# Time and position resolution of high granularity, high counting rate MRPC for the inner zone of the CBM-TOF wall

**M. Petris, D. Bartos, G. Caragheorgheopol, M. Petrovici, L. Radulescu, V. Simion**
**IFIN-HH Bucharest**

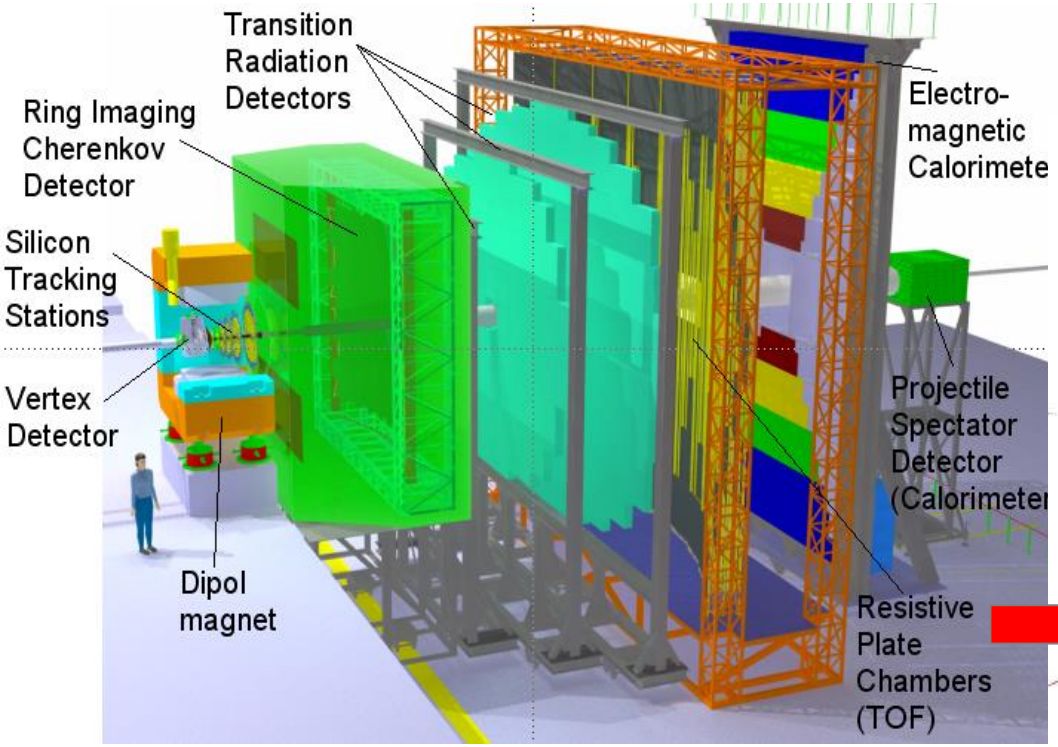
**J. Frühauf, P-A. Loizeau, M. Kis**
**GSI Darmstadt**

**I. Deppner, N. Herrmann, C. Simon**
**Heidelberg University**

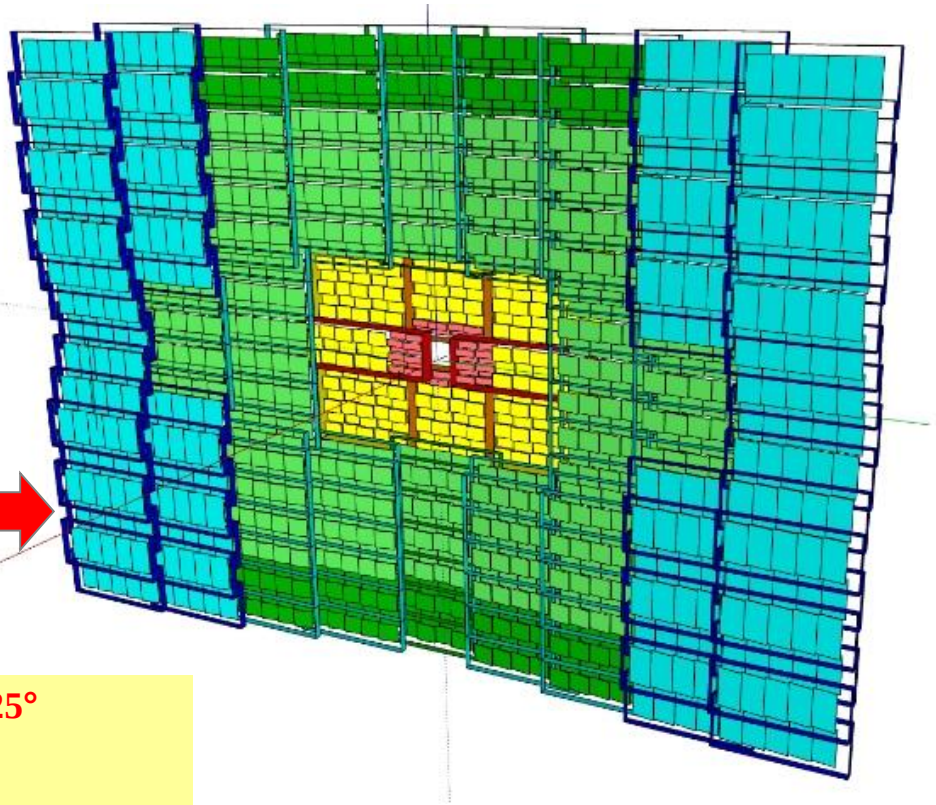
# Outline

- Motivation – CBM-TOF inner wall
- High counting rate, high granularity MGMSRPC – short review
- MGMSRPC performance in heavy ion beam-tests
  - Efficiency
  - Cluster size
  - Time resolution
- New prototypes for CBM-TOF inner wall at SIS100
- CBM-TOF inner wall design
- Conclusions and Outlook

# CBM – TOF wall



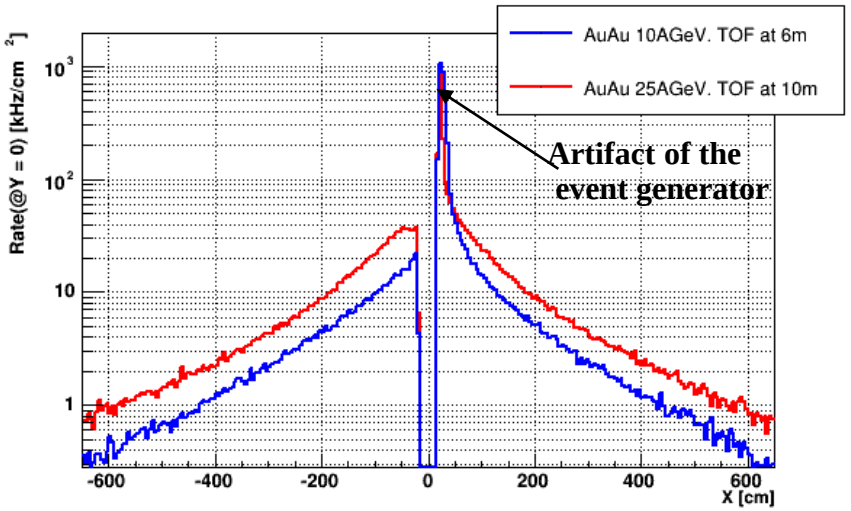

**Time-of-Flight (ToF) subsystem provides charged hadron identification**

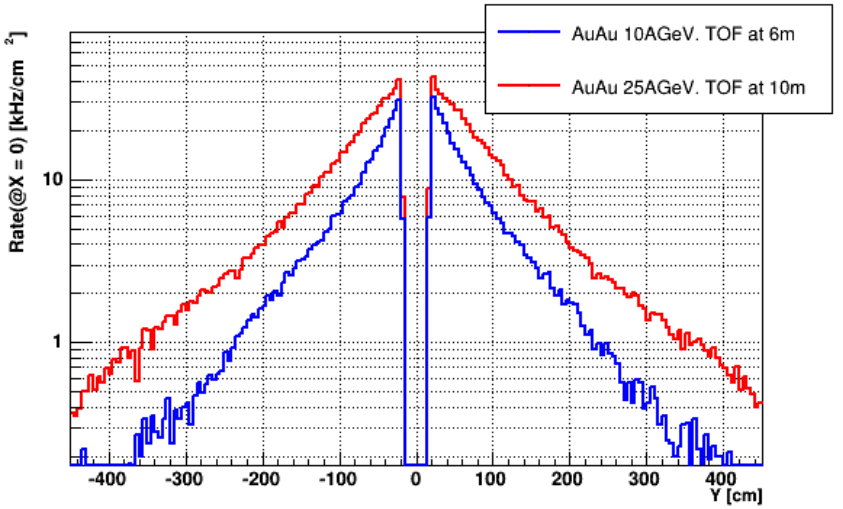


- **Polar angular range : 2.5° – 25°**
- **Active area: 120 $m^2$**
- **Full system time resolution : $\sigma_T \sim 80$ ps**
- **Efficiency: > 95 %**
- **Rate capability: > 30 $kHz/cm^2$**
- **Occupancy : < 5 %**
- **Free streaming data acquisition**

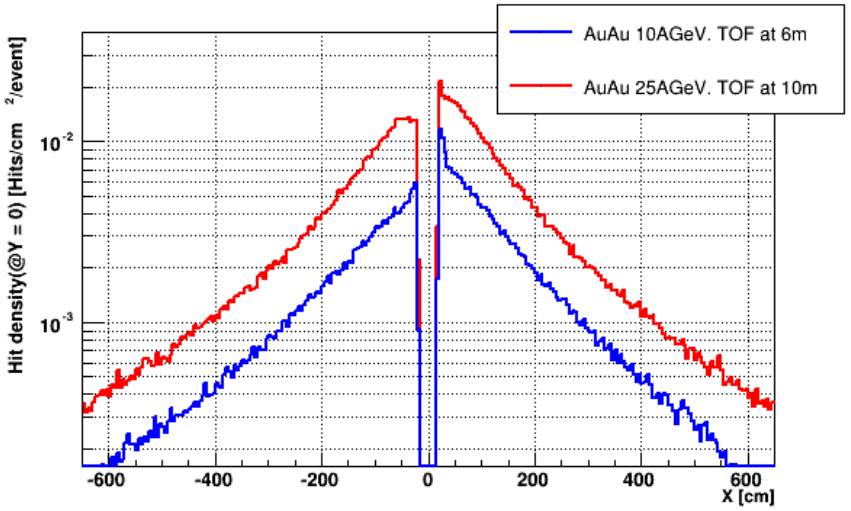
**CBM – TOF Technical Design Report, October 2014, GSI Darmstadt**

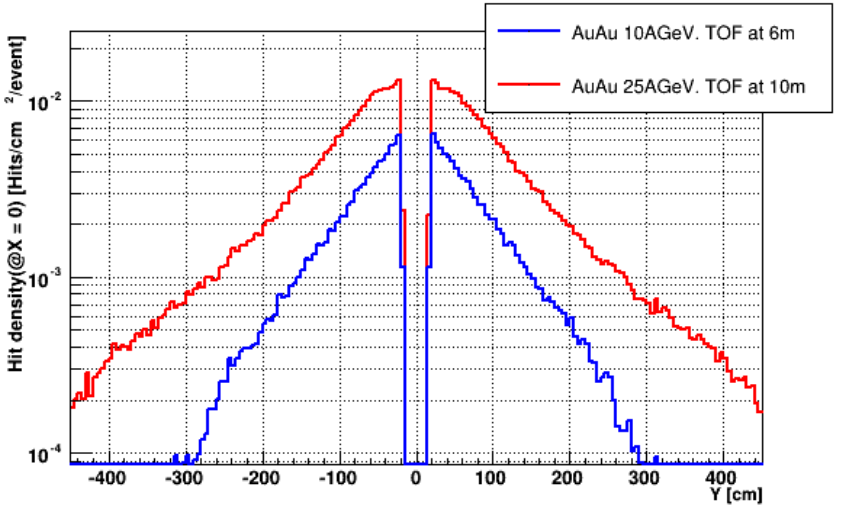
# Incident particle flux on CBM-TOF wall




# Hit density on CBM-TOF wall



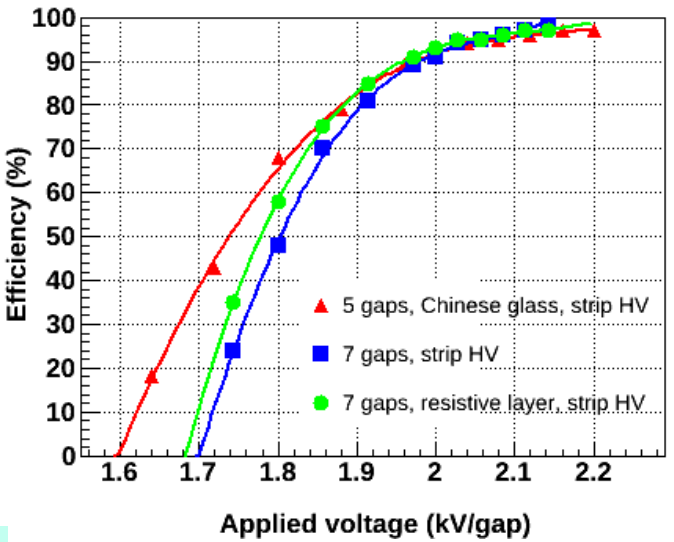



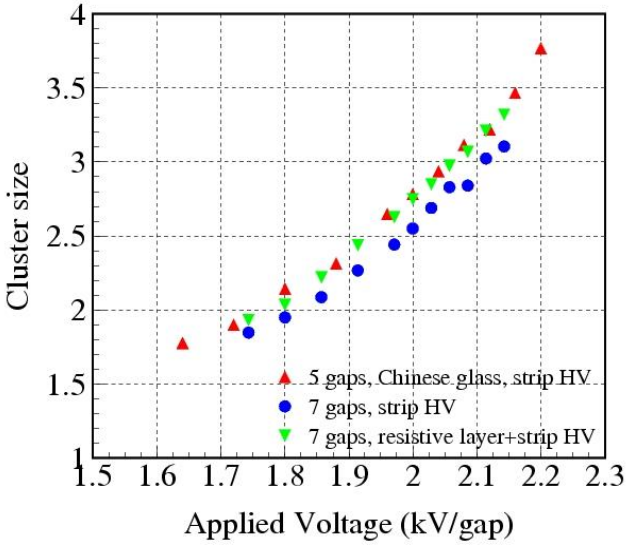

**CBM – TOF Technical Desig Report, October 2014, GSI Darmsadt**

# Performance of high granularity MGMSRPC prototype

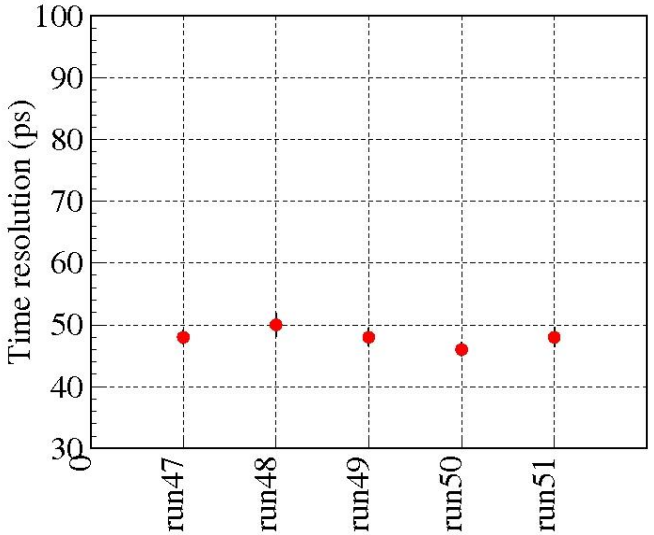
- ✓Symmetric two stack structure
- ✓2 x 5 gap architecture, strip readout
- ✓ Active area = 46mm x 183mm
- ✓Gas gap thickness: 140μm
- ✓2.54mm pitch = 1.1mm (w) + 1.44mm (g)
- ✓Differential readout, 100 Ω impedance
- ✓Low resistivity Chinese glass (~$10^{10}$ Ωcm)

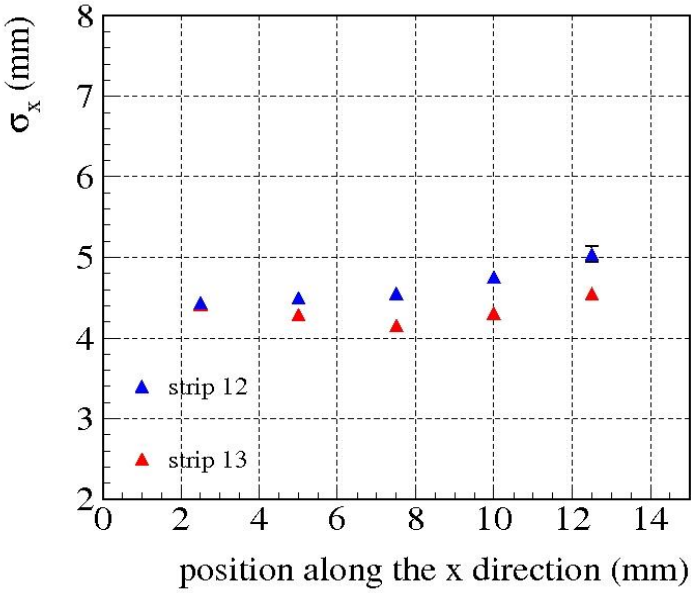
*PS – CERN, pion beam, 6 GeV/c momentum*

