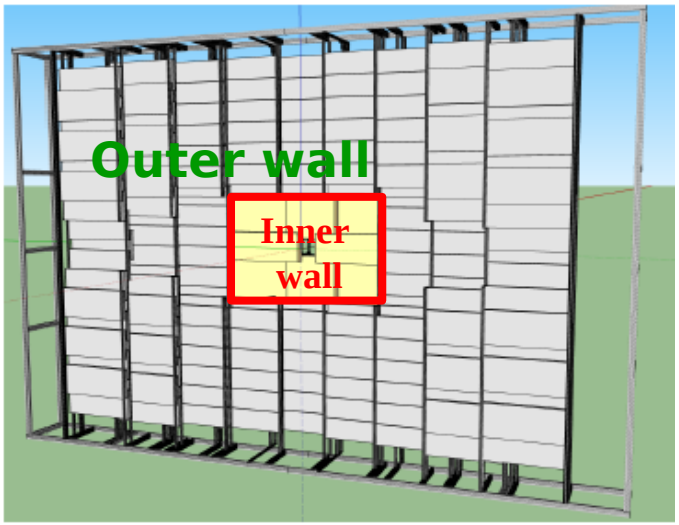
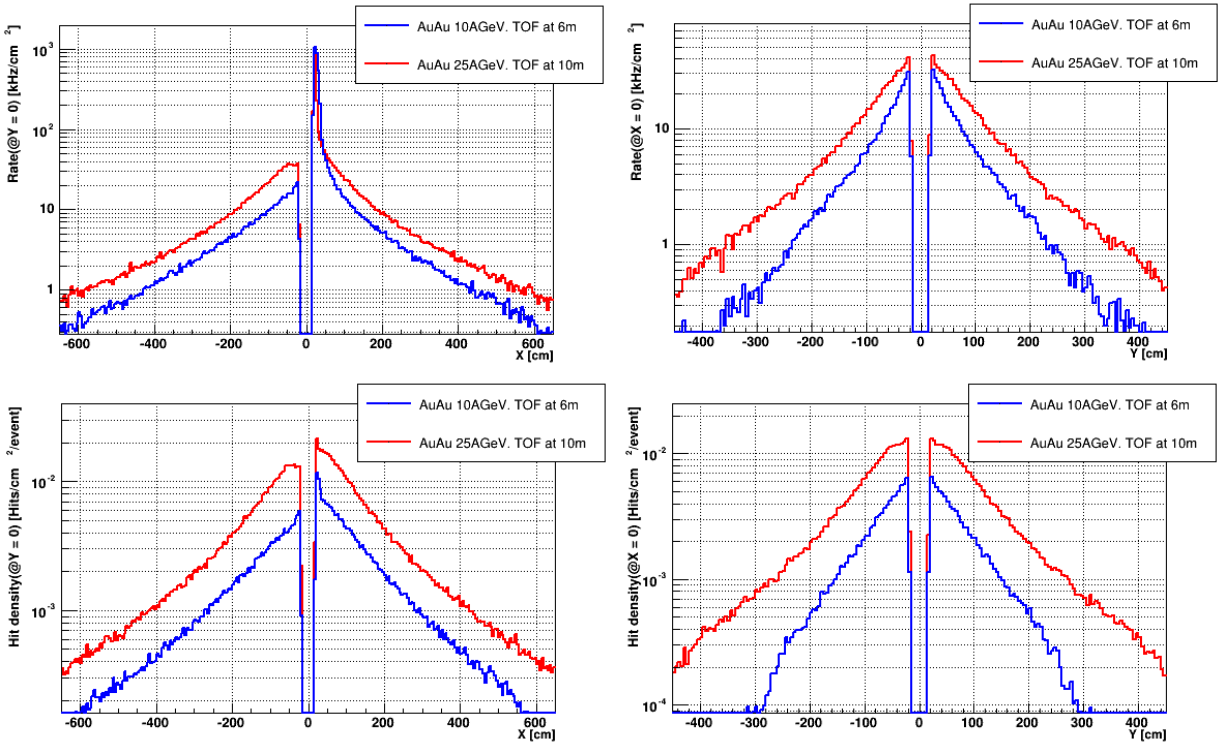
Aging studies and resulting design change considerations for MRPC1

CBM – TOF requirements



URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz



CBM-ToF Requirements

- **Full system time resolution σ_T ~ 80 ps**
- **Efficiency > 95%**
- **Rate capability ≤ 30 kHz/cm^2**
- **Polar angular range 2.5° – 25°**
- **Active area of 120 m^2**
- **Occupancy < 5%**
- **Low power electronics (~120.000 channels)**
- **Free streaming data acquisition**

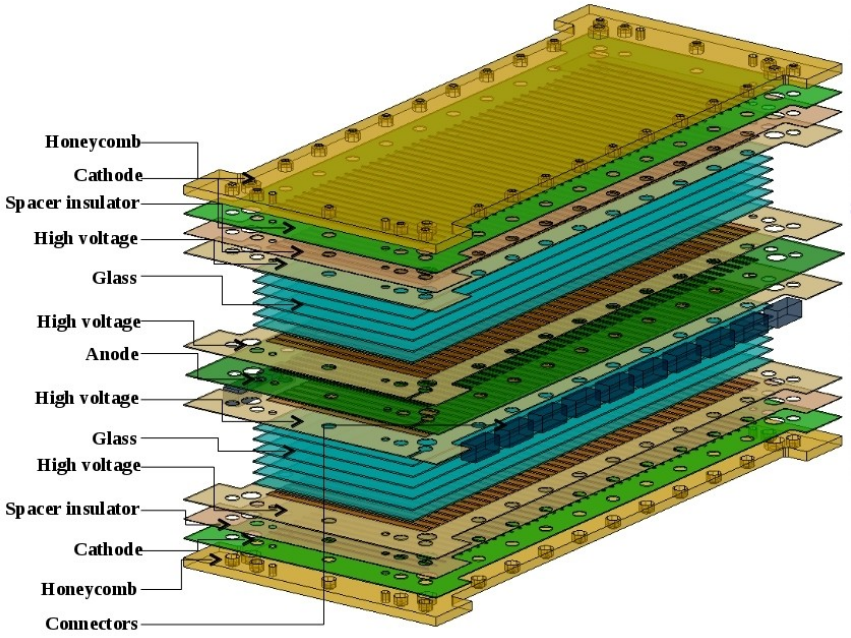
CBM Collaboration, "CBM – TOF Technical Desing Report", October 2014

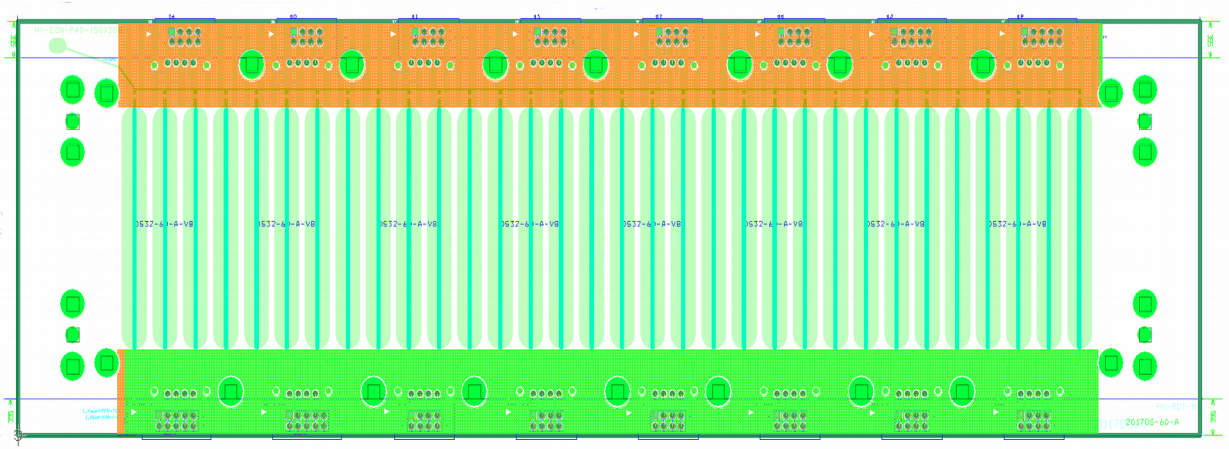
Detectors with different rate capabilities are needed as a function of polar angle

Our R&D activity addresses the CBM-TOF inner wall:

- highest counting rate
- highest granularity
- ~15 m^2 active area

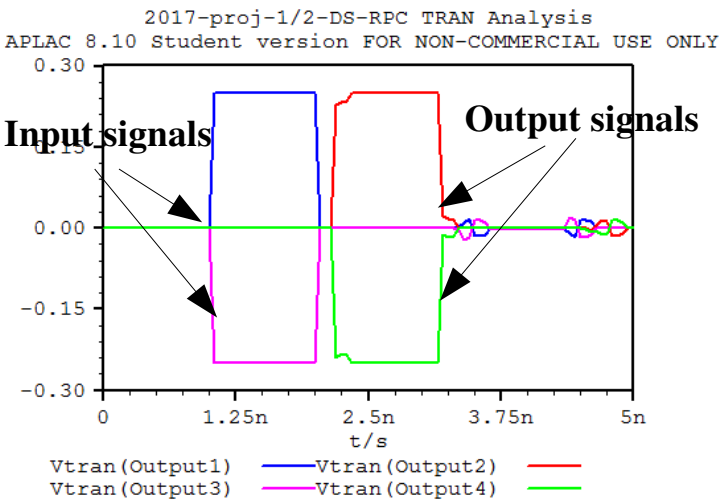
Prototype architecture





32 strips
Readout electrode: 9.02 mm pitch= 1.27 mm w + 7.75 mm g
High Voltage electrode: 9.02 mm pitch= 7.37 mm w + 1.65mm g

- ✓ **Symmetric two stack structure: 2 x 5 gaps**
- ✓ **Active area 60/100/200 x 300 mm^2**
- ✓ **Gas gap thickness: 140 µm / 200 µm**
- ✓ **Strip structure for Readout & HV electrodes**
- ✓ **Differential readout**
- ✓ **Resistive electrodes: Chinese glass**

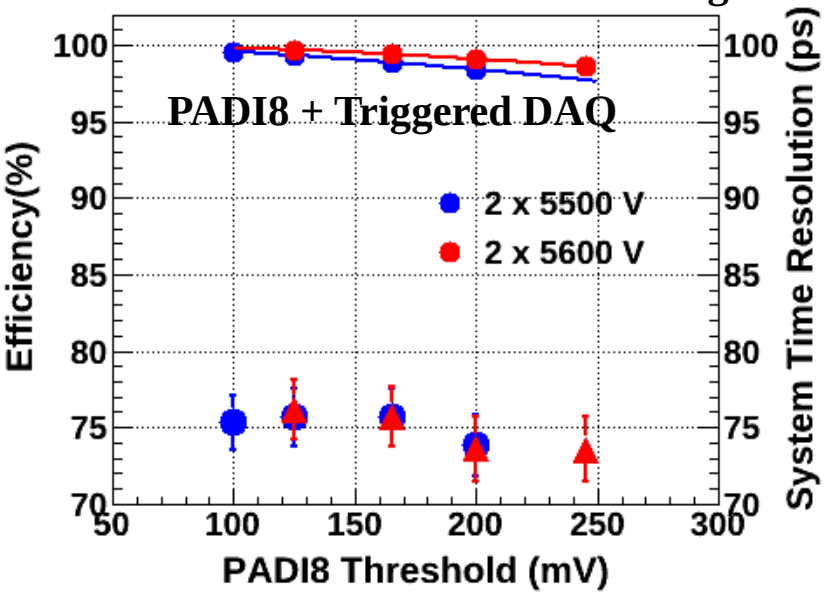


Input/Output signals are simulated using APLAC
~97 Ω transmission line impedance

Efficiency for MSMGRPCs with 140 µm gap size and triggered/free streaming DAQ systems

