Performance of the strip readout MRPC prototypes for the inner zone of CBM-TOF wall

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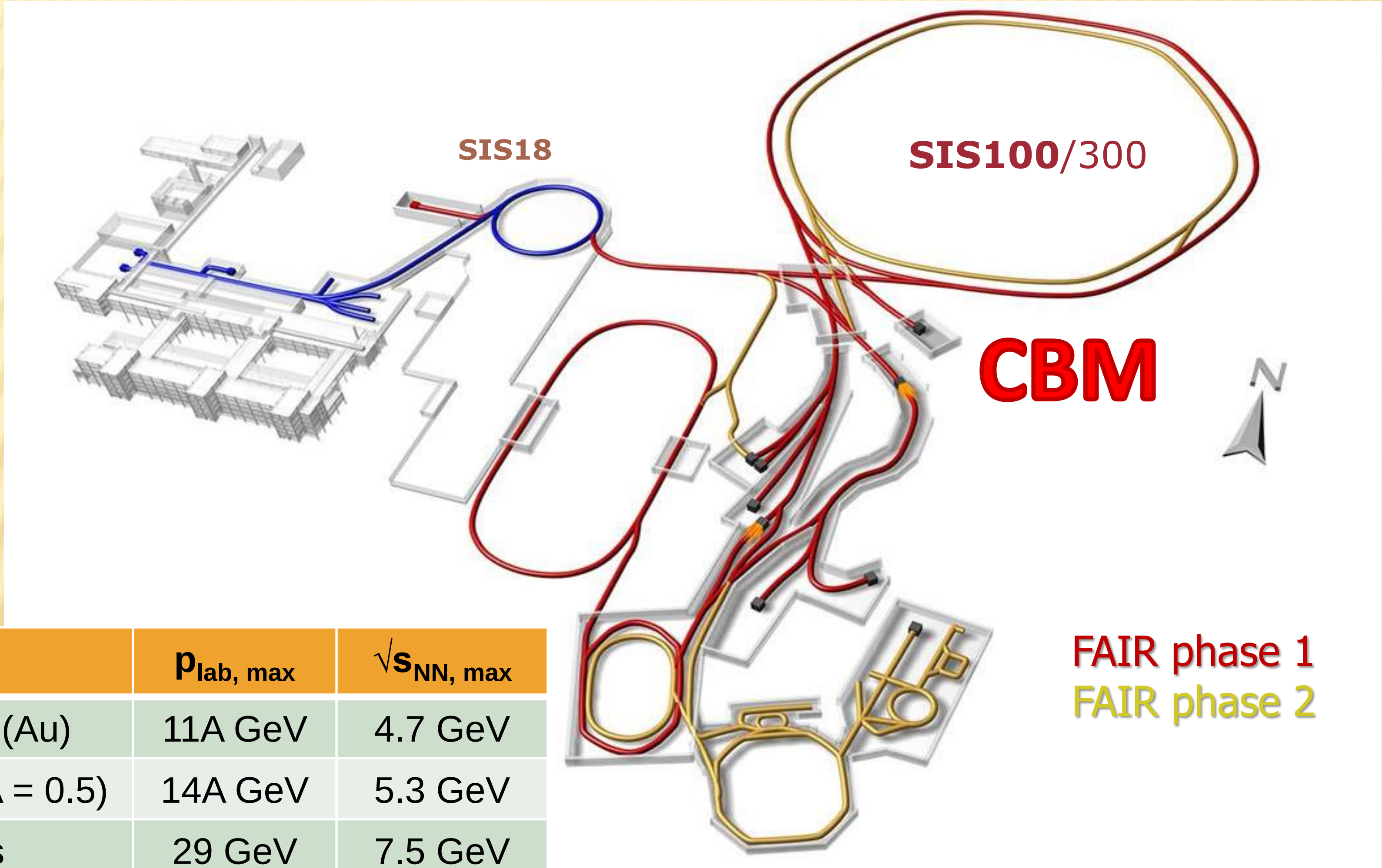
Outline

- Motivation – CBM-TOF inner wall
- High counting rate, high granularity MSMGRPC
- Performance in the in-beam tests in close to real conditions
- Conclusions and Outlook

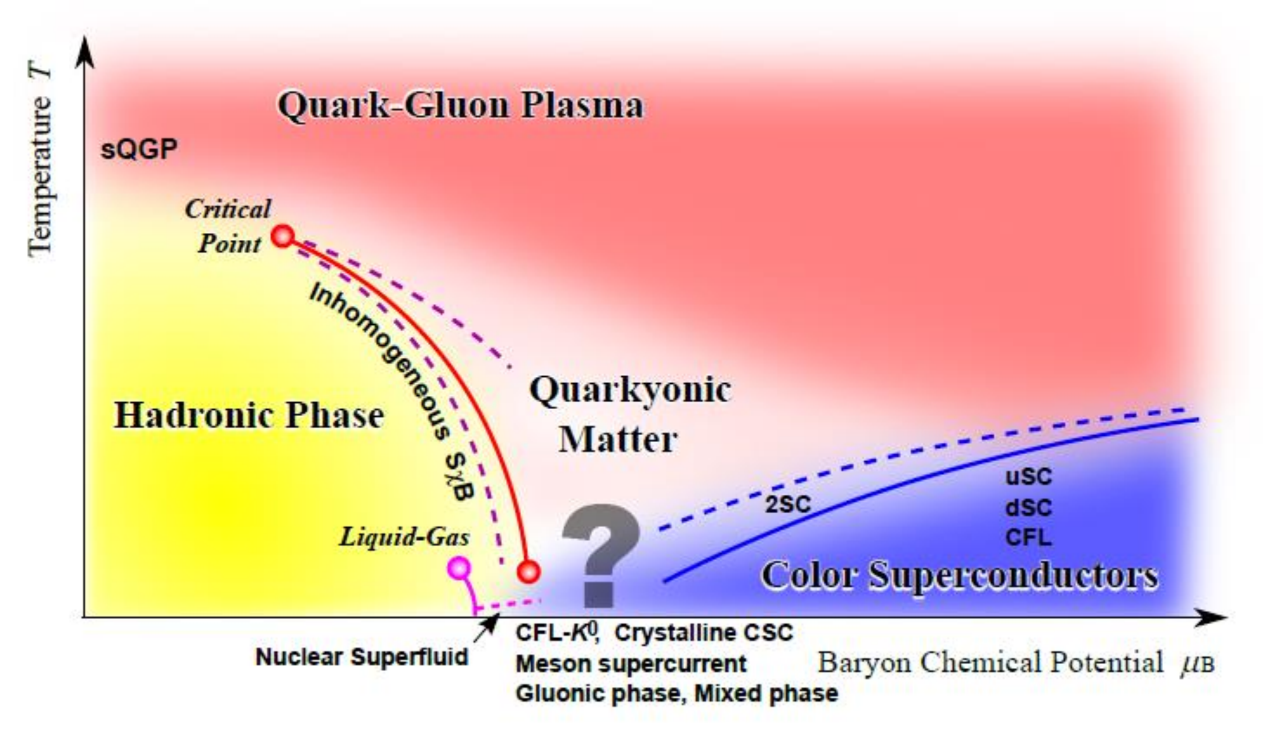
Facility for Antiproton & Ion Research



Beam	$p_{lab, max}$	$\sqrt{s_{NN, max}}$
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

Facility for Antiproton & Ion Research

Mapping the phase diagram with CBM



(K. Fukushima, T. Hatsuda, Rept.Prog.Phys.74:014001,2011)

Investigation of:

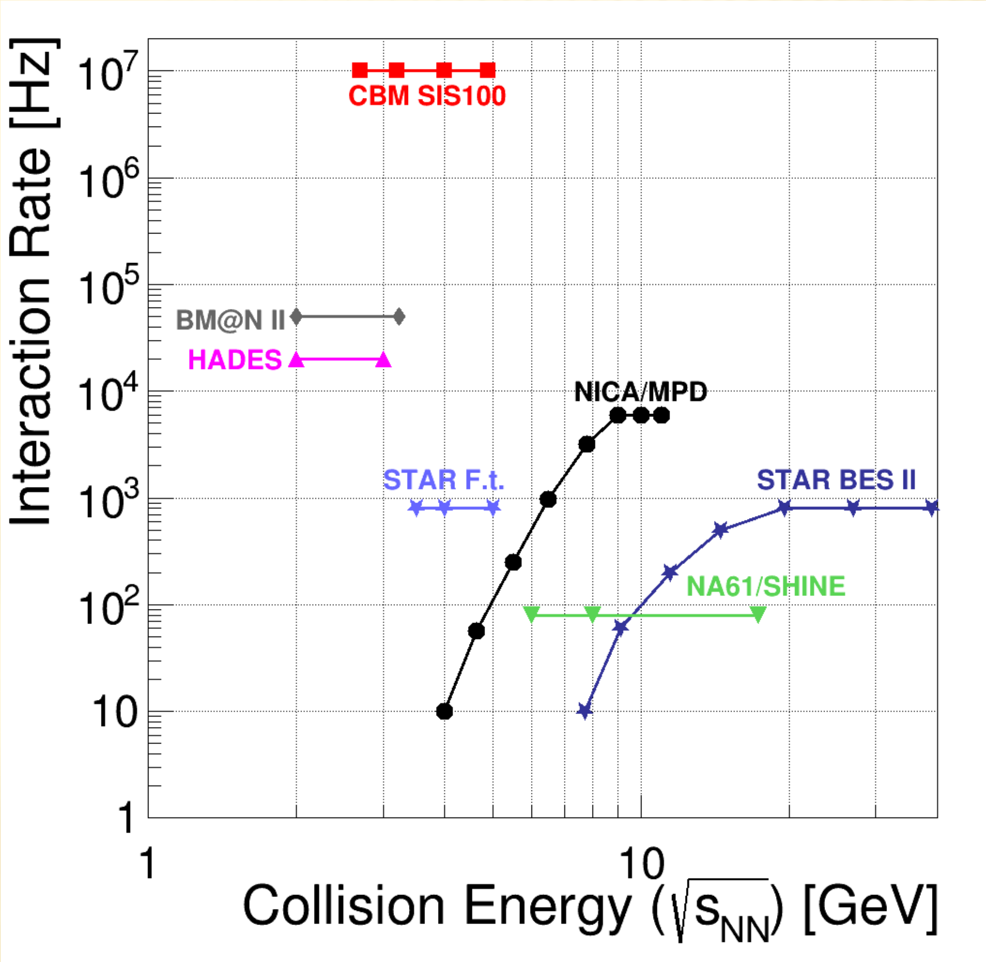
- **phase transitions,**
- **their type,**
- **possible critical point predicted by QCD**

CBM experiment

CBM:
is a high rate experiment!

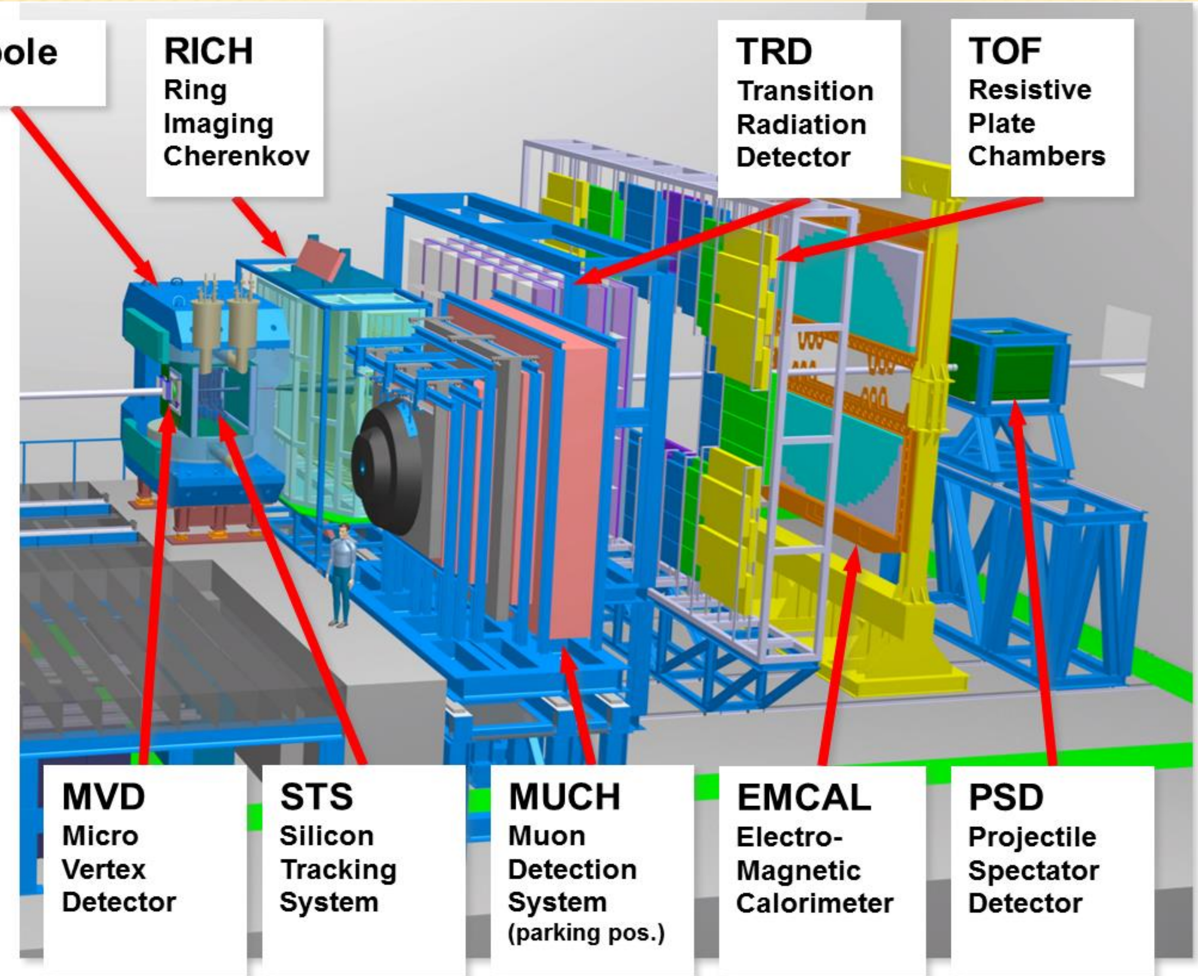
→ Opens up new possibilities!

