

# **Commissioning and Testing of Station-1 and Station-2 MuCh-GEM Modules with High-Intensity Beams at the mini-CBM (mCBM) Experiment at GSI**

**Chandrasekhar Ghosh**  
**VECC, Kolkata**  
(on behalf of MuCh Team)

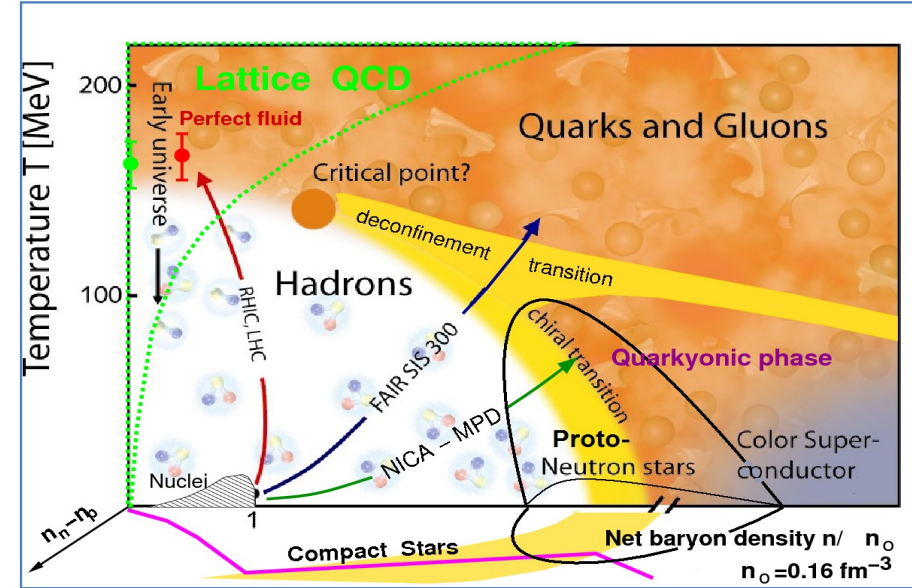
# Outline:

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.
5. Digi correlation between GEM and other sub systems.
6. Summary and Outlook.

# The Physics case of CBM:

1. The equation of state of QCD matter at neutron star core densities.
2. Phase transitions from hadronic matter to quarkyonic or partonic matter at high  $\rho_B$ , phase coexistence, critical point.
3. Chiral symmetry restoration in dense baryonic matter.
4. Extension of the nuclear chart into the strange domain: Hypernuclei.
5. Charm production at threshold energies in cold and hot matter.

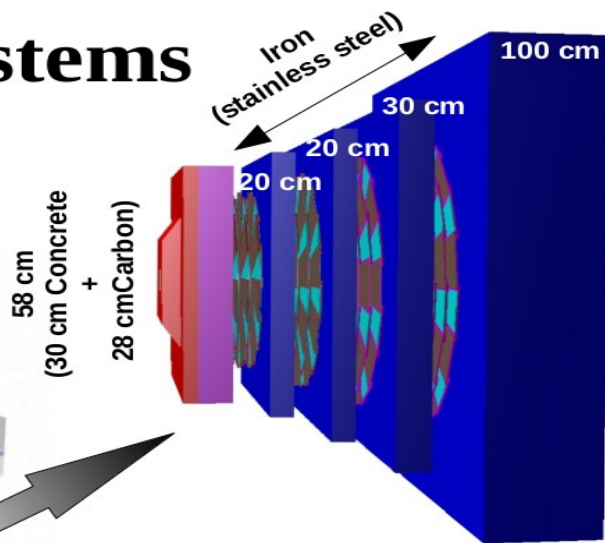
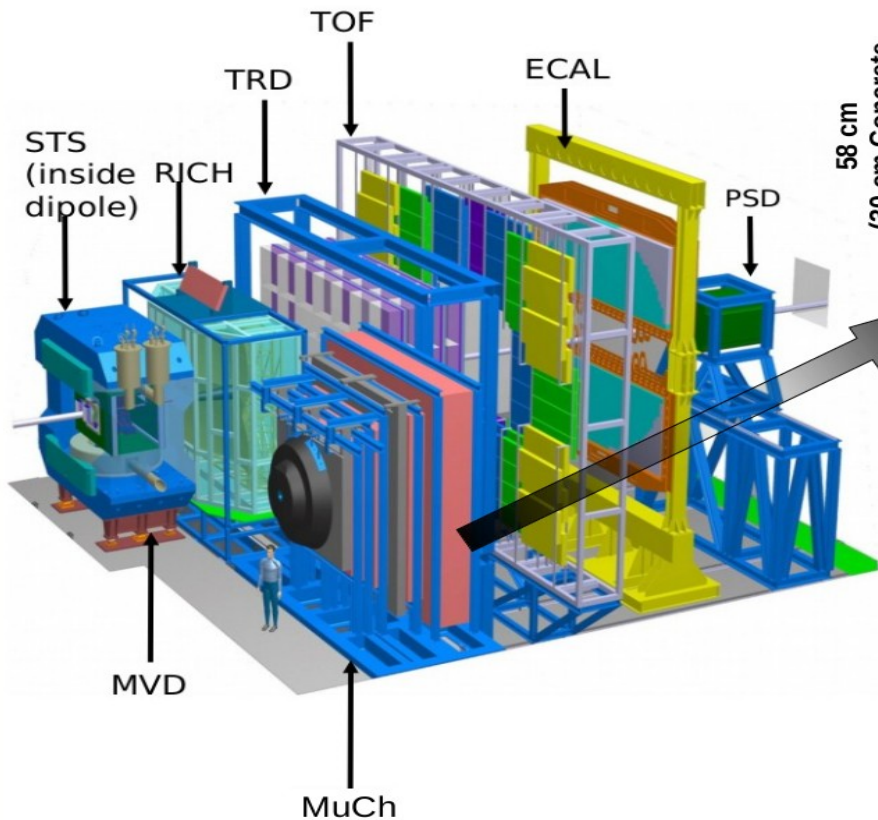
## The phase diagram of strongly interacting matter



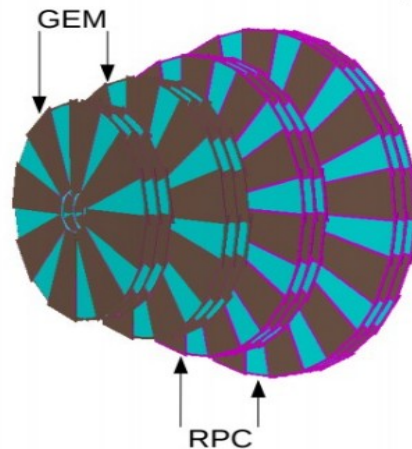
**RHIC, LHC:** High temperature, low baryon density.

