Future of the CMS Muon Systems

Upgrades and Aging

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on behalf of the CMS Collaboration

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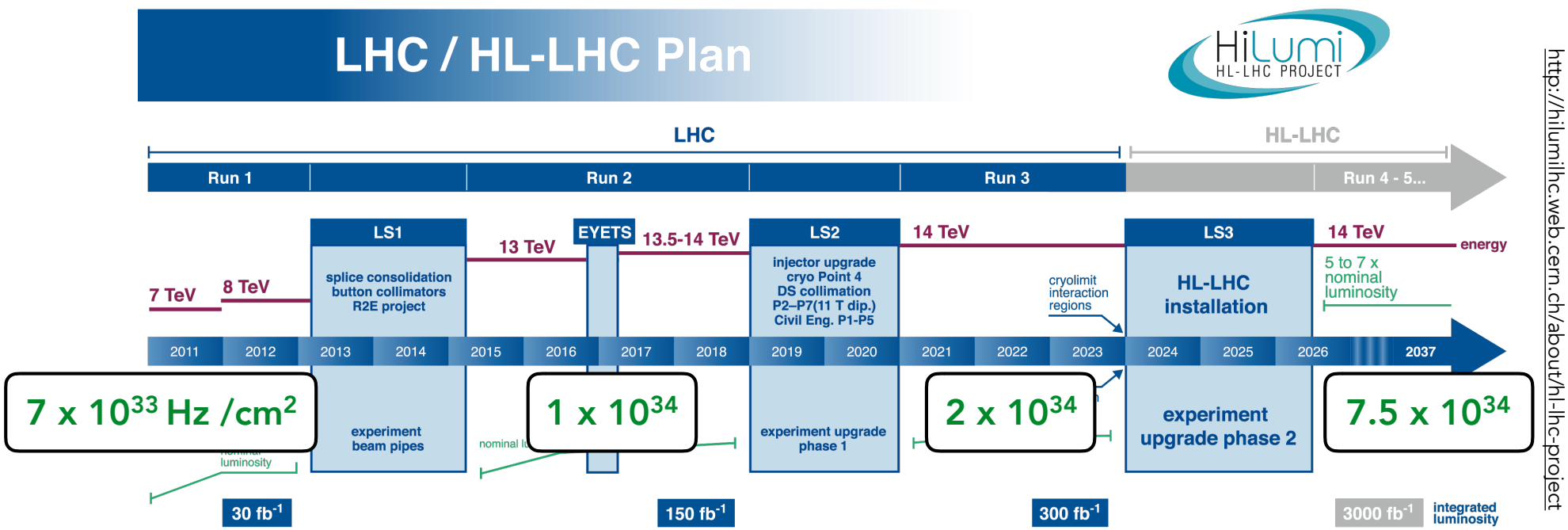
Introduction

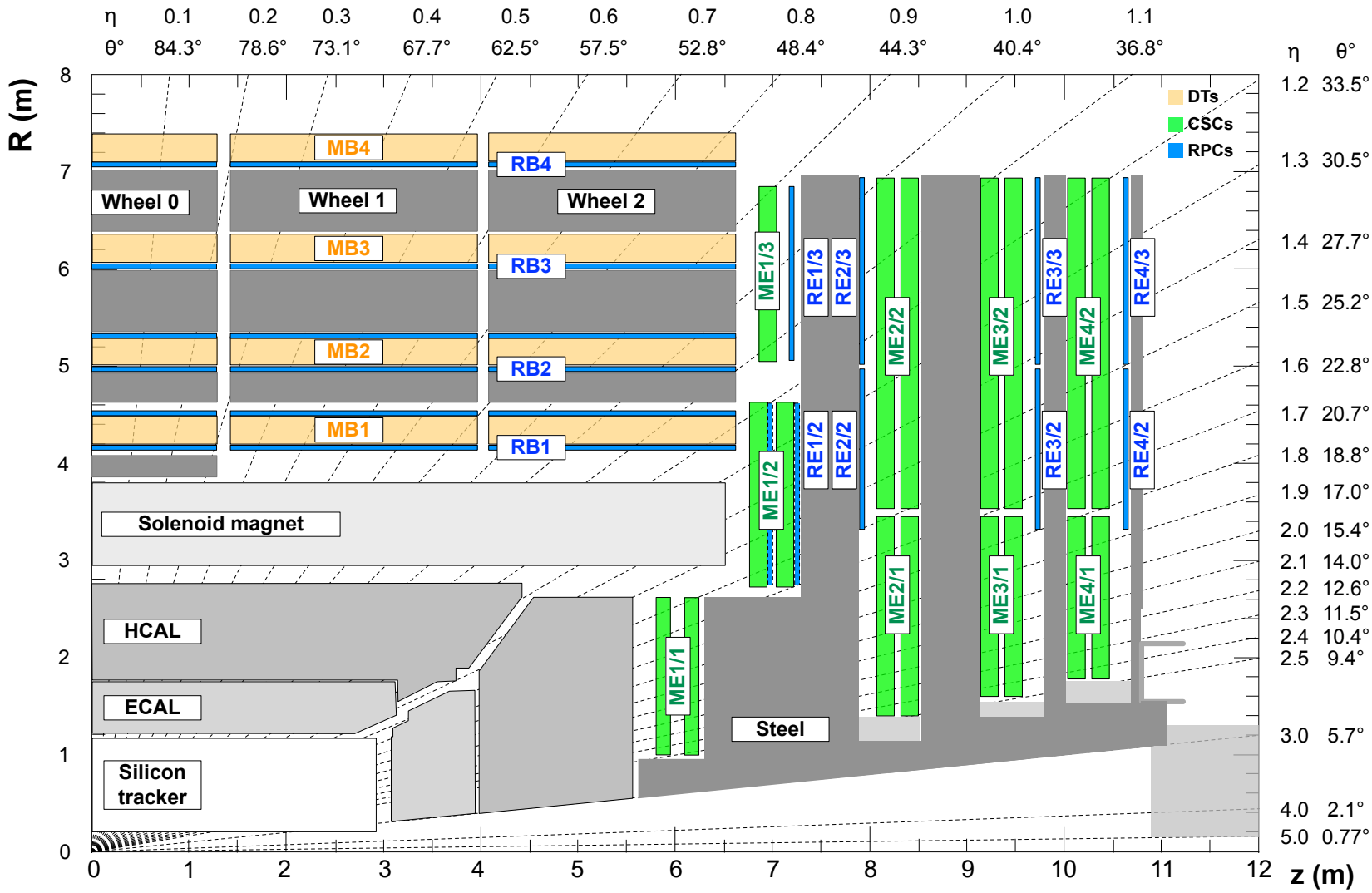
- LHC and experiments have been performing incredibly well
  - Record luminosities (1.25×10^{34} /cm^2/s)
- While we have had the last major jump in collision energy, the instantaneous luminosity is expected to increase by at least a factor of 5 in the future
  - HL-LHC expects 5–7 x 10^{34} Hz/cm^2
- Several upgrade projects on the horizon to maintain efficiency to physics processes in those conditions
  - Higher backgrounds (~140 pileup!)
- This talk will focus on the `Phase II' upgrade projects for the CMS muon systems