- Electromagnetic observables, charm production
- High statistics and good systematics on hadronic observables:
  multi-strange baryons, flow, fluctuations
- New (exotic) observables:
  kaonic clusters, hypernuclei



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

CBM experimental set-up



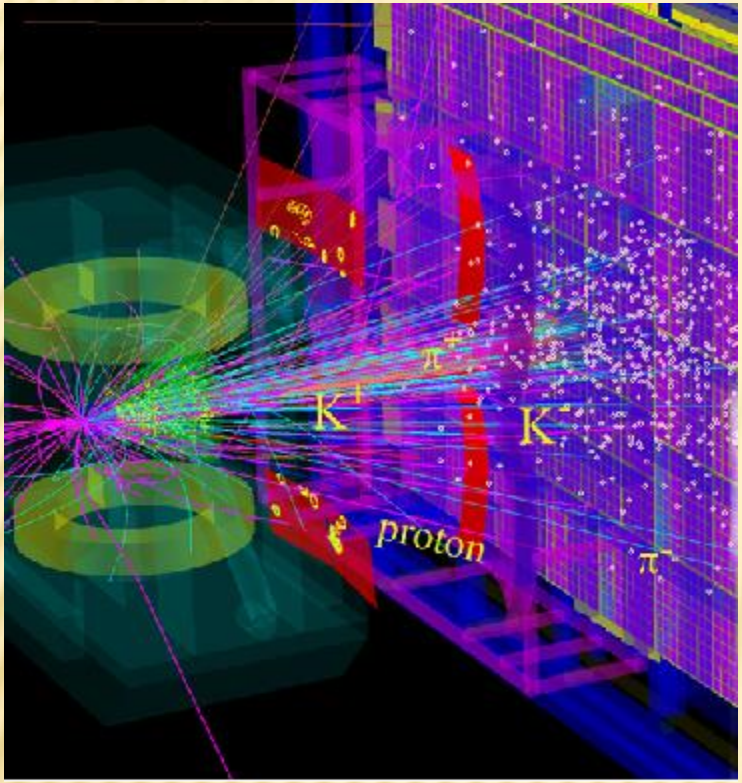
- Tracking acceptance: $2° < \theta_{lab} < 25°$
- Free streaming DAQ

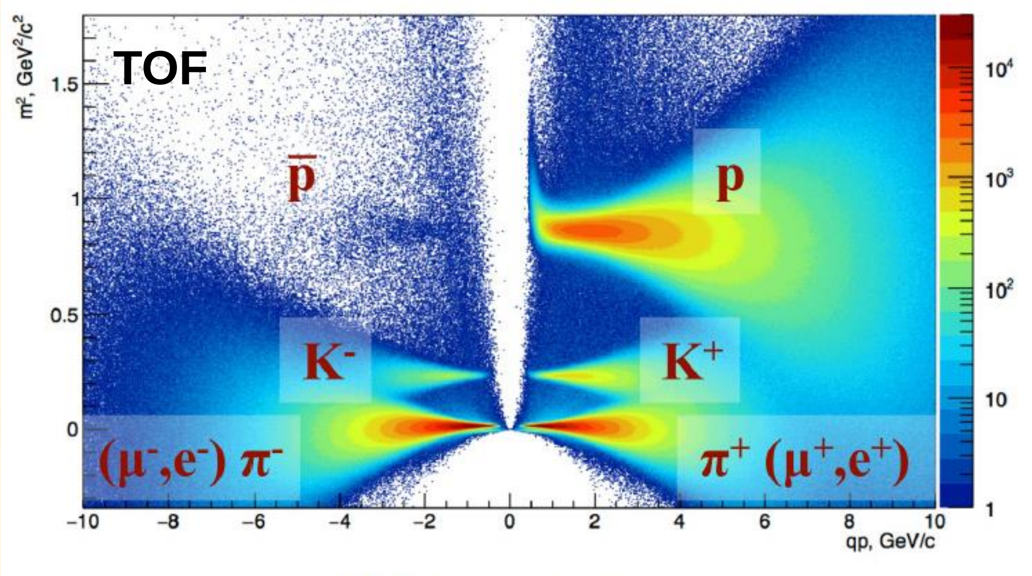
  R_{int} = 10 MHz (Au+Au)

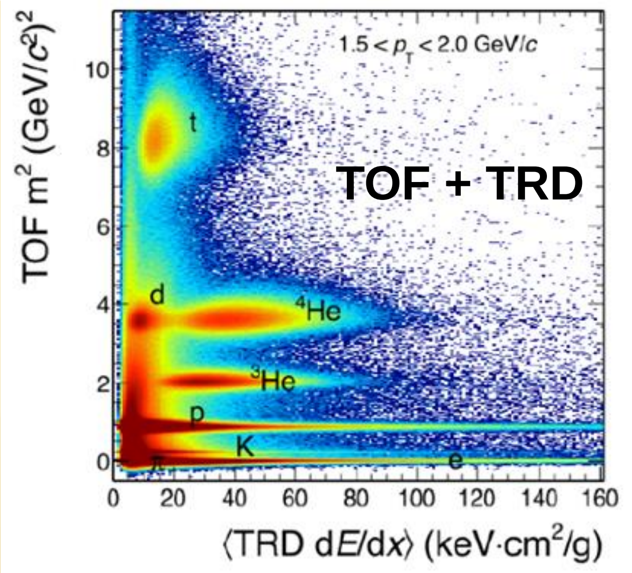
Novel readout system

- no hardware trigger on events, free streaming trigger-less data
- detector hits with time stamps
- full online 4-D track and event reconstruction

PID with CBM setup



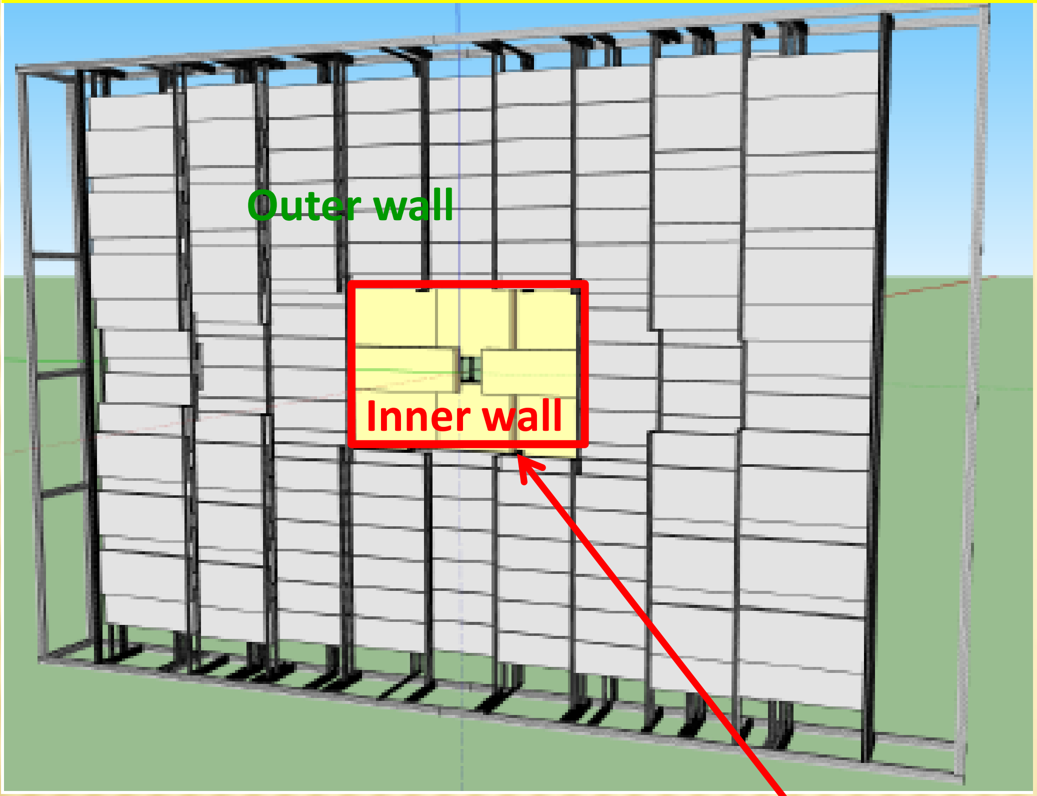




- **Hadron id: TOF (+TRD)**
- **Lepton id: RICH+TRD or MUCH**
- **γ, π^0: EMC (or RICH)**

CBM – TOF requirements

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

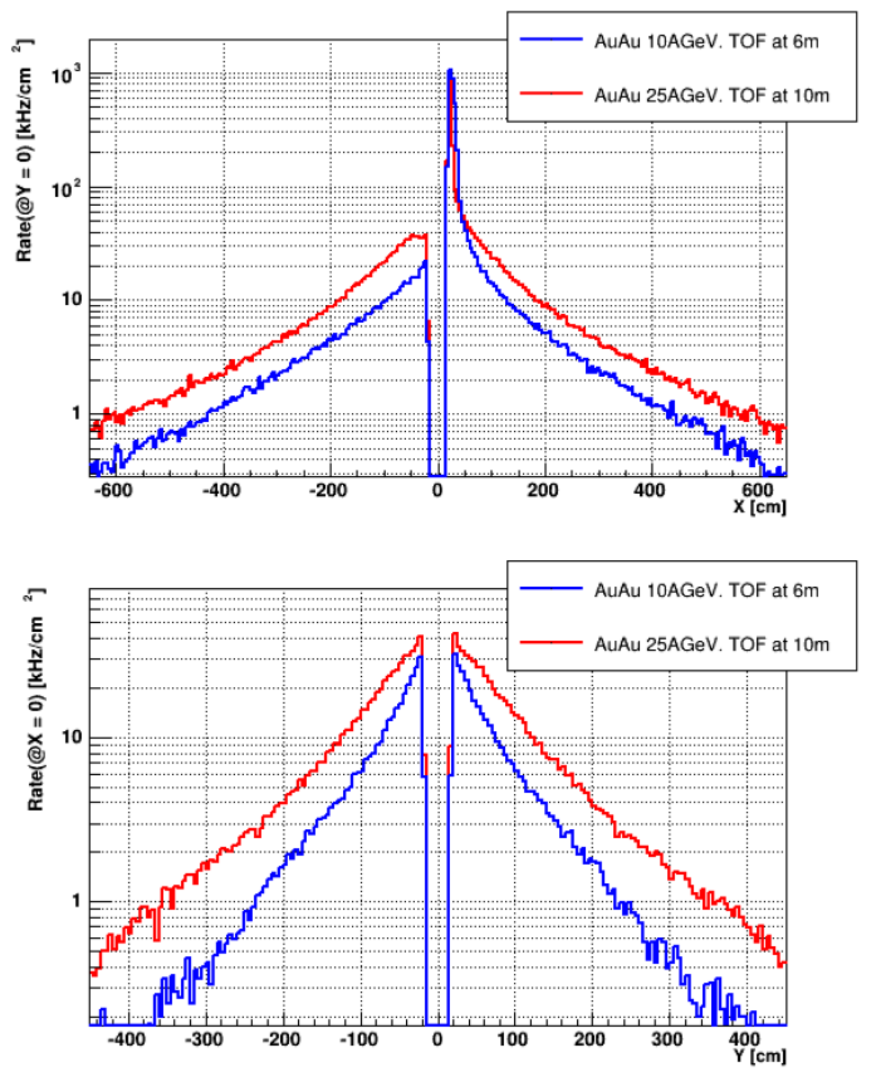


CBM-ToF Requirements

- 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

Active area = 15 m^2
Highest counting rate
Highest occupancy
Our R&D activity addresses this part of the CBM-TOF wall

Incident particle flux on CBM-TOF wall

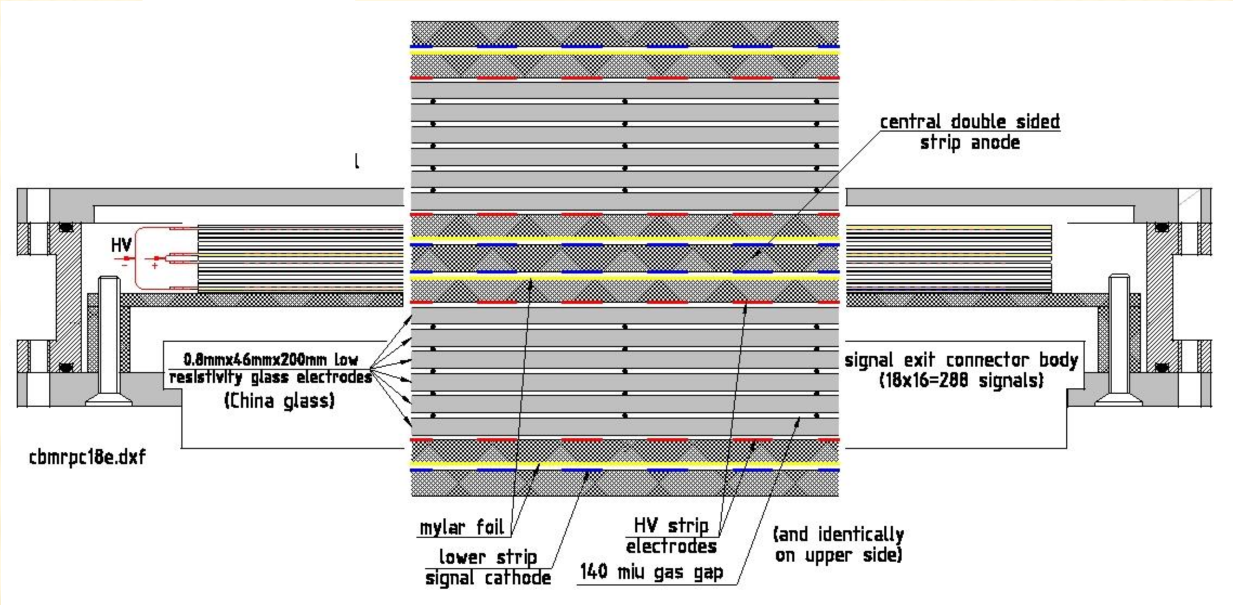


URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz

- Flux ranging from 0.1 to >30 kHz/cm^2
- Detectors with different rate capabilities are needed as a function of polar angle

CBM – TOF Technical Desing Report, October 2014, GSI Darmsadt

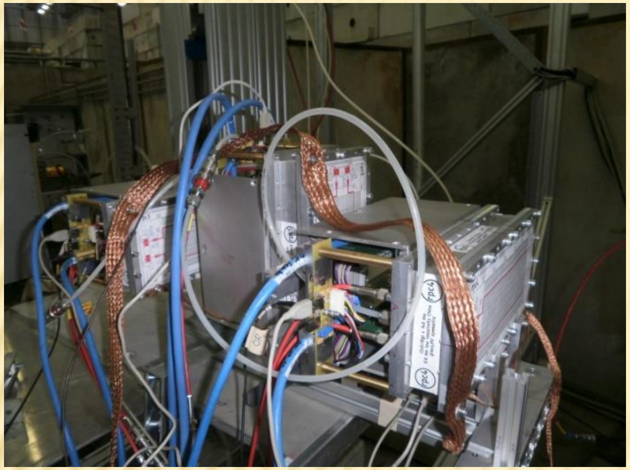
Double stack, strip readout, multigap, timing RPC concept - MSMGRPC

