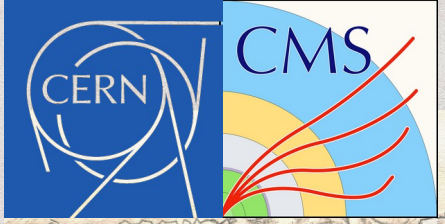


III. Physikalisches Institut A

RWTH AACHEN UNIVERSITY

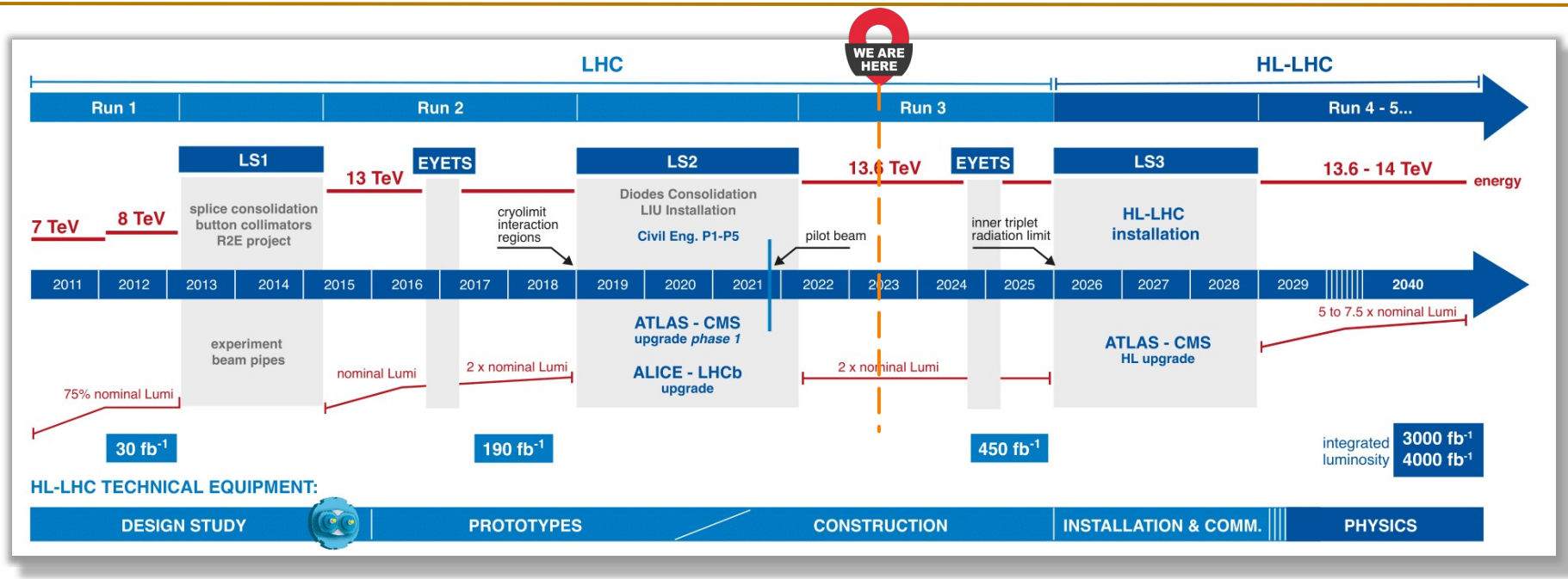
Longevity Studies for the CMS DT System towards HL-LHC

Valentina Sarkisovi (RWTH Aachen University)
on behalf of the CMS Muon Group

13th Beam Telescope and Test Beam Workshop
17-21.04.2023

Outline

HL-LHC & Phase II Upgrades

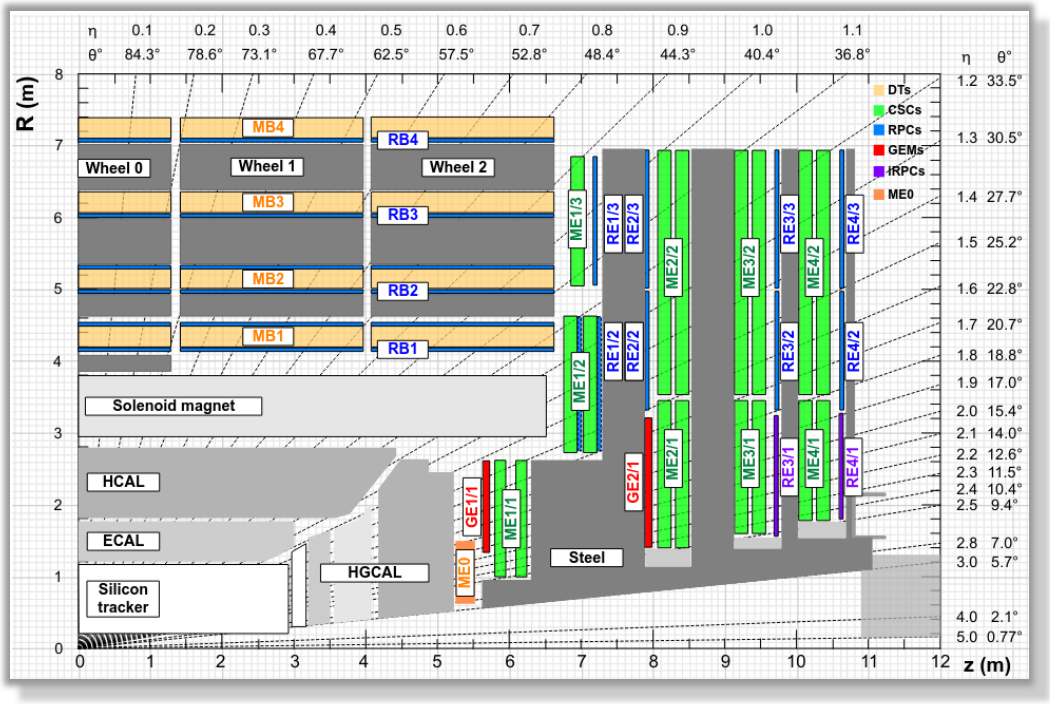


- ***HL-LHC*** - significant upgrade of LHC aiming for a tenfold increase of integrated lumi w.r.t. design
  - ➔ Expected L_{inst} = 5-7.5 x 10^{34} $cm^{-2}s^{-1}$, up to 140-200 pileup (PU)
- ***Phase II detector upgrades*** - significant upgrades of CMS detector for HL-LHC conditions
  - ➔ Increased radiation ➔ accelerated aging of detectors and electronic components
  - ➔ Raised trigger rates ➔ greater demands on electronics

