R&D for High Rate RPC detector for CMS

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RPC2018 : XIV Workshop on Resisitive Plate Chambers and Related Detectors, Puerto Vallarta,Jalisco State, MEXICO

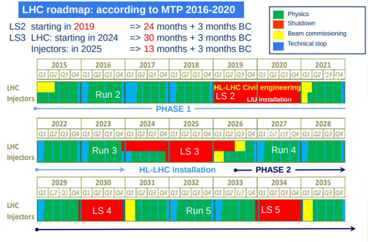
from  to 

High Luminosity LHC (2023-2035)

$\mathcal{L}_{HL-LHC} = (\times\ 3 \text{ to } 4)\mathcal{L}_{LHC}$

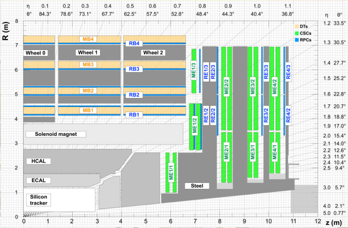
$\Rightarrow$ Higher particles fluxes.

$\Rightarrow$ CMS Muon Upgrade Project.



new forward muon detectors in the four stations

- *Gas Electron Multiplier*
- *improved RPC*



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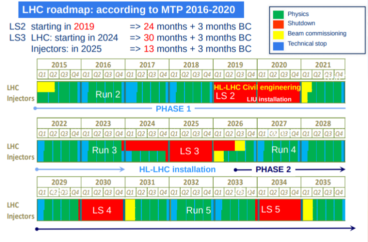
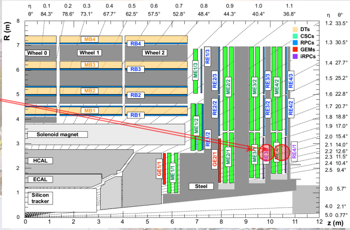
RE3/1 & RE4/1 Instrumentation (1.8<η<2.4)

- Background mitigation and better muon reconstruction
- Increase of the redundancy.





improved Resistive Plate Chambers

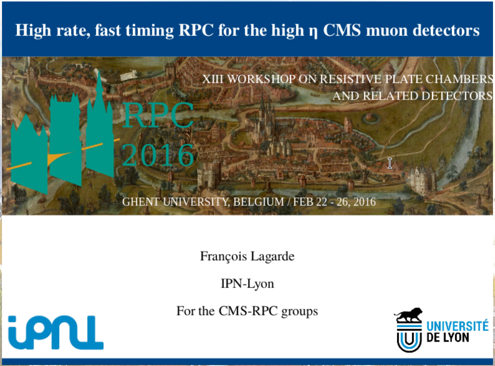
- To sustain the particle flux in the RE3/1 & RE4/1 regions : $\sim$700 Hz cm^{-2}
  $\Rightarrow$ Must be qualified for 2 kHz cm^{-2} ($\times$3 security factor).
  Reduce the produced charge and evacuate it faster.

Doped GRPC : one of the options considered in CMS TP

Combines all opportunities for improvement :

- Reduce the charge q created by the avalanch :
  Reduce the gas gap 2 mm $\rightarrow$ $\sim$1 mm.
- Reduce the electrode thickness d : 2 mm$\rightarrow$ 1 mm
- Reduce the electrode resistivity :
  Low Resistivity Glass (Tsinghua University) 1 to 5 $\times$ 10^{10} Ω cm.
- Fast electronics with low noise (Omega, IPNL).

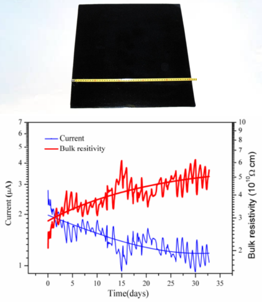
This R&D is the continuation of the one presented in RPC2016 : *High rate, fast timing RPC for the high η CMS muon detectors*



Proceeding : Here

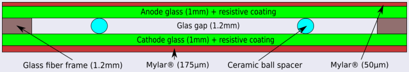
Characteristics

- Bulk resistivity : $10^{10}\ \Omega\,\mathrm{cm}$
- Thickness : 0.5 mm to 2 mm
- Thickness Uniformity : 0.02 mm
- Roughness : <10 nm
- Ohmic behavior : stable ($1\,\mathrm{C\,cm^{-2}}$)
- Maximal sizes : 32 cm × 30 cm



