MINISTERUL CERCETĂRII ȘI INOVĂRII

Testarea performantei prototipurilor de detectori cu electrozi rezistivi pentru masuratori de timp de zbor MGMSRPC, dezvoltati pentru CBM-TOF, folosind un sistem de achizitie cu electronica auto-trigerata similar cu cel ce va fi utilizat in experimentul CBM (partea I)

Proiect NUCLEU PN 19 06 01 03

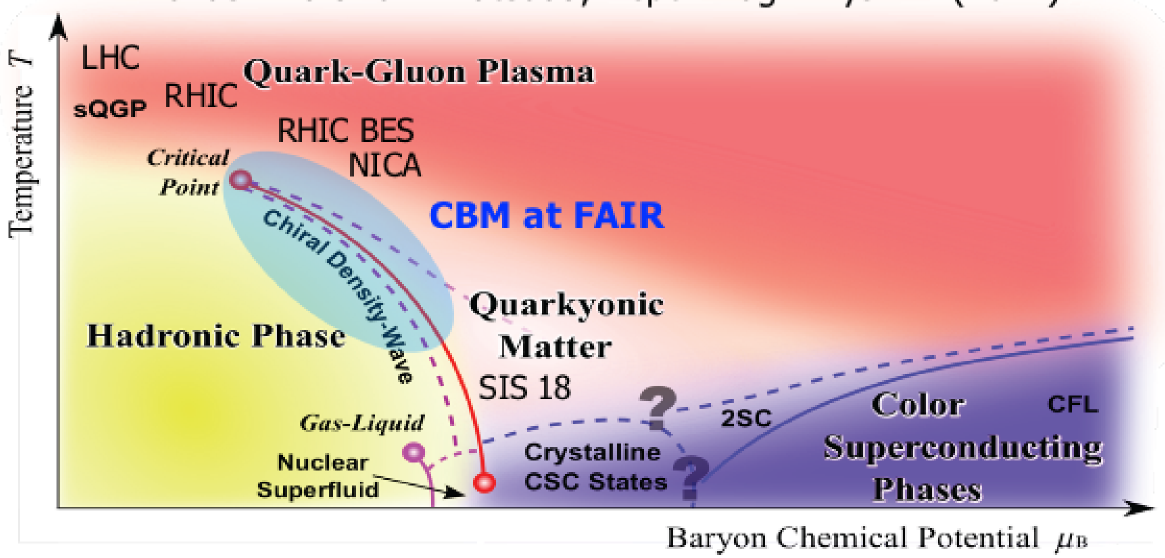
Mariana Petris, DFH Seminar, 25.07.2019

Outline

- Motivation – CBM-TOF inner wall
- MSMGRPCs with transmission line impedance matched to the input impedance of the FEE
- CERN-SPS fall 2016 heavy-ion in-beam tests with a free-streaming DAQ
- MSMGRPC performance in the in-beam test in close to real conditions
- Conclusions and Outlook

Mapping the phase diagram with CBM

K. Fukushima and T. Hatsuda, Rept. Prog. Phys. 74 (2011)



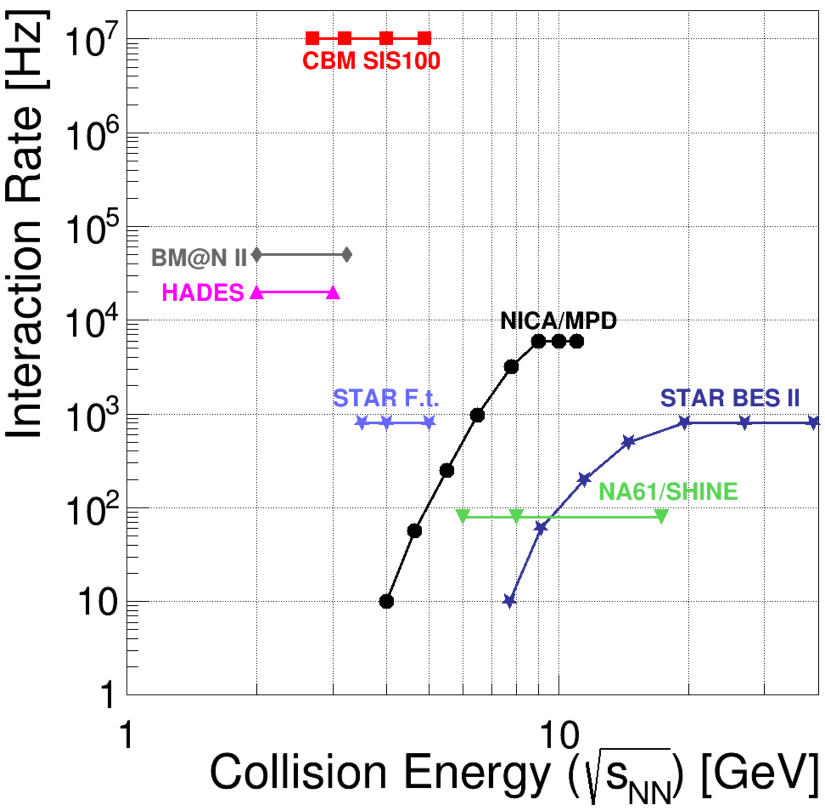
CBM aims to investigate strongly interacting matter in the region of high net baryon densities.

Investigation of:

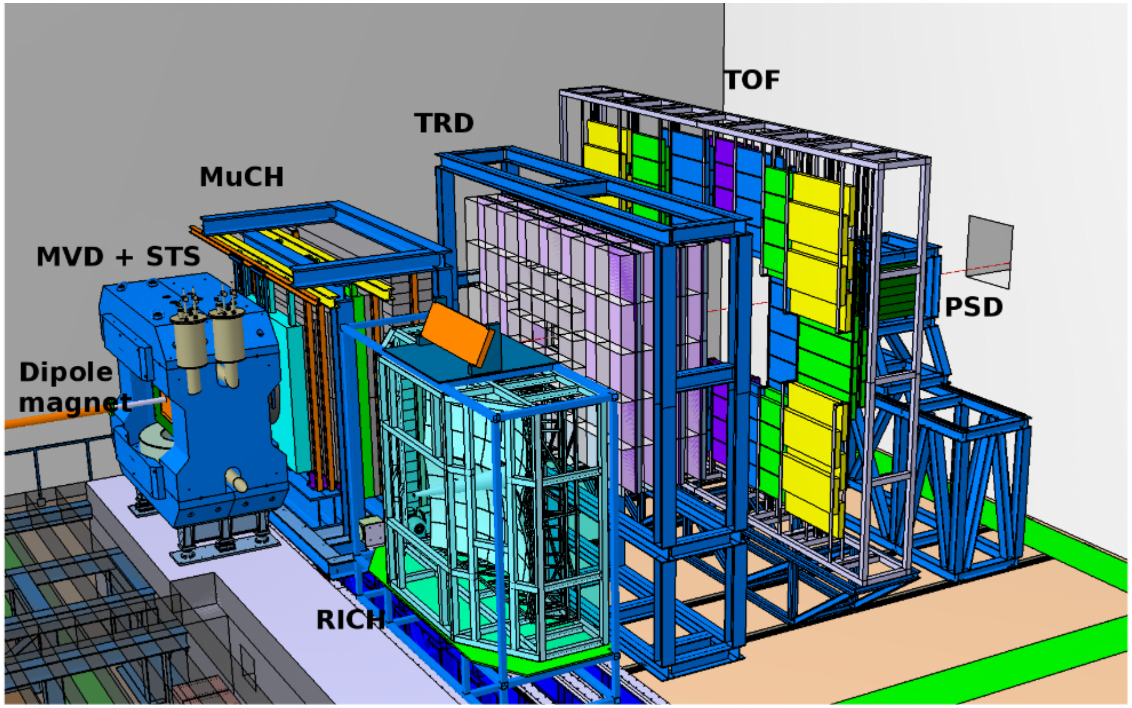
- **hadronic – partonic phase transition and its type**
- **equation of state at high baryonic densities**
- **possible critical point predicted by QCD**

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 detector systems

Tracking system:

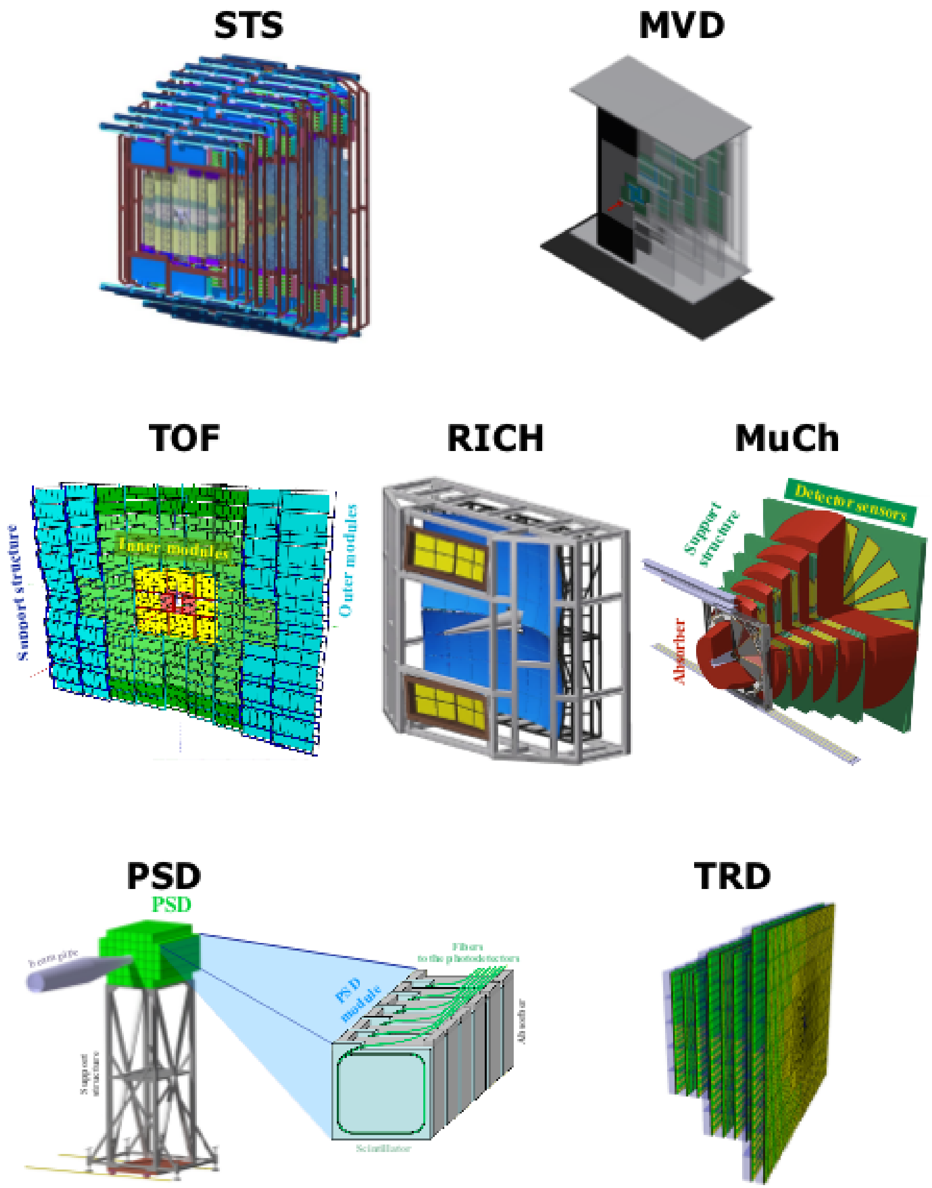
- Silicon Tracking System (STS) — main tracking system; fast double sided microstrip sensors;
- Micro Vertex Detector (MVD) — reconstruction of displaced vertices; MAPS pixel detectors with precision of about 5 μm.

