Interview for Chung-Yao Chao Fellowship 2018

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Shanghai Jiao Tong University

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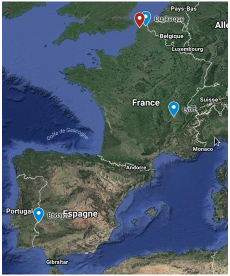
Curriculum Vitæ in a nutshell

2008-2012 : Bachelor of Physics (FRANCE + 1 year in SPAIN).
2012-2014 : Master in Subatomic Physics, *Lyon*.
2014-2017 : PhD in Particle Physics, *Lyon* :
Characterization of Resistive Plate Chambers Detectors of Low Resistivity Glass for the Upgrade of CMS.
2017-2018 : Research and Teaching Assistant, *Lyon*.



Presentations and Publications

Talks :

- Talk on R&D at RPC2016 (Ghent,BELGIUM) on behalf of CMS.
- Talk on R&D at RPC2018 (Mexico city, Mexico) on behalf of CMS.
- Invited talk (Puebla,Mexico) Feb.2018

Publications :

- Proceeding of the 13th Workshop on Resistive Plate Chambers and Related Detectors (RPC2016) : High Rate, Fast Timing Glass RPC for the High η CMS Muon Detectors ,*Journal of Instrumentation, Vol. 11*
- Proceedings of the Vienna Conference on Instrumentation 2016 : High Rate, Fast Timing Glass RPC for the High η CMS Muon Detectors, *Nuclear Instruments and Methods in Physics Research Section A, Vol 845*
- Technical Design Report : The Phase-2 Upgrade of the CMS Muon Detectors.
- Posters at IEEE 2016, Vienna Conference of Instrumentation 2016.
- Search for Two Higgs Bosons in Final States Containing Two Photons and Two Bottom Quarks in Proton-Proton Collisions at 8 TeV, *Phys. Rev. D*

High Luminosity LHC (2023-2035)

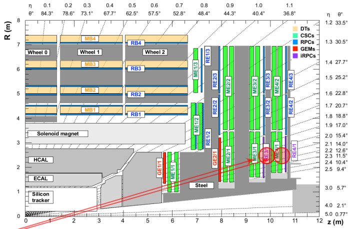
$\mathcal{L}_{HL-LHC} = (\times \text{ 3 to 4})\mathcal{L}_{LHC}$

⇒ Higher particles fluxes.

⇒ CMS Muon Upgrade Project.

New forward muon detectors in the four stations

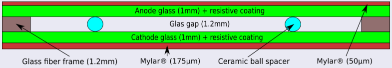
- *Gas Electron Multiplier.*
- *improved Resistive Plate Chamber.*



RE3/1 & RE4/1 Instrumentation ($1.8<\eta<2.4$)

- Background mitigation and improved muon reconstruction.
- Increase the redundancy.

CALICE ILD SDHCAL Design (Single gap)



Current CMS RPC (Double gap)

improved Resistive Plate Chambers

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

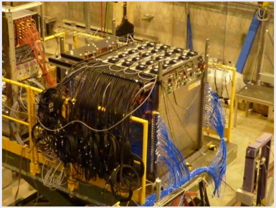
Doped Glass-RPC : one of the options considered in CMS

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

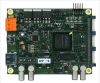
SDHCAL RPC with doped glass electrodes

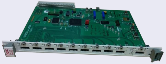
Transfer of the SDHCAL technology to test the Doped Glass RPC

- SDHCAL Electronics : HARDROC2B.



- Same Read-out : $1\,\text{cm} \times 1\,\text{cm}$ Pads.
- SDHCAL DAQ : DIF, SDCC.



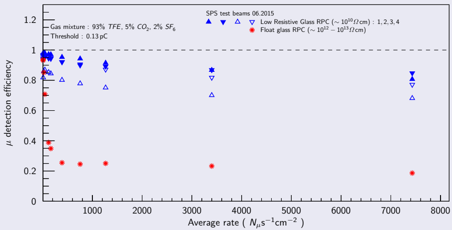


- ILC Data Format (LCIO).

I was heavy involved in beam tests at CERN (PS, SPS, GIF++) to compare the efficiency of the Low Resistivity GRPC with respect to the "float glass" RPC :

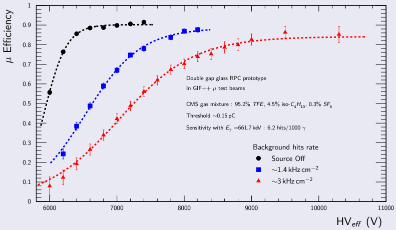
- Hardware installation
- Beam test shift
- Run coordination
- Analysis software development
- Production of analysis results

Efficiency vs muon flux at SPS (SDHCAL electronics, Single Gap)



Efficiency $\gg 70\% \Rightarrow \gg 90\%$ for double gap.