**FAIR:** Moderate temperature, high baryon density.

# CBM detector sub-systems



Simulated MuCh setup



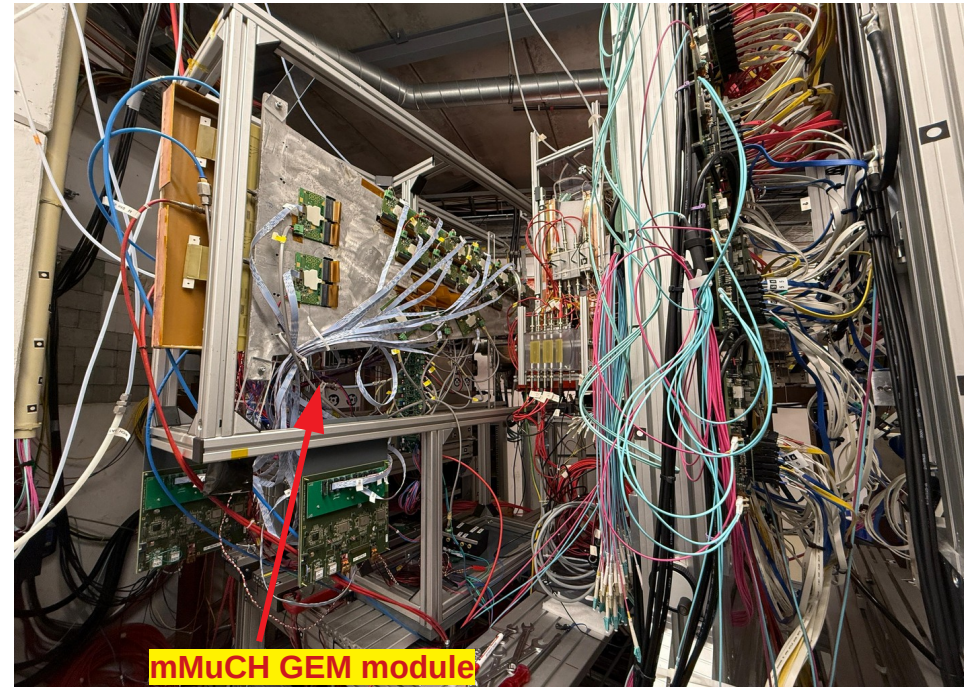
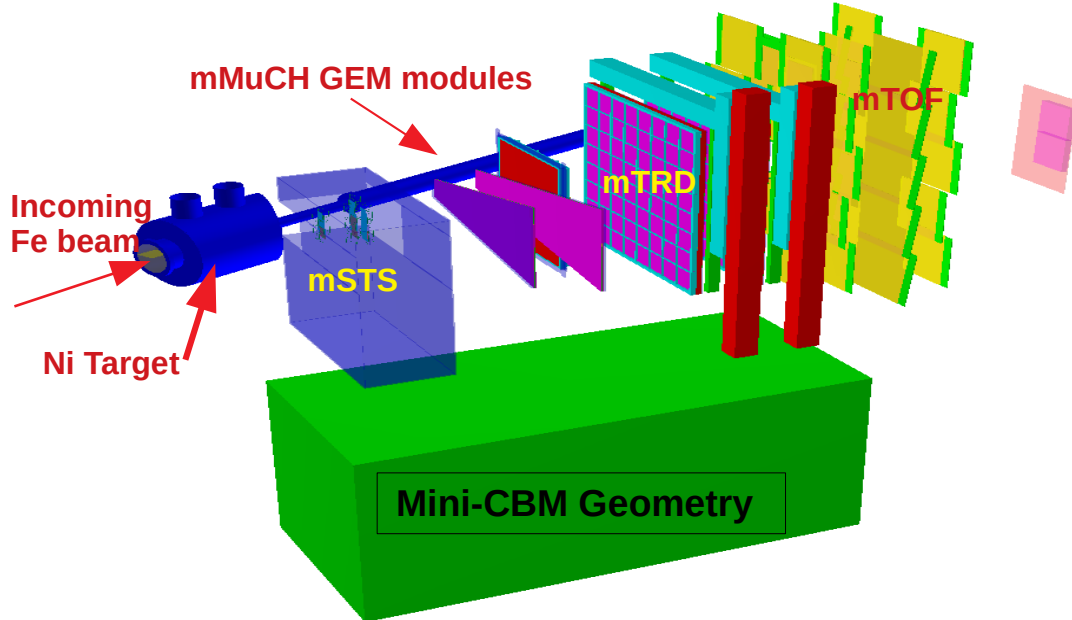
## Muon Chamber (MuCh):

- MuCh Comprises of several detectors & segmented hadron absorbers.
- Angular coverage  $\sim 5^\circ$  to  $25^\circ$
- 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 ( $\sim 570$  kHz/cm<sup>2</sup> in the 1<sup>st</sup> station).
- Self triggered Data Acquisition.
- Detectors with good rate handling capabilities and good spatial resolution are required.

# Commissioning of CBM MuCh GEM modules @ mini-CBM, May 2025



**Beam:**  ${}_{209}\text{Bi}^{68+}$  of 1.1 AGeV /  ${}_{56}\text{Fe}^{25+}$  of 1.7 AGeV

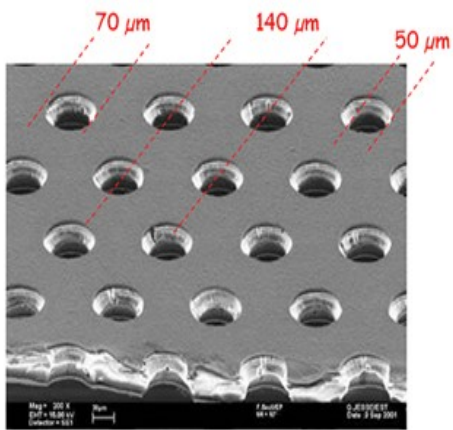
**Target:** 2.5 mm Au / 4 mm Ni

**Maximum Int:**  $8 \times 10^8$  / 6 sec spill ~ **13 MHz**  
**Interaction rate**

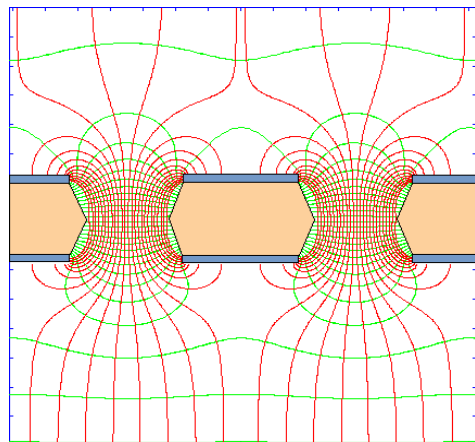
**Data acquired:** During May, 2025 mMuCH system recorded data at various beam intensities and voltages.

Special Thanks to:  
*Christian Sturm, GSI*  
and  
*David Emchermann, GSI*

# Basics of GEM detector

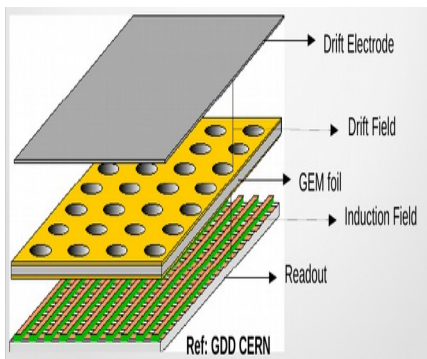


GEM Foil

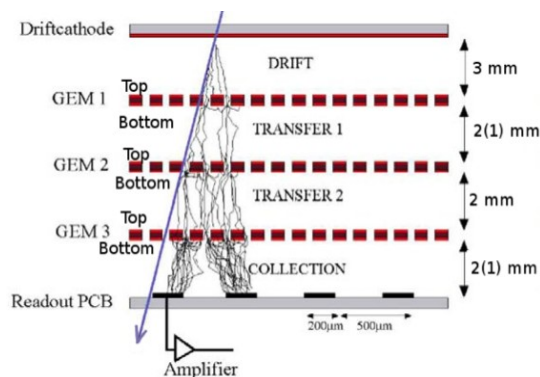


Electric Field Lines inside GEM

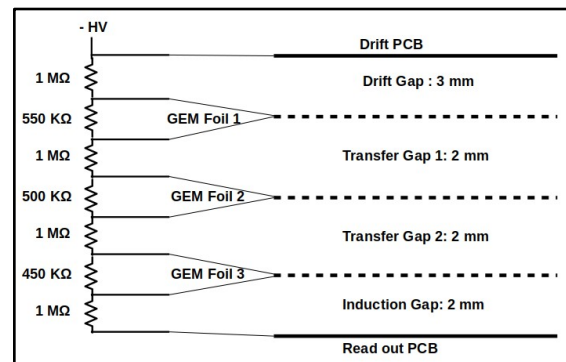
- GEM foil consists of **50 μm** thin dielectric polymer (polyimide) with **5 μm** copper layers on both sides.
- Holes of **diameter 70 μm** with a **pitch of 140 μm** are created.
- Potential difference of **500 V** results in electric field **~100 kV/cm**.
- When a charged particle passes through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