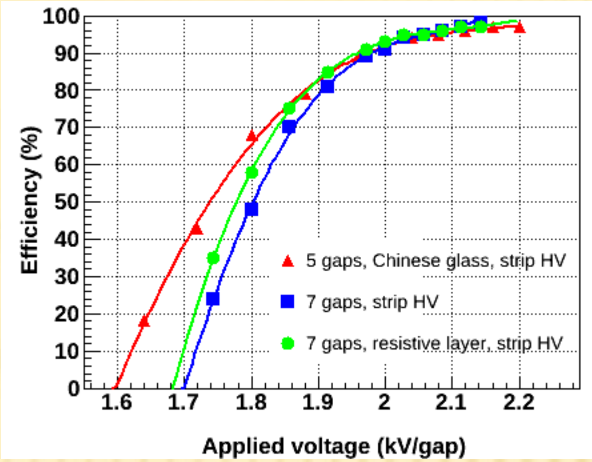


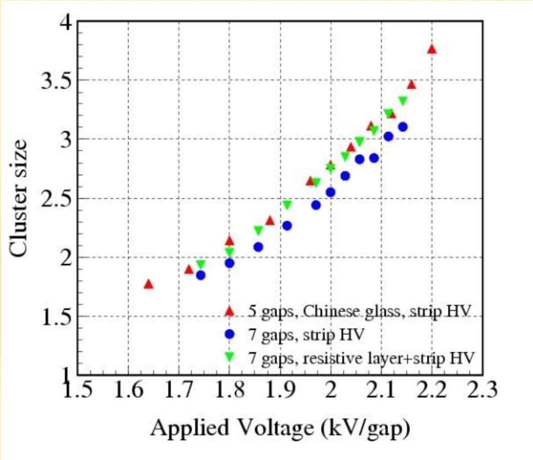
- ✓ Symmetric two stack structure
- ✓ Gas gap thickness: 140 μm
- ✓ Readout electrodes: anode + cathodes with narrow strip structure
- ✓ Differential readout, 100 Ω /50 Ω signal transmission line impedance
- ✓ High Voltage electrodes → strip structure also → **defines the granularity!**
- ✓ Low resistivity Chinese glass (~10^{10} Ωcm) electrodes → **high counting rate performance!**

Performance of high granularity MSMGRPC prototypes

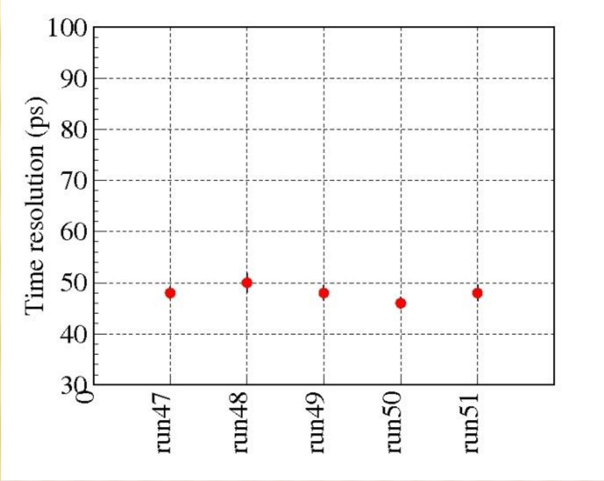
PS – CERN, pion beam, 6 GeV/c momentum

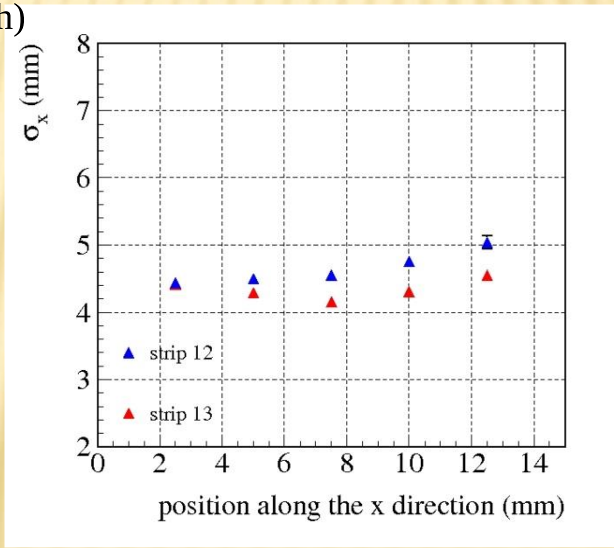


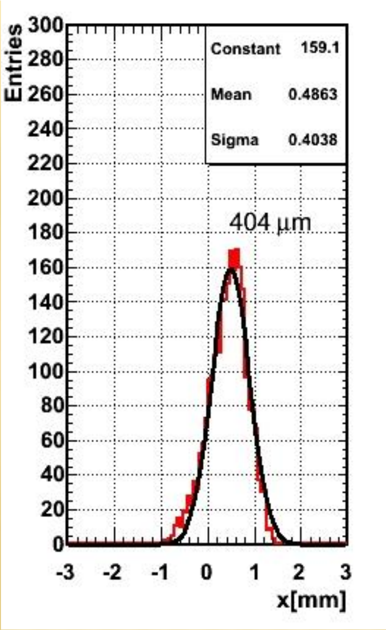




Readout cell = 2.54 mm (pitch) x 46 mm (length)

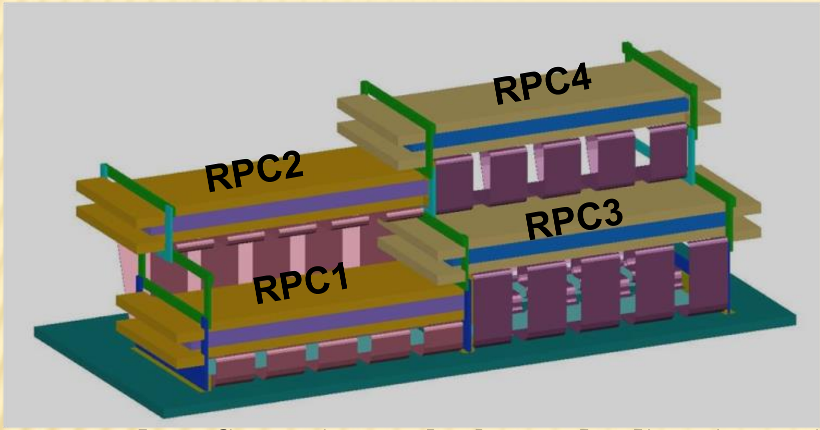


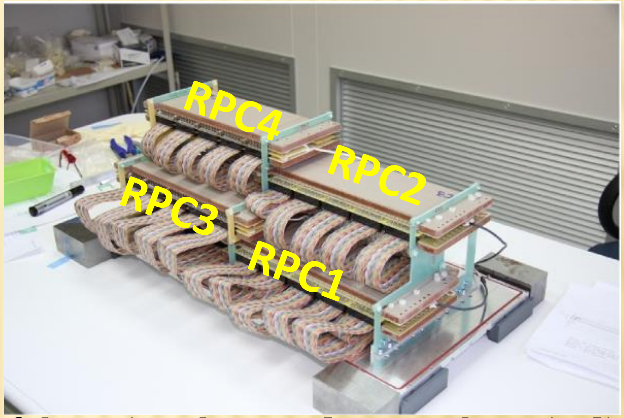




M.Petrovici et al. JINST 7 P11003, 2012

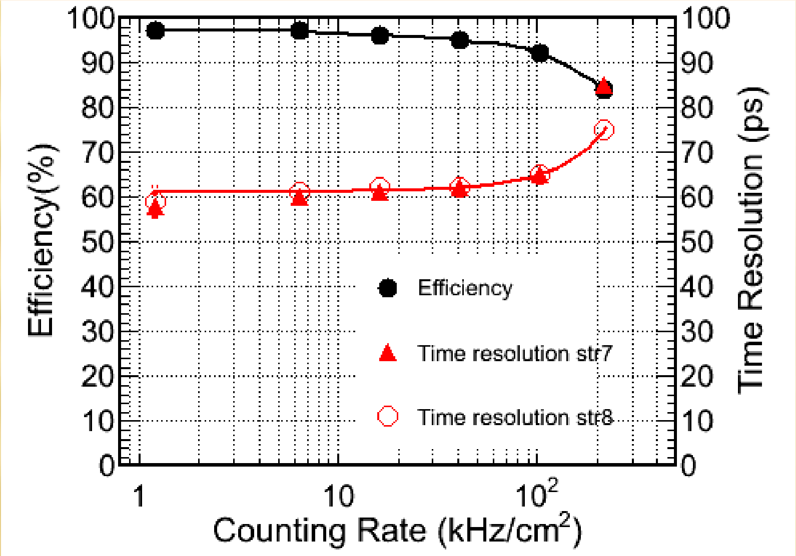
Basic architecture for MSMGRPC implementation in the inner zone of the CBM-TOF wall



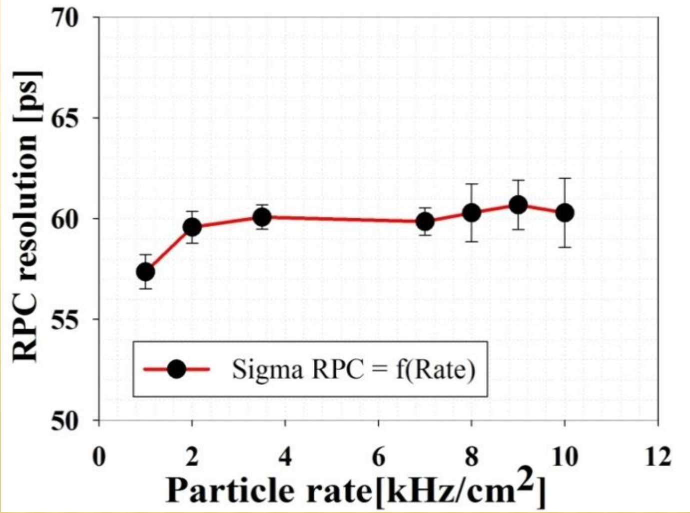


Staggered configuration on both x and y directions with an overlaps of the strips along and across the strip direction

Focused proton beam, 2.5 GeV/c @ COSY Jülich



Ni beam 1.9A GeV on Pb target,
GSI Darmstadt , exposure of whole active area



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

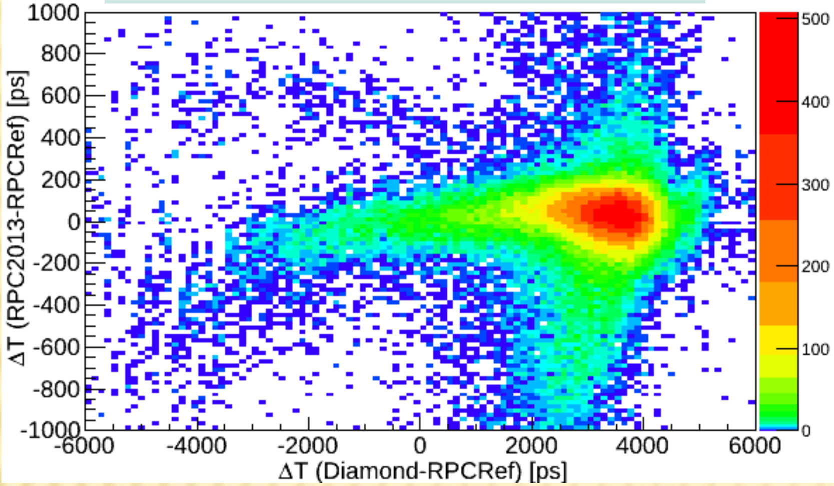
M. Petris et al., Journal of Phys: Conf. Series 724 (2016) 012037

In-beam tests in close to real conditions

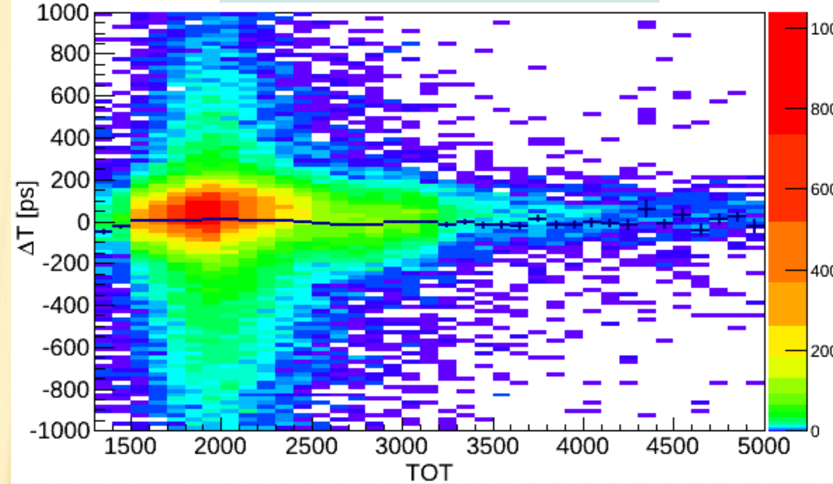
Goal: - to approach the experimental conditions to the future real ones in CBM

