High rate, fast timing RPC for the high η CMS muon detectors

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For the CMS-RPC groups

Outline

- Motivation
- Detector R&D
  - Single gap and multigap GRPC
  - Beam tests and GIF++ results
    - PS
    - SPS-H2
    - GIF++
  - Large CMS double single-gap Glass RPC
- Electronics R&D
  - Electronics for Multi-gap CMS-GRPC

Motivation

Luminosity at Phase II (HL-LHC) of CMS experience will be high with respect to Phase I (~X5).

High rate, high radiation, high pile-up (~140) → Upgrade CMS

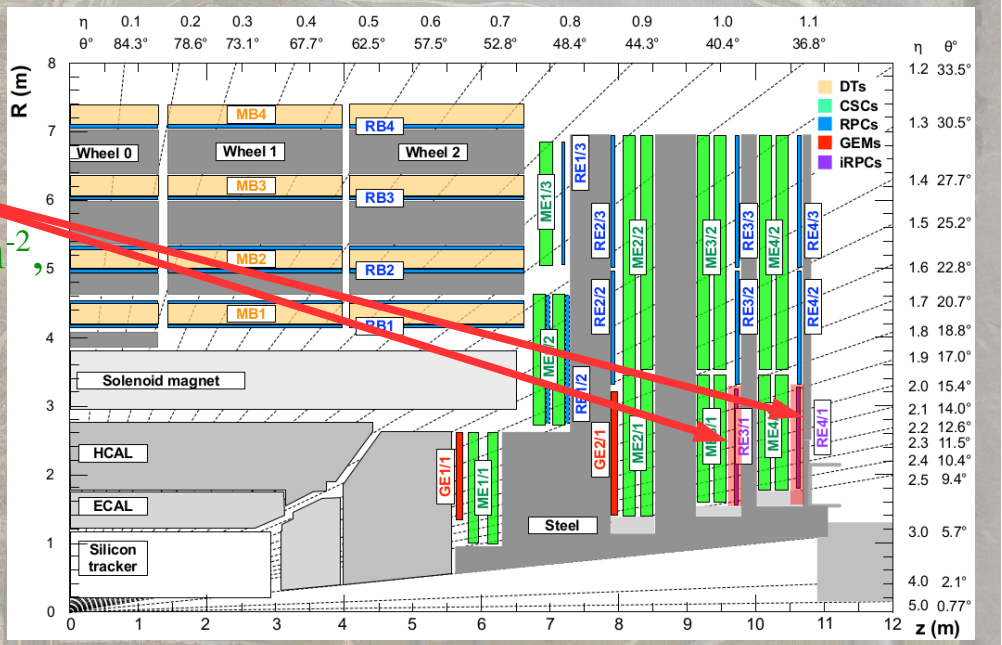
(see A. FAGOT's talk)

Low Resistivity GRPC has been developed to :

- Equip the high η muon stations (1.8<η<2.4).
- Withstand particles rates ~500 Hz.cm^{-2} (2 kHz.cm^{-2}, taking into account a safety factor).

A good time resolution :

- Reduce the background
- could help to assign muon to the right vertex
- could help to identify particles



Official CMS phase 2 quadrant

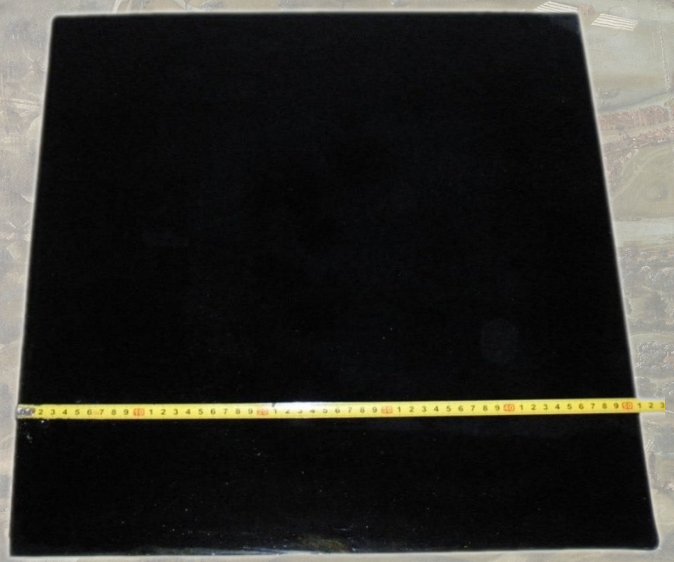
GRPC detectors R&D

Current CMS RPC have limited detection capabilities due to the resistivity **ρ** and the thickness **d** of their electrodes and the charge **q** created by the avalanche in the gas gap.

To increase rate capability you need to :

- Reduce ρ → Low-resistivity glass
- Reduce the electrodes thickness **d** → Easier for glass than Bakelite
- Reduce the charge **q** → Reduce the gas gap and if possible go multi-gap

(MRPC: excellent timing measurement)



Glass Specifications :

Present max. dimension : 32cm×30cm

Bulk resistivity : ≈10^{10} Ω.cm

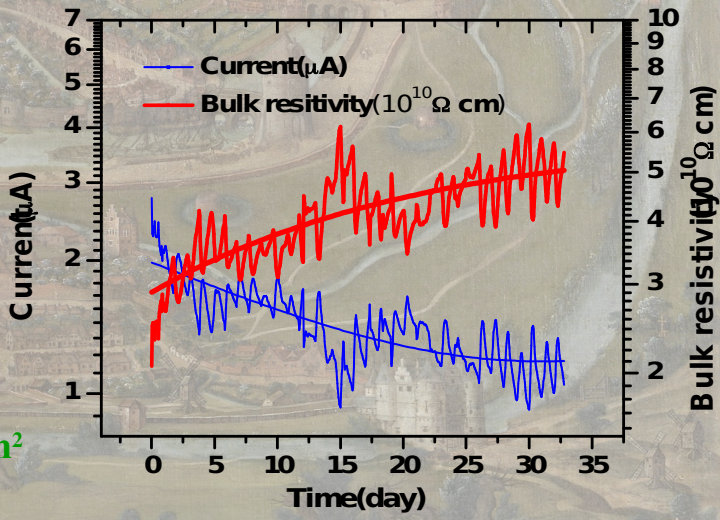
Standard thickness: 0.5mm--2mm

Thickness uniformity : 0.02mm

Dielectric constant : ≈ 7.5-9.5

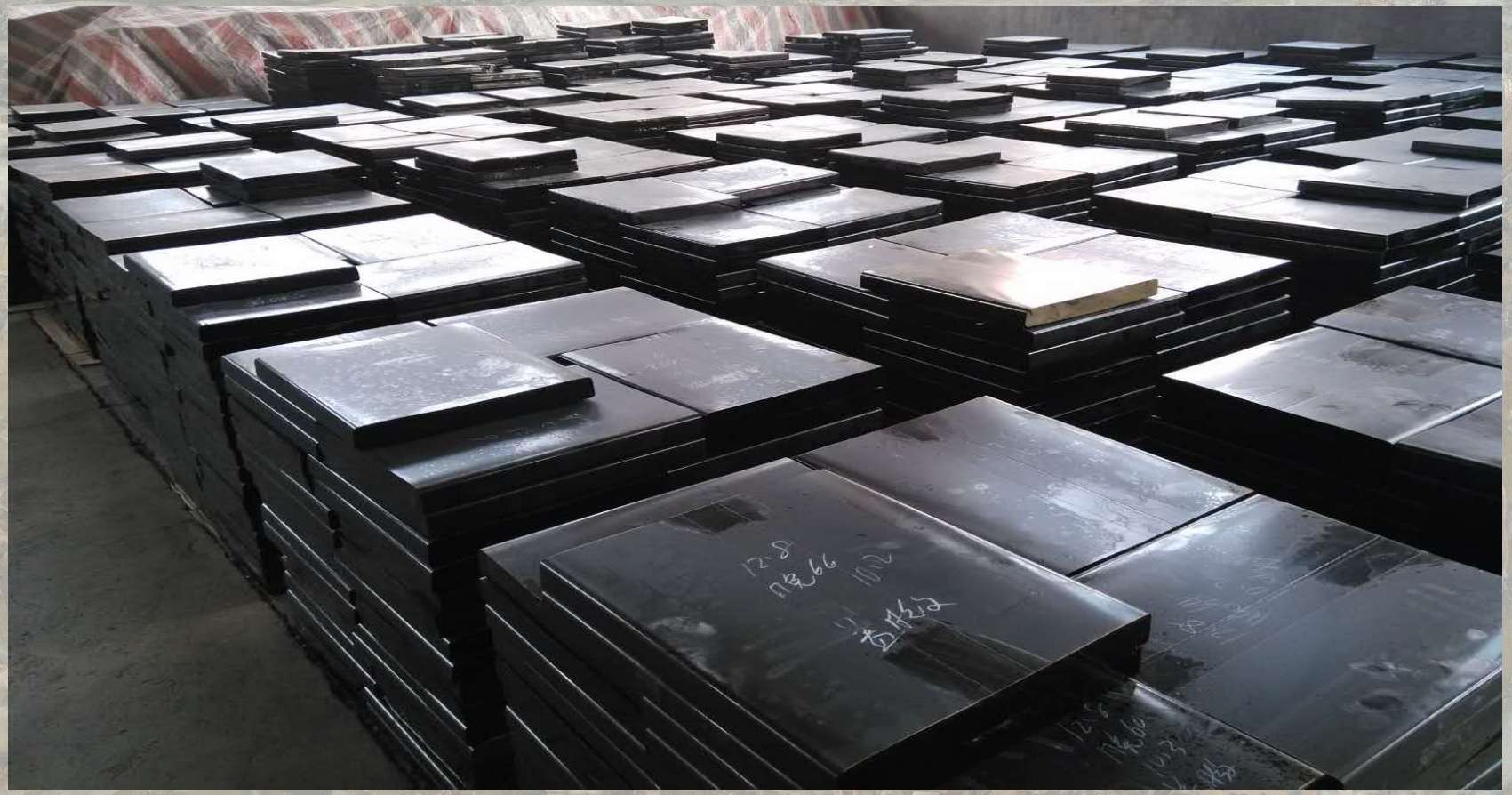
Surface roughness : < 10 nm

DC measurement : Ohmic behavior, stable up to 1 C/cm²



(see Prof. Y. Wang's talk)

There is already a factory producing these Low Resistivity Glass for other experiment.

