The CBM Time-of-Flight wall

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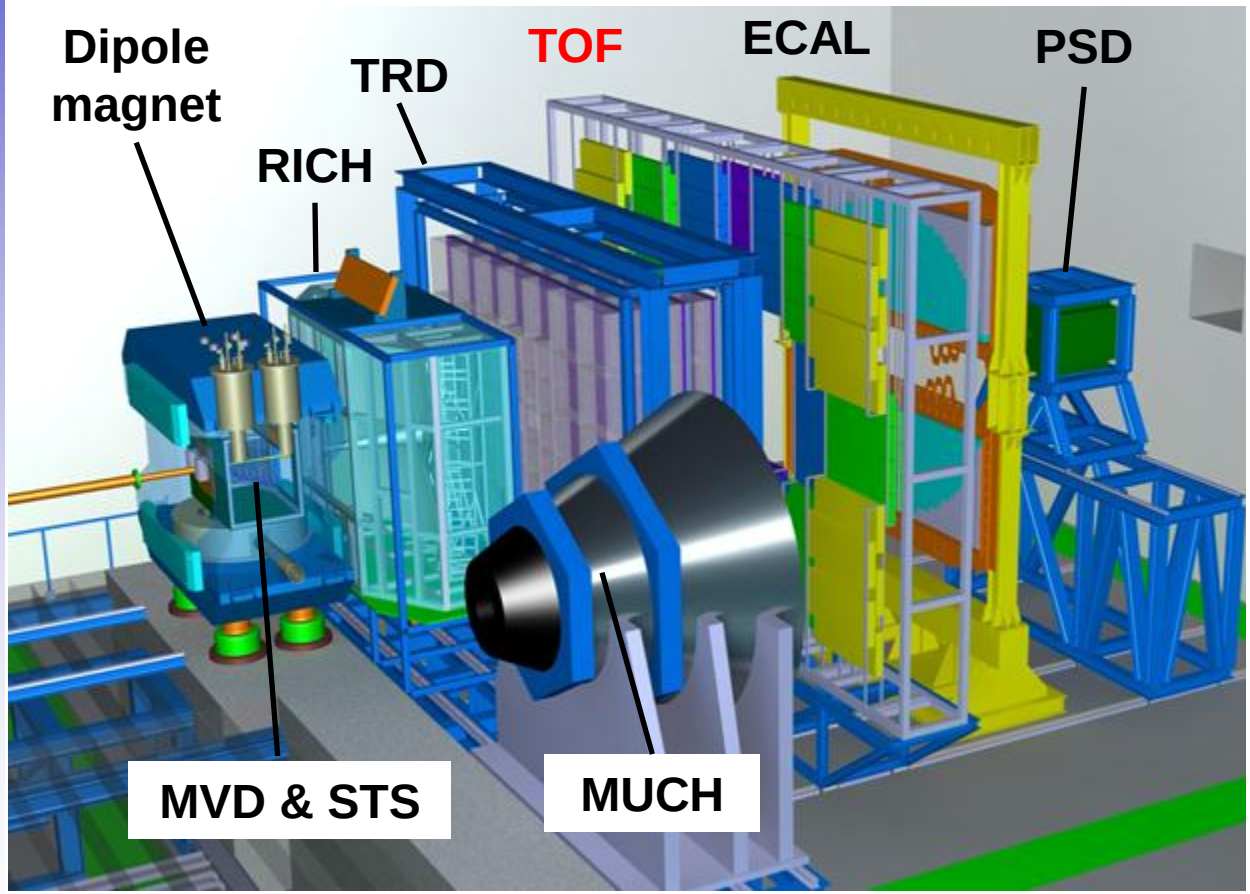
Outline:

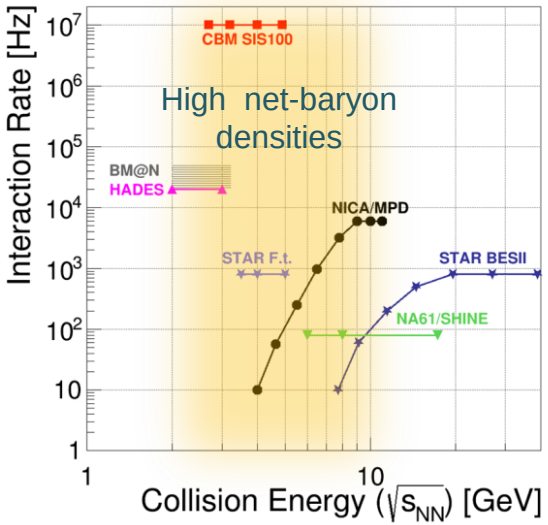
- **Introduction**
- **CBM TOF requirements**
- **Tof wall arrangements**
- **Ceramics RPC and the central region of the ToF wall**
- **Beam-time @ SPS Nov. 2015**
- **Beam-time @ SPS Nov. 2016**
- **TOF Project timeline**
- **TOF FAIR Phase 0 project**
- **Summary and Outlook**

Introduction

The Compressed Baryonic Matter Experiment

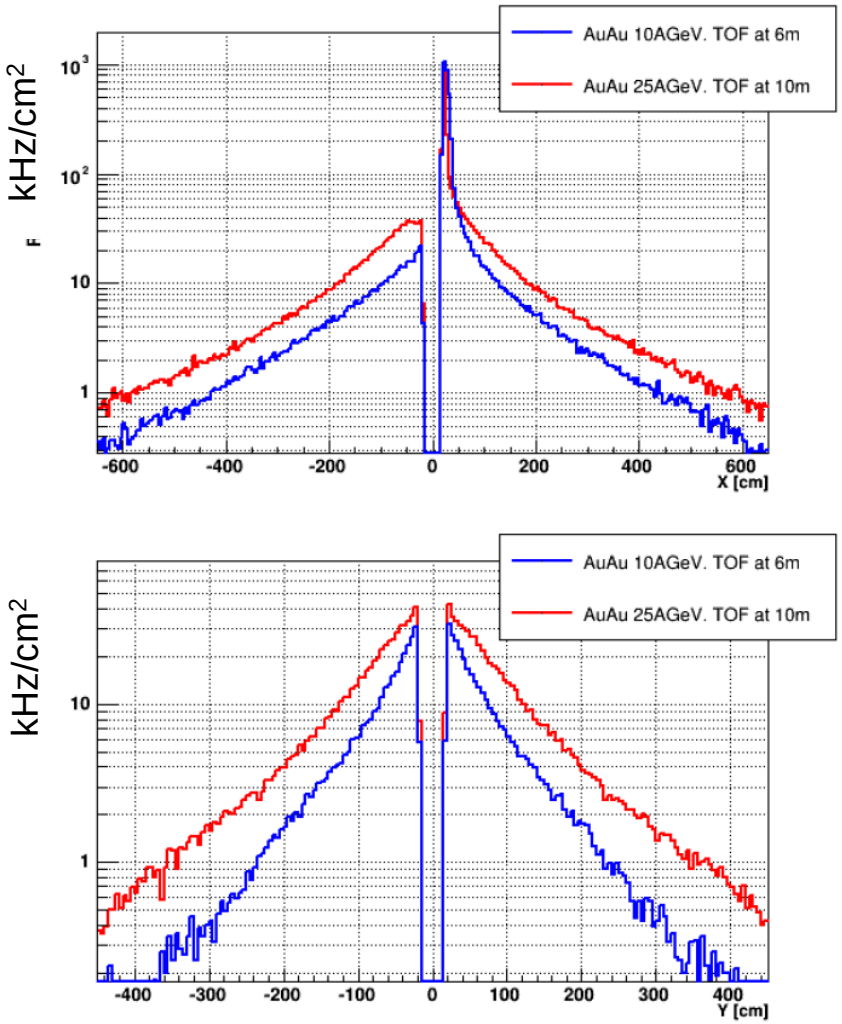


- Tracking acceptance: 2° < θ_{Lab} < 25°
- Free streaming DAQ
- Software based event selection
- R_{int} = 10 MHz (Au + Au)



CBM overview talk: HK30.1
Group reports: 6
Short reports: 41
Poster: 8

Incident particle flux

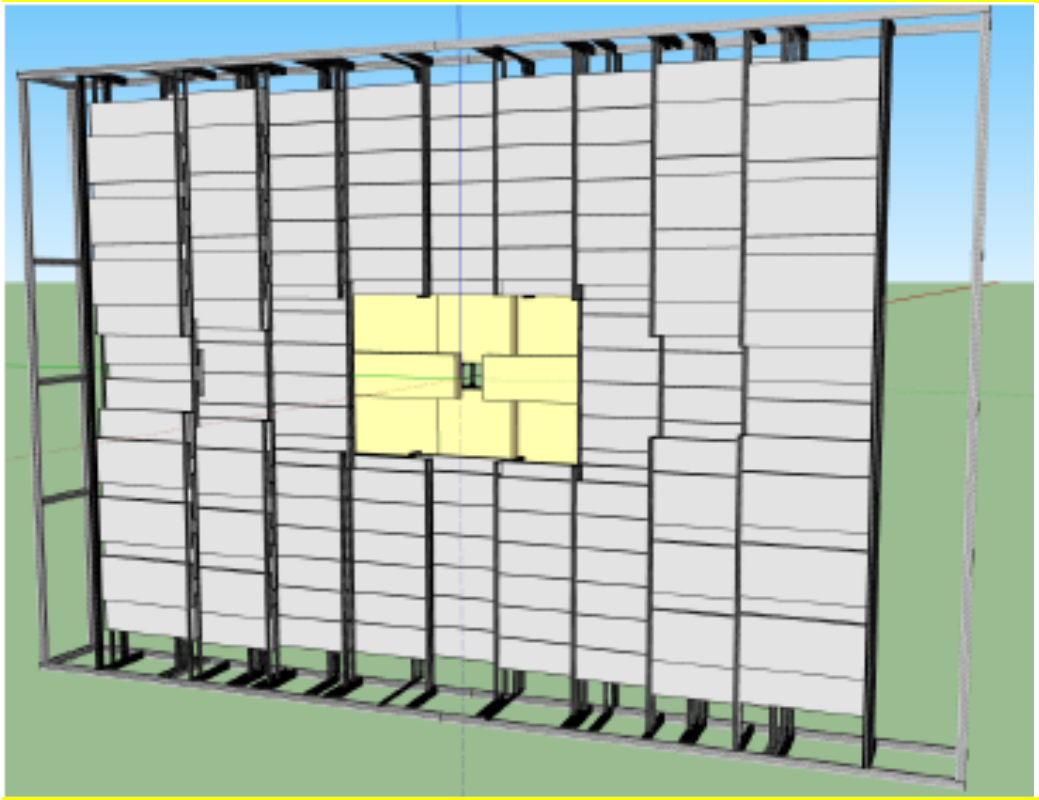


URQMD simulated charged particle flux from Au + Au events for an interaction rate of 10 MHz

- 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

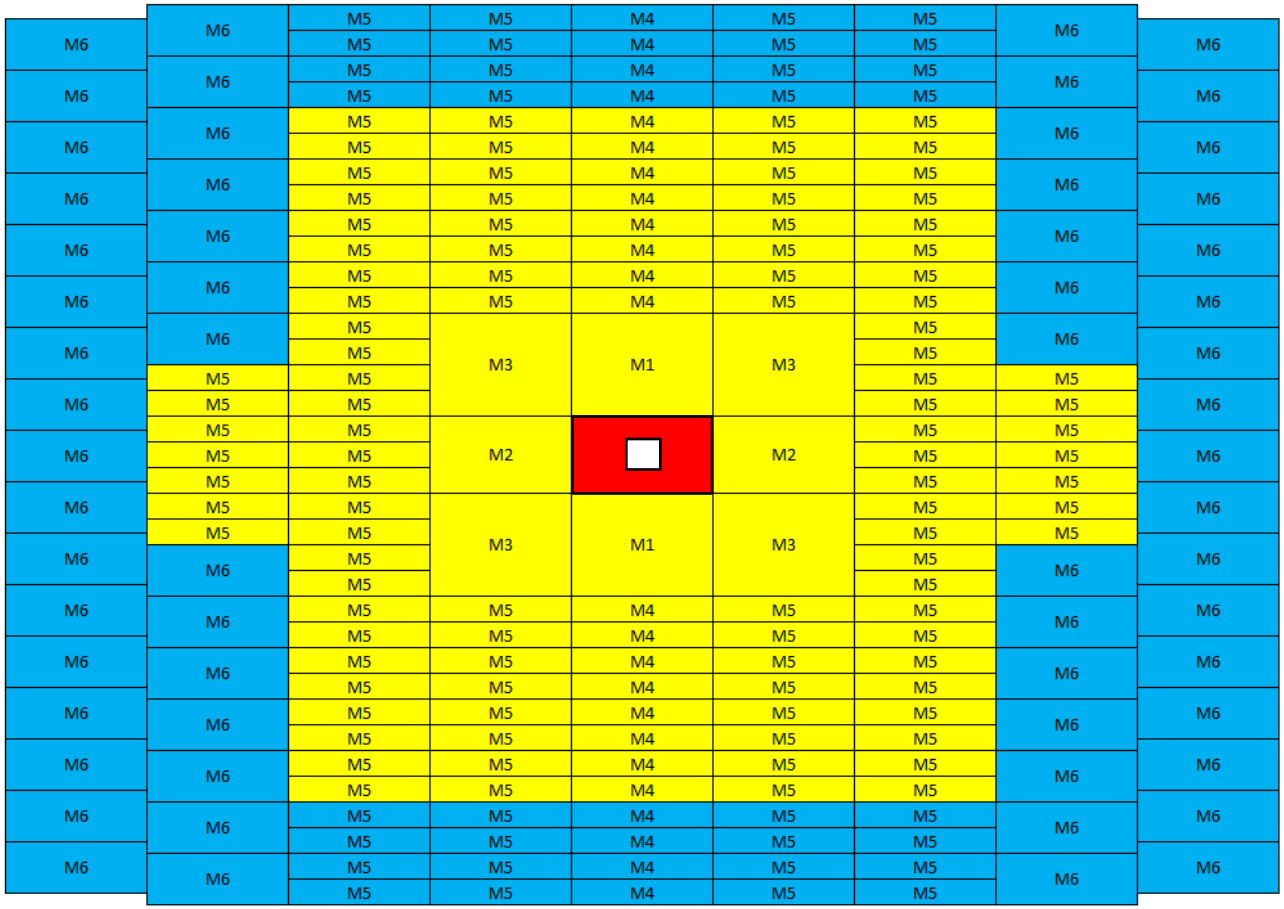


CBM-ToF Requirements

- Full system time resolution σ_T ~ 80 ps
- Efficiency > 95 %
- Rate capability ≤ 30 kHz/cm^2
- Polar angular range 2.5° – 25°
- Active area of 120 m^2
- Occupancy < 5 %
- Low power electronics (~120.000 channels)
- Free streaming data acquisition

