SciFi Threshold Calibration

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Jahrestreffen der deutschen LHCb-Gruppen

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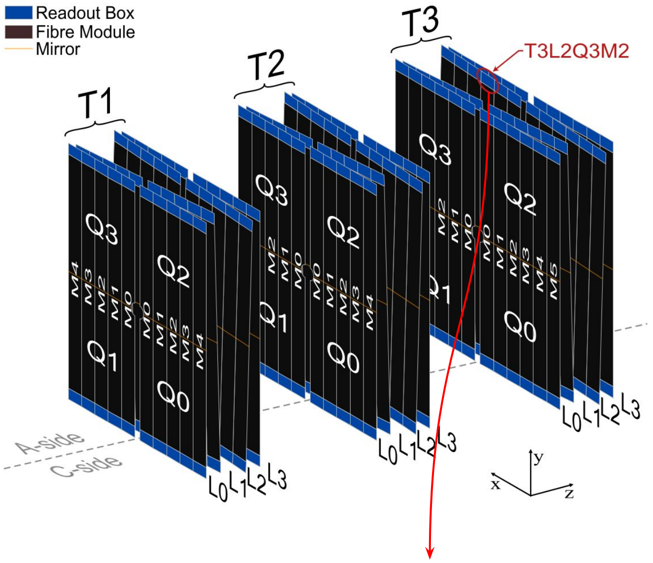
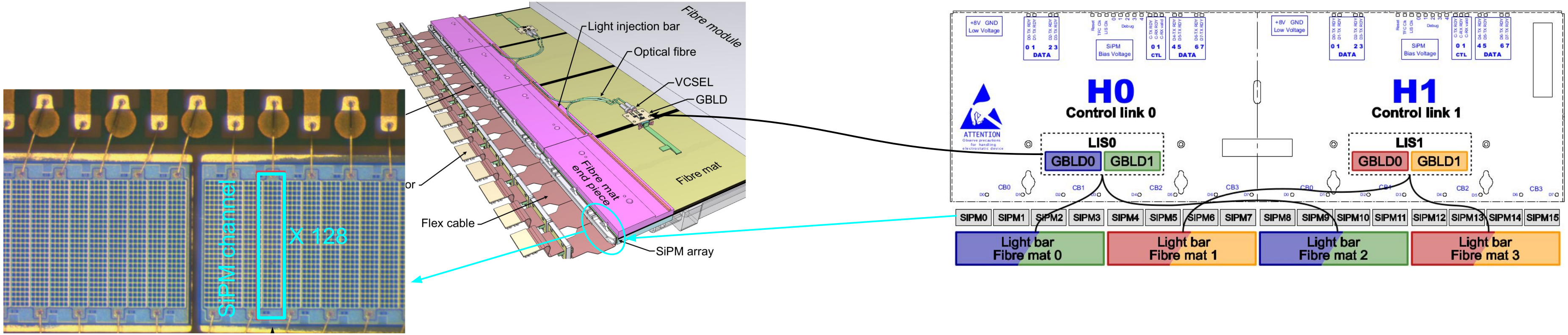
Overview of the talk

- ❏ Threshold calibration procedure
- ❏ Current status of LIS calibration
- ❏ Alternative calibration method

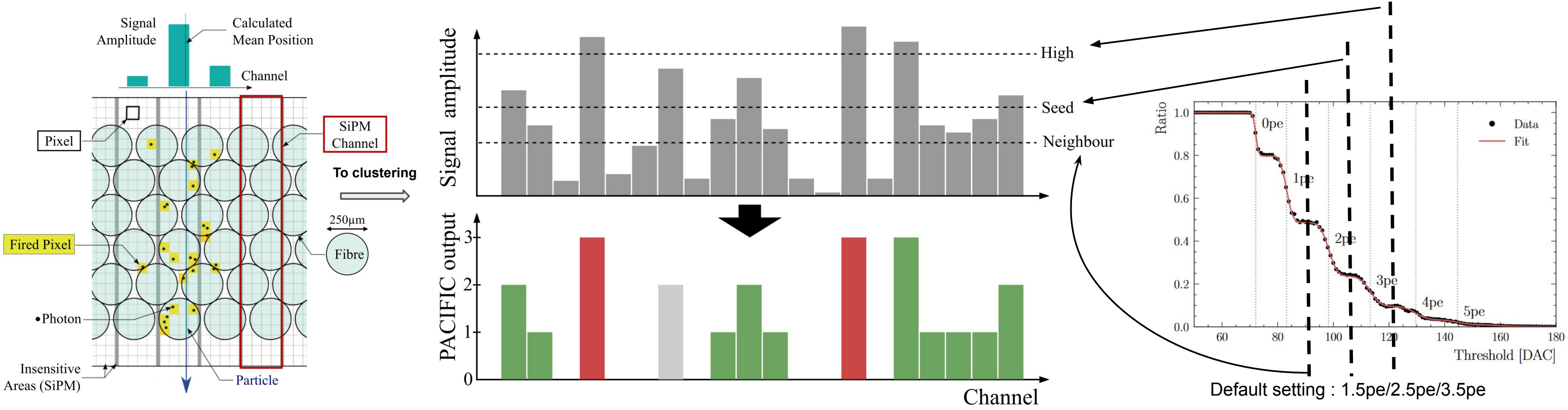
The SciFi tracker

- The SciFi tracker consists of three stations (T) each with four detection layers (L).
- Each detection layer has parallel rectangular modules (M) housing scintillating fiber mats.
- At the edges of each modules, readout boxes are instrumented to read signals from SiPMs.
- Each is mounted with light injection systems (LIS) for calibration.



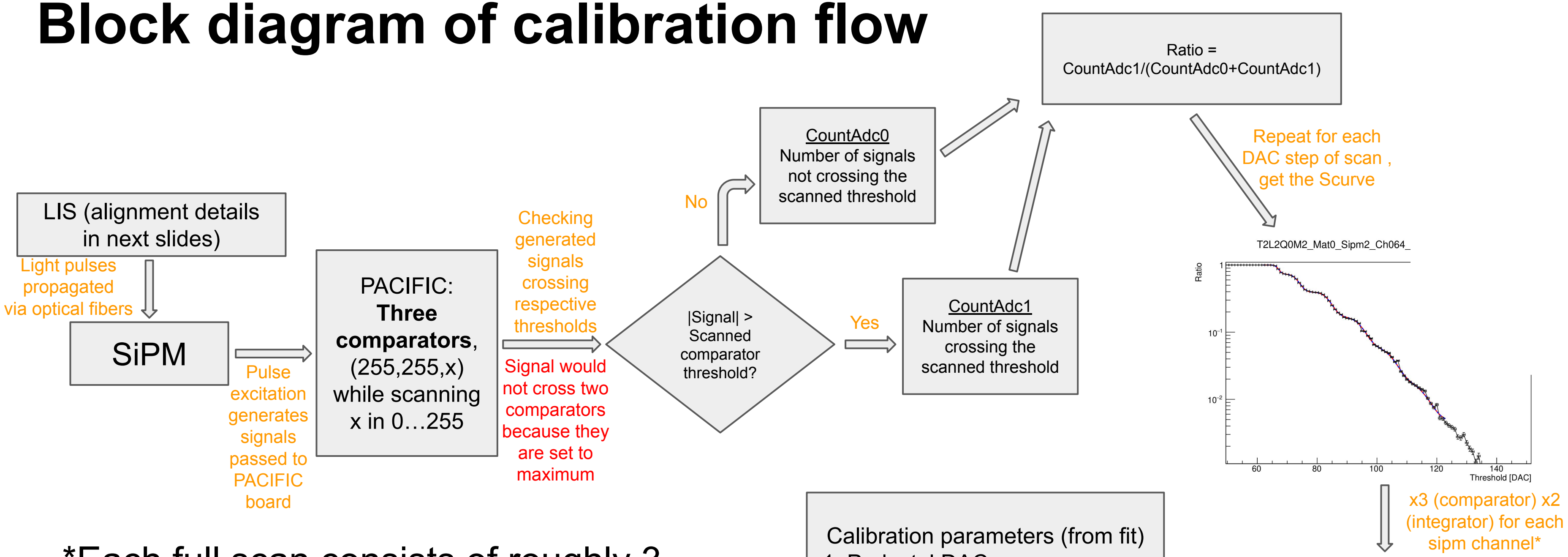


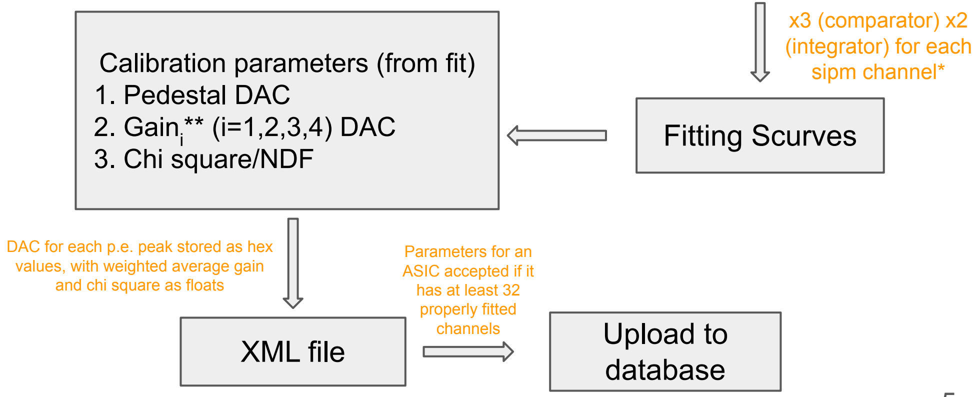
Need for calibration



- ❑ Clustering of channel data from sipms is done using a set of three "comparator" thresholds ⟶ Appropriate thresholds required for optimum efficiency
- ❑ Thresholds obtained from fitting Scurves ⟶ Determining location of corresponding p.e. peaks in terms of DAC steps.