Walk, Velocity spread & Position dependence corrections

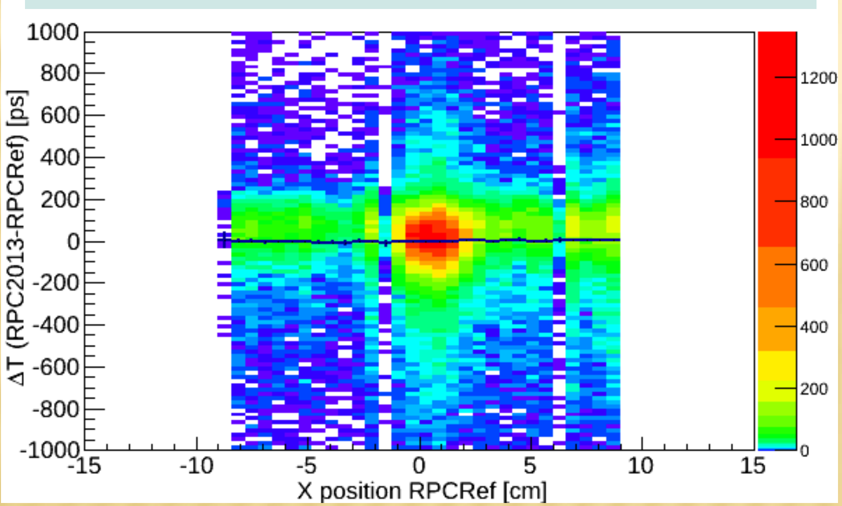
Velocity spread corrections



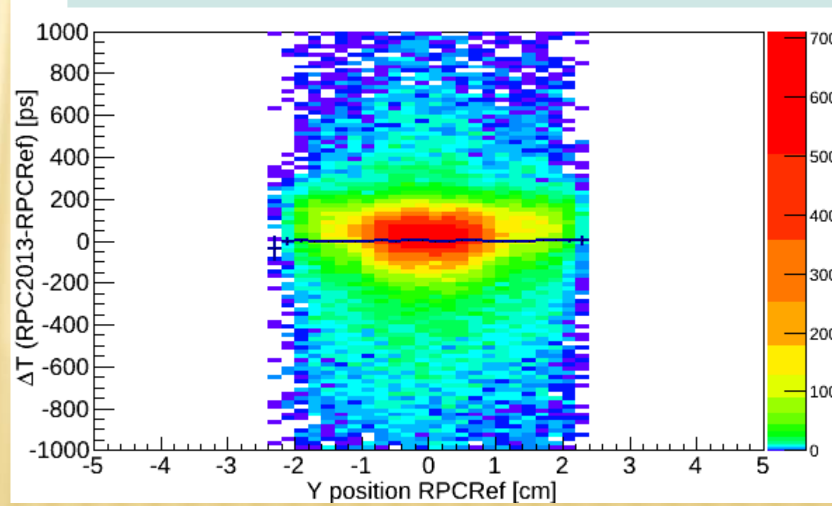
Slewing corrections



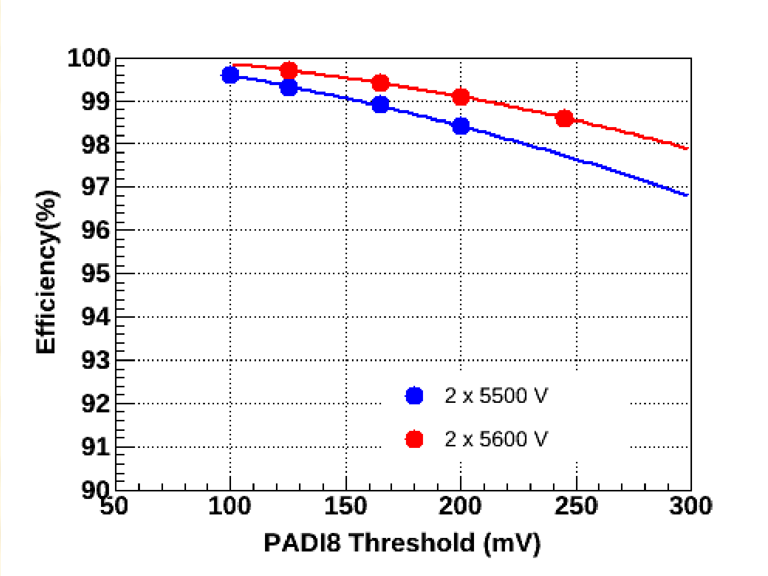
Position corrections across the strips

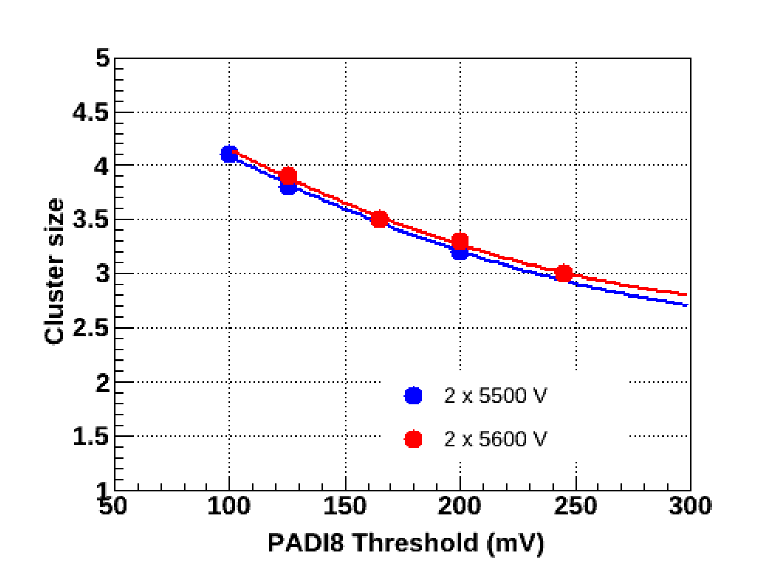


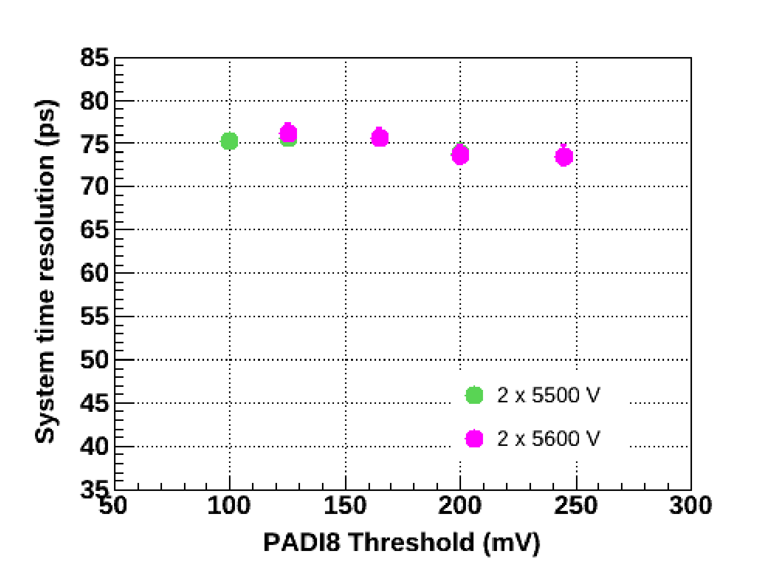
Position corrections along the strips



Efficiency, Cluster Size & Time Resolution

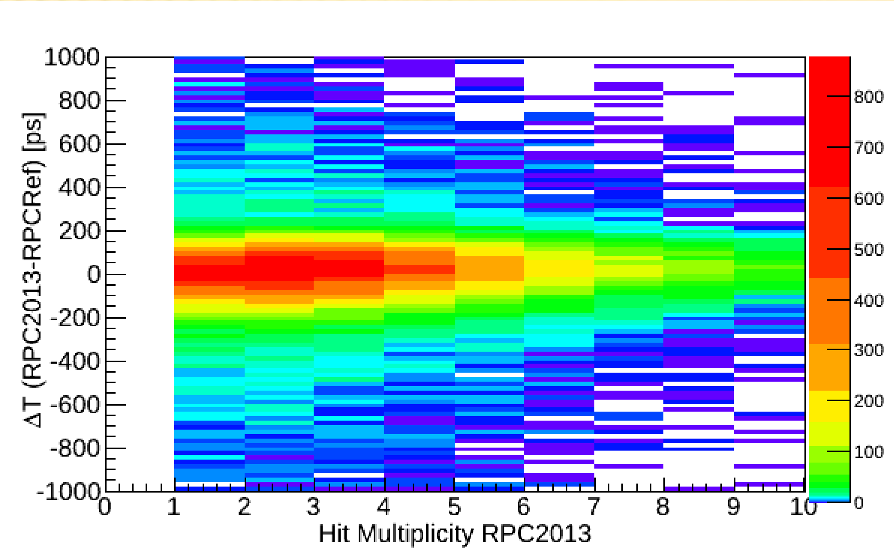


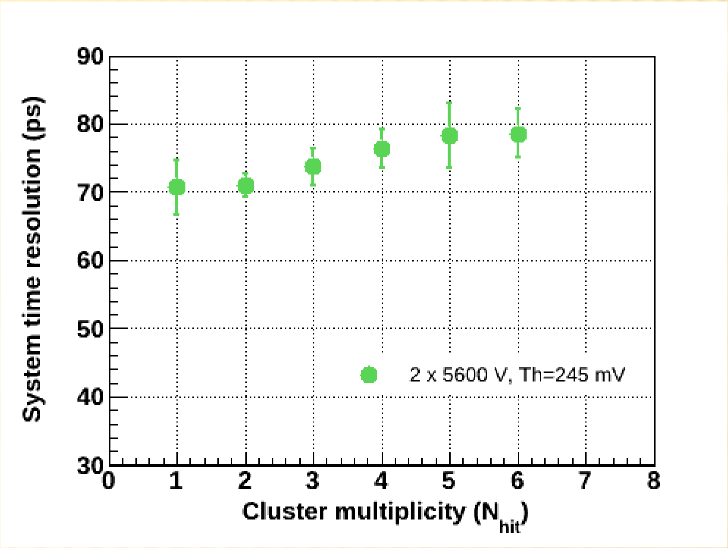




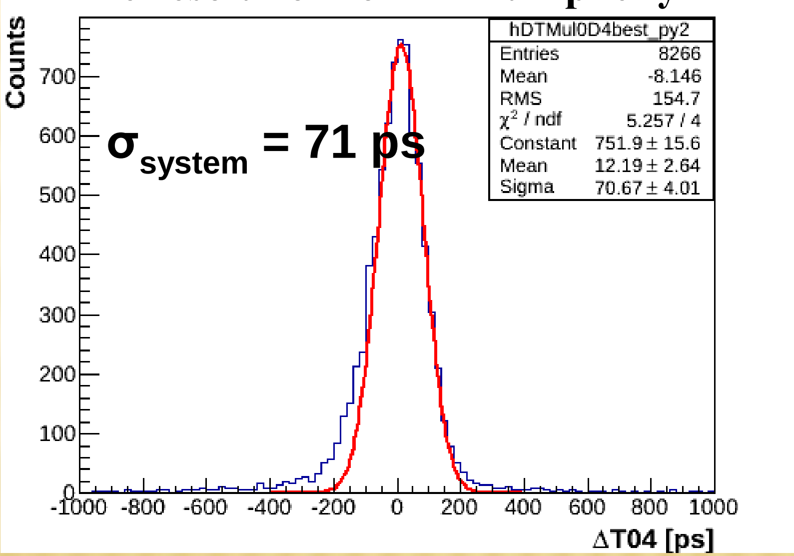
M.Petris et al. Journal of Instrumentation , Vol. 11 C09009, 2016

Hit multiplicity





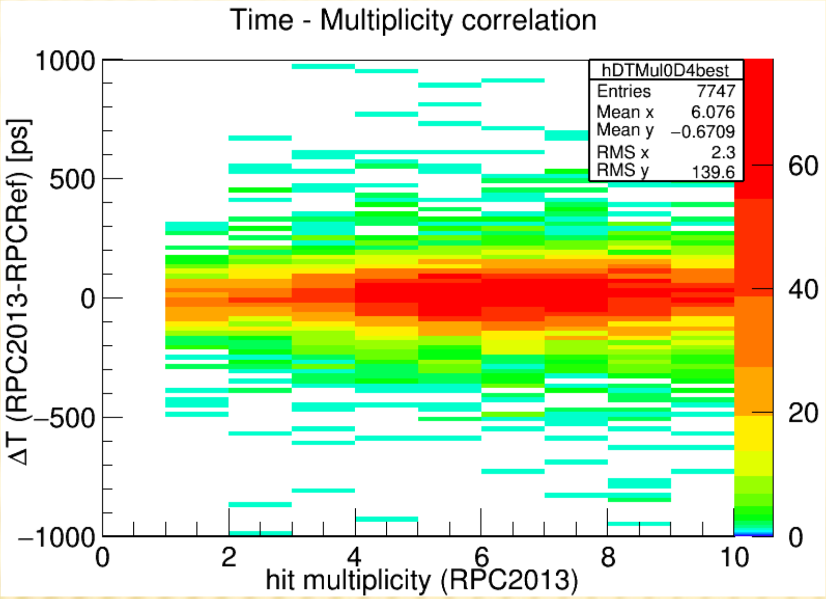
Time resolution for hit multiplicity = 1

