High rate time of flight system for FAIR-CBM

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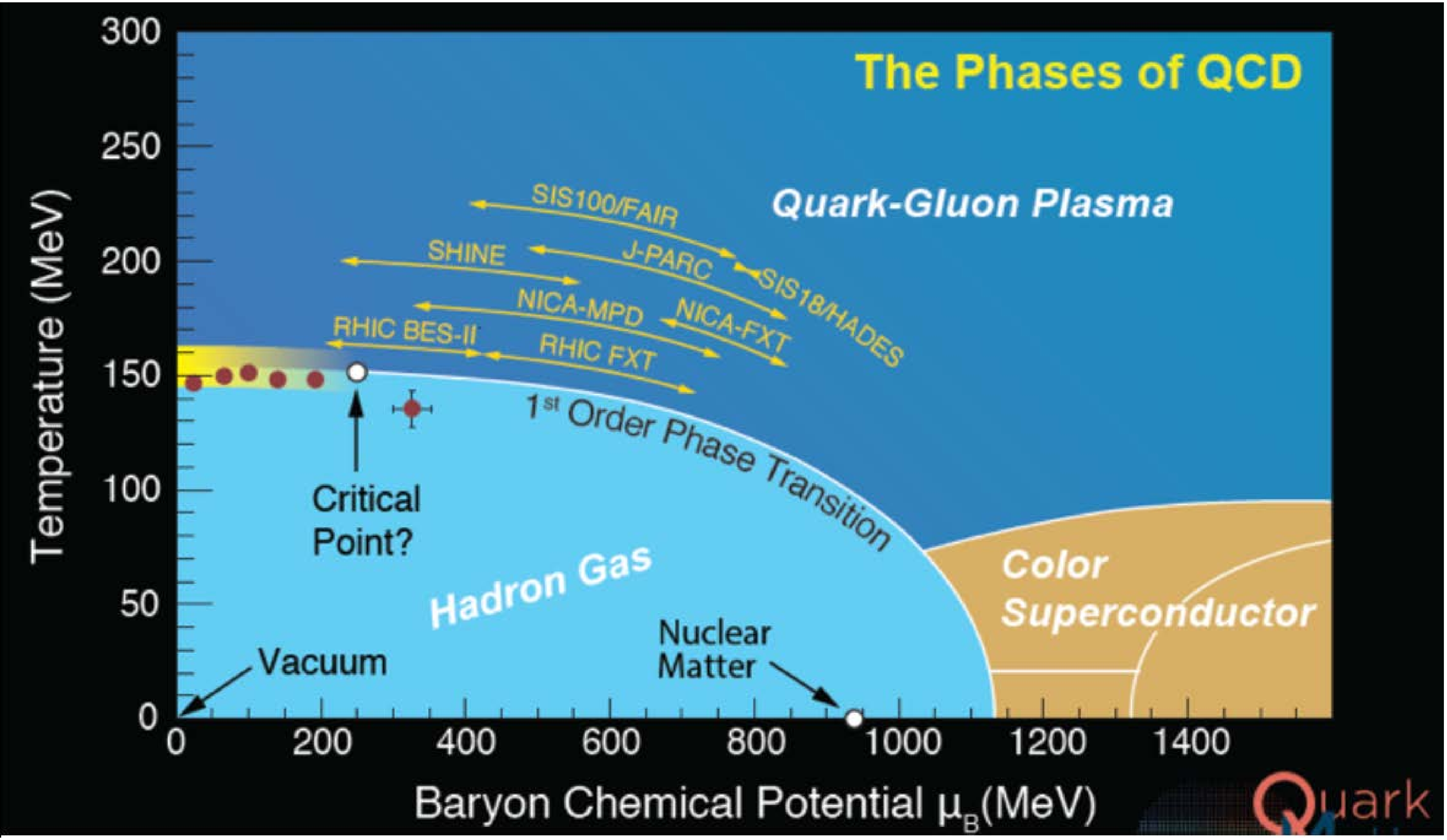
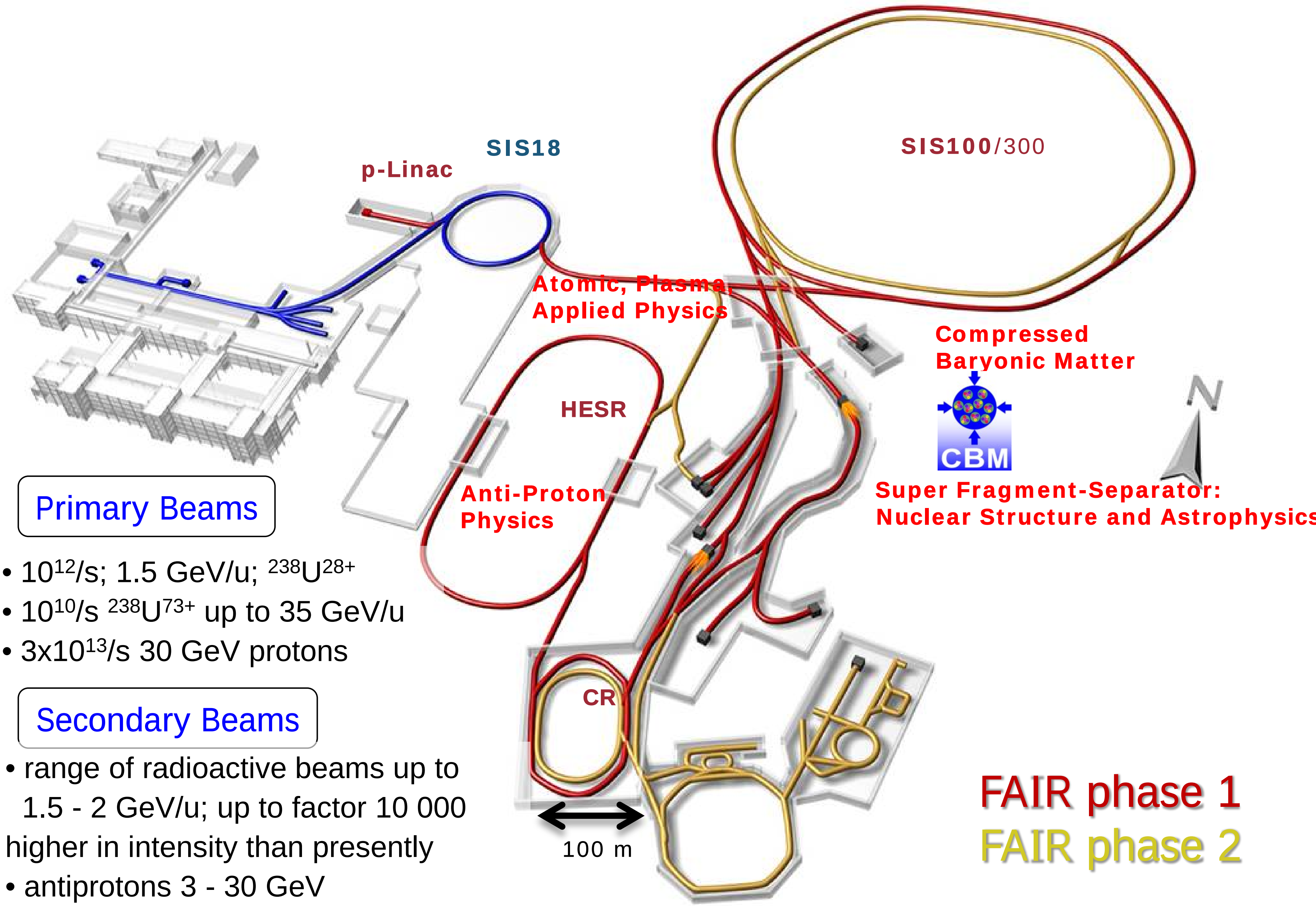
Outline

- Introduction on FAIR and CBM-TOF
- Structure of CBM-TOF
- Development of low resistive glass
- Design of strip-MRPC and pad-MRPC
- Beam test @GSI and SPS
- Conclusions

The phase diagram of strongly interacting matter



Facility for Antiproton and Ion Research



Primary Beams

- 10^{12}/s; 1.5 GeV/u; $^{238}U^{28+}$
- 10^{10}/s $^{238}U^{73+}$ up to 35 GeV/u
- 3×10^{13}/s 30 GeV protons

