CMS Phase-II Upgrade of the Muon System (iRPC)

XXX Reunión Anual de la División de Partículas y campos de la SMF

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México/General timezone

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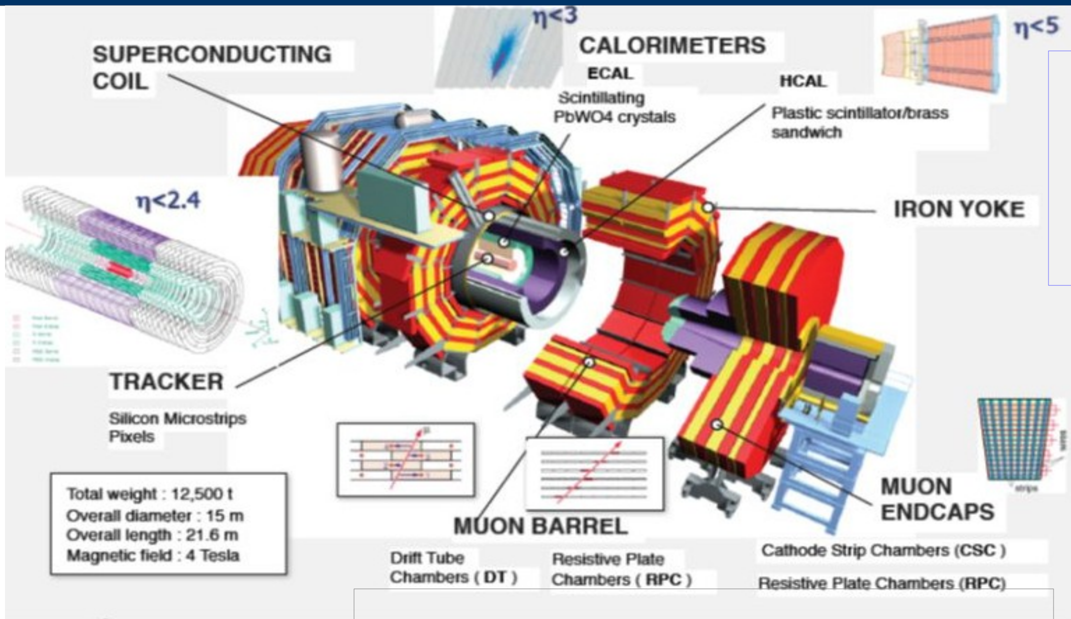
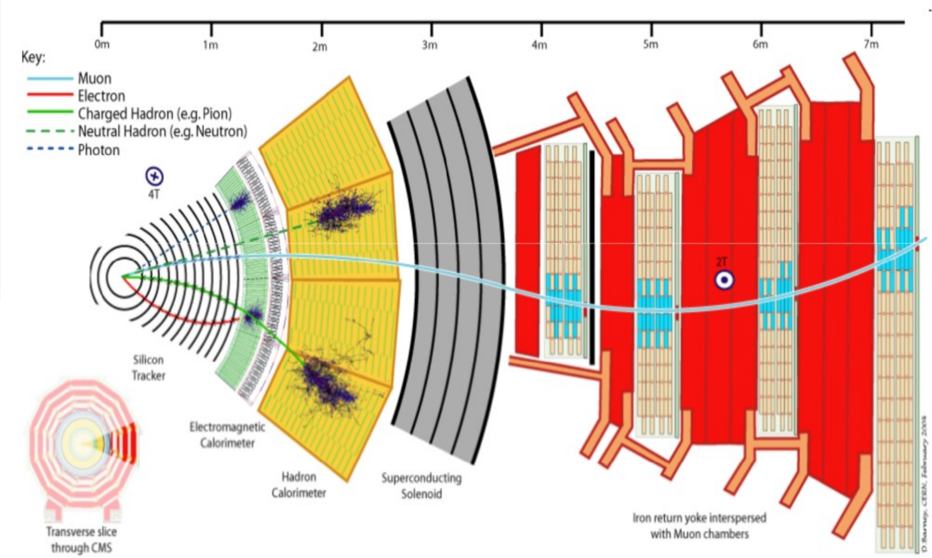
Compact Muon Solenoid (CMS)



"Compact Muon Solenoid"

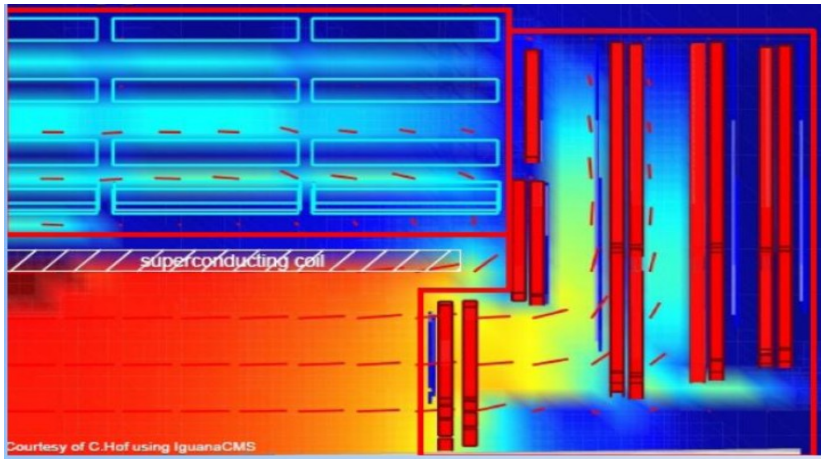
Detecting muons is one of most important tasks.

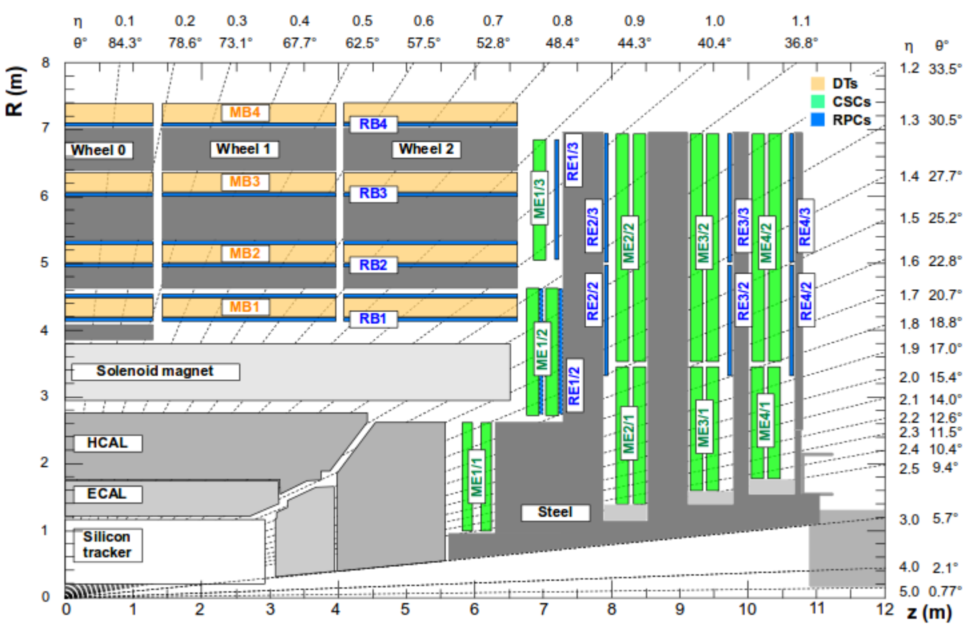
Is designed to see a wide range of particles and phenomena produced in high-energy collisions in the LHC



CMS Status Report.
Prof. Eduard de la Cruz Burelo
Sesión Matutina: 25 May 2016 at 09:30

CMS Muon System





B-Field 3.7T

Barrel Region: Almost uniform
End-Cap Region: Strong non-uniform

Drift Tubes (DT)

Central coverage | η | < 1.2
Measurement and triggering
12 layers each chamber, 8 in Φ, 4 in Z
Spacial 80–120μm ,Max drift time ~380ns.

