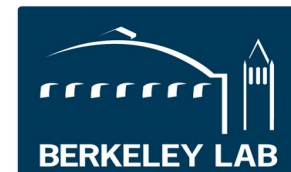# ITk DAQ SW: Pixels, Phase-I

(YARR developments + LLS feedback)

Angira Rastogi

(And many thanks to LLS sites for the updates)

BERKELEY LAB
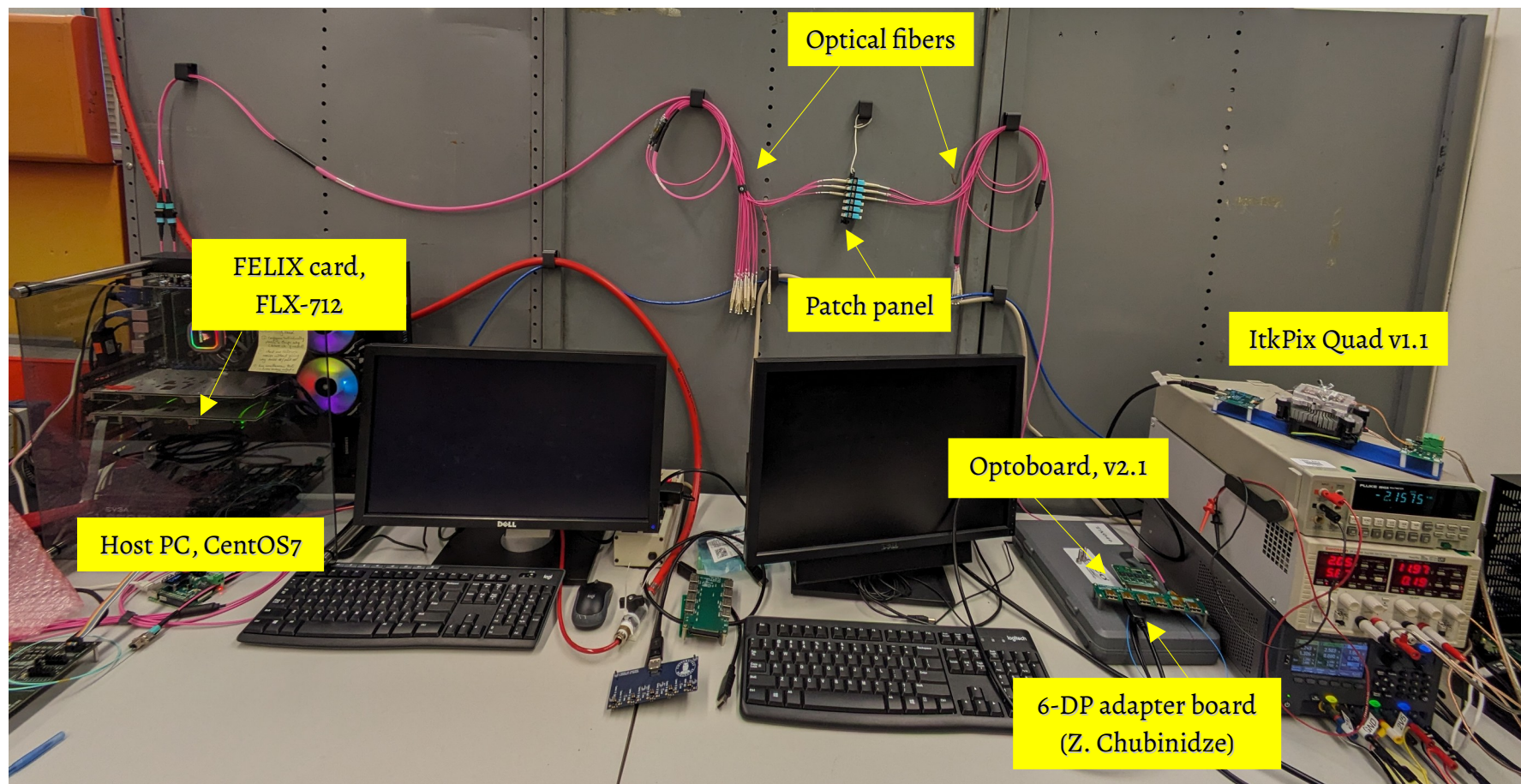
ATLAS ITk

Part I: YARR developments
(On behalf of YARR DAQ team at LBNL)

Outline

- Data processor feedback

- Running calibrations with firmware-trigger

- Running calibrations with software-trigger **New**

- Miscellaneous features (parallel pixel masking, register read)

- Pixel DAQ with FELIX-Star and FELIX-Client **New**

Optical fibers

FELIX card,
FLX-712

Patch panel

ItkPix Quad v1.1

Host PC, CentOS7

Optoboard, v2.1

6-DP adapter board
(Z. Chubinidze)