Single GEM Configuration



Triple GEM Configuration



Triple GEM for CBM-MuCh

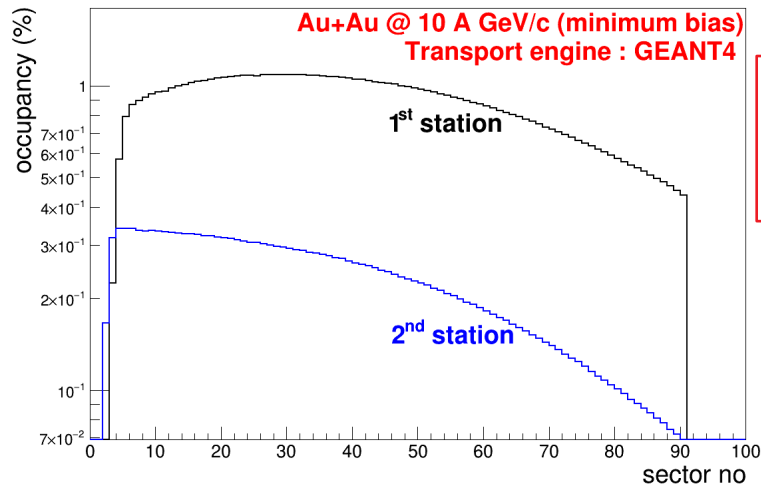
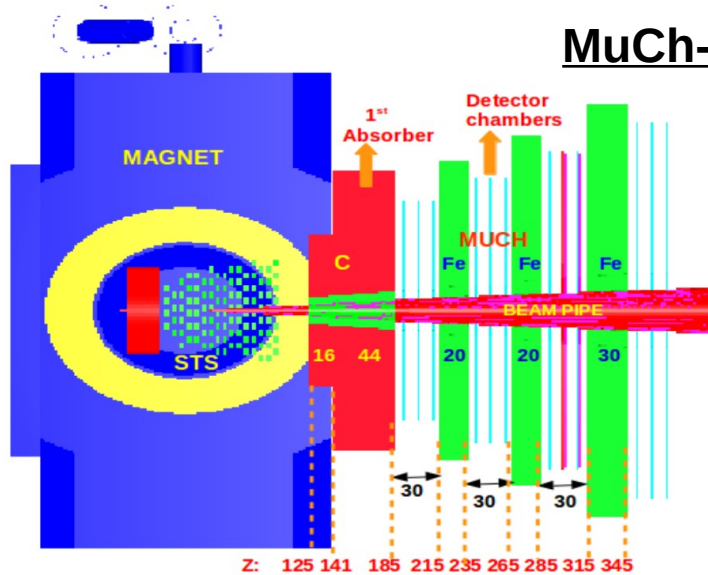
## Advantages of GEM

High rate capability

High gas gain

Good spatial resolution

# MuCh-GEM optimization for CBM experiment



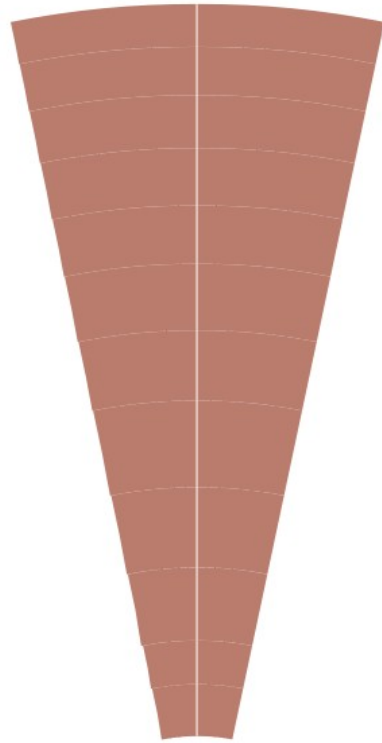
Occupancy defines the fraction of fired pads. Maximum occupancy ~ 1% for 1<sup>st</sup> station

Source: GEM CDR Review

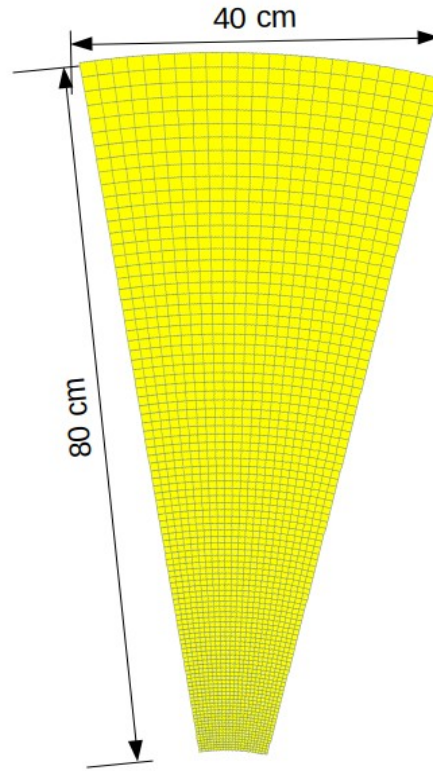
## MuCh Detector acceptance: 5.6° to 25°

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

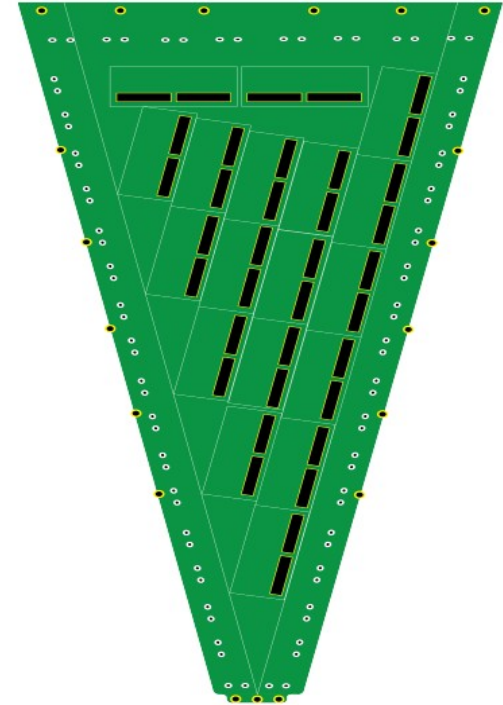
# CBM-MuCh first station GEM detector PCB design