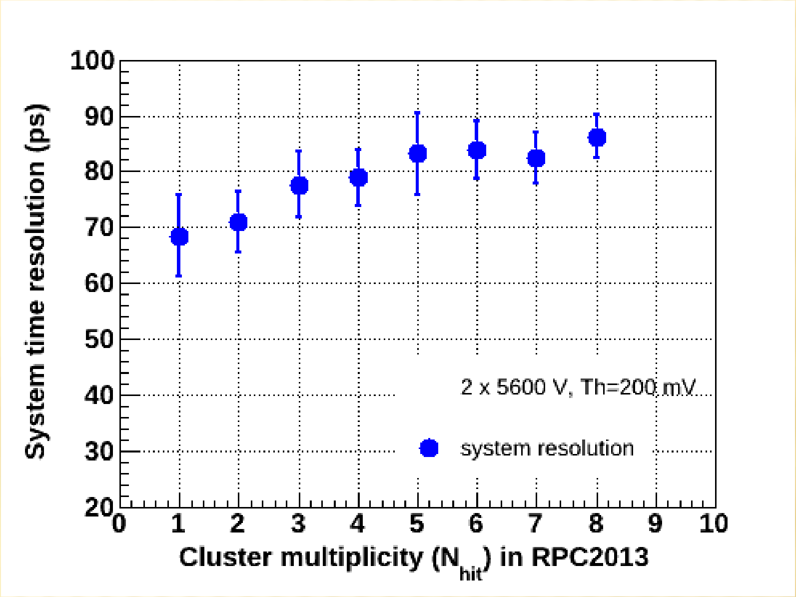


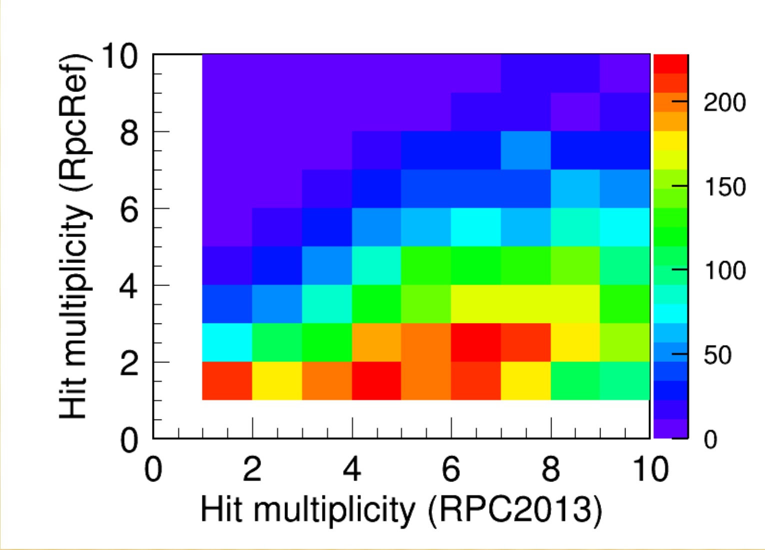
Average counting rate <1 kHz/cm²

CERN – SPS beam-time February 2015

- **Ar beam of 13A GeV on a Pb target**





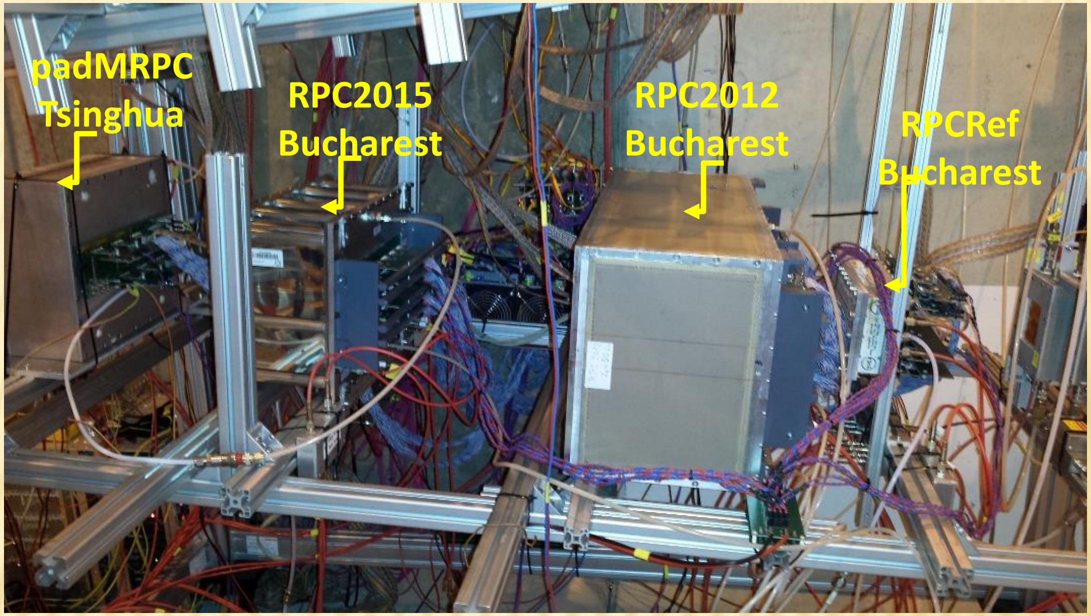


Average counting rate = 5 kHz/cm^2

Individual contribution of the two RPCs is not necessarily the same.

November 2015 CERN - SPS in-beam tests

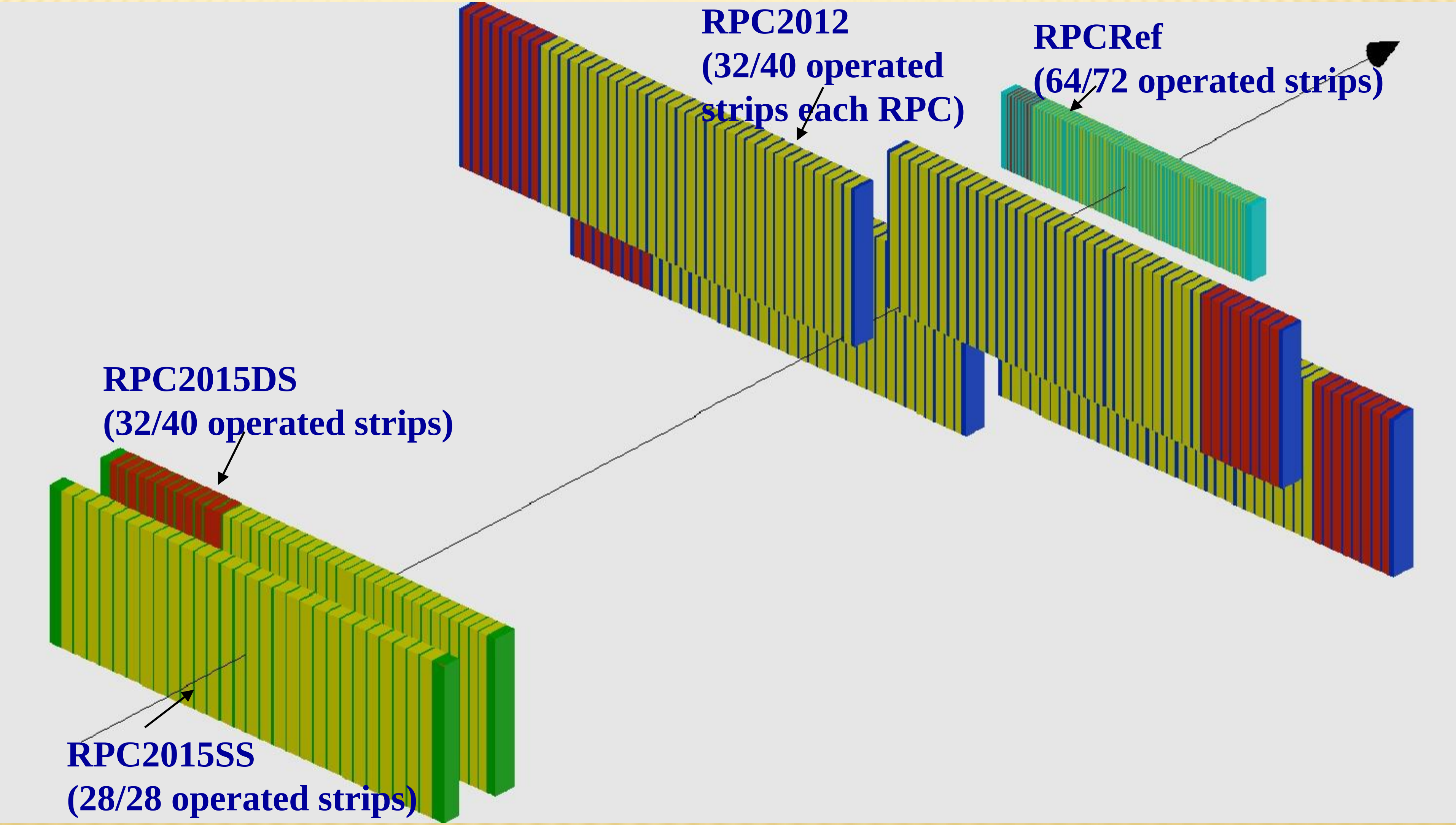
Pb beam of 30A GeV on a Pb target



High counting rate experimental set-up – ~3.^{0} relative to the beam line

- ***RPC Tsinghua University – 3 pad MRPCs***
- ***RPC2015 Bucharest – 2 new strip 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 Bucharest – 4 strip MRPCs – 32 operated strips/RPC out of 40/RPC – 80% active area***
- ***RPCRef – 1 strip MRPC – 64 operated strips out of 72/RPC - 89% active area***

November 2015 CERN - SPS in-beam tests
Spatial overlap of the Bucharest RPCs



Bucharest prototypes within SPS in-beam tests

Counter architecture:

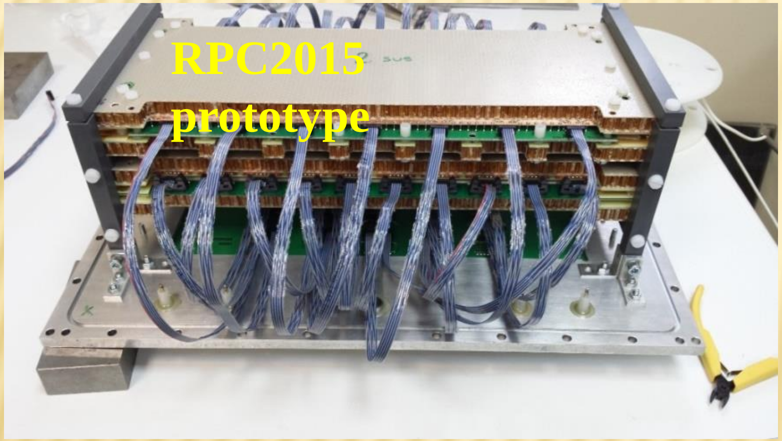
Electrodes:* *0.7 mm low resistivity Chinese glass

Gap size: 140 µm thickness

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

SS: Single stack structure: 1 x 8 gas gaps

DS: 7.2 mm strip pitch = 5.9 mm width + 1.3 mm gap
SS: 10.1 mm strip pitch = 8.6 mm width + 1.5 mm gap
Differential readout, 100 Ω impedance
Active area: 96 x 300 mm^2

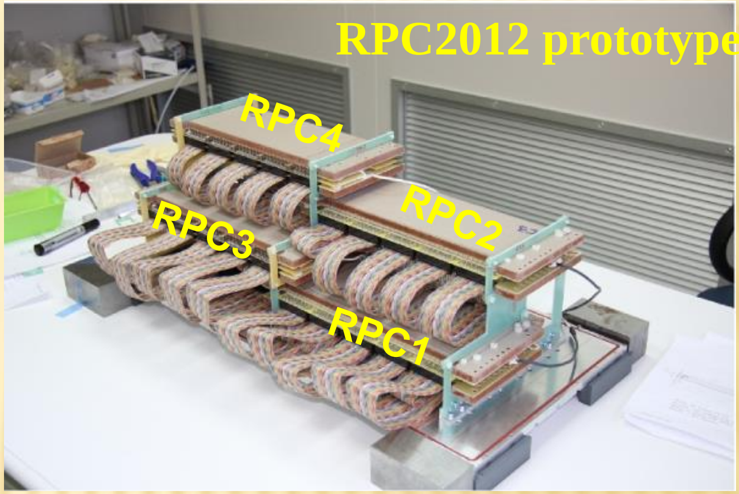


FEE for all RPCs = PADI
Readout FPGA TDC + TRB3

7.4 mm strip pitch = 5.6 mm width + 1.8 mm gap

Differential readout, 50 Ω impedance

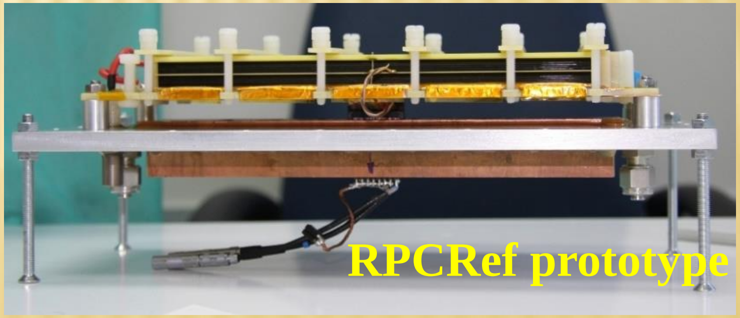
Active area: 96 x 300 mm^2



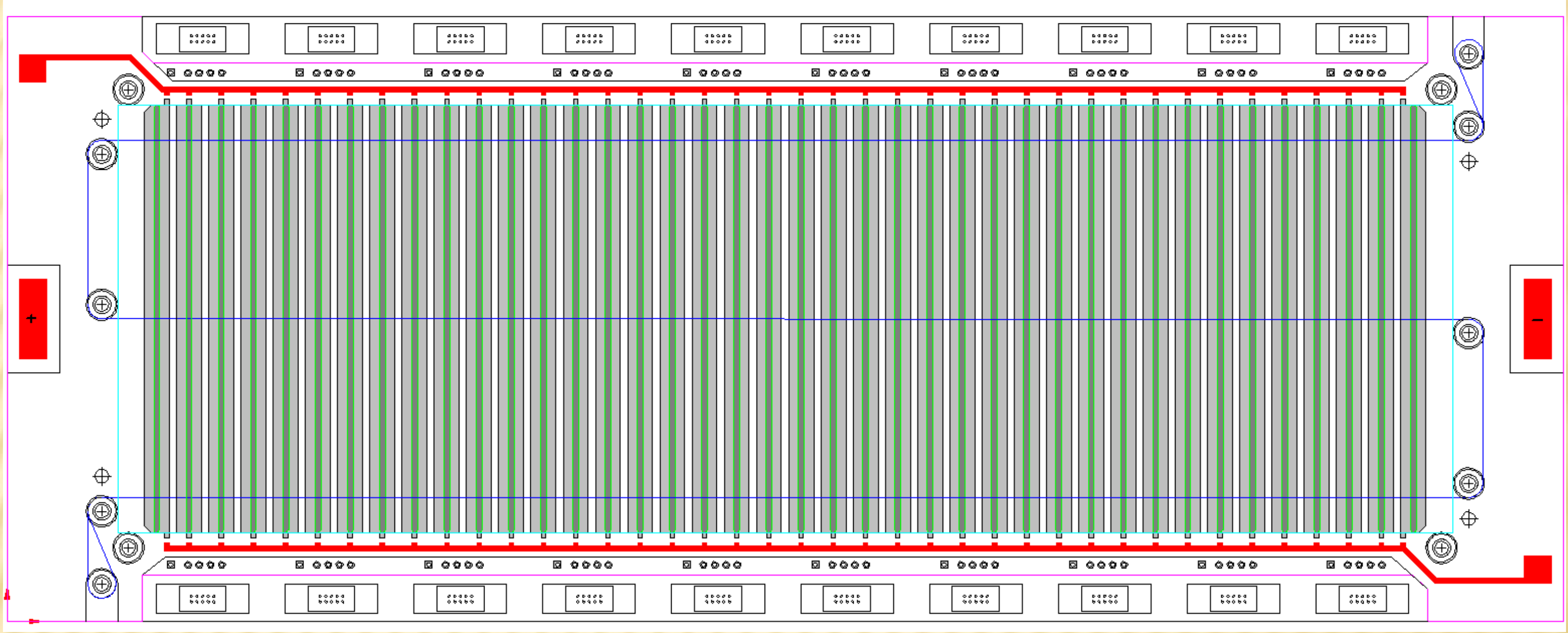
2.54 mm strip pitch = 1.1 mm width + 1.44 mm gap

