Toward the construction of the inner zone for the CBM-TOF wall

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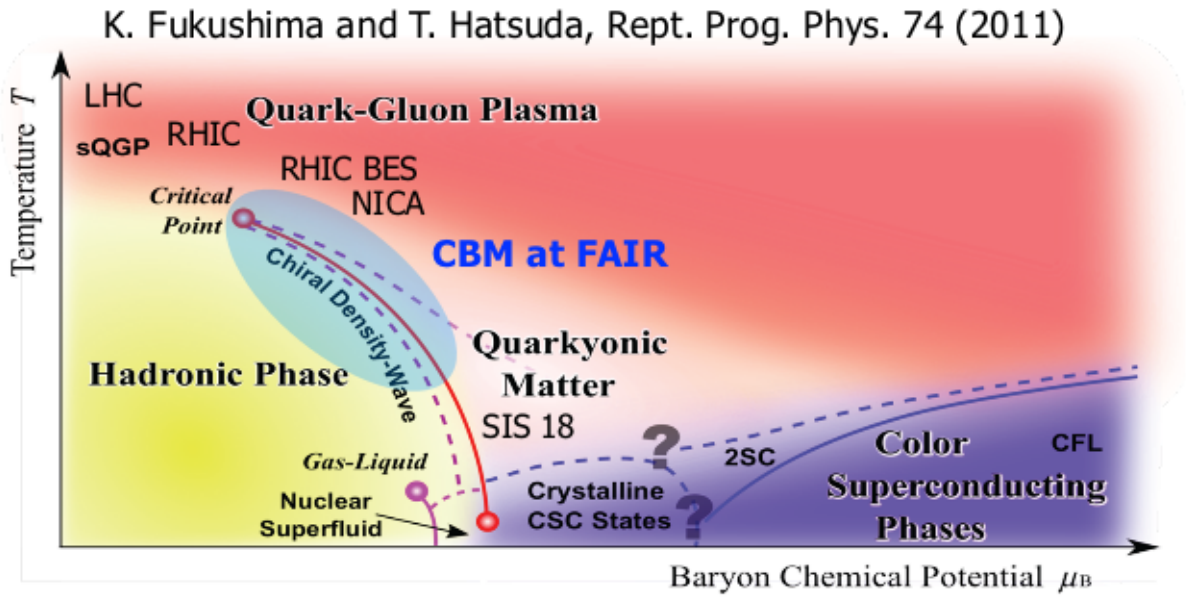
Outline

- 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
- Towards the construction of the CBM-TOF inner zone: infrastructure and expertise
- Conclusions and Outlook

Mapping the phase diagram with CBM



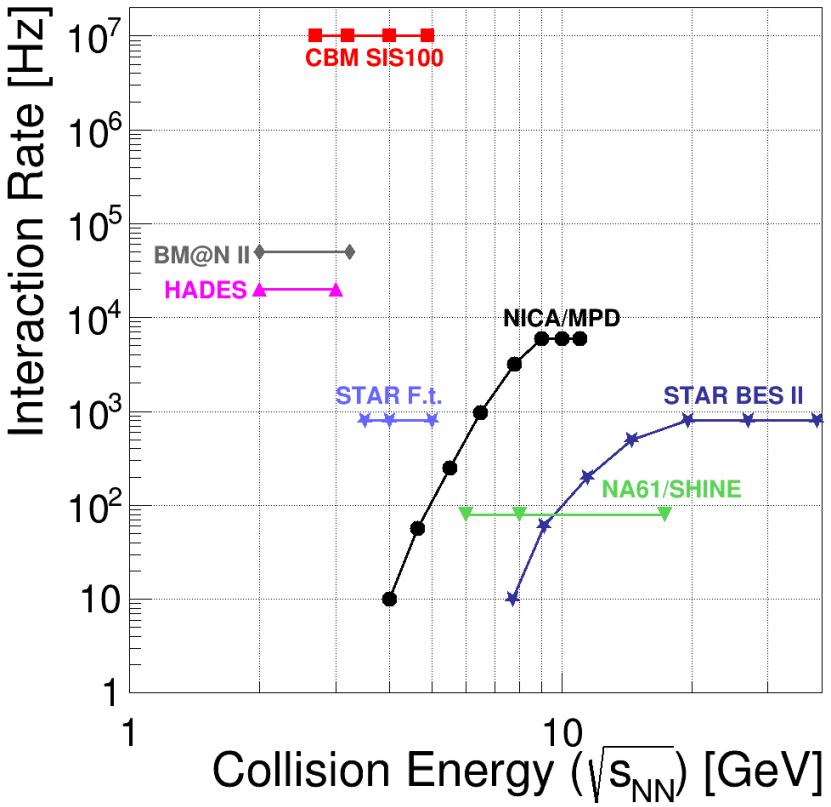
CBM aims to investigate strongly interacting matter in the region of high net baryon densities.

Investigation of:

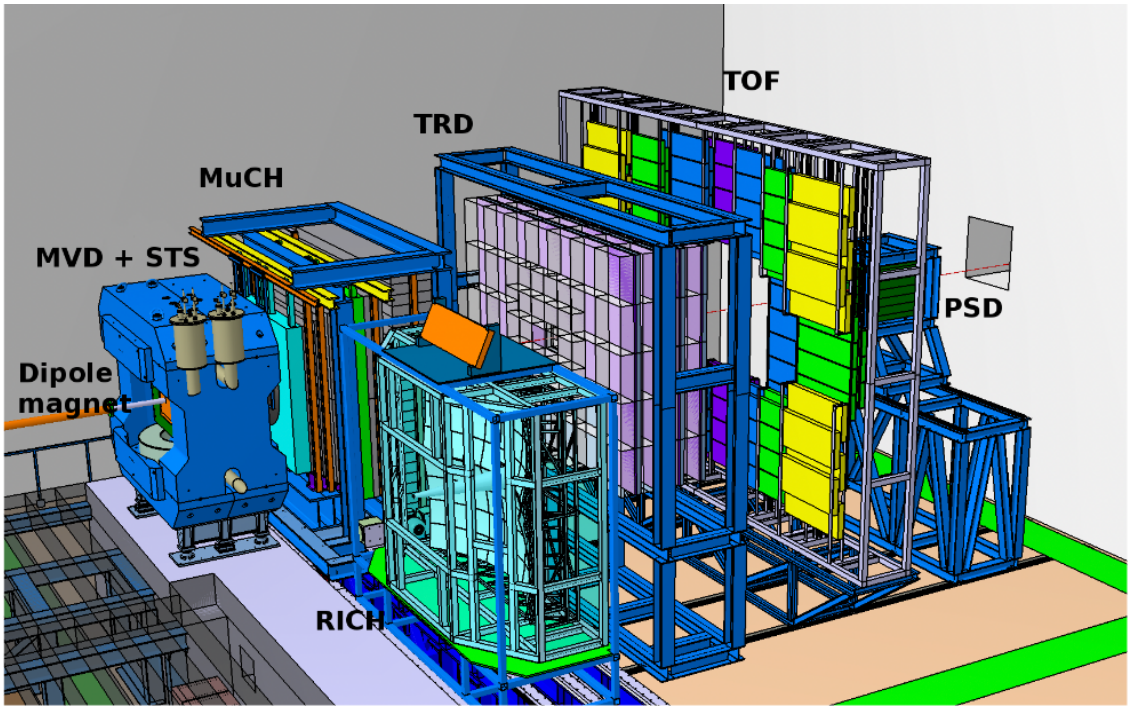
- **equation of state at high baryonic densities**
- **hadronic – partonic phase transition and its type**
- **possible critical point predicted by QCD**

SIS100 beam	Plab, max	$\sqrt{(s_{NN,max})}$
Heavy ions (Au)	11A GeV	4.7 GeV
Light ions (Z/A=0.5)	14A GeV	5.3 GeV
protons	29 GeV	7.5 GeV

Experiments exploring dense QCD matter



CBM experiment @ SIS100/FAIR



CBM will perform comprehensively high precision measurements of rarely produced observables. Multi-differential studies of rare probes (<1 particle per million events) require unprecedent statistics. Opens up new possibilities!

- ✓ **Hadrons in dense baryonic matter and possible modification of their properties;**
- ✓ **Charm production at threshold beam energies and its properties in dense baryonic matter.**

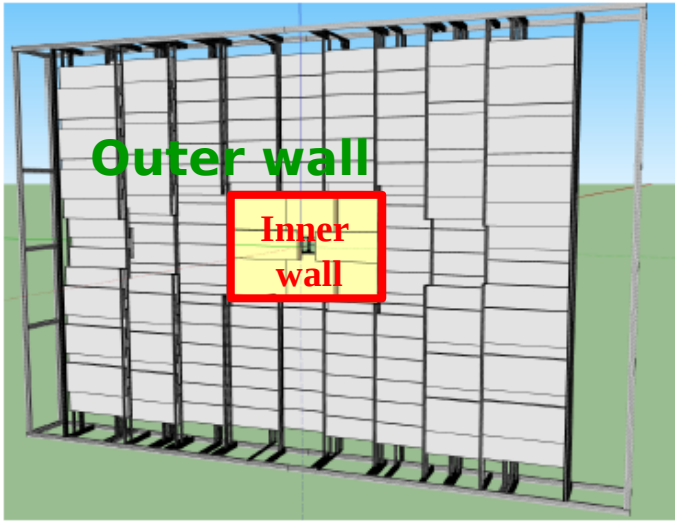
CBM Collaboration, Eur. Phys. J. A (2017) 53: 60

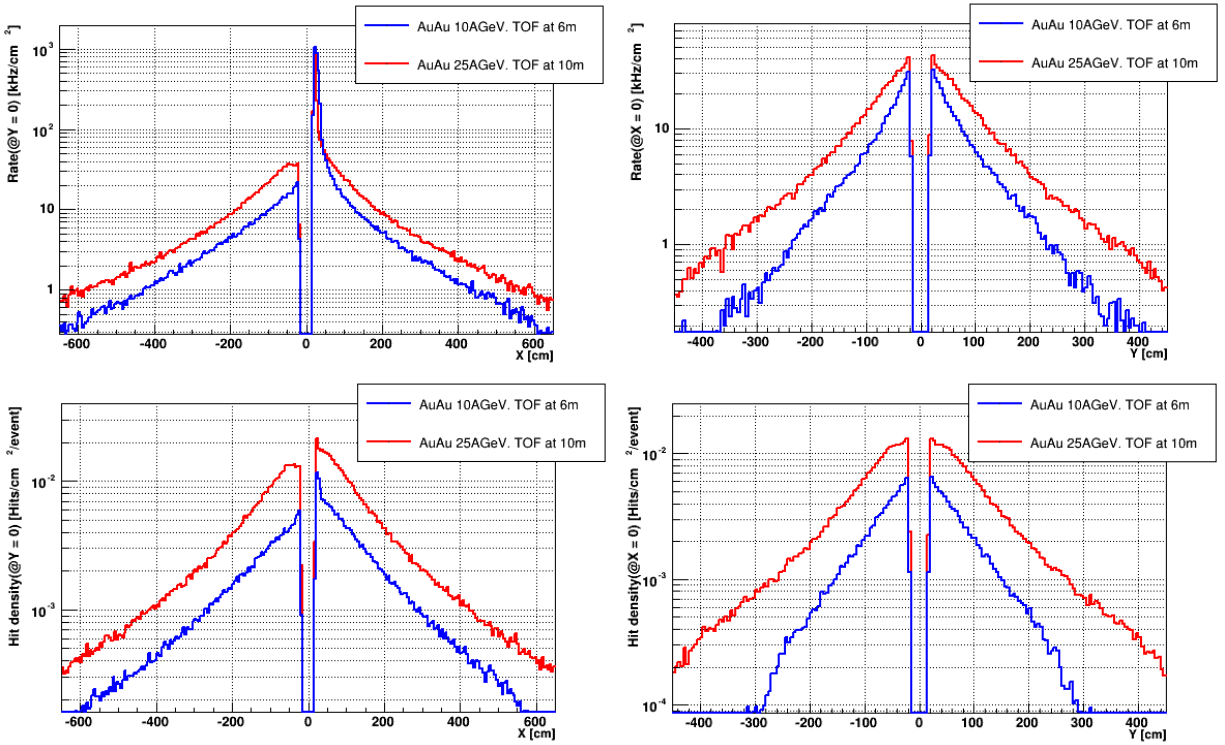
CBM: is a high rate experiment!

