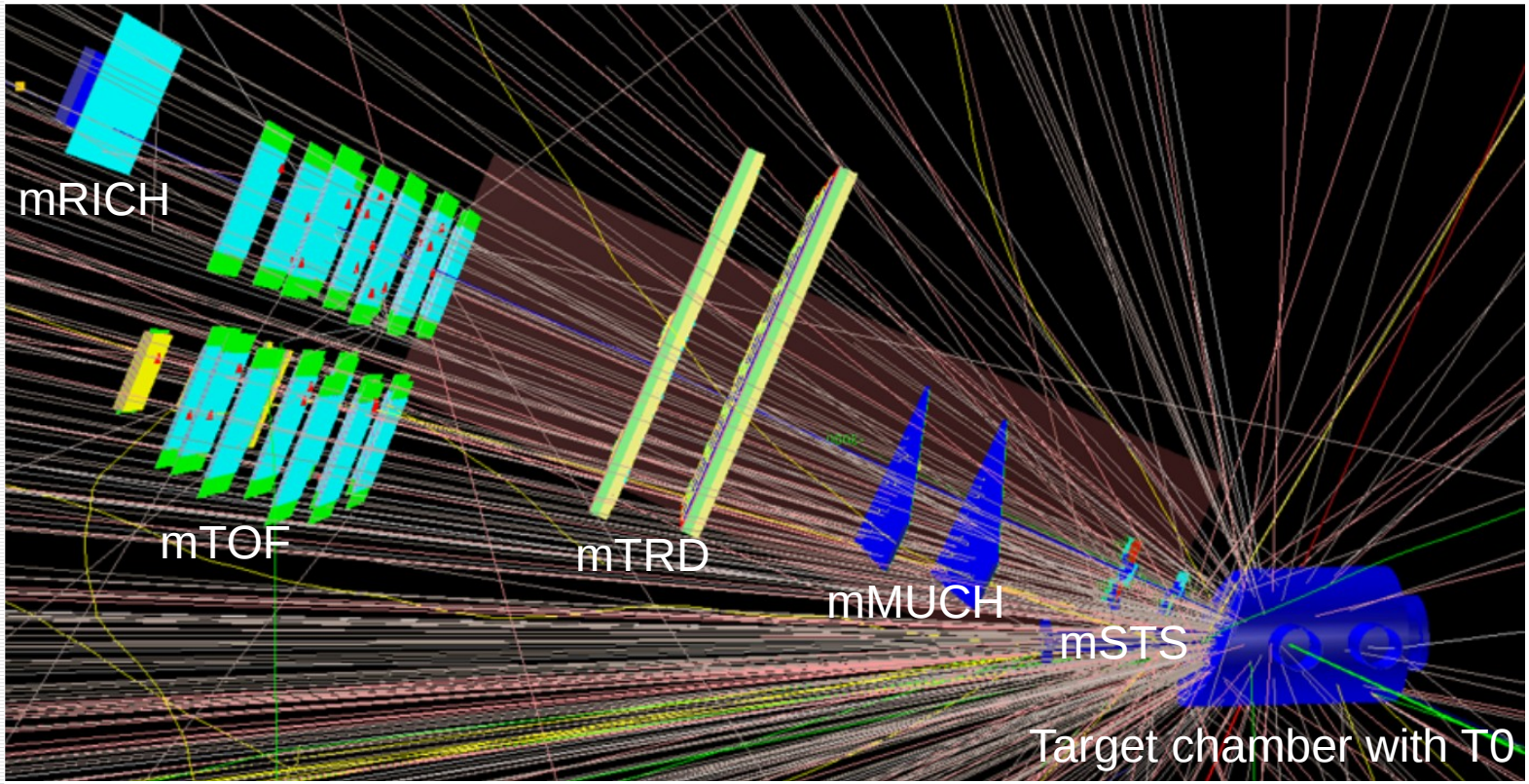
mTOF performance during mCBM beamtime at GSI



Qiunan Zhang
Tsinghua University & Heidelberg University

CBM ToF

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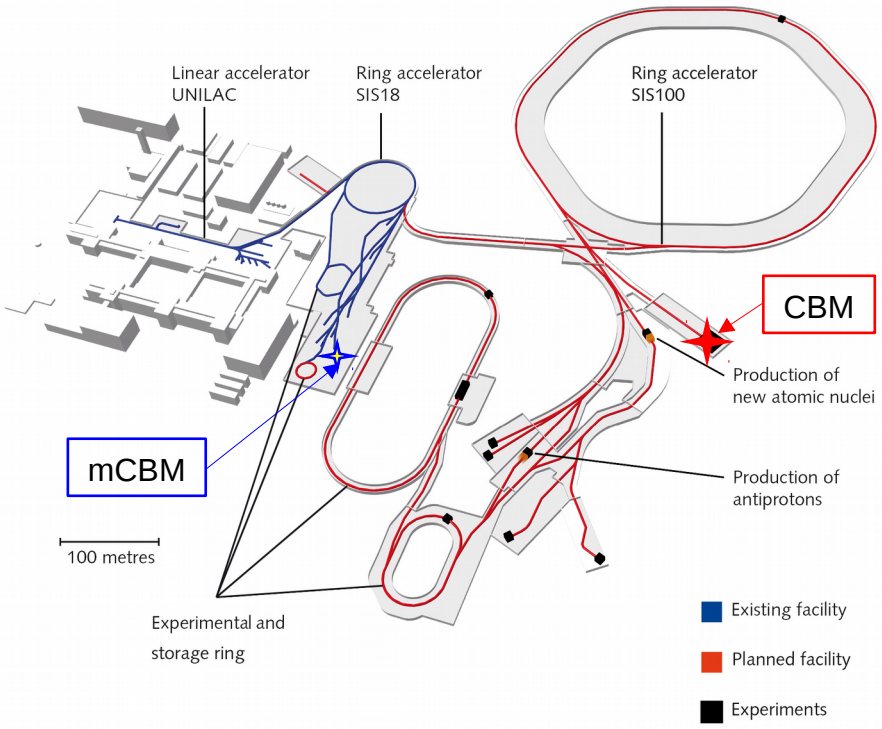
1. Introduction

