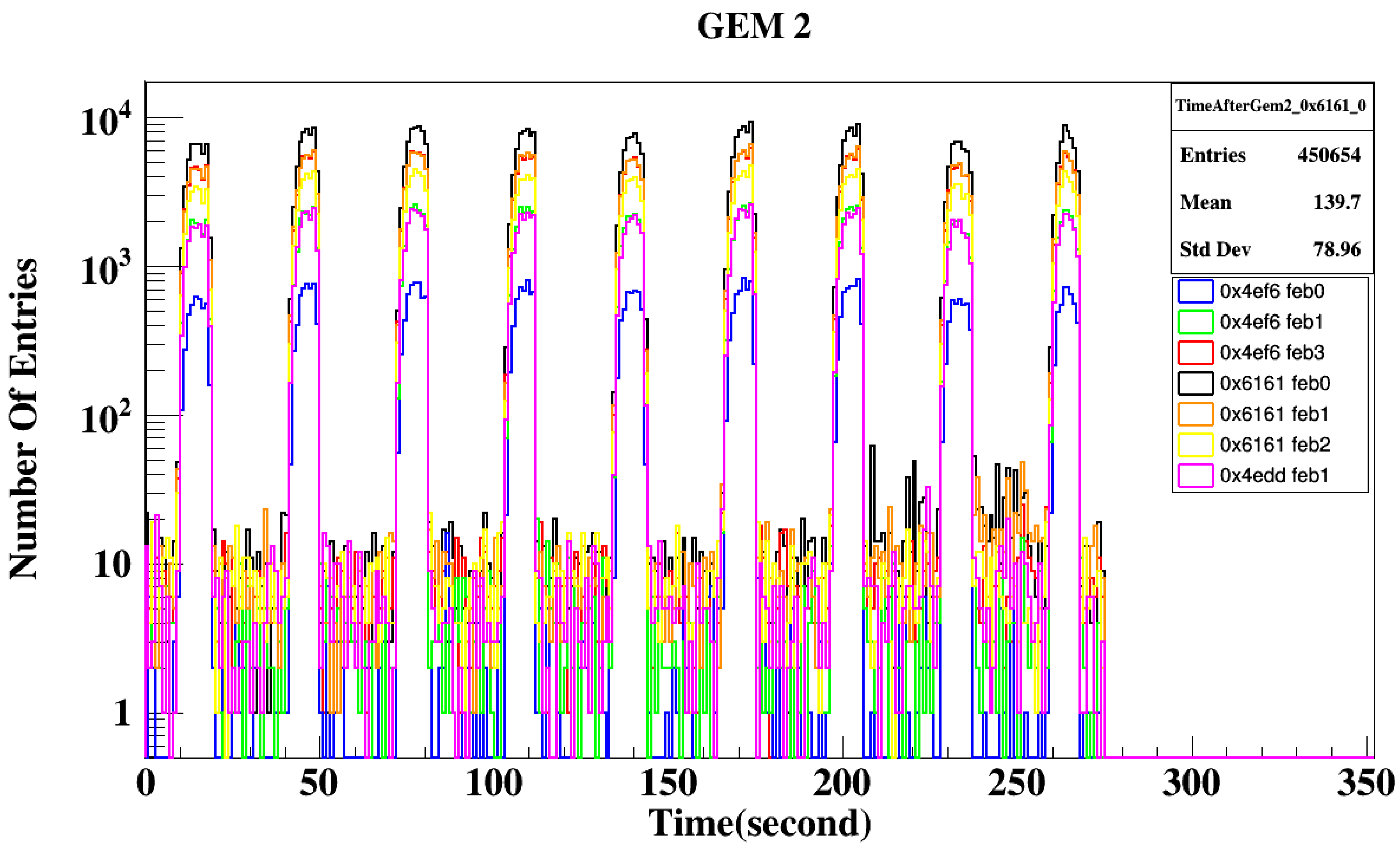




Spill Structure

Phase2, run43

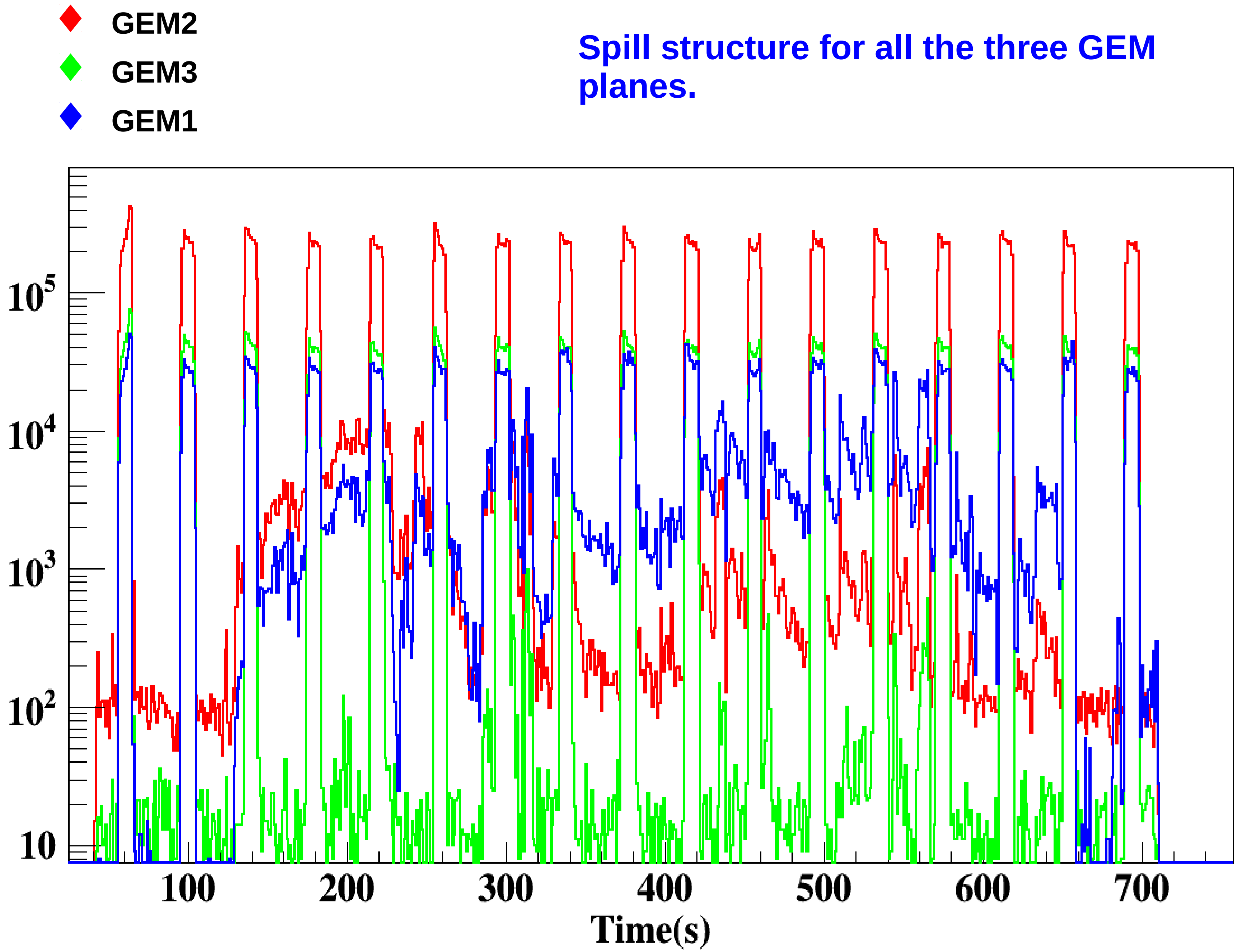
FEB wise hit distribution plot with time



Spill Structure

For phase3, run148
HV GEM1=GEM2 = 3400V, GEM3 =3860V

Spill structure for all the three GEM planes.



Event Reconstruction

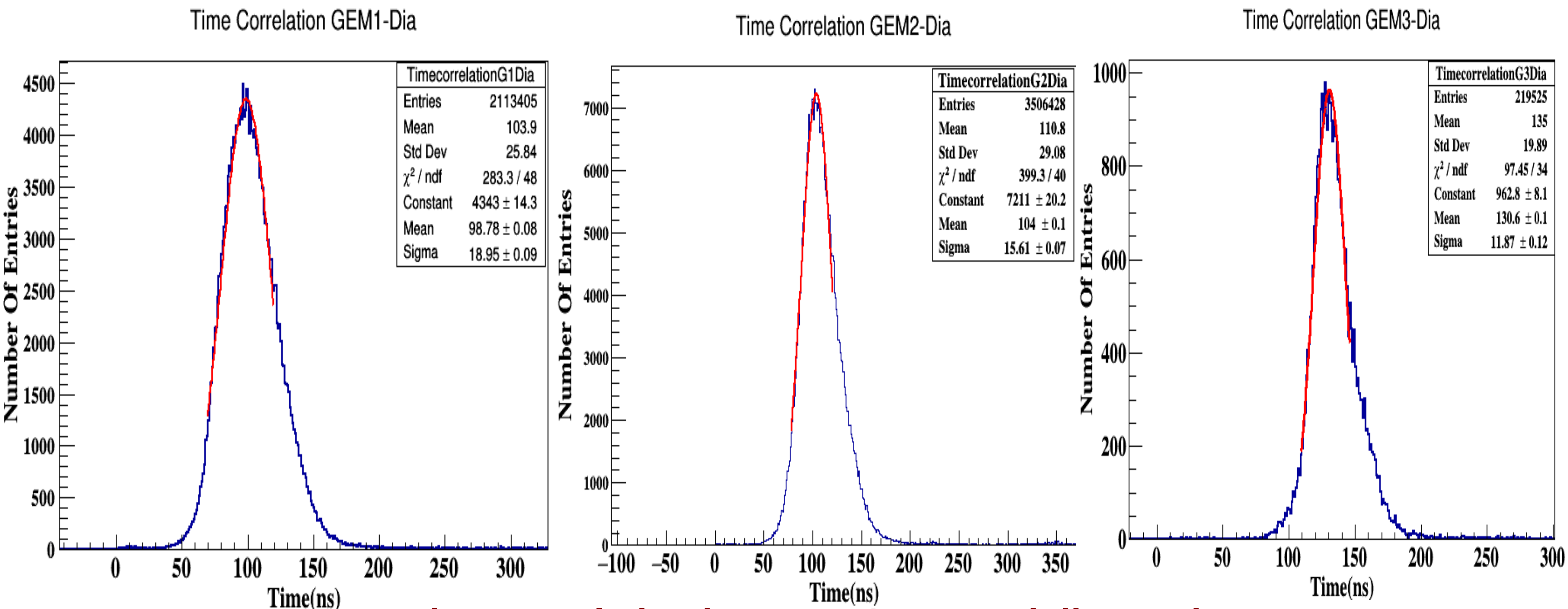
Algorithm:

In Time Slice (size of time slice is 10 ms) ---> Diamond hit as well as GEMs hit

--- we get the data in .tsa formate. We have to first convert to cbmroot format.

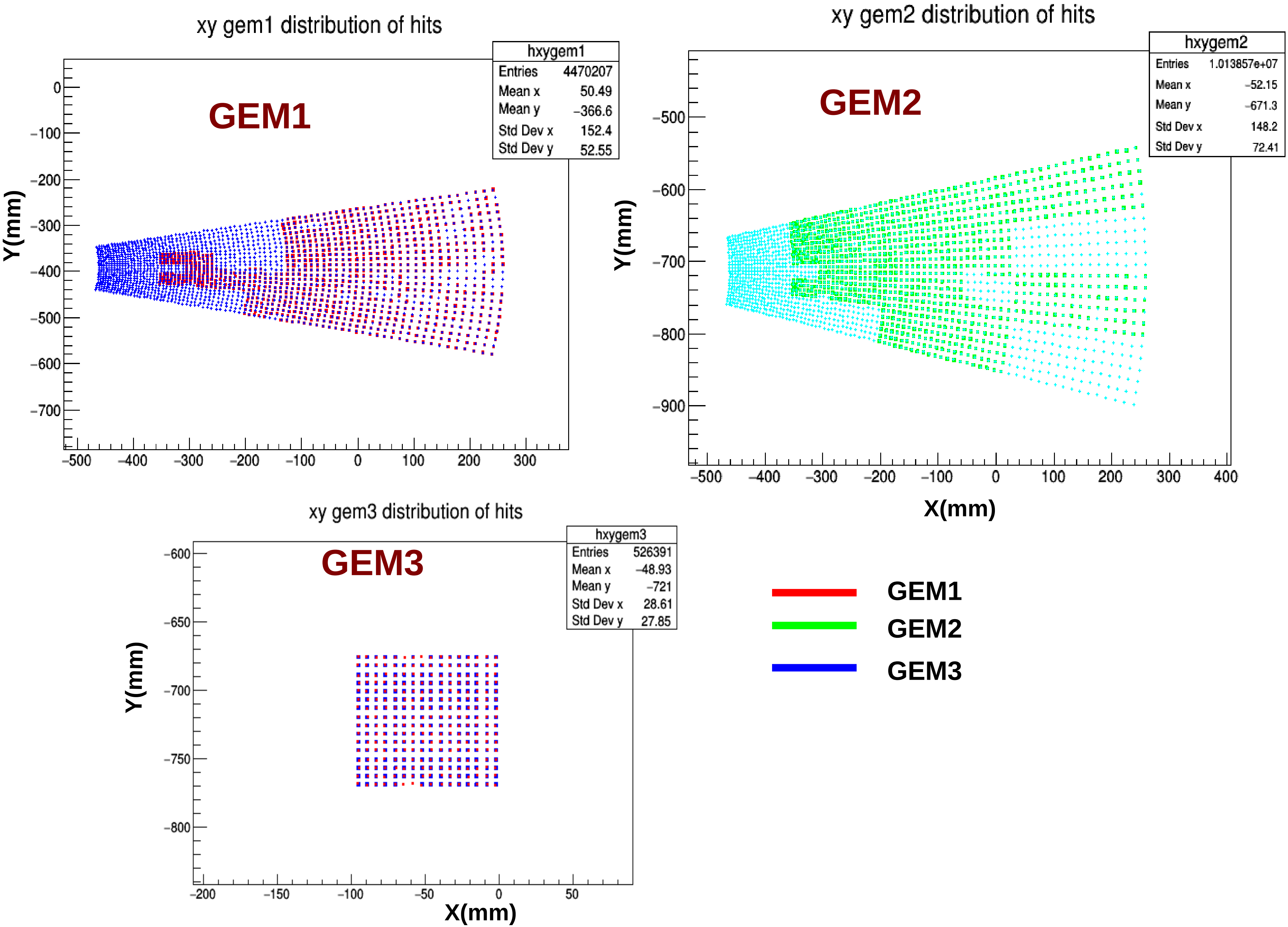
--- Select the GEM hits which lies between two consecutive diamond hit (in time) => **event**

--- This algorithm work if the diamond hits and GEM hits are time synchronised

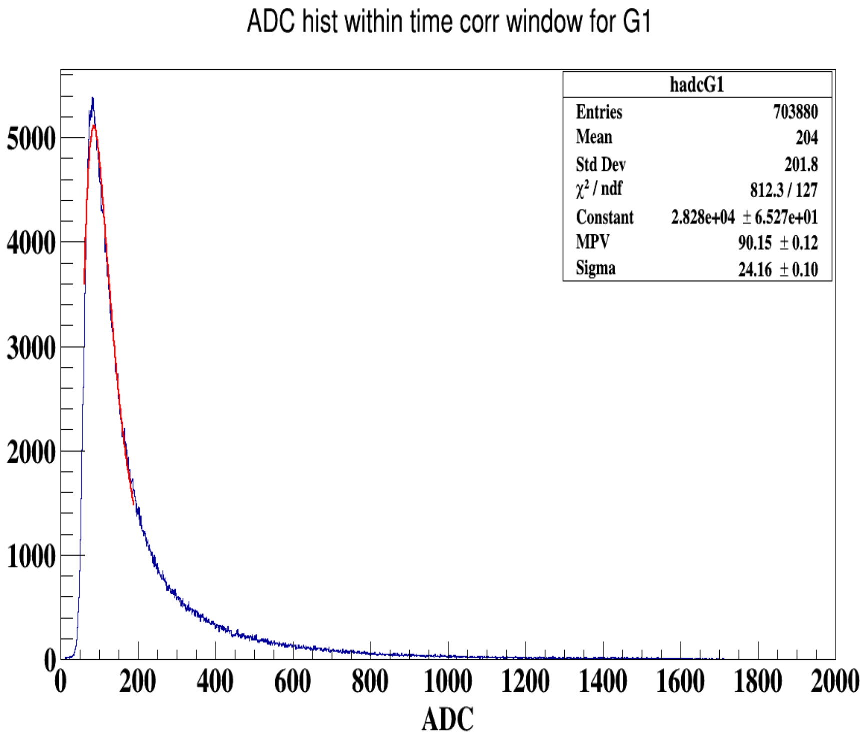


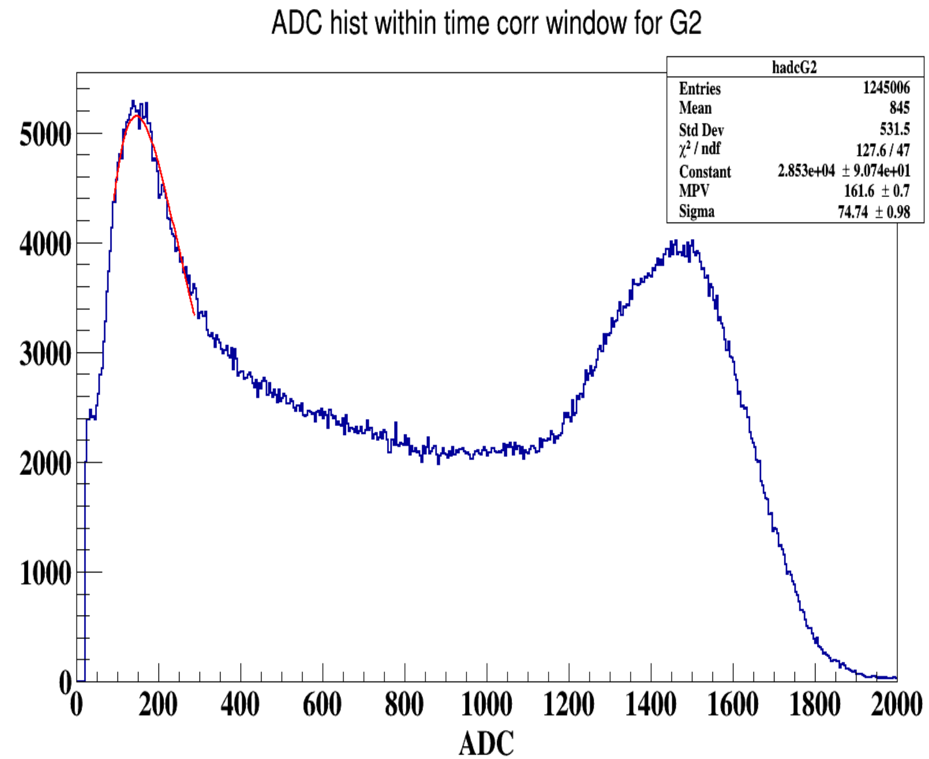
Time correlation between GEMs and diamond