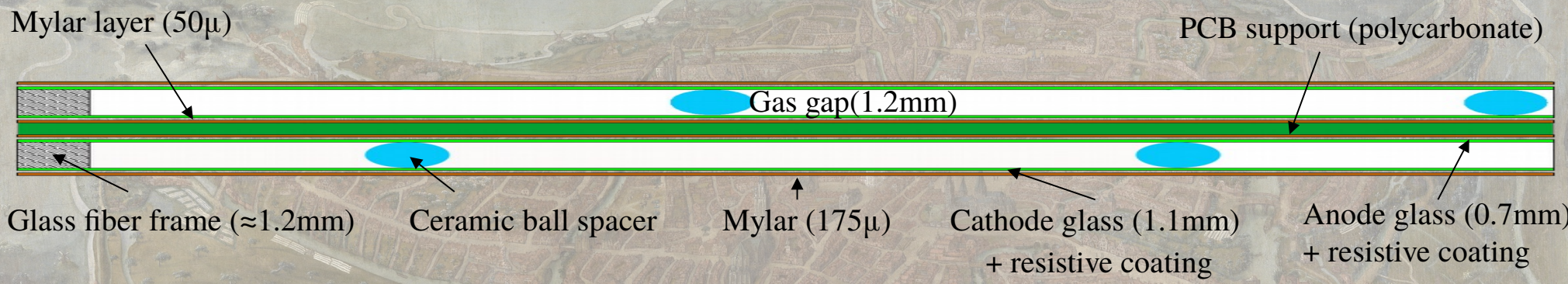


Low-resistivity glass mass production in China :
Yield >100m²/month

Two technologies are being proposed :

1) Double Single-gap GRPC :

Time resolution : ~1ns



2) Double Multi-gap GRPC :

Time resolution : ~100ps

Gas gap width : 250 um
Gas gap number : 5

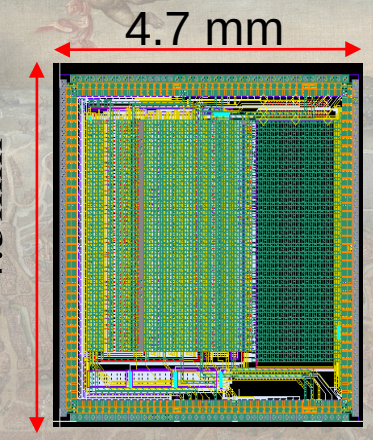
R&D on single gap GRPC

Several single gap GRPCs of **32cm x 30cm** were built and tested using :

HARDROC2B ASICs

Developed by OMEGA group,
SiGe technology,
64 channels,
3 thresholds,
Dynamic range : 10 fC-15pC,
low power consumption < 1mW/ch.

(see A. KUMAR's talk)

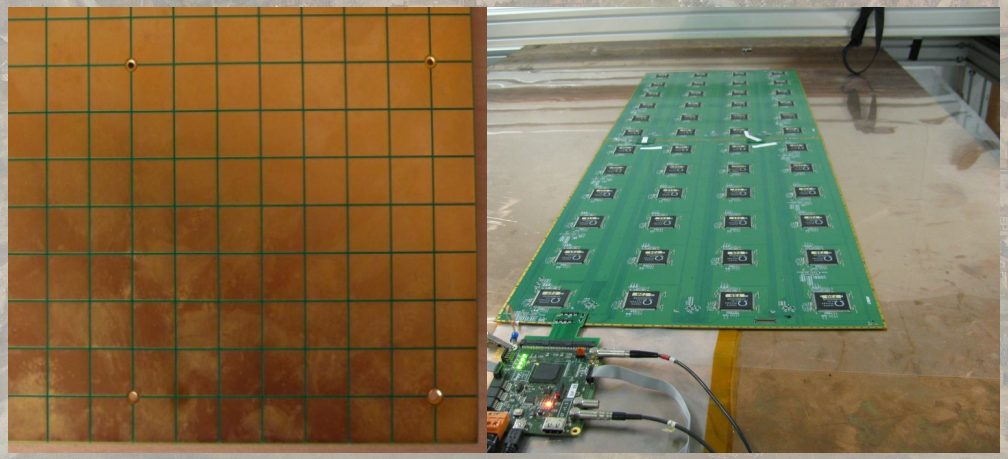


HARDROC2 and 2B : 160 pins

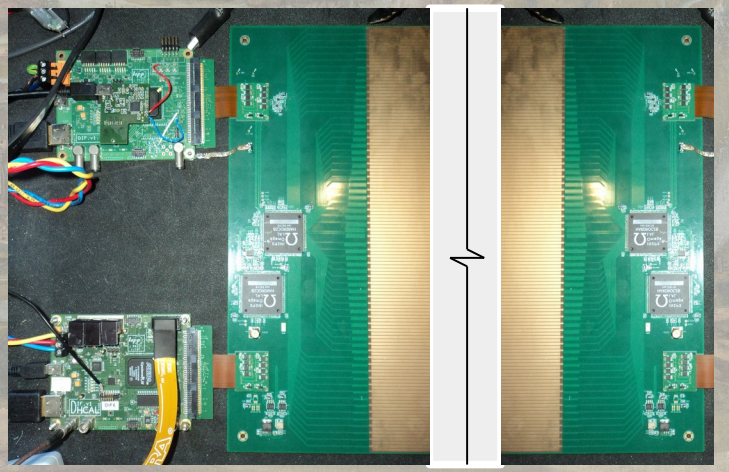
PCB

Two kinds of PCB were used :

a) PCB with pickup pads of 1cm x 1cm



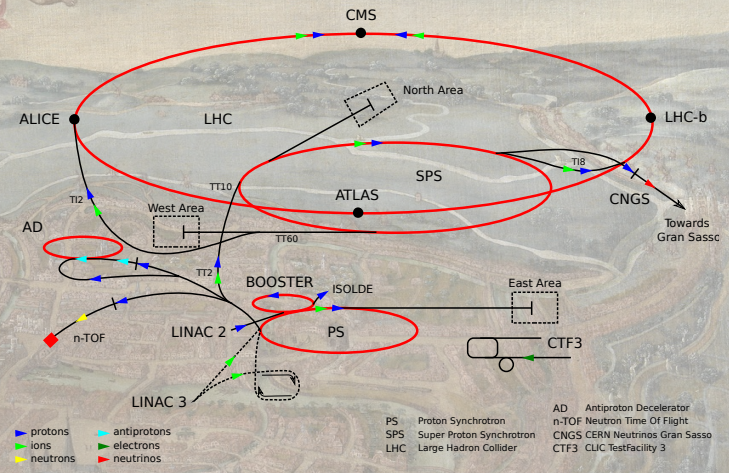
b) PCB with strips of 2.5 mm pitch

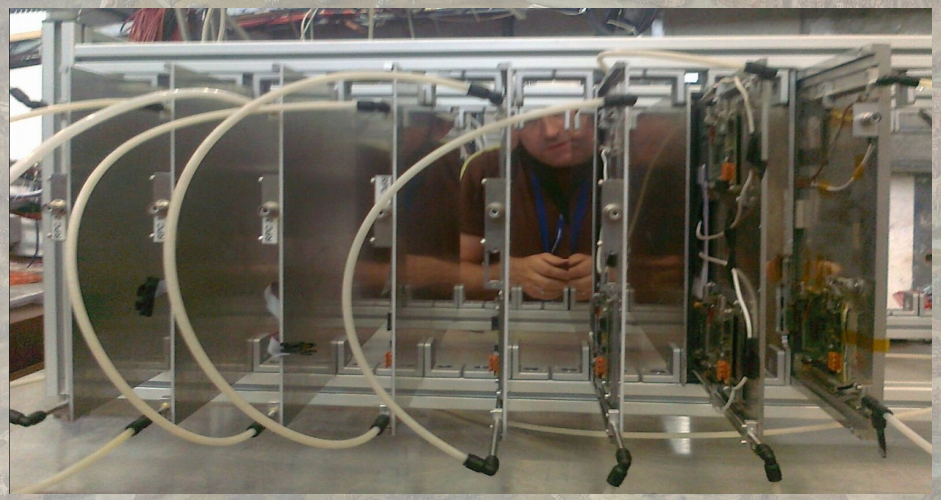


PS August 2014

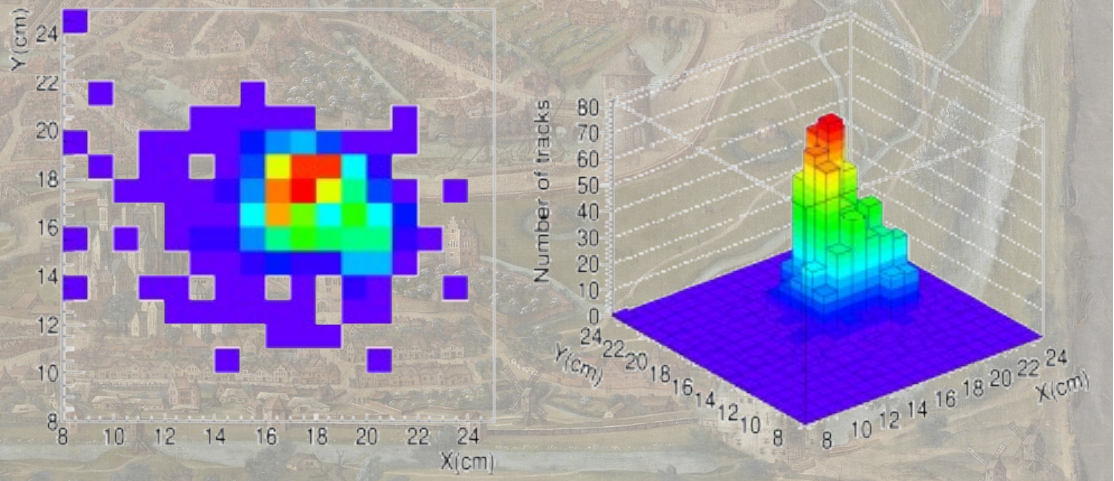
PS beam characteristics :