Block diagram of calibration flow

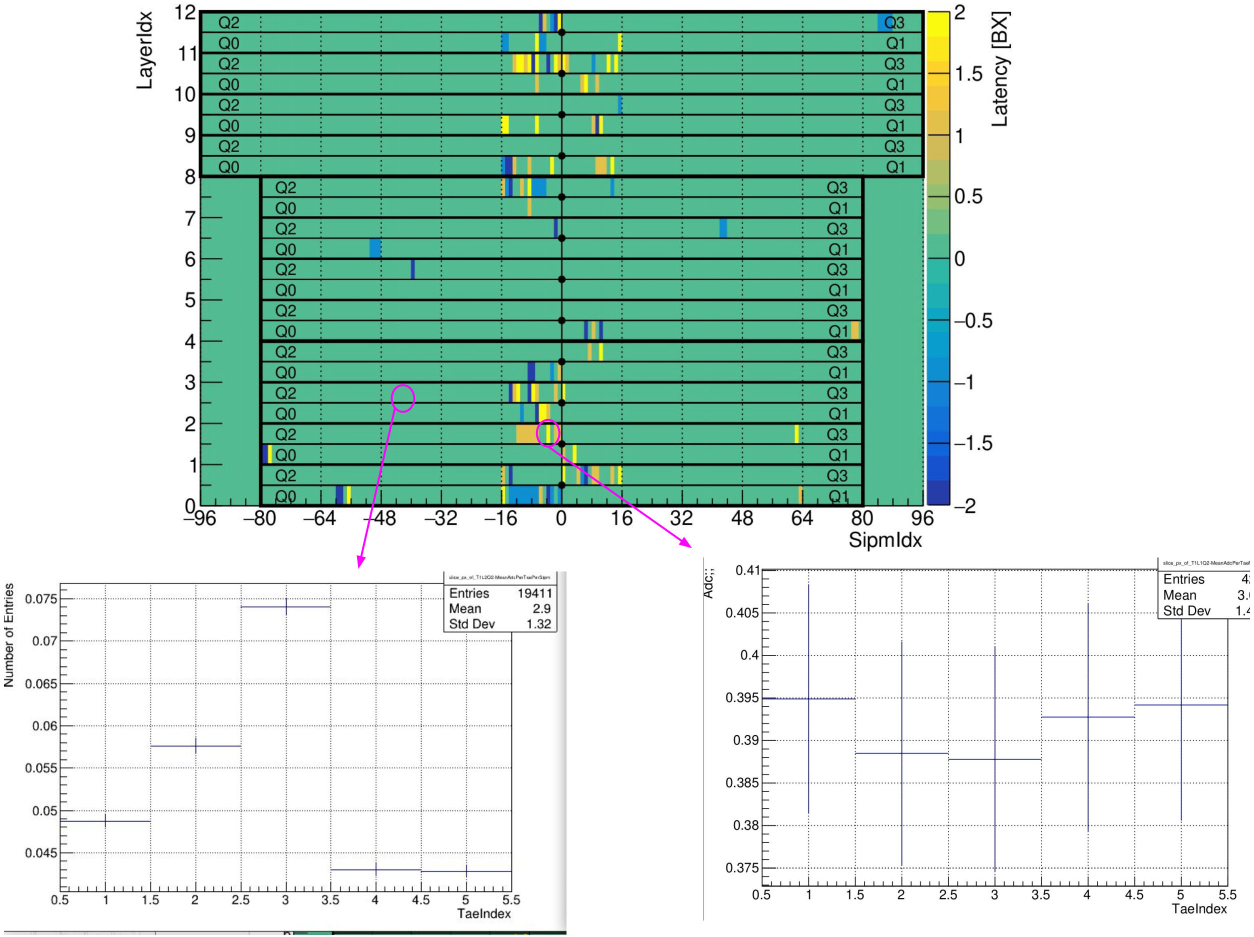




*Each full scan consists of roughly 3 million fits (2 integ x 3 comp x 128 ch x 4k SiPMs).

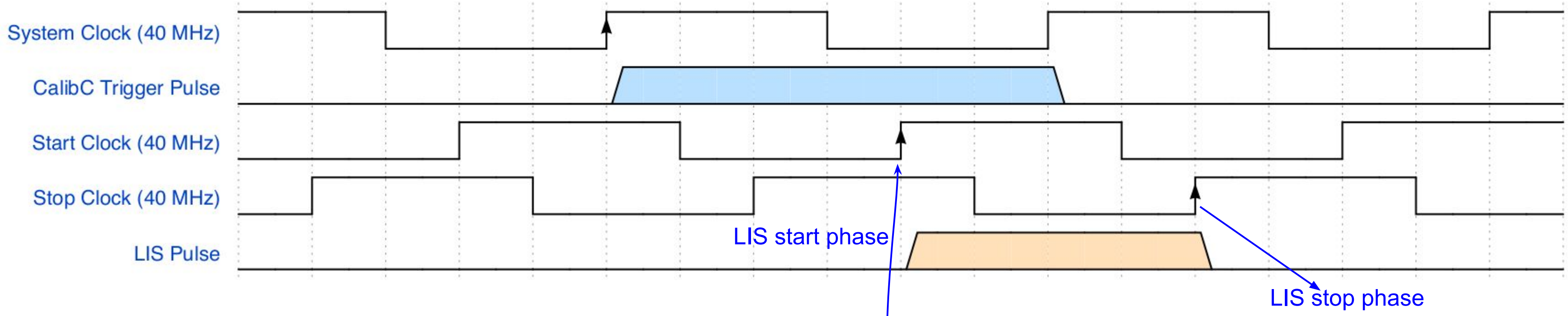
**$Gain_i = PE_{i+1} - PE_i$; generally expected to be similar across peaks.

LIS coarse time alignment

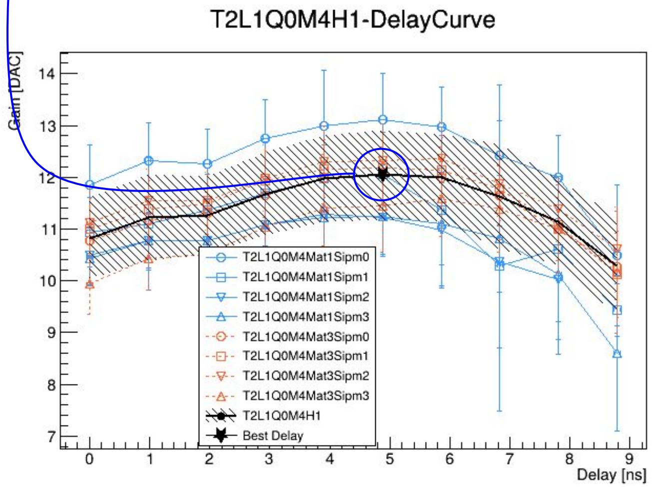


- ❑ Each LIS needs to be triggered at the correct bunch crossing with respect to expected LHC BX.
- ❑ This is confirmed by checking latencies (BX_{signal} - BX_{LHC}).
- ❑ If its off, its corrected using average of SiPMs for halfrob.

LIS fine time alignment

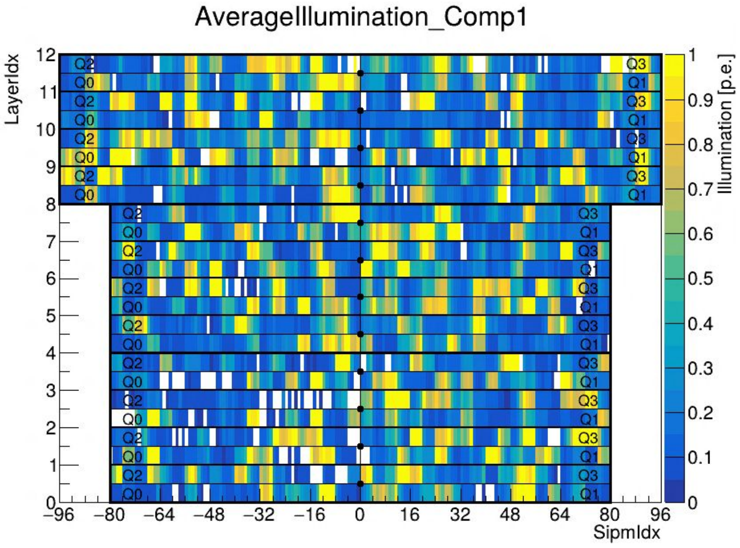


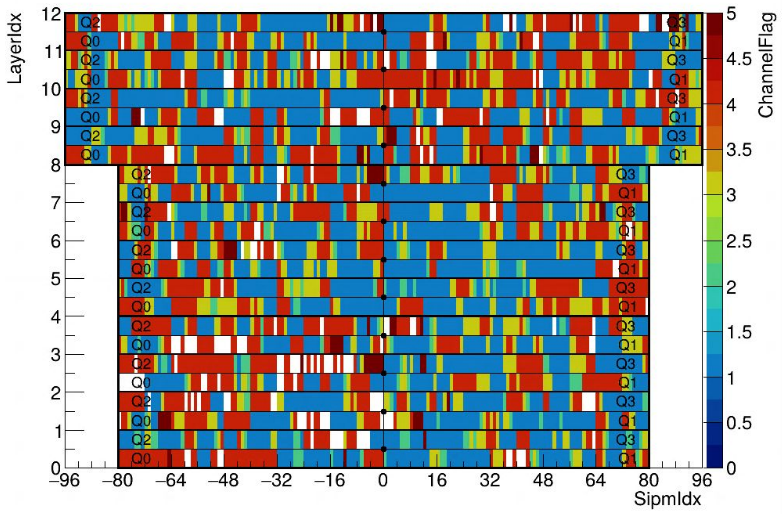
- ❑ Coarse time alignment ensures LIS is fired at the correct BX.
- ❑ Fine time alignment is done to ensure within the same BX, maximum signal is integrated.
- ❑ A delay threshold scan is taken to find the optimum delay (LIS start phase) based on optimum gain.



Everything seems ok and straightforward … isn’t it?

Classification of sipms from illumination





June 24

- ❏ Average illumination calculated using channel fits for sipms. This is used to classify sipms using number of channel fits.
- ❏ Roughly half of the channels cannot be fitted with current LIS configuration.
- ❏ Two reasons for white regions
  - ❏ Fits failing to converge
  - ❏ Fits failing to pass validation cuts

Flag1 **(blue)** : Illum. > 0.2 p.e , >80% channels (**best**)

Flag2 **(green)** : Illum. < 0.2 p.e, >80% channels (**surprisingly good**)

Flag 3 **(yellow)** : 50%-80% channels (**intermediate**)

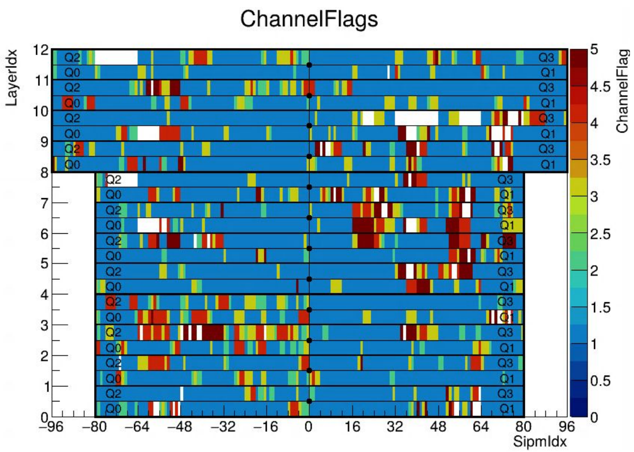
Flag 4 **(red)** : Illum < 0.2 p.e., <50% channels (**bad**)

Flag 5 **(dark red)** : Illum > 0.2 p.e., <50% channels (**surprisingly bad**)*

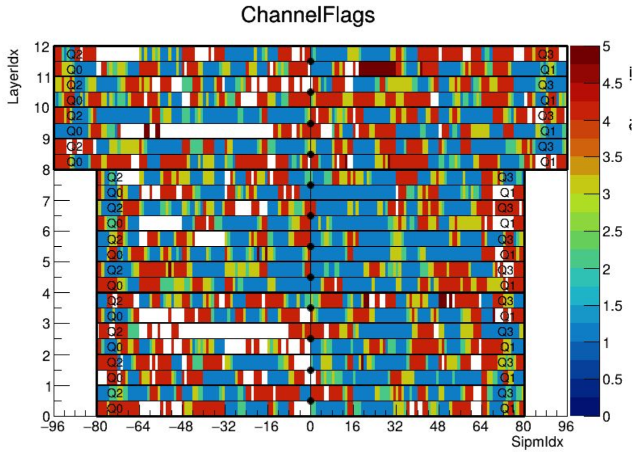
(blank): there is no channel that fit (**no idea**)

***We partly are responsible for some of them when we tried configuring the LIS settings manually. It improved the illumination … albeit bit more than the limit (details)**