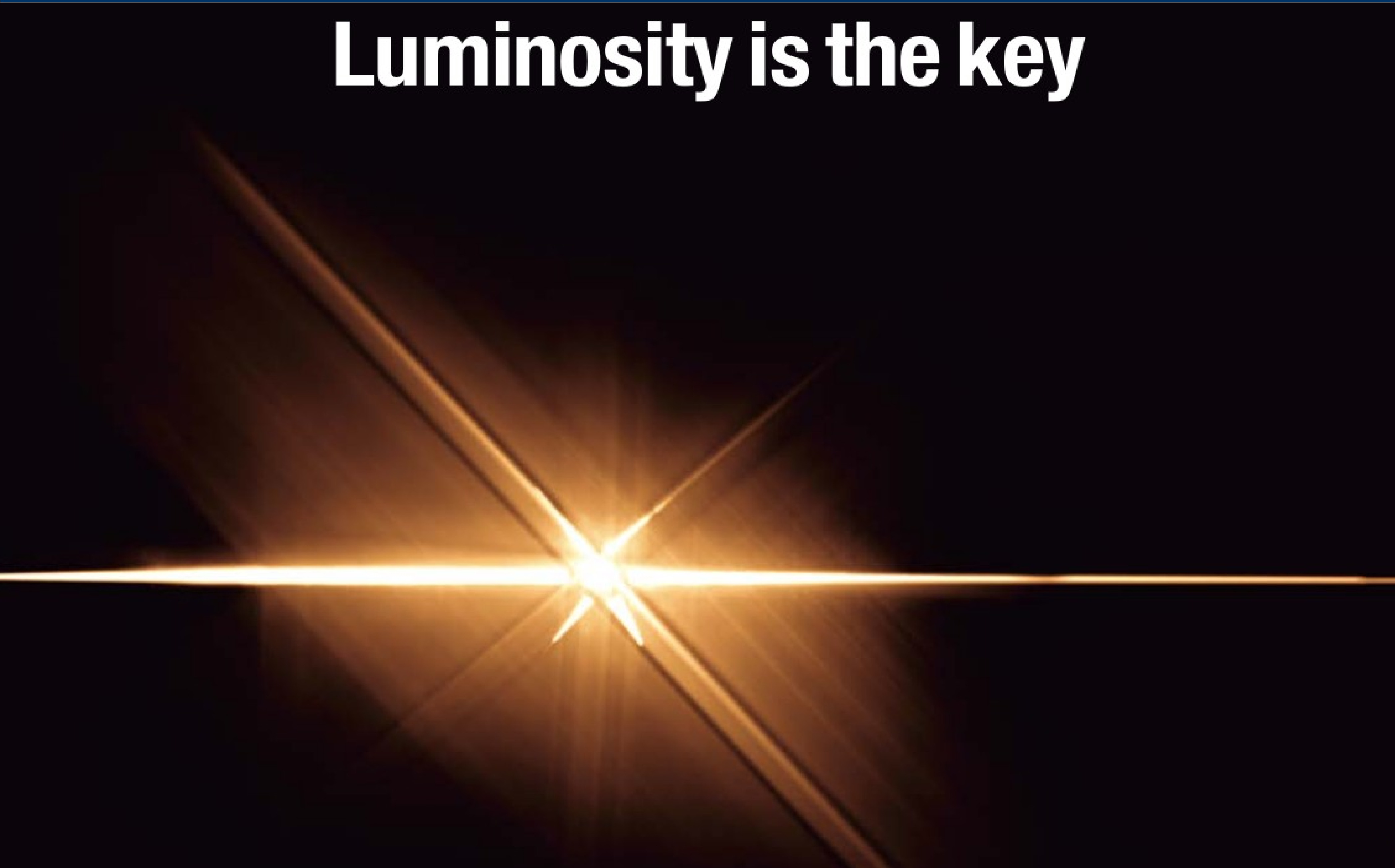
Catode Strip Chambers (CSC)

Forward coverage 0.9 < | η | < 2.4
Measurement and triggering
6 layers each chamber: each with Φ, Z
Spacial 40-150μm,Time~ 4.5 ns.

Resistive Plate Chambers (RPCs)

Centrlal and Forward coverage | η | < 2.4
Radudancy in triggering
2 gaps each chambe, 1 sensitive layer
Spacial 0.8-1.2cm, Time <3ns.

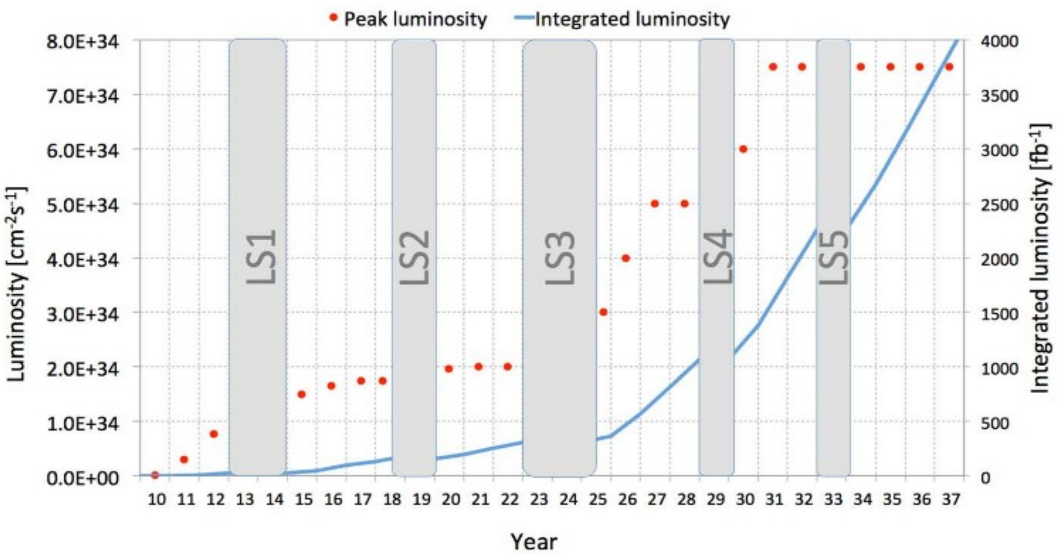
The HL-LHC: a bright vision



May 2016 issue of CERN Courier

The HL-LHC Project

The high-Luminosity LHC (HL-LHC) has ben identified as the highest priority program.



Enable a total integrated luminosity of 3000 fb-1

Enable an integrated luminosity of 250-300 fb-1 per year

Peak luminosity of 5-(7)x10E34 cm-2 s -1

Main differences between LHC & HL-LHC

	LHC	HL-LHC
Instantaneous luminosity $[cm^{-2}.s^{-1}]$	10^{34}	$7\ 10^{34}$
Number of events per BC at 25 *ns*	28	≈ 200
Number of events per BC at 50 *ns*	56	≈ 400
Integrated luminosity $[fb^{-1}]$	300	3000

