Study of the effects of radiation on the CMS Drift Tubes Muon Detector for the HL-LHC

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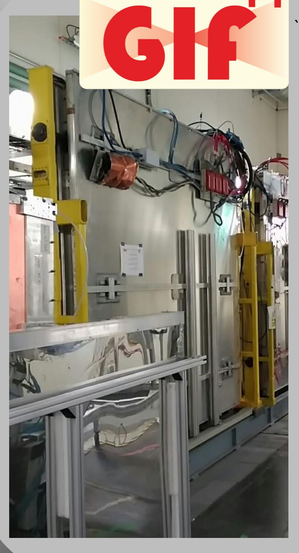
The CMS DT detector at the HL-LHC

During the High Luminosity LHC (HL-LHC) the CMS Drift Tube (DT) chambers will receive 10 times the radiation they were designed for. The extreme conditions of the HL-LHC may have an impact on the detector performance. The continuous operation of the DT chambers under a high radiation environment is known to produce the deposition of outgassing material on the anode wires (ageing), causing a reduction of the amplification and dropping efficiency of detecting the signal from passing muons. The effect of the ageing is being investigated. Several strategies of mitigating the ageing by removing the depositions or reducing the efficiency drop by changing the HV values are being developed.

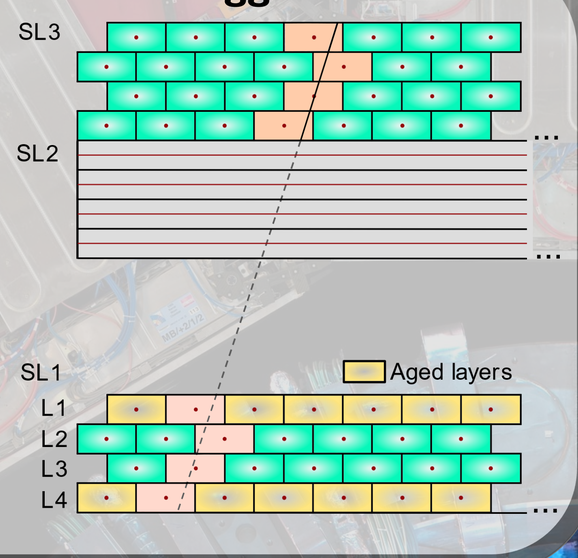
MB2 chamber irradiation at GIF++



A MB2 DT spare chamber was introduced in the bunker of the CERN Gamma Irradiation Facility (GIF++) in September 2017. Two layers, 1 and 4, of superlayer 1 (SL1L1, SL1L4), were irradiated while operated at 3550 V. The rest of the chamber was kept on standby. The exercise was mostly performed at a source rate equivalent to 10 times the expected background rate for the MB1 chambers on the external wheels (YB±2) during the HL-LHC.

