# RPC 2018 – XIV Workshop on Resistive Plate Chambers and Related Detectors

# The CBM Time-of-Flight wall

**Ingo Deppner**

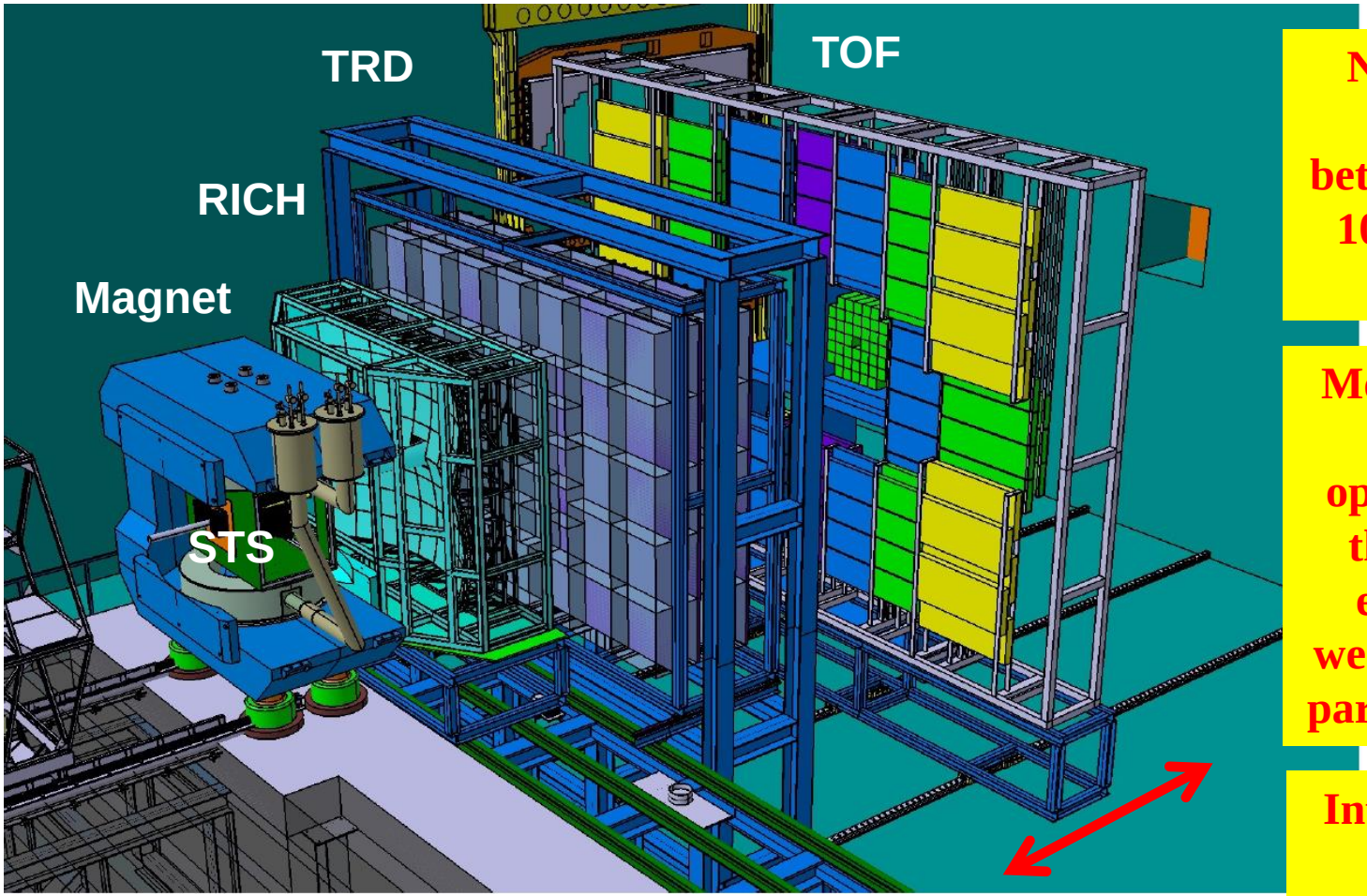
**Physikalisches Institut der Uni. Heidelberg**

