New timing Multi-Strip Multi-Gap Resistive Plate Chamber architecture with aging suppression for high interaction rate experiments

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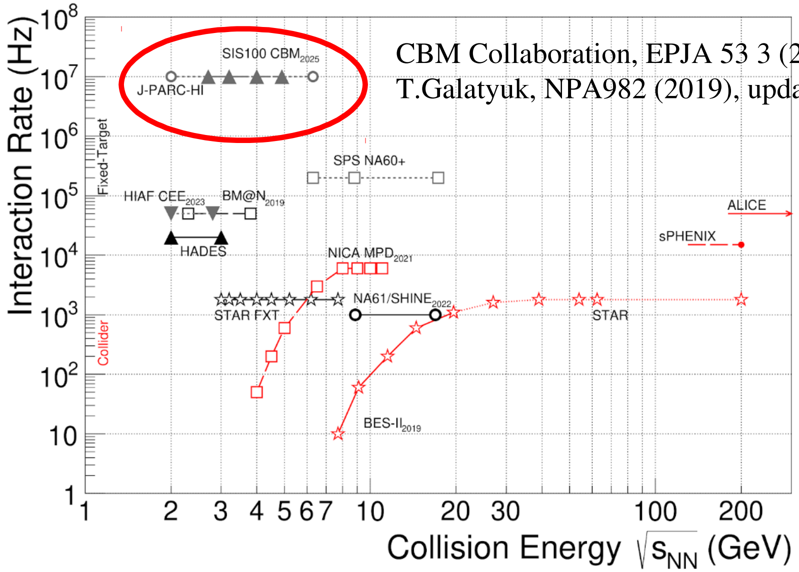
Outline

- Motivation – next generation 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 test of aged chambers
- In-beam tests of direct flow MSMGRPCs
- First CBM-TOF inner wall module
- Summary and Outlook

High interaction rate experiments

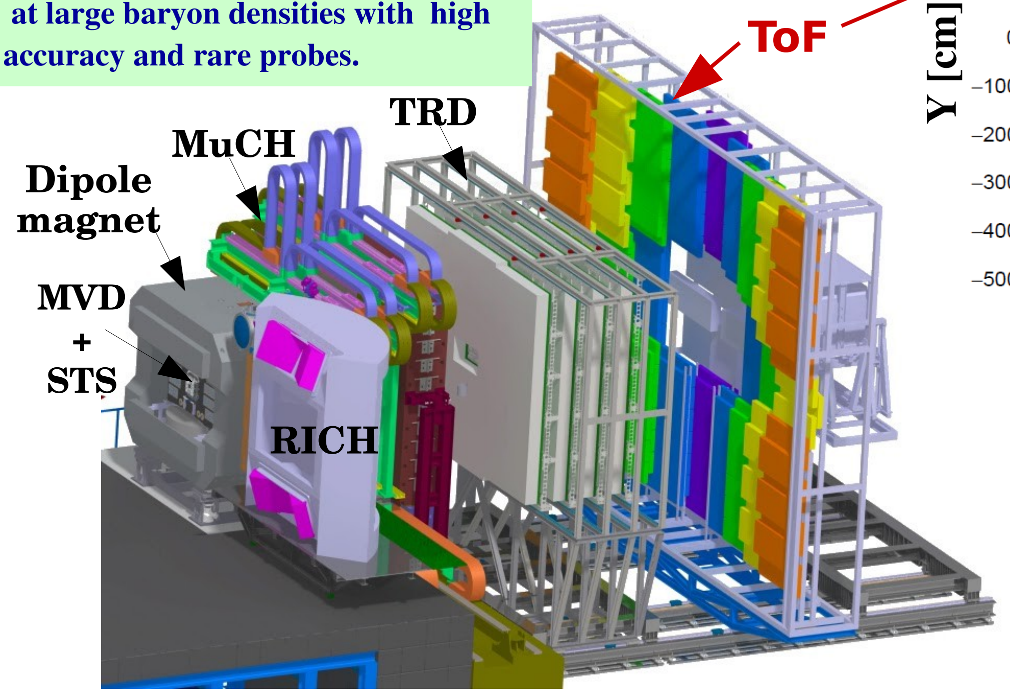


CBM Collaboration, EPJA 53 3 (2017) 60
T.Galatyuk, NPA982 (2019), update (2021)

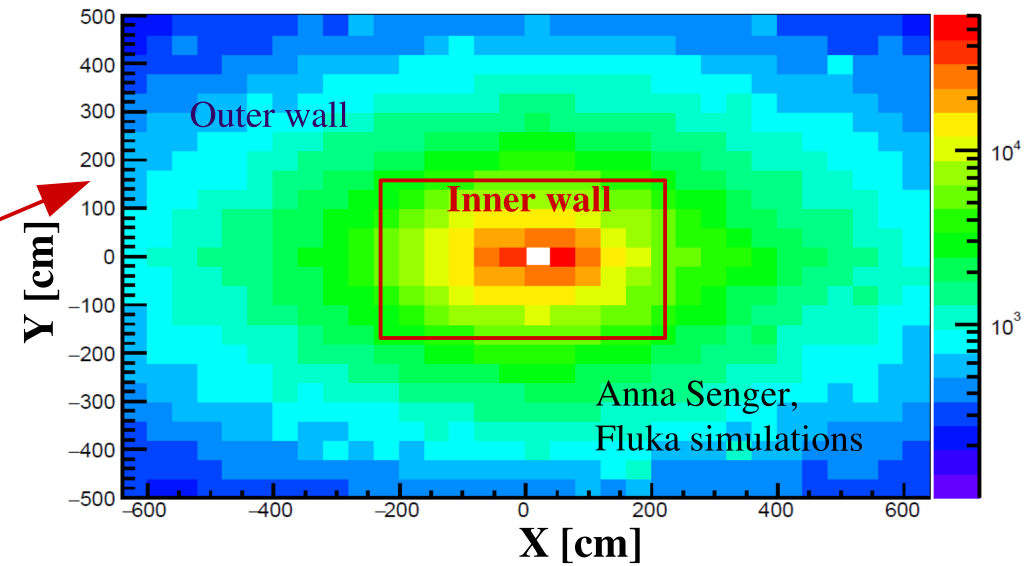
R&D for a new generation of :

- detectors
- front-end electronics
- acquisition systems
- data processing.

CBM experiment at FAIR/SIS100:
Systematically explore QCD matter at large baryon densities with high accuracy and rare probes.



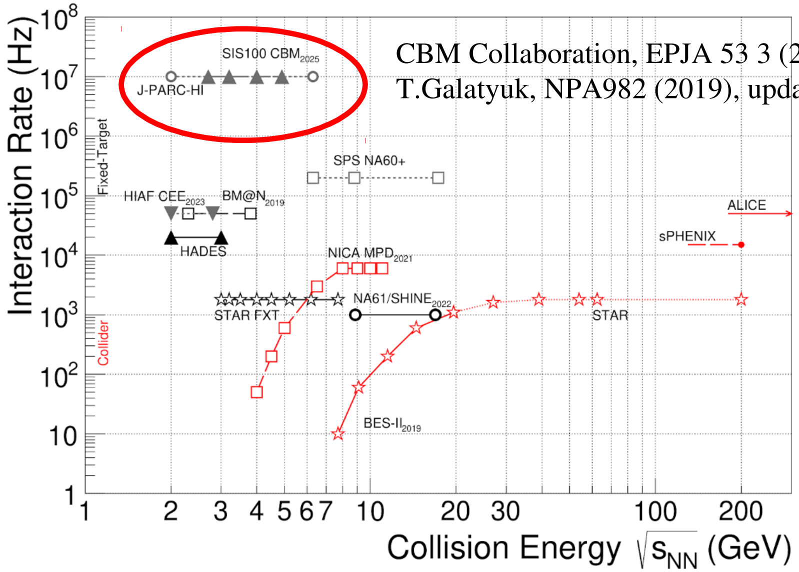
Charged particle flux on TOF wall @ 8 m from the target, Au + Au collisions at E_{kin} = 11A GeV, 10^7 interactions/s



Time of Flight (TOF) subsystem:

- **charged particle identification**
- **based on MRPCs with Multi-Strip readout**
- **system time resolution <80 ps; Efficiency > 95%**
- **up to 50 kHz/cm²**
- **occupancy < 5%**

High interaction rate experiments



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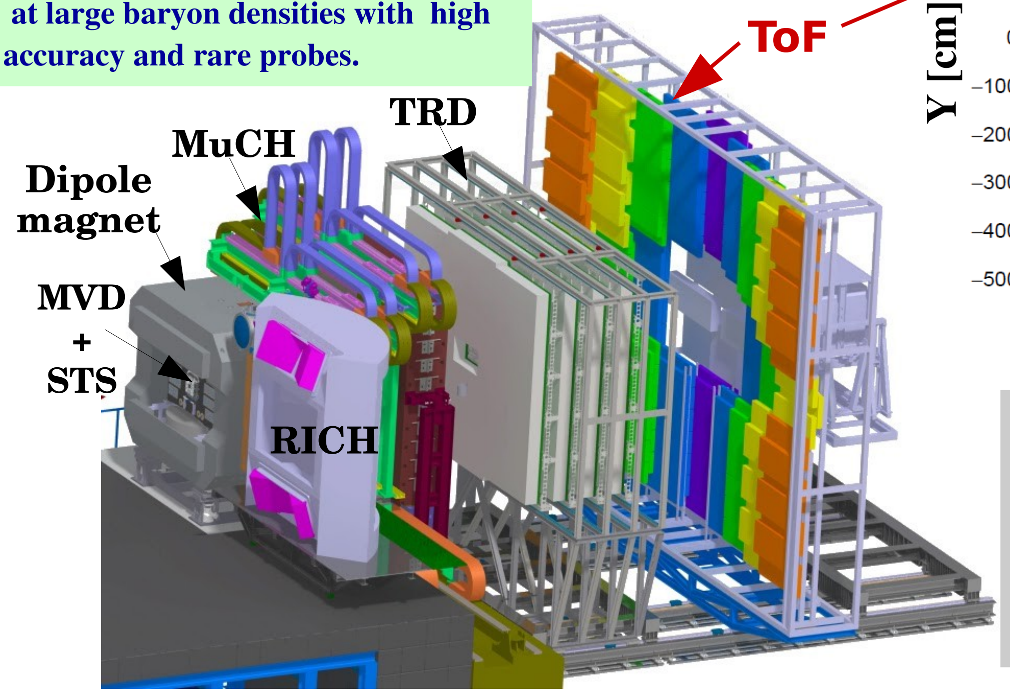