2. mTOF at mCBM experiment

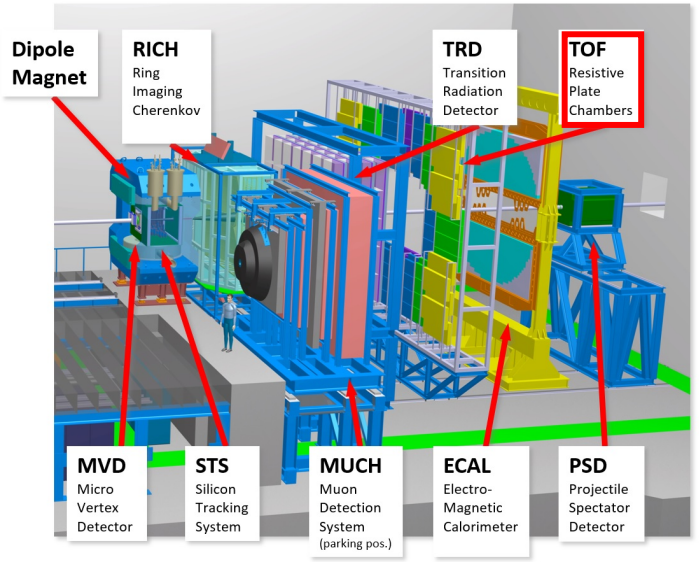
3. mTOF performance at mCBM

4. Summary and next steps

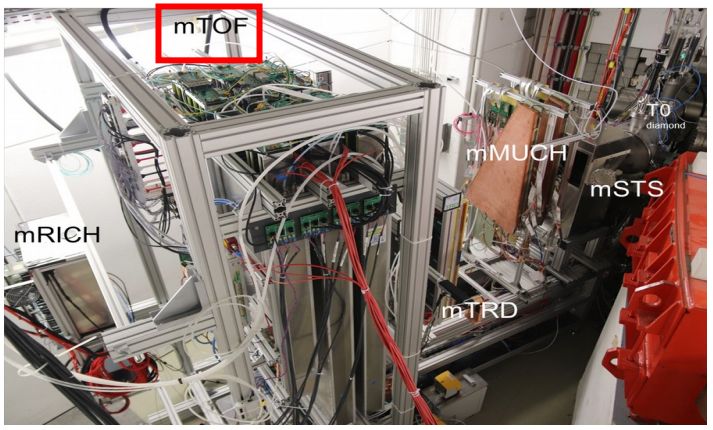
Introduction: CBM-TOF wall



Facility for Antiproton and Ion Research (FAIR) is under construction in Darmstadt, Germany. Compressed Baryonic Matter (CBM) is one of the experiments at FAIR to explore the QCD phase diagram in the region of high baryon densities at highest interaction rates up to 10 MHz.



Hadron PID is done with CBM-TOF wall: 120 m^2, 5 kinds of MRPC with rate capability from 1 kHz/cm^2 to 25 kHz/cm^2.

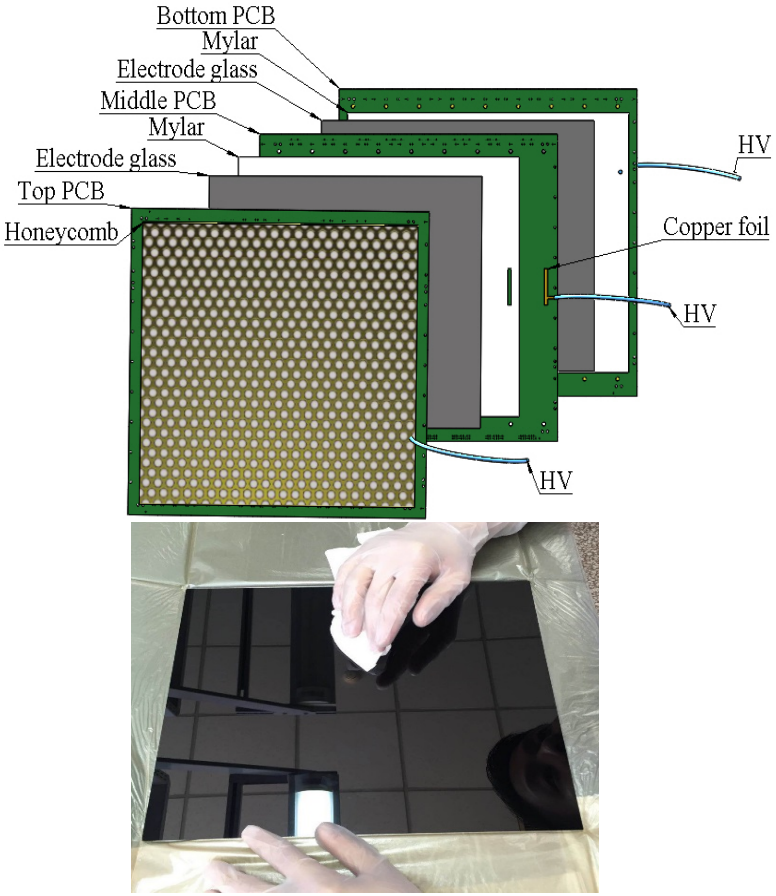


A CBM full system test-setup called mini-CBM (mCBM) has been installed for testing under CBM conditions.

Introduction: High-rate MRPC2

Structure parameters

Parameter	Value
Dimension	360 × 338 × 26 mm^3
Weight	3.3 kg
Gas gap number	4×2 stacks
Gas gap width	0.25 mm
Glass dimension	330 × 276 × 0.7 mm^3
Strip dimension	270 × 7 mm^2
Strip pitch	3 mm
Strip number	32
Electrodes	low resistive glass



Equipped with low resistive glass (~10^{10} Ω cm), the rate capability of MRPC2 meets the requirement of CBM-TOF at corresponding high rate area (1-10 kHz/cm^2).

Introduction: High rate MRPC2

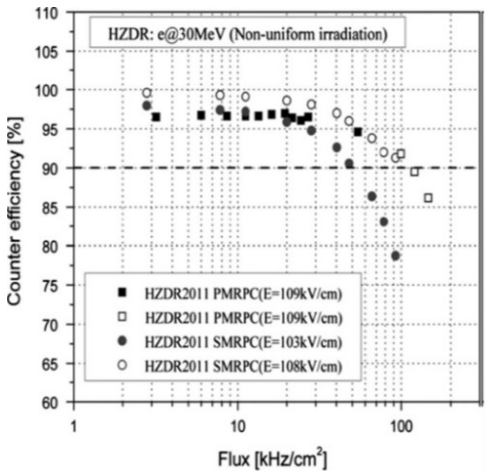
Prototype test

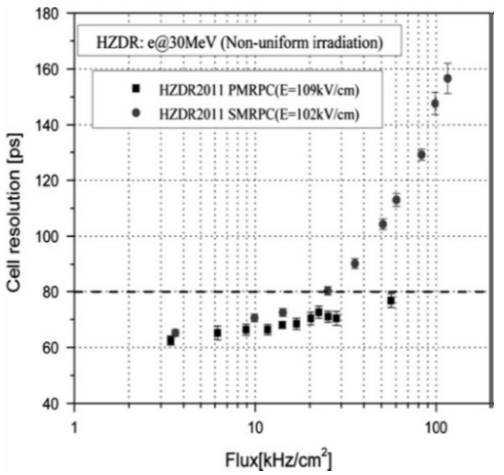
Rate: 70 kHz/cm^2

Efficiency: >90%

Time resolution: ~ 80 ps

(J. Wang et al., Nucl.Instrum.Meth. A713 (2013) 40-51)



