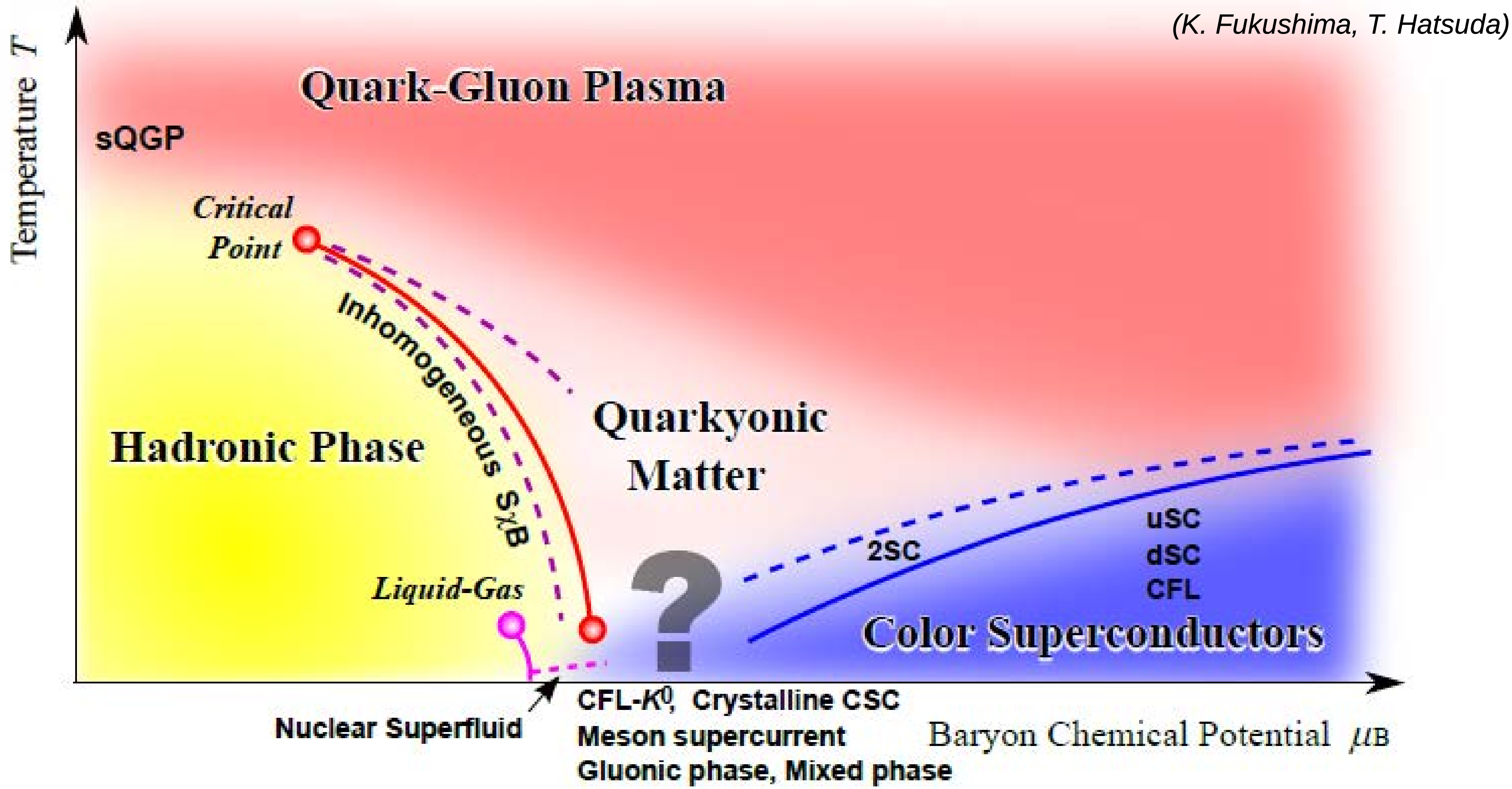
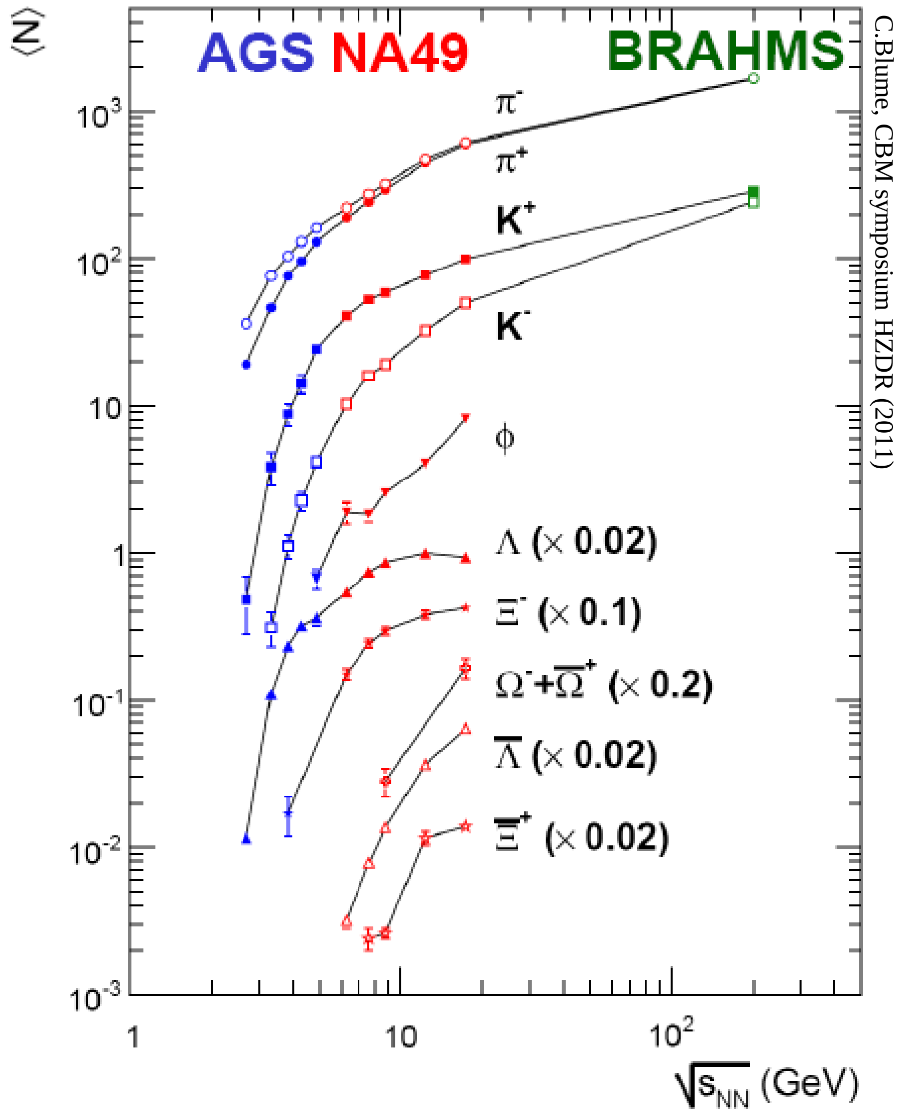
Overview on CBM – TOF



Outline:	**CBM – TOF mission**
	CBM – system
	Prototype performance
	Plans and milestones

Final state particle abundance

Particle yield ratios from central Au + Au collisions



Knowledge about strange baryons and antibaryons in FAIR energy range is rather limited.

Note:

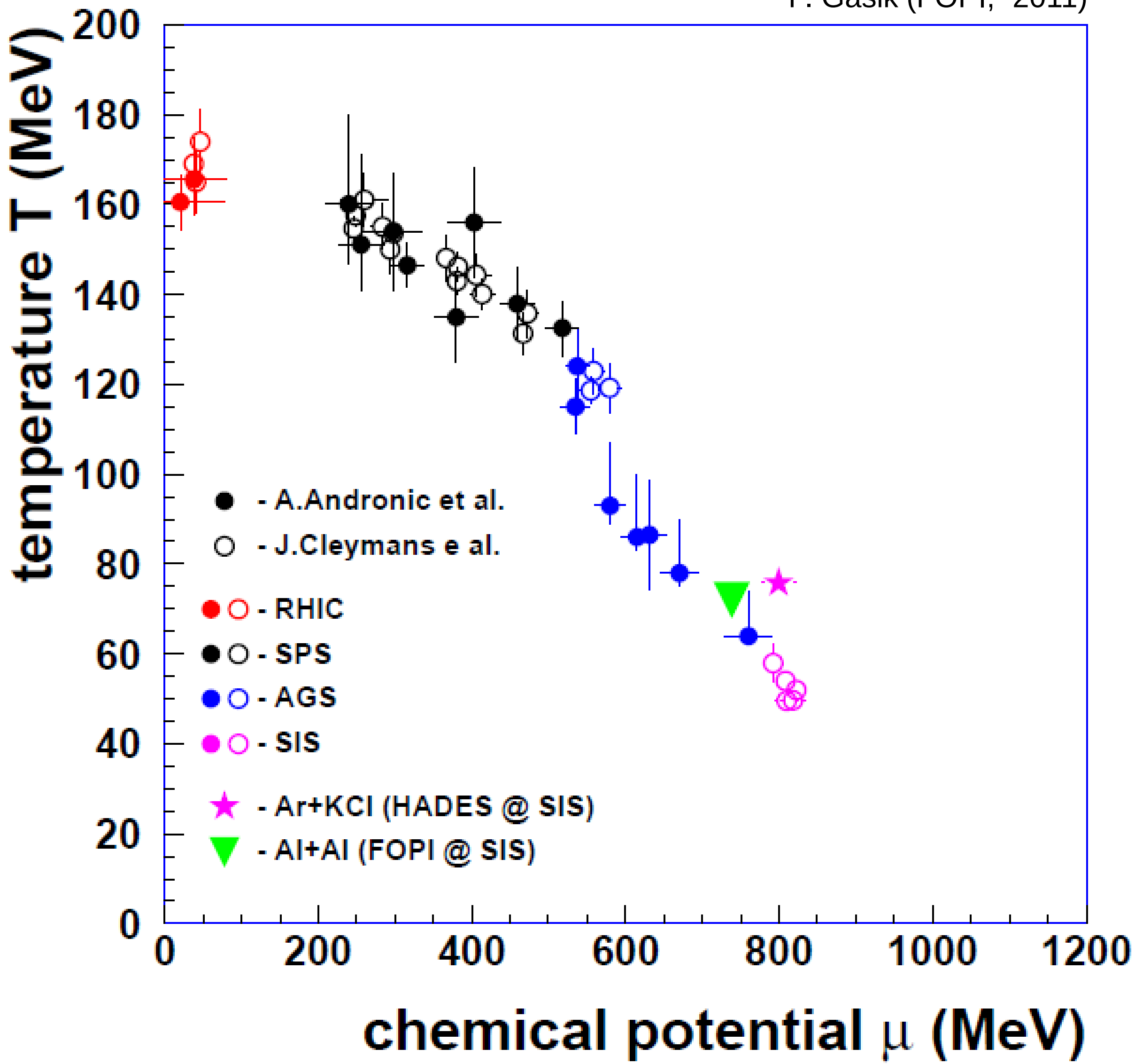
Direct multi-strange hyperon production:

$pp \rightarrow \Xi^- K^+ K^+ p$ $(E_{thr} = 3.7\ GeV)$

$pp \rightarrow \Omega^- K^+ K^+ K^0 p$ $(E_{thr} = 7.0\ GeV)$

Chemical Freeze-out data

P. Gasik (FOPI,~2011)



Assumption:
thermodynamic equilibrium

Errors include systematic errors (when given).

Data sources:

A. Andronic, P. Braun-Munzinger, J. Stachel, Nucl. Phys. A772 (2006) 167

J. Cleymans, H. Oeschler, K. Redlich, S. Wheaton, Phys. Rev. C73 (2006) 034905

G. Agakishiev et al. (HADES), Eur. Phys.J. A47 (2011) 21

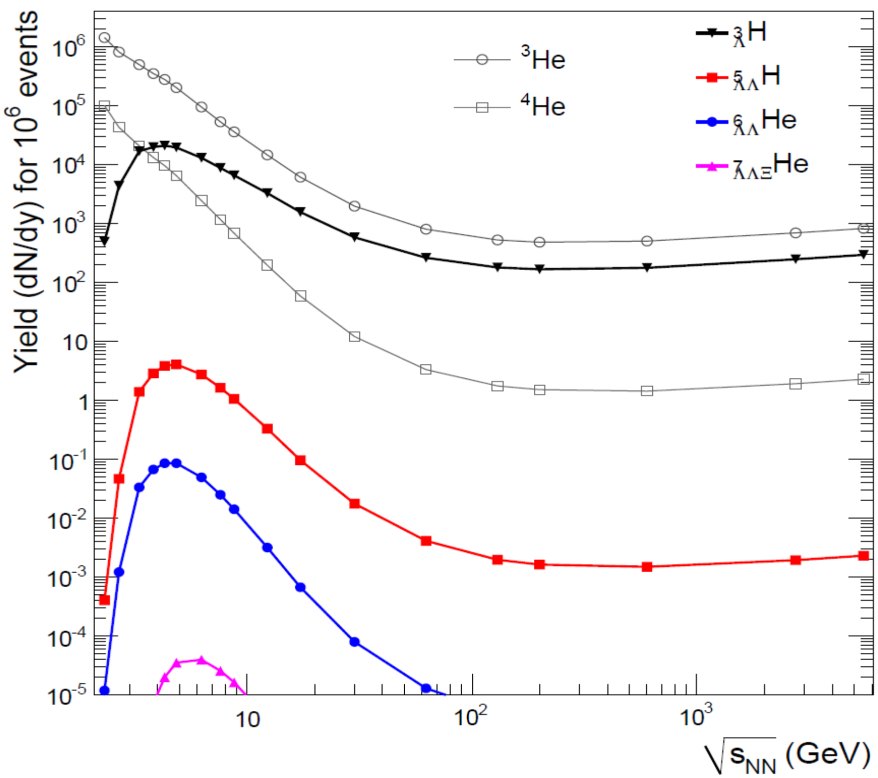
At lower energies canonical ensemble has to be used.

Equilibrium as signature for phase transition?

