Radiation hard Multi-Strip Multi-Gap Resistive Plate Chamber architecture for low polar angles of the CBM-TOF wall

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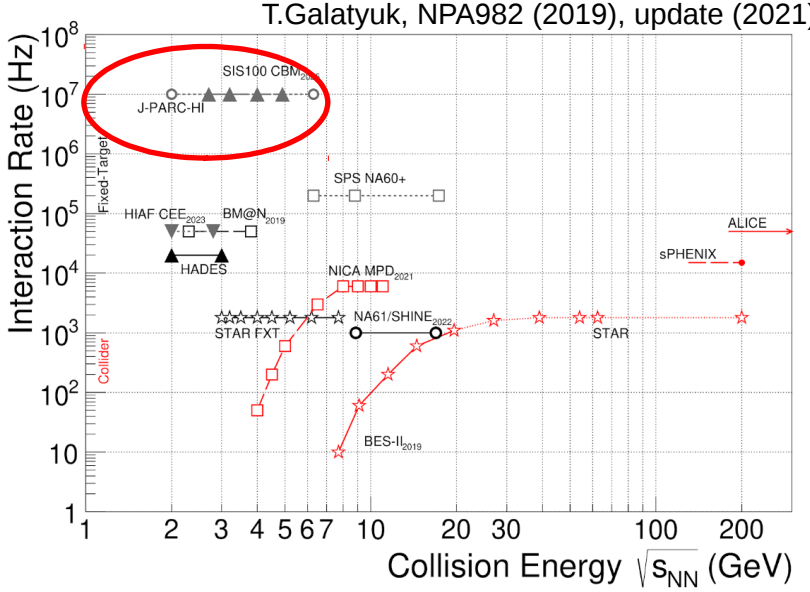
Outline

- **Motivation – next generation of high interaction rate experiments**

  (e.g. CBM/FAIR, Darmstadt ->TOF inner wall)
- **MSMGRPC: design considerations & high counting rate performance**
- **Aging studies of a MSMGRPC with gas exchange via diffusion**
- **Aging studies of MSMGRPC prototypes with direct gas flow**
  - **standard fishing line spacers**
  - **discrete spacers**
- **Cosmic rays and in-beam tests of direct flow MSMGRPCs**
- **First CBM-TOF inner wall module**
- **Summary and Outlook**

High interaction rate experiments

CBM Collaboration, EPJA 53 3 (2017) 60
T.Galatyuk, NPA982 (2019), update (2021)

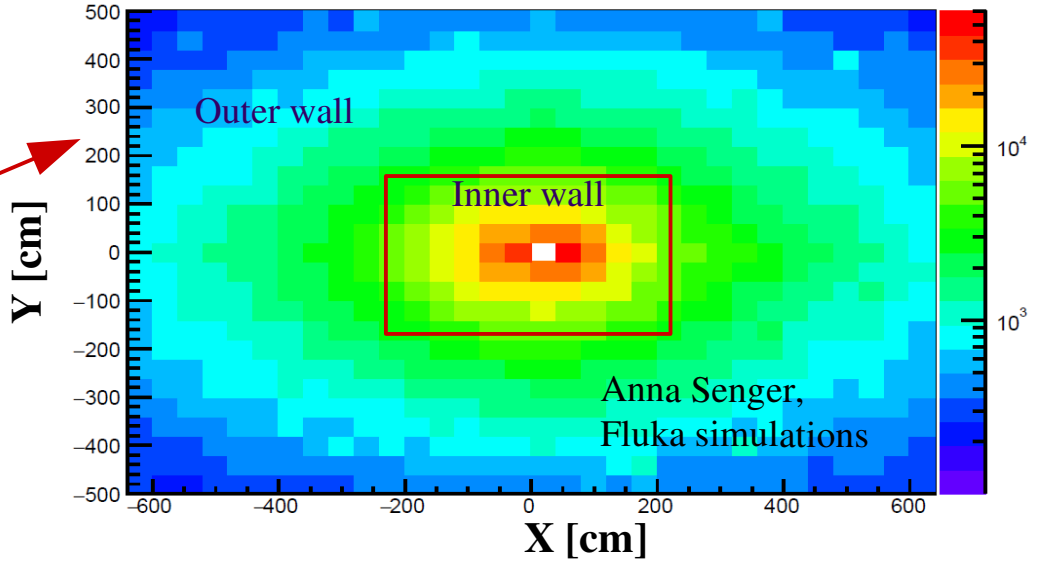


See also Ingo Deppner talk

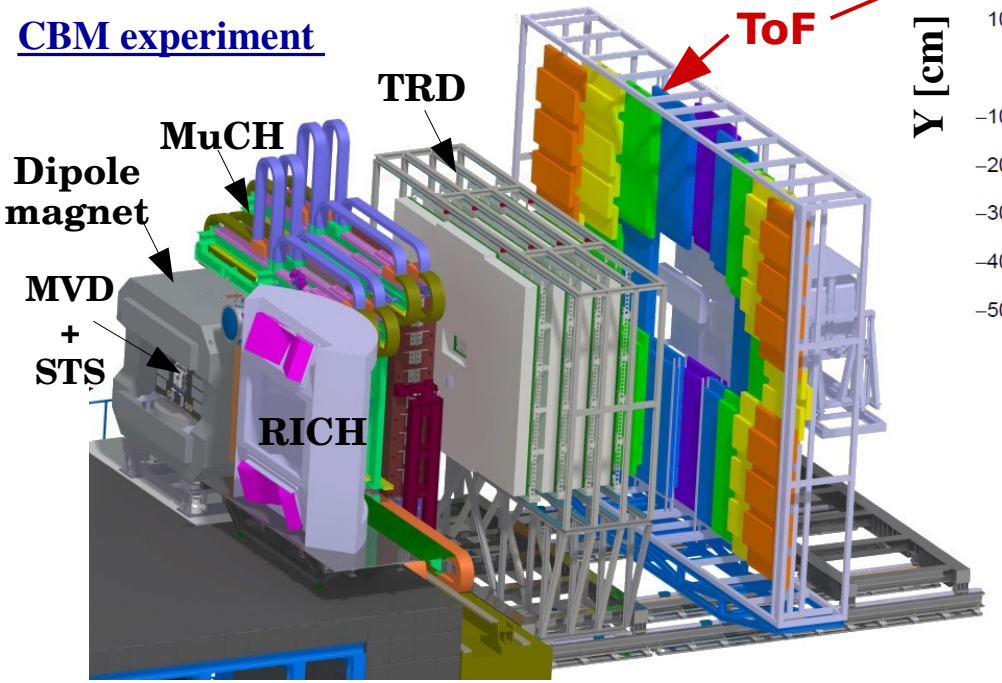
CBM experiment at FAIR/SIS100:

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

Charged particle flux on TOF wall @ 8 m from the target, Au + Au collisions at E_{kin} = 11A GeV, 10^7 interactions/s



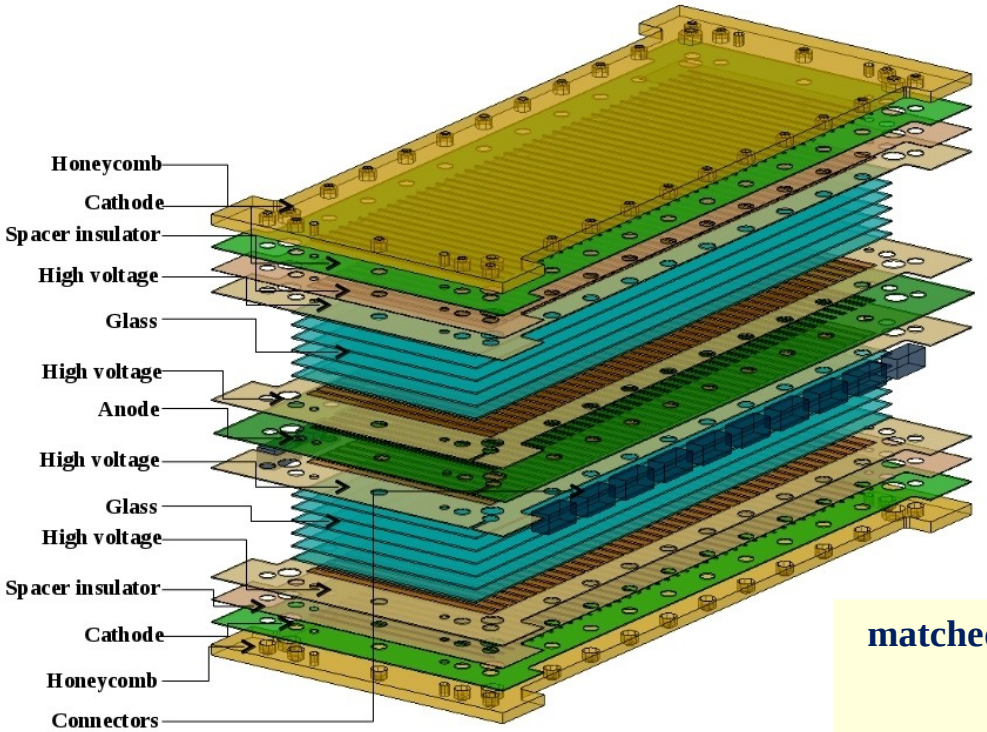
CBM experiment



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

- highest counting rate
- highest granularity
- ~15 m^2 active area (up to ~ 11° polar angle)

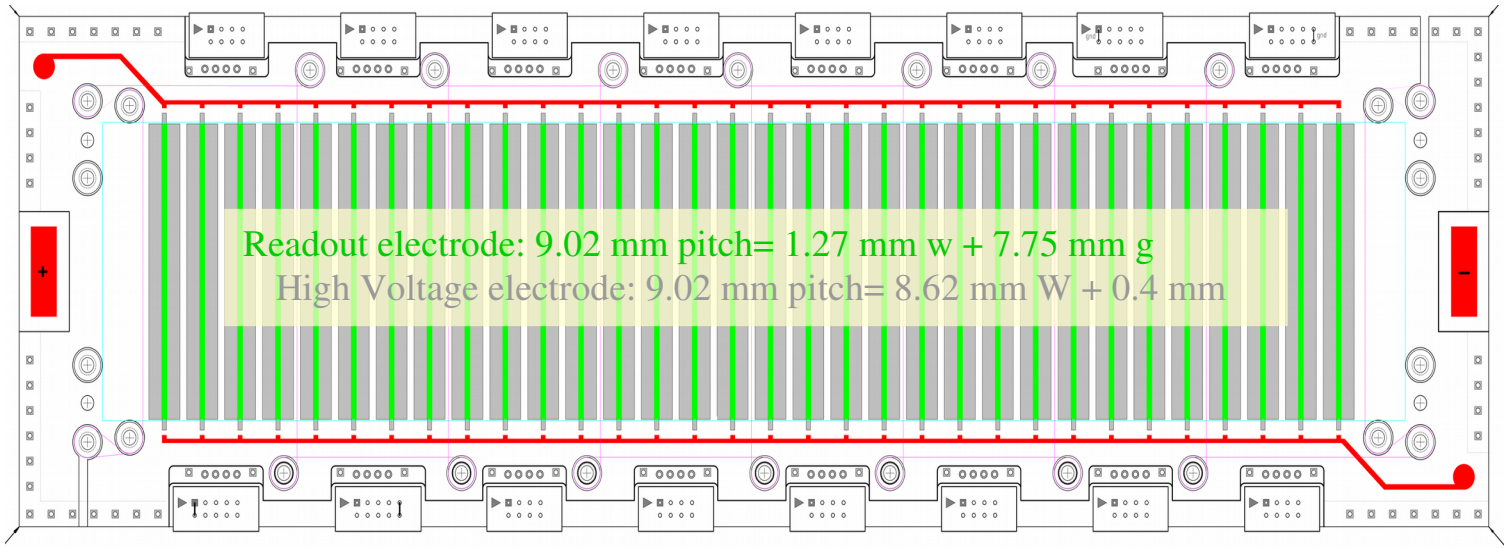
Chamber design considerations

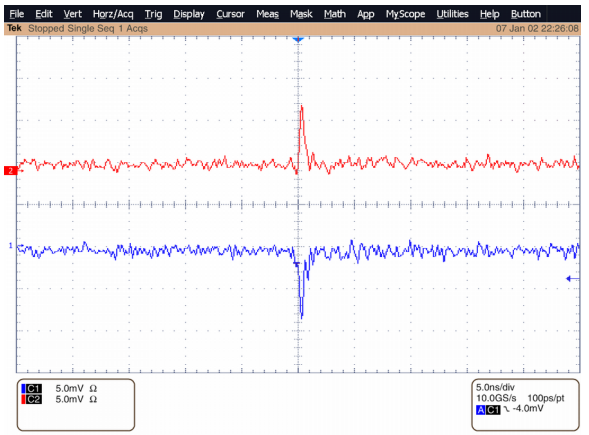


- ✓ Symmetric structure: 5 gaps x 2 stacks
- ✓ Gas gap thickness: 200 µm
- ✓ Active area: strip length x 9 mm pitch x 32 strips
- ✓ Strip length:56/96/196 mm (MRPC1a/MRPC1b/MRPC1c)
- ✓ Resistive electrodes: ~10^{10} Ωcm, 0.7 mm (Chinese glass)
- ✓ Strip structure for Readout & HV electrodes
- ✓ Differential readout
- ✓ Direct flow through the gas gaps

matched signal transmission line impedance to the input of the FEE

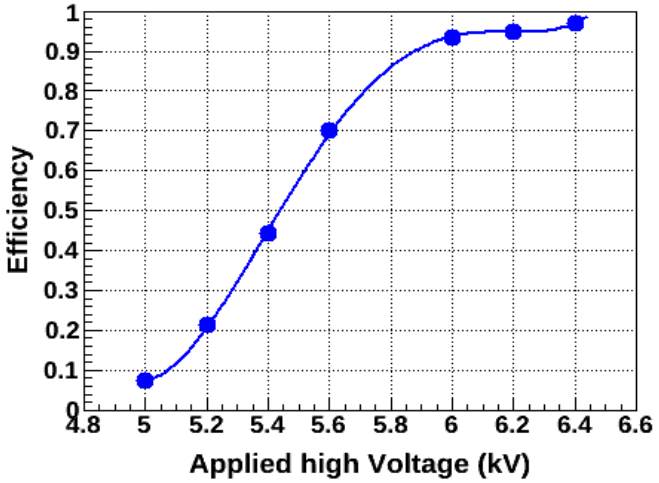
D. Bartos et al., Romanian Journal of Physics 63, 901 (2018)