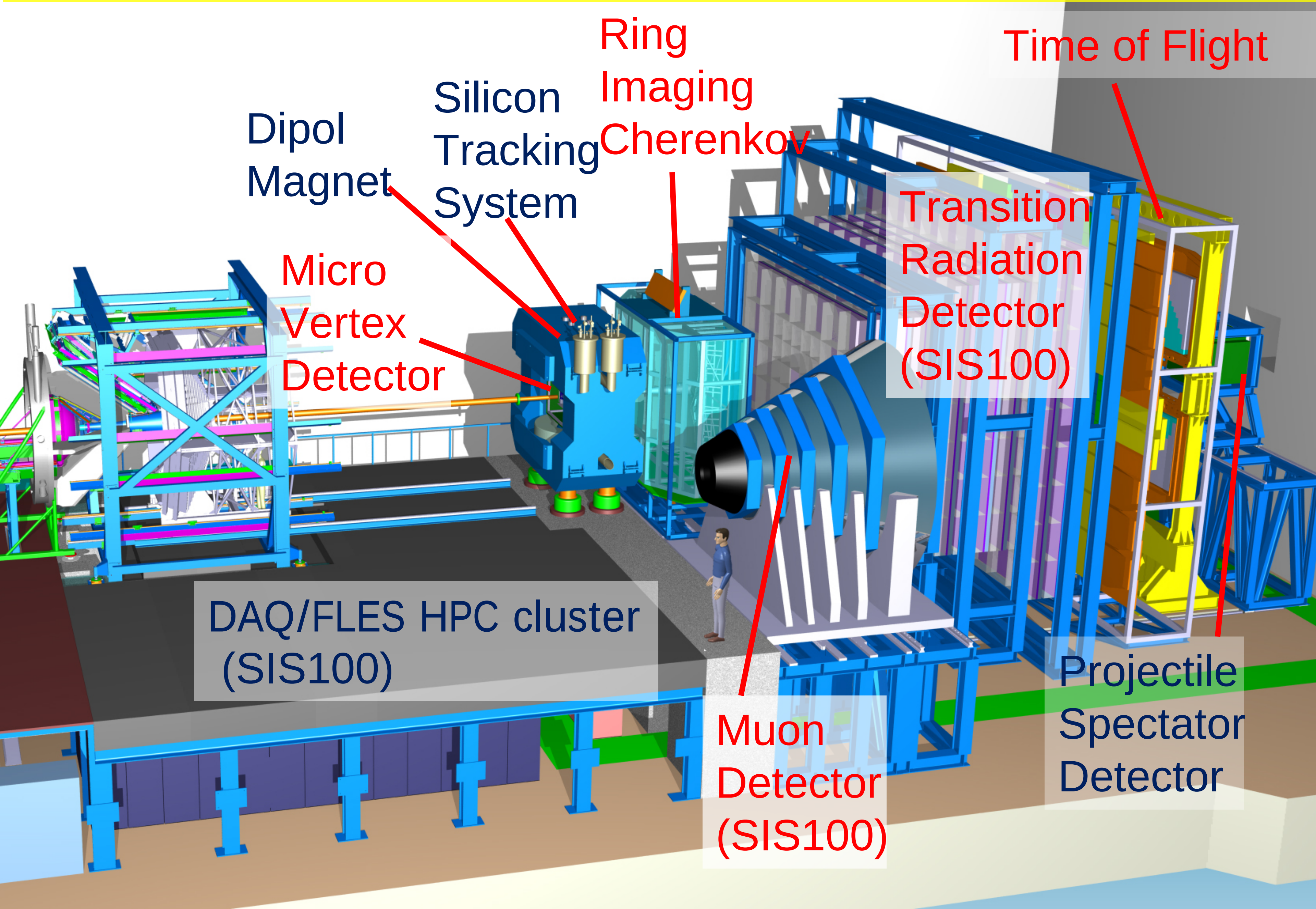
Secondary Beams

- range of radioactive beams up to 1.5 - 2 GeV/u; up to factor 10 000 higher in intensity than presently
- antiprotons 3 - 30 GeV

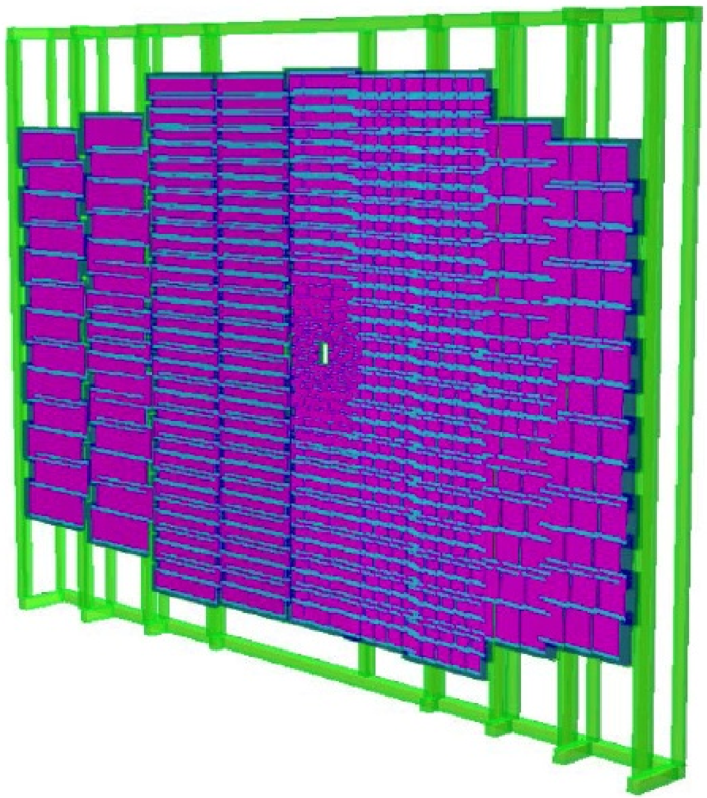
FAIR phase 1

FAIR phase 2

Layout of CBM detector

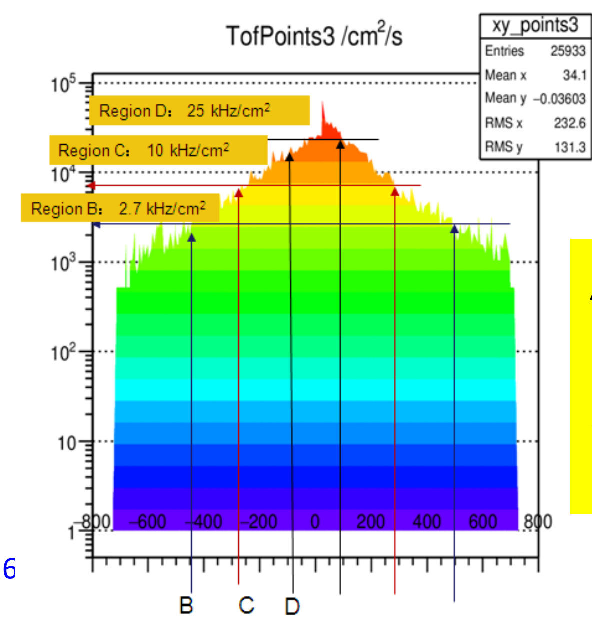


The structure of CBM-TOF wall



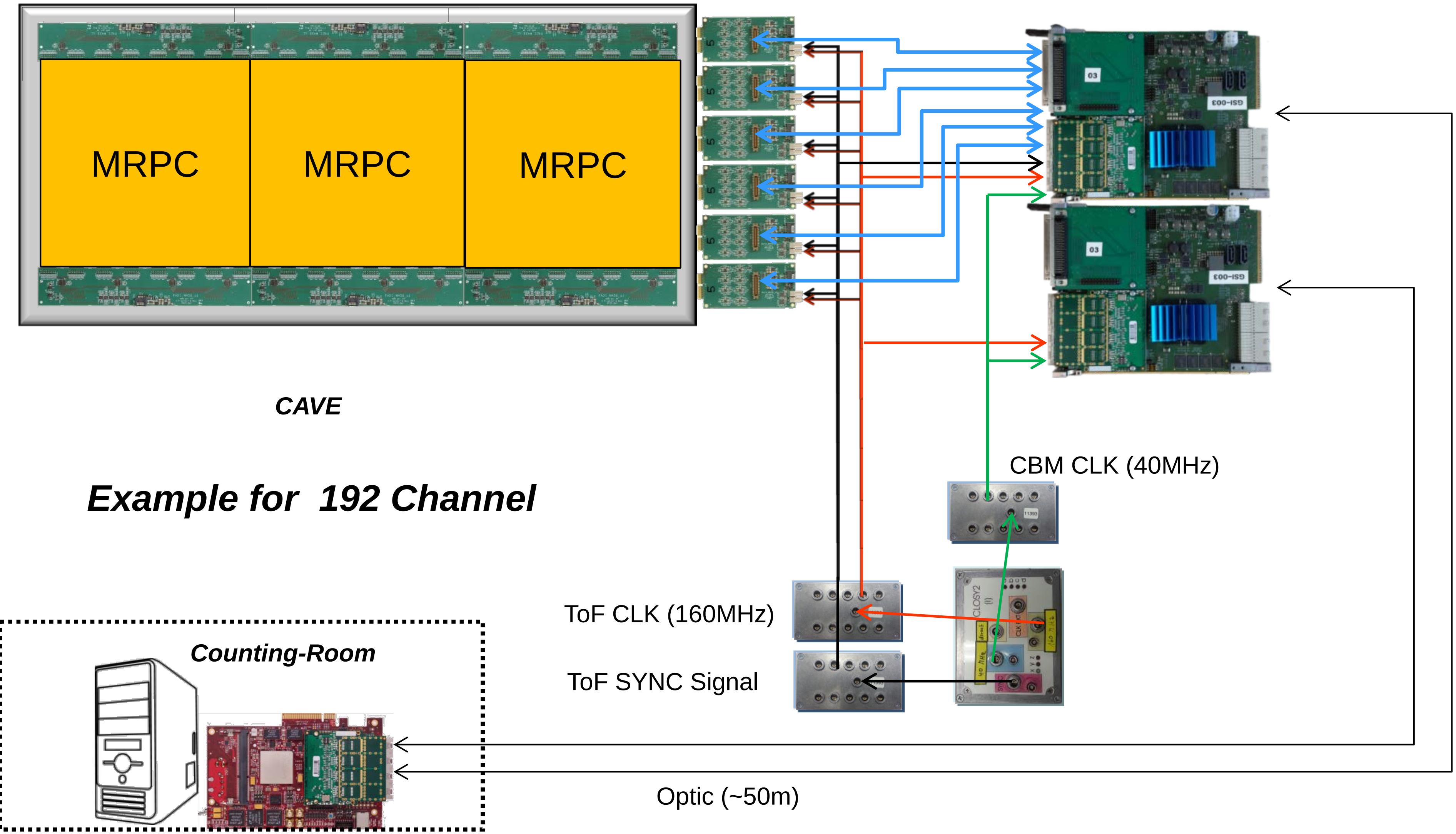
CBM-ToF Requirements

- Full system time resolution σ_T ~ 80 ps
- Efficiency > 95 %
- Rate capability ≤ 30 kHz/cm^2
- Polar angular range 2.5° – 25°
- Occupancy < 5 %
- Low power electronics (~100.000 channels)
- Free streaming data acquisition



