GEM Detector Development for high rate detectors for MuCh in CBM experiment @FAIR

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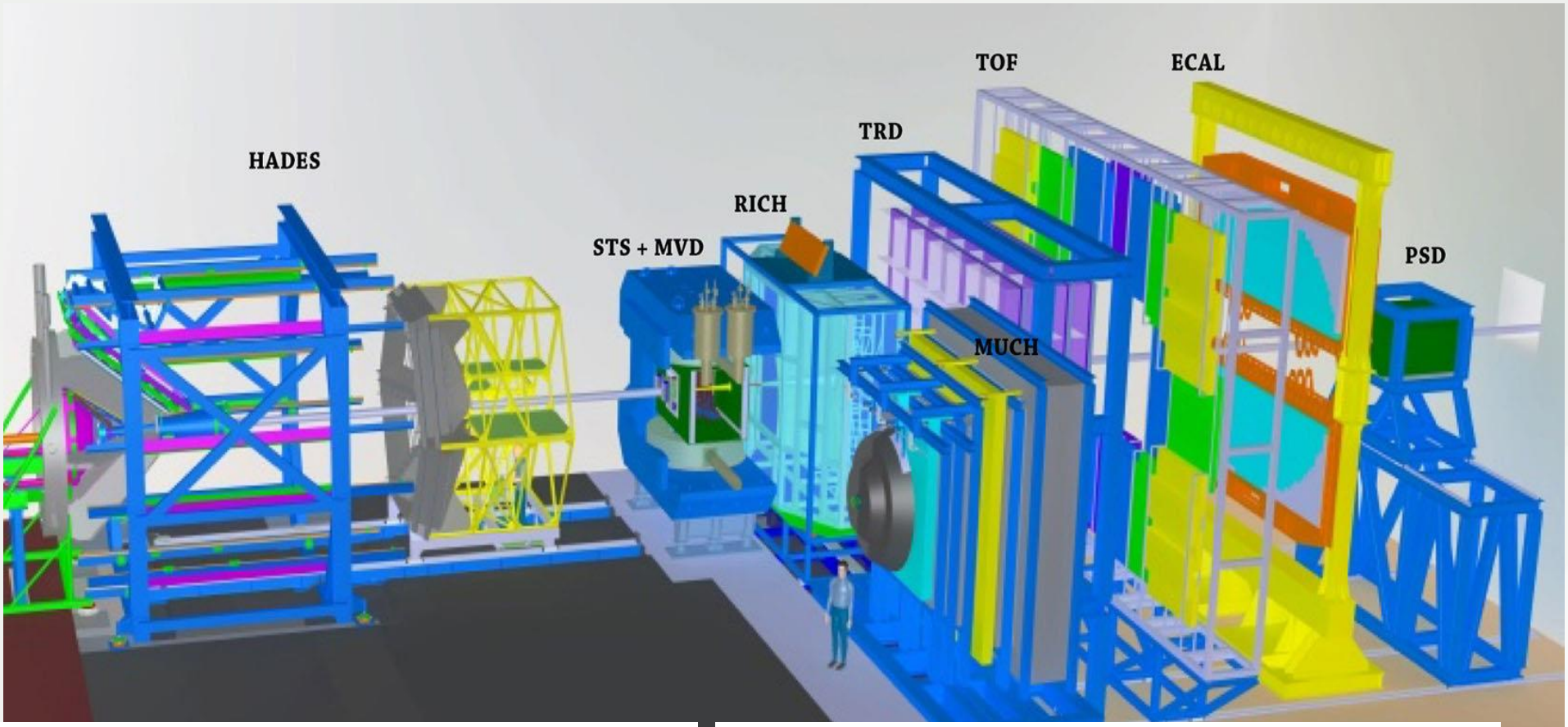
(For MUCH India Collaboration)

Compressed Baryonic Matter Exp.(CBM) @ FAIR



Fixed target experiment

Beam Energy

@SIS100

Beam energy: 2-14A GeV for heavy ions and 2-29A GeV for proton beams

@SIS300

Beam energy: 2-35A GeV for heavy ions and 2-89A GeV for proton beams

➔**Interaction rates will go up to 10 MHz**

Physics goals :

– Designed to explore QCD phase diagram at moderate temperature and high net baryon density : Eqn of state, Deconfinement phase transition, etc.

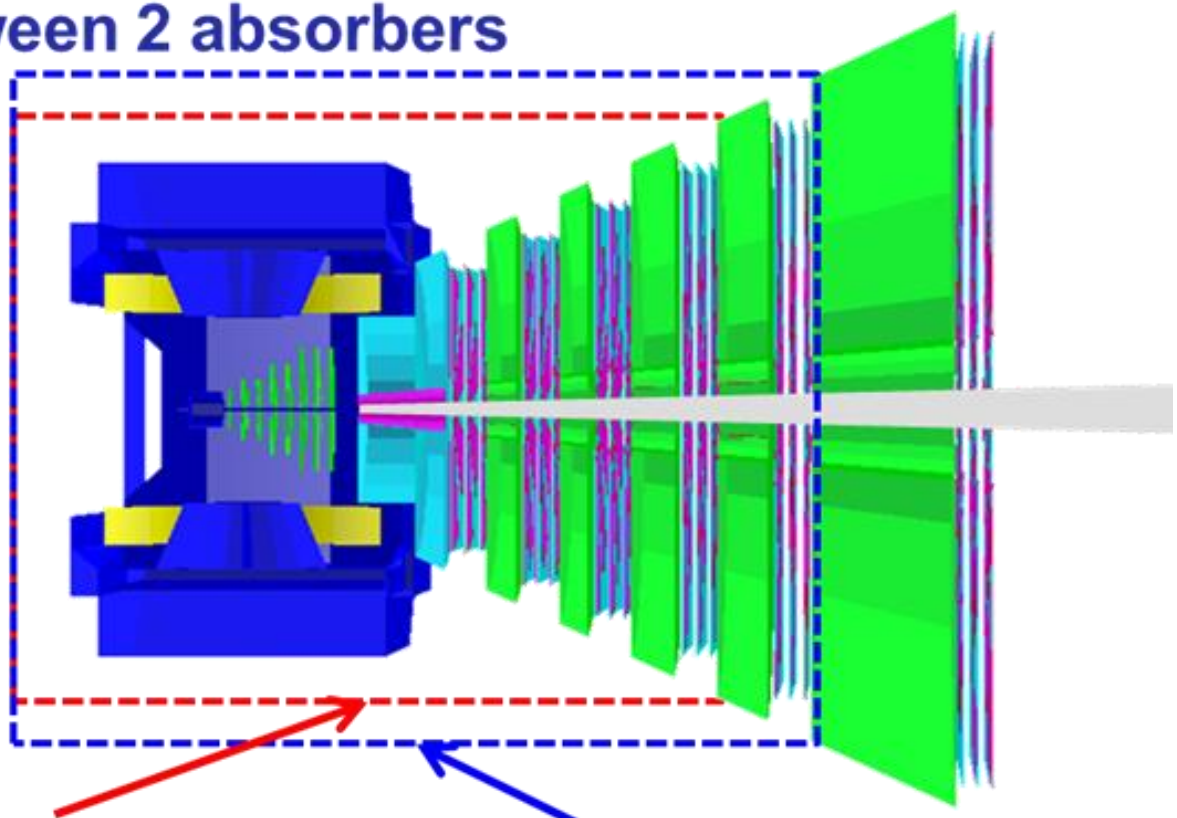
– Measure rare diagnostic probes :
multi-strange hyperons, charmed particles and vector mesons decaying into lepton pairs with unprecedented precision and statistics

Ref: Eur. Phys. J. A, 53 (3): 60, 2017

The Muon Chamber (MuCh) System @ CBM

60 (C) + 20 Fe + 20 Fe + 30 Fe + 35 Fe + 100 Fe (cm)
30 cm gap between 2 absorbers

GEM detectors for the first two stations



LMVM @ SIS100 + ToF

LMVM @ SIS300 + ToF

→ The main job of MuCh is to measure dimuon signals arising from the decay of LMVM and J/psi generated in nucleus-nucleus collisions.
→ The alternating detector stations will carry out the task of muon track reconstruction.

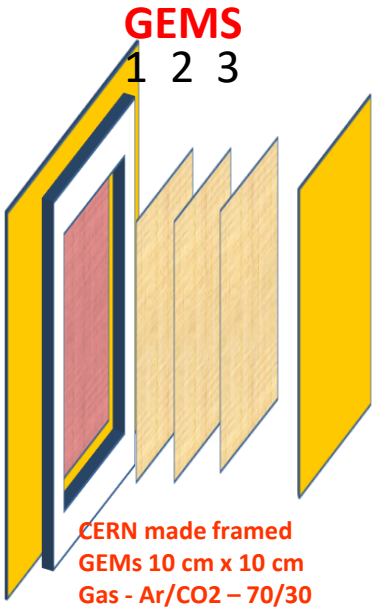
Challenges in Muon detection @CBM

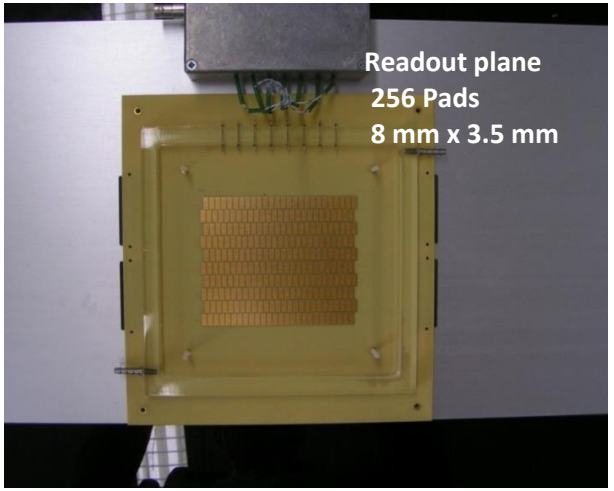
Main issues:

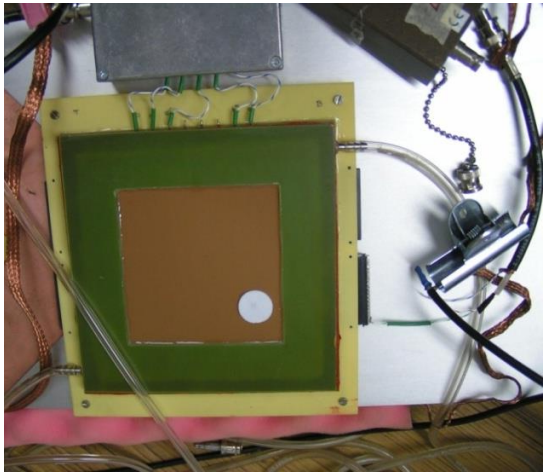
- High collision rates ~ 10 MHz
- The first plane(s) have a high density of tracks
  High granularity ~ average hit rate is about 0.4 hit/cm^2
- Should be radiation resistant –
  high neutron dose ~10^{13} n.eq./sq.cm/year
- Large area detector – with modular arrangement
- Data to be readout in a self triggered mode
  -- a must for all CBM detectors.
  -- and event reconstructed offline by grouping the timestamps of the detector hits.

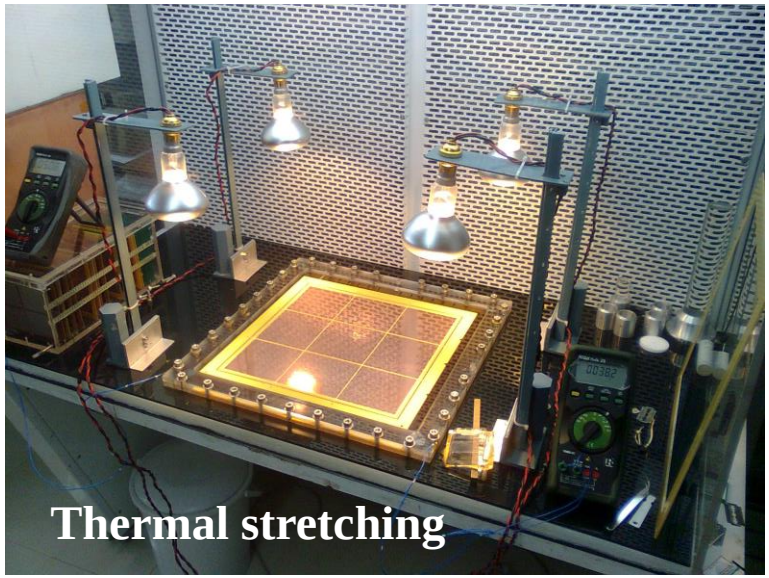
R&D with small size prototypes

Building small and medium size triple GEM prototypes at VECC

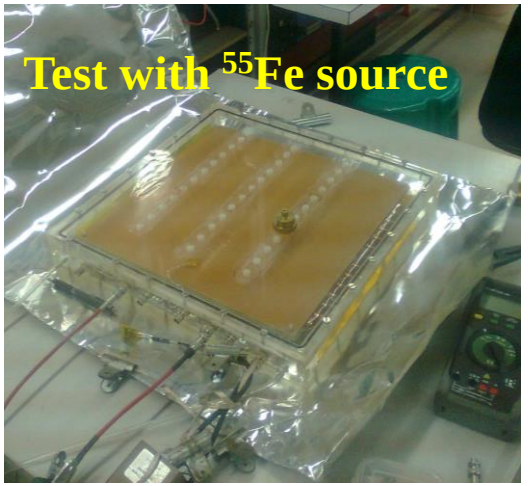


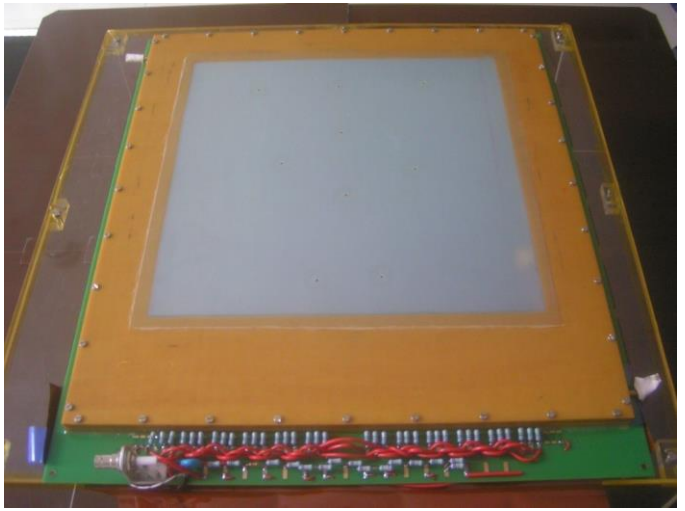






Results published in
2014 JINST 9 C06004





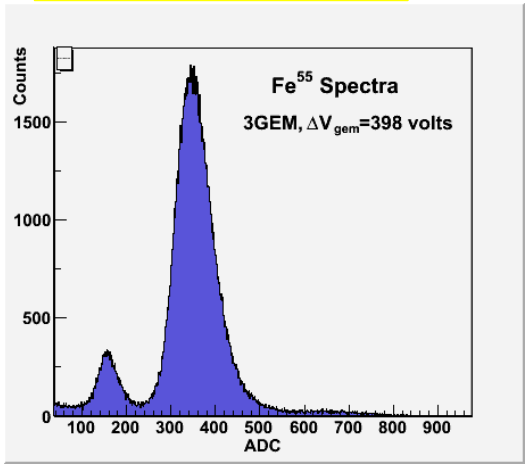
31 cm x 31 cm triple GEM module

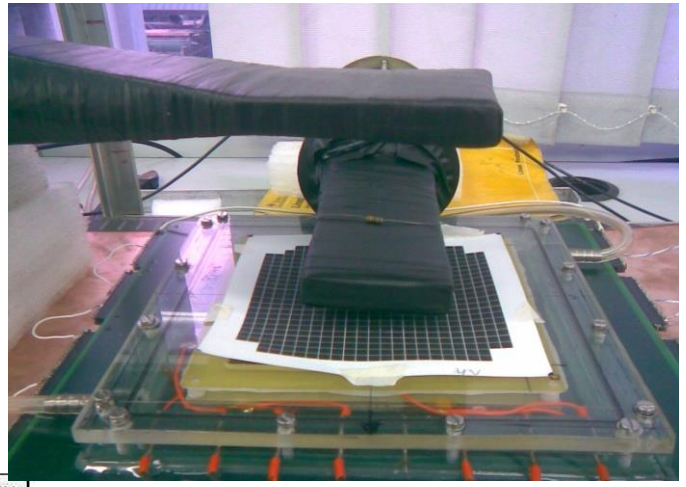
Results from Lab tests at VECC (using conventional electronics)

