RPC 2016 – XIII Workshop on Resistive Plate Chambers and Related Detectors

Performance studies of a single HV stack MRPC prototype for CBM

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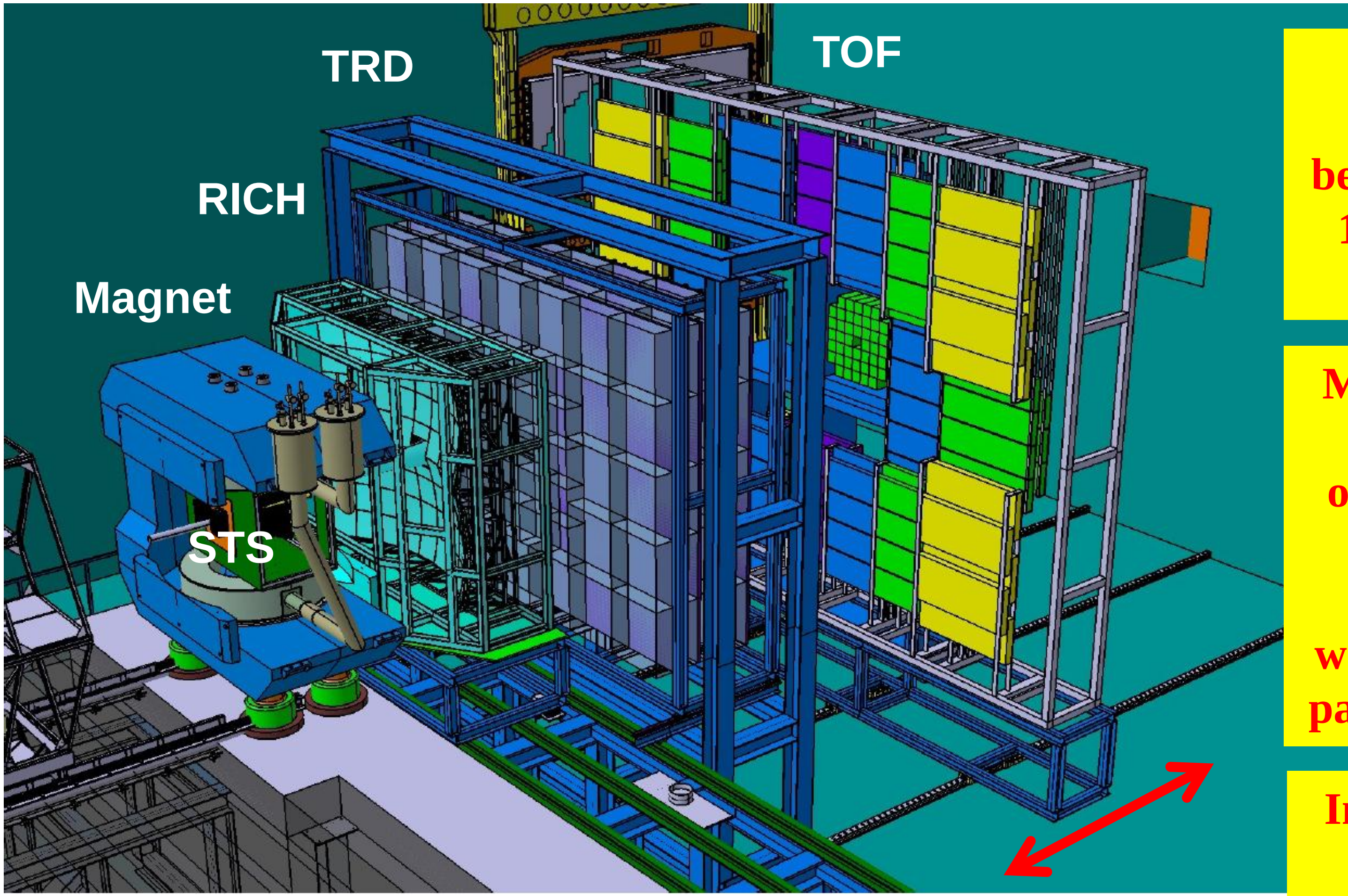
Outline:

- CBM-ToF requirements
- TDR Tof wall design
- Test beam time at GSI
- Single stack vs. double stack
- Performance results
- Summary / Outlook

CBM spectrometer

Engineering design of the CBM experiment



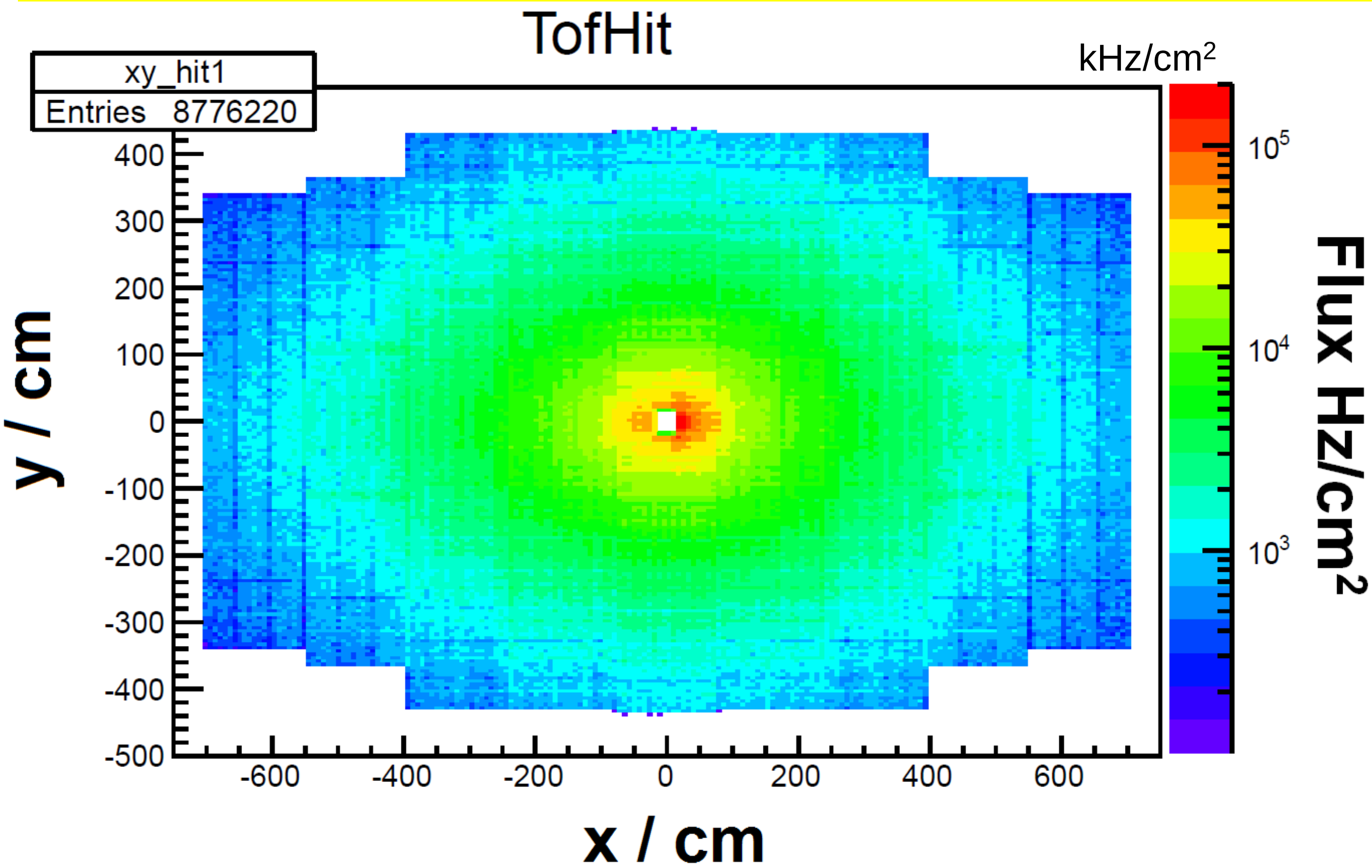
Nominal ToF position is between 6 m and 10 m from the target

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

Interaction rate 10 MHz

Incident particle flux

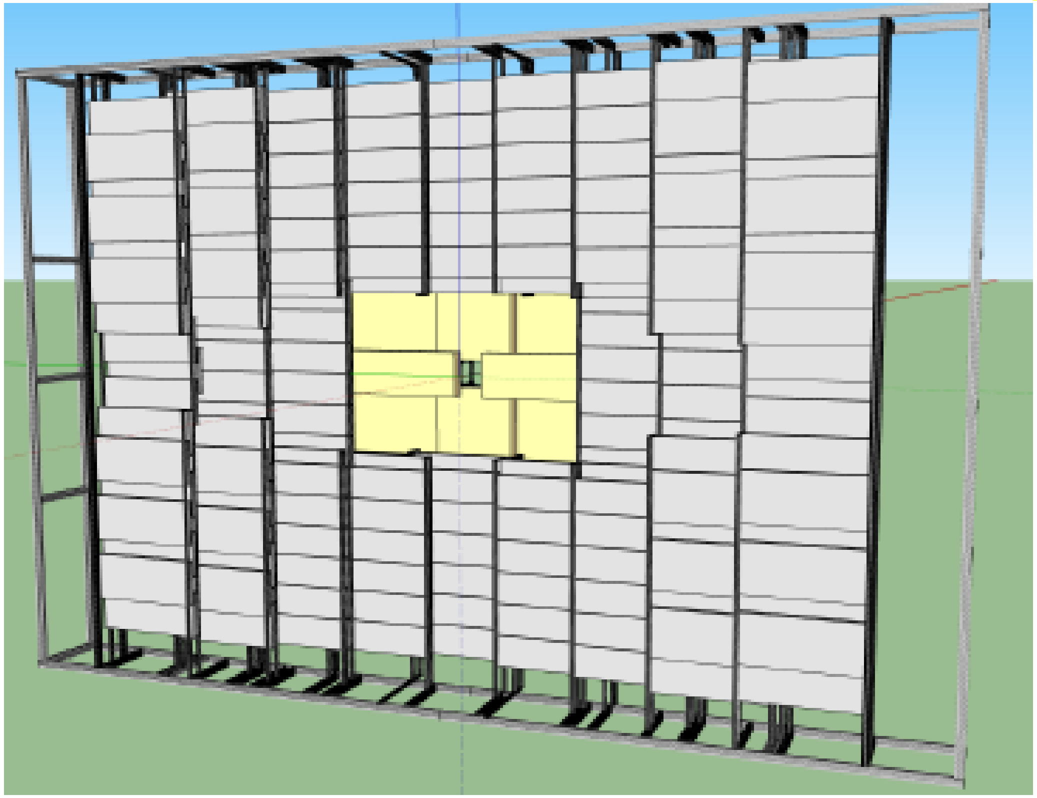
URQMD simulated charged particle flux for Au + Au (minimum bias) events at 25 AGeV assuming an interaction rate of 10 MHz



- Flux ranging from 0.1 to 100 kHz/cm^2
- At different regions MRPC counters with different rate capabilities are needed