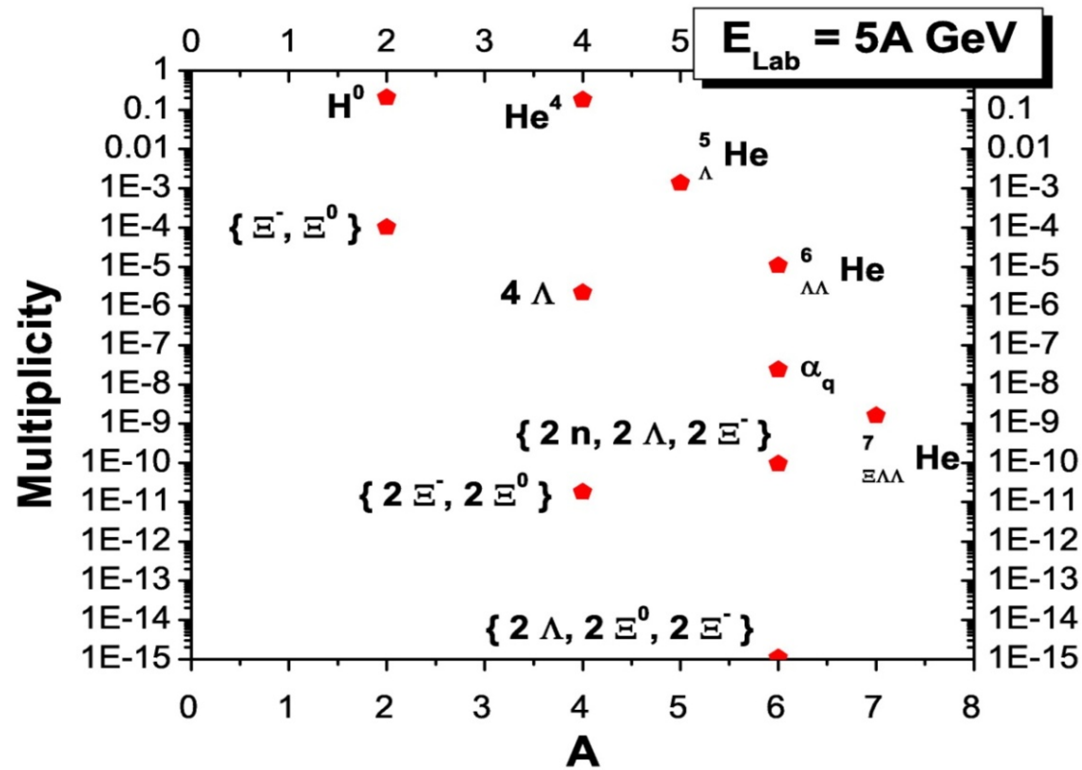
Strange baryonic bound states

- Single and double strange hypernuclei in heavy ion collisions at SIS100
- Strange matter in the form of strange dibaryons and heavy multi-strange short-lived objects.

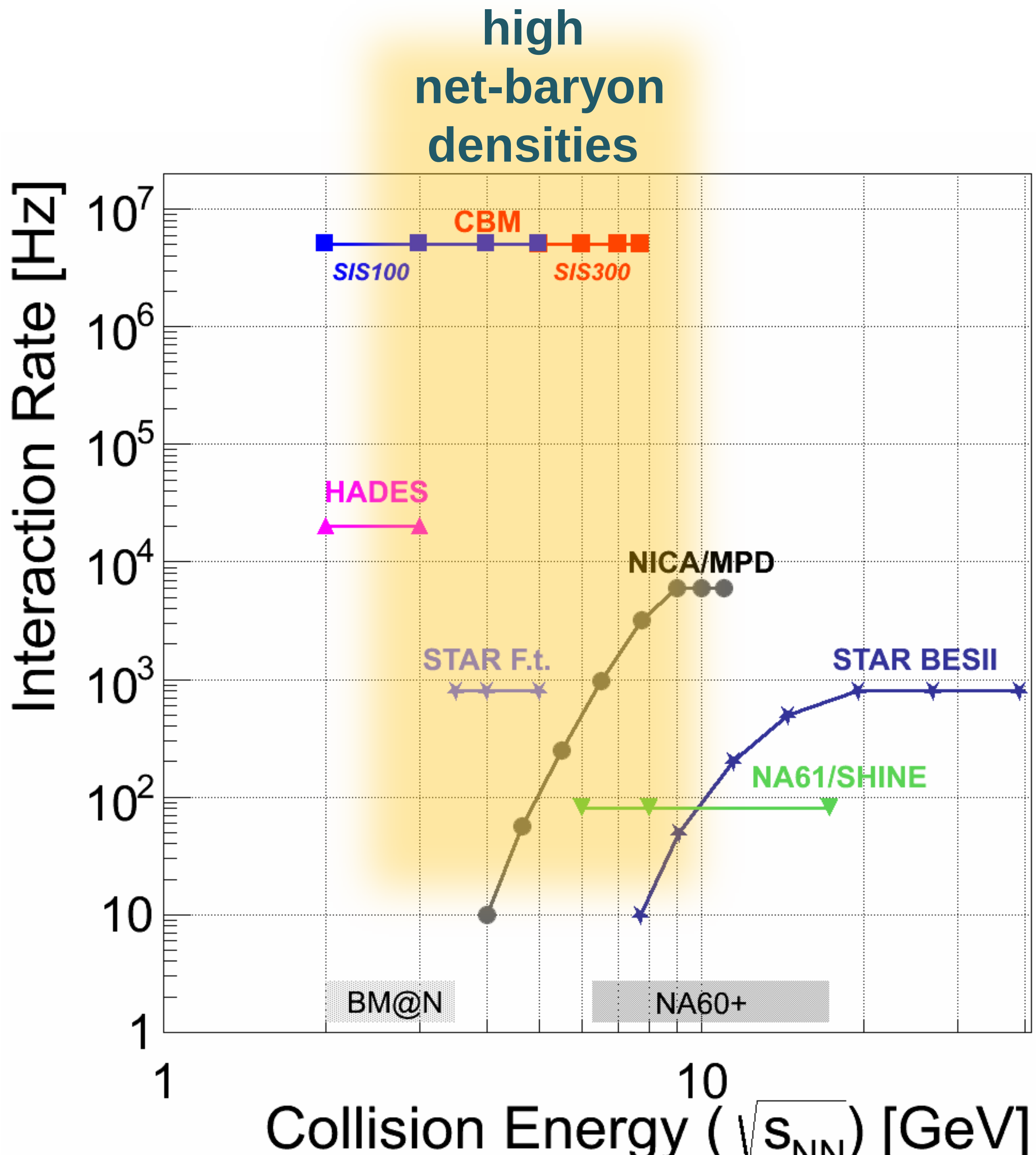
A. Andronic, P. Braun-Munzinger, J. Stachel, H. Stöcker, Phys. Lett. B697 (2011) 203



H. Stöcker et al., Nucl. Phys. A 827 (2009) 624c



Experiments exploring dense QCD matter



CBM – Detector Concept

Different detector setups for muon & electron measurements:

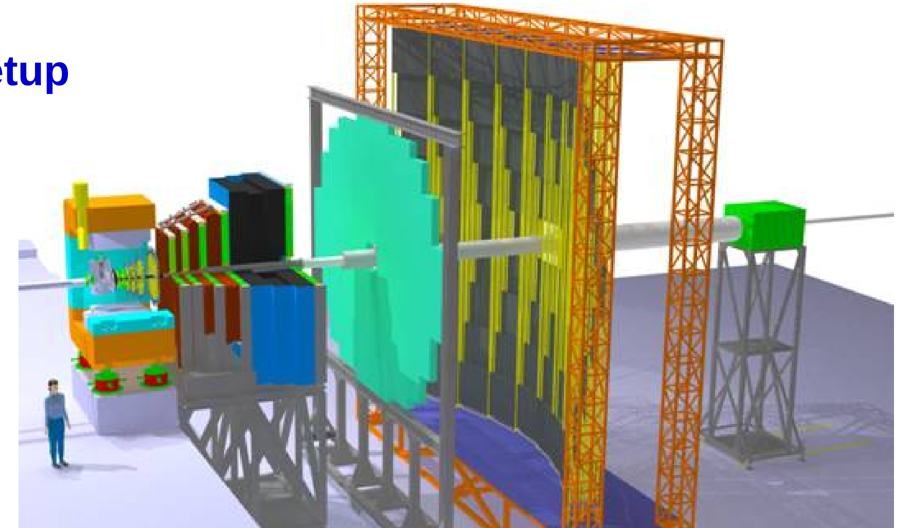
0) Core elements
- dipole magnet
- STS – silicon tracking system
- PSD – projectile spectator detector
- TOF – MRPC time-of-flight detector
- DAQ – data acquisition
- FLES – first level event selection

1) Muon setup
- MUCH – Muon detection system (active absorber)
- TRD – tracking station

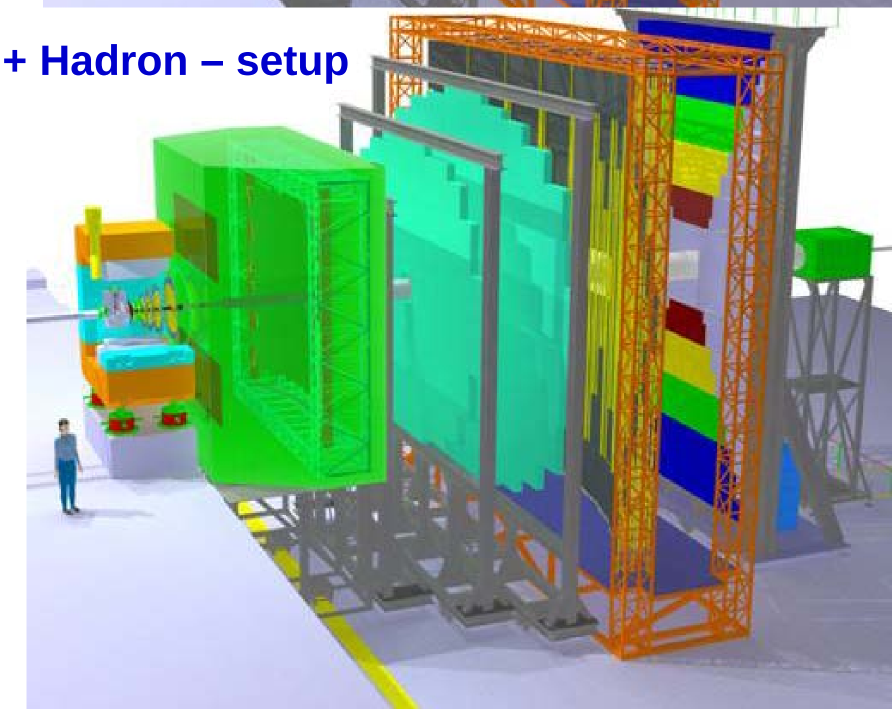
2) Electron/Hadron setup
- MVD – Micro vertex detector
- TRD – Transition radidation detector
- ECAL – Electromagnetic calorimeter

All core components designed with self triggered FEE and free running DAQ for 10 MHz Au + Au interaction rate.

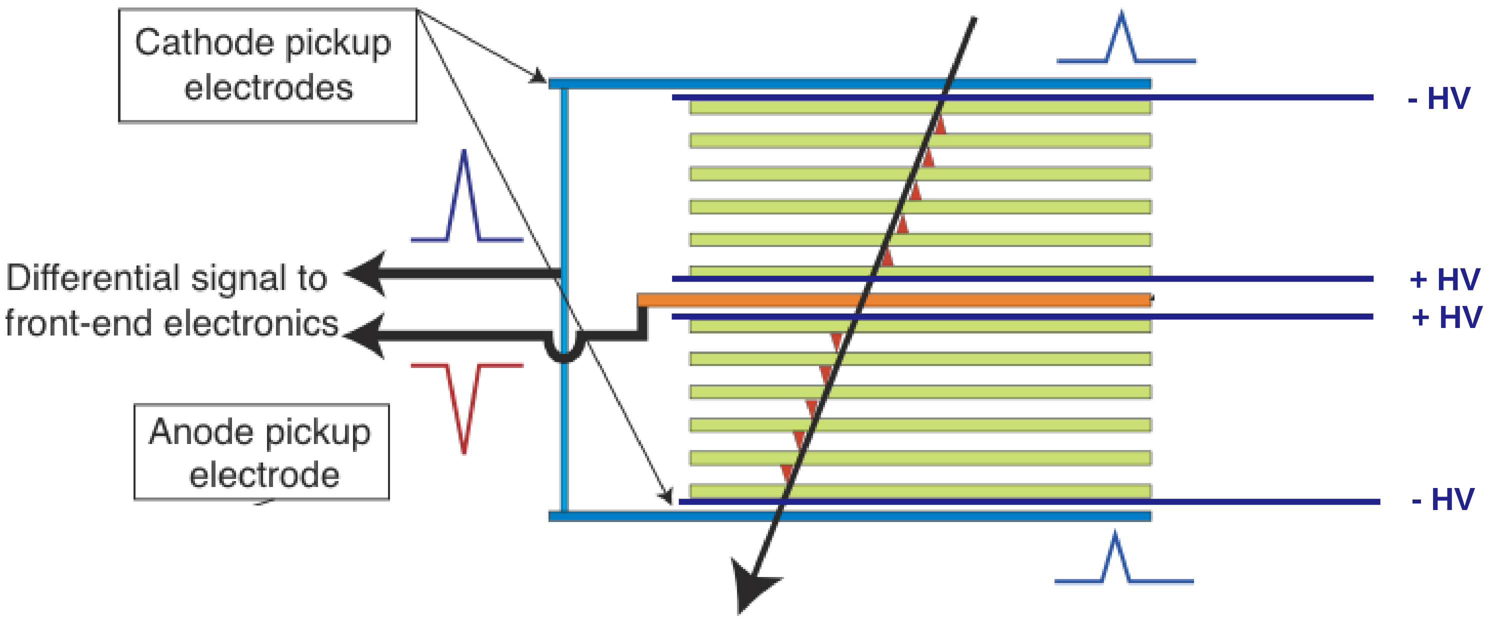
1) Muon – setup



2) Electron + Hadron – setup



MRPC working principle



Electric field
E ~ 100 kV/cm

Gas gap
d ~ 200 μm

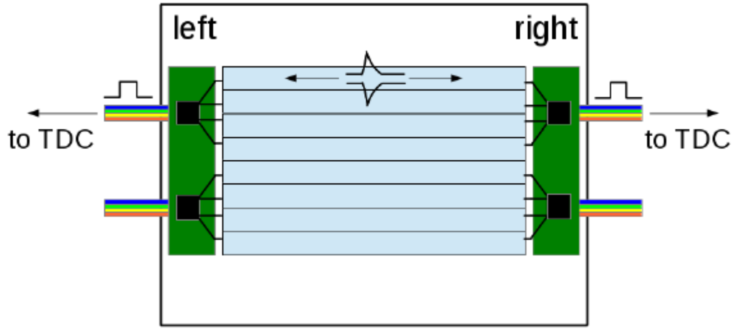
Electrode Thickness
D ~ 0.5 – 1 mm

Timing	**depends on individual gap**
Efficiency	**depends on total number of gas gap**
Rate capability	**depends on the resistance of electrodes**