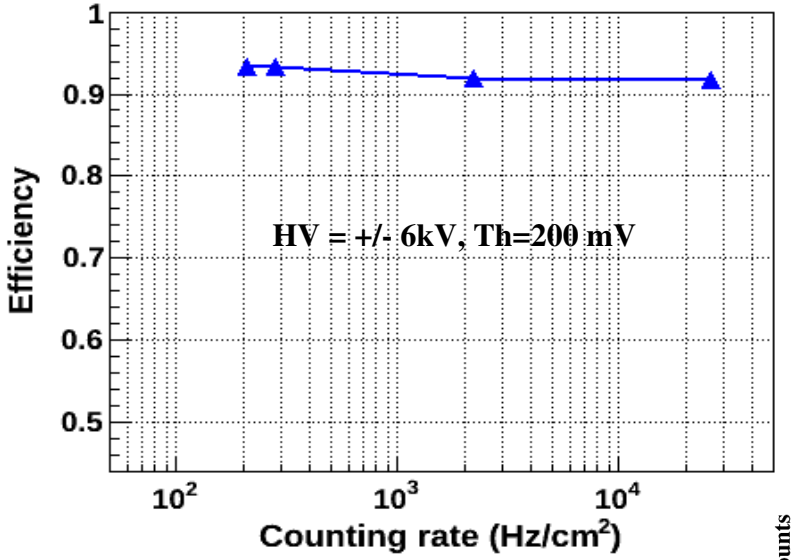


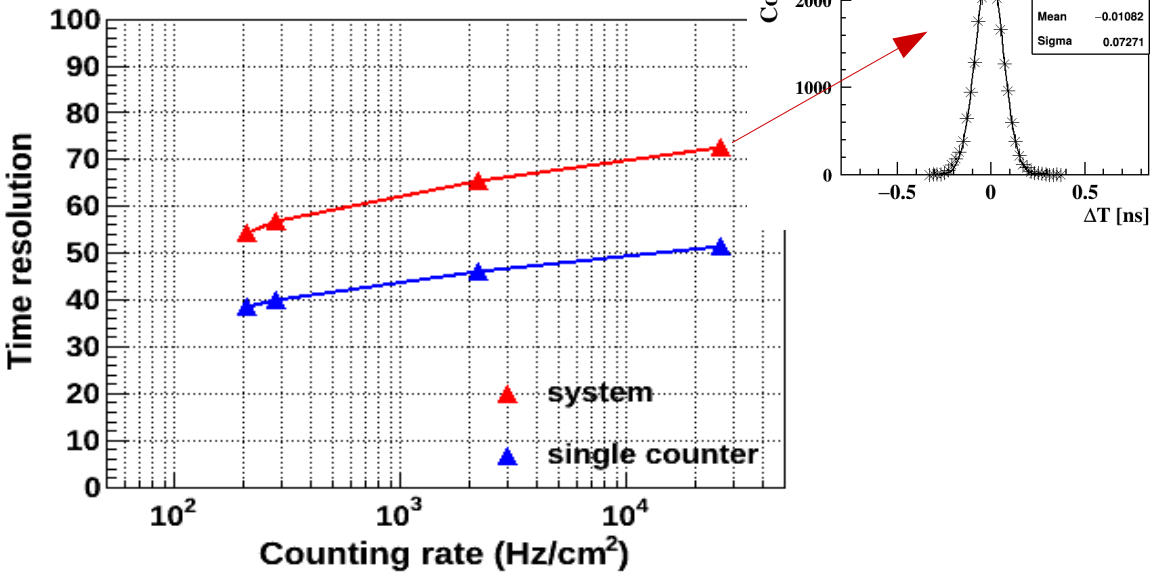


High Counting Rate Test of a MSMGRPC prototype with gas exchange via diffusion

mCBM/SIS18/GSI Darmstadt



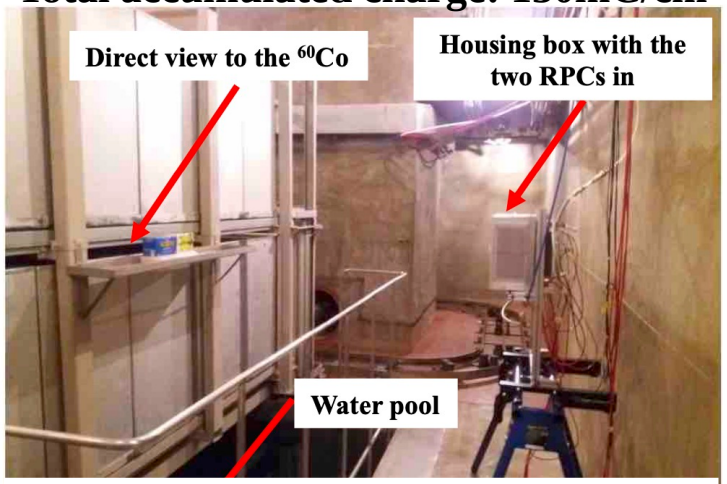




M. Petris et al., Nucl. Inst. and Methods A 1045 (2023) 167621

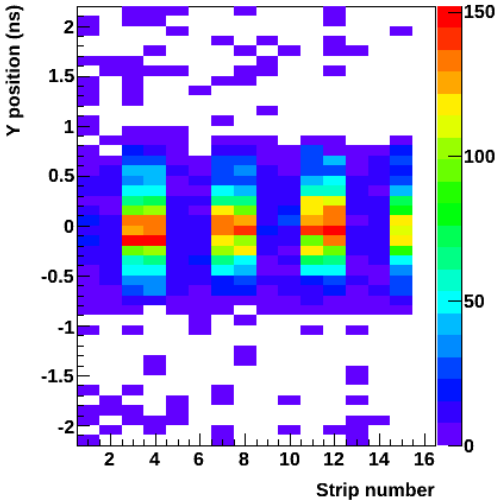
Aging investigations of MSMGRPC with gas exchange via diffusion

- **IRASM/IFIN-HH multipurpose irradiation center**
- **^{60}Co source: 360 kCi;**
- **Total accumulated charge: 130mC/cm^2**

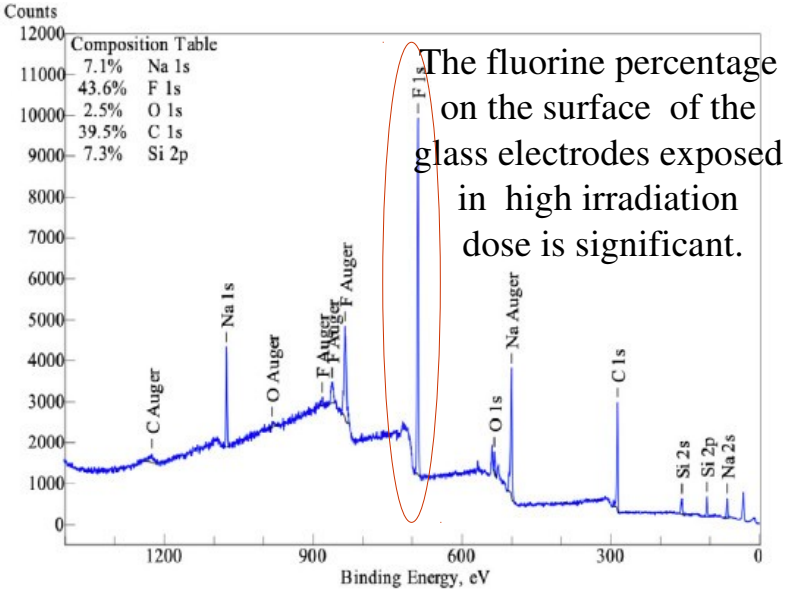


Gas mixture: 90% $C_2H_2F_4$ + +5%i-C_4H_{10}+5% SF_6

Dark rate generated around the spacers

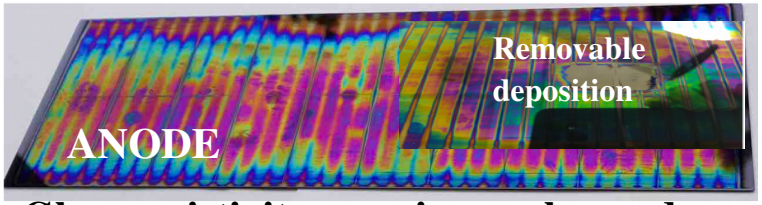


(XPS) analysis of the chemical composition of irradiated and non-irradiated glass plates

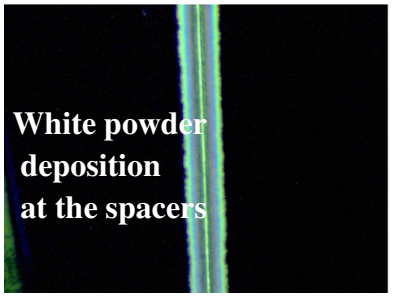


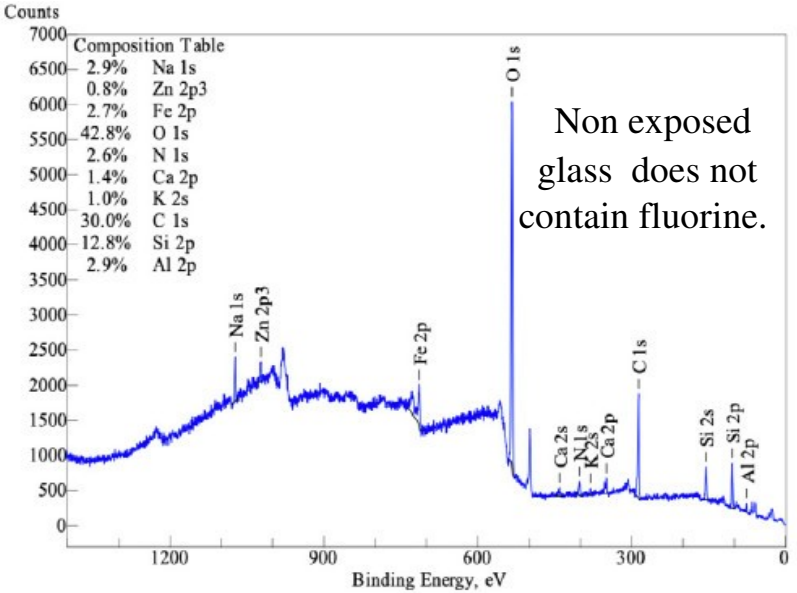
The fluorine percentage on the surface of the glass electrodes exposed in high irradiation dose is significant.

Glass inspections performed with various methods:
(SEM, XPS, AFM RBS, non-RBS, THz-TDS)



Glass resistivity remains unchanged

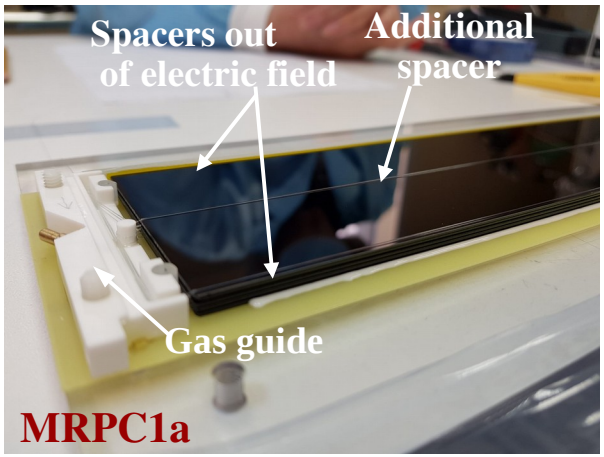


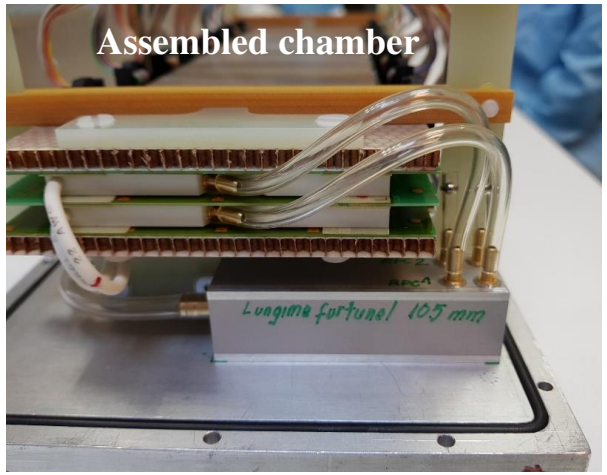


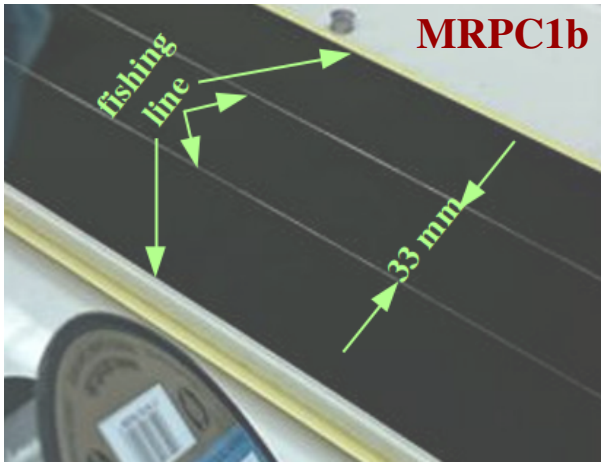
Non exposed glass does not contain fluorine.

