# The CBM Time-of-Flight wall

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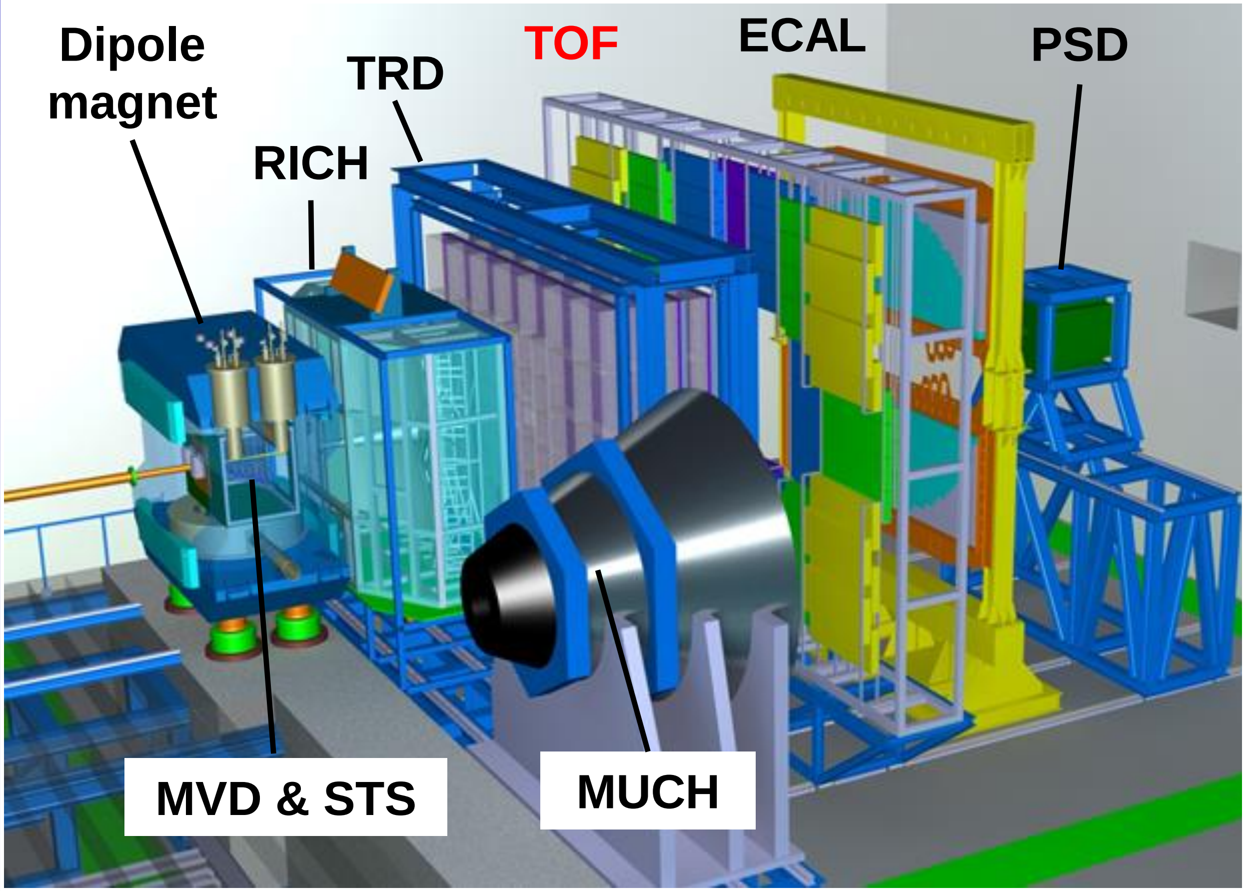
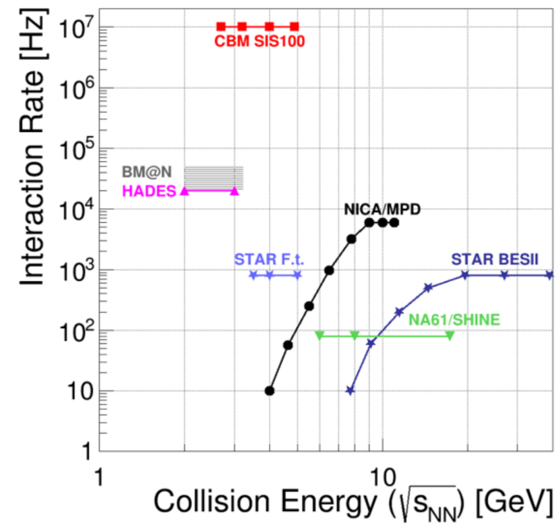
**Outline:**

- Introduction
- CBM-ToF requirements
- TDR ToF wall design
- Low resistive material and the BFTC
- Test beam time at CERN and the MRPC1/2 prototype
- Pre-mass production for MRPC3a/b counter
- FAIR Phase 0 program
- Summary

## The Compressed Baryonic Matter Experiment

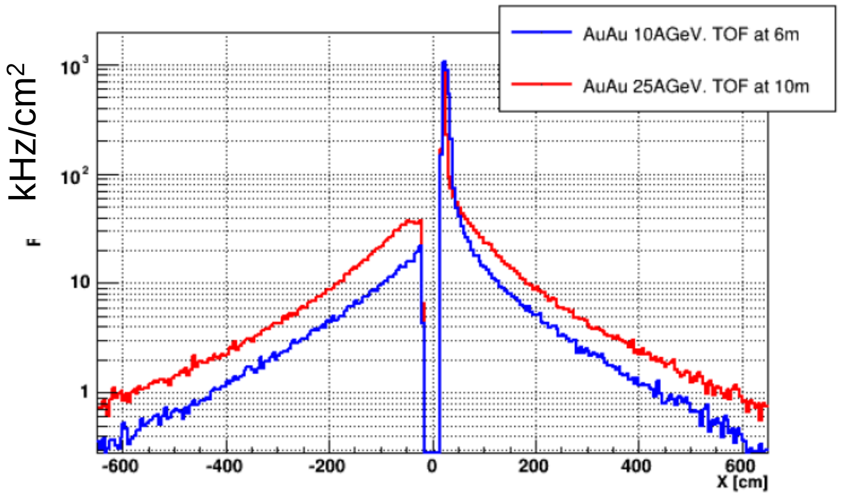


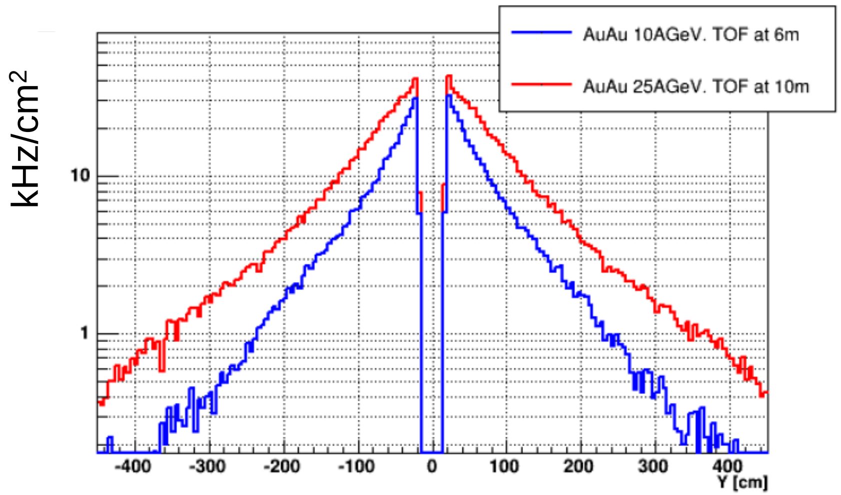

- Tracking acceptance: 2° < $\theta_{Lab}$ < 25°
- Free streaming DAQ
- Software based event selection
- $R_{int}$ = 10 MHz (Au + Au)




**CBM overview talk: HK46.1**
**Group reports: 5**
**Short reports: 23**
**Poster: 5**

# Incident particle flux



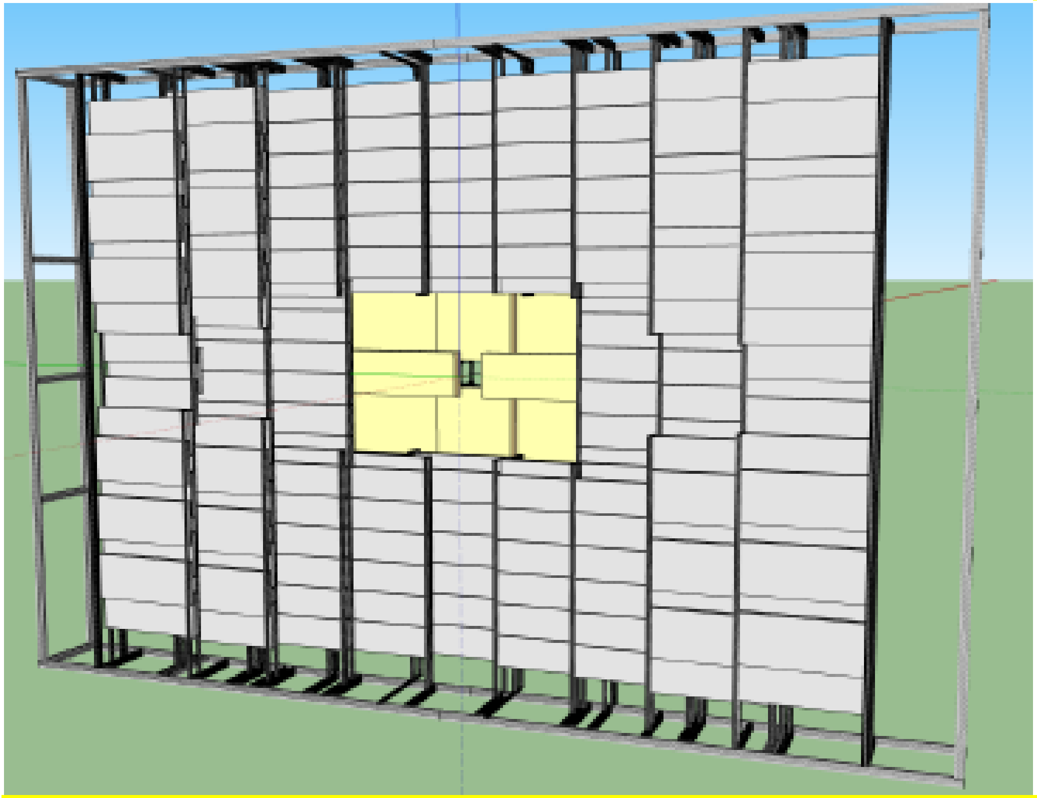




**URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz**

- Flux ranging from 0.1 to 100 kHz/cm$^2$
- At different regions Time-of-Flight detectors with different rate capabilities are needed

# Requirements

**Charged hadron identification is provided by Time-of-Flight (ToF) measurement**

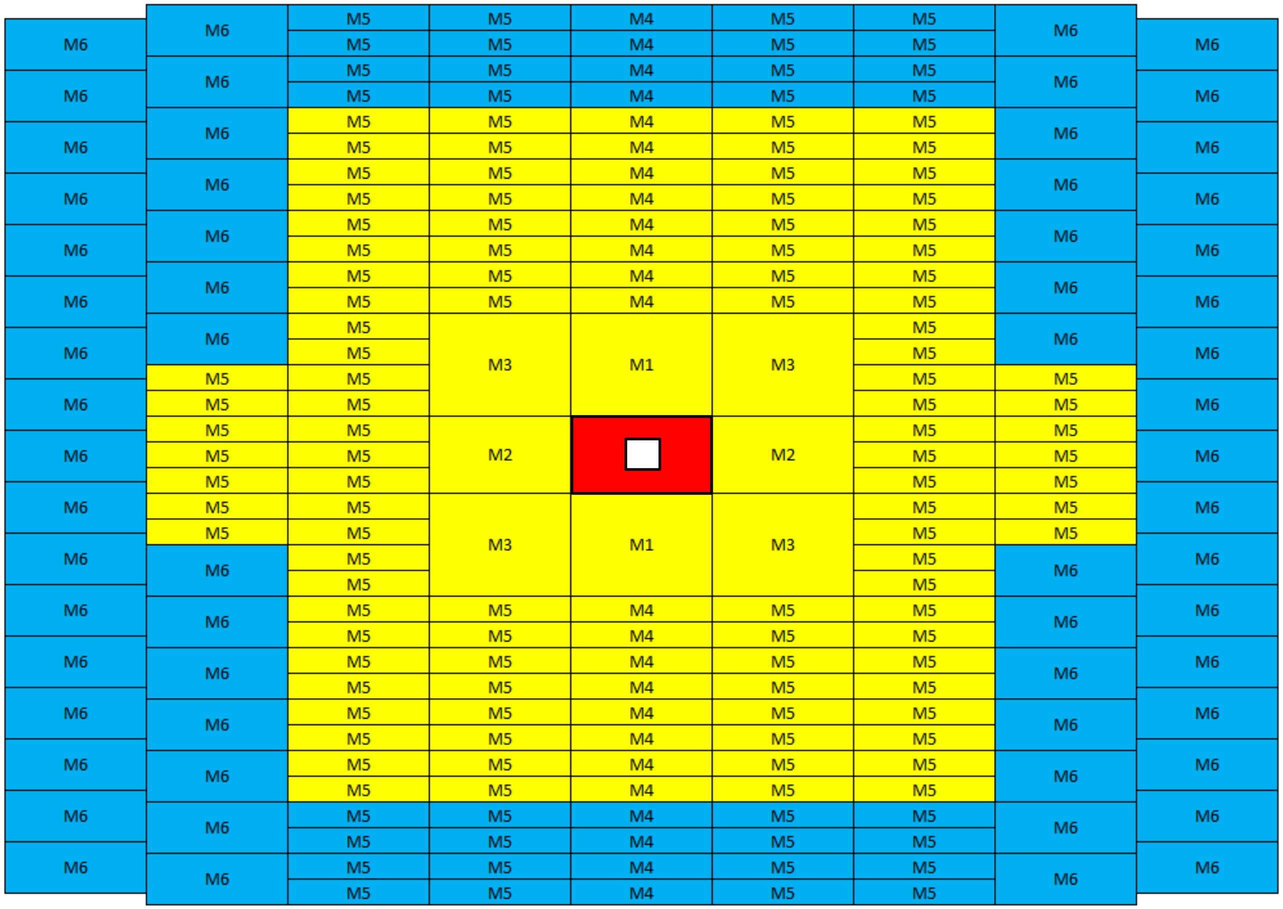


## CBM-ToF Requirements

- Full system time resolution $\sigma_T$ ~ 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