Typical Gas mixture: 85% CH_2FCF_3 (Freon), 10% SF_6, 5% C_4H_{10}

MRPC signals

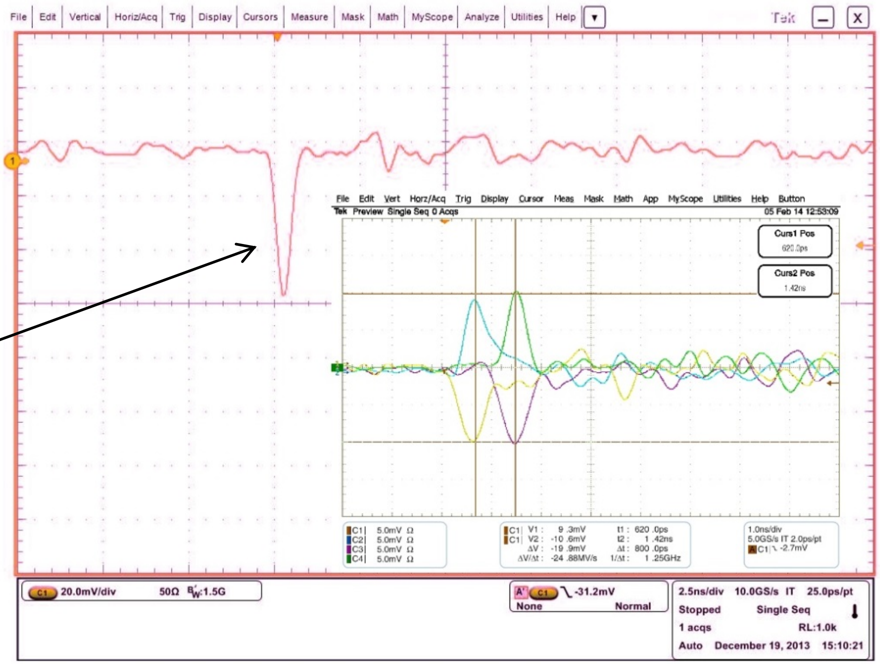
RPC strip readout



Analog signals:

amplitude: ~ 30 mV

rise time: ~ 200 ps



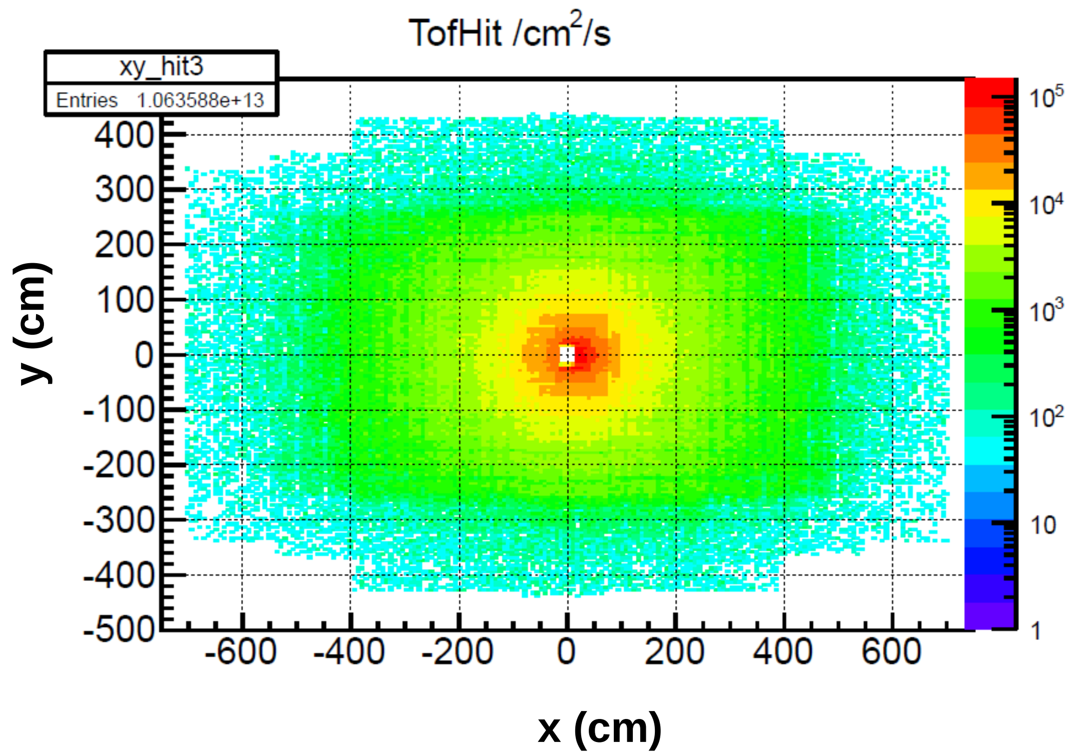
differential signal

Individual signals from both ends of readout strip

CBM TOF detector requirements

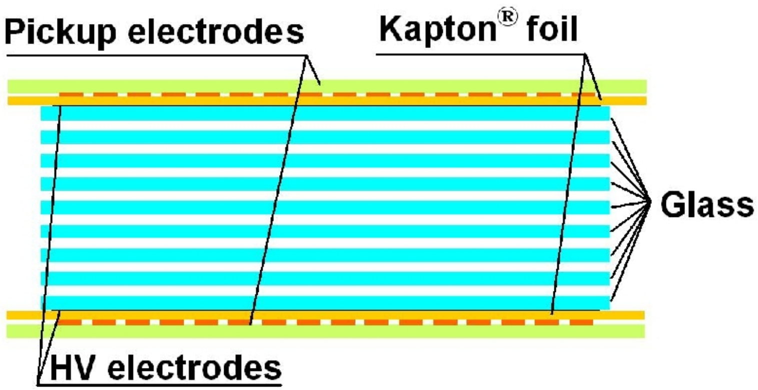
System time resolution:	**< 80 ps**
Counter time resolution:	**< 60 ps**
Efficiency:	**> 95%**
Granularity:	**cm^2 – dm^2**
Rate capability:	**20 - 50 kHz/cm^2**
Area:	**~ 120 m^2**
Number of cells:	**~ 10^5**
Cost:	**affordable**

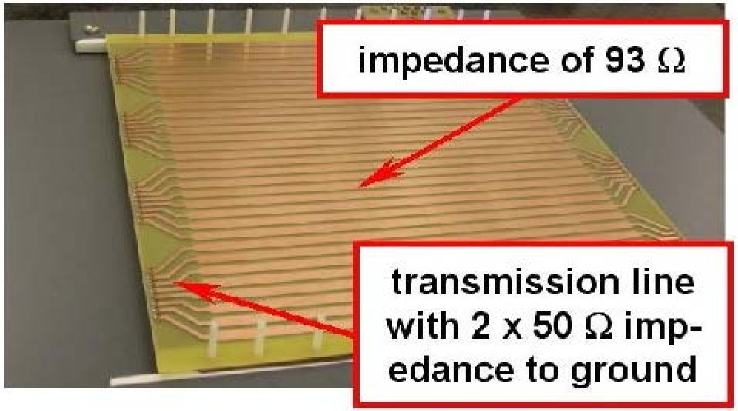
Particle flux in fixed target experiments:
Au+Au @ 25A GeV: 10 m downstream of target
Au+Au @ 10A GeV: 6 m downstream of target



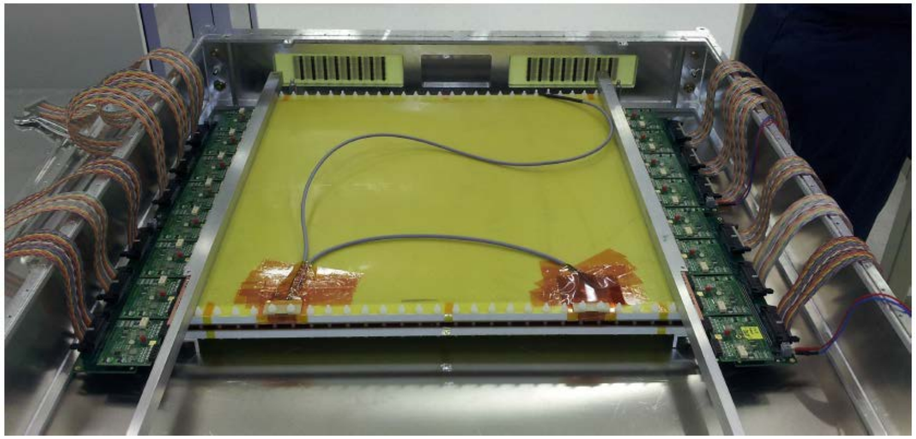
Signal integrity

Impedance matching of strip (transmission line) to input of preamplifier,
Direct coupling of preamplifiers to readout electrode





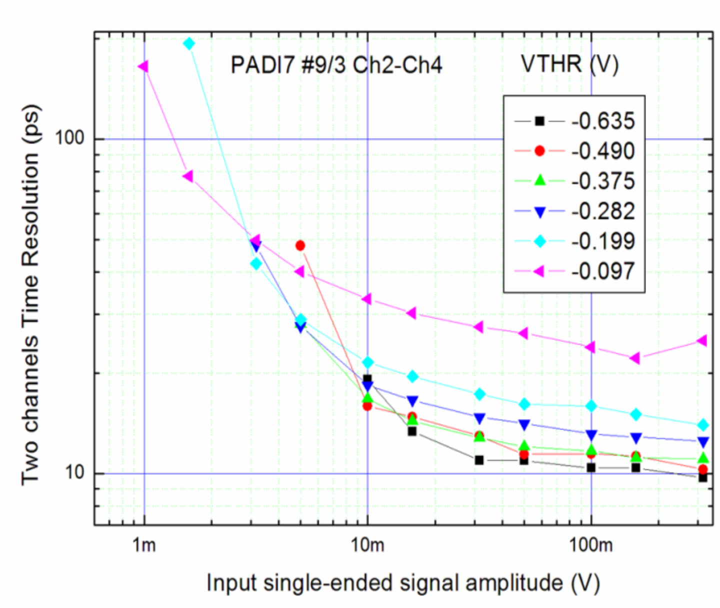
active area	32 x 27 cm^2
strips	32
strip / gap	7 / 3 mm
glass type	float glass
glass thickness	0.5 mm
number of gaps	8
gap width	220 μm
impedance	100 Ω



Electronics: Amplifier / Discriminator

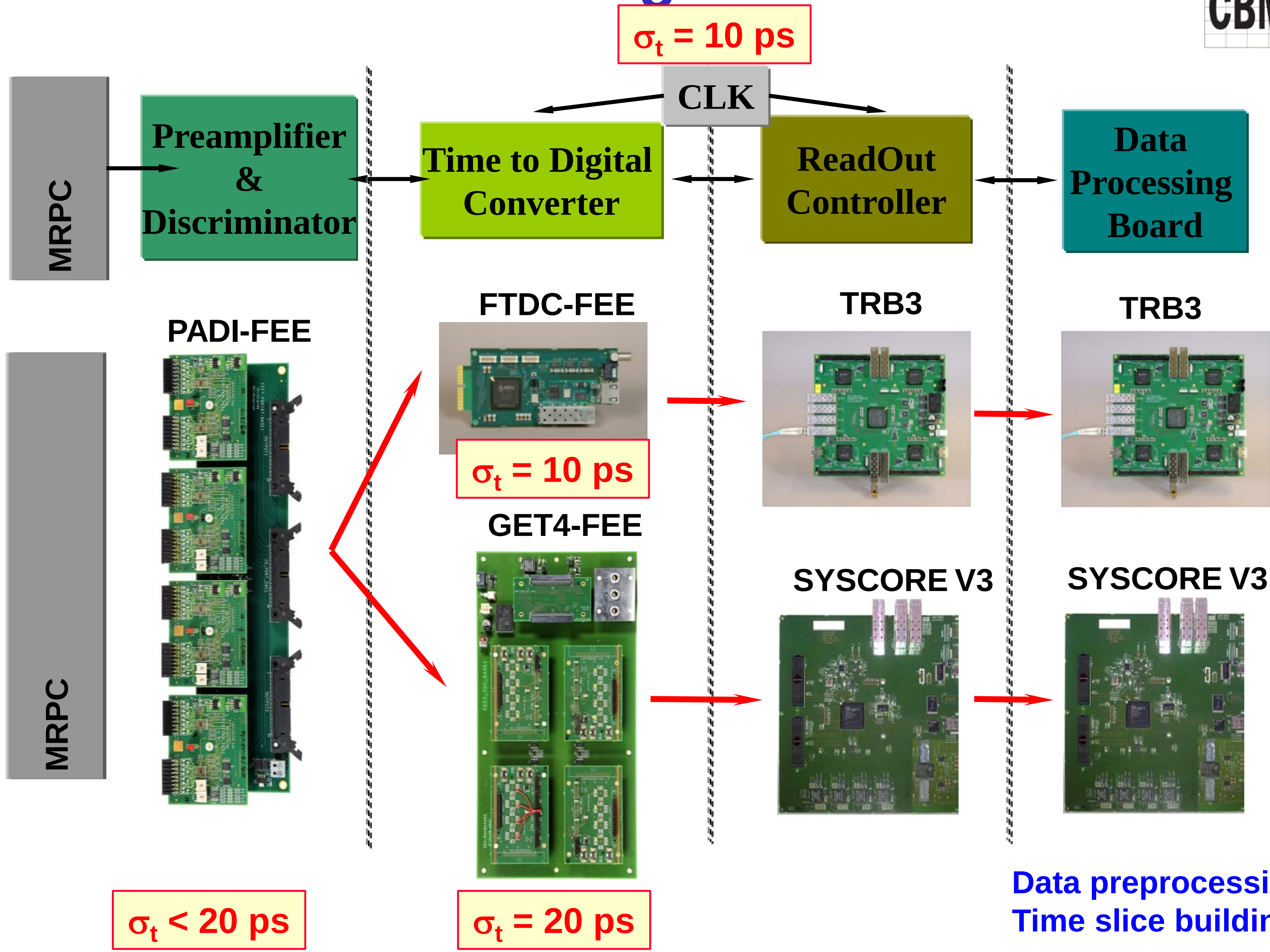
“Standard” (ALICE development): NINO discriminator

PreAmplifier DIscriminator ASIC PADI (UMC – 018 process)



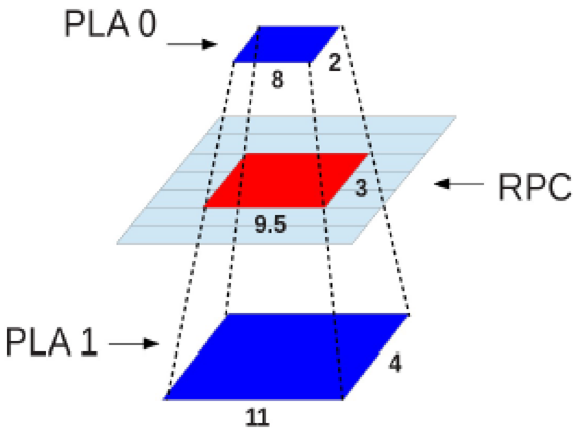
	PADI-6	PADI-8
Channels Number	4	8
PA Bandwidth (MHz)	416	411
PA Voltage Gain	244	251
conversion gain (mV/fC)	35	30
baseline DC offset, sigma (mV)	5.9	1
PA Noise (mV_{RMS})	5.82	5.5
Equivalent Noise Charge (e_{RMS})	1039	1145
Threshold type	Ext. & DAC	DAC
Threshold Dynamics +/-(mV)	Linear 500	Linear 750
Input Impedance Range (Ω)	38-165	30-160
Power consumption (mW/channel)	17.7	17

