Brazilian Participation on the Resistive Plate Chambers (RPC) upgrade project of the CMS Muon System

Sandro Fonseca de Souza
On behalf of CMS UERJ-Rio group

COVID effect

- We have now been working for more than a year under Covid-19 restrictions.
- The situation is easing in Europe and US but stays dramatic in other regions of the World where many members of the big CMS family live. Brazil is one of them. The personal and social tolls are immense.
- We look forward hoping that that the vaccination campaigns will be effective and will lead all of us out of this emergency.

- In CMS we are continuously monitoring the effect on our activities.
- The dedication and expertise of our community allowed to keep the delays to a minimum:
  - between 3 to 8 months delays in LS2 and Upgrades activities, respectively
  - the current paper production rate and the physics publications planning is sustained
  - many colleagues "keep up" with overtime work and increasing stress level
  - others with less favourable social conditions are severely affected

  This is a risk we cannot accept and with long term consequences


RE-organisation of the CMS control room at P5

Outline

- CMS RPC UERJ Rio group
  - CMS Muon System:Present Status
- Upgrade of the CMS Muon system in preparation of HL-LHC
  - CMS Upgrade towards HL-LHC
    - RPC Upgrade Phase II
    - Brazilian Participation on the CMS-RPC project
      - LS2 activities
      - RPC Upgrade Phase II
    - Estimated costs
    - Summary and conclusions

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CMS-RPC-UERJ-Rio group

- **Faculties:**
  - **Sandro Fonseca de Souza (UERJ)**
  - **Alberto Santoro (UERJ)**
  - **Felipe Silva (UEA)**
  - **Dilson de Jesus Damião (UERJ)**
  - **Eliza Melo da Costa (UERJ)**
  - **Helio Nogima (UERJ)**
- **Postdocs**
  - **Maurício Thiel (UERJ)**
- **PhD. Students:**
  - **Mapse Barroso and Kevin Mota (UERJ)**

- **External collaborators:**
  - Gabriella Pugliesi (Bari)
  - Salvatore Buontempo (Naples)
  - Roumyana Mileva (Bulgaria)
  - Mehar Ali Shah (Pakistan)
  - Andres Cabrera (Colombia)
  - Michael Tytgat (Ghent)
  - Davide Piccolo (Frascati)

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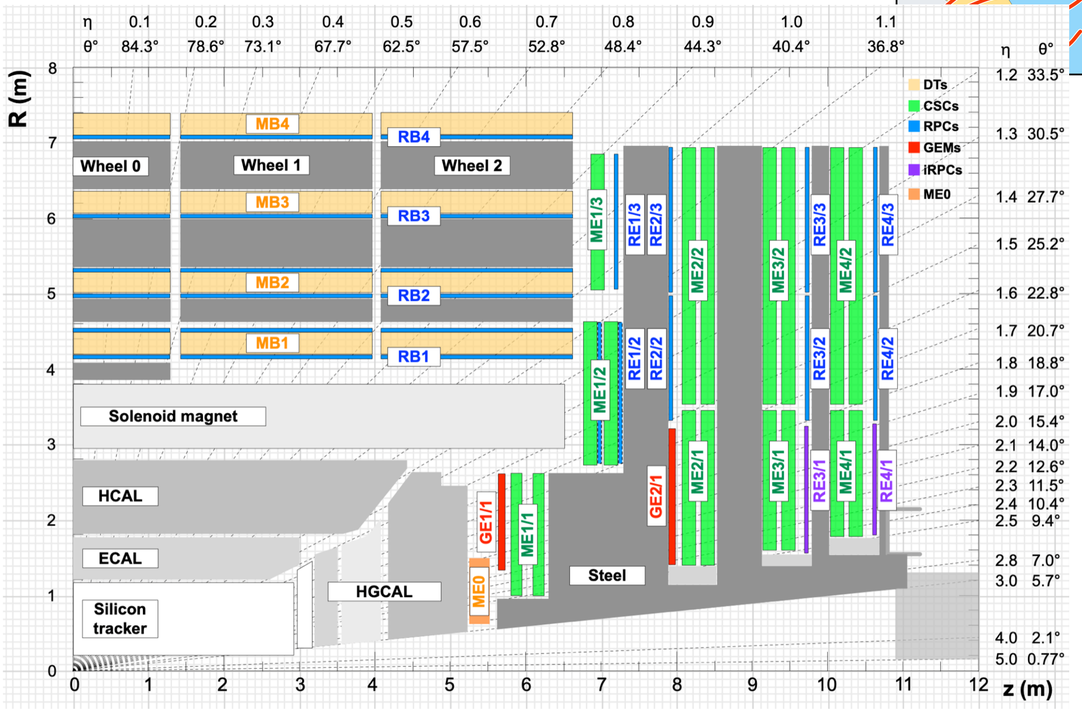
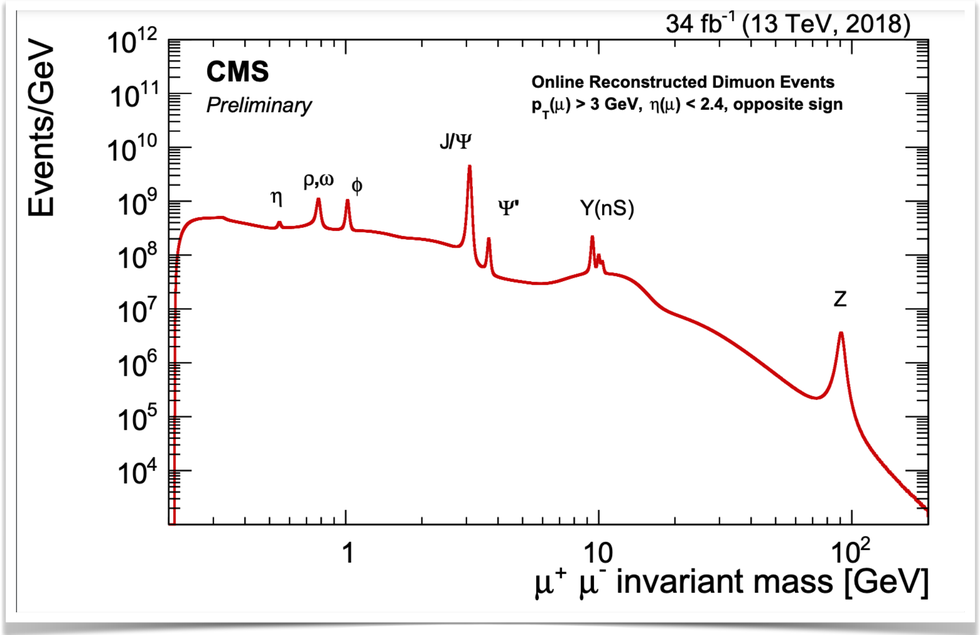
CMS Muon System

- Muons are present as final state in many Standard Model and Beyond Standard Model (BSM) processes.
- They are long-lived particles and have very small interaction with matter. Therefore, they are not stopped at the ECAL as electrons.
- The CMS Muon system uses gaseous detector technologies to make precise identification and measurement of muons properties in addition to triggering and charge identification.





Up to Run 2 there were three different technologies in the CMS Muon System:

- **DT:** Drift Tubes; $|\eta| < 0.8$
- **CSC:** Cathode Strip Chambers; $0.8 < |\eta| < 2.4$
- **RPC:** Resistive Plate Chambers; $|\eta| < 1.9$

The upgrade in the muon system will add new **GEMs** (Gas Electron Multiplier) and **iRPCs** in the higher η region.

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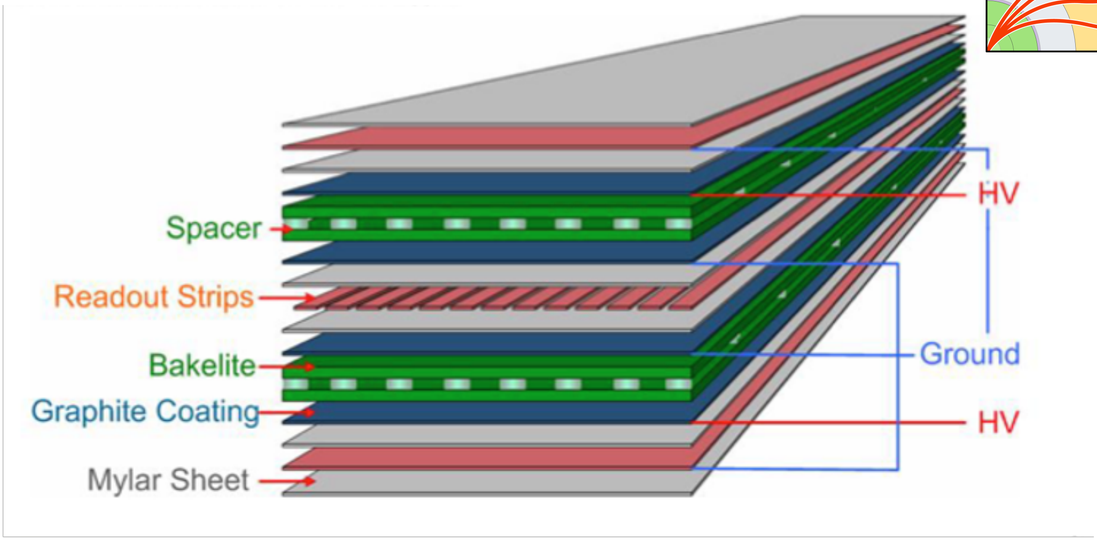
CMS Resistive Plate Chambers

- **CMS RPC present system**
- Double gap Bakelite RPC Chamber
  - ρ: 1-6 x 10^{10} Ω·cm
  - 2 mm gas width
- Coverage: |η| < 1.9
- 1056 chambers
  - 480 in Barrel (5 Wheels)
  - 576 in Endcap. (8 Disks)
- More than 110K electronic channels
- Rate capability: ~300 Hz/cm^2
- Intrinsic time resolution ~1.5 ns
  - Link boards only read during the LHC BX (25 ns)
  - Link System upgrade will enable CMS to use full RPC timing capability.



- Closed loop gas system:
  - Mixture: 95.2% $C_2H_2F_4$ **(Freon)**, 4.5% iC_4H_{10} **(Isobutane)**, 0.3%**(Sulphur Hexafluoride)** SF_6
  - Humidity: 40%
  - Replenishing rate: 10%

Due to its very good time resolution, the RPC is very important for CMS Trigger.

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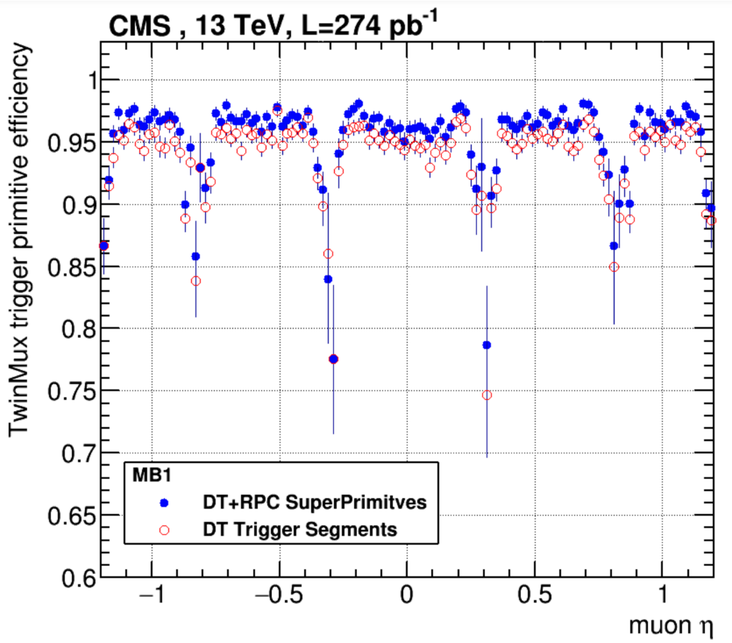
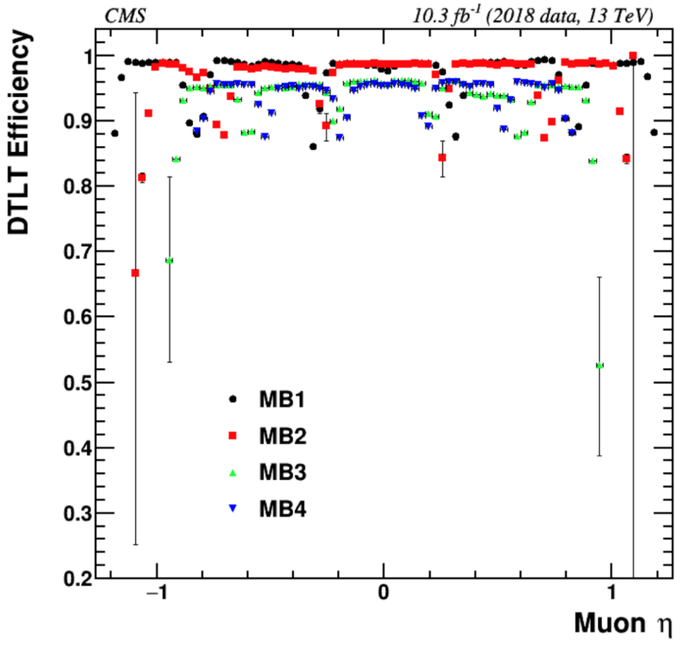
RPC Contribution to Muon Trigger

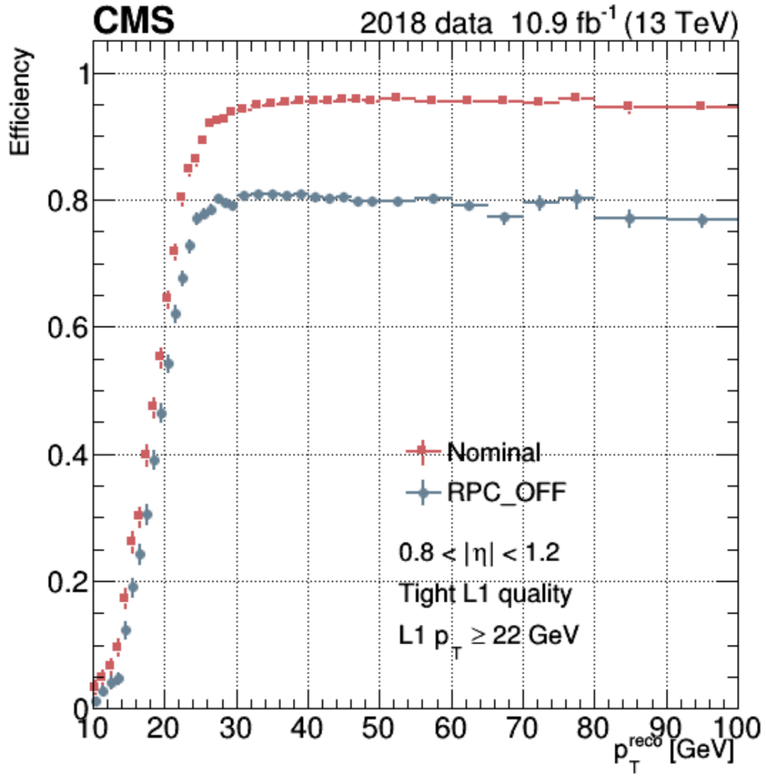
- The addition of RPC information to the DT segments increases the efficiency of the trigger primitives that will serve as input to the BMTF and OMTF.

- Also, RPC-only segments are built for stations MB1 and MB2 in case of DT segment absence. The efficiency for these stations are around 4% greater than stations MB3 and MB4.