**Multi-gap Resistive Plate Chambers (MRPC) are the most suitable ToF detectors fulfilling our requirements**

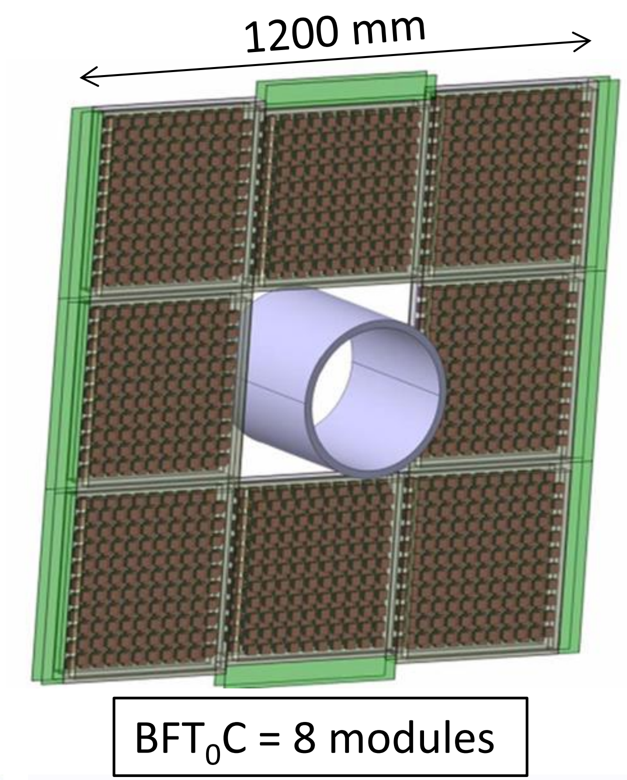
# TDR ToF wall layout

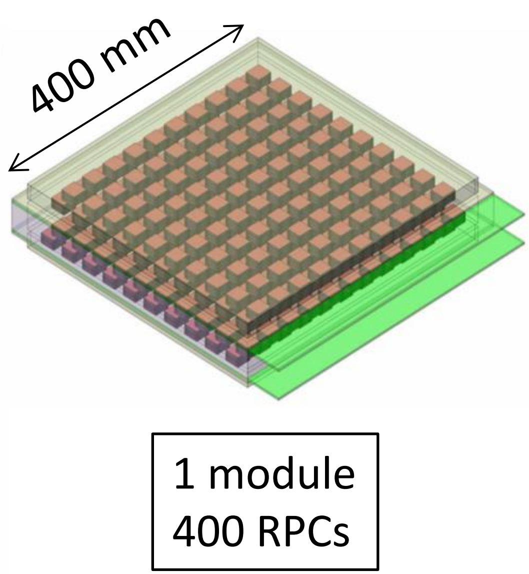


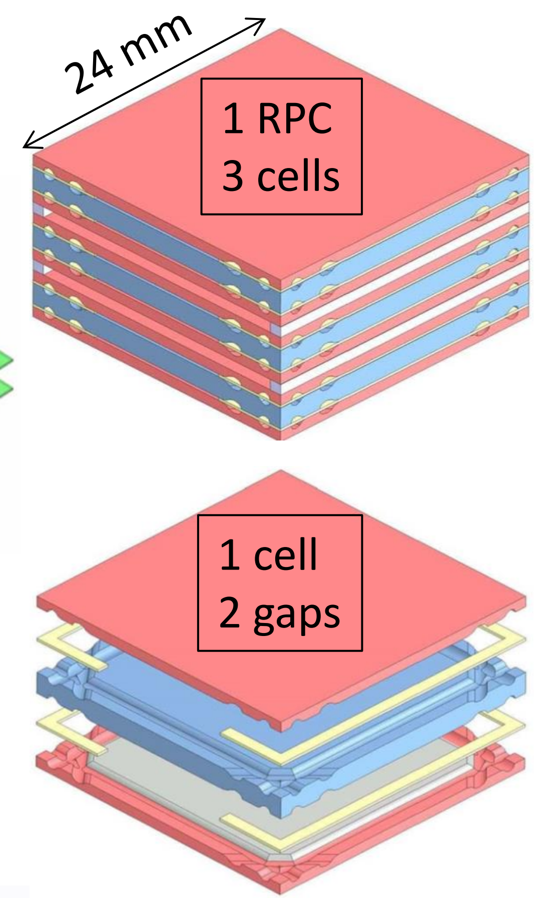

- 6 types of modules (M1 – M6) only
- A module contains several MRPC counters
- Region containing counters equipped with float glass
- Region containing counters equipped with low resistive glass
- Region containing counters equipped with ceramic material

# Ceramic RPCs for BFTC

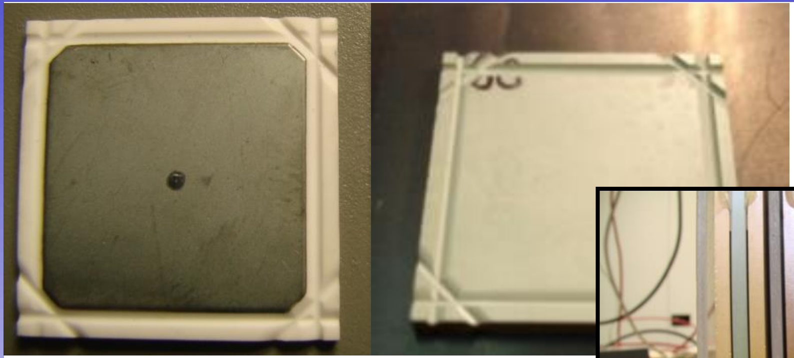
- start-time and the reaction-plane determination.
- For CBM the use of RPC for the Beam Fragmentation $T_0$ Counter ($BFT_0C$) with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration.



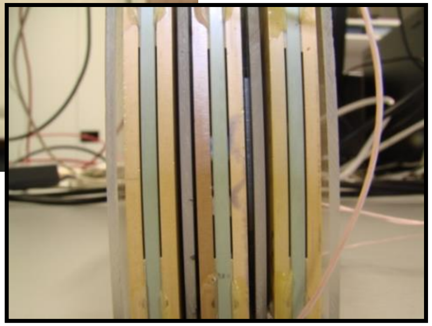



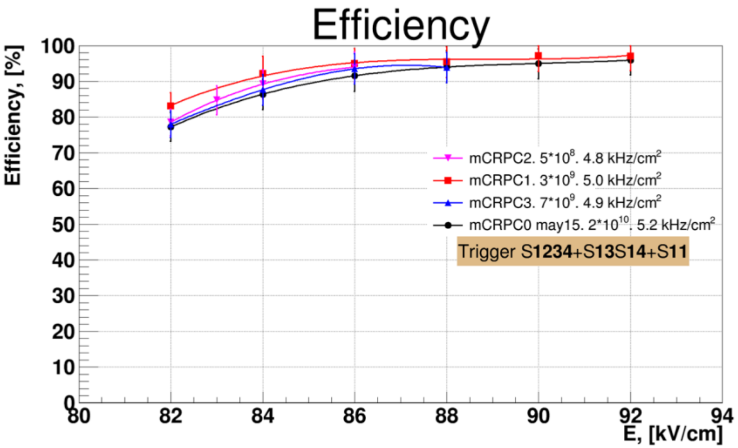
# Ceramic RPCs for BFTC

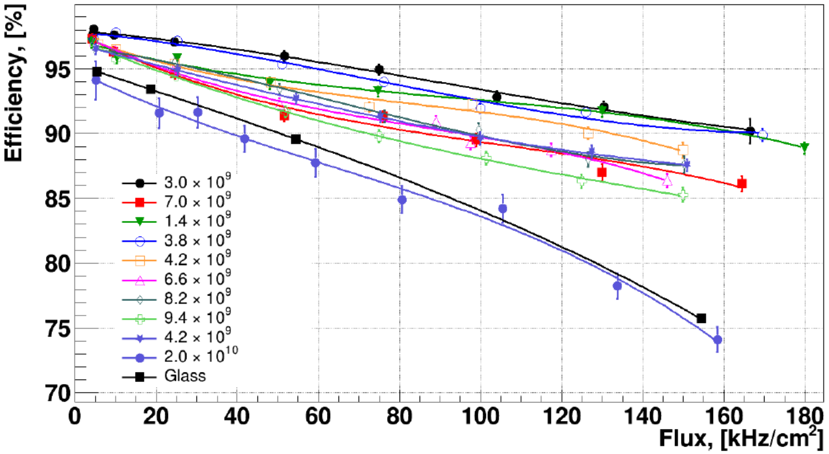


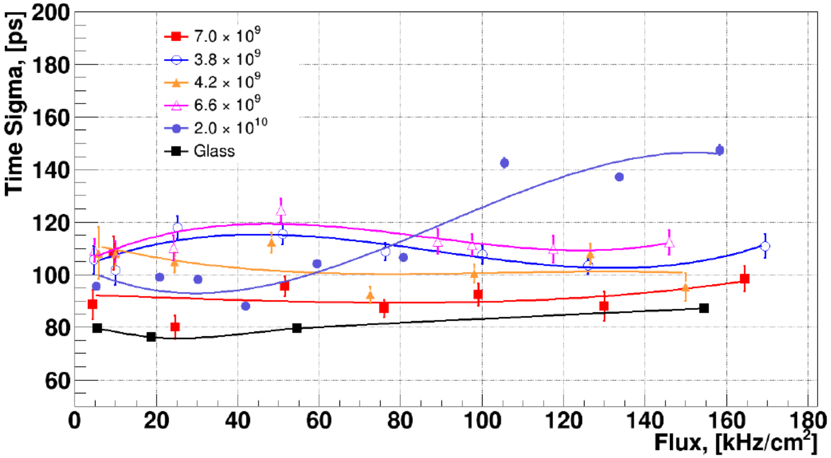
electrodes

RPC





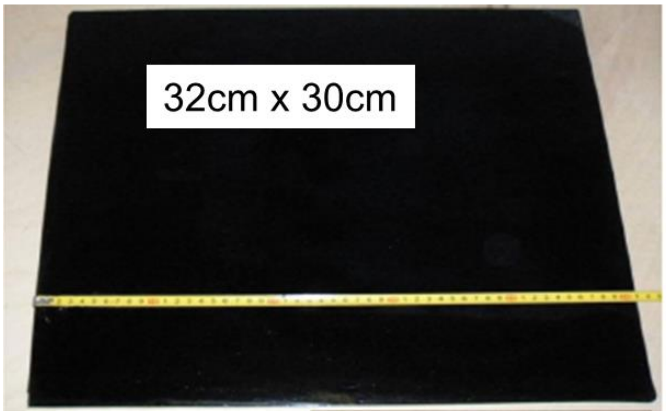

$4 \times 10^9\ \Omega$cm: most suitable resistivity order for application in CBM

# Resistive Glass Development

CBM ToF

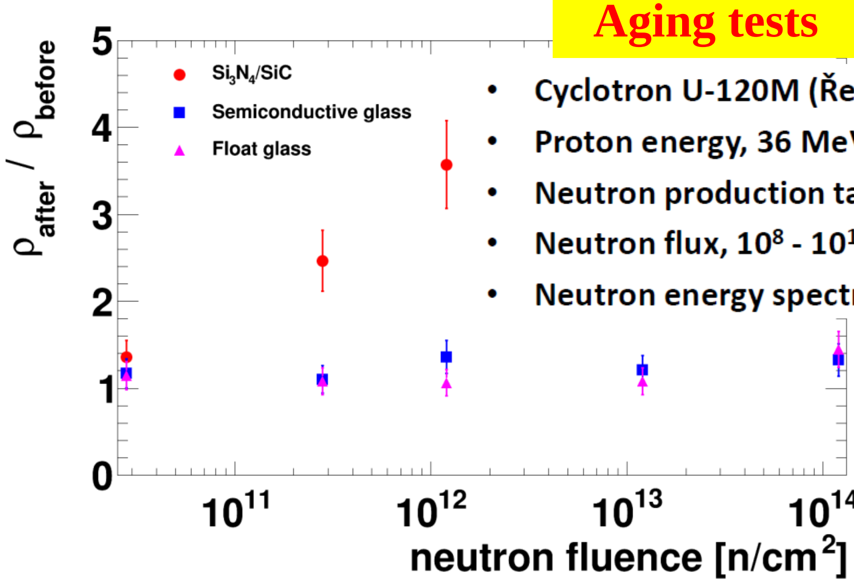
**Resistive glass for high-rate MRPCs is developed in Beijing, China**

