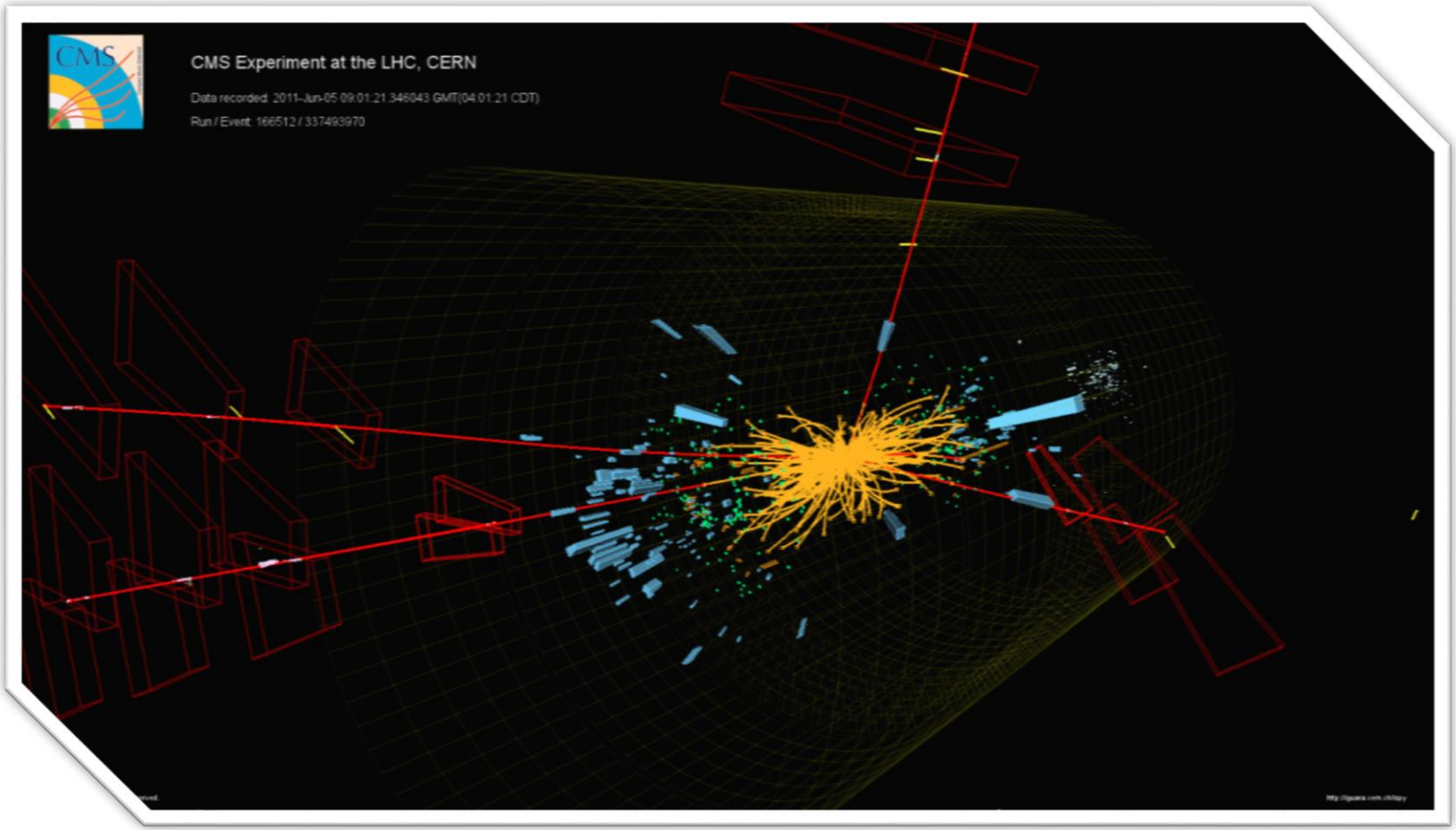
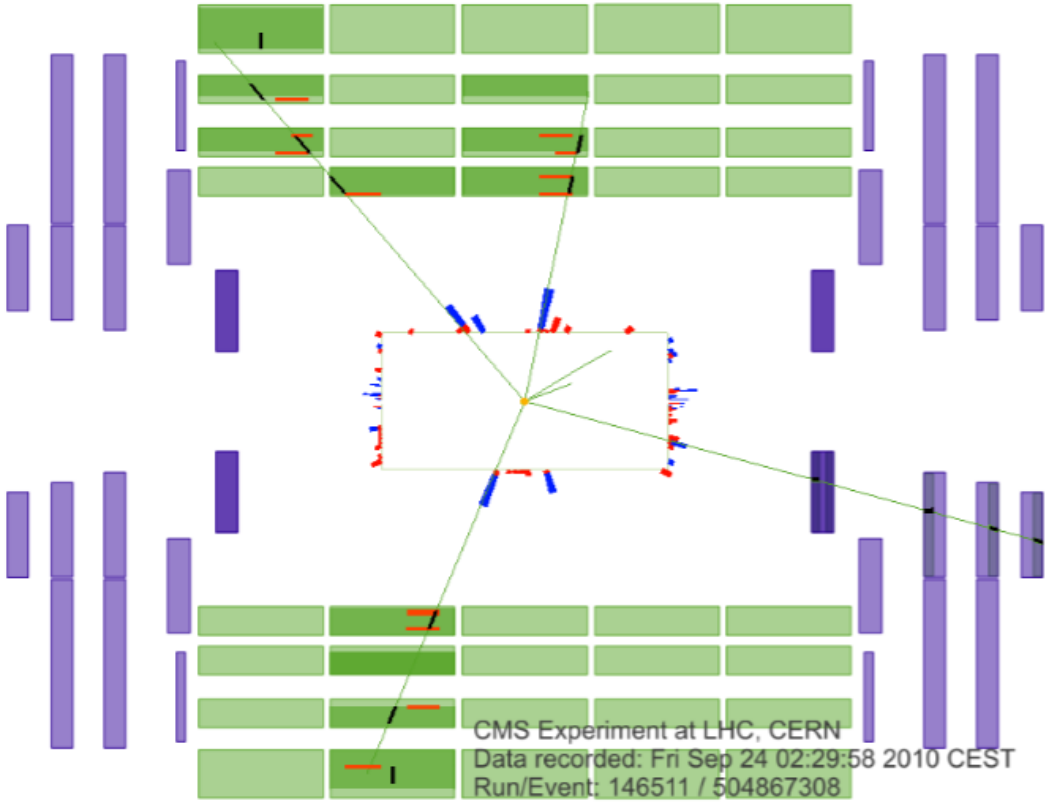


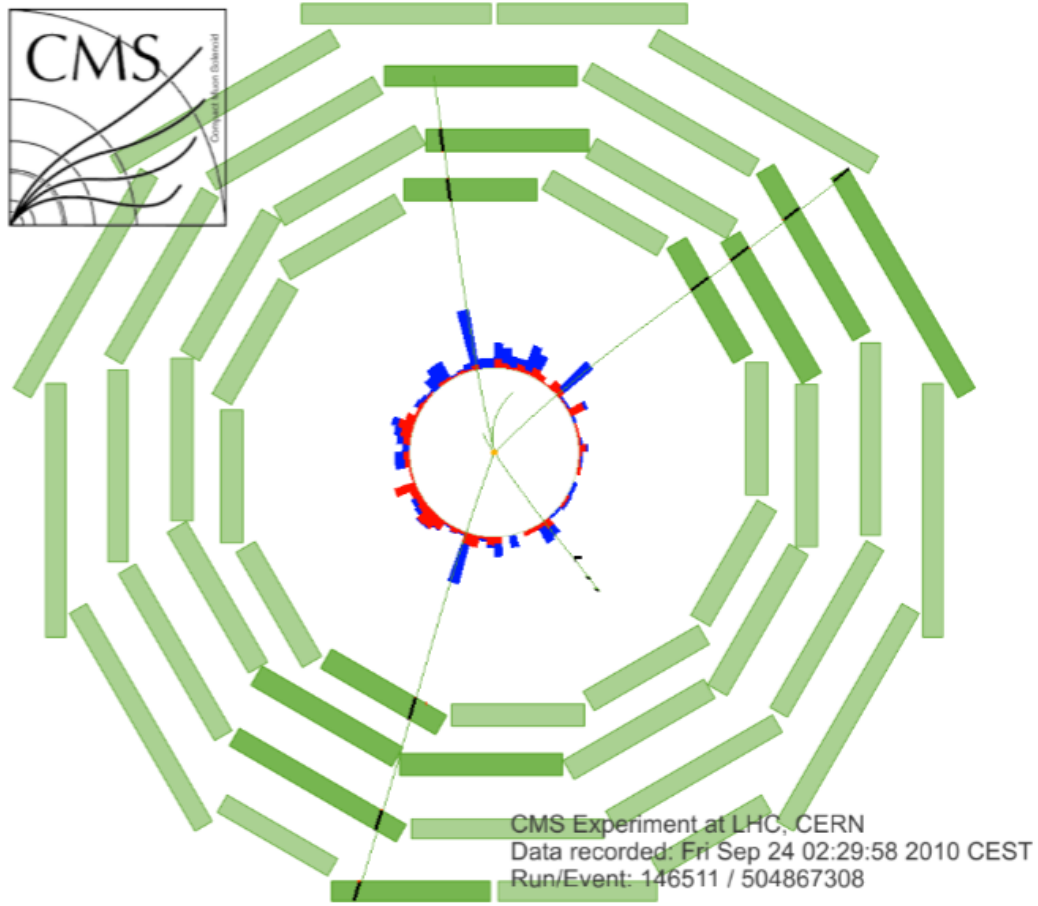
Impact of the GE1/1 station on the performance of the muon system in CMS