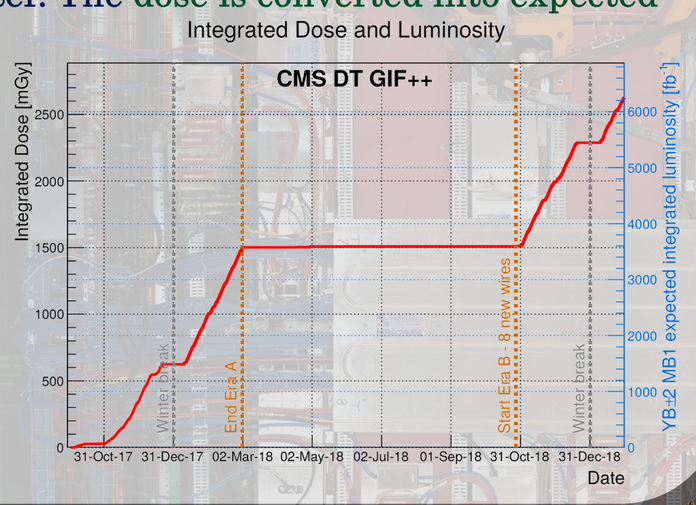
Hit efficiency definition and trigger

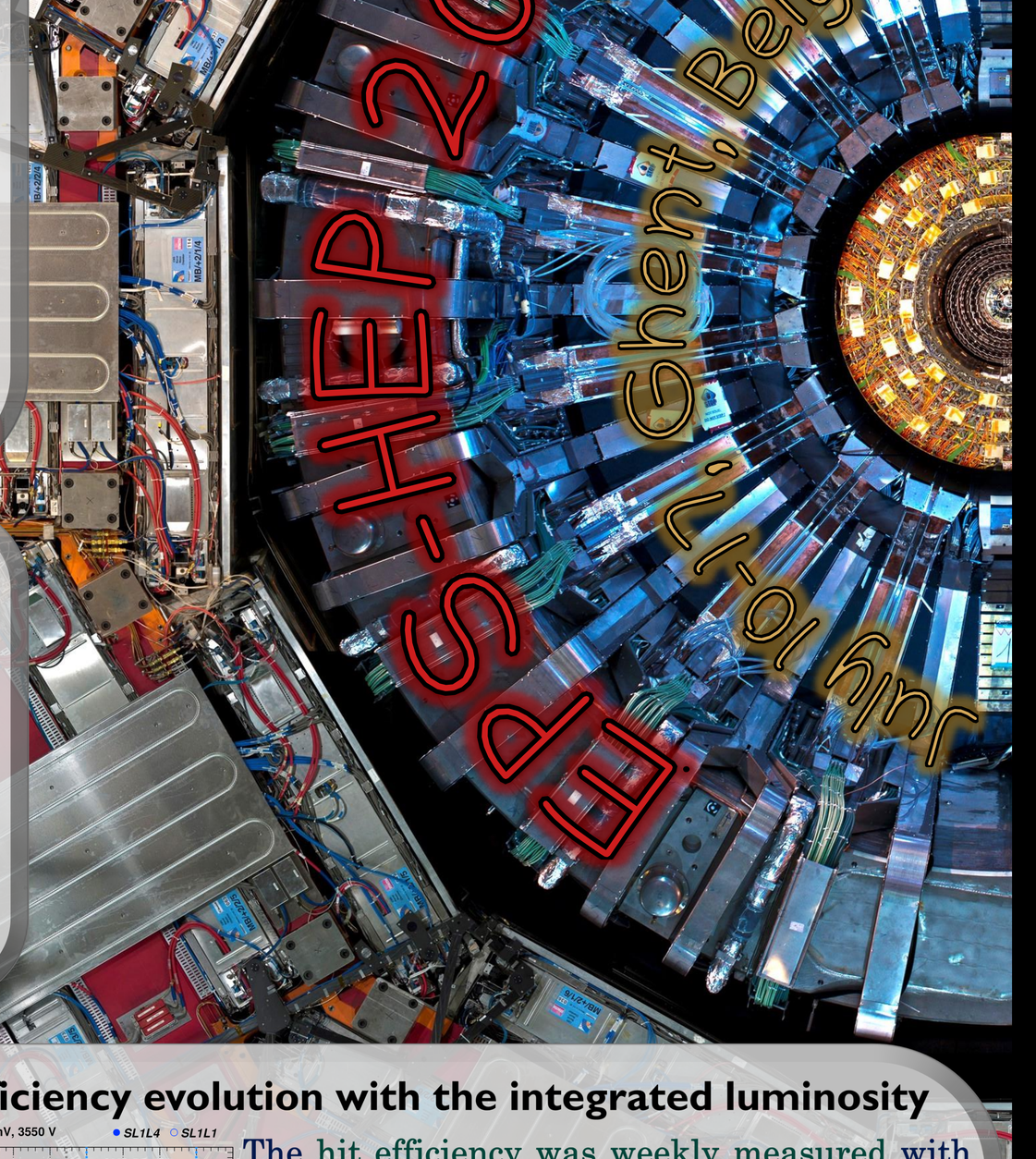
The efficiency to detect a hit in a cell of a layer is defined as the ratio between the numbers of detected and expected hits. The position of expected hits is determined using sets of well reconstructed track segments with 4 associated hits in SL3 and at least 1 hit in SL1. Internal trigger is used to measure cosmic muons. External scintillators are used to trigger events during muon beam runs.



Dose rate and extrapolation to HL-LHC conditions

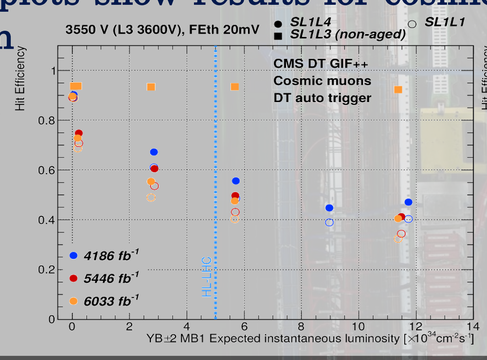
At GIF++, the dose rate is measured with a REMUS dosimeter situated inside the GIF++ bunker and it is extrapolated to the dose rate at the surface of the MB2 chamber using a portable dosimeter. The dose is converted into expected instantaneous and integrated luminosity for the MB1 chambers on the external wheels (YB±2) during the HL-LHC. A conversion factor of 1 fb^{-1} = 0.304 (0.42) mGy for the HL-LHC (x10) instantaneous luminosity has been calculated. By Feb. 2019, the chamber accumulated a dose equivalent to twice the one expected at the HL-LHC.