LBNL setup for Pixel-DAQ
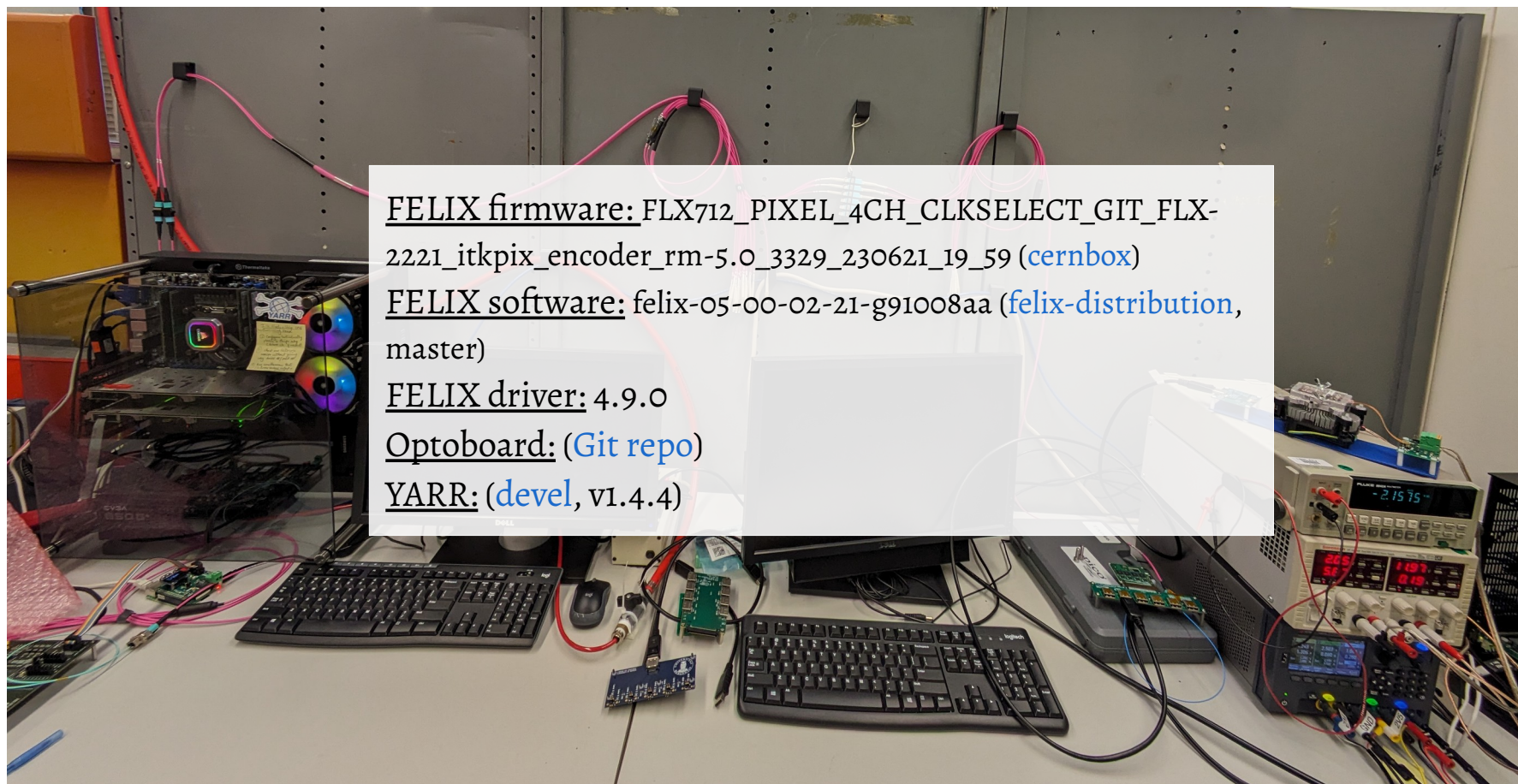
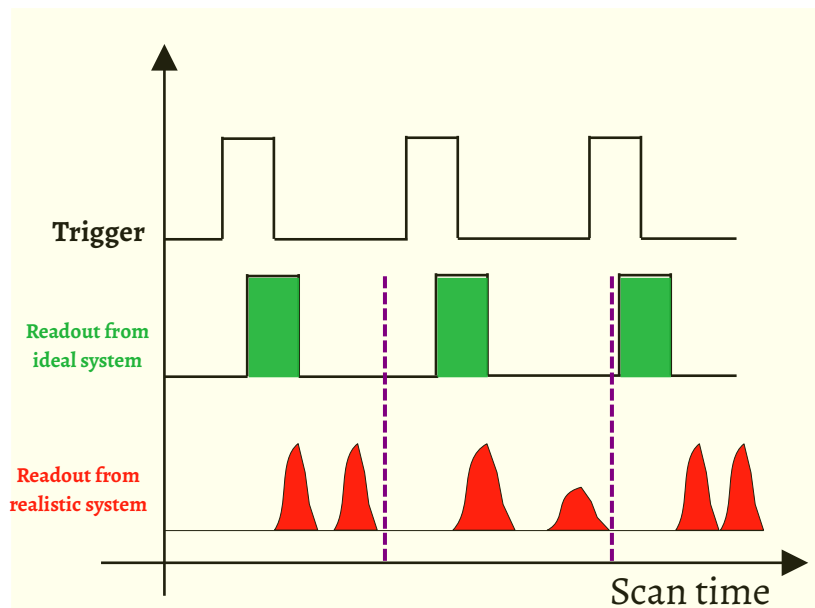

FELIX firmware: FLX712_PIXEL_4CH_CLKSELECT_GIT_FLX-2221_itkpix_encoder_rm-5.0_3329_230621_19_59 (cernbox)

FELIX software: felix-05-00-02-21-g91008aa (felix-distribution, master)

FELIX driver: 4.9.0

Optoboard: (Git repo)

YARR: (devel, v1.4.4)

Data processor feedback

Trigger

Readout from ideal system

Readout from realistic system

Scan time

- While running YARR calibration scans, we need finite wait time between two consecutive commands (masking, injection & trigger).
- For ideal systems, the wait time ~ HW controller latency.
- For realistic systems, wait time is not easily deterministic.

With feedback...

MR !582

- Setting a **very large time maximum (timeout) time per iteration** of scan.
- However, **stopping early** if all the data expected is already received (the **"feedback"**).

- Defining a new "feedback" clipboard for every FE.
- FE data processor pushes the event information (L1 ID, BCID & number of clusters) into feedback clipboard.
- StdDataLoop checks the feedback if all the data corresponding to that iteration has arrived on all the active channels.
- Stops if already collected, otherwise keeps looking up to a maximum iteration time.

