ITk Pixel DAQ with YARR-FELIX

Quad module & feedback mechanism

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LBL Weekly Instrumentation Meeting
Sep 8th, 2023

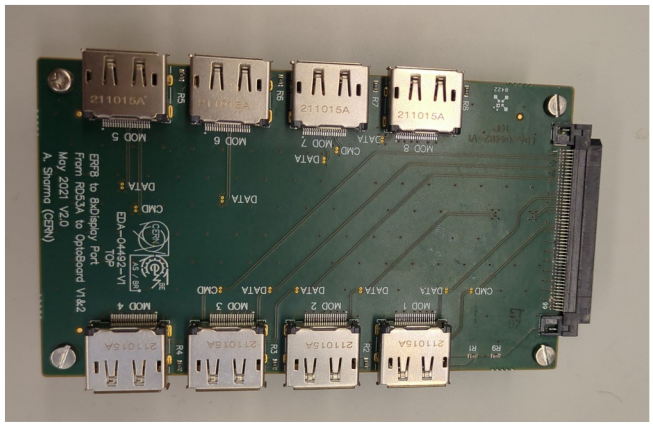
BERKELEY LAB

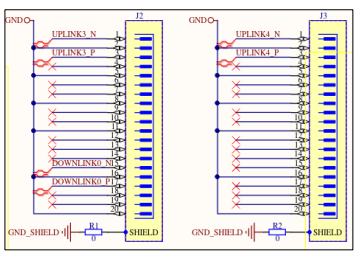
ATLAS ITk

Setting up ITkPix Quad v1.1

Old adapter board

(8DP_to_ERF8_Data_Adapter, A. Sharma)

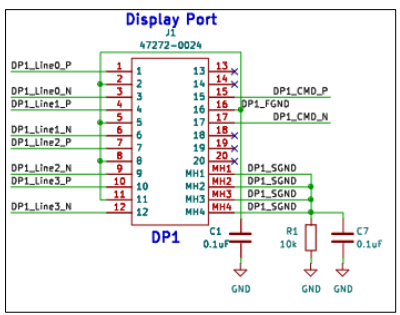




- Only one uplink per DP.
- Only 4 out of 8 DPs have downlink for sending CMD.
- Works out well for SCC (up to 4).

New adapter board

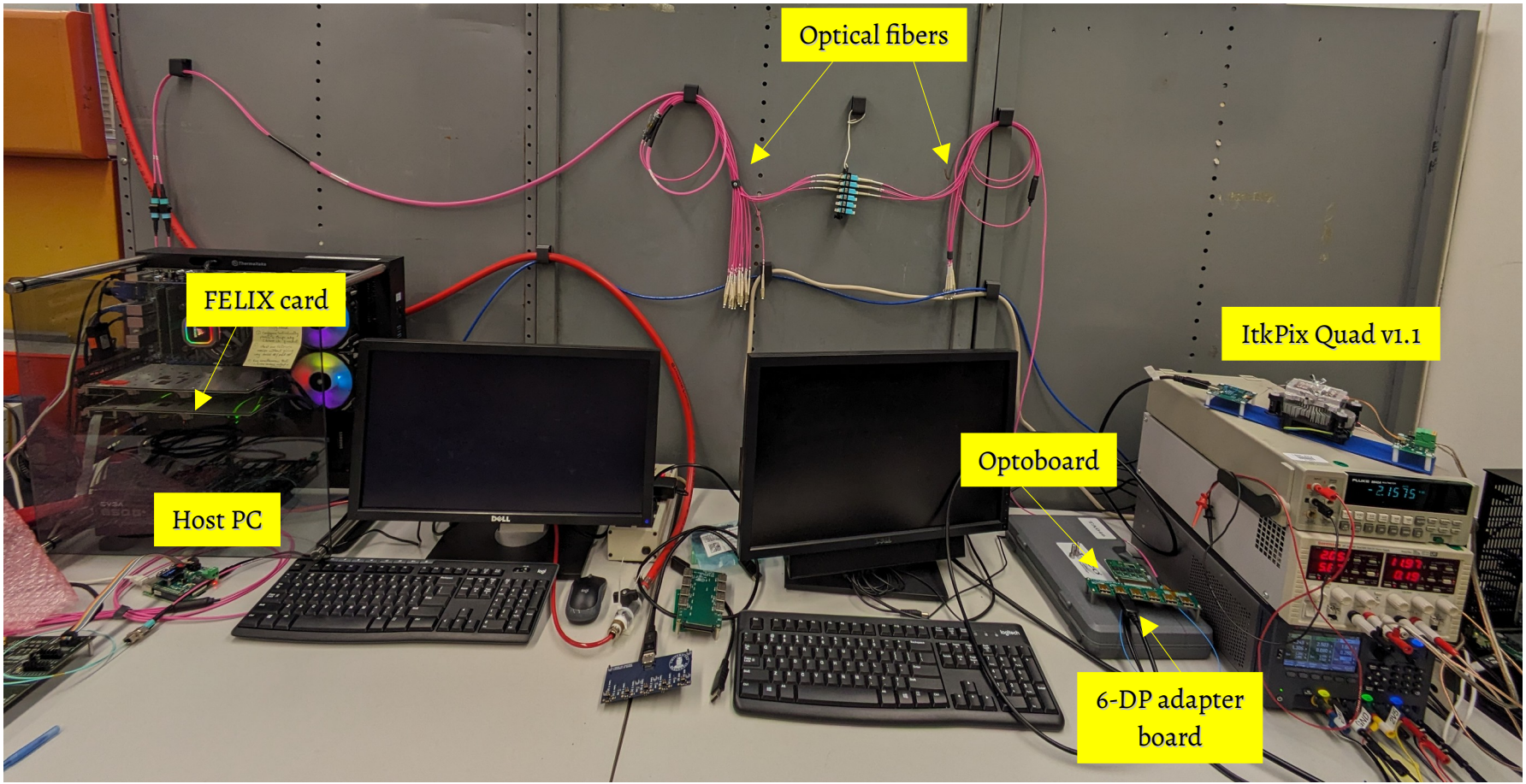
(6DP_to_ERF8_Data_Adapter, Z. Chubinidze)