**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**

# CBM spectrometer

## Engineering design of the CBM experiment

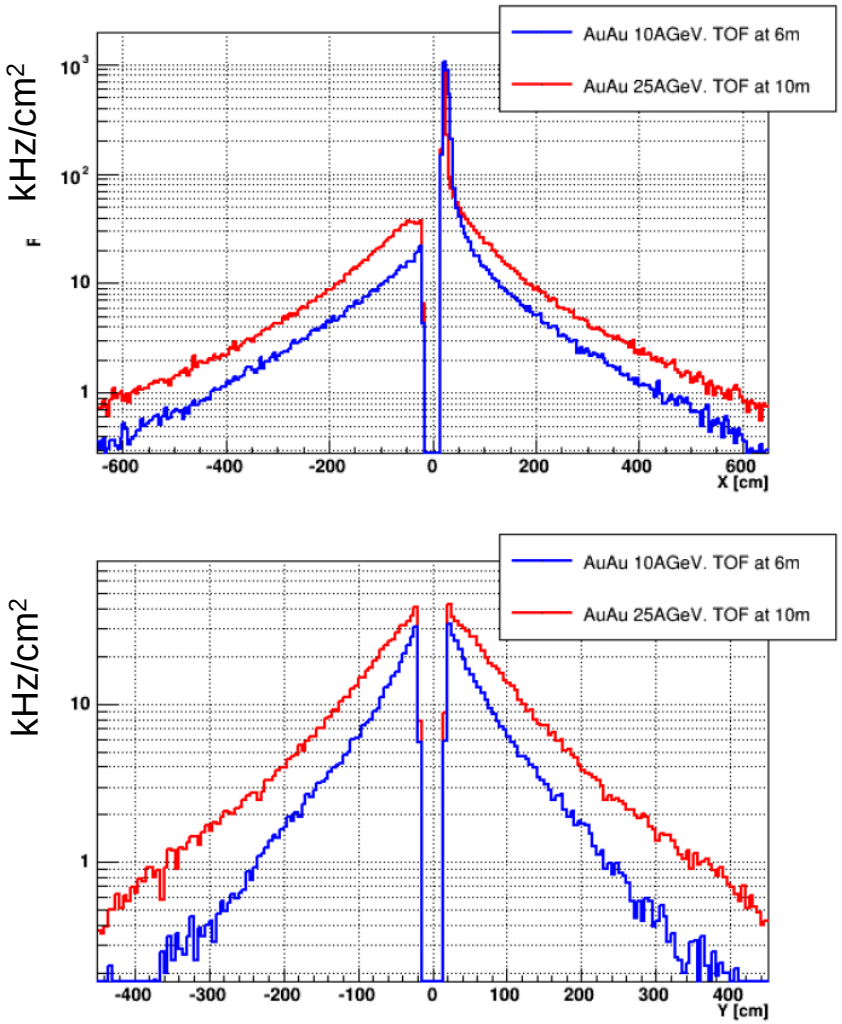



**Nominal ToF position is between 6 m and 10 m from the target**

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

**Interaction rate 10 MHz**

# Incident particle flux

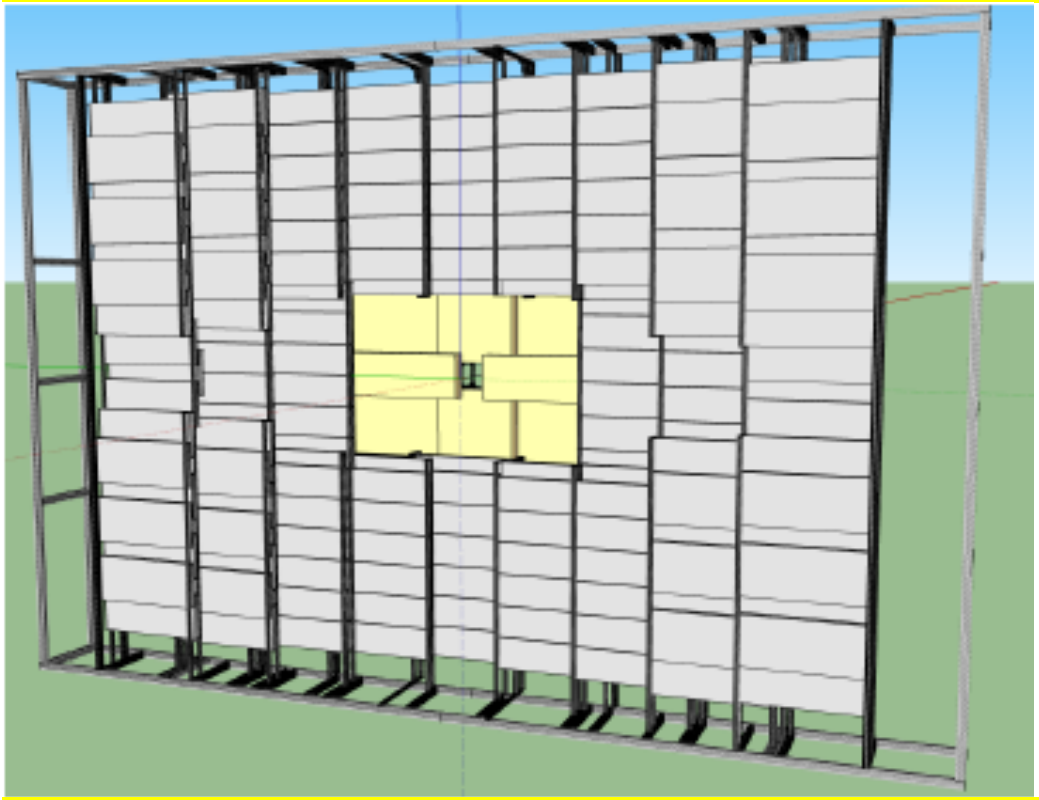



**URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz**

- 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**

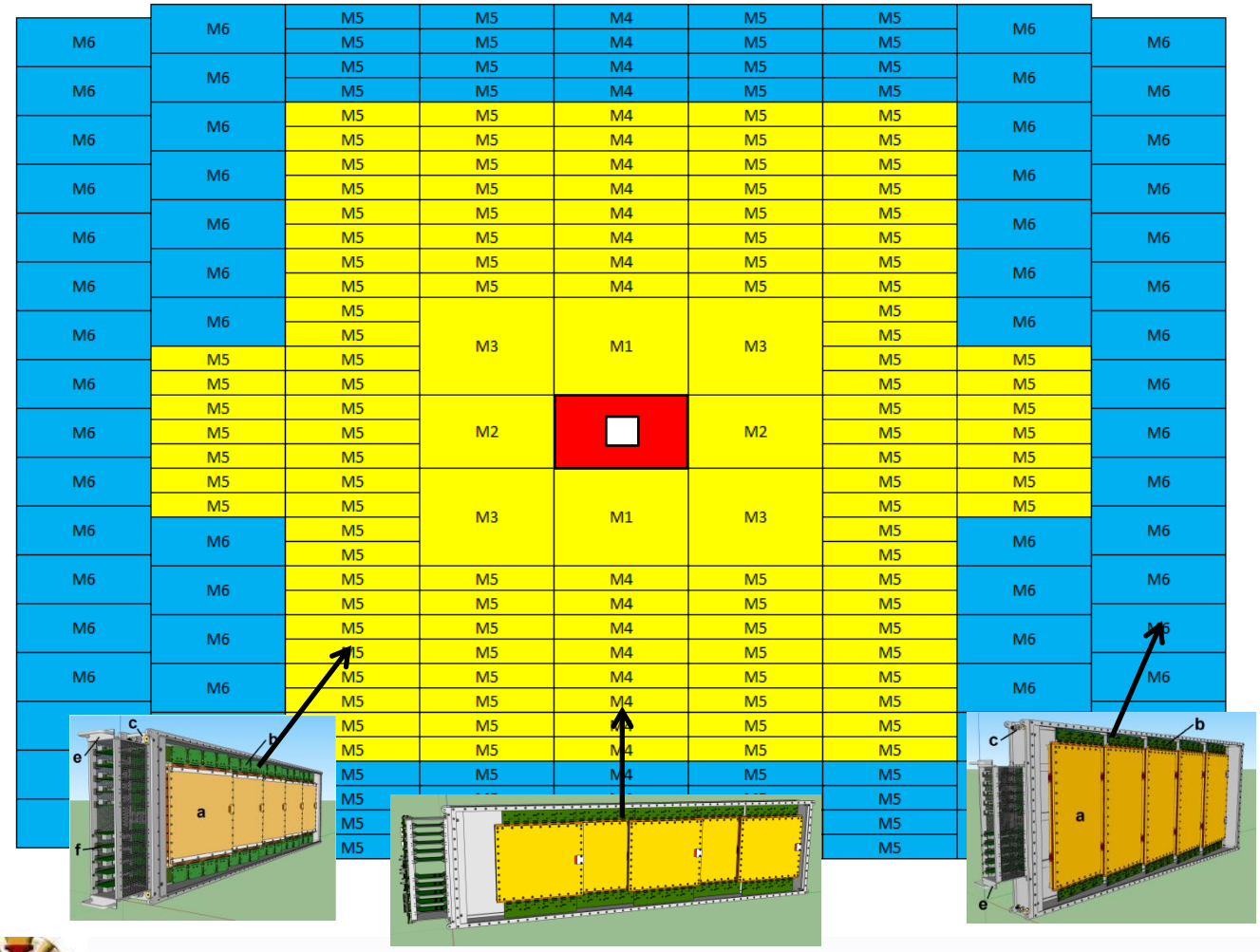


## CBM-ToF Requirements

- 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

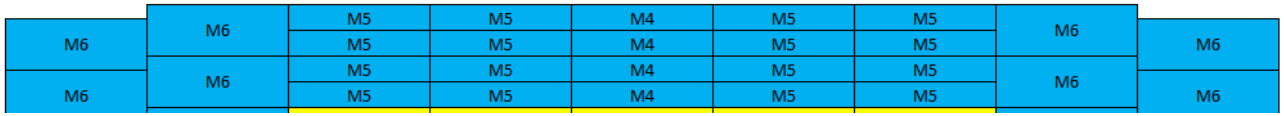
**Multi-gap Resistive Plate Chambers (MRPC) are the most suitable ToF detectors fulfilling our requirements**

# 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

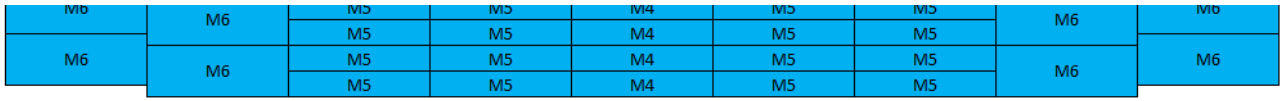
# TDR ToF wall layout




- **6 types of modules (M1 – M6) only**

| Module notation | Number of modules | Module size $mm^3$ | Number of MRPCs per module | Number of MRPCs in total | Number of cells per module | Number of cells in total |
|---|---|---|---|---|---|---|
| M1 | 2 | 1270 × 1417 × 239 | 32 | 64 | 2048 | 4096 |
| M2 | 2 | 2140 × 705 × 239 | 27 | 54 | 1728 | 3456 |
| M3 | 4 | 1850 × 1417 × 239 | 42 | 168 | 2688 | 10752 |
| M4 | 24 | 1802 × 490 × 110 | 5 | 120 | 160 | 3840 |
| M5 | 132 | 1802 × 490 × 110 | 5 | 660 | 160 | 21120 |
| M6 | 62 | 1802 × 740 × 110 | 5 | 310 | 160 | 9920 |
| Sum | 226 | | | 1376 | | 53184 |

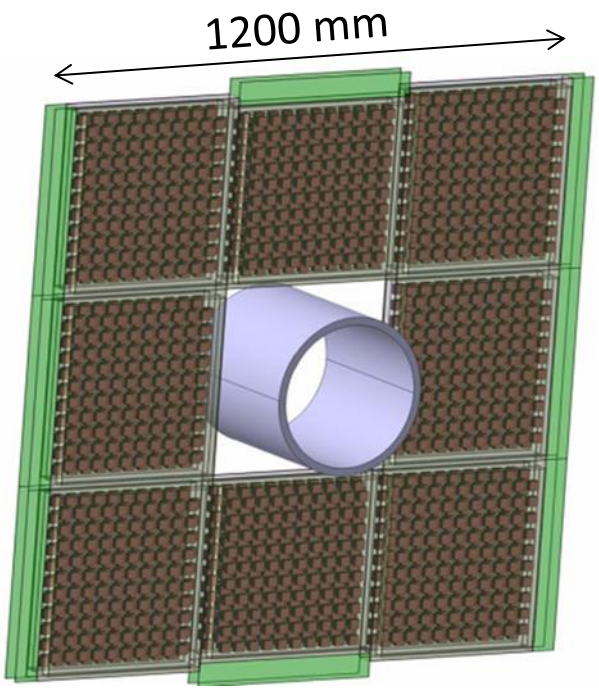
***Table 3.1:*** *Numbers and dimensions of the modules.*