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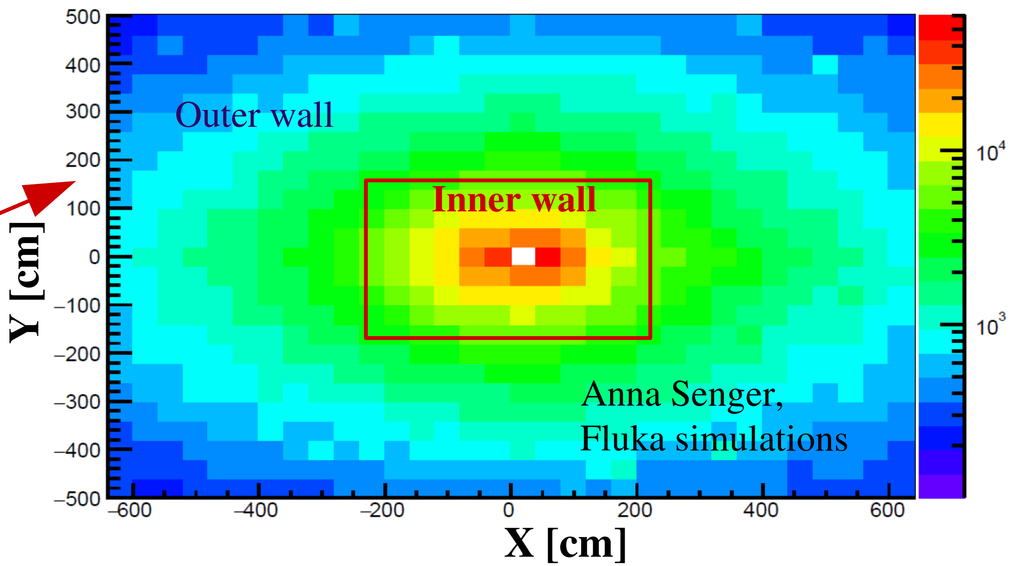
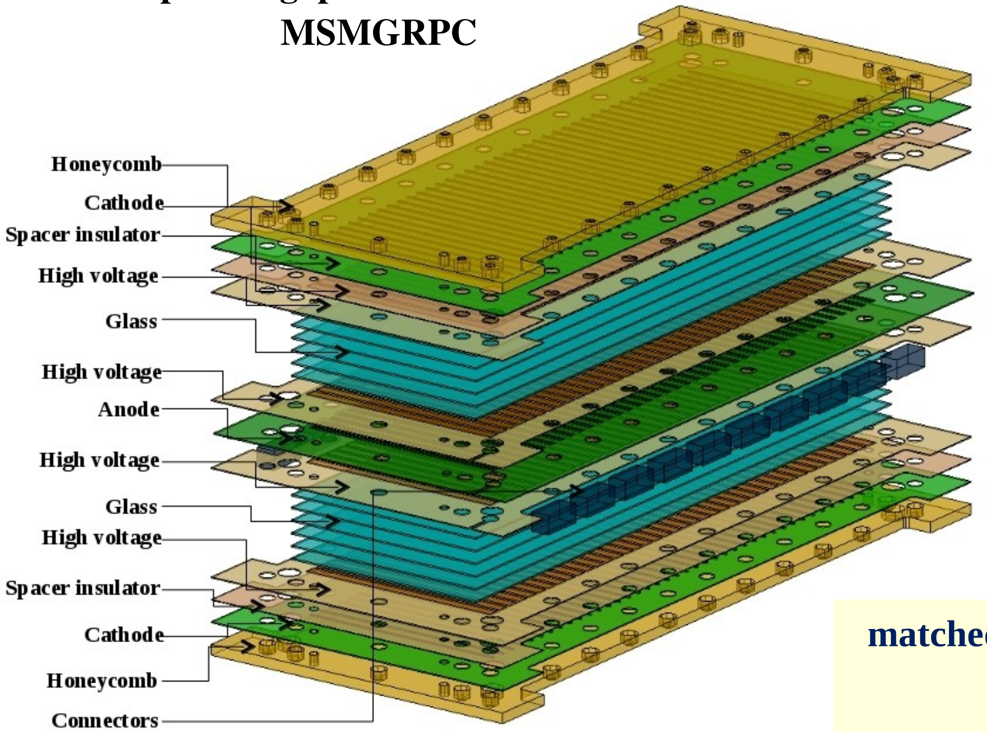


Our R&D activity → MSMGRPCs for the inner wall :

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

Chamber design considerations

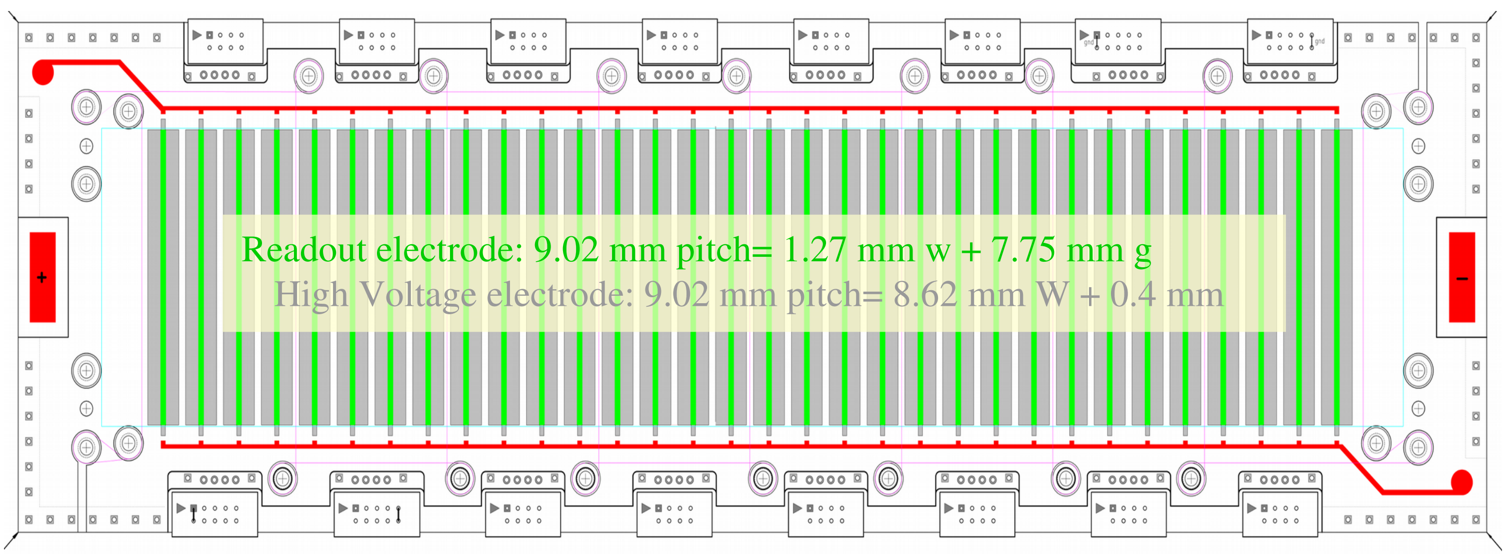
Multistrip Multigap Resistive Plate Chamber
MSMGRPC

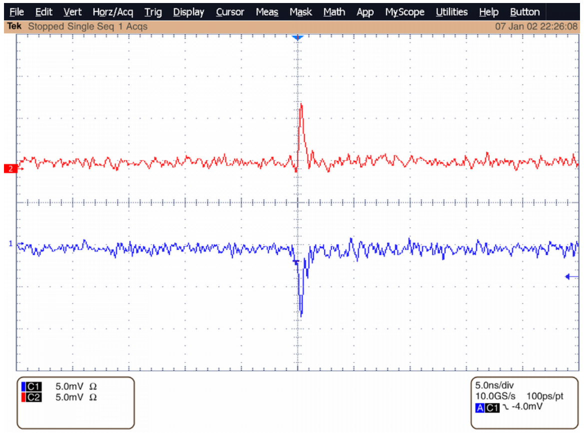


- ✓ Symmetric structure: 5 gaps x 2 stacks
- ✓ Gas gap thickness: 200 µm
- ✓ Active area: strip length x 9 mm pitch x 32 strips
- ✓ Strip length:56/96/196 mm (MRPC1a/MRPC1b/MRPC1c)
- ✓ Resistive electrodes: ~10^{10} Ωcm, 0.7 mm (Chinese glass)
- ✓ Strip structure for Readout & HV electrodes
- ✓ Differential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

matched signal transmission line impedance to the input of the FEE

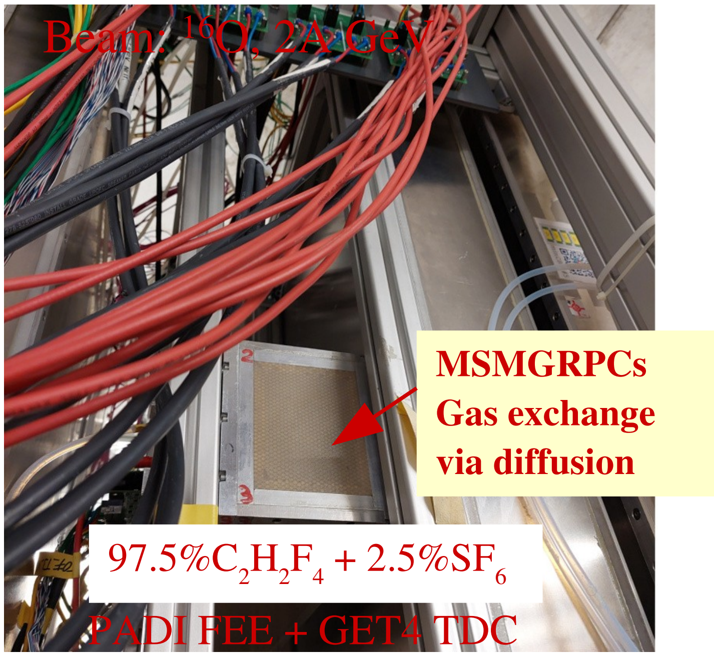
D. Bartos et al., Romanian Journal of Physics 63, 901 (2018)

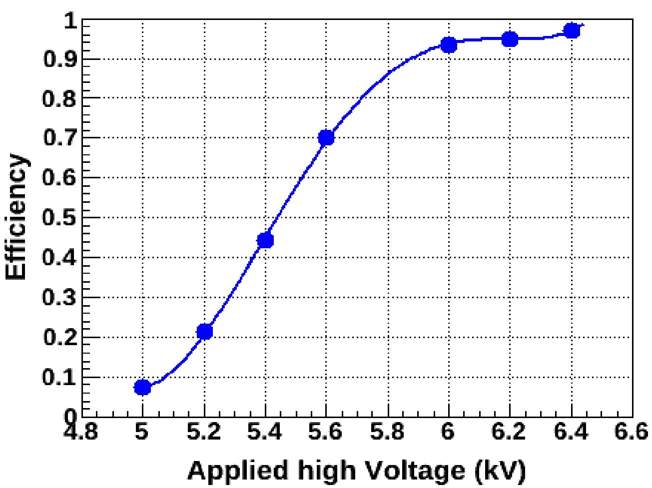


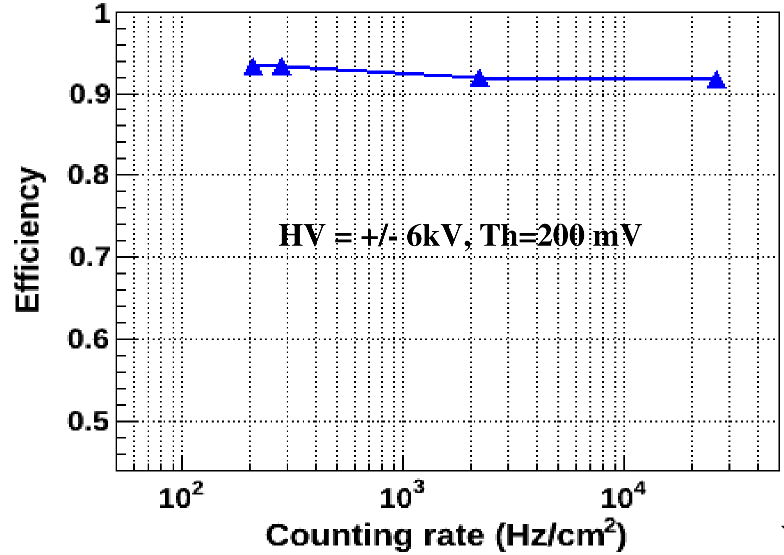


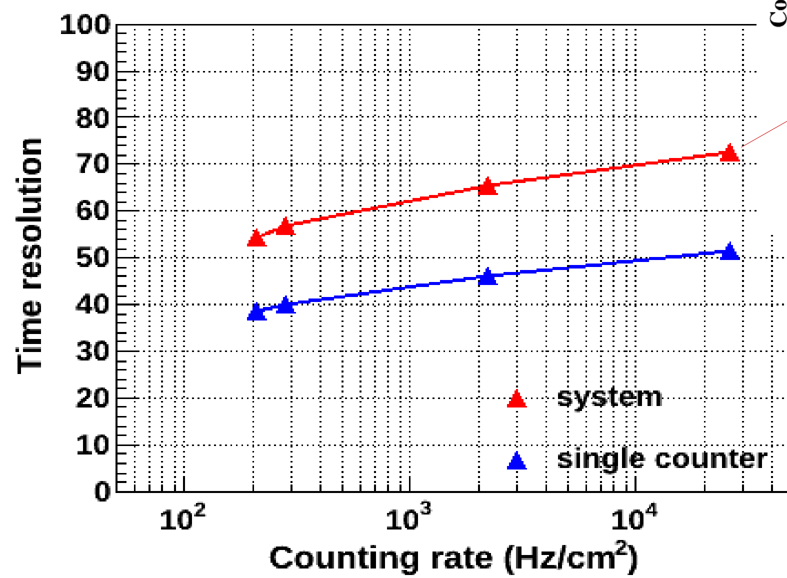
High counting rate test of a MSMGRPC prototype

