Test Results of a real size RPC for 3rd and 4th stations of CBM Muon Chamber

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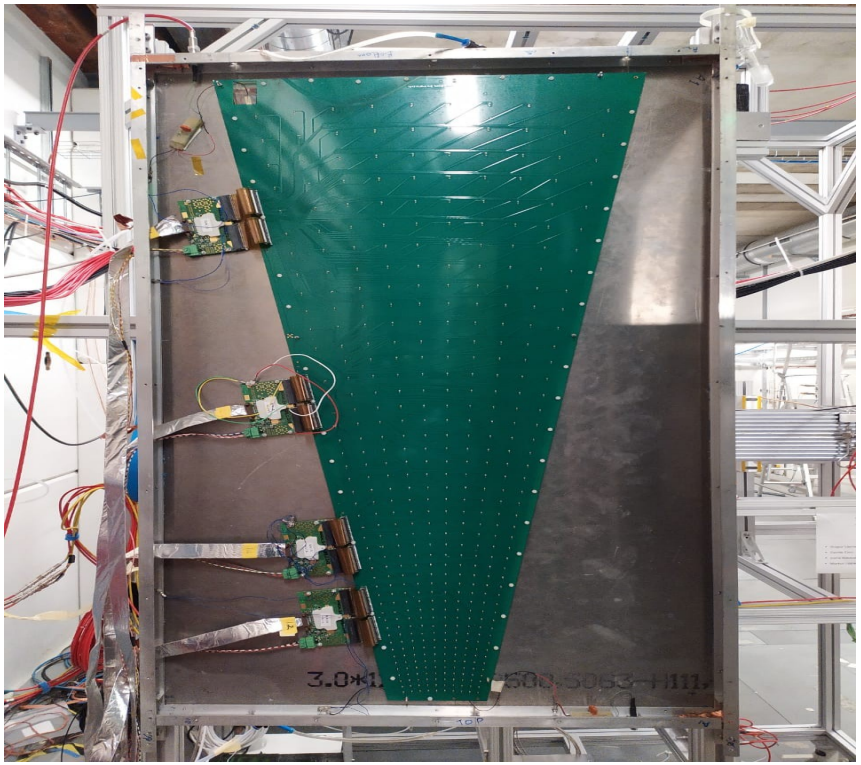
Outline:

- Introduction
- Detector details
- Test Setup
- Results
- Summary and Outlook



Introduction

- The Compressed Baryonic Matter (CBM) is an upcoming (under construction) experiment in the Facility for Anti-proton and Ion Research (FAIR) in Darmstadt, Germany.

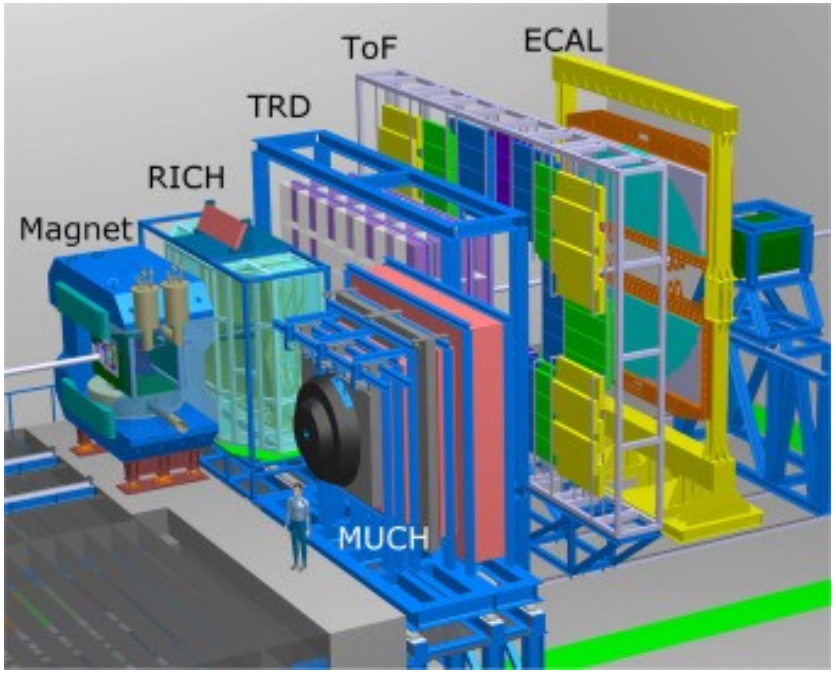


Figure 1: *Schematic layout of the CBM experiment.*

- Various detector systems:
  - Micro-Vertex Detector (MVD).
  - Silicon Tracking System (STS).
  - Ring Imaging Cherenkov detector (RICH).
  - Muon Chambers (MuCh).
  - Transition Radiation Detector (TRD).
  - Time-of-Flight Detector (ToF).

- MuCh will be the muon detection system of the CBM experiment.

Introduction

- The total absorber of MuCh will be sliced with muon-detectors placed in between them.
- It will facilitate momentum dependent track identification, improving the efficiency of detection of low momentum muons.

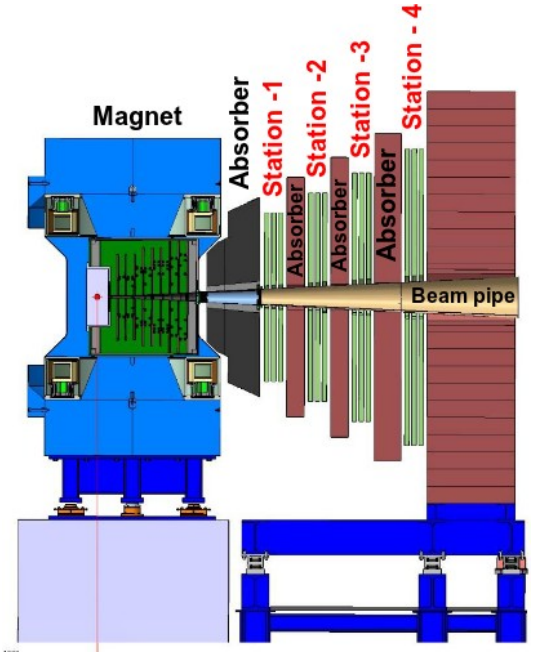
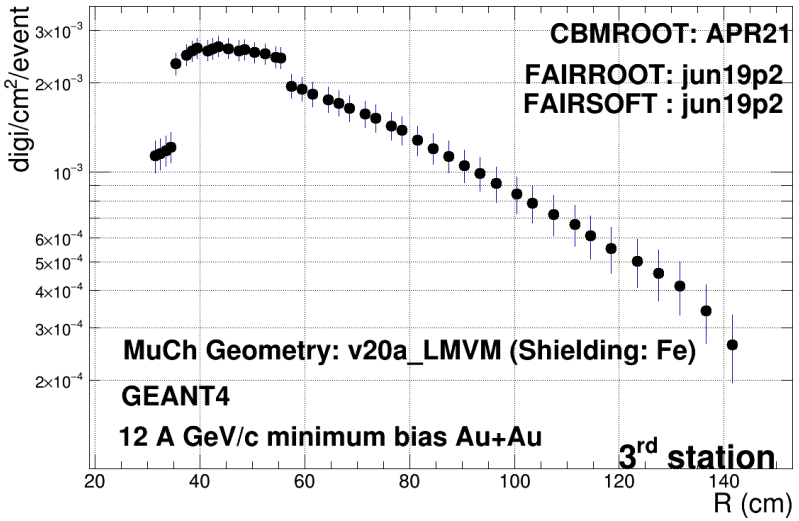


