TOP Trigger Status

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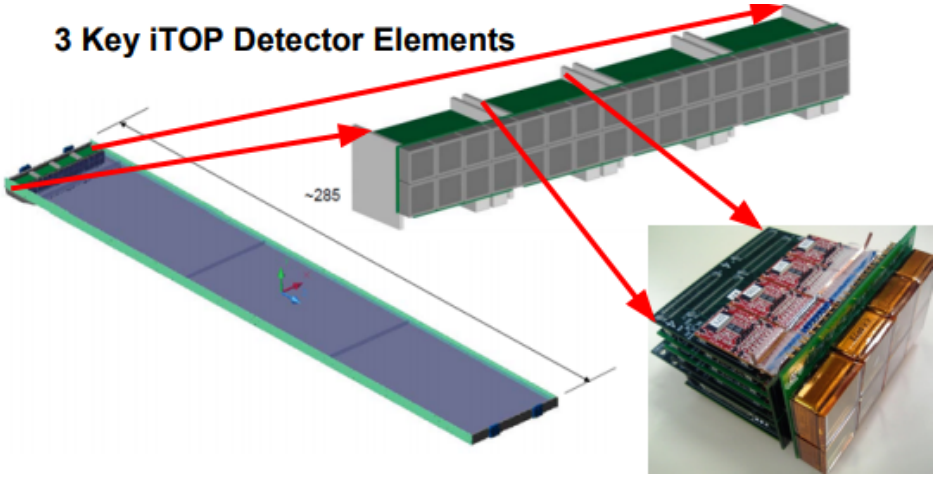
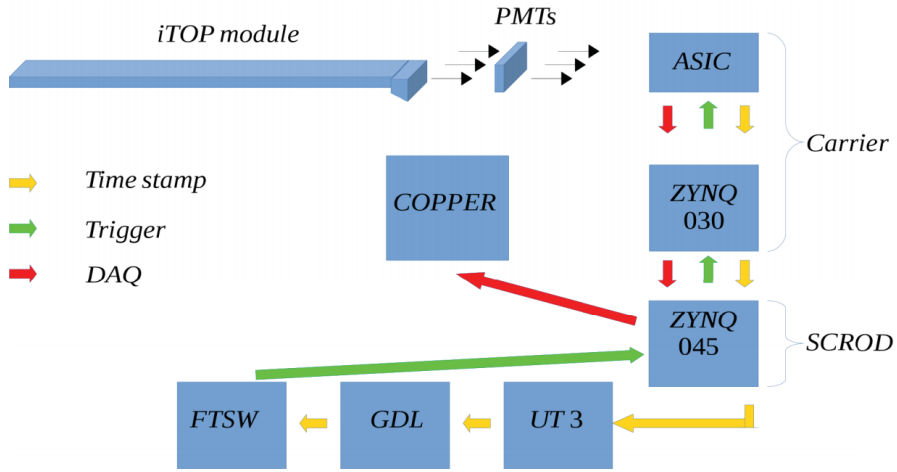
iTOP Overview

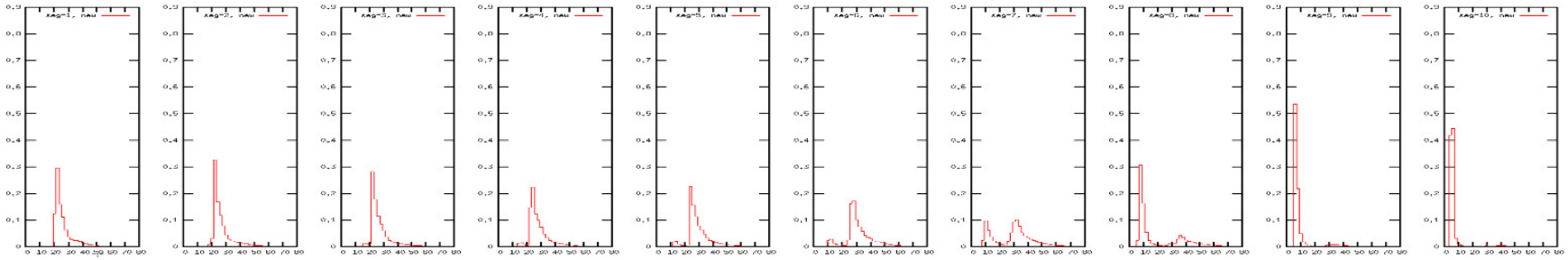
- TOP counter is designed for barrel particle identification
- Its good intrinsic time resolution enables $t0$ (time of arrival of charged particles on TOP) estimation with ns time resolution
- This $t0$ helps to reduce data volume of out-of-time hits in SVD

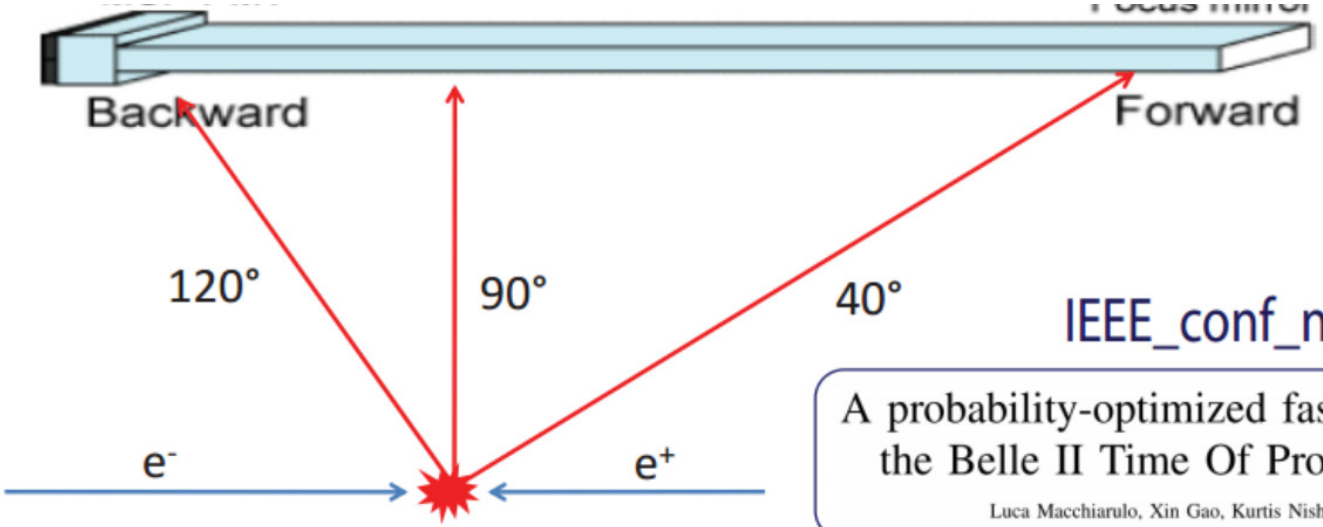




t0 estimation

- Timestamps: Time of arrival of photons on PMT
- Photons (timestamps) produced from a charged particle follow some pattern based on the location of hit on the bar