DOI: 10.1142/9789814675475_0004

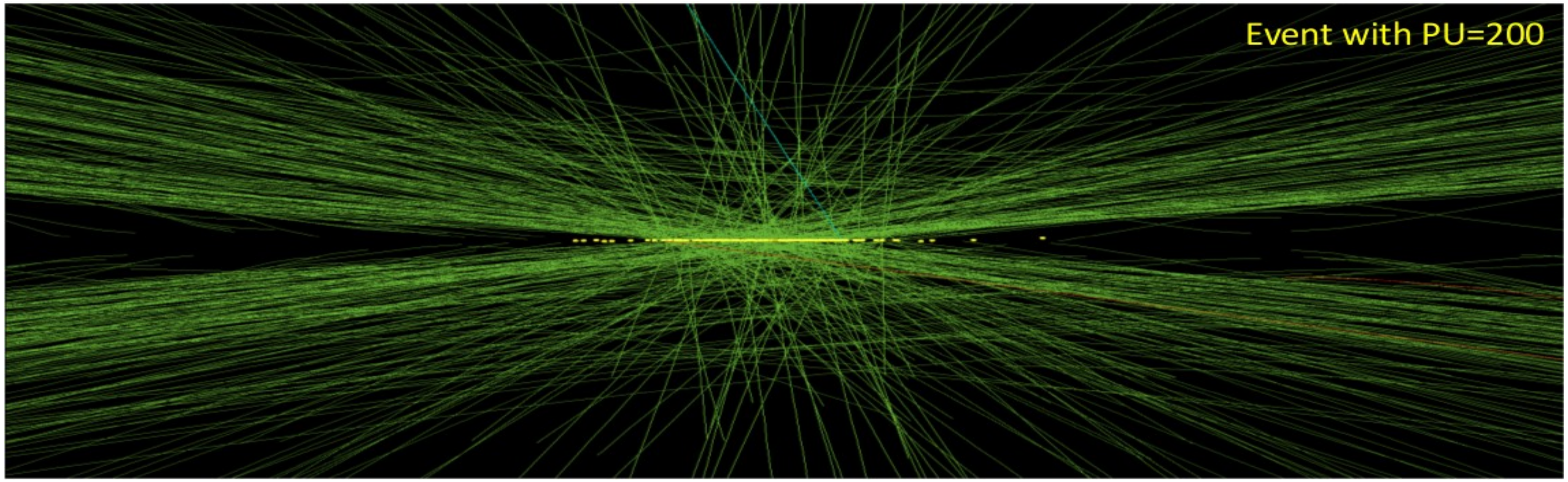
CMS HL-LHC challenges

High PU environment at HL-LHC (140-200 vertices per BX) in tracker

1. High vertex density along z-axis: 1.3 - 1.8 vtx/mm

2. High track density

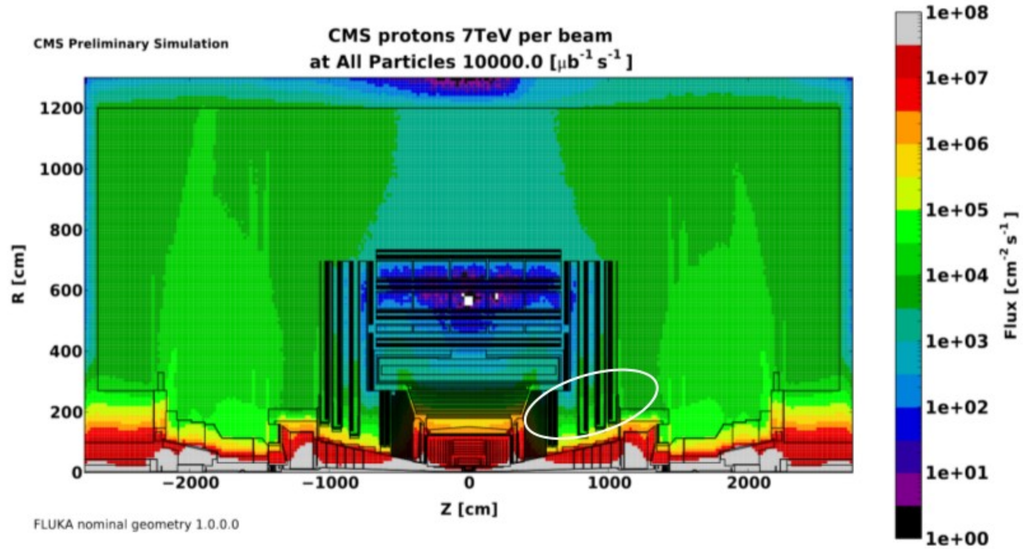
Is important to record a sufficient number of muon detector hits on each track.



It is important for Phase-II physics to keep the efficiency of the L1 muon triggers high, while maintaining pT thresholds low enough to collect a large fraction of Higgs, top quark, and electroweak bosons for more sophisticated analysis

CMS HL-LHC challenges

Background rates and dose during High Luminosity LHC



Harsh background environment

Highest rate:

RB4, MB4 background: neutron

RB1, MB1 background: charged particles and punch-through hadrons

RE2 background: ~50 Hz/cm 2 :

All major background sources affect mostly detectors at the highest pseudorapidity.

| η | > 1.6, there are no RPCs

At HL-LHC

ME1/1: ~4.5 kHz/cm 2

Neutron fluences: 3×10E12 cm-2 @ ~8 krad

RPC: maximum expected rate is ~250 Hz/cm 2 (innermost RE2/2 region)

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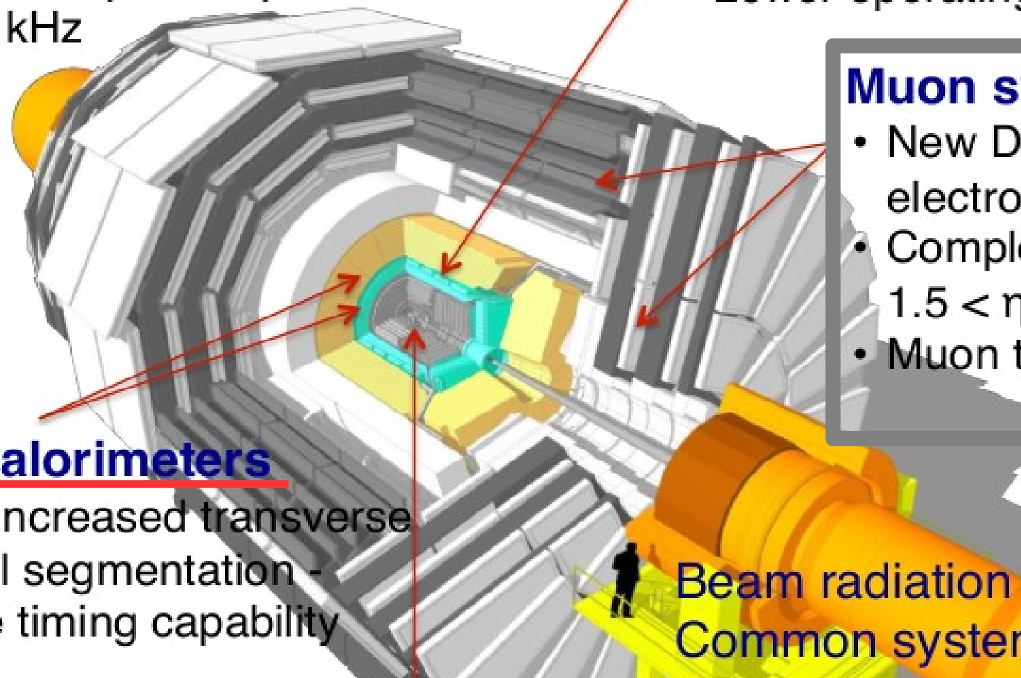
Expected CMS Upgrades

Trigger/HLT/DAQ

- Track information in Trigger (hardware)
- Trigger latency 12.5 μs - output rate 750 kHz
- HLT output 7.5 kHz

Barrel EM calorimeter

- New FE/BE electronics
- Lower operating temperature (8◦)



Muon systems

- New DT & CSC FE/BE electronics
- Complete RPC coverage $1.5 < \eta < 2.4$
- Muon tagging $2.4 < \eta < 3$

New Endcap Calorimeters

- Rad. tolerant - increased transverse and longitudinal segmentation - intrinsic precise timing capability

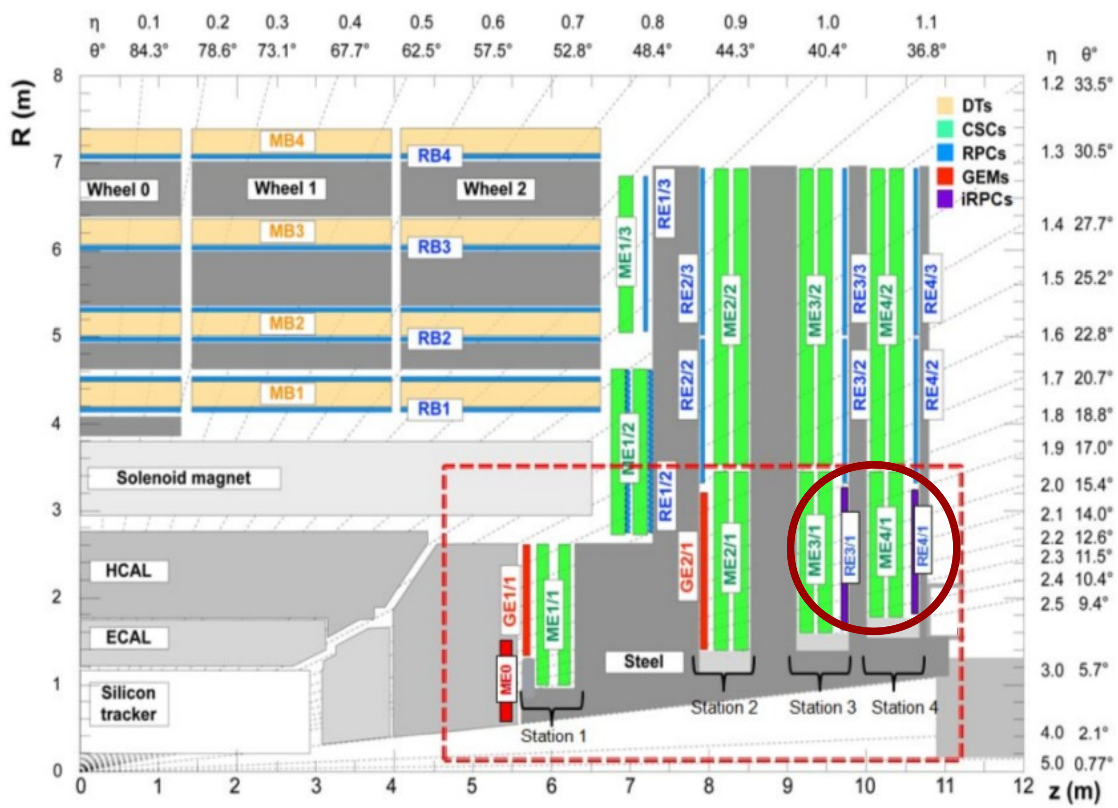
Beam radiation and luminosity
Common systems &infrastructure

New Tracker

- Rad. tolerant - increased granularity - lighter
- 40 MHz selective readout (Pt≥2 GeV) in Outer Tracker for Trigger
- Extended coverage to $\eta \simeq 3.8$