A. Toldaeiv

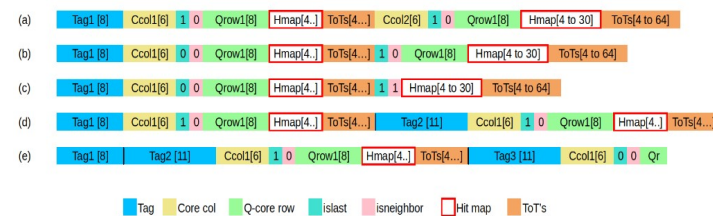# Data processor feedback for Pixels
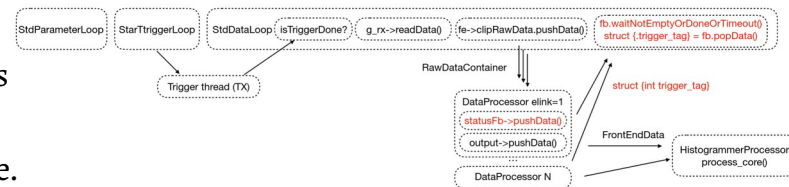
Implementation identical for every front-end (pixels or strips), but "feedback" condition is slightly different.

- **For pixels –** counting the number of **"trigger tags"** for feedback.
  - Tags (8-bit) with valid hit-data, e.g. in a) and b).
  - Tags (8-bit) with header but no hit-data, e.g. in e).
  - Internal tags (11-bit) in the same data stream with more hit-data, e.g. in d) and e).

Rd53b manual

- The number of tags per active channel is compared with the expectation - **trigger count times trigger multiplier**.

- Once all the active channels have received all the events, then only proceed to next iteration (core column loop or masking).

All changes are pushed to original MR, and are ready to use!

Feedback-less scans

- For the scans without injections such as noise scans, source scans...

- No intuition for expected events, so instead we just keep reading data until triggers are being sent and then stop; **"feedback-less"** scan.

- End of iteration processing is still made faster by pushing data to the histogrammer thread multiple times within an iteration.

- This is done in the class StdDataGatherer.

> *CAVEAT: The current FW only supports "count-based" trigger generation whereas injection-less scans are run for a set period of time (more on this on next slide).

A word on FW-trigger for Pixels

- Script provided by M. Trovato sets the calibration injection + trigger sequence in the FELIX registers, for the firmware-based trigger generation.
- However, the only provided sequence for FELIX registers was for the digital scan (ITkPix). Also, the digital scan sequence is missing the re-arm words in the end (for the next positive injection).

- I have created the calibration injection + trigger sequence for digital, analog, threshold, noise and TOT scans, script on cernbox
  This can be used temporarily for running these scans, including tunings, with FELIX.

```
#e.g: ./config_CalTrigSeq.sh 3 2 #3=DIGSCANSEQB, 2 is device number

SCANTYPE=$1 #1=digitalA, 2=analogA, 3=digitalB, 4=analogB, 5=thresholdB, 6=noiseB, 7=totB

DIGSCANSEQA=("817e" "6969" "6363" "a971" "a66a" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "566a" "566c" "5671" "5672" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969"
"6969" "6969")
ANASCANSEQA=("817e" "6969" "6363" "a66a" "716a" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "566a" "566c" "5671" "5672" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6969" "6363" "a96a"
"6a6a" "6969") #diff analog scan
DIGSCANSEQB=("817e" "817e" "aaaa" "63a6" "a66c" "936a" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "4e6a" "566c" "5671" "5672" "2e74" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "63a6" "a66a"
"6a6a")
ANASCANSEQB=("817e" "817e" "aaaa" "63a6" "6a6a" "716a" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "566a" "566c" "5671" "5672" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "63a6"
"a66a" "6a6a")
THRSCANSEQB=("817e" "817e" "aaaa" "63a6" "6a6a" "716a" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "566a" "566c" "5671" "5672" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "63a6"
"a66a" "6a6a")
NOISESCANSEQB=("817e" "817e" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "4e6a" "566c" "5671" "5672" "2e74" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa"
"aaaa" "aaaa")
TOTSCANSEQB=("817e" "817e" "aaaa" "63a6" "6a6a" "716a" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "566a" "566c" "5671" "5672" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "63a6"
"a66a" "6a6a")
```

- Note: Noise scans can also be run by giving scan time x trigger frequency as the count to the firmware.
  Done as a temporary fix – will talk to the FW experts soon about this.
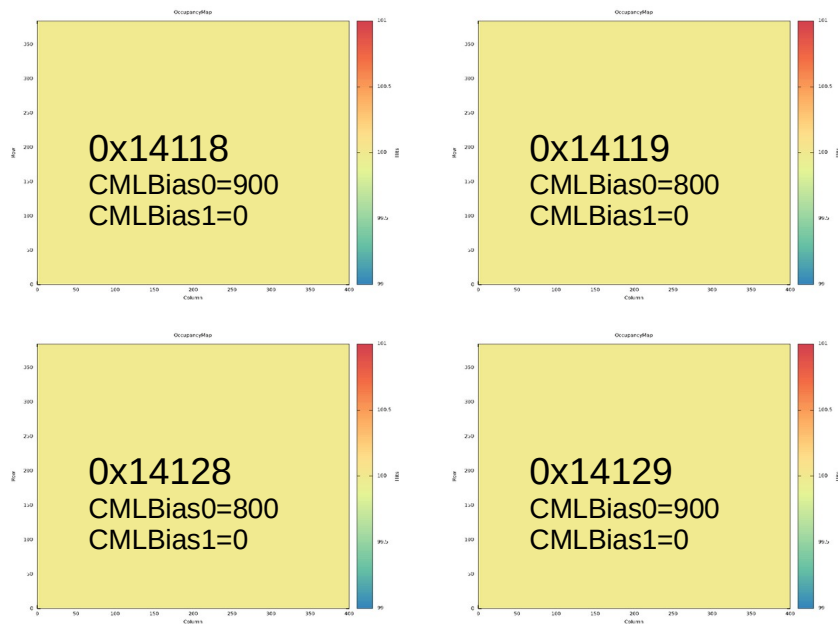
ITkPix FW limitations

- Minimum allowed trigger frequency ~ 5 KHz.
- Maximum number of injections+trigger sequence that can be sent = 127 (7-bit)
- Only allows for a count-based trigger generation.
- To run noise scan with min. 5 KHz frequency, the total scan time ~ 0.02 sec (so that injection+trigger counts < 127) – this is not suitable for time-based scans.