http://hilumilhc.web.cern.ch/about/hl-lhc-project

CMS Muon Systems

- Three separate technologies currently in use



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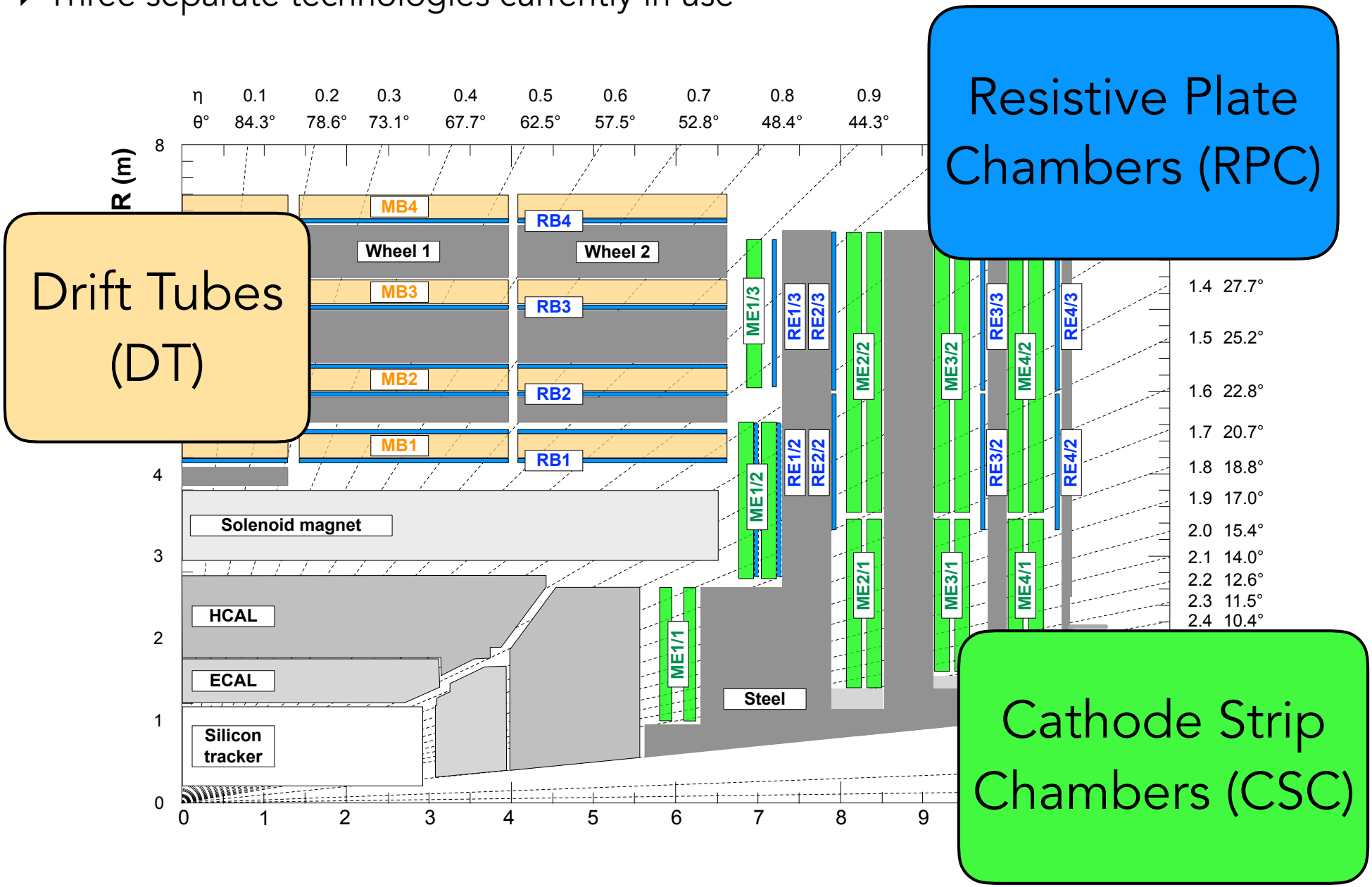
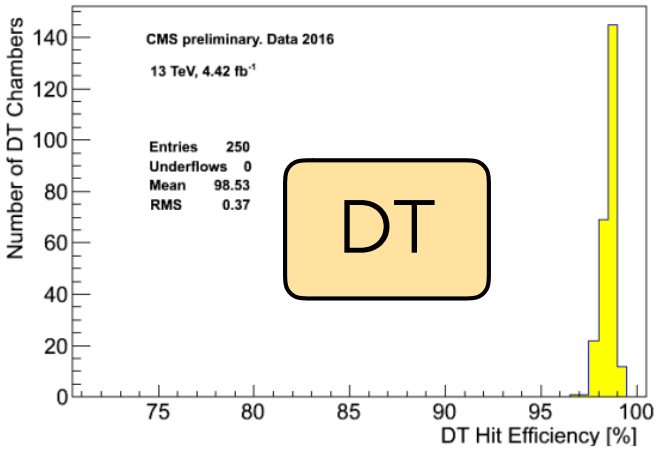
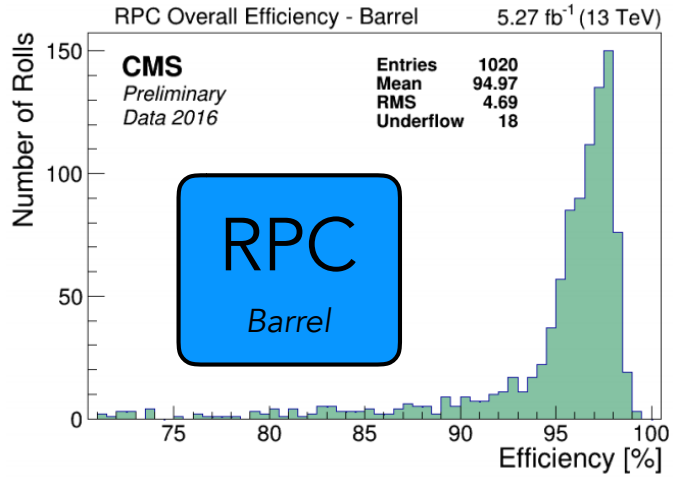
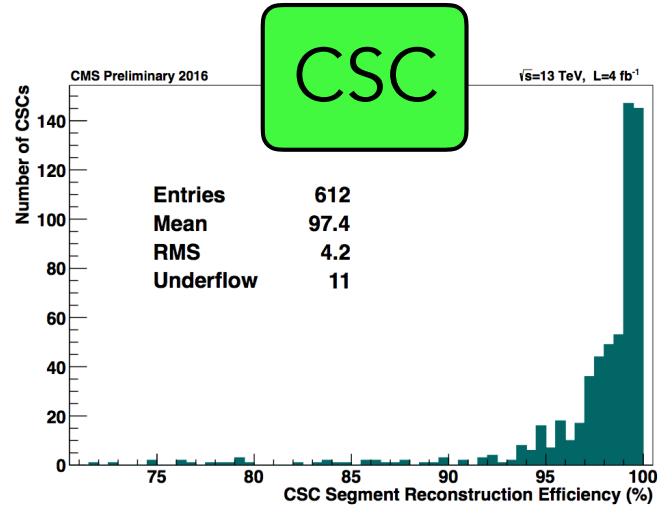