ALICE MAGNANI FOR THE CMS GEM COLLABORATION

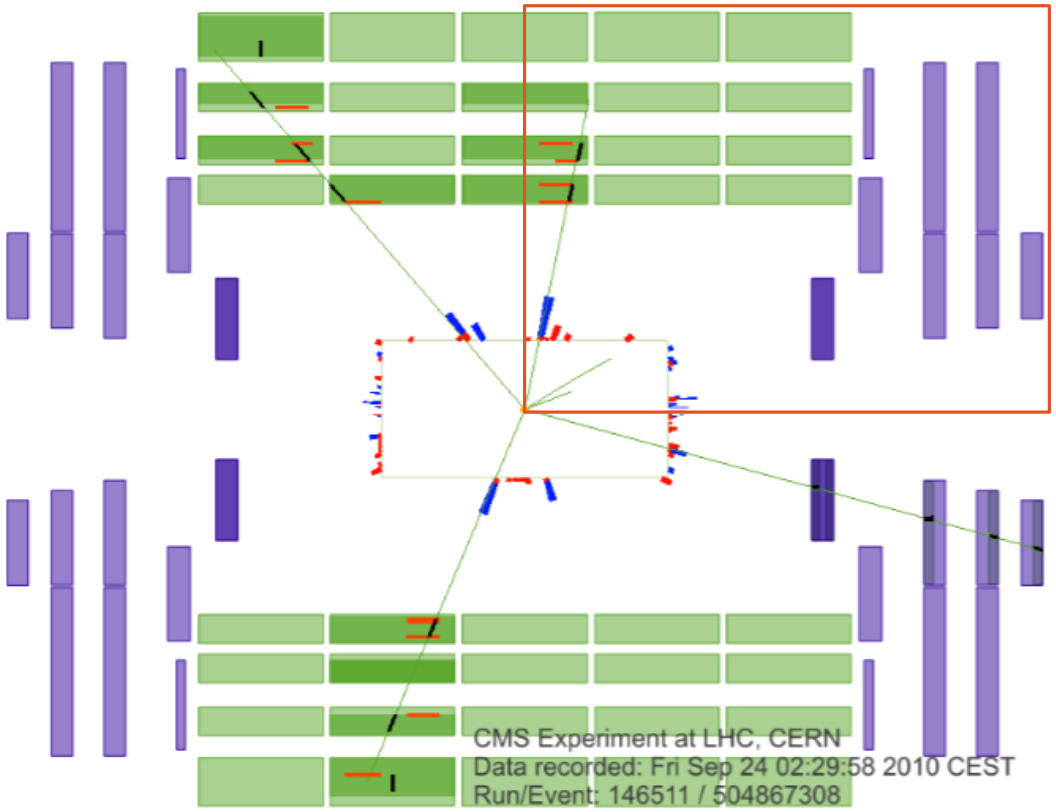
Roma 8-10 aprile 2015
IFAE
INCONTRI DI FISICA DELLE ALTE ENERGIE
2015

