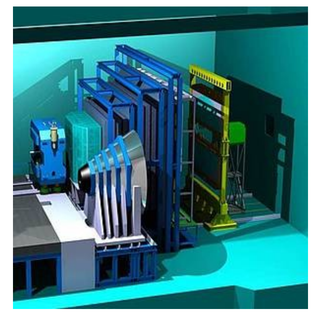
Testing large size triple GEM chambers in mCBM experiment at SIS18 facility of GSI



Ajit Kumar
VECC-HBNI Kolkata
For CBM-MUCH

RD51 Mini-Week
10-13 February 2020
CERN

Date: 11-02-2020

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.

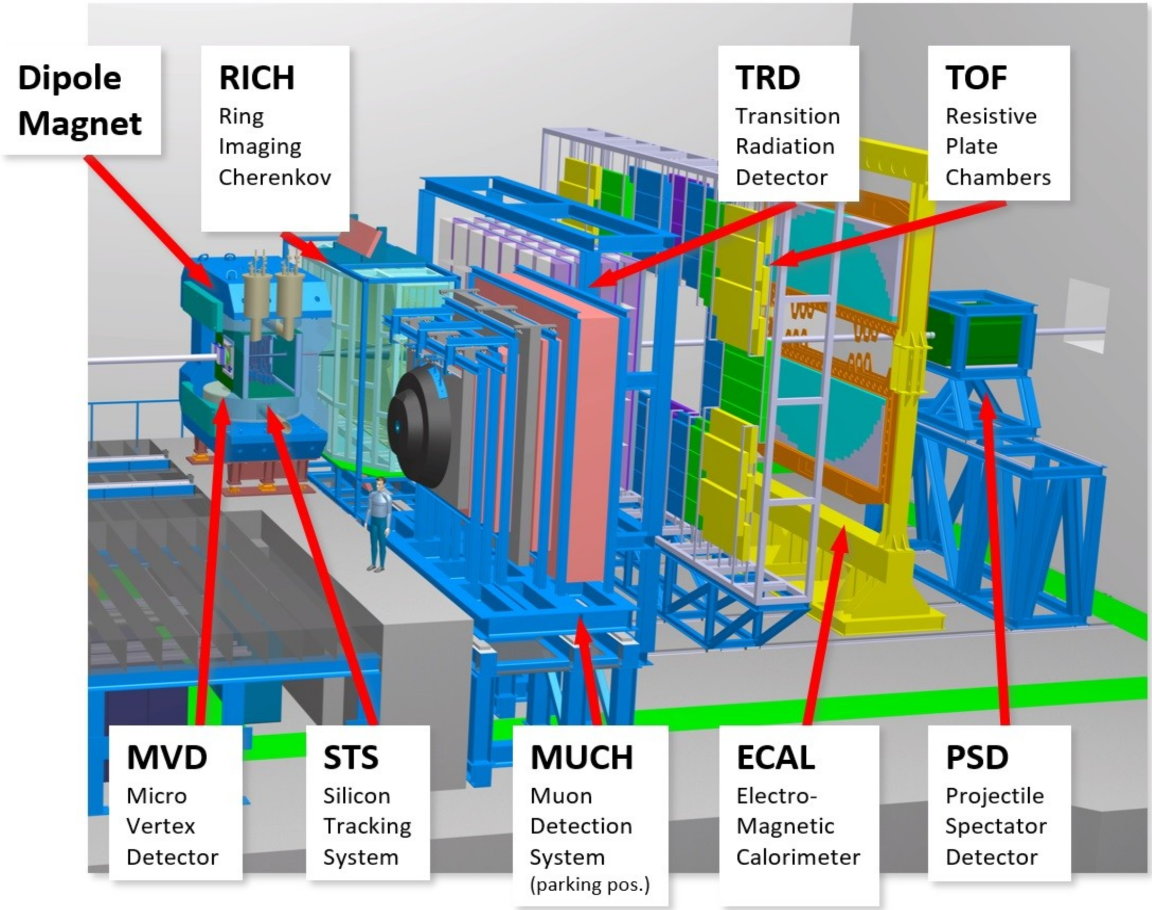
➔ **Energy range 2-35 AGeV**

CBM physics program:

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

Diagnostic probes of the high density phase:

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

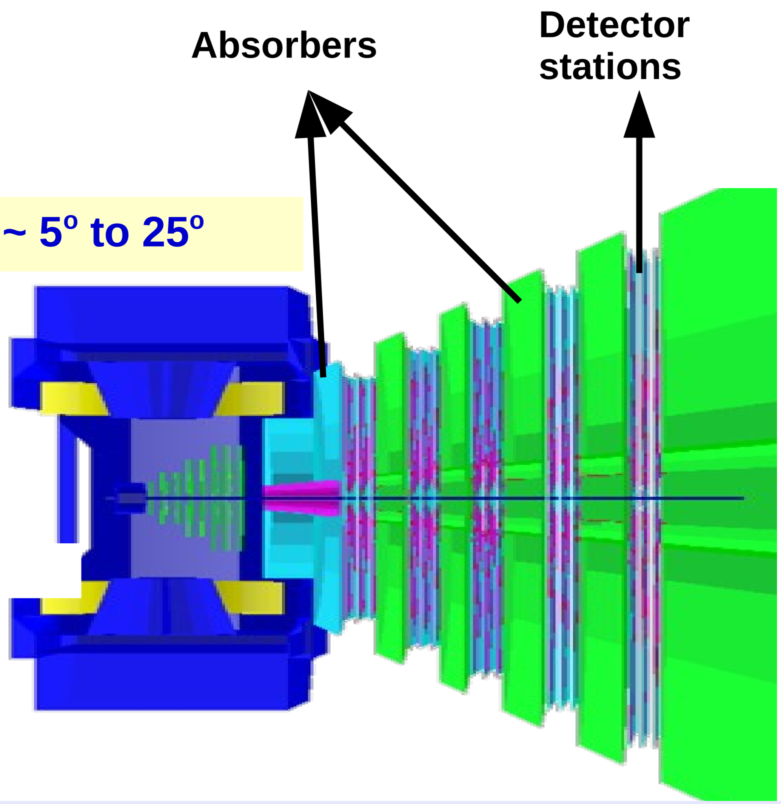


Muon Chamber (MUCH) of CBM

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

→ $\mu^+ \mu^-$

Angular coverage ~ 5^o to 25^o



Schematic of CBM-MUCH setup

Design criteria:

- **High interaction rate : up to 10 MHz**
- Maximum particle rate at 1st stations for Au+Au at 8A GeV minimum bias **collision ~ 200kHz/cm^2**
- **Radiation resistance (for Neutron ~10^{12} n_{eq}/cm^2 and for Gamma ~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

SIS100 setup

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

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

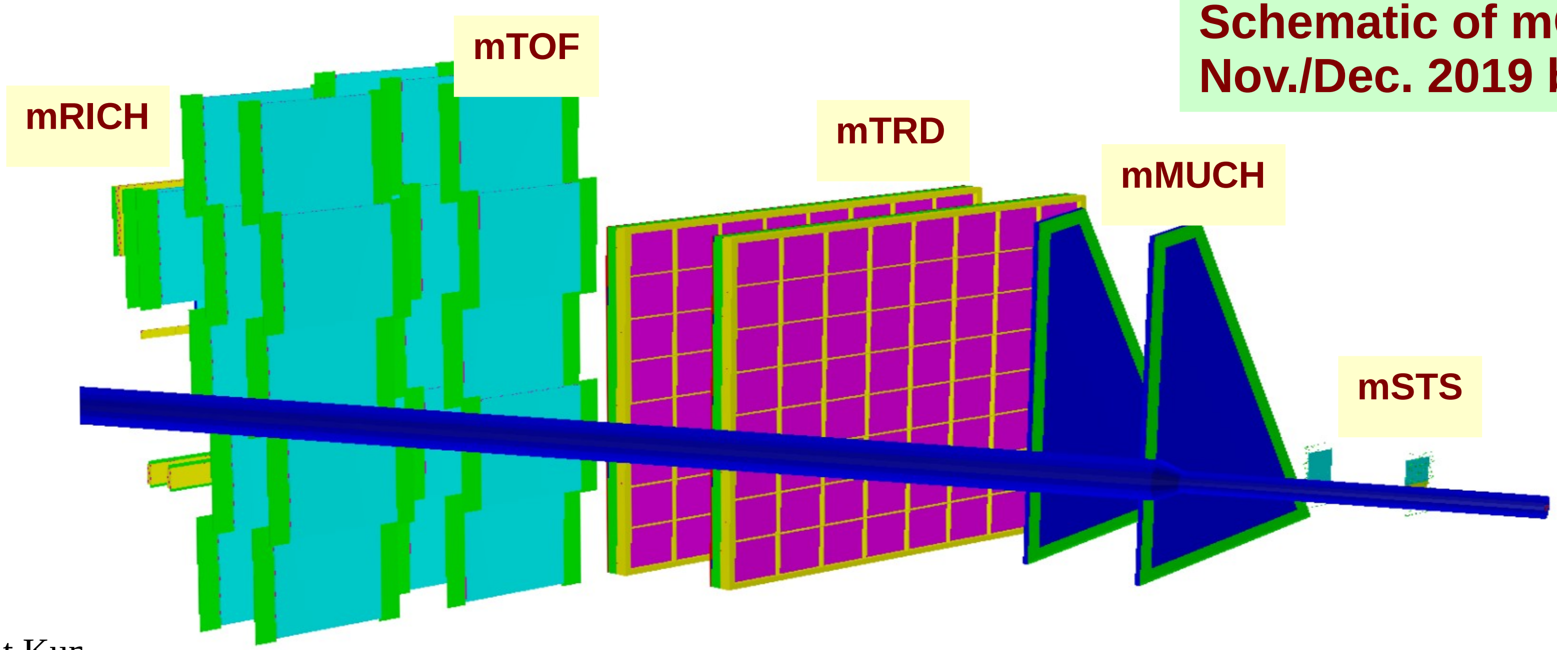
mCBM Experiment

This is part of FAIR phase-0 programme of GSI

mCBM --> A CBM full system test setup at SIS18 facility of GSI/FAIR. The mCBM experiment will additionally 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

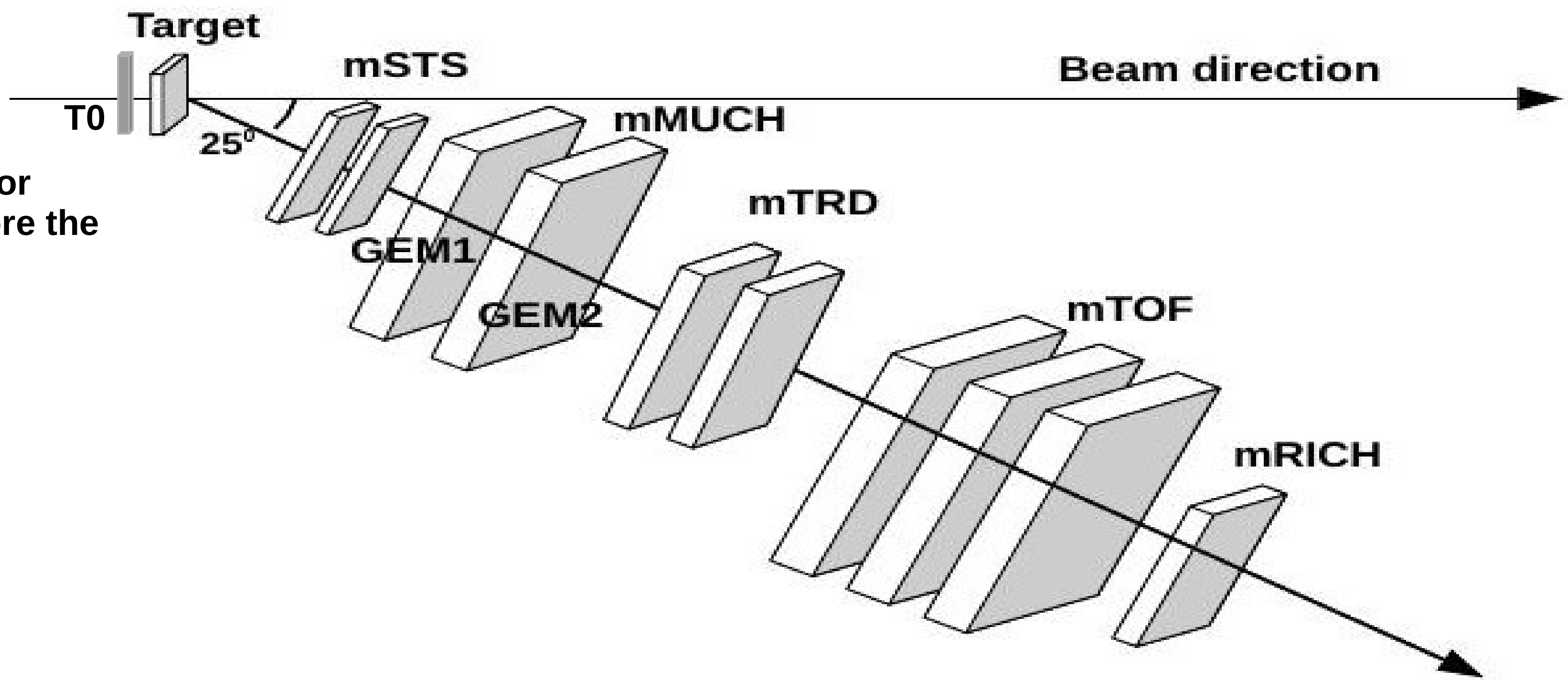
— Operation of the detector prototypes in a high-rate nucleus-nucleus collision environment
— Free-streaming data acquisition system including the data transport
— Online track and event reconstruction as well as event selection algorithms
— Offline data analysis and
— Detector control system
— Λ^0 reconstruction