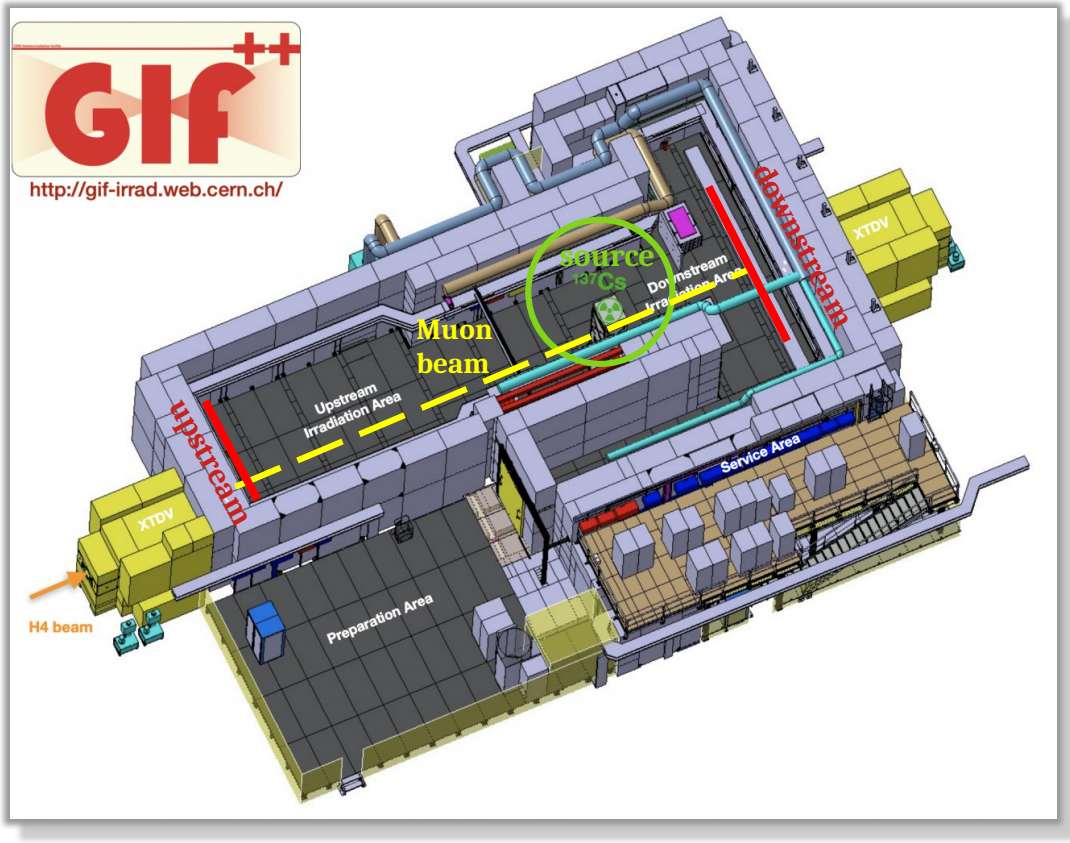
Muon System in Phase II

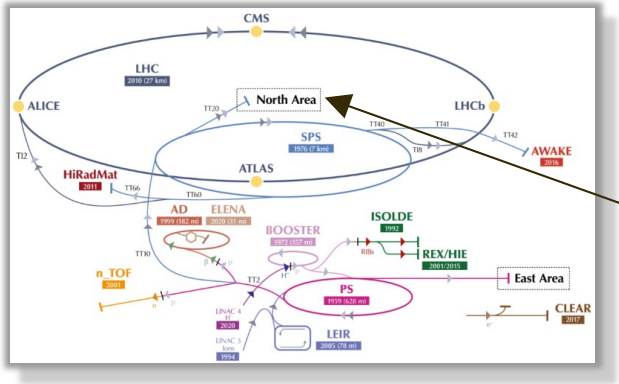
- ***Main challenges***:
  - Deal with the increased rate & sustain current great performance

- ***Strategy to tackle challenges***:
  - Upgrade of the electronics of the existing detectors during Long Shutdown (LS) 3
    - Drift Tubes (DTs) ➔ today's talk
    - Resistive Plate Chambers (RPCs)
    - Cathode Strip Chambers (CSCs)
  - Installation of new muon stations providing higher precision (already started during LS2)
    - Gas Electron Multipliers (GEMs)
    - Improved RPCs (iRPCs)
  - Long-term irradiation tests for performance check of muon chambers at high values of integrated charge