Au+Au, Center, 10AGeV
Simulated with CBM ROOT

Electronics & Readout chain

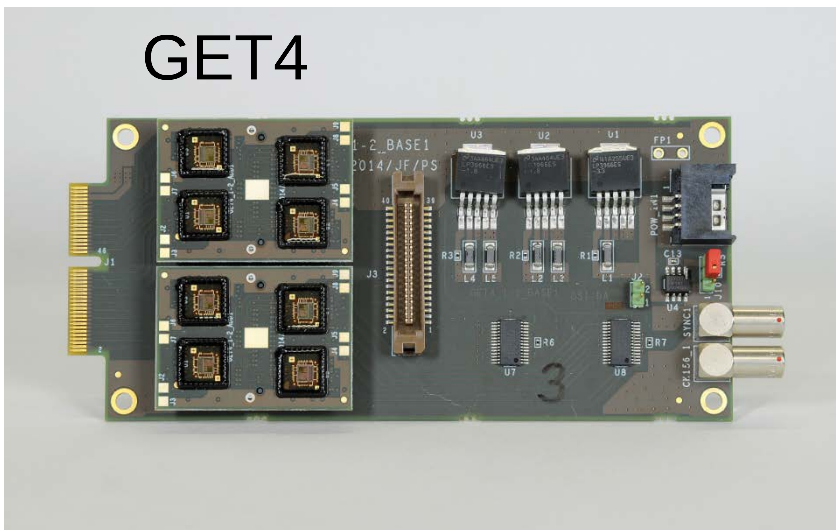


Example for 192 Channel

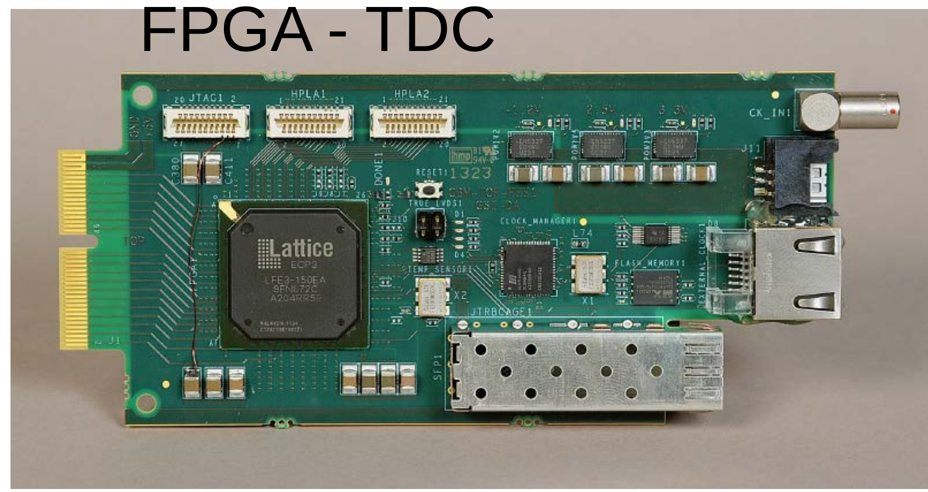
TOF electronics

Padi8

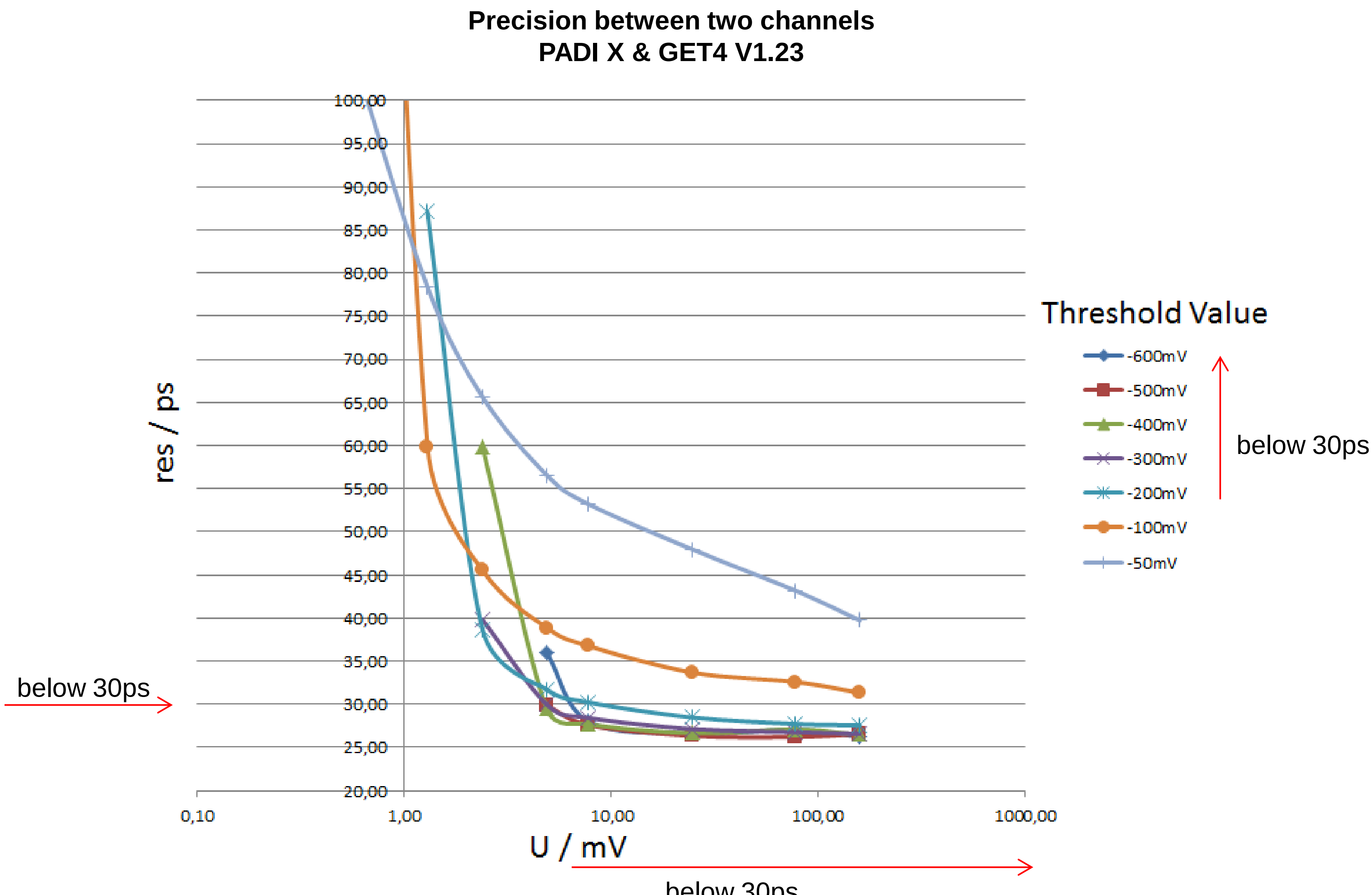
GET4



FPGA - TDC



Pulser test of PADIX & GET4



How to increase rate of MRPC

The voltage drop in the gas gap:

$$\bar{V}_{drop} = V_{ap} - \bar{V}_{gap} = \bar{I}R = \bar{q}\phi\rho d$$

The smaller the voltage drop, the higher efficiency and higher rate capability!

Two main ways to improve rate capability:

- Reducing bulky resistivity of electrode glass (CBM)
- Reducing the avalanche charge (ATLAS)

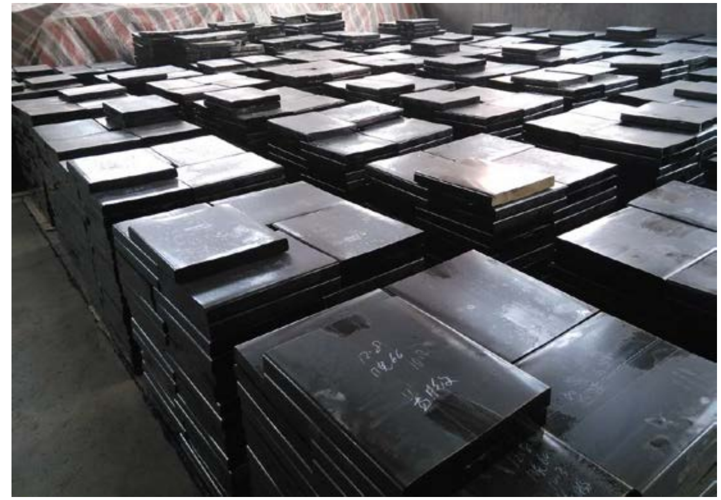
Other methods:

- Reducing the thickness of glass
- Warming the detector

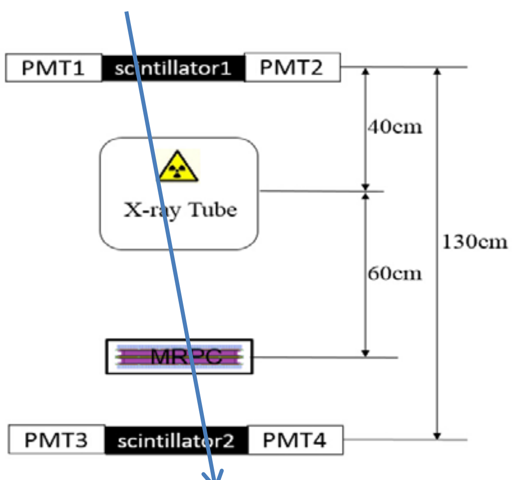
Development of low resistive glass

Performance of the glass

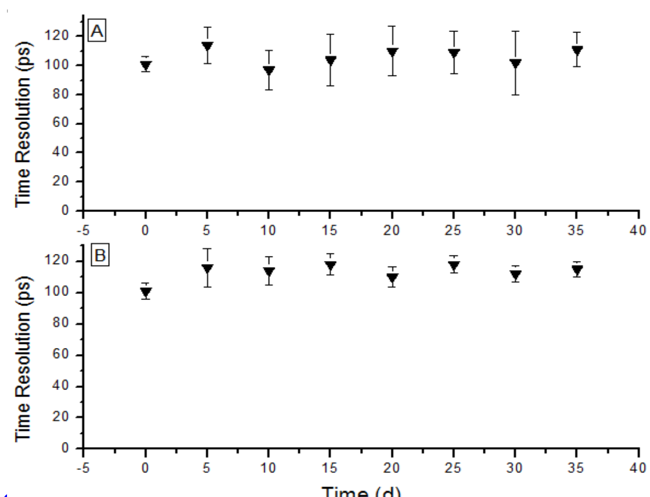
Maximal dimension	32cm $\times$ 30cm
Bulk resistivity	10^{10} Ωcm
Standard thickness	0.7, 1.1mm
Thickness uniformity	20 μm
Surface roughness	$<$ 10nm
Dielectric constant	7.5 - 9.5
DC measurement	Ohmic bebavior
	stable up to 1 C/cm^2



Glass mass production
Yield >100m^2/month

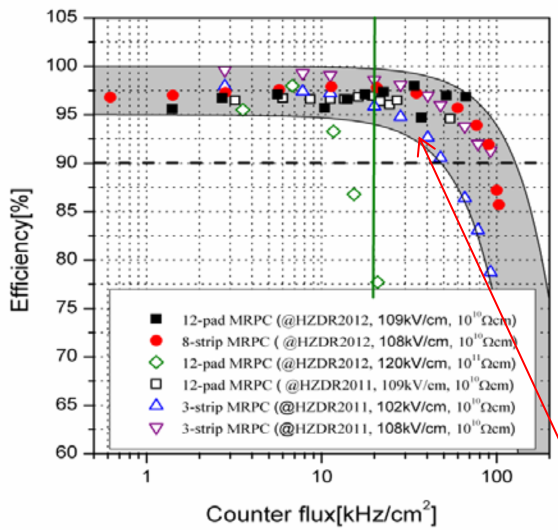


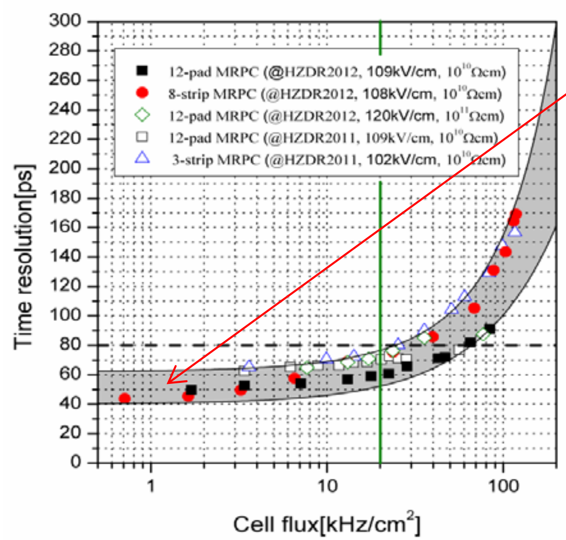
Aging test with X-ray source



Online test system. The efficiency and time resolution can be obtained by cosmic ray while irradiated by X-rays. 0.1C/cm^2 charge is accumulated in 35 days.

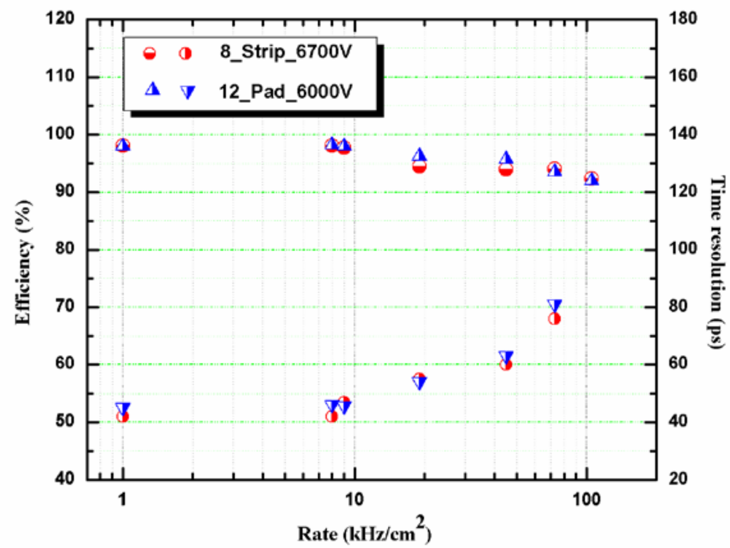
Rate capability of high rate MRPC





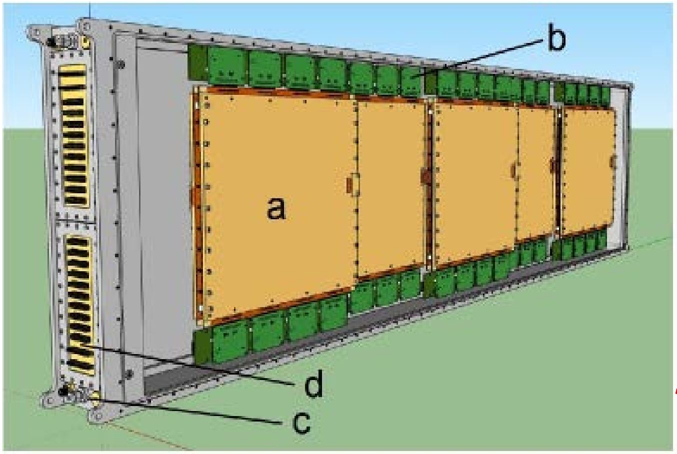
Rate: 70kHz/cm^2
Time resolution: 40 ps

Test results at Nuclotron, Dubna



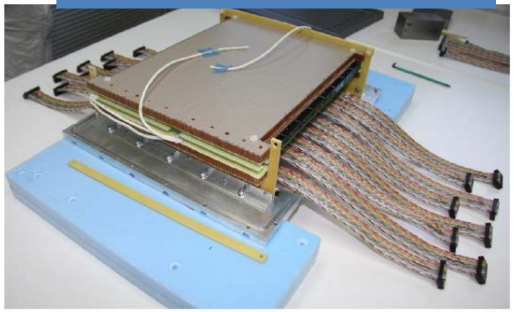
Even though the rate is 70kHz/cm^2, the efficiency is still higher than 90% and the time resolution is about 80ps.