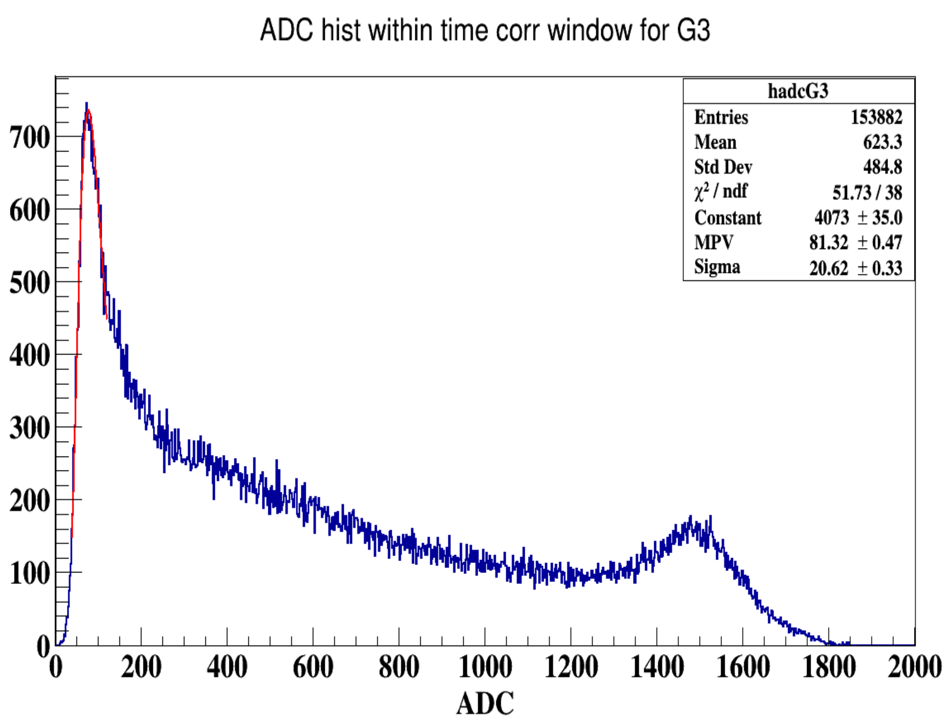
X-Y Hit distribution plot



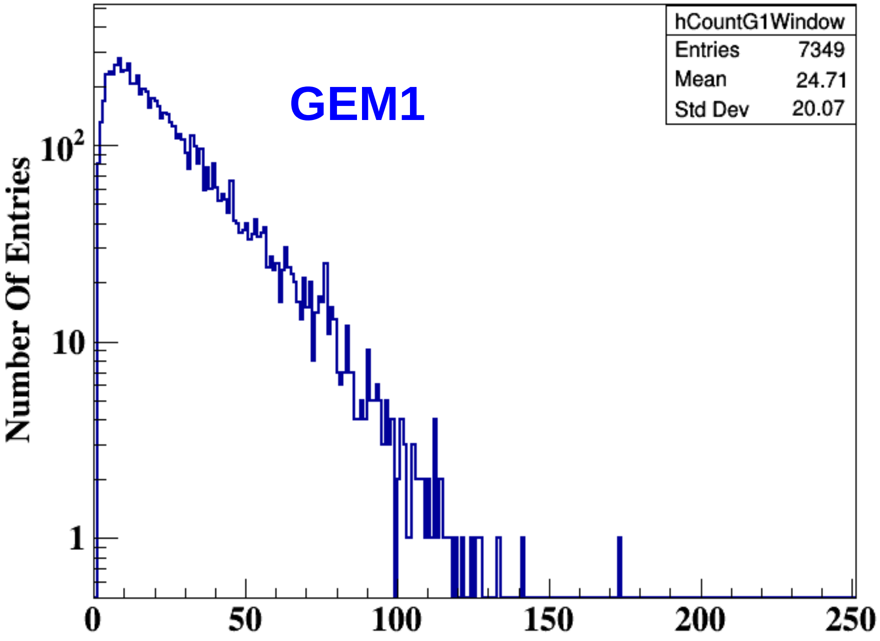
ADC histogram for GEM1 GEM2 and GEM3

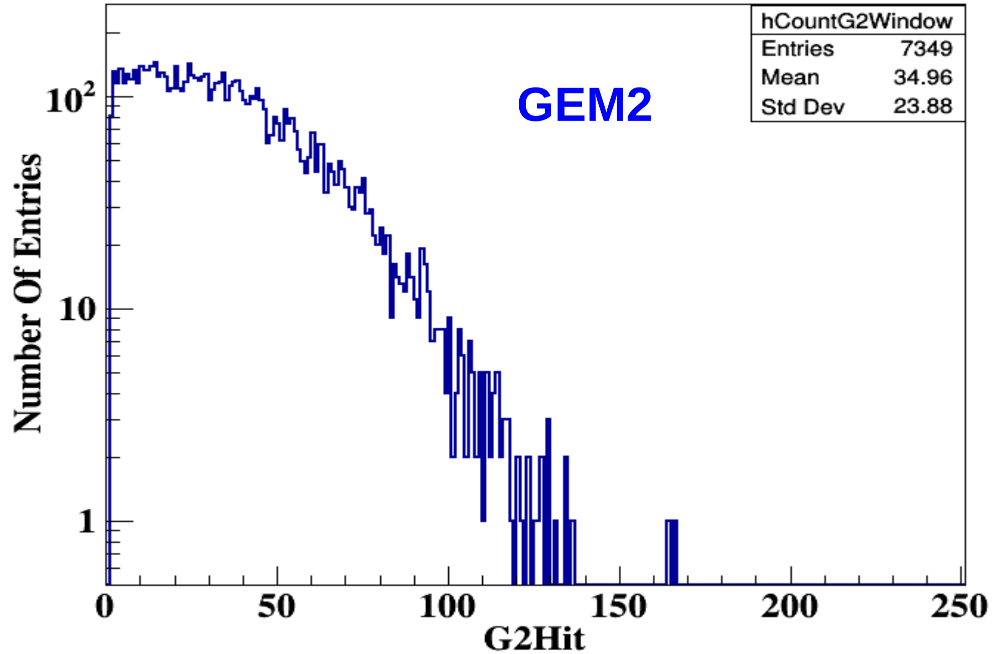


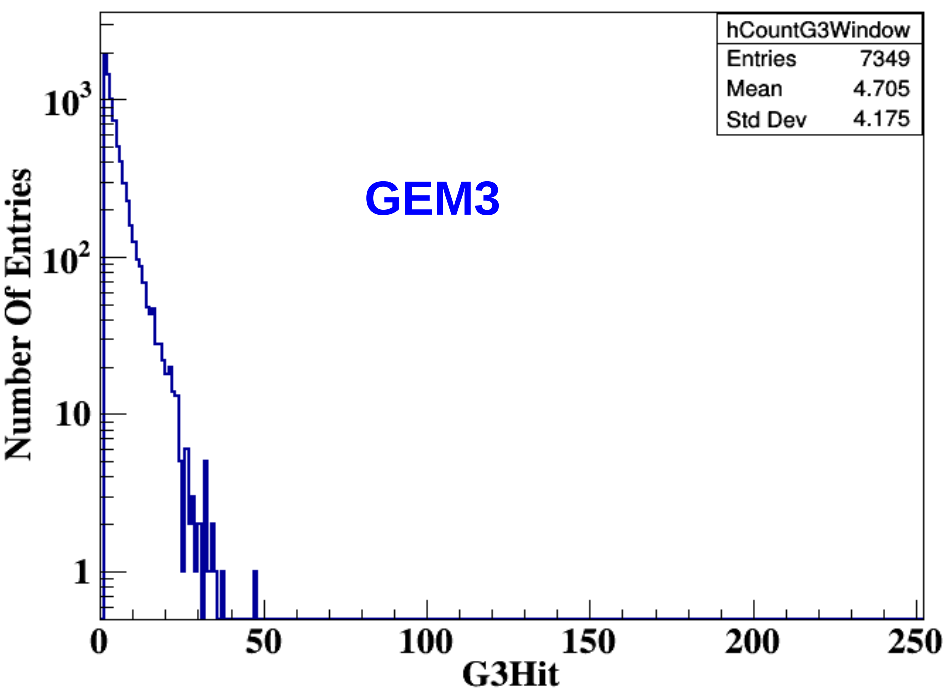




Number of hit/event





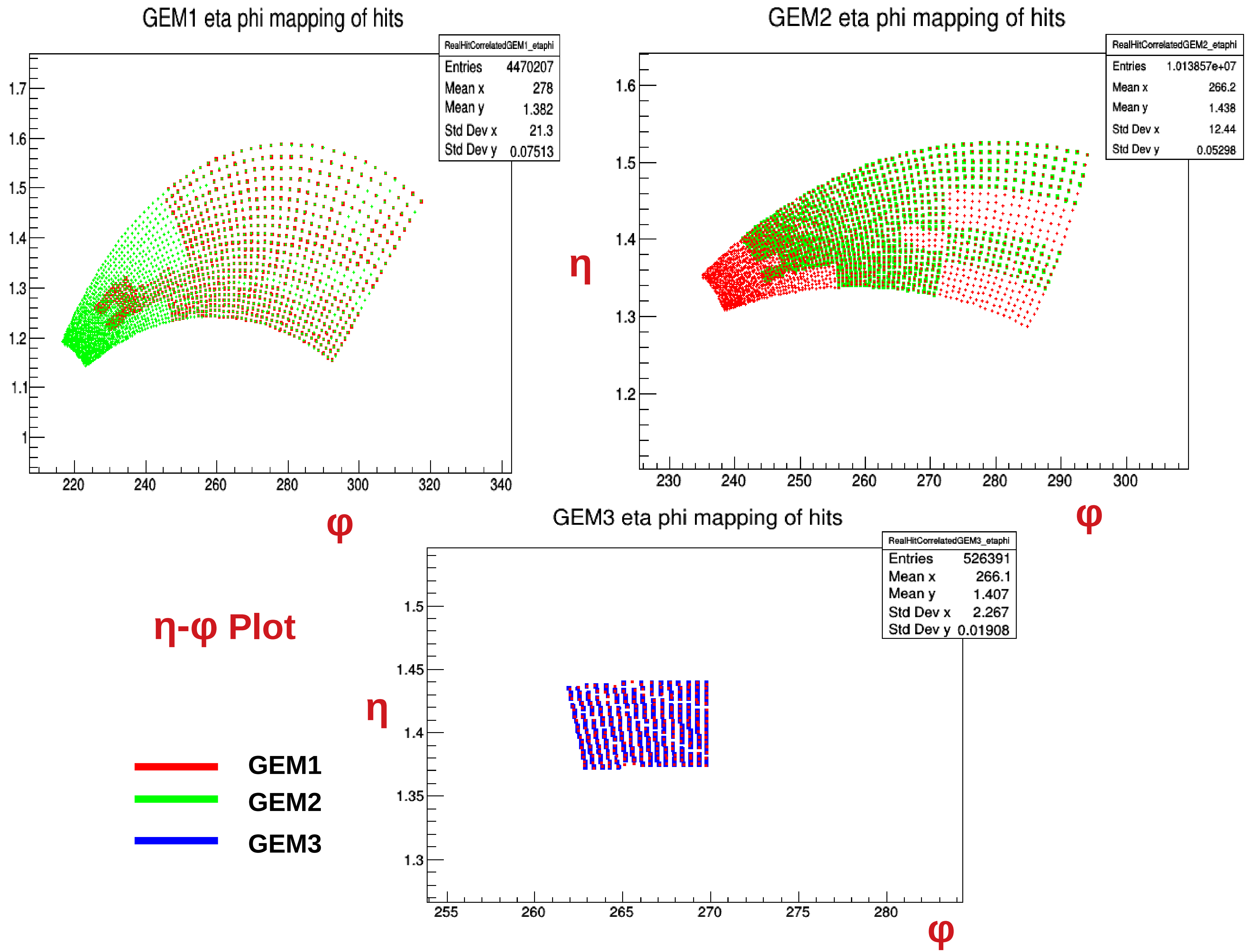


ADC cut in each plane 50

Average number of hits/event in each plane

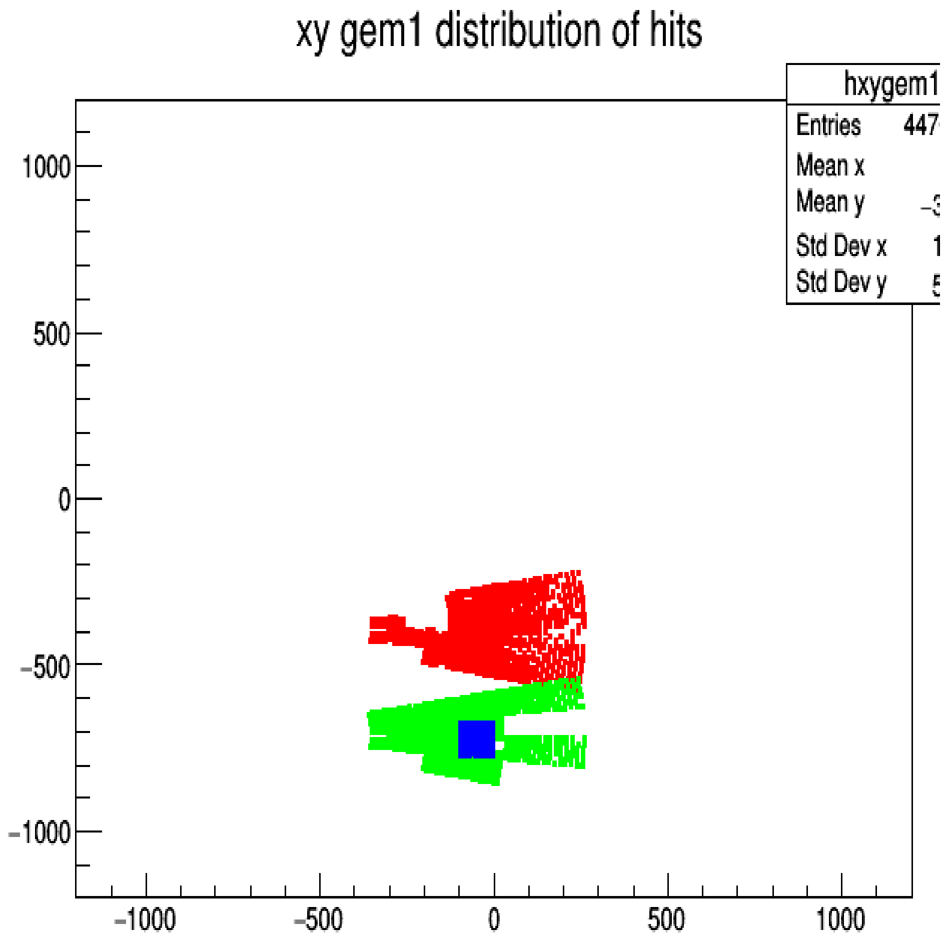
Adc cut	G1	G2	G3 (10 cm x 10 cm)
0	25.02	35.98	4.9
30	24.77	35.41	4.87
50	24.55	35.14	4.83
80	22.86	34.79	4.62
100	21.36	33.71	4.48
150	18.67	32.03	4.24
200	17.04	30.49	4.09

Average number of hit per event for three different GEM plane at various baseline ADC substracted cut.

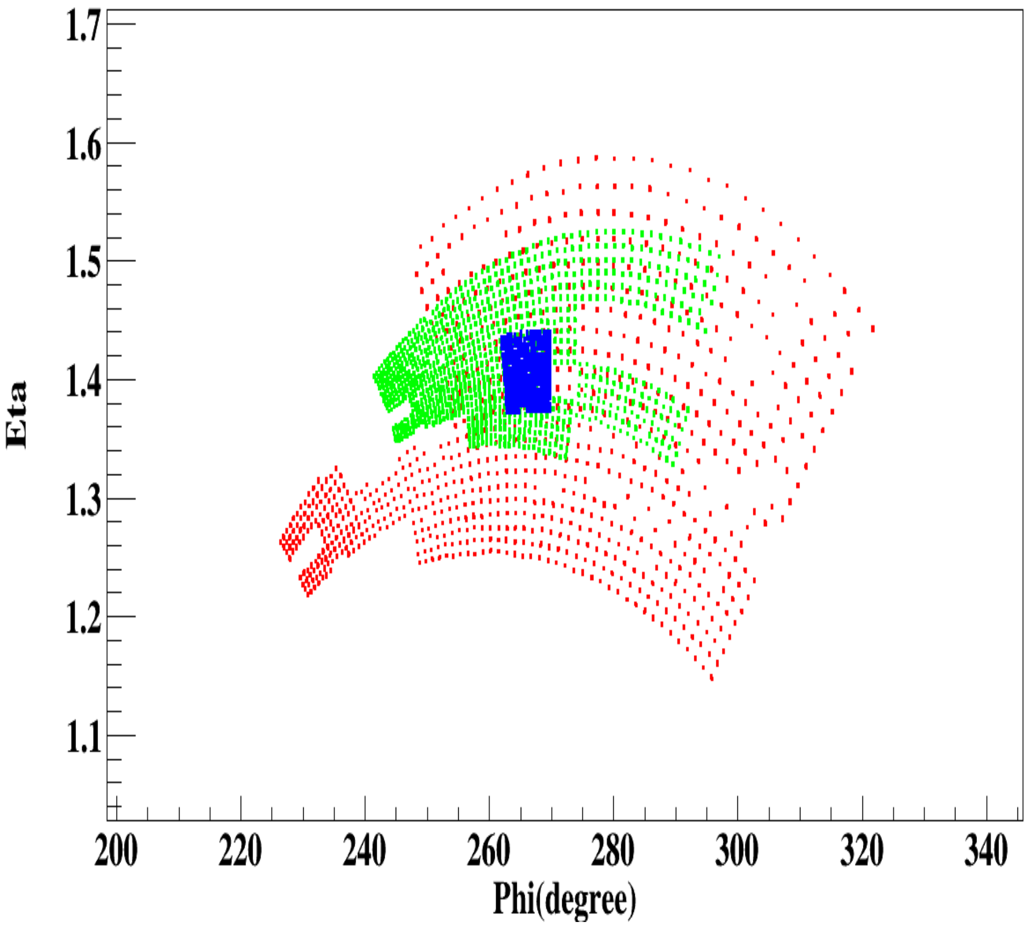

GEM1 eta phi mapping of hits
RealHitCorrelatedGEM1_etaphi
Entries 4470207
Mean x 278
Mean y 1.382
Std Dev x 21.3
Std Dev y 0.07513
GEM2 eta phi mapping of hits
RealHitCorrelatedGEM2_etaphi
Entries 1.013857e+07
Mean x 266.2
Mean y 1.438
Std Dev x 12.44
Std Dev y 0.05298
GEM3 eta phi mapping of hits
RealHitCorrelatedGEM3_etaphi
Entries 526391
Mean x 266.1
Mean y 1.407
Std Dev x 2.267
Std Dev y 0.01908
η
φ
η-φ Plot
GEM1
GEM2
GEM3

X-Y and η-φ plot

X-Y Plot



η-φ Plot



GEM1

GEM2

GEM3

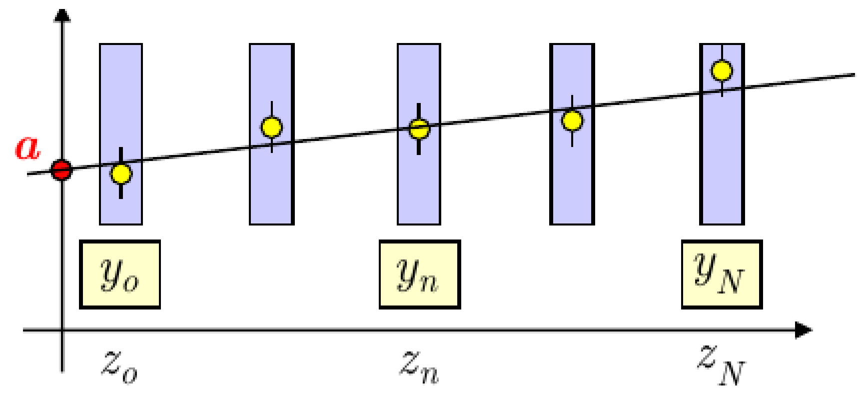
Straight line tracking algorithm

N+1 measuring detetectors at $z_0, \ldots, z_n, \ldots, z_N$

a particle crossing the detectors

N+1 coordinate measurements $y_0, \ldots, y_n, \ldots, y_N$

each measurement affected by uncorrelated errors $\sigma_0, \ldots, \sigma_n, \ldots, \sigma_N$



Find the best line $y = a + b\ z$ that fit the track

$$\chi^2 = \sum_{n=0}^{N} \frac{(y_n - a - bz_n)^2}{\sigma_n^2}$$

The solution is found by minimizing the χ^2

$$a = (S_y S_{zz} - S_z S_{zy}) / D$$

$$b = (S_1 S_{zy} - S_z S_y) / D$$

$$S_1 = \sum_{n=0}^{N} \frac{1}{\sigma_n^2} \qquad S_y = \sum_{n=0}^{N} \frac{y_n}{\sigma_n^2}$$

$$S_z = \sum_{n=0}^{N} \frac{z_n}{\sigma_n^2} \qquad S_{yz} = \sum_{n=0}^{N} \frac{y_n z_n}{\sigma_n^2}$$

$$S_{zz} = \sum_{n=0}^{N} \frac{z_n^2}{\sigma_n^2} \qquad D = S_1 S_{zz} - S_z S_z$$

Similarly for the x-cordinate.