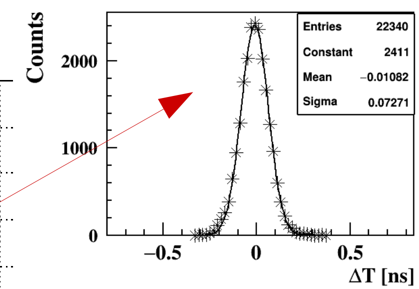
mCBM/SIS18/GSI Darmstadt







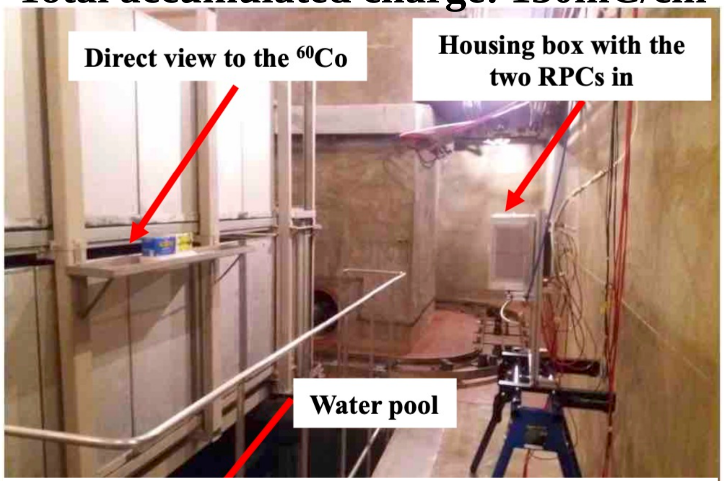




M. Petris et al., Nucl. Inst. and Methods A 1045 (2023) 167621

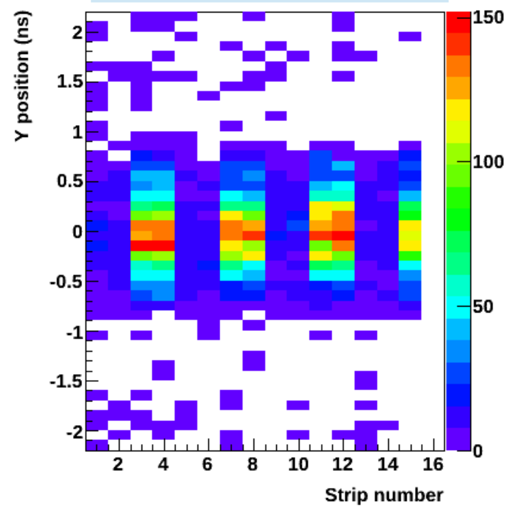
Aging investigations of MSMGRPC with gas exchange via diffusion

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

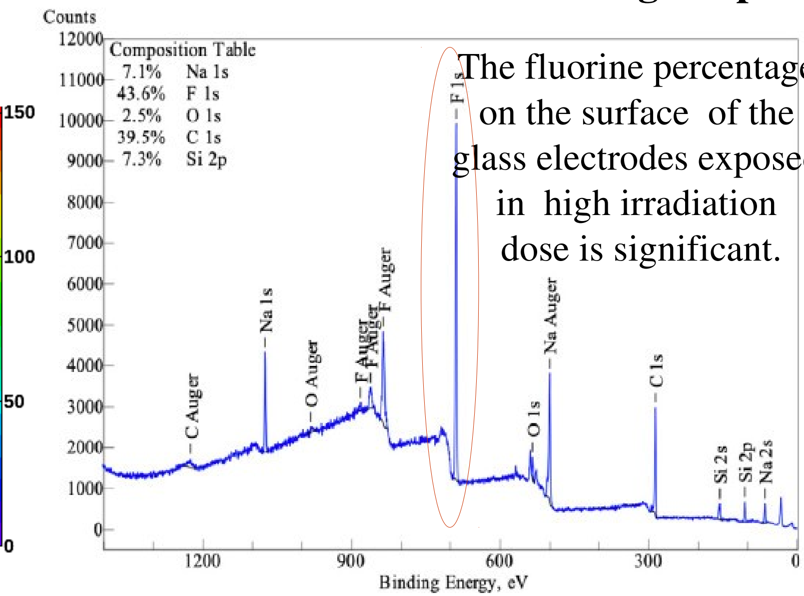


Gas mixture: 90% $C_2H_2F_4$ + +5%i-C_4H_{10}+5% SF_6

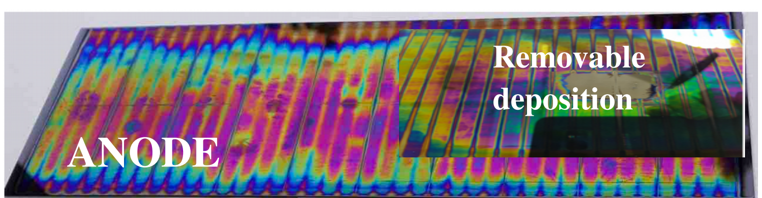
Dark rate generated around the spacers

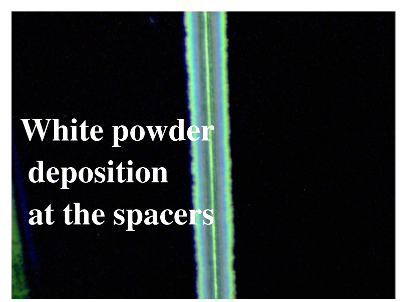


(XPS) analysis of the chemical composition of irradiated and non-irradiated glass plates

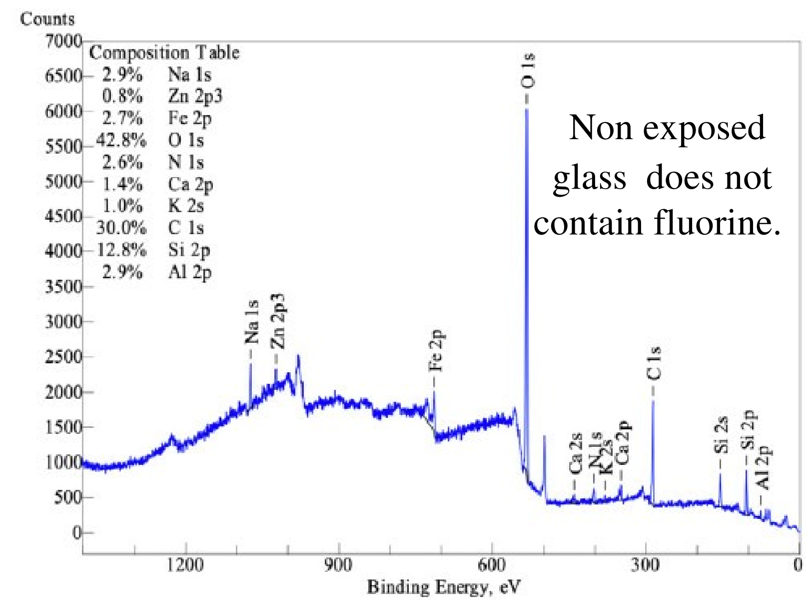


Glass inspections performed with various methods: (SEM, XPS, AFM RBS, non-RBS, THz-TDS)



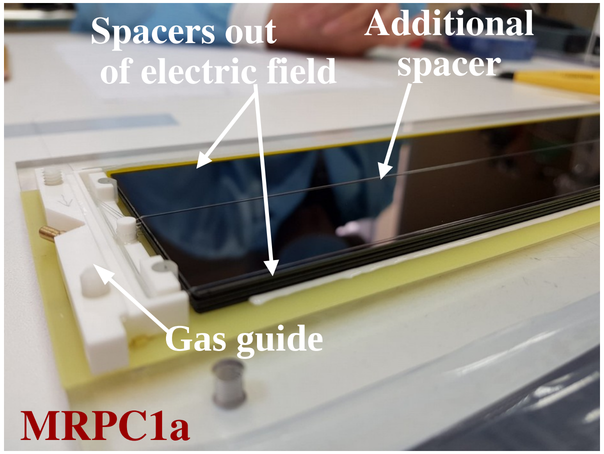


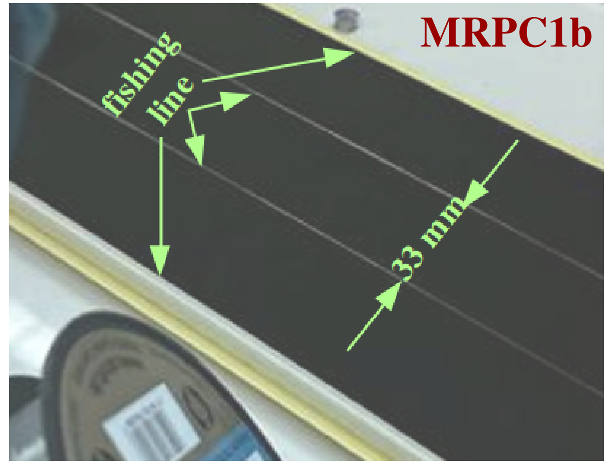
Glass resistivity remains unchanged



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

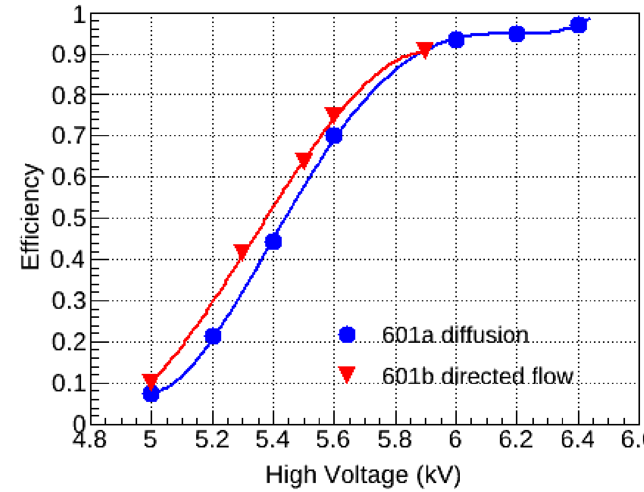
MSMGRPC prototypes with direct flow and nylon line spacers