Prototype design for CBM-TOF



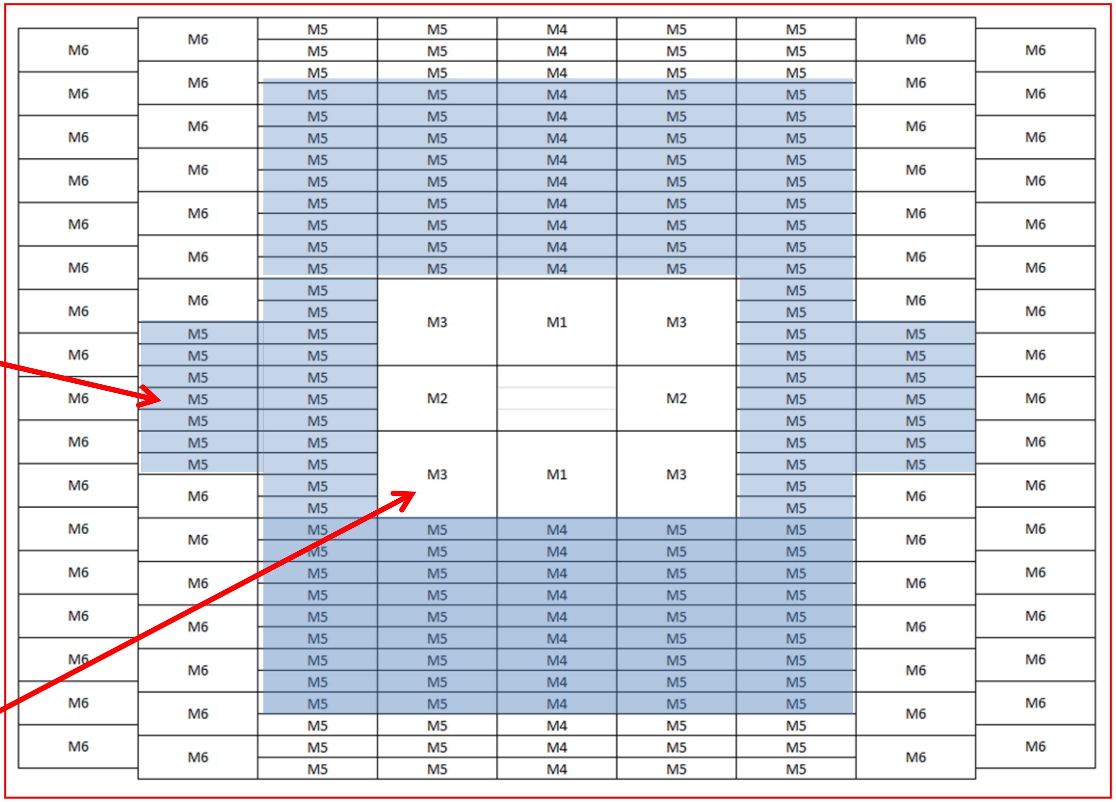
Strip-MRPC

Inner zone-MRPC

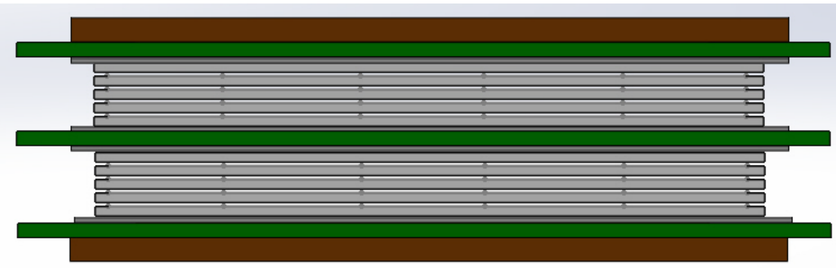


- ✓ Symmetric two stack structure: 2 x 5 gas gaps
- ✓ Resistive electrodes: low resistivity glass
- ✓ Gap size: 140 μm thickness
- ✓ Active area 200 x 266 mm^2
- ✓ Pitch=2.16 mm +2.03 mm = 4.19 mm
- ✓ Impedance matching:100 Omh differential

Mariana Petris, CBM Collaboration Meeting, 20-24 April 2015, GSI, Darmstadt



Design of strip-MRPC for high rate region



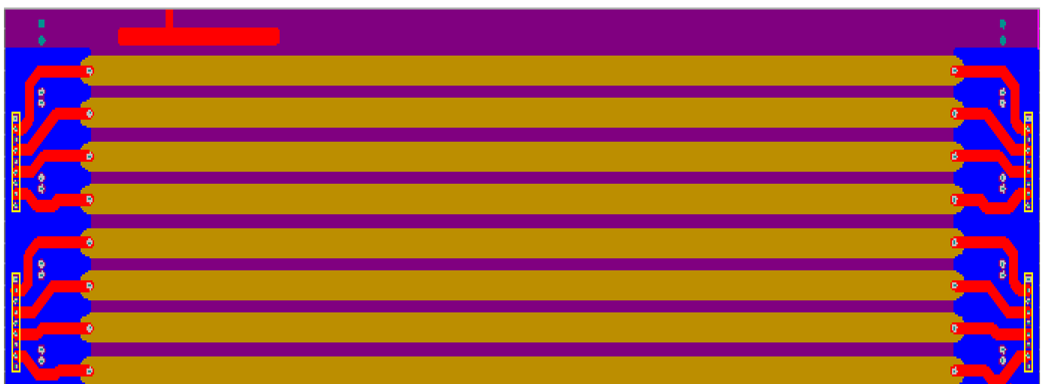
Glass: low resistive glass

0.7mm thick, 27cm x 25cm

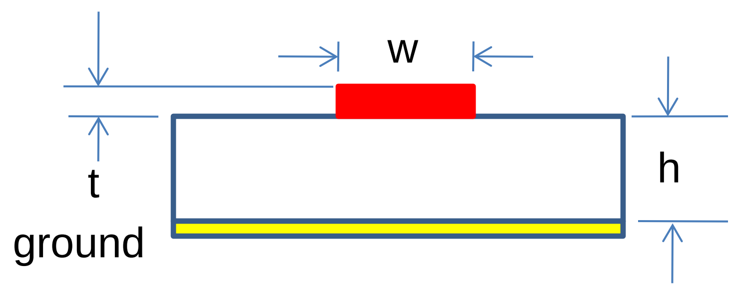
Strip: 27cm x 0.7cm, 0.3cm interval, 24 strips

Gas gap: 8 x 0.25mm, two stacks

Gas box: 600mm x 500mm x 72mm



Differential strip: 7mm wide+3mm interval

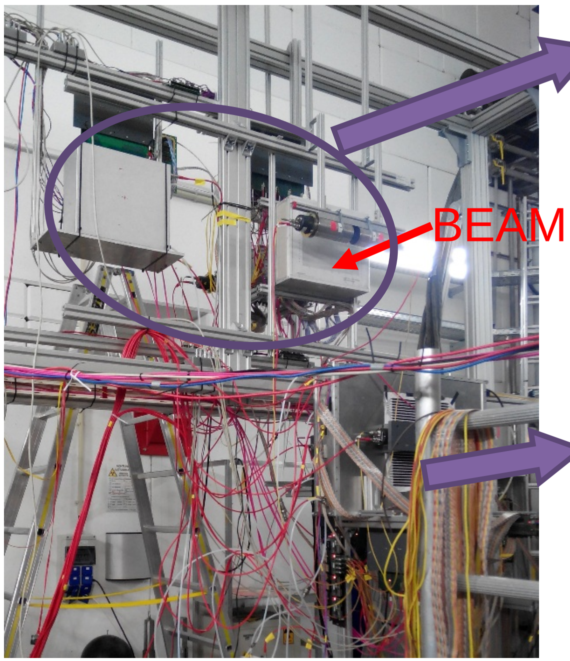


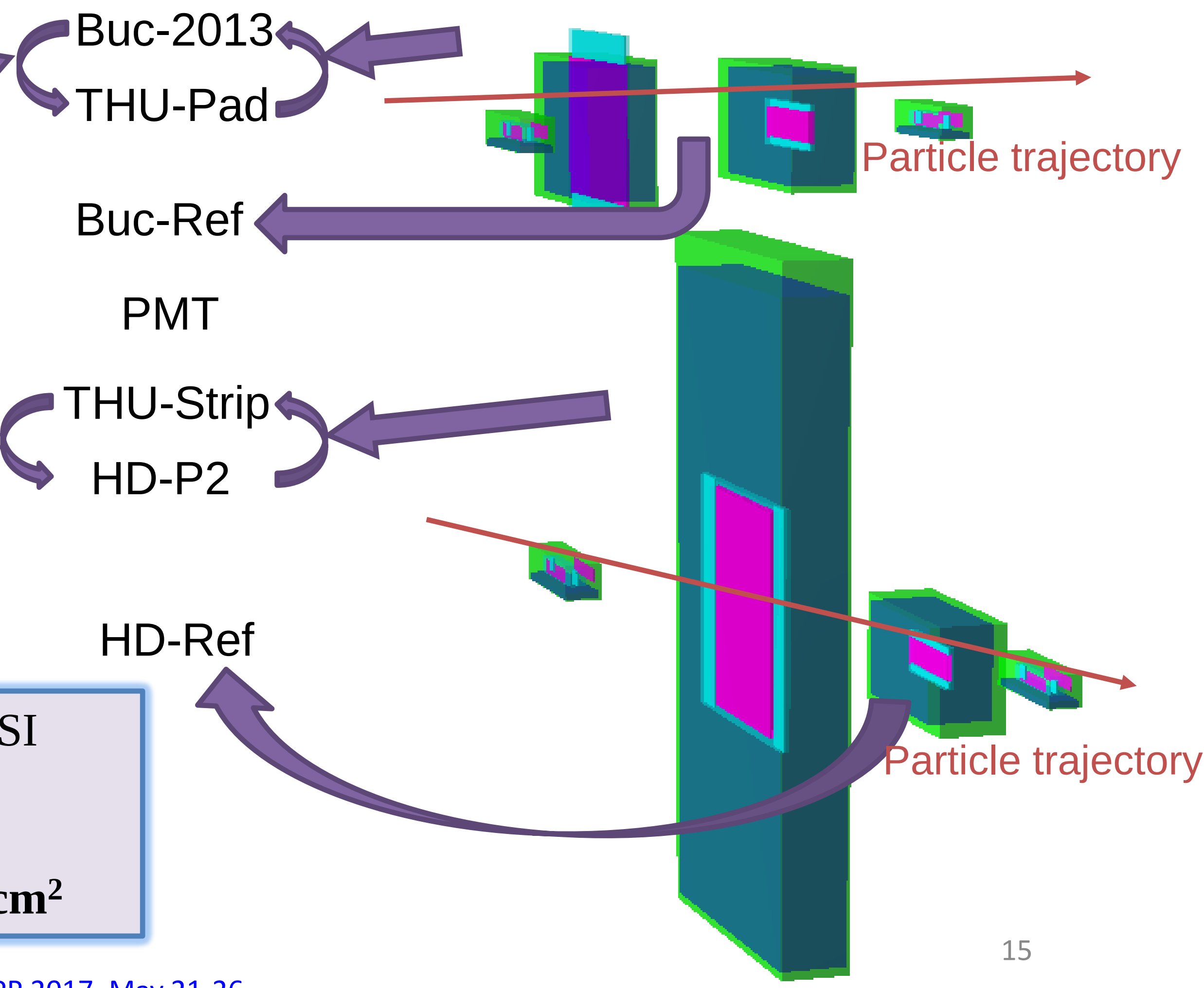
$$Z_0 = \frac{87}{\sqrt{\varepsilon_r + 1.41}} \ln\left(\frac{5.98h}{0.8w + t}\right)$$