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



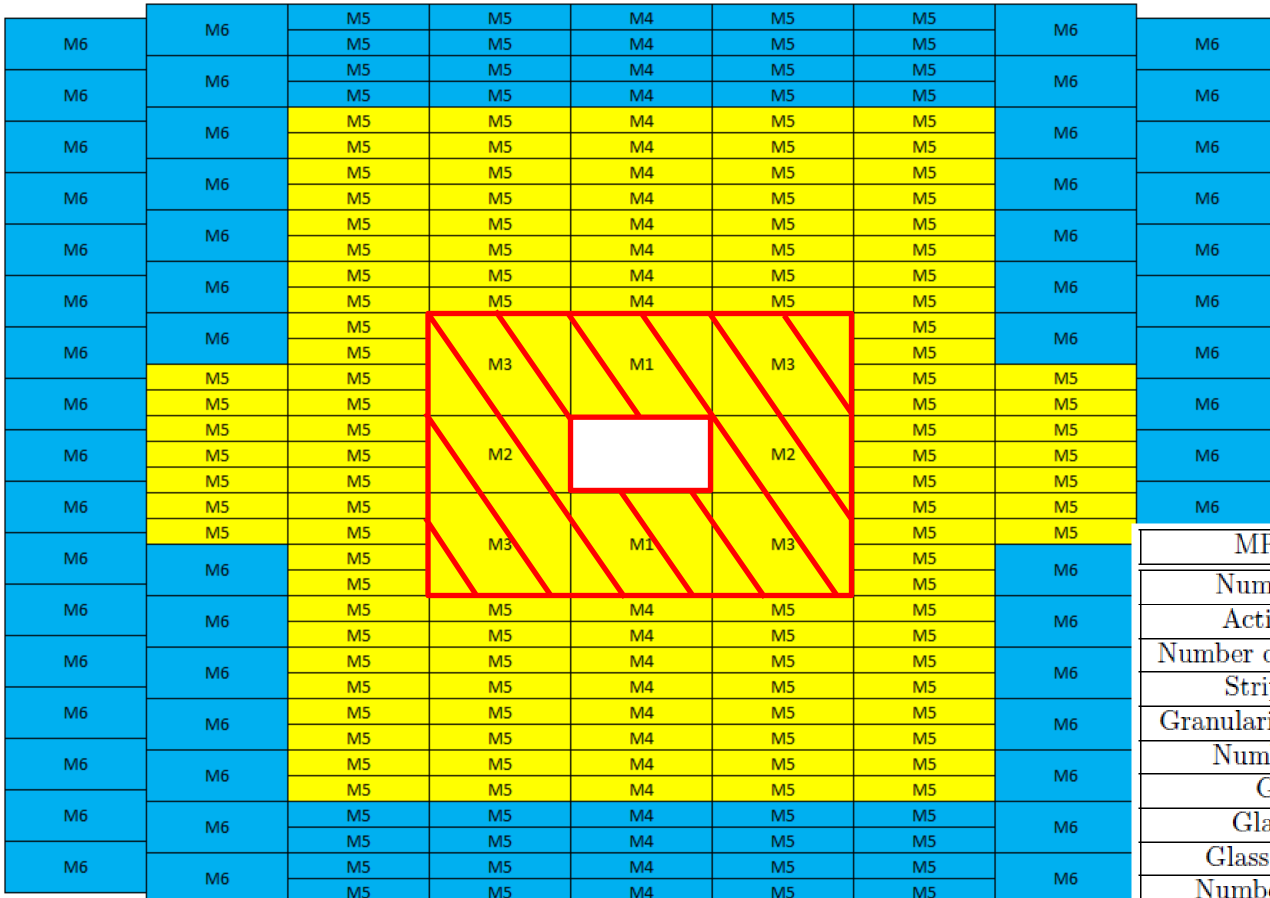

**Raw resistive glass material for 400 m$^2$**

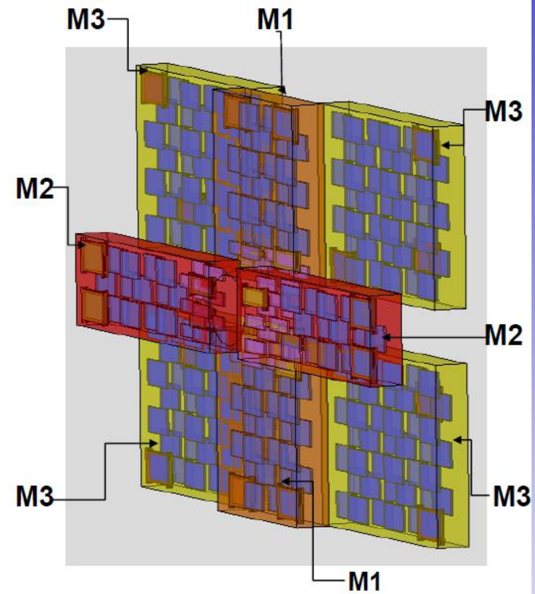
**Aging tests**




- Cyclotron U-120M (Řež)
- Proton energy, 36 MeV
- Neutron production target, Be
- Neutron flux, $10^8$ - $10^{10}$ n/cm$^2$/s
- Neutron energy spectra, 1 – 36 MeV

# TDR ToF wall layout high rate region



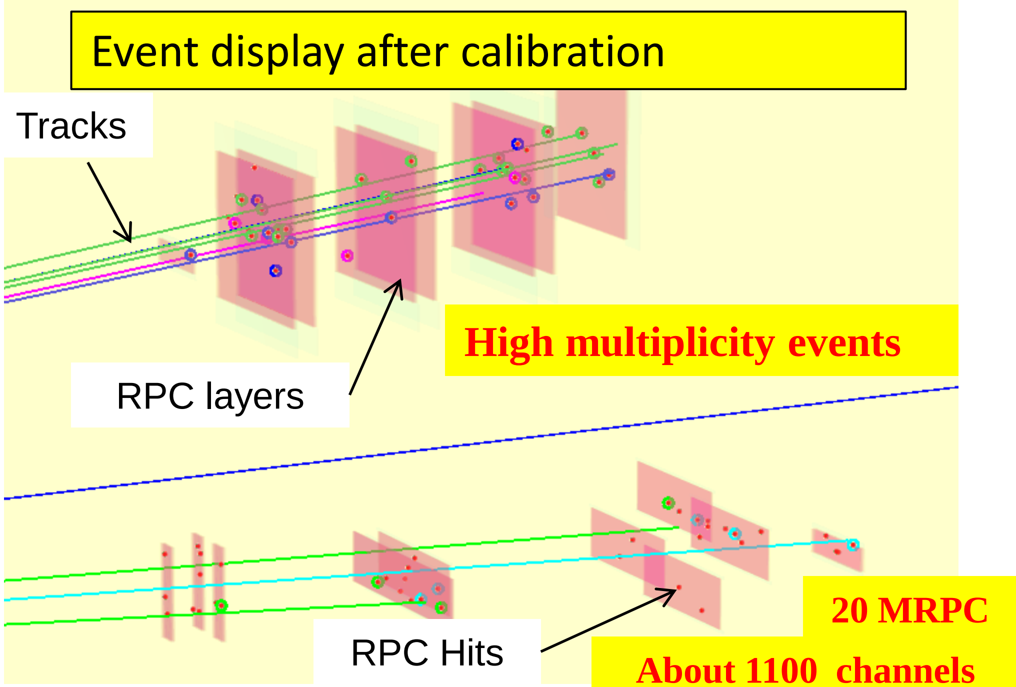




| MRPC notation | MRPC1 | MRPC2 |
|---|---|---|
| Number of MRPCs | 40 | 246 |
| Active area [mm$^2$] | 300 × 100 | 300 × 200 |
| Number of Strips per MRPC | 64 | 64 |
| Strip length [mm] | 100 | 200 |
| Granularity (cell size) [mm$^2$] | 472.4 | 944.8 |
| Number of gas gaps | 10 | 10 |
| Gap size $\mu m$ | 140 | 140 |
| Glass size [mm$^2$] | 320 × 100 | 320 × 200 |
| Glass thickness [mm] | 0.7 | 0.7 |
| Number of glass plates | 12 | 12 |
| Glass type | low res. | low res. |
| Total glass surface [m$^2$] | 15.36 | 188.93 |

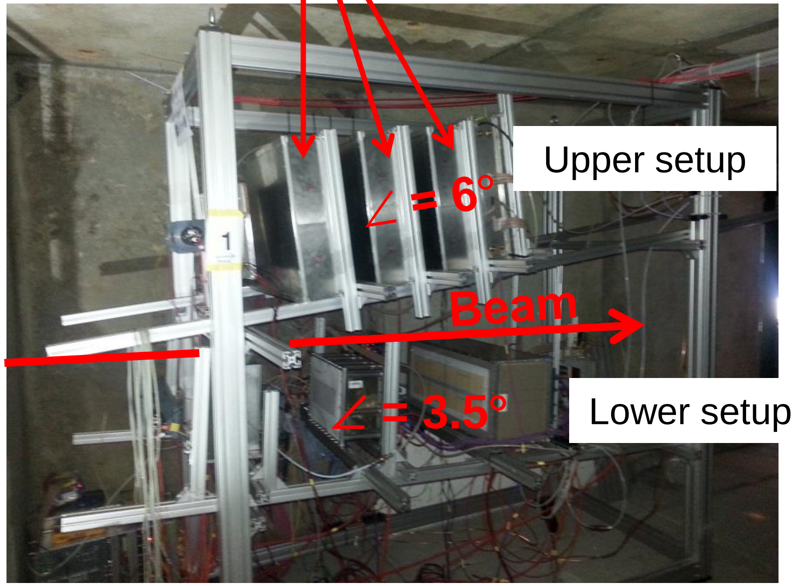
Alternative solution with Pad-MRPCs is available

# Beam-time @ SPS in Nov. 2015

Beam-time @ SPS North Area in Nov. 2015
Beam: Lead @ 30A GeV
Target: Lead 1 mm
Intensity: $10^7$ / spill
Spill length: 8 s
Rates: few 100 Hz/cm$^2$ - 1 kHz/cm$^2$
Energy close to SIS300 conditions

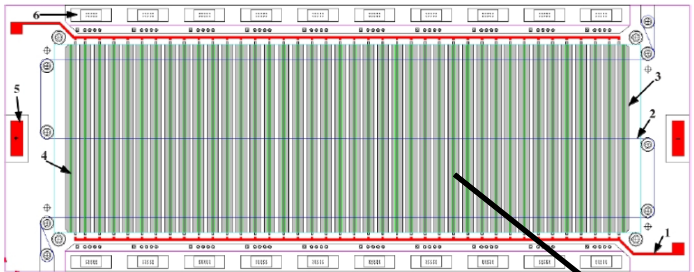






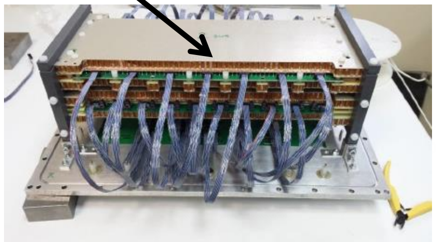
# Beam-time @ SPS in Nov. 2015

MRPC1/2 prototype developed at Bucharest

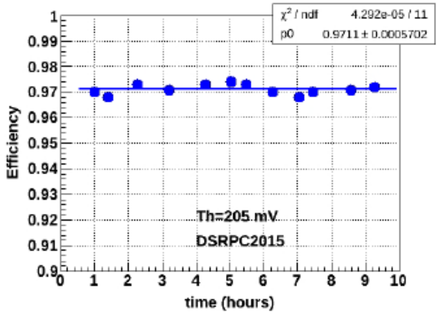


1 – HV strip; 2 – spacer (fising line); 3 – HV strips, 4 – signal strips; 5 – HV pad connection; 6 – signal connector

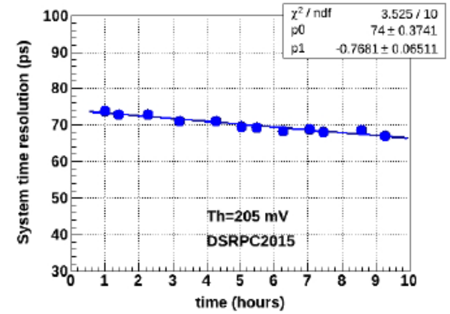
- Metal HV strip electrodes
- Innovative method of impedance matching
- Impedance independent of the granularity adjustable
- Impedance tuned to 100 Ω
- arXiv:1708.02707