ADC cut:

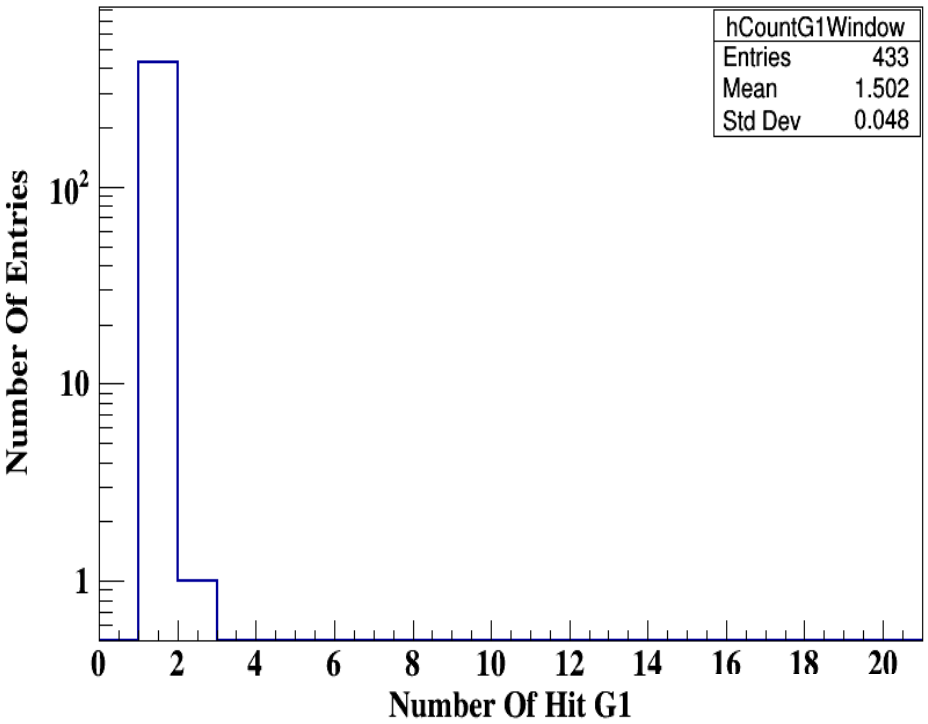
GEM1 : 50 adc channel
GEM2 : 100 adc channel
GEM3 : 100 adc channel

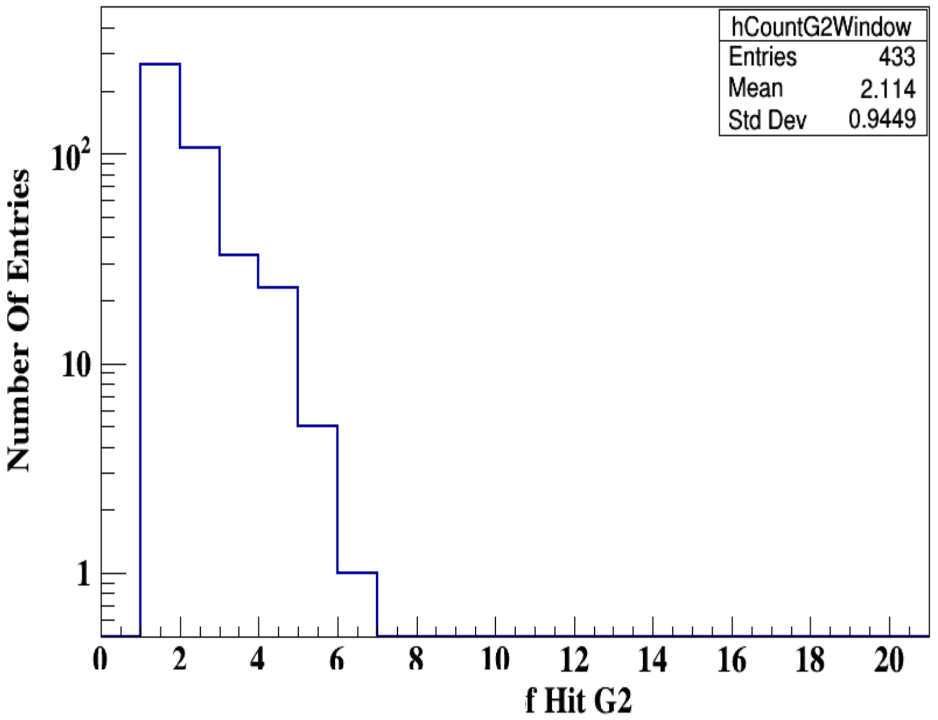
η-φ selection

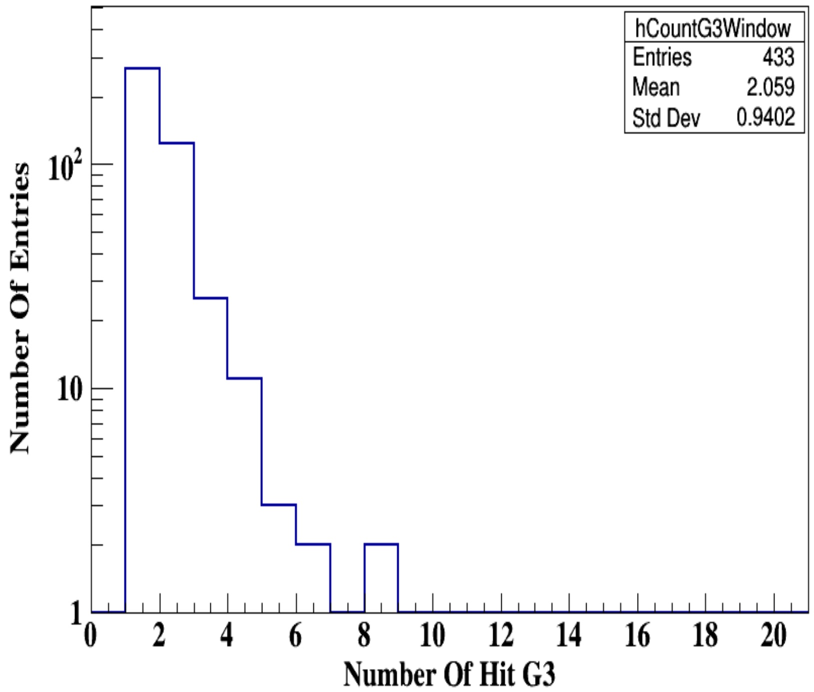
η-φ cut for all planes
$1.37 < \eta < 1.40$
$264 < \varphi < 266$

http://www.le.infn.it/lhcschool/talks/Ragusa.pdf

Number of hit/event in each plane within given η-φ window







ADC cut:

GEM1 : 50 adc channel

GEM2 : 100 adc channel

GEM3 : 100 adc channel

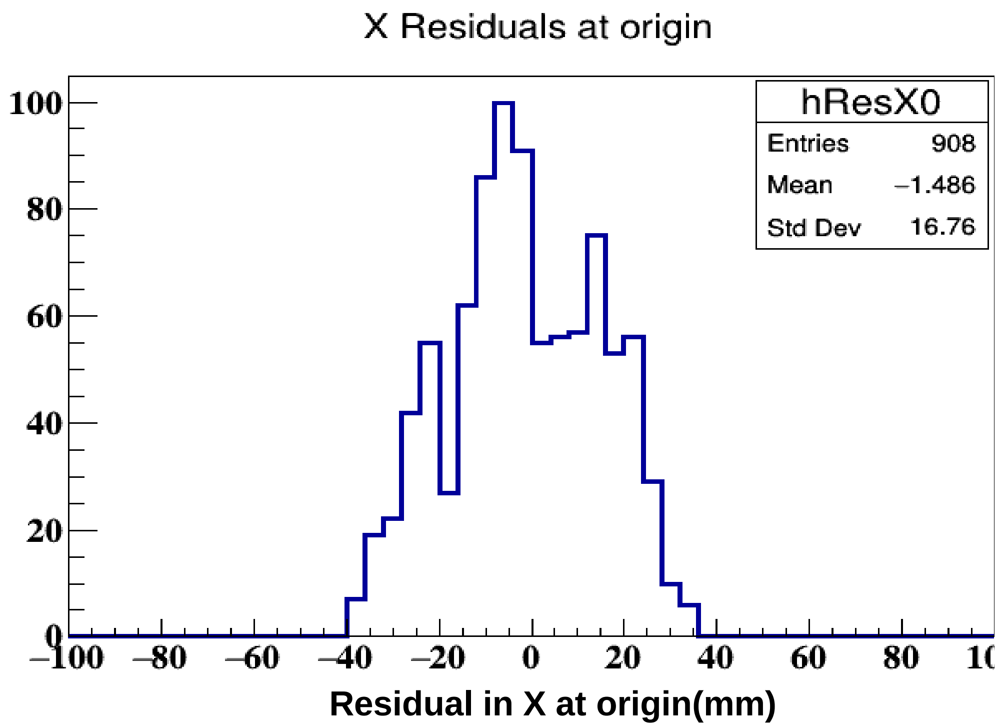
η-φ selection

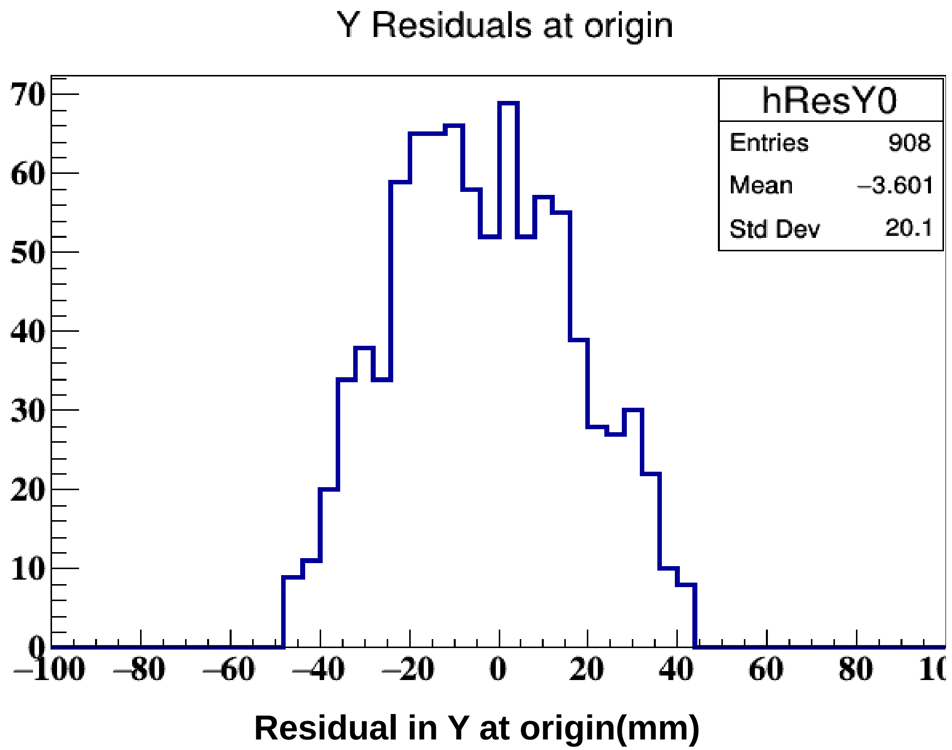
η-φ cut for all planes

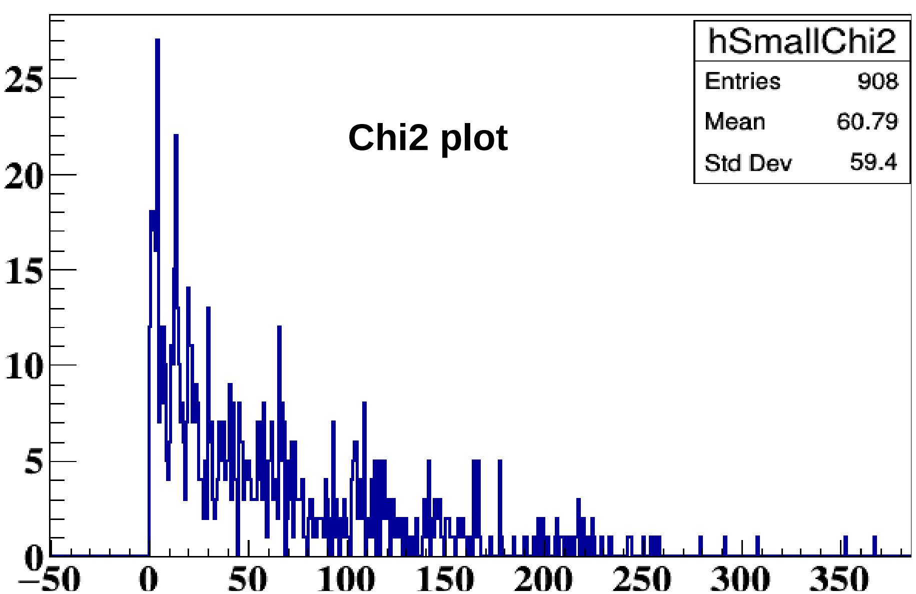
1.37<η<1.40

264<φ<266

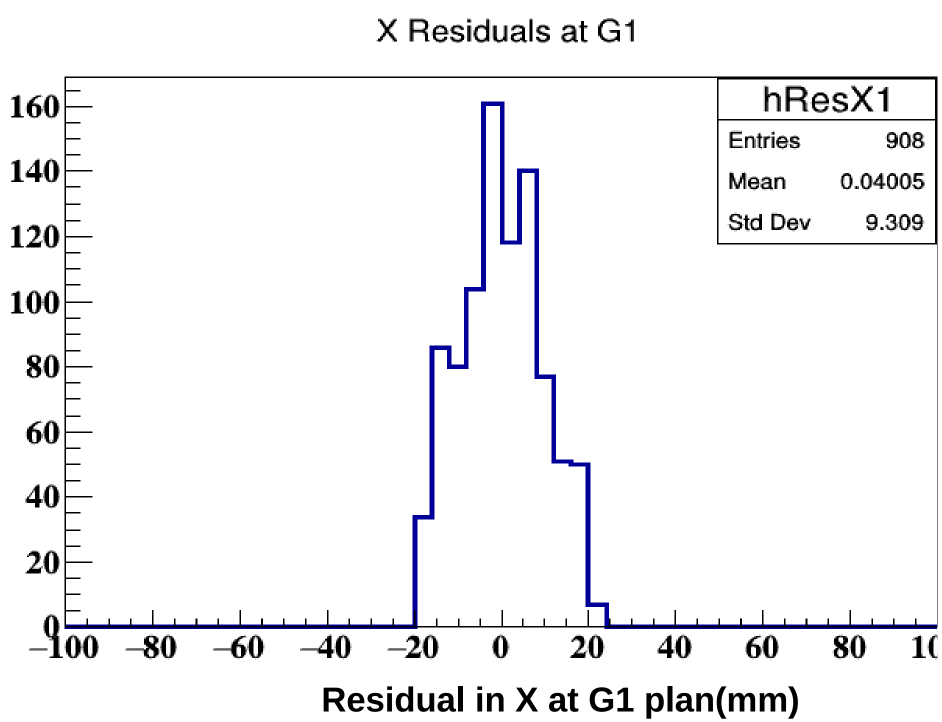
Residuals at origin (origin is not considered for chi2 minimization)

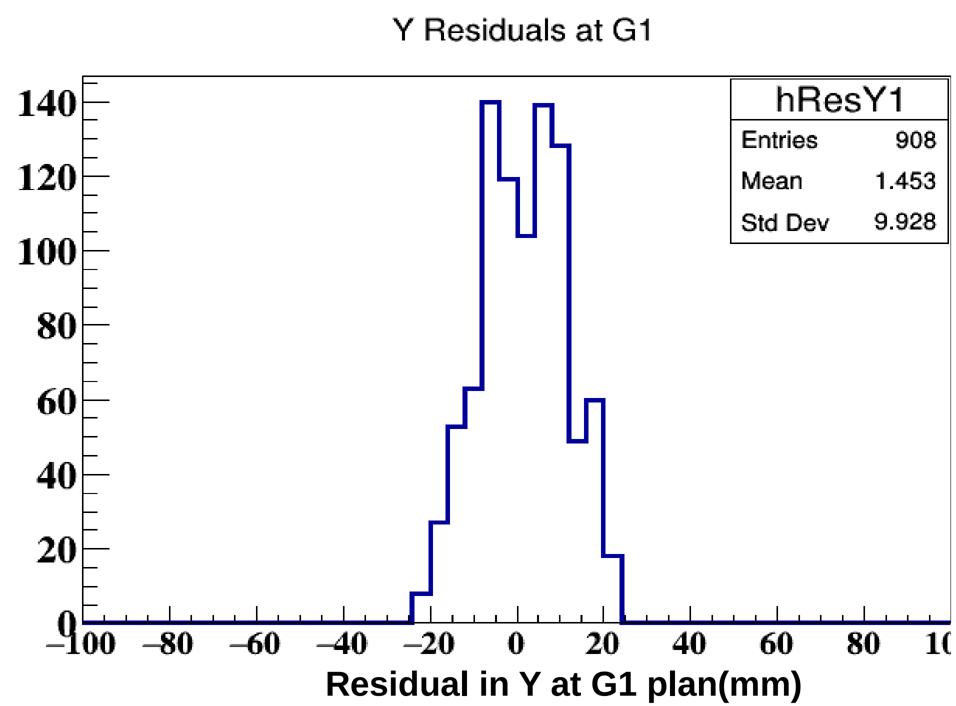


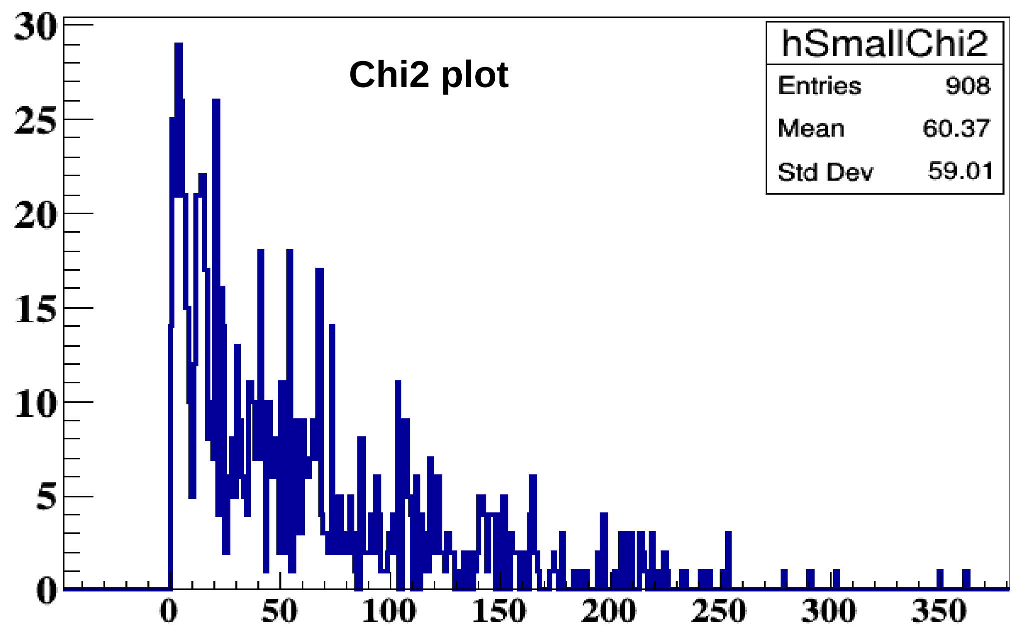




Residuals at GEM1 plane (GEM1 is not considered for chi2 minimization)