GIF++ Irradiation Setup



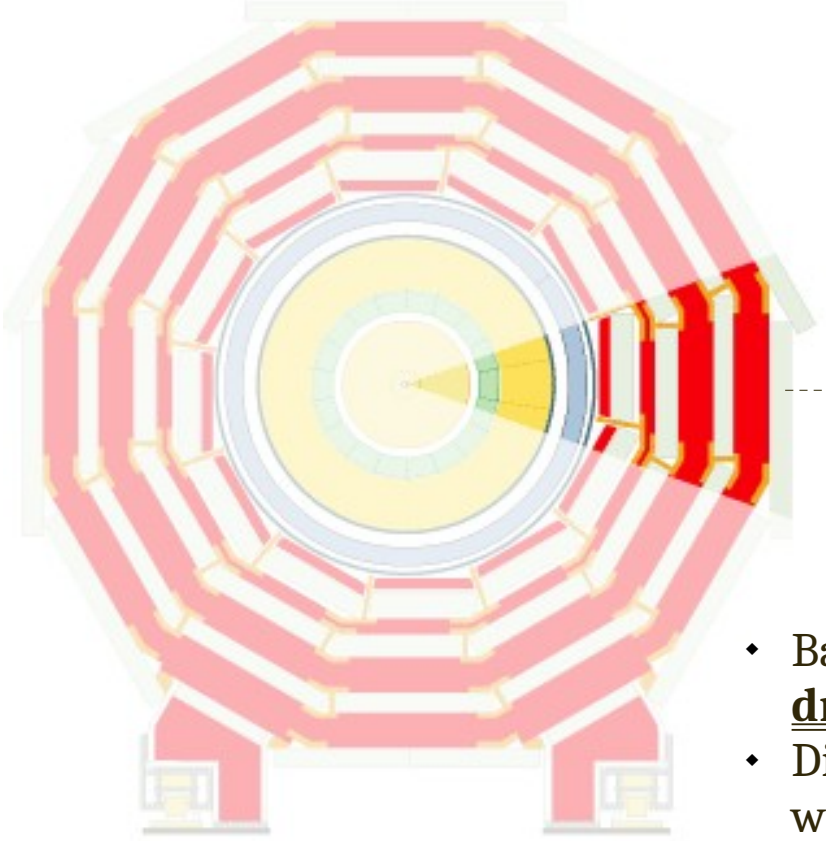


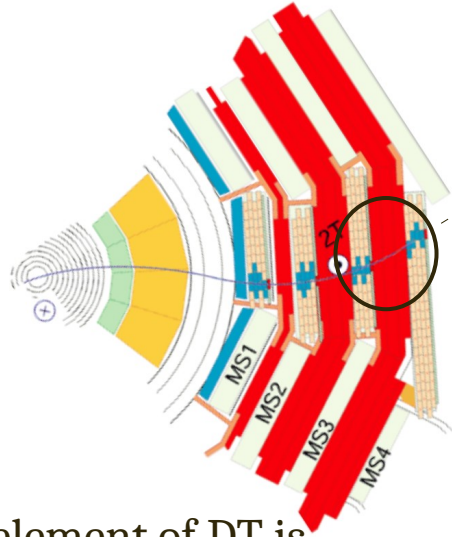
- Gamma Irradiation Facility (GIF++) delivers crucial services to High Energy Physics (HEP) community
  - ➔ Focus on validation and optimisation of detector technologies for HL-LHC upgrade & beyond

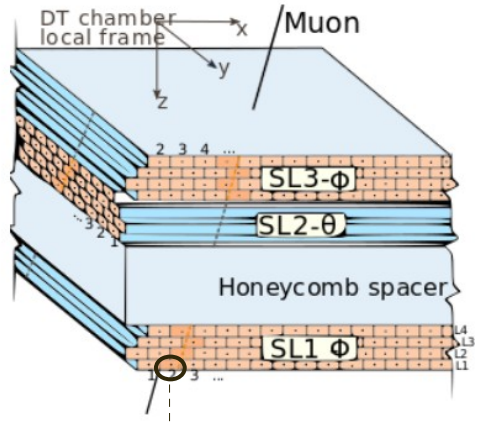
- Facility equipped with
  - ➔ high energy muon beam (≤ 150 GeV/c)
  - ➔ 13 TBq ^{137}Cs gamma source to reproduce expected background
  - ➔ movable filters to vary the gamma flux and generate background conditions similar to the ones expected at HL-LHC

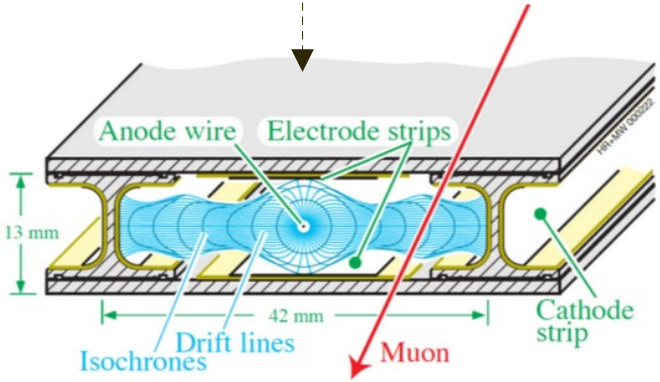
The Drift Tube (DT) Chambers

- Located in the CMS barrel region, DTs are responsible for μ tracking and triggering
  - ➔ DT subdetector consists of 250 DTs, > 170k channels, 5 wheels, 4 stations & 12 sectors



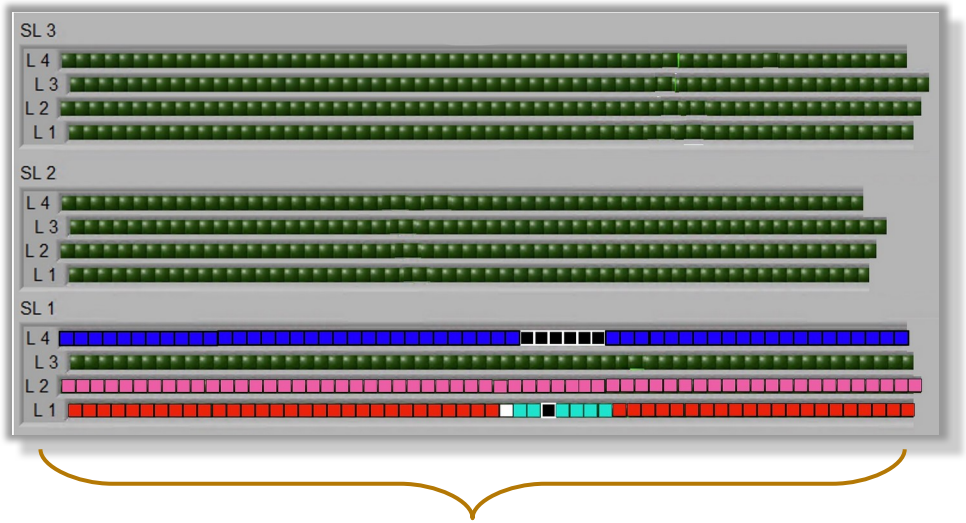






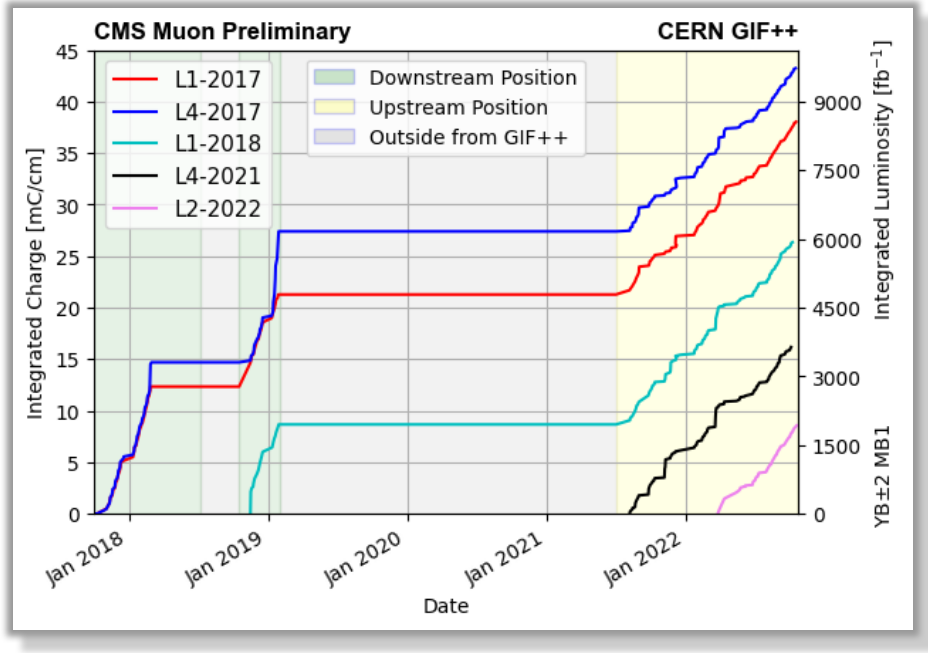
- Basic element of DT is **drift cell**
- Distance w.r.t. anode wire: $x \propto t_D \times v^{eff}{}_D$