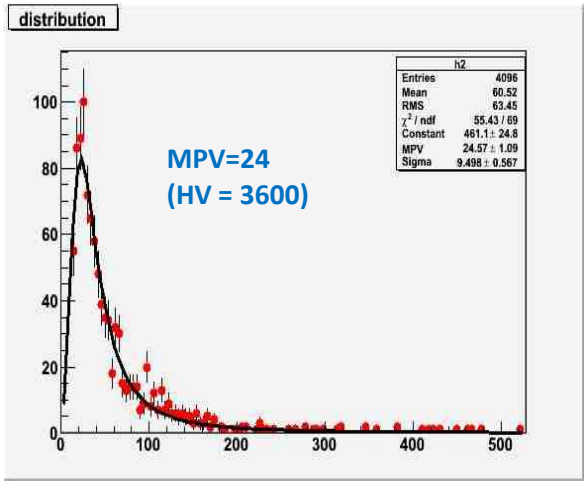
gap config : 3/1/1/1.5

Test with Cosmic muons in VECC lab

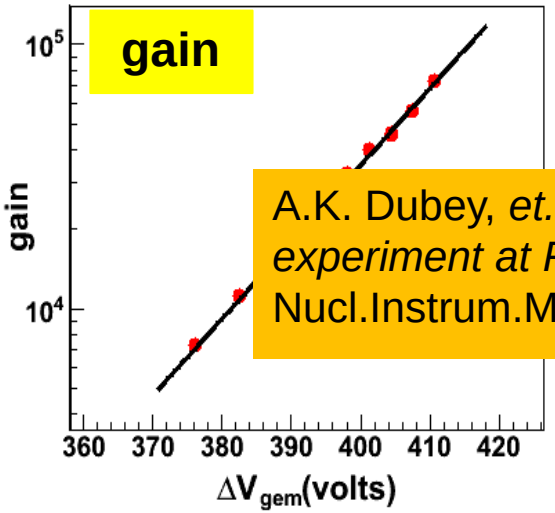
X-ray source

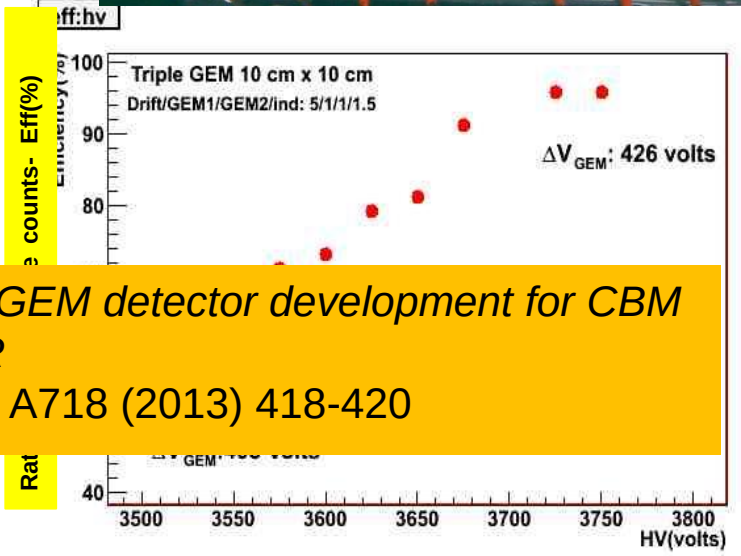


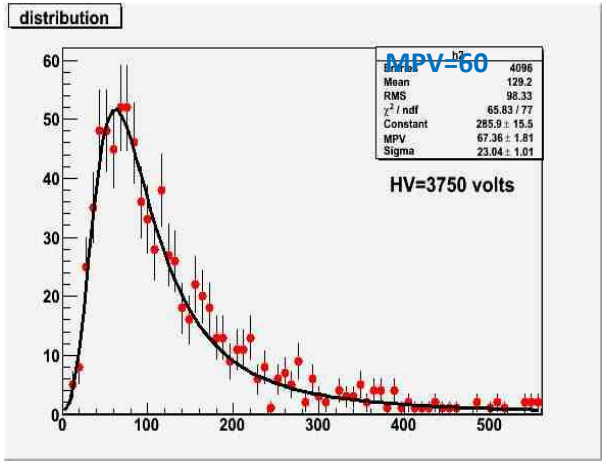




gain





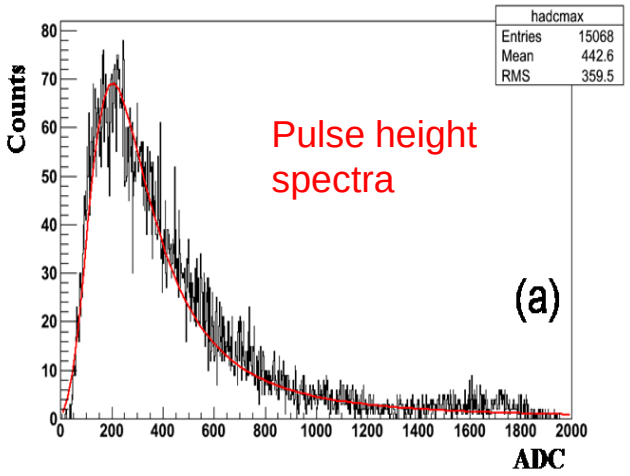


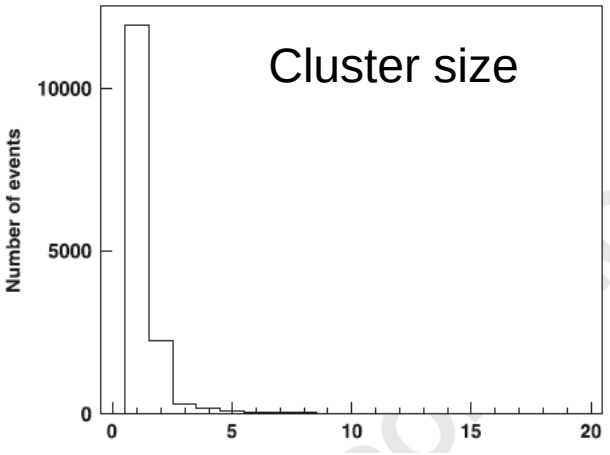
A.K. Dubey, *et. al*. *GEM detector development for CBM experiment at FAIR*
Nucl.Instrum.Meth. A718 (2013) 418-420

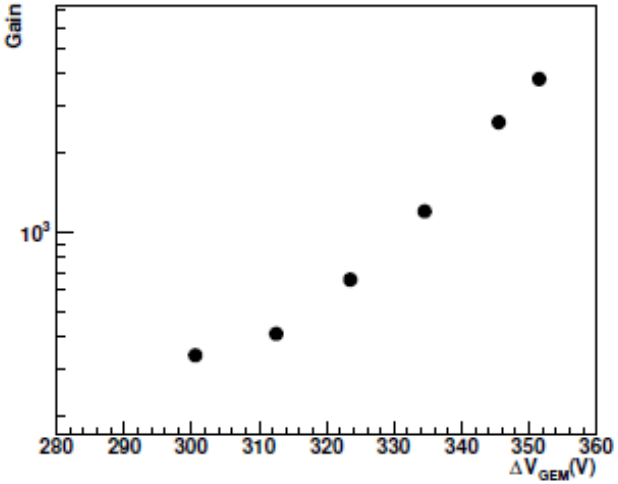
Test Results(10 cm x 10 cm)

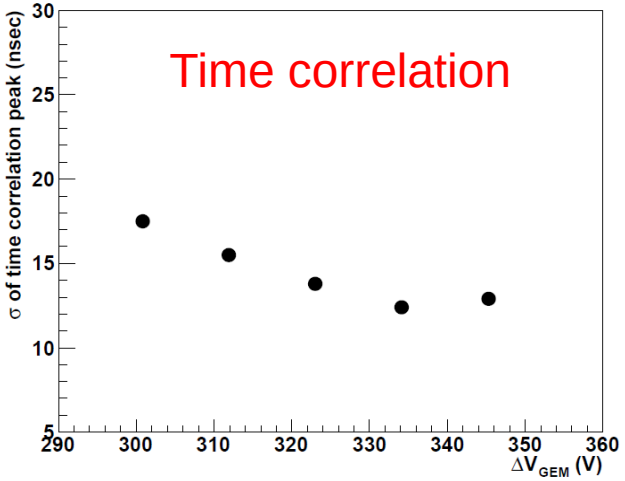
self triggered mode nXYTER electronics, (H4 beamline at SPS),

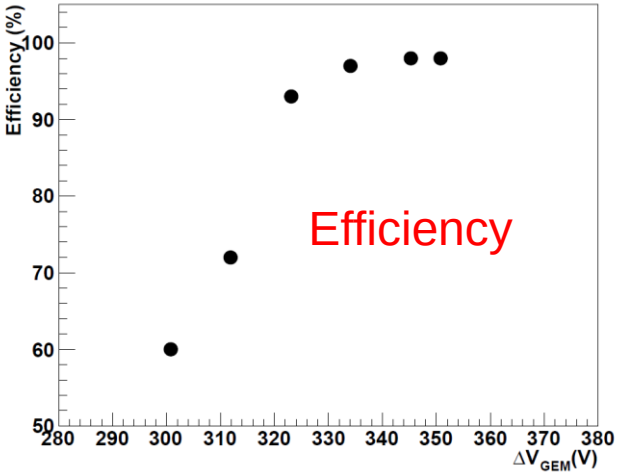
-- Ar/CO(70/30) has been the gas mixture.

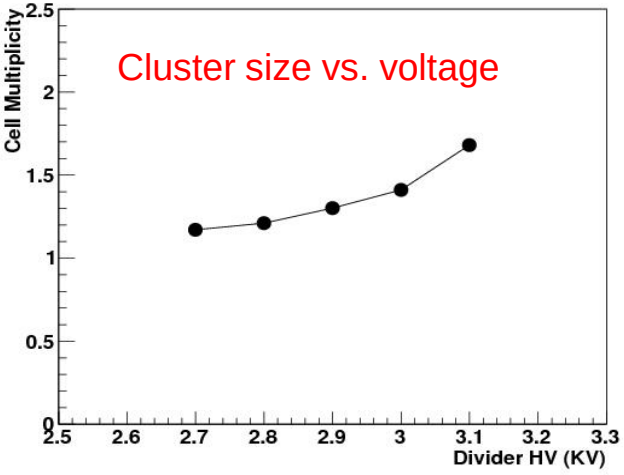








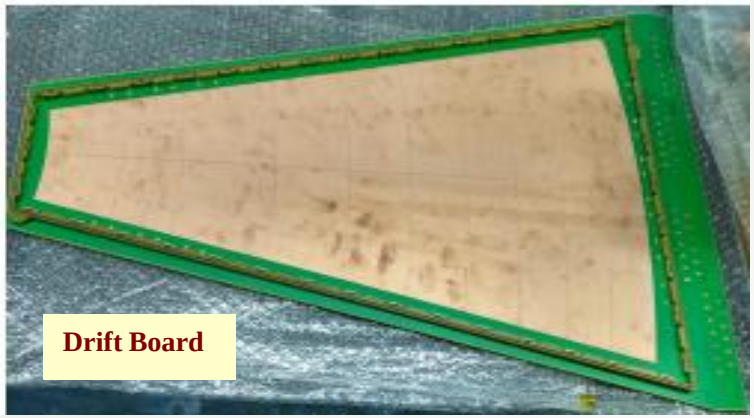




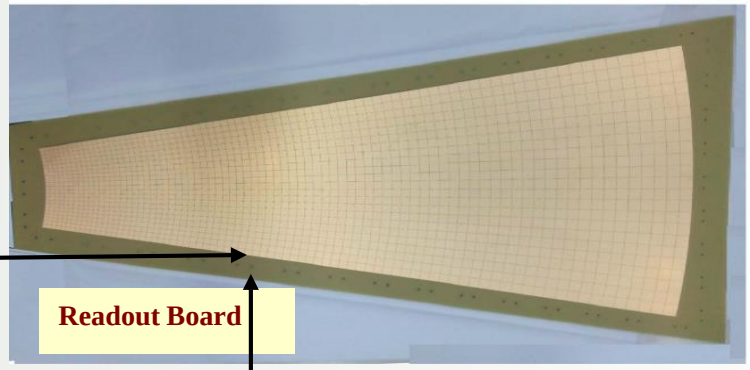
A.K. Dubey, et.al. NIMA 755(2014), 62-68