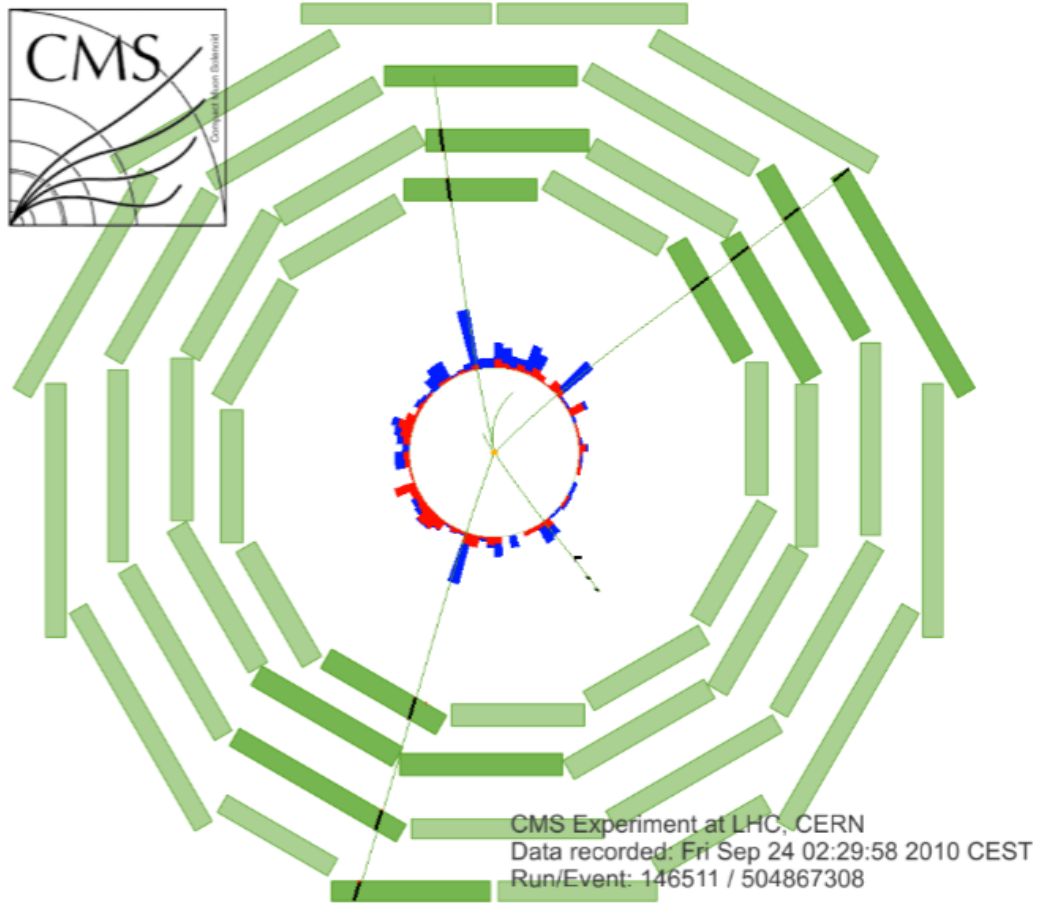
A good H → 4μ candidate in CMS



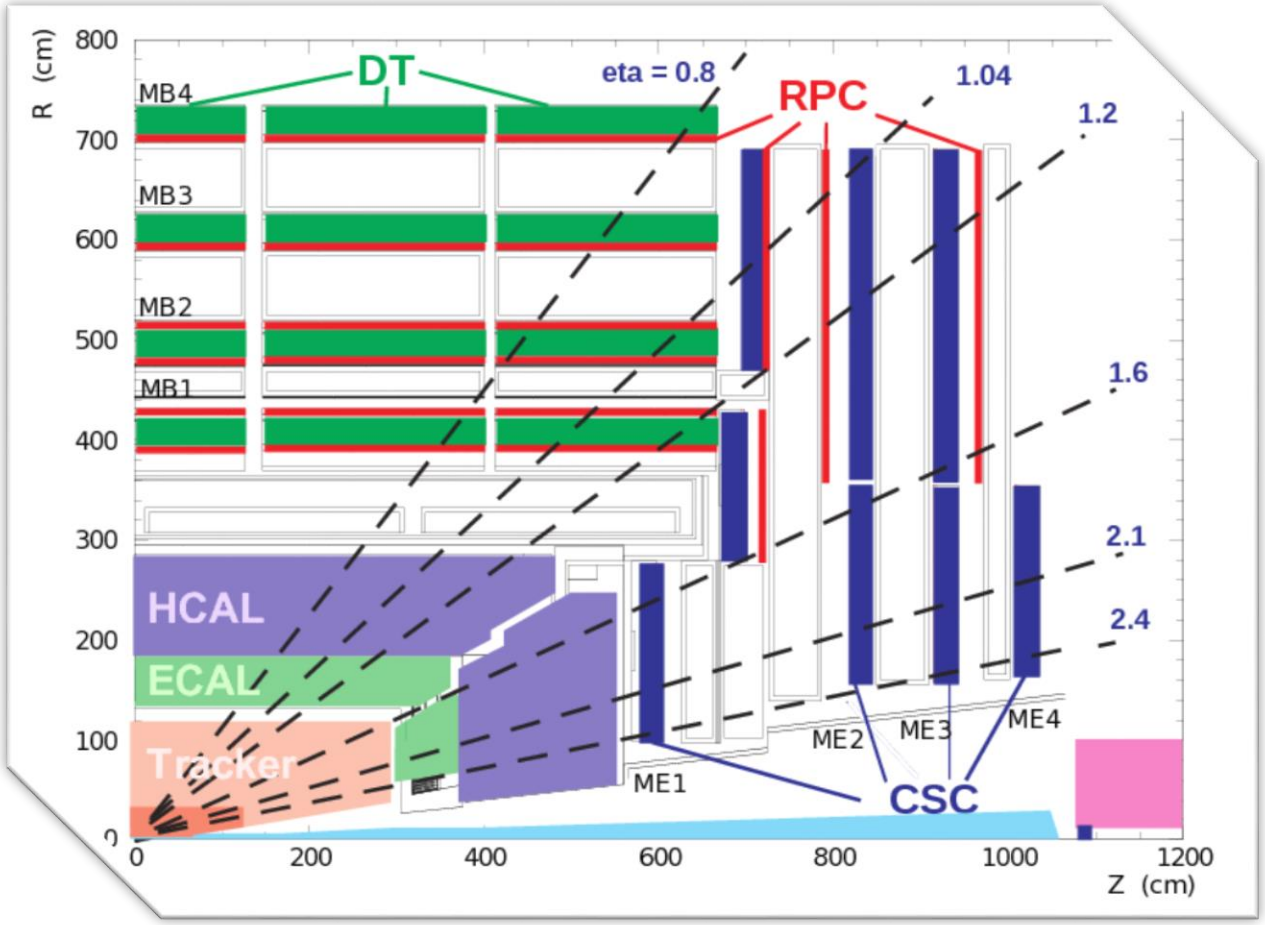


A good H → 4μ candidate in CMS





The CMS muon system in a nutshell



Status of the CMS muon system in Run 1

The **inner tracker** measures charged particles trajectories with $|\eta| < 2.5$

Muon system tasks:

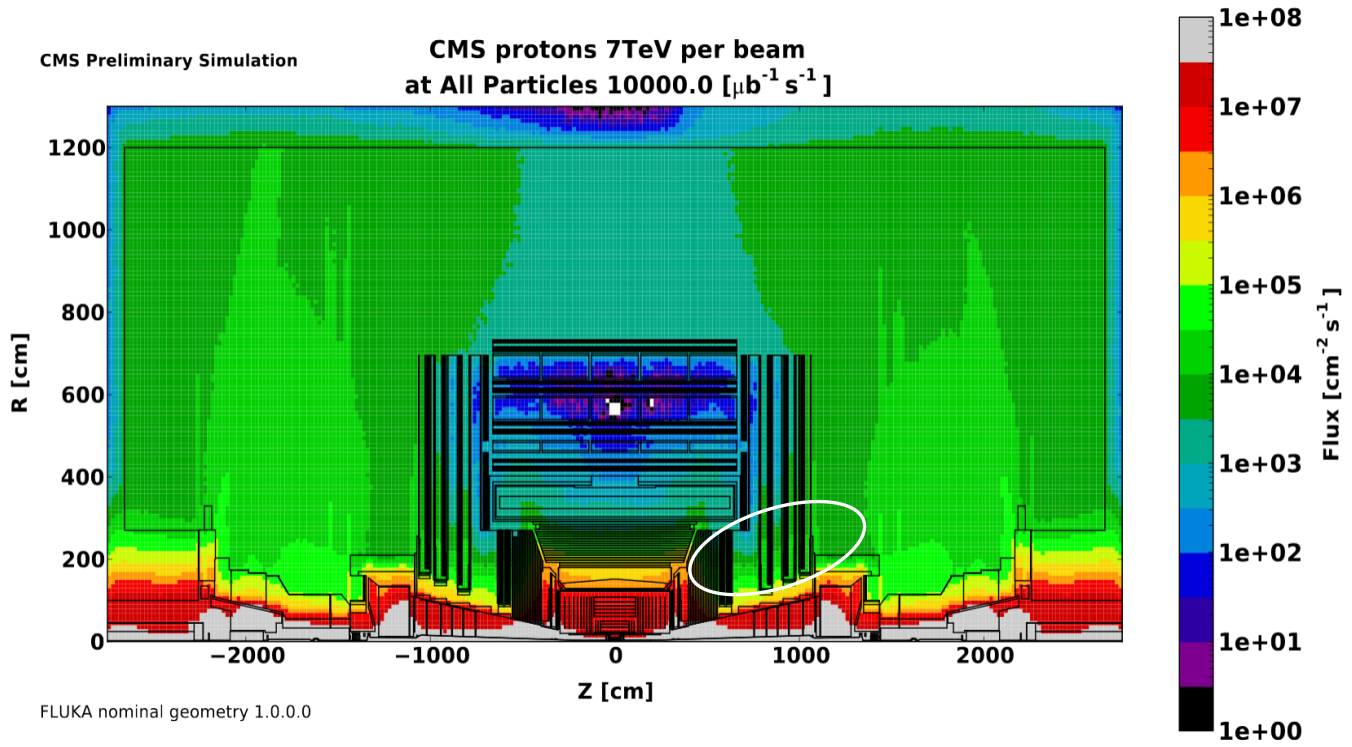
- triggering on muons,
- identifying muons,
- measuring muon p_t (together with the tracker)

Drift Tubes (DT) and **Cathode Strip Chambers (CSC)** detect muons in the region **$|\eta|<1.2$** and **$0.9<|\eta|<2.4$** respectively

For **$|\eta|<1.6$** they are complemented by **Resistive Plate Chambers (RPC)**

The muon system is included in the **Level 1 Trigger**, (maximum freq. of 100 kHz). The **High Level Trigger** uses the full event information, including the tracker

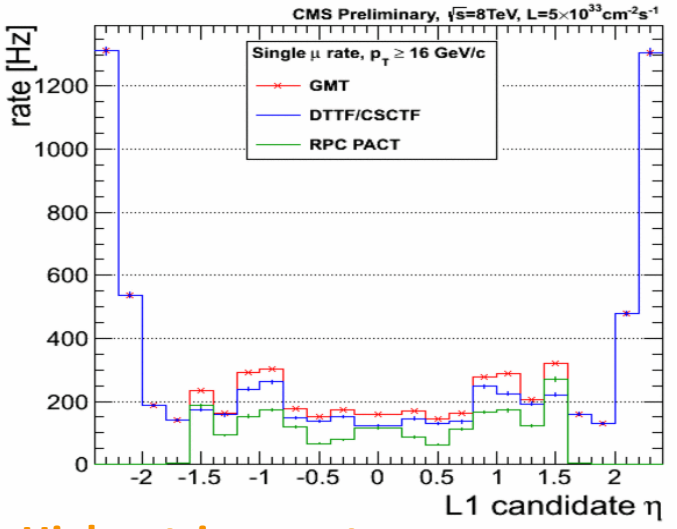
The high η region



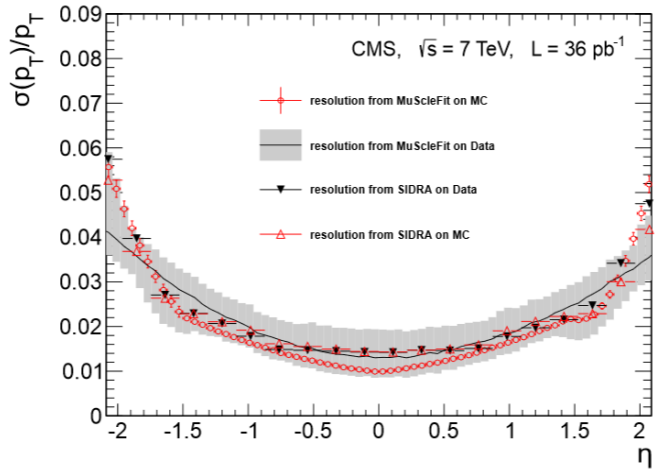
Harsh background environment

If RPC stations had been installed in η>1.6, their hit rate at $L=10^{34}$ cms^{-2} s^{-1} would have been ~ 1 kHz, too high for their rate capability

