TB 2021 empty events issue

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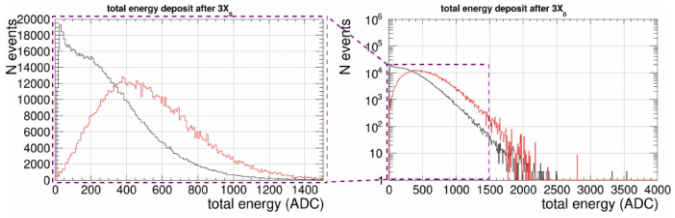
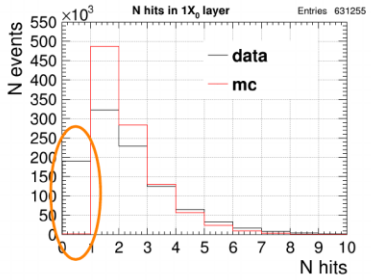
TB issues

We had two TBs with FLAME ASICs: TB2020 and TB2021

- TB2020 issues (*see Bohdan talk – S&A 8.12.2021*):
  - Disagreement with MC

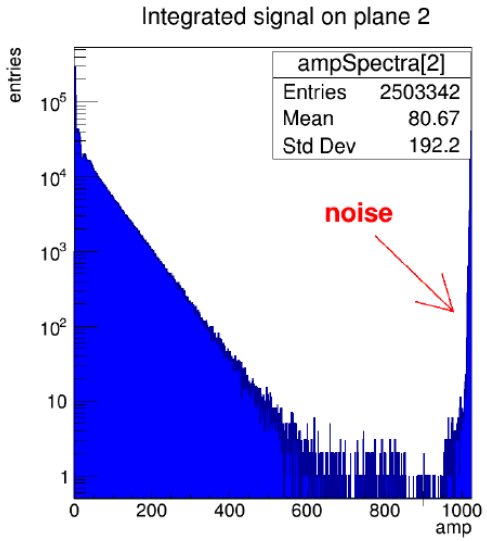


  - ~1/3(?) empty events



- Almost 1/3 of events are empty in DATA
- Use only NON-empty for normalization!
- I do "non-empty" check for each plane

  - Negative "noise" peak (*Roma & Szymon)*



- <u>TB2021 issue: almost all events are empty (*topic of this talk*)</u>

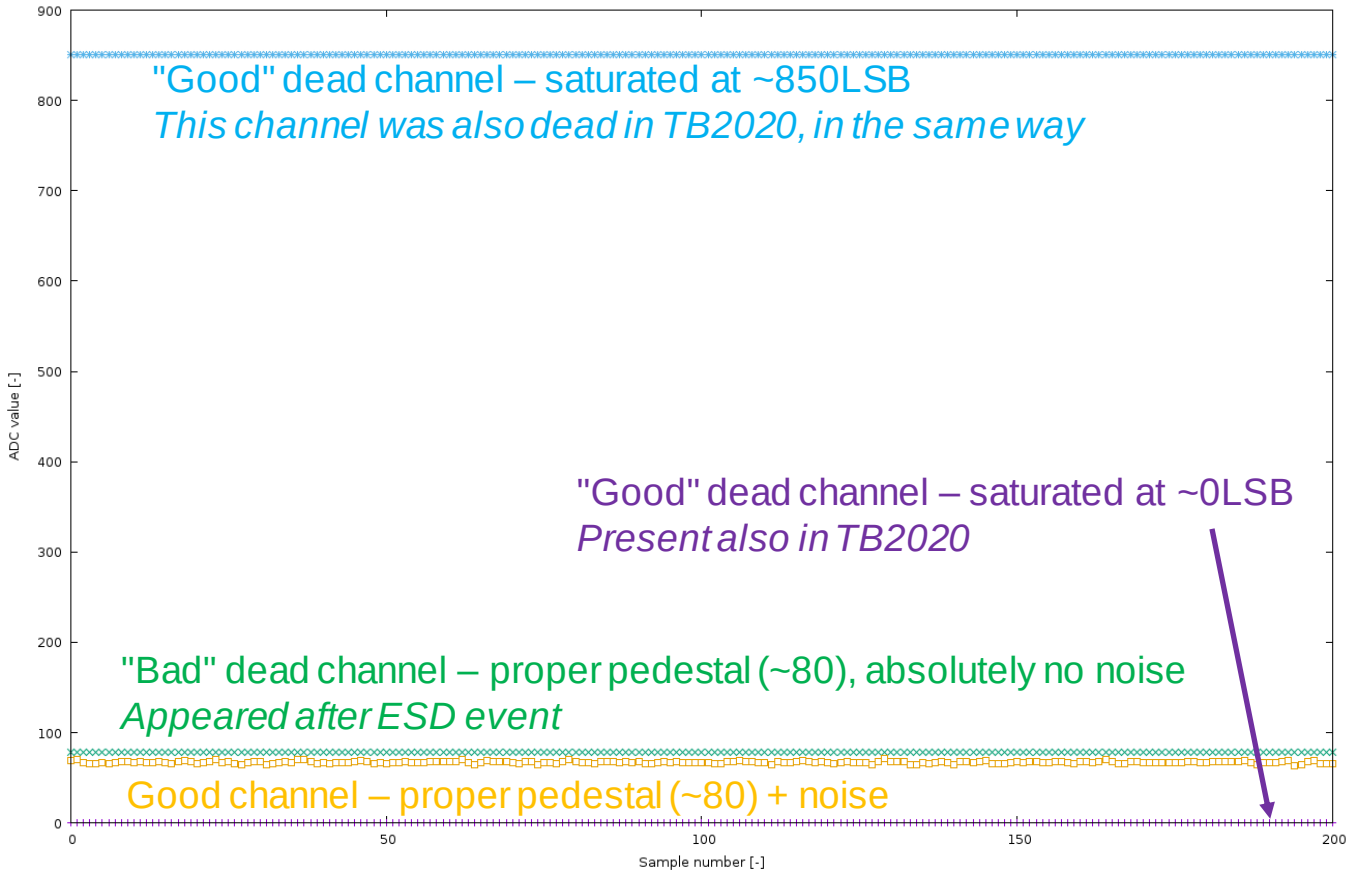
TB2021 issue have nothing to do with TB2020.
Those are two, completely separate issues!

