Status of the CMS Muon System

XII International Conference on New Frontiers in Physics

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University of Pavia & INFN Sez. Pavia

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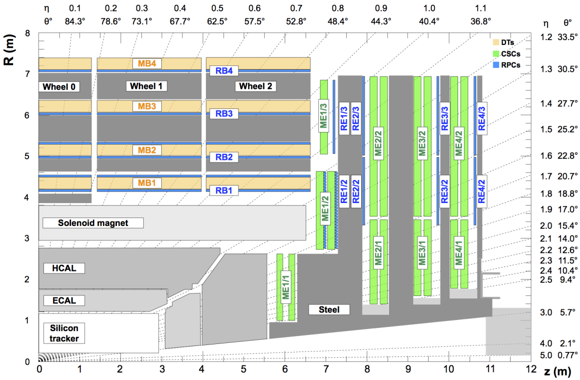
CMS Muon System – Run 1 & 2 configuration



Goal

Muon identification, momentum measurement and muon trigger

Gaseous detectors technologies

- Drift Tubes (DT)
- Cathode Strip Chambers (CSC)
- Resistive Plate Chambers (RPC)

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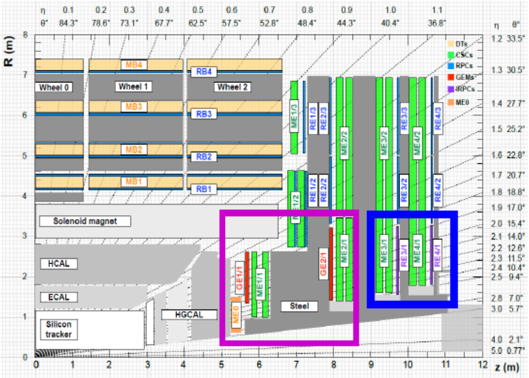
CMS Muon System Ugrade



HL-LHC → New muon stations to:

- Improve the redundancy in the high η region
- Handle a rate of 10's of kHz/cm^2
- Survive to an intense background rate

Gaseous detectors technologies

- Drift Tubes (DT)
- Cathode Strip Chambers (CSC)
- Resistive Plate Chambers (RPC) - improved-Resistive Plate Chambers (iRPC)
- Triple-Gas Electron Multiplier (GEM)

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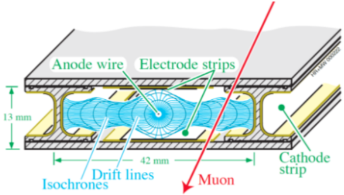
Drift Tubes

Responsible for identifying, measuring, and triggering muons by the precise measurement of their position.



250 DT chambers to cover the full barrel region:

- 4 concentric station *rings* (MB1 to MB4)
- 5 *wheels* parallel to the beam line (W-2 to W+2)
- each wheel subdivided into 12 sector *slices* (S1 to S12)
- smallest unit of a chamber is called *cell*

Performance:

- efficiency $> 99\%$
- position resolution $\sim 100\ \mu$m
- time resolution $\sim$ 2-3 ns

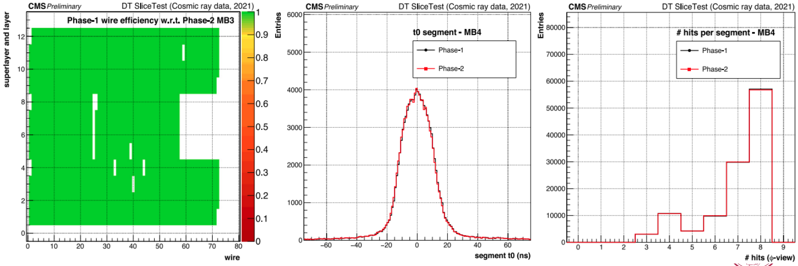
With HL-LHC DT performance *could degrade*:

- Ageing tests confirm chamber performance will remain within acceptable limits
- DT readout and trigger electronics must be relaced → *Phase-2 DT upgrade*

DT slice test

During Long Shutdown 2, 4 chambers of W+2 S12 were equipped with the new **On-Board DT (OBDT) electronics**, based on new Time-to-digital (TDC) electronics → *DT slice-test*.

The signals from the front-end electronics of all slice-test chambers are split and sent in parallel to the OBDTs and to the existing DT readout (RO) and trigger (TRG) electronics → preserve full DT coverage during Run3.