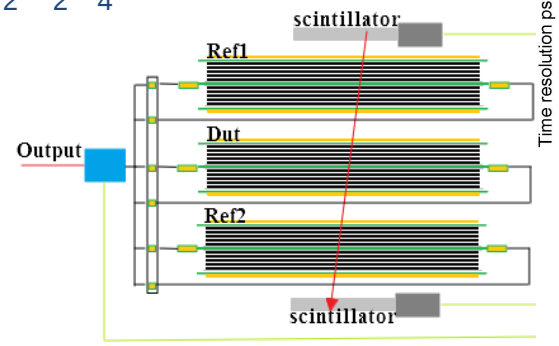


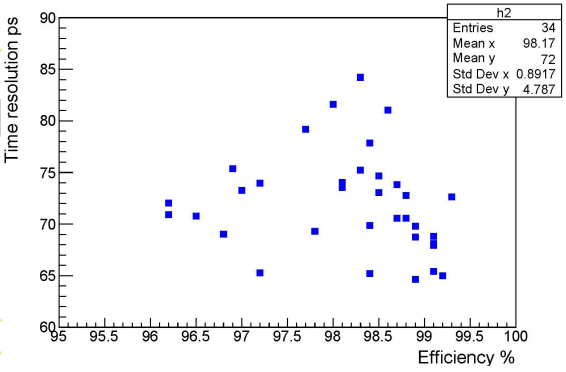
Cosmic test

Gas: 5% i-C_4H_{10}, 5% SF_6, 90% $C_2H_2F_4$

Efficiency: > 95%

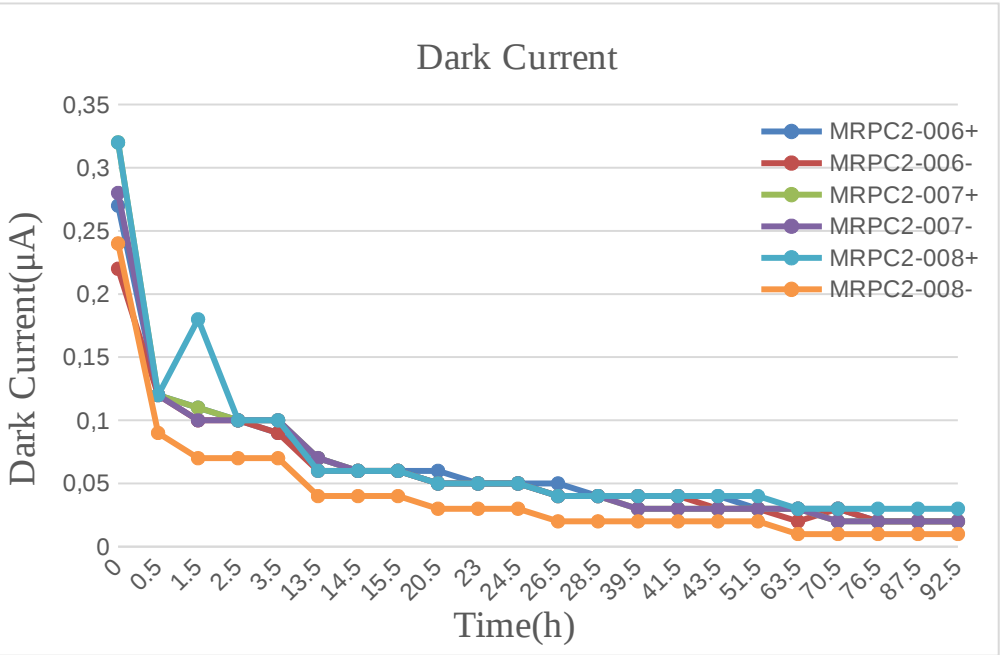
Time resolution: < 90 ps

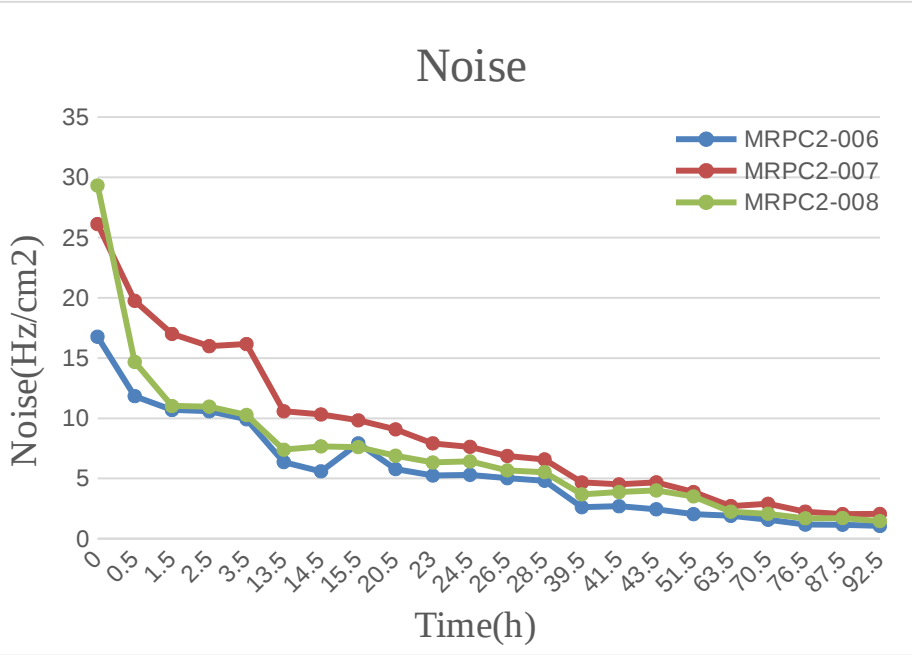




Introduction: High rate MRPC2

Dark current and noise rate





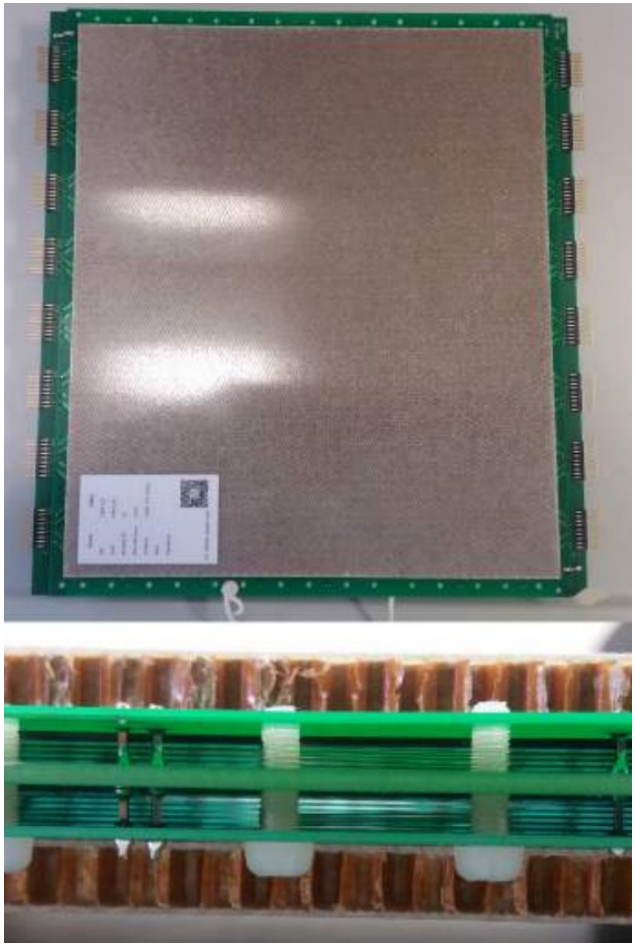
After applying HV @ ± 5600 V for ~ 2 days in Tsinghua University Lab,
Dark current < 50 nA
Noise < 5 Hz/cm^2

Cosmic test is low rate test and it is limited to statistics. The real performance of MRPCs for CBM should be finally tested with high-rate beam and CBM system under full illumination condition.

Introduction: MRPC3

Structure parameters

Parameter	Value
Gas gap number	5×2 stacks
Gas gap width	0.23 mm
Strip length	270 mm
Strip width	7 mm
Strip pitch	10 mm
Strip number	32
Electrodes	ultra-thin float glass
Thickness of glass	0.28 mm



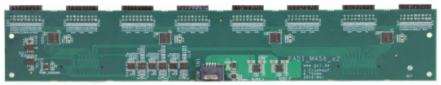
Developed and produced by University of Science and Technology of China (USTC) for CBM-TOF area where rate < 1 kHz/cm^2. Should be tested with CBM condition, too

mTOF at mCBM experiment

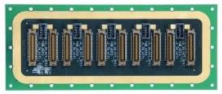
Data driven readout chain

- PreAmplifier DIscriminator (PADI): amplification (~250), threshold (10~20 fC)
- GSI Event-driven TDC with 4 channels (GET4): signal arriving time and TOT are measured
- Radiation hard ASIC GBTx: collects and combines GET4 data. Signal changed to optical signal
- Data Processing Board (DPB): collects data from GBTx and builds μ-time slices(data package)
- First Level event selector Interface Board (FLIB): combines μ-time slices for data selection and storage
- 1600 channels:32*2(sides)*5(MRPCs)*5(modules) + 128 channels: 32*2(sides)*2(MRPCs)

