Testing of station-1 GEM prototypes of CBM-MuCh in mini-CBM (mCBM) experiment at GSI

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(on behalf of MuCh Team)

Outline:

1. CBM and mini CBM setup

2. GEM detector assembly at VECC

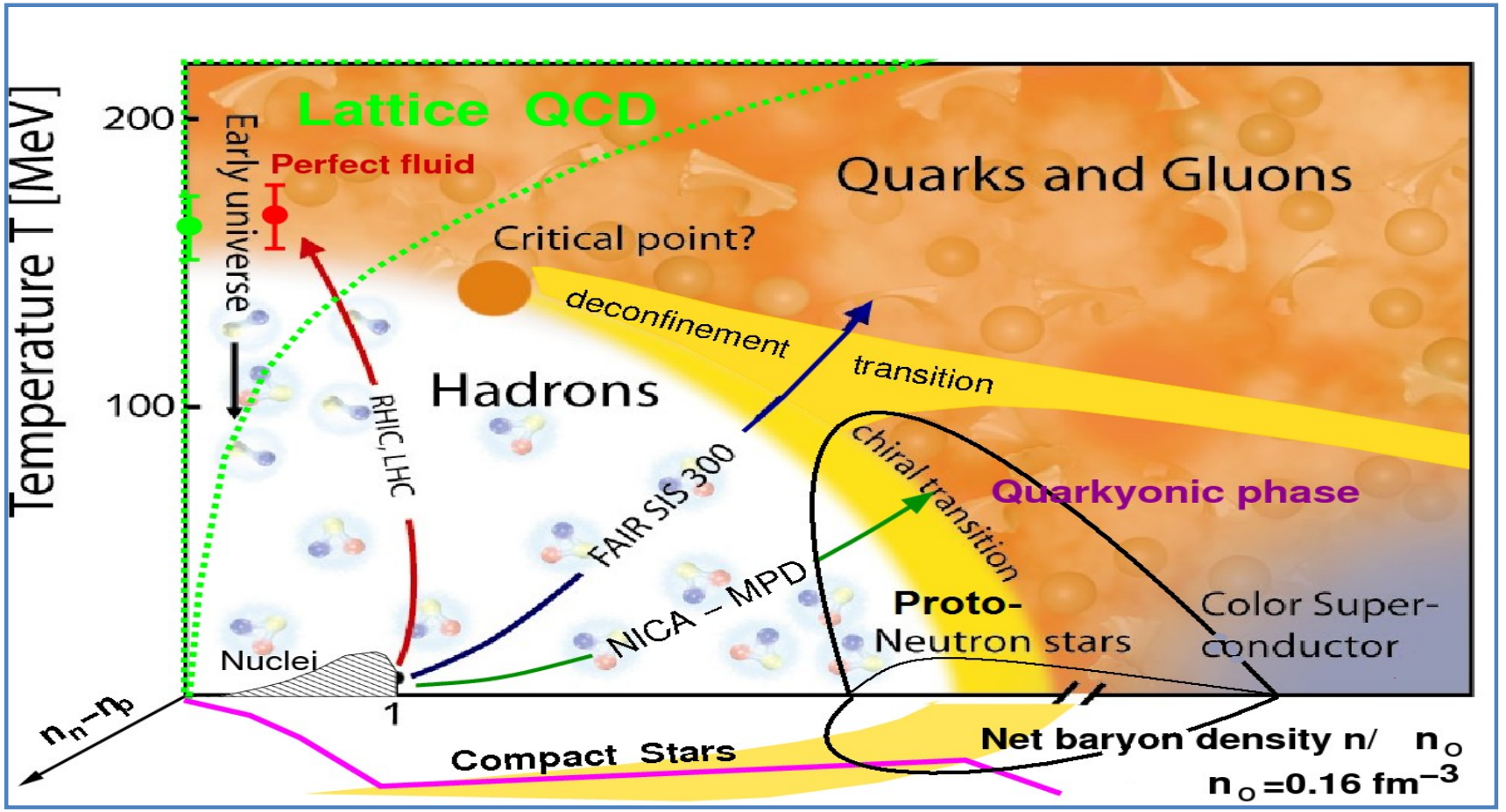
3. Digi rate calculations of MuCh GEM for High Intensity data

4. Time and spatial correlation of MuCh-GEM with TOF

5. Digi correlation between GEM and other sub systems

6. Summary

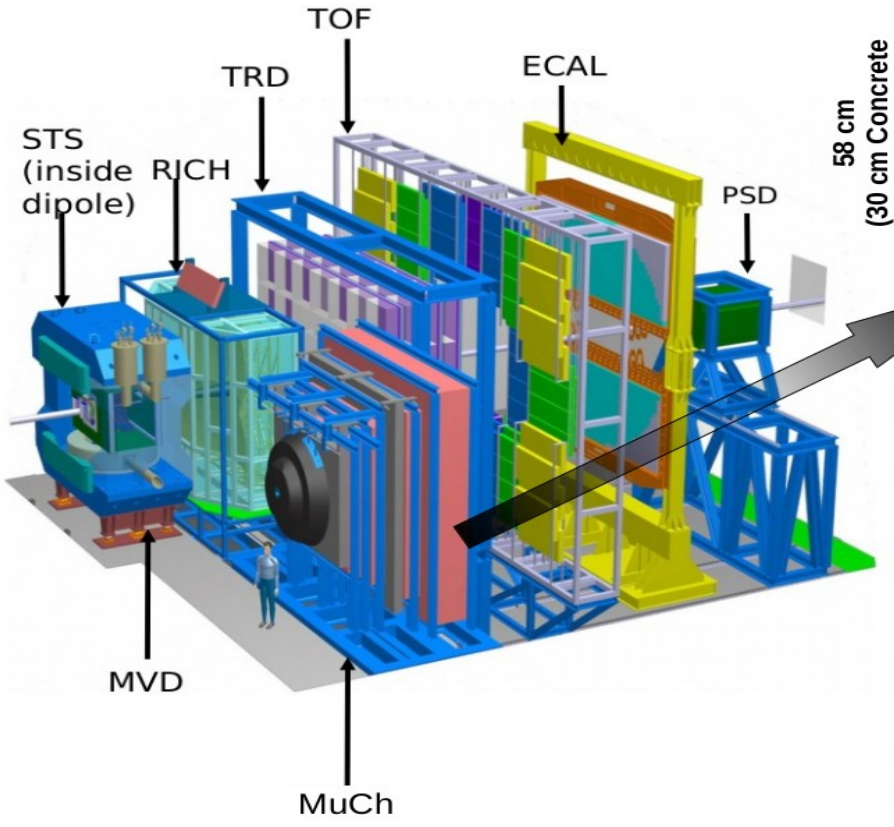
The phase diagram of strongly interacting matter

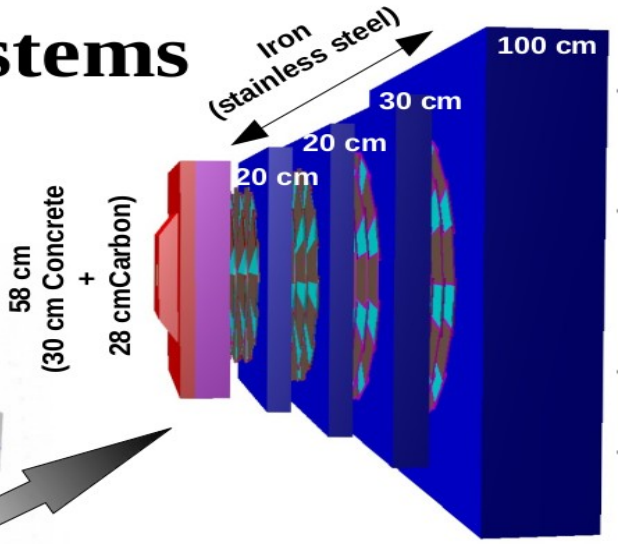


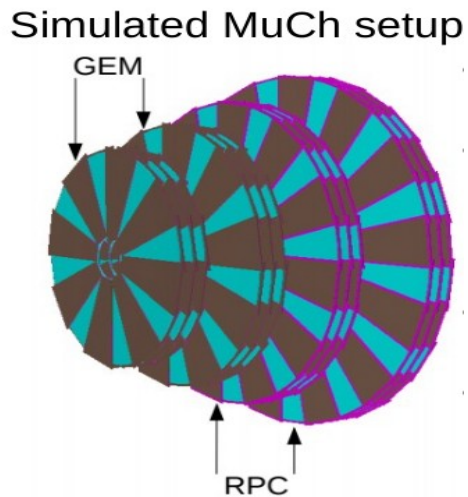
RHIC, LHC: high temperature, low baryon density