Lack or redundancy

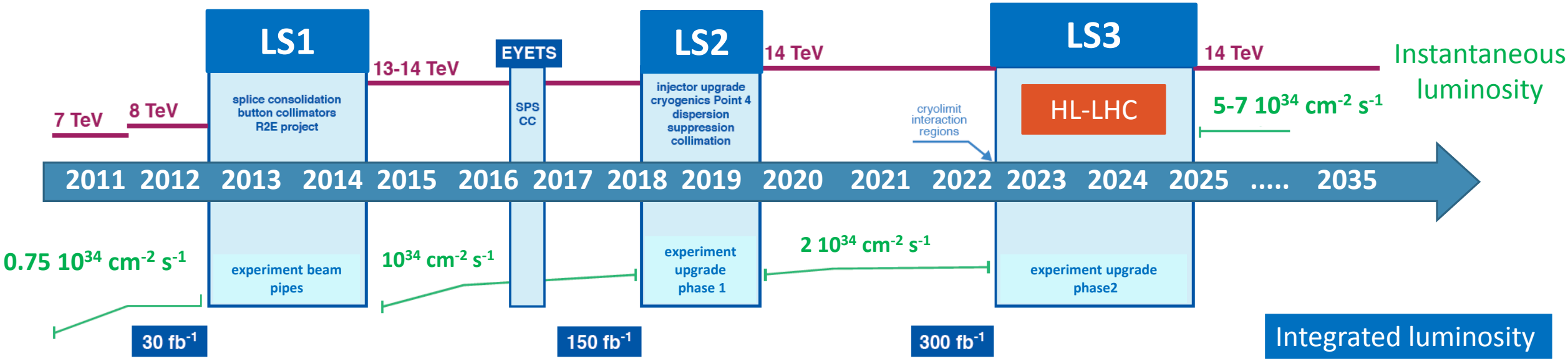


Higher trigger rate



Worse momentum resolution

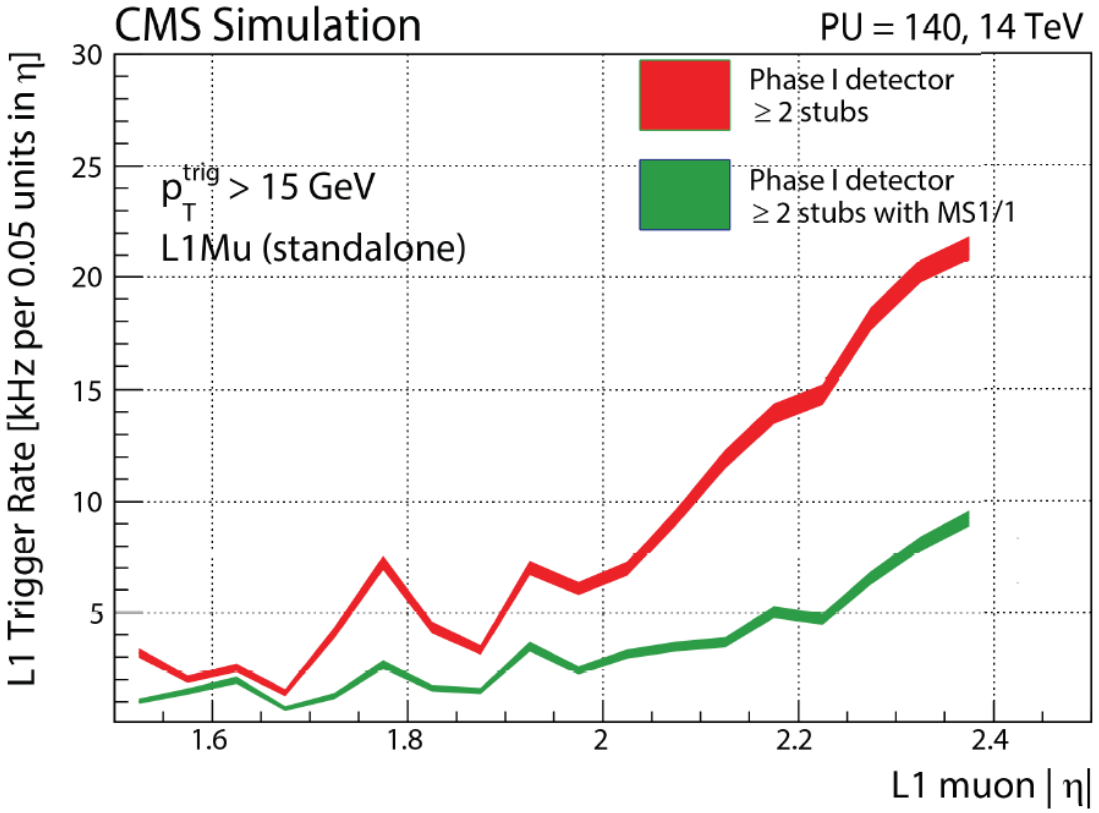
Towards HL-LHC



The current muon system was designed to operate at the nominal LHC luminosity.

What happens after LS2?

