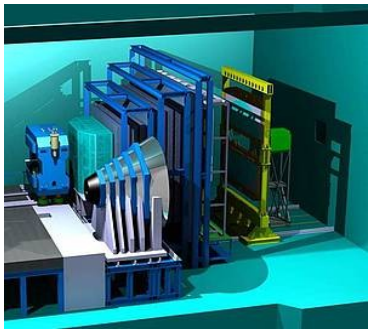
Large size triple GEM detectors for Muon Chamber of CBM experiment



Ajit Kumar

VECC Kolkata

(For CBM Collaboration)

RD51 Collaboration Meeting and the "MPGD Stability" workshop,
Munich
18-22 June 2018

Date : 19/06/2018

Plan of the talk

- CBM experiment - Layout of MUCH (MuonChamber) system
- Testing large size with Pb+Pb collision
- Analysis and results
- Testing first real size detector with novel HV biasing scheme
- Real size GEM detector for mCBM experiment at GSI

CBM experiment

Compressed Baryonic Matter (CBM) experiment is a fixed target heavy ion experiment
Aim of CBM experiment is to explore the properties of nuclear matter at high net baryonic matter and at moderate temperature.

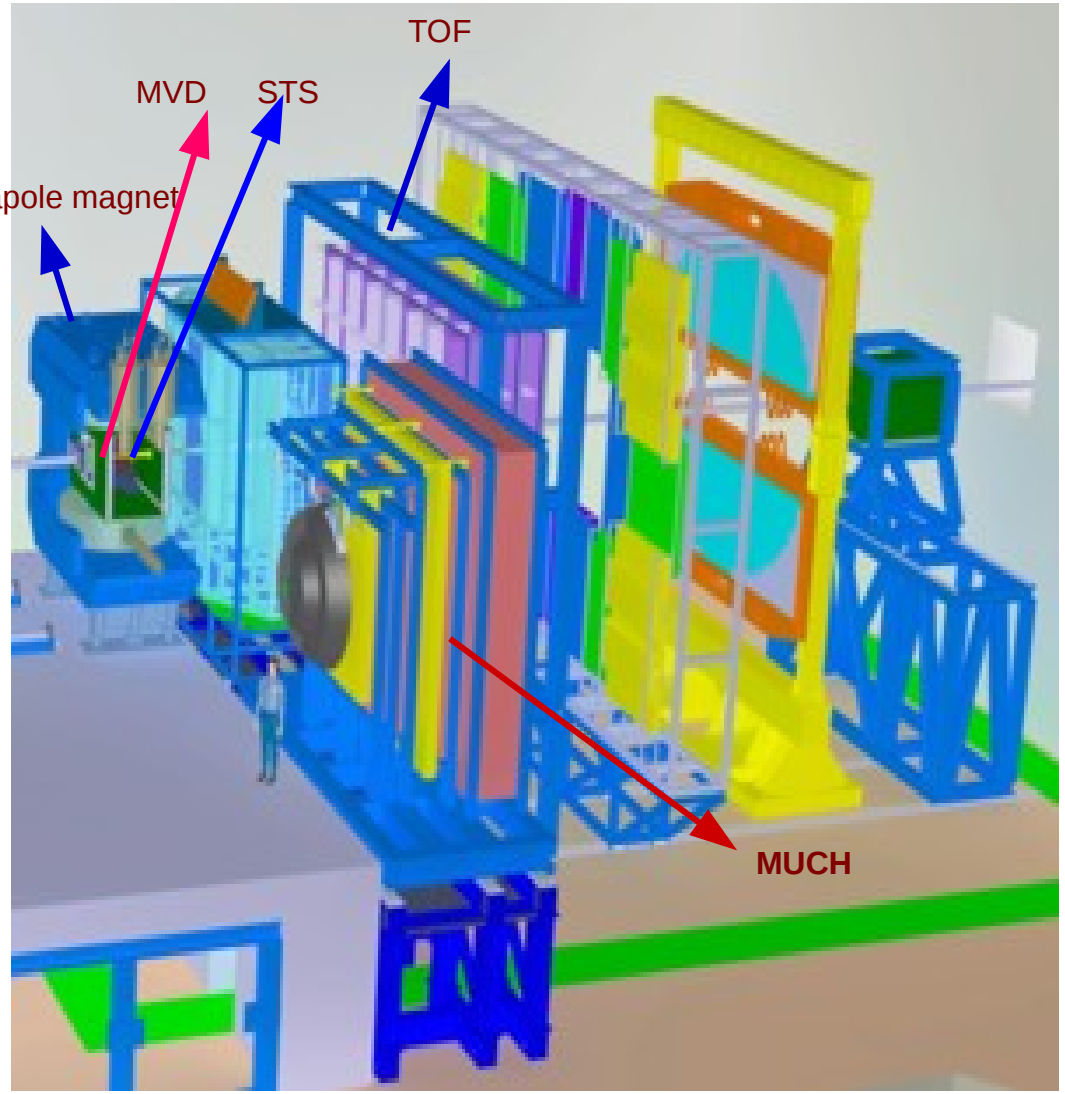
- ➔ Fixed target heavy ion experiment
- ➔ Energy range 2-45 AGeV

CBM physics program:

- ➔ Equation of state at high net baryonic density
- ➔ Deconfinement phase transition
- ➔ QCD critical endpoint
- ➔ Chiral symetry breaking

Diagnostic probes of the high density phase:

- ➔ Open charme, charmonia
- ➔ Low mass vector messons
- ➔ Multistrange hyprons
- ➔ Flow, fluctuations, correlations



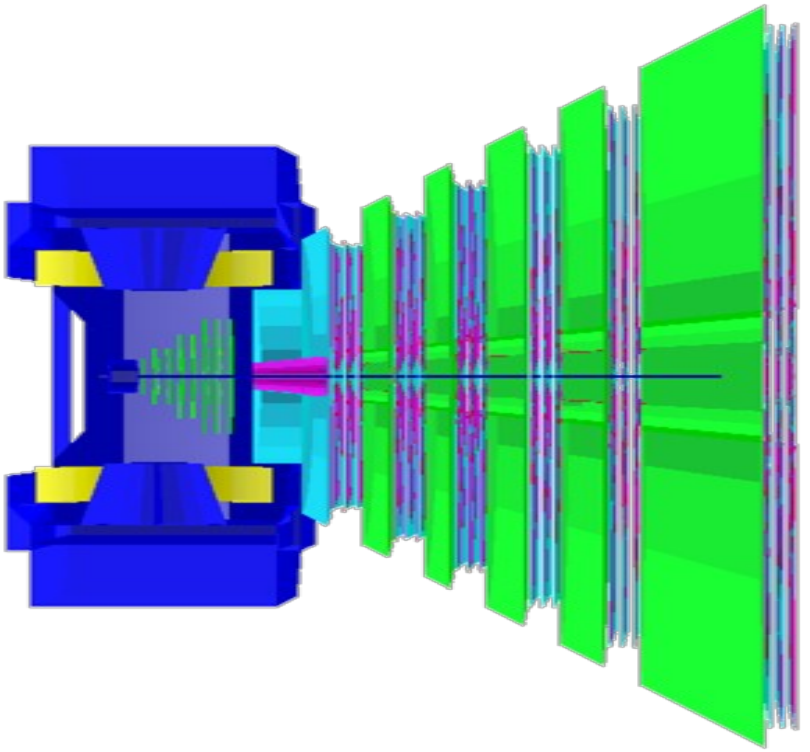
Muon detector system

Aim is to measure dimuon arises from:

1. Low mass vector messons and
2. Charmonia

Challanges in muon detection:

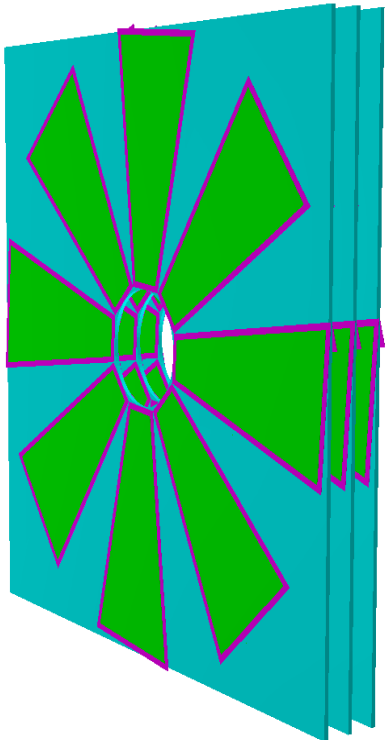
- High collision rates ~ 10 MHz
- The first plane(s) have a high density of tracks
  High granularity in the inner region ~ average hit rate is about **0.4 hit/cm^2/event**
- Should be radiation resistant –
  high neutron dose ~10^{13} n.eq./sq.cm/year
- Large area detector – with modular arrangement
- Data to be readout in a self triggered mode
  -- a must for all CBM detectors.
  -- and event reconstructed offline by grouping the timestamps of the detector hits.

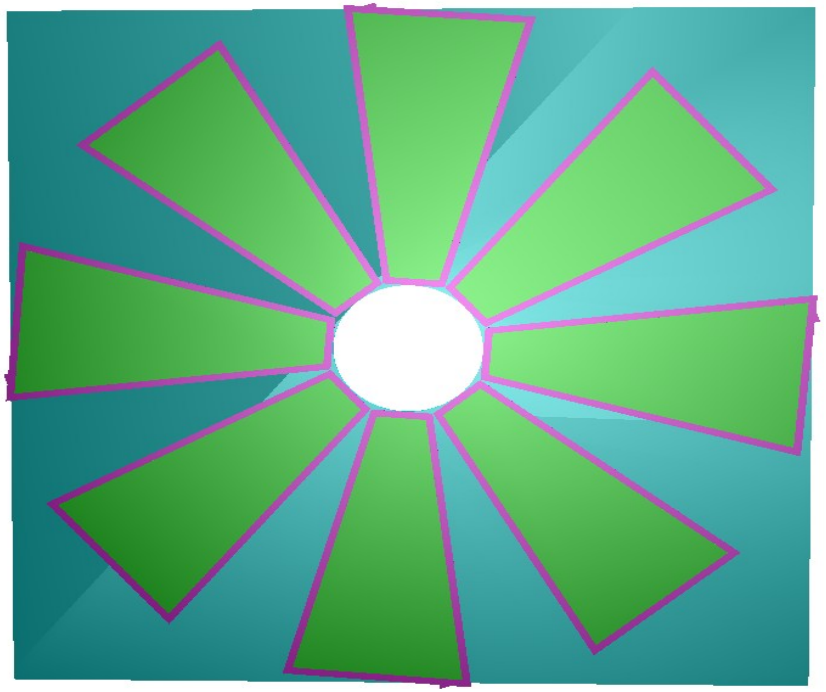


Schematic of CBM-MUCH setup

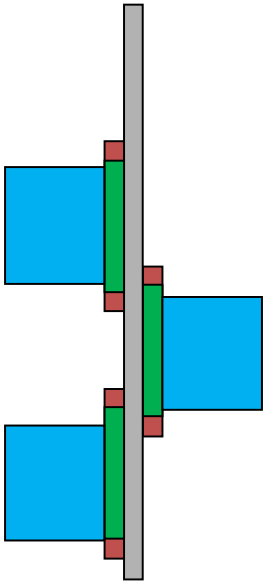
Trapezoidal shaped triple GEM chambers are being developed for dimuon measurement in CBM experiment.

Sector layout of GEM chambers





First layer



1st station 3 layers

Station # for SIS100	Layer #	Total no of pads	**R1 (cm)**	Pad size (min)	**R2 (cm)**	Pad size (max)	**Area (sq.mt)**	No of 128 channel FEB/layer (round off)	No of Sector per layer
1	1	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
	2	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
	3	28800	**25**	4.36mm	**100.25**	17.48mm	**2.95**	240	16
2	1	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24
	2	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24
	3	30600	**34.5**	5.9mm	**146.9**	25.4mm	**6.4**	240	24

SPS CERN 2016 test beam

Test beam members

Ajit Kumar[1], A. K. Dubey[1], J. Saini[1], V. Singhal[1], V. Negi[1], S. Mandal[1], S. K. Prasad[2], D. Nag[2], C. Ghosh[1], S. Chattopadhyay[1]

1. Variable Energy Cyclotron Centre (VECC) Kolkata INDIA

2. Bose Institute, Kolkata, West Bengal 700009, INDIA

Motivation for test beam

- Tested large size triple GEM detectors with spray of particles originitating from the Pb+Pb collisions

Highlights :

1. Testing the large size detectors with full coverage.

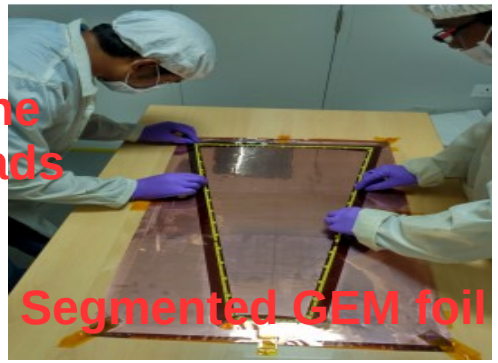
2. New CBM readout chain (including AFCK, FLIB and FLES with new version of electronics (n-XYTER, rev-F). --self triggered data aquisition system

3. Use of water cooling system for the first time – ~10 W heat from one FEB

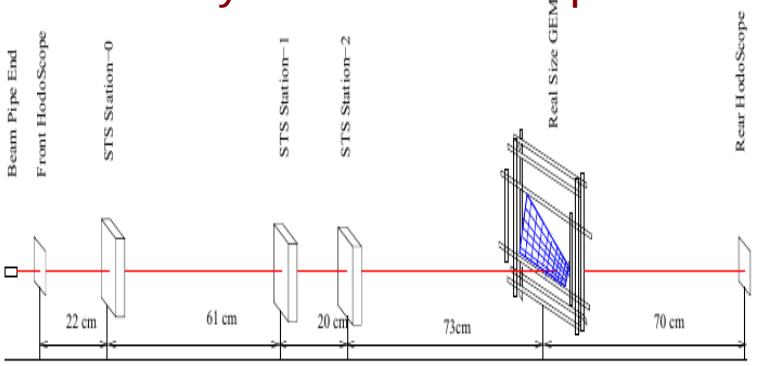
4. Tracking using hits in different GEM planes.

Building and testing large size triple GEM

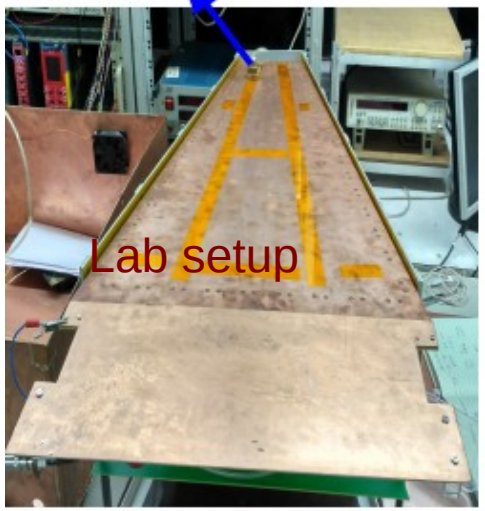
Two large size (Mv1C and Mv1V) and one small size (10 cm x 10 cm, GSI) detector were tested
-- one assembled at RD51 lab CERN (Mv1C)
-- second one assembled at VECC(*Thanks to CPDA lab*) (Mv1V)



Cosy test beam setup

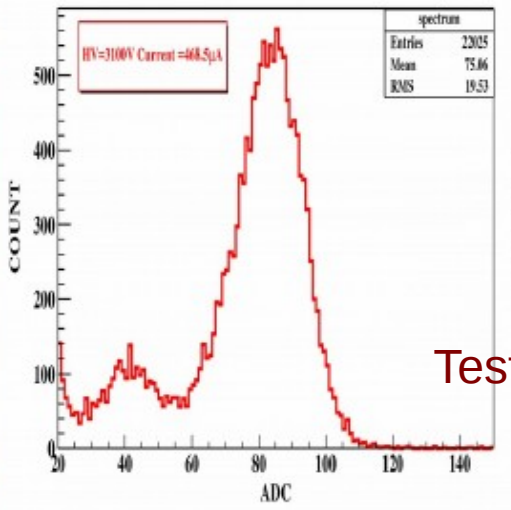


Fe-55

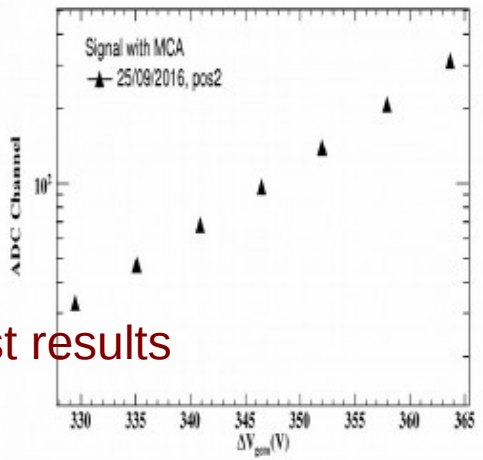


Test results

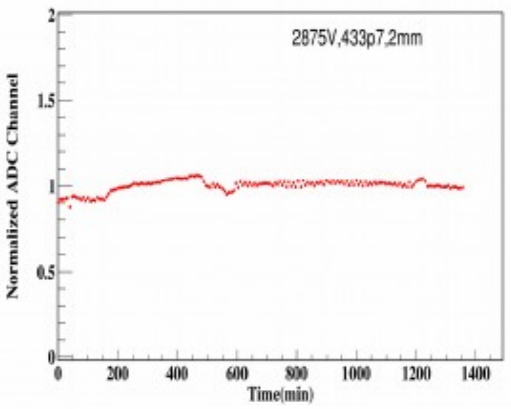
Pulse height spectra of Fe-55 source



Gain variation at different delta V of GEM.



Variation of normalized ADC channel with Time(min).

