DPG – Frühjahrstagung 2019

# Status of the CBM Time-of-Flight wall

Ingo Deppner for the CBM-TOF Group

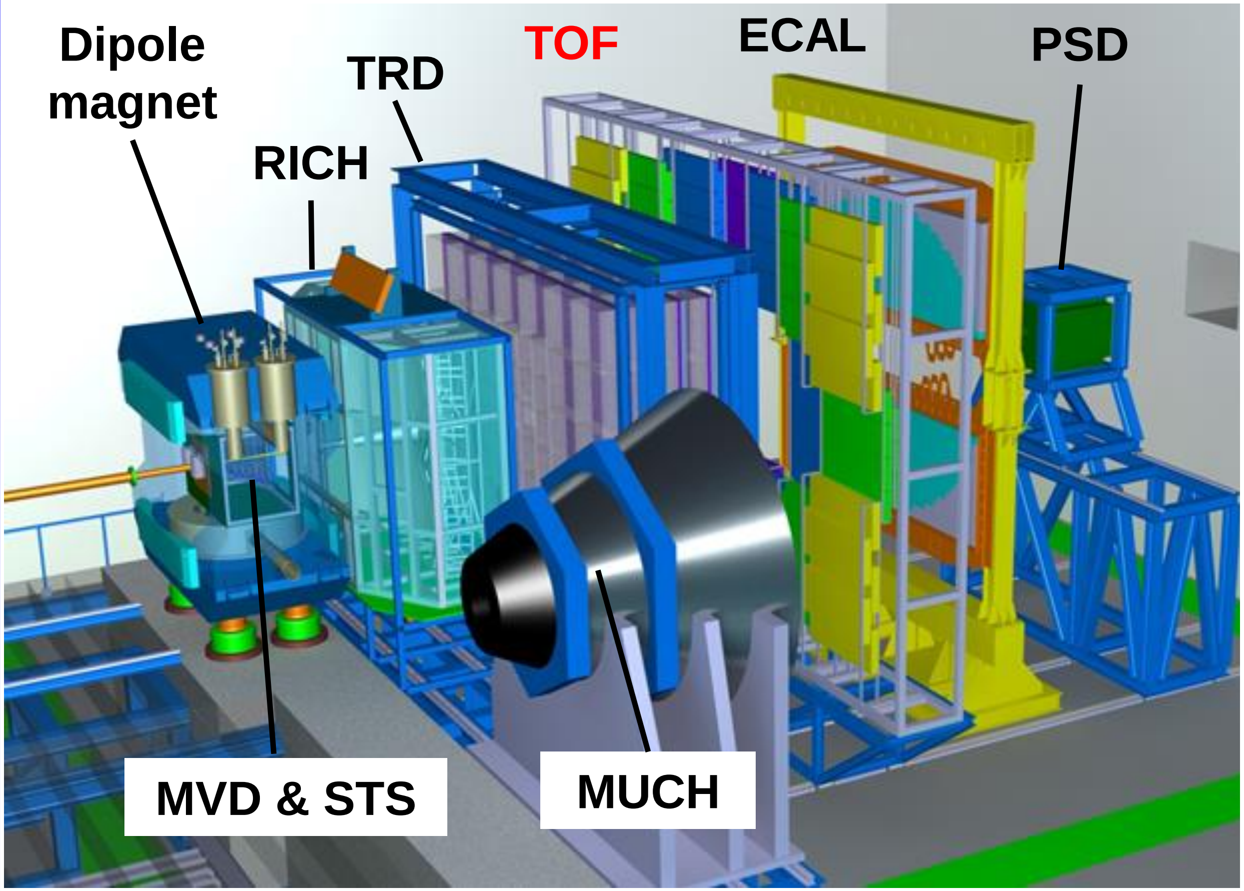
Physikalisches Institut der Uni. Heidelberg

**Outline:**

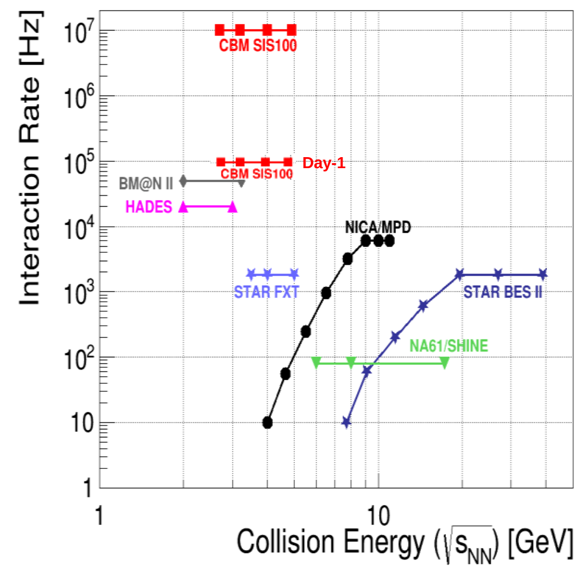
- Introduction
- CBM-ToF requirements
- TDR ToF wall design
- FAIR Phase 0 program
  - eTOF@STAR
  - mTOF@mCBM
- Summary

# Introduction

## The Compressed Baryonic Matter Experiment

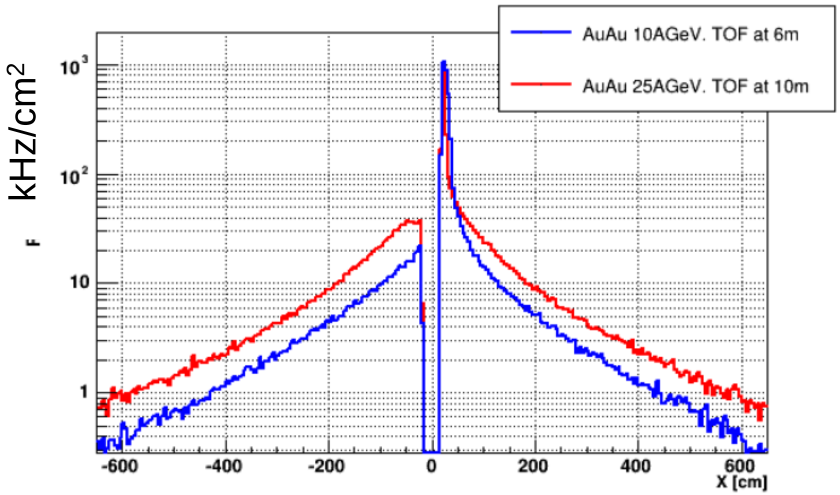


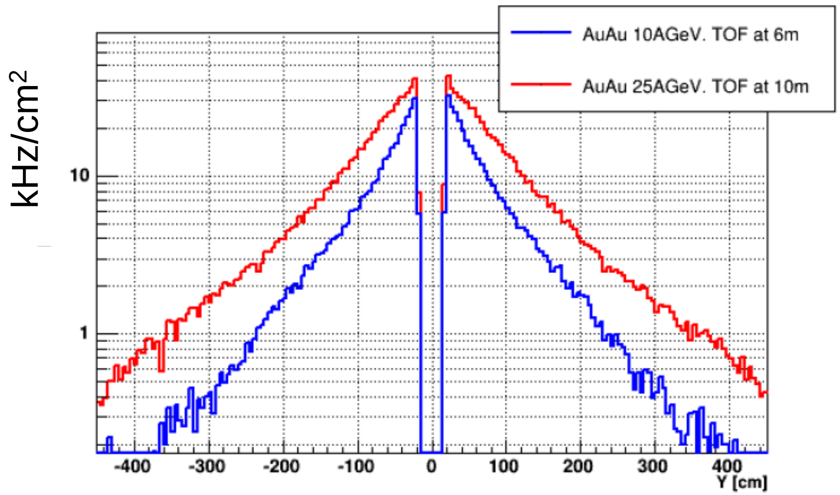

- Tracking acceptance: 2° < $\theta_{Lab}$ < 25°
- Free streaming DAQ
- Software based event selection
- $R_{int}$ = 10 MHz (Au + Au)




**Group reports: 4**
**Short reports: 22**
**Poster: 2**

# Incident particle flux



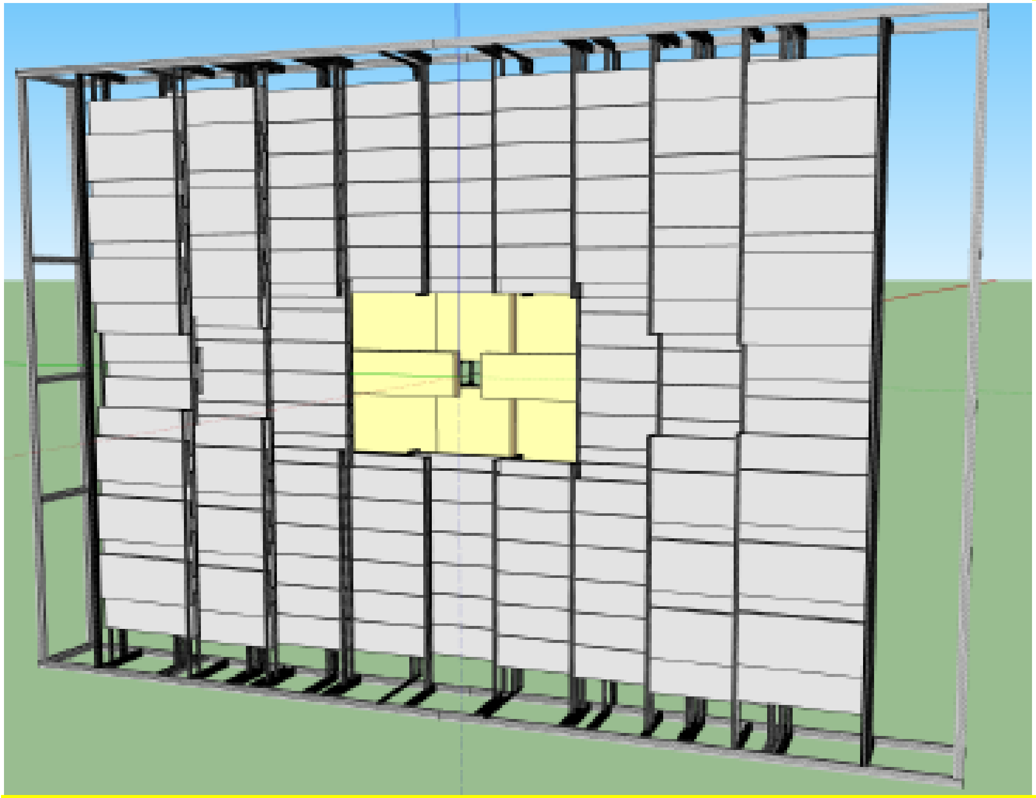




**URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz**

- 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**

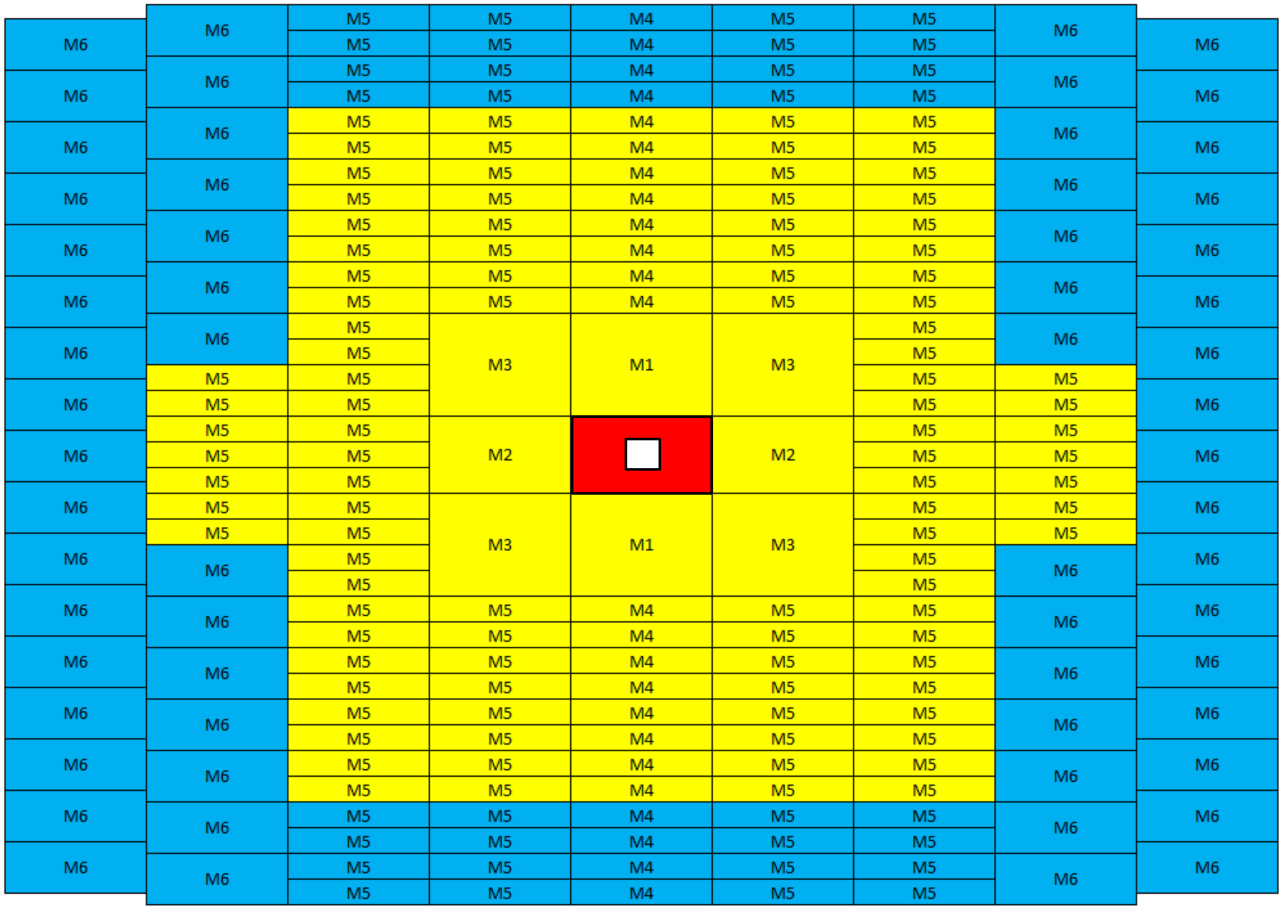


**CBM-ToF Requirements**

- 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 (~100.000 channels)
- Free streaming data acquisition

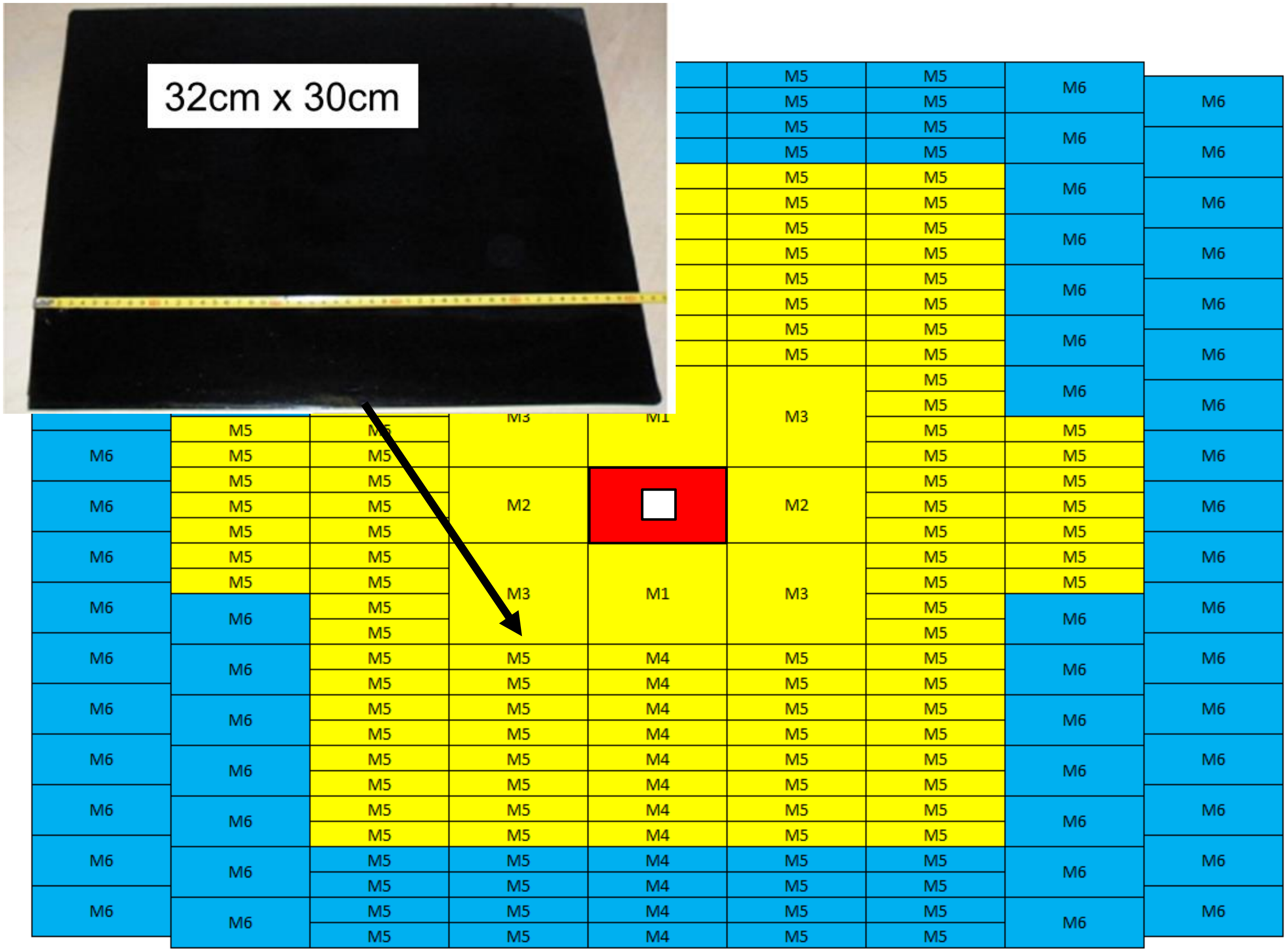
**Multi-gap Resistive Plate Chambers (MRPC) are the most suitable ToF detectors fulfilling our requirements**