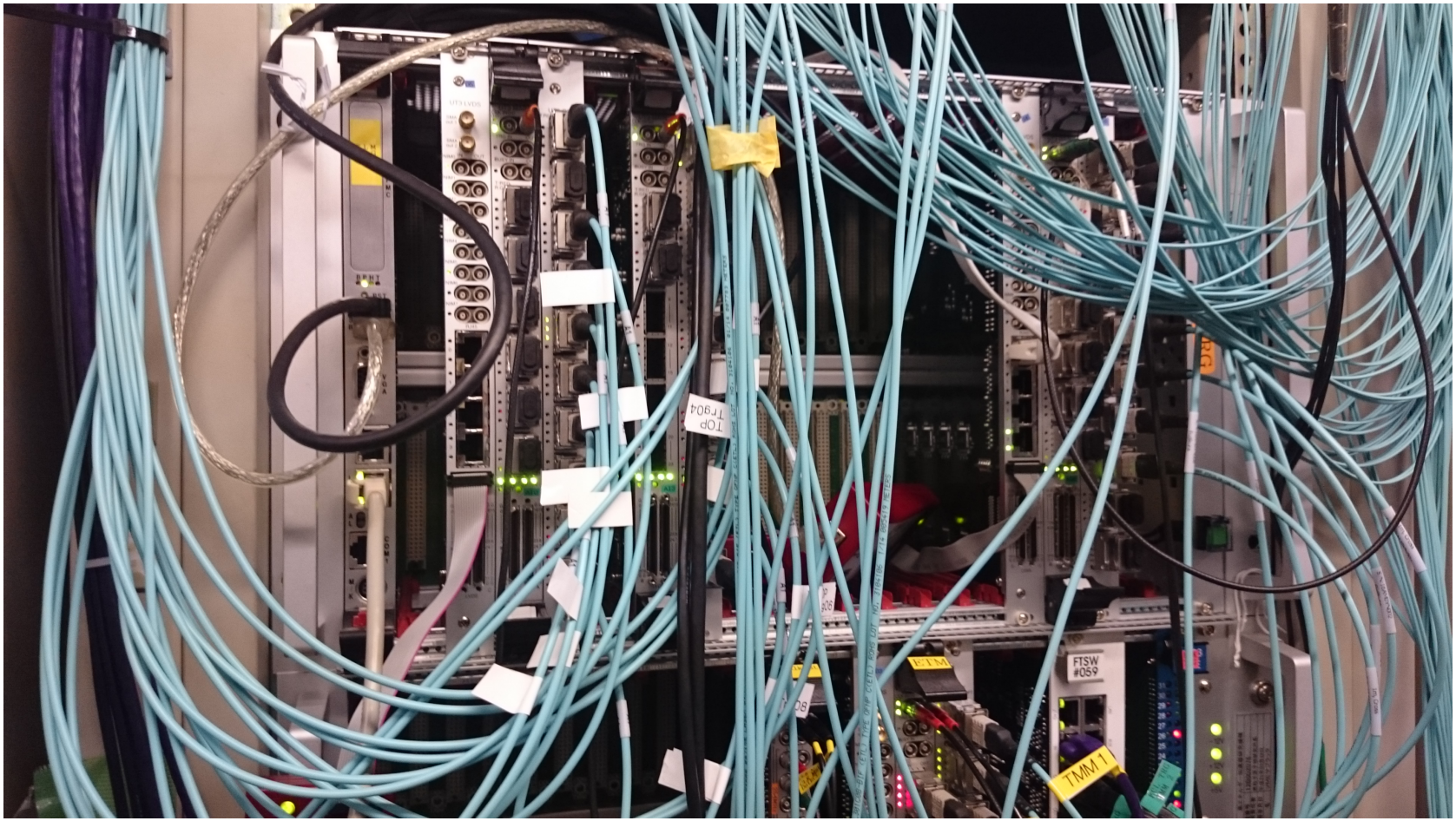


IEEE_conf_note_05873835

A probability-optimized fast timing trigger for the Belle II Time Of Propagation detector