- ➢ **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**

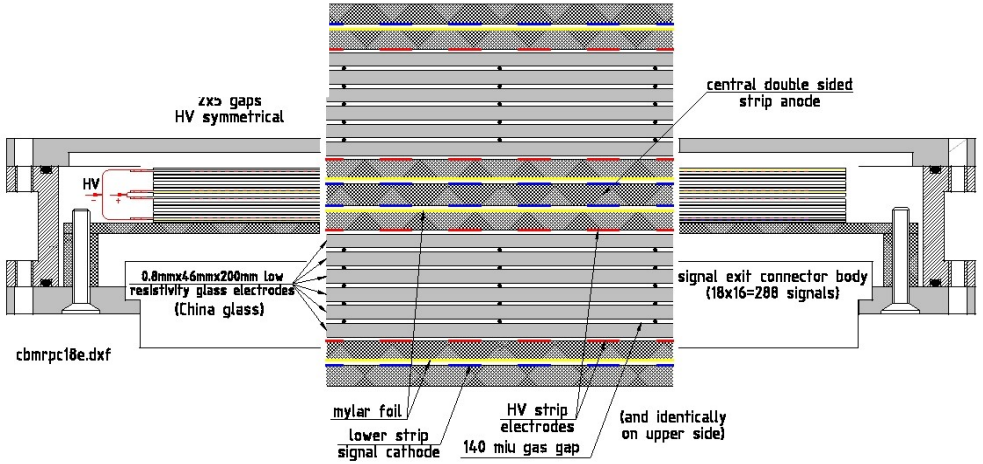
CBM Collaboration, "CBM – TOF Technical Desing Report", October 2014

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:

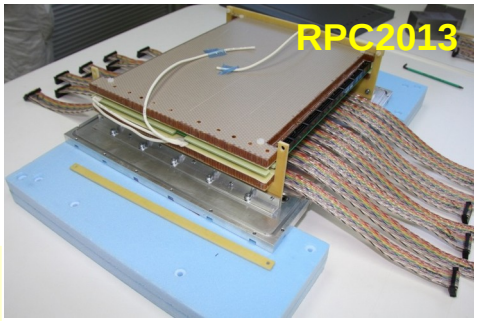
Electrodes: low resistivity (~10^{10}Ωcm) Chinese glass

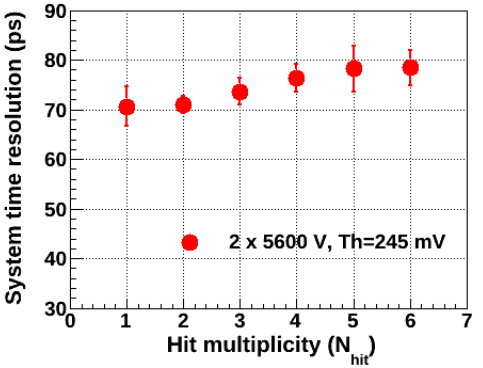
Gap size: 140 μm thickness

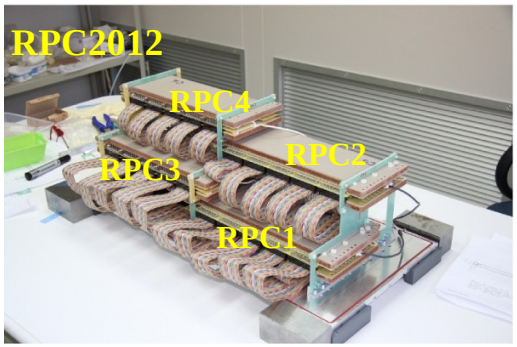
Symmetric two stack structure: 2 x 5 gas gaps

Strip geometry for both readout and high voltage electrodes

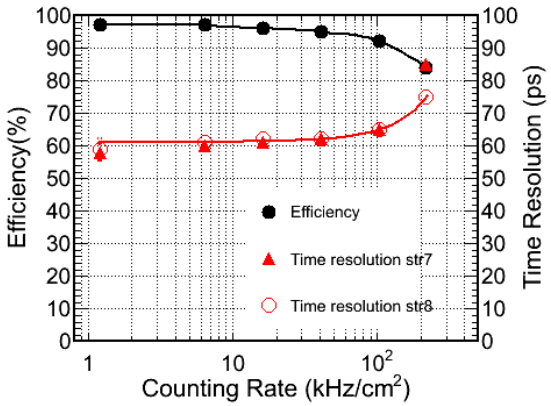
Differential readout





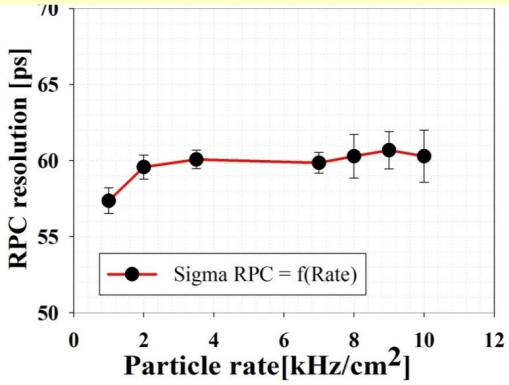


Focused p beam, 2.5 GeV/c @ COSY Julich



- ✓ **Active area 200 (strip length) x 266 mm^2**
- ✓ **Resistive electrodes: 1 mm**
- ✓ **4.2 mm strip pitch=2.16 mm (w) +2.04 mm (g)**
- ✓ **100 Ω transmission line impedance**
- ✓ **Anode architecture: Cu strips between two 0.25 mmFR4 layers**

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



- ✔ ***Active area: 46 (strip length) x 180 mm^2***
- ✔ **Resistive electrodes: 0.7 mm**
- ✔ ***2.54 mm pitch =1.1 mm(w)+1.44 mm (g)***
- ✔ ***100 Ω transmission line impedance***

- ✔ **Active area: 96 (strip length) x 300 mm^2**
- ✔ **Resistive electrodes: 0.7 mm**
- ✔ **7.4 mm pitch = 5.6 mm(w) + 1.8 mm(g)**
- ✔ **50 Ω transmission line impedance**

M.Petrovici et al. JINST 7 P11003, 2012

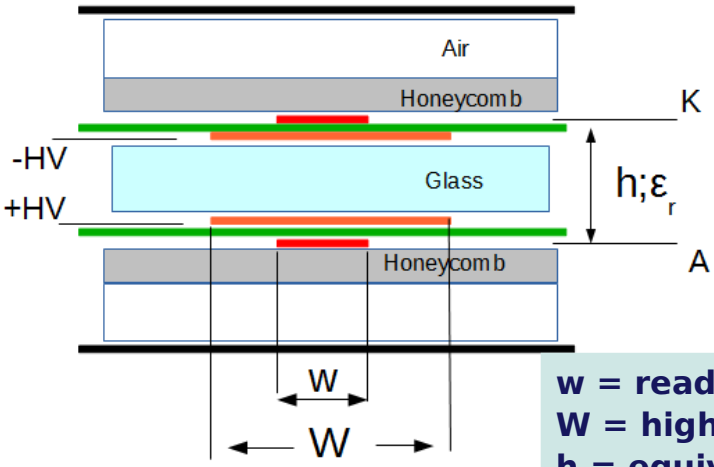
M. Petris et al., Journal of Phys: Conf. Series 533 (2014) 012009

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

M.Petris et al. JINST 11 C09009, 2016

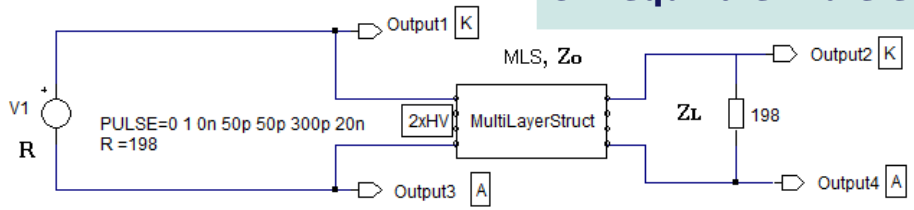
Method to adjust the signal transmission line impedance in MSMGRPCs

- 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 materials in between
- APLAC software used for impedance estimations



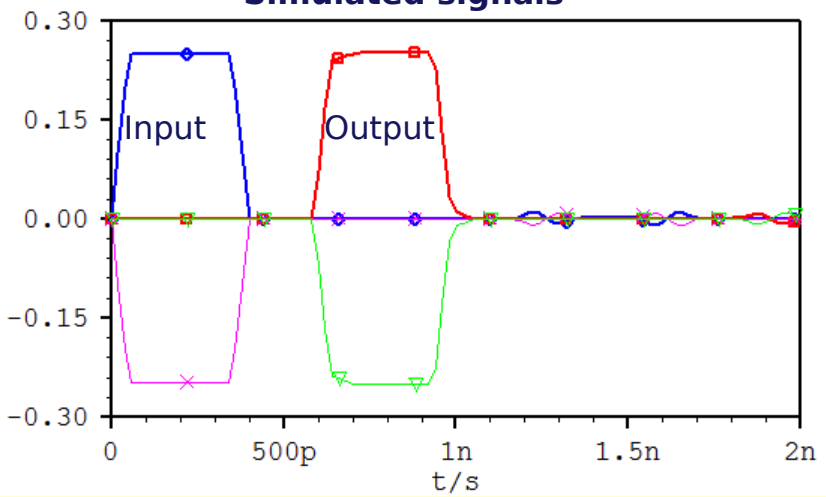
$$Z_0 = \sqrt{\left(\frac{L}{C}\right)}$$