Schematic of mCBM setup for Nov./Dec. 2019 beam tests



Schematic of Test Setup

Schematic of detector setup



Diamond (T0) detector was placed just before the target

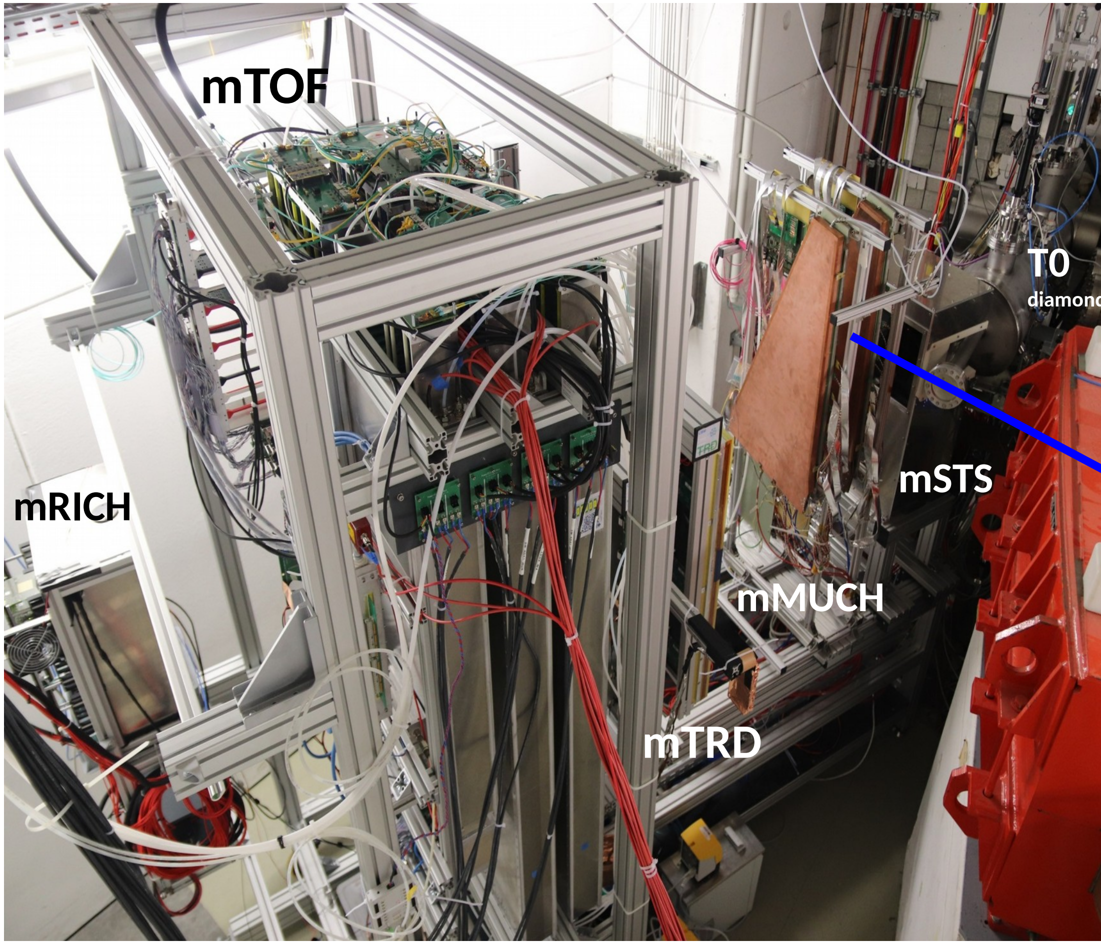
Z-position of MUCH

GEM1 : ~84 cm
GEM2 : ~106 cm

Transverse distance

~16.1 cm to 47.9 cm for GEM1

Picture of Test Setup in mCBM



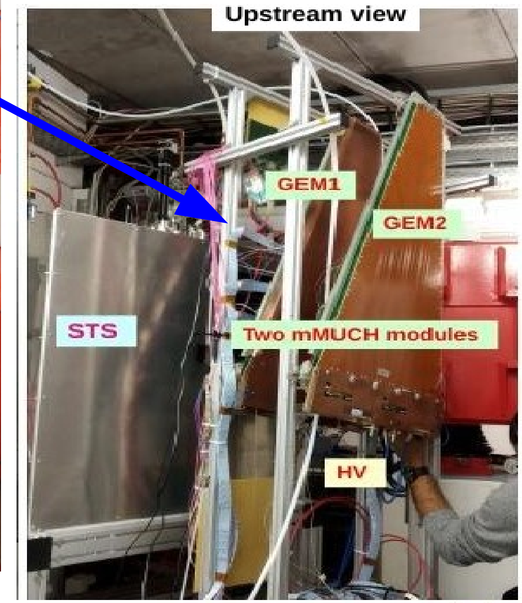
mCBM setup as of Dec. 2019, located at the SIS18 facility of GSI

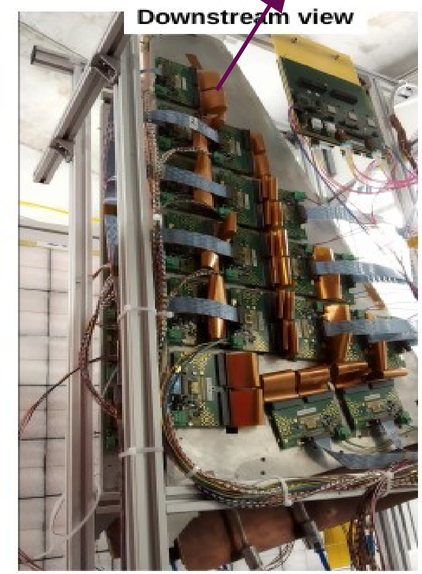
GEM1 acceptance : 17 FEBs
GEM2 acceptance : 10 FEBs

-> Readout channels per module = ~2200
-> Area = ~2000 cm^2

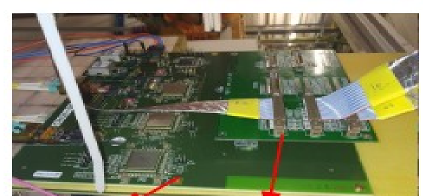
Minimum pad size = 3.2 mm
Maximum pad size = 17.2 mm