Single Gap Chamber

- Electrode Thickness 1 mm
- Gas gap 1.2 mm



Electronics

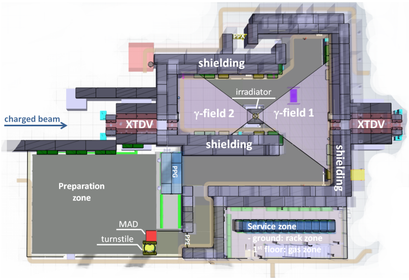
- HARDROC2 (64 channels)
- 3 thresholds
- Dynamical range : 10 fC-15 pC
- 1 cm × 1 cm Pads

GIF++

- Installed on the H4 line (SPS).
- muon beam 100 GeV
- Radioactive source : ^{137}Cs (13 TBq)

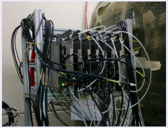
The Radioactive source

- γ 661.7 keV
- 2 independant attenuators : 3 planes of 3 filters $\Rightarrow$(Attenuator factor 1–46000)
- Angular corrector filter : uniformity of the flux along the xy plane



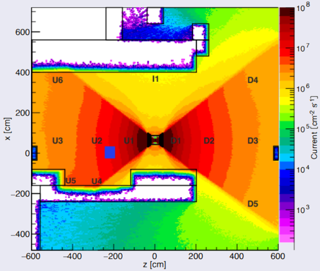
The telescope

- 3 *float glass*/4 low resitivity
- $\sim$2 m from the source



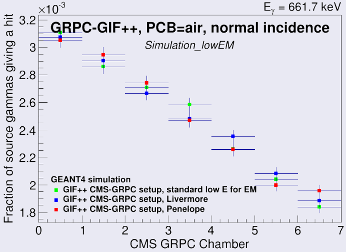
Gamma flux at GIF++

Gamma Flux : $1,5.10^{7}\gamma cm^{-2}s^{-1}$



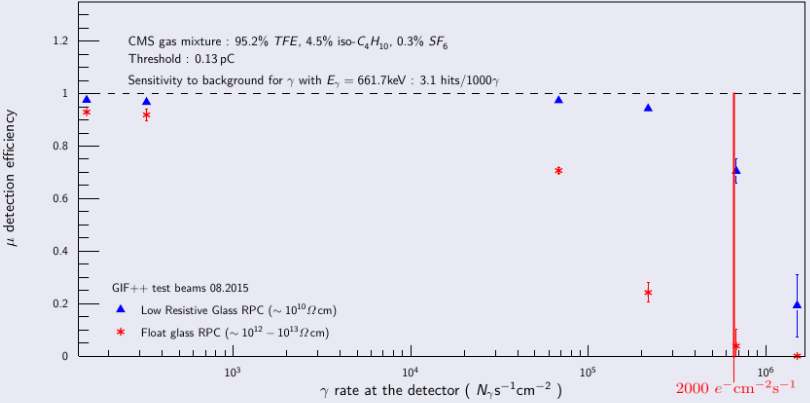
Conversion factor γ/e^{-}

GEANT4 simulation with "float glass".



$\Rightarrow$ 46500 $e^{-}cm^{-2}s^{-1}$

Efficiency vs γ flux (Single Gap)

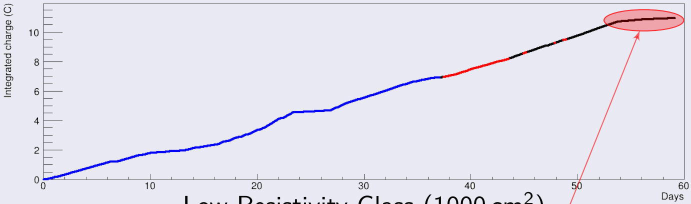


Efficiency is better than 70% for a flux of $\sim$2 kHz cm^{-2}

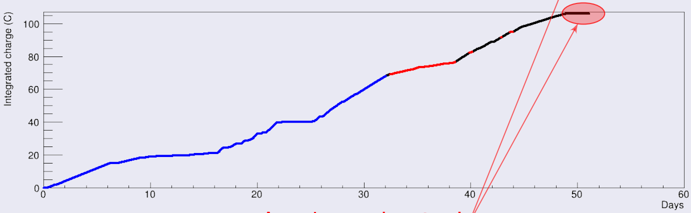
Chambers must sustain an integrated charge of $\sim 1\,\mathrm{C\,cm^{-2}}$.