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

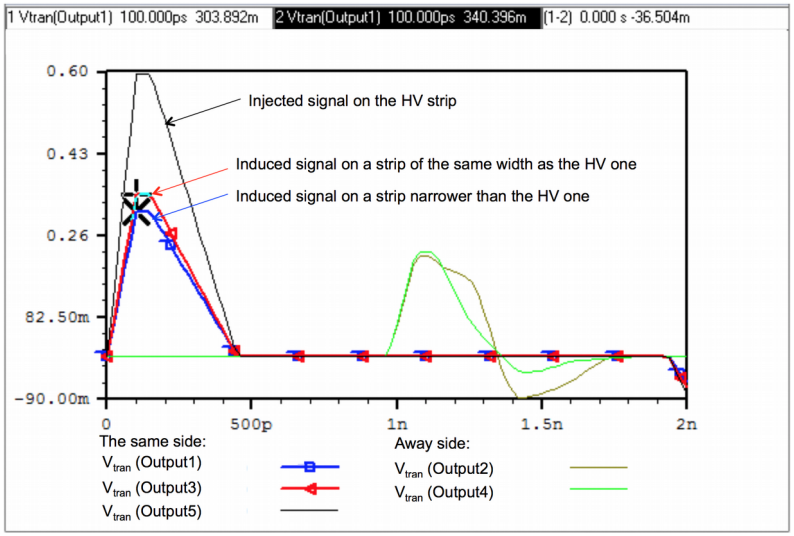


If R = Z_0 = Z_L the transmission line is matched;
Z_0 = characteristic impedance of a transmission line
Z_L = load resistor connected to the transmission line
R = internal resistance of the pulse generator

Simulated signals



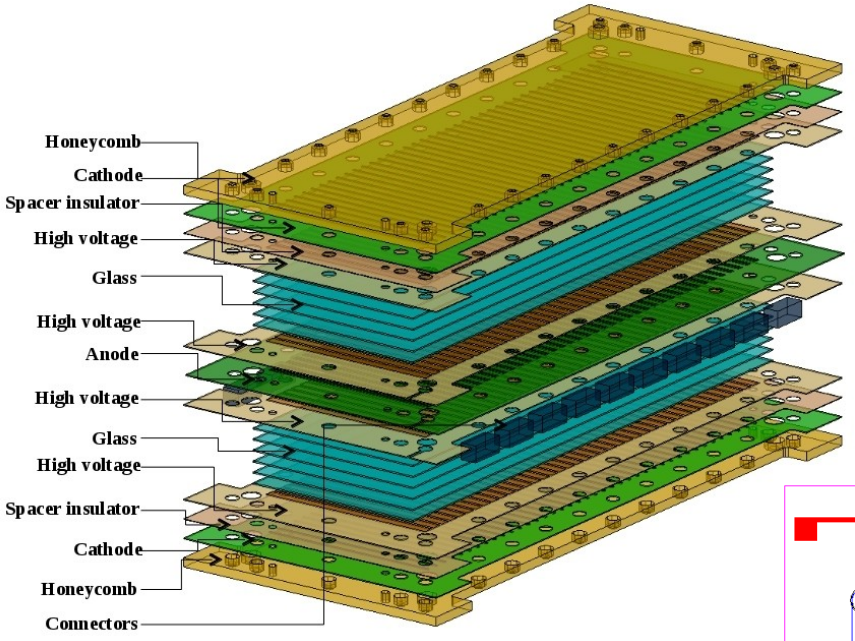
Input/Output signals are simulated using APLAC for different values of the readout strip width



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)

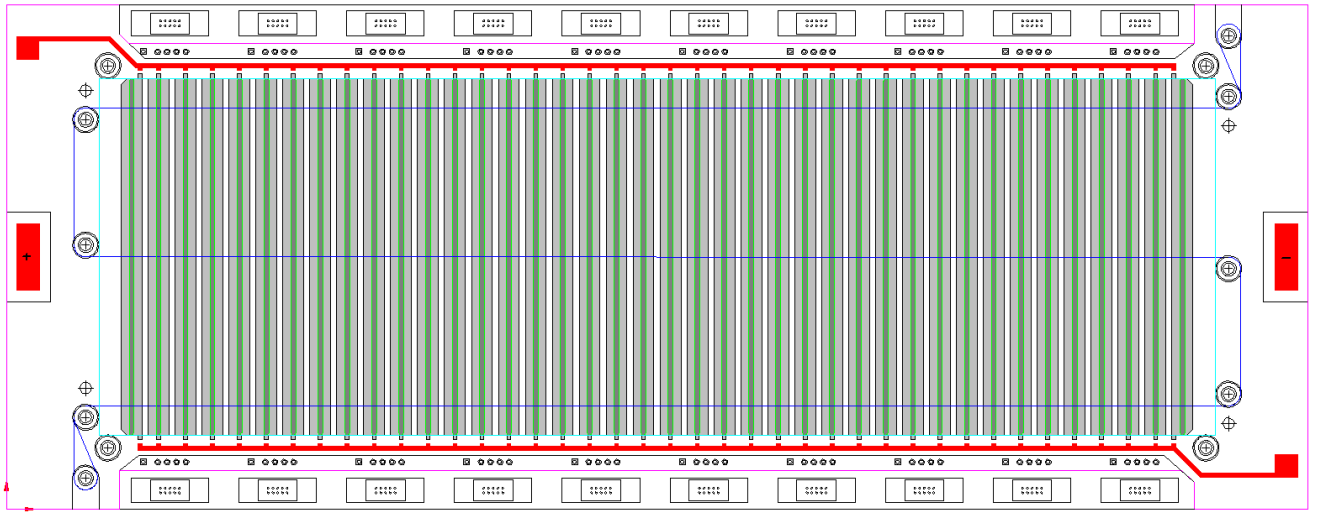
RPC2015DS prototype - strip impedance tuned through the readout strip width



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.

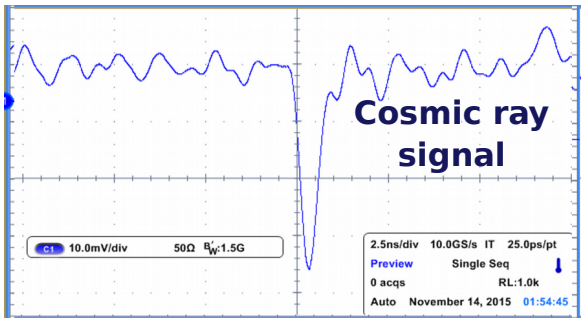
Simulations predicted ~99 Ω impedance for 1.3 mm readout and 5.6 mm high voltage strip widths

- ✓ 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



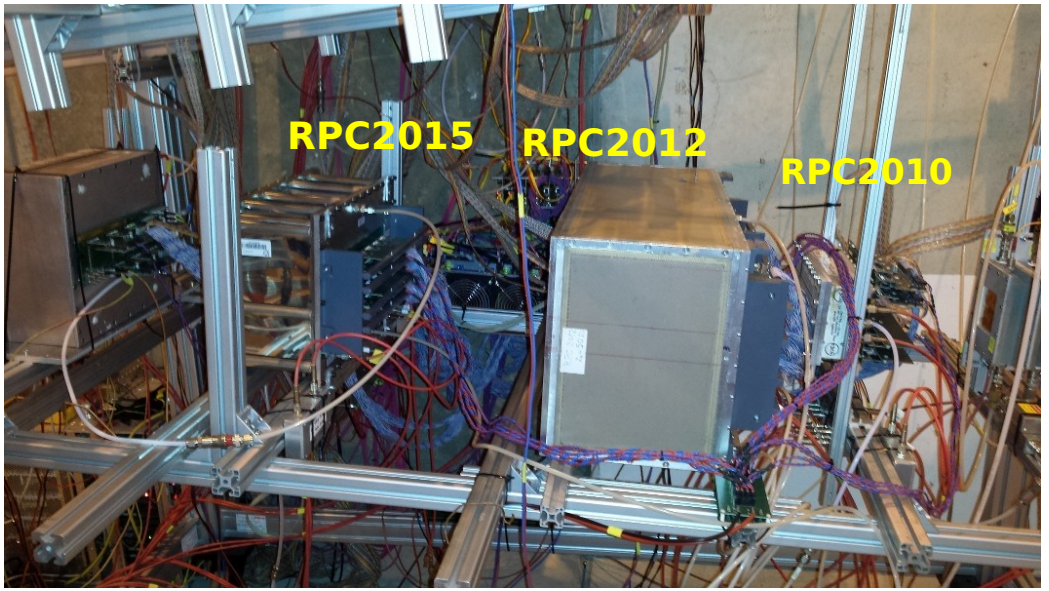
Readout electrode: 7.2 mm pitch= 1.3 mm width + 5.9 mm gap – define impedance

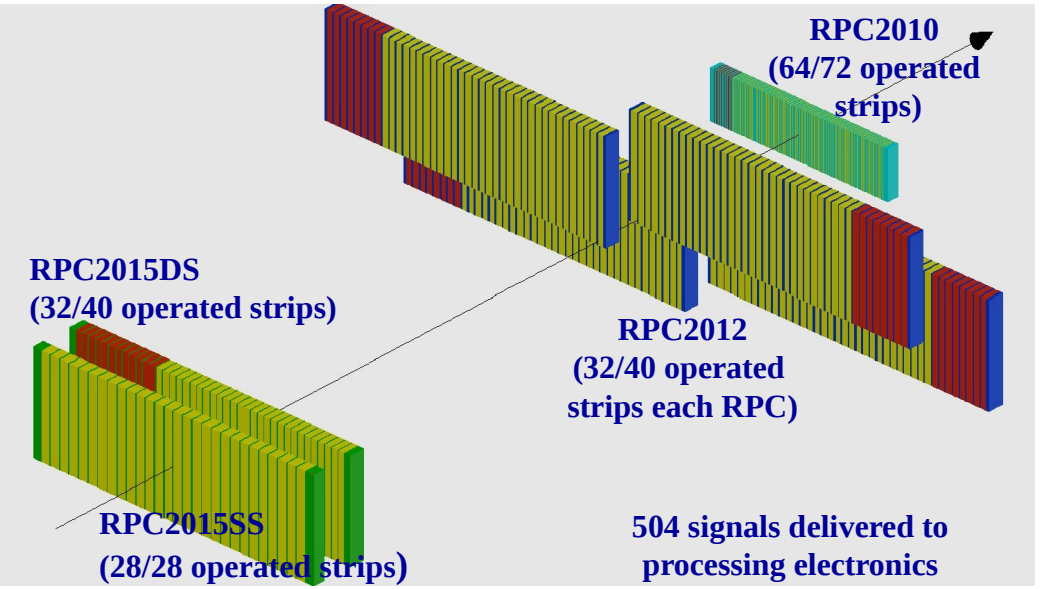
High Voltage electrode: 7.2 mm pitch= 5.6 mm width + 1.6 mm gap – define granularity



In-beam test using a triggered DAQ

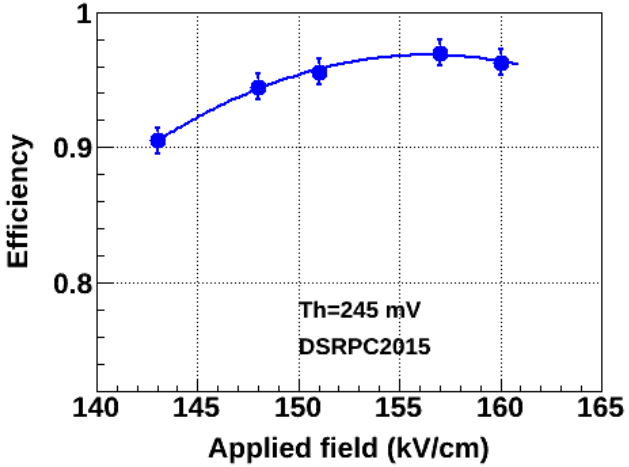
CERN-SPS Pb beam of 30A GeV on a Pb target