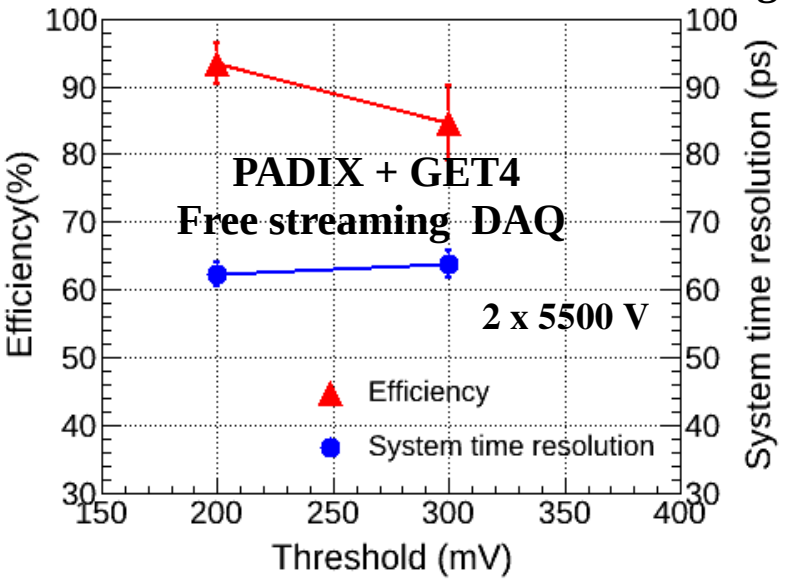
GSI Darmstadt

1.1 GeV/u ^{152}Sm beam on Pb target



CERN-SPS

Pb beam of 13/30/150 AGeV on a Pb target



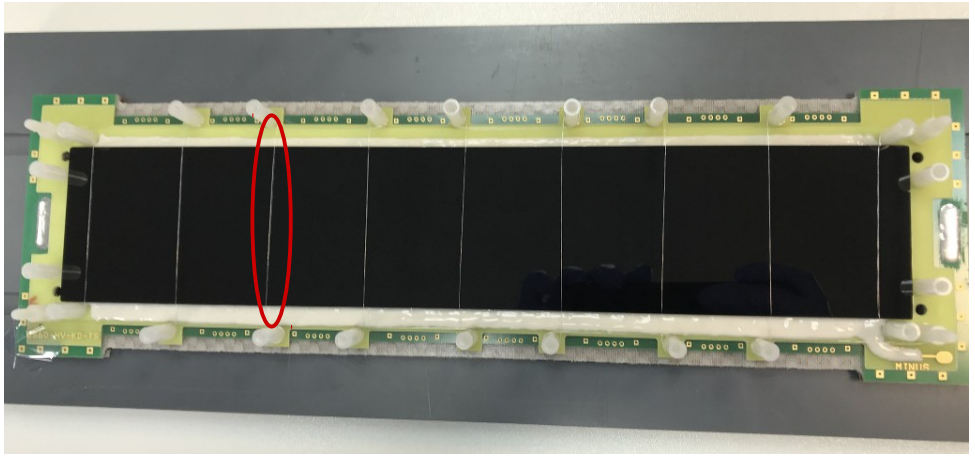
At the CBM Meeting (Kolkata, September 2019) we agreed to:

- assemble two new prototypes with 200 µm gap size, based on Chinese glass,

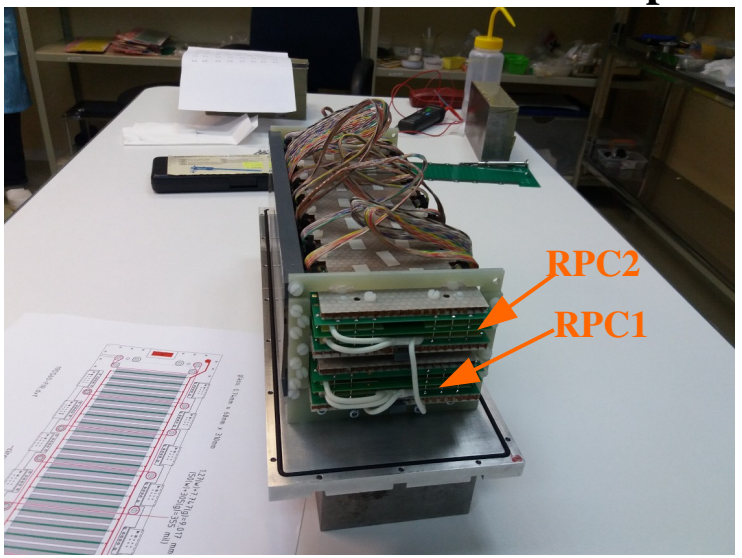
in order to increase the signal size at the input of PADI FEE for better efficiency;