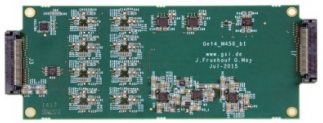
PADI: Preamplifier board 32 CH



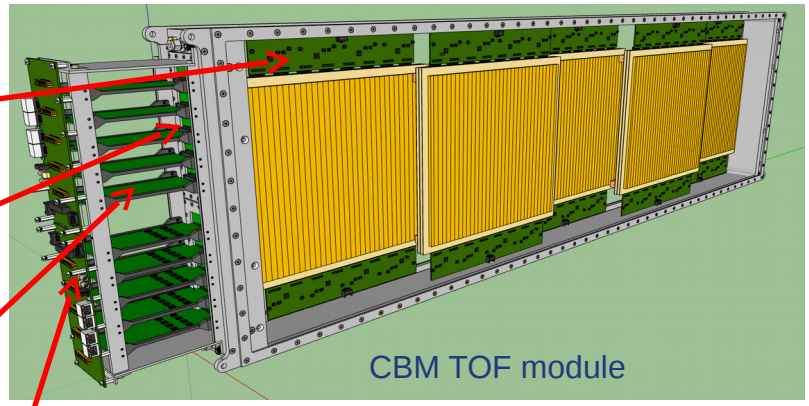
Feed through PCB



GET4: TDC board 32 CH



Backplane with GBTx chip



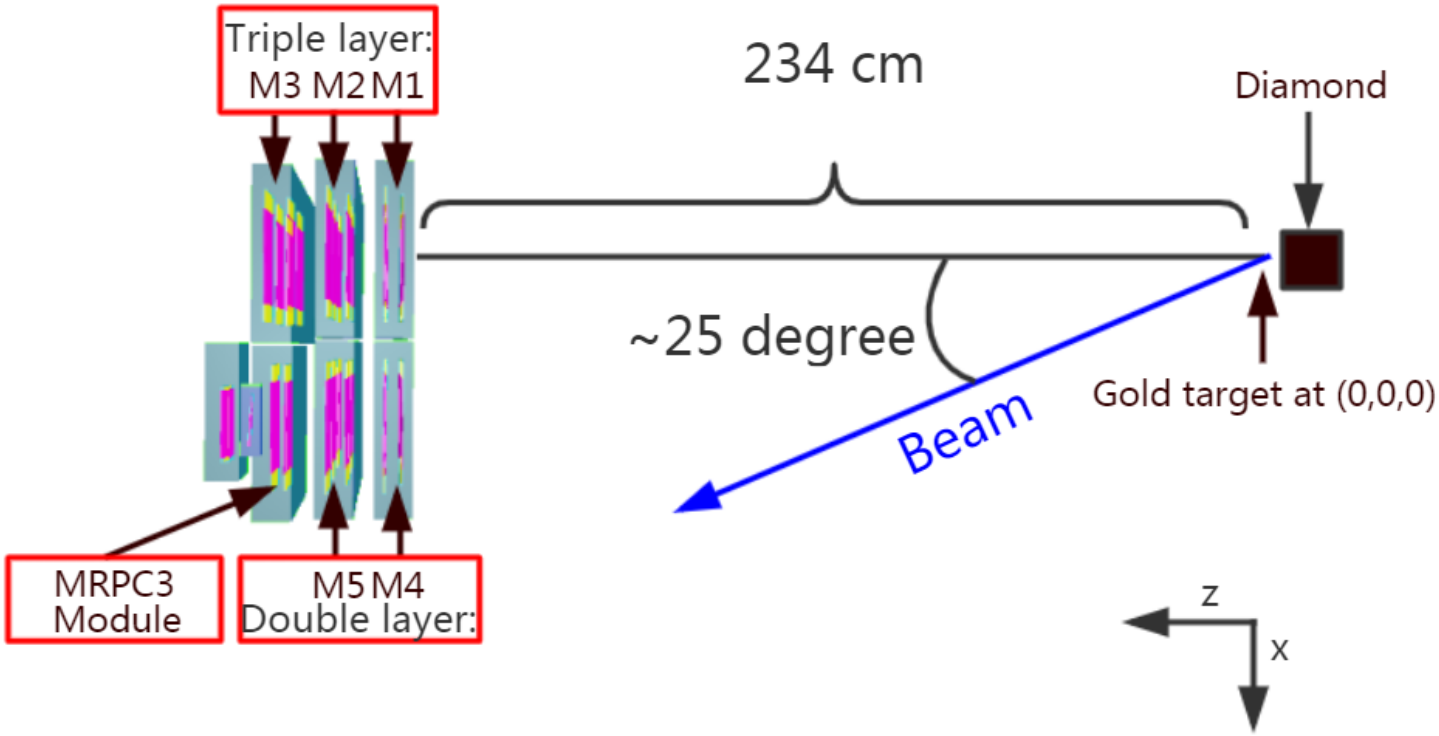
DPB: FPGA board

FLIB: FPGA card

mTOF at mCBM experiment

mTOF modules+testing counters

Top view of experiment layout



Double layer is closer to beam for rate investigation. Triple layer is meant for better track quality. Prototypes of some other counters are put behind mTOF modules to use mTOF modules as reference counter.

mTOF at mCBM experiment

Experiment conditions

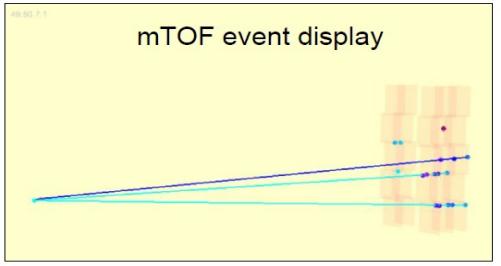
Gas mixture	90% $C_2H_2F_4$, 5% i-C_4H_{10}, 5% SF_6
Gas flow	110 ml/min in total Gas flows in parallel
HV	+ 5.3 kV for MRPC2 (106 kV/cm) + 6.4 kV for MRPC3 (116.4 kV/cm)
PADI threshold	-300mV for MRPC2 -250mV for MRPC3
