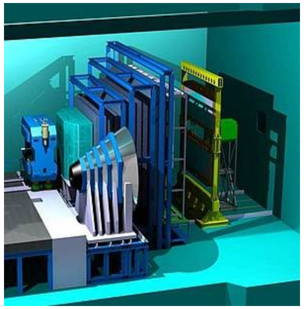
Commissioning and testing of large size GEM chamber in mCBM experiment at GSI



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For CBM-MUCH

15th Topical Seminar on Innovative Particle and Radiation Detectors (IPRD19) 14-17 October 2019 Siena, Italy

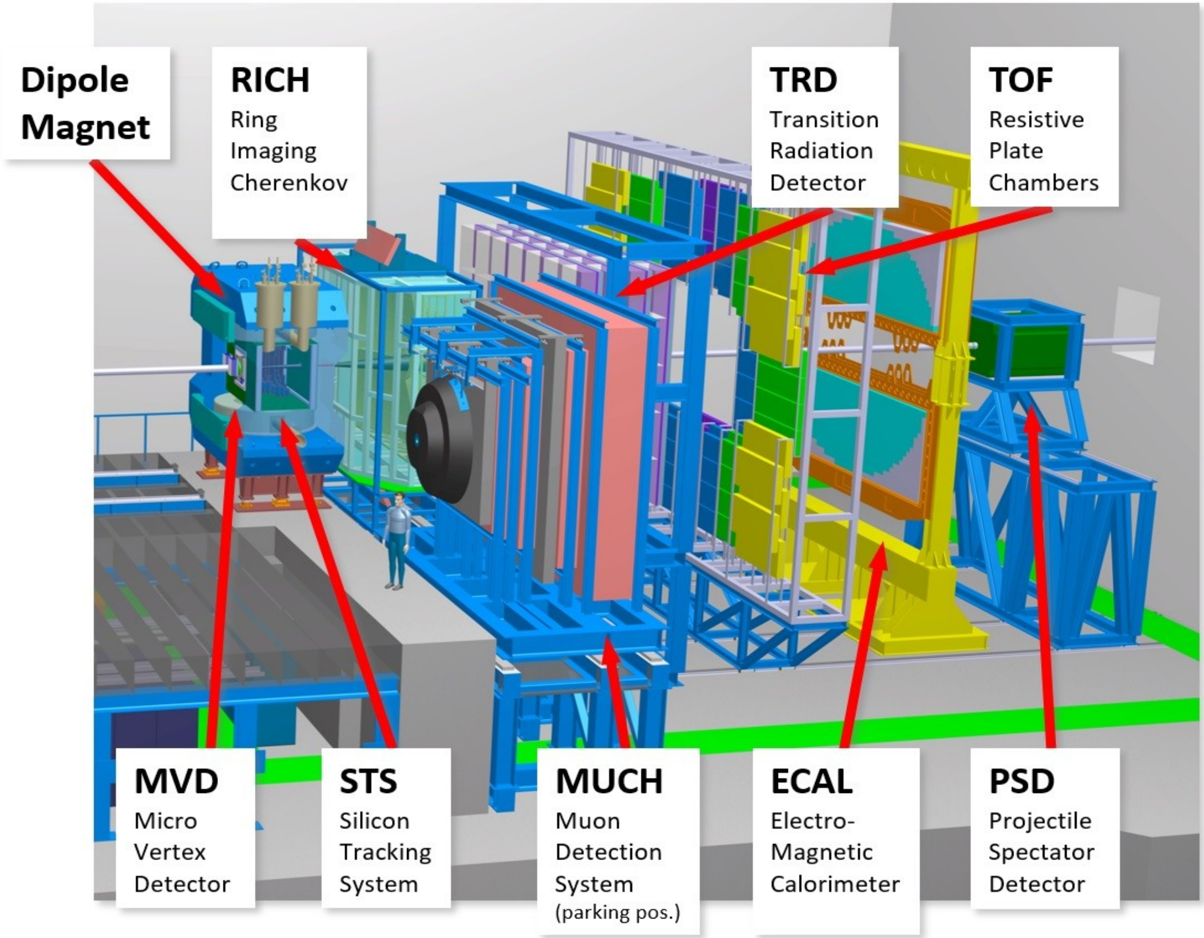
Outline

- CBM experiment, MUCH system
- Challenges in muon detection
- mCBM experiment
  - mCBM layout, Free-streaming DAQ
    mMUCH (GEM) modules
  - Preliminary results
- Summary and Next steps

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 baryon densities and at moderate temperature.

➔ Energy range 2-35 AGeV



CBM physics program:

➔ Equation of state at high net baryoni density
➔ De-confinement phase transition
➔ QCD critical endpoint
➔ Chiral symmetry breaking

Diagnostic probes of the high density phase:

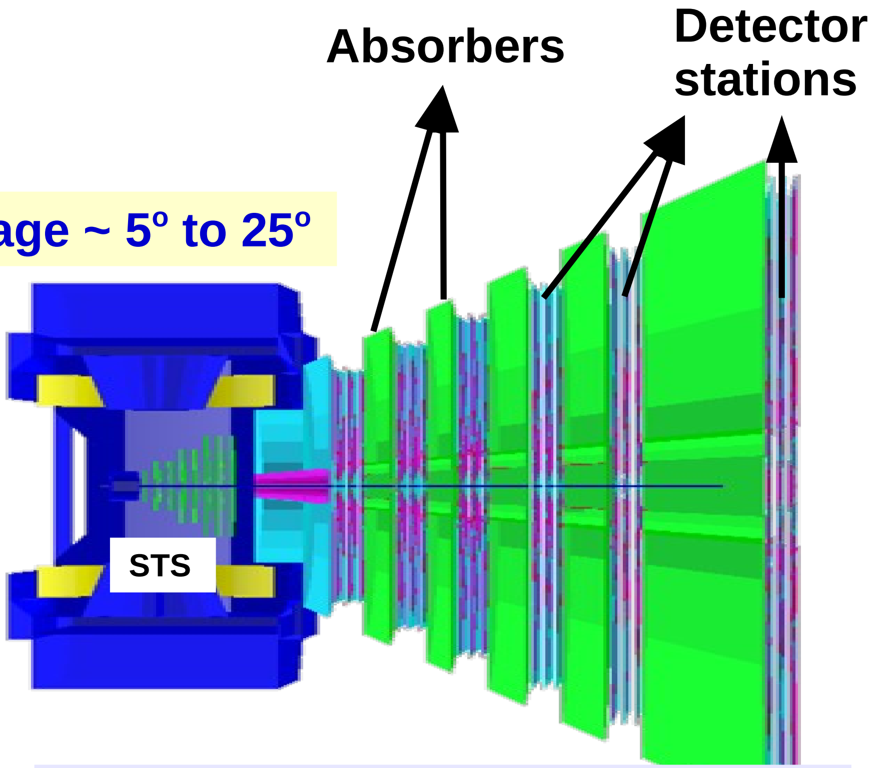
➔ Open charm, charmonia
➔ Low mass vector mesons
➔ Multistrange hyperons
➔ Flow, fluctuations, correlations

Muon Chamber (MUCH) of CBM

Aim is to measure dimuon arises from:
1. Low mass vector mesons and
2. Charmonia

→ $\mu^+ \mu^-$

Angular coverage ~ 5° to 25°



Schematic of CBM-MUCH setup

Design criteria:

- High interaction rate : 10 MHz
- The first plane have a high density of tracks
  High granularity in the inner region ~ average hit rate ~ 200 kHz/cm^2
- Should be radiation resistance
  (~10^{12} n_{eq}/cm^2 and for Gamma is ~30 krad
  –> equivalent to 10 year operation of CBM)
- Data to be readout in a self triggered mode
  -- must for all CBM detectors
  -- events reconstruction will be done off-line by grouping the time-stamps of the detector hits

Trapezoidal shaped triple GEM chambers will be used in the first two stations of MUCH.

SIS100 setup

Absorber	C	Fe	Fe	Fe
Thickness (cm)	60	30	30	20

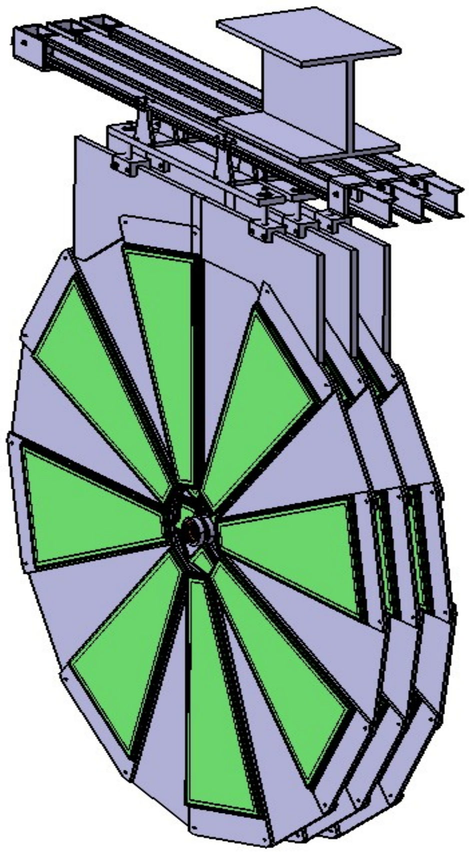
Sector Layout Of MUCH

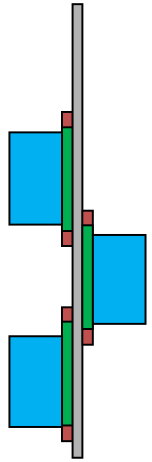
=> SIS100 setup => 4 station + 4 absorbers
=> First two stations :
--> GEM detector technology
--> due to high particle rate

Number sector for 1st station : **16 / layer = 48**
Rmax – Rmin = ~ 80 cm

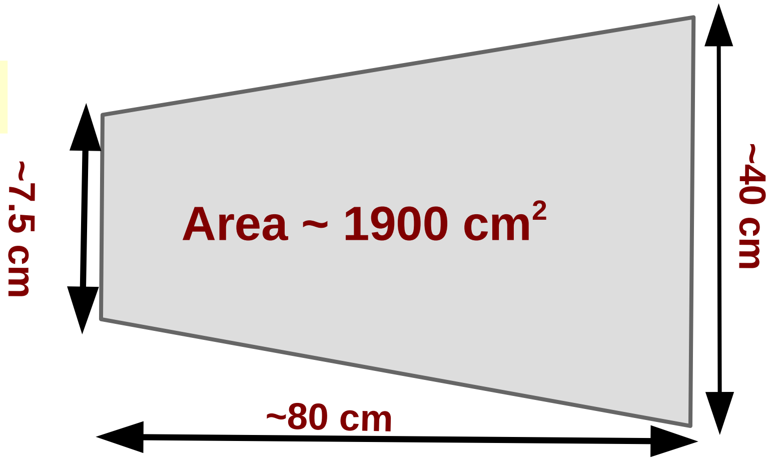
Number of sector for 2nd station : **20 / layer = 60**
Rmax – Rmin = ~ 100 cm

Readout channel : ~2231 per module
=> 107k for 1st station


Mechanical layout


Placement of modules

Typical dimension

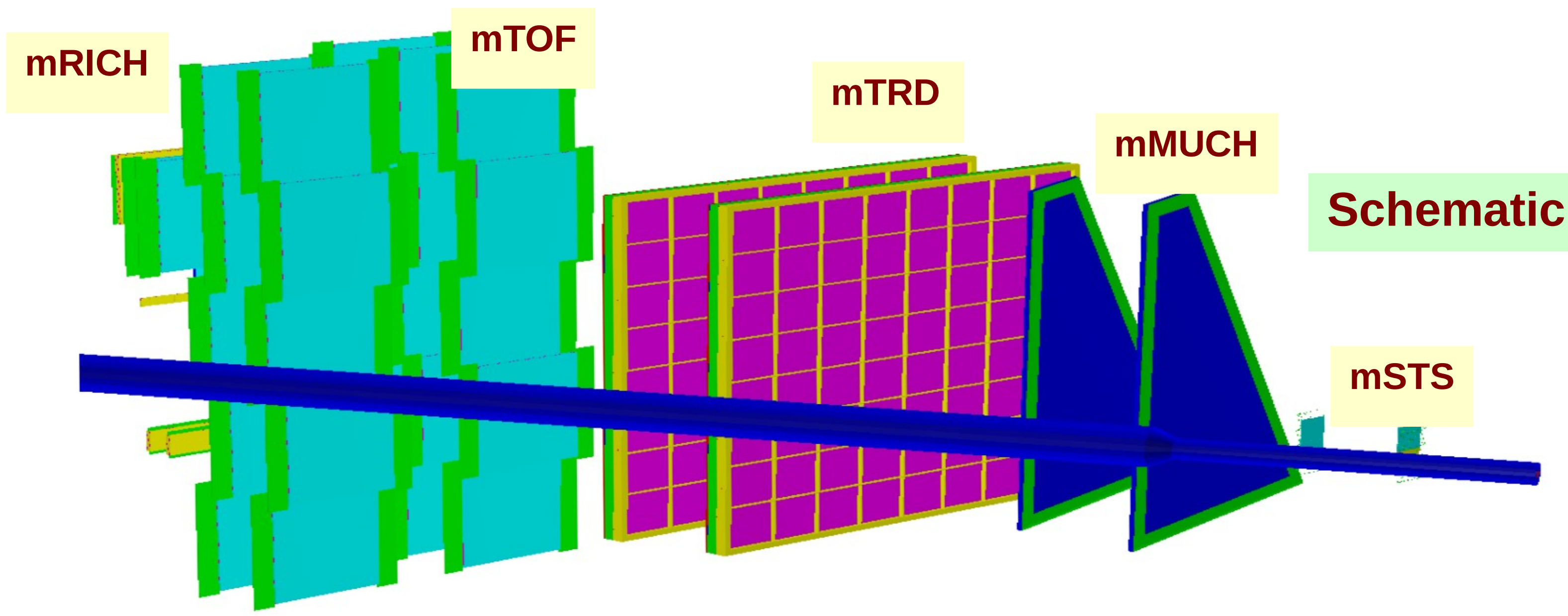


mCBM Experiment

This is part of FAIR phase-0 programme

mCBM --> A CBM full system test setup at 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 significantly reduce the commissioning time for CBM