MSMGRPC prototypes with 200 µm gas gap size – RPC2019

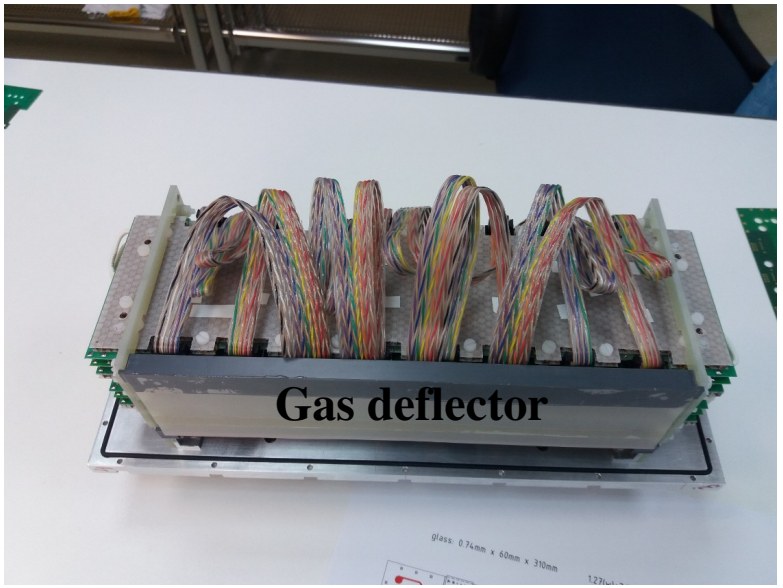
Spacer distribution across the surface



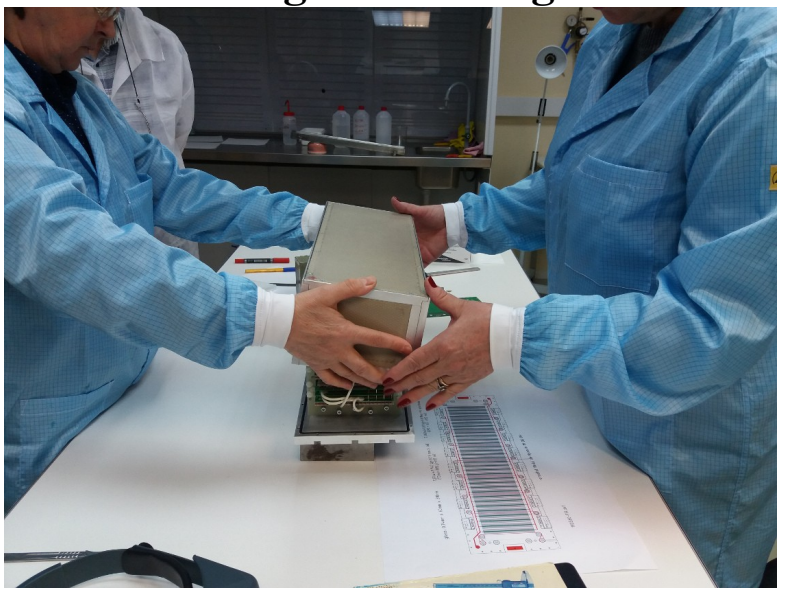
2 counters mounted on the back panel



Counters ready to be closed in the housing box



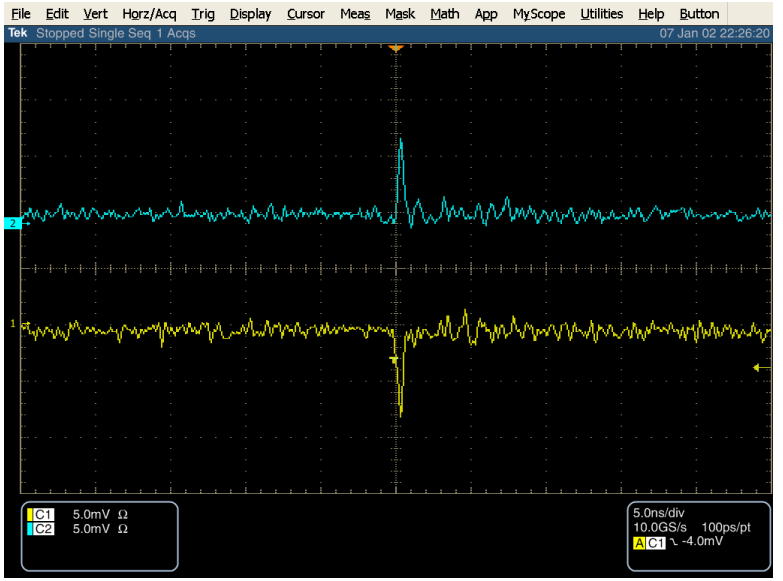
Mounting the housing box



CBM-TOF weekly meeting, 08.01.2020

Experimental setup for cosmic rays & ^{60}Co tests

Typical signals

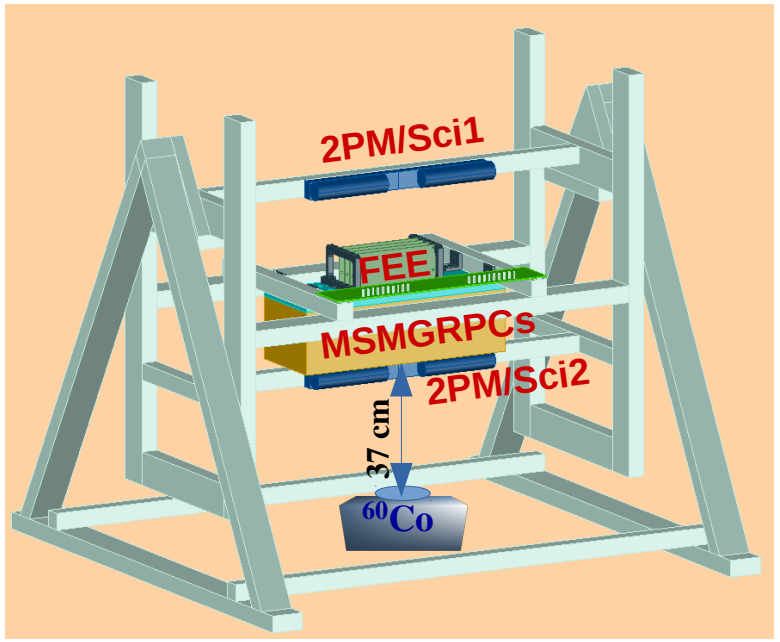


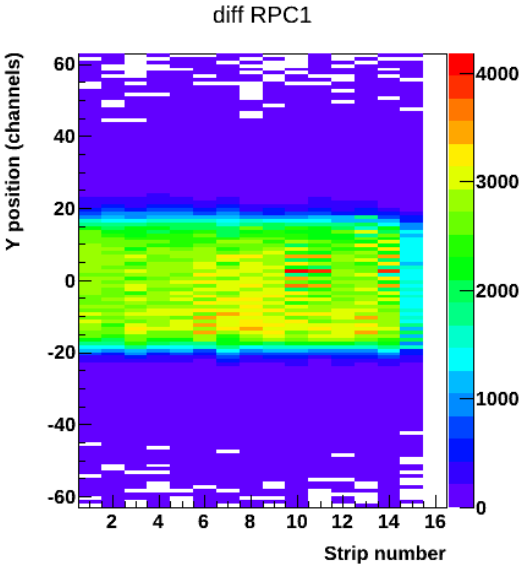
<u>for each RPC:</u>

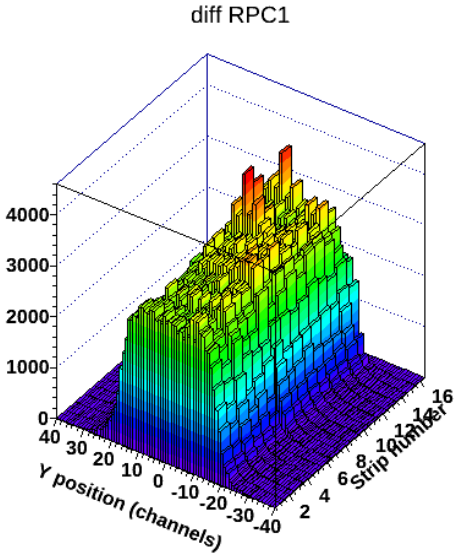
- 16 operated strips, readout at both ends
- (16 x 0.902 cm) x 6 cm = 86.6 cm^2 operated area
- NINO FEE, Threshold = 145 mV
- Plastic size = 1.5 cm x 1.5 cm x 10 cm
- Gas mixture: 90%$C_2H_2F_4$ + 5%SF_6 + 5%iso-C_4H_{10}

RPC2019 (Chinese glass)	I_{dark}	Dark rate
RPC1	< 1 nA	0.11 Hz/cm^2
RPC2	< 1 nA	0. 14 Hz/cm^2

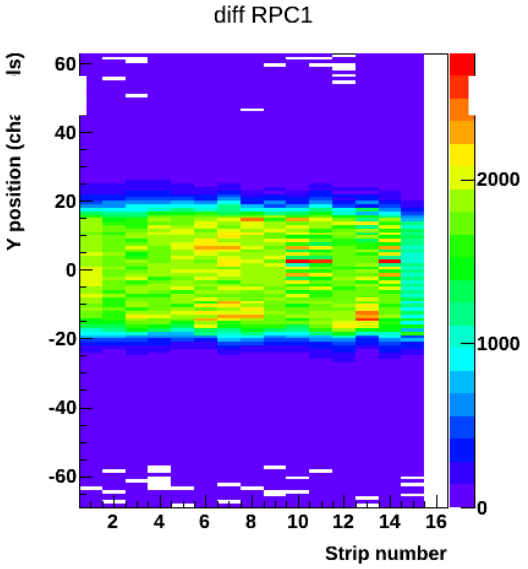
2D mapping in self-trigger mode using ^{60}Co source

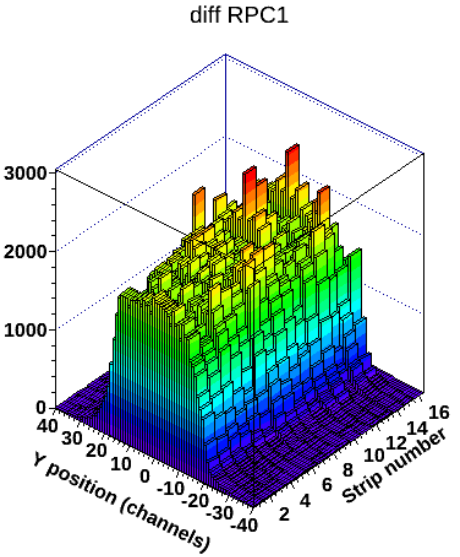




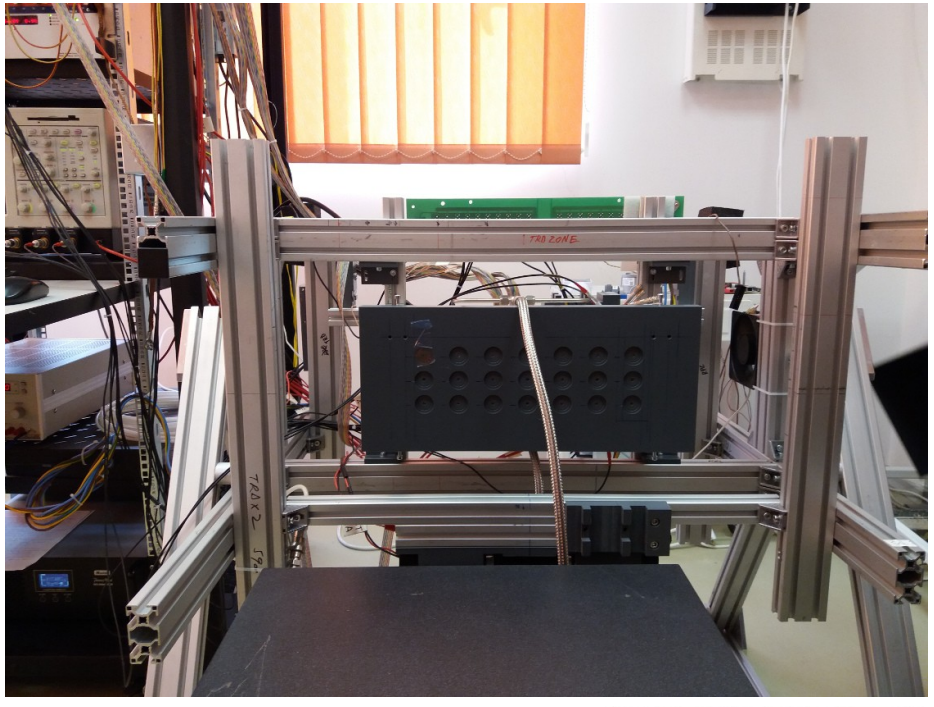


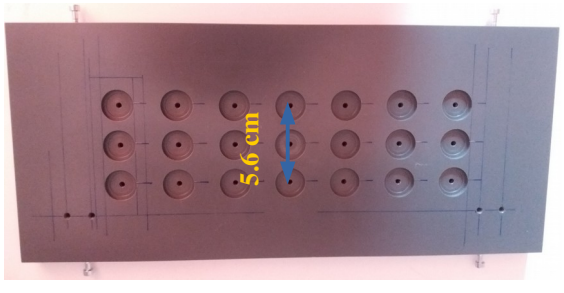
using cosmic rays

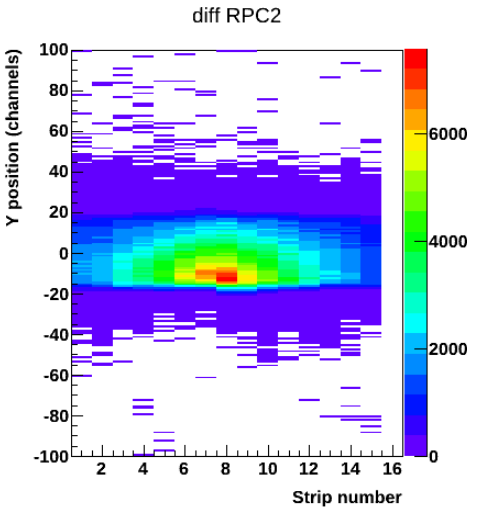


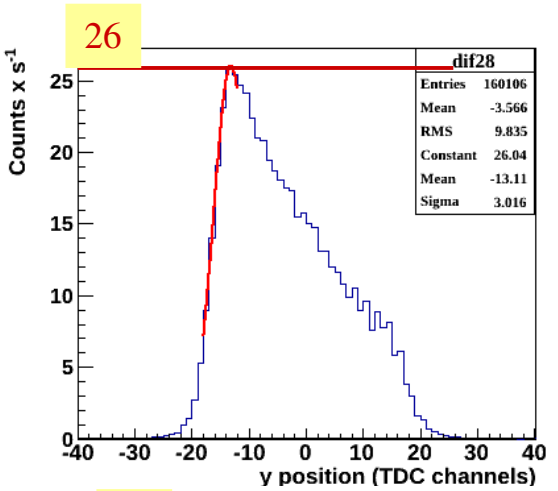


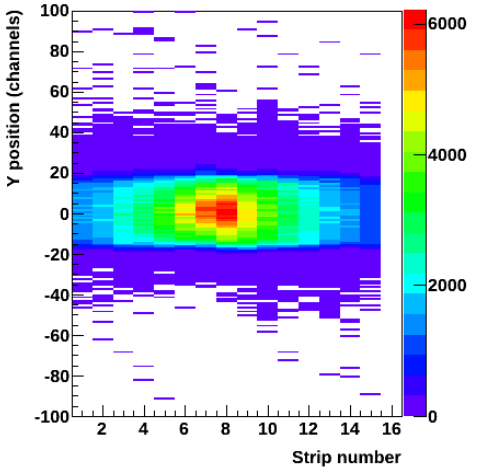
Collimator for edge scanning with ^{60}Co source

