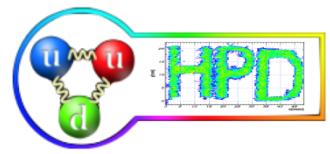


High Rate, High Granularity, Timing Multi-Strip Multi-Gap Resistive Plate Counter

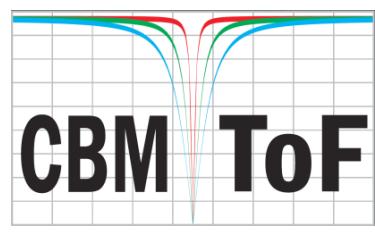
Mariana Petris, Daniel Bartos, Andrei Caragheorgheopol, Daniel Dorobantu, Mihai Petrovici
National Institute for R&D in Physics and Nuclear Engineering (IFIN-HH), Bucharest, Romania

Jochen Fröhlauf
GSI Helmholtz Center for Heavy Ion Research, Darmstadt, Germany

Ingo Deppner, Norbert Herrmann
Physikalisches Institut der Universität Heidelberg, Germany



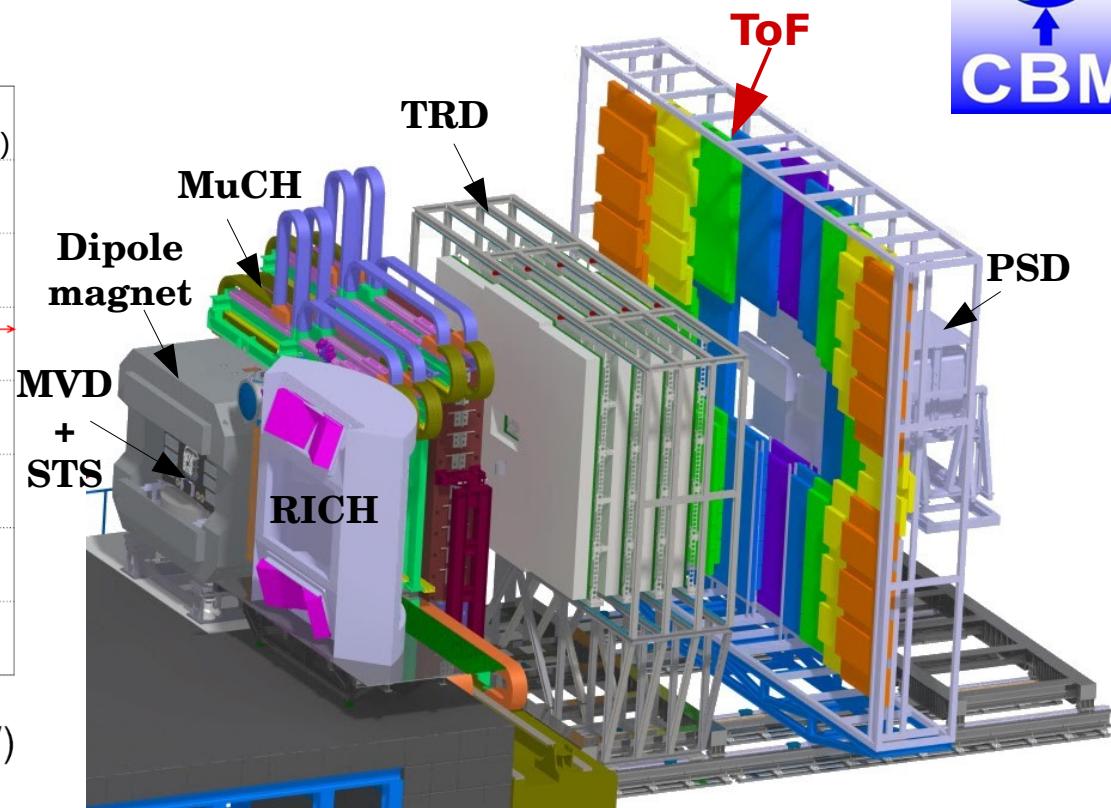
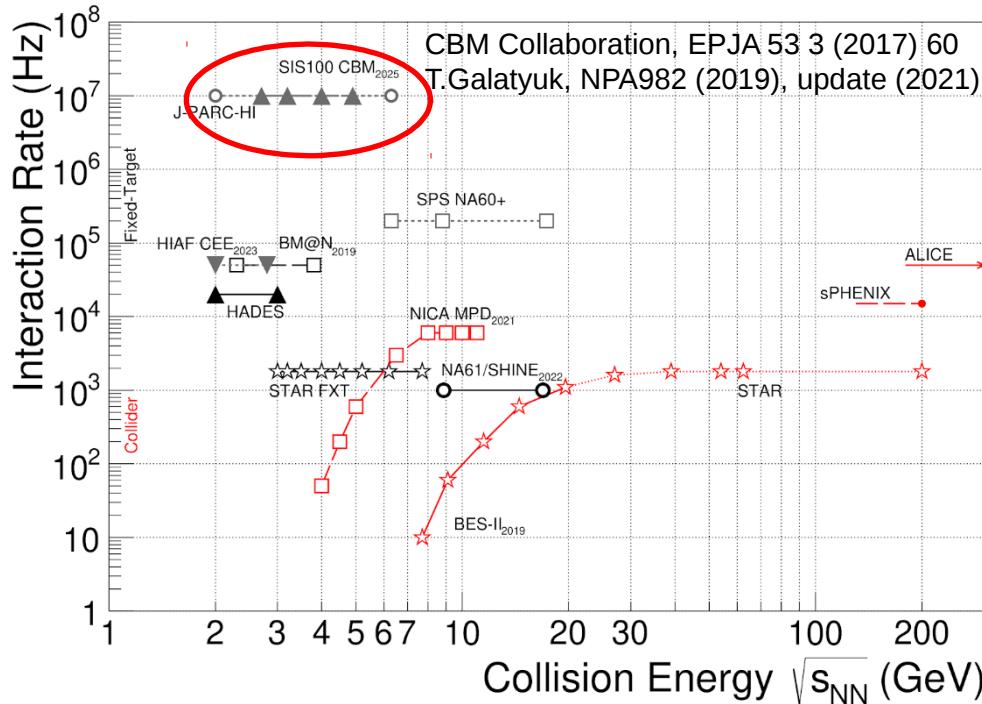
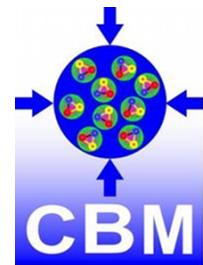
15th Pisa Meeting on Advanced Detectors



Outline

- Motivation – next generation high counting rate, high multiplicity experiments,
(e.g. CBM/FAIR, Darmstadt ->TOF inner wall)
- MSMRPC with high granularity and impedance matching
 - Construction details, cosmic rays and radioactive source tests
- In-beam and high counting rate test of the MSMRPC
- Aging investigations and observed effects
- First MSMRPC prototype with directed gas flow-> construction and in-beam tests
- Summary and Outlook

High interaction rate experiments -> CBM/FAIR



CBM experiment at FAIR/SIS100:

- A+A collisions, $E_{\text{kin}} = 2.5A - 11A \text{ GeV}$
- Systematically explore QCD matter at large baryon densities with high accuracy and rare probes

MVD: Micro Vertex Detector*

STS: Silicon Tracking System*

* inside magnetic field

MuCh / RICH

Muon Chamber System /
Ring Imaging Cherenkov Detector

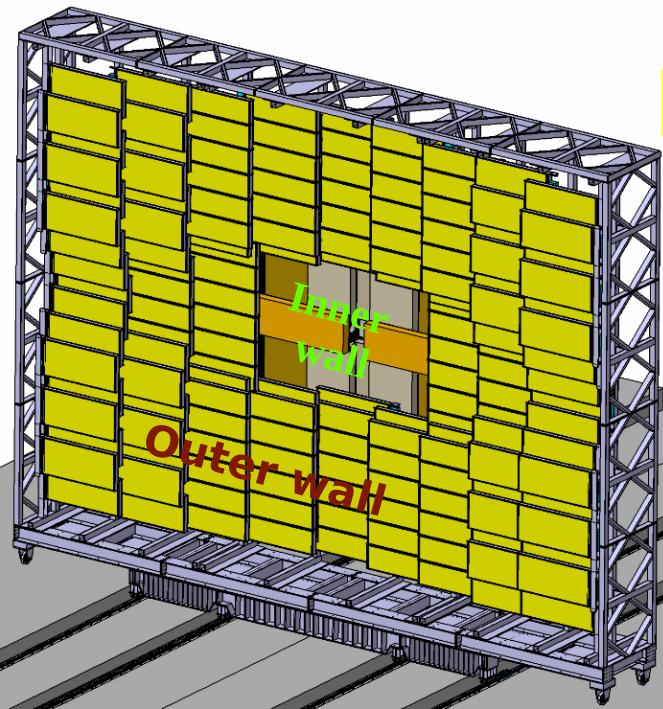
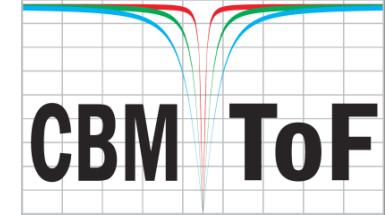
TRD: Transition Radiation Detector

ToF: Time-of-Flight Detector

PSD: Projectile Spectator Detector

- **Tracking acceptance:** $2.5^\circ < \theta_{\text{Lab}} < 25^\circ$
- **Peak R_{int} is 10 MHz for Au+Au**
- **Fast & radiation hard detectors**
- **Free-streaming DAQ**
- **4D tracking (space, time)**
- **Online event selection & reconstruction**
- **Data rate: 1 TB/sec**

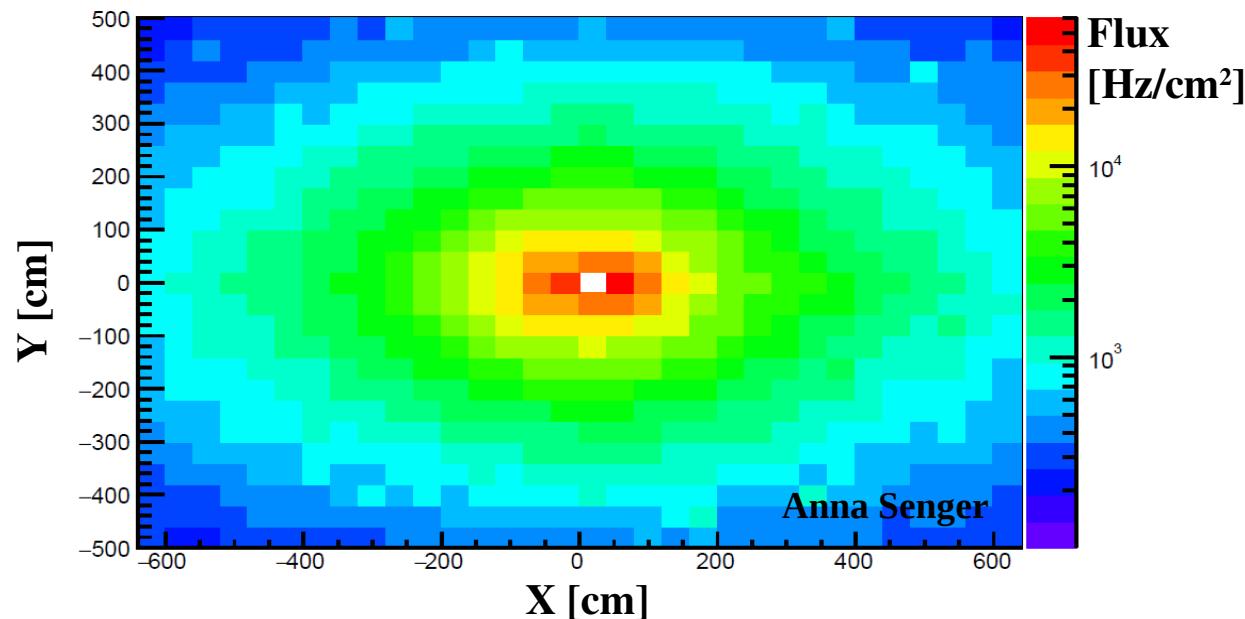
CBM – TOF wall



Charged hadron identification -> Time-of-Flight (TOF) measurement

FLUKA simulation: Au + Au collisions at $E_{\text{kin}} = 11A$ GeV, 10^7 interactions/s