# TDR ToF wall layout



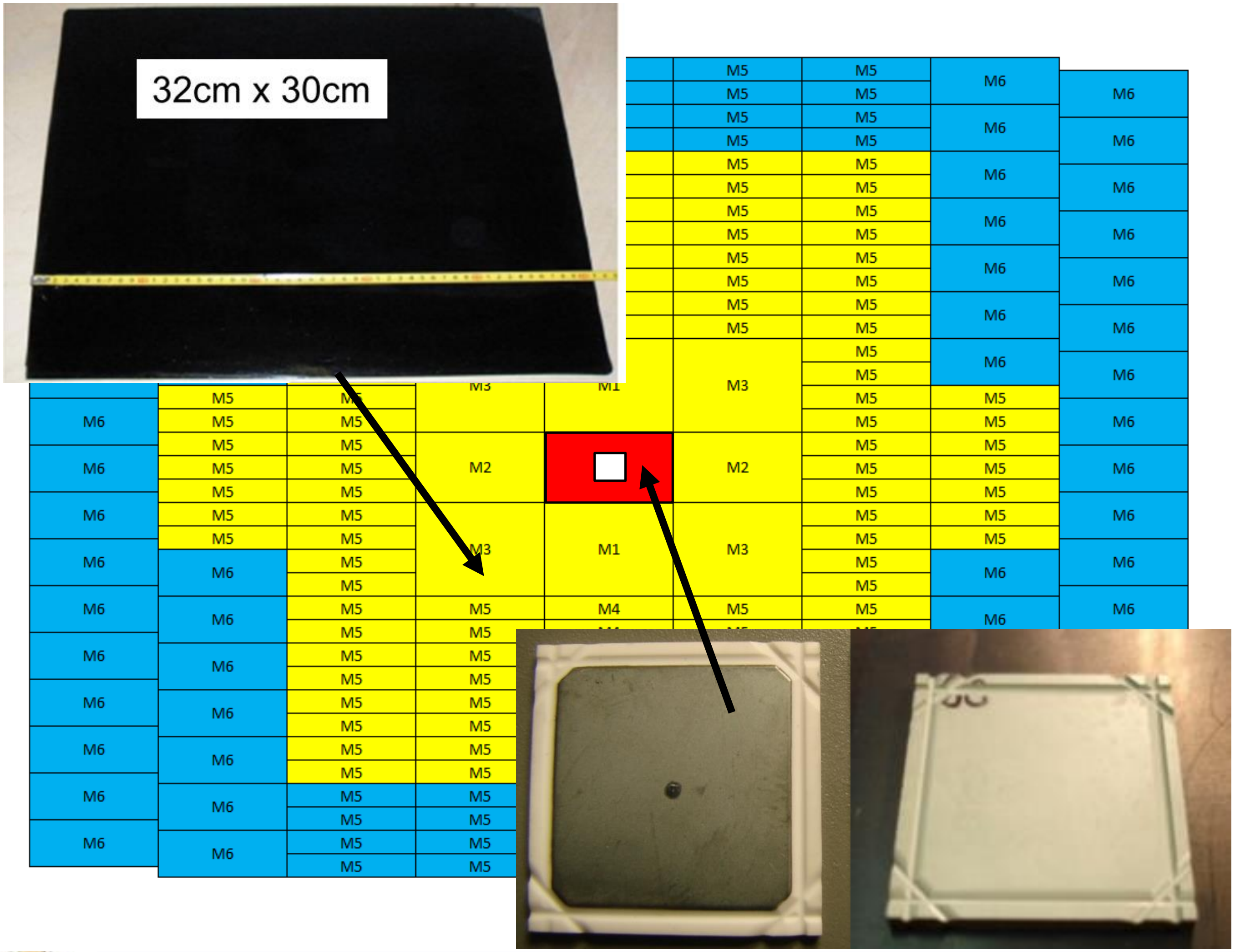

- 6 types of modules (M1 – M6) only
- A module contains several MRPC counters
- Region containing counters equipped with float glass
- Region containing counters equipped with low resistive glass
- Region containing counters equipped with ceramic material

# TDR ToF wall layout




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

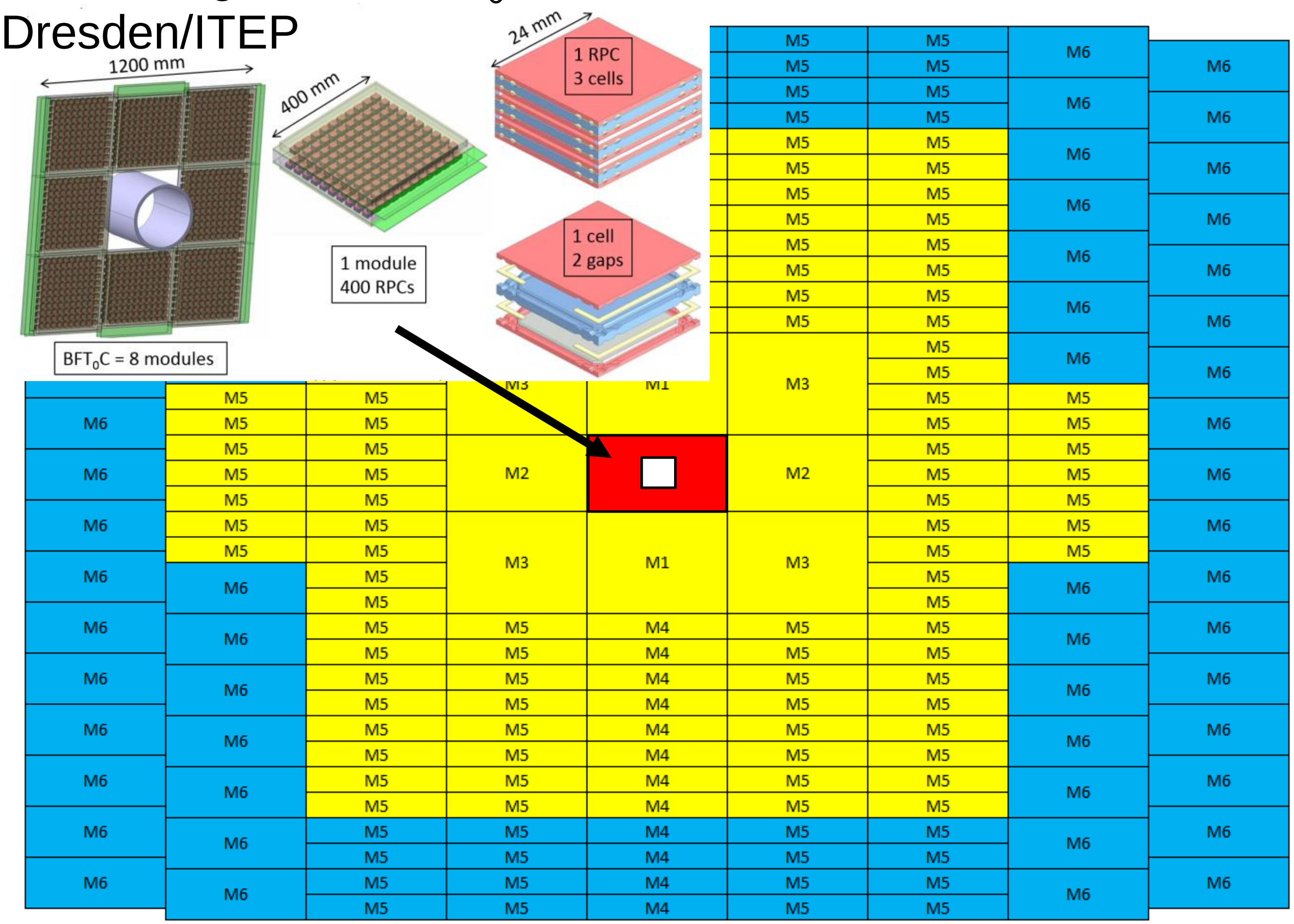
# TDR ToF wall layout




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

# TDR ToF wall layout

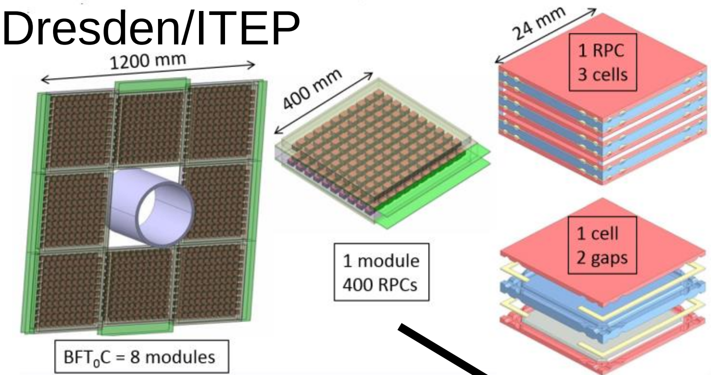
Beam Fragmentation $T_0$ Counter
Dresden/ITEP



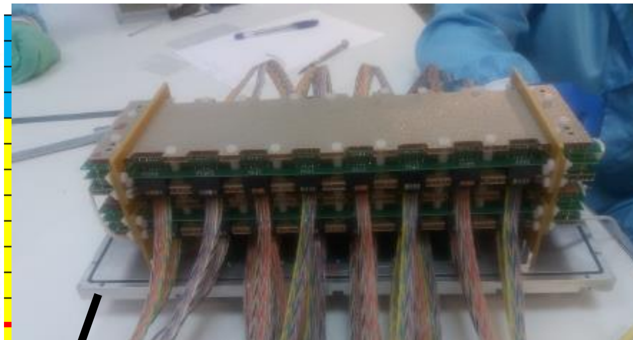

- **6 types of modules (M1 – M6) only**
- **A module contains several MRPC counters**
- (blue) **Region containing counters equipped with float glass**
- (yellow) **Region containing counters equipped with low resistive glass**
- (red) **Region containing counters equipped with ceramic material**

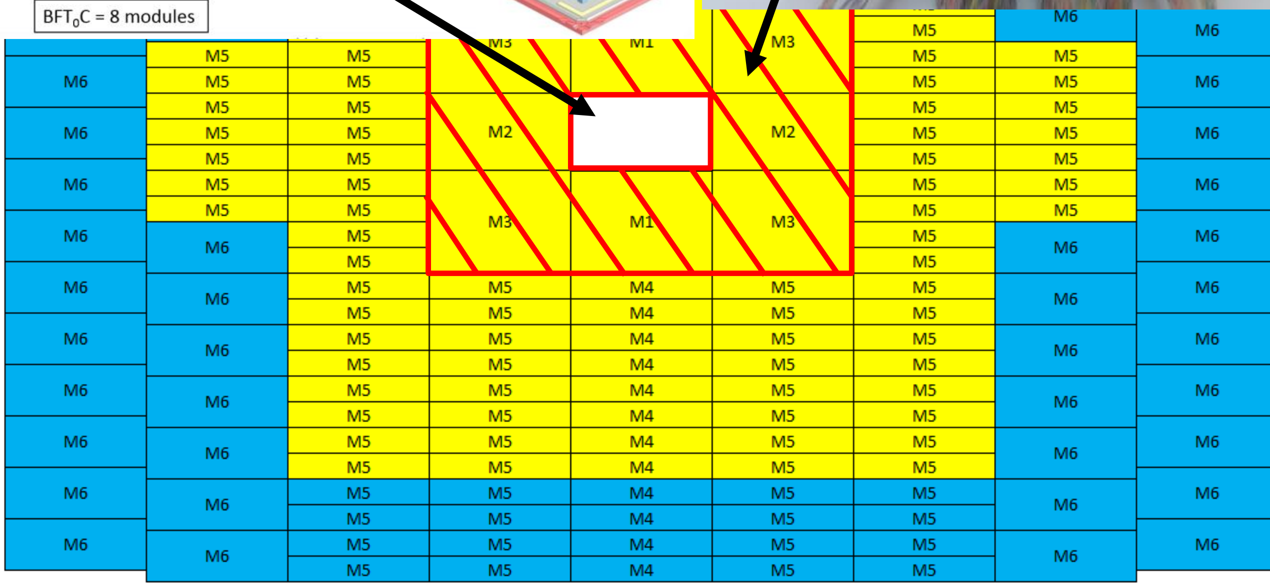
# TDR ToF wall layout

Beam Fragmentation $T_0$ Counter
Dresden/ITEP




MRPC1a/1b/2 (NIPNE)

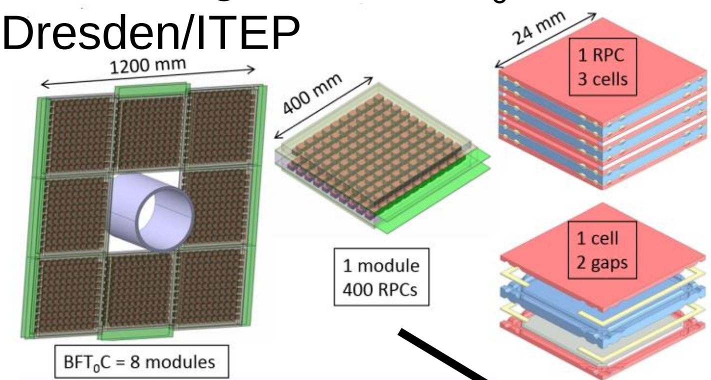




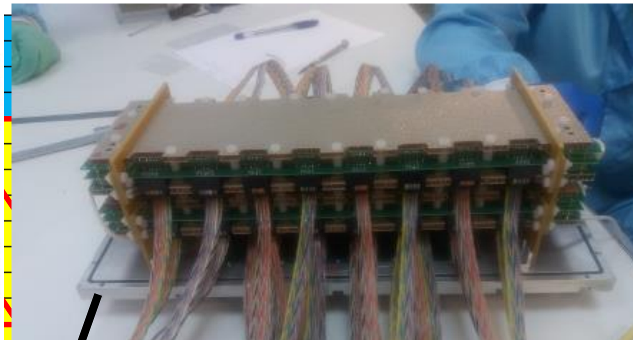

- **6 types of modules (M1 – M6) only**
- **A module contains several MRPC counters**
- **Region containing counters equipped with float glass** (blue)
- **Region containing counters equipped with low resistive glass** (yellow)
- **Region containing counters equipped with ceramic material** (red)

# TDR ToF wall layout

Beam Fragmentation $T_0$ Counter Dresden/ITEP




MRPC1a/1b/2 (NIPNE)

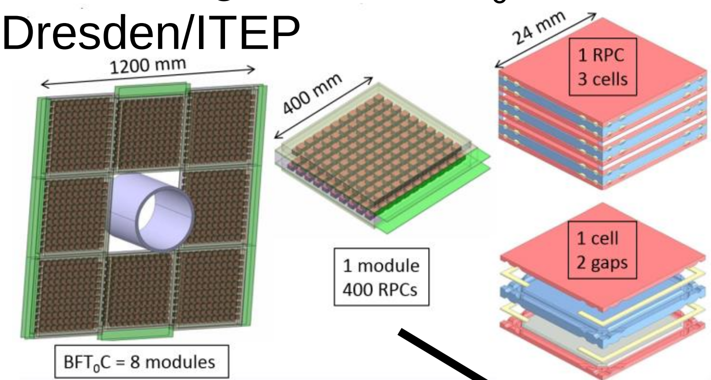



MRPC3a (Tsinghua)

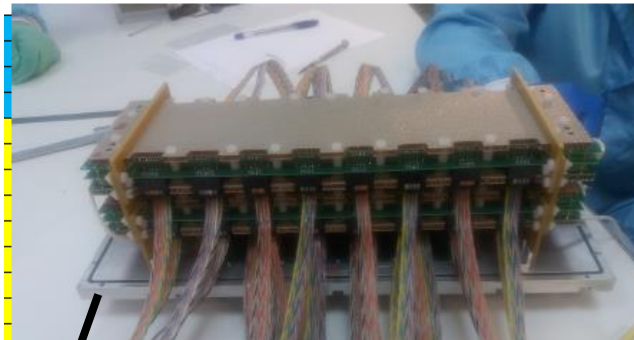
- **6 types of modules (M1 – M6) only**
- **A module contains several MRPC counters**
- **(blue) Region containing counters equipped with float glass**
- **(yellow) Region containing counters equipped with low resistive glass**
- **(red) Region containing counters equipped with ceramic material**