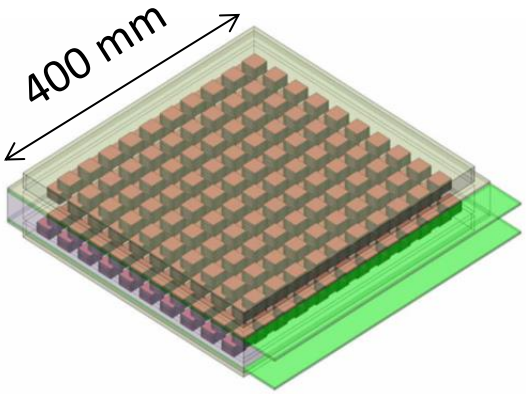

**⇒ 106368 read-out channels**

# Ceramic RPCs for BFTC

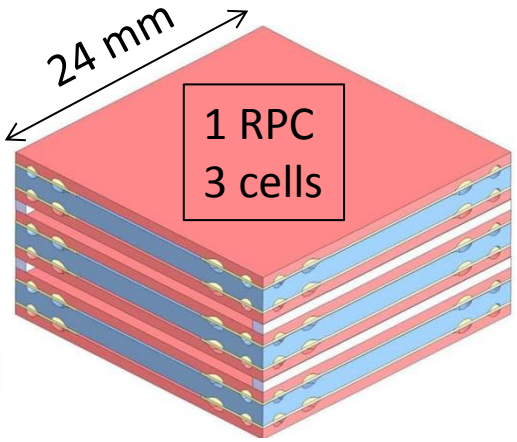
Important scopes of High Energy Heavy Ion experiments are the start-time and the reaction-plane determination. For CBM the use of RPC for the Beam Fragmentation $T_0$ Counter ($BFT_0C$) with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration.

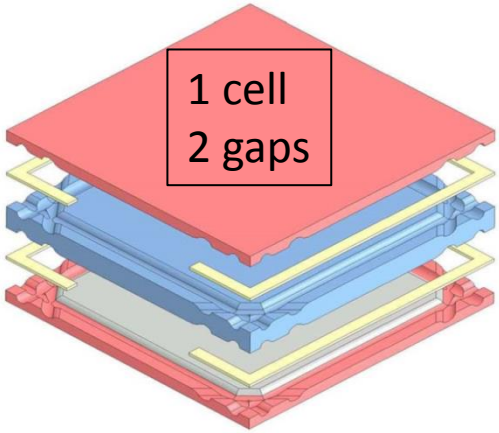



$BFT_0C$ = 8 modules




1 module
400 RPCs



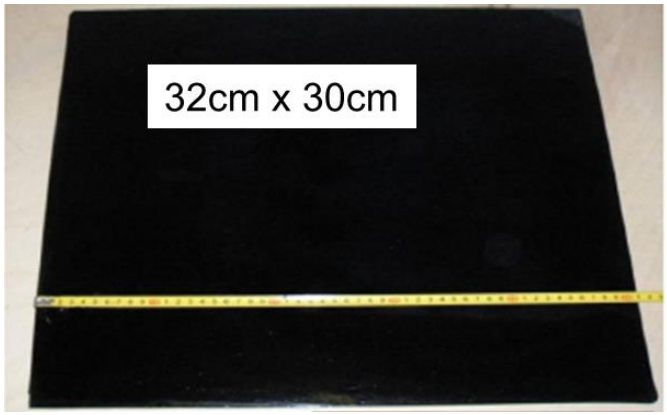



**See talk of Lothar Naumann on 23.02 at 11:10**

# Resistive Glass Development

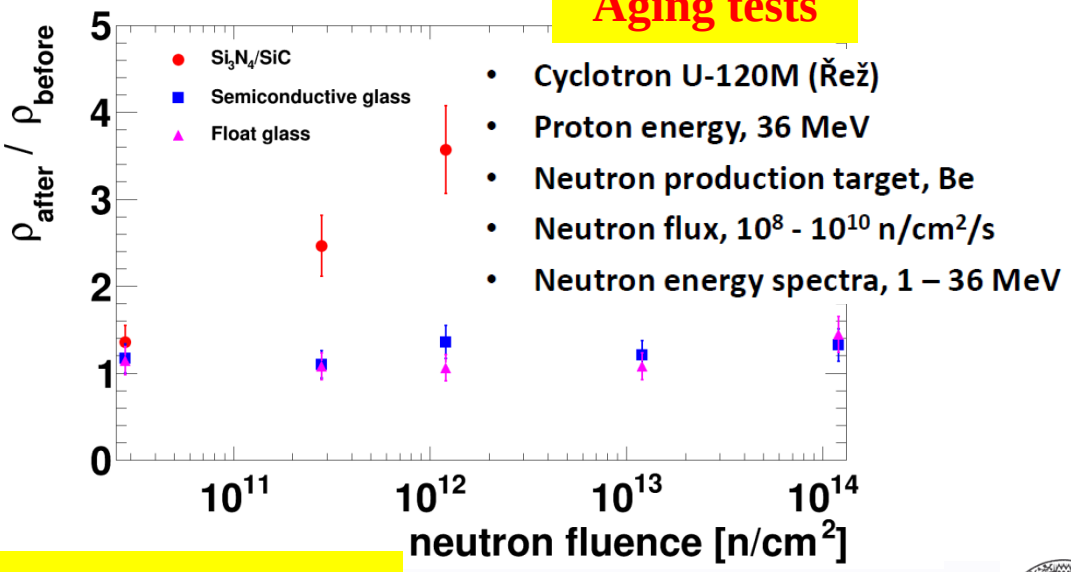
**Resistive glass for high-rate MRPCs is developed in Beijing, China**