ESD event

- On the very beginning of the TB2021 we have got an ESD event.
- Most likely the HV found a path to the FEBs...

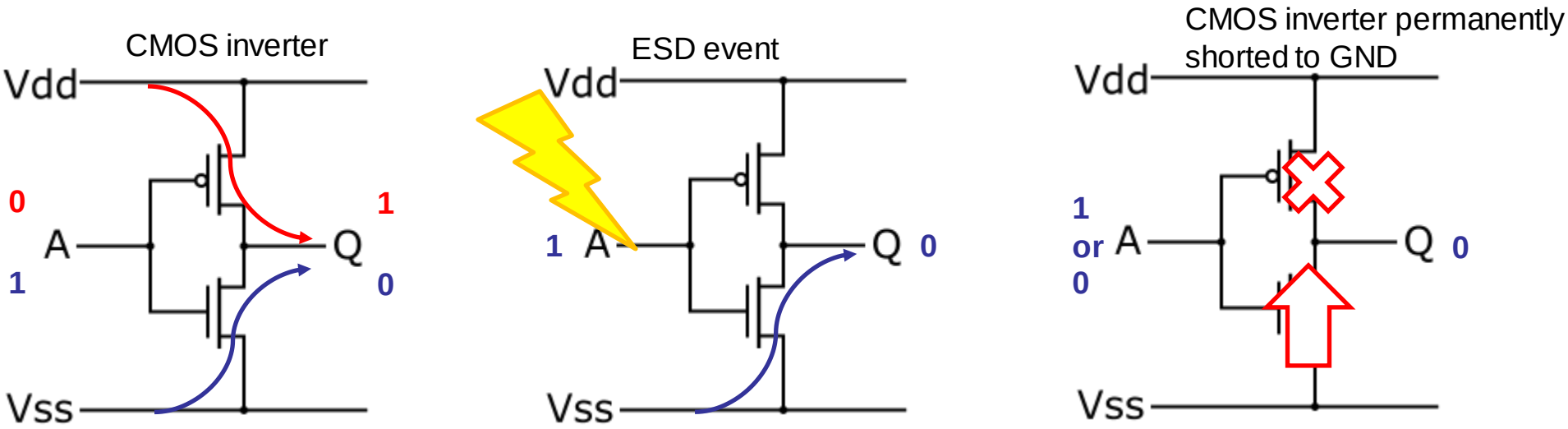
- We have lost ~20% of readout channels, but lost in a strange way...

- Usually, a dead channel means dead preamplifier – no feedback loop stabilizing the pedestal, so dead channel should have pedestal saturated to min or max value



Strangely dead channels

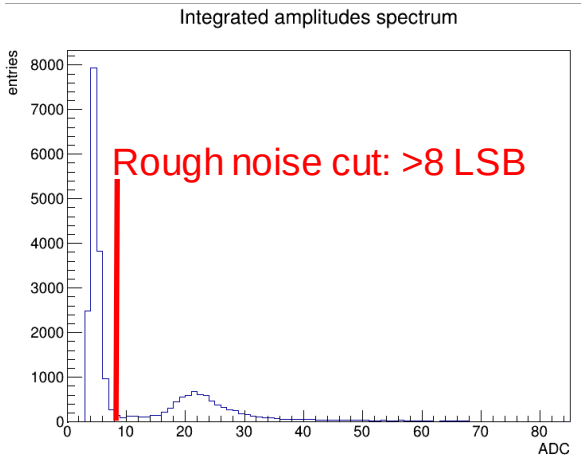
- Channels with proper pedestal value, but always constant cannot (to our understanding) originate from analogue circuitry in FLAME.
- There is a mechanism explaining this behavior – but in the digital part:



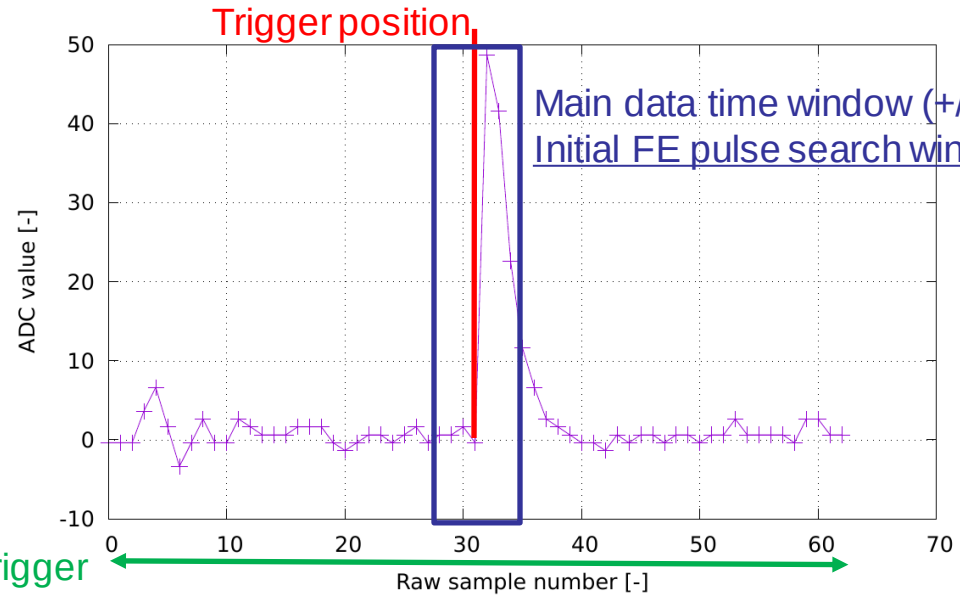
- The ESD event can permanently short the logic gate output (e.g. inverter) to 0 or 1.
- The proper pedestal value (sample taken just before ESD) was permanently burned out in the digital logic:
  - It is, and always will be constant (and proper)
  - We have no information what is happening with all the circuitry before damaged gate.

Raw data analysis

- Run **655** with raw ADC data - "Anton1" sensor, quite "clean" setup, 1'008'564 triggers.



1. "Landau" signal in reconstructed data found by applying rough threshold of 8 LSB cut.
2. FE pulse search by finding at least two samples >4 LSB in window around trigger:



Raw ADC data
+/- 1.5us around trigger

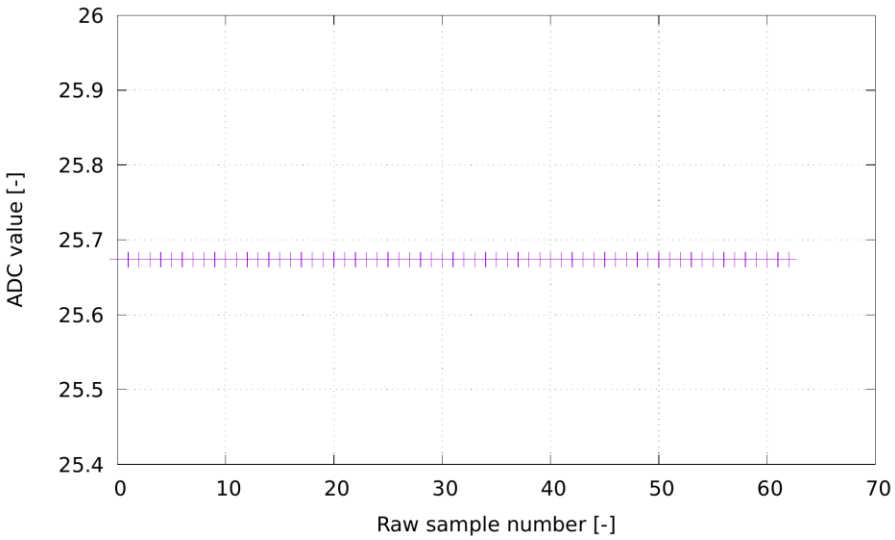
title

Only **8810** events with amplitude > 8LSB found in run 655 in reconstructed data: **0.87%** of triggers!

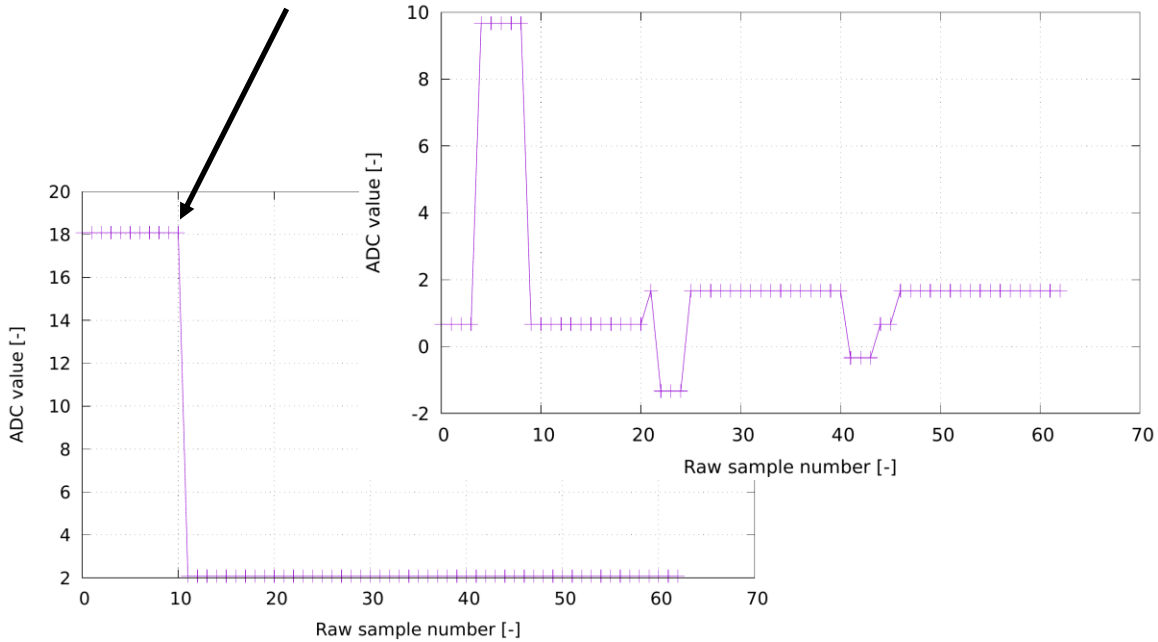
- In raw ADC data: **8810** FE pulses + **4445** fake signals (*I looked through them all manually...*)
- Every FE pulse discovered in raw ADC data matches one from the reconstructed data – the same channel for the same TLU number.
- DAQ was working perfectly fine – all the data sent by ASICs were properly reconstructed and collected.
- Data were already missing on the ASIC level.