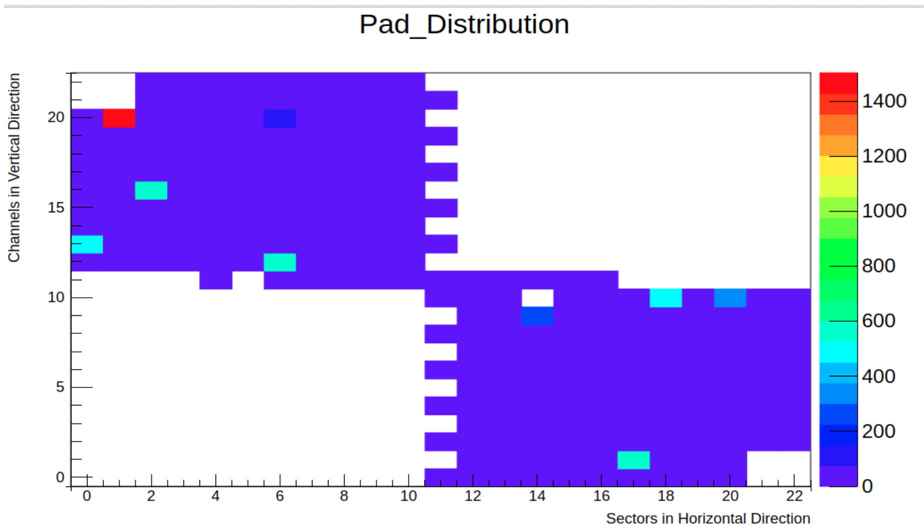




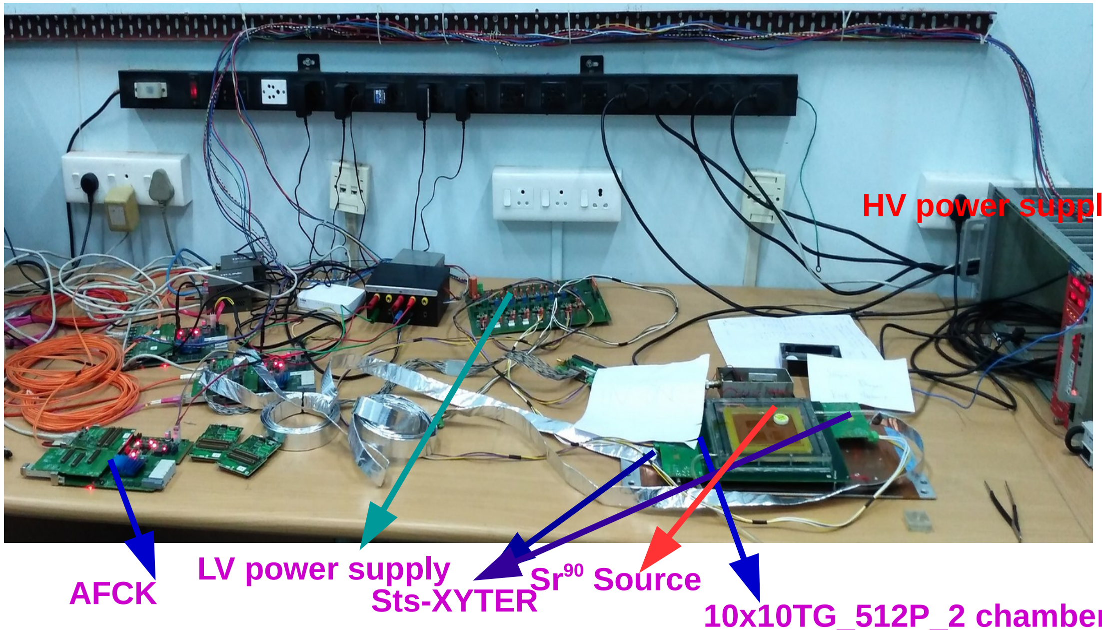
GEM detector test at VECC

Detector integration with sts-XYTER

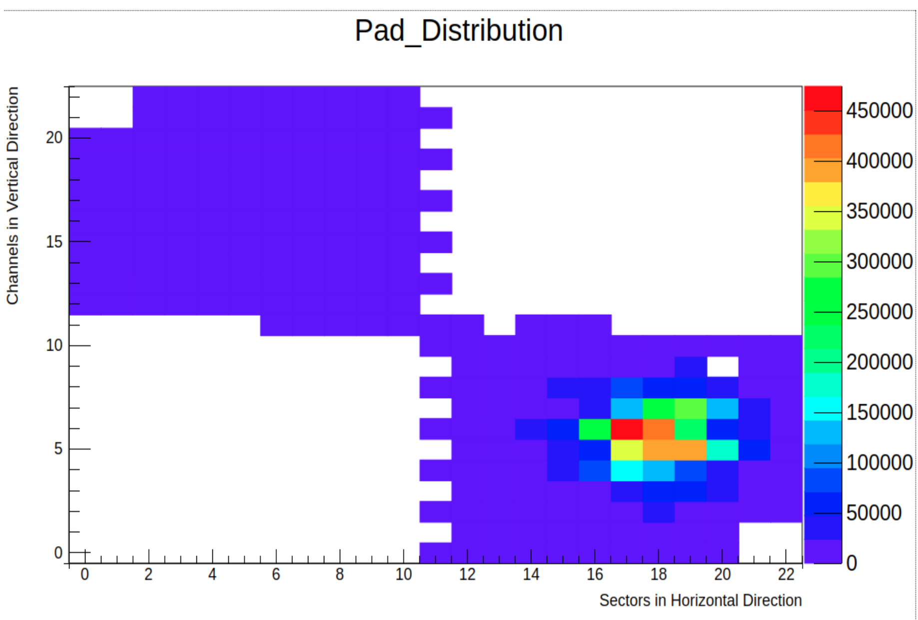
Without Source



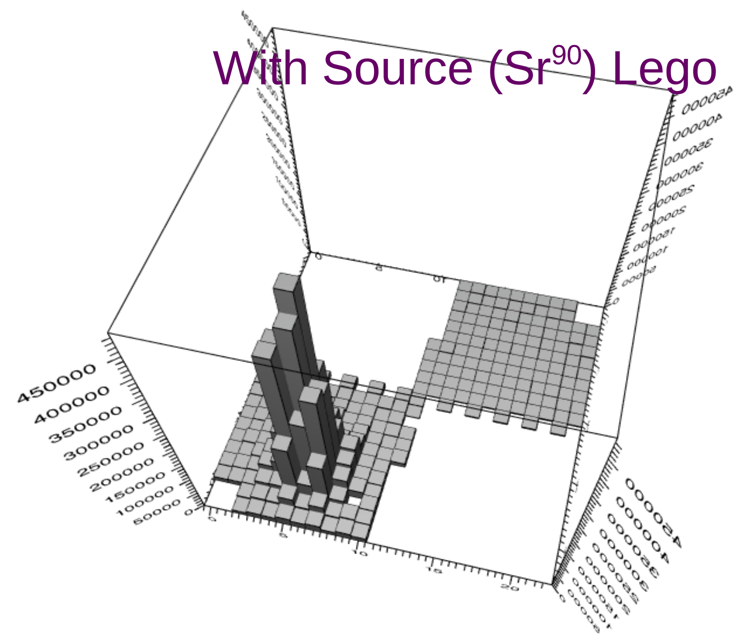
Picture of setup



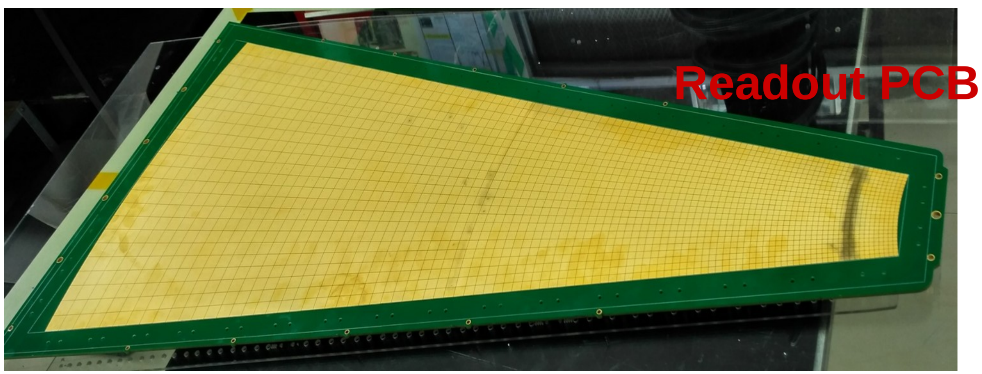
With Source (Sr^{90})

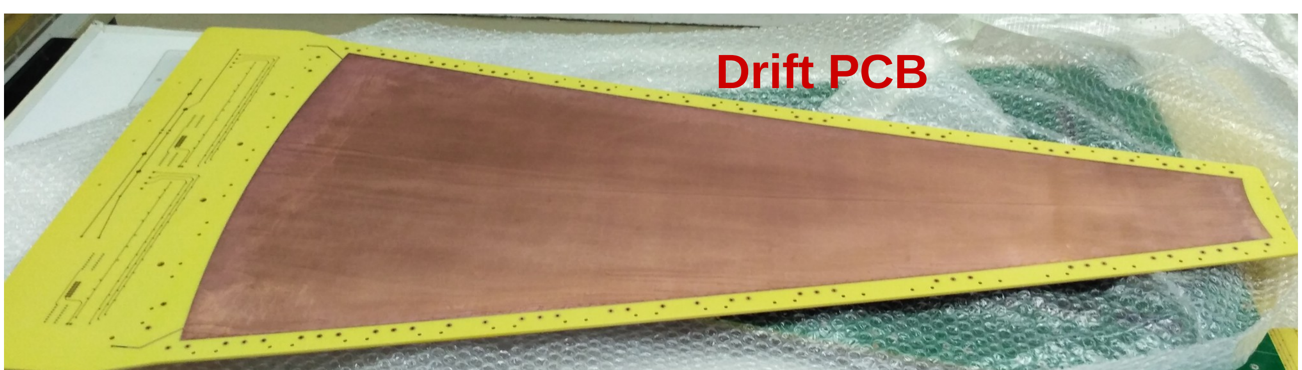


With Source (Sr^{90}) Lego



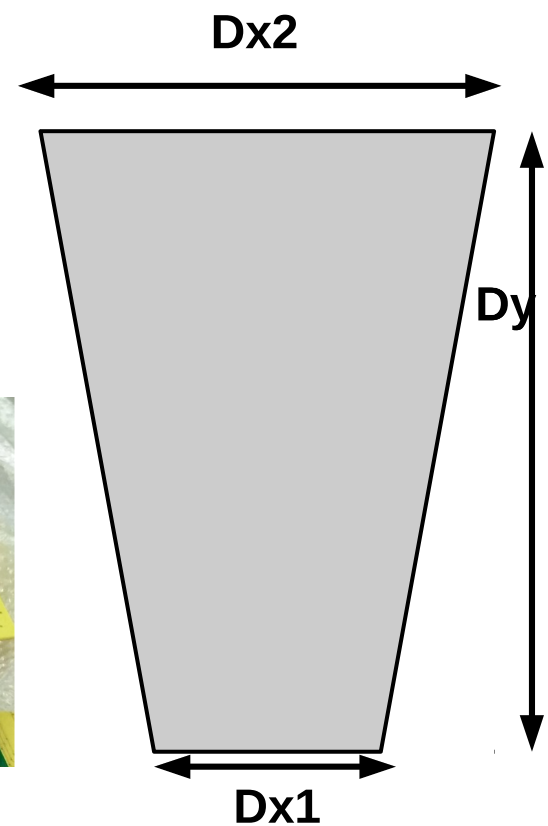
Mv2a/b chamber assembly and testing with Fe^{55} at VECC lab

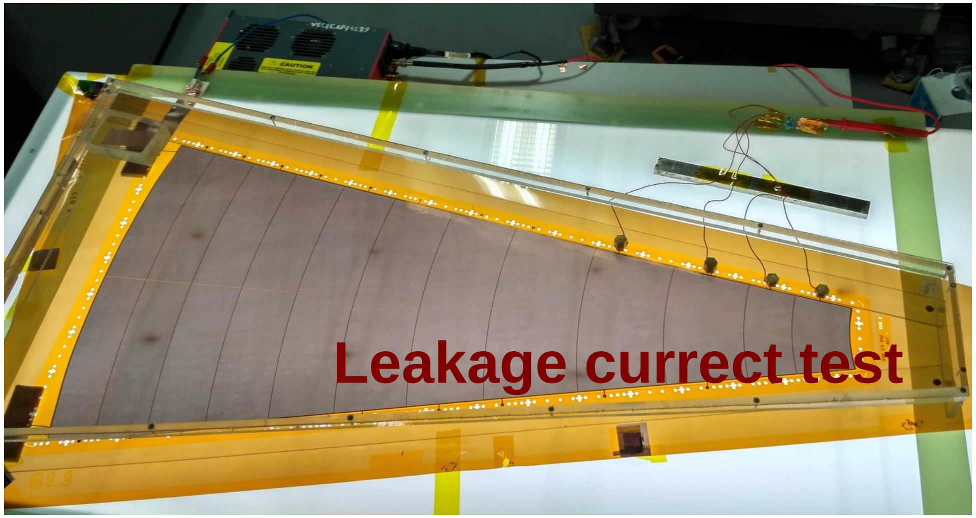




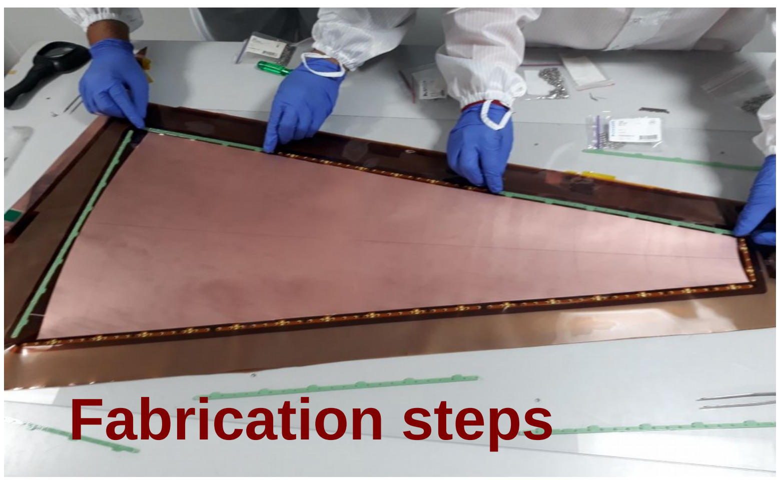
Readout PCB
--> ~2200 pad with gradually increasing sizes
--> total front end board needed = 18