Luca Macchiarulo, Xin Gao, Kurtis Nishimura, Gary S. Varner

Setup at KEK

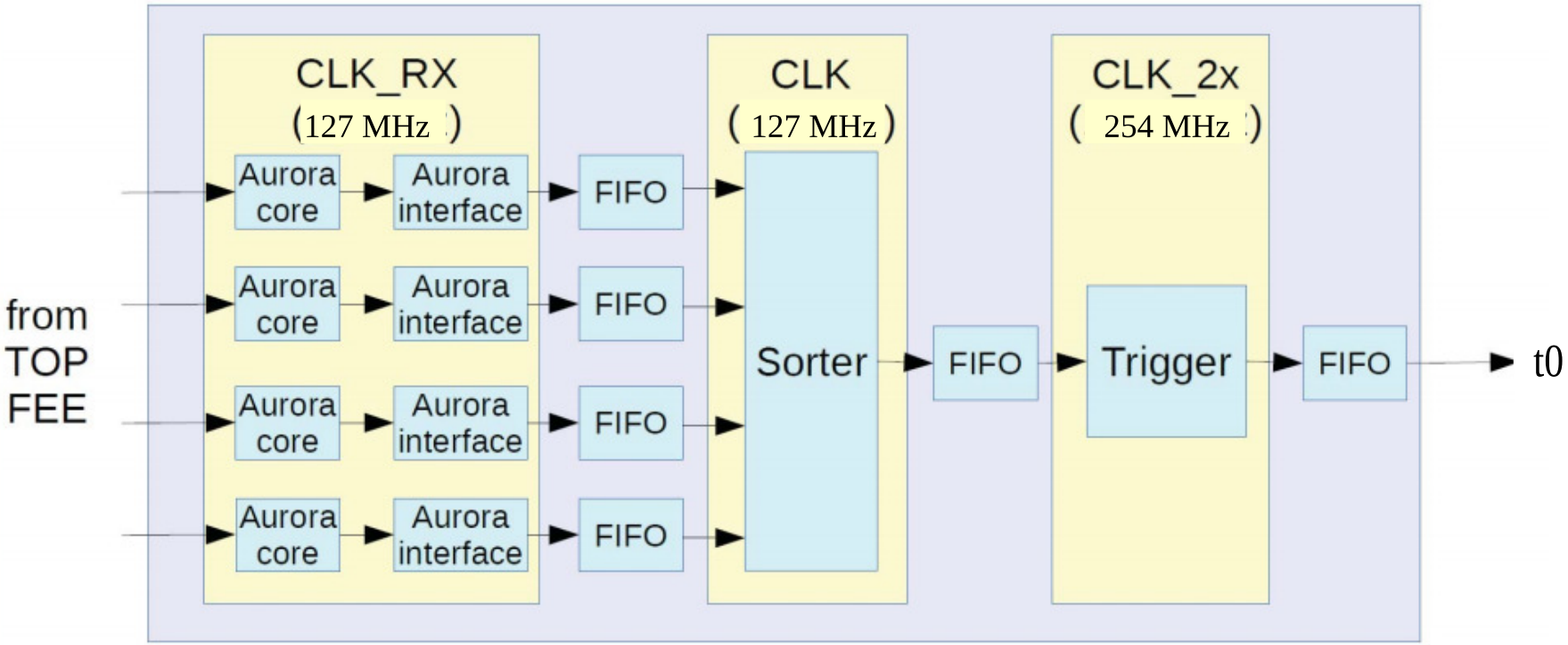


Timestamping

- Timestamps are produced on FEE and send to UT3 using AURORA 8b10b protocol at a line rate 5.08Gbps.
- Timestamping is based on revo9 marker synchronized with the accelerator clock
- revo9 marker is updated every 90us
- Timestamp is represented by the number of clock cycles since most recent revo9 marker
- Clock used for timestamps allows 3ns binning. Therefore 16 bits are sufficient for timestamping (timestamping is done on both edges of axiClk(169 MHz). axiClk= 8 $\times$ SSTClk= 8 $\times$FTSWClk/6, FTSWClk = 127 MHz)
- Timestamping at 1ns binning will improve trigger performance

TOP Trigger Firmware

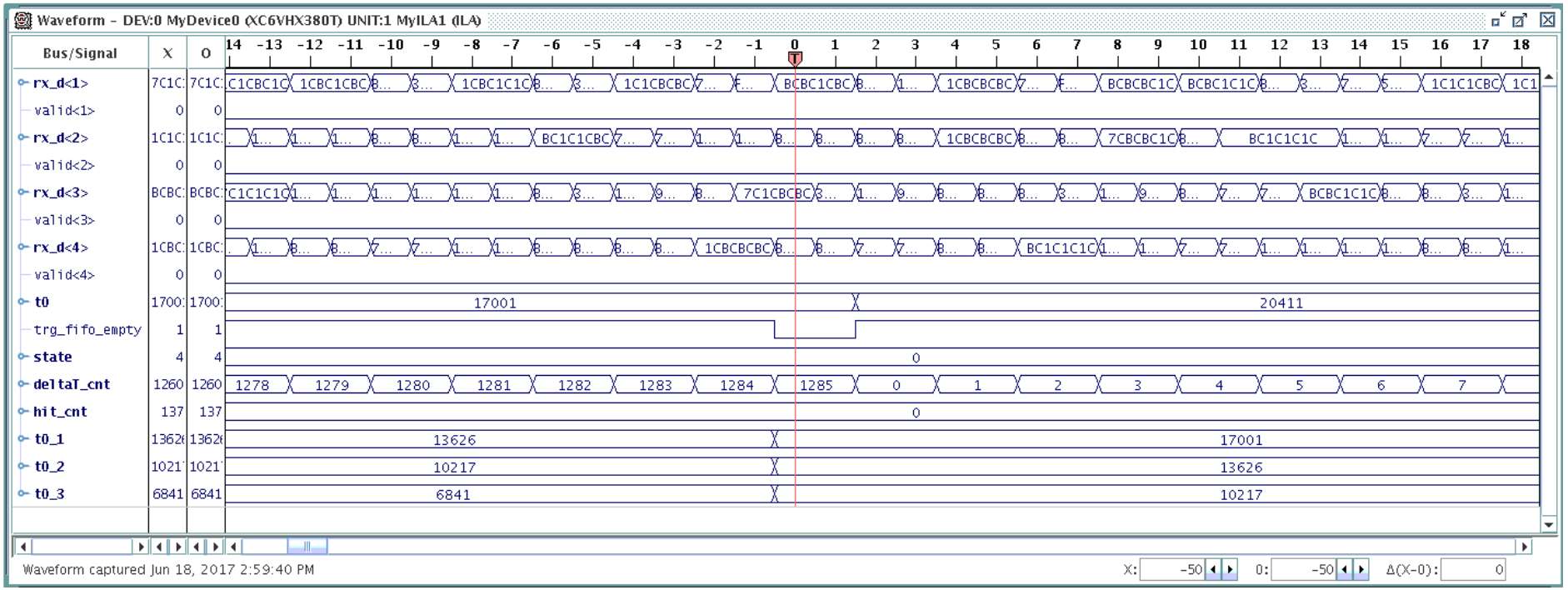
t0s are estimated separately on each TOP bar and are combined later



1. Receive: Timestamps come through 4 channels from FEE
2. Sorting: 4 channels are merged and Timestamps are sorted according to time
3. Trigger: $t0$ is estimated by fitting the Timestamps to PDFs by a Maximum Likelihood Fitting

TOP Trigger at 1 Bar

- TOP Trigger FW for single Bar is tested at KEK and estimate trigger rate
- FEE was pulsed with 100 kHz calibration pulses$->$ we expect t0 decision in every 10us
- The time interval between adjacent trigger decisions are estimated and they are consistent with the calibration pulses