- Every DP has 4 uplinks, to read out the full quad module.
- Every DP has a downlink for CMD.
- Works for SCC and quad module (max. 6).

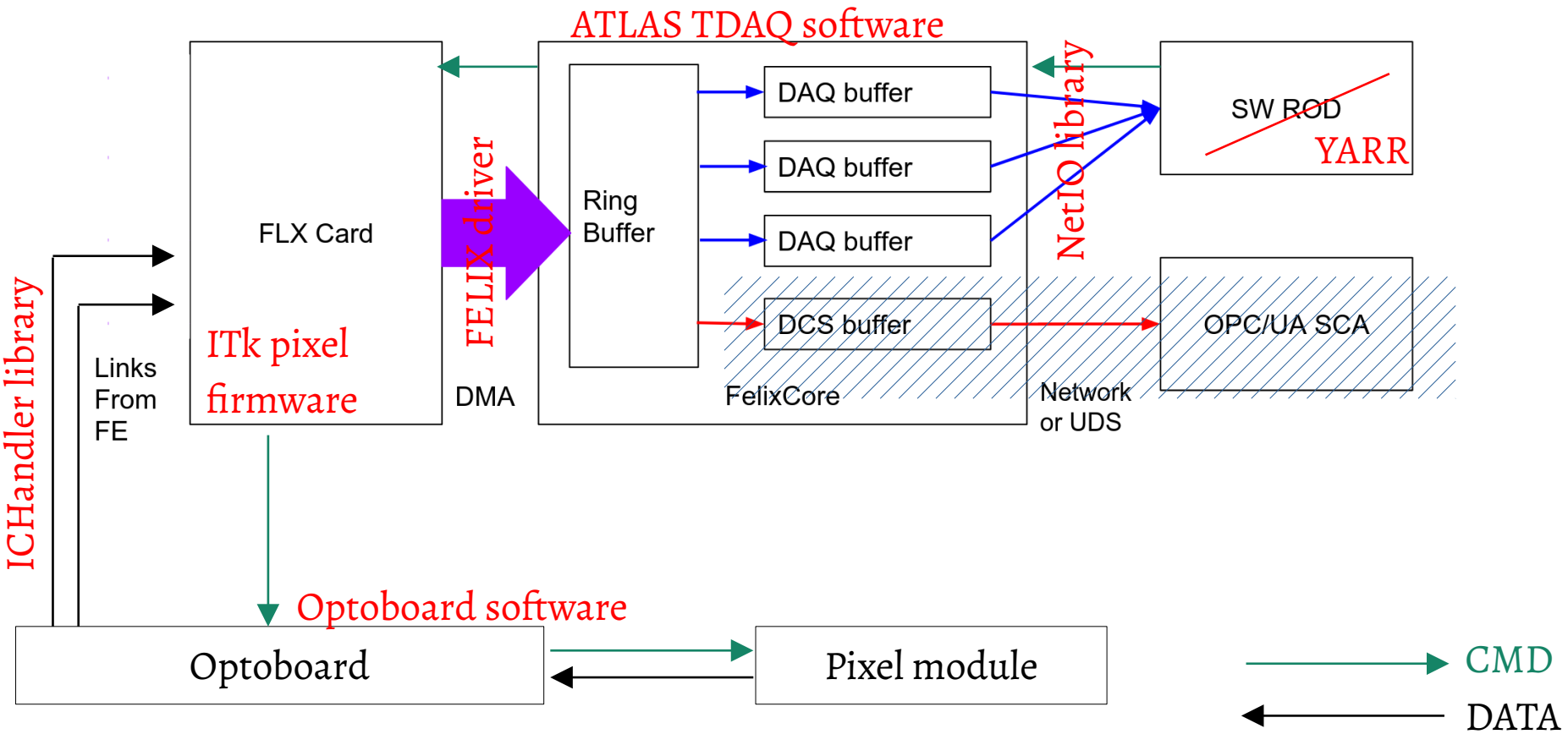
New setup with Quad module

50B-6038

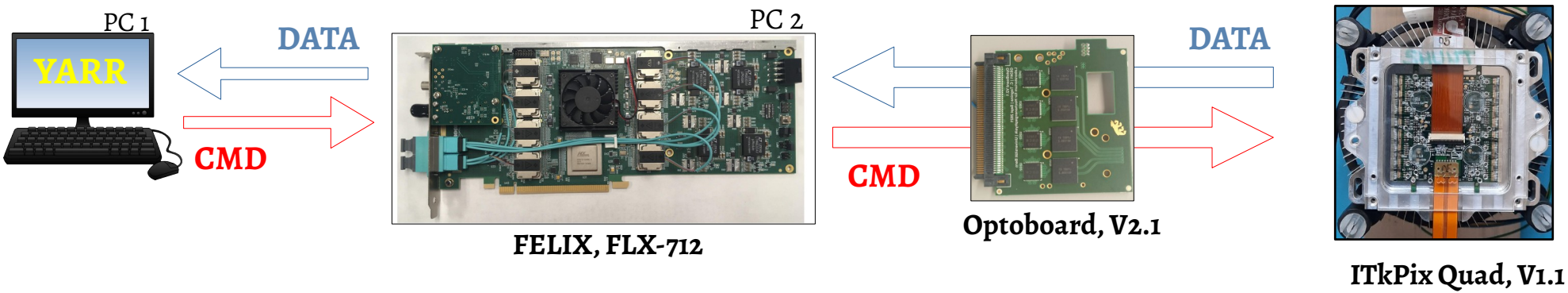


Driver, firmware & software

https://atlaswiki.lbl.gov/pixels/felixdaq



Running YARR scans



CMD: Sent from the YARR for:

- Configuring the chip (reset, syncs, configuring the global & pixel registers)
- Setting up pre-scan (writing some more named registers, CMD enable, injection charge etc.)
- Running the scan (masking, injection & trigger)

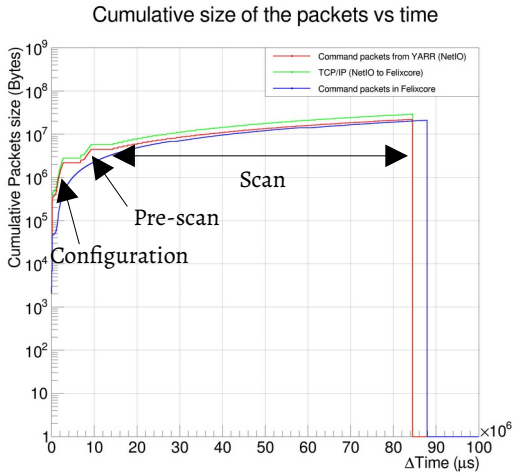
DATA: Hit data arriving from the chip to HW controller and back to YARR:

- Corresponding to every trigger command.
- Can be deterministic i.e. arrives at regular intervals or random i.e. more spread out in time.