Flex cable

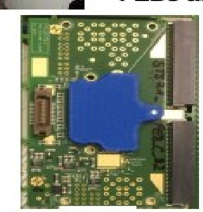




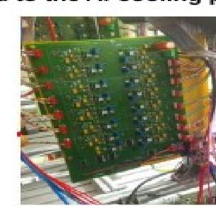
FEBs attached to the Al-cooling plate



CROB FMC



FEB

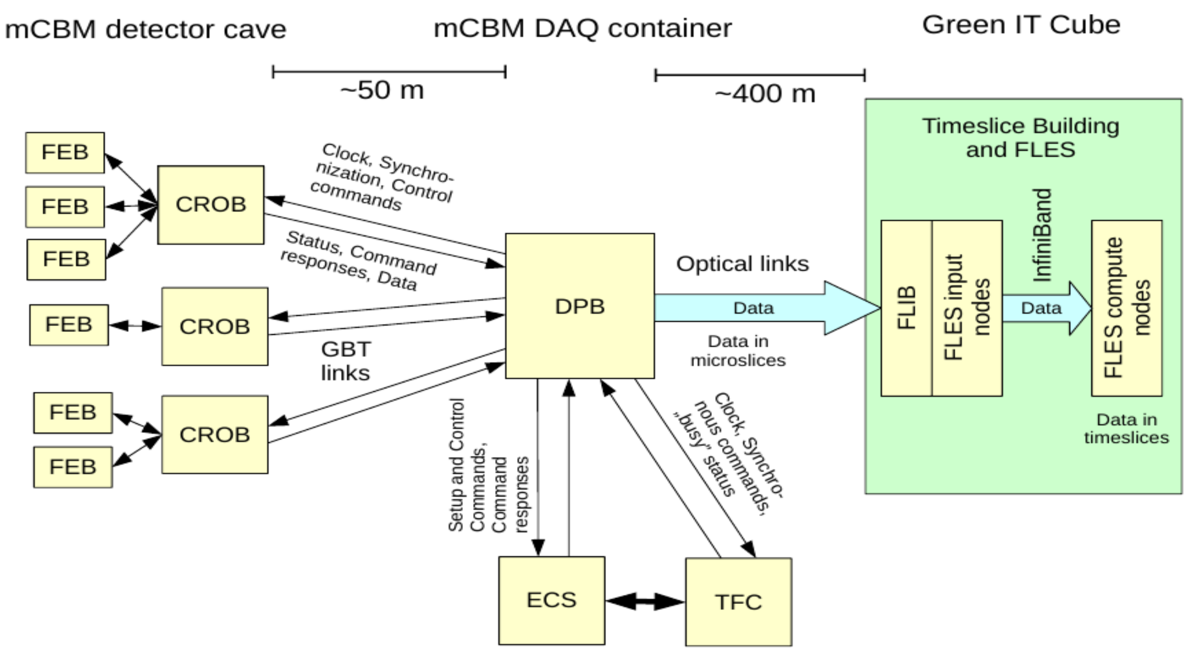


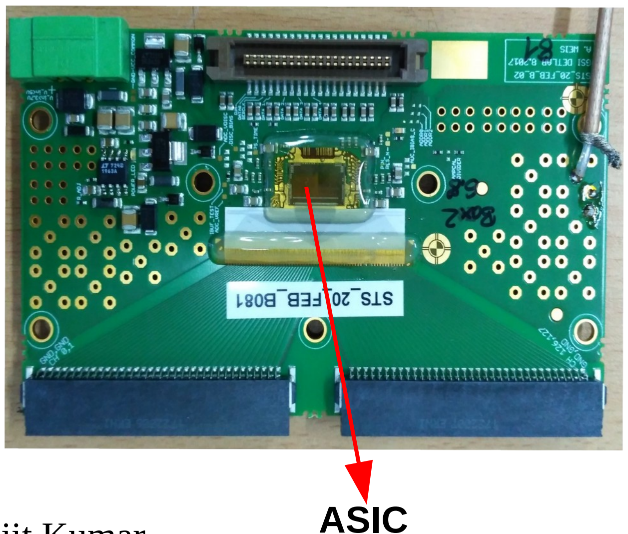
LVDB

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

mMUCH setup

mCBM DAQ





STS/MuCh-XYTER

-> self triggered electronics

-> 128 channels + 2 test channels

-> can handle average hit rate ~250 kHz/channel

-> Dynamic range = 1-100 fc

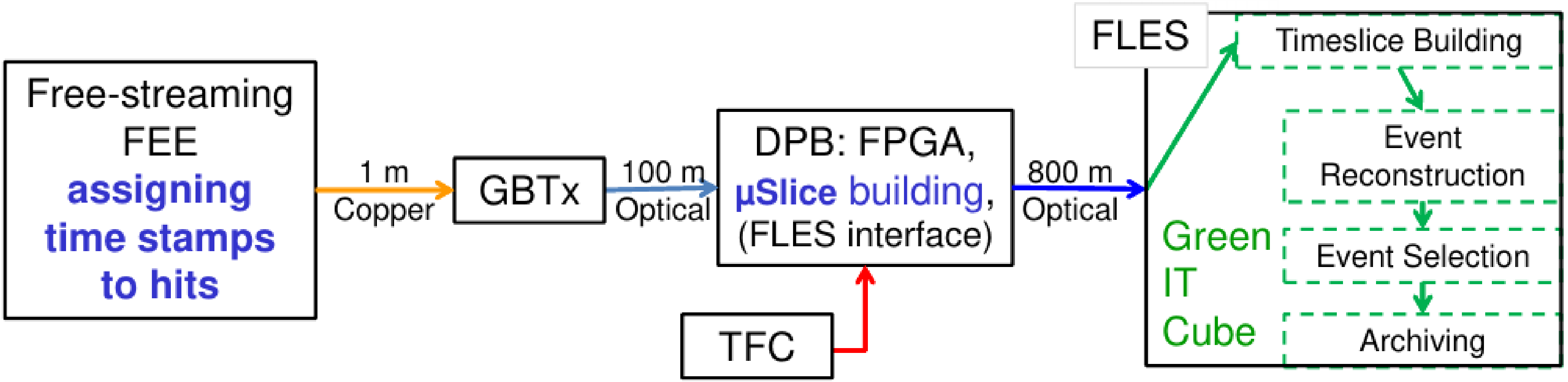
-> provides both timing and energy information

-> 5 bit flash ADC

-> Time resolution ~4-5ns

-> Heat generated = ~2-3 W / FEB

CBM data transport and processing



Acronyms

FPGA : Field Programmable Gate Array

DPB : Data Processing Board

TFC : Timing and Fast Control Syst.

FLES : First Level Event Selector

GBTx : CERN rad.-hard interface ASIC

µSlice (µS) : self contained data block for a subset of the experiment, minimal size depends on degree of data time sorting

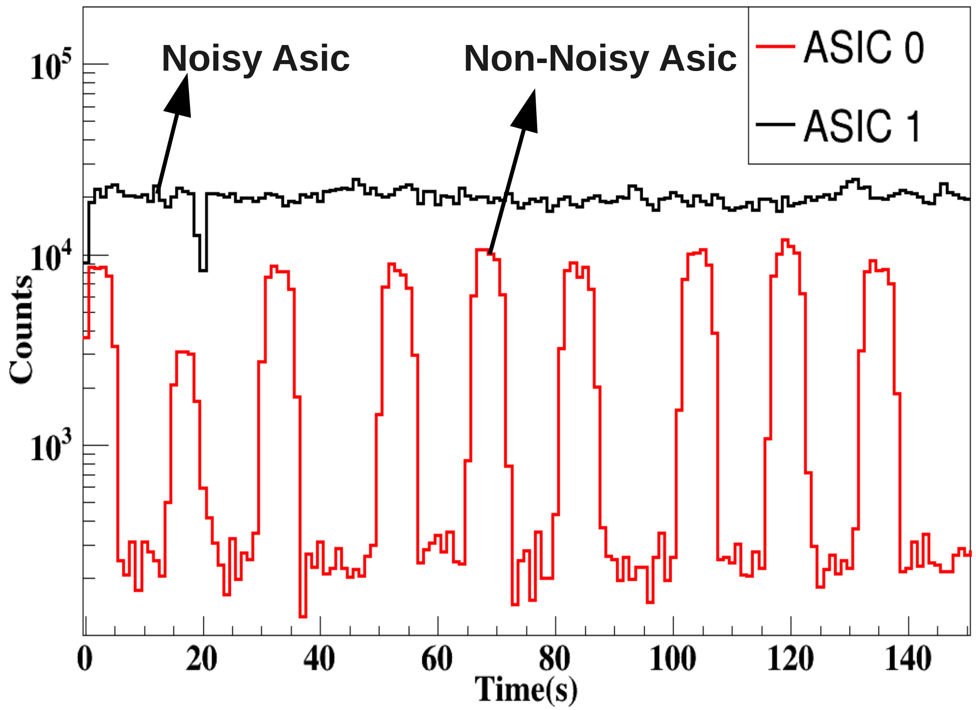
Timeslice : collection of µS, self contained data block for the full experiment and a given time interval, includes overlap to avoid edge losses