- **4445** fake signals are:

Channels stuck at a constant value in a given event (but working back again in some next events...)

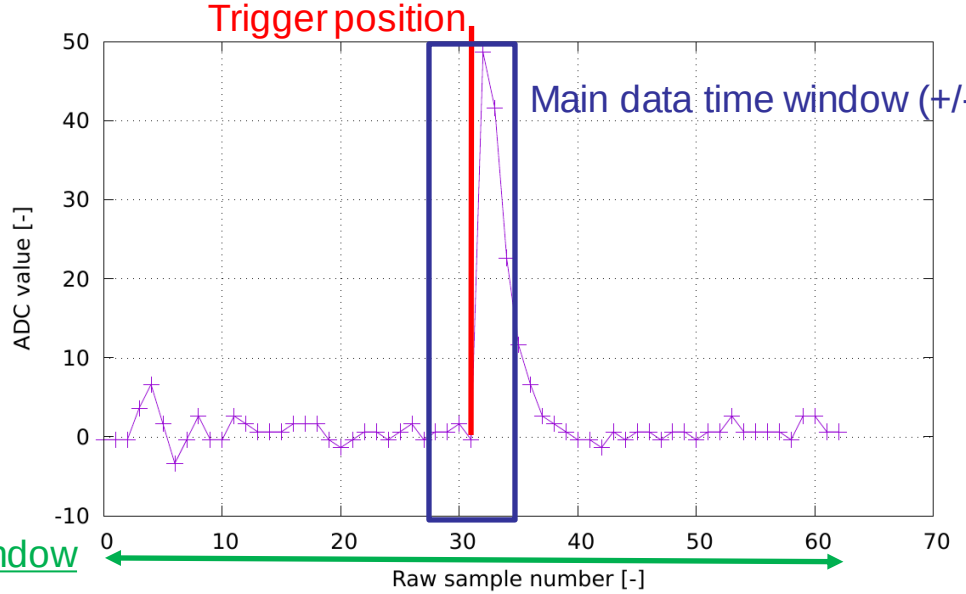


Channels with strange patterns of random(?) value constant for few samples.
For some channels few means few tens of samples...



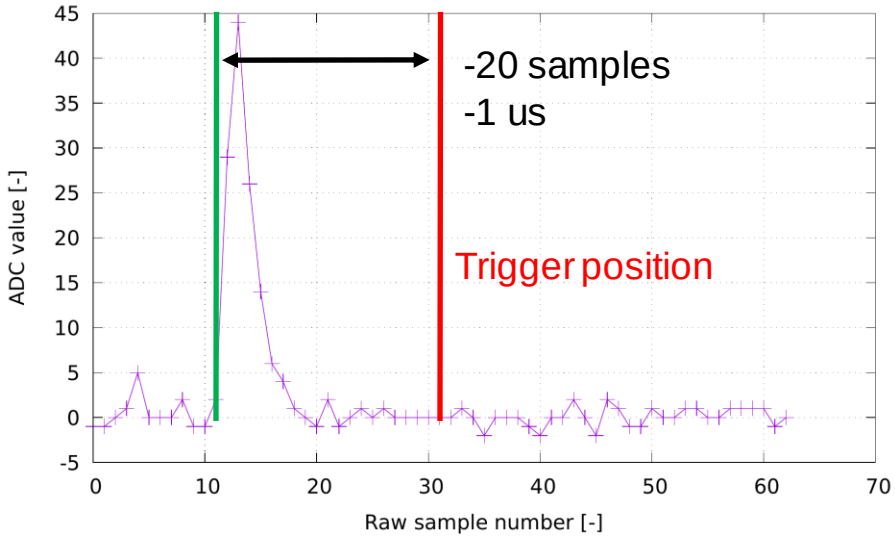
Raw data analysis

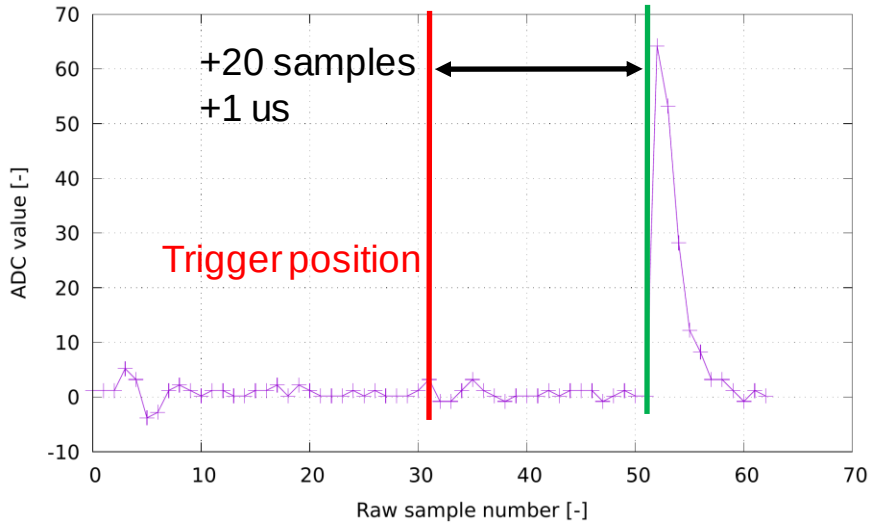
- FE pulse search window in raw ADC data was then removed:



Raw ADC data
+/- 1.5us around trigger
Full FE pulse search window

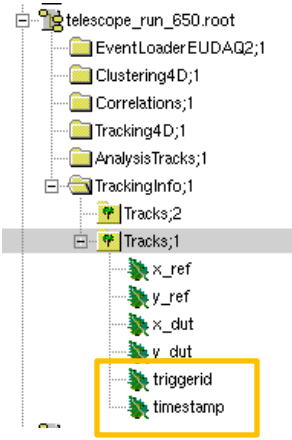
- Additional ~**17'200** pulses found: ~**8800** located 1 us before trigger and ~**8800** – 1 us after:





Trigger investigation

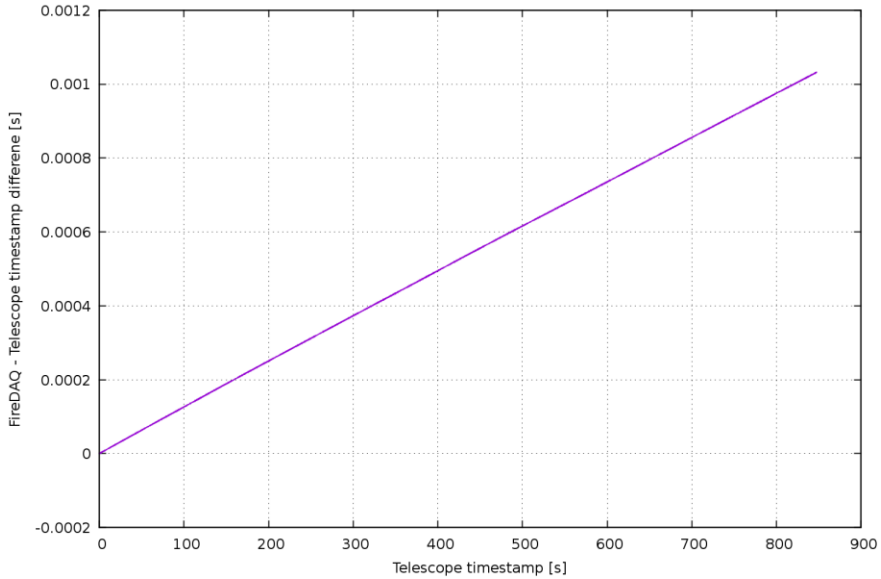
- Both Telescope and FireDAQ writes down the timestamp of each trigger:
  - Telescope – sub-ns step (*most likely PTP, I guess*)
  - FireDAQ – 50 ns step



- Issue with Telescope -- "triggerid" starts with **2**, TLU number starts with **1**...
  (at least for runs 650 and 655 – thanks Shan for the extraction of those data)

- If we assume that "triggerid" == TLU number, there is absolutely no correlations between timestamps...
- My assumption: **TLU number == "triggerid" - 1**

- I have merged events from FireDAQ and Telescope with the above assumption.
  Only triggers with event data in both systems were taken into consideration.
- The timestamps cannot be compared directly, because were counted using different, separate clocks.