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

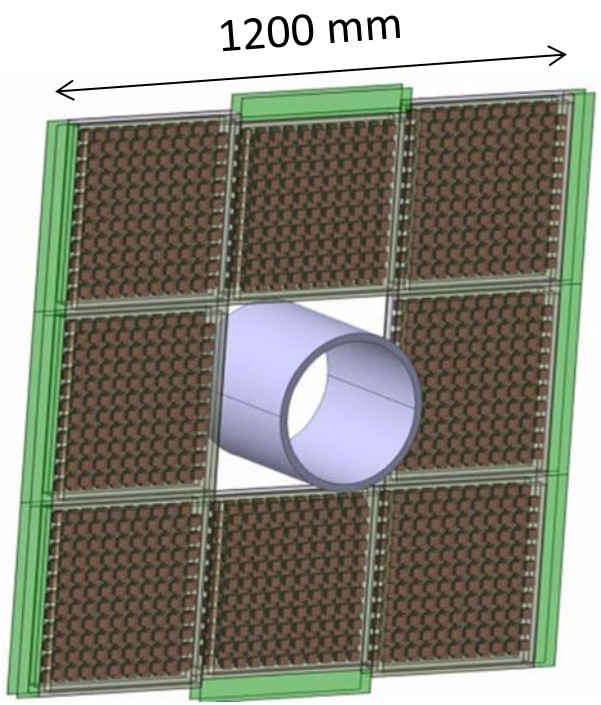
TDR ToF wall layout



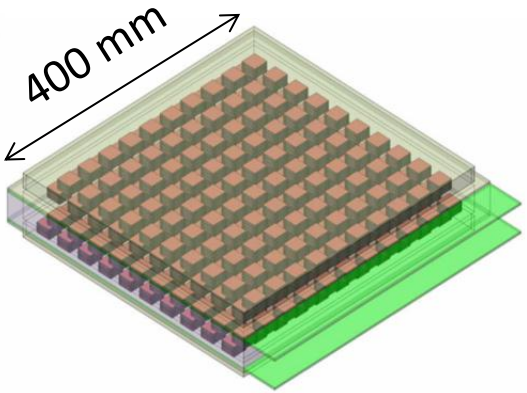
- 6 types of modules (M1 – M6) only
- A module contains several MRPC counters
- Region containing counters equipped with float glass
- Region containing counters equipped with low resistive glass
- Region containing counters equipped with ceramic material

Ceramic RPCs for BFTC

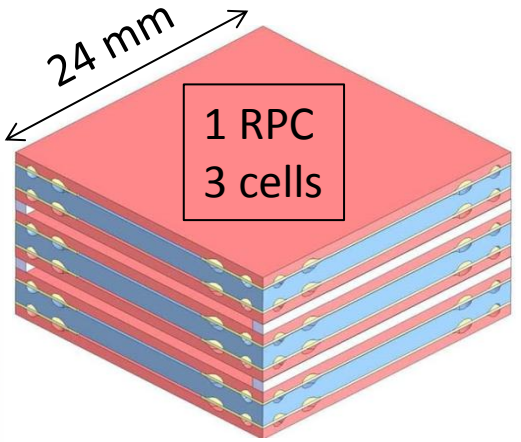
Important scopes of High Energy Heavy Ion experiments are the start-time and the reaction-plane determination. For CBM the use of RPC for the Beam Fragmentation T_0 Counter (BFT_0C) with low resistive radiation hard ceramics electrodes and small chess-board like single cells is under consideration.

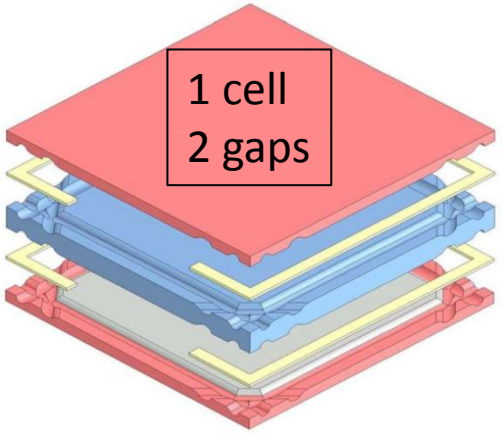


BFT_0C = 8 modules

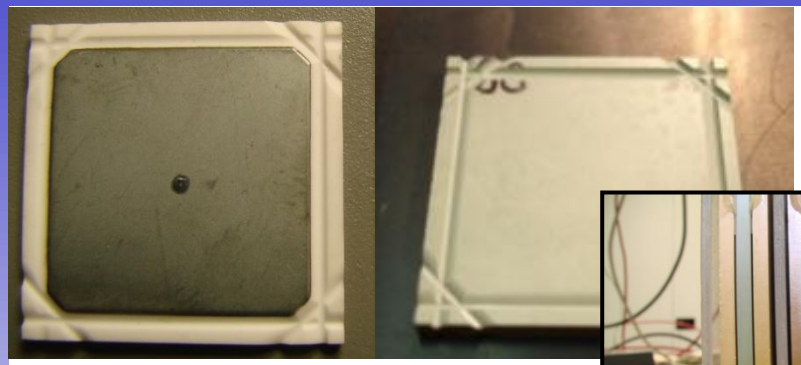


1 module
400 RPCs



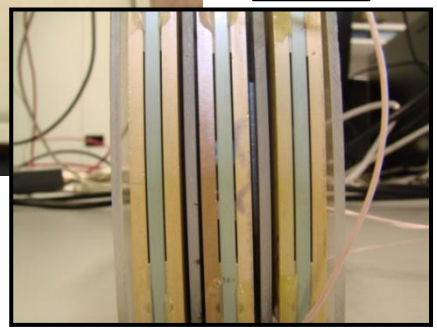


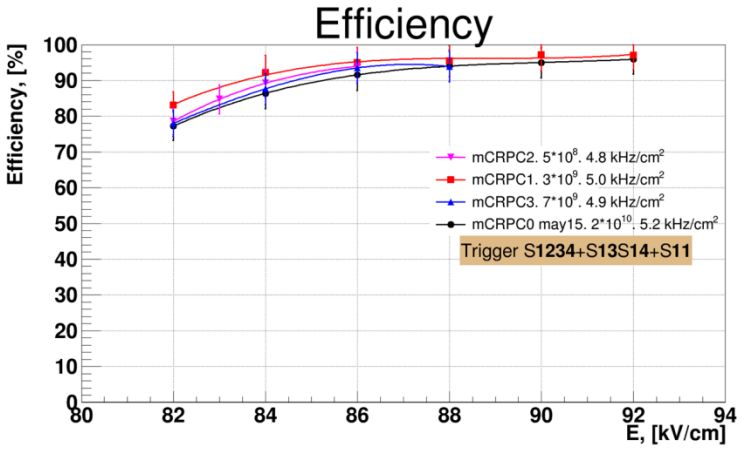
Ceramic RPCs for BFTC

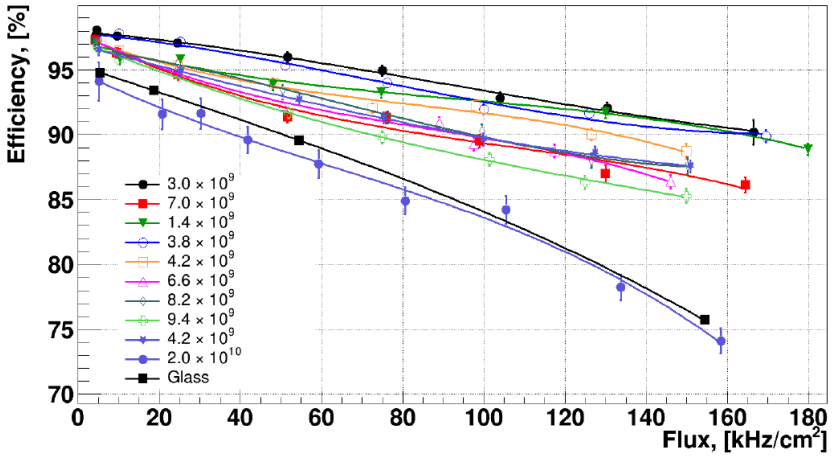


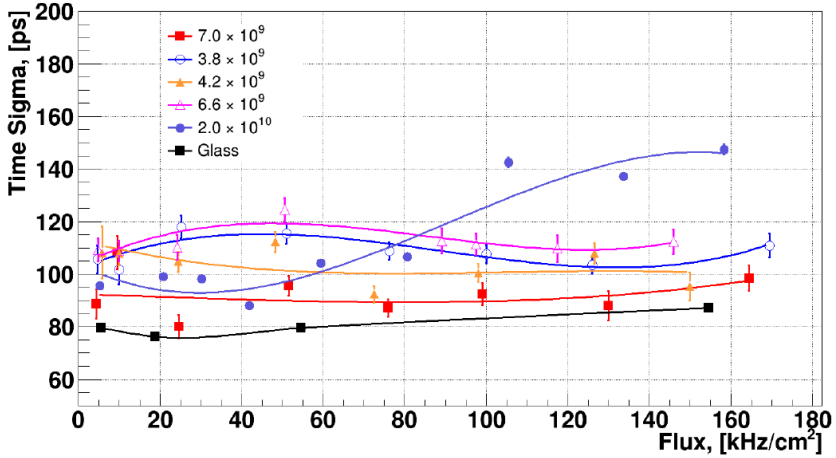
electrodes

RPC







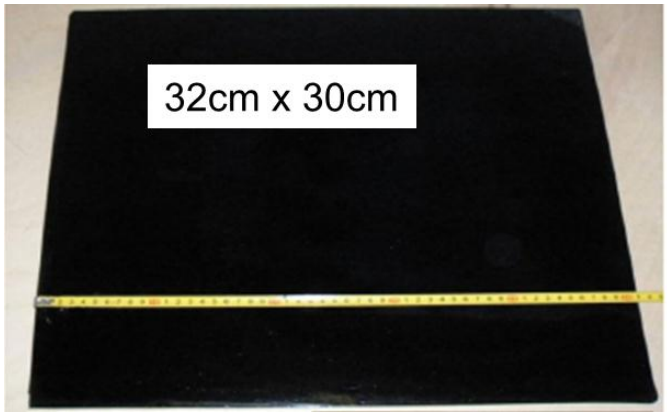


$4 \times 10^9\ \Omega$cm: most suitable resistivity order for our aims

Resistive Glass Development

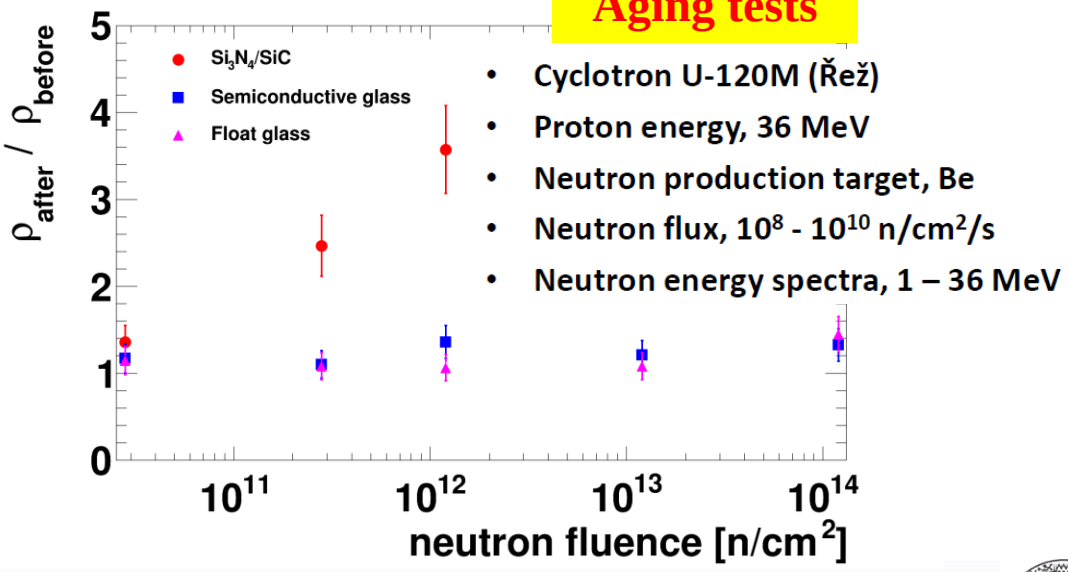
Resistive glass for high-rate MRPCs is developed in Beijing, China

Maximal dimension	32cm × 30cm
Bulk resistivity	10^{10} Ωcm
Standard thickness	0.7, 1.1mm
Thickness uniformity	20 μm
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