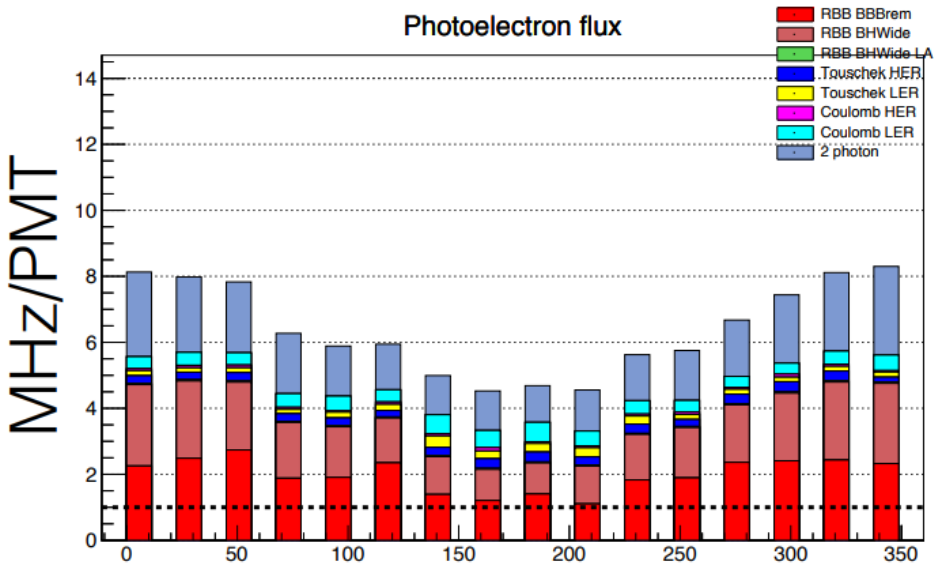


TOP Beam Background

- Photon Flux significantly above desired levels

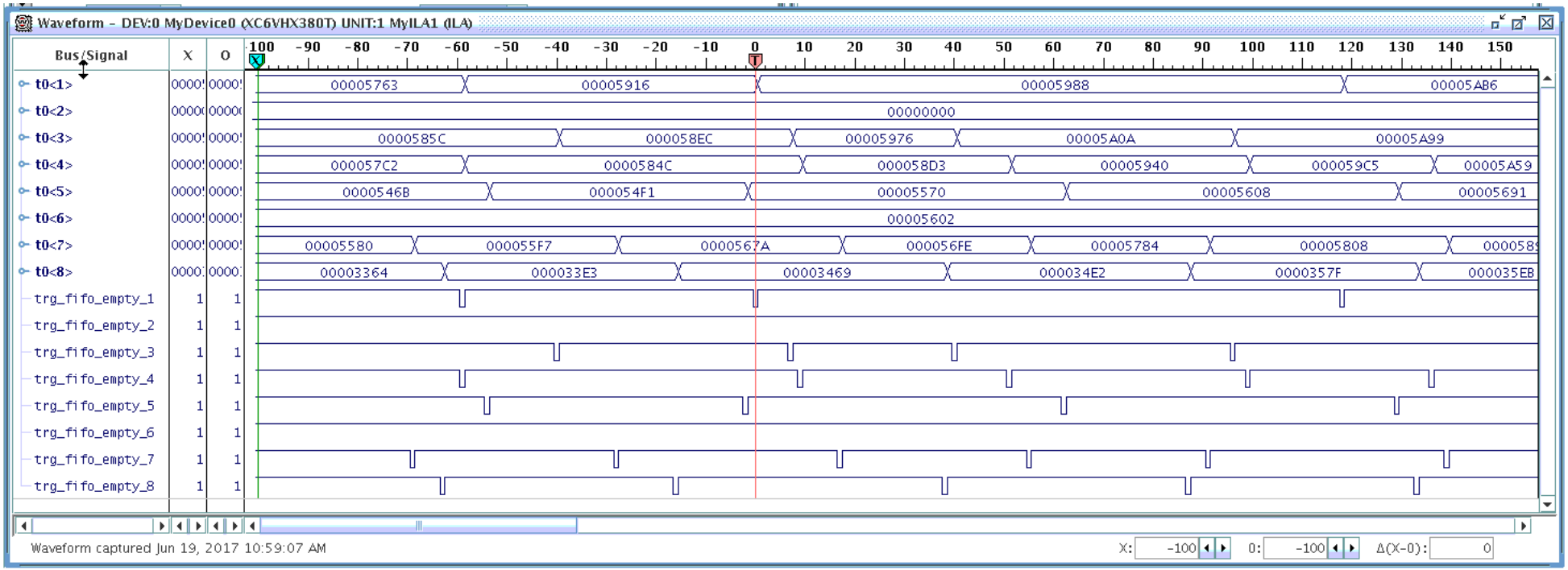
Beam Background

1. 8 MHz/PMT
2. 64 MHz/Board Stack
3. 256 MHz/TOP Bar



T. Nanut, 27th B2GM (June 21, 2017)

t0s in presence of Background (electronic noise)

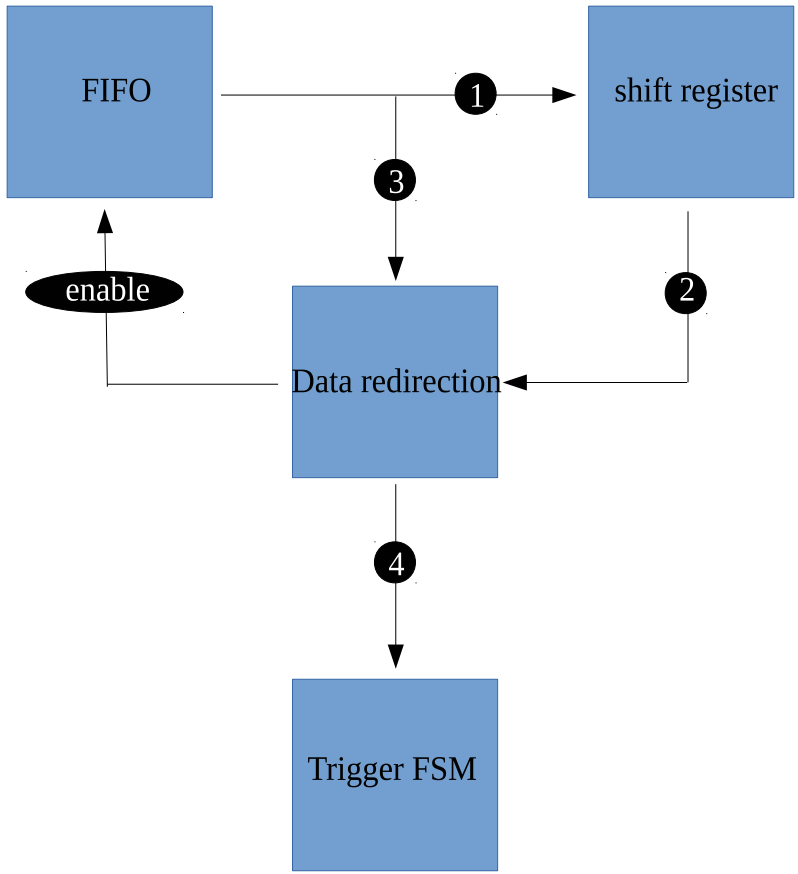


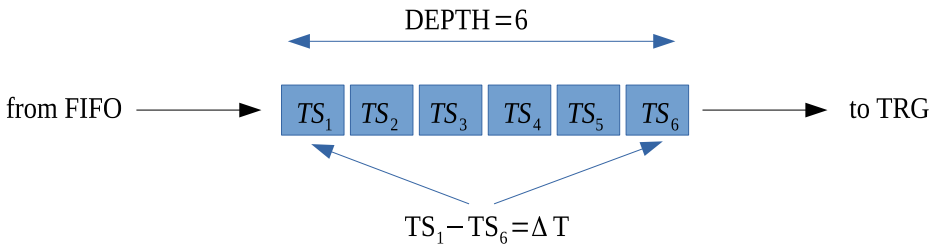
- Triggers are too frequent in presence of background since every timestamp arrive at UT3 are processed
- This problem is already known from a software simulation
- Possible solution: Run Trigger algorithm only during the arrival of timestamps belong to a signal

Instantaneous Hit Time Density (IHTD)

1. Initially, TSs go to "Shift register" and continuously monitored by "Data redirection" (path 1)
2. whenever $\Delta T <$ THRESHOLD
   i. Stop taking TSs from FIFO
   ii. Recover the 6 TS which is already in Shift reg.

