16TH PISA MEETING ON ADVANCED DETECTORS

Longevity studies for the CMS Muon System towards HL-LHC

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1 Introduction

The longevity studies of the Compact Muon Solenoid (CMS) is a critical area of research aimed at ensuring that the detectors can withstand the increase in radiation expected during the Phase-II upgrade of LHC (HL-LHC), after already more than 15 years of operation. For the Muon System, GIF++ (Gamma Irradiation Facility) was the main testing ground for the four detectors (RPC, CSC, DT and GEM) during these years, although the GEM results presented here are from Aachen University. In GIF++, the chambers are exposed to a radiation source of ^{137}Cs (662 keV). The idea is to subject the detector to a high rate of radiation in order to accumulate the same charge expected after 3000 fb^{-1}, what is expected at the end of the HL-LHC.

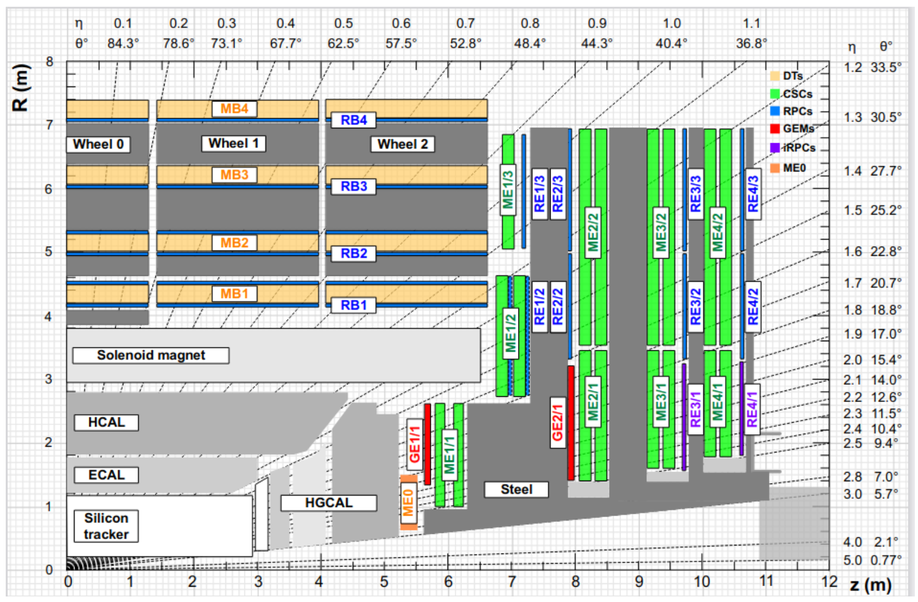

Figure 1: Schematic longitudinal view of one quarter of the CMS detector with the different subsystems which compose the Muon Detector for the Phase-II upgrade of LHC.

2 CSC longevity studies at GIF++

Cathode Strip Chambers have accumulated a significant radiation dose since the beginning of LHC. There are two approaches to study chamber longevity: Irradiation of CSCs at GIF++ and in-situ measurements of the gas gain in the CSCs at CMS. Observing the relative current in GIF++ under irradiation can show the behavior in a high luminosity environment as the CMS. The relative current remains stable over time, leading us to conclude that there are no aging effects in either chambers. The accumulated charge expected is 200 mC/cm for ME1/1 chambers in the end of HL phase.