Charged particle flux at a distance of 8 m from the target



CBM-ToF Requirements

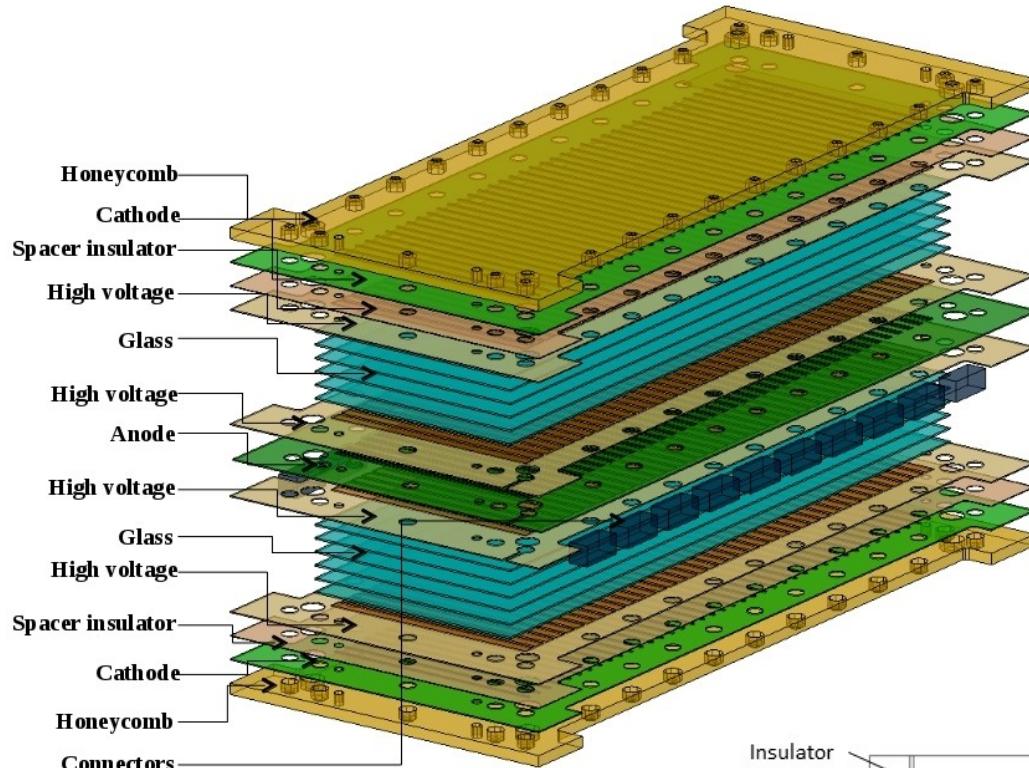
- Full system time resolution $\sigma_T \sim 80$ ps
- Efficiency > 95%
- Rate capability ≤ 30 kHz/cm²
- Polar angular range $2.5^\circ - 25^\circ$
- Active area of 120 m²
- Occupancy < 5%
- Low power electronics (~ 120.000 channels)
- Free streaming data acquisition

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

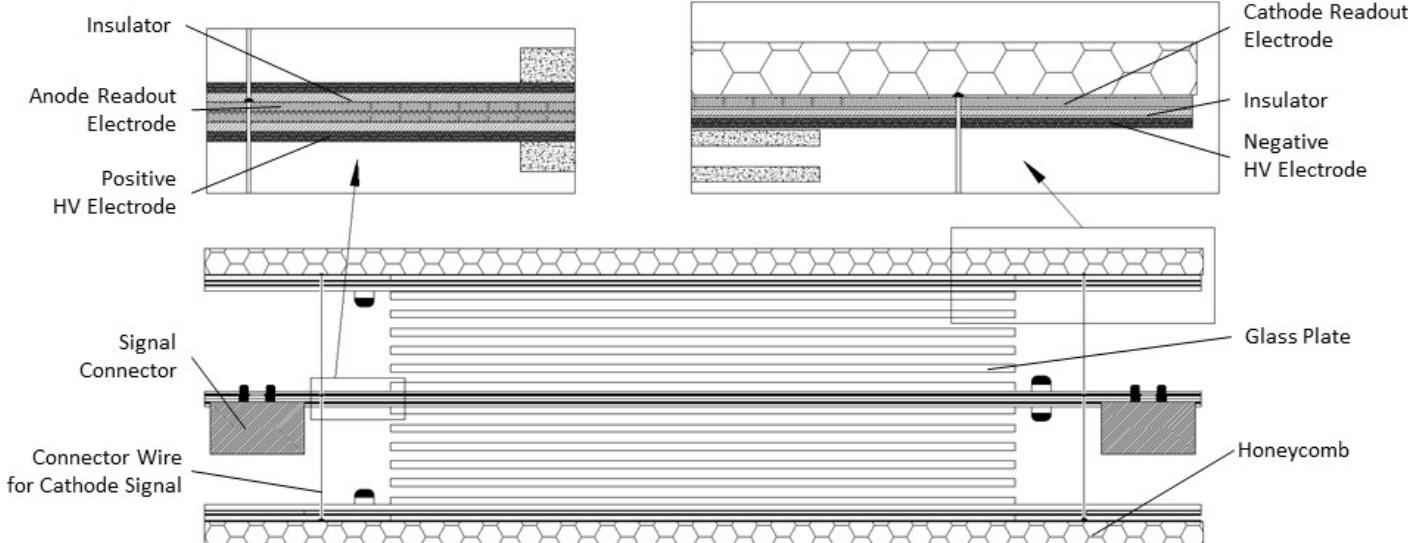
Our R&D activity → MSMGRPCs for the inner wall :

- highest counting rate
- highest granularity
- ~ 15 m² active area

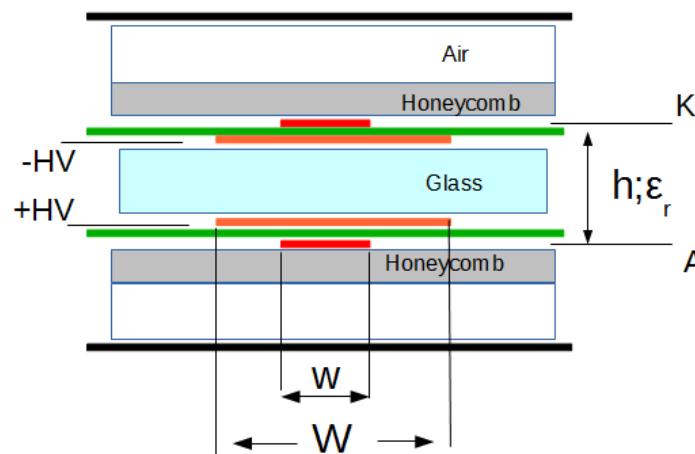
Prototype design considerations



- ✓ Symmetric structure: 5 gaps x 2 stacks
- ✓ Gas gap thickness: 200 µm
- ✓ Active area 60 mm x 300 mm
- ✓ Resistive electrodes: $\sim 10^{10} \Omega\text{cm}$ glass
- ✓ Strip structure for Readout & HV electrodes
- ✓ Differential readout

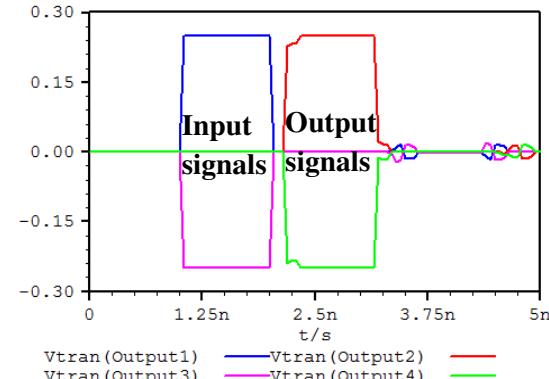


Prototype design considerations

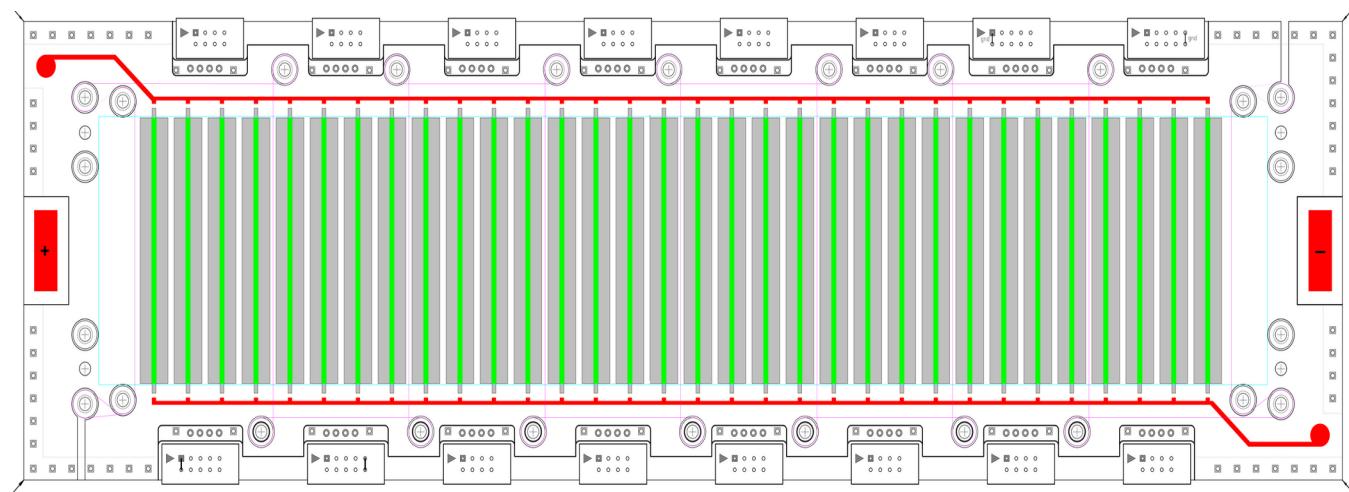
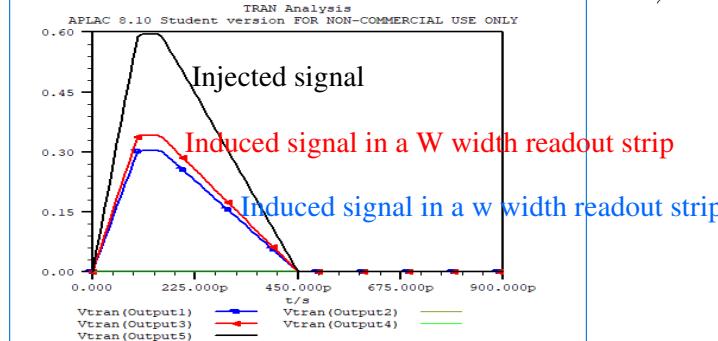


- The overlapped readout strips and the materials in between define a signal transmission line (STL)
- STL impedance depends on the readout strip width and the properties of the material layers in between

2017-proj-1/2-DS-RPC TRAN Analysis
APLAC 8.10 Student version FOR NON-COMMERCIAL USE ONLY



APLAC Simulator graphics 0 - READY
File Edit Scales Options Report Help



**97 Ω signal transmission line impedance (APLAC simulation)
matched to the FEE input impedance**

Romanian Journal of Physics 63, 901 (2018)

