MINISTERUL CERCETĂRII ȘI INOVĂRII

High time resolution, two-dimensional position sensitive MSMGRPC for high energy physics experiments

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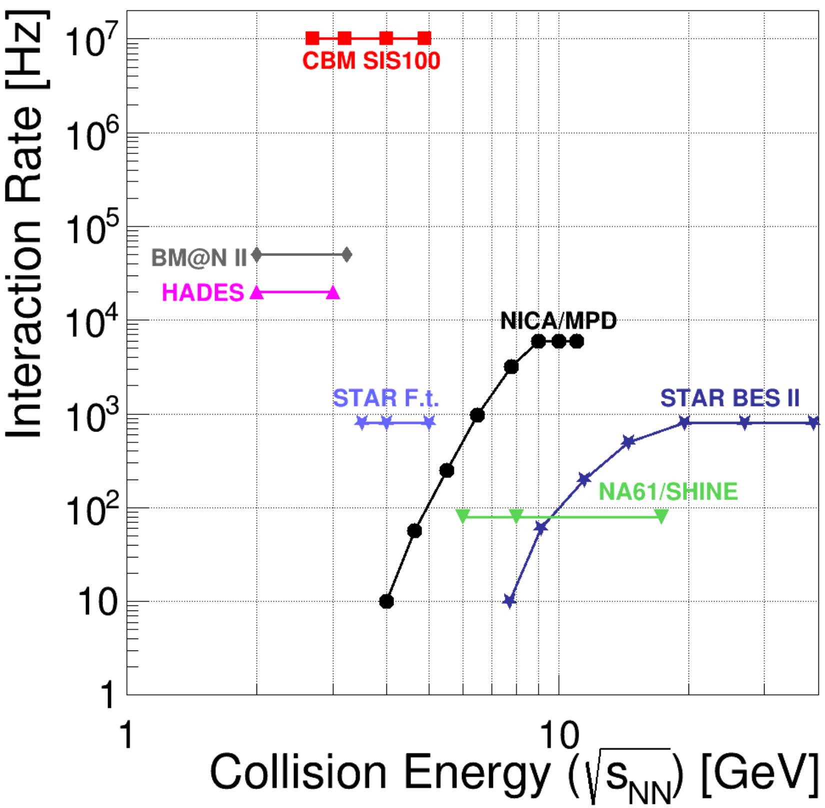
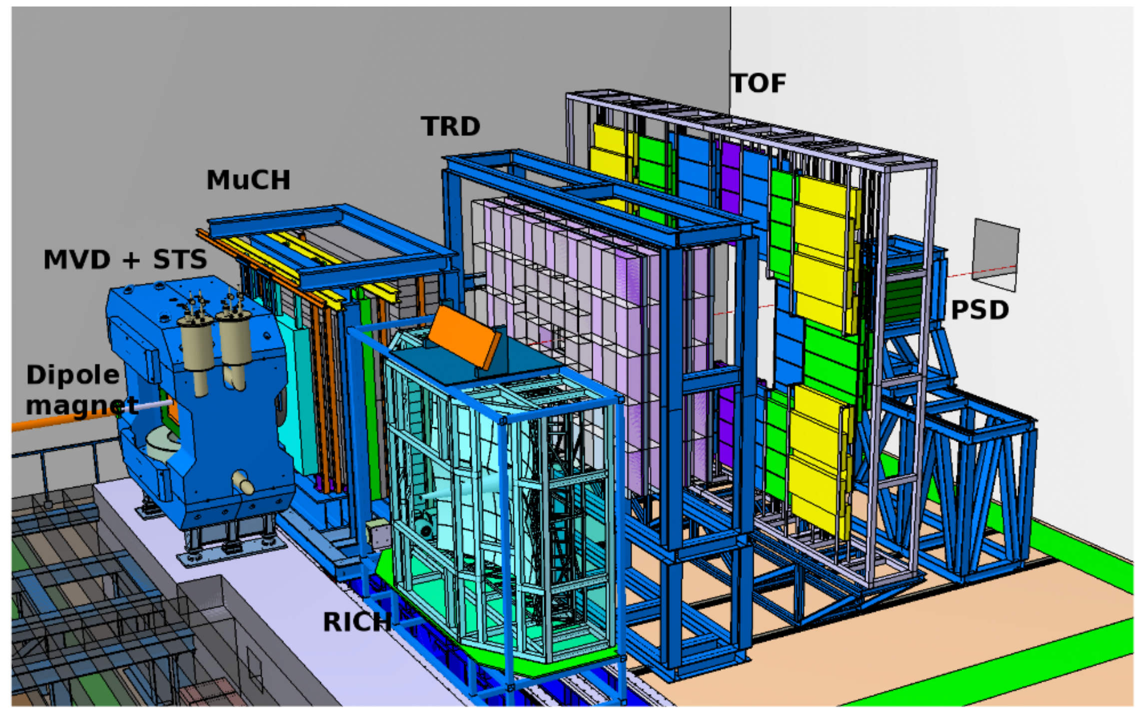
Outline

- Motivation – high counting rate, high multiplicity experiments,
  (e.g. CBM@FAIR, Darmstadt ->TOF inner wall)
- MSMGRPC with a high granularity and impedance matching to FEE
- Performance in the in-beam tests in triggered and trigger-less mode operation
- Conclusions and Outlook

Experiments exploring dense QCD matter

CBM experiment @ SIS100/FAIR





CBM physics goal: explore the QCD phase diagram at high net baryon densities.

Opens up new possibilities!

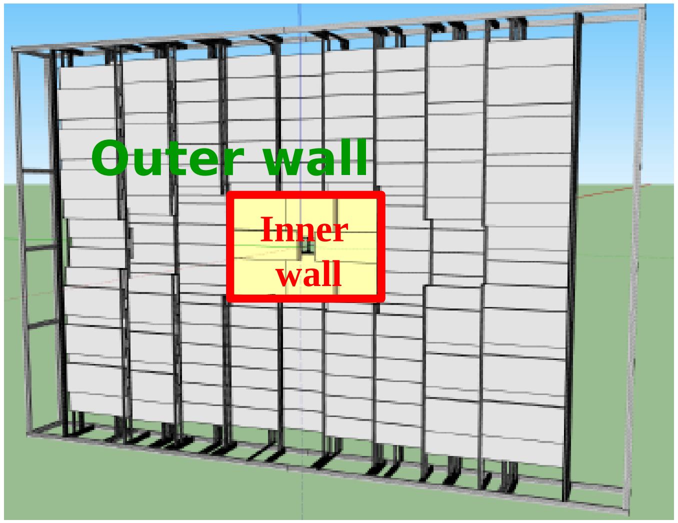
- ✓ **Electromagnetic observables, charm production**
- ✓ **High statistics and good systematics on hadronic observables: multi-strange hyperons, collective flow, fluctuations**
- ✓ **New (exotic) observables: hypernuclei, strange states.**

CBM Collaboration, Eur. Phys. J. A (2017) 53: 60

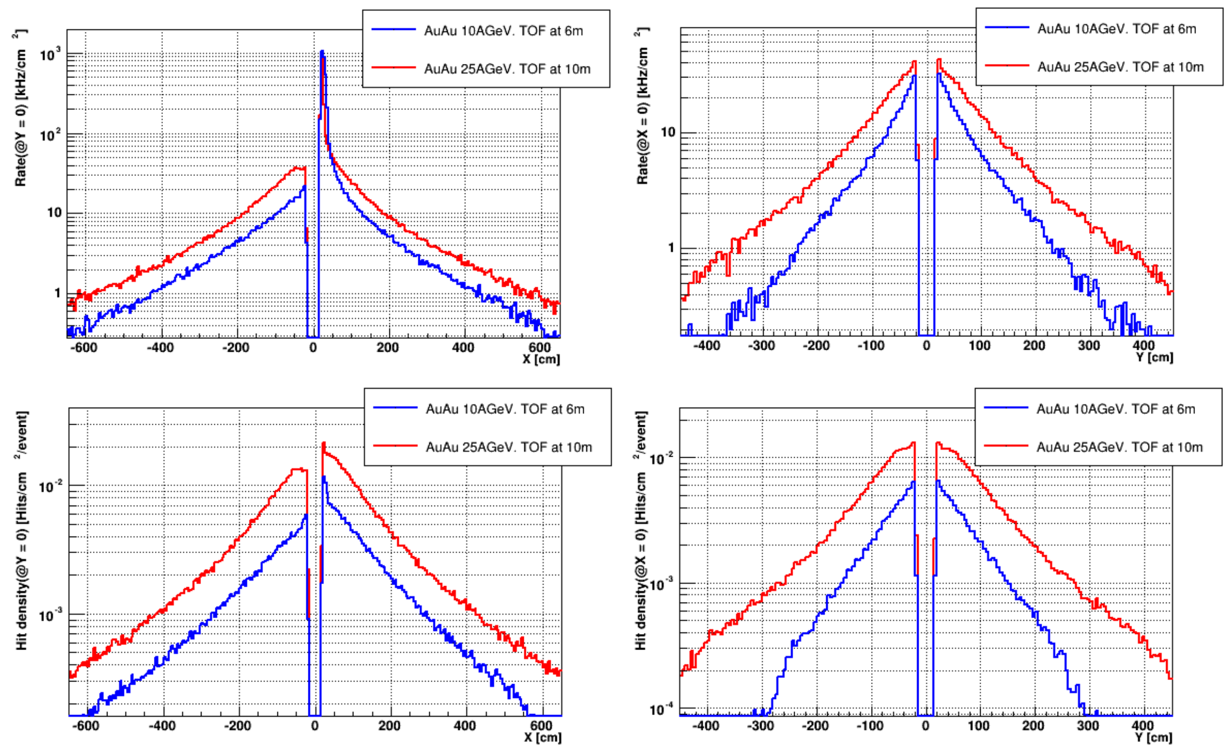
CBM: is a high rate experiment!

- **Fast, radiation hard detectors and front-end electronics**
- **Novel readout system**
  - **Free-streaming readout,**
  - **detector hits with time stamps**
  - **4-D (space+time) event reconstruction**
- **High speed data acquisition & performance computing farm for on-line event selection**

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**

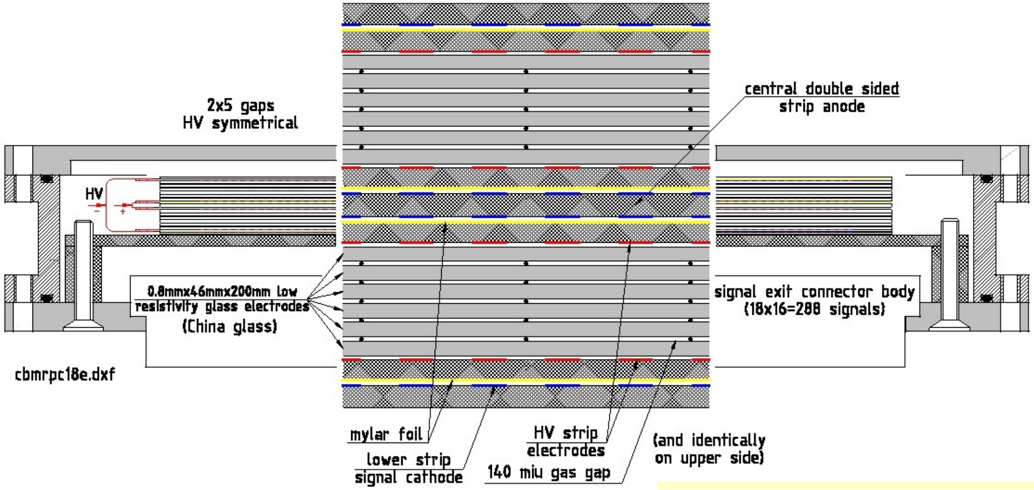
CBM Collaboration, "CBM – TOF Technical Desing Report", October 2014

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

Double stack, strip readout, multigap, timing RPC concept - MSMGRPC



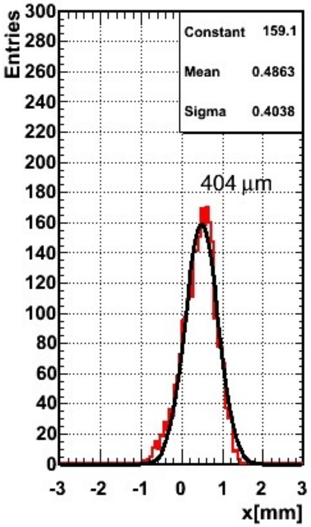
Counter architecture:

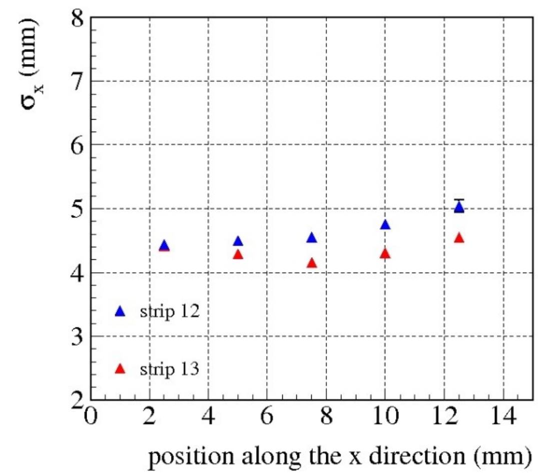
Electrodes: 0.7 mm low resistivity (~$10^{10}\Omega$cm) Chinese glass

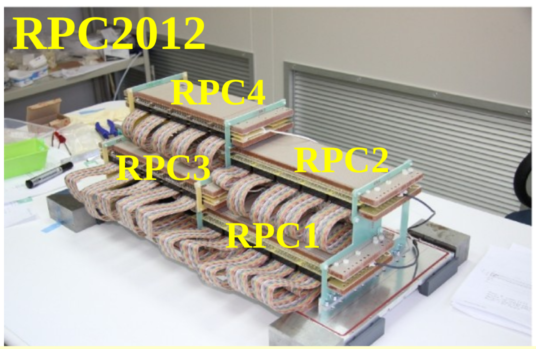
Gap size: 140 µm thickness

Symmetric two stack structure: 2 x 5 gas gaps

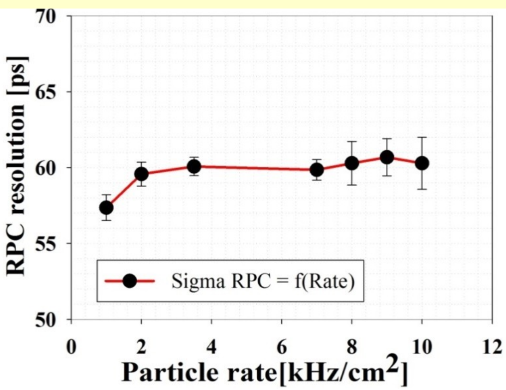
Strip geometry for both readout and high voltage electrodes



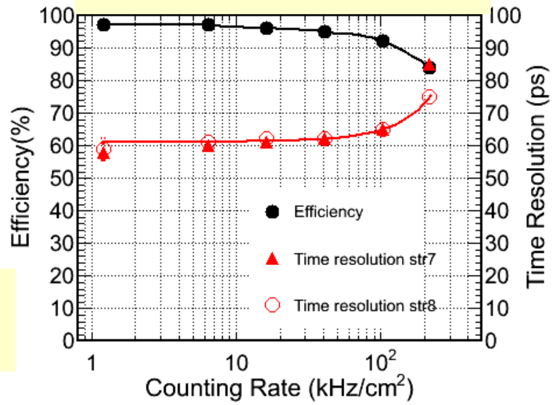




Ni 1.9 GeV/u on Pb target GSI Darmstadt, exposure over whole active area



Focused p beam, 2.5 GeV/c @ COSY Julich



Differential strip readout

2.54 mm pitch =1.1 mm(w)+1.44 mm (g)

100 Ω transmission line impedance

Active area: 46 (strip length) x 180 mm²

7.4 mm strip pitch = 5.6 mm w + 1.8 mm g

Differential readout, 50 Ω impedance

Active area: 96 (strip length) x 300 mm²

FEE based on NINO chip (ALICE-TOF Collaboration)

M.Petrovici et al. JINST 7 P11003, 2012

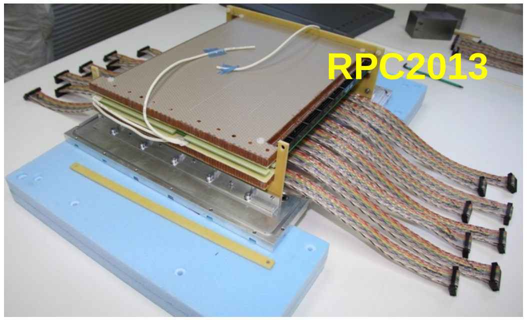
M. Petris et al., Journal of Phys: Conf. Series 533 (2014) 012009

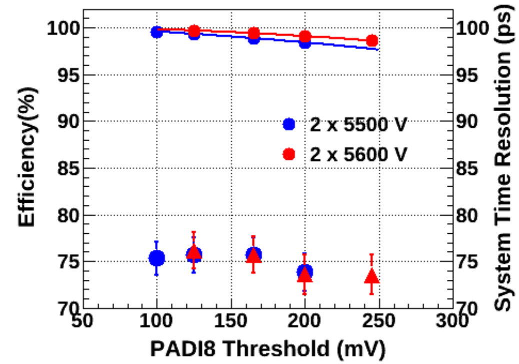
M. Petris et al., Journal of Phys: Conf. Series 724 (2016) 012037

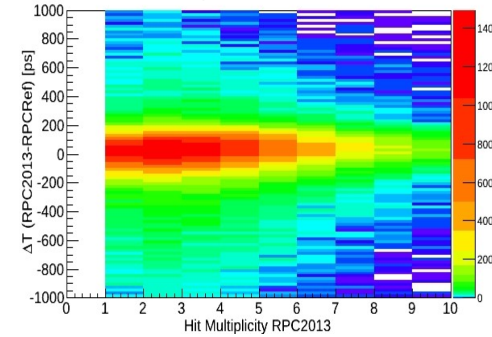
Performance in multi-hit environment

GSI Darmstadt, October 2014 **1.1 GeV/u ^{152}Sm beam on Pb target**

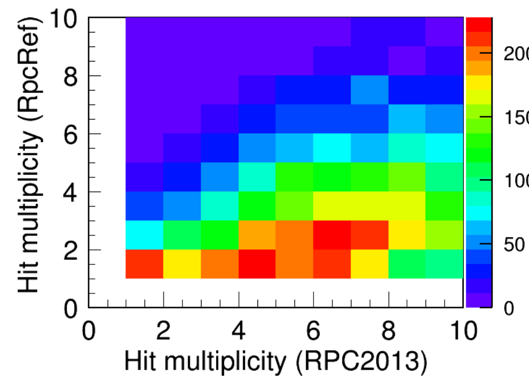
Counting rate = ~1 kHz/cm^2

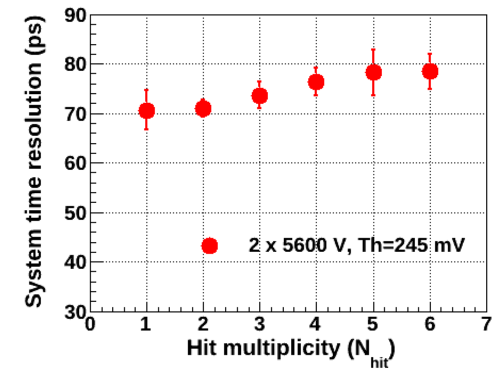




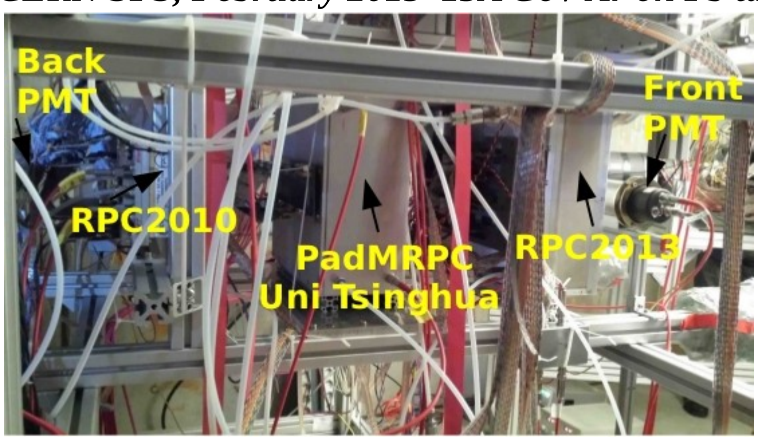


- ✓ **Active area 200 (strip length) x 266 mm^2**
- ✓ **Resistive electrodes: 1 mm, ~10^{10}Ωcm Chinese glass**
- ✓ **Pitch=2.16 mm (w) +2.04 mm (g) = 4.2 mm**
- ✓ **Differential readout, 100 Ω impedance**
- ✓ **Anode architecture: Cu strips between two FR4 layers of 0.25 mm**





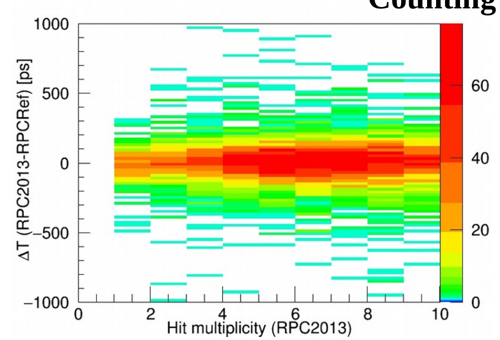
CERN SPS, February 2015 13A GeV Ar on Pb target

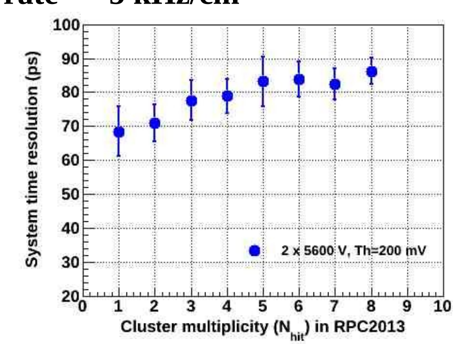


Goal – compatibility with PADI FEE developed within CBM-TOF Collaboration

CERN SPS, February 2015, 13 GeV/u Ar on Pb target

Counting rate = ~5 kHz/cm^2





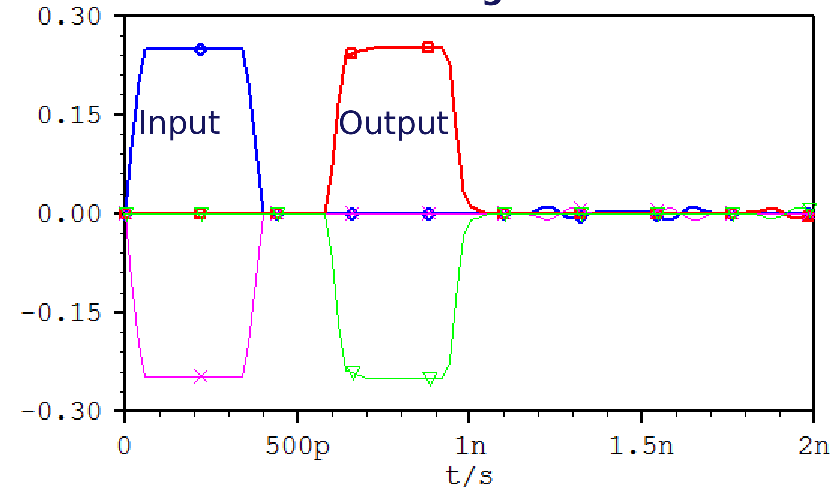
FEE based on PADI chip (CBM-TOF Collaboration)
(IEEE Trans. Nucl. Sci. 61 (2014), 1015
DAQ: FPGA TDC (GSI Scientific Report 2014 (2015), 121
+ TRB3 data hubs (http://trb.gsi.de/)

M.Petris et al. JINST 11 C09009, 2016

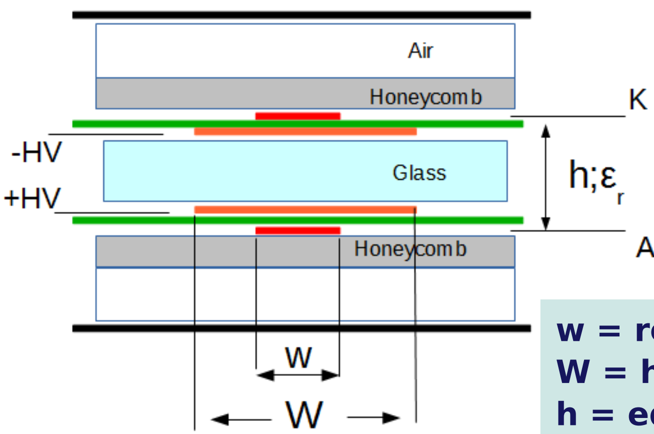
Method to adjust the signal transmission line impedance in MSMGRPCs

- **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**
- **APLAC software used for impedance estimations**