--> Active area
Dx1 = ~ 7.5 cm
Dx2 = ~ 40 cm
Dy = ~ 80 cm

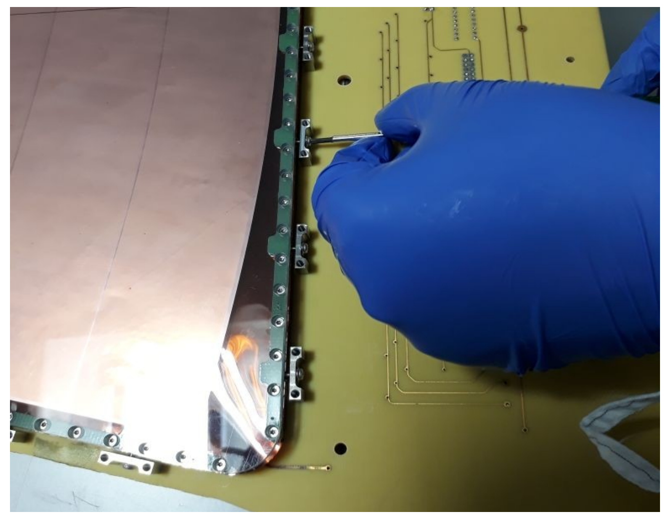




Leakage currect test

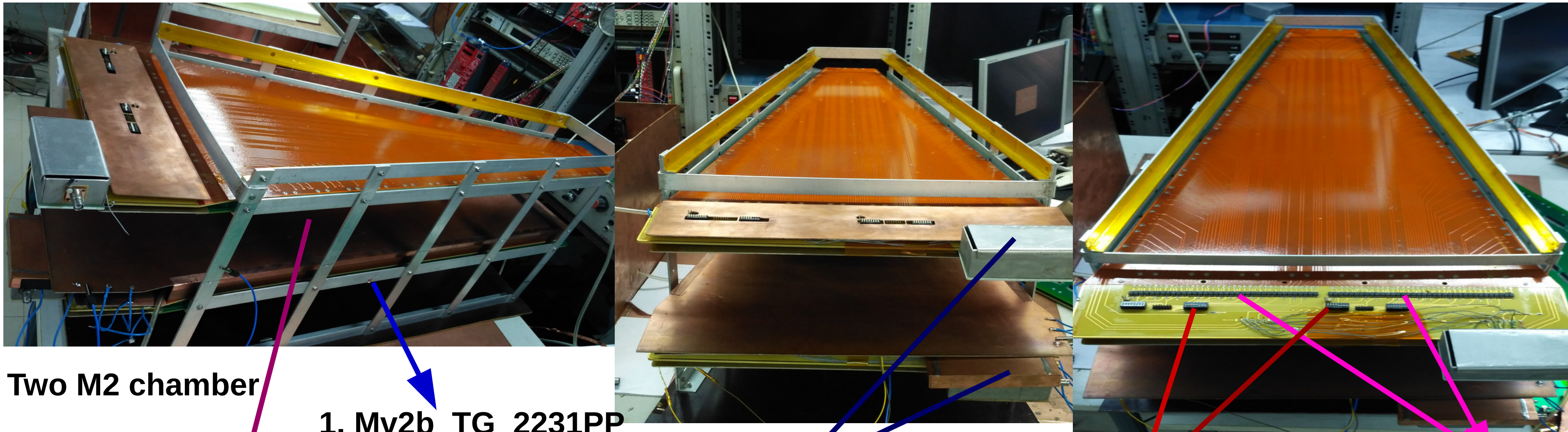


Fabrication steps



Using NS-2 technique

Mv2a/b chamber testing



Two M2 chamber

1. Mv2b_TG_2231PP

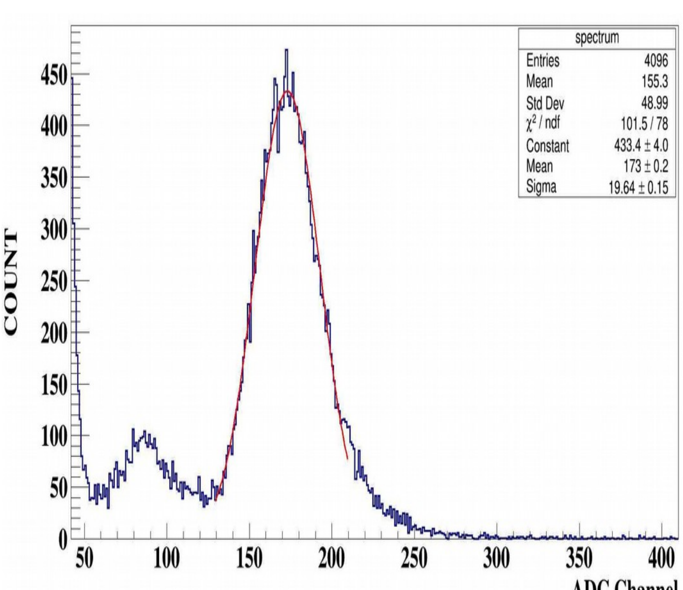
Resistive chain box for biasing

switches

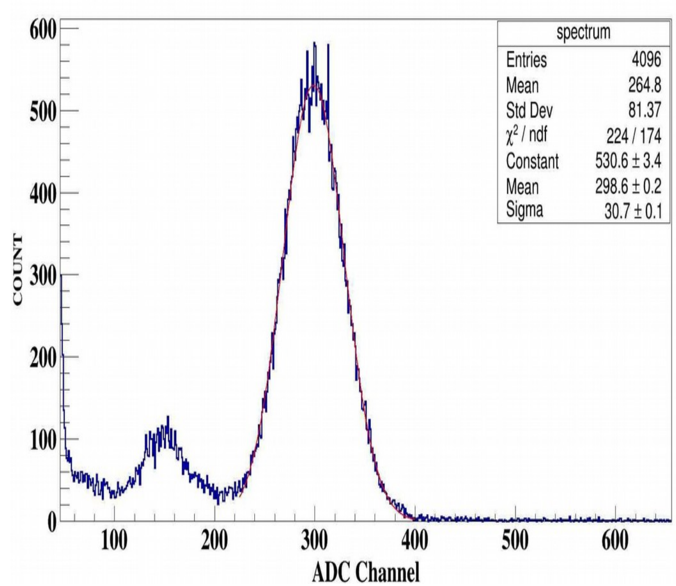
optocouplers

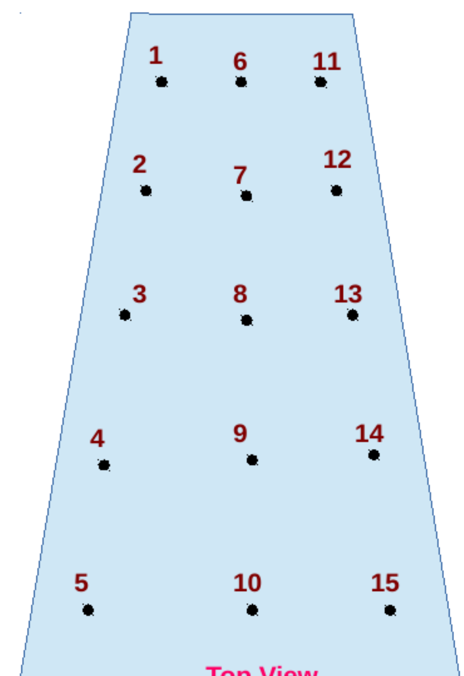
2. Mv2a_TG_2231PP

Source Pos = 11, HV = 4900V,
Current = 757p2 micro amp



Source Pos = 15, HV = 4900V,
Current = 757p2 micro amp



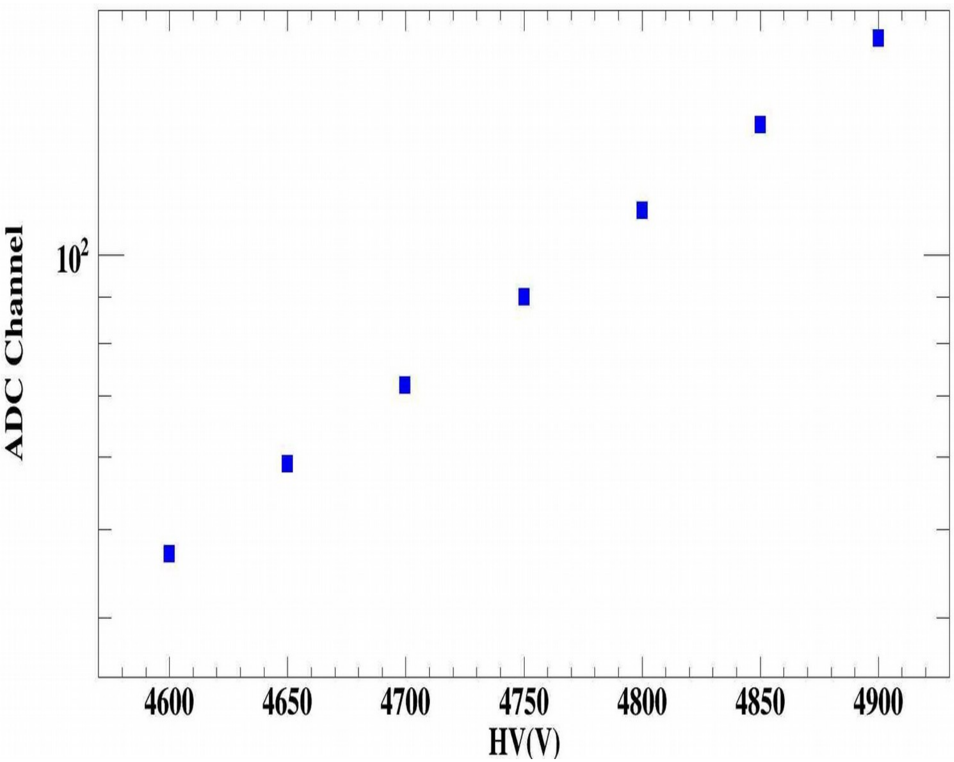


Drift side is above the plane

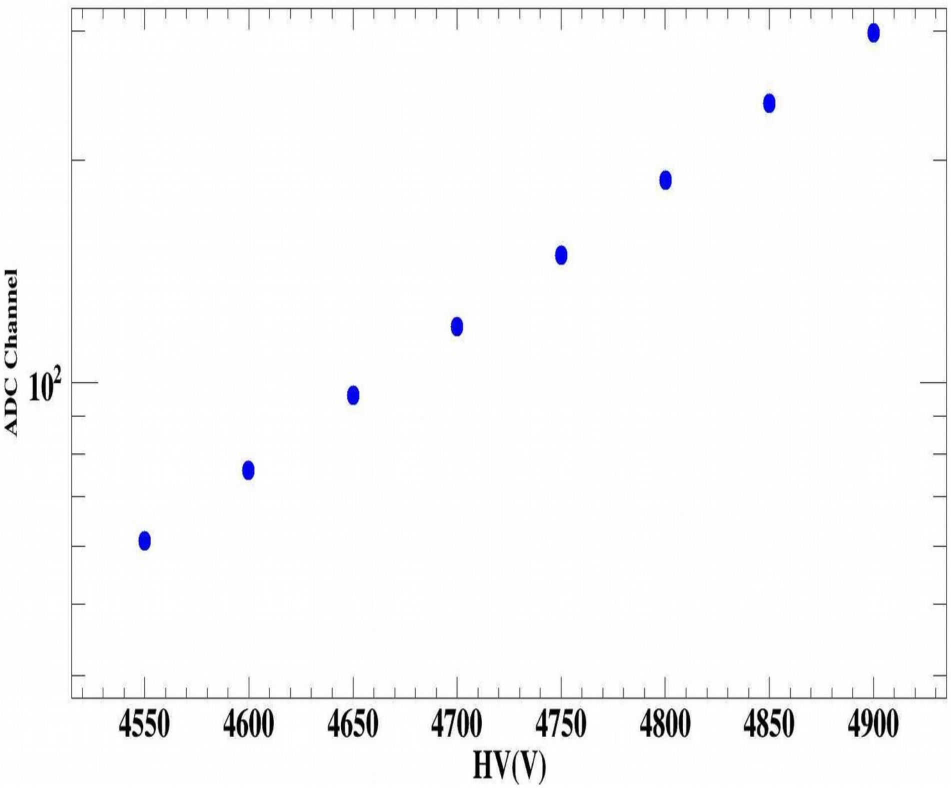
Mv2a/b chamber...

Mv2b GEM chamber test with Fe55
ADC channel vs HV

Pos = 11
ADC vs HV

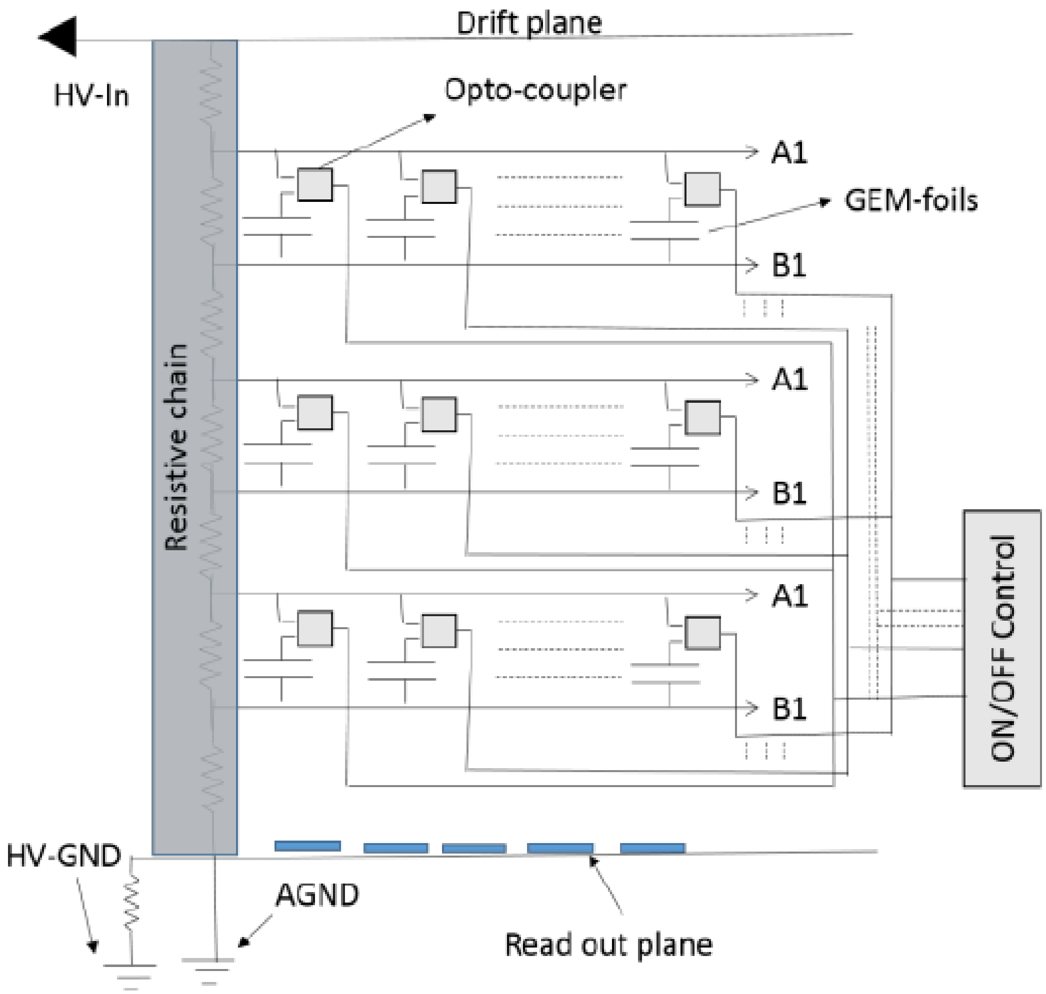


Pos = 15
ADC vs HV



Mv2a/b chamber optocoupler test

HV = 4550V I = ~688 μA => noraml
HV = 4550V I = 754 μA => short
HV = 4550V I = 688.8 μA => opt off for that segment



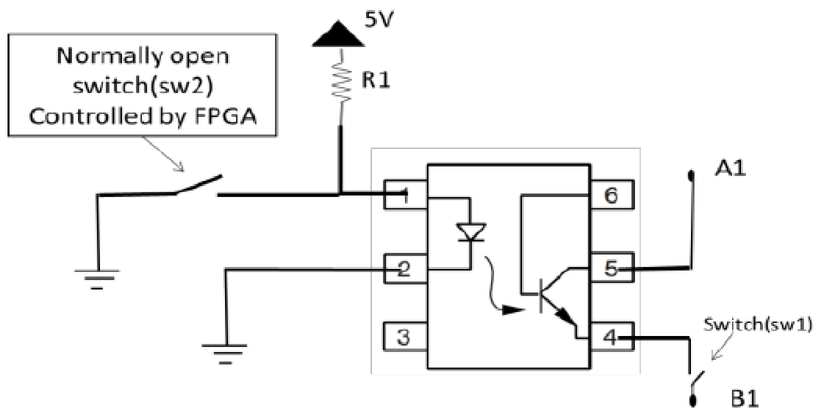


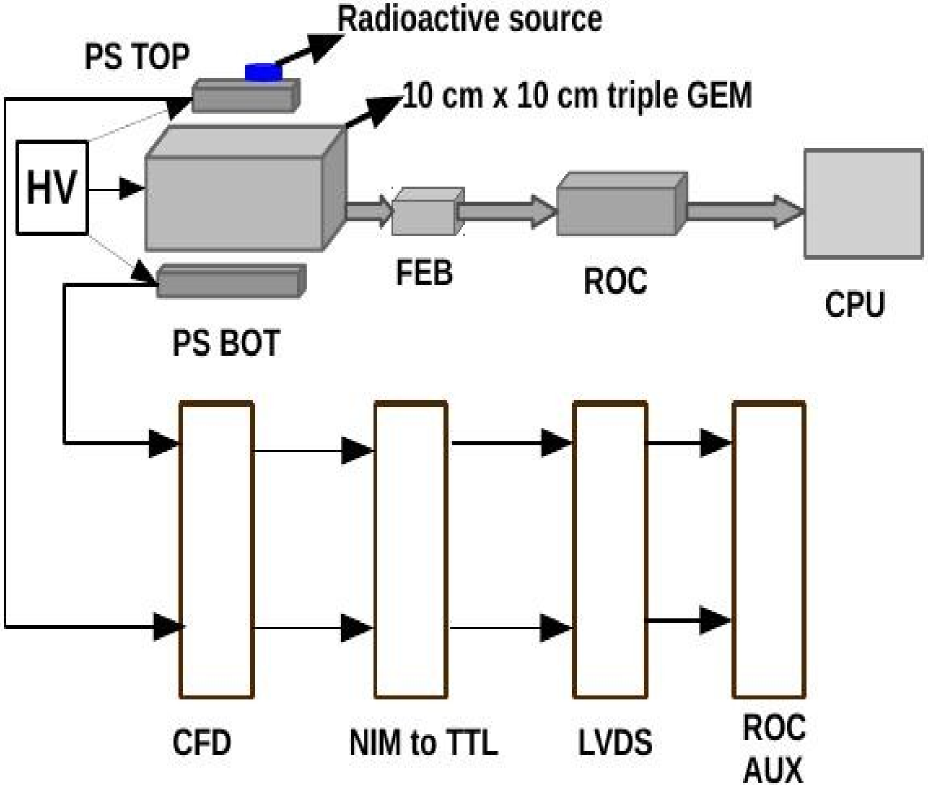
Image : http://www.sympnp.org/proceedings/61/G30.pdf

Efficiency measurement of 10x10 cm^2 triple GEM chamber with beta source at VECC lab

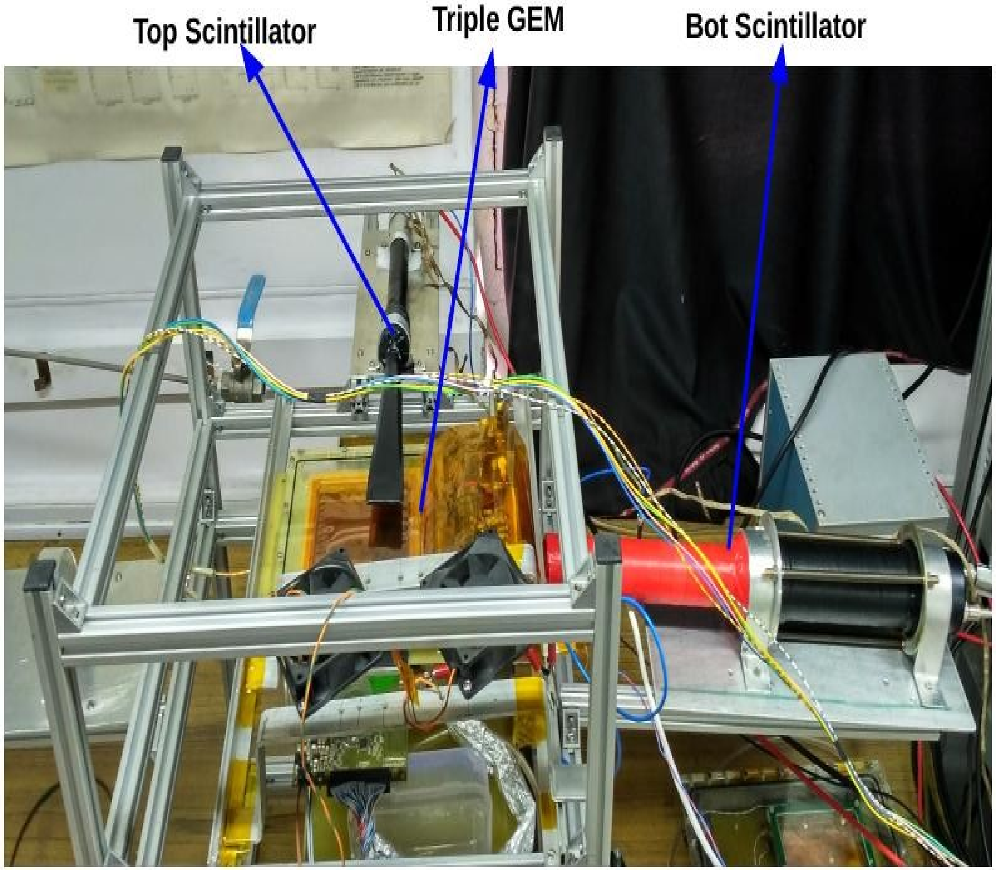
Efficiency measurement of triple GEM detector with beta source

For quality assurance in production of large size triple GEM detector

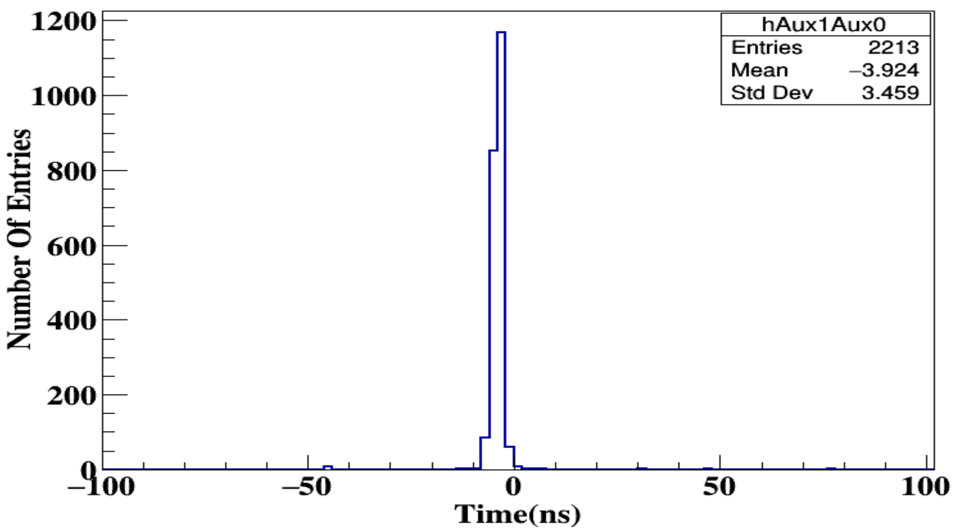
Schematic of experimental Setup



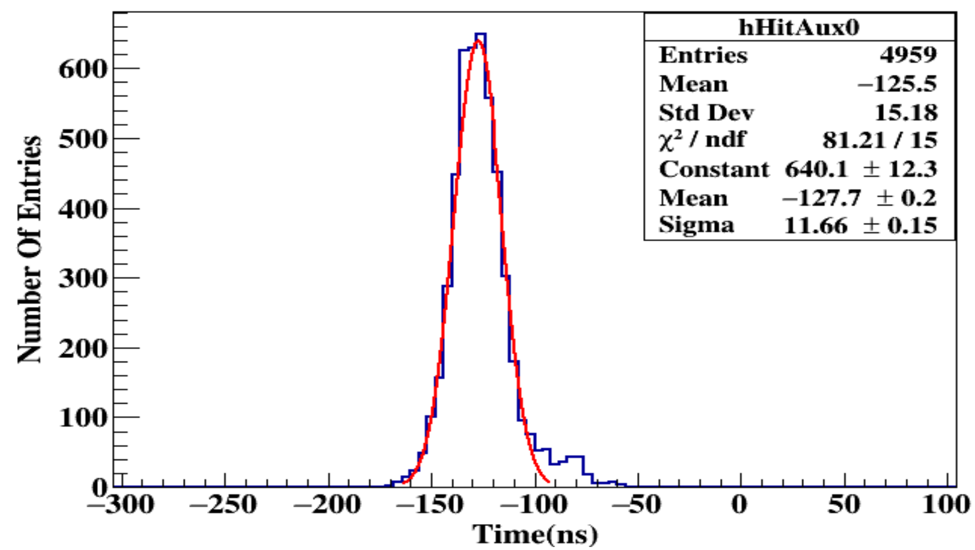
Picture of experimental Setup



Aux-Aux time correlation



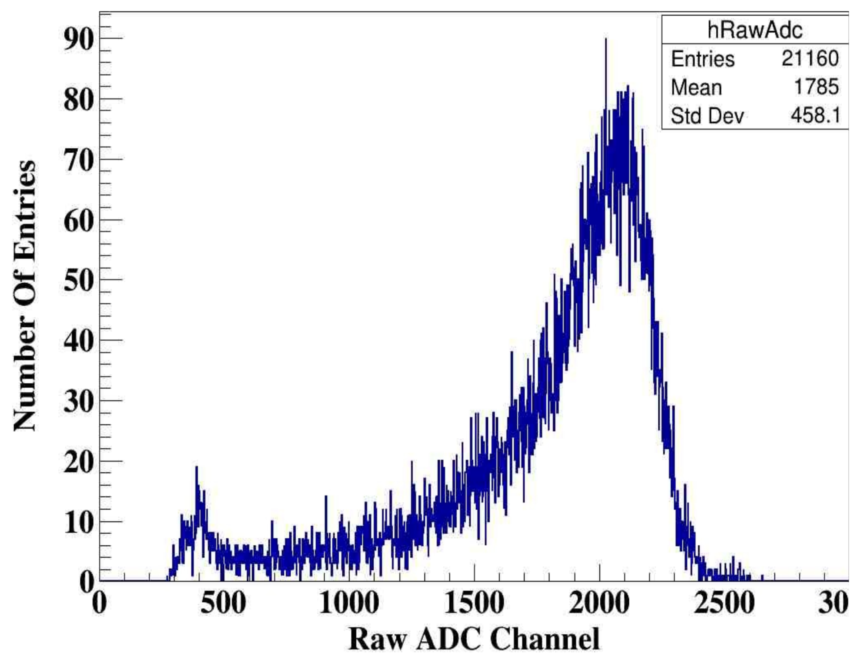
Aux hit time correlation



Average number of coincidence count with varying thickness of material and at fixed CFD threshold..