| | |
|---|---|
| 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$^2$

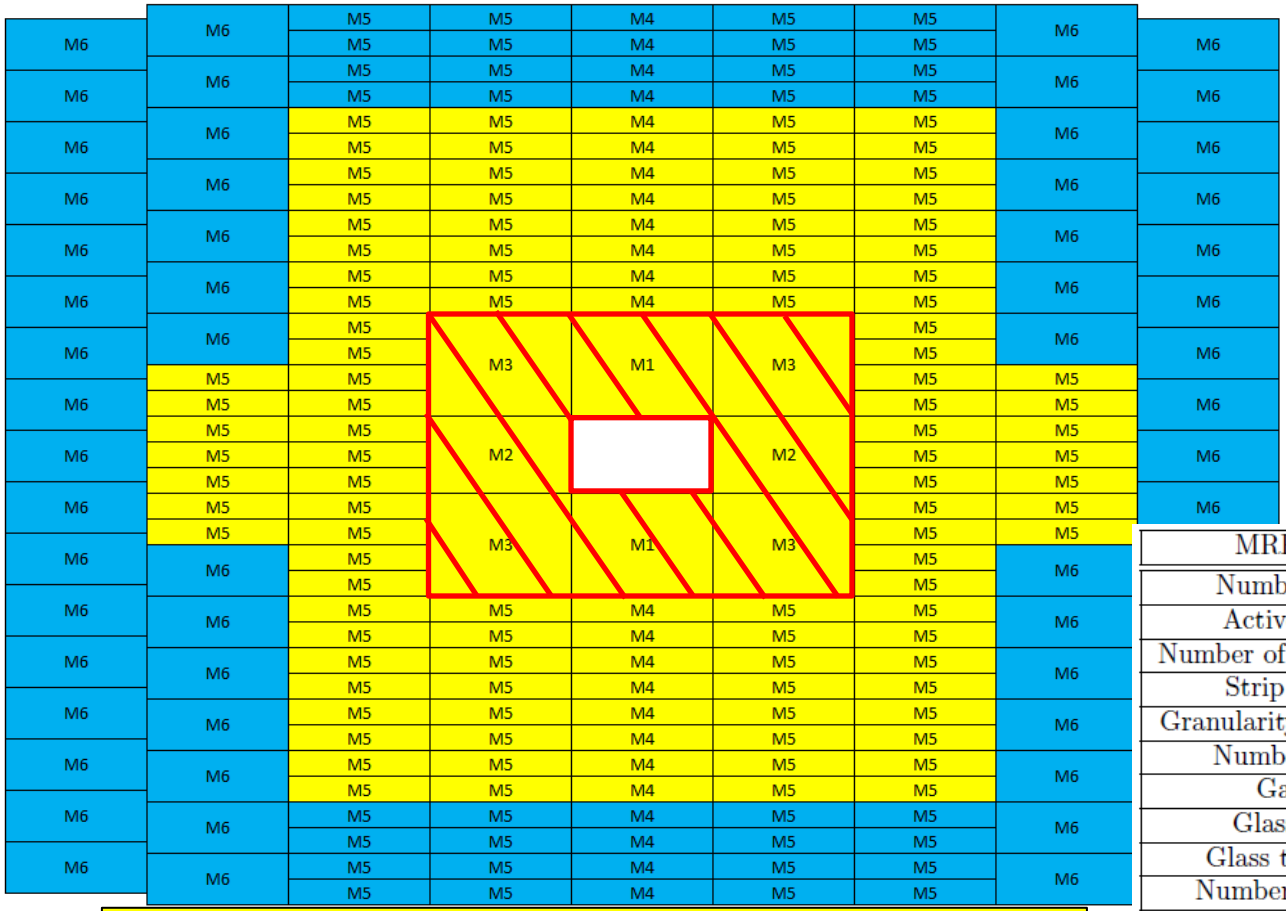
**Aging tests**

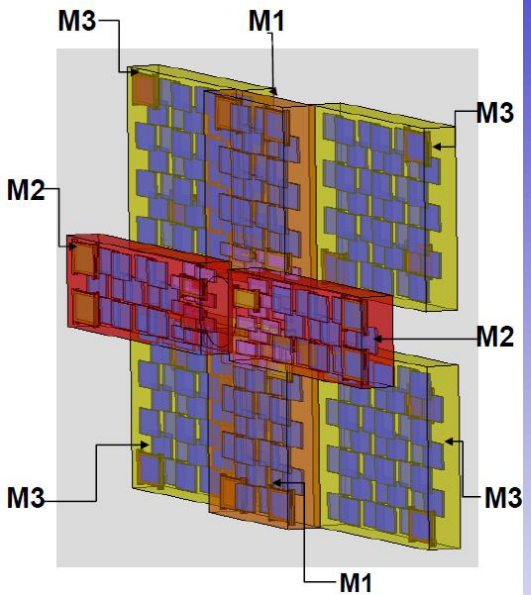



- Cyclotron U-120M (Řež)
- Proton energy, 36 MeV
- Neutron production target, Be
- Neutron flux, $10^8$ - $10^{10}$ n/cm$^2$/s
- Neutron energy spectra, 1 – 36 MeV

**See talk of Yi Wang on 23.02 at 09:30**

# TDR ToF wall layout high rate region



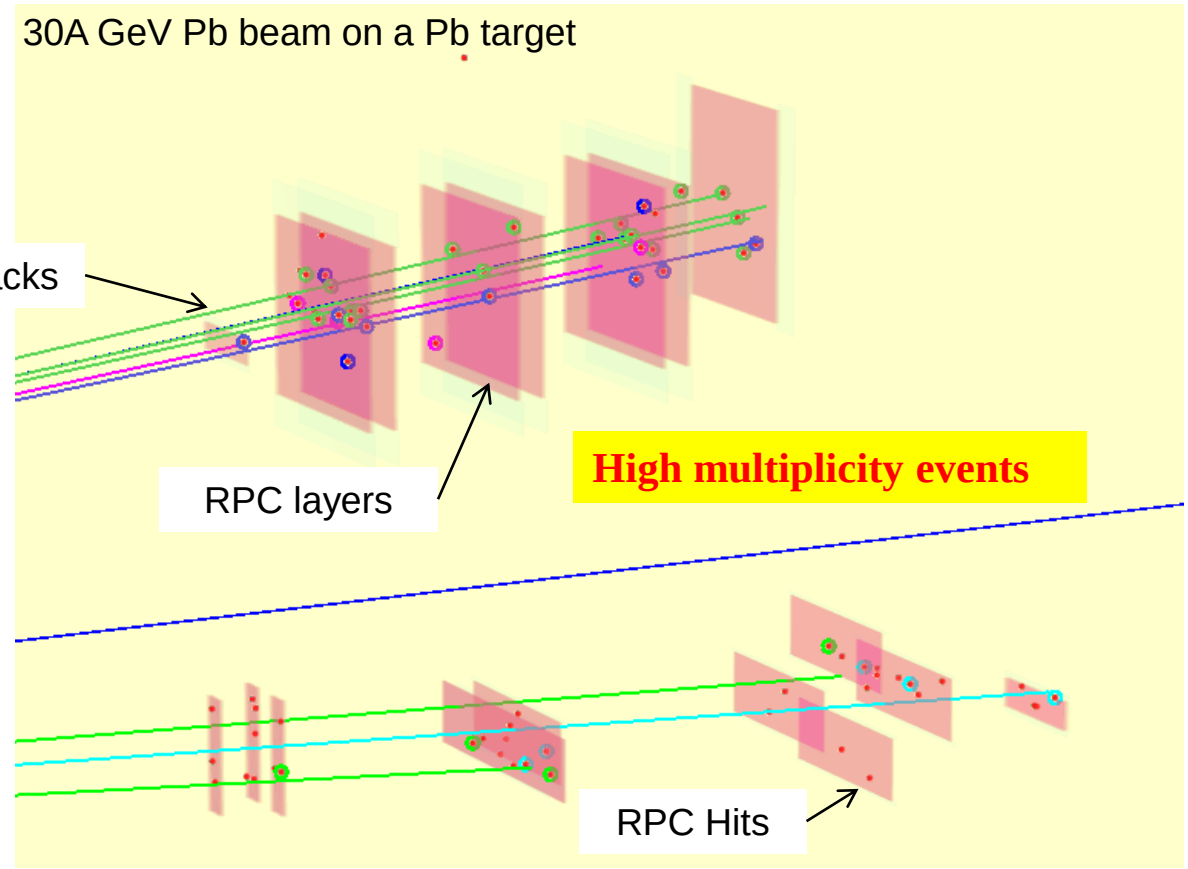




| MRPC notation | MRPC1 | MRPC2 |
|---|---|---|
| Number of MRPCs | 40 | 246 |
| Active area [mm$^2$] | 300 × 100 | 300 × 200 |
| Number of Strips per MRPC | 64 | 64 |
| Strip length [mm] | 100 | 200 |
| Granularity (cell size) [mm$^2$] | 472.4 | 944.8 |
| Number of gas gaps | 10 | 10 |
| Gap size $\mu$m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

Event display after position calibration

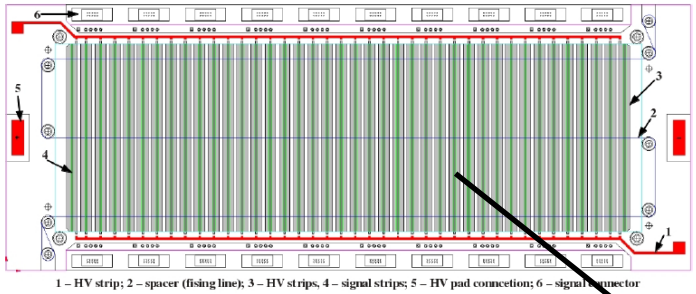


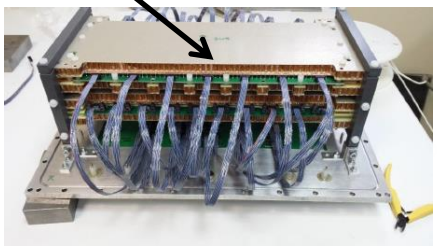

- 1 Track (blue) with hit multiplicity 8
- 2 Tracks (green) with hit multiplicity 7
- 1 Track (light blue) hit with multiplicity 6
- 1 Track (pink) with hit multiplicity 5

**The opportunity to reconstruct tracks offers new possibilities to analyze and study the counters in much greater detail:**
**multi hit response,**
**2d position dependencies**

# Beam-time @ SPS in Nov. 2015

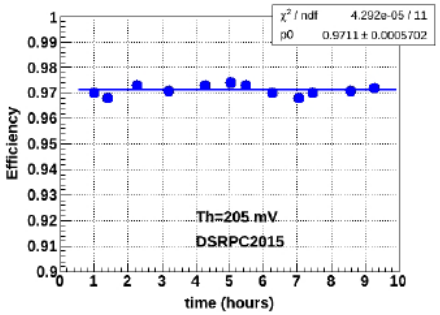
MRPC1/2 prototype developed at Bucharest



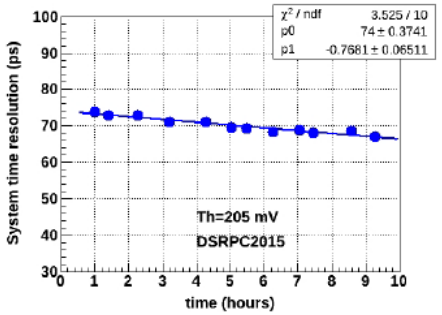



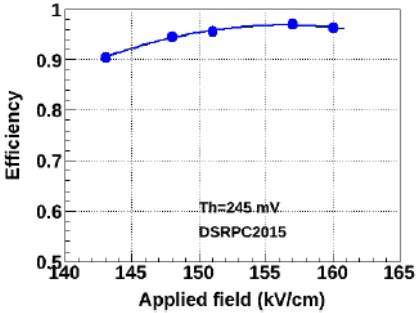
- Metal HV strip electrodes
- Innovative method of impedance matching
- Impedance independent of the granularity adjustable
- Impedance tuned to 100 Ω
- arXiv:1708.02707