Additional muon detectors in the forward region

Complement existing ME3/1and ME4/1 CSC stations



72 chambers, each spanning 20°

1.6 < | η | < 2.4, 5 η-partitions

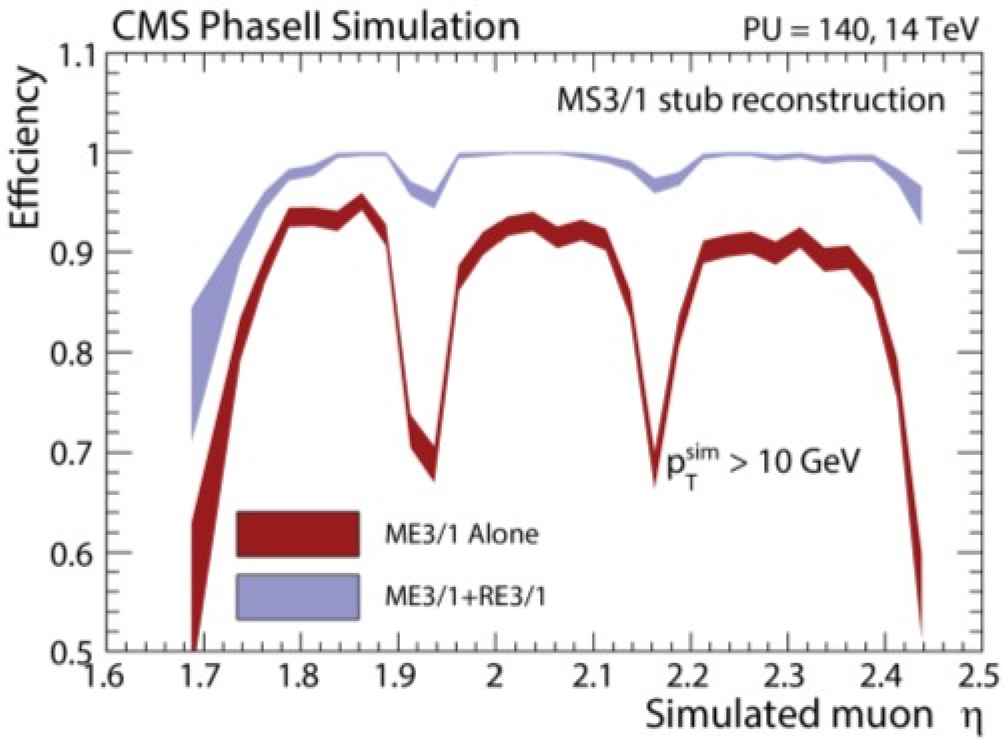
192 read-out strips per η-partitions

Pitch ranging from 0.30 to 0.62 cm (present endcap RPCs: 1.30 to 3.93 cm) → improvement of the spatial resolution

Increase redundancy and enhance the trigger and reconstruction capabilities → improvement of the L1 muon trigger

These chambers could provide an improved time resolution down to better than 100ps, which may be exploited, for instance for pileup mitigation

Muon trigger perfomance at HL-LHC



PU: 140, 14TeV

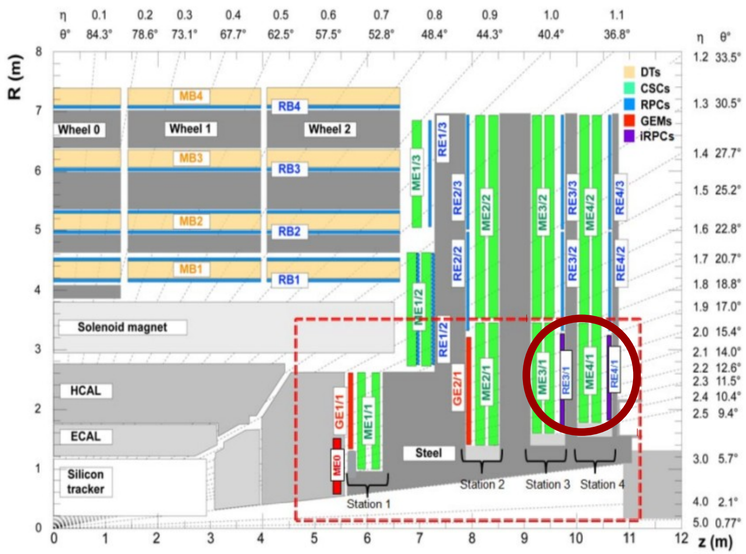
Stub reconstruction efficiency drops below 90% due to the high-voltage spacers inside the CSCs.

The installation of station RE3/1 (the RE4/1 case is very similar to RE3/1) restores the local-reconstruction (stub) efficiency

Reduction in the average number of reconstructed stubs on a track → increases the frequency of muon pt mismeasurements → inflates the trigger rate & flattens the rate curve.

Forward RPC detector requirements

Rate capability in RPCs can be improved in many ways:



Reducing the electrode resistivity (to be < 10E10 Ωcm)

Reduces the electrode recovery time needed for the electrodes to be charged up again after a discharge in the gas gap needs important R&D on electrodes materials

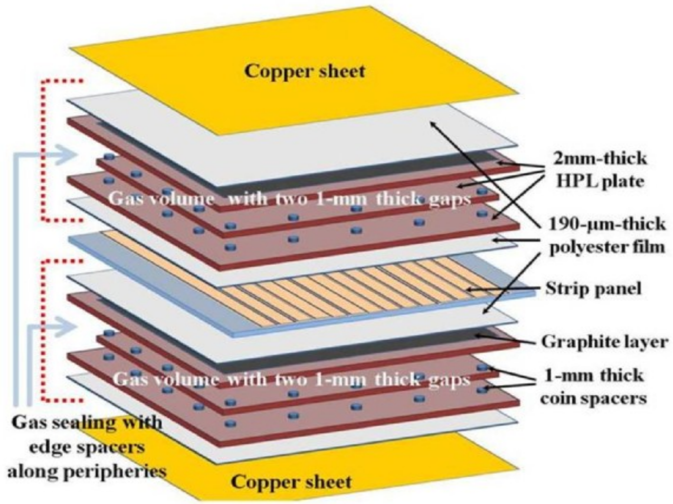
Changing the operating conditions
-Reduces the charge/avalanche, i.e. transfers part of the needed amplification from gas to FE electronics needs an improved detector shielding against electronic noise

Changing detector configuration
-Improves the ratio (induced signal)/(charge in the gap)
-Just some of these possibilities are being explored in present R&D

- High-Pressure Laminate is already industrially produced (lower cost, bigger surfaces)
- Glass and ceramics can achieve lower resistivity values than Bakelite
- Glass and ceramics have very smooth surfaces providing very consistent electric fields

CERN-LHCC-2015-010 ; LHCC-P-008.

Forward RPC technologies under study



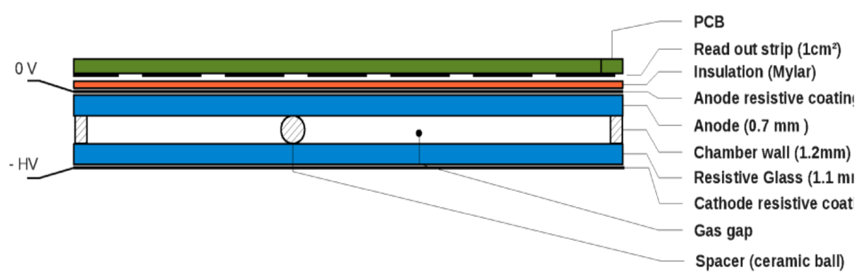
Multi-gap HPL

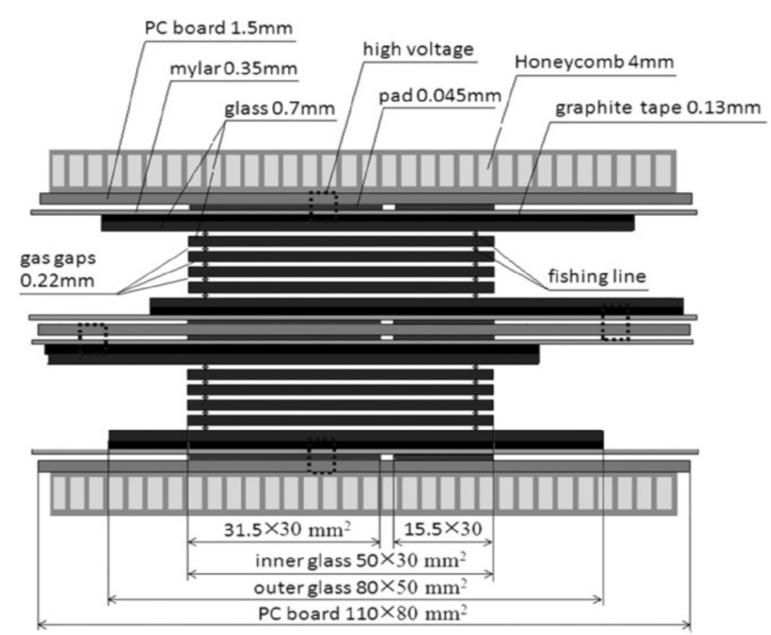
Modified standard bi-gap configuration using 2 double-gaps

- Thickness of the four gaps is 0.8 mm
- Same electrodes and front-end electronics as standard CMS chambers
- Efficiency for cosmic muons vs. operating voltage (with and without irradiation via 137 Cs γ-ray source)