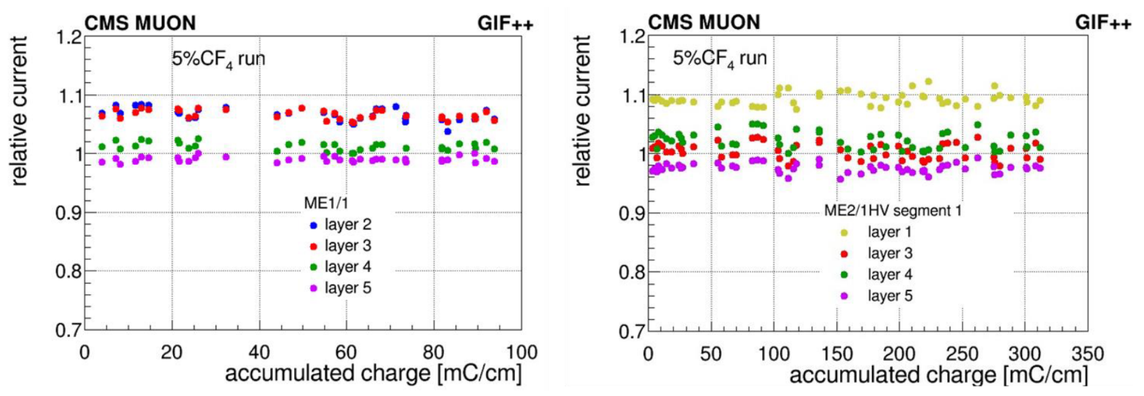

Figure 2: ME1/1 (left) and ME2/1 (right) plots of the relative currents in irradiated layers vs accumulated charge.

3 RPC efficiency studies in GIF++

Reference and irradiation chambers are kept in GIF++ bunker and the performance is measured for both of them and compared afterwards.

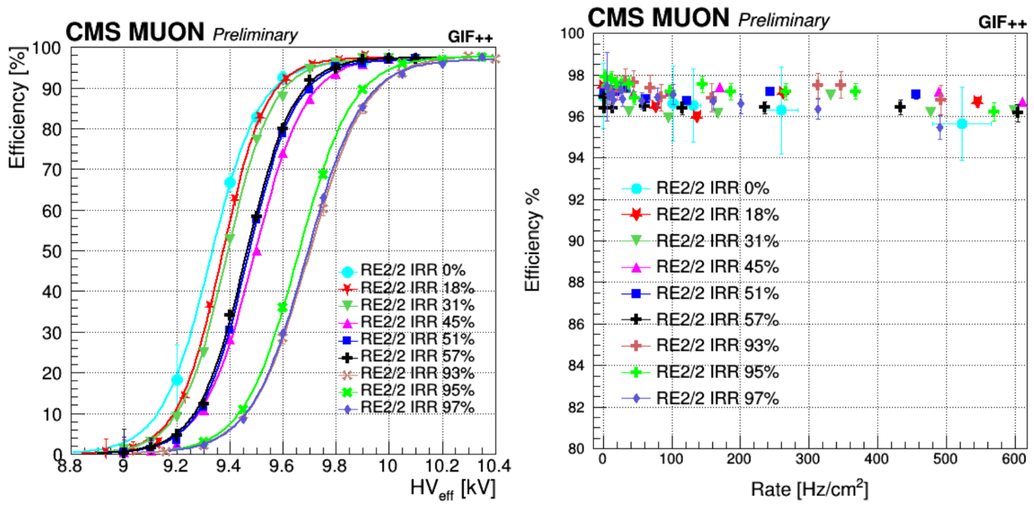

Figure 3: LEFT: RE2/2 irradiated chamber efficiency measured as a function of the effective high voltage, under a gamma background rate of about 600 Hz/cm^2 which represents the expected background rate at HL-LHC phase including safety factor of 3. RIGHT: RE2/2 irradiated chamber efficiency measured at the detector working point as a function of the background rate at different values of collected integrated charge.

The measurements have been performed before the irradiation (0%) and have been repeated after different periods of irradiation up to 97% of the expected integrated charge at HL-LHC phase including safety factor 3. The expected integrated charge for the RPCs are 840 mC/cm^2 (safety factor 3) in HL phase. No aging effects are observed.

4 GEM Aging studies

Gas Electron Multipliers (GEMs) are a recent enhancement to the CMS muon system. They augment the existing detectors in the forward regions near the beam pipe, where radiation levels and event rates are expected to rise significantly during Phase-II upgrade of the LHC. The ME0 system will extend the CMS muon coverage to higher pseudo-rapidity, requiring the detectors to operate under even more extreme conditions compared to current technologies.