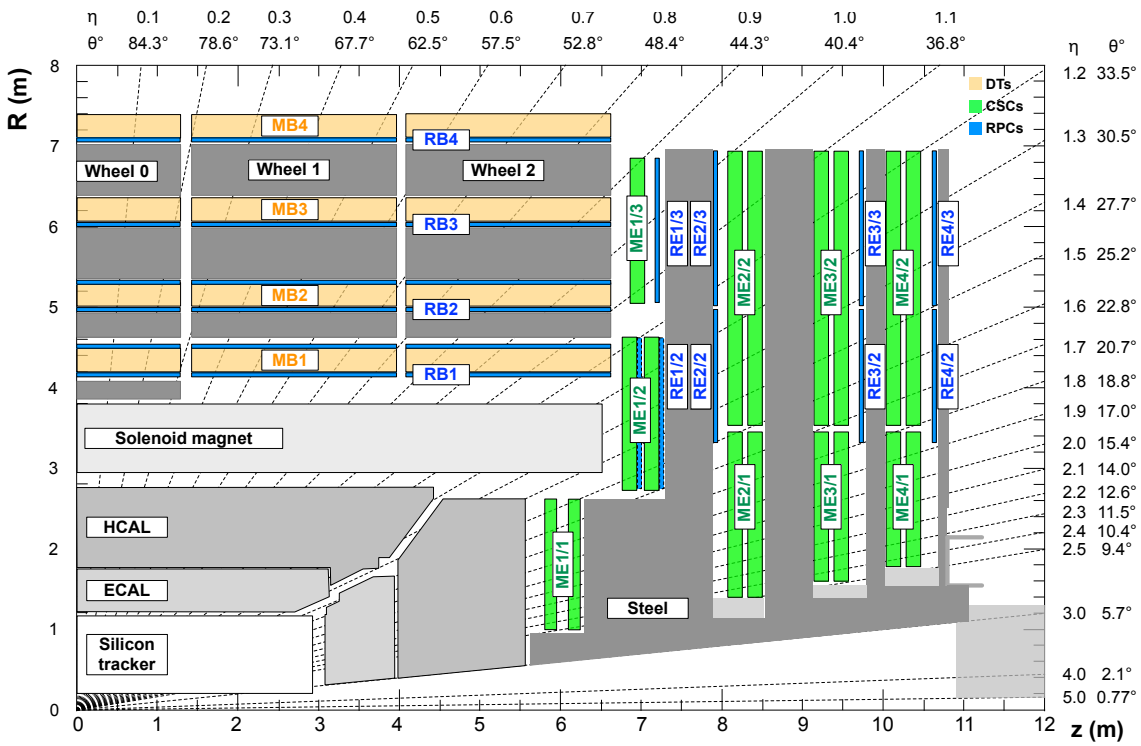
CMS 2016 Muon Performance

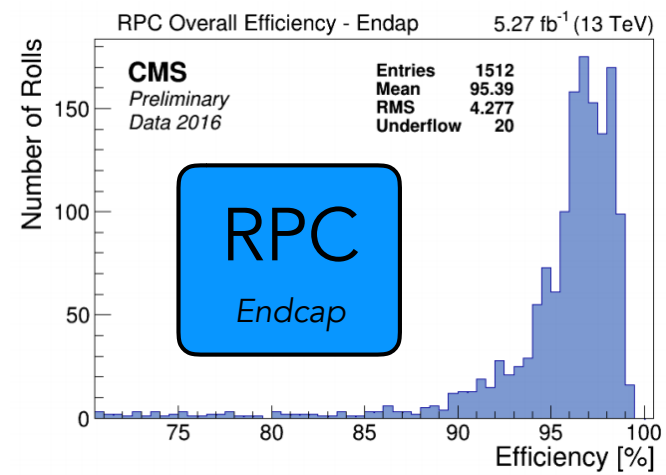
- Muon systems are efficiently taking high-quality data!





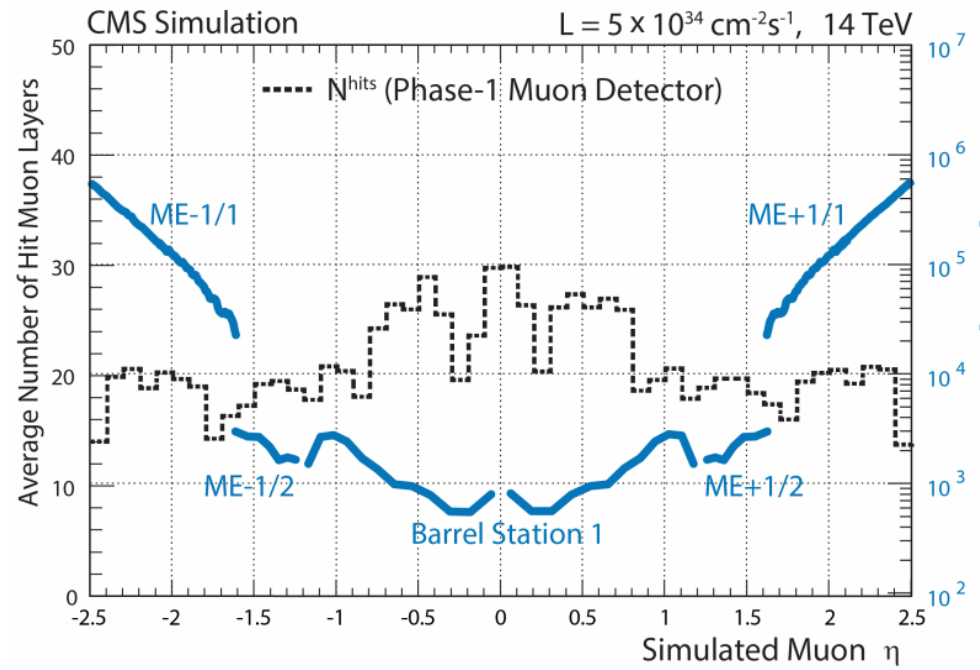


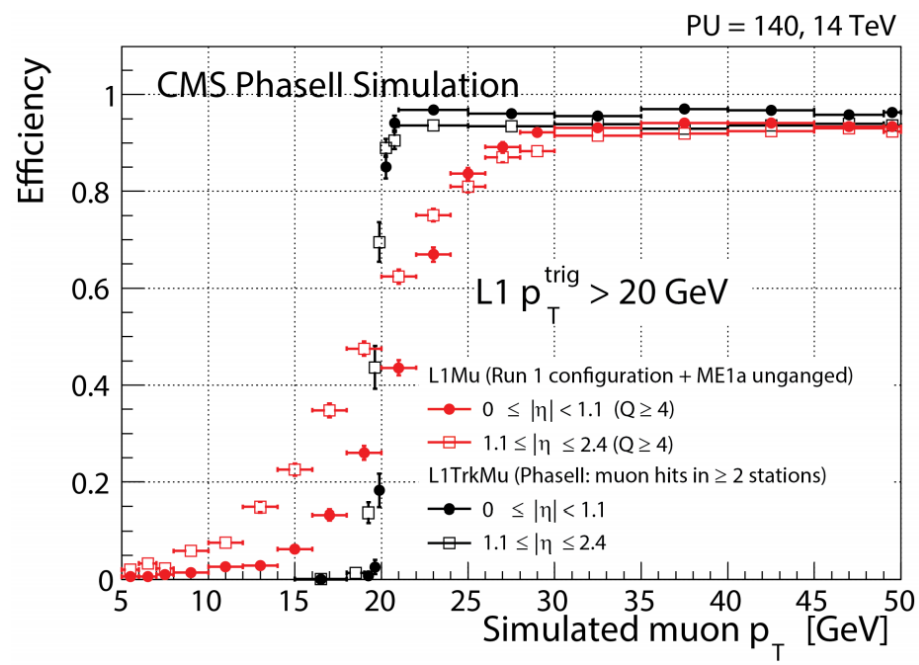




Phase II Upgrade Strategy

- **Ensure detector longevity**
  - Electronics and chamber operation
- **Increase redundancy**
  - Add layers in $1.5 < |\eta| < 2.4$, currently CSC coverage only
- **Mitigate rate increases**
  - Changes to readout electronics
  - New improved detectors for better discrimination of backgrounds
  - Adopt new trigger strategies
- **Retain sensitivity to physics processes**
  - Maintain reasonable trigger thresholds
  - Add forward coverage to $|\eta|$ of 2.8