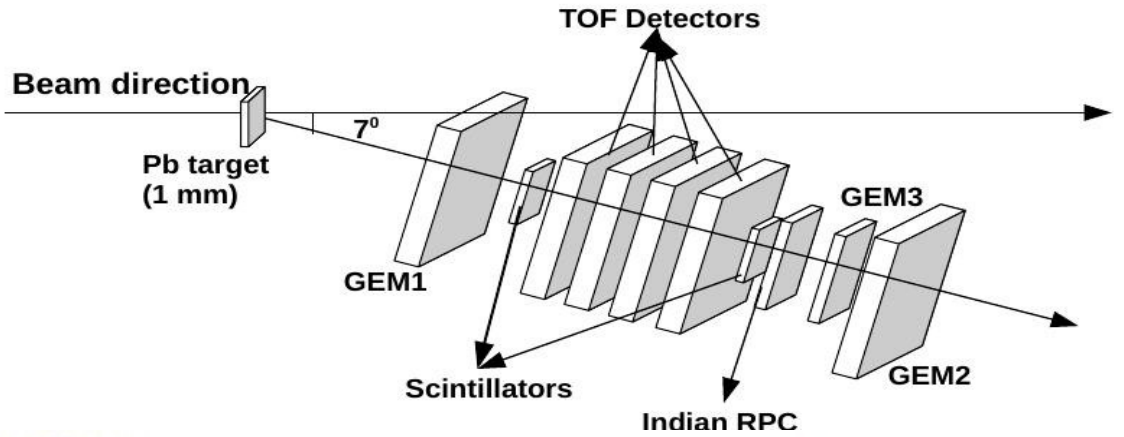


Test of large size chamber with single particle beam is published in NIM paper -(R. Adak, Ajit Kumar, et al. Nucl. Instrum. Methods A, 846 (2017), 29-35)

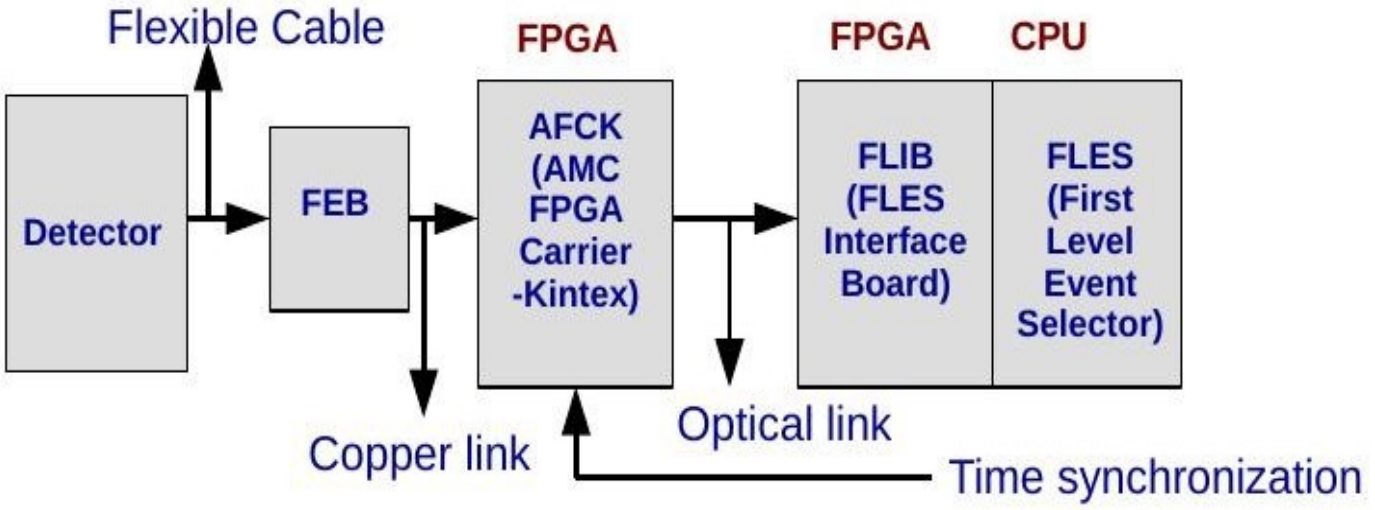
Experimental Setup at CERN SPS

1. Detector setup:

A diamond detector was placed just before the target.



2. Daq setup:



3. Data taking

Data Taking : Data were taken in 3 phases

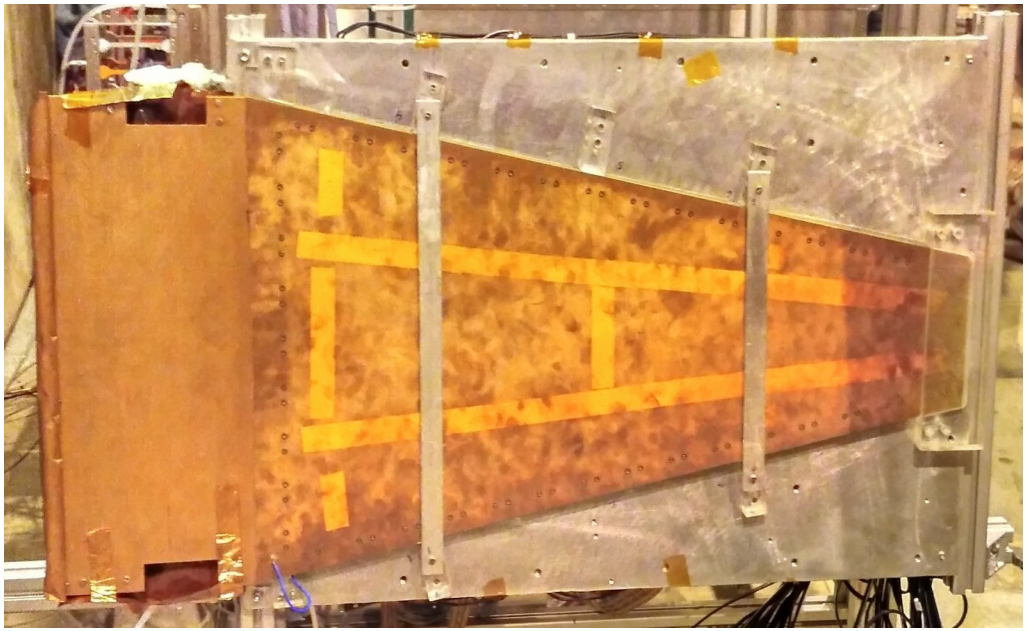
Phase1 : 13 AGeV/c, Pb beam , 1mm thickness Pb target-- Only one large size detector

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

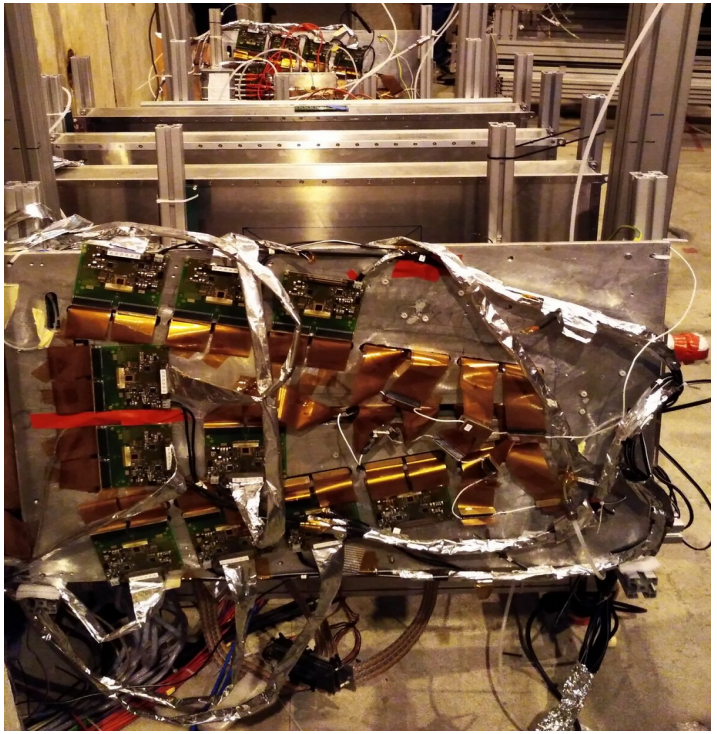
Phase3 : 150 AGeV/c, Pb beam , 1mm thickness Pb target + extra Fe block were used as target to increase the ineraction rate--Two large size detector + one small (10 cm x 10 cm)

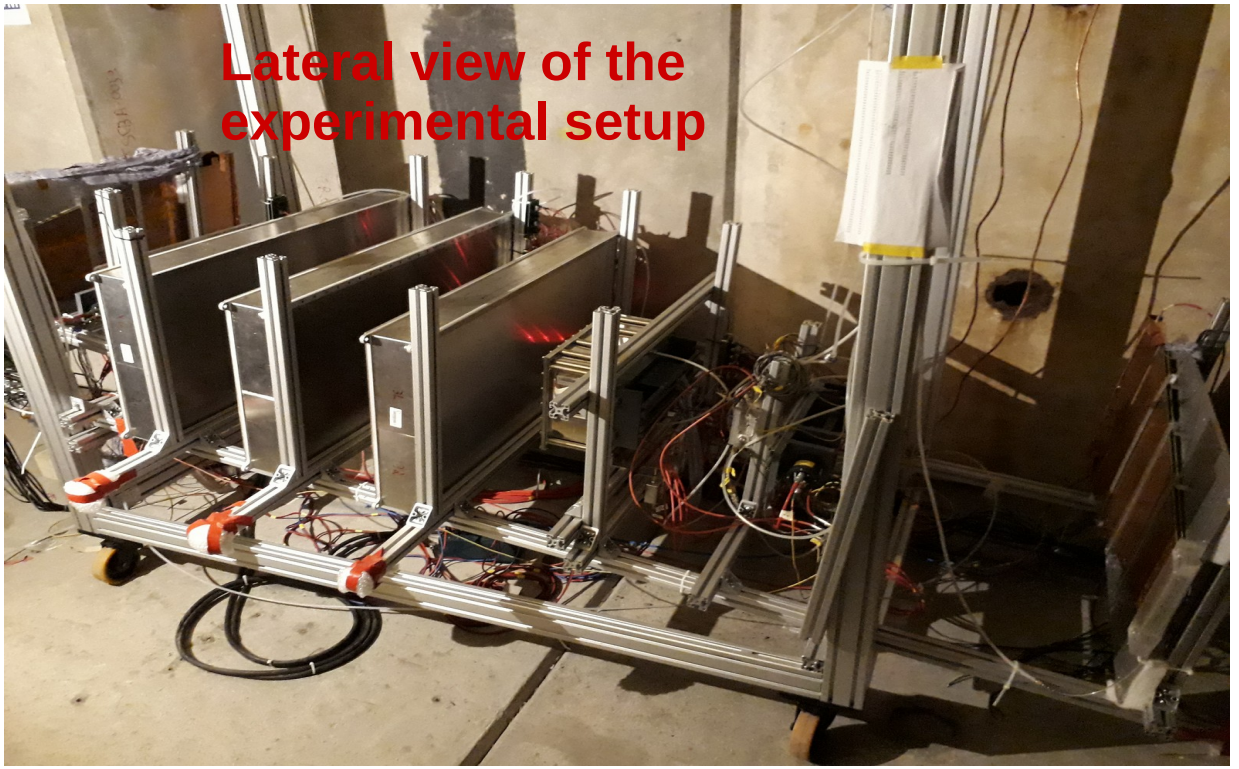
-- we have used two large size triple GEM detectors and one 10 cm x 10 cm detector.

Drift side



Connector side

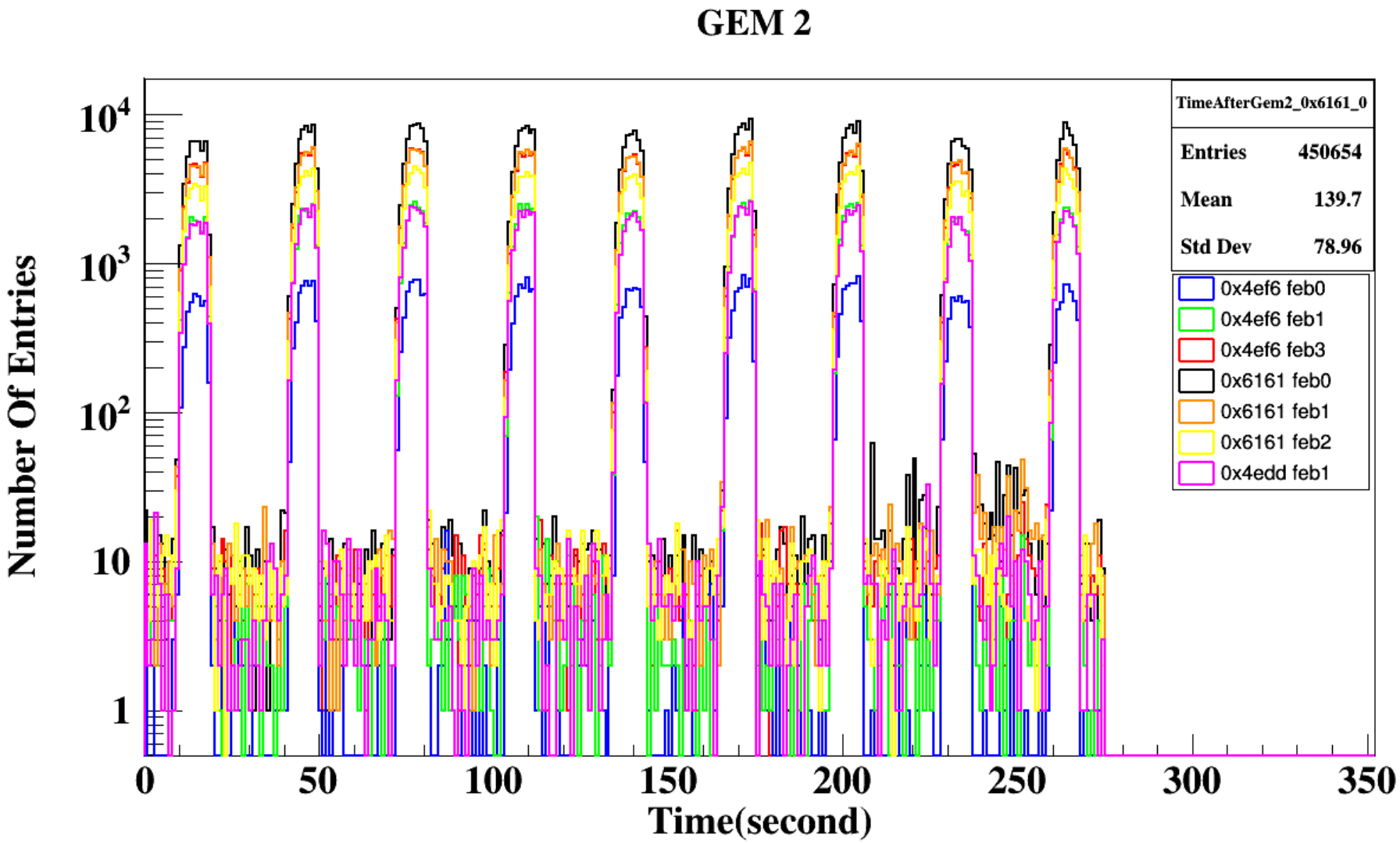




Spill Structure

Phase2, run43

FEB wise hit distribution plot with time

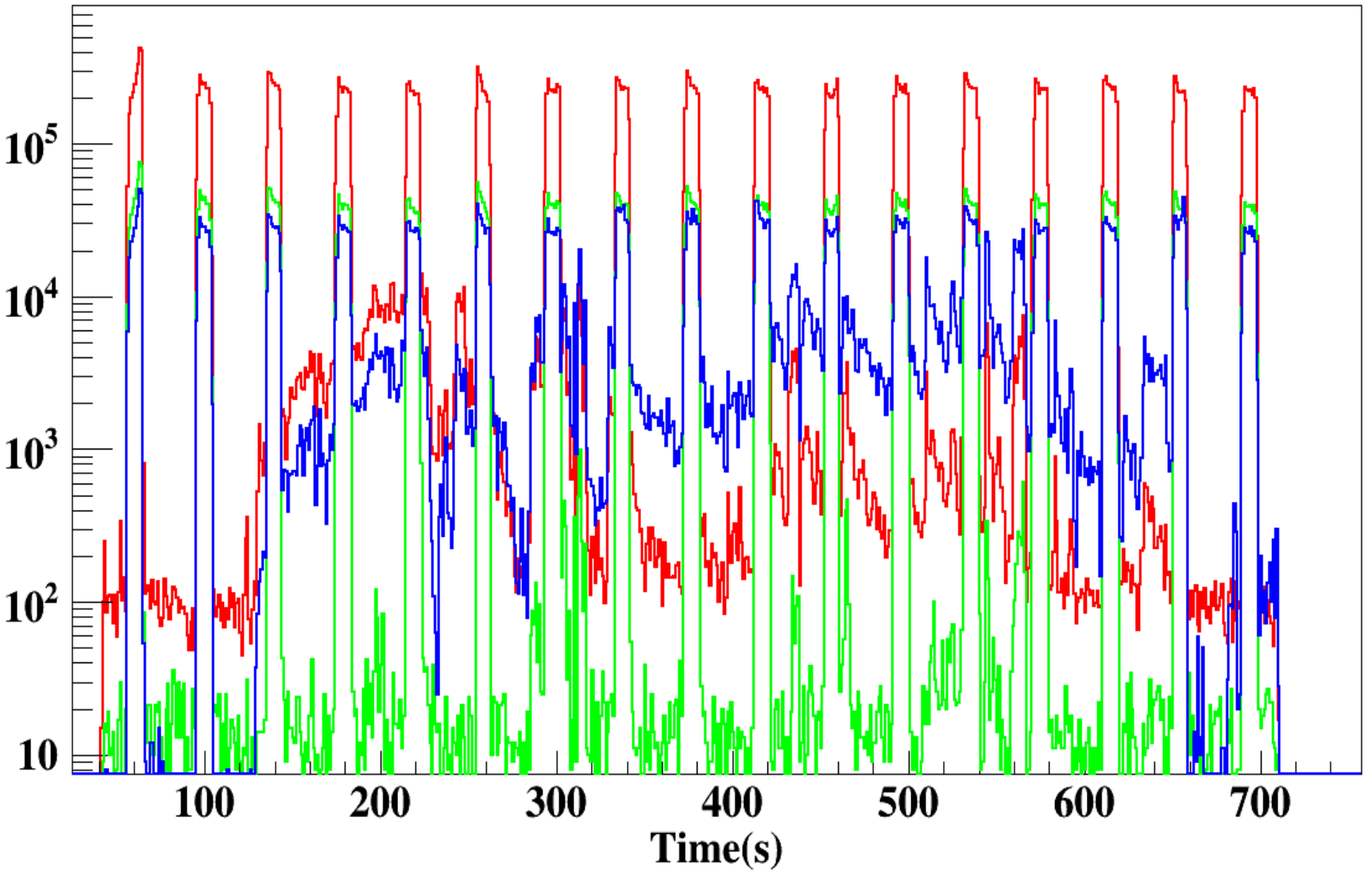


Spill Structure

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

- GEM2
- GEM3
- GEM1

Spill structure for all the three GEM planes.