Building and testing Real-size prototypes

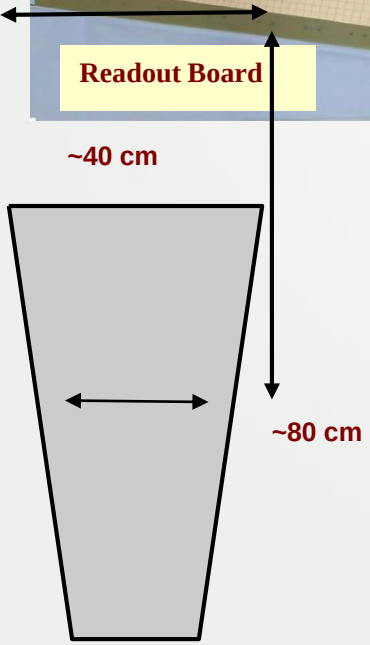
Assembly of Real-size Chamber at VECC



Drift Board

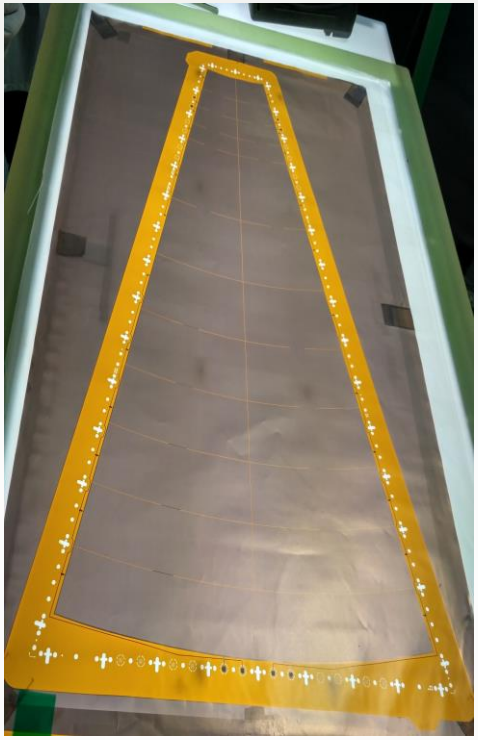


Readout Board

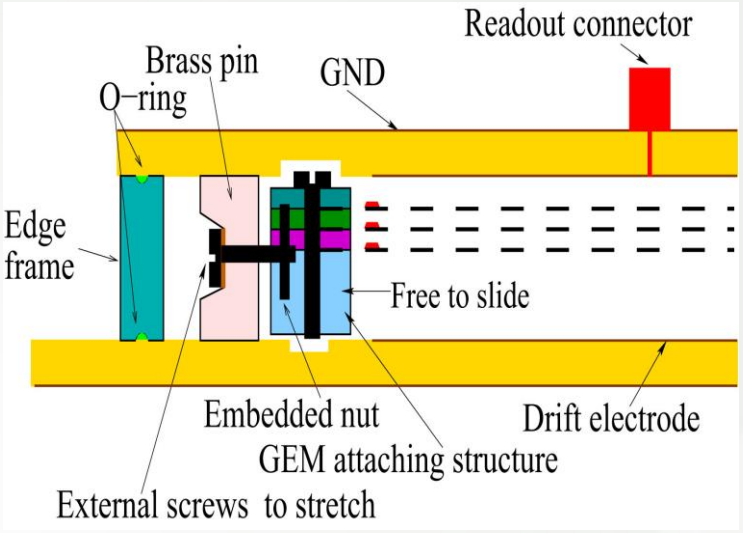


Dimensions

Segmented GEM foil

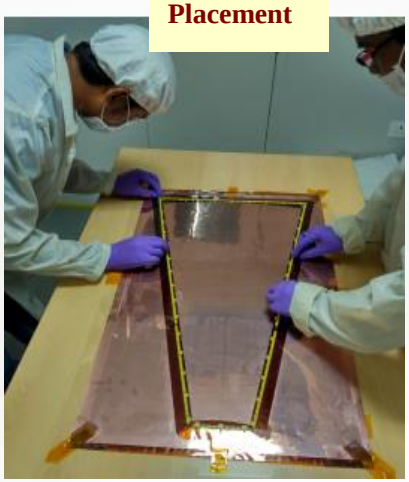


NS2 stretching

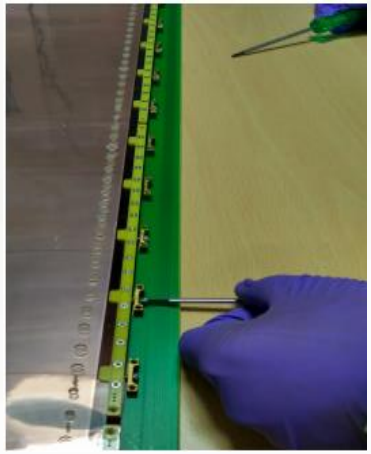


Inspection

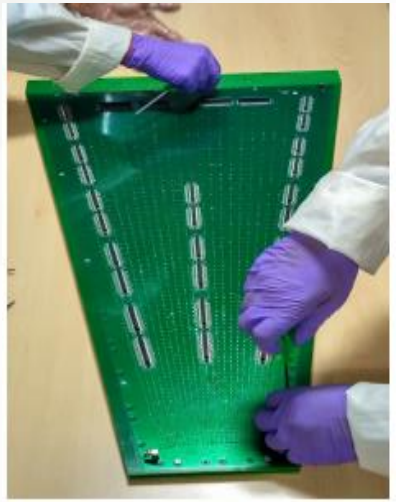
Placement



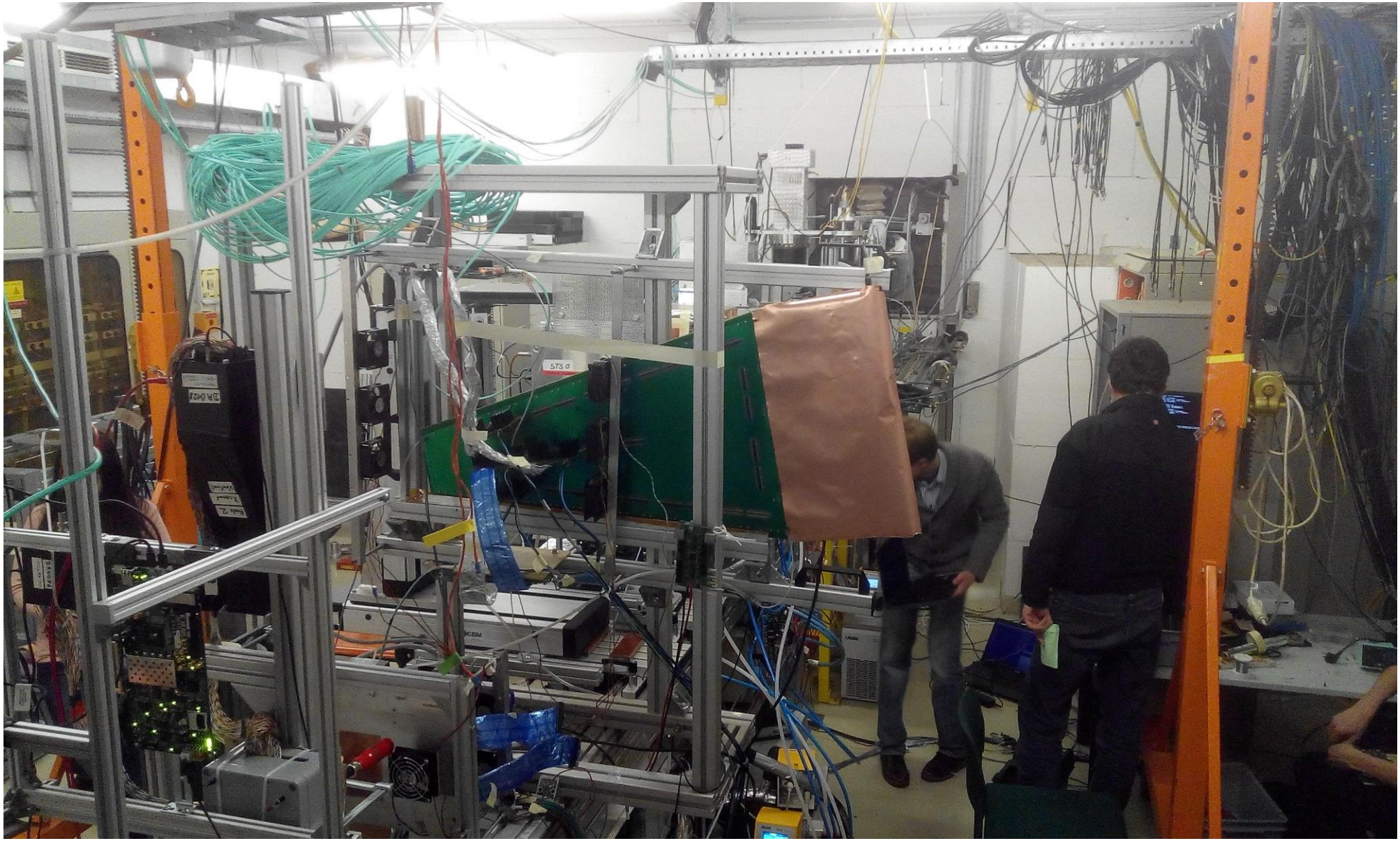
NS2 stretching



Ready Chamber

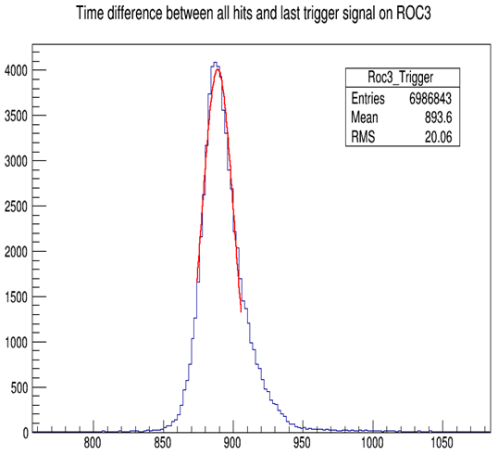


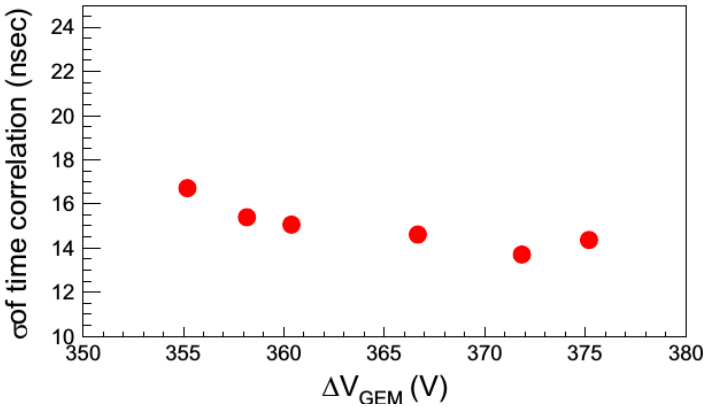
Beamtest of real size prototype at JESSICA@COSY, Juelich (2014)

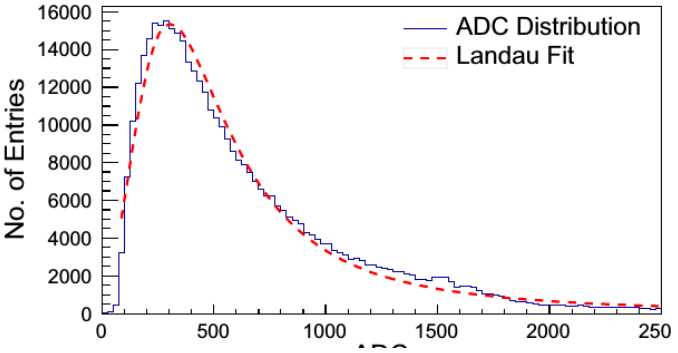


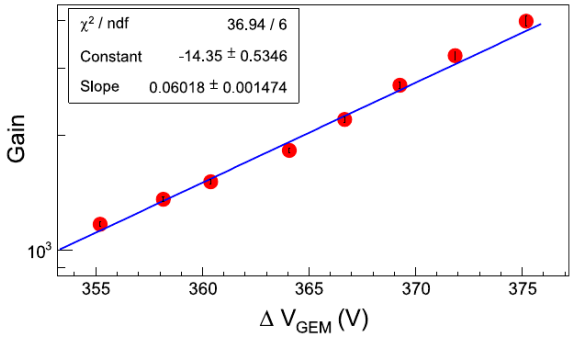
BeamTest Results First Real-size Prototype

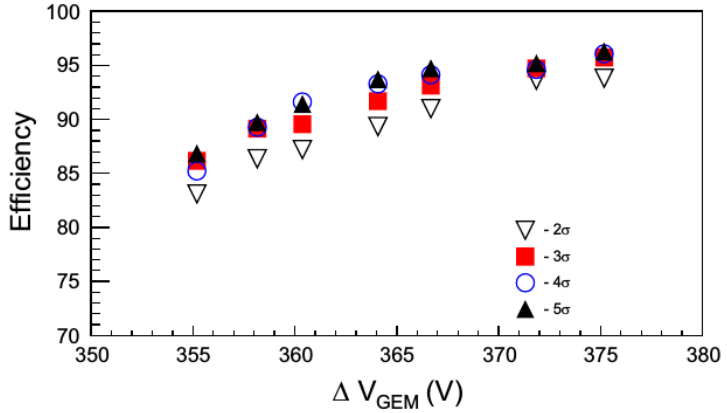
(self triggered mode)