Integrated charge Vs effective days

Float glass ($1000\,\mathrm{cm^2}$)

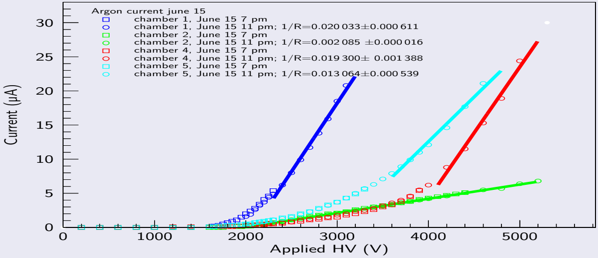


Low Resistivity Glass ($1000\,\mathrm{cm^2}$)



Accelerated aging!

Resistivity measurement with Argon



Resistivity estimation

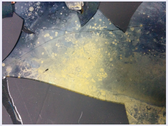
$$\rho = \frac{RS}{e}$$

R : electrode Resistivity
S : surface of the electrodes
e : electrode thicknesses.

Low Resistivity 1	$2.4 \times 10^{11}\ \Omega\,\mathrm{cm}$
Float Glass	$3.60 \times 10^{12}\ \Omega\,\mathrm{cm}$
Low Resistivity 4	$2.49 \times 10^{11}\ \Omega\,\mathrm{cm}$
Low Resistivity 5	$3.94 \times 10^{11}\ \Omega\,\mathrm{cm}$

Resistivity is much higher than expected $\sim 1 \times 10^{10}\ \Omega\,\mathrm{cm}$ to $5 \times 10^{10}\ \Omega\,\mathrm{cm}$. Resistivity mesurement in laboratory on bare electrode increased by $\sim \times 2$ after $1\,\mathrm{C\,cm^{-2}}$

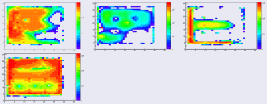
Inside of one chamber



- no more spacers !
- some deposits

Could explain :

- High Resistivity
- The hit distributions

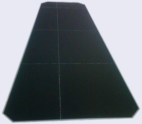


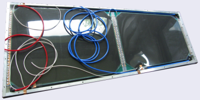
Possible Causes

- Humidity contamination (droplets observed)
  $\Rightarrow$ switch from plastic to copper pipes
- Isobutane polymerisation
  $\Rightarrow$ deposits
- hydrofluoric acid attacks
  $\Rightarrow$ fluorosilicic acid deposit (H_2SiF_6)

Low Resistivity Glass have limited size : $32\,\text{cm} \times 30\,\text{cm}$
$\Rightarrow$ Build bigger size Chambers ($1.1\,\text{m} \times 60\,\text{cm}$)

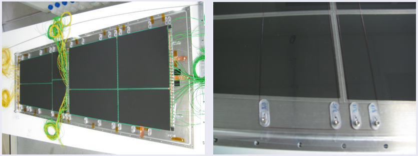
Gluing Method

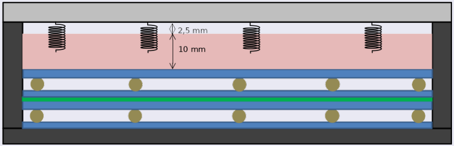




Hermetic gaps.

Mechanical Fixing Method

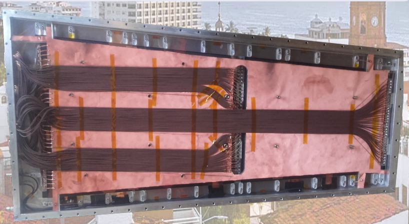




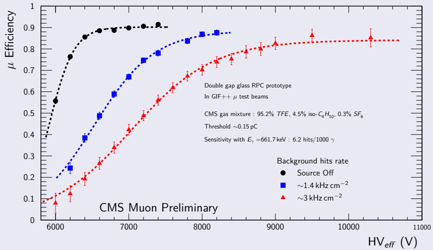
The cassette is hermetical.

