CMS Drift Tubes

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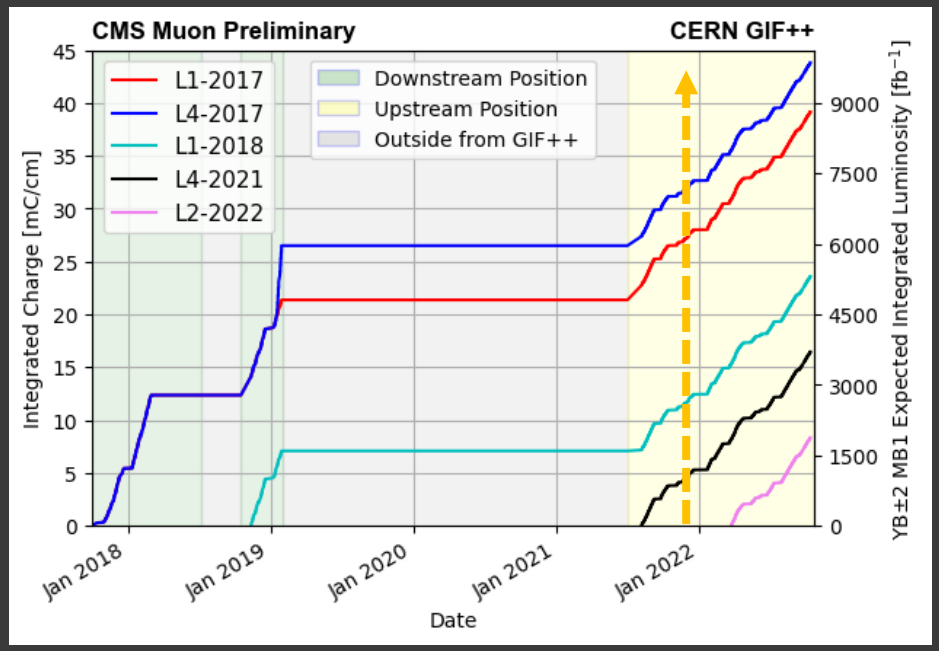
on behalf of the CMS DT Collaboration

6st Annual GIF++ User Meeting 2022 – 1st of December 2022

Outline

- History of the DT irradiation
- Studies done at GIF++
  - Gain
  - Efficiency
    - Cosmics
    - Test Beam
- Studies done at P5
  - Gain
- Summary and next steps at GIF++

GIF++ Irradiation history

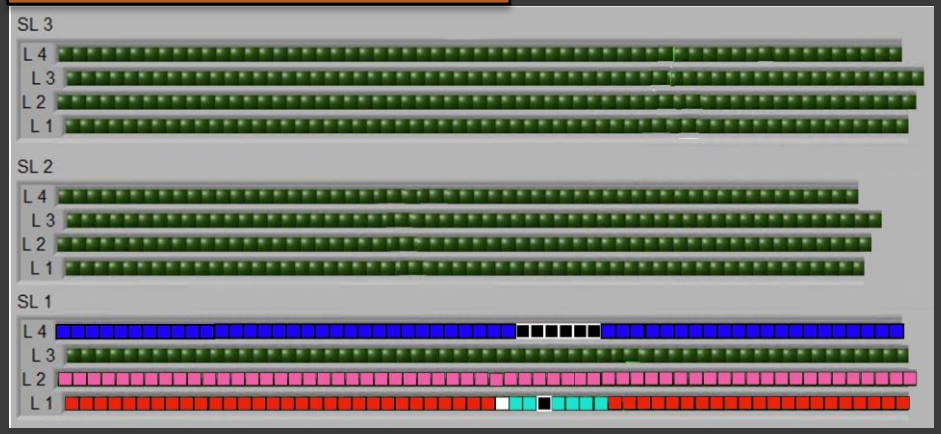


A spare MB2 chamber, with 12 Layers (**L**), organized in 3 Super Layers (**SL**), is irradiated since the 2017:

- only **L1, L2 and L4 of SL1 are on during the irradiation (attenuator 2.2)**, while L3 is kept off and used as reference
- SL2 and SL3 are used for internal trigger