Will get in touch with FW experts about this!

As a long-term solution for setting the FELIX registers (FW-trigger) for the various scans, there are two ways:
   1) Creating a configuration script through YARR to generate the command words dynamically before actually running scans – Felix-core based systems (two-step, not very elegant).
   2) To dynamically set those registers from YARR – Can be done via Felix-client for Felix-star systems - More on this later.

Digital Scan

Analog Scan

0x14118
CMLBias0=900
CMLBias1=0

0x14119
CMLBias0=800
CMLBias1=0

0x14128
CMLBias0=800
CMLBias1=0

0x14129
CMLBias0=900
CMLBias1=0

0x14118
Failing pixels = 314

0x14119
Failing pixels = 34

0x14128
Failing pixels = 1

0x14129
Failing pixels = 30

Scan time: 39.198 s

Analysis: 740 ms

Configuration: 620 ms

Processing: 0 ms

(From scan log)

Trigger frequency = 5 KHz
Trigger multiplier = 16
Injections = 100
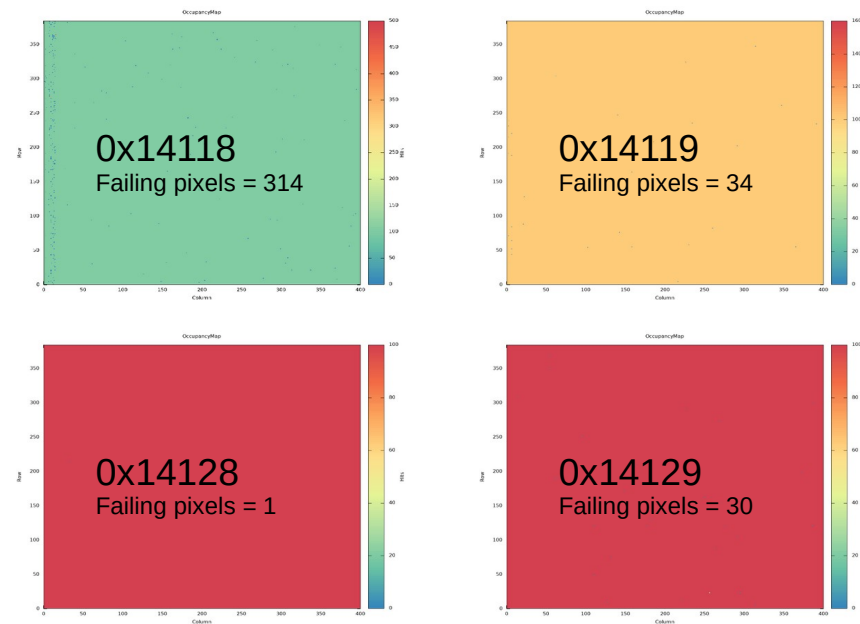
Scan time: 43.065 s

Analysis: 729 ms

Configuration: 703 ms

Processing: 0 ms

(From scan log)

ITkPix Quad v1.1 – with FW trigger (2/2)