FAIR: moderate temperature, high baryon density

CBM detector sub-systems







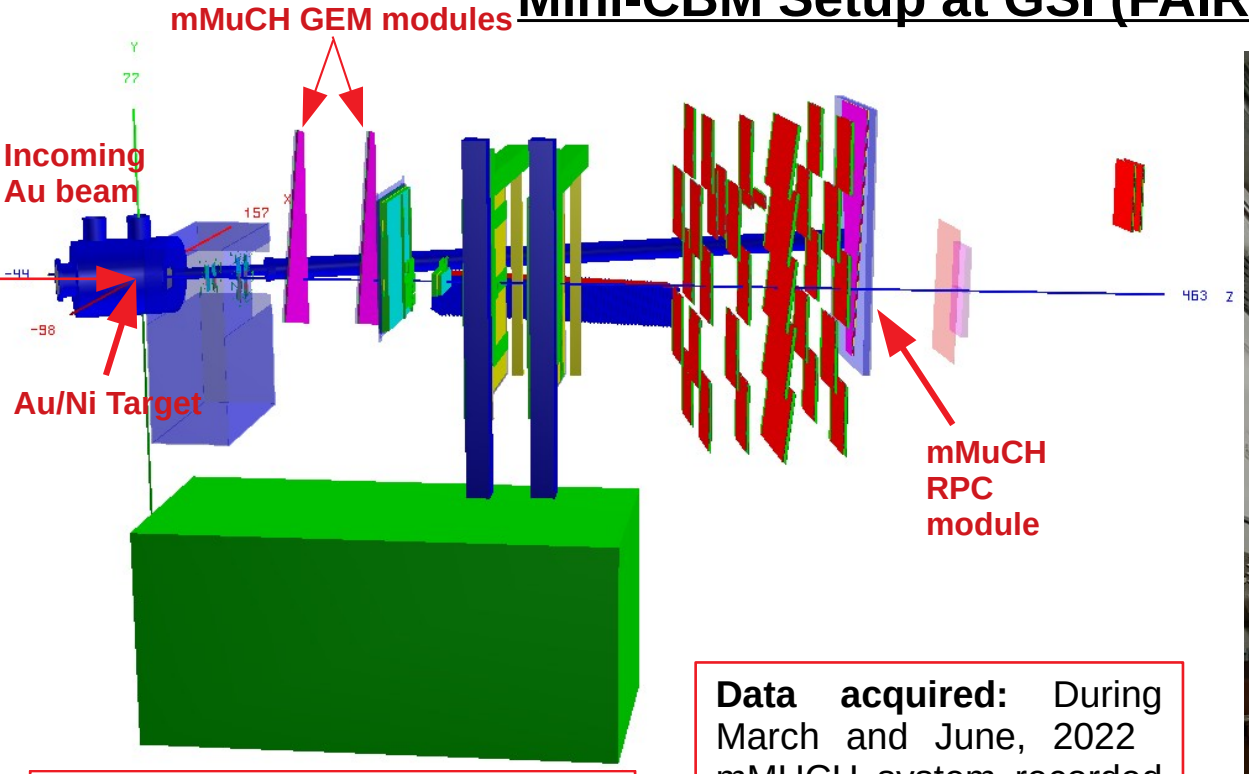
Muon Chamber (MuCh):

- MuCh Comprises of several detectors & segmented hadron absorbers.
- Angular coverage ~ 5^0 to 25^0
- GEM will be used in the first two stations and RPC for the last two stations.

Main Design requirements:

- High interaction rate (up to 10 Mhz).
- High particle flux at the detector stations (~ 570 KHz/cm^2 in the 1st station).
- Self triggered Data Acquisition.
- Detectors with good rate handling capabilities and good spatial resolution are required.

Mini-CBM Setup at GSI (FAIR Phase 0 Programme)

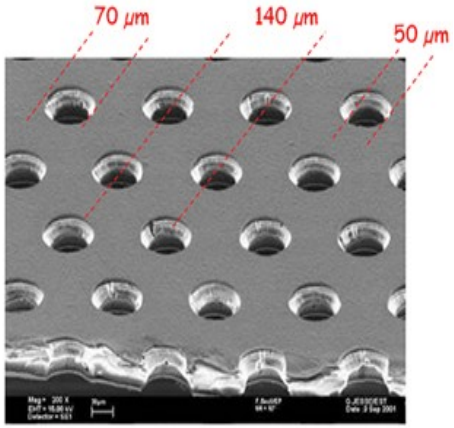


Beam: **Au**$^{69+}$ of 1.23 AGeV
Uranium of 1.0 AGeV
Target: Au (0.25 mm or 2.5 mm)/ Ni (0.4 mm or 4 mm) target

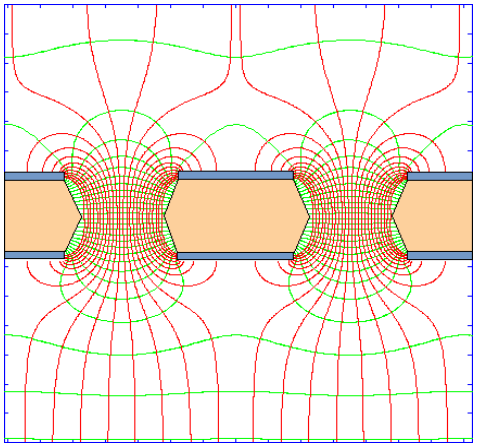
Maximum Int: 8 x 10^8 / 9 sec spill

Data acquired: During March and June, 2022 mMUCH system recorded data for more than 100 runs with various beam intensities, voltages and thresold values.