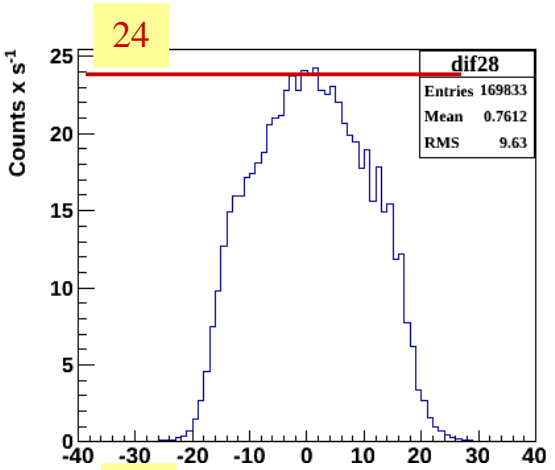


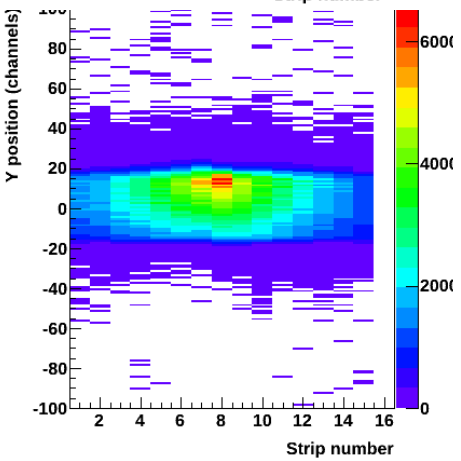


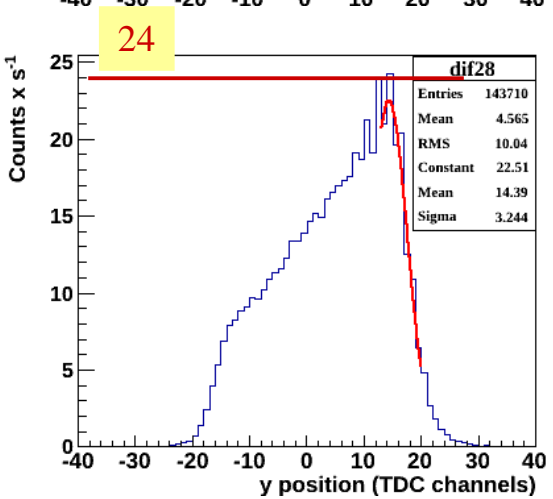






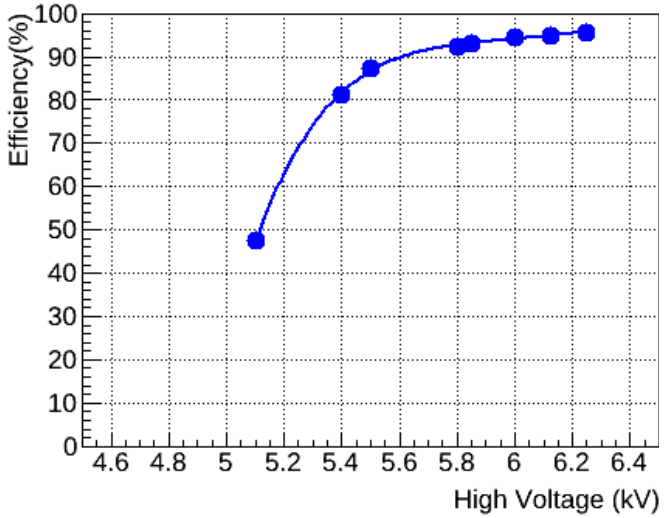


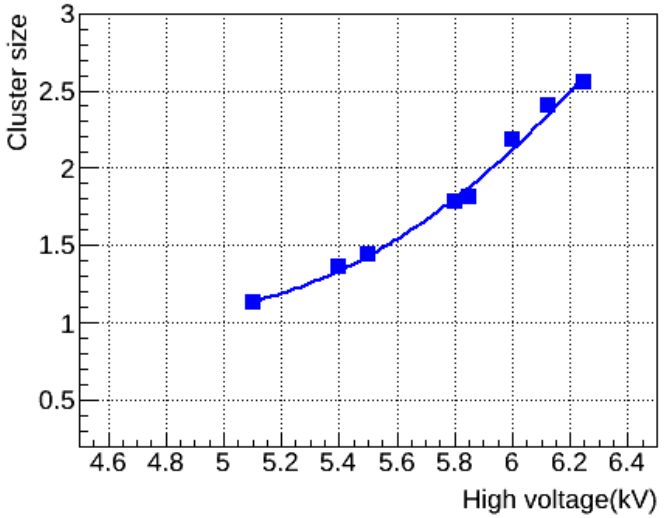


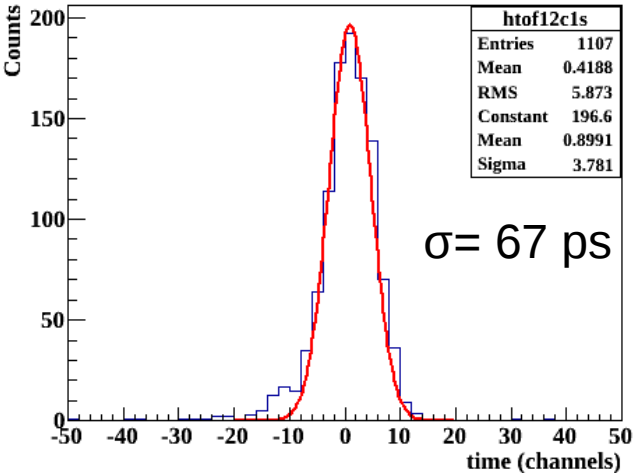


Mariana Petris, MRPC design chan

Cosmic rays tests in HPD/IFIN-HH Bucharest
NINO FEE + CAEN TDC







Cosmic rays tests in PI/UNI Heidelberg
PADI X/XI + GET4

Efficiency Bucharest counter

Efficiency	Gap 140 µm	Gap 200 µm
PADI X	81 %	93 %
PAD XI	91 %	98 %

2021 mCBM@SIS18 beam time – test counters in mTOF

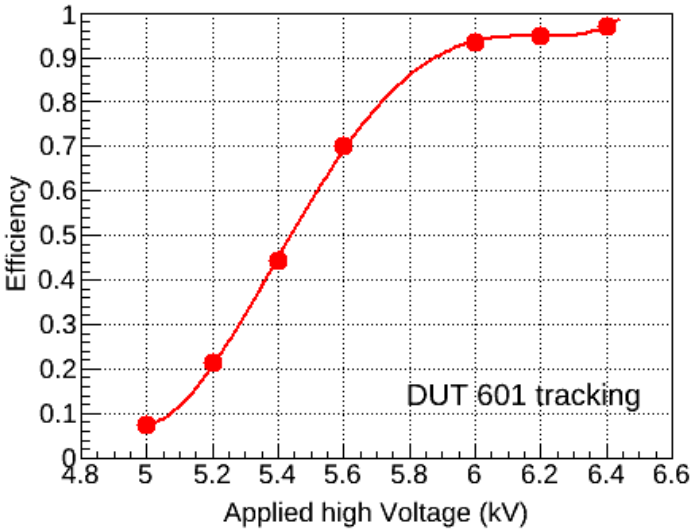
June runs

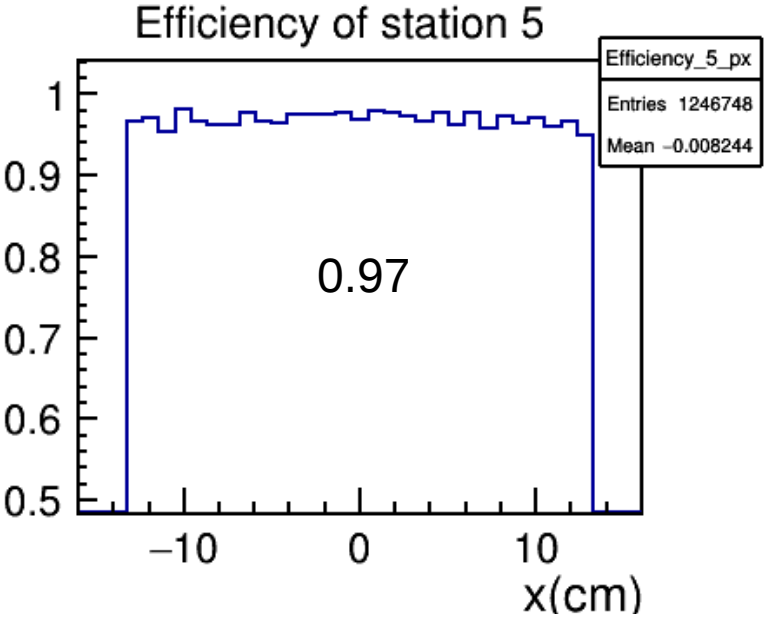
Beam: ^{16}O, 2.0 AGeV

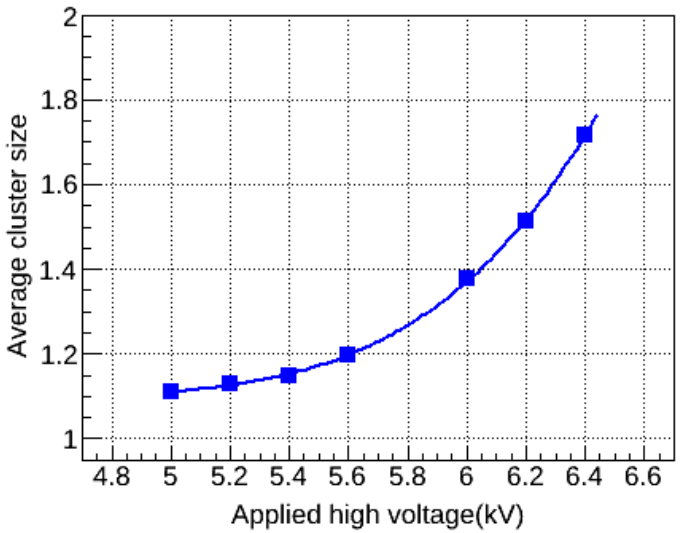
- **New readout electronics for inner zone counters**

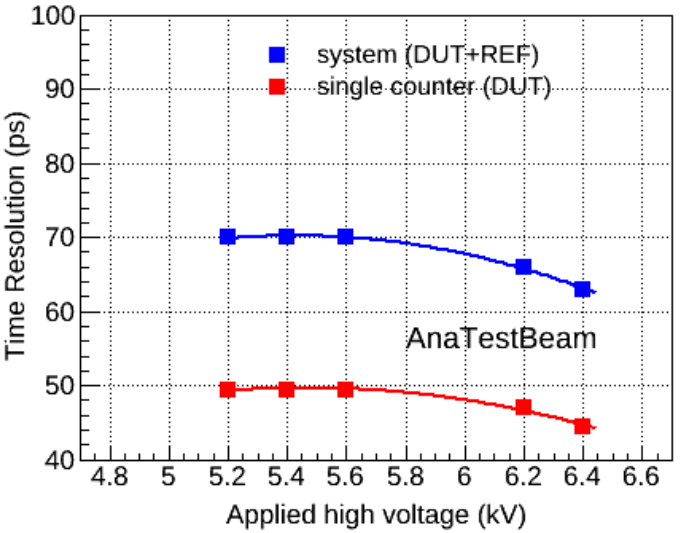
M4_5
MRPC3, 911 (USTC, float)
MRPC3, 910 (USTC, float)
MRPC2, 901 (sealed) (TSU)
MRPC2, 900 (TSU)
M4_3
MRPC1, 600 (Buc.)
MRPC1, 601 (Buc.)