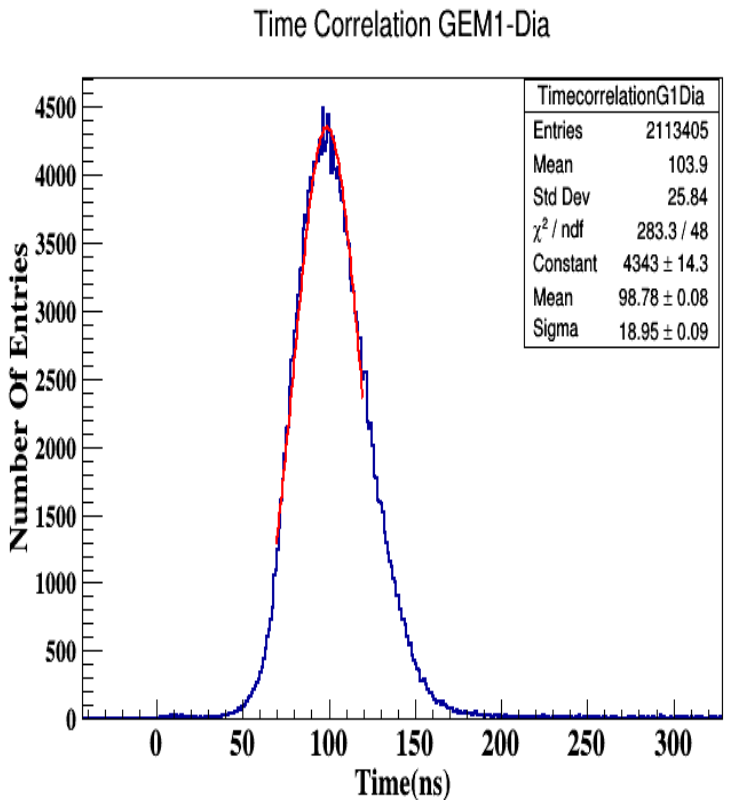
Time correlation

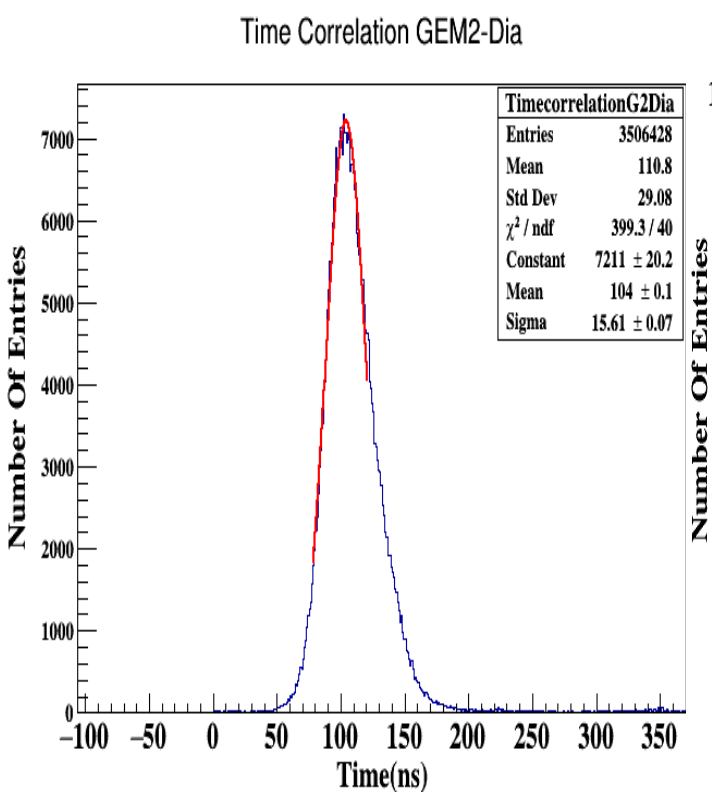
Event reconstruction algorithm:

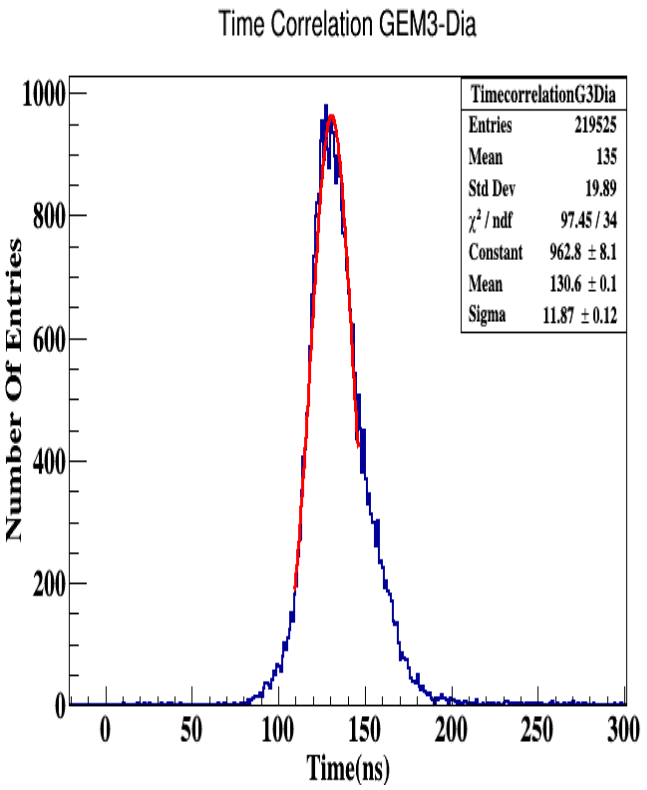
In Time Slice (size of time slice is 10 ms) ---> Diamond hit as well as GEMs hit

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

--- Time difference spectra plotted within event

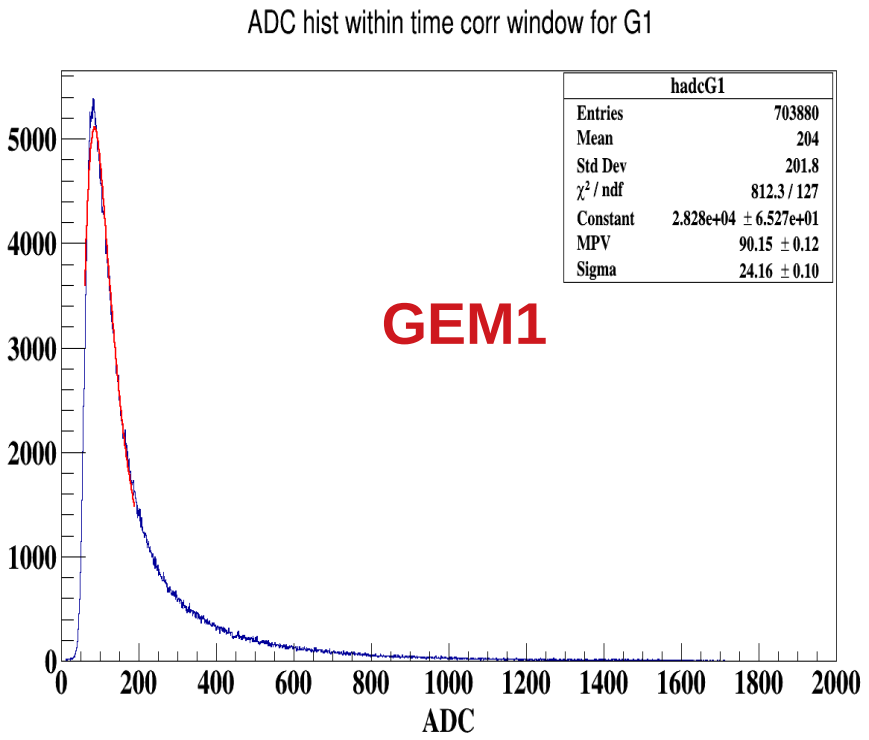


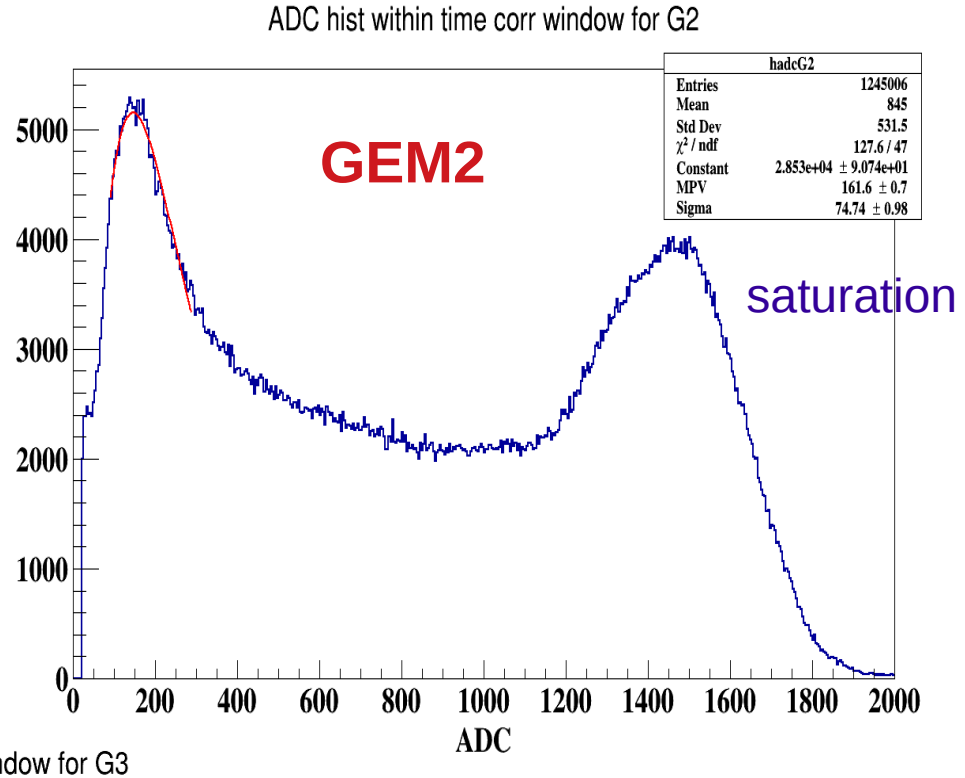


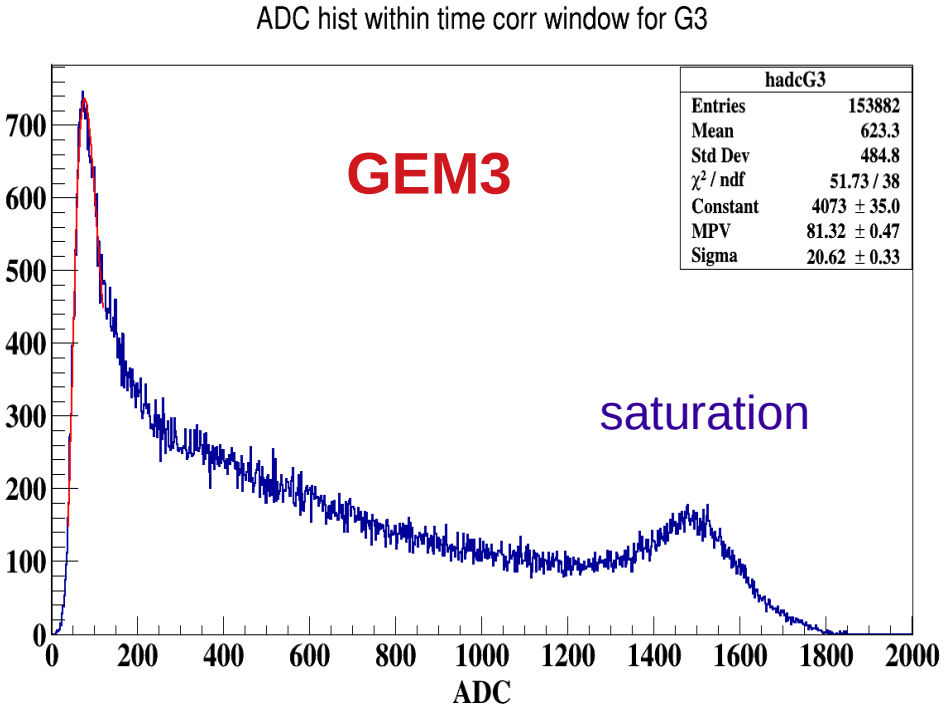


Time correlation between GEMs and diamond

Pulse height histogram

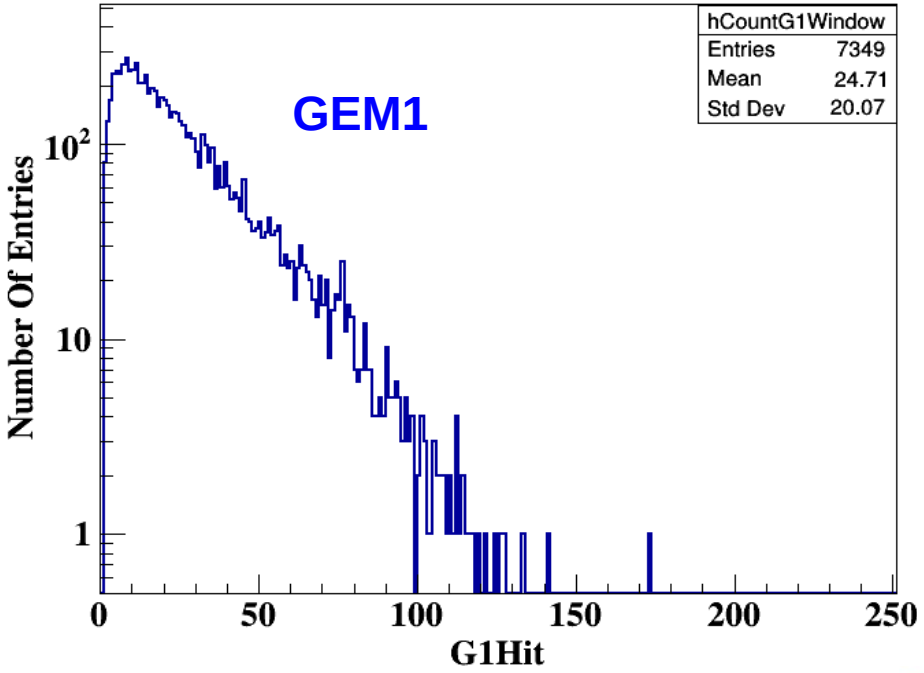


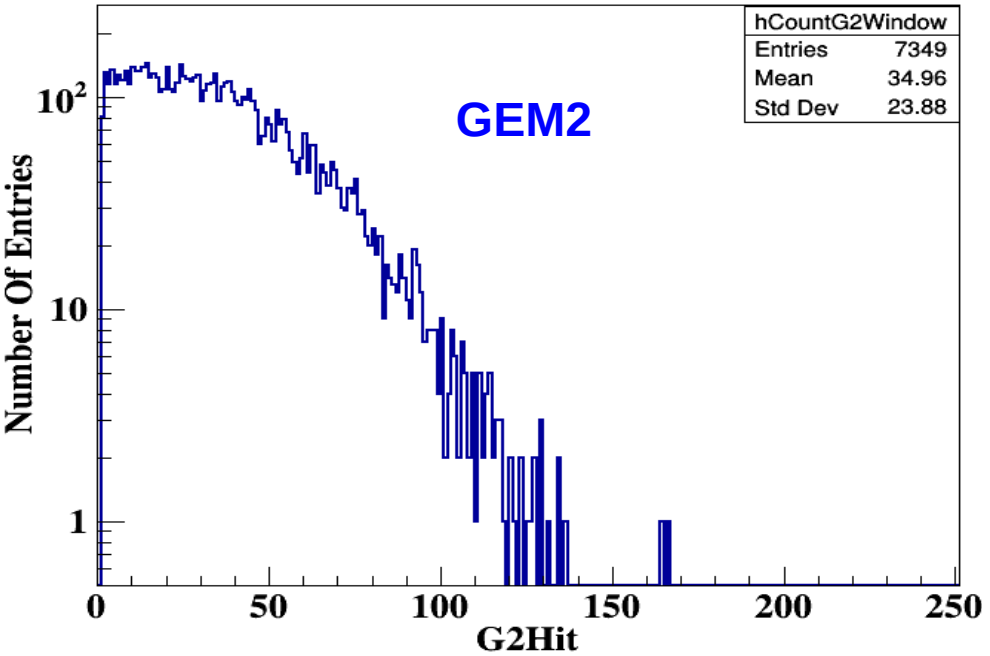


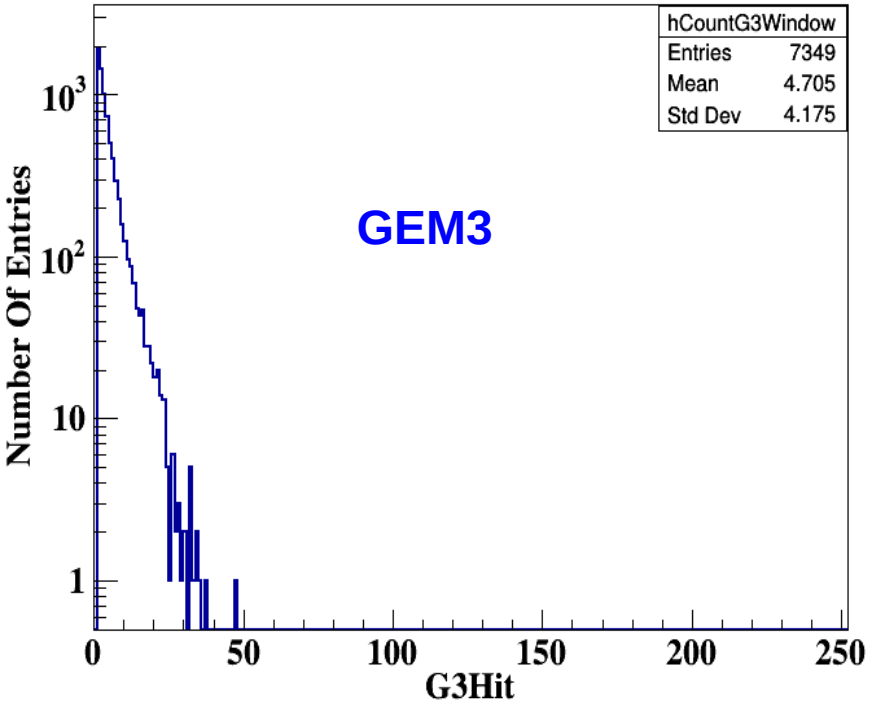


Number of hit/event

ADC cut in each plane 50





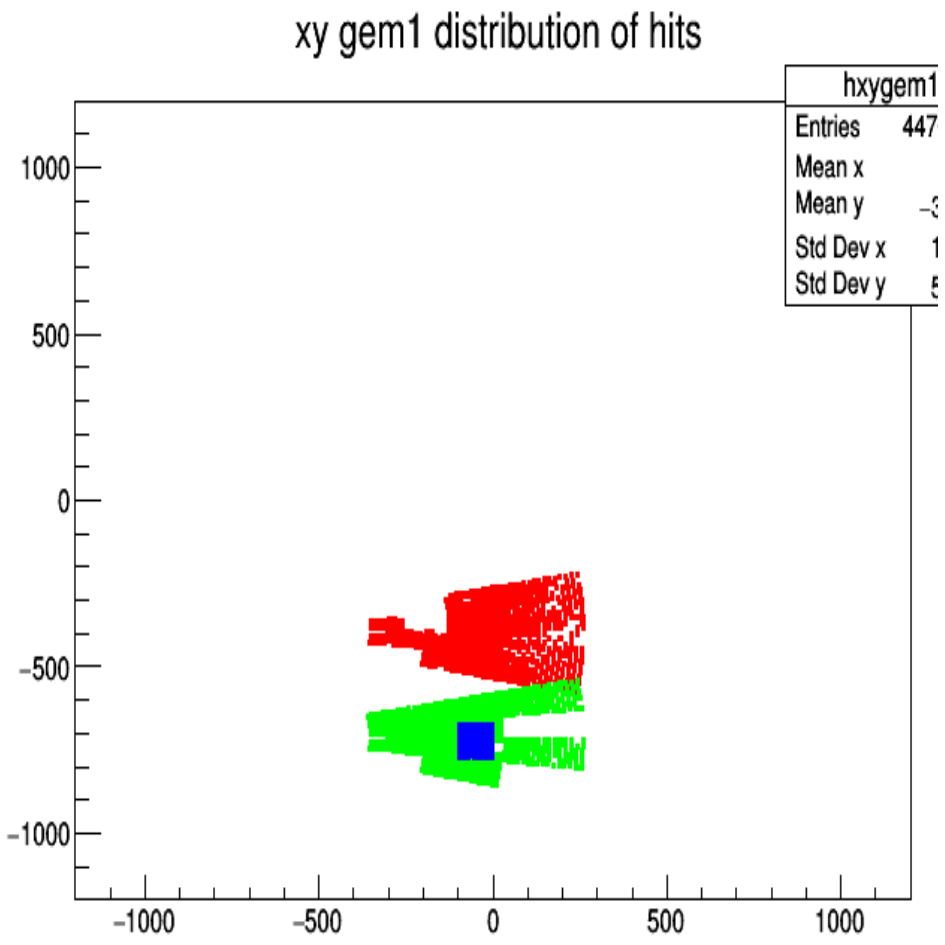


Adc cut	G1	G2	G3 (10 cm x 10 cm)
0	25.02	35.98	4.9
30	24.77	35.41	4.87
50	24.55	35.14	4.83
80	22.86	34.79	4.62
100	21.36	33.71	4.48
150	18.67	32.03	4.24
200	17.04	30.49	4.09