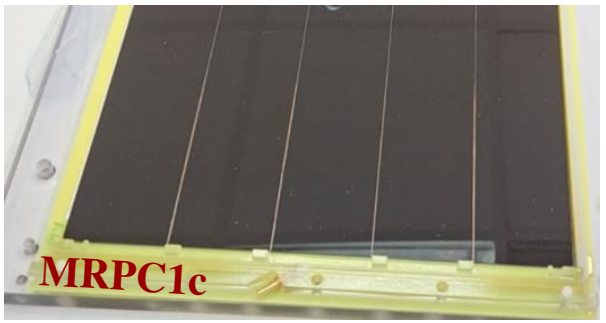
D. Bartos et al., Nucl. Inst. and Methods A 1024 (2022) 166122

MSMGRPC prototypes with direct flow and fishing line spacers





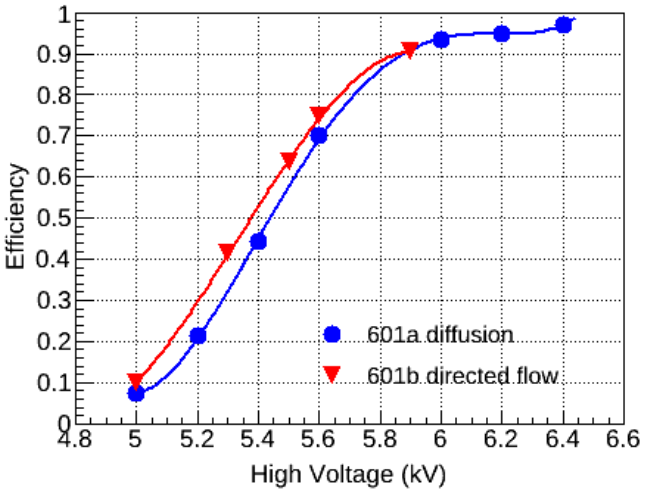




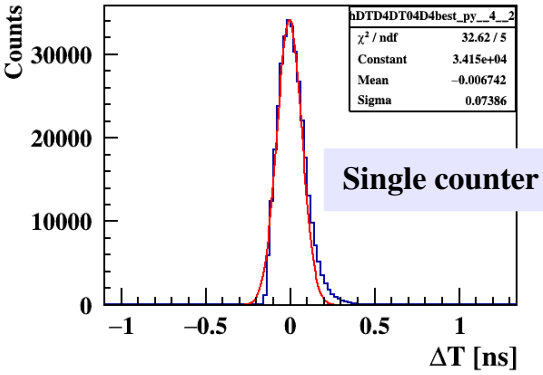
- **Direct gas flow through the gas gaps.**
- **Spacers run across the strips.**
- **Outermost spacers positioned outside electric field area.**

Gas mixture: 97.5% $C_2H_2F_4$ + 2.5% SF_6

High voltage scan in mCBM setup



Time resolution @±5.9 kV



Single counter = 51 ps

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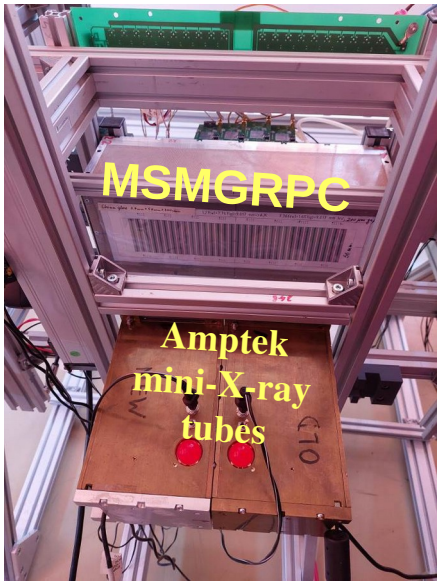
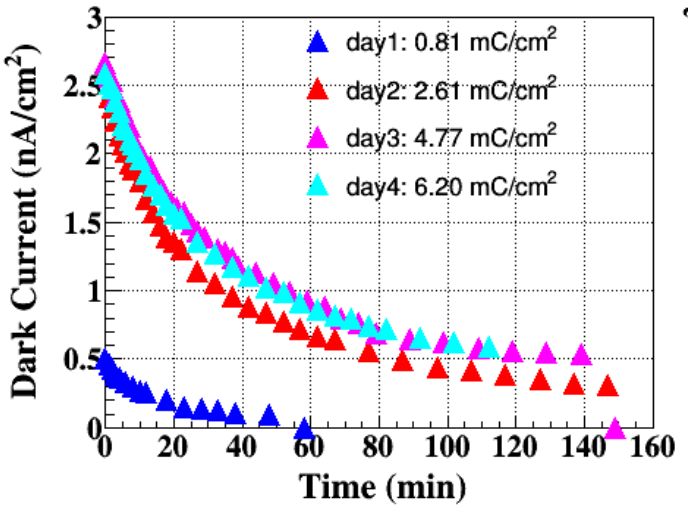
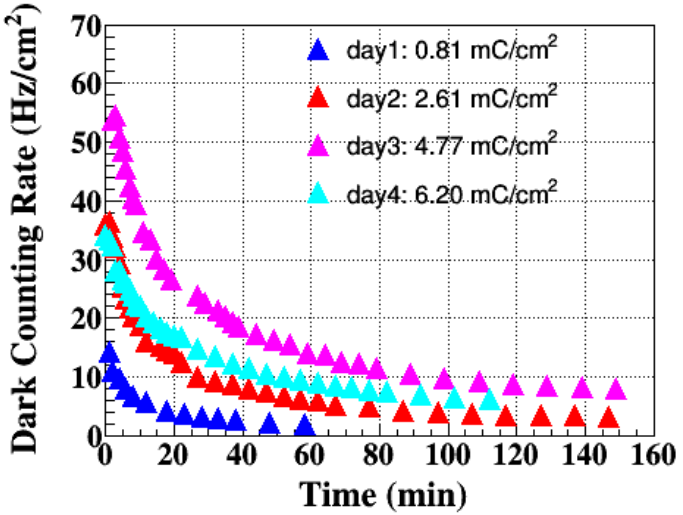
High intensity X-ray irradiation of direct flow prototypes



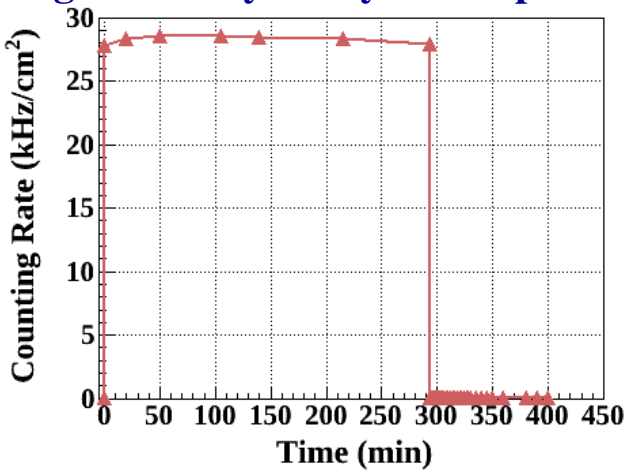
Gas mixture: 97.5% $C_2H_2F_4$ + 2.5% SF_6

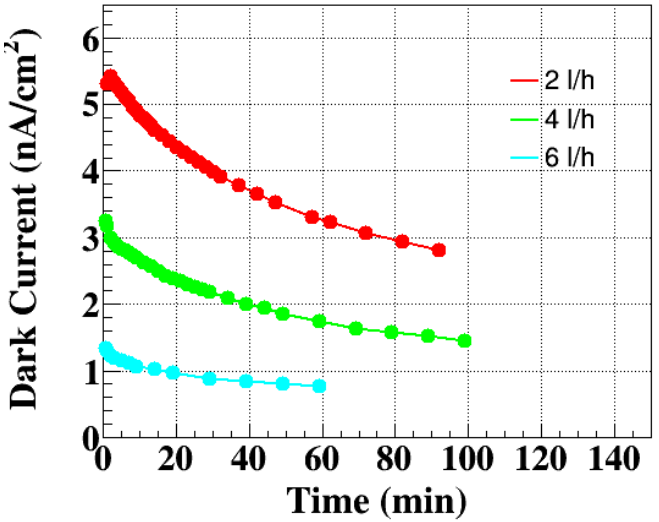
Dark current & dark counting rate after X-ray exposure

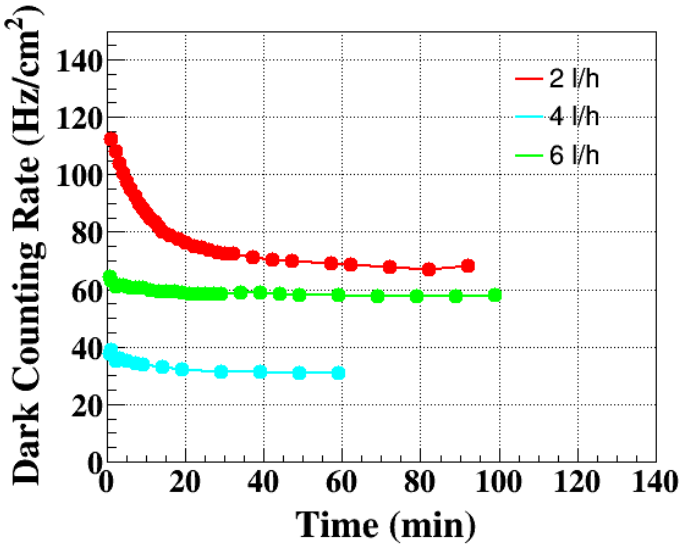




High intensity X-ray flux exposure



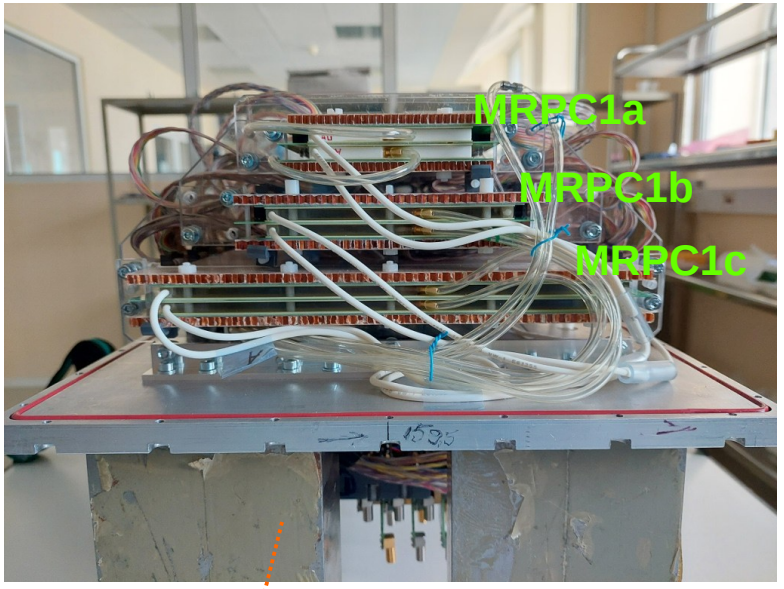


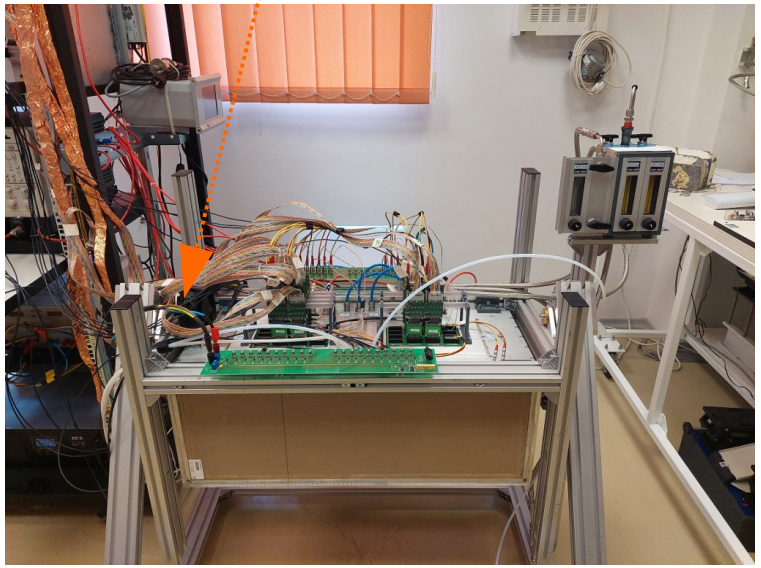


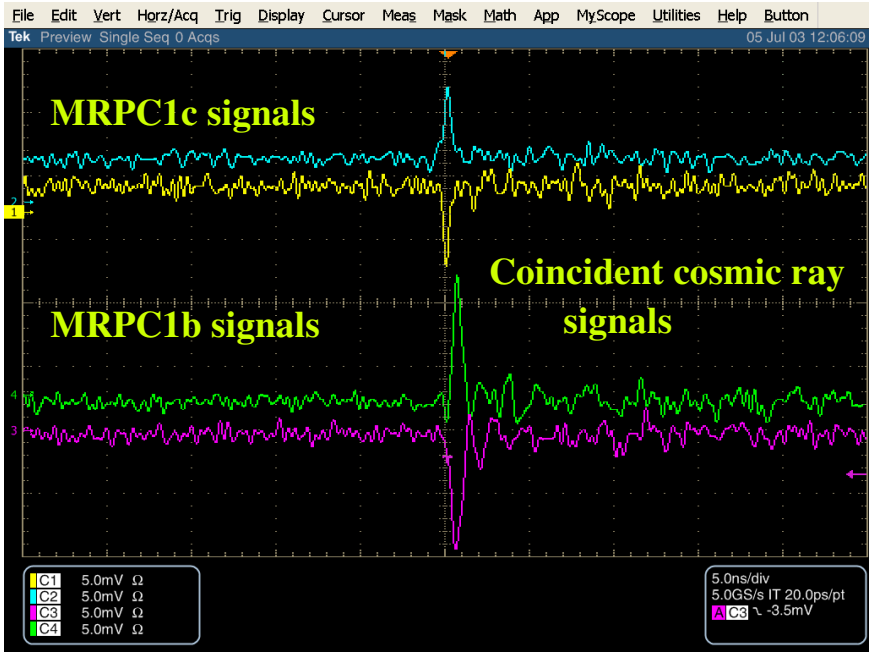
V. Aprodu et al., Nucl. Inst. and Methods A 1049 (2023) 168098

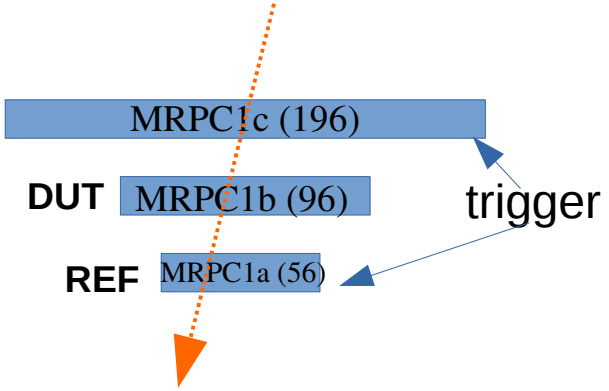
Cosmic - ray tests of the direct flow prototypes