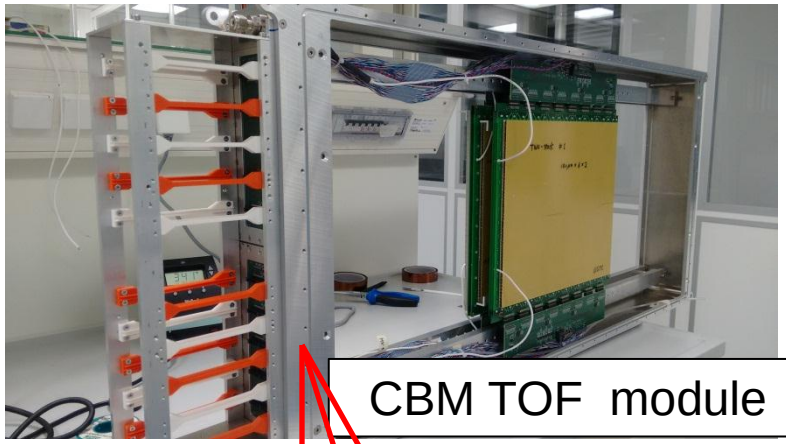
Aging tests

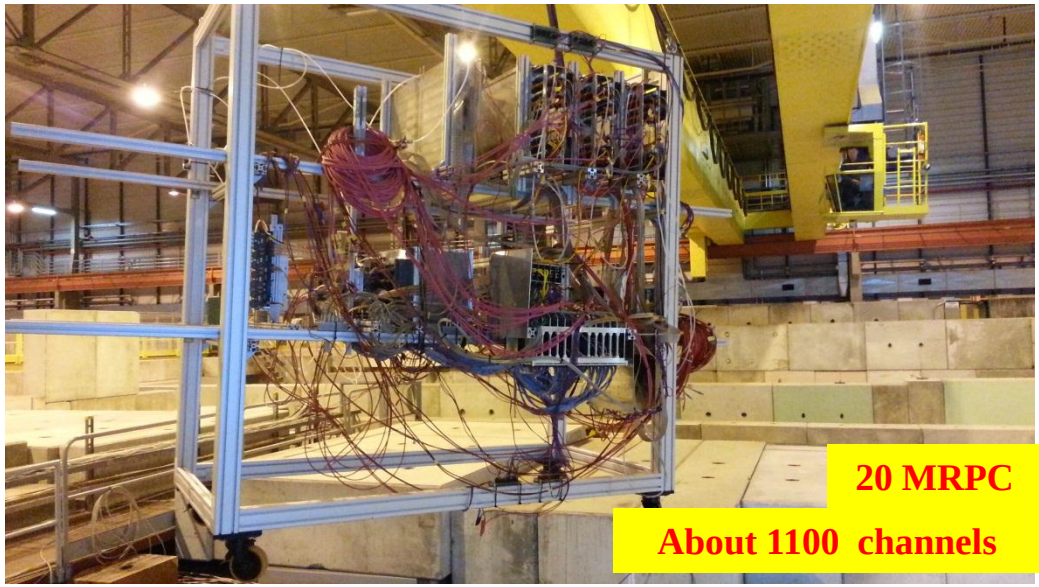


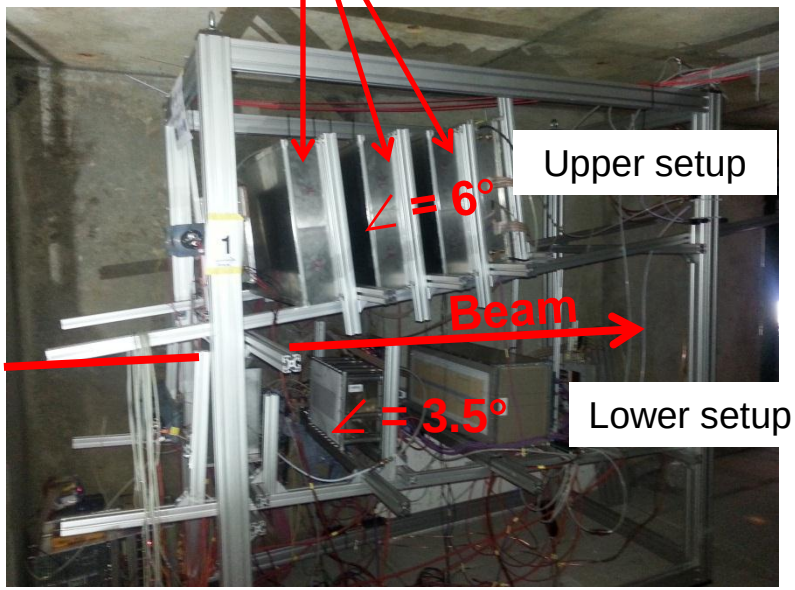
- Cyclotron U-120M (Řež)
- Proton energy, 36 MeV
- Neutron production target, Be
- Neutron flux, 10^8 - 10^{10} n/cm^2/s
- Neutron energy spectra, 1 – 36 MeV

Beam-time @ SPS in Nov. 2015

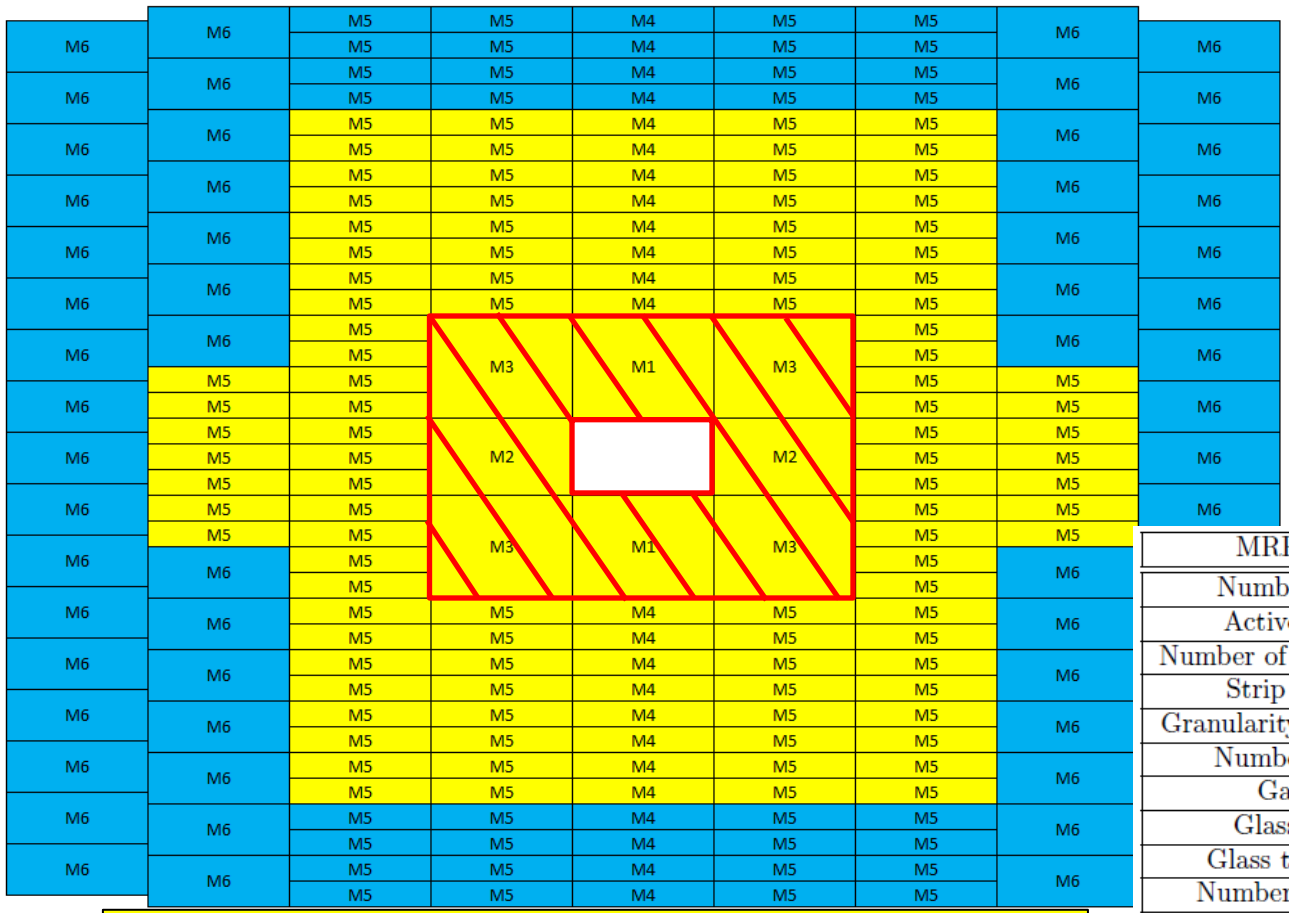
Beam-time @ SPS North Area in Nov. 2015
Beam: Lead @ 30A GeV
Target: Lead 1 mm
Intensity: 10^7 / spill
Spill length: 8 s
Rates: few 100 Hz/cm^2 - 1 kHz/cm^2
Energy close to SIS300 conditions

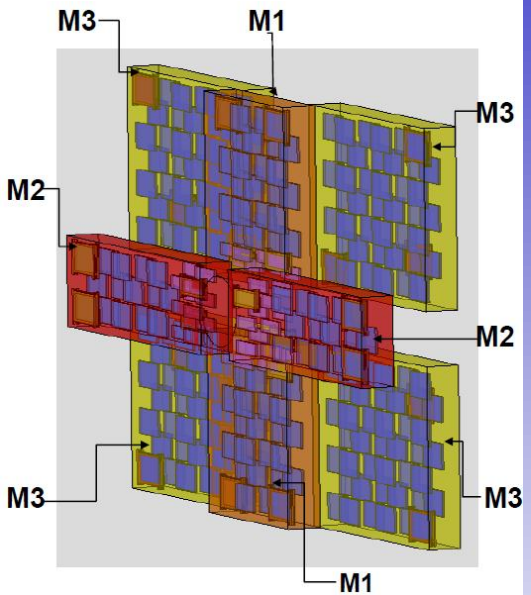






Beam-time @ SPS in Nov. 2015

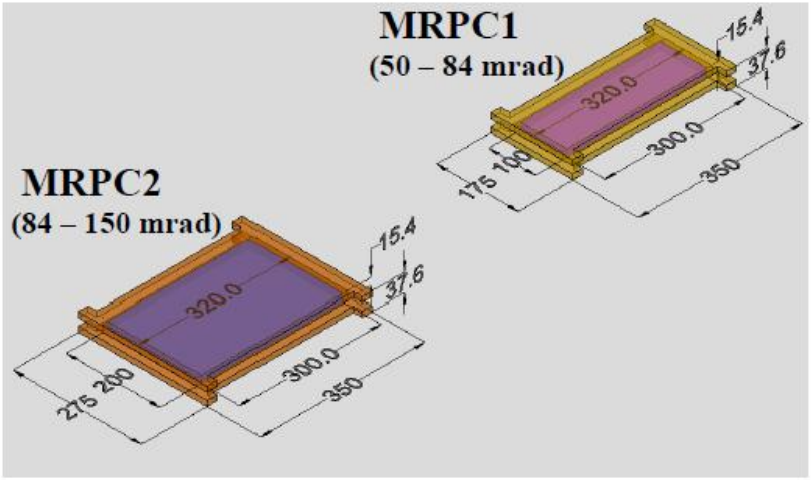


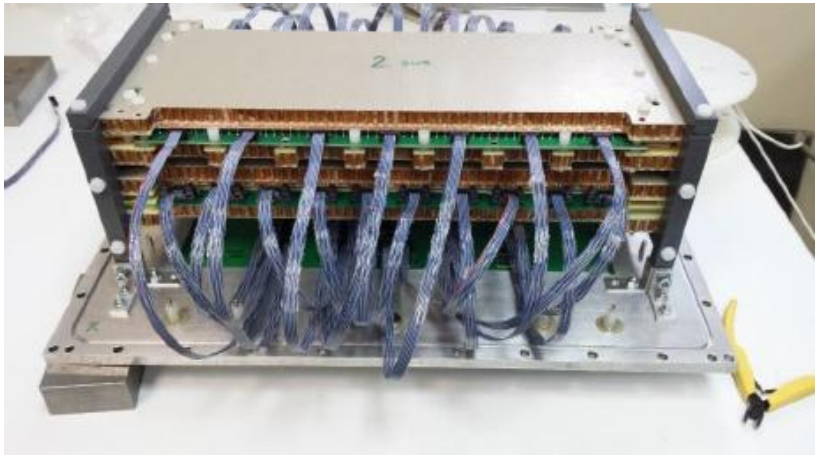


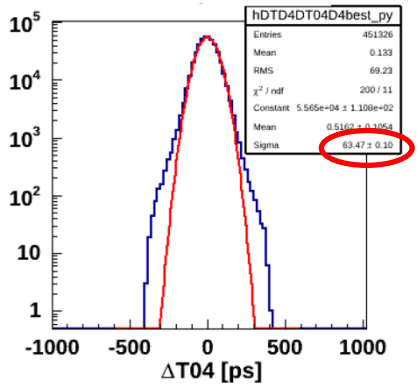
MRPC notation	MRPC1	MRPC2
Number of MRPCs	40	246
Active area [mm^2]	300 × 100	300 × 200
Number of Strips per MRPC	64	64
Strip length [mm]	100	200
Granularity (cell size) [mm^2]	472.4	944.8
Number of gas gaps	10	10
Gap size μm	140	140
Glass size [mm^2]	320 × 100	320 × 200
Glass thickness [mm]	0.7	0.7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

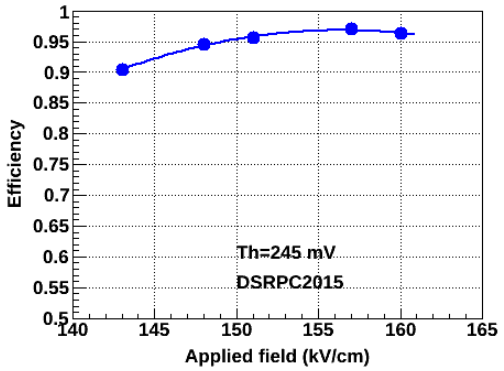
Alternative solution with Pad-MRPCs is available