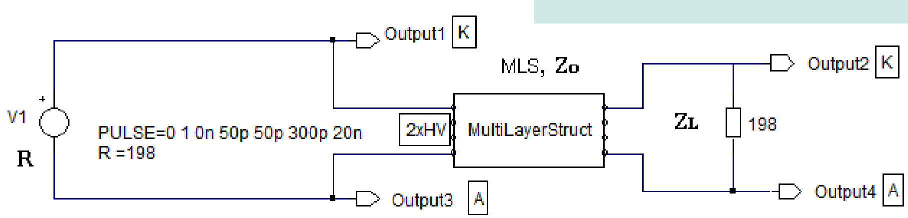
Simulated signals

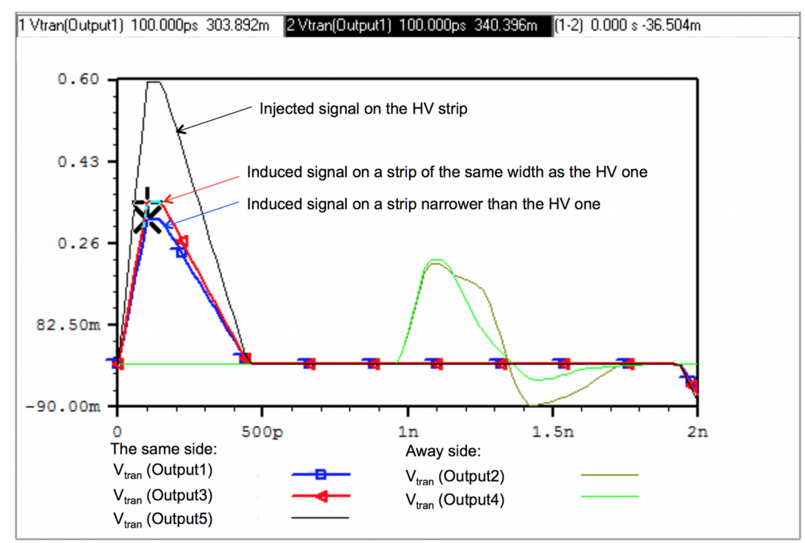


Input/Output signals are simulated using APLAC for different values of the readout strip width



w = readout strip width
W = high voltage strip width
h = equivalent dielectric thickness
ε = equivalent dielectric constant



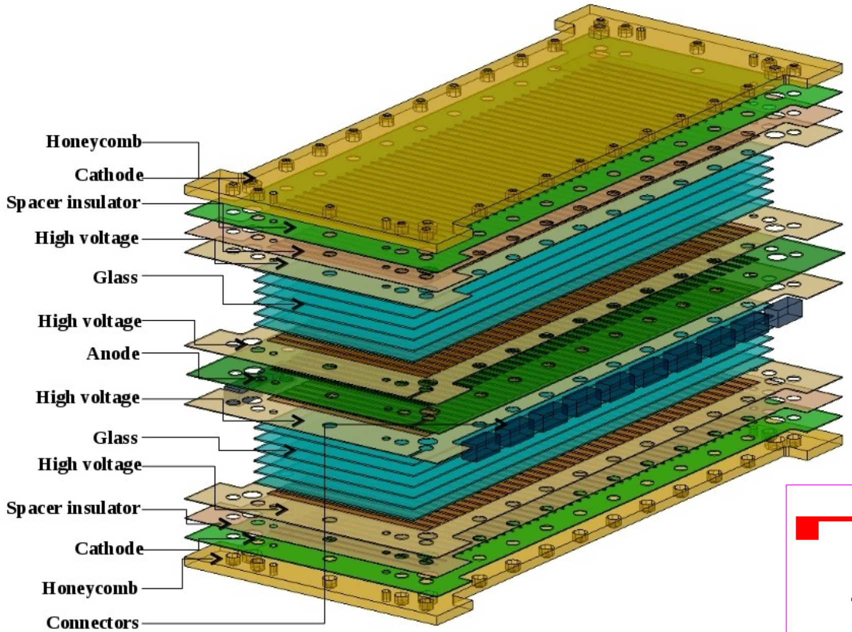


If R = Z_0 = Z_L the transmission line is matched;
Z_0 = characteristic impedance of a transmission line
Z_L = load resistor connected to the transmission line
R = internal resistance of the pulse generator

No significant signal loss occurs due to the narrow readout strip in comparison with the HV one

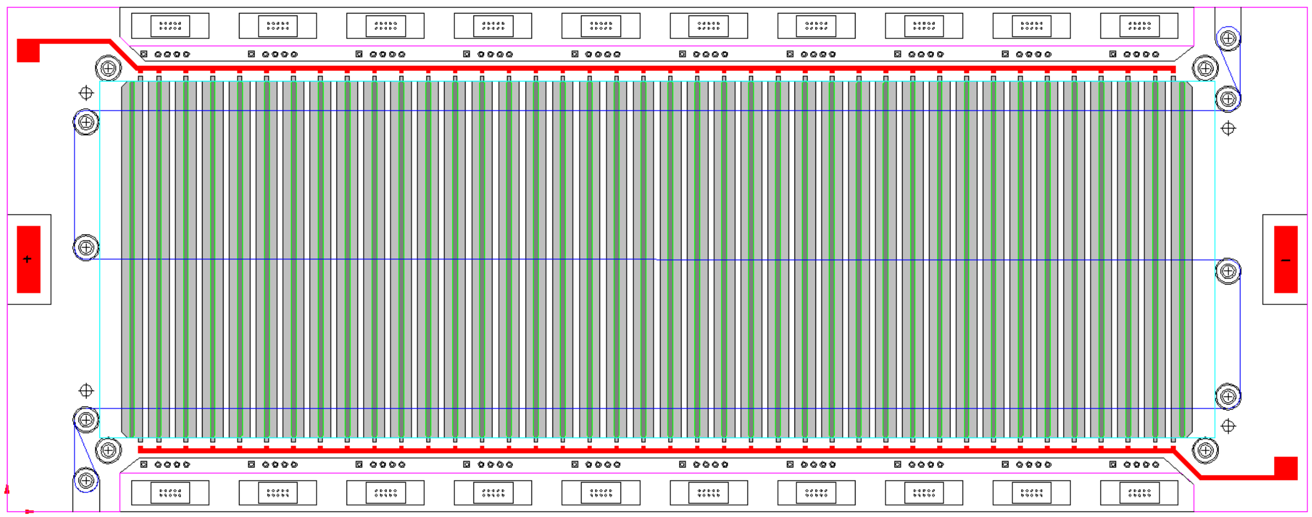
D. Bartos et al. Romanian Journal of Physics 63, 901 (2018)

RPC2015DS prototype - strip impedance tuned through the readout strip width



Goal – perfect matching of the impedance of the signal transmission line to the imput impedance of the FEE, in order to reduce the amount of fake information resulted from reflections.

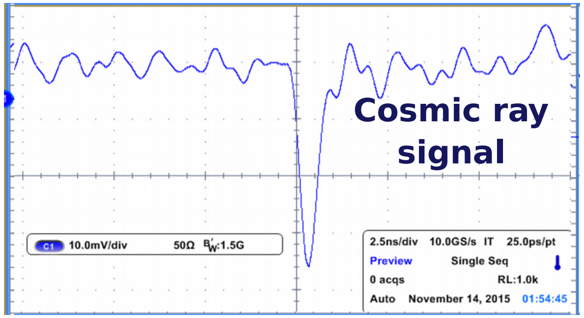
Simulations predicted ~99 Ω impedance for 1.3 mm readout and 5.6 mm high voltage strip widths



Readout electrode: 7.2 mm pitch= 1.3 mm width + 5.9 mm gap – define impedance

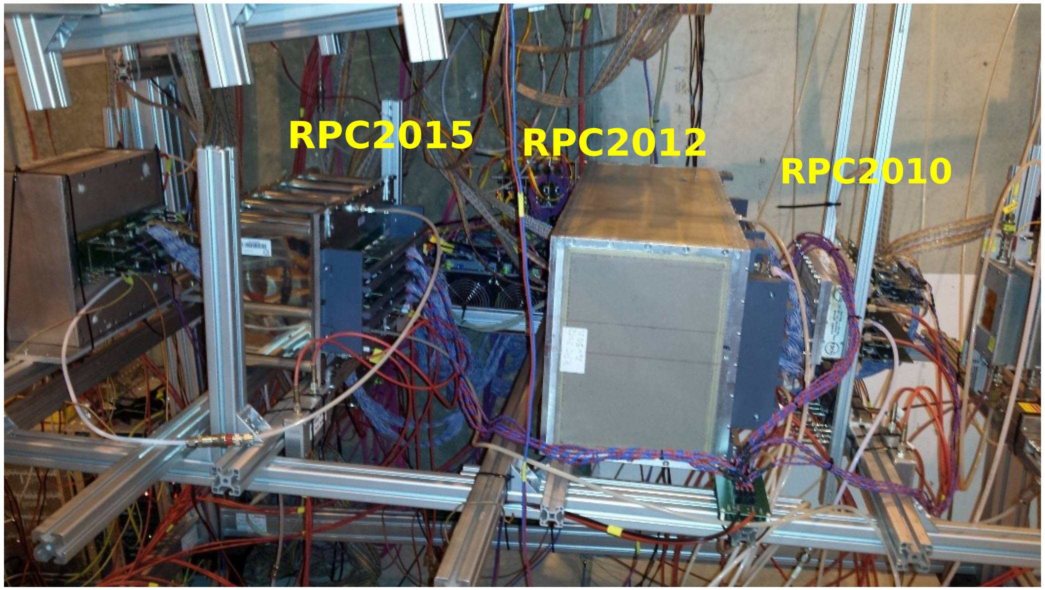
High Voltage electrode: 7.2 mm pitch= 5.6 mm width + 1.6 mm gap – define granularity

- ✓ Symmetric two stack structure: 2 x 5 gaps
- ✓ Active area 96 x 300 mm2
- ✓ Gas gap thickness: 140 μm thickness
- ✓ Readout electrode = 40 strips
- ✓ Differential readout
- ✓ Resistive electrodes: low resistivity glass

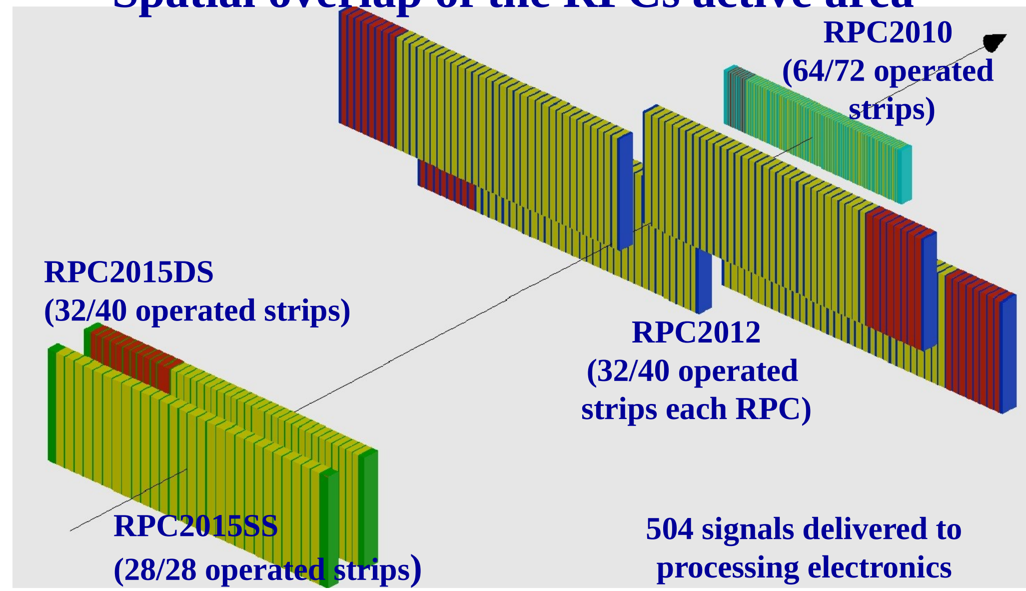


In-beam test using a triggered DAQ

CERN-SPS Pb beam of 30A GeV on a Pb target



Spatial overlap of the RPCs active area



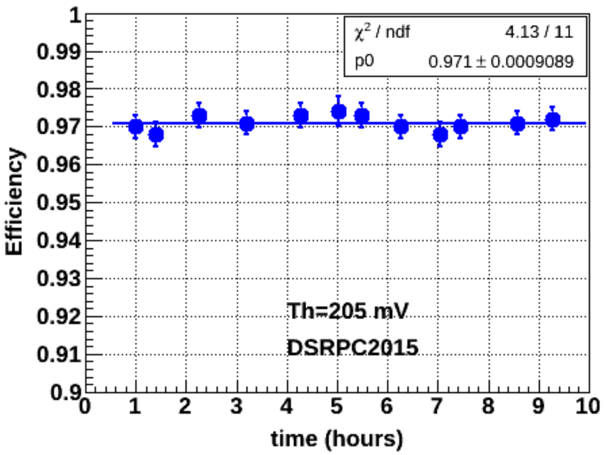
Gas mixture: 85%$C_2H_2F_4$ + 5%iso-C_4H_{10} +10%SF_6