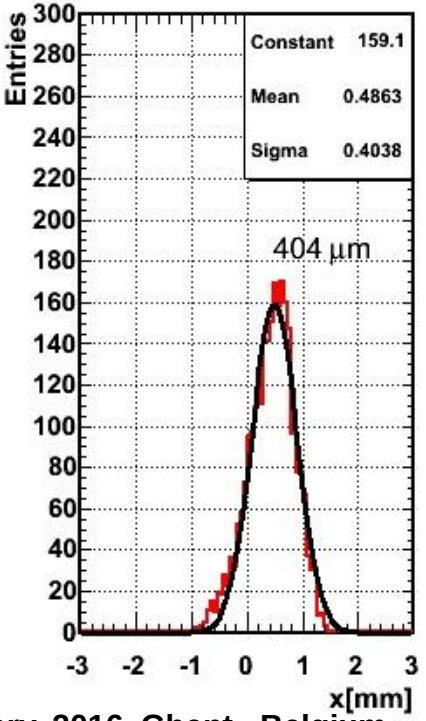



**FEE = NINO ASIC (ALICE Collaboration)**
**Convertors = CAEN V1290 A TDC**

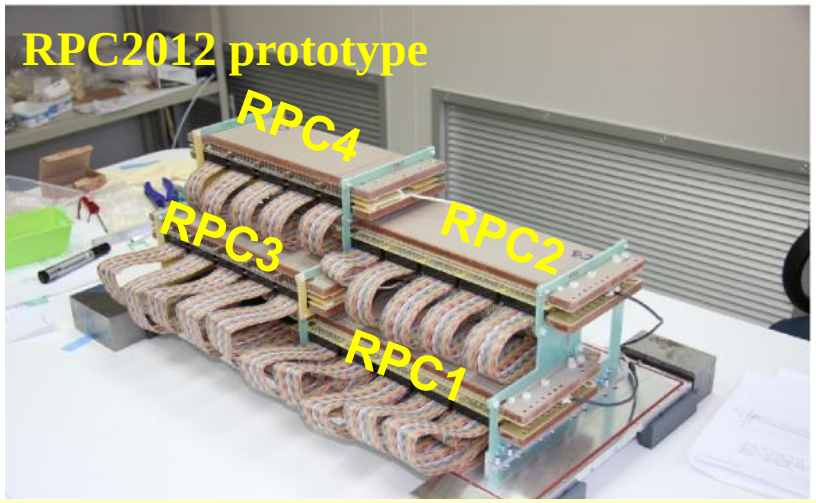


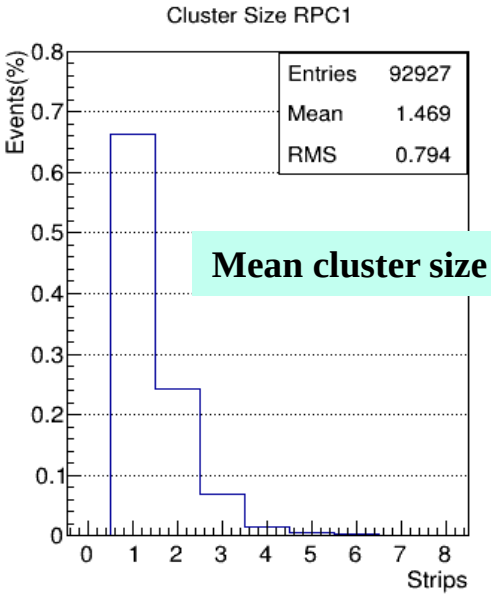




*M.Petrovici, M. Petris et al. JINST 7 P11003, 2012*

# Basic architecture for MGMSRPC implementation in the inner zone of the CBM-TOF wall

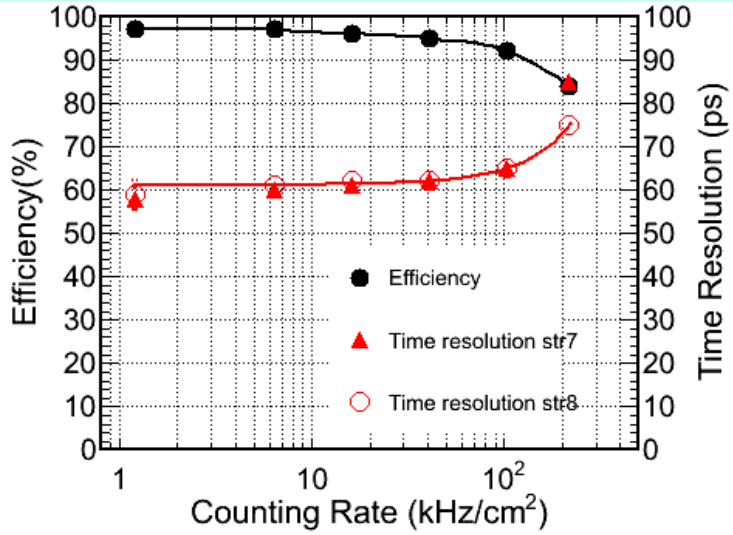



- 7.4 mm strip pitch = 5.6 mm width + 1.8 mm gap
- Differential readout, 50 Ω impedance
- Low resistivity Chinese glass (~$10^{10}$ Ωcm)



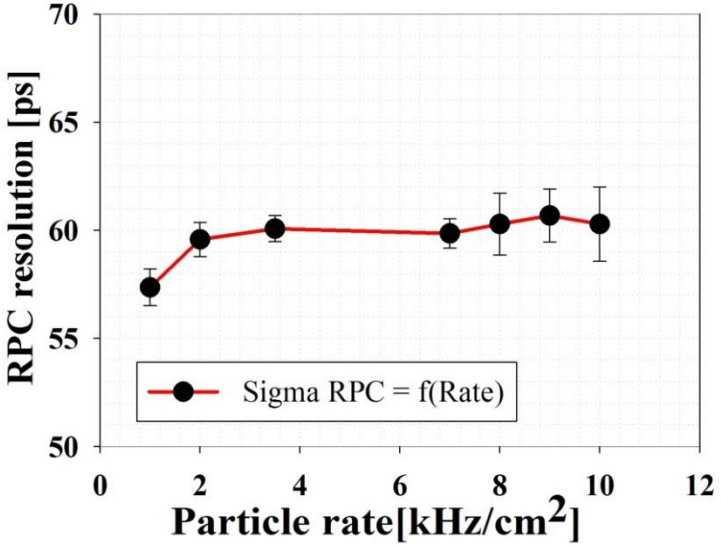

**Mean cluster size = 1.5 strips**

*Focused proton beam, 2.5 GeV/c @ COSY, Jülich*

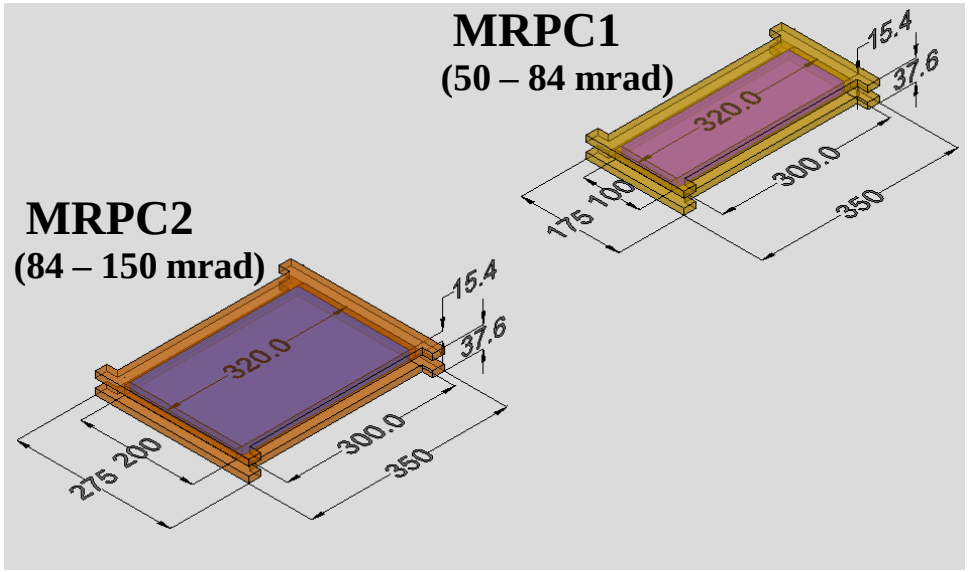


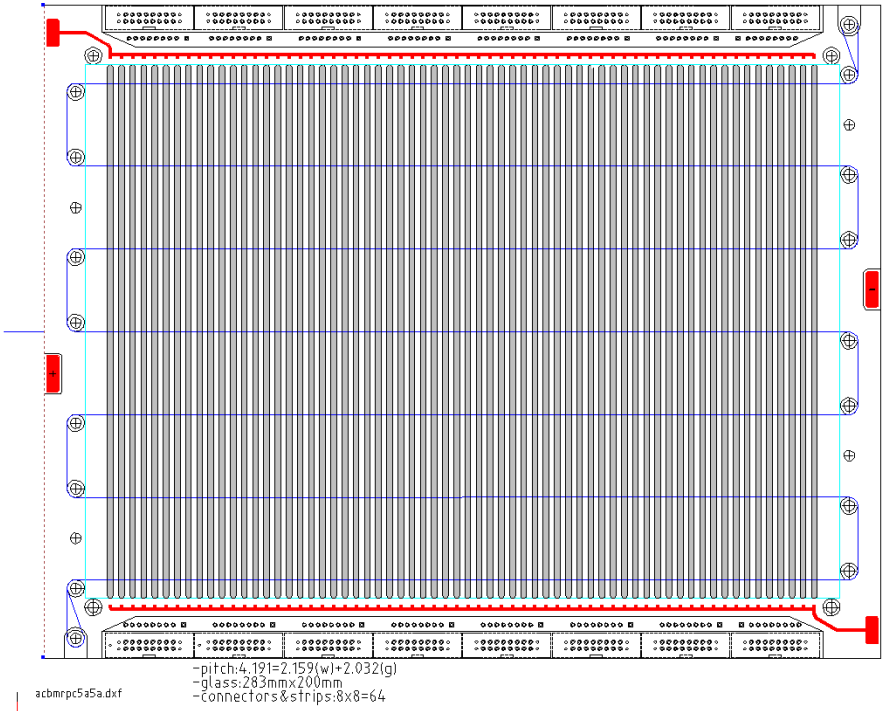

*Ni beam of 1.9A GeV on Pb target, GSI Darmstadt*

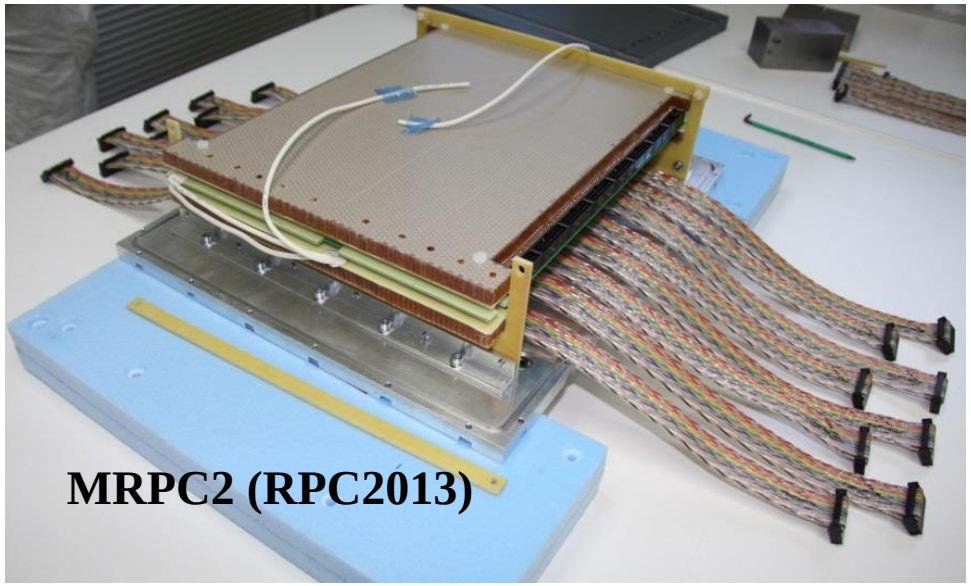
*exposure of whole active area*



# Real size MGMSRPC prototype for the inner zone of the CBM-TOF wall

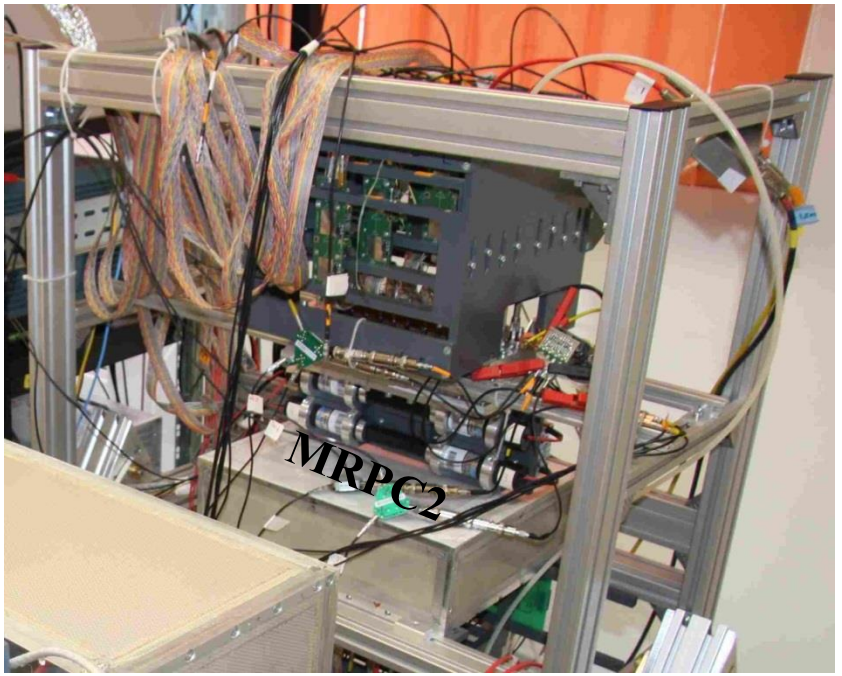


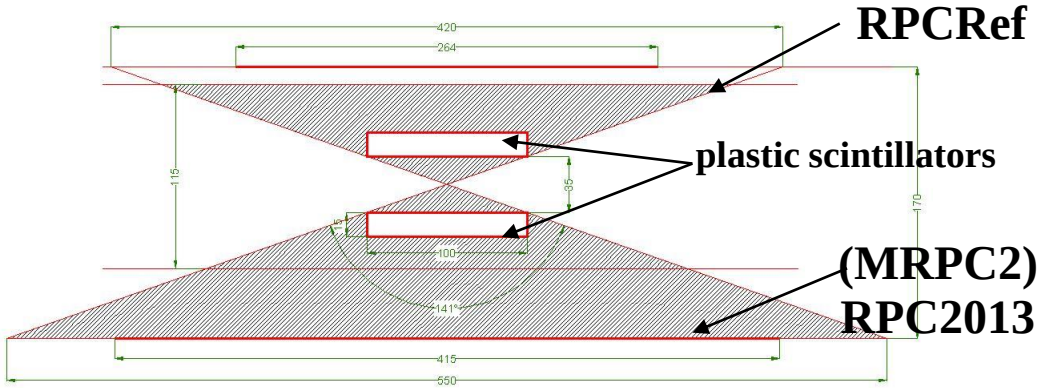



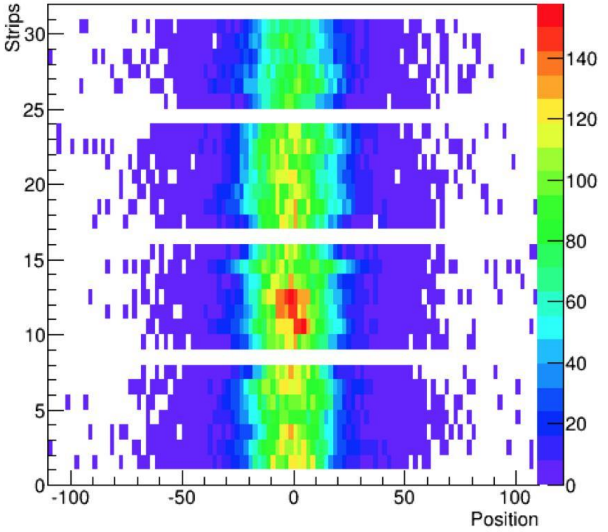

- ✓ Symmetric two stack structure: **2 x 5 gas gaps**
- ✓ Resistive electrodes**: low resistivity glass**
- ✓ Gap size: 140 µm thickness
- ✓ Active area 200 x 266 $mm^2$
- ✓ Pitch=2.2mm (w) +2.0 mm (g) = 4.2 mm
- ✓ Differential readout, **100 Ω impedance**