Beam condition	^{107}Ag+ empty target ^{107}Ag+thin target (0.25 mm) ^{107}Ag+thick target (2.5 mm)

Run 159: beam intensity: $2*10^5$ thin target (1% interaction probability)
Particle flux on counters is ~10 Hz/cm^2

mTOF performance

Steps of analysis

- **Step 1: Unpacking and event building**
  - Digi info: logical address (layer, MRPC, strip, side), TOT, time
  - Event: At least 10 counters fired within 50 ns
- **Step 2: Calibration and hit finding**
  - Position calibration (different cable length)
  - TOT calibration (amplifier differences)
  - Walk correction (slewing correction)
- **Step 3: Tracking**
  - Track-finding in events (as shown in example)
- **Step 4: Performance evaluation**
  - Derive counter properties by comparing measured hits to track fit expectations



mTOF performance

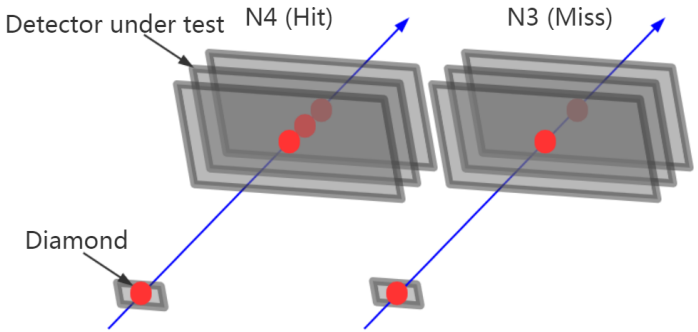
Performance evaluation

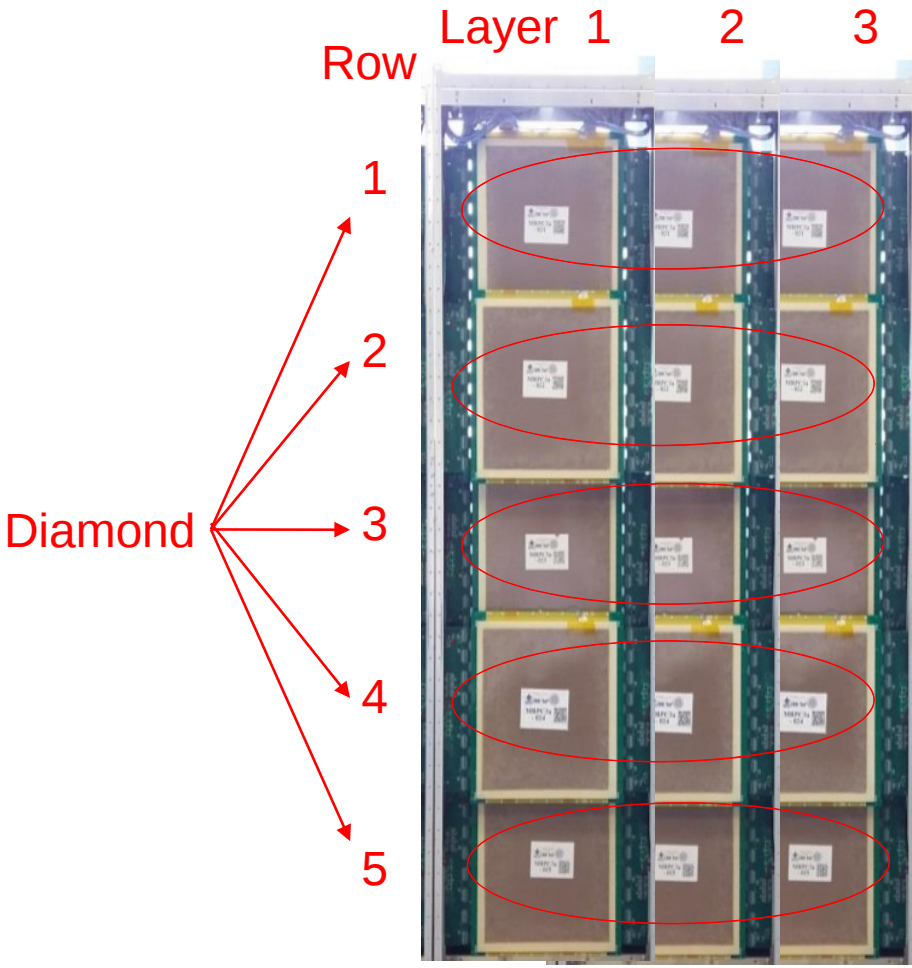
- Analysis within groups:
  - Diamond and MRPCs