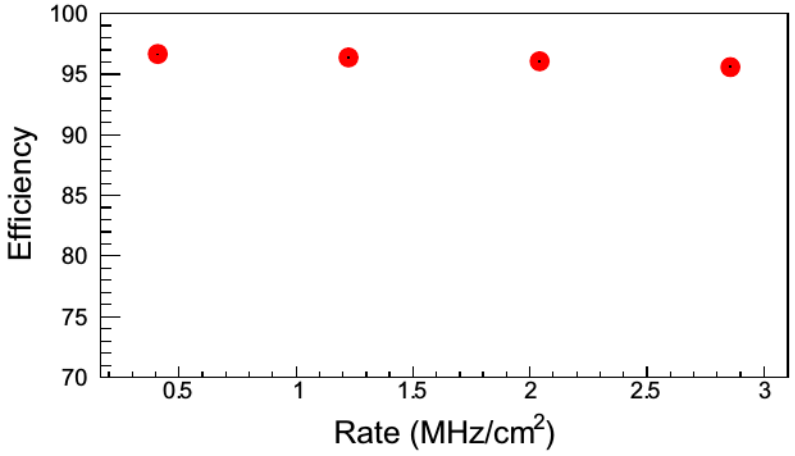


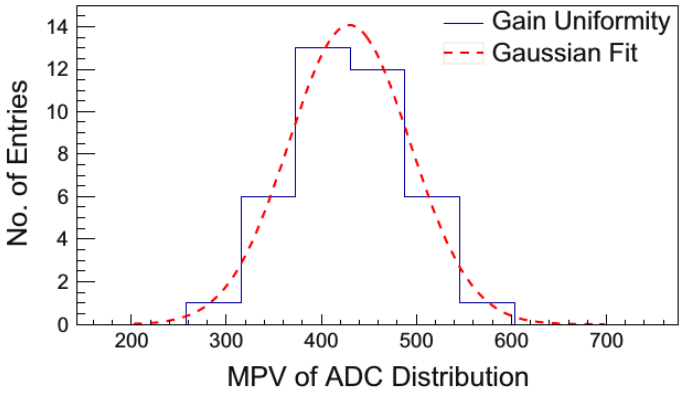






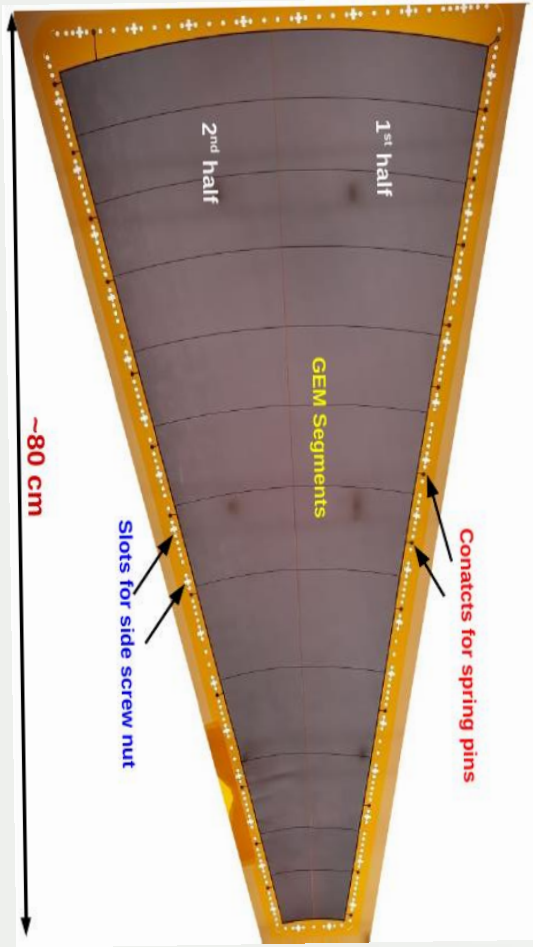


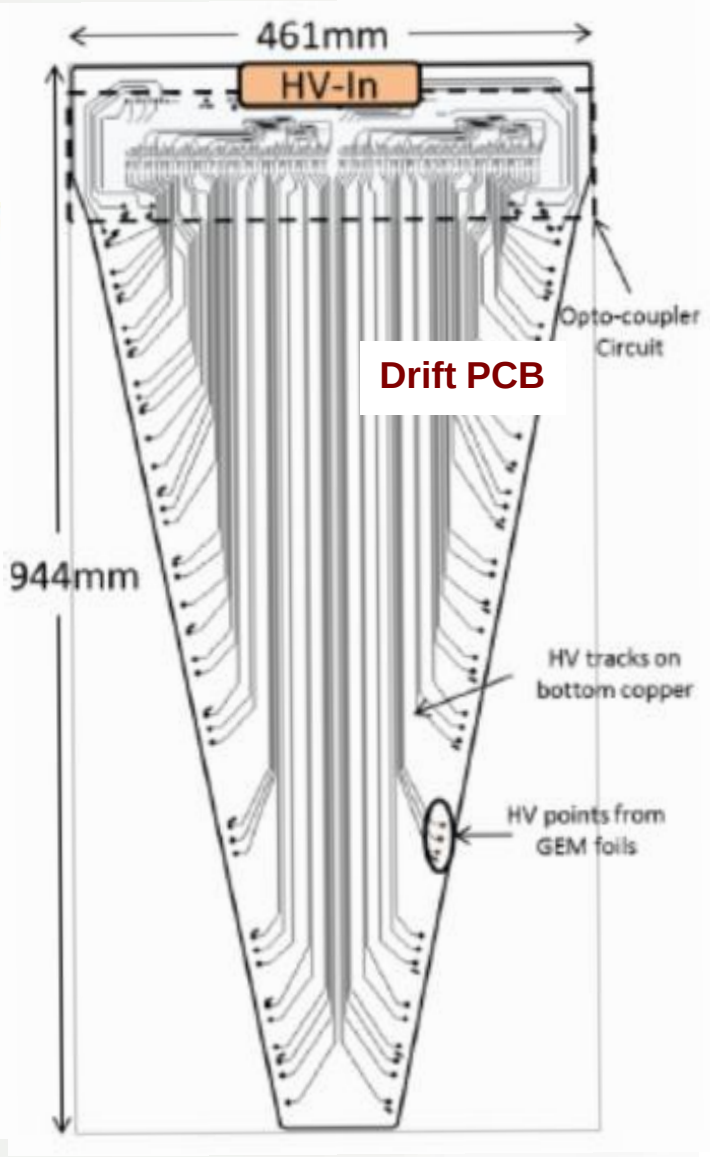




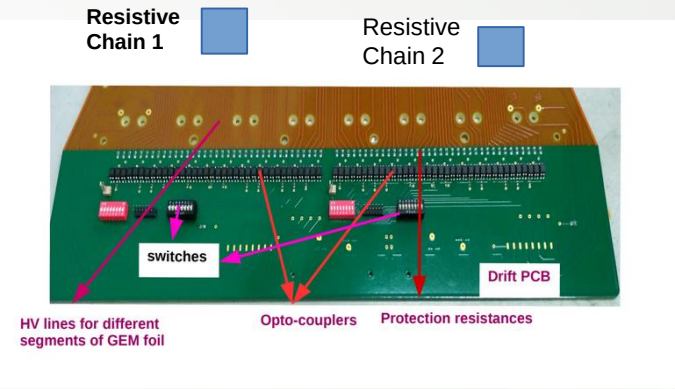
Optocoupler Design for GEM

Schematic of HV lines for GEM foil on the drift PCB





– 24 segments on top side
– One HV connection for each segments
– Optocoupler based biasing scheme



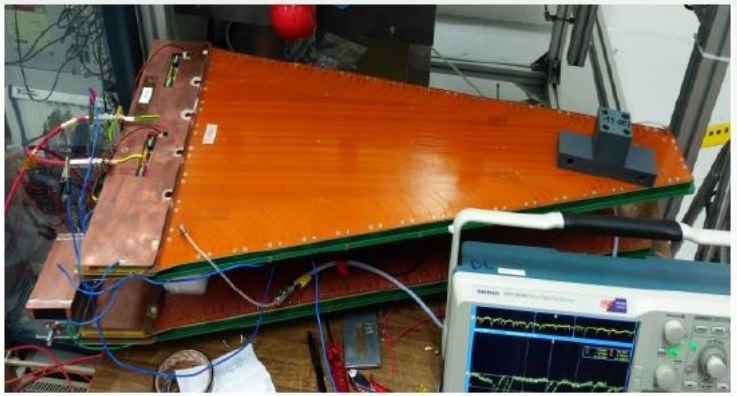
Readout PCB (first station of CBM-MuCh)
--> ~2200 pad with gradually increasing sizes
--> Total front end board needed = 18

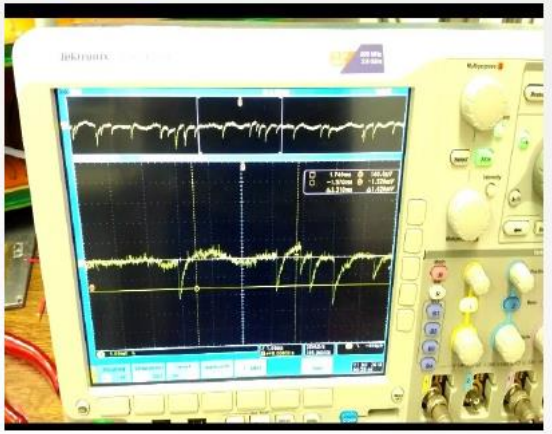
--> Active area
Dx1 = ~ 7.5 cm
Dx2 = ~ 40 cm
Dy = ~ 80 cm

In case of any short, We identify and disconnect the particular Segment zone – i.e a set of three Optocouplers(top, middle and bottom).

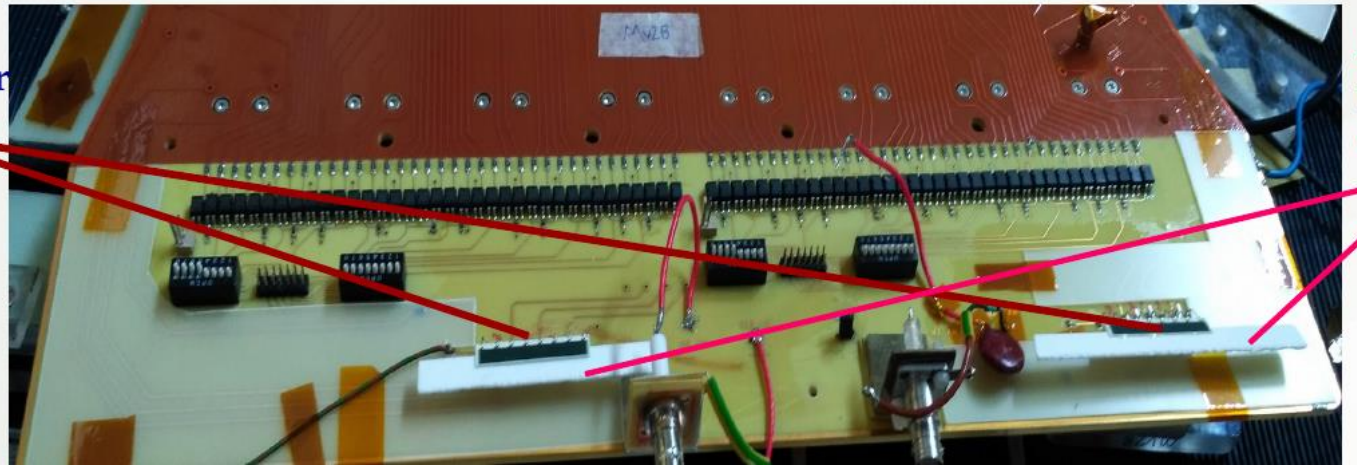
Ref: A. Kumar, et.al., Nucl. Inst. and Meth. A 958, 162905 (2020)

Testing Module at GSI With Radioactive Source



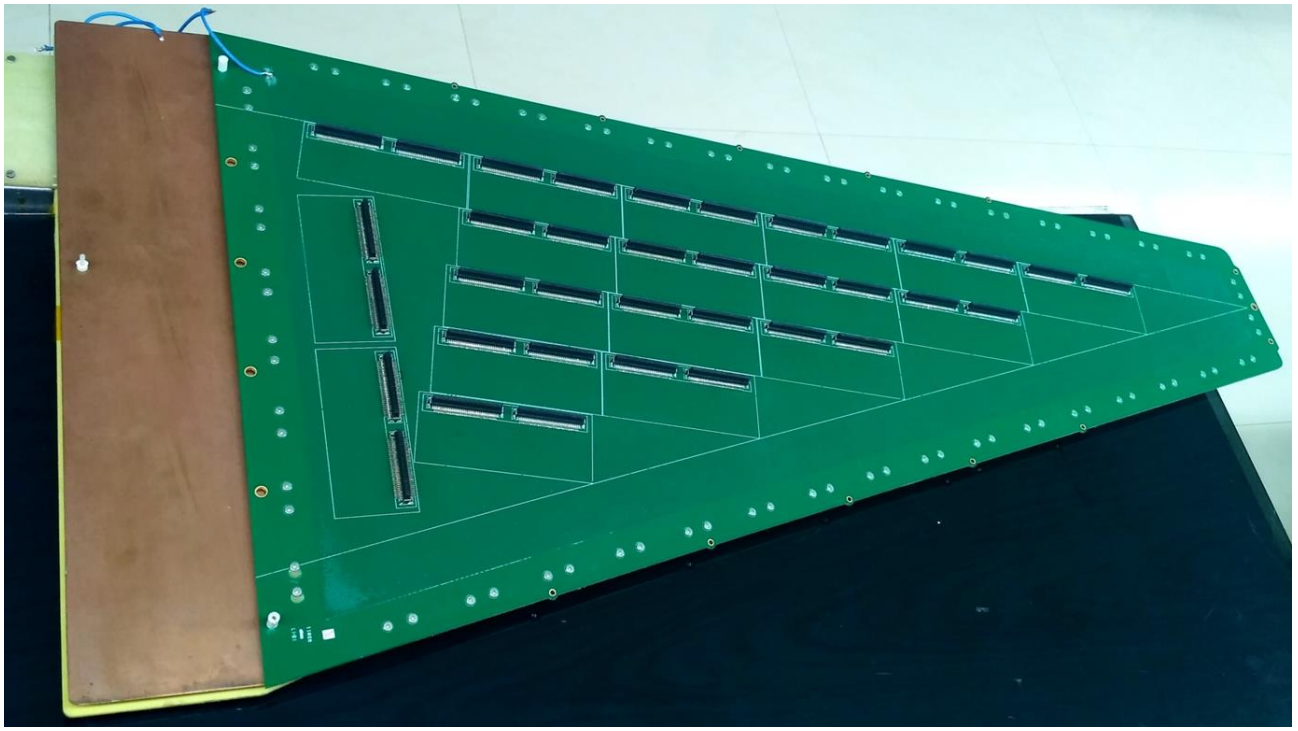


Ceramic Divider



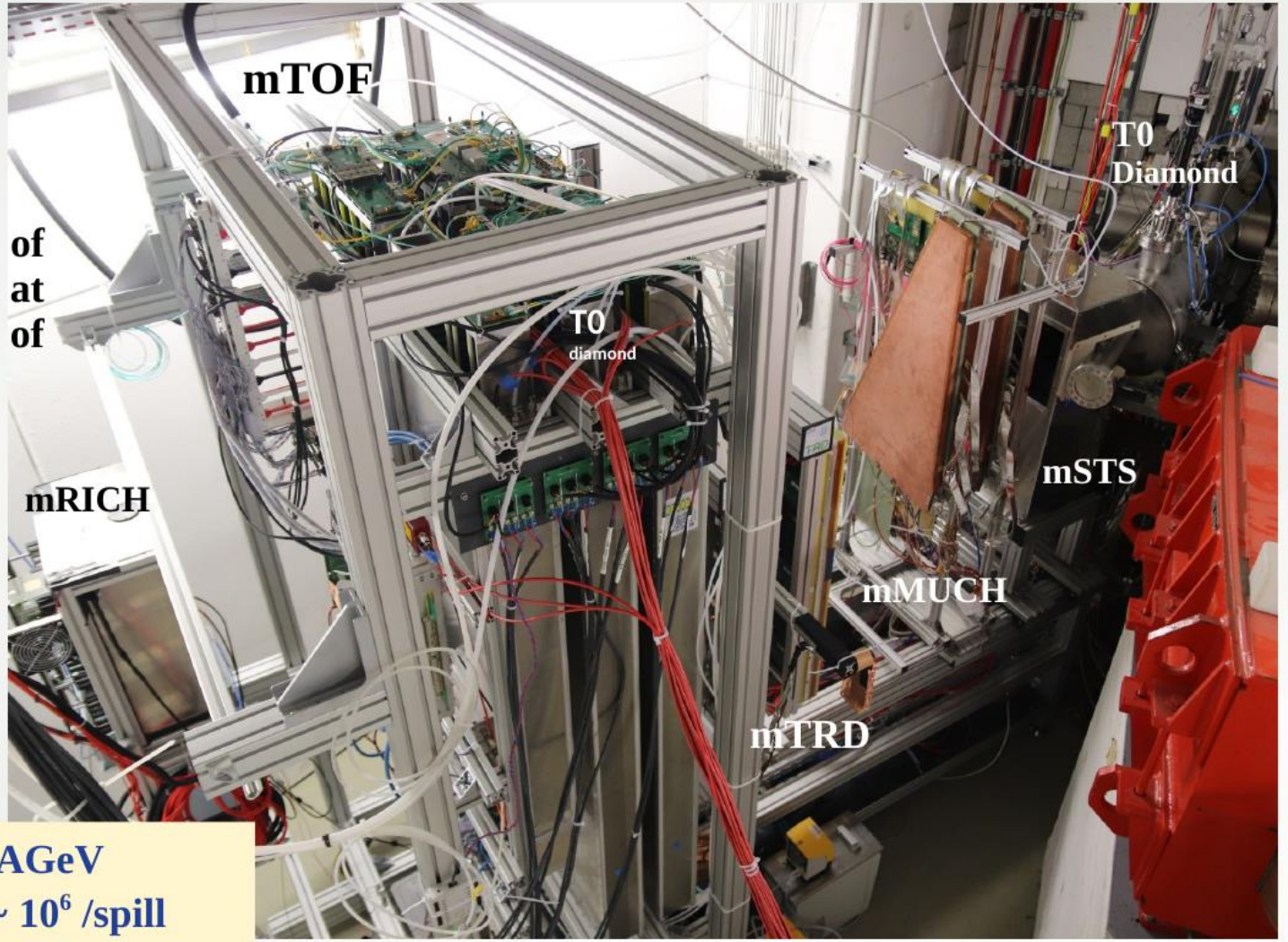
Alumina sheets for cooling the ceramic divider