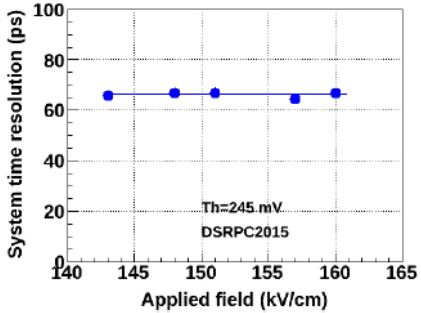
Efficiency



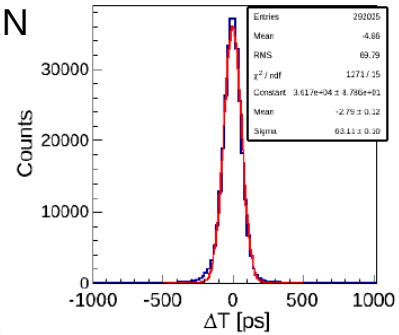

System time resolution

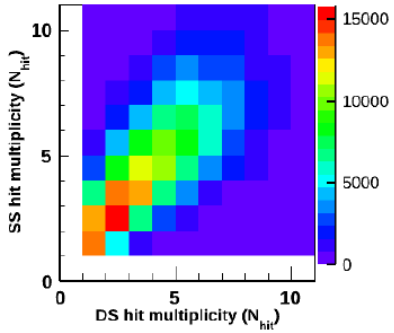


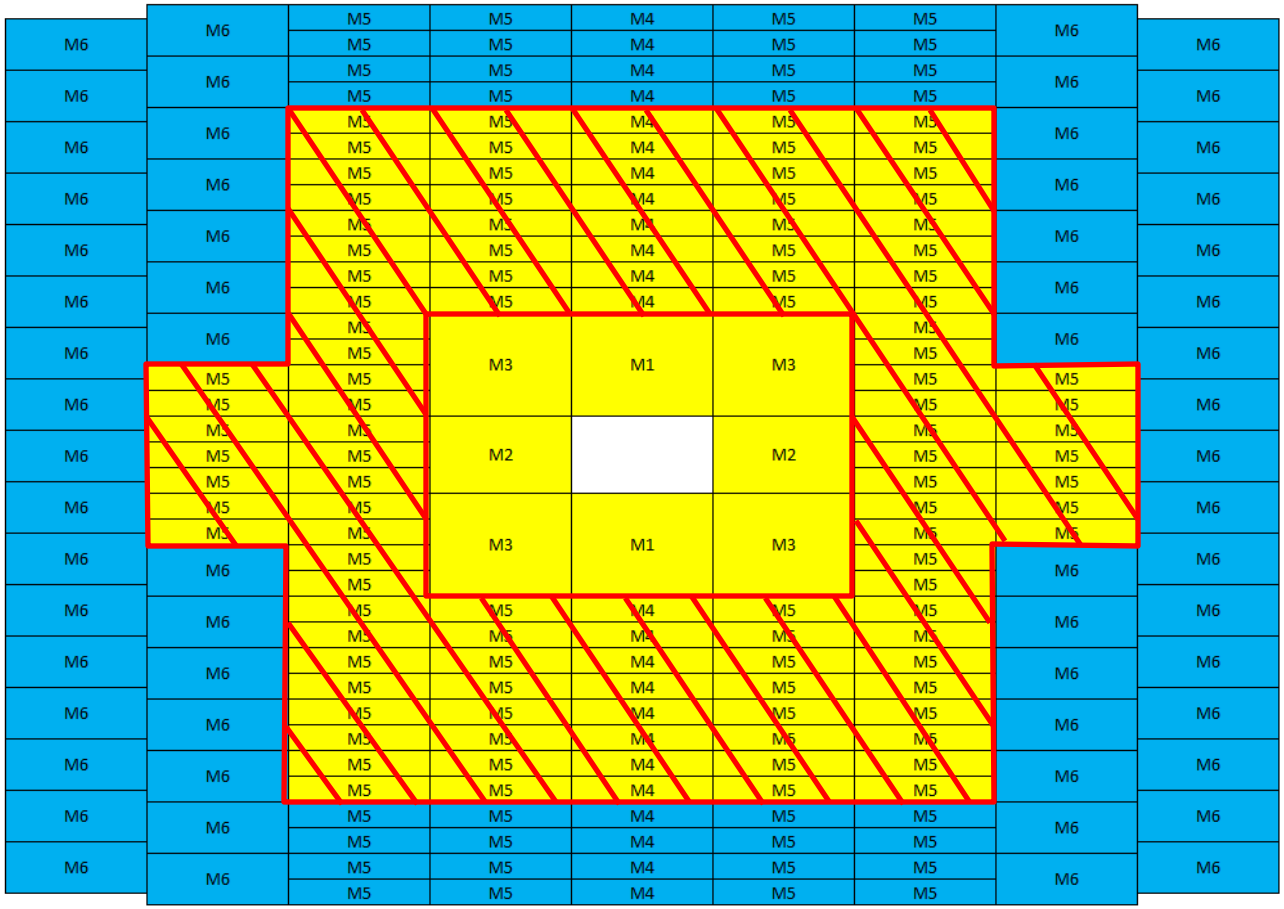




Beam time setup at CERN

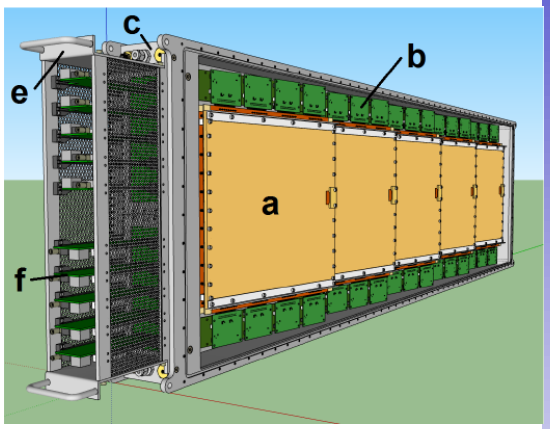



# TDR ToF wall layout intermediate rate region

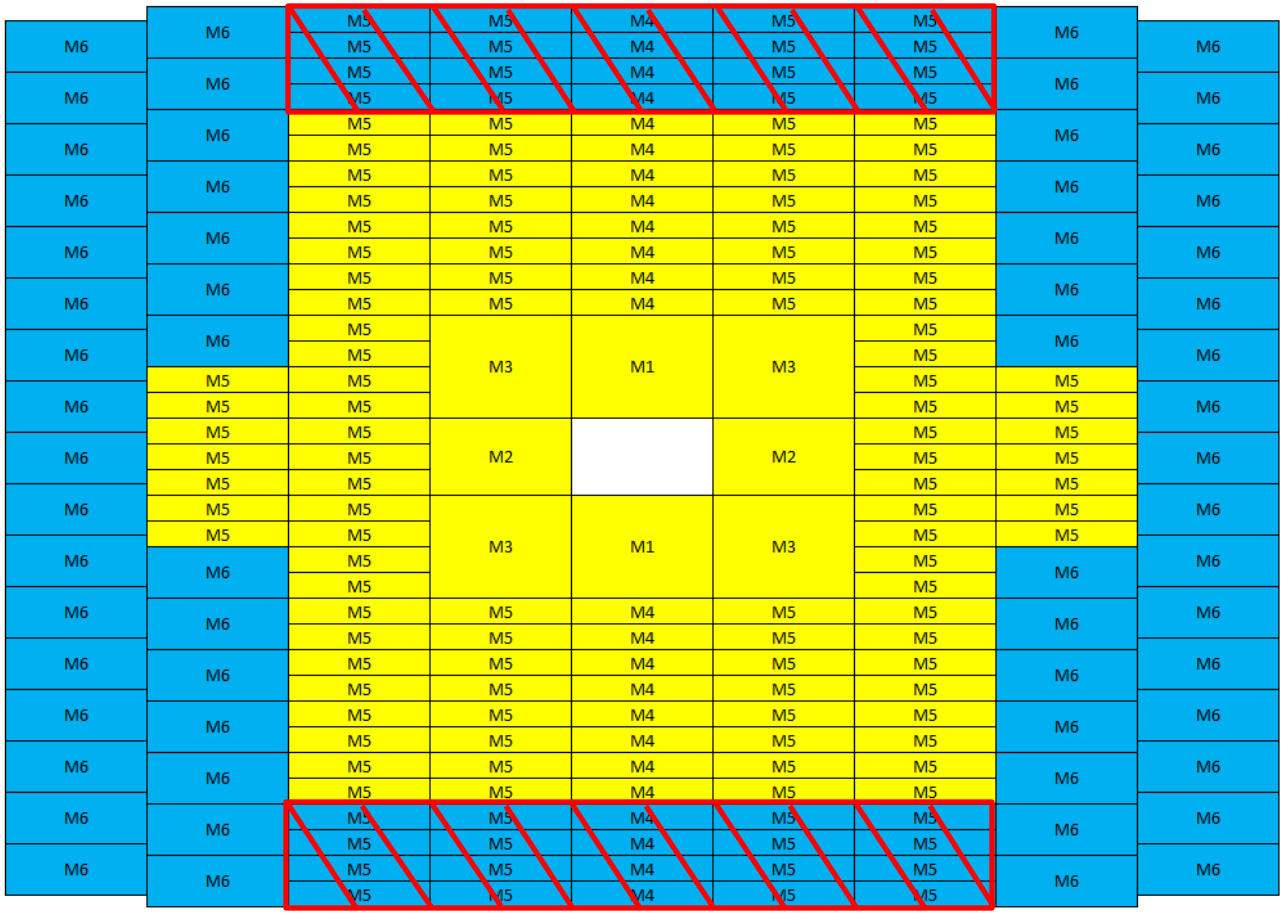



Module M5

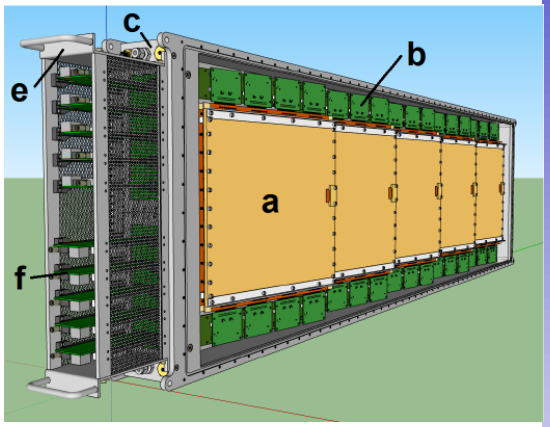



| MRPC notation | MRPC3a |
|---|---|
| Number of MRPCs | 580 |
| Active area [mm$^2$] | 320 × 270 |
| Number of Strips per MRPC | 32 |
| Strip length [mm] | 270 |
| Granularity (cell size) [mm$^2$] | 2700 |
| Number of gas gaps | 8 |
| Gap size $\mu$m | 250 |
| Glass size [mm$^2$] | 330 × 280 |
| Glass thickness [mm] | 0.7 |
| Number of glass plates | 9 |
| Glass type | low res. |
| Total glass surface [m$^2$] | 482.33 |

# TDR ToF wall layout low rate region




Module M5

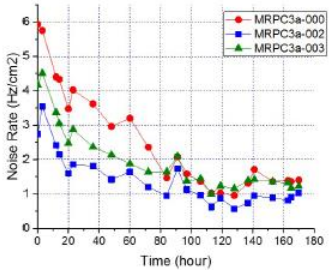


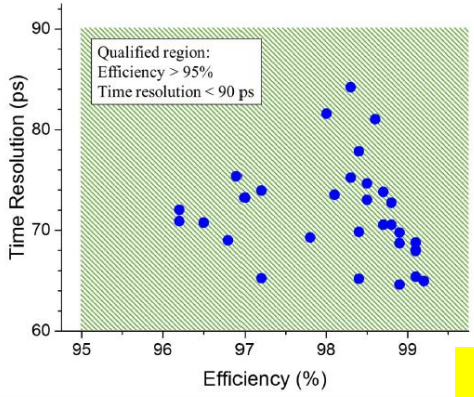

| MRPC notation | MRPC3b |
|---|---|
| Number of MRPCs | 200 |
| Active area [mm$^2$] | 320 × 270 |
| Number of Strips per MRPC | 32 |
| Strip length [mm] | 270 |
| Granularity (cell size) [mm$^2$] | 2700 |
| Number of gas gaps | 10 |
| Gap size $\mu$m | 230 |
| Glass size [mm$^2$] | 330 × 280 |
| Glass 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