# Cosmic rays test in HPD Detector Laboratory

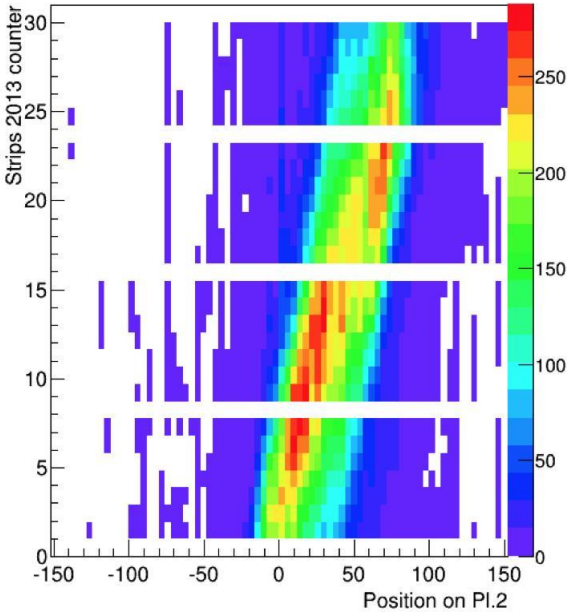



**Position along the strip as a function of strip number**

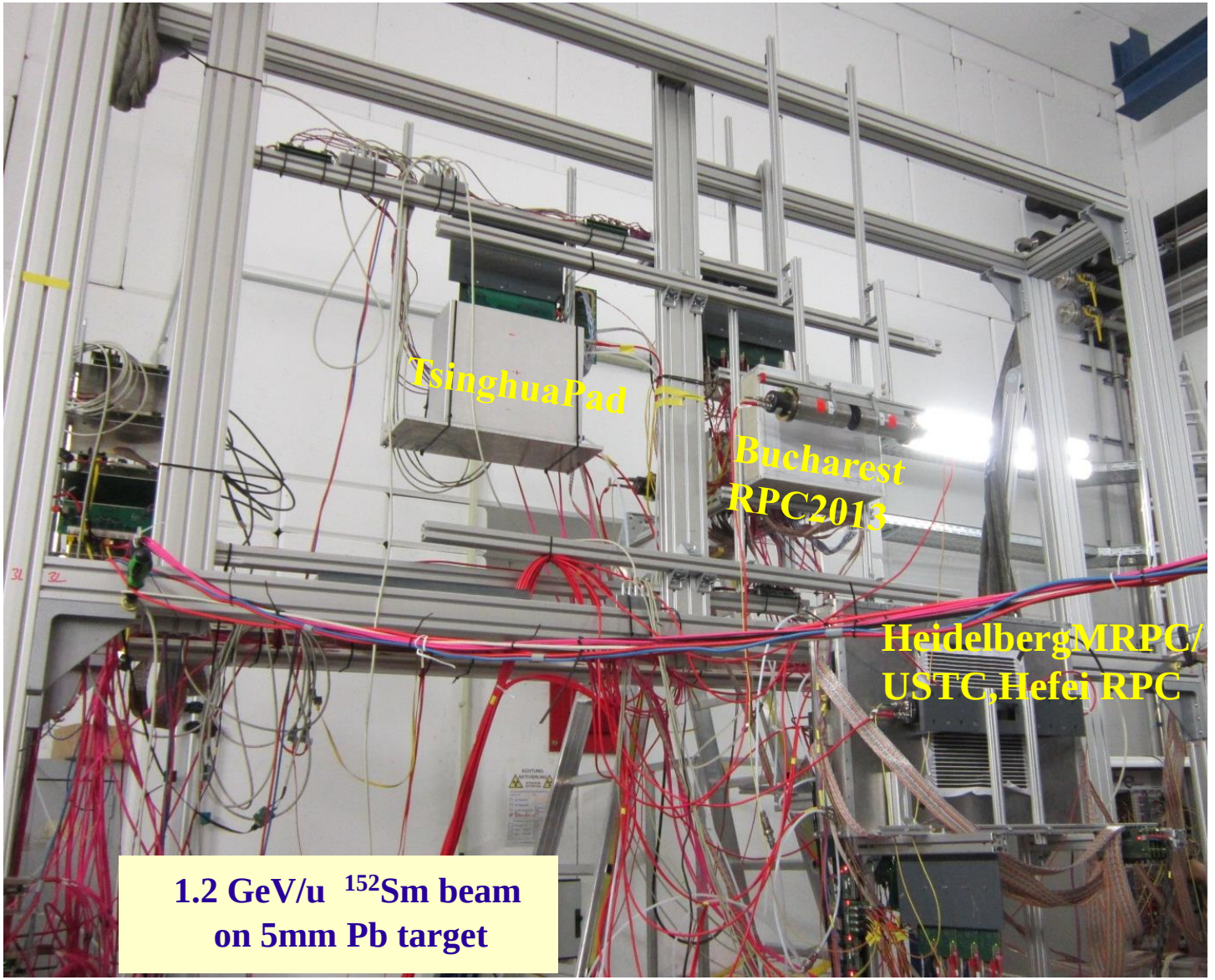



**Correlation between position along the strips and position in the plastic scintillator**

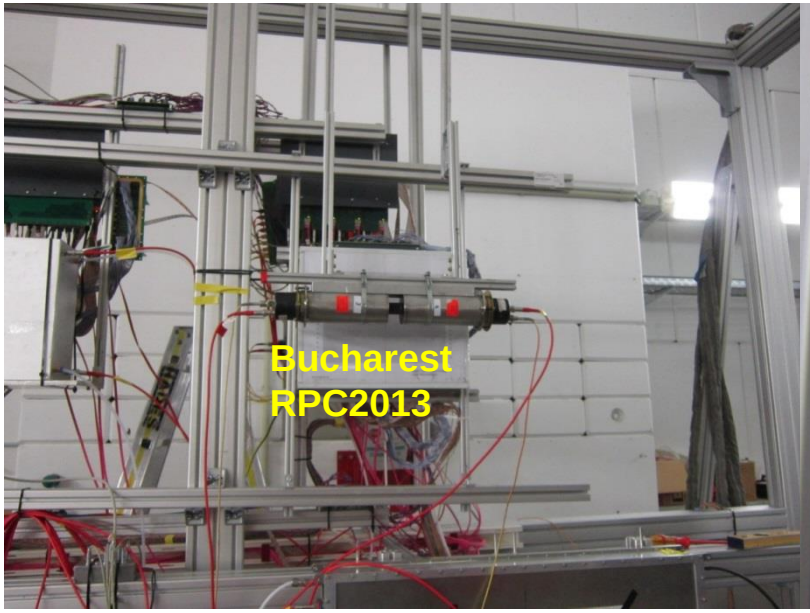


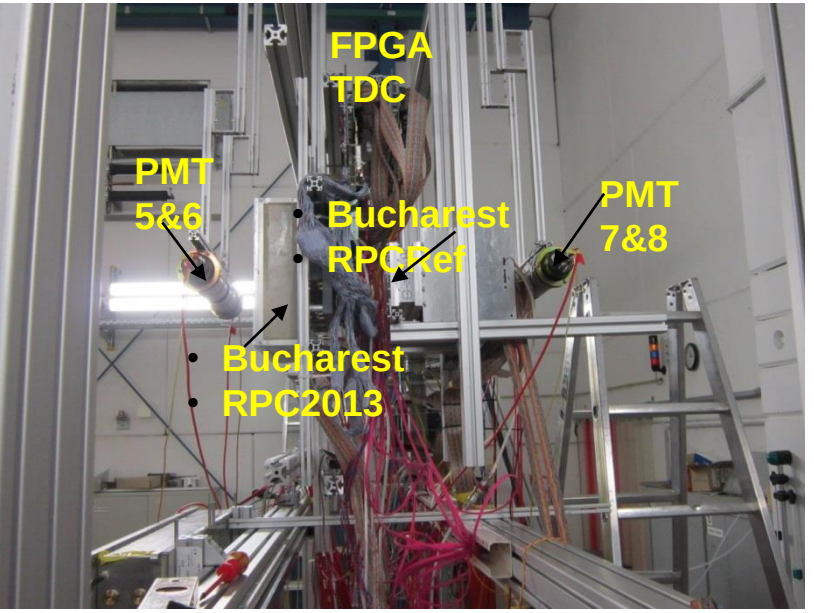
# Multihit in-beam test with uniform exposure

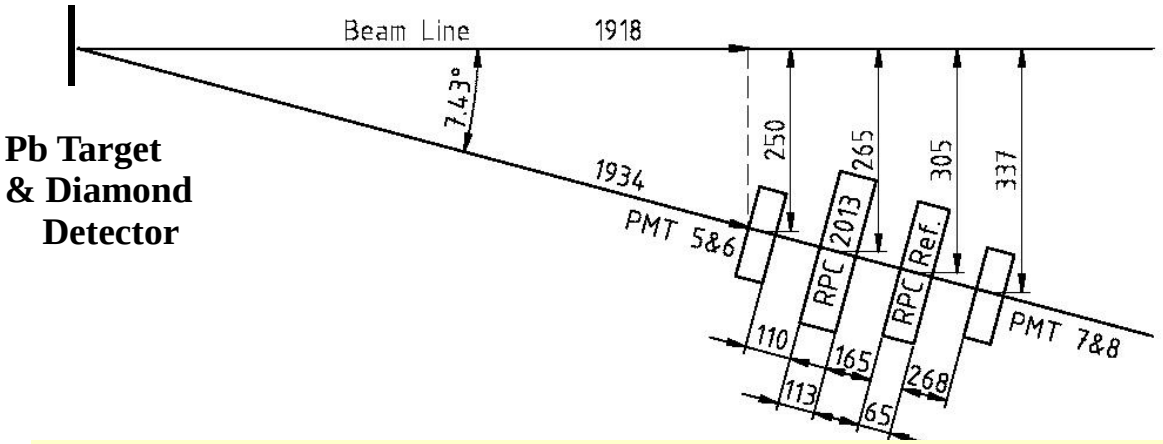
***GSI Darmstadt, October 2014***



# Bucharest MGMSRPCs in the Experimental Setup




Pb Target
& Diamond
Detector

- RPCRef = 2.54 mm strip pitch
- 85%$C_2H_2F_4$+10%$SF_6$+5%iso-$C_4H_{10}$
- Average counting rate = 1 kHz/cm$^2$

**RPC2013 - FEE = PADI8**

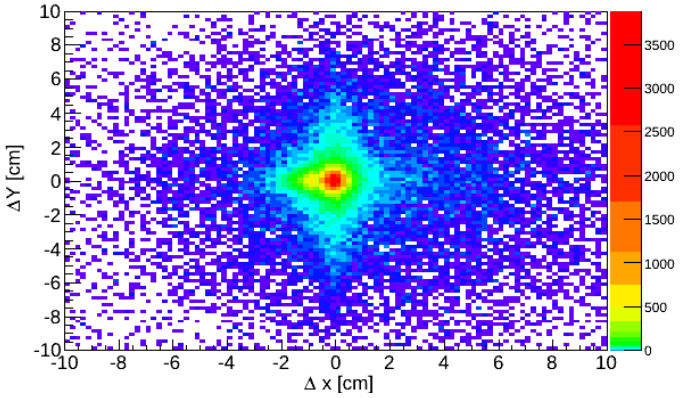
**RPCRef - FEE = PADI3**

**Goals: - counter performance in multi-hit environment**

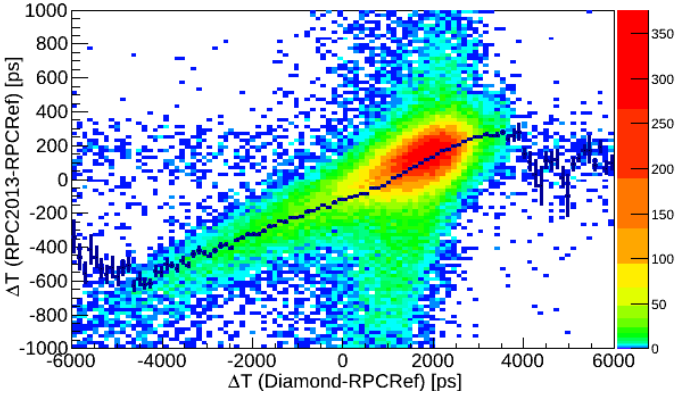
**- compatibility with the PADI8 FEE developed within CBM-TOF collaboration**