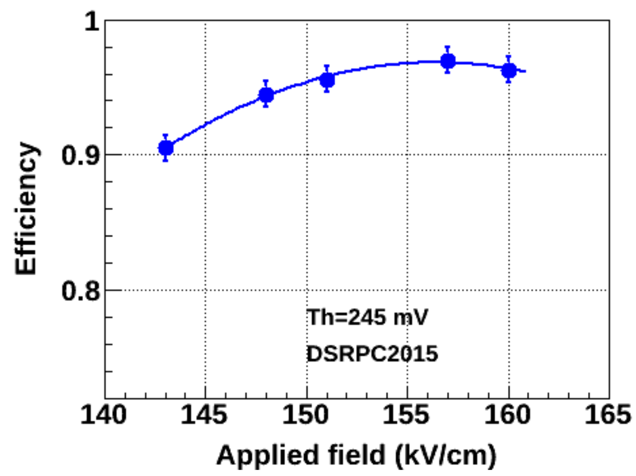
Experimental set-up – ~3.0 relative to the beam line

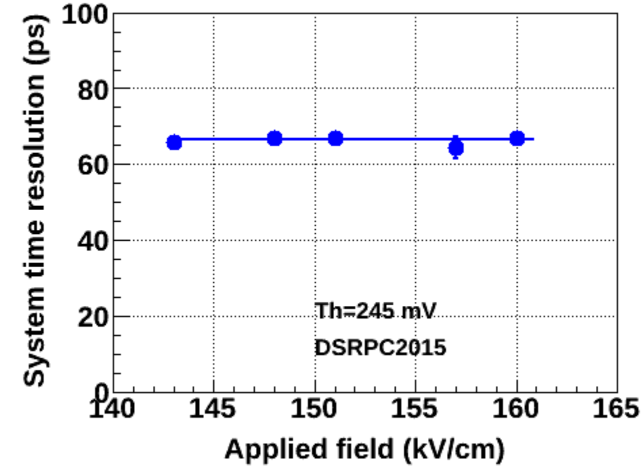
- *RPC2015 – 2 MRPCs*
  - *SS. 10.1 mm strip pitch (see next slide) – 28 operated strips out of 28/RPC – 100% active area*
  - *DS. 7.2 mm strip pitch (see next slide) – 32 operated strips out of 40/RPC – 80% active area*
- *RPC2012 – 4 MRPCs – 32 operated strips/RPC out of 40/RPC – 80% active area*
- *RPCRef – 1 MRPC – 64 operated strips out of 72/RPC - 89% active area*
- *FEE based on PADI chip (CBM-TOF Collaboration)*
- *Triggered DAQ based on FPGA TDCs & TRB3 data hub*

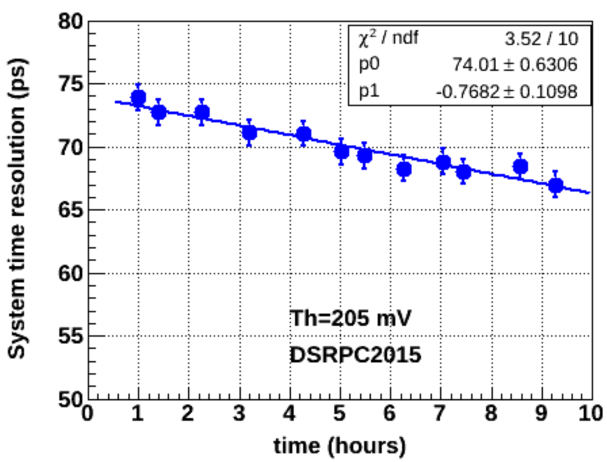
Efficiency and time resolution in high multiplicity environment

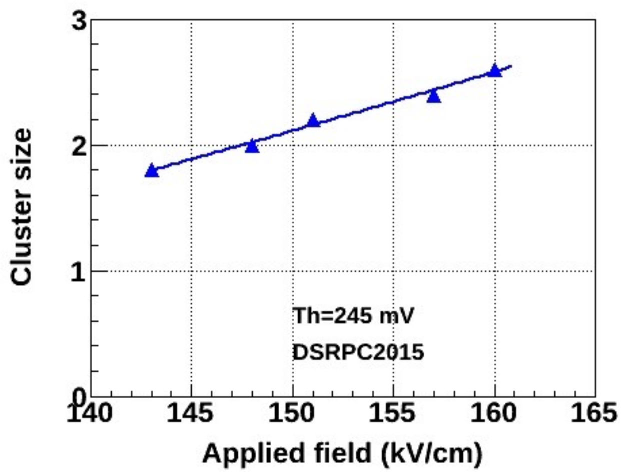
28 Nov0001 - 28Nov0829











Single counter time resolution = 45 ps

System time resolution

(including electronics contribution)

$$\sigma_{TOF} = \sqrt{\left(\left(\sigma_{RPC\,2015}\right)^2 + \left(\sigma_{RPCRef}\right)^2\right)}$$

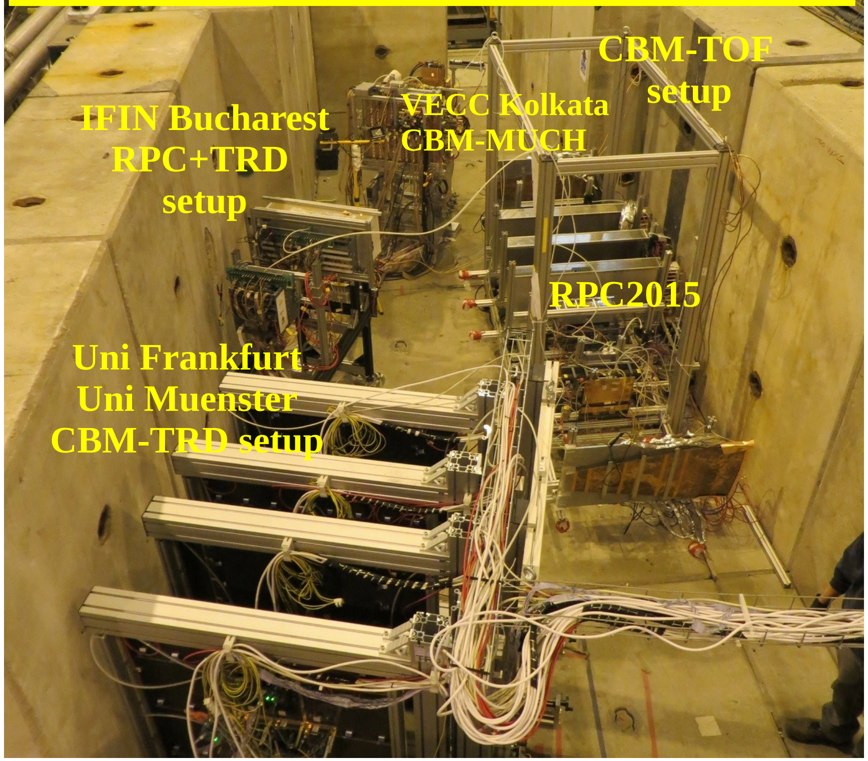
- ✓ **System time resolution = 66 ps**
- ✓ **The efficiency plateau is reached @ 96% -97%**
- ✓ **The cluster size is 2.2 – 2.6 @ efficiency plateau**

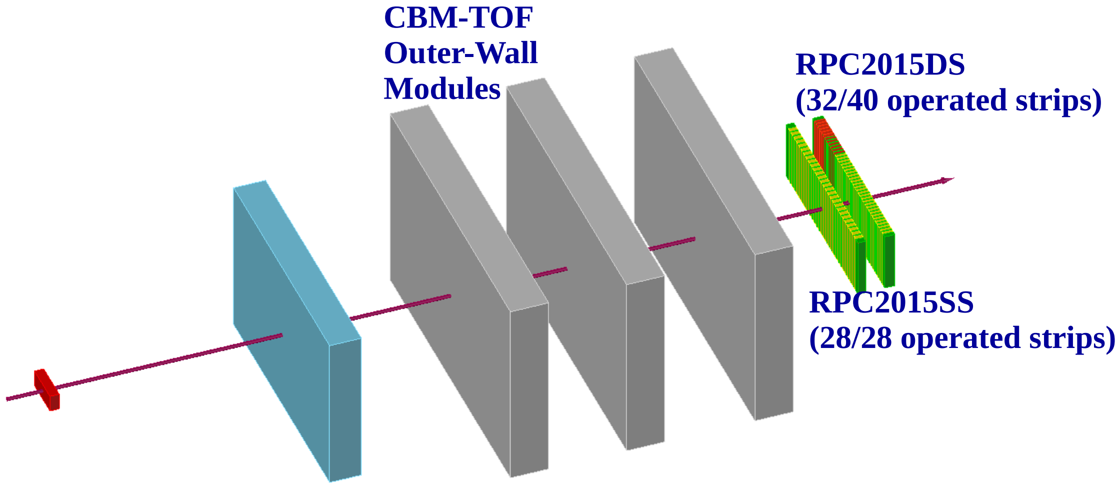
M. Petris et al., Nuclear Inst. And Meth. A 920 (2019), 100.

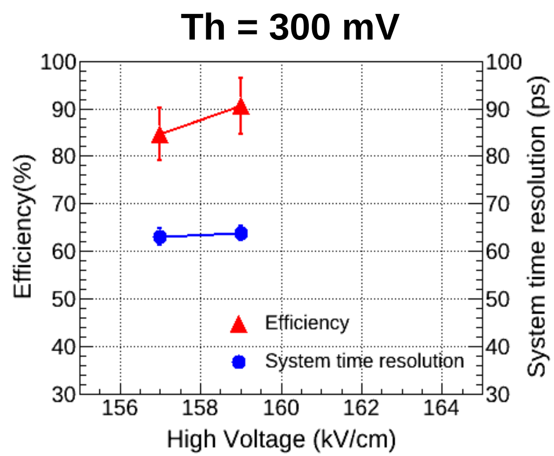
Free - streaming readout

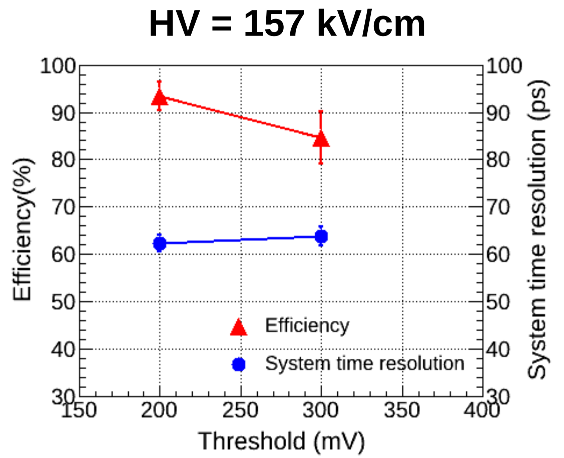
CERN-SPS Fall 2016 in-beam test

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









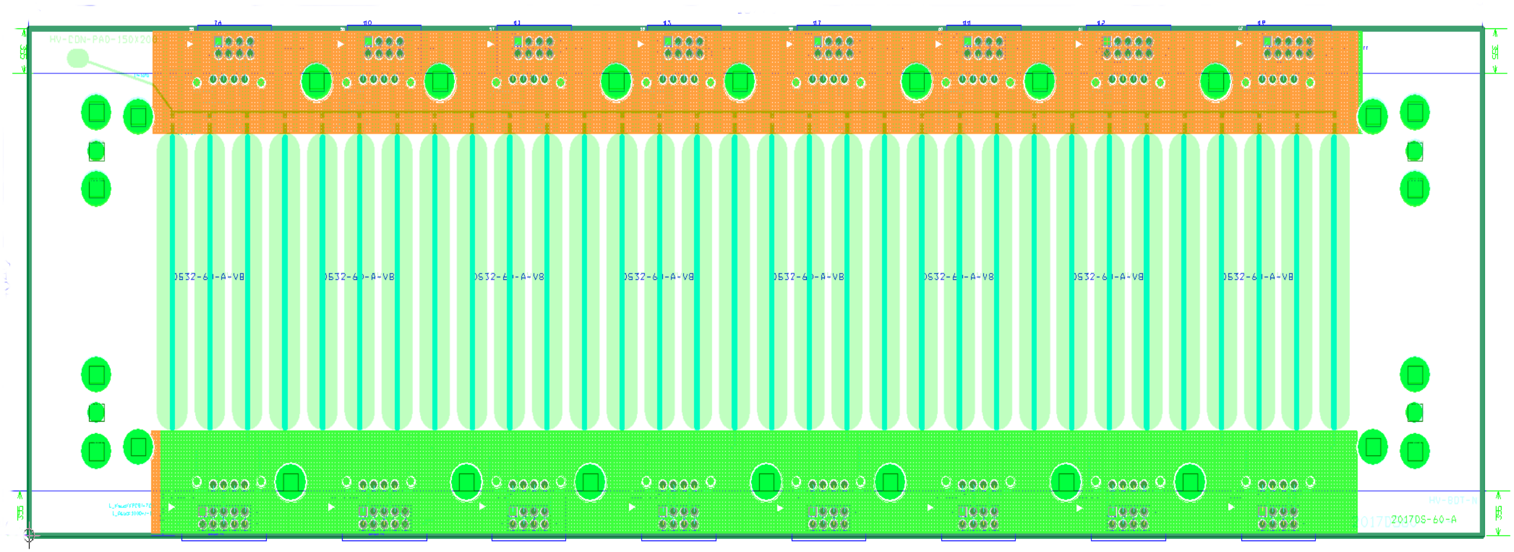
CBM-TOF setup: GSI – Darmstadt, IFIN-Bucharest, Uni Heidelberg, Uni Tsinghua – Beijing, USTC Hefei

readout: ~ 500 Channels with a new readout-chain based on:

- **PADI + GET4 TDC (https://wiki.gsi.de/pub/EE/GeT4/get4.pdf)**
- **DAQ: DPB (Data Processing Board) + FLIB (First Level Interface Board)**

The influence of the readout scheme on the slight lower efficiency is under investigation

MSMGRPC2018 prototype for the CBM-TOF highest granularity zone

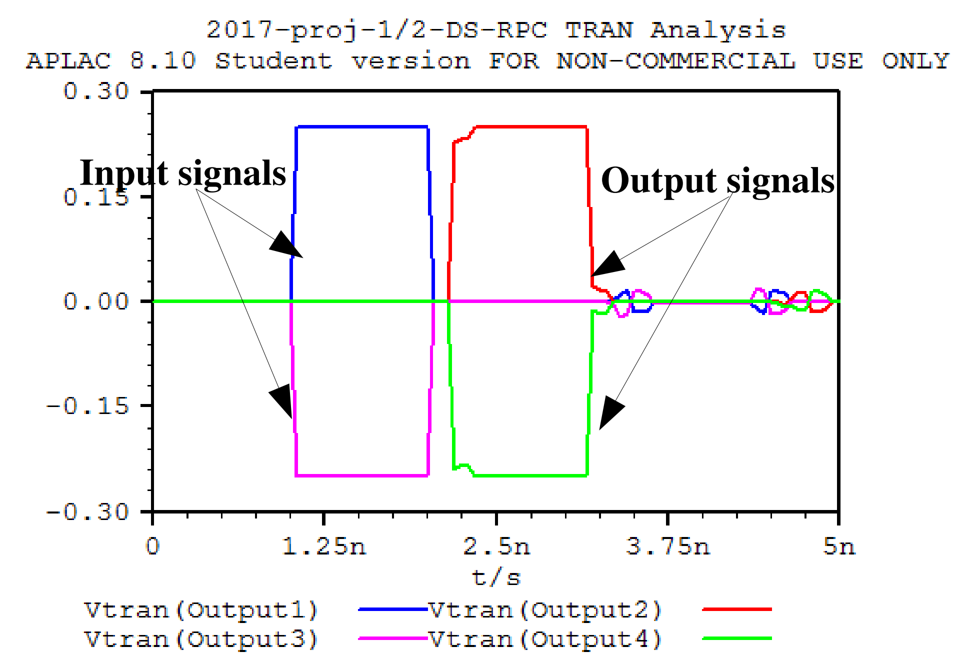


Goal – Electronic channels cost optimization

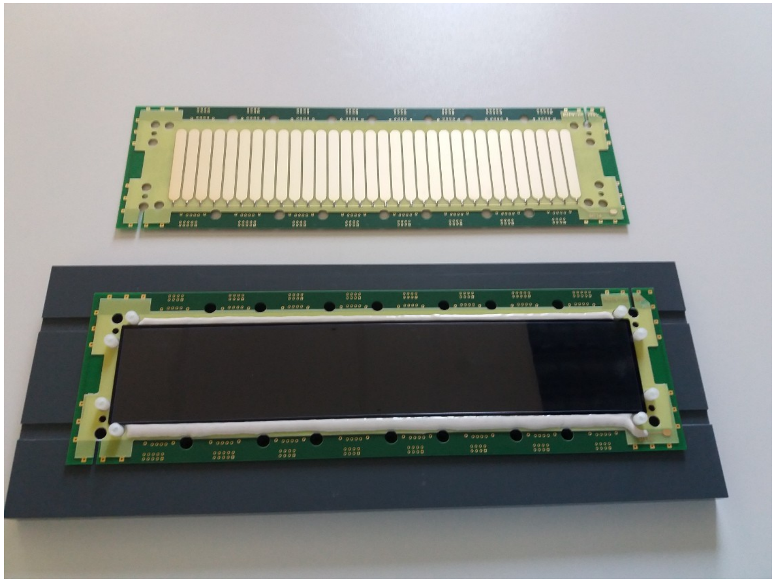
32 strips; 60 mm (strip length) x 300 mm
Readout electrode: 9.02 mm pitch= 1.27 mm w + 7.75 mm g
High Voltage electrode: 9.02 mm pitch= 7.37 mm w + 1.65mm g

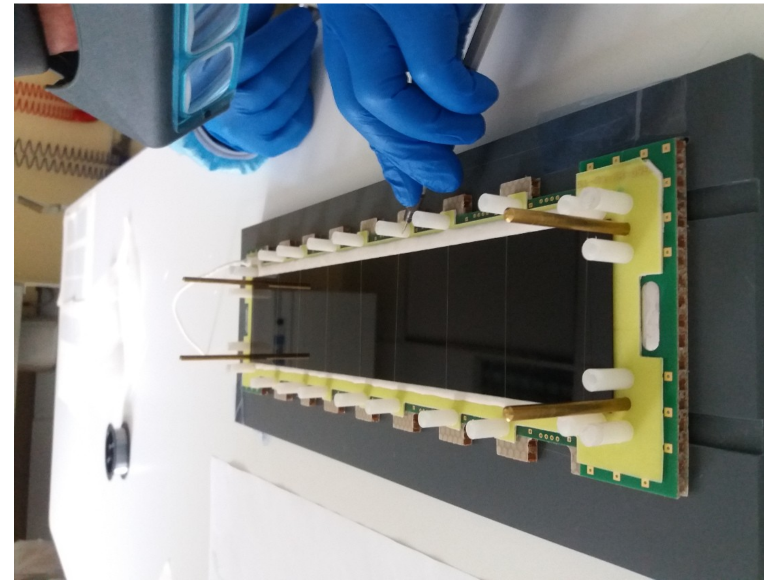
APLAC predicted ~97 Ω for

1.27/7.37 mm readout/HV strip width

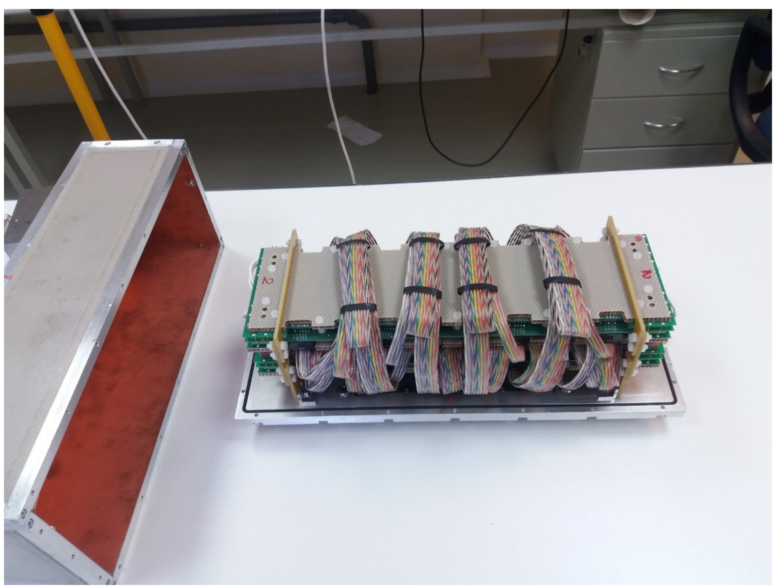


Prototype assembling



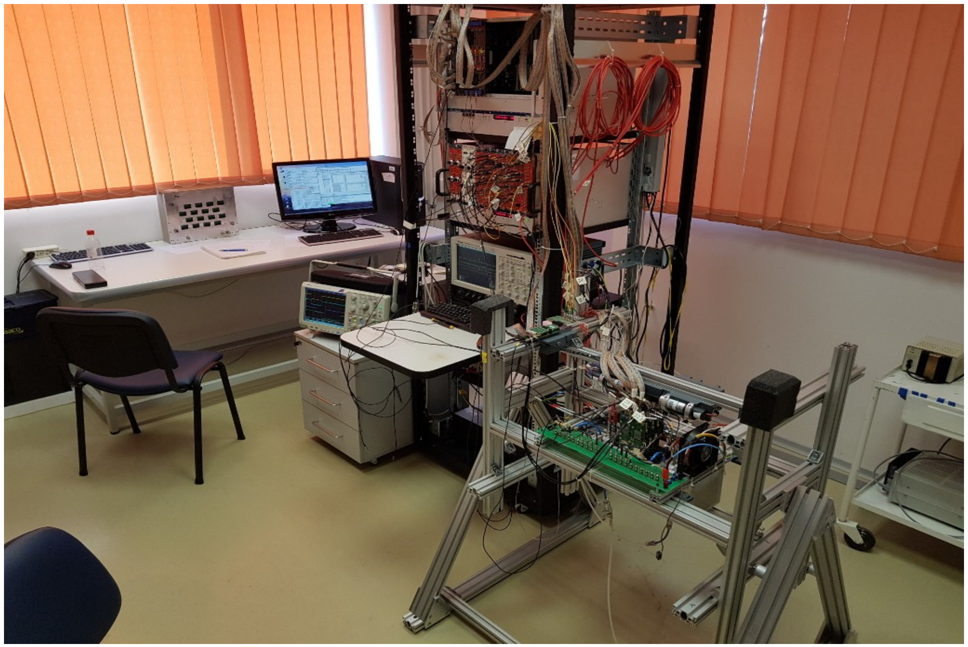


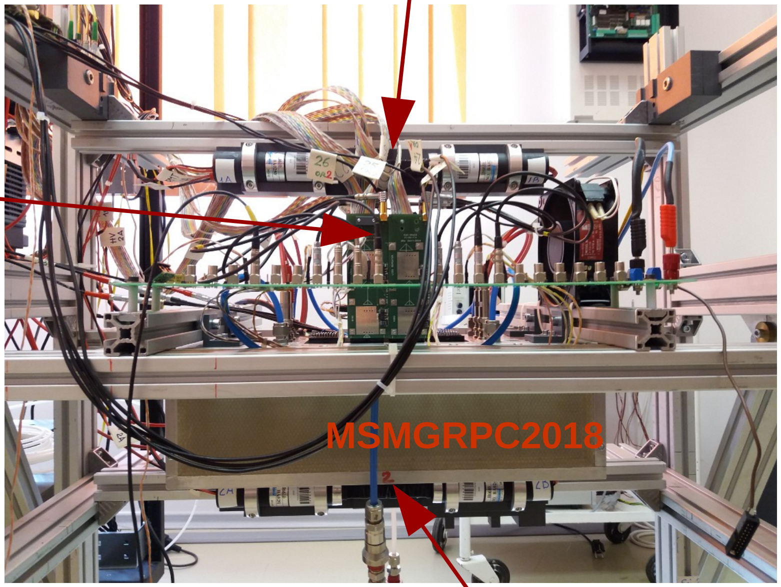
<10 000 part/ft3 clean room for MSMGRPC assembling