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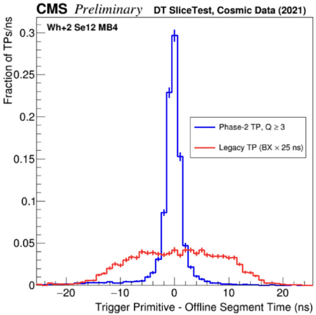
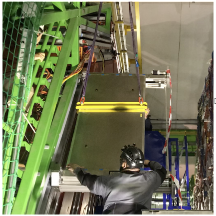
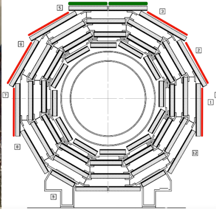
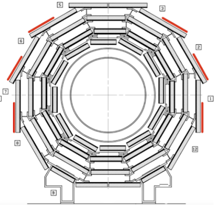


DT: background and ageing monitoring

The background induced by LHC colliding beams in the DT concentrates in two main regions:

- the chambers located in high $|\eta|$ regions
- the topmost chambers, exposed to a *gas* of thermal neutrons filling the space between the detector and the cavern ceiling.

→ shieldings[1] installed above the detector in order to reduce the background of the second type

[1] in memory of Alberto Benvenuti

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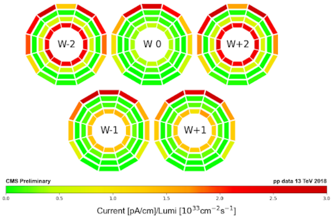

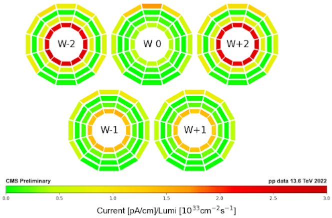

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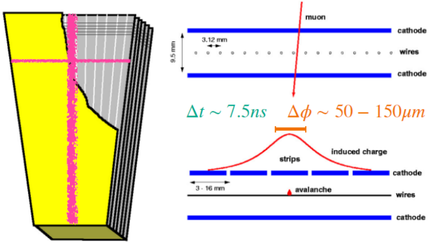
Cathode Strip Chambers

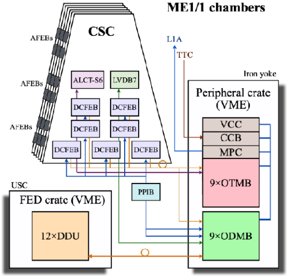


- CSCs are 6-layers of wires (anodes) and strips (cathodes) in $Ar/CO_2/CF_4$ gas mixture
  - Traversing muons ionize gas
  - Avalanche signal read by anode and cathode electronics
- CSCs measure 2D position
- Time resolution $\sim$ 3-4 ns

CSCs upgrades for HL-LHC:

- Cathode Front End Board (CFEB) needs more memory, analog storage replaced with digital/flash (D)CFEB
- Local track builder need more memory and bandwidth, install new FPGAs with better buffer
- New electronics increase power consumption
- Optical readout necessary throughout muon systems

Cathode Strip Chambers electronics



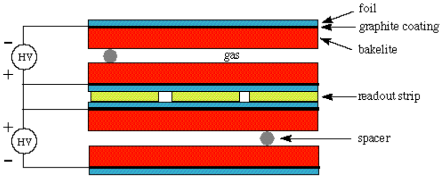
Phase-2 upgrade

- DCFEBv2+Cooling for ME1/1
- DCFEBs for ME234/1
- LV for ME1234/1
- ALCT Mezzanine for ME1234/1, ME123/2
- Upgrade Trigger Electronics

Upgrade of the LV system

- Need to satisfy new power requirement of DCFEBs in ME234/1
- Low-Voltage Distribution Boards produced and installed on each of 18 chambers for the inner-rings (1) of 2/3/4 stations, 108 total
- Junction Boxes distributing LV supply installed in Summer 2020
- Additional 12 Marathon power supplies installed