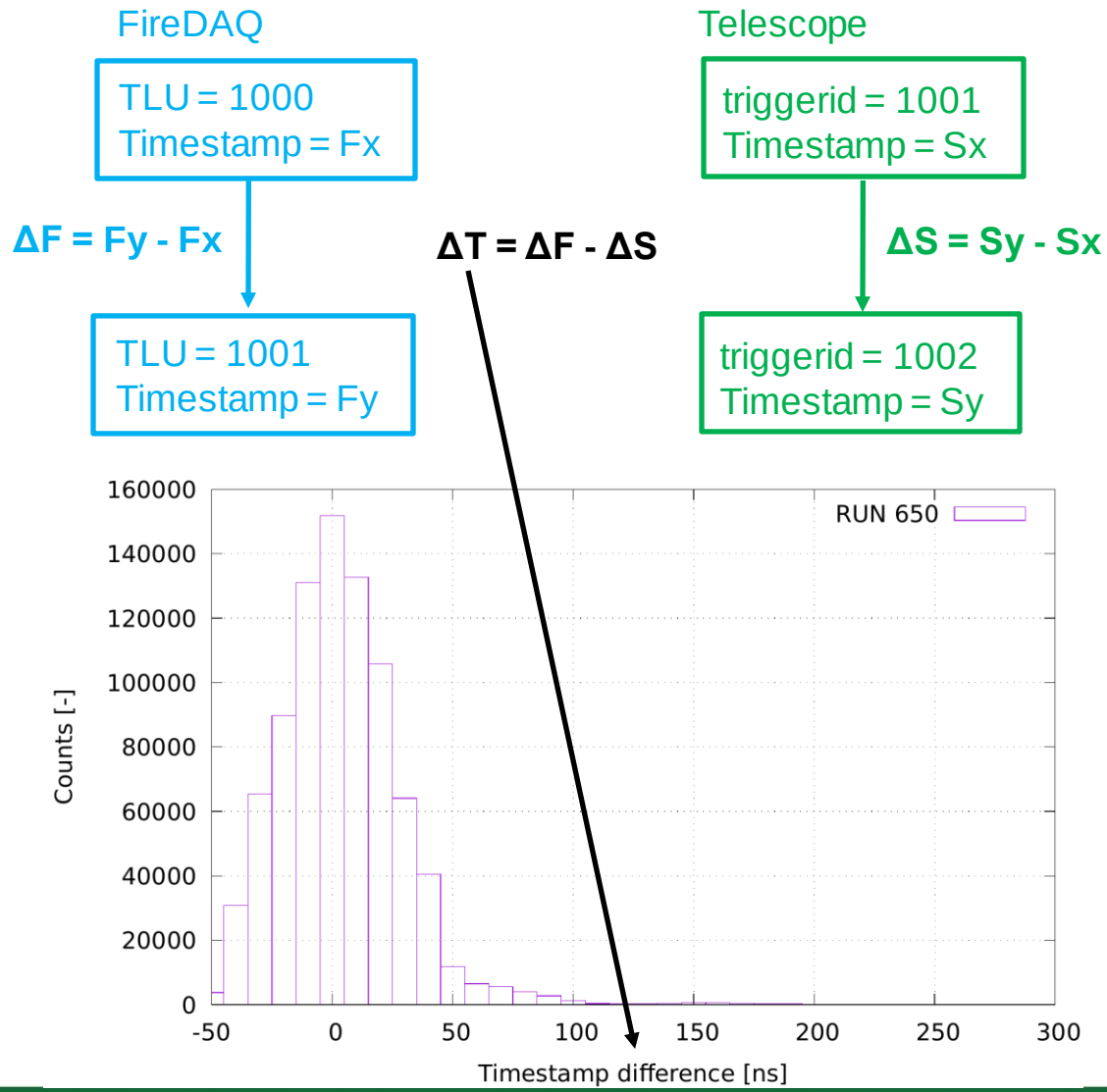


FireDAQ timestamp is faster than Telescope one by **1.032 ms** over the whole run – **847.365 s**

This gives a difference in clock frequencies of **1.22 ppm**
Very reasonable value for clock source which is not an atomic clock...

Trigger investigation

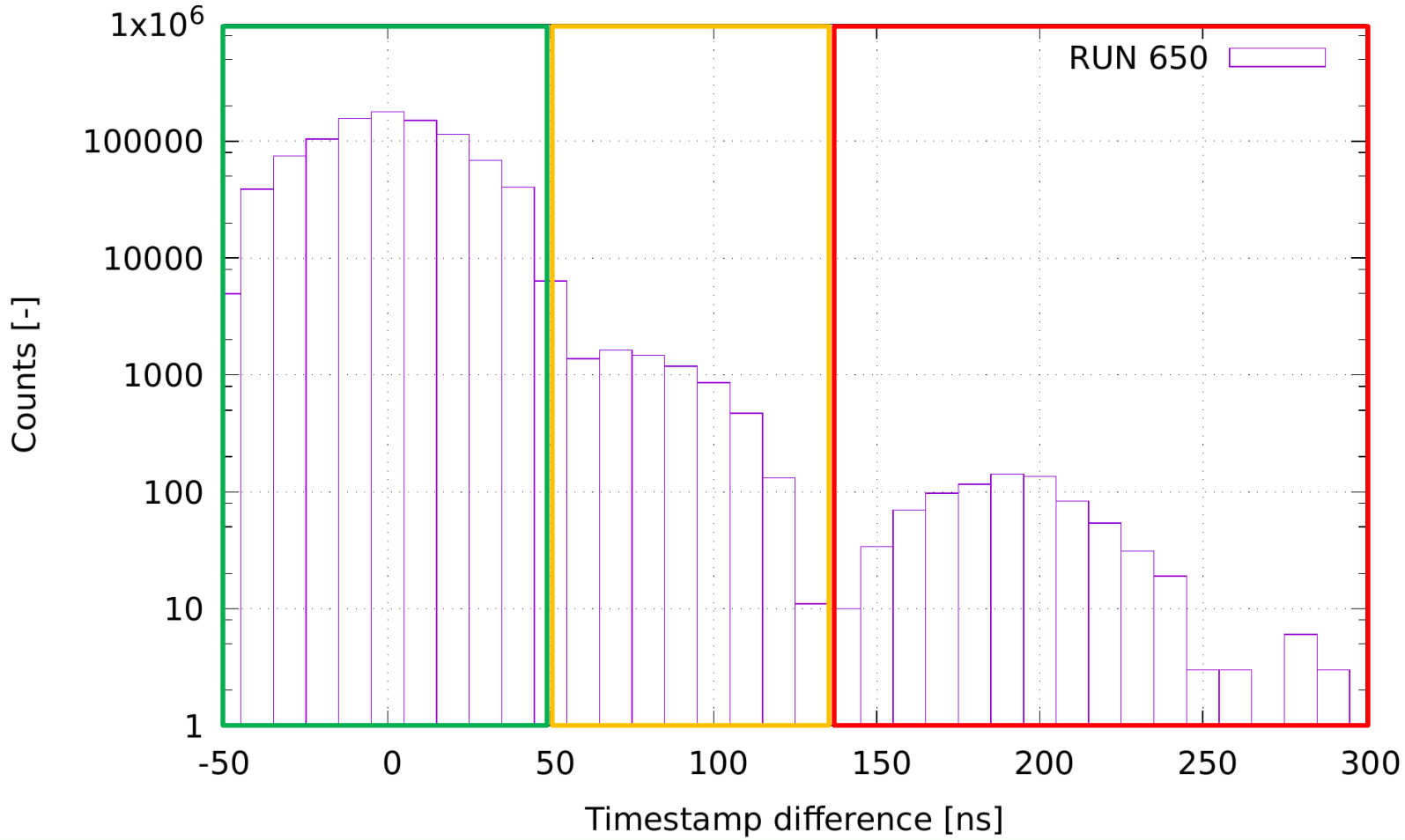
- Instead of comparing the timestamps directly, I have calculated the difference between timestamps of the consecutive events in both systems.
- Then I calculated the difference of those differences – in the ideal case, it should be zero all the time.