In-house electronics and cosmic – ray test of MGMSRPC2018 prototype

dedicated MSMGRPC test laboratory



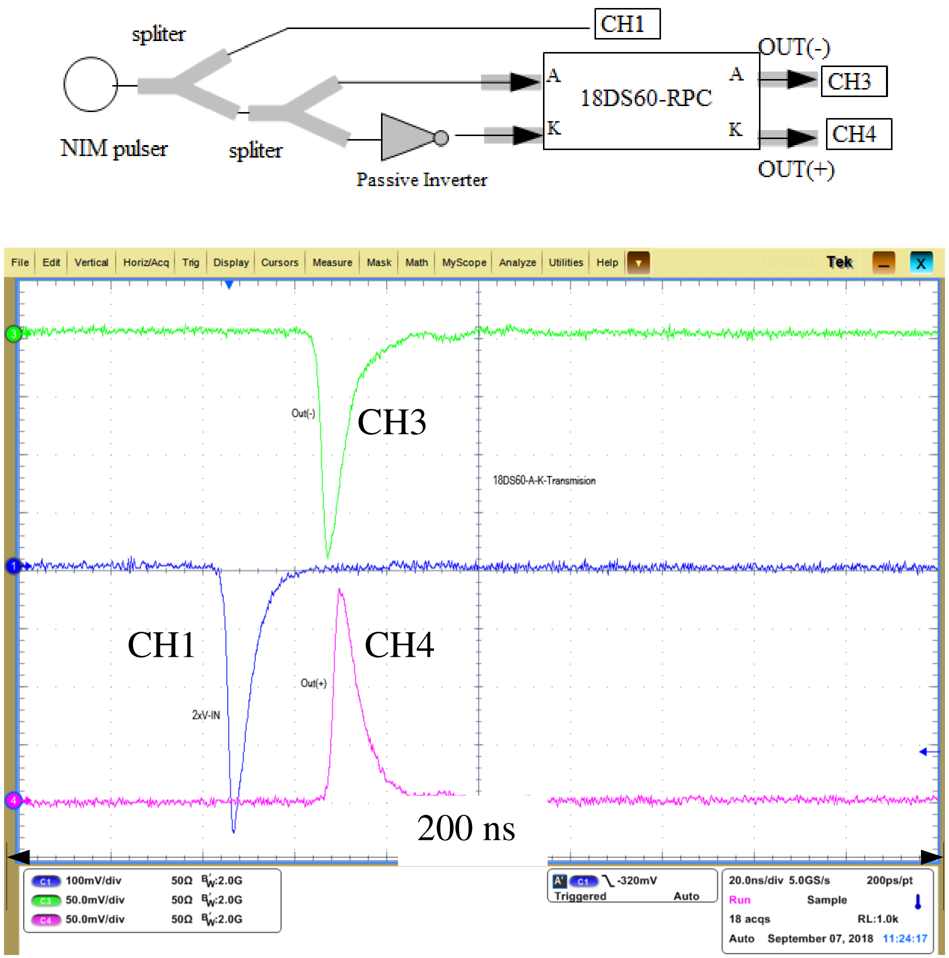


	I_{dark}	Dark rate
RPC1	< 1 nA	0.43 Hz/cm²
RPC2	< 1 nA	0.46 Hz/cm²

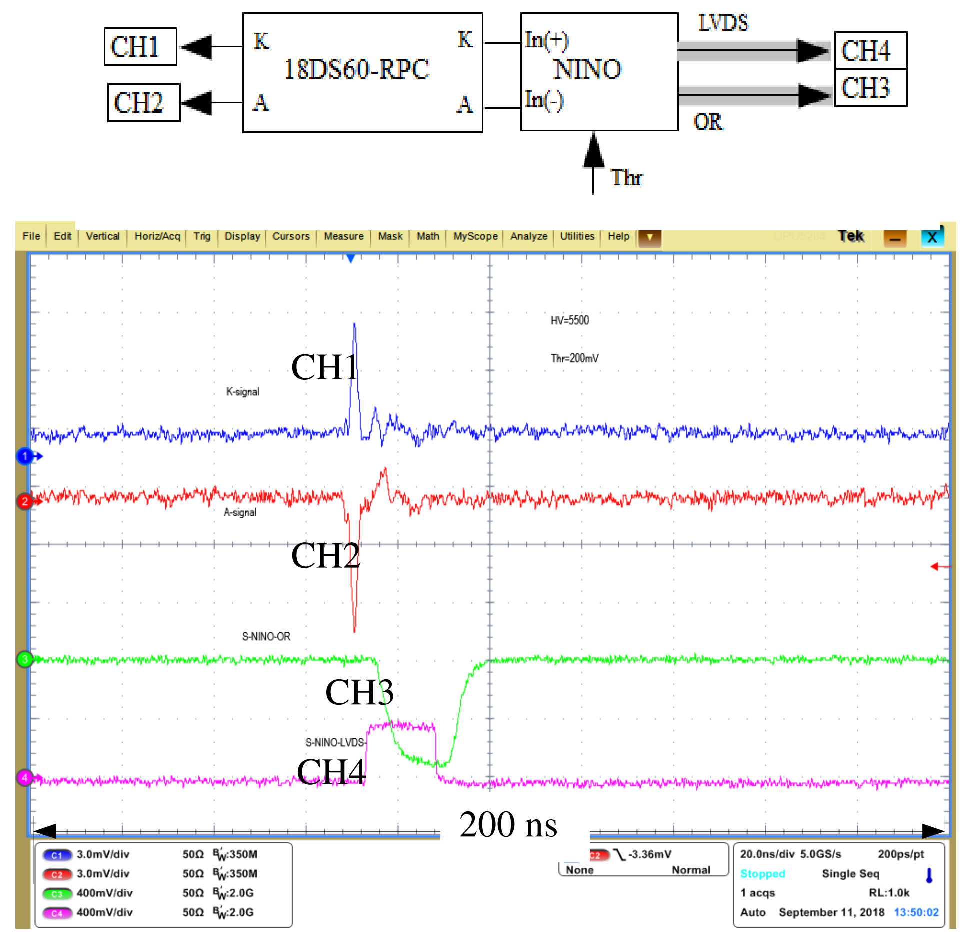
for each RPC:

- **16 operated strips, readout at both ends**
- **(16 x 0.902 cm) x 6 cm = 86.6 cm² operated area**
- **HV = ± 5500 V**
- **NINO FEE + CAEN TDCs**
- **NINO Threshold = 160 mV**
- **Gas mixture: 90% $C_2H_2F_4$ + 10% SF_6**