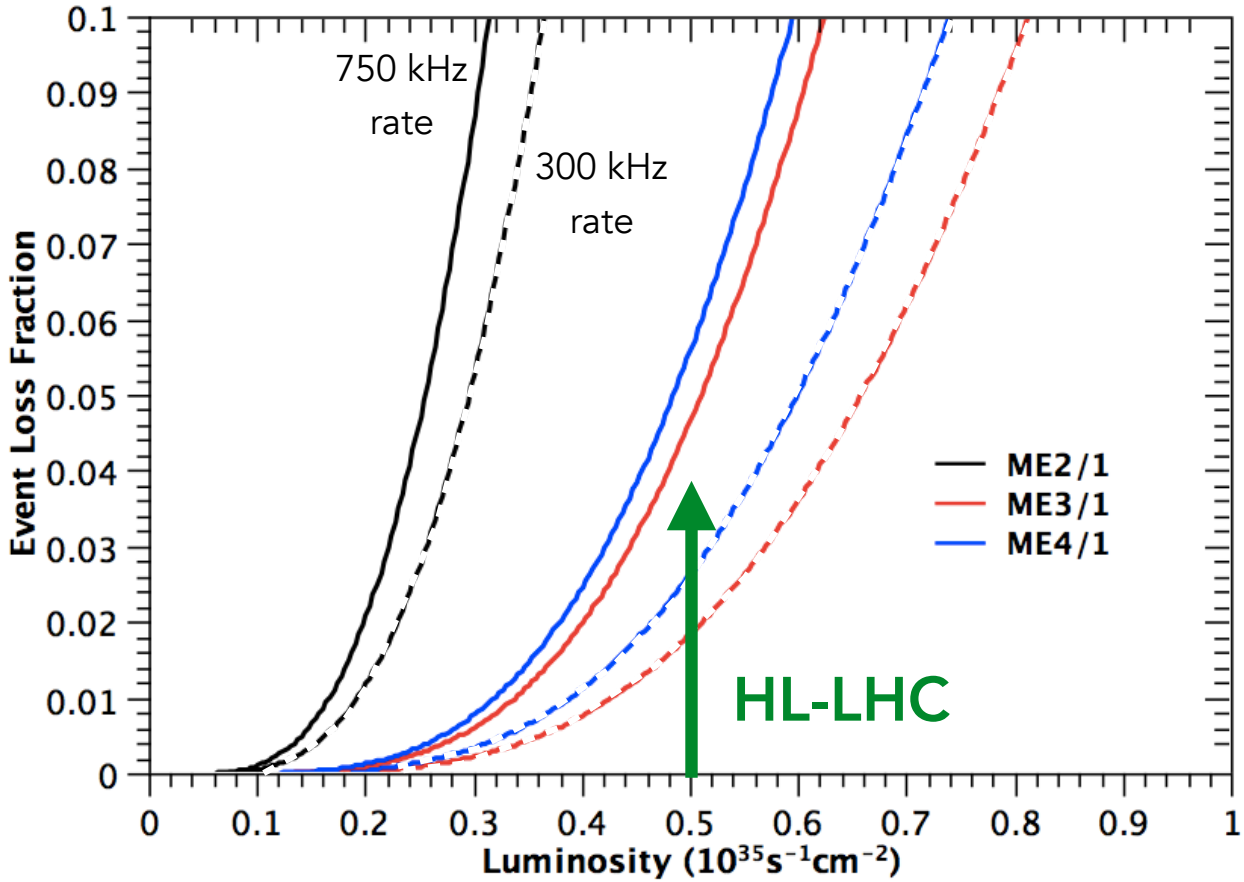




Upgrades of Existing Detectors

CSC Detectors

- Cathode strip chambers used in the endcap sections of CMS
- Current electronics for readout cannot sustain the planned trigger rates and latency
  - Analog pipelines fill up → data loss
- Proposal to replace by digital readout boards for stations MEx/1
  - $1.6 < |\eta| < 2.4$
  - 108 chambers x 5 boards
  - Improved memory depth
  - Fast optical links



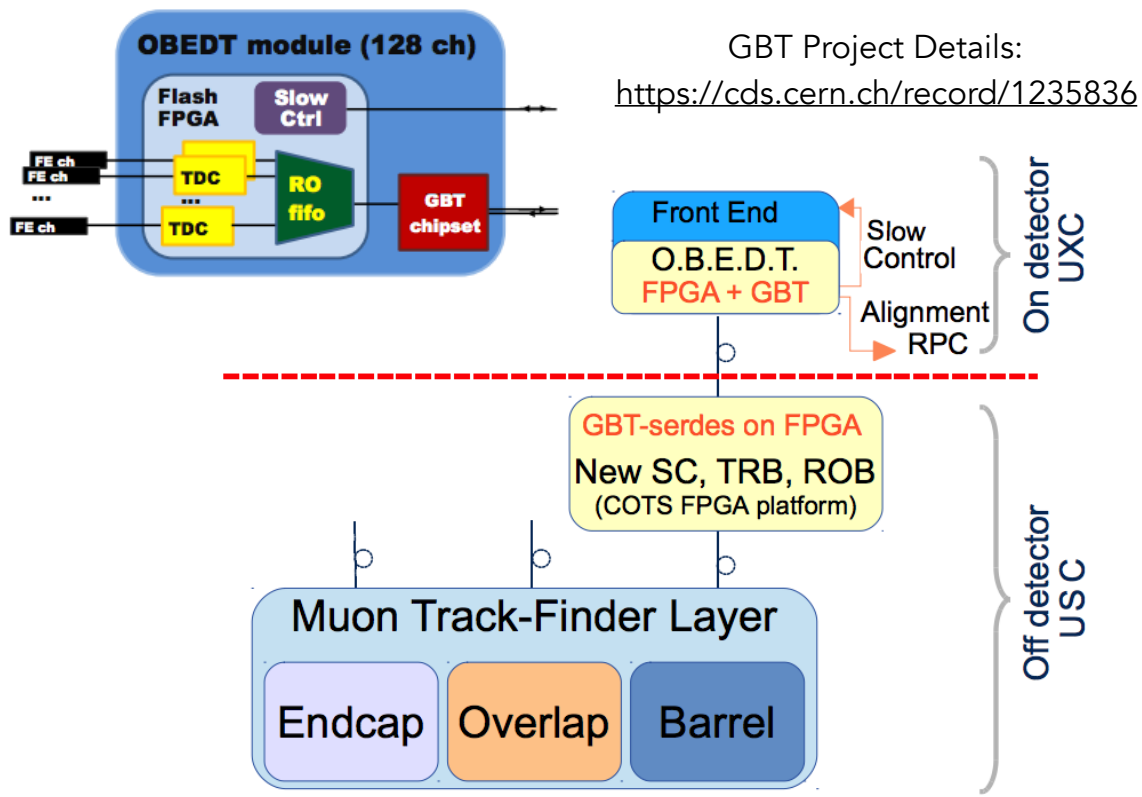
DT Detectors

- Detectors expected to operate for the HL-LHC data-taking up to 3000 fb^{-1}
  - Conservative estimate of 6.3% efficiency loss
  - Can be mitigated further by HV setting changes, e.g.

Failure rates after 10 yrs @ HL-LHC

Lifetime of the tubes	1%
FEB failure rate	2.8%
HVB failure rate	1.5%
Lower efficiency due to radiation	1%
Total chamber efficiency loss	6.3%