- In the Overlap region, The RPC system plays a key role there as it provides 8 measurements for muon trajectory reconstruction. The muon trigger efficiency is increased in about 15%



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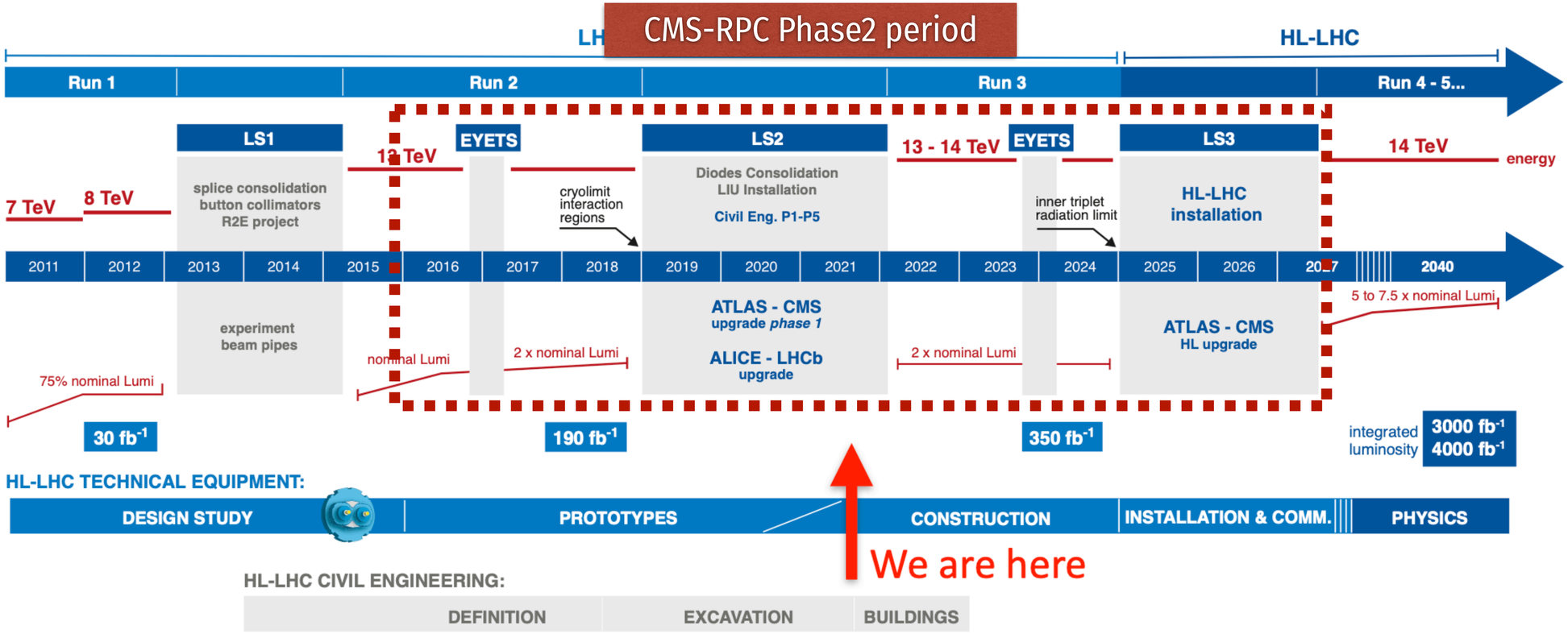
LHC Timeline

LHC / HL-LHC Plan



Luca Malgeri for CMS Collaboration (LISHEP 2021, July 08th)

https://cds.cern.ch/record/1975962

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HL-LHC: Muon requirements

1. Detector electronics must be upgraded

- to handle high particles rates and to deal with longer latency

2. longevity : aging electronic parts need to be replaced

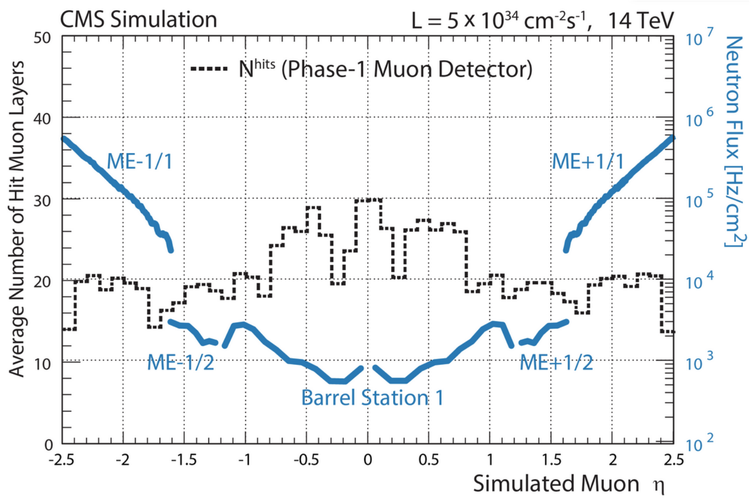
- while detector life expectancy (related to radiation damage) is more than acceptable

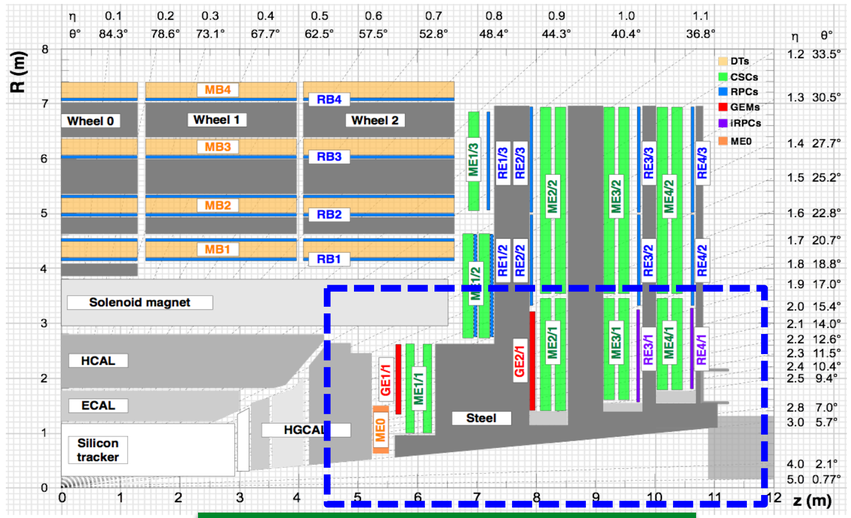
3. event reconstruction capabilities (trigger and offline) require, particularly in forward region:

- to enhance redundancy (increase # of measurements with good spatial and time resolution), to solve track reconstruction ambiguities.

4. extended acceptance

- to complement the wider tracking and calorimeter coverage and to reduce physics backgrounds from “lost leptons”

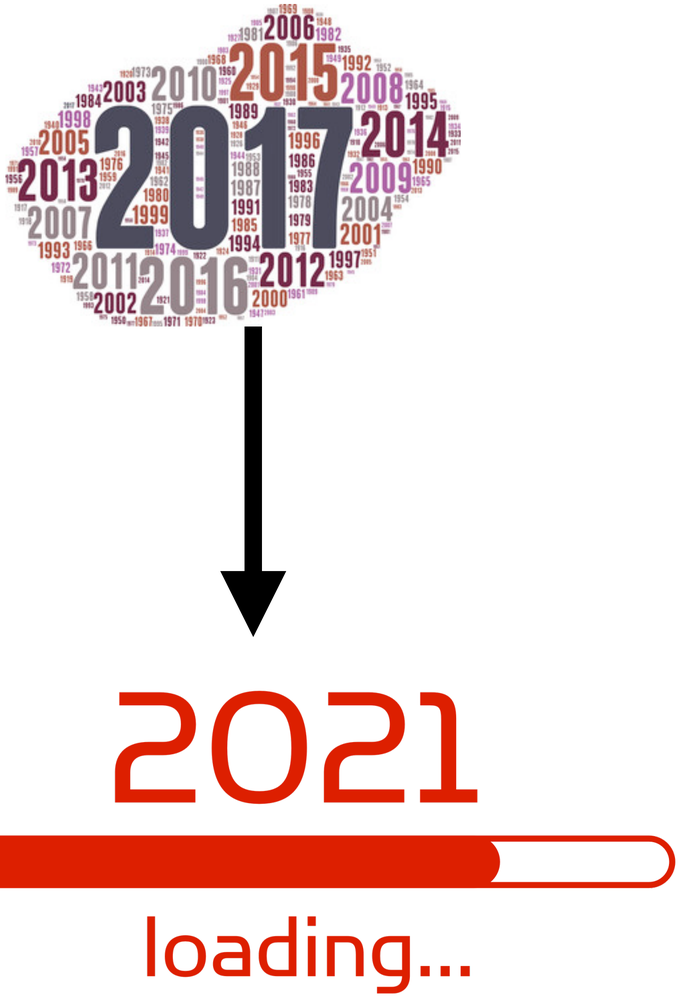




Anna Collaleo presented in ICHEP 2018

Brazilian Participation on the CMS-RPC project

- CMS-RPC Muon Run coordination: Felipe Silva (deputy)
- Online SW for current system and Upgrade: Kevin Mota and Felipe Silva
- DCS maintenance: Helio Nogima and Kevin Mota
- Ecogas studies, GIF++ and R4+ activities: Mapse Barroso
- MC Trigger Legacy SW: Dilson de Jesus Damião
- Data Manager remote shifts: Eliza Melo and Maurício Thiel
- Common DPG Ntuple: Eliza Melo
- RPC Muon Reco: Sandro Fonseca (convener) and Maurício Thiel



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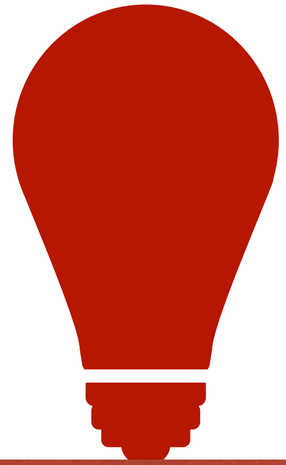

Maintenance, R&D (ecogas), Online SW, Upgrade Phase 2 activities-demonstrator

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Brazilian Participation on the CMS-RPC project

- CMS-RPC
- Online SW
- DCS main
- Ecogas st

The Compact Muon Solenoid Collaboration
confers on
Felipe Torres da Silva deAraujo
Universidade do Estado do Rio de Janeiro
a
CMS 2020 Award
For
his significant contribution to the development of a new version of the online software for control, monitoring and efficiency performance of the phase 1 RPC and for the development of a new RPC system for the LHC Phase 2

The Collaboration Board Chairperson
(Harrison B. Prosper)

The Experiment Spokesperson
(Luca Malgeri)

February 1st, 2021

nline SW,
ies

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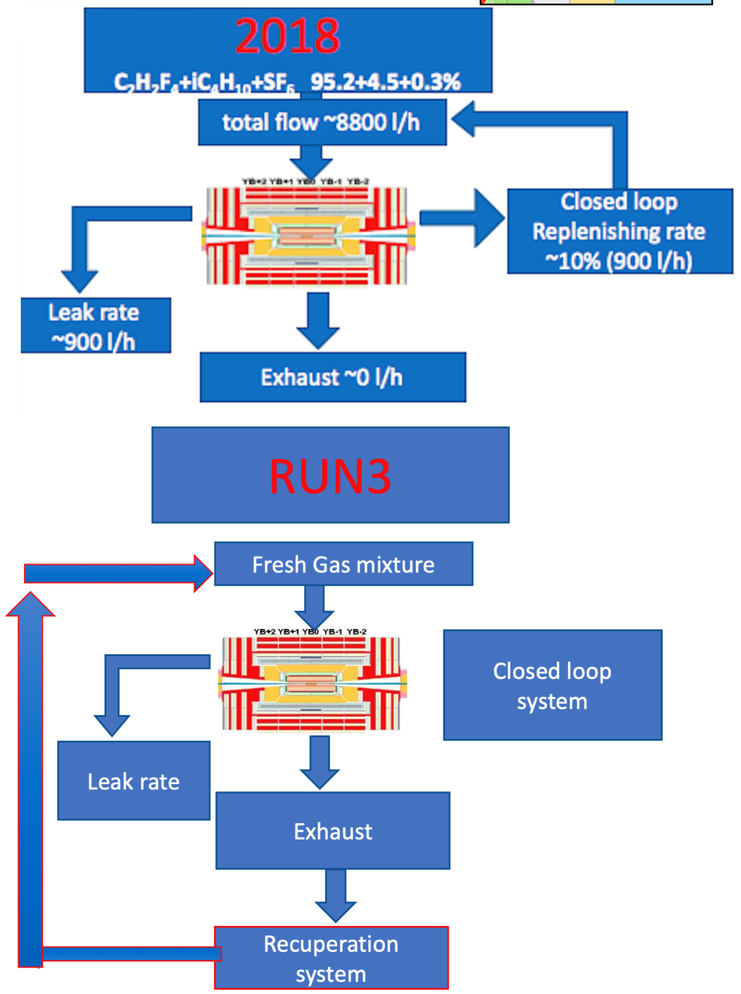
LS2 Activities

- Installation of thousands of kilometers of HV, LV cables, support equipment, gas pipes from gas distributor racks to the chambers and optical fibers for servicing and reading the signals of new detectors (iRPC)
- HV/LV Maintenance
  - **65 HV** repairs performed
  - **12 LV (TH)** repairs
- Extraction of the chambers of the two RE4 stations.
  - The chambers were brought to the surface, revalidated and reinstalled.
- Gas System Interventions
  - Main activities of LS2, aiming to minimize the environmental impact of the RPC
- system ($C_2H_2F_4$ and SF_6 have very high GWP-Global Warming Potential).
  - **49 out of 99 gas leaky** RPCs were repaired.
  - Recuperation of the Exhaust (not working during Run-2)
  - CERN EP-DT Gas team R&D to develop the first $C_2H_2F_4$ recuperation system with
- efficiency of 80%.



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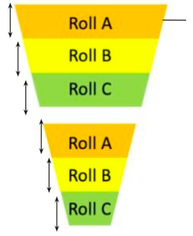
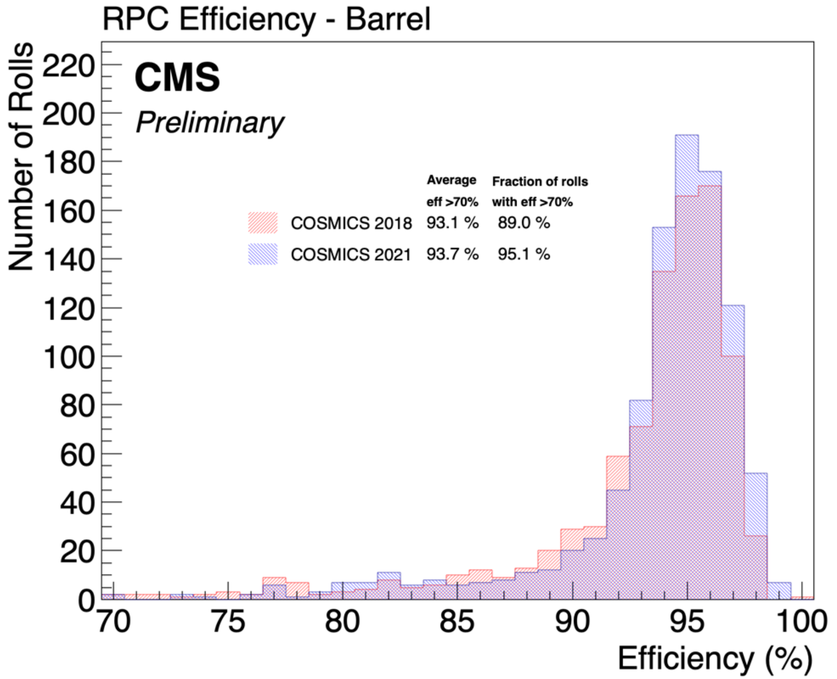
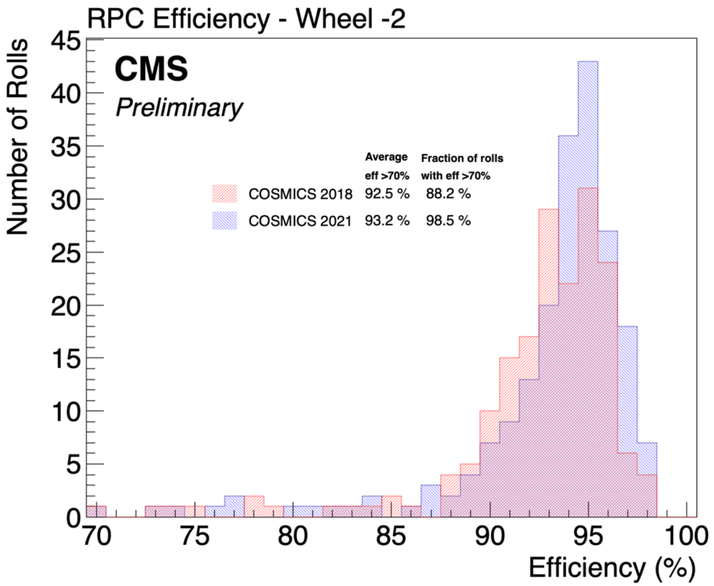
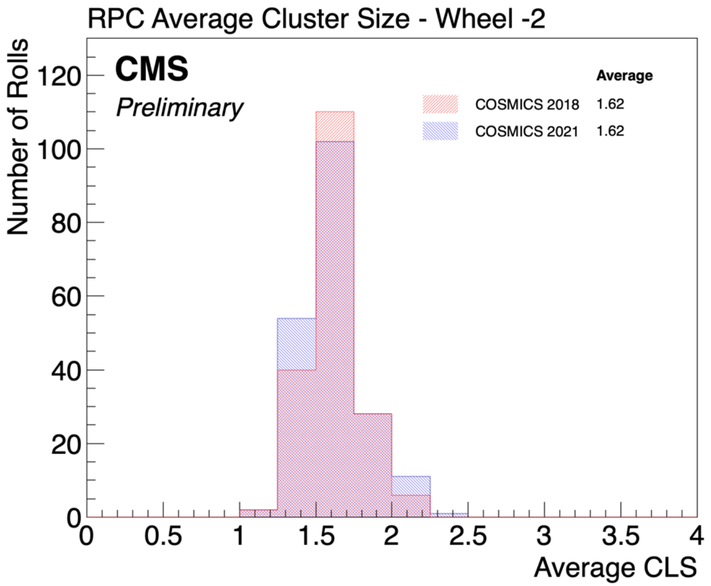
Performance Comparison (Cosmics)



- After all the LS2 interventions, we can see that the performance of the detector in 2021 is much better than in the end of Run 2 (2018).
- The number of chambers in good condition is increased (more than 6% for the full Barrel). The overall efficiency and cluster size is in accordance with the expected.