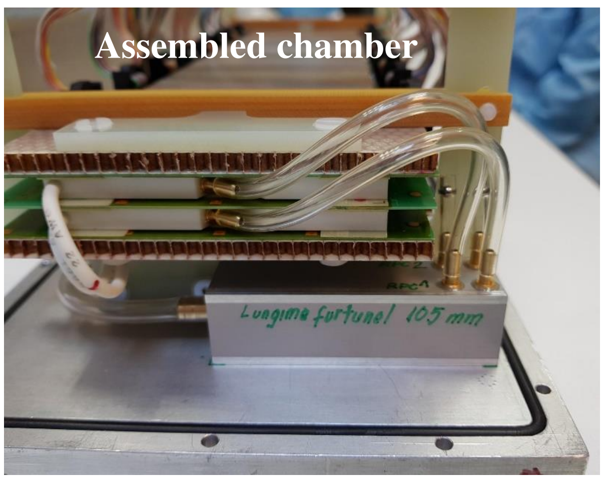


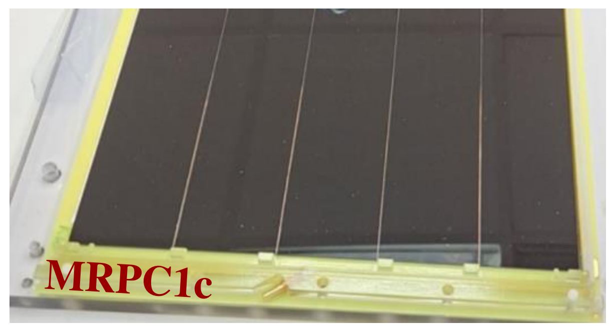


Gas mixture: 97.5% $C_2H_2F_4$ + 2.5% SF_6

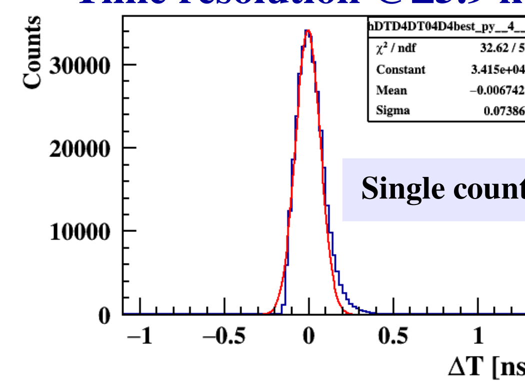
High voltage scan in mCBM setup



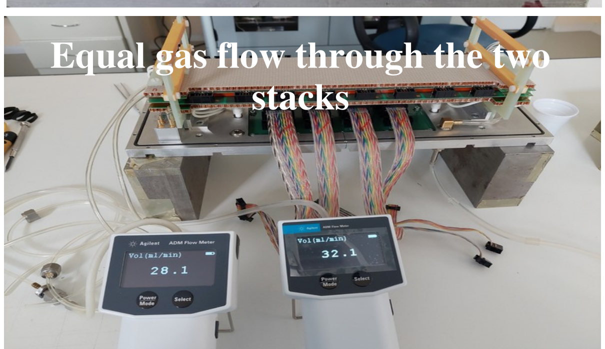




Time resolution @±5.9 kV



Single counter = 51 ps



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

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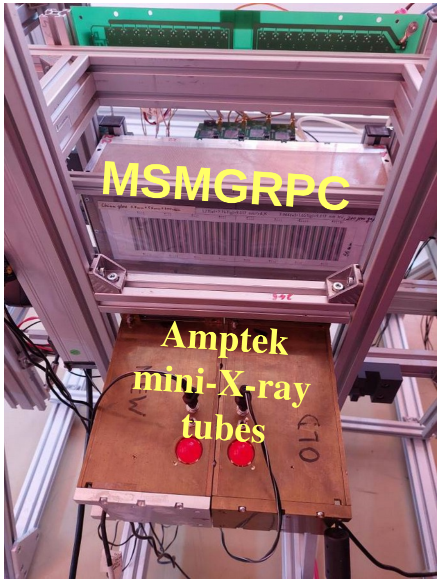
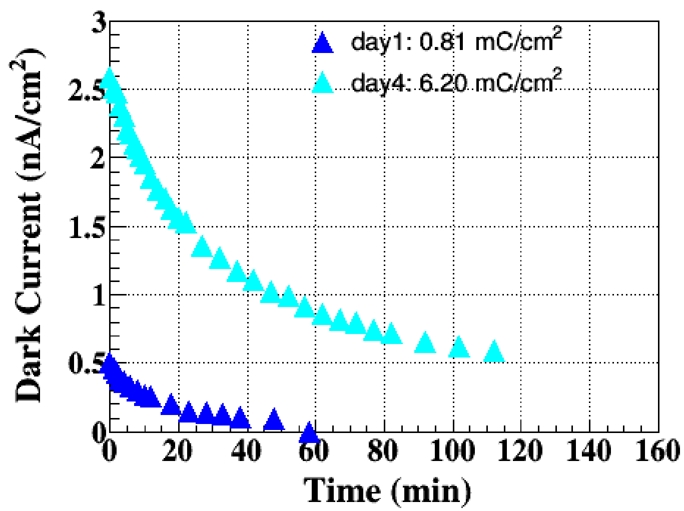
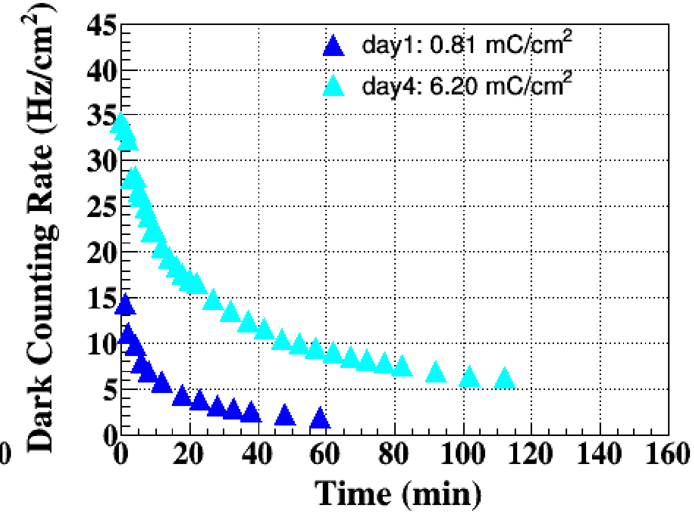
High intensity X-ray irradiation of direct flow prototypes based on nylon line spacers



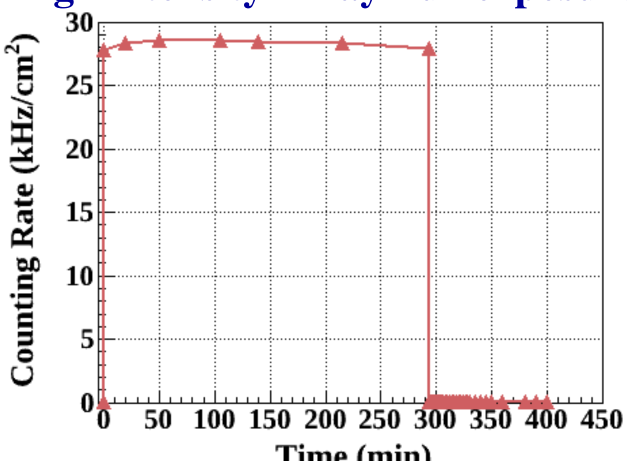
Gas mixture: 97.5% $C_2H_2F_4$ + 2.5% SF_6

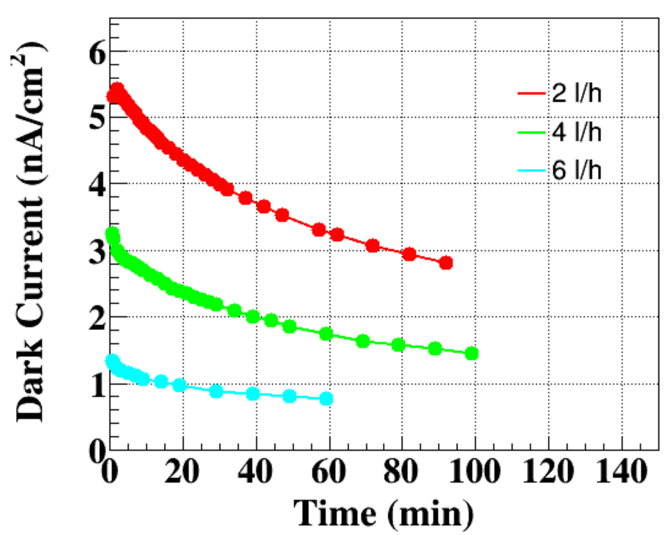
Dark current & dark counting rate after X-ray exposure

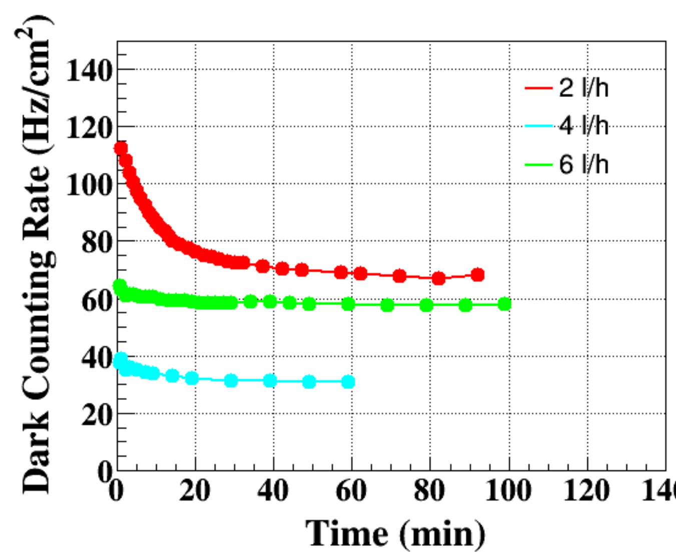




High intensity X-ray flux exposure



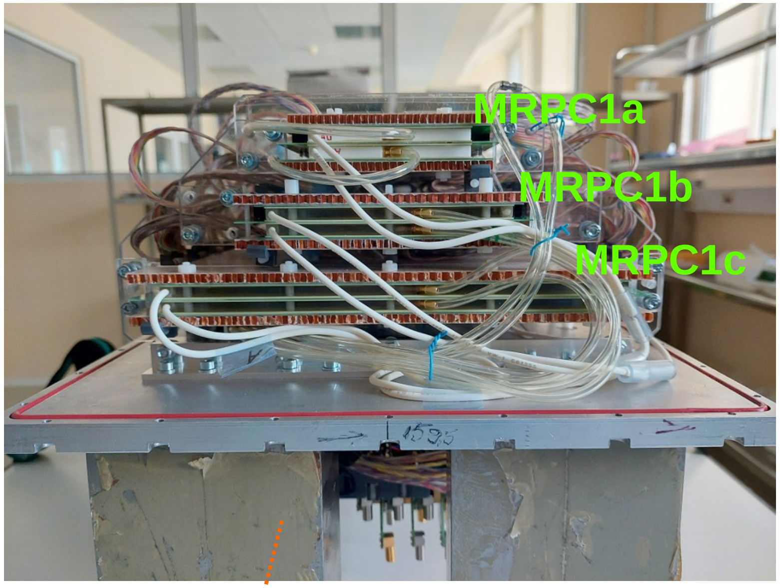


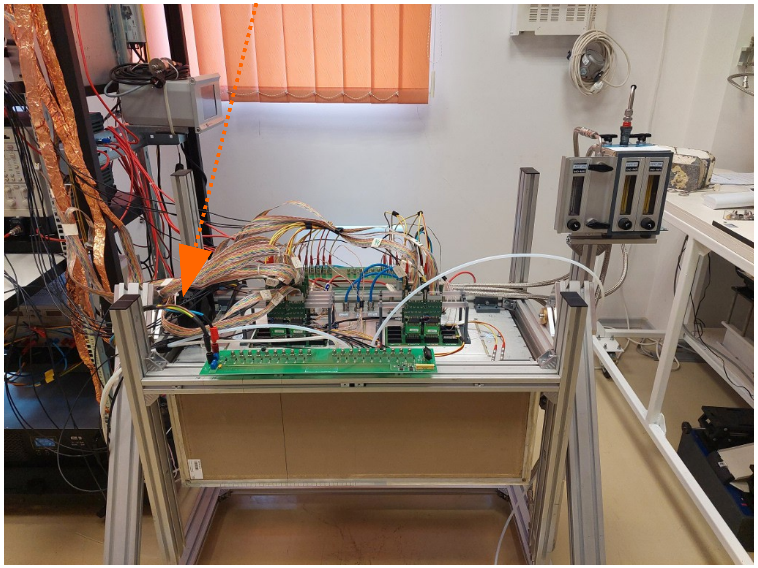


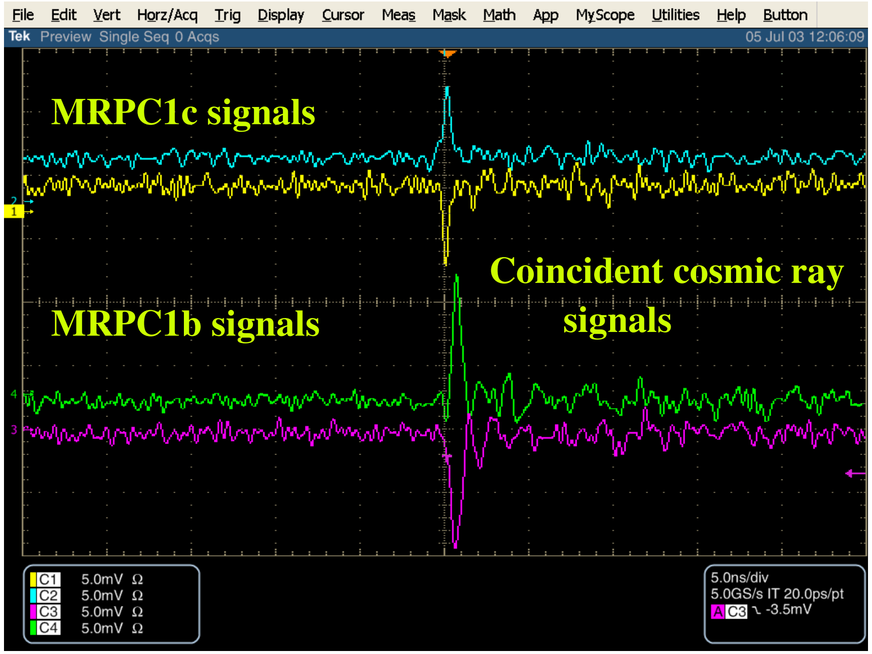
V. Aprodu et al., Nucl. Inst. and Methods A 1049 (2023) 168098