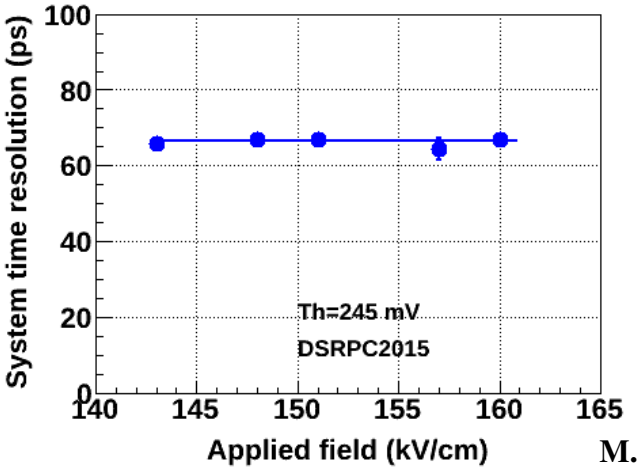




Gas mixture: 85%$C_2H_2F_4$ + 5%iso-C_4H_{10} +10%SF_6

System time resolution (STR) includes contributions of both detector under study and reference counter (including electronics contribution)





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

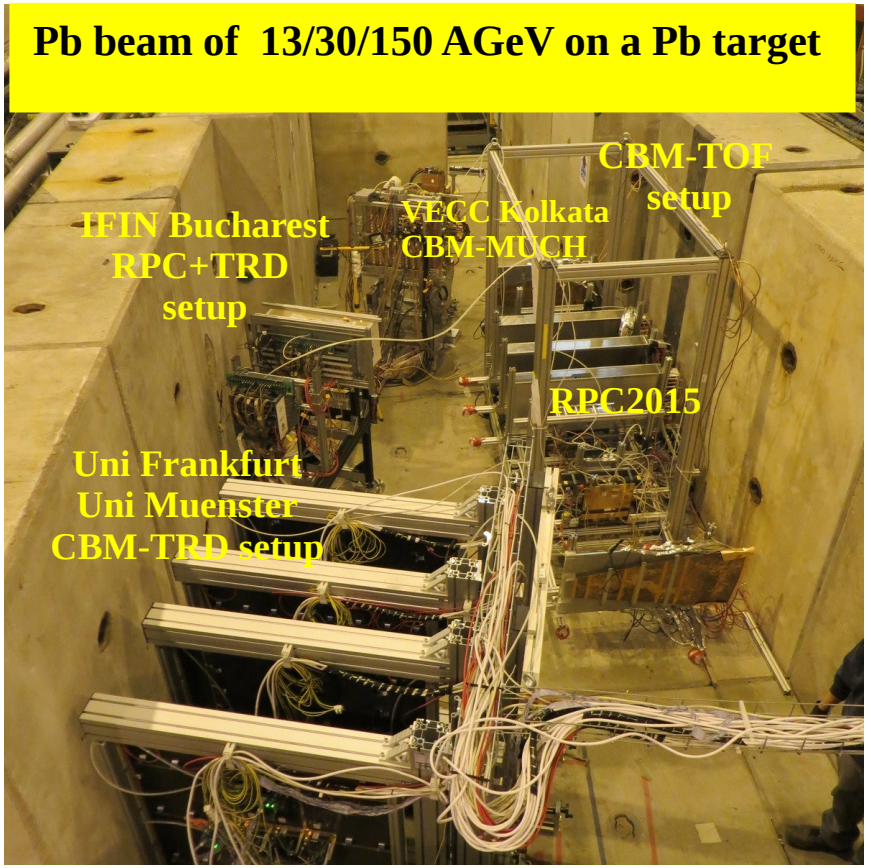
- ✓ System time resolution = 66 ps
- ✓ Single counter time resolution ~44 ps
- ✓ The efficiency plateau is reached @ 96% -97%
- ✓ The cluster size is 2.2 – 2.6 @ efficiency plateau

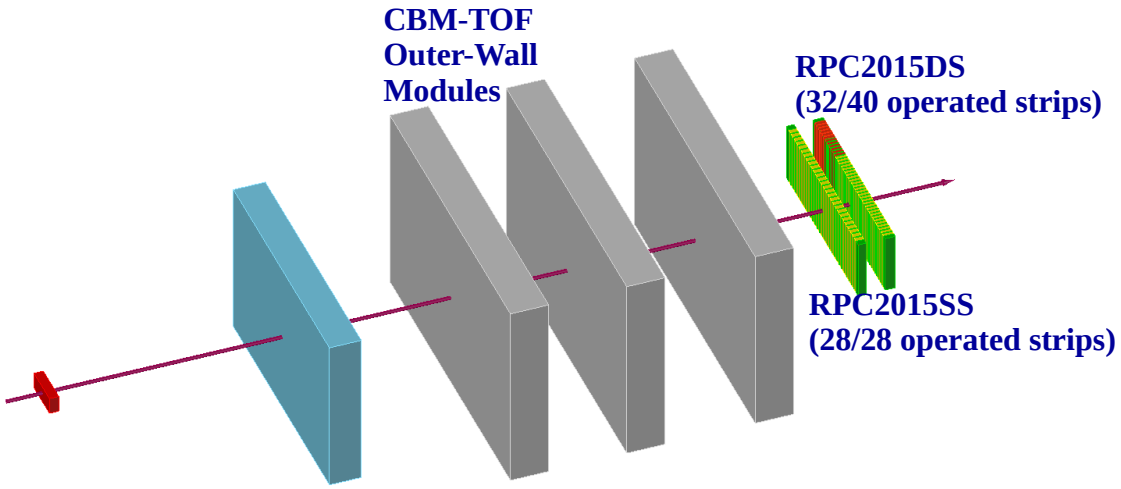
M. Petris et al., Nucl. Instr. and Meth. A 920 (2019), 100

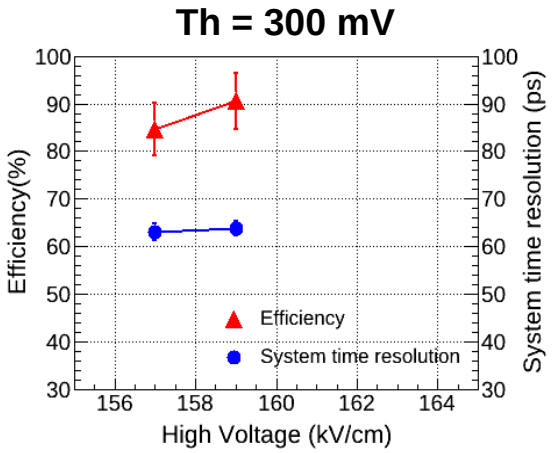
Free - streaming readout

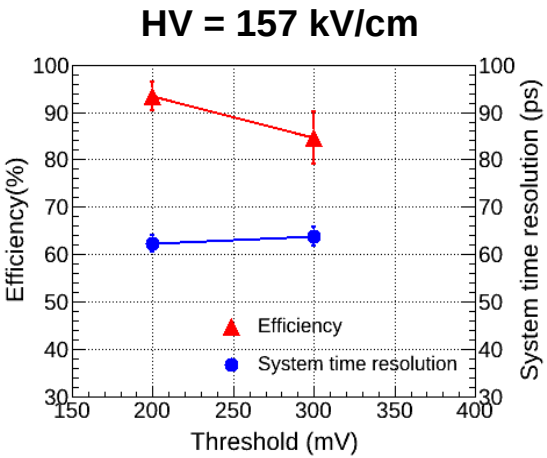
CERN-SPS Fall 2016 in-beam test
First operation of a triggerless DAQ

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)

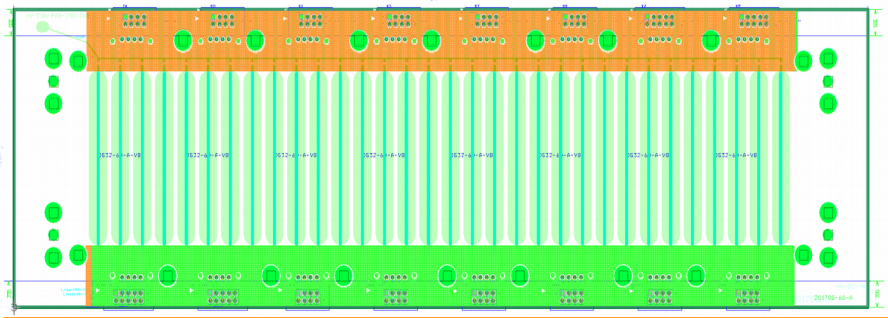
- DAQ: DPB (Data Processing Board) + FLIB (First Level Interface Board)

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

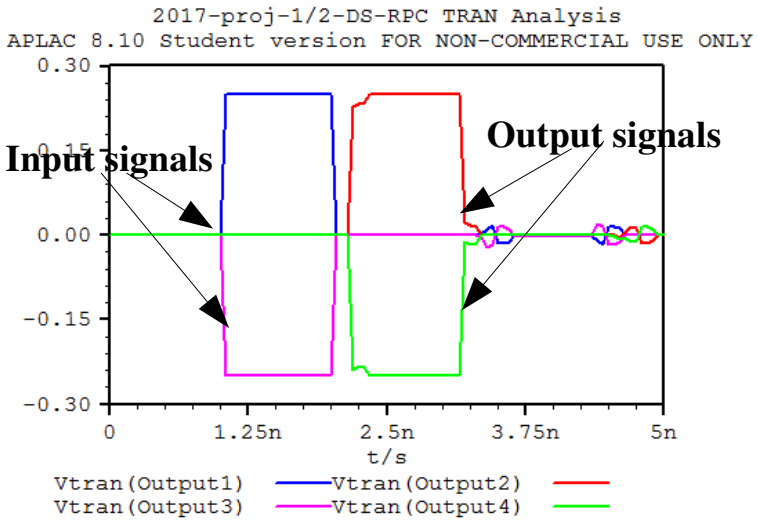
MSMGRPC2018 prototype for the CBM-TOF highest granularity zone

Design

Goal – Electronic channels cost optimization

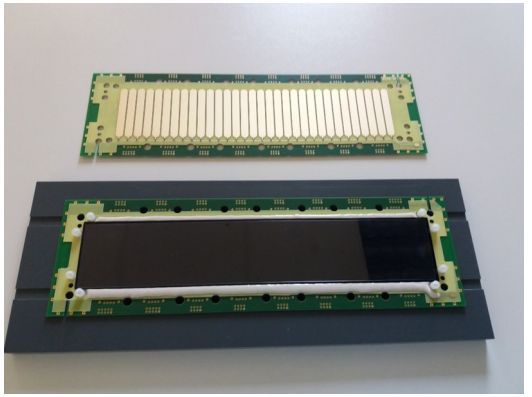


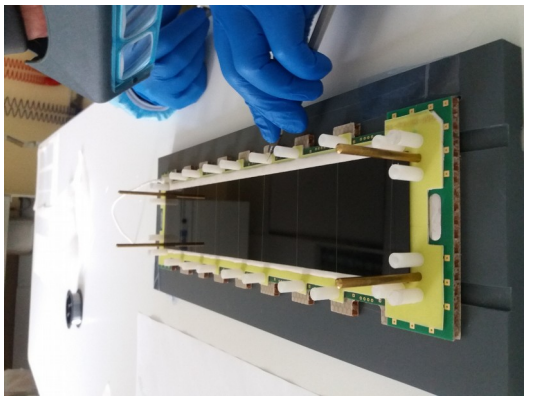
32 strips; 60 mm (strip length) x 300 mm
Readout electrode: 9.02 mm pitch= 1.27 mm w + 7.75 mm g
High Voltage electrode: 9.02 mm pitch= 7.37 mm w + 1.65mm g