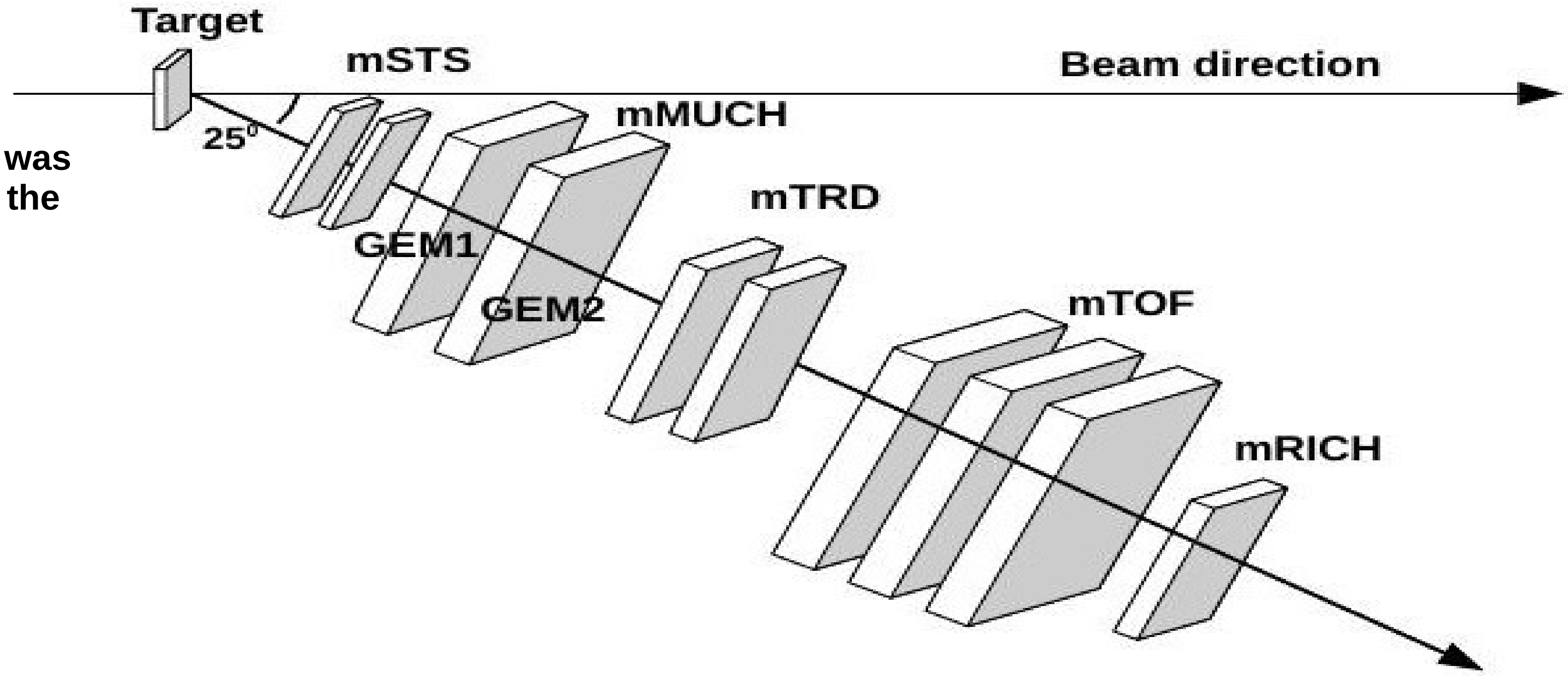
— Operation of the detector prototypes in a high-rate nucleus-nucleus collision environment
— Free-streaming data acquisition system including the data transport
— Online track and event reconstruction as well as event selection algorithms
— Offline data analysis and
— Detector control system
— Λ^0 reconstruction



Schematic of mCBM setup

Test Setup Schematic

Schematic of detector setup



Diamond detector was placed just before the target

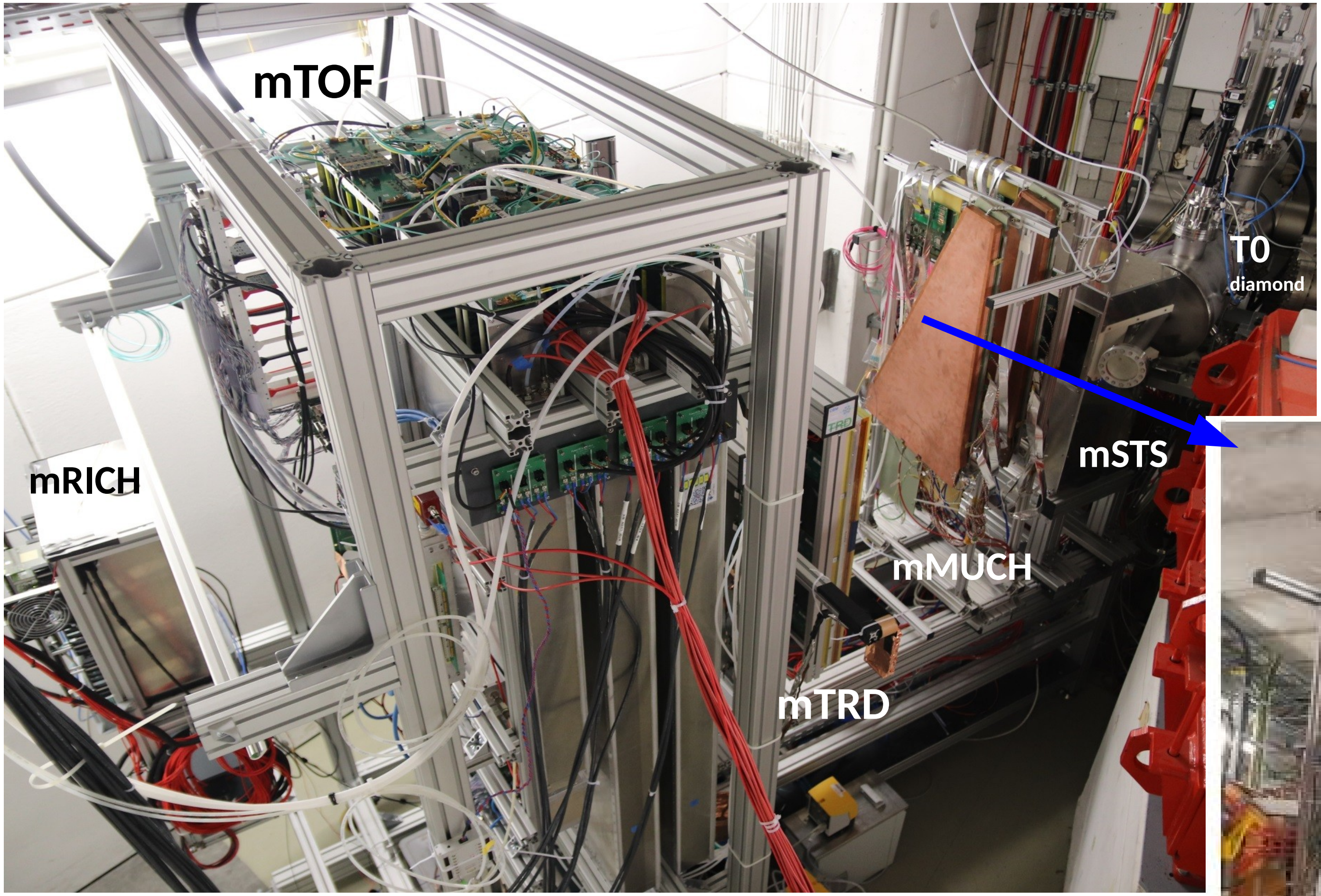
Z-position of MUCH

GEM1 : ~84 cm
GEM2 : ~106 cm

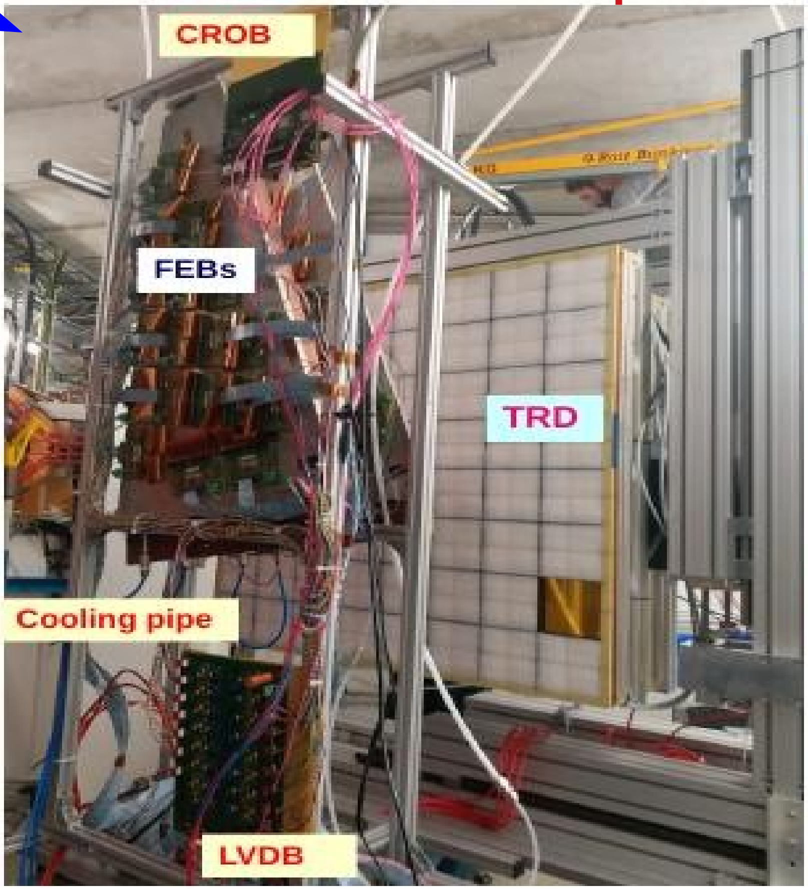
Transverse distance

~16 cm to 48 cm for GEM1

Picture of Test Setup in mCBM



mMUCH setup

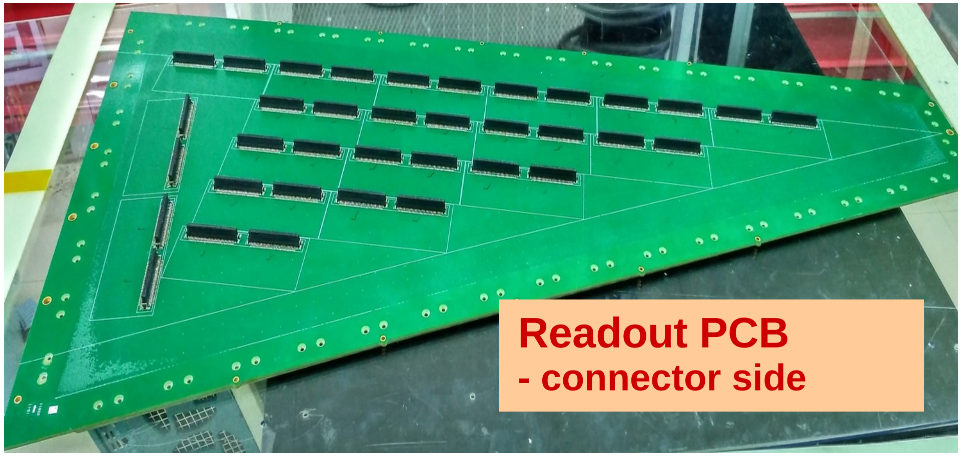


Total FEB connected per module = 12

Channels per FEB = 128

Minimum pad size = 3.2 mm
Maximum pad size = 17.2 mm

mMUCH Modules (Triple GEM detector)