High voltage scan & Th =200 mV

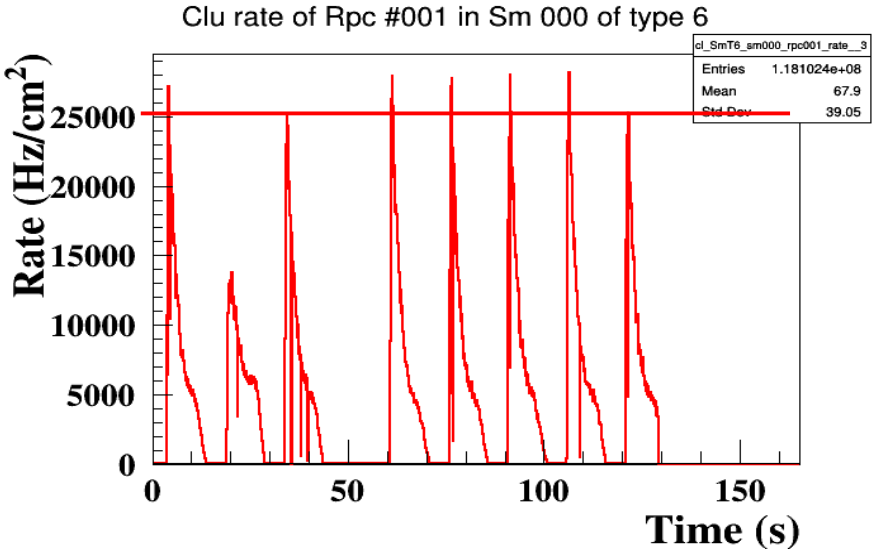


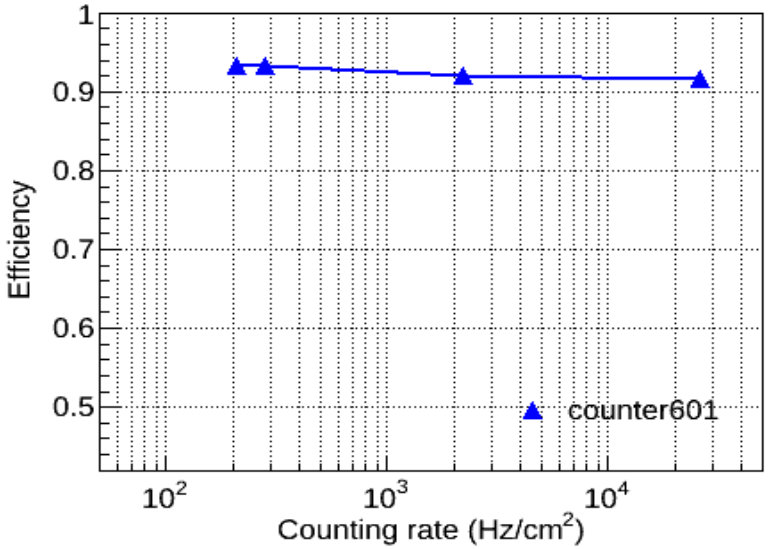


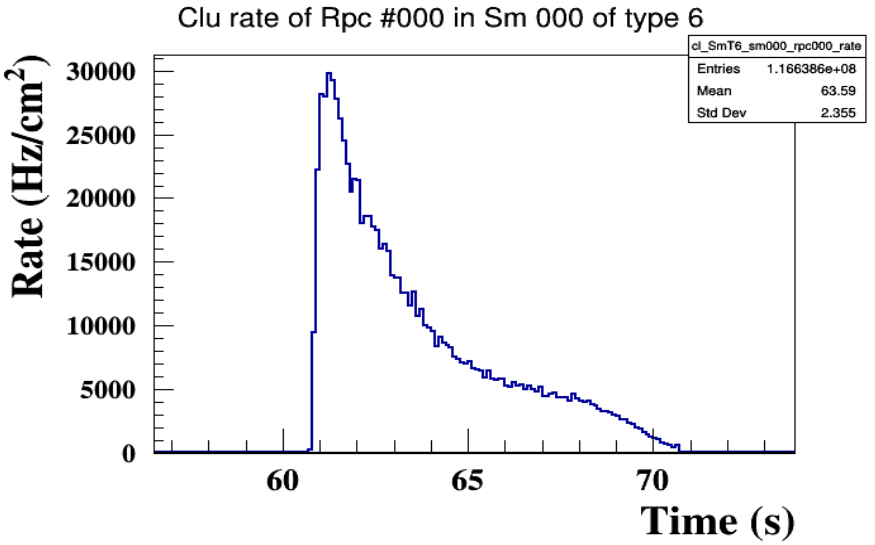


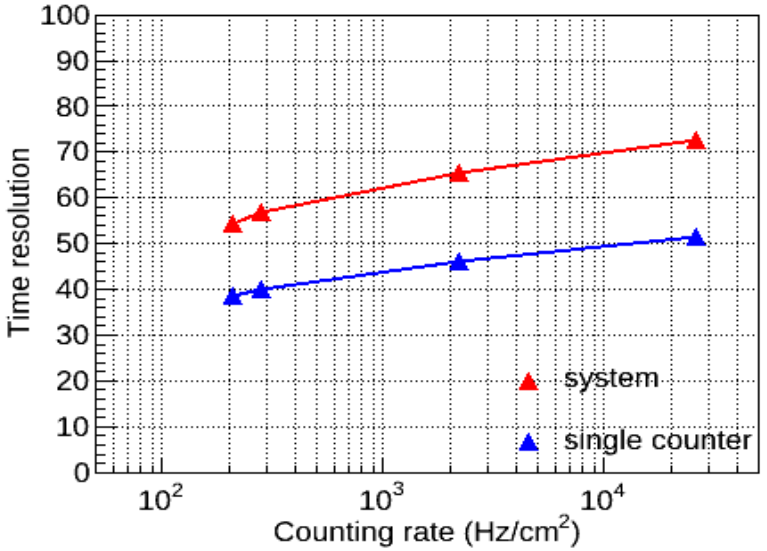


Efficiency & time resolution @ counting rate (@ +/- 6kV, Th=200 mV)

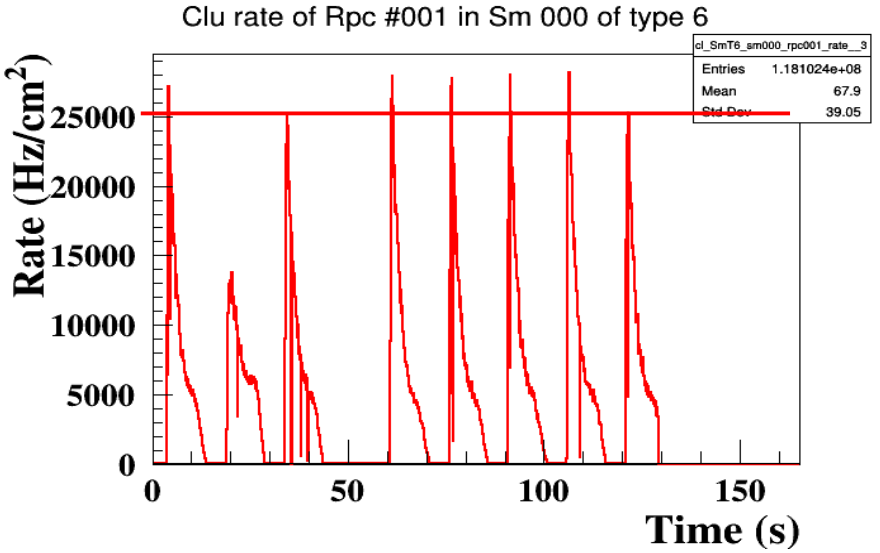


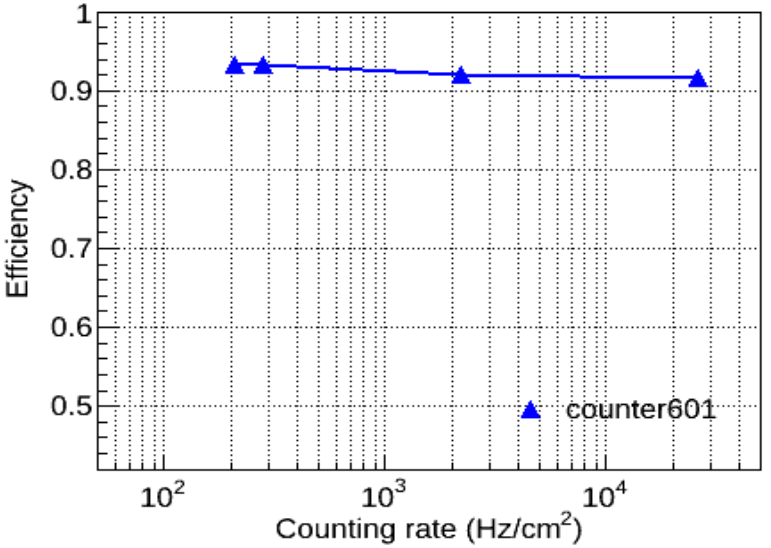


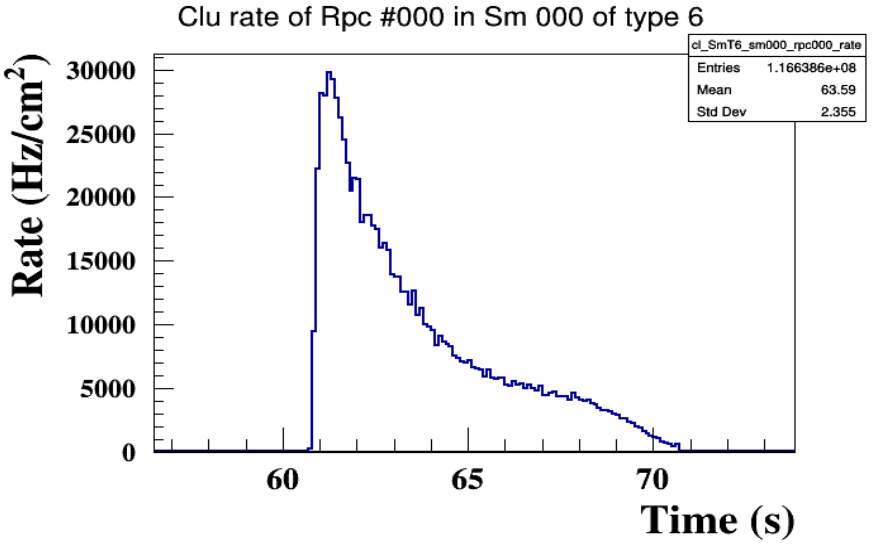


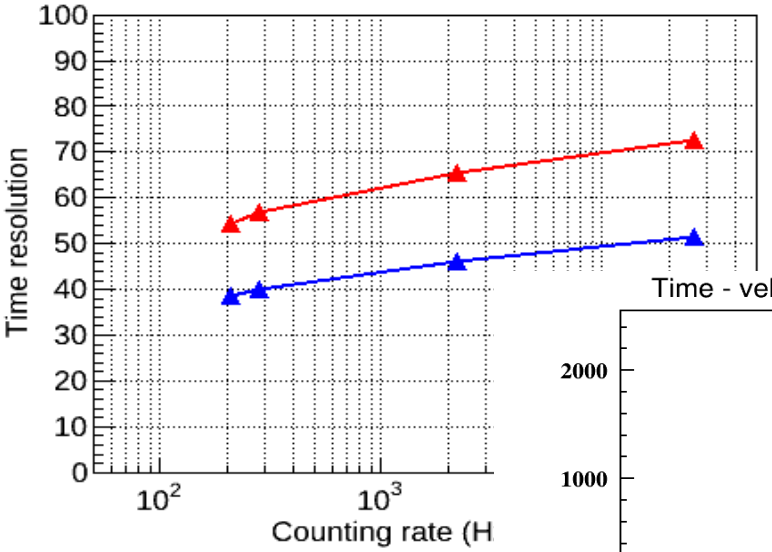


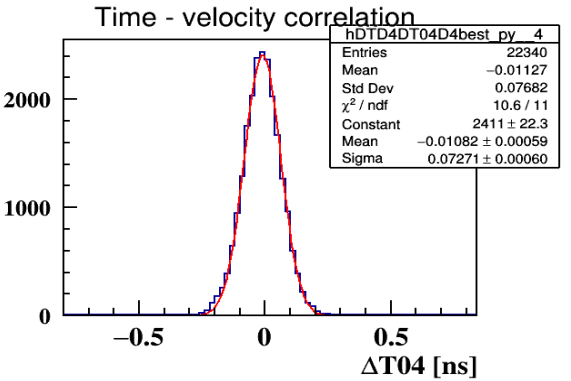
Efficiency & time resolution @ counting rate (@ +/- 6kV, Th=200 mV)