   (path 2& 4)
3. Continue to take TSs from FIFO, after recovering 6 TS in shift reg. (path 3& 4)

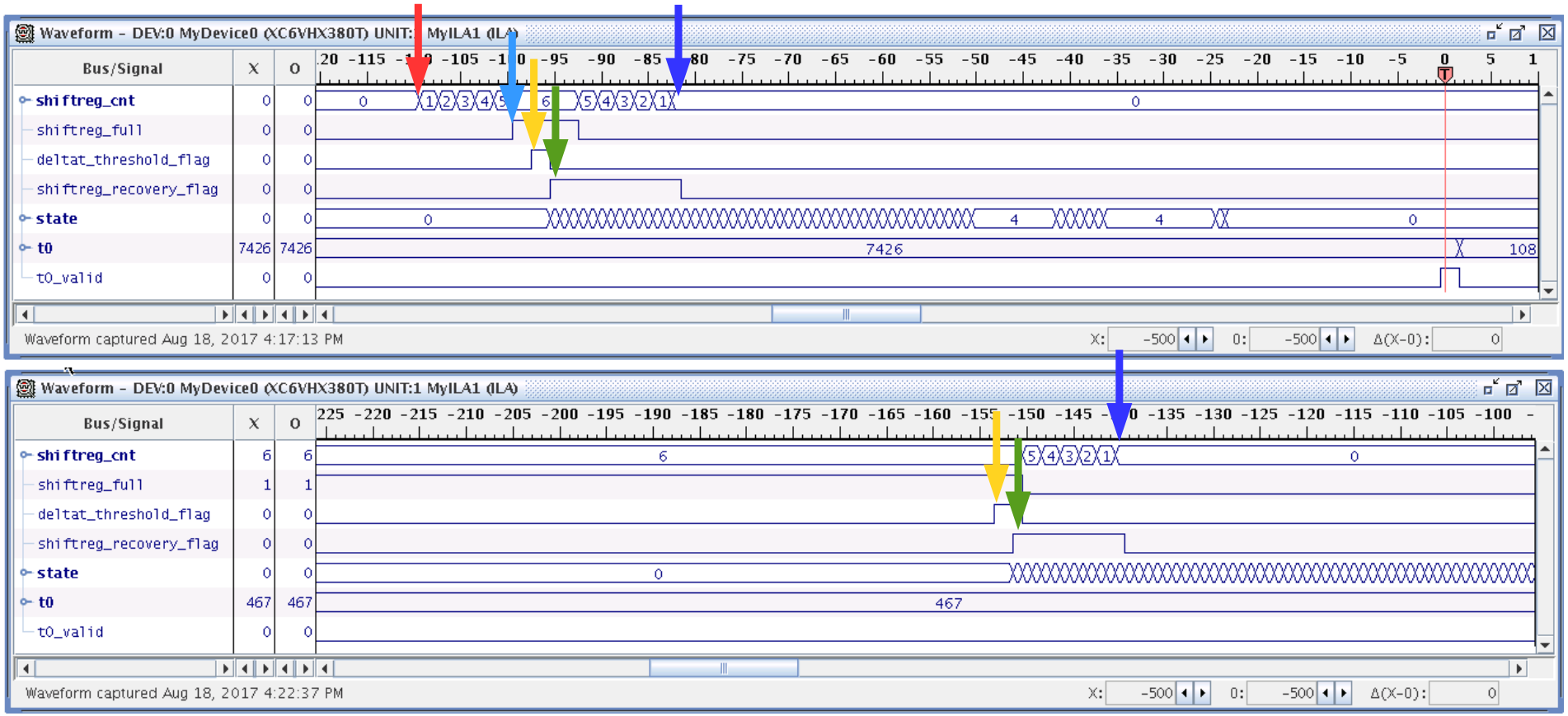




- Signal identification efficiency should be maximized by optimizing THRESHOLD and DEPTH

Firmware with IHTD

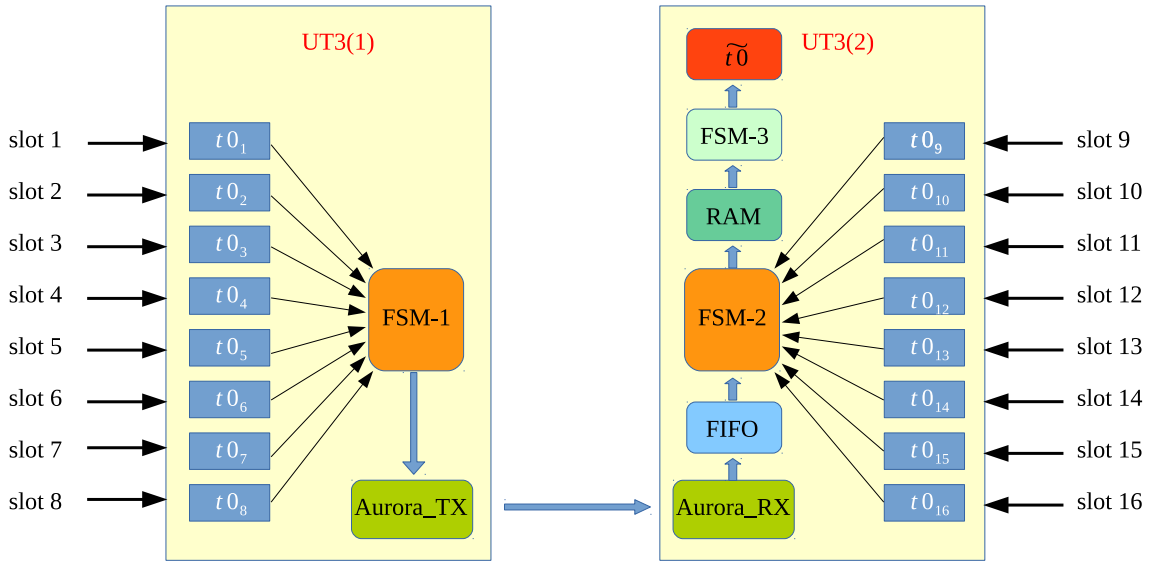
1. shiftreg_cnt
2. shiftreg_full
3. deltat_threshold_flag
4. shiftreg_recovery_flag