- RUN3: RPC plan to turn off all the leaky chambers (3.5% of total system) to reduce it from 900 to ~200 l/h by:
  - Restoring the exhaust
  - Reduce the fraction of fresh gas

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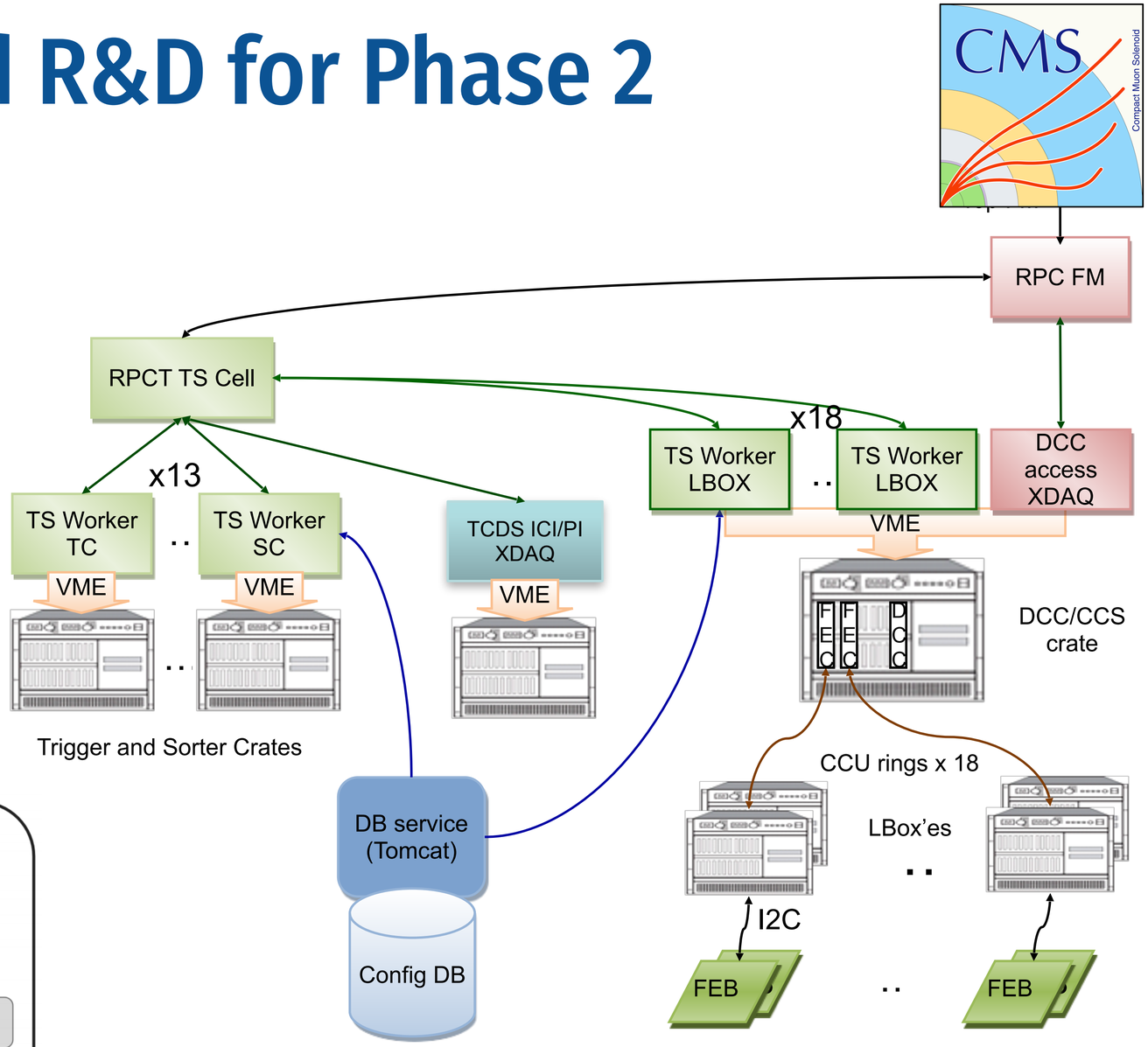
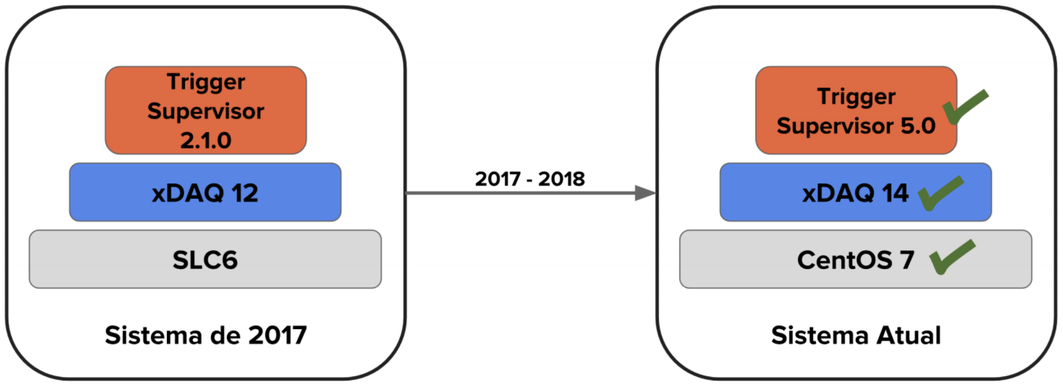
Online Software and R&D for Phase 2 Upgrade

- Trigger Supervisor is the framework for the RPC Online Software.
- Control and monitoring the RPC system (trigger, daq, configuration).
- **Maintenance and upgrade by UERJ-Rio group.**





RPC Upgrade Phase II

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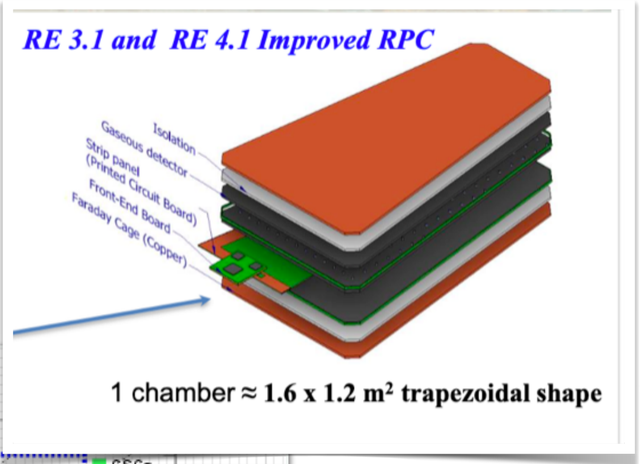
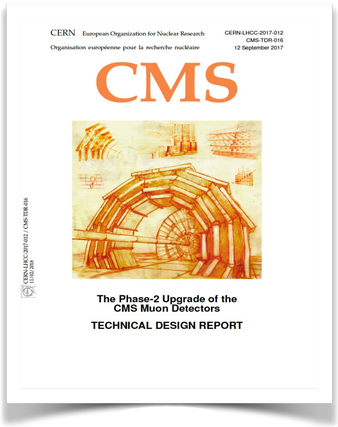
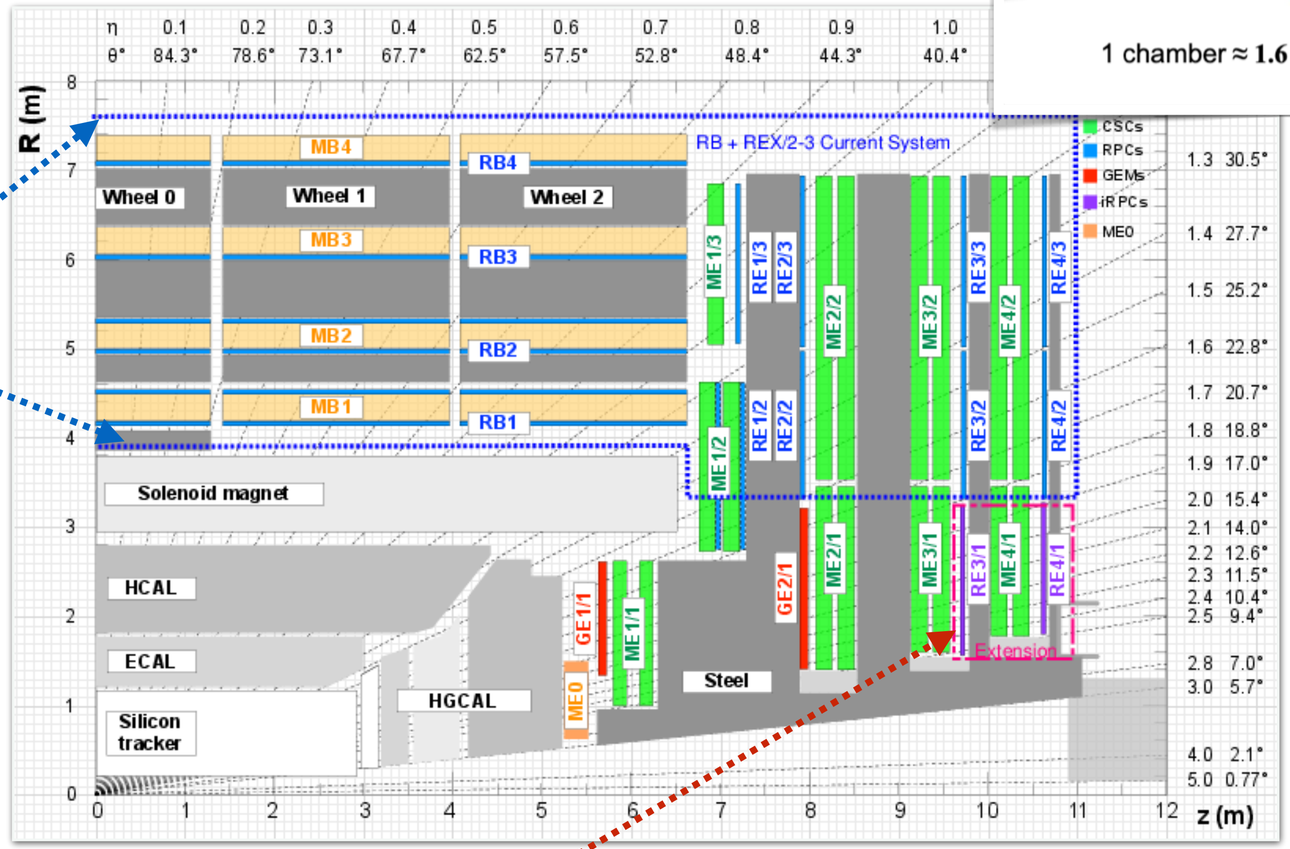
RPC Upgrade Phase II



Eco-gas studies to reduce the Global Warming Potential (GWP)

Upgrade of Link Board System (LB) to improve timing resolution for existing RPC (|η| < 1.9) installation during LS3





Extend the RPC coverage up to |η | = 2.4 to increase redundancy in high eta region in stations 3 and 4. (72 iRPCs)

CMS CR-2018/130

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Eco-gas studies to reduce the Global Warming Potential (GWP)

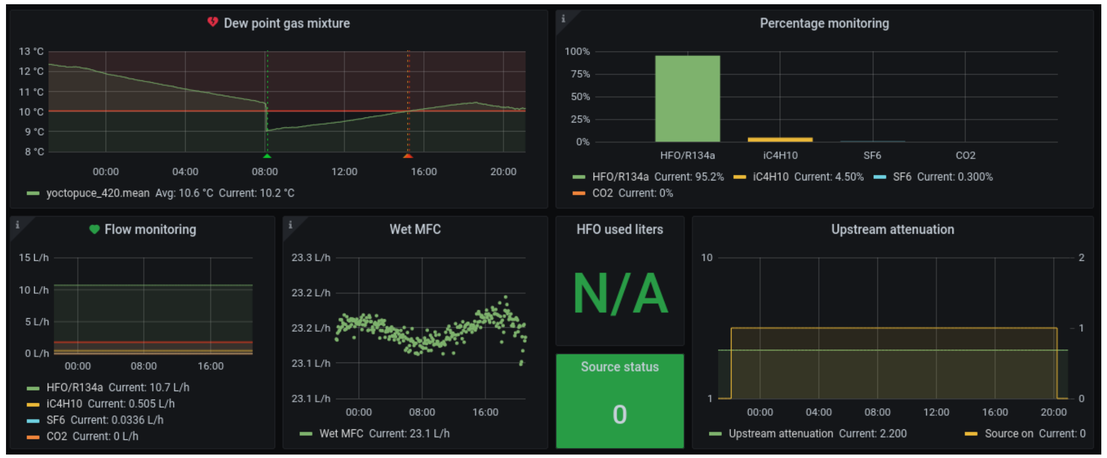
See more details in Poster session LISHEP 2021

- Collaboration (since 2019) with different groups and institutes: CMS-RPC, ATLAS-RPC, EP-DT, ALICE-MTR, LHCb, SHiP.
- CERN is pushing the LHC experiments to replace the $C_2H_2F_4$, as it has a high global warm potential (GWP) ~ 1430, with gases with lower GWP.
- Goal of the collaboration: Characterization of HFO-Based gas mixtures with LHC-like background.
- Detectors with different technologies and shared parts: CMS-RPC WebDCS, CMS Mechanics Trolley, EP-DT Gas System, EP-DT Monitoring tools.

Detectors

RPC	Gap type
CMS-GT	2 mm, double gap
CMS-K	1.4 mm, double gap
ALICE	2 mm, single gap
EP-DT	2 mm, single gap

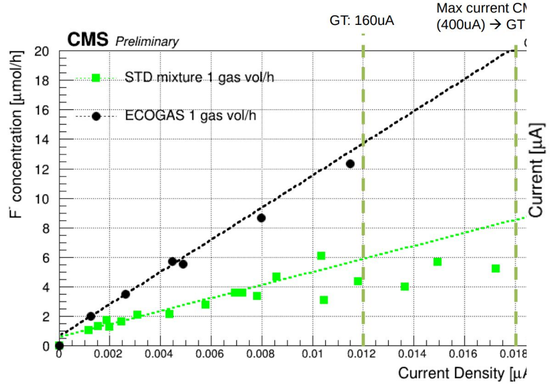
Monitoring on grafana

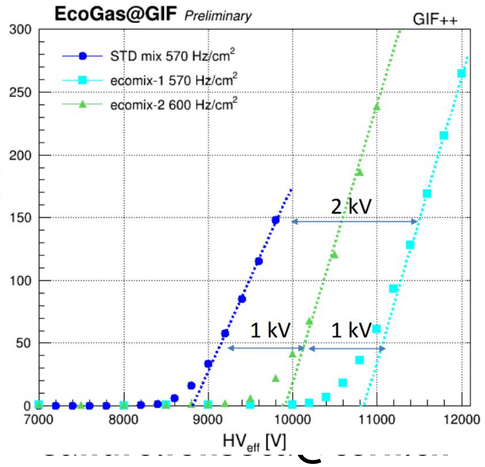


Setup

Results

- HFO-based gas mixture chosen to be tested: HFO 35 %, CO_2 60 %, iC_4H_{10} 4 %, SF_6 1 %.
- No clear sign of aging so far.
- Detector working point found 1 kV higher than the standard gas mixture.
- Stable ohmic current, while some increase and/or fluctuation (under study) is visible at working voltage.
- Ongoing studies: (F^- production, rate scan studies, long term monitoring).
- Test beam 2021: First beam test on the setup to be done this year -> Study of rate, cluster size, efficiency.