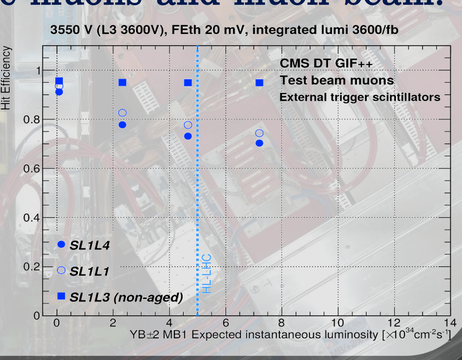




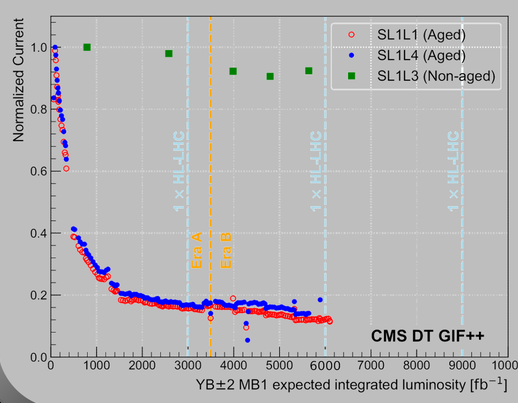
Hit efficiency as a function of the instantaneous luminosity

The hit efficiency is measured as a function of the background rate, at 3550 V, for the aged layers. The plots show results for cosmic muons and muon beam. Non-aged SL1L3 is shown as a reference. A decrease of the hit efficiency of about 25% is observed at the HL-LHC rate, after accumulating 3600 fb^{-1}, for test beam muons.



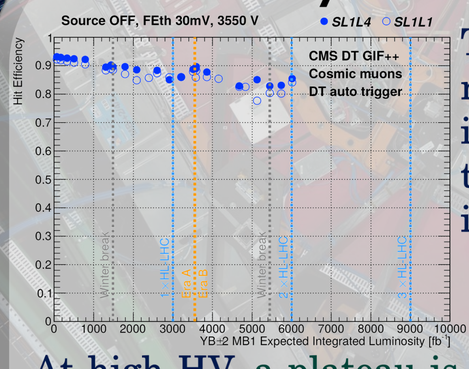


Evolution of currents with the integrated luminosity



The currents in the aged layers (SL1L1, SL1L4) were monitored during the irradiation period. The currents on the non-aged layer SL1L3 are used as reference. Most of the drop of currents is observed during the first 1000 fb^{-1} of accumulated luminosity.

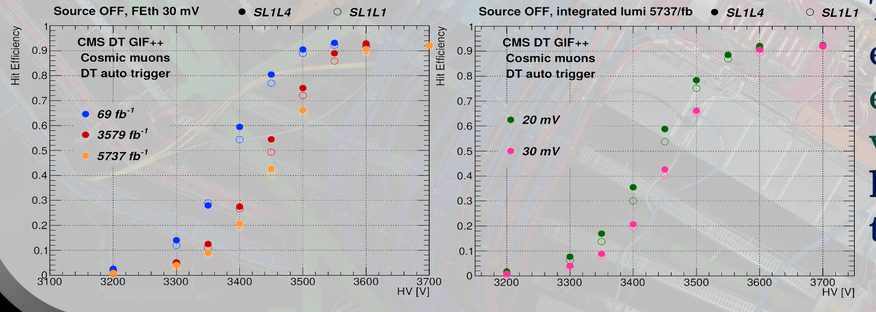
Hit efficiency evolution with the integrated luminosity



The hit efficiency was weekly measured with no background (source off) during the irradiation of the chamber. For a HV of 3550V, the hit efficiency is reduced <10% after integrating 2xHL-LHC expected luminosity.

Hit efficiency as a function of the high voltage

At high HV, a plateau is reached and the change of the efficiency with the integrated luminosity is small.



The drop of efficiency for a front-end threshold (FEth) value of 20 mV and high HV values is of the order of a few %.

Extrapolation to the full CMS DT system - conclusion

For an ageing scenario at the end of the HL-LHC and safety factor 2 in integrated and instantaneous luminosity, the hit efficiency is expected to drop to 62% for the most exposed chambers while the big majority of the system stays well above 90%. Very preliminary muon trigger and reconstruction studies show a mild localized effect in the overlap region.