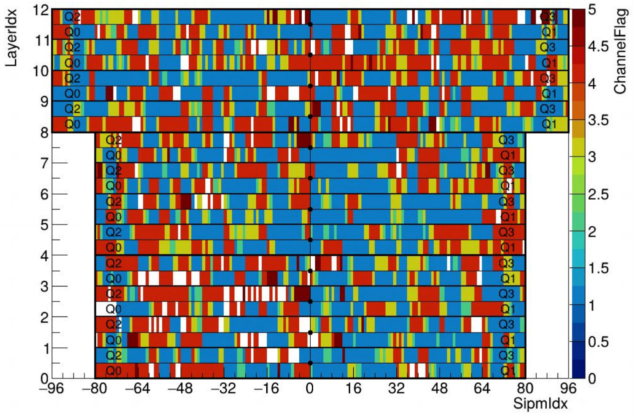
Calibration stability over time



Oct 2023



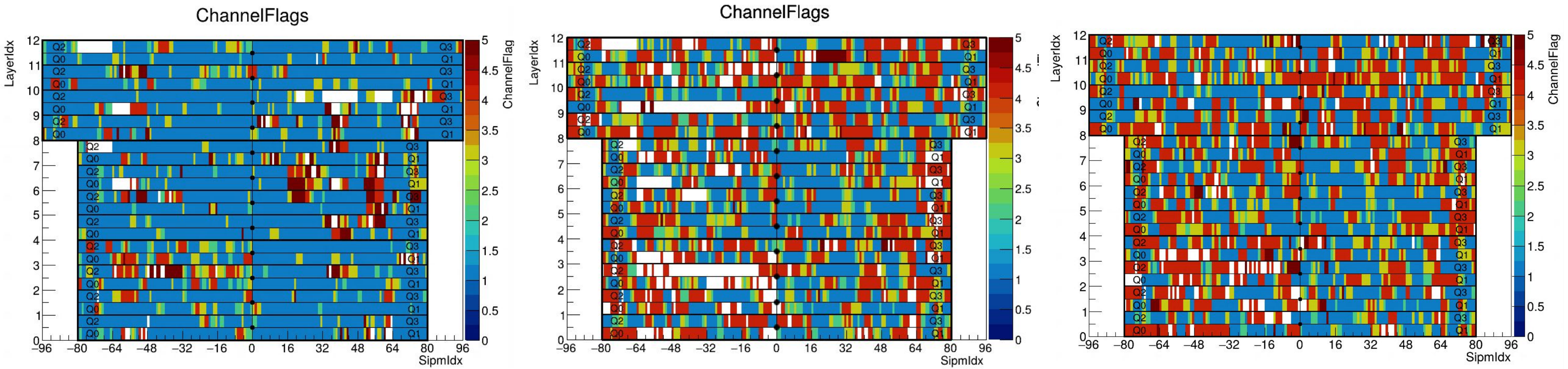
End of March 2024



June 2024

- Significant drop in calibration fits observed over a period of around a year
- We suspect that the stability “switch” happened around March 2024.
- The exact cause of this drop is under investigation (Alignment? LIS itself?).
  - Current hypothesis is messed up fine time alignment …

Calibration stability over time



Oct 2023 **End of March 2024** **June 2024**

- ❑ Significant drop in calibration fits observed over a period of around a year
- ❑ We suspect that the stability “switch” happened around March 2024.
- ❑ The exact cause of this drop is under investigation (Alignment? LIS itself?).
  - ❑ Current hypothesis is messed up fine time alignment … stay tuned until the end of this year for an answer (hopefully) ;)

Ok, so if LIS is not effective for now, what can be done to get thresholds for all the channels?

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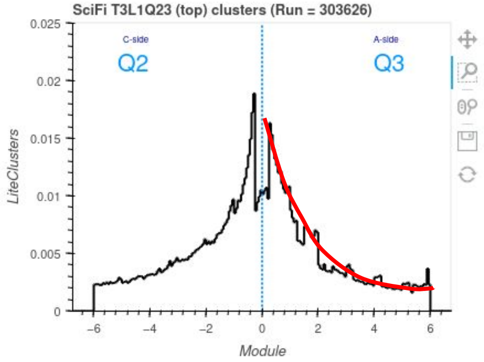
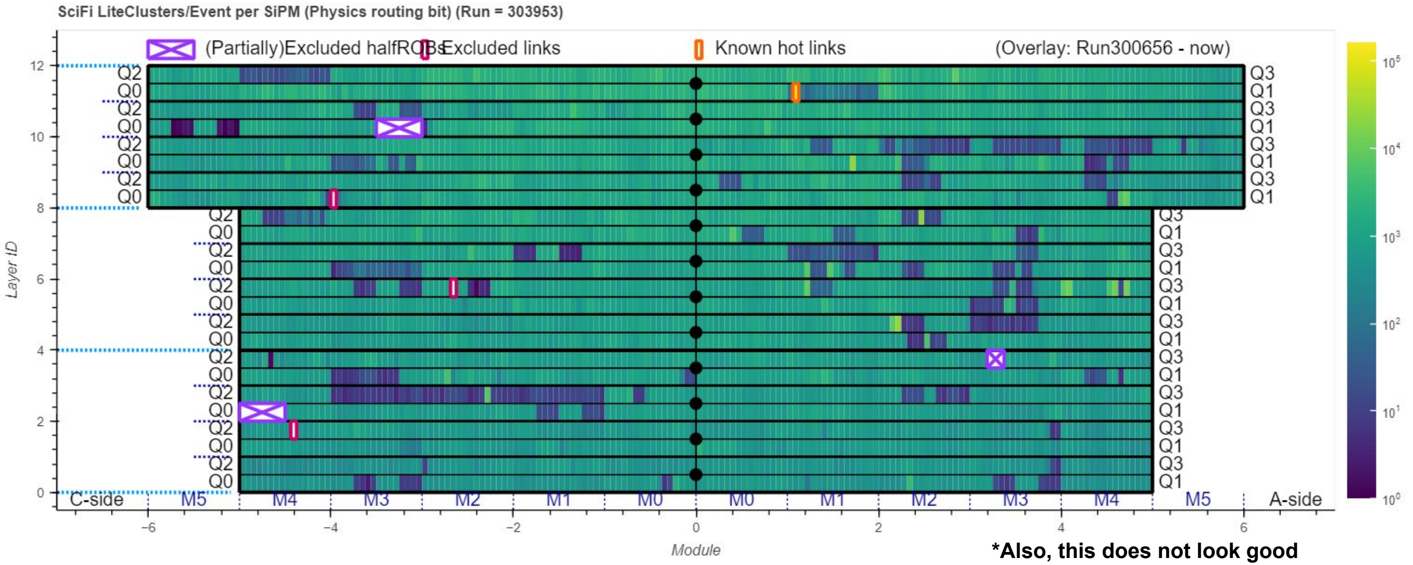
There is a way, lets understand it through an example.

Impact of high thresholds

- Around 11% of the sipms (dark blue) observing a drop in the number of hit clusters.
- These sipms can affect the hit efficiencies, hence we considered to update the thresholds for these regions.





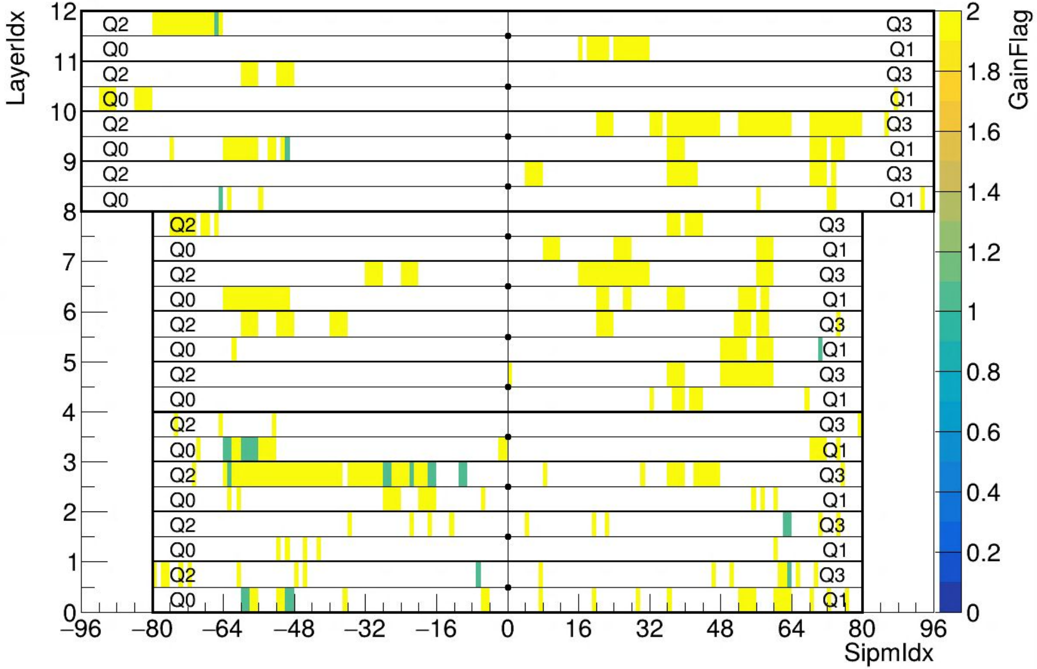
*Also, this does not look good

Threshold settings

- Threshold settings are generally calculated using pedestals and gain measured from threshold scans
  - $PE_{0.5} = \text{Pedestal} + 0.5 \times \text{Gain}_0$
  - $PE_{1.0} = \text{Pedestal} + \text{Gain}_0$
  - $PE_{1.5} = \text{Pedestal} + \text{Gain}_0 + 0.5 \times \text{Gain}_1$
- “Odd” thresholds can be calculated by interpolating the known thresholds. For eg,
  - $PE_{1.6} = PE_{1.0} + 0.6 \times (PE_{2.0} - PE_{1.0})$
- Overall, you need only pedestals and suitable gains to calculate respective thresholds.
  - Pedestals can be effectively measured from pedestal scans (Do a scan without triggering the LIS, only fit for the pedestal).
  - Assuming uniformity of gains, a common gain can be considered for sipm from average of fitted channels (Need a LIS threshold scan run for this).
- Specific set of “odd” threshold settings were considered : 1.6pe/2.0pe/2.7pe.
  - Tests from RTA showed these settings to be reducing spillover by 30% (Detailed talk by Elisabeth here)

Alternative method for calibration

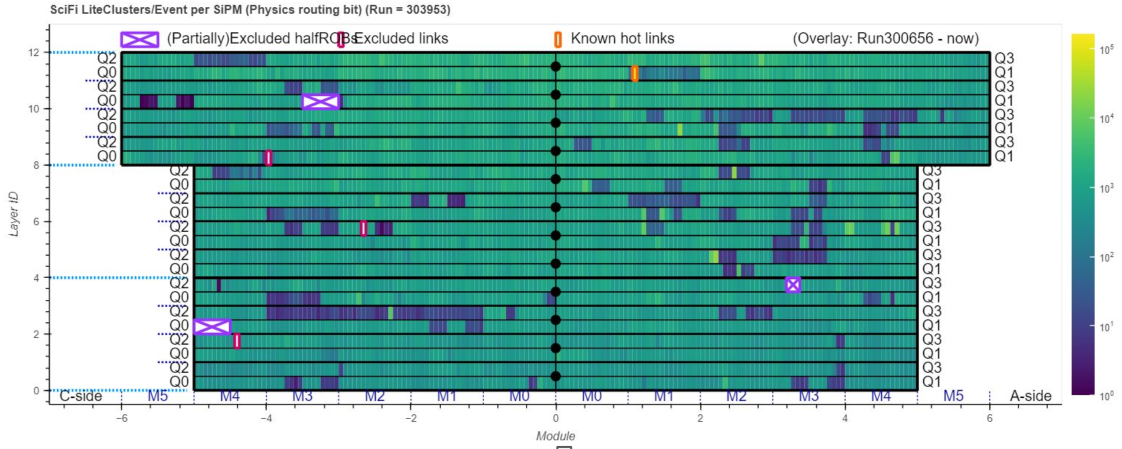
- For the highlighted areas, thresholds are calculated using
  - Pedestals from a pedestal scan (5374).
  - Average gain for the sipm from June 2024 LIS threshold scan (5105).
- For the white areas, thresholds from database were appropriately modified.