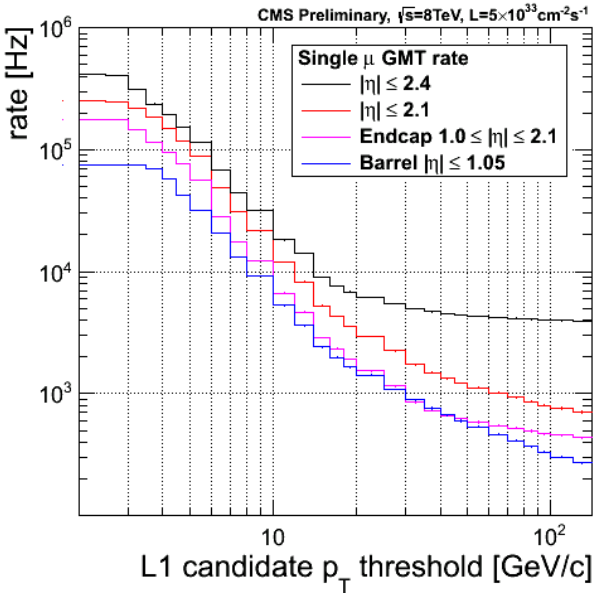
Muon trigger post LS2

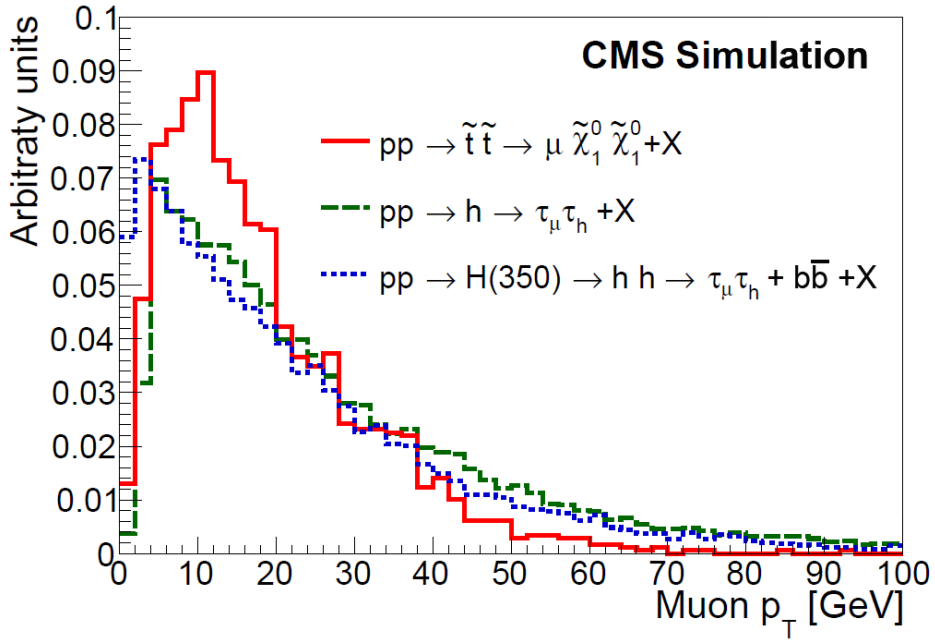


The trigger rate can be reduced increasing the *p_t threshold*

BUT

many physics channels have signatures with *soft muons*

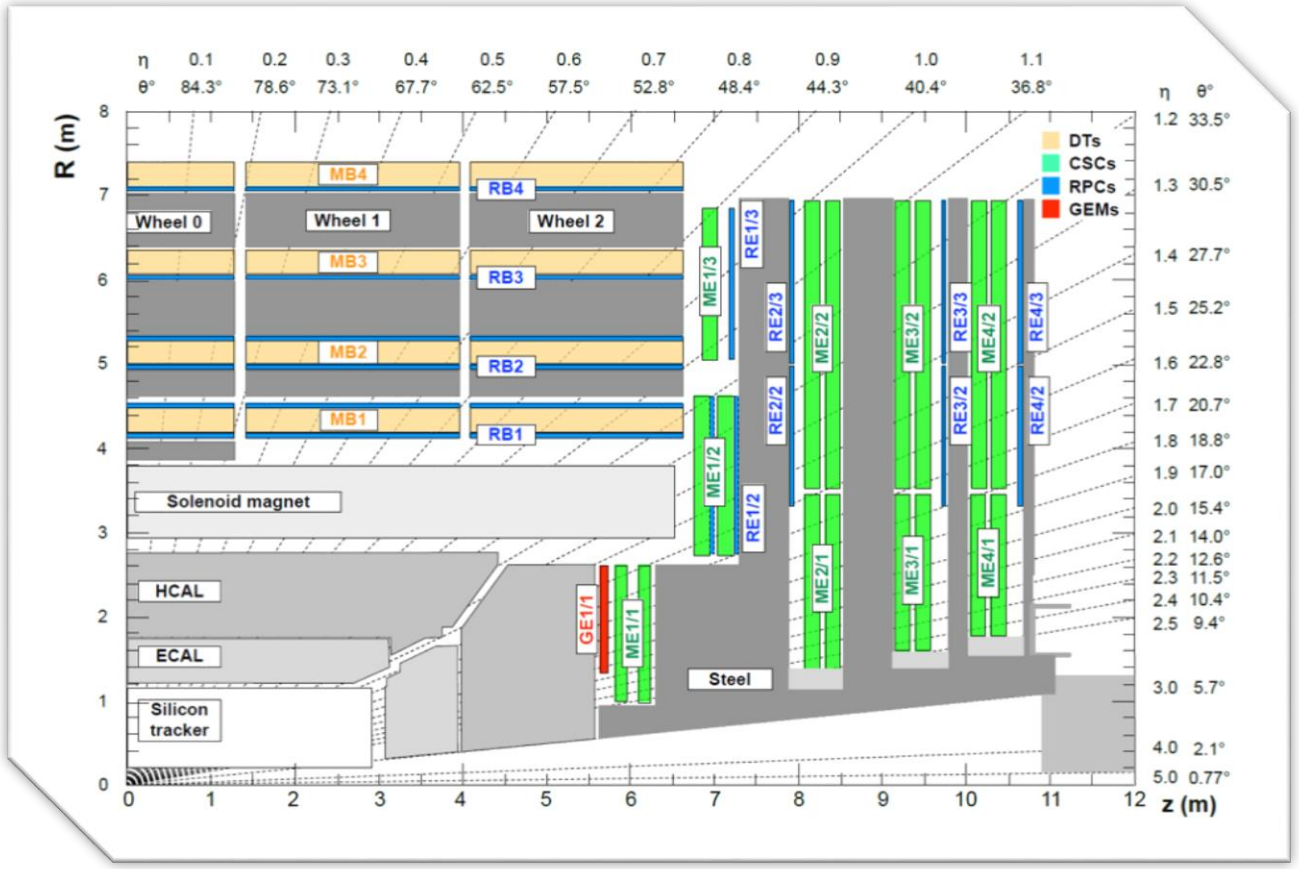




Expected trigger rate after LS2 with the Run 1 detector

Already at L=1.7cm^{-2} s^{-1} we have a single muon trigger rate of 10 kHz, 1/10 of the entire CMS L1-bandwidth

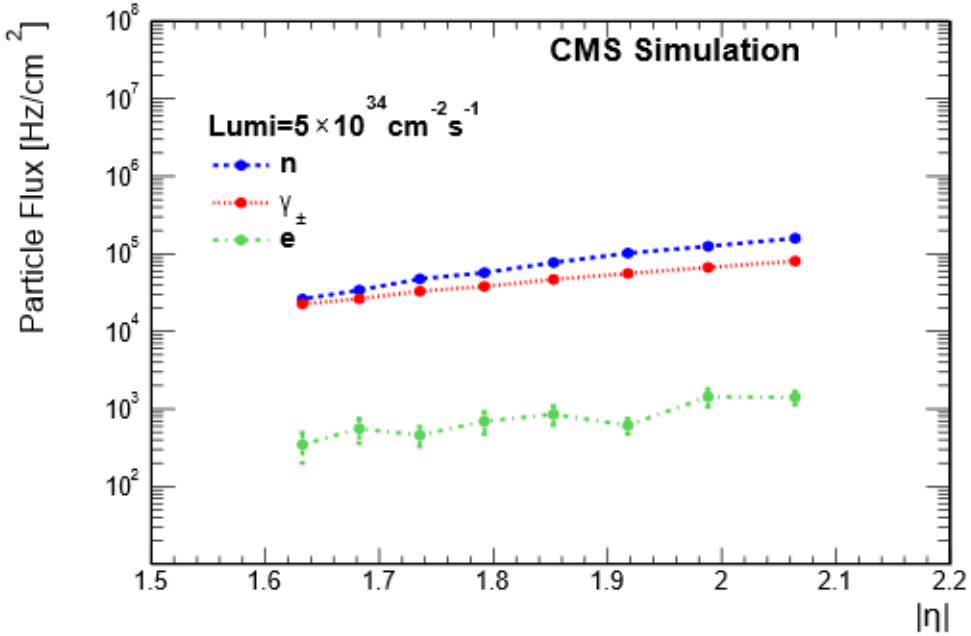
Upgrading CMS with the GE1/1 station



Post LS2 scenario

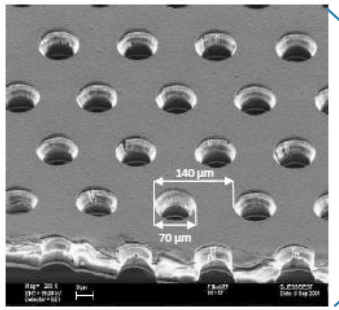
Expected radiation environment

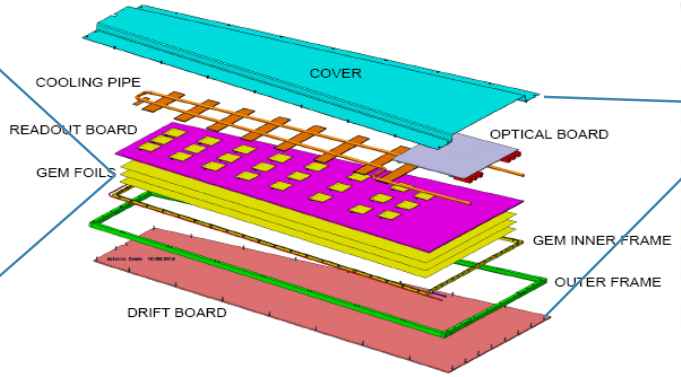
FLUKA SIMULATION

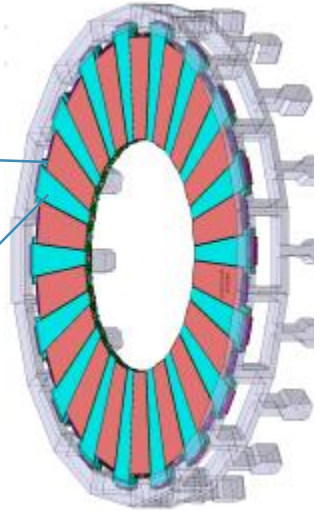


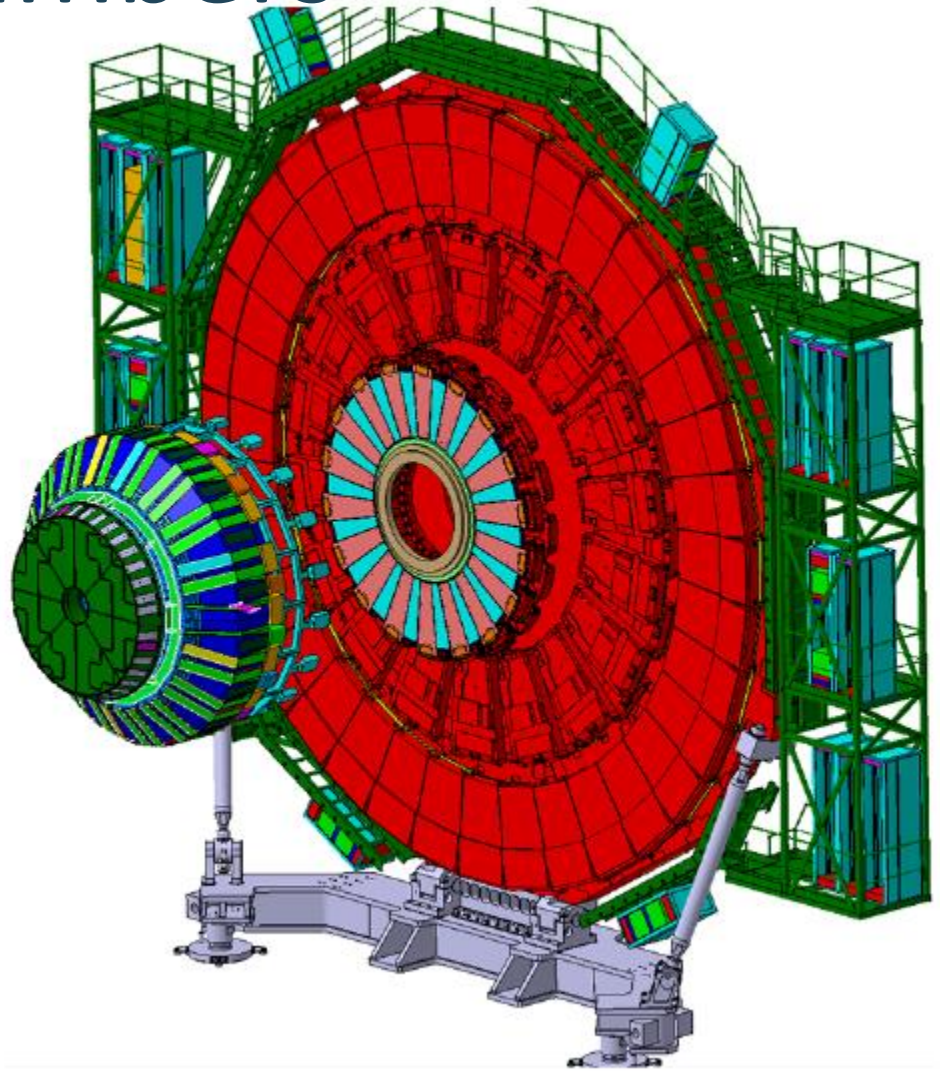
Gas Electron Multipliers technology is suitable thanks to its radiation hardness and rate capability (100 MHz/cm^2)