Differential readout, 100 Ω impedance

Active area: 46 x 180 mm^2



RPC2015DS prototype - strip impedance tuned through the readout strip width



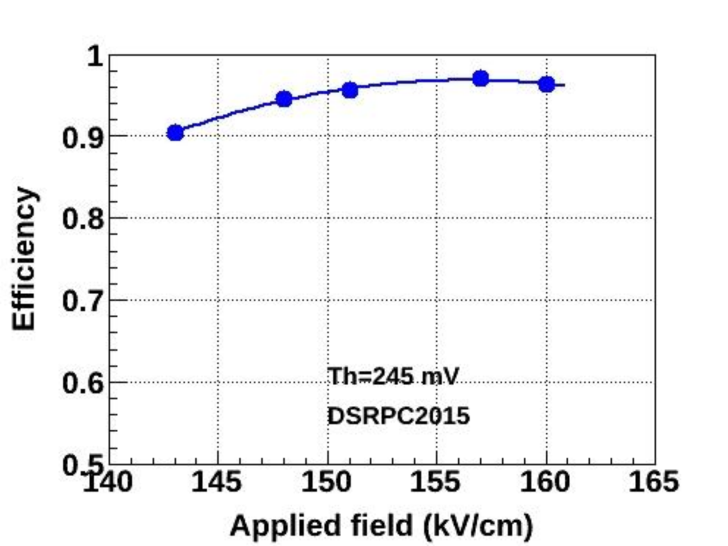
Readout electrode: 7.2 mm pitch= 1.3 mm width + 5.9 mm gap

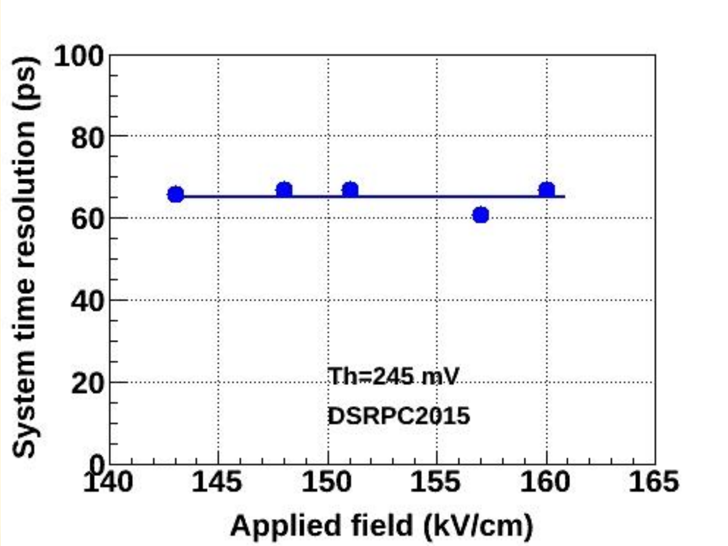
High Voltage electrode: 7.2 mm pitch= 5.6 mm width + 1.6 mm gap

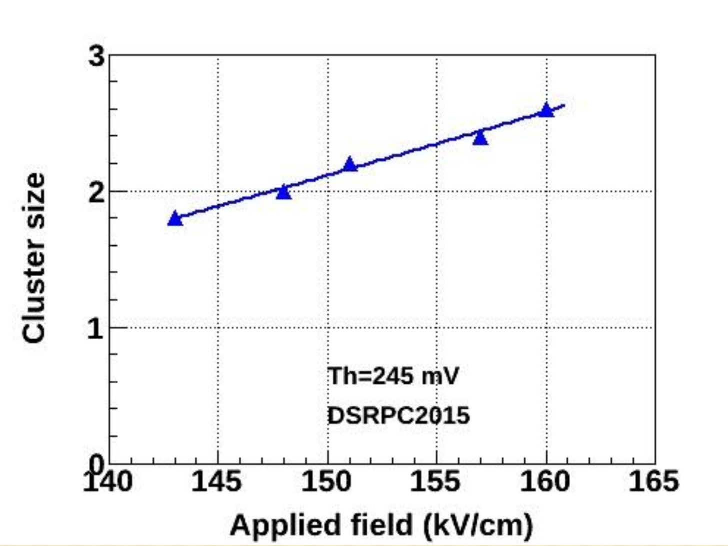
- ✓ Symmetric two stack structure: 2 x 5 gaps
- ✓ Active area 96 x 300 mm^2
- ✓ Gas gap thickness: 140 µm thickness
- ✓ Readout electrode = 40 strips
- ✓ Differential readout = 100 Ohm impedance
- ✓ Resistive electrodes: low resistivity glass

RPC2015DS performance in Nov15 beam test

DUT = Buc2015DS, Ref = Buc2015SS, Sel2 = BucRef



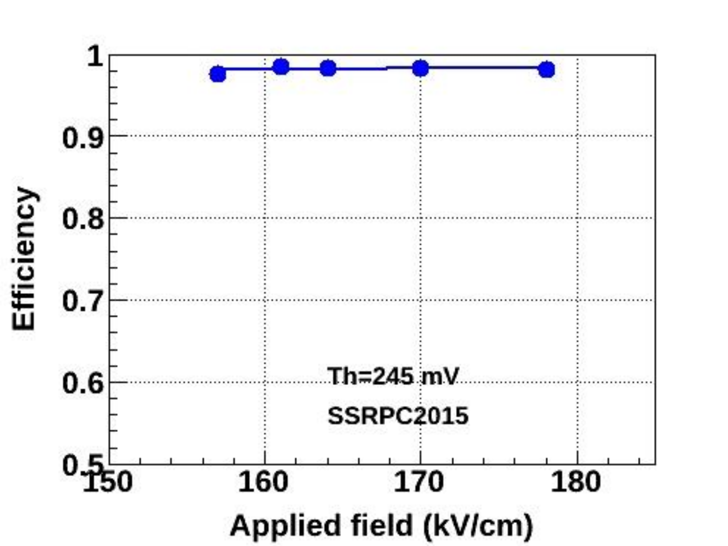


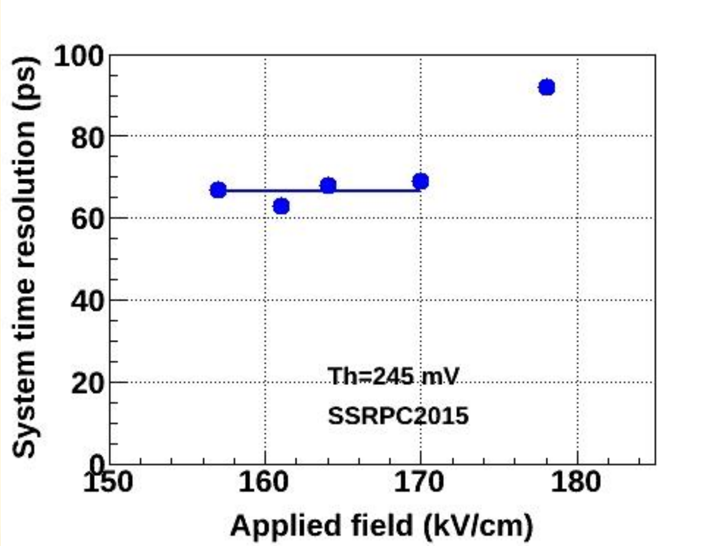


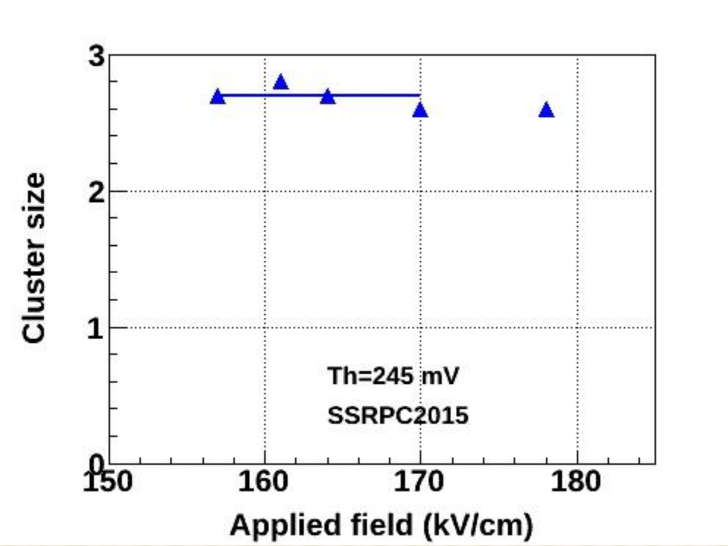
- ✓ **System time resolution = 66 ps**
- ✓ **The efficiency plateau is reached @ 96% -97%**
- ✓ **The cluster size is 2.2 – 2.6 @ efficiency plateau**

RPC2015SS performance in Nov15 beam test

DUT = Buc2015SS, Ref = Buc2015DS, Sel2 = BucRef





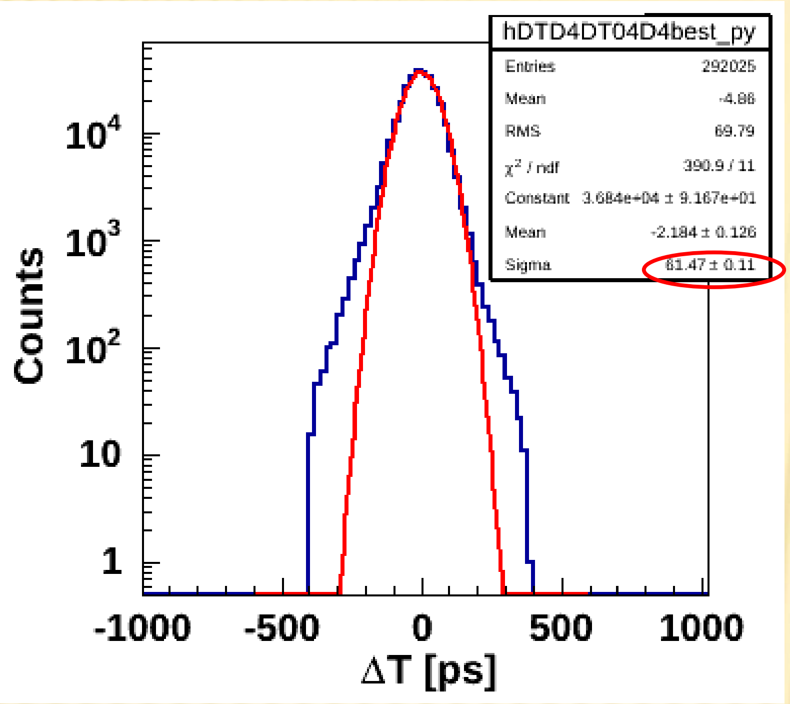


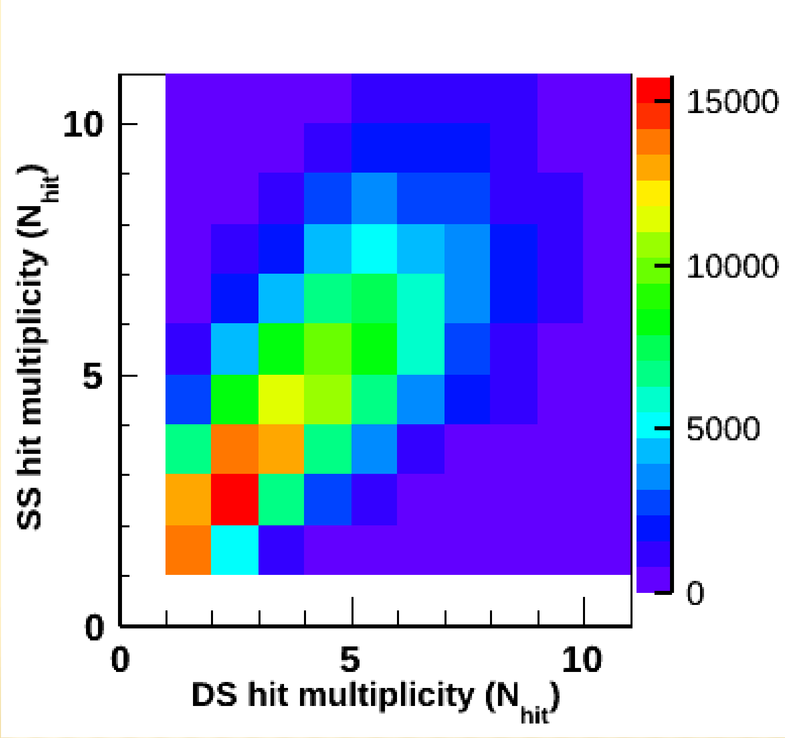
- ✓ **System time resolution = 67 ps**
- ✓ **The efficiency plateau is reached @ 97% -98%**
- ✓ **The cluster size is 2.7 @ efficiency plateau**