Tests for reflections

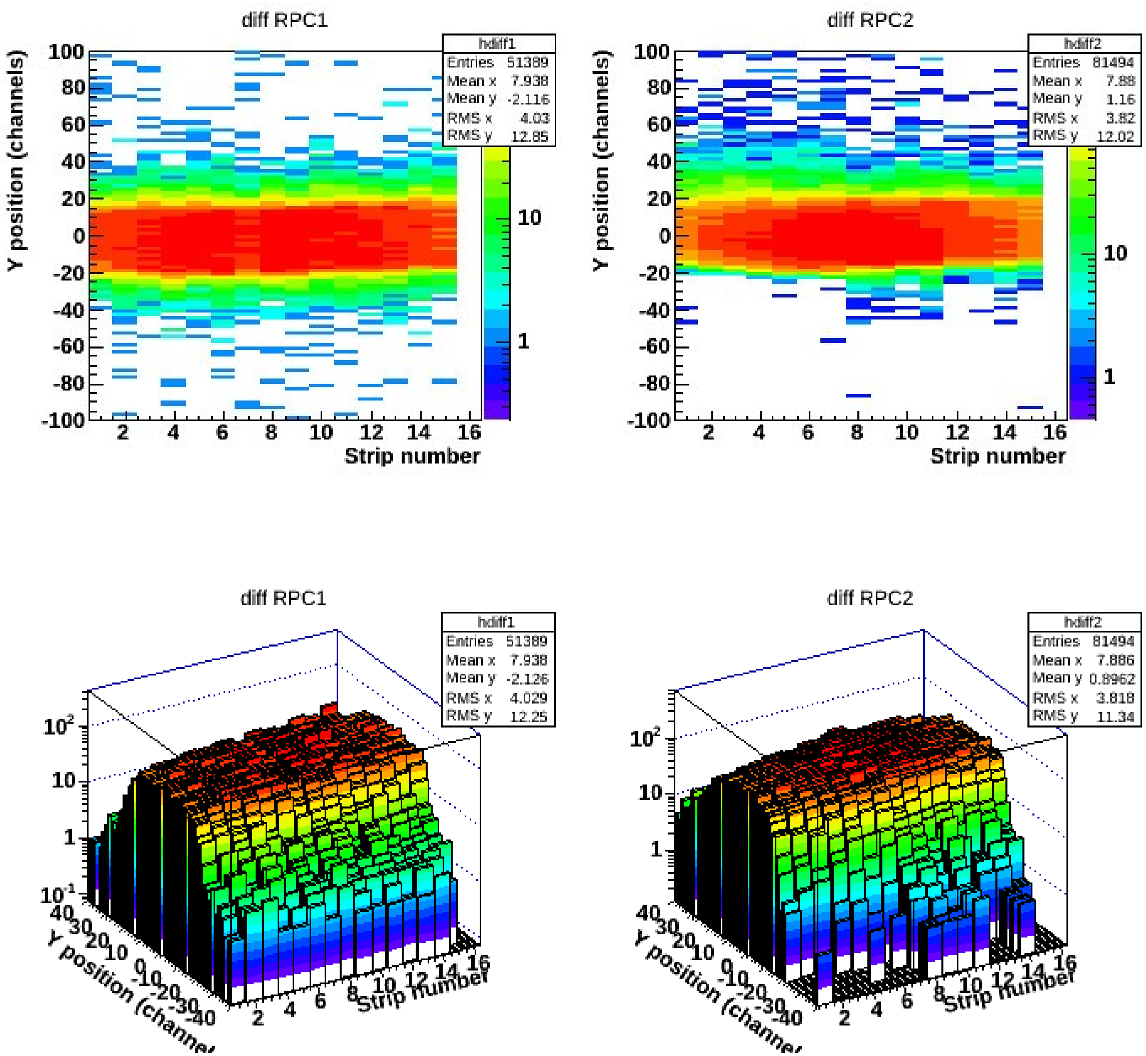


Pulser test

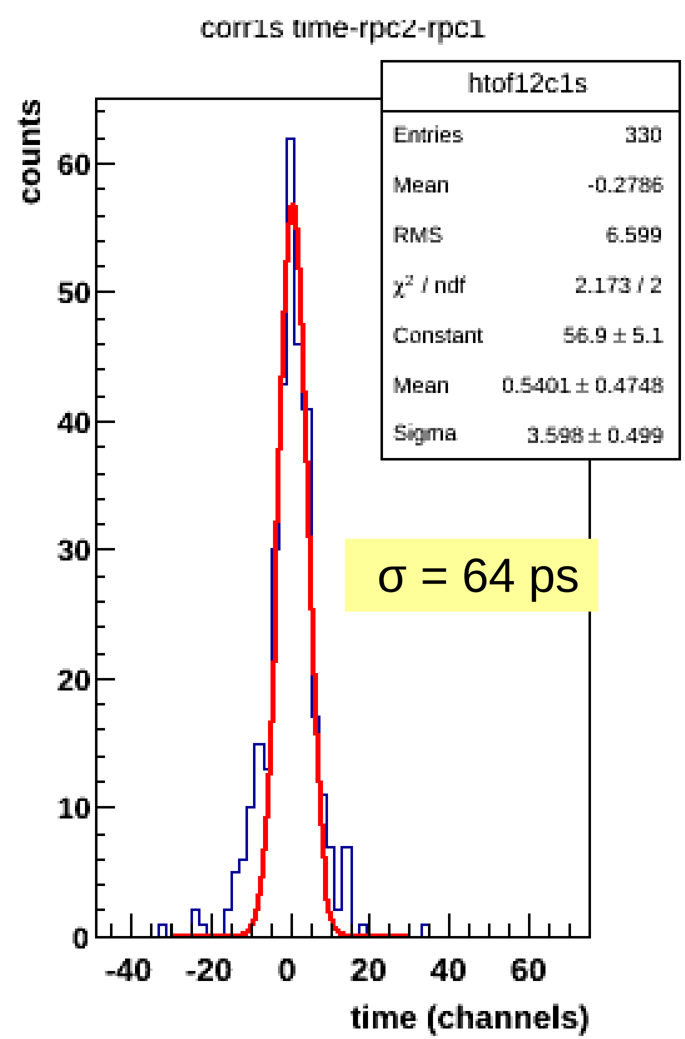


Cosmic – ray signal

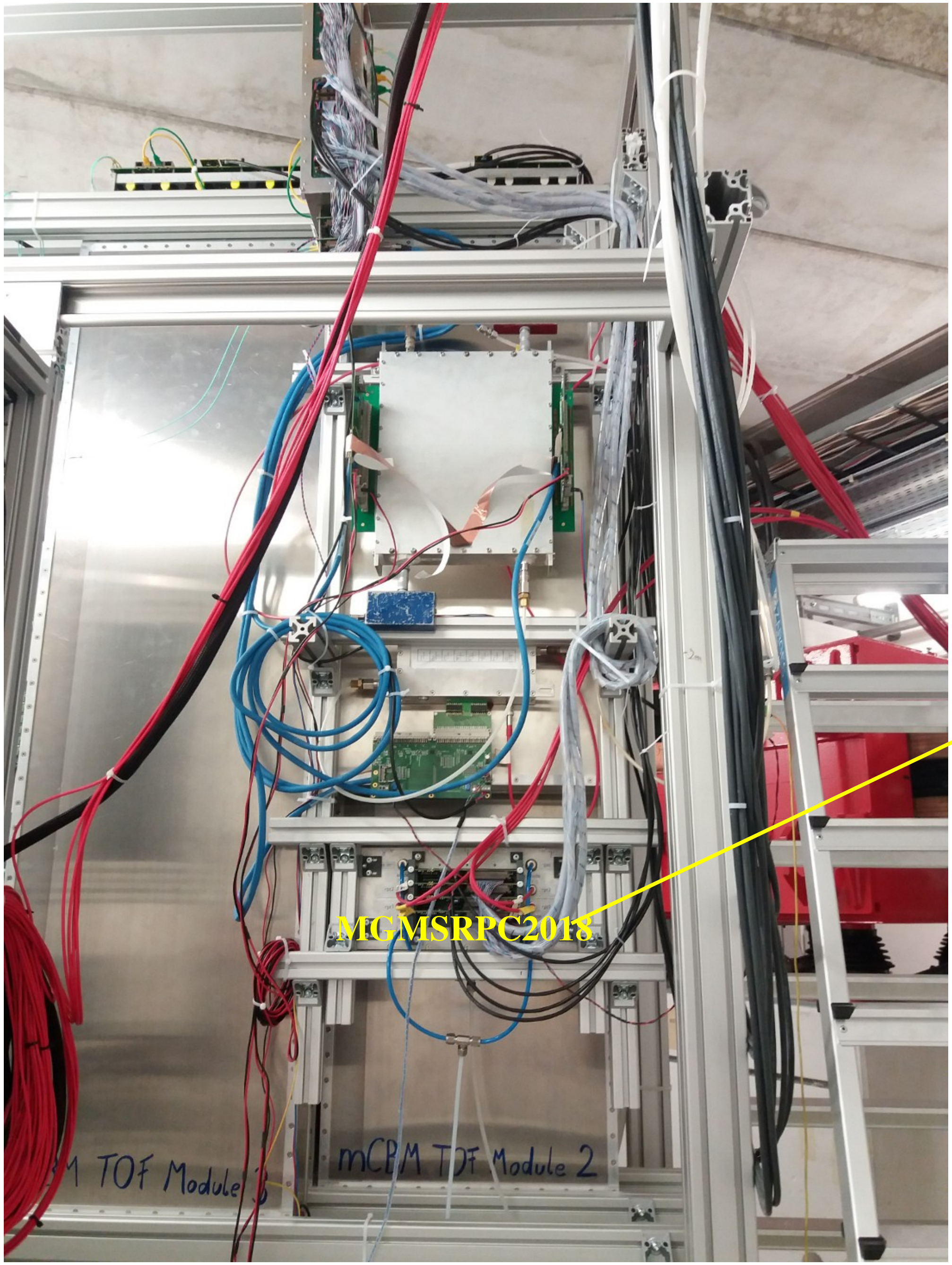
In-house cosmic – ray test of MSMGRPC2018 prototype



Efficiency = 95%

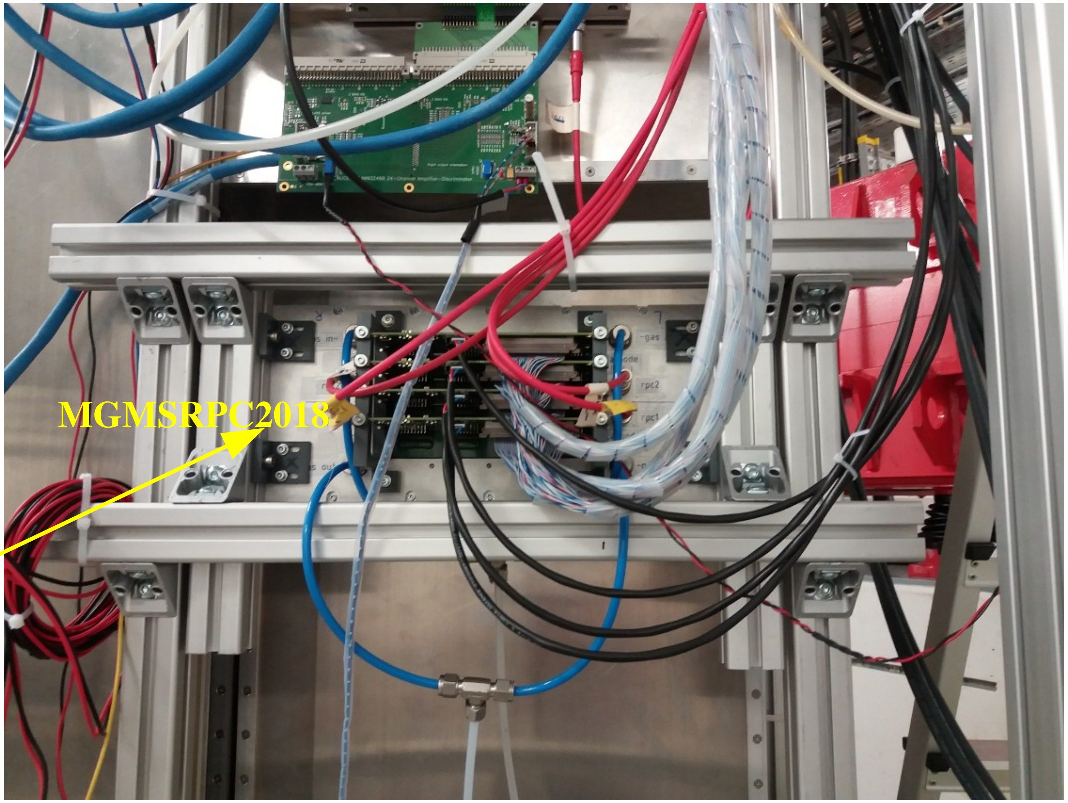


March 2019 in-beam test in the mCBM setup @ SIS18/GSI



Beam: ^{107}Ag of 1.6 GeV/u on Au target

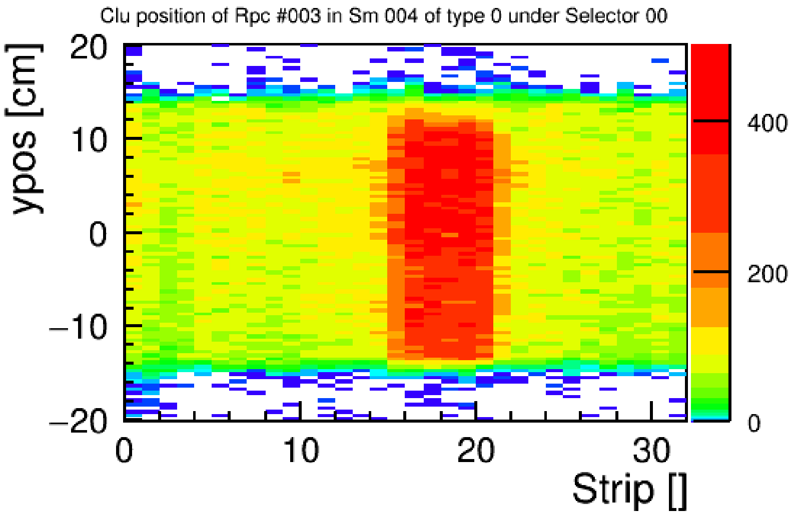
Readout: PADIX + GET4, free-streaming DAQ

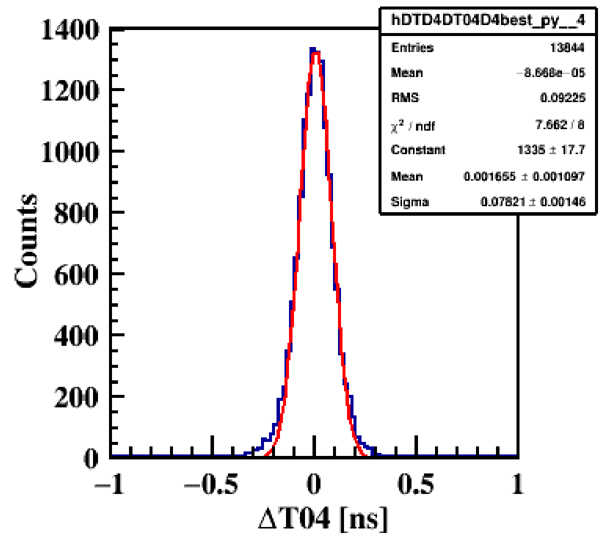


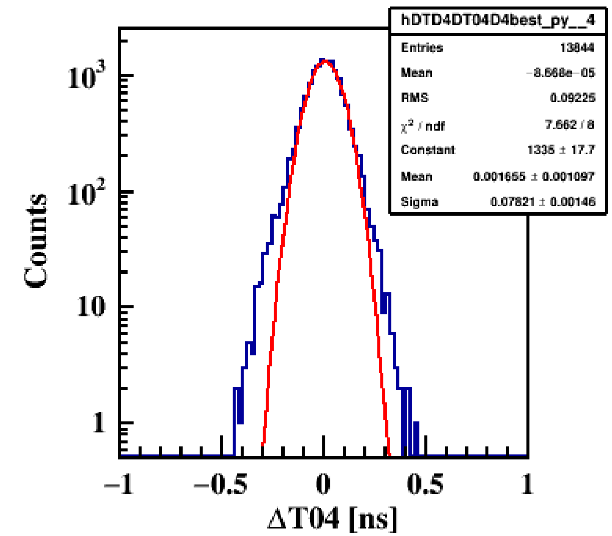
- Threshold scan @ given high voltage
- High voltage scan at given threshold
- High rate scan at given high voltage and threshold:

  from low rate: I_{RPC}= 0.15 μA to 'high rate': I_{RPC} = 3.5 μA

Preliminary results of mCBM beam time





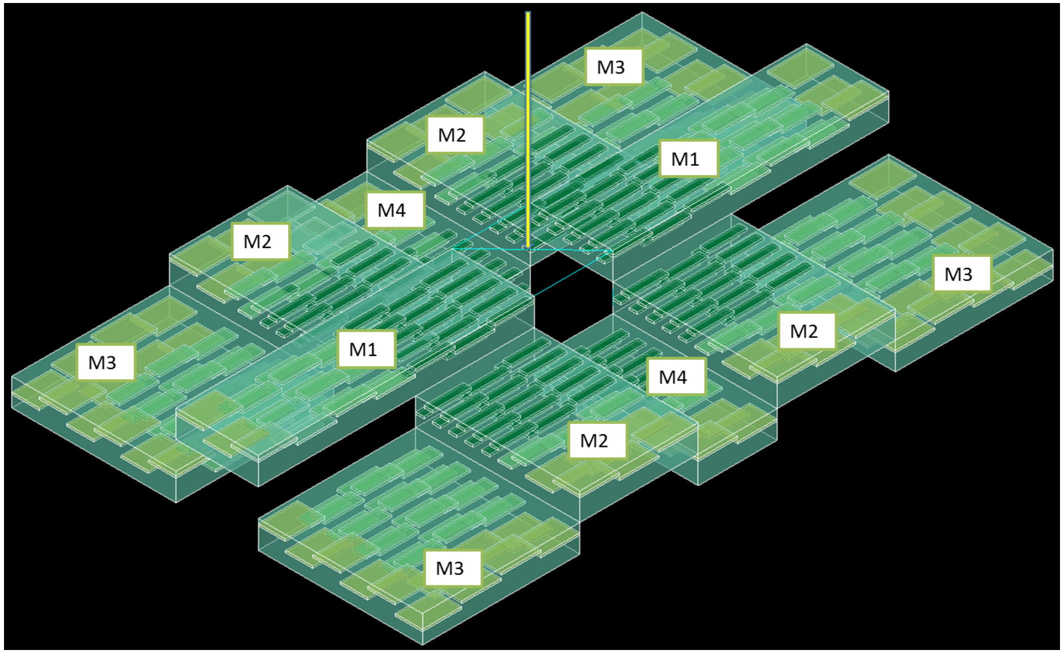


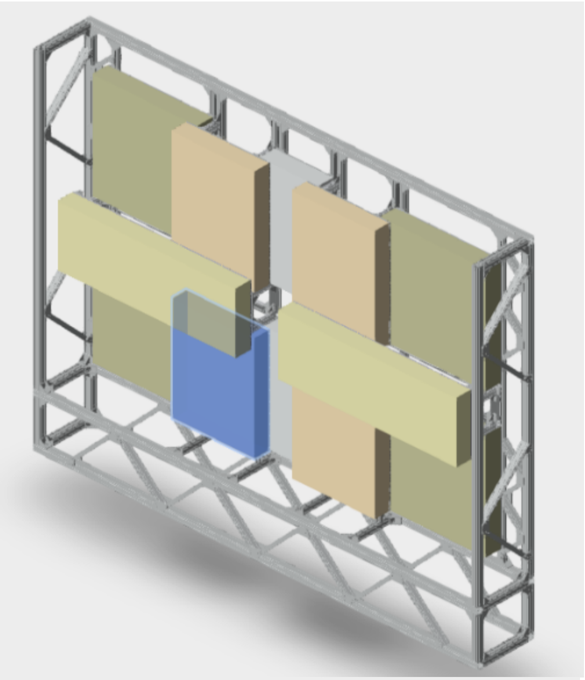
Projection of the MSMGRPC2018 on a CBM-TOF outer-wall counter