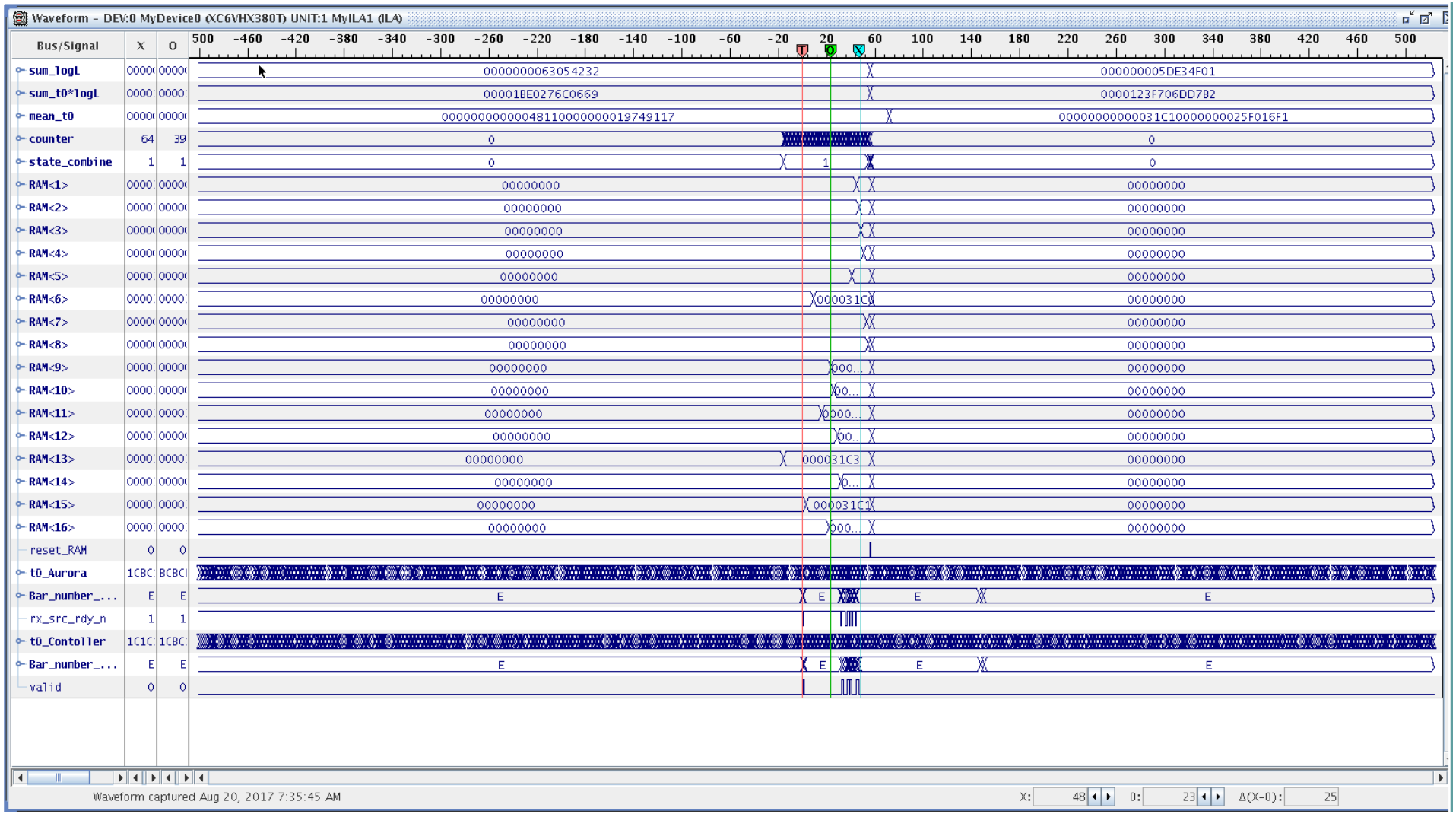
Combined $t0$

$$\tilde{t0} = \frac{\left(\sum_{i=1}^{i=16} t0_i L_i\right)}{\left(\sum_{i=1}^{i=16} L_i\right)}$$

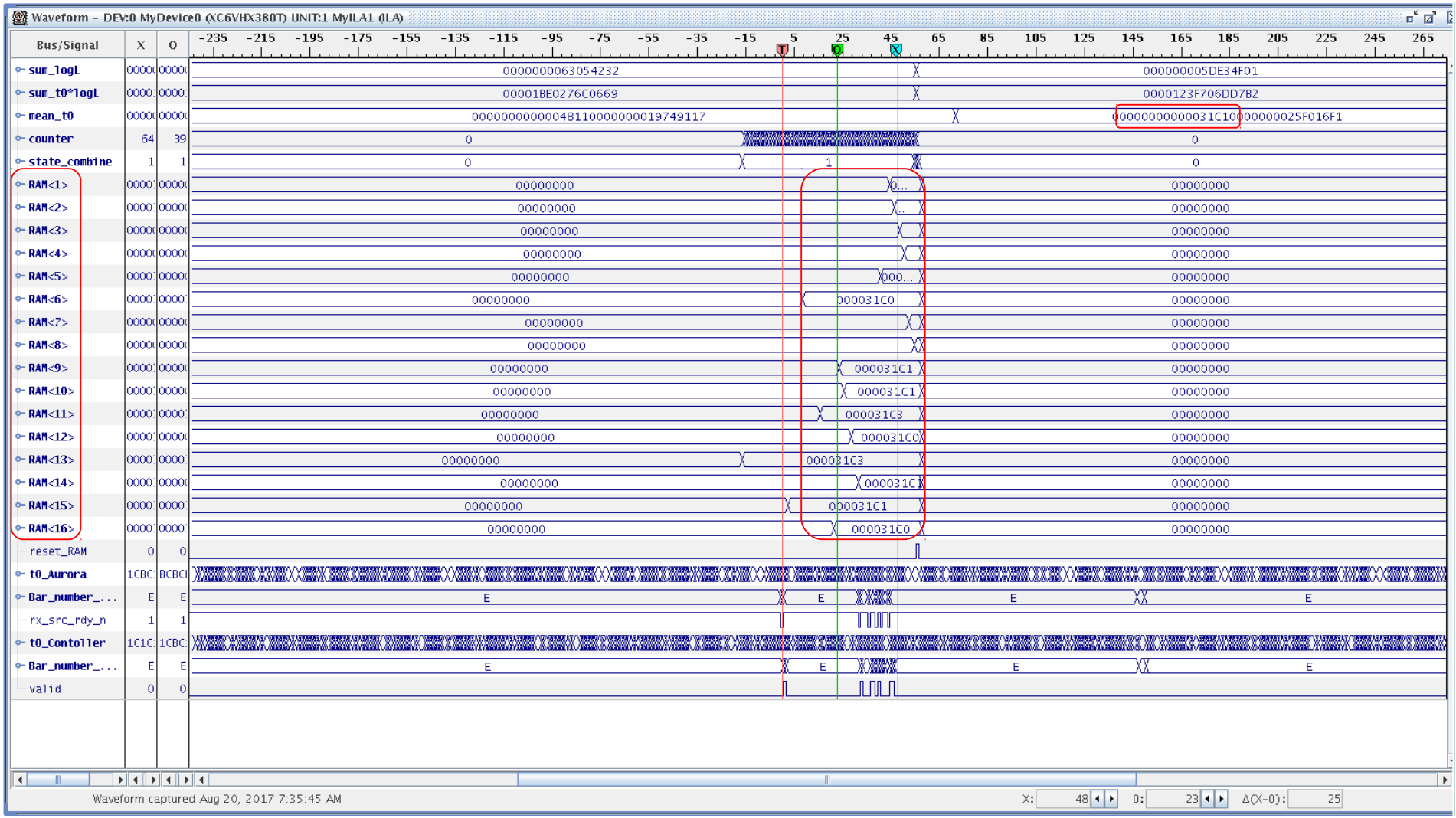
- $t0_1$-$t0_8$ on UT3(1) and $t0_9$-$t0_{16}$ on UT3(2)
- All t0s on UT3(1) are send to UT3(2) (4-lane AURORA with each lane is 5.08 Gbps)
- All t0s are temporarily stored on a RAM until $\tilde{t0}$ is estimated