Requirements

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

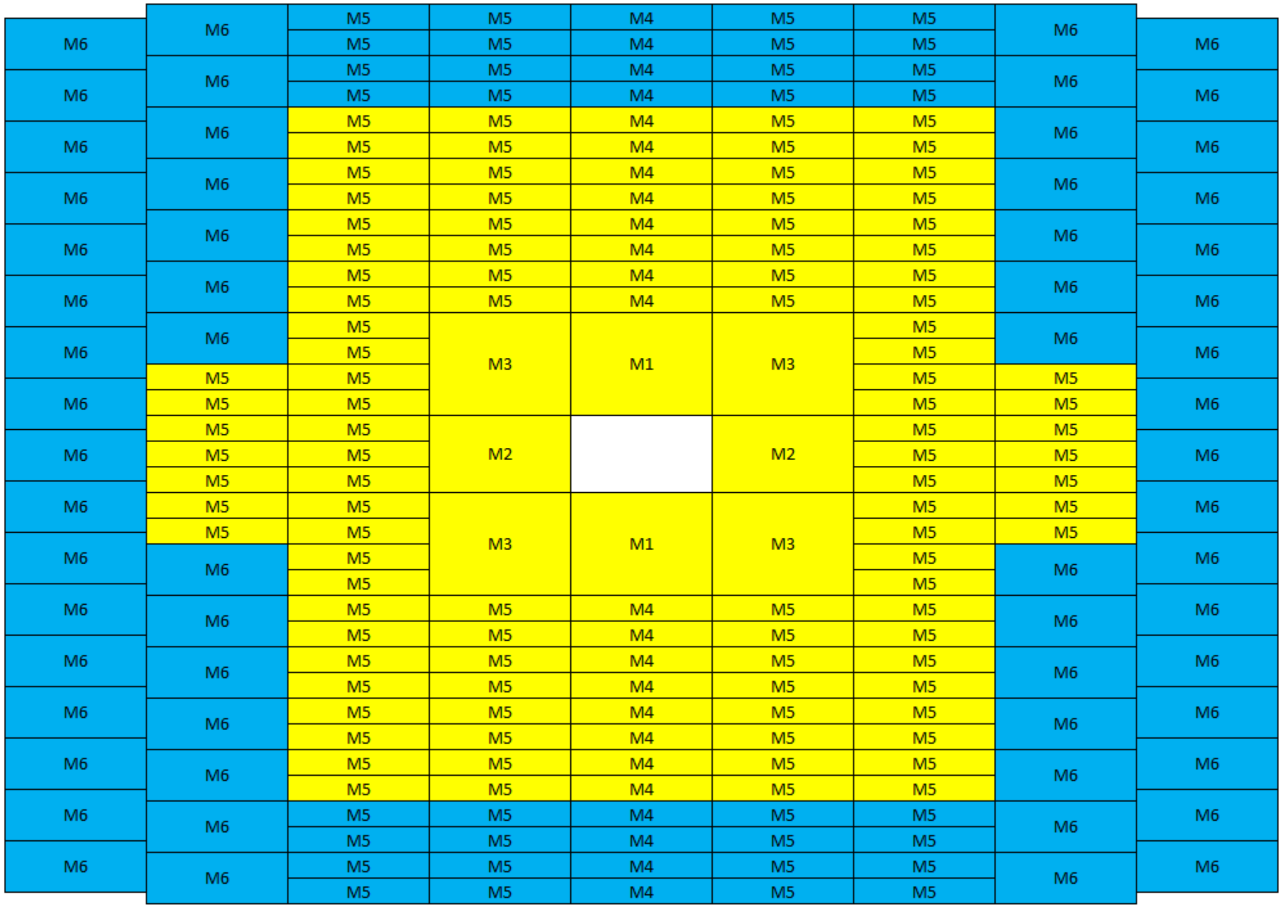


CBM-ToF Requirements

- **Full system time resolution σ_T ~ 80 ps**
- **Efficiency > 95 %**
- **Rate capability ≤ 30 kHz/cm^2**
- **Polar angular range 2.5° – 25°**
- **Occupancy < 5 %**
- **Low power electronics**

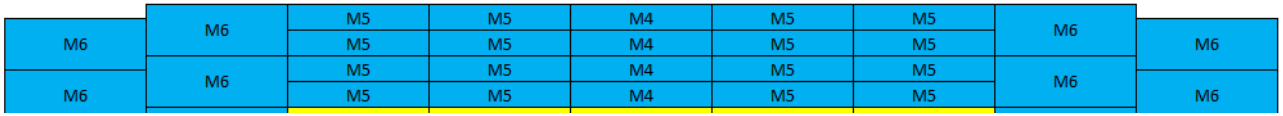
  (~120.000 channels)
- **Free streaming data acquisition**

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

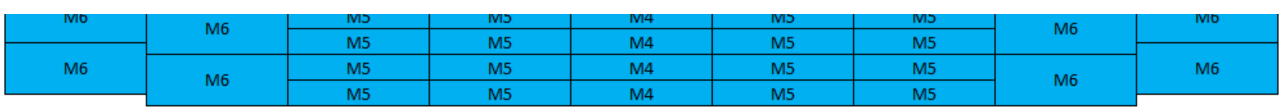
TDR ToF wall layout



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

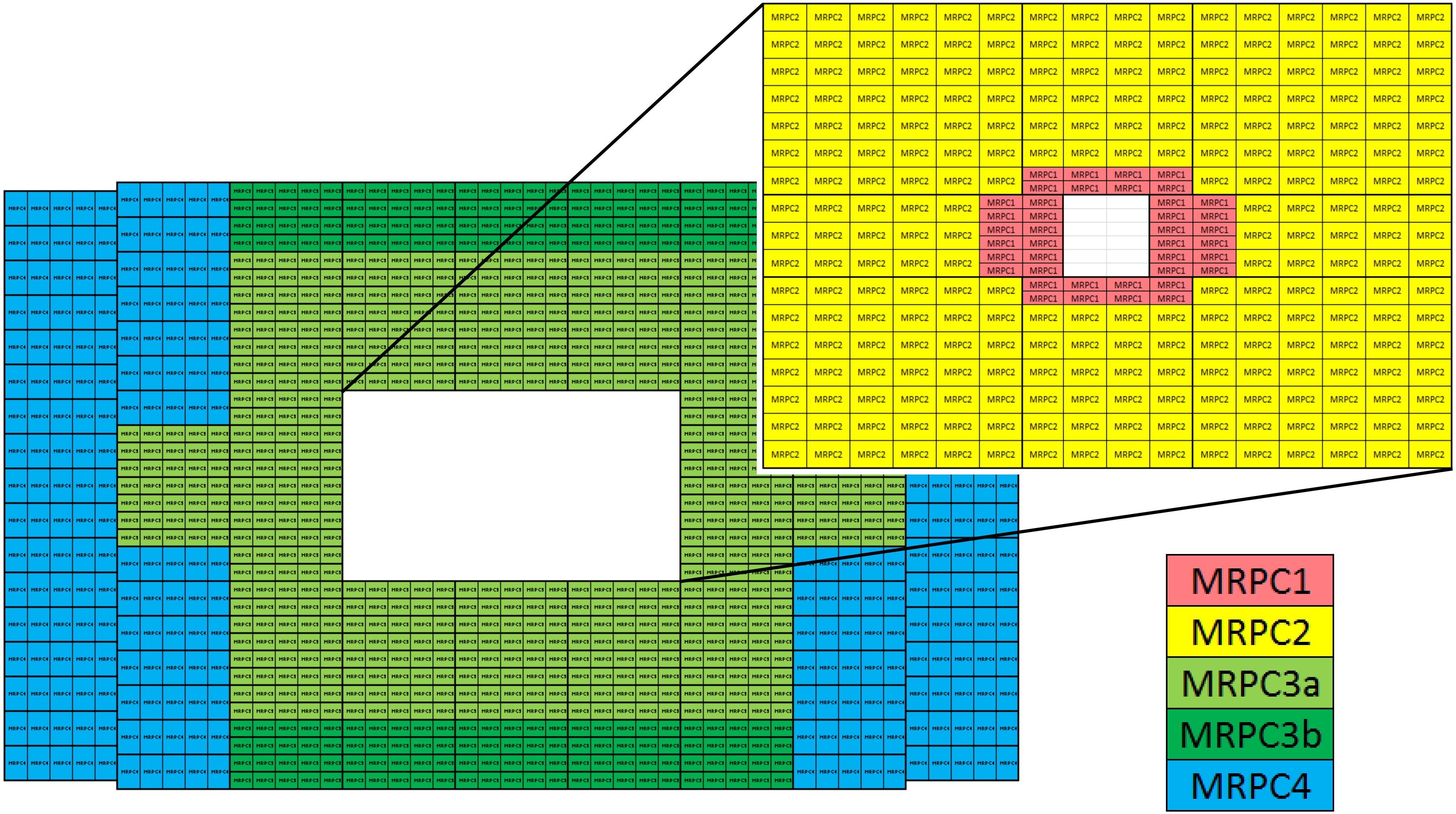
Module notation	Number of modules	Module size mm^3	Number of MRPCs per module	Number of MRPCs in total	Number of cells per module	Number of cells in total
M1	2	$1270 \times 1417 \times 239$	32	64	2048	4096
M2	2	$2140 \times 705 \times 239$	27	54	1728	3456
M3	4	$1850 \times 1417 \times 239$	42	168	2688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

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

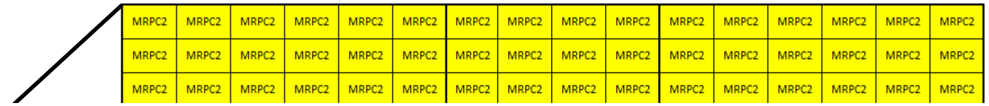


⇒ 106368 read-out channels

TDR MRPC arrangement

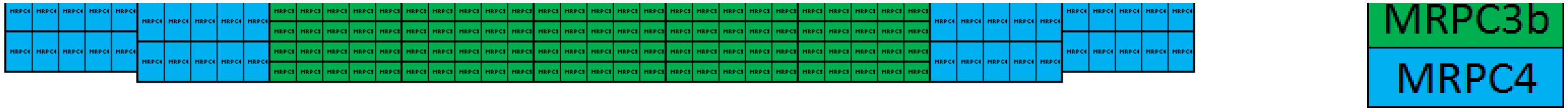


TDR MRPC arrangement



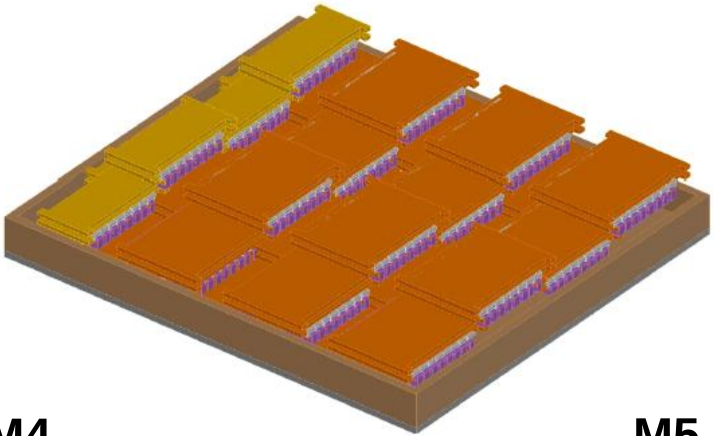
MRPC notation	MRPC1	MRPC2	MRPC3a	MRPC3b	MRPC4
Number of MRPCs	40	246	580	200	310
Active area [mm^2]	300 × 100	300 × 200	320 × 270	320 × 270	320 × 530
Number of Strips per MRPC	64	64	32	32	32
Strip length [mm]	100	200	270	270	530
Granularity (cell size) [mm^2]	472.4	944.8	2700	2700	5300
Number of gas gaps	10	10	8	8	8
Gap size μm	140	140	220	~~220~~ 140	~~220~~ 140
Glass size [mm^2]	320 × 100	320 × 200	330 × 280	330 × 280	330 × 540
Glass thickness [mm]	0.7	0.7	~~1.0~~ 0.7	~~0.5~~ 0.28	~~0.5~~ 0.28
Number of glass plates	12	12	9	~~8~~ 12	~~9~~ 12
Glass type	low res.	low res.	low res.	float	float
Total glass surface [m^2]	15.36	188.93	482.33	166.32	497.18