Commissioning GEM detector modules in mini-CBM at SIS18 beamline at GSI



Picture of mCBM Setup

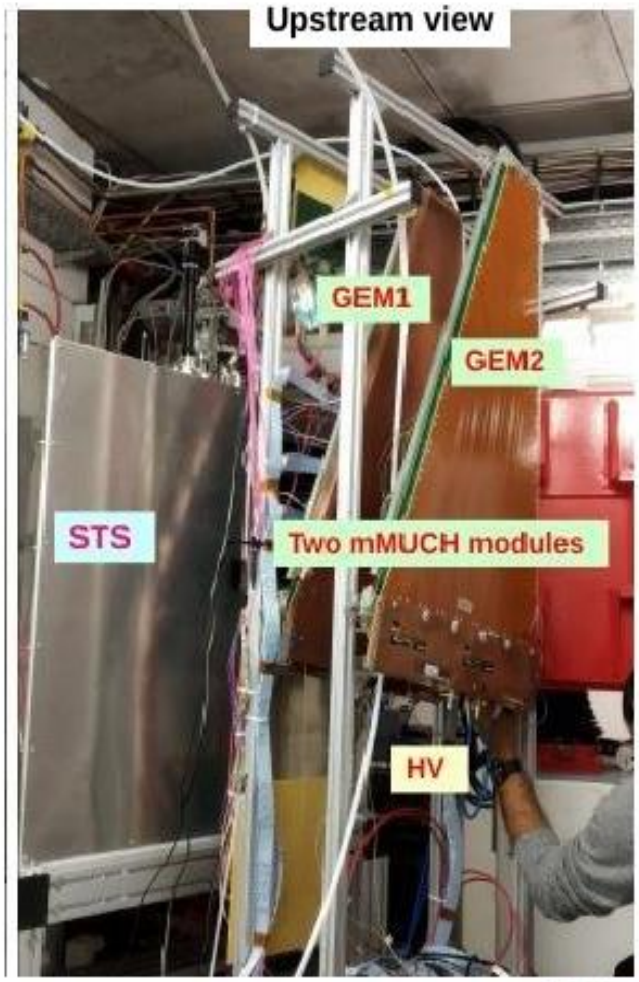
mCBM setup as of Dec. 2019, located at the SIS18 facility of GSI

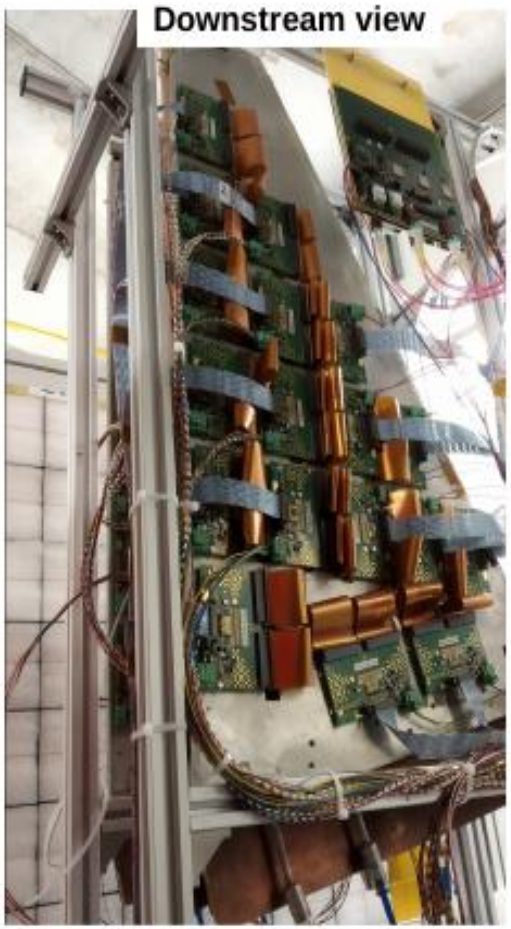


- **Ar + Au @ 1.70 AGeV**
- **Beam intensity ~ 10^6 /spill**
- **Target thickness 0.25 mm**

Participation in mini CBM experiment → FAIR Phase-0 program

Picture of mMuCh Setup





FEBs attached to the Al-cooling plate

FEB

LVDB

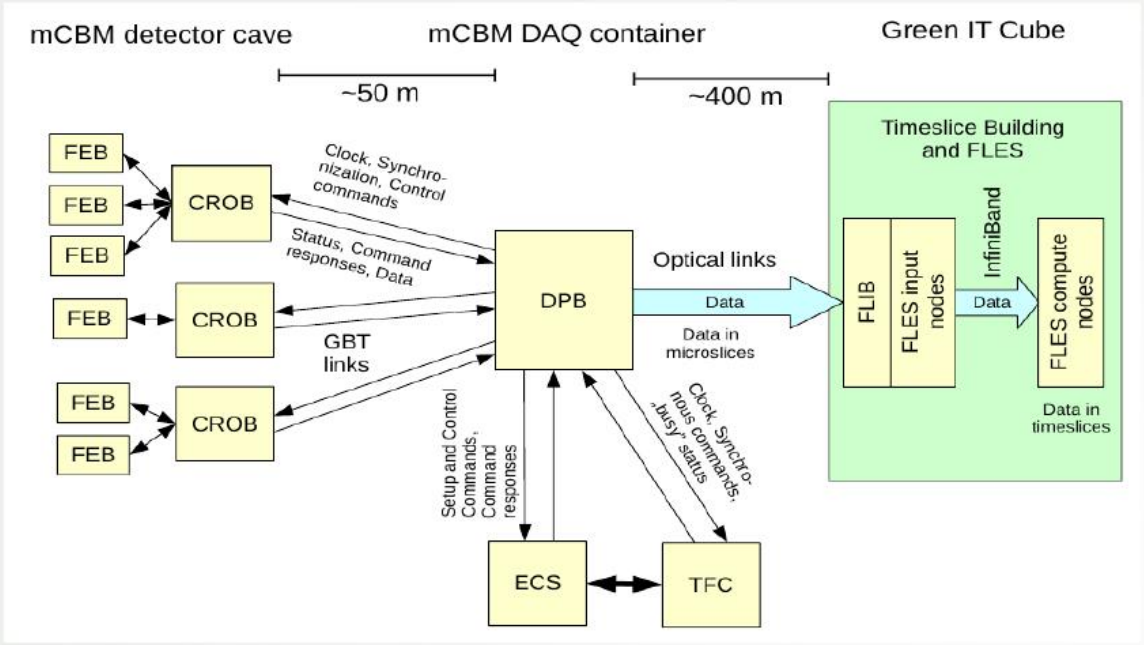
Z-position of MUCH
GEM1 : ~84 cm
GEM2 : ~106 cm

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

Minimum pad size = ~4 mm
Maximum pad size = ~17 mm

GEM1 acceptance : 17 FEBs
GEM2 acceptance : 10 FEBs

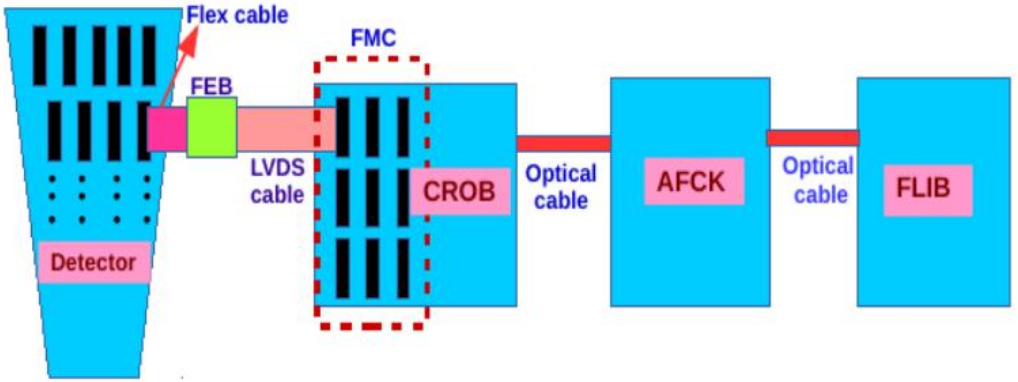
mCBM DAQ



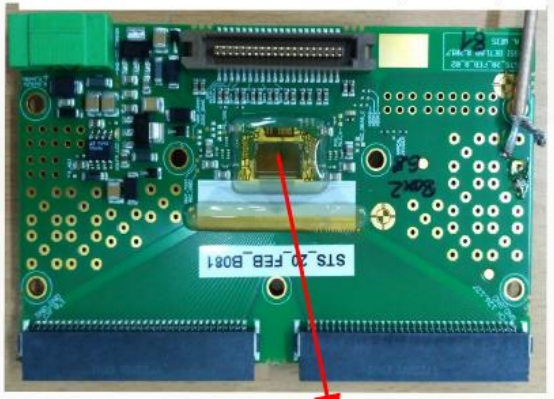
STS/MuCh-XYTER

-> Self-triggered electronics
-> 128 channels + 2 test channels
-> Can handle average hit rate ~250 kHz/channel
-> Dynamic range = 100 fC
-> Provides both timing and ADC information
-> 5 bit flash ADC
-> Time resolution ~4-5 ns
-> Heat generated = ~2-3 W / FEB

One module require 18 FEBs
Heat generated for one module = 2.5 x 18 = 45 W



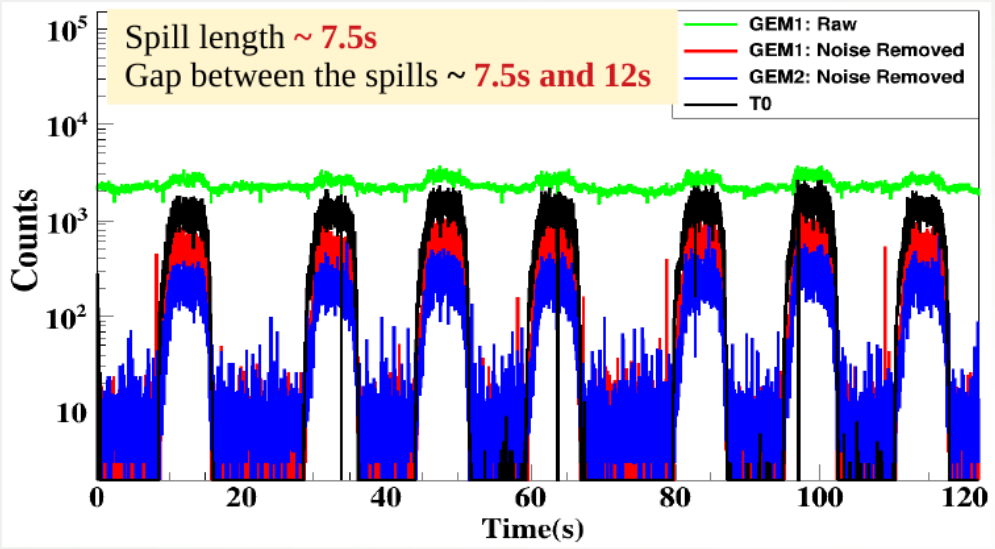
Front-End-Board (FEB)

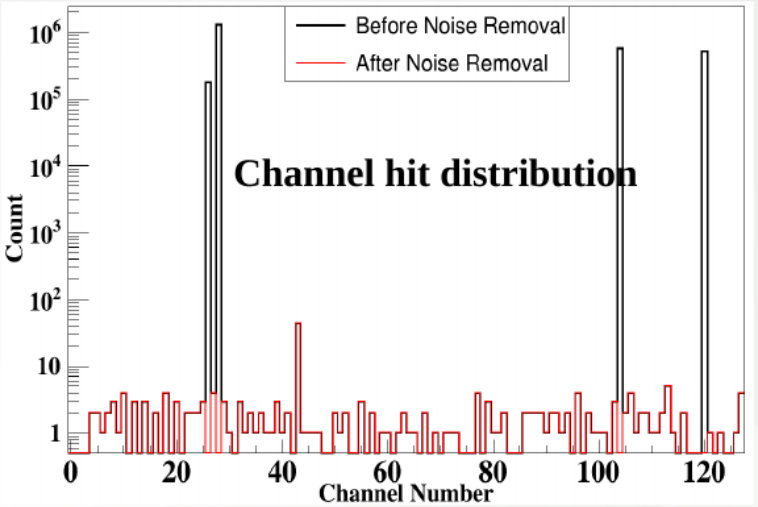


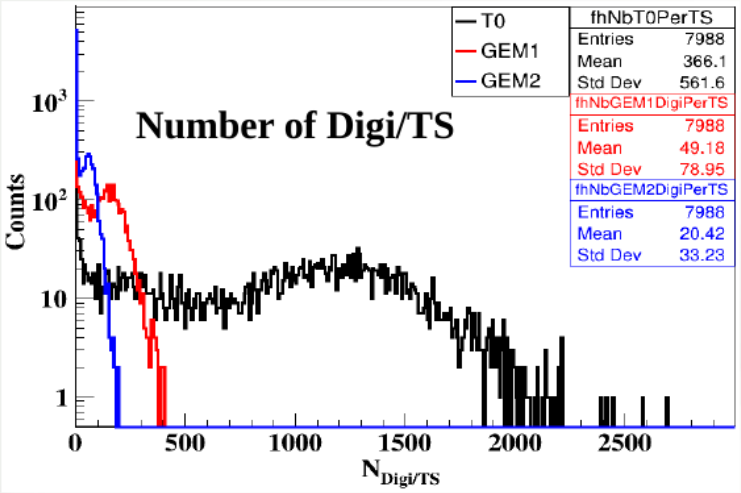
Data recorded in Time slices (TS), 1TS ~ 10ms