- Particles : electrons,hadrons,muons…
- Momentum range : 1-15GeV/c
- Particle intensity : 1-2.10^6 particles per spill
- Spill Structure :
  - 400ms spill length
  - 1 spill every 33.6s (more on request)



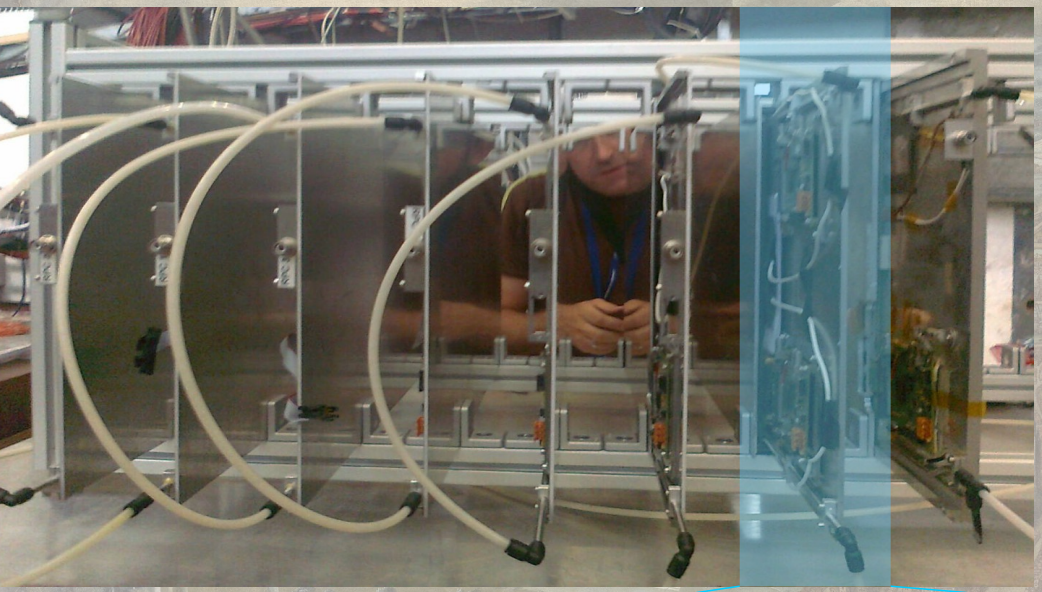


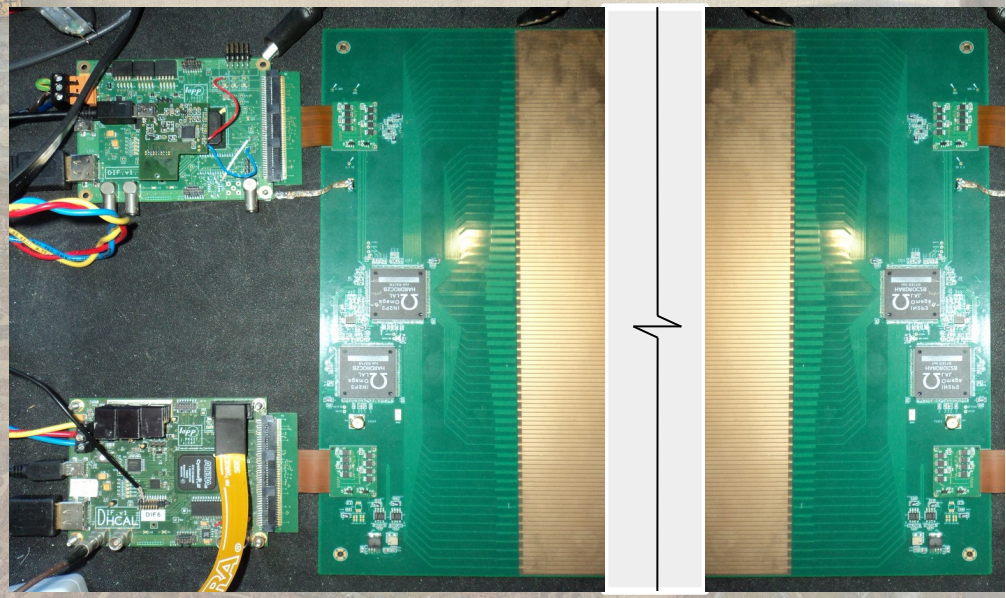
Picture of the setup.



Beam seen by one detector

PS August 2014

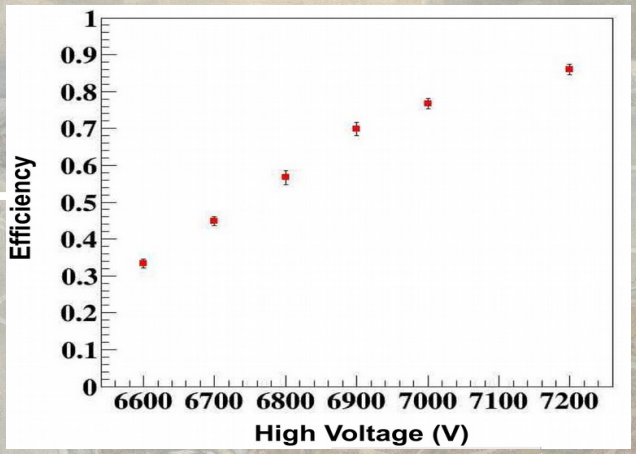




Picture of the strip PCB

Scheme of the strip chamber

PS August 2014



High Voltage Scan for High Rate pickup strip Glass RPC.

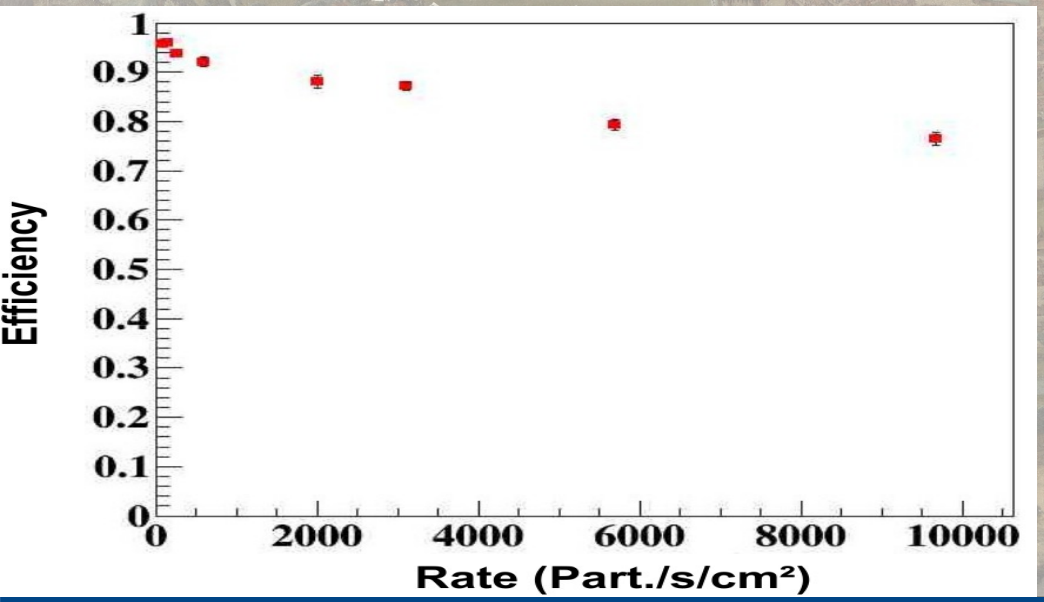
These scans are made at fixed rate (3500 part.s^{-1}.cm^{-2})

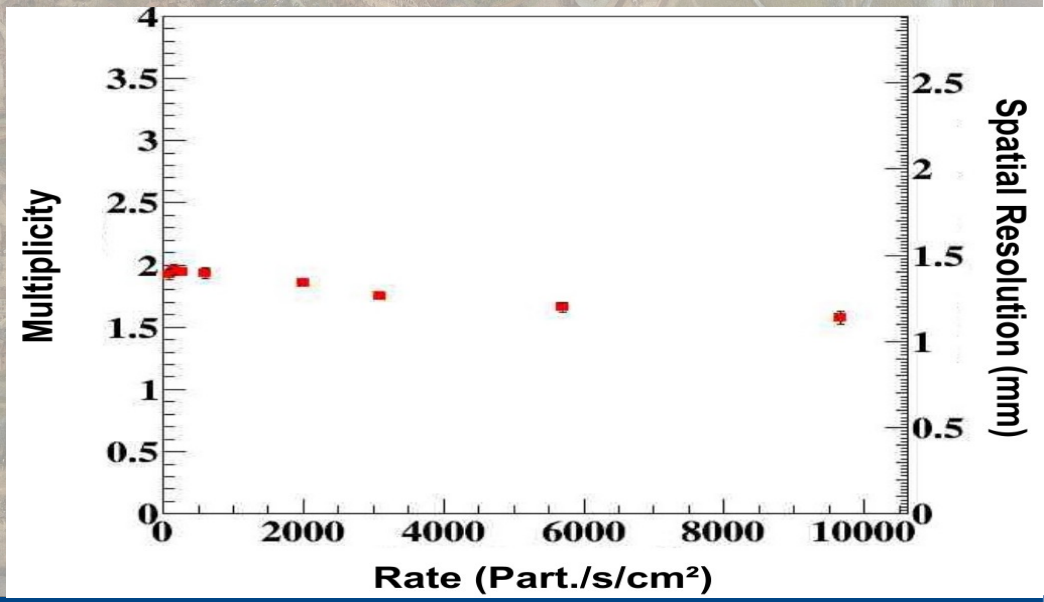
Gas mixture : 93% TFE, 5% CO2, 2%SF6.

Thr : 0.13 pC

Efficiency and cluster size of High Rate pickup-strip Glass RPC as function of particle rate.