Table 3.2: *Numbers and dimensions of different MRPC counters.*

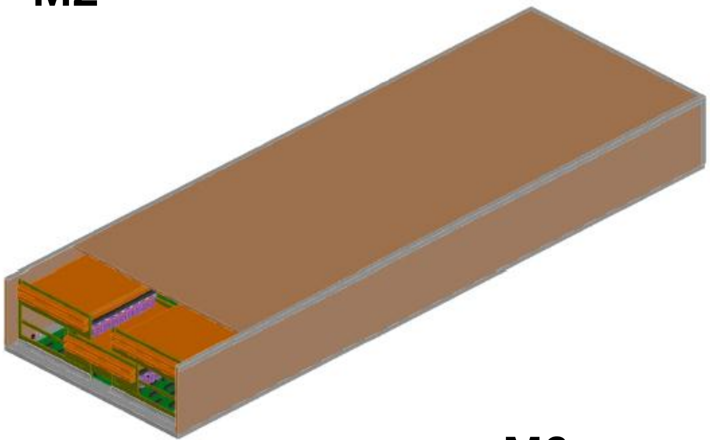


Modules

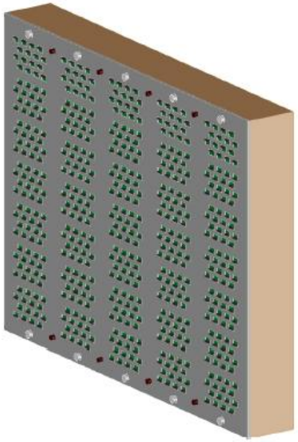
M1



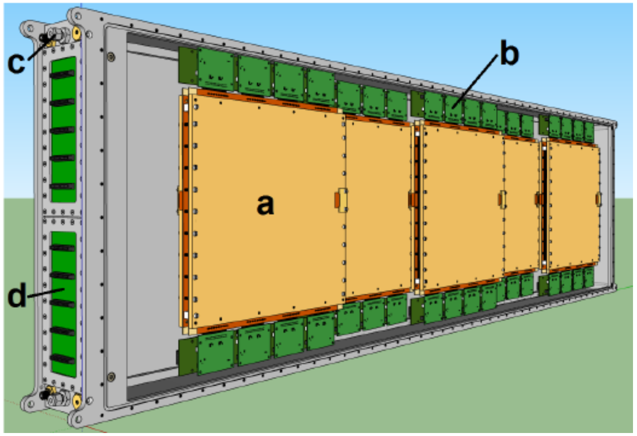
M2



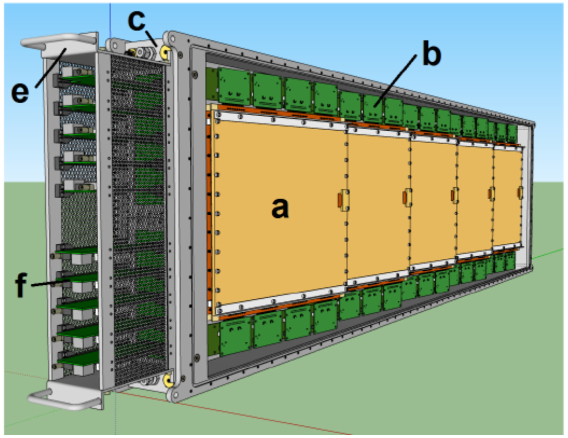
M3



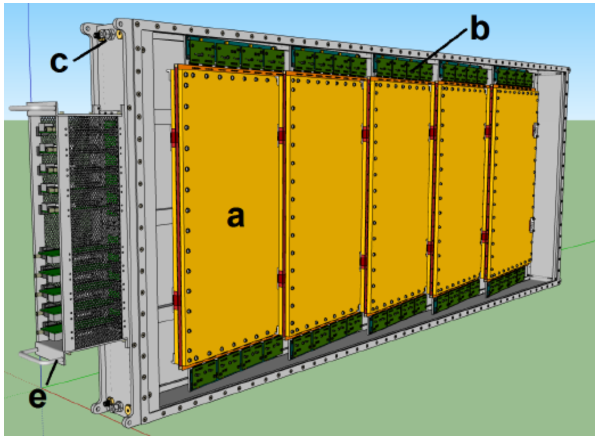
M4



M5

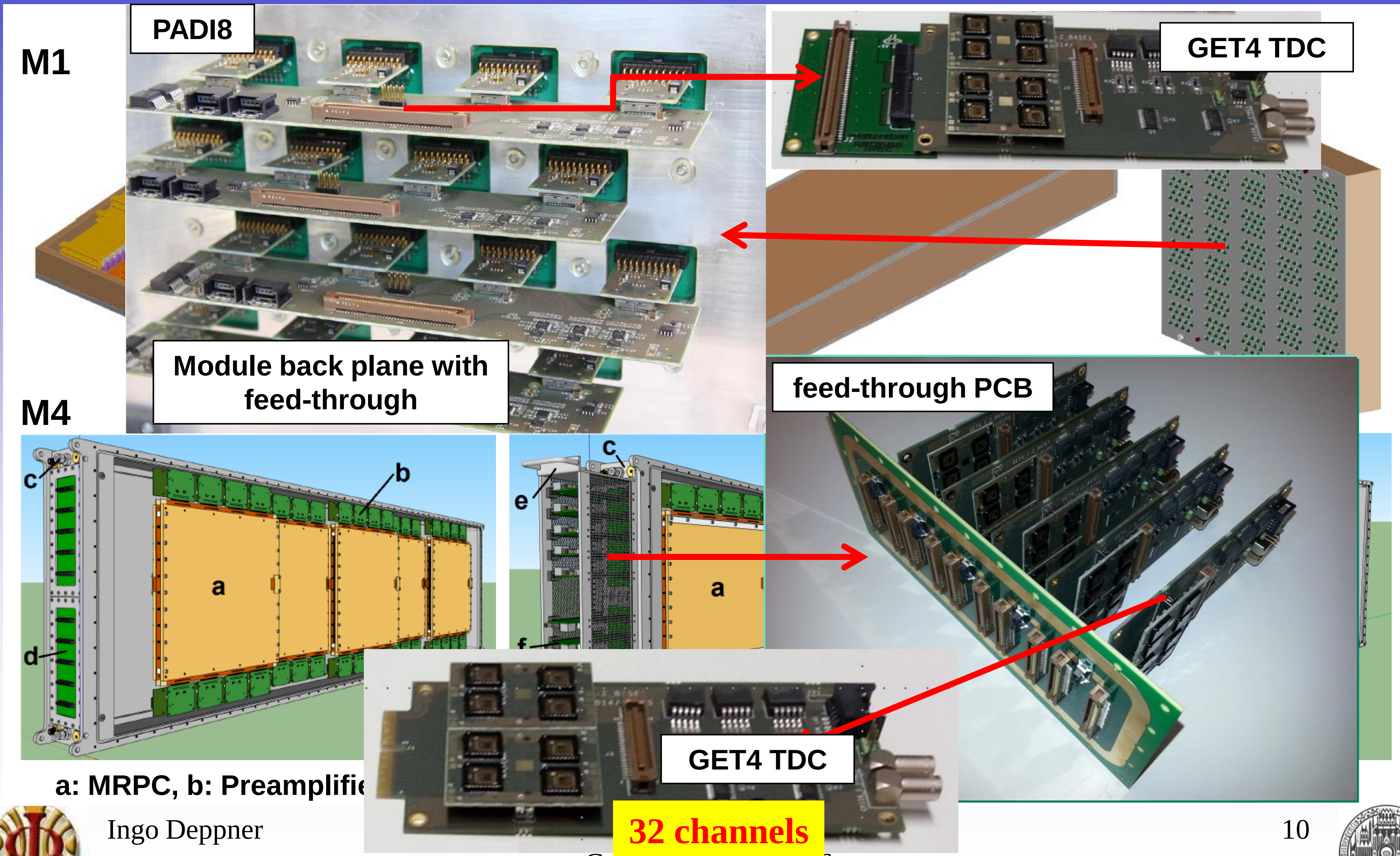


M6



a: MRPC, b: Preamplifier (PADI), c: feed-through PCB, d: connectors, e: crate, f: TDC and read out

Modules



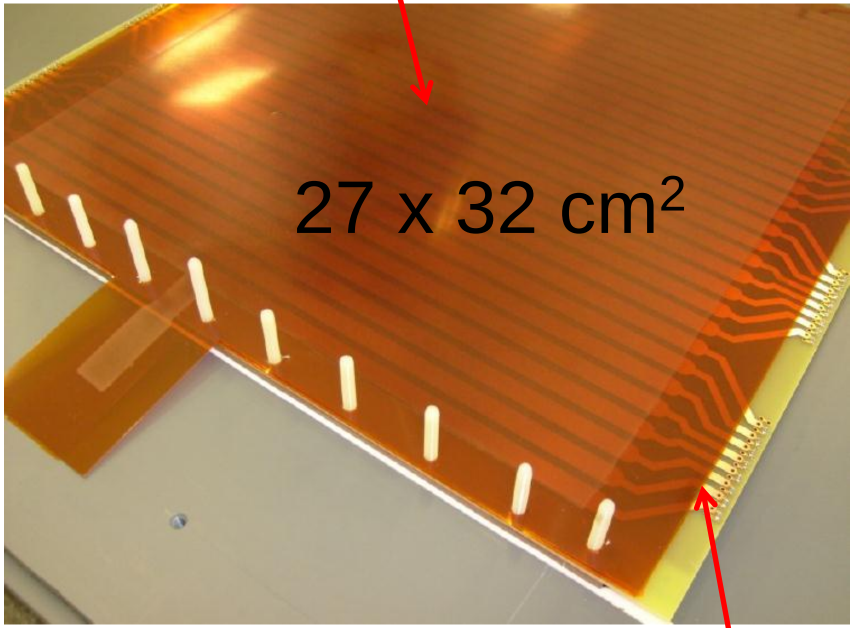
a: MRPC, b: Preamplifie

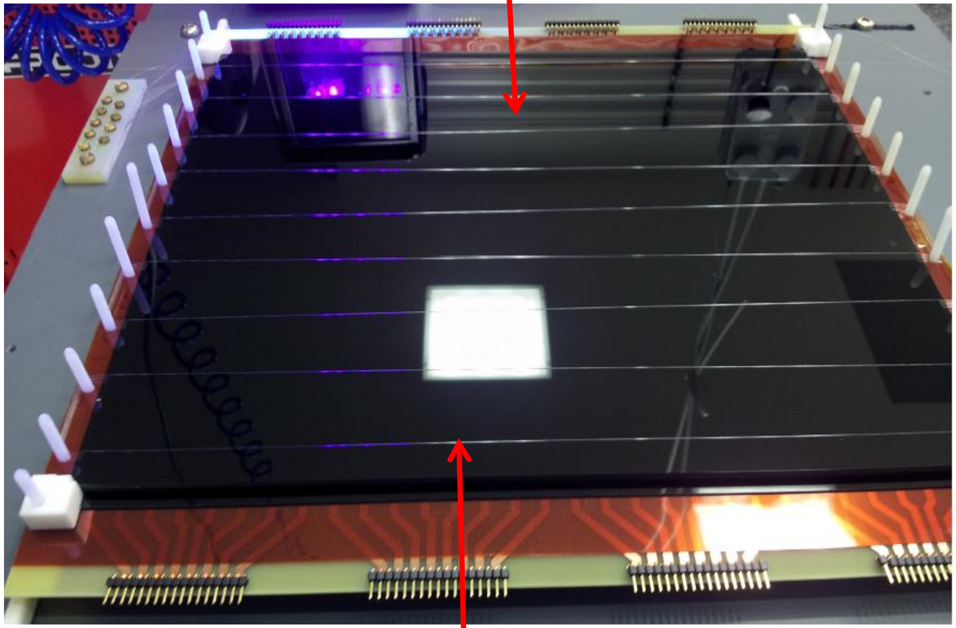
MRPC-P2 prototype

Full size demonstrator for high rates (1 - 10kHz/cm^2)

HV electrode
(Licron®)

Low resistive
glass





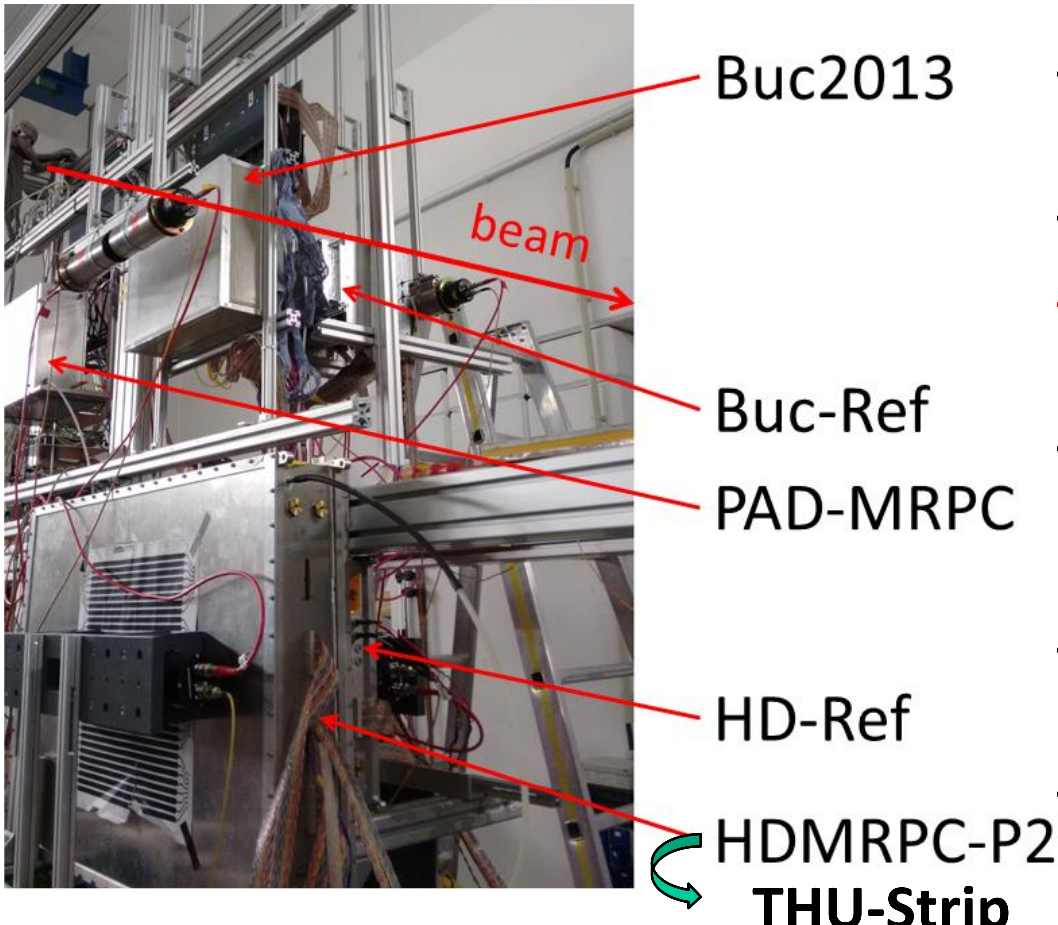
Pickup
electrode

Spacers
(fishing line)