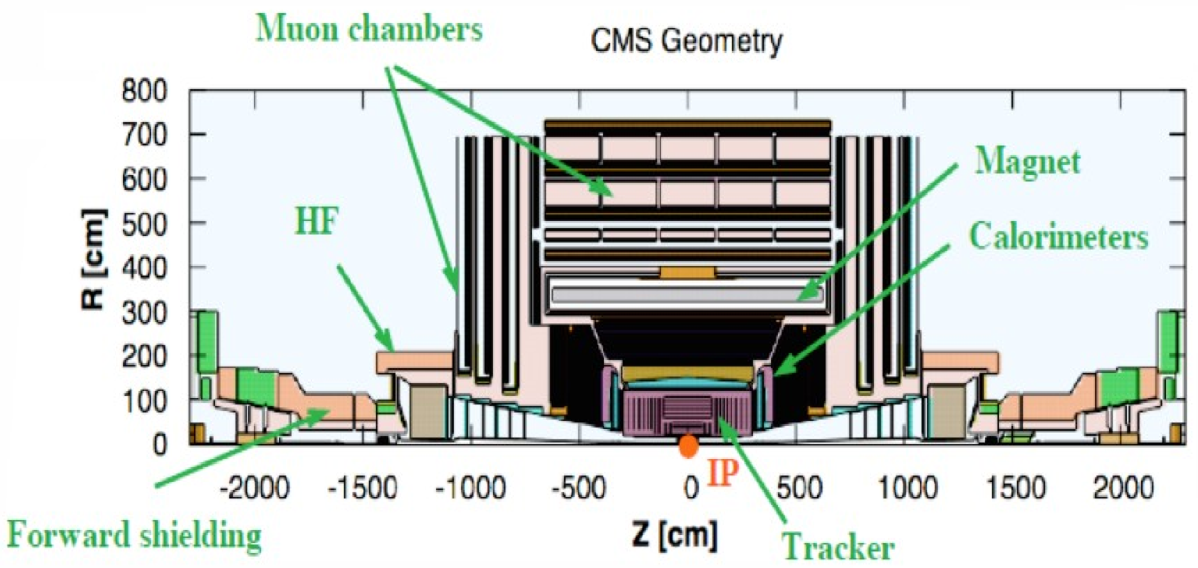
Single and Multi-gap glass RPCs

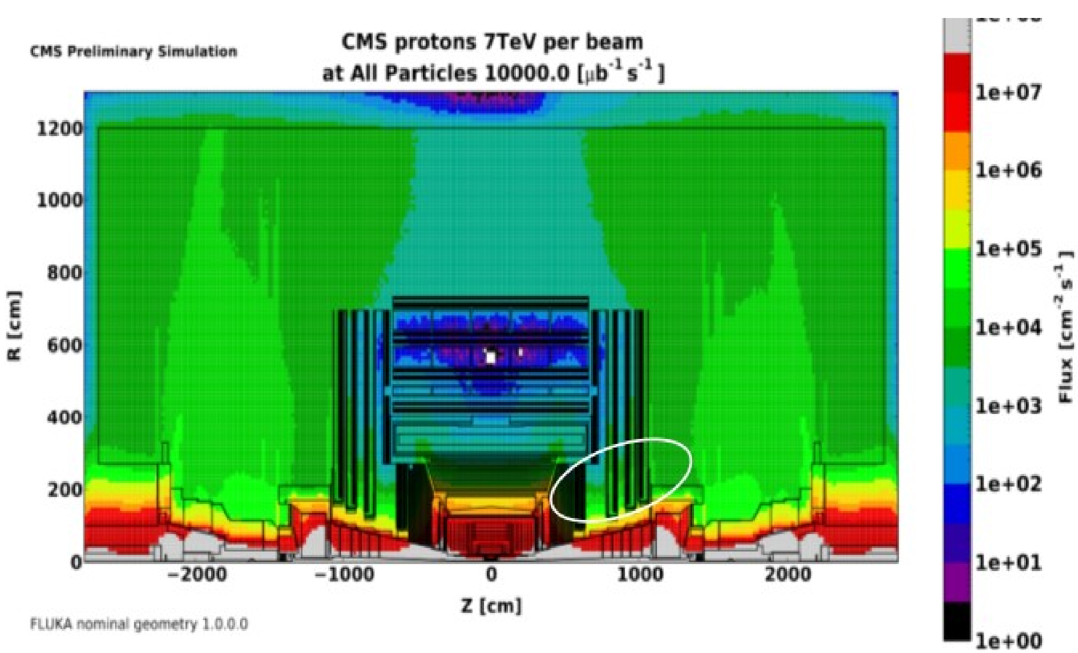
- Tests performed with a rate capability exceeding 10 kHz/cm 2
- Time resolution better than 100 ps for a multi-gap configuration





Background rates and dose during High Luminosity LHC





HL-LHC: drive the choice ofthe most suitable technology for the detector upgrade.

Predict the radiation levels for the CMS at LH-LHC: determine detector performance, longevity of materials and expected dose to personnel.

FLUKA (MC): general purpose tool for calculation of particle transport and interactions with matter

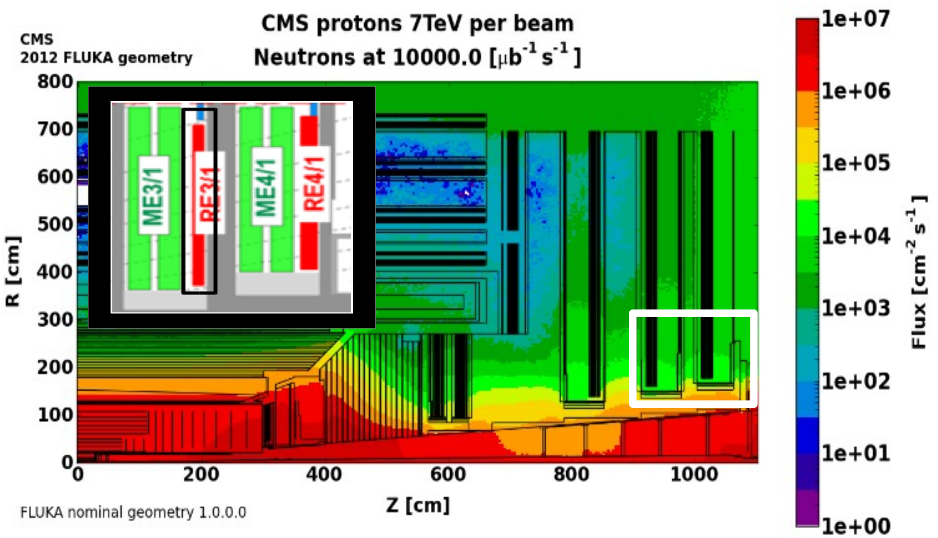
The FLUKA: handle complex geometries such as the CMS detector.

But it does not give information about the energy of the particles, Time of Flight, position, etc..

CERN-LHCC-2015-010 ; LHCC-P-008.
https://twiki.cern.ch/twiki/bin/view/MPGD/NPBgkSim

Estimation of the expected bakground RE3/1 & RE3/1

A phase-2 CMS geometry scenario was built for FLUKA simulation based on the best knowledge of the detector at that time.



- •We want to estimate the radiation environment for the Phase-2 muon upgrade scenario
- •Considering an instantaneous luminosity of 5x10E-34cm-2s-1
- •FLUKA is used to estimate the contribution of neutron induced backgrounds (neutrons, photons, electron/positrons)
- •Phase-2 CMS geometry used in FLUKA (CSM FLUKA v.3.7.2.0) and simulated data has been provided by the BRILgroup (Many Thanks!)
- •Geometry used is similar to the one used in the TP with the inclusion of the High Granularity Calorimeter (HGC)
- •We want to cover all the Phase-2 upgrade detectors RE4/1 & RE3/1

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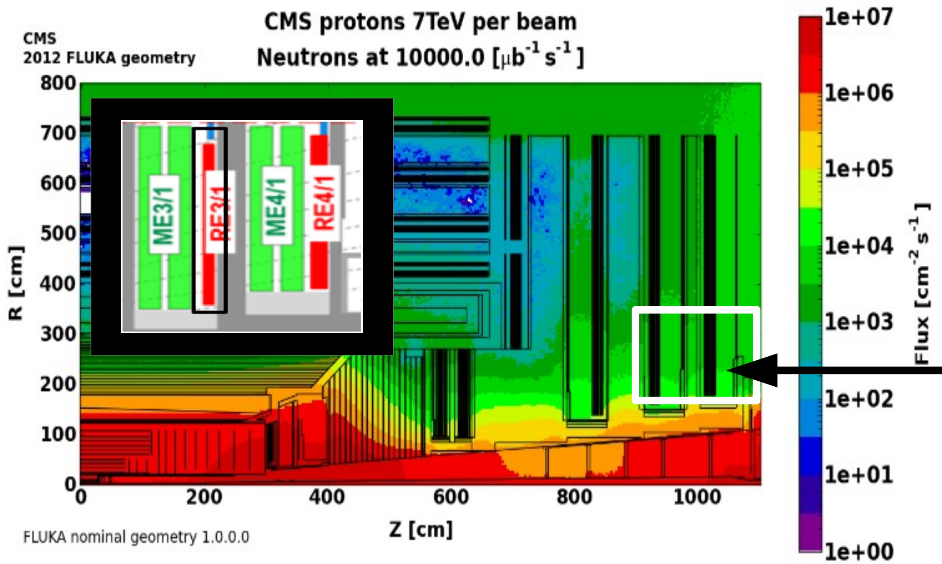
https://twiki.cern.ch/twiki/bin/view/MPGD/NPBgkSim