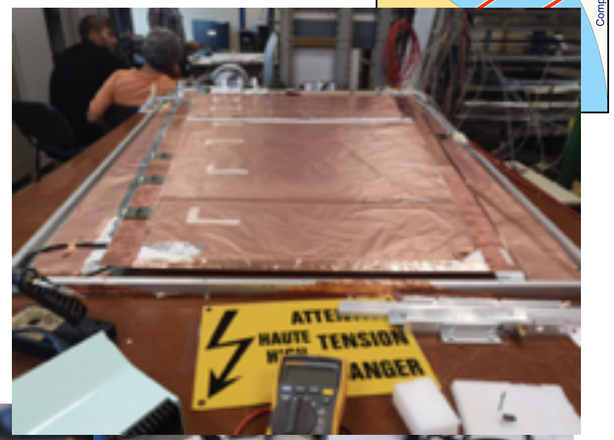


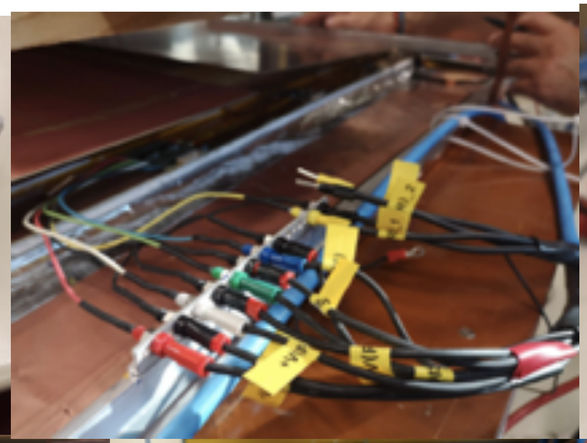


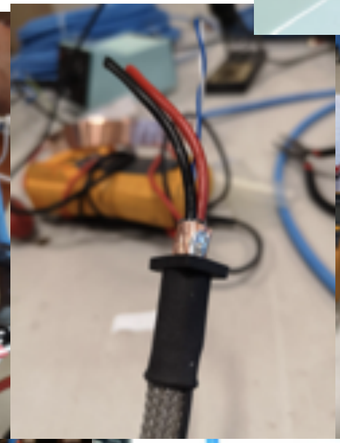
Participation in the assembly of the iRPCs

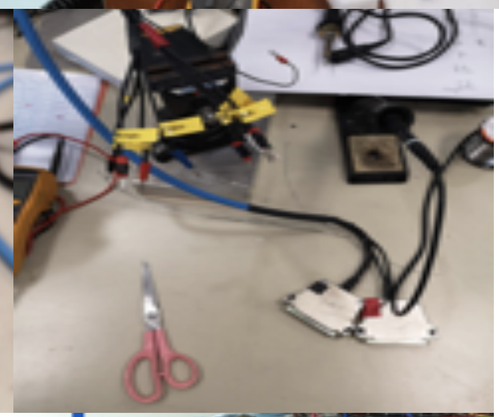
electronic instrumentation at iRPCs (KODEL and ROMAN)

- LV cables, converters, flat cables, patch panel, resistors solder SMDs
- test chamber mounting





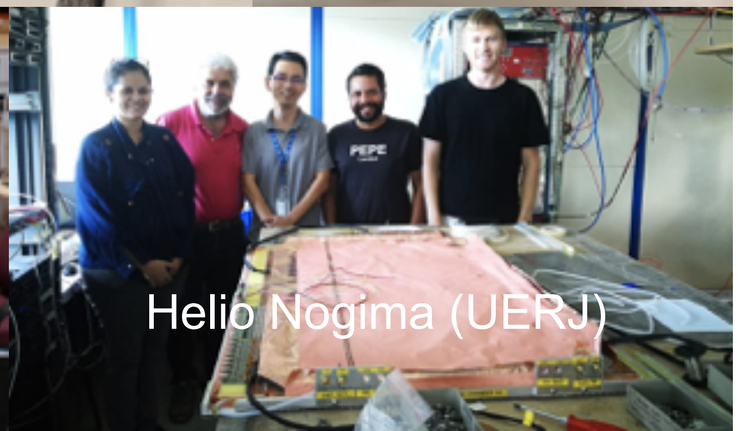





Fabio Marujo (CBPF)


Felipe Silva (UEA)

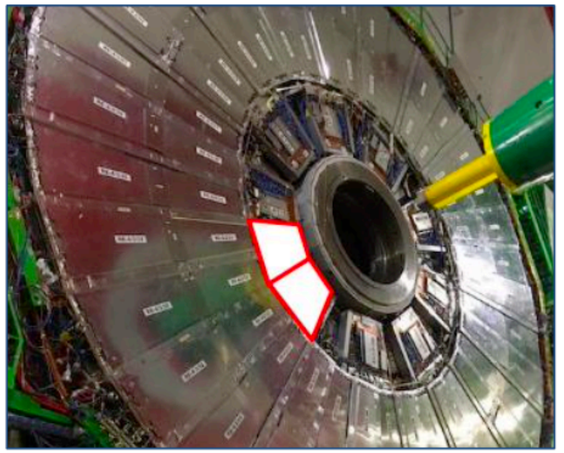
Eliza Melo (UERJ)


Helio Nogima (UERJ)

Demonstrator: Installation @CMS in 2021

Goals

- Study detector performance in real P5 conditions during RUN3. (background, noise, B Field) and LHC particle rate.
- To get new chamber installation expertise and validation of P5 services.
- To get commissioning expertise first in local and then in global run mode.
- To integrate new RPC chambers into CMS DCS and DAQ system.



Roadmap

- Services already installed during LS2.
- Spring 2021: Chamber construction. Gaps received in Gent. QC ongoing.
- Chamber arrival in 904 (without FEBs): May 2021.
- Chamber QC with FEBV2.1: June 2021 (@904), July 2021 (@GIF++)
- August-October 2021: Chamber validation with Cosmics @904 and @ GIF++ (1 chamber long term) using FEBV2.2.
- November 2021: Installation of 4 demonstrator chambers (2 type 3.1 + 2 type 4.1) in P5.

Demonstrator: Installation @CMS in 2021

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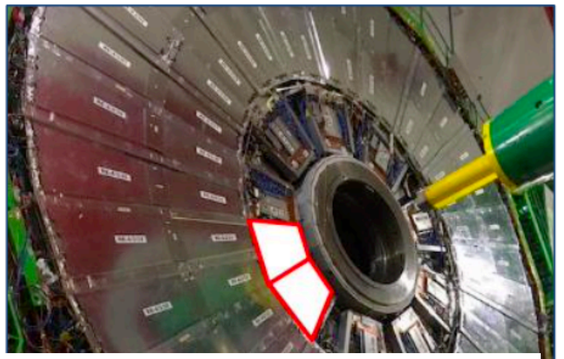
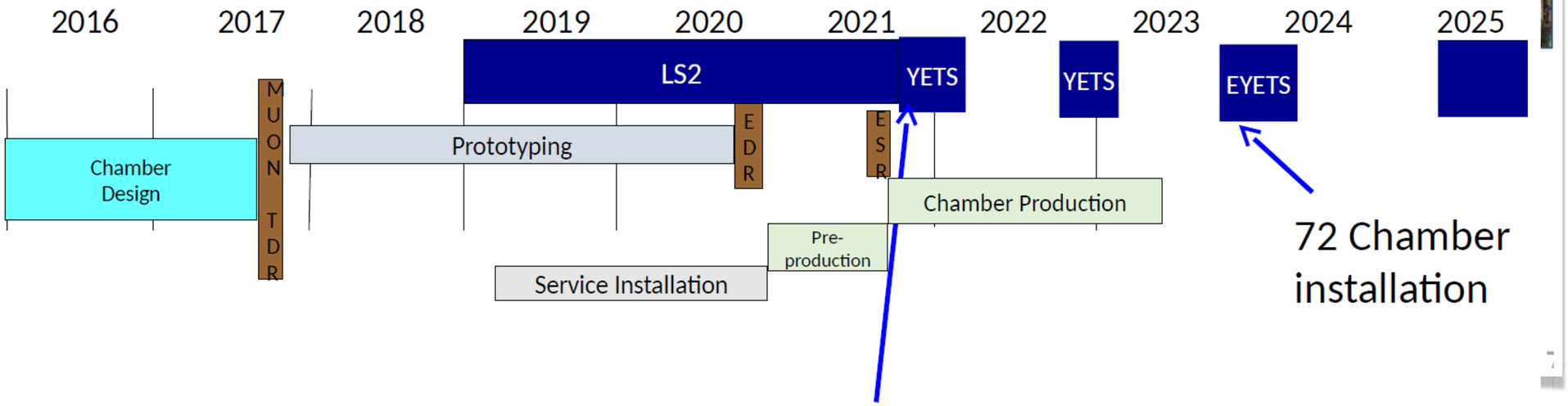




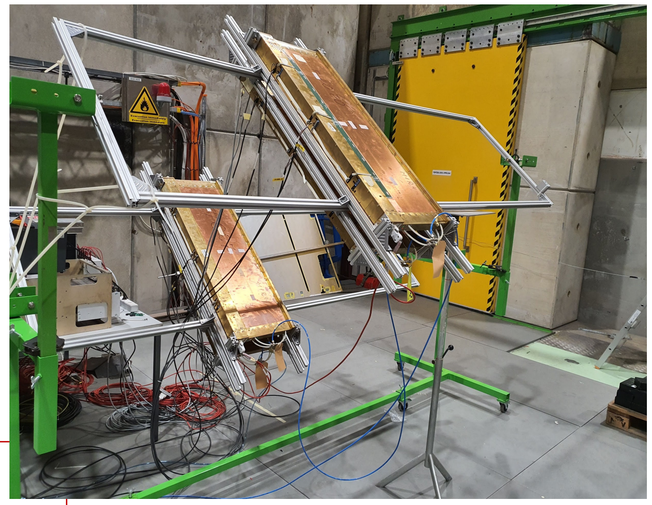
Installation Demonstrator Chambers
+ BackEnd (µTCA)

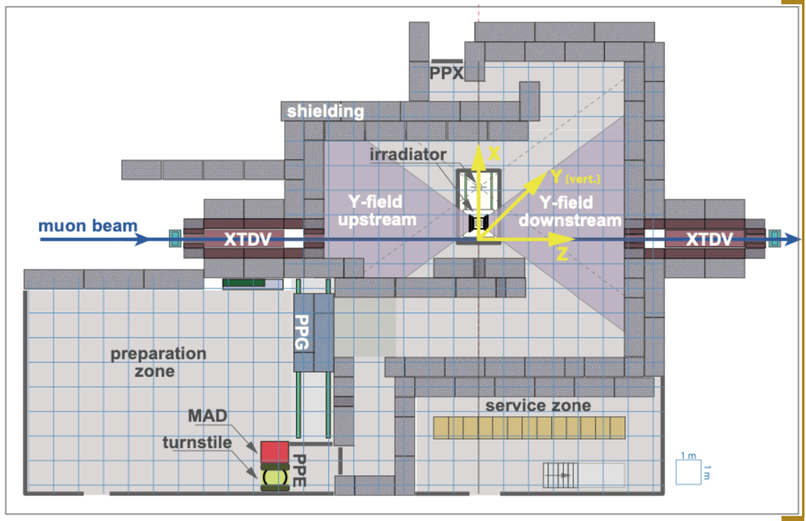
MWPC Based Muon Trigger At GIF++

Motivations

To provide a reliable, flexible cosmic muons trigger for tests of RPC and other technologies in GIF++.

The need of a sustainable trigger at high gamma ray flux.



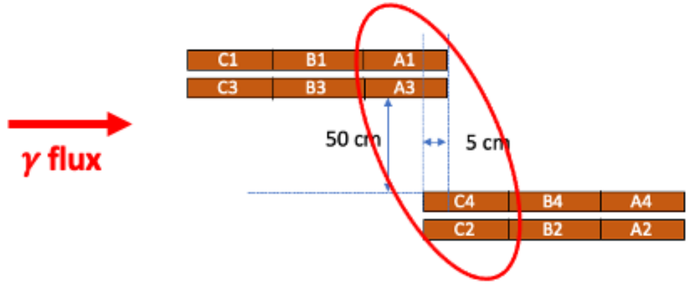


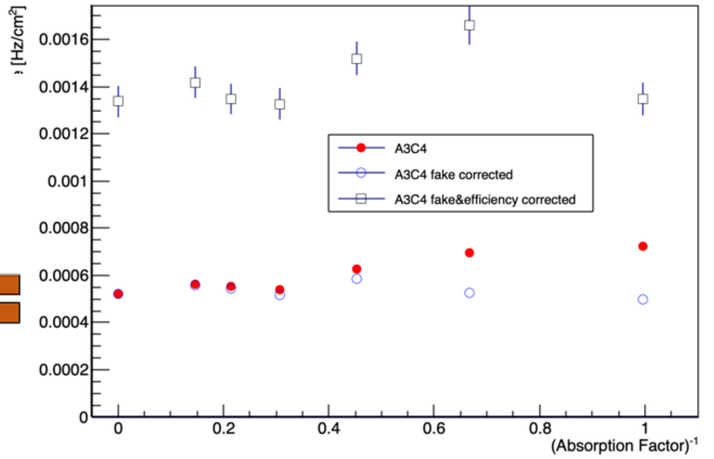
Setup

- Two layers of two LHCb Multi Wire Proportional (MWPCs) chambers.
- 24 readout channels per chamber.
- Active area of 968 x 200 mm^2 per chamber.
- Granularity of 40 x 200 mm^2.

Work done

- Setup construction.
- Characterization with gamma irradiation.
- Estimates of cosmic muon spot size.





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Participation in conferences and publications

- SBF 2018: Dilson de Jesus and Sandro Fonseca
- RENAFAE 2018: Sandro Fonseca
- TIPP 2021: Kevin Mota and Felipe Silva
- LHCP 2021: Mapse Barroso
- EPS-HEP 2021: Maurício Thiel (ongoing)
- Contribution for Muon Run 3 paper (ongoing)
  PRF-21-001: Felipe, Kevin and Mapse by RPC

CMS PAPER PRF-21-001

DRAFT
CMS Paper

The content of this note is intended for CMS internal use and distribution only

2021/05/27
Archive Hash: 6acdec2
Archive Date: 2021/04/05

The evolution and performance of the CMS detector at the CERN LHC

The CMS Collaboration

Abstract

DRAFT

This box is only visible in draft mode. Please make sure the values below make sense.

PDFAuthor: G. Boudoul
PDFTitle: The evolution and performance of the CMS detector at the CERN LHC
PDFSubject: CMS
PDFKeywords: CMS, your topics

Please also verify that the abstract does not use any user defined symbols 1

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Estimated Costs Proposal

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Estimated costs table

Run3/Pre-LS3

LS3

CERN travel (30 days) + tickets

	2022	2023	2024	2025	2026	2027	Total project cost (KCHF) full period
Total Estimated costs ((KCHF)	129,8	129,8	139,4	184,4	184,4	184,4	952,2
PhD students per year	2	2	2	2	2	2	
Faculties and postdocs	5	5	8	8	8	8	
CERN Travel per year (30 days)	2	2	2	4	4	4	

Ph.D. student subsistence + tickets + health insurance

Total estimated costs (CERN Travel + M&OB + PhD students)

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Summary and Conclusions

- We presented highlights of the main activities and contributions of the UERJ-Rio group for the CMS-RPC project together with LS2 activities and Phase 2 Upgrade.
- These contributions are showing solid and consistent maturation in different areas of the CMS-RPC project, presenting a leadership in several tasks exemplified in the participation in conferences and CMS paper.
- Felipe Silva from Universidade Estadual do Amazonas (UEA) will present the plans for local activities with gas detectors and possible unfolding in his talk.
- We believe that the acquired expertise could be shared in other detector projects developed by the Brazilian HEP community.
- We had a partial grant to scholarships and short travel to CERN supported by UERJ CAPES PrInt Program and short individual grants (e.g. CNPq and FAPERJ) but we do not have any primary financial source to cover full estimated costs for Run 3 and LS3 activities as presented on the previous slide.

