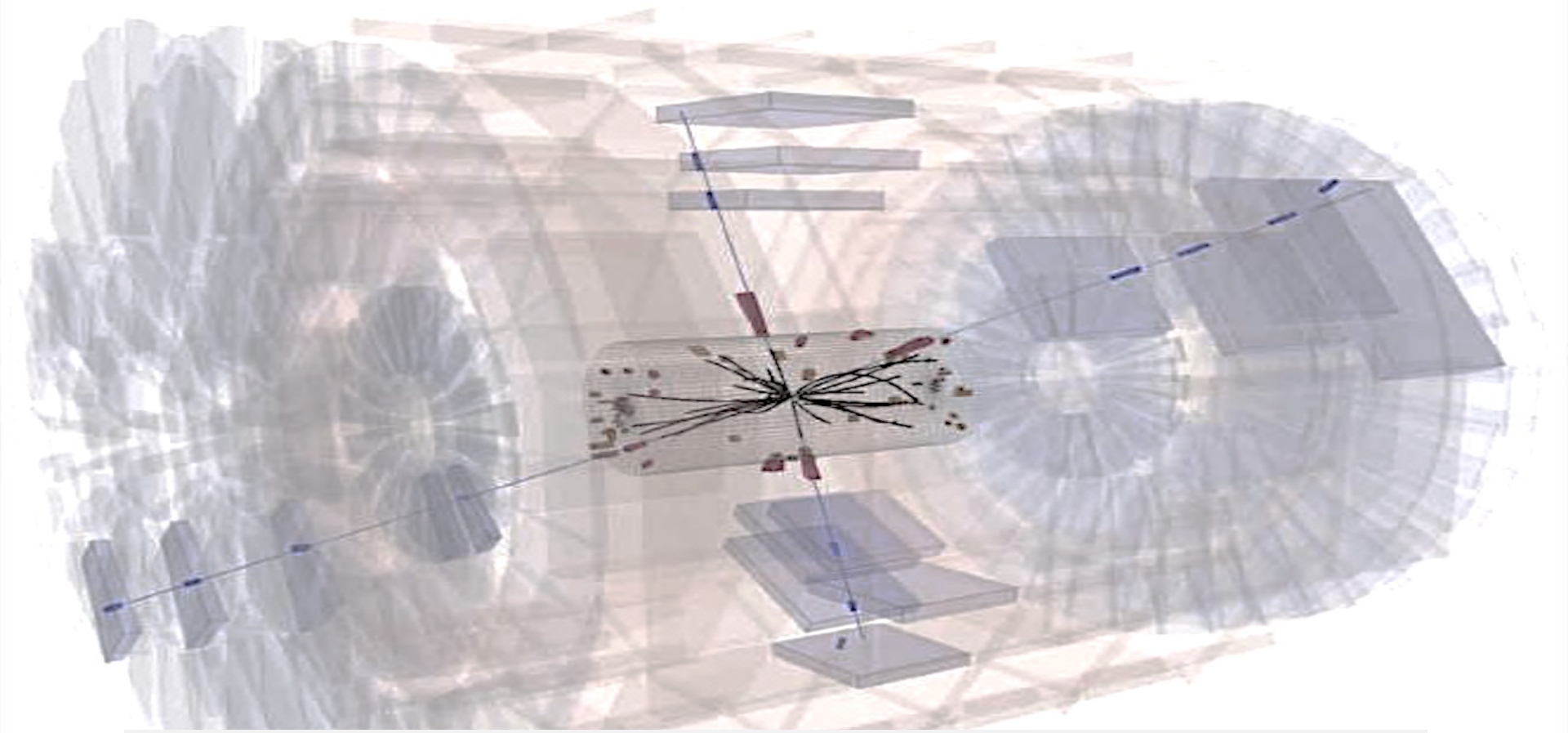
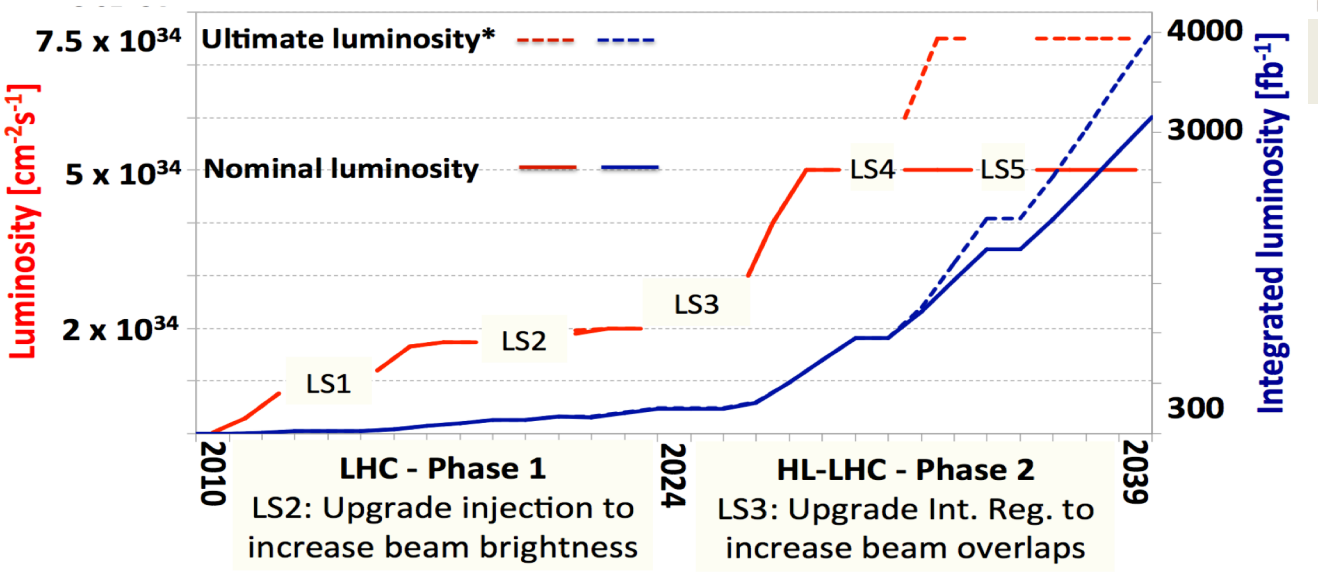