Estimation of the expected bakground RE3/1 & RE3/1

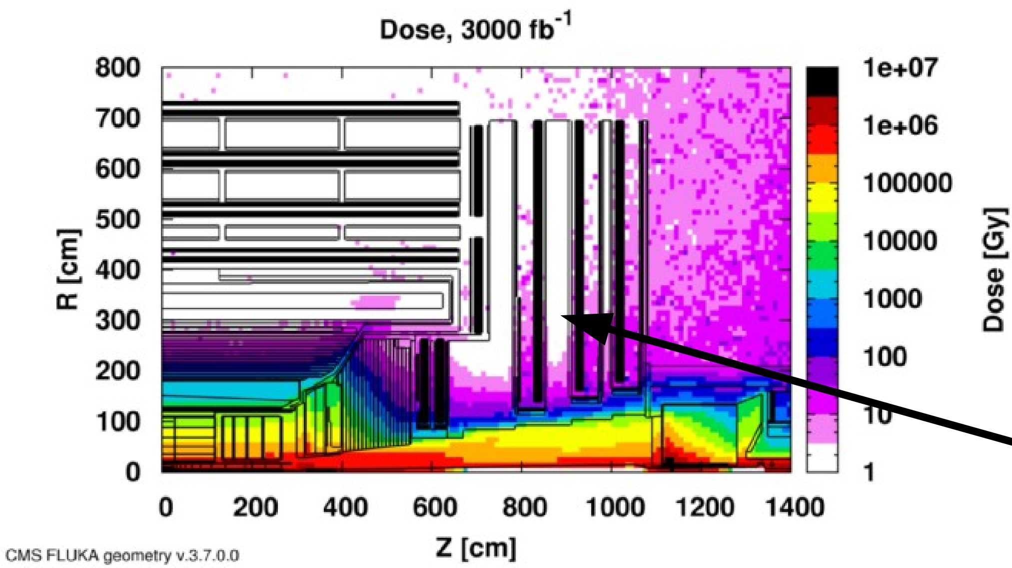


Using FLUKA simulation the expected radiation environment is estimated for the regions of interest

FLUKA v3.7.2.0

Region: **160 < R < 320 & 950 < Z < 1100**

Regions that simulate the iRPCS in the forward muon detectors muon for phase-II, it is made of layer of Bakelite and RPC Gas.

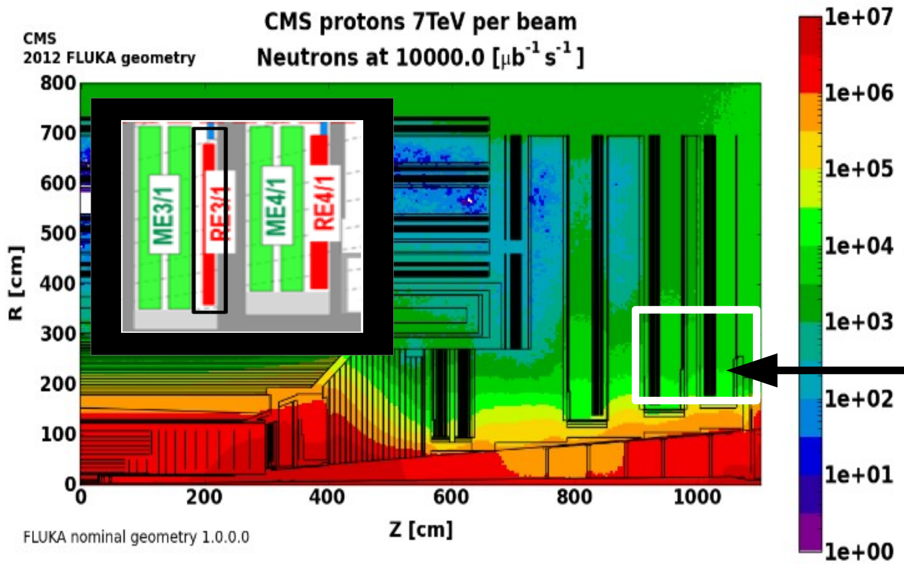


Proton-proton collisions with an energy of 7 TeV per beam were used.

Variation of Flux of Photons in R direction

Some regions do not have enough statistics

Estimation of the expected bakground RE3/1 & RE3/1



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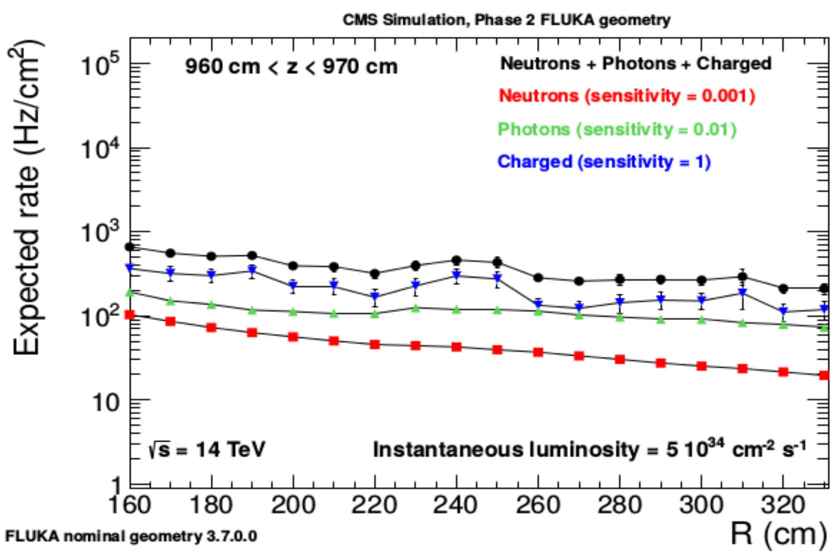

Proton-proton collisions with an energy of 7 TeV per beam were used.

Convolute fluxes with detector sensitivities (when ready) to obtain the Hit Rate

Plans for coming

- Get the 2D flux maps for RPCs.
- Get 1D projections: Flux vs R (average value in z direction)
- Include statistical uncertainties
- Convolute fluxes with detector sensitivities (when ready) to obtain the Hit Rate
- Fit Hit Rate vs R distributions to get the background modeling
- Update the background model in the digitizer


GRACIAS
photo M.Hoch
CMS

References

- The muon System of the CMS Experiment of the CMS Experiment at LHC, S. Macellini
- arXiv:0911.4991v3 [physics.ins-det]
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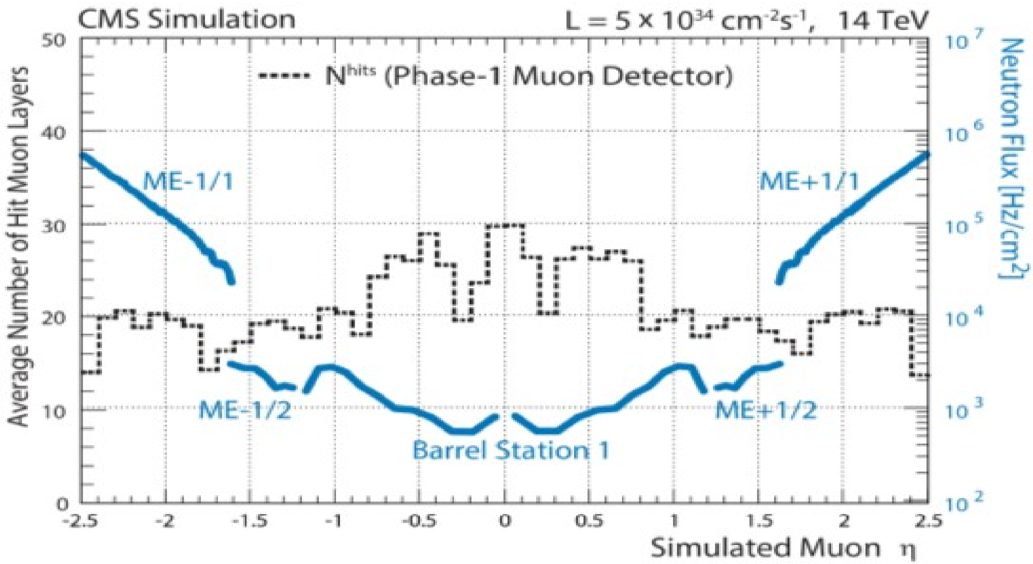
- DOI: 10.1142/9789814675475_0004
- Physics motivation for the forward muon system upgrade F.R. Cavallo
- Impact of the GE1/1 station on the performance of the muon system in CMS, Alice Magnani
- Philippe Lebrun, CERN
- DOI: 10.1142/9789814675475_0004
- A Novel Calorimeter for HL-LHC and Beyond, T. S. Virdee, Imperial College London
- Piet Verwilligen, Muon Upgrade Workshop, 2016-02-04
- A.Fagot - RPC2016 - 24th February, 2016
- CERN-LHCC-2015-010 ; LHCC-P-008
.
- https://twiki.cern.ch/twiki/bin/view/MPGD/NPBgkSim