Issues with sending commands

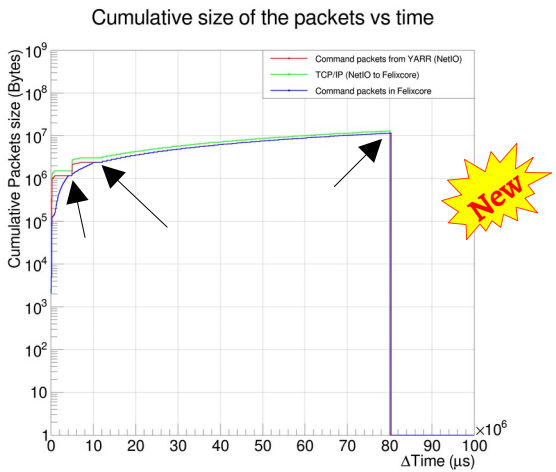
Problem:

- Commands sent out from YARR (NetIO) gets split into many small-sized packets in the network. Hence, FELIX software receives much fewer commands in the equivalent time.
- These smaller-sized commands are then bunched up in the buffers instead of being sent out to the chip immediately. This leads to a delay or mismatch in synchronicity between the YARR scans (setup, injections & triggering) and the chip operations.



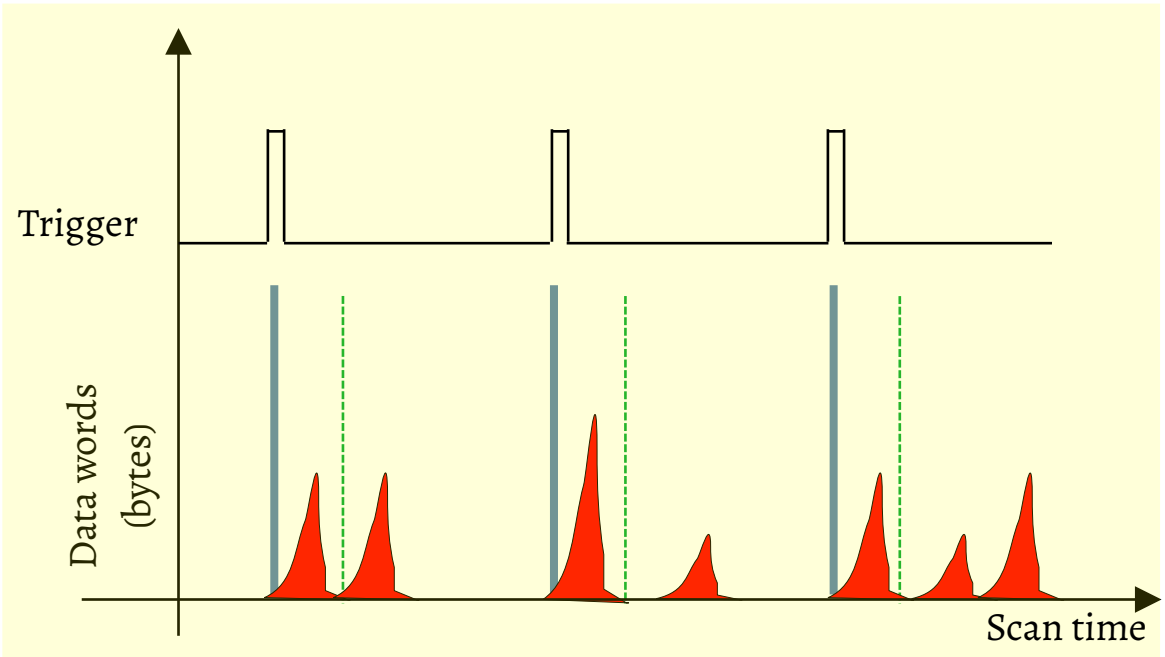
Fix:

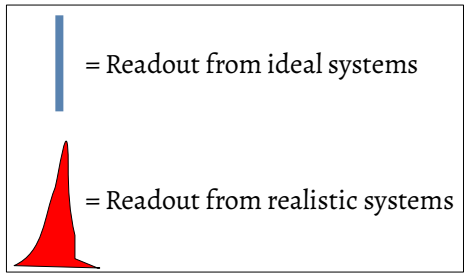
- Aggregating commands in YARR (NetIO) to send out longer packets above a minimum threshold size. These are then forwarded more regularly from FELIX software to the chip.
- Changes already integrated in YARR-devel branch.