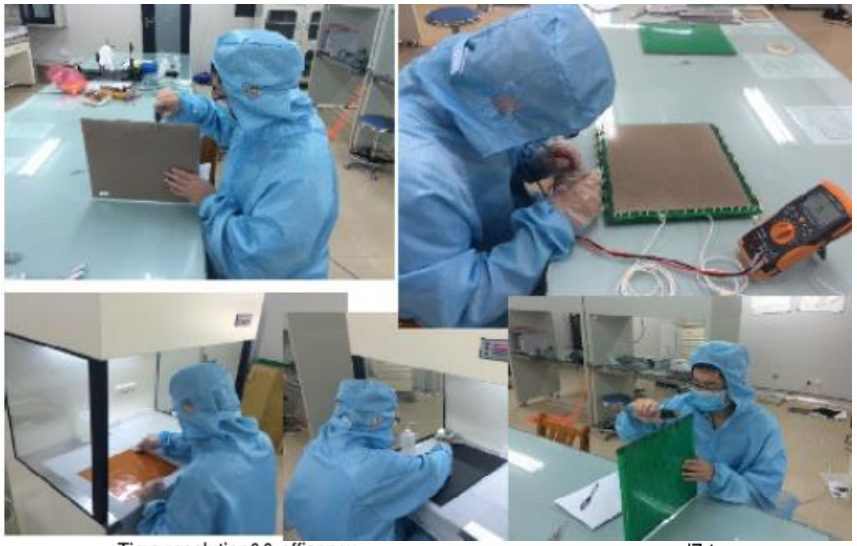
MRPC3a mass prod at Nuctech, Beijing

**See talk of Pengfei Lyu on 23.02 at 10:10**

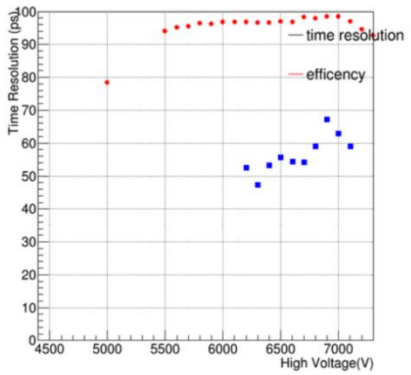


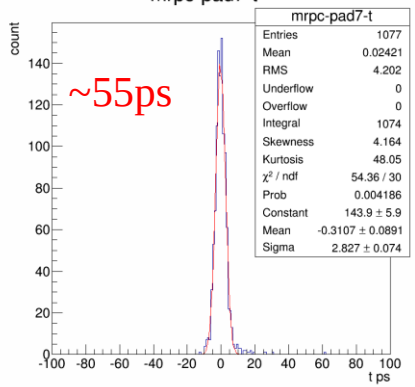

MRPC3b mass production at USTC/China



Time resolution&& efficency



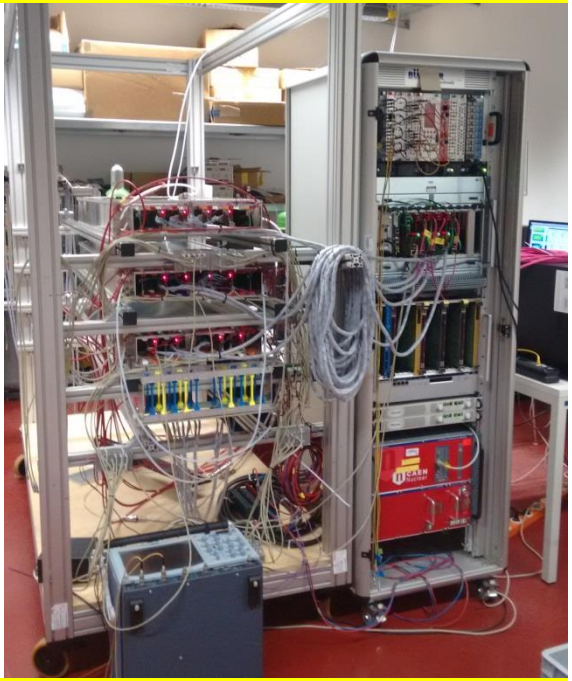

mrpc-pad7-t



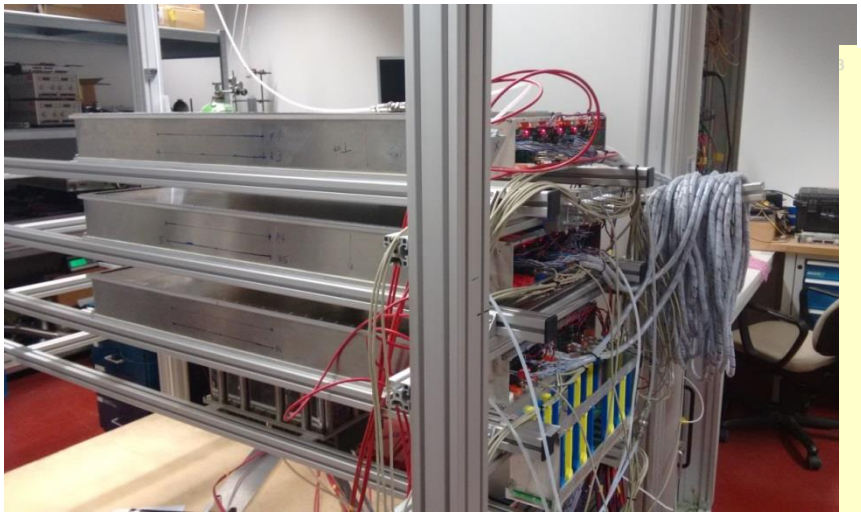

**See talk of Yongjie Sun on 22.02 at 10:40 and posters of Dongdong Hu, Xinjian Wang, Jian Zhou**

# Module integration and cosmic test stand in HD

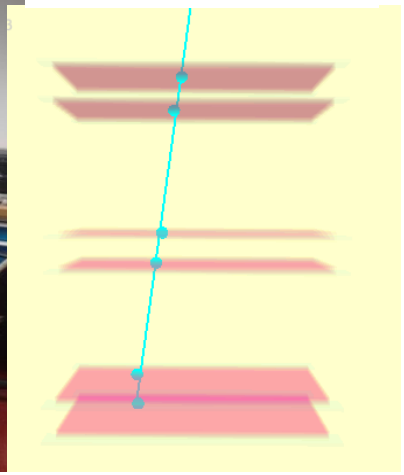
**Multi differential analysis of counter properties with cosmic tracks**