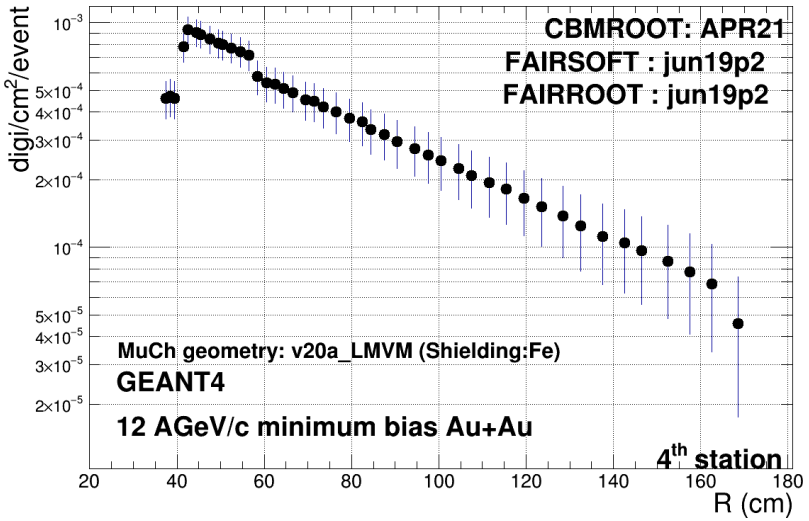
Figure 2: *Schematic layout of the CBM-MuCh.*

- MuCh will have 4 different stations to house detectors for muon detection.
- Each station will house 3 detector layers.
- Station-1 and Station-2 ⟶ Gas Electron Multipliers (GEMs).
- Station-3 and Station-4 ⟶ Resistive Plate Chambers (RPCs).

Expected rate



Digi density for 3rd station



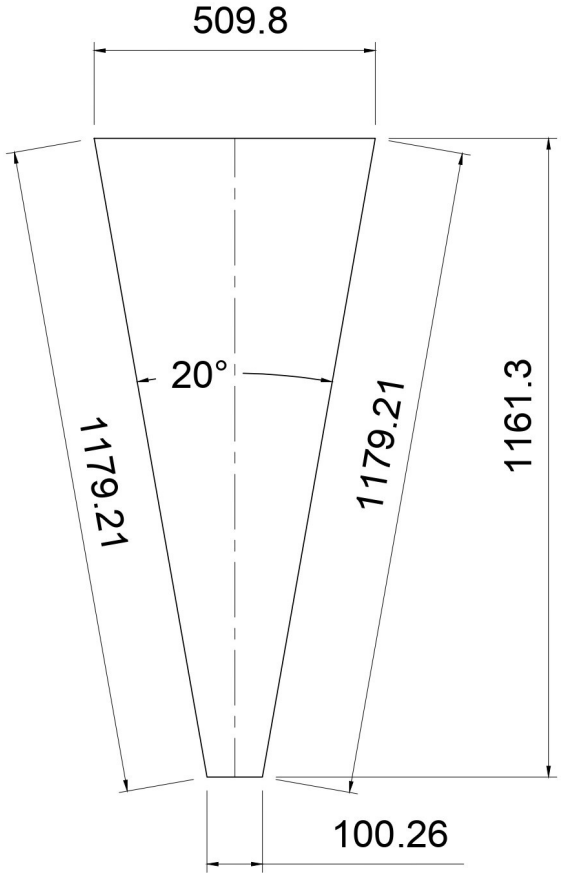
Digi density for 4th station

The numbers on the Y-axis when multiplied with the interaction rate (~10 MHz) gives the expected particle rate on the detectors.

- 3rd station –→ ~30 kHz/cm^2
- 4th station –→ ~10 kHz/cm^2

Chamber Design Parameters

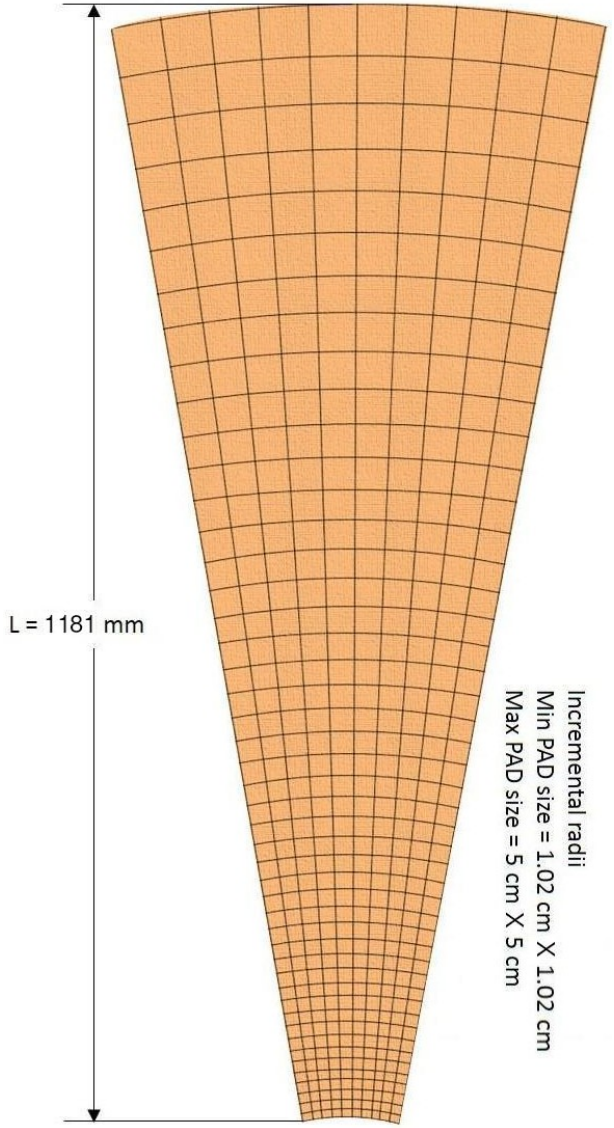
One real size detector(**Bakelite RPC**) was developed, clubbed with specially designed PCB, integrated with MuCh-XYTER, tested rigorously in local laboratory with cosmic rays and then tested at GIF++, CERN, Switzerland.



Detector dimensions for 3rd stattion (mm).

- Shape: Trapezoidal.
- Segmentation: 20°.
- Each electrode thickness: 1.2 mm.
- Bulk resistivity of electrodes: $\sim(3\times10^{9} - 1\times10^{10})$ Ωcm.
- Gas gap thickness: 2 mm.