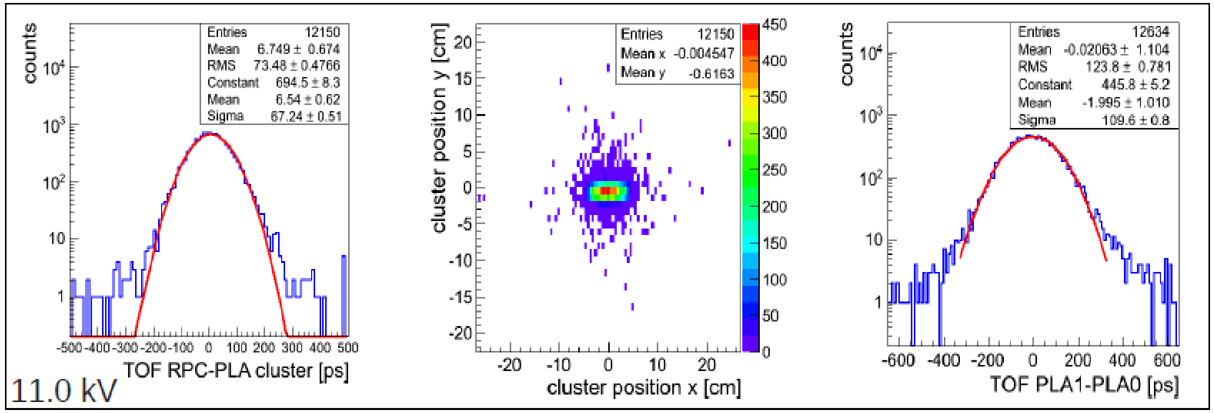
Free streaming TOF Readout



Data preprocessing
Time slice building

50 x 50 cm^2 - strip detector performance





	10.2 kV	**11.0 kV**
total number of events	10204	15960
number of good PLA hits	7850	12333
number of RPC matches	7408	12150
efficiency	**94.4 +/- 0.2 %**	**98.5 +/- 0.1 %**
system time resolution	70.4 +/- 0.6 ps	67.2 +/- 0.5 ps
PMT time resolution	110.7 +/- 1.0 ps	109.6 +/- 0.8 ps
reference time resolution	55.4 +/- 0.5 ps	54.8 +/- 0.4 ps
RPC time resolution	**43.5 +/- 1.2 ps**	**39.0 +/- 1.0 ps**
mean cluster size	1.24	1.39
mean cluster multiplicity	1.26	1.26

Rate capability of MRPCs

Efficiency and resolution depend on voltage across the gap, reduced by currents caused by avalanches:

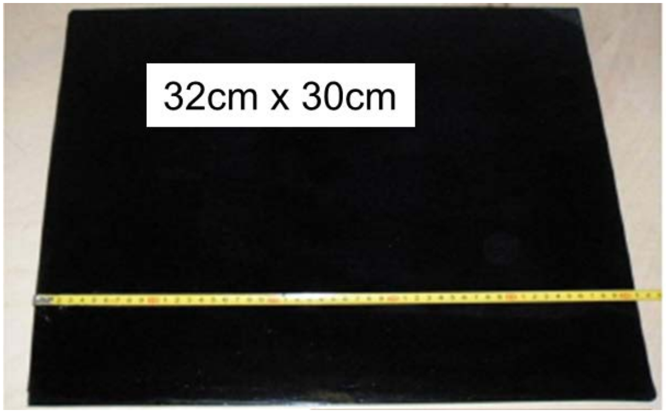
$$\overline{V}_{gap} = V_{ap} - \overline{V}_{drop} = V_{ap} - \overline{I} \cdot R = V_{ap} - \overline{q}_{av}\phi \cdot \rho d$$

Φ – flux of charged particles
q_{av} – charge of avalanche
ρ – resistivity
d – electrode thickness

Methods to increase the rate capability of MRPC counters

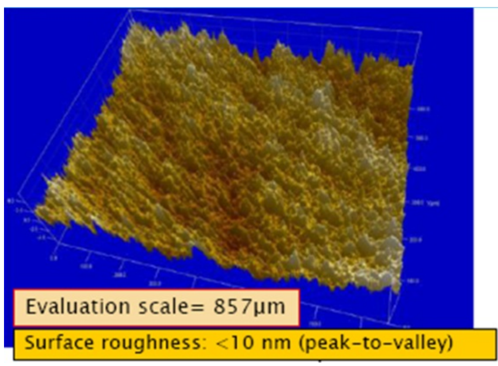
- **Reduce bulk resistivity of electrode glass**
- **Reduce the glass thickness**
- **Warming technology**
- **Reduce the charge**

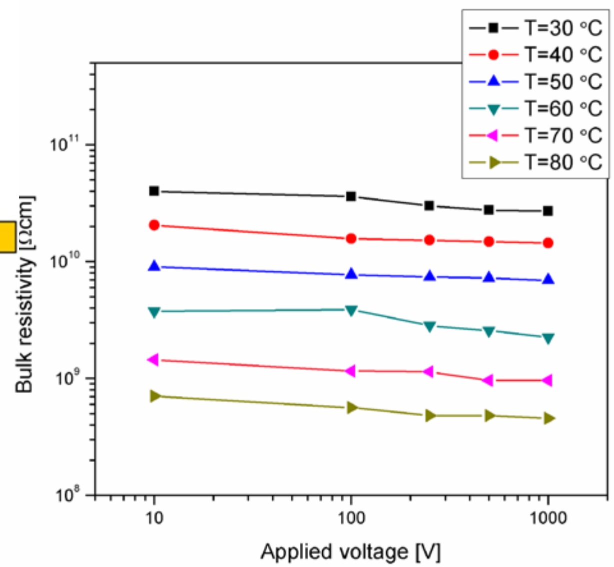
Low resistivity glass

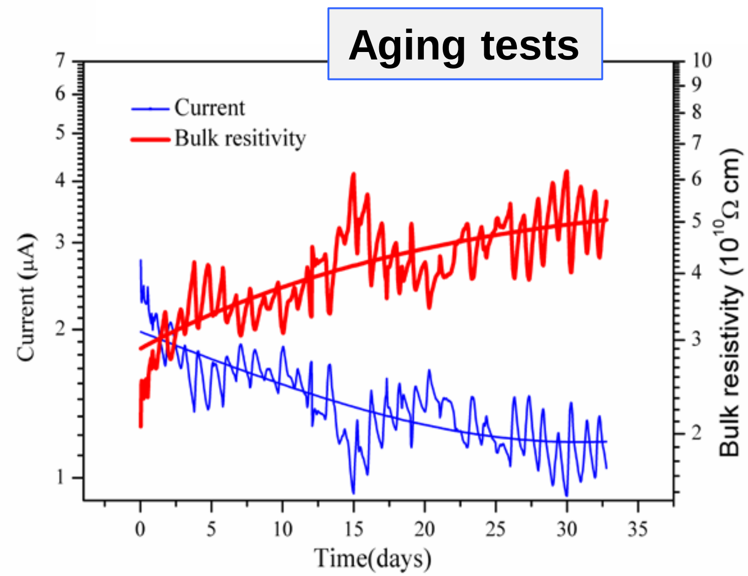


Tsinghua University, Beijing, Y. Wang et al.

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/cm²

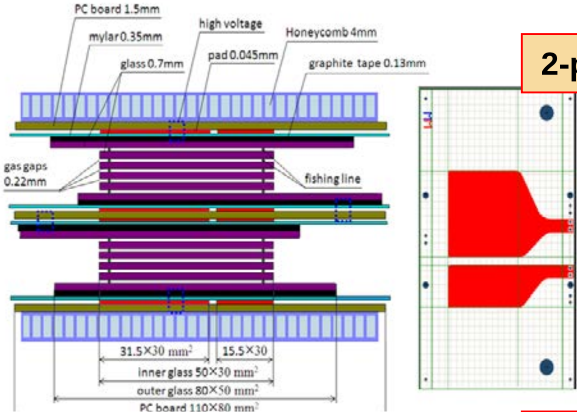




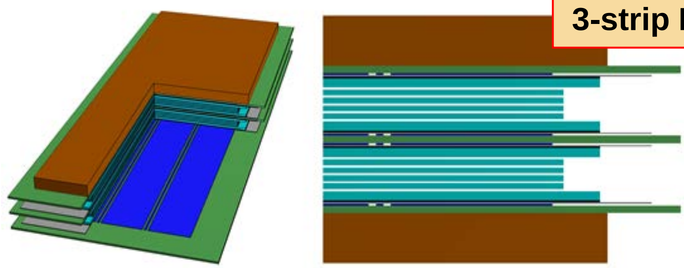


THU counter development

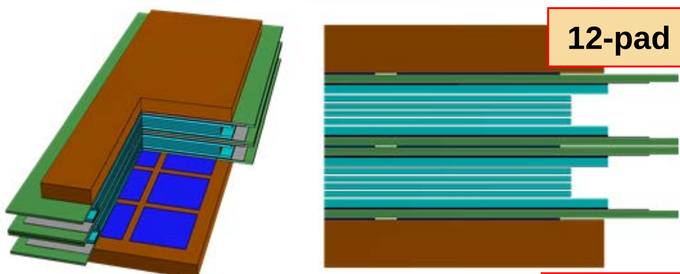
2-pad MRPC



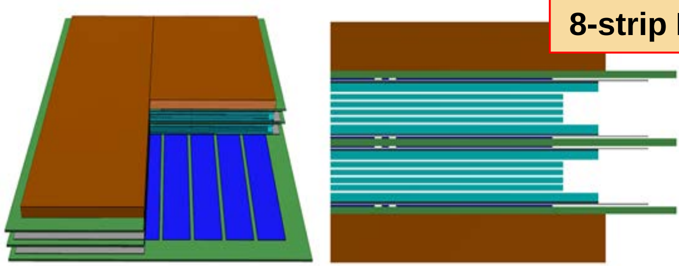
3-strip MRPC



12-pad MRPC

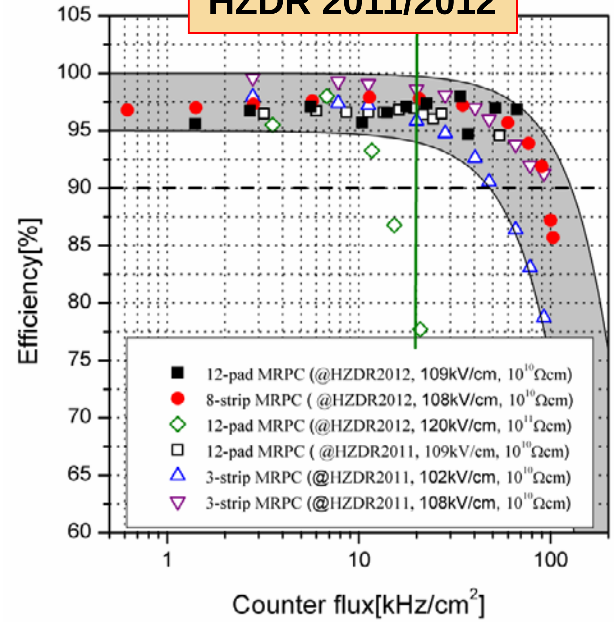


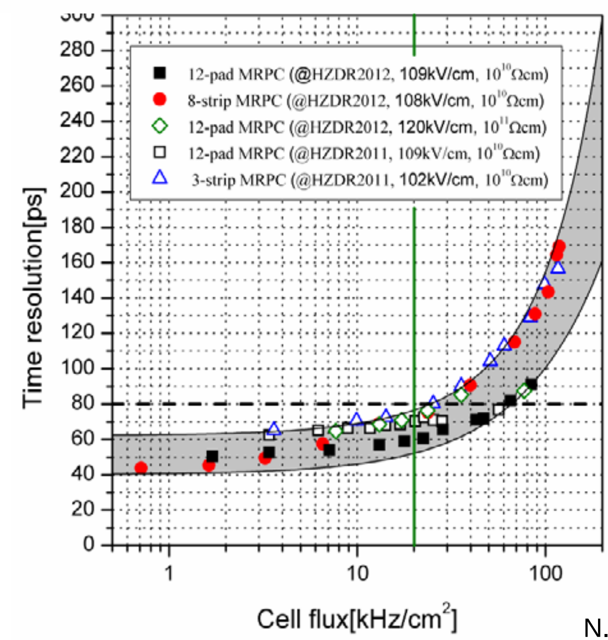
8-strip MRPC



16

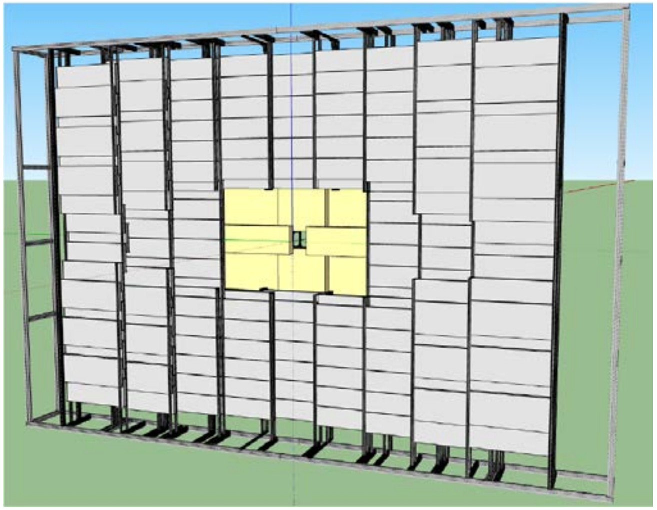
HZDR 2011/2012





Yi Wang,
RPC2014

Baseline system



Modules & counters

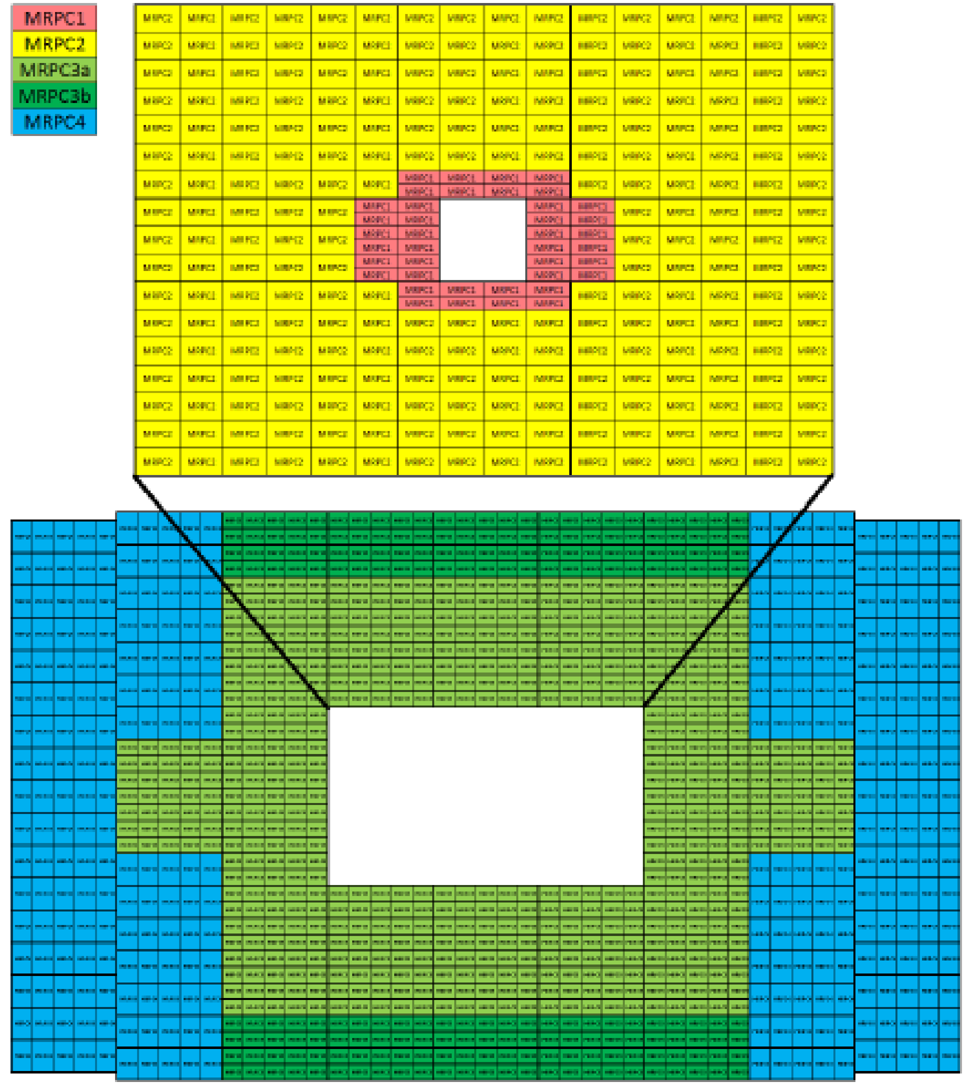
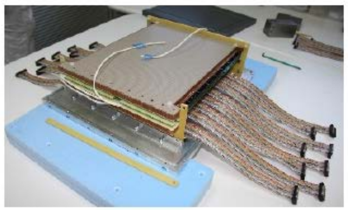
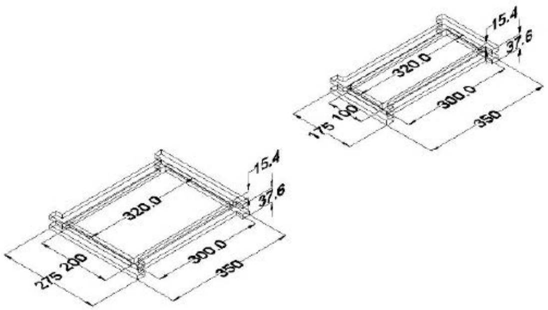