Irradiation of the Drift Tube Chamber



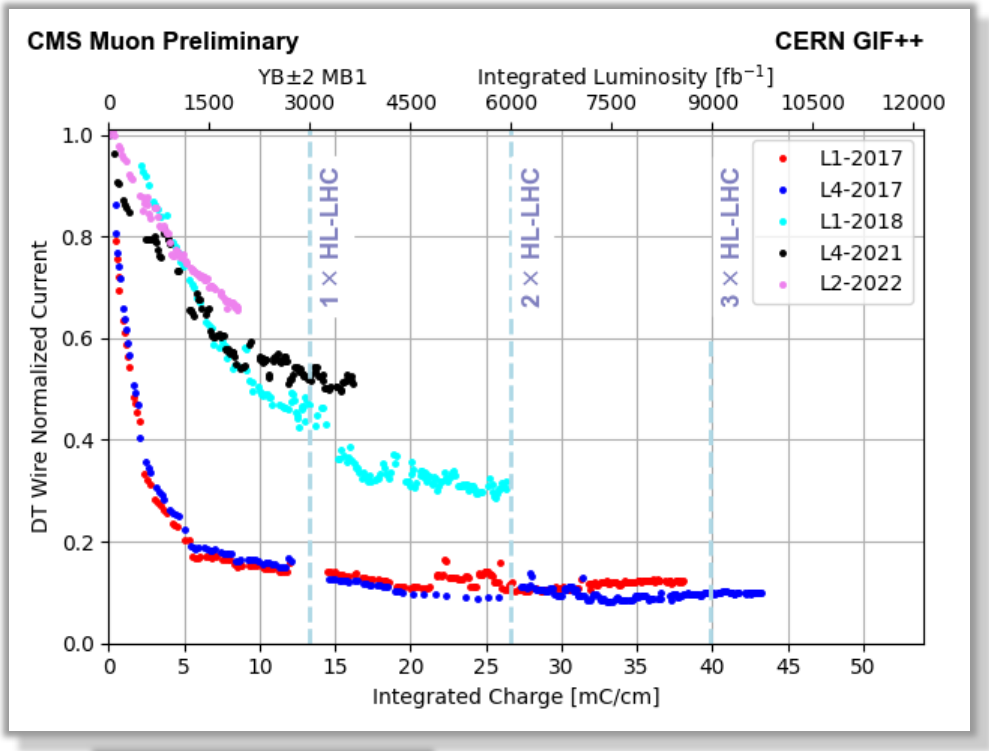
Layout of wire positions in MB2 chamber:
3 Super Layers (SL), 12 Layers (L)

- Spare MB2 irradiated since 2017:
  - *SL1 L1*, *L2* & *L4* ➔ on during the irradiation
  - *SL1 L3* ➔ kept off & used as reference
- *SL2* & *SL3* ➔ used for internal trigger (cosmics)



- *Brief DT irradiation history*:
  - 2018 ➔ 8 wires from SL1 L1 were extracted, inspected & replaced with new wires
  - 2020 ➔ same was done for 5 wires of SL1 L4
- Translation into integrated lumi is done considering the chambers with higher background

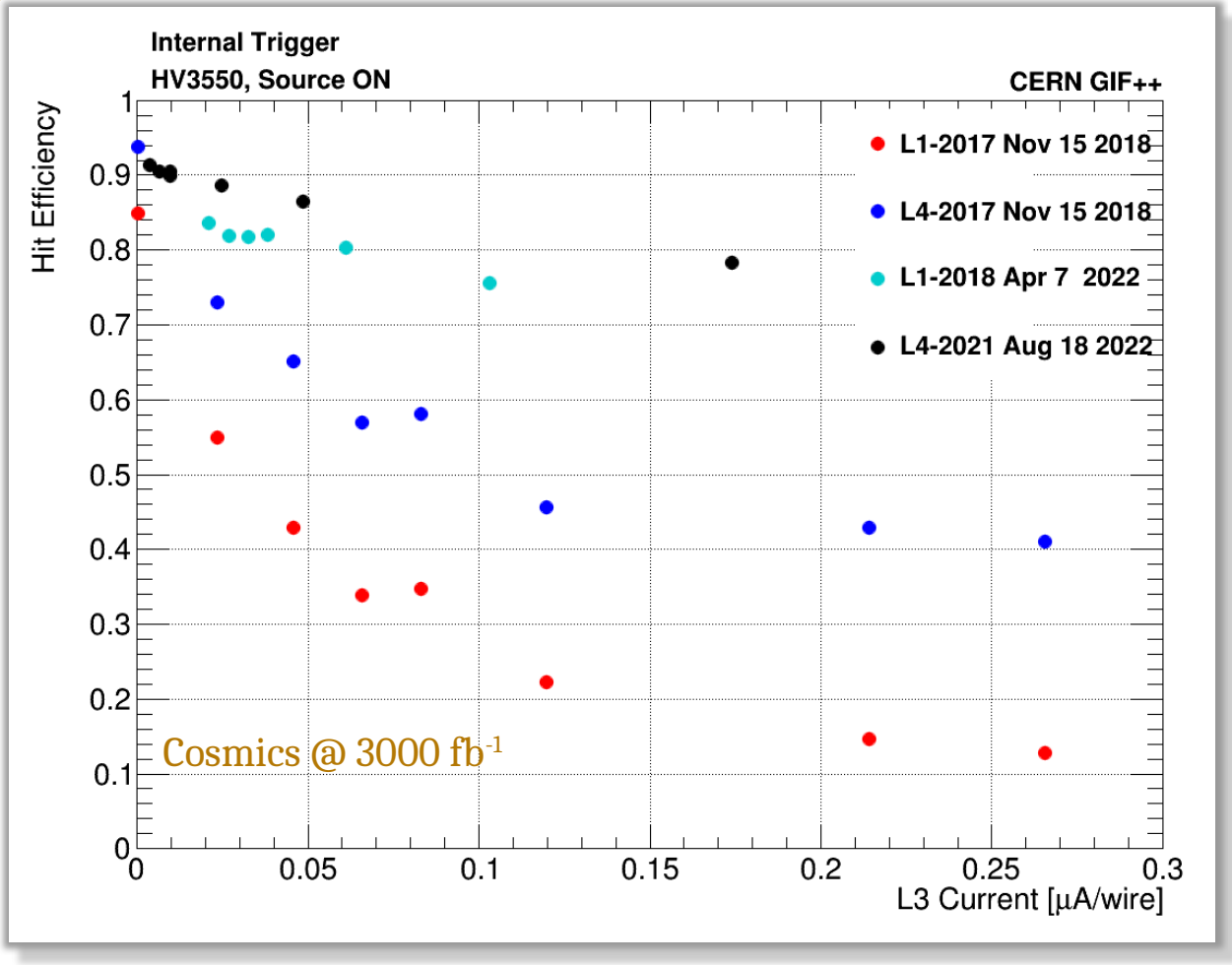
Drift Tube Aging Studies



Electron avalanche allows contaminants to react chemically ➔ coating on the wires