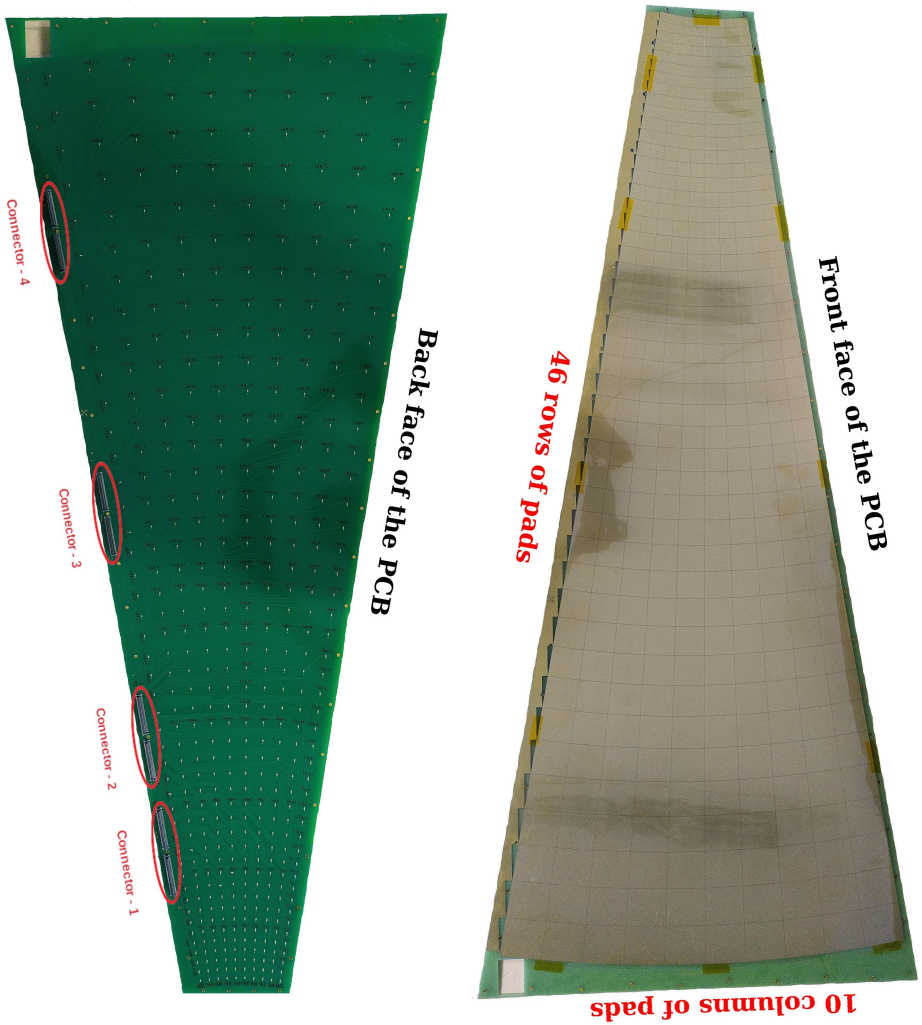
Readout PCB



Schematic design of readout PCB for 3rd Station

- The PCB is of 1181 mm in length, and 2.4 mm thick.
- The trapezoidal shaped signal pickup PCB contains trapezoidal pads of progressive dimensions.
- There are 46 rows and 10 columns of pads $\Longrightarrow$ 460 pads in total.
- Each column segmentation $\longrightarrow 2^{\circ}$.
- The size of the smallest trapezoidal pad is $\sim(1.01\ \text{cm} \times 1.01\ \text{cm})$.
- The size of the largest trapezoidal pad is $\sim(5.0\ \text{cm} \times 5.0\ \text{cm})$.
- The dimensions of all the pads in each row are exactly the same.

Readout PCB Design



Actual image of the readout PCB.

- In the back side of the PCB there are total 04 numbers of connectors with 1.27 mm pitch for insertion of FEE boards.
- Each pad is connected via a 10 nF capacitor to the respective channel of the FEE connector.
- The PCB has been outlined with the through holes for screwing at the board edge in order to attach it to the detector firmly for efficient charge collection.

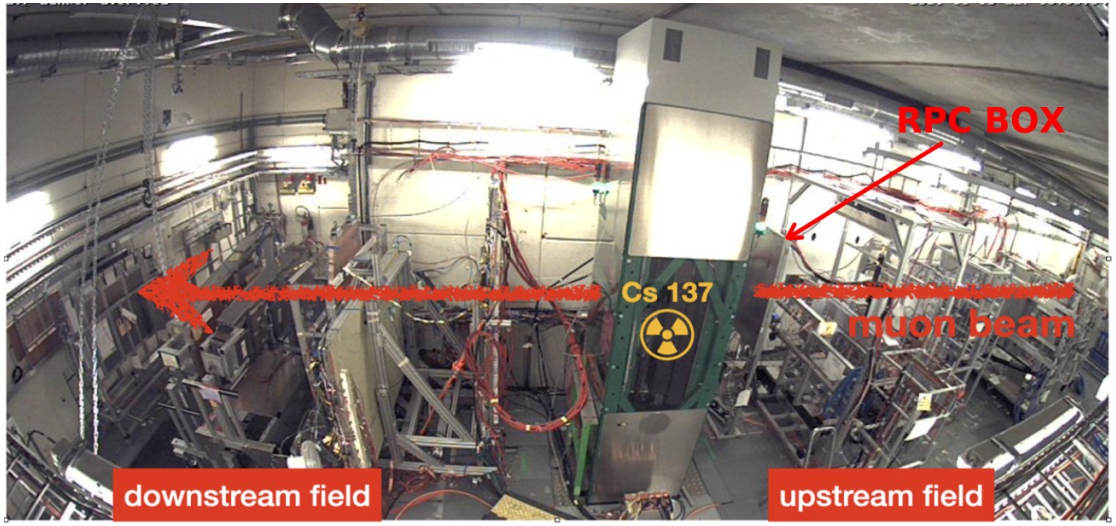
Electronics and DAQ chain:

- ⟶ **MuCh-XYTER based.**

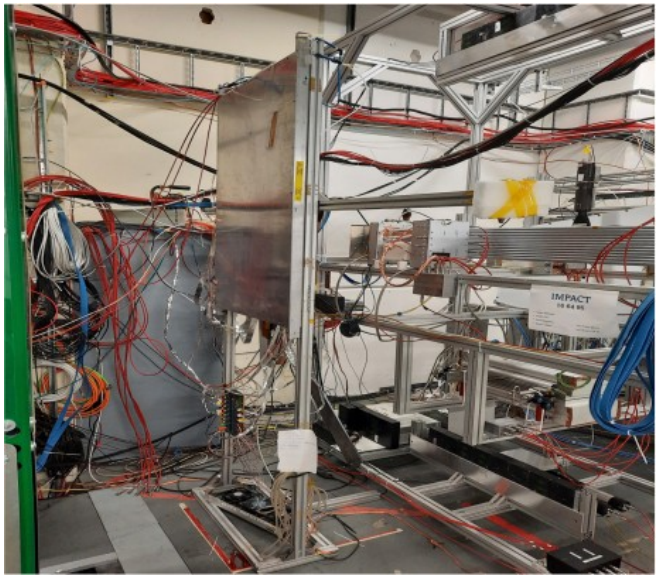
Self-triggered electronics.

GIF++ Setup(2021)

- GIF++ is located on the H4 beamline which provides high-energy muon beam ($\leq$ 150 GeV/c) in EHN1 North Area of CERN.
- It houses Cs-137 gamma source.
- Our RPC detector was tested in GIF++ **during November-2021** beamtime.
- The RPC was positoned at ~84 cm away from the Cs-137 source in the upstream region.