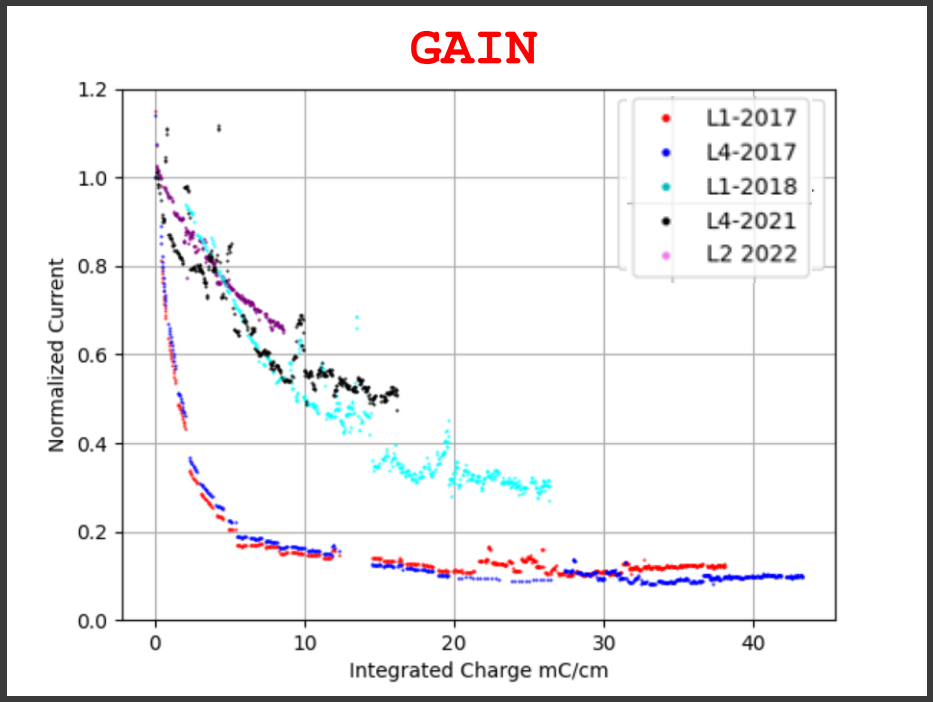
- **L1-2017** and **L4-2017** wires started the irradiation in the 2017 collecting the same dose up to Jan. 2019, after the **L4-2017** was kept at very high HV for mistake, collecting more charge
  - in Summer 2018 8 wires in the L1 were extracted, analysed, and replaced with the **L1-2018** wires
  - the same happened in the 2021 for 5 wires in L4, the **L4-2021** wire (black)
  - **L2-2022 wires started the irradiation in the 2022 with the goal of checking the aging effects on a further full layer**

MB2: position of the wires



Analysis of the currents at GIF++

During this year the goal has been to check the behaviour of the replaced wires as well as the behaviour of a full layer