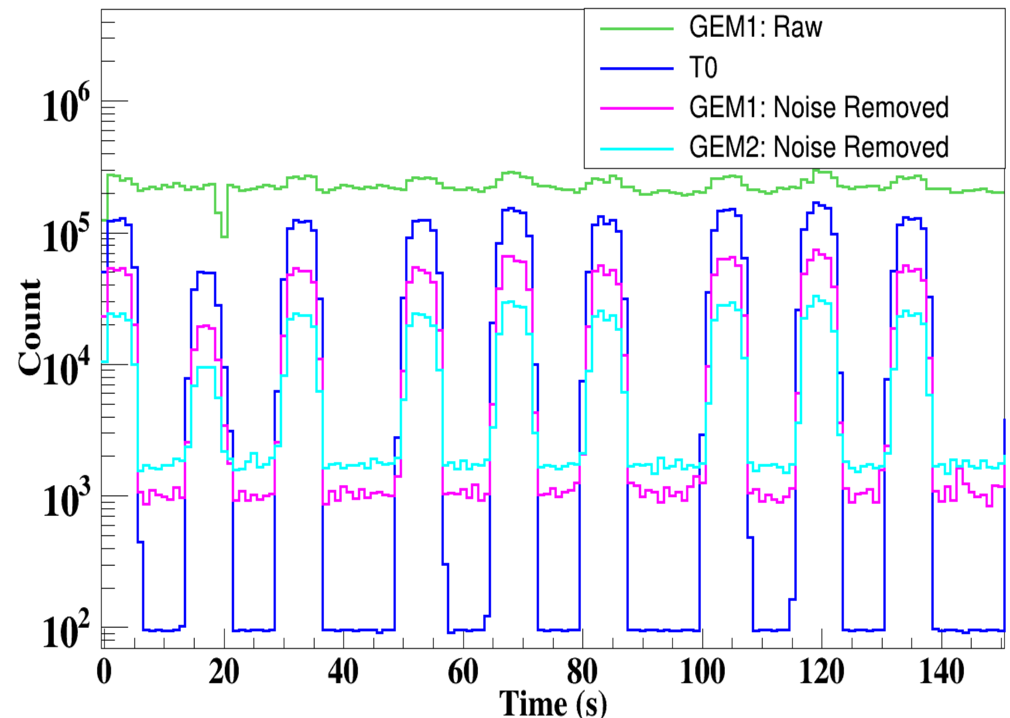
Slide Courtesy: Christian Sturm, GSI

Results:1

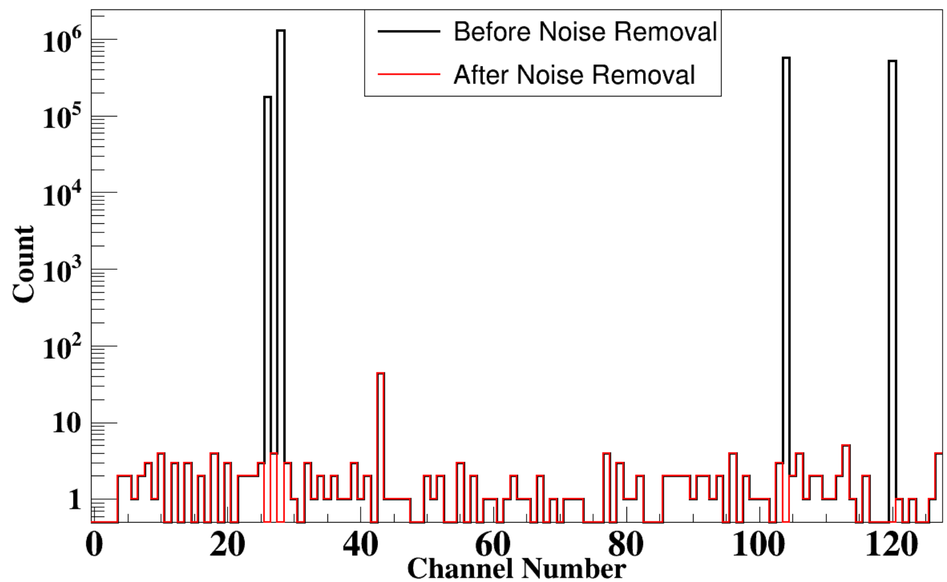
Ar + Au at 1.7AGeV, Nov./Dec. 2019

Spill structure





Spill length ~ 7.5s
Gap between the spills ~ 7.5s and 12s



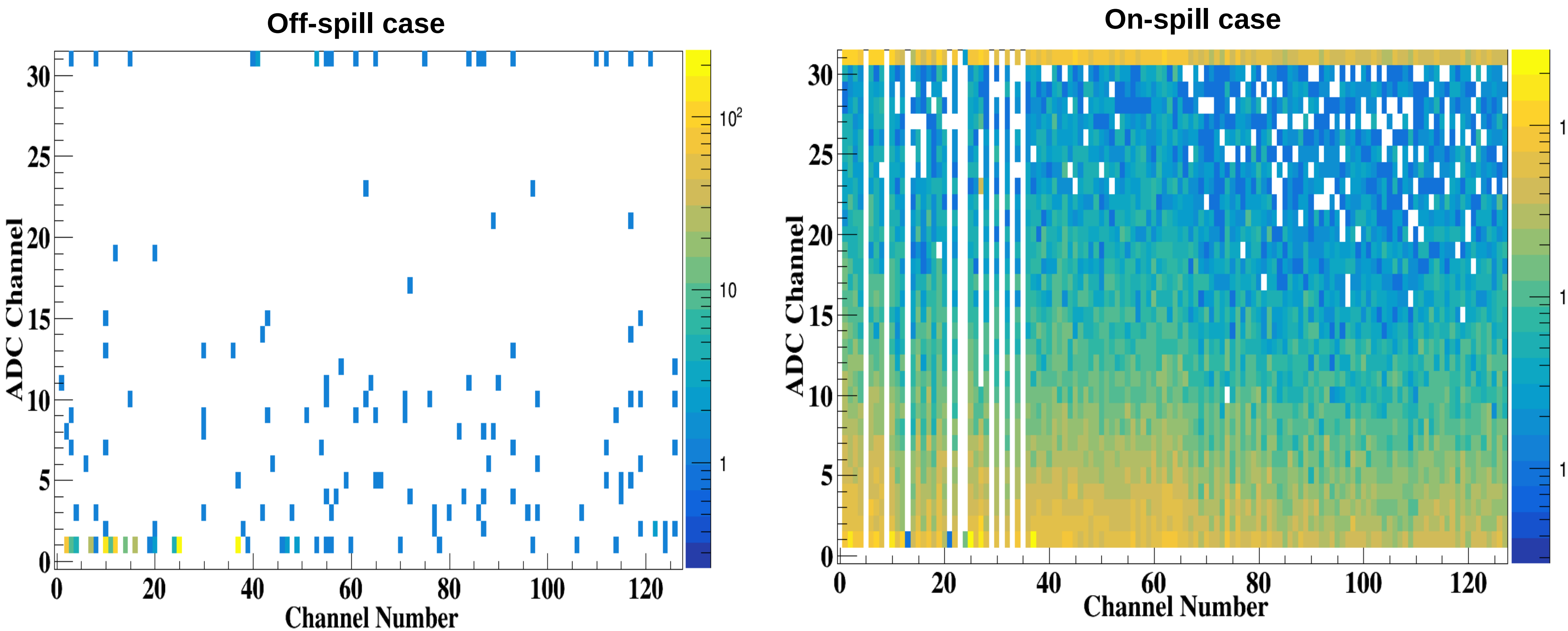
Preliminary

Channel hit distribution in off-spill case

Results:3

Ar + Au at 1.7AGeV, Nov./Dec. 2019

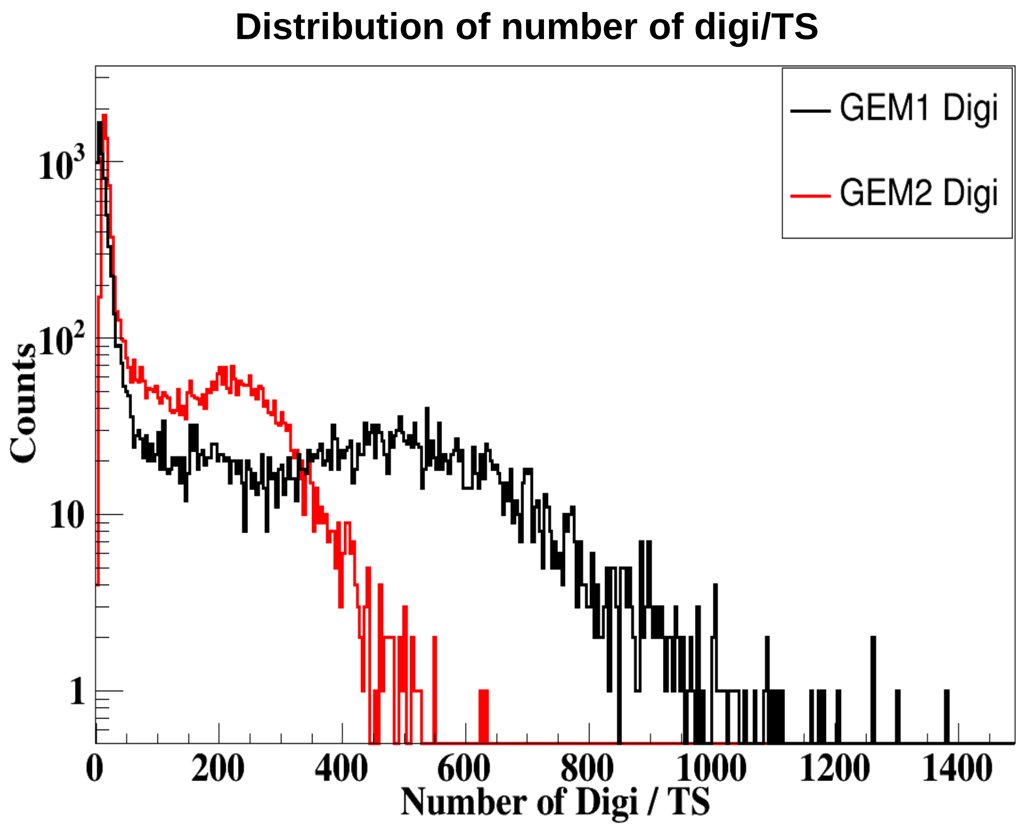
ADC with Channel number

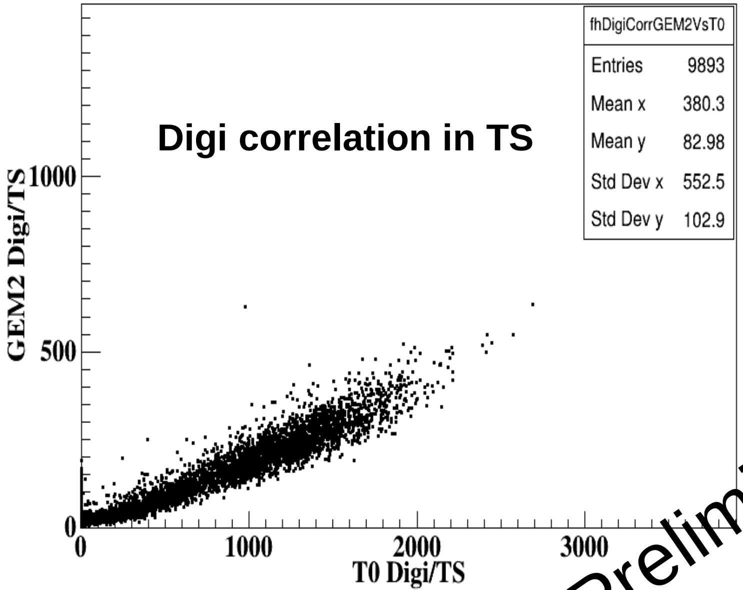


Preliminary

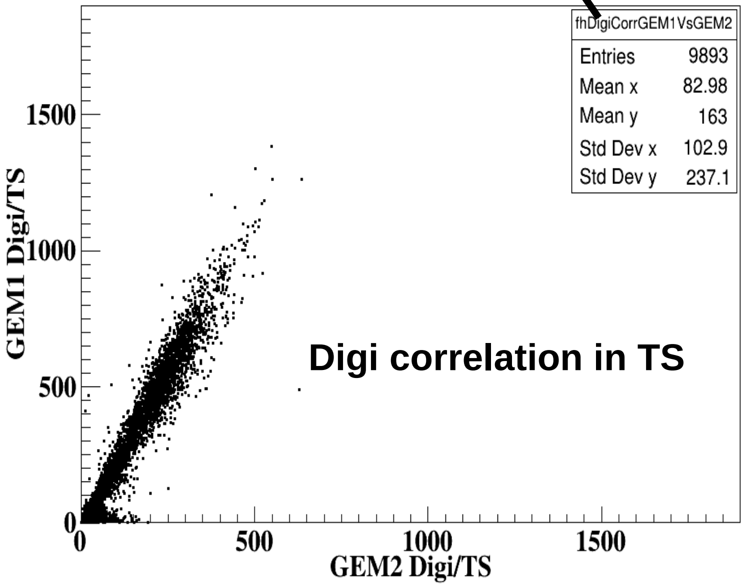
Results:2

Ar + Au at 1.7AGeV, Nov./Dec. 2019





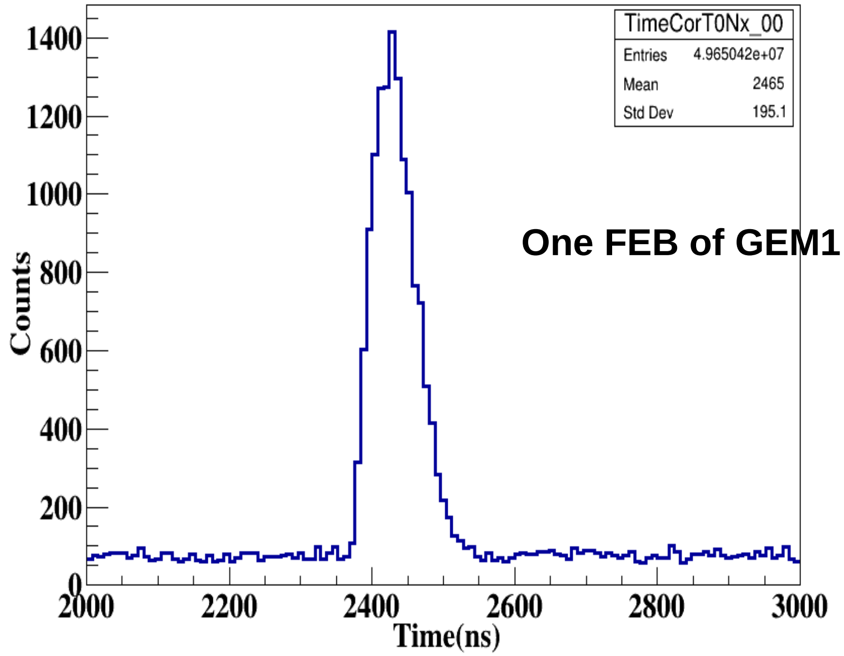
Preliminary

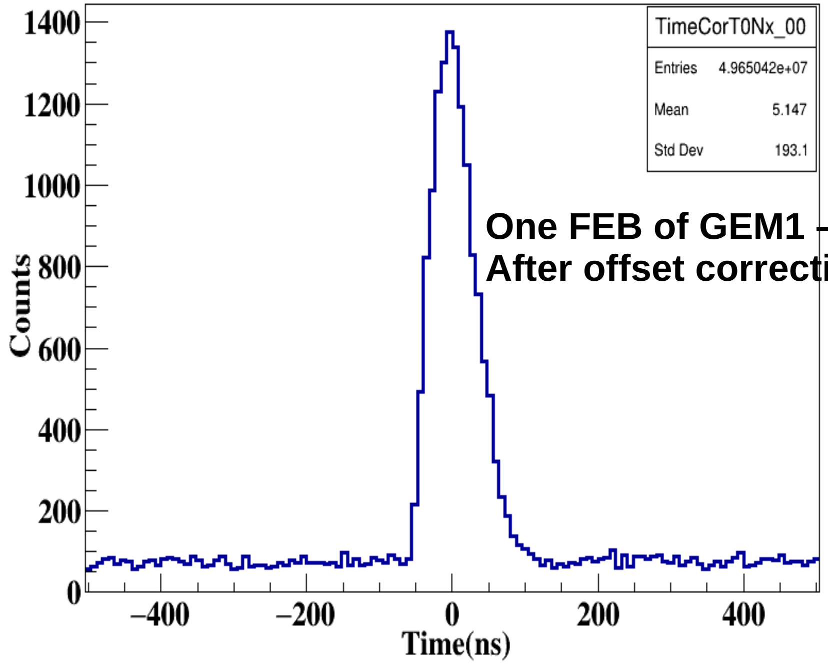


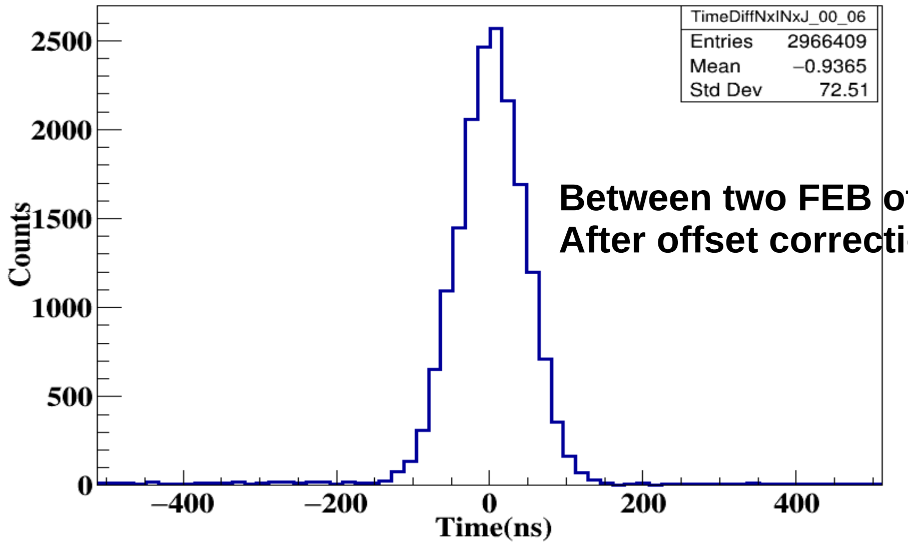
Results:4

Time correlation

Ar + Au at 1.7AGeV, Nov./Dec. 2019







Preliminary

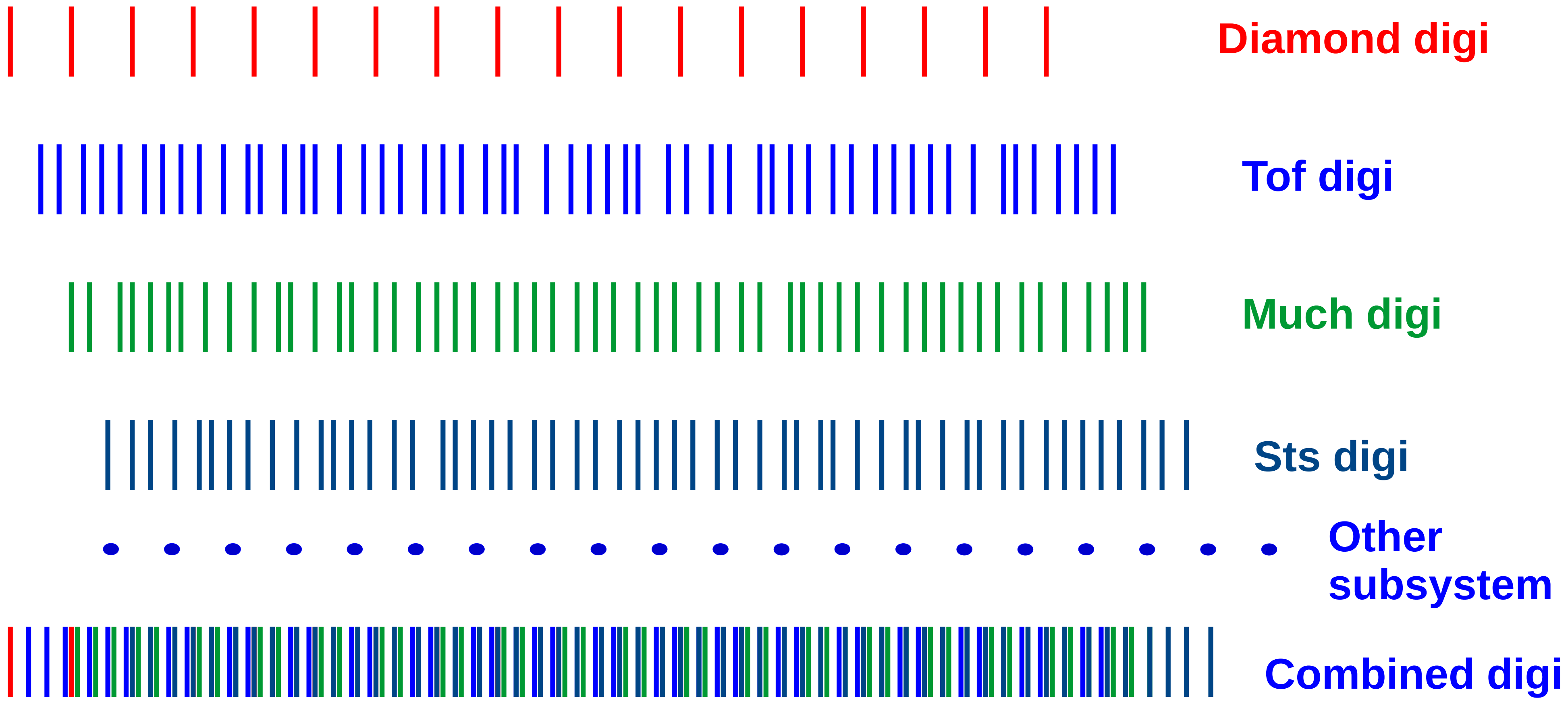
Event building in free-streaming data

- Event reconstruction of “nucleus+nucleus” collision data, acquired in the self-triggered system, is very uncommon and a challenging task.

- mCBM provides suitable platform for testing and optimizing time based event reconstruction.