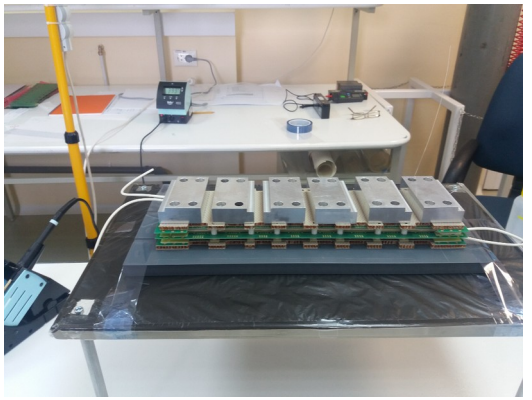


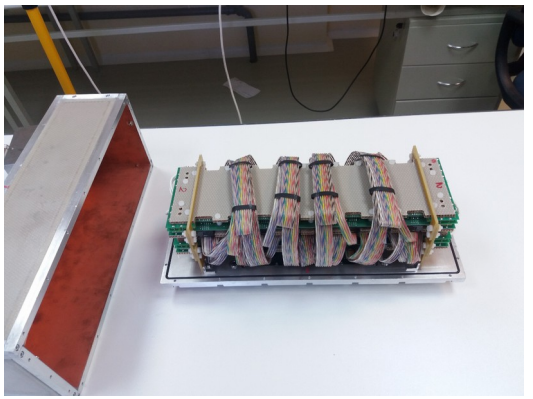
APLAC predicted ~97 Ω for
1.27/7.37 mm readout/HV strip width

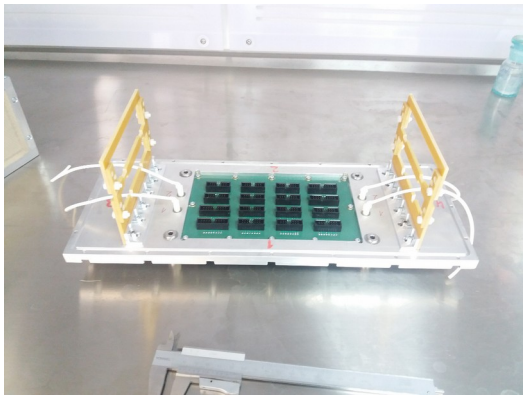
Assembling





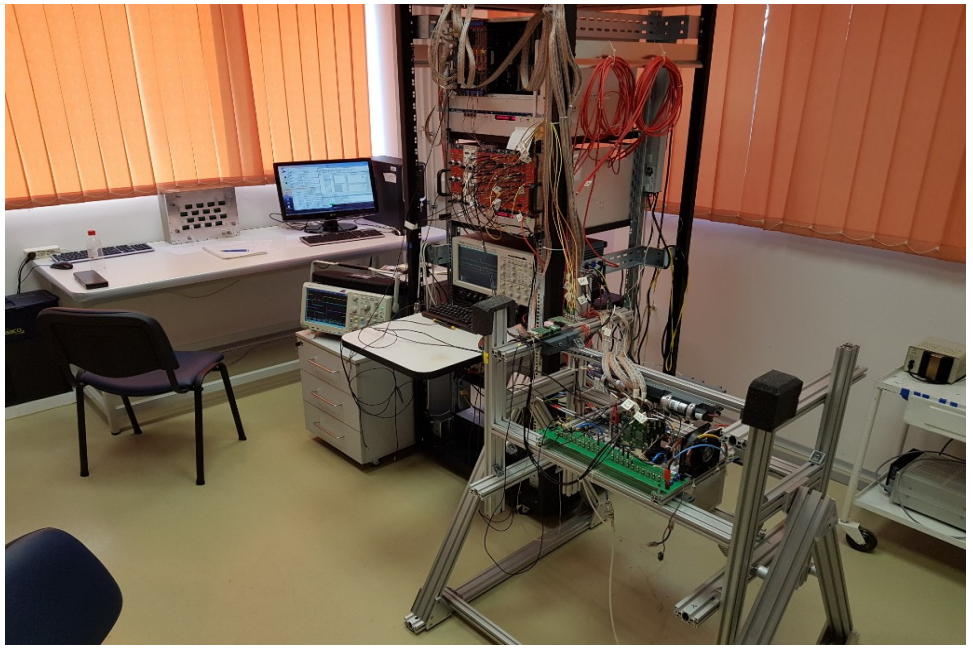


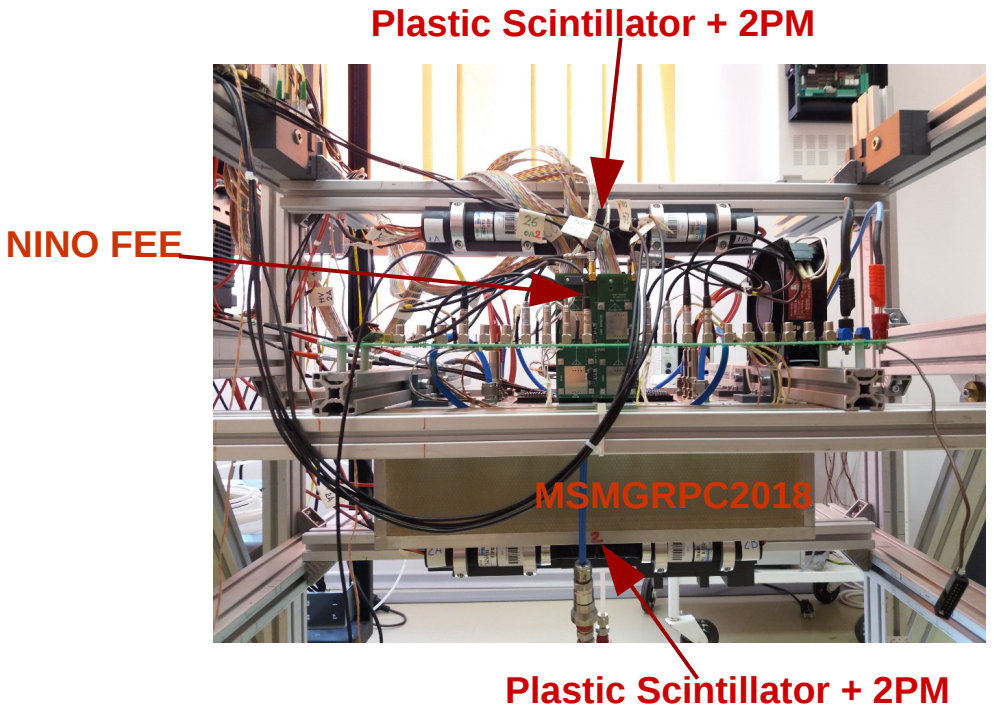




In-house electronics and cosmic – ray test of MGMSRPC2018 prototype

dedicated MSMGRPC test laboratory





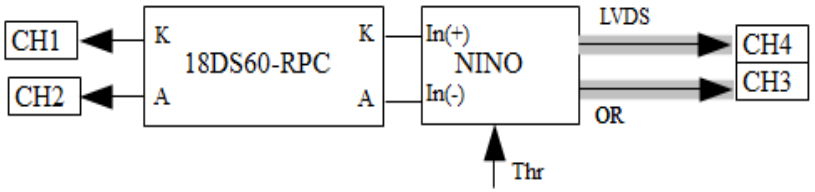
	I_{dark}	Dark rate
RPC1	< 1 nA	0.43 Hz/cm^2
RPC2	< 1 nA	0.46 Hz/cm^2

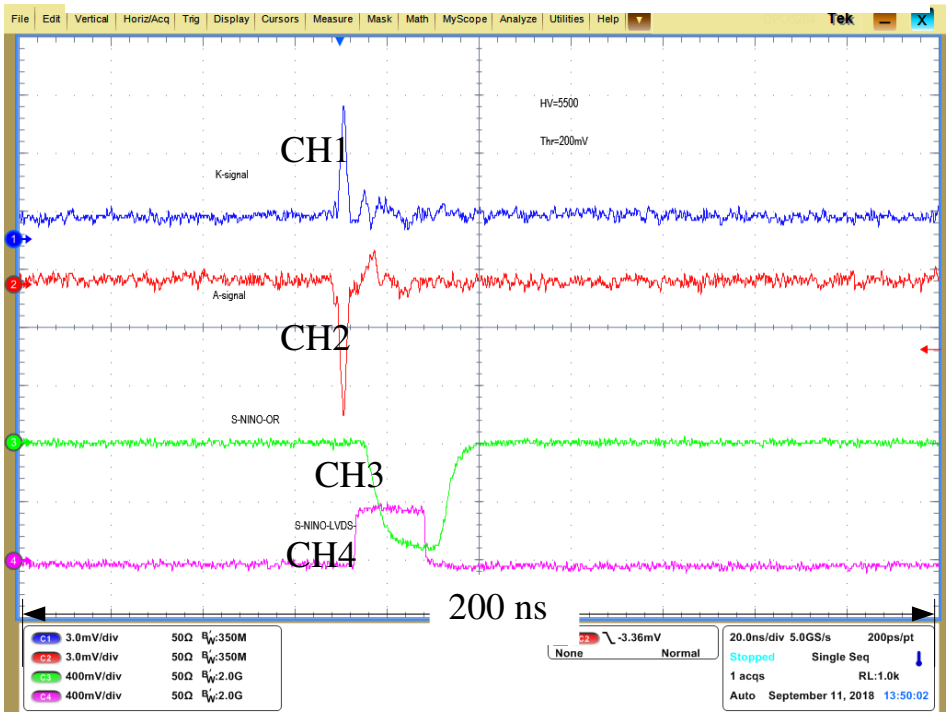
for each RPC:

- 16 operated strips, readout at both ends
- (16 x 0.902 cm) x 6 cm = 86.6 cm^2 operated area
- HV = ± 5500 V
- NINO FEE + CAEN TDCs
- FEE Threshold = 160 mV
- Gas mixture: 90% $C_2H_2F_4$ + 10% SF_6