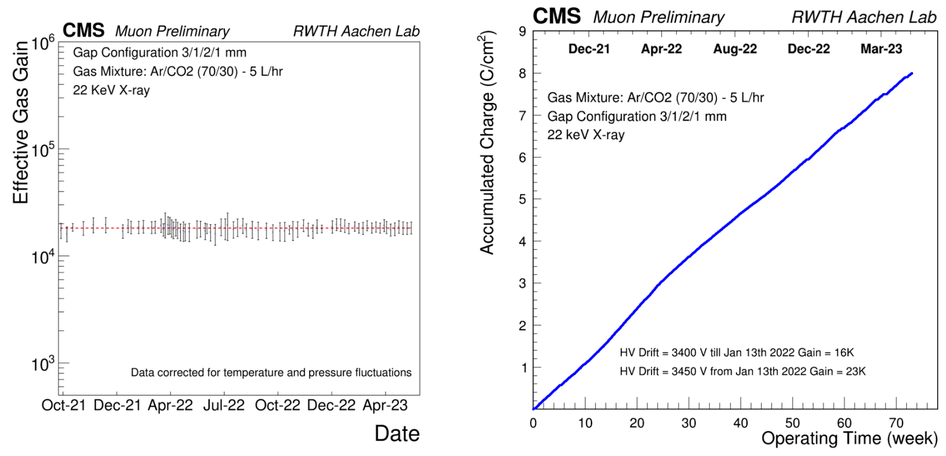

Figure 4: LEFT: Accumulated charge as a function of operating week targeting 8 C/cm^2 which corresponds to the hottest point of the ME0 station. Irradiation occurred between Oct 2021 and May 2023 (top x-axis). RIGHT: Continuous irradiation of a CMS ME0 chamber between Oct 2021 - May 2023. No drop in gas gain is observed.

5 DT aging studies in GIF++

Aging in the Drift Tubes (DT) chambers has been observed at GIF++ due to the accumulation of pollutants on the wires. These pollutants decrease the gain on the wires, which in turn affects 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. The accumulated charge expected is close to 15 mC/cm with the HL phase.

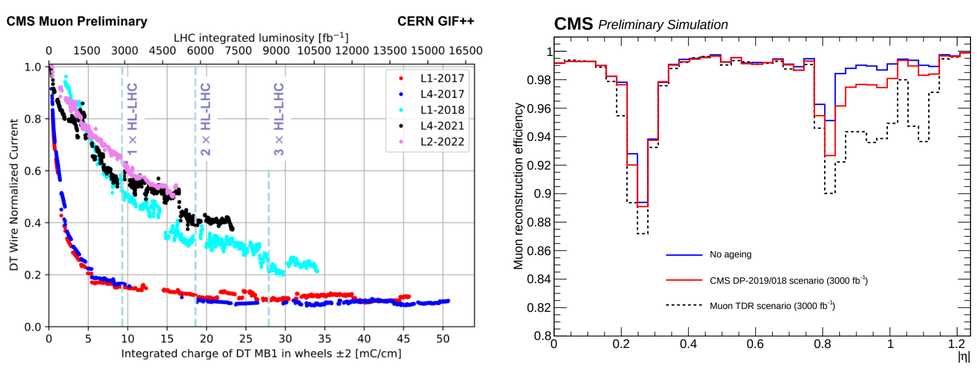

Figure 5: LEFT: Normalized current for different sets of irradiated wires as function of the integrated charge (dose). RIGHT: Muon reconstruction efficiency at CMS as a function of absolute η for non-aged DT chambers and aged DT chambers. The efficiencies have been calculated using simulated sample of dimuon events.

6 Conclusion

The study of the stability of each subdetector is a continuous task since the high radiation can have a lot of impact on the material and consequently the efficiency of the detector. But the most recent longevity results of each subsystem show that the muon system is capable to keep its good performance and withstand the expected high luminosity, delivered by LHC.

References

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