First (preliminary) event building procedure

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



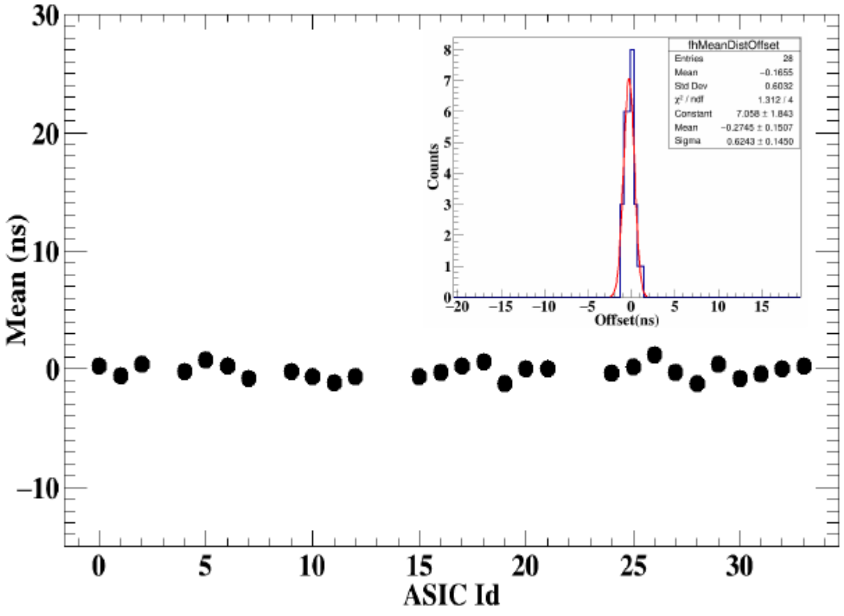
If the time gap < 60ns (say) => Then count as one event
with minimum TOF and T0 trigger condition for cleaning the events.

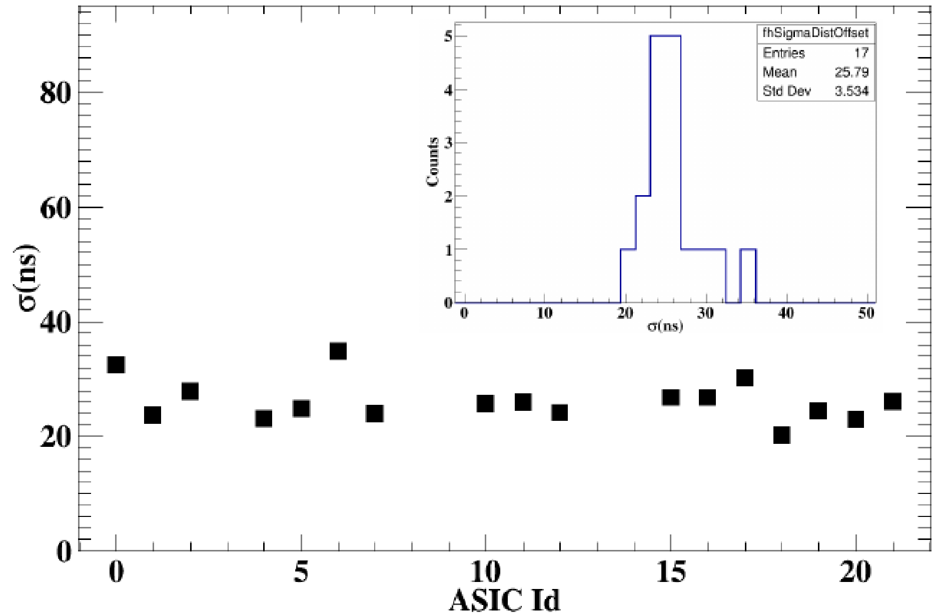
Results:5

Event Building and Hit Reconstruction

Ar + Au at 1.7AGeV, Nov./Dec. 2019

Offset correction





σ(ns) is large (~25ns) compared to previous test beam results (13-14ns), which done using nXYTER.

n-XYTER has 12-bit ADC with time resolution of 1-2ns while the STS/MuCh-XYTER has 5-bit ADC

Preliminary

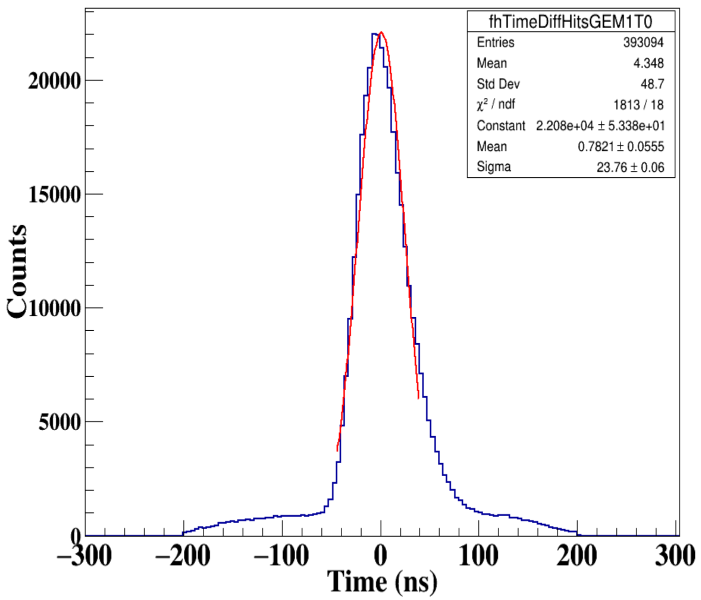
Algorithm: **Fixed time window = 200 ns with a condition of 6 TOF + 1T0 digi**

Results:6

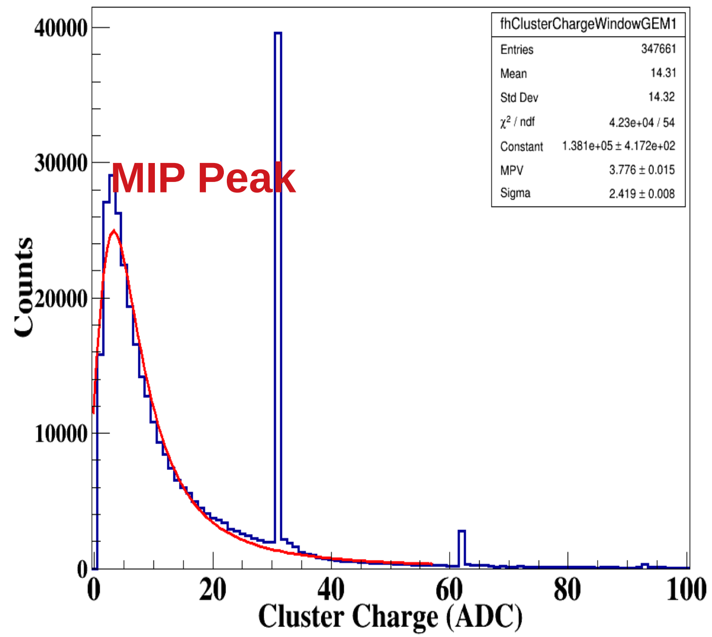
Event Building and Hit Reconstruction

Ar + Au at 1.7AGeV, Nov./Dec. 2019

Time difference between GEM1 hit - T0



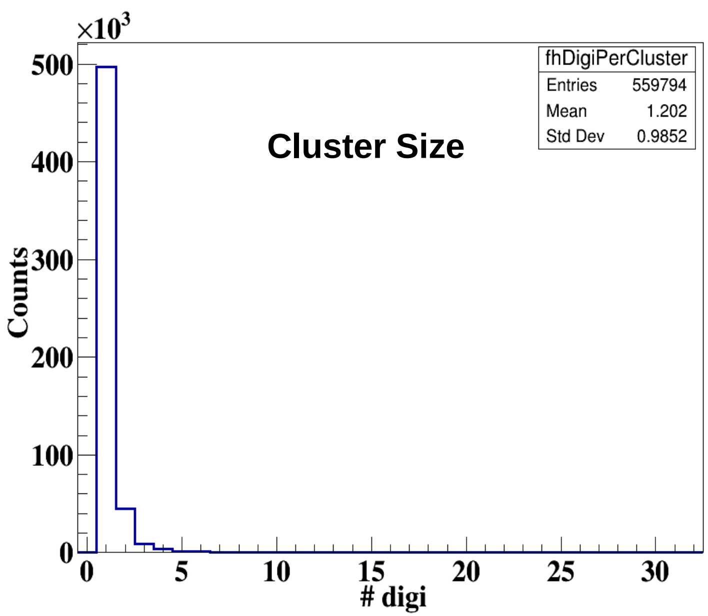
Cluster charge



ASIC calibration:
=> Starting from 6fc with a gap of 2.5fc

MPV = ~3.8 ADC

Gain ~ 3200



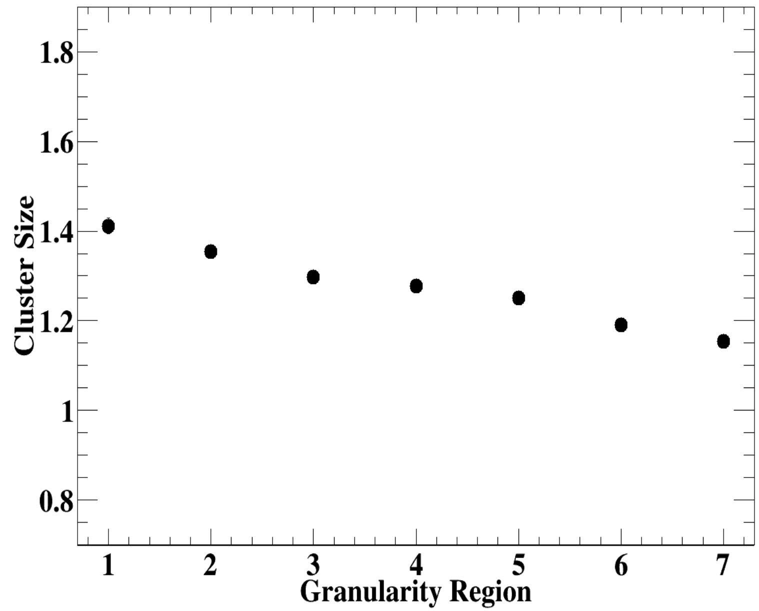


Table 1. Table for pad size at different granularity regions.