**24- Segment GEM Foil**

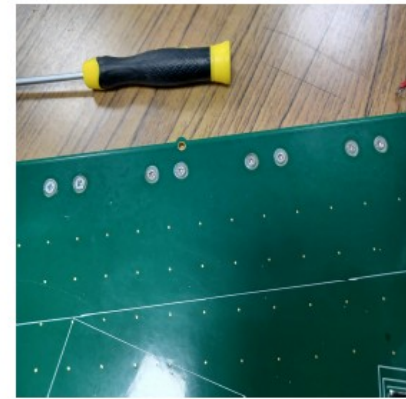
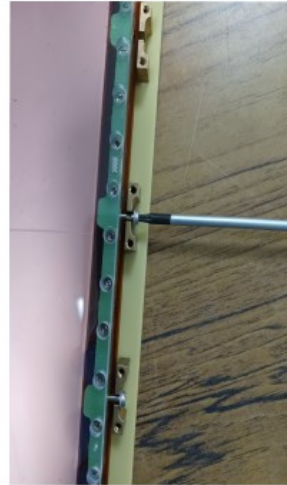
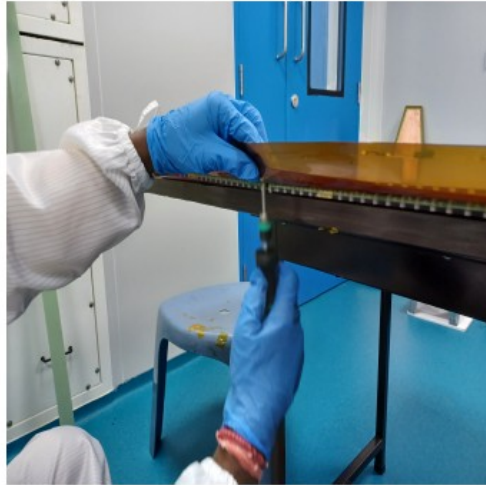
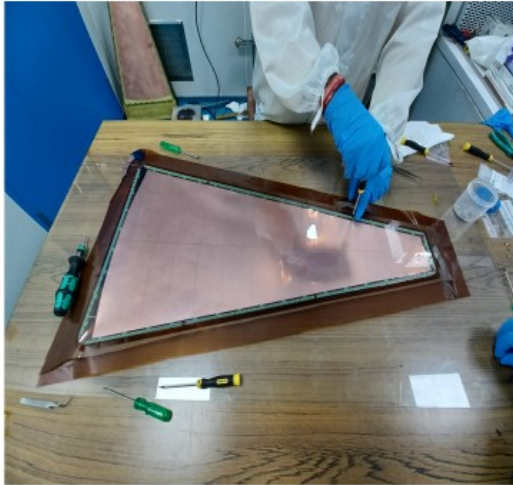
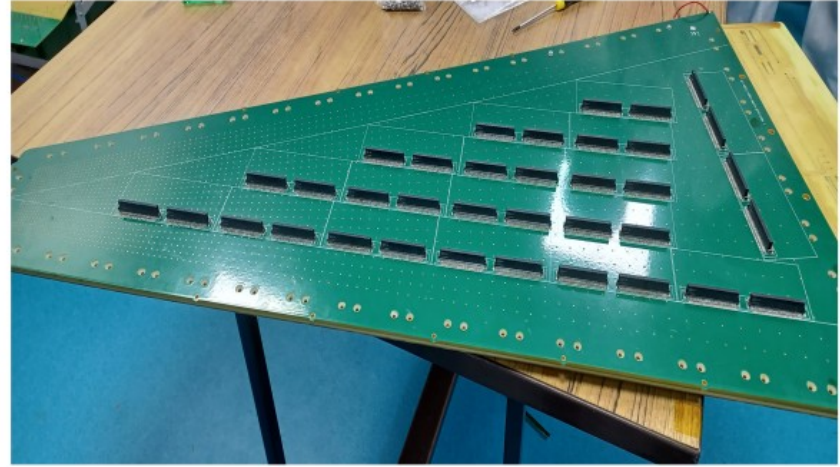


**2231 Pads 8-layer readout PCB  
With progressive pad geometry**



**18- Connector readout**

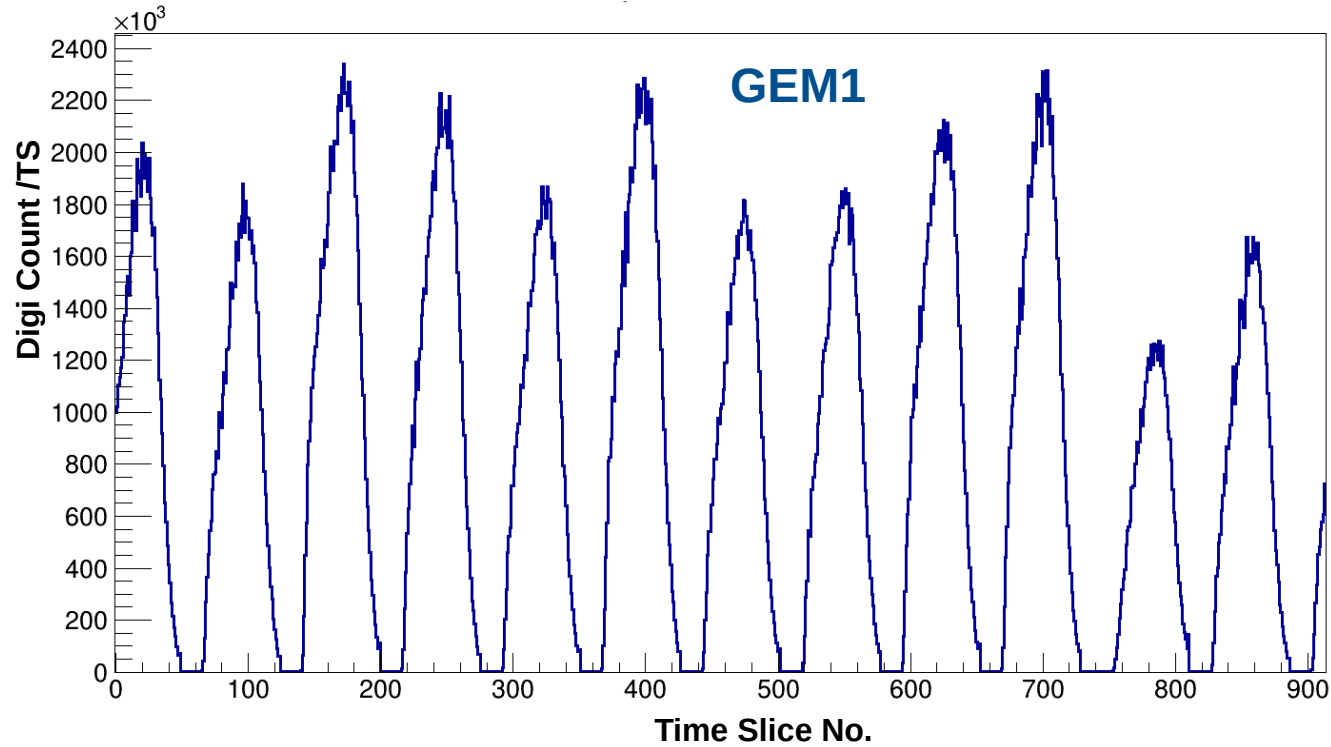
## First station module assembly at VECC



02/02/2026

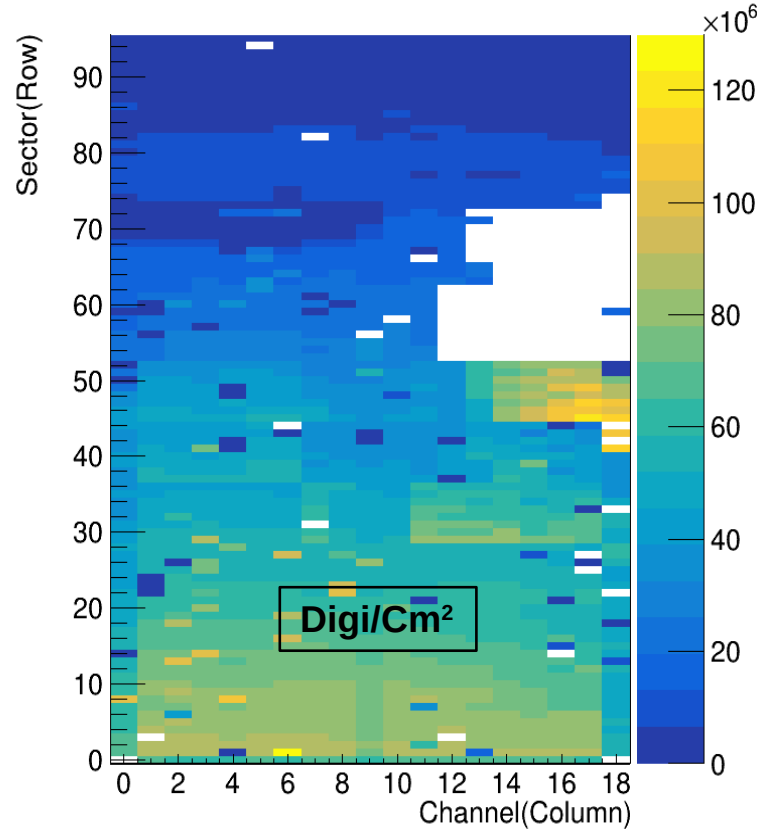
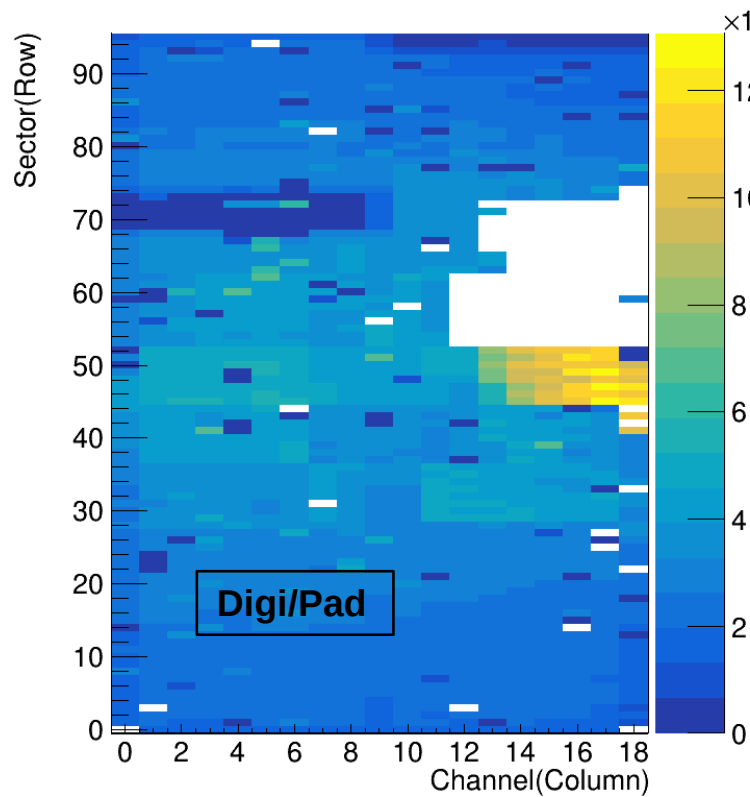
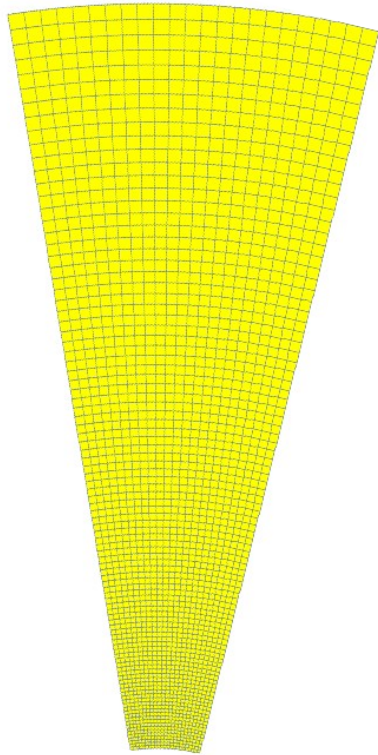
C. Ghosh, TIPP-2026, TIFR, Mumbai, India