Experimental setup for cosmic rays test

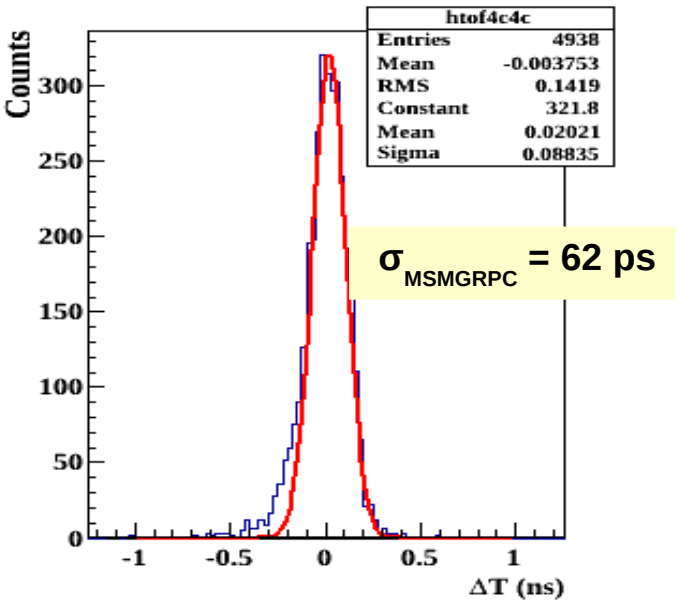






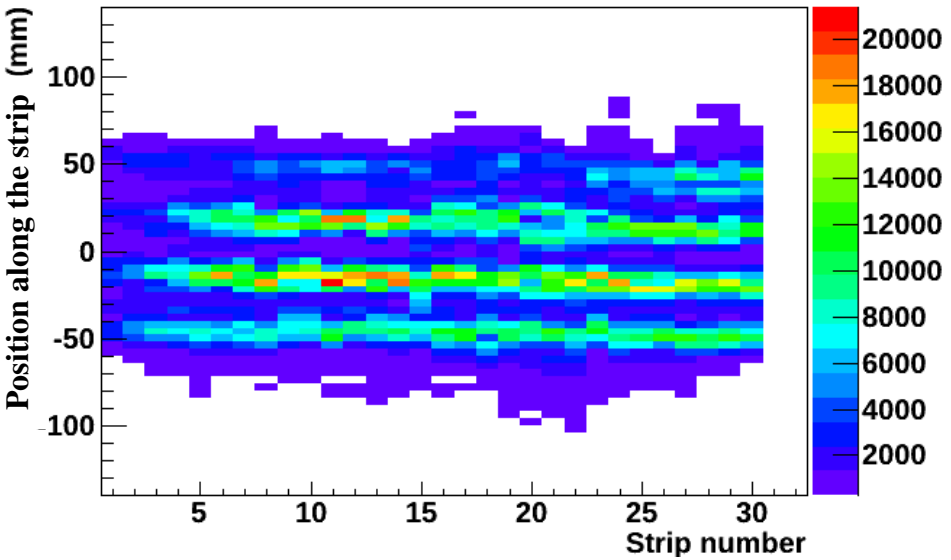


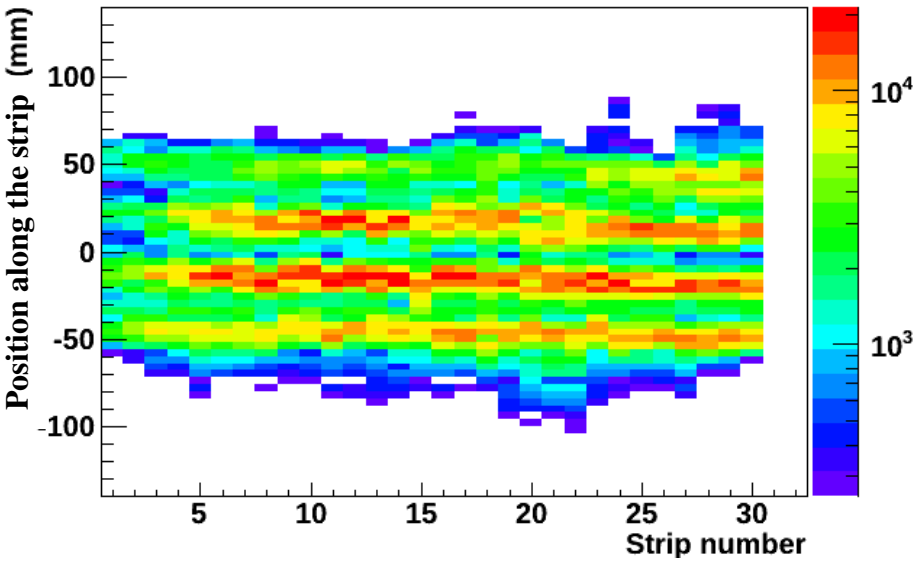
Efficiency = 95 %

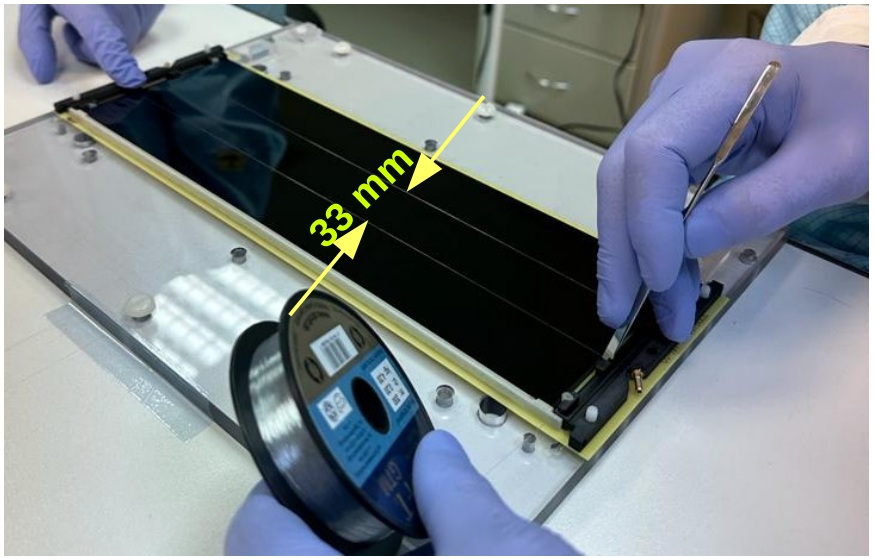


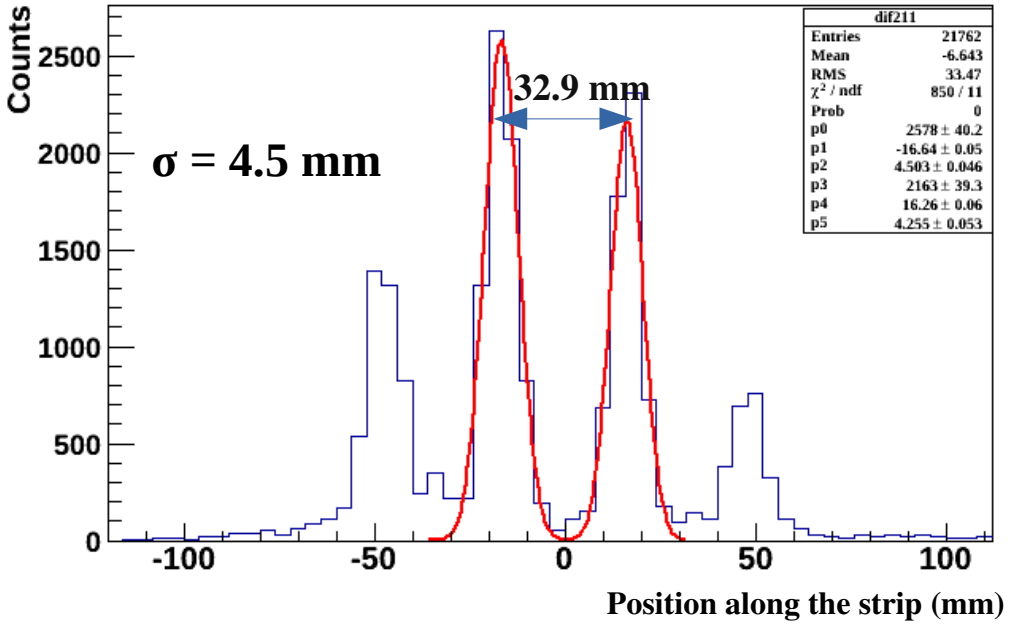
$\sigma_{MSMGRPC}$ = 62 ps

2D mapping of MRPC1b active area in self-triggered mode



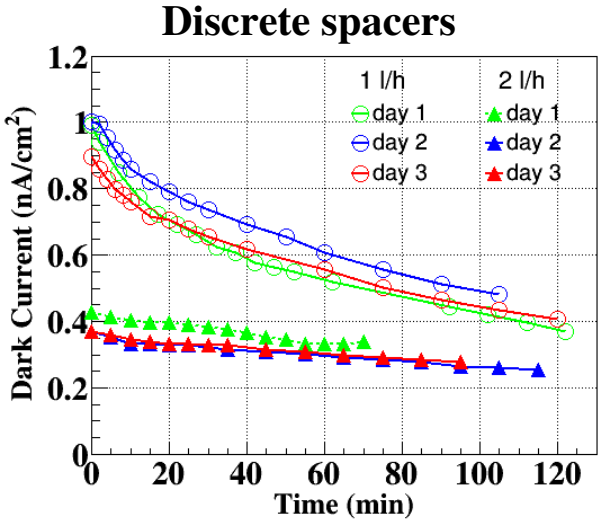


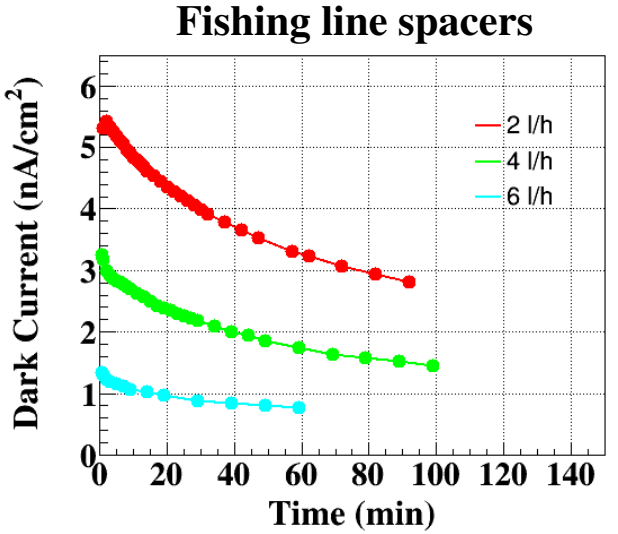


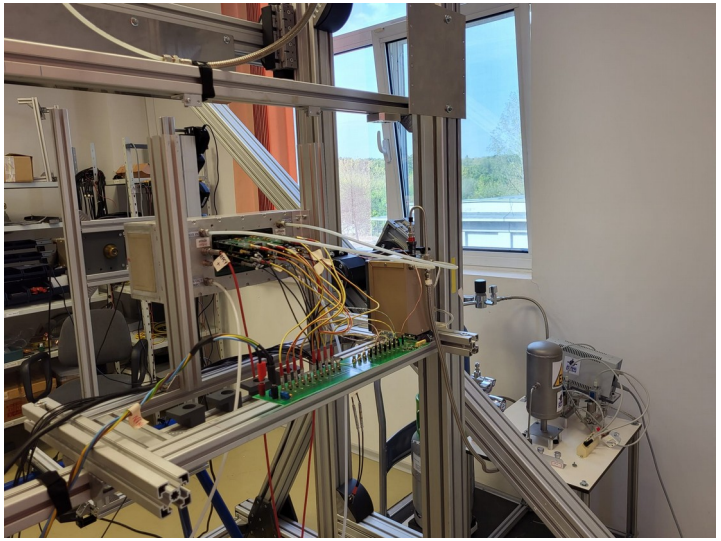


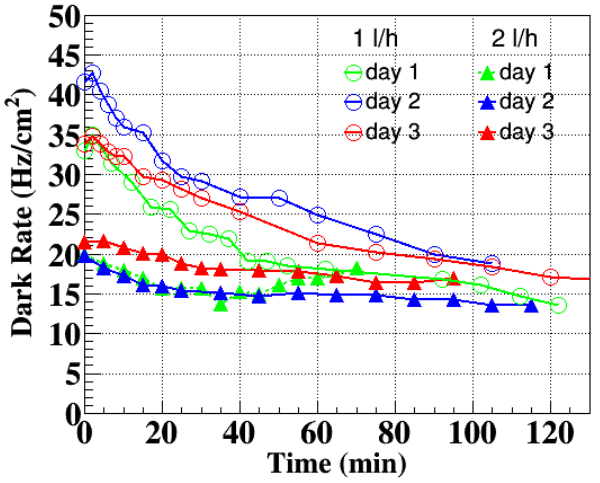
Direct flow MSMGRPC based on discrete polyimide spacers