Material	Thickness	Count (5min)	Count per minute
Nothing		~230446	~46089
GEM Detector(Kapton window)	2.5 cm	~4938	~986
Copper-clad(one side) G10	1.6 mm	~11200	2240
2 piece Copper-clad(one side) G10	(1.6+1.6) mm	~320	~63

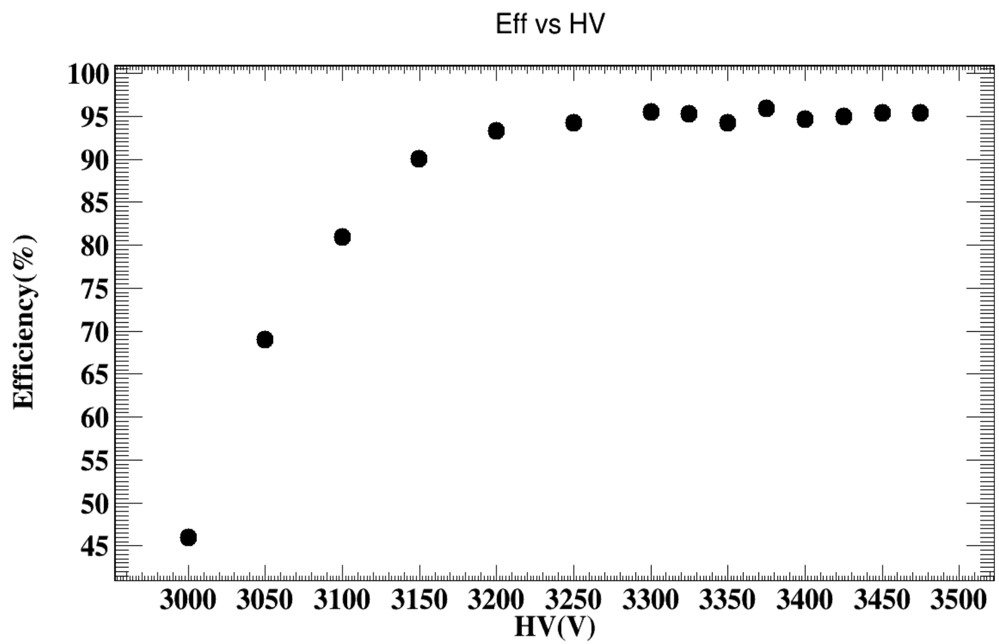
Raw adc value within time correlation window

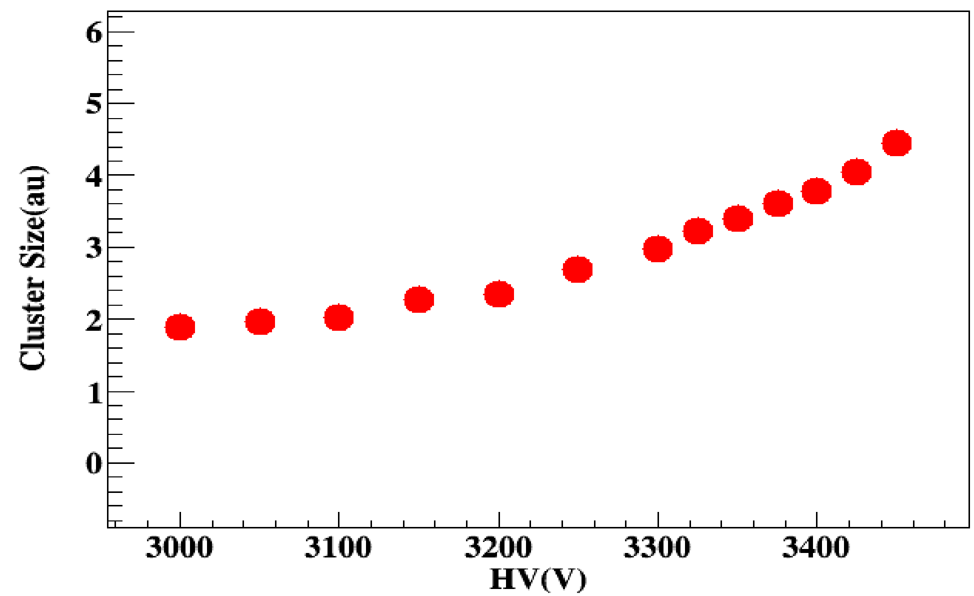


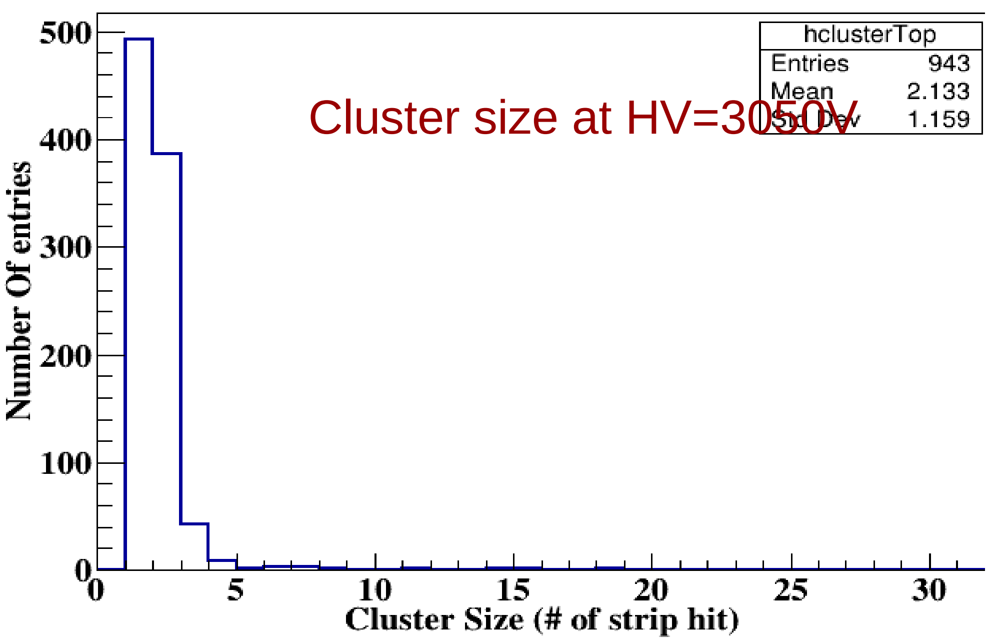
Variation of efficiency with high voltage (V)

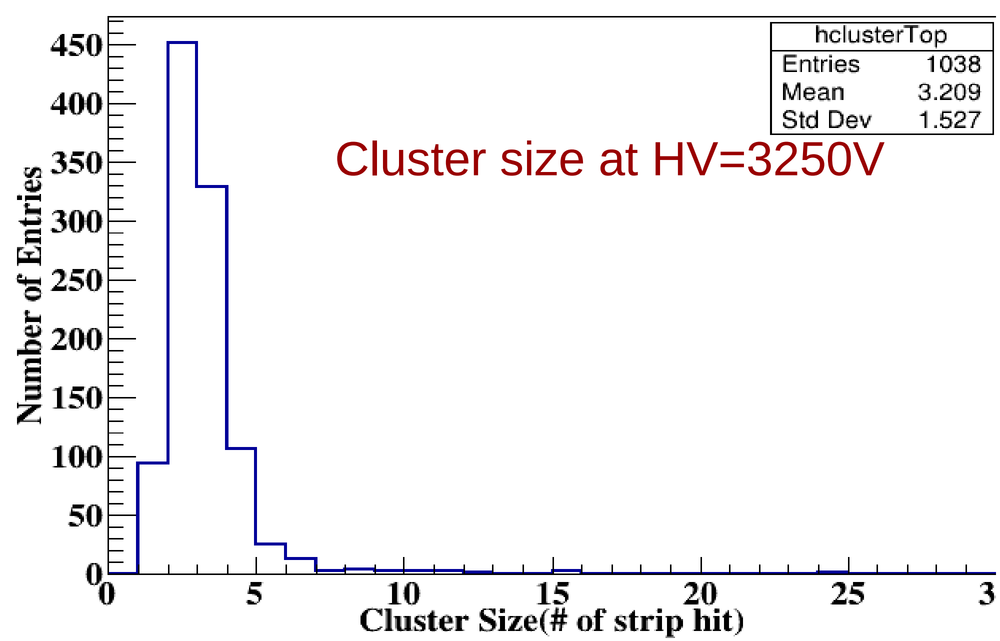
$$Efficiency = \frac{Three\ fold\ count}{Two\ fold\ count}$$

Variation of cluster size (# of strips) with high voltage (V)

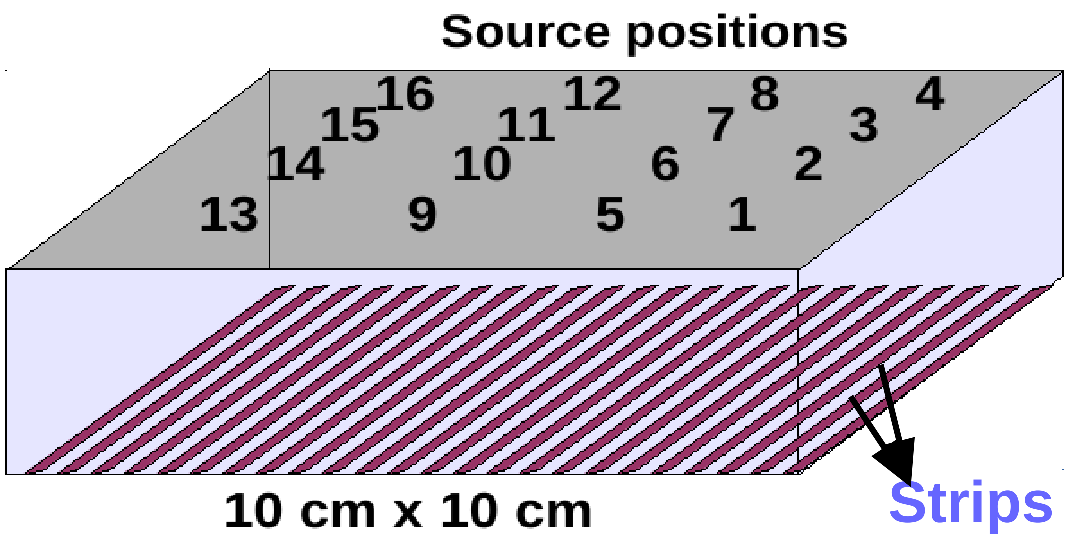


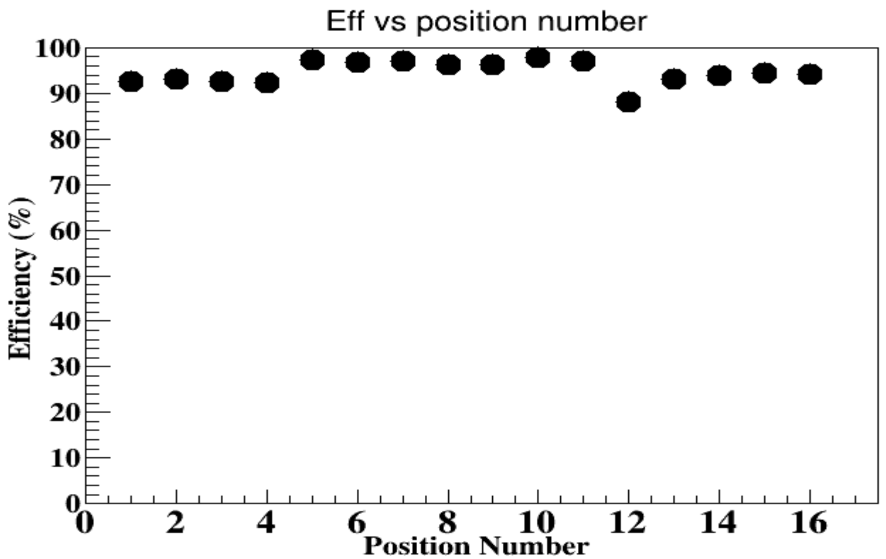


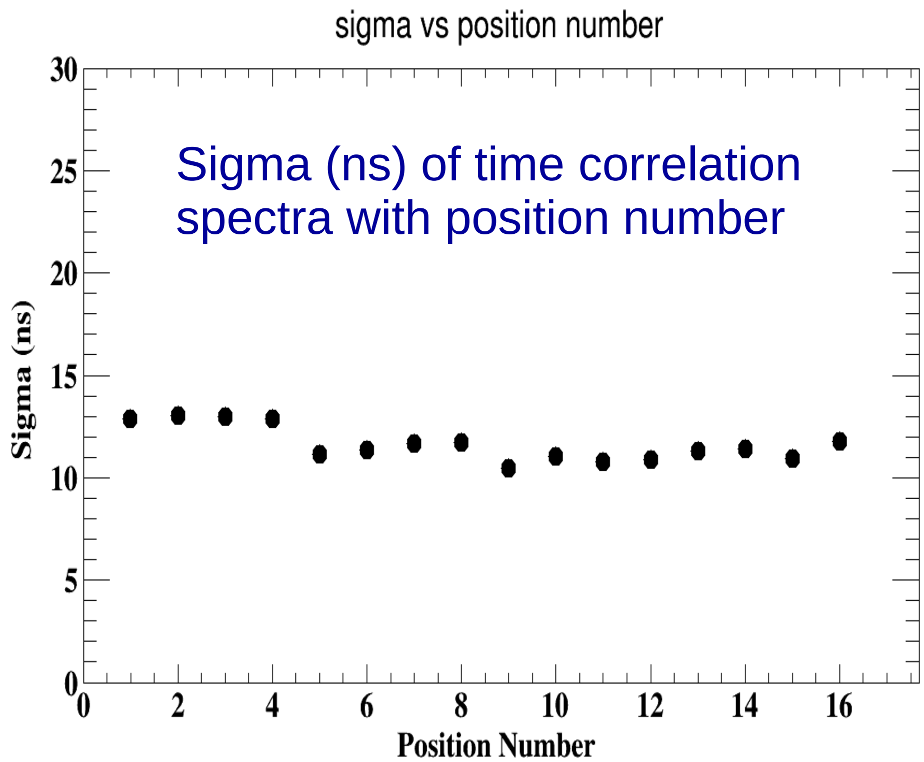


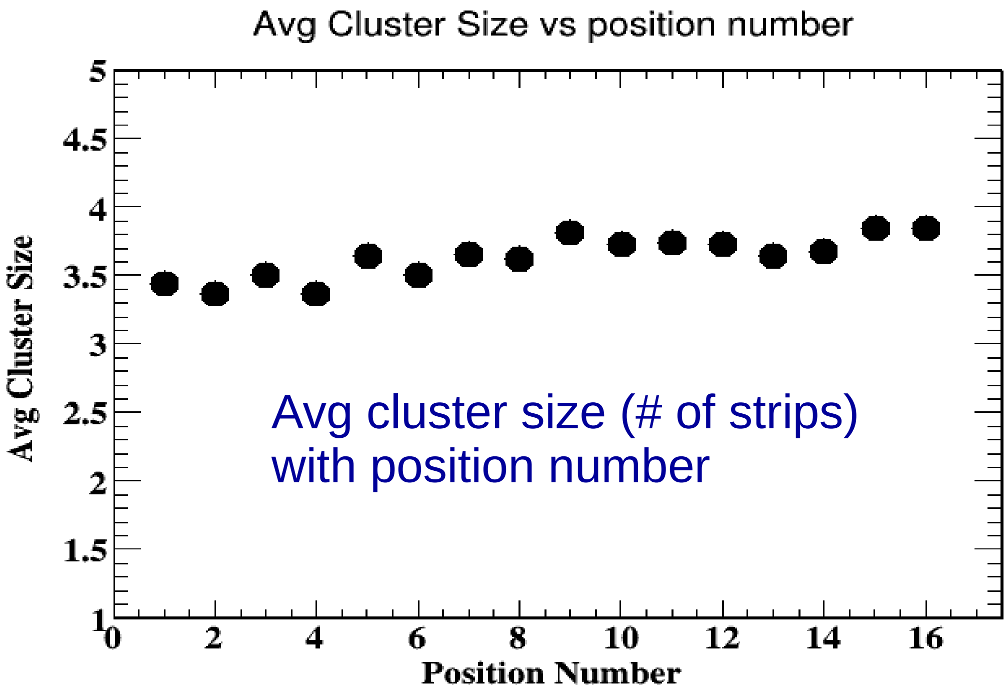


Uniformity


Source positions
16
12
8
4
15
11
7
3
14
10
6
2
13
9
5
1
10 cm x 10 cm
Strips


Eff vs position number
Efficiency (%)
Position Number

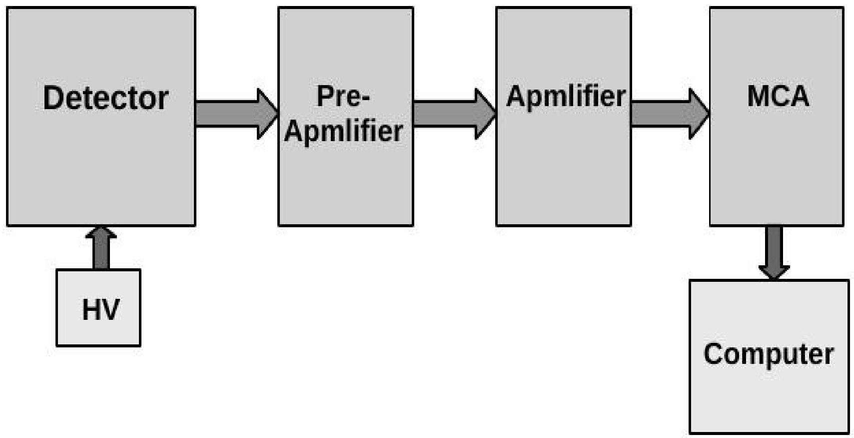

sigma vs position number
Sigma (ns)
Position Number
Sigma (ns) of time correlation
spectra with position number