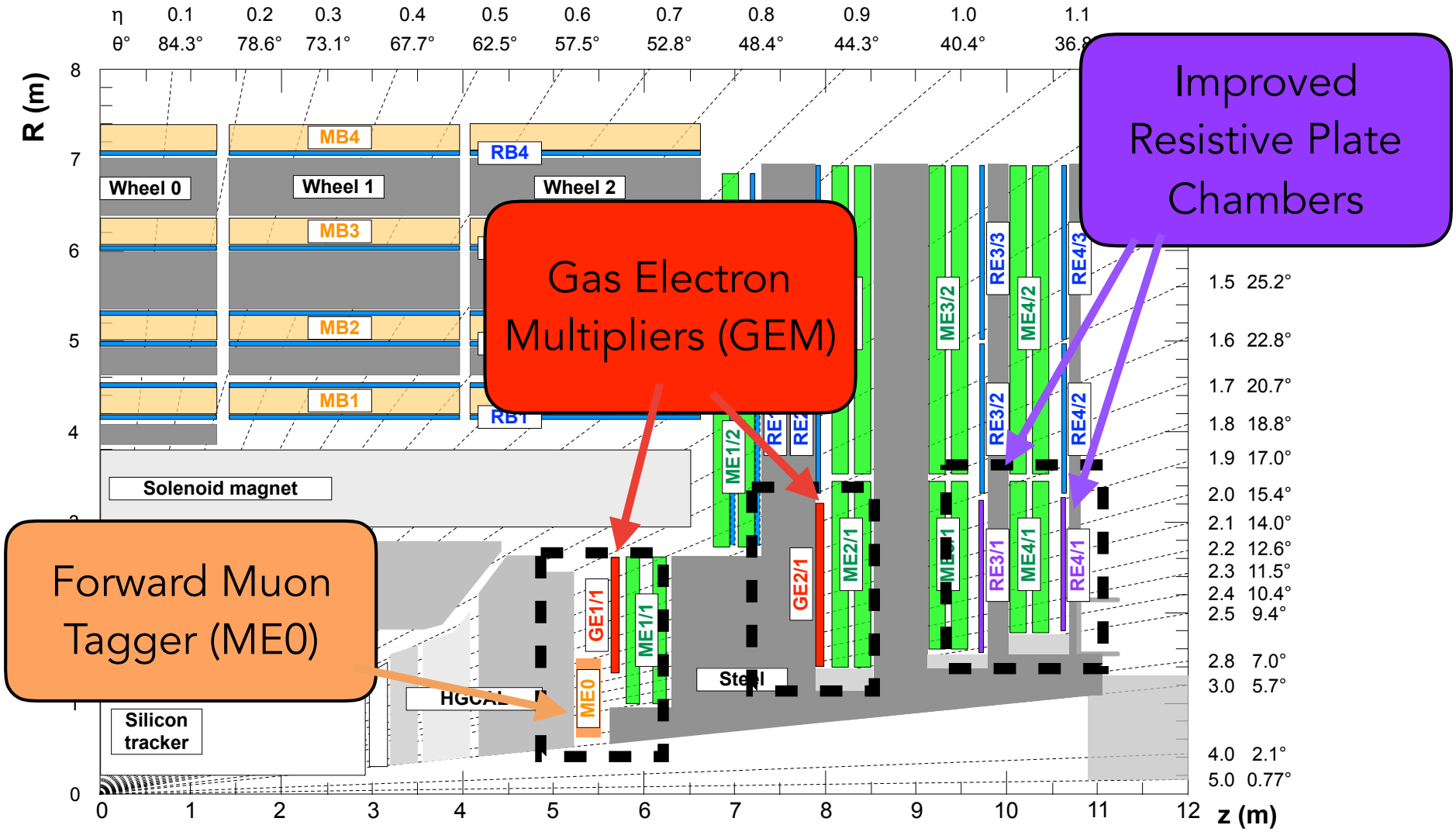
- Changes to electronics needed to maintain performance
  - Move part of readout chain off-chamber
    - Implemented through fast optical links
  - Improved time resolution from 12.5 ns to 3 ns, factor of 4 reduction in deadtime



New Forward Detectors

Phase II Scenario

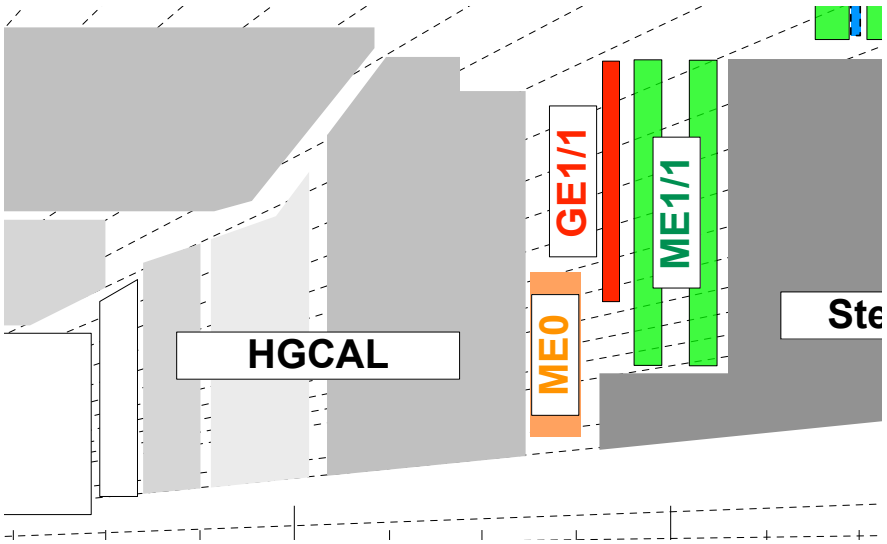
- New detectors to be installed
  - GEM detectors — GE1/1, GE2/1
  - Improved RPC chambers — RE3/1, RE4/1
  - Forward muon tagger — ME0

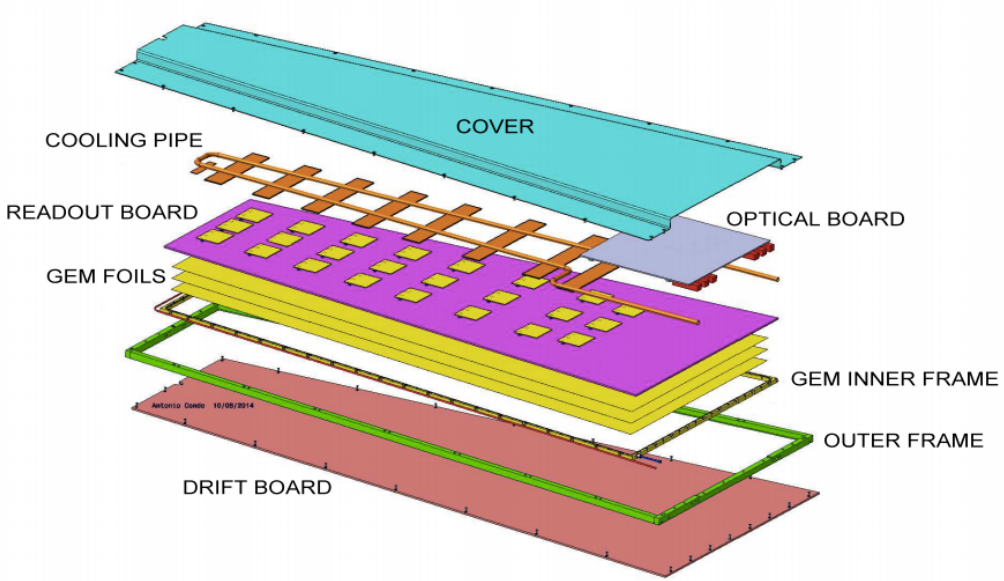


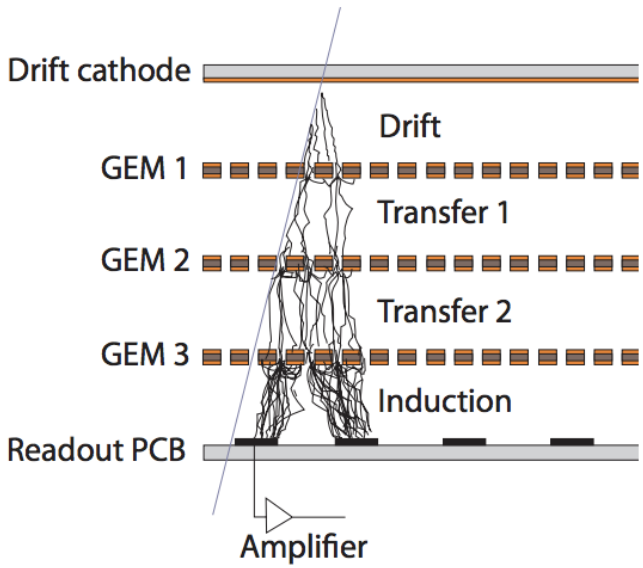
GEM Detectors

- Gas electron multiplier detectors new technology for CMS
  - 2 layers of triple-foil GEM chambers to be installed in front of existing CSC-ME1/1 chambers
  - Covers $1.6 < |\eta| < 2.2$

- Signals to be used in conjunction with CSC trigger primitives
  - See slides from J. Ruiz Alvarez for details on DAQ and control systems (4 Aug, 16:15)