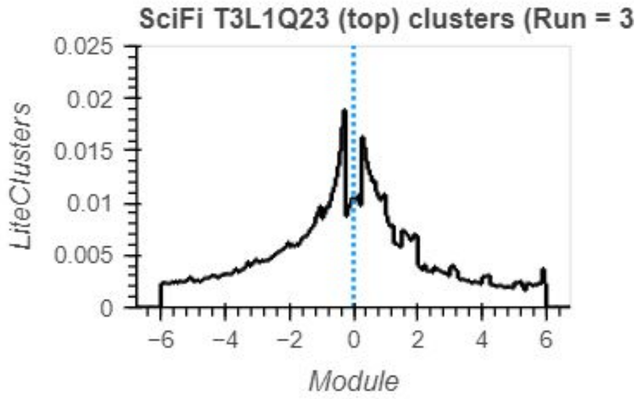


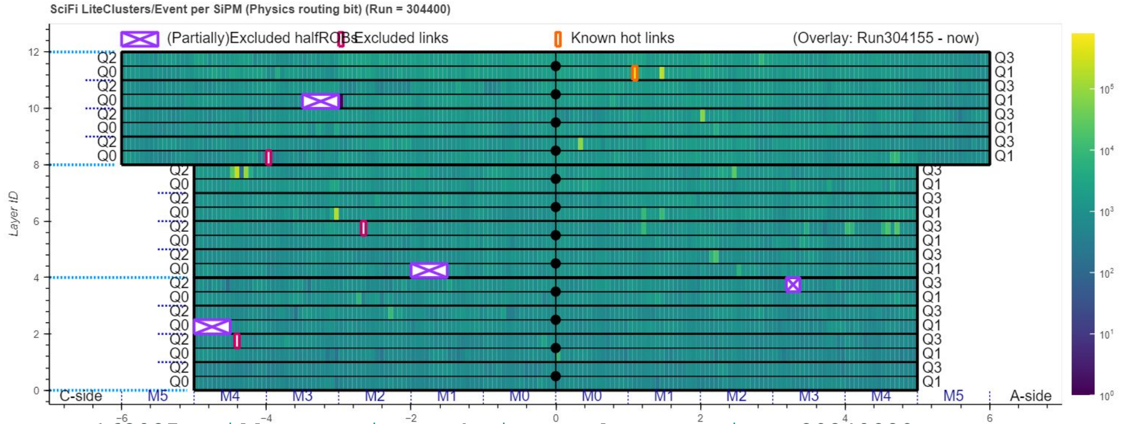
Sipm average considered

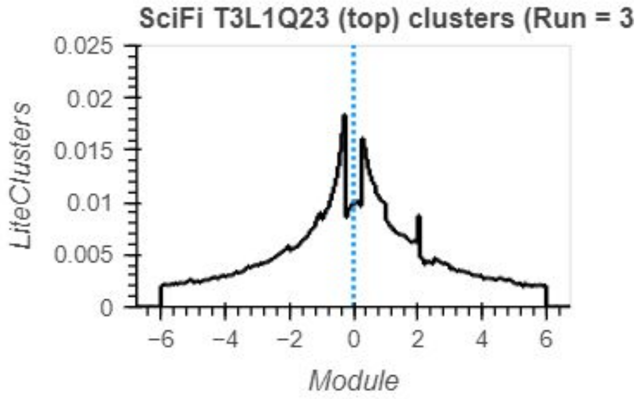
Detector average considered

Improved thresholds since September 2024



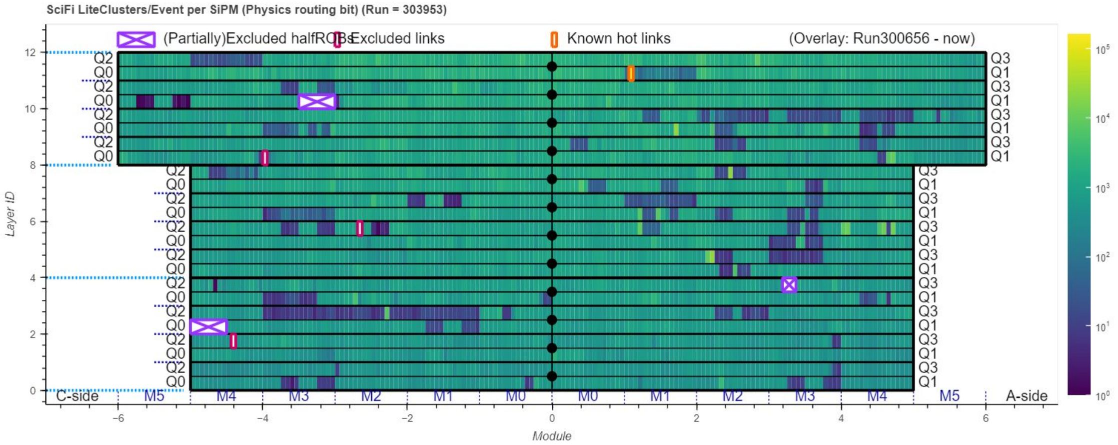


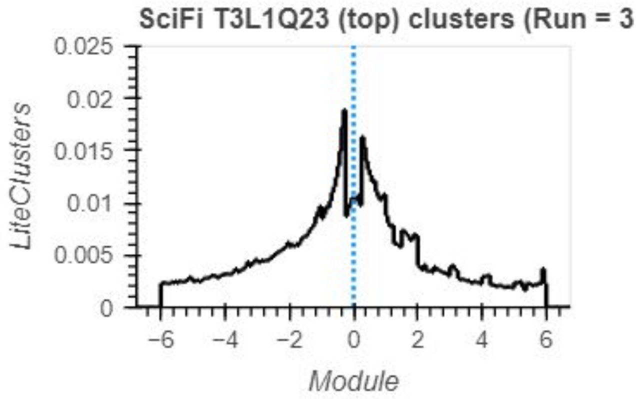




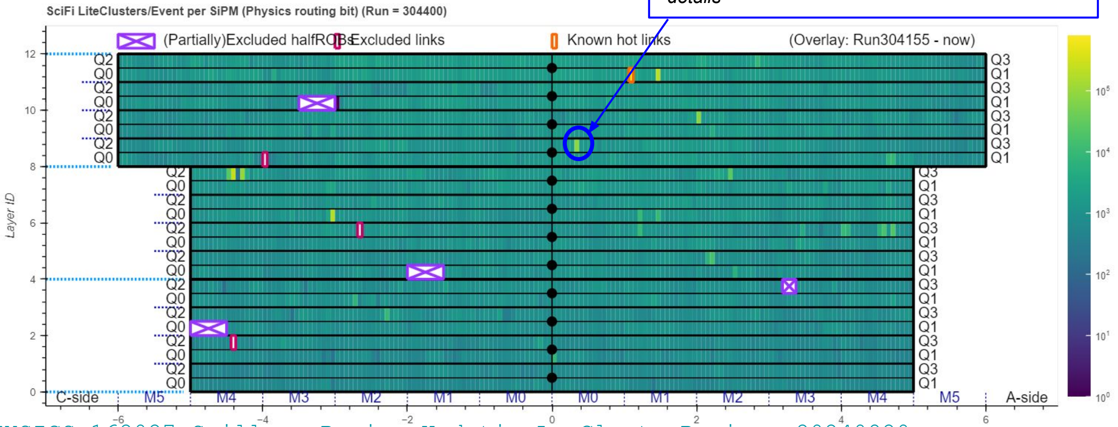
PHYSICS_162027_SpilloverRecipe_UpdatingLowClusterRegions_20240820

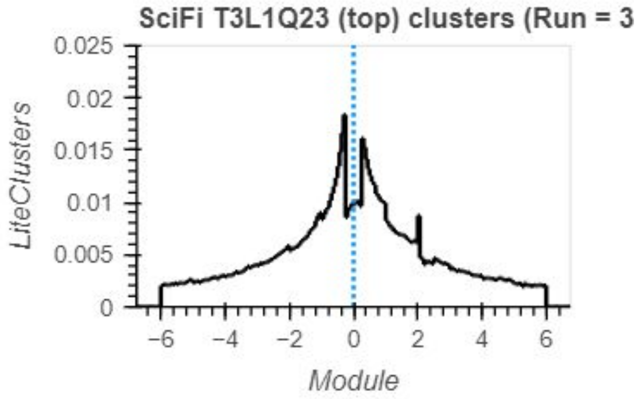
Improved thresholds since September 2024





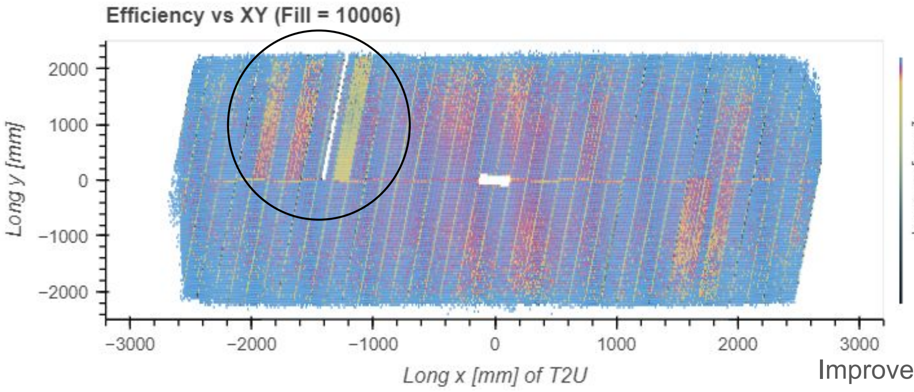
How to deal with these guys? Follow [here]() for details



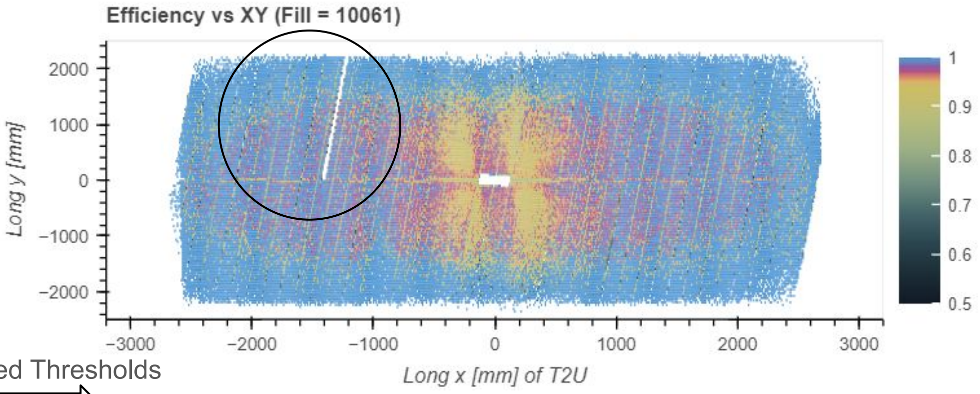


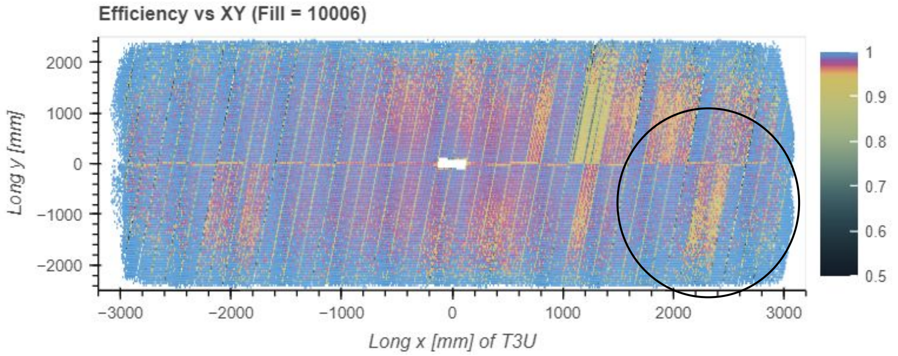
[PHYSICS_162027_SpilloverRecipe_UpdatingLowClusterRegions_20240820]()

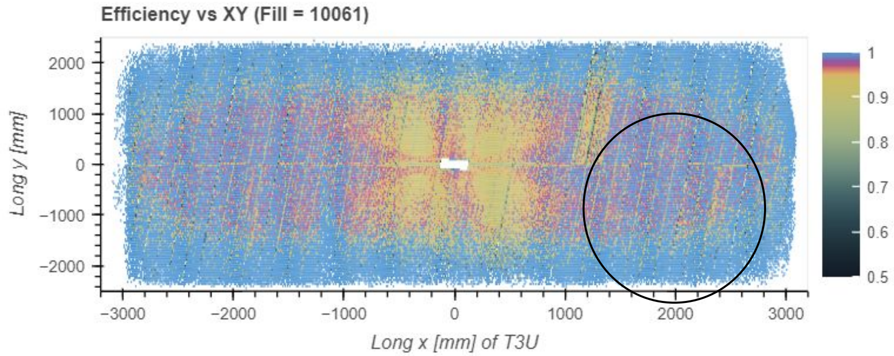
Improvement in Efficiency(?)