Particle identification detectors:

- Ring Image Cherenkov Detector (RICH) — separation of electrons and pions; gaseous RICH;
- Transition Radiation Detector (TRD) — separation of electrons and pions, dE/dx for light nuclei;
- Muon Chambers (MuCh) — identification of muons; set of absorbers followed by GEM detectors;
- Time Of Flight (TOF) — identification of hadrons; fast MRPC sensors.

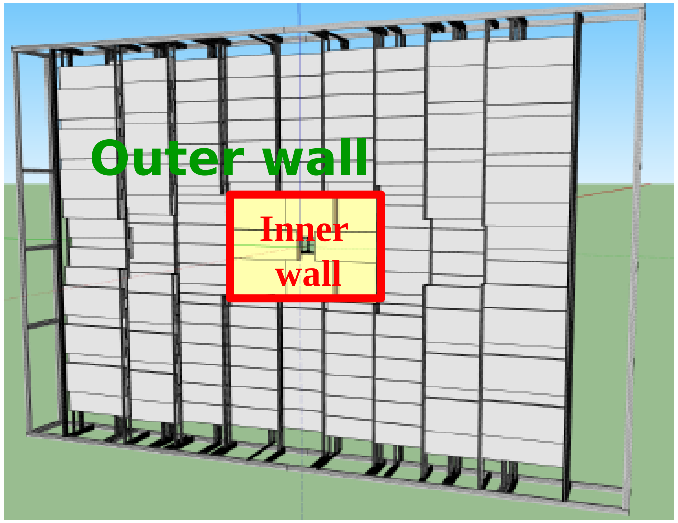
Detector for event characterisation:

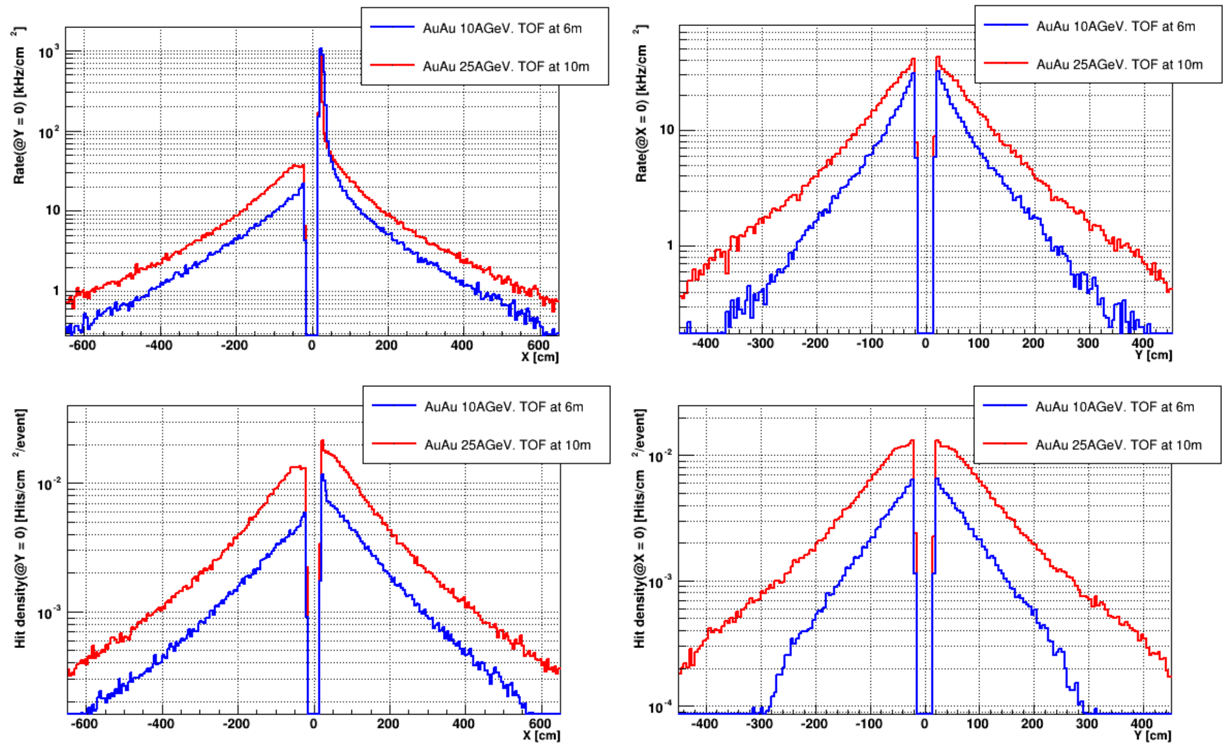
- Projectile spectator detector (PSD) — forward calorimeter; determination of the reaction plane, collision centrality.



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/cm²**
- **Polar angular range 2.5° – 25°**
- **Active area of 120 m²**
- **Occupancy < 5%**
- **Low power electronics (~120.000 channels)**
- **Free streaming data acquisition**

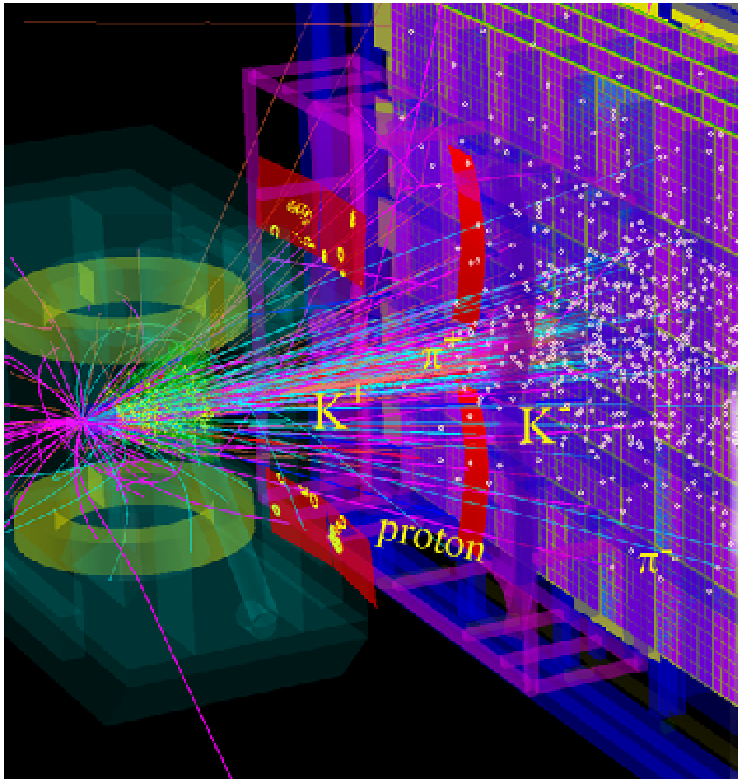
CBM Collaboration, "CBM – TOF Technical Desing Report", October 2014

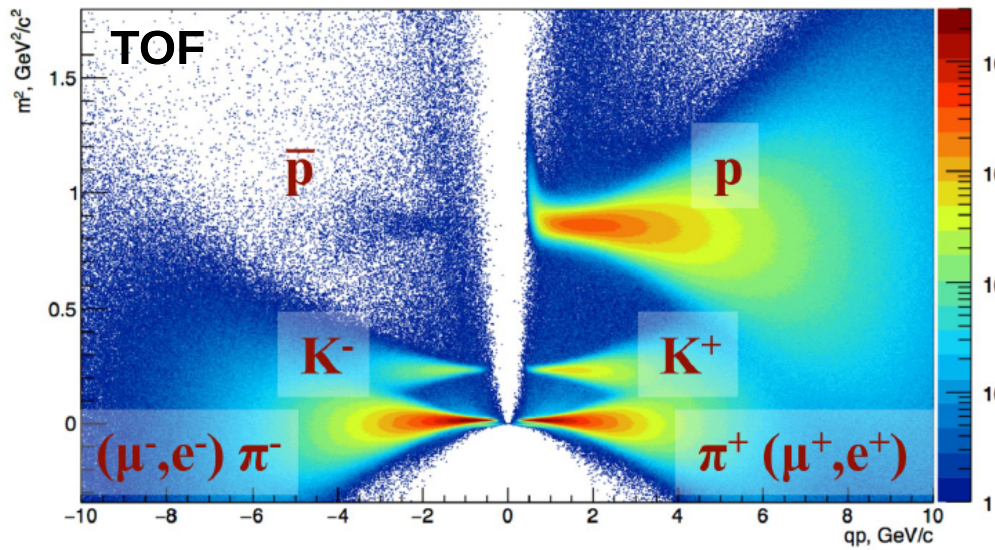
Detectors with different rate capabilities are needed as a function of polar angle