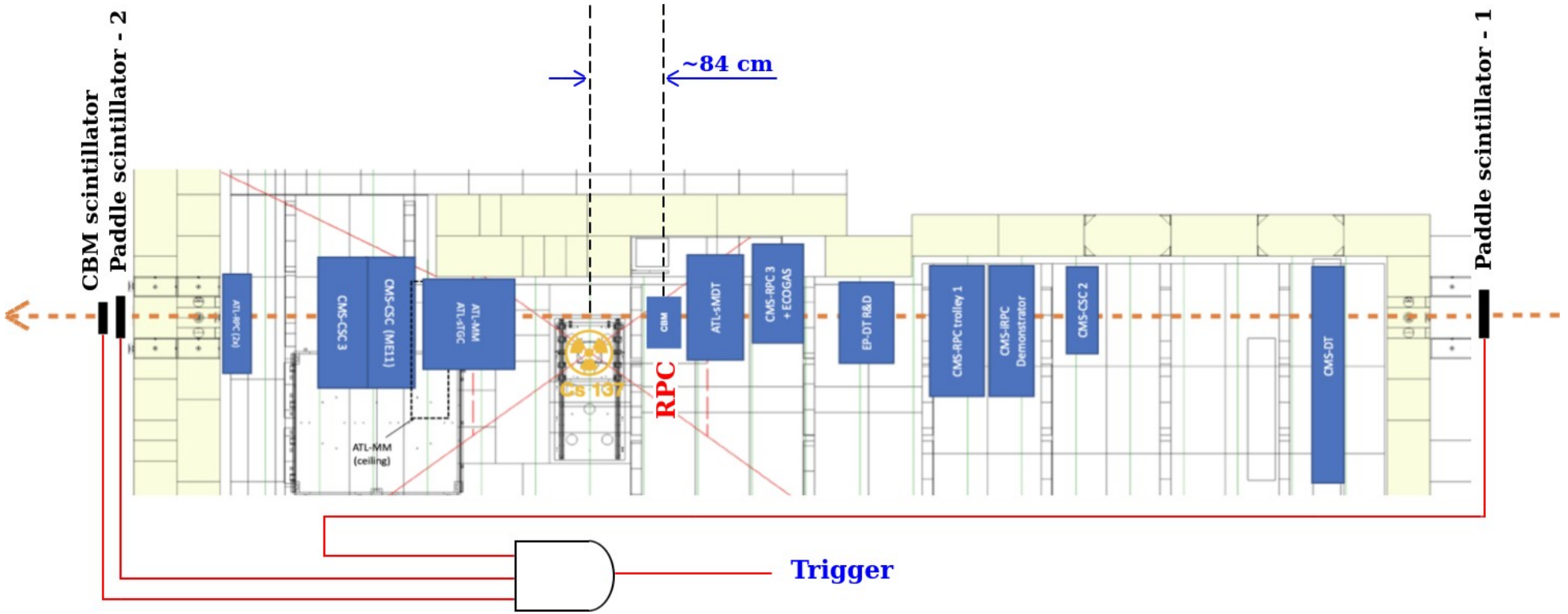
Experimental facility site atGIF++.



The RPC box in the upstream region.

Trigger Scheme

- Coincidence signals from three different scintillators were used:
  - Paddle scintillator -1 and 2 (At the begining and end of the hall).
  - CBM scintillator $\longrightarrow$ $\sim(45\ \text{mm} \times 50\ \text{mm})$ positioned behind the second paddle scintillator.



A schematic representation of the experimental site along with the generated trigger scheme. The figure is not to scale.

Operation of the Detector

Data recording conditions

- Different photon rates incident on the detector.
- Different applied high voltage to the detector.
- Different signal threshold (will discuss only at one threshold here).
- Different position of the beam hitting the detector (will discuss only at one such position here).

Gas

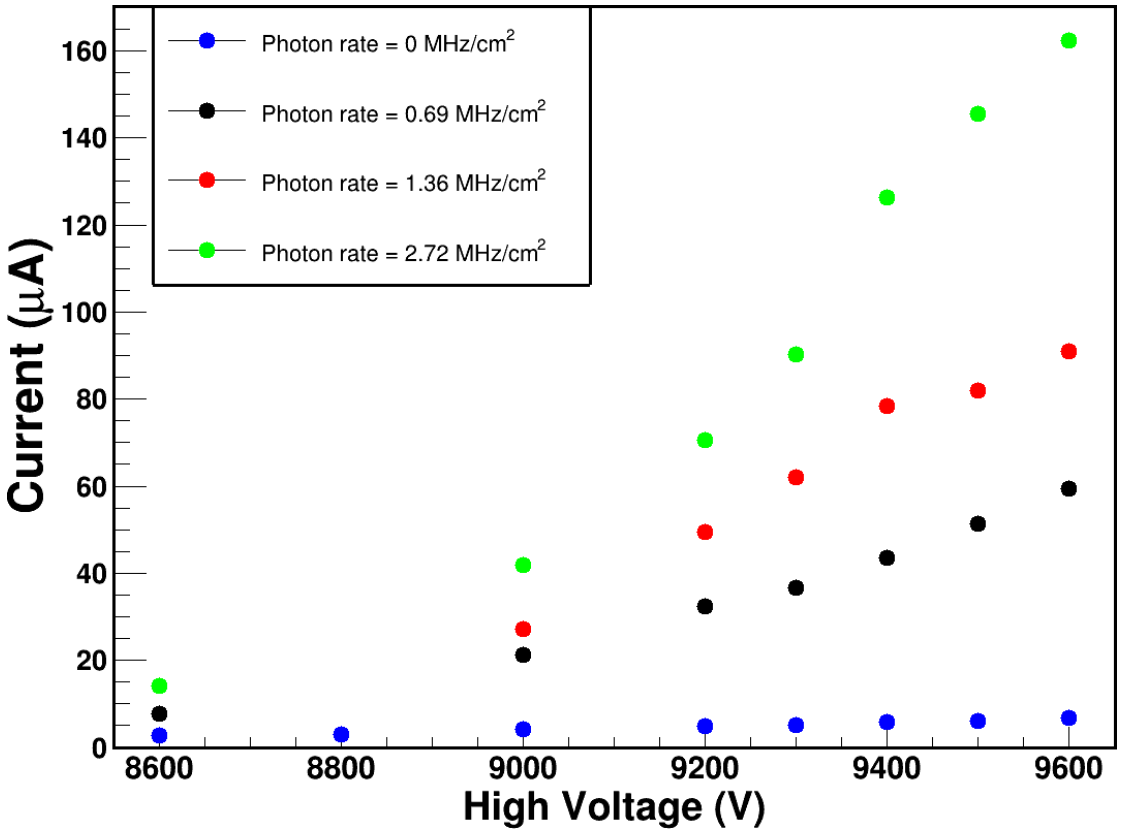
Mixture components & ratio:

- $R134a : i-Butane : SF_6 :: 95.2\% : 4.5\% : 0.3\%$ (*by volume*)
  - Similar to MuCH RPC gas ratio
- Humidity in gas: $\longrightarrow$ 40%.
- Flow rate: $\longrightarrow$ 5 l/hr.