Test beam time @ GSI

CBM ToF

Setup



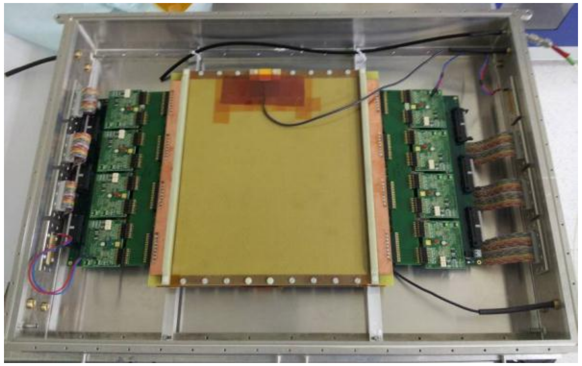
- Test beam time in October 2014 at GSI (Hades cave)
- Sm beam with 1.2A GeV kin. energy
- 5 mm thick lead target
- „Uniform“ illumination of the counter surface
- Flux on the lower part of the setup was about few hundred Hz/cm^2
- Delivered flux does not meet the CBM requirements
- R143a 85%, SF6 10%, iBut 5%

Test beam time @ GSI

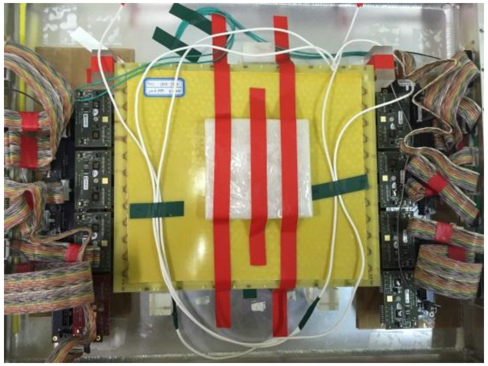
Full size demonstrator and reference MRPC used for the performance analysis

	MRPC-P2 (HD)	THU-strip (Beijing)	MRPC-P5 (HD)
MRPC	differential	differential	differential
glass stack	single	double	single
active area	32 x 27 cm^2	24 x 27 cm^2	15 x 4 cm^2
strips	32	24	16
strip / gap	7/ 3	7/ 3	7.6 / 1.8 mm
glass type	low resistive glass	low resistive glass	low resistive glass
glass thickness	0.7 mm	0.7 mm	1.0 mm
number of gaps	8	2 x 4	6
gap width	220 μm	250 μm	220 μm

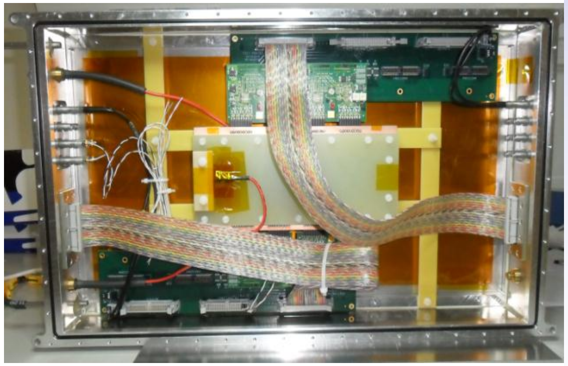
MRPC-P2



THU-strip

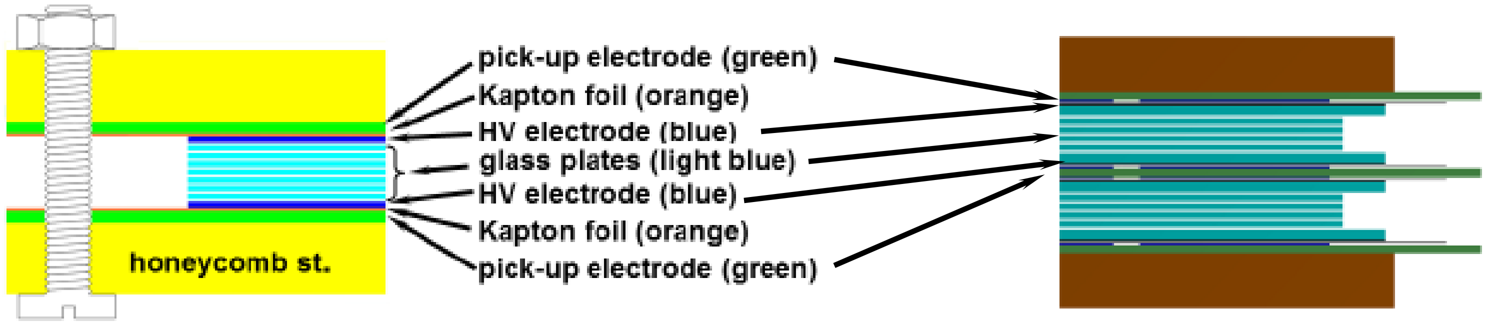


MRPC-P5



2 MRPC concepts

Differential singel stack MRPC with 8 gaps **vs.** Differential double stack MRPC with 2 x 4 gaps



Differential singel stack MRPC with 8 gaps

Advantages
- simpler construction
- symmetric signal path
- fewer glass plates (#9)
- lower weight
- impedance matching easy possible (100Ω)

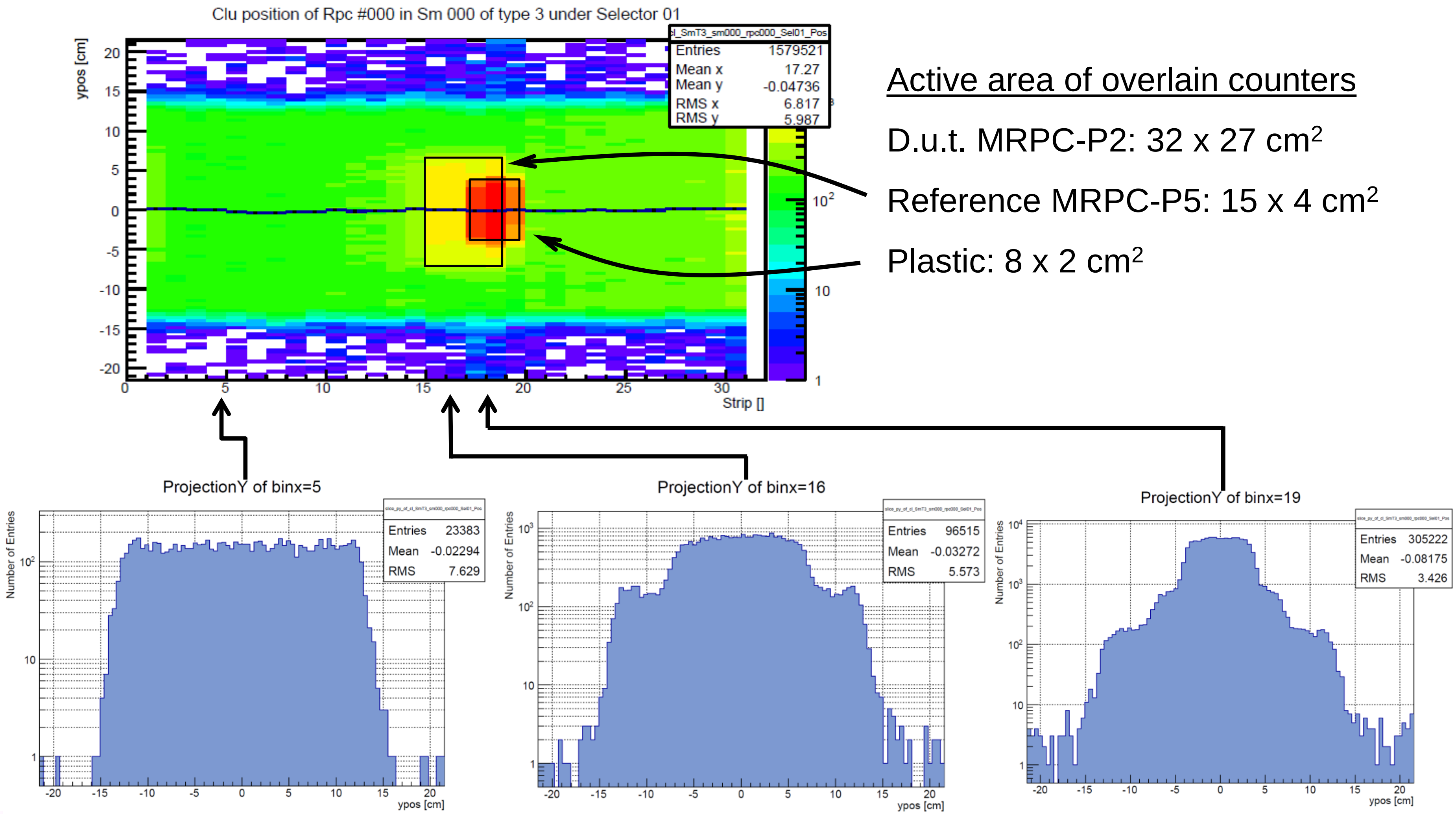
Disadvantages
- higher High Voltage (> ±10 kV)
- bigger cluster size

Differential double stack MRPC with 2 x 4 gaps

Advantages
- lower High Voltage (< ±6 kV)
- smaller cluster size

Disadvantages
- more complex construction
- more glass plates (#10)
- impedance matching hardly possible (100Ω)

Counter occupation



Active area of overlain counters

D.u.t. MRPC-P2: 32 x 27 cm^2

Reference MRPC-P5: 15 x 4 cm^2

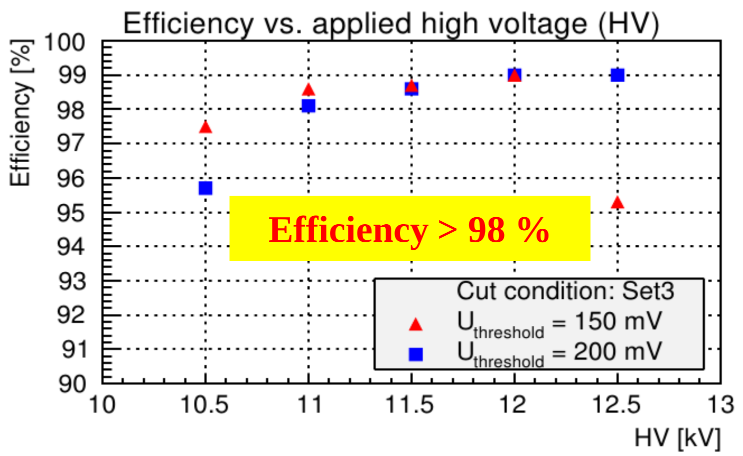
Plastic: 8 x 2 cm^2

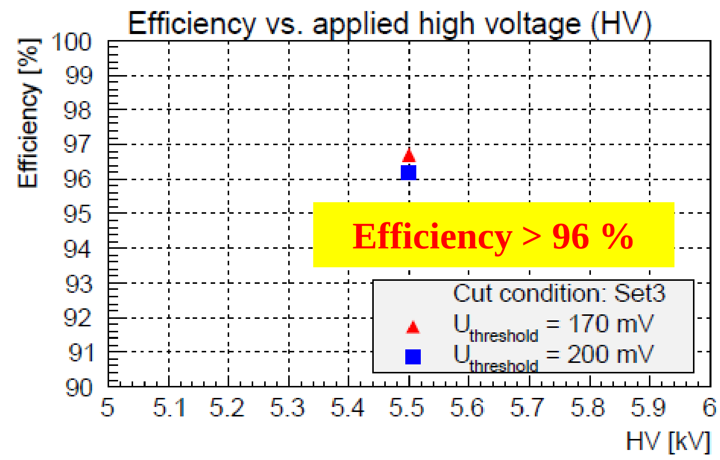
Efficiency

Differential singel stack MRPC with 8 gaps

vs.