Readout PCB
- connector side

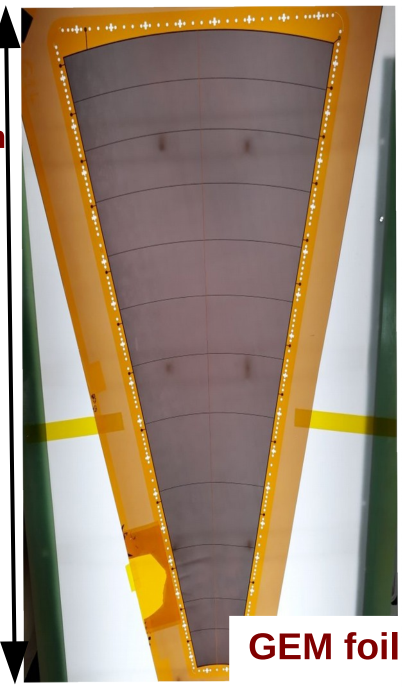
Readout PCB (designed and fabricated in INDIA)
- Pad side

Drift PCB designed at VECC
fabricated at CERN
more PCB fabricated in India

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

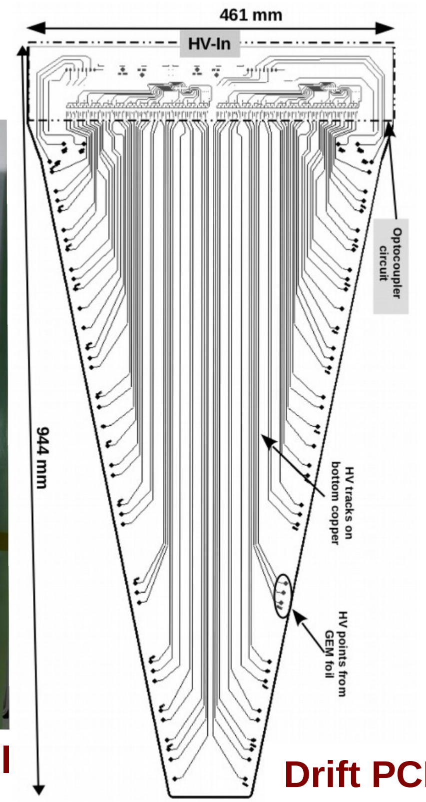
24 segments on top side
One HV connection for each segments

~80cm



GEM foil

Schematic of HV lines for GEM foil on the drift PCB

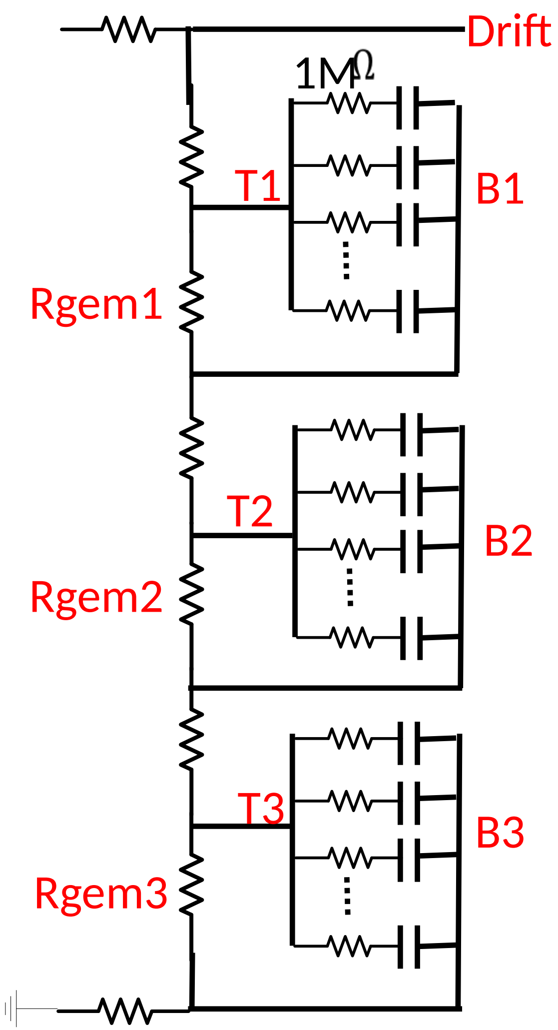


Drift PCB

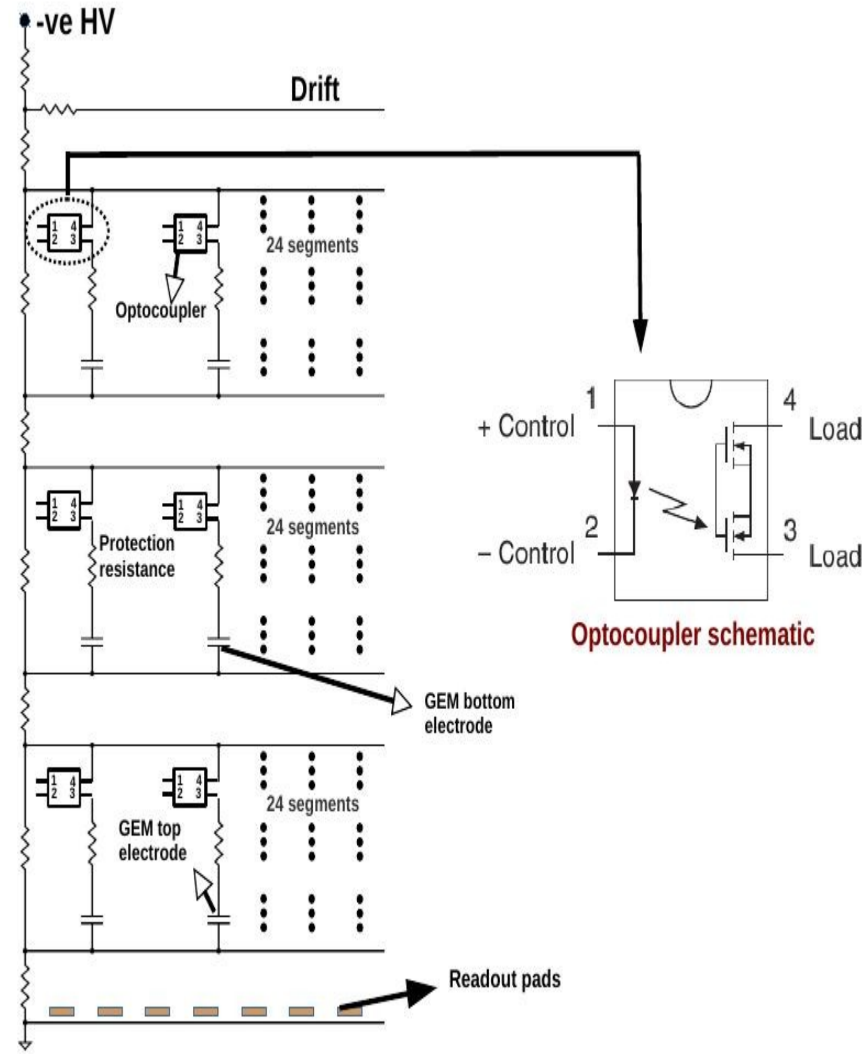
Two chambers were assembled using “NS2” technique at VECC (Thanks to CPDA lab of VECC for clean)

Handling Short Segment

Conventional approach



Optocoupler based design:



24 segments

⇒ 72 optocoupler switches/ module

Ref: https://doi.org/10.1016/j.nima.2019.162905

Testing large size chamber in mCBM experiment

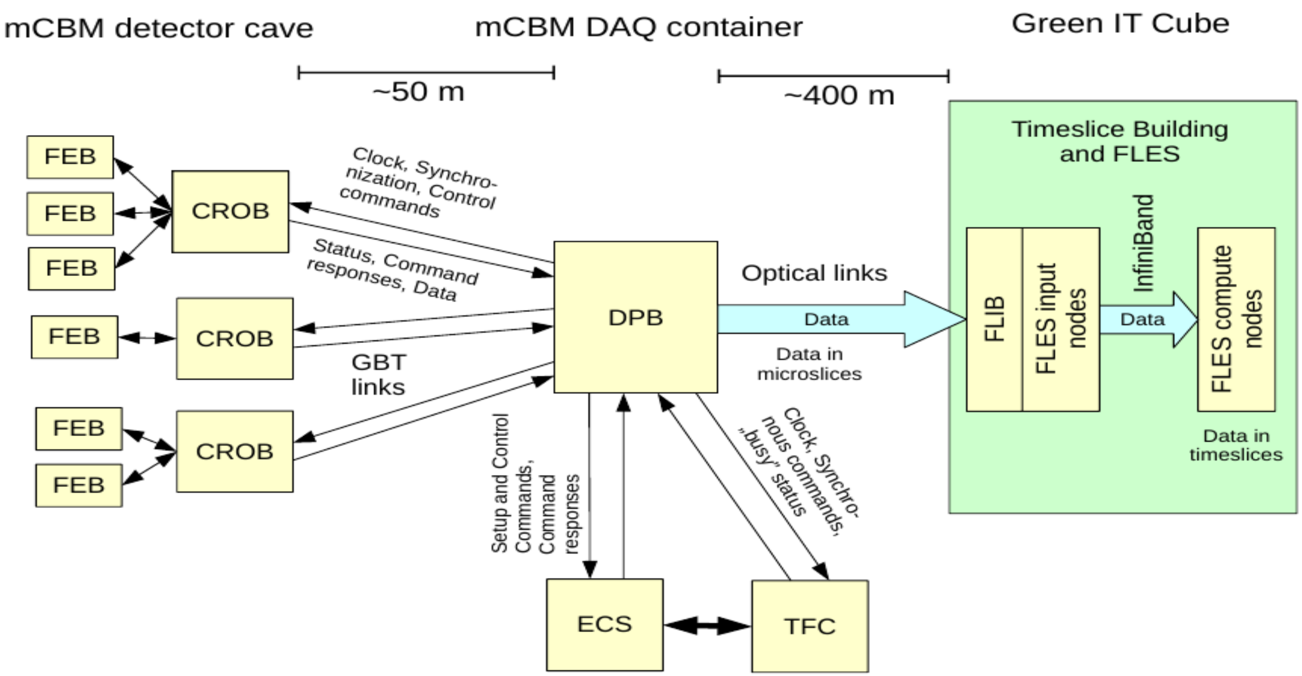
Beam information

Beam	: Ag 45+
Energy	: 1.59 AGeV
Beam Intensity	: $5x10^5$ to $7x10^8$

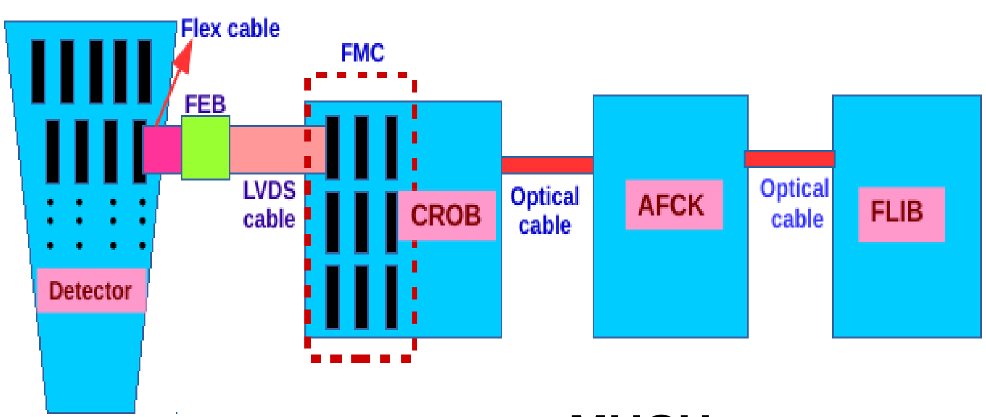
Target information

Target :	Au		
		Thick	~ 2.50 mm
		Thin	~ 0.25 mm

mCBM DAQ



STS/MUCH XYTER Chip



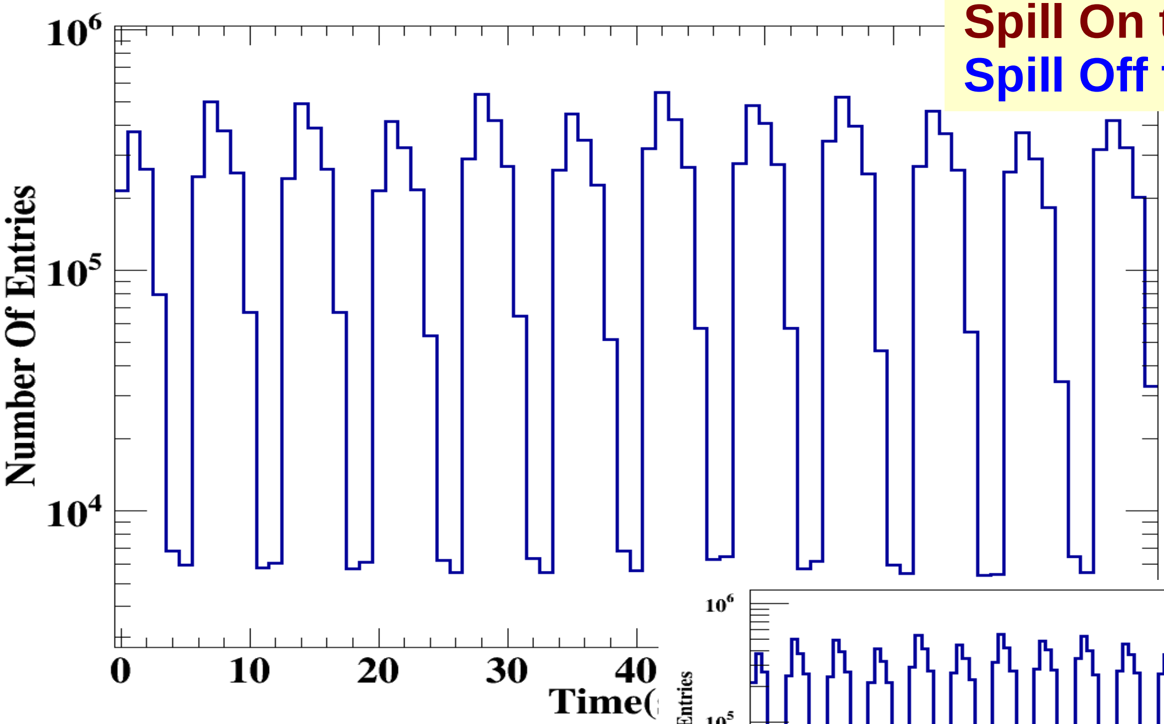
mMUCH

Specifications:

-> self triggered electronics
-> can handle data rate upto 32 MHz
-> Dynamic range = 1-100 fC
-> provides both timing and energy information
-> 5 bit flash ADC

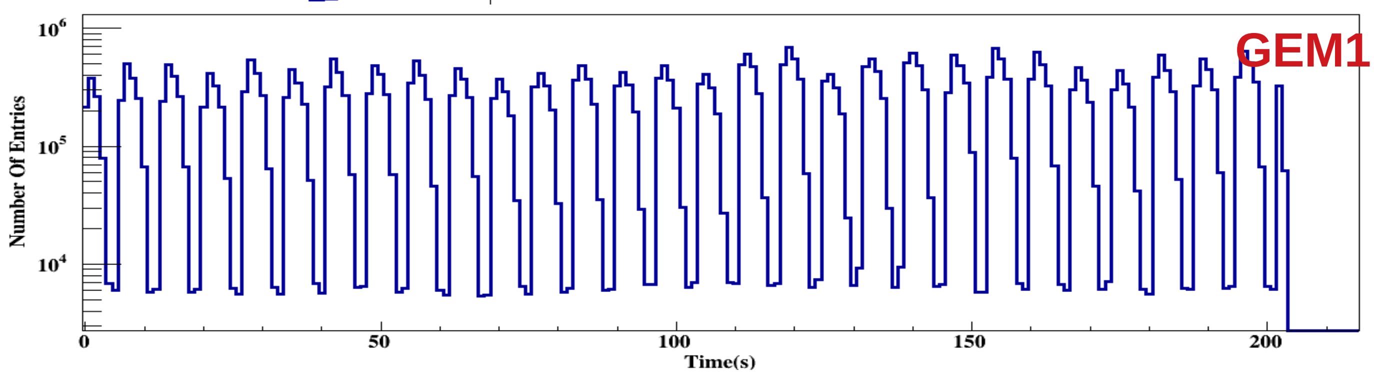
Results:Spill Structure

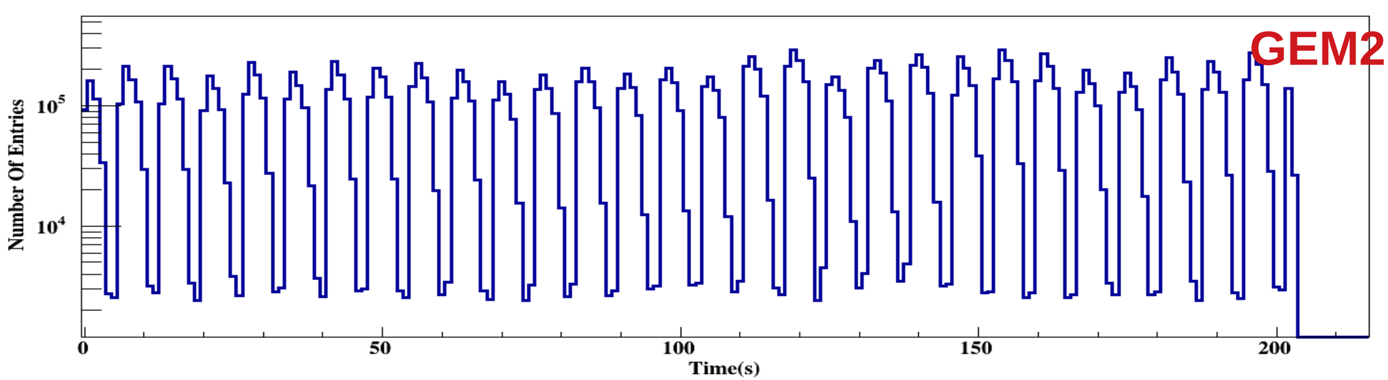
Run number : 160 (2.5 mm target)



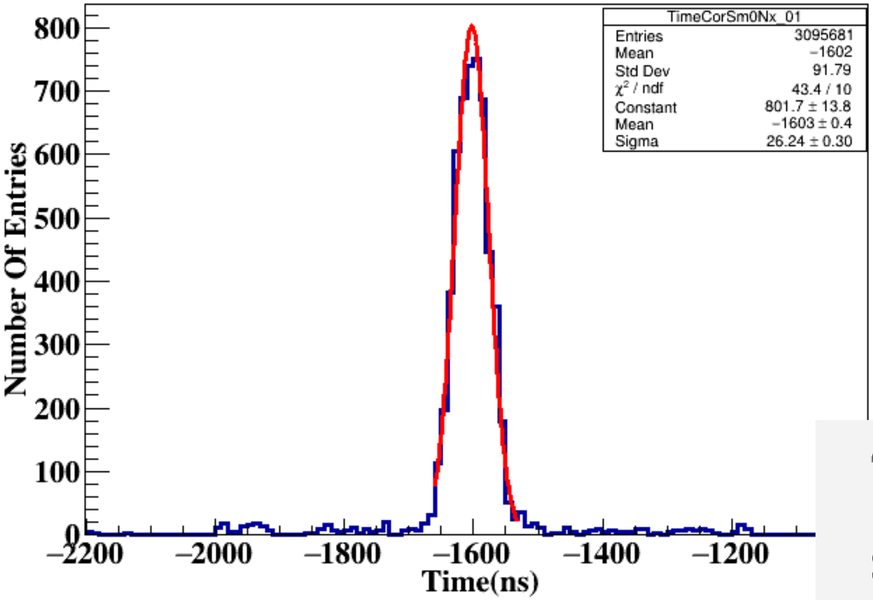
Spill On time ~ 4-5s
Spill Off time ~ 2-3s