Improved Thresholds







Summary and next steps

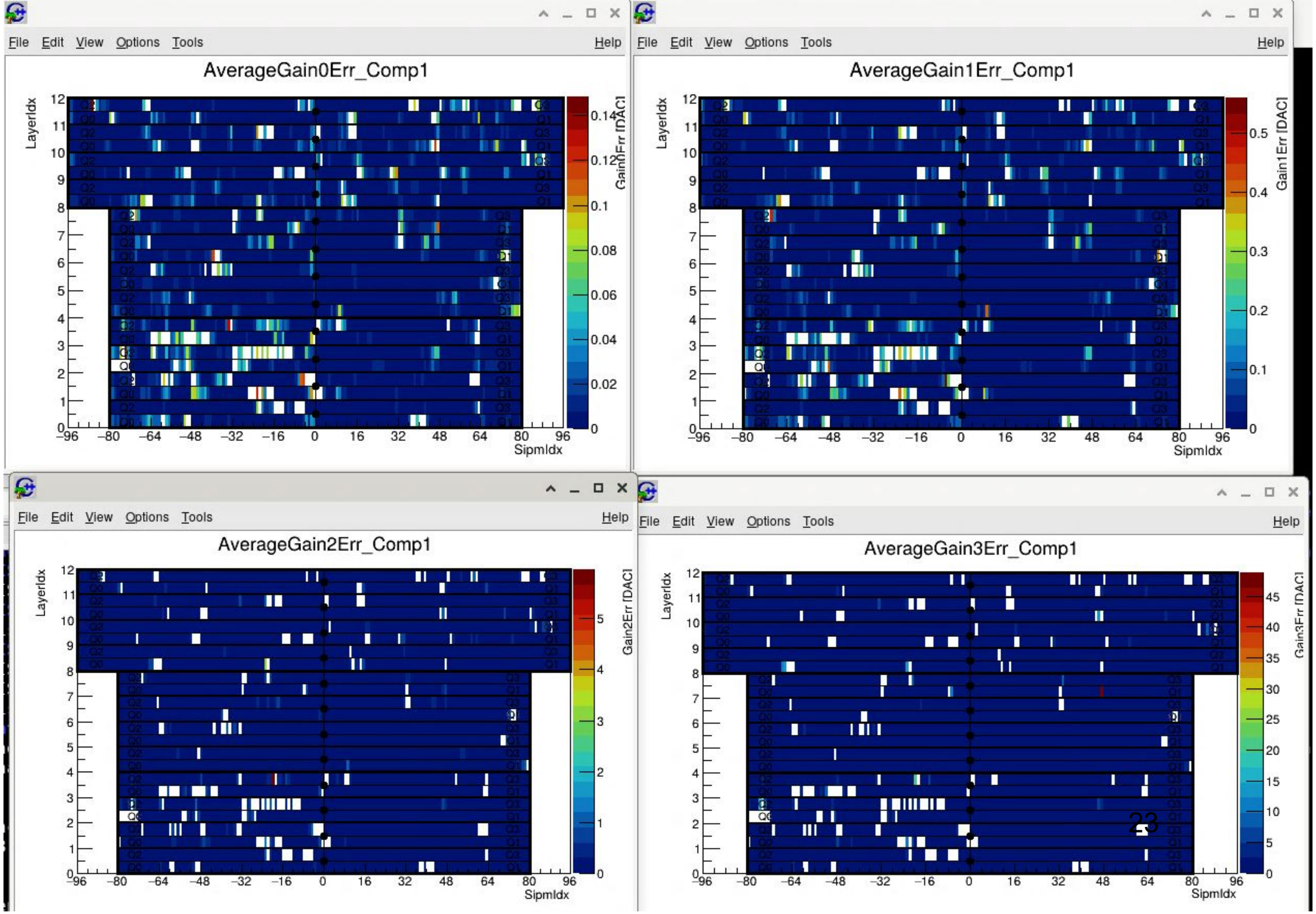
- ❏ The procedure of fitting around million channels is a hefty task; this process is incredibly simplified and robust thanks to scurvefit tool developed by Lukas Witola.
- ❏ LIS calibration currently failing on account of poor number of fitted channels, mostly pointing towards low light intensity.
- ❏ However, thresholds can still be obtained by measuring pedestals and using suitable gain values.
- ❏ Currently, SciFi running smoothly with the new set thresholds. We see a uniformity in the hitmaps, which has improved efficiency.
- ❏ The issue of light intensity is ”work in progress”.

BACKUP

List of abbreviations

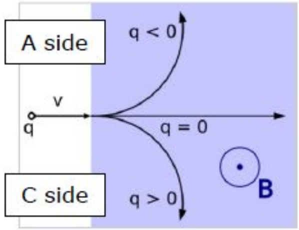
- ❖ LIS : Light Injection System
- ❖ GBLD : GigaBit Laser Driver
- ❖ FEB : Front End Box
- ❖ TAE : Time Alignment Event
- ❖ FE : Front-End
- ❖ TFC : Timing and Fast Commands (Trigger)
- ❖ SiPM : Silicon PhotoMultiplier
- ❖ ROB : Read-Out Box (sorta another name for FEB)

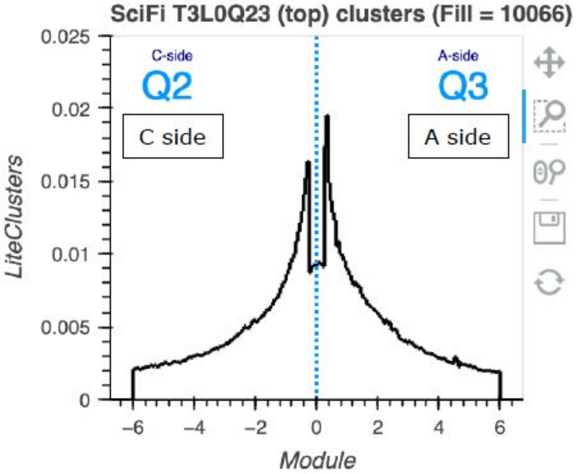
Gain Uncertainty Map



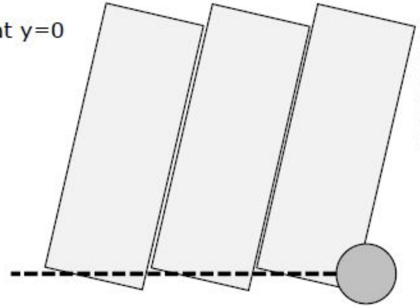
Magnet effect on hit clusters

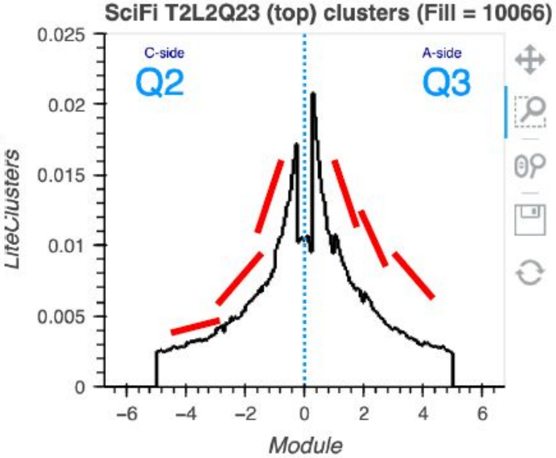
- X-layer:
  - Almost symmetric
  - More particles on A-side:
    - Electrons from secondaries





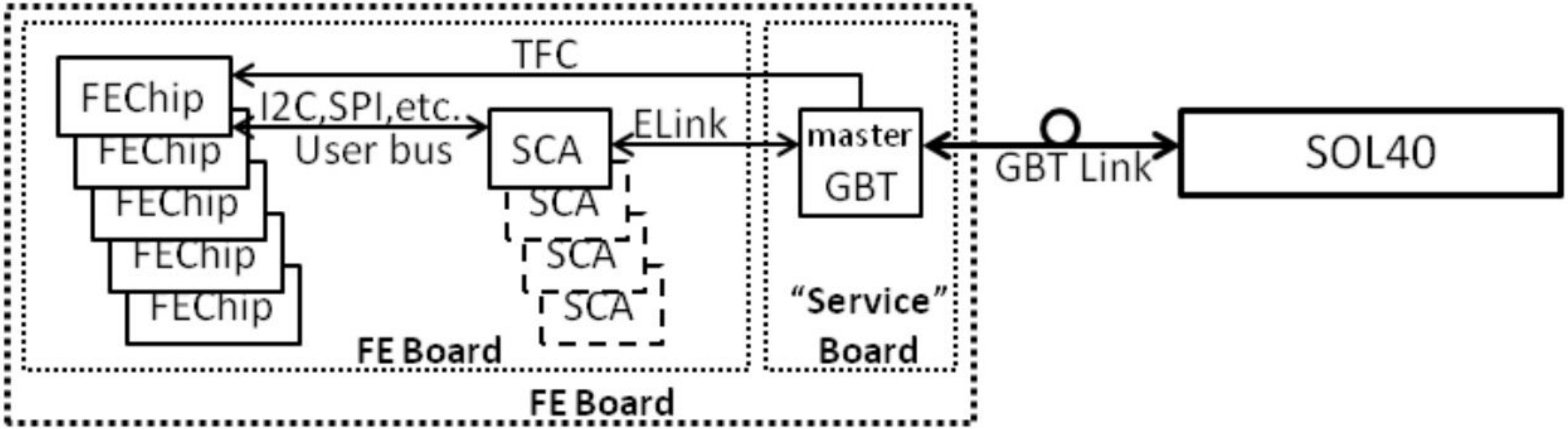
- Stereo layer
  - Discontinuities from module to module
  - Geometric pattern
    - Large variation of occupancy at y=0