Electronics

- Signal threshold: $\longrightarrow \sim$15 fC.
- MuCh-XYTER based electronics and DAQ chain

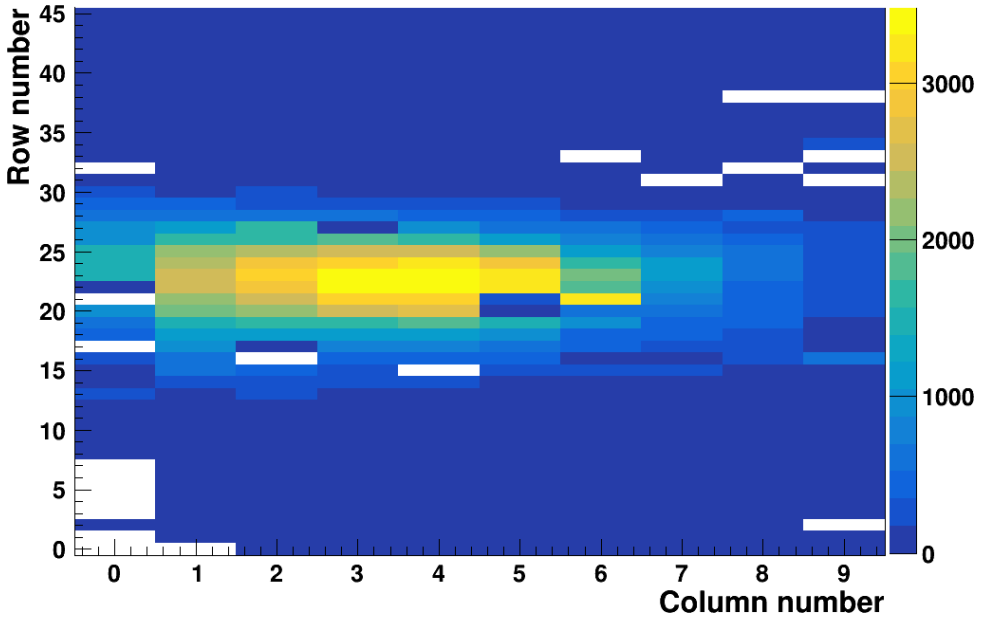
Current vs. photon flux



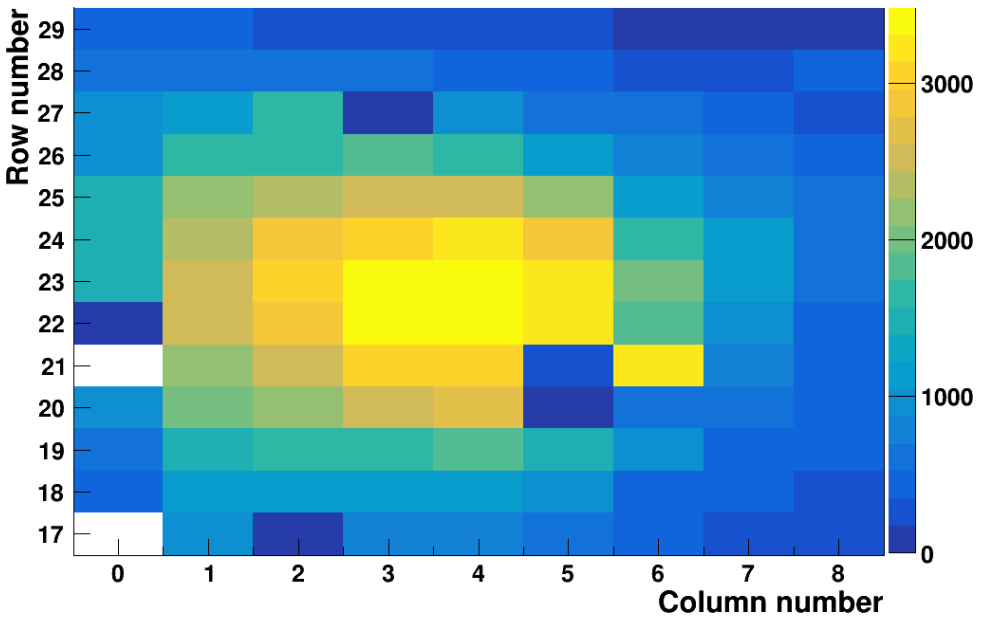
Current variation as a function of high voltage at different γ-intensities.

- *γ*-intensities −→ 0 MHz/cm^2, 0.69 MHz/cm^2, 1.36 MHz/cm^2, and 2.72 MHz/cm^2.
- The current increased with an increase in the photon rate falling on the detector.

Hit distribution



Hit distribution of the pads throughout the whole detector.

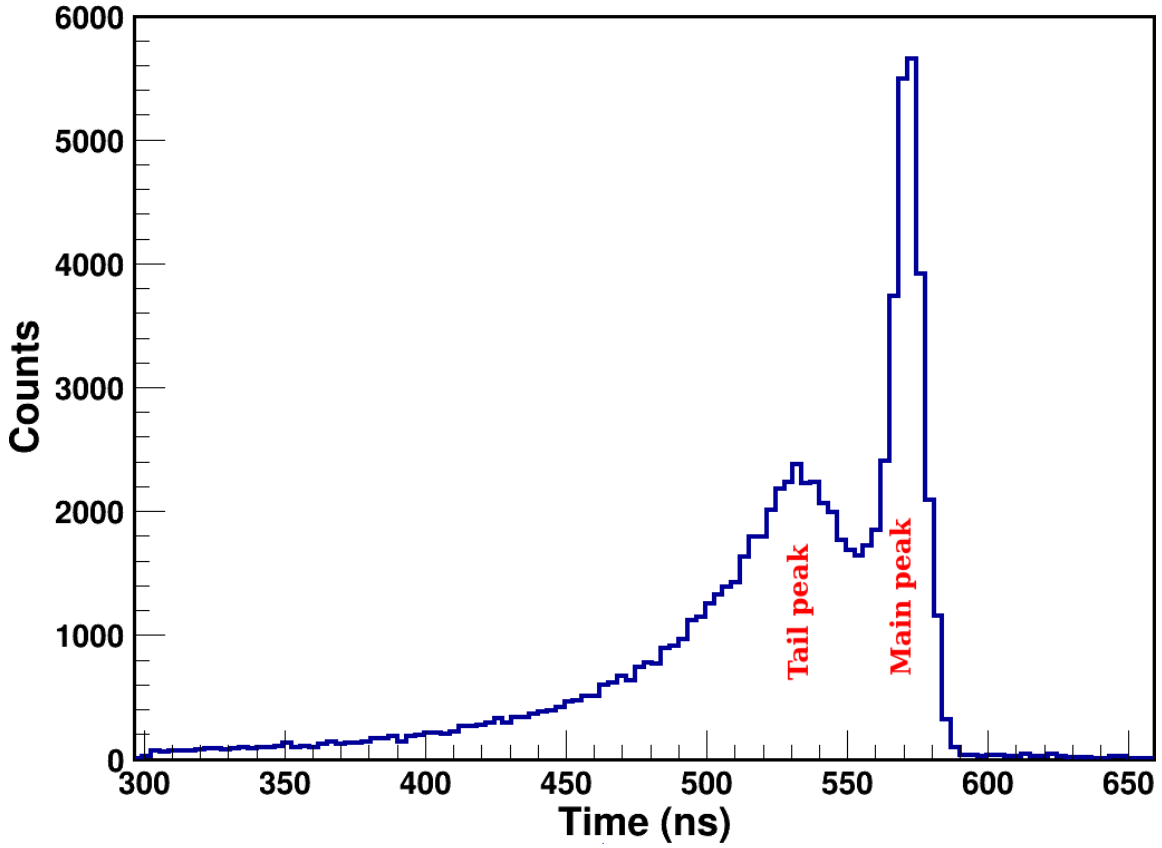


Hit distribution of the pads in and around the beam spot region.