Backups

Qualitative indication

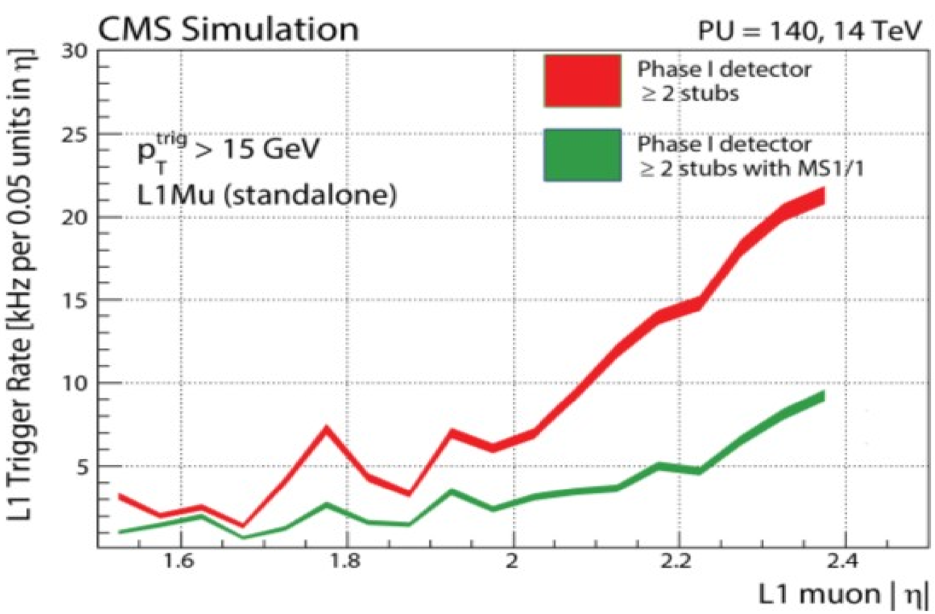


Average number of muon hits associated with a global muon track

η < 0.8, muon tracks are associated with an average of 25 hits

η > 1.6, 18 hits

Rate neutron flux



Fast growth of the muon trigger rate in the forward region, for a pt threshold at 15 GeV.

Of the four muon stations,
the first one is of special importance

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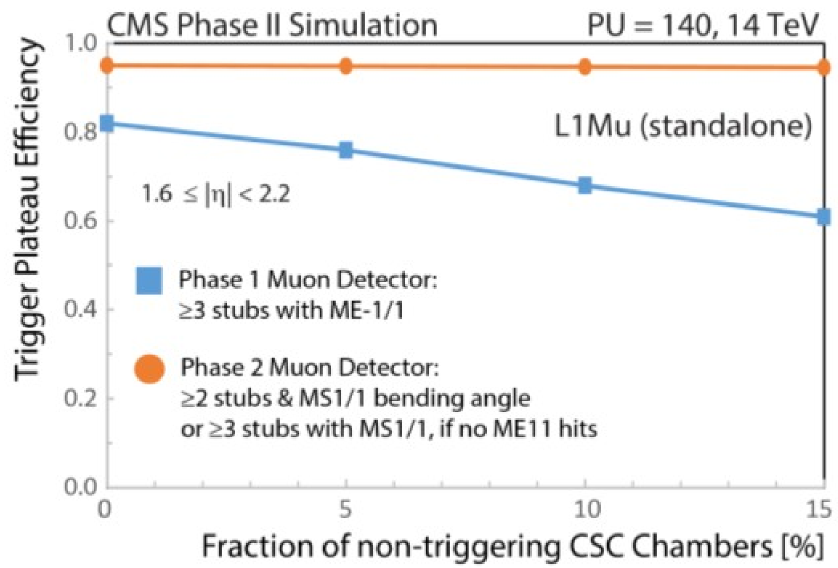
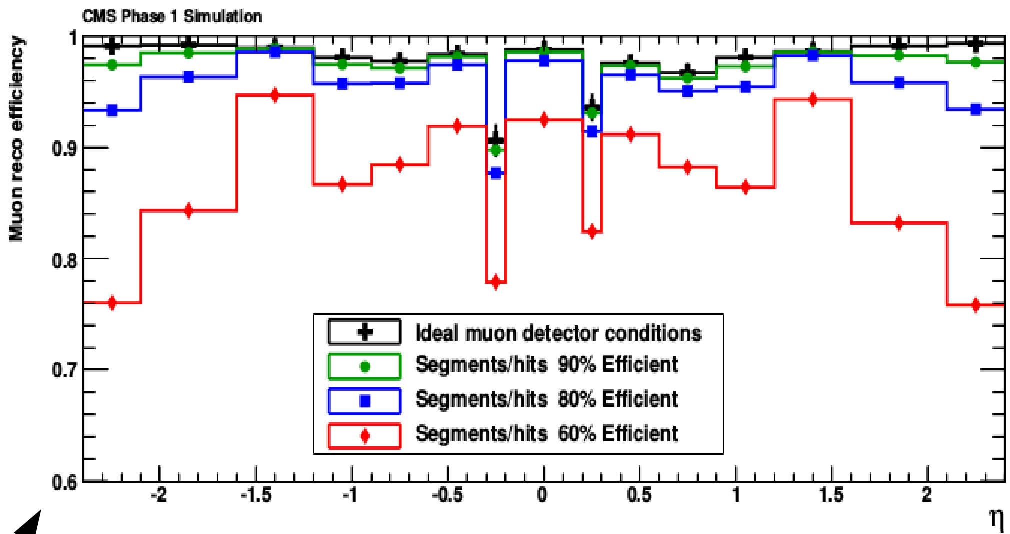
Forward muon redundancy

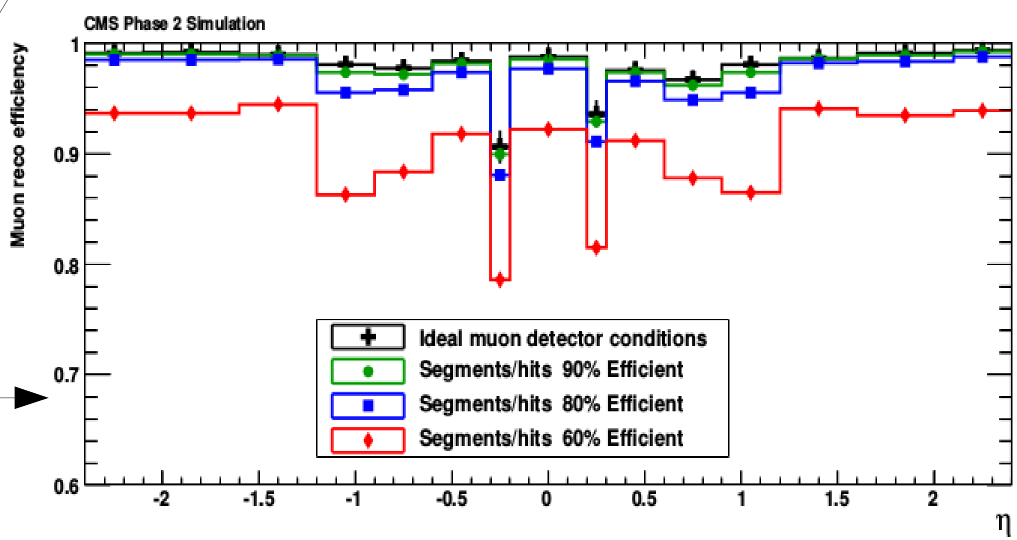




Fast deterioration of the muon trigger efficiency with even a moderate fraction of non-triggering CSC chambers is presented.