# Off-set Calibrations and Clusterization

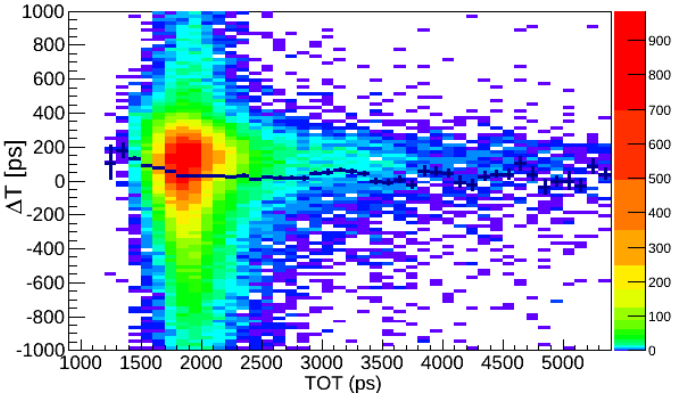
**Hit correlation RPC2013 - RPCRef**



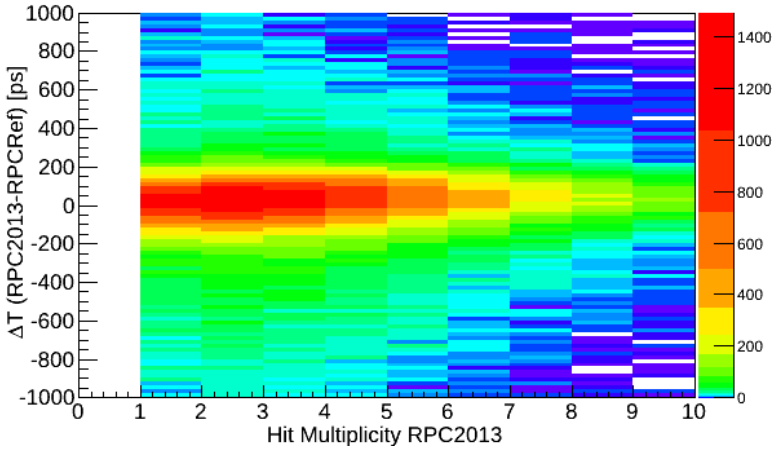

**Velocity spread effect**



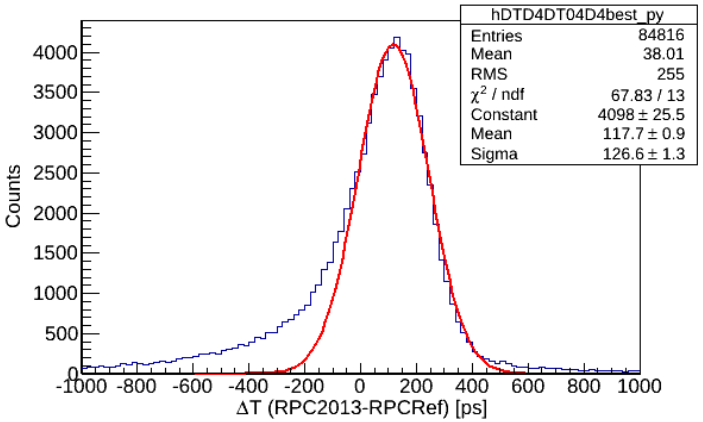

**Slewing effect**




**RPC2013 Time – hit multiplicity**

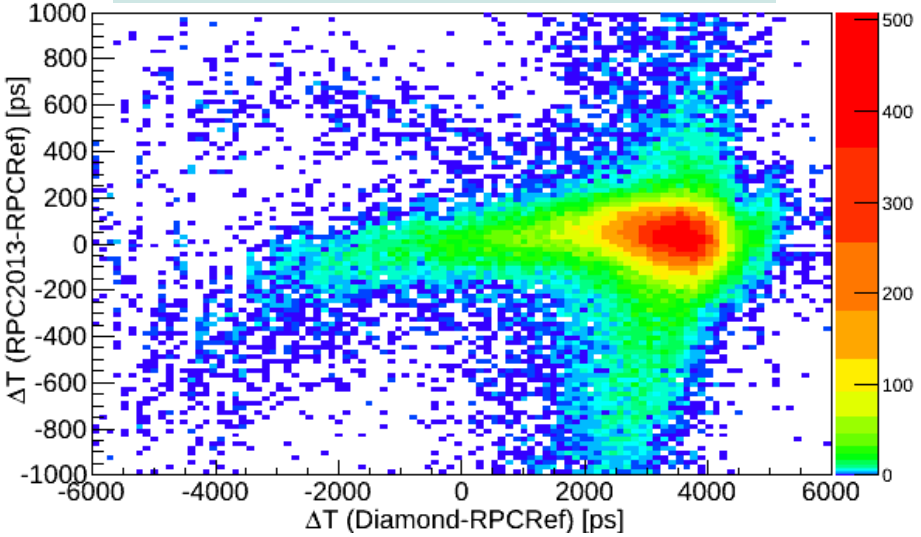



**Raw time spectrum**

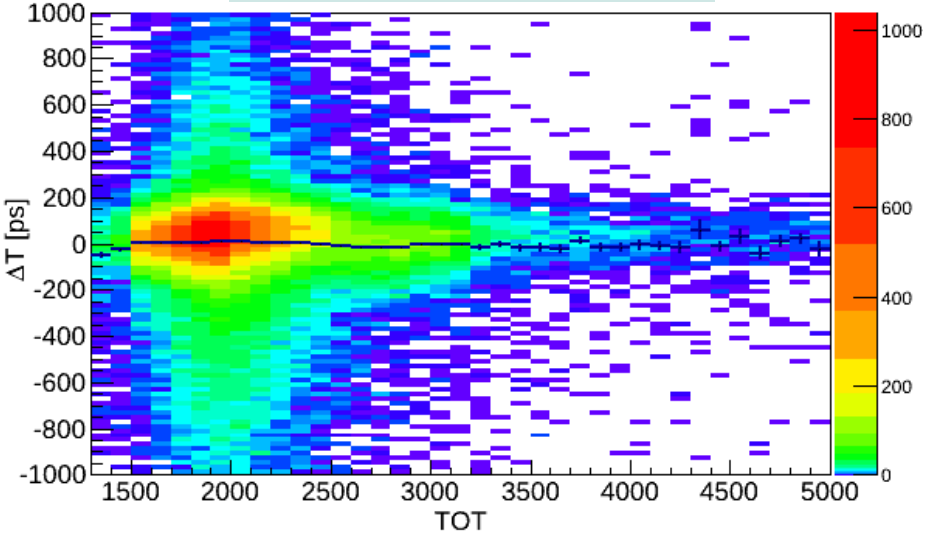


# Walk, Velocity spread & Position dependence corrections

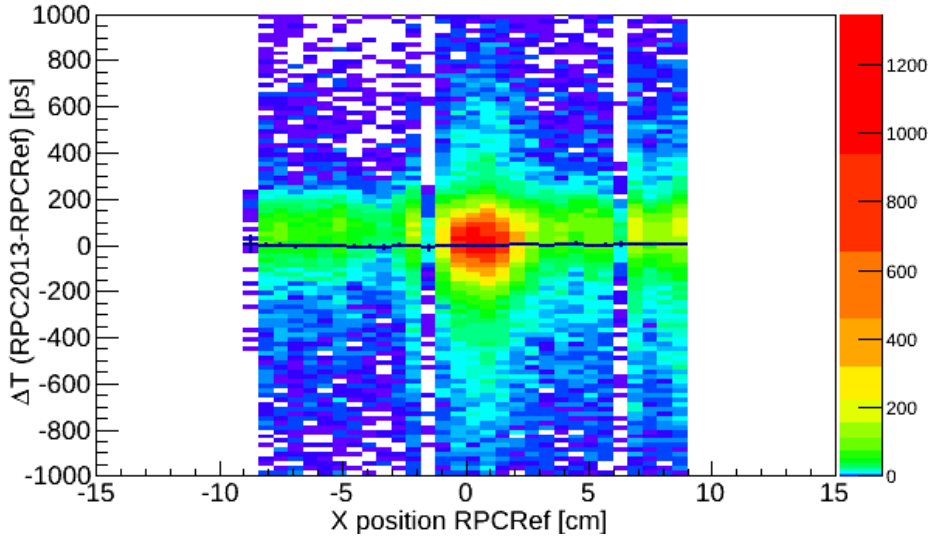
## Velocity spread corrections



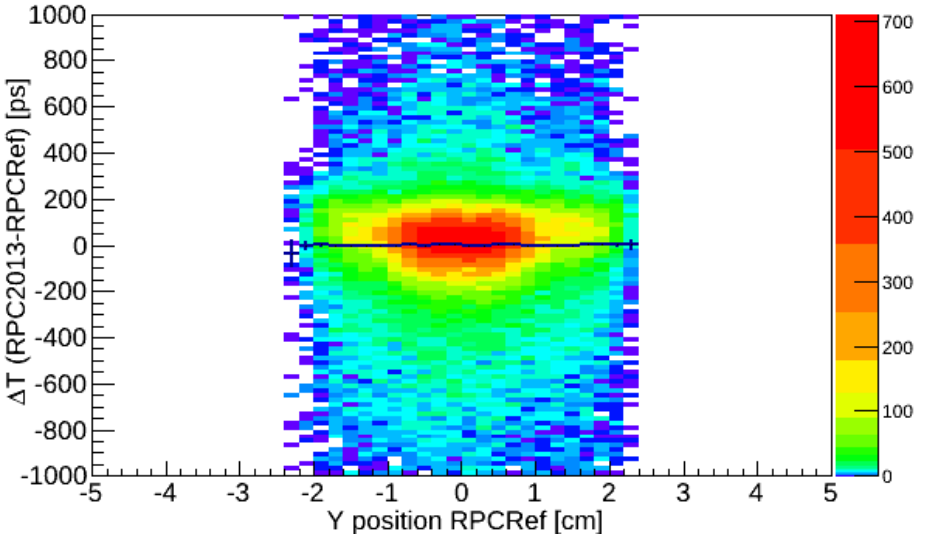

## Slewing corrections




## Position corrections across the strips

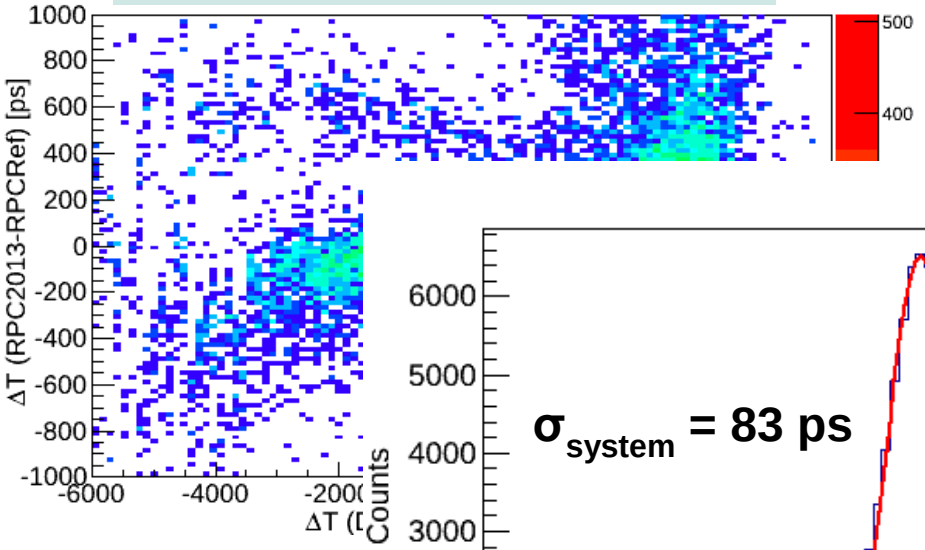



## Position corrections along the strips

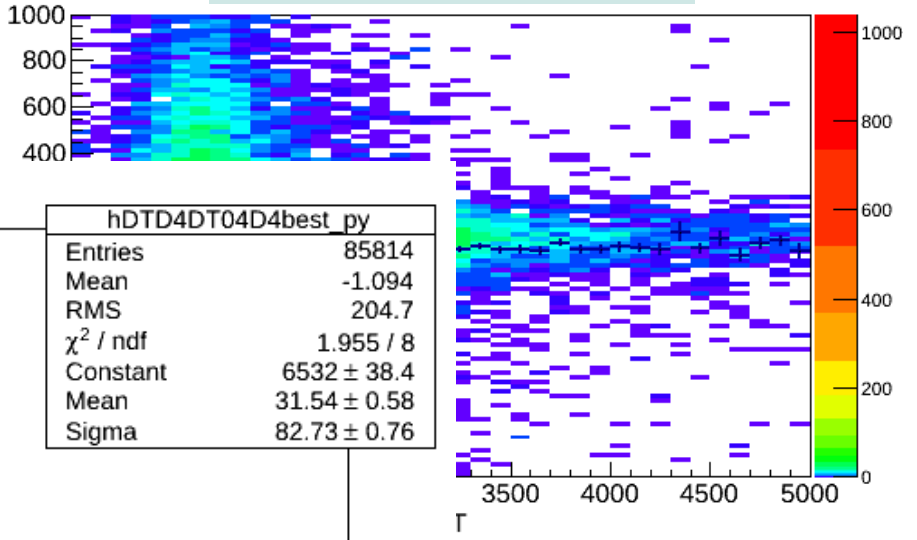


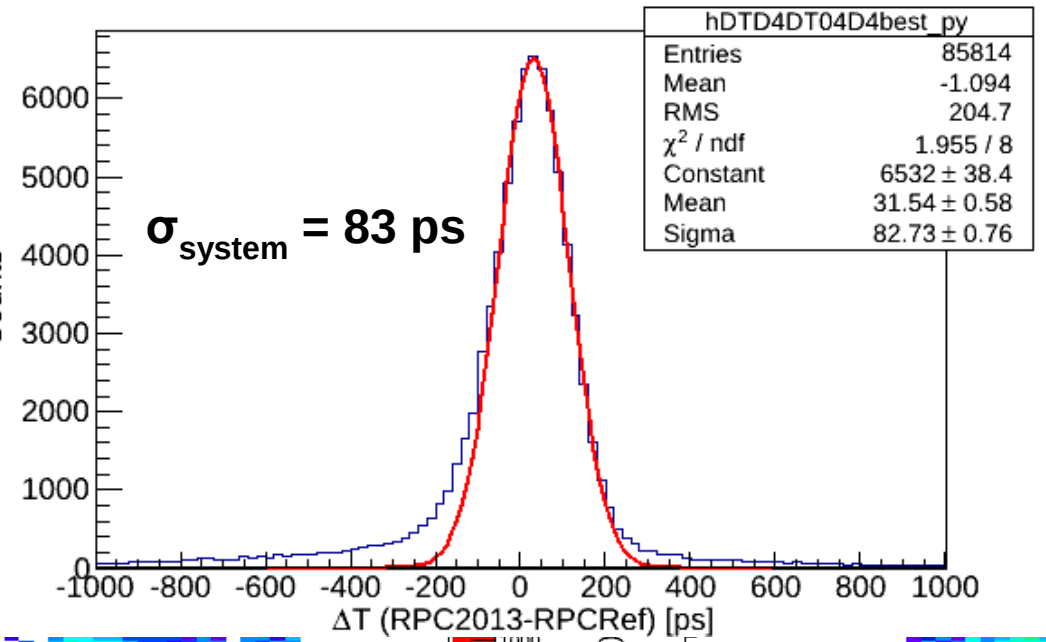
# Walk, Velocity spread & Position dependence corrections