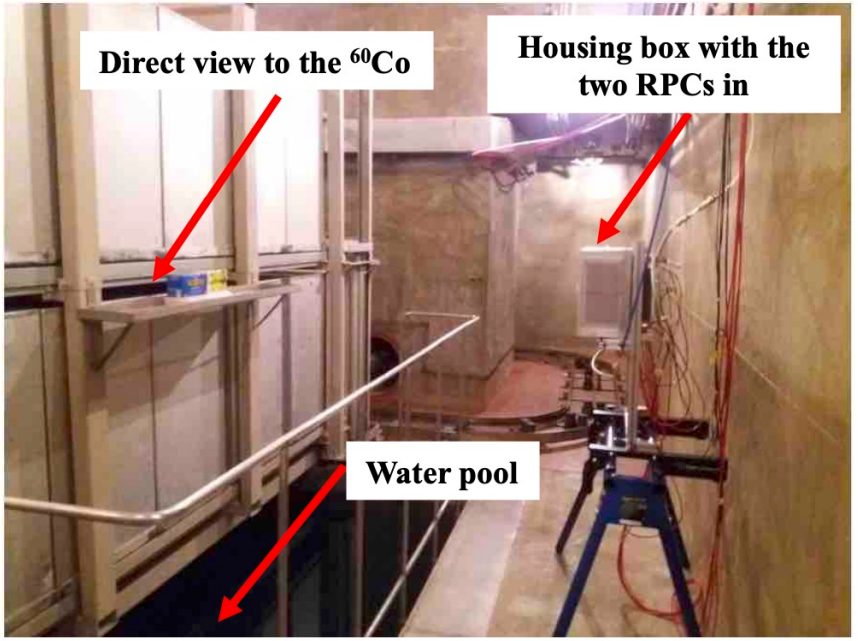


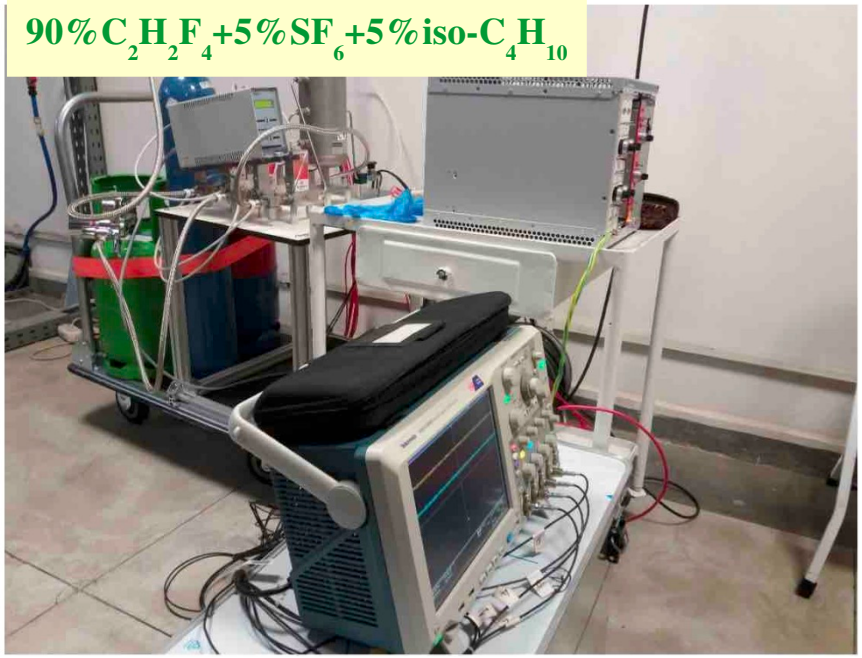






Ageing investigations





- **IRASM/IFIN-HH multipurpose irradiation center**
- **^{60}Co source activity: 360 kCi**

Table 1:

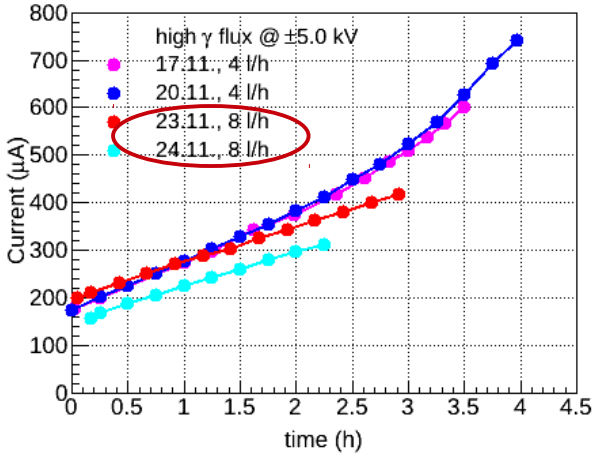
Date (dd/mm)	Gas flow (l/h)	Duration (hours)	I (μA)	$< Q >$ (C)	Doze rate (kGy/h)	Cumulated dose (kGy)
10.11	4	3:45	105	1.4175	0.3267	1.225
11.11	4	2:30	125	1.125	0.3267	2.096
12.11	4	3:00	106	1.1448	0.3267	3.076
13.11	4	3:00	168	1.8144	0.3267	4.056
16.11	4	3:20	289	3.468	0.3222	5.130
17.11	4	3:30	363	4.5738	0.3222	6.258
18.11	8	6:35	254	6.0198	0.3222	8.379
20.11	4	4:00	397	5.7168	0.3145	9.637
23.11	4	3:10	233	2.6562	0.3145	10.633
23.11	8	3:00	288	3.1104	0.3145	11.577
24.11	8	4:30	246	3.990	0.3145	12.992
	Total	40:33		35.0367		12.992

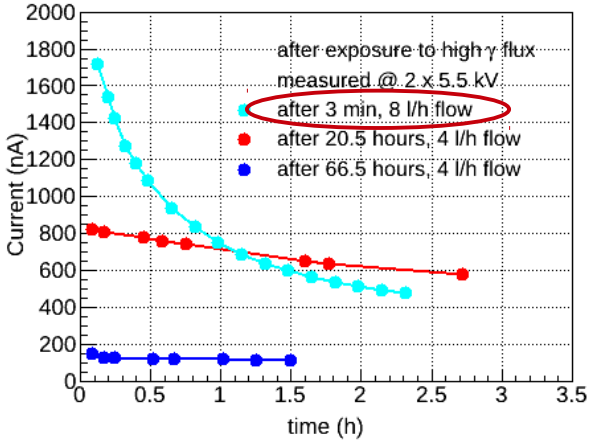
Accumulated charge by the exposed MSMGRPC:
35.0367 C / 276.5 cm^2 = 0.1266 C/cm^2 = 127 mC/cm^2

Accumulated charge in CBM in 1 month of running at the highest interaction rate:
10^7 int/s x 0.6x10^{-2} hits/cm^2/event x 4.6x10^{-12} C x 2.592x10^6 s = 0.7154 C/cm^2/month

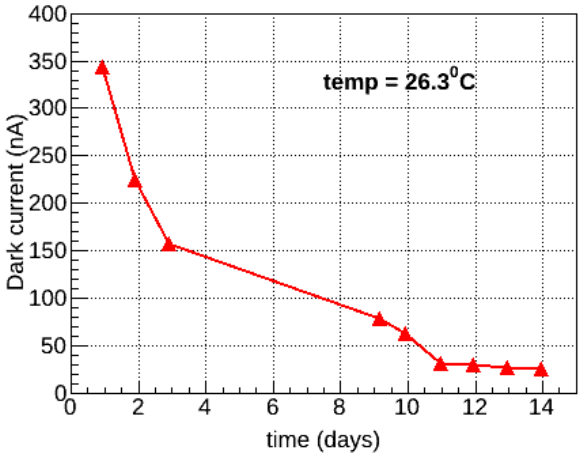
Ageing investigations

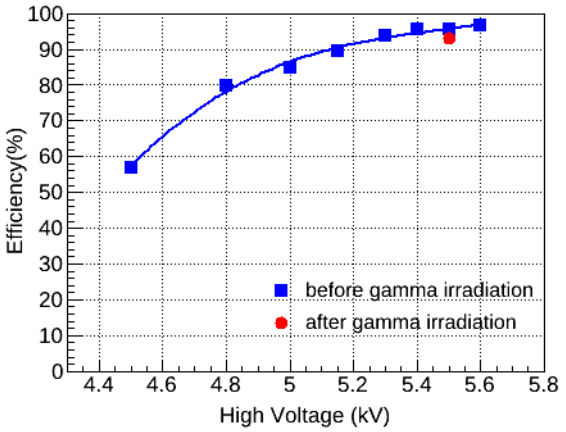
Counter irradiation

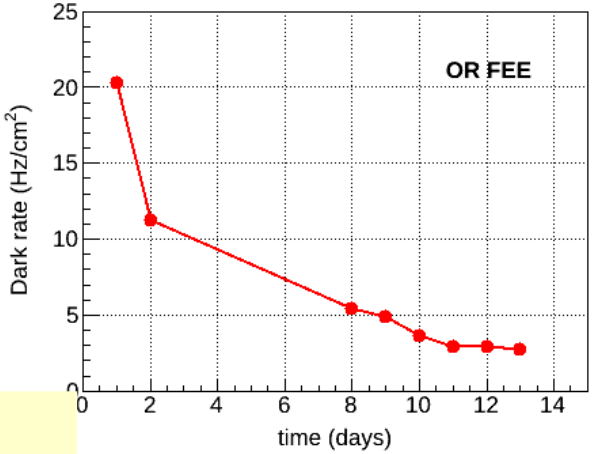


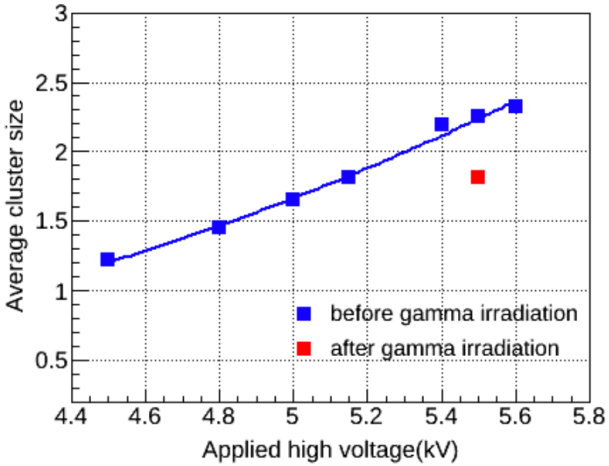


Counter recovery after the end of the exposure









DSRPC2015: 140 μm gas gap, A = 276.5 cm^2

Avalanche charge = 4.6 pC (estimated from a mCBM beam time)

Maximum equivalent particle flux = 310 kHz/cm^2

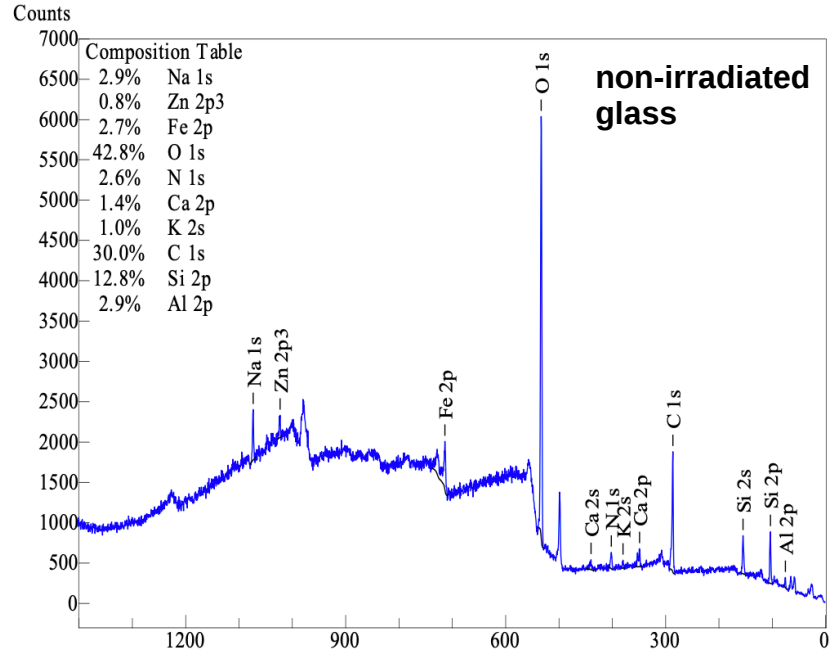
After flushing the counter with fresh working gas for two weeks:

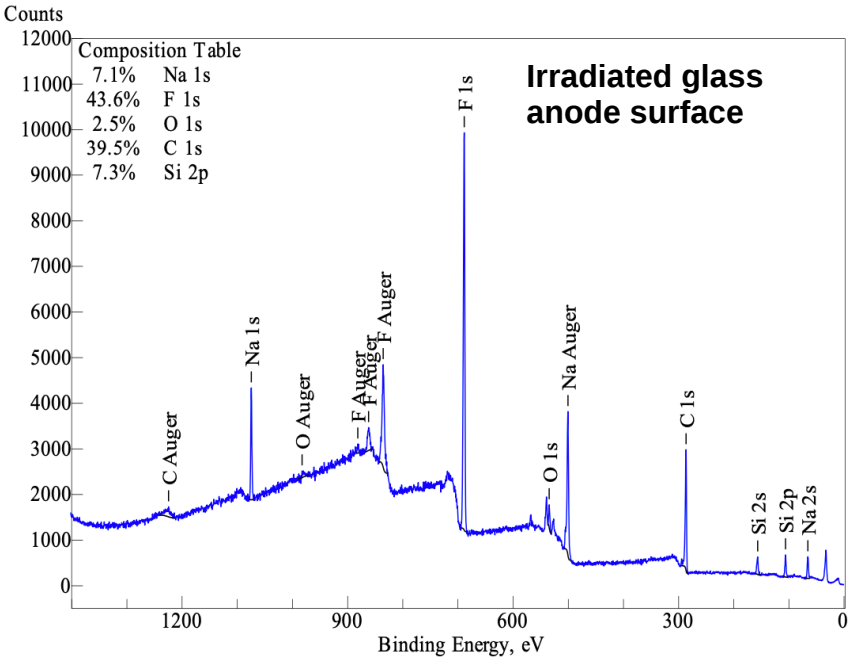
- dark current and dark rate reached almost the same values as before the irradiation

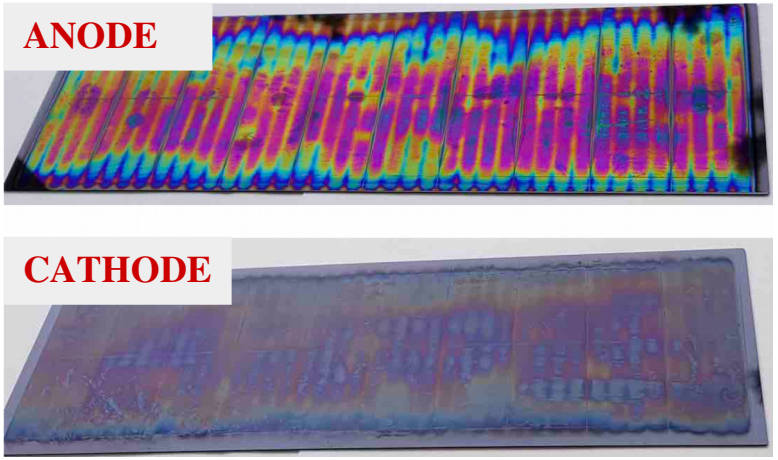
- efficiency and cluster size are wa not significantly affected.

Analysis of the chemical composition of the deposited layers

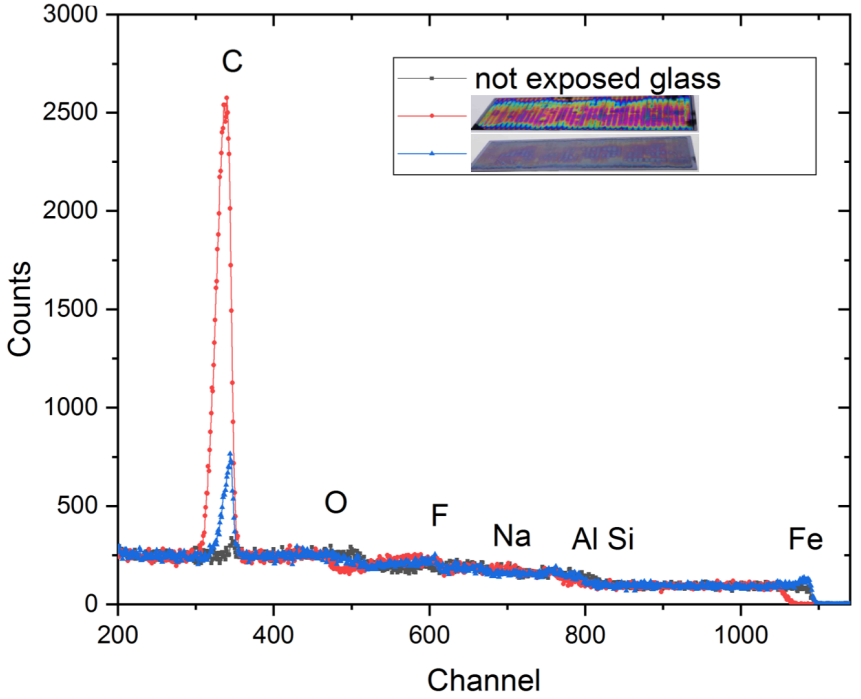
XPS - analysis







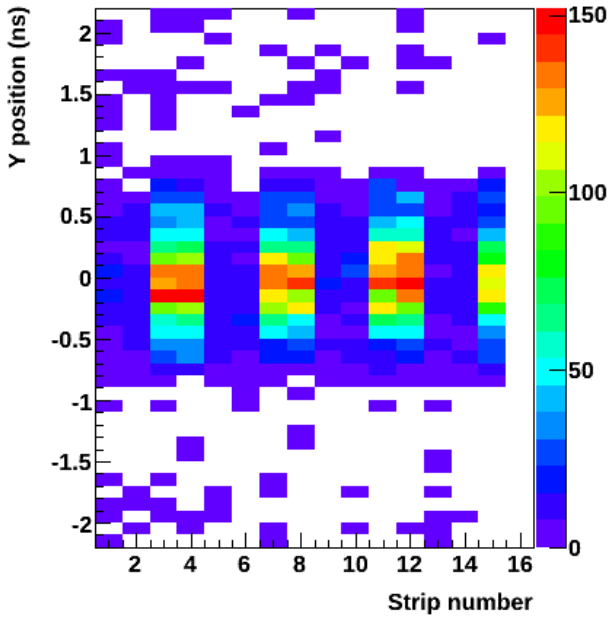
RBS – analysis: overlapped ^{12}C- ^{4}He resonance spectra for a non-irradiated glass plate and the cathode and anode surfaces of an irradiated one



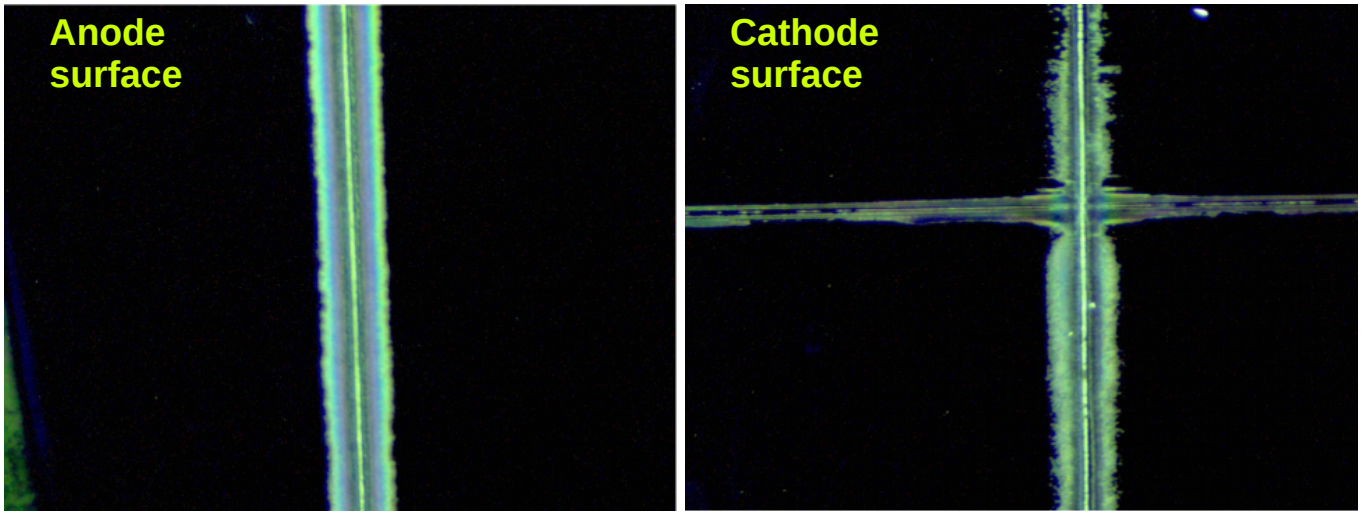
https://arxiv.org/abs/2105.12214v2

Ageing investigations

Random conicidences with an other MSMGRPC



Photos of the regions around the spacers



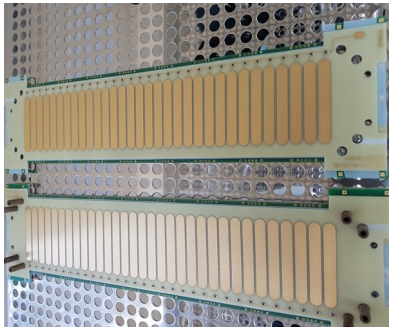
enhanced activity in the adjacent strips, (left-right,) to the spacers positioned in between them

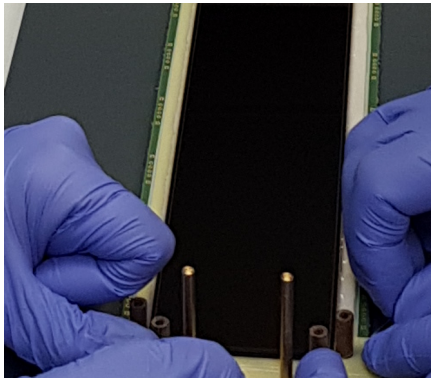
Resistivity measurements

Probe	R_V (GΩ·cm)	R_S ($G\Omega/\square$)
irradiated cathode surface	67.4	20.0
irradiated anode surface	61.5	21.1
non-irradiated glass	65.2	20.2

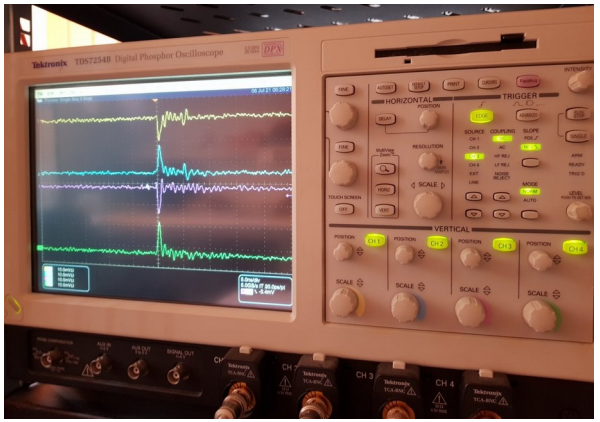
First prototype with a directed flow
- design consideration and assembling -

- Directed gas flow through the gas gaps.
- 5.6 cm strip length instead of 6 cm (previous ones).
- Spacers run across the strips, not along the strips, as for previous counters.
- Spacers positioned outside the electric field area.



