Test results (Preliminary) of Real size Station-1 MuCh modules in the nucleus-nucleus collisions at mini-CBM experiment at GSI

FOR CBM-MuCh COLLABORATION

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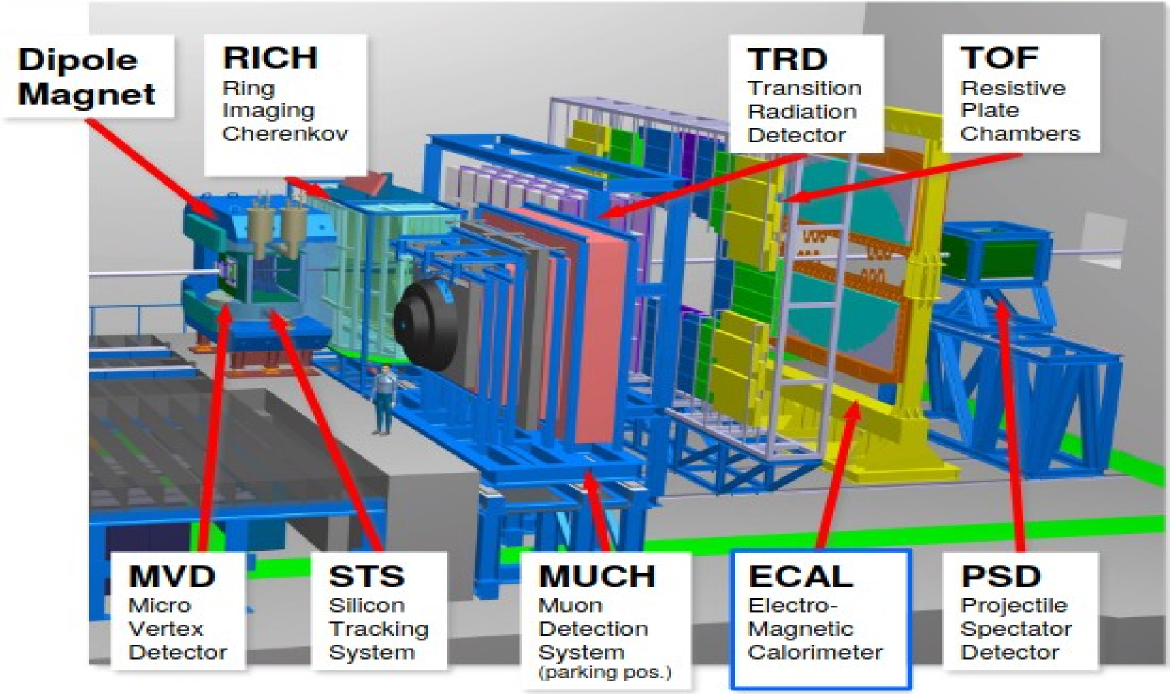
XXV DAE-BRNS HIGH ENERGY PHYSICS SYMPOSIUM AT IISER, MOHALI (12-16 DEC '22)

OUTLINE

- INTRODUCTION
  1) Compressed Baryonic Matter (CBM) Experiment
  2) Basics of Gaseous Electron Multiplier (GEM) Detectors
  3) Detector Construction for CBM
  4) miniCBM (mCBM) Experiment
- ABOUT mCBM 2022 CAMPAIGN
- PRELIMINARY TEST RESULTS FROM mCBM 2022
- SUMMARY AND OUTLOOK

PROPOSED CBM SIS-100 EXPERIMENT

- **Fixed Target Experiment**
- **Beam Energy: $\sqrt{s_{NN}}$ = 2.9–4.9 AGeV**
- **Baryon Chemical potential(μ_B): ~540–800 MeV**
- **Highest Intensity: ~10 MHz**



PHYSICS AT CBM

- **Aims to study EoS of strongly interacting QCD matter dominated by baryons.**
- **Search for First-order phase boundary, QCD Critical point, Chiral symmetry restoration, hypernuclear interactions etc.**
- **Unprecedented Rates will allow to study several rare probes for the first time in this energy range like multistrange (anti-)particles, dileptons, hypernuclei etc.**

GEM Detector

- The “standard” GEM foil consists of **50 μm** thin dielectric polymer (polyimide), **5 μm thick metal (copper)** layers are coated on both side of it
- Regular holes of **diameter 70 μm** with a **pitch** of **140 μm** is created using photo-lithographic technique
- Potential difference between of **500 V** (say) applied on the electrodes – High 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 holes