- The detector has been positioned in such a way the beam hit around the middle region.
- The approximate pad dimension−→ 23 mm × 23 mm.
- The most intense region of the muon beam has an area of ∼ (92.6 mm × 92.6 mm)

Timing Spectra

- The timing information of the hits have been measured w.r.t to the trigger time.

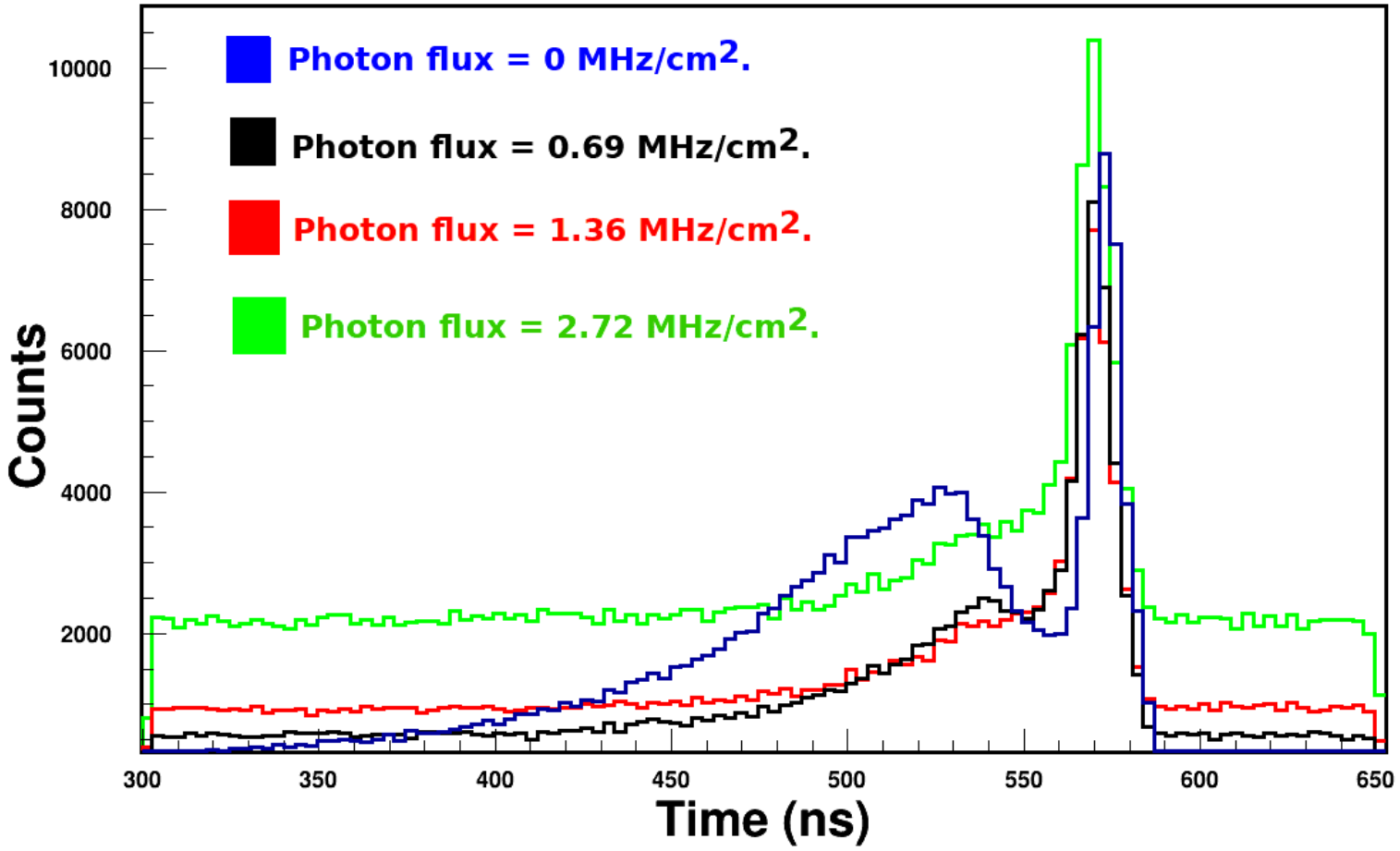


Time correlation spectra at 9200 V in absence of photon flux.

- The single channel resolution of MuCh-XYTER is ~3.125 ns.
- Observation: Two peaks in the time correlation spectra v.i.z ″Main peak″ and ″Tail peak″.

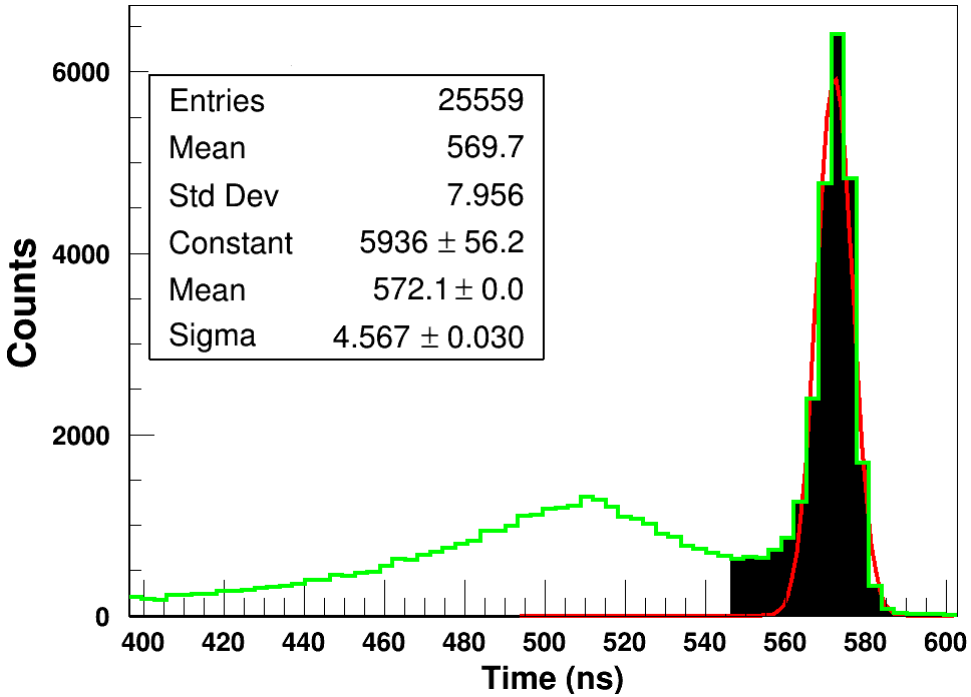
Timing Spectra

- Applied voltage to the RPC −→ 9600 V.