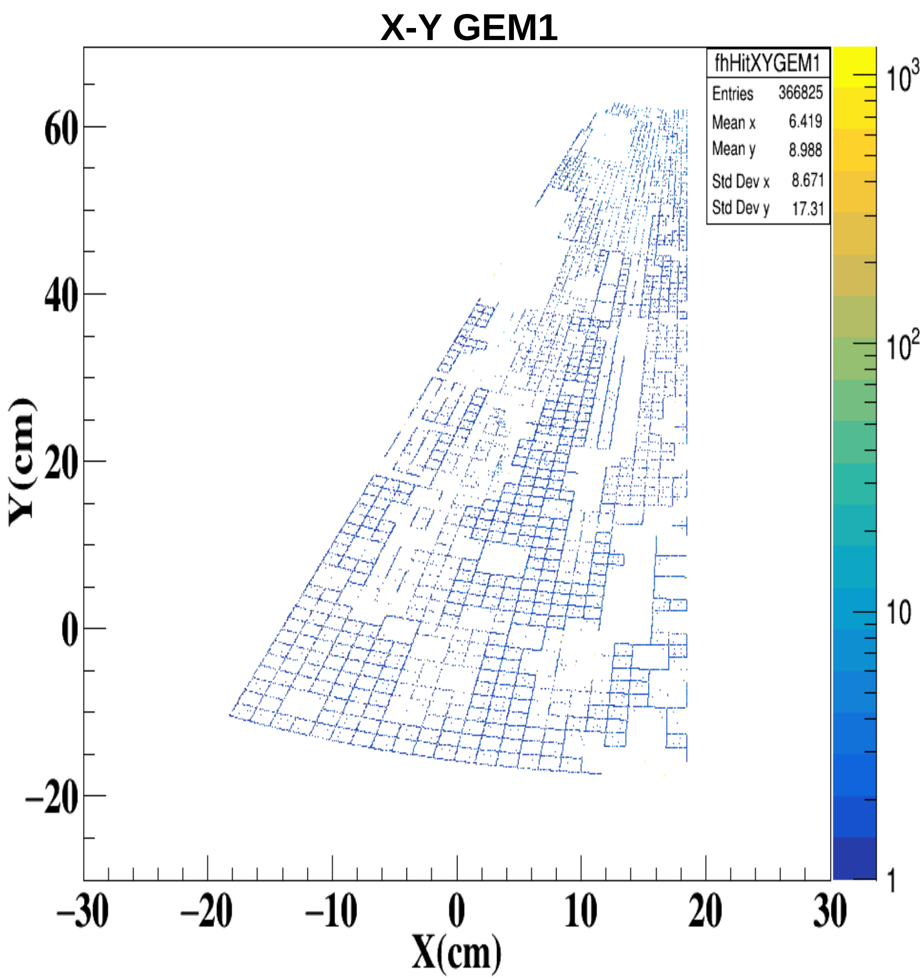
Granularity Region	Pad Size (mm)
1	~3.22 - ~4.55
2	~4.55 - ~6.22
3	~6.44 - ~8.49
4	~7.66 - ~10.09
5	~9.59 - ~11.40
6	~11.59 - ~14.02
7	~14.02 - ~16.97