Feed trough: Micro-strip, 50Ω

Beam test @GSI, Oct.2014

Experimental Setup:

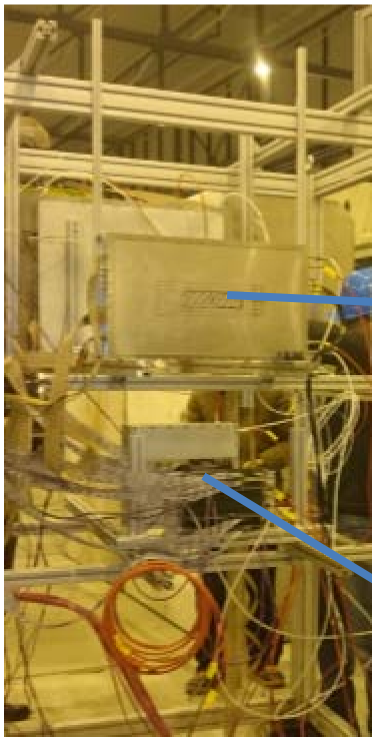




Beam time in October 2014 at GSI
1.1 GeV ^{152}Sm beam On
0.3mm/4mm/5mm Pb target
Flux rate **several hundreds Hz/cm^2**

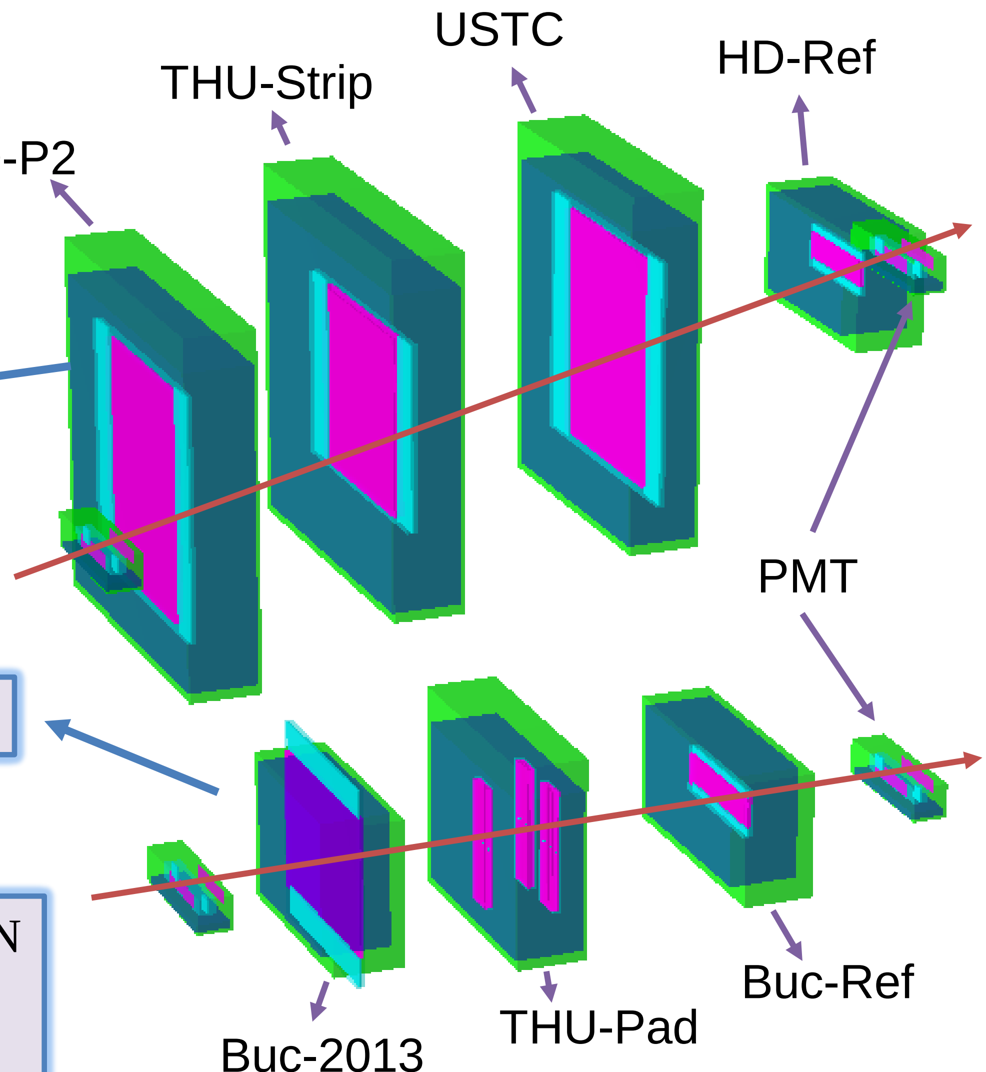
Beam test @ SPS Feb 2015

Experimental Setup:



Up setting

Down setting



High rate test in February 2015 at SPS CERN
13 GeV Ar beam
Flux rate **around 1kHz/cm²**

Data analysis method

The data analysis is based on CBM ROOT, macro developed by **TOF Group**.
Analysis Procedure: **3 Main Steps**.

1 — Unpacking

Converting LMD files into unpacked ROOT file, containing timing, TOT, super module type, super module, RPC, strip, side information of each hit.

2 — Cluster Building

- **Initial calibration**: Align center of each strip in Detector Under Test and Reference Detector.
- **Iterative calibration**: Calibrate data in time-walk, gain and velocity correction.

→ Build calibrated hits into clusters.

3 — Analysis

Calculating observables from fully calibrated hits include cluster size, time resolution and efficiency.

Calibration method

Time-walk correction

Large signals arrive at discriminator threshold faster, leading to a dependence of measured time and amplitude of the analogue signal.

Gain correction

Amplification gain of PADI varies between each channel, which should be corrected out to get initial amplitude for time-walk correction.

Strip alignment correction

Different cable length and electronic delay lead to the shifting of calculated center of different strip, influencing the position of hits.

Velocity correction

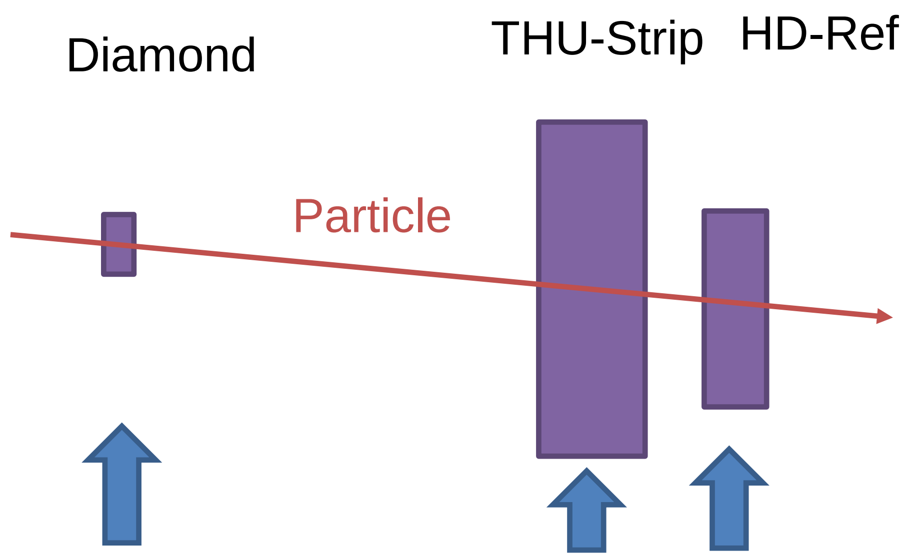
Slower particles need a longer time to cross the distance between Dut and Mref, widen the time difference distribution.

Analysis results: GSI Oct 2014

Analysis Setting:

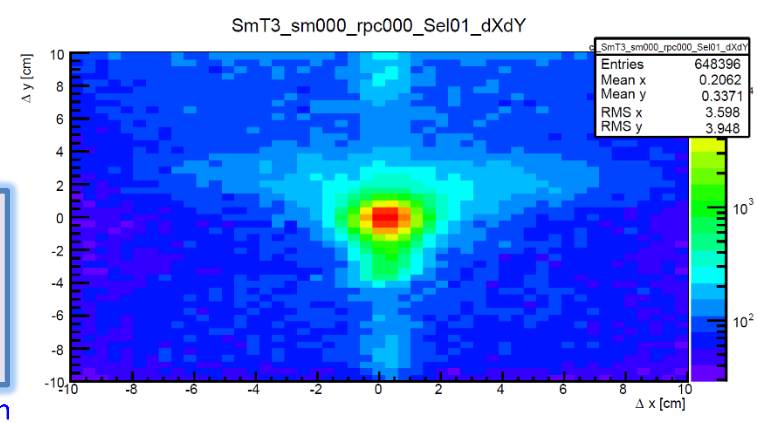
Lower part of setup:

Analysis Procedure:
- Init_calib.sh (Initial calibration)
- Iter_calib.sh (Iterative calibration)
  - iteration procedure: 1-6-8-2-10-2-10
- Iter_hits.sh (Analysis)
  - analysis correction procedure: 1-2-3-4-1



Cut Selection: **Cut 1**

```
tofAnaTestbeam->SetMul4Max(1.);
tofAnaTestbeam->SetCh4Sel(8.);
tofAnaTestbeam->SetDCh4Sel(7.);
tofAnaTestbeam->SetPosY4Sel(0.5);
tofAnaTestbeam->SetMulDMax(1.);
tofAnaTestbeam->SetDTDia(0.);
```



BRef: Starting counter for events.