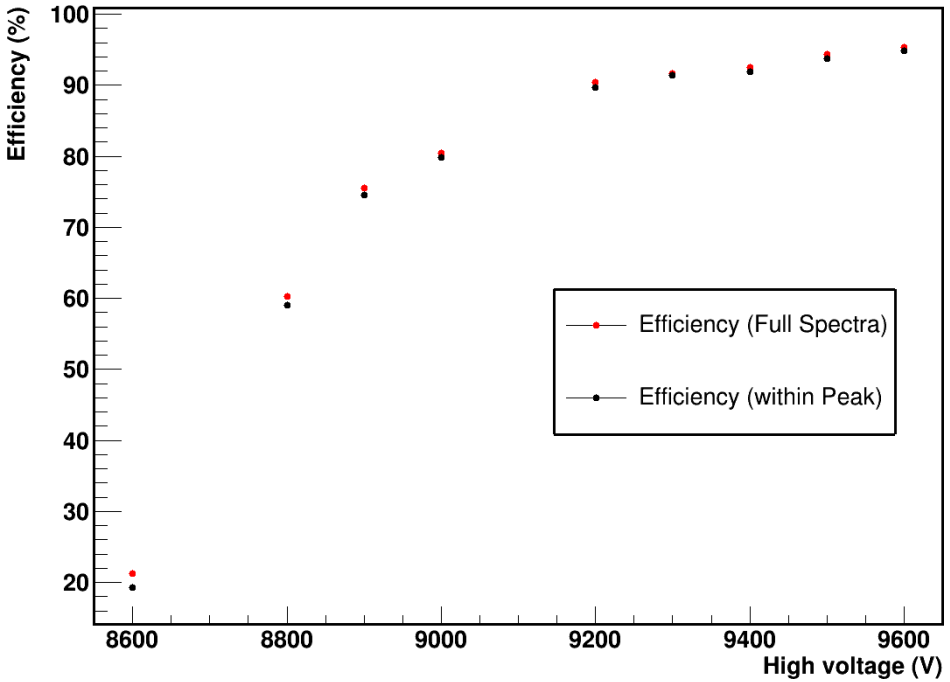


Time correlation spectra at different photon flux.

Timing Spectra and efficiency



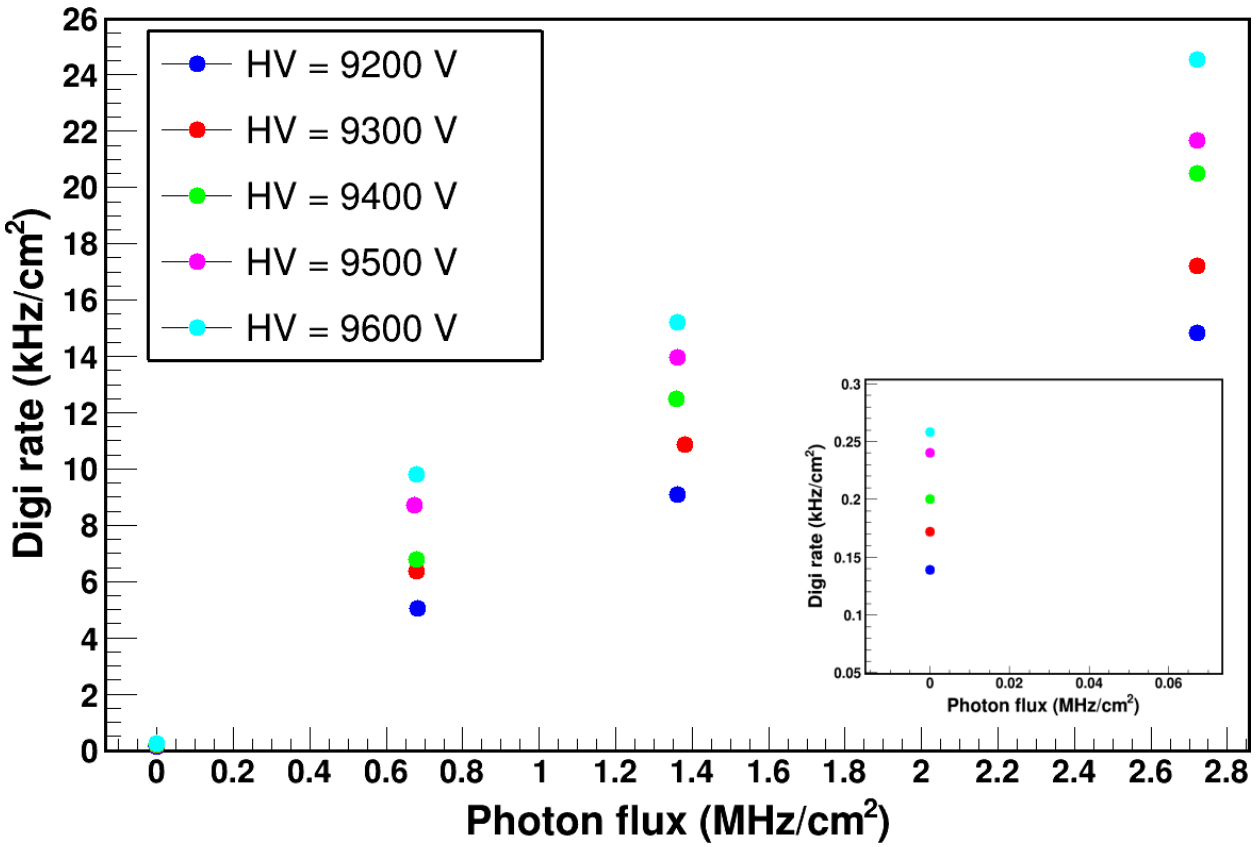
A typical measured time spectra at 9300 V



Comparison of efficiency corelation for different regions of the photon spectra

- Observation: No significant change in the efficiency values.
- For further efficiency calculations, the hit(s) lying within the "Main peak" have been considered.