Threshold Scan

0x14118
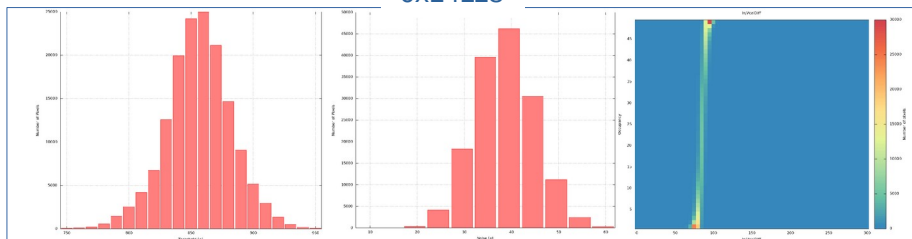
Threshold mean ~ 855 ± 30

Noise mean ~ 38 ± 6

0x14119
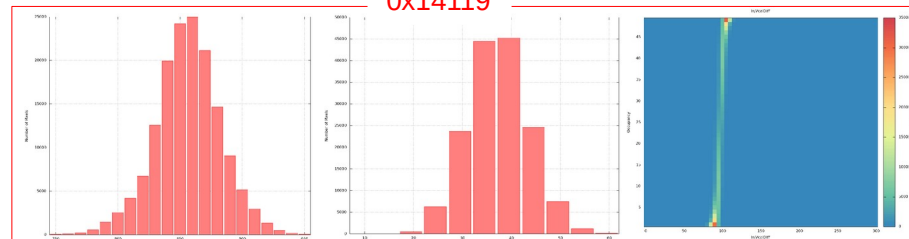
Threshold mean ~ 946 ± 26

Noise mean ~ 37 ± 6

0x14128
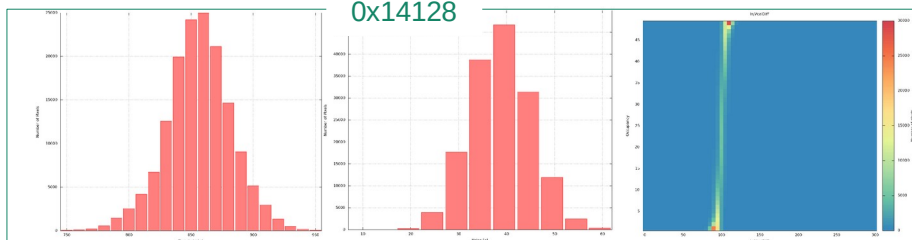
Threshold mean ~ 979 ± 31

Noise mean ~ 39 ± 6

0x14129
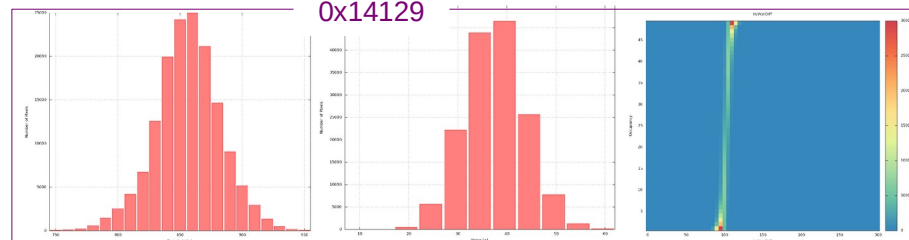
Threshold mean ~ 963 ± 26

Noise mean ~ 38 ± 6

Scan time: 1733.258 s

Analysis: 787 ms

(From scan log)

Configuration: 696 ms

Processing: 0 ms

(From scan log)

Module tuned to 1000 e.

Running scans with SW trigger

- Previously, data losses pattern was observed in the scans.

Digital scan
Trigger frequency = 100 Hz
Injections = 100
Number of mask stages = 64
rxWaitTime = 1 sec.
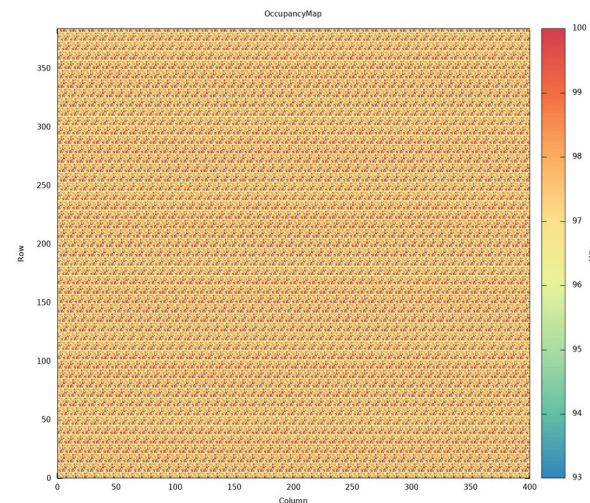
- Fixed now in MR !659 and works with the latest felix-distribution package (important).

- All the scans can be run normally with up to 5KHz trigger frequency.

ITkPix Quad v1.1 – Timing comparison

Scan configuration	FW-trigger (SPEC card)	FW-trigger (FELIX)	SW-trigger (FELIX)
Digital scan (Trigger frequency = 5KHz, trigger multiplier = 16, injections = 100)	**Scan time: 9.871 s** Analysis: 625 ms Configuration: 1443 ms Processing: 0 ms	**Scan time: 39.198 s** Analysis: 740 ms Configuration: 620 ms Processing: 0 ms	**Scan time: 175.066 s** Analysis: 760 ms Configuration: 797 ms Processing: 0 ms
Analog scan (Trigger frequency = 5KHz, trigger multiplier = 16, injections = 100)	**Scan time: 8.353 s** Analysis: 800 ms Configuration: 1450 ms Processing: 0 ms	**Scan time: 43.065 s** Analysis: 729 ms Configuration: 703 ms Processing: 0 ms	**Scan time: 168.273 s** Analysis: 490 ms Configuration: 745 ms Processing: 0 ms
Threshold scan	**Scan time: 181.629 s** Analysis: 836 ms Configuration: 1443 ms Processing: 0 ms	**Scan time: 1733.258 s** Analysis: 787 ms Configuration: 696 ms Processing: 0 ms	**Scan time: 2020.552 s** Analysis: 791 ms Configuration: 745 ms Processing: 0 ms
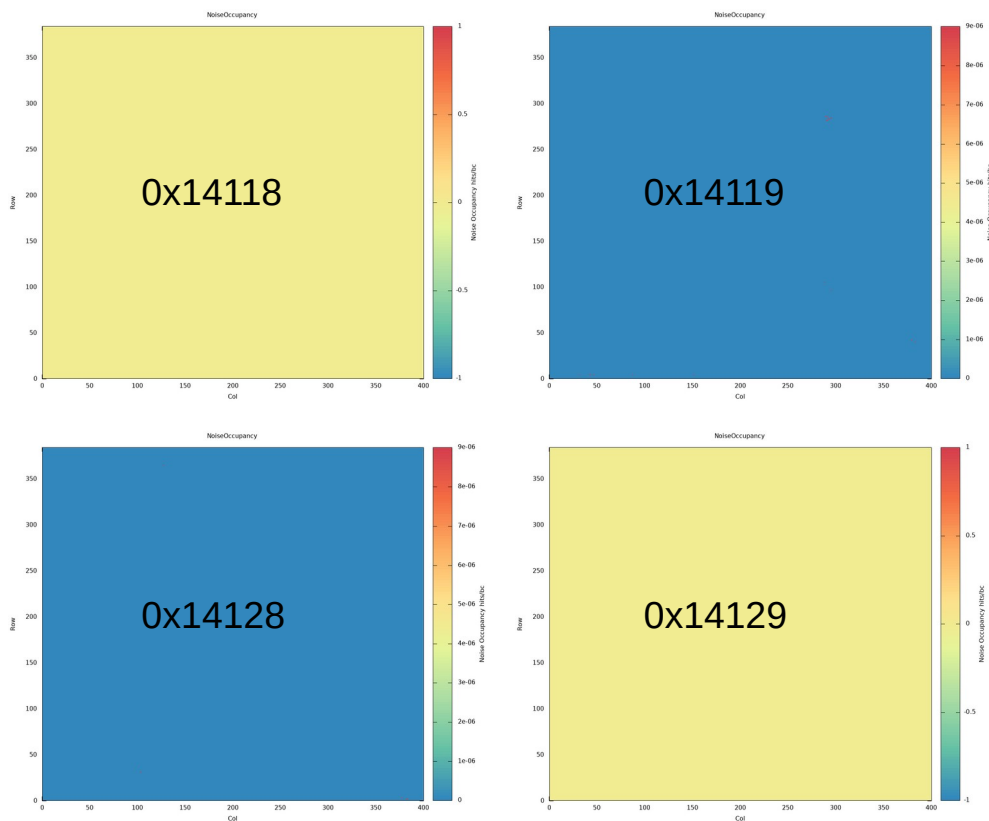
Noise scan configuration:

- **SW-based trigger generation**
- Trigger frequency = 12 KHz
- Trigger multiplier = 16
- Scan time = 60 s

ITkPix v1.1 module tuned to 1000 e.

Scan time: 64.067 s
Analysis: 772 ms
Configuration: 710 ms
Processing: 0 ms
(From scan log)

Miscellaneous features

Running parallel pixel masking

- A new class Rd53bParMaskLoop in YARR (v1.4.4) which sends very long WrReg(1) command for one core column, which then gets broadcasted to all other core columns to set the masking in-parallel.

- Works out of the box now with the FW version >= June 2023 (FLXUSERS-615).

Register reading

- Works on a dedicated elink (dcs elink = data elink+1), after filtering out auto reads (by setting FELIX register: DECODING_MASK64B66BKBLOCK = 0x0) and with latest Felix SW (master branch) from felix-distribution – many thanks Sasha, Ismet and Valerio for the help with debugging!

- Register read scan can be run after changing rx in connectivity configuration to rx+1.

- To read a register value during a scan, we need an additional fix from firmware (allowing required service data on data elink).

Pixel DAQ with FELIX-star

- FELIX-star and YARR (libFelixClient) works for pixels in the preliminary tests, many thanks Zhengcheng for the help!

- Two processes, Felix-tohost (upstream) and Felix-toflx (downstream) needs to run on separate terminal.

- Also, Felix-register process of FELIX-star allows to read/write FELIX registers from YARR SW.

  - Really useful to set the scan configuration from YARR to the FELIX registers during run-time (to be tested).

- Broadcasting command also works in true parallel manner. Hence, the scan timings with a quad module or with a multi-module setup can be improved.

- More studies will be followed with FELIX-star and YARR.

Part II: Feedback from LLS sites

(SR1 and INFN Genova)

SR1, CERN

Leyre Flores, Gerahrd Brandt, Ali CanBay, Nico Malinowski,
Ismet Siral and Benedikt Vormwald

Firmware: Pixel-Felix 4 CHN from 21/06/2023
Felix software: master branch (felix-distribution)
YARR DAQ: Tag v1.4.4
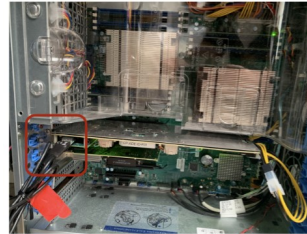
Felix Server
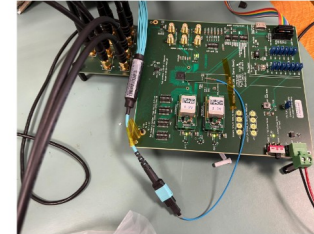

VLDB+ with SMA adapter
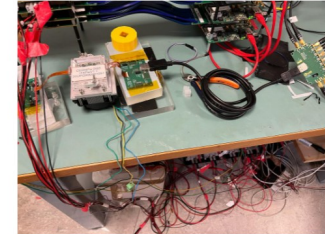
SMA-DP to digital quad

- Scan time can be reduced to < 1 min by changing in rxWaitTime parameter in the controller config to a lower value.
- Register read works after setting the FELIX register DECODING_MASK64B66BKBLOCK = 0x0 on the DCS elink.
- Need to test data merging and fully go through all the scans in detail.
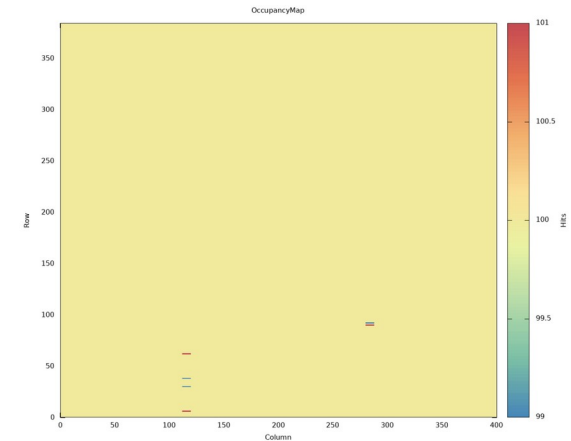
**Example of 1 chip in quad digital scan with VLDB+ setup
(Not the LLS setup in SR1, being used for MOPS tests)**

INFN Genova (1/2)

Paolo Morettini et al

Details about the setup

- FELIX server with 1 board (24 ch).
- 8ch «new» firmware (locally compiled).
- Up to date FELIX software.
- Optobox + 1 V2 optoboard.
- "Zaza" adapter (optoboard to DP cable, 6 ch).
- One ITkPixV1 SCC, one ITkPixV1 digital quad connected to the Zaza adapter via DP cable.