These measurements are made at **fixed HV (7200 V).**

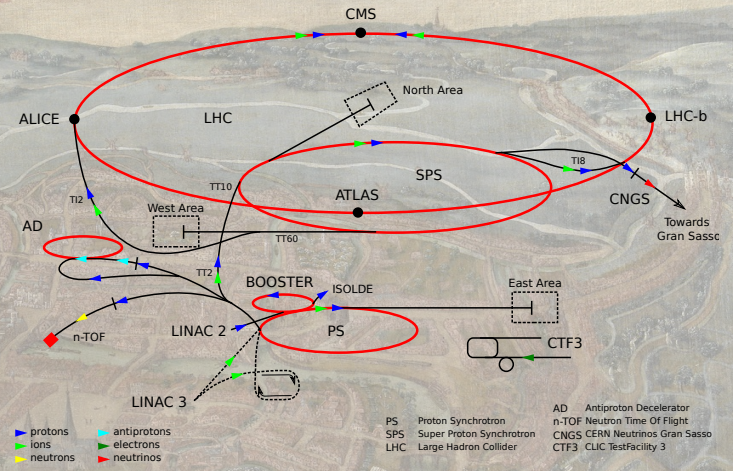




SPS-H2 June 2015

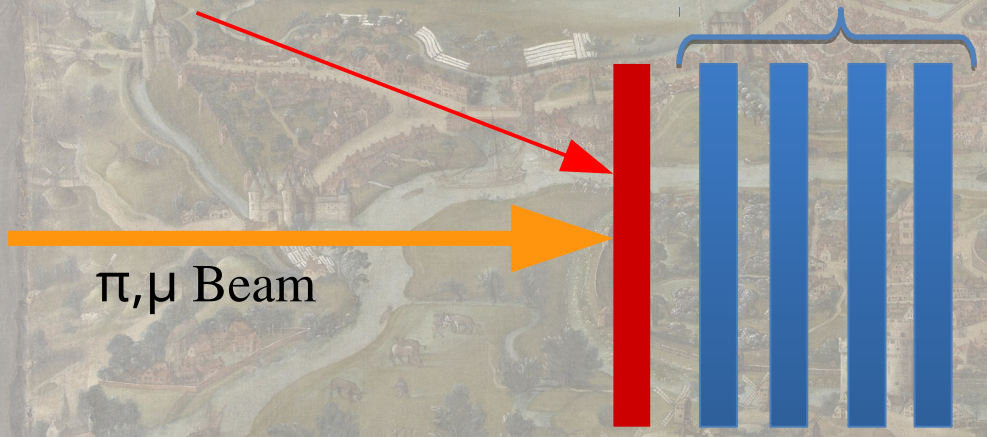
SPS- H2 line caracteristics :

- Particles : electrons,hadrons,muons…
- Momentum range : 10-400GeV/c
- Particle intensity : 2.10^8 particles per spill
- Spill Structure :
  - 4.8s-9.6s spill length
  - 1 spill every 14-~48s

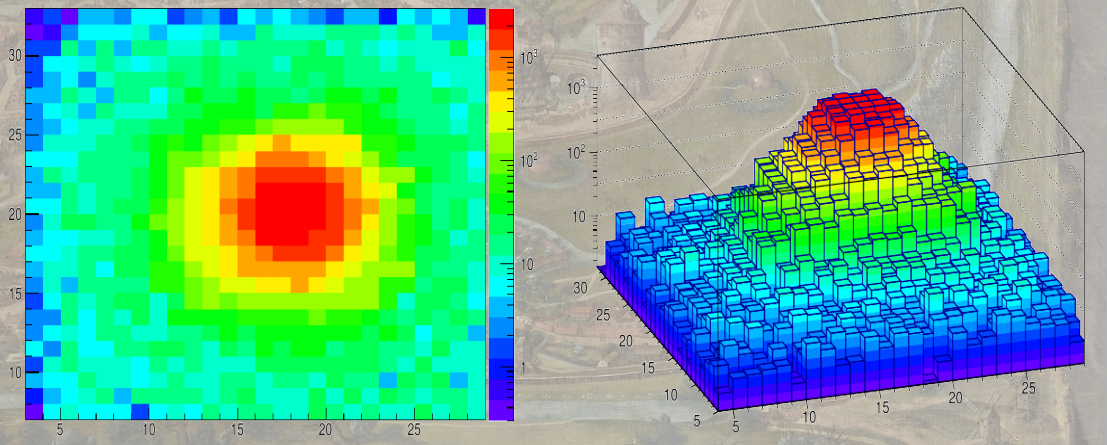


The H2 line provided a **π,μ (150GeV/c) beam** with spill length of **7s**

Standard GRPC Low Resistyvity-GRPC



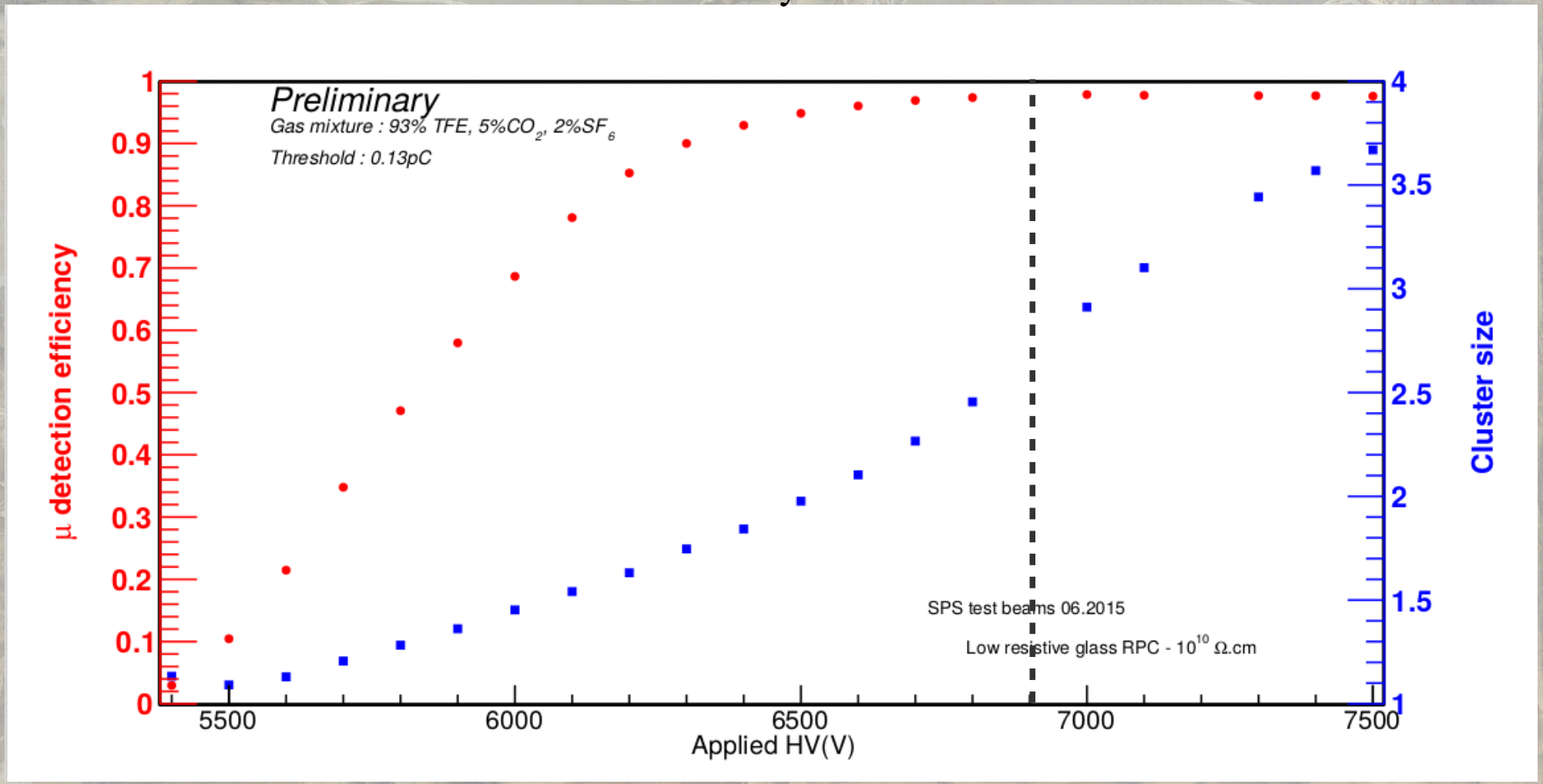
Scheme of the setup



Beam seen by one detector

SPS-H2 June 2015

HV scan, LR-GRPC, second position, intensity : **120 000/spill** (provided by SPS counter).
The chamber was studied in terms of efficiency and cluster size.