Thanks for your attention

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Backup

LS2 activities

LS2 = Long Shutdown 2 since 2019
Collisions to return mid 2022

Strip tracker
- kept cold to avoid reverse annealing (but warmed during beam pipe bake-out)

HCAL
- completion of Phase-I upgrades

Pixel detector
- replace first barrel layer
- replace all DCDC converters

Magnet
- at room temperature since mid 2020
- maintenance work: free wheel thyristor, cryo-cooling, power, pumps, etc.

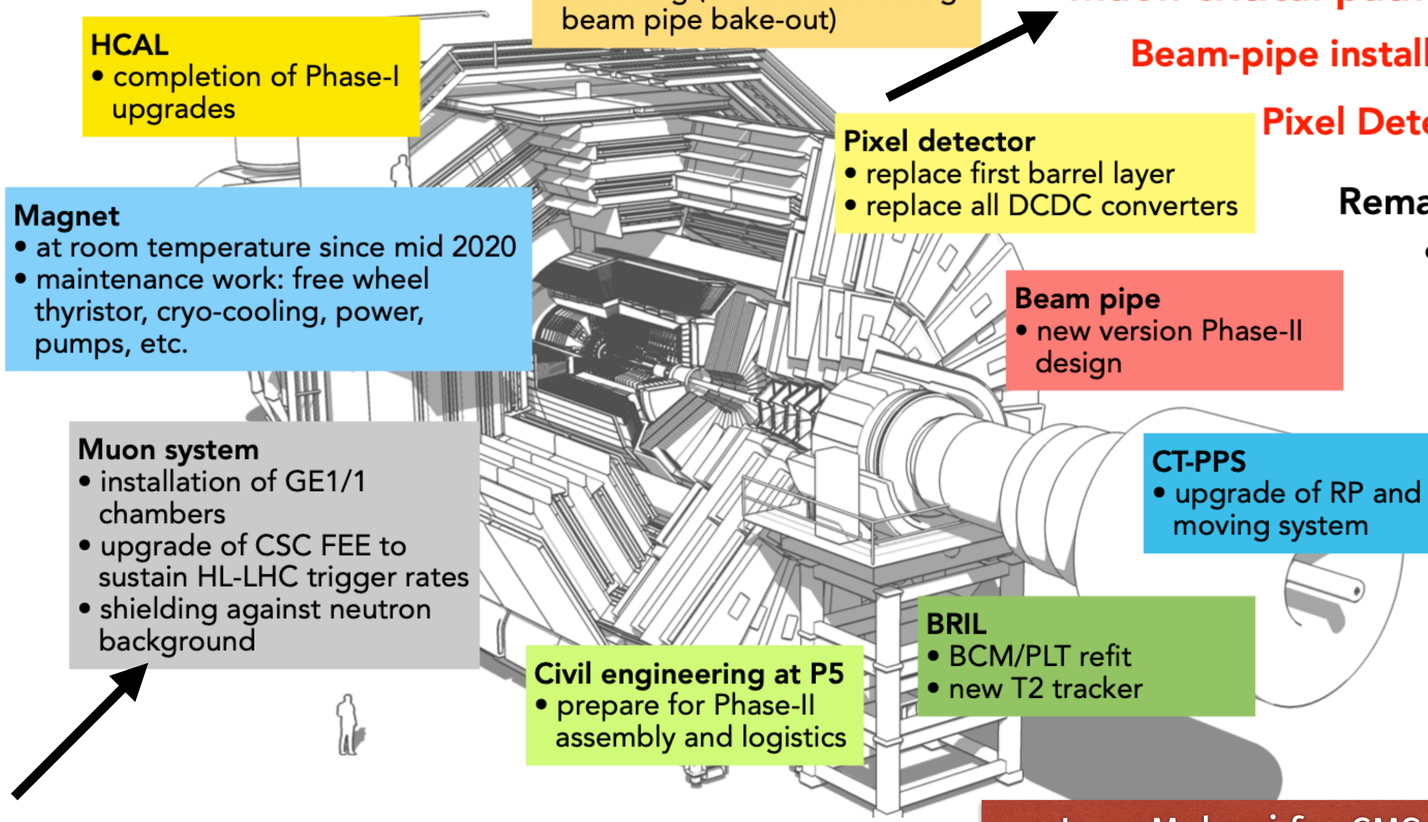
Beam pipe
- new version Phase-II design

Muon system
- installation of GE1/1 chambers
- upgrade of CSC FEE to sustain HL-LHC trigger rates
- shielding against neutron background

CT-PPS
- upgrade of RP and moving system

BRIL
- BCM/PLT refit
- new T2 tracker

Civil engineering at P5
- prepare for Phase-II assembly and logistics



Work on HCAL Barrel (SiPM readout) completed in Oct. 2019

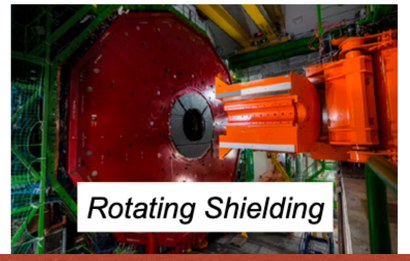
Muon critical path completed in Dec. 2020

Beam-pipe installation and bake-out completed in May 2021

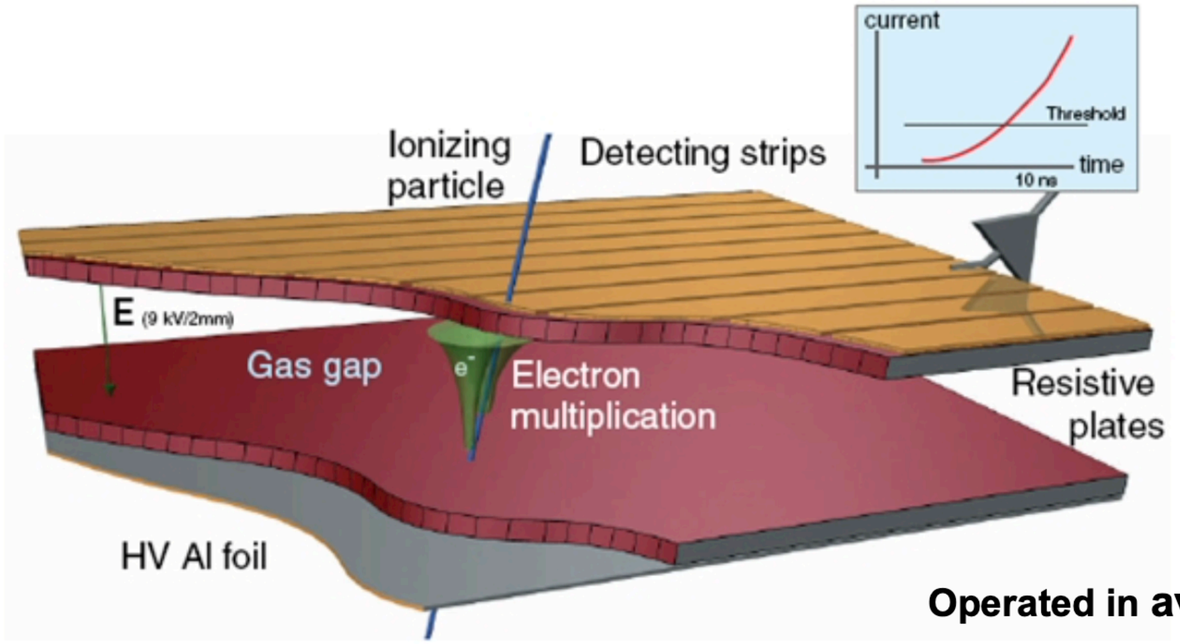
Pixel Detector installation completed in June 2021

Remaining activities:
- yoke closing (starting mid July)
- magnet restart (3.8T) and tests
- comics runs at ~4T (CRAFT, 24/7)

After Pilot Beam Test in Oct 2021
- Phase-II muon demonstrators
- new forward shielding

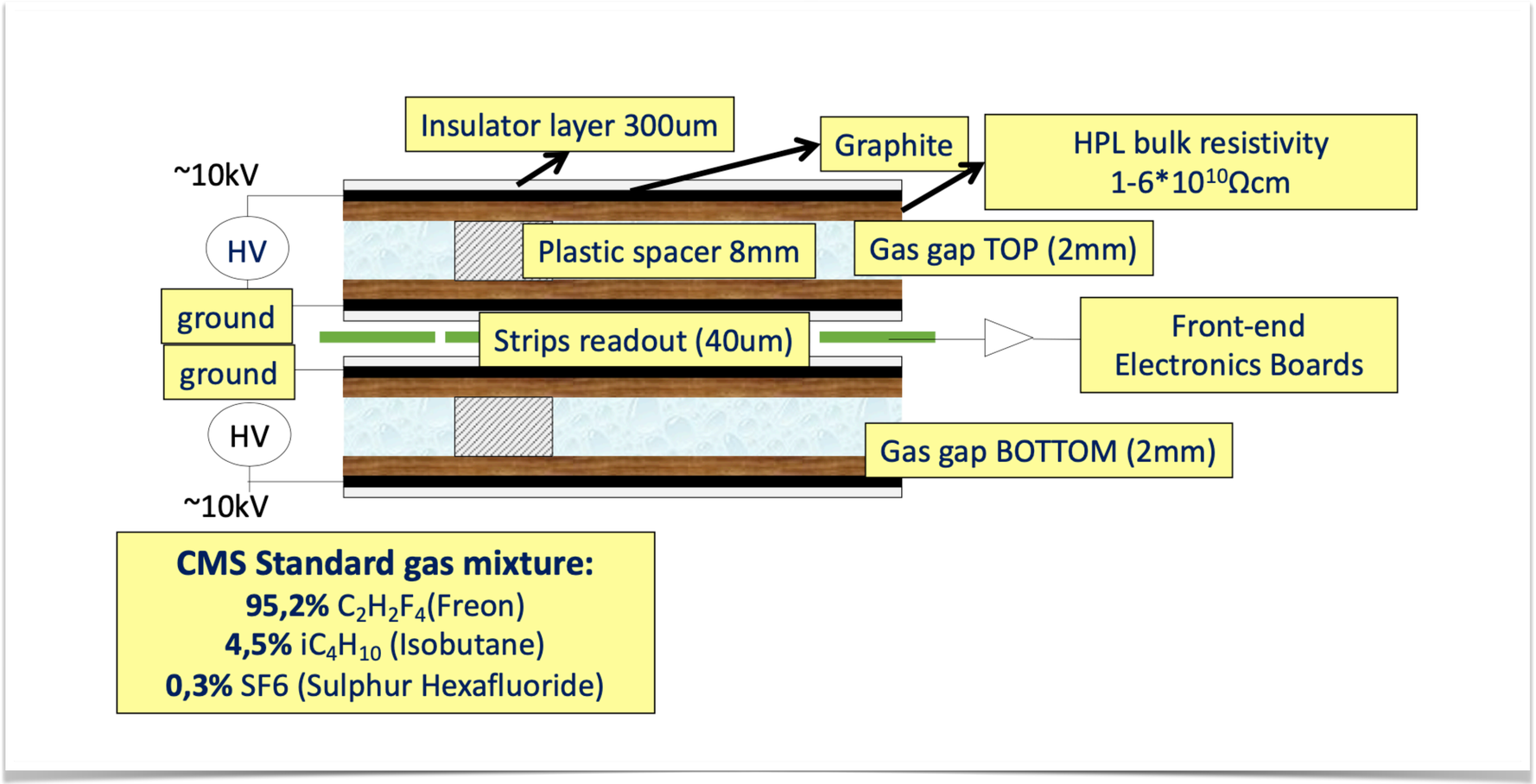


Resistive Plate Chamber

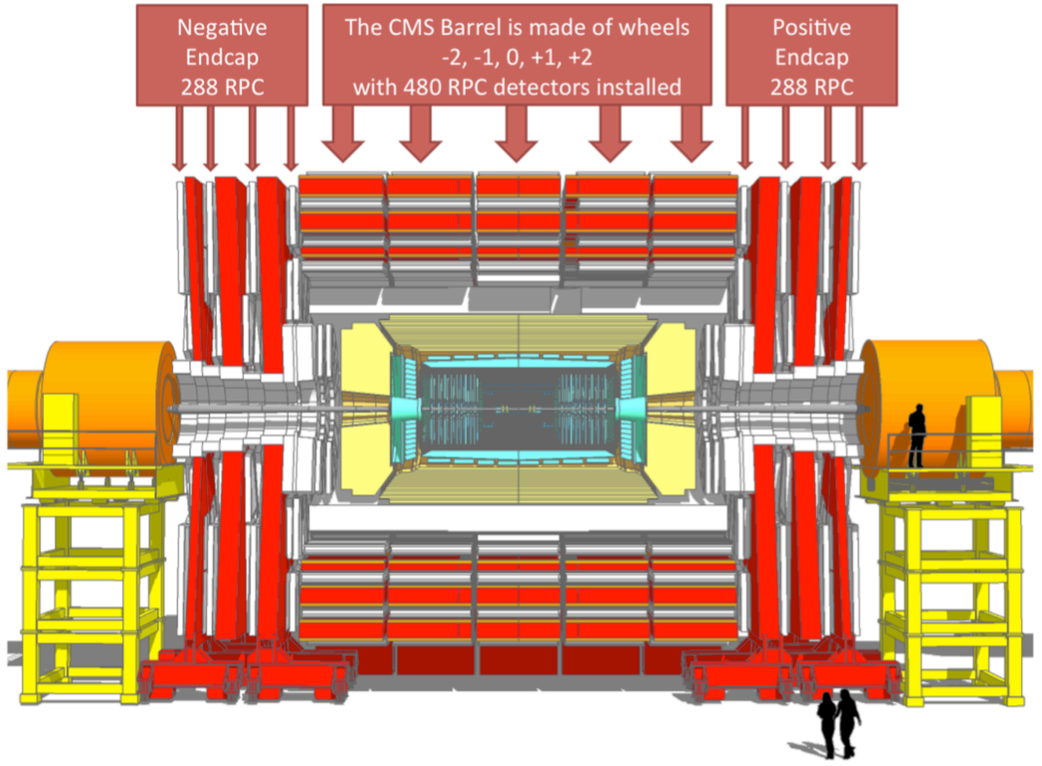


Operated in avalanche mode

Resistive Plate Chamber - Configuration



Resistive Plate Chamber - Geometry



1056 RPCs in total

Barrel:
5 Wheels:
W-2
W-1
W 0
W+1
W+2

Endcap:
8 Disks or Stations (4 positive, 4 negative)
RPC Endcap -4: RE-4
.
.
.
RPC Endcap +4: RE+4

Demonstrator Chambers

6 Demonstrator chambers (RE3.1 and RE4.1) successfully built at Ghent and transported to 904 yesterday (21/Jun).

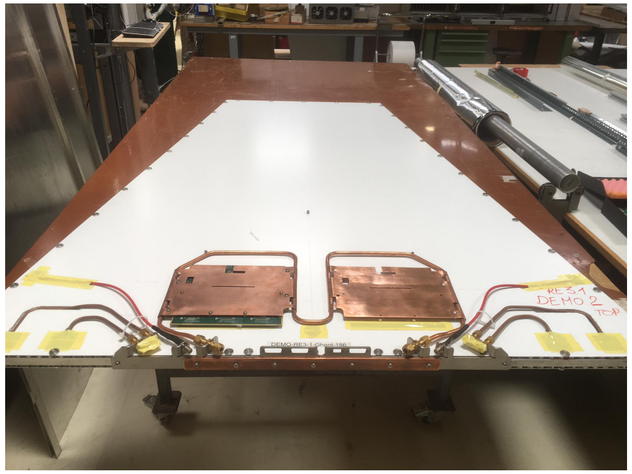
Cooling plates received from Georgia and installed on the demonstrator chambers this morning.

