Study of the Effects of Radiation at the CERN Gamma Irradiation Facility on the CMS Drift Tubes Muon Detector for the HL-LHC

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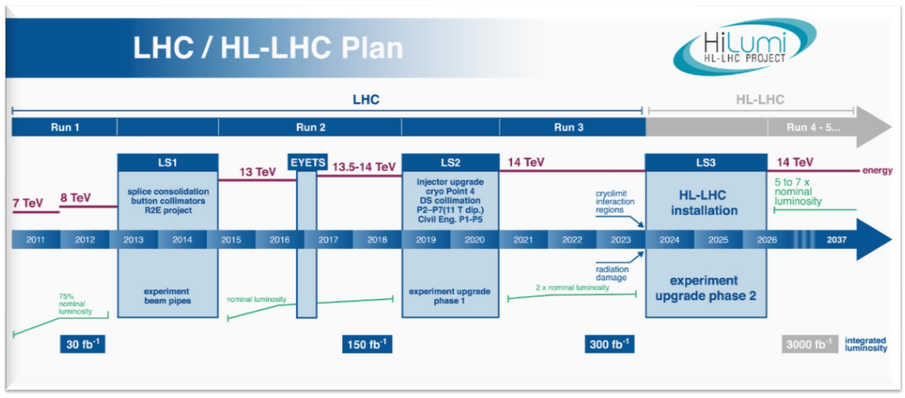
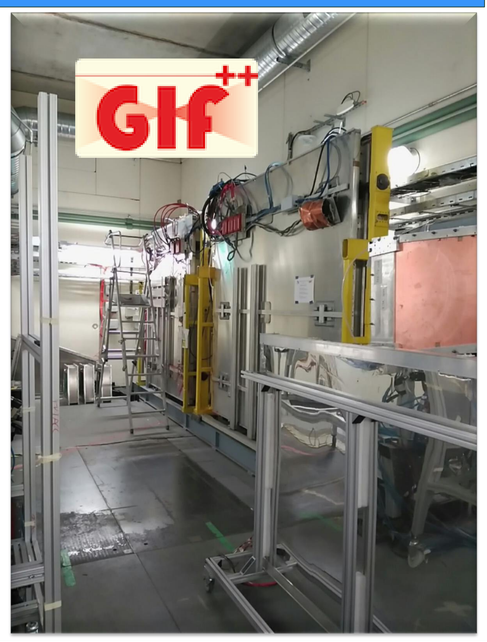
Motivation

The CMS drift tubes (DT) muon detector, built for standing up the **LHC** expected integrated and instantaneous luminosities, will be used also in the High Luminosity LHC (**HL-LHC**) at a **5x** larger instantaneous luminosity and, consequently, much higher levels of radiation, reaching **~10x** the LHC integrated luminosity. **Irradiation campaigns** have been performed in order to assess the capability of operating under such conditions and to investigate the aging induced by radiation.



One DT chamber (MB2 DT spare chamber) installed at the Gamma Irradiation Facility (GIF++) at CERN was irradiated with a high activity Cesium 137 source along a period of 2 years at different source intensity. An integrated dose equivalent to 2x the expected integrated luminosity of the HL-LHC run has been absorbed by this spare DT chamber and the final impact on the muon reconstruction efficiency is under study. Strategies to mitigate the aging effects are also being developed.

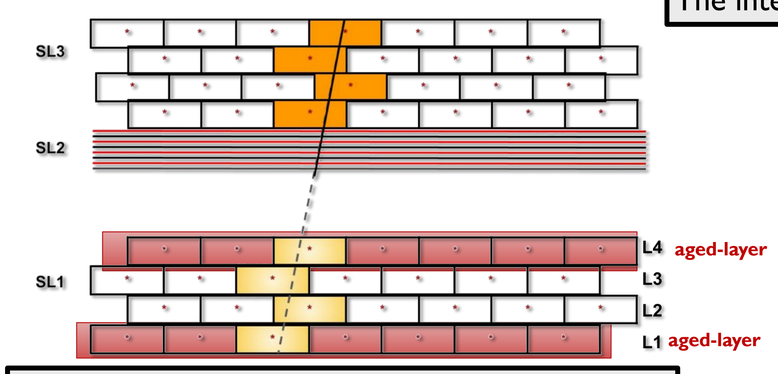


Irradiation and Data-taking

The MB2 DT spare chamber was irradiated at a large (O(10)) acceleration factor, and only **2** out of the **12** layers of the chamber were switched on at working voltage (3550 V) when the radioactive source was active, being the other layers in standby (1900 V). In this way the other non-aged layers are used as reference and as a precise and unbiased telescope of muon tracks for the efficiency computation of the aged layers of the chamber.

Hit efficiency definition

The efficiency to detect a single hit in a cell of a layer was defined and measured as the ratio between the number of detected and expected hits.