INFN Genova (2/2)

Paolo Morettini et al
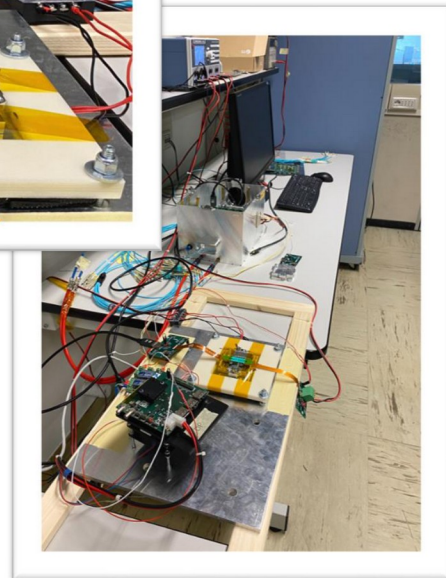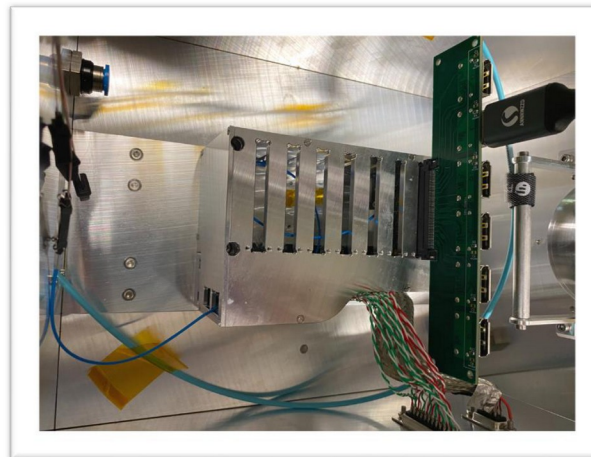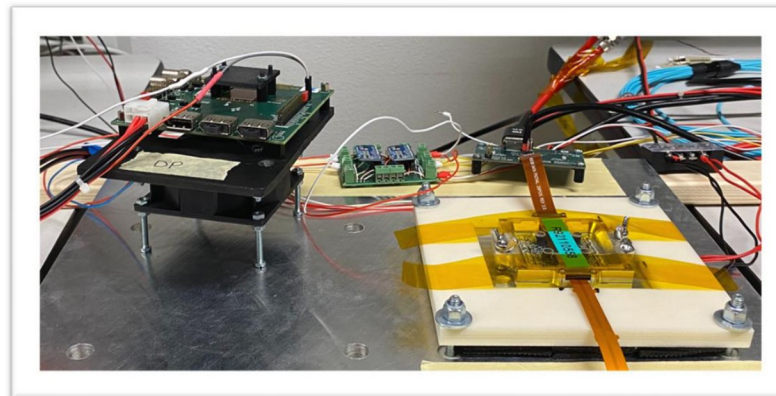
YARR usage

- Can run scan with the most recent YARR software (some significant speedup achieved in August).
- Can run BER test using GBCR and lpGBT and the optoboard software.
- The next step will be to connect ITkPixV1 modules loaded on a Layer 4 Half Ring using a Data PP0.
- All the elements are available (loaded modules, Data PP0, prototype twinax bundle), so we hope to have results soon.
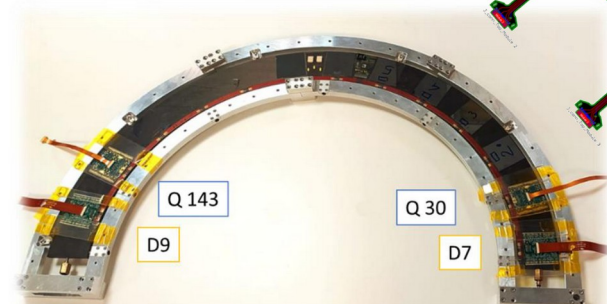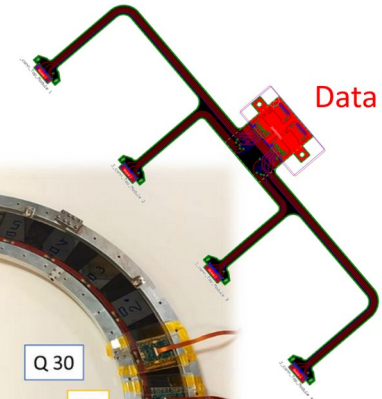
SCC card BER test
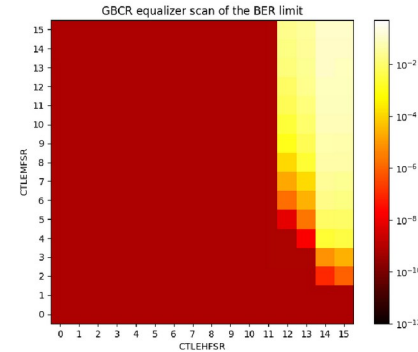
Digital quad card BER test
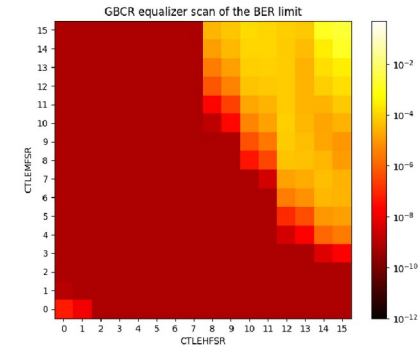
Partially loaded L4 HR

Data PP0

Summary

- Data transmission with ItkPix Quad V1.1 via YARR-FELIX interface in place now.
- Can run all the calibration scans (including the tunings), as well as noise scans with firmware-based trigger generation.
- New improved YARR data loop with a feedback mechanism, which is immune to latencies in the network and data buffering as well as variability of different setups. MR !582
- Software-based trigger generation is also fixed - sync commands to be inserted for ITkPix before sending the calibration injection and trigger sequence. All scans can be run successfully at 5KHz frequency (merged now!) MR !659

Currently prepping release 1.4.5 from YARR (minor release for module QC). Then will tackle the data processor feedback with release 1.5.