Figure 3.2: Module names

TOF baseline MRPCs

M1, M2





M3, M4

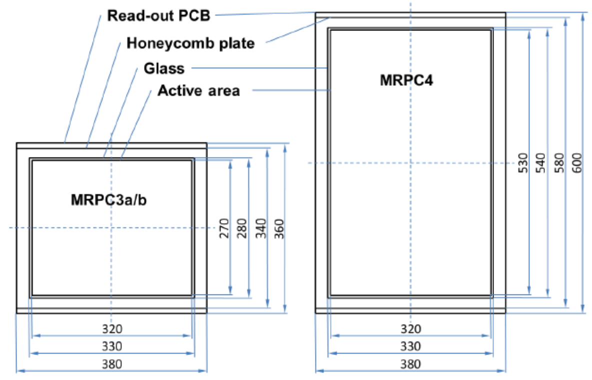


Figure 3.24: 2d drawing of MRPC3a/b (left) and MRPC4 (right).

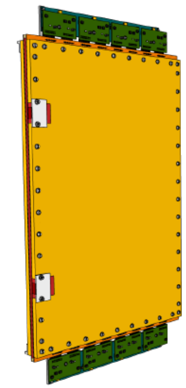
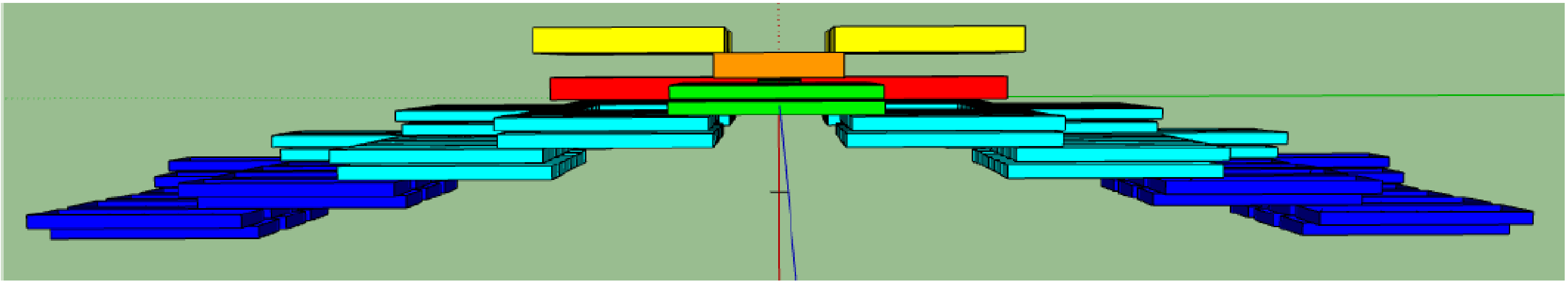


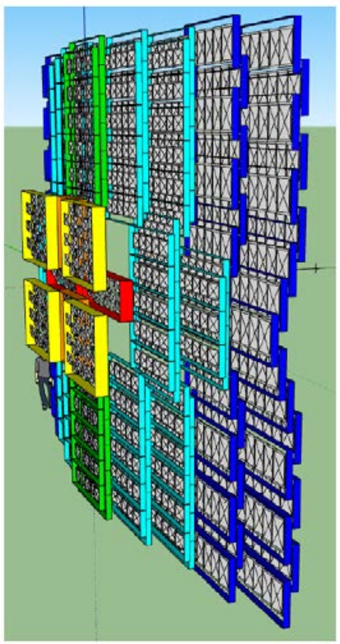
Figure 3.25: 3d view of the MRPC4 counter

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	220
Glass size [mm^2]	320 × 100	320 × 200	330 × 280	330 × 280	330 × 540
Glass thickness [mm]	0.7	0.7	1.0	0.5	0.5
Number of glass plates	12	12	9	9	9
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

TOF modules of baseline geometry

M1	M2	M3	M4	M5	M6





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

Number of Readout channels:106.368

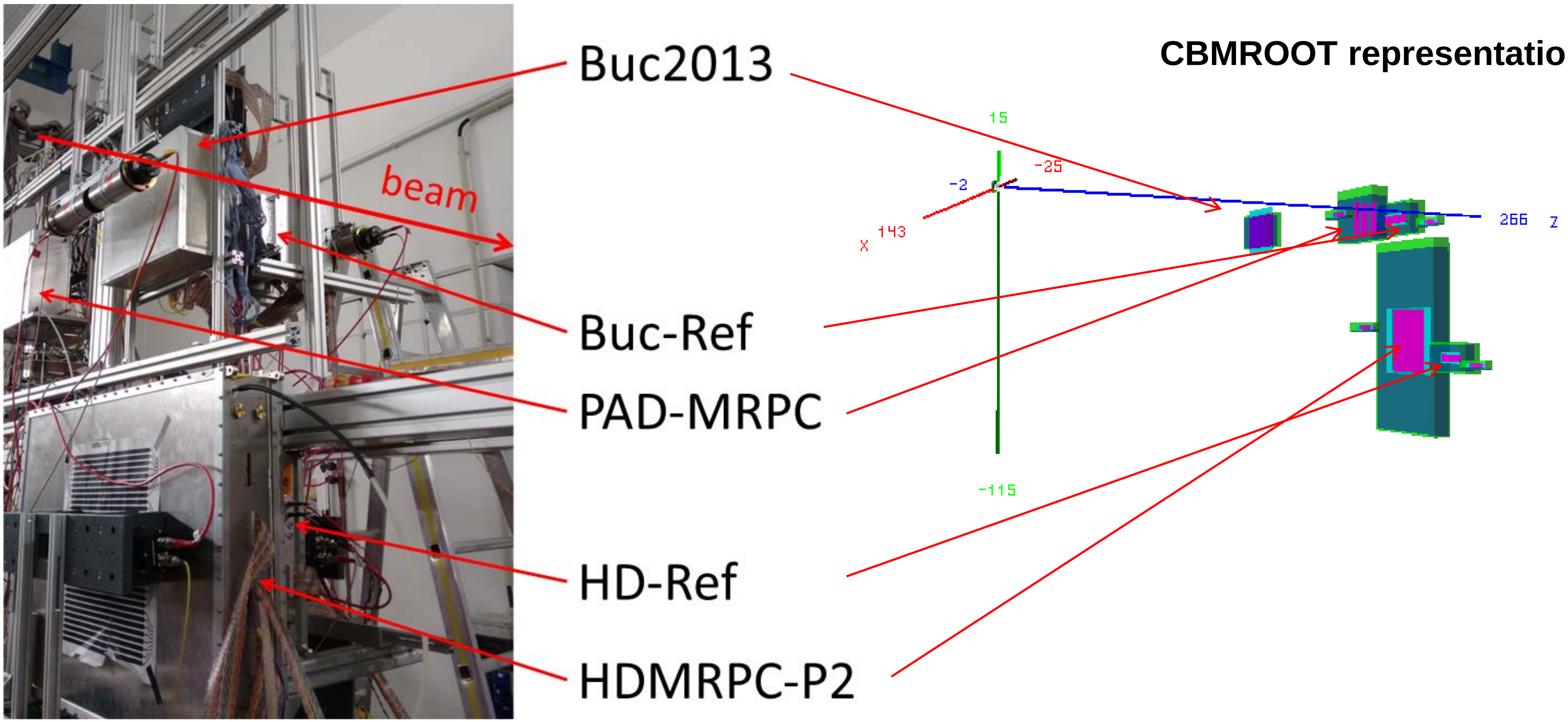
Heavy Ion Test beams

Motivation

analyze performance of prototypes under realistic conditions, develop software to be used in data analysis and MC simulation.

Example: Sm + Pb @ SIS18 (HADES cave, Oct.2014)

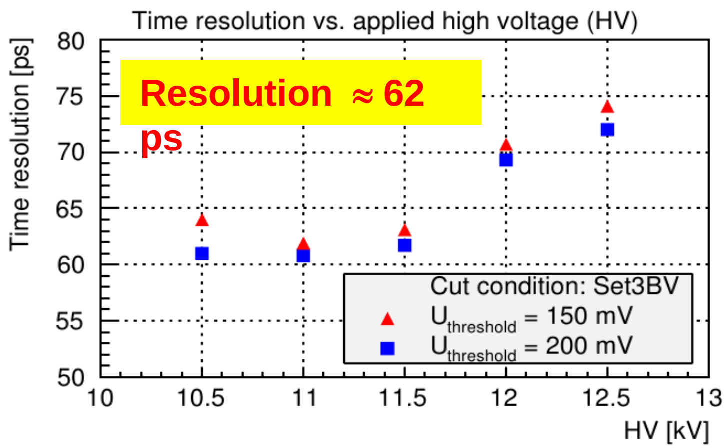
CBMROOT representation

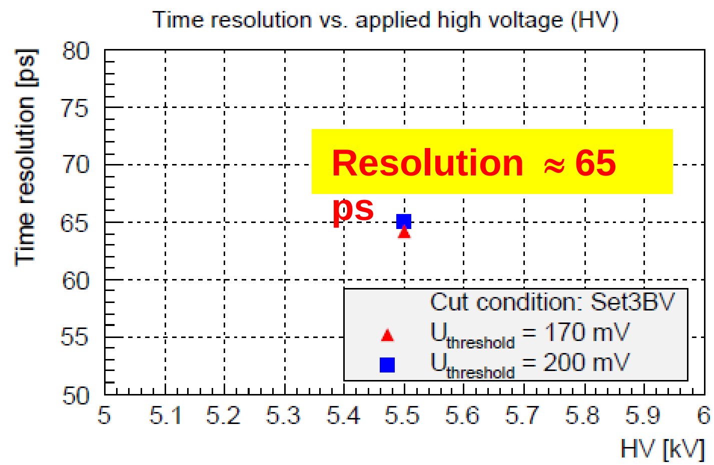


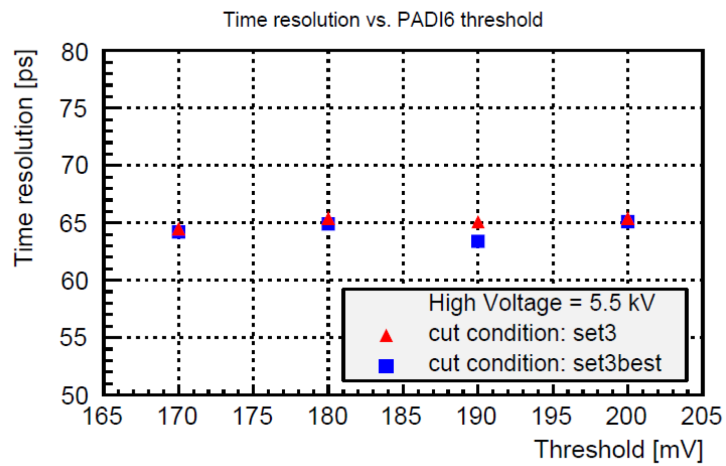
Comparison of time resolution

I. Depppner

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



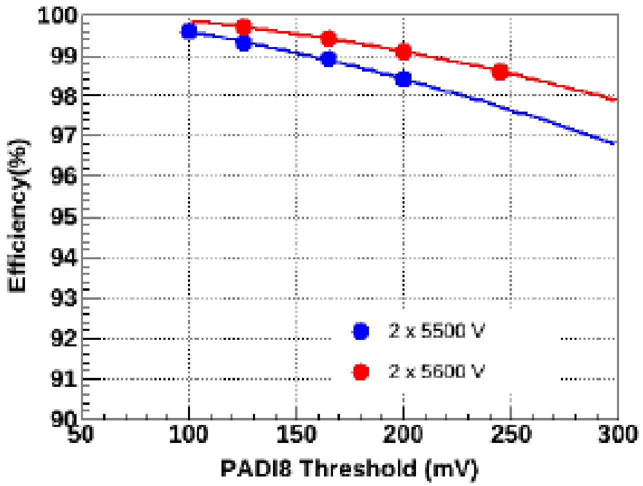


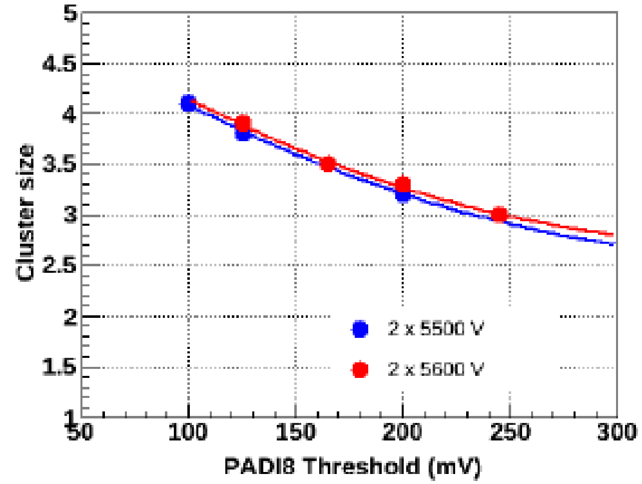


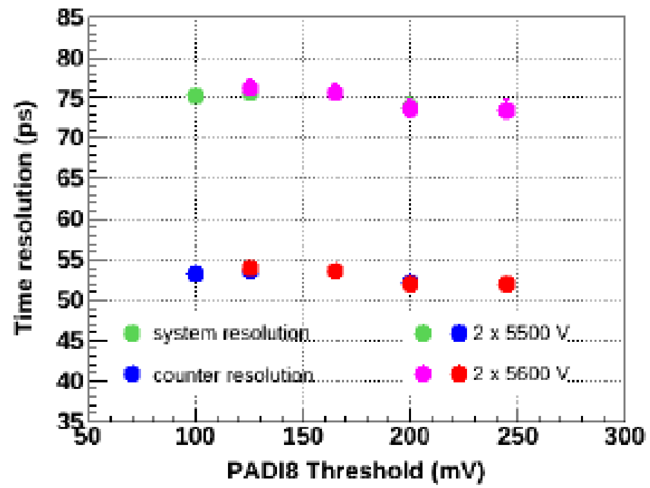
- Data points at ±11 kV in the left plot can be compared with ±5.5 kV in the right plot.
- Single stack MRPC shows slightly time resolution.
- Single counter resolution is in the order of 45 ps including all electronic components.