Avg Cluster Size vs position number
Avg Cluster Size
Position Number
Avg cluster size (# of strips)
with position number

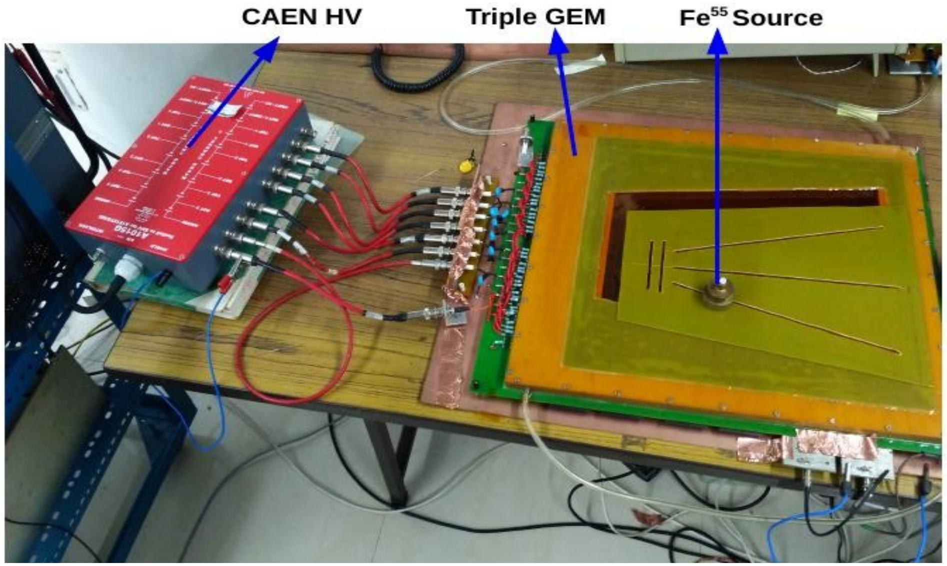
Testing triple GEM chamber with independent power supply

Testing 31x31 cm^2 chamber with independent power supply

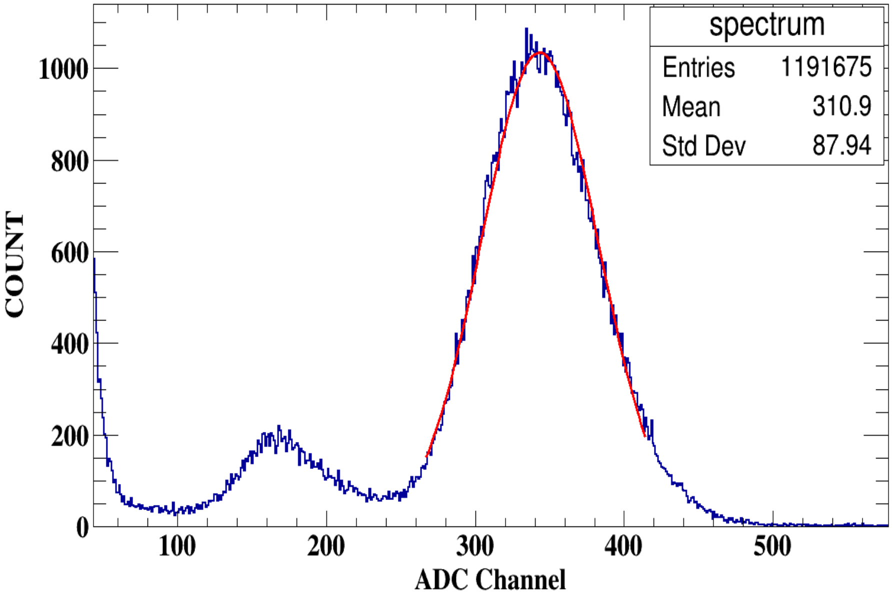
Schematic of experimental setup

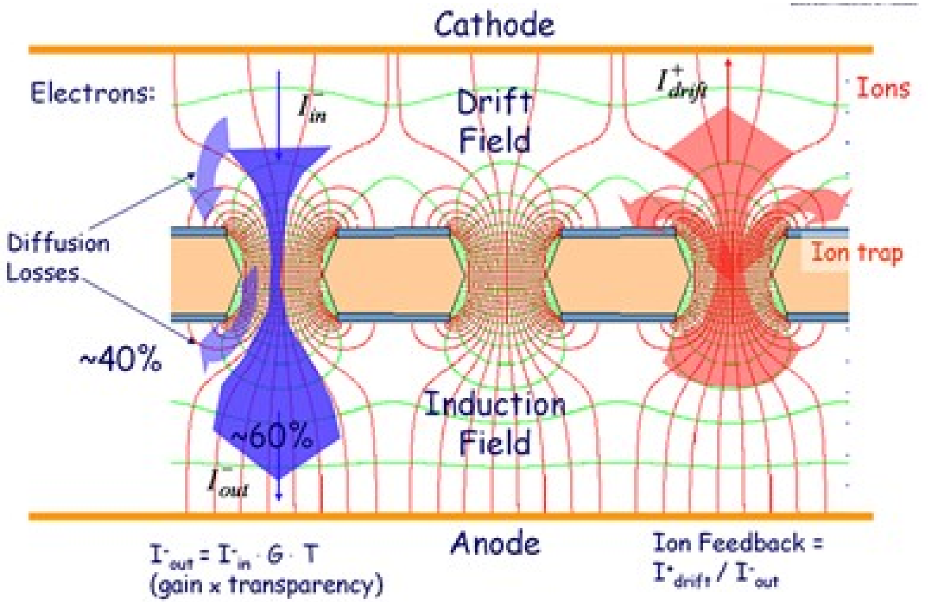


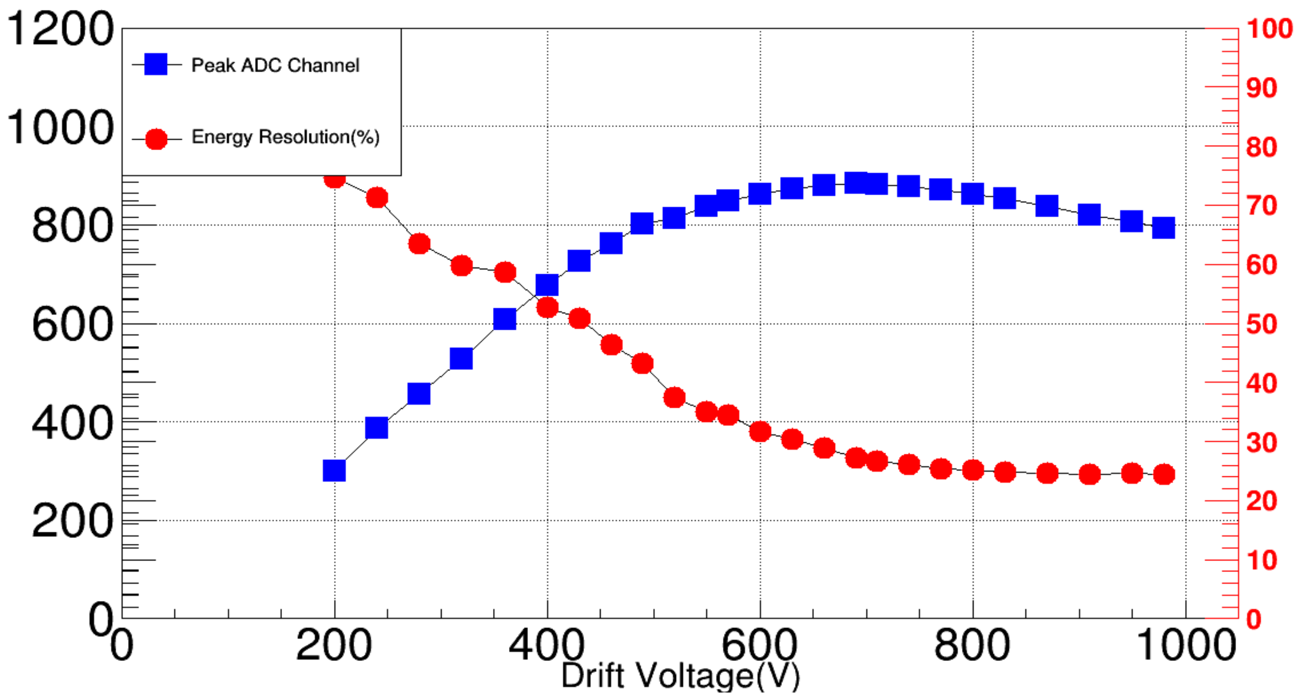
Picture of experimental setup



Typical Fe^{55} spectrum. Mean and sigma of the gaussin fit was used to calculate the resolution

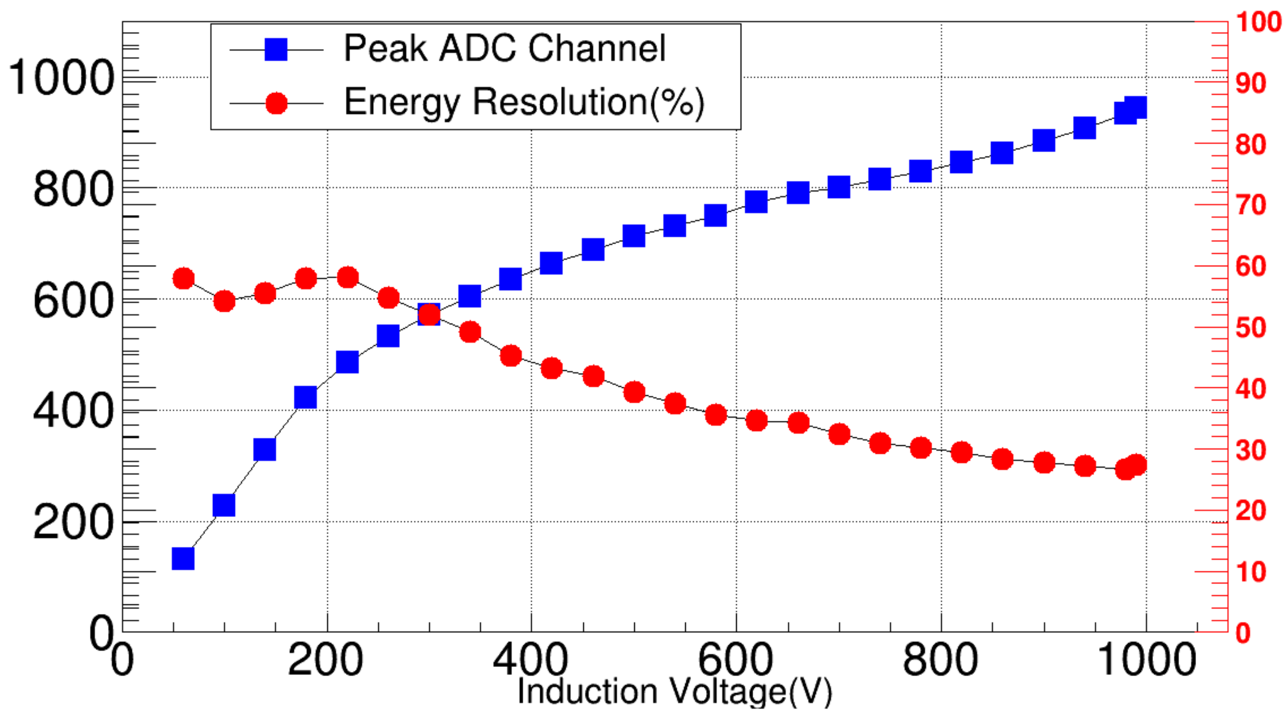






Variation of peak adc channel and resolution with drift voltage

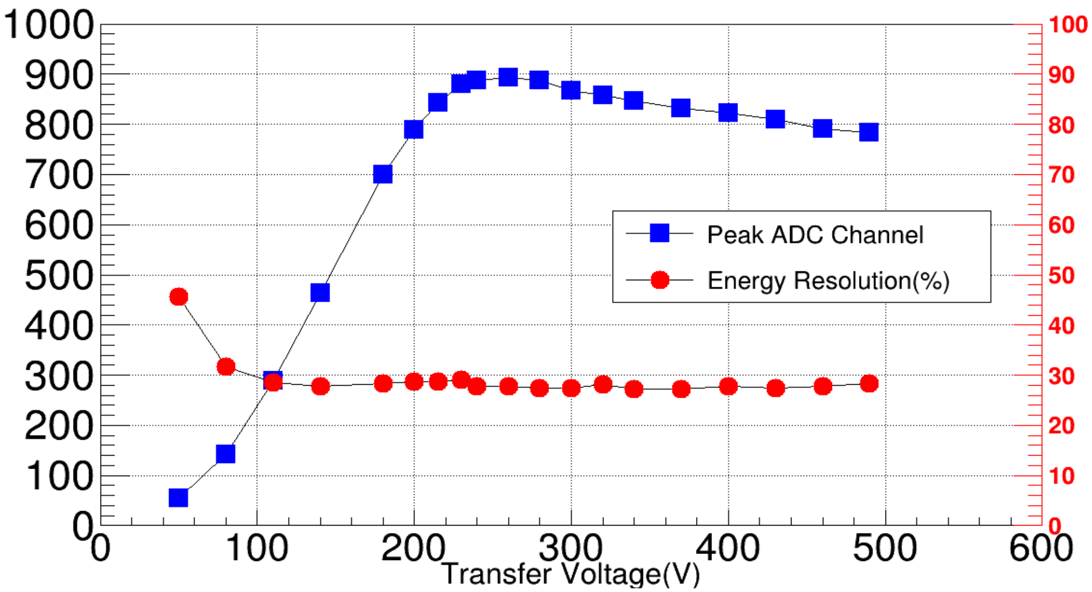
Keeping
V_{T1} = V_{T2} = 280V, V_{I} = 660V,
V_{G1} = V_{G1} = V_{G1} = 370V



Variation of peak adc channel and resolution with Induction voltage

Keeping
V_{T1} = V_{T2} = 280V, V_{D} = 680V,
V_{G1} = V_{G1} = V_{G1} = 370V

Keeping
V_D = 680V, V_I = 660V, V_{G1}= V_{G1}= V_{G1}= 370V

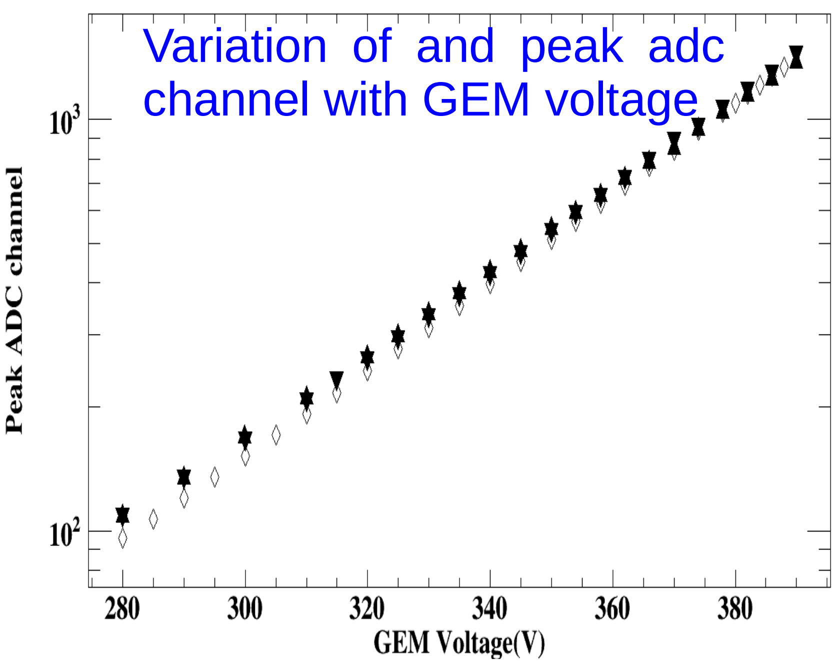


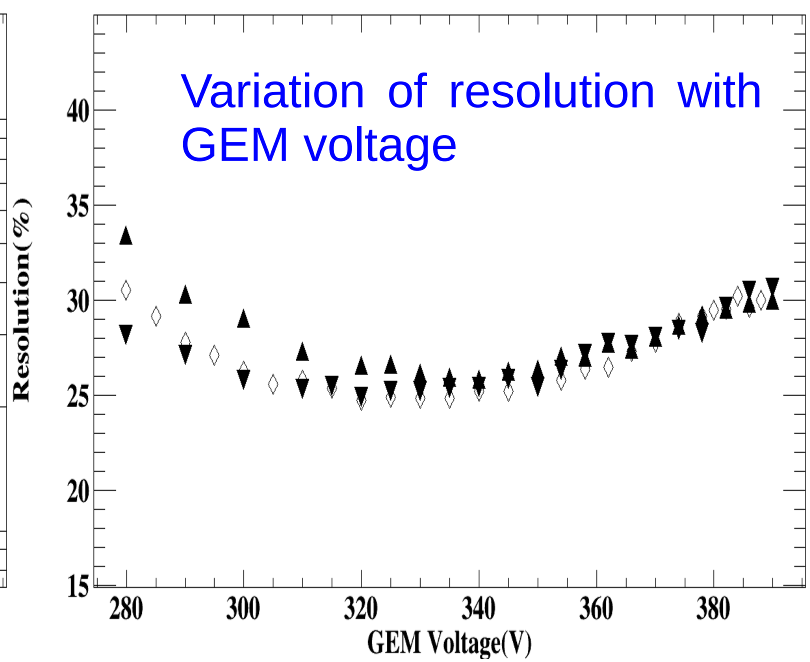
Variation of peak adc channel and resolution with transfer voltage

Both transfer voltage increases simultaneously

Upper triangle --> Top GEM
Lower tringle --> Middle GEM
Star --> Bottom GEM

Keeping
V_D = 680V, V_I = 660V, V_{T1}= V_{T2}= 280V





Summary

- Tested two real size (Mv1V and Mv1C) and one small size (10 cm x 10 cm) triple GEM with Pb-Pb collision at CERN SPS
- Event reconstructed using consecuitive hits of diamond detector
- Straith line tracking fitting has been done
- Residuals were calculated by extrapolating the line at each plane

- Efficiency of the 10x10 cm^2 triple GEM measured using beta source and n-XYTER (self triggered electronics). Efficiency at different position of the chamber has been calculated
- Gain and energy resolution of triple GEM chamber has been tested using CAEN made independent power supply and Fe^{55} source
- Two large size triple GEM detector (Mv2a and Mv2b) for mCBM experiment has been fabricated and tested with Fe55 in the VECC lab. Further testing is going under process
- Detector (10x10 cm^2) integration with sts-XYTER has been done and beam spot using beta source has been seen. Further testing is under process.