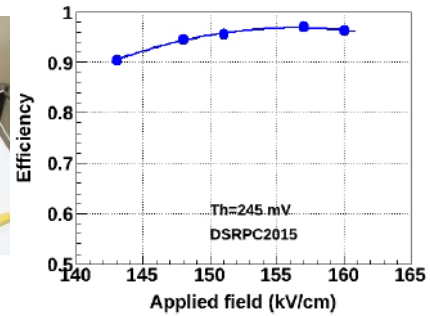


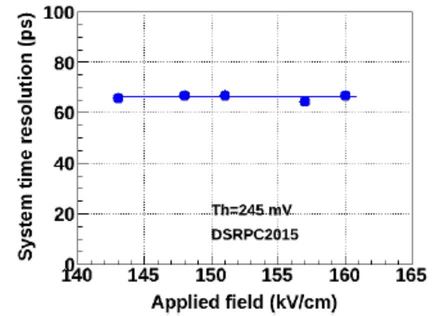
Efficiency



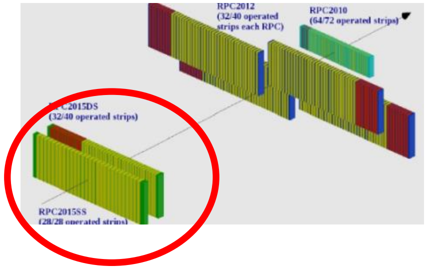

System time resolution

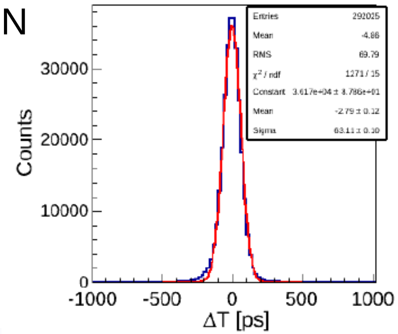


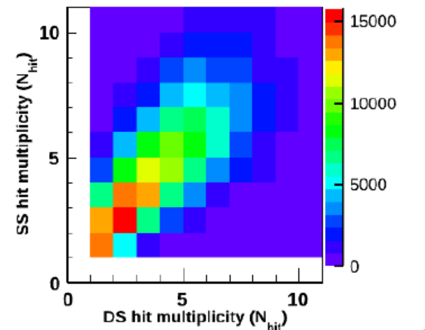



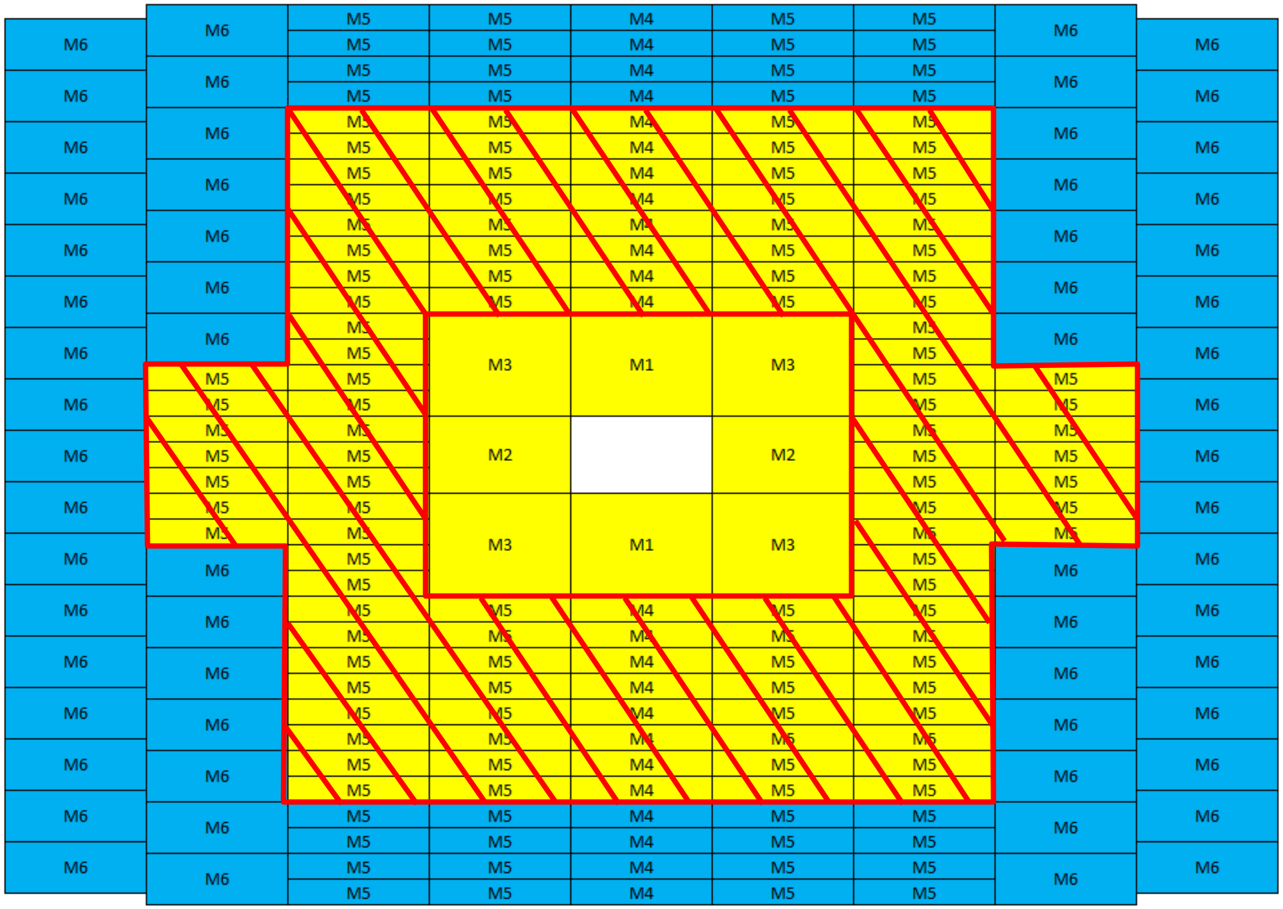

Beam time setup at CERN



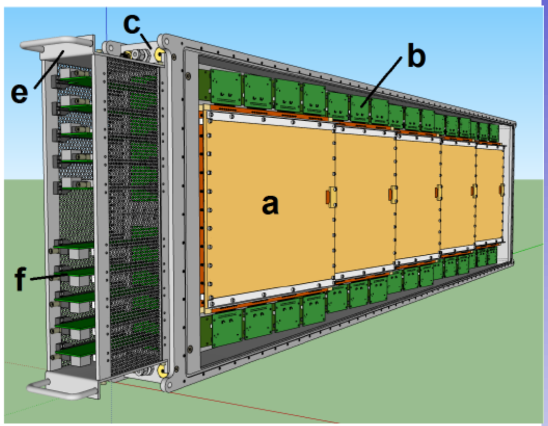



# TDR ToF wall layout intermediate rate region

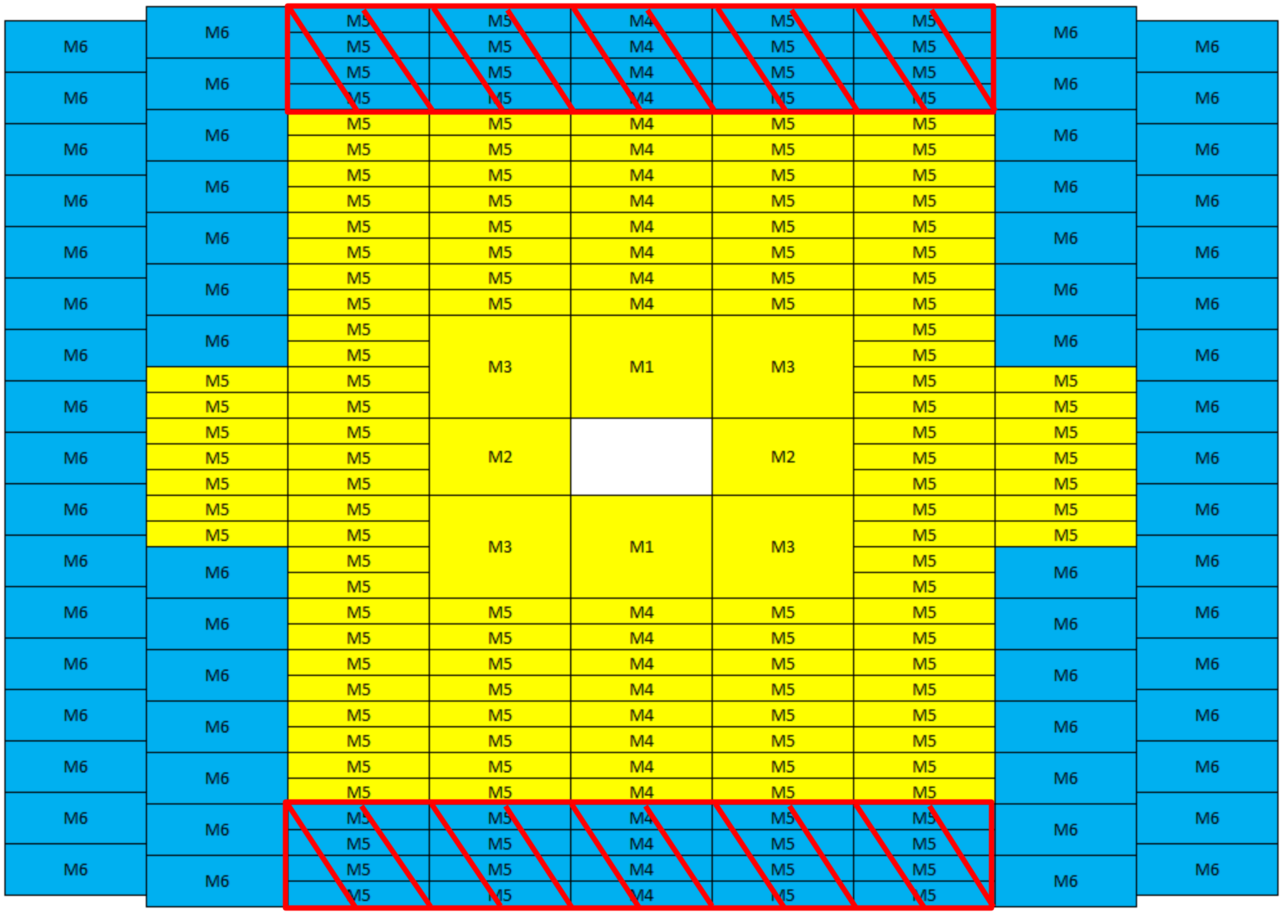



Module M5

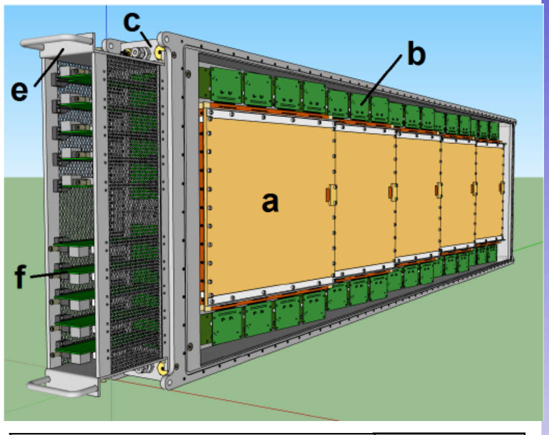



| MRPC notation | MRPC3a |
|---|---|
| Number of MRPCs | 580 |
| Active area [mm$^2$] | $320 \times 270$ |
| Number of Strips per MRPC | 32 |
| Strip length [mm] | 270 |
| Granularity (cell size) [mm$^2$] | 2700 |
| Number of gas gaps | 8 |
| Gap size $\mu$m | 250 |
| Glass size [mm$^2$] | $330 \times 280$ |
| Glass thickness [mm] | 0.7 |
| Number of glass plates | 10 |
| Glass type | low res. |
| Total glass surface [m$^2$] | 482.33 |

# TDR ToF wall layout low rate region



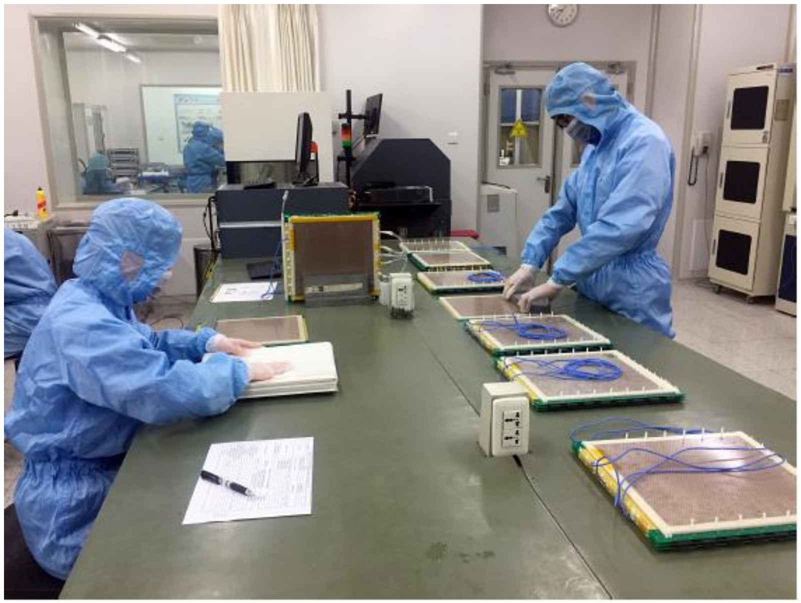

Module M5

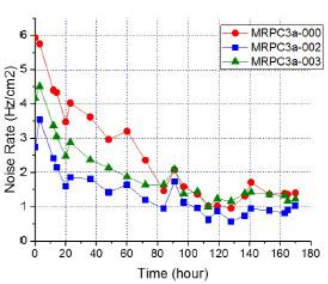


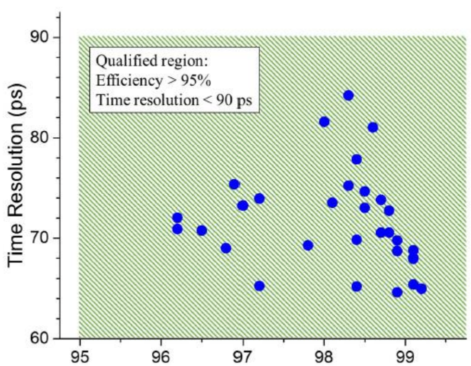

| MRPC notation | MRPC3b |
|---|---|
| Number of MRPCs | 200 |
| Active area [mm$^2$] | $320 \times 270$ |
| Number of Strips per MRPC | 32 |
| Strip length [mm] | 270 |
| Granularity (cell size) [mm$^2$] | 2700 |
| Number of gas gaps | 10 |
| Gap size $\mu$m | 230 |
| Glass size [mm$^2$] | $330 \times 280$ |
| Glass thickness [mm] | 0.28 |
| Number of glass plates | 12 |
| Glass type | float |
| Total glass surface [m$^2$] | 166.32 |