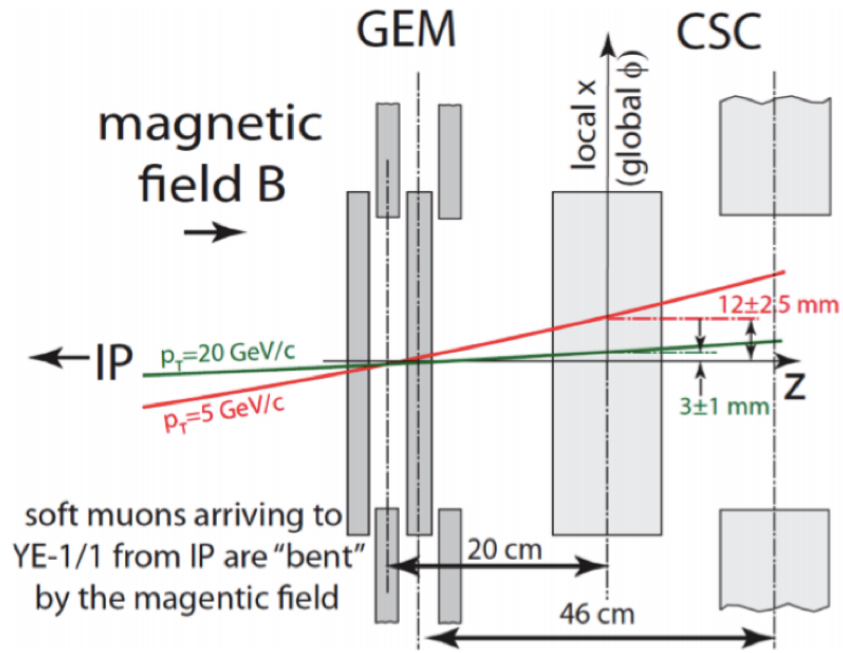




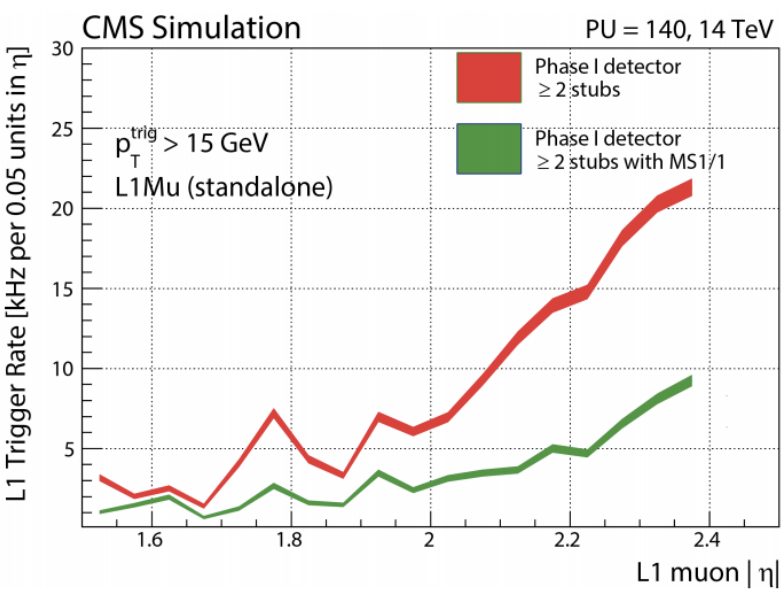


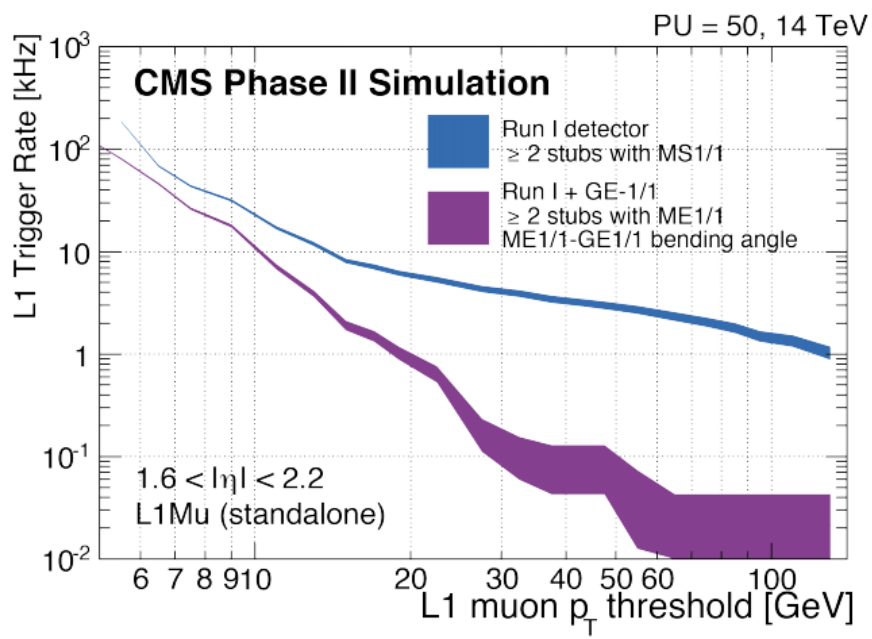
GEM Detectors

- Addition of GE1/1 reduces trigger rate by factor of 2-4 or more
  - Bending angle between GE1/1 and CSC-ME1/1 chambers used for discrimination
  - Retain efficiency for physics processes



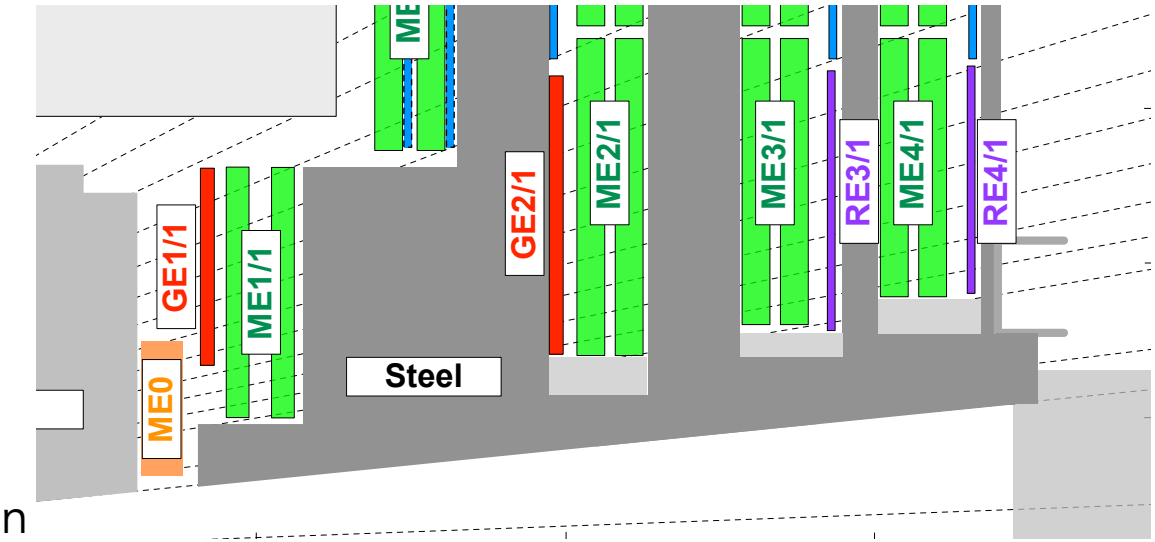
- GE1/1 scheduled for LS2 and GE2/1 for LS3 or sooner

