Longevity study of CMS Muon Detector facing the High Luminosity LHC phase

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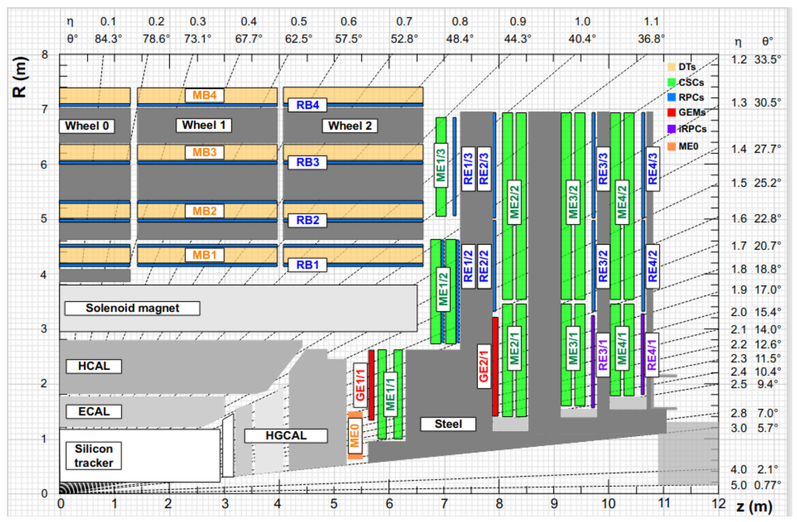
Introduction

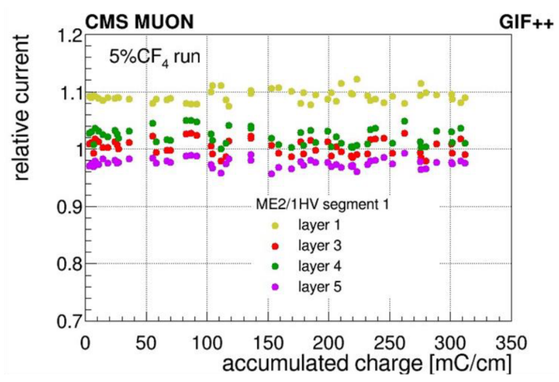
The longevity studies of CMS Muon Detector is a critical area of research aimed at ensuring that the subdetectors can withstand the increase in radiation expected during the High Luminosity Phase-II upgrade of LHC (HL-LHC), after already more than 15 years of operation. The four subdetectors types (CSC, RPC, GEM and DT) have been tested mainly in CERN Gamma Irradiation Facility (GIF++) [1] during the last years, although the GEM results presented are from Aachen University. At GIF++, the chambers are exposed to a ^{137}Cs radiation source (662 keV). The aim is to subject the subdetectors to a high radiation rate to accumulate the same charge anticipated after 3000 fb^{-1}, which is expected at the end of the HL-LHC.



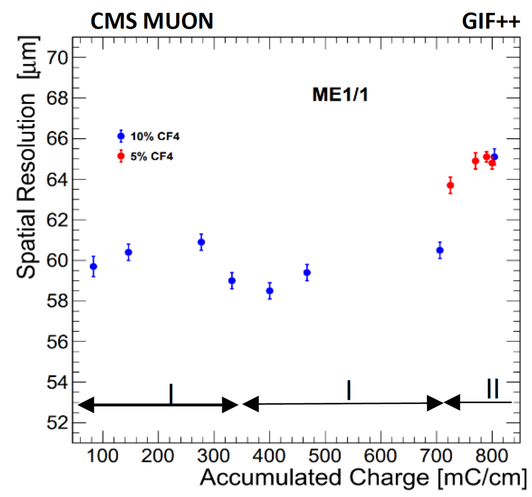
Schematic longitudinal view of one quarter of the CMS detector with the different subsystems which compose the Muon Detector for the Phase-II upgrade of LHC.

Cathode Strip Chamber (CSC)

Cathode strip chambers, ME1/1 and ME2/1, have been irradiated at GIF++ since 2016. The accumulated charge for ME1/1 reached 800 mC/cm, while for ME2/1 it reached 610 mC/cm, more than three times the charge expected during HL-LHC operation [2]. Observing the relative current to a reference layer not irradiated of the same chamber can show the behavior in a high luminosity environment as the CMS. The relative current, time resolution, and dark rate remain stable over time, leading us to conclude that there are not degradation effects in either chambers after irradiation.