Data acquired in time slice manner
Size of one Time Slice ~ 10ms



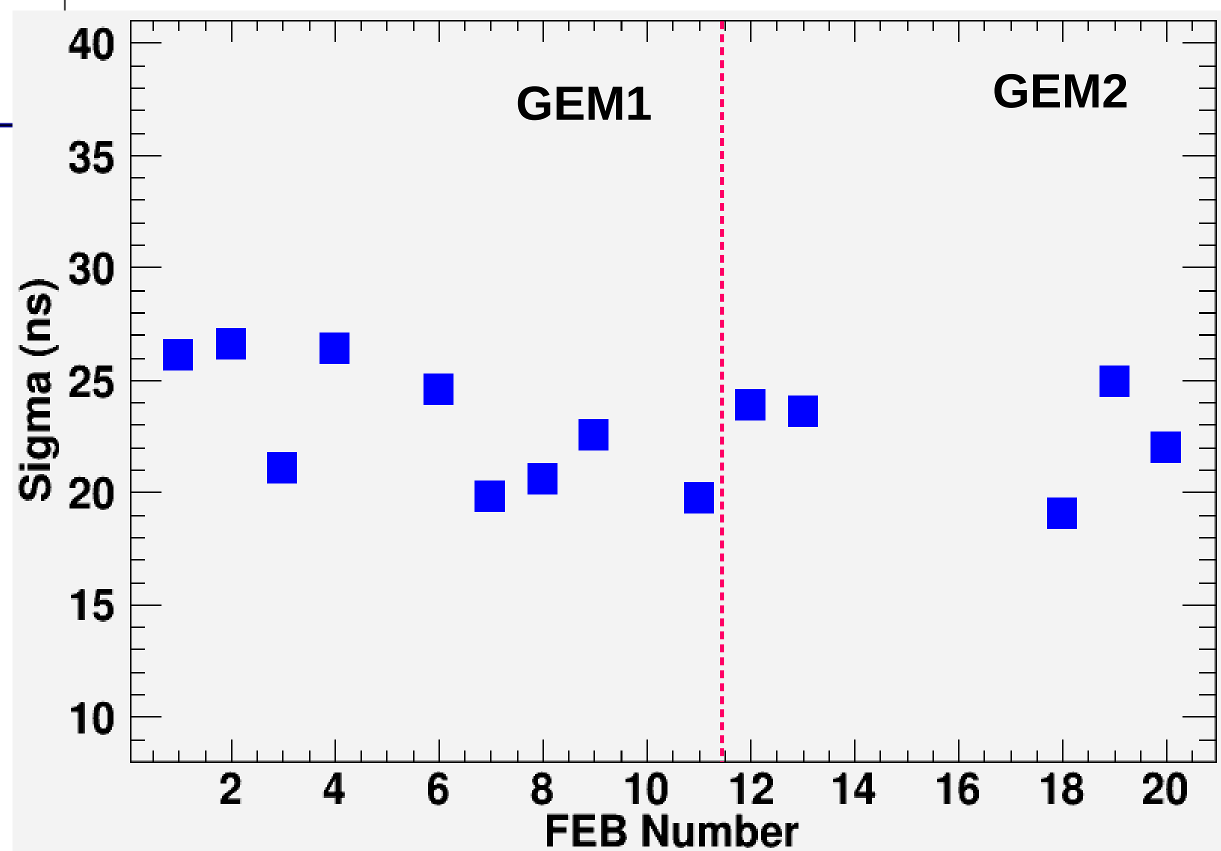


Results: Time Correlation

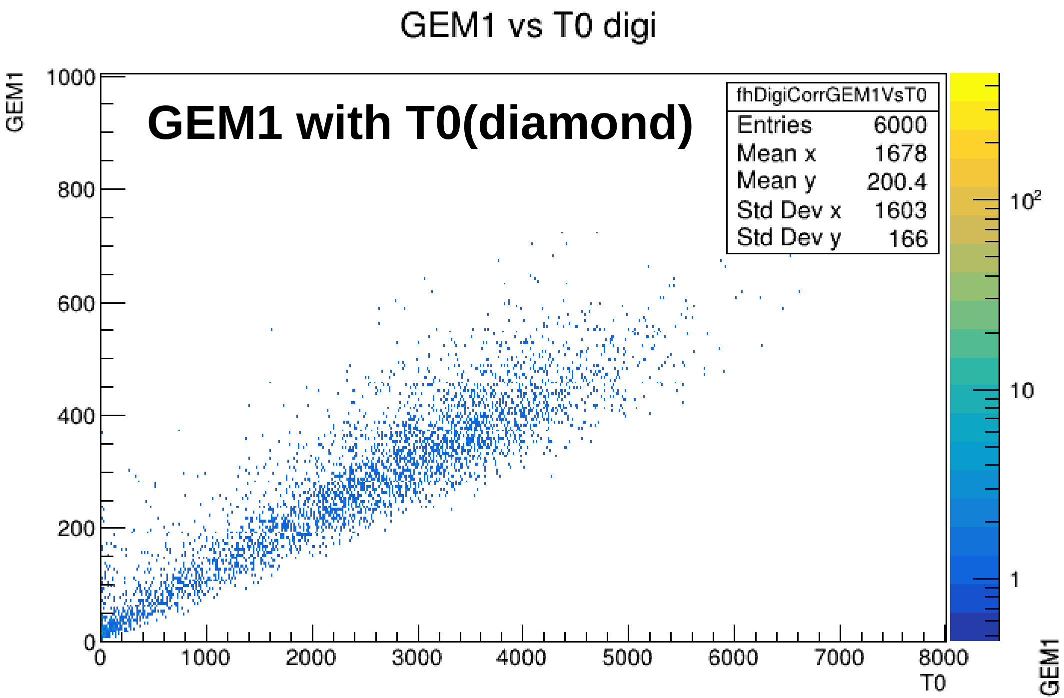


Time correlation between T0 and one of GEM1

Variation of sigma (ns) for different FEBs pof GEM

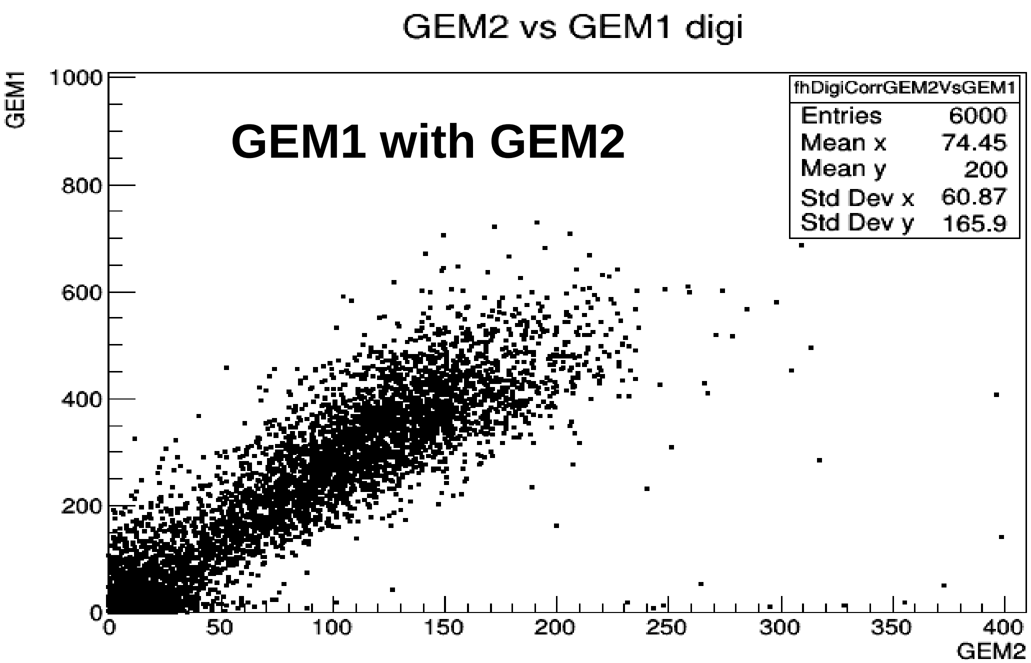


Results: Digi Correlation

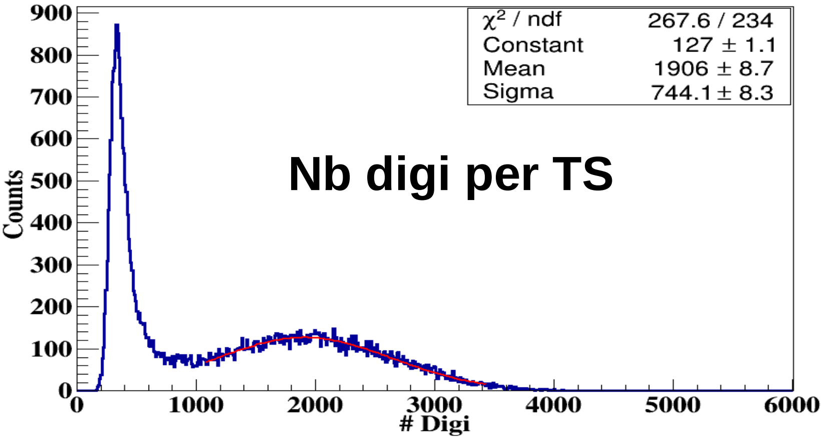


Digi correlation between GEM1 and diamond in time slice

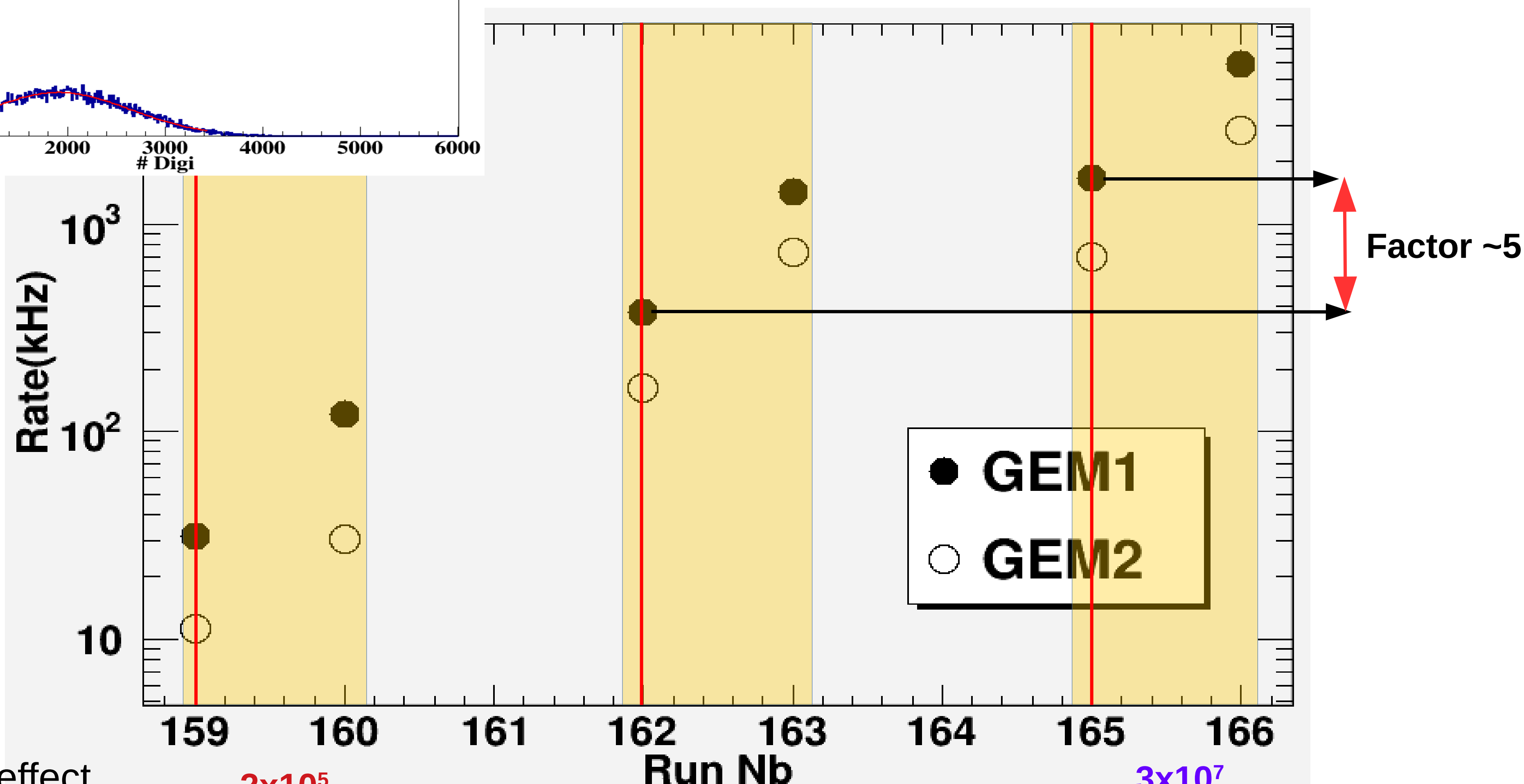
Digi correlation between GEM1 and GEM2 in time slice



Results: Particle Rate



This is not normalized with area



Target effect

0.25 to 2.5 => ~3-4 factor

2×10^5

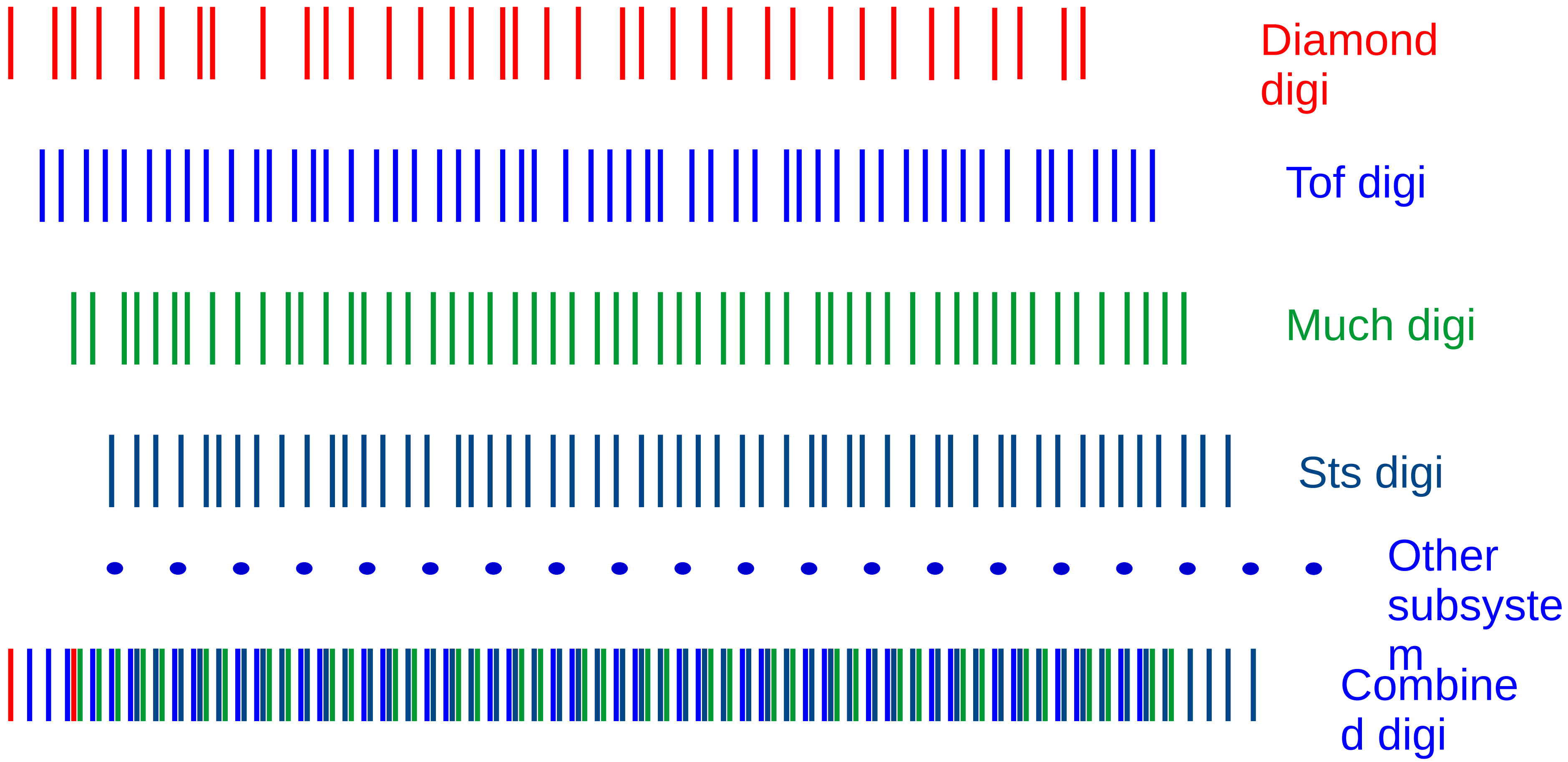
7×10^6

3×10^7

Intensity increase factor ~4.4

Results: Event Building

Algorithms : ==> Consecutive time gap between the digis.
==> Fixed time gap.