Cosmic - ray tests of the direct flow prototypes based on nylon line spacers

Experimental setup for cosmic rays test







MRPC1c (196)

MRPC1b (96)

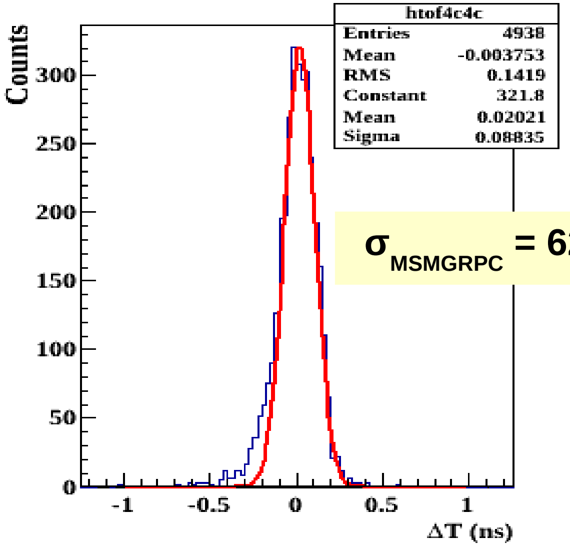
trigger

DUT

REF

MRPC1a (56)

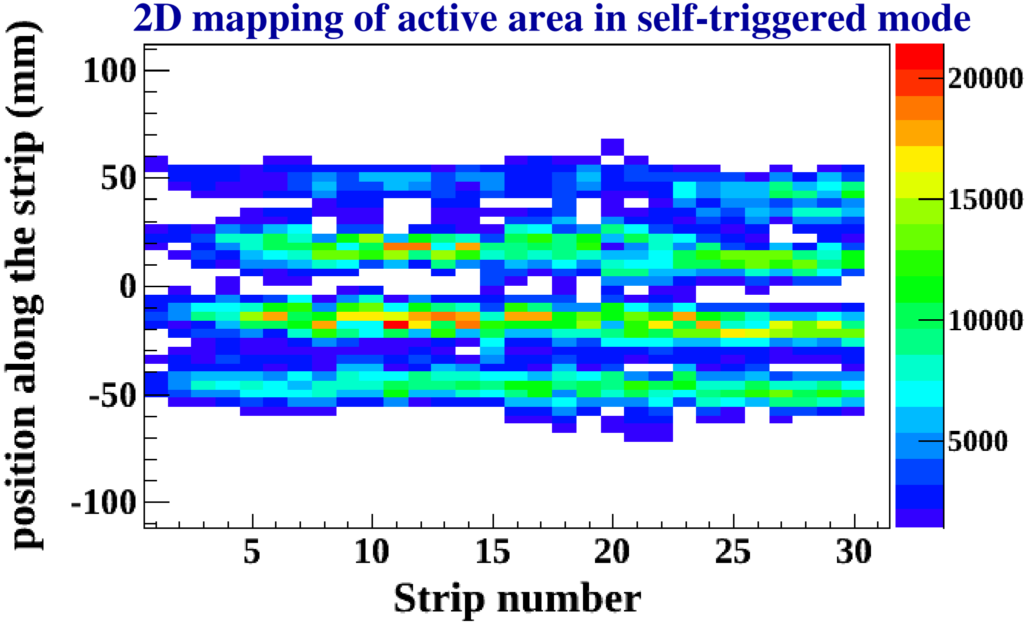
Efficiency = 95 %

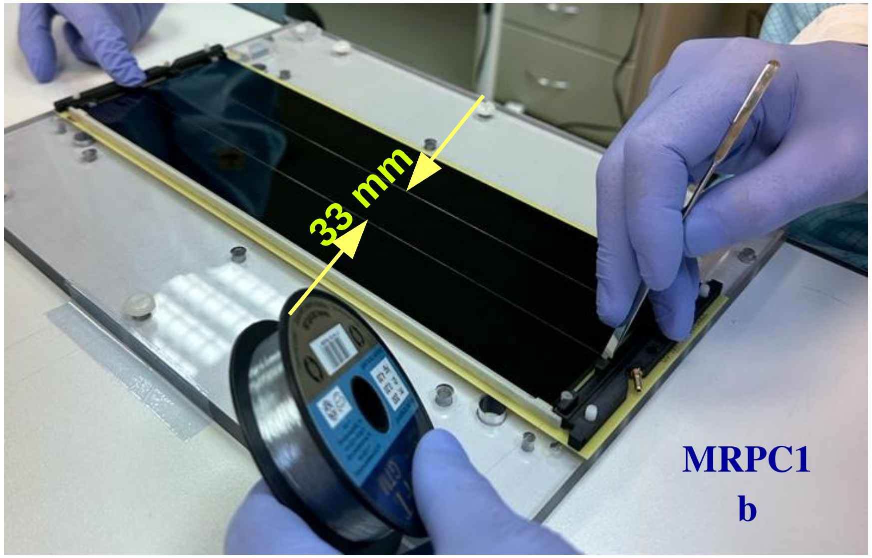


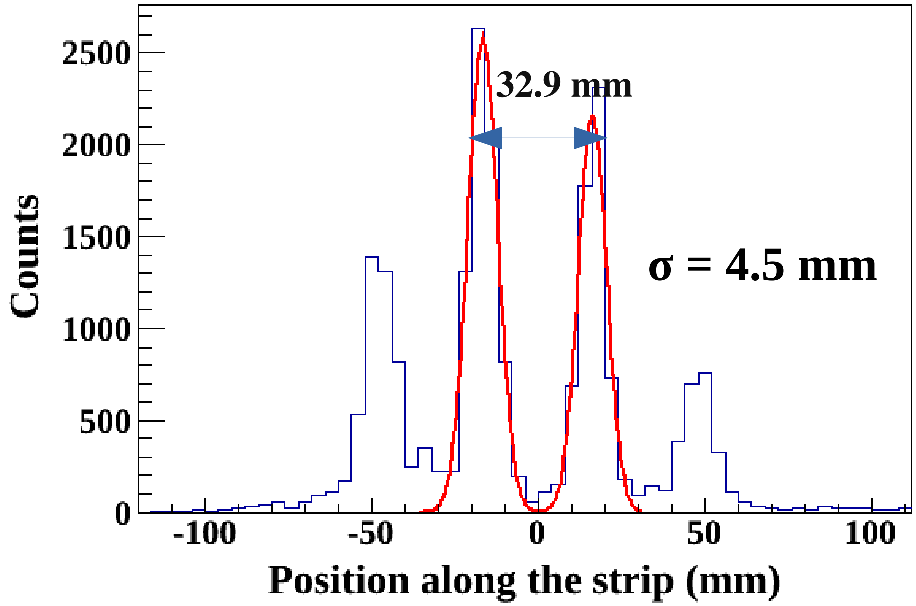
$\sigma_{MSMGRPC}$ = 62 ps

Cosmic - ray tests of the direct flow prototypes based on nylon line spacers

2D mapping of active area in self-triggered mode



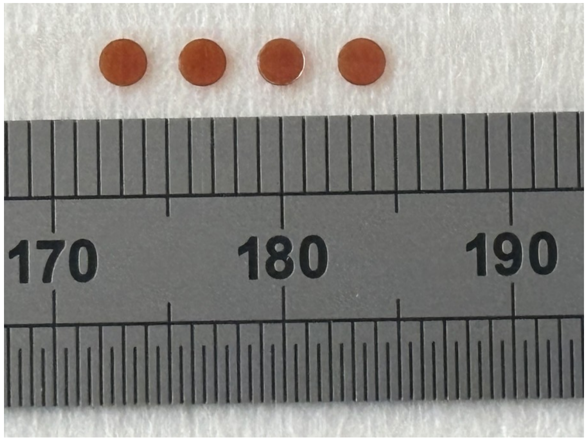


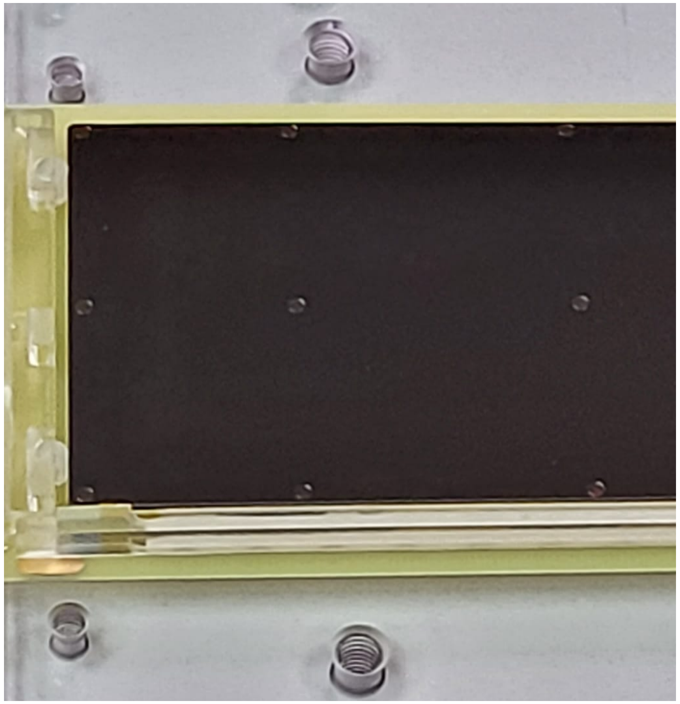


Direct flow MSMGRPC prototype based on polyimide spacers

Home made rectangular spacers:
2 mm x 2 mm, 200 µm

Commercial disc spacers:
2 mm diameter, 170 µm thickness





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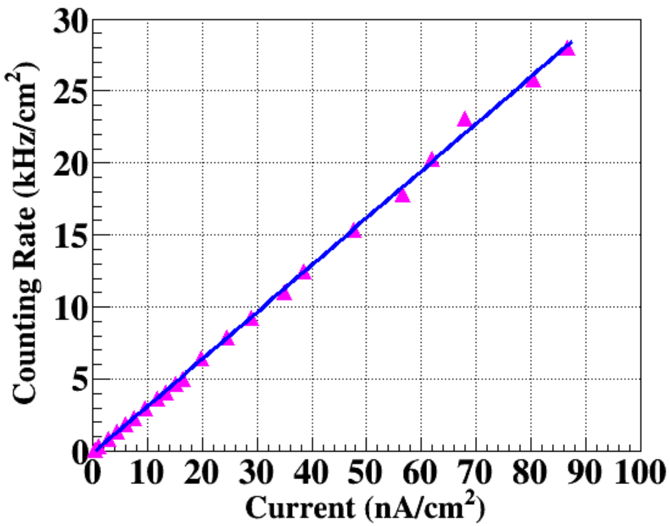
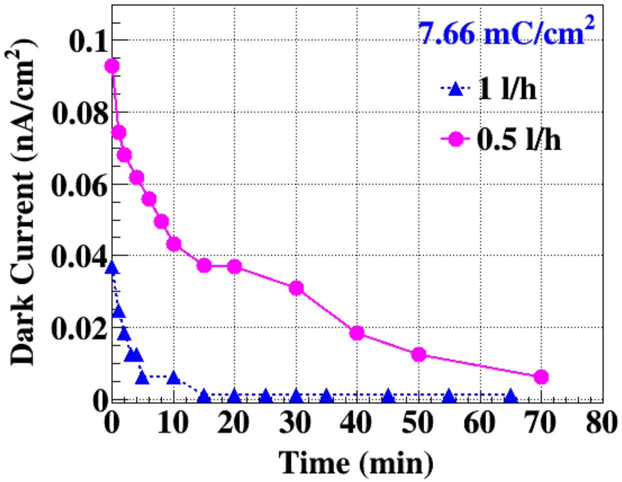
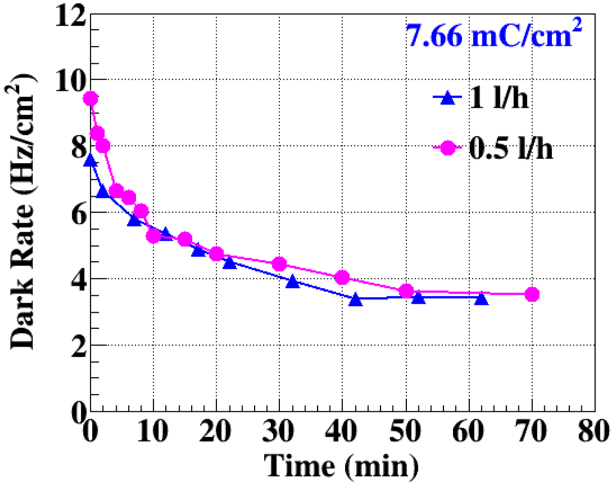
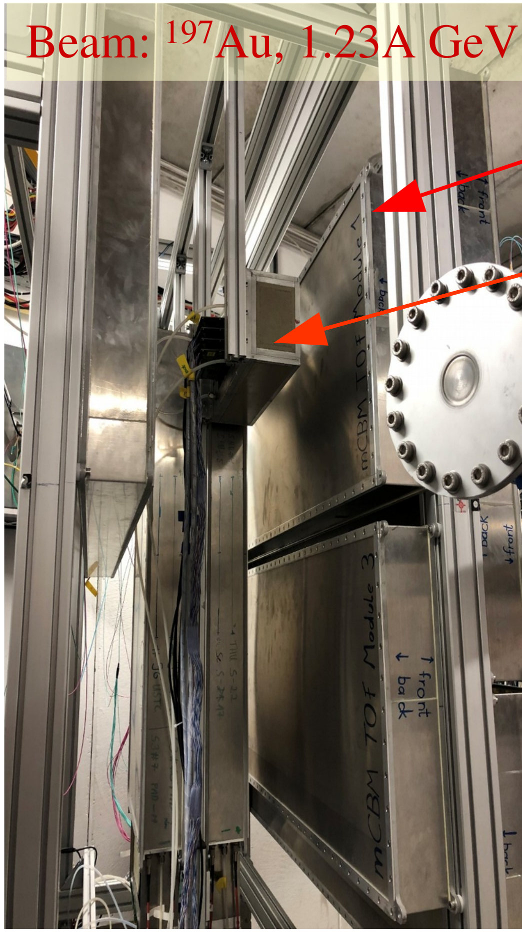