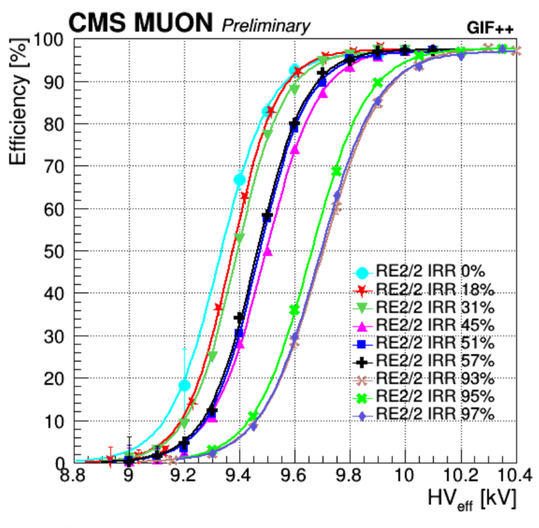
Relative currents measured in irradiated layers of ME2/1 as a function of the accumulated charge.



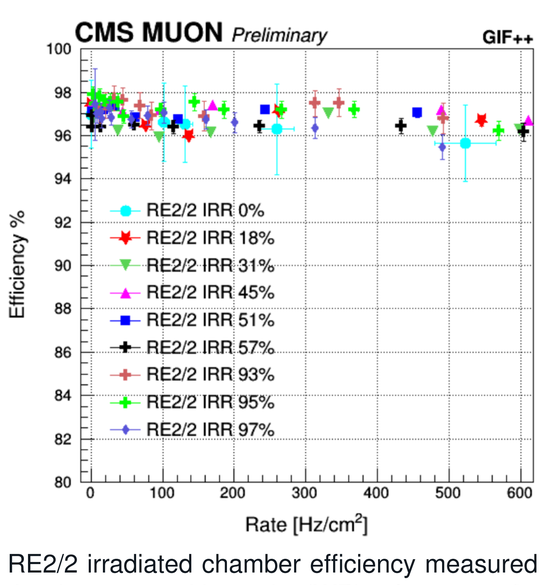
Spatial resolution of ME1/1 measured with a muon beam as a function of the accumulated charge.

Resistive Plate Chamber (RPC)

Reference and irradiation RPCs are kept in GIF++ bunker and the performance is measured for both of them and compared afterwards [3].
The measurements have been performed before the irradiation (0%) and repeated after different periods of irradiation up to 97% of 840 mC/cm^2, expected integrated charge at HL-LHC phase considering a safety factor 3. No aging effects are observed.



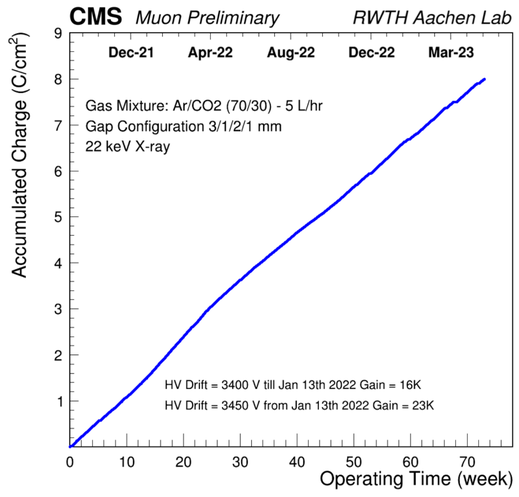
RE2/2 irradiated chamber efficiency measured as a function of the effective high voltage, under a gamma background rate of about 600 Hz/cm^2 which represents the expected background rate at HL-LHC including safety factor of 3.