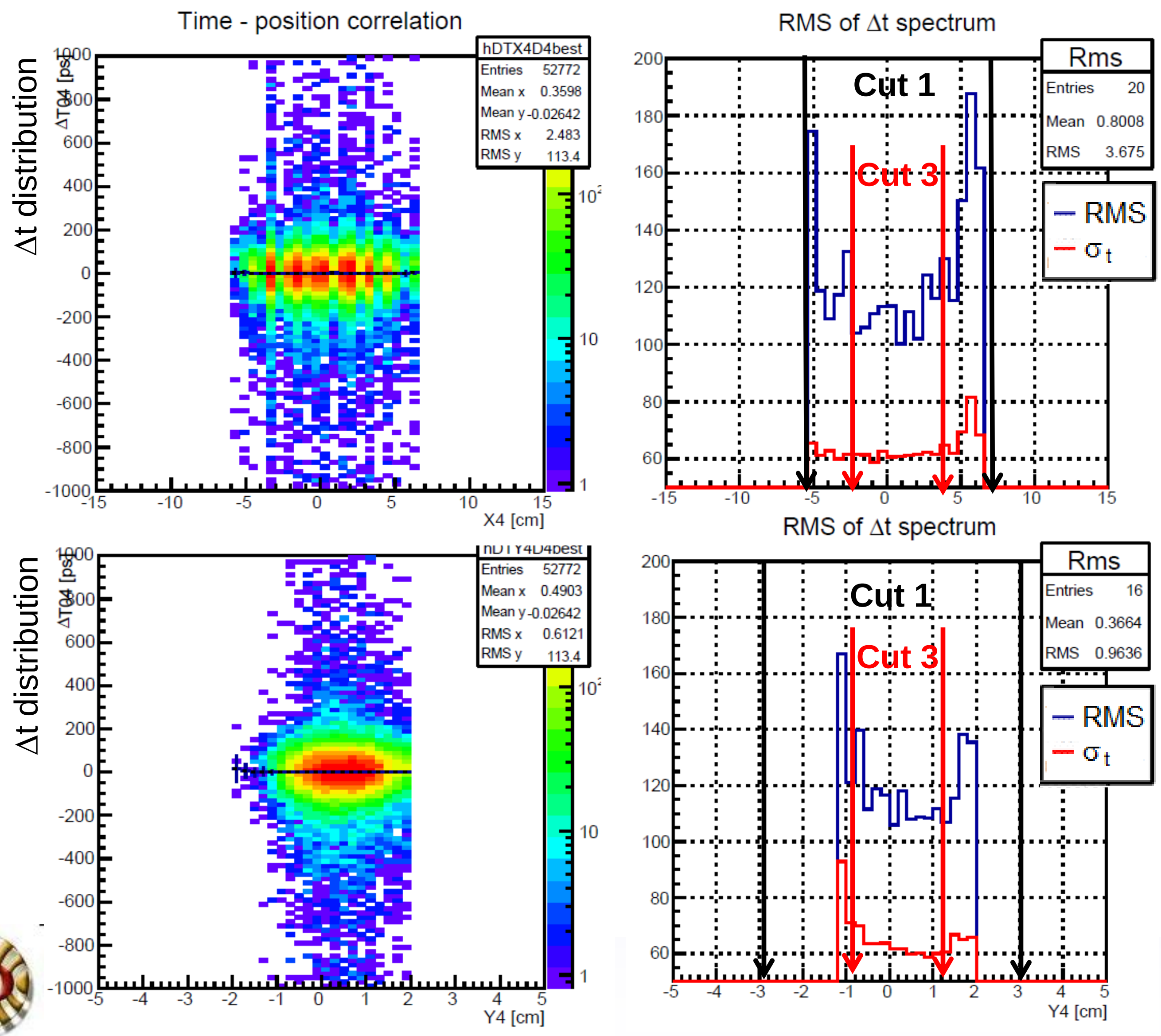
Differential double stack MRPC with 2 x 4 gaps





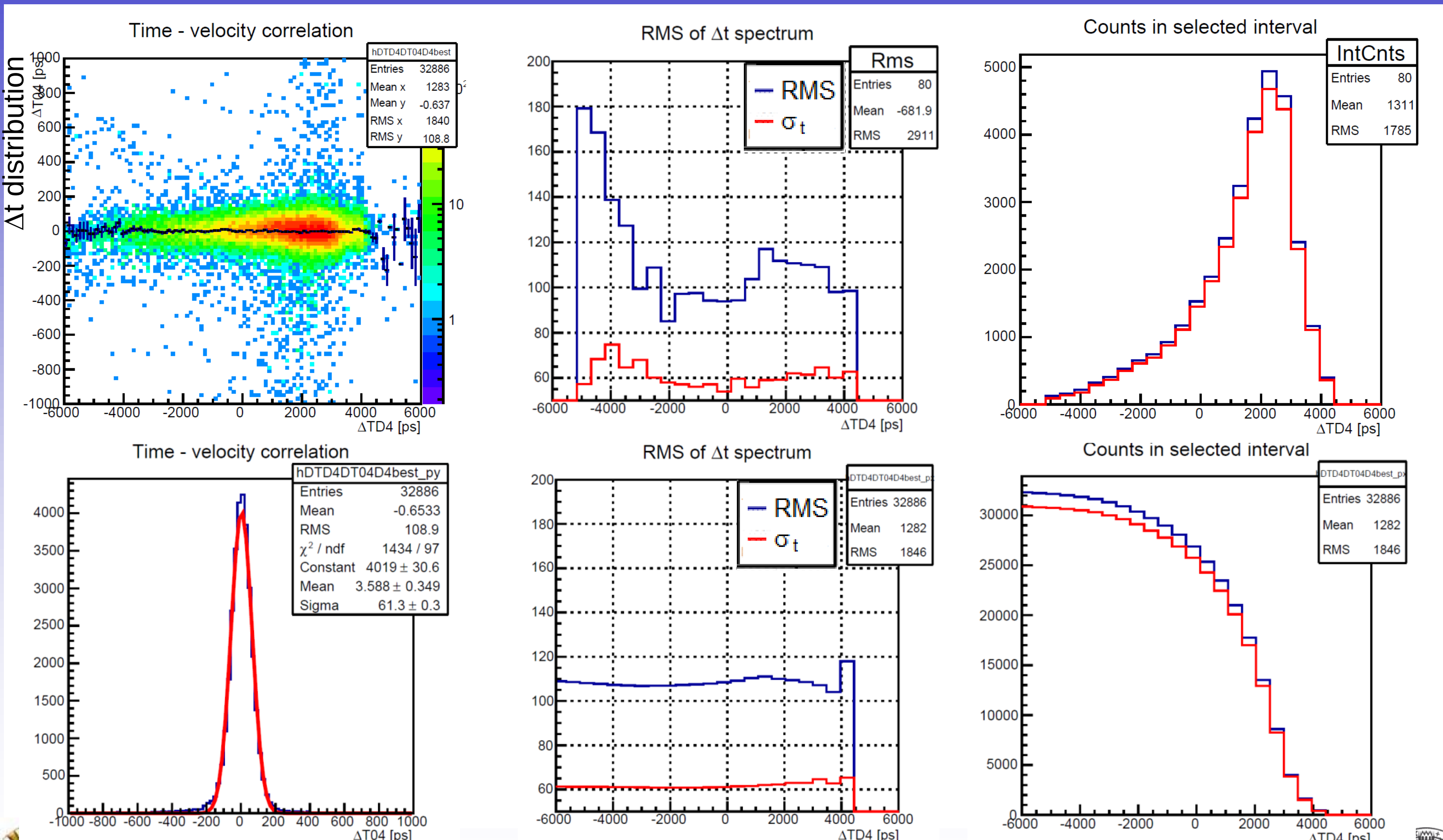
- Efficiency= $\frac{\text{Matched hit pairs in dut - ref}}{\text{Matched hit pairs in dia - ref}}$
- Data points at ±11 kV in the left plot can be compared with ±5.5 kV in the right plot.
- Single stack MRPC shows slightly better efficiency

Edge effects



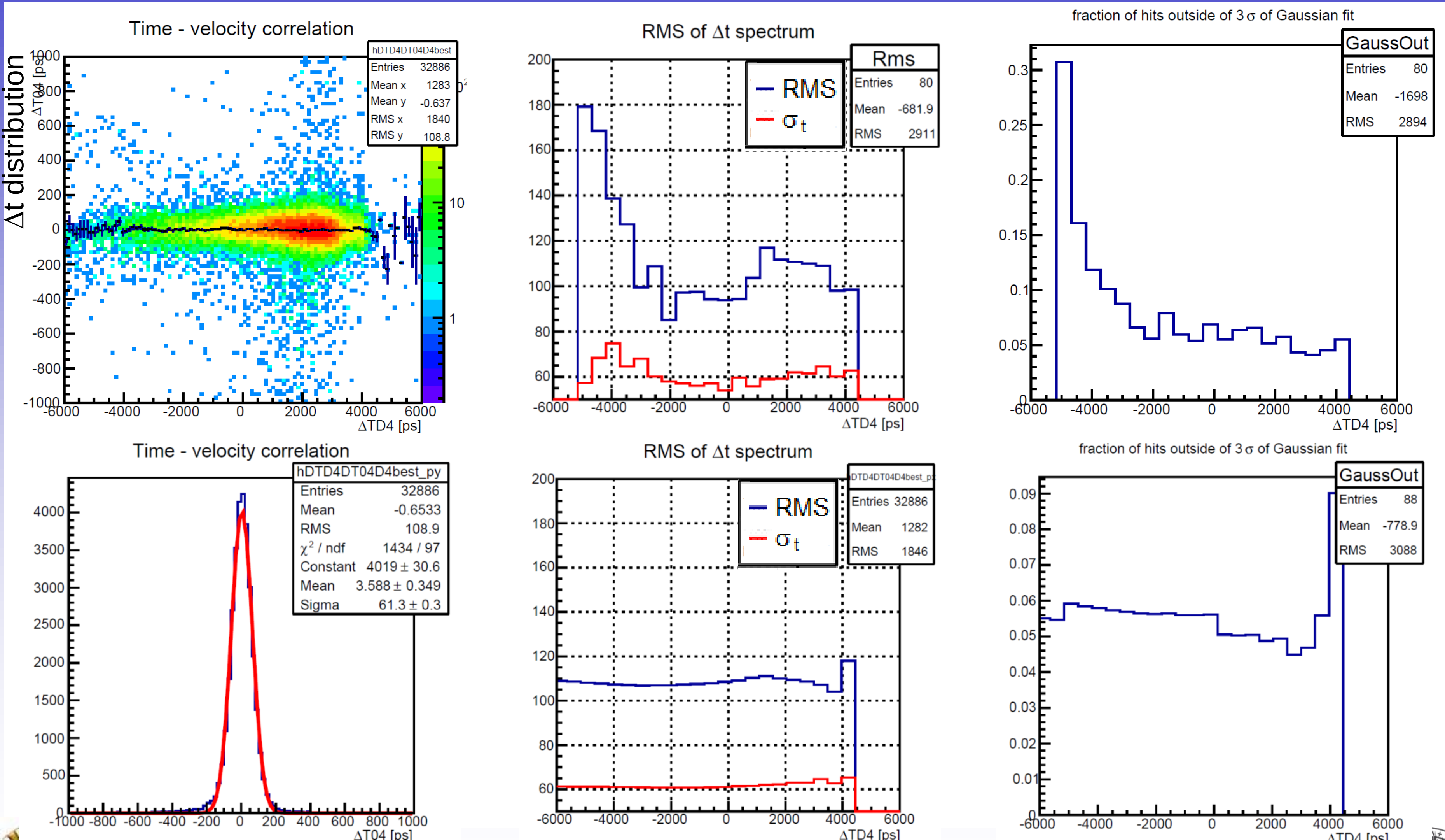
Cut selection on the reference counter

Time difference vs. particle velocity



HV = 11 kV, U_{thr} = 200 mV

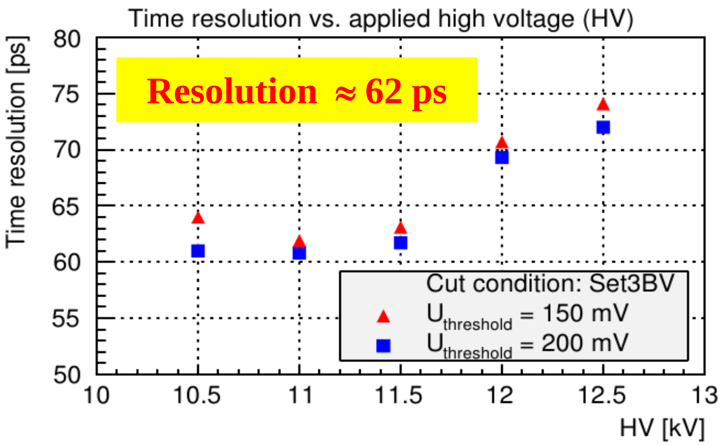
Time difference vs. particle velocity

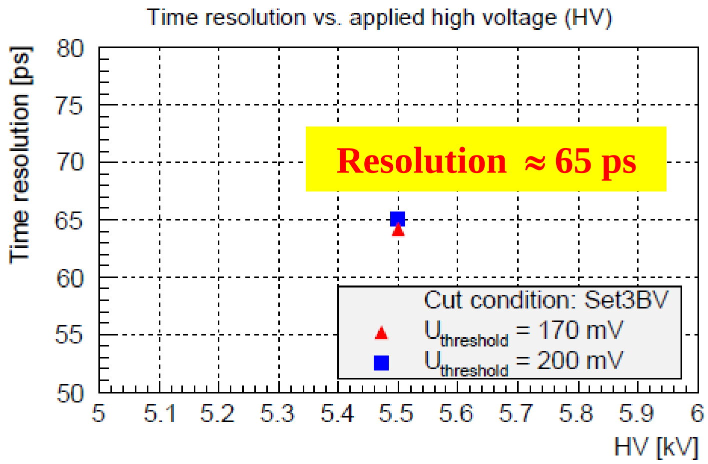


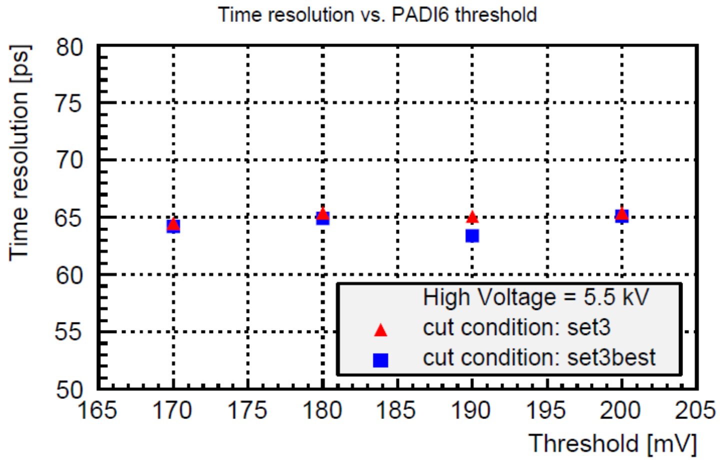
HV = 11 kV, U_{thr} = 200 mV

Time resolution

Differential singel stack MRPC with 8 gaps vs. Differential double stack MRPC with 2 x 4 gaps