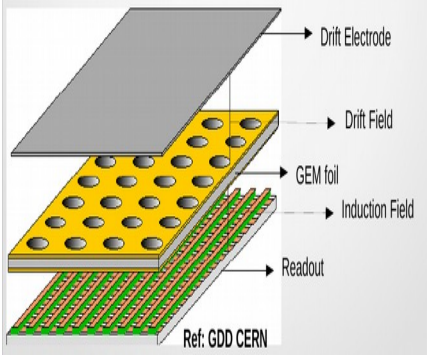
Basics of GEM detector



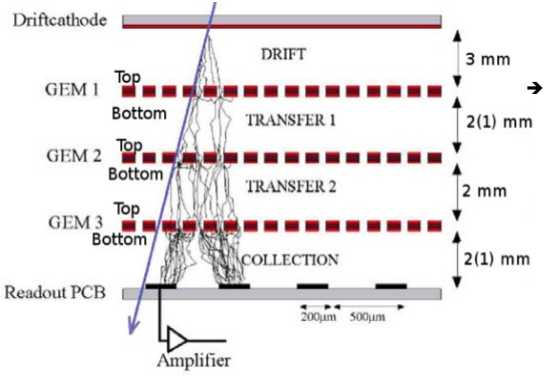
GEM Foil



Electric Field Lines inside GEM



Single GEM Configuration



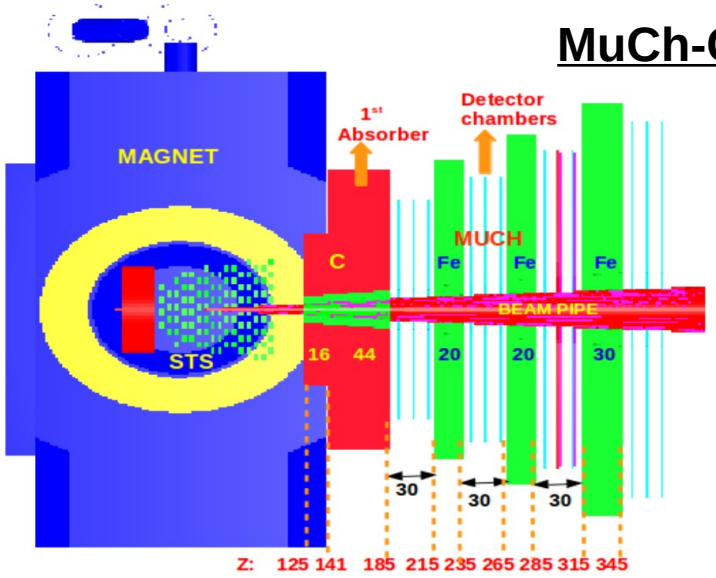
Triple GEM Configuration

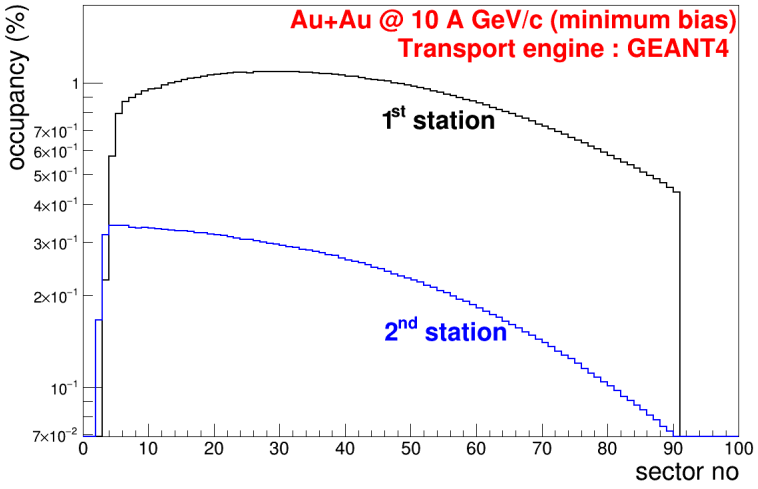
- GEM foil consists of **50 μm** thin dielectric polymer (polyimide) with **5 μm** copper layers on both sides.
- Holes of **diameter 70 μm** with a **pitch** of **140 μm** are created.
- Potential difference of **500 V** results in electric field **~100 kV/cm.**
- When a charged particle passes through the active medium, it ionizes gas and creates **e^--ion pair**. These electrons then multiplied inside the GEM holes.
- The amplified electrons gives signal on the readout electrode

Advantages of GEM

– High rate capability
– High gas gain
– Good spatial resolution

MuCh-GEM optimization for CBM experiment





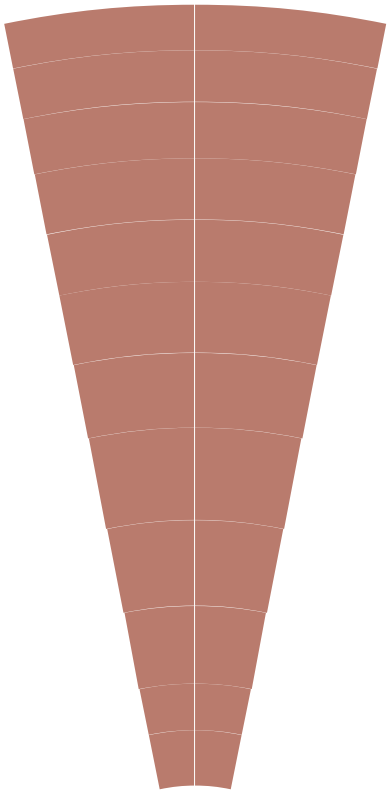
Occupancy defines the fraction of fired pads. Maximum occupancy ~ 1% for 1st station

Source: GEM CDR Review

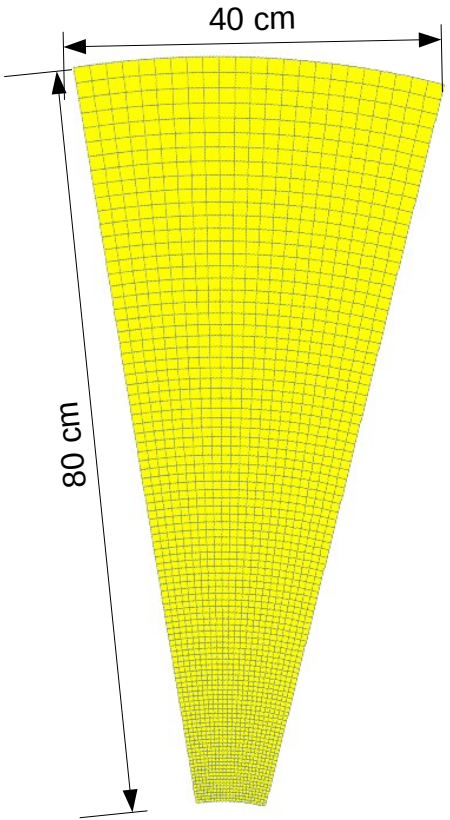
MuCh Detector acceptance: 5.6^0 to 25^0

Station	Z- Position (cm)	Inner Radius (cm)	Outer radius (cm)	Active length (cm)	Remarks	Maximum Digi Rate handling capacity
1(GEM)	190	18.63	97.92	79.29	**8 Layer PCB (87 cm x 47 cm) Segmentation: 1^0**	**570 KHz/cm^2**
2(GEM)	240	23.53	121.24	97.71	**8 Layer Joining PCB (107 cm x 48 cm) Segmentation: 1^0**	**170 KHz/cm^2**

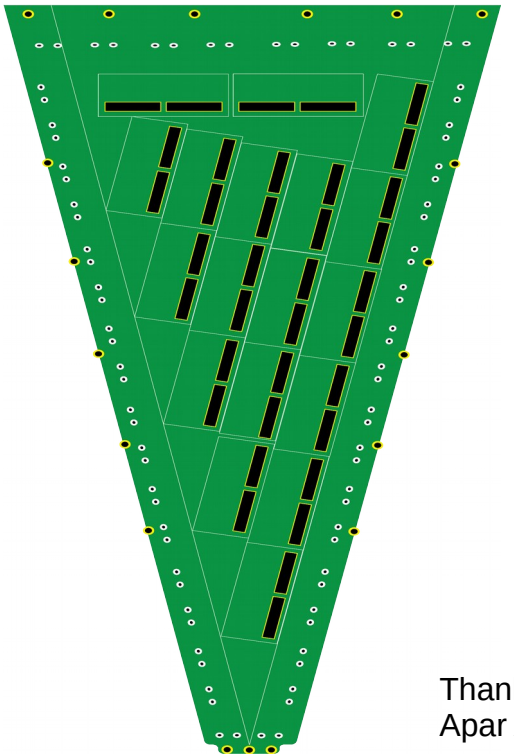
CBM-MuCh first station GEM detector assembly



24- Segment GEM Foil



2231 Pads 8-layer readout PCB
With progressive pad geometry

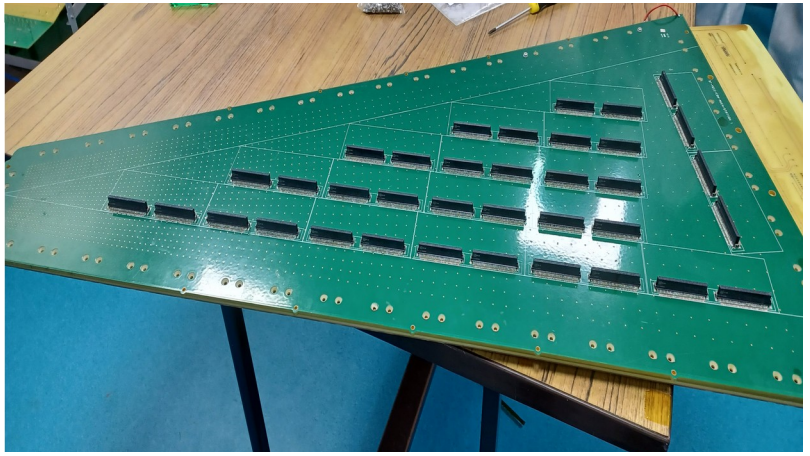
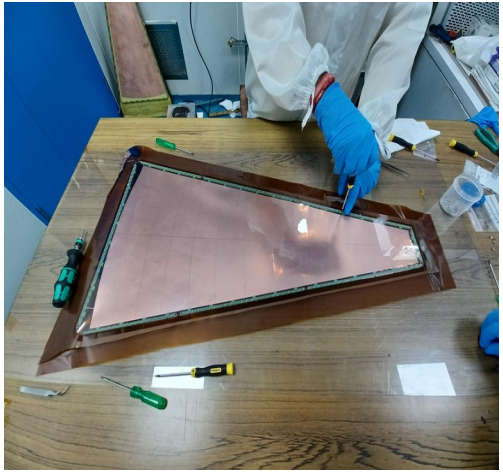
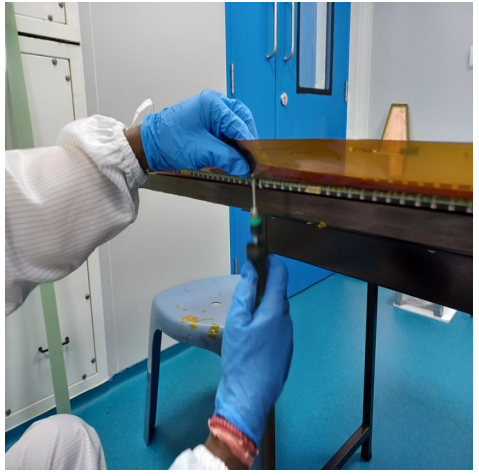
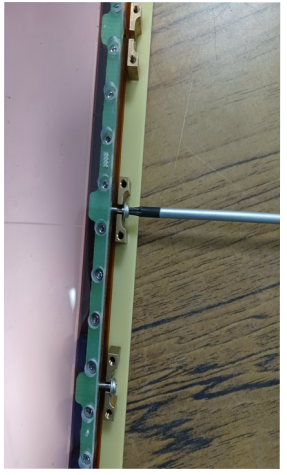
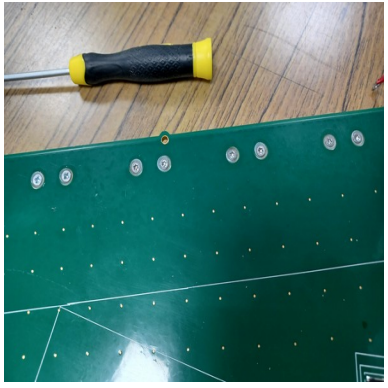