- The amplified electrons gives signal on the readout electrode

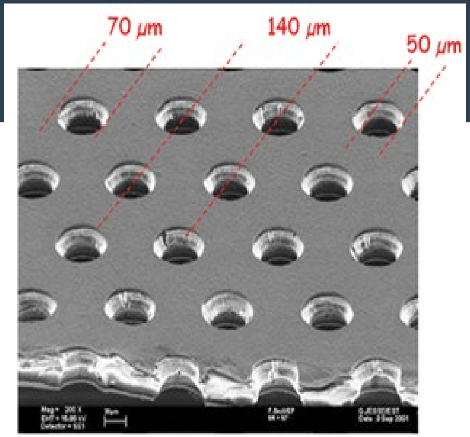
Advantages of GEM

– High rate capability

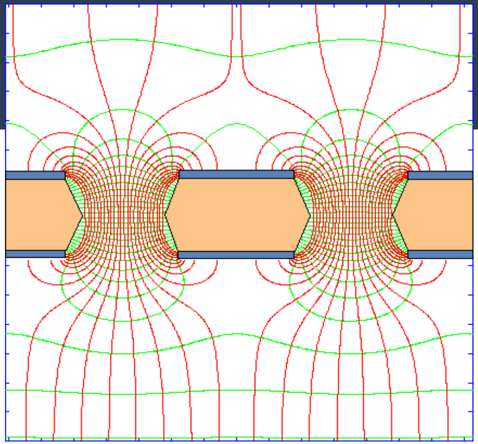
– High gas gain

– Low discharge probability

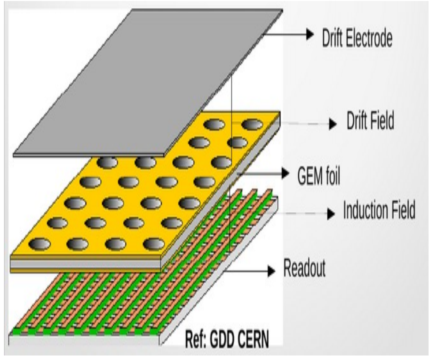
– Good spatial resolution



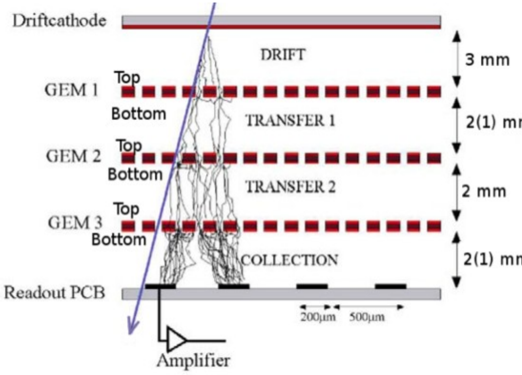
GEM FOIL



Electric Field Lines

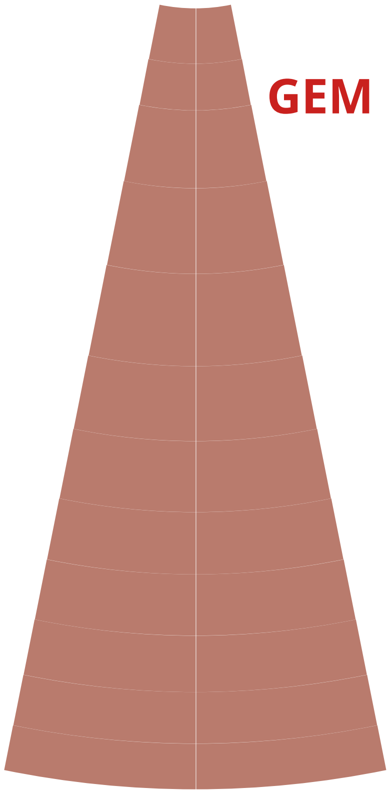


Single GEM



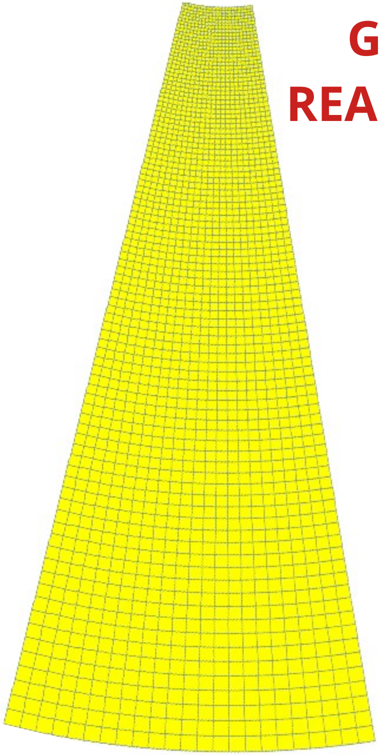
Triple GEM

COMPONENTS OF LARGE SIZE GEM MODULE FOR STATION 1 DEVELOPED AT VECC



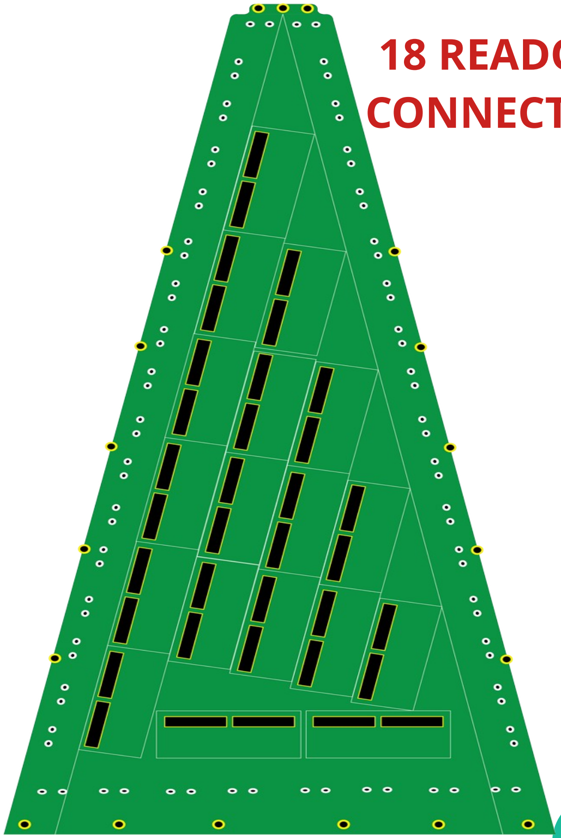
GEM FOIL

12 Segments on two sides



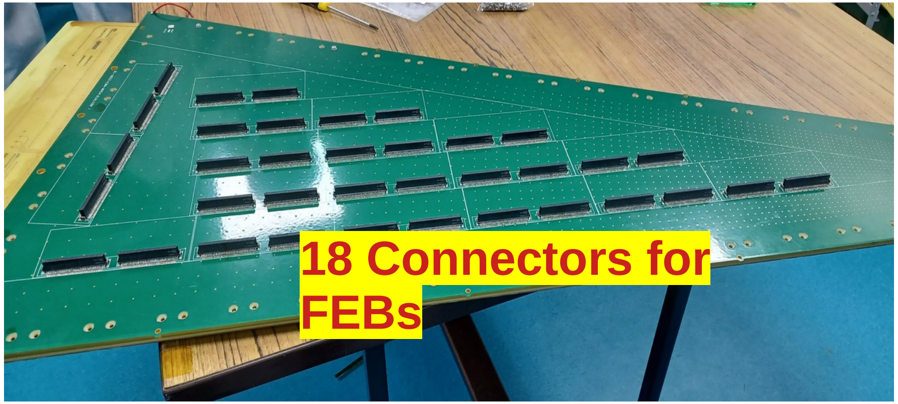
GEM READOUT

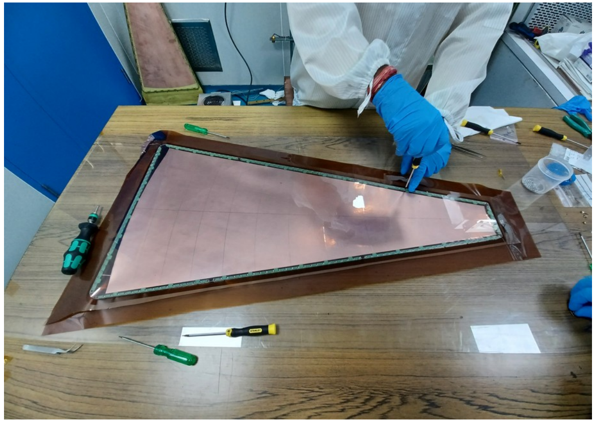
23 X 97 Pads



18 READOUT CONNECTORS

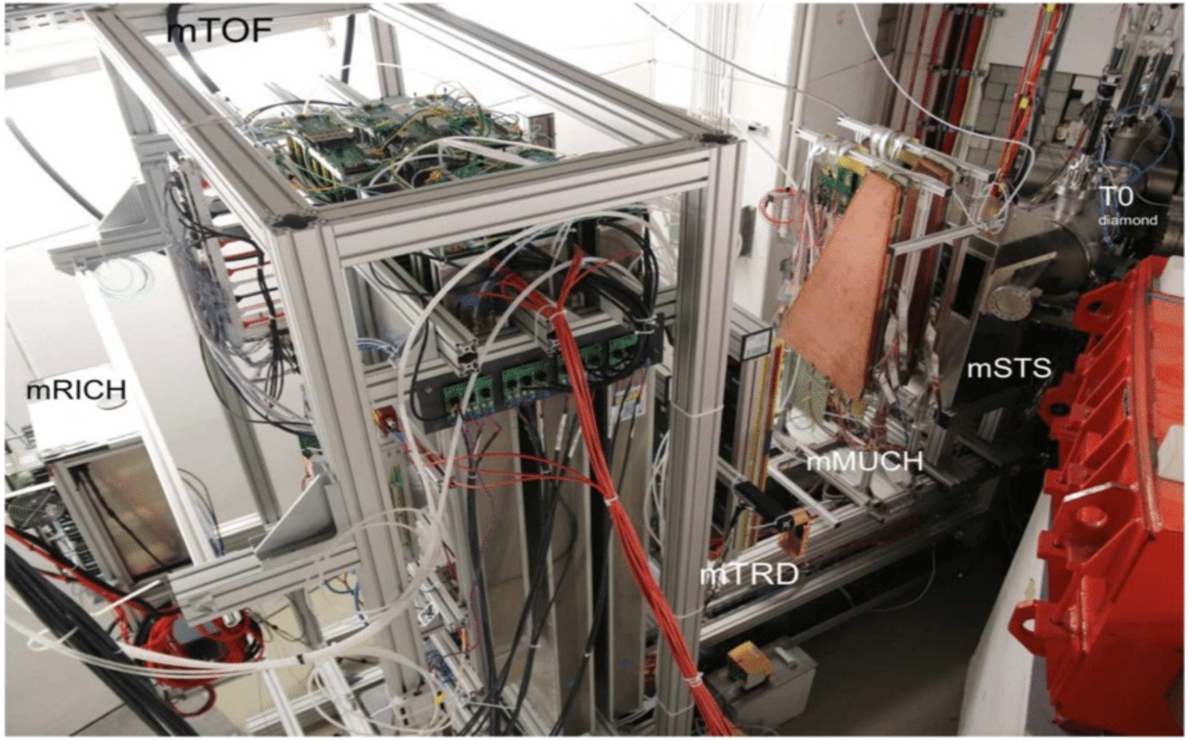
GEM MODULE ASSEMBLY WITH UPGRADED PCB at VECC





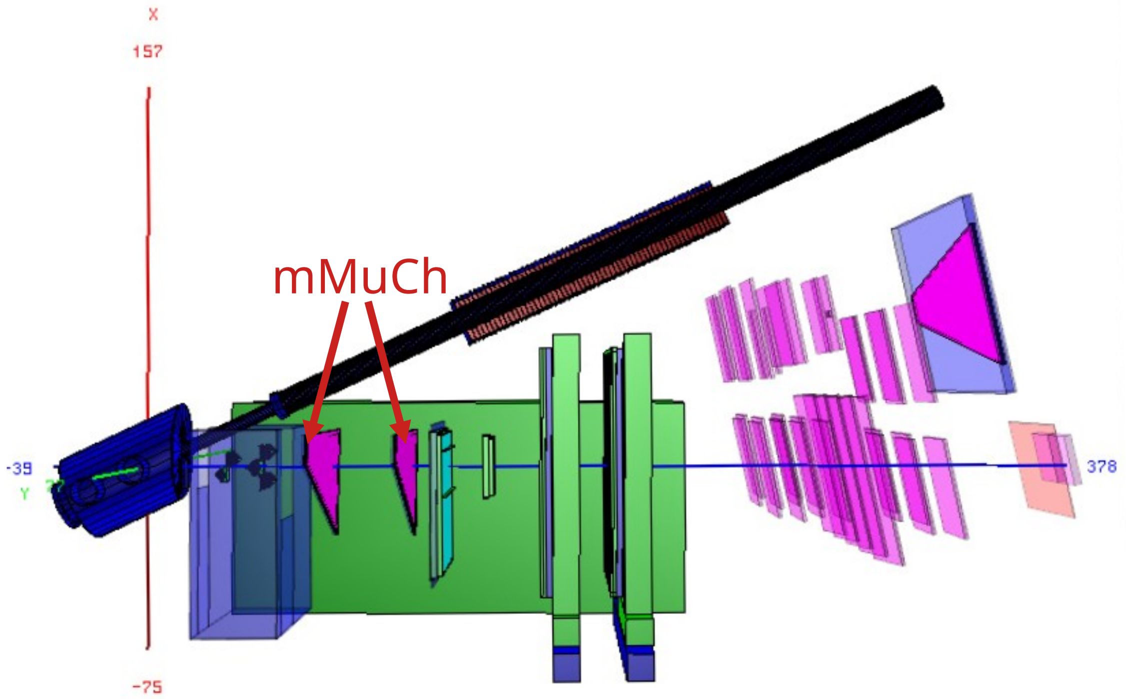
mCBM EXPERIMENT AT SIS-18 AT GSI, GERMANY

- **Facilitates testing for all CBM detector prototypes together.**
- **Development of hardware and software capabilities for high rate trigerless data acquisition and analysis.**



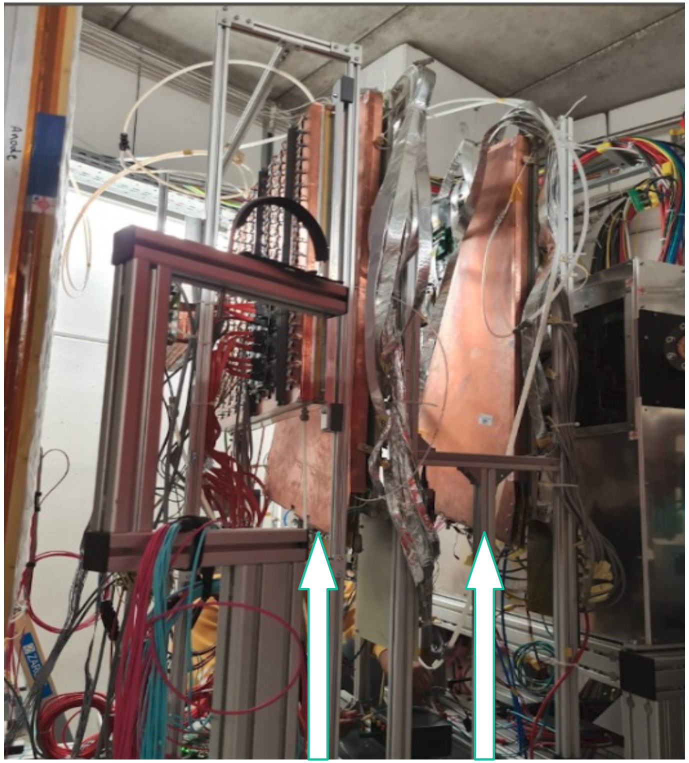
mCBM CAMPAIGN OF 2022

- U-Au at T = 1.0 AGeV, Ni- (Au & Ni) at T = 1.23 AGeV.
- Highest Rates achieved : 10^9 ions per spill (~10s).
- Upgraded MuCh Station 1 modules (with opto-couplers in staggered arrangement) tested with CRI based DAQ for the first time.