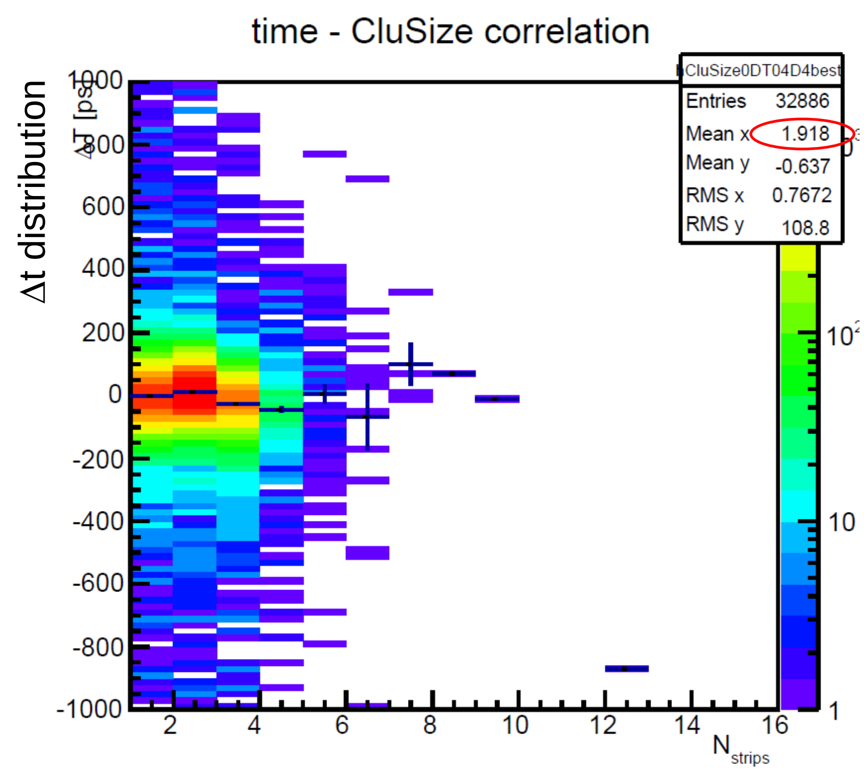


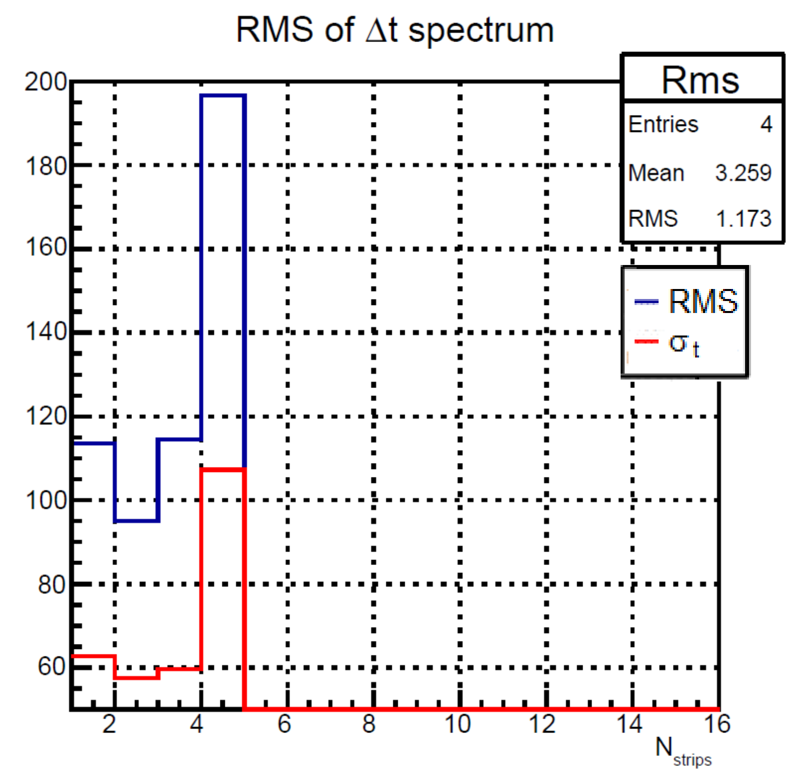




- Data points at ±11 kV in the left plot can be compared with ±5.5 kV in the right plot.
- Single stack MRPC shows slightly time resolution.
- Single counter resolution is in the order of 45 ps including all electronic components.

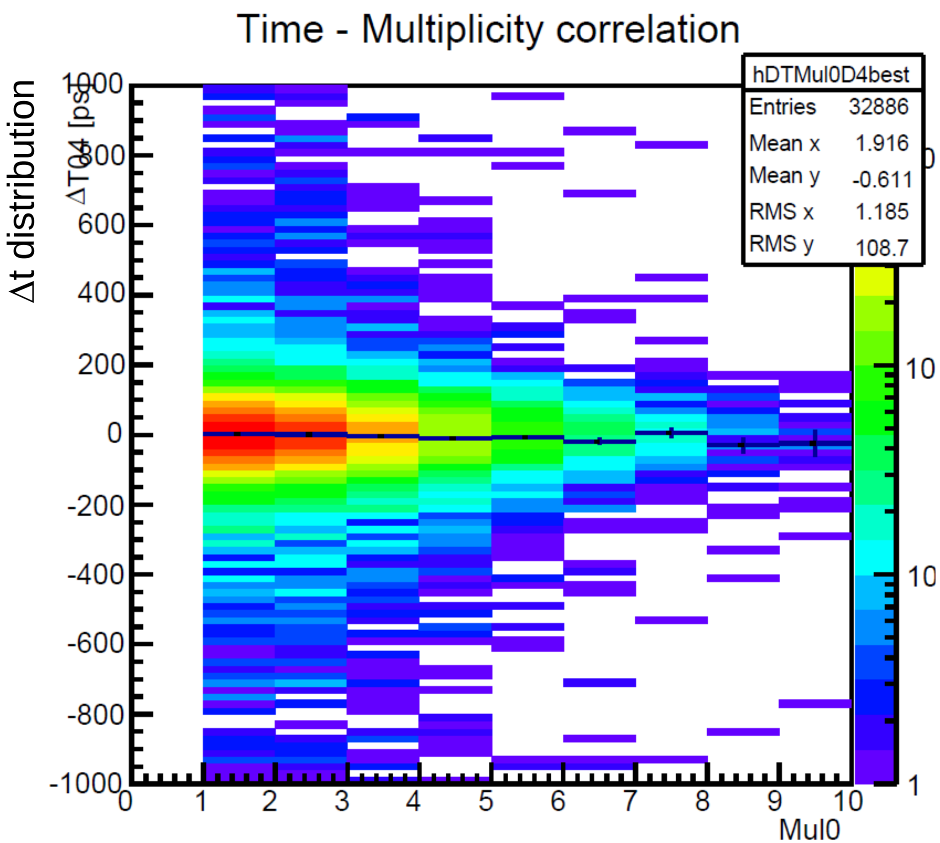
Cluster size

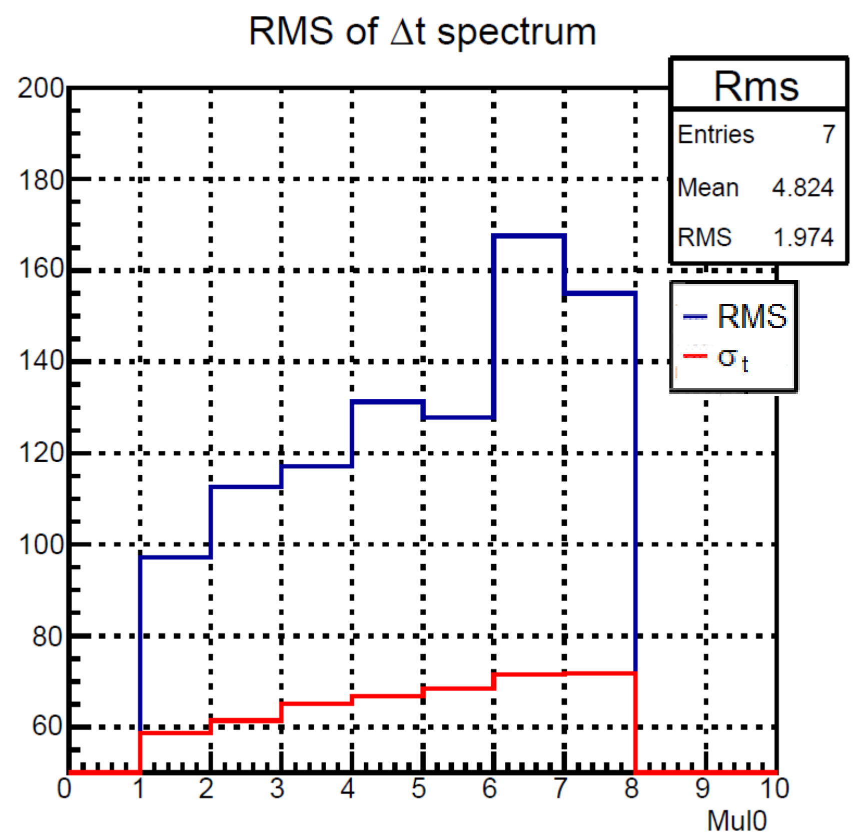




- Time resolution does not deteriorate with cluster size bigger than one

Cluster multiplicity





- Counter time resolution below 50 ps up to the highest multiplicity @ an occupancy of about 50%

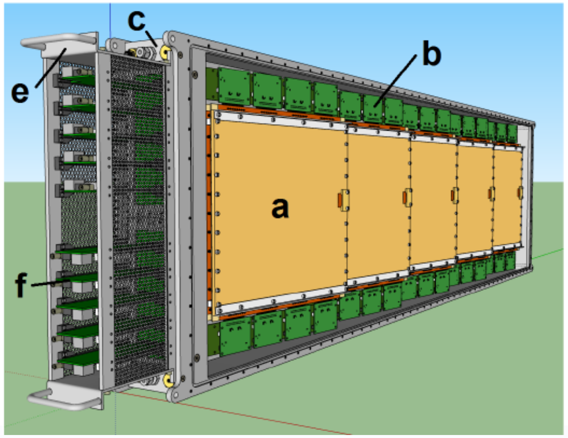
Summary/Outlook

Summary

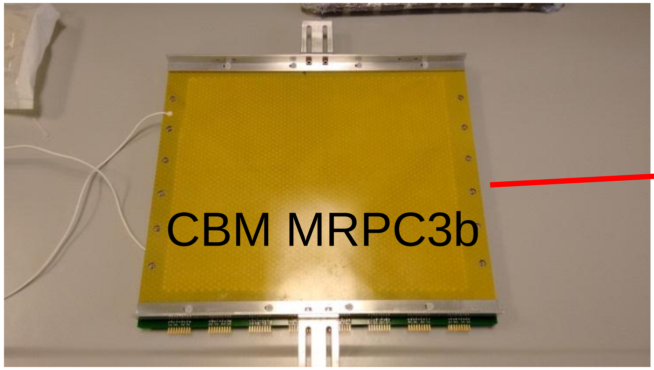
- TDR is approved. However no final decision regarding counter design is taken.
- The design of the differential single stack MRPC from Heidelberg is driven by the free-streaming readout ⇒ impedance matching is realized.
- The single stack MRPC shows slightly better efficiency and time resolution in comparison to a double stack MRPC.
- The double stack MRPC shows a smaller cluster size (about 1.6).
- Single counter resolution is in the order of 45 ps including all electronic contributions.
- However, in a free running mode an impedance matched MRPC might show a better performance due to minimized signal reflections.