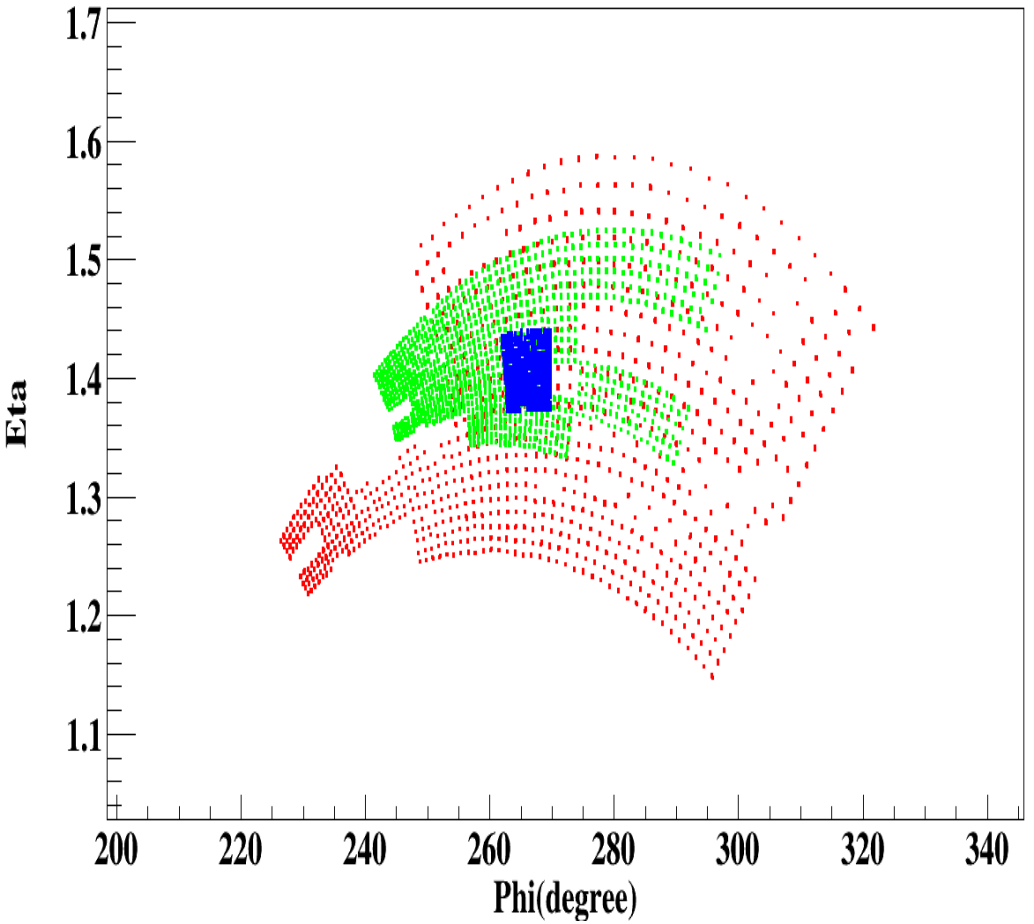
Average number of hit per event for three different GEM plane at various baseline ADC substracted cut.

X-Y and η-φ plot

X-Y Plot



η-φ Plot



ADC cut:

GEM1 : 50 adc channel

GEM2 : 100 adc channel

GEM3 : 100 adc channel

GEM1

GEM2

GEM3

η-φ selection

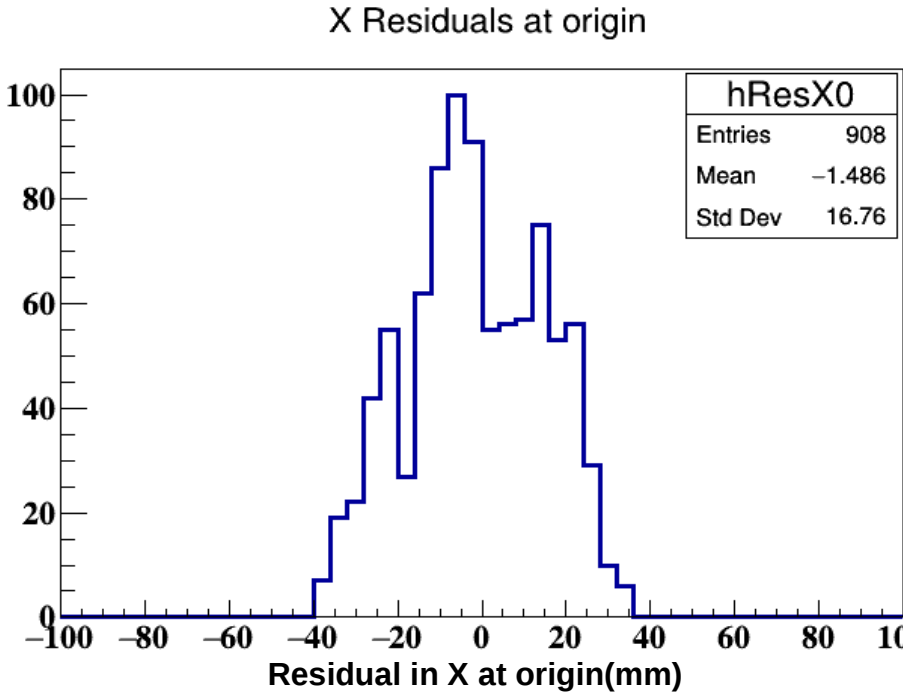
η-φ cut for all planes

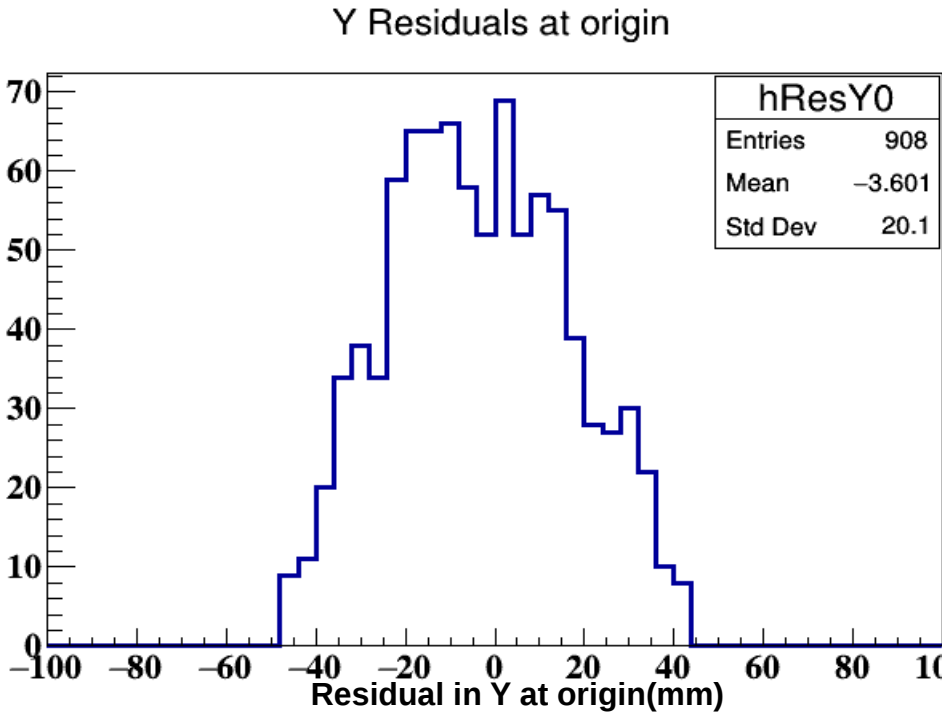
1.37<**η**<1.40

264<**φ**<266

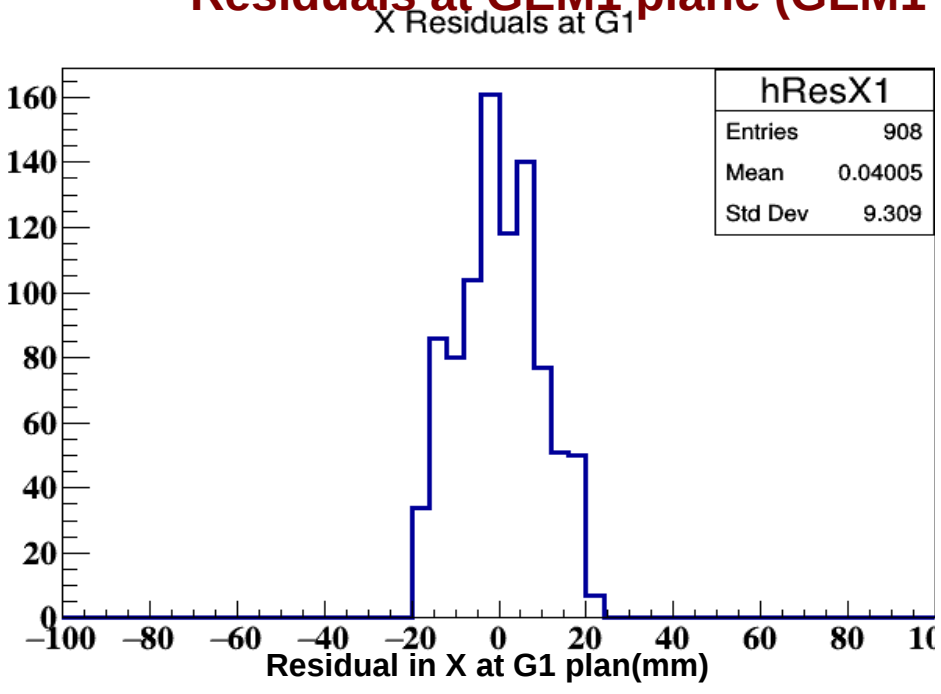
Tracking

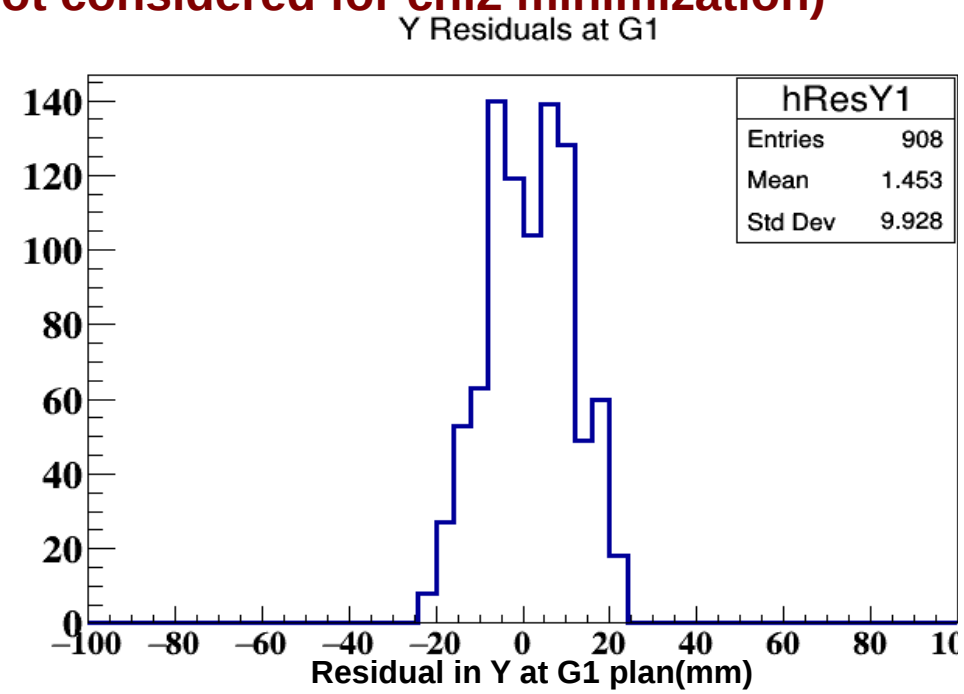
Residuals at origin (origin is not considered for chi2 minimization)





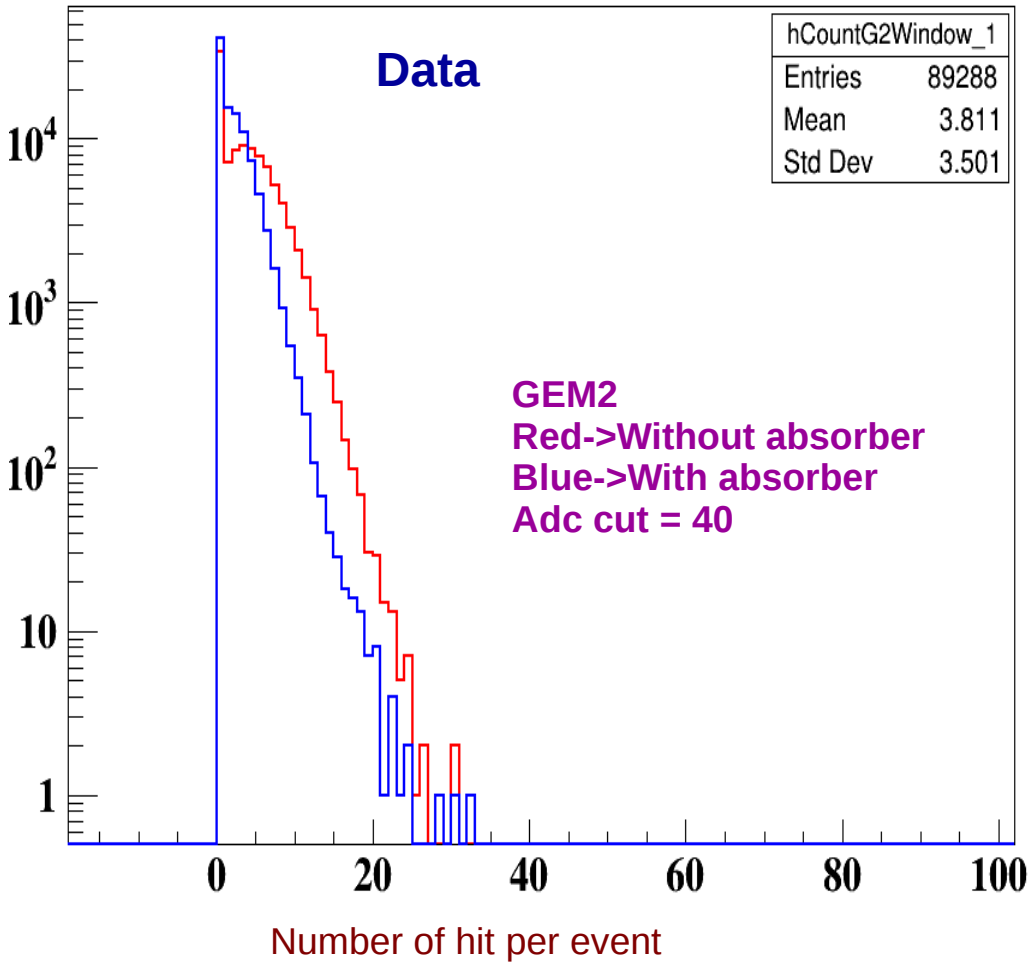
Residuals at GEM1 plane (GEM1 is not considered for chi2 minimization)