  (same geometry acceptance)
- Efficiency:

$$\frac{N_i(Hit)}{N_i(Hit) + N_{i-1}(Miss)}$$

N_i: Number of tracks with i hits

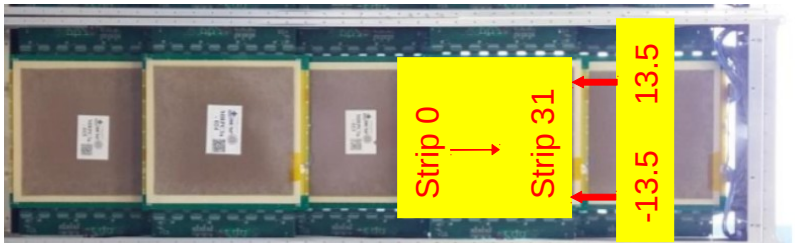


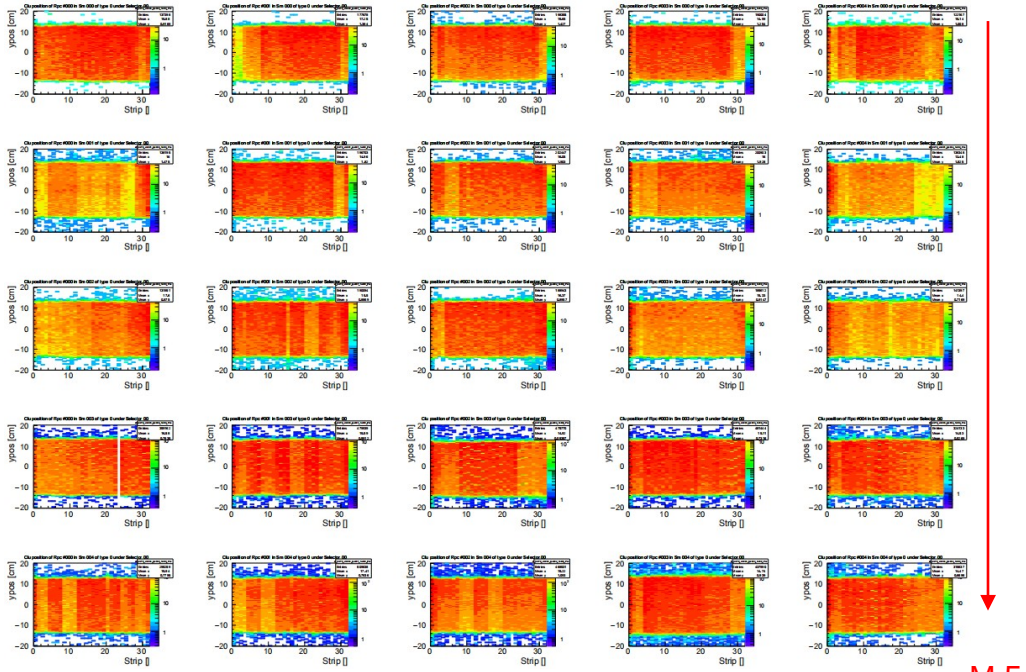


- Time resolution:
  - σ (Expected time from track fit – Measured time)

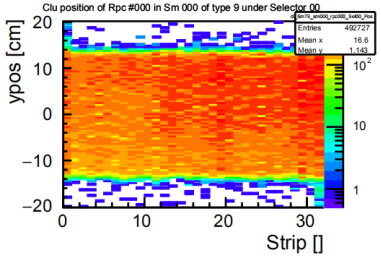
mTOF performance

mTOF position distribution

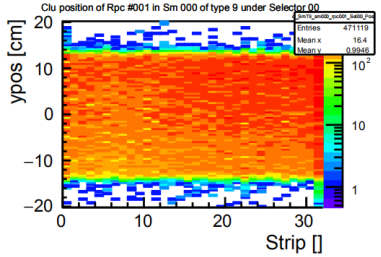




Front MRPC3



Back MRPC3



The active area of the detectors is shown after calibration

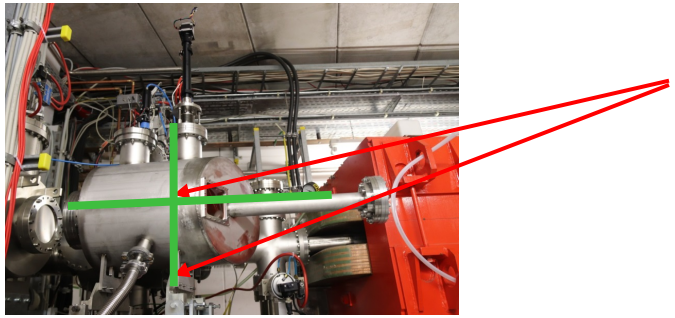
Only 1/(1600+128) dead channel

Structures are visible due to problems in data acquisition system (firmware in DPB) leading to partial data loss