Next steps

- Talk to FW experts about the various wishlist items concerning FW-triggers.
- To switch to FELIX-star completely for running YARR scans.
- Better parallelization for configuring the module and other timing optimizations to be done in YARR.
- Test data transmission with YARR-FELIX for data-merging.

- Test ITkPixv2 (need new firmware first!).

- To setup the data transmission for SP quad module chain with FELIX (need another optoboard and the new Zaza adapter board).

https://atlaswiki.lbl.gov/pixels/felixdaq
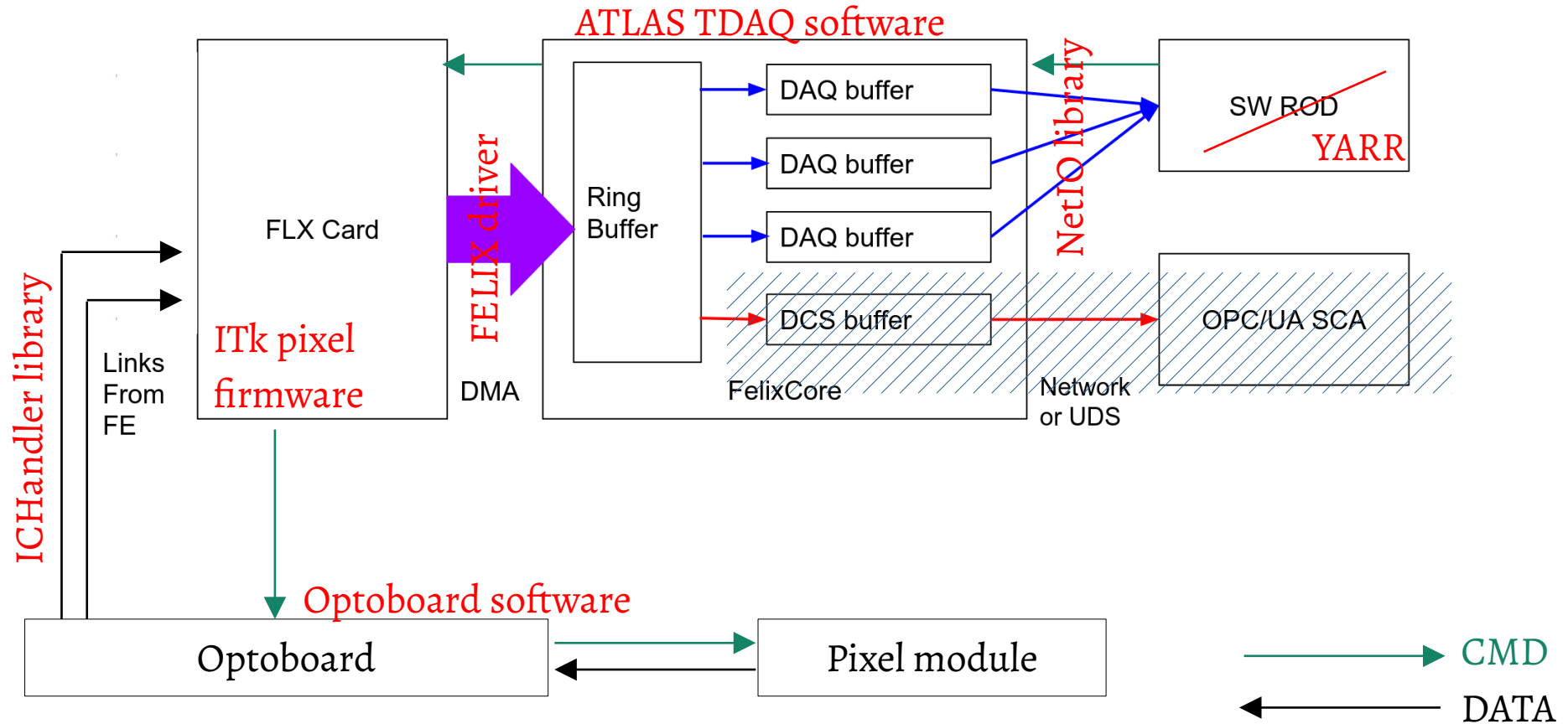
Scans	1 FE	2 FE	3 FE	4 FE (full quad)
Digital	"analysis": 563 ms, "config": 191 ms, "scan": 27788 ms	"analysis": 770 ms, "config": 401 ms, "scan": 32795 ms	"analysis": 800 ms, "config": 569 ms, "scan": 37742 ms	"analysis": 740 ms, "config": 775 ms, "scan": 42364 ms
Analog	"analysis": 556 ms, "config": 206 ms, "scan": 28238 ms	"analysis": 465 ms, "config": 377 ms, "scan": 34853 ms	"analysis": 496 ms, "config": 548 ms, "scan": 39639 ms	"analysis": 800 ms, "config": 748 ms, "scan": 44799 ms
Threshold	"analysis": 704 ms, "config": 186 ms, "scan": 1251930 ms	"analysis": 734 ms, "config": 399 ms, "scan": 1430736 ms	"analysis": 621 ms, "config": 538 ms, "scan": 1594621 ms	"analysis": 886 ms, "config": 704 ms, "scan": 1743871 ms

With FW-triggers. DataProcessor feedback + FELIX setup.