Upgrade of the CMS Muon system in preparation of HL-LHC

Anna Colaleo - INFN-Bari
On behalf of CMS Muon group

ICHEP 2018, Seoul July 5th

CMS Upgrade towards HL-LHC



PU ~200

Goal: keep the same performance as in Phase-1

CMS Upgrades

- New tracker (4 pixel layers +3 disks)
- New trigger/DAQ:
  - Track information at L1 with extended trigger latency (total of 12.5 μs)
  - Increased L1 bandwidth to 750 kHz
- Calorimeters with higher granularity
- Upgrade of Muon system

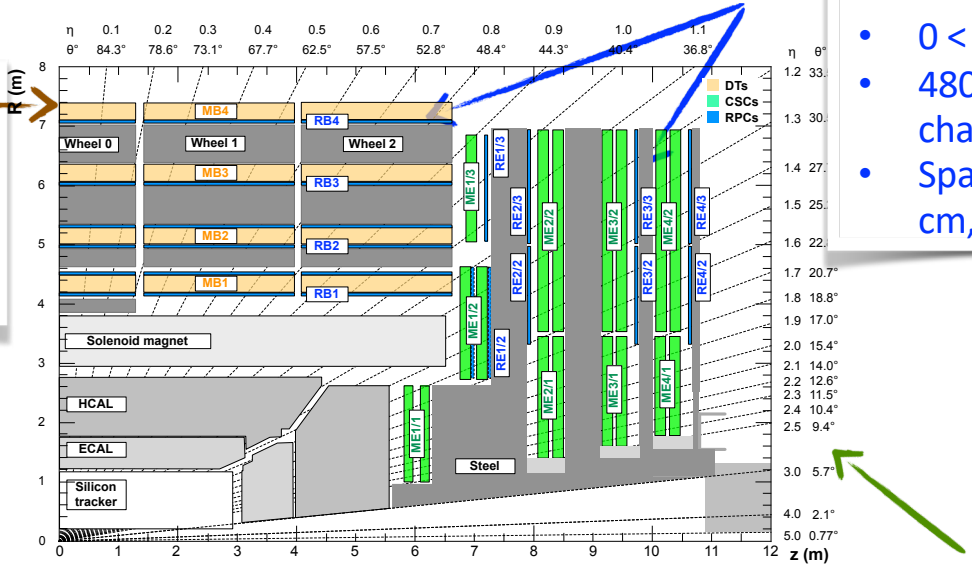
$|\eta| < 3$

Present muon system

Robust trigger and efficient muon reconstruction

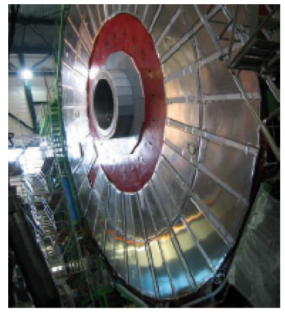
Drift Tube (DT):

- $0 < |\eta| < 1.2$
- 250 chambers
- Spatial resolution 100 µm time resolution 2 ns



Resistive Plate Chamber (RPC)