The GE1/1 triple GEM chambers



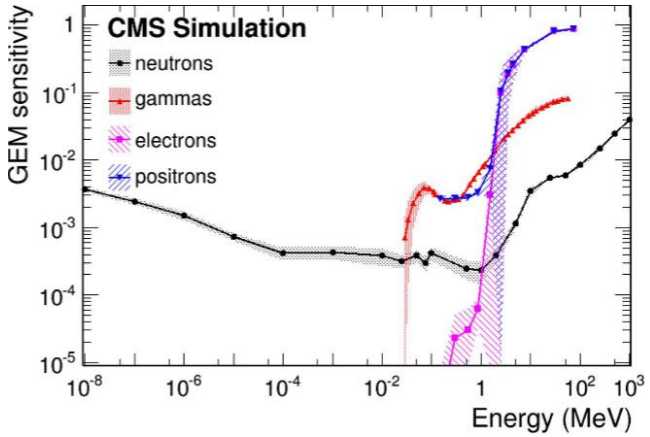






- Spatial resolution ≈ 100 um
- Time resolution 4-5 ns
- Efficiency 98%
- Rate capability 100 MHz/cm^2

	Sensitivity [%]
neutrons	0.18 ± 0.05
photons	0.97 ± 0.04
electrons	8 ± 3
positrons	8 ± 3

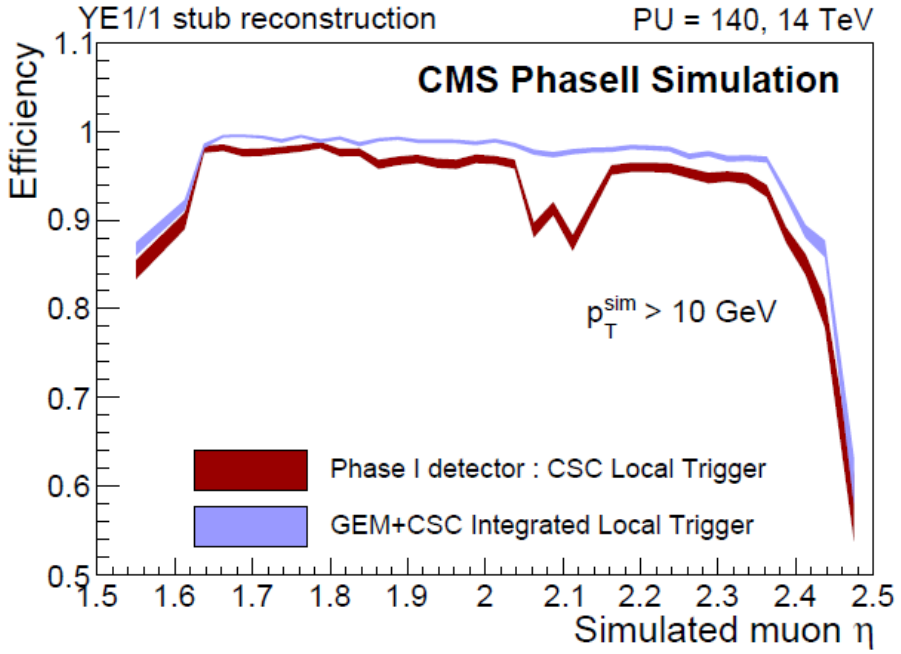


Sensitivity to cavern background evaluated using Geant4

See Ilaria Vai's poster in this Conference about the R&D of triple GEM prototypes

Advantages of a GEM CSC integrated trigger

A local trigger algorithm reconstructing local charged tracks segments based on input received from the CSC and GEM detectors has been developed