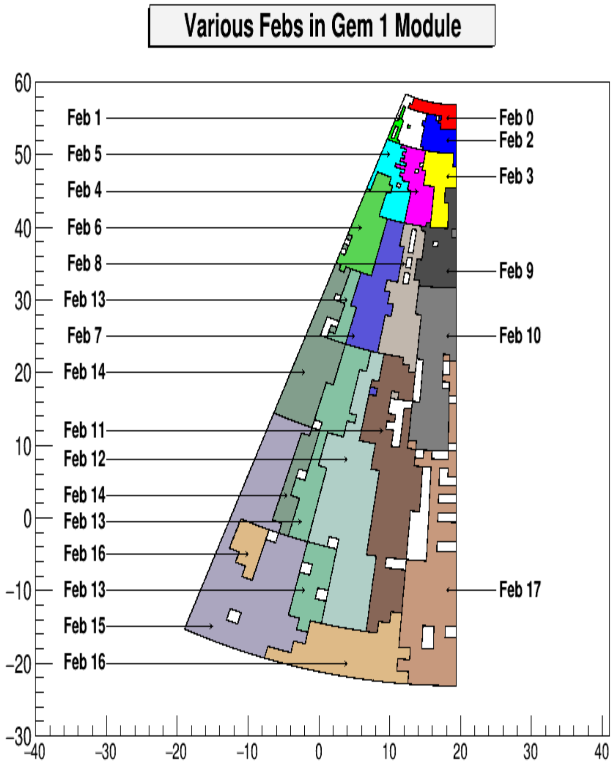


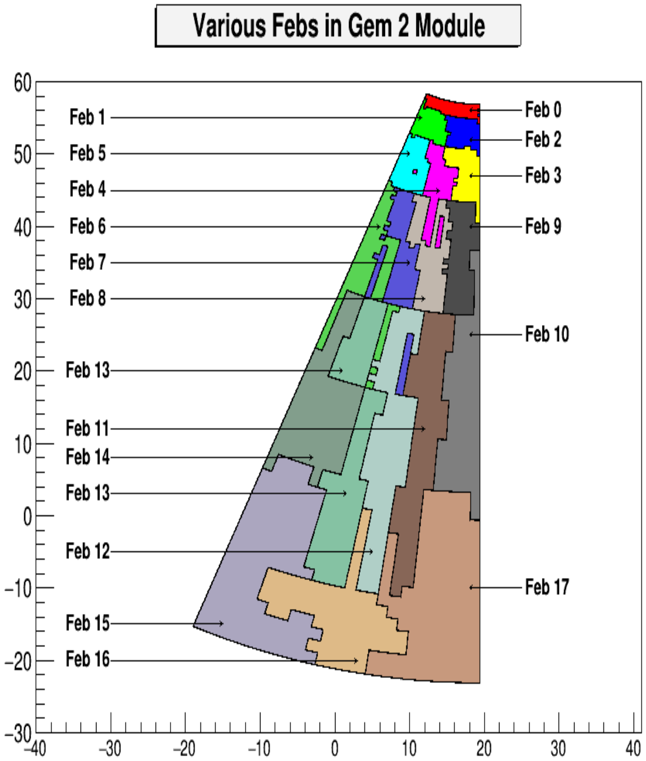
Geometry for U-Au Run

mCBM 2022 March-April BeamTime



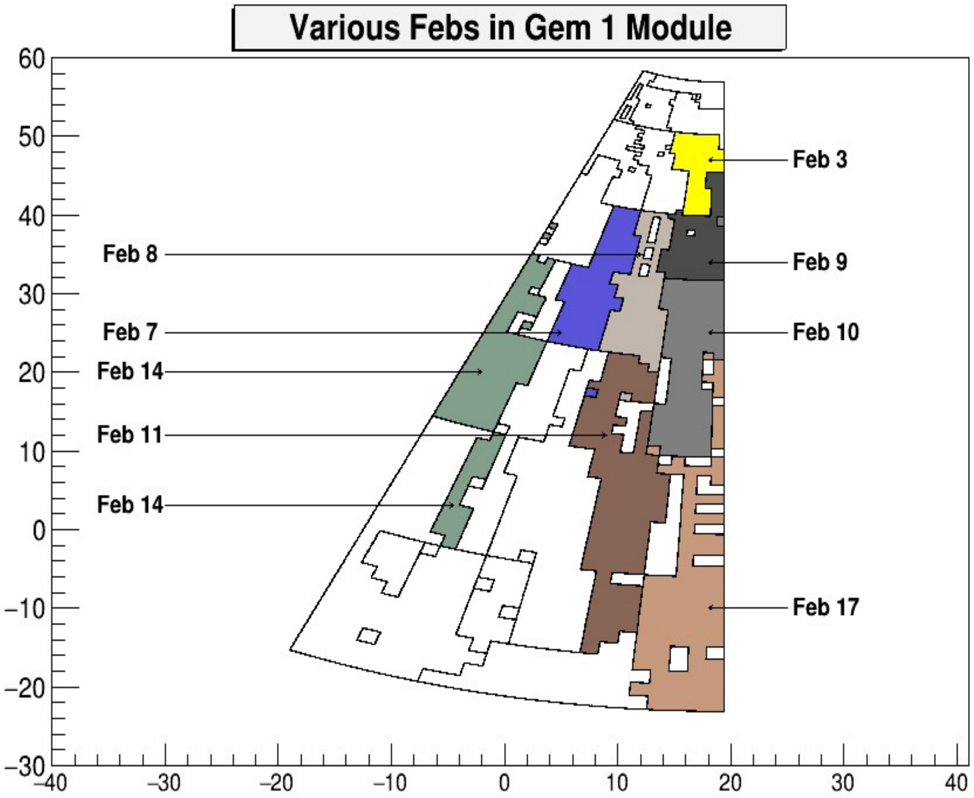
Gem2 Gem1



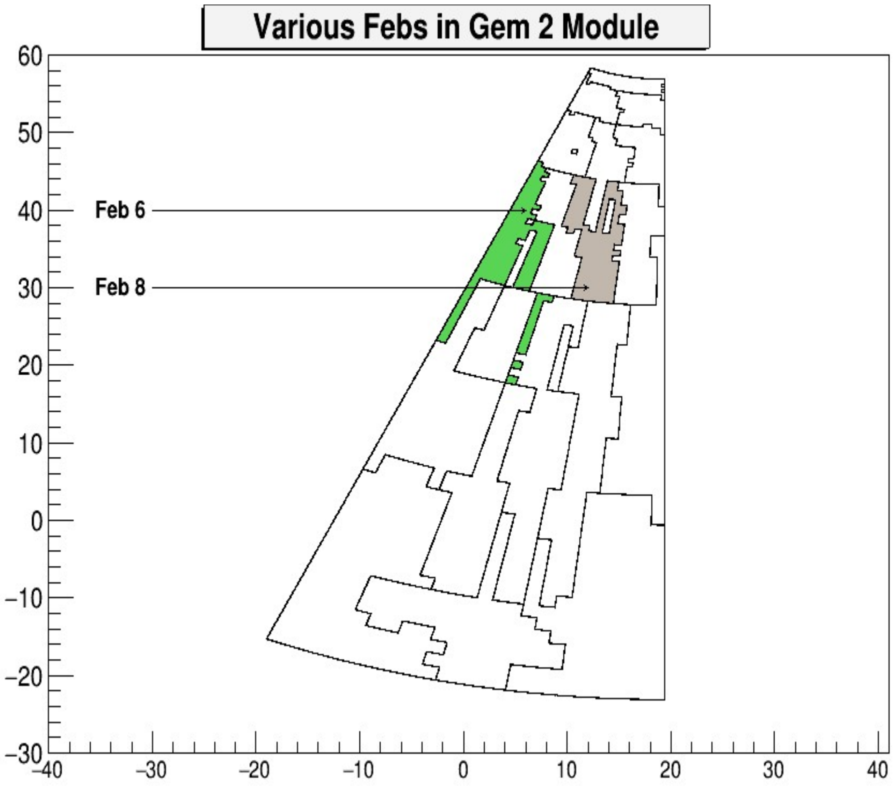


FEB Layout at mCBM for GEM 1 and GEM 2

WORKING FEBs IN MARCH-APRIL RUNS



8/12 Febs operational



2/5 Febs operational

PRELIMINARY DATA ANALYSIS RESULTS FROM MARCH-APRIL 2022

U-Au(2.5 mm target) @ T=1.0 AGeV AT mCBM 2022

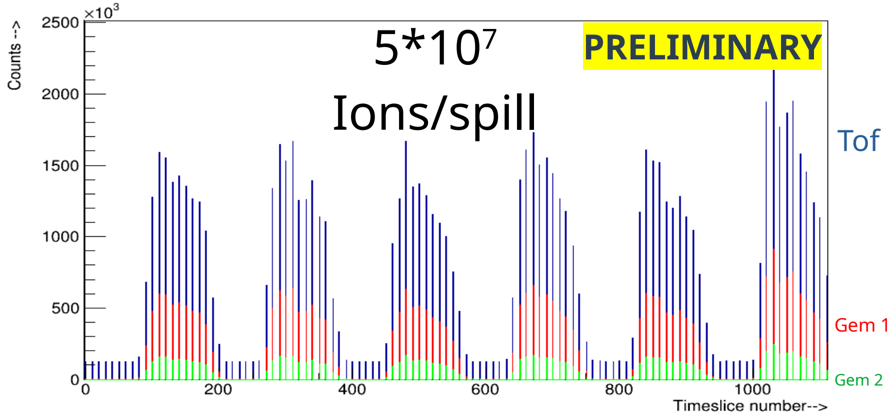
Voltage (Gem 1, Gem 2) --> / Intensity (ions/spill)	4600, 4218	4650, 4266	4700, 4312	4750, 4359	4800, 4402	4850, 4447	4900, 4496	4950, 4543
10^7		Yes	Yes	Yes	Yes	Yes	Yes	Yes
$5* 10^7$					Yes			
10^8			Yes	Yes	Yes	Yes	Yes	Yes
$5*10^8$					Yes			
10^9	Yes	Yes	Yes	Yes	Yes	Yes		