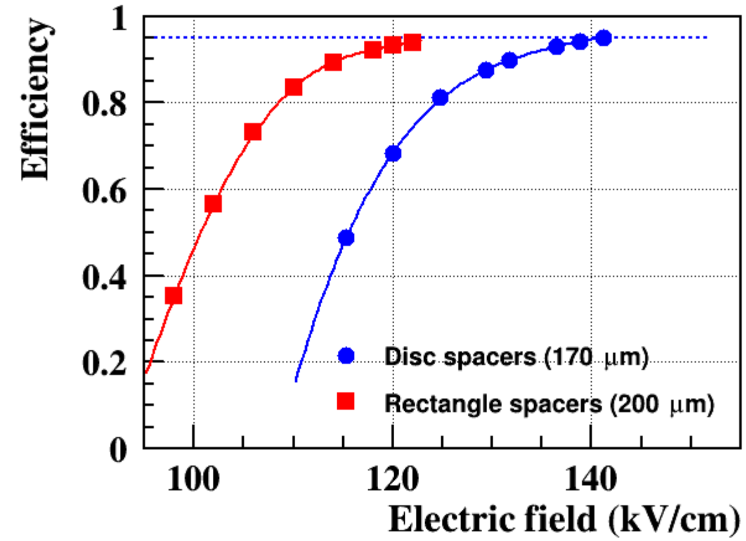
M. Petris et al., Nucl. Inst. and Methods A 1066 (2024) 169584

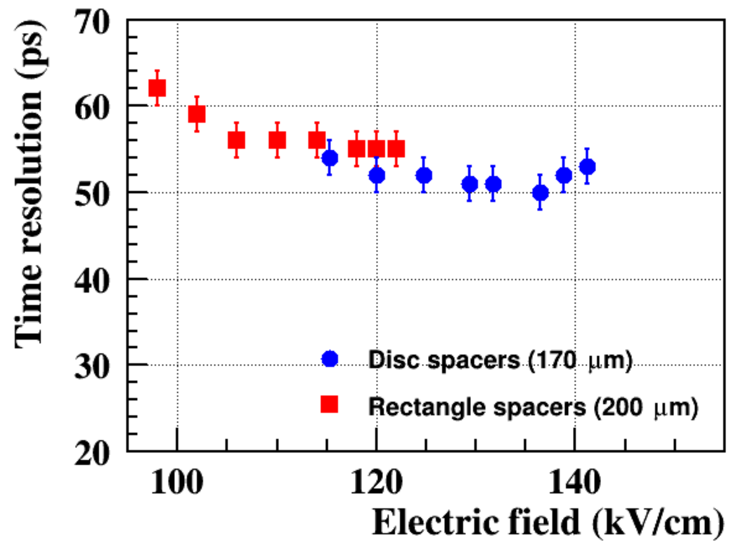
In-beam test in mCBM @ SIS18/GSI

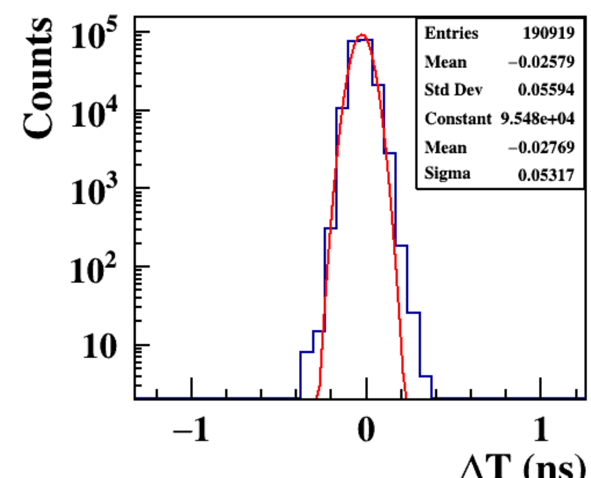


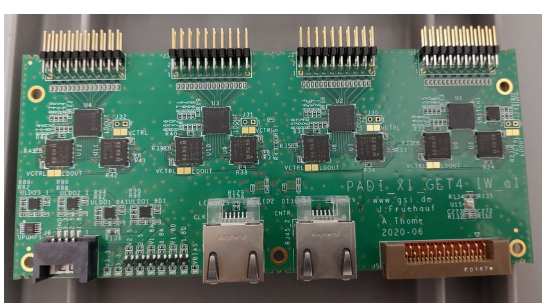
mTOF module:
(033, 043)

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









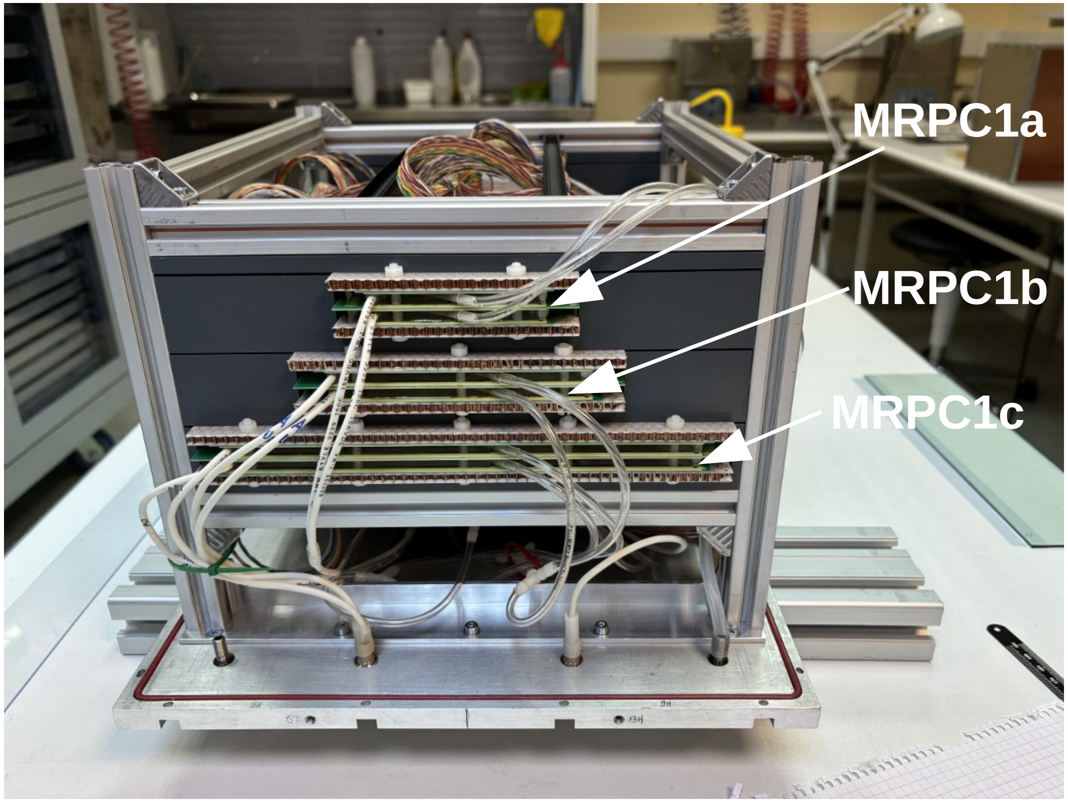
Inner TOF FEE board(J. Frünhauf)

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

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

M. Petris et al., Nucl. Inst. and Methods A 1078 (2025) 170580

MRPC1 chambers of the CBM-TOF inner wall based on discrete spacers and direct flow

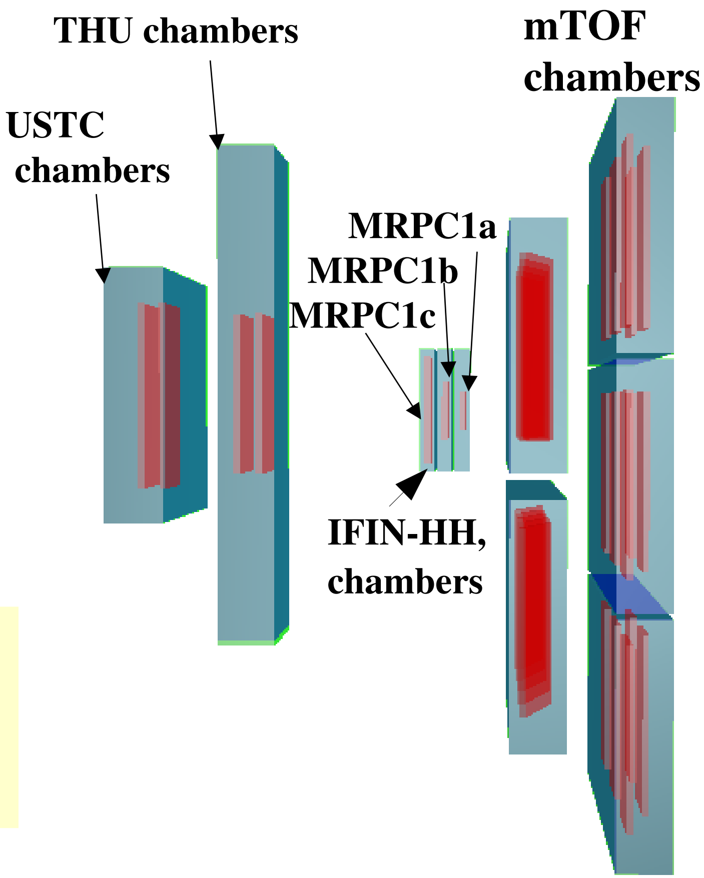


Test counter	Strip length	Granularity	Spacer disc	Glass	Max rate in CBM
MRPC1a	5.6 cm	5.05 cm^2	200 µm	Low res.	50 kHz/cm^2
MRPC1b	9.6 cm	8.66 cm^2	200 µm	Low res.	15 kHz/cm^2
MRPC1c	19.6 cm	17.68 cm^2	200 µm	Low res.	7 kHz/cm^2