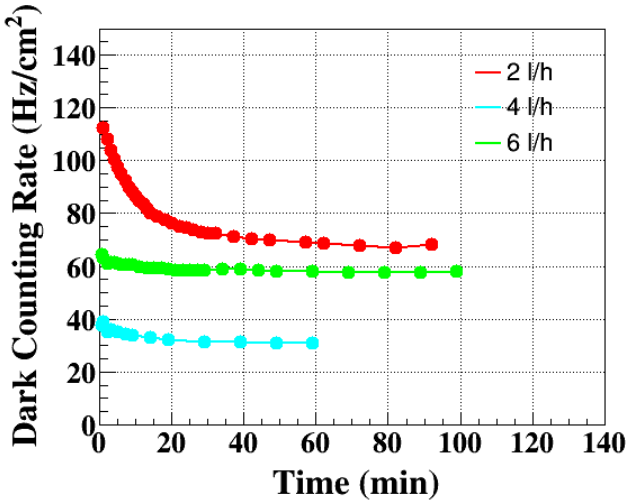
After high X-ray flux exposure







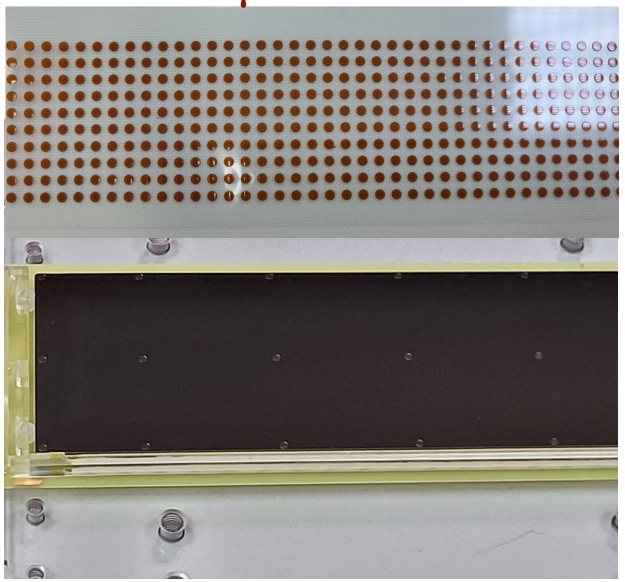


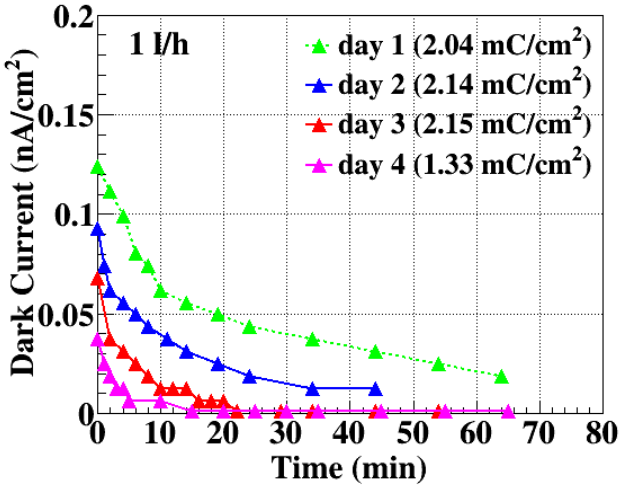


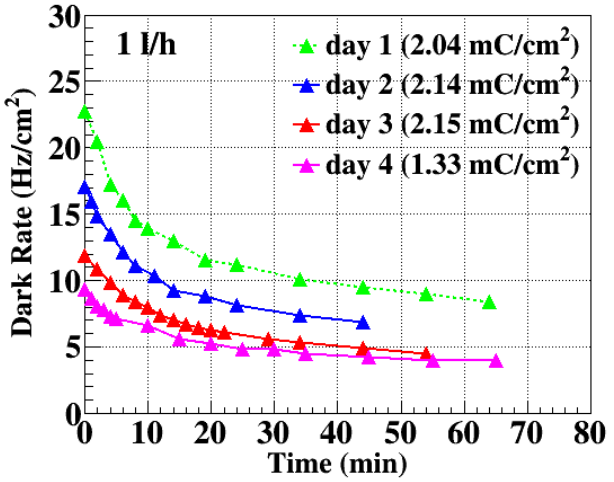
Gas mixture: 97.5% $C_2H_2F_4$ + 2.5% SF_6

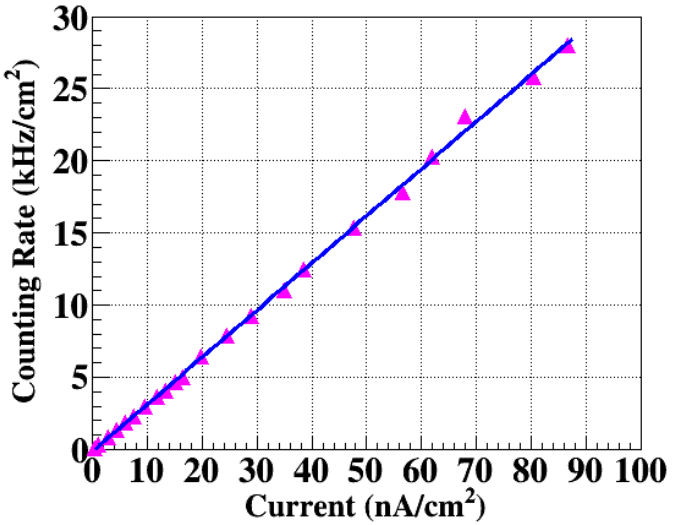
Direct flow MSMGRPC prototype based on commercial polyimide disc spacers

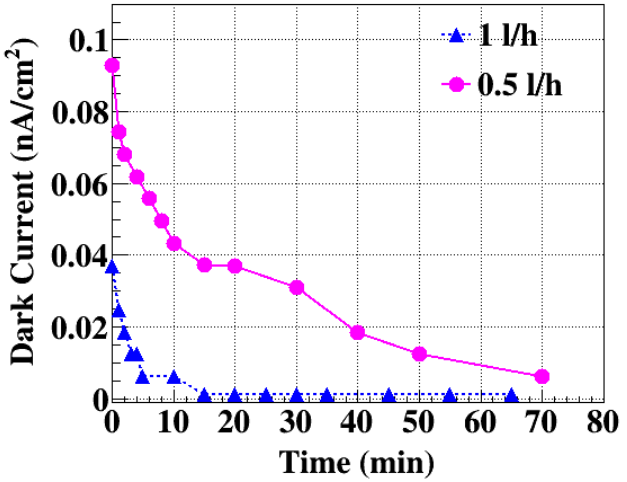
Disc spacers: 2 mm diameter
170 μm thickness

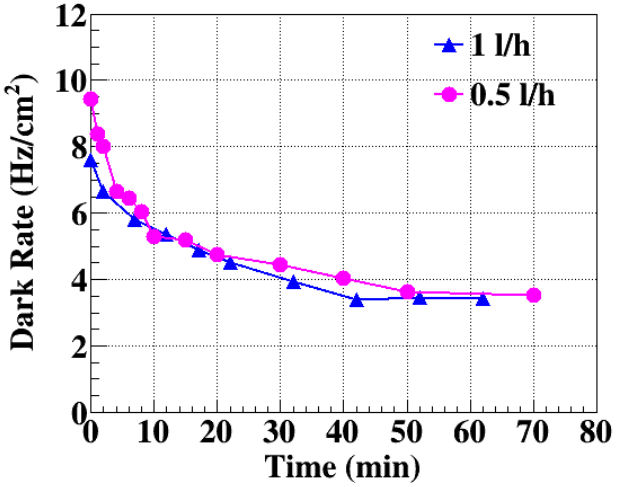












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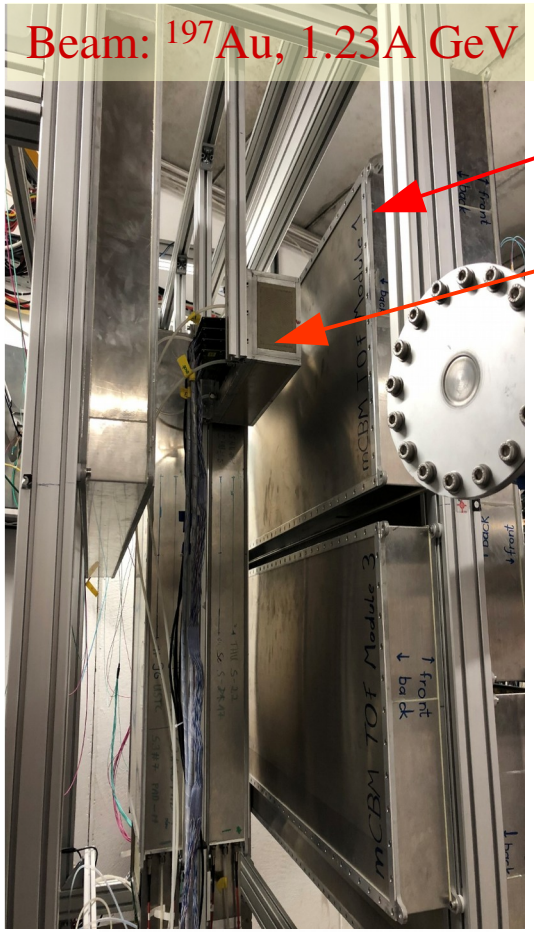
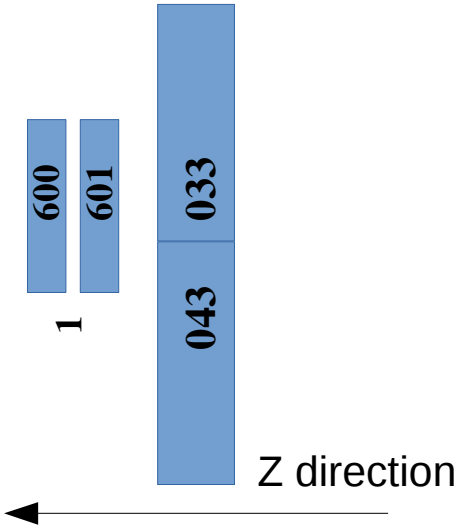
Prototype in-beam test in mCBM @ SIS18/GSI

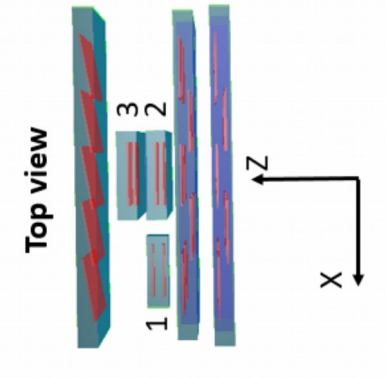


mTOF module: (033, 043)

Test chambers: MRPC1a (600, 601) IFIN-HH, Bucharest

Tracking setup 1:

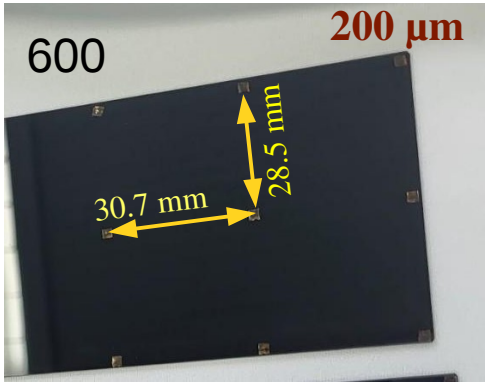


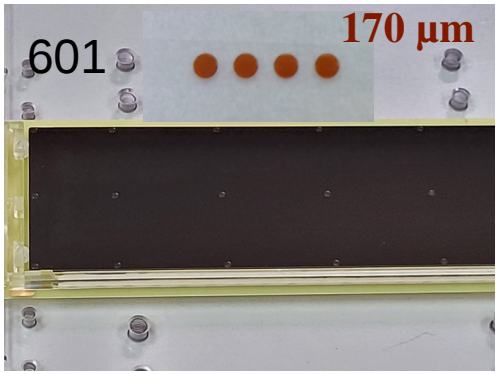


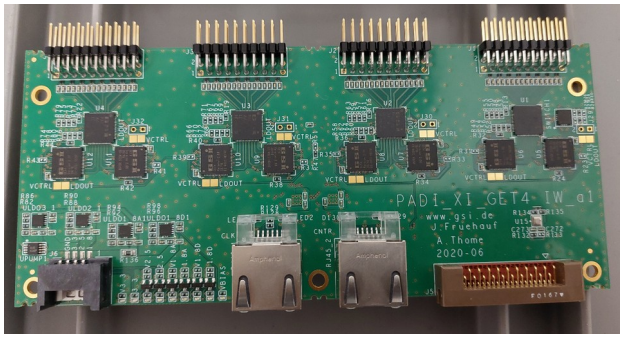
Tracking setup 1:

- **4 tracking stations: 3 MRPCs + diamond (beam ref.)**
- **Analysis → 1 station as DUT and 3 as Reference**

Test MSMGRPCs:





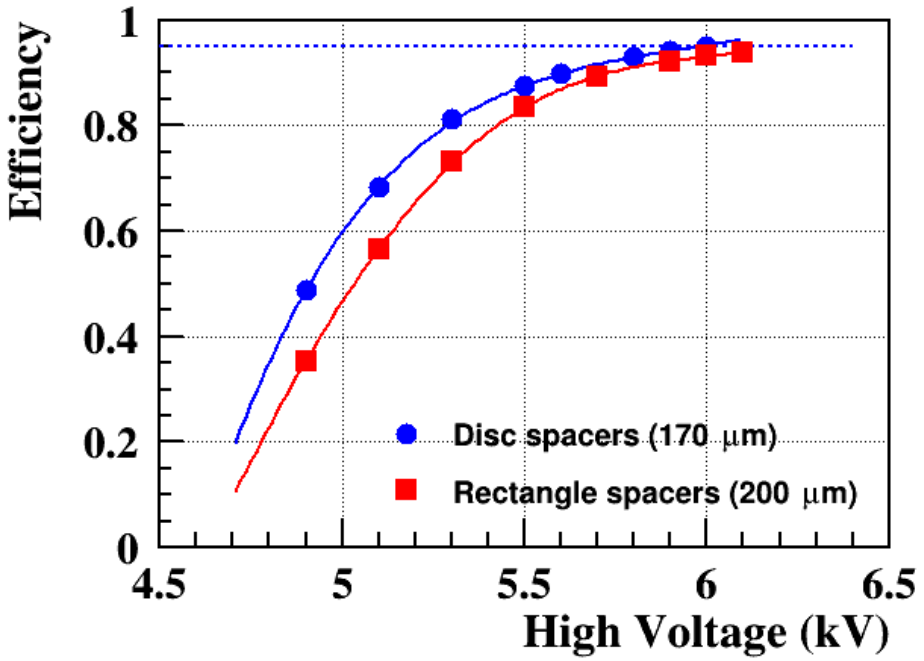


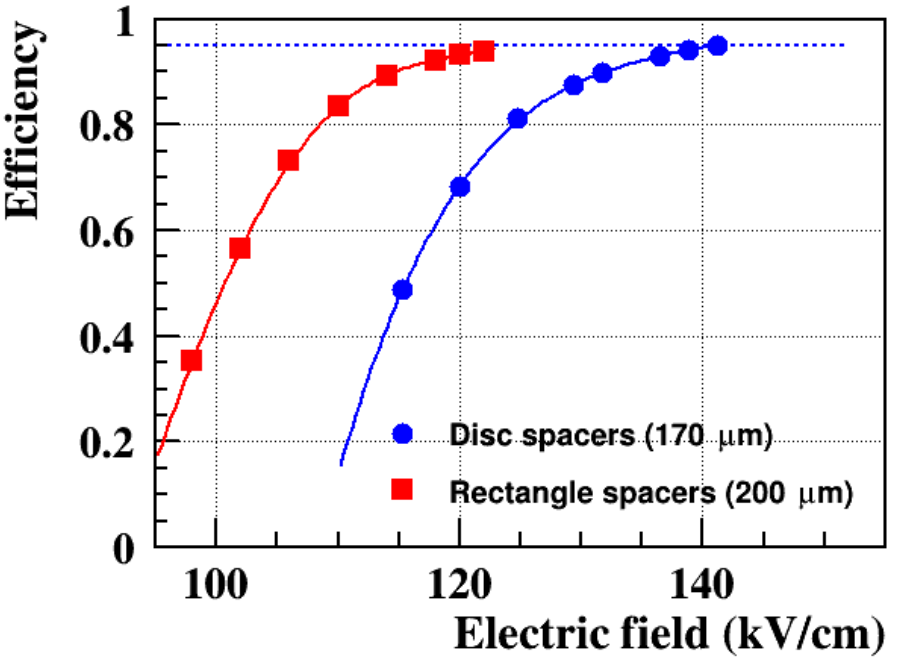
FEE board for the inner TOF wall (J. Frünhauf)