In-house cosmic – ray test

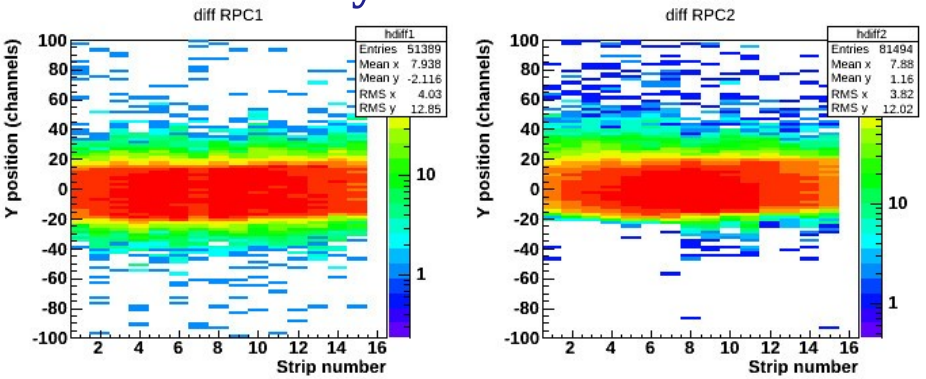
Tests for reflections with real signal

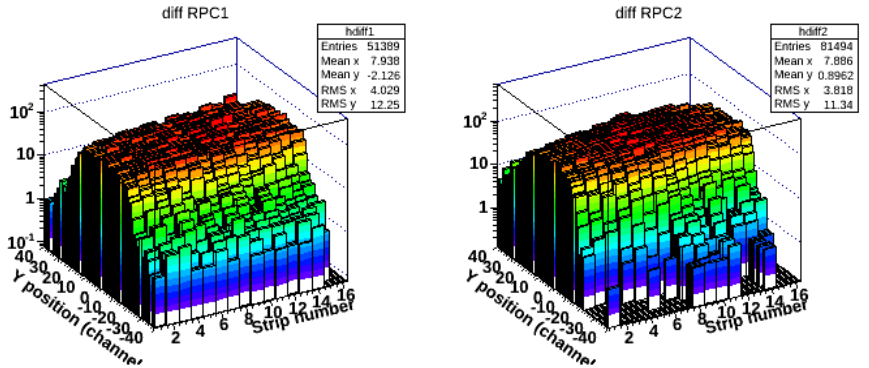




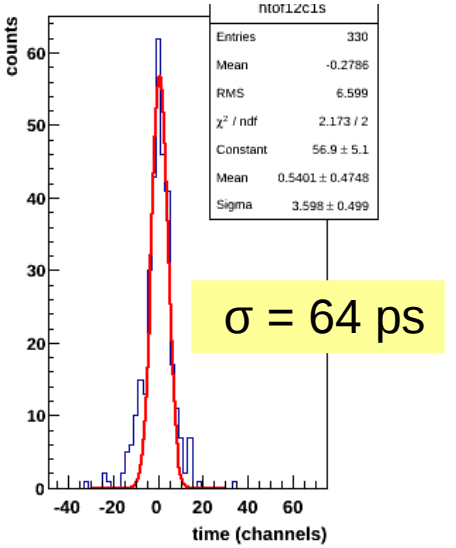
Cosmic – ray signal → no reflections

Efficiency & time resolution





Efficiency = 95%

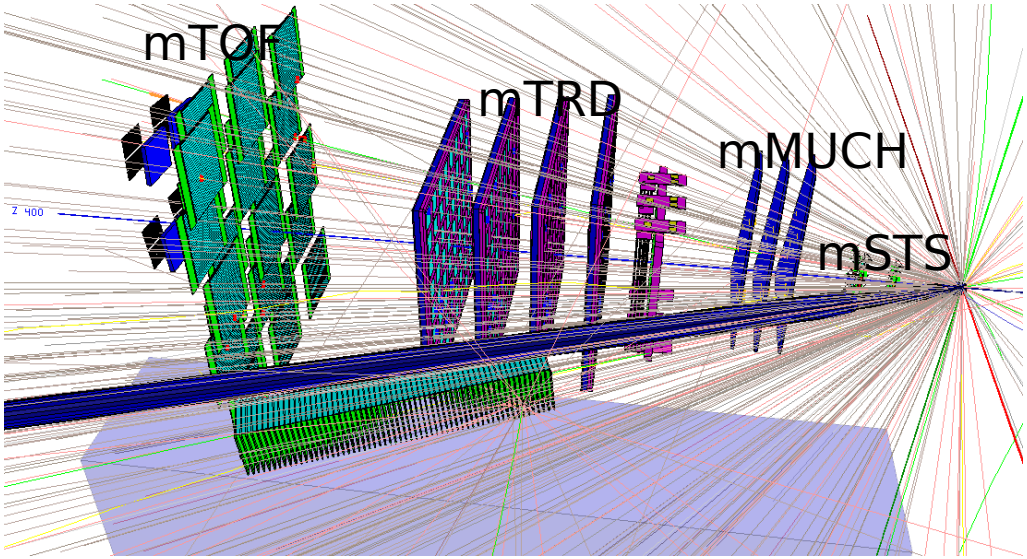


σ = 64 ps

mCBM@SIS18

- **a CBM full system test 2018 – 2021**

in high-rate nucleus-nucleus collisions at GSI/FAIR



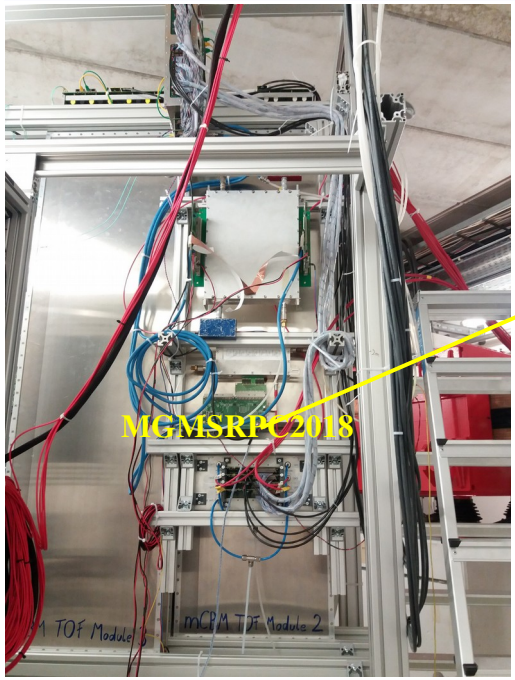
mCBM test-setup will focus on the

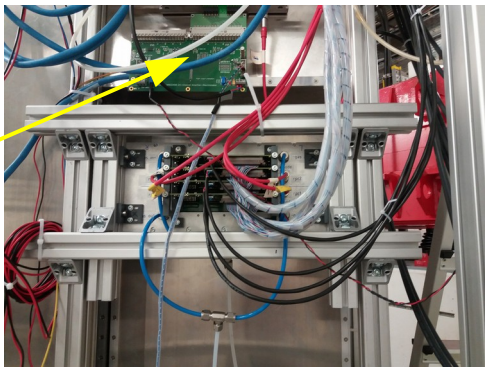
- **test of final detector prototypes**
- **free streaming data transport to a computer farm**
- **online reconstruction and event selection**
- **offline data analysis**

March 2019 in-beam test

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

Readout: PADIX + GET4, free-streaming DAQ





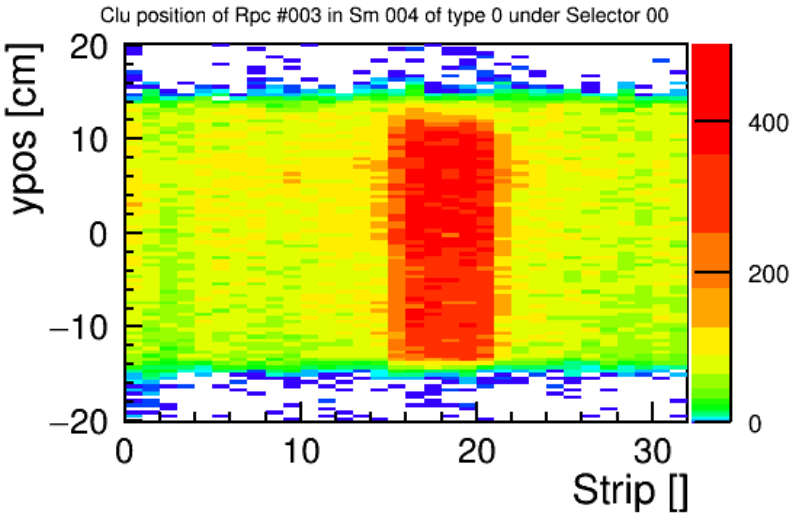
- Threshold scan @ given high voltage

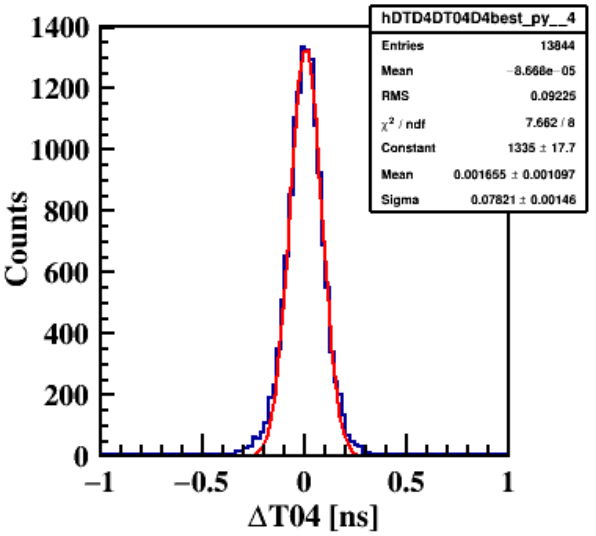
- High voltage scan at given threshold

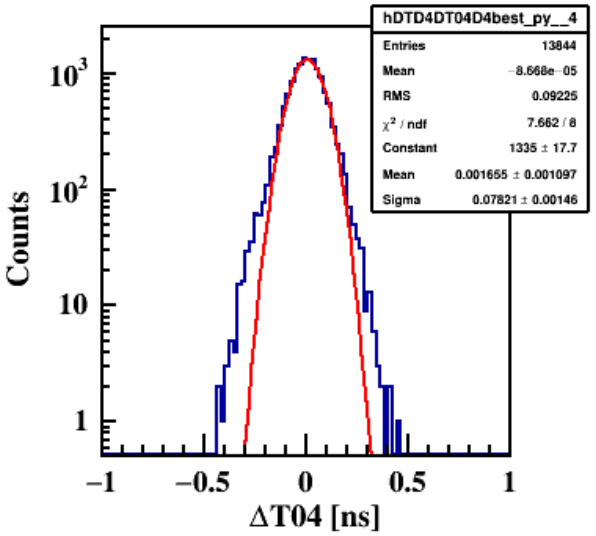
- High rate scan at given high voltage and threshold:

from low rate: I_{RPC}= 0.01 µA to 'high rate': I_{RPC} = 8 µA

Preliminary results of mCBM beam time





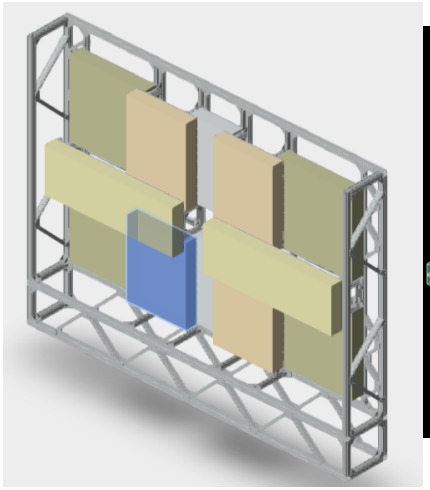


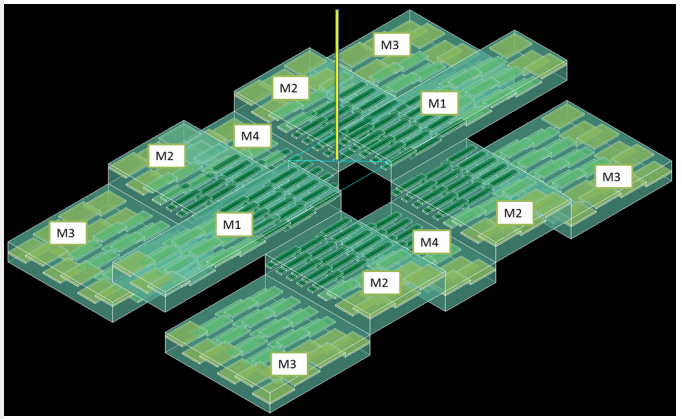
Projection of the MSMGRPC2018 on a CBM-TOF outer-wall counter