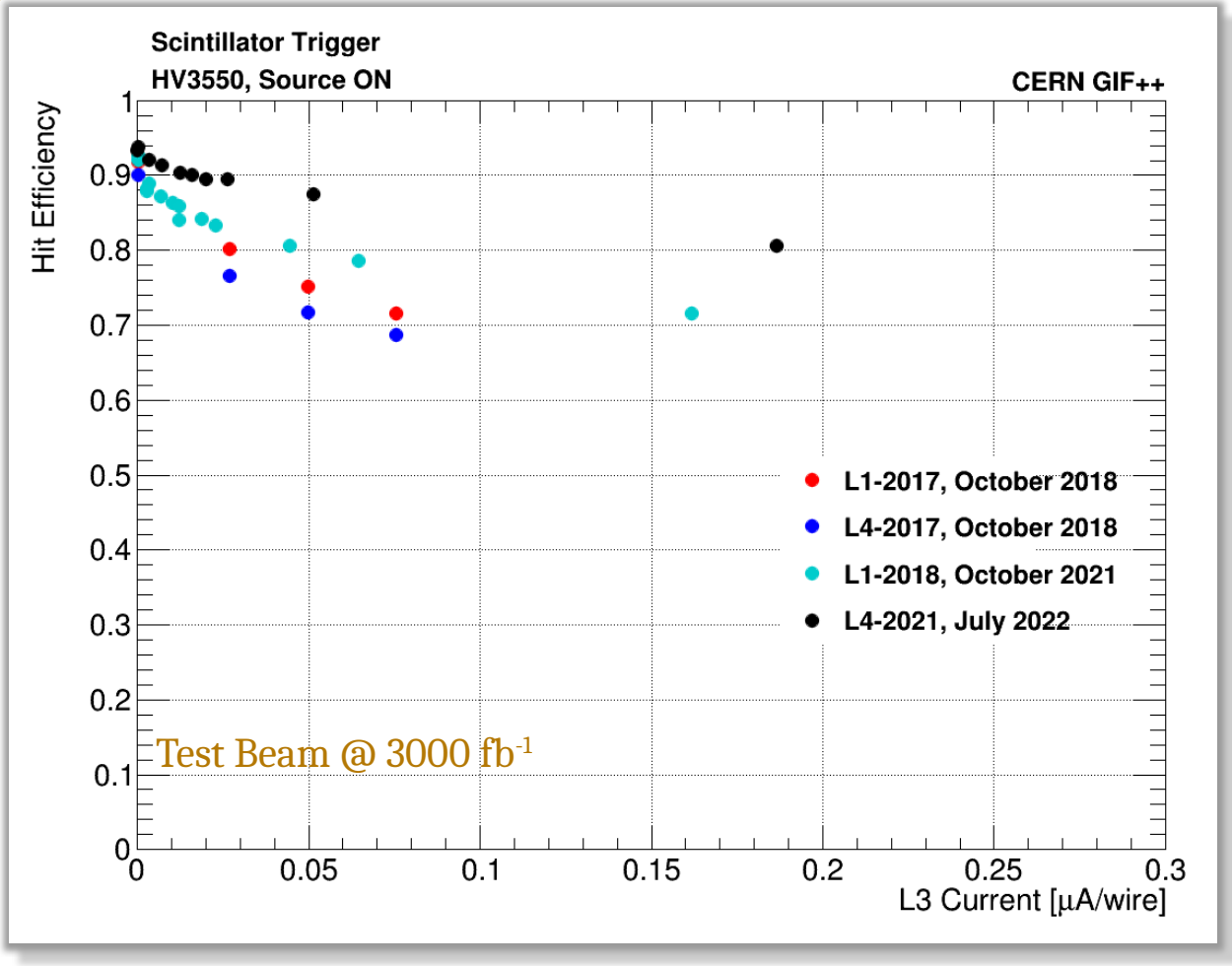
- Analysis of the currents monitored by the HV boards gives an estimation of the slope of gain
  - Gain ≈ $I_{inst.}$ / $I_{SL1,L3}$
- A very fast degradation was seen in the wires of the two layers in the beginning of September 2017-March 2018 irradiation period
- Few wires, replaced in *SL1 L1* (Autumn 2018), in *SL1 L4* (2021) and all wires of *SL1 L2* (2022) were irradiated for checking the previous results
  - ➔ all presented a much slower and smaller degradation
- Correlated to the presence of a carbon peak in the spectroscopy analysis in the wires irradiated w. "HV On" in 2017

Hit Efficiency w. Cosmics data



- Hit efficiency for cosmic muons as a function of the background (current measured in *SL1 L3*) for the 4 sets of wires w. "HV On" along the irradiation
- Efficiency in each set of wires is considered at the expected integrated charge in MB1 chamber of the external wheels after 1 HL-LHC integrated lumi
- DT internal trigger was used for cosmic muon tracks
  - tracks in both projections on *SL2* and *SL3* of the DT chamber identified
  - trigger bias from the layers irradiated with "HV On" avoided