Analysis and Results

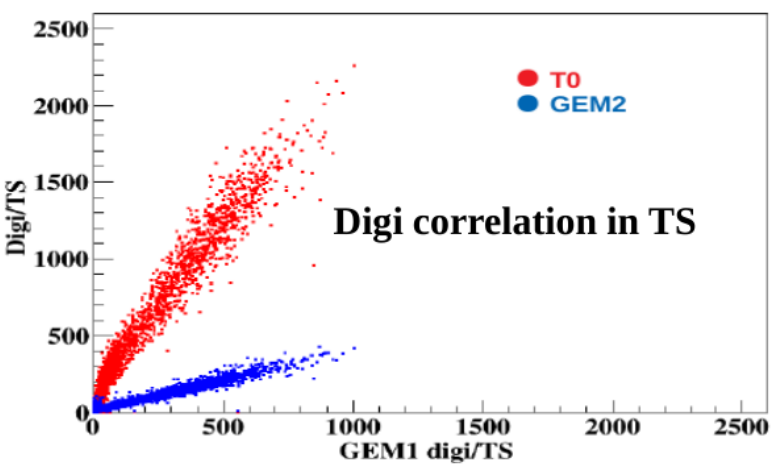
Ar + Au at 1.7 A GeV, Nov./Dec. 2019







Preliminary

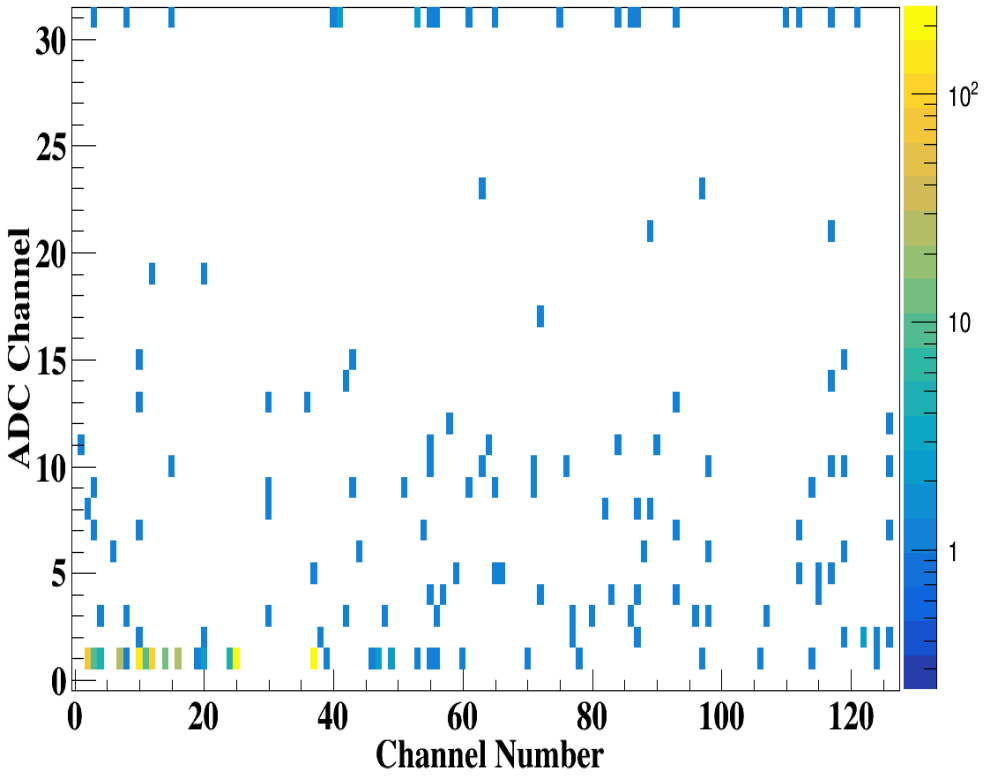


Preliminary

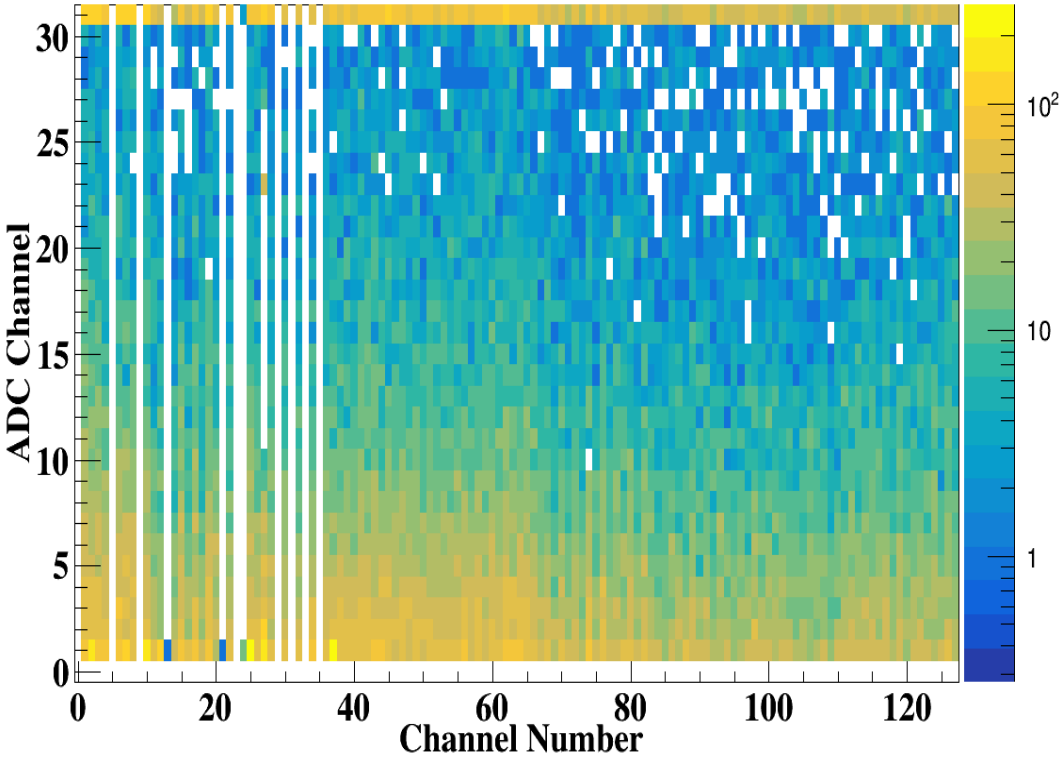
Ar + Au at 1.7AGeV, Nov./Dec. 2019

ADC with Channel number

Off-spill case



On-spill case

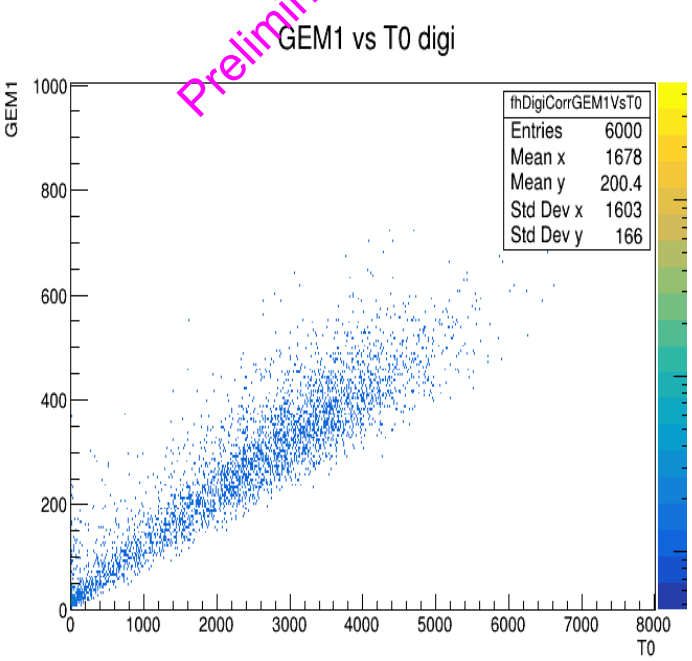


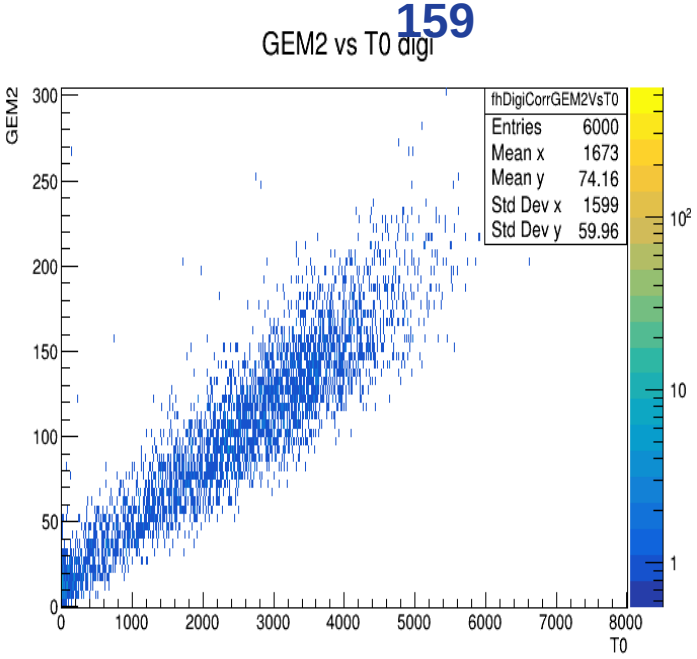
Digi correlation in TS

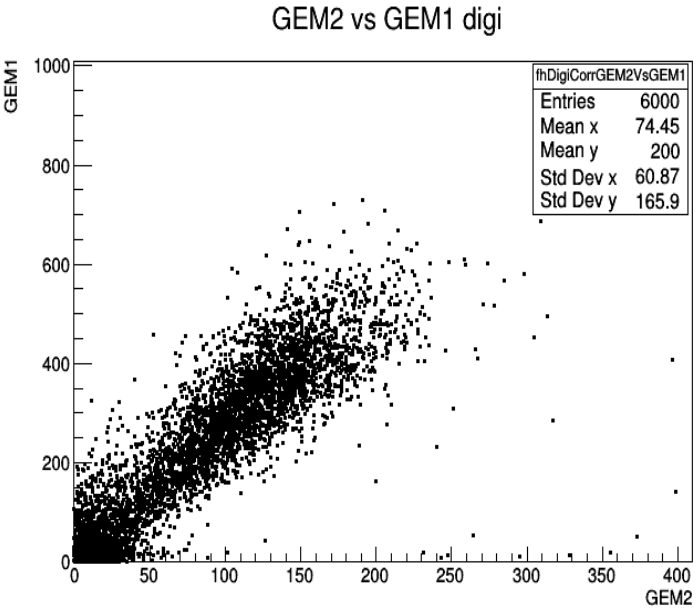
Preliminary

intensity (2x10^5/spill)

159

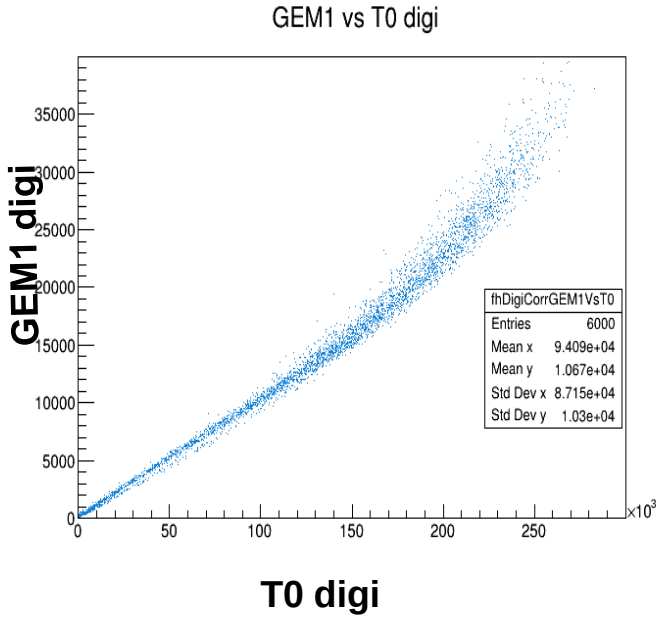


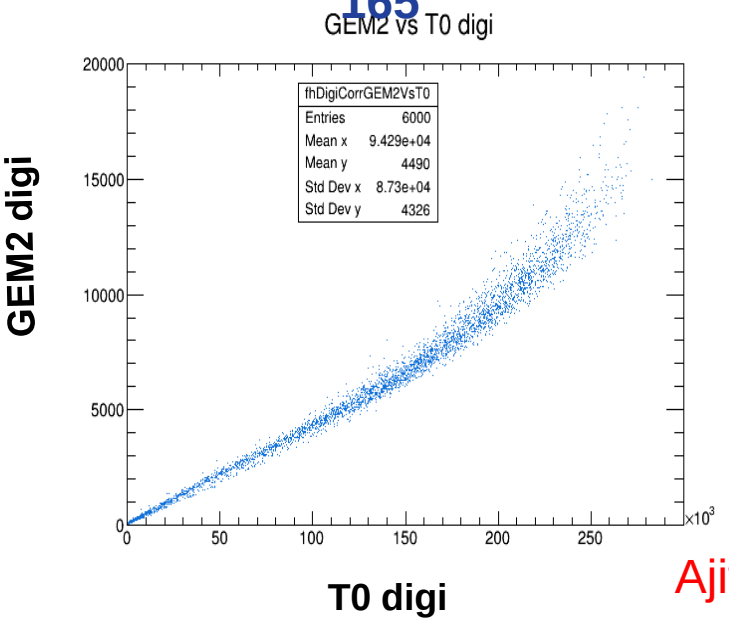


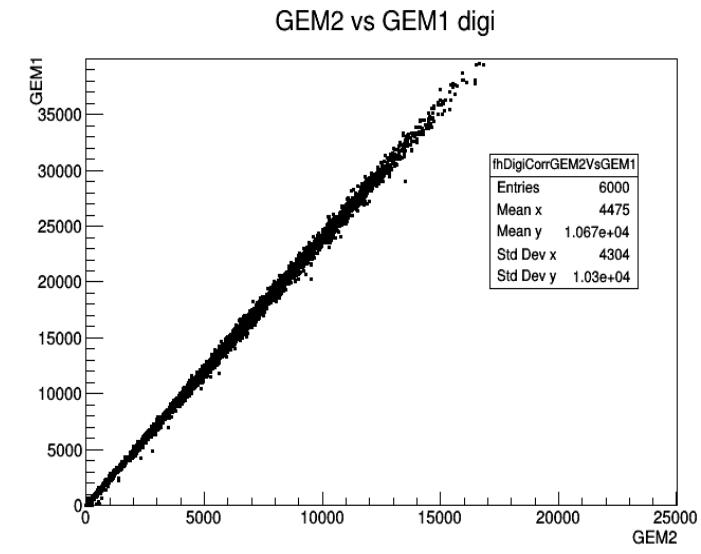


High intensity (3x10^7)