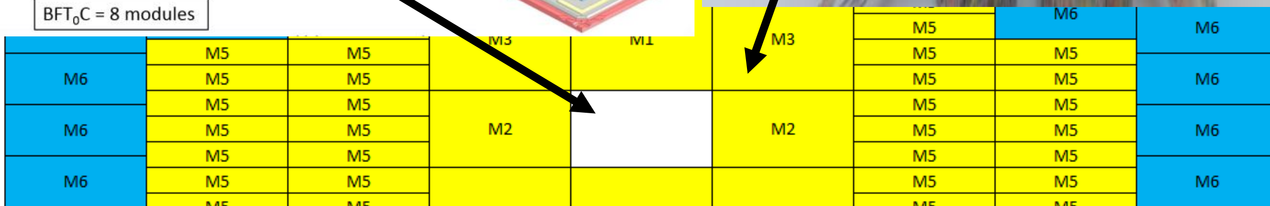
# TDR ToF wall layout

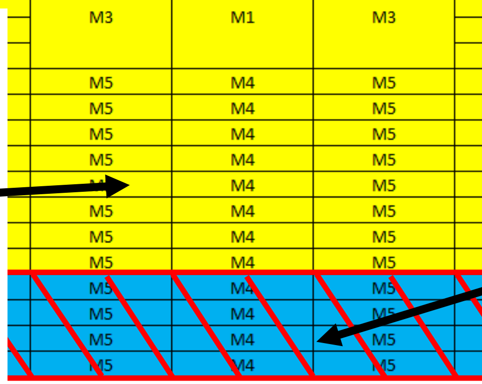
Beam Fragmentation $T_0$ Counter
Dresden/ITEP



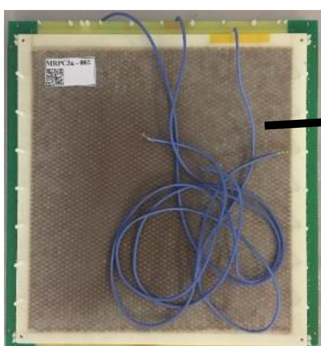

MRPC1a/1b/2 (NIPNE)



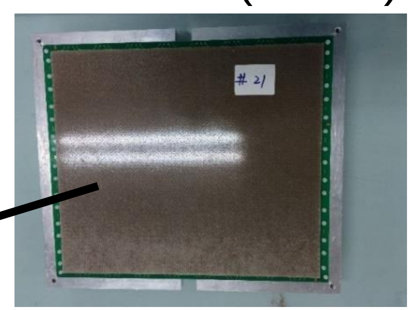




MRPC3a (Tsinghua)



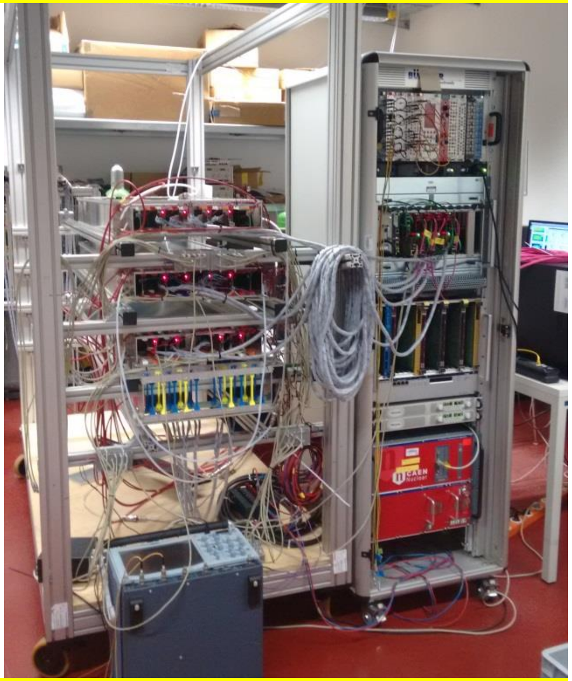
MRPC3b (USTC)



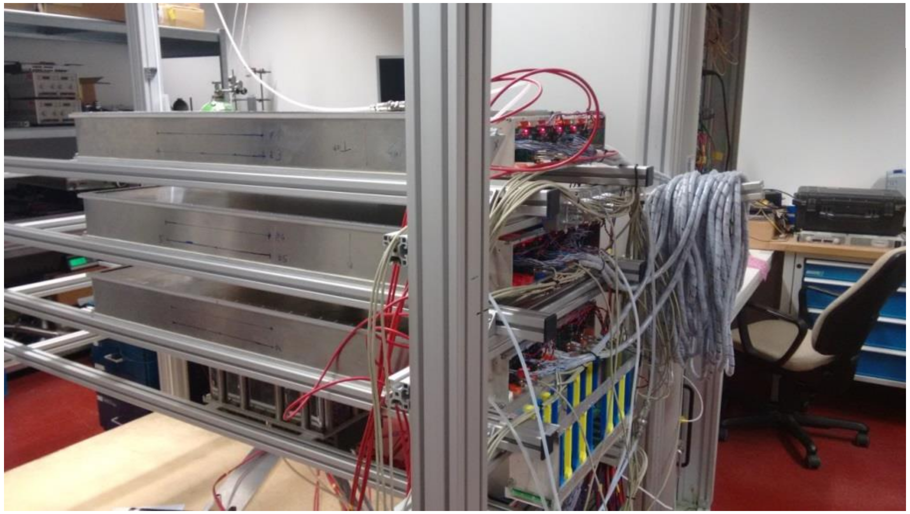
- **6 types of modules (M1 – M6) only**
- **A module contains several MRPC counters**
- **Region containing counters equipped with float glass** (blue)
- **Region containing counters equipped with low resistive glass** (yellow)
- **Region containing counters equipped with ceramic material** (red)

# Module integration and cosmic test stand in HD

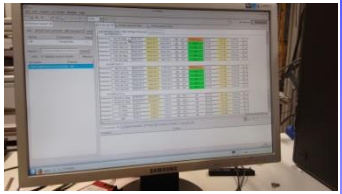
**Multi differential analysis of counter properties with cosmic tracks**



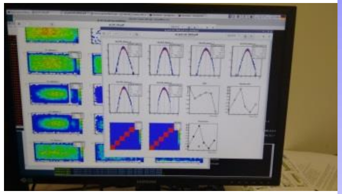
**About 100000 good tracks per day**

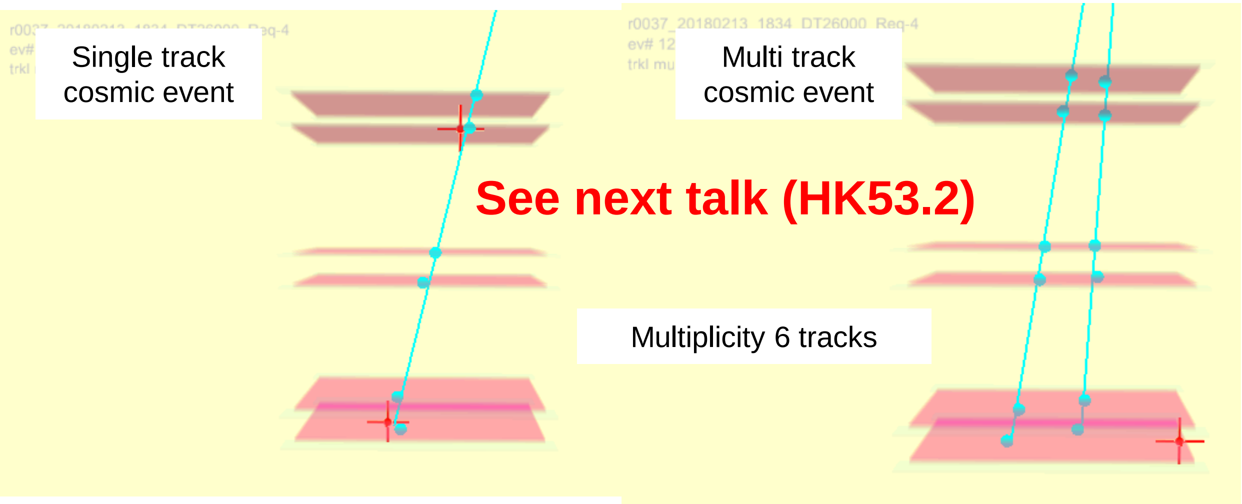


DCS system (EPICS)



Online Monitor






**See next talk (HK53.2)**

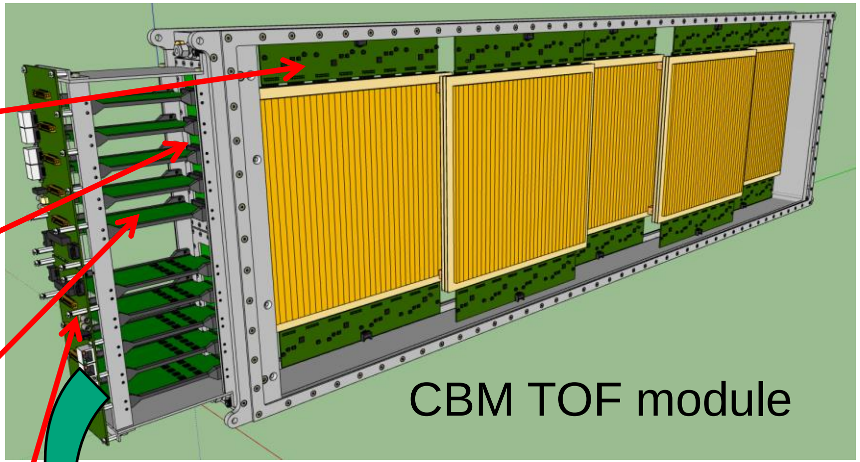
# FAIR Phase 0 programs

- FAIR Phase 0 is a bridge program until the start of FAIR in 2025
- It comprises the installation and testing of developed equipment in running Experiments

## FAIR Phase 0 programs of CBM-TOF

1. eTOF project at STAR@BNL (6912 channel)
   P. Weidenkaff - HK15.5
2. mTOF project at mCBM@SIS18 (1600 channel)
   C. Sturm - HK15.1

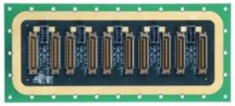
# Electronic readout chain for the FAIR Phase 0 setups



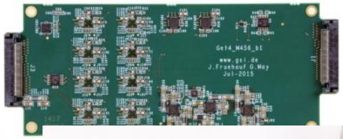

**Readout chain**

- PADI: Preamplifier board 32 ch

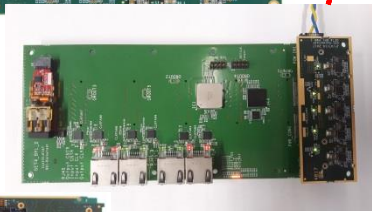
- Feed through PCB



- GET4: TDC board 32 ch

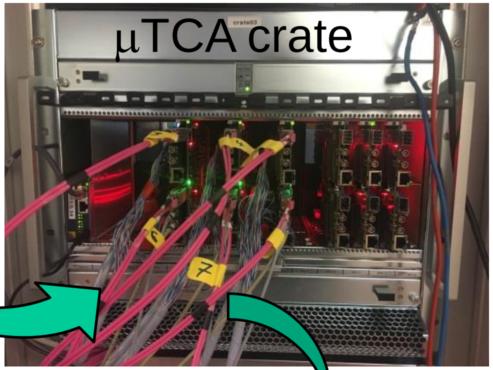


- Backplane with GBTx chip

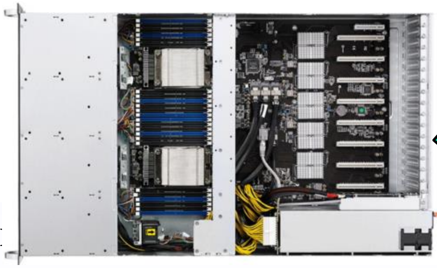


- AFCK: FPGA board

- FLIB: FPGA PCI express card

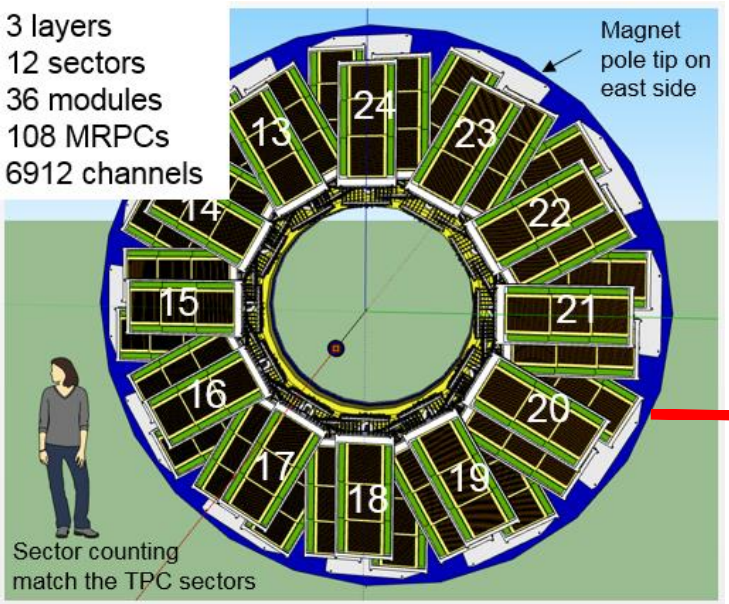


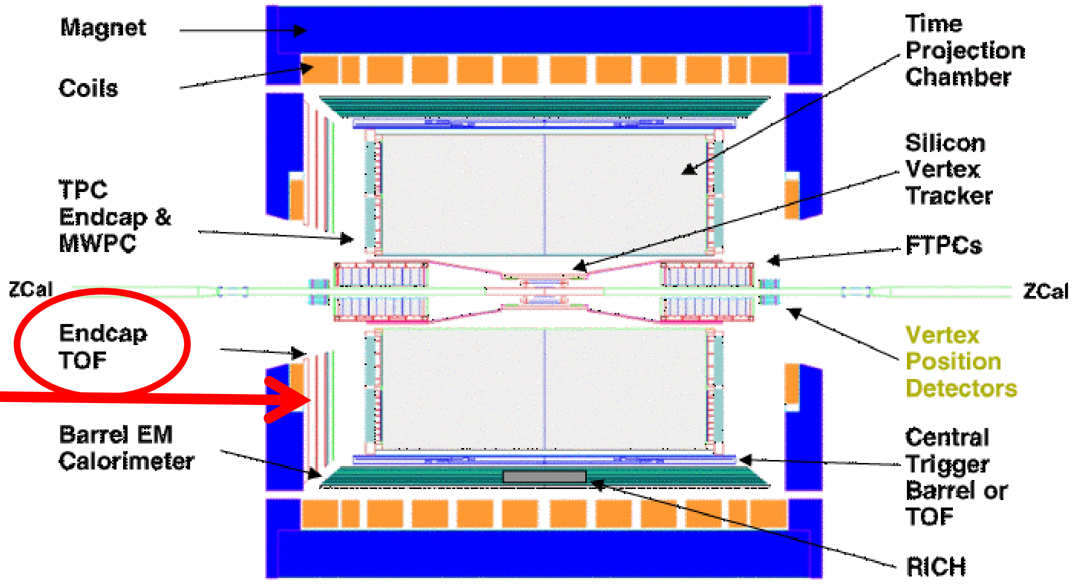

HP-PC



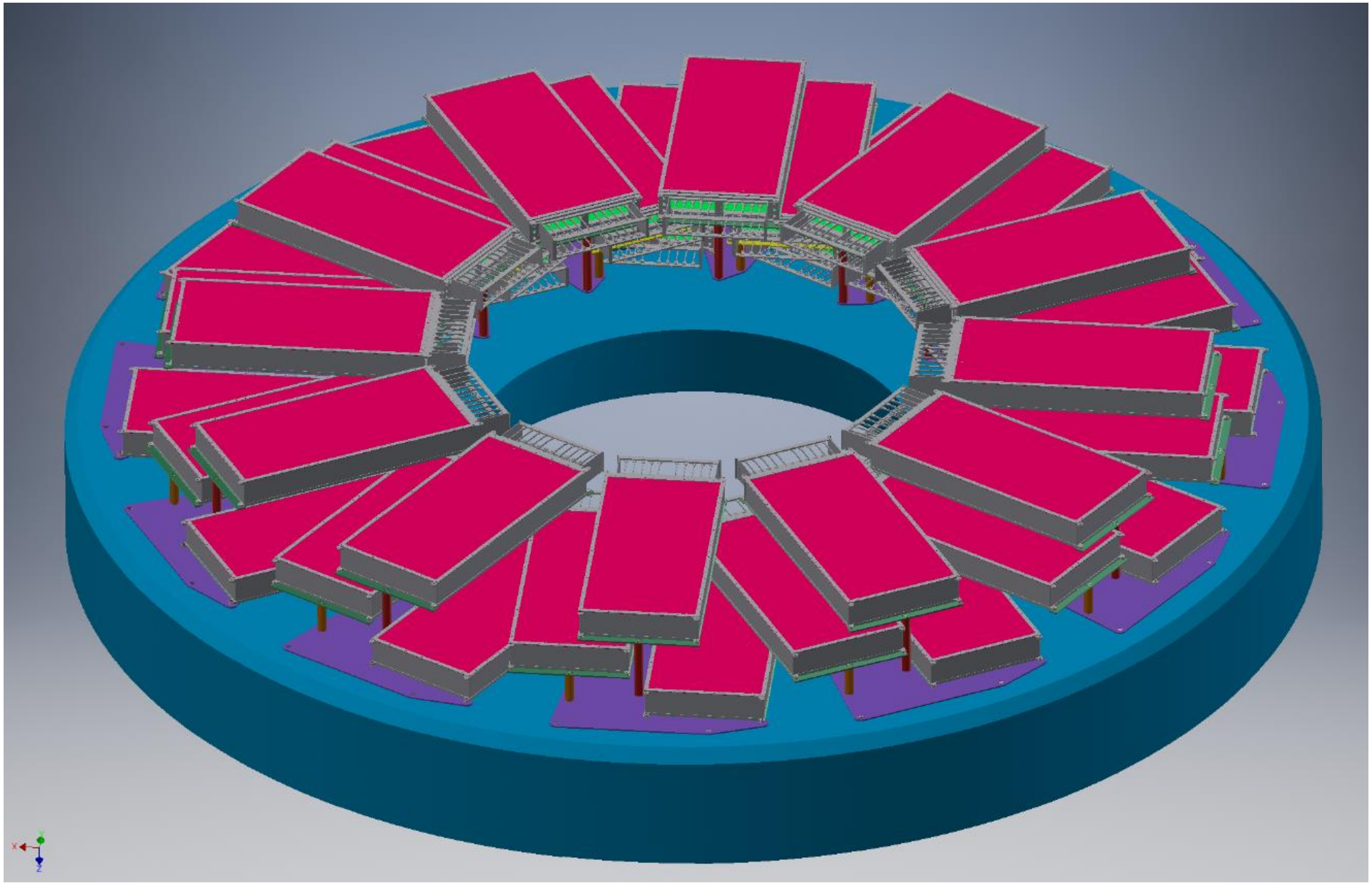
## What is the eTOF project

- eTOF project is a joint project between CBM and STAR
- eTOF project is part of the BESII detector upgrade at STAR
- It comprises the installation, commissioning and operation of CBM TOF modules positioned at the east pole tip of the STAR apparatus during the BESII campaign
- It is part of the FAIR phase 0 program