Trigger investigation

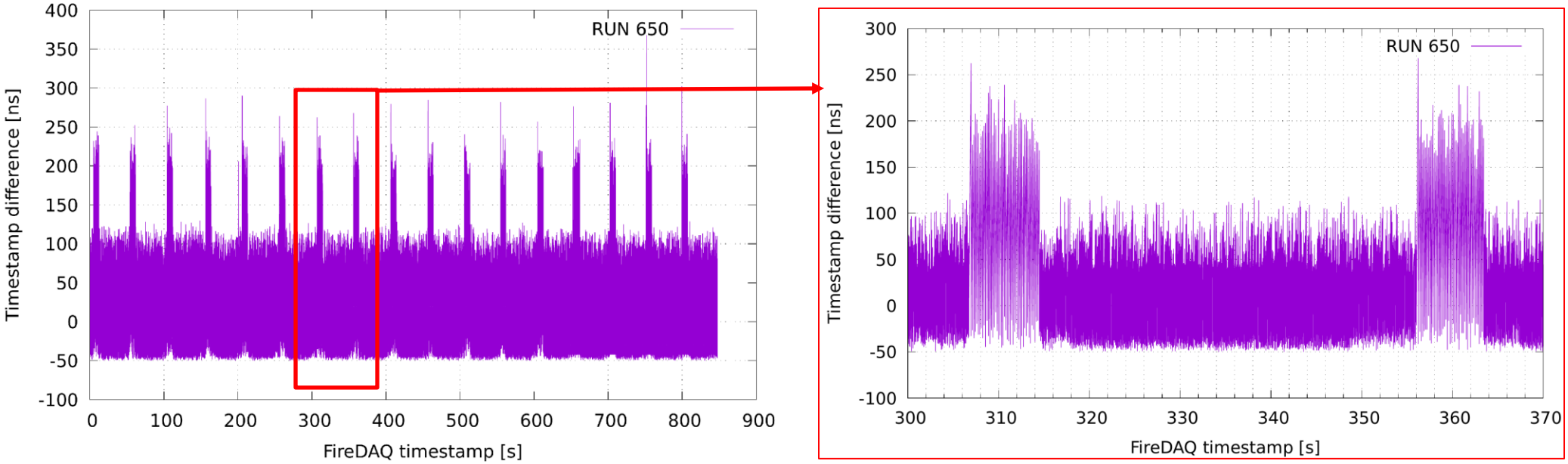
Three main components:

1. **+/- 50ns spread around 0** – due to timestamp step (FireDAQ – 50 ns, Telescope -- < 1ns)
2. **~50ns spread around ~100ns** – always observed (even for TB2014 with Szymon's readout)
   Most likely TLU jitter (tbd.) - not "dangerous" - trigger shifted by 100ns is still in main data time
3. **+/- 50ns spread around ~200ns** – unknown reason, more about it on the next slide...



Trigger investigation

The third case is very strange, especially looking at the timeline.
Short bursts repeating every ~48s with <u>every second</u> event shifted by ~200ns...



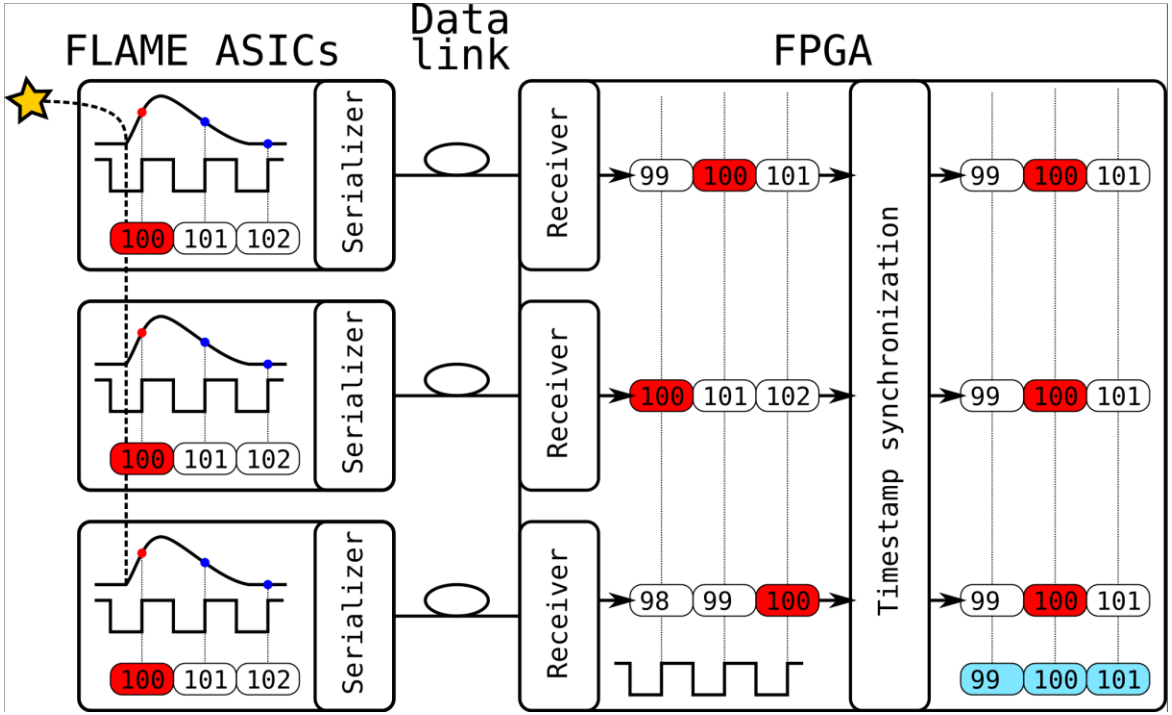
- For those cases data are shifted out of the main data time window (and lost)
- There is around ~1000 cases (0.1% triggers)
- Must be investigated, but it is possible only having the TLU in Krakow