# Spill Structure of GEM1 during a high intensity run

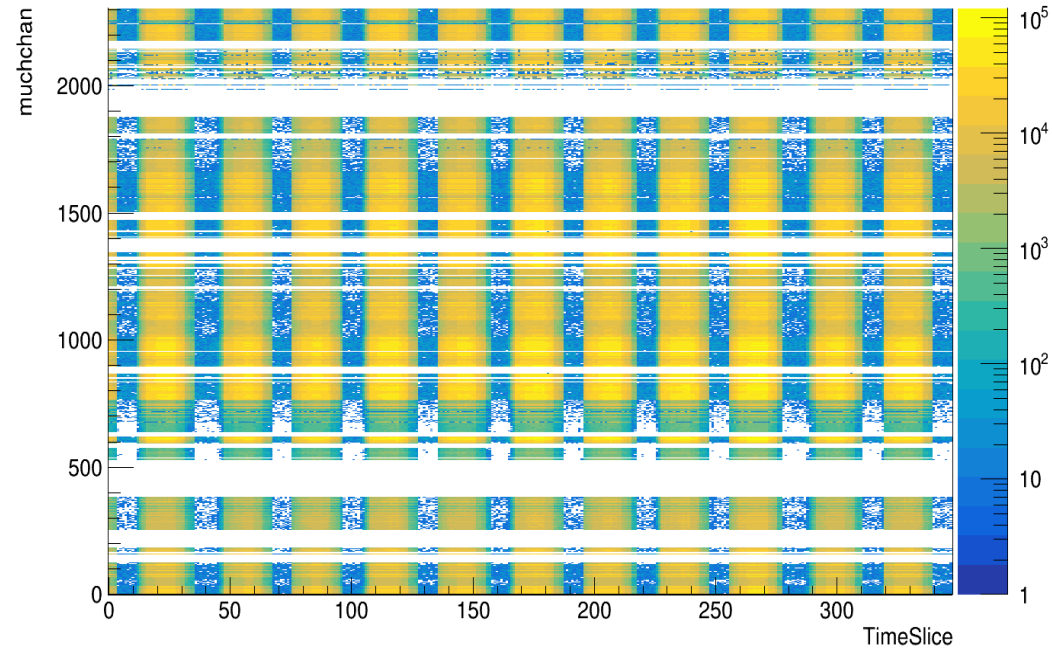


**Run: 3994**  
Gem1 HV= 4000 V  
I = 1509 uA  
Target= 2.5 mm Gold  
Beam Intensity=  $5 \times 10^8$  / Spill  
Time= 19:29:48  
Date: 17<sup>th</sup> May, 2025

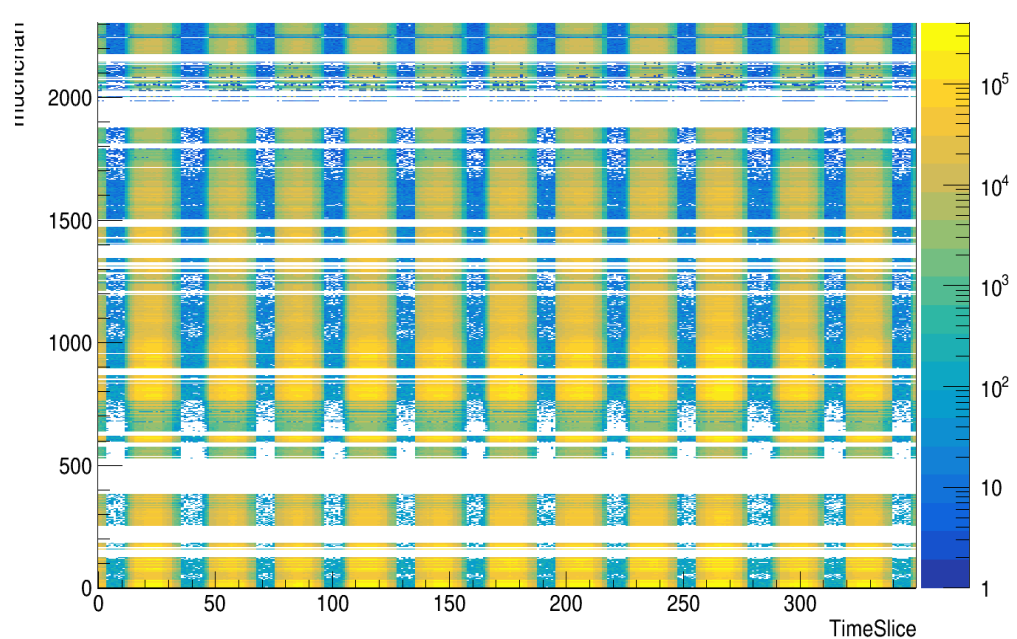
# Particle density on GEM1 during a high intensity run