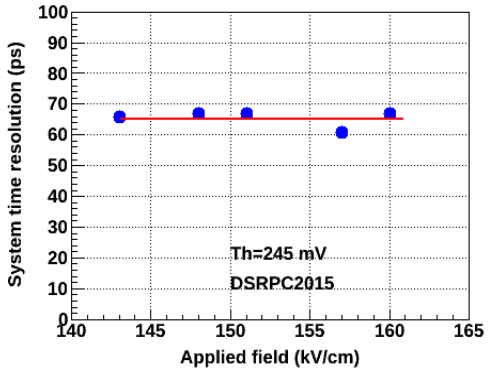
Beam-time @ SPS in Nov. 2015

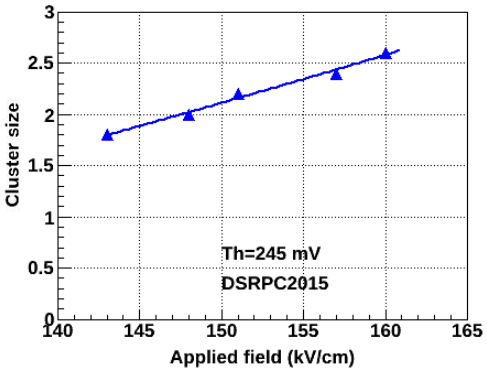






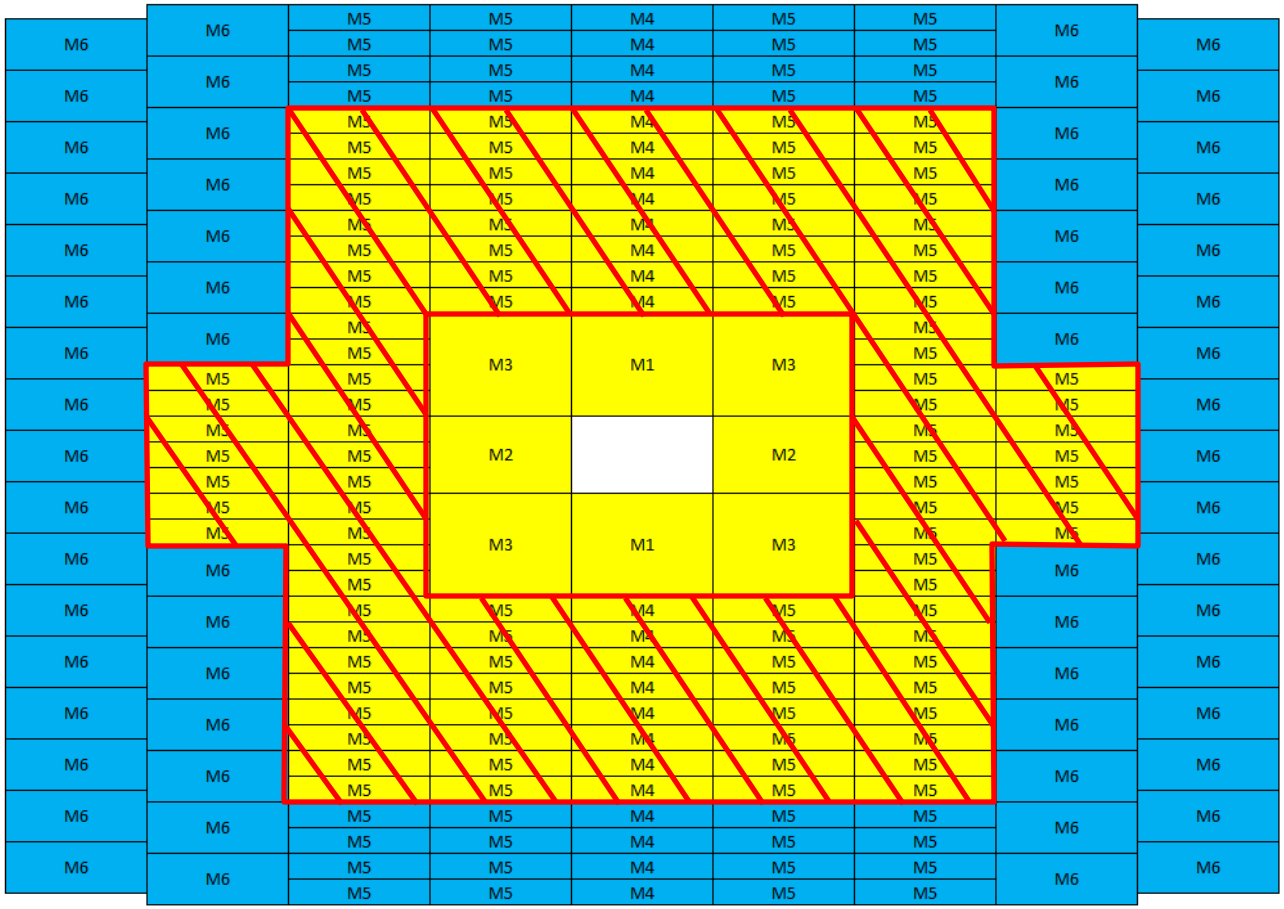




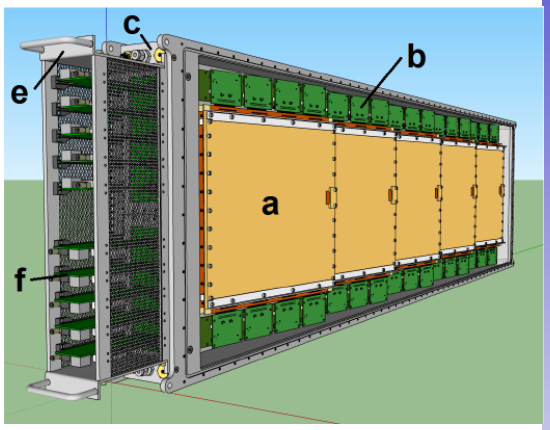


Counter time resolution about 46 ps
Efficiency about 97 %
Cluster size > 2
Particle flux only a few hundred Hz/cm^2

Beam-time @ SPS in Nov. 2015



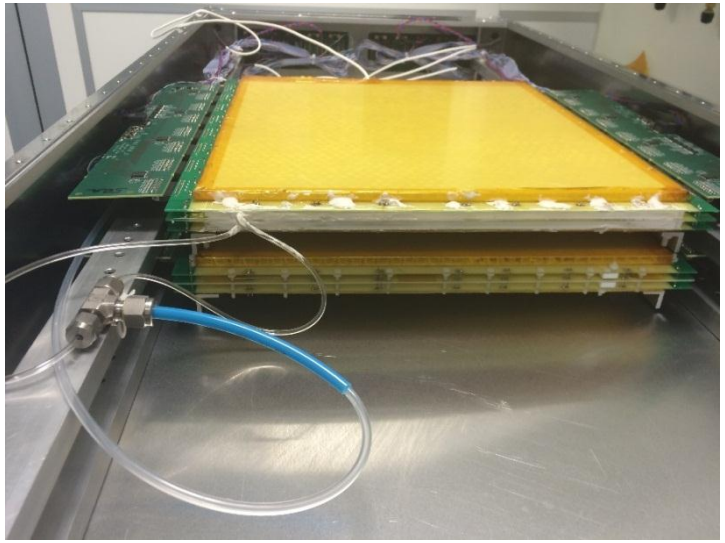
Module M5

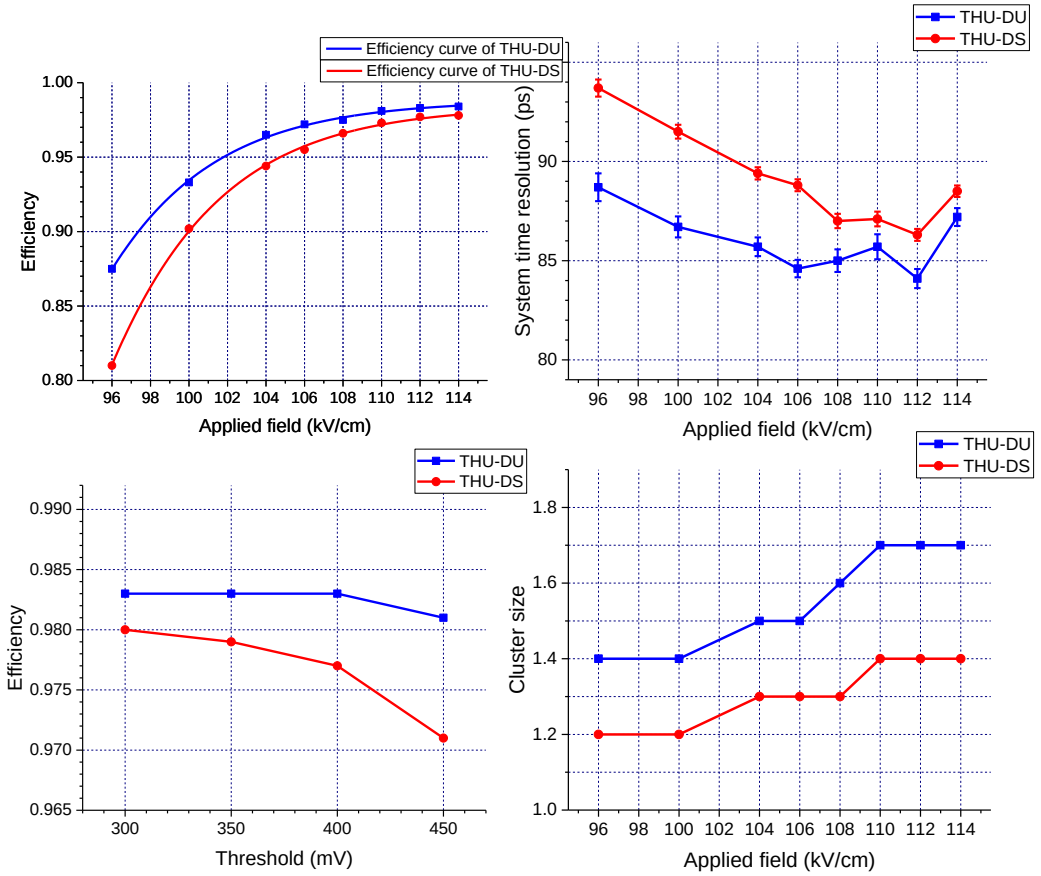


MRPC notation	MRPC3a
Number of MRPCs	580
Active area [mm^2]	320 × 270
Number of Strips per MRPC	32
Strip length [mm]	270
Granularity (cell size) [mm^2]	2700
Number of gas gaps	8
Gap size μm	220
Glass size [mm^2]	330 × 280
Glass thickness [mm]	1.0
Number of glass plates	9
Glass type	low res.
Total glass surface [m^2]	482.33