Efficiency vs HV at GIF++ (CMS electronics, Double Gap)



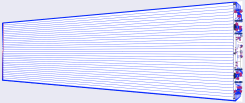
$\Rightarrow$ Reaches CMS specification.

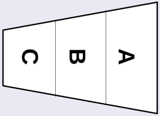
New electronics : use timing to improve spatial resolution.

The new electronics

- Goal : time resolution $< 100\,\text{ps}$.
- No η segmentation (A,B,C).
- Reading from both side to measure the position along the strip.

$$Y = \frac{L}{2} - \frac{v(T_2 - T_1)}{2} \tag{1}$$

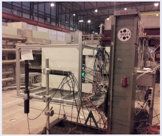




Bonus : Time of flight !

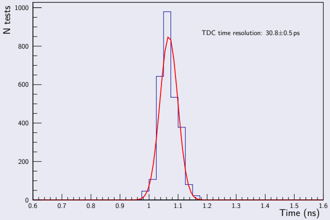
CMS RPC prototype with new electronics

- Gas gap : 1.4 mm
- Bakelite electrodes : 1.4 mm.
- 32 strips, 50 cm long,4 mm pitch

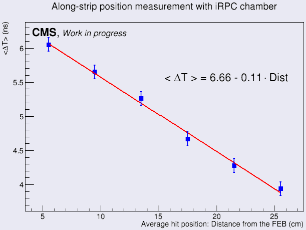


Time resolution of the PCB

- $\frac{\sigma_{T_1+T_2}}{\sqrt{2}} = \sigma_{elec} = 30.8 \pm 0.5 \text{ps}.$



Spatial Resolution (all the detector)



$$\sigma_Y = \sigma_{T_2 - T_1} \frac{v}{2} \approx 1.8\,\text{cm}$$

⇒ Improves by a factor 15 CMS RPC best spatial resolution.

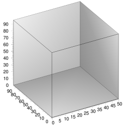
Summary

- Participation at 8 beam tests at CERN, managed 3 of them.
- Participation in the installation, data-taking and data analysis.
- Talks on R&D at RPC2016 (Ghent,BELGIUM) and RPC2018 (Mexico city, Mexico) on behalf of CMS.
- I worked with SDHCAL, CMS RPC electronics.
- I have tested the iRPC electronics. It is selected as baseline in the CMS Muon Detector TDR.

Starting my Post-doc on May 2018 at Shanghai Jiao Tong University

- ATLAS Phase-2 Upgrade :
  Strong collaboration with University of Science and Technology of China (USTC) and Shangdong University (SDU).
- Circular Electron Positron Collider (CEPC).

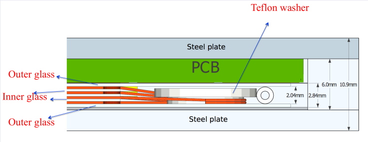
Study impact of improved time resolution on particle flow algorithms for SDHCAL ⇒Could follow particles in the shower layer by layer.

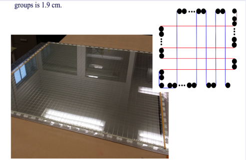


Timing could be an important factor to separate showers, better reconstruct their energy and separate them from background and noise. ⇒Need to go to Multi-Gap RPC

Multi-gap RPC

Excellent fast timing detectors. Several were designed and built (Korea). Excellent efficiency when tested with HARDROC ASICs (SDHCAL electronics).





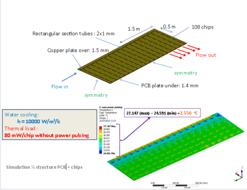
Next step : use PETIROC (< 20 ps time jitters) to single out neutron contributions.

SDHCAL prototype uses power pulsing to reduce power consumption and avoid the use of a cooling system.

The power pulsing is unusable for CEPC, so the power consumption of the electronics must be reduced or a cooling system must be installed.

Water cooling inside the absorber layers

Simulation was performed to see the feasibility of inserting a cooling system inside the absorber layers of the SDHCAL.



Next step : Study the effects of such cooling system on the energy resolution, efficiency and multiplicity etc.

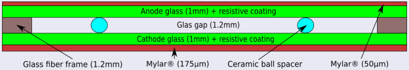
BACKUP...