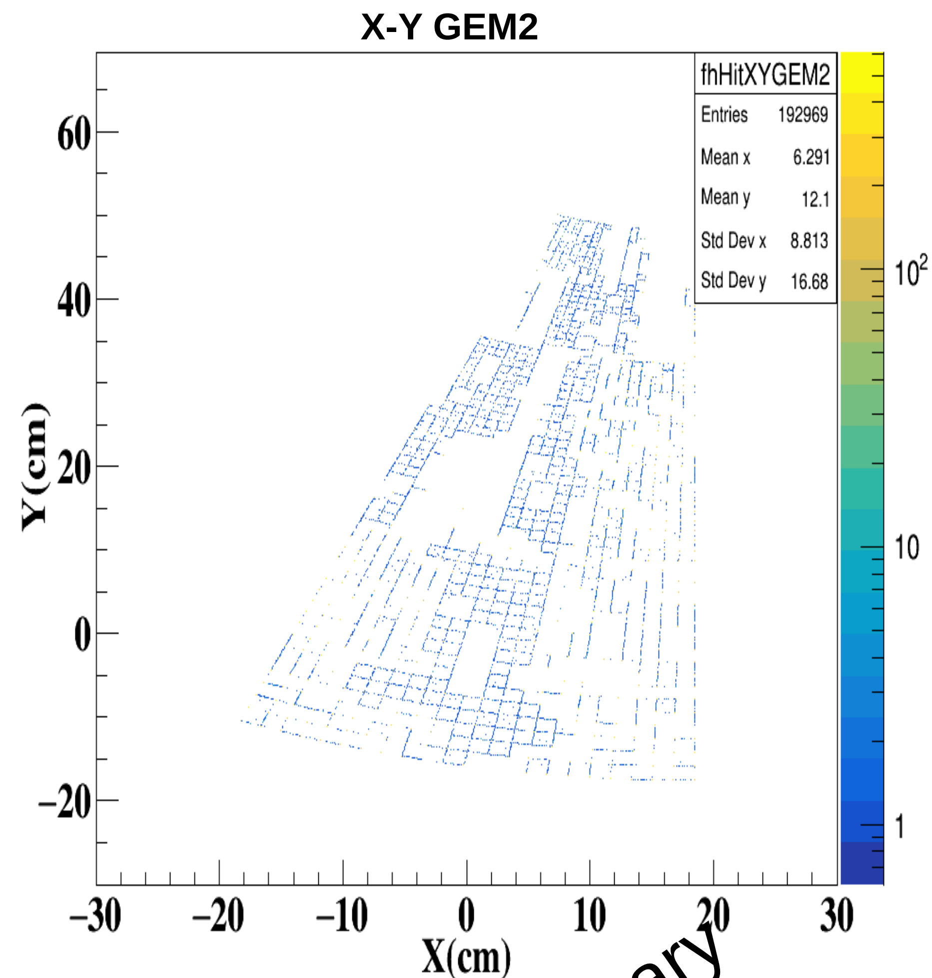
Preliminary

Results:7

Clustering and hit reconstruction

Ar + Au at 1.7AGeV, Nov./Dec. 2019



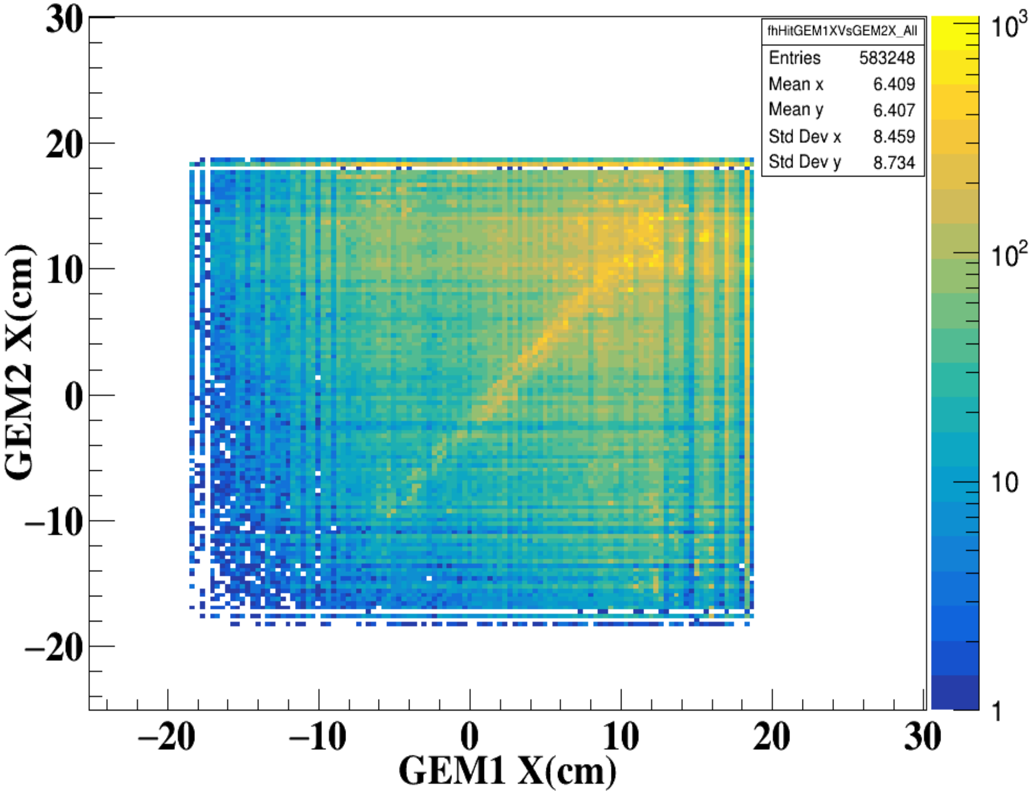


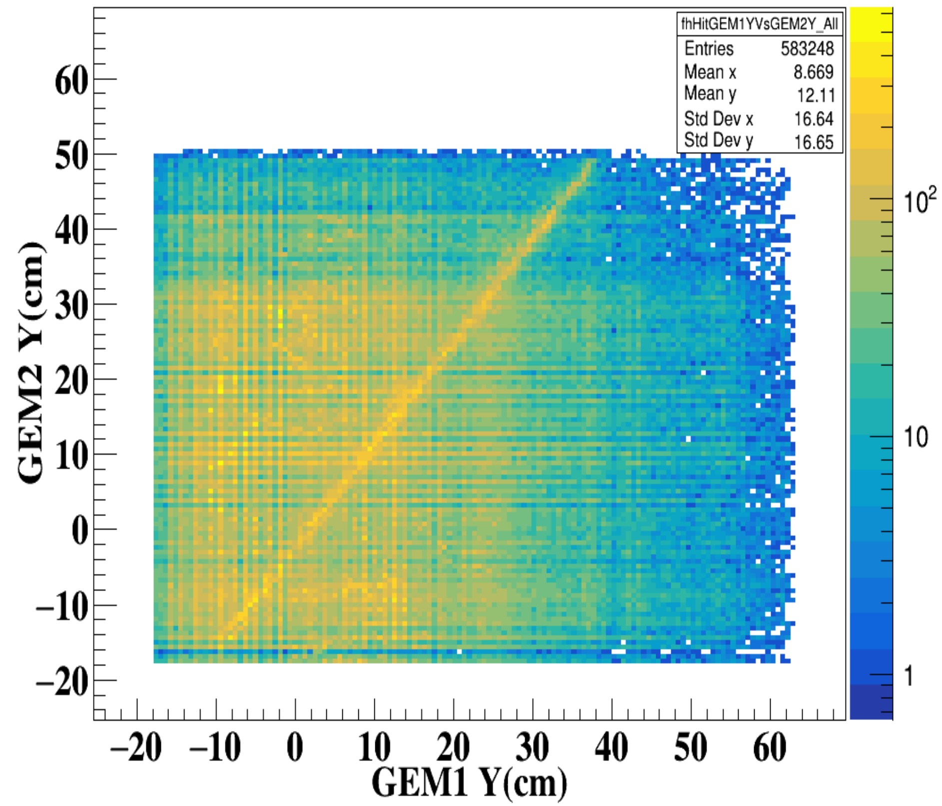
Preliminary

Results:8

Ar + Au at 1.7AGeV, Nov./Dec. 2019

Spatial correlation between GEM1 and GEM2 hits



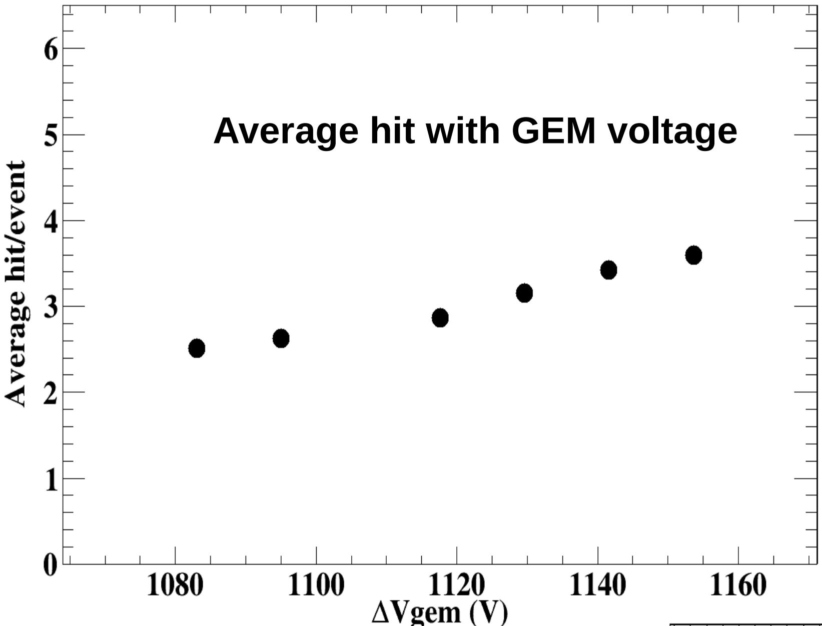


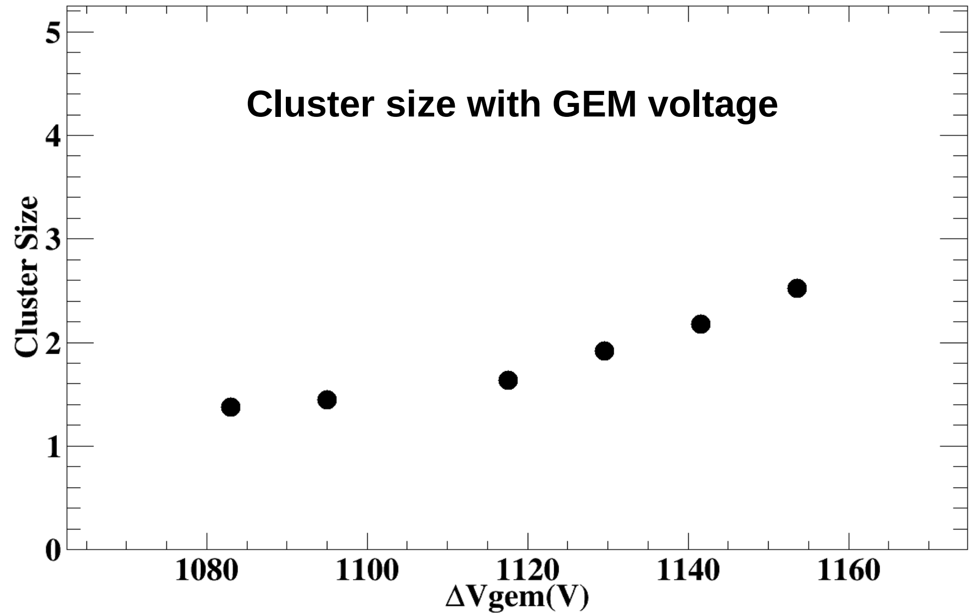
Preliminary

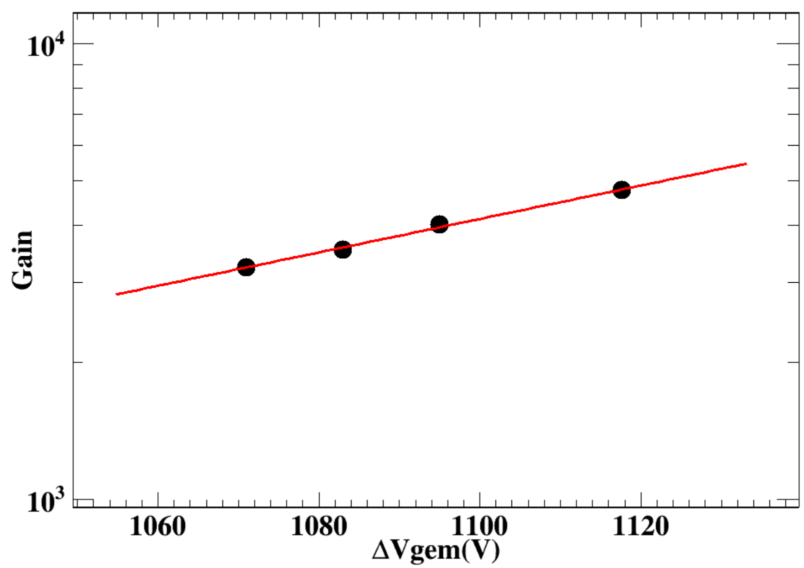
Results:9

Detector characteristics with GEM voltage

Ar + Au at 1.7AGeV, Nov./Dec. 2019







Gain with GEM voltage

Preliminary

Summary

- **Two chambers have been tested and preliminary results show promising performance**
- **Time resolution looks higher compare to our previous results (~13ns). More investigation ongoing.**
- **Hit reconstruction of mMUCH data has been done. Spatial correlation between GEM1 and GEM2 identified.**
- **Detector characteristics for different GEM voltage has been studied.**

Next Steps

- **Full track reconstruction**
- **Efficiency study of GEM modules**
- **High rate test in March 2020**
- **Test with MuCh FEB in Dec2020**

Acknowledgments

-> We very much acknowledge Christian Sturm (mCBM project leader) and the GSI CBM team for intense support and fruitful discussions.

-> We gratefully acknowledge BI-FCC for supporting this project.

-> The results presented here are based on the mCBM@SIS18 experiment, which was performed at the SIS18 facility at the GSI Helmholtzzentrum fuer Schwerionenforschung, Darmstadt (Germany) in the frame of FAIR Phase-0.

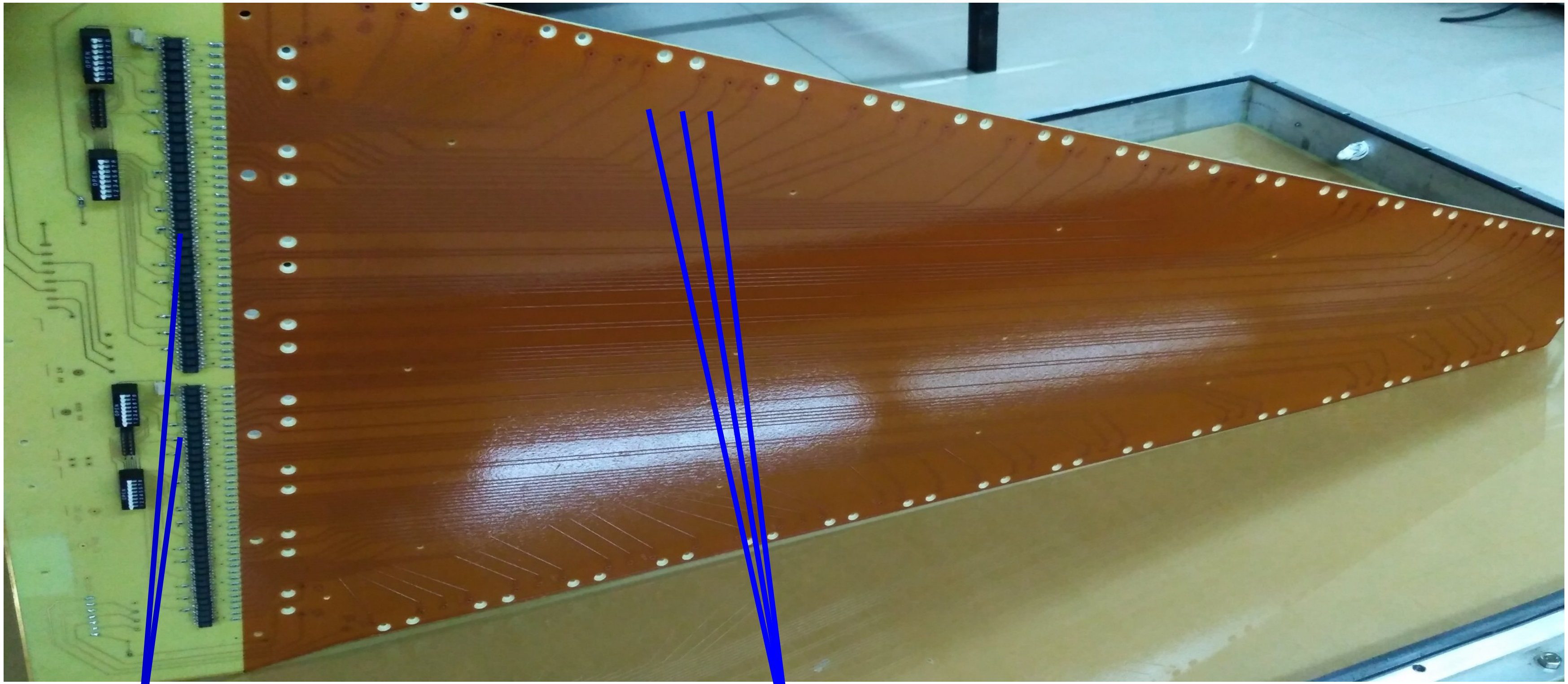
References

- 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
- https://iopscience.iop.org/article/10.1088/1748-0221/12/01/C01053/pdf