18- Connector readout

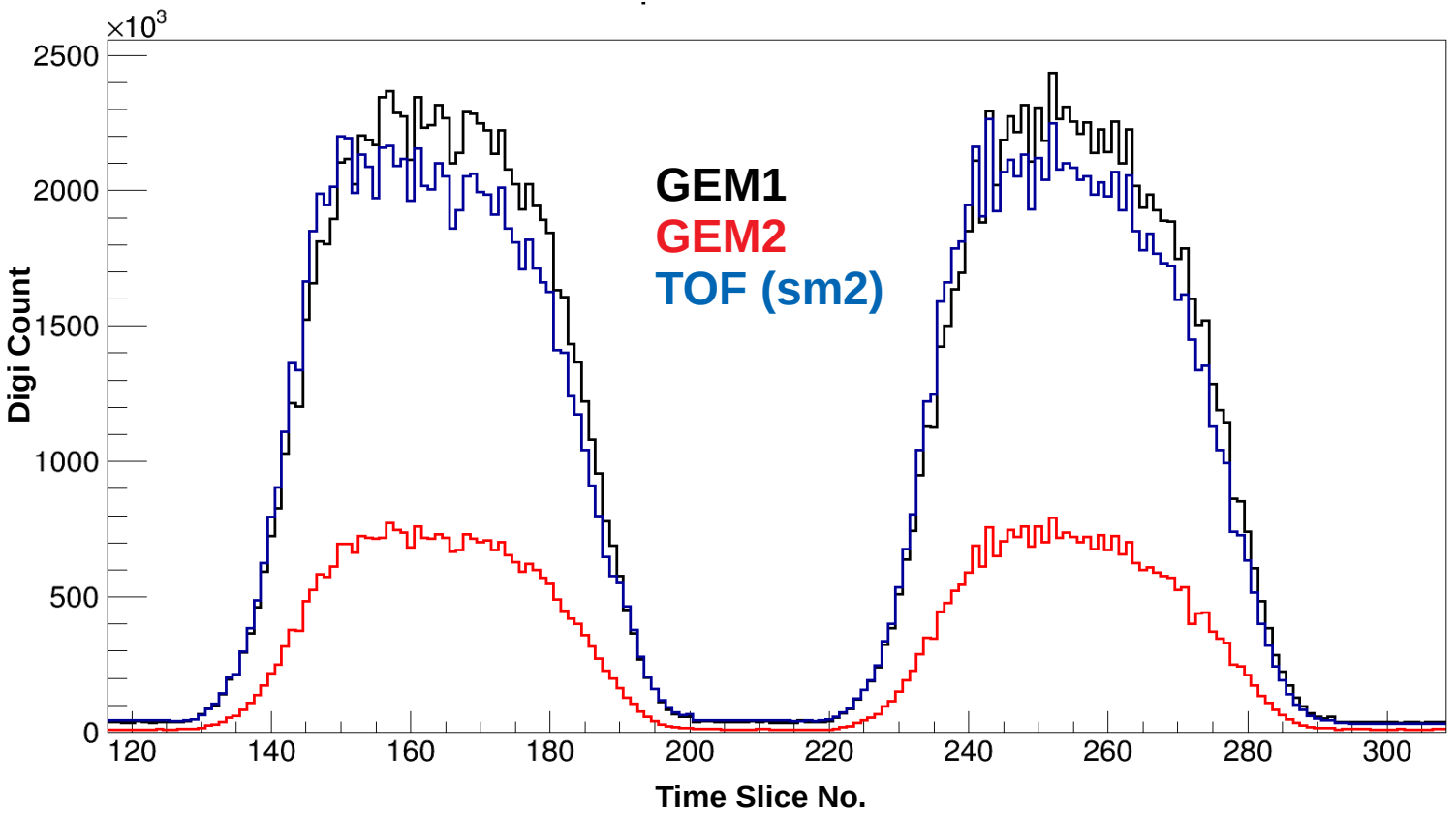
Thanks
Apar Agarwal

First station prototype assembly at VECC



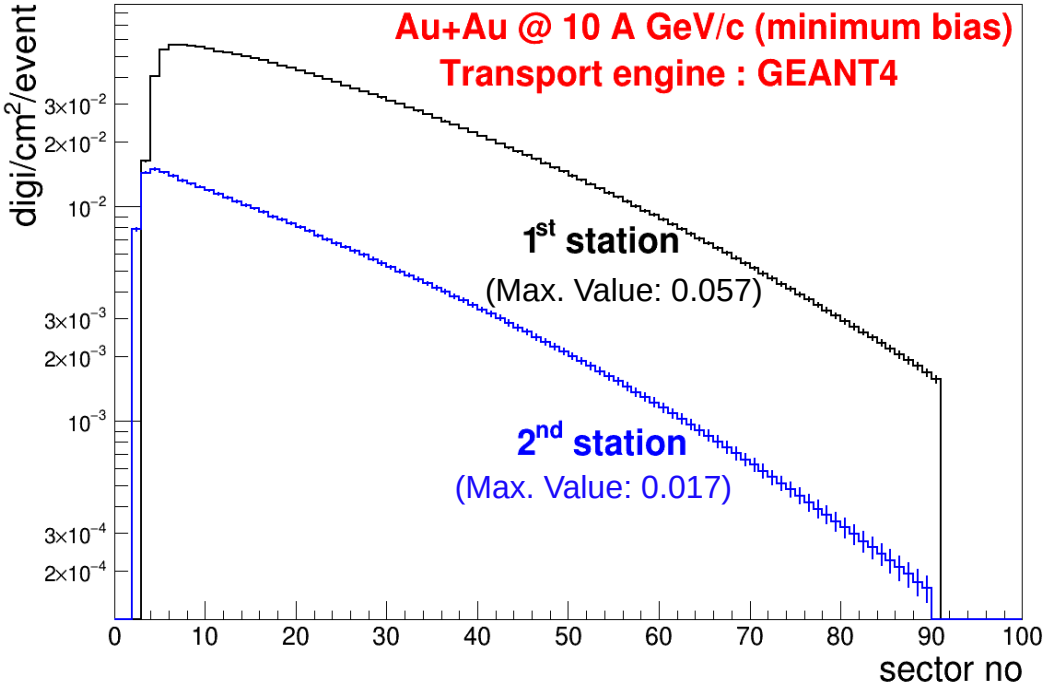






Spill Structure of a high intensity run



Run: 2570
Gem1 HV= 4800V
Gem2 HV= 4412V
Target= Thick Nickel (4mm)
Beam Intensity= 2.5×10^8/Spill
Time= 21:54:27
Date: 19th June, 2022

Particle rate estimation by Simulation



- For a **10 MHz** average minimum bias event rate, maximum digi rate of **570 kHz/cm²** (**station 1**) and **170 kHz/cm²** (**station 2**).
- In main CBM these rates will be handled by lowest pad size region of the detector, but in mini-CBM the maximum rate is handled by the higher pad size region, due to the detector orientation.