# MRPC3a and MRPC3b mass production for eTOF

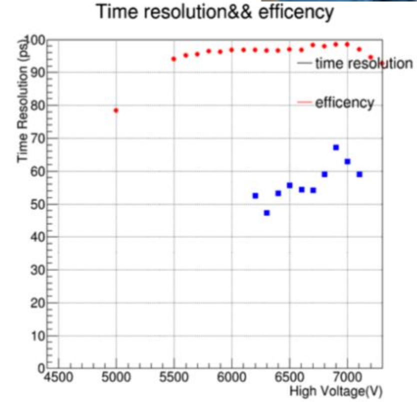
## MRPC3a mass prod at Nuctech, Beijing

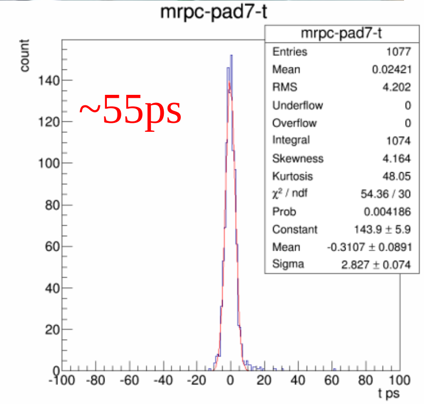




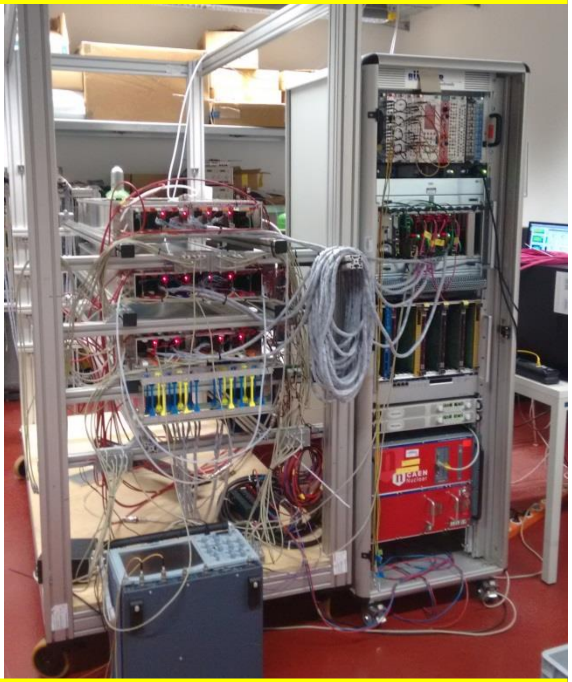

## MRPC3b mass production at USTC/China



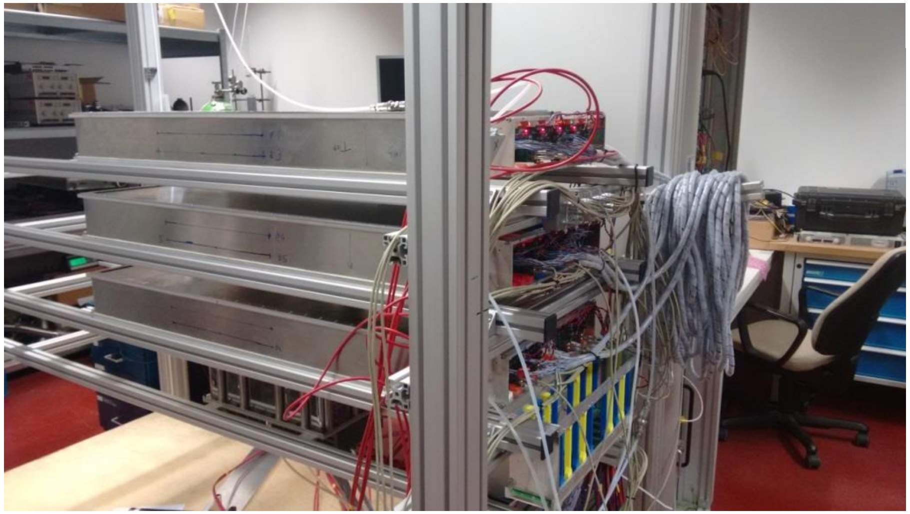



# Module integration and cosmic test stand in HD

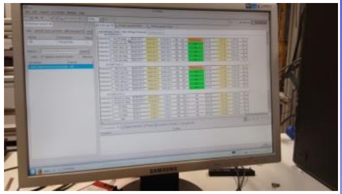
**Multi differential analysis of counter properties with cosmic tracks**



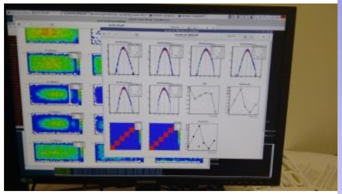
**About 100000 good tracks per day**

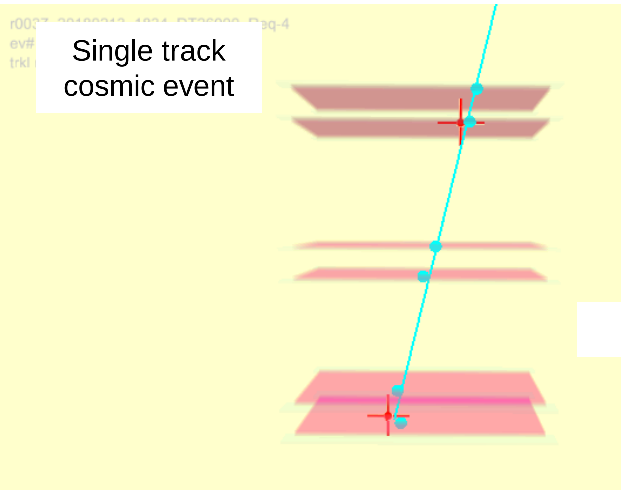


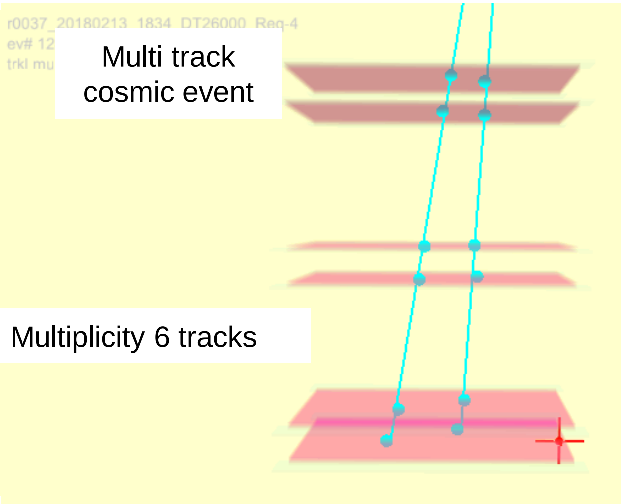
DCS system (EPICS)



Online Monitor

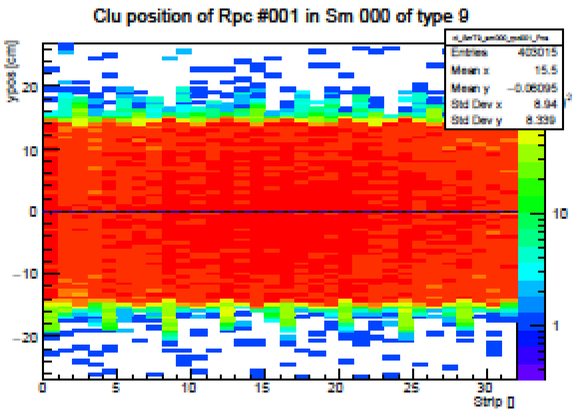


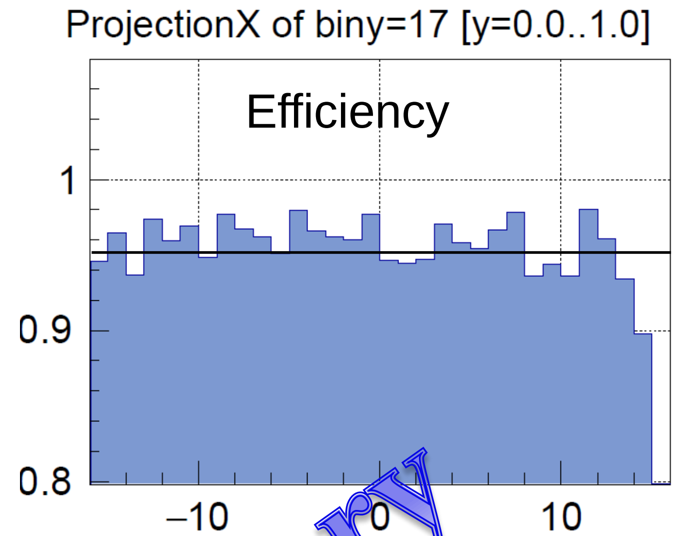


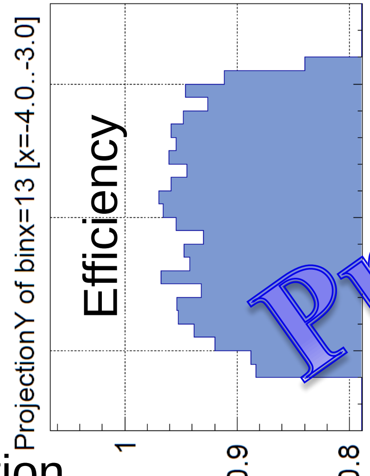



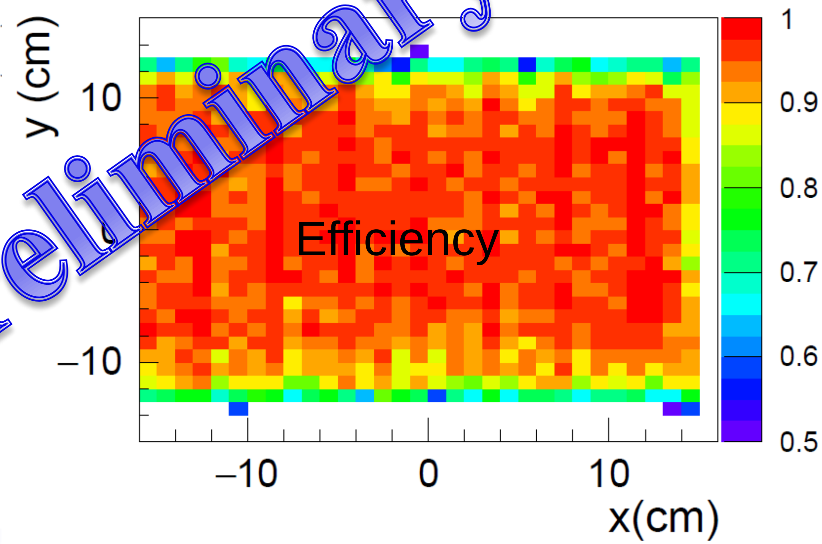
# Cosmic results

Hit distribution after calibration
on the MRPC active area



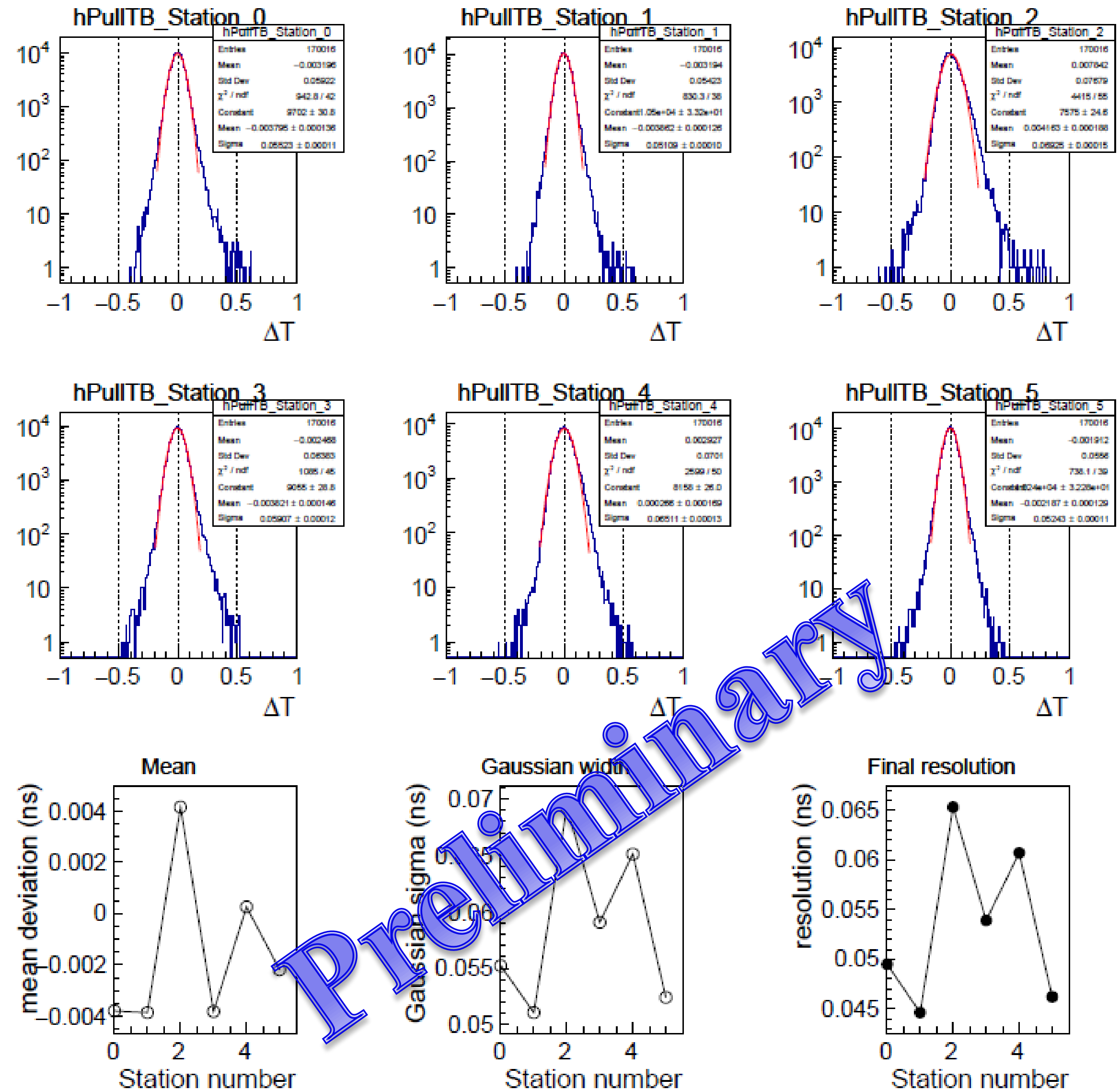




Bulk efficiency > 95%
Edge effects under investigation.