**Credits : Niels Tuning*

SOL40



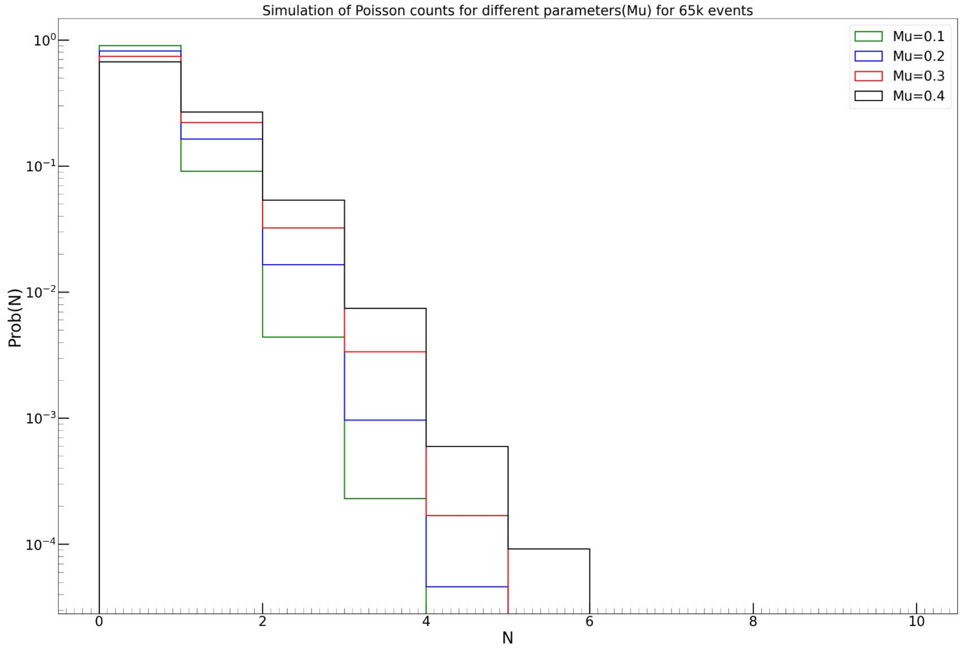
- ❖ Transmission of information from ECS and TFC to FE is controlled via same physical GBT-based link.
- ❖ These links are monitored and authenticated by the SOL40 for link robustness.

List of cuts for detector overview maps

Parameter	Acceptable range
Crosstalk (measure of secondary avalanches in SiPMs caused by primary photoelectrons)	(0.0001, 0.1)
$Gain_i$ ($i+1^{th}$ p.e peak - i^{th} p.e peak)	(0, 20) DAC
$Width_0$ (Gaussian width of 0 pe signal)	(0.8, 2) DAC
$Width_1$ (Gaussian width of 1 pe signal)	(0.5,3.5) DAC
χ^2/NDF (of the Scurve fit)	(0,100)
Pedestal (Comparator baseline)	> 0.0 DAC

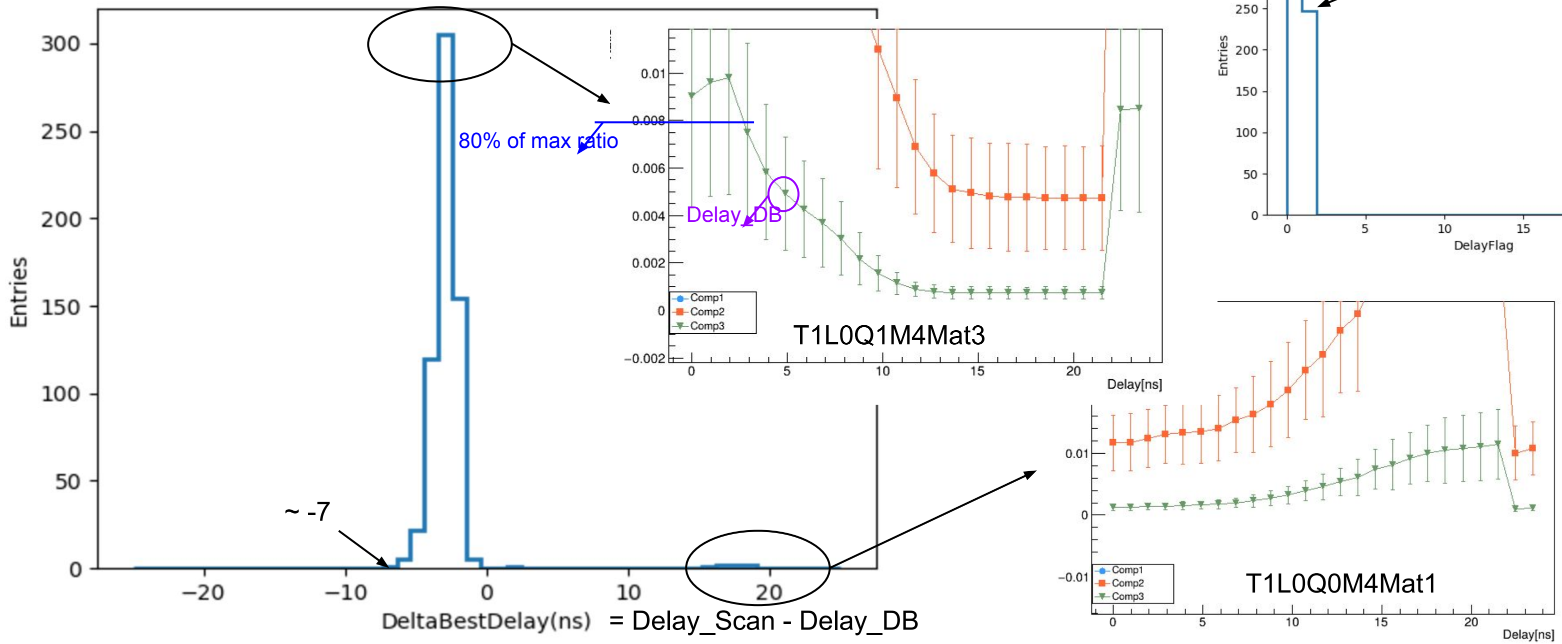
- The following cuts were applied while selecting Scurves of SiPM channels to remove bad fits from analysis.
  - Removes SiPM channels with invalid parameters interfering with average computation during analysis.
  - Ensures SiPMs with poor channel statistics do not show up in the final results (no set value for this, but would expect at least one-third of SiPM channels fitted).

Lower limit for illumination



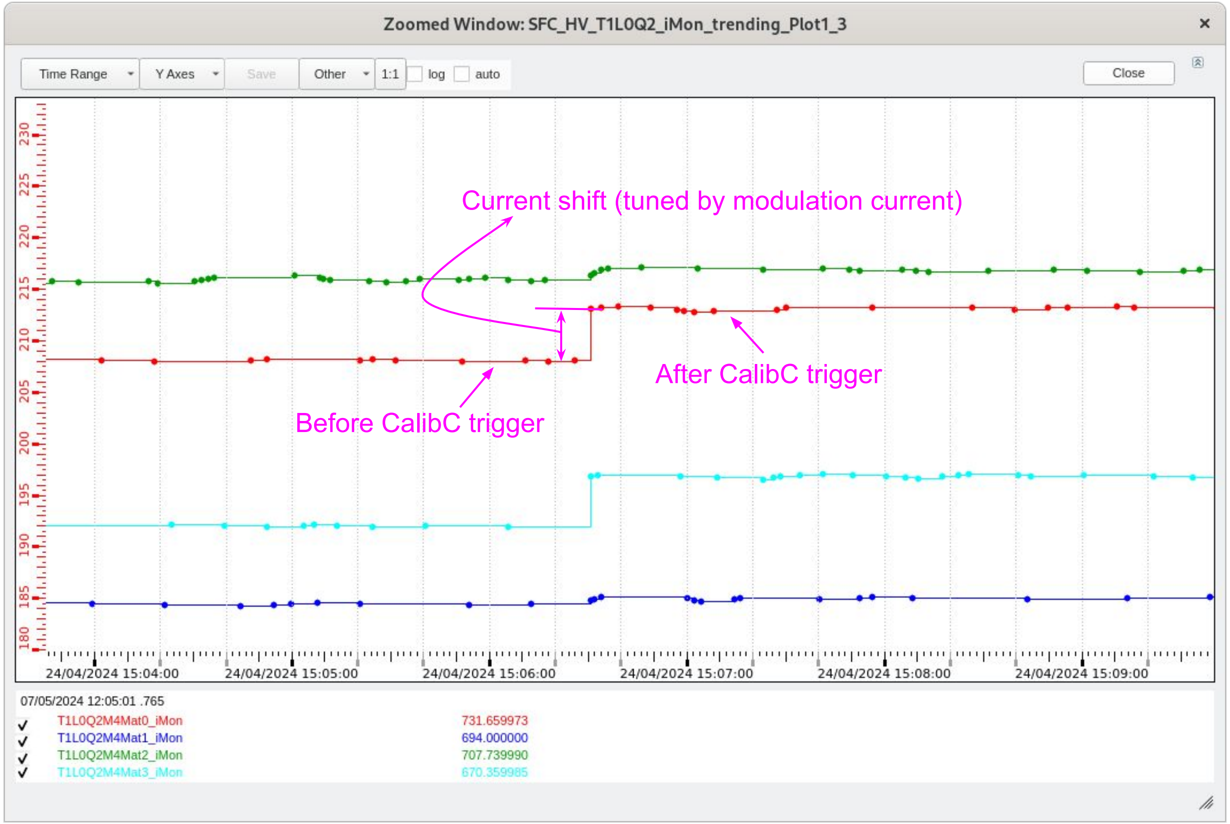
- Illumination limits are set in a such a way to get at best 5 p.e signal in the spectrum.
- A simple simulation in left of Poisson distribution shows at least 3 p.e signal for μ=0.2 and higher.
- This is roughly half the signal expected from a 5 p.e

Fine time alignment deviations from DB



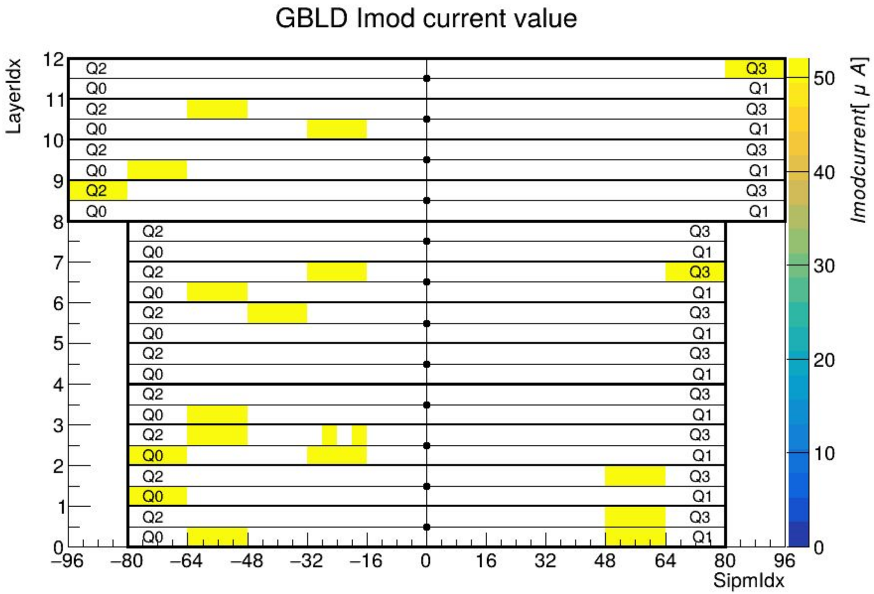
- ❏ Delay range measured from delay scan lite run for the good mats (620 in total), which includes delays for 80% of max ratio observed.
- ❏ Most of the delays estimated from delay scan lite (Delay_Scan) are off by at most 3 ns (465 mats) wrt current DB values (Delay_DB)
- ❏ Around 7 mats observed with difference around 18-20 ns