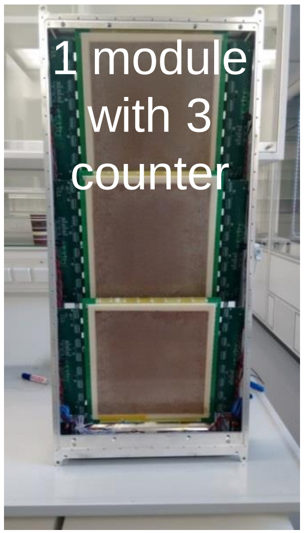



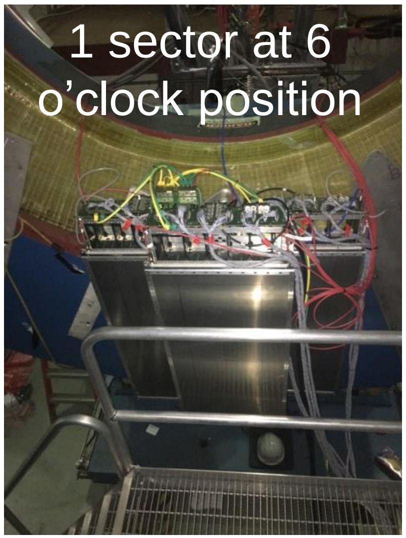
# Mounting scheme



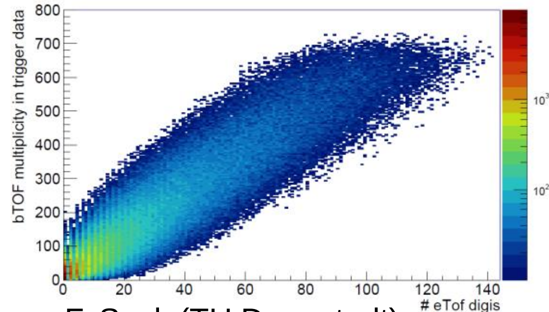
# FAIR Phase 0 – eTOF@STAR commissioning RUN18

## 1 sector operated in RUN18



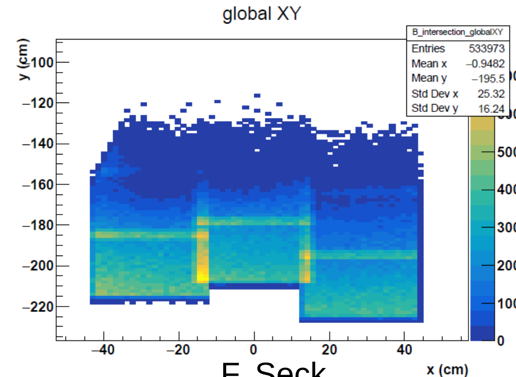




eTOF-barrel TOF correlation



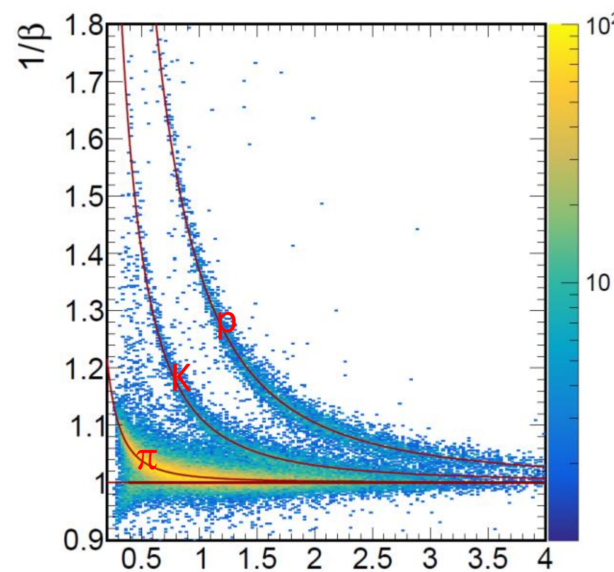

F. Seck (TU Darmstadt)

TPC track matching

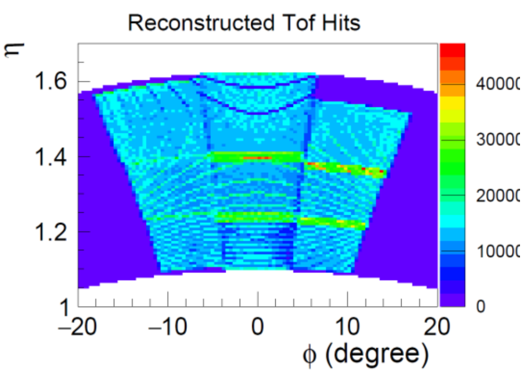


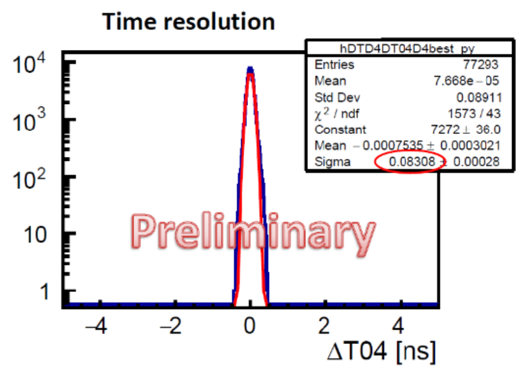

F. Seck

1st PID plot



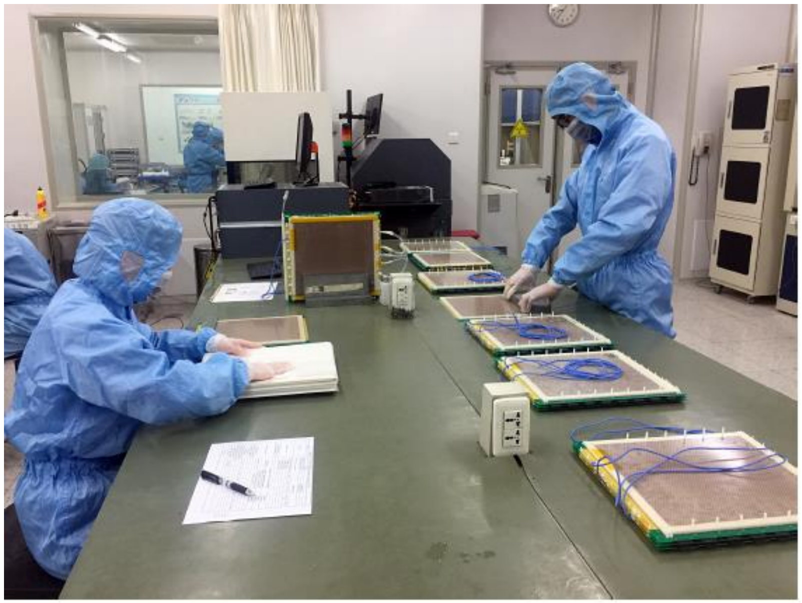

F. Seck

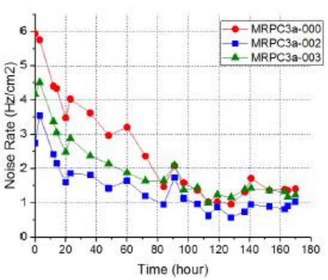


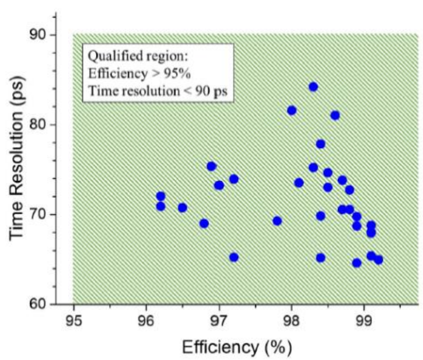



# MRPC3a and MRPC3b mass production for eTOF

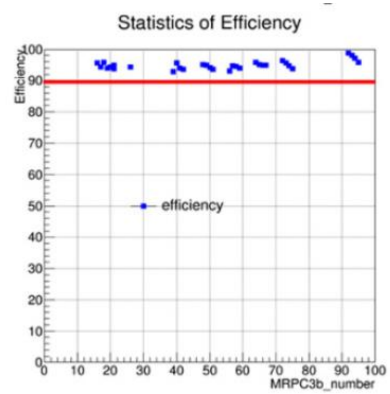
MRPC3a mass prod at Nuctech, Beijing

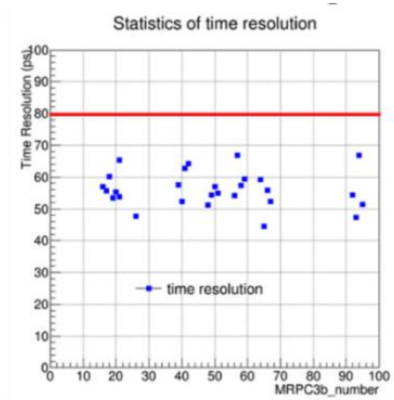





MRPC3b mass production at USTC/China

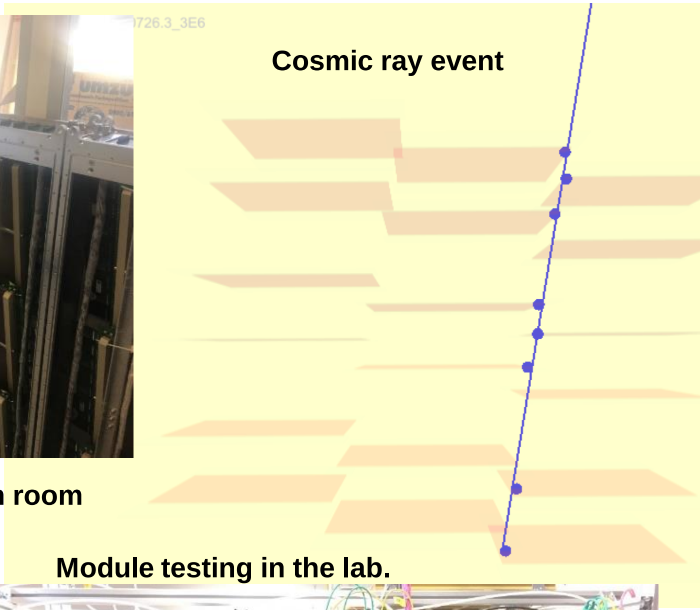


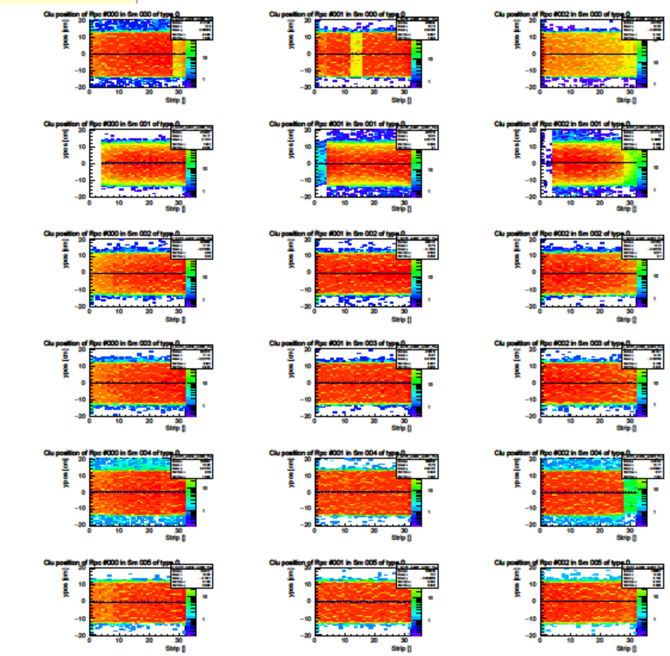
# FAIR Phase 0 – eTOF@STAR

## Module production and testing in HD (Jun – Oct. 2018)

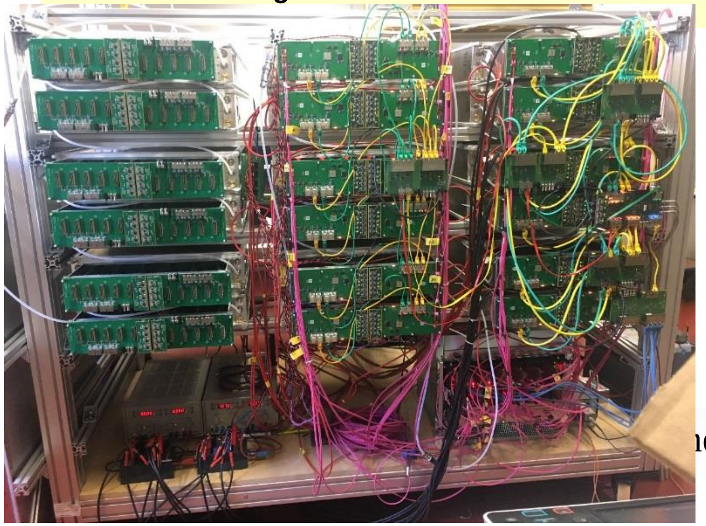
Module production in the clean room



Cosmic ray event



Module testing in the lab.

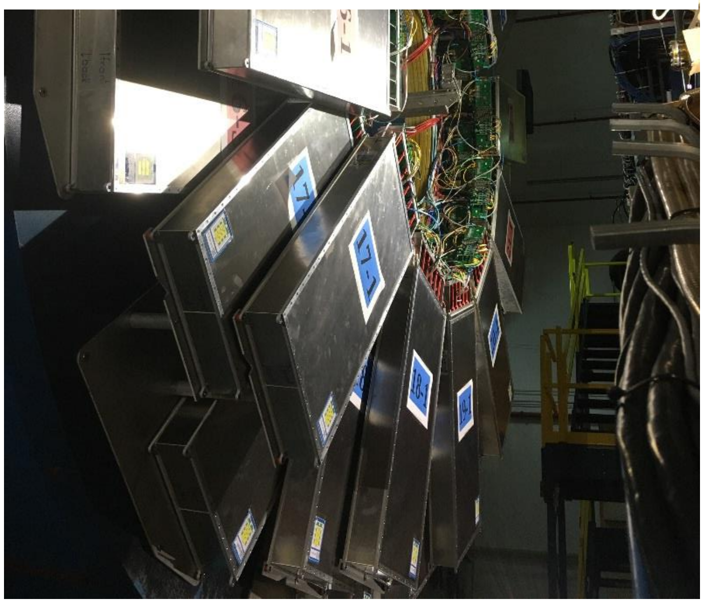


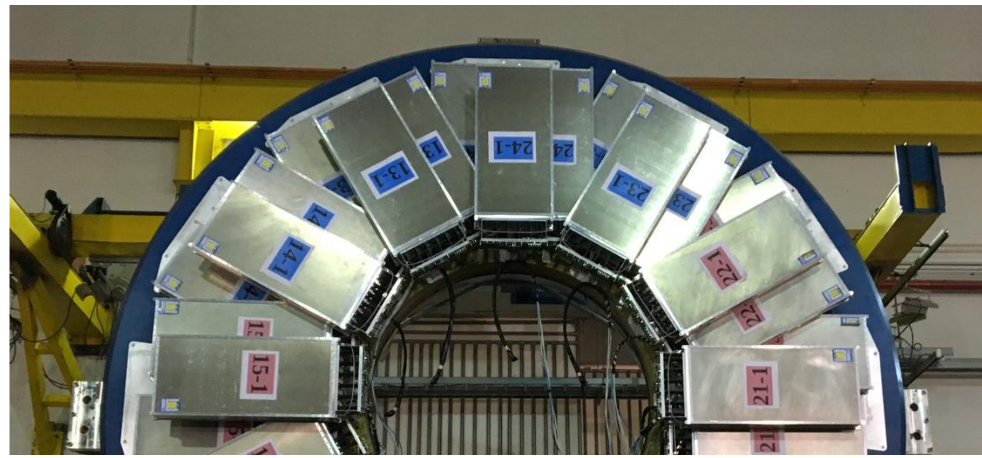
36 modules
108 MRPCs
72 GBTX PCBs
216 GET4 PCBs
216 PADI PCBs
6912 channels