Buc2013 performance (Oct 2014)

Efficiency, Cluster Size & Time Resolution

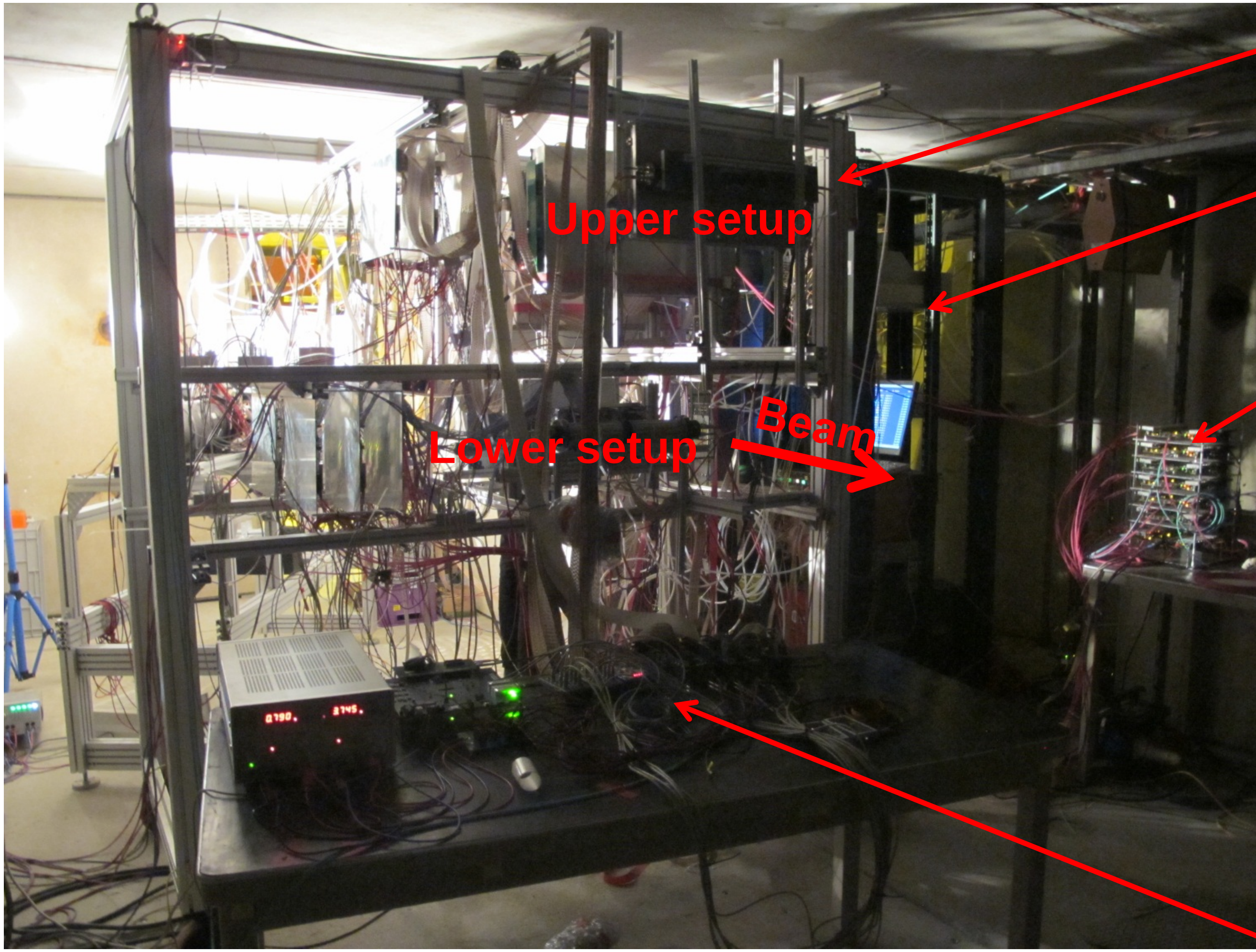






Mariana Petris, CBM Meeting, 14 - 18 september, 2015, Prague

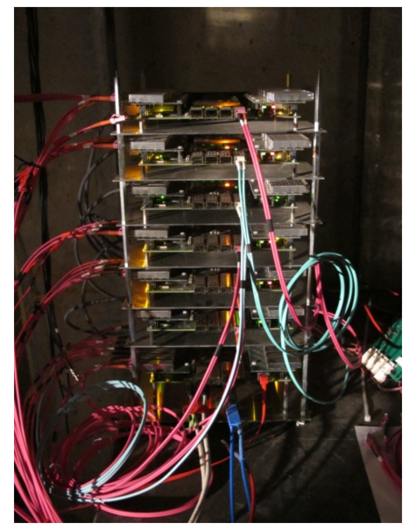

RE 21
CBM



MRPC setup

Rack

Readout electronics

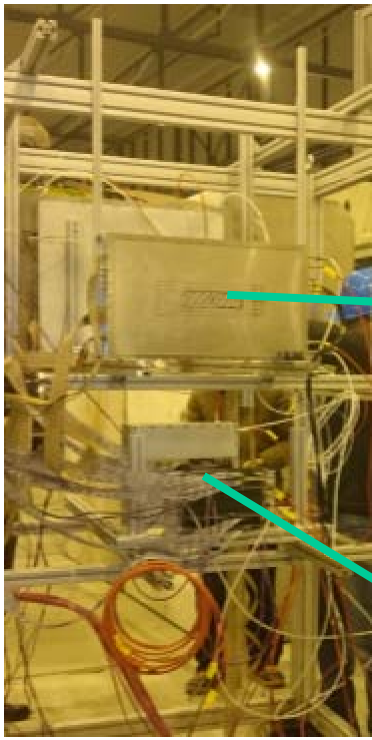


GET4 setup

Pengfei Lyu

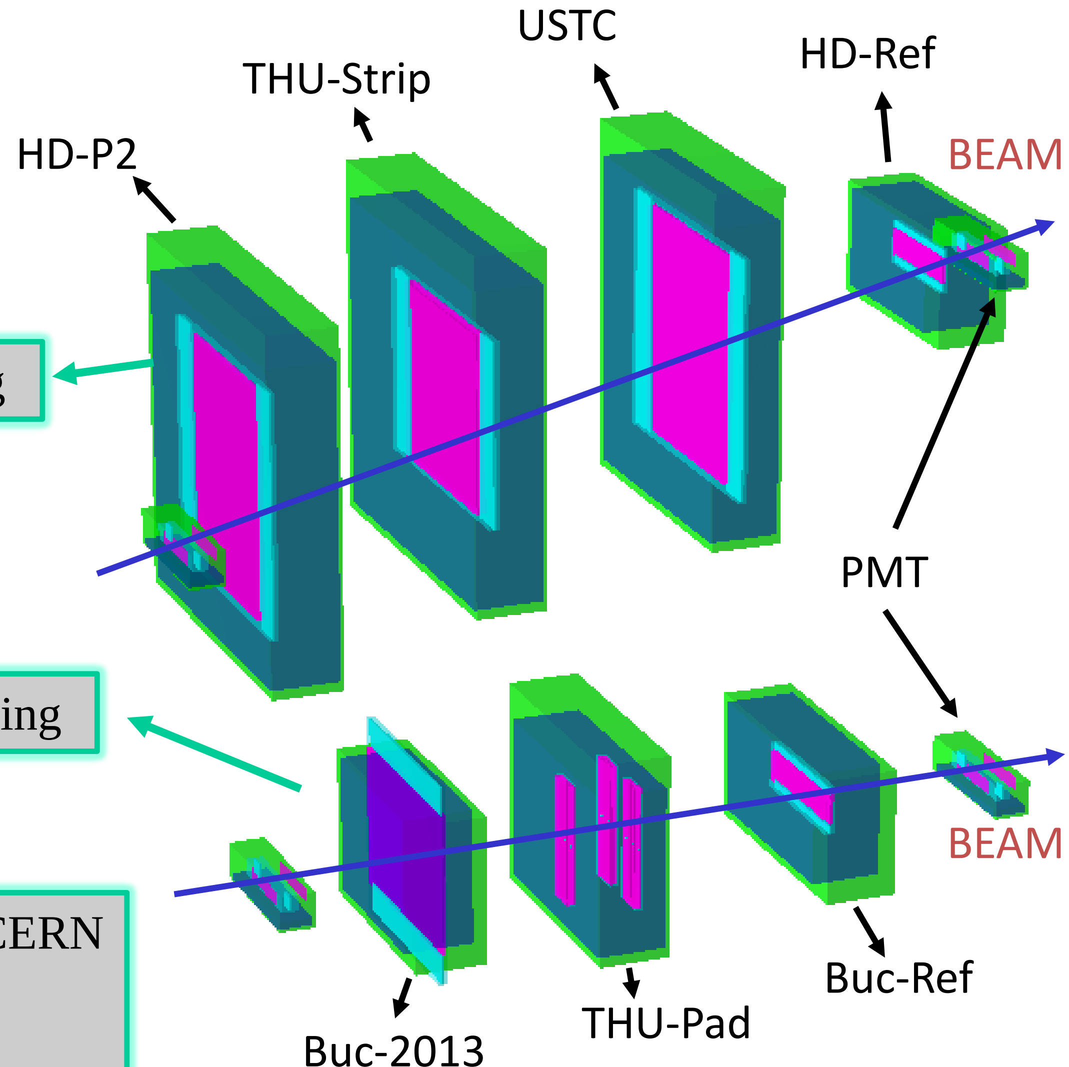
Analysis Results: CERN Feb 2015

Experimental Setup:



Up setting

Down setting



High rate test in February 2015 at SPS CERN
13 GeV Ar beam
Flux rate **around 1kHz/cm^2**

Analysis Results: CERN Feb 2015

Cut Selection: Cut 93
tofAnaTestbeam->SetDut(9);
tofAnaTestbeam->SetMrpcRef(3);
tofAnaTestbeam->SetCh4Sel(16.5);
tofAnaTestbeam->SetDCh4Sel(16.);
tofAnaTestbeam->SetPosY4Sel(0.3);
tofAnaTestbeam->SetChi2Lim(10.);
tofAnaTestbeam->SetSel2TOff(-170);

Analysis Procedure:

- Init_calib.sh (Initial calibration)
- Iter_calib.sh (Iterative calibration)
  - iteration procedure: 1-6-8-2-10-2-10
- Iter_hits.sh (Analysis)
  - analysis correction procedure: 1-2-3-4-1

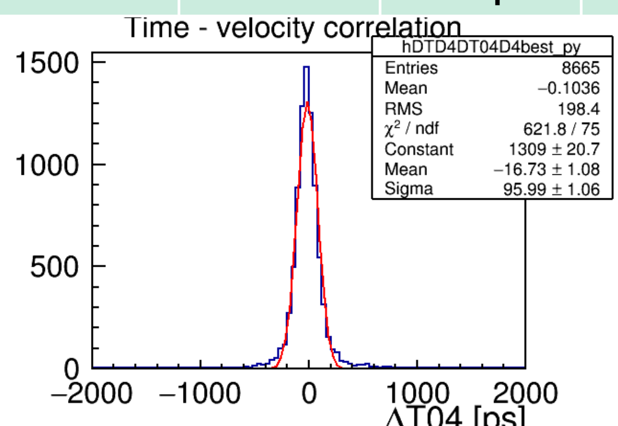
SetChi2Lim(x) —— initialization of Chi2 selection limit

SetChi2Lim	Efficiency	Resolution	Cluster Size
6	98.4%	108.4ps	1.6
10	**98.3%**	**96.0ps**	**1.6**
12	98.2%	96.8ps	1.6
15	98.1%	98.3	1.6
50	98.0%	110.3	1.6

SetPosY4Sel(x) —— Y Position selection in fraction of strip length

SetPosY4Sel	Efficiency	Resolution	Cluster Size
1	97.9 %	98.6ps	1.6
0.5	97.9%	98.5ps	1.6
0.3	**98.3%**	**96.0ps**	**1.6**

When the cut is set to:
tofAnaTestbeam->SetPosY4Sel(0.3);
tofAnaTestbeam->SetChi2Lim(10.);
We can get the best results.