Beam-time @ SPS in Nov. 2015

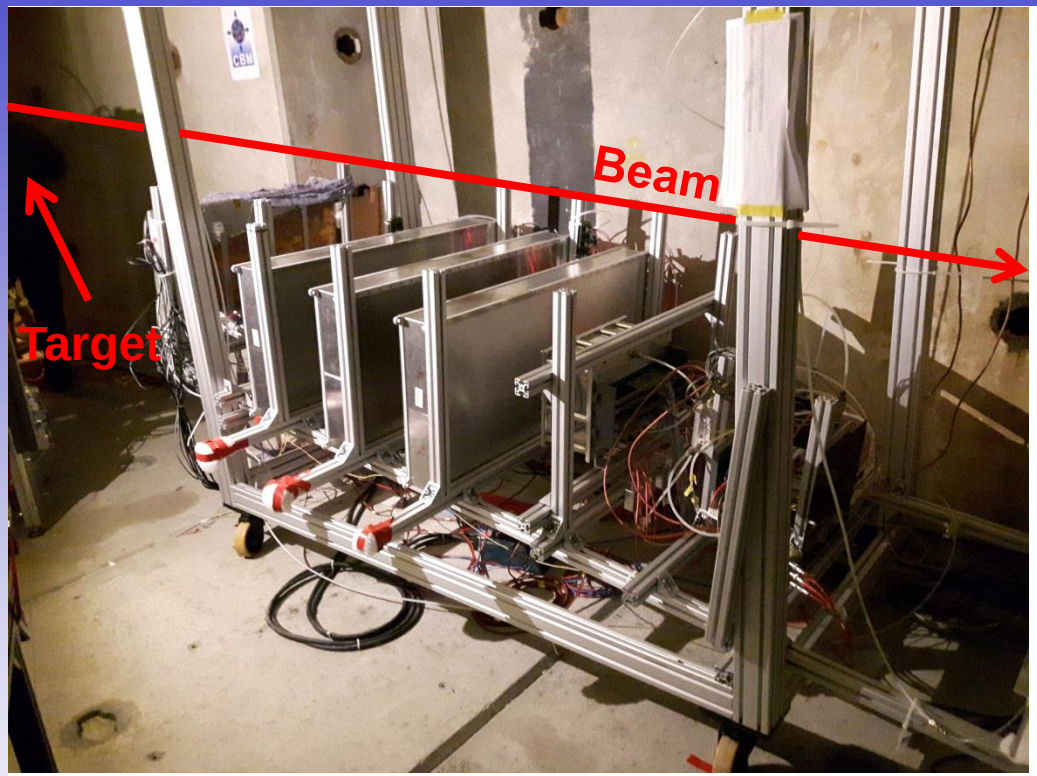
MRPC3a prototypes

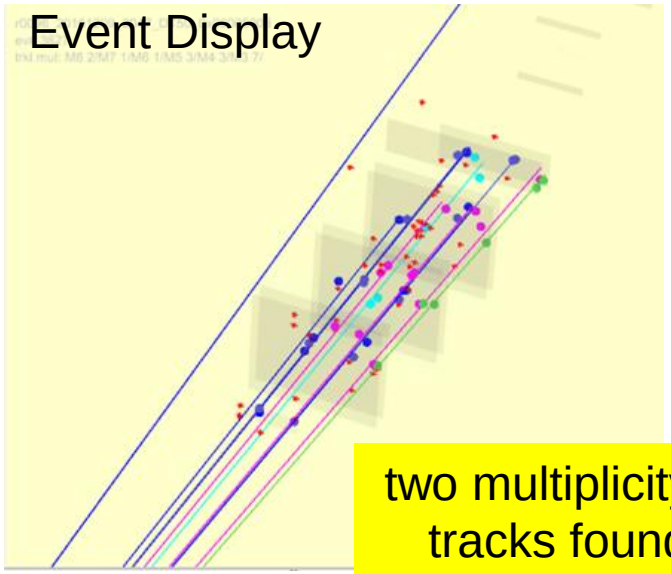




Counter time resolution about 60 ps
Efficiency about 97 %
Cluster size about 1.5

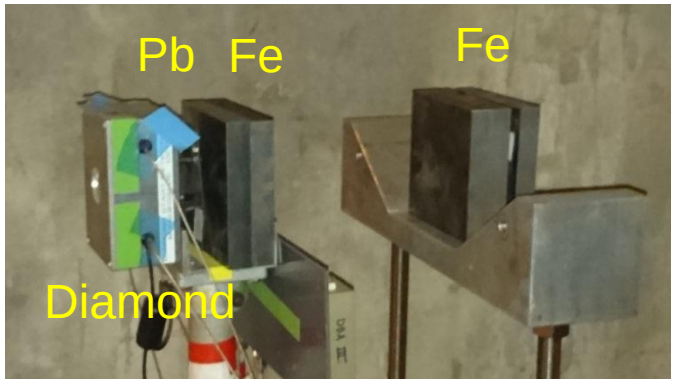
Beam-time @ SPS in Nov. 2016





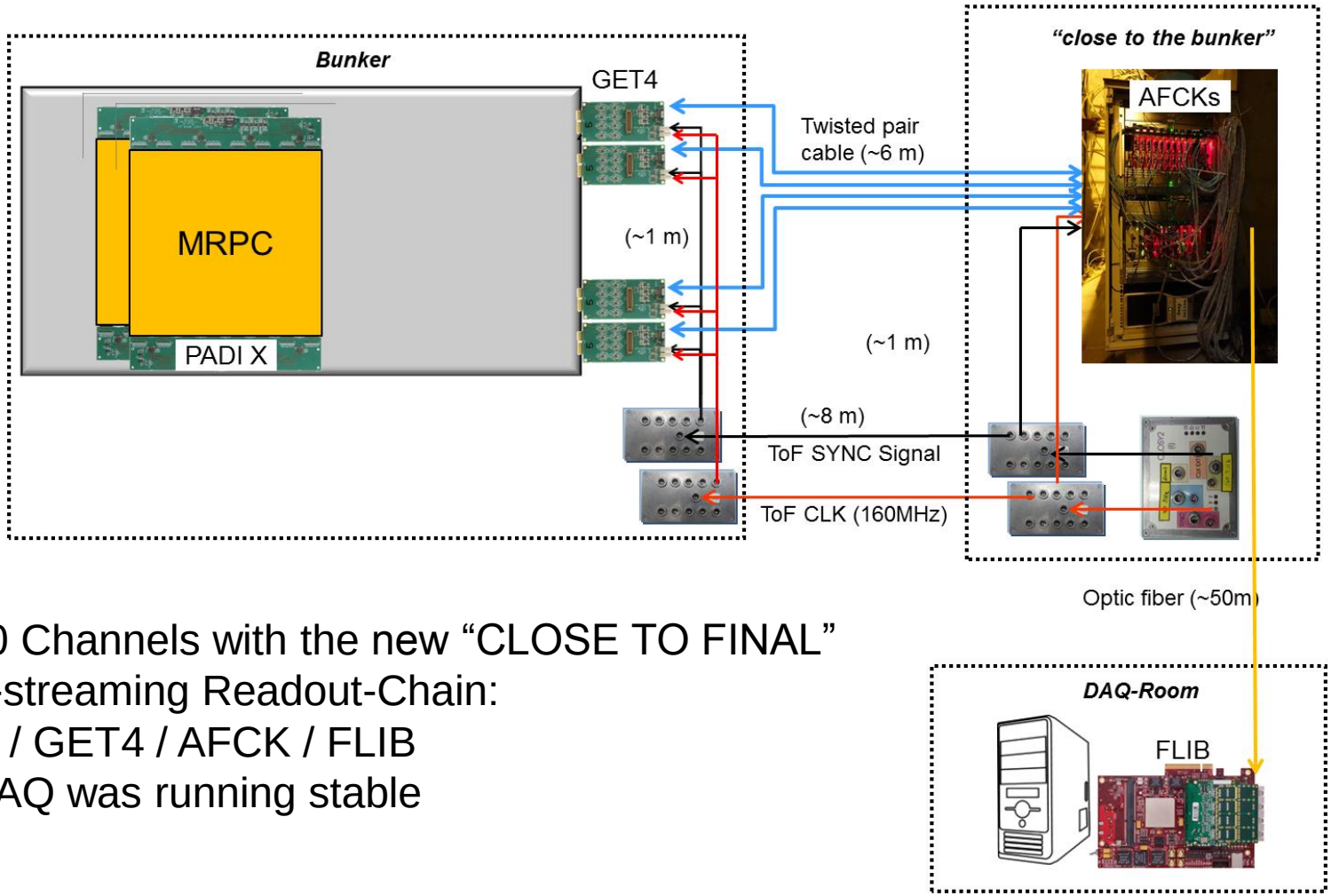
two multiplicity 8 tracks found

Target



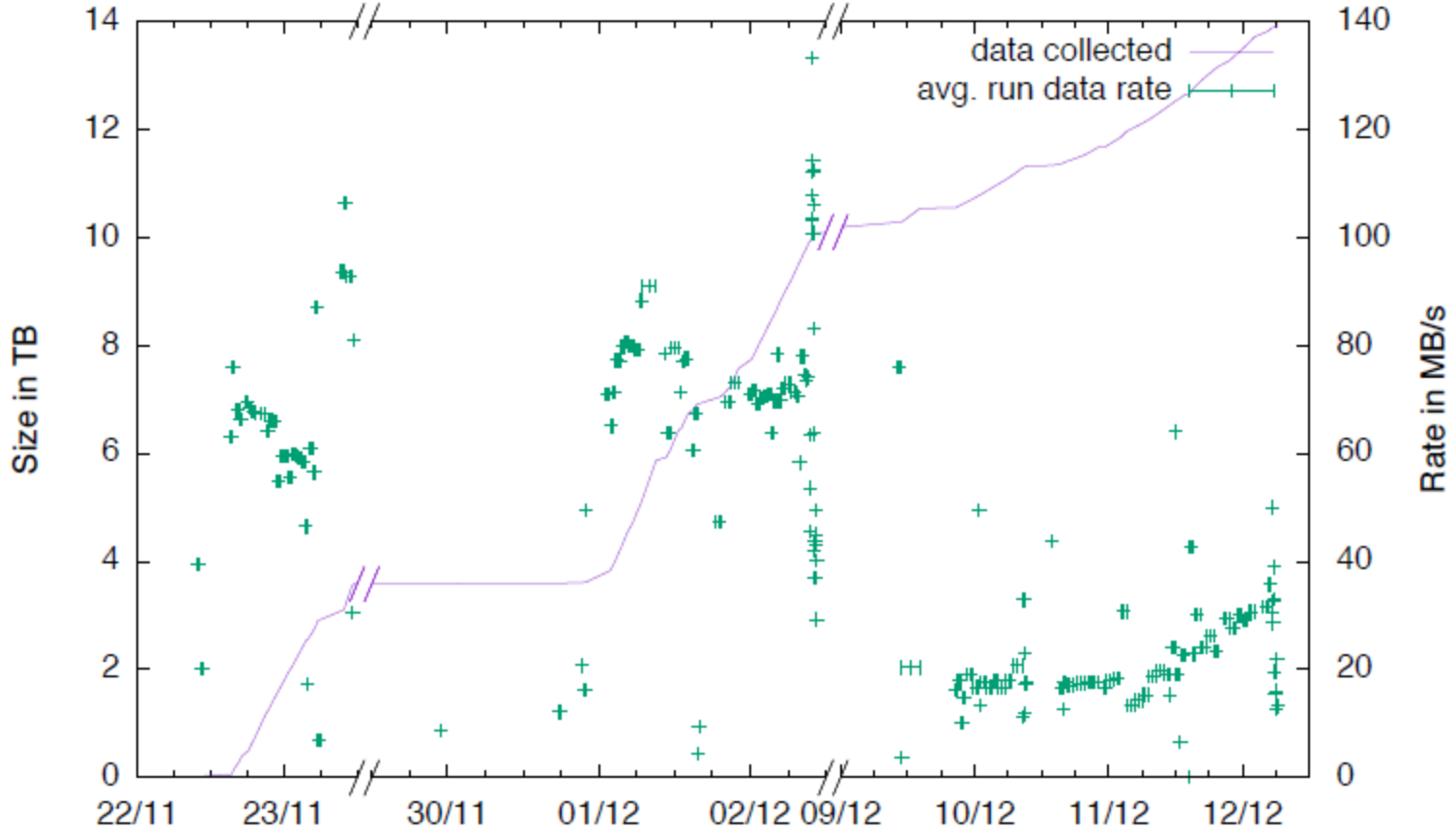
Beam-time @ SPS North Area in Nov. 2016
Beam: Lead @ 158A GeV
Target: 4 mm Pb (+ 10 cm Fe)
Rates: few 200 Hz/cm^2 - 1 kHz/cm^2

Beam-time @ SPS in Nov. 2016



~ 500 Channels with the new "CLOSE TO FINAL"
Free-streaming Readout-Chain:
PADI / GET4 / AFCK / FLIB
=> DAQ was running stable

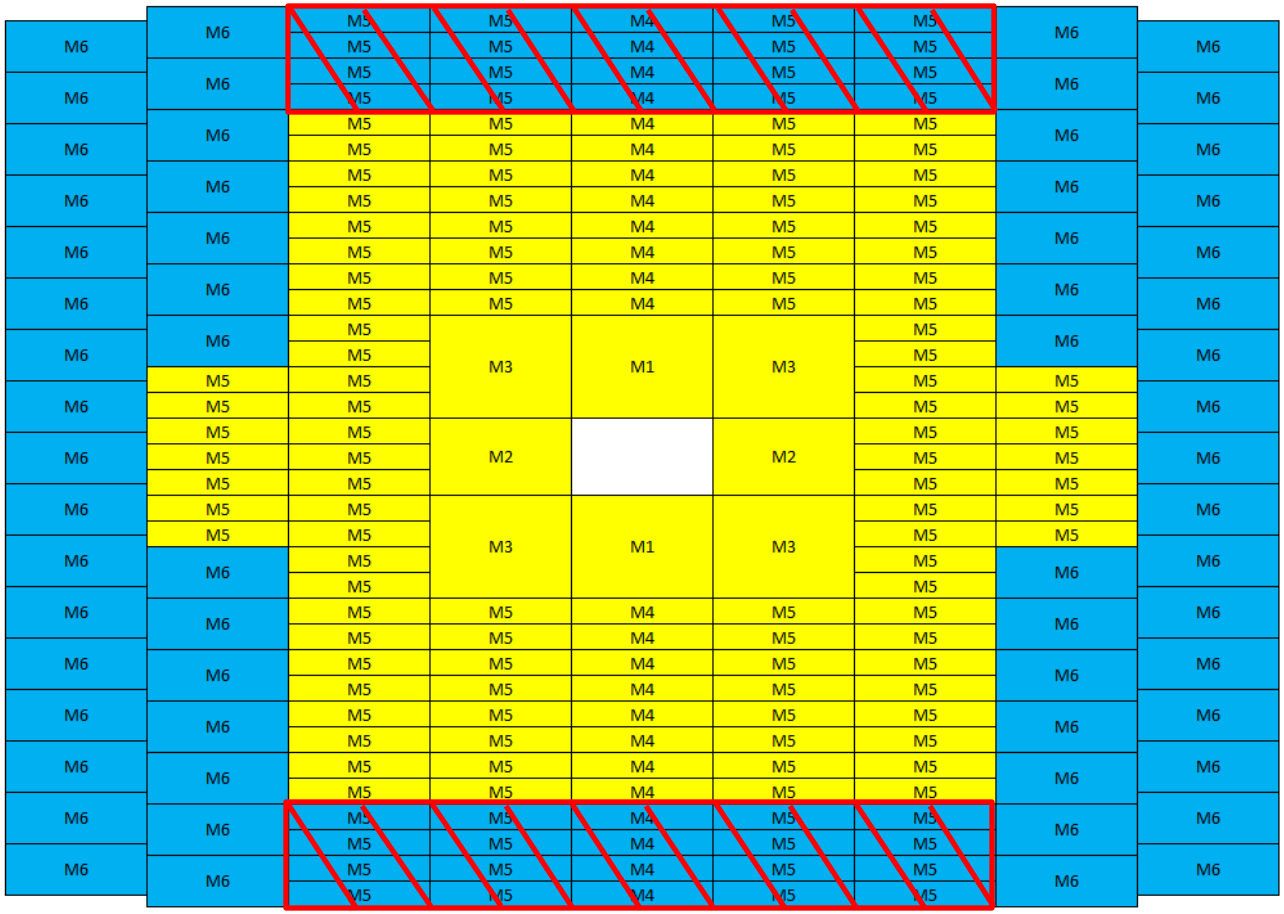
Beam-time @ SPS in Nov. 2016



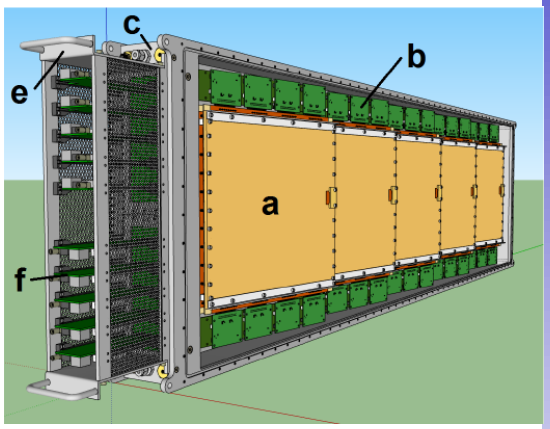
176 successful runs with a total of **14 TB timeslice data**

Mostly epoch markers!