After loading in Gent lab (21 June)

Kevin Mota (UERJ)

Assembly in Gent

Tests with DUMMY FEB



Cooling plate mounting in 904

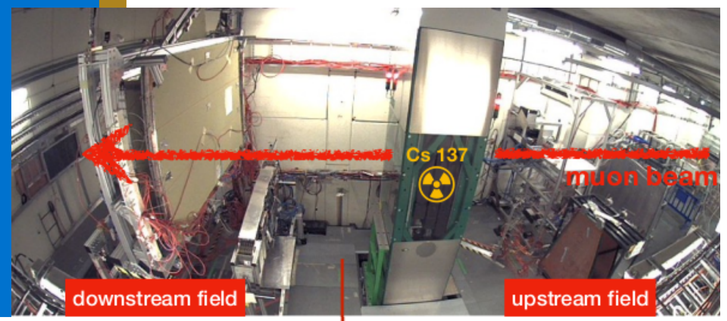
rn.ch

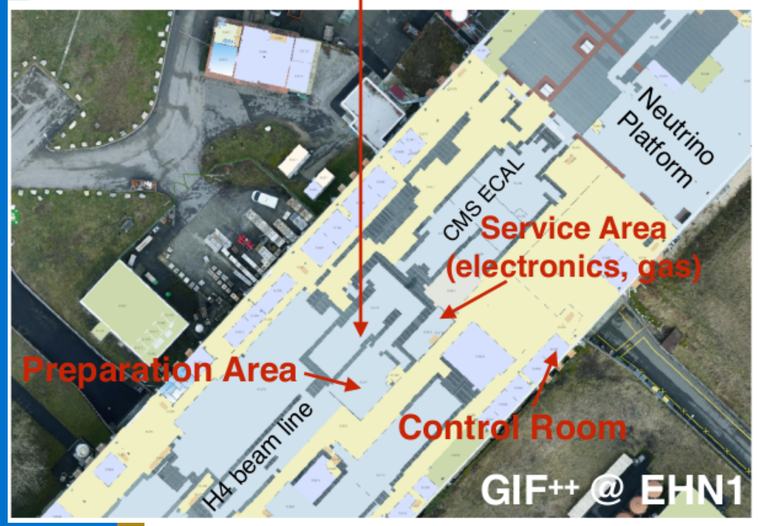
Gamma Irradiation Facility activities

Mapse's poster during LISHEP 2021- Poster session

- Gamma irradiation facility (GIF++) is a unique place, combining a high energy **muon beam** with a 14 TBq ^{117}Cs **gamma source**.

- Designed for testing real size detectors as well as smaller prototypes.

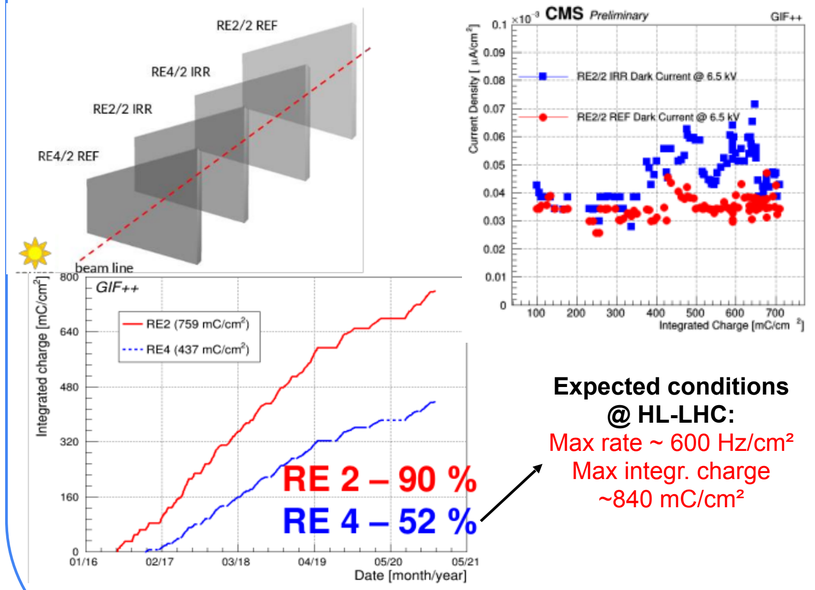




RPC activities in GIF++

Consolidation studies

- 2 RE2 chambers (Irrad. & Ref.)
- 2 RE4 chambers (Irrad. & Ref.)
- Environmental and gas parameter constantly monitored.
- Daily measurements: Current & rate with background
- Weekly measurements: Current & rate at different background conditions
- Resistivity measurements 3-4 times per year.



Expected conditions @ HL-LHC:
Max rate ~ 600 Hz/cm²
Max integr. charge ~840 mC/cm²

iRPC gap Validation in GIF++

- In March 2020 a final validation was performed in GIF ++ with gammas and cosmics.
- Efficiency at plateau: 98 %: source-off
- Efficiency at plateau: 92 %: at 2 kHz/cm² (expected condition in HL-LHC, including a safety factor ~3)
- Objective from CMS-TDC-016: 95 %
- Drop by 6 %: 3 % from the detector, 3 % from dead-time in petiroc2B (ongoing studies to improve this).
- 4 new gaps 70 cm x 100 cm received from Kodel and installed in GIF.
- Humidification of Bakelite (HPL) reached equilibrium at RH=40 % after two months.
- Dark currents fluctuations followed the humidification of the HPL.

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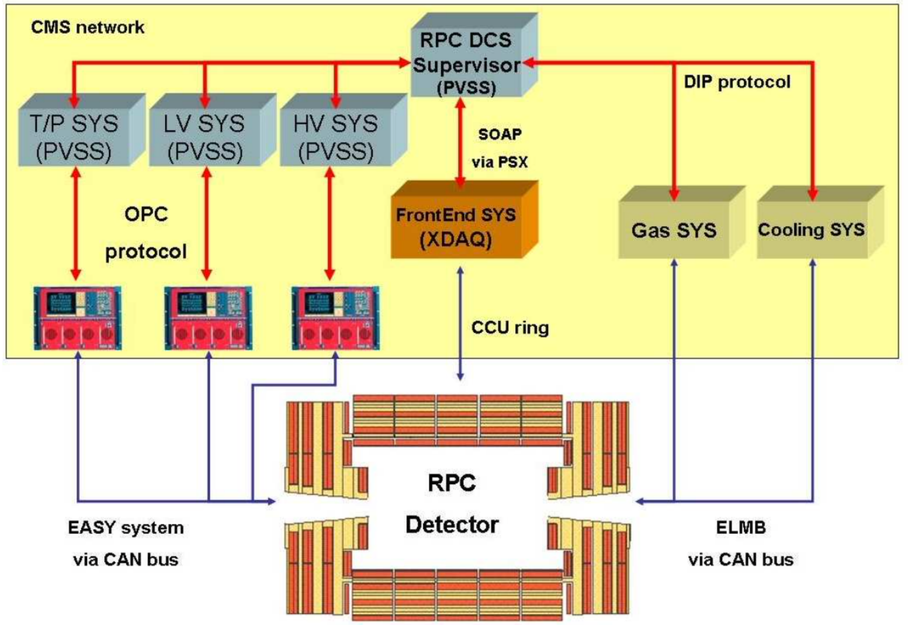
DCS (Detector Control System)

The correct and safe operation of the RPC system requires a sophisticated and complex online Detector Control System.

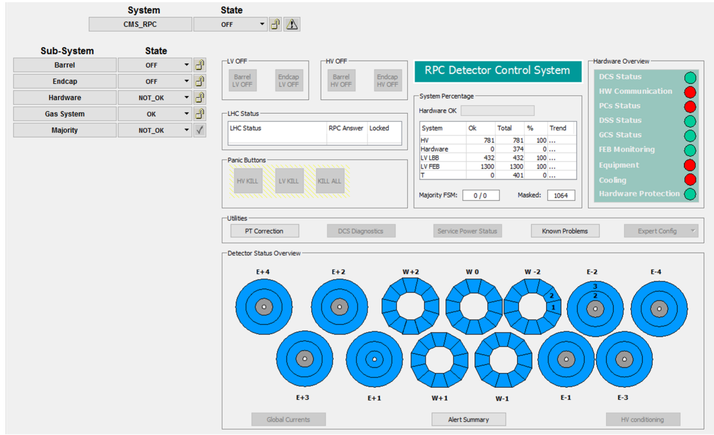
- It is able to control and monitor more than 2.10^4 pieces of hardware
- it stores about 10^5 parameters from the detectors, the electronics, the power, cooling and gas systems.

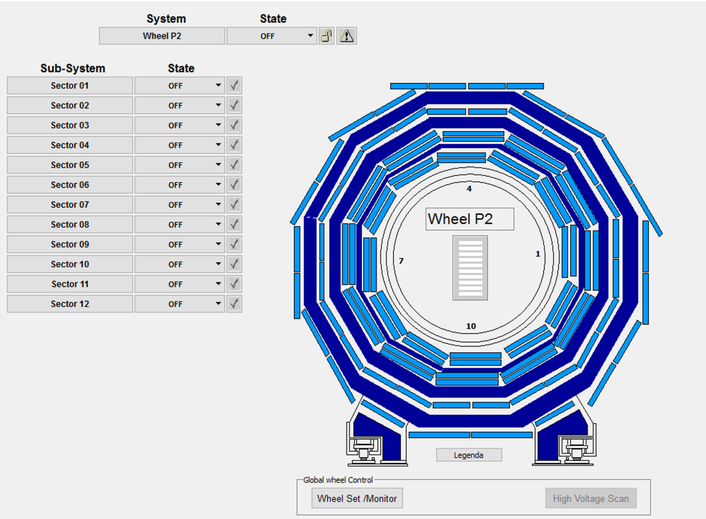


During LS2, a lot of activities DCS are ongoing.

- Many bug fixes for the next data-taking operation.
- The gas system database tables and the DCS panels will be fully reformulated.
- Addition of the new iRPC chambers that will be installed for the demonstrator.

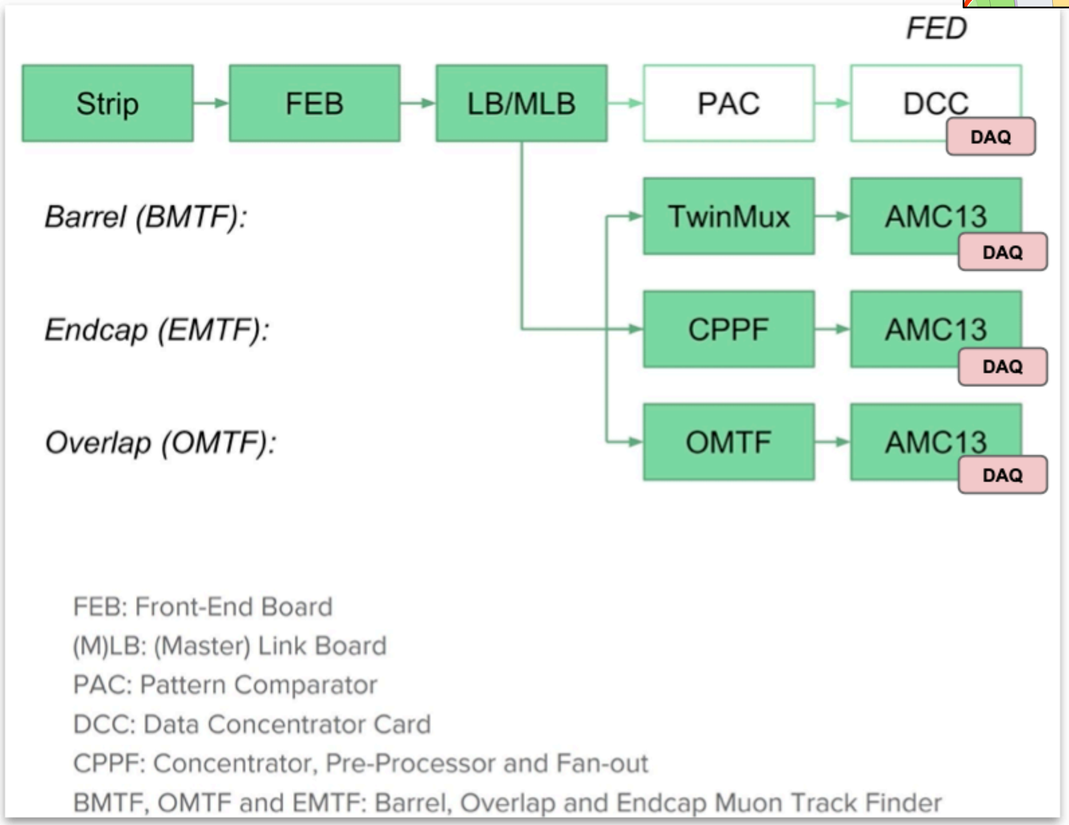
Maintenance of the DCS by UERJ-Rio Group.





Legacy System

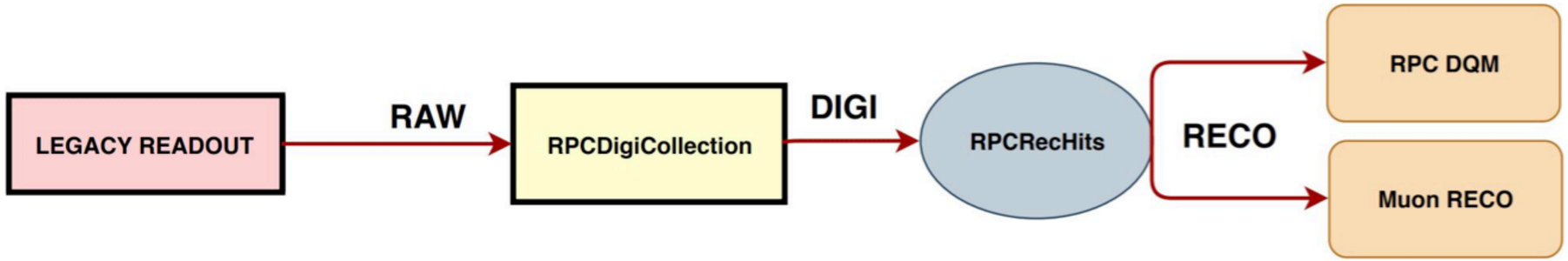
- System = Trigger/Readout
- Located in USC.
- Trigger and Readout system until 2016.
- Will be dismounted during the LS2.