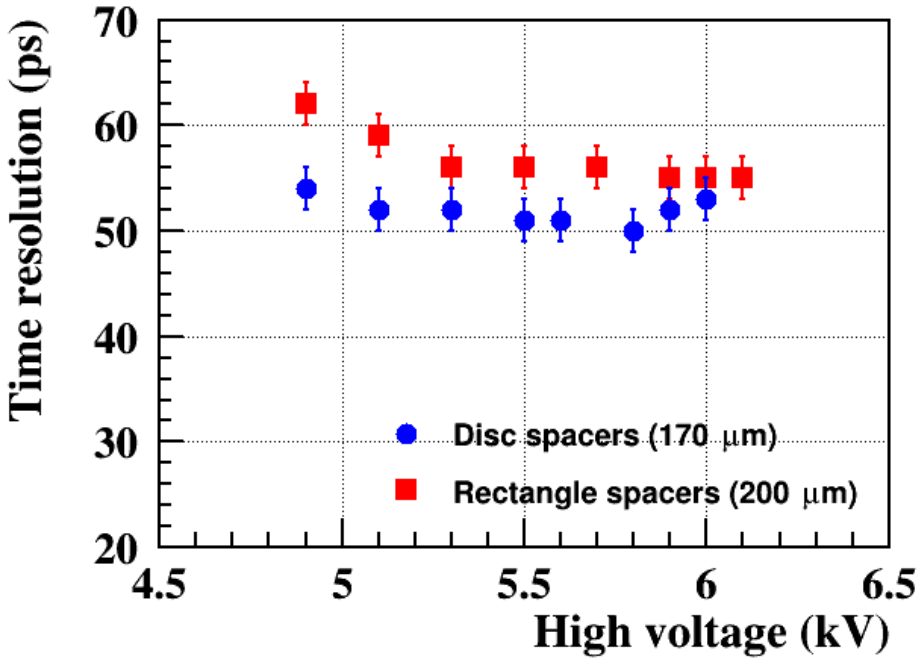
PADI XI (IEEE Trans. Nucl. Sci., vol. 68, no. 6, p. 1325)

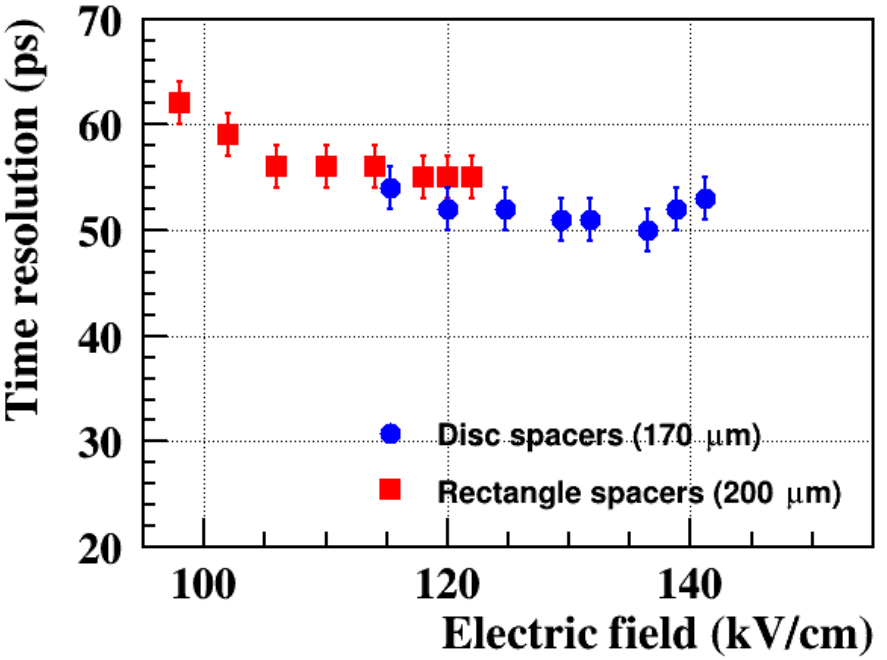
+ GET4 (IEEE Nucl. Sci. Sym. Conf. Rec. (2009) 295)

Performance evaluation - HV scan

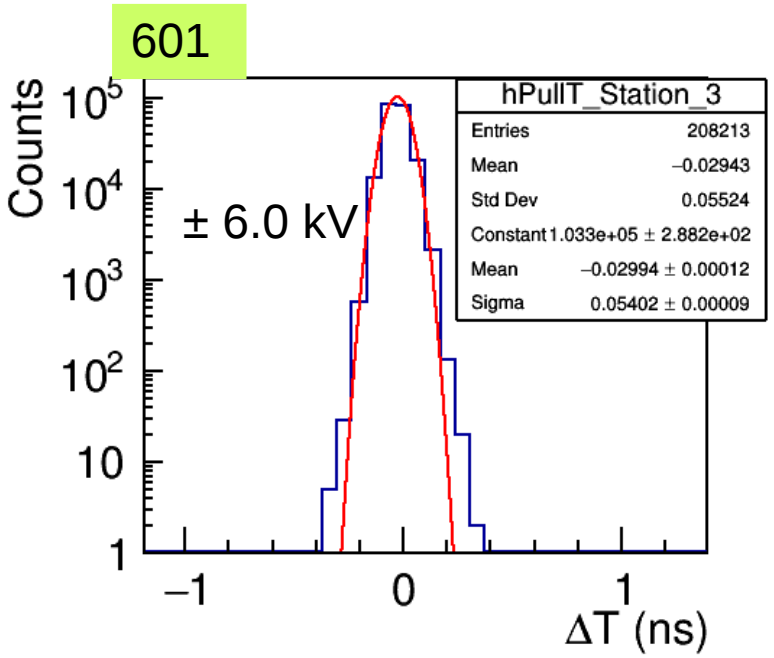


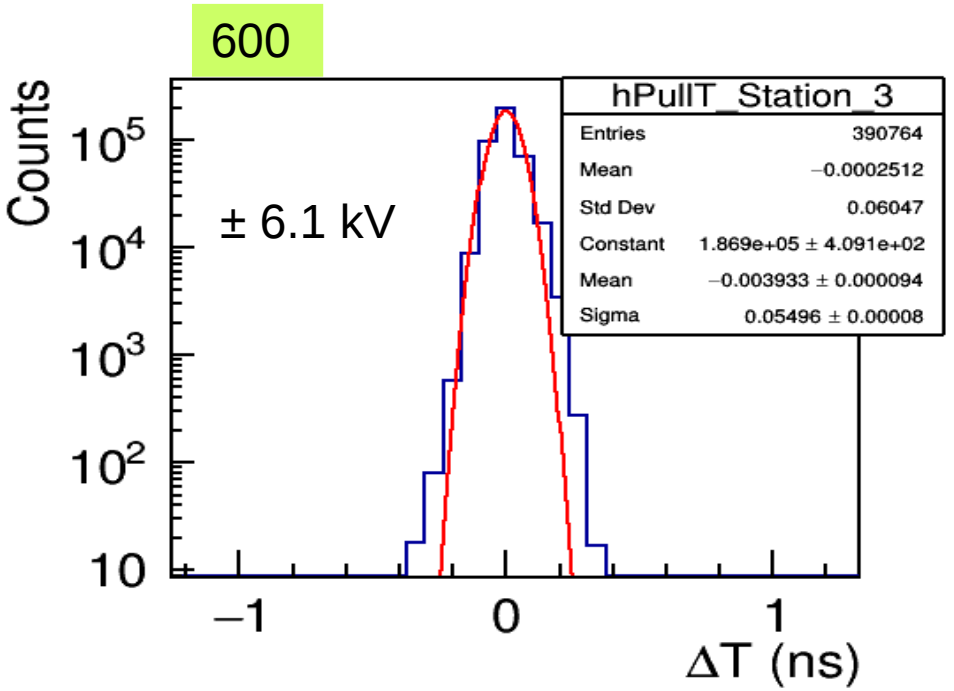




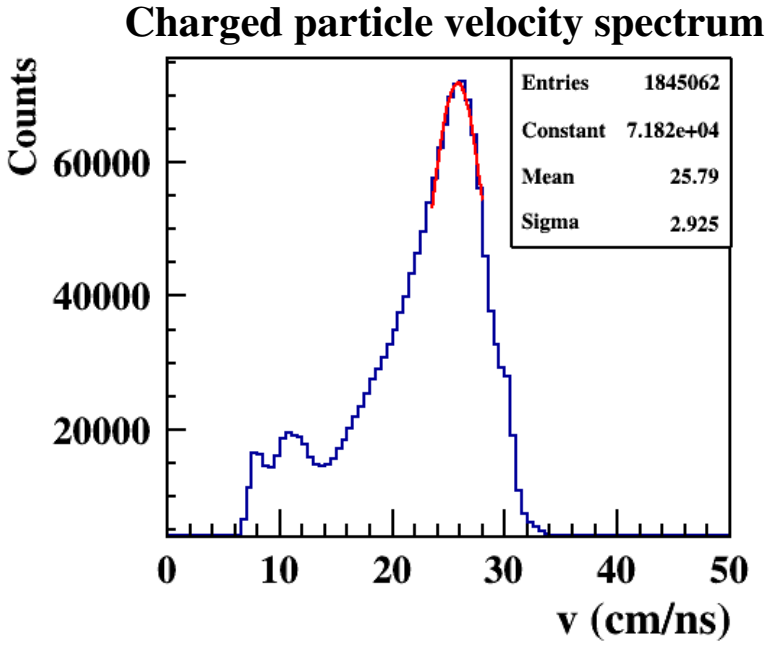


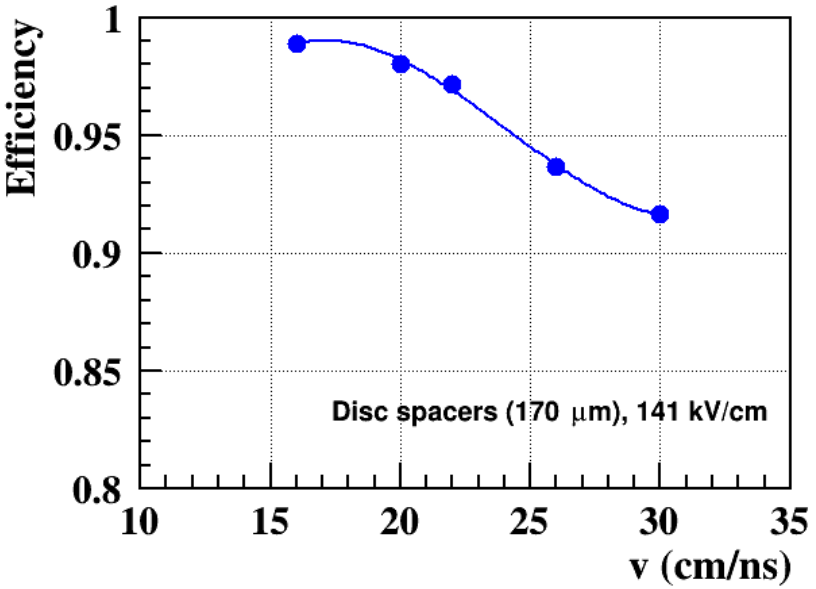
Performance evaluation - time resolution