- $0 < |\eta| < 1.8$
- 480 (barrel) + 576 (endcap) chambers
- Spatial resolution 0.8-1.3 cm, time resolution 1.5 ns



Cathode Strip Chamber (CSC)

- $0.9 < |\eta| < 2.4$
- 540 chambers
- Spatial resolution 50-140 µm, time resolution 3 ns

All currently installed Muon detectors will be kept operational at HL-LHC

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

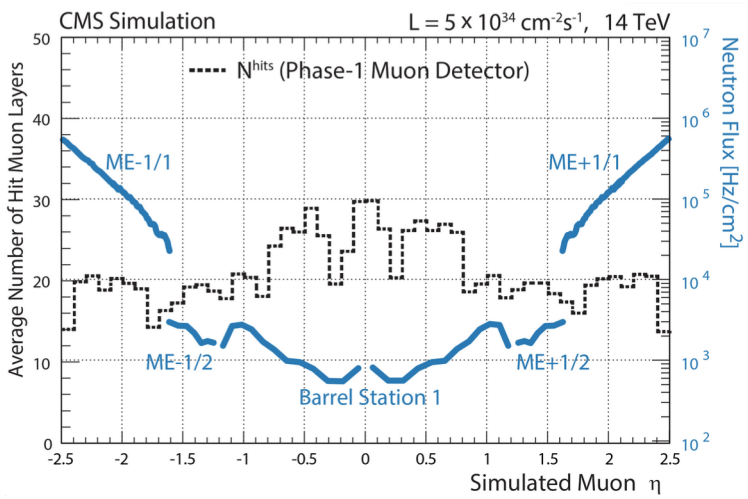
- while detector life expectancy (related to radiation damage) is more than acceptable

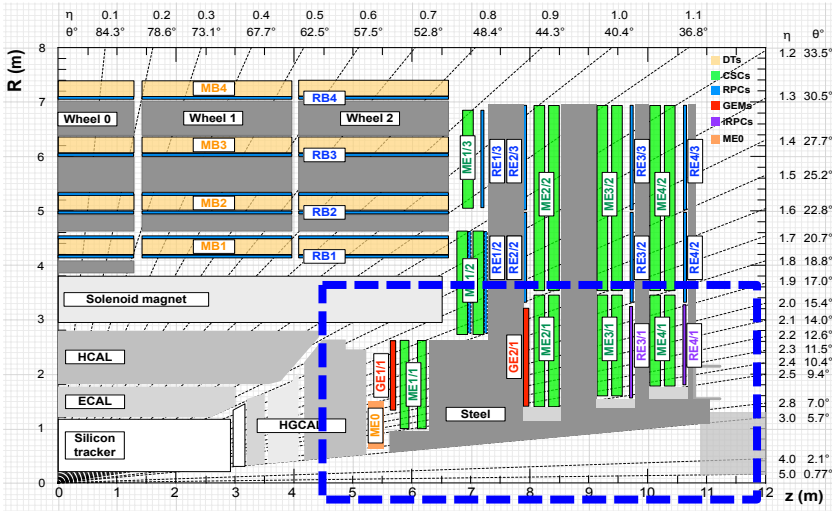
3. event reconstruction capabilities (trigger and offline) require, particularly in forward region:

- 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"