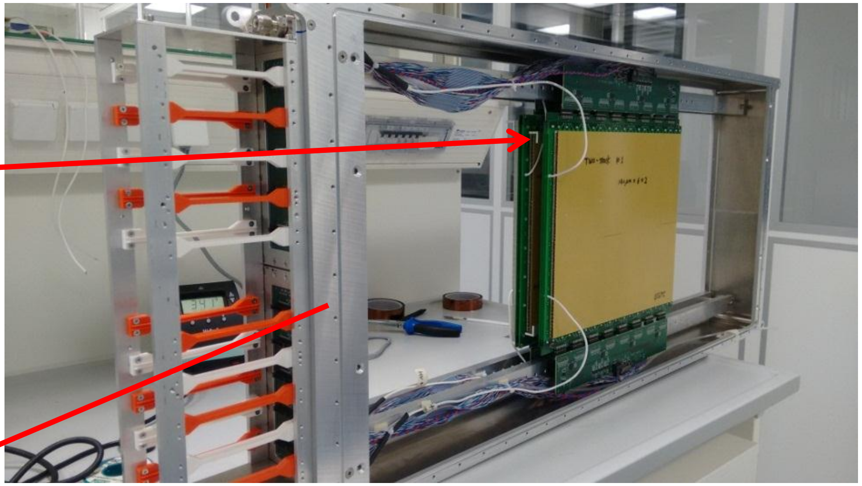
Outlook

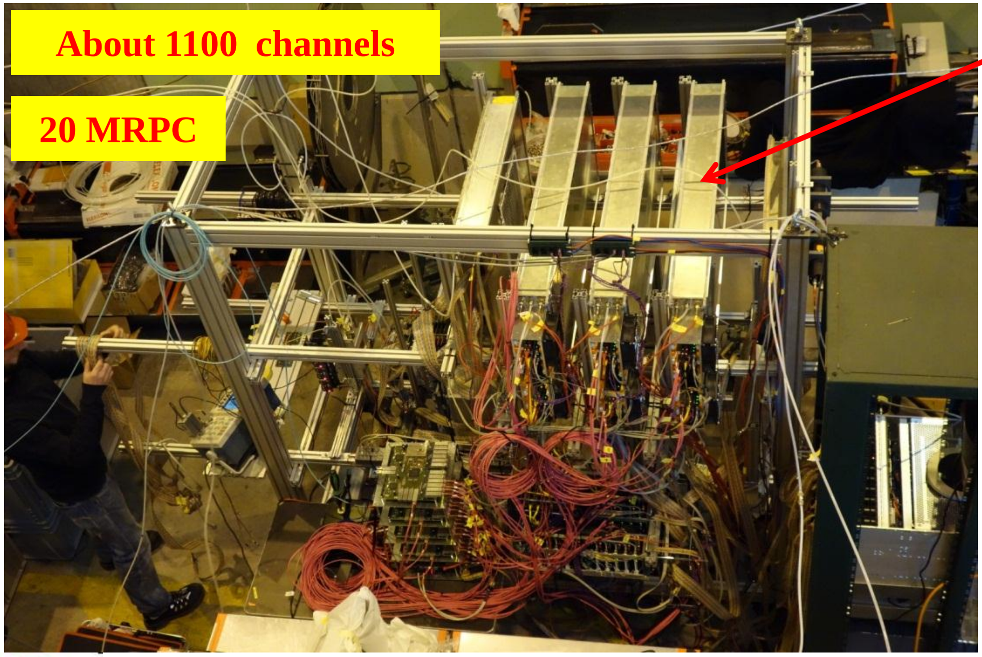
- Load test for all available full size prototypes in Nov. 2015 with heavy ions at SPS CERN
- Among them 3 full size modules M4 with counters MRPC3a and MRPC3b were tested
- Data analysis is still ongoing
- Selection of the final layout and counter configurations this year based on beam time results.
- Start of the low resistive glass production this year

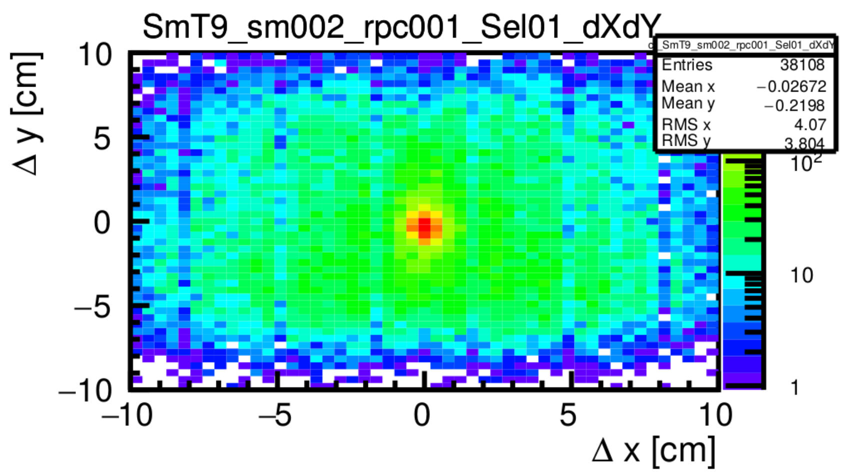


Outlook





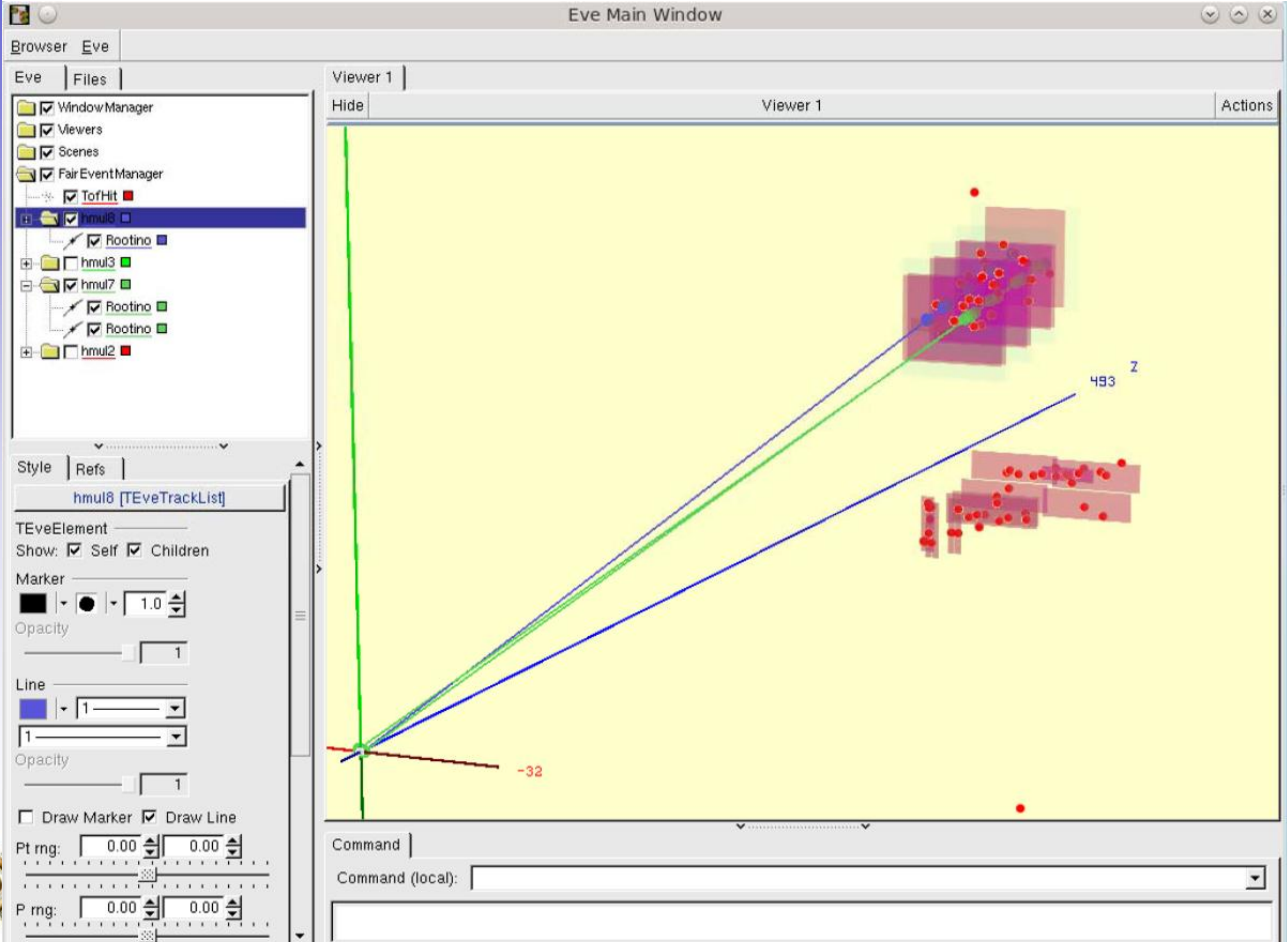




$\sigma_x \approx 2.3$ mm & $\sigma_y \approx 3$ mm

Outlook

Event display after calibration



- 1 Track (blue) with mult. 8
- 2 Tracks (green) with mult. 7

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

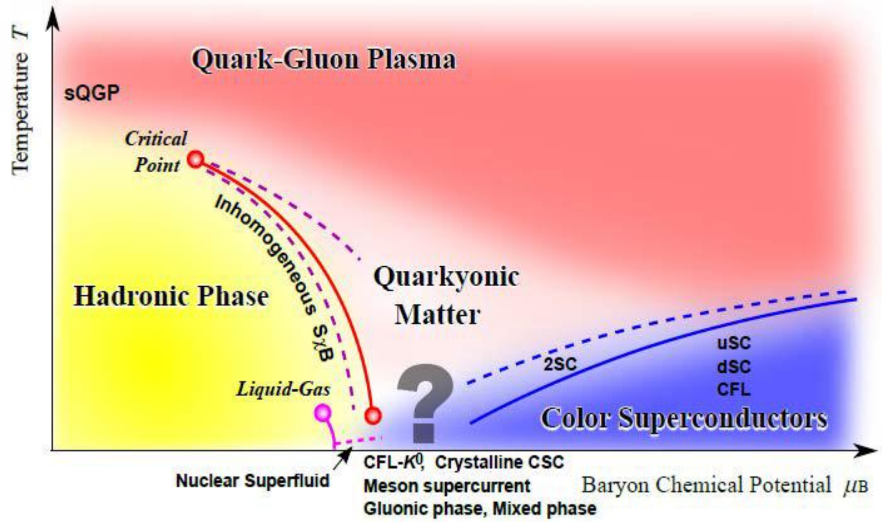
Backup Slides

Backup Slides

CBM ToF

CBM Physics topics

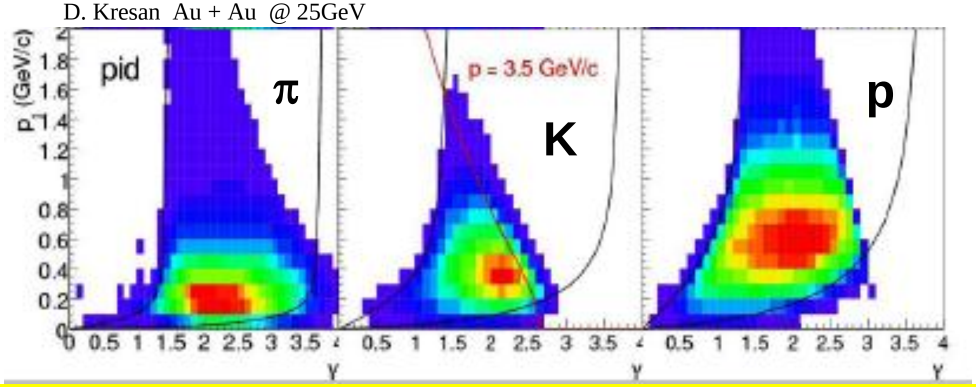
- Deconfinement / phase transition at high ρ_B
- QCD critical endpoint
- The equation-of-state at high ρ_B
- chiral symmetry restoration at high ρ_B



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-(μ+μ-), 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)

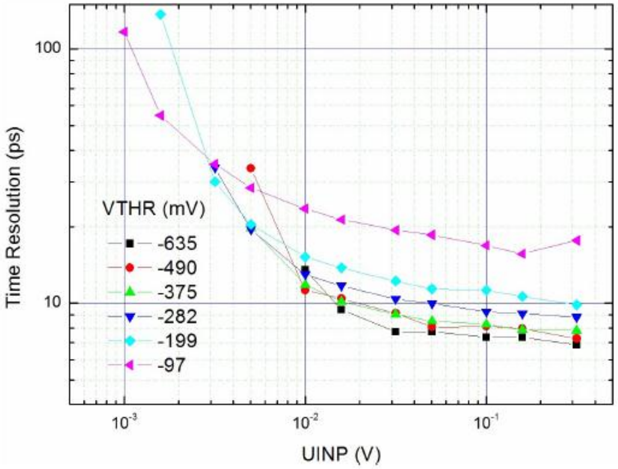
Reaction counter

- 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 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