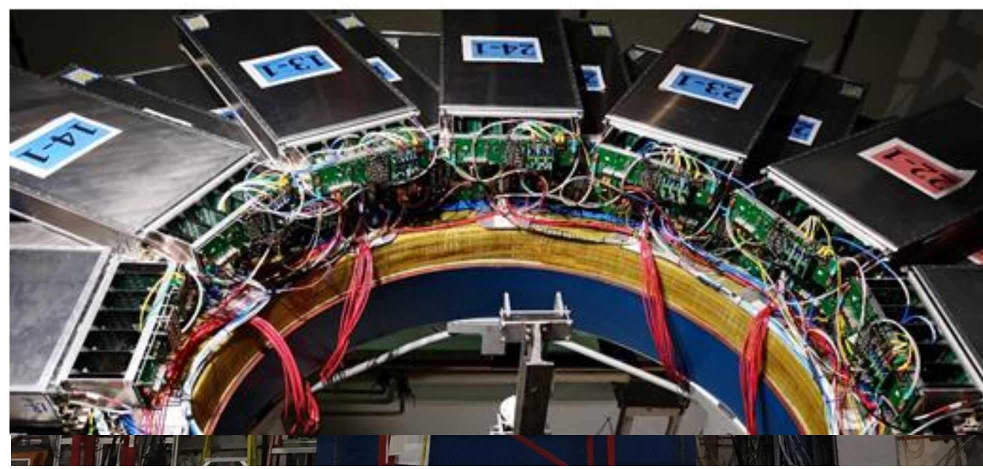
Preparation for transport

# FAIR Phase 0 – eTOF@STAR

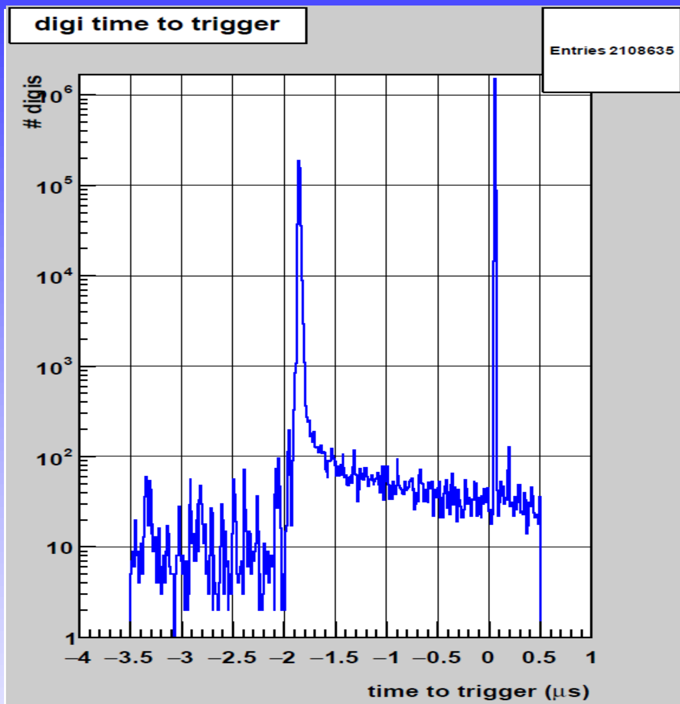
## Full installation in Nov. 2018

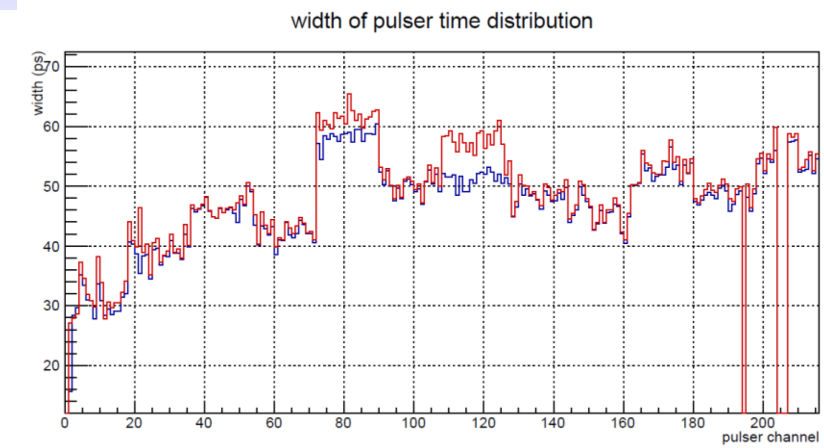




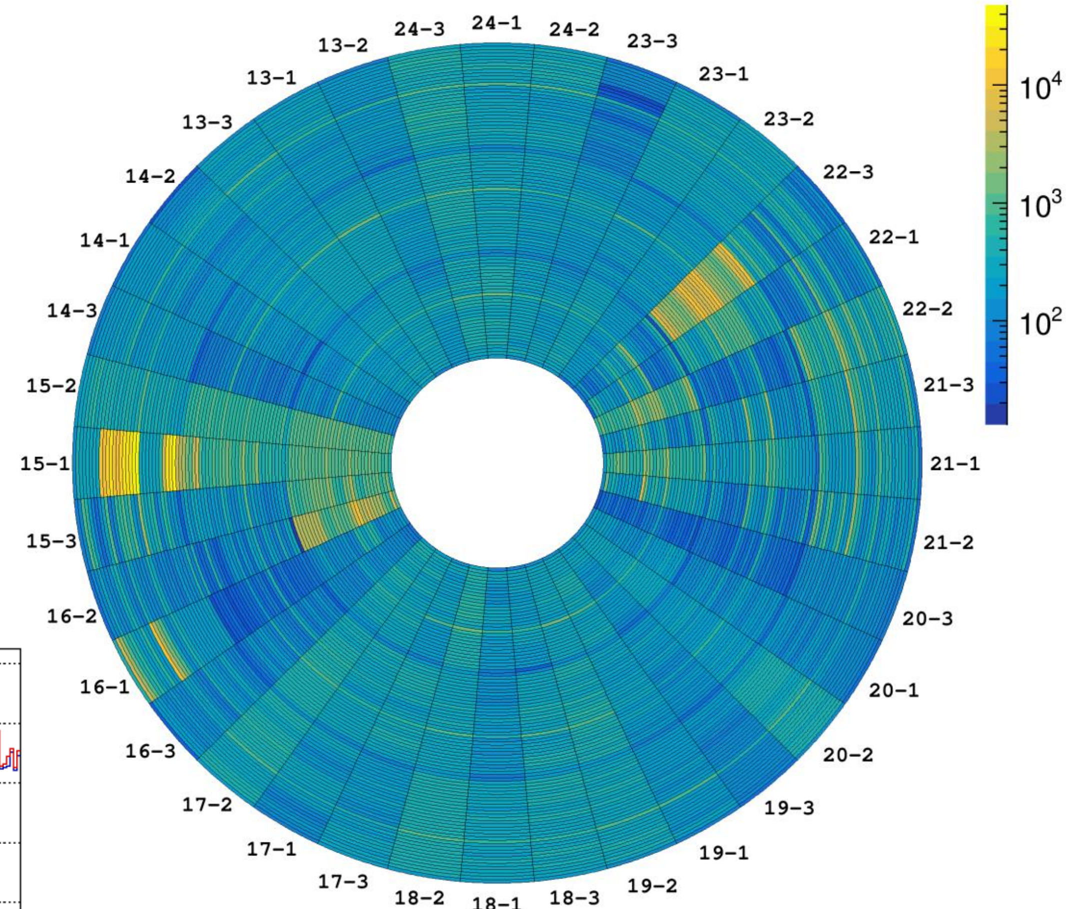



# FAIR Phase 0 – eTOF@STAR



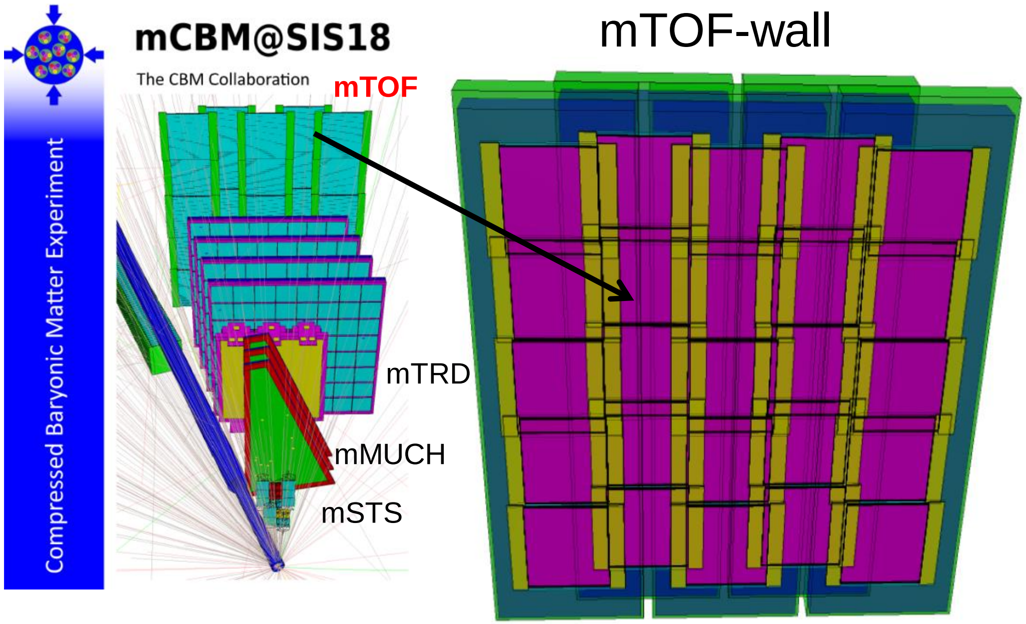




## Full installation in Nov. 2018



# FAIR Phase 0 – mCBM@SIS18

mCBM is a CBM full system test setup at GSI

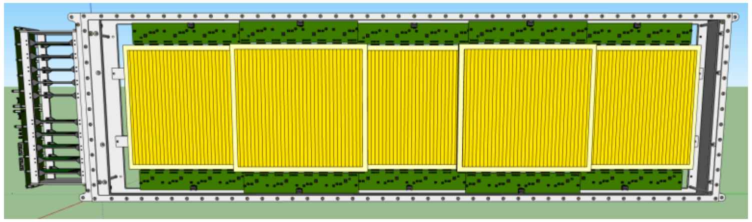



**mCBM program:**

Q1 2019 detector & daq commissioning
Q1 2020 high rate demonstrator
Q1 2021 physics benchmark ($\Lambda$ – prod)
Q1 2022 $\Lambda$ – excitation function

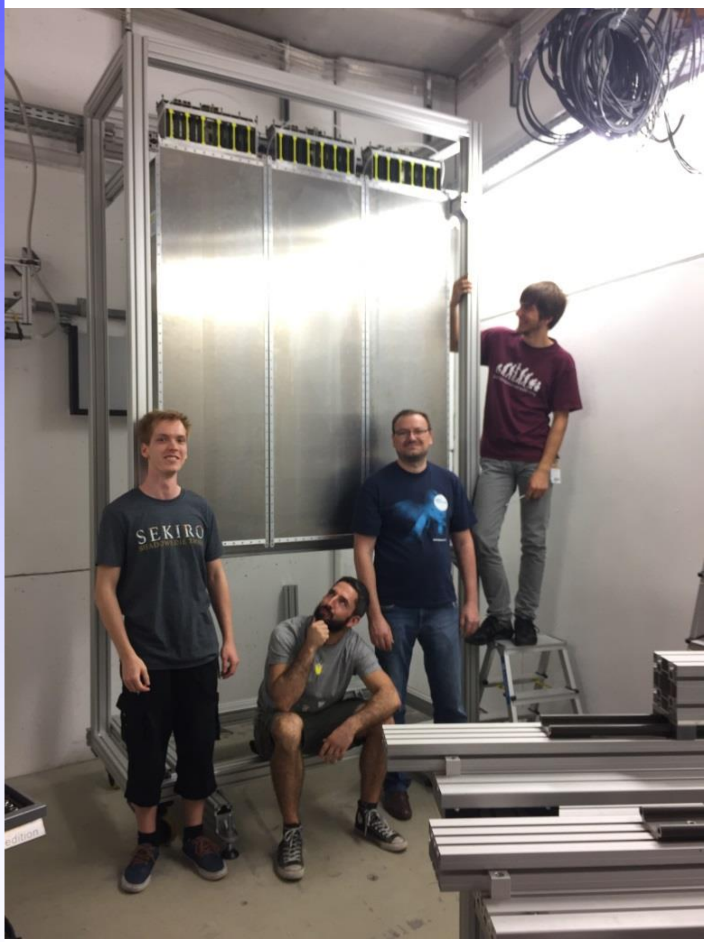
**mTOF setup**

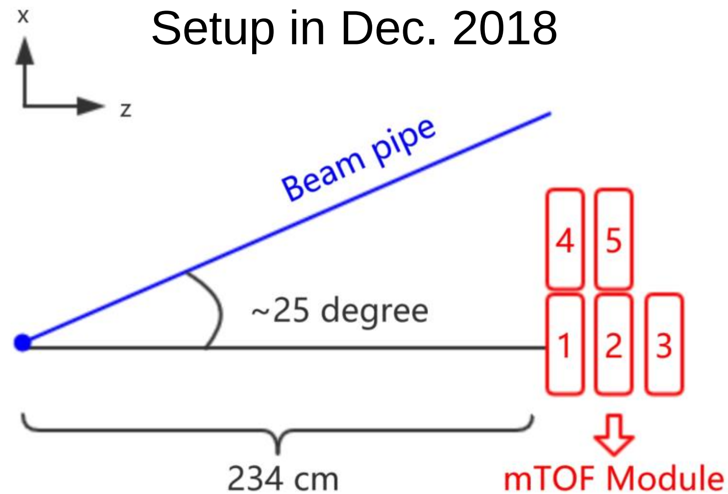
- 25 MRPC3a counters
- 5 M4 modules + 10 CROB(GTBx)
- Active area: 150 x 120 $cm^2$
- # of readout channels: 1600
- T0 diamond counter (8 channels)
- Intended interaction rate: 10 MHz

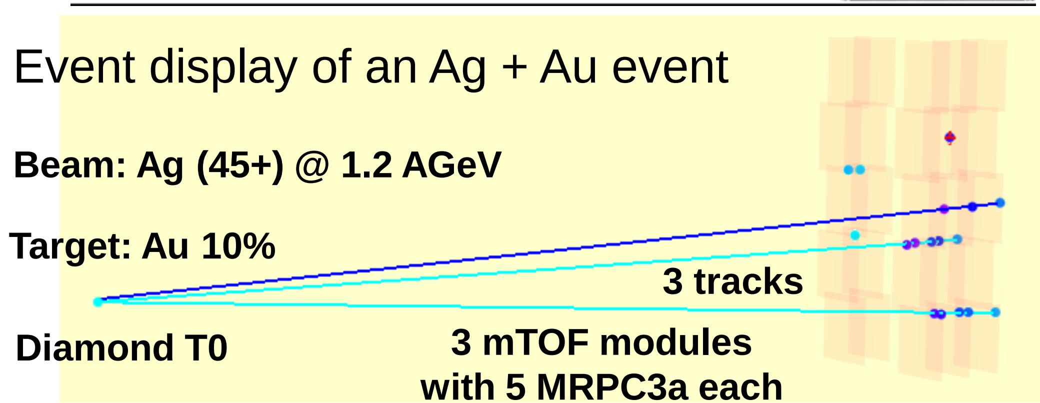


M4 module: 5 MRPC3a counters, 10 PADI, 2 Feed-through PCBs, 10 Get4, 2 backplane PCBs (with GTBx)