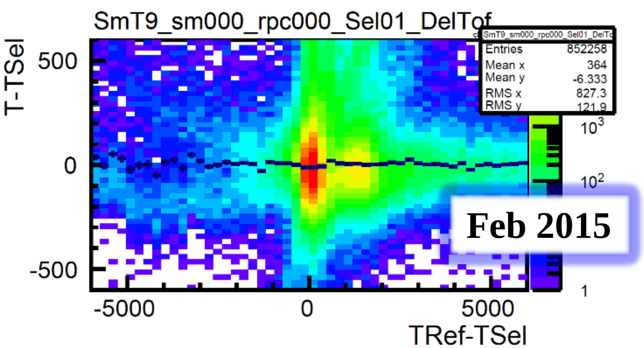
Time velocity correlation result for Run 01Mar 1126-5500V /190mV

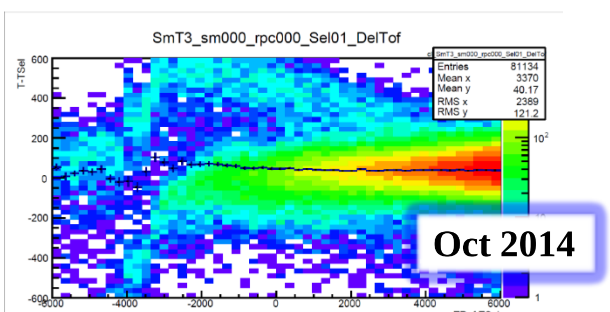
Pengfei Lyu

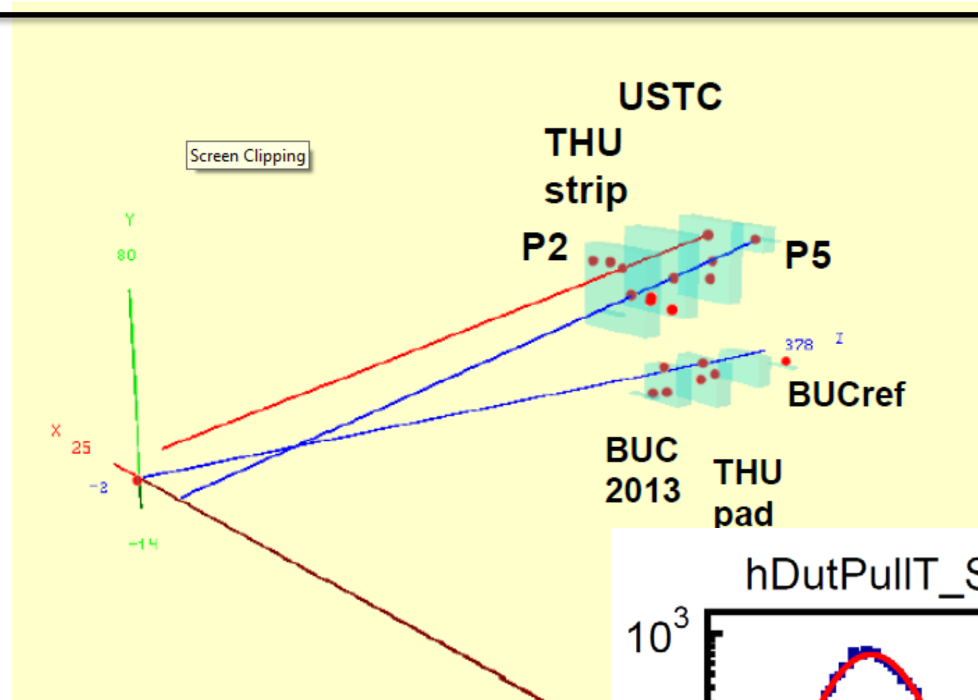
Analysis Results: CERN Feb 2015

February resolution higher than October, probably two reasons:

- **Flux rate is higher.**
- **Diamond is eliminated from the analysis, distance between Dut/Mref and Bref is closer, and velocity correction can't be effective enough.**

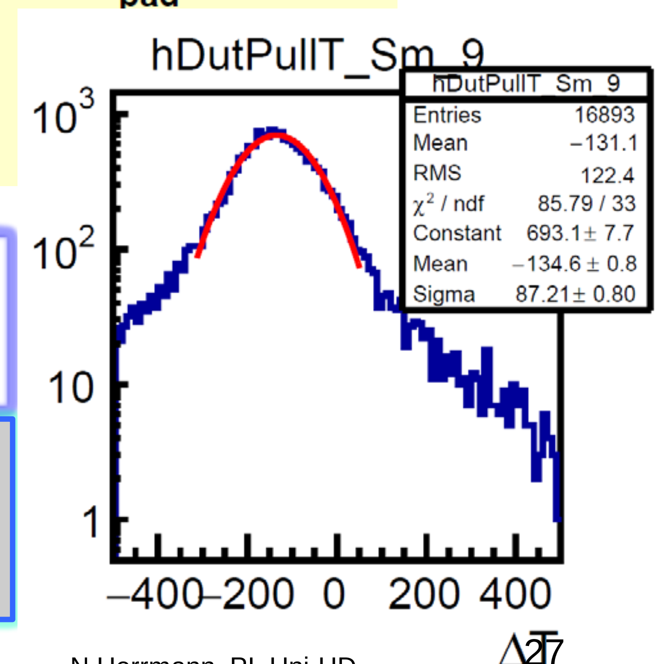






Correct efficiency and calibrate time and space for hits in Dut.

Tracking setup:
tofFindTracks->SetMinNofHits(2);
tofFindTracks->SetNStations(3);
tofFindTracks->SetStations(374);



M.Petris

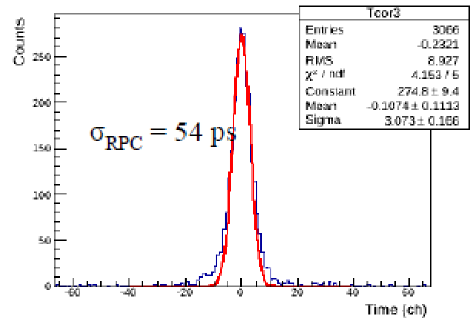
Buc2012 performance (Feb. 2015)

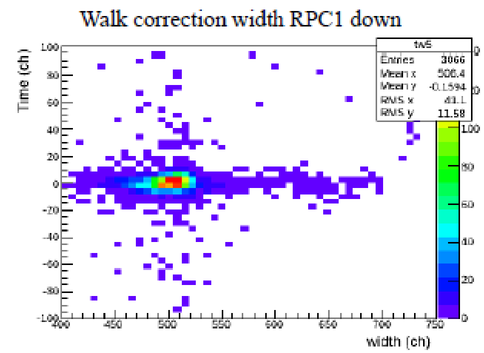
Coincidence between RPC1 & RPC2

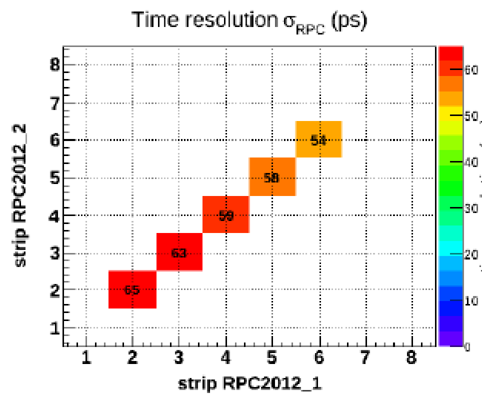
Overlap along the strips = 16.5 mm

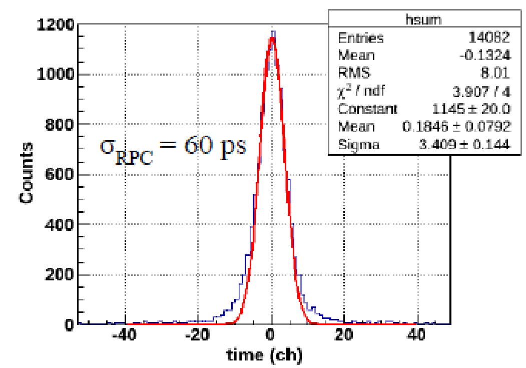
Cuts: cluster size = 1, cluster multiplicity = 1

Time resolution RPC1&RPC2









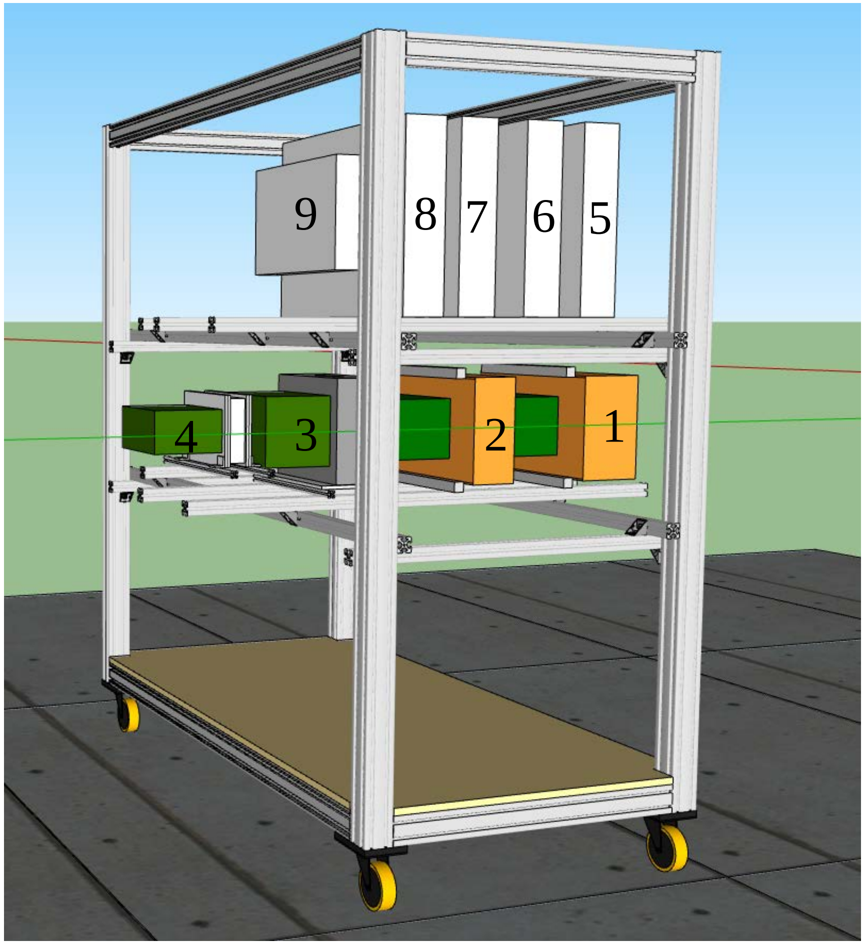
Great!
However: small area response!

Conclusion from HI - testbeams

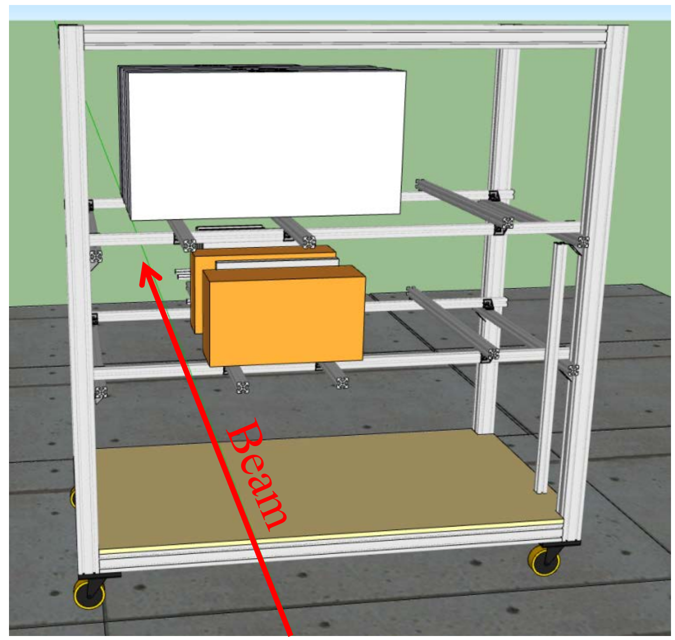
- **Need working start counter system**
- **Need redundancy in tracking -> more stations**
- **Need higher interaction rates**
- **Need better beam diagnostics**

Next chance: Nov. 2015 @ SPS, 30A GeV Pb - beam

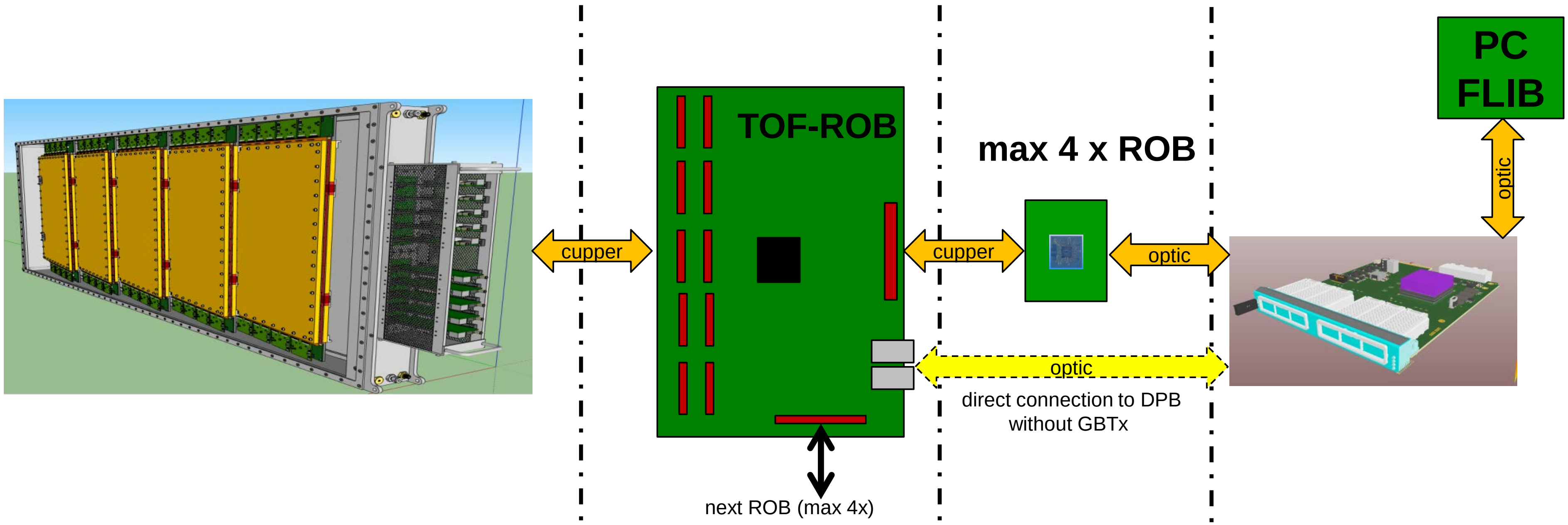
Nov.201 setup @ SPS



1. Buc. 2012, 4 MRPC (same)
2. Buc. 2015, 1 MRPC single stack
   1 MRPC double stack
3. Tsinghua Pad, 3 MRPC (same)
4. Buc. Reference, 1 MRPC nar. Strip
5. Tsg. strip, 2 MRPC, double stack
6. Tsg. strip, 1 MRPC single stack
   USTC strip, 2 MRPC, single stack
7. USTC strip, 2 MRPC, double stack
8. HD strip, 1 MRPC single stack
9. HD Ref, 1 MRPC, single stack