σ_{system} = 78 ps

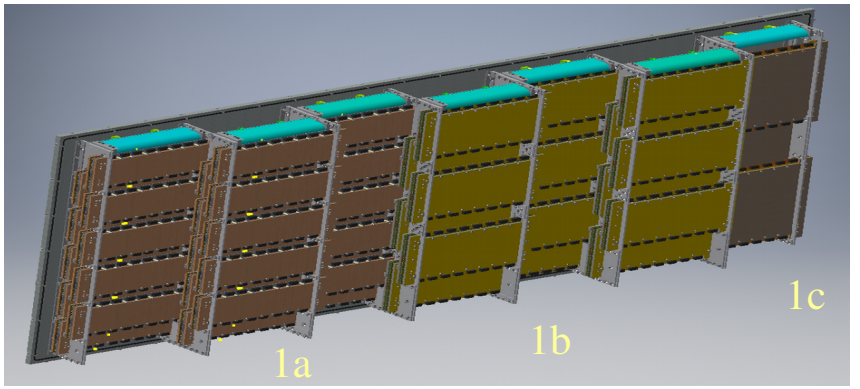
$\sigma_{counter}$ = 55 ps

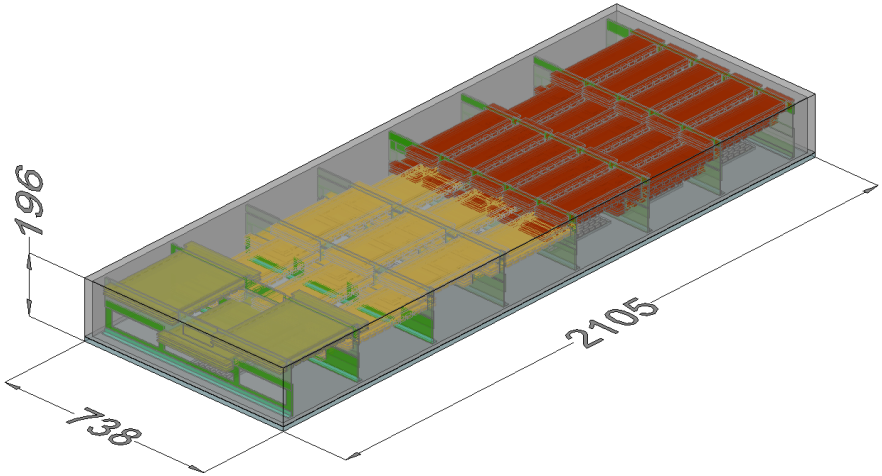
Cbm-TOF Inner Wall Design





Module M1





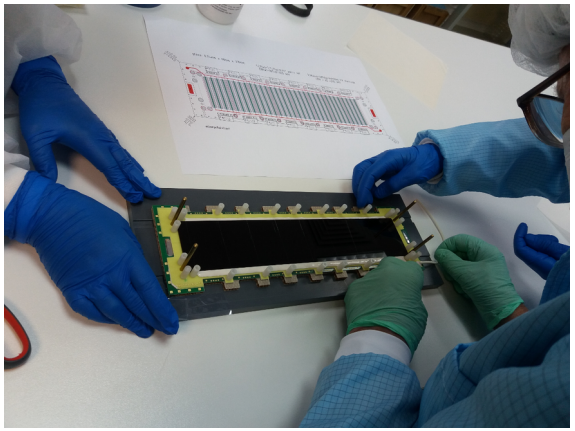
CBM-TOF inner zone

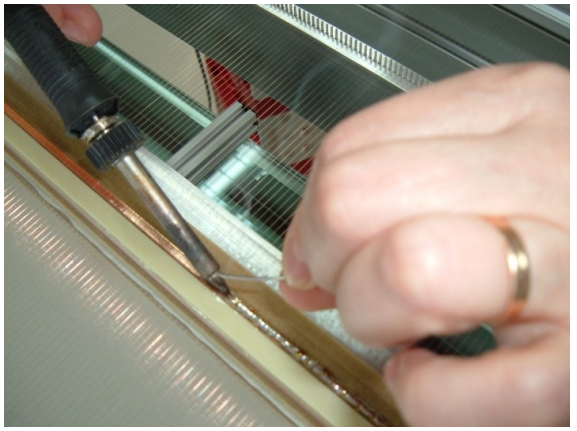
- *~15 m^2 active area*
- *12 modules of 4 types (M1, M2, M3, M4)*
- *470 MGMSRPC counters with 0.9 mm strip pitch,*
  of 3 types (60 mm (1a), 100 mm (1b) and 200 mm (1c) strip length)
- *30 080 readout channels*

Module M1:

- *51 MGMSRPC counters: (30 (1a), 18 (1b), 3 (1c))*
- *3264 readout channels*
- *its construction will start in the near future*

Do we have





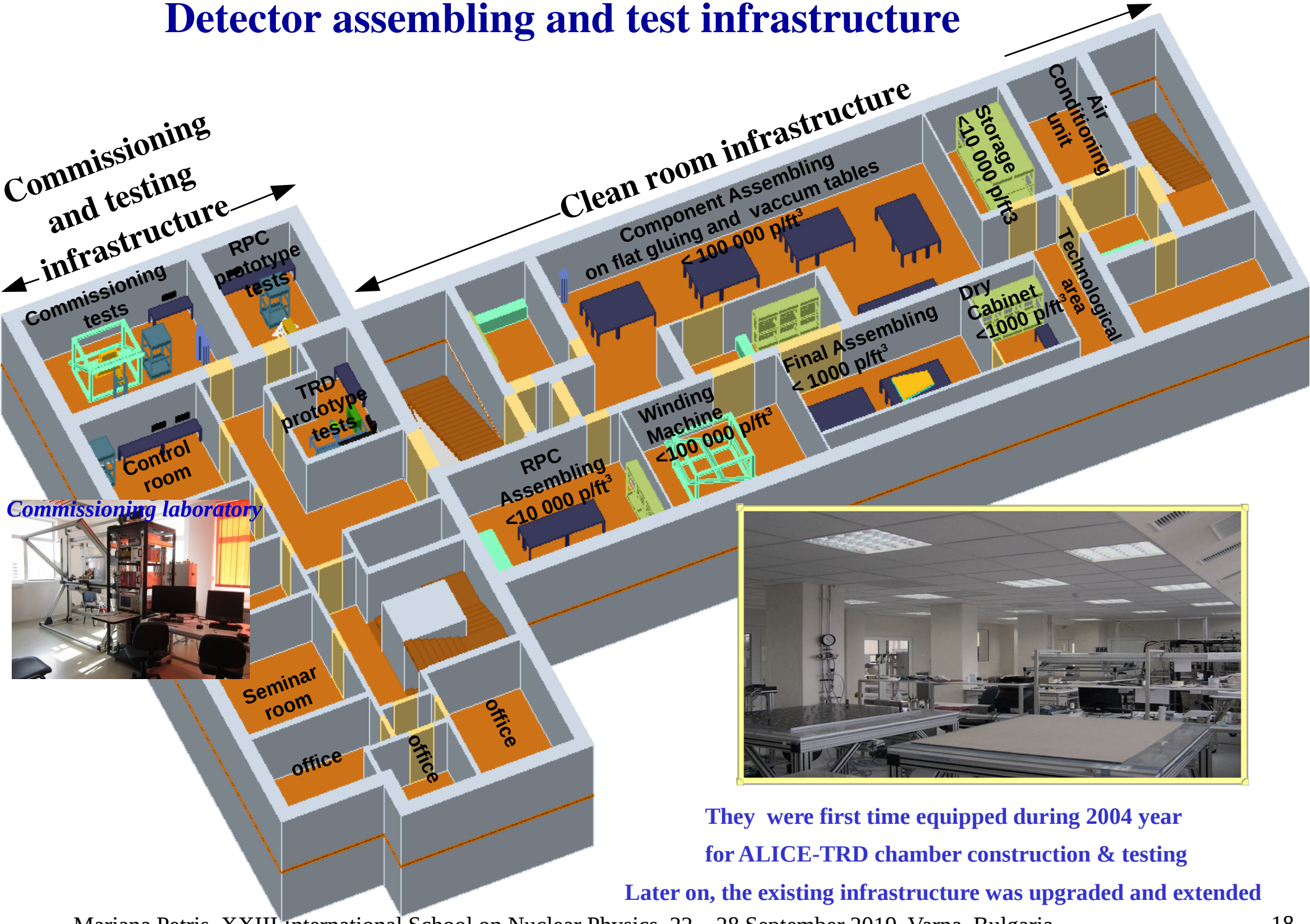
experience

infrastructure

manpower

for involving in the construction of the CBM-TOF inner zone?