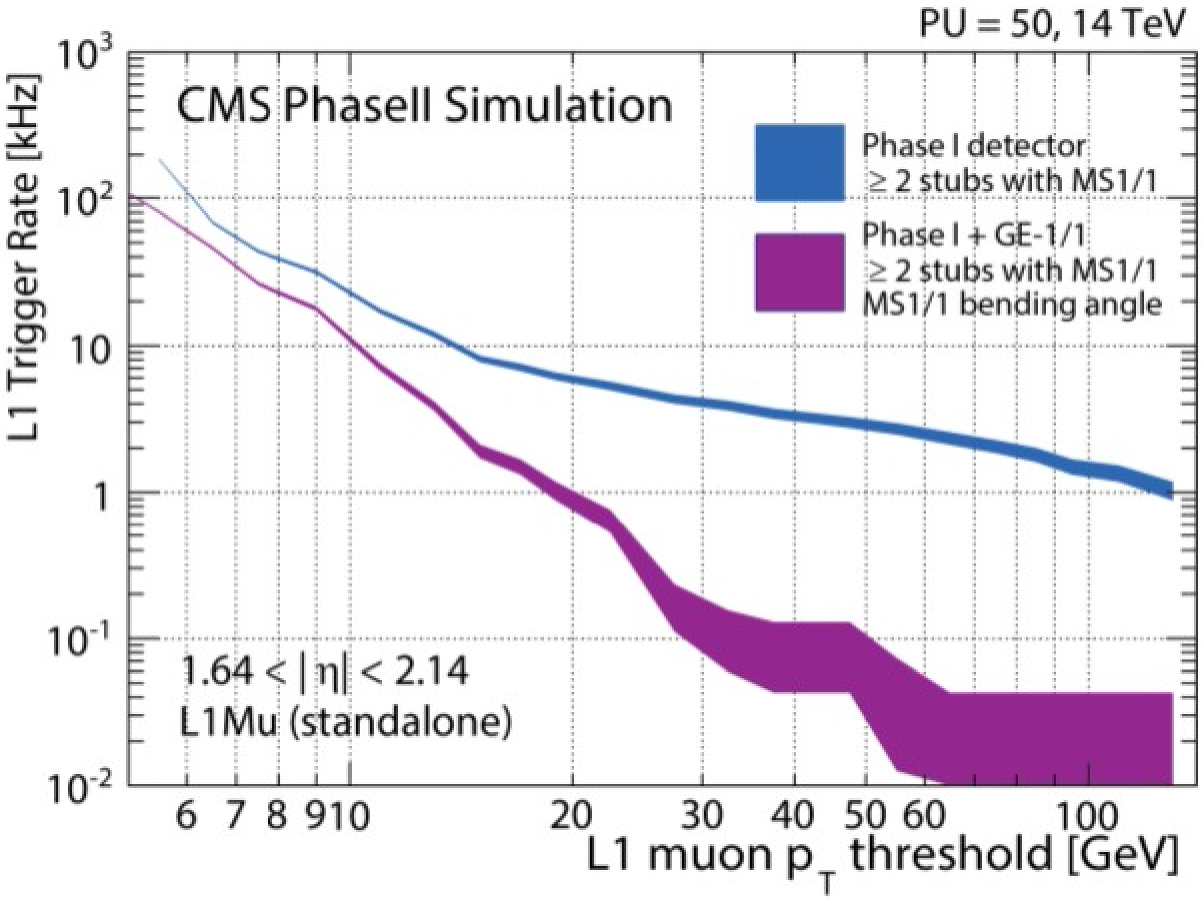
Degradation of muon reconstruction and identification (ID) efficiency is small in the central region, | η | > 1.6,

The efficiency is mostly recovered over the full detector coverage with the new chambers (2023 geometry)



CERN-LHCC-2015-010 ; LHCC-P-008.

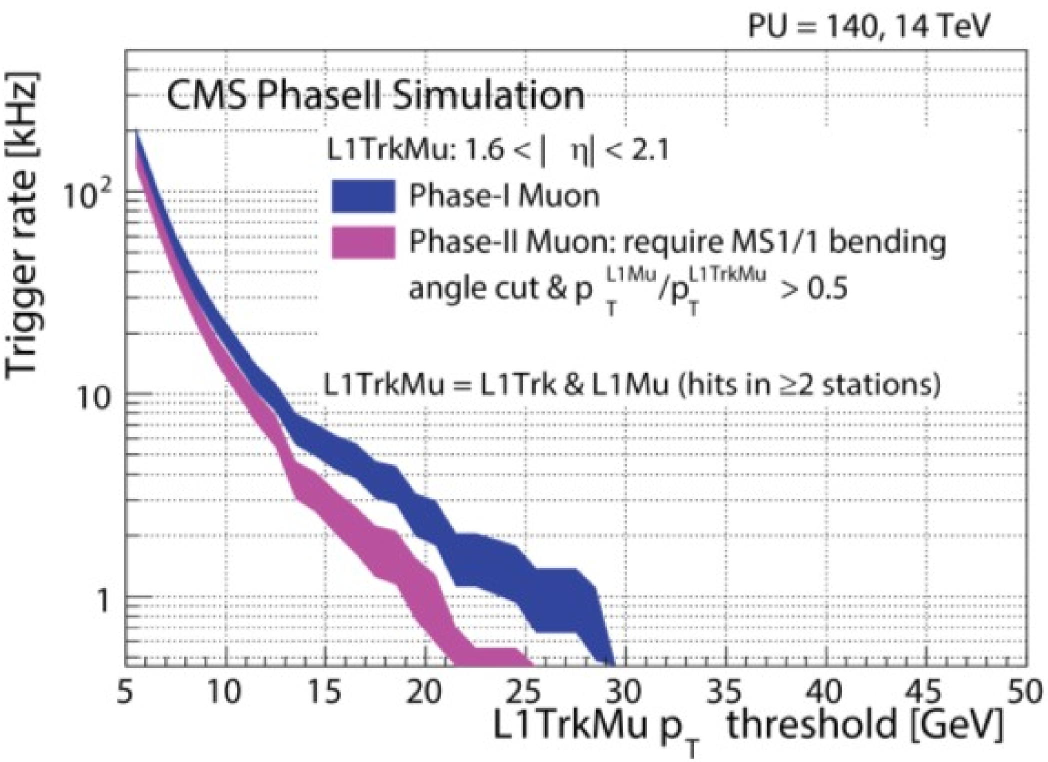
The HL-LHC Projct

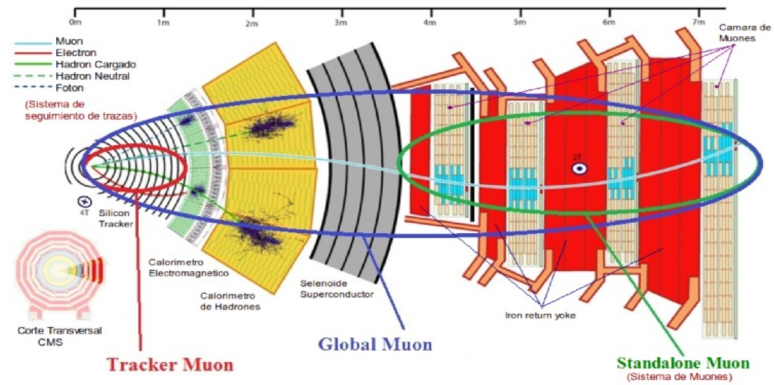


L1 muon trigger rate at a luminosity of 2 × 10 34 cm − 2 s − 1 as a function of pT threshold. For the Phase-I system, 2 or more stubs, one of which is in the ME1/1 station are required. With the addition of GE1/1, the bending angle between the two stations can be used and the trigger rate is greatly reduced.

The HL-LHC Project

Designing and optimizing an efficient trigger with low thresholds and low trigger rate for Phase-II.





L1TkMu, use track-trigger tracks extrapolated to the muon station planes and matched with L1 standalone muon candidates.

A standalone muon: track with hits in two or more stations (including the first muon station)

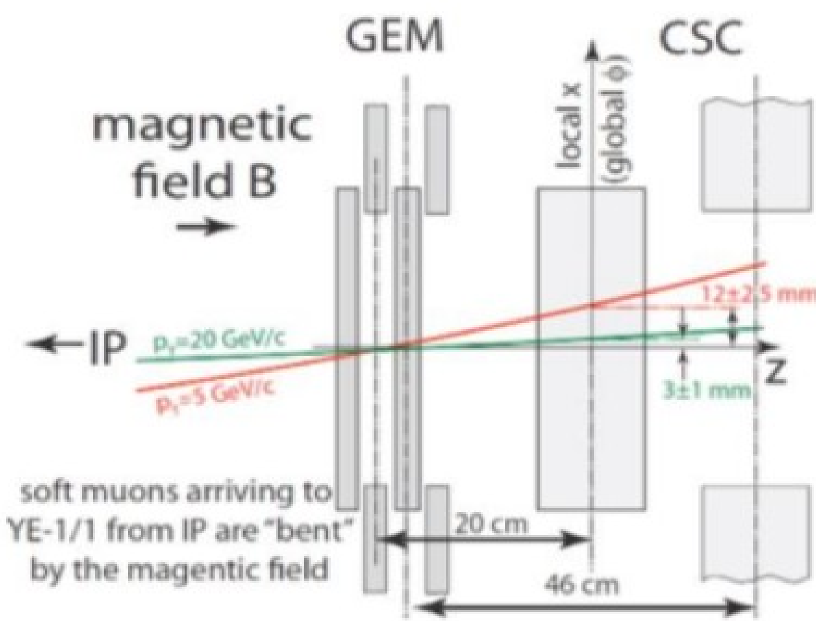
Rate of the L1TkMu trigger as a function of the pT threshold for 1.2 < η < 2.4 and 140 PU.

The HL-LHC Project

The trigger rate is driven by muon momentum mis-measurement.
The CSC trigger measures muon p_t using the positions of stubs reconstructed in the various muon stations. A soft muon can be reconstructed as a high p_t candidate due to scattering processes.

The lever arm between GE1/1 and ME1/1 enables an independent p_t measurement.

A muon candidate can be rejected if the p_t reconstructed in GE1/1 does not match the track finder measurement



Reducing momentum mis-measurement of soft muons