Thank you for your kind attention

Backup

Drift PCB

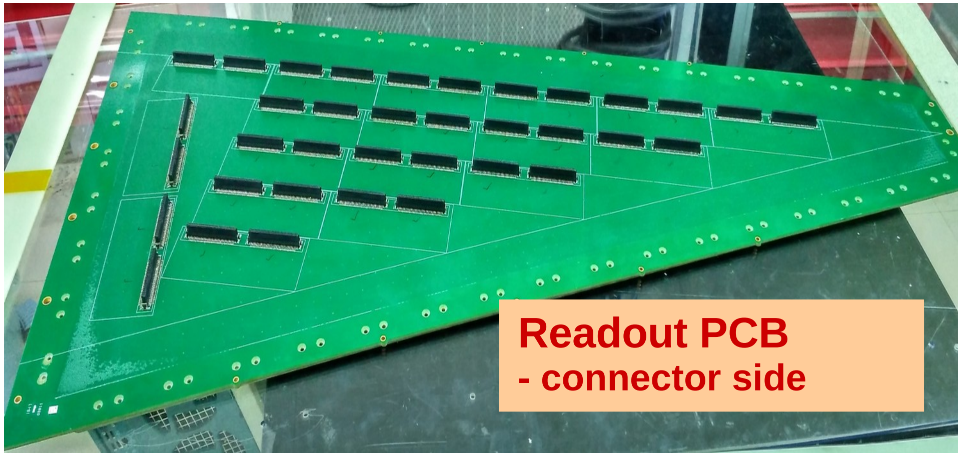


Opto-coupler

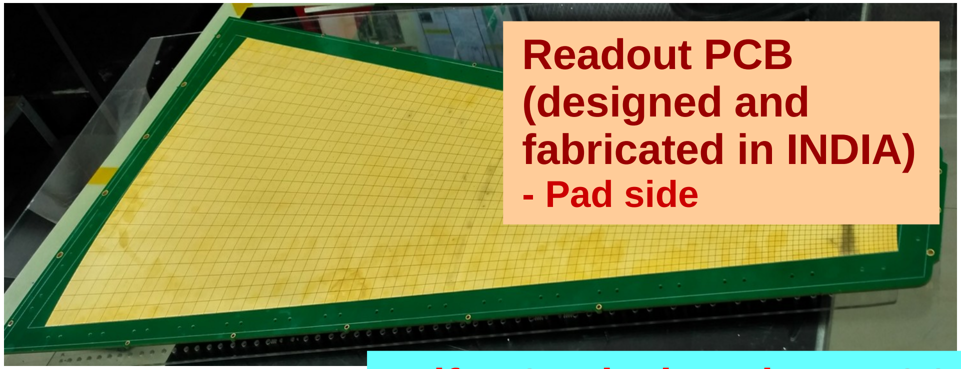
HV lines for individual segments of GEM

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

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

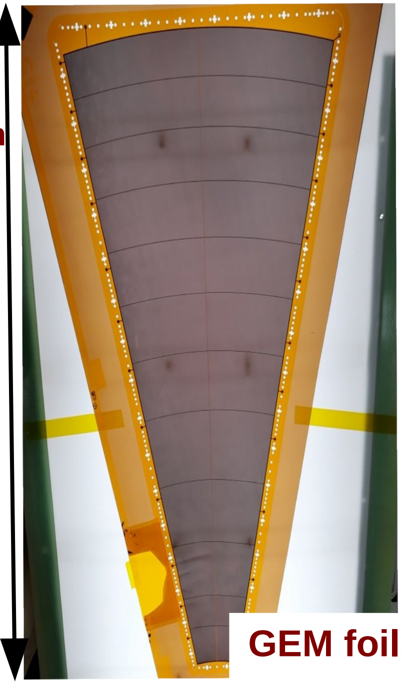
Readout PCB

--> ~2200 pad with gradually increasing sizes

--> total front end board needed = 18

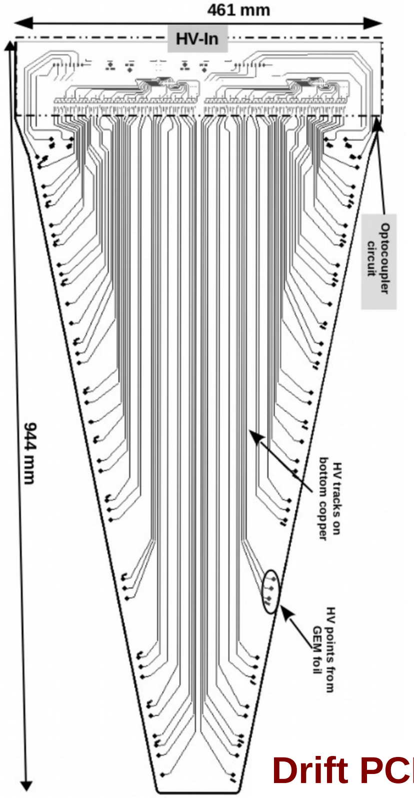
24 segments on top side
One HV connection for each segments

~80cm



GEM foil

Schematic of HV lines for GEM foil on the drift PCB

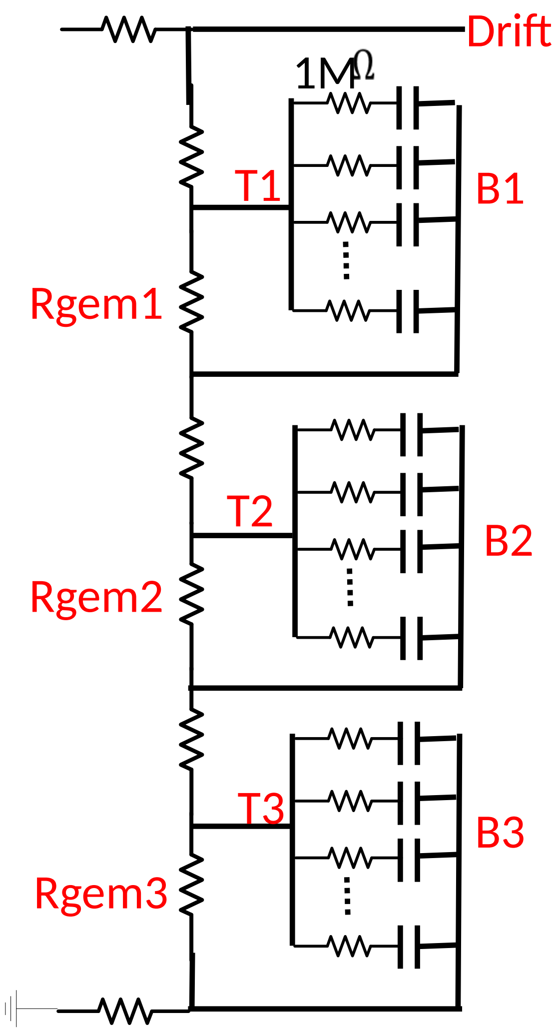


Drift PCB

Two chambers were assembled using “NS2” technique

Handling Short Segment

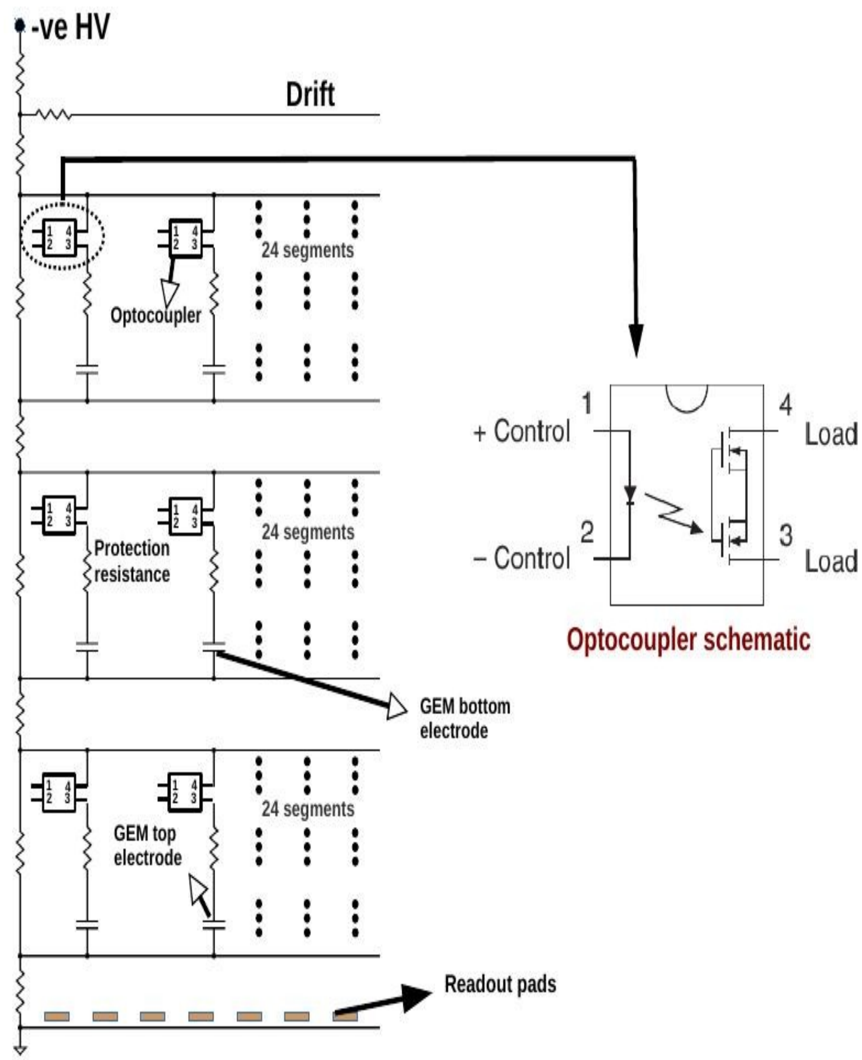
Conventional approach



24 segments

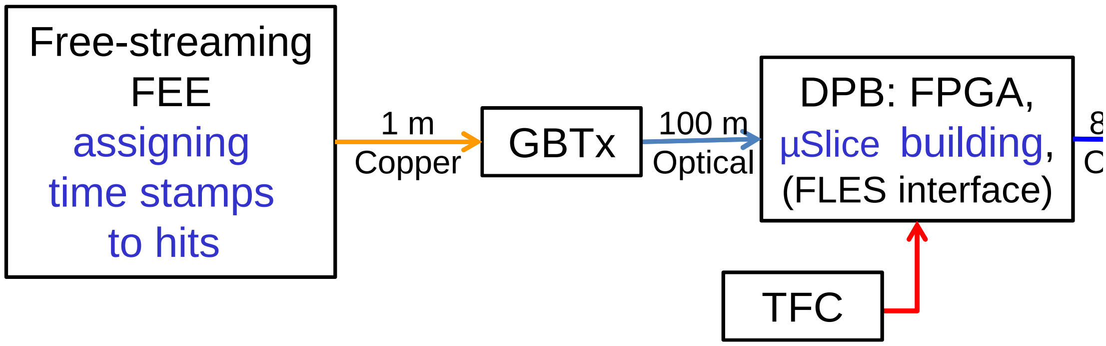
⇒ 72 optocoupler switches/ module

Optocoupler based design:



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

CBM data transport and processing



FPGA : Field Programmable Gate Array
DPB : Data Processing Board
TFC : Timing and Fast Control Syst.
FLES : First Level Event Selector
GBTx : CERN rad.-hard interface ASIC

µSlice (µS) : self contained data block for a subset of the expe
depends on degree of data time sorting

Timeslice : collection of µS, self contained data block for the fu
time interval, includes overlap to avoid edge losses

FAIR GmbH | GSI GmbH C.Sturm, mCBM

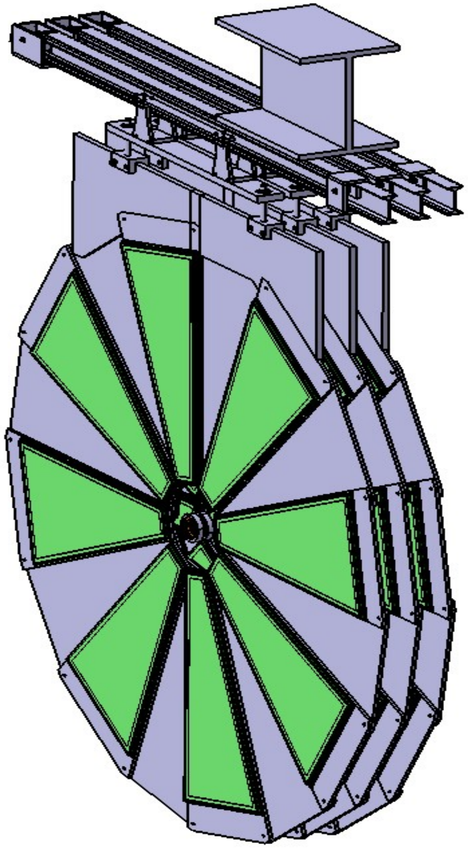
Sector Layout Of MUCH

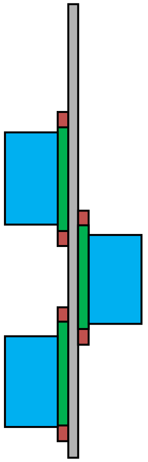
=> SIS100 setup => 4 station + 4 absorbers
=> First two stations :
--> GEM detector technology
--> due to high particle rate

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