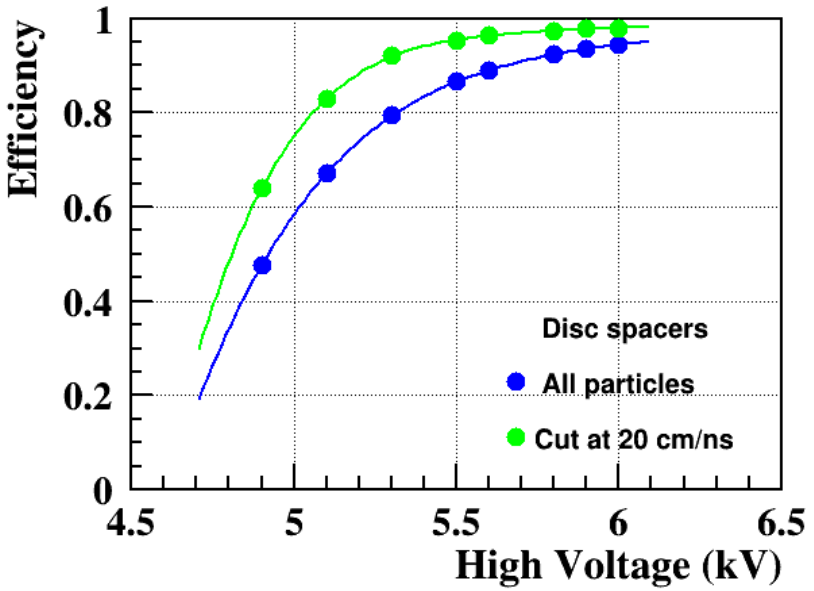




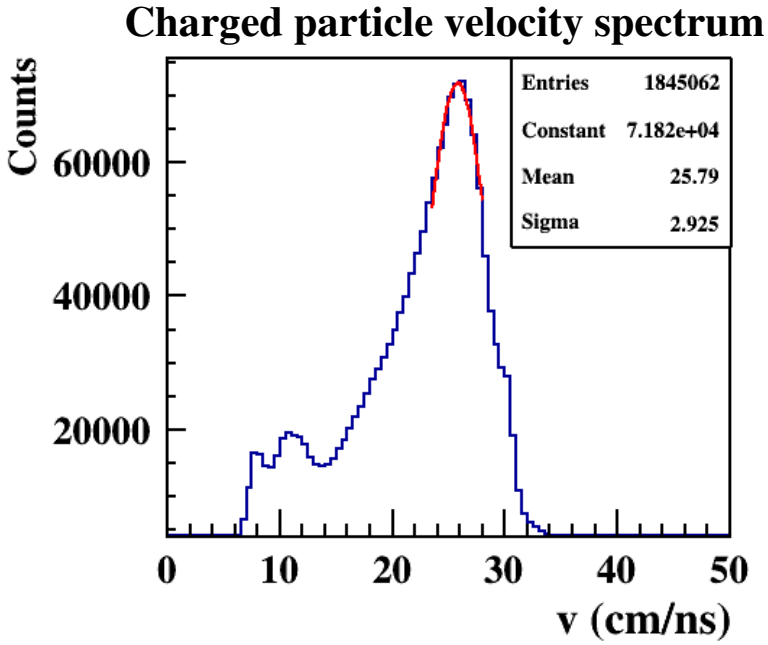
Velocity/Q cuts

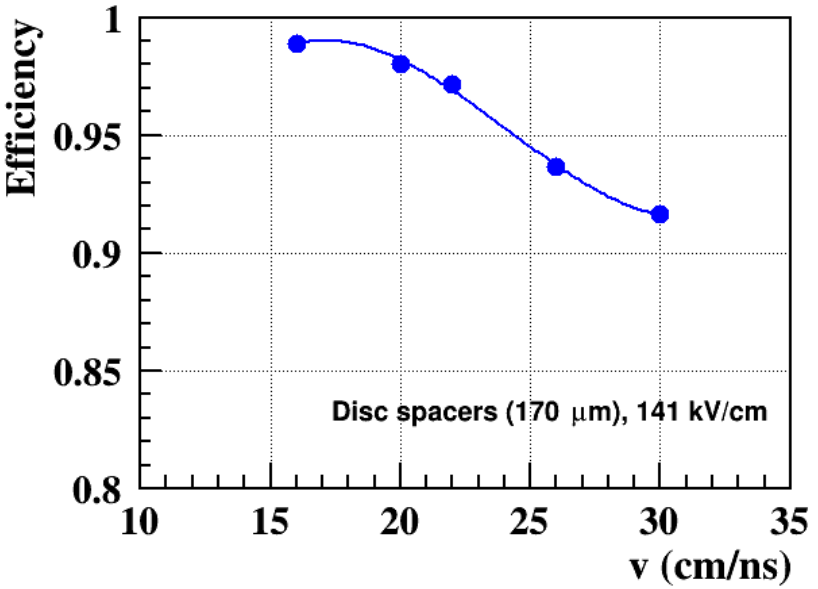


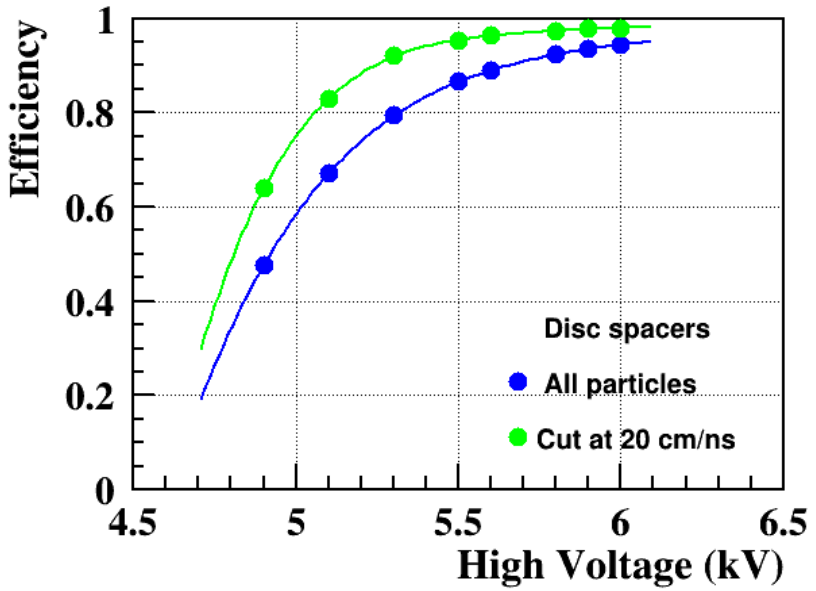




Velocity/Q cuts







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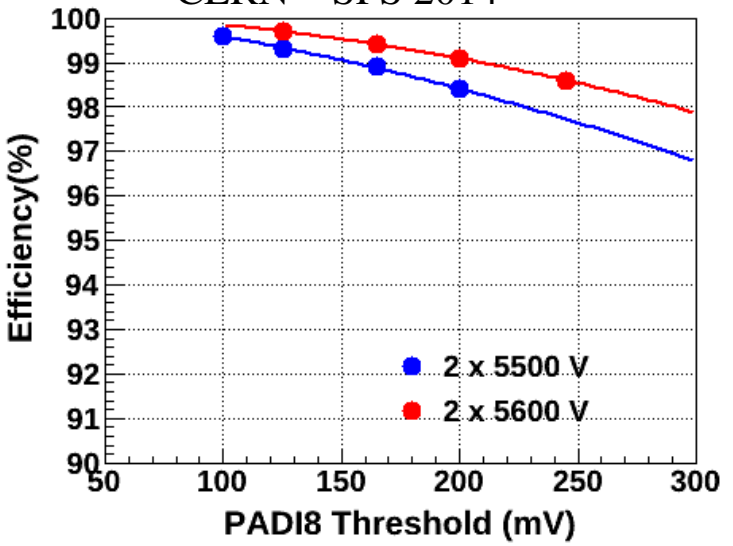

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Assembling of the first module -M0- of the CBM-TOF inner wall

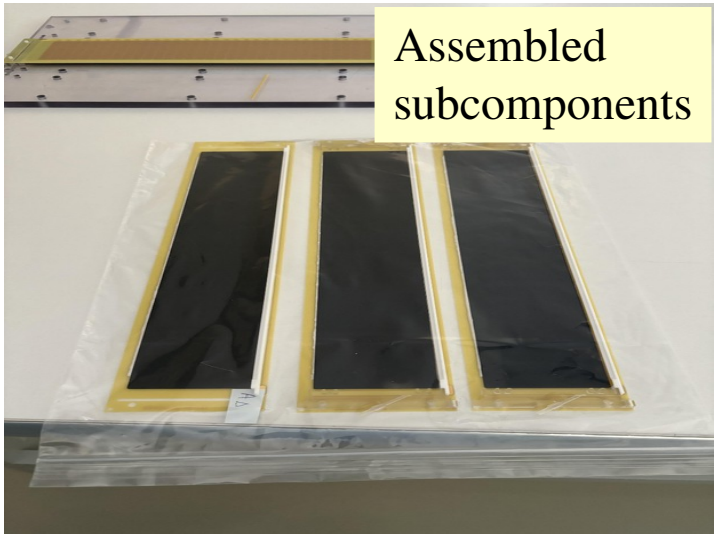
Chamber main components – already manufactured and procured

HV PCBs

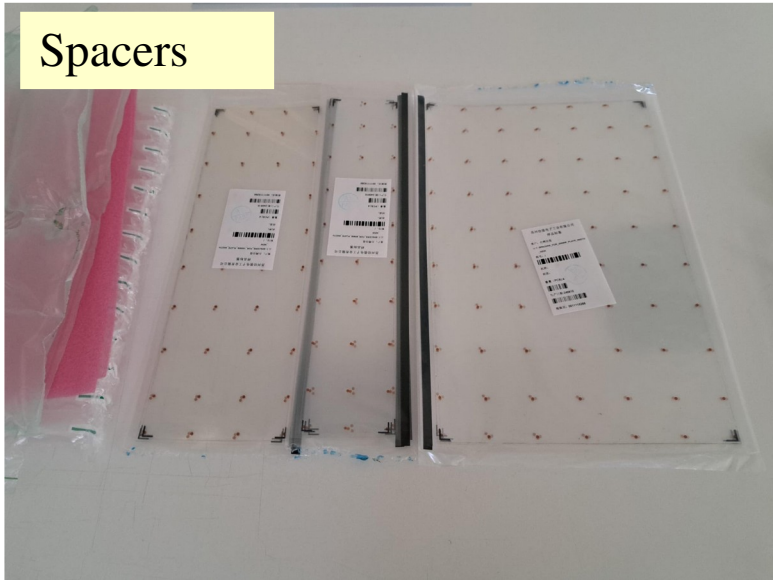
Readout PCBs

Low resistivity glass plates

Assembled subcomponents

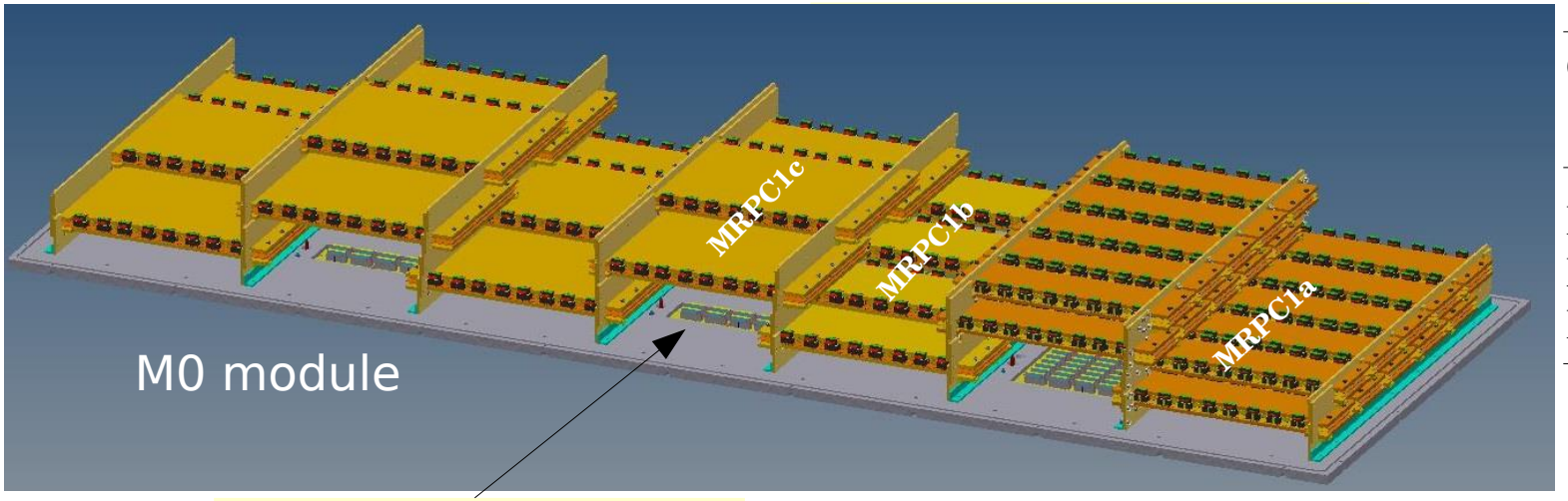


Spacers



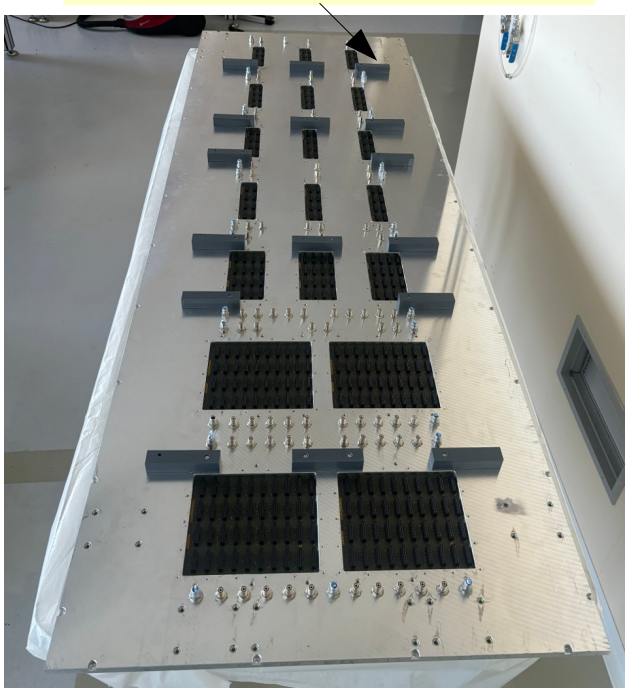
Spacers to be used: 2 mm diameter, 200 µm thickness – samples received from Panel Group, Taiwan