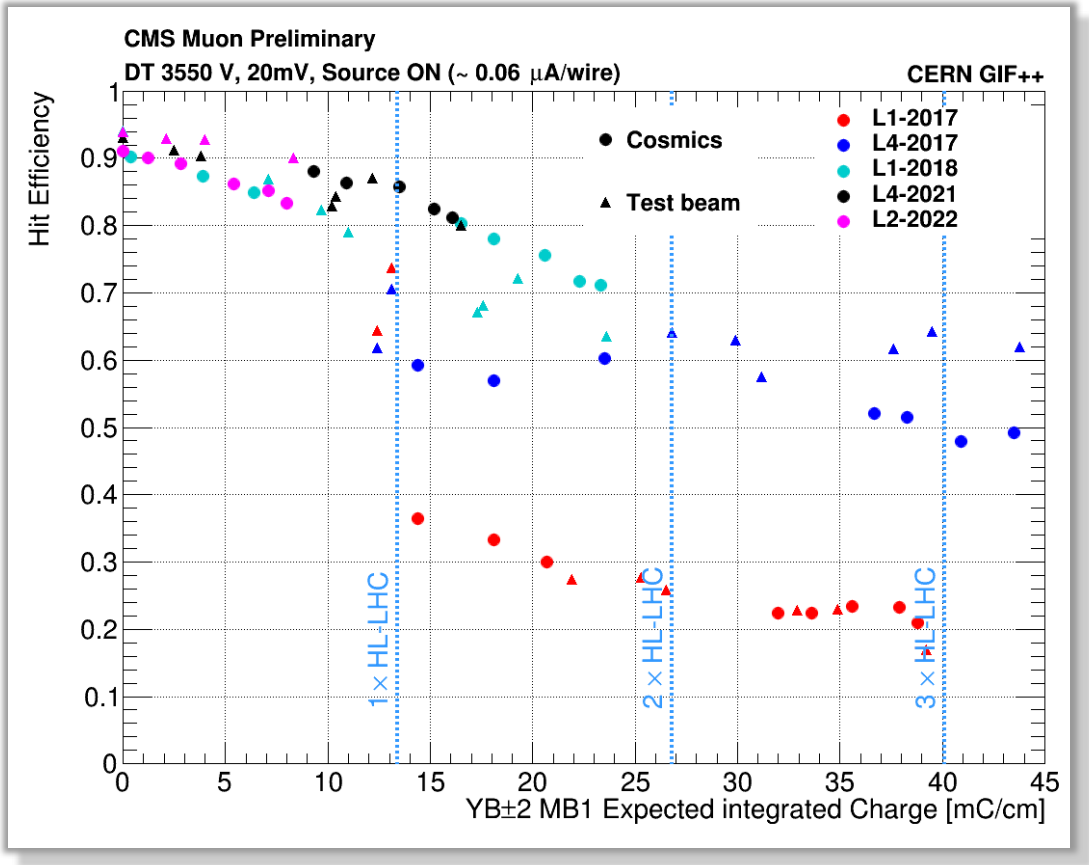
Hit Efficiency w. Test Beam (TB) data



- Hit efficiency for test beam muons as a function of the background (current measured in *SL1 L3*) for the 4 sets of wires w. "HV On" along the irradiation
- Efficiency in each set of wires is considered at the expected integrated charge in MB1 chamber of the external wheels after 1 HL-LHC integrated lumi
- Two different scintillator triggers used as an external trigger
  - "Up & Down" scintillator pointing to the position of old wires
  - "Displaced" scintillator pointing to the position of new wires

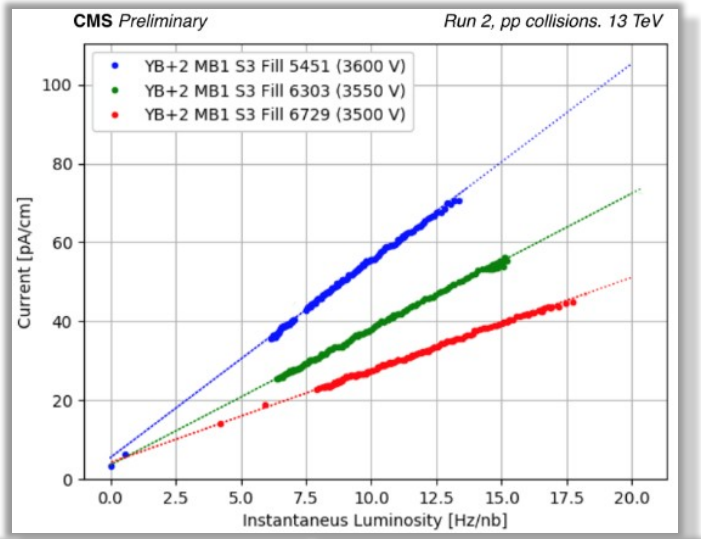
Hit Efficiency vs. Integrated Charge

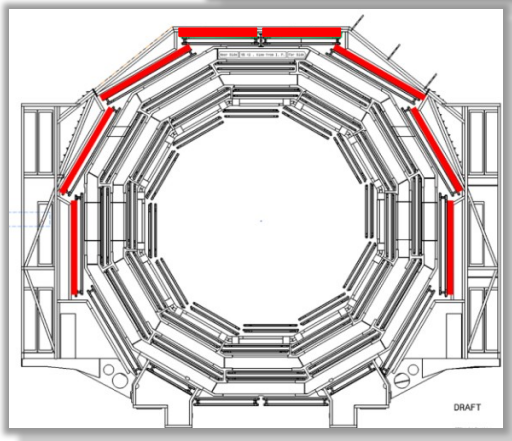
- The plot is obtained by fitting the data taken during a source scan
- Source intensity value producing a measured inst. current of ~0.06 microA/wire in the reference *L3* was considered in each source scan
  - ➔ such current corresponds to the one expected for the MB1 chambers in the CMS detector's external wheels (YB+2/-2) during the HL-LHC, $L_{inst} \approx 5 \times 10^{34}$ cm^{-2}s^{-1}
- Efficiency between Cosmics and TB data are compatible w/in few %
  - ➔ SL1 L4_2017 wires are in agreement w/in ~10%
- Measurement of efficiency at 3 x HL-LHC done ✅

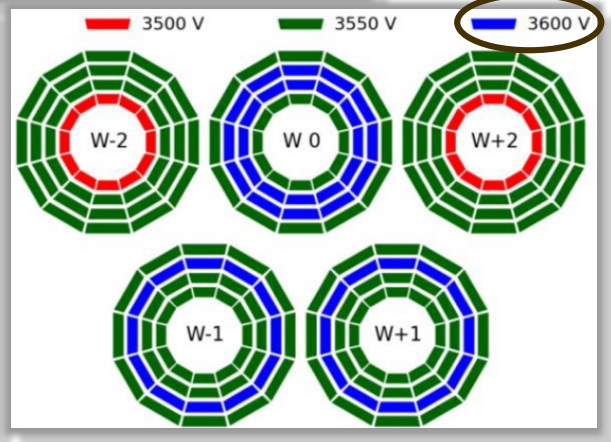


Ongoing DT Mitigation Strategy

- Voltage reduction of the wires by 50 V in the most exposed chambers ➔ decreases by ~30% of the integrated charge
- Reduction of readout threshold from 30 mV to 20 mV applied in all chambers ➔ keeps high efficiency
- Modification of the gas system to operate in open loop in 2017 ➔ minimizes re-circulation of impurities
- Shielding during LS2 for the neutron background reduction in top sectors ➔ responsible for a 30-40% reduction of thermal neutron rates measured in Run-3