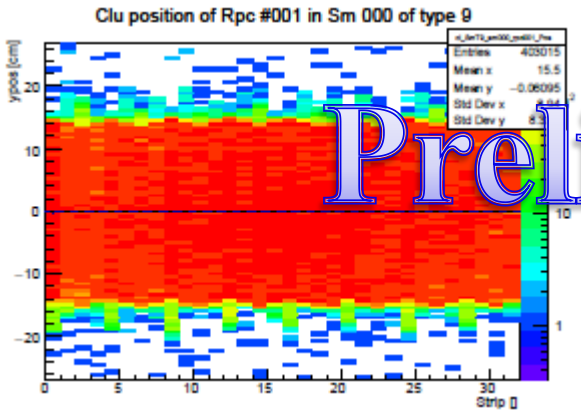
**About 100000 good tracks per day**

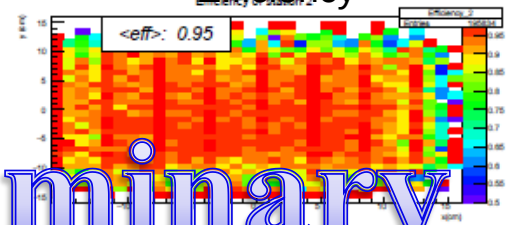


Multiplicity 6 track

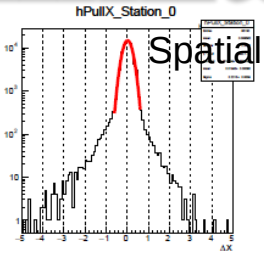


Efficiency

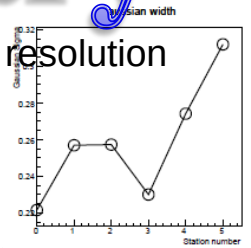



Preliminary



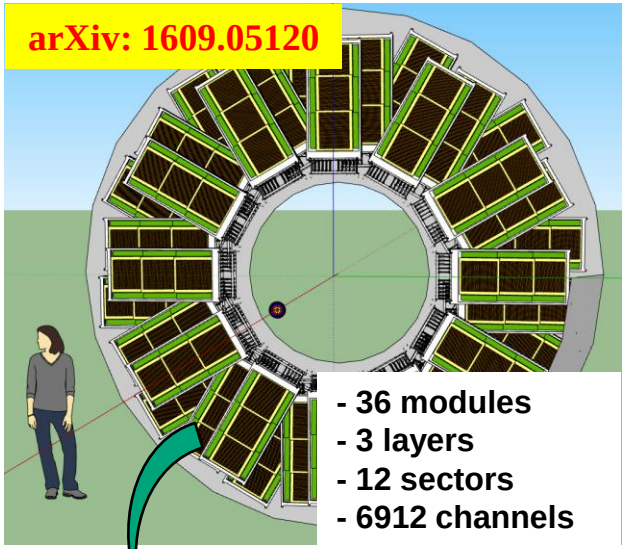

Spatial resolution



# FAIR Phase 0 – eTOF@STAR

CBM ToF

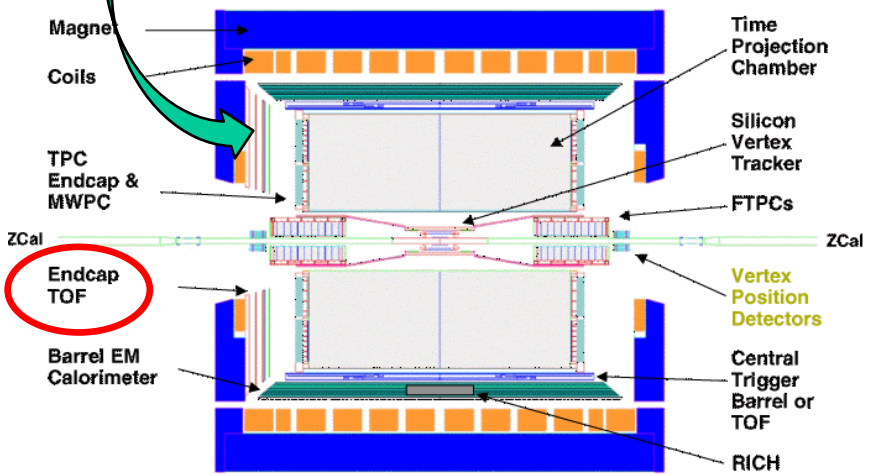
arXiv: 1609.05120

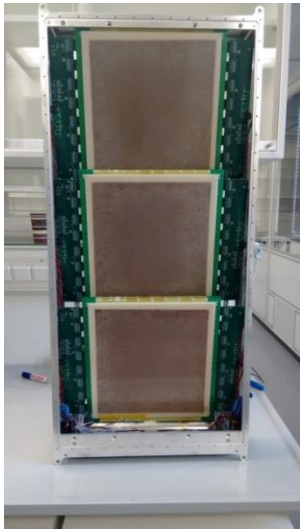


- 36 modules
- 3 layers
- 12 sectors
- 6912 channels

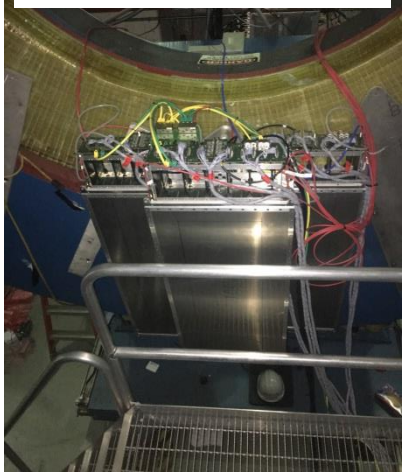
## Time line

| | |
|---|---|
| ➢ 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 |



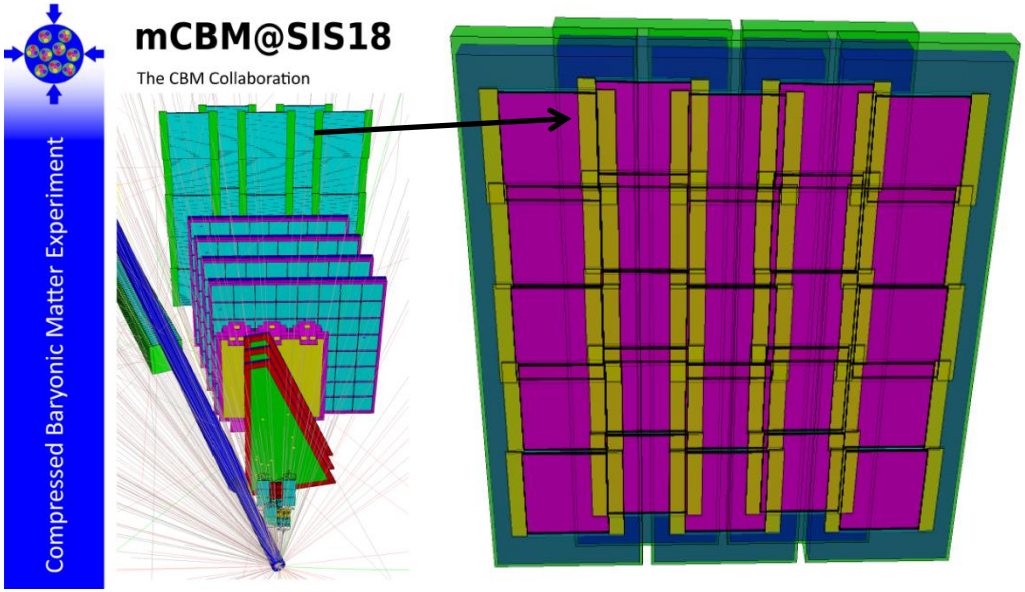
First sector installed



# FAIR Phase 0 – miniCBM

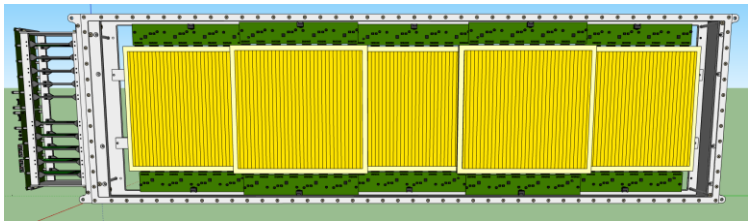
**mTOF setup**

- 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)

# 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 ⇒ 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

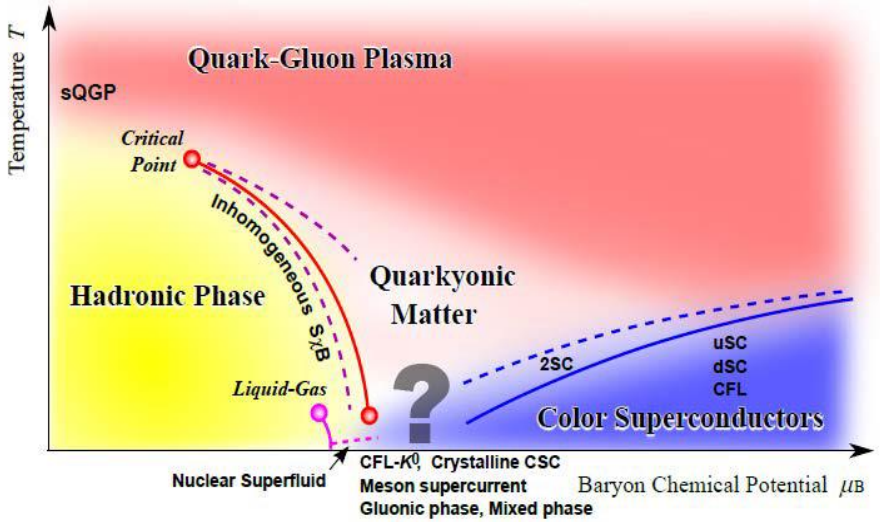