## mTOF 1st “commissioning” beam-time in Dec. 18

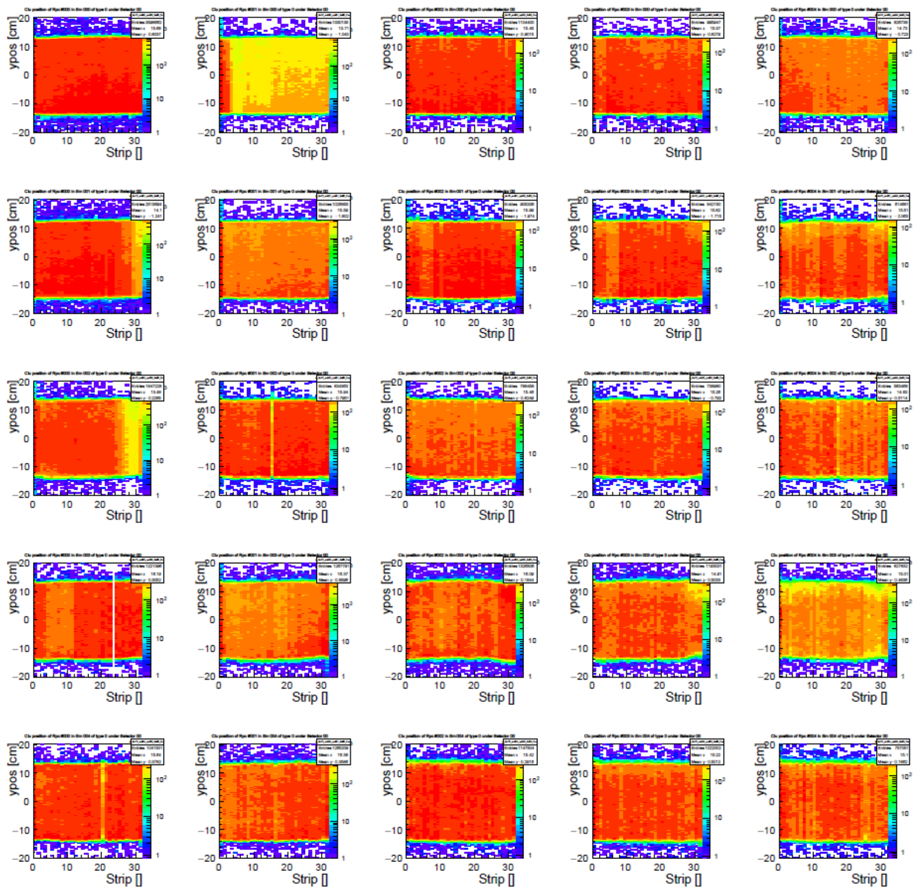




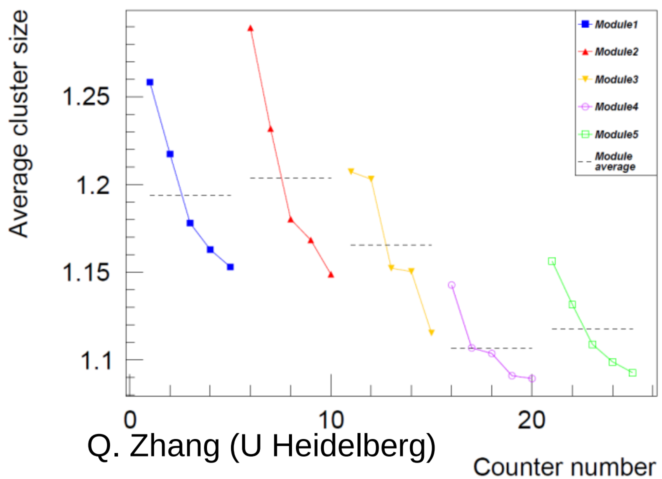



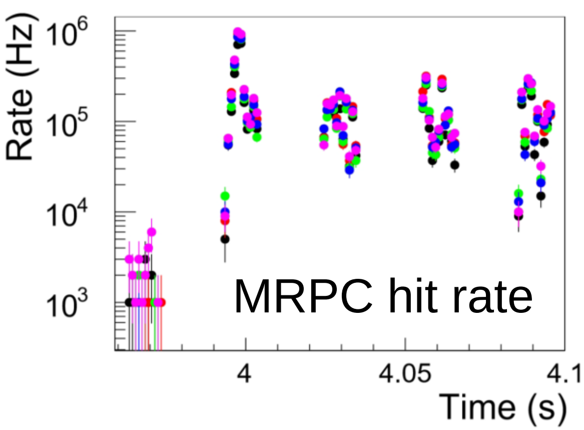
# 1st “commissioning” beam-time in Dec. 18

## Hit occupation on the MRPC surface




## Average cluster size of each counter




**MRPC3a (5 counters)**

**Active area 864 $cm^2$**

**Dark rate 1 – 2 $Hz/cm^2$**

**Flux up to 1 $kHz/cm^2$**

# Summary

- Counters are fulfilling the specs
- R&D for BFTC ongoing
- Innovative impedance matching solution developed
- Preproduction for MRPC3a/b counter finished
- FAIR phase 0 started - looking forward to physics
- Ultra high rate test still pending $\Rightarrow$ miniCBM
- CBM TOF ready for beam in 2024

# Thank you for your attention

CBM ToF

**Contributing institutions:**

Tsinghua Beijing,
NIPNE Bucharest,
GSI Darmstadt,
TU Darmstadt,
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

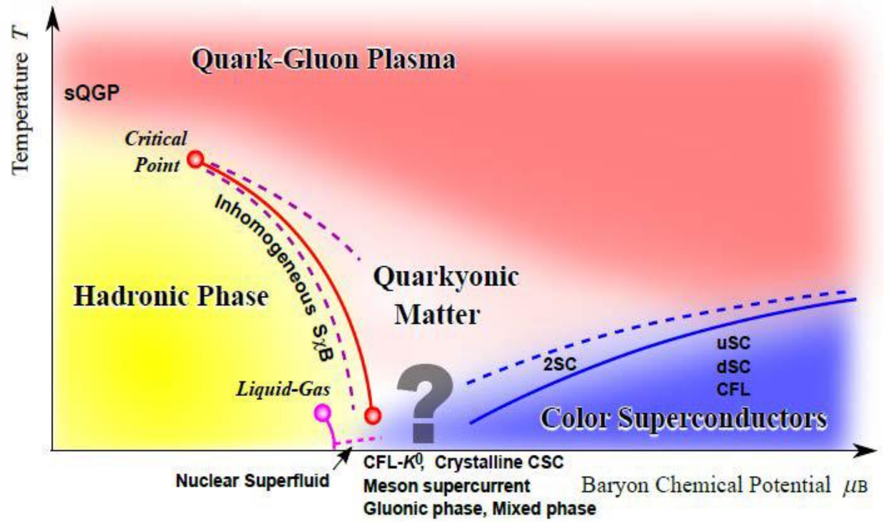
# Backup Slides

# Backup Slides



## CBM Physics topics

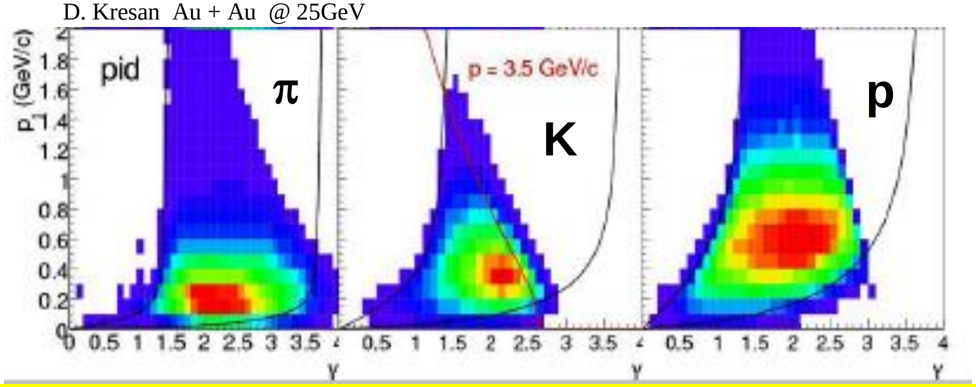
- Deconfinement / phase transition at high $\rho_B$
- QCD critical endpoint
- The equation-of-state at high $\rho_B$
- chiral symmetry restoration at high $\rho_B$




## Observables

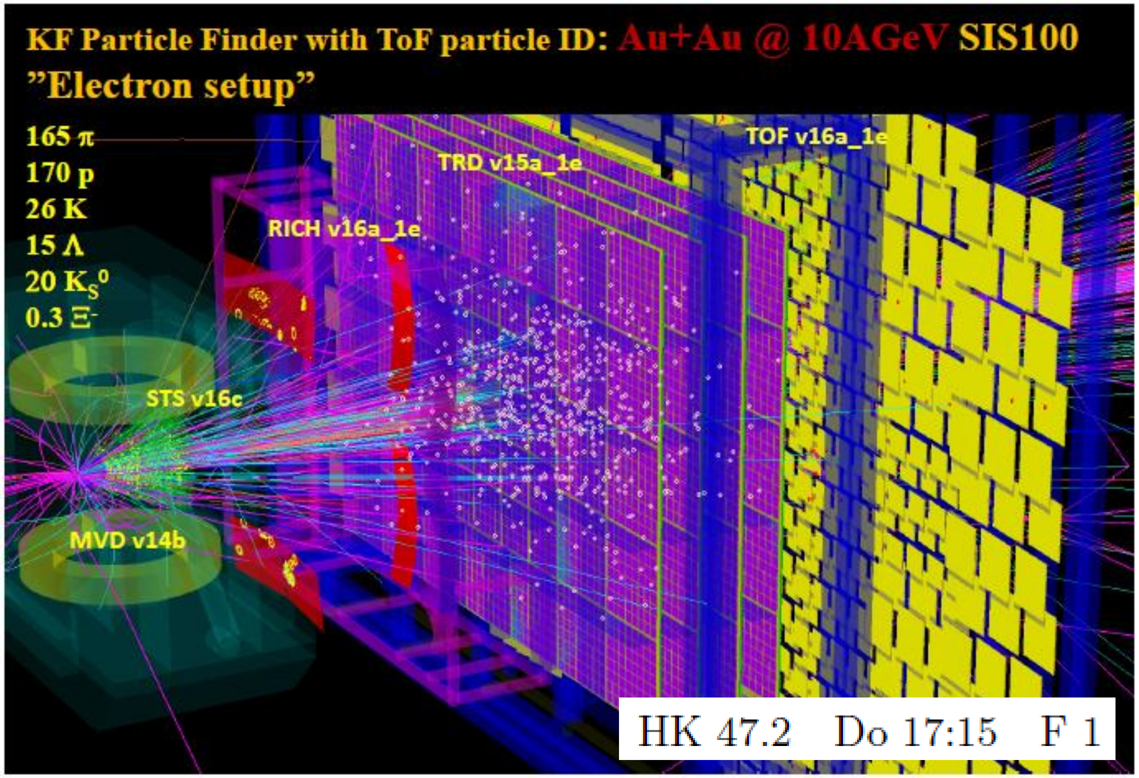
- excitation function and flow of strangeness and charm
- collective flow of hadrons
- particle production at threshold energies
- excitation function of event-by-event fluctuations
- excitation function of low-mass lepton pairs
- in-medium modifications of hadrons ($\rho,\omega,\varphi \rightarrow e^+e^-(\mu^+\mu^-)$,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

D. Kresan Au + Au @ 25GeV

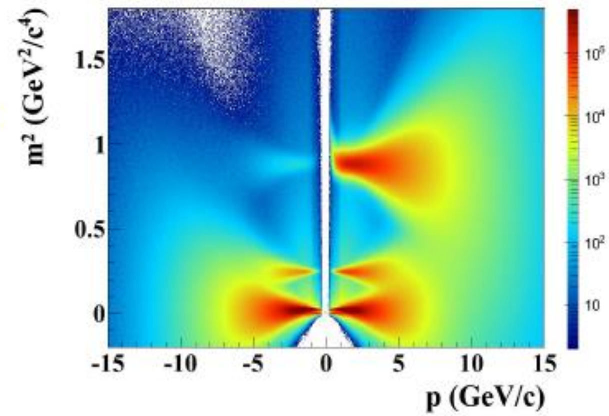


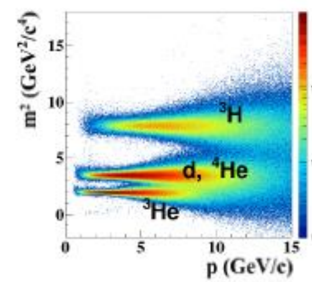

**Kaon acceptance depends critically on TOF resolution**

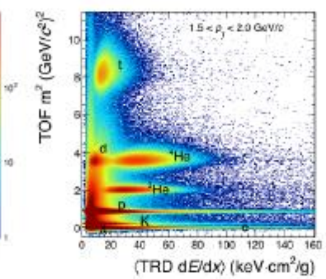
# PID capability

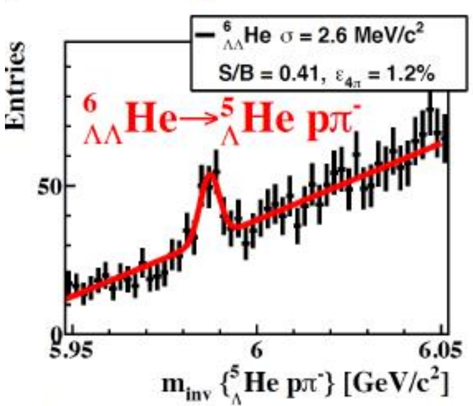


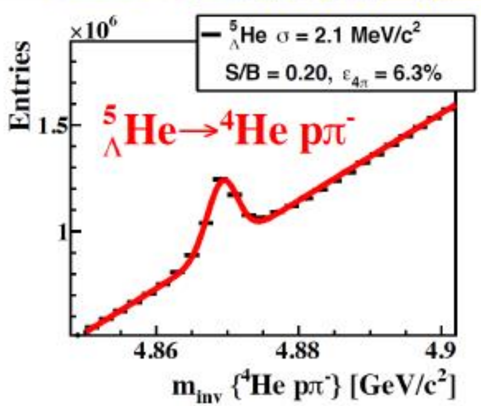

## Particle Identification



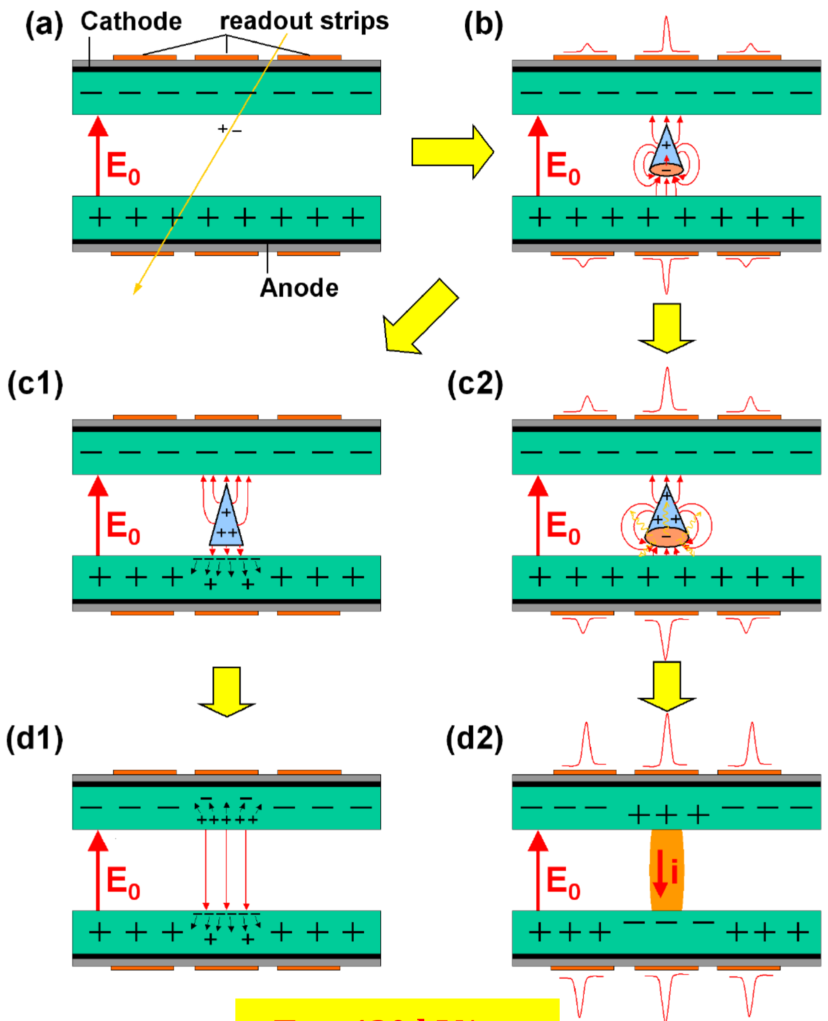




## Reconstruction of double Λ-hypernuclei

- 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

CBM ToF




**First Multi-gap RPC 1996**

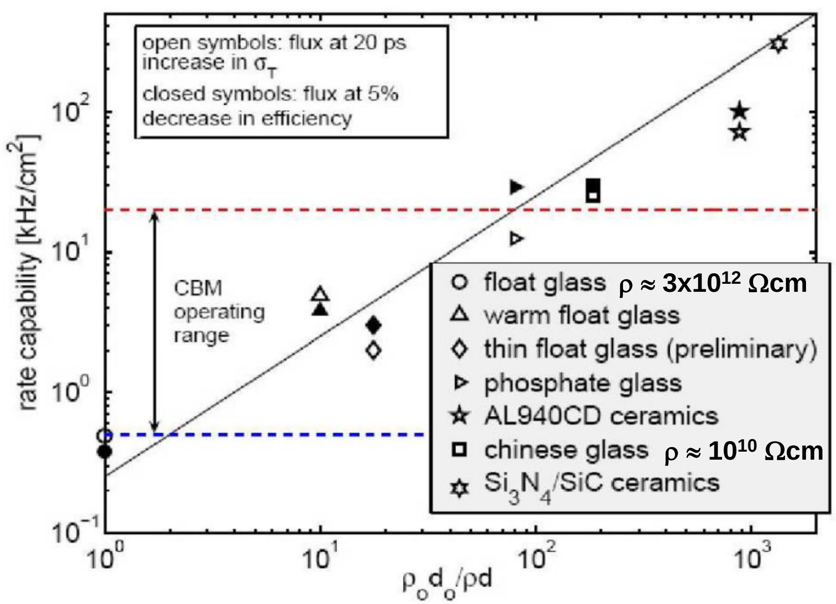
E. Cerron Zeballos et al., **Nucl.Instrum.Meth. A374 (1996) 132-13**