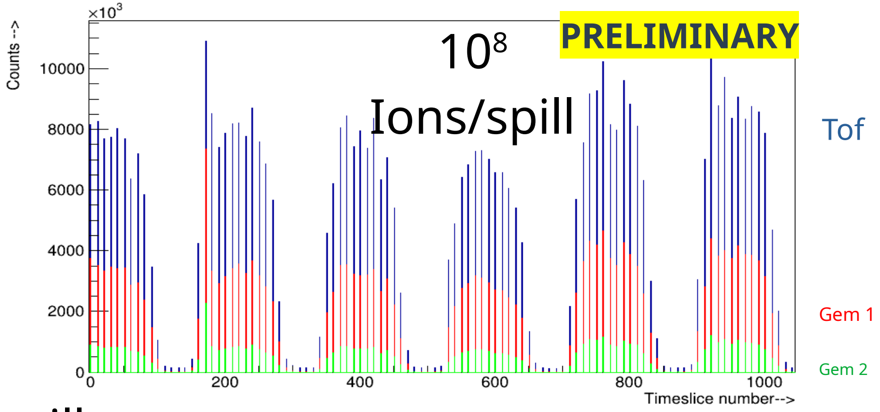
***Analysed in RED**

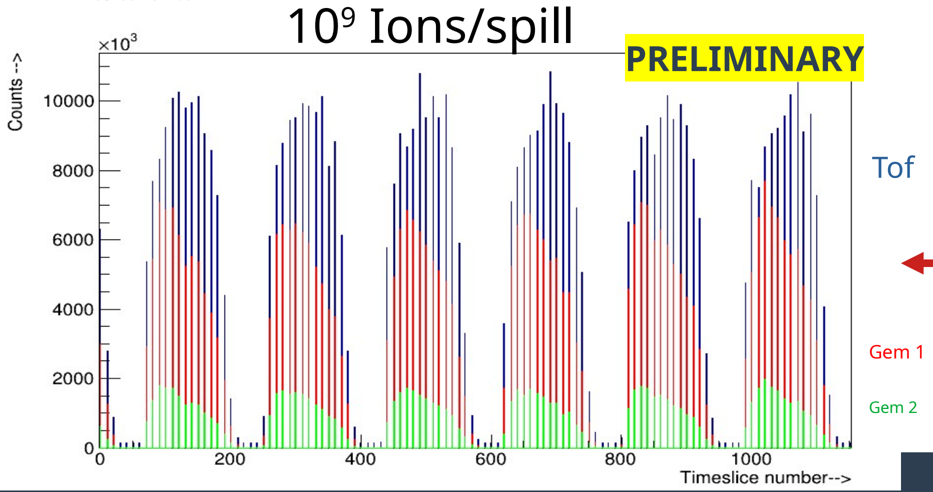
LIST OF ANALYSED RUNS FOR U-Au DATA

Run Number	Intensity (ions/spill)	Timeslice length (ms)	Downscaling	Gem 1 Voltage (V)	Gem 2 Voltage (V)
2254	10^7	64.0	10	4800	4402
2256	$5*10^7$	64.0	10	4800	4402
2257	10^8	64.0	10	4800	4402
2258	$5*10^8$	64.0	10	4800	4402
2262	10^9	64.0	10	4800	4402

SPILLSTRUCTURES FOR SOME RUNS



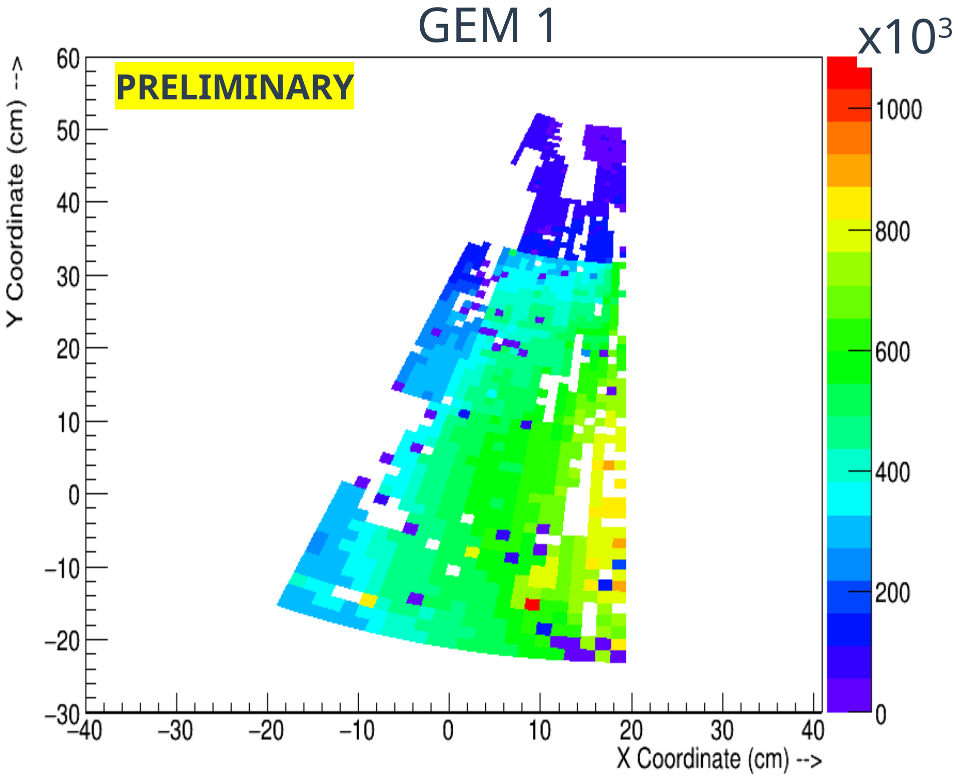


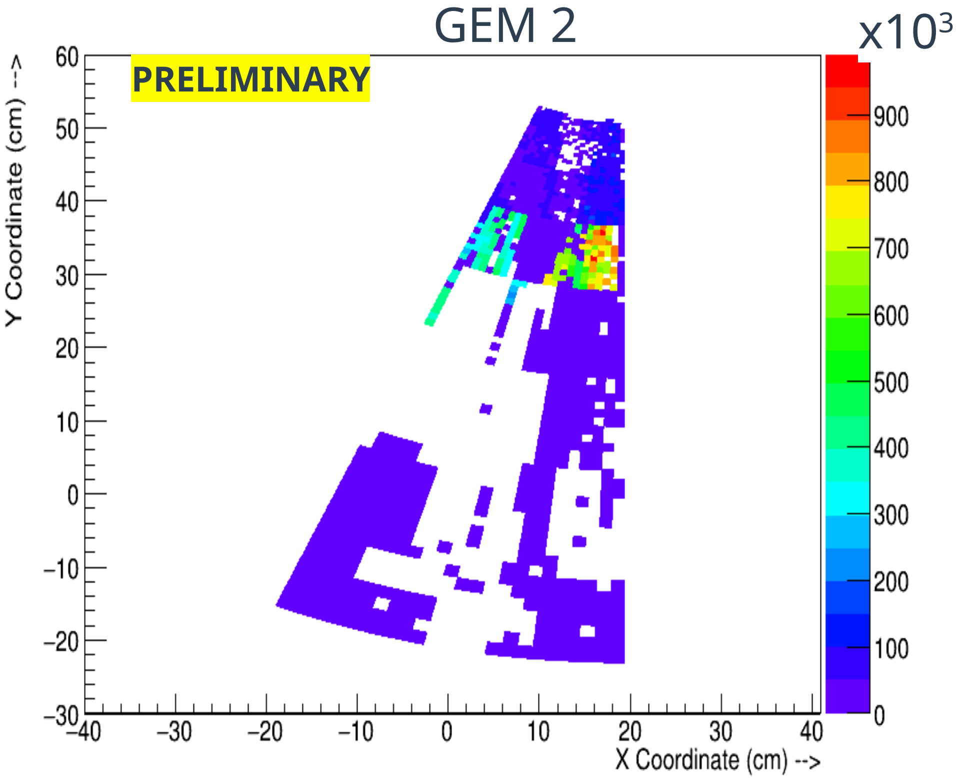


This is the highest intensity for which MuCh has ever been been tested

PADWISE HIT DISTRIBUTIONS (HIGHEST INTENSITY)

(U-Au @ T= 1.0 AGeV Runs)

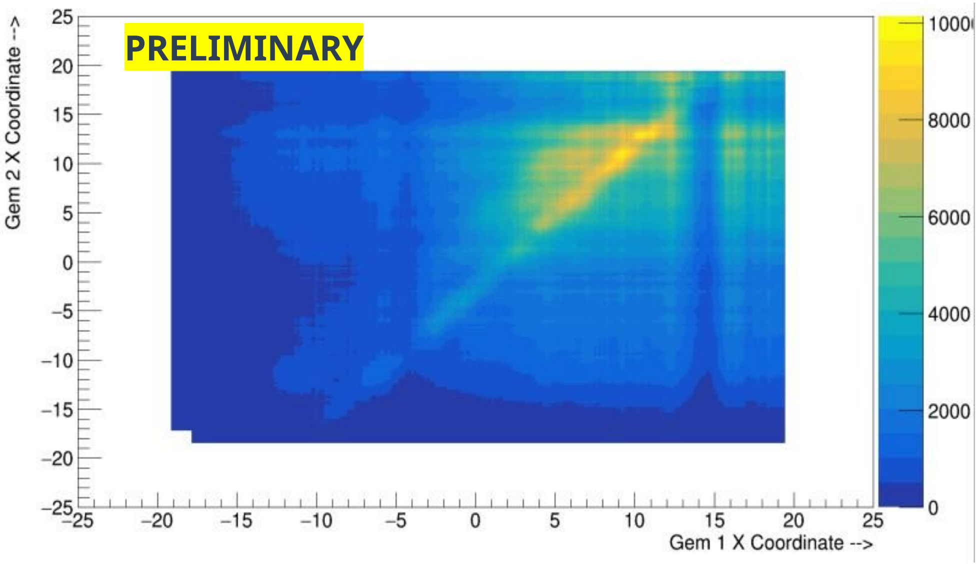




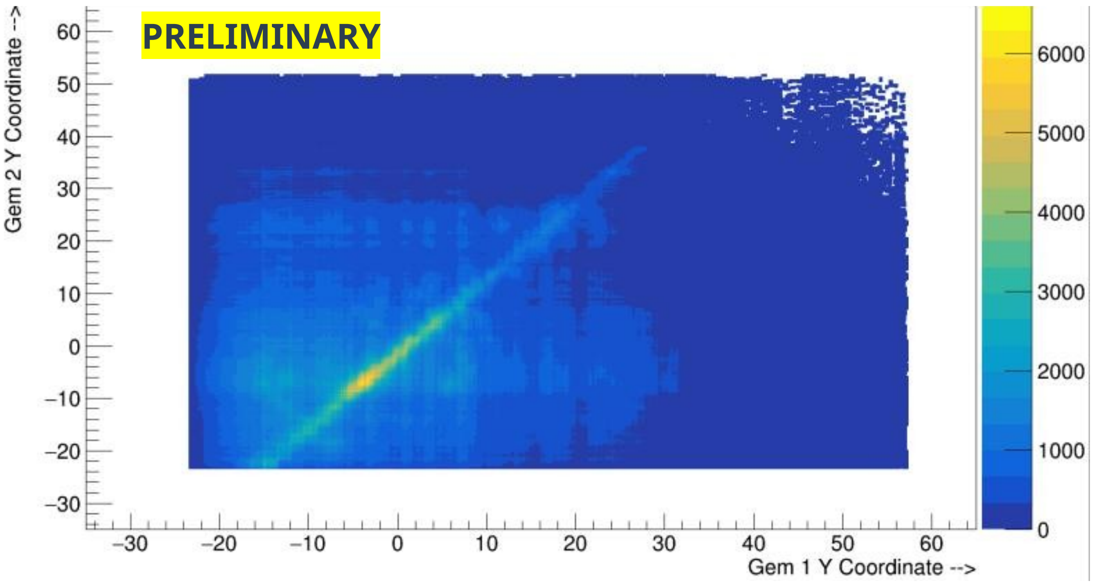
SPATIAL CORRELATION GEM 1 vs. GEM 2 (10^7 Ions/spill)