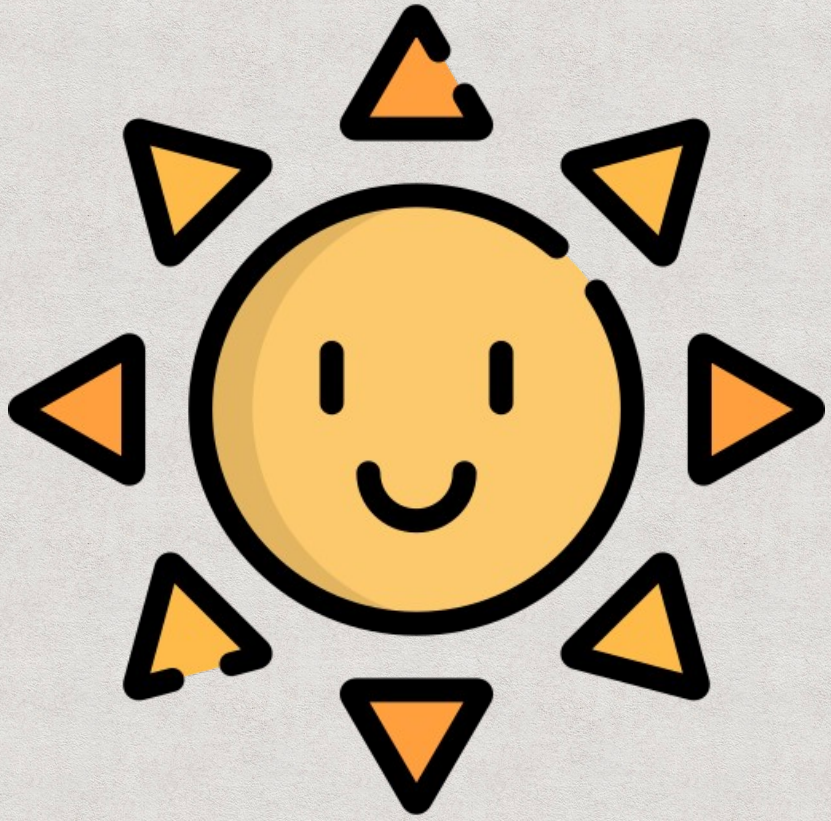


nominal value

Summary

- GIF++ ➔ unique & essential facility for new detector developments and detector longevity studies
- Performance checks of the CMS DT detector in the challenging HL-LHC circumstances have been carried out for several years
- Findings from CERN GIF++ demonstrate that the CMS DT system can continue to operate efficiently
  - ➔ All periods of data taking have been analysed
  - ➔ Main achievement/conclusion for GIF++ analysis: the goal of 3 × HL-LHC equivalent charge has been reached
  - ➔ Mitigation strategy is already in place in anticipation of future activities

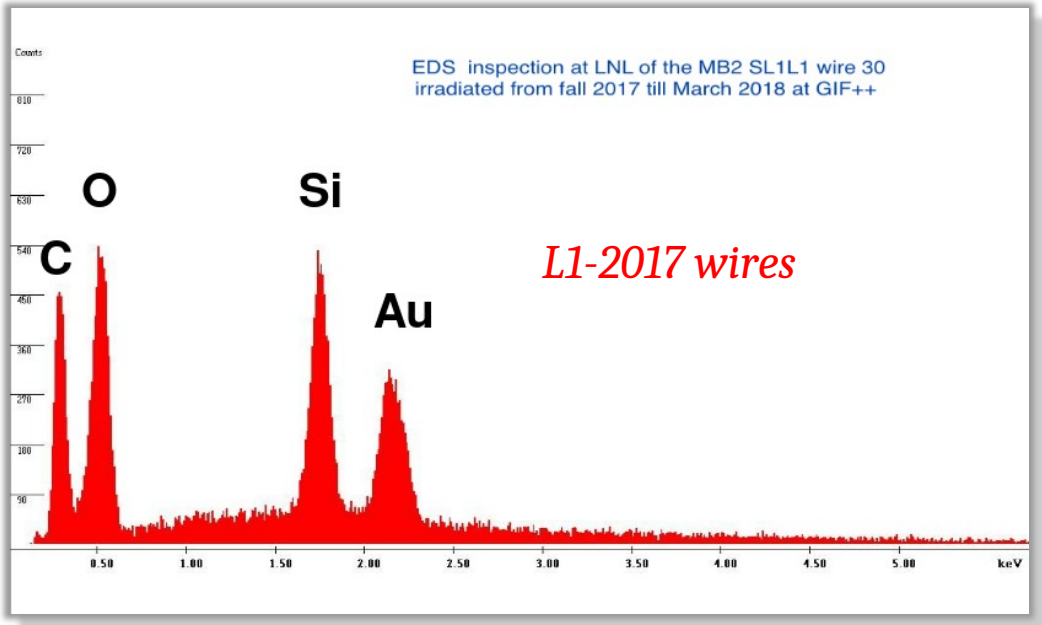
Thank you for your attention !

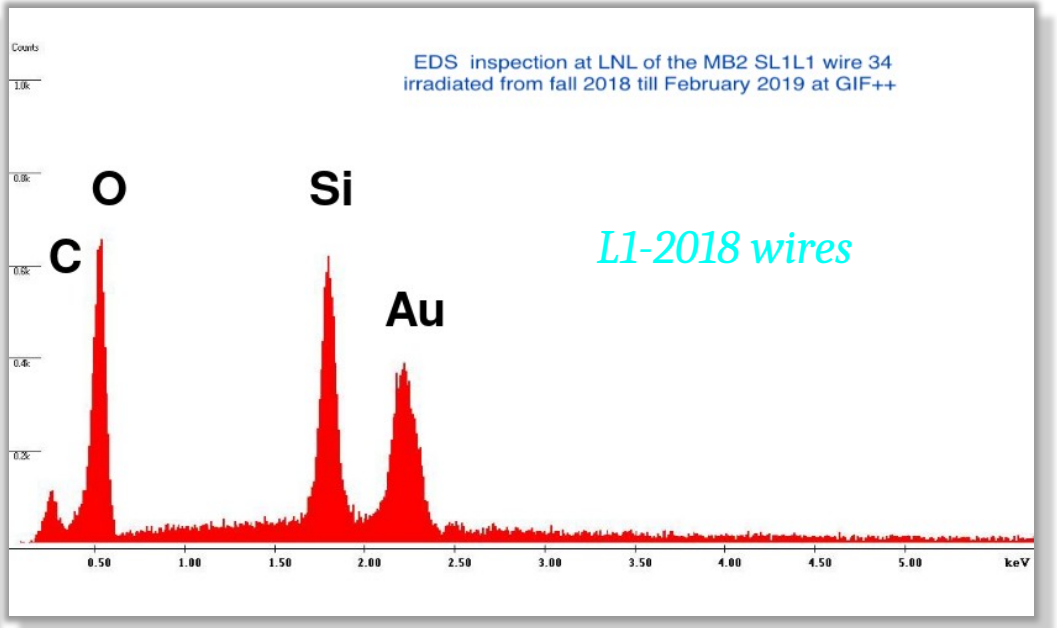


Special thanks to members of DT DPG for the efforts!