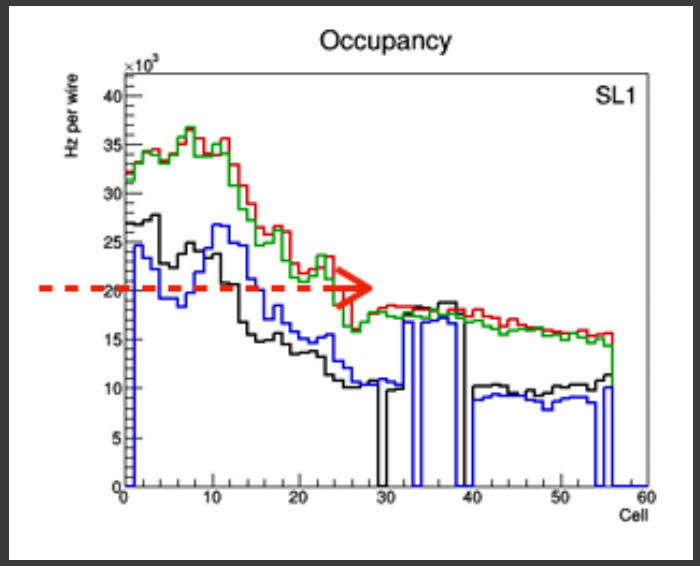


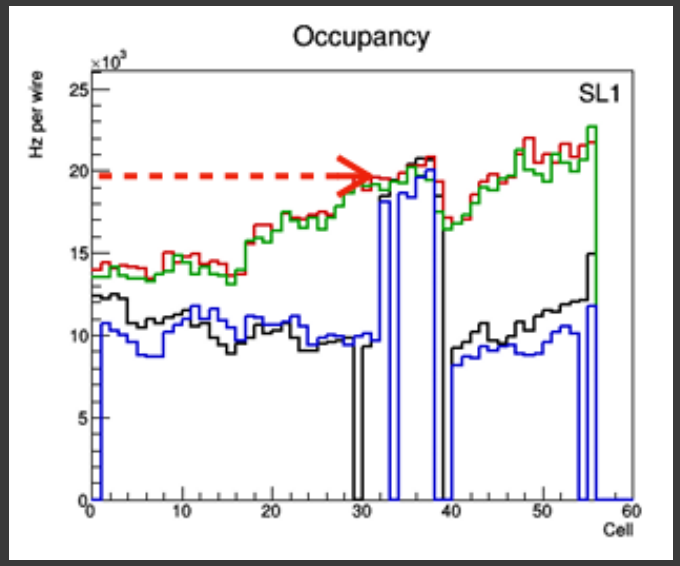
- Analysis of the currents monitored by the HV boards gives an estimation of the gain (L_i/L_3 normalized current)
- layers irradiated since the beginning show a fast degradation of the performance(red and blue markers)
- replaced wires (cyan and black) as well as the L2-2022 wires show a significantly slower reduction of gain

Data taking at GIF++

To study the aging effects on the hit efficiency the comparison should be done between data taken in conditions as much similar as possible, but:

- the position of the chamber changed during these 4 years
- the position and the intensity (Att. 2.2) of the gamma-ray source changed, also due to the movement of other detectors in front of us
  - **current of the reference layer is used to estimate the "received dose"**
  - **some runs with random trigger are regularly taken to measure the spatial distribution of the hit rate in an unbiased way**





For example: **occupancy in random trigger data before/after 25th of April 2022:**

- changes in the shape of the rates has been found
- mainly affecting the position of the replaced wires
- **Rate distributions are used to reweight the monitored currents**

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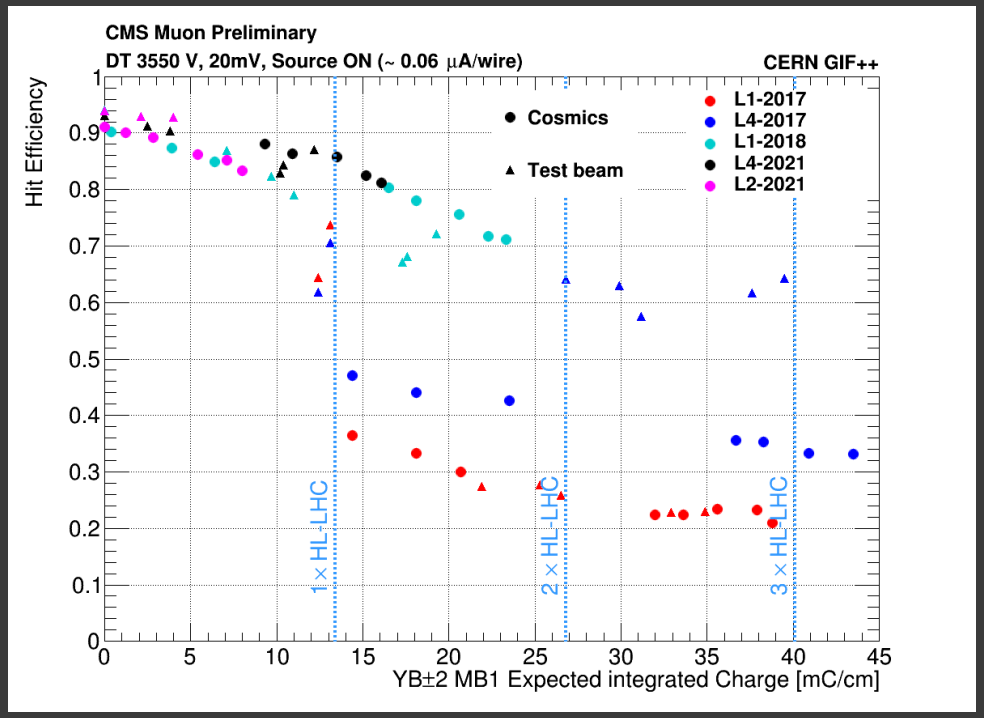
Cosmics-rays data:

- **Homogeneous** along the time, more suitable to measure the aging effect
- **Triggered by the chamber itself (SL3)** validated w.r.t. external trigger
- **Source scan** with the same (along the time) set of attenuation filters (Att 10 reproduces the HL-LHC bkg conditions for the most exposed DT chambers)
- **HV scan with source off**

Test Beam data:

- variation of the beam intensity and position along the time makes sometimes difficult to measure the aging effects trough the efficiency
- Scintillator triggers (each set of data is taken twice):
  - UP/DOWN scint. along the beam
  - DISPLACED scint. 50 cm far to fall in the region of the replaced wires
- source scan with attenuation filters decided by GIF++
- HV scan with source off
- HV scan with source on to test the limit of the system in presence of background

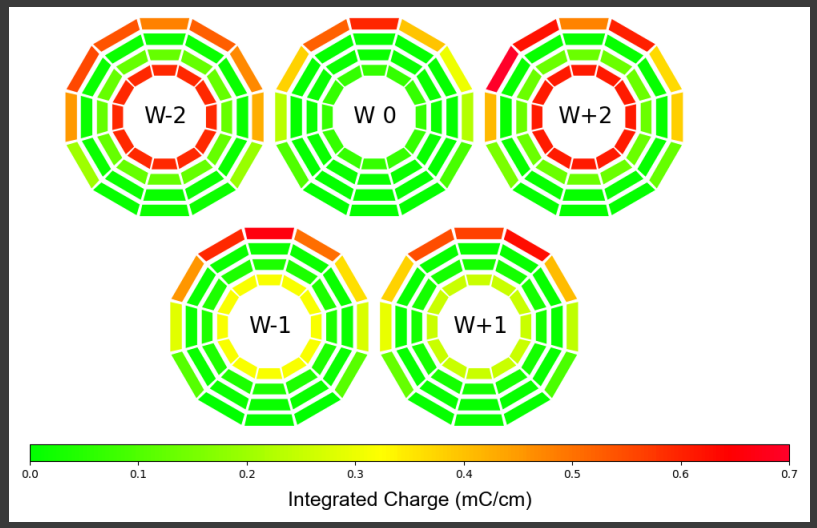
Hit efficiency at GIF++



Main conclusion: measurement of the efficiency at 3 HL-LHC has been done

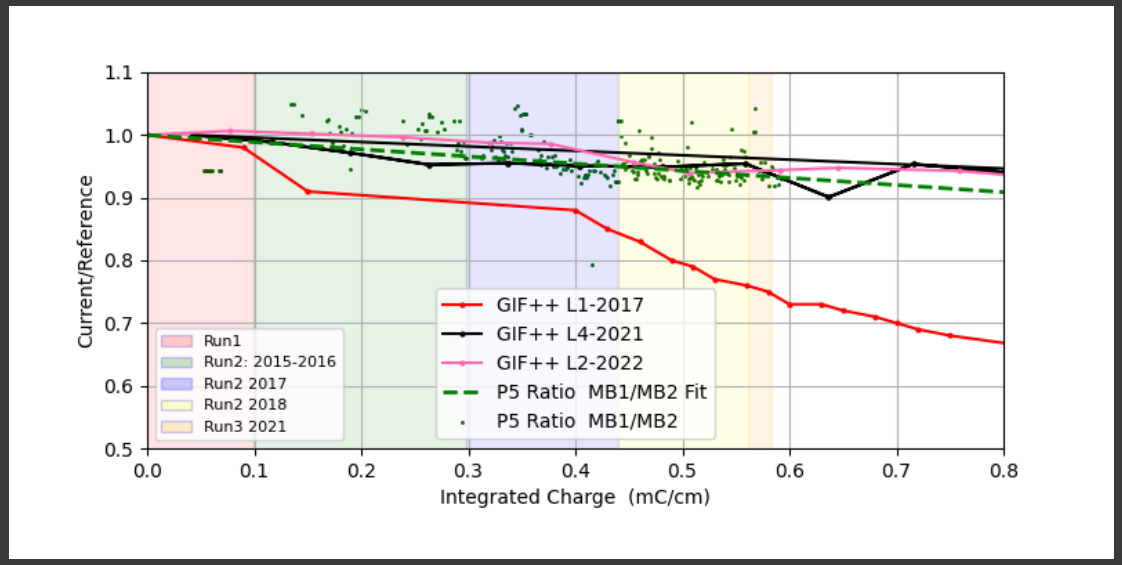
- each point in this plot is obtained fitting the data taken during a source scan
  - the prediction at 0.06 microA/wire is reported
- a different efficiency between Cosmics and TB is expected, and mainly due to the intrinsic difference of the two sources
- **two different predictions are obtained also for the efficiency confirming the gain measurements, and the P5 data are much more compatible with the results obtained from 2018 on (next slide)**