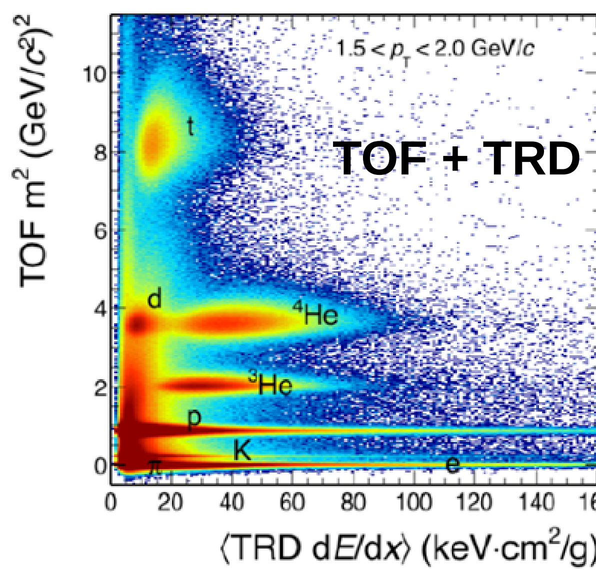
Our R&D activity addresses the CBM-TOF inner wall:

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

PID with CBM setup







- **Hadron id: TOF (+TRD)**
- **Lepton id: RICH+TRD or MUCH**
- **γ, π0: EMC (or RICH)**

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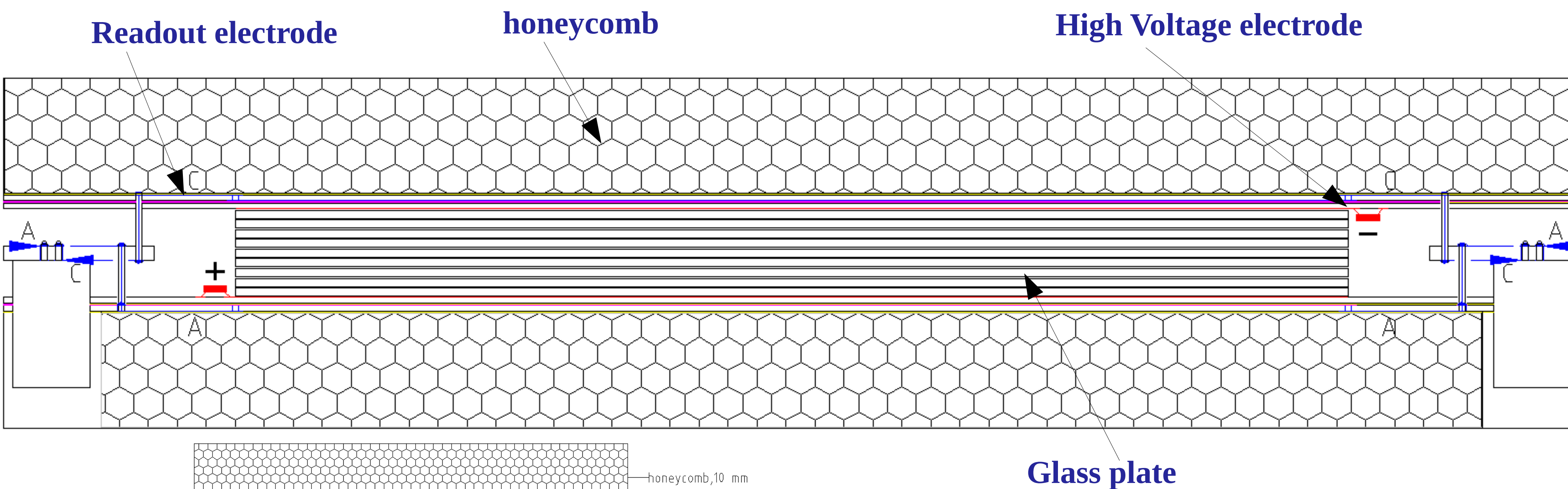
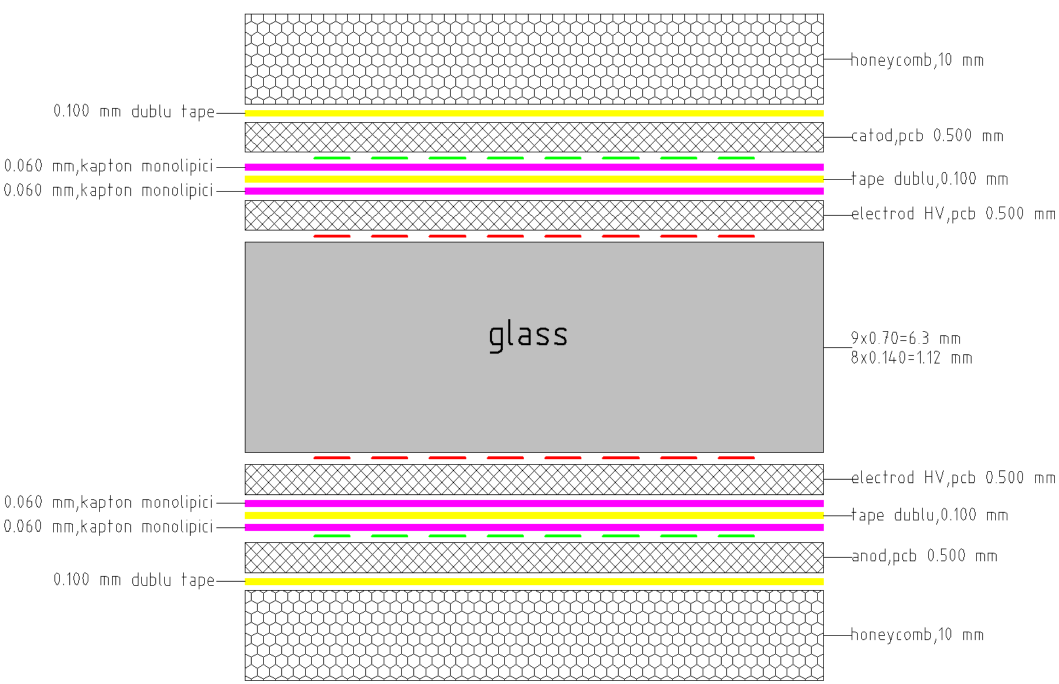
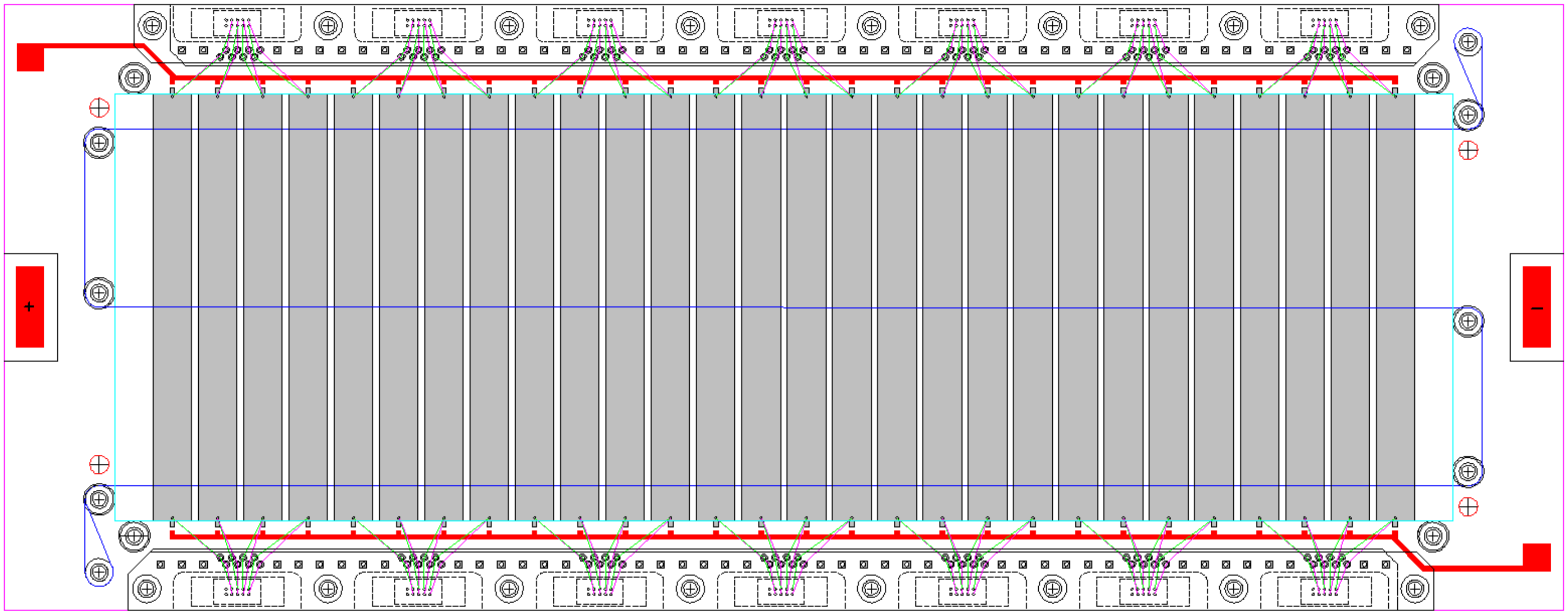
SS-RPC2015 prototype with 100 Ohm transmission line impedance





- ✓ **Single stack structure: 8 gaps**
- ✓ **Active area 96 x 300 mm2**
- ✓ **Gas gap thickness: 140 μm thickness**
- ✓ **Readout electrode = 28 strips**
- ✓ **Differential readout = 100 Ohm impedance**
- ✓ **Resistive electrodes: low resistivity glass**