# Achieved rates @ mCBM Bi + Au @1.1 A GeV, 13 MHz Event Rate

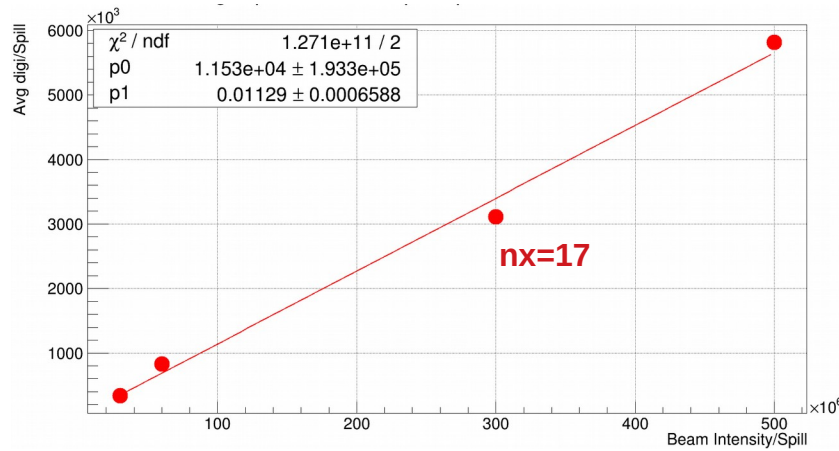
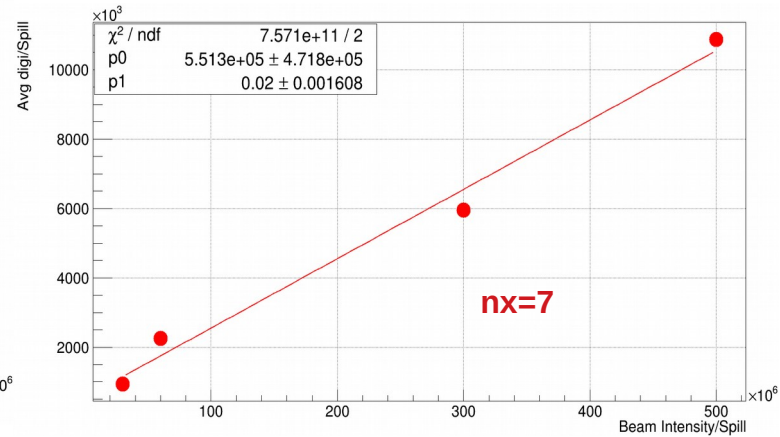
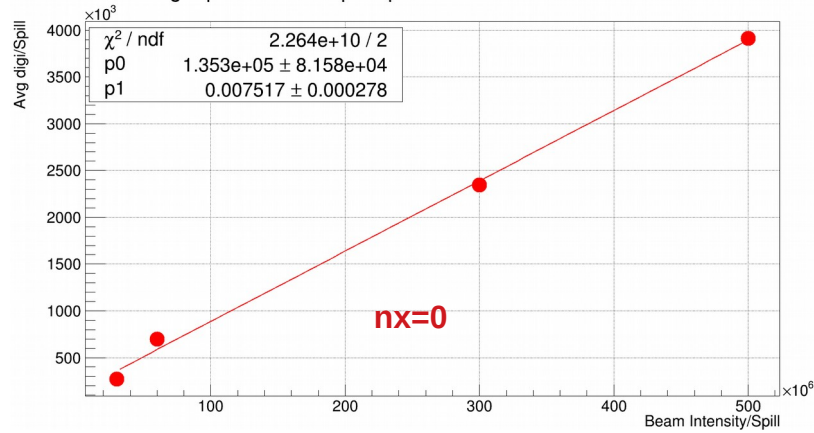
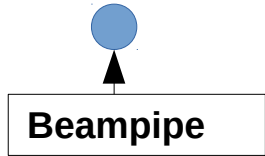
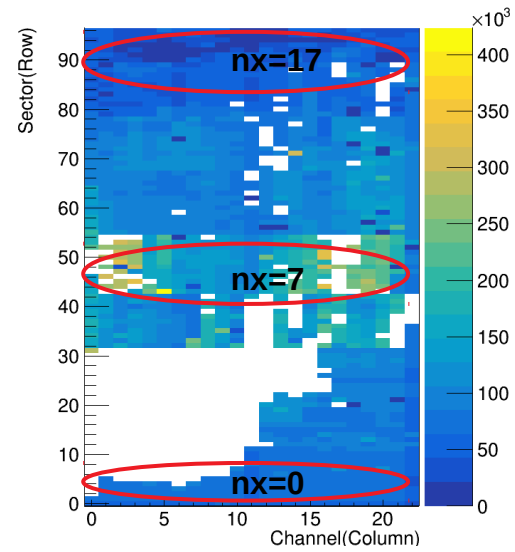


**Digi Rate ~ 100 kHz/Pad**



**Digi Rate ~400 kHz/cm<sup>2</sup>**

# Intensity Vs Digi of GEM1

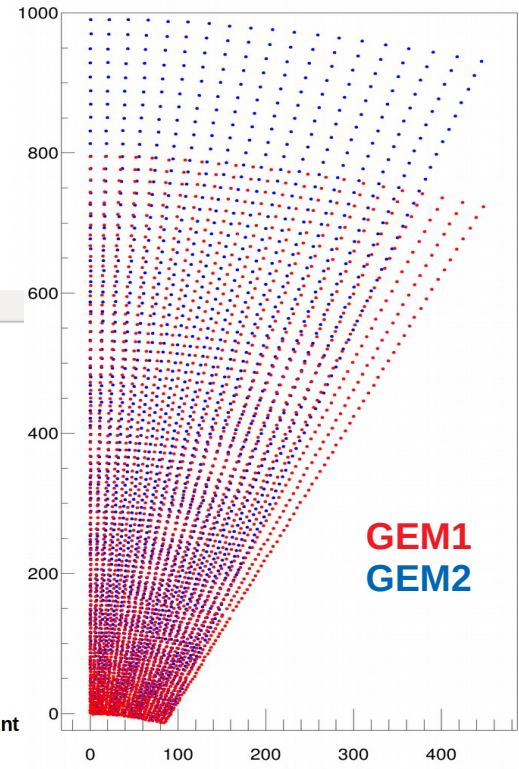
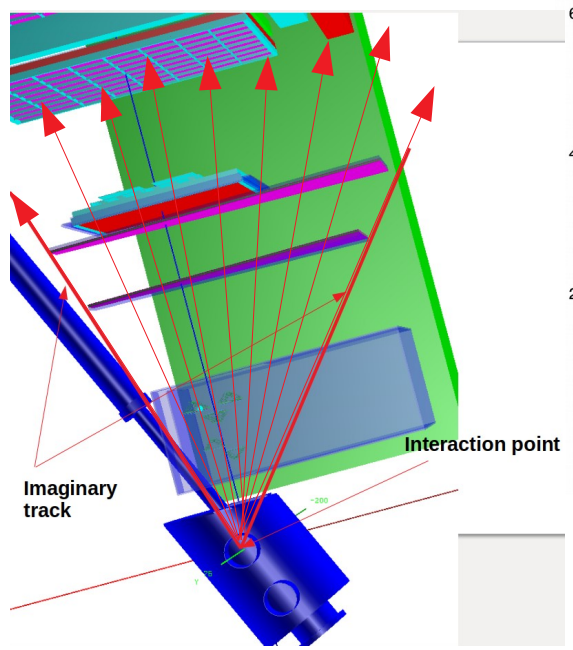
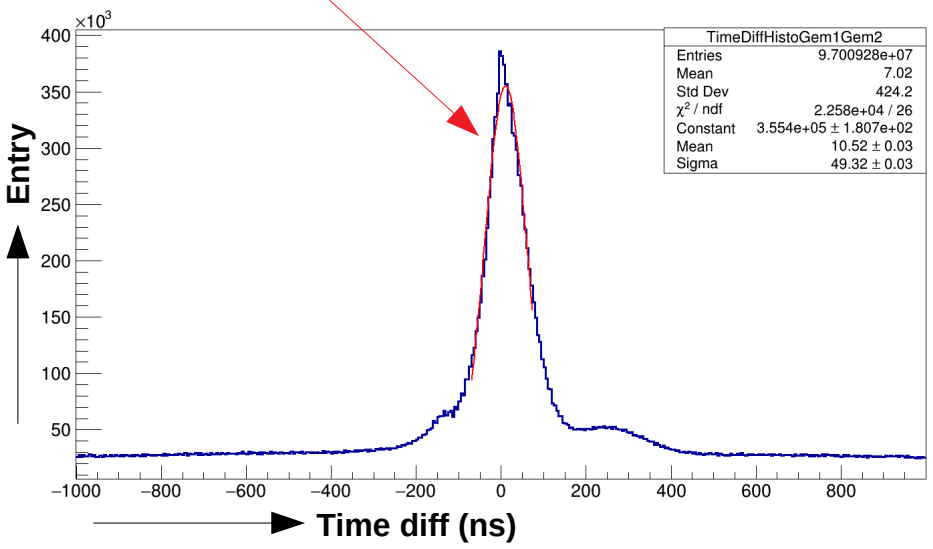
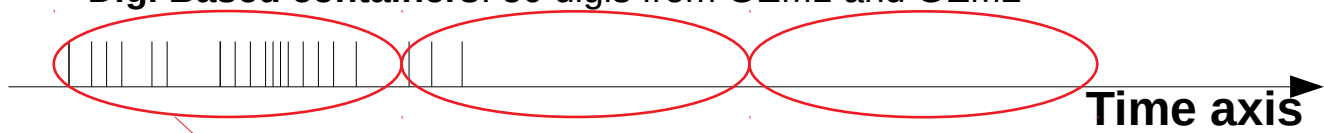