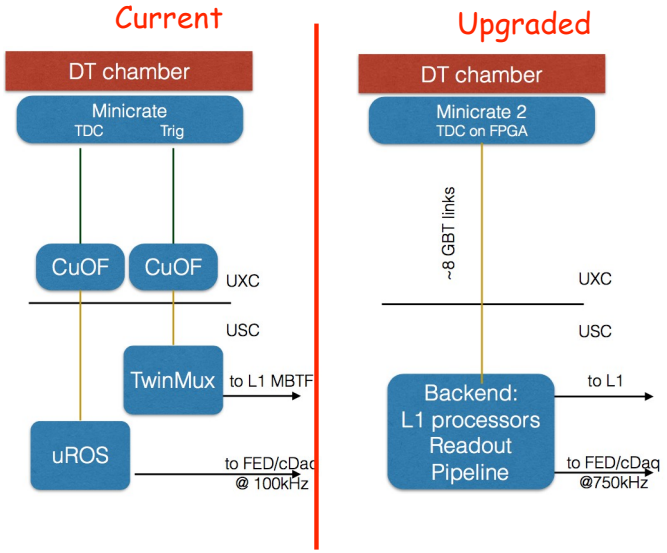




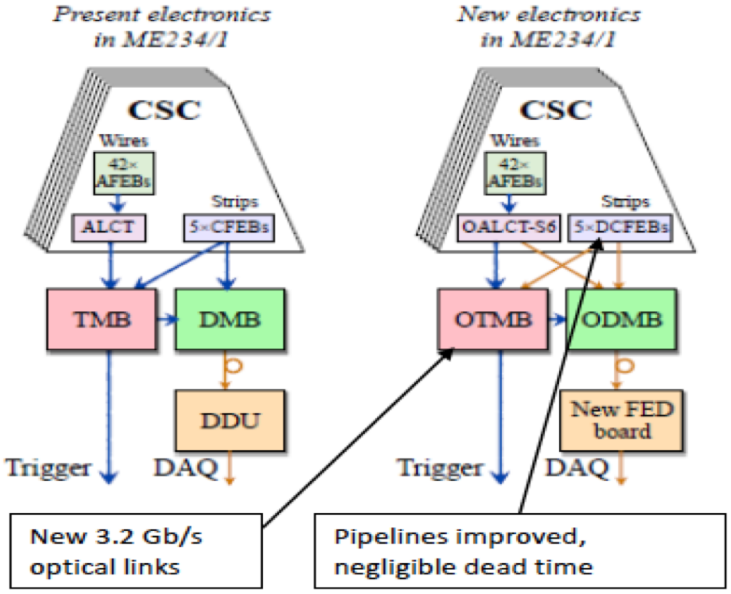
Electronics upgrade

DT: on-chamber readout and trigger electronics to be replaced, to cope with higher rate and radiation.

Trigger logic system to be moved to the service room easy to maintain



CSC: Selective replacement of electronics for inner ring chambers - high speed optical links, faster processor, deeper buffer



RPC: The Link System, connecting the on-chamber board to the trigger processors to be replaced

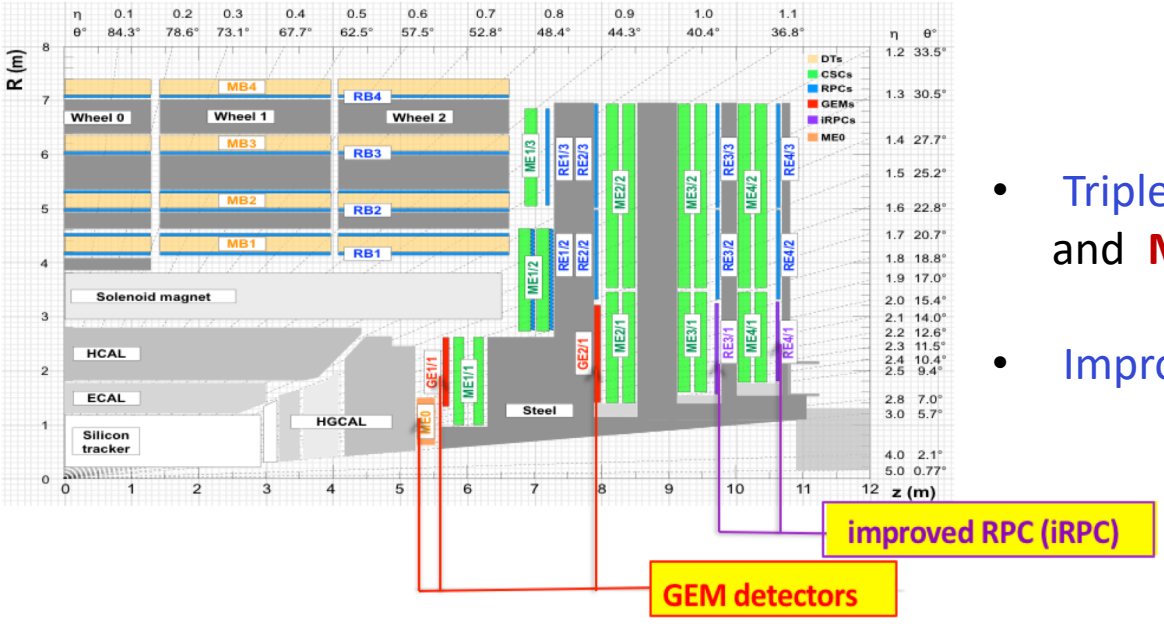
- For convenience of operation and maintenance
- To full exploit the detector timing information (resolution ~1.5ns) thus improving the L1 trigger capabilities.

Enhancement and extension of the forward region

New forward muon detectors:

- to handle the most difficult region with high backgrounds, high readout and trigger rates and limited muon-bending at higher pseudo-rapidity.