Detector assembling and test infrastructure



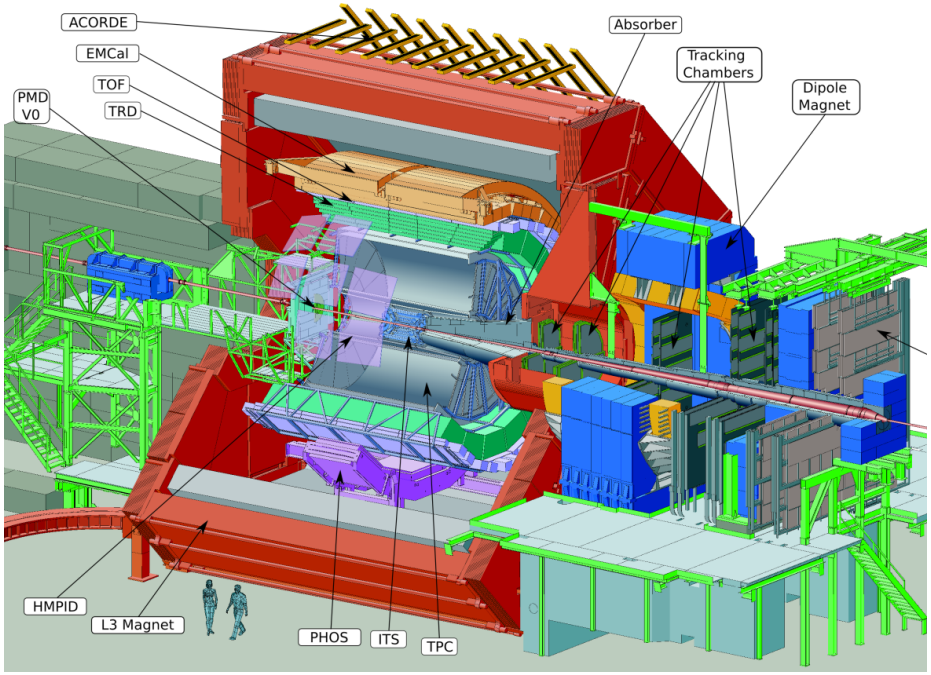
Commissioning laboratory

They were first time equipped during 2004 year

for ALICE-TRD chamber construction & testing

Later on, the existing infrastructure was upgraded and extended

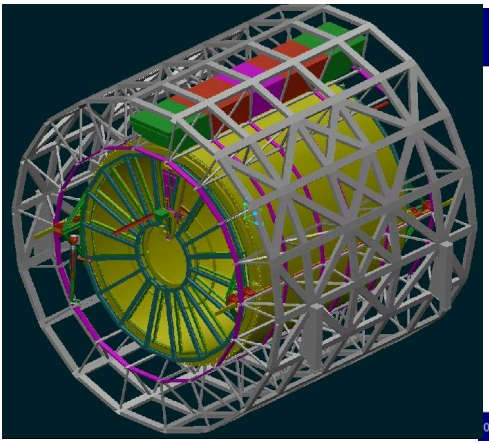
ALICE experiment @ LHC

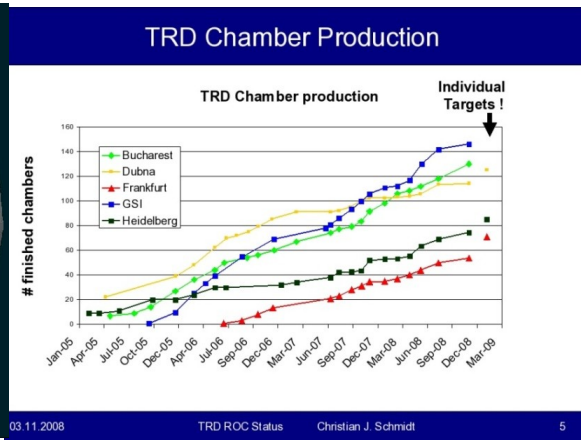


HPD involvement in ALICE

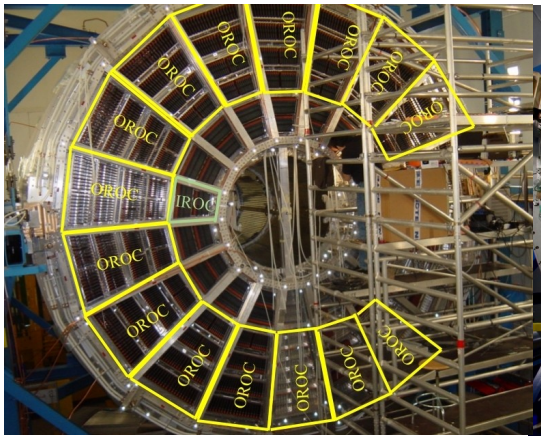
- ***ALICE-TRD prototype tests***
- ***Design of the FEE chip (PASA)***
- ***ALICE-TRD chamber assembling & tests***
- ***ALICE-TRD SMs installation***
- ***ALICE-TPC upgrade based on GEM technology, OROC assembling & tests***
- ***Data analysis***

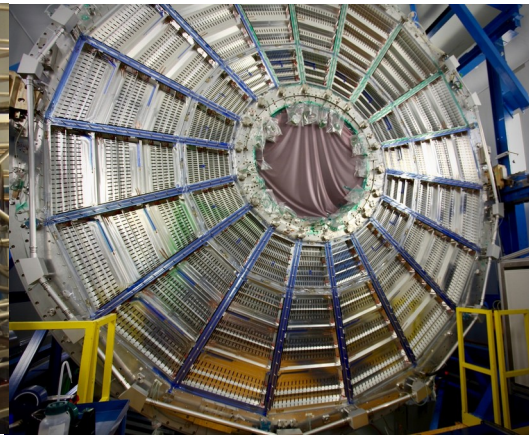
Construction of 130 (24%) out of 540 ALICE-TRD chambers





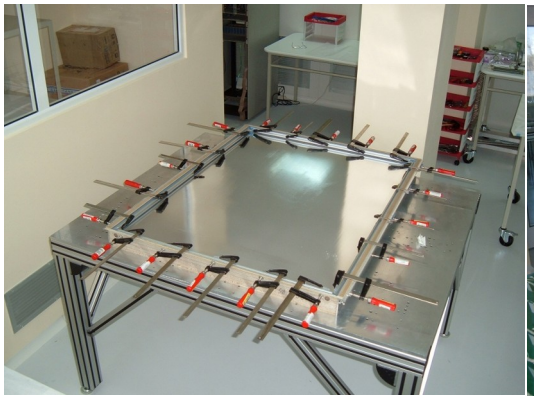
Construction of 20 (50%) out of 40 OROCs ALICE-TPC upgrade based on GEMs





ALICE-TRD chamber construction

Frame assembly on the gluing table



Pad plane assembling on the vacuum table

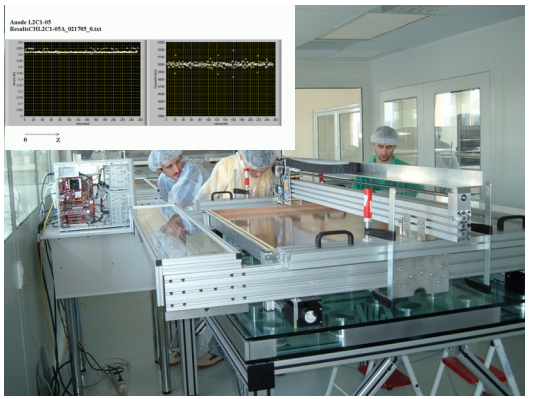
Multiwire electrodes winding using winding machine

Soldering of the electrical connections of the multiwire electrodes

ALICE-TRD chamber tests

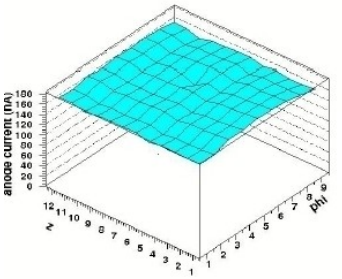
Checks of electrical connections of multiwire electrodes

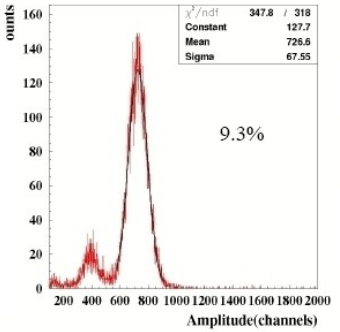
Wire tension & pitch measuring



Absolute gain, gain uniformity & energy resolution @^{55}Fe source

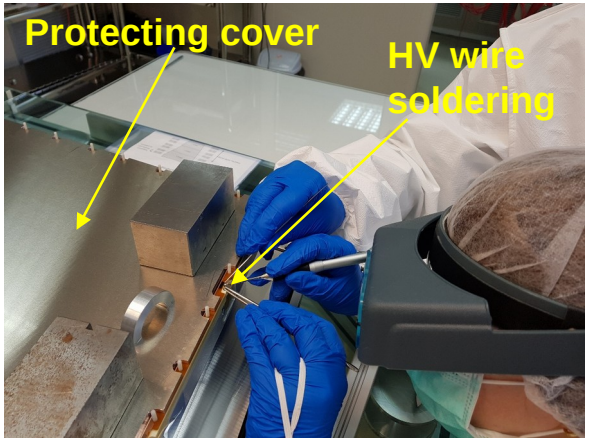
Oxygen = 15 ppm
I^{dark} = 1-2 nA
70% Ar + 30% CO_2

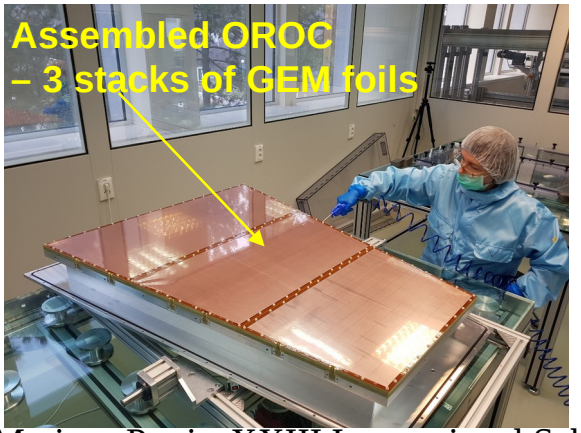




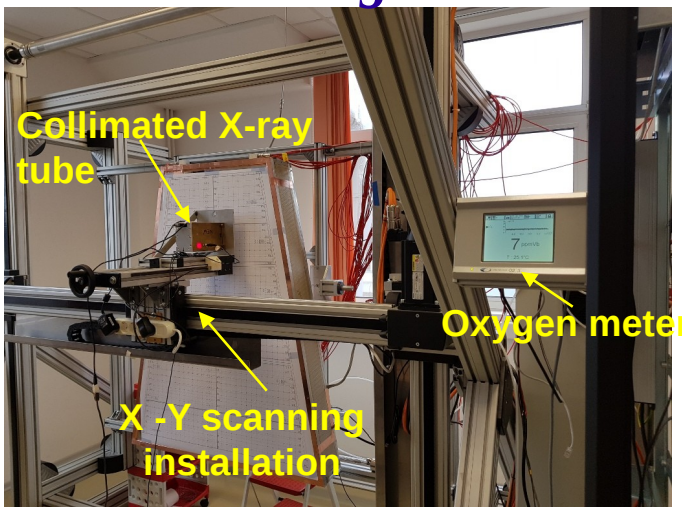
ALICE-TPC upgrade - OROC assembling and testing

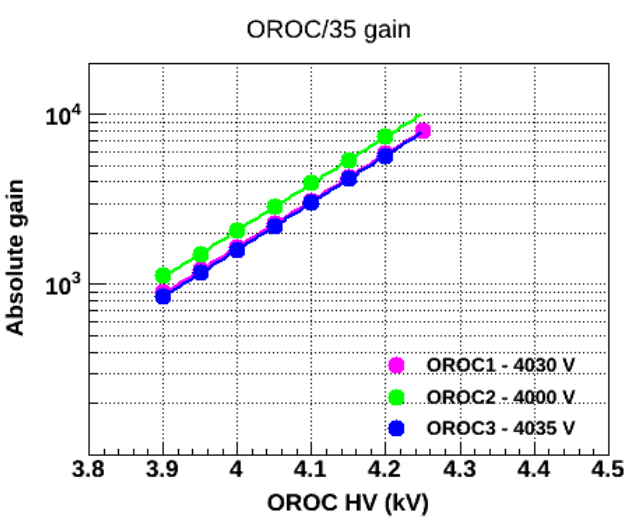
Assembling

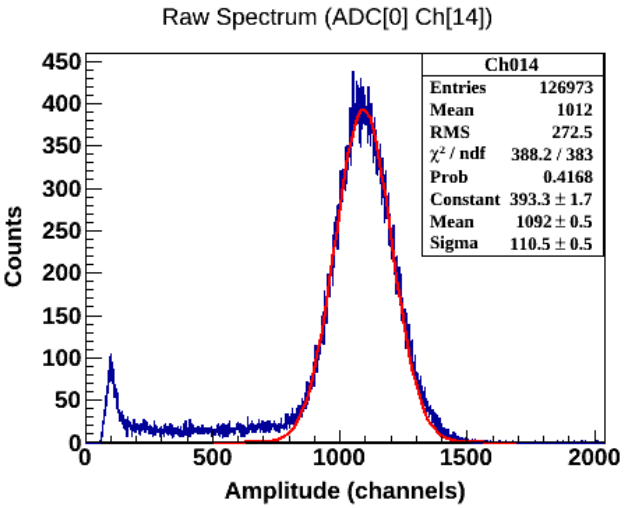




Testing







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.**
- **We have the infrastructure, experience and manpower for involving in the CBM – TOF inner wall construction.**

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HADRON PHYSICS DEPARTMENT


Thank you for your attention!
FAIR tunnel