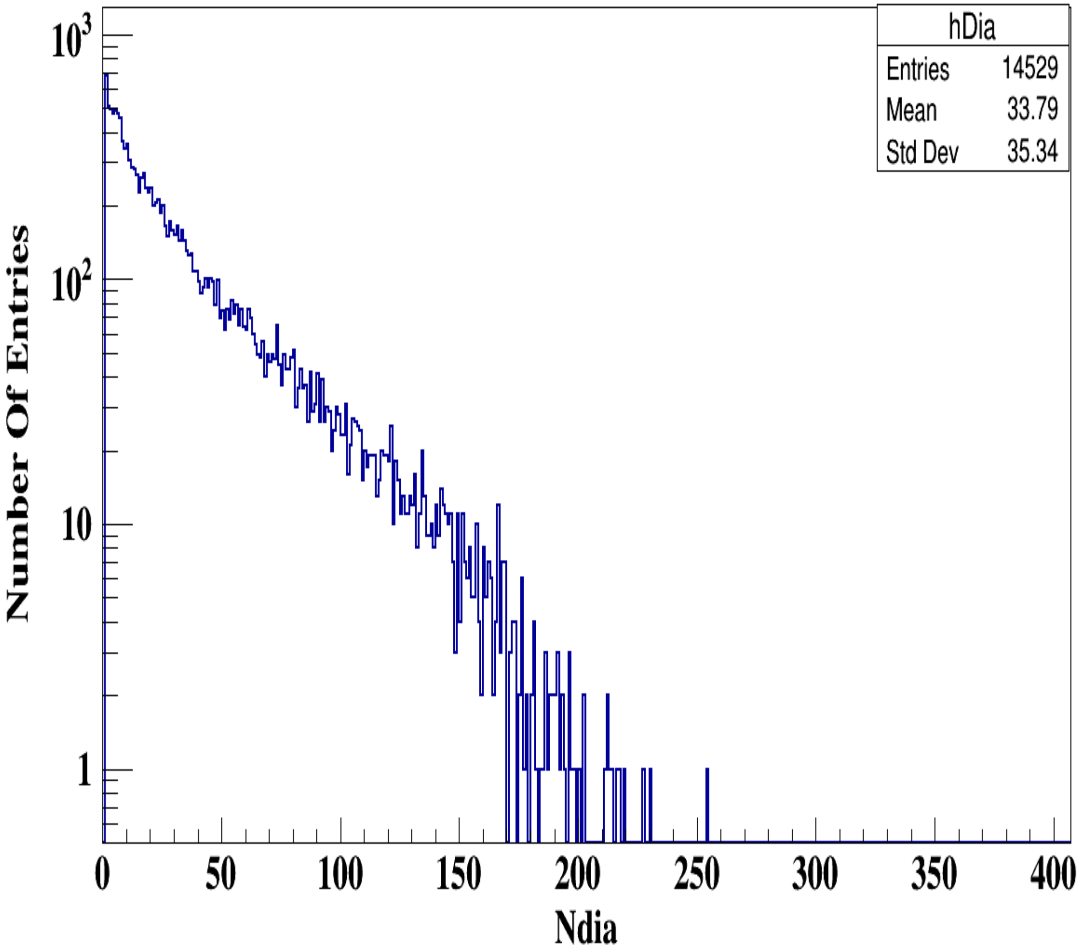
To Do

- Clusterization of the detector hits. Then redo track fitting.
- Effect of absorber data on detector hits.
- Test beam simulation with segmented geometry => as the segmentation of singal module with any orientation has been done by Omveer Singh
- Efficiency measurement with β source for large size triple GEM module at VECC lab

Thank you for your kind attention

Backup slides

Number of diamond hits in each time slice

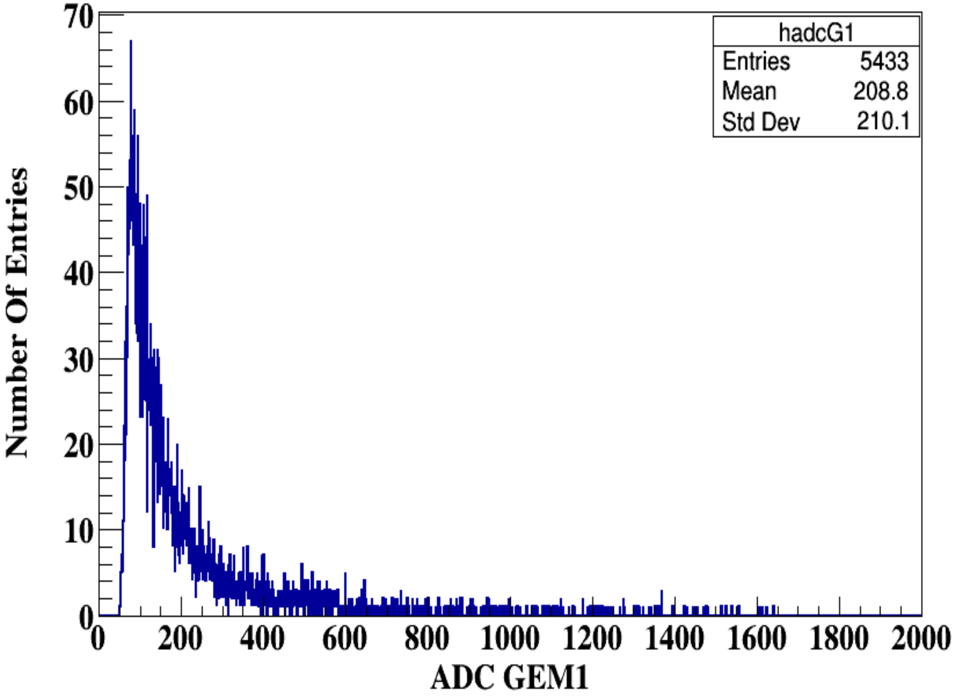


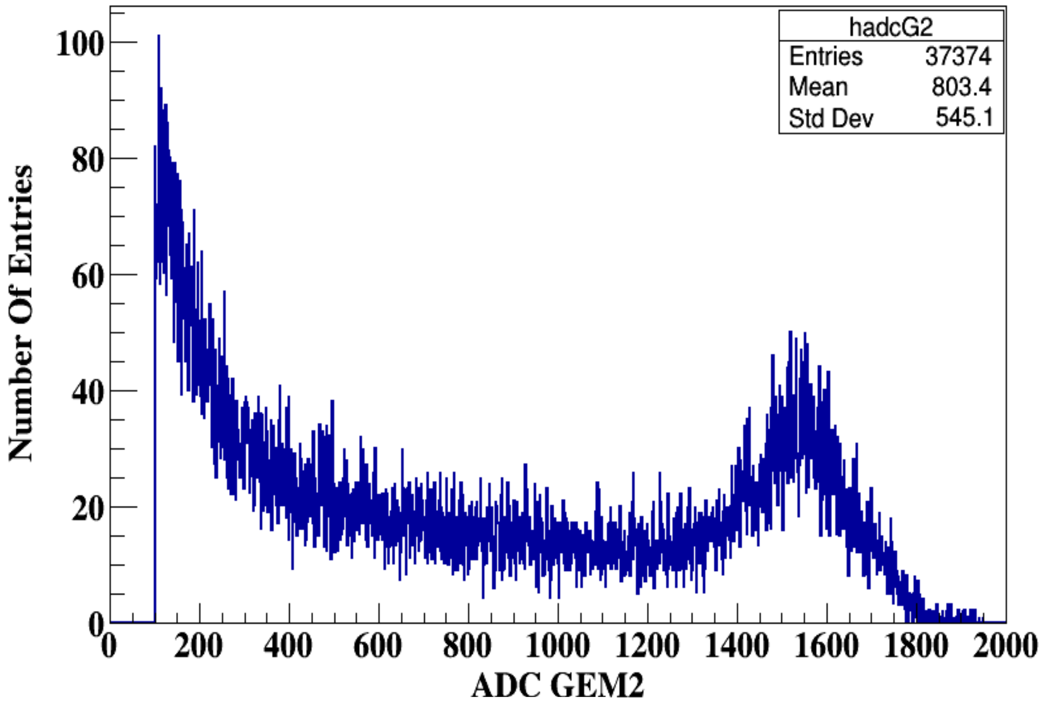
Average number of diamond per time slice ~ 34

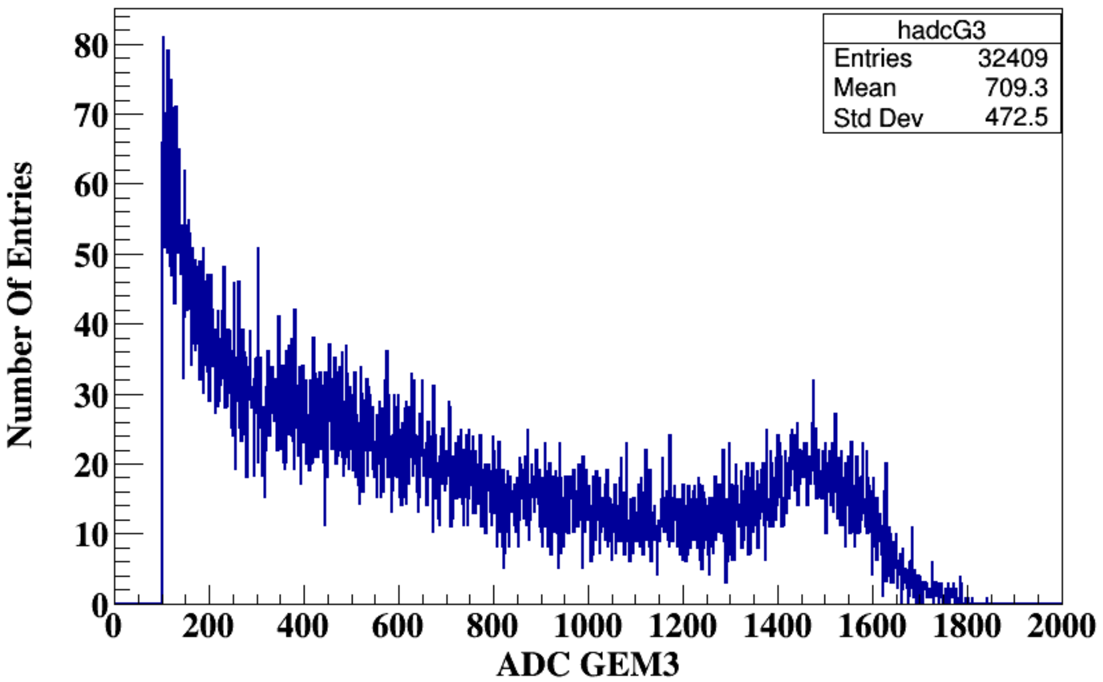
=> roughly beam rate = 34/10ms

=> beam rate = **~3.4 kHz**

Adc histogram for each plane within given η-φ window







Particle rate per event for one FEB in GEM2

FEB = 4edd_f2
Area ~ 59.49 cm2

Number of hit in above FEB with per event = ~2

Number of hit per event per unit area = 2/59.5 = 0.034 hit/event*cm2

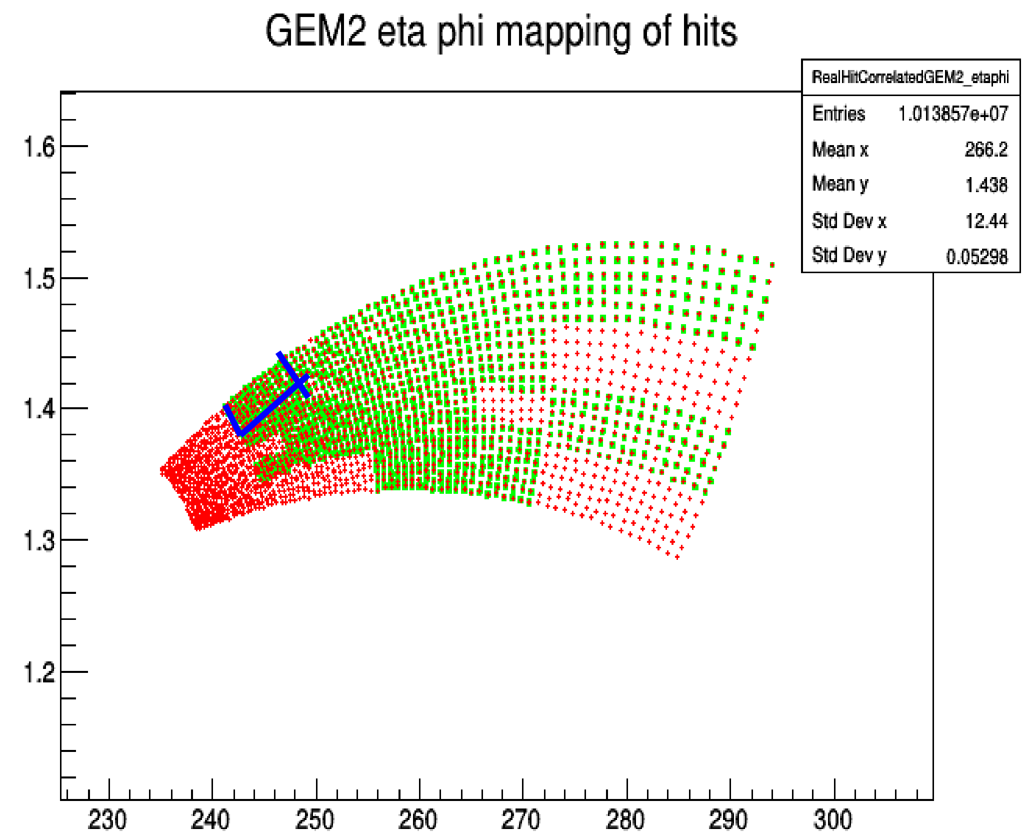
Similarly for GEM3

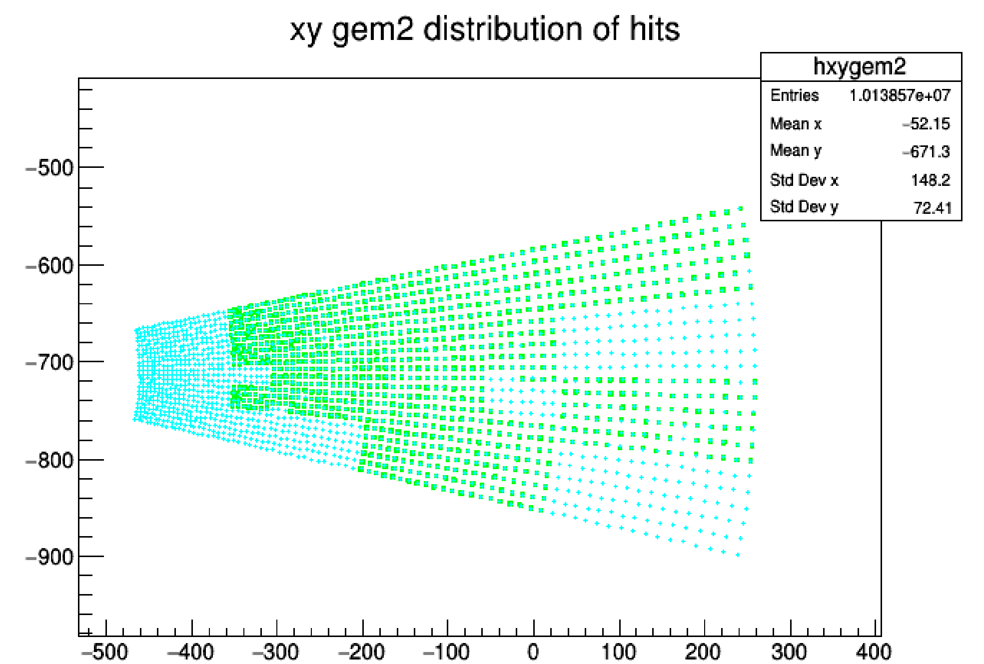
Area of GEM3 = 10 cm x 10 cm = 100 sq. cm

Total hit in GEM3 per event = 3.7

So, 3.7/100 sq cm = 0.037/event*cm2

For 150 AGeV/c, run101
HV GEM1=GEM2 = 3200V, GEM3 =3610V

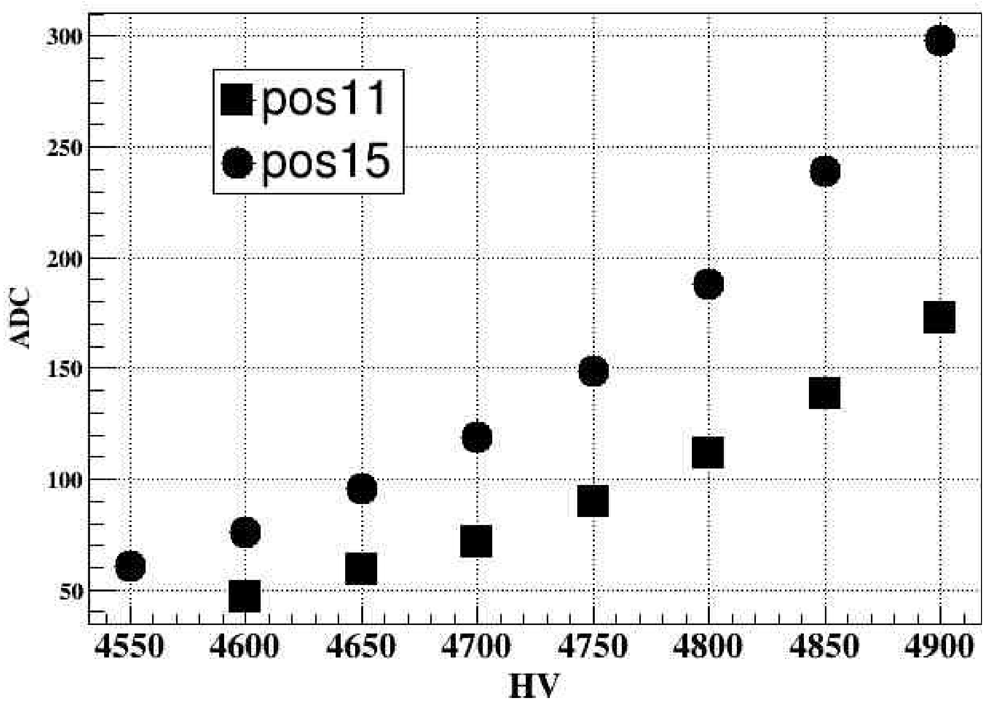


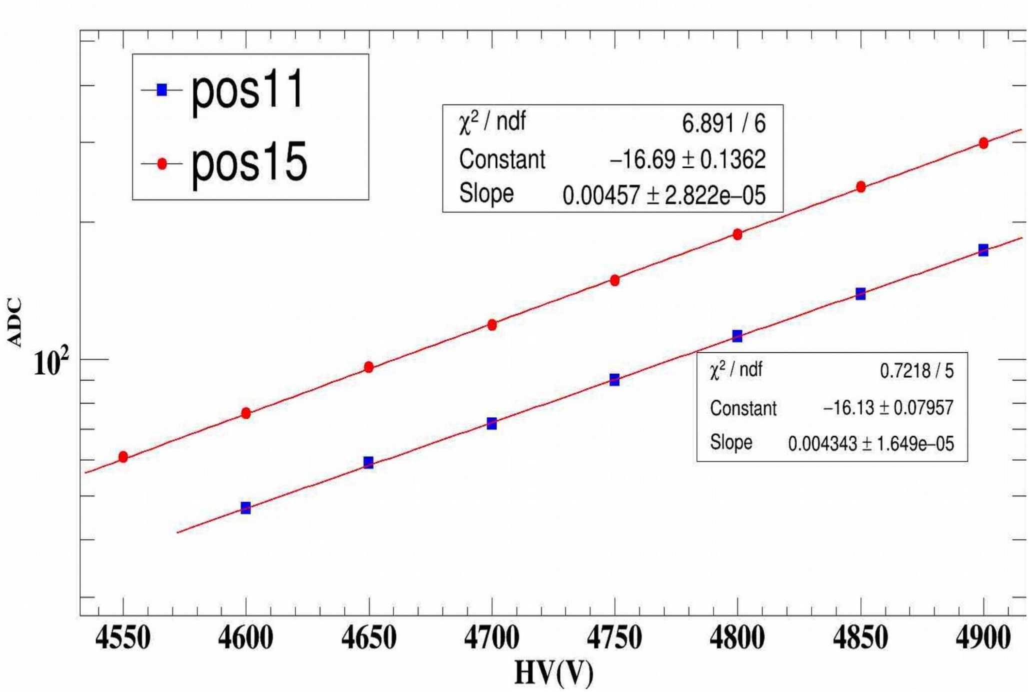


Study regarding to low gain of Mv2a/b chamber

The possibilities of low gain can be:

1. One the GEM foil is not connected
    --> a. Top foil disconnected from the resistive chain ==> no signal seen
    --> b. Middle foil is disconnected from resisitive chain ==> no signal seen
    --> c. Bottom foil is disconnected to from resisitive chain ==> signal seen from Sr90 but not with Fe55
2. Gain variation due to long and short track length
    --> Short track has low gain and long track has high gain
        ==> But the gain varries within 10%
3. etc..





- Particle rate on detector for one FEB for GEM2 ~ 0.034hit/event*cm2 and for GEM3 ~0.037 hit/event*cm2 has been estimated

Mv2a/b chamber assembly and testing with Fe^{55} at VECC lab

Motivation :

1. Triple GEM detector integration with sts-XYTER

--> With the old version of front end board

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