(U-Au @ T= 1.0 AGeV Runs) (Time Window : 500 ns)

X-X Correlation



Y-Y Correlation

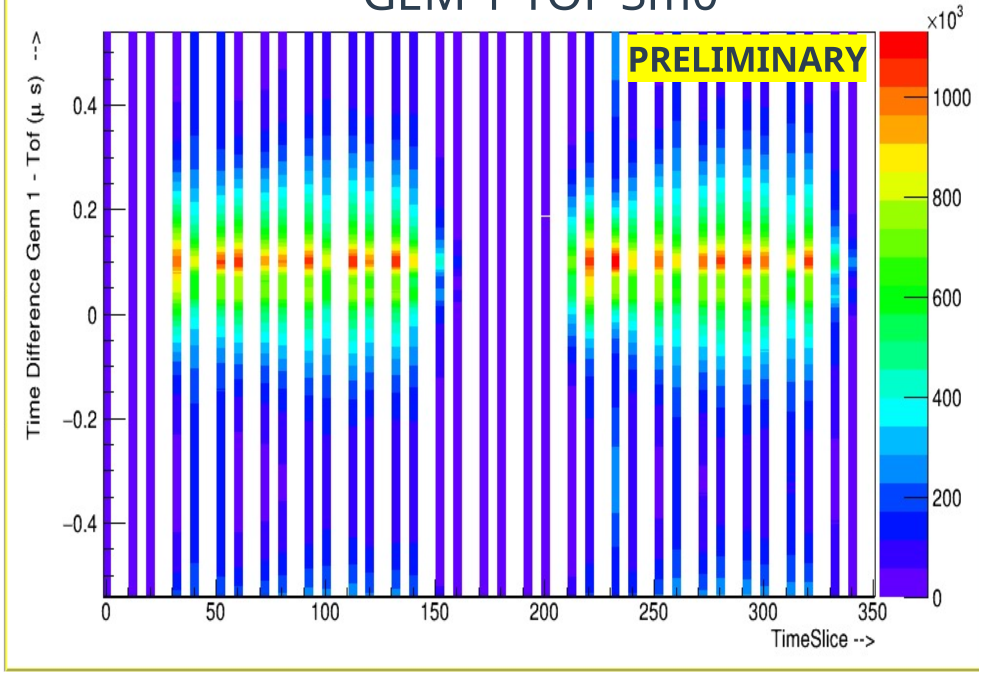


OVERLAPPING ACCEPTANCE IN YELLOW

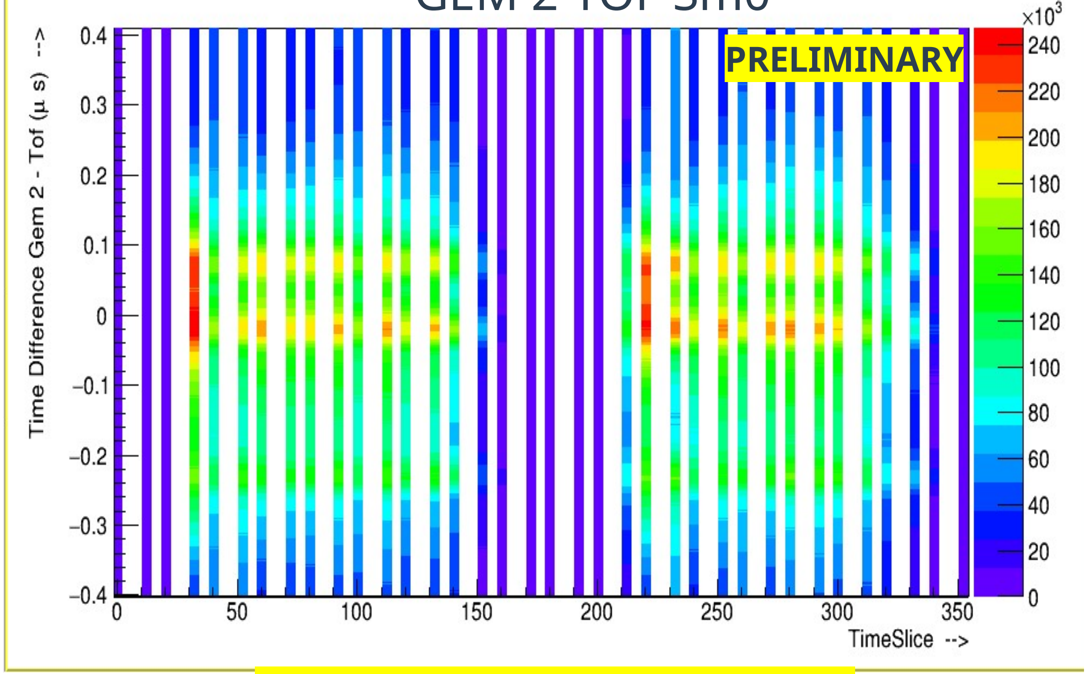
TIMECORRELATIONS FOR HIGHEST INTENSITY

(U-Au @ T= 1.0 AGeV Runs)

GEM 1-TOF Sm0



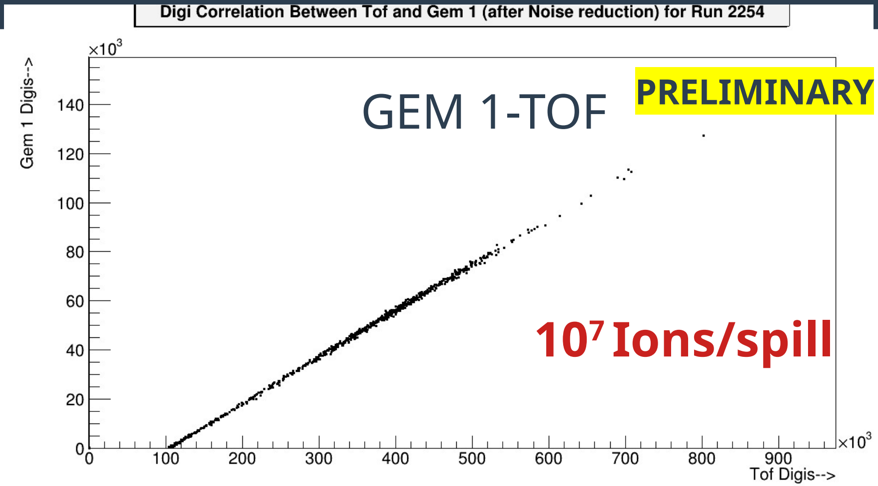
GEM 2-TOF Sm0

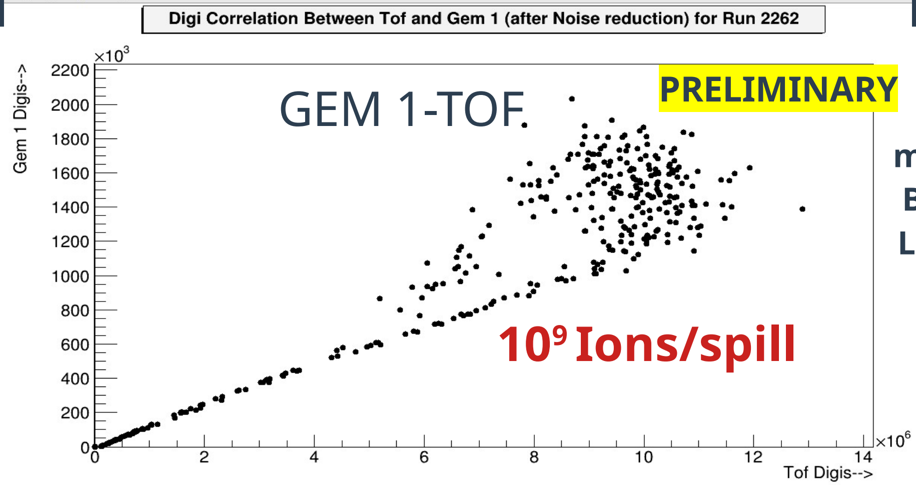


Individual FEB correlations visible as bands

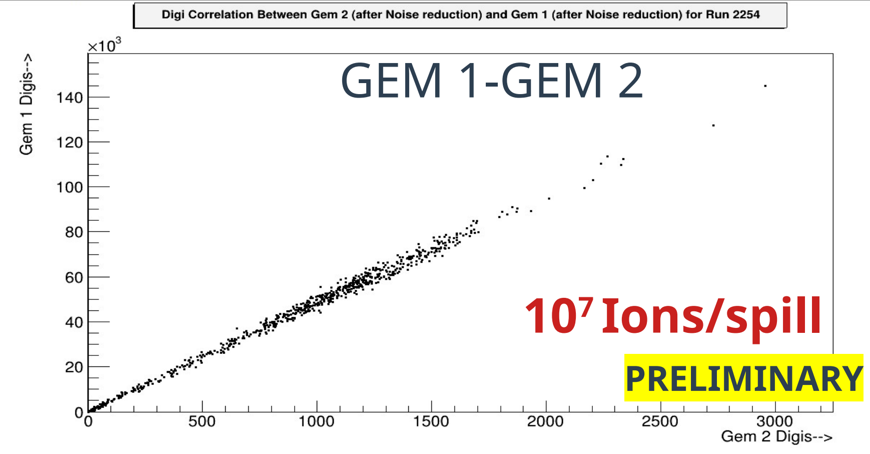
DIGI CORRELATION (LOWEST AND HIGHEST INTENSITY)