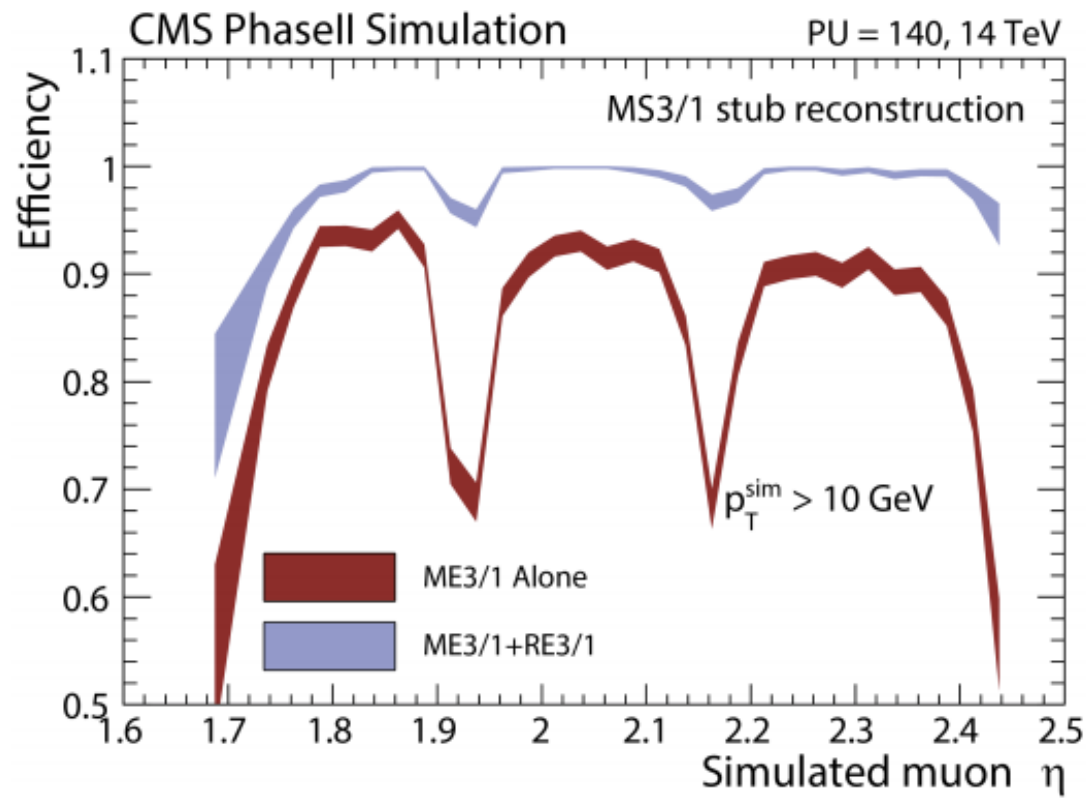




RPC Detectors

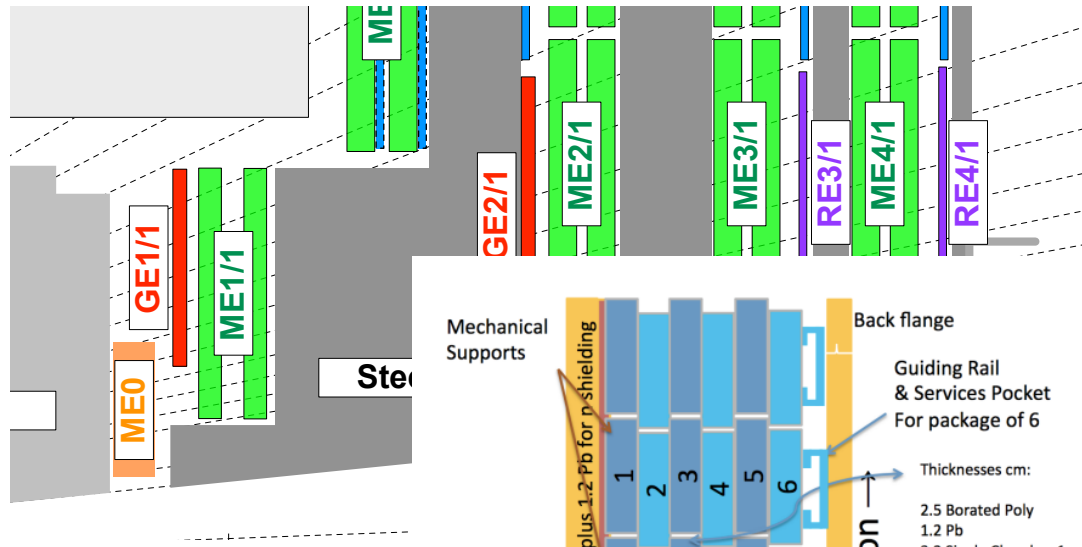
- Resistive plate chambers currently in use in both the barrel and endcap regions of CMS
  - Existing detectors can cope with rates through HL-LHC period
- Addition of rings RE3/1 and RE4/1 restores redundancy in forward region
  - $1.6 < |\eta| < 2.4$
  - Improved chamber design
  - Option considered for timing resolution of ~100 ps → mitigate rate increases from neutron background
- High rate capability needed!
  - Can perform with particle rates up to 2 kHz/cm^2

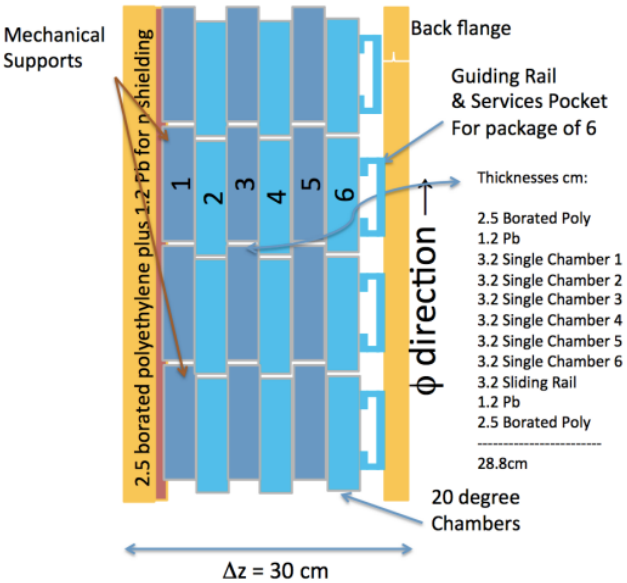


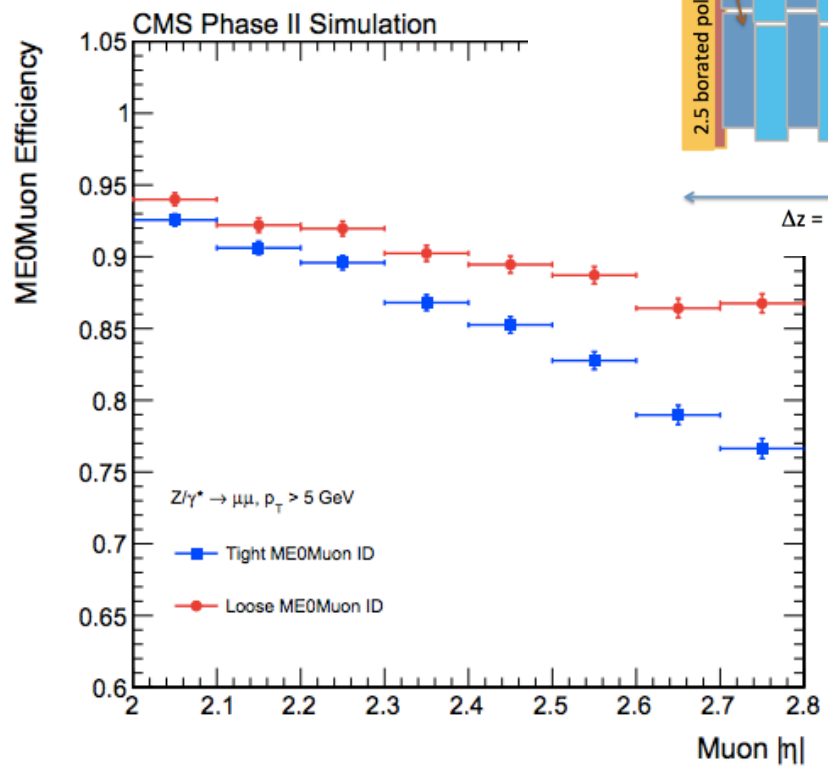


ME0 Forward Muon Tagger

- With the new forward calorimetry (HGCAL), space is freed behind for additional instrumentation
- 6 successive GEM triple-foil chambers
  - Shielding surrounding active elements
- Increases muon coverage and trigger capability
  - Also provides neutron background discrimination
- Efficiency of ~90% for muon identification up to $|\eta| < 2.8$ and $p_T > 5$ GeV