No. of digis increases linearly wrt beam intensity

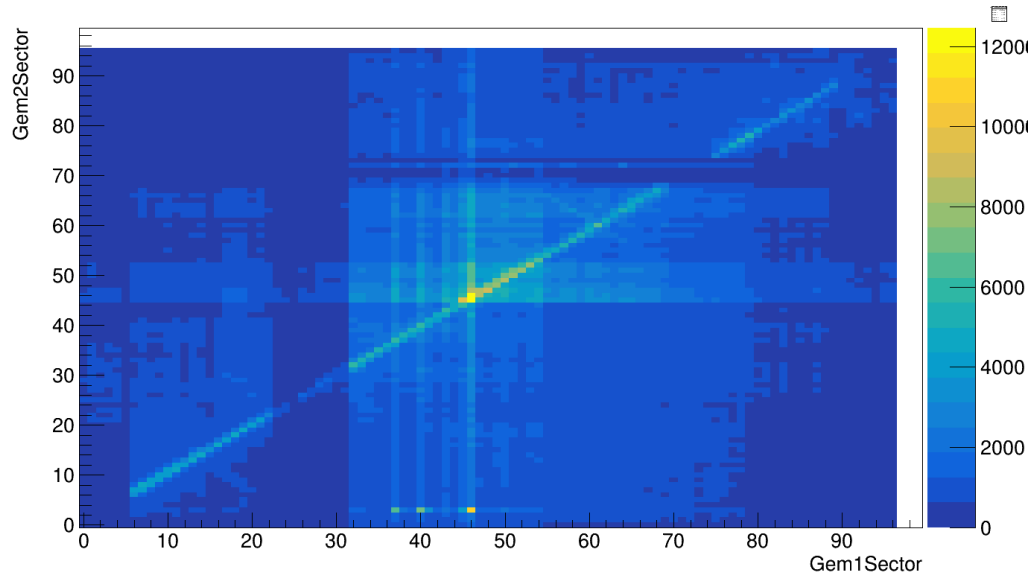
# XX and YY Correlation of GEM1 and GEM2

Run: 3887

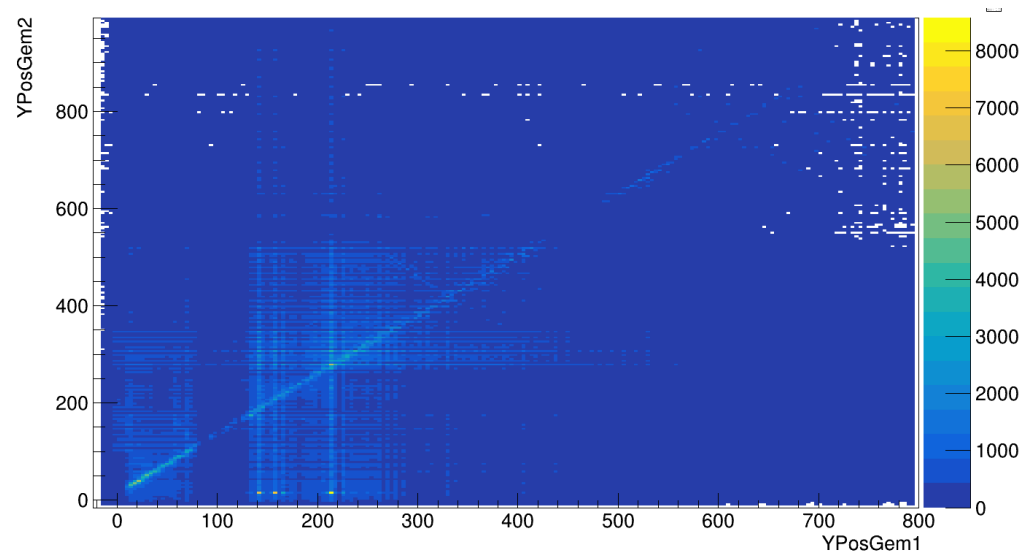
Digi Based containers: 50 digis from GEM1 and GEM2



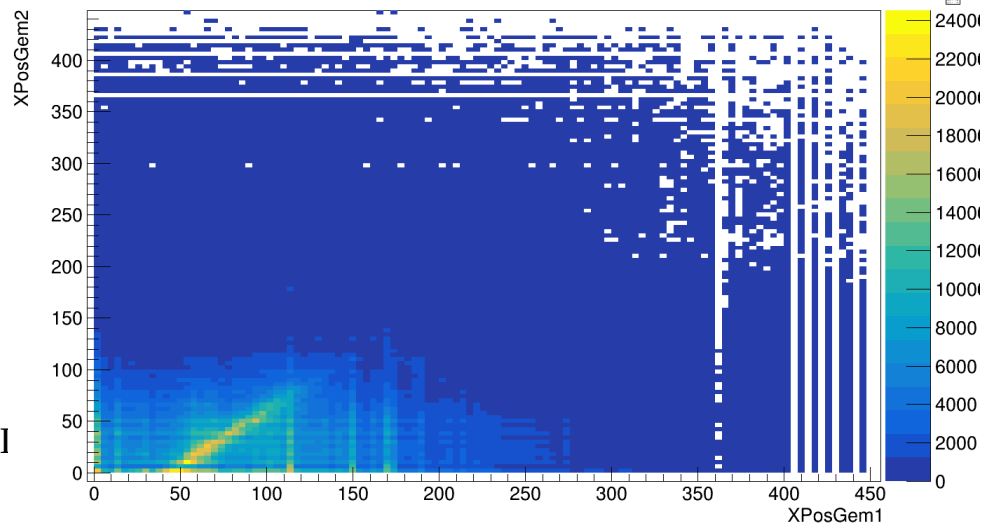
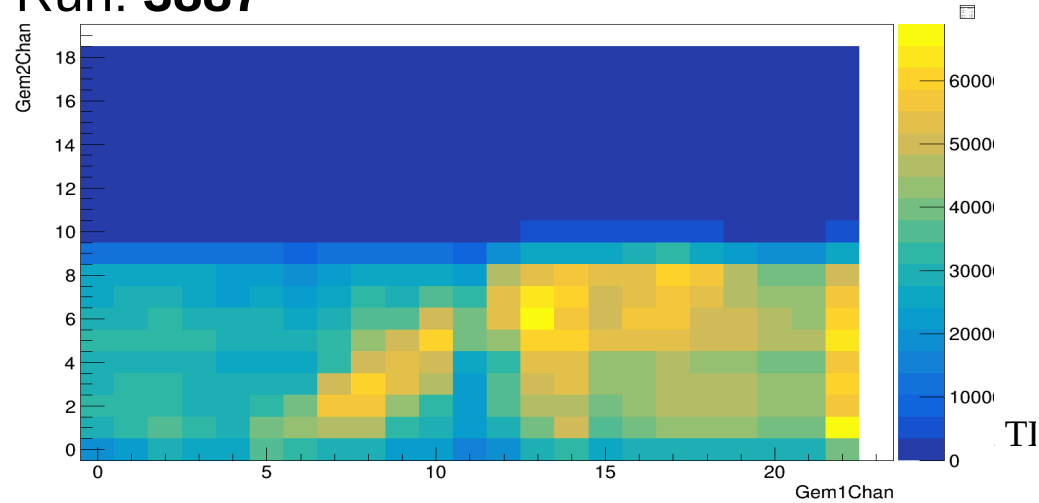
Gem1Gem2SectSectCorr