## Velocity spread corrections



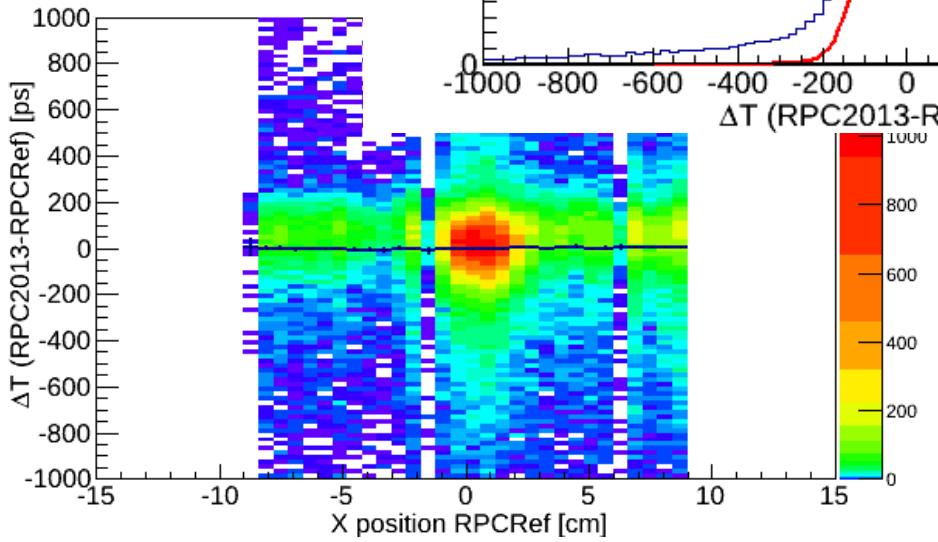

## Slewing corrections

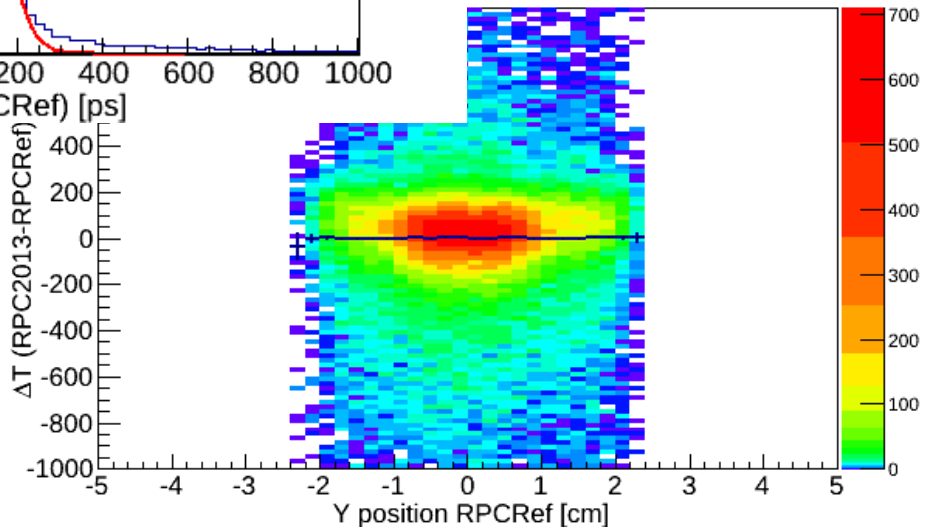



## Position corre

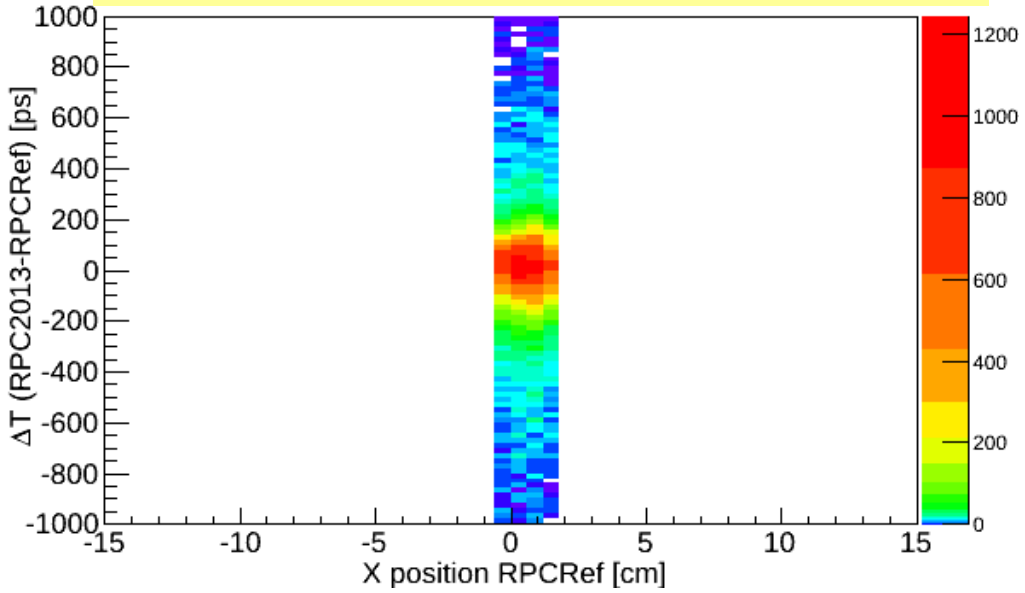
## ons along the strips



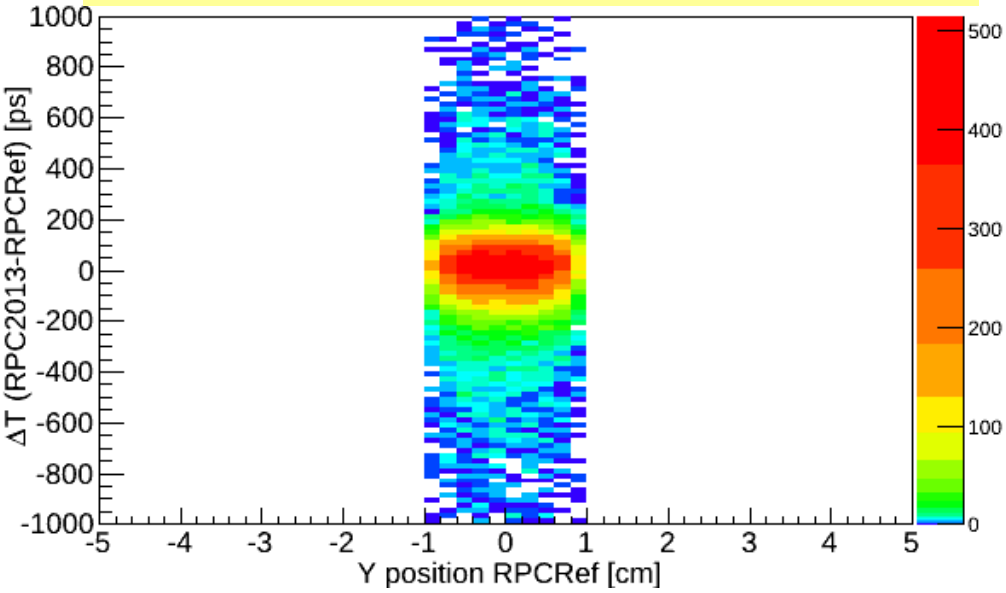



# Selection of good reference hits

**Position cut in RPCRef across the strips**



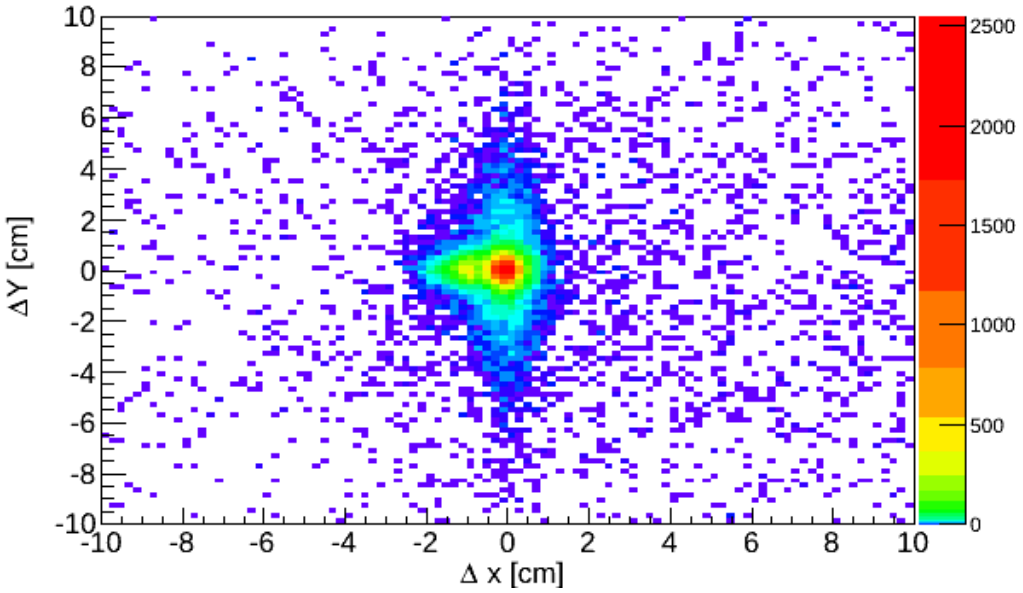

**Position cut in RPCRef along the strips**

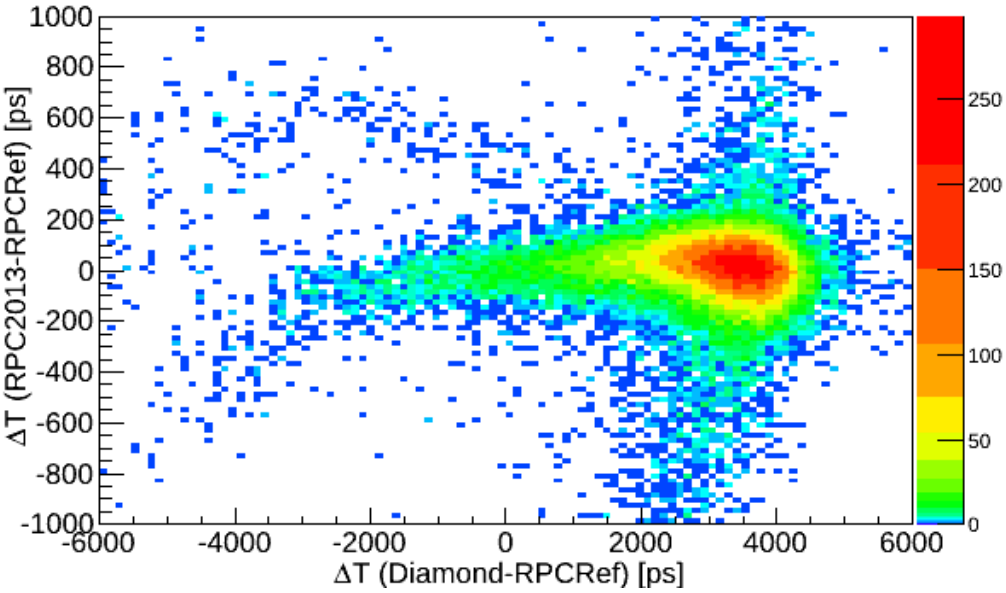



2.8 cm across the strips

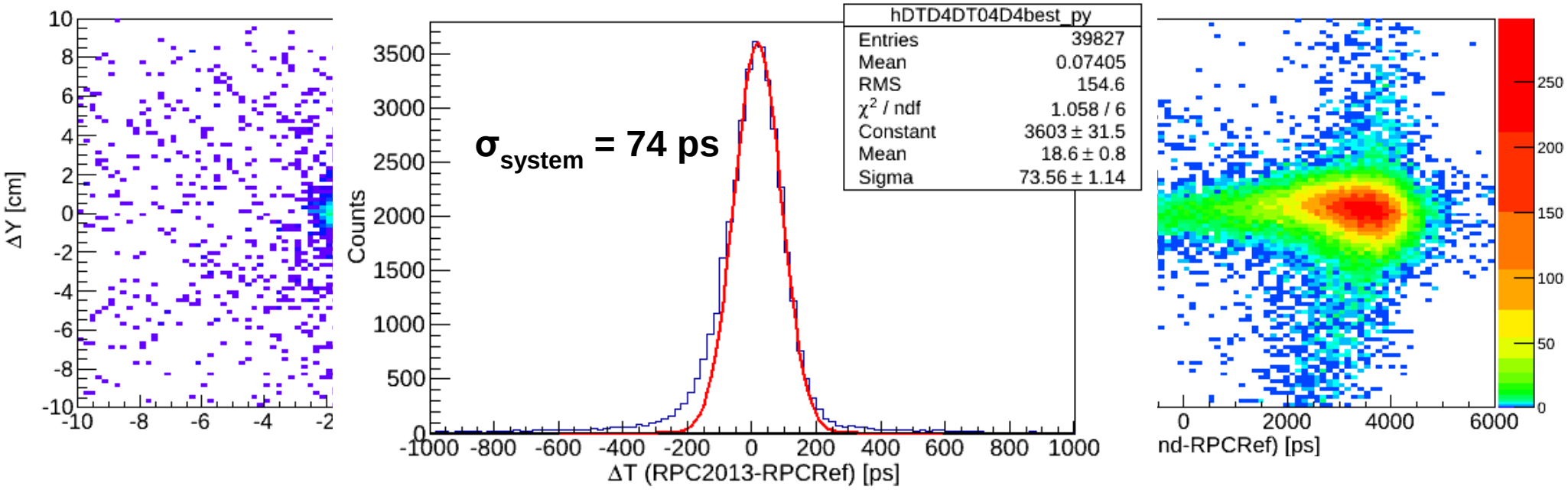
2 cm along the strips

# Time resolution with good reference hits

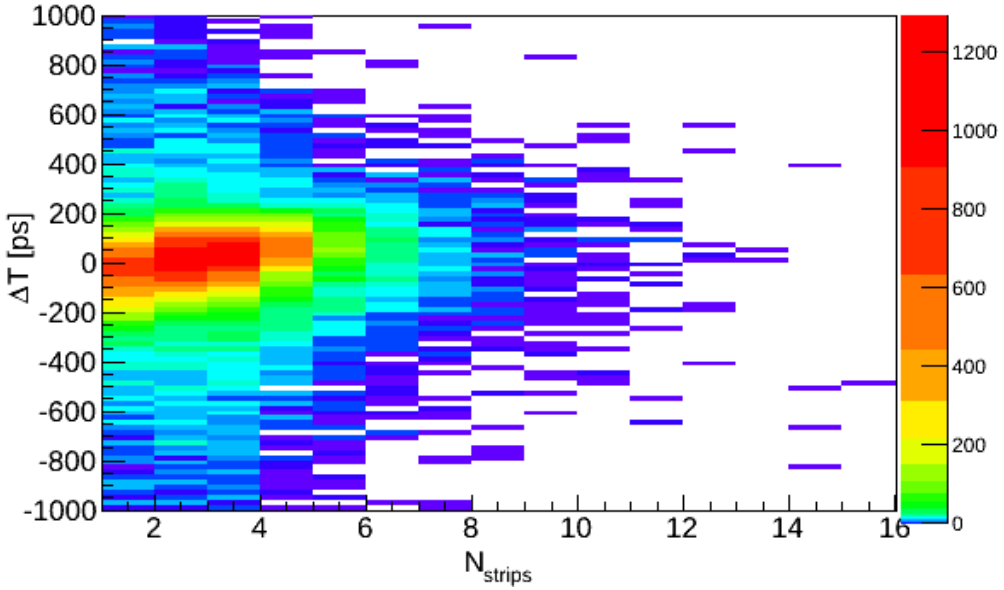


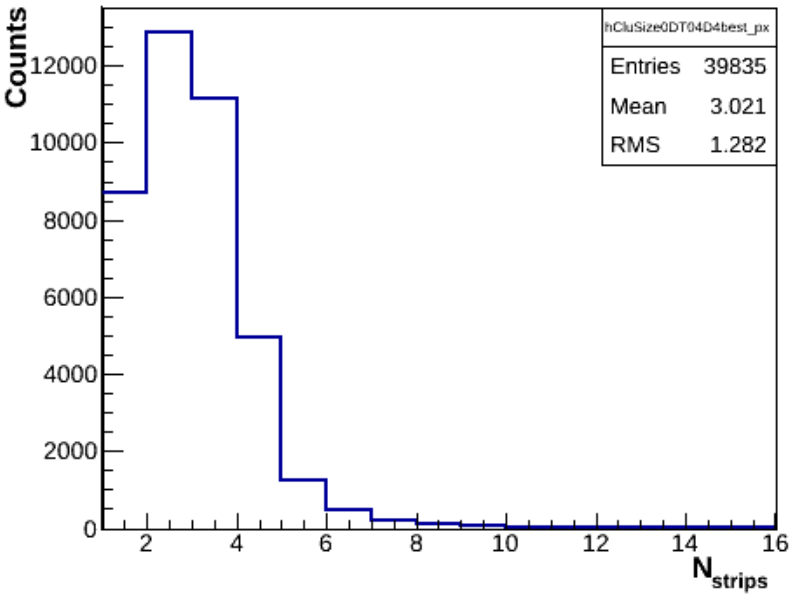



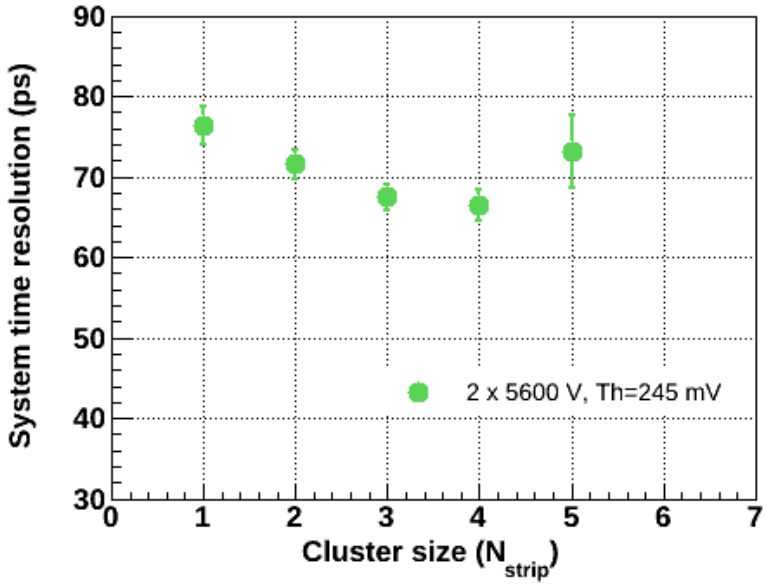
# Time resolution with good reference hits



# Cluster size @ HV= ± 5.6 kV, Th=245 mV

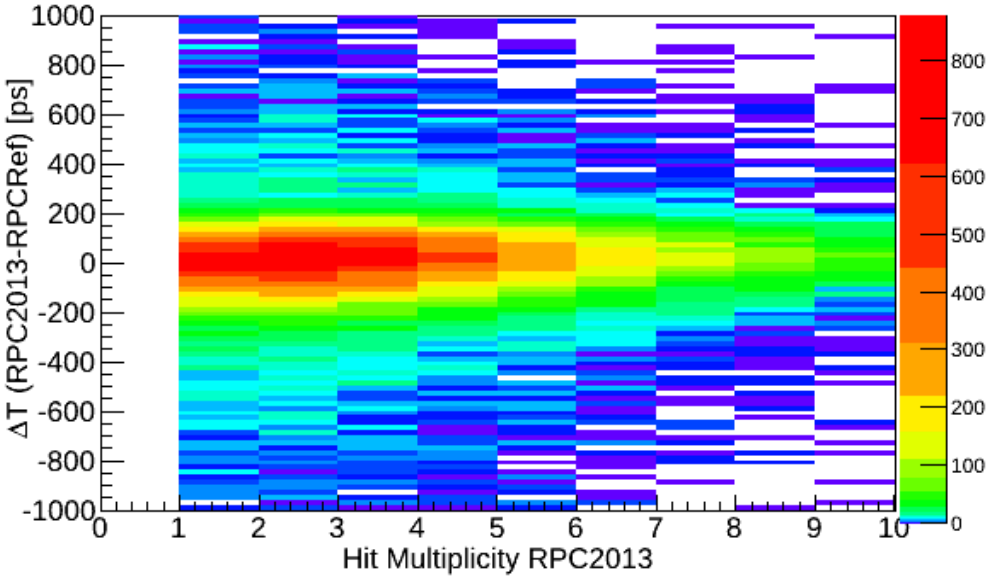


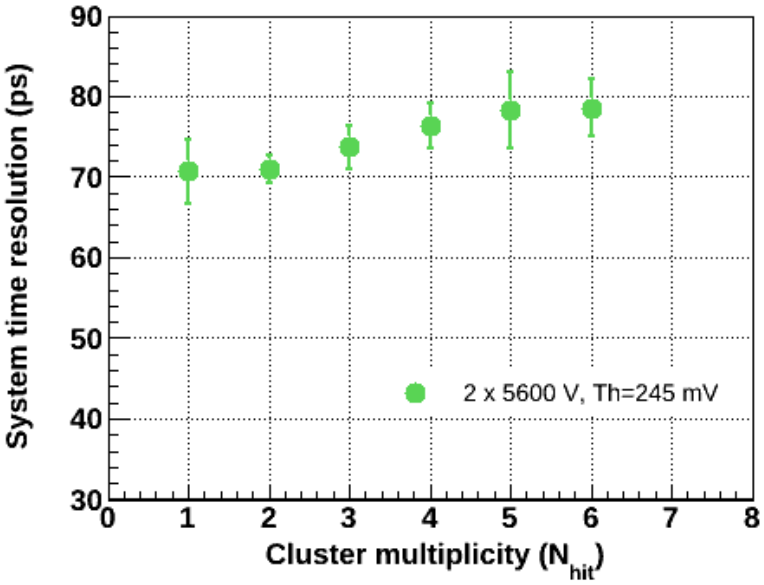



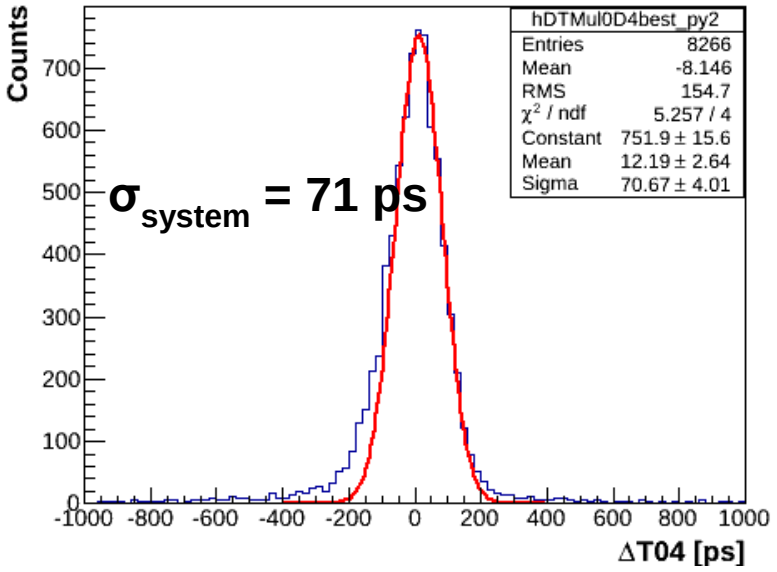

**Average cluster size = 3 strips**

# Hit multiplicity

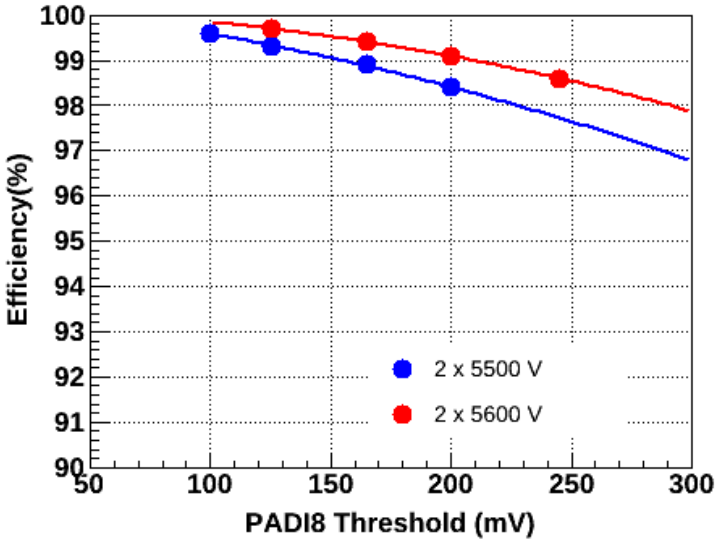


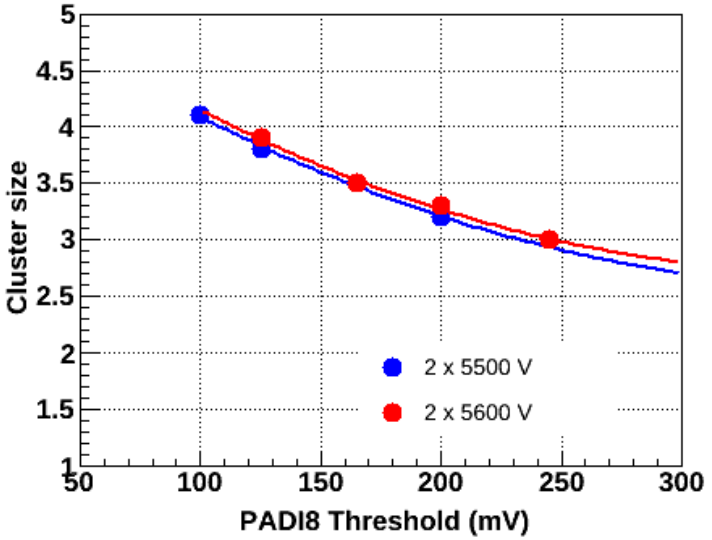



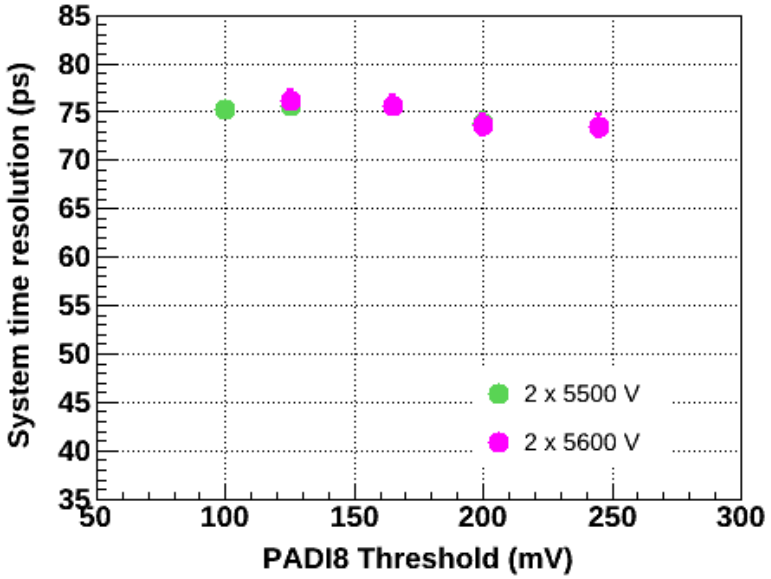

**Time resolution for hit multiplicity = 1**



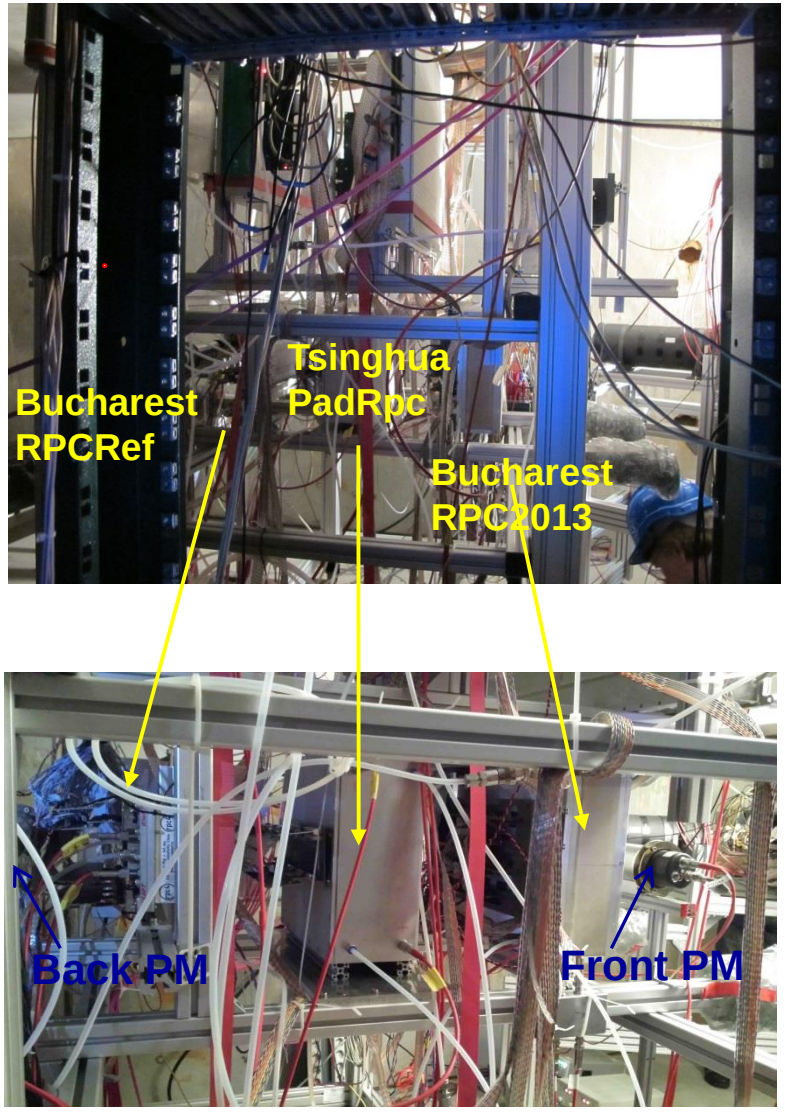
# Efficiency, Cluster Size & Time Resolution



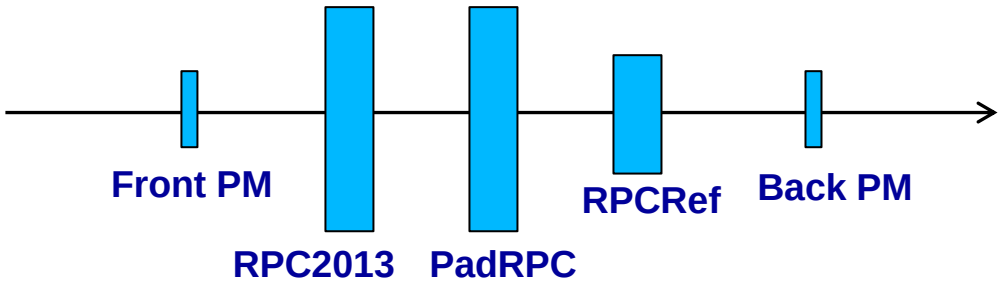



# CERN – SPS beam-time February 2015




**Joint in-beam test of the CBM-TOF Collaboration**

- **Ar beam of 13A GeV on a Pb target**
  - $85\%C_2H_2F_4+10\%SF_6+5\%iso\text{-}C_4H_{10}$
- **FEE – PADI8 cards both RPC2013 & RPCRef**
- **PADI8 threshold = 200 mV**
- **Convertors – FPGA TDC**