- to extend the μ coverage by up to η=2.8
  - useful for muon-tagging and triggering, allows reduction of the lost-muon background



- Triple GEM technology in **GE1/1**, **GE2/1** and **ME0**

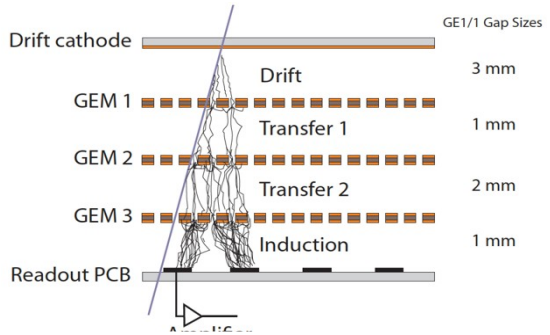
- Improved RPC (iRPC) in **RE3/1** & **RE4/1**

The GE1/1 and GE2/1 detectors

Two additional detectors with good spatial resolution for triggering and reconstruction purpose

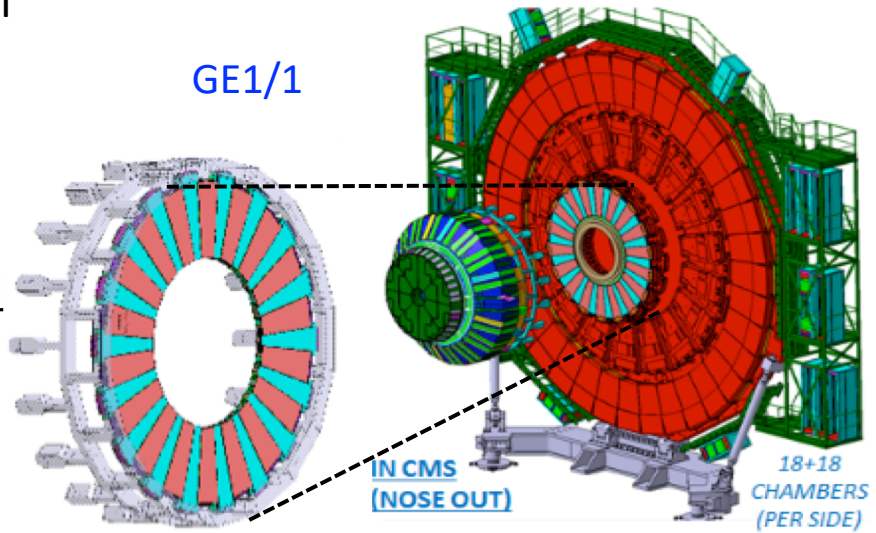
Based on triple-GEM technology:

- High spatial resolution O(100 μm)
- Rate capability to MHz/cm2
- very resistant to aging



Two layers of triple-GEM (super-chamber) in front of existing CSC chamber.

GE1/1

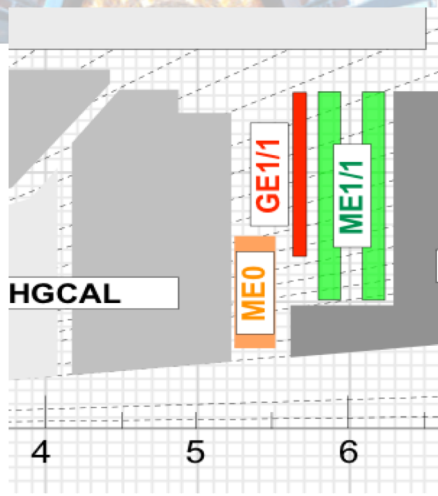


- GE1/1 consists of 72 10° triple-GEM super-chambers
  - Covers 1.6 < |η| < 2.2 and it would be installed already in LS2.
- GE2/1 consists of 20° 36 triple-GEM super-chambers
  - Covers 1.6 < |η| < 2.4 and it would be installed in YETS after LS2

See also M. Gruchala's and I. Yoon's talk in this session

The ME0 Detector

New station to efficiently identifying and triggering muons, low in transverse momentum (but large in momentum) while maintaining a low rate of background in the harsh HL-LHC conditions up to η=2.8.
Installation scheduled in LS3.



- ME0 consists of 6 layers of triple-GEMs arranged in 20^0 super-module wedges: 216 chambers.

High granularity and spatial segmentation for:

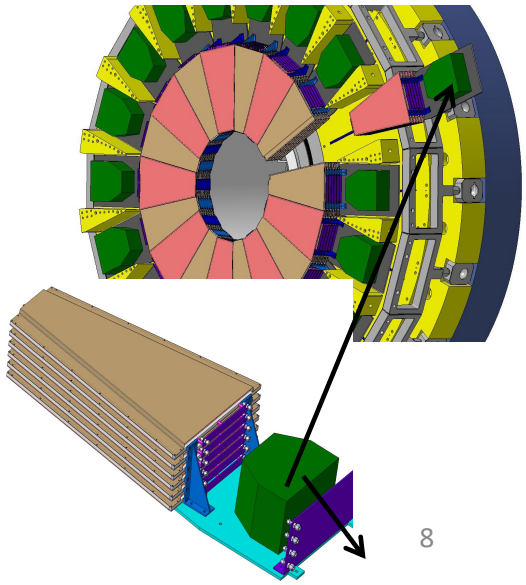
- Position and bending measurement of the muon stubs for efficient matching of the offline pixel tracks.