mCBM in - beam test May 2025

^{56}Fe run
E_{kin} = 1.7A GeV
Target: Ni 10%
HV Scan

^{209}Bi run
E_{kin} = 1.1A GeV
Target: Au 10%
Rate Scan

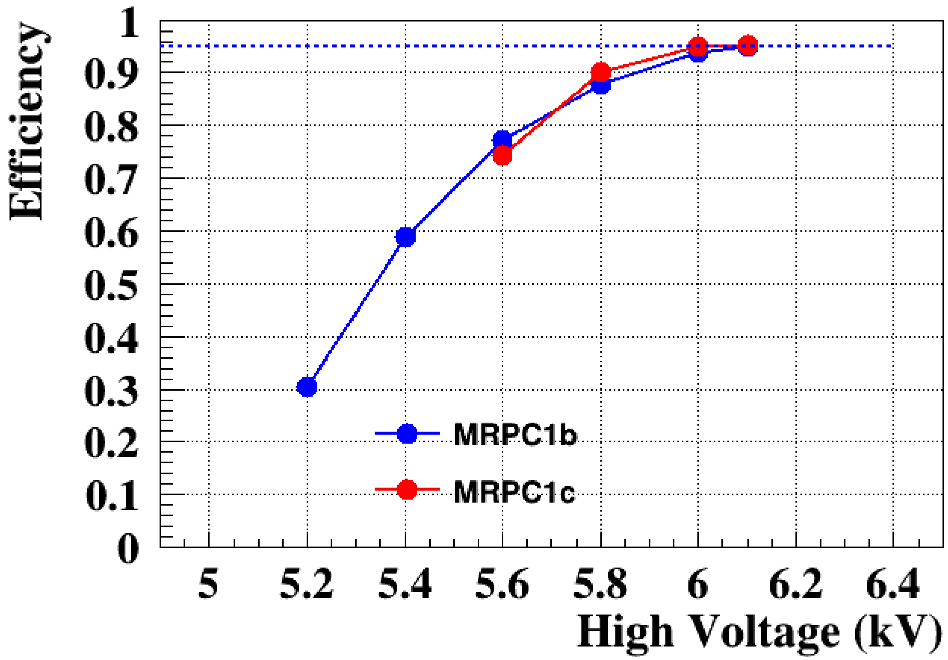


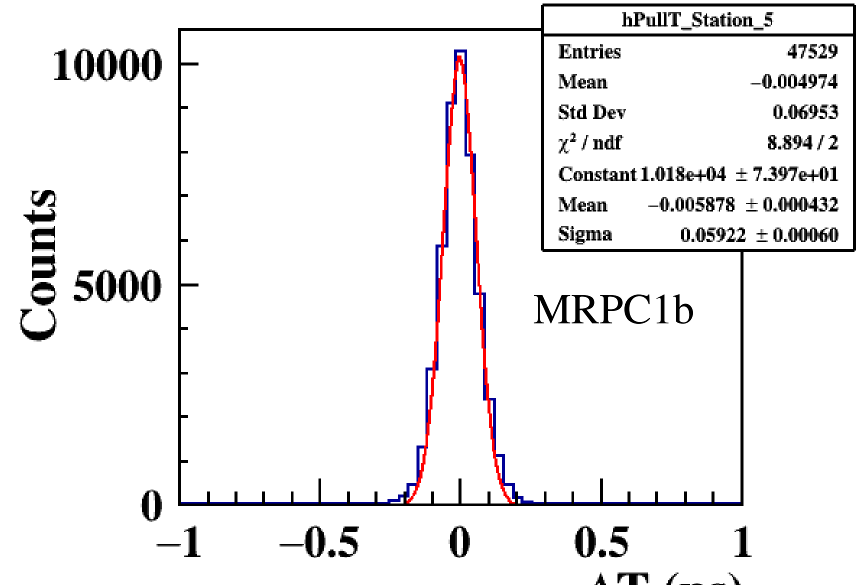
Setup and Tracking:

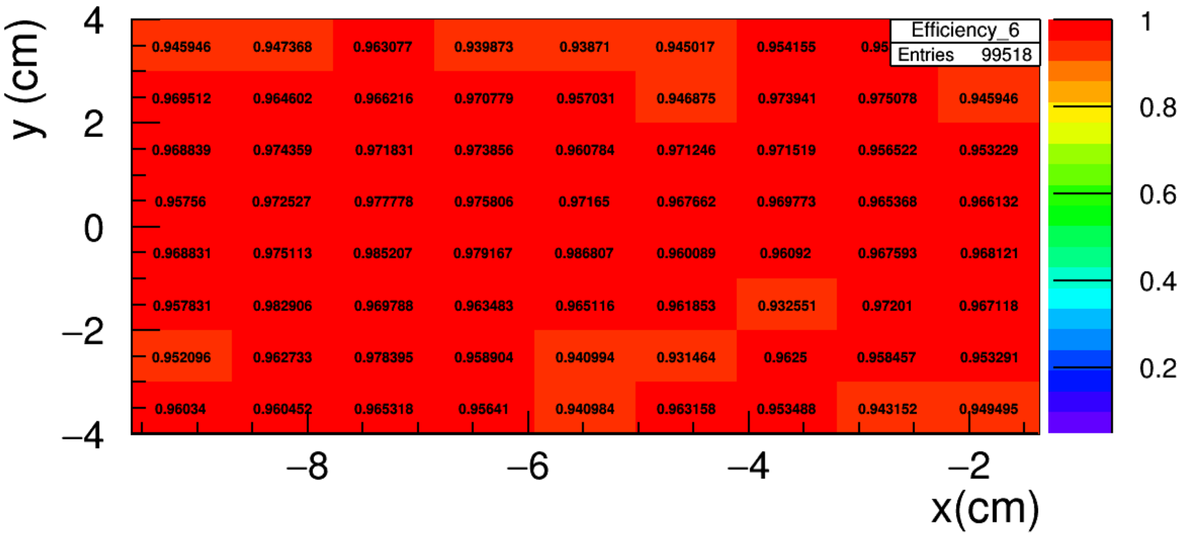
- **Dia + 7 chambers = 8 tracking stations**
- **Analysis → 1 DUT and 7 reference stations**

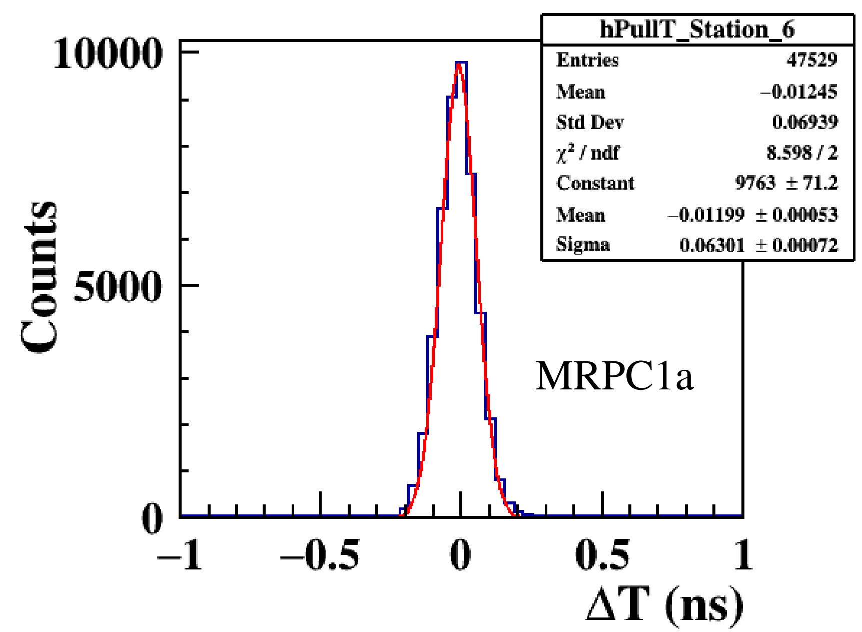
Data analysis is in progress.

Preliminary results of the in-beam test of MRPC1 chambers of the CBM-TOF inner wall







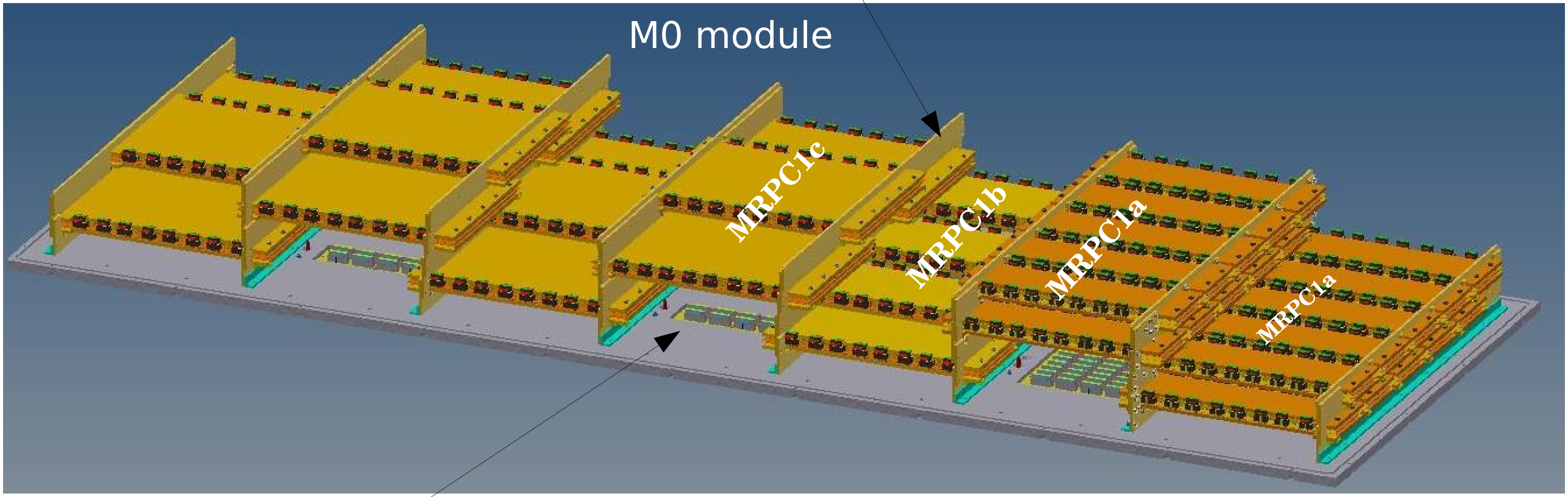


First module (M0) of the CBM-TOF inner wall

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

2432 readout channels = 12% of inner wall channels

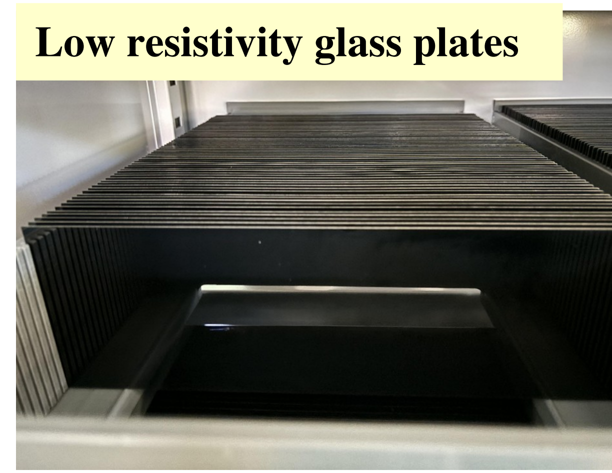
Mechanical supports

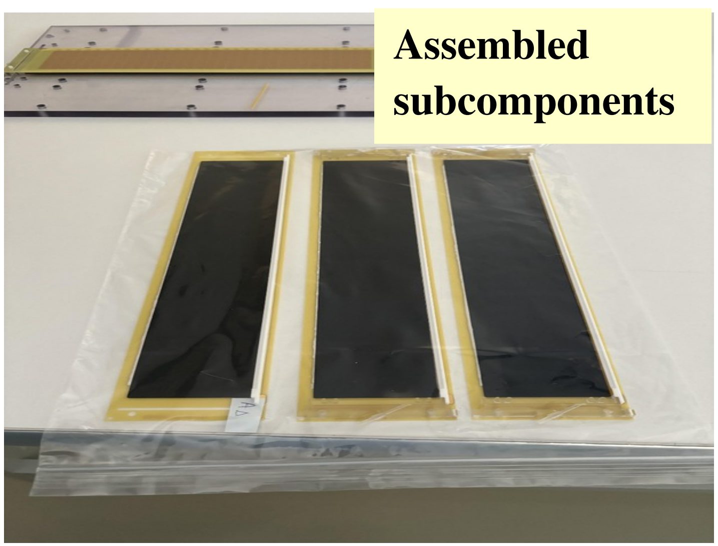


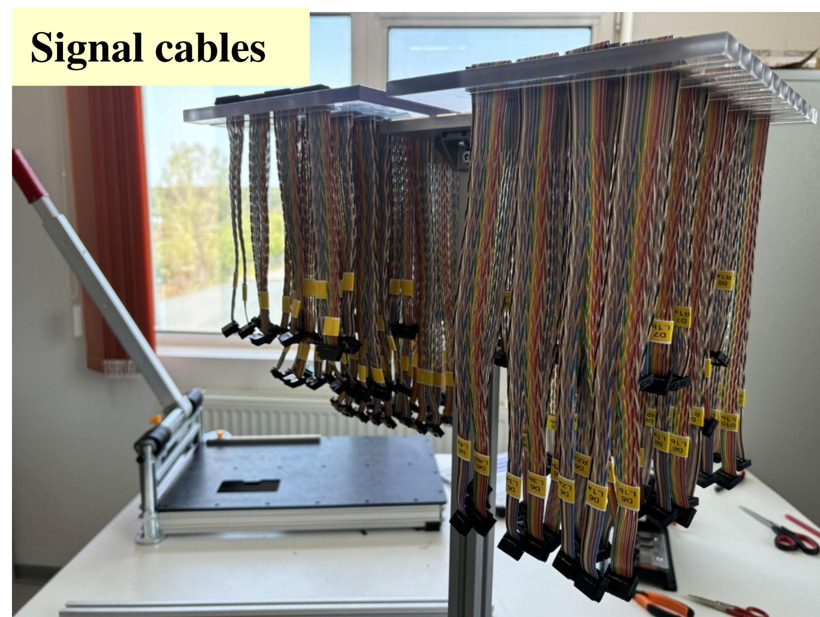
Backpanel with HV,
gas and signal connectors