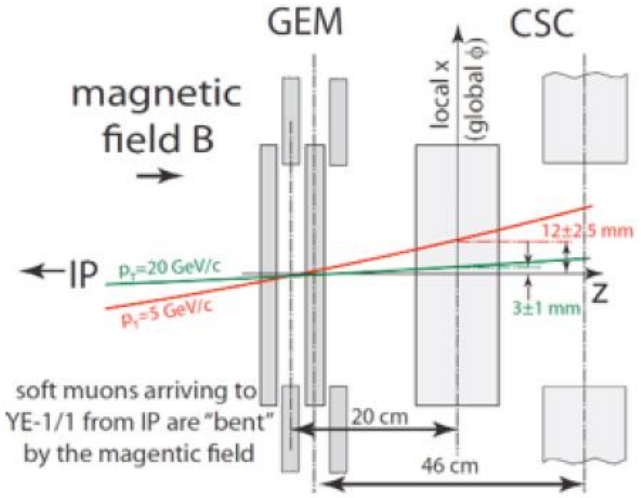


Improving the local trigger efficiency

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

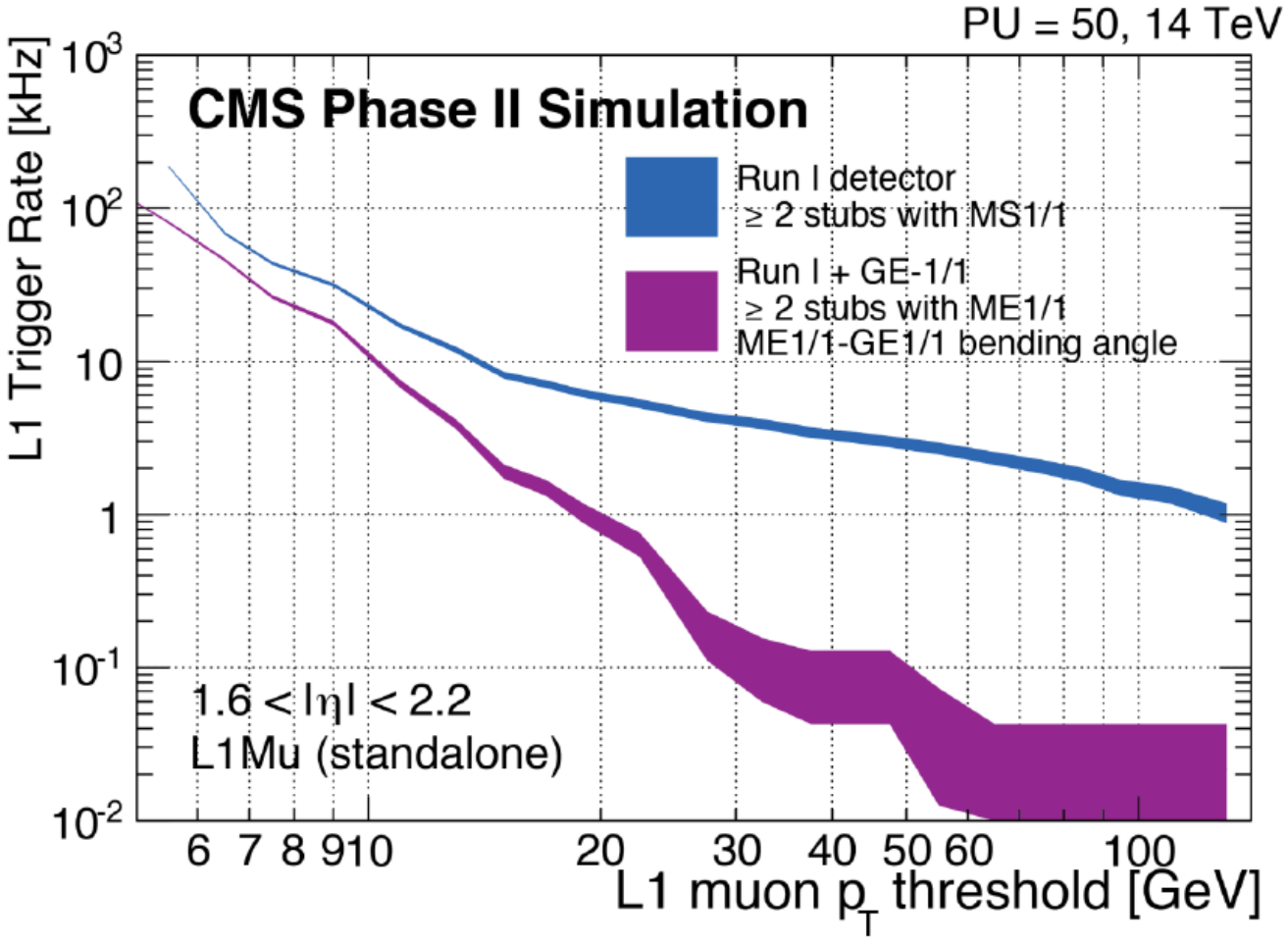


Reducing momentum mis-measurement of soft muons

What GE1/1 can do for the Trigger Rate

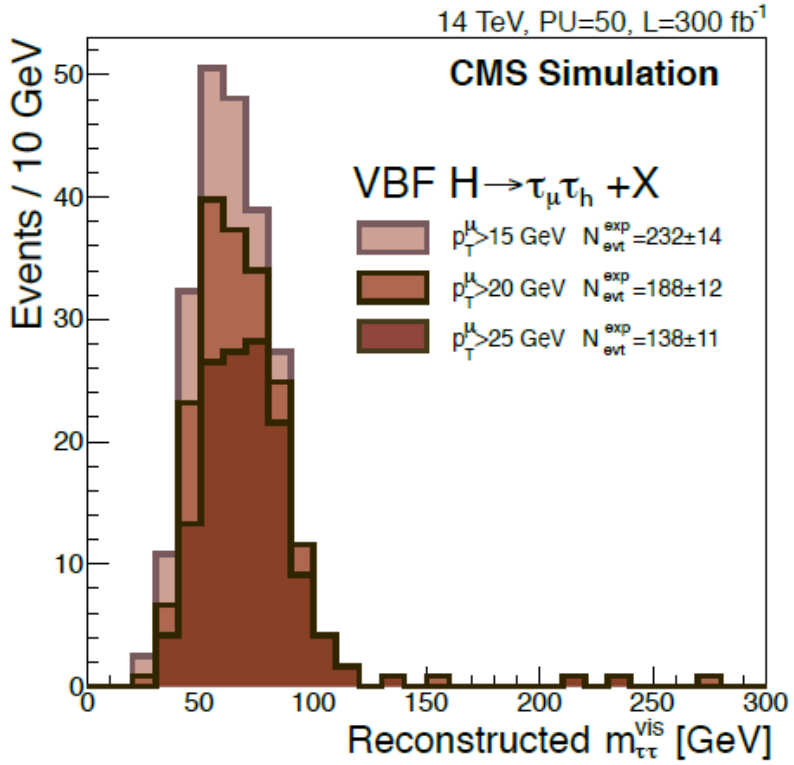
Reducing the L1 trigger rates would allow to keep low p_t thresholds

Not only the single muon trigger, but also other trigger paths would benefit: *dimuon, tri-muon, muon+ hadronic, muon+jets*

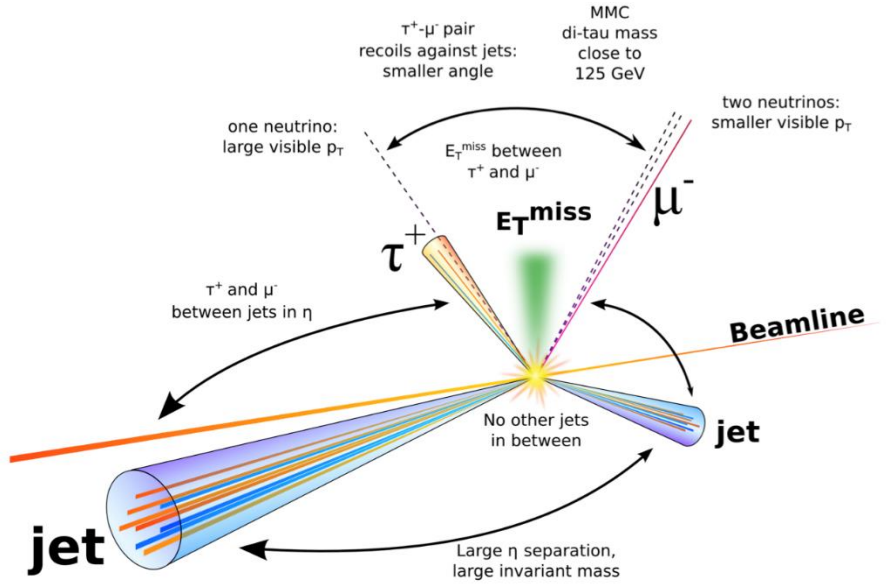


An example: VBF H → $\tau_\mu \tau_h$

Large sensitivity compared to other H -> $\tau\tau$ channels



Distribution of the reconstructed mass for a p_t threshold of 15 GeV, 20 GeV, 25 GeV



Simulation performed using common CMS analysis techniques and selections closely resembling the CMS Run I h-> 2τ observation paper

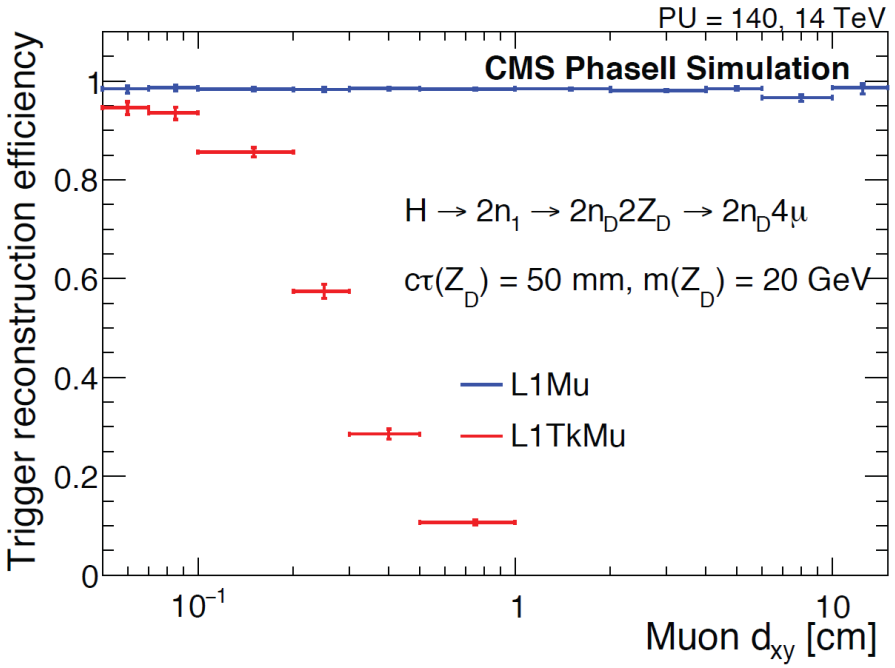
In **23%** of the events passing the selections, the muon candidate **falls into the GE1/1** chambers, independently of the p_t threshold

HL-LHC trigger performance

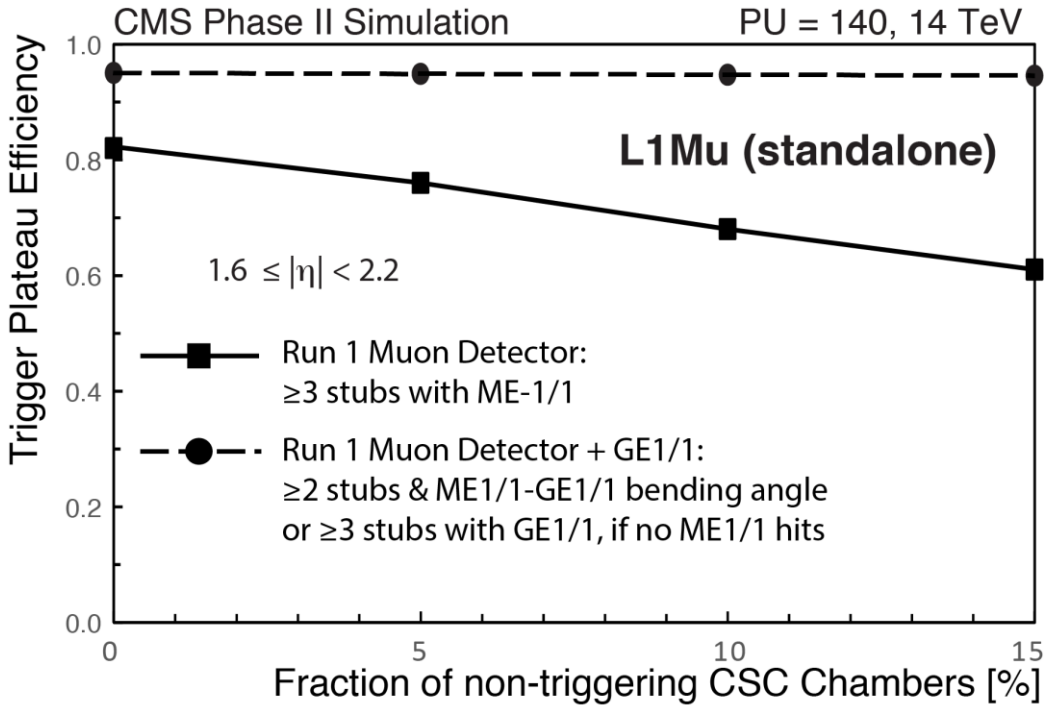
Information from the **tracker** will be included for an ultra-high purity and low-rate L1 trigger algorithm