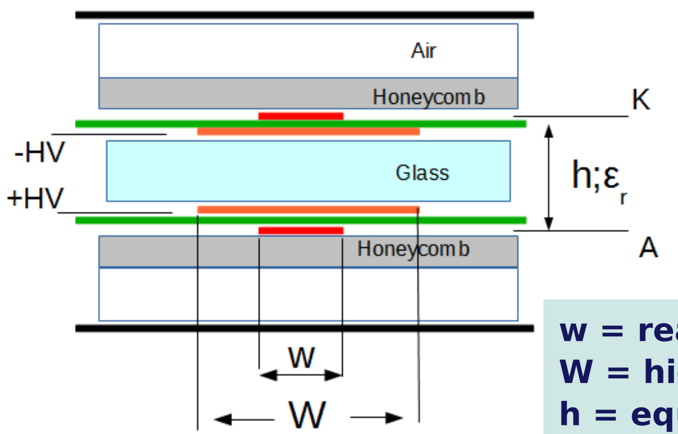
SS-RPC2015 prototype with 100 Ohm transmission line impedance



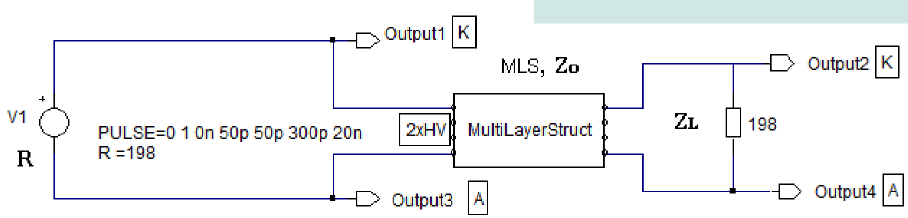
Readout electrode & HV electrode : 10.1 mm pitch= 8.6 mm width + 1.5 mm gap

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

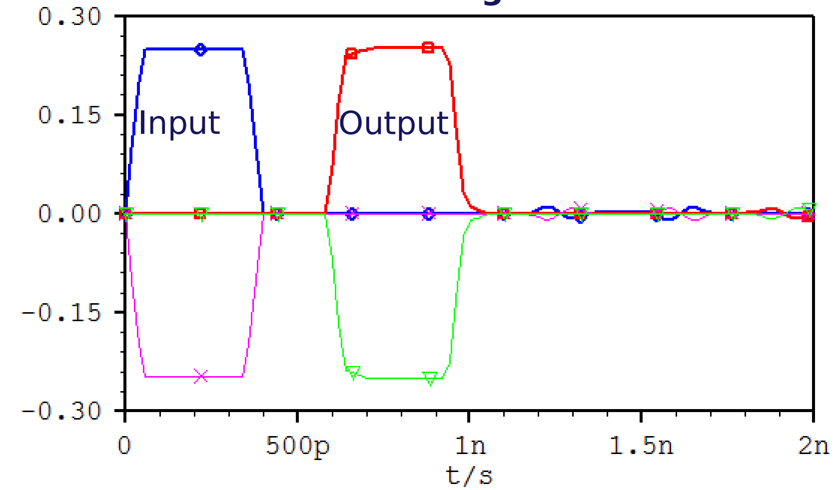


w = readout strip width
W = high voltage strip width
h = equivalent dielectric thickness
ε = equivalent dielectric constant

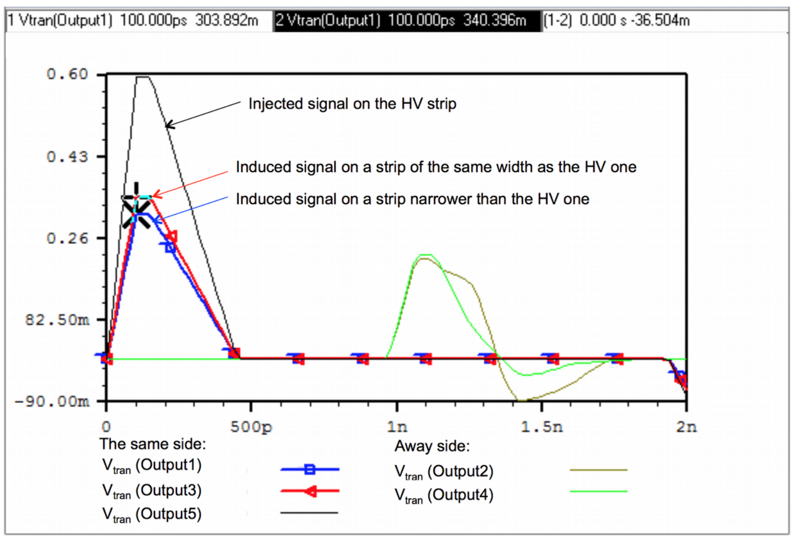


If $R = Z_0 = Z_L$ the transmission line is matched;
Z_0 = characteristic impedance of a transmission line
Z_L = load resistor connected to the transmission line
R = internal resistance of the pulse generator

Simulated signals



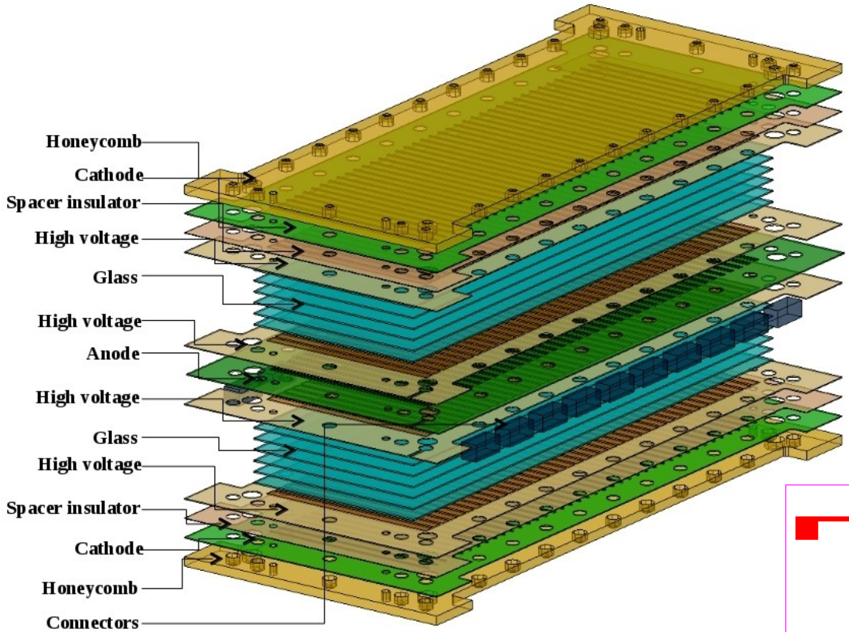
Input/Output signals are simulated using APLAC for different values of the readout strip width



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)

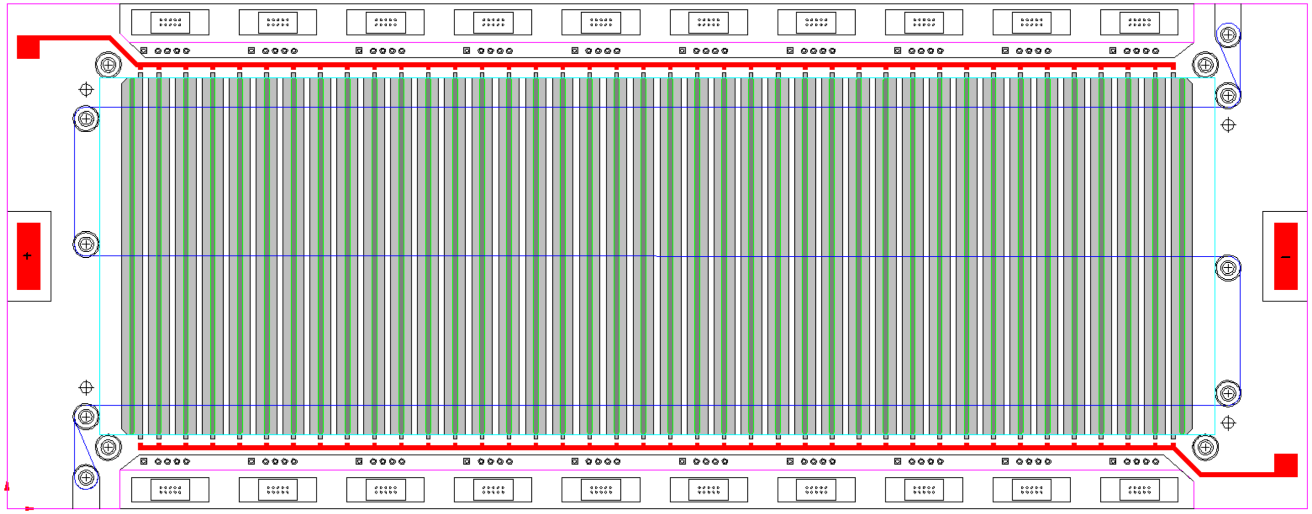
RPC2015DS prototype - strip impedance tuned through the readout strip width



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.

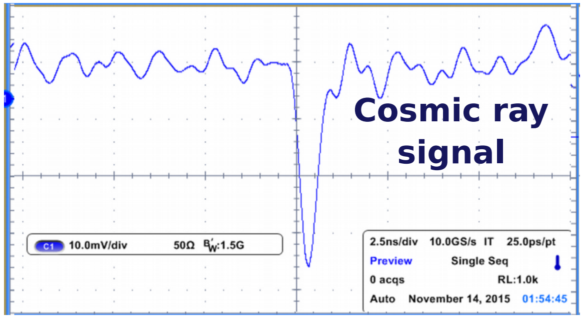
Simulations predicted ~99 Ω impedance for 1.3 mm readout and 5.6 mm high voltage strip widths