Beam-time @ SPS in Nov. 2016



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	12
Gap size μm	140
Glass size [mm^2]	330 × 280
Glass thickness [mm]	0.28
Number of glass plates	13
Glass type	float
Total glass surface [m^2]	166.32

Beam-time @ SPS in Nov. 2016

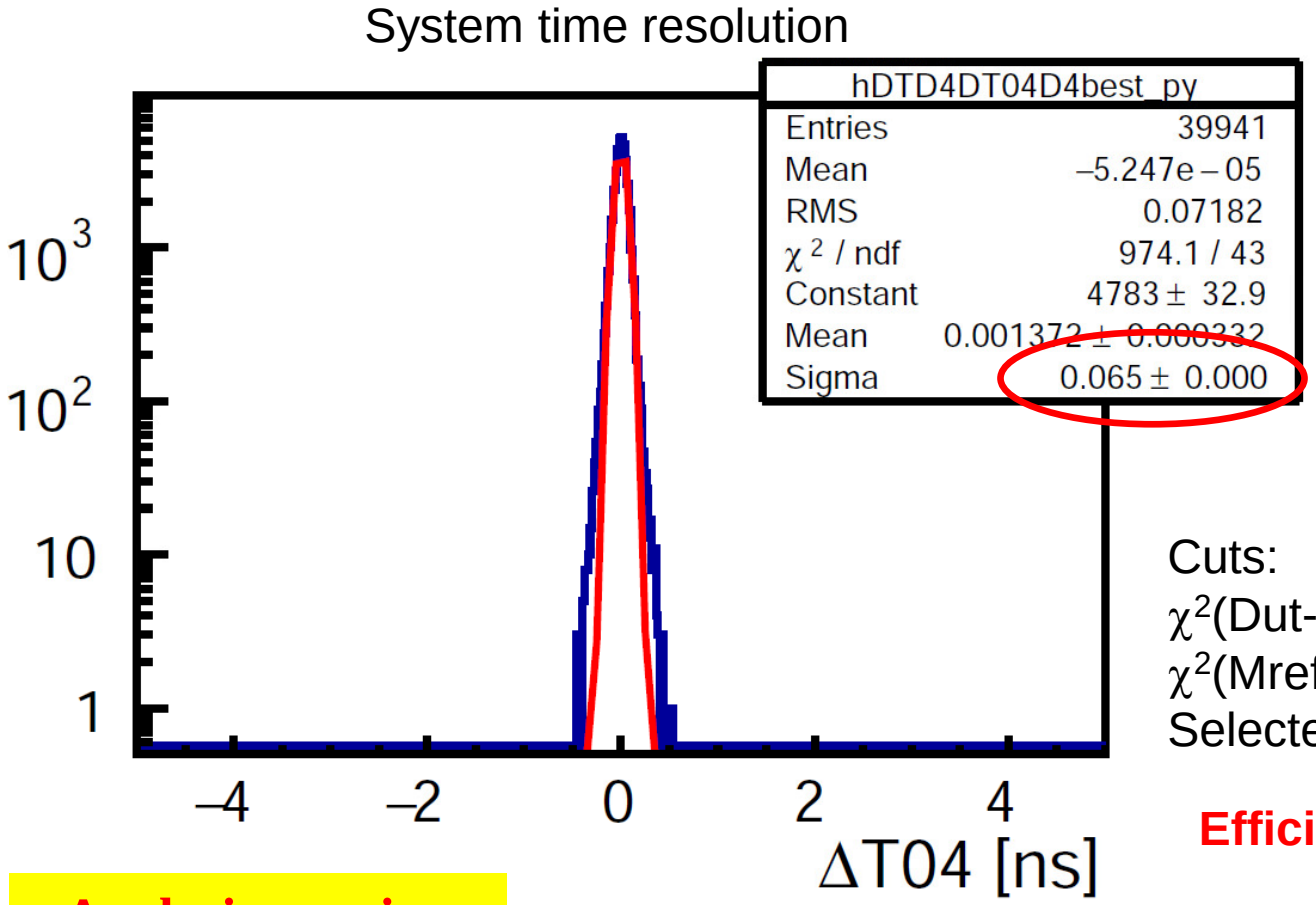
MRPC3b

Dut: 911

Mref: 910

Bref: 500

Sel2: 921



Cuts:

χ^2(Dut-Mref) = 10

χ^2(Mref-Sel2) = 3

Selected Mref area 0.5

Efficiency about 93%

Analysis ongoing

ToF – Project Timeline

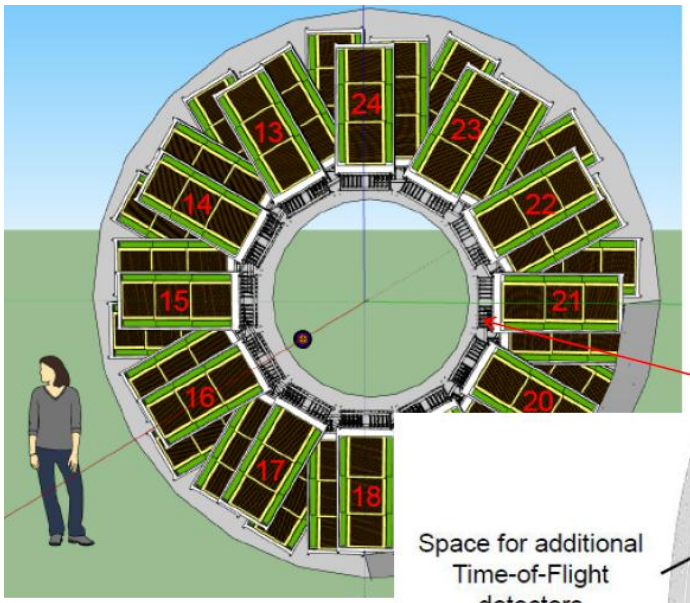
RPC type	res. material	efficiency	time resolution	rate capability
Ceramic MRPC	Ceramic	≈ 90 %	≈ 100 ps	≈ 150 kHz/cm^2
MRPC1/2	sem. glass	> 95 %	≈ 50 ps	> 30 kHz/cm^2
MRPC3a	sem. glass	> 95 %	≈ 60 ps	> 30 kHz/cm^2
MRPC3b	float glass	> 95 %	≈ 50 ps	≈ 1.5 kHz/cm^2

The prototype MRPC counters fulfill the CBM TOF requirements

Time line

✓ Full-size demonstrator	end 2012
✓ TDR approved	mid. 2015
✓ Full-size modules	mid. 2015
✓ Full-size modules with 'final' electronics	mid. 2016
➢ Construction of the modules	2017- 2020
➢ Integration in STAR@RHIC@BNL	2017- 2018
➢ eTOF ready for beam	01.01.2019
➢ Integration in CBM@SIS100@FAIR	2019- 2021
➢ ToF ready for beam	01.06.2023

The TOF FAIR Phase 0 program



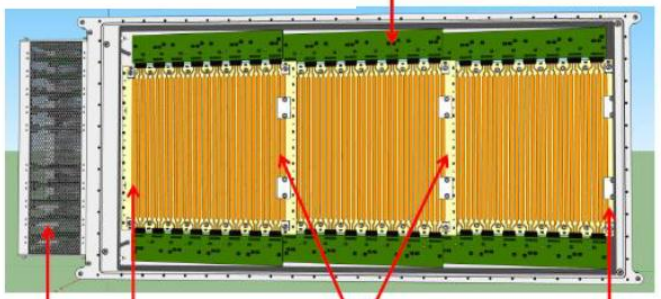
36 modules
3 layers
12 sectors
6912 channels

Sector counting match the TPC sectors

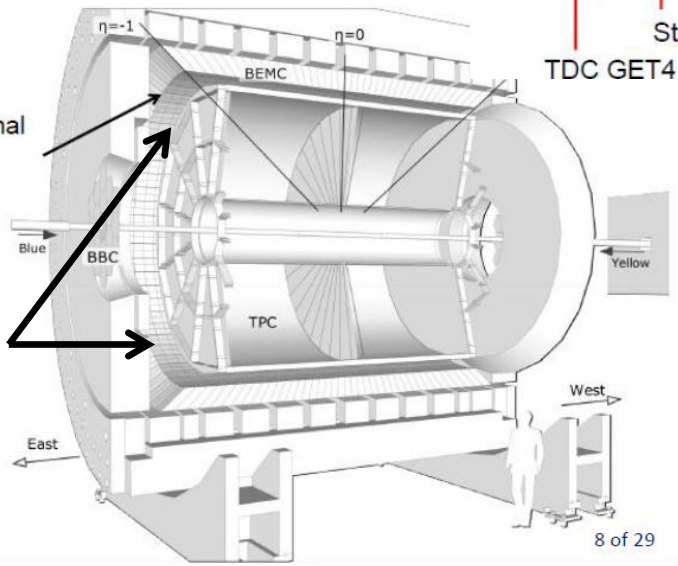
Total depth about 14.2" (36 cm)

GET4 Electronics Boards on inn

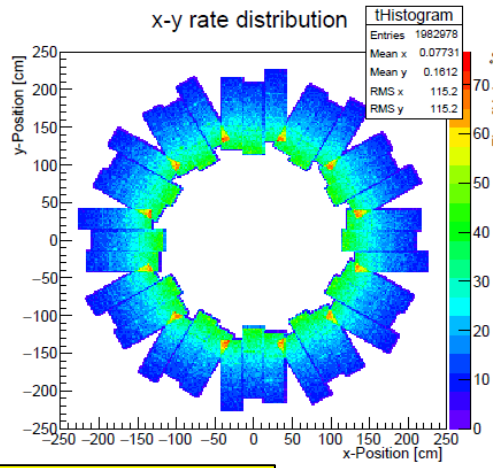
3 MRPCs
32 strips/MRPC with pitch of 1 cm
27 cm strip length
Active area ~ 92 X 27 cm
192 readout channels



Space for additional Time-of-Flight detectors



Location of CBM eTOF modules



Particle flux < 45 Hz/cm², Multi-hit probability < 7.4%

The TOF FAIR Phase 0 program

Benefit for STAR:

- providing critical TOF coverage for BES II
  - PID extension to y = 1.2 in collider mode
  - access to energies from 4.5 to 7.7 GeV in the fixed target program

Benefit for CBM:

- providing a large-scale integration test of the CBM TOF system, including PID and calibration of the detectors (hardware and software)
- preparation for day one experiment at SIS 100

Benefit for CBM-TOF group members:

- participation in the analysis of the physics data provided by the CBM TOF detectors, including authorship of any publications from this data.

Milestones

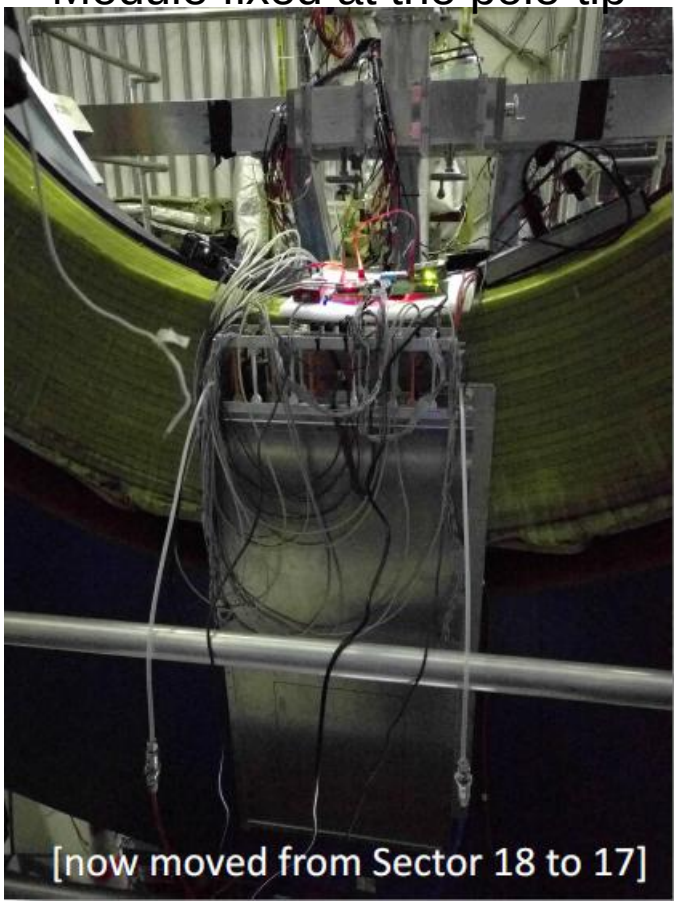
✓ Summer 2016	shipping a real size module to BNL and installing it on the east side pole of STAR
✓ Feb. 2017	1st system integration test with one module by participating in the Run17 beam time in STAR
➢ Fall 2017	shipping and installation of one sector
➢ Feb. 2018	2nd system integration test with one sector by participating in the Run18 beam time in STAR
➢ Summer 2018	shipping all 36 modules including infrastructure (gas system, LV-, HV-power supply) to BNL
➢ Fall 2018	Installation and commissioning
➢ Feb 2019	Start of the BES II campaign
➢ Summer 2021	Decommissioning and shipping of all modules including infrastructure to FAIR

The TOF FAIR Phase 0 program

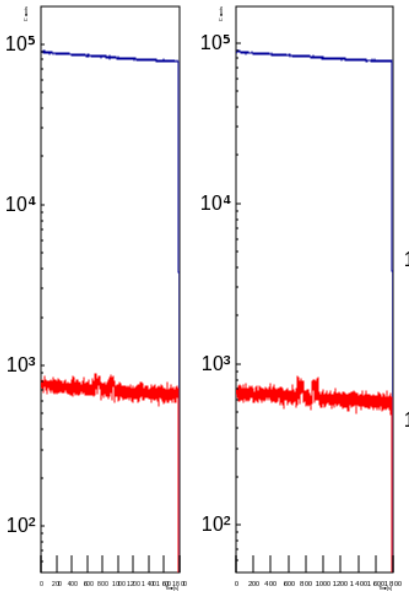
Module installation in Oct. 2016

Open module

Module fixed at the pole-tip



Running (Mar. 2017)



about 100 Hz/cm²

Summary and outlook

- CBM TOF started system performance tests under realistic load conditions
- Counters maintain their performance so far
- Preproduction about to start (QC, QA procedures initiated)
- R&D for BFTC ongoing
- FAIR phase 0 started - looking forward to physics