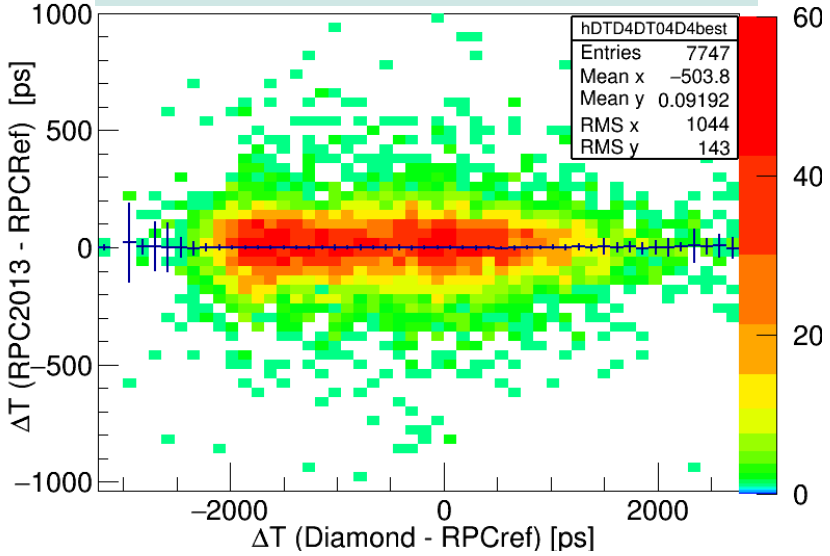



- **Positioned at 4 degree relative to the beam line**

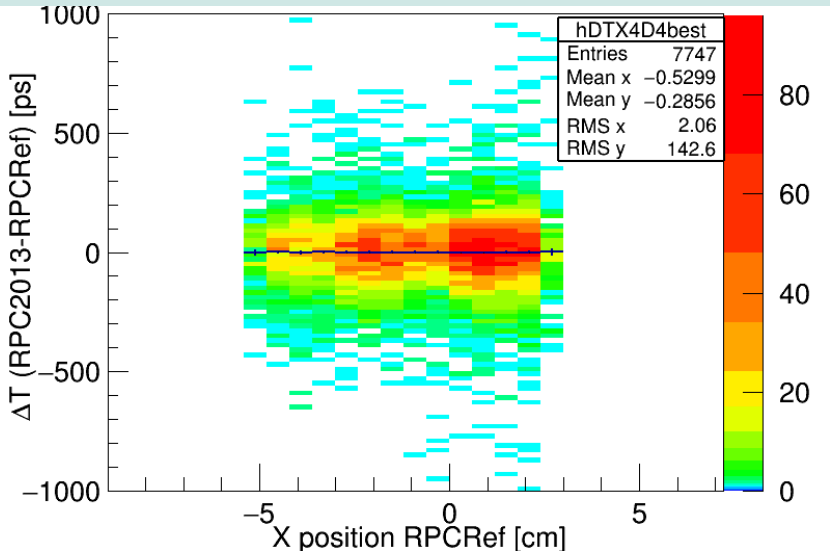
**Goals: - to approach the experimental conditions to the future real ones in CBM**

# Detector under test (DUT) =RPC2013, Ref=RPCRef

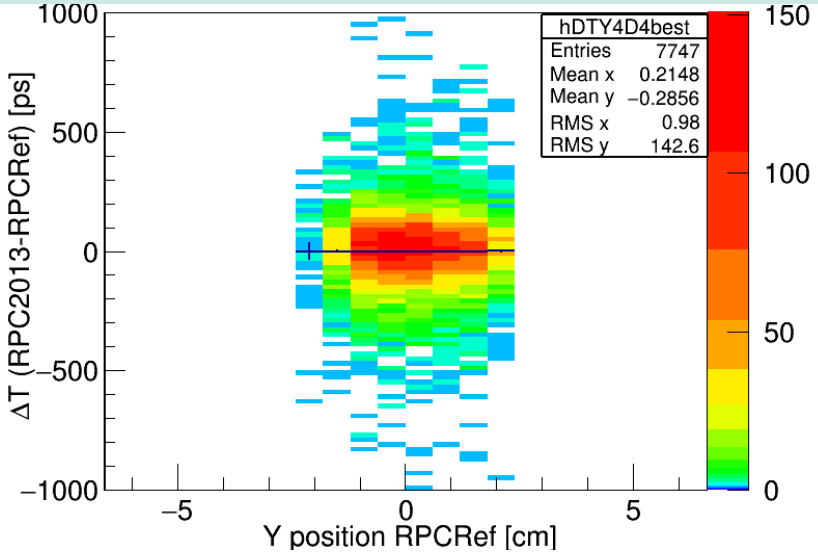
## Velocity spread correction



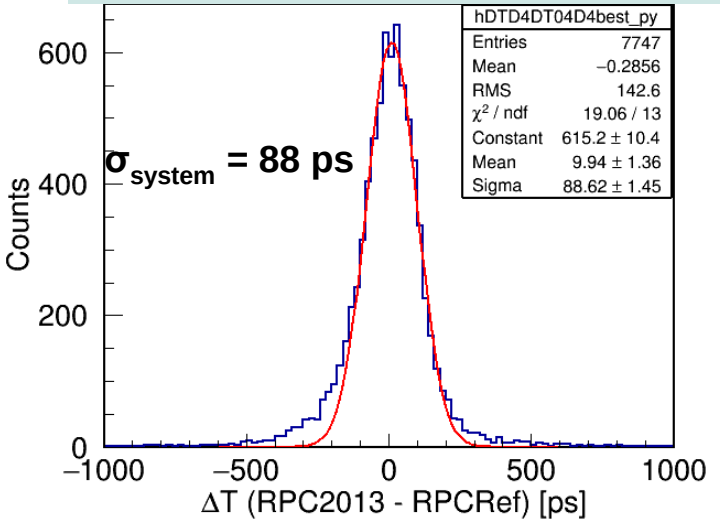

## Position correction across the strips



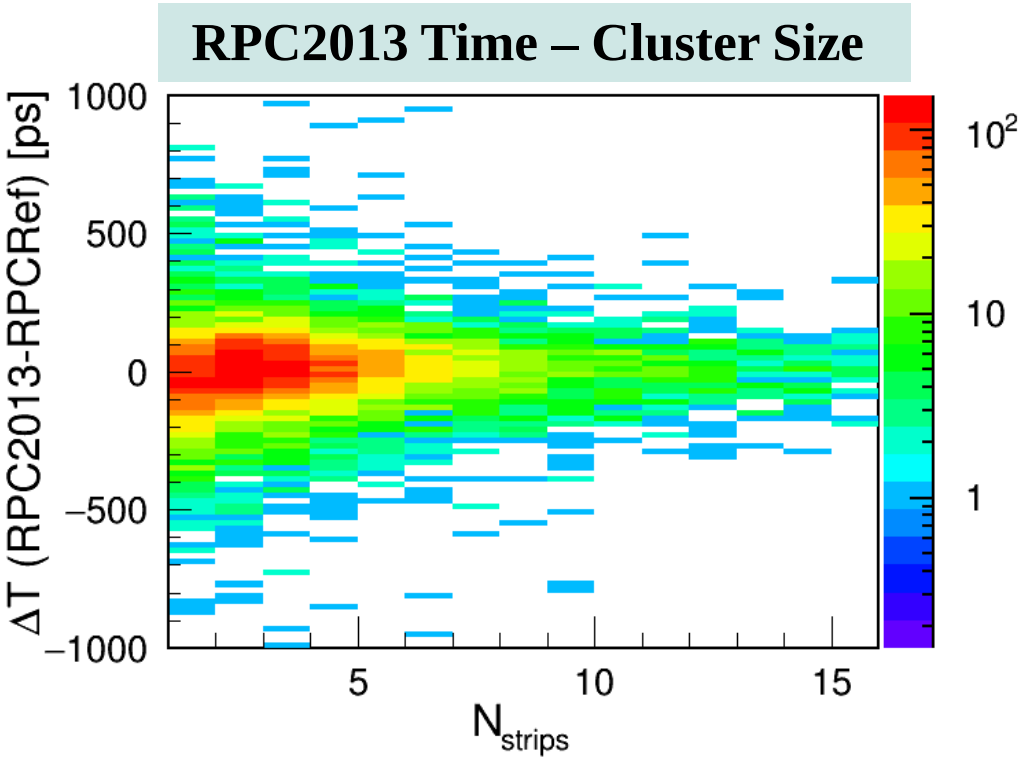

## Position correction along the strips

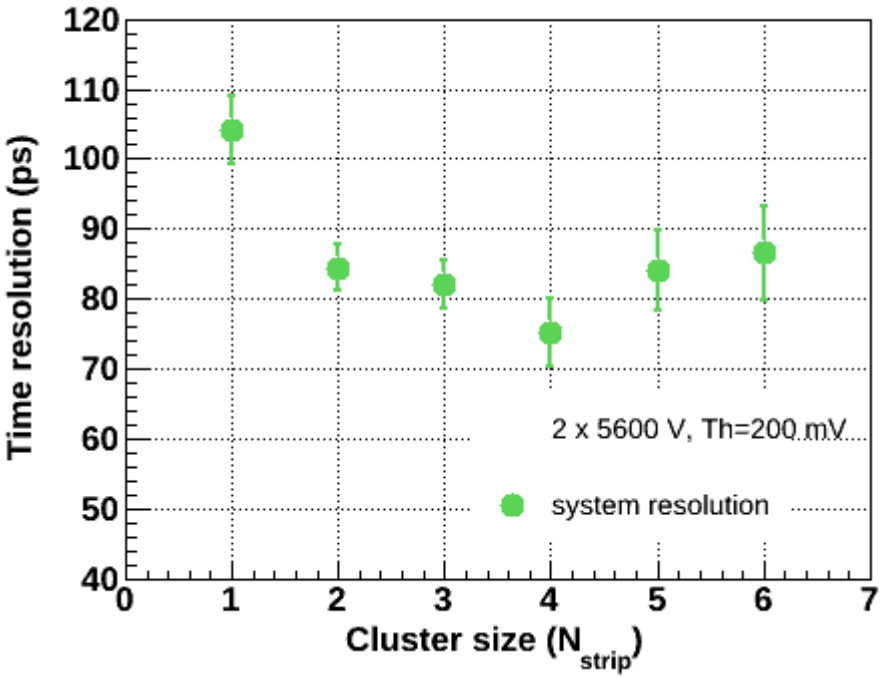



## System time resolution



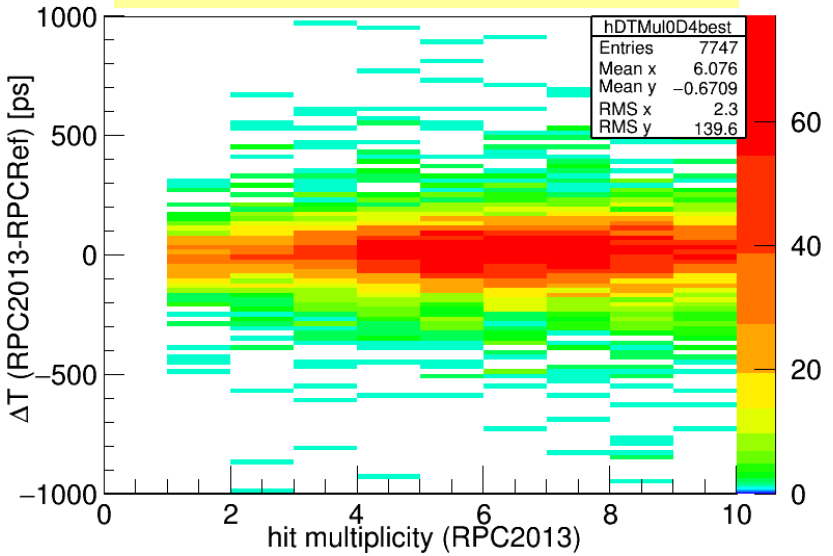
# System time resolution as a function of cluster size in RPC2013