Source: GEM CDR Review

Achieved rates in mCBM Au + Ni @1.23 A GeV, 2.7MHz Event Rate

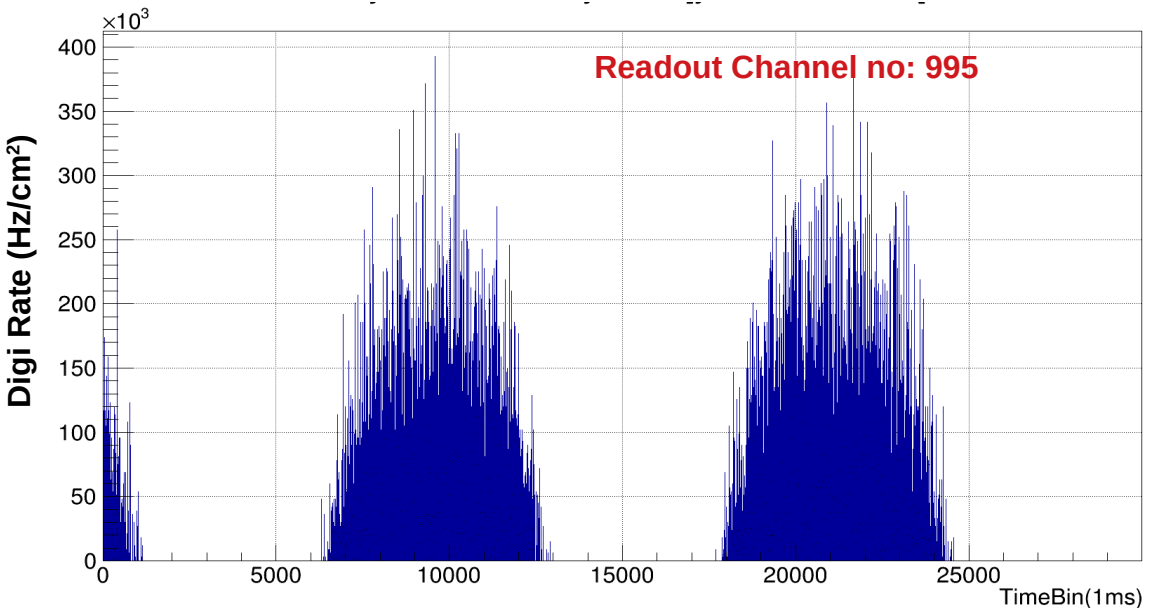
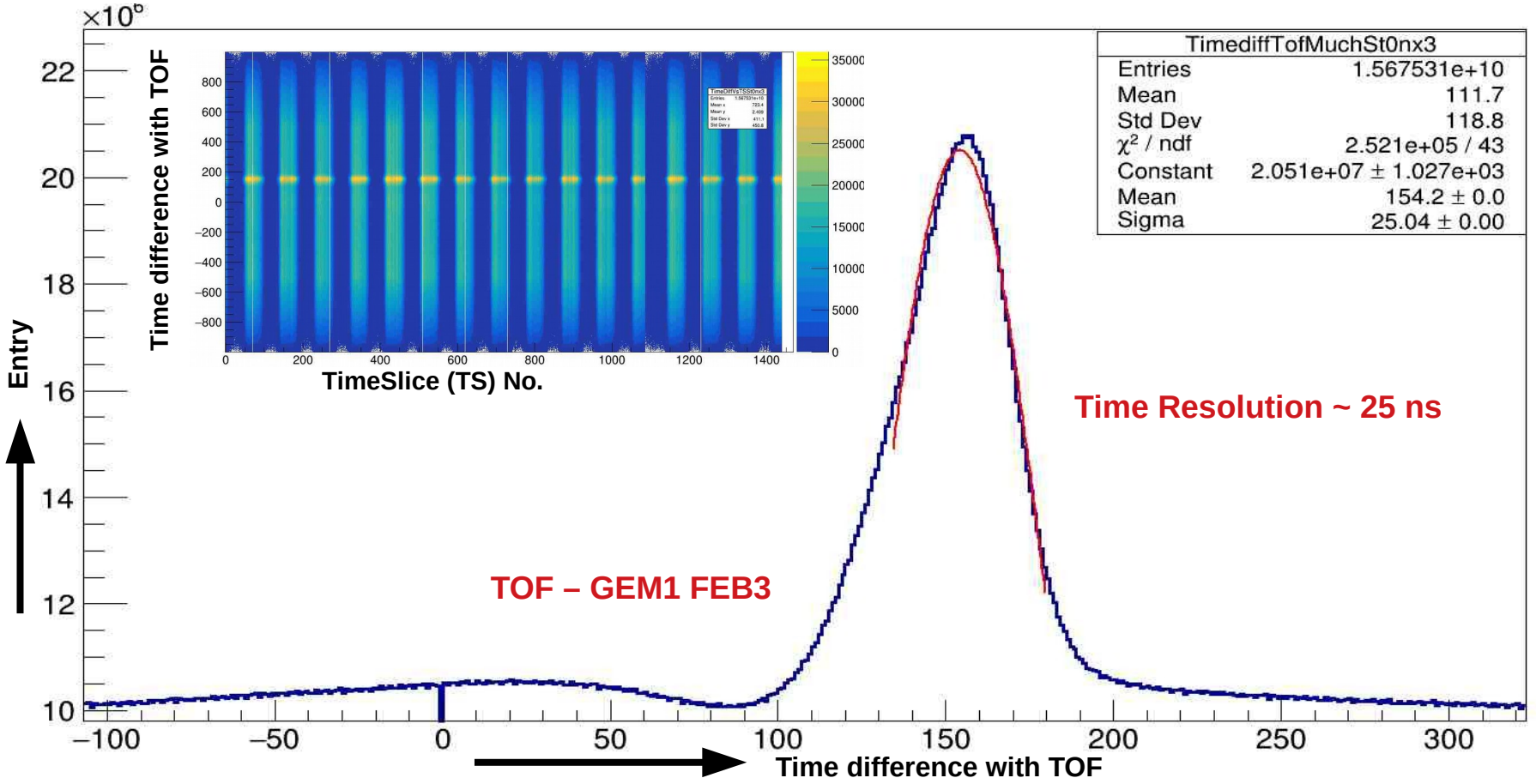


Fig 1. Shows the area normalized digi rate of channel 995 with a time bin of 1 ms, data is shown for 1 on-spill and 1 off-spill. Digi rate is observed around **200 KHz/Cm²**