# Cosmic results

## Time resolution




Time resolution about 55 ps

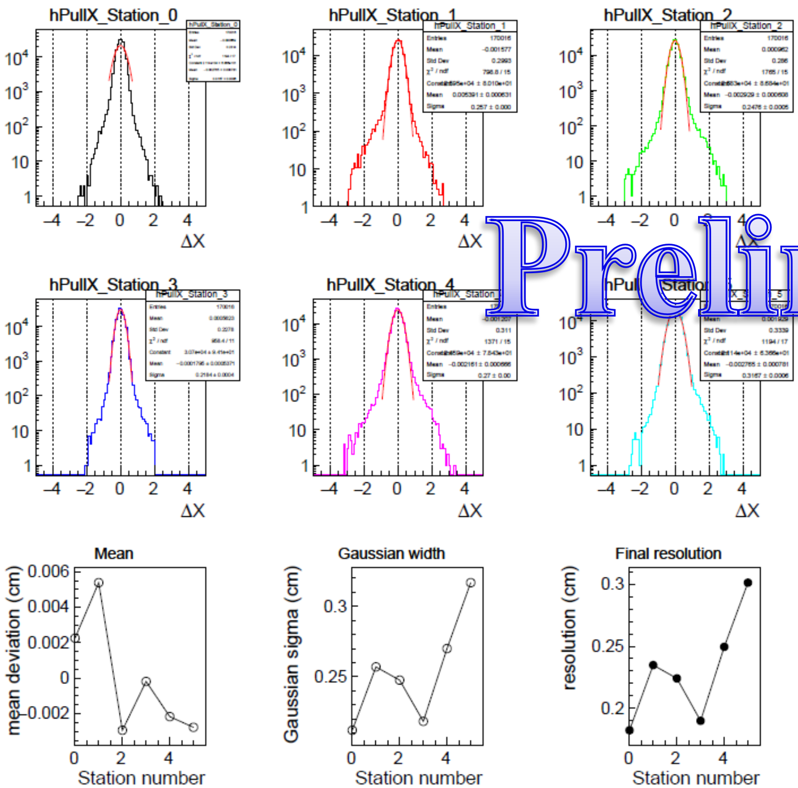
Systematic errors under investigation

See next talk by Phillip Weidenkaff

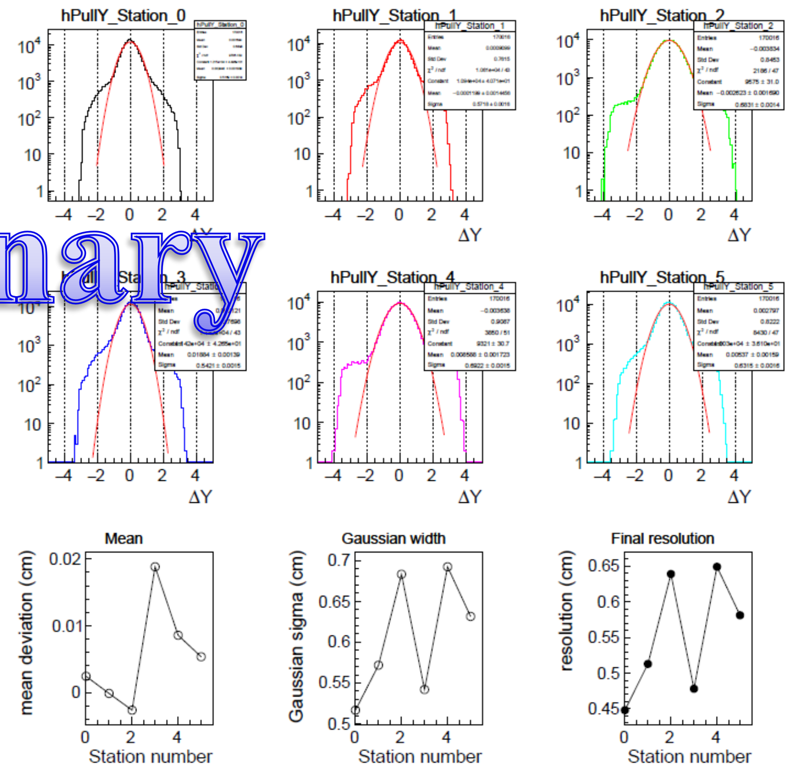
# Cosmic results

## Spatial resolution

Residuals in X



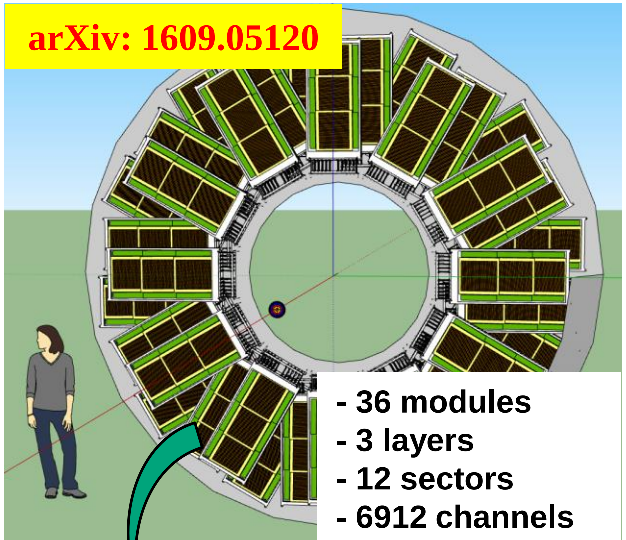

Residuals in Y




Spatial resolution about 2.5 mm in X and 5.5 mm in Y
Systematic errors under investigation.

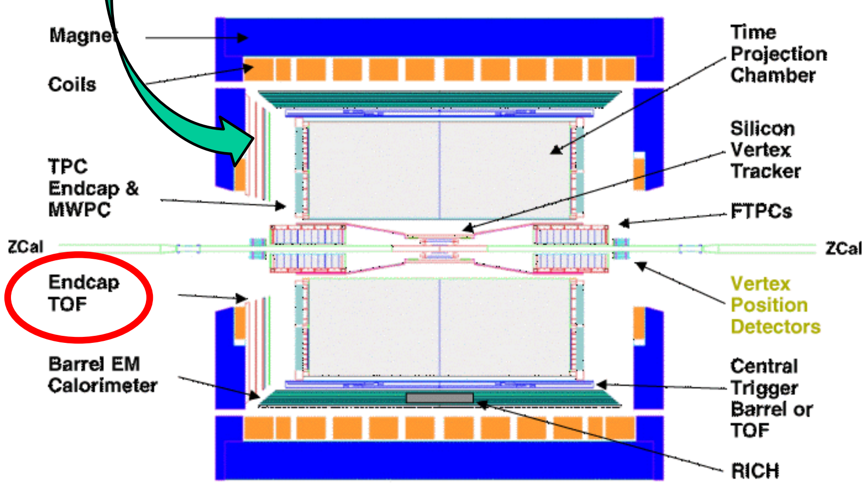
# FAIR Phase 0 – eTOF@STAR

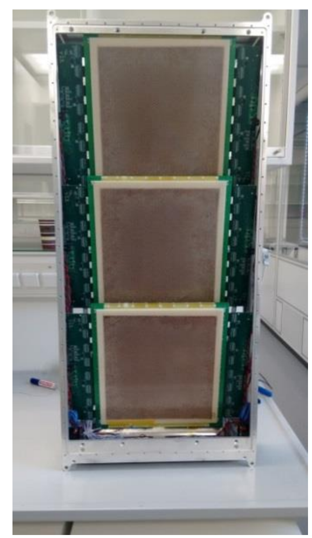


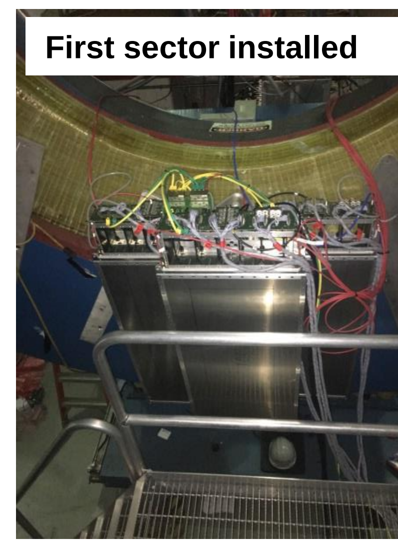



## Time line

- Jan 2018 — shipping and installation of one sector
- Mar. 2018 — 2nd system integration test with one sector by participating in the Run18 beam time in STAR
- Fall 2018 — shipping all 33 modules including infrastructure (gas system, LV-, HV-power supply) to BNL
- Fall 2018 — Installation and commissioning
- Feb 2019/2020 — Start of the BES II campaign
- Summer 2021 — Decommissioning and shipping of all modules including infrastructure to FAIR



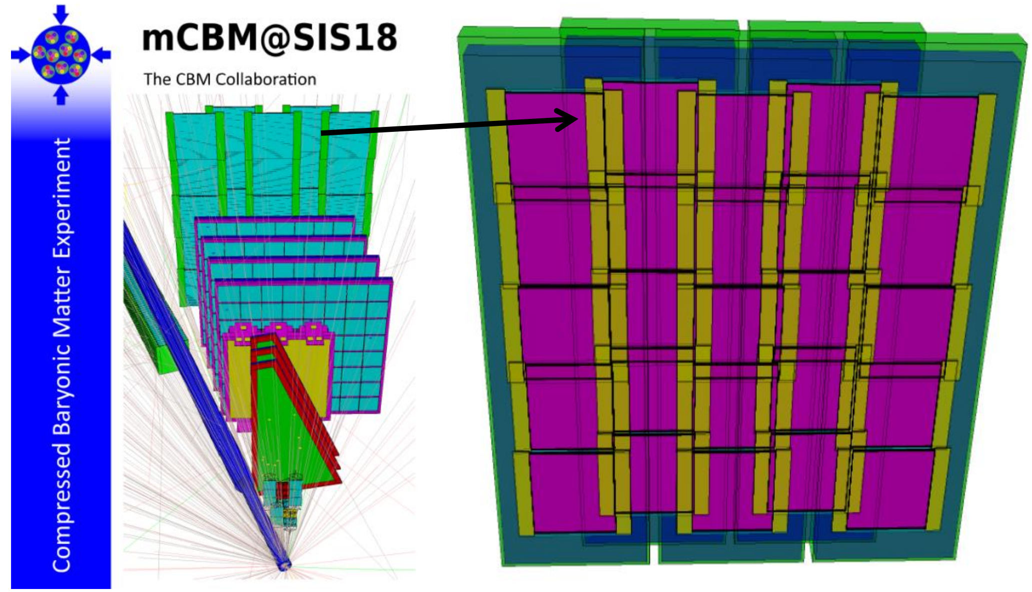


# FAIR Phase 0 – miniCBM

CBM ToF

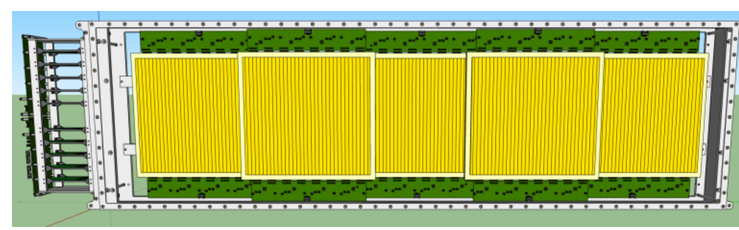
**mTOF setup**

- 25 MRPC3a counters
- 5 M4 modules + 10 CROB(GTBx)
- Active area: 150 x 120 cm$^2$
- # of readout channels: 1600
- T0 diamond counter
- Intended interaction rate: 10 MHz




**Milestones**

| | |
|---|---|
| Counter production finished | Dec. 2017 |
| FEE ready | Mar. 2018 |
| Module production finished | Mar. 2018 |
| Module test with cosmics in HD | Apr. - Jul. 2018 |
| Installation | Jul. 2018 |
| First beam time | Aug 2018 |



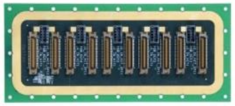
M4 module: 5 MRPC3a counters, 10 PADI, 2 Feed-through PCBs, 10 Get4, 2 backplane PCBs (with GTBx)

# Electronic readout chain

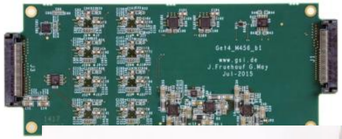
**Readout chain**

- PADI: Preamplifier board 32 ch

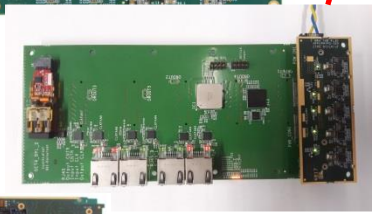
- Feed through PCB



- GET4: TDC board 32 ch

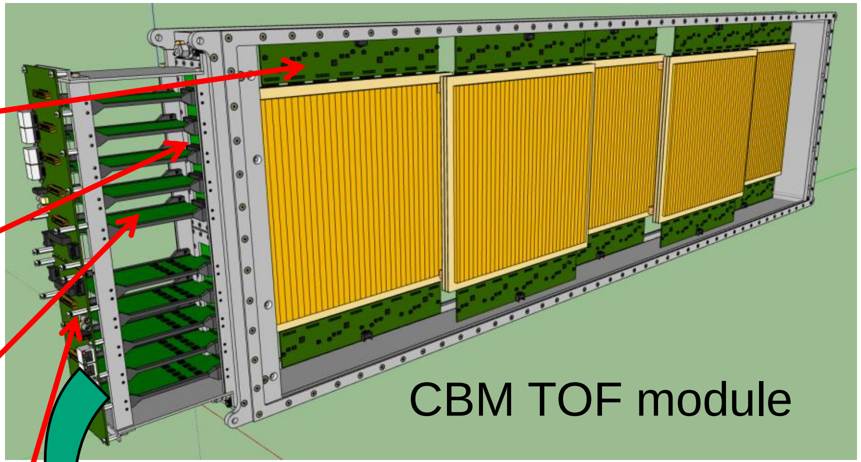


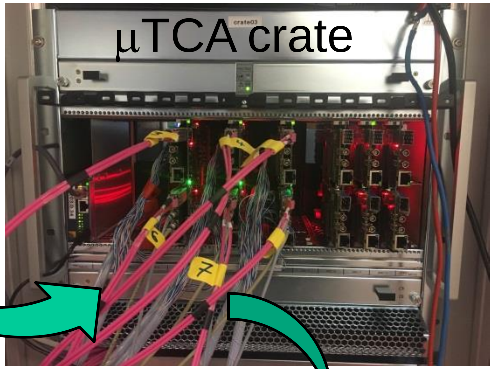
- Backplane with GBTx chip



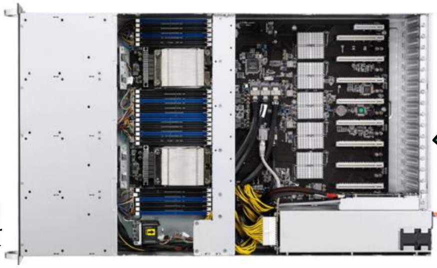
- AFCK: FPGA board

- FLIB: FPGA PCI express card




HP-PC



# Summary

- Counters are fulfilling the specs
- Innovative impedance matching solution developed
- Preproduction for MRPC3/b counter started (QC, QA procedures initiated)
- R&D for BFTC ongoing
- Ultra high rate test still pending $\Rightarrow$ miniCBM
- FAIR phase 0 started - looking forward to physics
- CBM TOF ready for beam in 2023