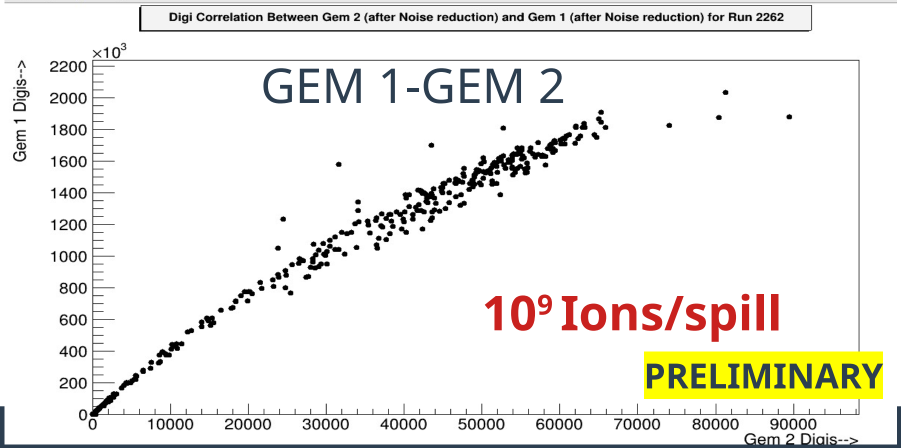
(U-Au @ T= 1.0 AGeV Runs)





mTOF faces Bandwidth Limitations





STUDY OF INTENSITY RESPONSE OF GEM

OUR GOAL IS TO STUDY THE INTENSITY RESPONSE OF GEM

WE ACHIEVE THIS BY STUDYING:

- **Mean number of digis in runs of different intensities**
- **Mean number of hits in runs of different intensities**

RoadMap to Study Intensity response using mean number of Digis in a Timeslice

Step 1:
Identify Runs with identical configurations

→

Step 2:
Find Noisy Pads and uncallibrated Febs

→

Step 3:
Make a pool of noisy channels from all Runs

↓

Step 4:
Mask the union of all noisy/buggy pads and mask them

←

Step 5:
Plot 1D Histogram for number of digis per TS. Fit the plot to find mean and error. Subtract any remanant Noise.

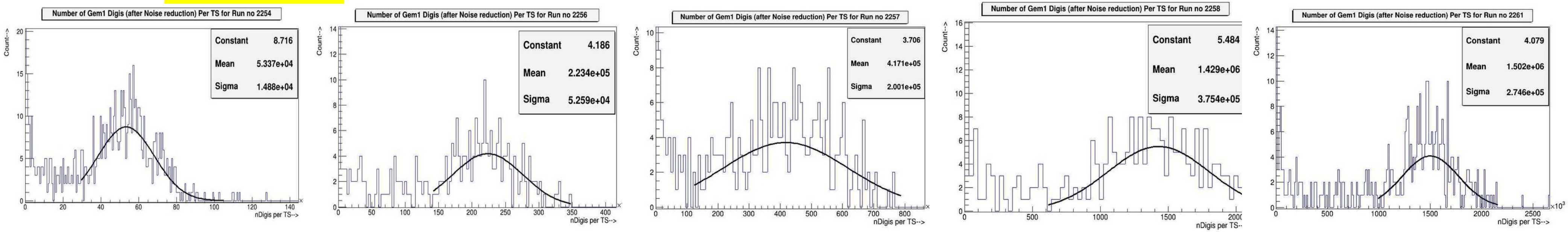
←

Step 6:
Plot Mean of nDigis vs. Beam intensity and study response

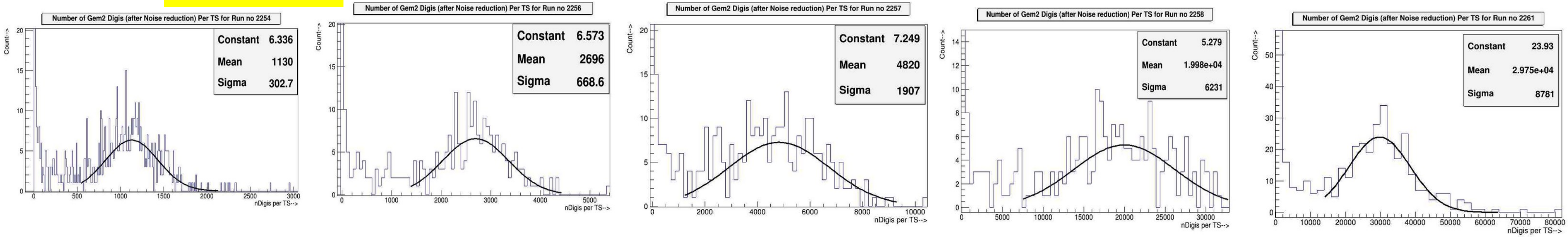
nDIGIS PER TIMESLICE (64ms) FOR ALL INTENSITIES

(U-Au @ T= 1.0 AGeV Runs)

GEM 1 **PRELIMINARY**



GEM 2 **PRELIMINARY**



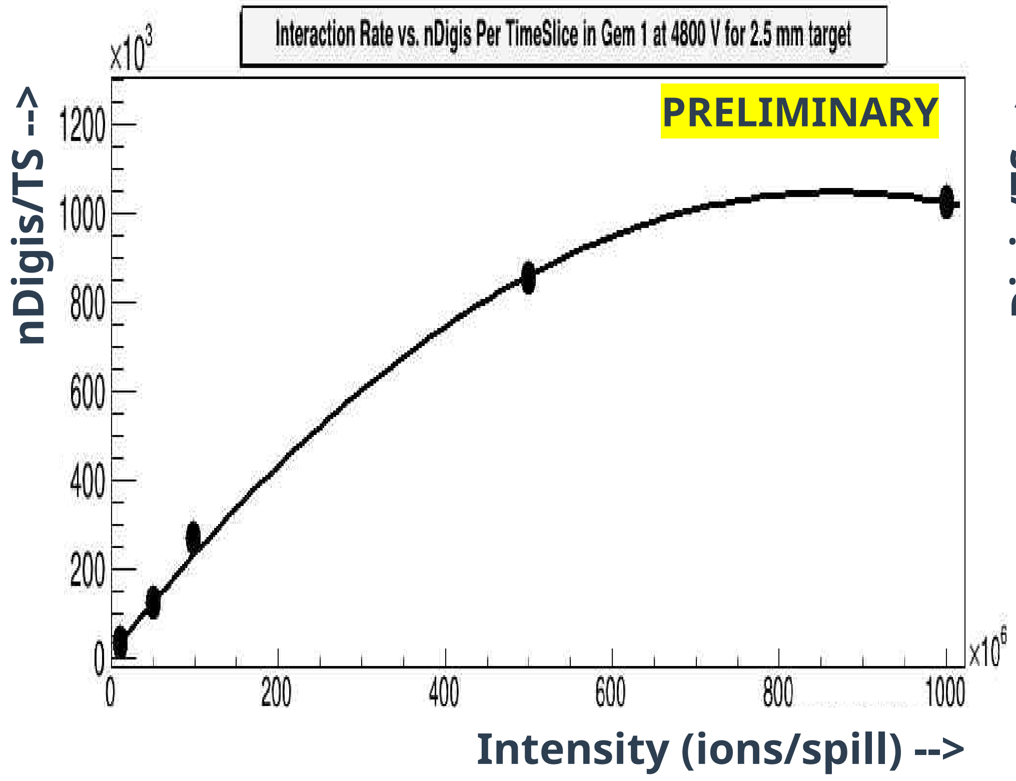
10^7 $5*10^7$ 10^8 $5*10^8$ 10^9

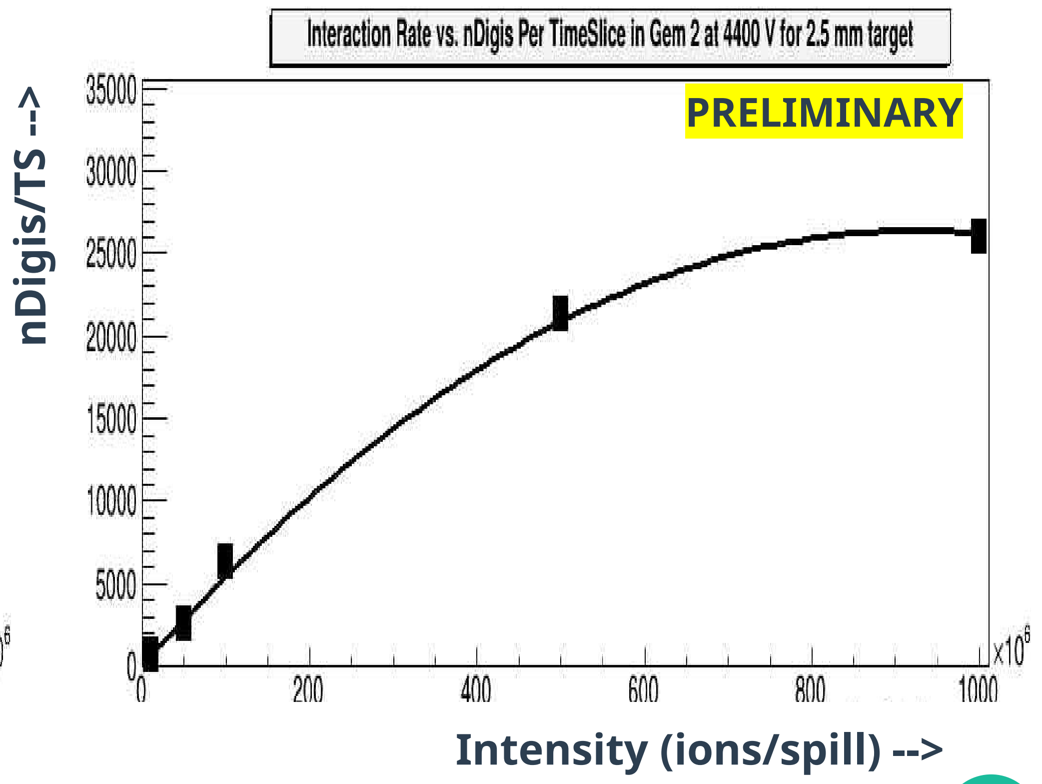
Increasing Beam Intensity-->

X -Axis Scales are different!