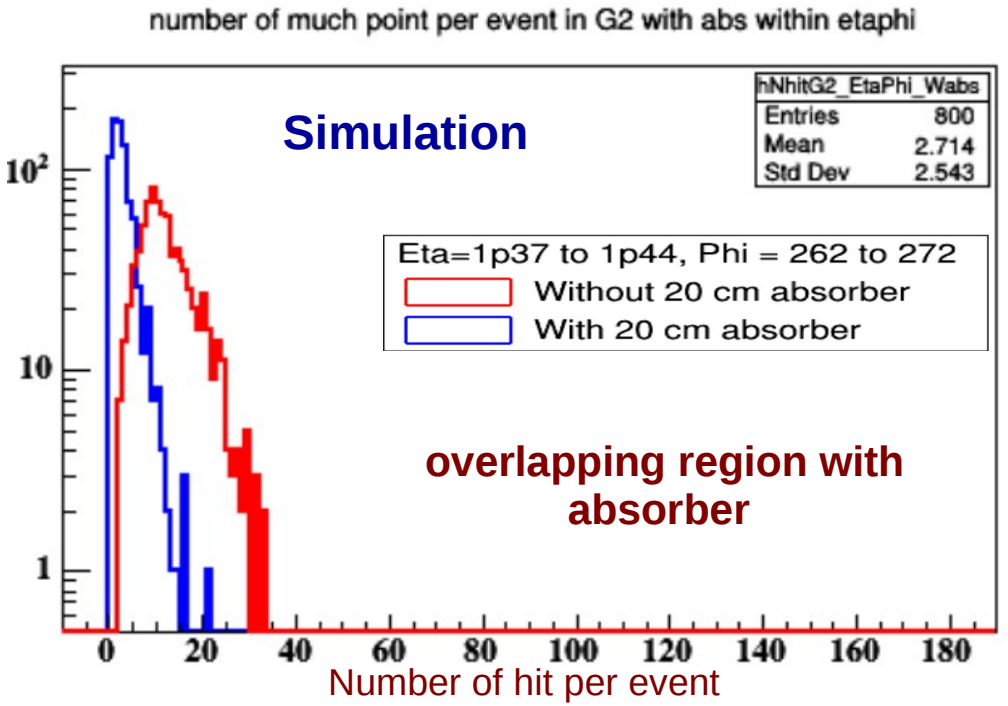


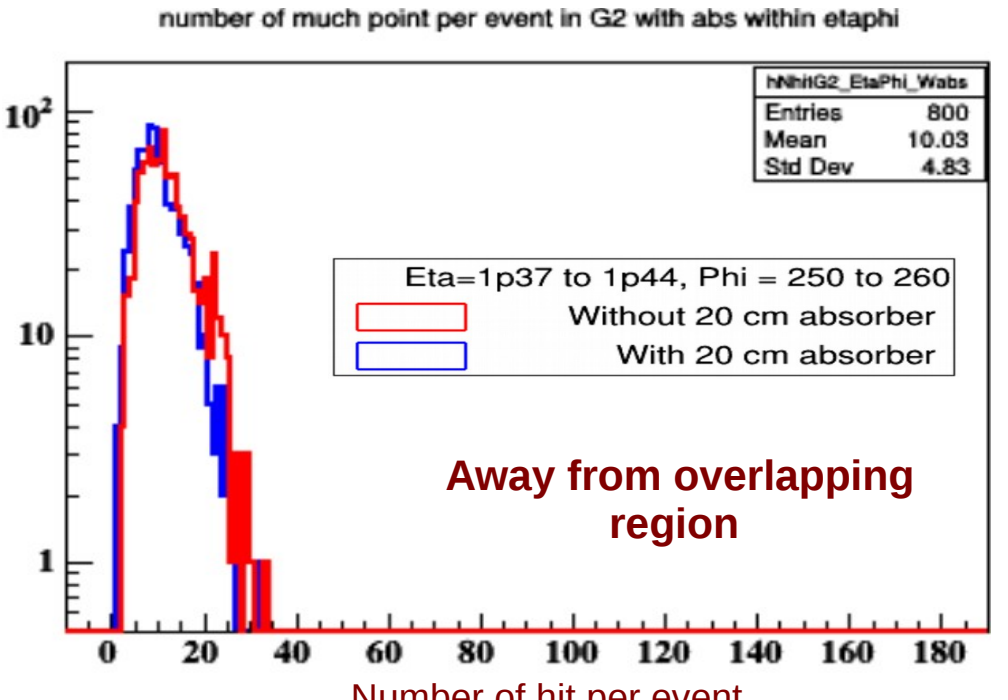
Absorber effect on detector hits

Effect of absorber within GEM3 eta-phi window



Data and simulation results are consistance





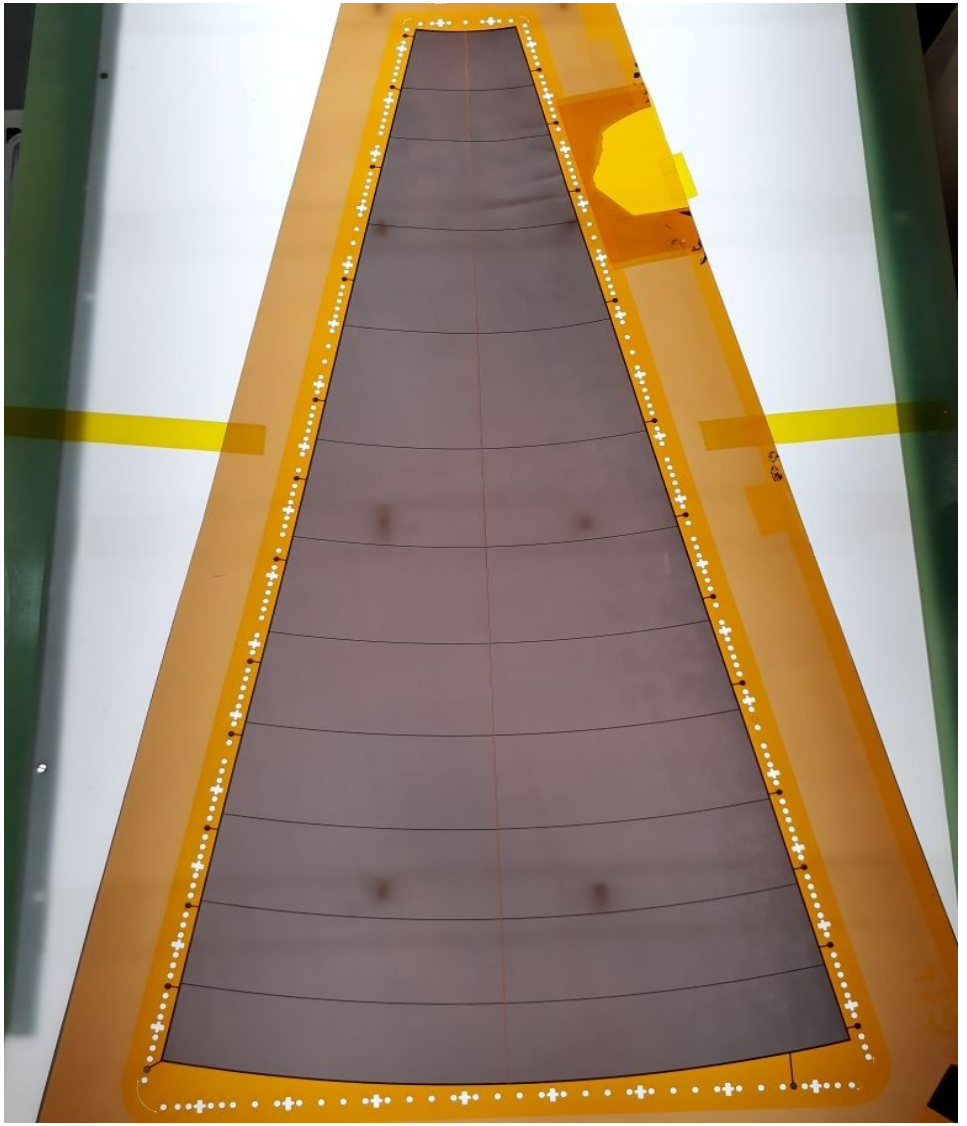
Moving towards new HV biaising scheme for GEM..

Mv1-

1. 24 segments on top side
2. One HV connection for 6 segments
3. HV design was not optimised

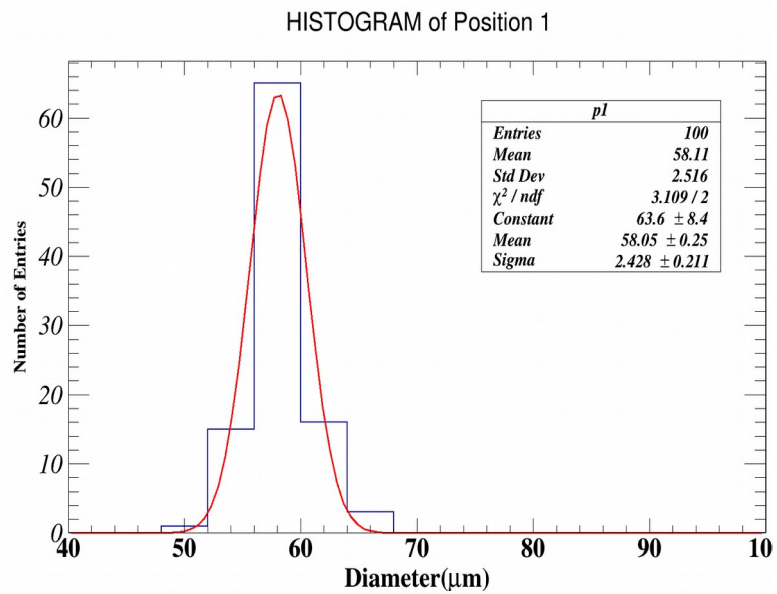
Mv2-

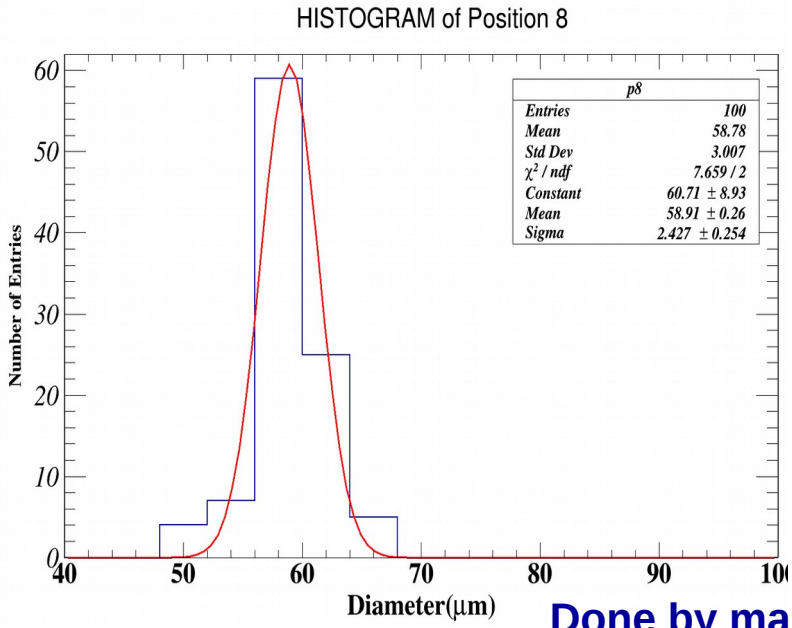
1. 24 segments on top side
2. One HV connection for each segments optimized for CBM rates
3. Larger in size than Mv1



Mv2 GEM foil hole size measurement

First batch of GEM foil MUCH





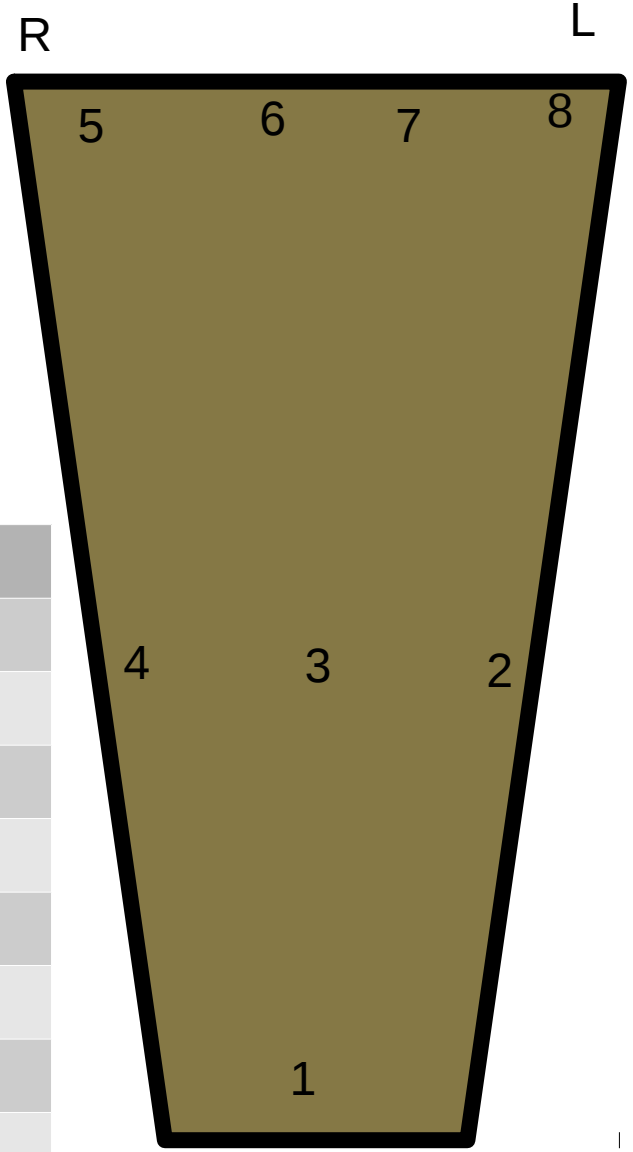
Distance from frame (TOP)

1= (3-6) cm from R
2=(4-7)cm from L
3=(16-19) cm from L
4=(2-6) cm from R
5=(1-6) cm from R
6=(16-20) cm from R
7=(21-25) cm from R
8T=(1-5) cm from L

#1 position from Bottom
8B = (2-6) cm from L

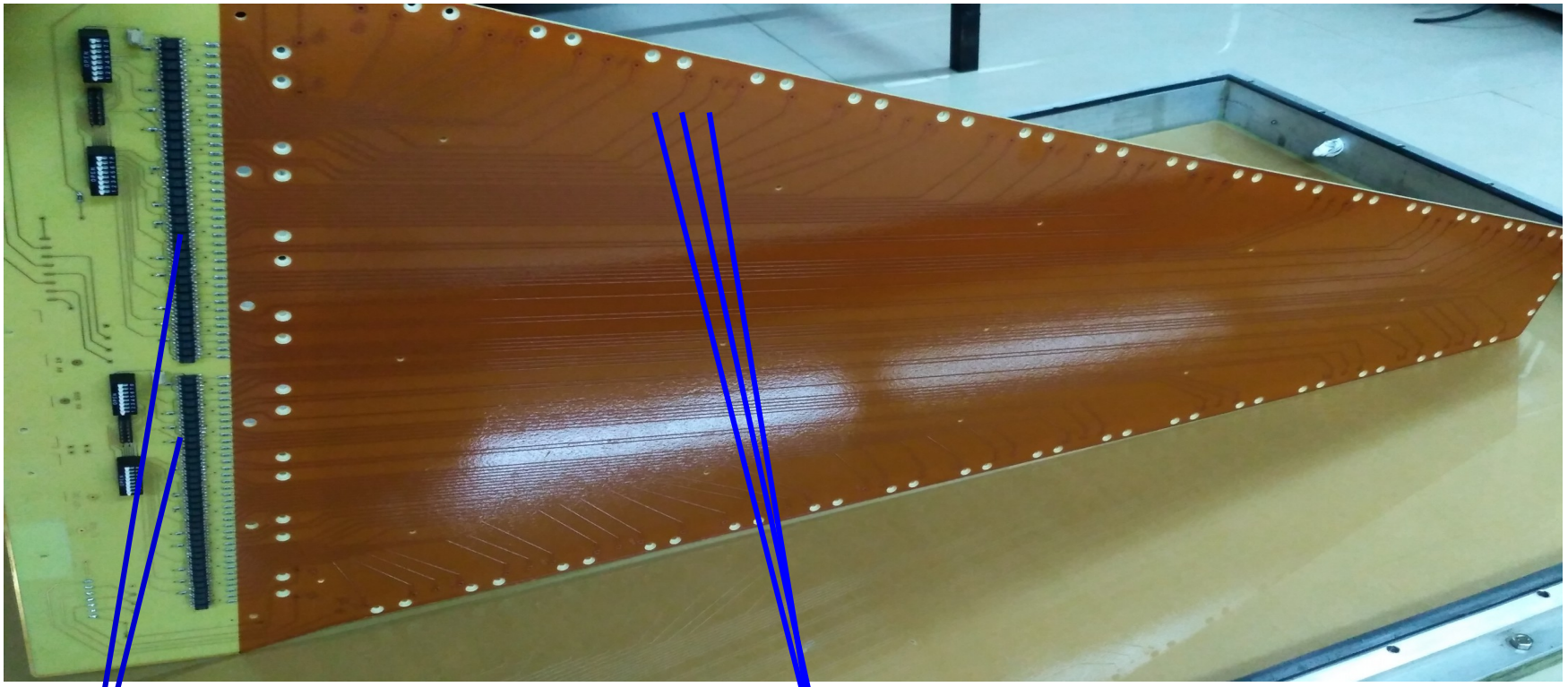
Pos	Dia(μm)	σ(μm)
1T	58.08	2.35
2T	61.79	2.30
3T	62.24	2.80
4T	59.12	2.54
5T	63.8	3.38
6T	57.95	2.29
7T	61.57	2.79
8T	59.02	2.80
8B	60.82	2.39

GEM foil



Done by master project students : Amit Poudyal and Needia Sharma
SMIT, Sikkim

Drift PCB (Mv2)



Opto-coupler

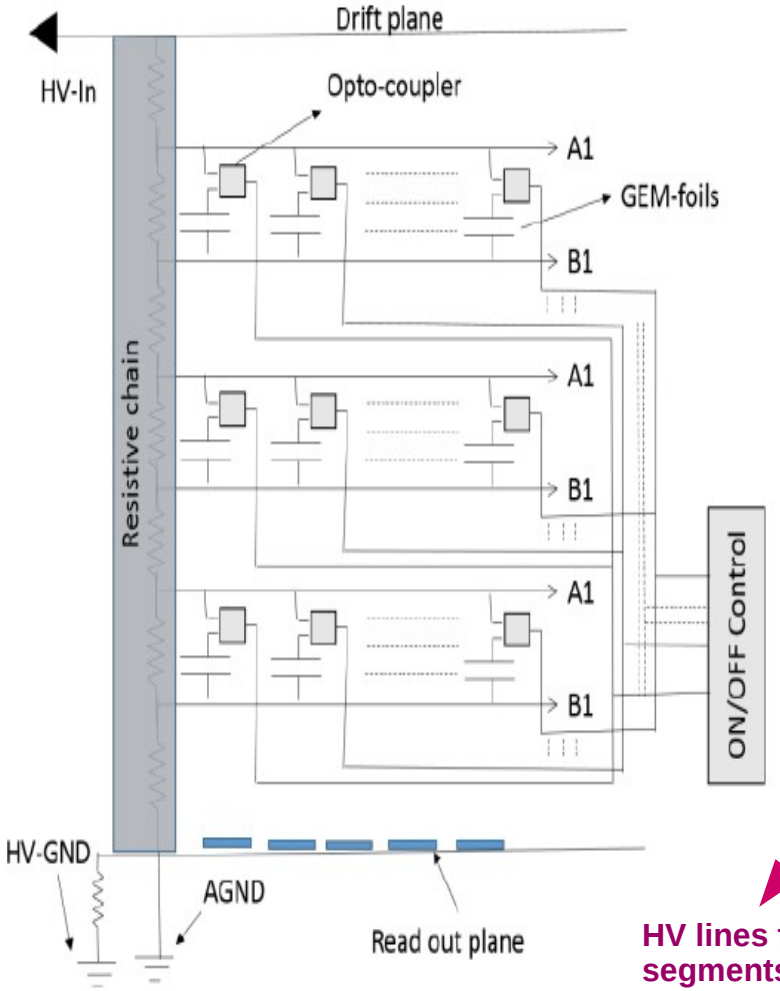
HV lines for individual segments of GEM

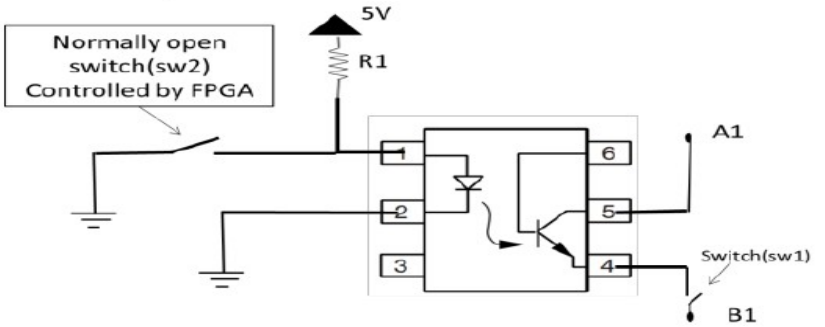
The opto-coupler indigenously designed & interfaced with the drift PCB connector with **Rui's** help

Mv2 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

No effect on gain with optocoupler
These opto-coupler are tested for radiation hard –> by Vinod Singh Negi
Gamma dose upto ~ **70 kRad**
Neutron dose upto ~ **10^{12} neq/cm^2**