Achieved Digi Rate @ mCBM~ 200 KHz/Cm²

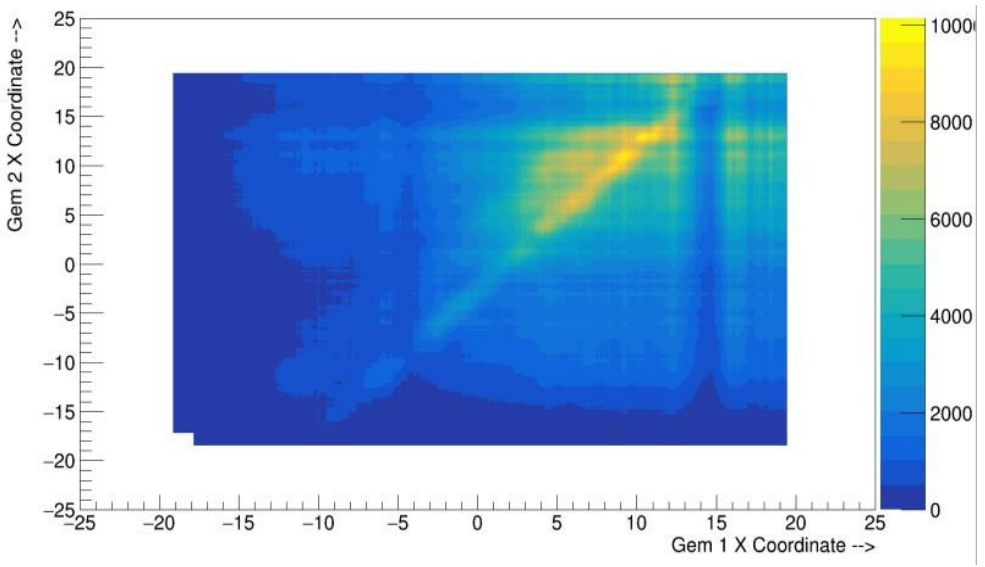
Time Correlation of GEM1 with TOF



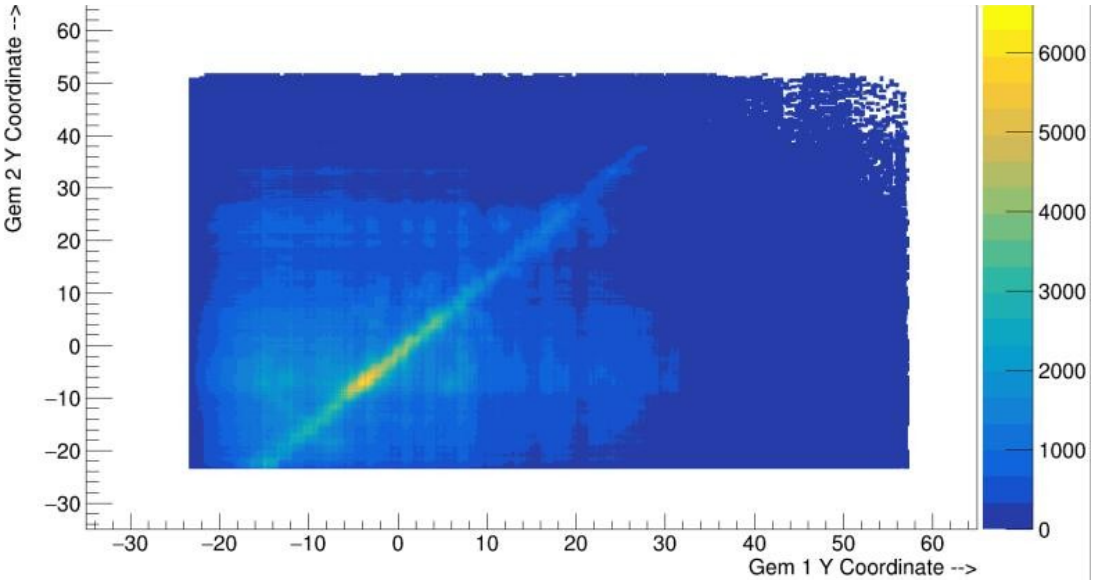
Such Stable Offset were observed for all the other FEBs

Spatial Correlation of GEM 1 vs. GEM 2 (10^7 Ions/spill), U-Au DataMarch, 2022 mCBM

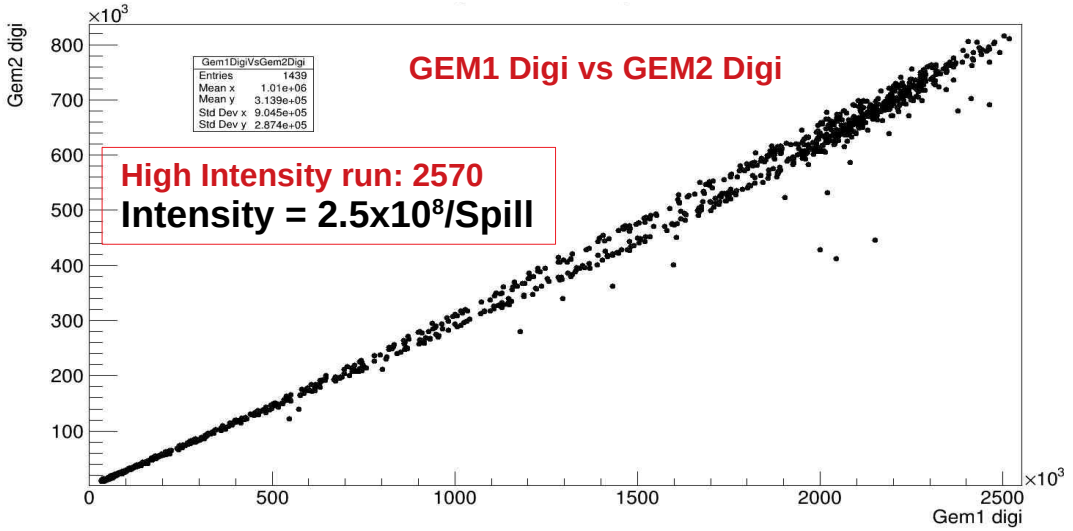
X–X Correlation

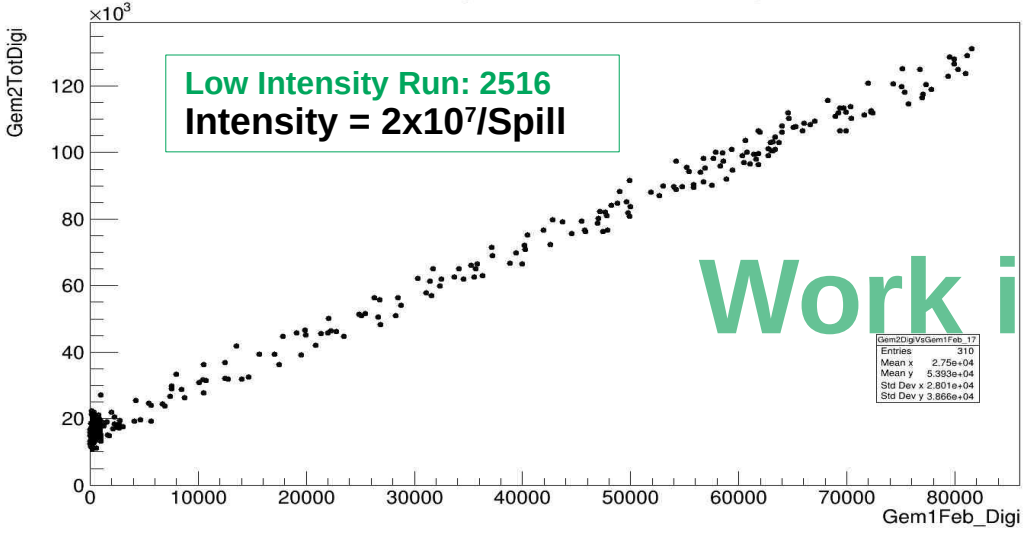


Y–Y Correlation



Ref:Apar Agarwal





Observations:

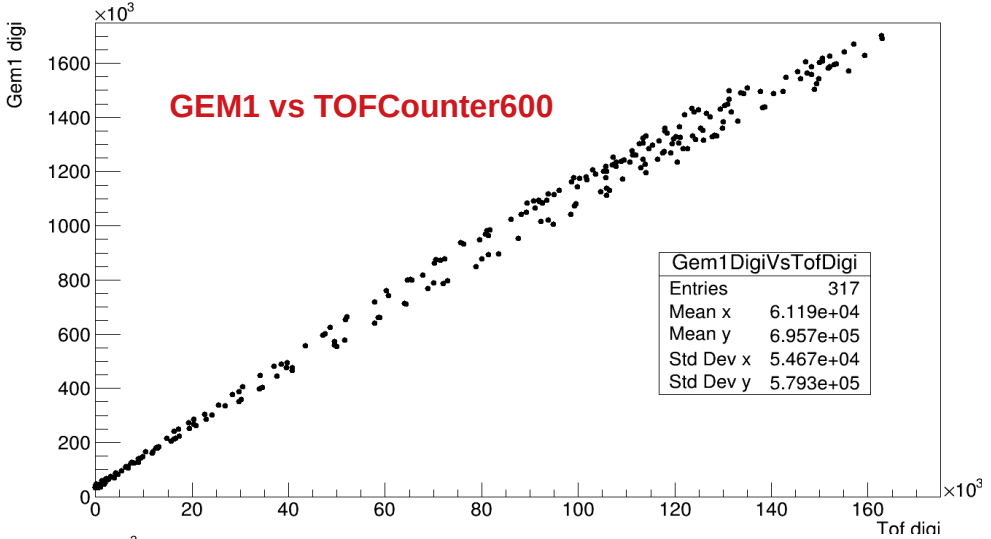
1. Double line in GEM1 vs GEM2 digi corr observed:

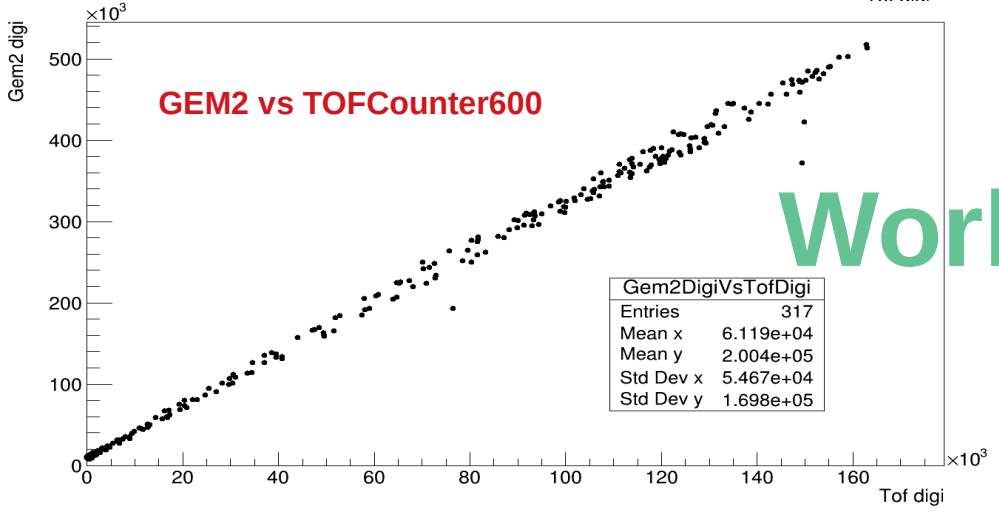
Preliminary investigations show two different slopes of digi correlation for rising and falling part of a spill.