INTENSITY RESPONSE OF GEM MODULES

(U-Au @ T= 1.0 AGeV Runs)



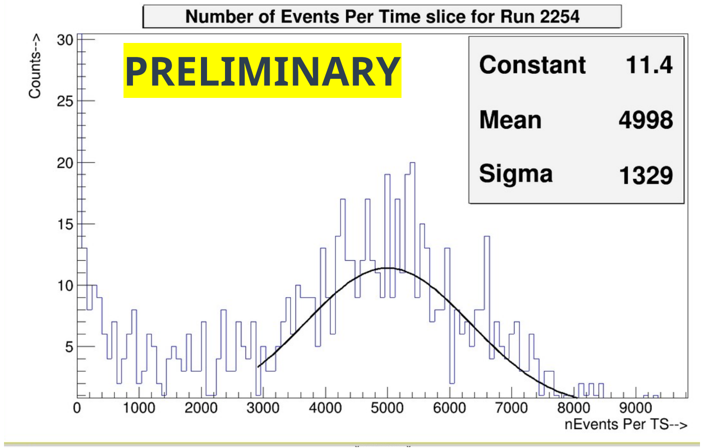


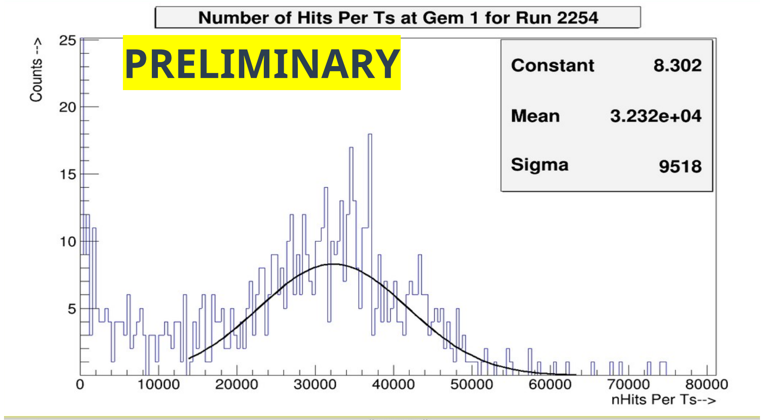
nDigis/TS -->

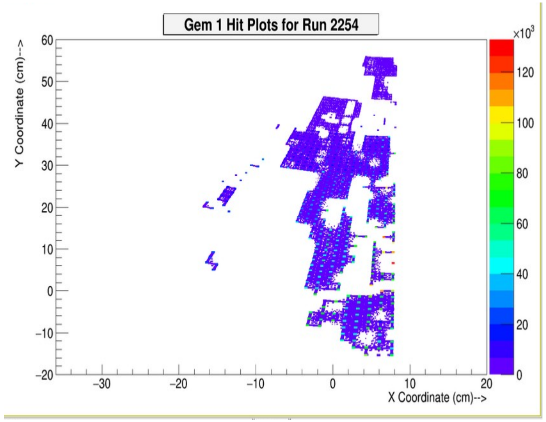
Intensity (ions/spill) -->

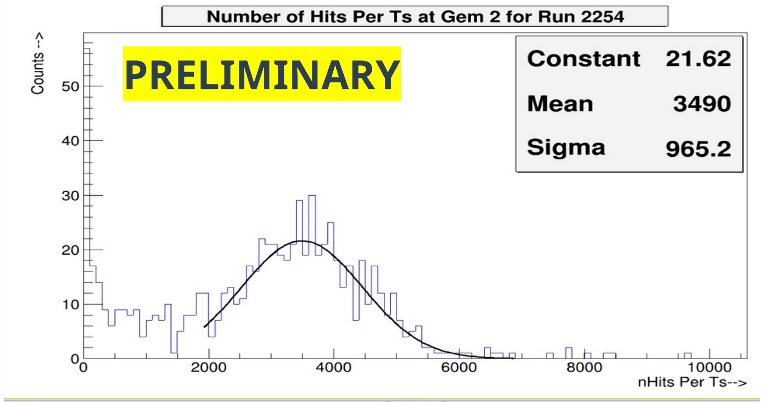
Event and Hit Reconstruction

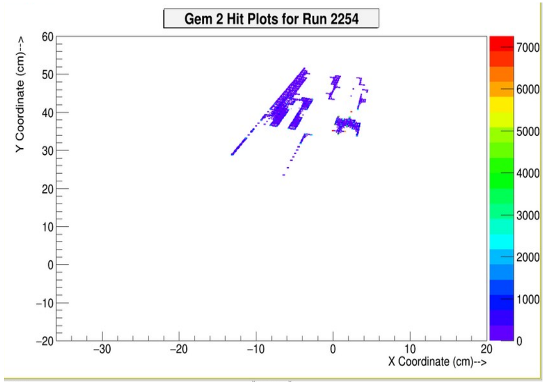
10^7 Ions/spill (U-Au @ T= 1.0 AGeV Runs) Data Worth 1000 TS











- **Criteria for Digi: Nearby Digis in Time interval of 200ns.**
- **Criteria for Event: 2 MuCh and 10 TOF digis in a window of 200 ns**

RoadMap to study Intensity Response using Hit and Event Reconstruction

Step 1:
Plot Time difference spectra for MuCh with reference detector

Step 2:
Identify all Time offsets

Step 3:
Remove Time offsets and Noise and make a new digi file

Step 4:
Run Hit Reconstruction Algorithm for MuCh

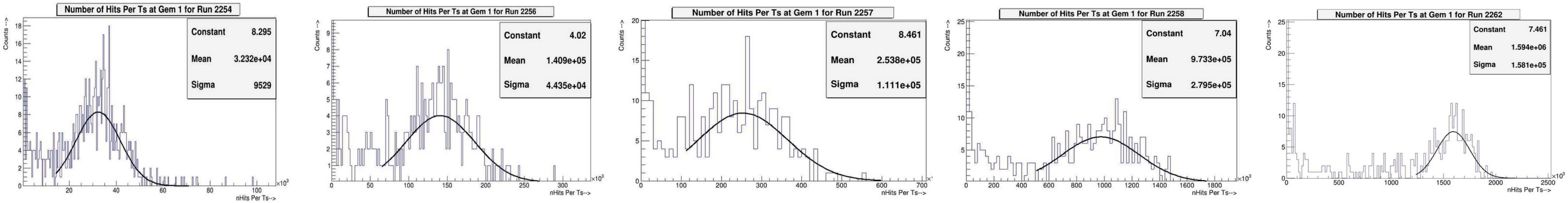
Step 5:
Run Event Reconstruction Algorithm

Step 6:
Plot Mean of nHits and nEvents vs. Beam intensity and study response

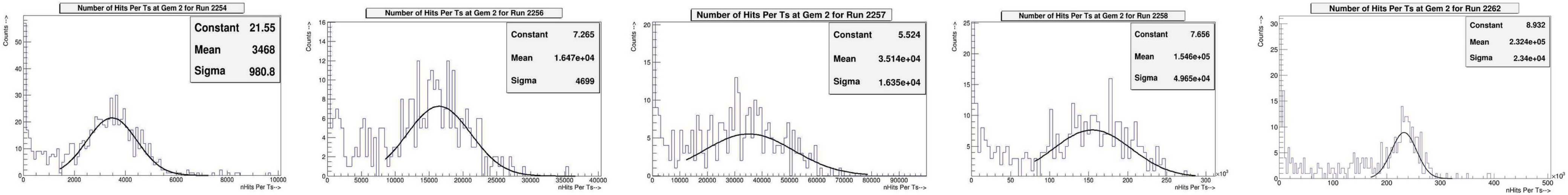
nHits PER TIMESLICE (64ms) FOR ALL INTENSITIES

(U-Au @ T= 1.0 AGeV Runs)

GEM 1 PRELIMINARY



GEM 2 PRELIMINARY

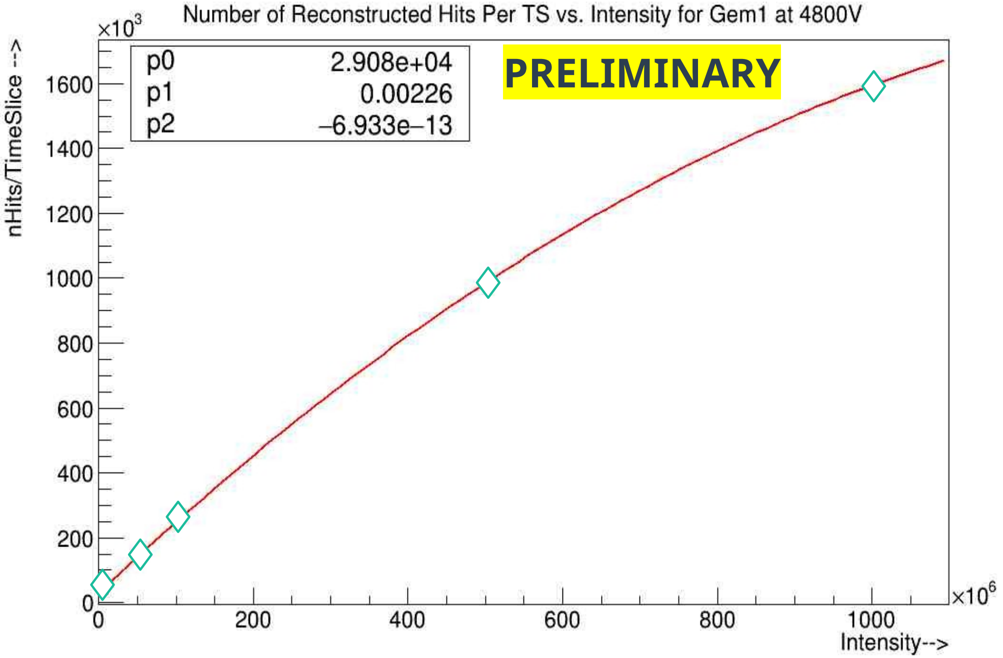


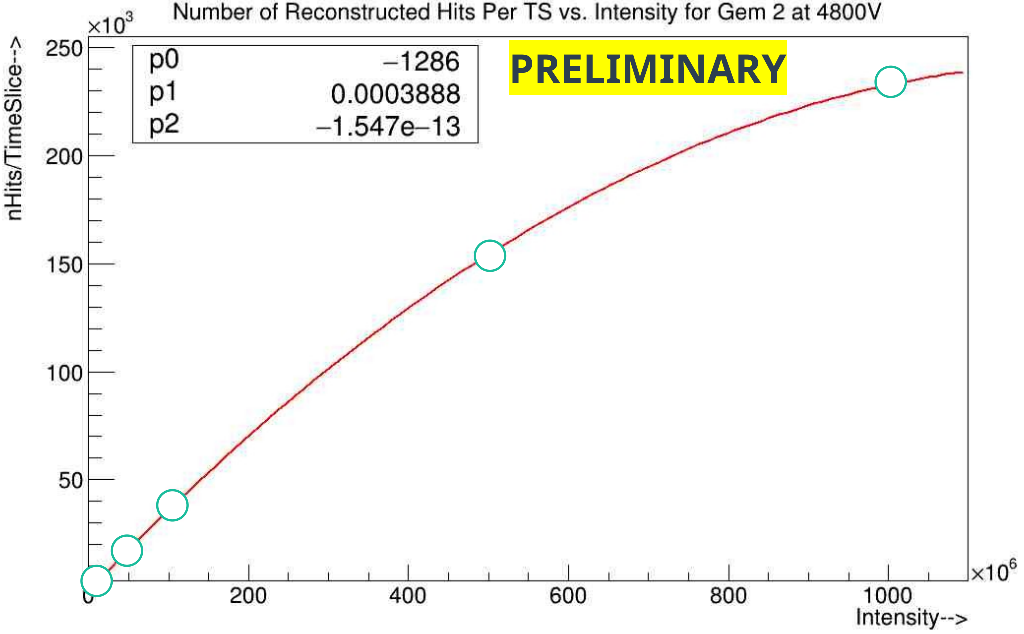
10^7 $5*10^7$ 10^8 $5*10^8$ 10^9

Increasing Beam Intensity-->

X -Axis Scales are different!