Resistive Plate Chambers

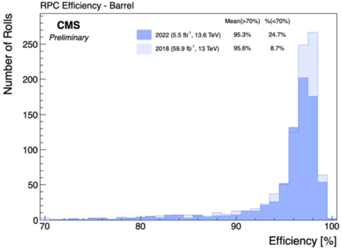


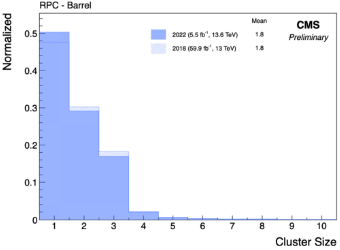
RPC present system

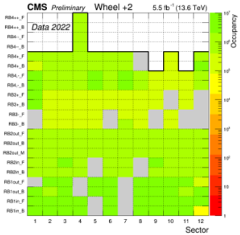
- Covers $|\eta| < 1.9$
- Total of 1056 chambers (480 in barrel and 576 in endcap)
- More than 110000 electronic channels
- Strip width: 1-4 cm.
- Operated in avalanche mode

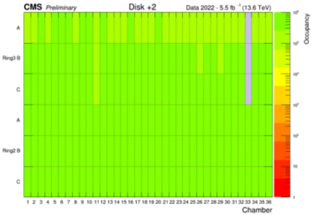
- High rate capability ($\sim$300 Hz/cm^2)
- Intrinsic Noise $<$ 5 Hz/cm^2
- High detection efficiency $>$ 95%
- Average cluster size $\sim$2 strips
- Intrinsic time resolution $<$ 1.6 ns (BX identification)
- Spatial resolution $\sim$ 10 mm
- Ability to withstand in long term operation and high background radiation

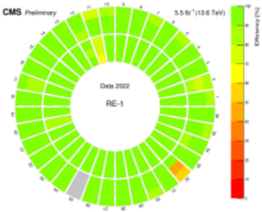
RPC early Run 3 performance



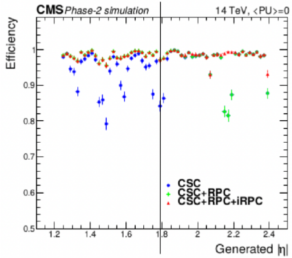








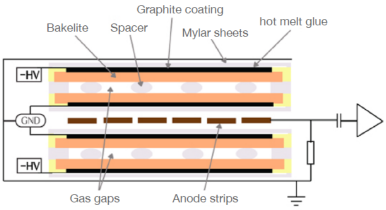
iRPC upgrade



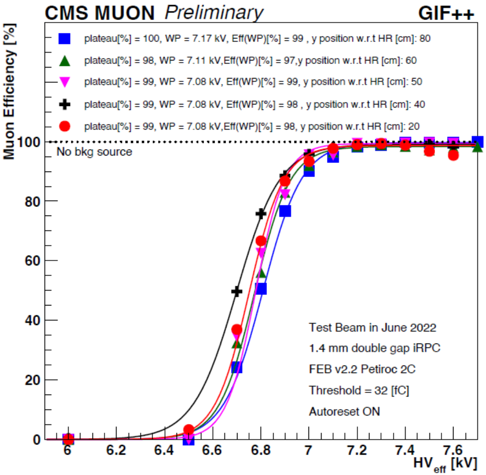
Motivation: The inclusion of iRPC hits in the endcap muon track finder algorithm allows to have an efficiency >90% everywhere.

Which kind of detectors?

- Double-gap iRPC detectors
- Each gap made of two 1.4 mm low-resistivity (10^{10} Ωcm) HPL electrode
- 1.4 mm gas gap

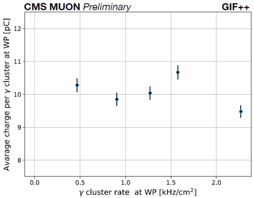


iRPC at GIF++

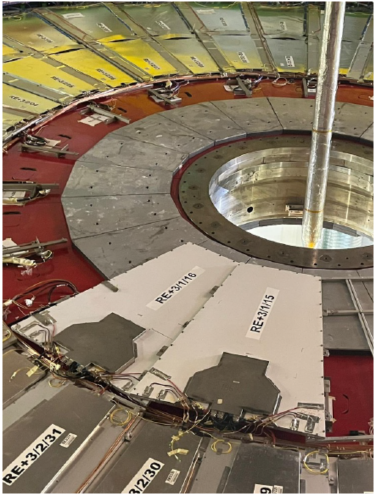


iRPC were extensively tested at GIF++ in the past years, to verify their performance in a CMS-like environment

- efficiency in the different regions of the detectors is 98±1%
- WP = HV_{knee}+120 V

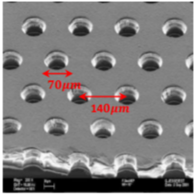


iRPC demonstrator



Four demonstrator chambers were installed in CMS at the end of LS2 and are currently taking data in Run3.