- ✓ 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



Assembled MSMGRPC2015 prototypes

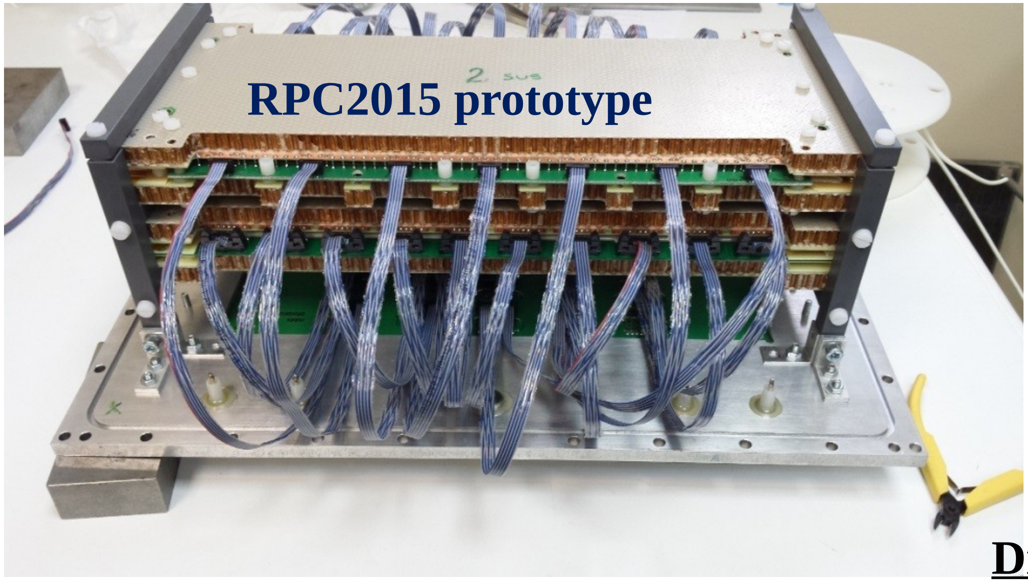
Common in counter architecture:

Electrodes: 0.7 mm low resistivity Chinese glass

Gap size: 140 μm thickness

Differential readout, 100 Ω impedance

Active area: 96 x 300 mm²



Differences in counter architecture:

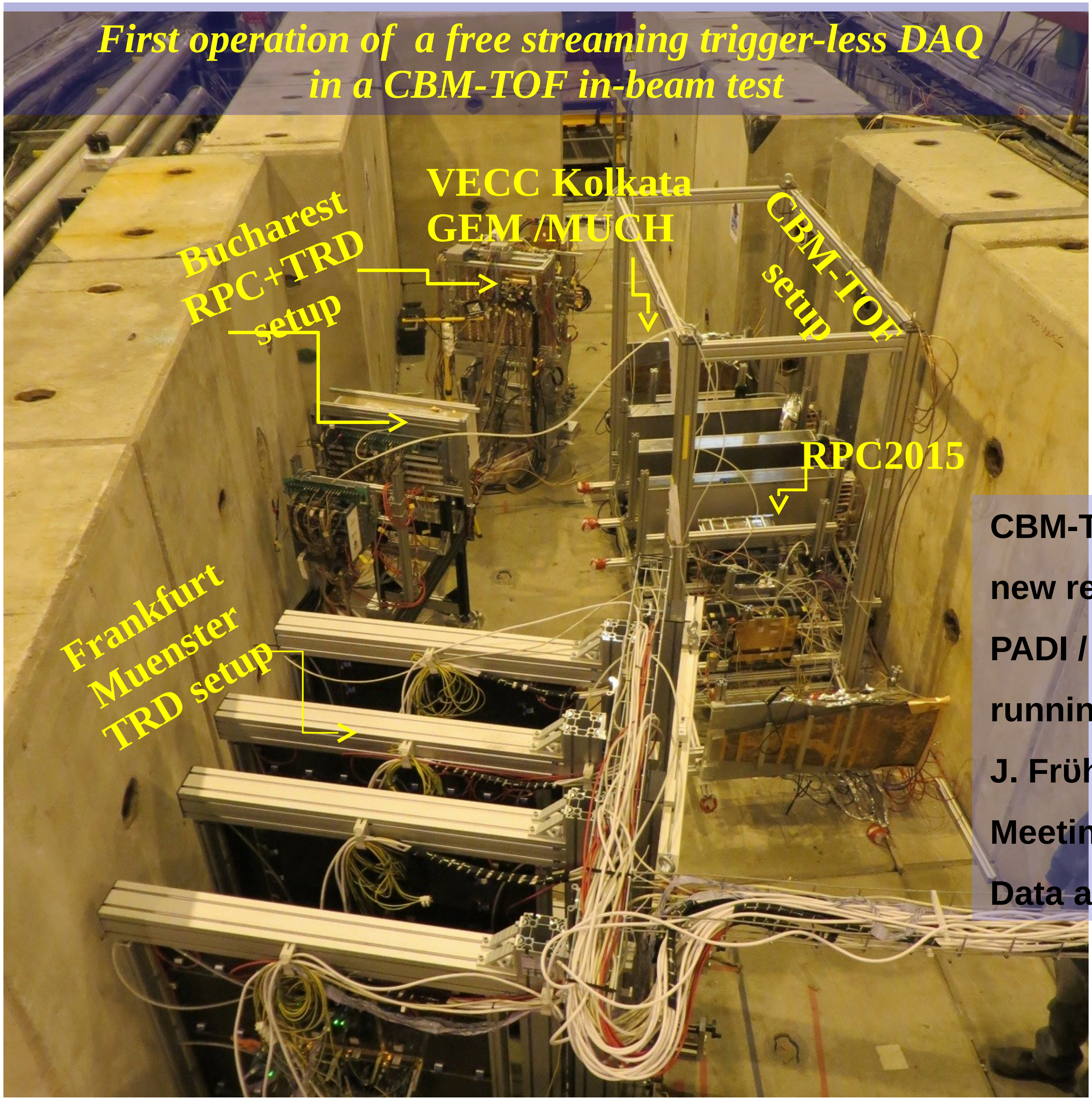
DS: ***Symmetric two stack structure: 2 x 5 gas gaps***

SS: Single stack structure: 1 x 8 gas gaps

Fall 2016 CERN - SPS in-beam tests

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

First operation of a free streaming trigger-less DAQ in a CBM-TOF in-beam test



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

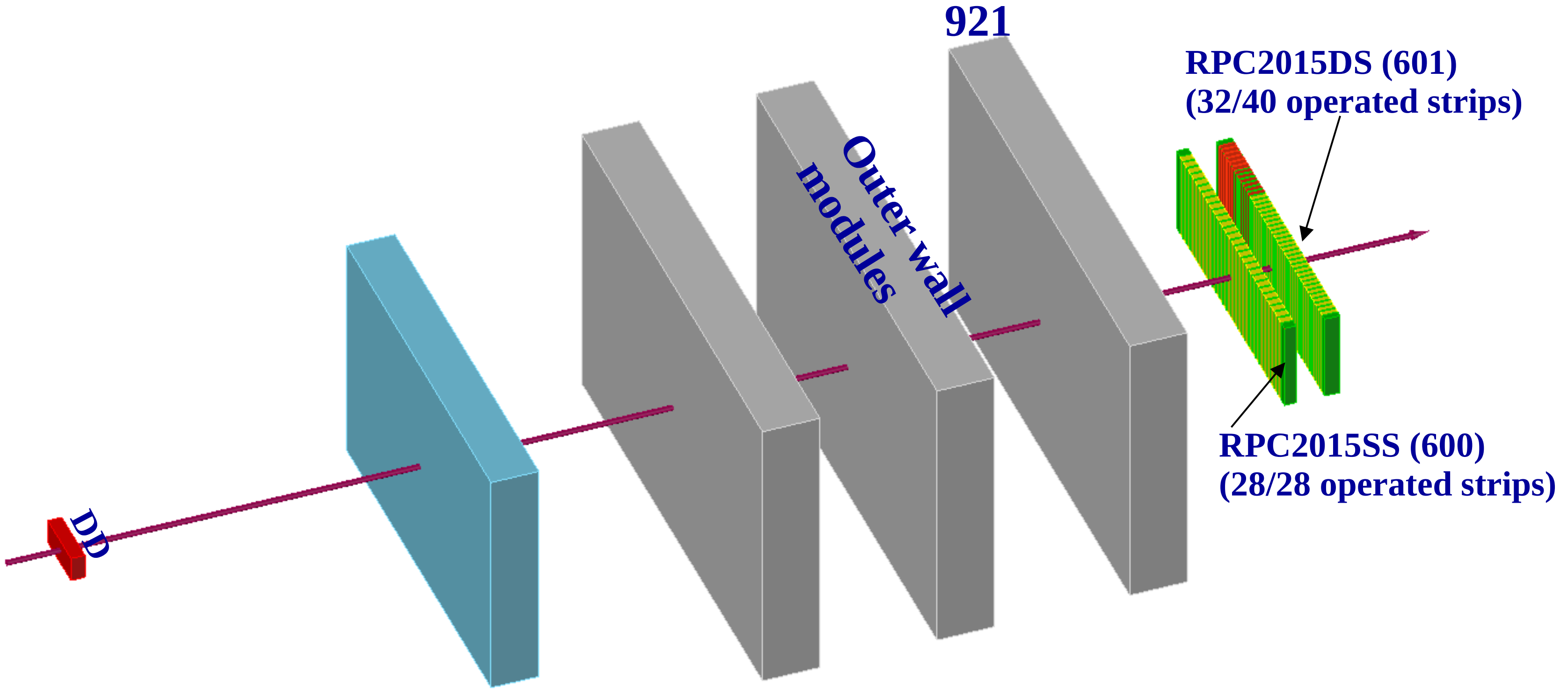
PADI / GET4 / AFCK / FLIB => DAQ was running stable.

J. Frühauf, 29th CBM Collaboration Meeting, March 2017.

Data analysis is still on going work.