HIT RESPONSE OF GEM MODULES





Some Non Linearity is still observed at Highest Intensity

SUMMARY

- **We have achieved stable operation of GEM detector at such high particle rates for the first time.**
- **Any pre-existing issues with the link stability of the detector have been resolved after upgrades.**
- **Detector electronics also show stable response.**
- **The response is largely linear and shows a hint of non linearity only at the highest intensity. This result is still preliminary and further studies are required on this front.**

OUTLOOK

- The intensity numbers have been taken from the accelerator but the studies suggest that these numbers might not be correct. Proper estimation of interaction rates will give us the correct response of the detector. We are hoping for a linear response at highest intensities.
- Branch current based studies to estimate detector stability over long periods are to be performed.
- Gain and efficiency estimation needs to be performed.

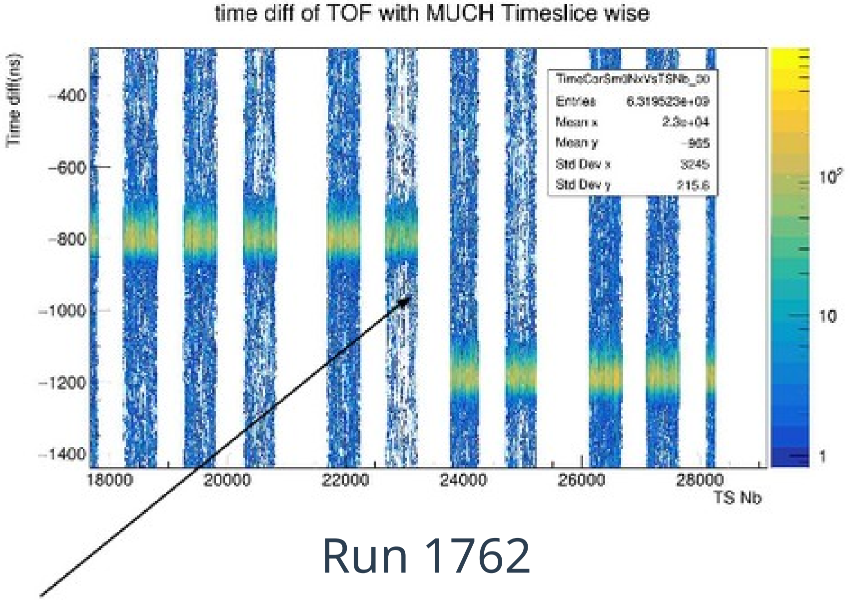
Thank You

BACKUP

Recap from previous mCBM Runs

mCBM Runs	MuCh Participation
mCBM 2018	Participated
mCBM 2019	Participated
mCBM 2020	Participated
mCBM 2021	Not Participated

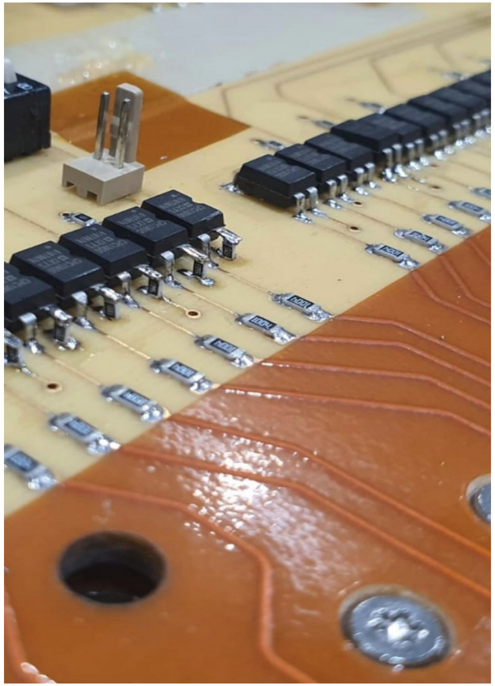
- **Communication with ASIC got Lost**
- **During a Run offset jumps were observed particularly at higher voltages.**



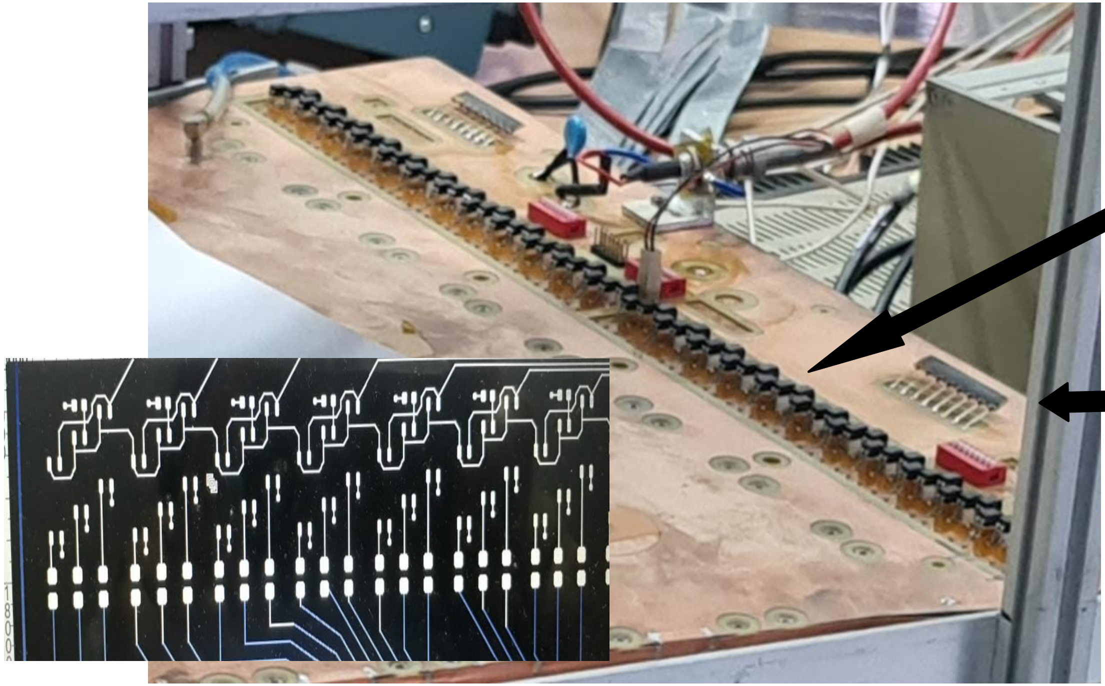
Run 1762

Offset jump of 400ns mid Run

PCB UPGRADE



Gem1 : Module tested at GIF++ 2022

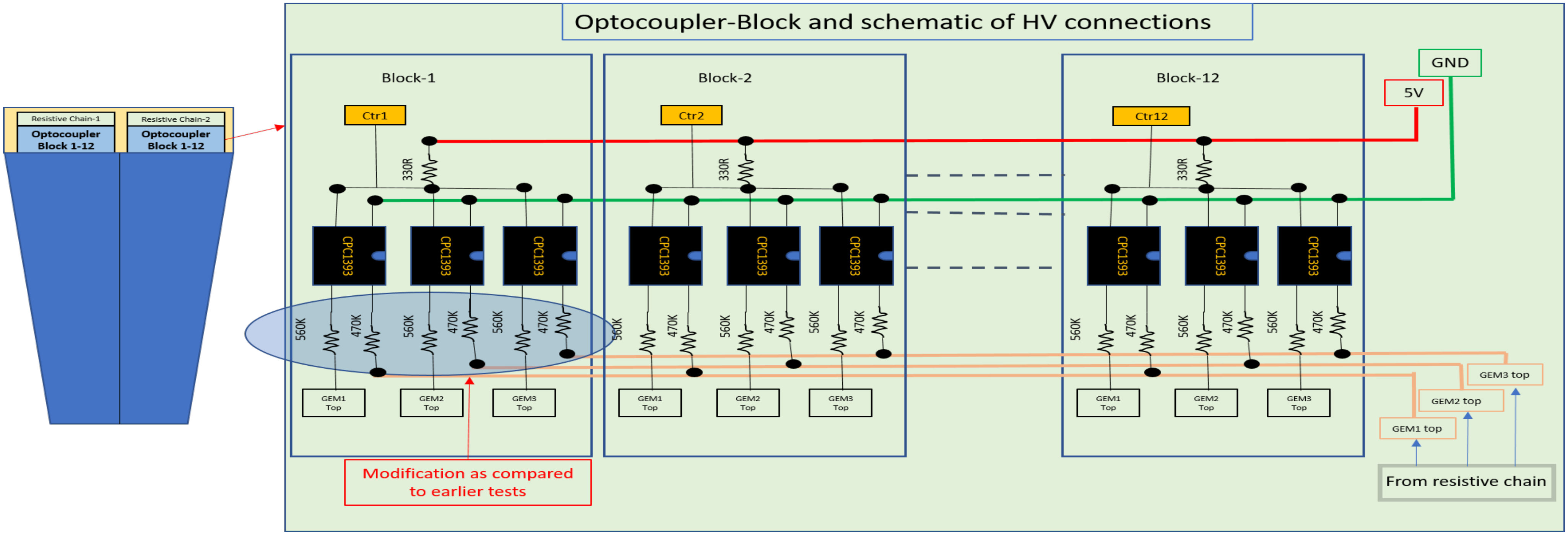


Gem2 : Module with new drift PCB was build at VECC

Optocoupler in staggered form

Resistance between OC input and HV supply is placed on PCB

SCHEMATIC OF THE HV LAYOUT ON THE DRIFT PCB



1. **Left half HV layout is identical to the right half. Two resistive chains per module.**
2. **Branch current monitored by HV supply**

Note: Block shown for Right half

BACKUP