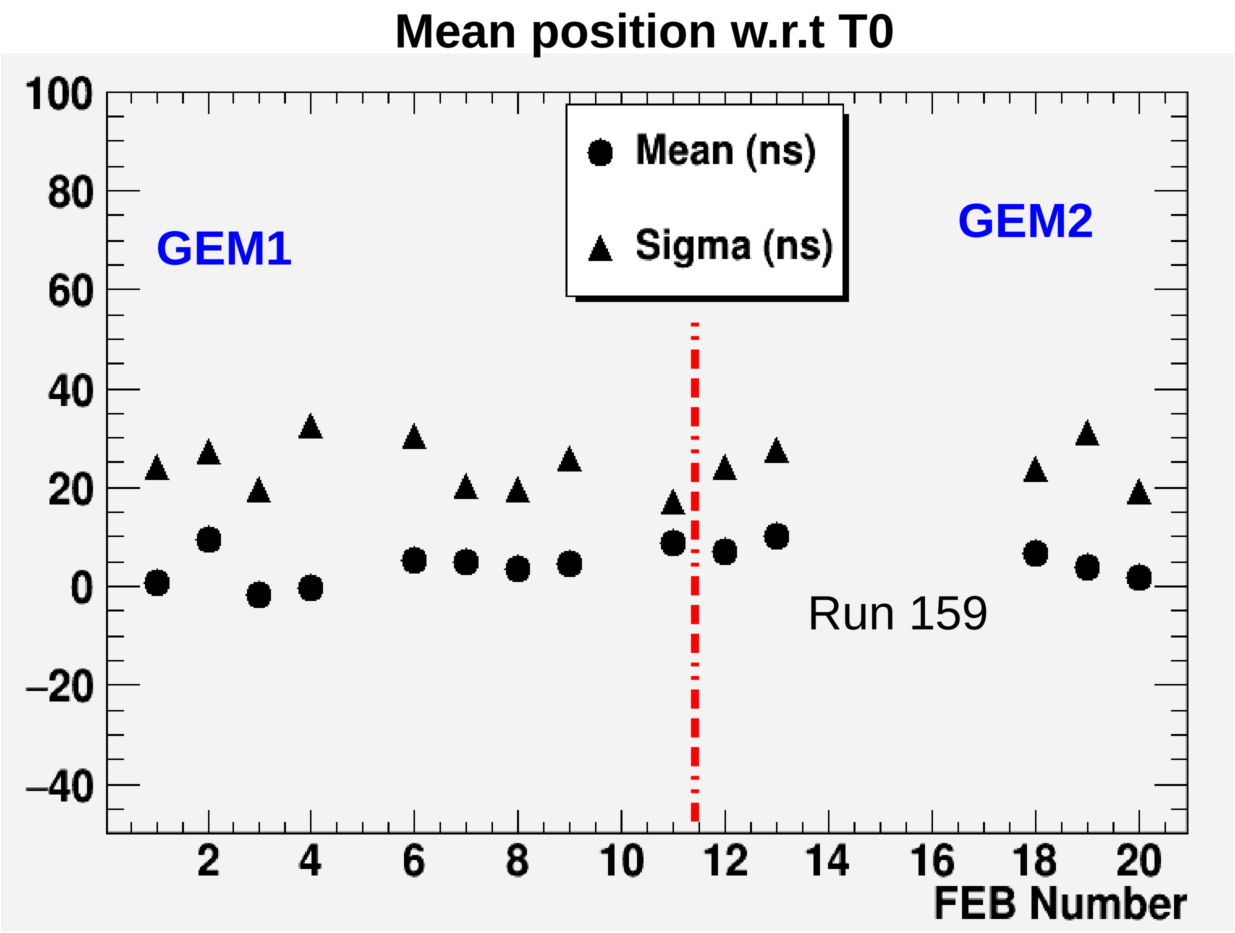


time gap < 200 ns (say) => Count as one event

With minimum TOF and T0 trigger condition

Results: Event Building and Hit Reconstruction

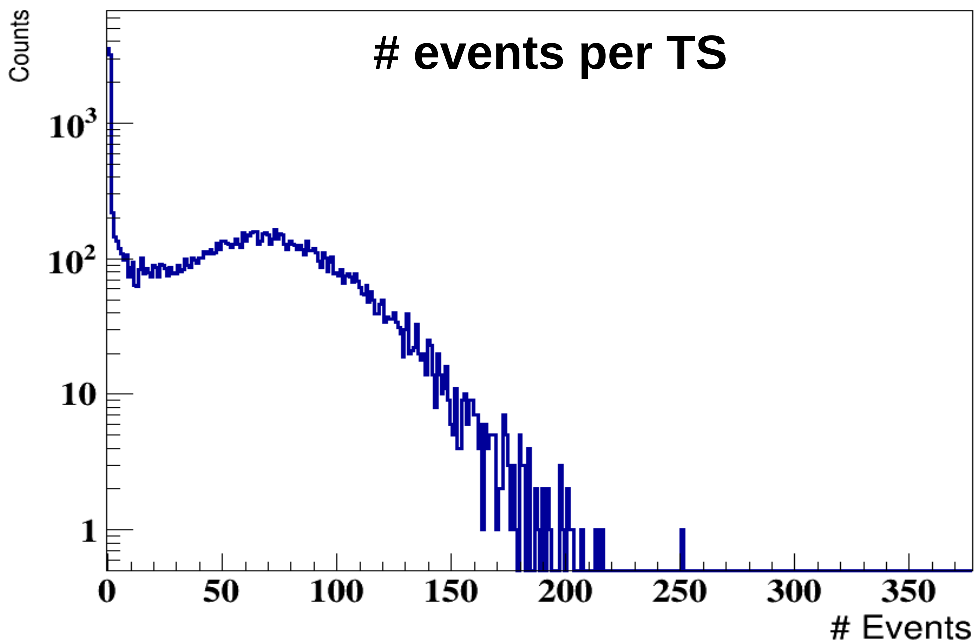
Offset correction

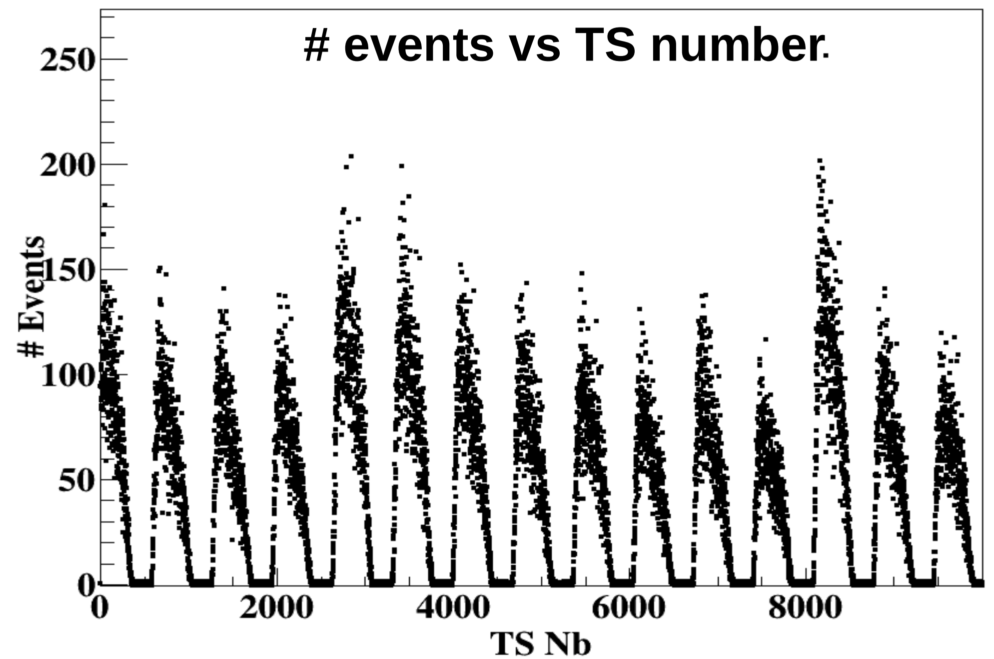


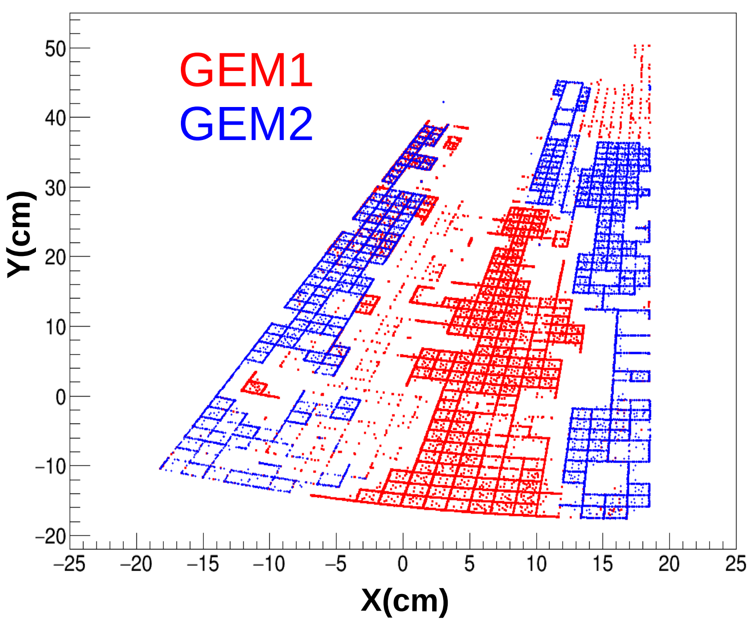
Algorithm:

Fixed time window = 200 ns
with a condition of 10 TOF + 1T0 digi

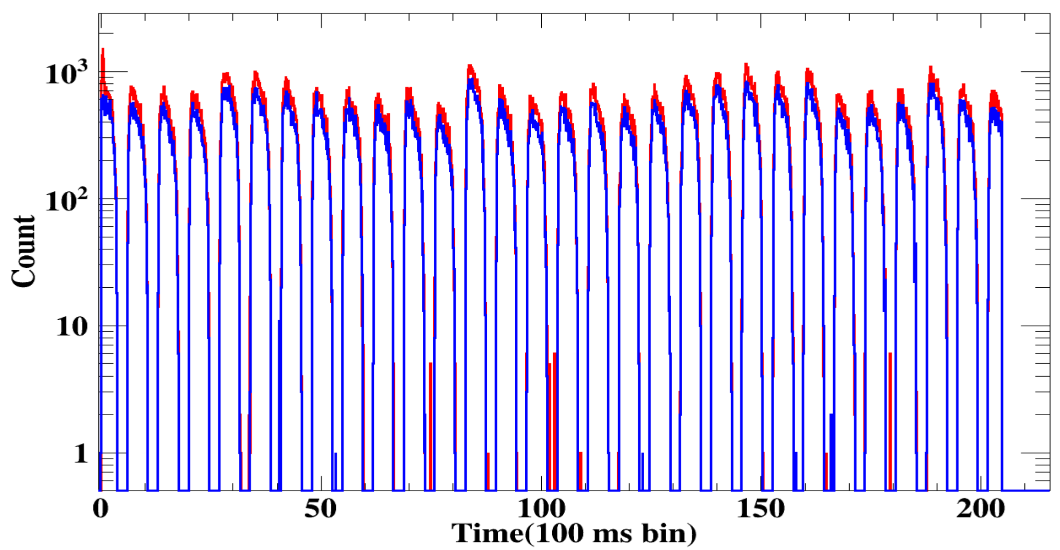
Results: Event Building and Hit Reconstruction