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,

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Norbert Herrmann

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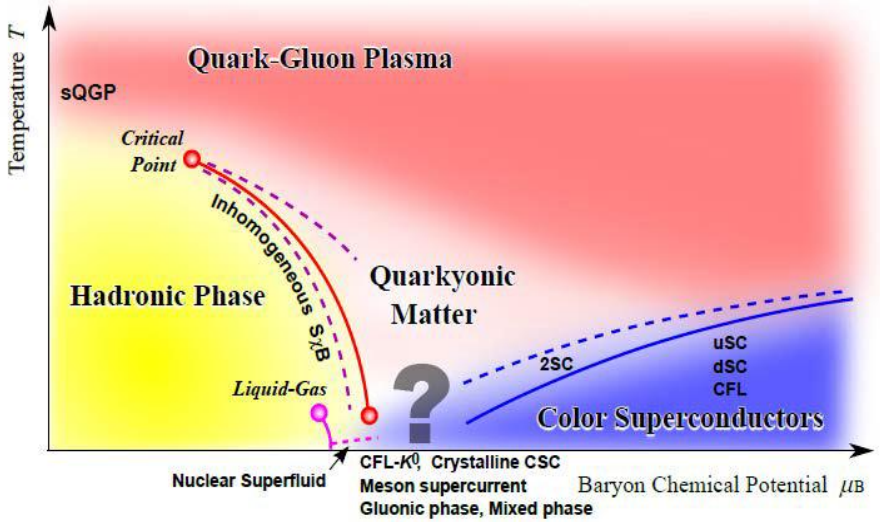
Backup Slides

Backup Slides

CBM Physics topics

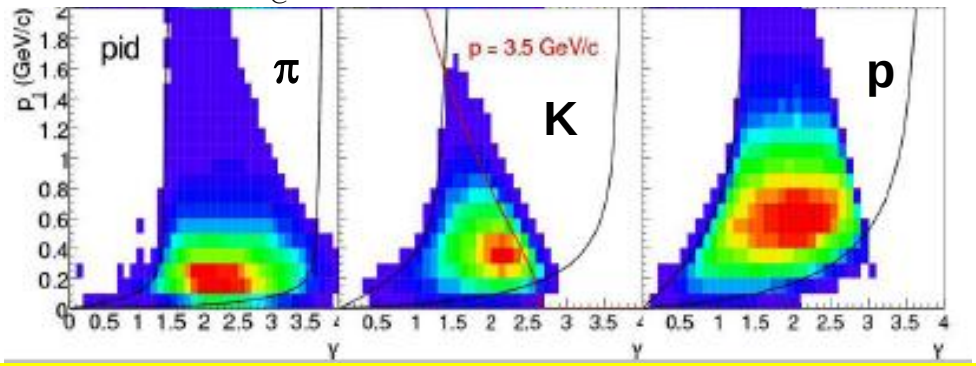
- Deconfinement / phase transition at high ρ_B
- QCD critical endpoint
- The equation-of-state at high ρ_B
- chiral symmetry restoration at high ρ_B



Observables

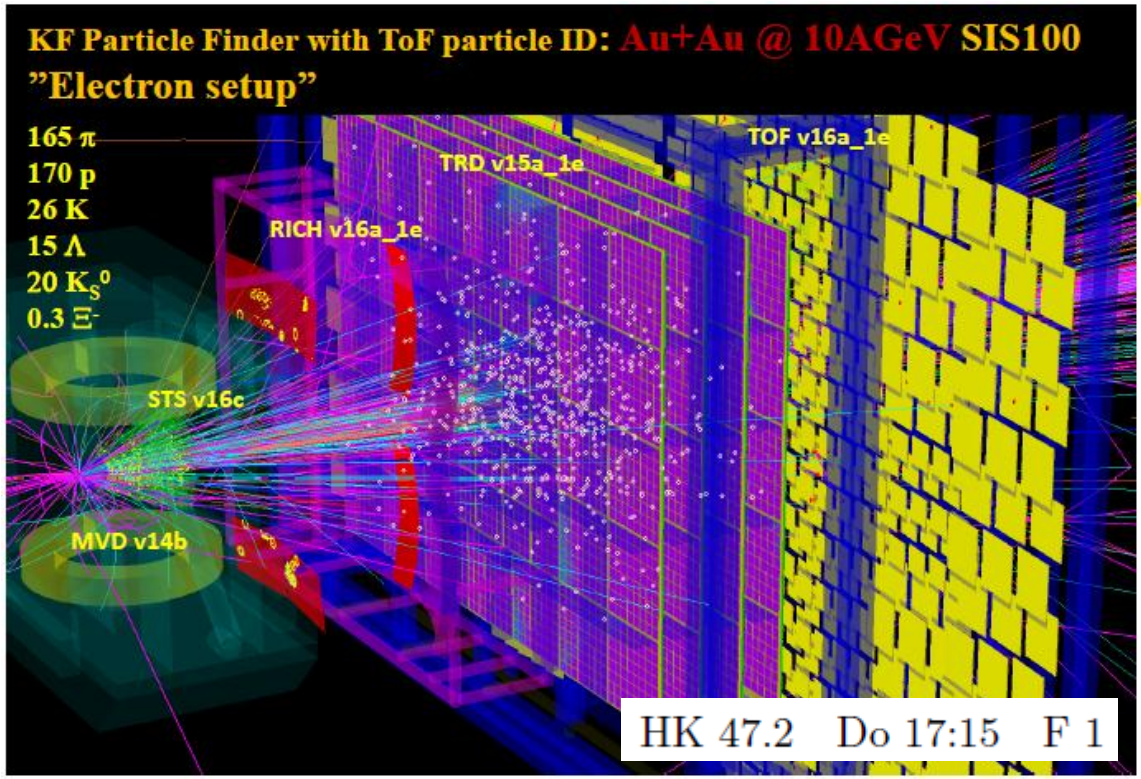
- excitation function and flow of strangeness and charm
- collective flow of hadrons
- particle production at threshold energies
- excitation function of event-by-event fluctuations
- excitation function of low-mass lepton pairs
- in-medium modifications of hadrons ($\rho,\omega,\varphi \rightarrow e^+e^-(\mu^+\mu^-)$,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

D. Kresan Au + Au @ 25GeV

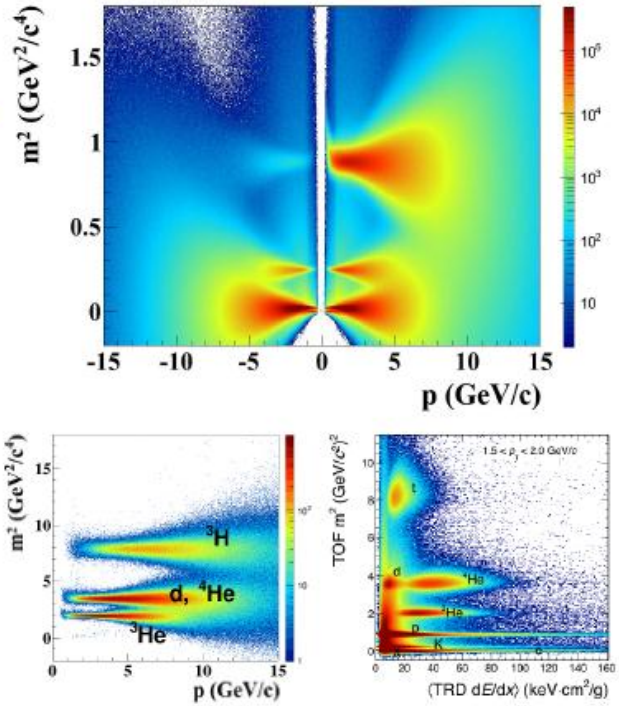


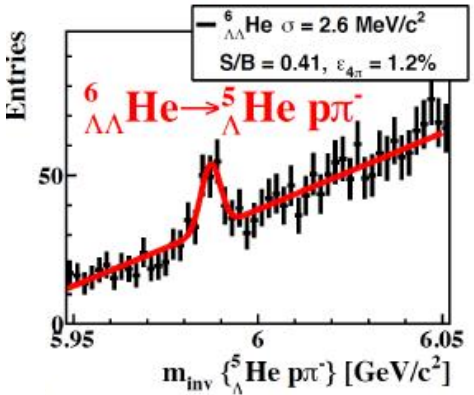
Kaon acceptance depends critically on TOF resolution

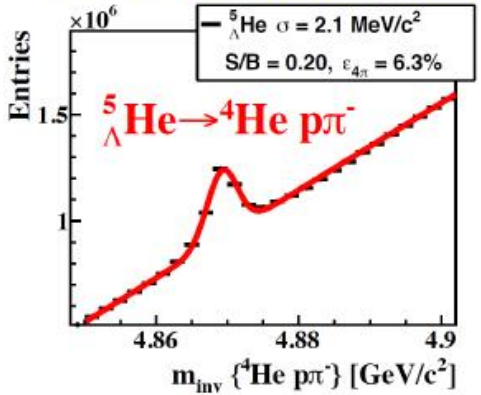
PID capability



Particle Identification



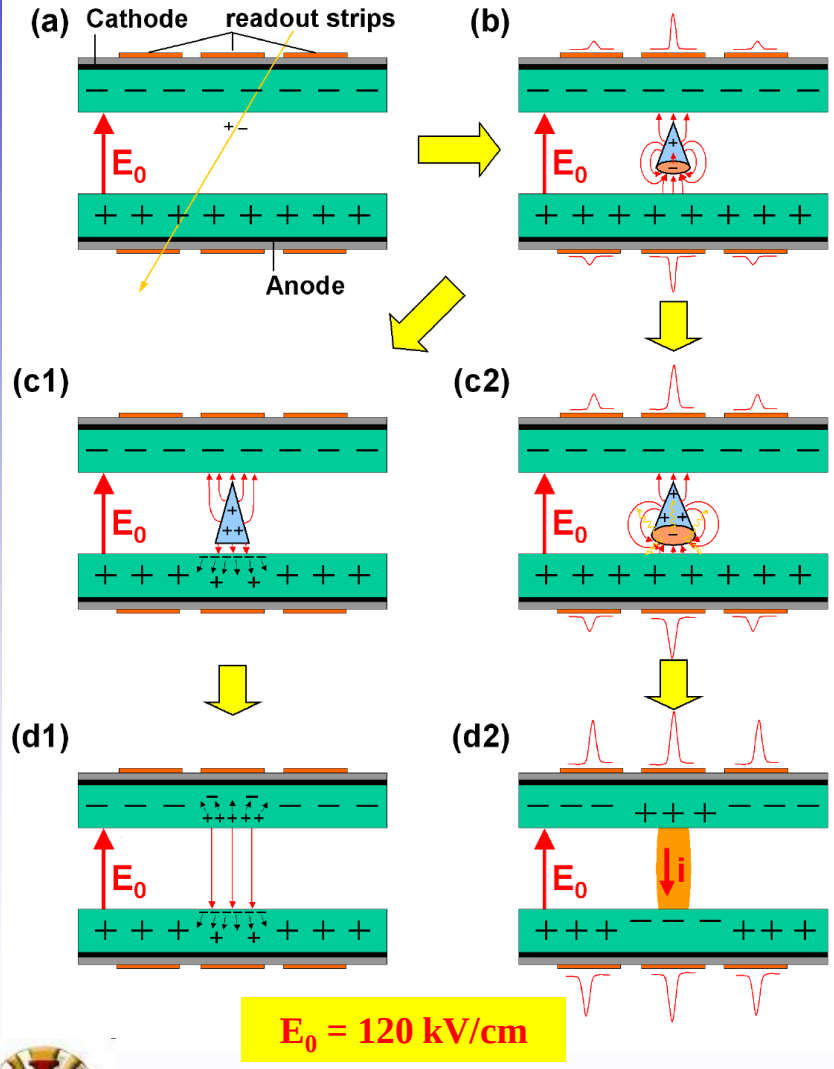




Reconstruction of double Λ-hypernuclei

- 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



E_0 = 120 kV/cm

First Multi-gap RPC 1996

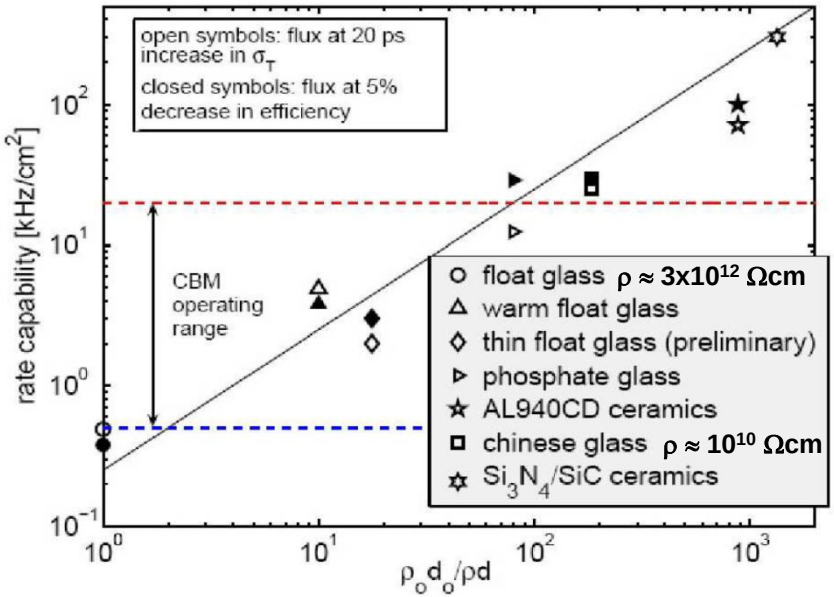
E. Cerron Zeballos et al., **Nucl.Instrum.Meth. A374 (1996) 132-13**