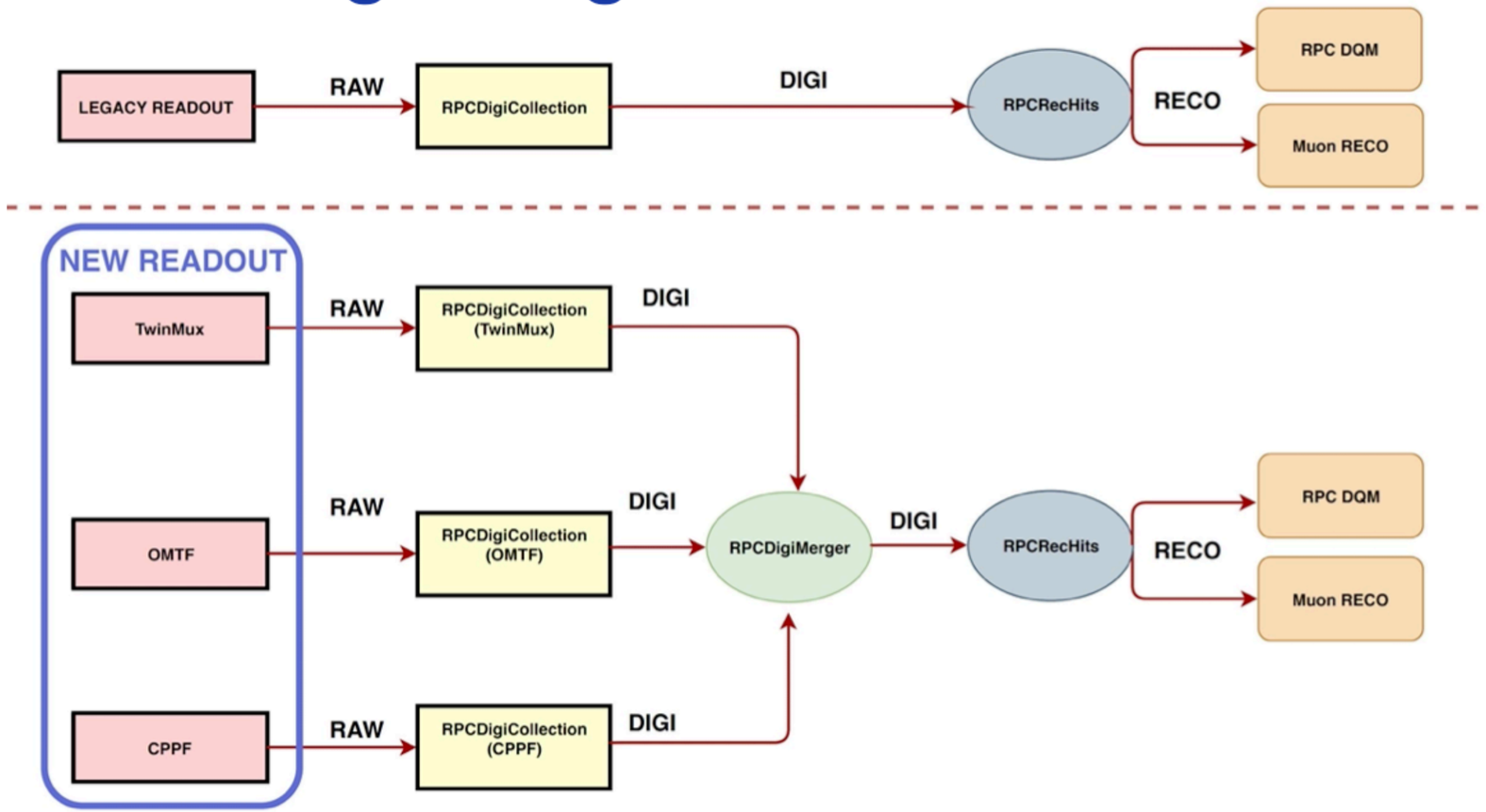
[ref]

Reconstruction

- **Current RECO:**
  - The DCCs (FEDs) send RPC raw to DAQ.
  - CMSSW unpacks the FED raw data and produces the RPC Digis.
  - The RPC Digis are used by the RPCRecHitsProducer (clustering algo) to reconstruct hits in the RPC chambers.
  - Those hits are provided for Muon RECO and DQM.



RPC Digi Merger



Overlap OMTF X TwinMux:

- W+2 and W-2

Overlap OMTF X CPPF:

- RE+/-3_R3
- RE+/-1_R2

Overlap strategy: If it is a overlap region ➔ Exclude OMTF.

Bx ranges:

- **Legacy**: -2 < Bx < 3
- **TwinMux**: -2 < Bx < 2
- **OMTF**: -3 < Bx < 4
- **CPPF**: -2 < Bx < 2

MC Legacy Contributions

RPC DigiMerger - The RPC Digi Merger reads the unpacked data of the three muon processors and merge them in the proper way. This is already implemented for the Data workflow.

Fixe the MC chain in the CMSSW flow accepted as a temporary solution

RPC CPFF PACKER - request from the simulation team and the status is in progress

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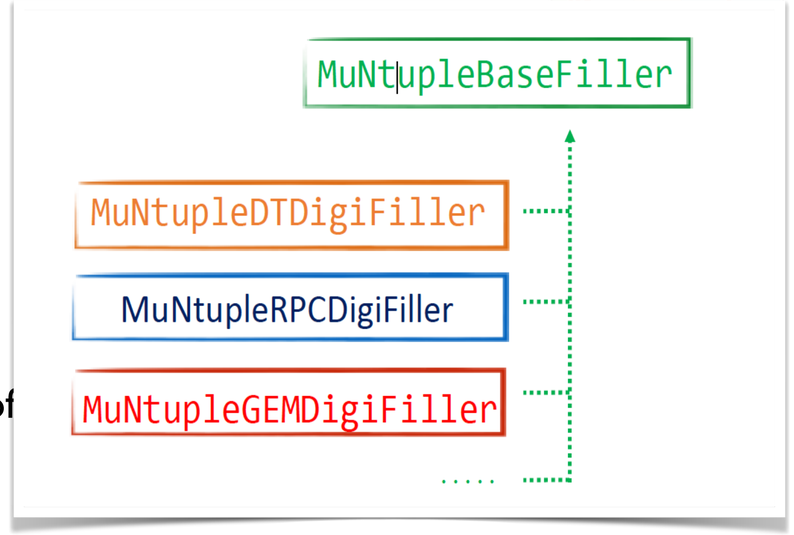
Common DPGO ntuple: the basic idea

moving to a **common muon DPGO tuple** can be **more efficient**:

- The production of ntuples on some reference dataset (ZMuskim?) could be run centrally by DOC3 shifters
- Regular maintenance (e.g. to follow "central" CMSSW code evolution) can be done "just once"
- If one uses quantities from other DPGs (or POG), he/she knows that "that part of the code is maintained by experts"



- **Ntuples** are based on a **modular** approach:

  Basic unit are fillers(inheriting from MuNtupleBaseFiller)

  Fillers are easily plugged into a steering class (MuNtupleProducer)

  Fillers can be reused if they fill "similar" quantities, e.g.: phase-1 and slice-test DT segments, TwinMuxinput/output, BMTF input

- Current Ntuples(under development)include:

  DT:digis, segments, TwinMuxinput/output, BMTF, **RPC:**digis, rec-hits , **GE1/1:**digis, rec-hits, segments, **CSC** only info used by GEM implemented, plan to add digis, rec-hits, segment

  General event information: run/lumi/event number, pile-up, generator-level muons

  Muon object: kinematics, quality variables, isolation, specific quantities for DT and GEM studies (e.g.extrapolation)

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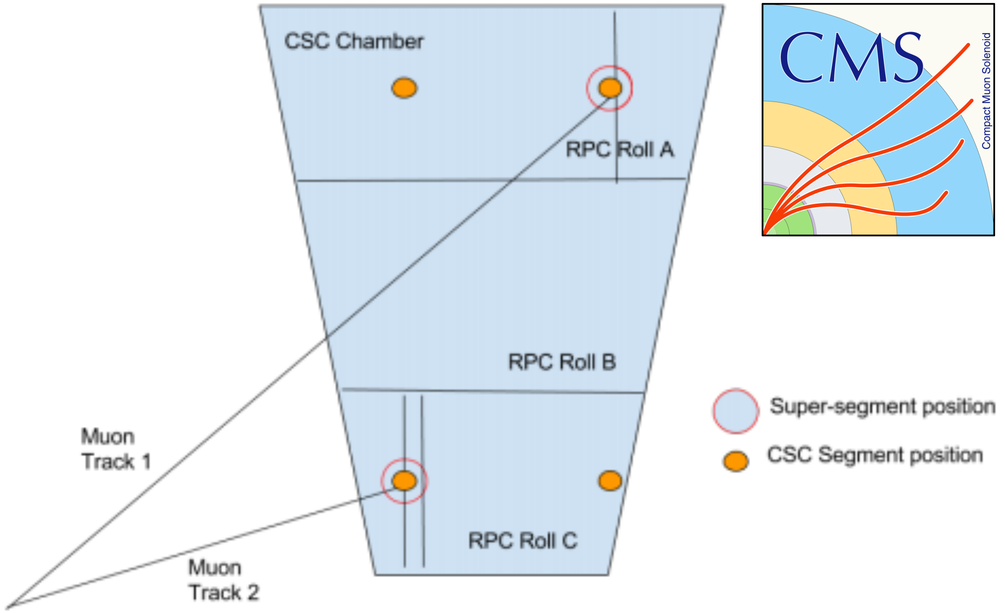
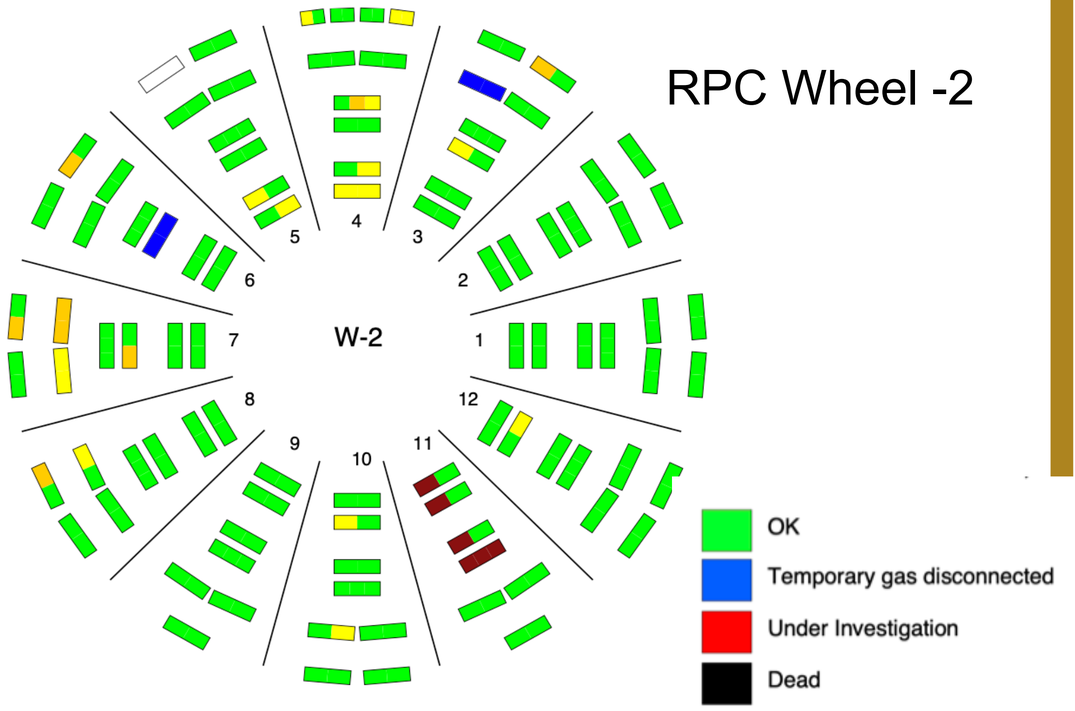
Offline Contributions

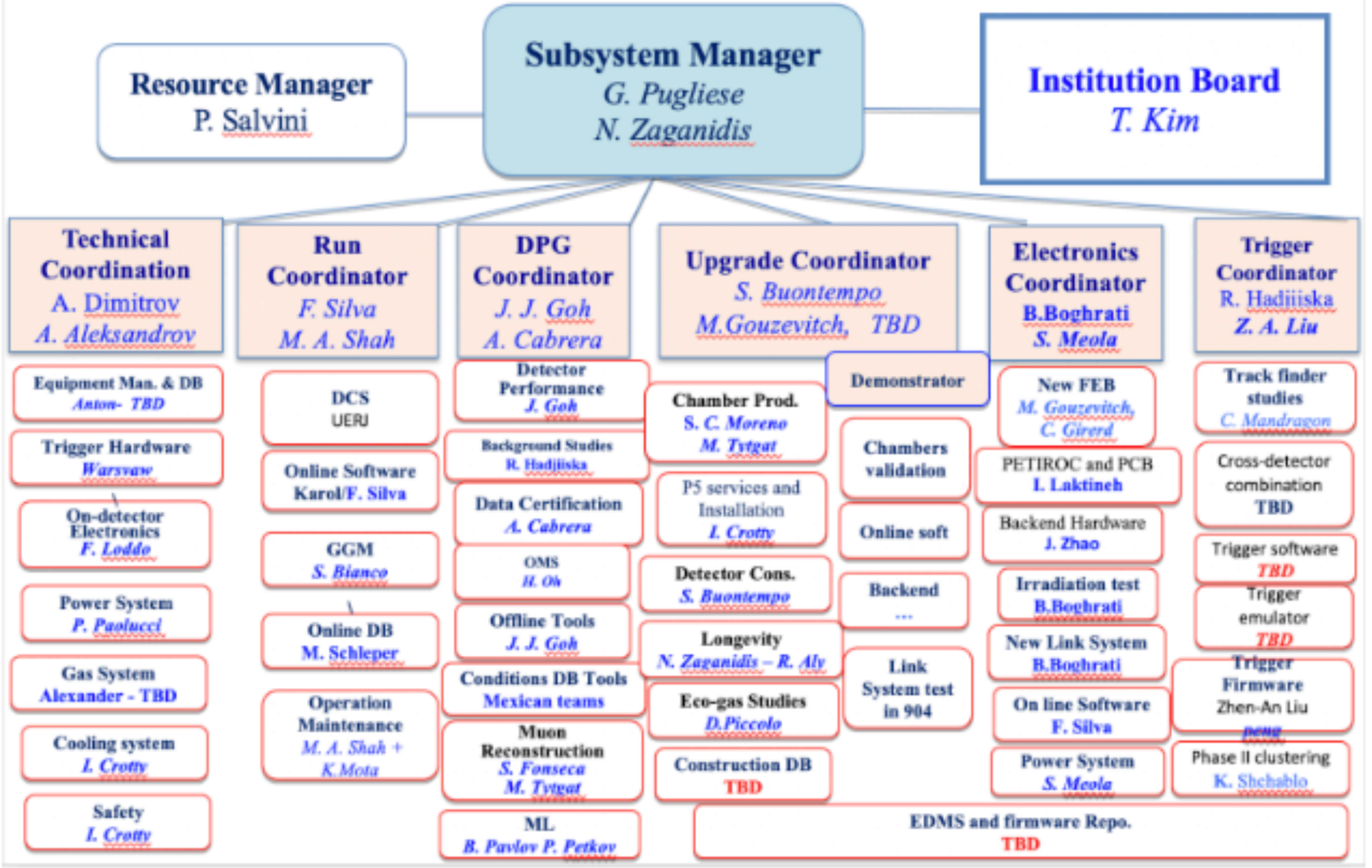
- RPC Muon Reco:
  - A super-segment object is being developed for muon reconstruction. Two of the CMS muon systems in the endcap region are being used: CSC (Cathode Strip Chamber) and RPC. The idea is to improve the muon reconstruction efficiency and resolution and help CSC with the fake tracks.
  - A similar idea is also being developed for CMS triggering combining CSC and RPC information in a lower level of data format.



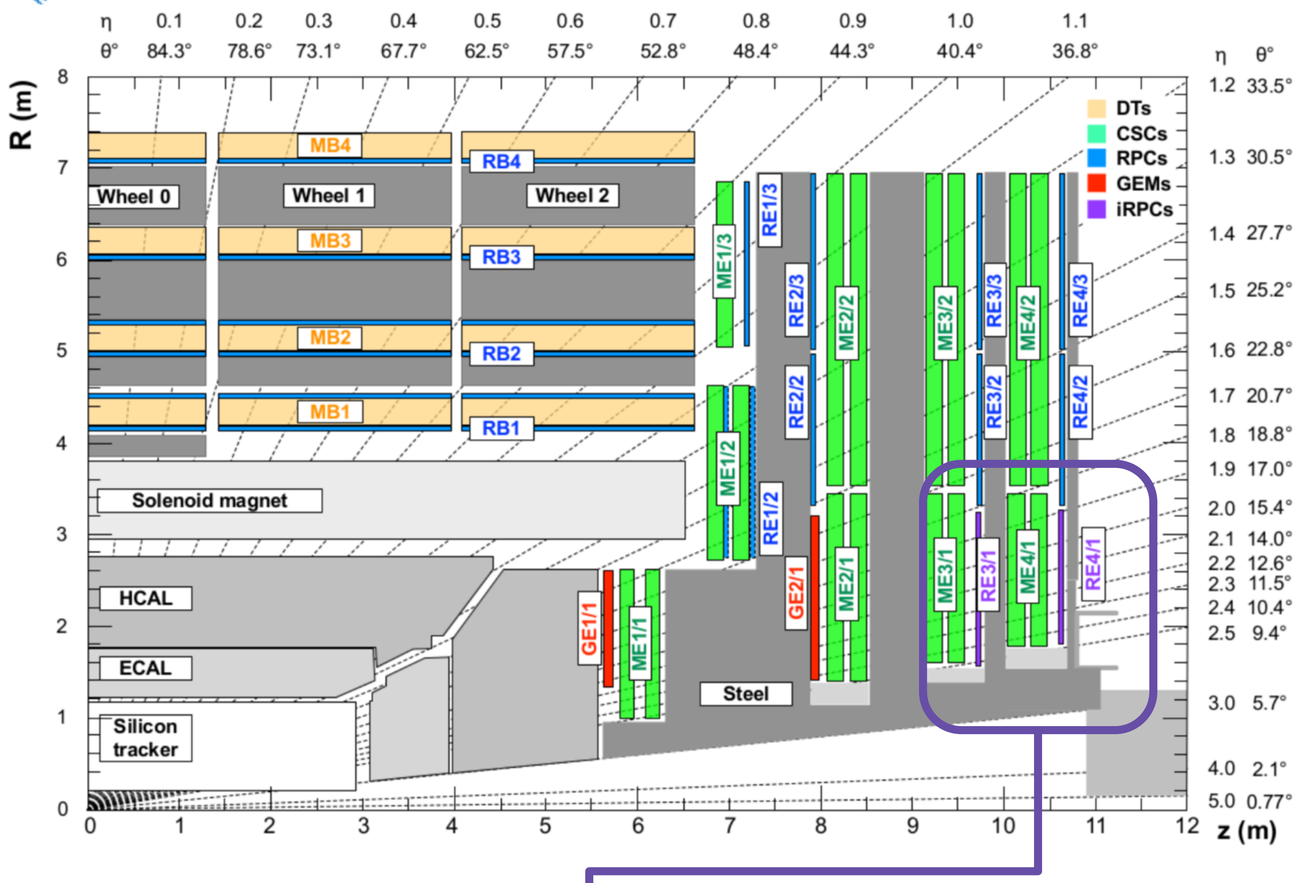
- Data Manager shifts:
  - CMS is taken data in 2021 for Run III preparation, the Middle Week Global Runs (MWGR). These periods are crucial for the commissioning of software and hardware. In the shifts, offline analysis of the collected data is made, and monitoring of the online tools for specific runs. More than 60 shift days were taken for us just in 2021.
  - Due to the pandemic, these shifts could be taken remotely this year. For next year, presence at CERN will be required to attend to the shifts.