Sketch of the experimental set-up involved in the analysis

Dut = detector under test = SS2015 (600)
Ref = reference RPC = DS2015 (601)
BRef = beam reference = DD (500)
Sel2 = second selector = Outer wall module (921)



Results of Fall 2016 in-beam test

Detector performance in terms of:

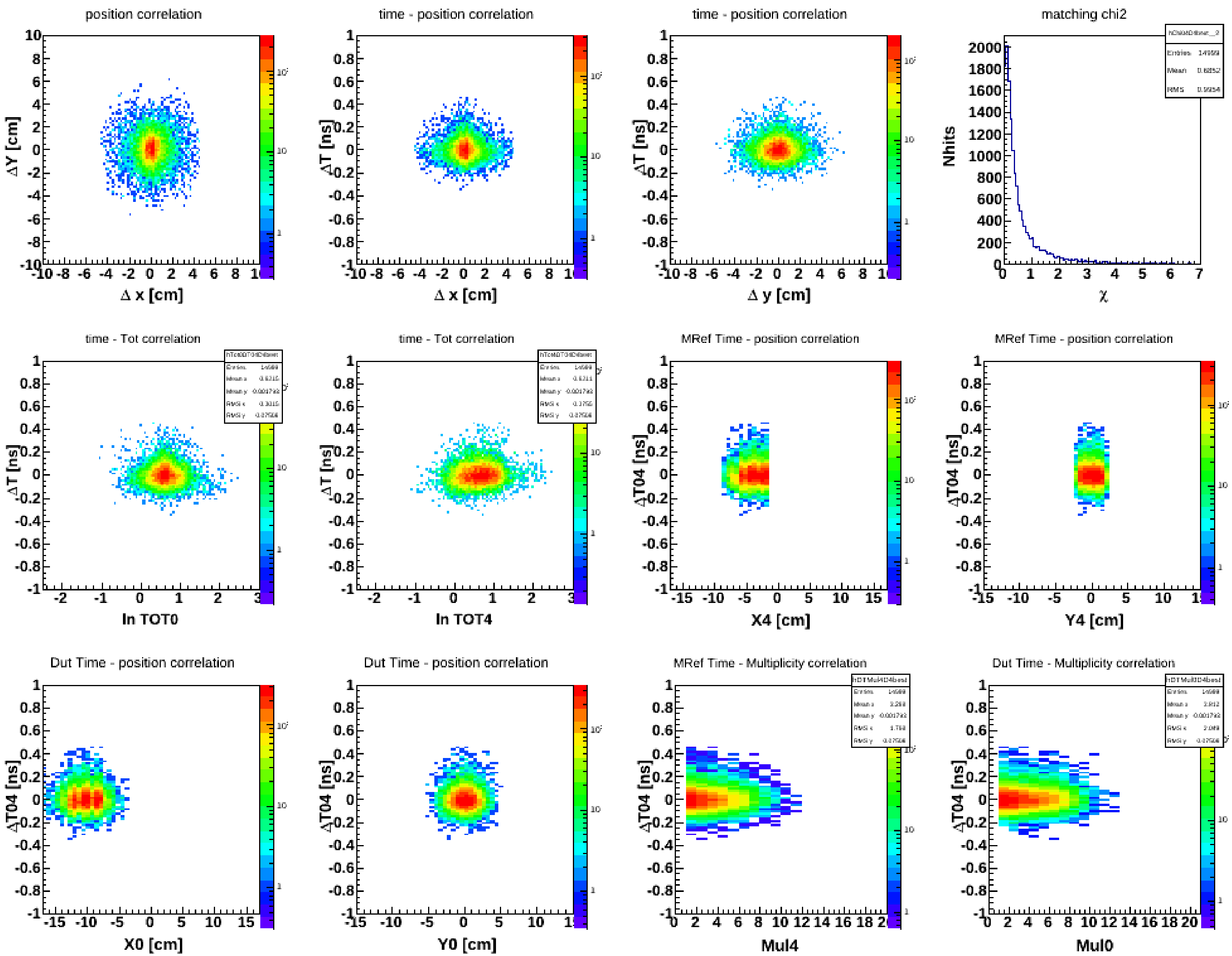
- **efficiency**
- **time resolution**

as a function of high voltage and FEE threshold

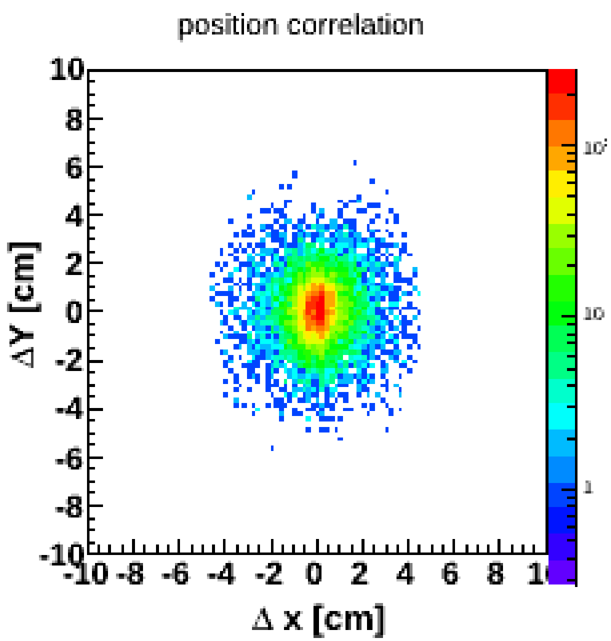
in a close to real free-streaming signal processing

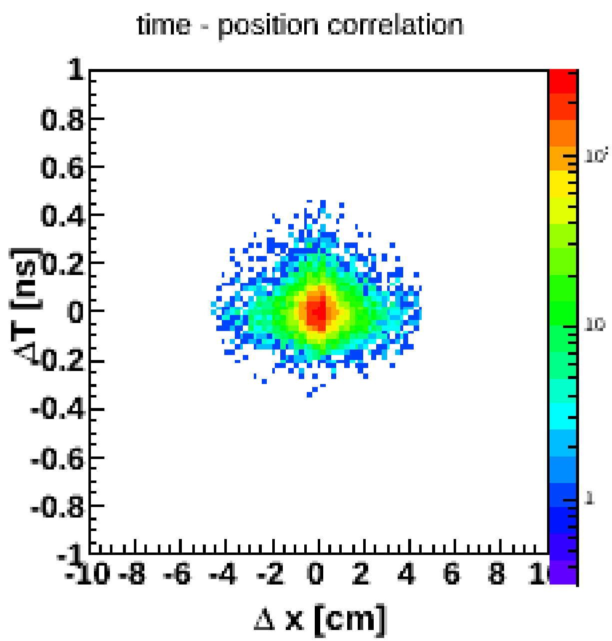
and data acquisition.