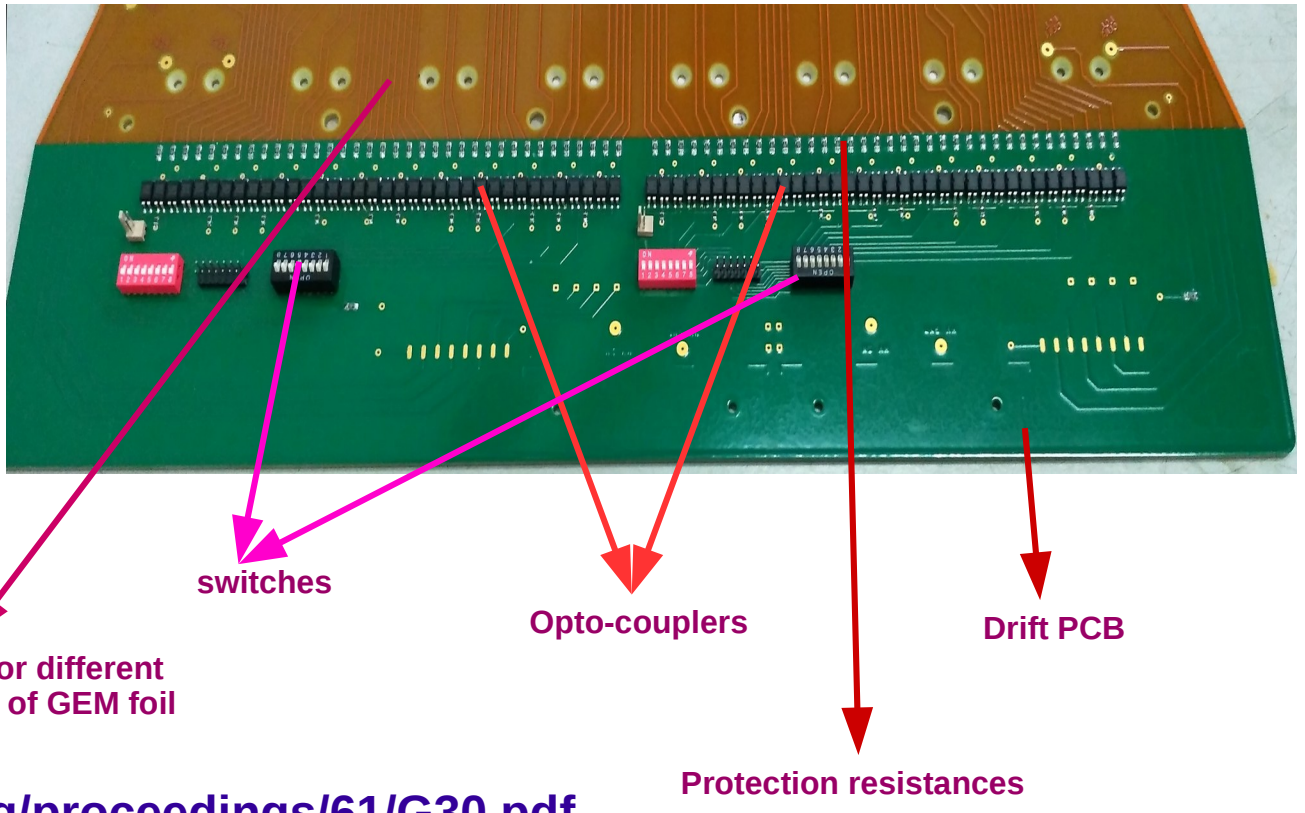
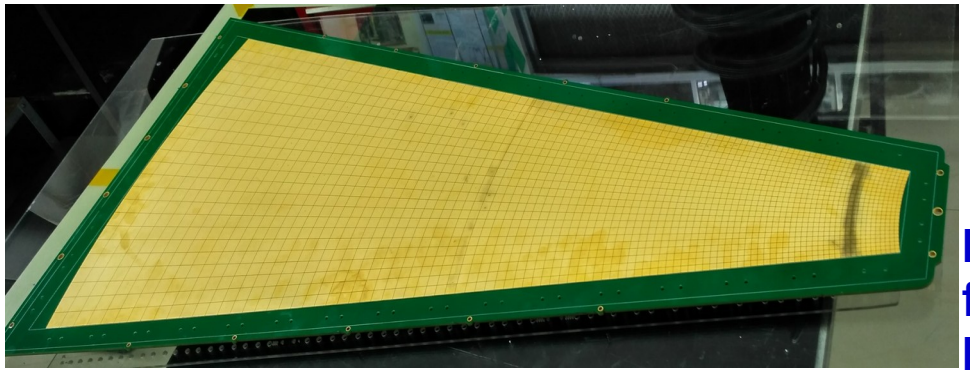


Image : http://www.sympnp.org/proceedings/61/G30.pdf

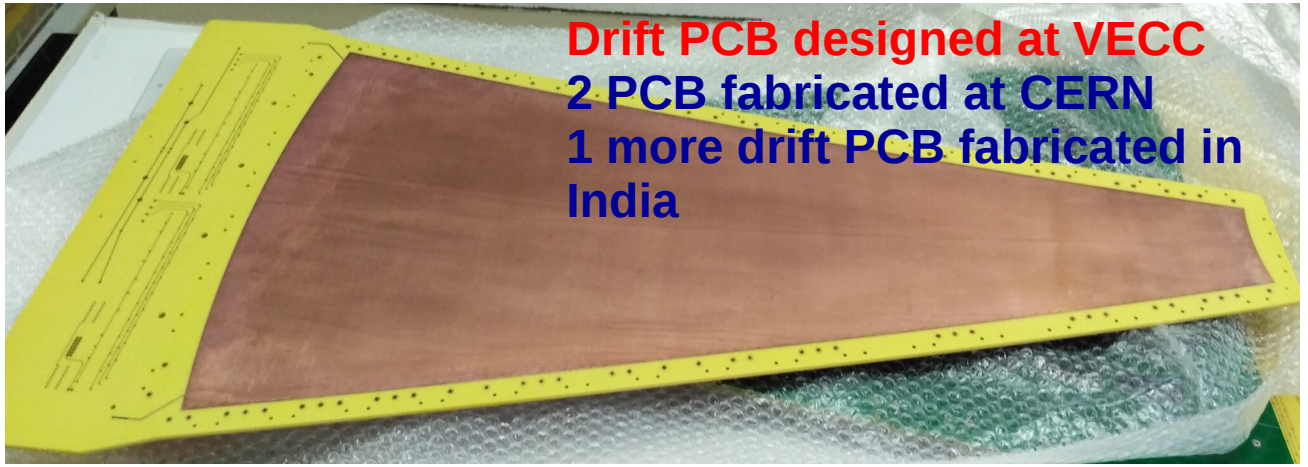
Mv2 chamber assembly and testing with Fe^{55} at VECC lab

Readout PCB (first station of CBM-MUCH)
--> ~2200 pad with gradually increasing sizes
--> total front end board needed = 18

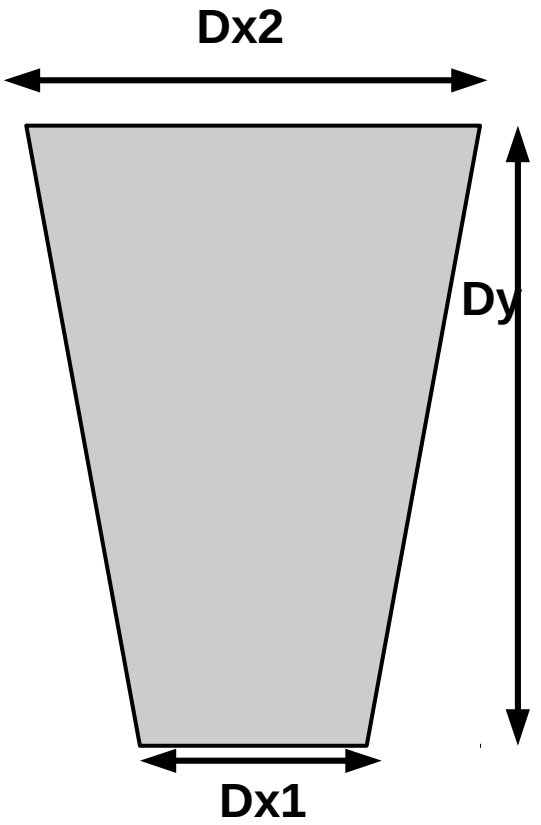
--> Active area
Dx1 = ~ 7.5 cm
Dx2 = ~ 40 cm
Dy = ~ 80 cm



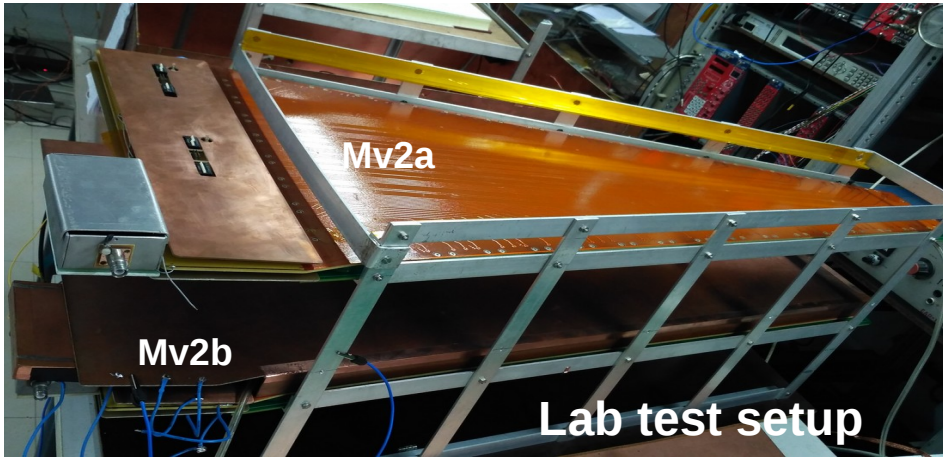
Readout PCB fabricated in India

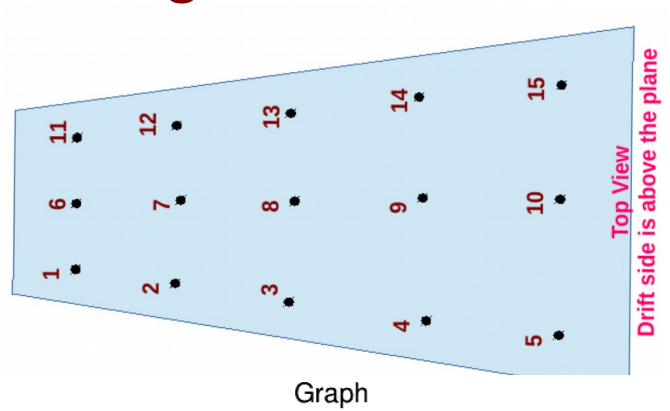


Drift PCB designed at VECC
2 PCB fabricated at CERN
1 more drift PCB fabricated in India

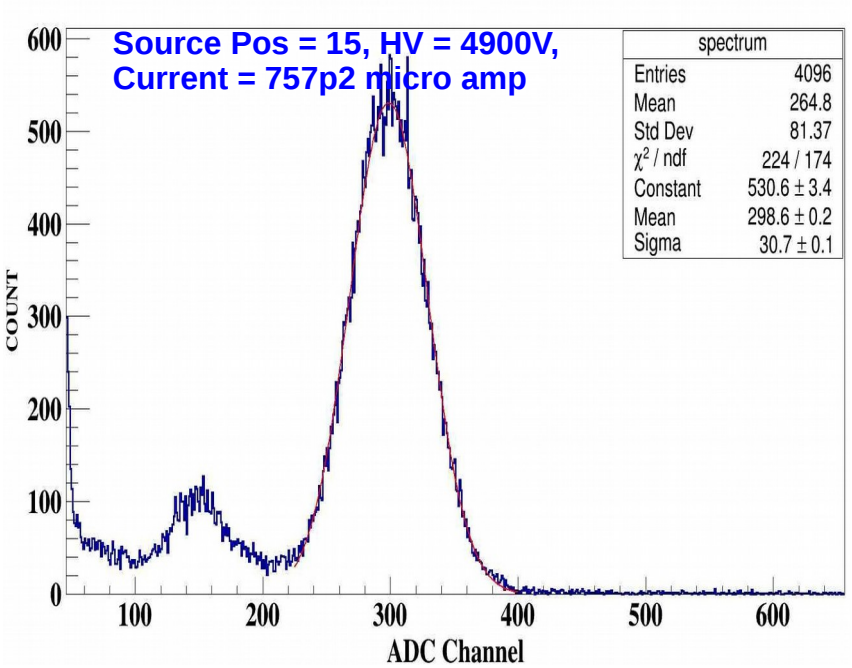


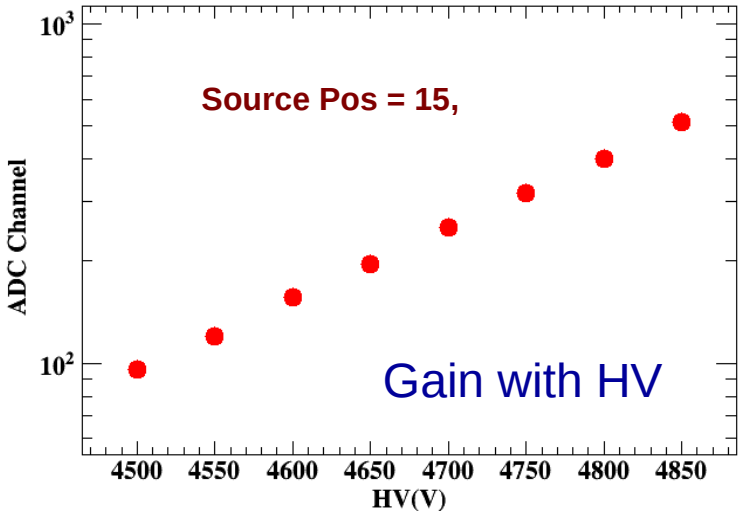
Mv2 chamber testing





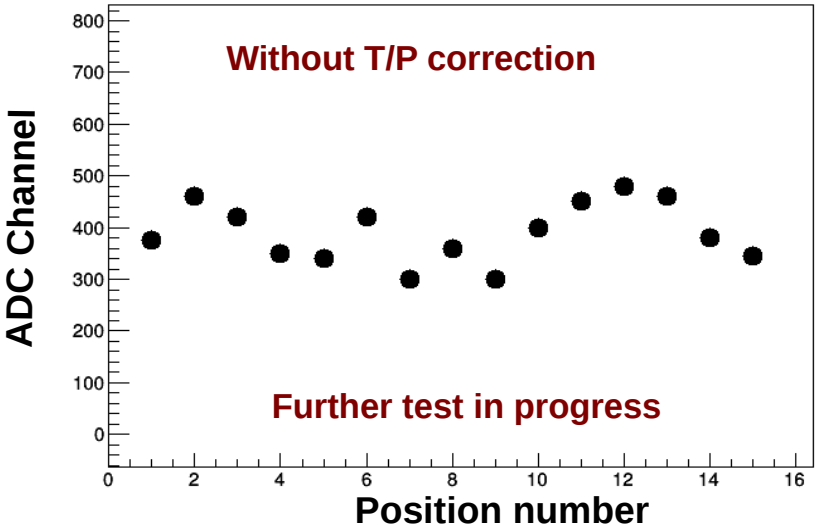
Graph





Gain Comparison of Mv2b with 10x10 chamber :

Mv2b shows ~28 % less gain than 10x10 chamber

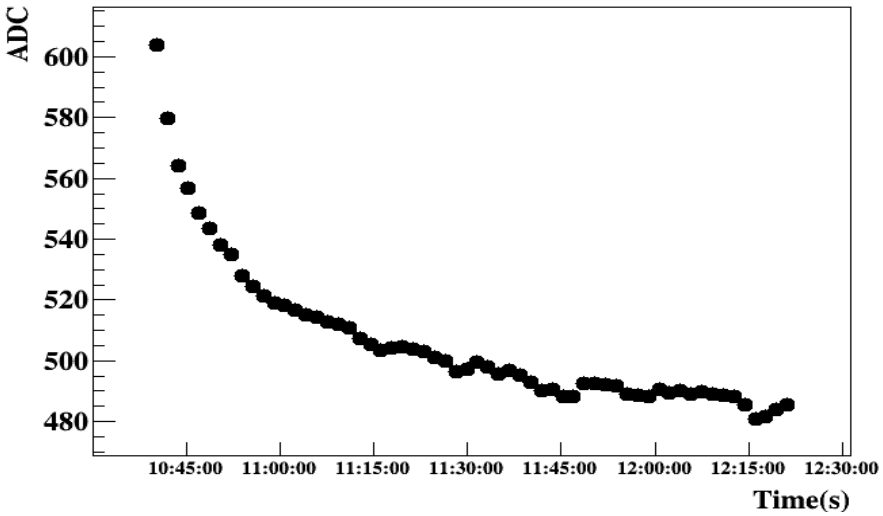


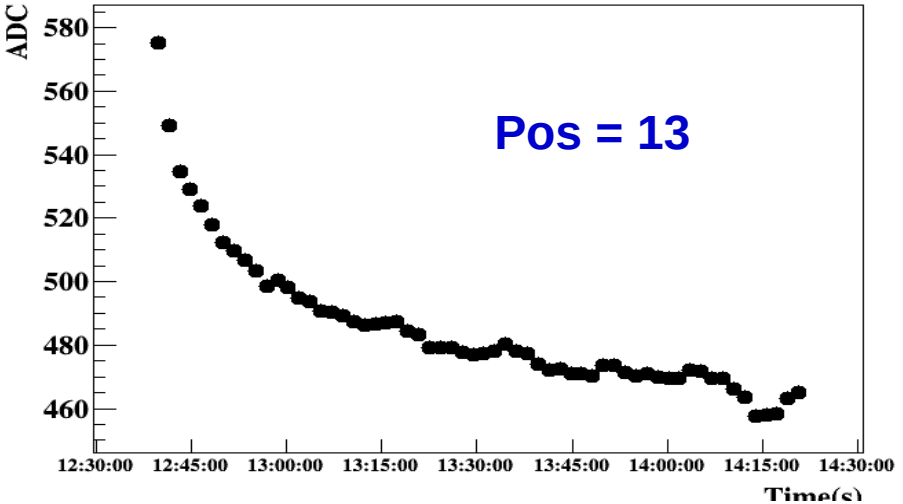
Mv2 GEM chamber test with Fe55 : Gain with time

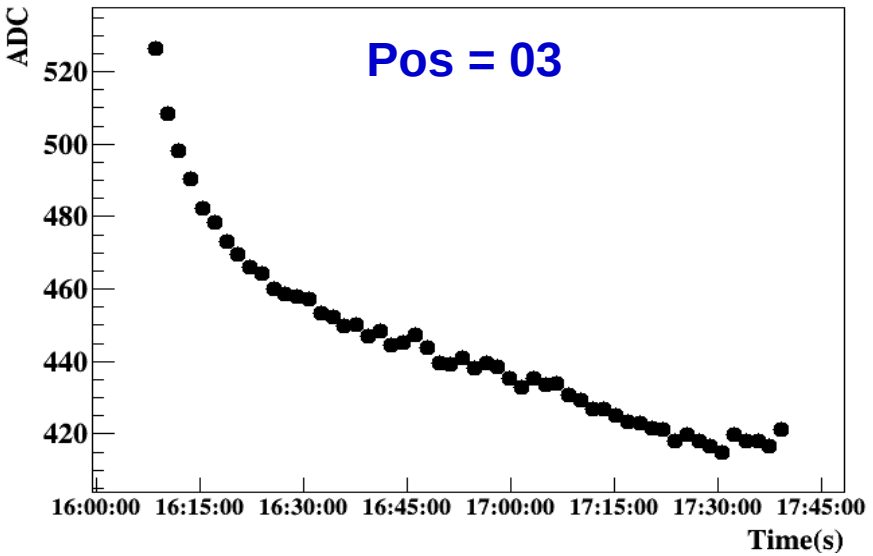
Gain measurement just after puting the source on the detector.
For several position the gain decreases with time as shown in the plots.