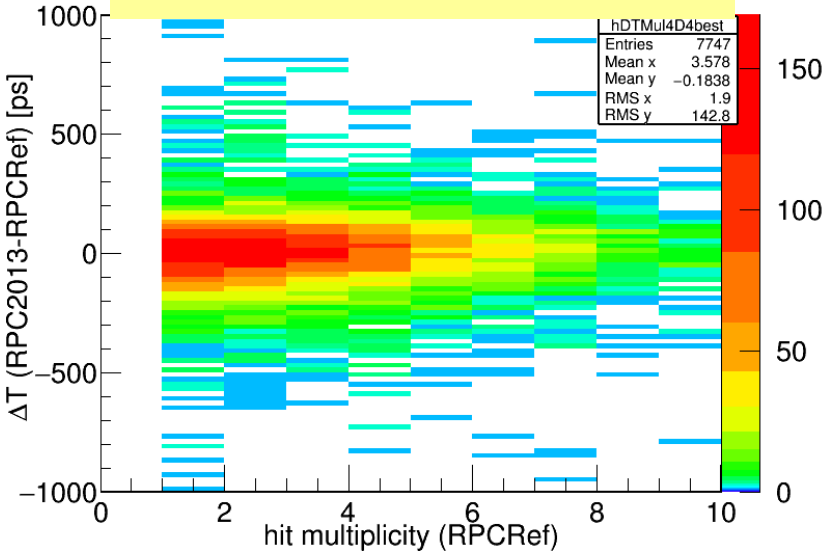



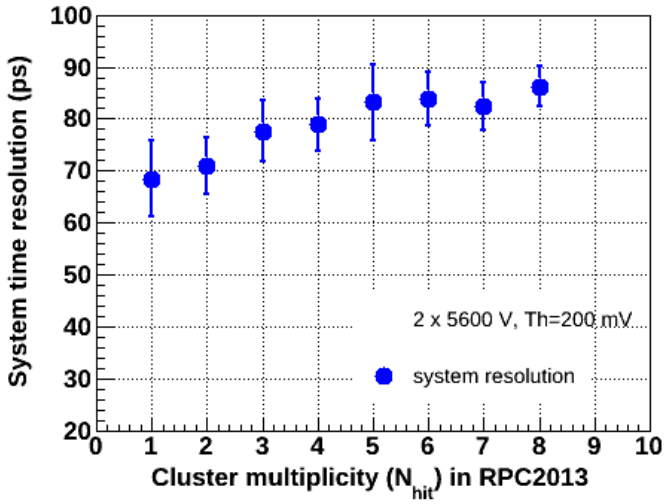
# Hit multiplicity in Bucharest RPCs

**RPC2013 Time – hit multiplicity**




**RPCRef Time – hit multiplicity**

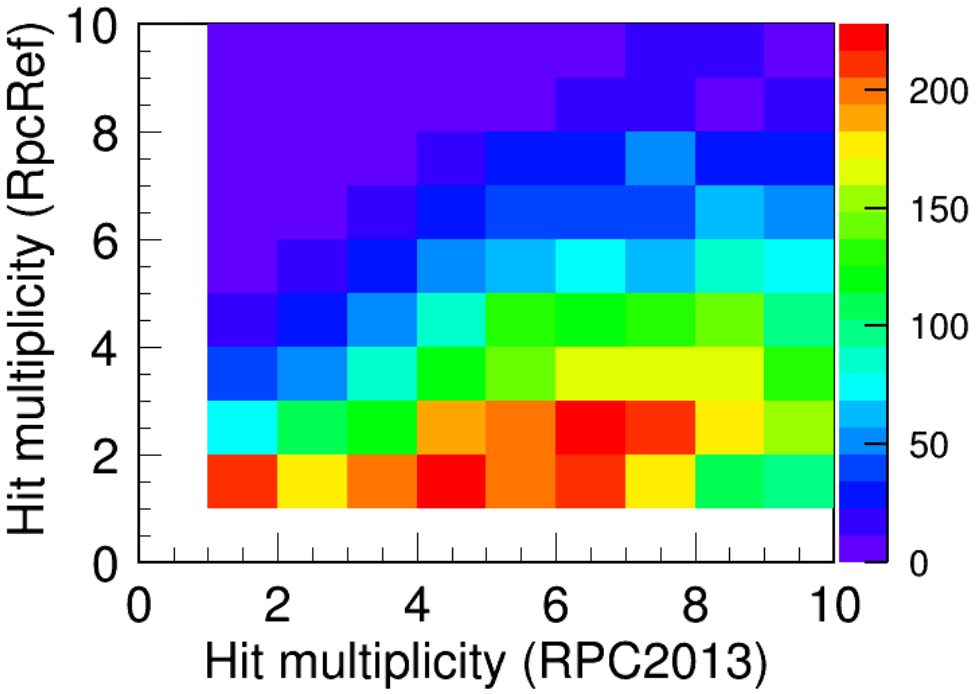


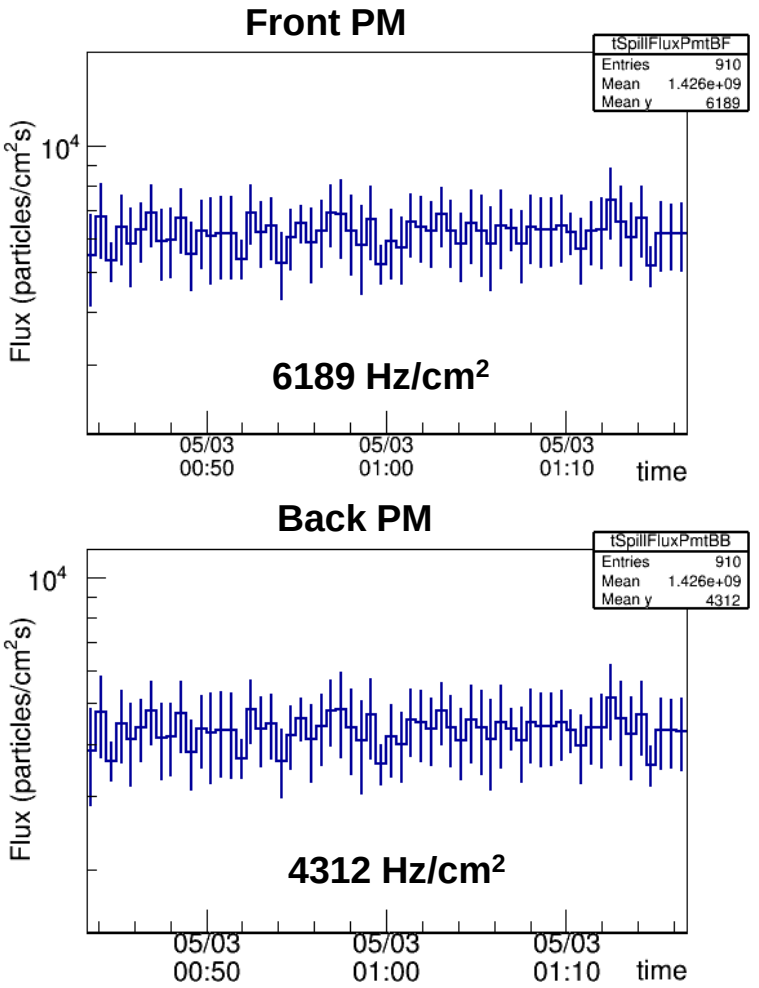

**RPC2013:** Efficiency = 0.99
Cluster Size = **3.6**

} @ 2 x 5.6 kV & 200 mV PADI Threshold

# Hit multiplicity correlation in Bucharest RPCs



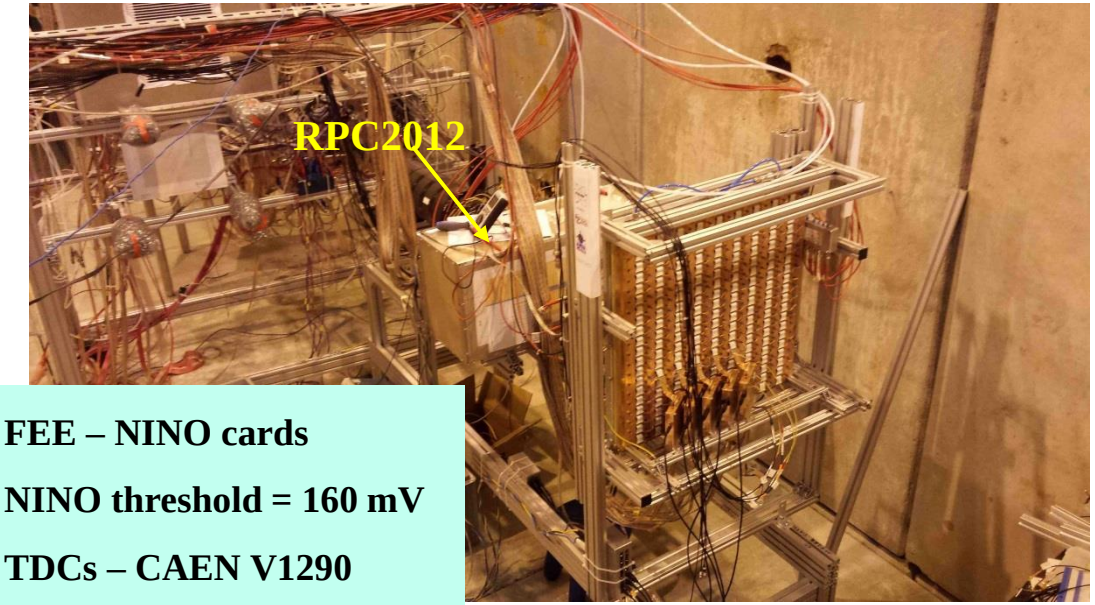

# Counting rate estimation from plastic scintillators




**Average counting rate = 5 kHz/cm²**

**Individual contributions of the two RPCs is not necessarily the same.**

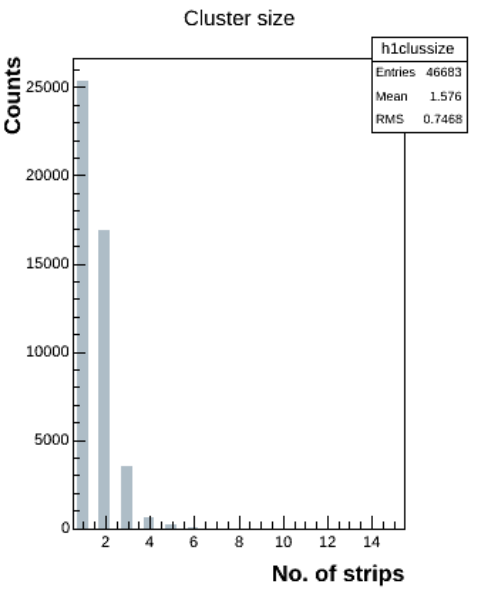
# CERN – SPS beam-time February 2015

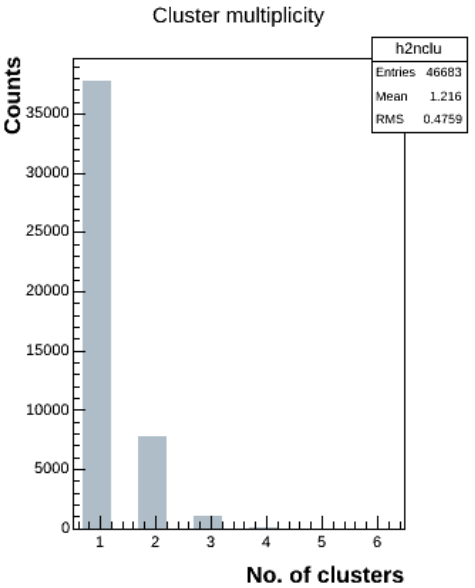



**FEE – NINO cards**

**NINO threshold = 160 mV**

**TDCs – CAEN V1290**

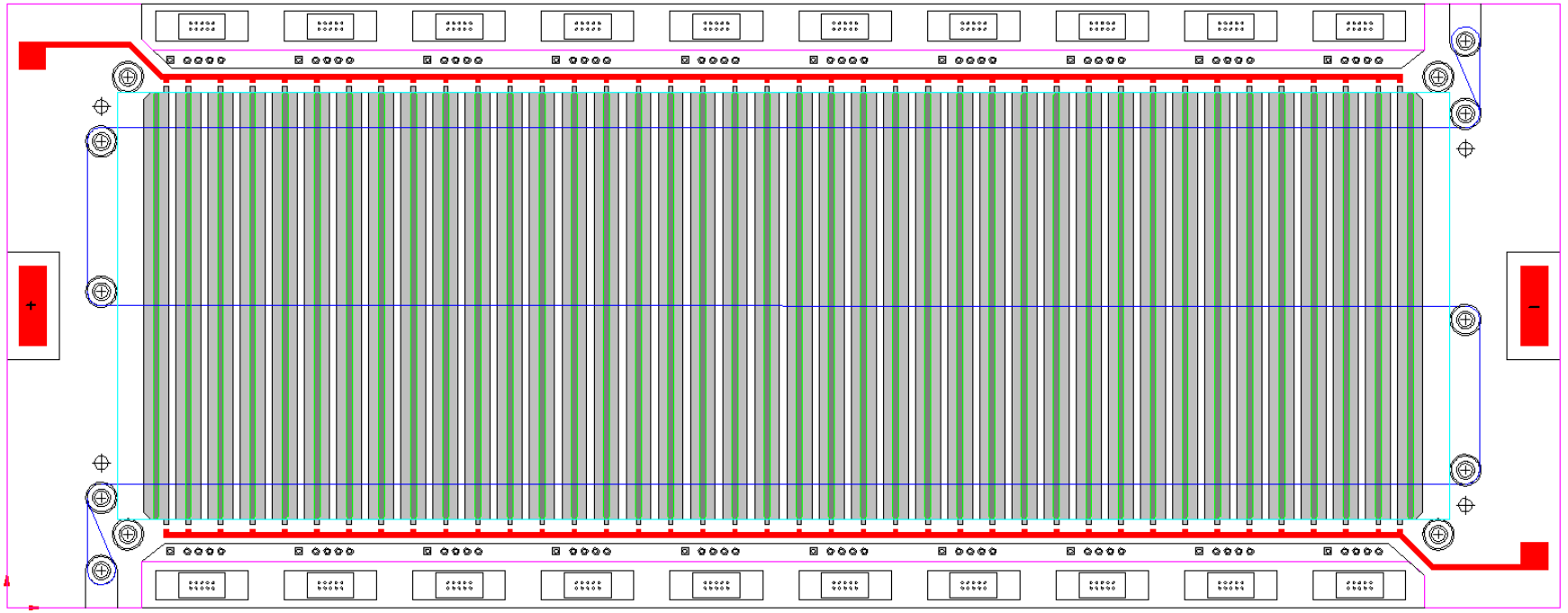



- **60 ps time resolution**
- **1.5 strips mean cluster size**
- **50 Ohm transmission line impedance**

- **MGMSRP architecture of ~1.5 strips cluster size could reduce the costs of the electronic readout channels**

# MGMSRPC prototype with a transmission line impedance tuned through the readout strip width

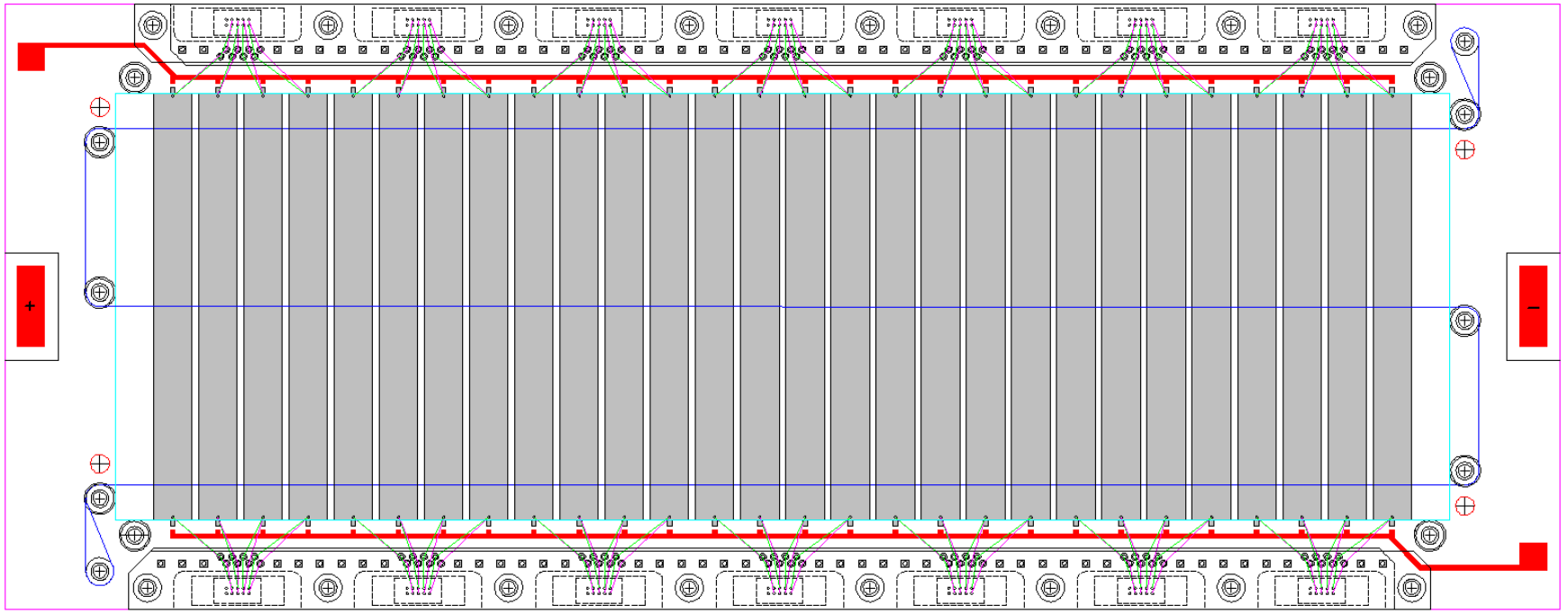


**Readout electrode: 7.2 mm pitch= 1.3 mm width + 5.9 mm gap**

**High Voltage electrode: 7.2 mm pitch= 5.6 mm width + 1.6 mm gap**

- ✓ **Symmetric two stack structure: 2 x 5 gaps**
- ✓ **Active area 96 x 300 mm$^2$**
- ✓ **Gas gap thickness: 140 µm thickness**
- ✓ **Readout electrode = 40 strips**
- ✓ **Differential readout = 100 Ohm impedance**
- ✓ **Resistive electrodes: low resistivity glass**

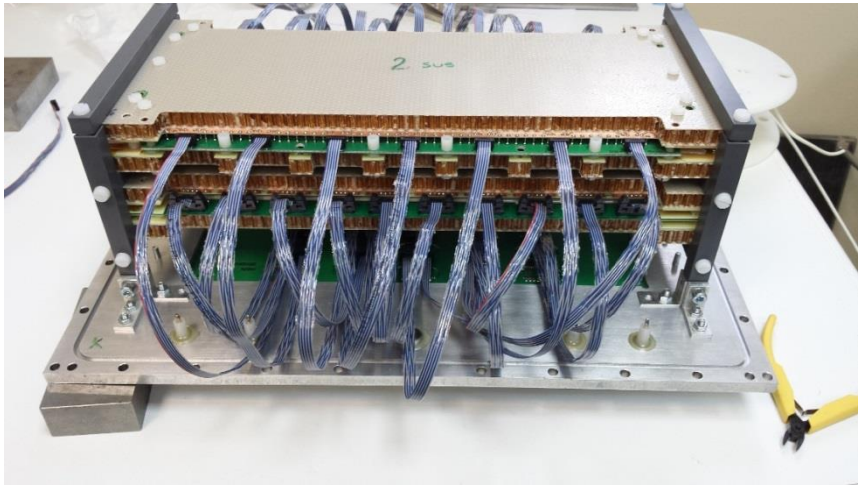
# Single stack MGMSRPC prototype with 100 Ohm transmission line impedance




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

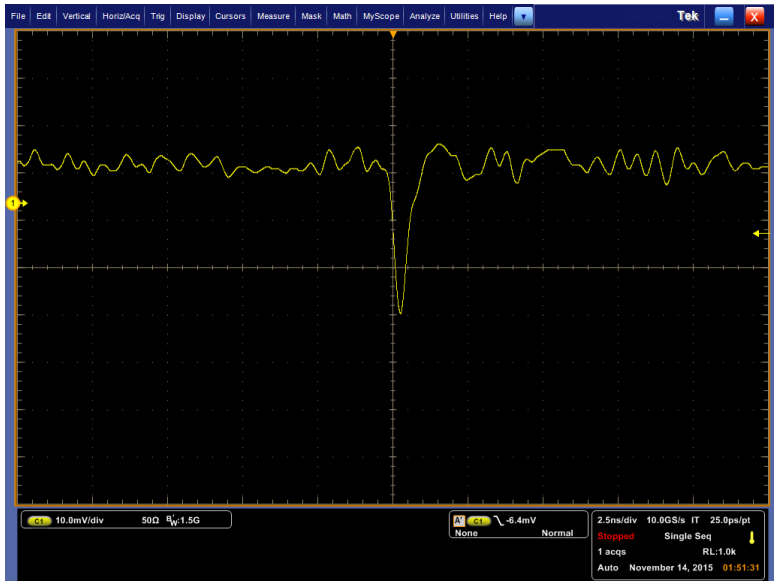
- ✓ **Single stack structure: 8 gaps**
- ✓ **Active area 96 x 300 mm$^2$**
- ✓ **Gas gap thickness: 140 µm thickness**
- ✓ **Readout electrode = 28 strips**
- ✓ **Differential readout = 100 Ohm impedance**
- ✓ **Resistive electrodes: low resistivity glass**

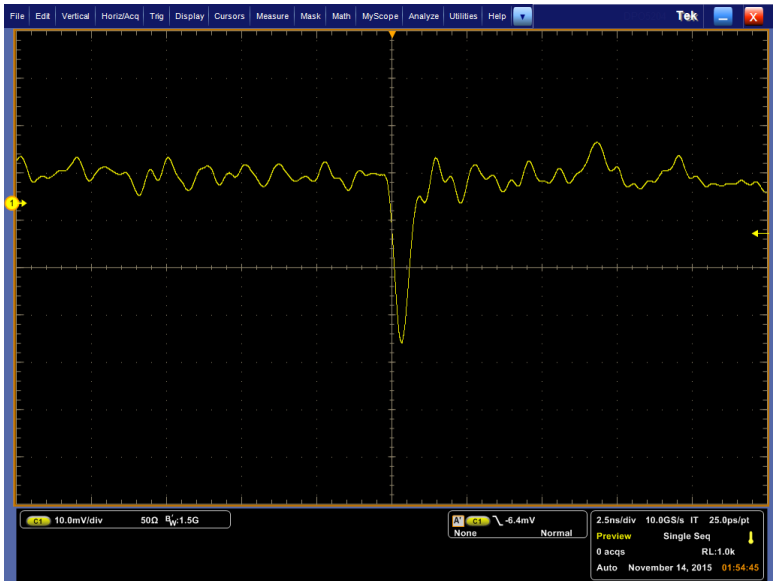
# $^{60}$Co and cosmic rays laboratory tests of the new prototypes