Gas Electron Multipliers

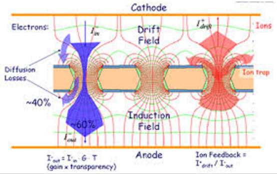


GEM foil:

- 50 μm-thick polyimide foil copper-cladded on both sides
- Holes in hexagonal pattern, with 70 μm diameter and 140 μm pitch

Functioning criterion:

- Ionization happens in the drift region ($E_d \sim few\ kV/cm$)
- Electrons move towards the GEM holes → inside the holes the electric field is much more intense ($E_d \sim few\,10\ kV/cm$) → amplification region
- Amplified electrons move towards the anode, while the ions go back

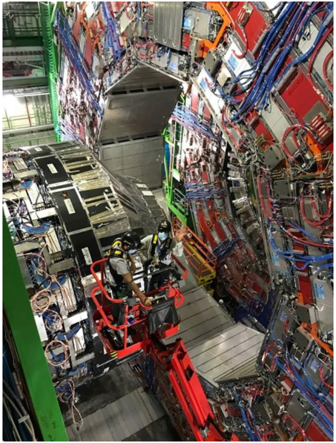


https://sal.aalto.fi/publications/pdf-files/twar15_public.pdf

GE1/1 in CMS

GE1/1 project

- 144 Trapezoidal Chambers → coupled in 72 superchambers (36 per endcap), each spans ∼10°
- Long and Short superchambers alternate to maximize the η coverage
- Installation completed in 2020, currently taking data in Run3.



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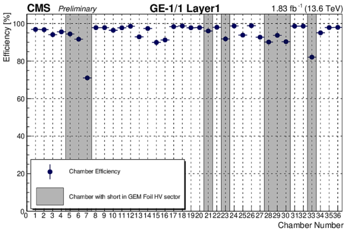
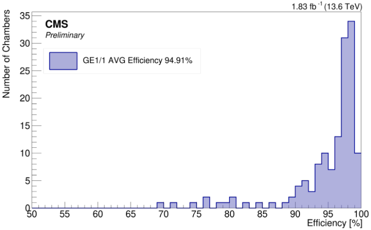
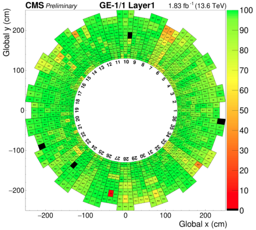
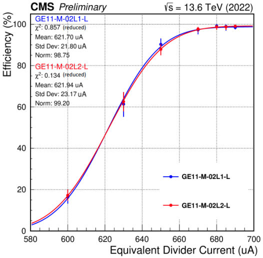
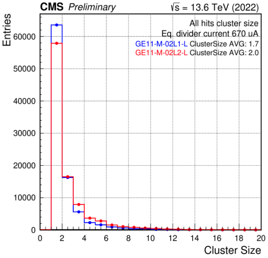
GE1/1 early Run3 performance







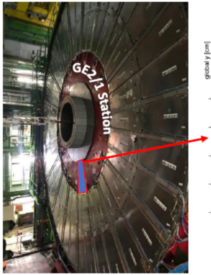


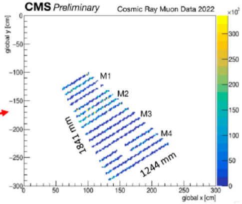


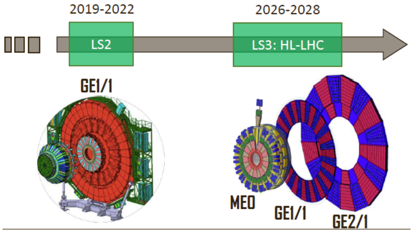
The future: GE2/1 and ME0

GE2/1 and ME0 stations

- GE2/1:
  - Mass production started; installation foreseen for winter 2023 & 2024
  - Demonstrator chamber installed and included in data taking
- ME0:
  - High background rate expected in O(100 kHz/cm^2)
  - Design optimization for the harsh environment.







Summary

The CMS muon system is being upgraded to improve the redundancy in the high η region and to cope with the expected harsh environment of HL-LHC.

Interventions are being performed on the existing detectors and new stations equipped with different technologies are being installed.

The early performance obtained from the first year of Run3 datataking show that the system is healty and functioning as expected.

Thanks for your attention!

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