Triggers used for the data taking

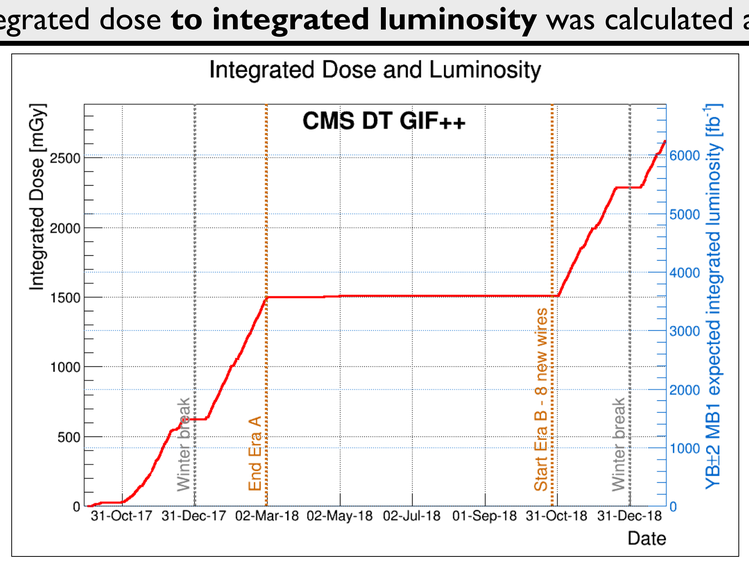
During *muon test beams*: external scintillators. When no beam, *cosmic muons* were recorded using the DT auto trigger.

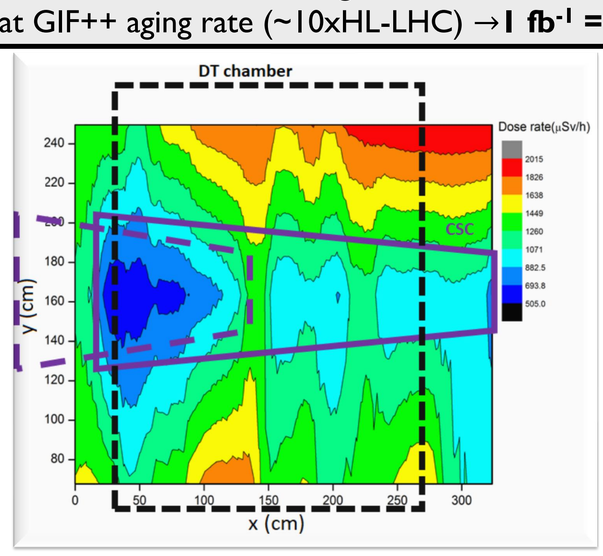
Dose and Luminosity

The dose rate and integrated dose are converted to **expected instantaneous and integrated luminosities** at the HL-LHC from extrapolation of CMS Run2 measurements for the most exposed DT chambers located at high pseudorapidity in the innermost part of the muon system, the MB1 chambers on the external wheels (YB±2).

The dose rate **to instantaneous luminosity** conversion was calculated at HL-LHC background rate → **10^{34} cm^{-2}s^{-1} = 0.0109 mGy/h**

The integrated dose **to integrated luminosity** was calculated at GIF++ aging rate (~10xHL-LHC) → **1 fb^{-1} = 0.42 mGy**





Dose rate just in front of the chamber installed at GIF++. Other detectors under irradiation are placed between the source and the DT chamber. This produces an inhomogeneous irradiation profile on the detector. The dose rate was averaged over the whole chamber to calculate the accumulated dose.

Results and Conclusions

Evolution of the hit efficiency

Hit efficiency for cosmic muons as a function of integrated luminosity for the aged layers (**SL1L1 and SL1L4**) at 3550 V. Each of the points in this plot corresponds to the data-taking during HV scans (with the **source off**) that were collected about every week. *No atmospheric condition corrections have been applied.* The hit efficiency is reduced **<10%** after integrating **2xHL-LHC** expected luminosity.

Hit efficiency vs High Voltage (HV)

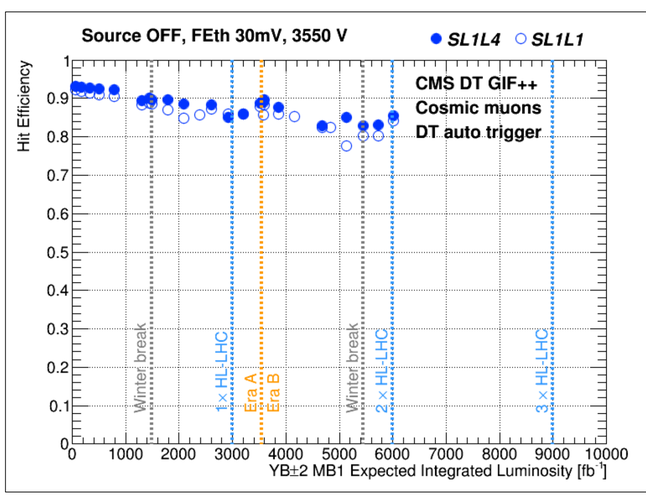
Hit efficiency for cosmic muons as a function of HV for the aged layers (**SL1L1 and SL1L4**) when **the source is off** and the front-end threshold 30 mV. Three series of datasets, each corresponding to a different integrated luminosity: *beginning, middle and end* of the irradiation period of MB2. At high HV, a plateau region is reached and the change of the efficiency with the integrated luminosity is small.