mTOF performance

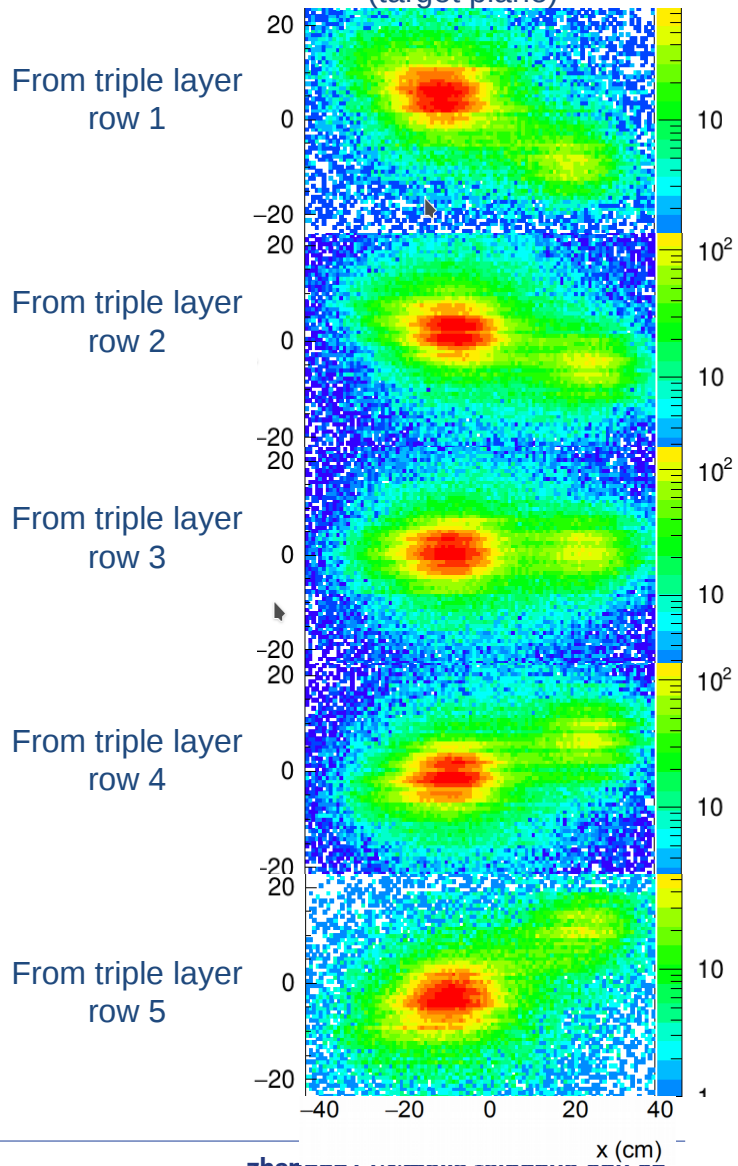
Position resolution

- project MRPC-based tracks to target plane



- Evident phenomenon:
  - Different track sources
  - Position of second source caused by geometry
  - Hypothesis: a third source (T0 diamond counter) is close to target and causes elliptical shape
  - Position resolution is quiet good

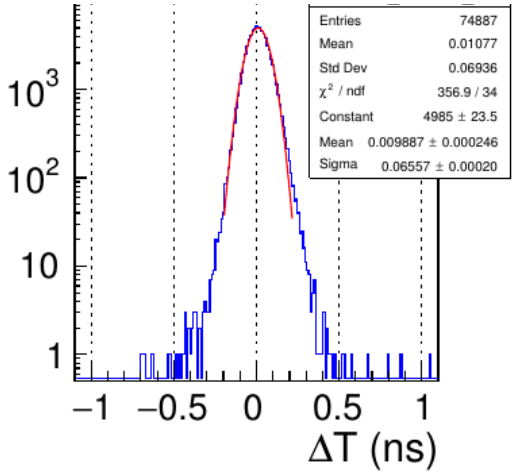
Extrapolated intersept with z= 0 plane (target plane)



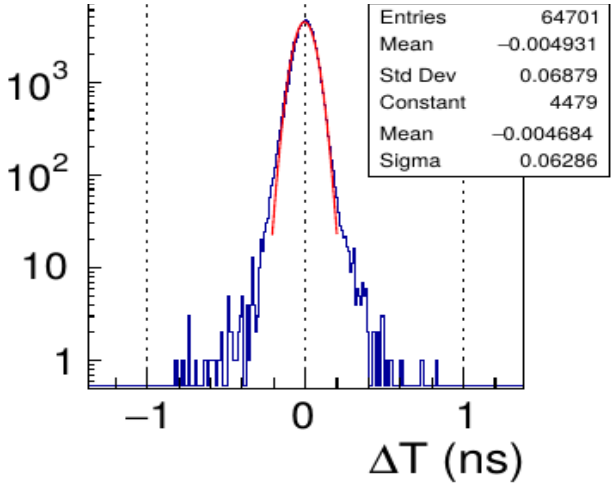
mTOF performance

Preliminary time resolution of mTOF

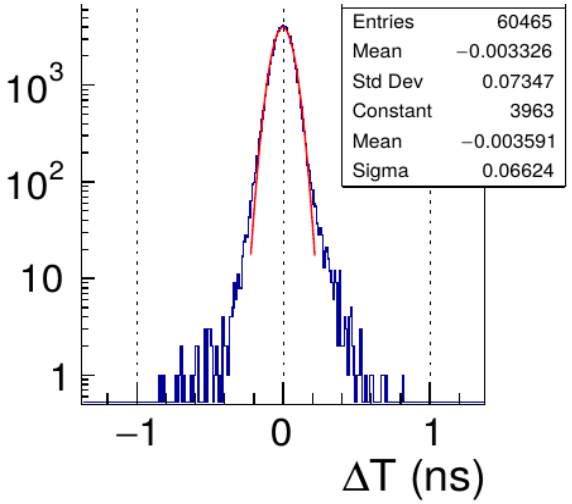
Layer 1 row 2
MRPC2



Front MRPC3



Back MRPC3

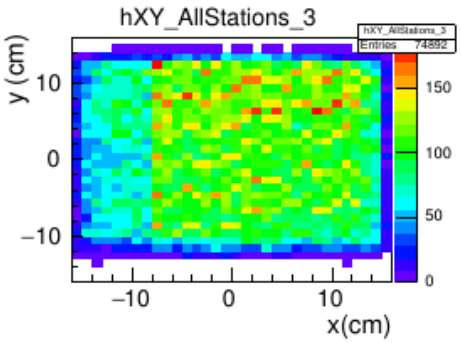


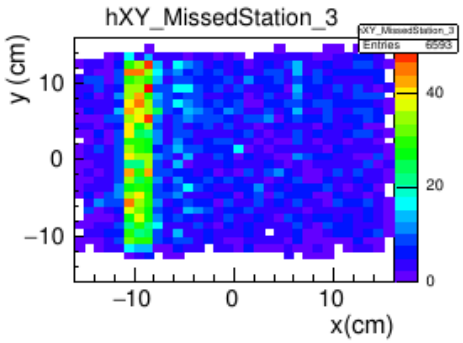
Time resolution of mTOF counters is ~ 65 ± 5 ps.