DT irradiation at P5



Amount of **integrated charge collected on the DT up to now** for about 200 fb^{-1} of integrated luminosity measured by CMS:

- **MB1 of the external wheels** and MB4 of the top sectors are the most exposed chambers
- about 10 times less charge on the MB2 and a "negligible" amount of charge on the MB3
- MB2 wires extracted during LS2, analysed with the SEM didn't show any deposit of pollution
- first attempt to compare the gain estimated at P5 and those obtained at GIF++ (their normalization represents a big challenge):



- MB1/MB2 ratio (to factorize systematic effects) at P5
- L-x/L3-reference ratio at GIF++
- **a trend of decrease of gain can be measured also at P5** and it looks more **compatible to the L2-2022 and L4-2021** wires than to the ratio of the L1-2017 wires(red)

Summary and outlook

- **The goal of 3 HL-LHC equivalent charge has been reached, and we close the data taking with the HV and gas conditions adopted until now, we also stopped the irradiation taking measurements done during the November TB as last reference**

- We obtained two different results:
  - a correlation between the very degraded performance and the presence of a large peak of carbon on the polluted surface of the 2017-wires has been found, but causes are still unclear
  - results from P5 are compatible with the more optimistic measurements obtained at GIF++

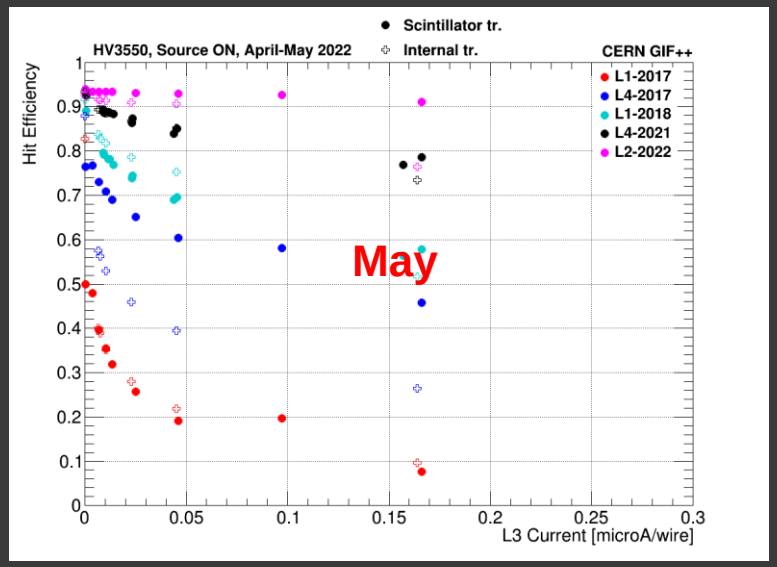
- In any of the two cases DT system can continue to efficiently operate at HL-LHC (only 10% of the chambers are the most exposed, another 10% will receive an half of the dose and the rest a negligible percentage):
  - HV scan with source-on also showed that we can recover the nominal efficiency also in the most aged wires
  - **We would like to measure for how long this recovery can be stable before to start to age again (next year)**