MSMGRPC prototype assembling

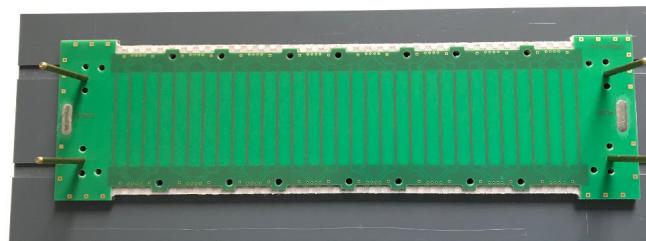
High voltage (HV) electrode



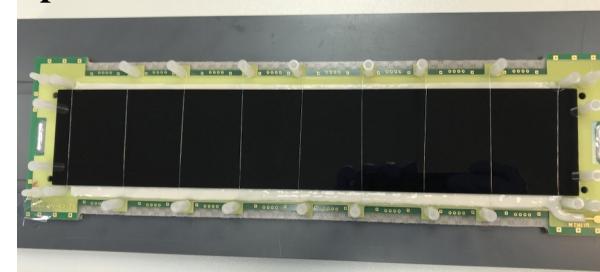
Anode readout electrode



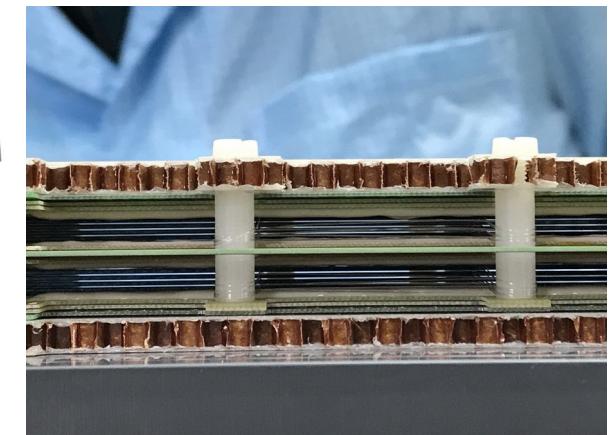
Cathode readout electrode



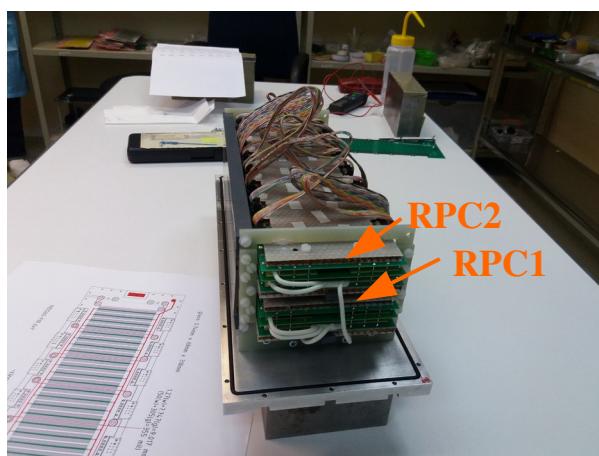
Spacer distribution across the surface



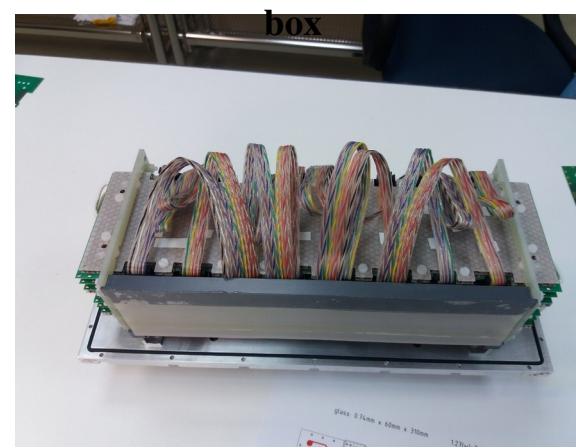
Two stacks



Two counters mounted on the back panel



Ready to be closed by the housing box



Mounting the housing box



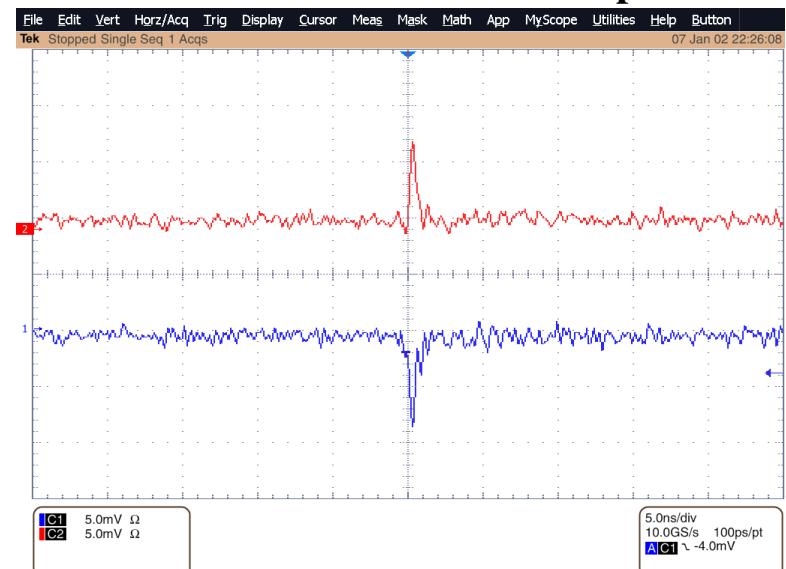
Experimental setup for cosmic rays & ^{60}Co tests in HPD/IFIN-HH DetLab



for each RPC:

- 16 operated strips, readout at both ends
- $(16 \times 0.902 \text{ cm}) \times 6 \text{ cm} = 86.6 \text{ cm}^2$ operated area
- NINO FEE (ALICE Coll.)+CAEN TDCs
- Plastic size = 1.5 cm x 1.5 cm x 10 cm
- Gas mixture: 90% $\text{C}_2\text{H}_2\text{F}_4$ + 5% SF_6 + 5%iso- C_4H_{10}

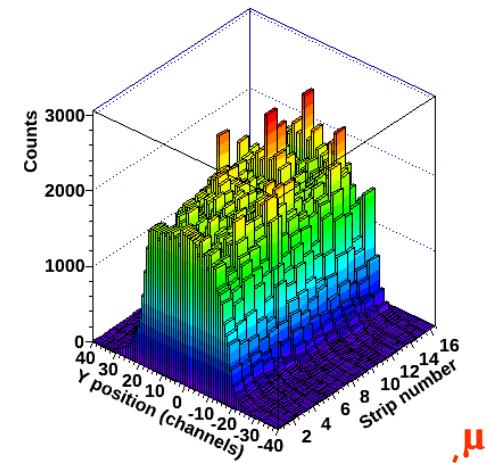
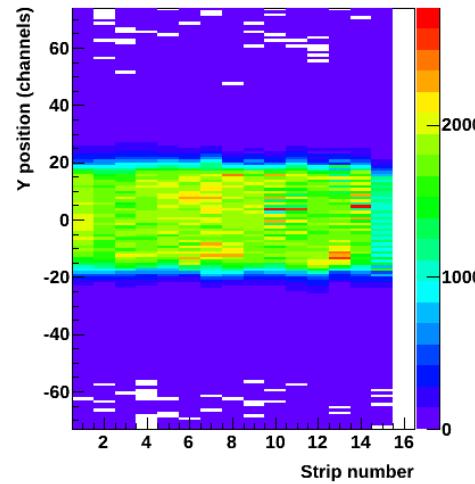
Typical signals recorded directly from one MSMGRPC strip



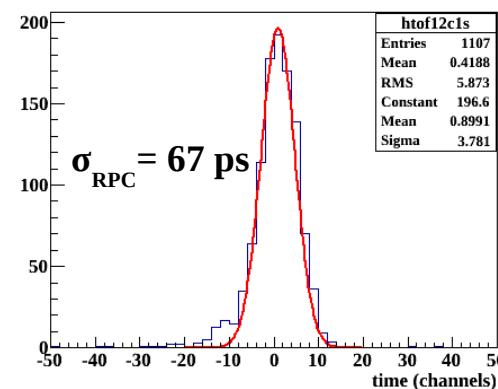
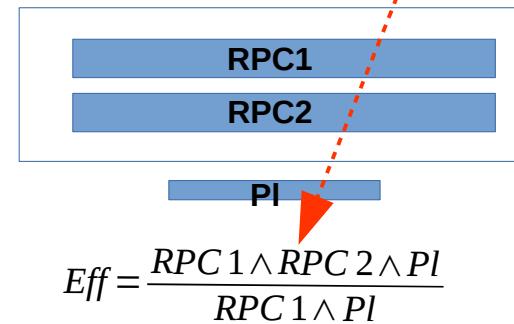
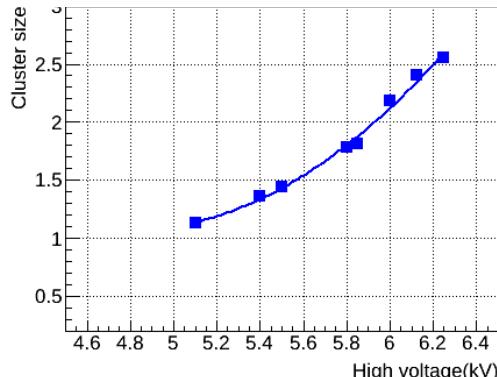
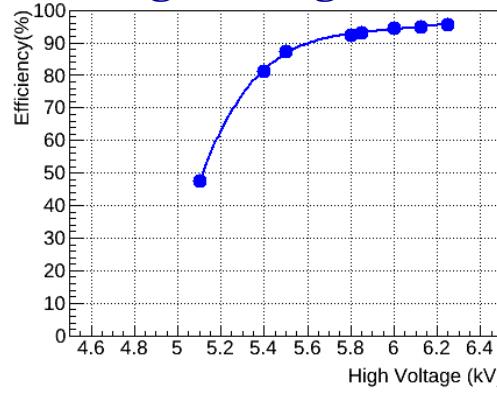
MSMGRPC	I_{dark}	Dark rate
RPC1	< 1 nA	0.11 Hz/cm ²
RPC2	< 1 nA	0.14 Hz/cm ²

I. Cosmic ray measurements

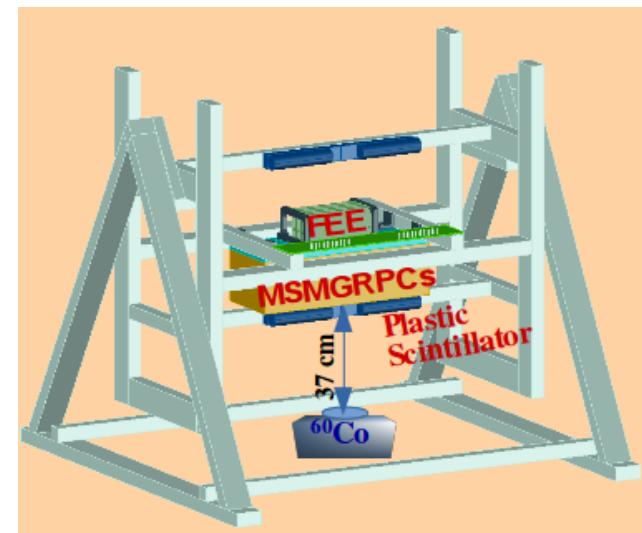
2D mapping in self-trigger mode



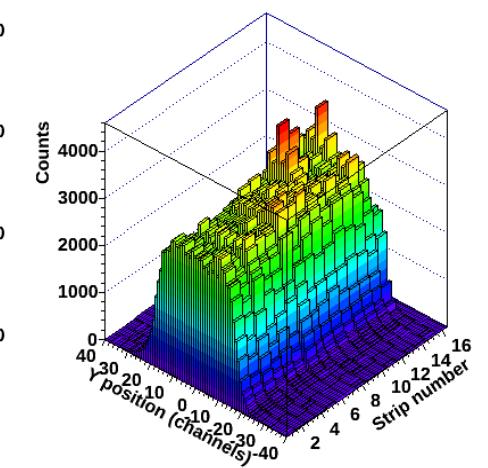
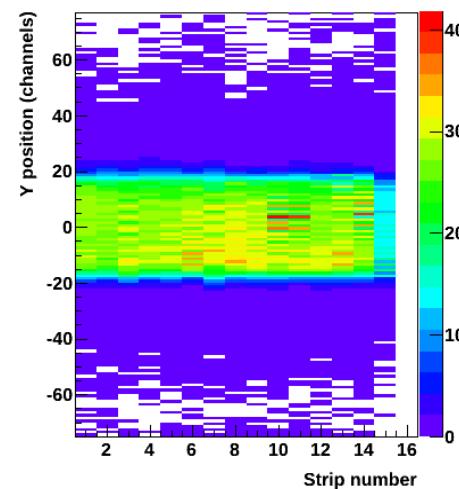
High voltage scan