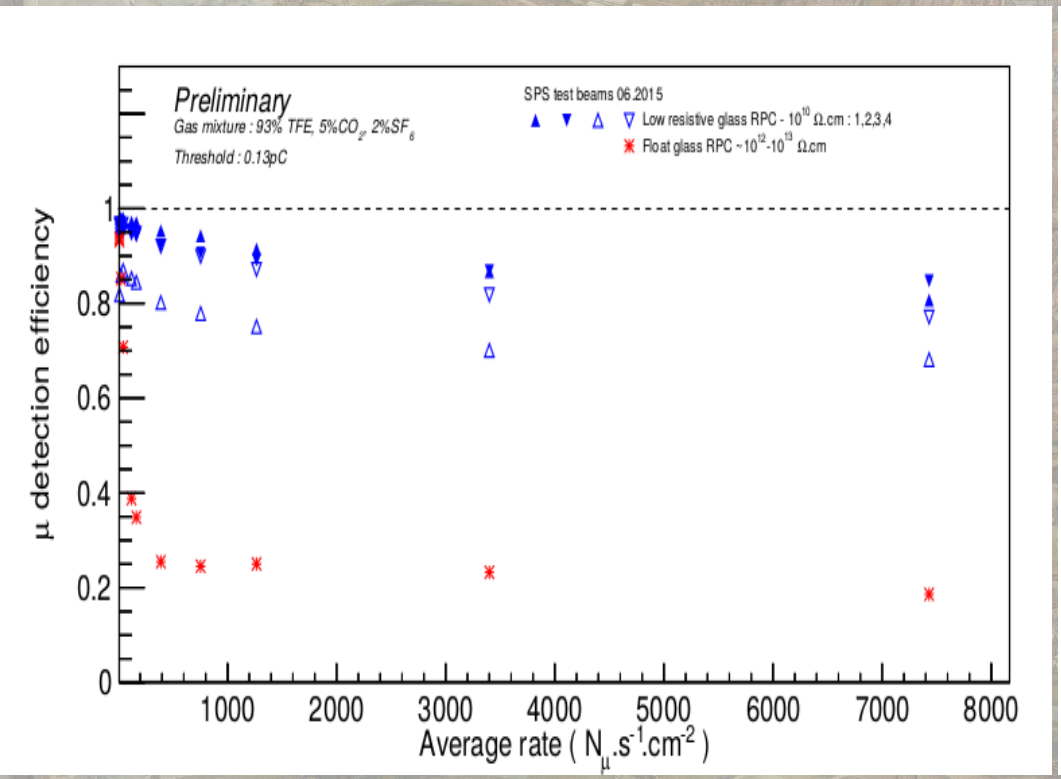


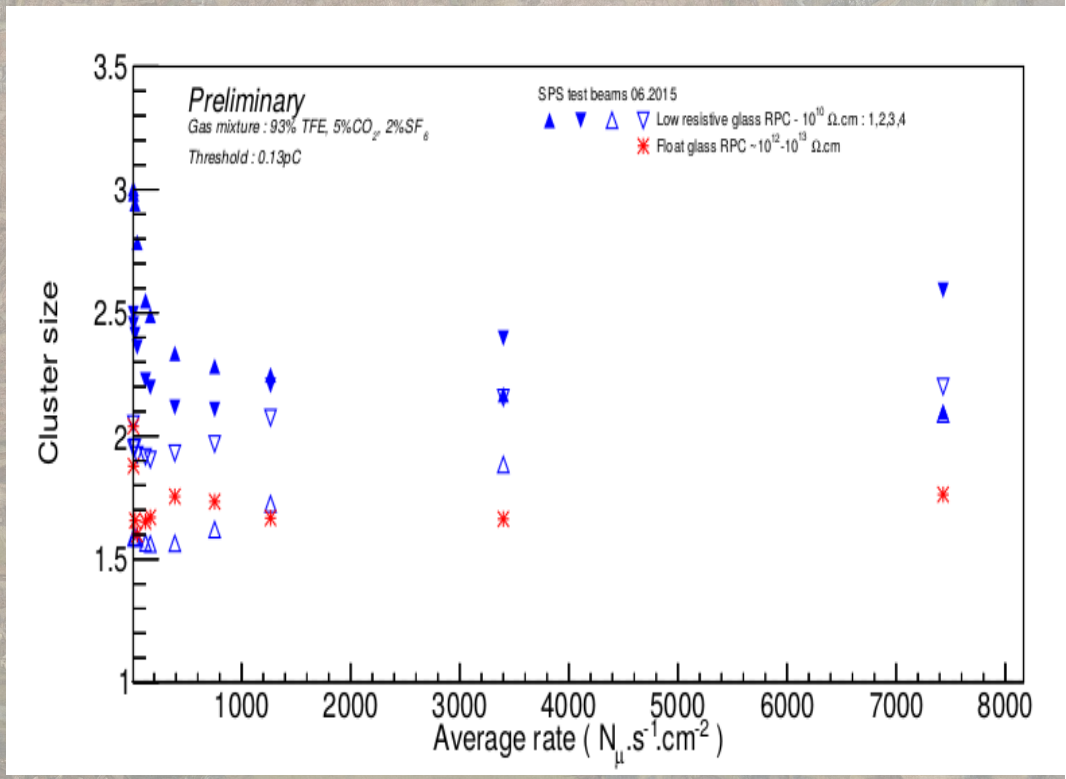
At 6900V : Efficency up to 95% and cluster size ~2,7 pads

SPS-H2 June 2015

Rate scan for all the detectors, rate provided by SPS counter and checked by the number of tracks in the GRPCs.

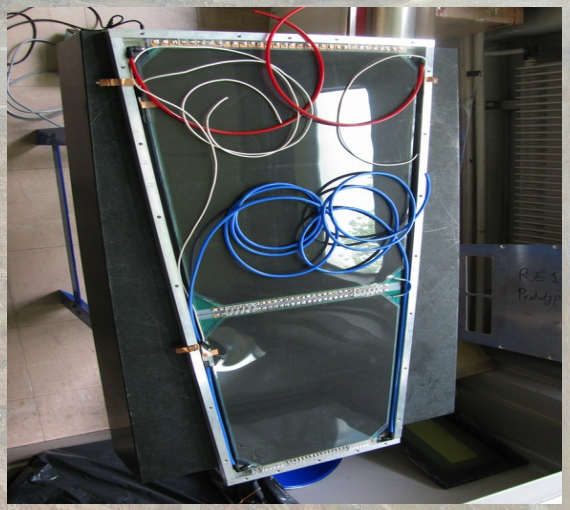
The chambers were studied in terms of efficiency and cluster size.





Large CMS single gap Glass RPC :

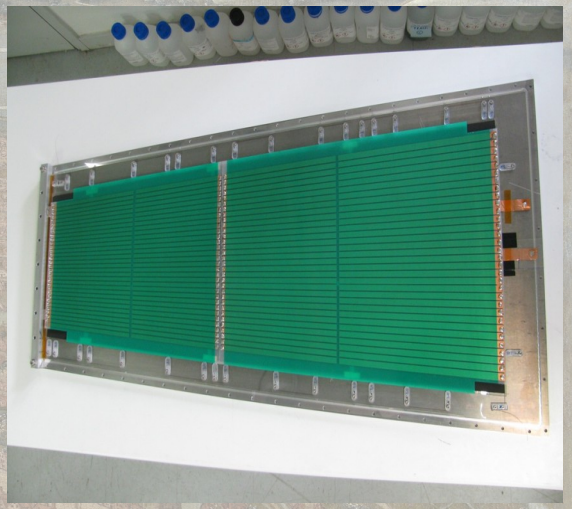
Gluing small pieces of glass, gluing zone < 100 µm. Half size of the RE4/1



HR2 is used to read out the strips

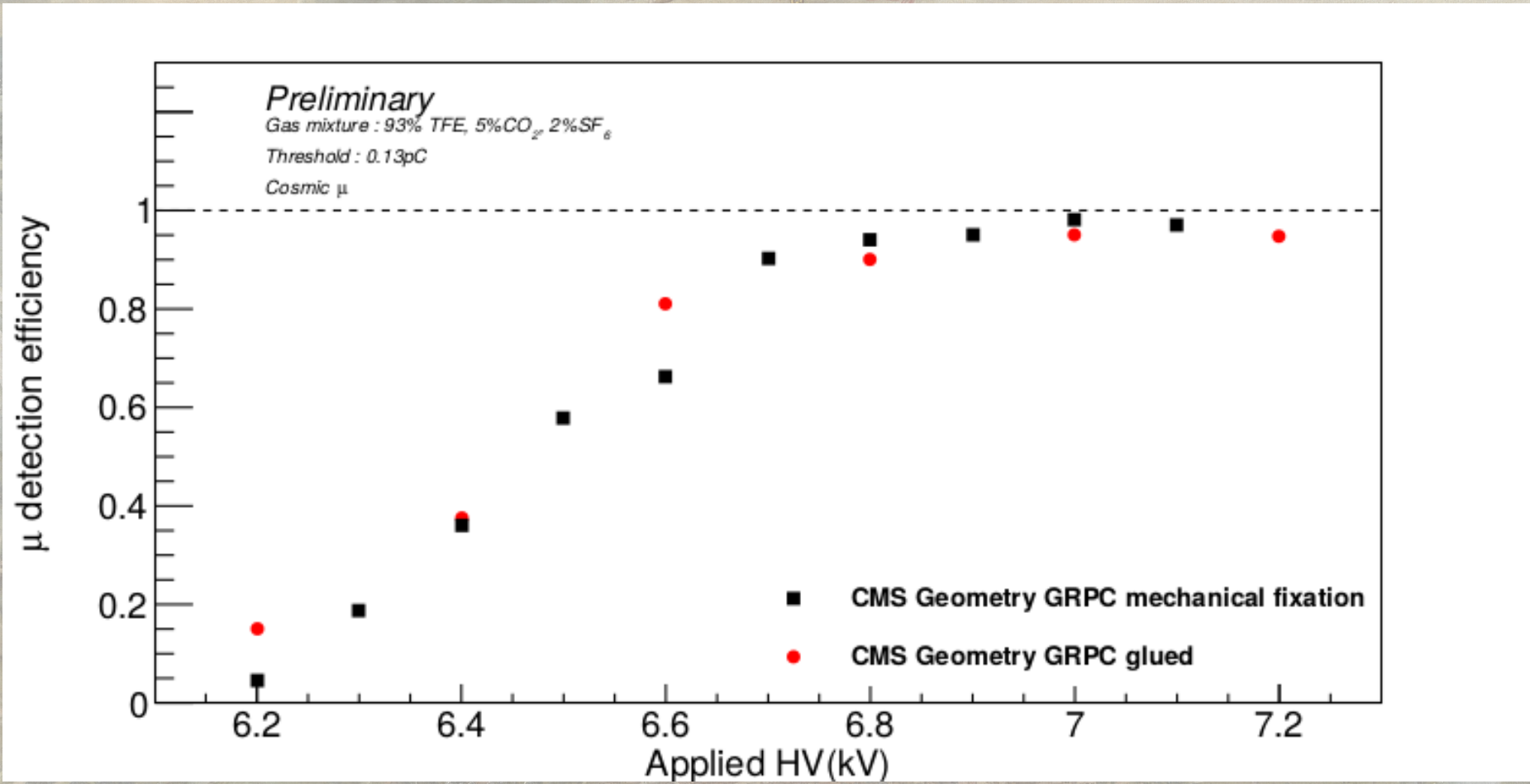
Large CMS single gap Glass RPC :