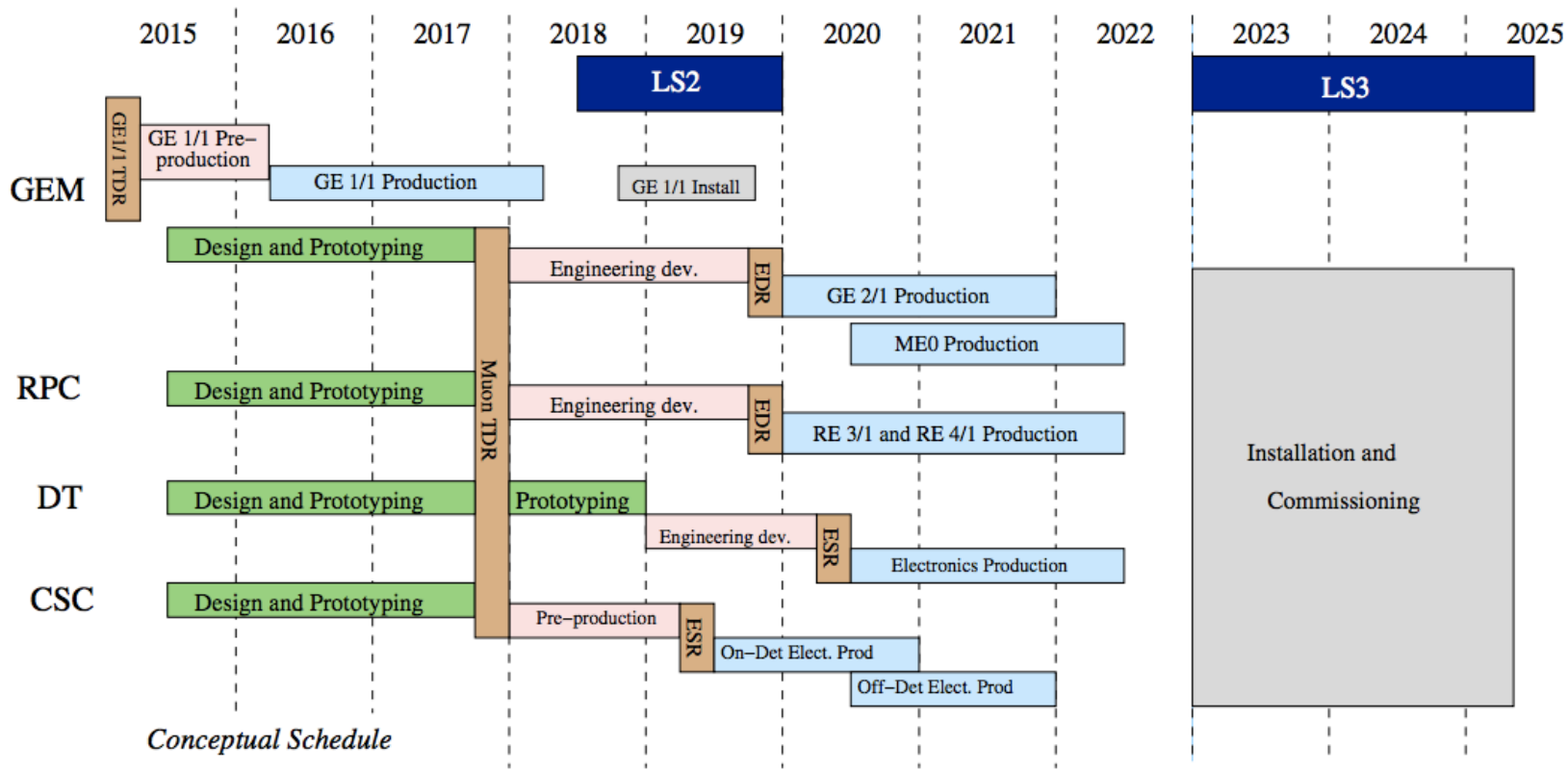






Summary

- Plans for upgrades of the CMS muon systems are well underway!
  - **Improvements** to electronics of existing detectors
  - **New high-rate, rad-hard detectors** in forward regions
- Maintain operation through 10 yr HL-LHC operation with **high efficiency**!
- More information available in CMS Phase II Technical Proposal [1]
  - Many talks/posters here at ICHEP also!



[1] https://cds.cern.ch/record/2020886

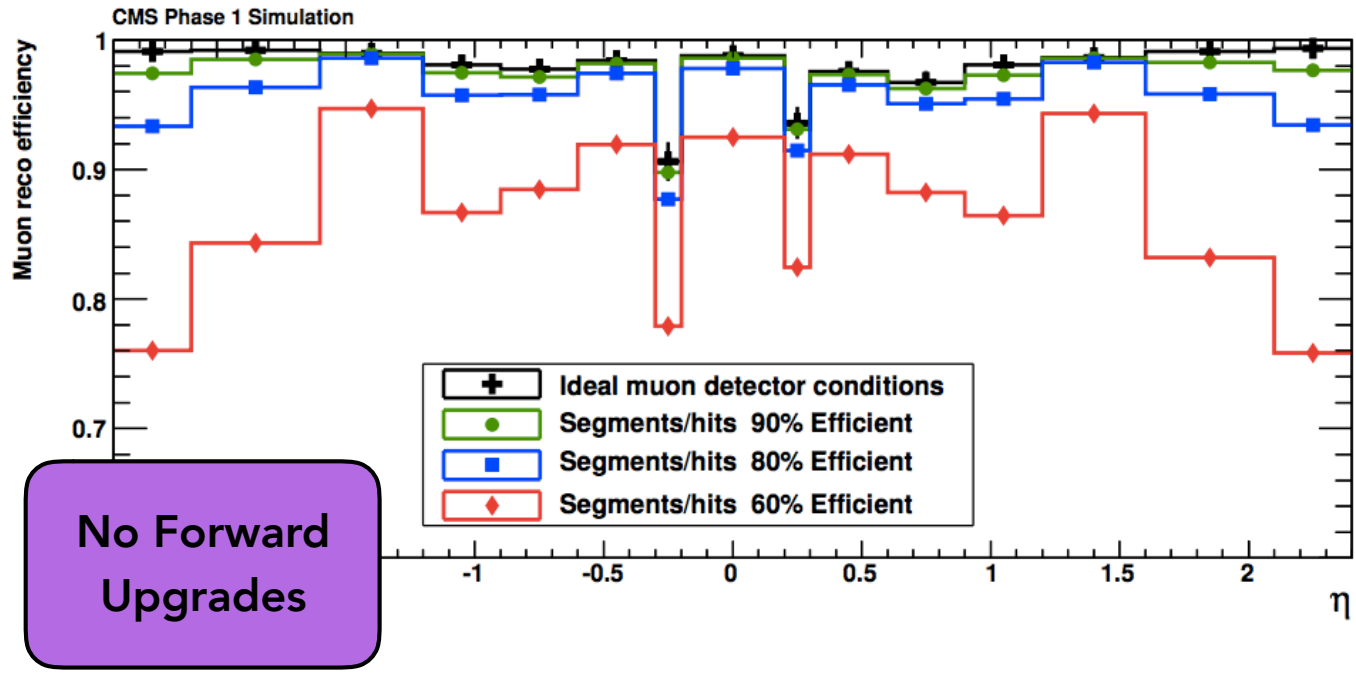
Backup Material

References:

Technical Proposal for the Phase-II Upgrade of the CMS Detector
https://cds.cern.ch/record/2020886
CMS Technical Design Report for the Muon Endcap GEM Upgrade
https://cds.cern.ch/record/2021453

Aging Scenarios

- Assuming some degradation in chamber operation, system loses reconstruction efficiency without upgraded detectors
  - Degradation of CSC, RPC segments/hits included



- With upgrades, ~90% efficiency is maintained due to increased redundancy

- Note: DT aging scenarios not accounted for