Assembling of the first module -M0- of the CBM-TOF inner wall

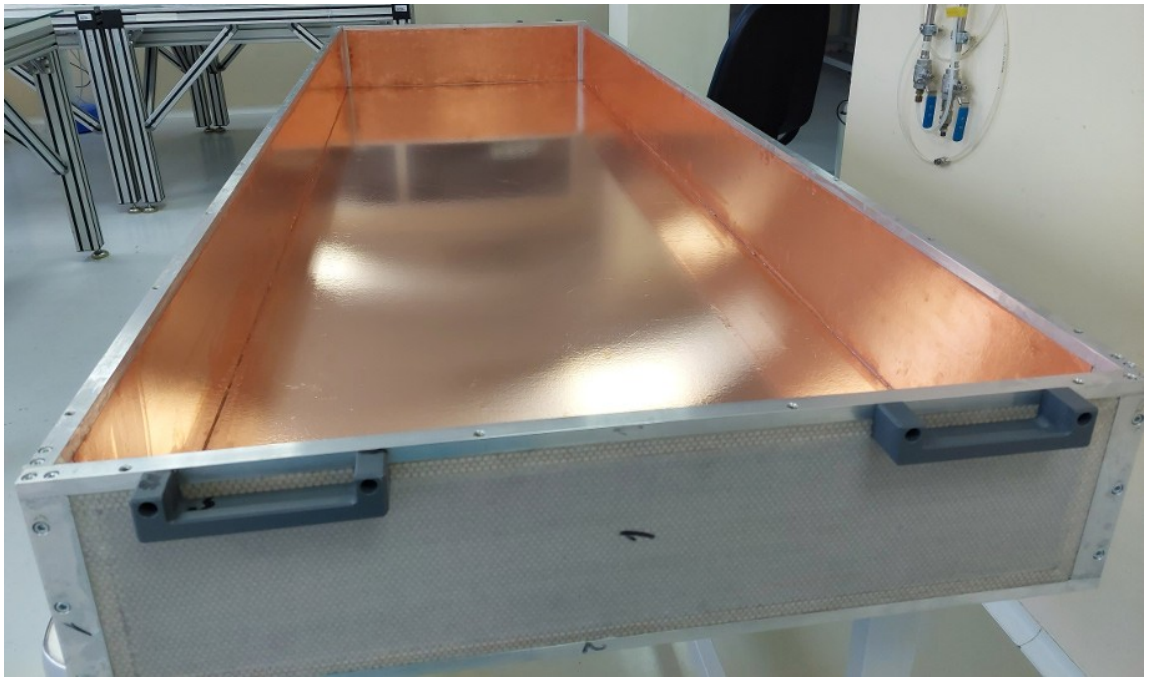


Chamber type	Strip length	No.
MRPC1a	56 mm	20
MRPC1b	96 mm	6
MRPC1c	196 mm	12

Back panel with HV, gas and signal connectors

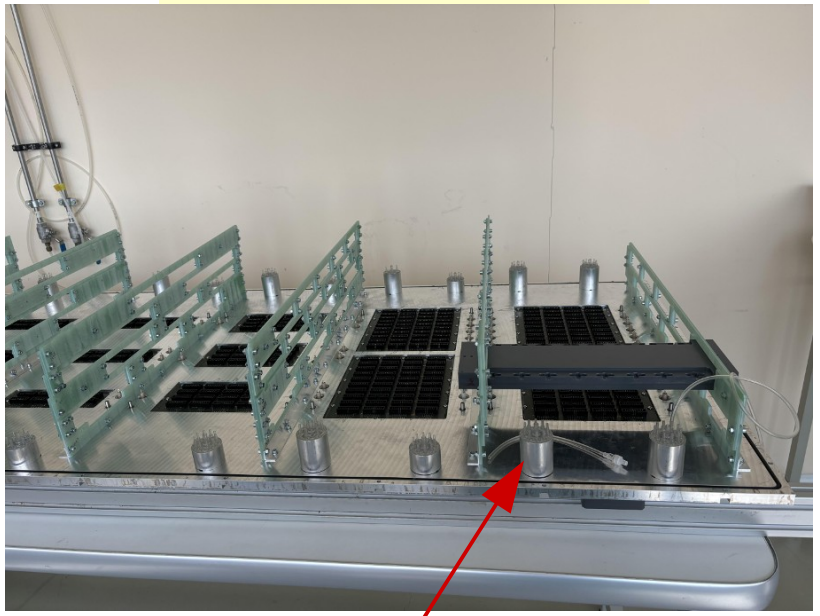


Housing Box

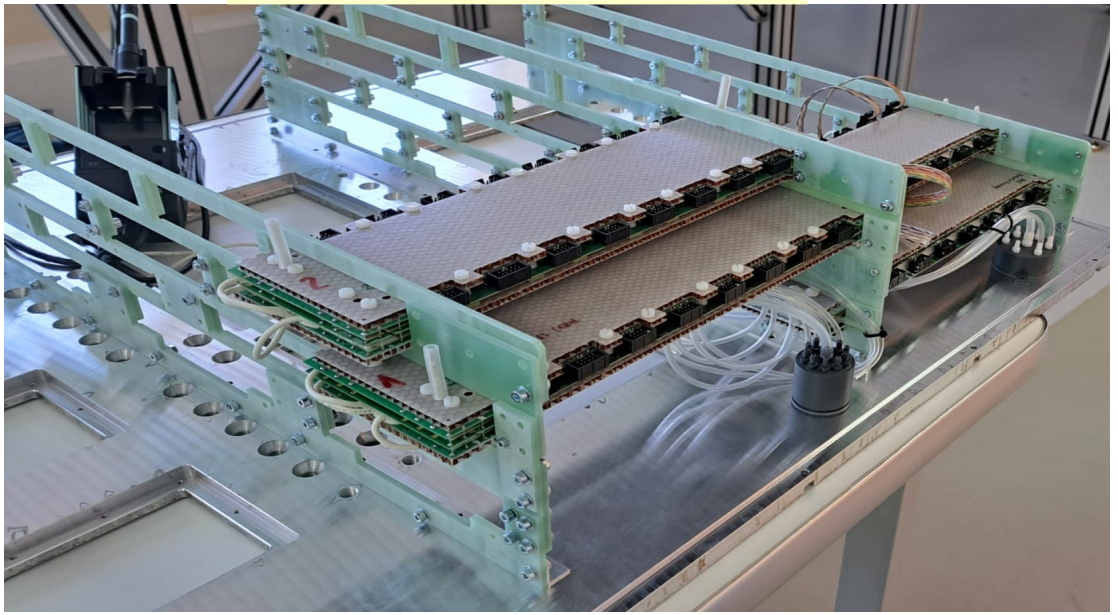


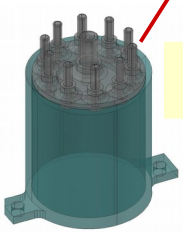
Assembling of the first module -M0- of the CBM-TOF inner wall

Mechanical supports

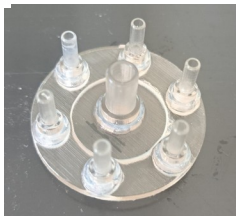


Chamber installing demo

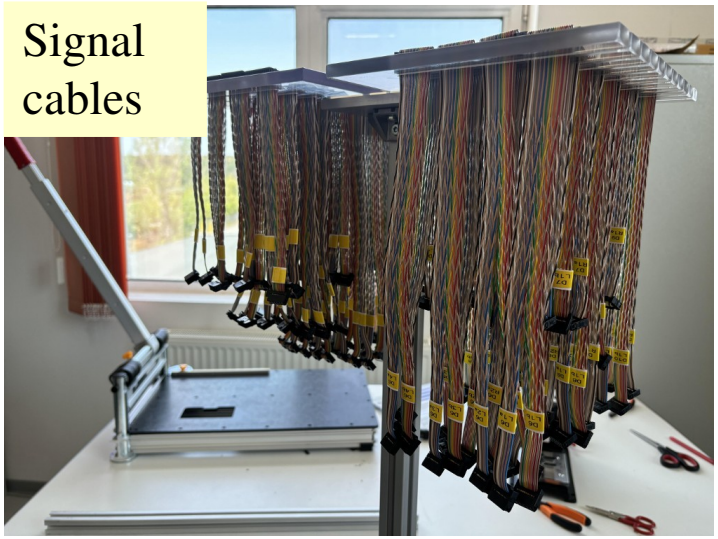




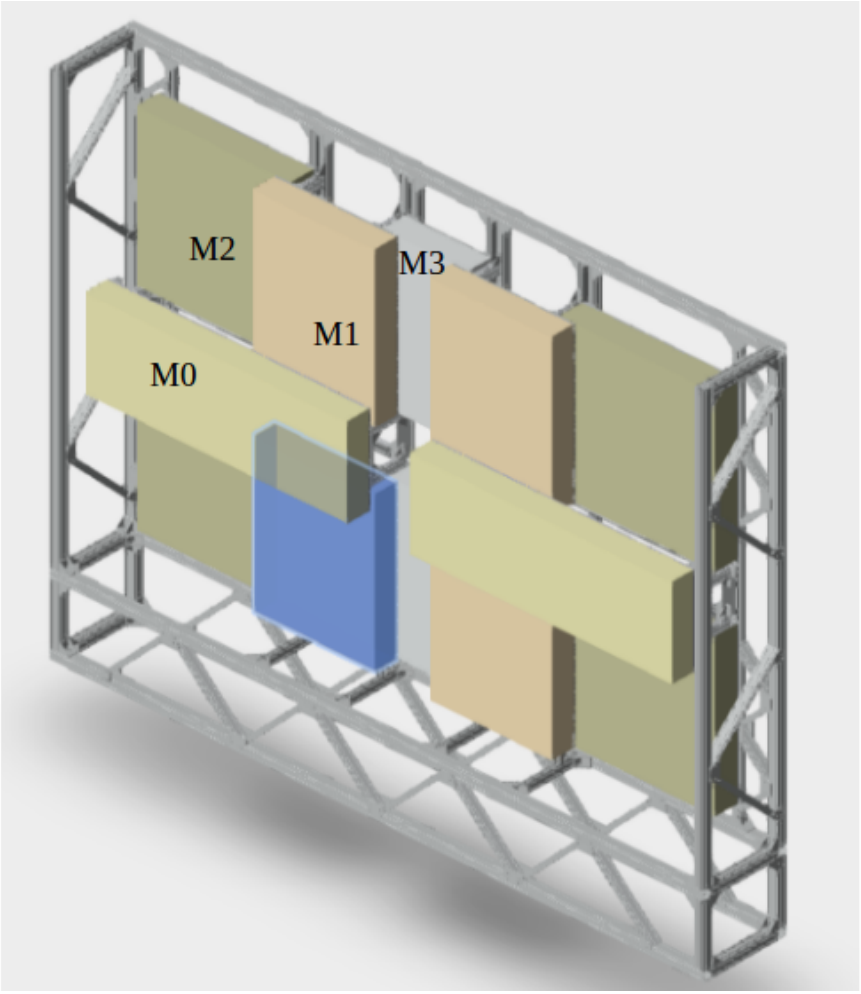
Gas distributors



Signal cables

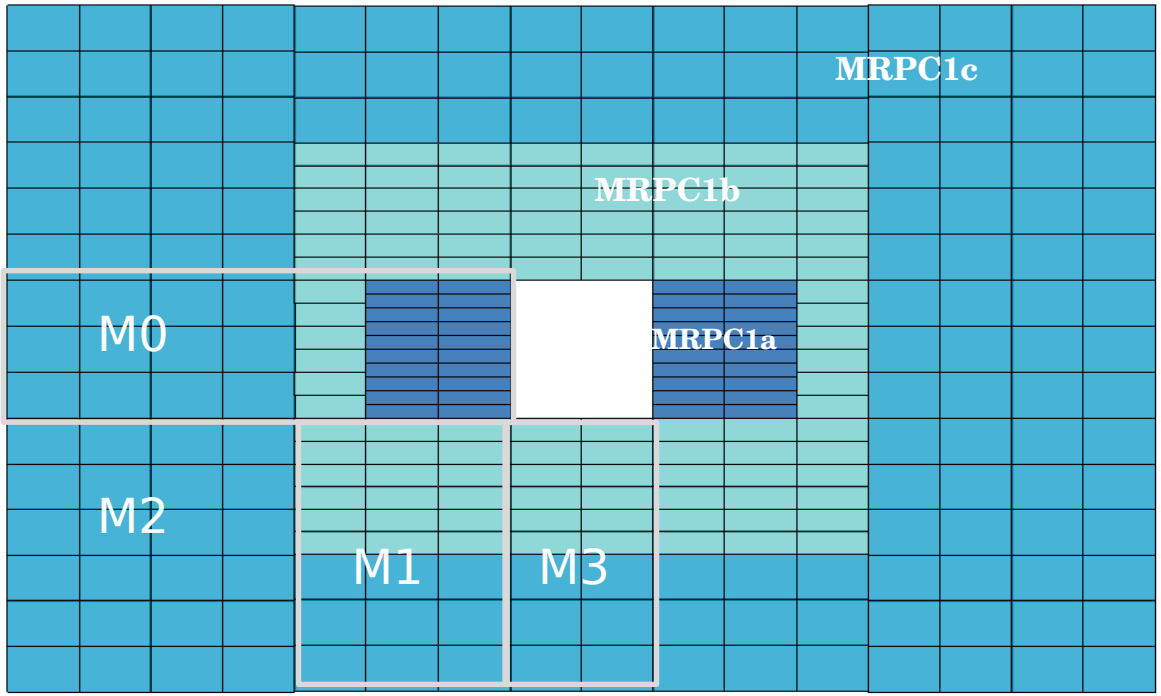


CBM – TOF inner wall



CBM-TOF inner zone

- *~15 m^2 active area, modular architecture:*
  - *12 modules*
  - *4 types (M0, M1, M2, M3)*



	MRPC1c (196 mm)	MRPC1b (96 mm)	MRPC1a (56 mm)	Total
No. MRPCs	168	108	40	316
No. channels	10752	6912	2560	20224

Counters with different granularities are used.

3 chamber types: 56/96/196 mm (strip length) x 300 mm

Summary & Outlook

- The MSMGRPCs for the CBM-TOF inner zone performed in high counting rate tests up to 30 kHz/cm^2 counting rates.

- The mitigation solutions for the aging effects observed in the MSMGRPCs based on gas exchange via diffusion was to modify their architecture in such a way to constrain a direct flow of the gas mixture through the gaps and to reduce the number of the fishing line spacers inside the active area.

-Although a significant reduction in the dark current and dark counting rate was evidenced, noise rate localized around the fishing line spacers, even though reduced, still remains. In the new proposed MSMGRPC architecture, the fishing line spacers were replaced with discrete spacers, reducing the active area in contact with spacers.

- The X-ray aging investigations showed very promising results: dark current and dark counting rate are independent of gas flow and goes to negligible values in hours, even at low gas flow (i.e. 0.5 l/h).

- Cosmic ray tests showed that X-ray irradiated counters maintain their performance in terms of time resolution and efficiency.

- The in-beam tests performed in the mCBM experimental setup confirmed the performance of this architecture in real experimental conditions.

- The assembling of the first module (M0) of the CBM-TOF inner zone based on direct flow MSMGRPCs with discrete spacers is on-going.

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Universität Heidelberg

Esteban Rubio

Norbert Herrmann

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Thank you for your attention!
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