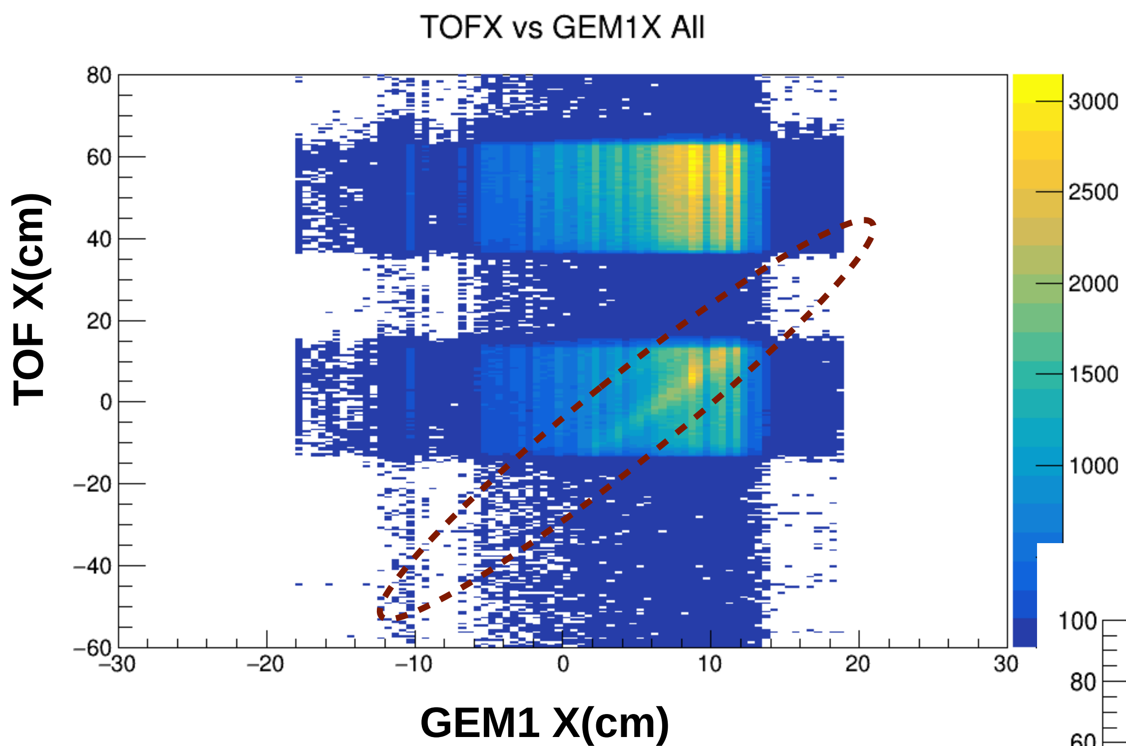


Hit distribution with time



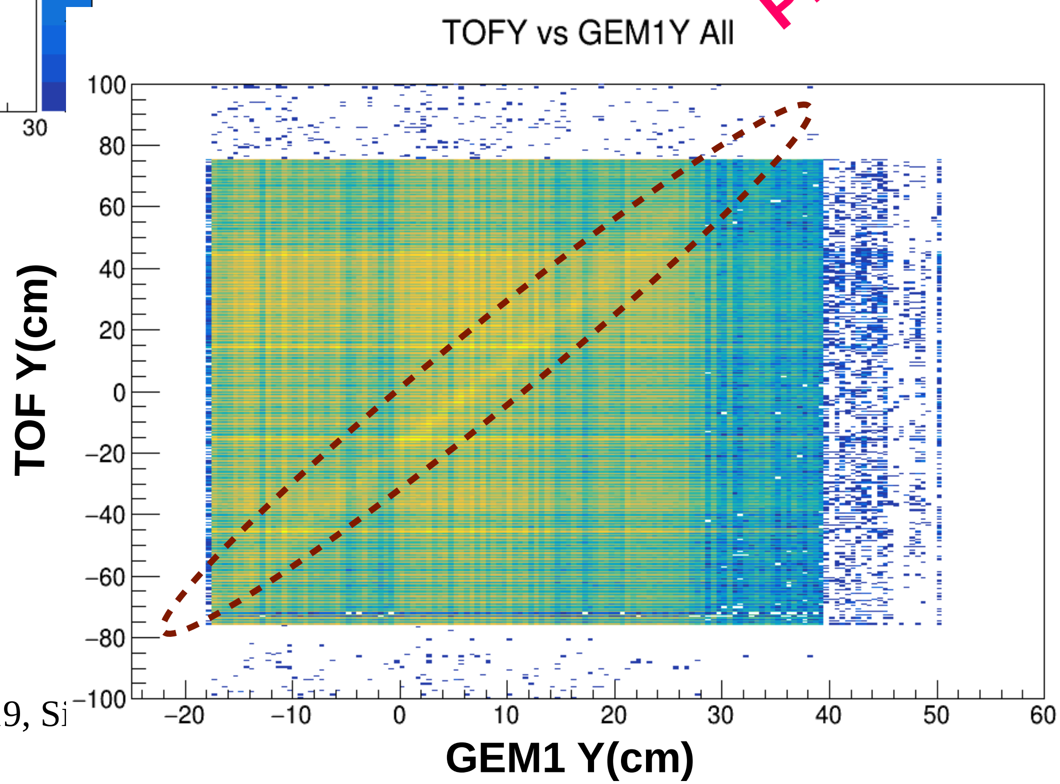
TS Nb TS Nb

Results: Spatial Correlation



TOF – Time of Flight detector (MRPC)

Preliminary



Clear spatial correlation between hits of GEM with TOF

Summary

- Two real size triple GEM chambers (mMUCH) commissioned in mCBM experiment at GSI, Darmstadt.
- First beam test with MUCH-XYTER and a first tests with novel Optocoupler based HV biasing scheme has been done
- mCBM data taken in a free streaming mode in a common DAQ chain which included all the subsystems
- Data taken for a range of detector/electronics settings, for two different target thickness and different beam intensities to study rate effects
- With a crude event algorithm, clear spatial correlations of mMUCH with mTOF observed

Next Steps

- A detailed data analysis
- Event reconstruction optimization
- Performance of detector with full acceptance
- Commissioning of a third mMUCH chamber
- Upgraded version of MUCH-XYTER and eventually to a CRI-based DAQ in mCBM 2020

References

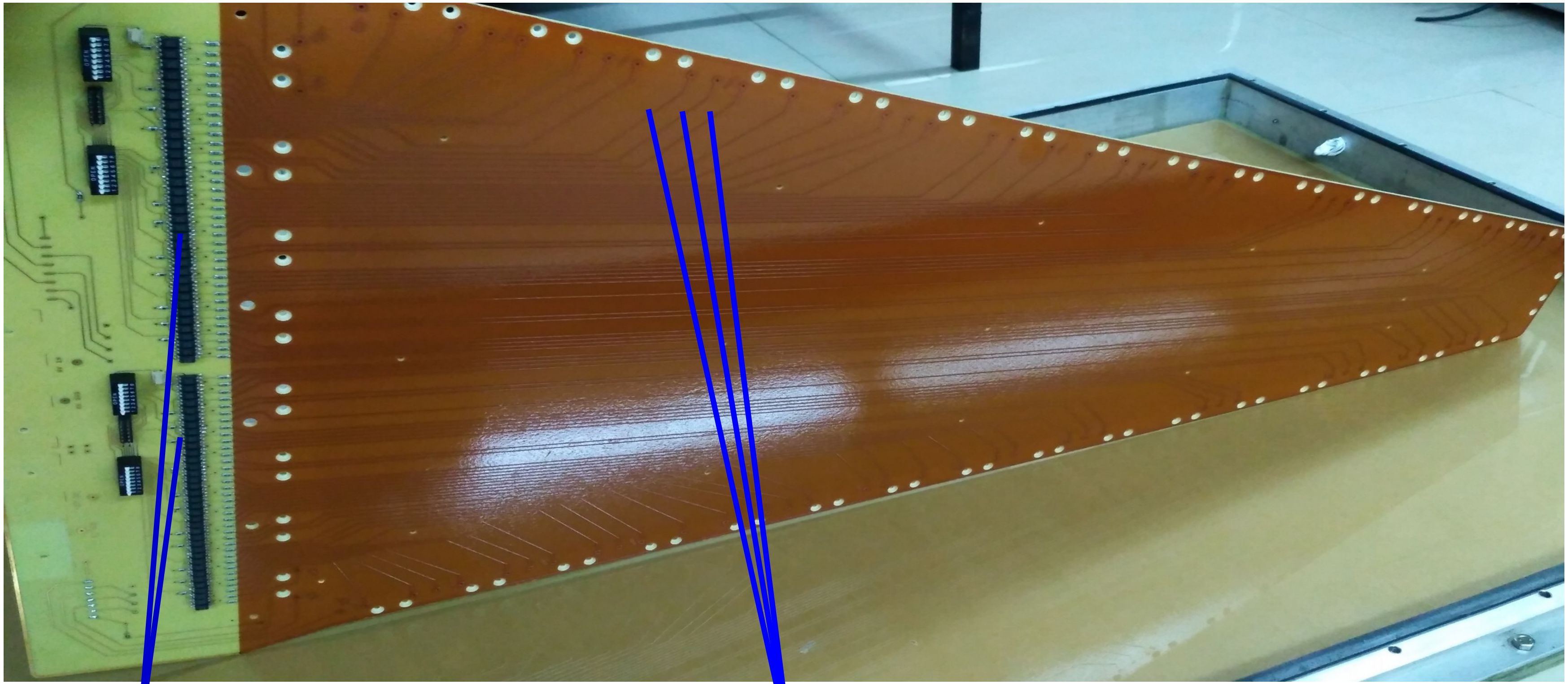
- https://fair-center.eu/
- https://www.gsi.de/work/forschung/cbmnqm/cbm.htm
- https://www.gsi.de/en/work/research/cbmnqm/cbm/activities/mcbm.htm
- Muon Cbamber (MUCH) TDR (http://repository.gsi.de/record/161297)
- MCBM experiment (http://p31769.typo3server.info/fileadmin/fair/experiments/CBM/documents/mcbm-proposal2GPAC-WebVersion0619-SVN7729.pdf)

We would like to thank GSI colleagues for their help in the beam time.

Thank you for your kind attention!