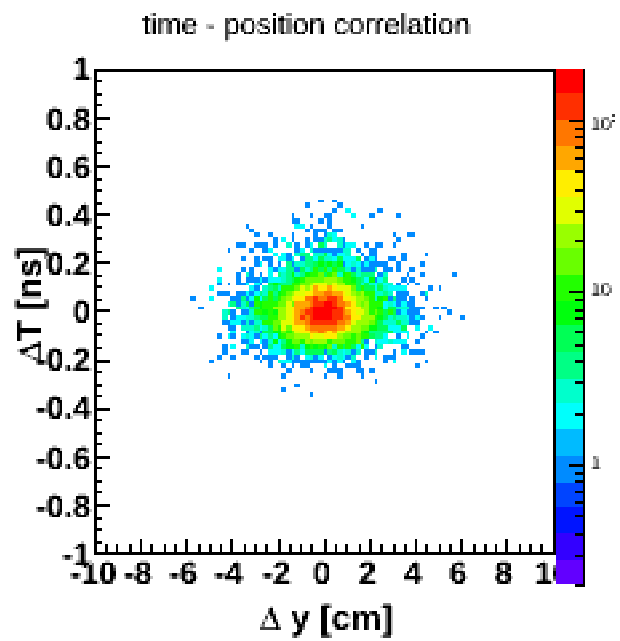
Analysis cuts and correlations



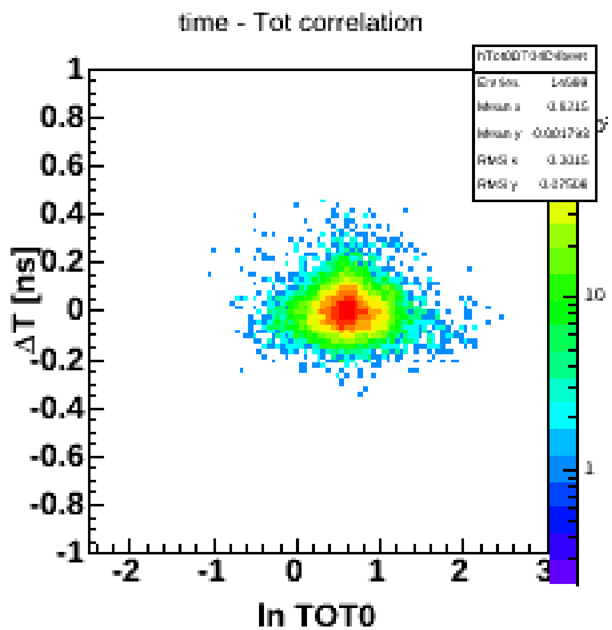
Hit position correlations

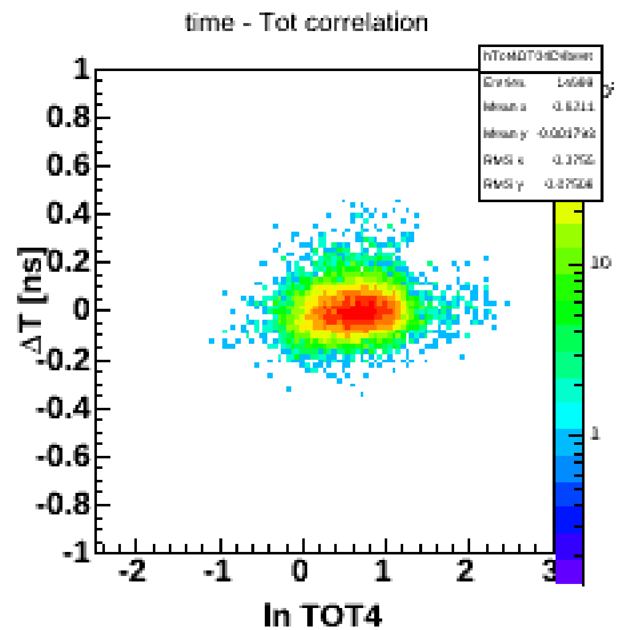


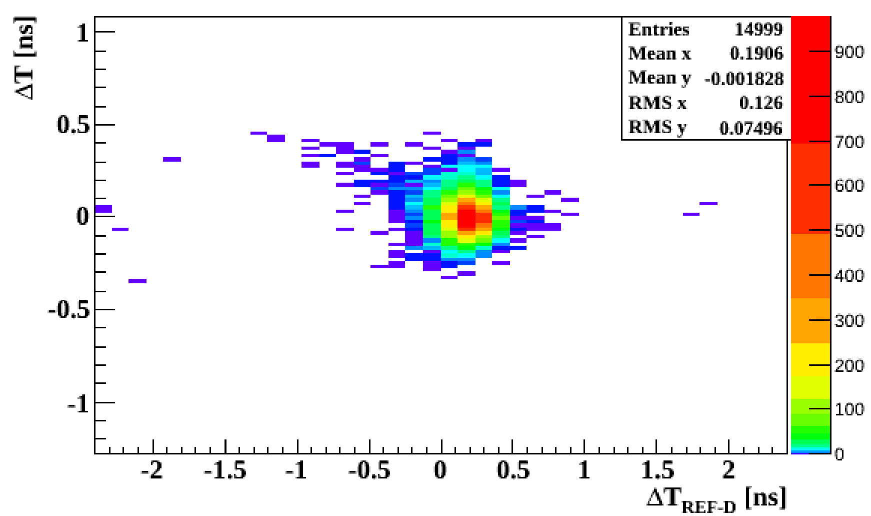




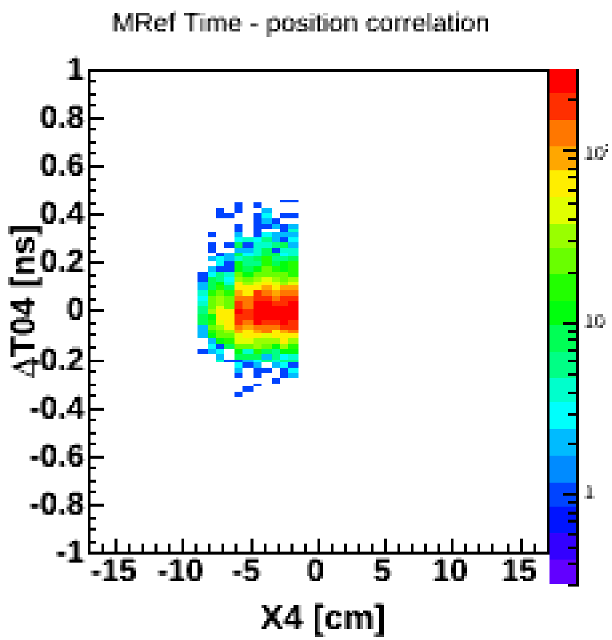
Slewing and velocity corrections

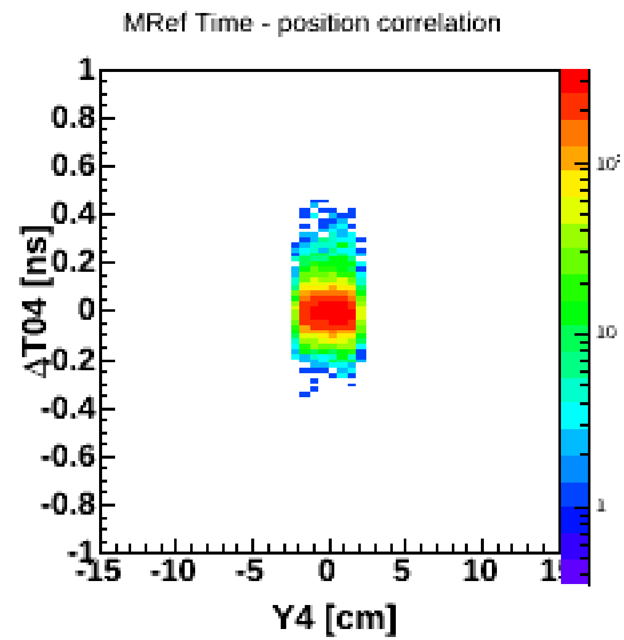


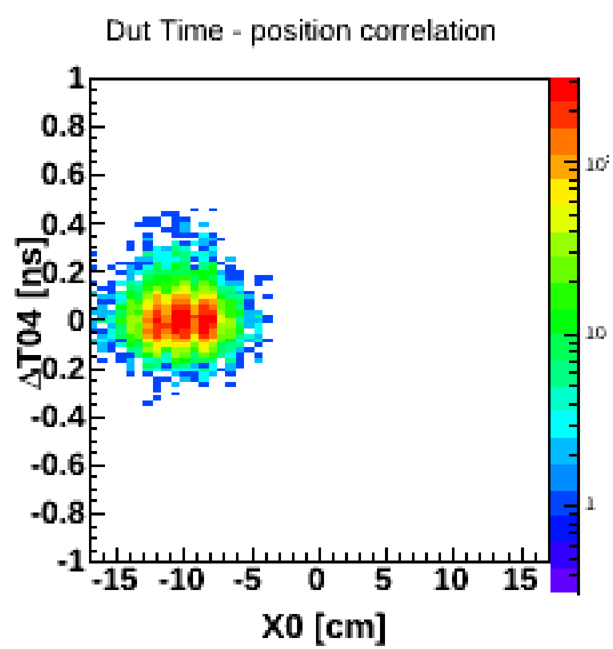


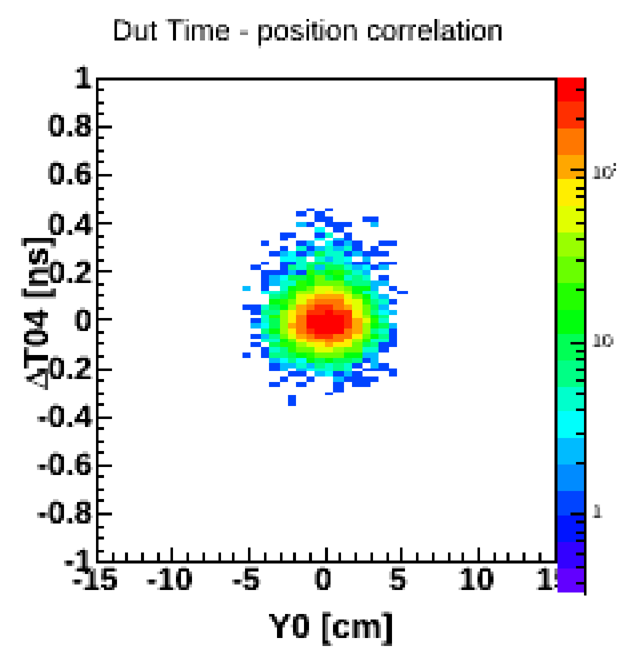


Hit position corrections

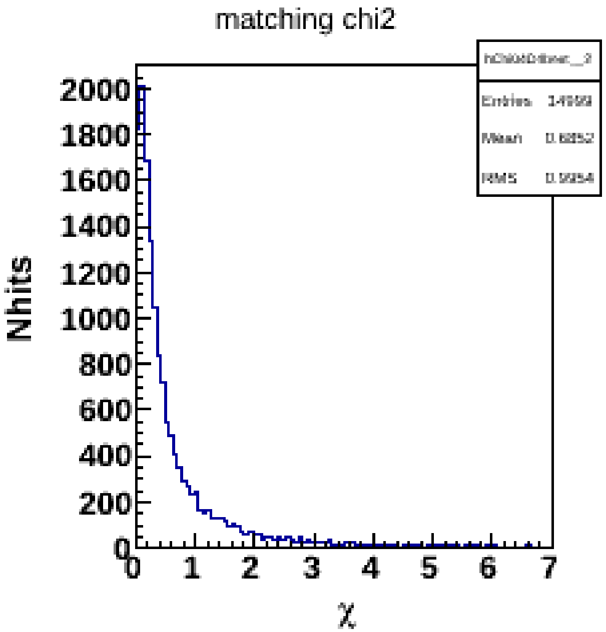


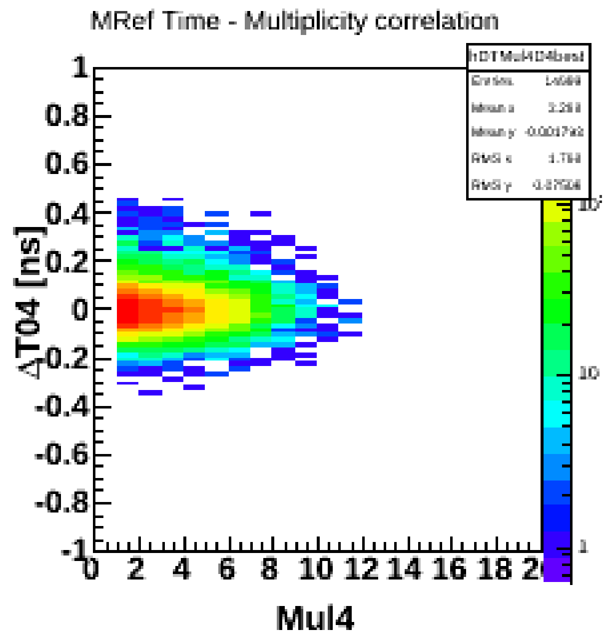


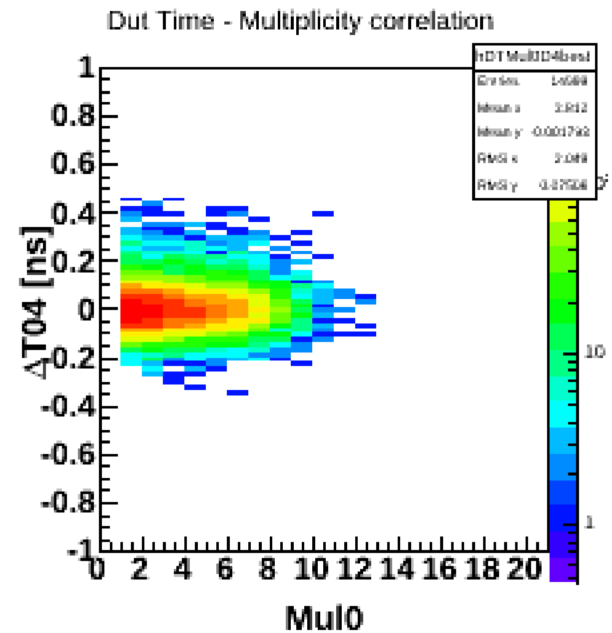




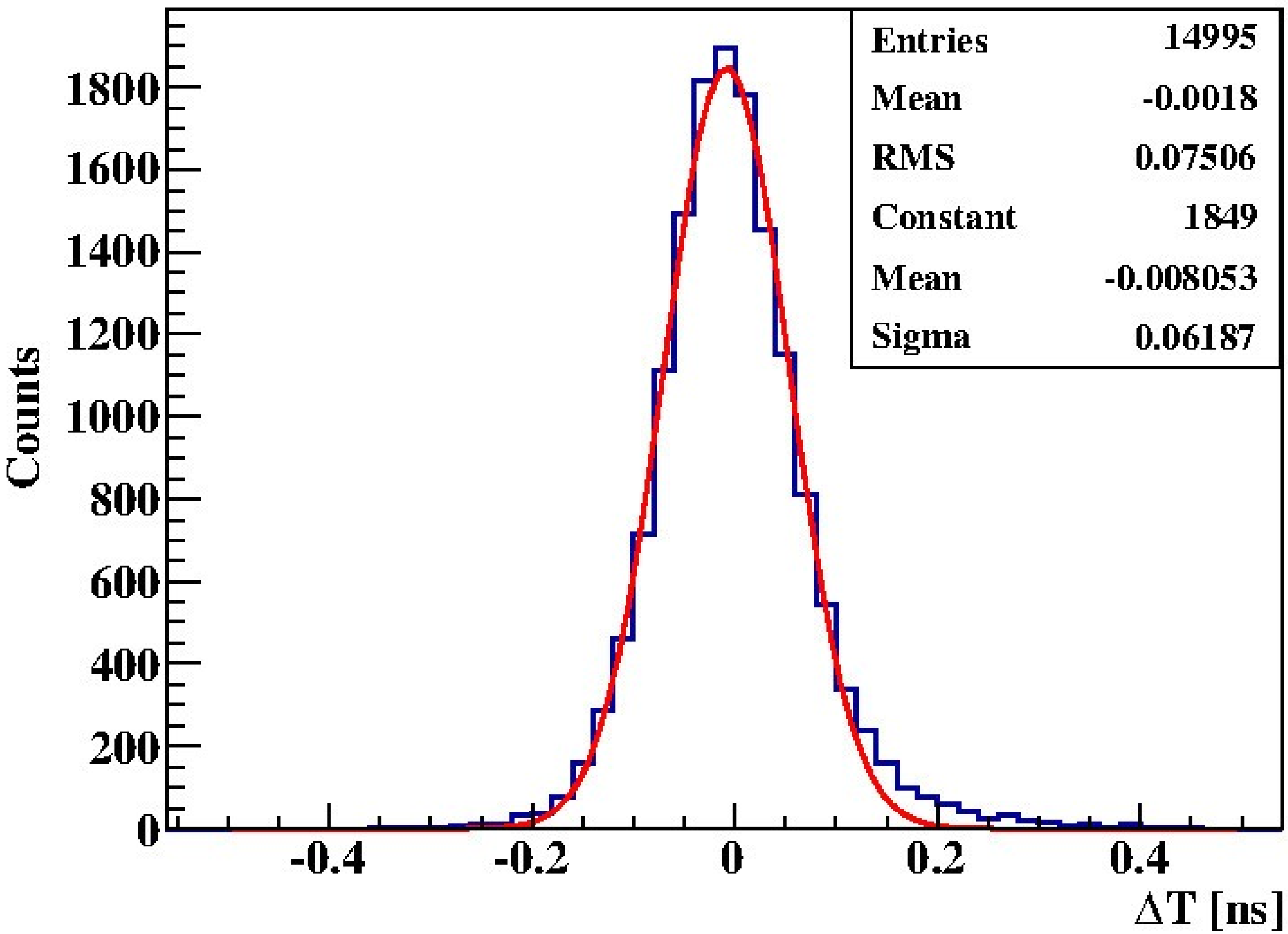
Matching χ and hit multiplicities







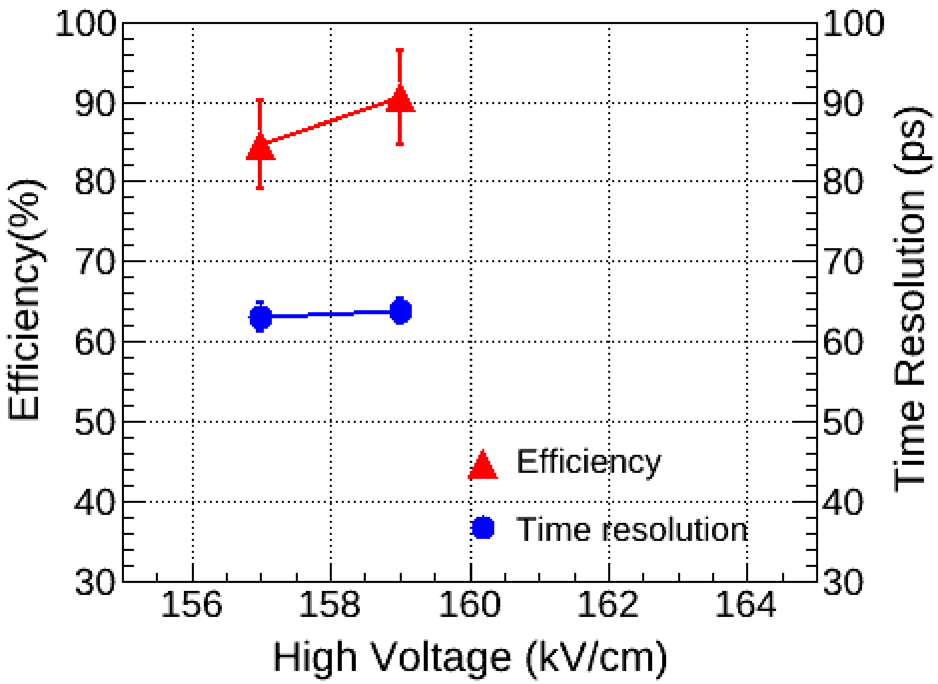
Time difference spectrum



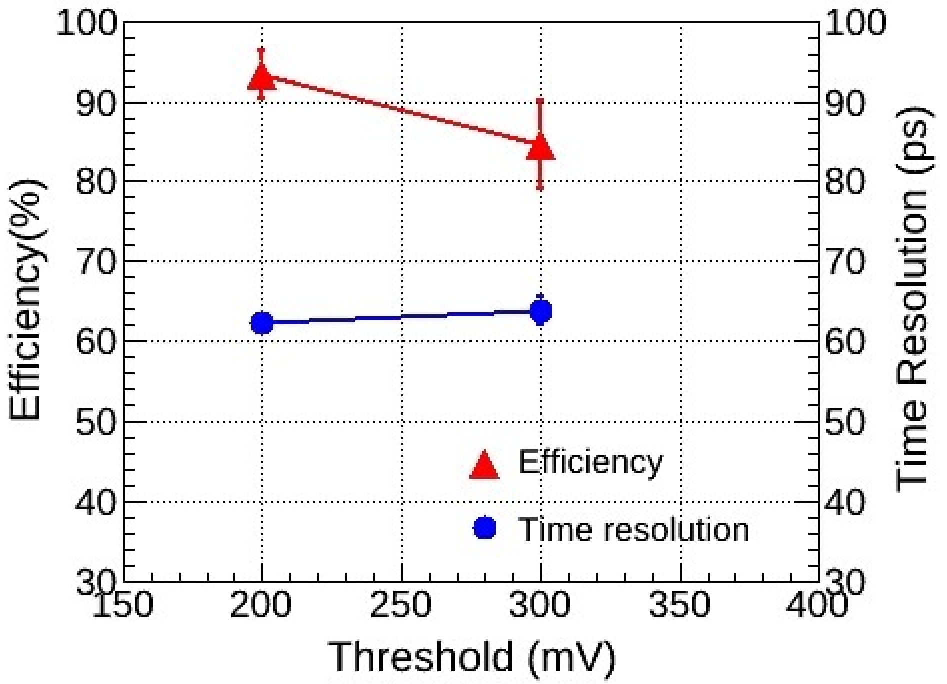
System time resolution = 62 ps

Single counter time resolution = 44 ps

Efficiency and time resolution
as a function of high voltage and FEE threshold



FEE threshold = 300 mV



Electric Field = 157 kV/cm

Conclusions and Outlook

- The results of 2016 SPS in-beam test for RPC2015 prototype in a free-streaming signal processing show:
  - ✓ detector performance in terms of time resolution is very good and not change significantly with high voltage (HV) and applied threshold.
  - ✓ the obtained efficiency behaves as expected as a function of applied HV and threshold.
  - ✓ The slightly lower value of the efficiency in the treager-less operation in comparison with a triggered one is still under investigation.