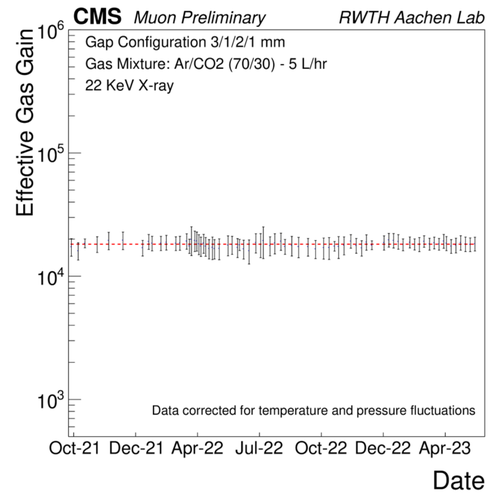
RE2/2 irradiated chamber efficiency measured at the detector working point (WP) voltage as a function of the background rate at different values of collected integrated charge.

Gas Electron Multiplier (GEM)

Gas Electron Multipliers are a recent enhancement to the CMS muon detector to extend its coverage in the very forward region where radiation levels and event rates are expected to rise significantly during HL-LHC. A triple-GEM chamber was irradiated over 18 months with photons up to 8 C/cm^2 accumulated charge. The results show no degradation of gas gain. Moreover, material analysis on the foils reported no oxidation of copper or change in the element composition [4].



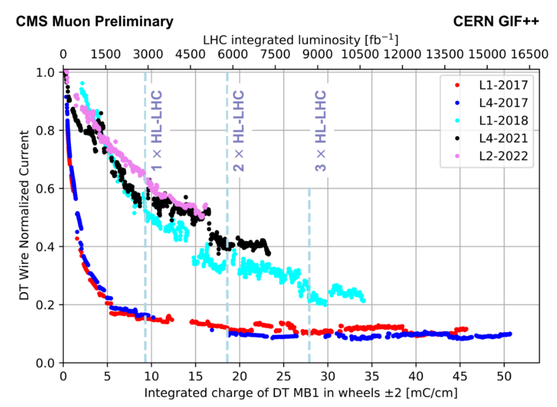
Accumulated charge as a function of the operating week counting only the active irradiation time, not the periods of chamber characterization.



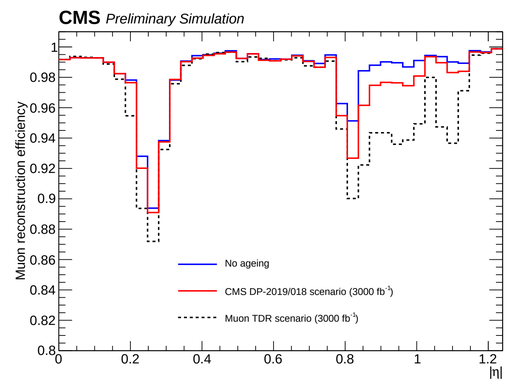
Monitored gas gain as a function of time. The error bars reflect the uncertainty on the readout current.

Drift Tube (DT)

Aging in the Drift Tubes chambers has been observed at GIF++ due to the accumulation of pollutants on the wires [5]. These pollutants decrease the gain on the wires, which in turn affects the hit efficiency. Over the year, multiple measurements were taken to gauge the speed of this process. Even in the worst-case scenario, the reduction in efficiency will affect only a small part of the detector, specifically the most exposed region in the forward area (YB2), leading to a limited loss of efficiency in muon reconstruction.



Normalized current for different sets of irradiated wires as function of the integrated charge (dose).



Muon reconstruction efficiency at CMS as a function of absolute η for non-aged DT chambers and aged DT chambers. The efficiencies have been calculated using simulated sample of muon events.

Conclusions

The study of the stability of each subdetector has been an ongoing task since 2015 at the CMS muon laboratories and GIF++ given the upcoming HL-LHC. The operation of the detectors under high radiation flux could directly have an impact on the material aging, thereby affecting detector efficiency. Therefore, these studies are vital to maintain good performance and high redundancy in the experiment. The latest results show all subdetectors in good shape, and no major degradation has been observed in the long-term operation of the muon system. The estimation of the Drift Tubes performance, considering the wire degradation, reported a not significant loss of efficiency during their future operation.

References

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[5] D.D. Redondo Ferrero et al. “Irradiation aging of the CMS Drift Tube muon detector”. In: *Radiation Physics and Chemistry* 172 (2020), p. 108747. ISSN: 0969-806X. DOI: https://doi.org/10.1016/j.radphyschem.2020.108747. URL: https://www.sciencedirect.com/science/article/pii/S0969806X19310230.