# Backup Slides

# Backup Slides

## CBM Physics topics

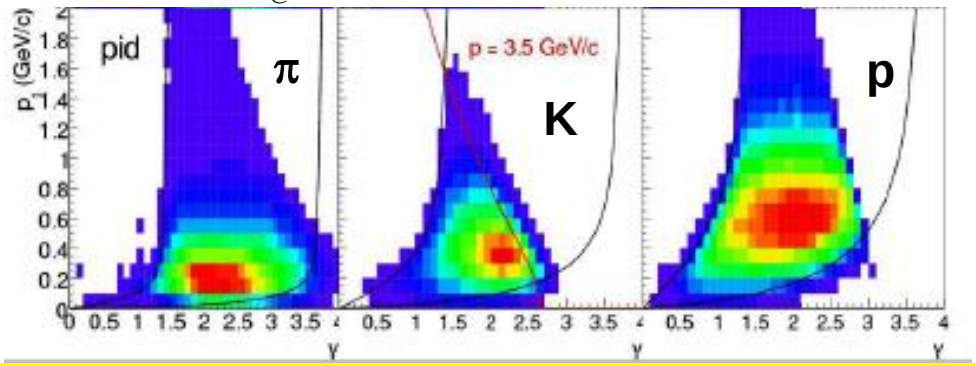
- Deconfinement / phase transition at high $\rho_B$
- QCD critical endpoint
- The equation-of-state at high $\rho_B$
- chiral symmetry restoration at high $\rho_B$




## 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**

# 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)

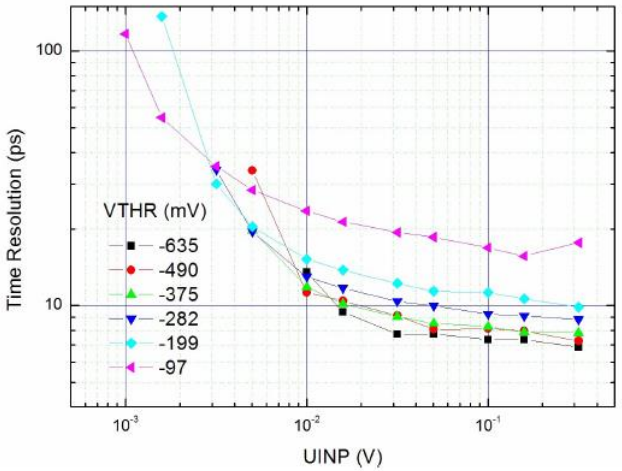
**Reaction counter**

- 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 |

***Table 3.4:*** *Main parameters of the PAD*

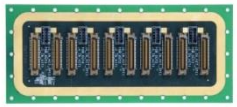


# Backup Slides

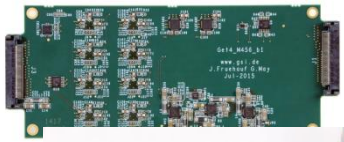
**Readout chain**

- PADI: Preamplifier board 32 ch

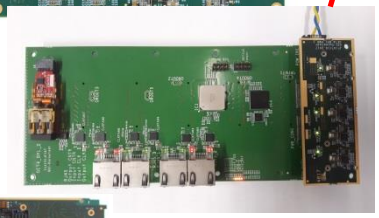
- Feed through PCB



- GET4: TDC board 32 ch

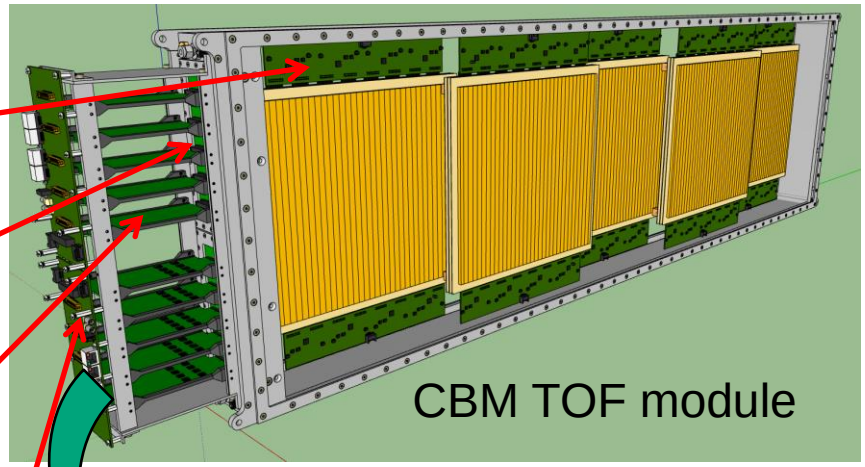


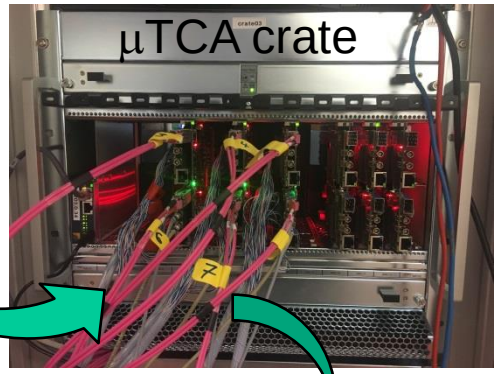
- Backplane with GBTx chip



- AFCK: FPGA board

- FLIB: FPGA PCI express card




HP-PC