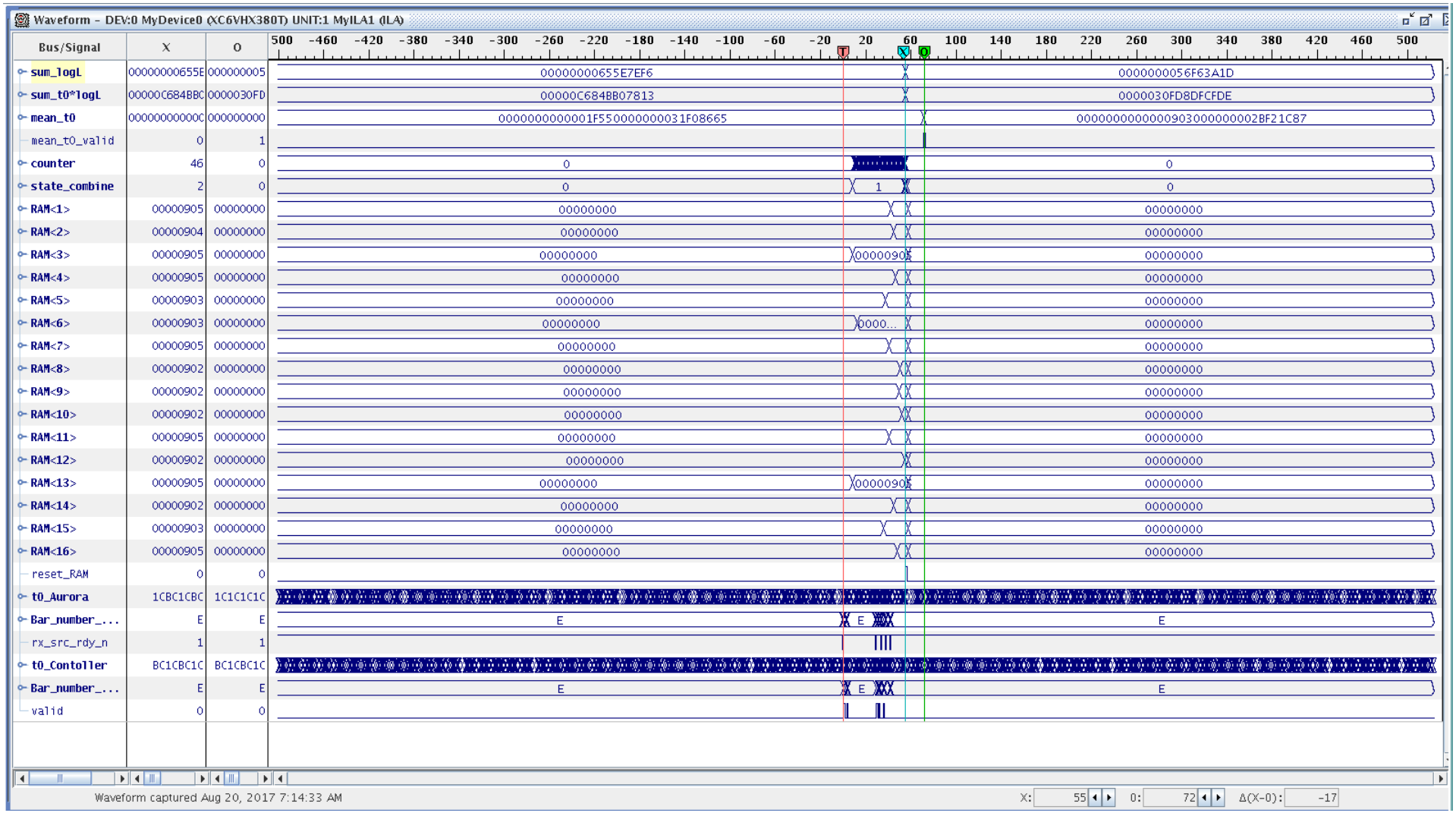
Combined $t0$ on UT3(2)