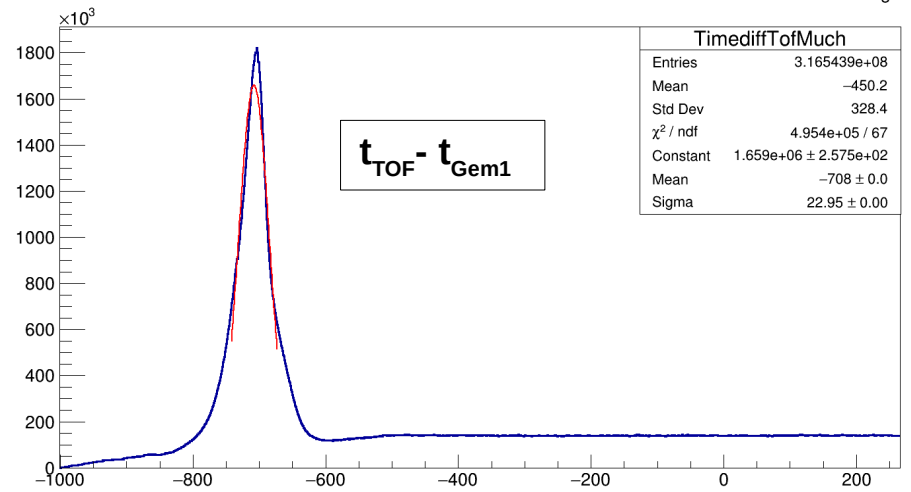
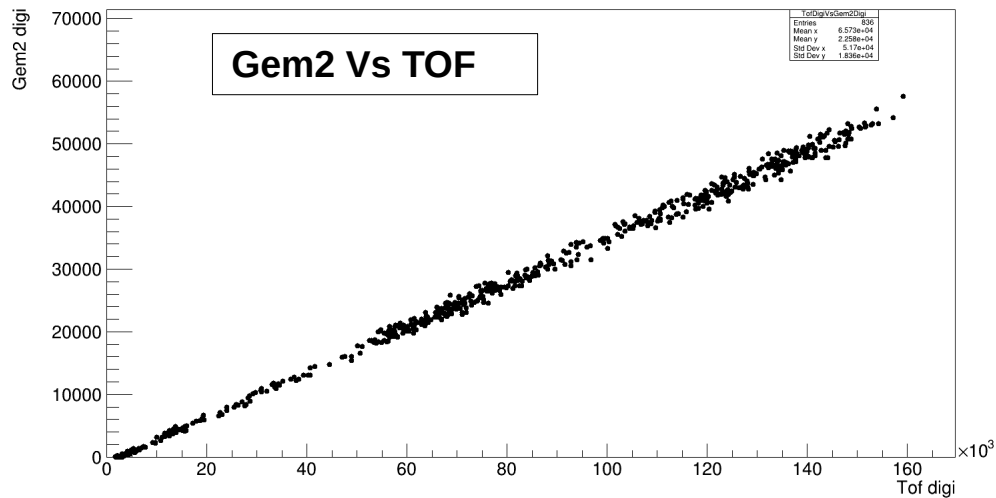
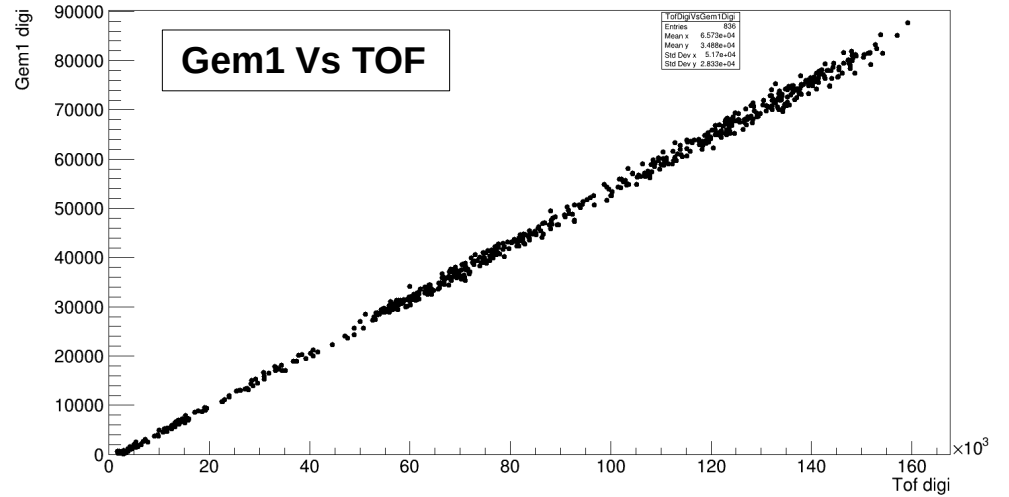
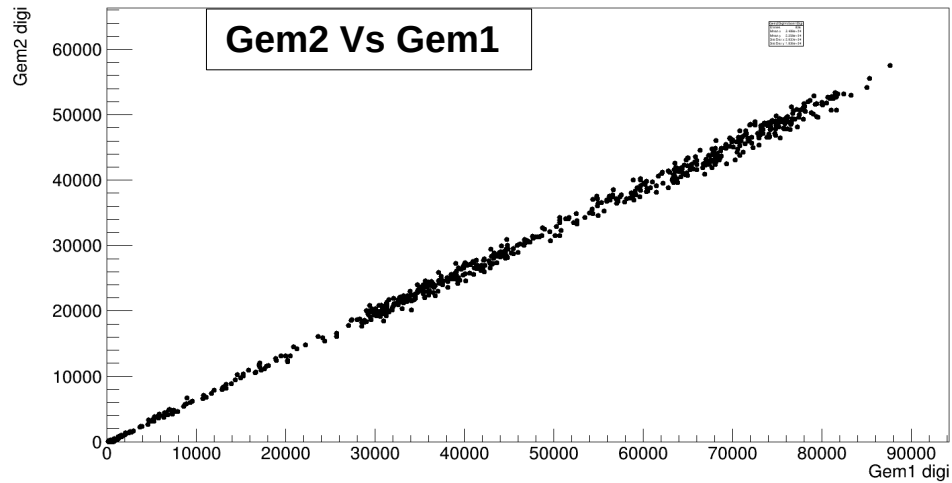
In mm scale

Run: **3887**

Gem1Gem2ChanChanCorr



# Digi and Time Correlation between MuCh and TOF



## Summary:

1. Two trapezoidal triple-GEM modules corresponding to MuCh Station-1 (GEM1) and Station-2 (GEM2) were operated in mCBM, 2025 May Beamtime.
2. Both GEM modules exhibit a linear response with respect to beam intensity up to  $5 \times 10^8$  particles per spill. This linear behaviour is consistently observed across the detector when analysed zone-wise, namely in the narrow, middle, and broad regions of the module.
3. Time correlation studies between MuCh and TOF, as well as between GEM1 and GEM2, reveal stable timing offsets.
4. Spatial correlation analyses show one-to-one correspondence between hits in GEM1 and GEM2, demonstrating correct geometrical alignment and common detector acceptance.
5. Digi/TS correlation between MuCh and TOF confirm that both GEM stations scale linearly with TOF.
6. Rate capability studies show that GEM1 and GEM2 handled particle fluxes of up to approximately 400 kHz/cm<sup>2</sup> and 300 kHz/cm<sup>2</sup>, respectively, with the highest rates observed at the narrow ends of the detectors facing the beam pipe.

## Outlook:

1. The fabrication, assembly, and QA procedures developed in VECC will help in series production of GEM detectors for the CBM MuCh system.
2. Development of MuCh Gas distribution system and Integration into Final MuCh Infrastructure.
3. Production of MuCh Electronics cooling plates along with MuCh support mechanics.
4. Production of MuCh Absorber blocks.
5. Integration of GEM hits into L1 tracking using mCBM data to enhance real-time tracking performance at high interaction rates.

**Thank you**