Single counter time resolution

DUT = Buc2015DS, Ref = Buc2015SS, Sel2 = BucRef

System time resolution = 61 ps

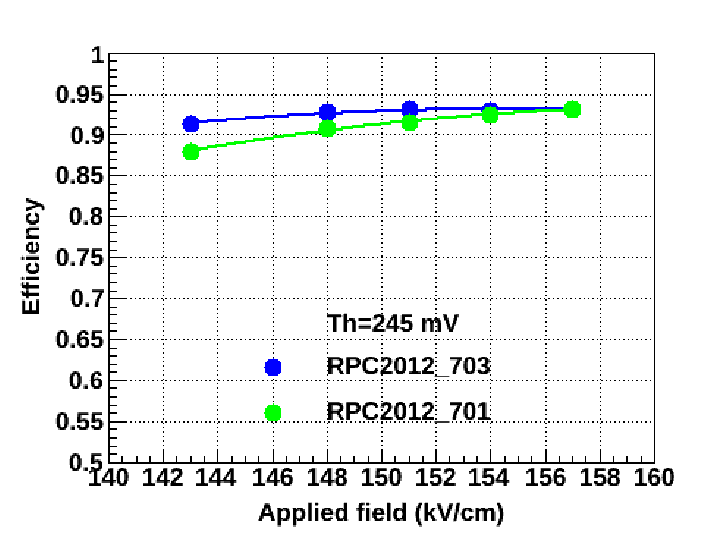


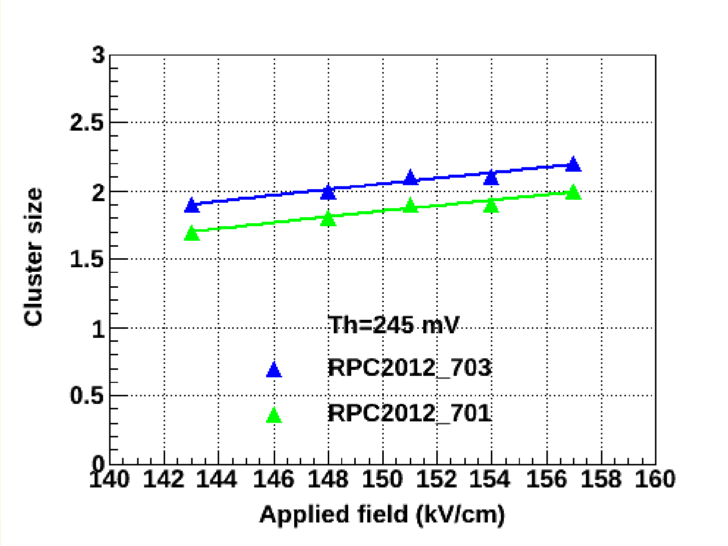


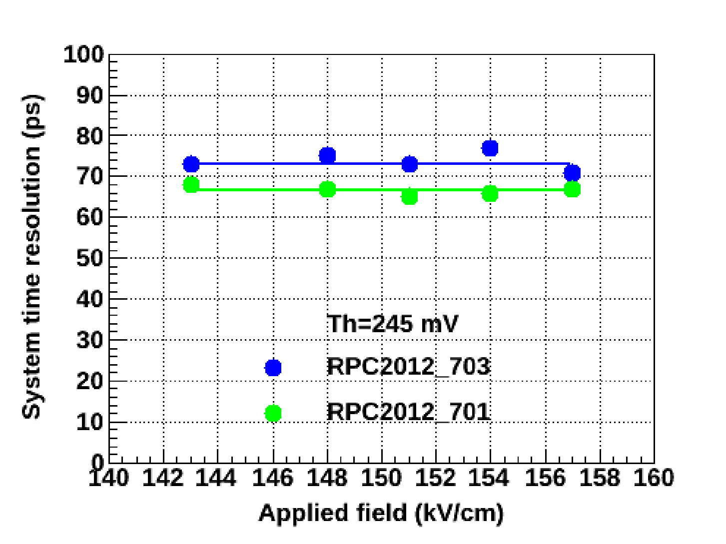
Single counter time resolution = 43 ps

RPC2012 performance in Nov15 beam test

DUT = Buc2012, Ref = Buc2015DS, Sel2 = BucRef





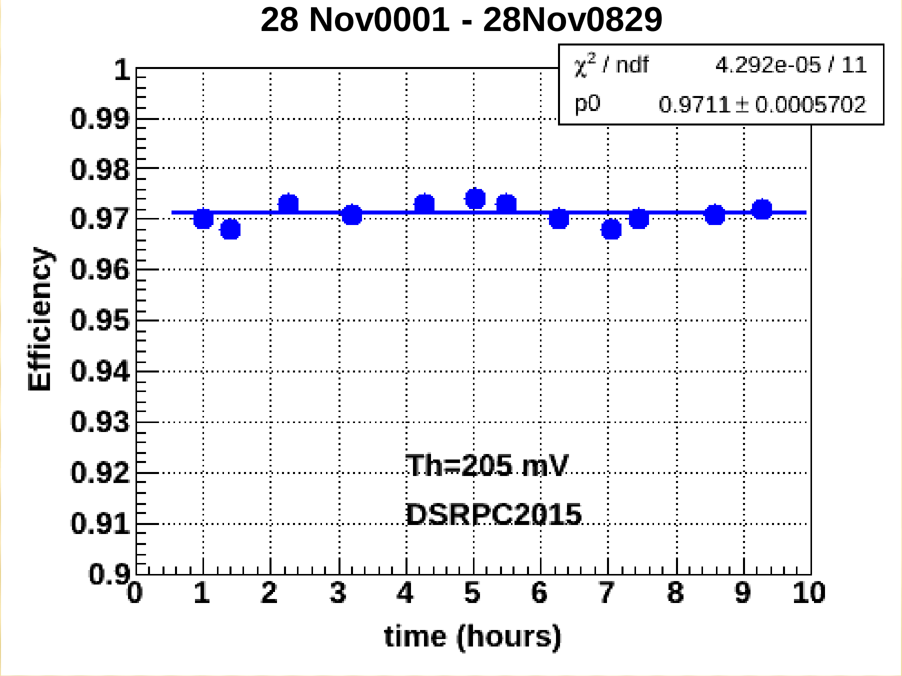


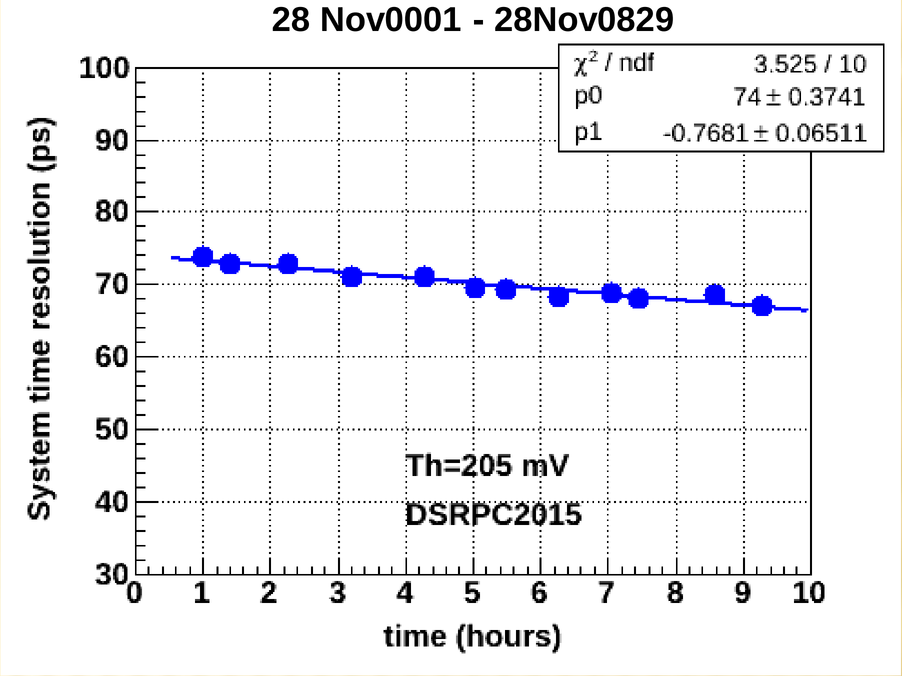
- ✓ System time resolution = 66 ps
- ✓ The efficiency plateau is reached @ 94% (affected by the active area overlap with the reference counter)
- ✓ The cluster size is 1.9 – 2.2 @ efficiency plateau

Long term operation studies

Conditioning effect - first part of the beam time

~8 hours operation with constant settings





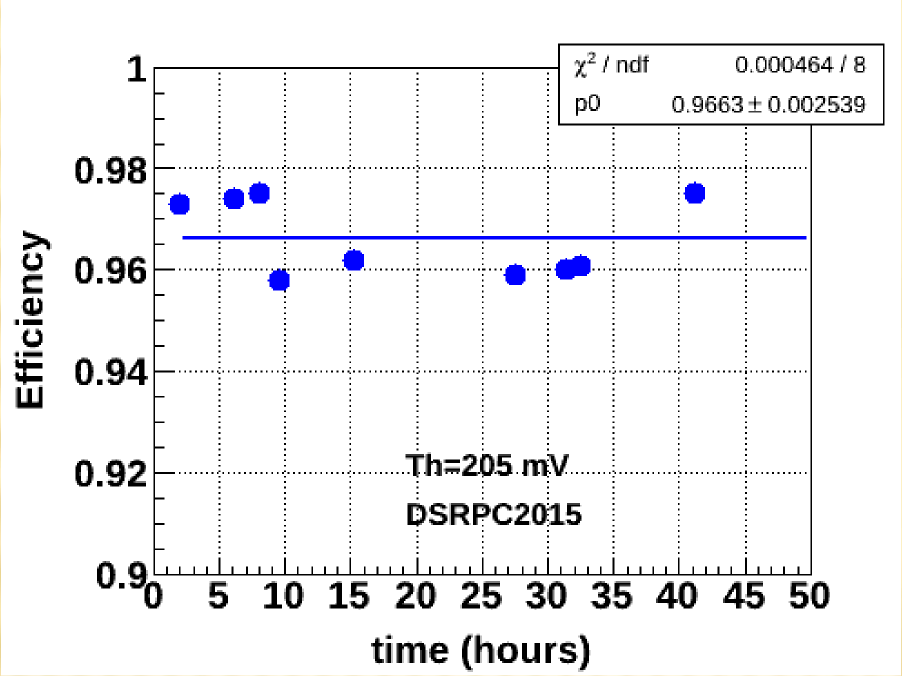
DUT = Buc2015DS, Ref = Buc2015SS

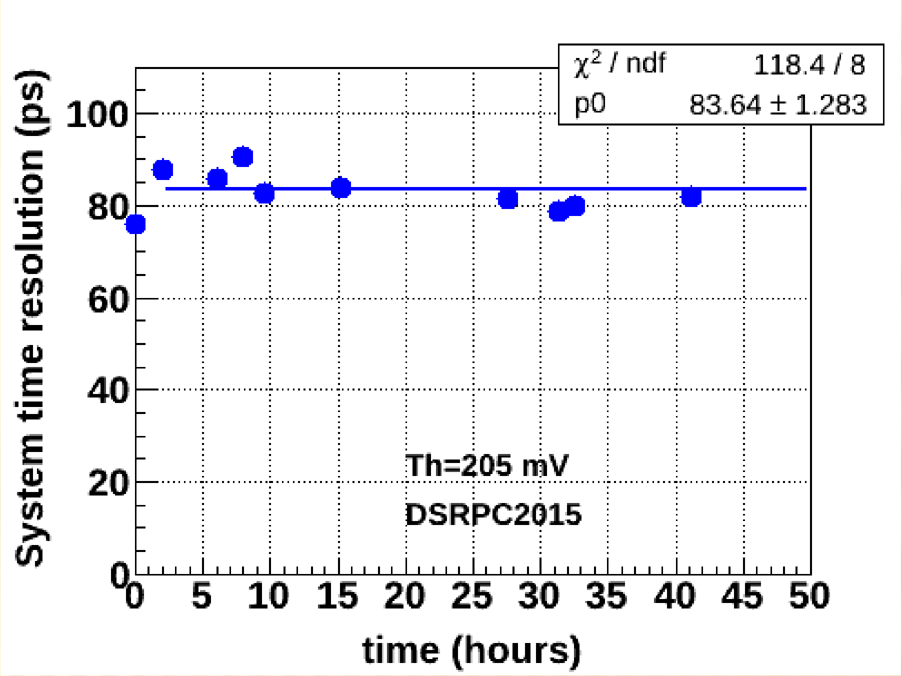
HV Buc2015SS = 157 kV/cm, Th = 205 mV

HV Buc2015DS = 157 kV/cm, Th = 205 mV

Long term operation studies

Second part of the beam time
~40 hours operation with constant settings



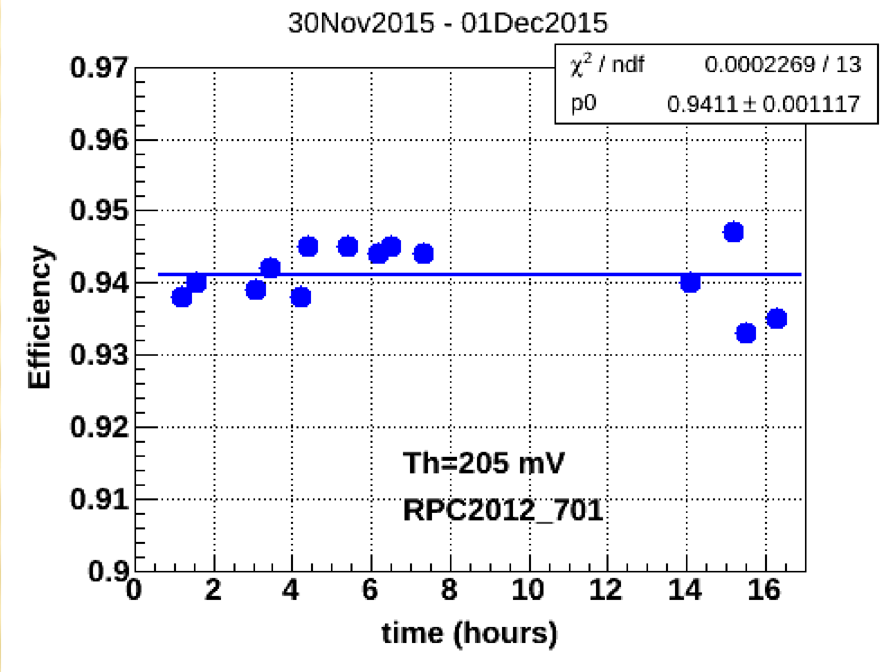


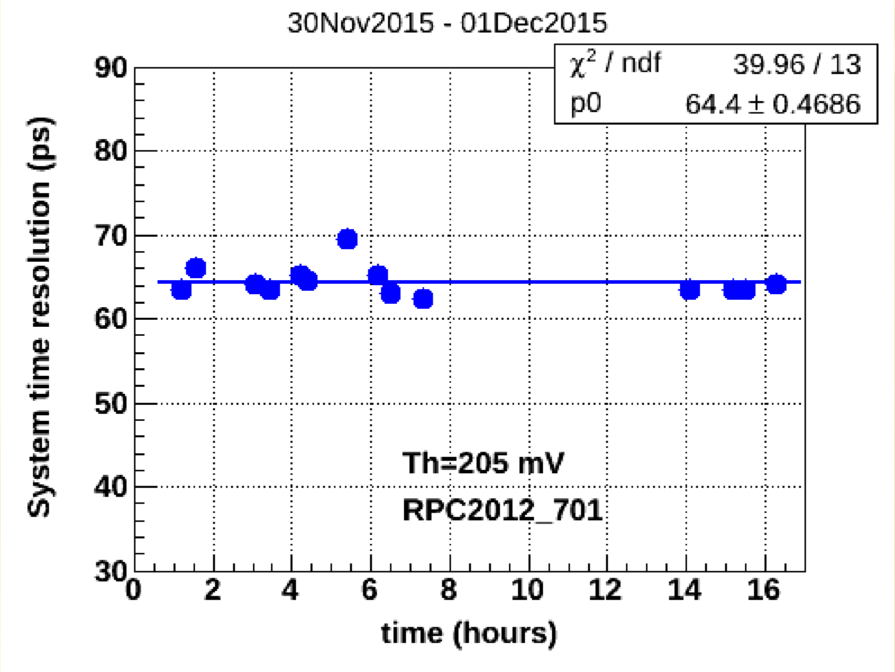
DUT = Buc2015DS, Ref = Buc2015SS
HV Buc2015SS = 178 kV/cm, Th = 205 mV
HV Buc2015DS = 157 kV/cm, Th = 205 mV