## two stacks MRPC

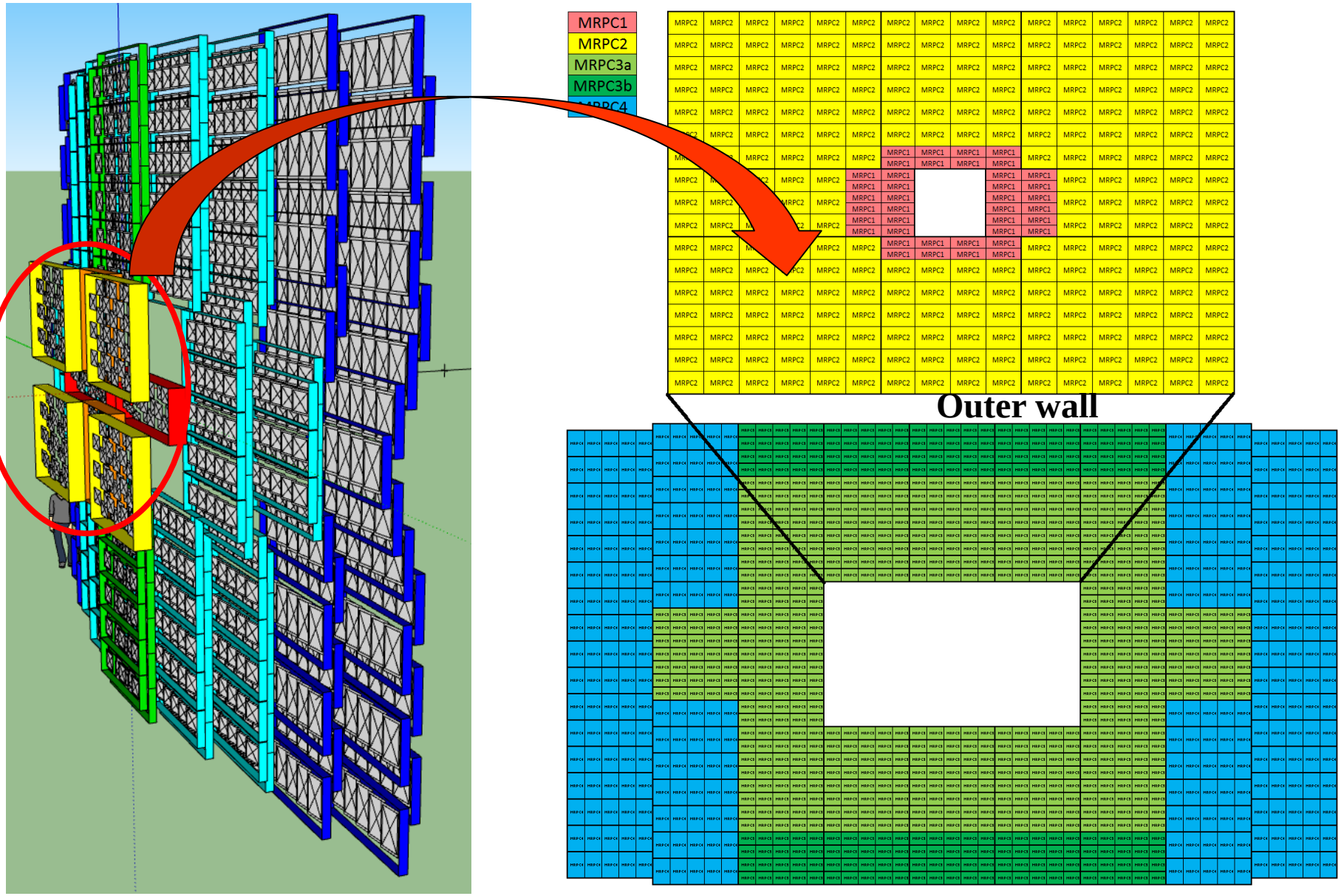

## single stack MRPC



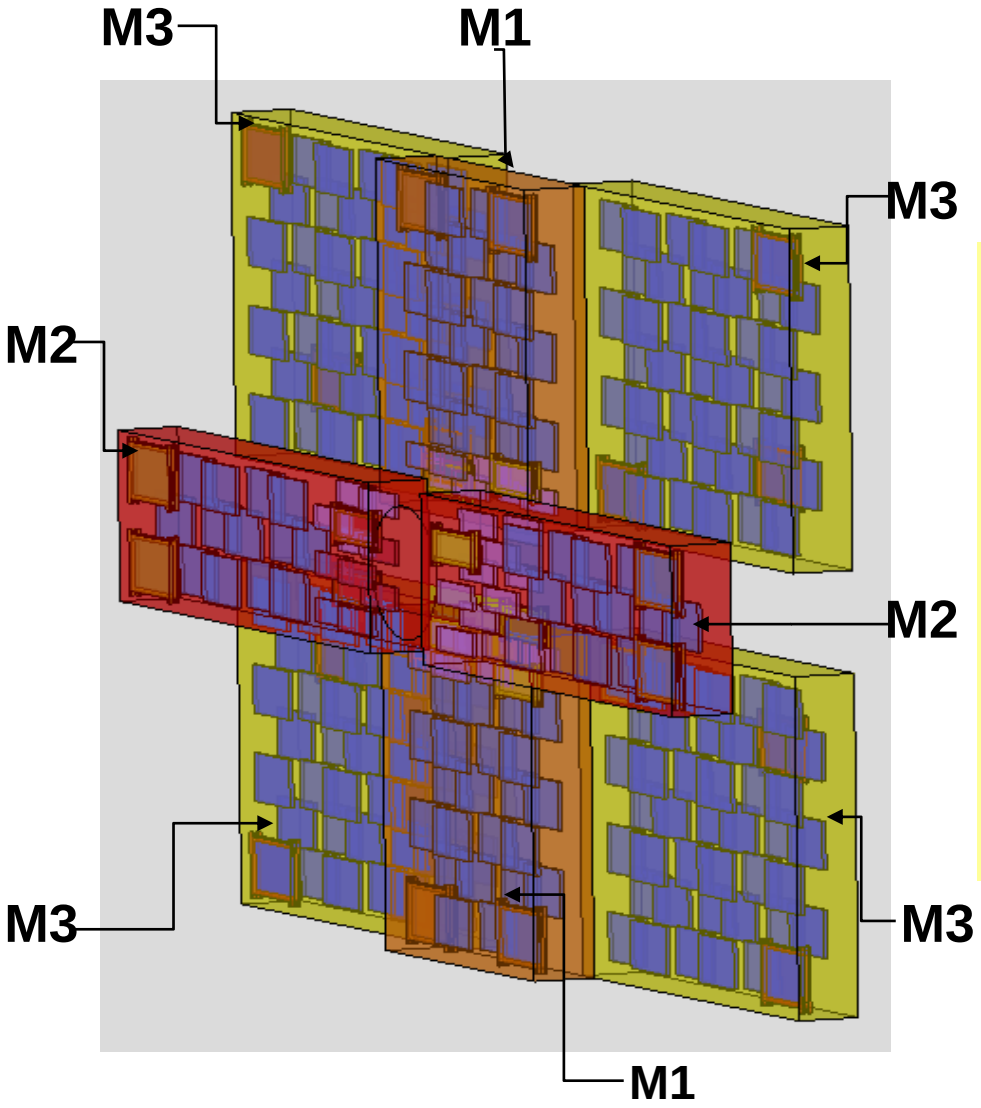

**Tested at CERN SPS with a Pb beam (30A GeV) in November 2015: data analysis in progress**

# CBM-ToF wall




**CBM – TOF Technical Design Report, October 2014, GSI Darmstadt**

# CBM – TOF Small Polar Angle Architecture based on Bucharest MGMSRPC

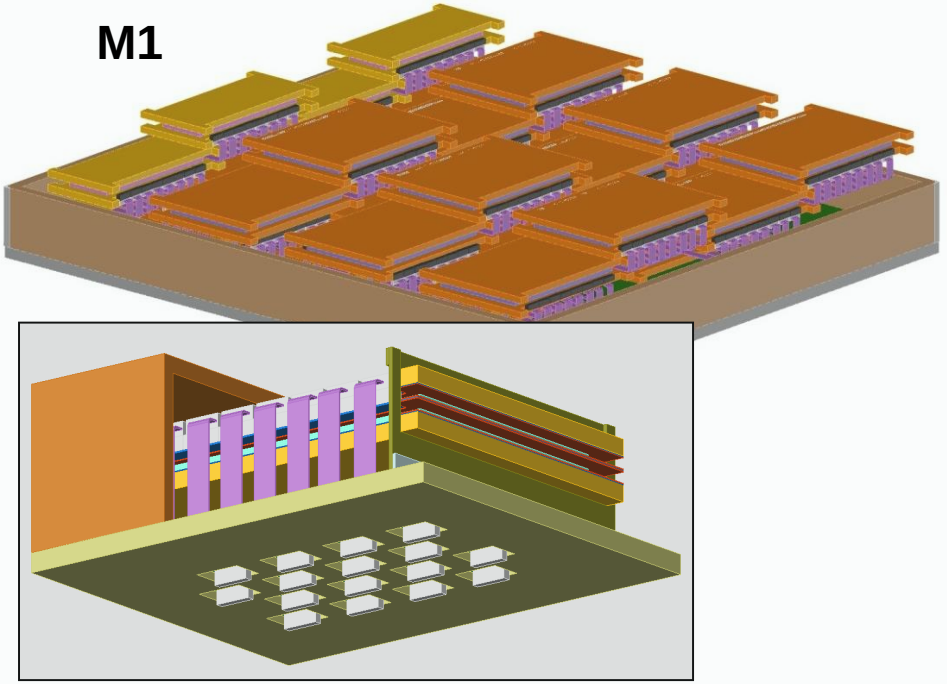



- ✓ **the design of the inner zone is based on MGMSRPCs**
- ✓ **main requirements:**
  - **- uniform active area coverage**
  - **- lowest possible overlap between counters and modules, respectively**
  - **- minimization of the readout channels**
  - **- merging with the design of the outer wall**

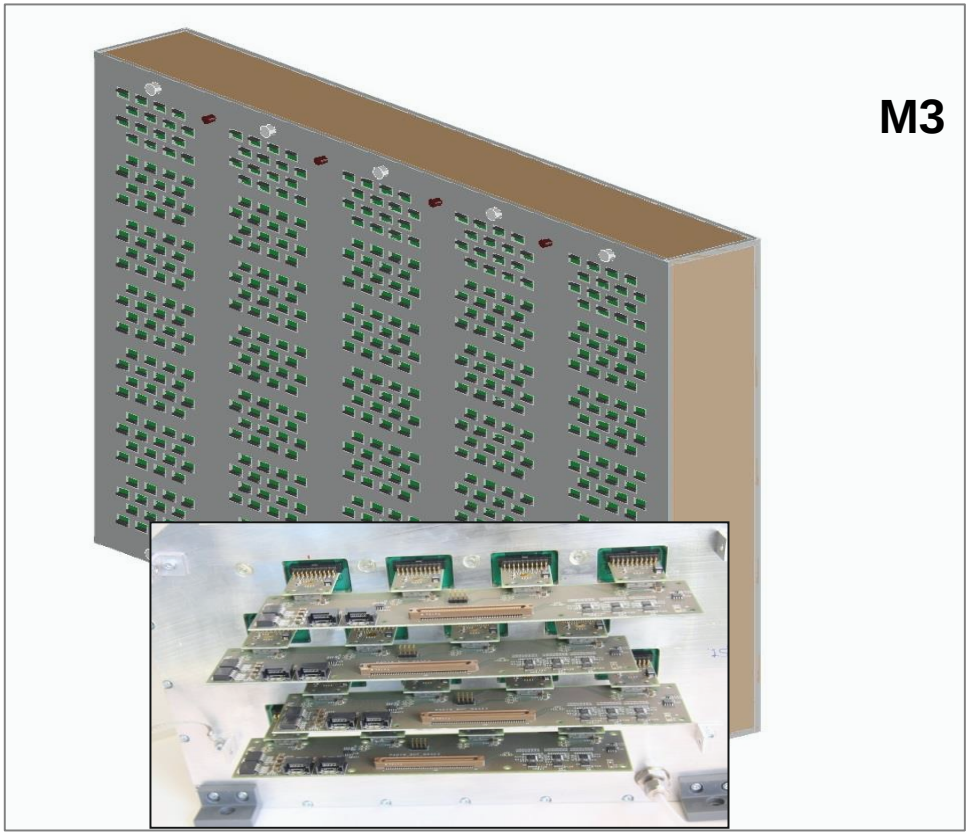
**CBM – TOF Technical Design Report, October 2014, GSI Darmstadt**

# CBM – TOF Small Polar Angle Module Architectures

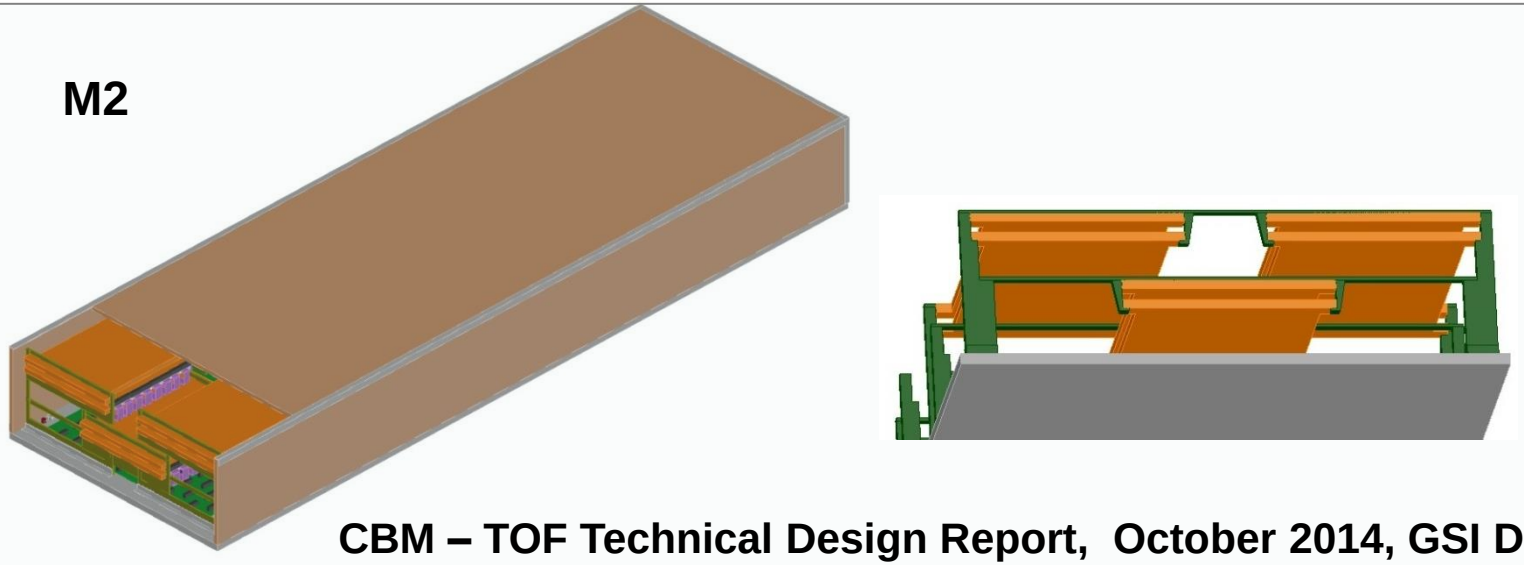
M1



M3



M2



CBM – TOF Technical Design Report, October 2014, GSI Darmstadt

# CBM – TOF inner zone in numbers

| Module notation (number of modules) | Module size (mm) | Number of MRPC per module | Total number of MRPC | Number of strips per module | Total number of strips |
|---|---|---|---|---|---|
| M1(2) | 1270x1417x239 | 32 | 64 | 2048 | 4096 |
| M2(2) | 2140x705x239 | 27 | 54 | 1728 | 3456 |
| M3(4) | 1850x1417x239 | 42 | 168 | 2688 | 10752 |

**Total number of readout channels = 18304 x 2 = 36608**

**CBM – TOF Technical Design Report, October 2014, GSI Darmstadt**

# Outlook of the next activities

- **Finalization of data analysis for the last two developed prototypes**
- **Basic solution for the inner zone of the CBM-TOF wall is under control**

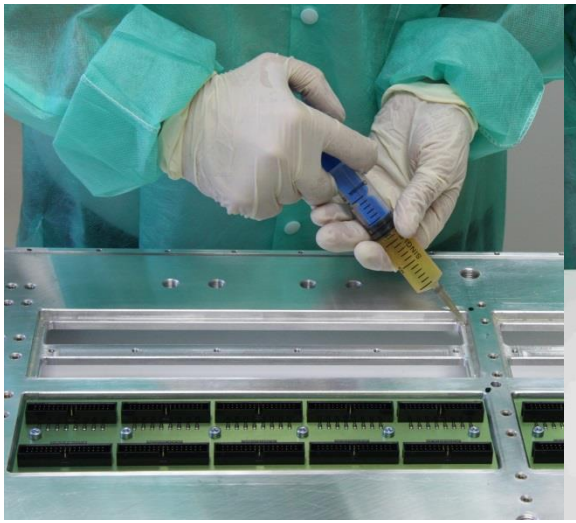
**CBM-TOF inner zone**

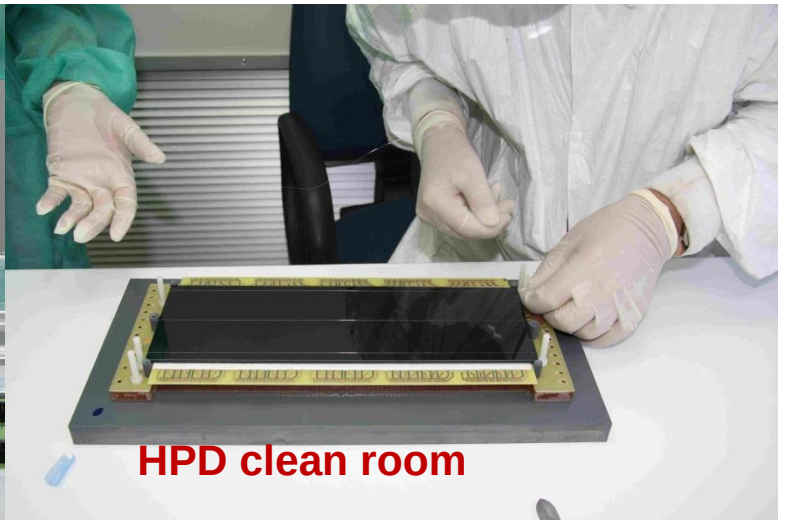
- *~15 m$^2$ active area*
- *~300 MGMSRPC counters*
- *~ 40 000 readout channels*

**HPD main infrastructure:**

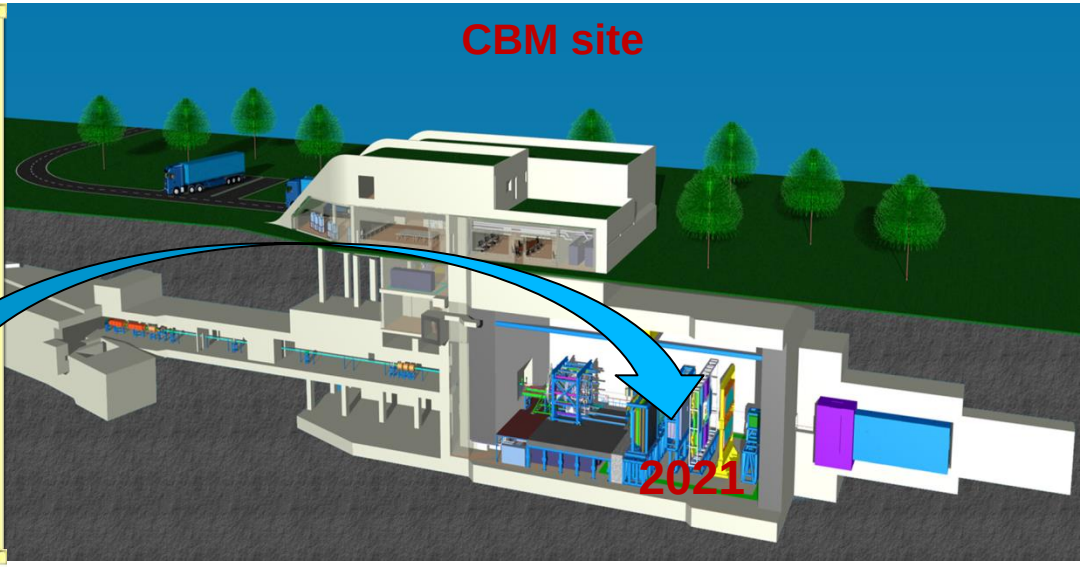
- *<10 000 part/ft$^3$ clean room for construction*
- *dedicated RPC test laboratory*

- **We have the expertise and infrastructure needed to involve in the construction of the MGMSRPCs for CBM-TOF inner zone**









# Conclusions

**The performance of the MGMSRPCs in conditions approaching those of the CBM experiment satisfies the CBM-TOF wall requirements:**

- Efficiency over 98%.
- System time resolution of ~70 ps - 80 ps .
- The detector performance is very good in high multiplicity and counting rate environment.
- Basic solution for the inner zone of the CBM-TOF wall is under control
- New prototypes were developed in order to satisfy both requirements concerning impedance matching and reduced number of readout channels.
- We have the expertise and infrastructure needed to start the construction of MGMSRPCs for the inner zone of CBM-TOF wall.


***Thank you for your attention!***