No such “Double Line” is observed in Low intensity runs

Work in Progress

Run: 2565
Intensity = 1.5x10^8/Spill, 2.5 mm Au Target





Observations:

1. Similar double line observed in GEM vs TOF digi corr:

Preliminary investigations show two different slopes of digi correlation for rising and falling part of a spill.

Work in Progress

Summary:

1. We have installed 2 GEM1 prototypes in mCBM experiment.

2. Time offset of GEM with TOF remains stable over all the runs.

3. Clear spatial correlations are observed within GEM1 and GEM2.

4. Digi rate of GEM1 is found upto 200 KHz/cm^2 at high intensity run.

5. Difference in digi correlations during different regions of the spill are under investigations.

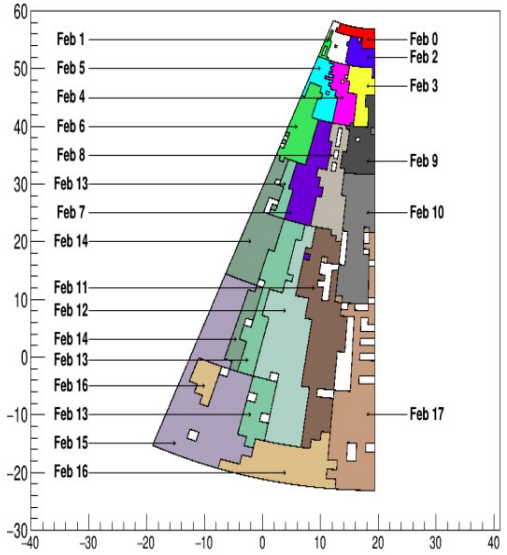
6. Further studies on hit reconstruction, clustering etc are ongoing to find out the gain, efficiency etc of the detector during high intensity.

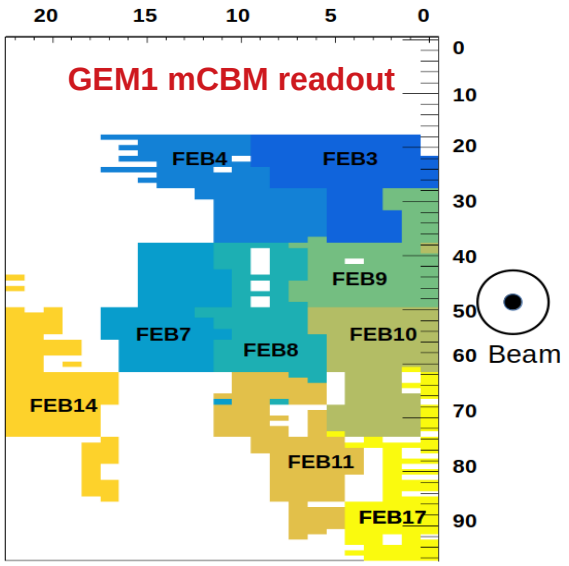
Thank you

Back up slides

mCBM Readout

GEM1 readout PCB layout

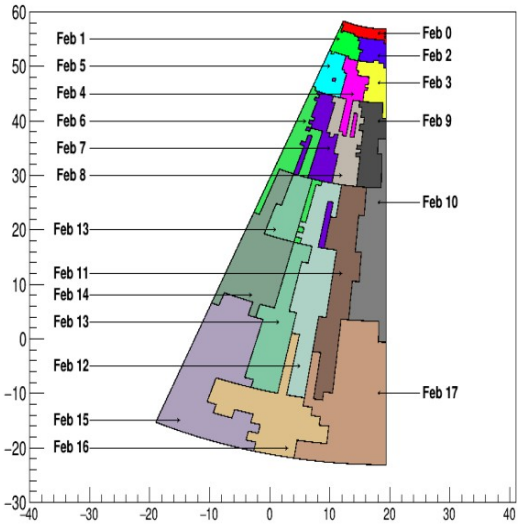


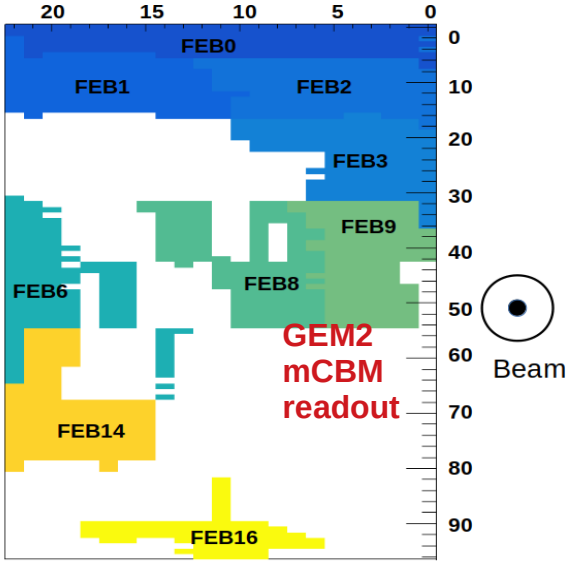


Each module requires 18 Front End Boards (FEB).

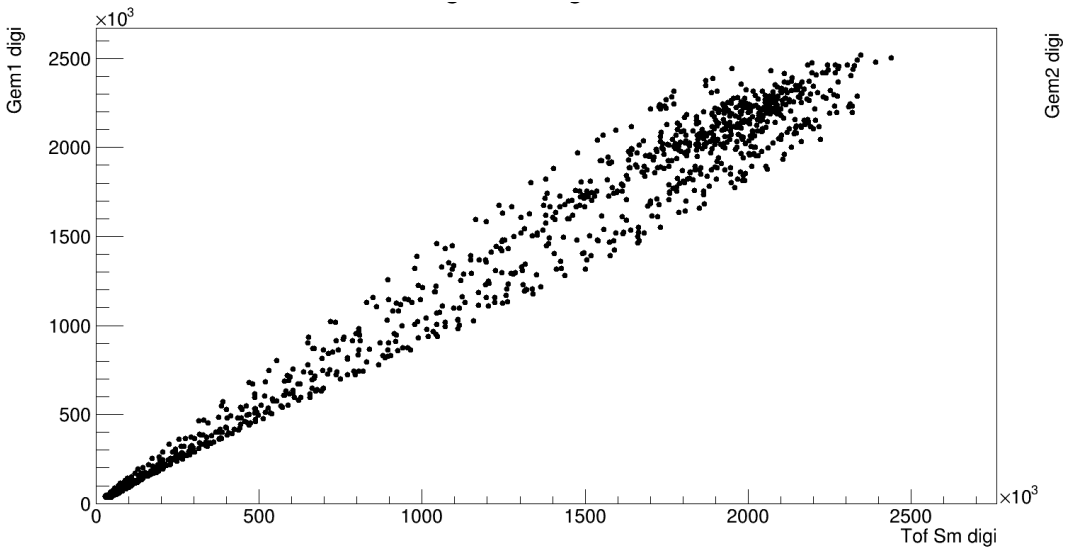
In mCBM we could readout 9 FEBs from each module.