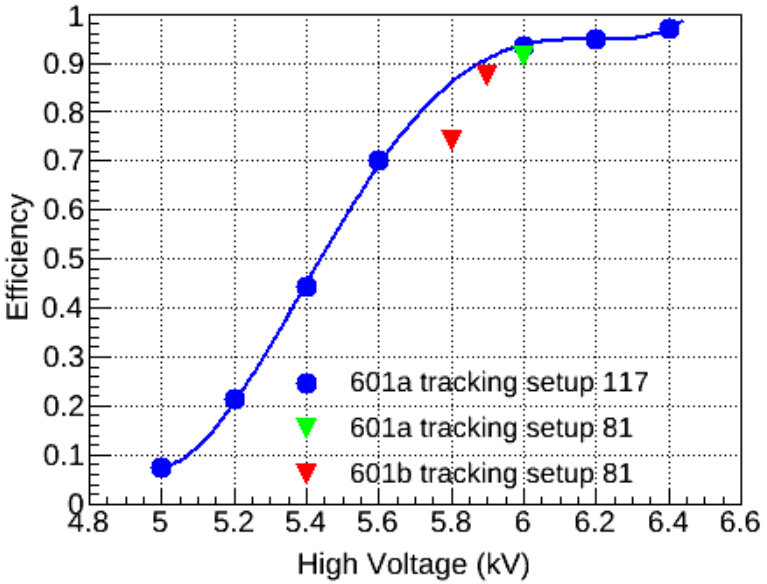


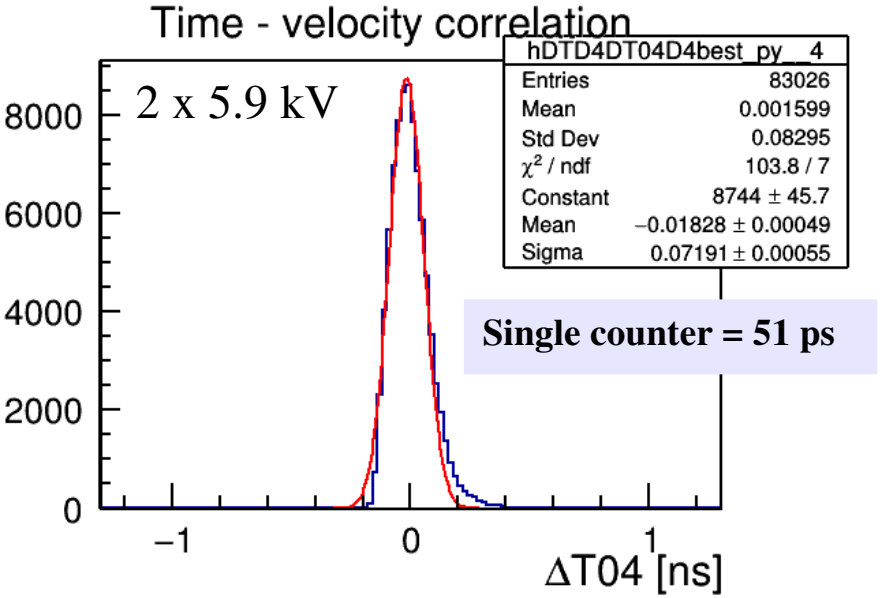
HV conditioning & first signals



First prototype with a directed flow

July mCBM@SIS18 beam - test→preliminary results



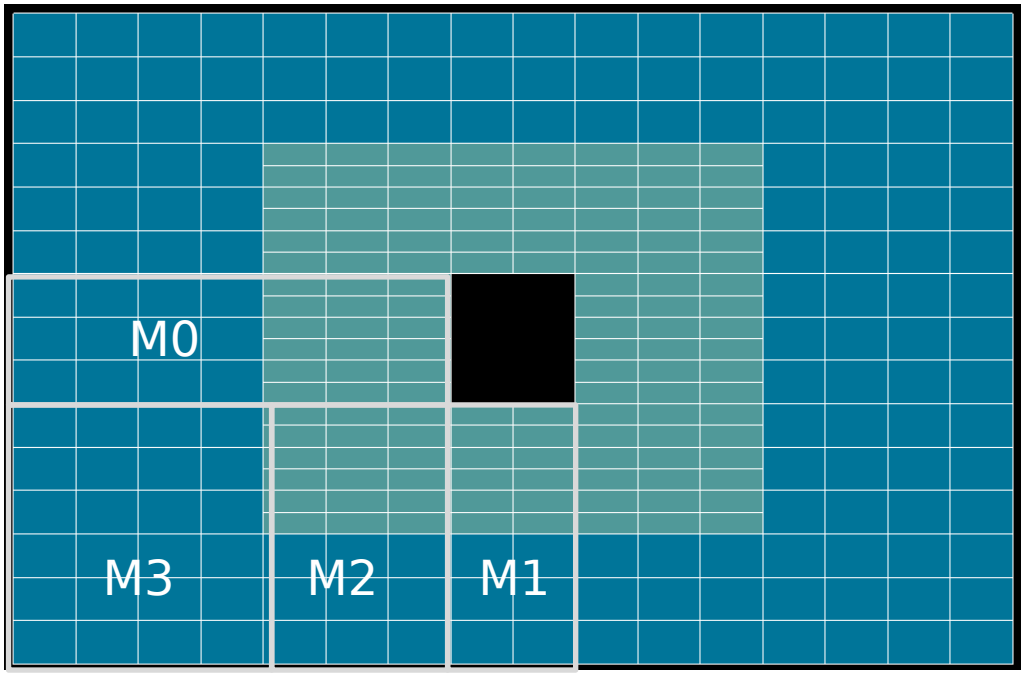


Single counter = 51 ps

601a → gas exchange via diffusion
601b → direct gas flow through the gaps
601b→ operated only up to 2 x 5.9 kV

Analysis is in progress

Current design of the CBM-TOF inner wall



- 4 module types
- 12 modules
- 2 counter types: 100/200 x 300 mm^2
- 300 counters
- 19,200 readout channels

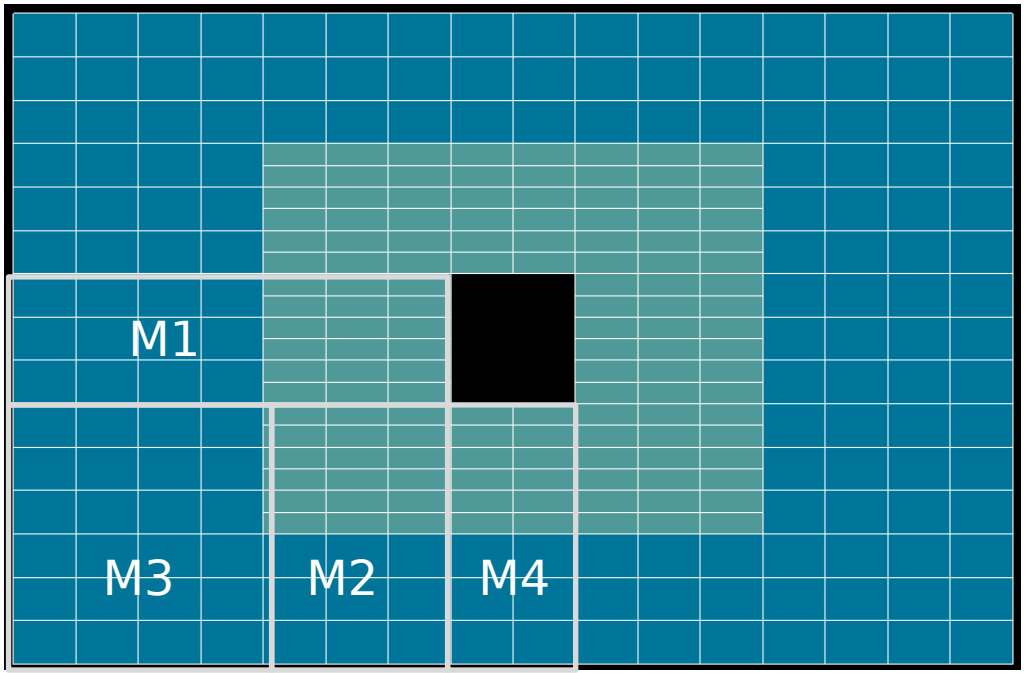
	RPCs (200)	RPCs (100)	Total
No. RPCs	168	132	300
No. channels	10752	8448	19200

- For the 100 mm width counter a spacer will be positioned in the middle of the active area, while for the 200 mm width counter two spacers will be positioned in the active area.
- Technological solutions for a directed gas flow in the 100/200 mm wide MSMGRPCs will be developed in the near future based on the gained experience.

Summary & Outlook

- Two MSMGRPC prototypes with 200 um gas gap were assembled and successful tested (^{60}Co source & cosmics rays) in HPD/IFIN-HH (Bucharest) with NINO +CAEN TDCs readout, proving very good efficiency and time resolution.
- Similar results have been obtained in the cosmic ray tests in PI Heidelberg using PADI XI +GET4 TDCs .
- These prototypes were successfully tested in mCBM (including high counting rates), equipped with the readout electronics developed for the inner wall (PADI XI + GET4 mounted on the same motherboad). They demonstated a very good performance in terms of efficiency and time resolution up to a counting rate ≥ 25 kHz/cm^2.
- Aeging tests showed an important effect of gas polution. Proposed mittigation solutions is a MSMGRPC prototype with a directedd flow through the gaps. It was assembled and tested in the mCBM/SIS18 setup.
- Analysis of the data obtained in July mCBM beam time is in progress, showing promising preliminary results.
- Technological solutions for a directed gas flow in the 100/200 mm wide MSMGRPCs will be developed in the near future based on the already gained experience.

Current design of the CBM-TOF inner wall



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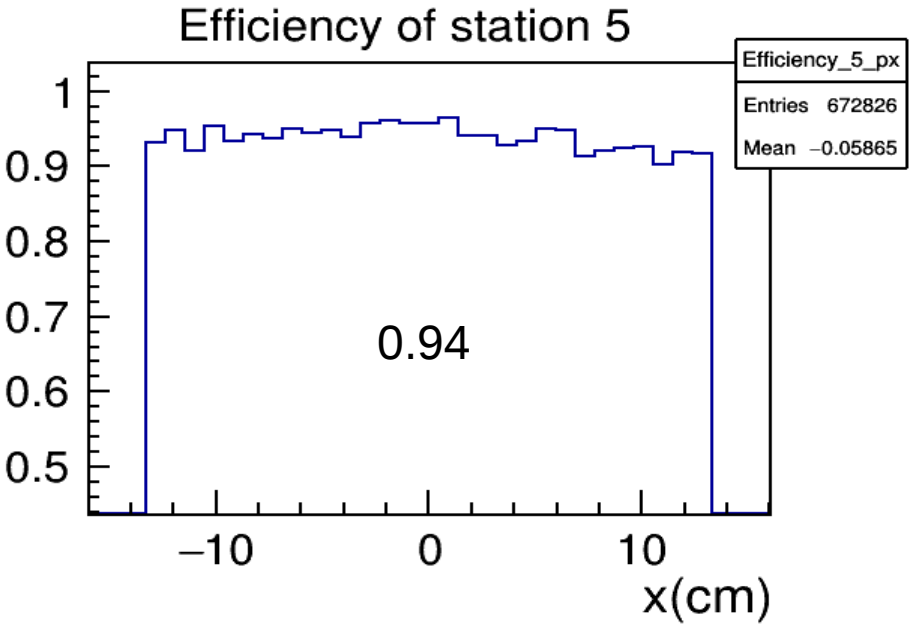
Threshold scan

Run 1454: **200 mV**, 2 x 6 kV



Run 1482: **150 mV**, 2 x 6 kV