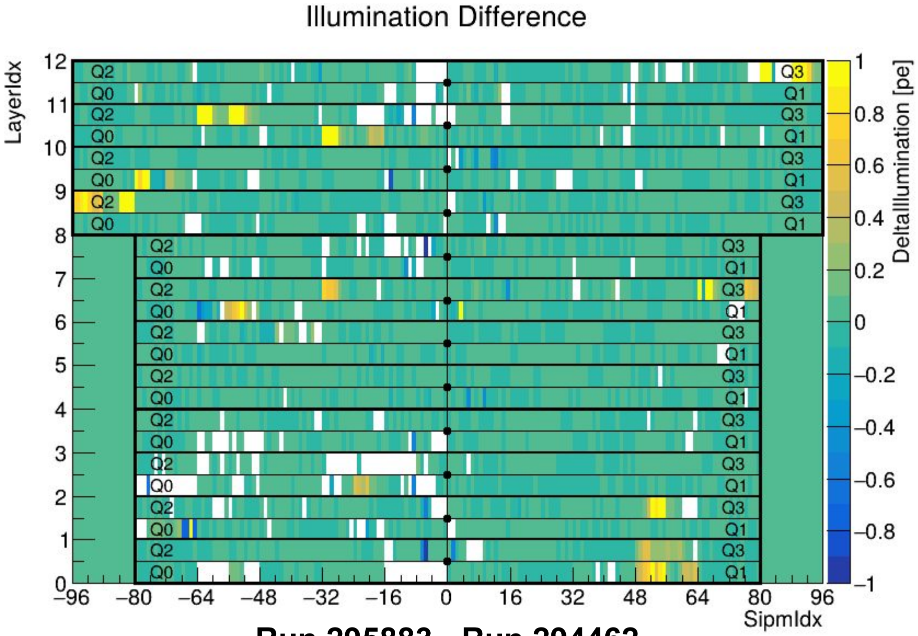
Tuning GBLD modulation current



- When CalibC command is given, it triggers the GBLD to turn on, thereby increasing the current in the mat.
- This current rise is proportional to light intensity.
- Hence, tuning the GBLD can help increase the light in the FEB.

First GBLD tuning



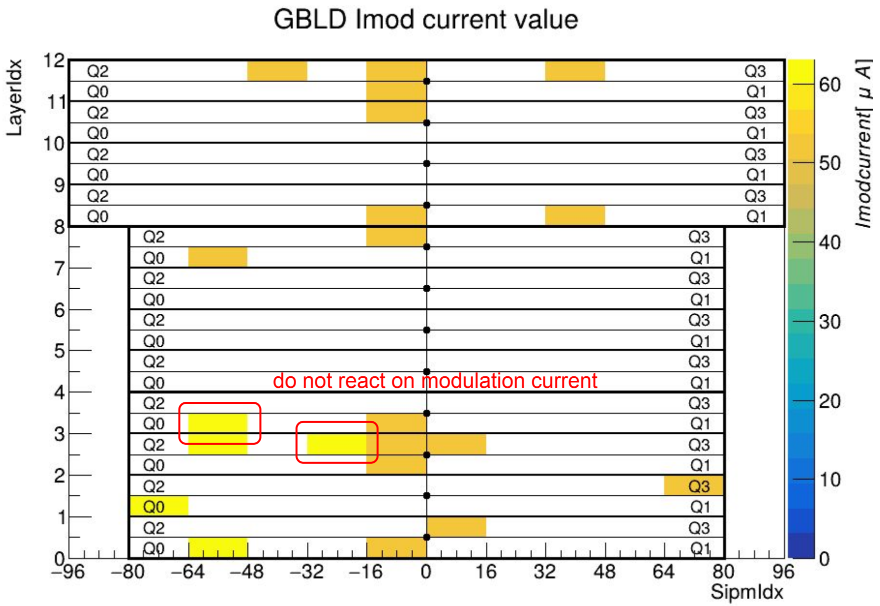


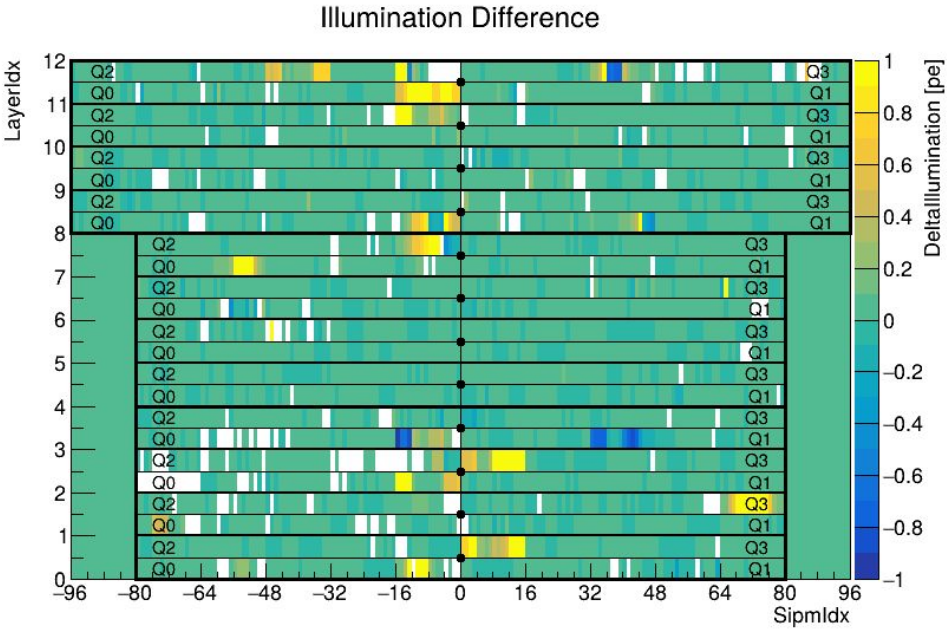
Run 295883 - Run 294462

SiPMs with illumination > 0.2 p.e.	1824 (44.5%)	193996(83.09%)
SiPMs with illumination < 0.2 p.e.	1870 (45.6%)	69629(29.09%)
SiPMs with fit concerns	402 (9.9%)	
Total number of fitted channels	263625 (50.3%)	

- Selected modules had Imod value set to 52 μA (Register value : 180)
- Right plot shows an increase in intensity for around 90% of the tuned GBLDs.

Second GBLD tuning



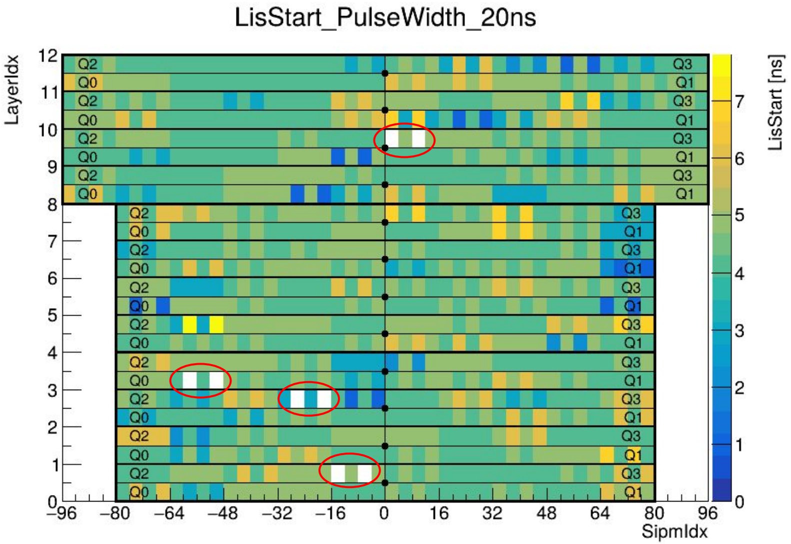


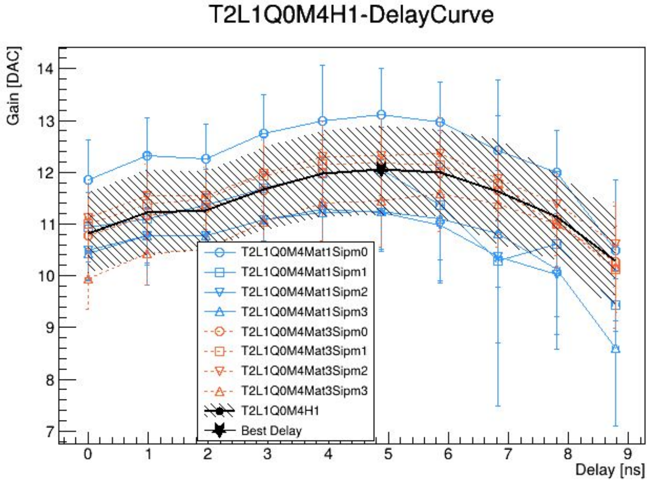
- Second tuning happened in two stages:
  - Setting to select T1 FEBs to maximum Imod of 63 μA (Register value : 191)
  - Select M0 modules tuned to Imod of 52 μA after corresponding TELL40 upgrade
- Setting to maximum value still didn't affect T1 FEBs T1L2Q2M1 and T1L3Q0M3.

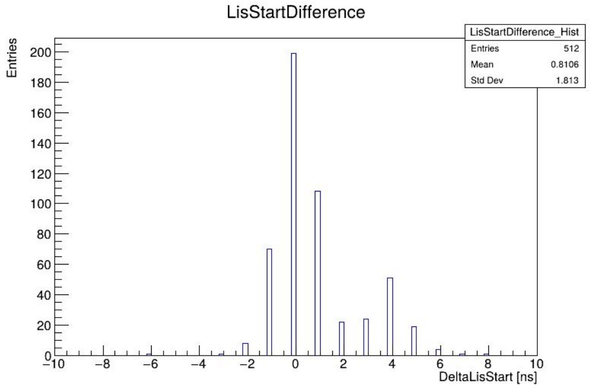
Run 297389 - Run 295883

SiPMs with illumination > 0.2 p.e.	2029 (49.5%)	196586(75.69%)
SiPMs with illumination < 0.2 p.e.	1658 (40.5%)	44867(21.1%)
SiPMs with fit concerns	409 (10%)	
Total number of fitted channels	241453 (46%)	