II. ^{60}Co source measurements



2D mapping in self-trigger mode

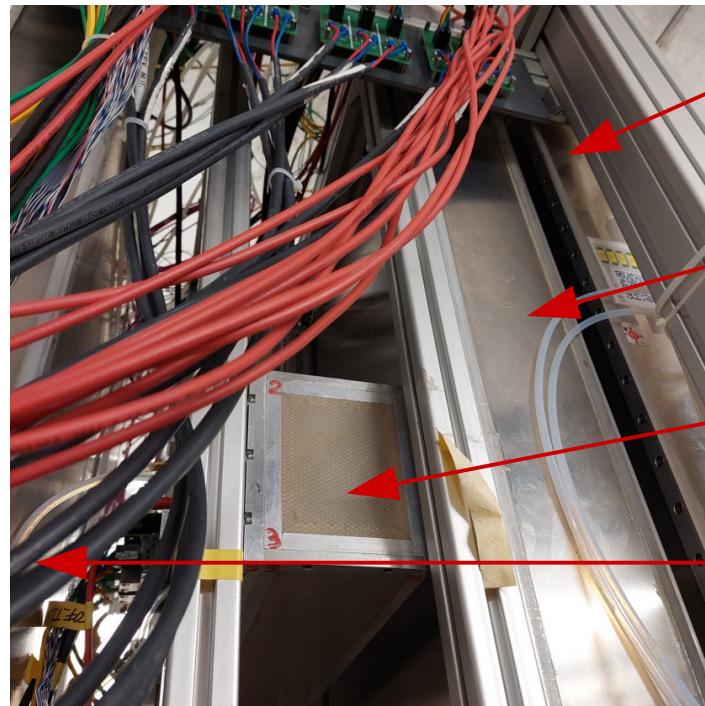
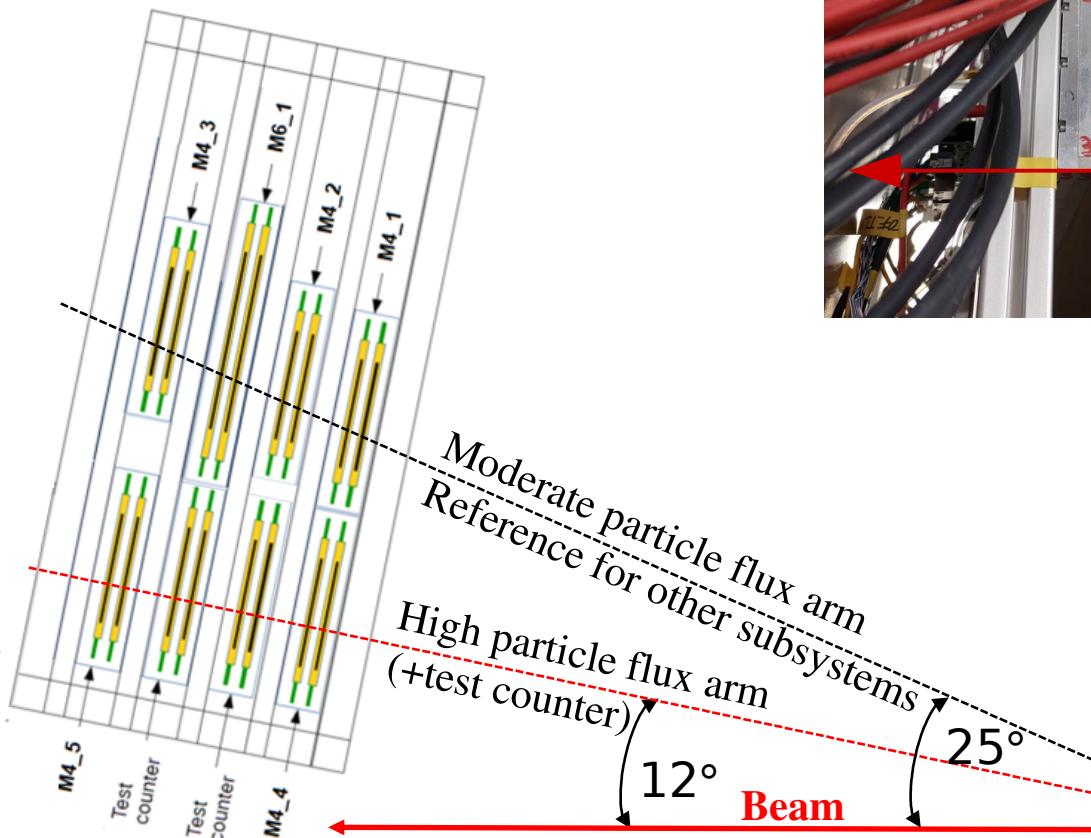


CBM Technical Note (2021), CBM-TN-21004

In-beam tests 2021 → mCBM@SIS18/GSI

Tracking setup:

- 6 counter stations in stack
- Analysis → one station as DUT and 5 reference stations as tracking



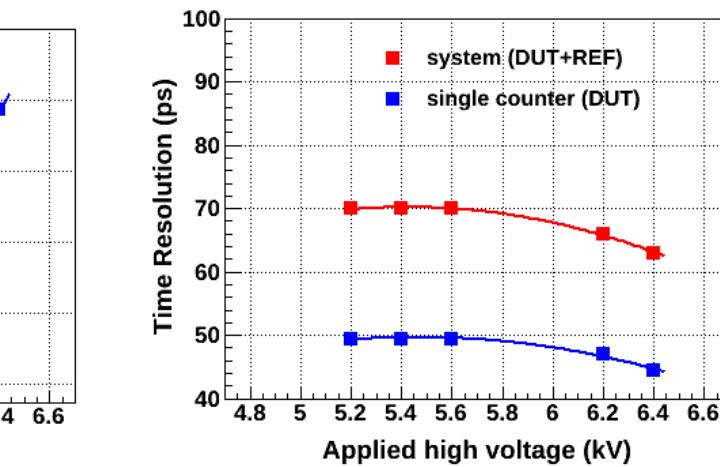
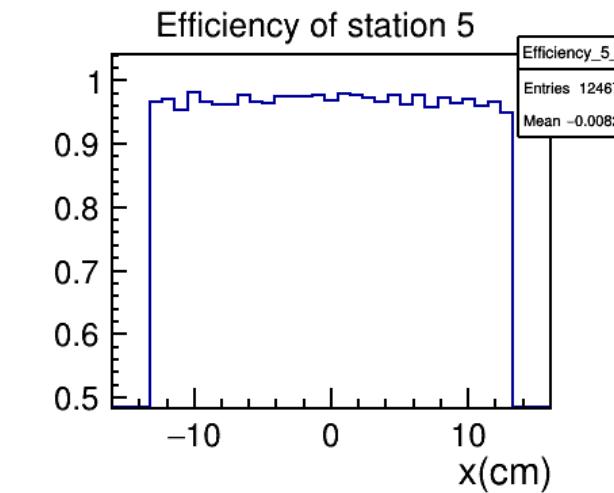
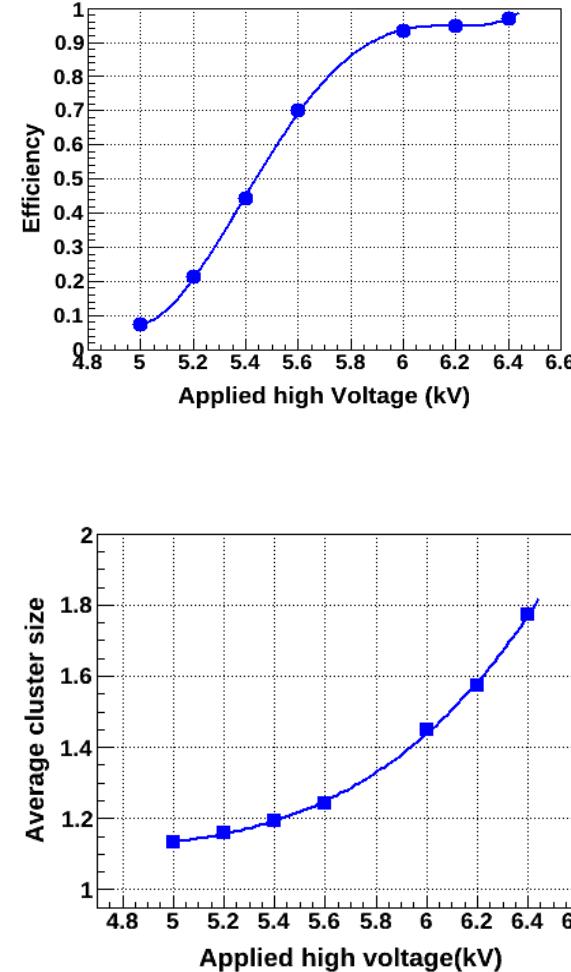
FEE board for the inner TOF wall (J. Frünhauf)

PADI XI (IEEE Trans. Nucl. Sci., vol. 68, no. 6, p. 1325)
+ GET4 (IEEE Nucl. Sci. Sym. Conf. Rec. (2009) 295)



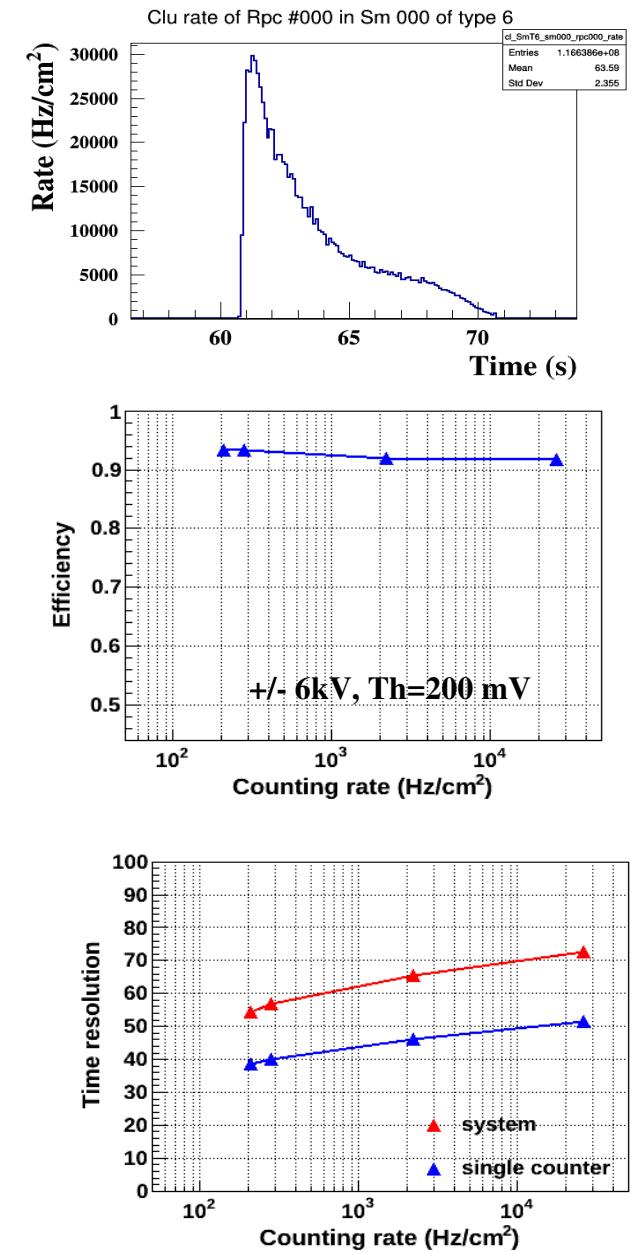
In-beam test results

High voltage scan



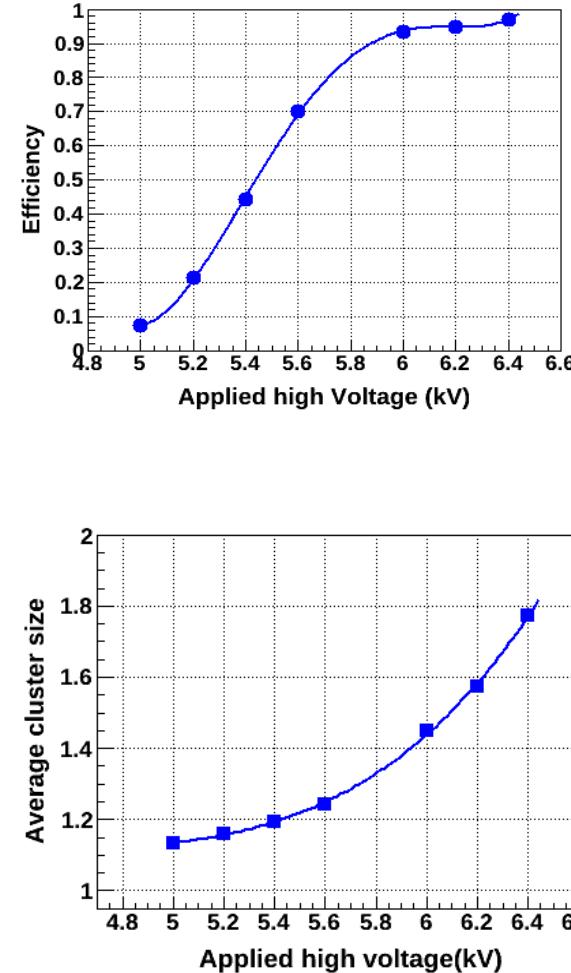
Gas mixture: 97.5% $\text{C}_2\text{H}_2\text{F}_4$ + 2.5% SF_6