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

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

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

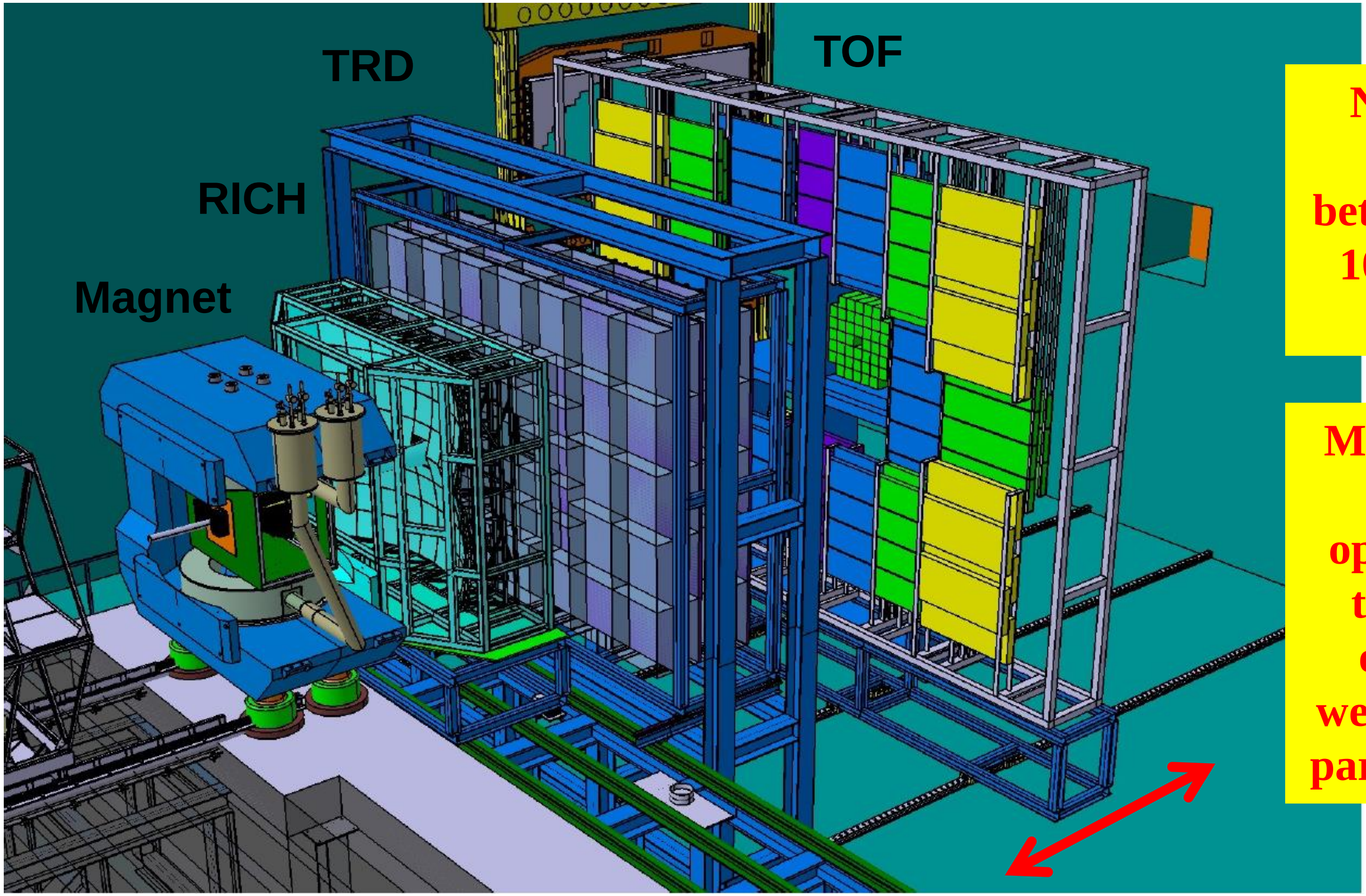
## How to increase the rate capability?




$E_0$ = 120 kV/cm

# 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)**

# Backup Slides

## 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**

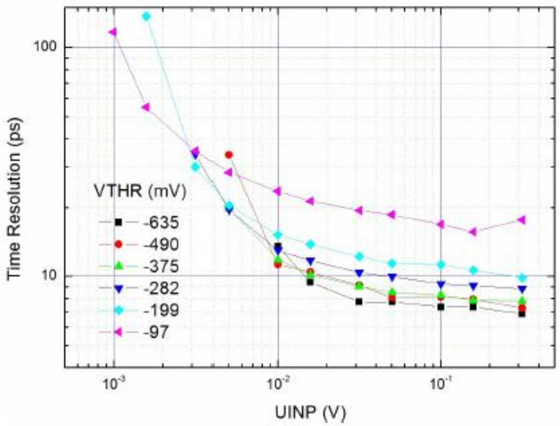
- peripheral HI – reaction have fast particles from projectile fragmentation
- equip region E with timing counters (BFTC)

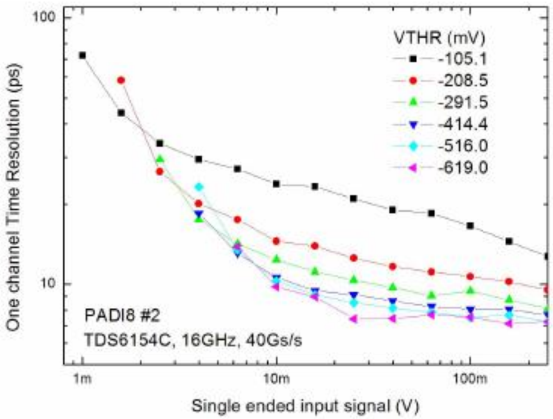
**Reaction counter**

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

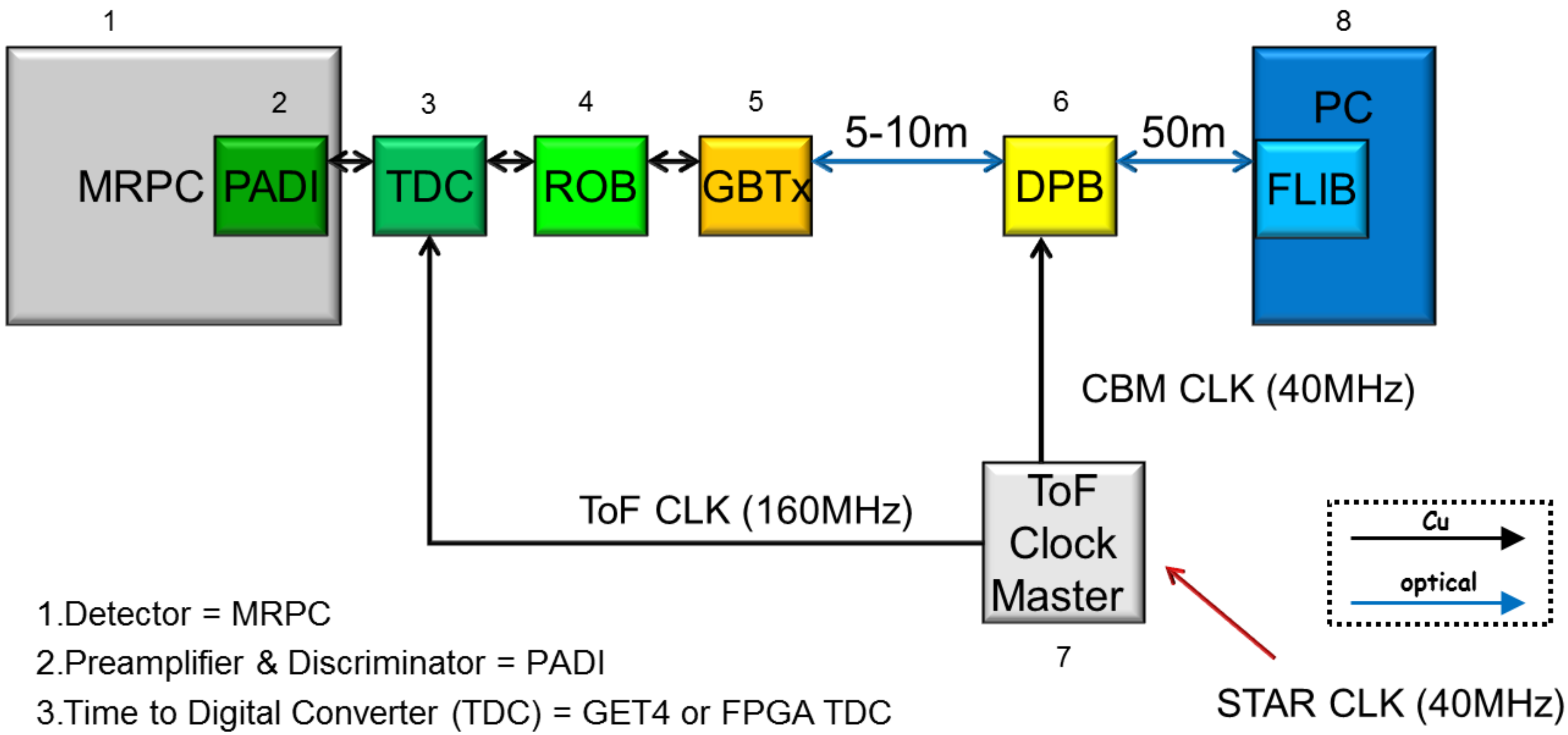
# Backup Slides

| 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

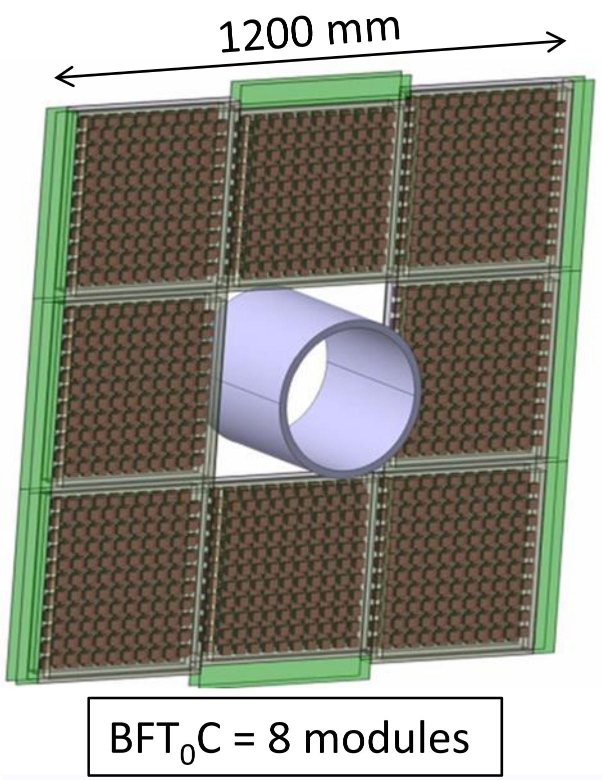


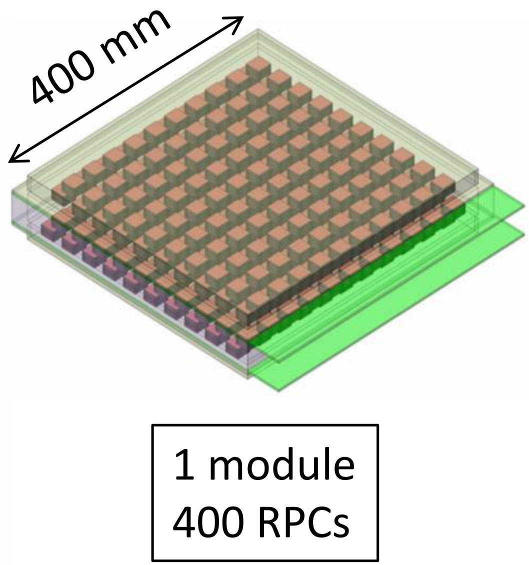

1. Detector = MRPC
2. Preamplifier & Discriminator = PADI
3. Time to Digital Converter (TDC) = GET4 or FPGA TDC
4. Readout board for TDC = **1st concentrator stage**
5. GBTx = Data Concentrator ASIC from CERN = **2nd concentrator stage**
6. Data Processing Board = **3rd concentrator stage**
7. Clock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

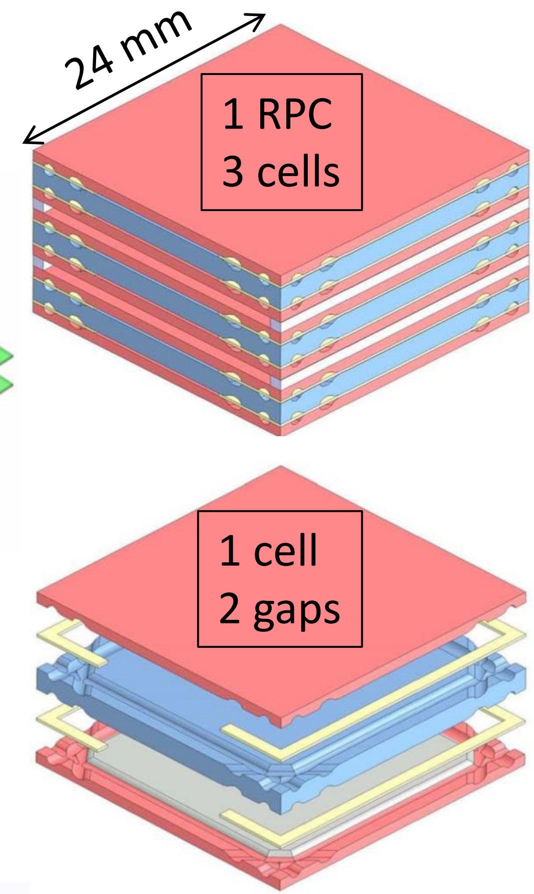
# Ceramic RPCs for BFTC



- 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.

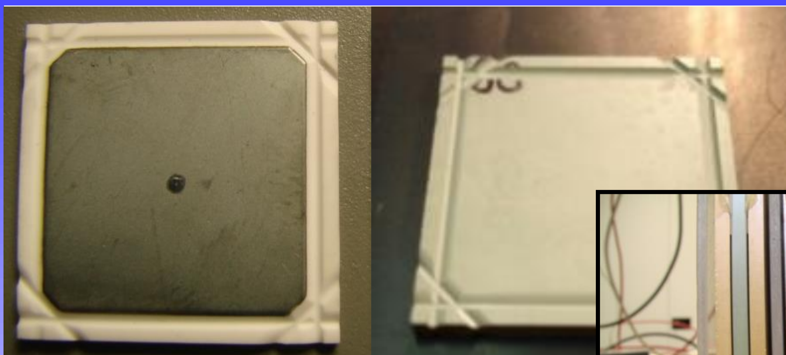


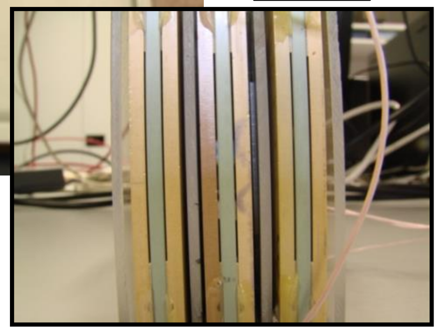
# Ceramic RPCs for BFTC

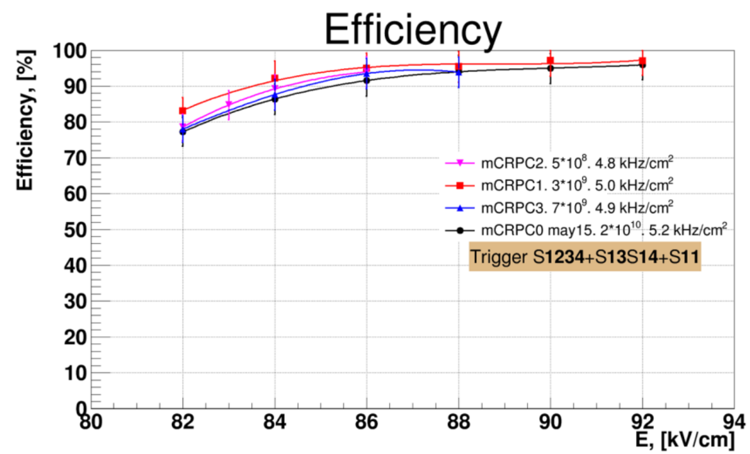
CBM ToF

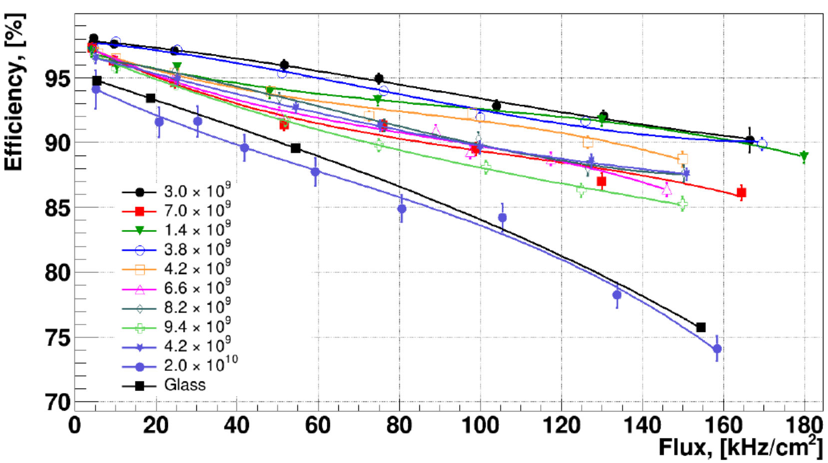


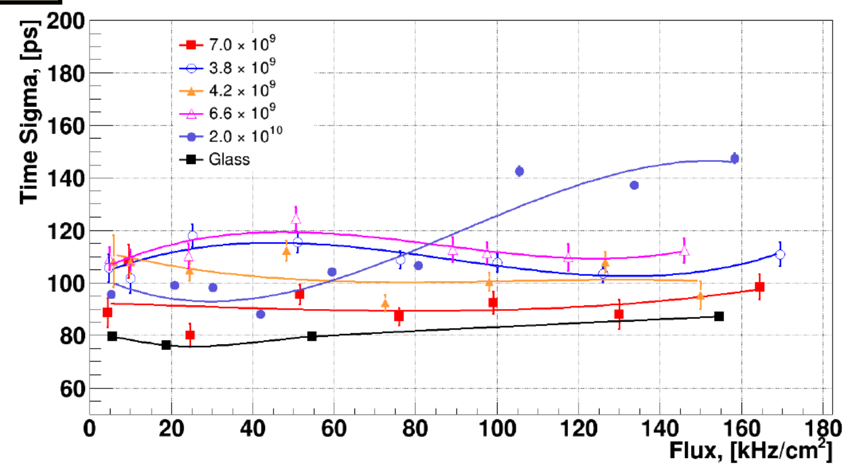
electrodes

RPC





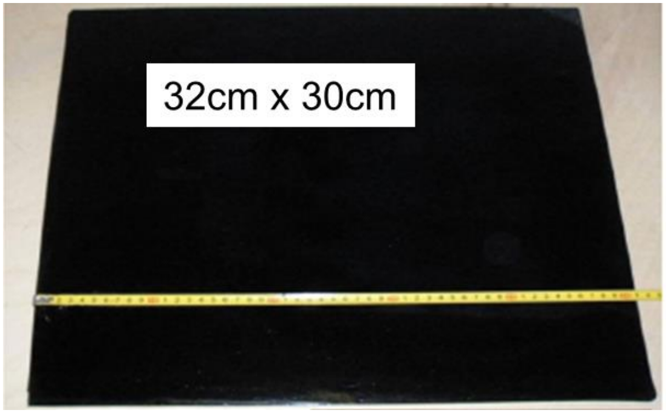

$4 \times 10^9\ \Omega$cm: most suitable resistivity order for application in CBM