165







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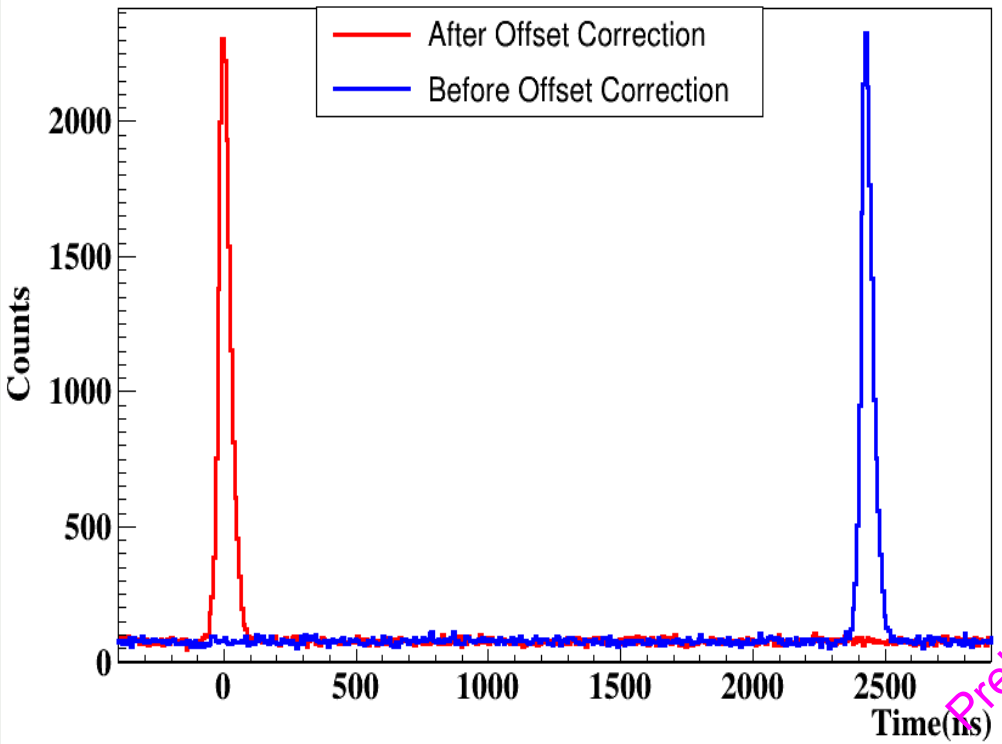
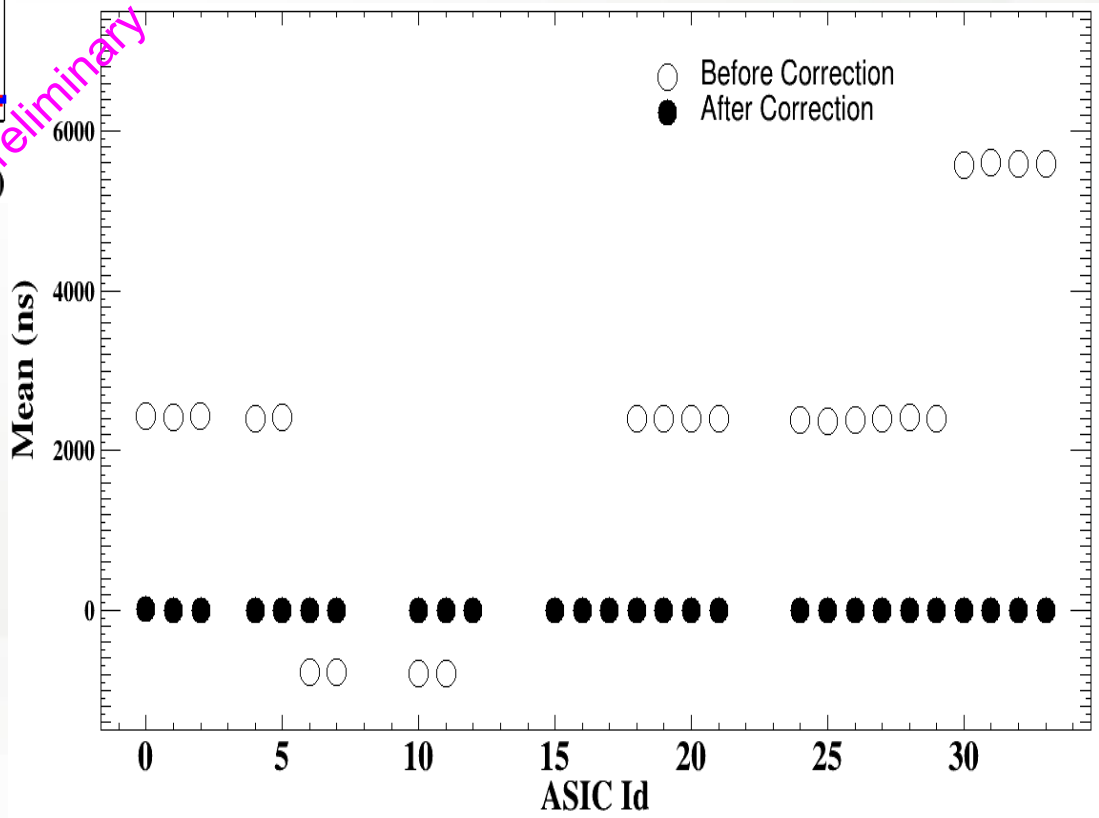
Time-Offset and Correction



Time correlation between one FEB of GEM1 with T0 in time-slice (TS)

- **Before time-offset correction**
- **After time-offset correction**



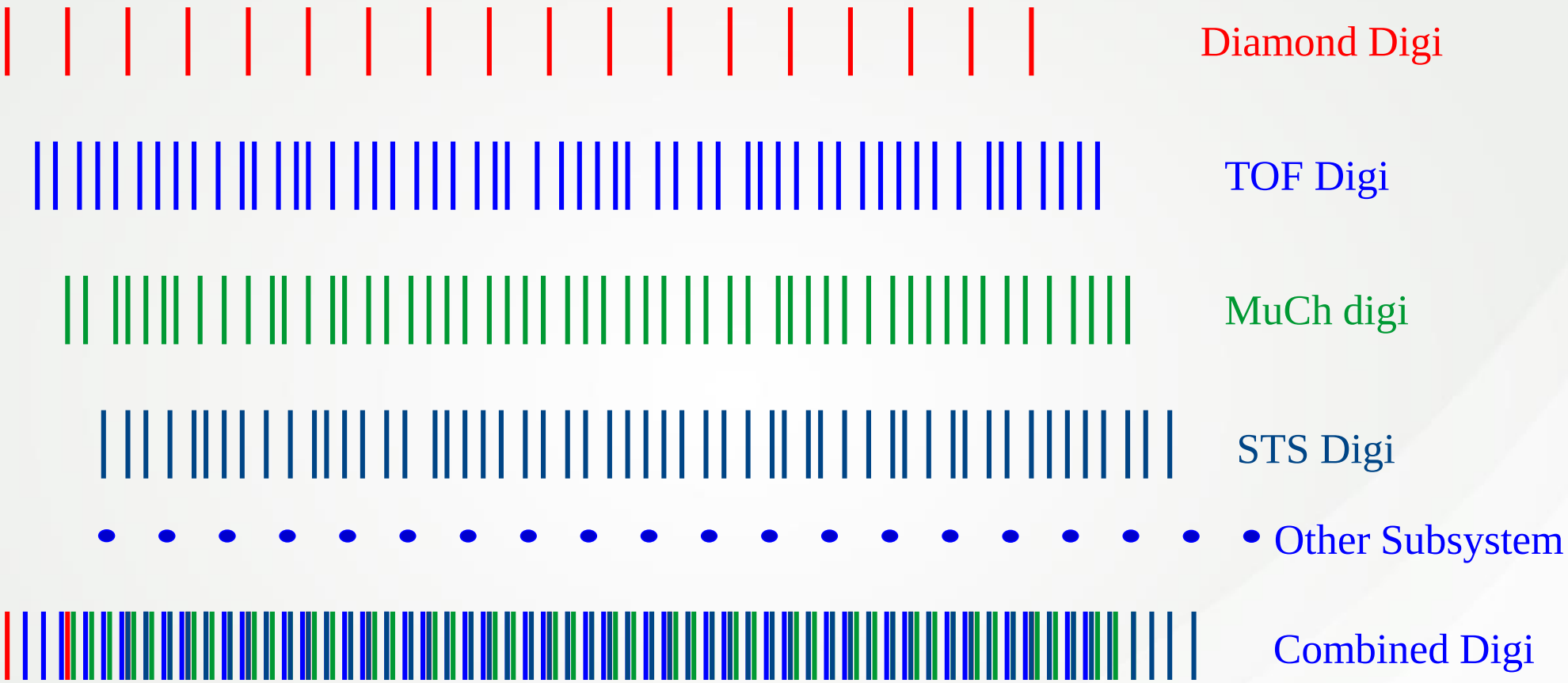
Variation of time-offset with ASIC Id

- **ASIC Id from 0-23 – GEM1**
- **ASIC Id from 24-36 – GEM2**

Event Building

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

==> Fixed time window.



If the time gap between two consecutive Digi < 200ns (say) => Then count as one event

With minimum TOF and T0 trigger condition

For the current analysis ➡

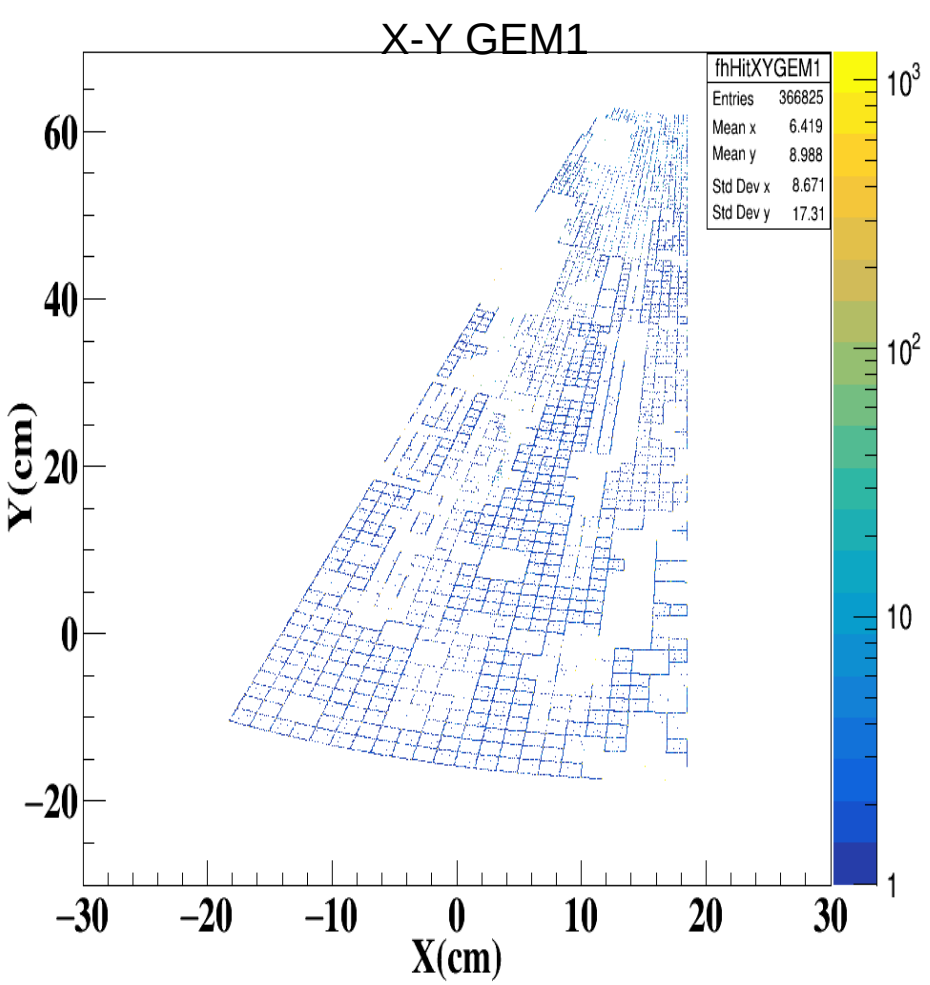
Algorithm:

Fixed time window = 200 ns

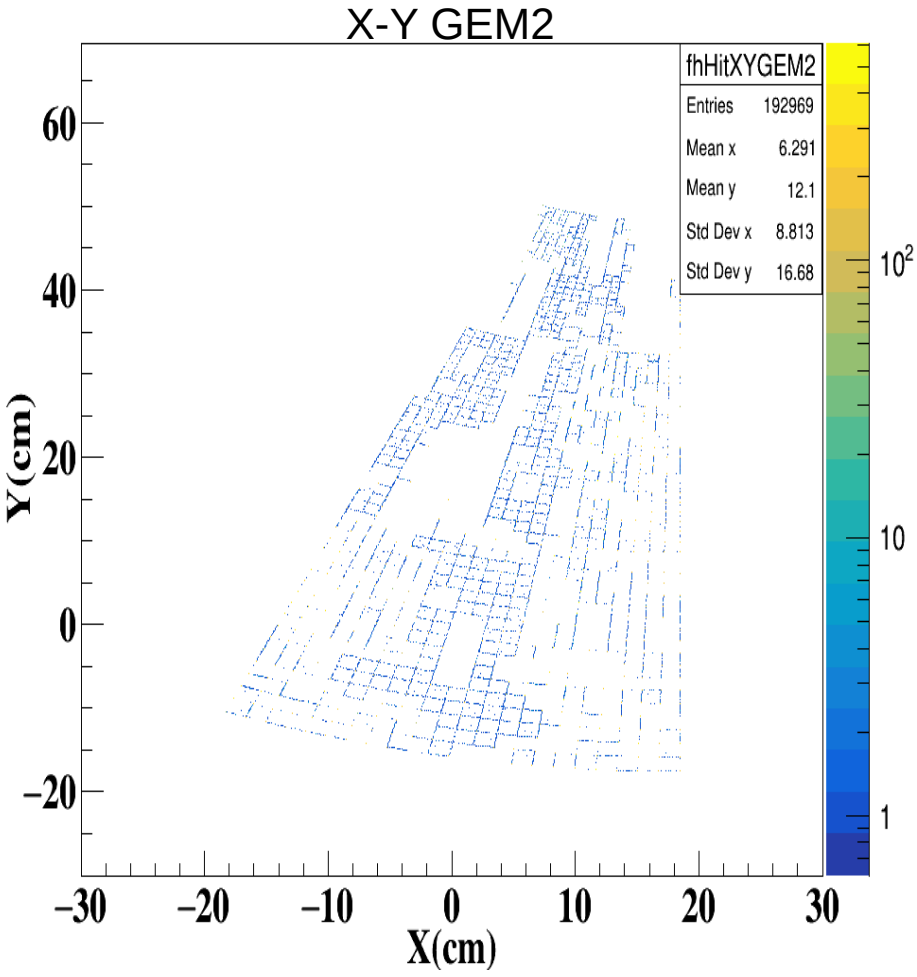
Minimum 6 TOF + 1 T0 Digi

Clustering and hit reconstruction

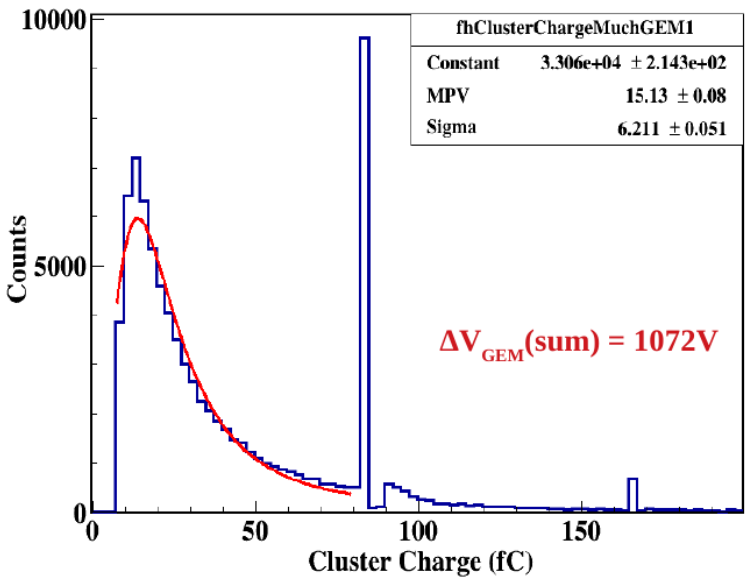
Ar + Au at 1.7AGeV, Nov./Dec. 2019

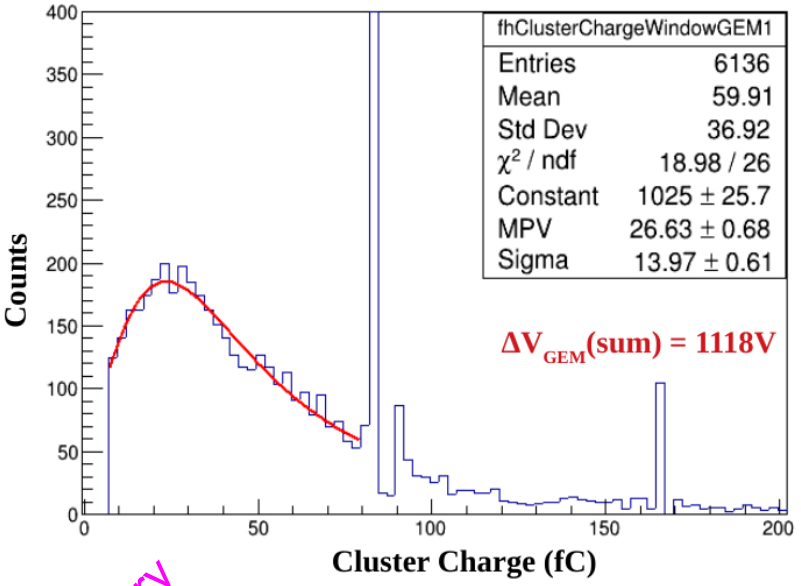


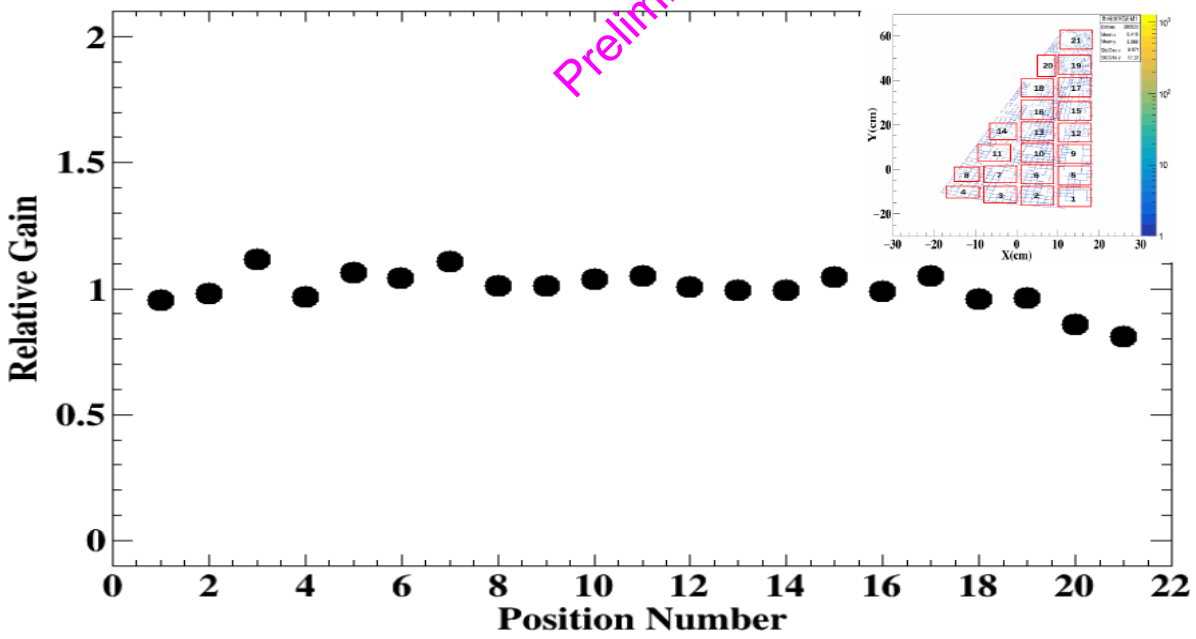
Preliminary



Pulse height spectra and Relative gain

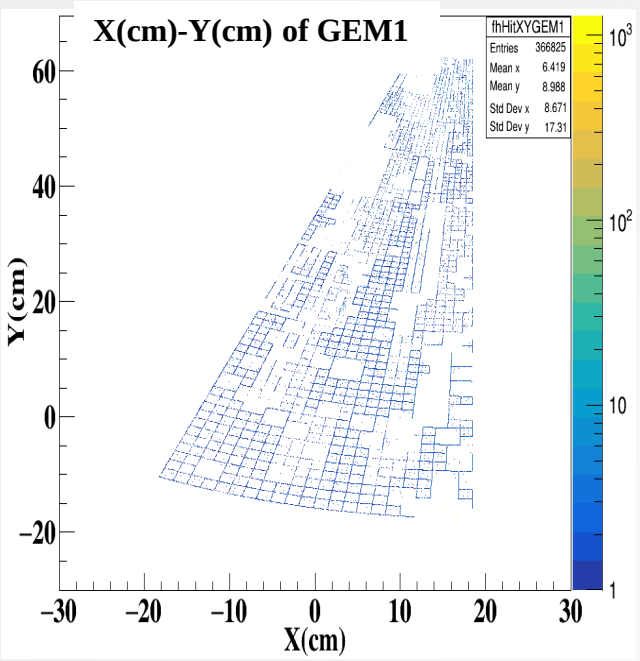


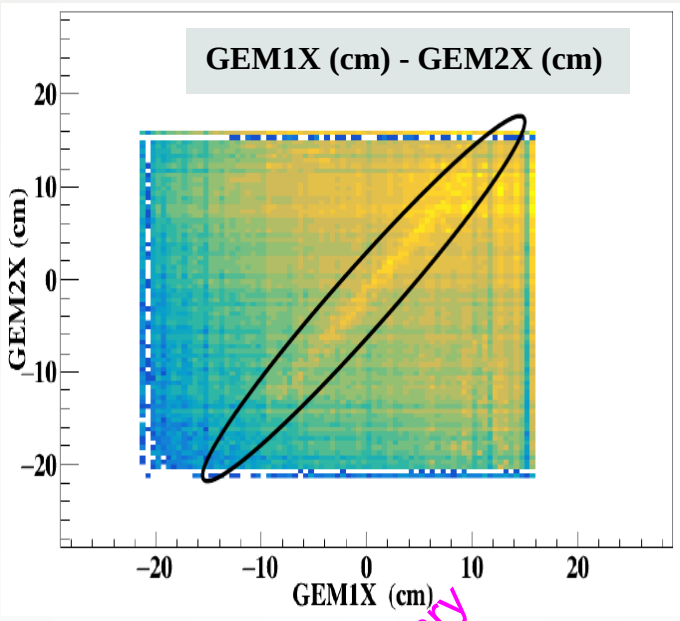


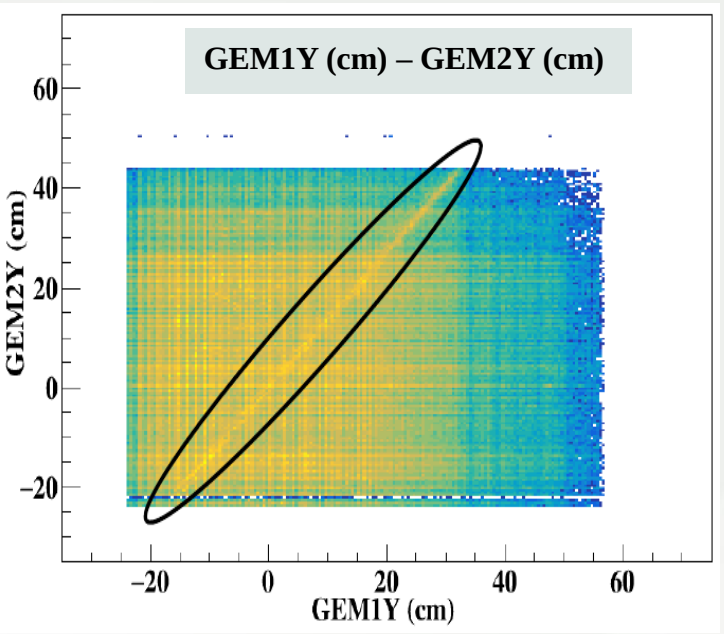


Spatial Correlation

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







Preliminary

TOFX (cm) – GEM1X (cm)

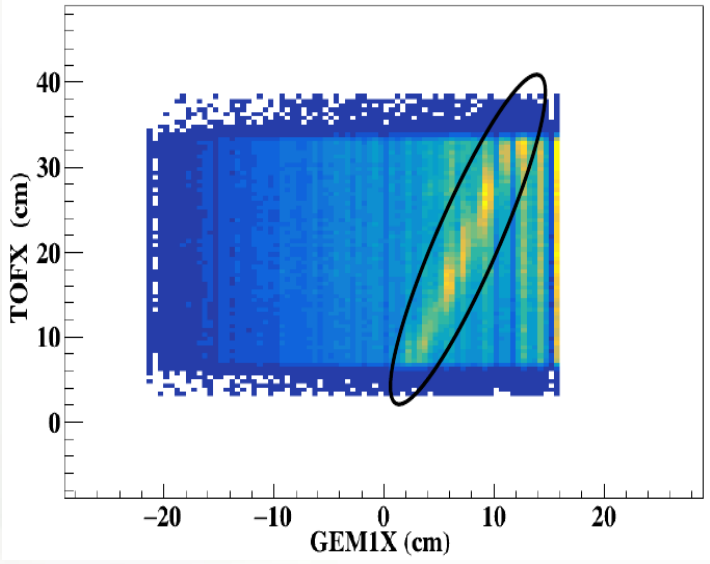
TOF triple stack only

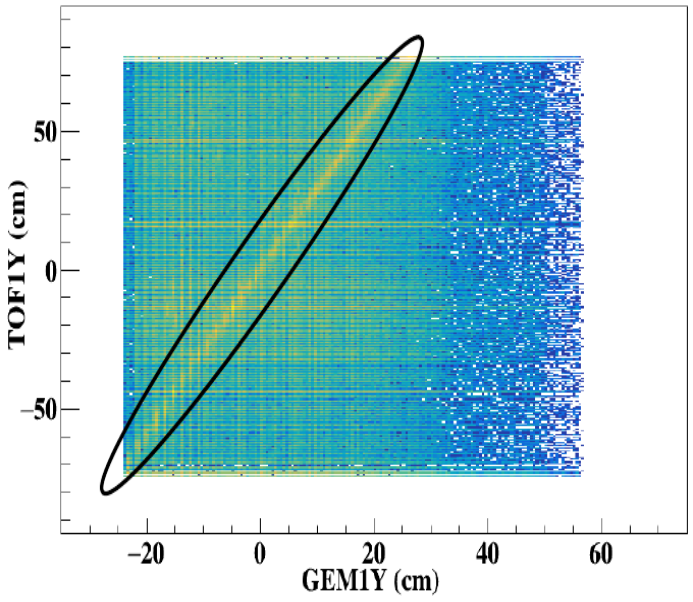
TOFY (cm) – GEM1Y (cm)

– Convey an effective event reconstruction

– Also demonstrate the time-synchronous behavior of two different detectors

– Even two different subsystems employing entirely different detector technologies and readout electronics.





Ref: A. Kumar, et.al., JINST Communicated

SUMMARY :

1. Have built and tested several prototypes
   -- 10 cm x 10 cm , 31 cm x 31 cm and real size prototypes, tests using single particle beams at SIS18, COSY, CERN and mCBM
   -- all test using self-triggered electronics
-- validation of a high charged particle detection efficiency(>90%) using self-triggered approach.

2. High rate test using single particle beams on real-size prototype– showed a stable behaviour in the range measured upto 2.8 MHz/cm2

3. Real-size GEM modules coupled to STS/MUCH XYTER commissioned and tested in mCBM expt. as part of phase-0 experiment.

4. Optocoupler based biasing adopted for mMUCH modules to power the GEM segments.

5. Obtained reasonable spill structures, time correlation spectra.

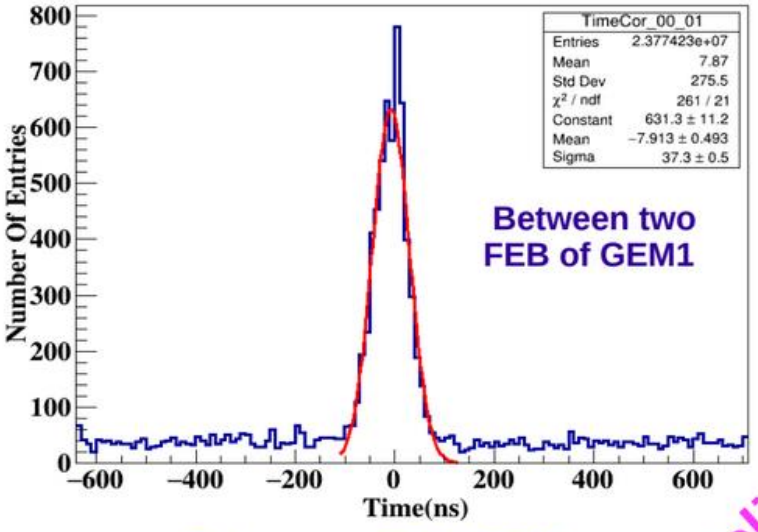
6. A correlated response of GEM modules with different subsystems observed in the free-streaming data.

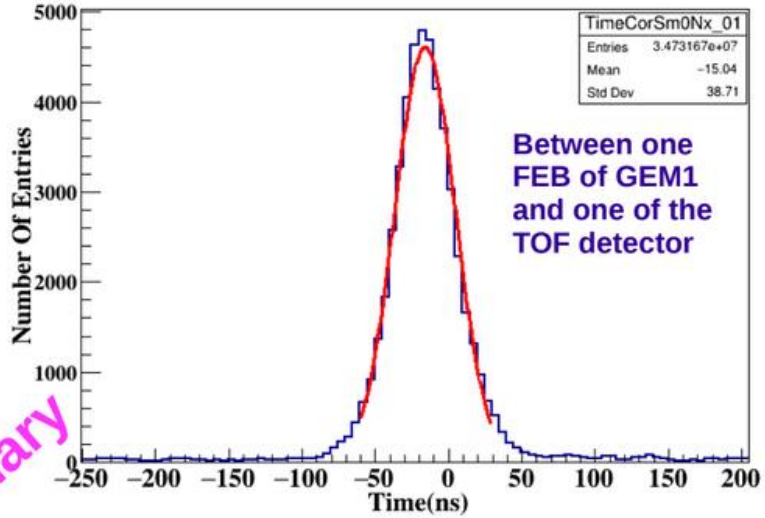
7. Further test of detectors at high intensity to be carried out in mCBM

Thank You

Backups

Time Correlation





Preliminary

Between one FEB of GEM2 and one of the TOF detector