# Thank you for your attention

**Contributing institutions:**

| | |
|---|---|
| Tsinghua | Beijing, |
| NIPNE | Bucharest, |
| GSI | Darmstadt, |
| IRI | Frankfurt |
| USTC | Hefei, |
| PI | Heidelberg, |
| ITEP | Moscow, |
| HZDR | Rossendorf, |
| CCNU | Wuhan, |

**Special thanks go to:**

Norbert Herrmann

SEVENTH FRAMEWORK PROGRAMME

bmb+f Großgeräte der physikalischen Grundlagenforschung

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AIDA 2020

# Backup Slides

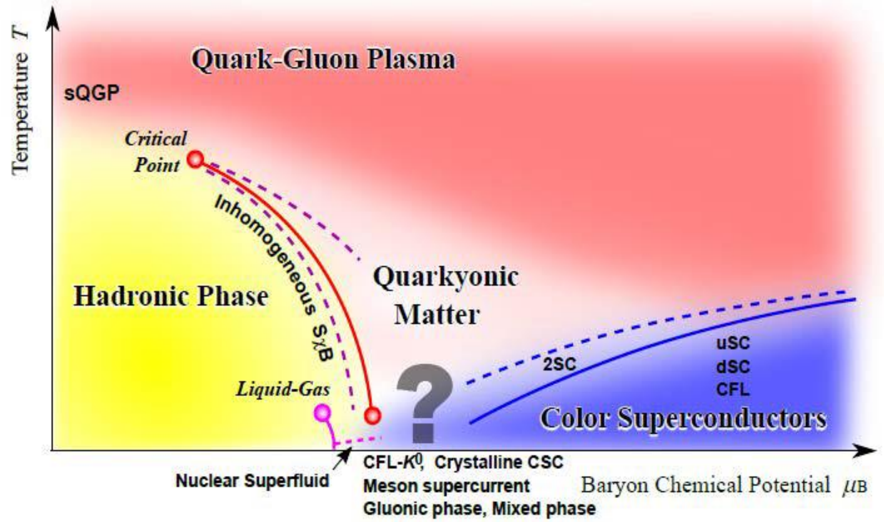
# Backup Slides

## CBM Physics topics

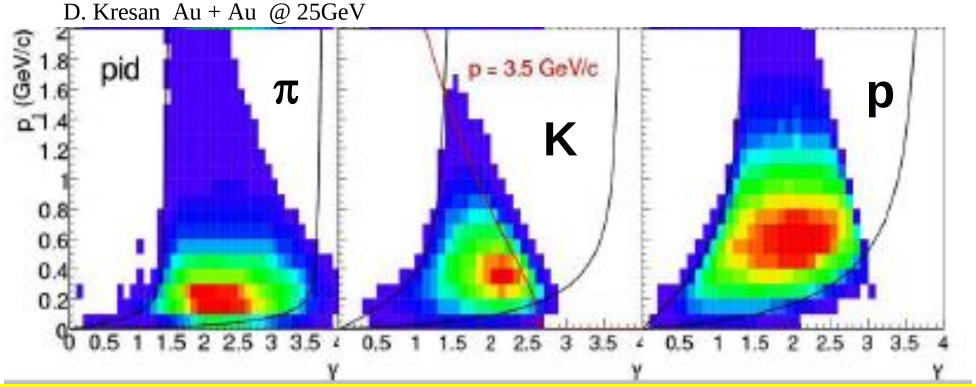
- Deconfinement / phase transition at high $\rho_B$
- QCD critical endpoint
- The equation-of-state at high $\rho_B$
- chiral symmetry restoration at high $\rho_B$

## Observables

- excitation function and flow of strangeness and charm
- collective flow of hadrons
- particle production at threshold energies
- excitation function of event-by-event fluctuations
- excitation function of low-mass lepton pairs
- in-medium modifications of hadrons ($\rho,\omega,\varphi \rightarrow$ e+e-(μ+μ-), D)

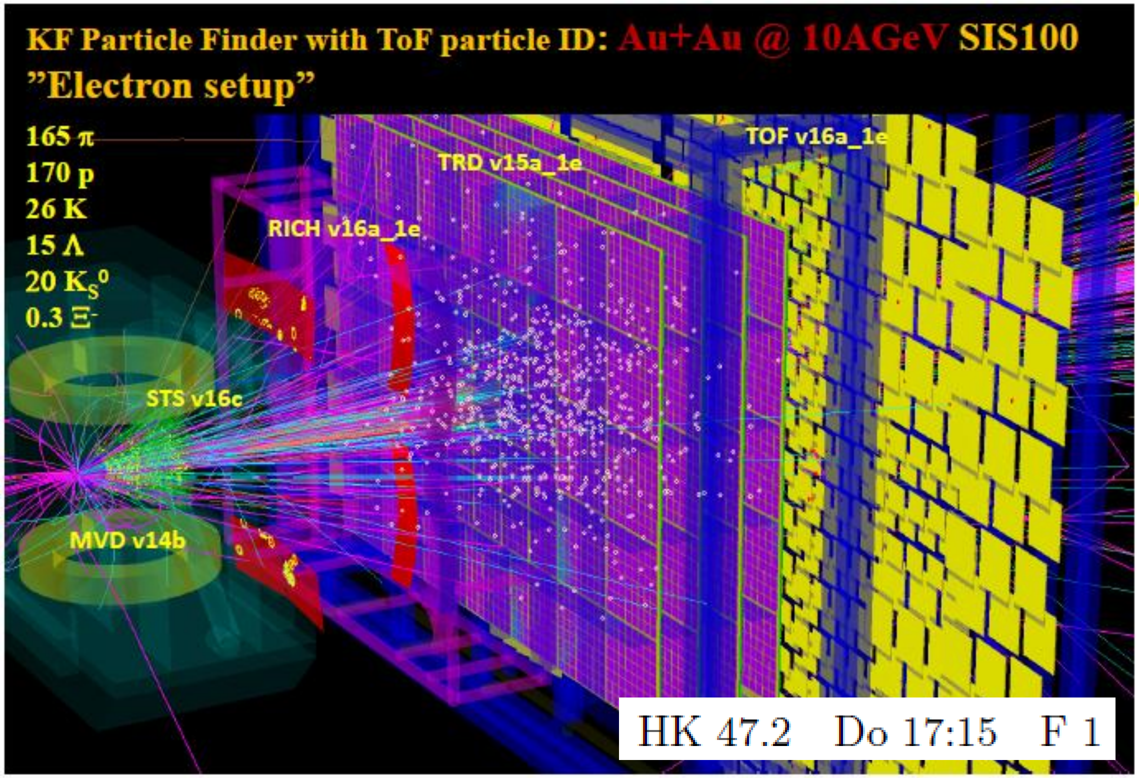



D. Kresan Au + Au @ 25GeV

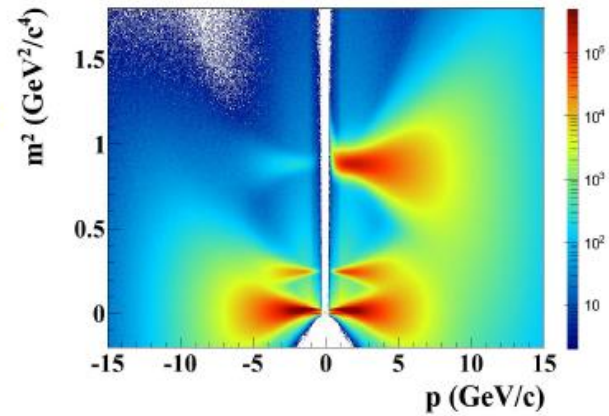


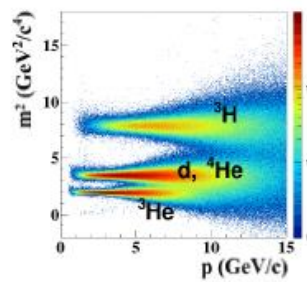

**Kaon acceptance depends critically on TOF resolution**

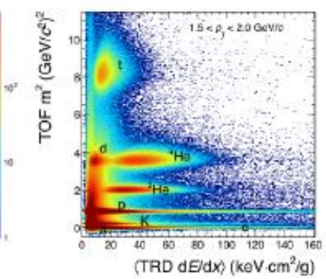
# PID capability

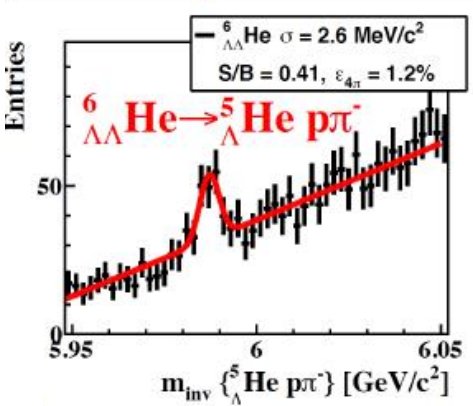


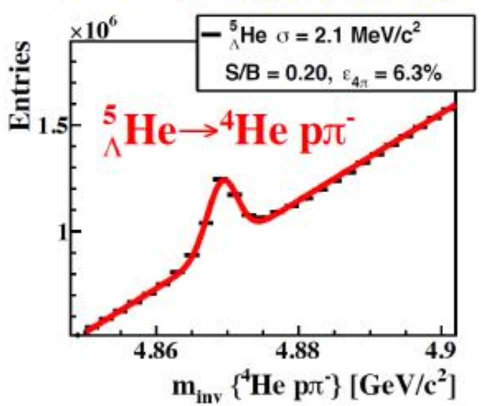

## Particle Identification



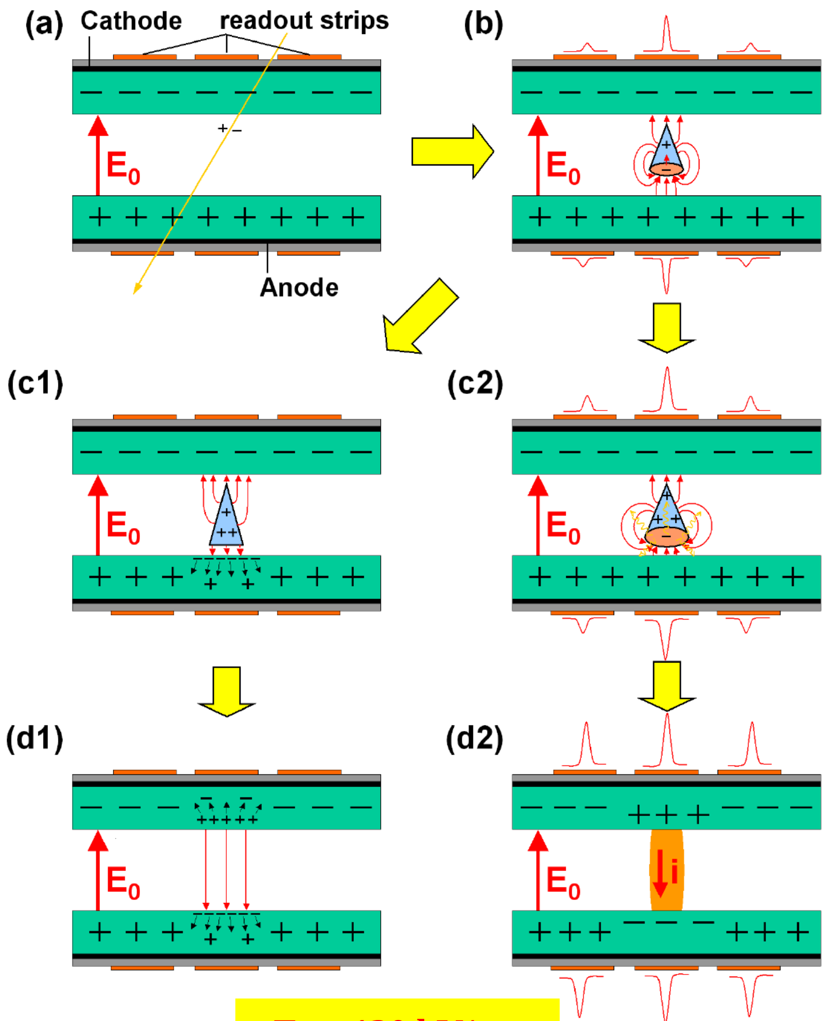




## Reconstruction of double Λ-hypernuclei

- 10A GeV Au + Au
- $10^{12}$ central events
- High interaction rate is essential
- Large d background for $^4$He
- $^4$He can not be separated from d with TOF
- Additional dE/dx information is necessary