Setup

- mechanical fixation
- Double gap
- CMS electronics, strip pitch : $\sim 1\,\mathrm{cm}$
- DAQ from CMS at GIF++

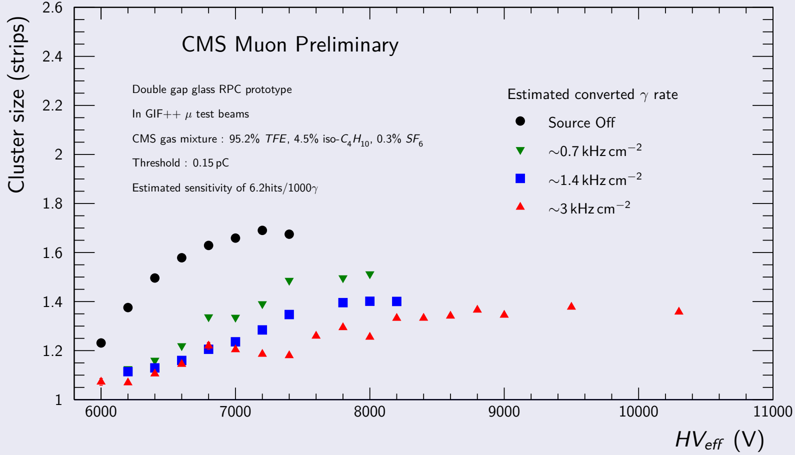


Efficiency Vs HV



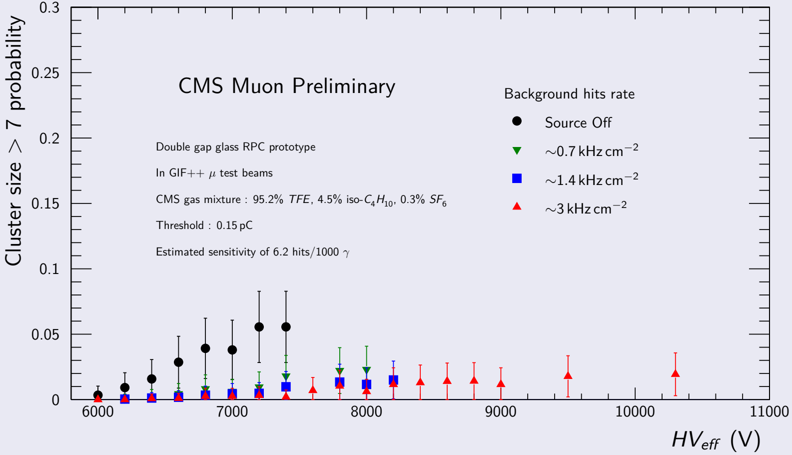
$\sim$5% of the inefficiency is coming from geometrical acceptance.

Cluster Size Vs HV

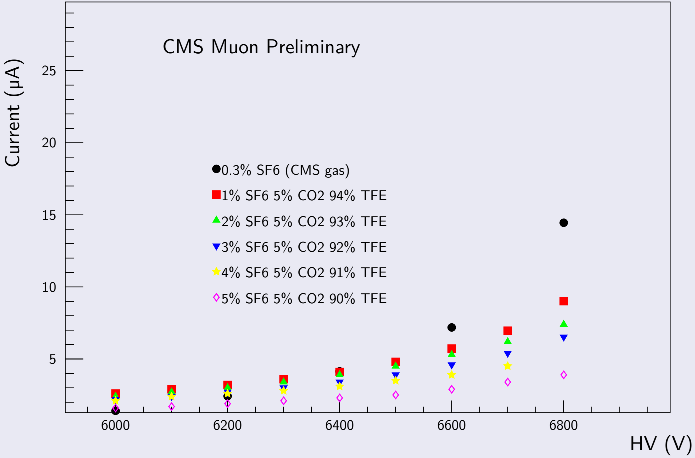


Streamer probability

Probability that cluster size > 7.



Large size prototype current vs % SF_6



Conclusion

- First R&D with doped glass for CMS.
- Low Resistivity glass sustain the expected RE3/1 et RE4/1 fluxes.
- Big Chamber can be build with $32\times30\,\mathrm{cm}^2$ glass (2 methods).
- The percent of SF_6 seems determinant for the noise reduction.

Final Statements

- If one wants to make double gap detectors with doped glass electrodes and low level of SF6 more R&D is required.
- Double gap Backelite detector with thin electrodes was proven to fulfill the Scope statements. Therefore, this technology was retained as baseline for the CMS Muon TDR.
- Multi-gap doped glass RPC detector shows good results with CMS gas. See Yancheng Yu talk : *Performance of a real-size Mosaic MRPC developed for CMS upgrade*