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

Chambers: main components – already manufactured and procured





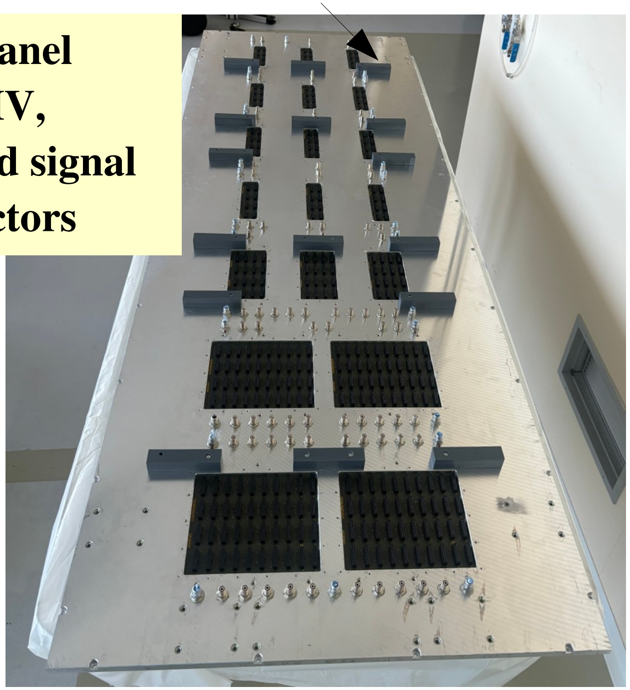


Spacers to be used: 2 mm diameter, 200 µm thickness PC samples received from Panel Group, Taiwan

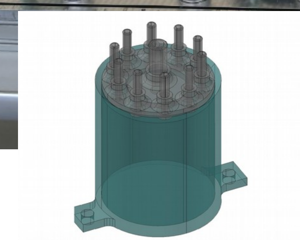
Assembling of the first module (M0) of the CBM-TOF inner wall

Housing box: cover, backpanel, mechanical supports

Backpanel with HV, gas and signal connectors

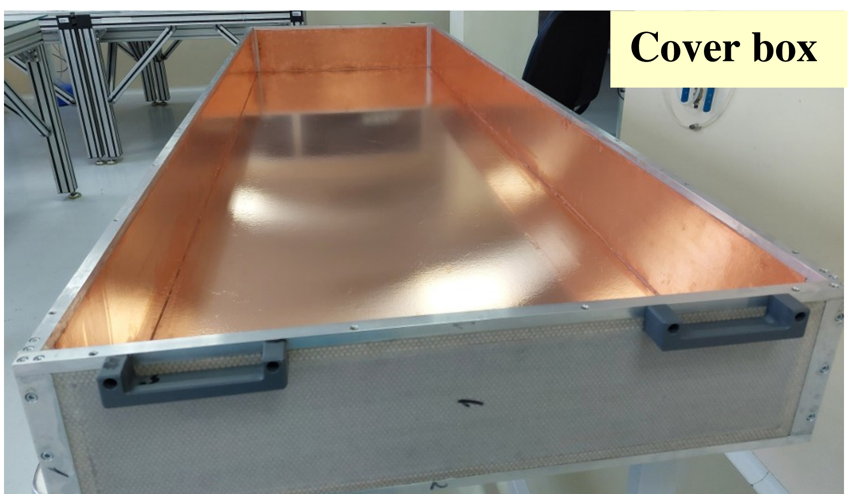


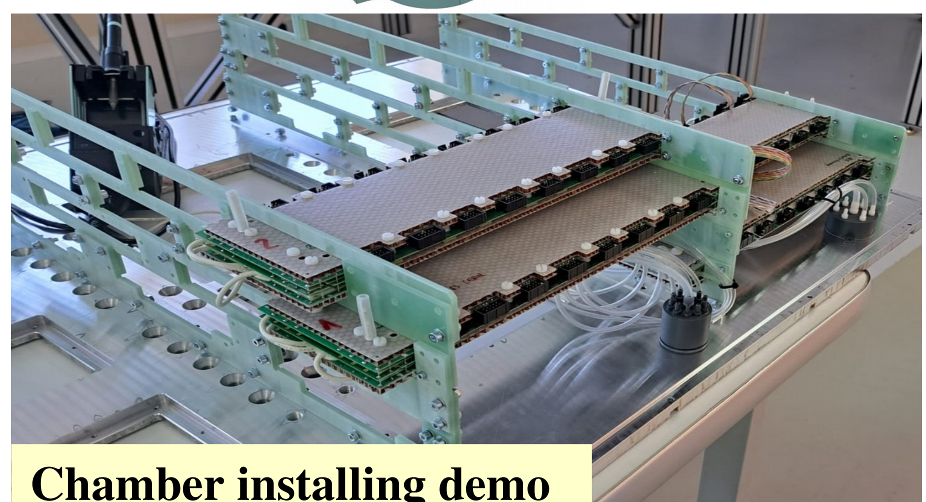
Mechanical supports



Gas distributors

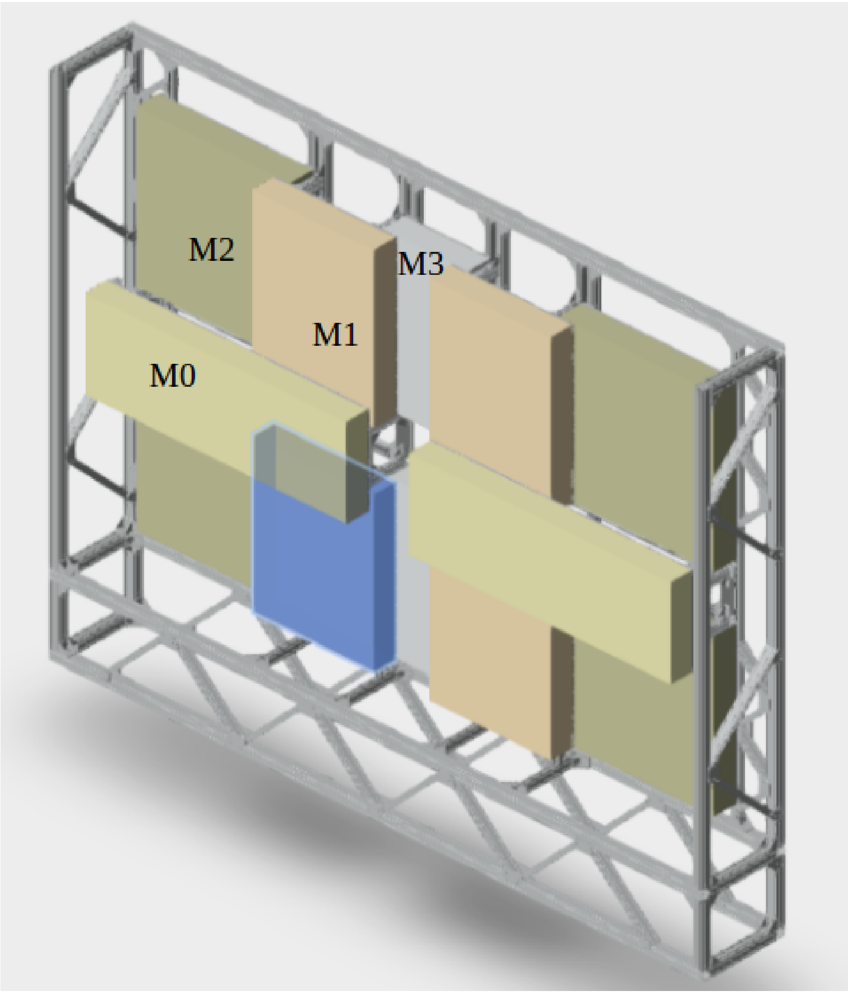
Cover box





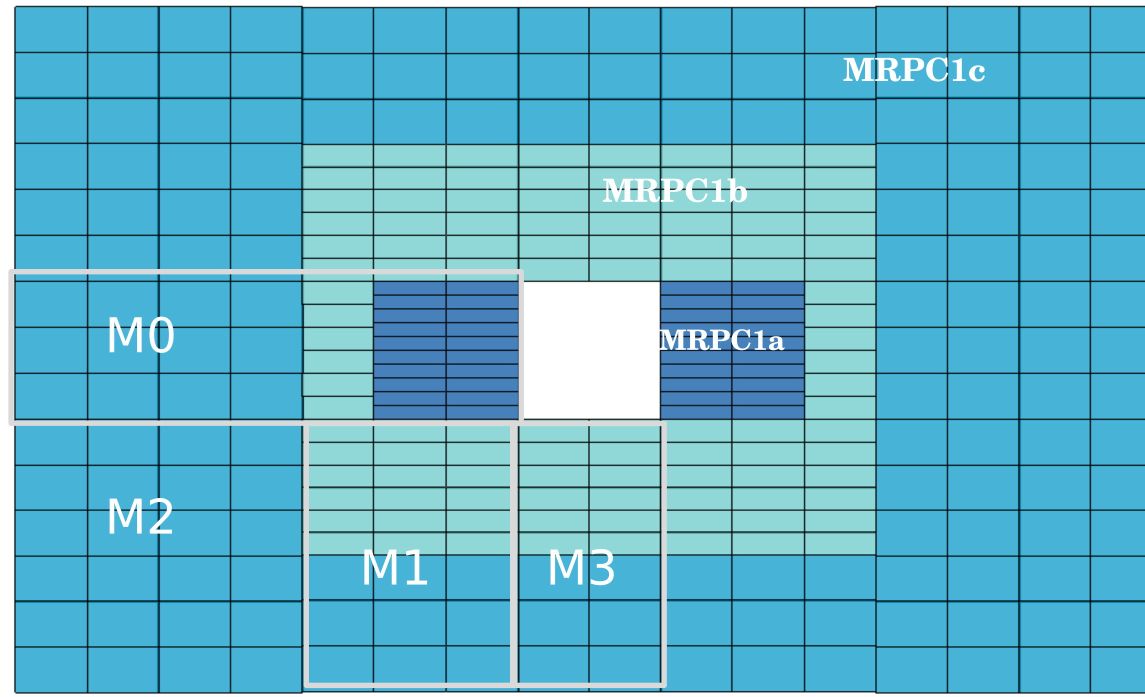
Chamber installing demo

Design of the CBM – TOF inner wall



<u>CBM-TOF inner zone</u>

- ***~15 m² 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 new MSMGRPC architecture with discrete spacers and direct flow for the CBM-TOF inner zone showed very promising results in the in-house aging studies:
  - dark current and dark counting rate have a weak dependence on the gas flow and decrease to negligible values in hours, even at low gas flows (i.e. 0.5 l/h).
  - cosmic ray tests show that X-ray irradiated counters maintain their performance in terms of time resolution and efficiency.

- The in-beam tests performed in mCBM/SIS18, GSI Darmstadt confirmed the performance of the new 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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