Table 3.4: *Main parameters of the PAD*



Cuts

Selection cuts in ana_hits.C

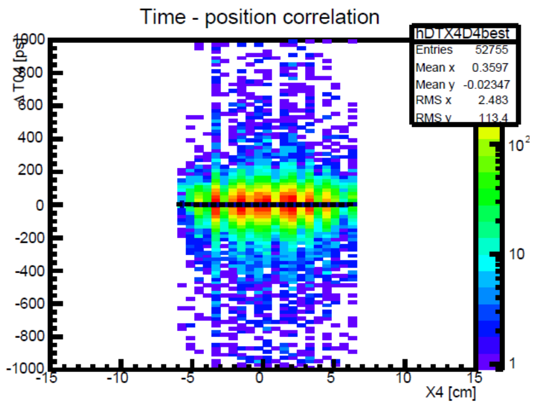
```
switch(iSet){
case 0:
  switch(iSel){   // selection cuts
  case 0:
 tofAnaTestbeam->SetMul4Max(10);     // Max Multiplicity in Ref - RPC
 tofAnaTestbeam->SetCh4Sel(8.);     // Center of channel selection window
 tofAnaTestbeam->SetDCh4Sel(70.);     // Width  of channel selection window
 tofAnaTestbeam->SetPosY4Sel(10.5);  // Y Position selection in fraction of strip length
 tofAnaTestbeam->SetMulDMax(10.);     // Max Multiplicity in Diamond
 tofAnaTestbeam->SetDTDia(0.);      // Time difference to additional diamond
 break;
  case 1:
 tofAnaTestbeam->SetMul0Max(10);     // Max Multiplicity in dut - RPC
 tofAnaTestbeam->SetMul4Max(1);     // Max Multiplicity in Ref - RPC
 tofAnaTestbeam->SetCh4Sel(8.);     // Center of channel selection window
 tofAnaTestbeam->SetDCh4Sel(7.);     // Width  of channel selection window
 tofAnaTestbeam->SetPosY4Sel(0.5);  // Y Position selection in fraction of strip length
 tofAnaTestbeam->SetMulDMax(1.);     // Max Multiplicity in Diamond
 tofAnaTestbeam->SetDTDia(0.);      // Time difference to additional diamond
 break;
  case 2:
 tofAnaTestbeam->SetMul4Max(1);     // Max Multiplicity in Ref - RPC
 tofAnaTestbeam->SetCh4Sel(8.);     // Center of channel selection window
 tofAnaTestbeam->SetDCh4Sel(7.);     // Width  of channel selection window
 tofAnaTestbeam->SetPosY4Sel(0.5);  // Y Position selection in fraction of strip length
 tofAnaTestbeam->SetMulDMax(1.);     // Max Multiplicity in Diamond
 tofAnaTestbeam->SetDTDia(500.);     // Time difference to additional diamond
 break;
  case 3:
 tofAnaTestbeam->SetMul4Max(1);     // Max Multiplicity in Ref - RPC
 tofAnaTestbeam->SetCh4Sel(8.);     // Center of channel selection window
 tofAnaTestbeam->SetDCh4Sel(4.);     // Width  of channel selection window
 tofAnaTestbeam->SetPosY4Sel(0.3);  // Y Position selection in fraction of strip length
 tofAnaTestbeam->SetMulDMax(1.);     // Max Multiplicity in Diamond
 tofAnaTestbeam->SetDTDia(500.);     // Time difference to additional diamond
 break;
  default :
```

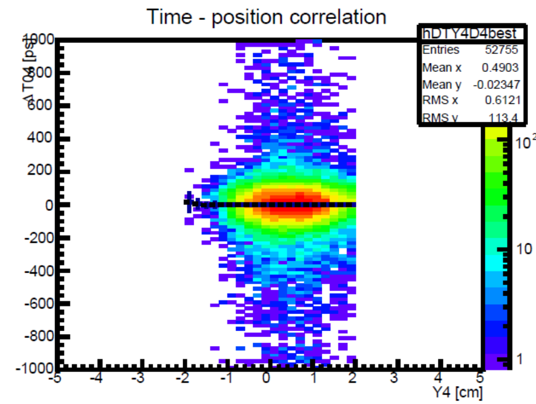
Cut 1

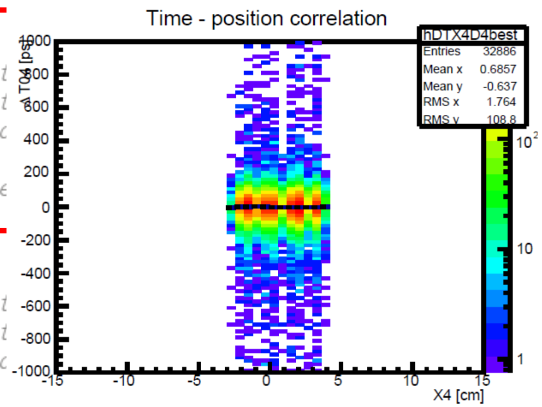
Cut 3

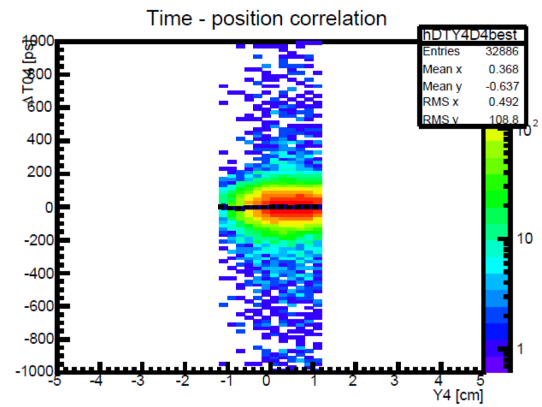
Selection cuts in ana_hits.C

```
switch(iSel){
case 0:
  switch(iSel){   // selection cuts
  case 0:
 tofAnaTestbeam->SetMul4Max(10);      // Ma
 tofAnaTestbeam->SetCh4Sel(8.);       // Cer
 tofAnaTestbeam->SetDCh4Sel(70.);     // Wi
 tofAnaTestbeam->SetPosY4Sel(10.5);   // Y
 tofAnaTestbeam->SetMulDMax(10.);     // Ma
 tofAnaTestbeam->SetDTDia(0.);        // Tin
 break;
  case 1:
 tofAnaTestbeam->SetMul0Max(10);      // Ma
 tofAnaTestbeam->SetMul4Max(1);       // Max
 tofAnaTestbeam->SetCh4Sel(8.);       // Cer
 tofAnaTestbeam->SetDCh4Sel(7.);      // Wic
 tofAnaTestbeam->SetPosY4Sel(0.5);    // Y F
 tofAnaTestbeam->SetMulDMax(1.);      // Max Multiplicity in Diamond
 tofAnaTestbeam->SetDTDia(0.);        // Time difference to additional diamond
 break;
  case 2:
 tofAnaTestbeam->SetMul4Max(1);       // Max
 tofAnaTestbeam->SetCh4Sel(8.);       // Cent
 tofAnaTestbeam->SetDCh4Sel(7.);      // Widt
 tofAnaTestbeam->SetPosY4Sel(0.5);    // Y Po
 tofAnaTestbeam->SetMulDMax(1.);      // Max
 tofAnaTestbeam->SetDTDia(500.);      // Time
 break;
  case 3:
 tofAnaTestbeam->SetMul4Max(1);       // Max
 tofAnaTestbeam->SetCh4Sel(8.);       // Cent
 tofAnaTestbeam->SetDCh4Sel(4.);      // Widt
 tofAnaTestbeam->SetPosY4Sel(0.3);    // Y Po
 tofAnaTestbeam->SetMulDMax(1.);      // Max
 tofAnaTestbeam->SetDTDia(500.);      // Time difference to additional diamond
 break;
  default :
```



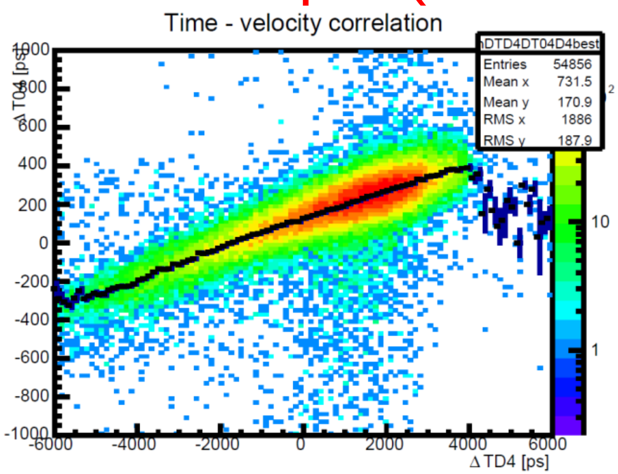


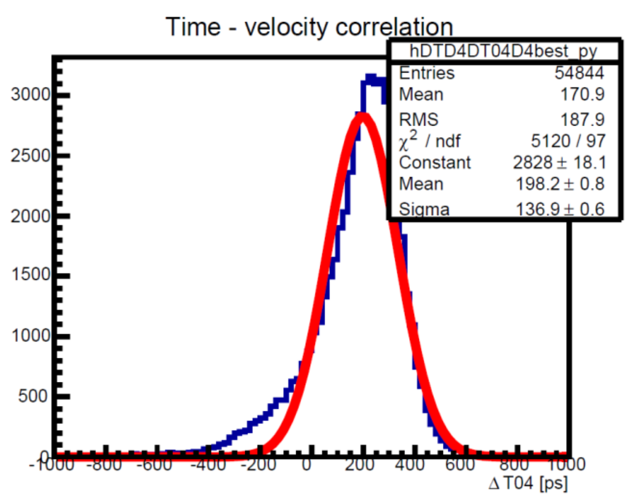




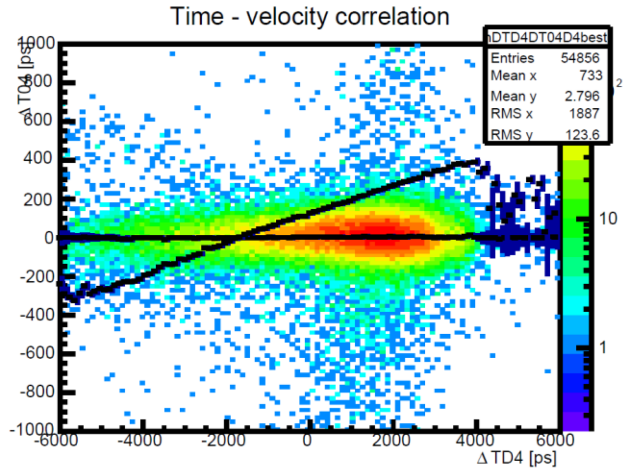
Time – velocity correlation

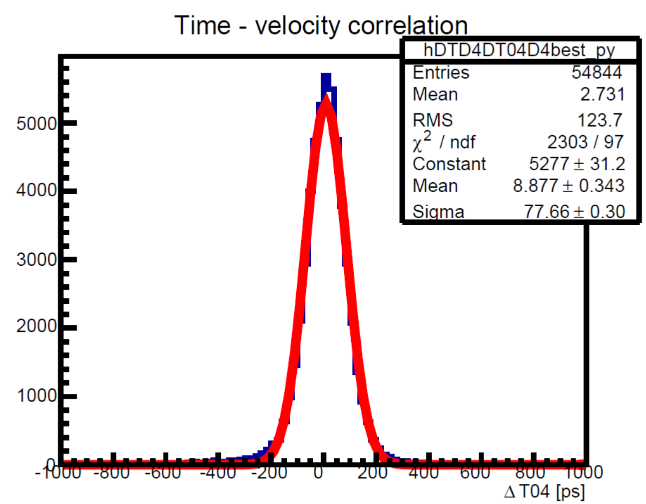
Step 1 (after init_calib)





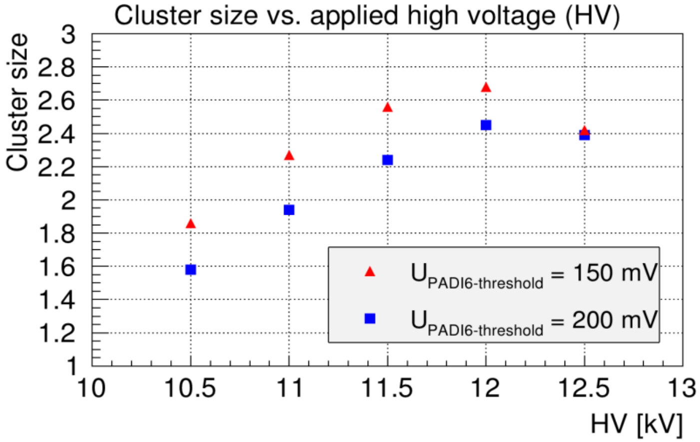
Step 2

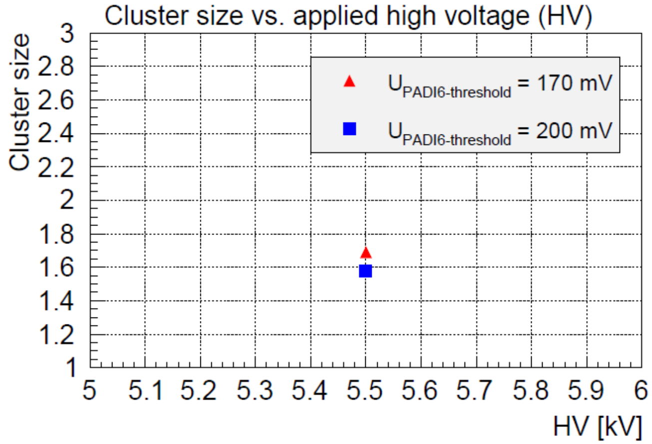




Results

Differential single stack MRPC with 8 gas gaps **vs.** Differential double stack MRPC with 2 x 4 gas gaps





Cluster size vs. PADI6 threshold