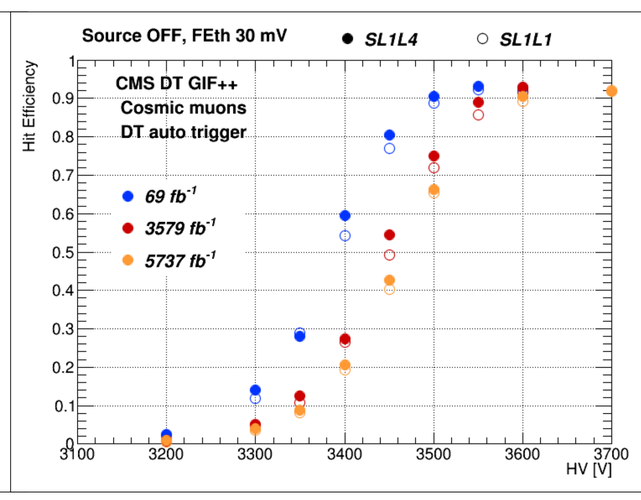
Hit efficiency vs inst. luminosity

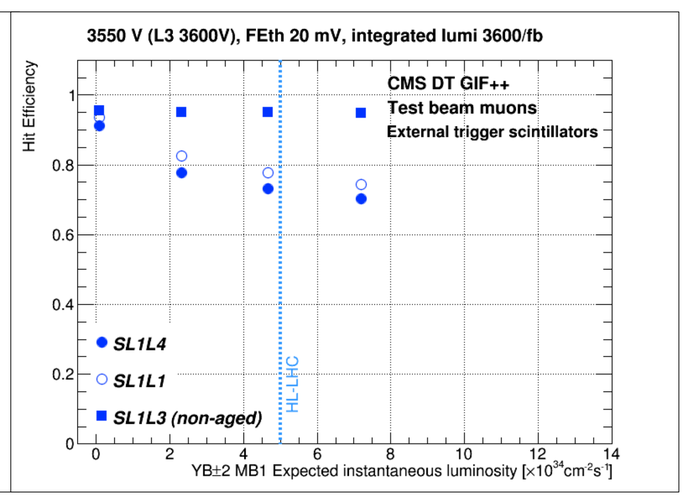
Hit efficiency for test beam muons as a function of inst. lumi for the aged layers (**SL1L1 and SL1L4**) at 3550 V and for **SL1L3** (non-aged) at 3600 V at a front-end threshold of 20 mV. A decrease of the hit efficiency of about **25%** is observed at the HL-LHC background rate, after an irradiation integrated dose equivalent to a HL-LHC integrated luminosity of 3600 fb^{-1}.

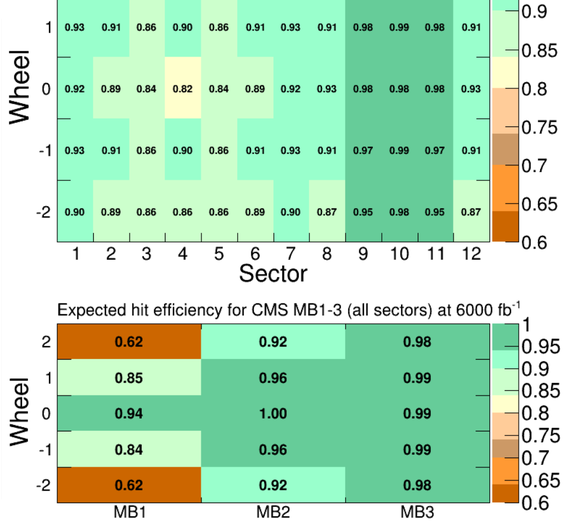
HL-LHC expected hit efficiency

Expected hit efficiencies **at the end of the HL-LHC** for all the DT chambers of the CMS muon system, MB4 chambers (upper) and for MB1, MB2 and MB3 (lower). These efficiencies have been estimated considering a **safety factor** of 2 for the expected HL-LHC background rate and a safety factor of 2 for the expected integrated luminosity.









HL-LHC will create a **difficult environment** for CMS subdetectors, and in particular for the DTs that may degrade the performance on some of the chambers. A big effort has been done **to characterize the radiation effects** and to develop strategies to guarantee the muon reconstruction and identification stay at an optimal level in CMS throughout the HL-LHC operation. Very preliminary studies including the expected hit efficiency **at the end of the HL-LHC** from GIF++ results implemented in the full CMS simulations have shown almost no impact in the muon reconstruction efficiency over the full barrel acceptance and for the full integrated luminosity.

Lepton Photon Conference, Toronto (Canada), August 2019