Delay settings update post GBLD tuning

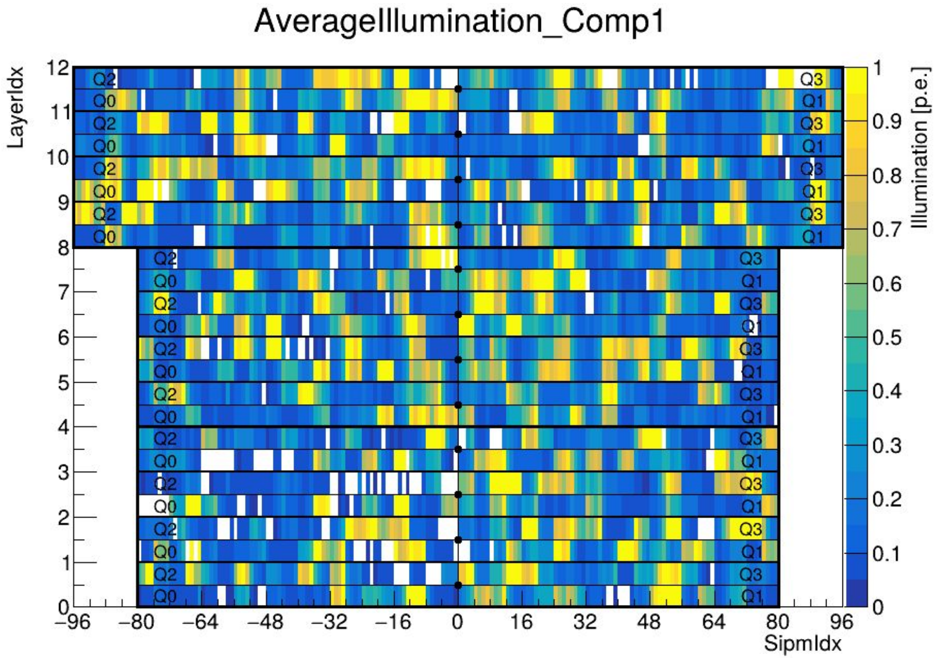




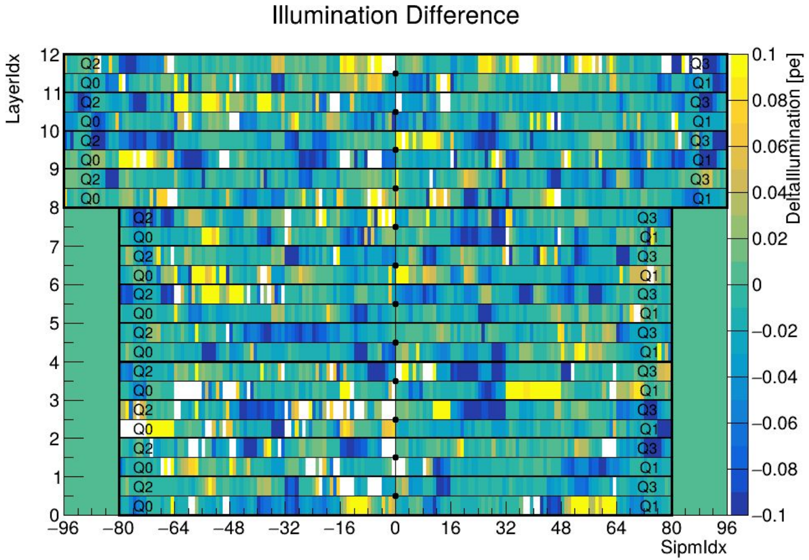


- Fine time alignment performed to find the best settings for LIS start phase using delay scan with 20 ns pulse width
  - Removed the illumination cut (0.2 p.e.) to adjust as many FEBs as possible.
- For most of the halfrobs, the LIS start phase is changed by roughly 1 ns.

Post delay settings update (width+fine time alignment)



June 24 runs

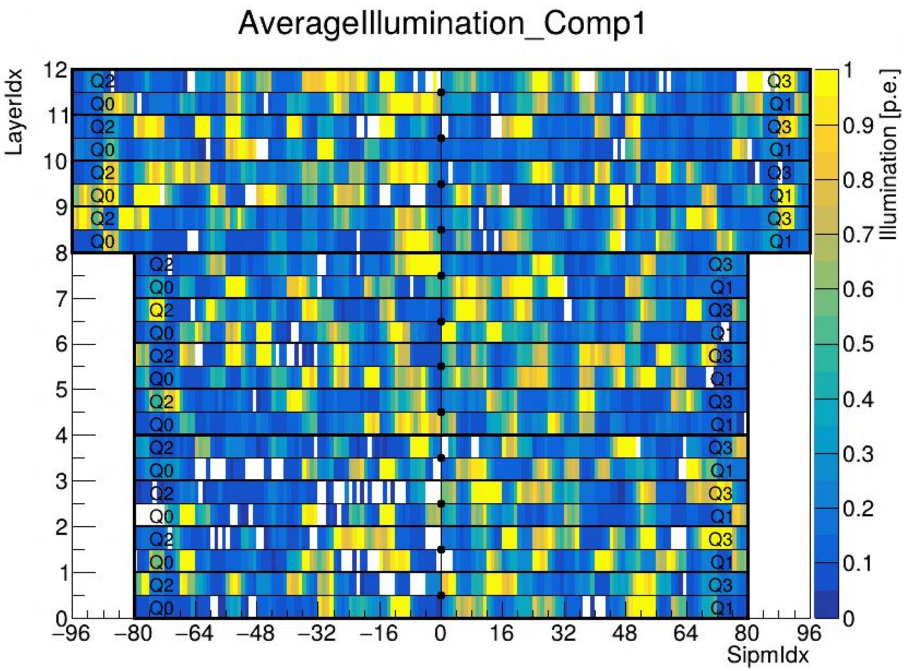


June 24 runs - Run 297389

- ❑ Currently we now have roughly 95% of the SiPMs illuminated.

SiPMs with illumination > 0.2 p.e.	1940 (47.4%)	157159(63.28%)
SiPMs with illumination < 0.2 p.e.	1930 (47.1%)	83470(33.78%)
SiPMs with fit concerns	226 (5.5%)	
Total number of fitted channels	240629 (45.8%)	

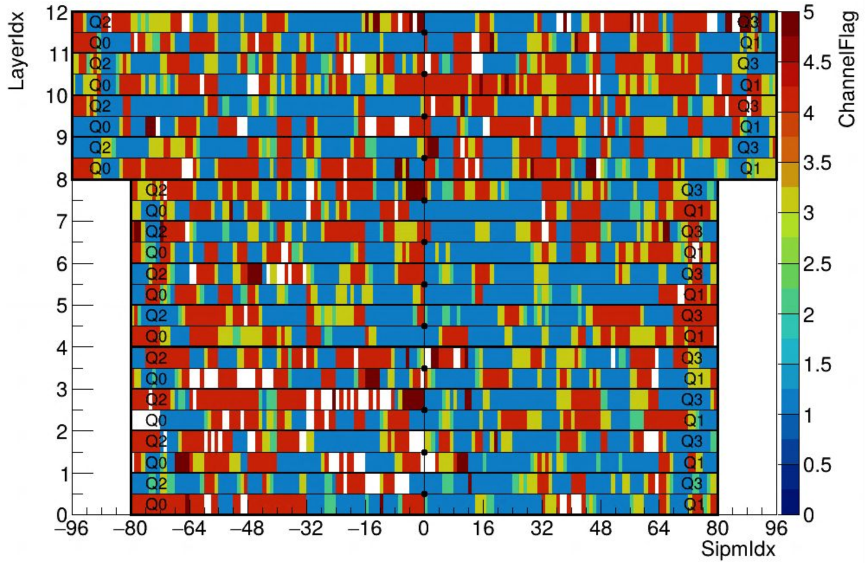
Classification of sipms from illumination



June 24

- Attempts have been made to improve the light intensity of the LIS:
  - Manually tuning the GBLD drivers for around 12% of the FEBs
  - Raising pulse width to 20ns and appropriately changing LIS start and stop phases for most of detector
- The map to the left shows the average illumination after all of the above attempts. Green to yellow colored regions are good, blue and white are bad.
- Two reasons for white regions:
  - Fits failing to converge
  - Fits failing to pass validation cuts
- **Q : What is the channel distribution of acceptable fits across the detector?**

Illumination flags



June 24

- Sipms are classified based on number of fitted channels and corresponding average illumination.
- Roughly half of the channels cannot be fitted with current LIS configuration

Flag1 **(blue)** **:** Illum. > 0.2 p.e , >80% channels (**best**)

Flag2 **(green)** **:** Illum. < 0.2 p.e, >80% channels (**surprisingly good**)

Flag 3 **(yellow)** **:** 50%-80% channels (**intermediate**)

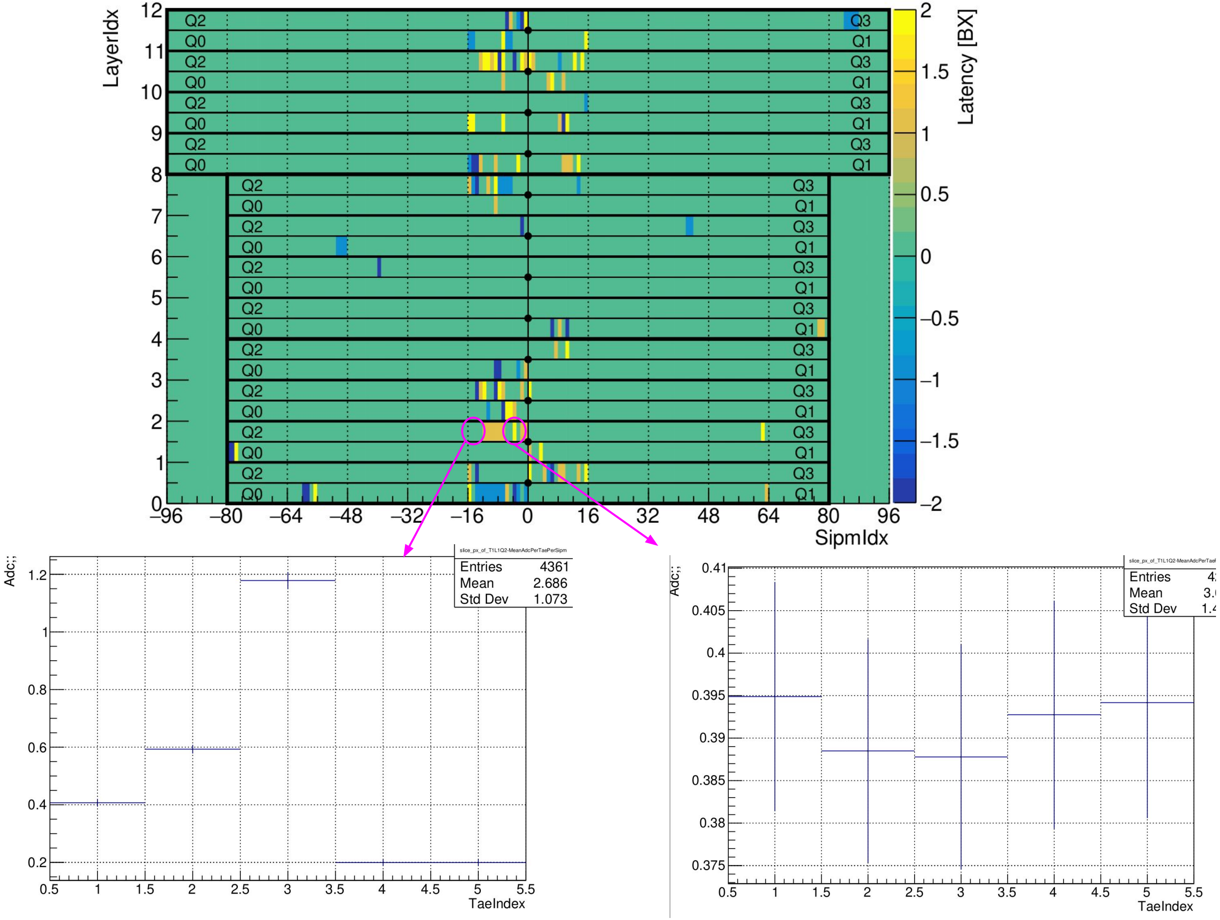
Flag 4 **(red)** **:** Illum < 0.2 p.e., <50% channels (**bad**)

Flag 5 **(dark red)** **:** Illum > 0.2 p.e., <50% channels (**surprisingly bad**)

(blank): there is no channel that fit (**no idea**)

Illumination flag	# of Sipms	# of channels
1	**1769**	**216021 (95.4%)**
2	**193**	**21502 (87.04%)**
3	**630**	**52515 (65.12%)**
4	**1234**	**30888 (19.55%)**
5	**76**	**1763 (18.12%)**
6	**194**	**0**

LIS coarse time alignment



- ❑ Each LIS needs to be triggered at the correct bunch crossing with respect to expected LHC BX.
- ❑ This is confirmed by checking latencies (BX_{signal} - BX_{LHC}).
- ❑ If its off, its corrected using average of SiPMs for halfrob.