Multi-layered structure to:

- improve local muon track reconstruction
- discriminate muon (segment) against neutrons (uncorr hits).

Large lever arm between ME0 and CSC (ME1/1) up to η~2.4

- Allows large trigger rate reduction

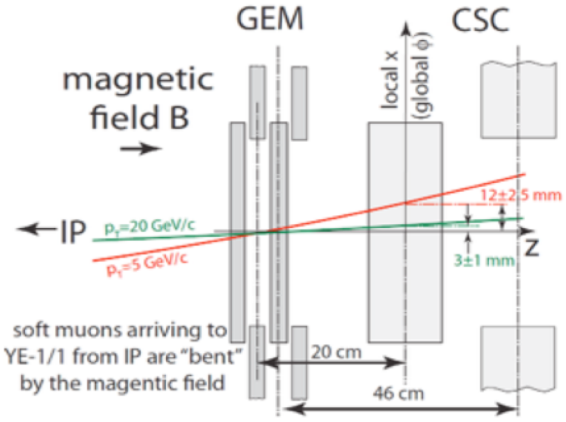


Muon trigger improvement

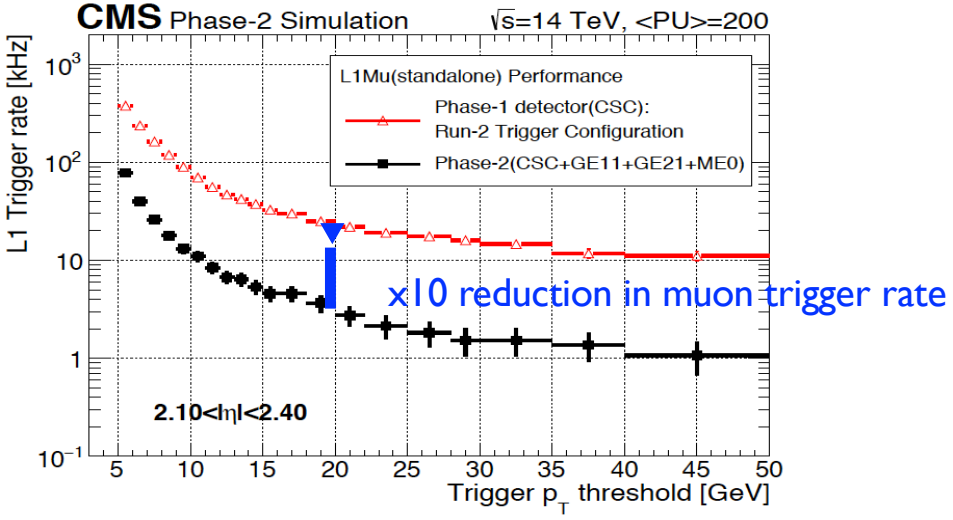
CSC-GEM tandem improves trigger-level muon momentum measurement, by providing the local direction measurement

Background has steeply falling momentum spectrum

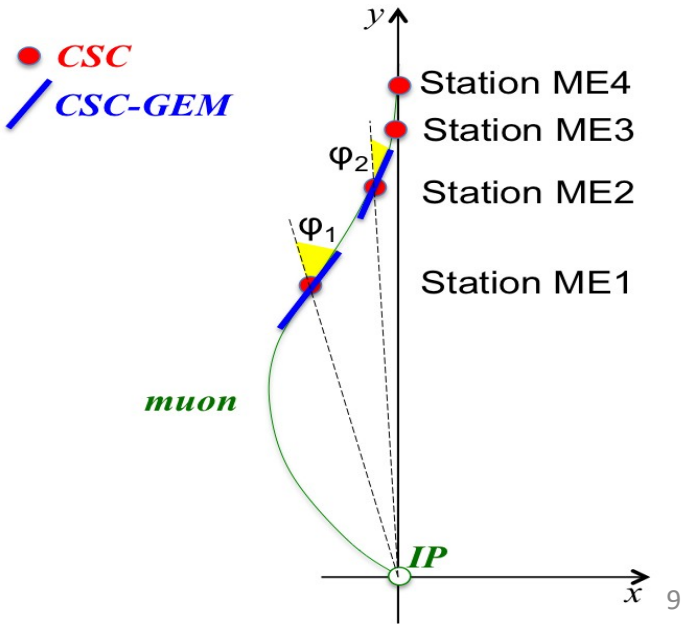
- Trigger rate reduction (otherwise raising trigger thresholds would harm physics acceptance)