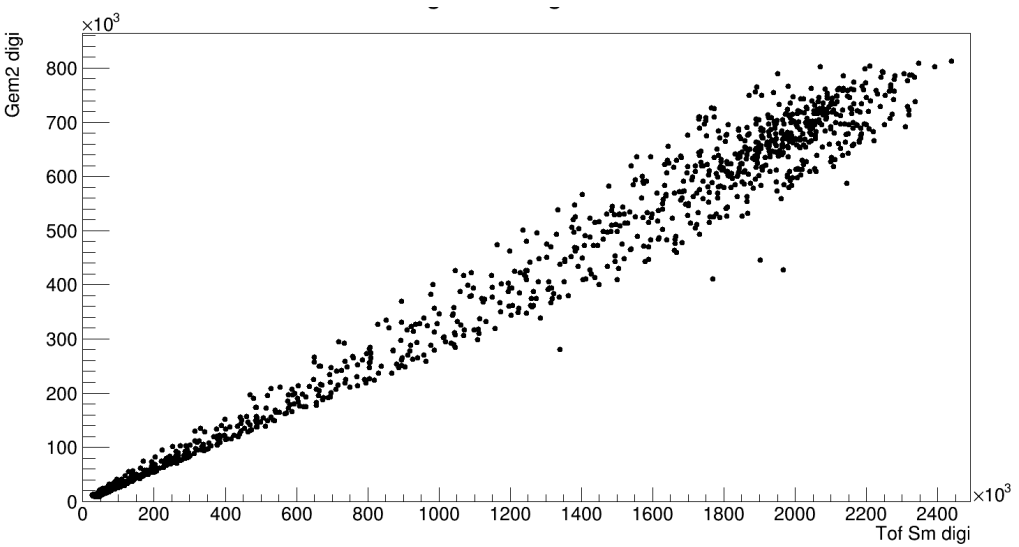
GEM2 readout PCB layout





Digi Correlation of GEM1 and GEM2 wrt TOF (sm2) at highest intensity





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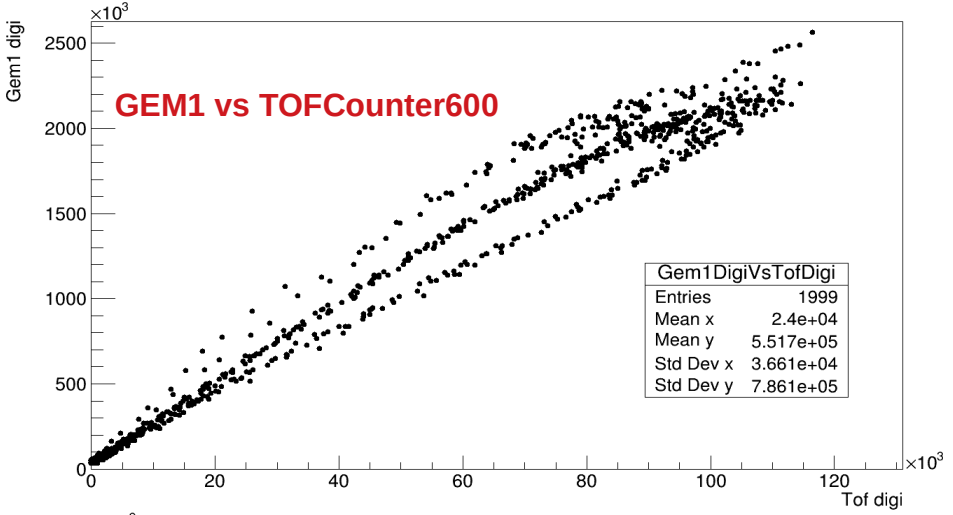
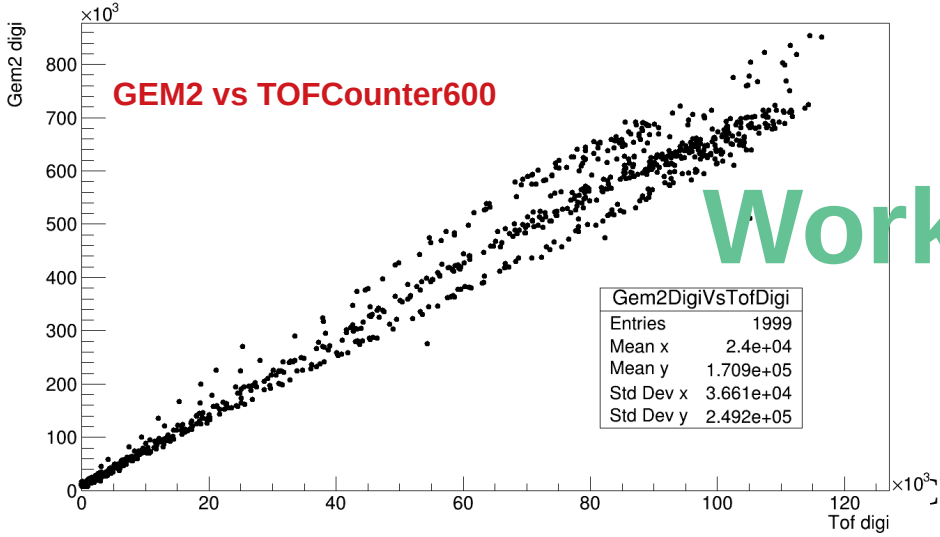
Gem1 HV= 4800V
Gem2 HV= 4412V
Target= Thick Nickel (4mm)
Beam Intensity= 2.5×10^8/Spill
Time= 21:54:27
Date: 19th June, 2022

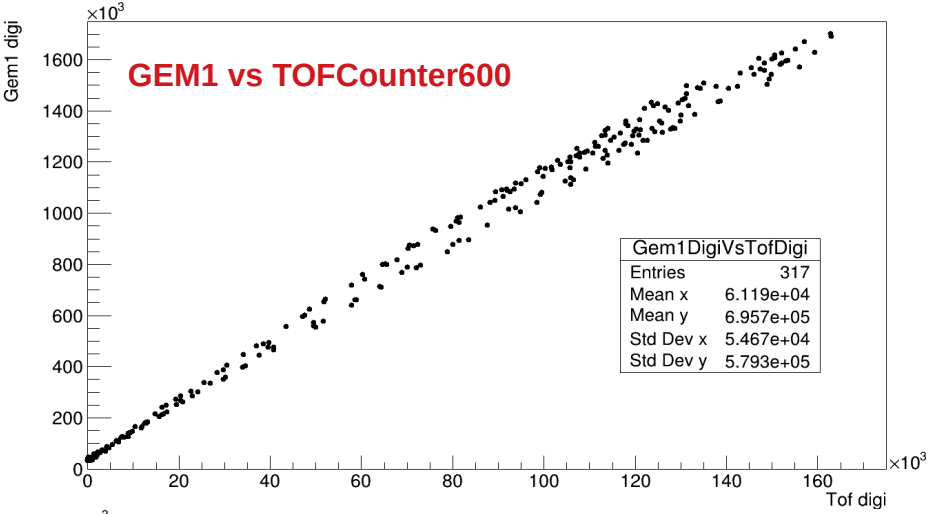
The digi correlation of GEMs with reference detector TOF at highest intensity shows linear behaviour.

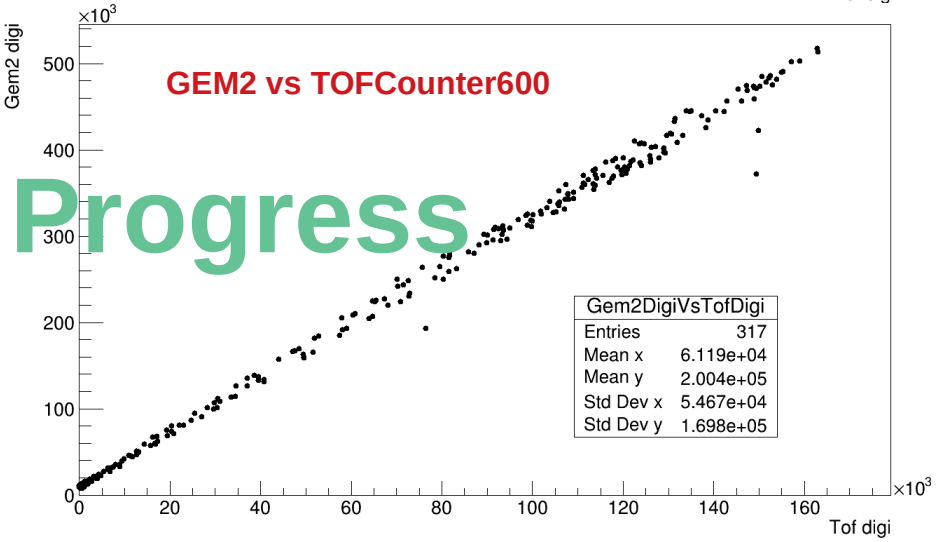
Run: 2569, Highest Intensity
Intensity = 2.5x10⁸/Spill, 4 mm Ni Target





Run: 2565, Lower Intensity
Intensity = 1.5x10⁸/Spill, 2.5 mm Au Target





Work in Progress