Issues with receiving data

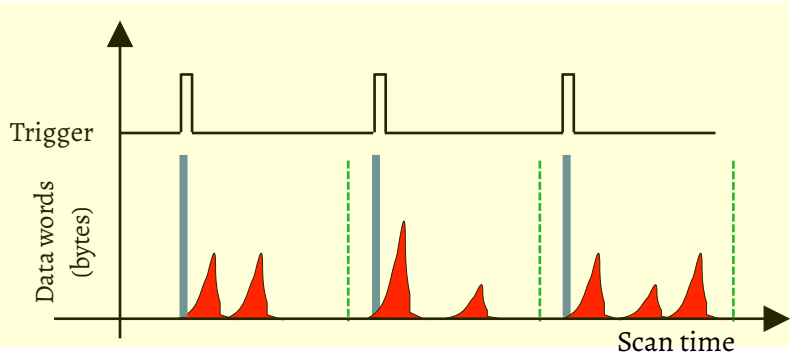
Ideal systems: Data arrives at a regular interval and all at once. For ex, PC with spec card controller.
Can choose a safe boundary **(green)** at which we expect all data to have been received from the HW controller (it's latency) for that parameter settings (mask stage, core column loop) before moving on to the next iteration.





Realistic systems: For ex, with FELIX as HW controller and a server-based data readout, data arrival can be very unpredictable. This is due to network latencies and data buffering. Other factors affecting the readout are if server (FELIX software) and client (YARR) are running on different PCs, or non-uniform setups such as longer cables introducing extra delays etc.
Hence, unclear where to set the boundary unanimously. Not good to set to a very large (unknown) value because it will make the scans slow.

Hence, feedback…

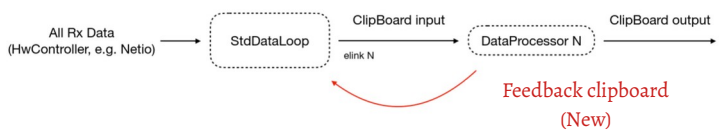


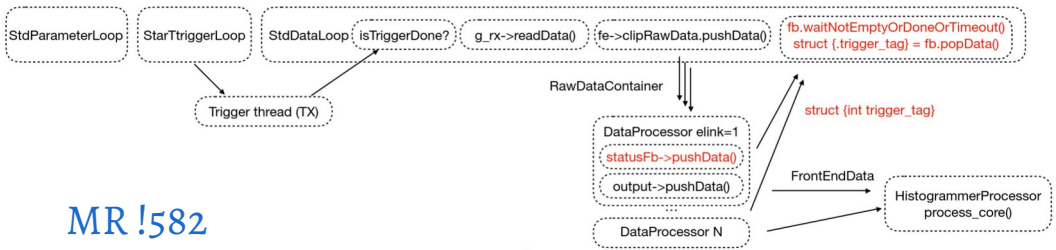
- Setting a **very large time per iteration** of scan up to when we want to keep reading data from the HW controller.
- However, **stop early** if all the data expected from the iteration is already received (the **"feedback"**).
- Hence making the scan results stable, and also a more universal software that can be used across different setups.

The "feedback"

- We know, from the scan configuration, how many triggers are to be sent (trigger count x multiplier). Hence, we should receive those many event headers (trigger tags).

- Counting the number of tags received, and ending the iteration whenever all of them are received. Also, pushing the collected data from every feedback cycle for histogramming and analysis, making the processing faster.





- Finally, proceeding onto the next iterations of the scan.