- The obtained results demonstrate the possibility to operate MSMGRPCs in a free-streaming readout mode with minimum fake signals produced by reflections, thus becoming a real candidate for high interaction rate experiments.

Conclusions and Outlook

- The presented activity was reported in:
  - ✓ M. Petris D. Bartos, M. Petrovici, L. Radulescu, V. Simion, P-A. Loizeau, J. Fruehauf, I. Deppner, N. Herrmann, C. Simon
    "Performance of a two-dimensional position sensitive MRPC prototype with adjustable transmission line impedance",
    Nuclear Inst. and Methods in Physics Research, A, 920(2019),100.
  - ✓ M. Petris D. Bartos, M. Petrovici, L. Radulescu, V. Simion, P-A. Loizeau, J. Fruehauf, I. Deppner, N. Herrmann, C. Simon.
    "Performance in heavy -ion beam tests of a high time resolution and two-dimensional position sensitive MRPC with transmission line impedance matched to the FEE".
    Accepted for publication in POS, Proceedings of "XXXIX International Conference on High Energy Physics" (ICHEP2018), July 4-11, 2018, Seoul, KoreaI
  - ✓ M. Petris D. Bartos, M. Petrovici, L. Radulescu, V. Simion, J. Fruehauf, I. Deppner, N. Herrmann
    "High time resolution, two-dimensional position sensitive MSMGRPC for high energy physics experiments"
    "European Physical Society Conference on High Energy Physics" (EPS-HEP2019), July 10 – 18, 2019, Ghent, Belgium

The main part of the CBM cave is fully excavated and the ground is prepared for the floor slab.


Thank you for your attention!