Mechanical fixation small pieces of glass, separation distance of few mm but up and down gaps are staggered . Gas tightness is ensured by the cassette



HR2 is used to read out the strips

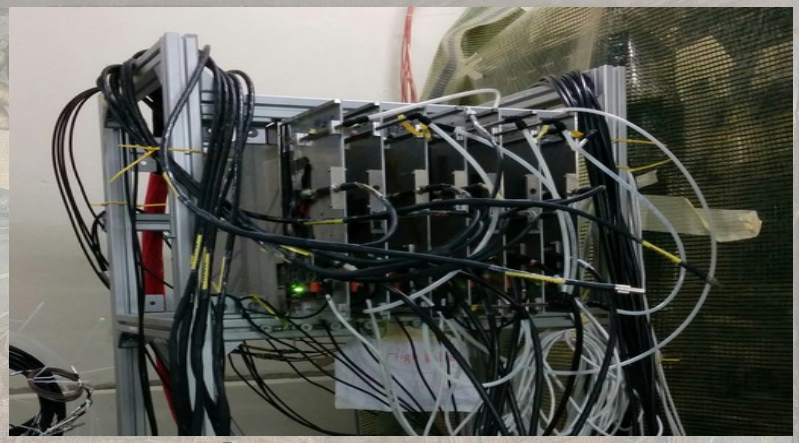
Efficiency comparison :



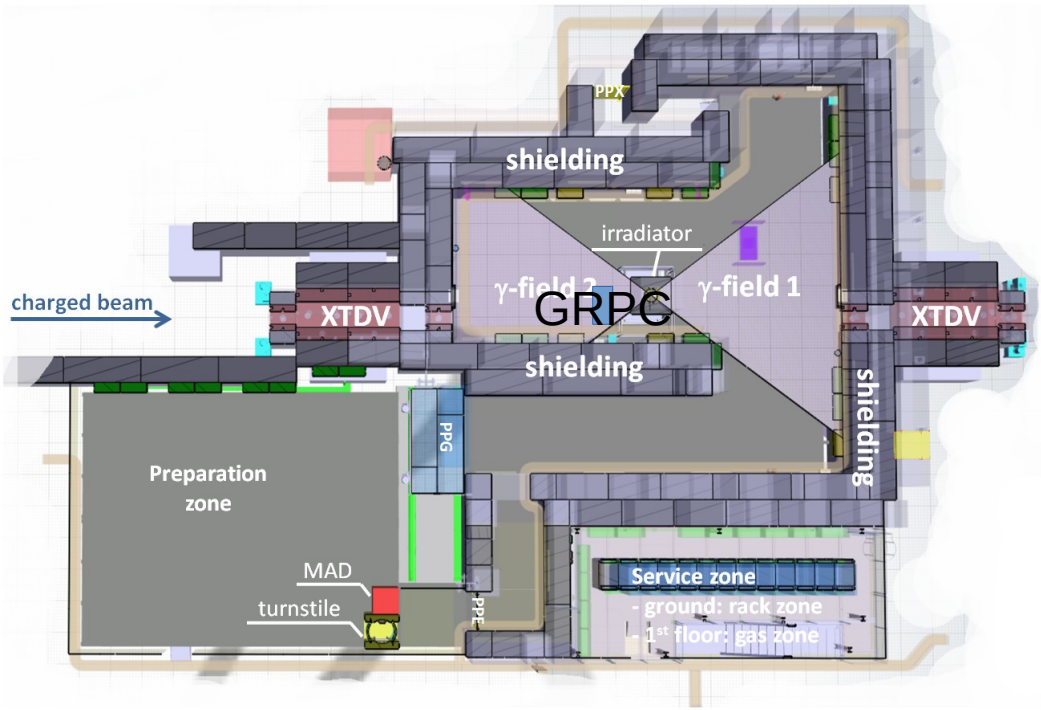
Both have identical behaviour and have efficiency up to 95%

GRPC at GIF++

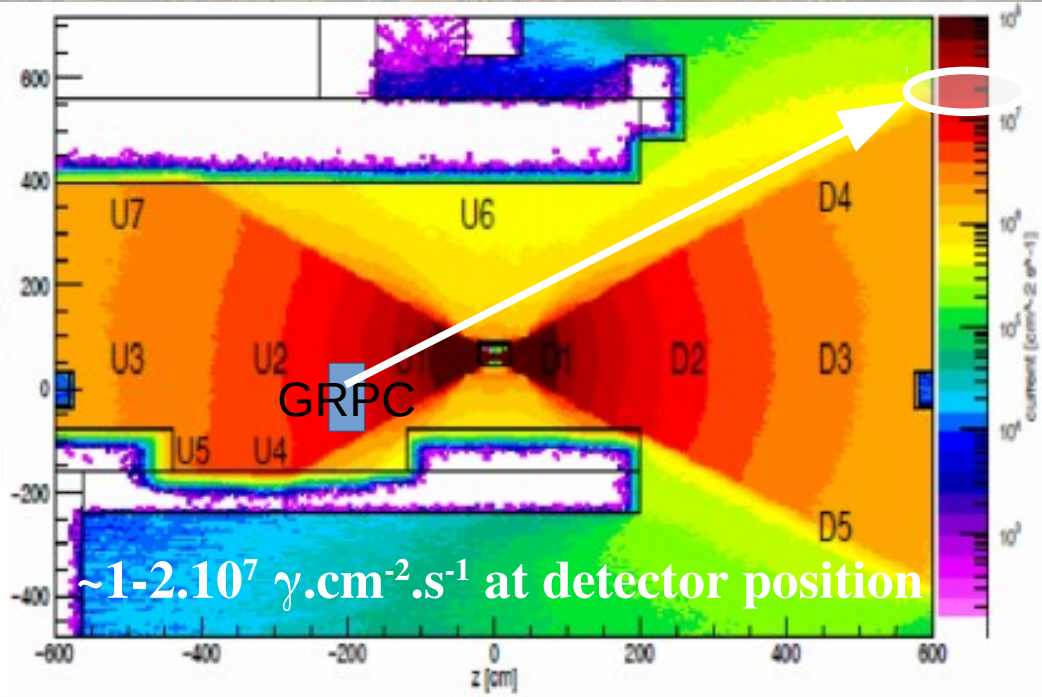
The Gamma Irradiation Facility (GIF++) characteristics :
- **μ particle beams (up to 100 GeV/c),**
- **10 TBq ^{137}Cesium source.**



→ Perform aging study of the detectors and accumulate doses equivalent to HL-LHC experimental conditions in a reasonable time.



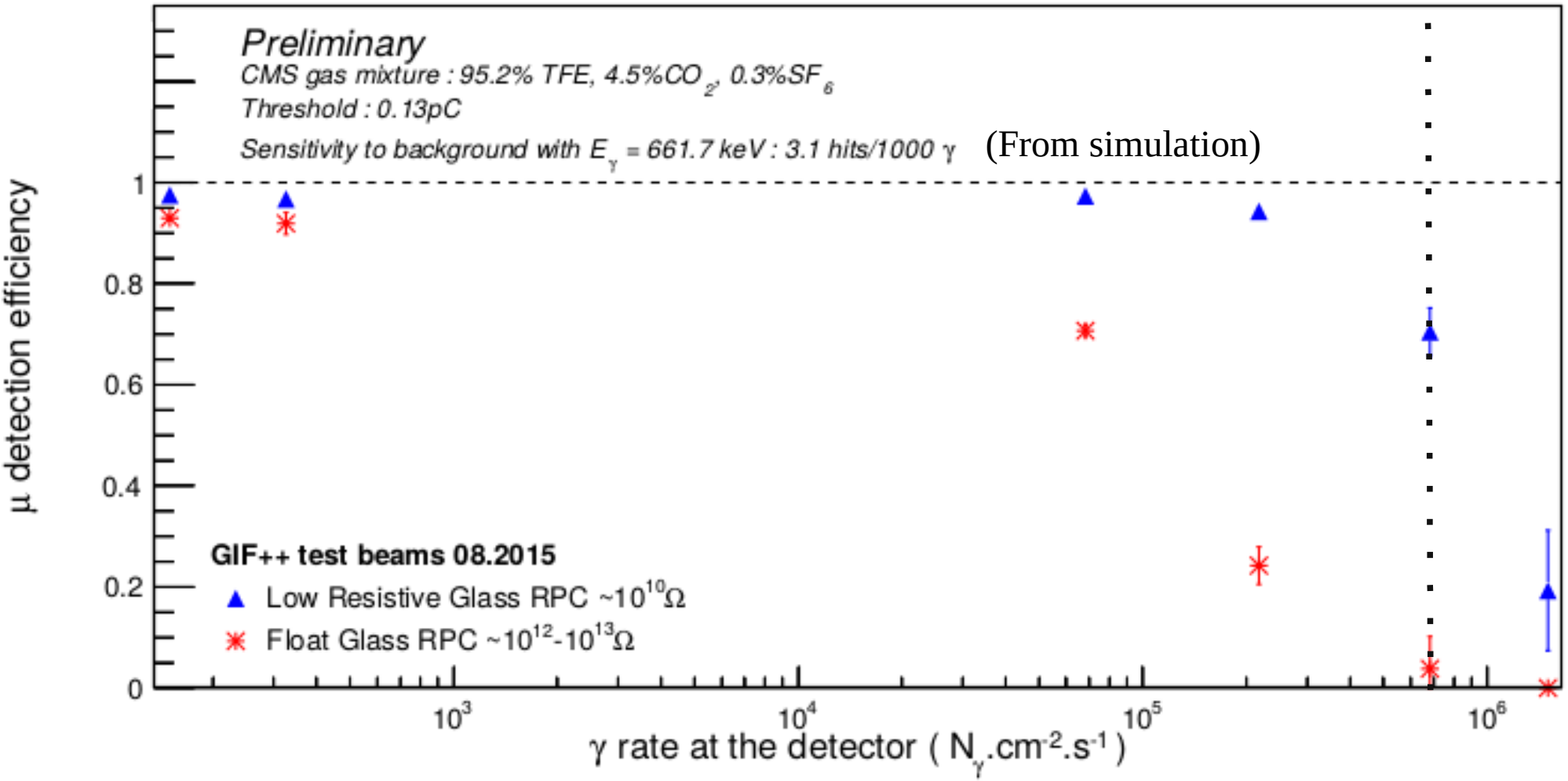
Scheme of the GIF++ installation



Map of the γ rate in the GIF++ installation

Single gap GRPC

γ Rate scan, for a Low Restivity GRPC and a Float GRPC



Electronics for Multi-gap CMS-GRPC

PETIROC ASIC :

- 32-channel,
- High bandwidth preamp (GBWP> 10 GHz),
- <3 mW/ch,
- Dual time and charge (160 fC-400 pC) measurement,
- Very fast and low-**jitter < 25 ps rms**

TDC :

- Developed by the Tsinghua university,
- 25 ps time resolution,
- 24 channels.