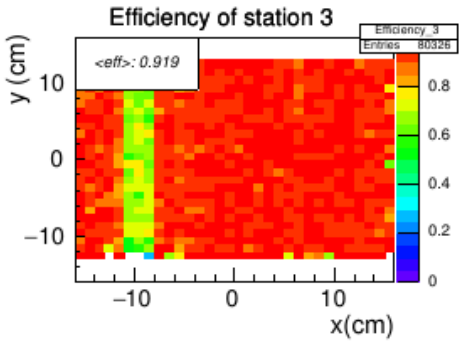
mTOF performance

Preliminary efficiency

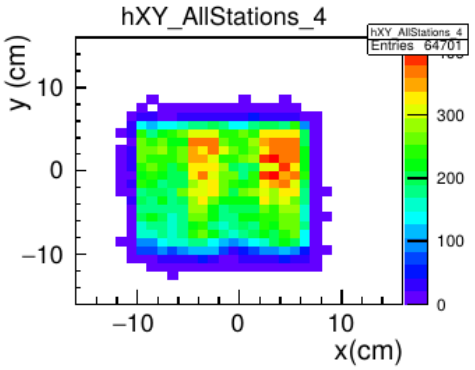
Efficiency of MRPC2 (layer 1 row 2) above 90% in DAQ error free regions

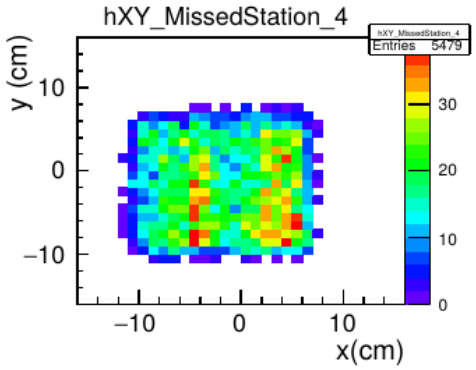


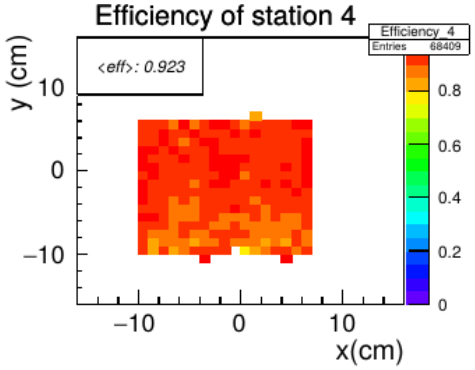




Efficiency of MRPC3 (Front) above 90%







Summary and next steps

- The time resolution of mTOF is better than 80 ps.
- Effective area efficiency above 90% is demonstrated.
- Beam test with higher particle flux, new glass material, and stable DAQ is scheduled in Q2 2020.
- Aging tests will be finished this year.

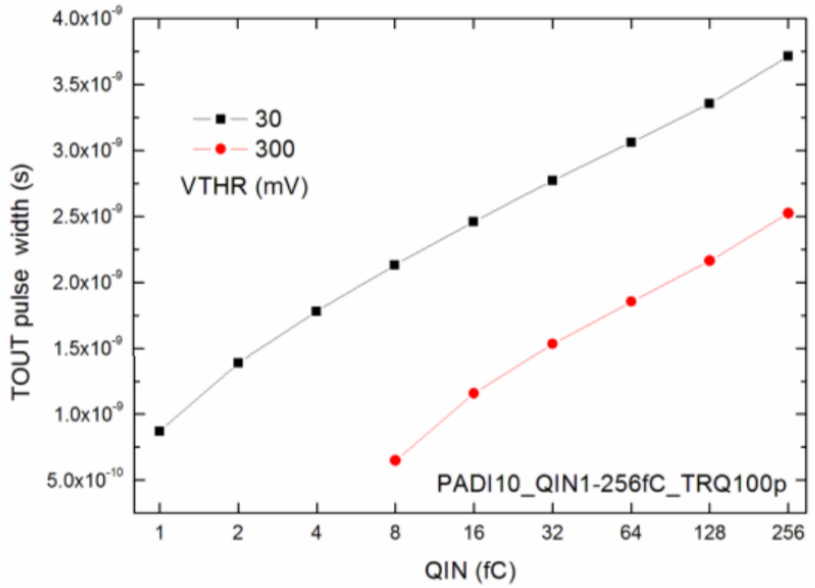
Thank You !

Back up

- MRPC2 with eco-friendly gas mixtures is ongoing

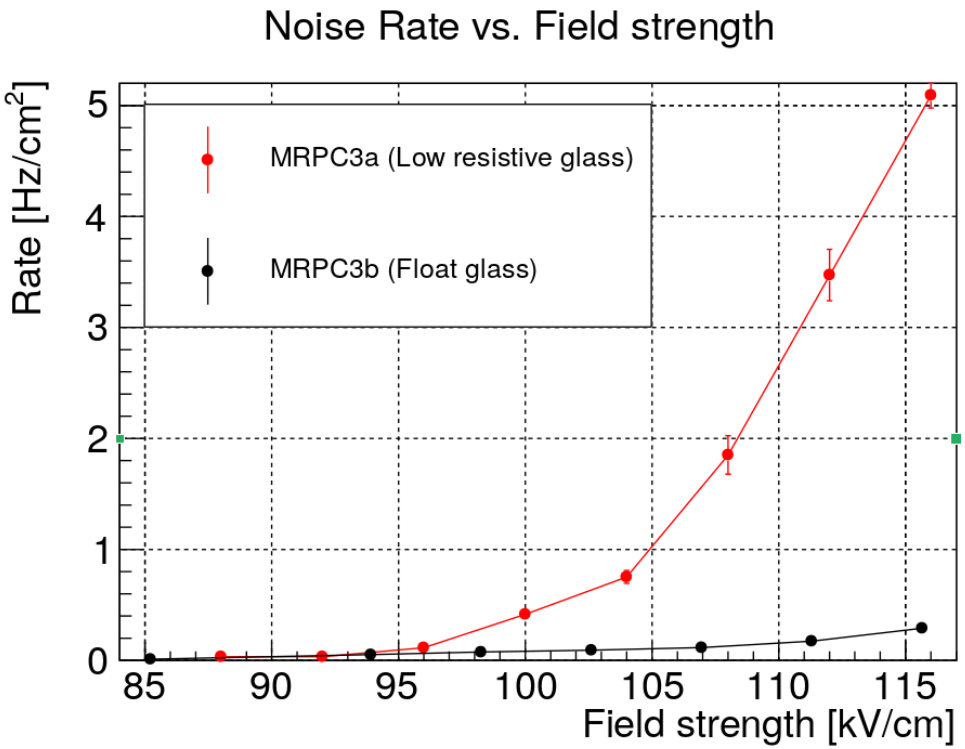
  See Botan Wang's talk:
  https://indico.gsi.de/event/7101/session/8/contribution/85/material/slides/1.pdf

- PADI threshold



Back up

- Noise of MRPC2 and MRPC3 tested in Heidelberg



Tested by Dennis Sauter