High counting rate scan

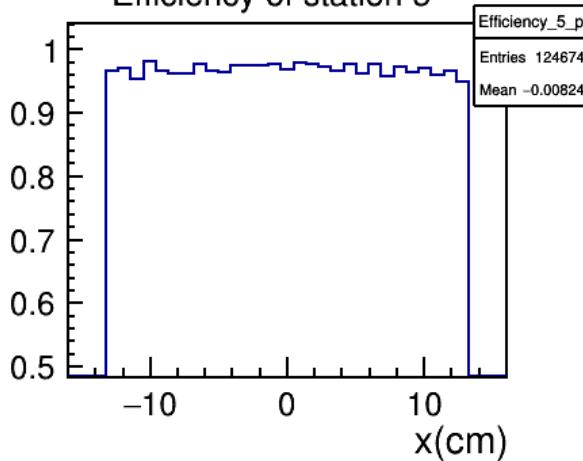


In-beam test results

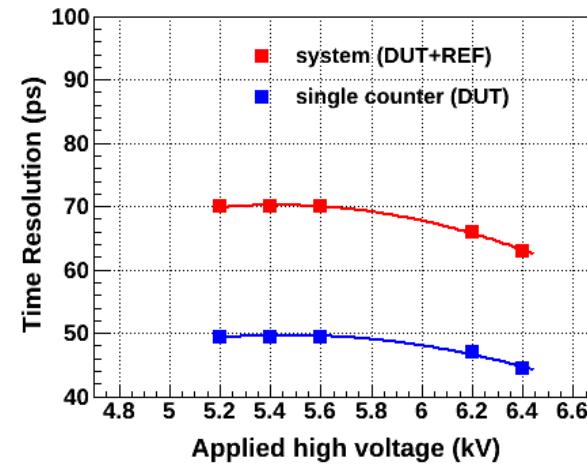
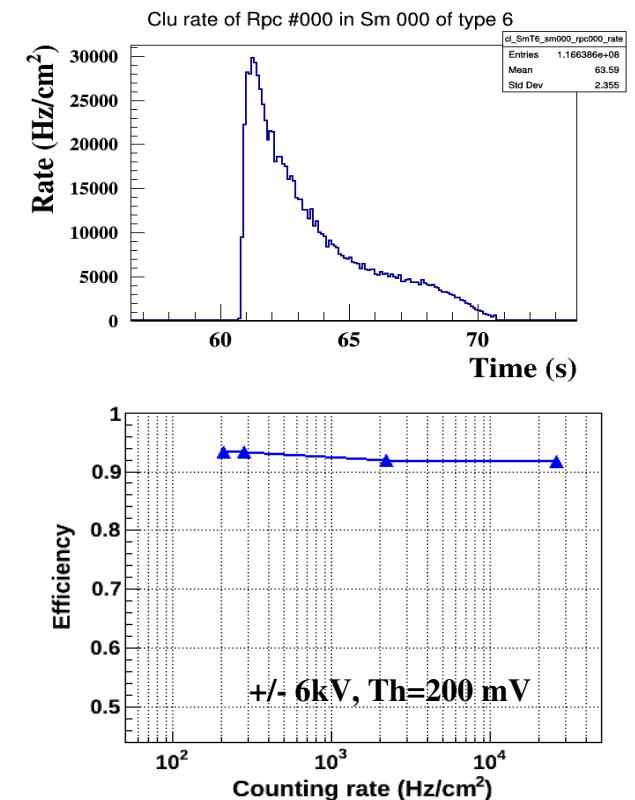
High voltage scan



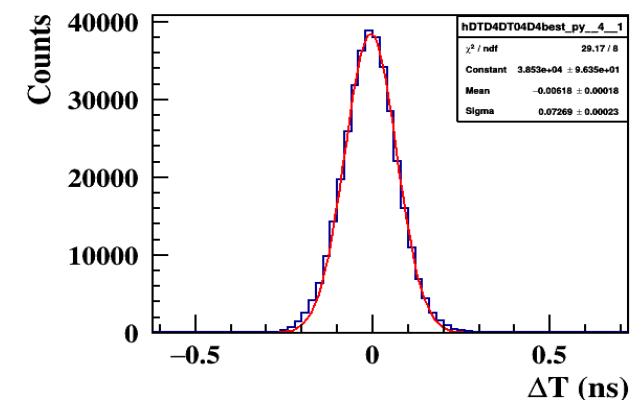
Efficiency of station 5



High counting rate scan

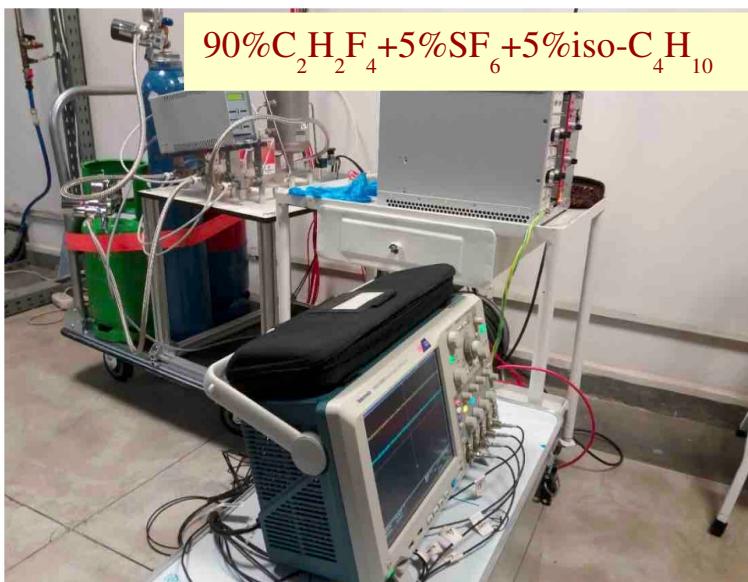


ΔT spectrum at the highest counting rate



Aging investigations

- IRASM/IFIN-HH multipurpose irradiation center
- ^{60}Co source activity: 360 kCi; Dose rate = 0.3 kGy/h



Equivalent particle flux = 80 - 310 kHz/cm²

Motivation: the detector will maintain its performance over the lifetime of the experiment

Date (dd/mm)	Gas flow (l/h)	Duration (hours)	I (μA)	$< Q >$ (C)	Dose 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	

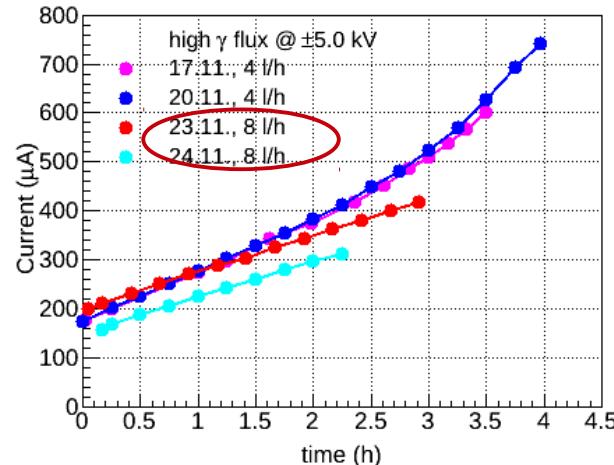
Total accumulated dose (w/o HV) = 77 kGy

Accumulated charge by the exposed MSMRPC:
 $35.0367 \text{ C} / 276.5 \text{ cm}^2 = 0.127 \text{ C/cm}^2$

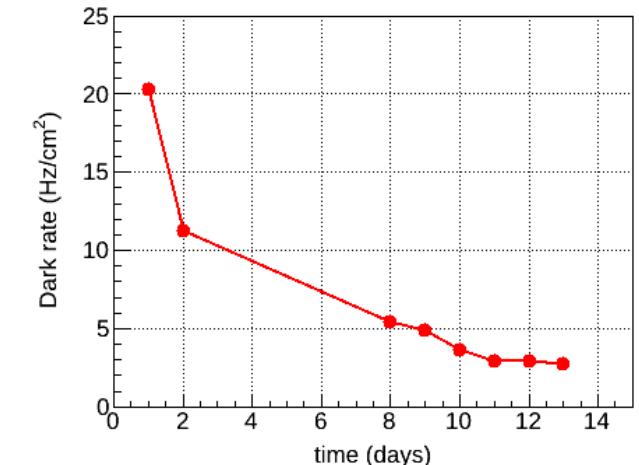
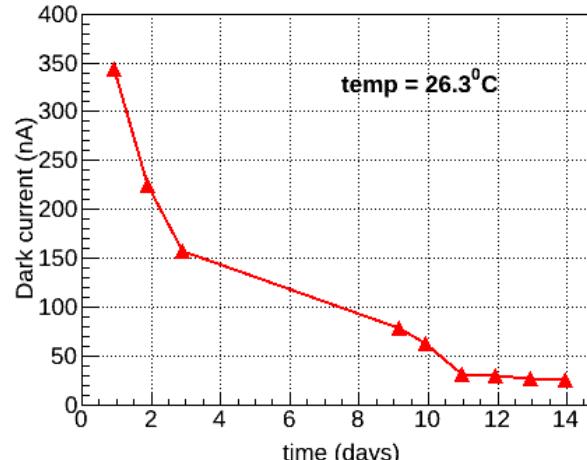
Estimated accumulated charge in the CBM TOF inner zone in 1 month of running at the highest interaction rate: (10^7 int/s) = $0.7154 \text{ C/cm}^2/\text{month}$

Aging effects on MSMRPC performance

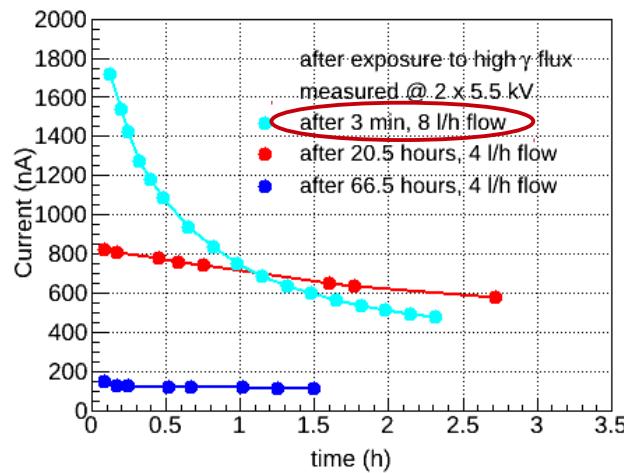
MSMGRPC under high γ flux



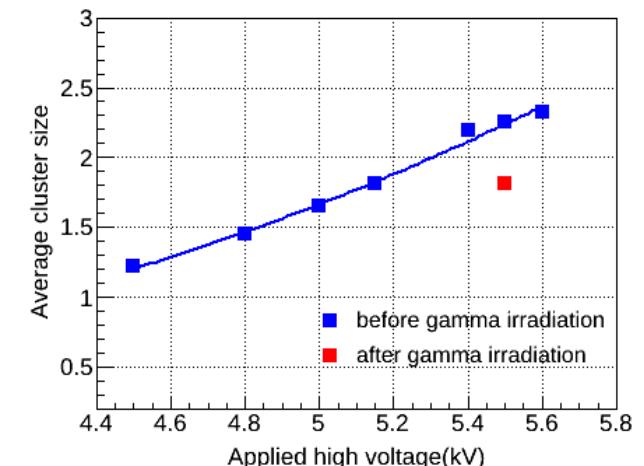
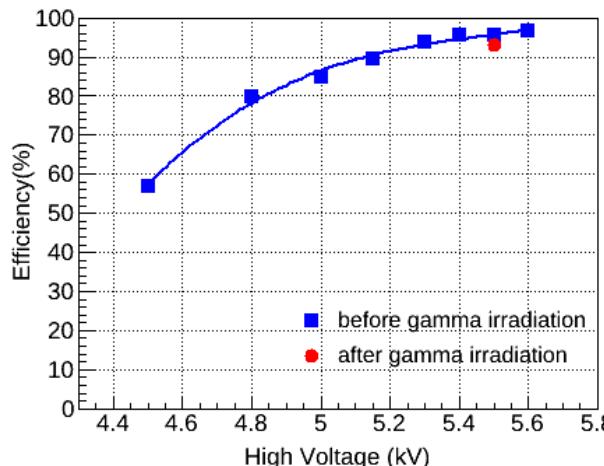
MSMGRPC “long” term recovery