# Resistive Glass Development

CBM ToF

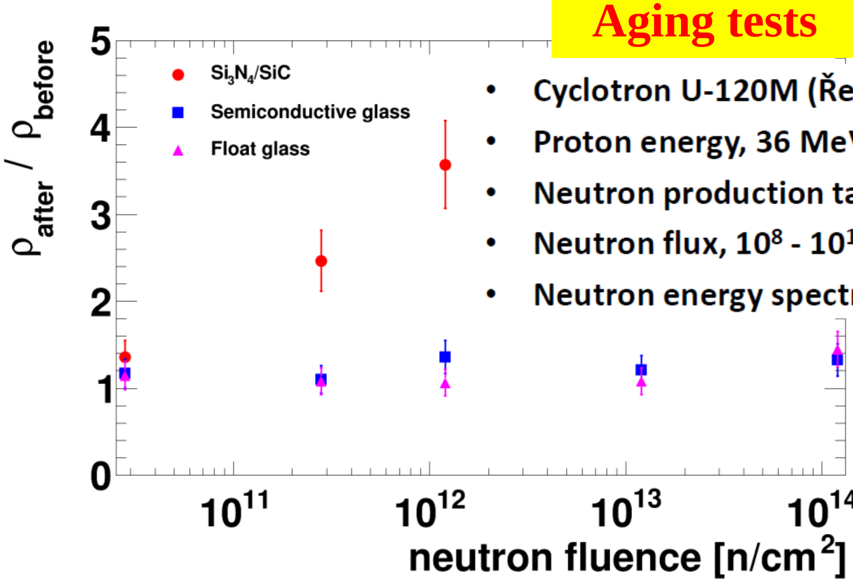
**Resistive glass for high-rate MRPCs is developed in Beijing, China**

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



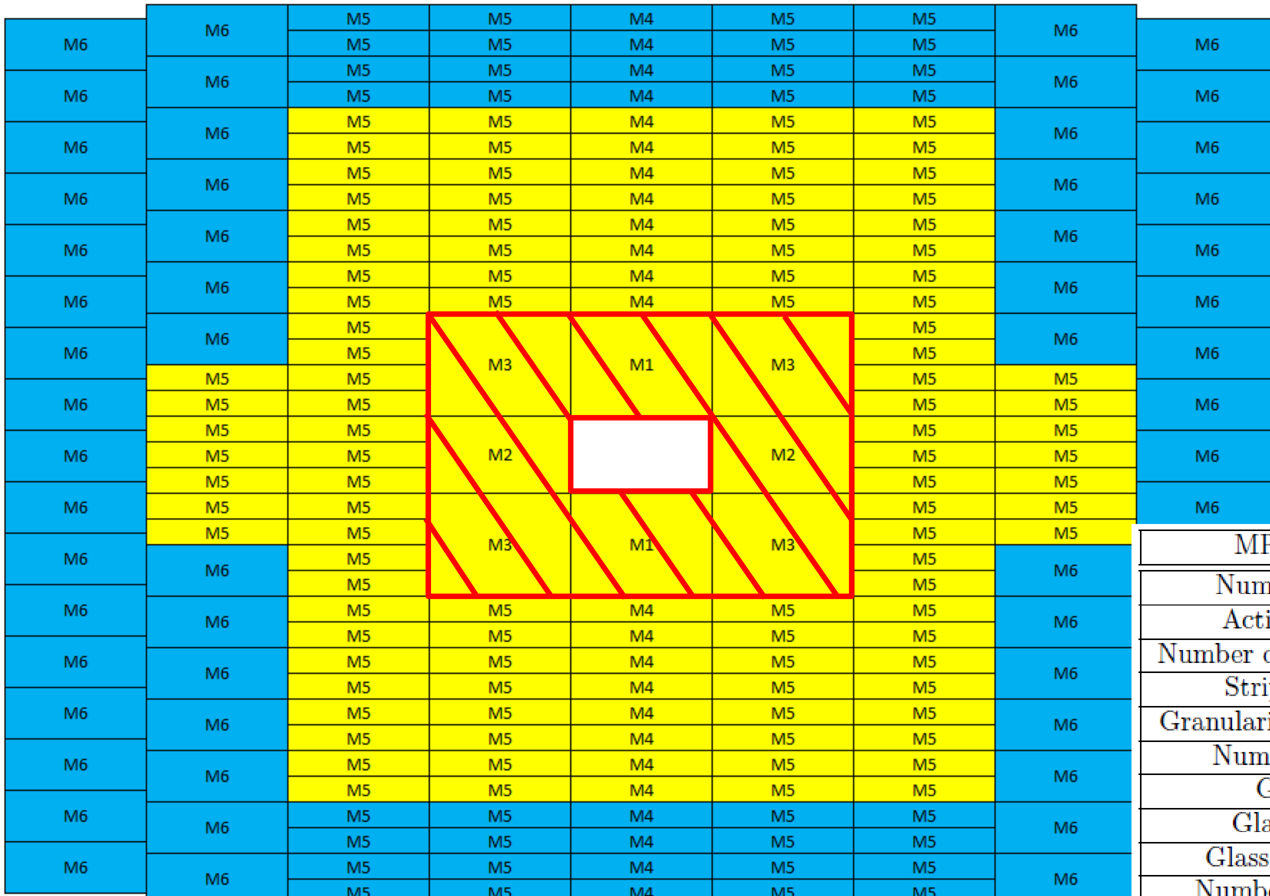

**Raw resistive glass material for 400 $m^2$**

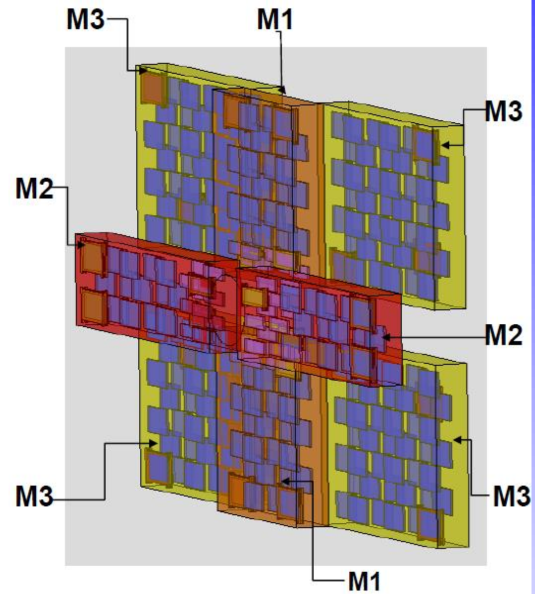
**Aging tests**




- 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



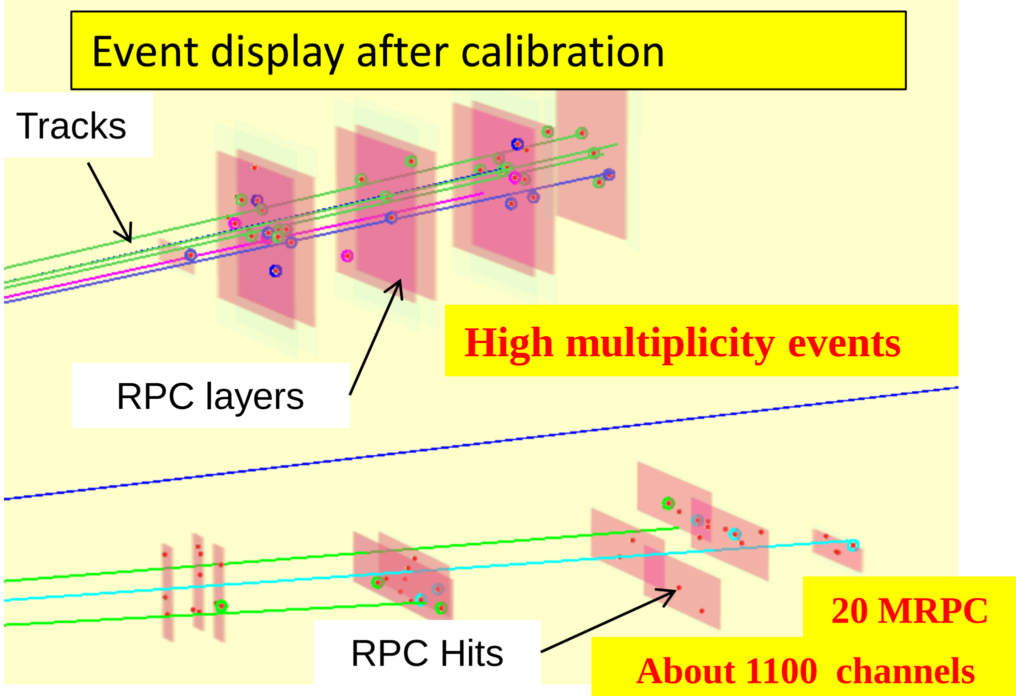



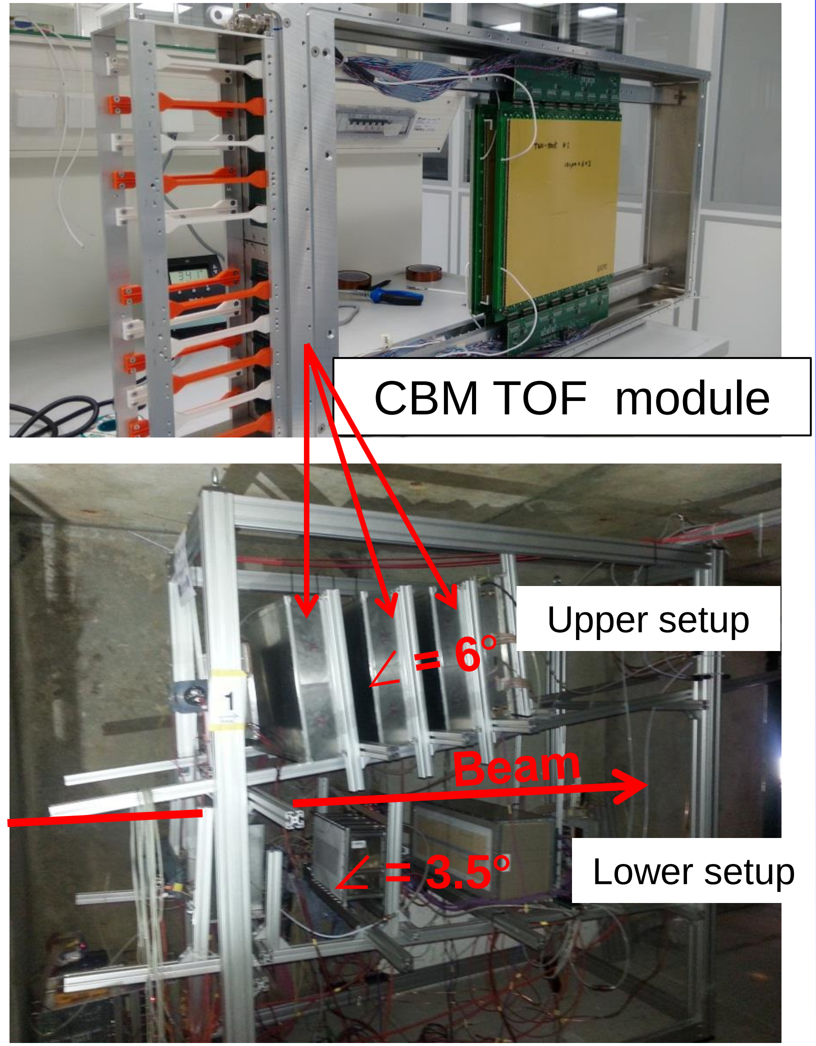

| MRPC notation | MRPC1 | MRPC2 |
|---|---|---|
| Number of MRPCs | 40 | 246 |
| Active area [$mm^2$] | $300 \times 100$ | $300 \times 200$ |
| Number of Strips per MRPC | 64 | 64 |
| Strip length [mm] | 100 | 200 |
| Granularity (cell size) [$mm^2$] | 472.4 | 944.8 |
| Number of gas gaps | 10 | 10 |
| Gap size $\mu m$ | 140 | 140 |
| Glass size [$mm^2$] | $320 \times 100$ | $320 \times 200$ |
| 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

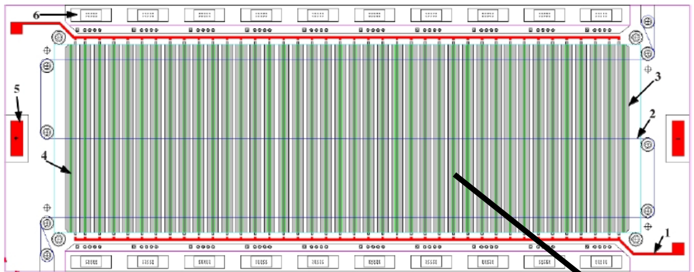
Beam-time @ SPS North Area in Nov. 2015
Beam: Lead @ 30A GeV
Target: Lead 1 mm
Intensity: $10^7$ / spill
Spill length: 8 s
Rates: few 100 Hz/cm$^2$ - 1 kHz/cm$^2$
Energy close to SIS300 conditions



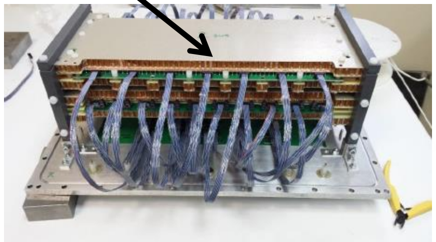



# Beam-time @ SPS in Nov. 2015

MRPC1/2 prototype developed at Bucharest

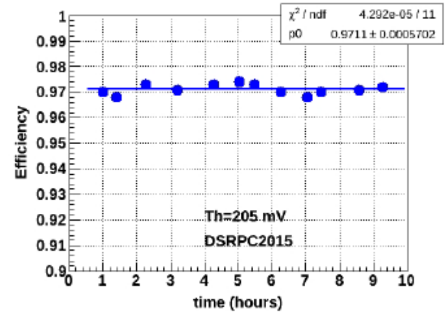


1 – HV strip; 2 – spacer (fising line); 3 – HV strips, 4 – signal strips; 5 – HV pad connection; 6 – signal connector

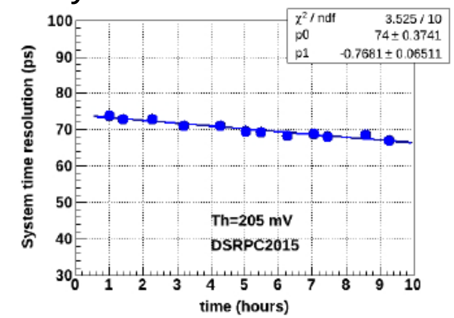


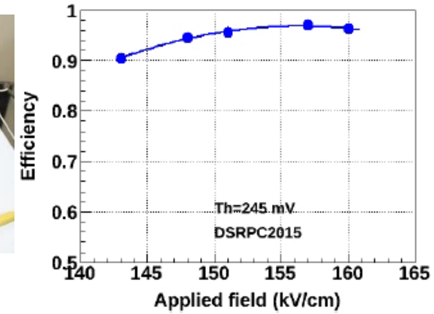
- Metal HV strip electrodes
- Innovative method of impedance matching
- Impedance independent of the granularity adjustable
- Impedance tuned to 100 Ω
- arXiv:1708.02707

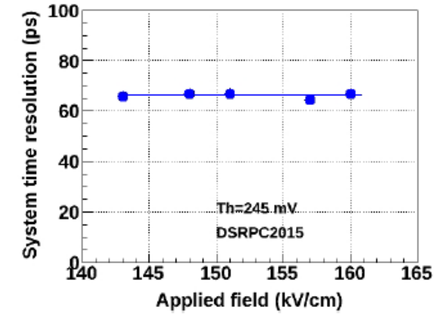
Efficiency




System time resolution




Beam time setup at CERN