Dut: Counter under test.

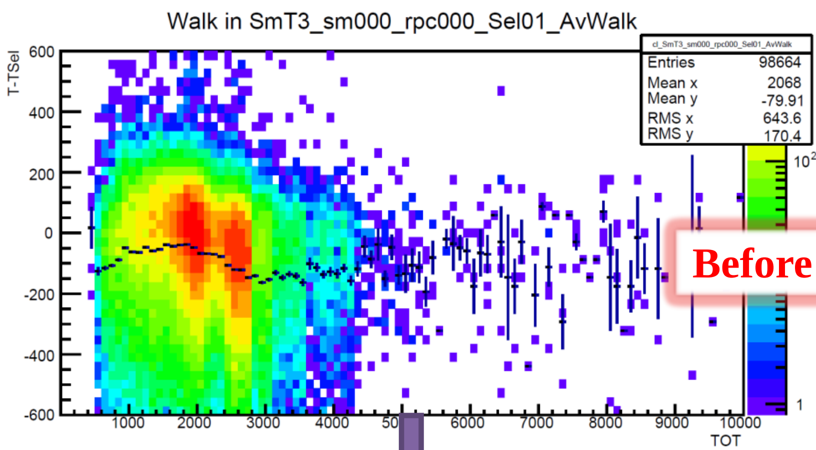
MRef: Reference measure for Dut.