Schematic view of a muon trajectory from the collision point



x10 reduction in muon trigger rate

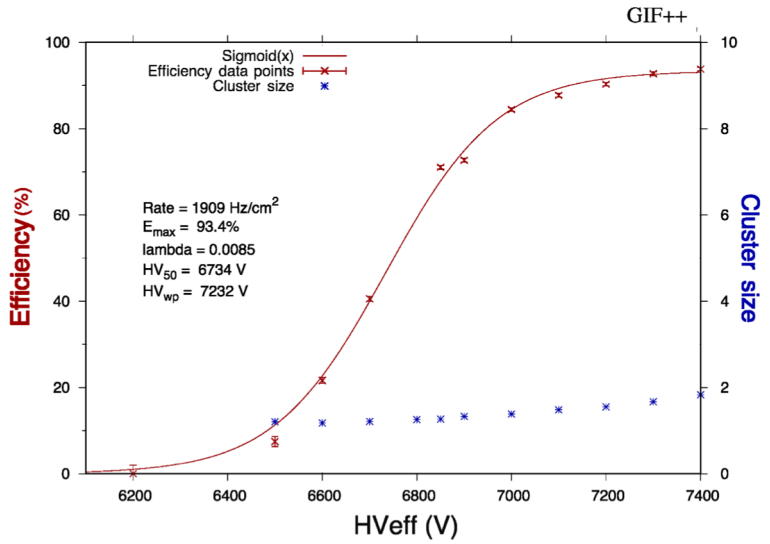


RPCs for RE3/1 and RE4/1

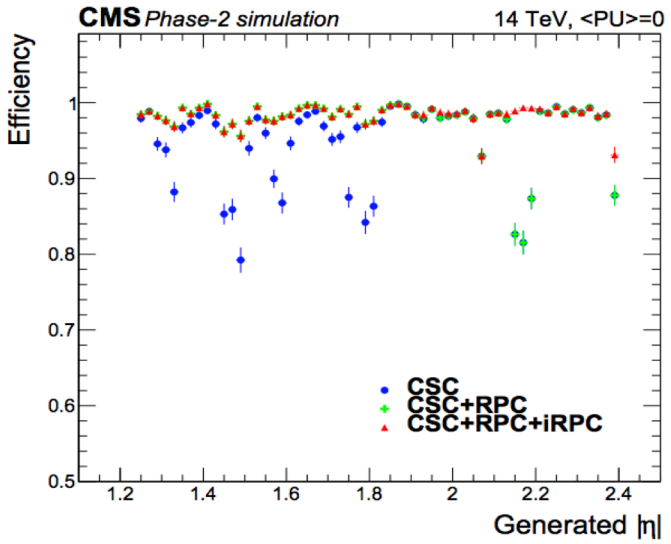
New 72 detectors (RE3/1 and RE4/1) provide additional hits in $1.8 < |\eta| < 2.4$ and remove ambiguities at the L1 trigger. Installation already in YETS after LS2

- **improved design of RPCs** (iRPCs), able to handle the particle rates in the high pseudo-rapidity region (2 KHz/cm^2 with safety factor 3)
  - Reduced electrode and gas gap thickness (<1.4 mm vs present 2 mm)
  - New generation low-noise FE electronics for high efficiency and less aging and two-ended strip readout to improve spatial resolution.