MSMGRPC short term recovery



MSMGRPC performance before/after exposure

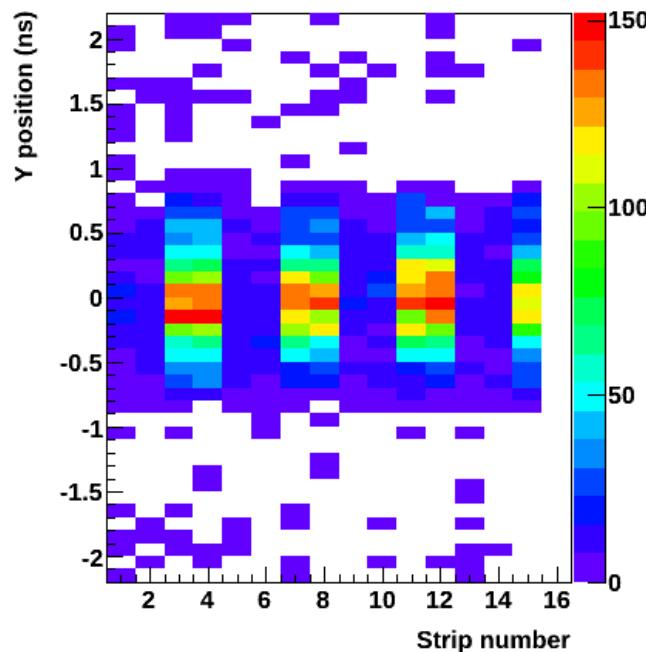


After flushing the counter with fresh working gas for two weeks:

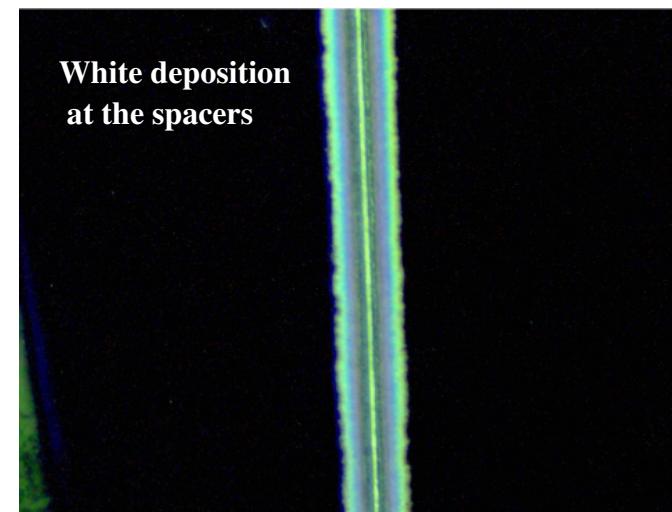
- dark current and dark rate reached almost the same values as before the irradiation
- efficiency and cluster size were not significantly affected

Aging effects – optical investigations

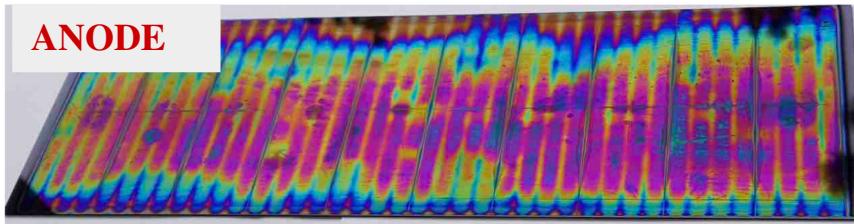
Dark rate generated around the spacers



Spacer – microscope photo



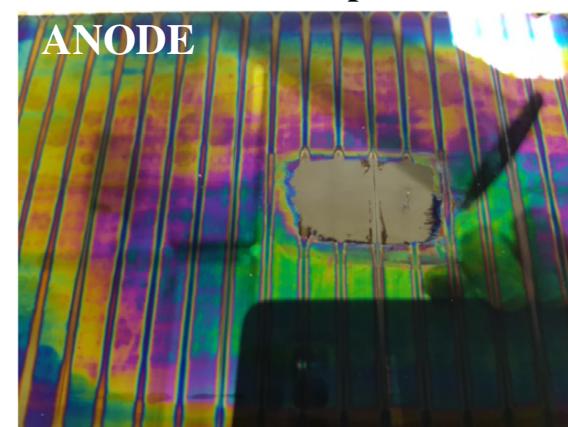
ANODE



CATHODE



Removable deposition



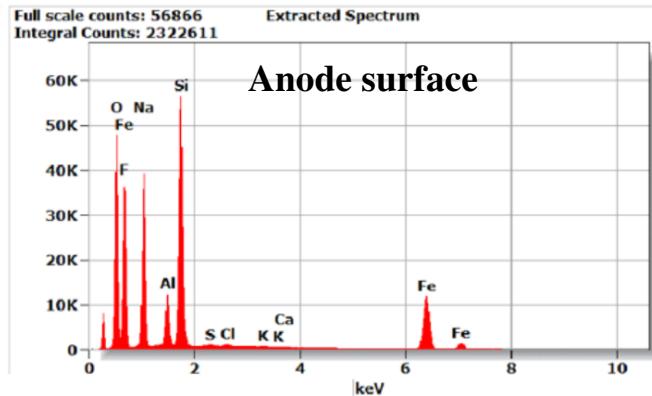
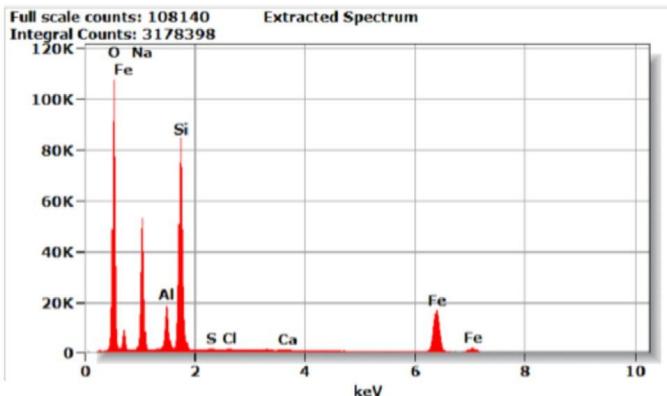
Non-removable deposition



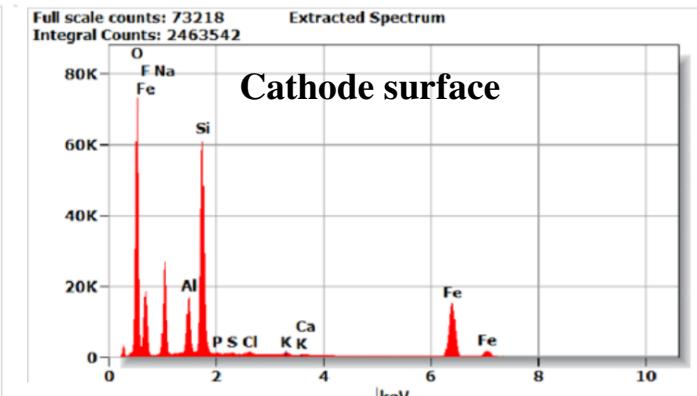
Aging effects – chemical composition of the deposited layers

Energy- Dispersive X-ray (EDX) spectrometry analysis of the chemical composition of non-irradiated and irradiated glass plates

Non-irradiated glass plate



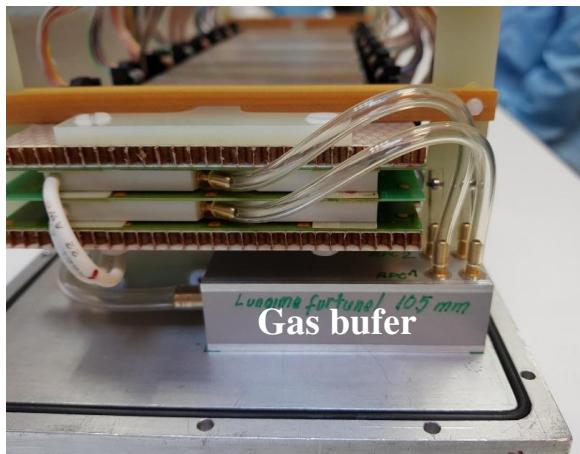
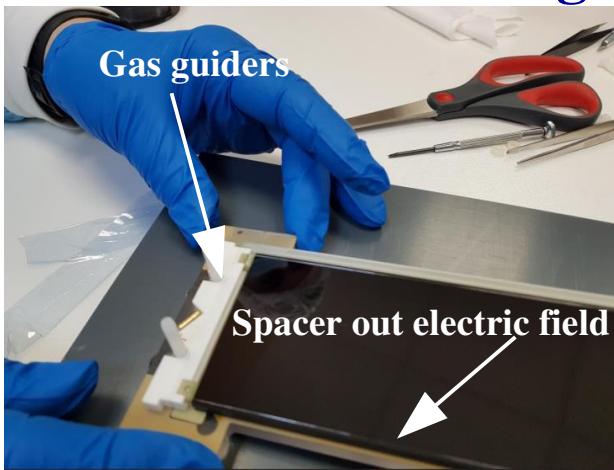
Irradiated glass plate



The fluorine percentage on the surface of the glass electrodes exposed in the MSMGRPC in high irradiation dose is significant and different for the two surfaces. Not exposed glass does not contain fluorine.

First prototype with a directed flow

- design consideration and assembling -



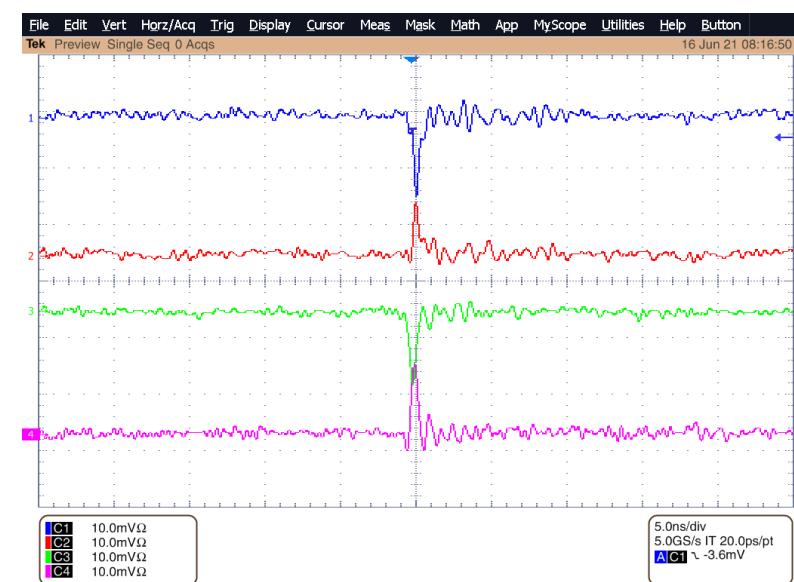
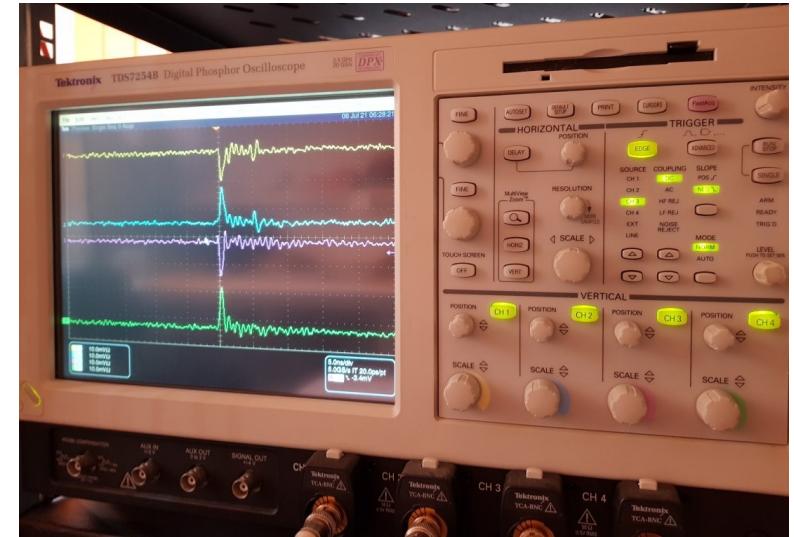
- Directed gas flow through the gas gaps.
- Spacers run across the strips, not along the strips, as for previous counters.
- Spacers positioned outside the electric field area.
- 5.6 cm strip length instead of 6 cm (previous ones).