Doped Glass Characteristics

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

Single Gap Chamber

- Electrode Thickness 1 mm
- Gas gap 1.2 mm



Transfert of the SDHCAL technology to test the Doped Glass RPC

- SDHCAL Electronics : HARDROC2B
- SDHCAL Read-out : 1 cm × 1 cm Pads.
- SDHCAL DAQ : DIF, SDCC.
- ILC Data Format (LCIO).

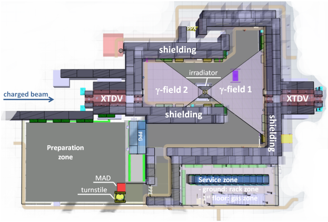
Rate sustainability on large surface

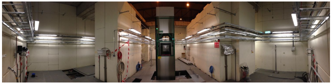
Gamma Irradiation Facility (GIF++)

- Installed on the H4 line (SPS).
- Muon beam 100 GeV.
- Radioactive source : ^{137}Cs (13 TBq).
- Test detector efficiency in radiative environment.

The Radioactive source

- γ 661.7 keV
- 3 planes of 3 filters (Attenuator factor 1–46000)
- Uniform γ flux along the xy plane.

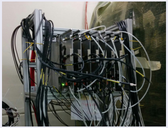




Tested up to HL-HLC expected background rate and higher

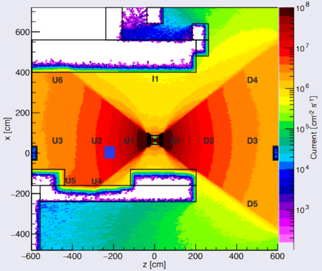
Installed telescope

- 3 *float glass*/4 low resitivity
- ∼2 m from the source



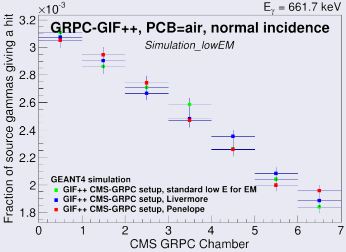
Gamma flux at GIF++

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



Conversion factor γ/e^-

GEANT4 simulation with "float glass".



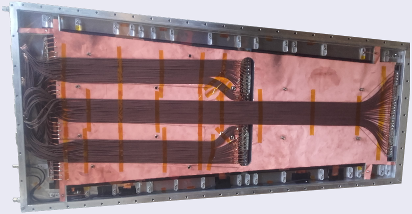
$\Rightarrow 46500\ e^- cm^{-2} s^{-1}$

- Low Resistivity Glass manufacturing are size limited : 32 cm × 30 cm.
- CMS sizes are much bigger.

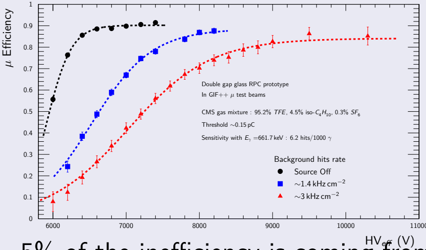
⇒ Build bigger size chamber prototypes : 1.1 m × 60 cm with the actual CMS RPC electronics (Double gap, strips ∼ 1 cm)

Setup

- Mechanical fixation.



Efficiency Vs HV at GIF++

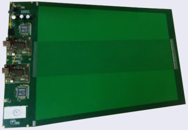


∼5% of the inefficiency is coming from geometrical acceptance.

Reaches CMS efficiency specification even at 3 kHz cm^{-2} but at high HV.

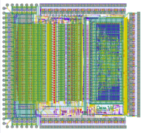
Prototype of the new electronics

- 50 cm long
- 32 strips, 4 mm pitch

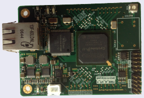


Electronics

- 2 PETIROC (32 entries each).



- 2 TDC (24 entries each).



Time resolution of the PCB

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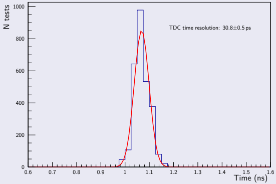
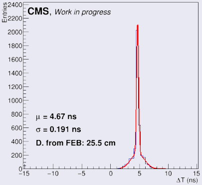


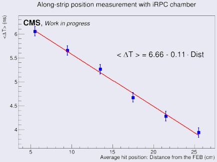
CMS RPC prototype with new electronics

- Gas gap : 1.4 mm
- Bakelite electrodes : 1.4 mm.

Arrival time difference (T2-T1)



Spatial Resolution



$$v = 2\frac{\mathrm{d}Y}{\mathrm{d}\langle\Delta T\rangle} = 2 * \frac{1}{0.11} = 18.18\,\mathrm{cm\,ns^{-1}} => \sigma_Y = \sigma_{T_2 - T_1}\frac{v}{2} \approx 1.8\,\mathrm{cm}$$