RPC Management Board (2019-21)



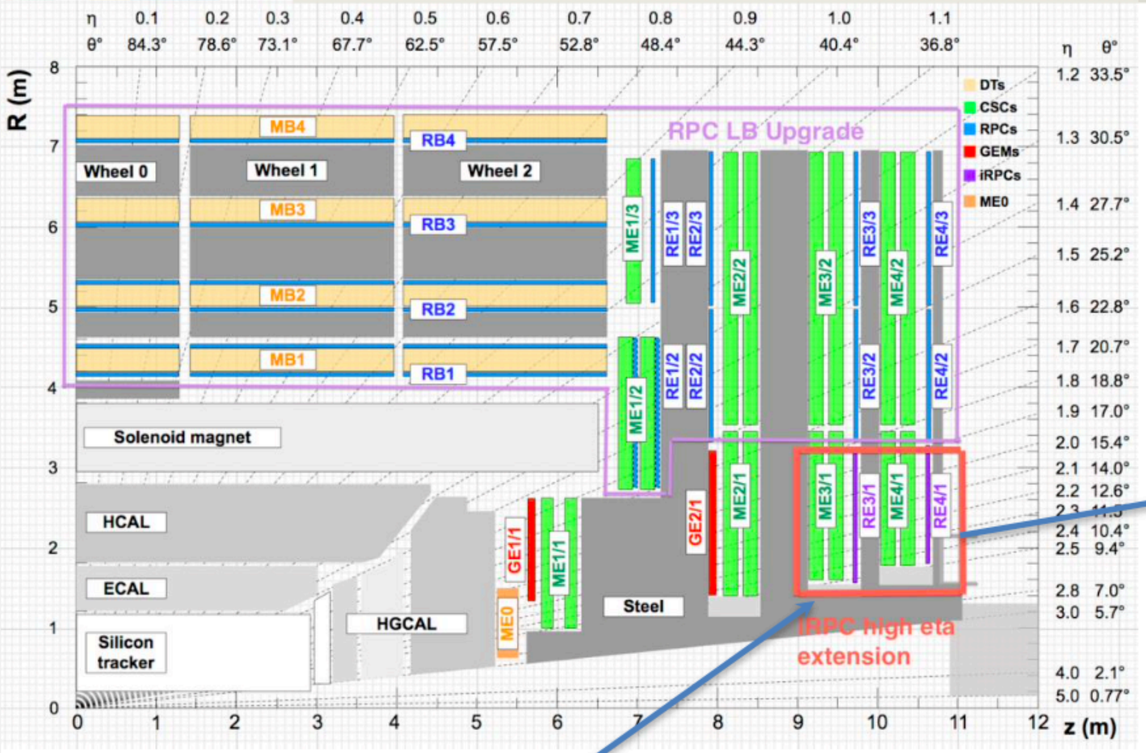
RPC Phase-2 Upgrade and RPC R&D



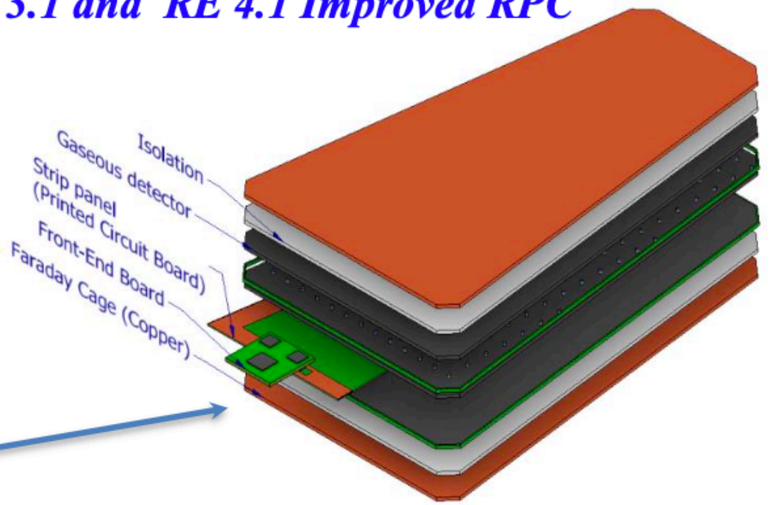
Phase-2 upgrade: RE3/1 and RE4/1: RPC extended η region.

- RPC will install 72 chambers in the high-η region (R&D ongoing).
- R&D at GIF++ (Upgraded version of the Gamma Irradiation Facility).
- The GIF++ is located at the H4 beam line in providing high energy charged particle beams (mainly muon beam with momentum up to 100 GeV/c), combined with a 14 TBq 137-Cesium source.
- Without LHC, GIF++ has no muon beam.
- For RPC R&D, can we have a cosmics trigger system not sensible to fakes from gamma background?

RPC Upgrade Project



RE 3.1 and RE 4.1 Improved RPC



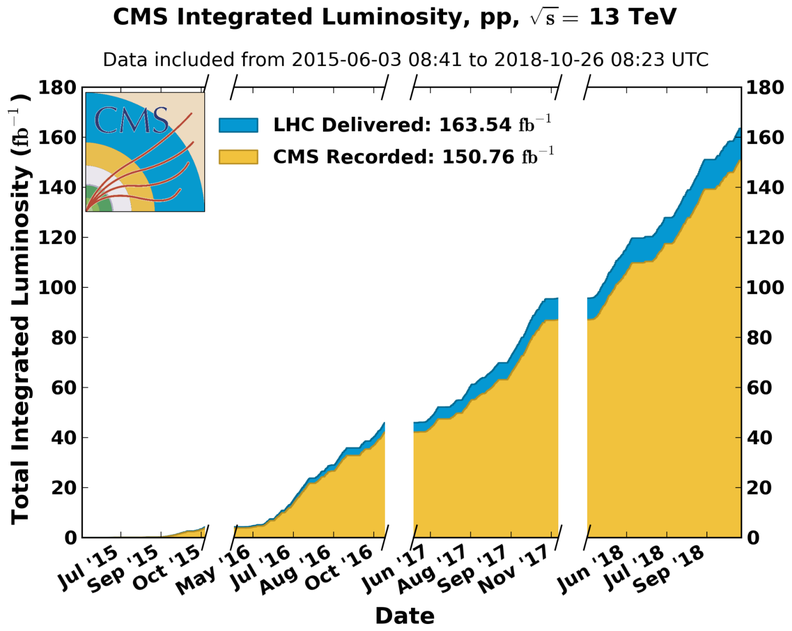
1 chamber ≈ **1.6 x 1.2 m² trapezoidal shape**

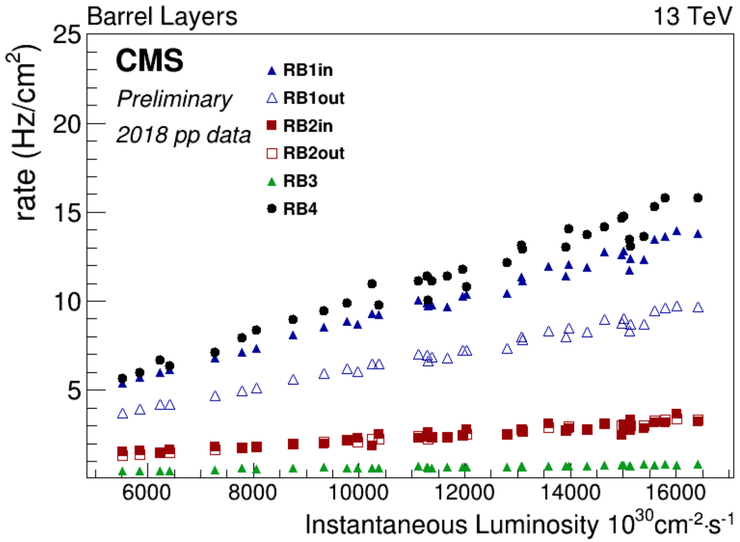
20° in φ ⟶ 18 chambers/disk

Total of 72 iRPC chambers

Extend the RPC coverage up to |η | = 2.4 to increase redundancy in high eta region in stations 3 and 4

Run-2 Data Taking summary





- CMS Recorded L_{int} ~150 fb^{-1} in Run 2:
- RPC run effectiveness was 99.97 %
- The amount of data classified as bad due to RPC was ~0.15 % (concentrated mainly in 6 events, because of electronic failures and software configuration errors).

- Background at L=1.5x10^{34}cm^{-2}s^{-1}:
- In Barrel RB1 and RB4 were the most exposed layers. Rate ~20 Hz/cm^2
- In Endcap RE4 station was the most exposed. Rate ~40 Hz/cm^2

- After ~ 9 years operation (~185 fb^{-1} integrated luminosity), the integrated charge is:
- ~2.3 mC/cm^2 for Barrel
- ~7.5 mC/cm^2 for Endcap

- Run 2 Experience : Crucial to study the system's longevity in view of Run 3 and High Luminosity LHC.

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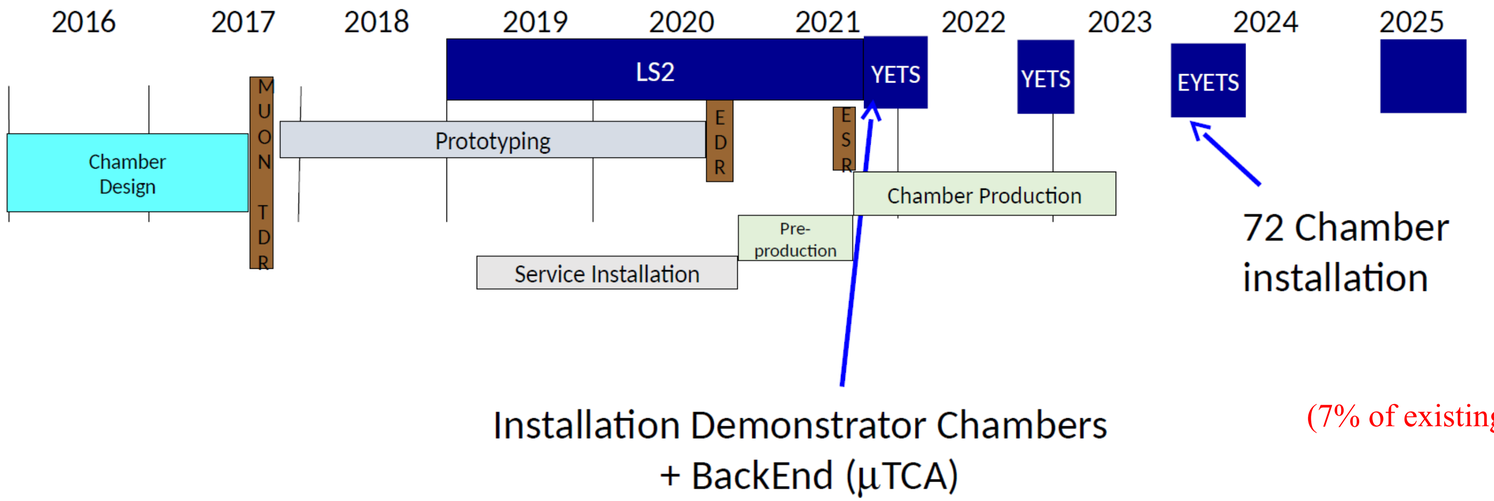
Demonstrator Project Timeline

- Services already installed for what requires the access to disks.
- Chamber assembled and arrival in 904 (without FEBs): Yesterday.
- Chamber QC with FEBV2.1: June 2021 (@904), July 2021 (@GIF++).
- Irradiation tests with photons in Caliope 12 of July.
- August-October 2021: Chamber validation with Cosmics @904 and @ GIF++ (1 chamber long term) using FEBV2.2 .
- Power and BE system to be installed (for Demonstrator only) in October 2021.
- Installation of 4 demonstrator chambers in P5: **2 RE4.1 (08/Nov) + 2 RE3.1 (15/Nov)**.
  - Installed, connected and commissioned in two separate configurations.



(7% of existing RPC)

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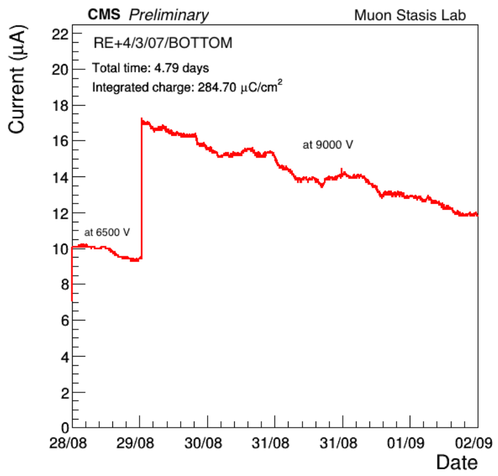
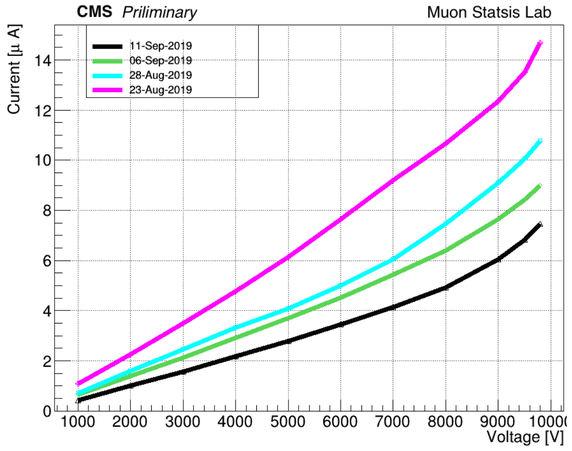
RE4+ activities

- The fourth endcap muon stations RE+4 and RE-4 were extracted during LS2 to allow the CSC ME4/1 extraction to replace their electronics.
- A new lab with controlled environmental conditions (temperature and relative humidity) was built in a building at CMS to house these detectores.
- After their powering on the surface the currents on the detectors were found higher than their last values at the end of RUN 2. The reason is unknown but could be due to the different environmental conditions. This is not clear yet and the reasons are under study.
- The chambers were put under stable HV for long periods, then the currents decreased to their normal value, as in the end of RUN 2.
- The recovery time of the currents was found to be around 15 days in average. This information is valuable as we can estimate how many days would take to return the currents back to the good values for other detectors in the future.
- Besides that, dedicated noise studies were performed in order to evaluate if the front-end-electronics of theses chambers were in a good stage, i.e., no noise and all strips with signal.
- The chambers were installed back at CMS cavern and are now prepared to take data for the RUN 3.





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