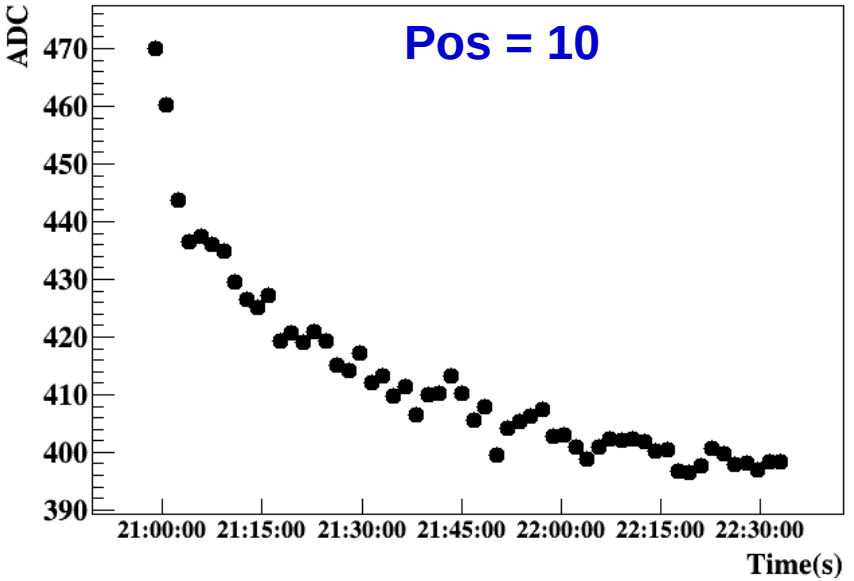
However we saw opposite (increasing trend) for old chamber

Pos = 12



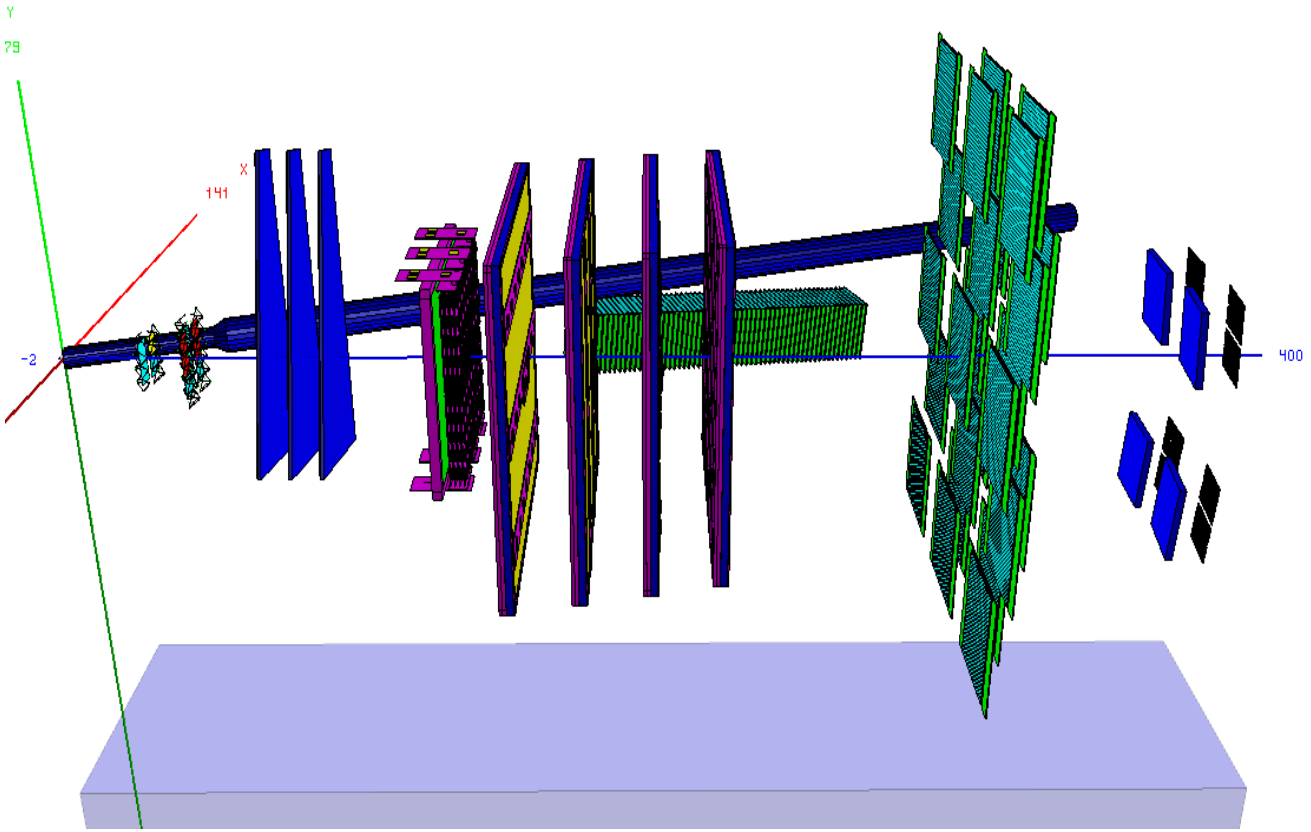


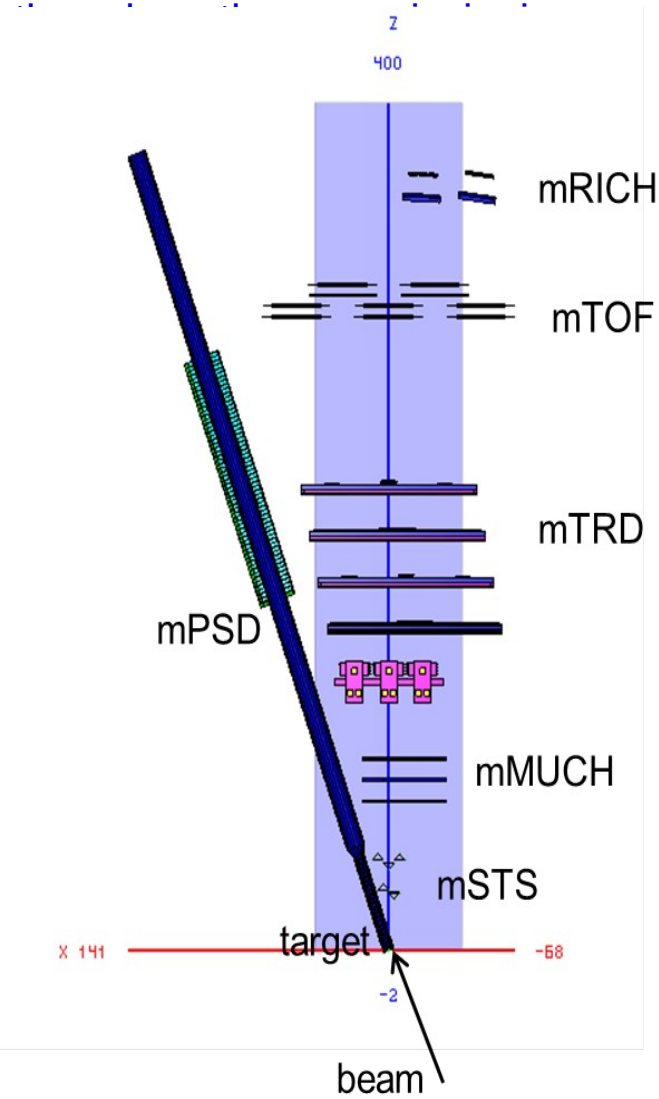




Large size GEM chambers for mCBM experiment

mCBM experiment: A CBM full system test-setup called mCBM@SIS18 (**"mini-CBM"**, shortened to mCBM) is presently being installed at the SIS18 facility of GSI/FAIR. The mCBM experiment will allow to test and optimize the performance of the detector subsystems including the software chain under realistic experiment conditions which will significa
time for CBM at SIS100.





Large size GEM (Mv2a/b) chambers for mCBM experiment ...

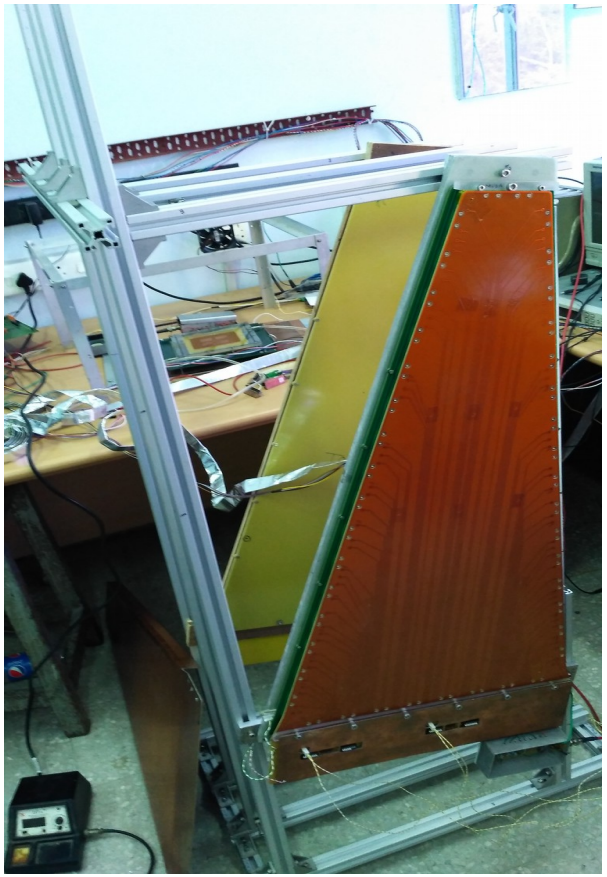
- free streaming data transport to a mFLES or FLES
- online reconstruction
- offline data analysis
- controls
- **permanent test-setup at the host lab**

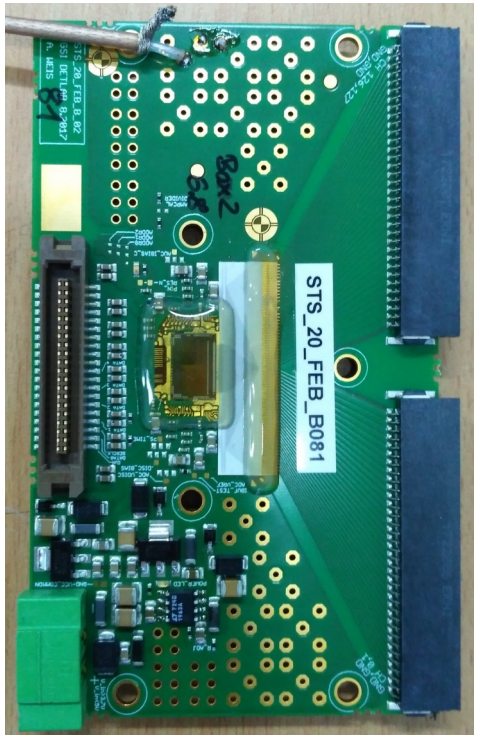
➢ detector prototypes at $\theta_{lab} \approx 13.1^{\circ} - 36.9^{\circ}$

➢ straight tracks, no B-field

➢ high resolution TOF (t_0 – TOF stop wall)

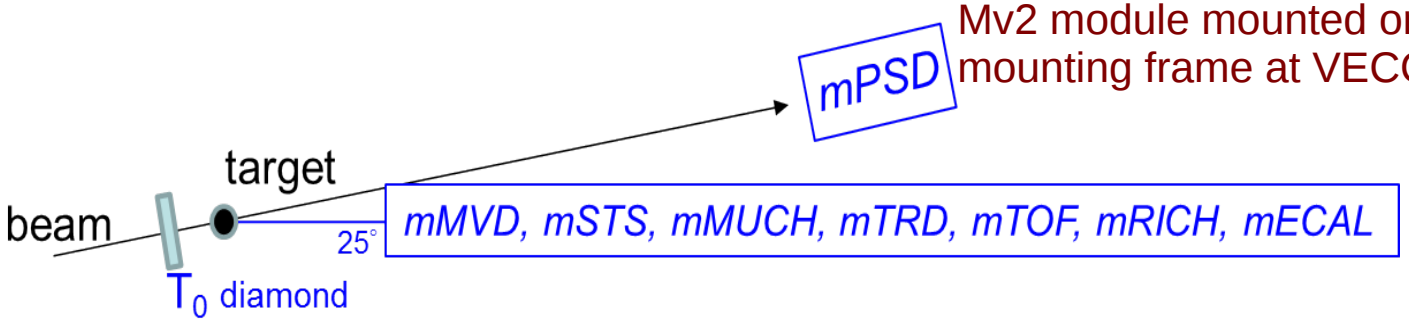
➢ event characterization with PSD prototype





Mv2 module mounted on mounting frame at VECC

First version of Much-XYTER
-> self triggered electronics
->provides both timing and energy information
-> 5 bit flash ADC



Three such modules will be used in mCBM experiment

Summary

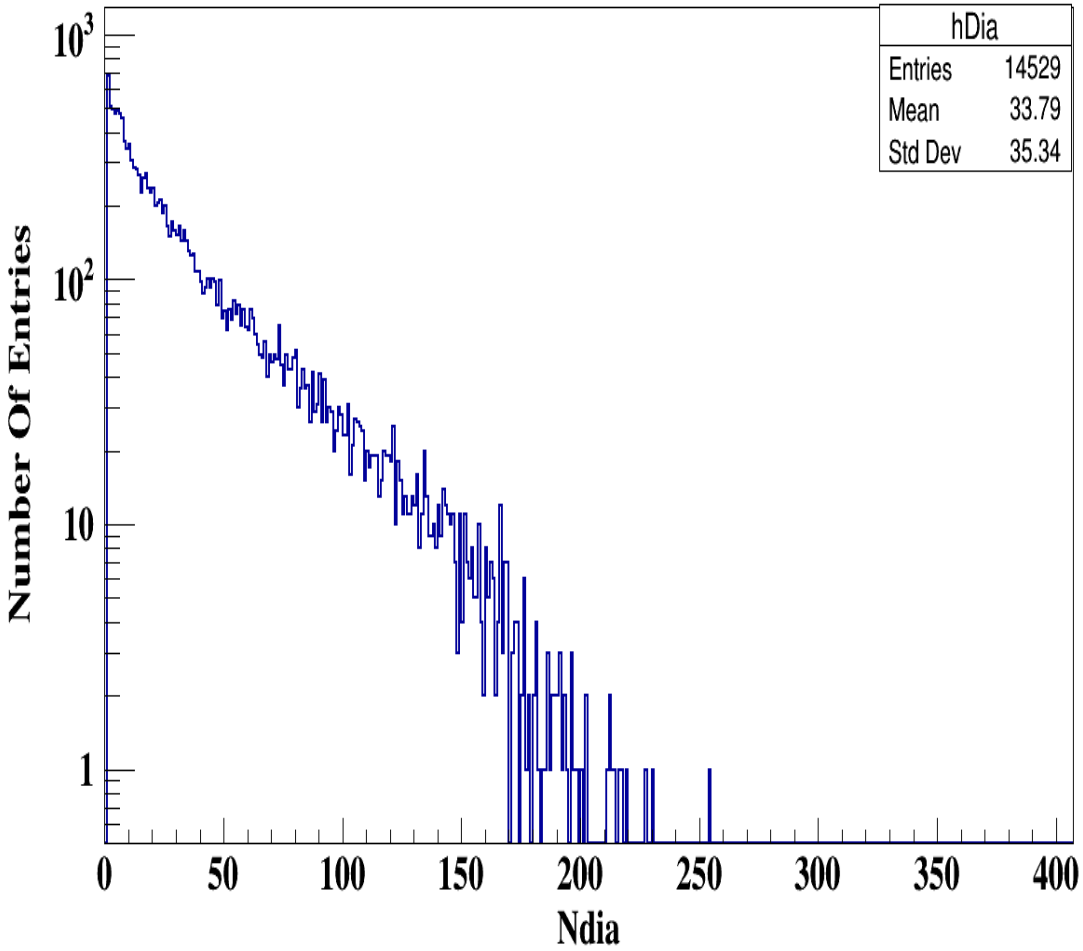
- Tested two real size (Mv1V and Mv1C) and one small size (10 cm x 10 cm) triple GEM with Pb+Pb collision at CERN SPS
- Event reconstructed using consecuitive hits of diamond detector
- Straith line tracking fitting has been done
- Effect of 20 cm thick absorber on detector hits has been studied. Simulation and data are in agreement

- Novel high voltage powering scheme tested with X-Ray source
- Two large size triple GEM detector (Mv2a and Mv2b) for mCBM experiment has been fabricated and tested with Fe55 at VECC lab. Preliminary test with self triggered electronics has been done
- These detectors will be used for mCBM experiment