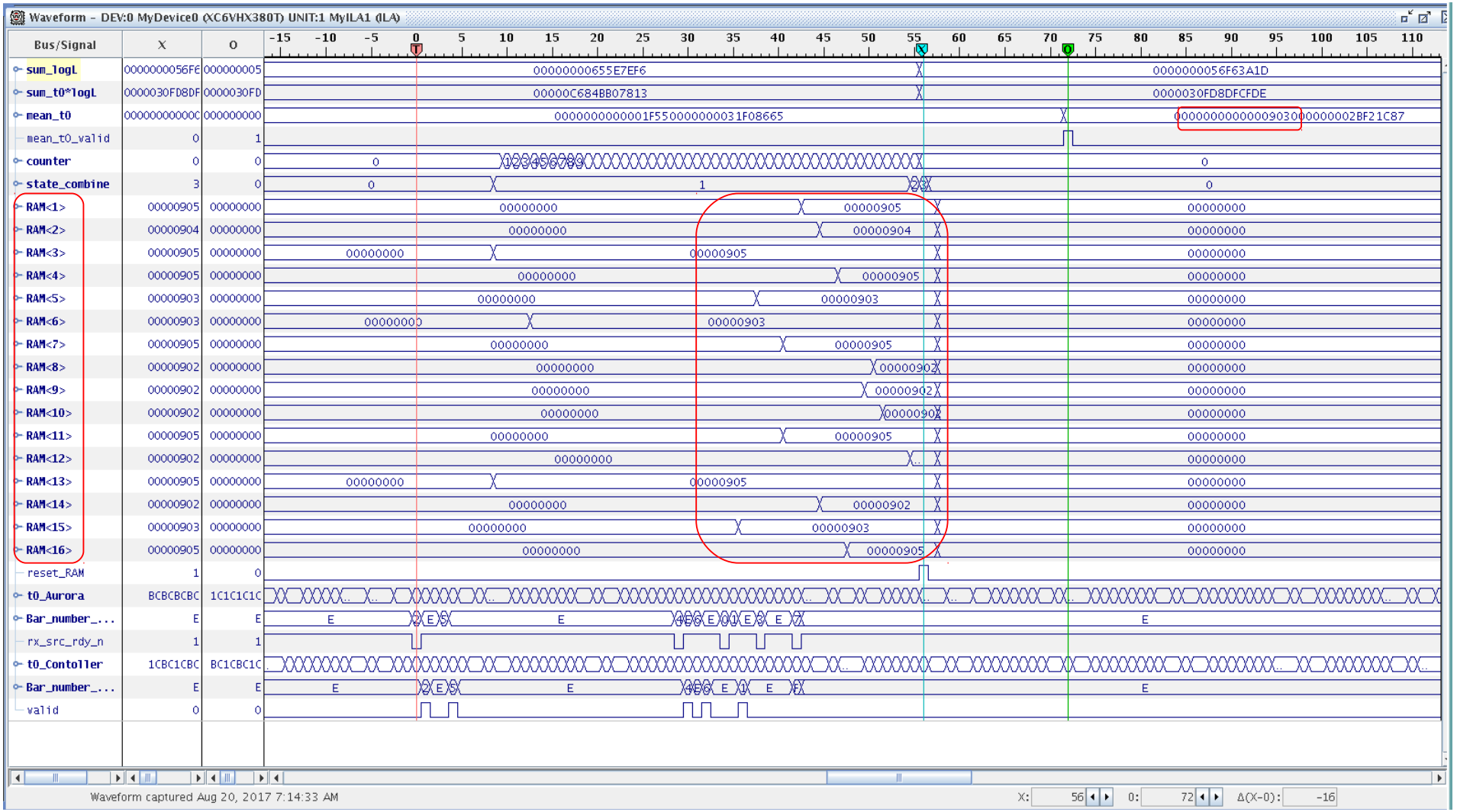
Combined $t0$ on UT3(2)



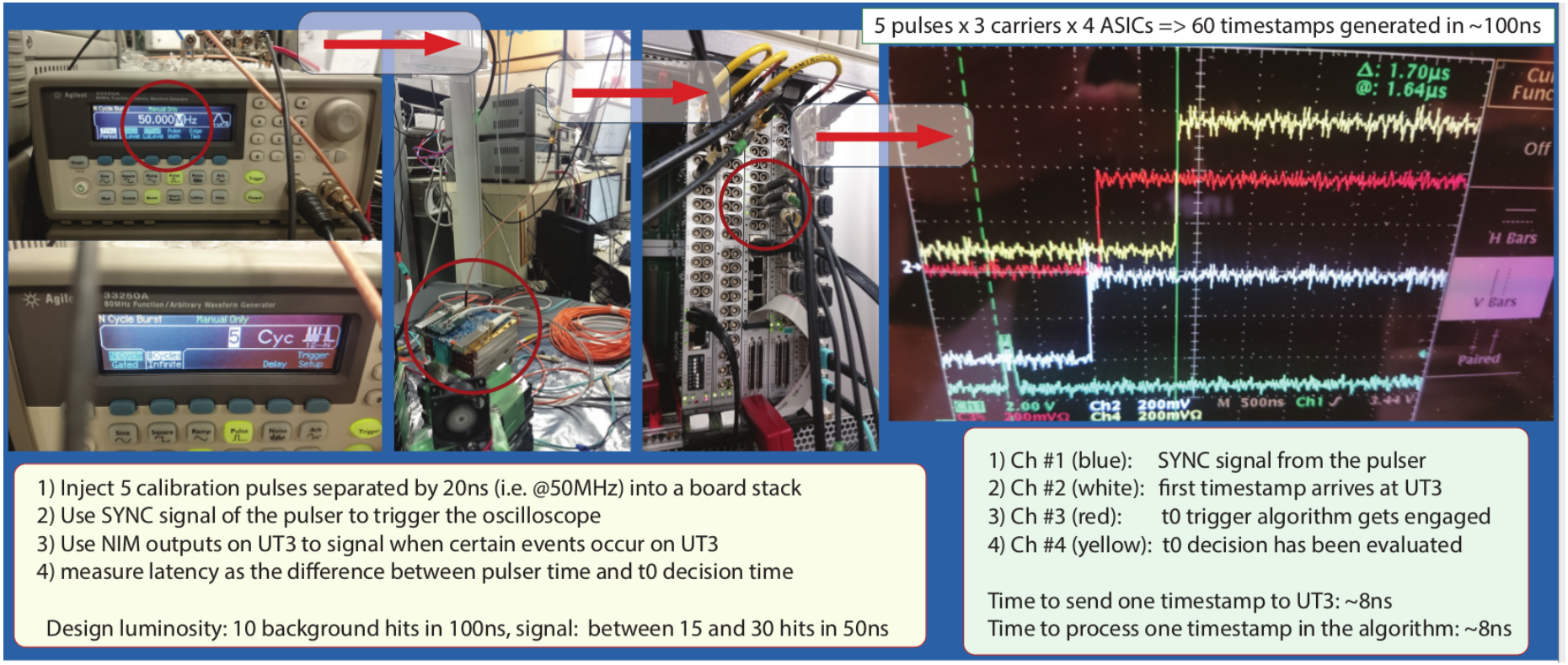
Combined $t0$ on UT3(2) (latency added)



Combined $t0$ on UT3(2) (latency added)



Latency



- Latency estimated for single Bar by injecting calibration pulses in to FEE
- Latency depends on number of hits and have contribution from AURORA, XILINX cores used for weighted sum of t0 etc.
- Overall expected latency below 2.5 us

Summary and plan

- Timestamping is implemented in all latest FEE FW and reliably transmitting them to UT3 at 5.08 Gbps
- The algorithms for collecting and combining t0 decisions from individual bars have been designed and tested at KEK
- TOP Trigger latency is measured and the value is well within maximum allowed limit
- TOP Trigger FW with Instantaneous Hit Time Density (IHTD) is designed and tested at Pittsburgh. Working on optimization of various parameters to get best possible performance of Trigger FW.
- Soon start working on interface to GDL.