Back-Up

Back-up: Drift Tube Spectroscopy Analysis





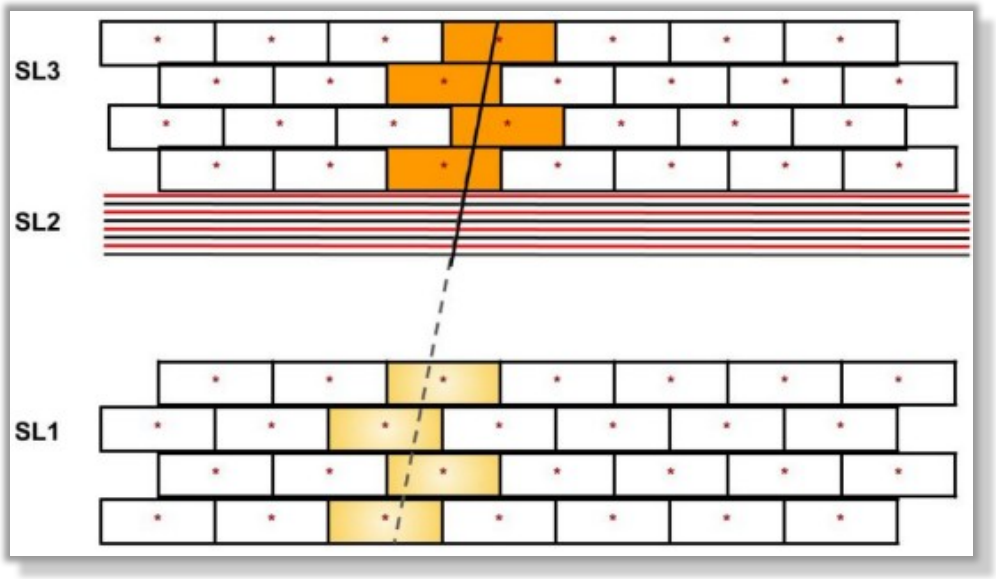
Plots taken from: *CMS DN-2017/040*

- Energy dispersive X-ray spectroscopy (EDS) of a wire of SL1L1 of MB2 chamber exposed at GIF++:
  - Left: on the first irradiation, 2017-2018, extracted after ~1 HL-LHC integrated charge
  - Right: on 2018-2019, extracted after ~0.7 HL-LHC integrated charge

Back-up: Hit Efficiency Estimation

Hit efficiency is computed as follows:

- Offline segments reconstructed in *SL3* are propagated to layers of *SL1* to identify cells where hits are expected
- Cell is considered to be efficient if hit is found where expected



Number of selected segments

- Requirement: 4 hits in *SL3* & min 1 hit in *SL1*

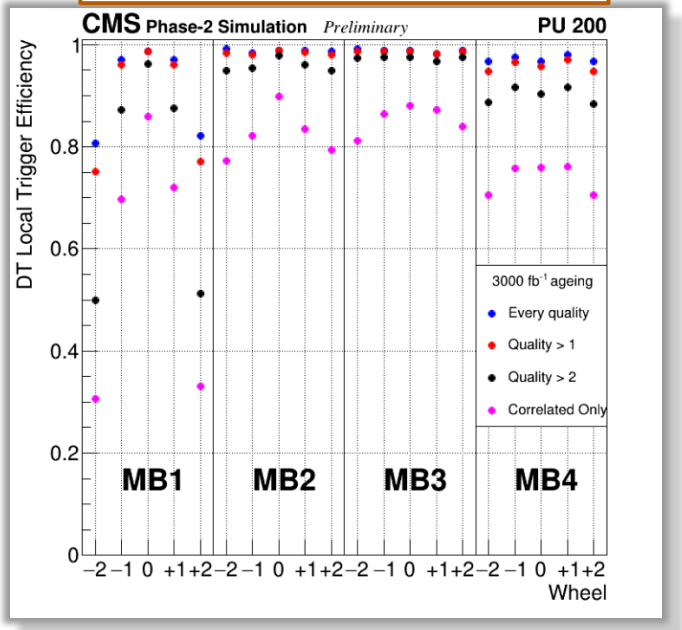
$$\epsilon_{hit} = \frac{\sum hit_{detected}}{\sum hit_{expected}}$$

Number of times that a hit is found

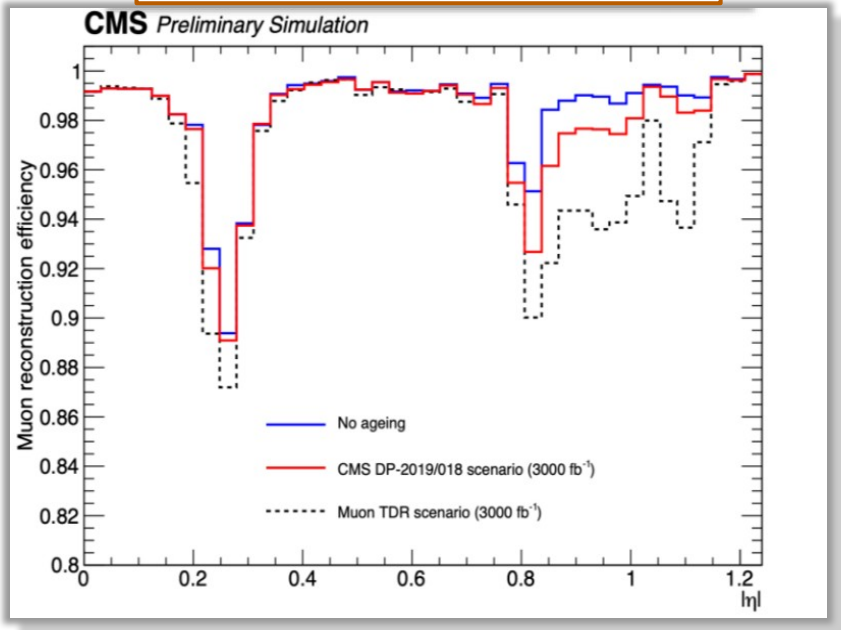
- Search for a hit in the expected wire & position in test layer

Back-up: Towards the Aging Scenarios

DT trigger segment efficiency



Standalone muon reco efficiency



- The expected hit efficiency (worst case scenario) has been used to evaluate the final impact at HL-LHC:
  - Major effect seen in DT local trigger efficiency of MB1 is effectively mitigated by
    - Multiple layers per chamber (3 out of 8 needed)
    - Handling of TDC hits in back-end in Phase II
    - Redundancy of the CMS Muon system
  - Minor impact on the overall reconstruction of the standalone muons