Measured Digi Rate

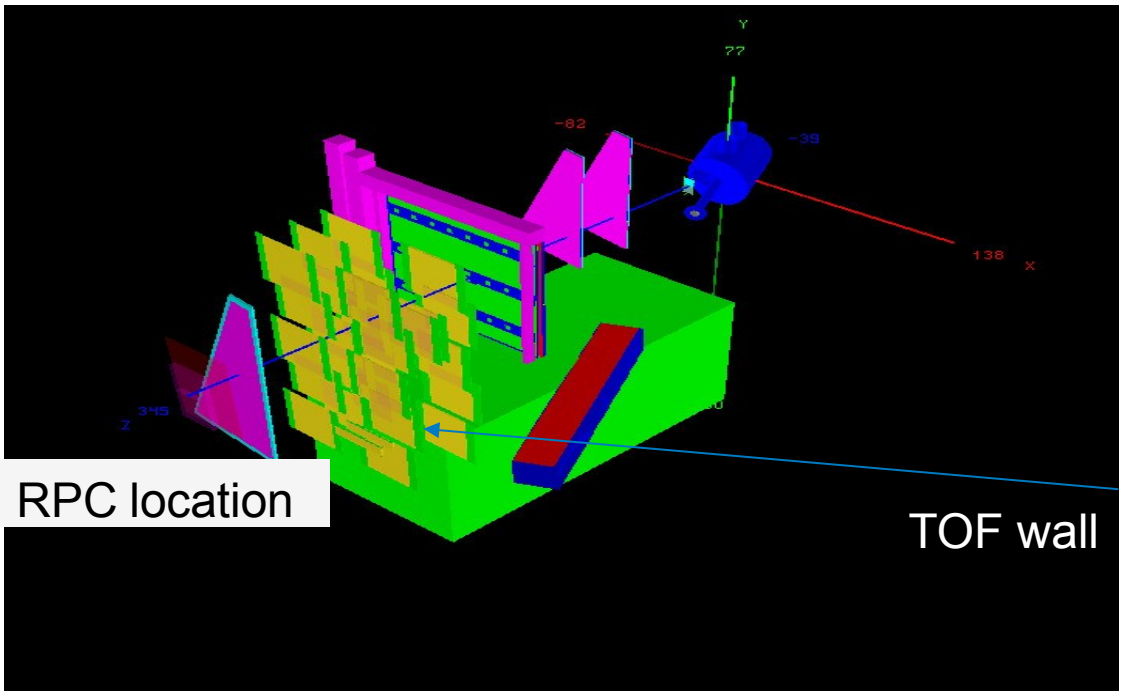


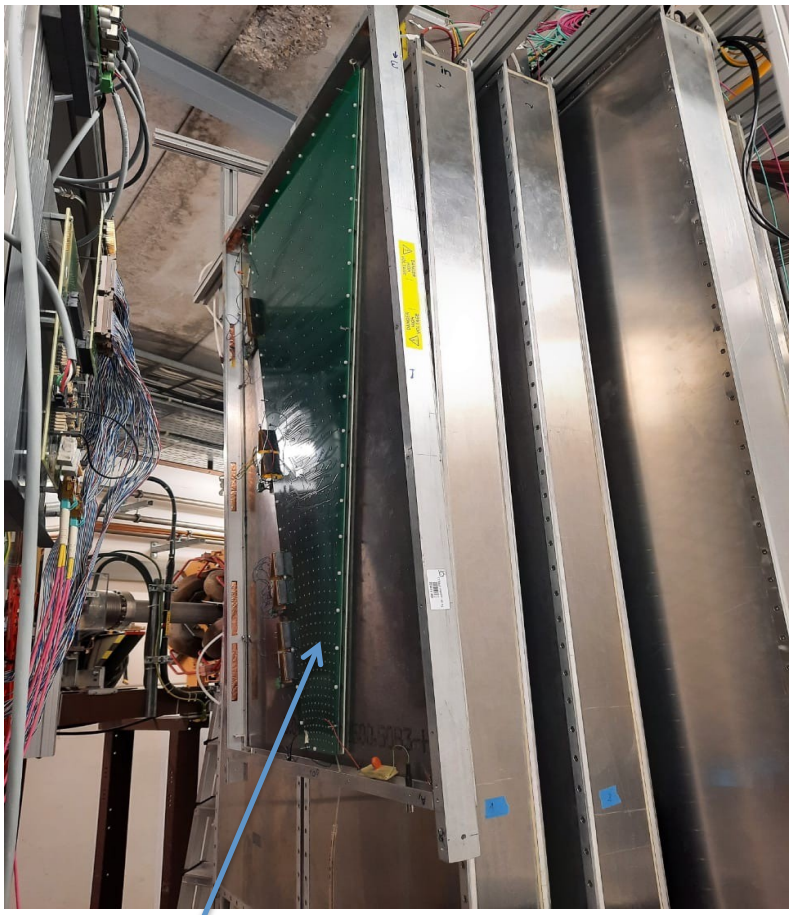
Variation of digi rate as a function of incident photon flux at different applied high voltages. The photo in the inset shows the variation during source OFF condition.

Observations:

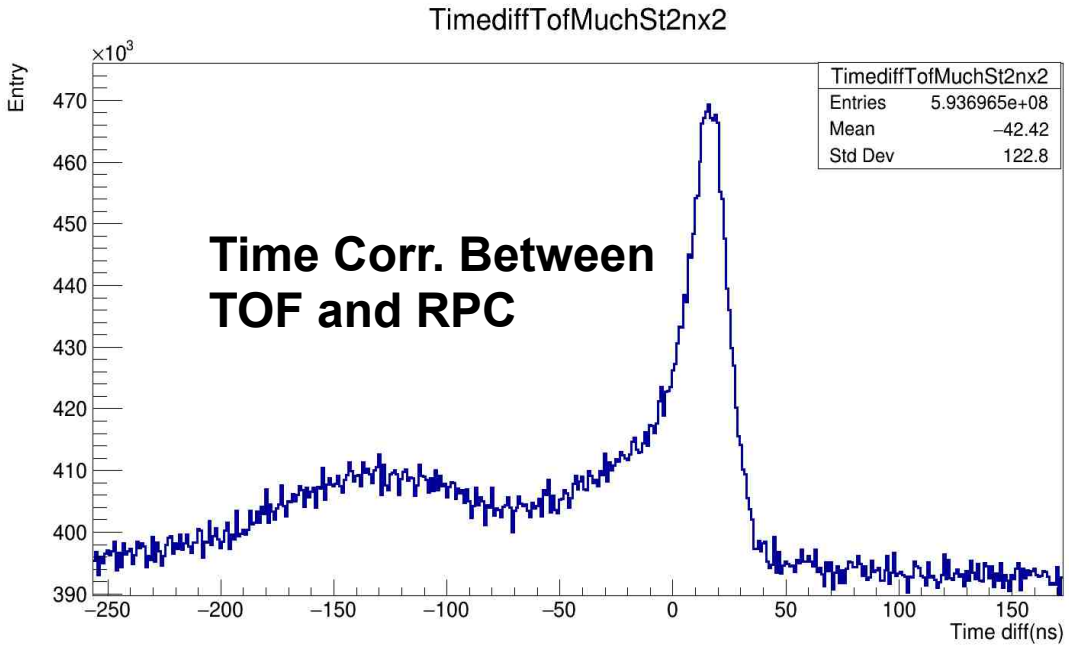
- At any particular voltage the digi rate increases as the number of incident photon increases.
- At any particular photon flux the digi rate increases as the applied voltage increases.
- Maximum digi rate of $\sim 24.56 kHz/cm^2$, @ 9600 V with γ-flux of $\sim 2.72 MHz/cm^2$.

Tests@mCBM





MuCH RPC



Further data analysis ongoing
Plan to have further tests for optimization of various parameters

Conclusion and Summary

- A real-size single gas RPC along with paded structure read-out PCB (different from standard strip read-out technique) and dedicated self triggered electronics chain has been developed for its application in 3^{rd} station of MuCh detector set-up of the CBM experiment.
- The detector has been successfully tested for its muon detection efficiency in absence and presence of intense photon flux at GIF++ facility in CERN, Switzerland with an idea to study its performance and determine the optimum operating voltage at a high photon environment.
- The detector has shown muon detection efficiency of > 90% and maximum digi rate 25 kHz/cm^2 (in presence of $\sim 2.72 MHz/cm^2$ photon flux as background) at an operating voltage of 9600 V.
- One can effectively infer that the developed real-size RPC can work successfully with a charged particle detection efficiency of >90% even at harsh photon environment.
- Test data analysis at mCBM is ongoing. Plan to have further tests aiming optimization of detector parameters.

Thank you

Various Febs in mRPC Module