# Working principle of an RPC




$E_0$ = 120 kV/cm

**First Multi-gap RPC 1996**

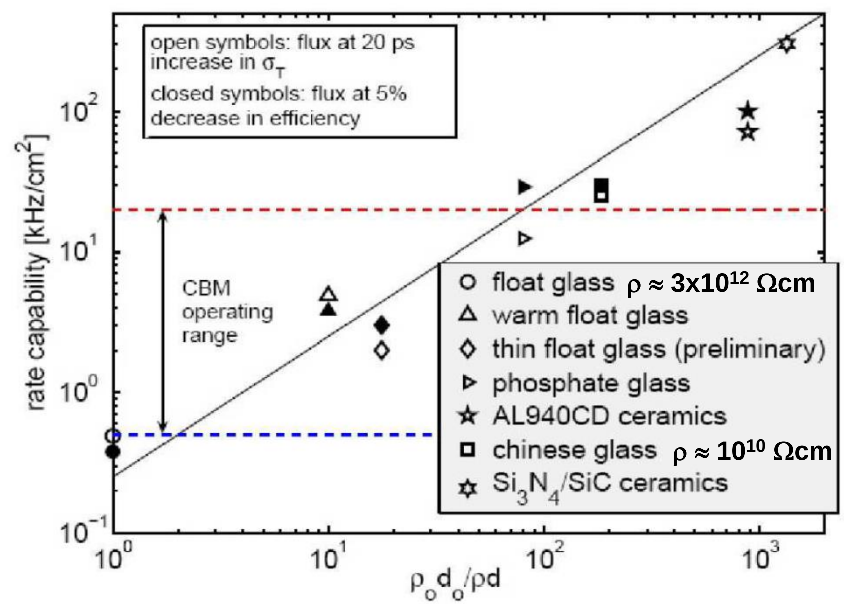
E. Cerron Zeballos et al., **Nucl.Instrum.Meth. A374 (1996) 132-13**

$$\text{Time resolution:} \quad \sigma_T = \sigma_0 + K_T \bar{q}\phi\boxed{\rho d}$$

$$\text{Efficiency:} \quad \epsilon = \epsilon_0 - K_\epsilon \bar{q}\phi\boxed{\rho d}$$

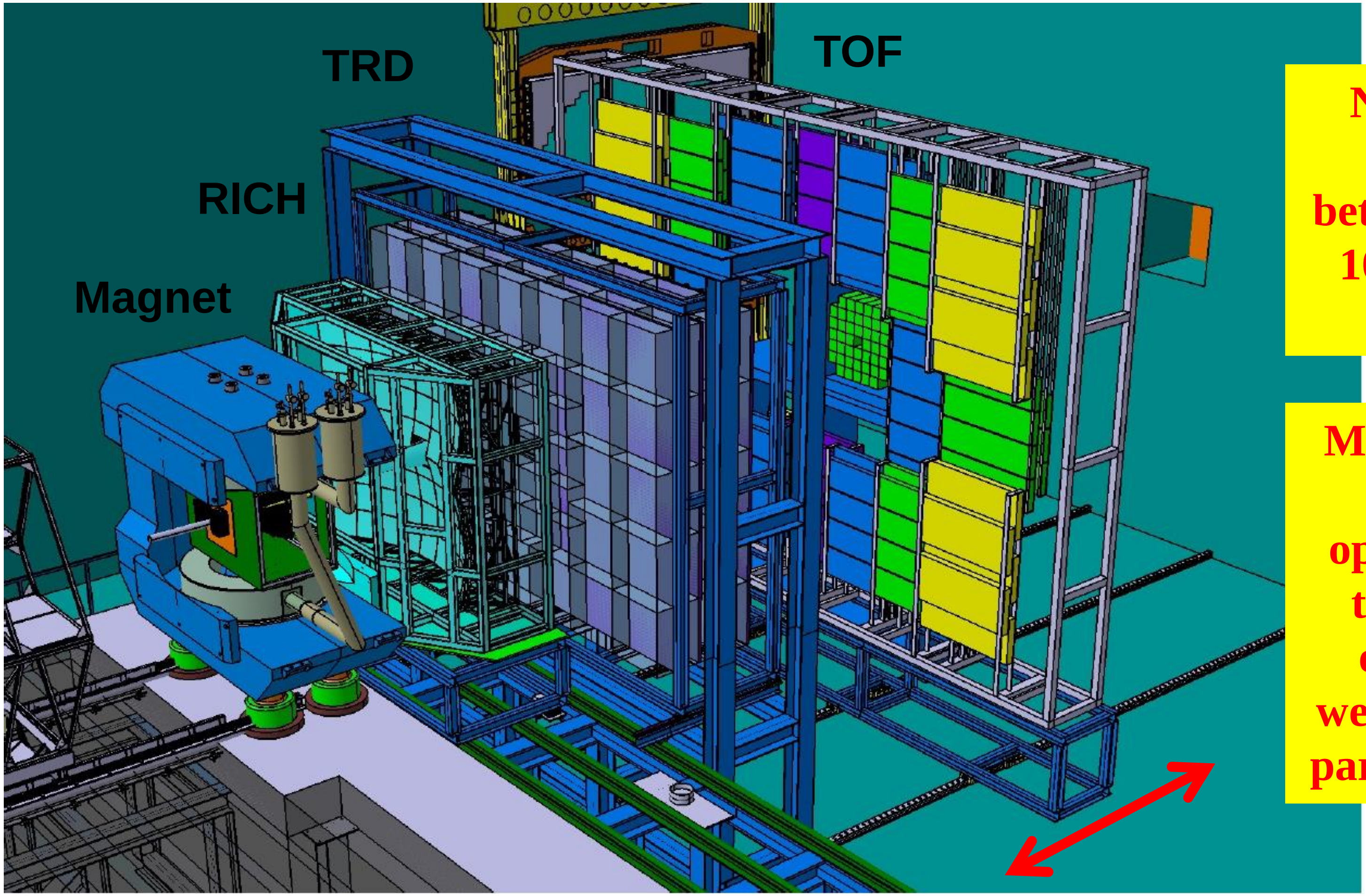
$\phi$: incident ch. particle flux, $\rho$: electrode bulk resistivity, d: electrode thickness

## How to increase the rate capability?



# Backup Slides

## Engineering design of the CBM experiment




**Nominal ToF position is between 6 m and 10 m from the target**

**Movable design allows for optimization of the detection efficiency of weakly decaying particles (Kaons)**

## T0 – determination

**Diamond start counter**

- use HADES development,
- develop DAQ interface,
- limited to reaction rates ~ 100kHz

**Software solution**

- available for all systems
- needs fast particles from reaction
- demonstrated to work for central and semi-central heavy system

**Beam fragmentation counter**

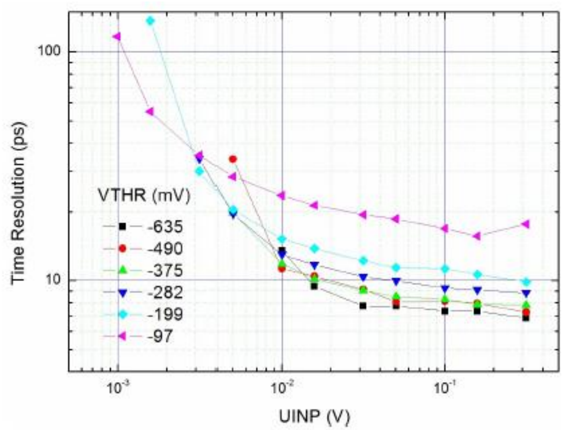
- peripheral HI – reaction have fast particles from projectile fragmentation
- equip region E with timing counters (BFTC)

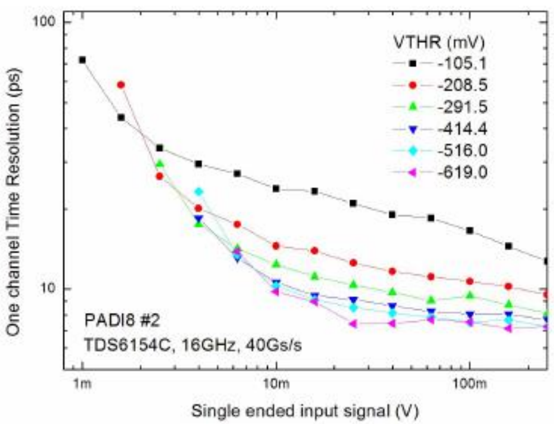
**Reaction counter**

- needed for high rate pA – reactions (charm at SIS 100)
- reaction counter at polar angles 35° < θ < 60°.

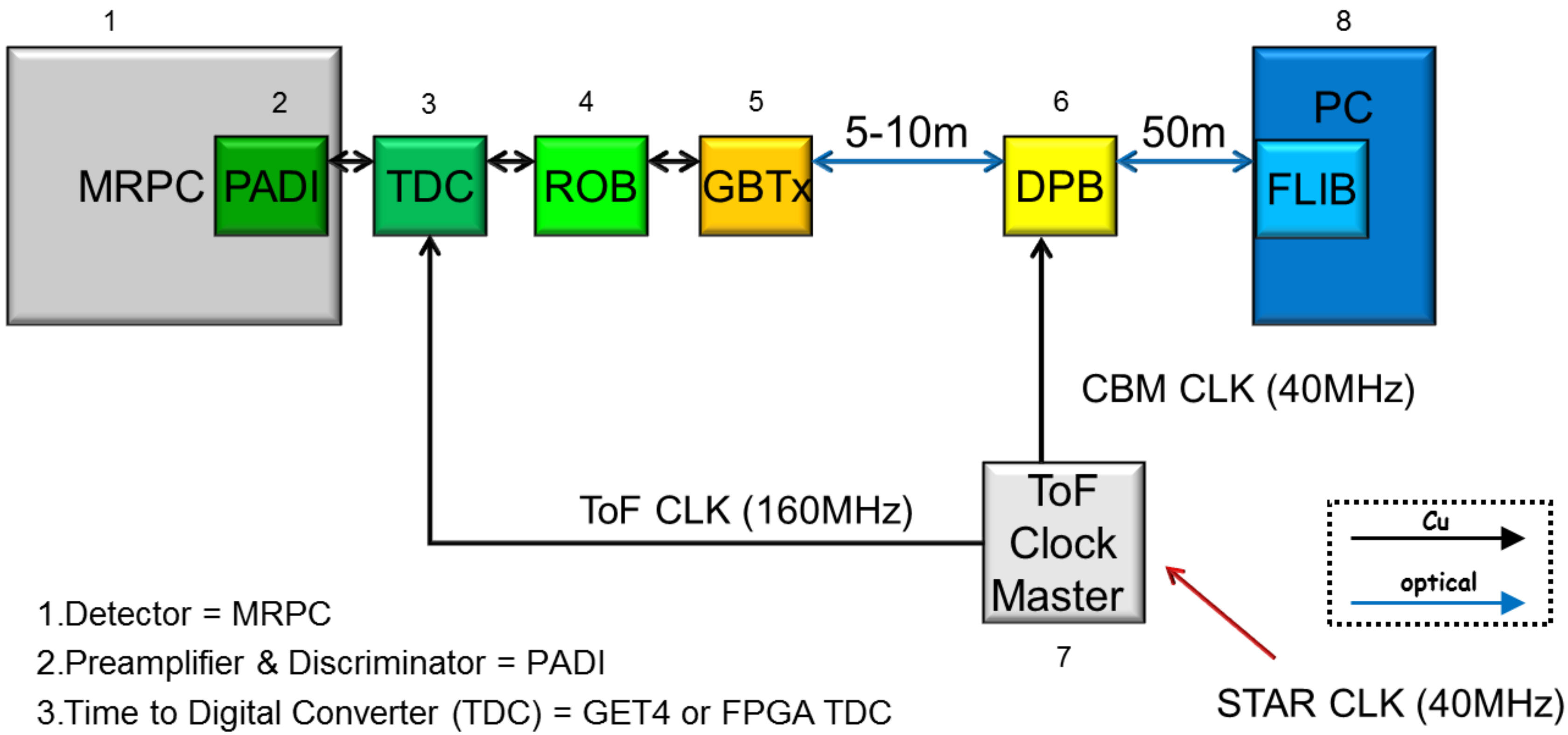
# Backup Slides

| Main parameters comparison | PADI-1 | PADI-2 | PADI-6 | PADI-8 |
|---|---|---|---|---|
| Channels per chip | 3 | 4 | 4 | 8 |
| PA Bandwidth (MHz) | 280 | 293 | 416 | 411 |
| PA Voltage Gain | 74 | 87 | 244 | 251 |
| Conversion Gain (mV/fC) | 6.3 | 7.8 | 35 | 30 |
| Baseline DC offset $\sigma$ (mV) | 6.7 | 21.9 | 5.9 | 1 |
| PA Noise ($mV_{RMS}$) | 3.37 | 2.19 | 5.82 | 5.5 |
| Equivalent Noise Charge ($e_{RMS}$) | 3512 | 1753 | 1039 | 1145 |
| Threshold type | Extern | Extern | Ext. & DAC | DAC |
| Threshold dynamics ($\pm$ mV) | Non.lin. 280 | Non.lin. 300 | Lin. 500 | Lin. 750 |
| Input Impedance Range ($\Omega$) | 30-450 | 37 - 370 | 38 - 165 | 30 - 160 |
| Power consumption (mW/channel) | 21.6 | 17.4 | 17.7 | 17 |



# Backup Slides




1. Detector = MRPC
2. Preamplifier & Discriminator = PADI
3. Time to Digital Converter (TDC) = GET4 or FPGA TDC
4. Readout board for TDC = **1st concentrator stage**
5. GBTx = Data Concentrator ASIC from CERN = **2nd concentrator stage**
6. Data Processing Board = **3rd concentrator stage**
7. Clock Master (CLOSY) & Clock Distribution for ToF
8. PC = storage Device