Thank you for your kind attention

Backup slides

Number of diamond hits in each time slice

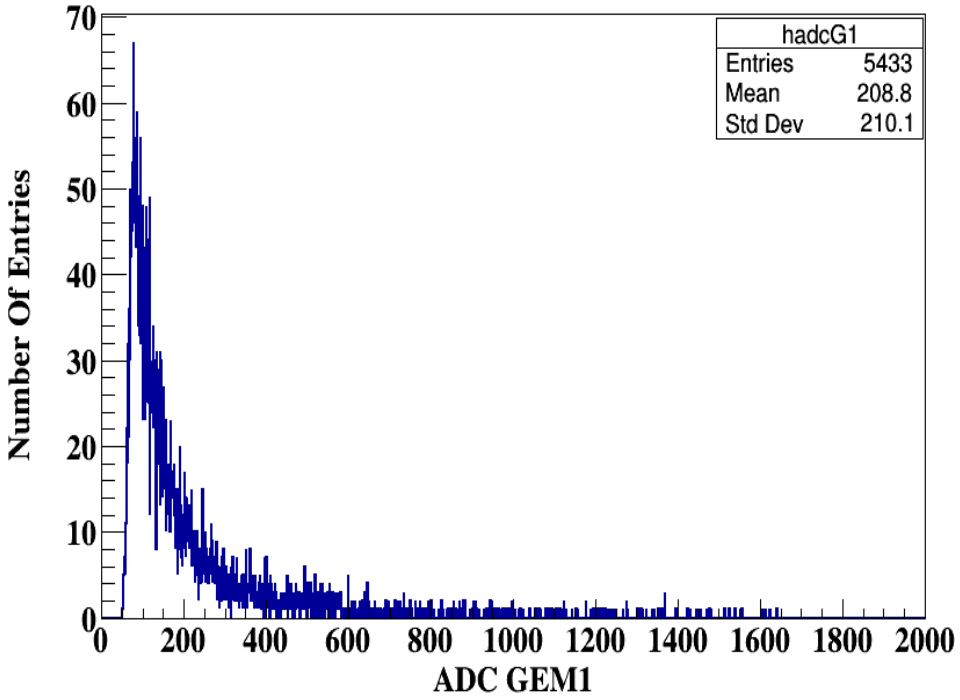


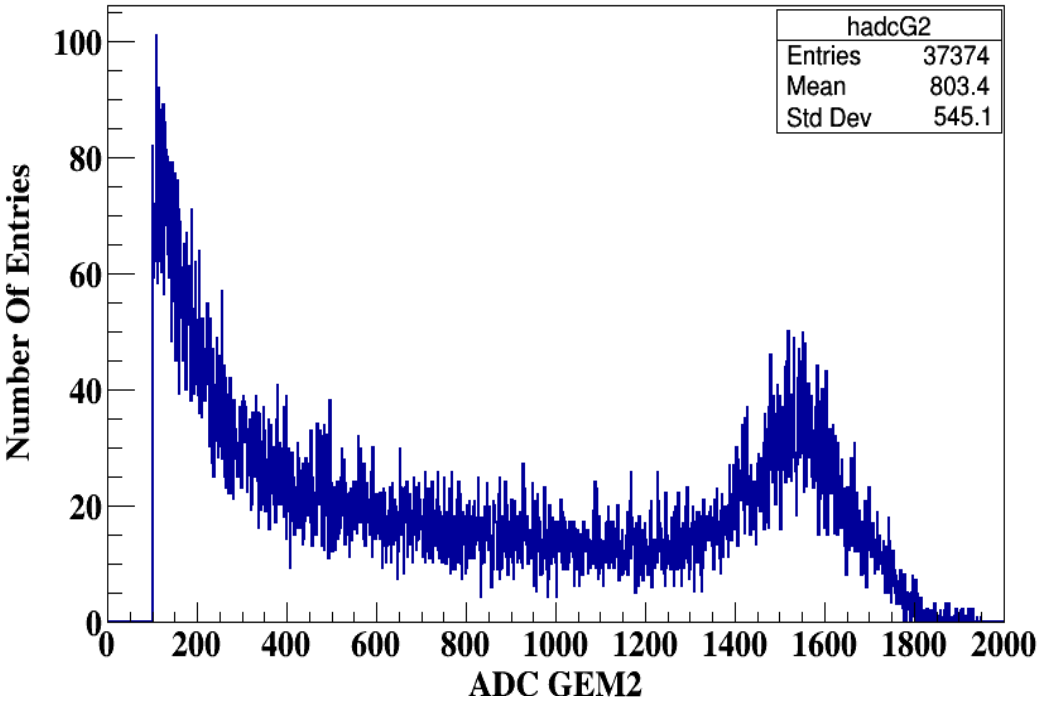
Average number of diamond per time slice ~ 34

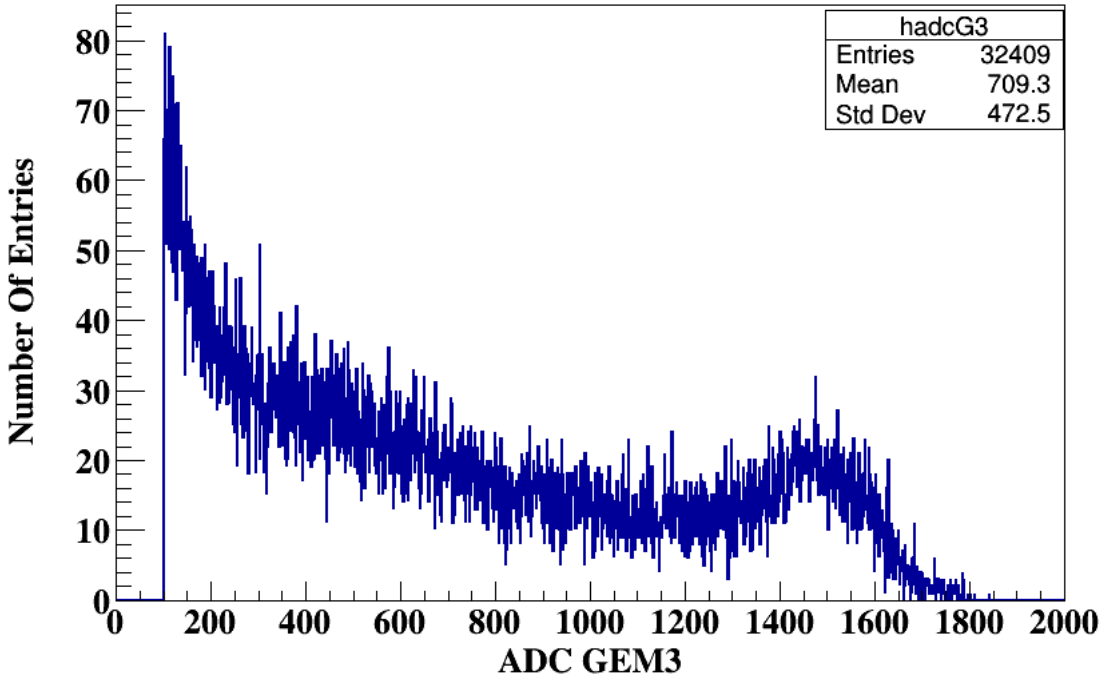
=> roughly beam rate = 34/10ms

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

Adc histogram for each plane within given η-φ window



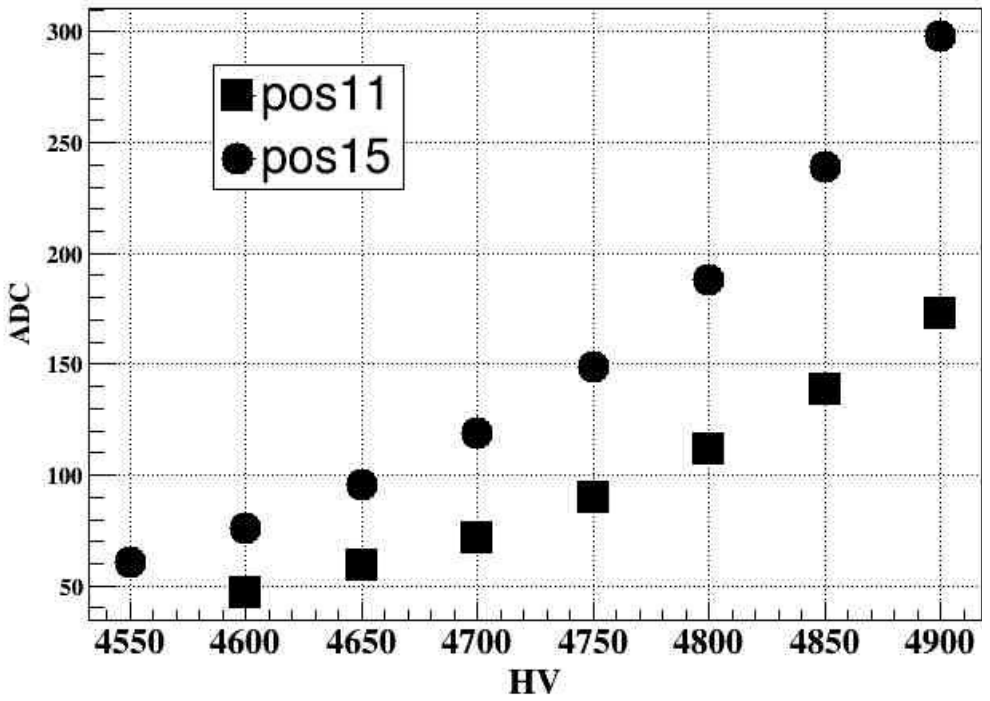


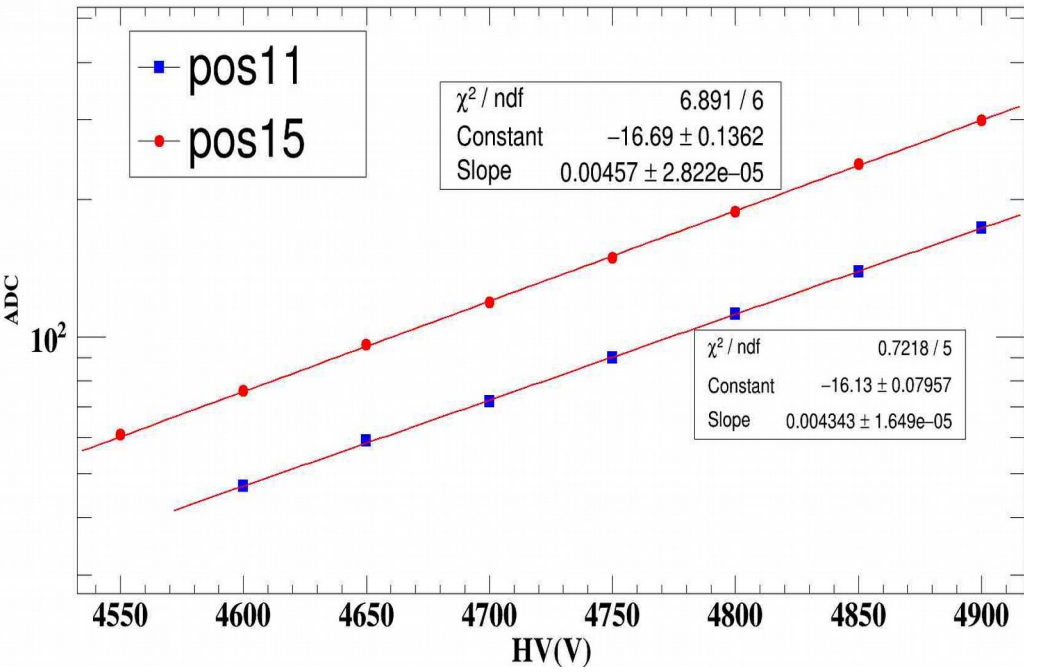


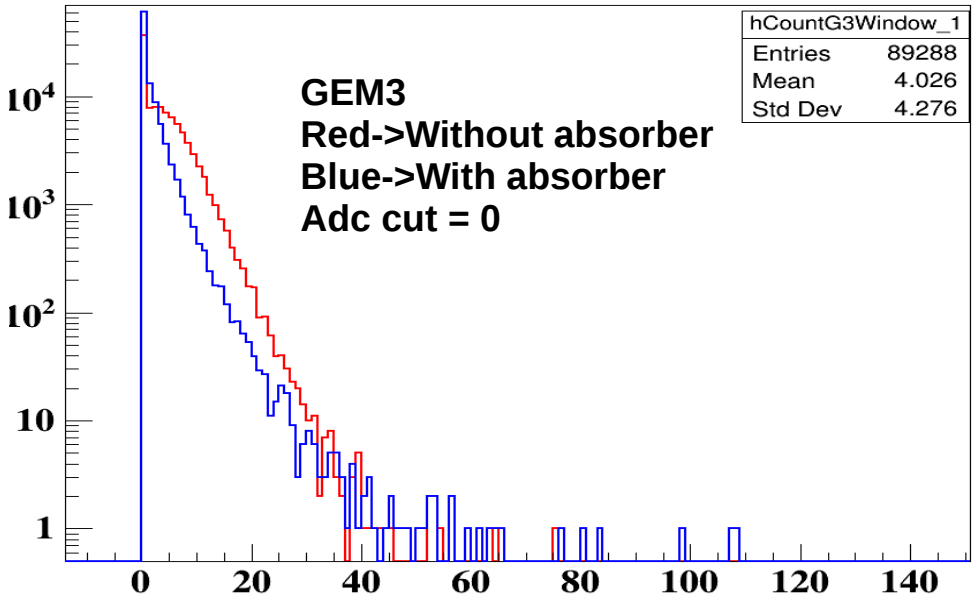
Study regarding to low gain of Mv2a/b chamber

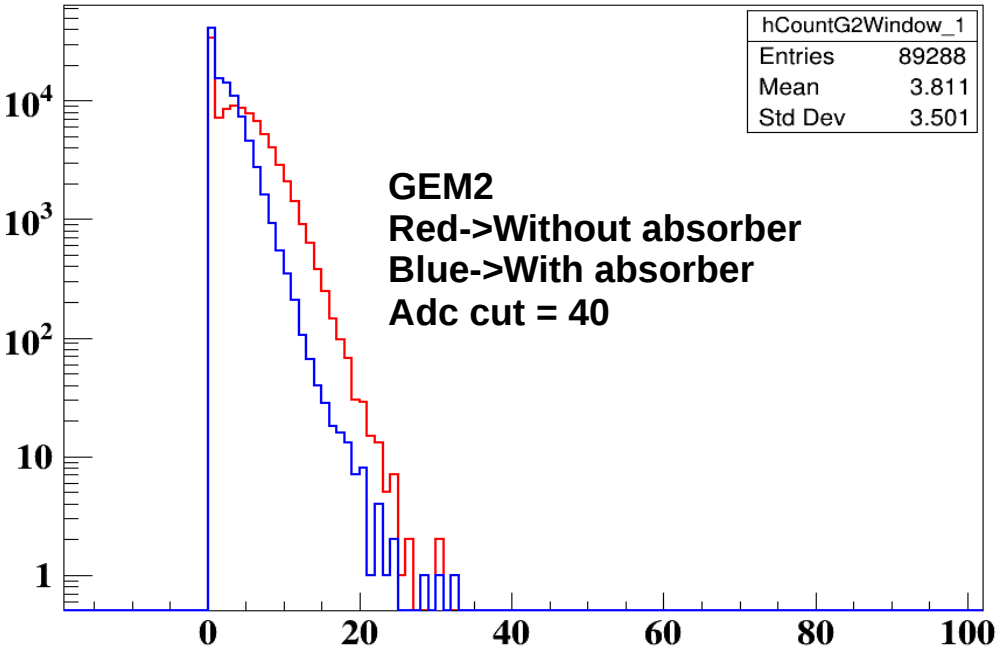
The possibilities of low gain can be:

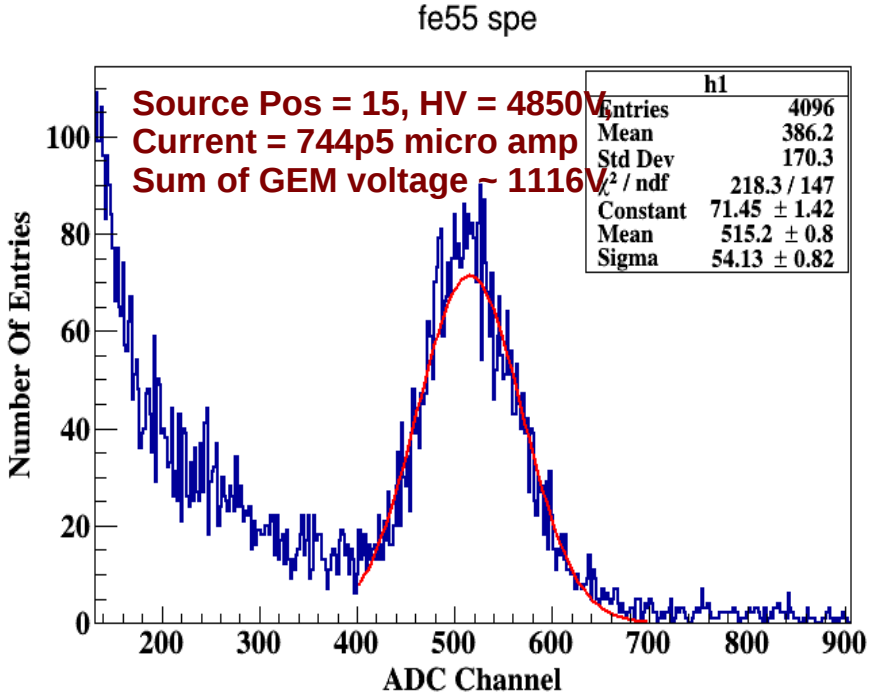
1. One the GEM foil is not connected
   --> a. Top foil disconnected from the resistive chain ==> no signal seen
   --> b. Middle foil is disconnected from resisitive chain ==> no signal seen
   --> c. Bottom foil is disconnected to from resisitive chain ==> signal seen from Sr90 but not with Fe55
2. 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..

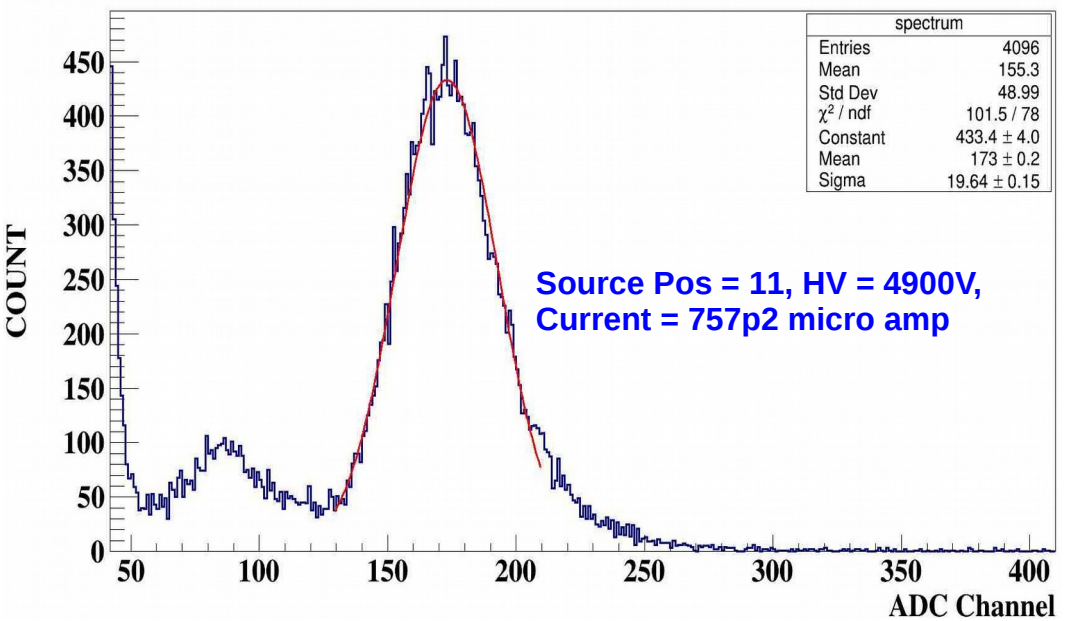





hCountG3Window_1
Entries 89288
Mean 4.026
Std Dev 4.276
GEM3
Red->Without absorber
Blue->With absorber
Adc cut = 0


hCountG2Window_1
Entries 89288
Mean 3.811
Std Dev 3.501
GEM2
Red->Without absorber
Blue->With absorber
Adc cut = 40


fe55 spe
Source Pos = 15, HV = 4850V,
Current = 744p5 micro amp
Sum of GEM voltage ~ 1116V
h1
Entries 4096
Mean 386.2
Std Dev 170.3
χ² / ndf 218.3 / 147
Constant 71.45 ± 1.42
Mean 515.2 ± 0.8
Sigma 54.13 ± 0.82
Number Of Entries
ADC Channel


spectrum
Entries 4096
Mean 155.3
Std Dev 48.99
χ² / ndf 101.5 / 78
Constant 433.4 ± 4.0
Mean 173 ± 0.2
Sigma 19.64 ± 0.15
Source Pos = 11, HV = 4900V,
Current = 757p2 micro amp
COUNT
ADC Channel

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