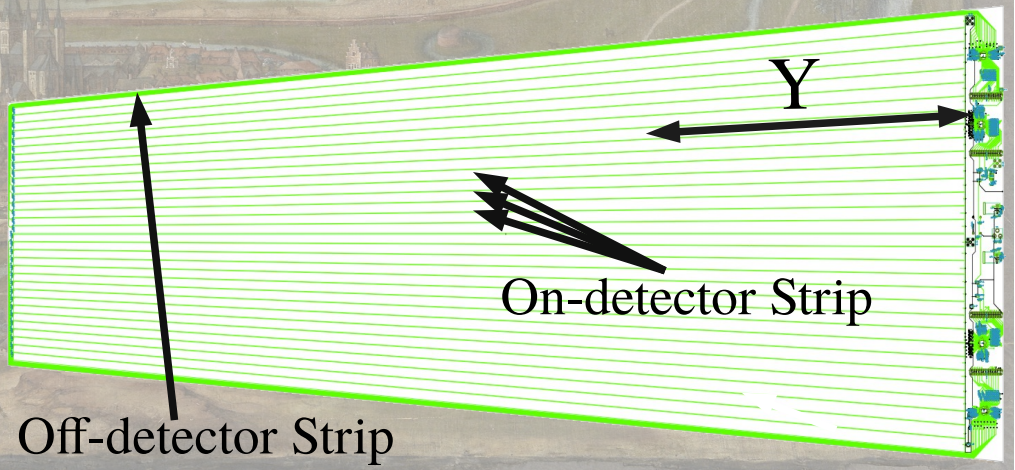
New PCB with pick-up strips read from both sides :

- Y-position determination :

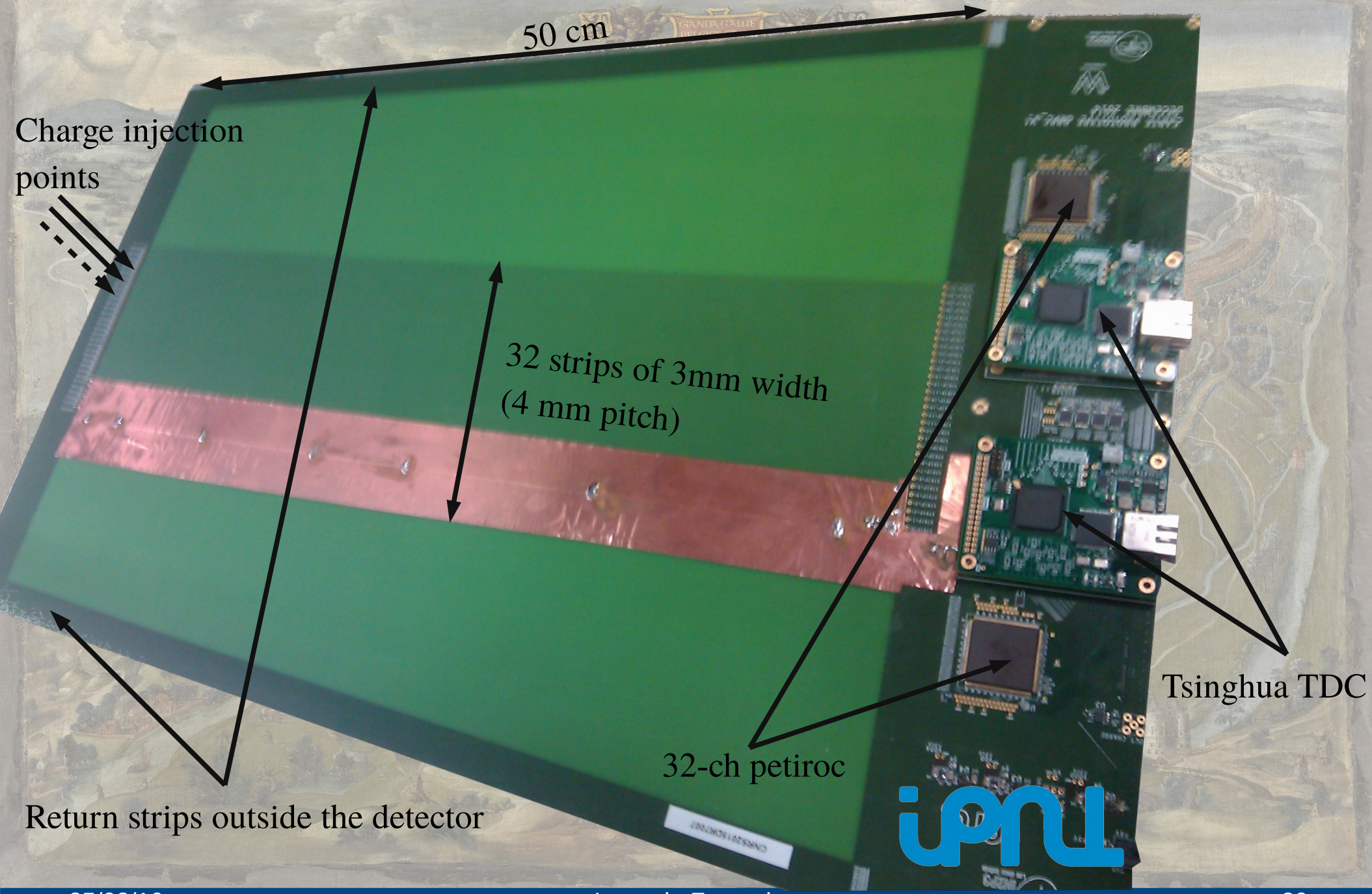
$$Y = L/2 - v*(t_2 - t_1)/2.$$

- Time resolution can be measured :