Long term operation studies

Second part of the beam time

~15 hours operation with constant settings



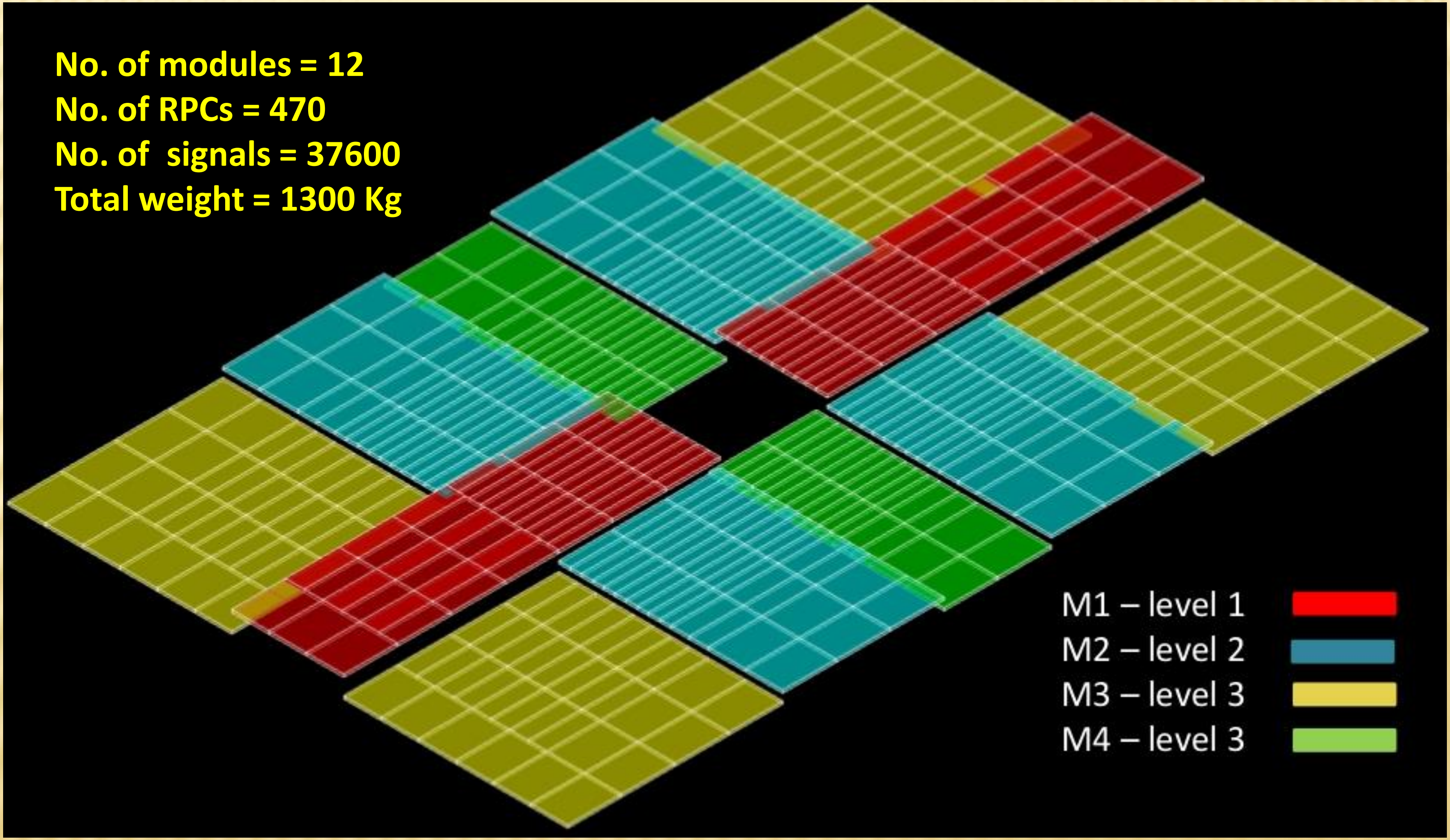


DUT = Buc2012_701, Ref = Buc2015DS

HV Buc2012 = 157 kV/cm, Th = 205 mV

HV Buc2015DS = 157 kV/cm, Th = 205 mV

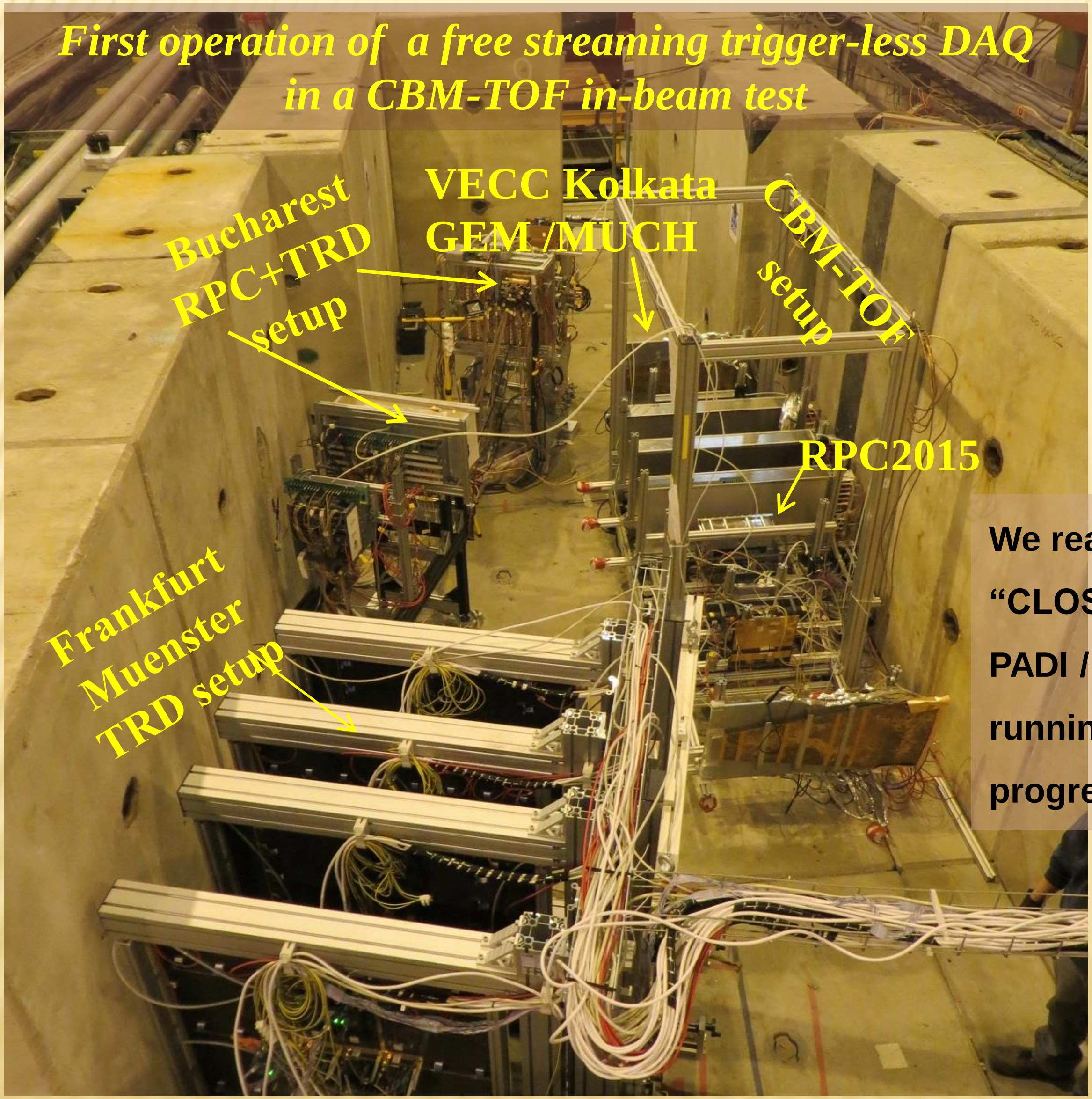
Inner wall design based on RPC2015DS prototype



L. Radulescu et al. , IBWAP, Constanta, Romania, July, 2017

Fall 2016 CERN - SPS in-beam tests

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



We readout ~ 500 Channels with our new "CLOSE TO FINAL" readout-chain: PADI / GET4 / AFCK / FLIB => DAQ was running stable. Data analysis is in progress. Results are promising.

Outlook of the next activities

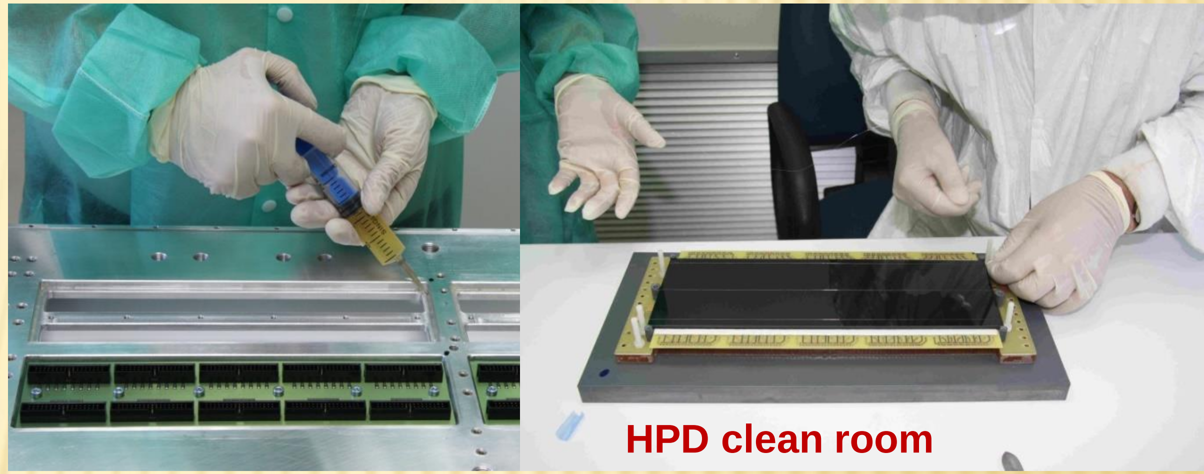
Second half of 2018 – construction of the first module for CBM-TOF inner zone

CBM-TOF inner zone

- ***~15 m^2 active area***
- ***~470 MGMSRPC counters***
- ***~ 37 600 readout channels***

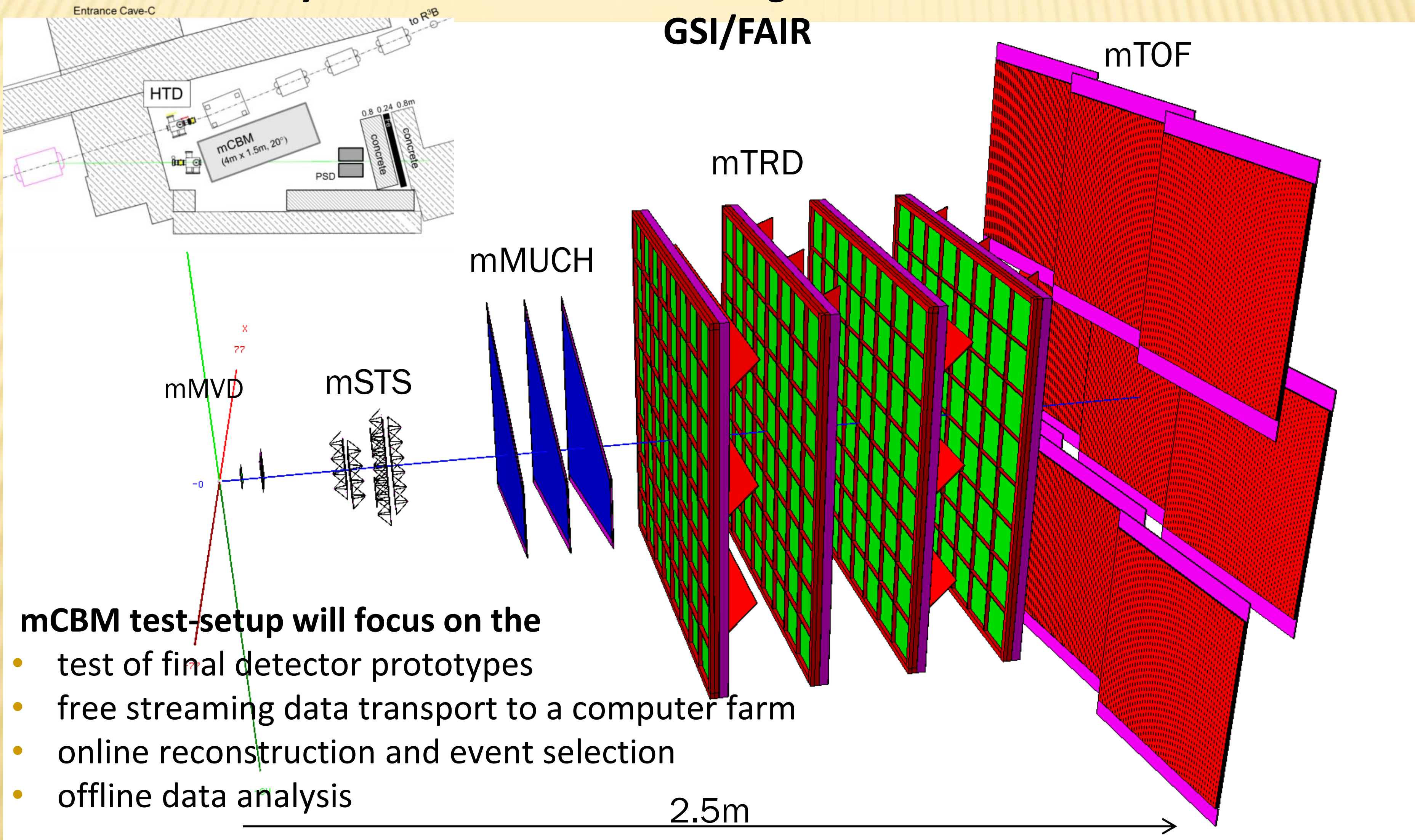
HPD main infrastructure:

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



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

Conclusions & Outlook

- Performance of the developed prototypes, in terms of time resolution and efficiency, was demonstrated
- The data analysis of the last 2016 in-beam test campaign – free streaming DAQ – is on-going work
- A prototype of a module will be constructed
- We are going to operate it in the mCBM setup

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Thank you for your attention!