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

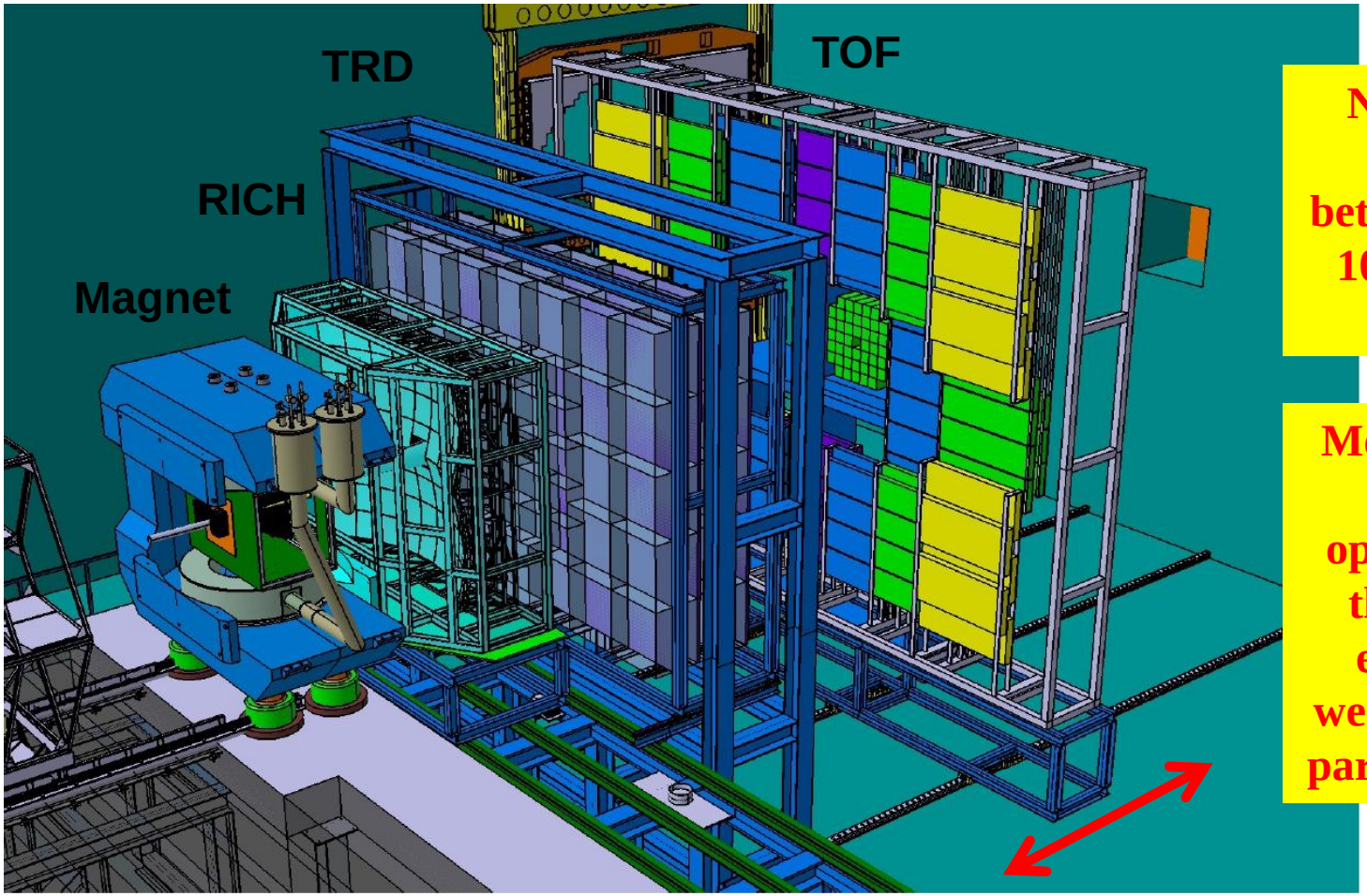
Efficiency: $\epsilon = \epsilon_0 - K_\epsilon \bar{q} \phi \rho d$

ϕ: incident ch. particle flux, ρ: electrode bulk resistivity, d: electrode thickness

How to increase the rate capability?



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

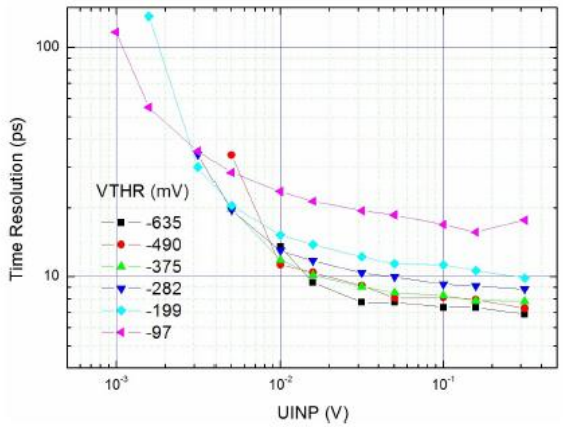
- peripheral HI – reaction have fast particles from projectile fragmentation
- equip region E with timing counters (BFTC)

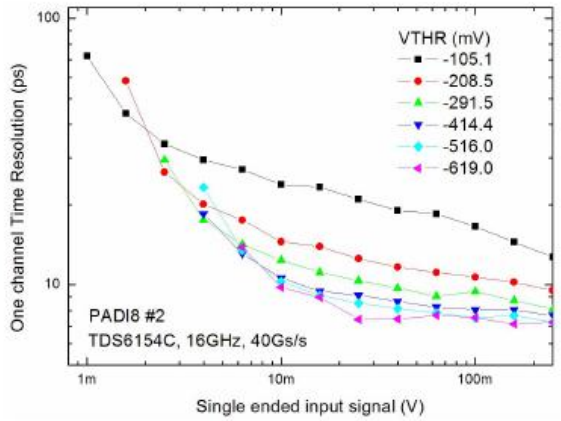
Reaction counter

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

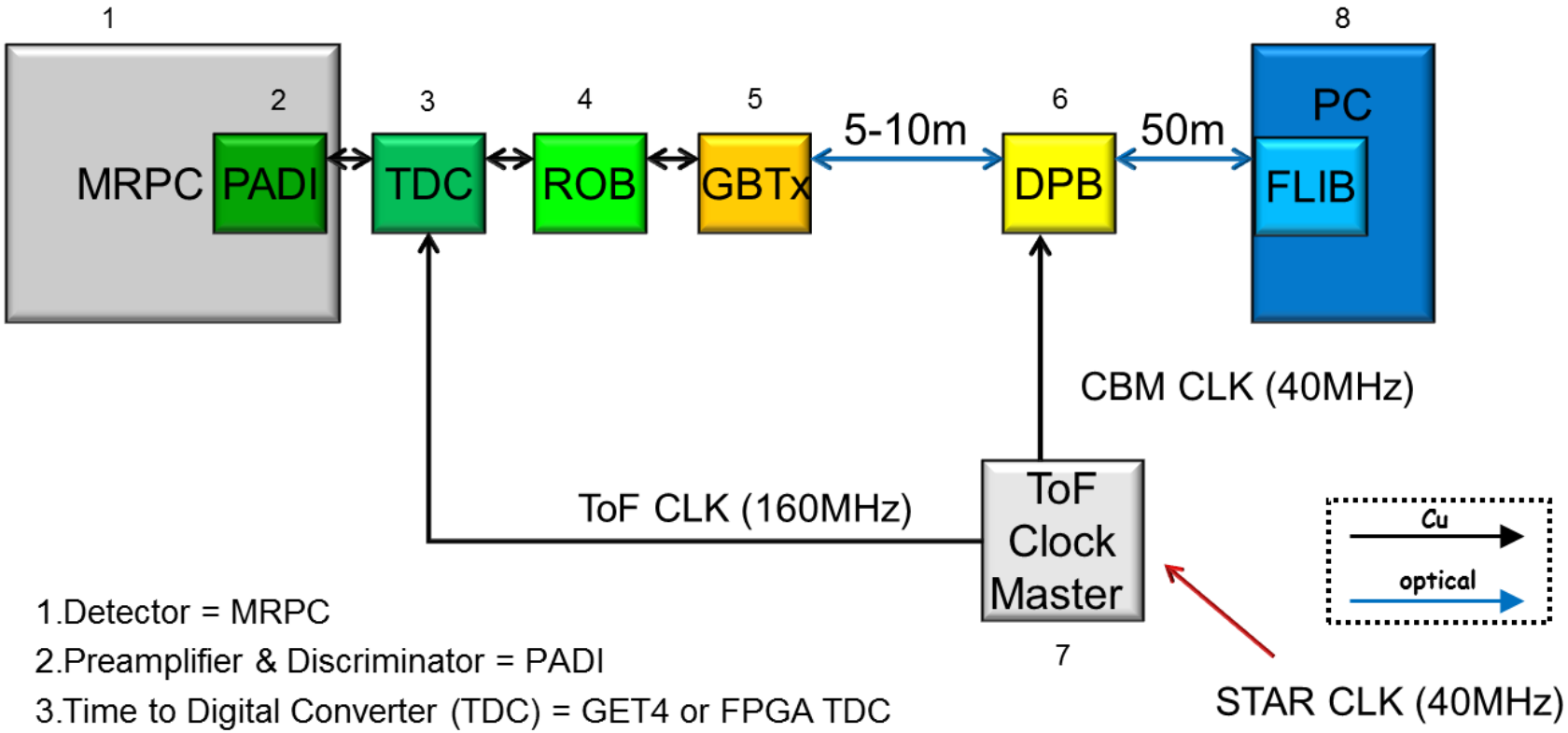
Backup Slides

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 σ (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 (Ω)	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

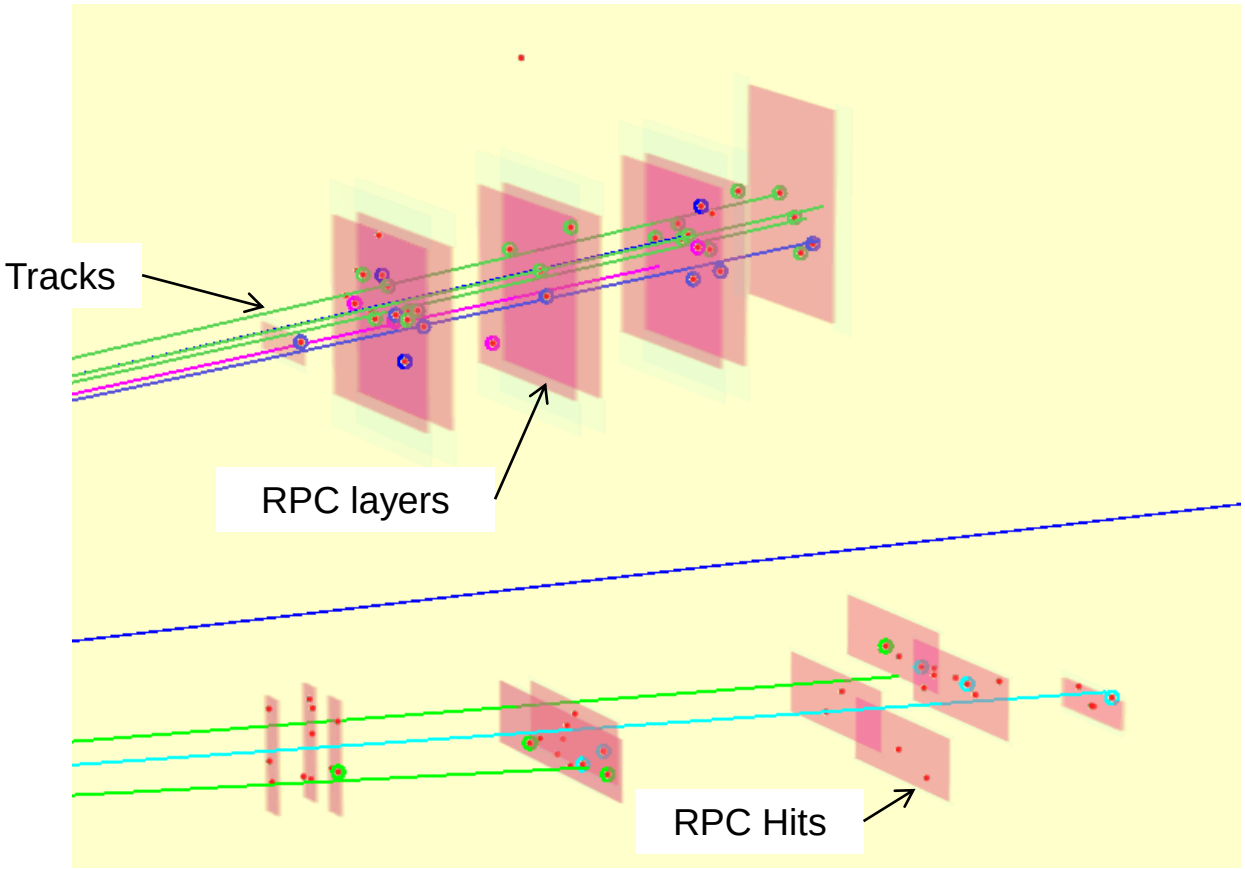
Production Readiness Review

2017	J	F	M	A	M	J	J	A	S	O	N	D	J
R&D													
Counter component production													
Counter assembly				5	5		10	10	10	15	15	10	
Preparation for quality assurance													
Quality assurance				5	5		5	10	15	15	15	10	
MRPC shipment					10					30			40

- Freeze the design by March. Start counter assembly from April.
- Produce 10 MRPC3a/b as "Pre-mass production".
- Check the performance and use for summer installation @ STAR.
- Finish production by November.
- Send to Heidelberg in three batches.

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