Backup

Drift PCB

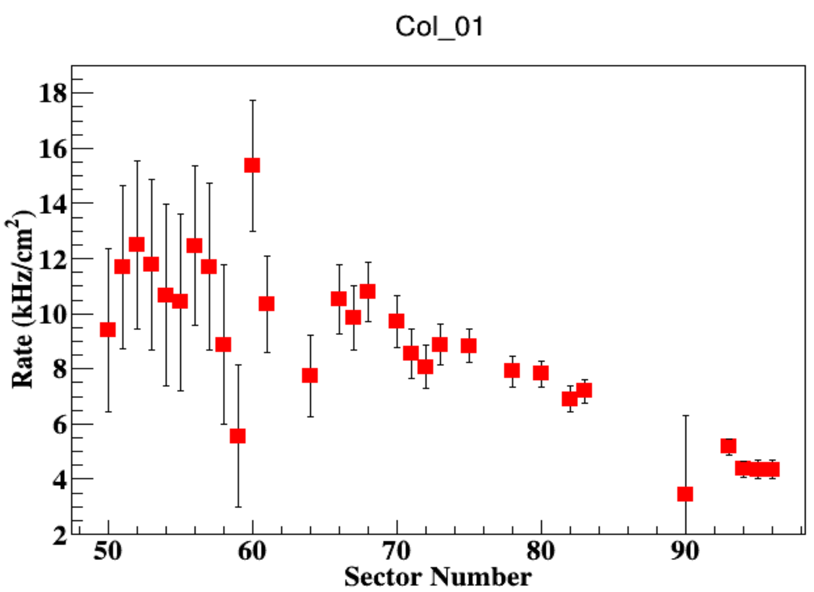


Opto-coupler

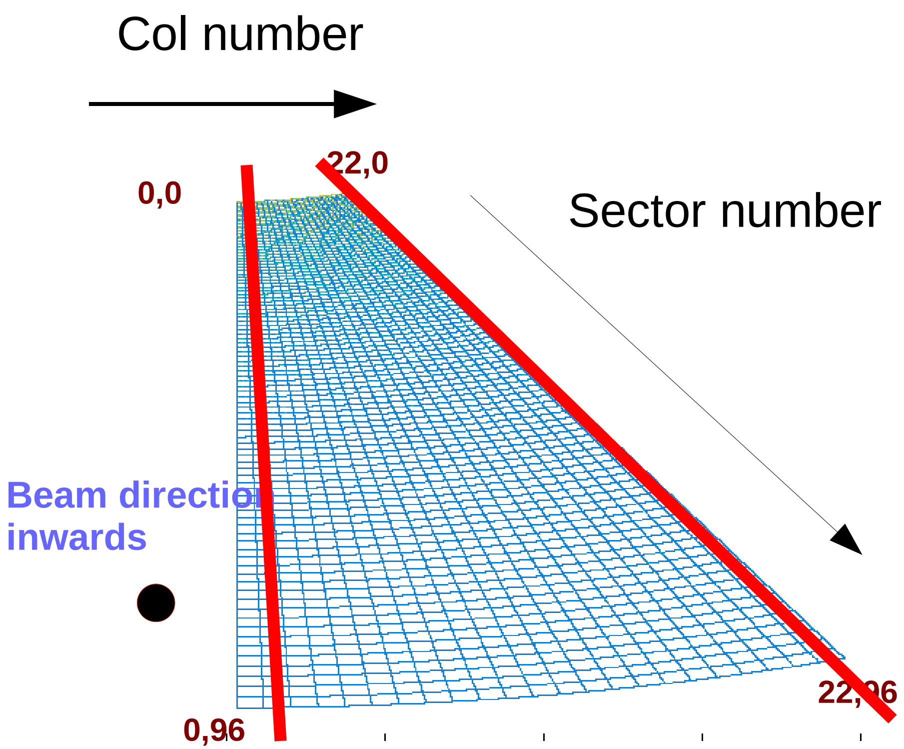
HV lines for individual segments of GEM

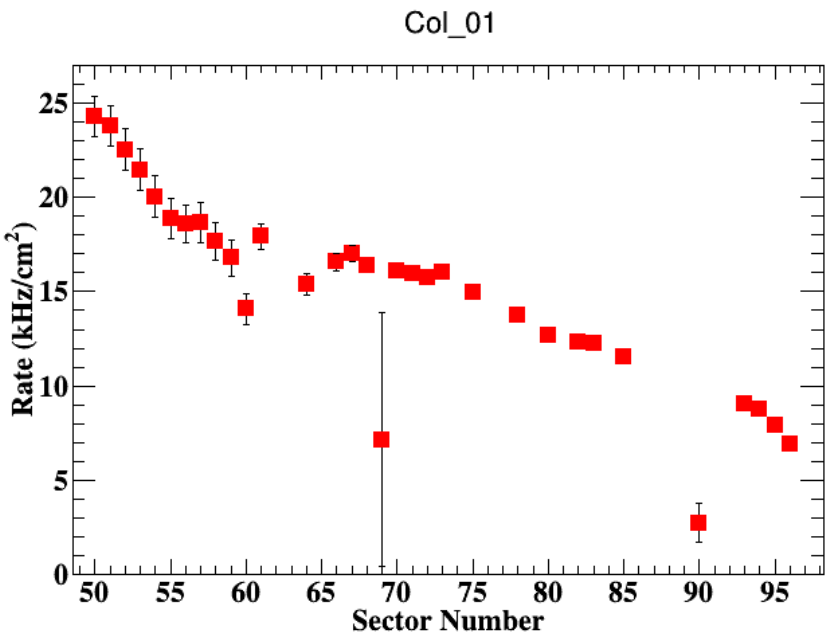
The opto-coupler indigenously designed & interfaced with the drift PCB connector with **Rui's** help

Results:2



Beam Intensity=10^7/sec
Target thickness : 0.25mm
GEM1

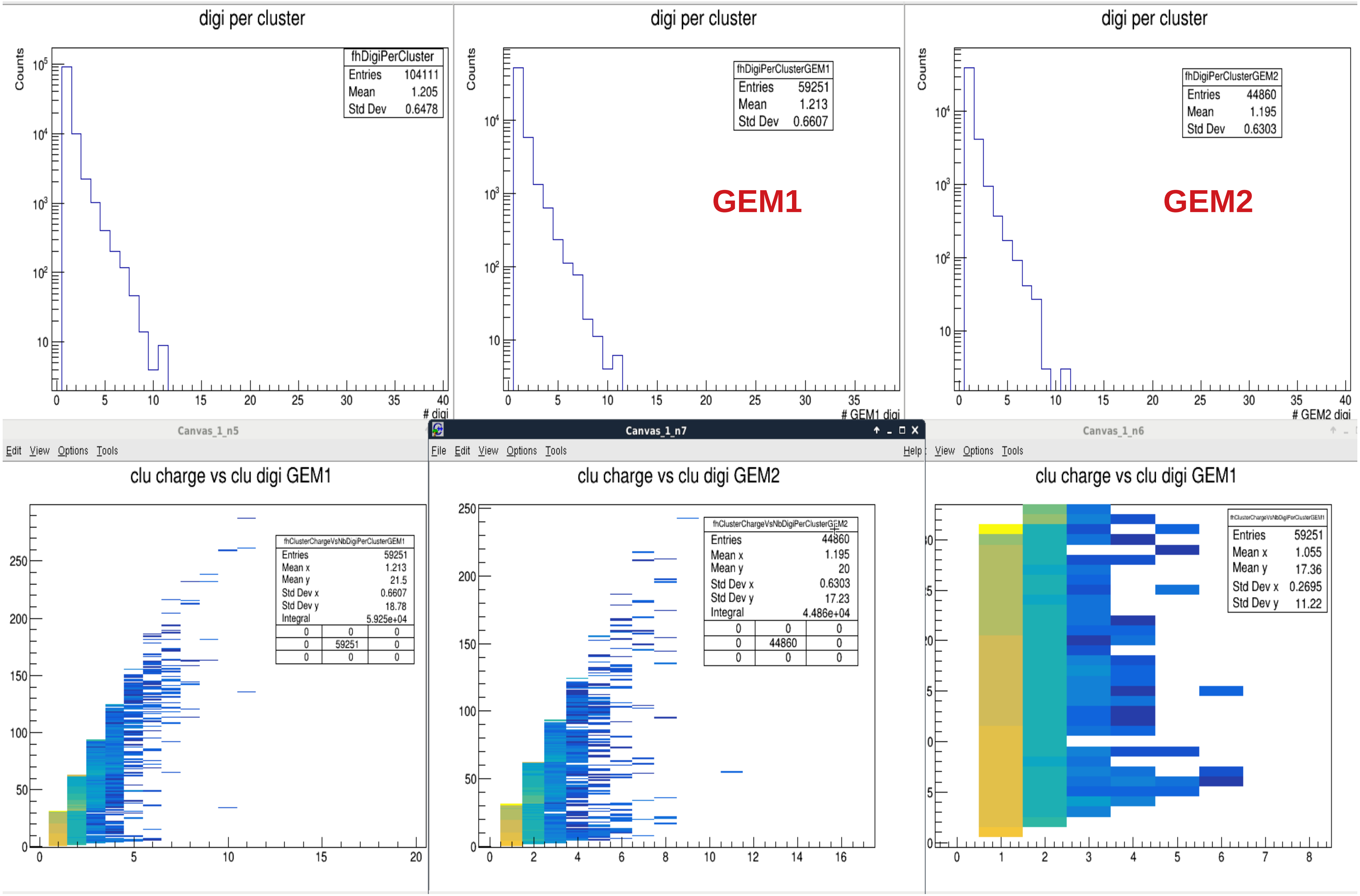




Beam Intensity=10^7/sec
Target thickness : 2.5mm
GEM1

Factor of ~2 increase in the particle rate for 2.5 mm target thickness

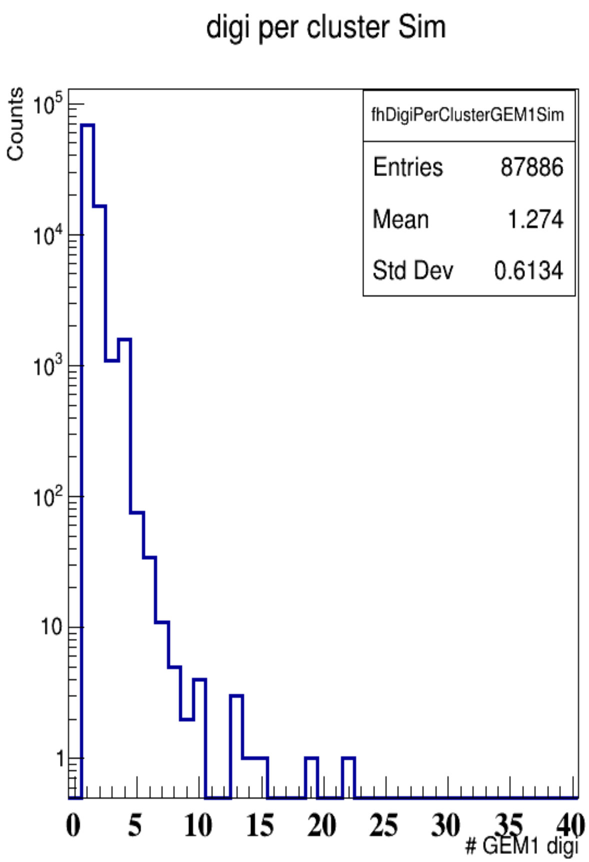
Cluster size and cluster charge

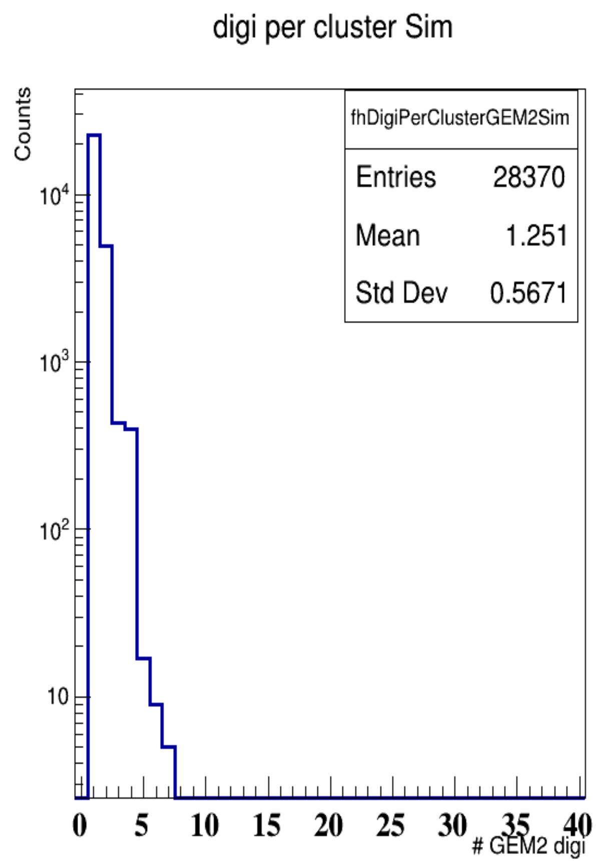


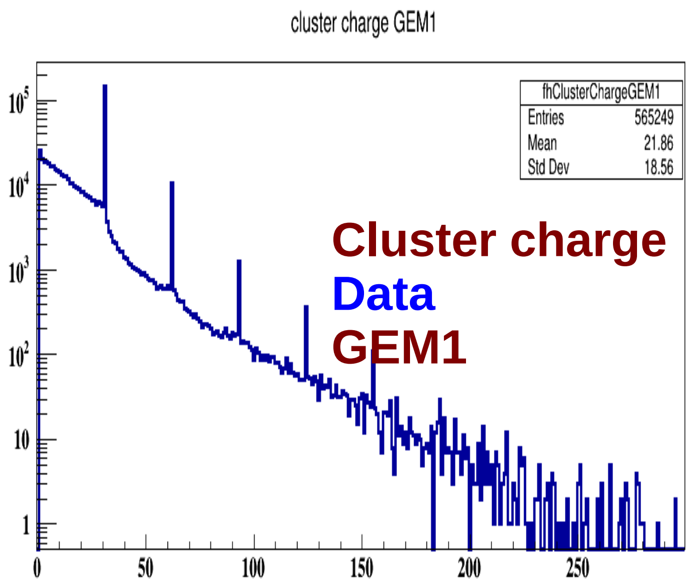
Cluster size: Simulation

Detector gain = 2000
Threshold = 5fc

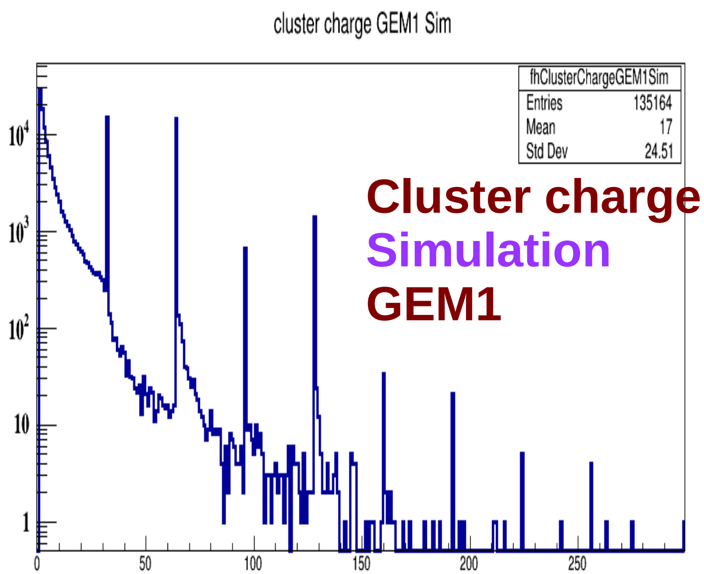
With same acceptance as data







Cluster charge
Data
GEM1



Cluster charge
Simulation
GEM1

Looks similar to the data

ADC and Channel hit distribution