- No significant issues with the trigger found.
- Triggering scheme was not the reason for the data lost.
- No 1 us trigger shift observed – pulses found in raw ADC data were shifted due to some other reason...

FLAME timestamp

FLAME to FPGA time synchronization mechanism works as follows:

- Small 8b timestamp counter embedded in each FLAME ASIC
- ASIC counters are fully synchronized with each other and with the FPGA
- Event is read by all ASICs at the same time and labelled with the same timestamp
- Each ASIC has its own serializer -> data link -> FPGA receiver chain, and each chain has a different latency. So, data appears in FPGA misaligned.
- FPGA re-aligns the data from FLAMEs to the internal FPGA timestamp counter (48b) relying on the timestamp labels assigned by the ASICs



FLAME timestamp

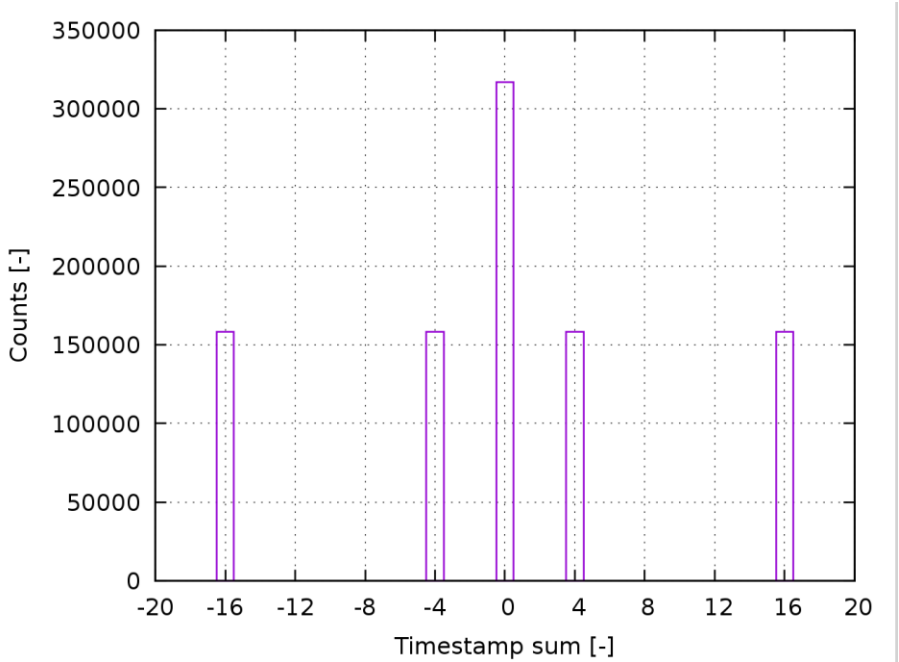
FLAME to FPGA time synchronization mechanism was fully verified and checked multiple times. It was working flawlessly, until ESD event on the begin of the TB2021 happend...

- There is a deep-debug function which verifies this mechanism.
- This function calculates the differences between timestamp labels for every packet received from FLAMEs.
  - If no packet is lost, this difference always should be 1
  - In case of one packet lost, the difference should be 2, but also 2 clock cycles (2 timestamps) separates such packets.

- These differences are sum up by the 16b counter, which overflows from 65'535 to 0 (instead of having the value of 65'536).
- Therefore, after 65'536 clock cycles, the sum counter should be always exactly equal 0.
- Value of these counters after 65'536 clock cycles are histogrammed (unfortunately there is no history in time of the received FLAME timestamps...)

FLAME timestamp

For TB2021 there are +/-4 and +/-16 jumps in FLAME timestamp counter



- Jumps in FLAME timestamp counter means that data are improperly aligned in time
- 4+16 = 20 samples = 1 us shift in time – just as it can be seen in raw ADC data
- There is no way to understand from the histogram how the counter was really counting.
  For example sequence 1-2-3-4-25-26-27-28-49-50-51... (consecutive jumps by +20, followed by consecutive jumps by –20) will look exactly the same as interleaved jump +20, -20, +20, etc.
  Counters could also freeze at some point, eg. 0,1,2,3,24,24,24,24,24,24,24...

- This, most likely, means than majority of the data was shifted by +1, +2us, etc. and -1, -2us, etc. from the real position in time and, due to this, completely lost.

Summary

- On the very beginning of the TB2021 we have got an ESD event.
- This event was much more severe than we initially thought:
  - Not only the analogue, but mainly the digital part was damaged.

- Some channels have permanently burned out constant value.
- Some channels freeze periodically.
- Timestamp counters in ASICs are significantly damaged and are not counting sequentially.

- **The last of the failures caused the data lost.**

- DAQ and reconstruction was working correctly.
- TB2021 data lost have nothing to do with TB2020 issues.