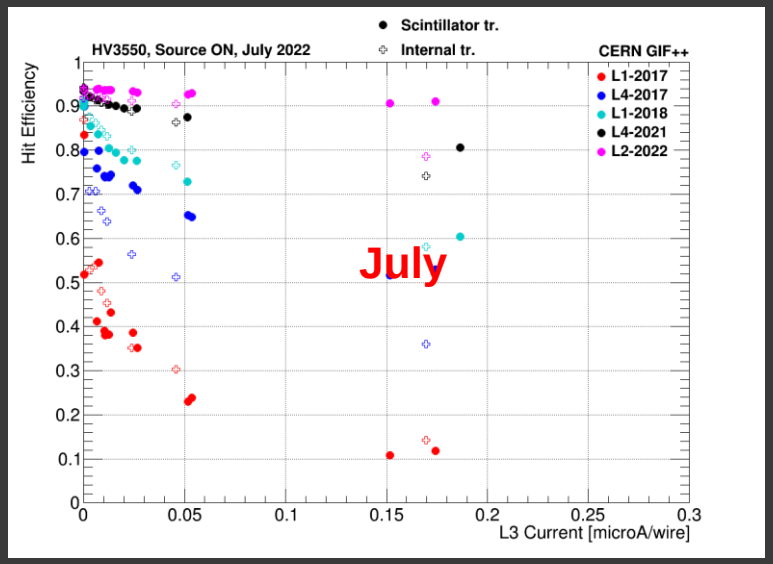
- A mitigation strategy is already in place since many years either at P5 than in the GIF++ operation
  - a last test on the gas has been planned to check if increasing the flow (almost doubling it) we can obtain a mitigation in the trend of decrease seen in the gain
  - Ongoing since this week, it should take at least 3 months
  - Irradiation at Att. 2.2 will continue for all the test

Back-up

DT Eff. vs inst. current in Test Beam (source on)

Scintillator vs Internal trigger

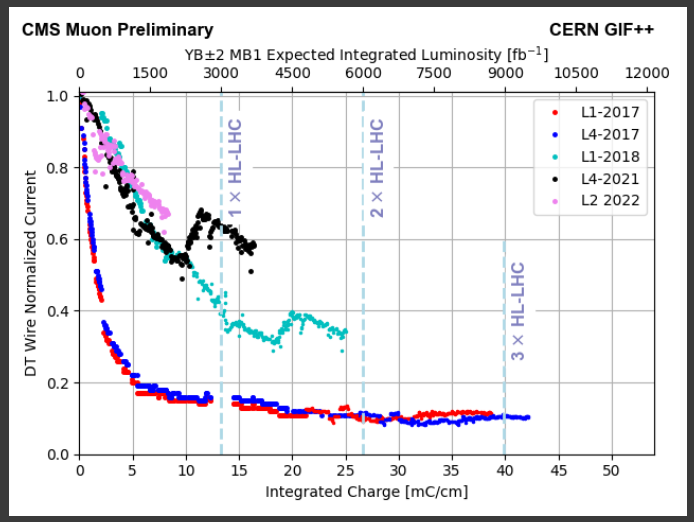




For the same «source of data»

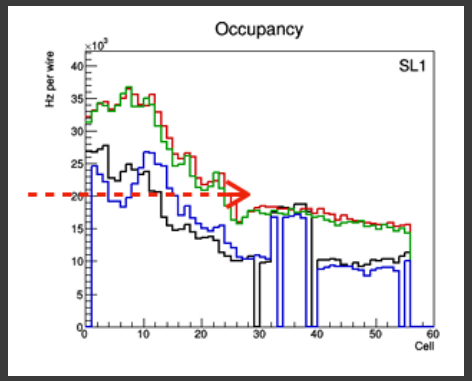
- reasonable agreement between Scintillators and Internal trigger for all the sets of wires except for the L4-2017

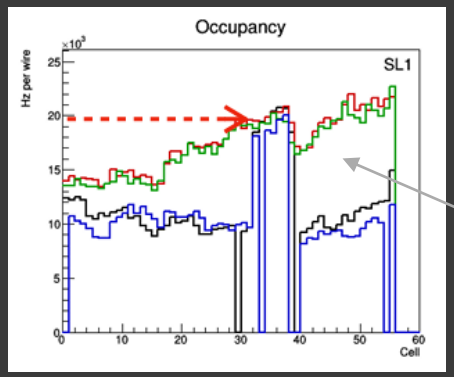
DT currents at GIF++



Analysis of the currents monitored by the HV boards gives an estimation of the gain:

- all the set of wires show a coherent trend of decrease of the gain until roughly the end of April
- since May 2022 (last 6 mC/cm), an unexpected raise and decrease of gain has been observed in L1 and L4
  - less pronounced in the old wires (blue and red)
  - L2 apparently seems to be not affected by this



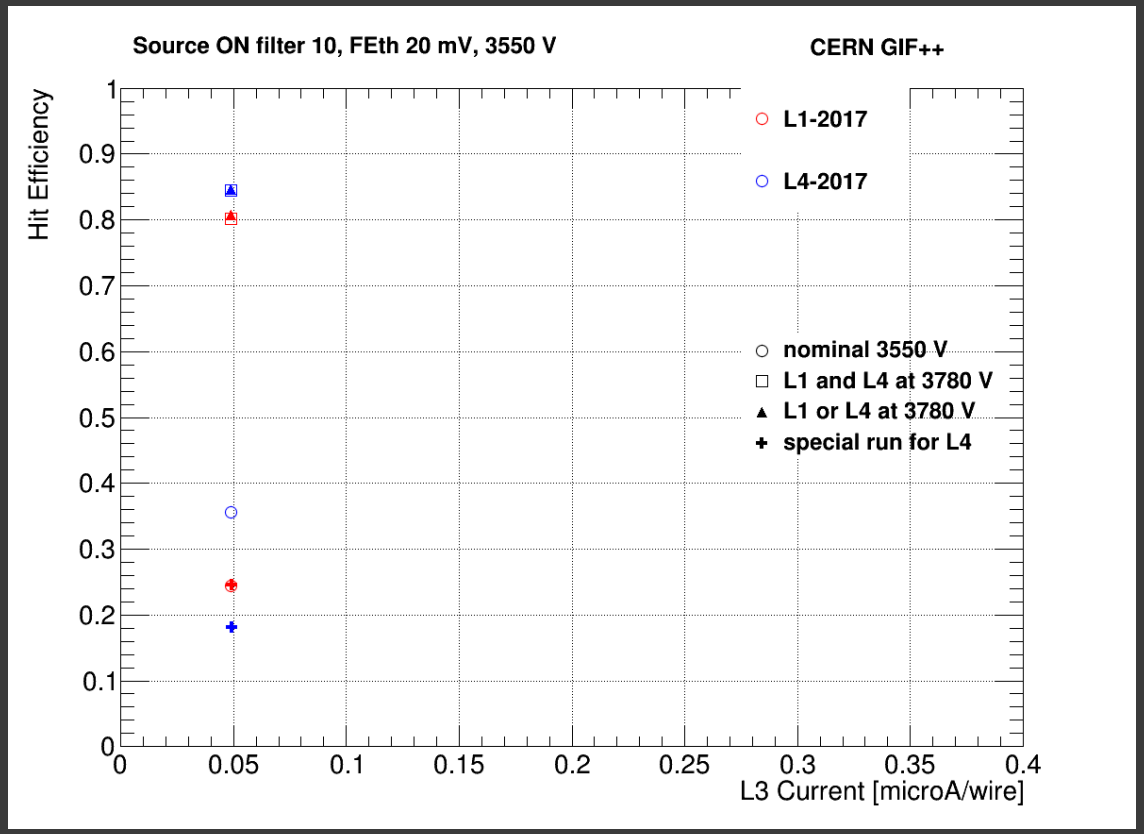


Looking at the occupancy during runs taken with the Random trigger before/after 25th of April 2022:

- changes in the shape of the rates has been found
- mainly affecting the position of the NEW wires

Working is ongoing to reweight the currents for the shape of the rate, not so easy because the currents are always monitored, while the rates are estimated only during the runs

Results from special runs



Special runs taken in August with the idea of checking whether the aging-effects (lower gain and inefficiency) seen in the 2017 wires are recoverable:

Increasing the HV to 3800 V:

- shows a big recover (also seen in the currents (Imon) during the data taking)
- no difference if both or only one layer is at 3800 V

Quick test, decreasing the HV to 2000 V with strips off :

- efficiency lower than the nominal (blue cross)
- no effect on L1(red cross)