ε ~95% at 2 kHz/cm^2 rate, with cluster size < 2 strips

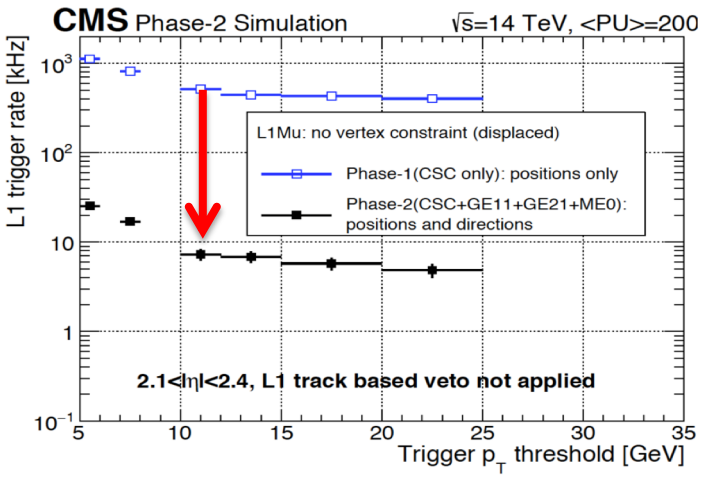


ε > 90% everywhere if RPC hits in the track finder trigger algorithm



See also M. Gouzevitch's talk in this session

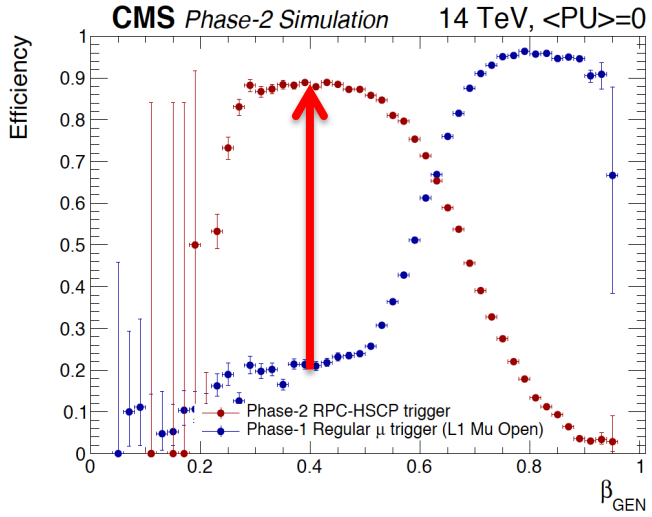
New physics search: triggering on unconventional signals



Trigger on highly displaced muons

Adding GEM makes it possible to build trigger- level muons without assuming muons come from the proton collision point

factor of 50 improvement



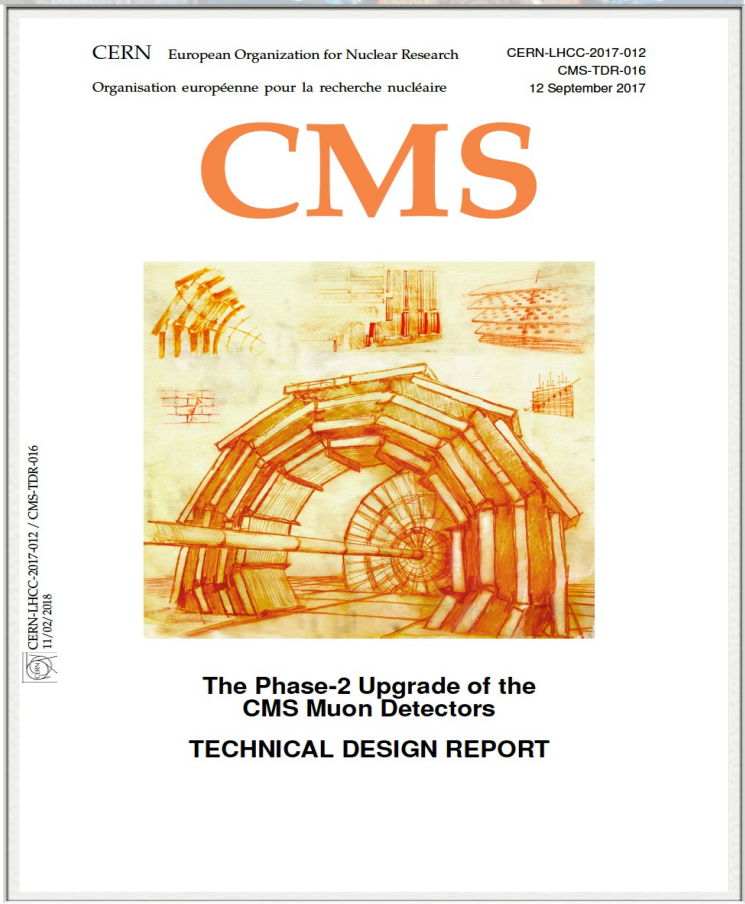
Trigger on Heavy Stable Charge Particles

The upgraded RPC link system fully exploits the RPC time resolution, enabling to identify patterns of delayed hits from one station to the next, with a precision of ~1 ns

up to a factor 4-5 improvement

Summary

- Present detectors will stay.
- Some electronics to be replaced to meet HL-LHC requirements.
- The high η region to be enhanced with additional GEM and iRPC detectors.
- Upgraded detector capabilities open windows for new physics opportunities.
- Installation starts in the Long Shutdown2 (2019-2020); continues in Year-End-Techinical-Stops; and finishes in the Long Shutdown 3 (2024-mid 2026)
- CMS Muon Upgrade TDR is published



Additional info in posters:

- Measurement and simulation of the background in the CMS muon detectors. Speaker: Y. Kang
- Aging Studies of the triple-GEM detectors for future upgrades of the CMS muon high rate region at the HL-LHC Speaker: F. Fallavollita