BUT

this combined tracker-muon trigger fails with signatures with ***displaced vertexes***



Importance of the standalone muon trigger during HL-LHC

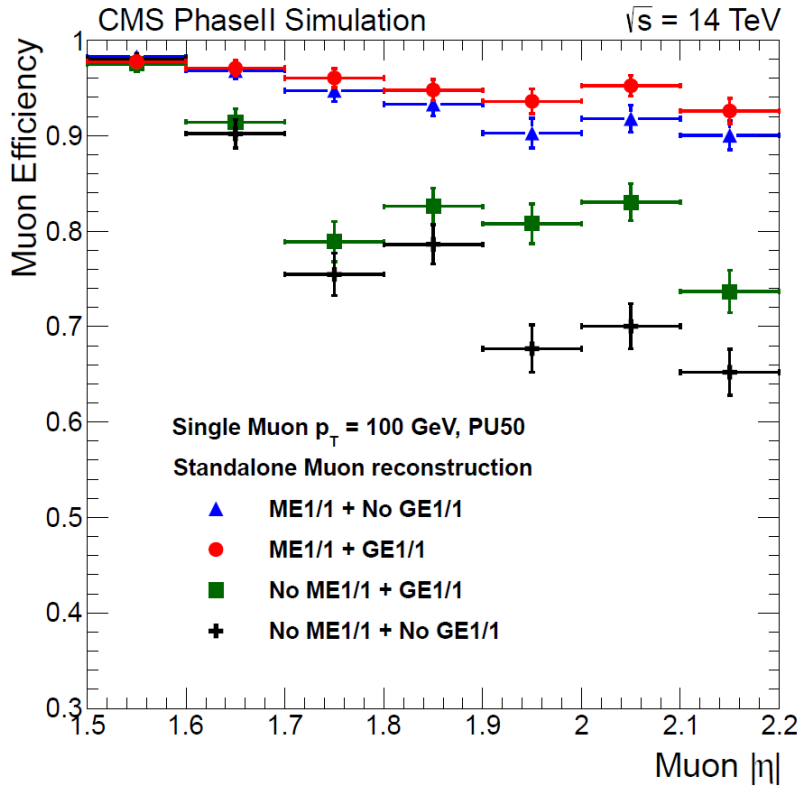


GE1/1 will allow to mantain trigger efficiency if part of the CSCs becomes inoperable

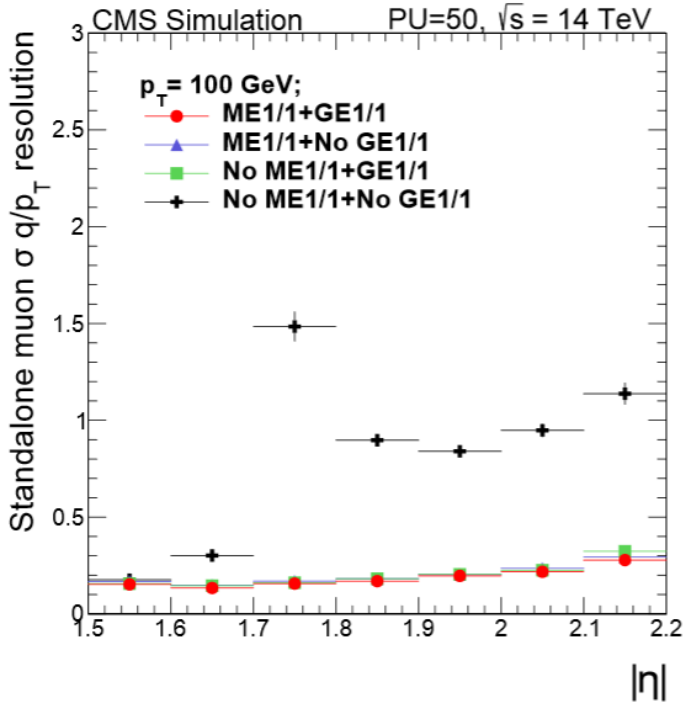
The benefits of redundancy

Muon reconstruction

The **first muon station**, where multiple scattering is the lowest and the bending of tracks in the magnetic field is the largest, has a strong impact on the quality of muon standalone reconstruction.



Standalone reconstruction efficiency for *high quality* muons



Mean of the residual distribution of the measured muon curvature q/p_t

$$\frac{q^{Rec}/p_t^{Rec} - q^{Sim}/p_t^{Sim}}{q^{Sim}/p_t^{Sim}}$$

GE1/1 will prevent deterioration in momentum resolution in case CSCs become inoperable

GE1/1 impact on momentum resolution

Conclusions

The GE1/1 station

will prevent the deterioration of the muon system improving:

- trigger rate at low p_t threshold
- redundancy at high η
- reconstruction performance

In view of LS3

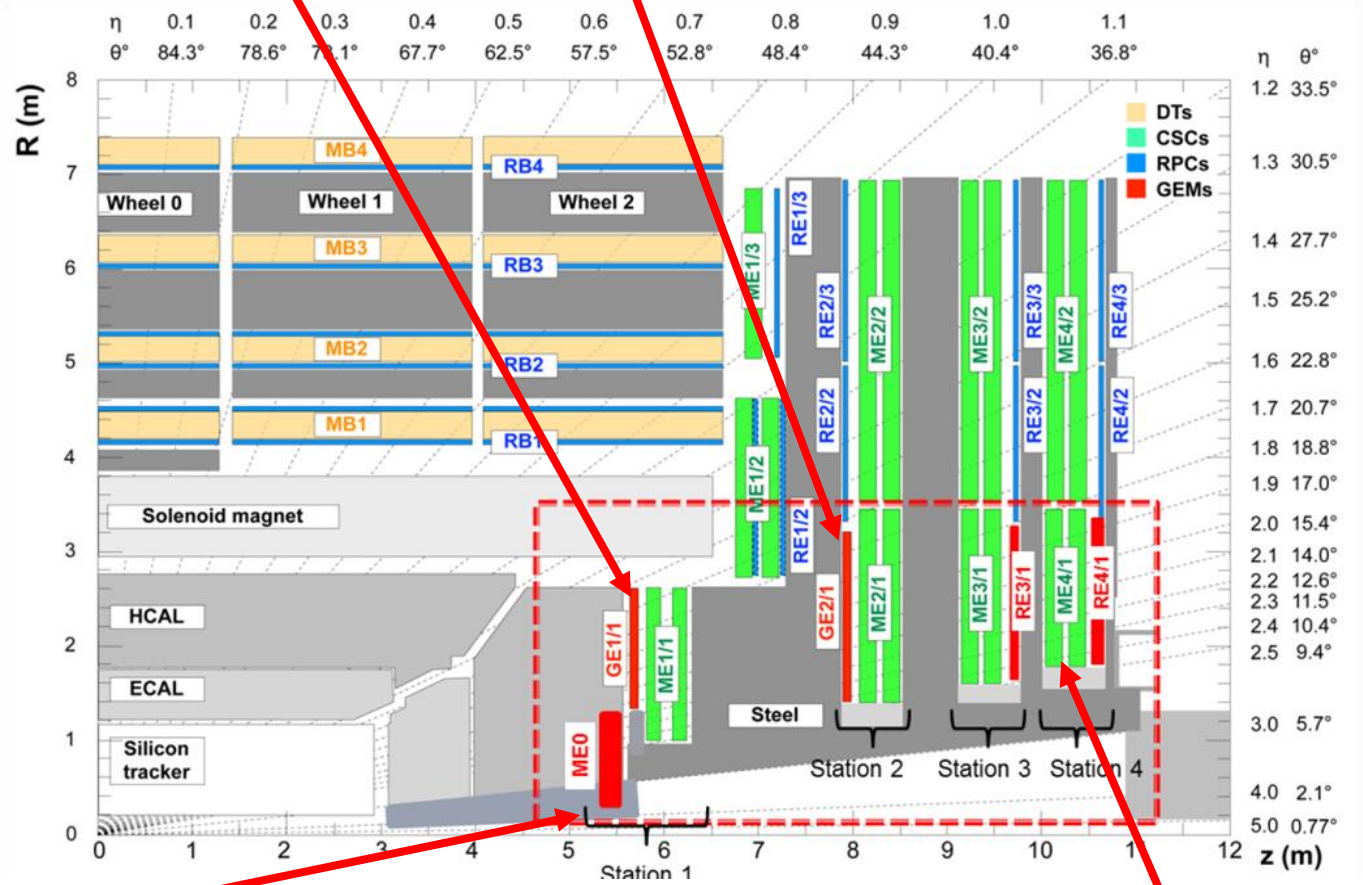
the implementation of additional muon stations

ME0, GE2/1, RE3/1, RE4/1

has been proposed.

GE1/1 LS2
GEM chambers

GE2/1 LS3
GEM chambers



ME0 LS3
GEM / other prototypes

RE3/1 RE4/1 LS3
Improved RPC, GEM?