Equal gas flow through the two stacks



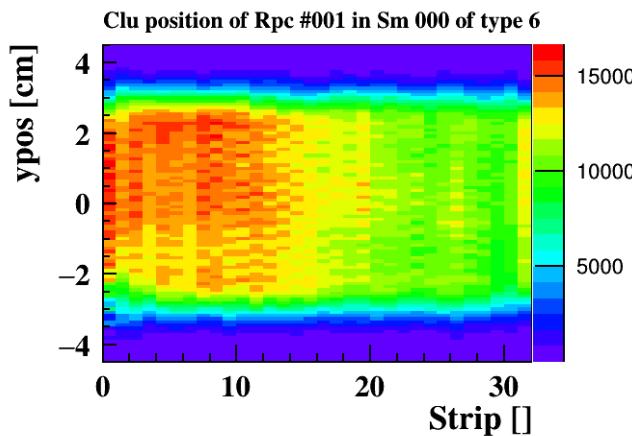
First prototype with a directed flow - laboratory tests -

HV conditioning & first signals @ HPD/IFIN-HH DetLab

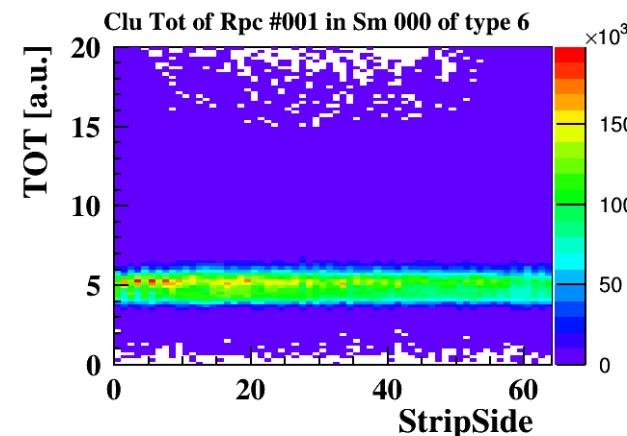


mCBM@SIS18 July 2021 in-beam test results

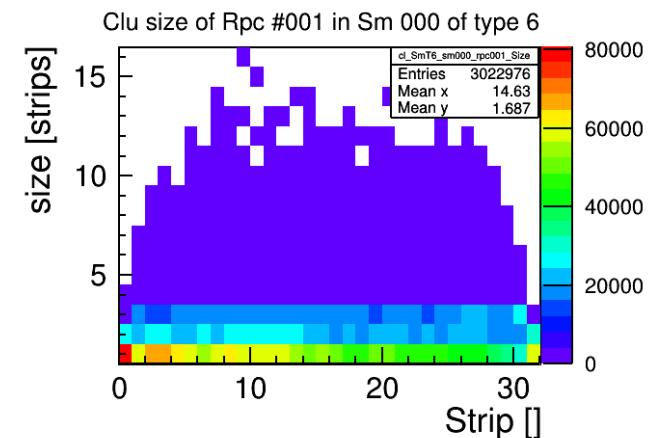
Hit position



ToT distribution

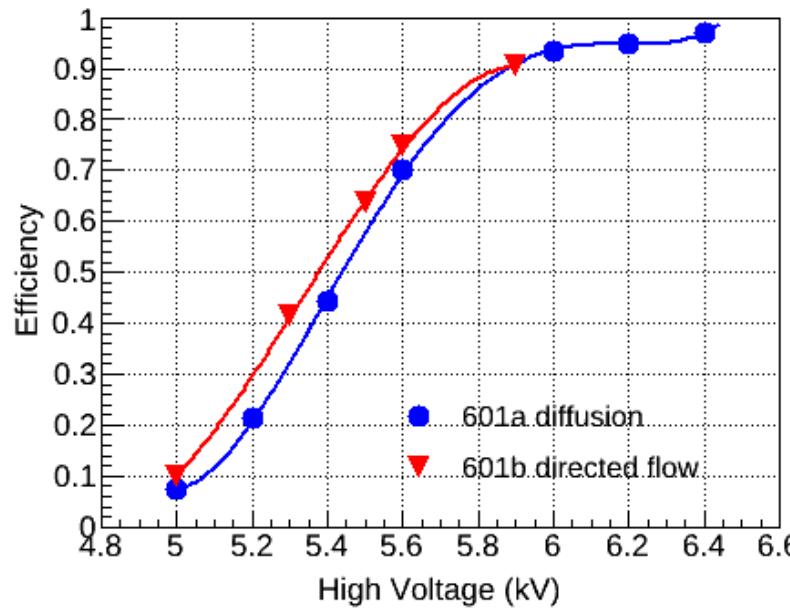


Strip multiplicity

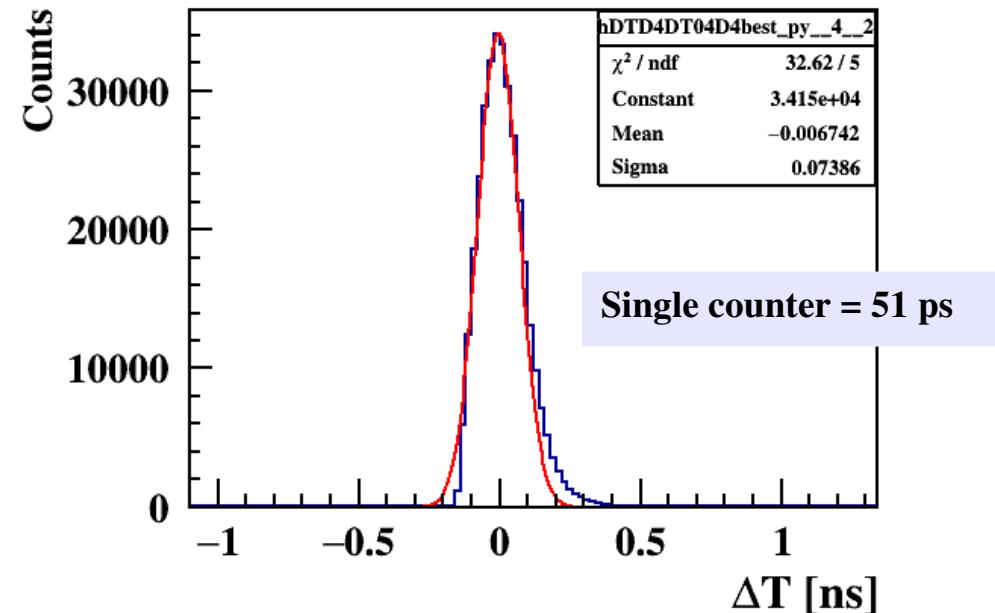


HV = 2 x 5.9 kV ; FEE thr = 200 mV

High voltage scan

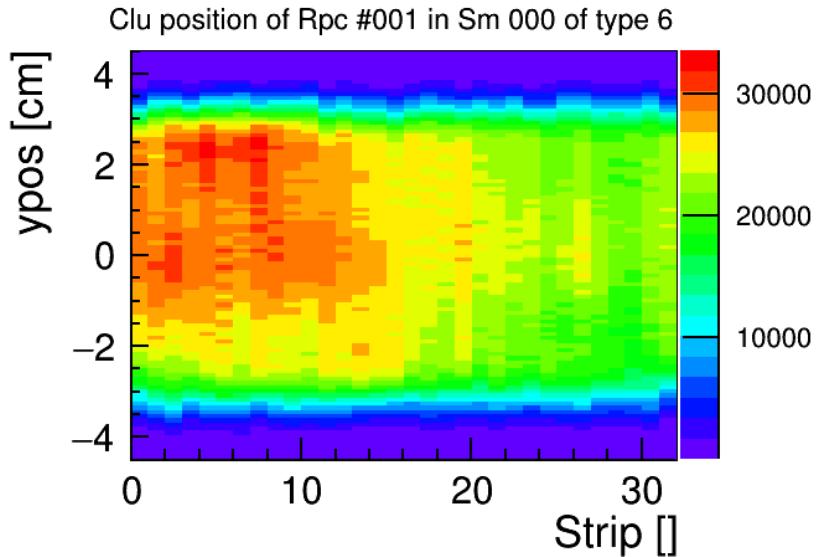


Time resolution @ ± 5.9 kV

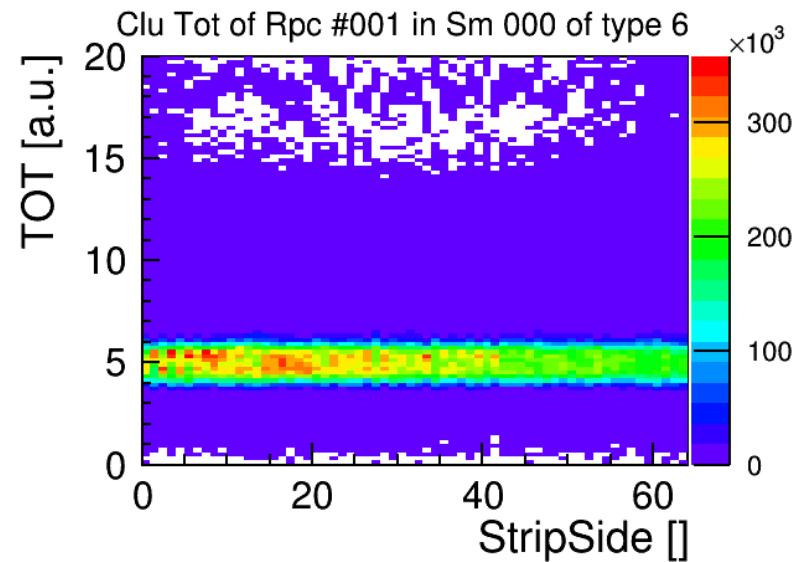


mCBM@SIS18 July 2021 in-beam test results high counting rate

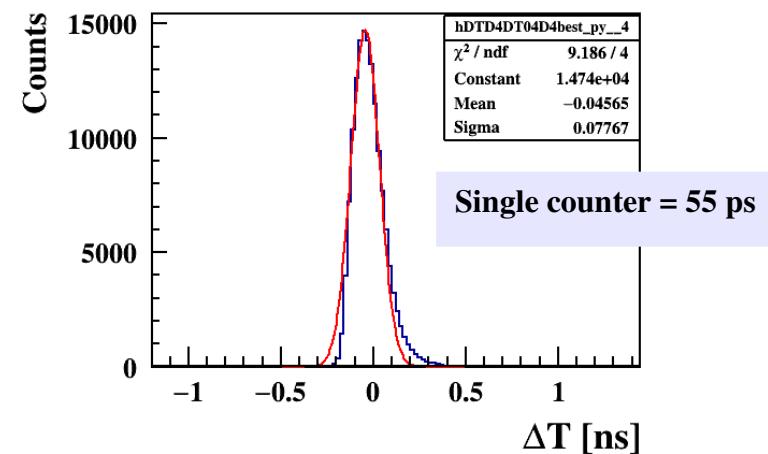
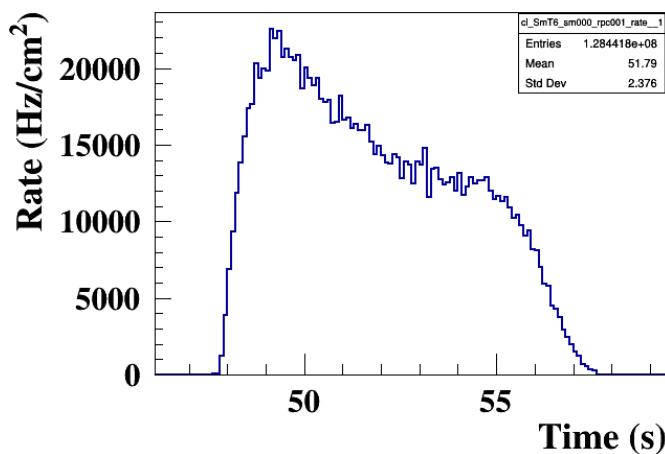
Hit position



ToT distribution



Clu rate of Rpc #001 in Sm 000 of type 6



HV = 2 x 5.9 kV ; Th = 200 mV;