Status: Planed Readout Chain for TOF



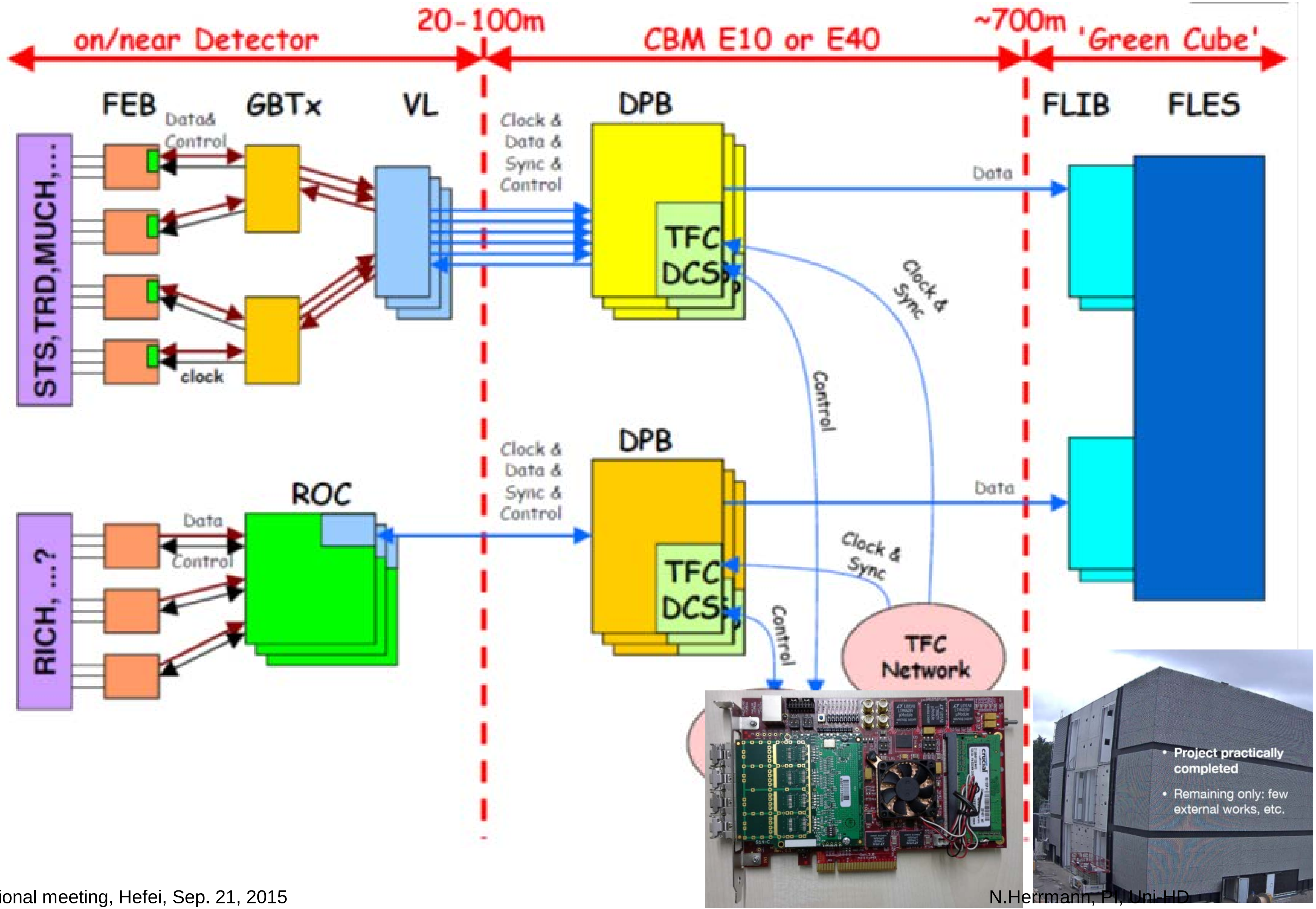
MRPC Module connect to PADI with crate for TDC

ROB = first concentration stage

GBTx = second concentration stage

DPB = third concentration stage

1. 1 x Module = 320 Channel = 80 GET4 / 10 FPGA TDC = 1 TOF-ROB
2. 1 x GBTx can handle up to 4 TOF- ROB
3. 1 x DPB can handle 8 x GBTx



on/near Detector
20-100m
CBM E10 or E40
~700m
'Green Cube'
FEB
Data&
Control
GBTx
VL
Clock &
Data &
Sync &
Control
DPB
FLIB
FLES
STS,TRD,MUCH,...
clock
TFC
DCS
Data
Clock &
Sync
Control
RICH, ...?
Data
Control
ROC
TFC
Network
Project practically completed
Remaining only: few external works, etc.

Milestones of STAR - eTOF programme

STAR involvement of CBM groups only possible with additional funds (manpower, travel, shipping of material)!

- **October 2015** — submit LoI to BMBF and DFG,
- **December 2015** — submit the physics proposal to FAIR/GSI, BNL and funding agencies for approval and support,
- **Summer 2016** — shipping a real size module to BNL and installing it on the east side pole of STAR
- **Feb. 2017** — system integration test with one module by participating on the Run17 beam time in STAR
- **June 2017** — submit the plan and schedule for the endcap TOF installation to STAR operations.
- **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 2020** — Decommissioning and shipping of all modules including infrastructure to FAIR

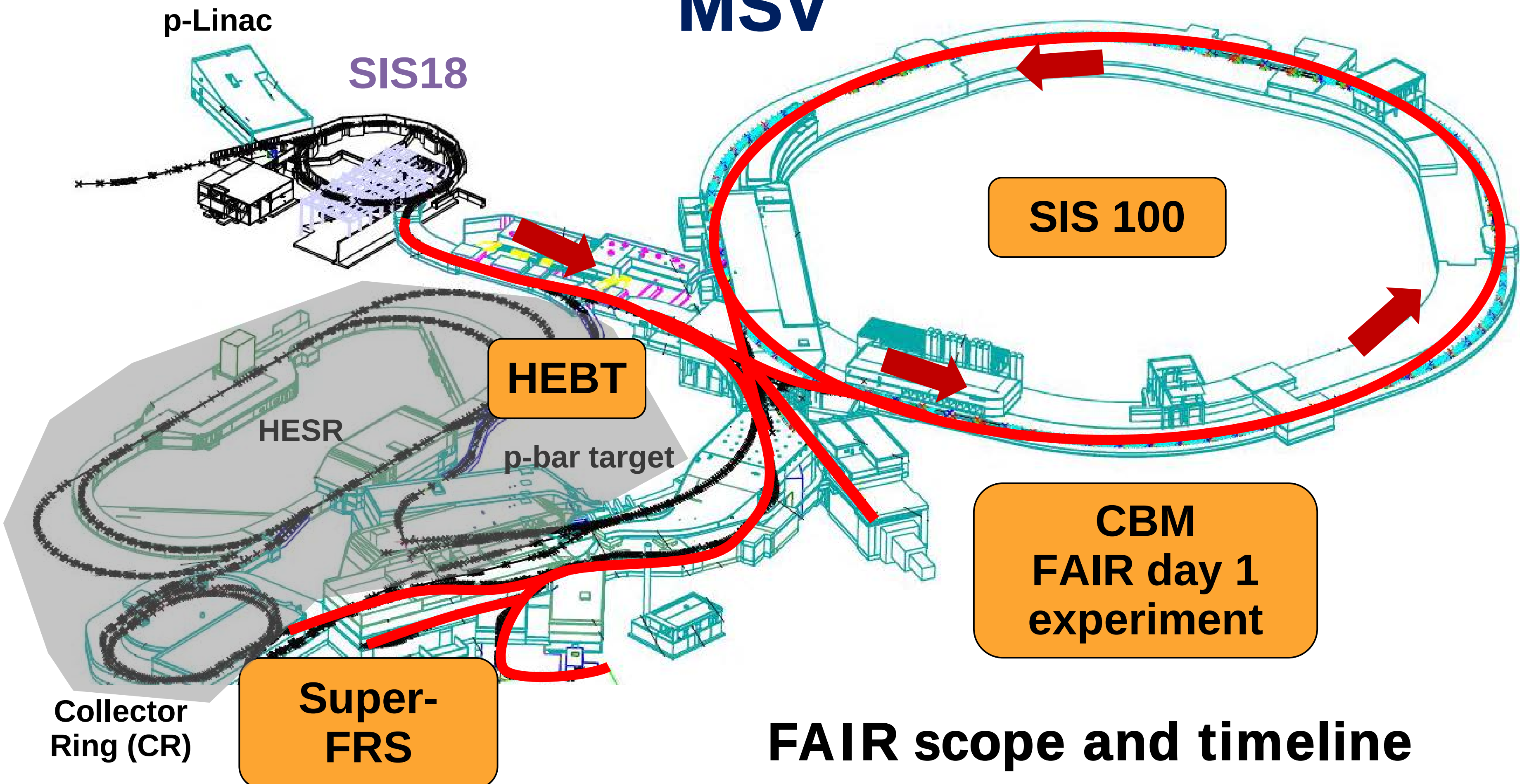
CBM – TOF – Plans

Continue beam tests with heavy ion reactions

- system operation
- physics data analysis

July 2016	**Installation of 1 CBM (GET4) – TOF module in STAR @ BNL**
Nov. 2016 **Nov. 2017**	**Standalone (high rate) test of selected MRPC architecture(s) @ SPS**
2018ff	**High rate integration tests @ mCBM @ GSI** **Stress test with 5 modules, 1.600 channels**
2019	**STAR BES2, fixed target run** **Operation of A~10m^2, ~30 CBM - modules, ~ 10.000 channels**
2021	**CBM @ SIS100** **Operation of A~120m^2, ~200 CBM - modules, ~ 100.000 ch.**

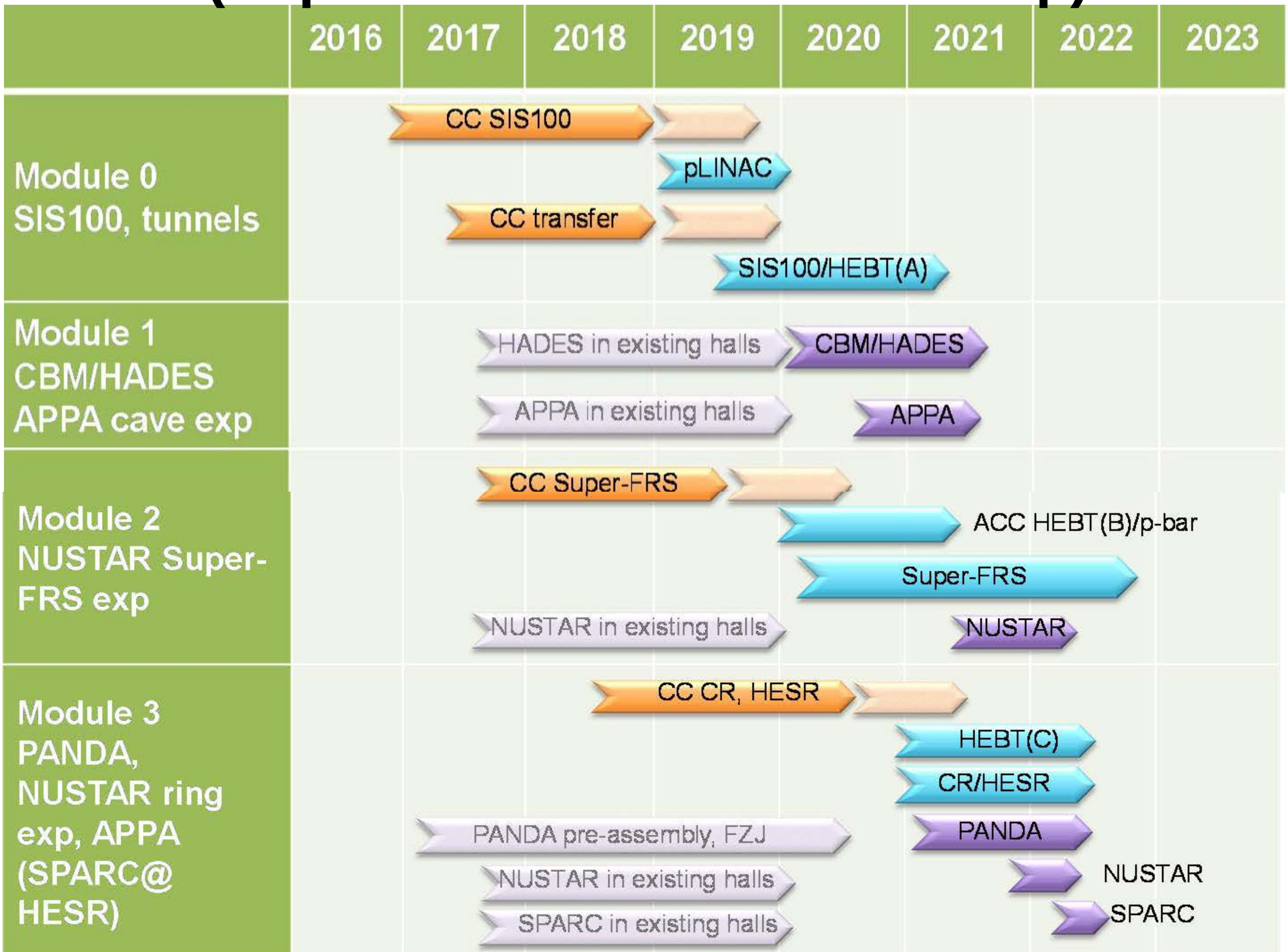
GSI / FAIR strategy: Staged realization along the beam towards MSV



FAIR scope and timeline to be decided at FAIR Council on Sept. 29, 2015

FAIR timeline

(as presented at tunnel workshop)



Summary / Conclusion

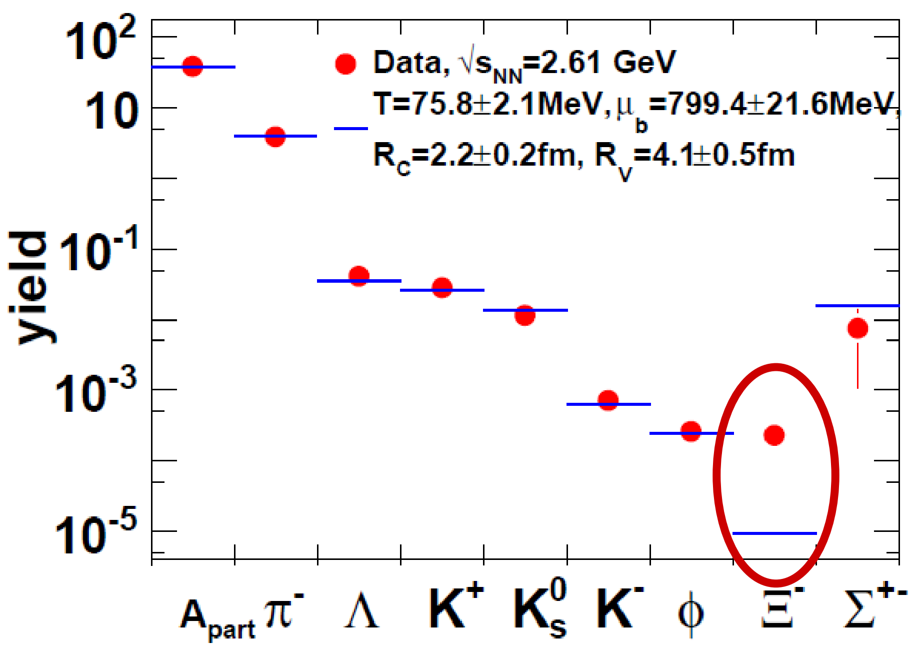
- **Phase structure of QCD will not be revealed by a single measurement.**
- **QCD matter physics needs a facility for systematic studies.**
  and a 3. generation experiment -> CBM
  rate capability: 10 MHz interaction rate
- **CBM physics program**
  many open physics questions
  substantial discovery potential at BESII / SIS100 / 300
- **CBM strategy**
  systematic measurement of multi-dimensional observables of (rare) probes
  use detector components as tool kit.
- **CBM status**
  well advanced with respect to overall FAIR timeline,
  allows for TOF participation in BES II provided the funding is secured.

Thanks for your attention!

HADES: Sub-threshold Ξ^- - production

Ar+KCl reactions at 1.76A GeV

- Ξ^- yield by appr. factor 25 higher than thermal yield
- strangeness exchange reactions like
  $\overline{K}Y \rightarrow \pi\Xi$ (Y=Λ,Σ) ?



G. Agakishiev et al. (HADES), PRL103, 132301, (2009)