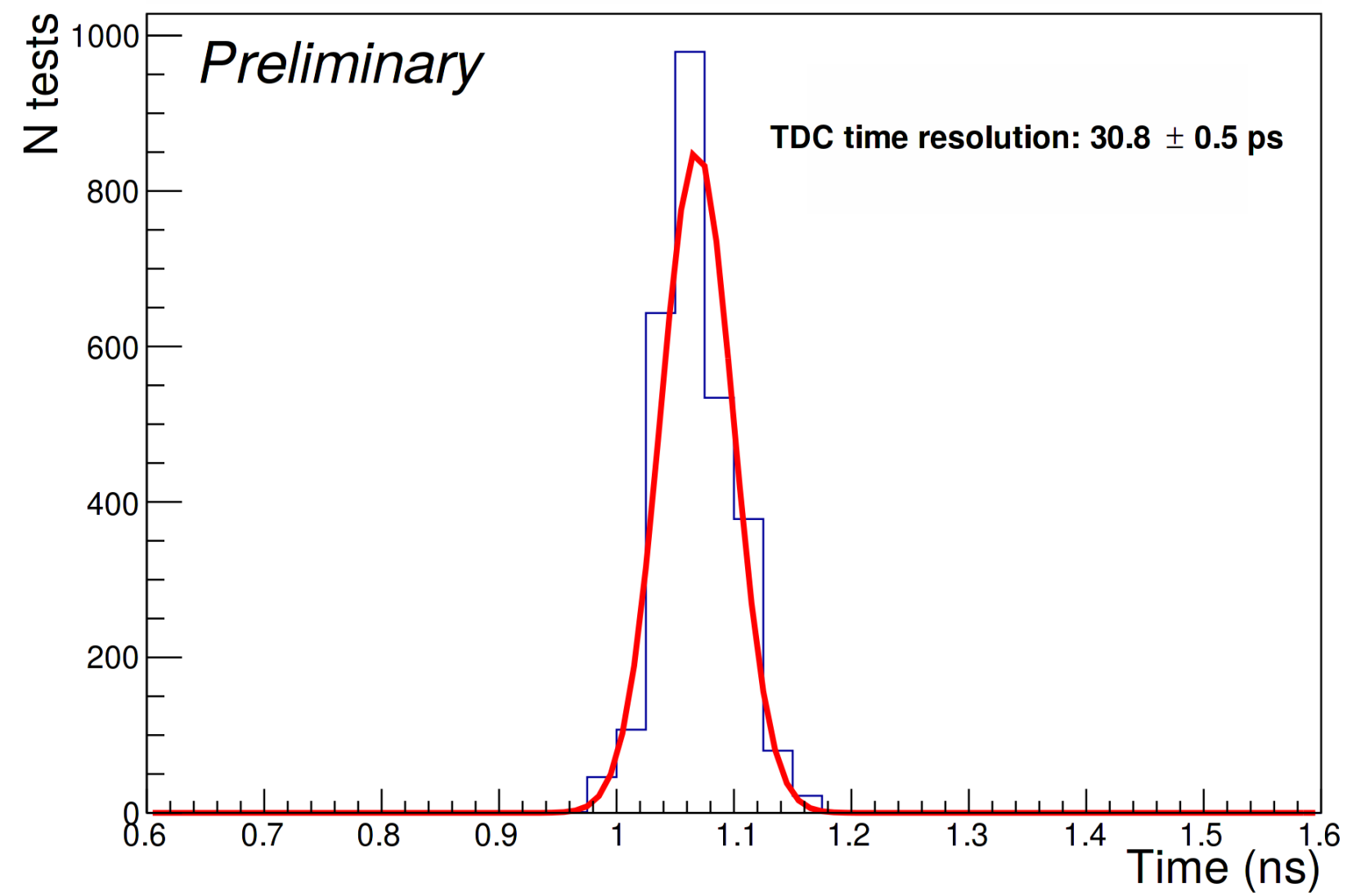
$$(t_1 + t_2) - L/v$$



Electronics for Multi-gap CMS-GRPC



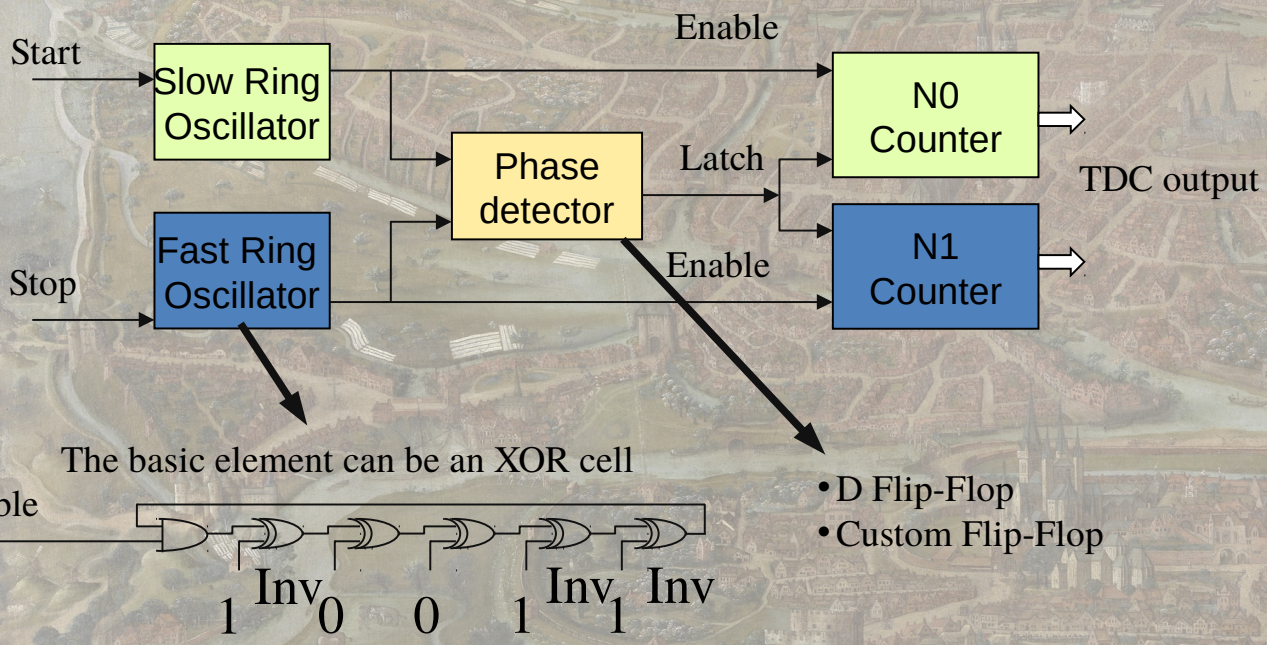
Injecting charge (**10 pC**) on test points and then recording **time difference $\Delta T=T_2-T_1$**

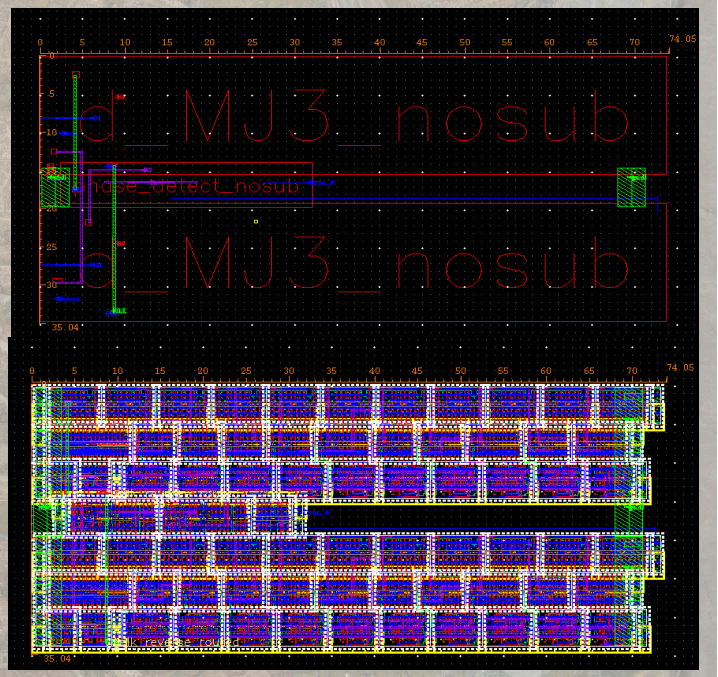


$\sigma_t \simeq$ 20-30 ps

To ensure an excellent timing measurement while **reducing, jitters, power consumption**, we proposed to **include the TDC in PETIROC**.

A **TDC based on the Vernier architecture** was successfully tested on FPGA (**10 ps RMS resolution over a range of 1 ns**).





130nm IBM MOSIS run : 3 TDC

Preliminary results give 64 ps time resolution for a dynamic range of 1 ns

Conclusion

-Using **low resistivity** material allows to reach high rate detection capability.

Building large detector using small glass plates was demonstrated using two methods:

- Gluing,
- Mechanical fixation/Mosaic.

For the 2- single gap (G)RPC :

HR2 is an adequate ASIC:

- Simple, easily built detector,
- It is low-noise, low-consumption, three thresholds (could be very helpful for space precision).

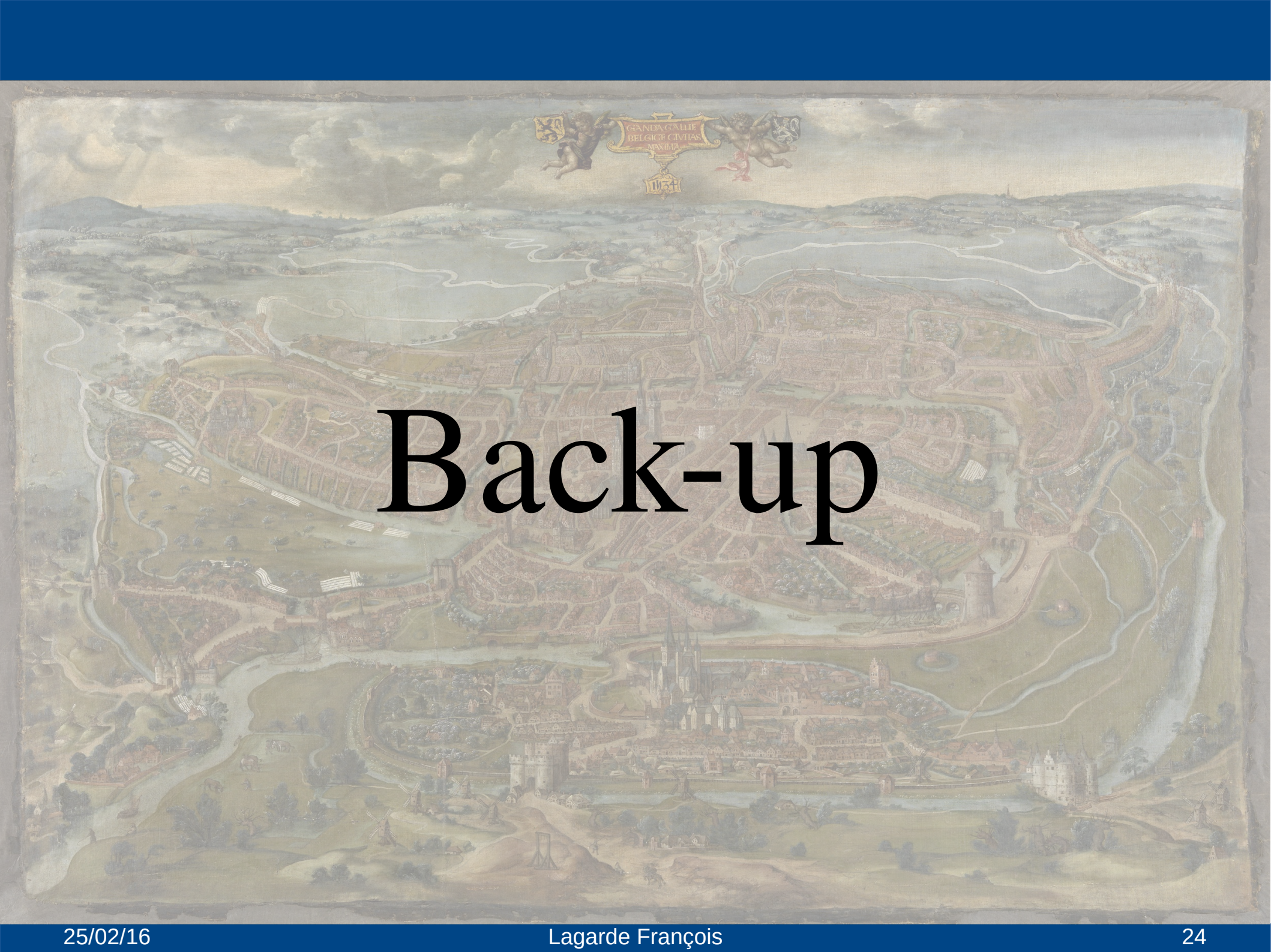
-Extensive tests on small and large GRPC have been performed.

For M(G)RPC scenario with timing:

PETIROC is an appropriate ASIC :

- It provides excellent charge and time measurement.
- Time related jitters < 20-25 ps.
- A TDC with 25 ps is available and was successfully tested in association with PETIROC on a large PCB.
- Development to include TDC/ch in PETIROC is ongoing.

We started to work on a CMS compatible DAQ system.



Back-up

Single gap GRPC