Summary & Outlook

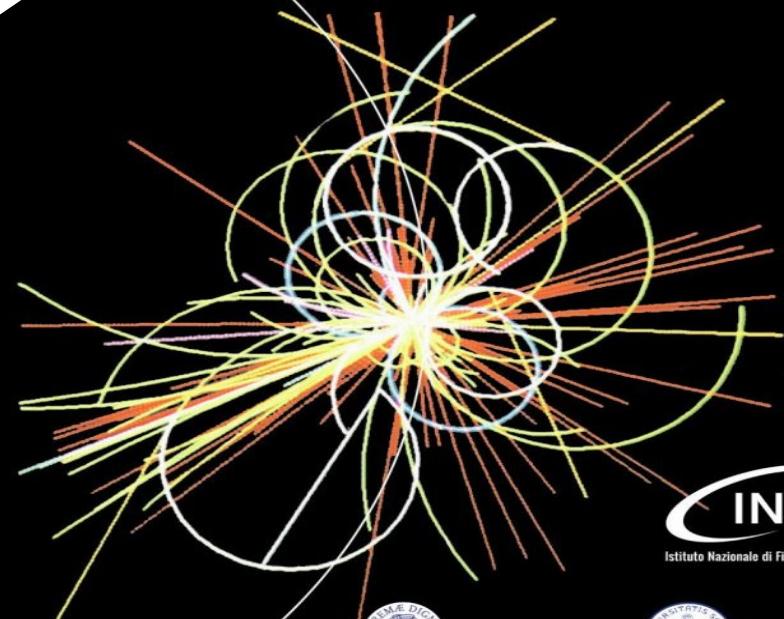
- MSMRPC prototypes with high granularity and impedance matched to the FEE were assembled and tested in the Lab with ^{60}Co source & cosmic rays proving very good efficiency and time resolution.
- In-beam tests in the mCBM setup confirmed the obtained results and showed that the efficiency and time resolution are still very good up to a counting rate $\geq 25 \text{ kHz/cm}^2$.
- The aging tests showed an important gas pollution effect which could limit the lifetime of the counter.
- Proposed mitigation solutions is a MSMRPC prototype with a directed flow through the gaps. It performed in the in-beam test in the mCBM/SIS18 setup in July 2021; it was also tested in March 2022 (data analysis is in progress).
- Aging tests using this prototype will be performed in the near future at a lower dose rate and longer exposure time.
- Design of a directed gas flow in wider counters (100/200 mm wide) are in progress based on the already gained experience.

Thank you for your attention!

Frontier Detectors for Frontier Physics

15th Pisa meeting on advanced detectors

La Biodola • Isola d'Elba • Italy
22 - 28 May, 2022



Istituto Nazionale di Fisica Nucleare



Università di Pisa
Dipartimento di Fisica



Università di Scienze
e Tecnologie
Cinese
Sezione Fisica



Società Italiana
di Fisica



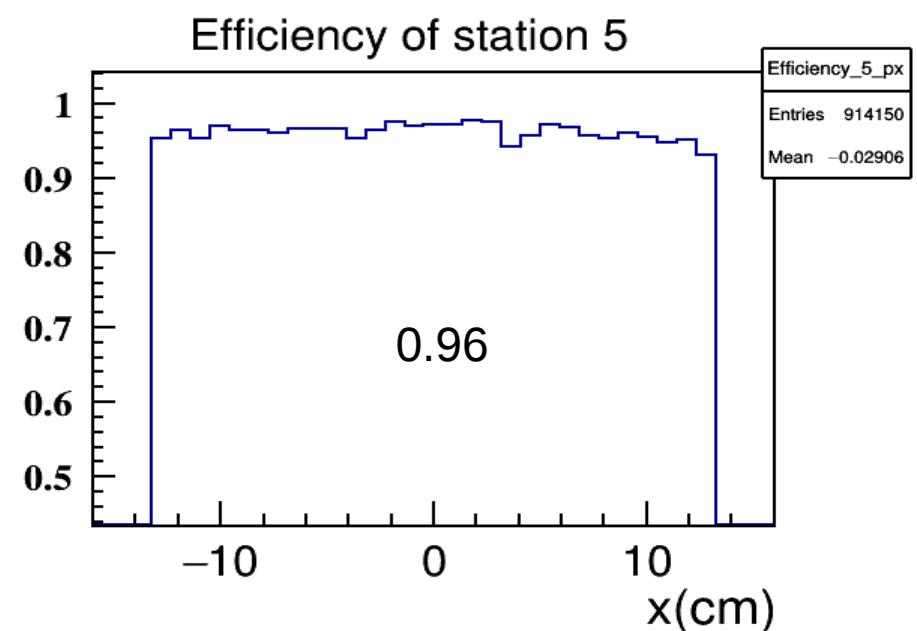
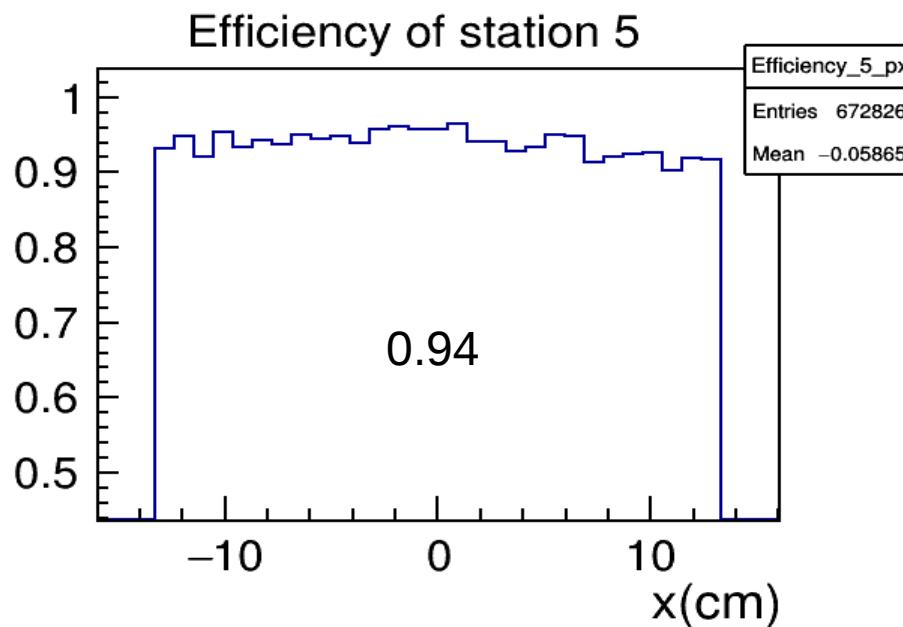
European
Physical
Society

Back up

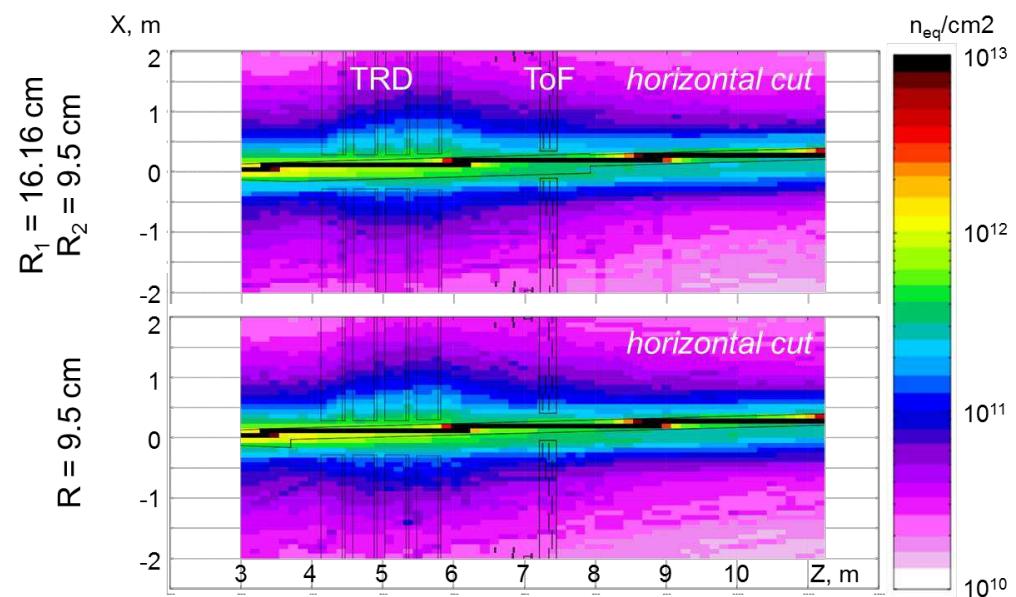
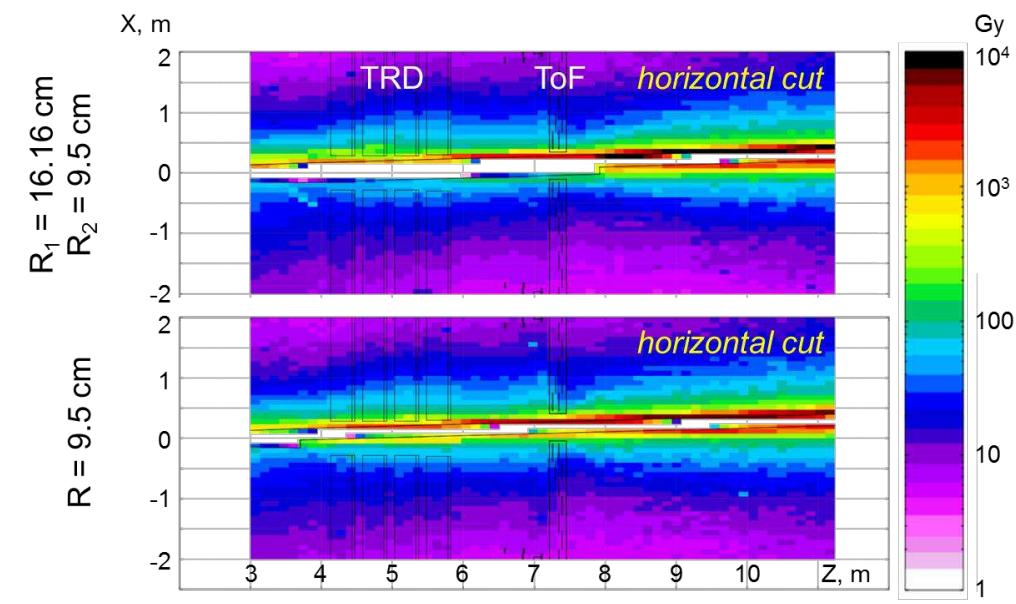
Threshold scan

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

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

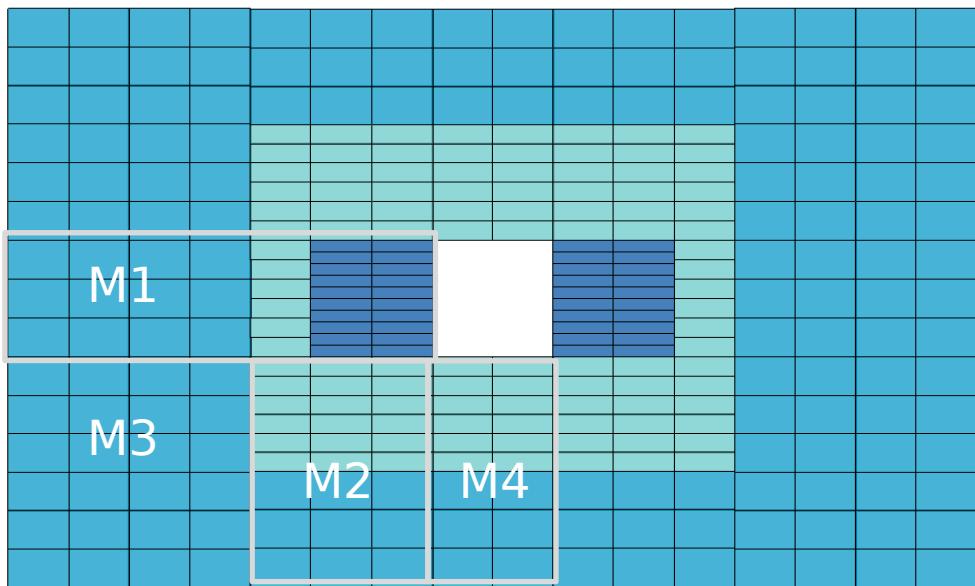


FLUKA simulations



A.Senger, CBM-TN-18001

Current design of the CBM-TOF inner wall



- 4 module types
- 12 modules
- 3 counter types: $60/100/200 \times 300 \text{ mm}^2$
- 316 counters
- 20,224 readout channels

	RPCs (200)	RPCs (100)	RPCs (60)	Total
No. RPCs	168	92	40	316
No. channels	10752	5888	2560	20,224