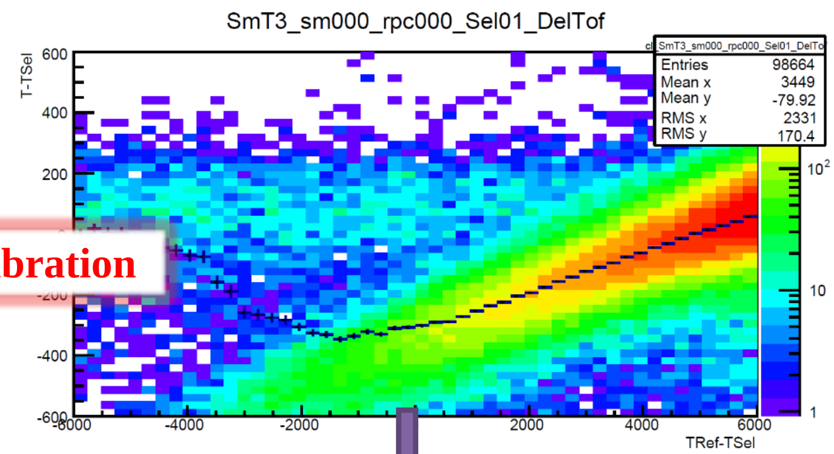
Run: Sun1205 – 5500V: Analysis Process

Time-walk correction

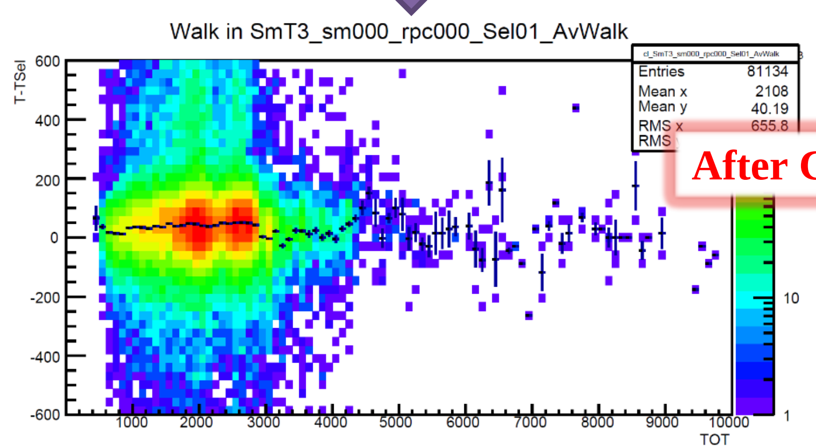
Velocity correction

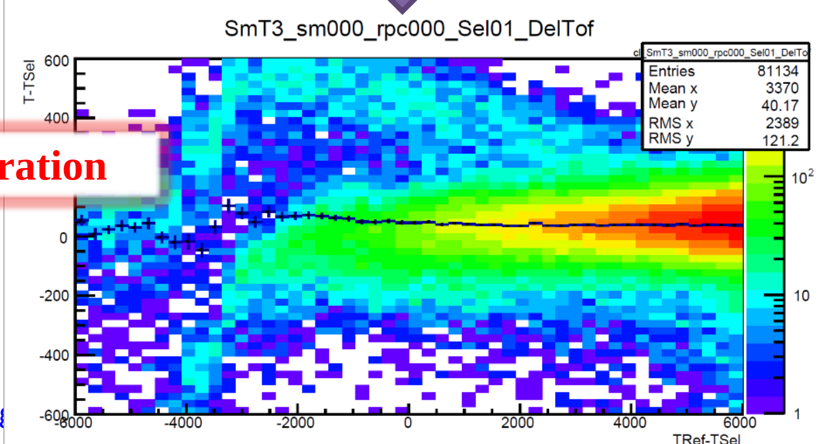
Before Calibration





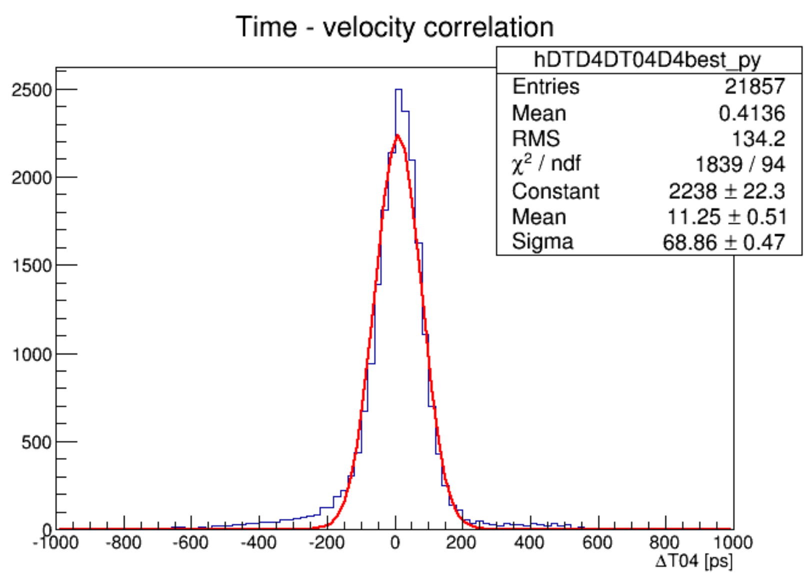
After Calibration





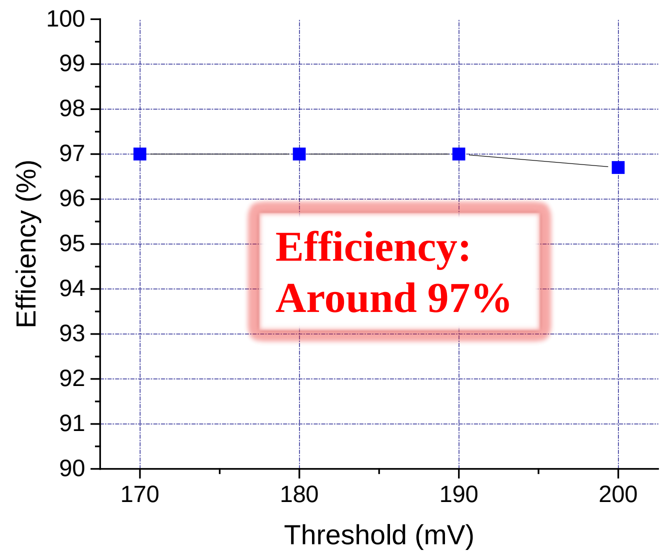
Results of strip-MRPC

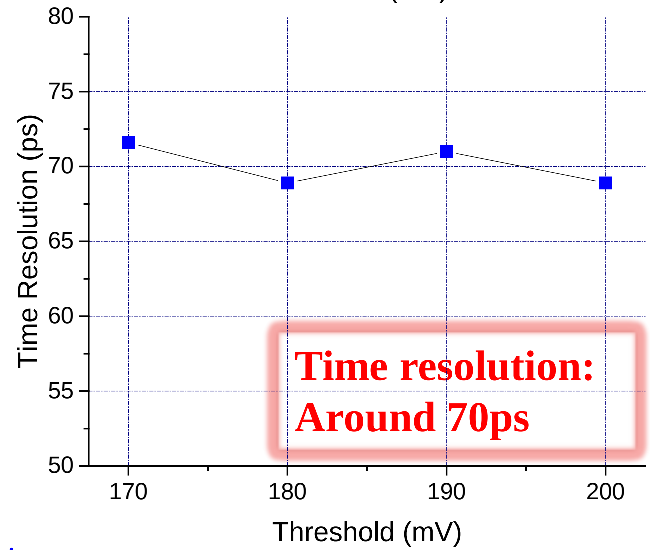
Run: Sun1205 – 5500V Time Resolution



Analysis Result under Different Threshold

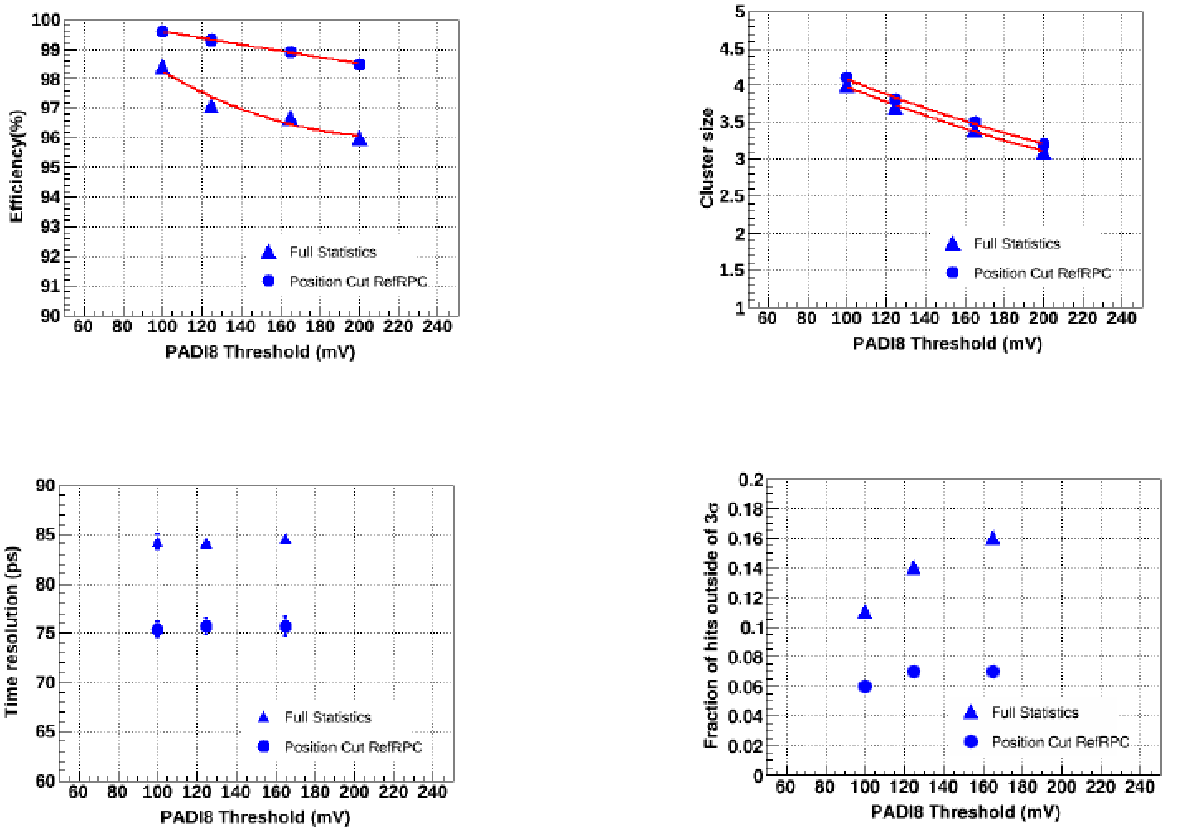
Threshold	Efficiency	Time Resolution	Cluster Size
170mV	97.0%	71.6ps	1.7
180mV	97.0%	68.9ps	1.7
190mV	97.0%	71.0ps	1.6
200mV	96.7%	68.9ps	1.6





Performance of Inner zone-MRPC

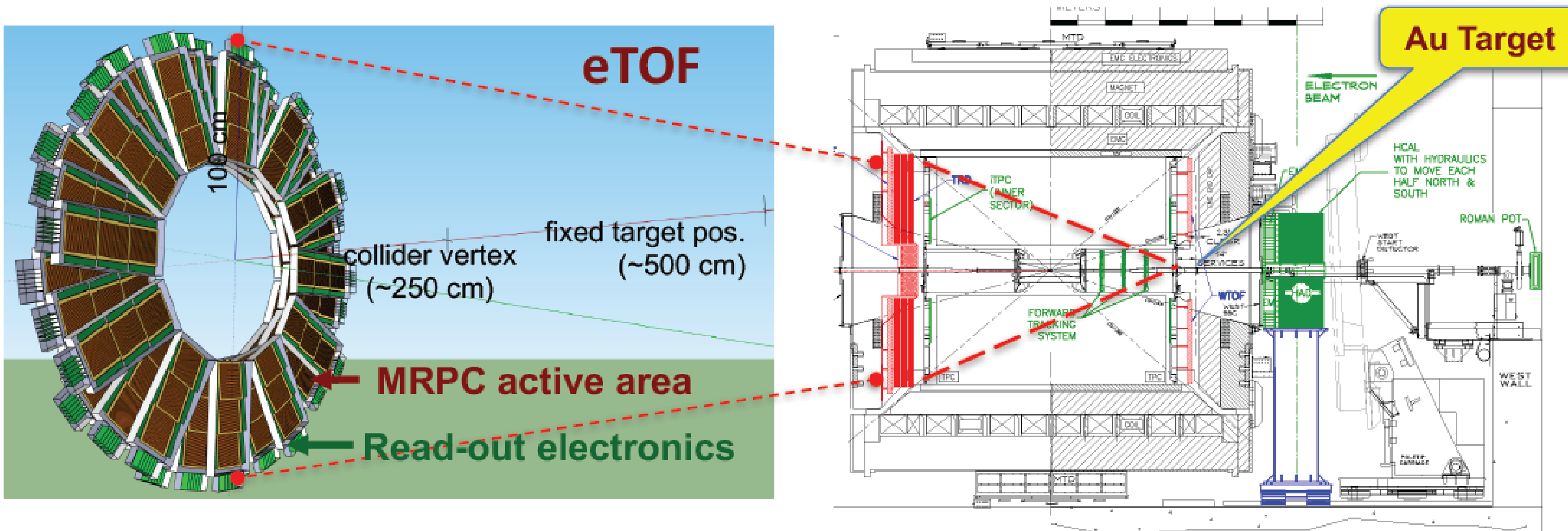
Efficiency, Cluster Size & System Time Resolution



CBM mile stones

CBM components	TDR approved	Start production	Ready for installation	Ready for beam
Micro Vertex Detector (MVD)	01.04.17	30.04.18	31.12.19	30.06.20
Silicon Tracking System (STS)	05.07.13	31.03.17	31.03.20	31.12.20
Ring Imaging Cherenkov Detector (RICH)	07.01.14	31.12.16	31.12.19	31.12.20
Muon Detector (MUCH)	28.02.15	31.12.16	31.12.19	31.12.20
Transition Radiation Detector (TRD)	01.04.17	31.12.17	31.12.20	31.12.21
Time of Flight System (TOF)	30.04.15	01.01.17	31.12.19	31.12.20
Electromagnetic Calorimeter (ECAL)	31.12.16	30.06.18	31.12.19	31.12.20
Projectile Spectator Detector (PSD)	28.02.15	31.12.15	31.12.18	31.12.19
Dipol Magnet	01.10.13	30.06.17	31.12.19	30.06.20
Online Systems (DAQ and FLES)	31.12.17	30.06.18	30.06.19	31.12.19

CBM Phase-0 Exp: eTOF at STAR



Install, commission and use 10% of the CBM TOF modules, including the read-out chains at STAR, starting in 2019

CBM participating in RHIC Beam Energy BES-II in 2019-2020:

- Complementary to part of CBM's physics program:
  $\sqrt{s_{NN}}$ = **3**, **3.6**, **3.9**, **4,5**, 7.7 GeV ($750 \leq \mu_B \leq 420$ MeV)
  especially for ***B-*** & ***s-hadrons*** production and fluctuations

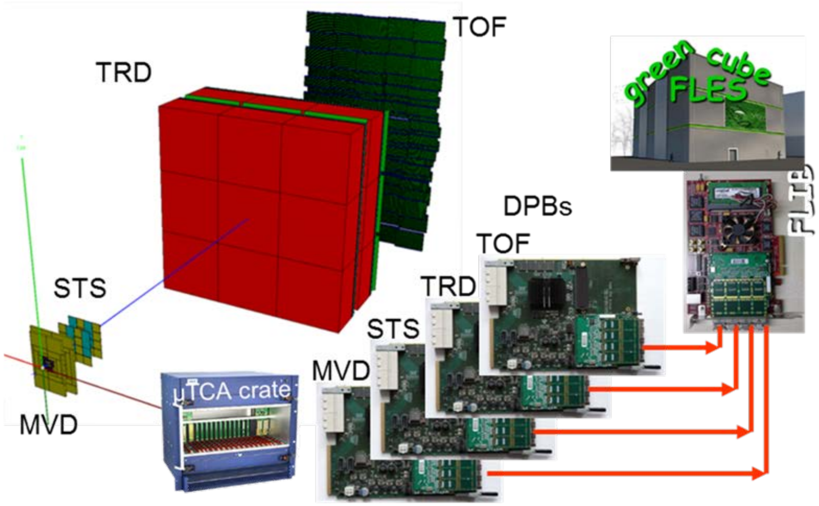
Summary

- The rate of CBM-TOF reach 25kHz/cm2

  Time resolution ~60ps

  Free running mode

  120 square meters
- It will first used in STAR-eTOF
- Mini CBM will be set up soon!
- Participate FAIR Phase 0 experiments…



Structure of Mini CBM

Thanks for your attention !