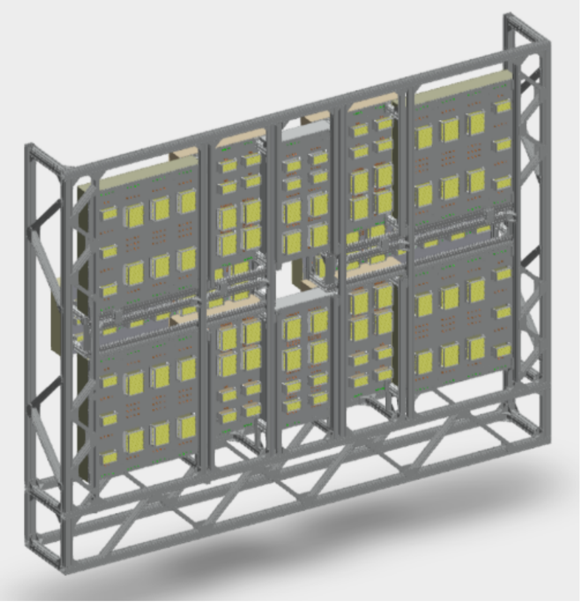
σ_{system} = 78 ps

$\sigma_{counter}$ = 55 ps

Cbm-TOF Inner Wall Design







CBM-TOF inner zone

- ~15 m^2 active area

- 12 modules of 4 types (M1, M2, M3, M4)

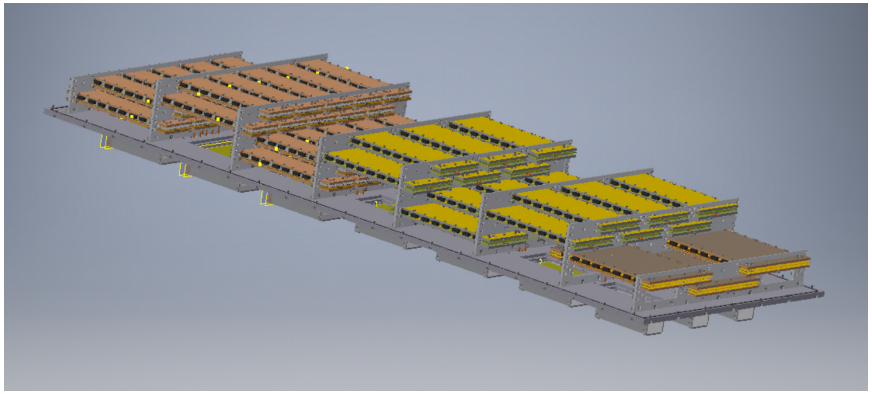
- 470 MGMSRPC counters with 0.9 mm strip pitch,

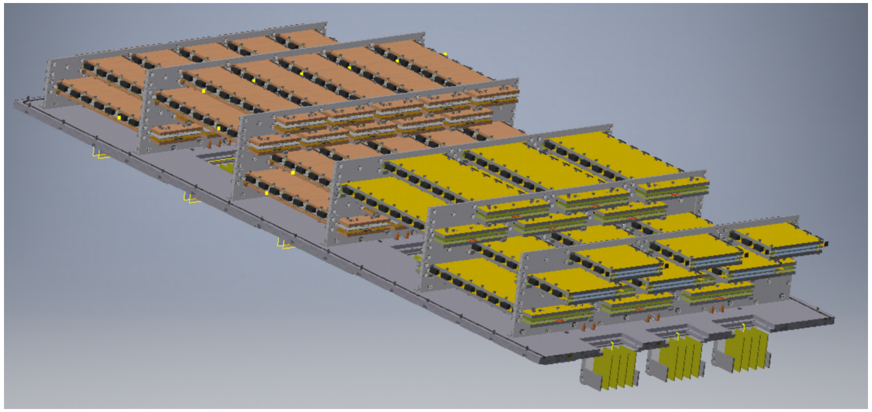
of 3 types (60 mm (1a), 100 mm (1b) and 200 mm (1c) strip length)

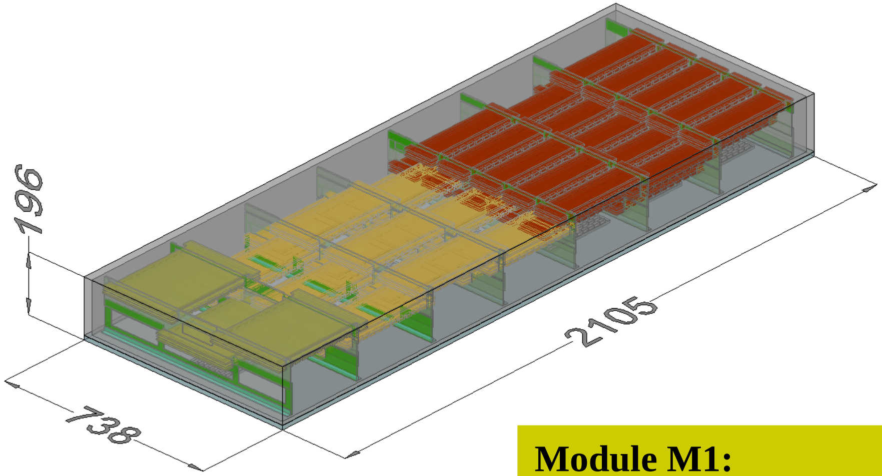
- 30 080 readout channels

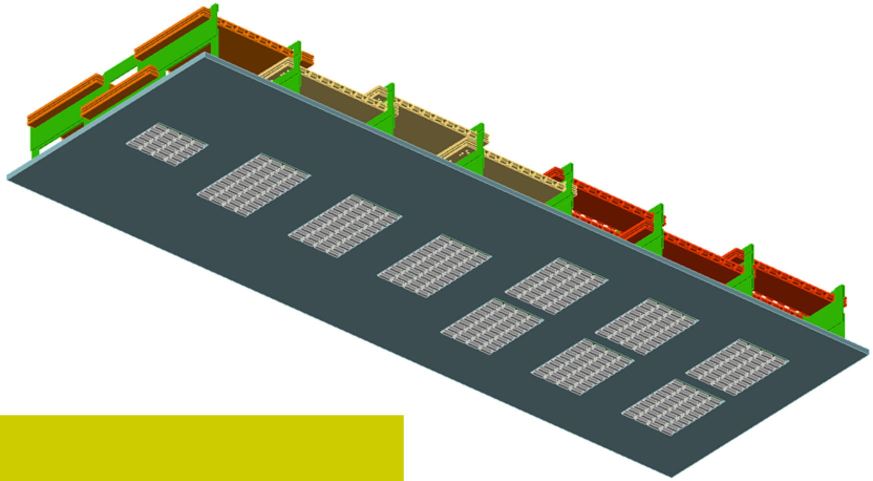
Cbm-TOF Inner Wall Design

Module M1









Module M1:

- 51 MGMSRPC counters: (30 (1a), 18 (1b), 3 (1c))

- 3264 readout channels

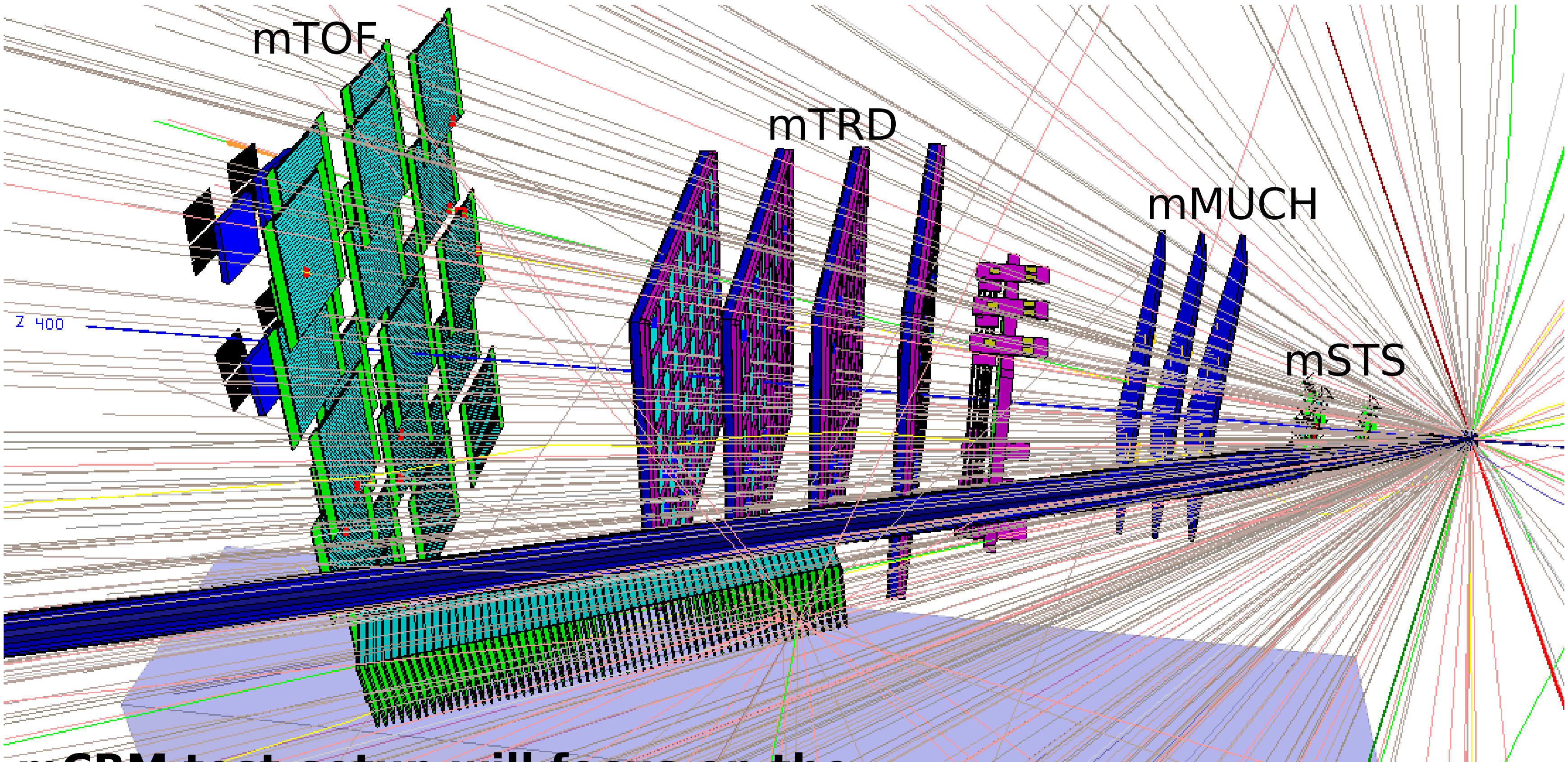
Conclusions & Outlook

- **A method to tune the MSMGRPC signal transmission line impedance such to match the input impedance of the corresponding front-end electronics was developed, exploiting the MSMGRPC architecture developed in our group. The required matching can be achieved independent on the adjustment of the MSMGRPC granularity.**
- **Performance of the prototypes based on this method was confirmed by the in-beam test results.**
- **Inner-zone of the CBM-TOF subsystem will be based on such architecture.**
- **Assembling of a full size module will start in the near future.**

Back-up slides

mCBM@SIS18

- **a CBM full system test 2018 – 2021 in high-rate nucleus-nucleus collisions at GSI/FAIR**



mCBM test-setup will focus on the
- test of final detector prototypes
- free streaming data transport to a computer farm
- online reconstruction and event selection
- offline data analysis