MR !582

CML bias settings

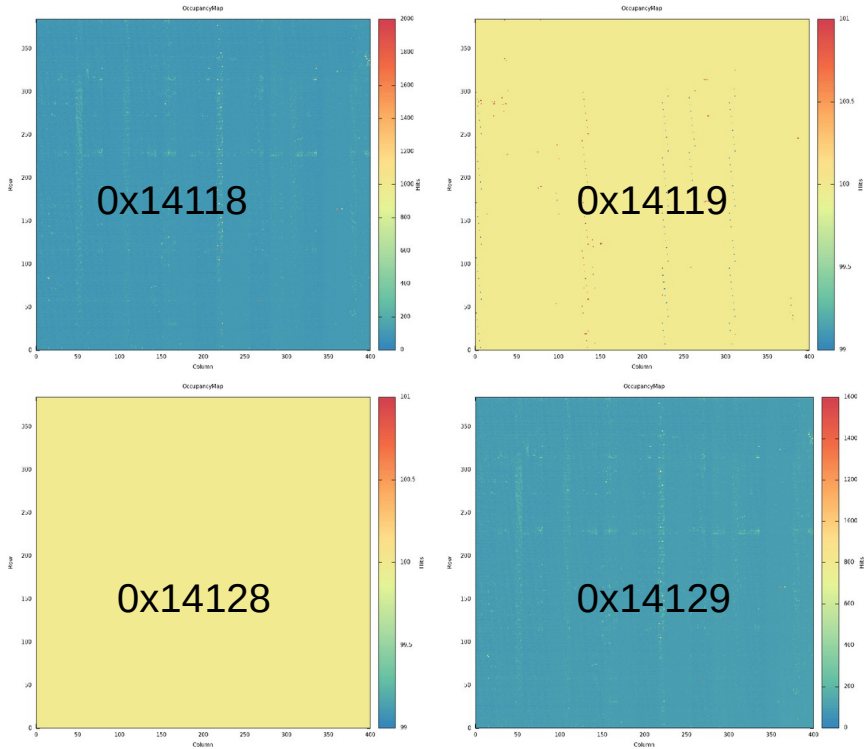
Chip ser. no.	CML Bias0	CML Bias1
0x14118	900	0
0x14119	800	0
0x14128	800	0
0x14129	900	0

Most optimum values

CML bias scan

- **0x14118:** CML Bias1 >0 gives much fewer events e.g. 500-1000 (expected 1600) per iteration. Slightly higher no. of events received with CML Bias0 = 900 than 800.
- **0x14119:** No. of failing pixels = 239 (no unfinished stream errors).
- **0x14128:** No. of failing pixels = 0 (no unfinished stream errors).
- **0x14129:** Doesn't see any data words when CML Bias1 >0. Slightly higher no. of events received with CML Bias0 = 900 than 800.

Digital scan results



Trigger frequency = 5 KHz
Injections = 100
Trigger multiplier = 16

After some debugging, we found that the pull-down resistor on the data adapter board was the reason behind unsuccessful digital scan.

A word on FW-triggering

- 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). This needs to be fixed from the firmware-side.
- Also, the digital scan sequence is missing the re-arm words in the end (for the next positive injection).

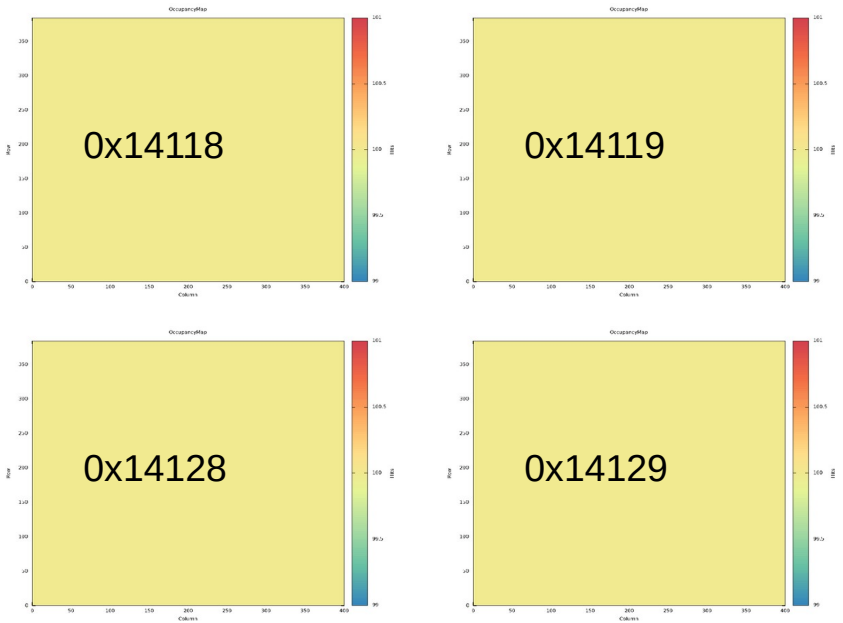
- I have created the calibration injection + trigger sequence for digital, analog, threshold, noise and TOT scans, script on cernbox

```
#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" "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" "6969" "6969" "566a" "566c" "5671" "5672" "6969" "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" "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" "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" "aaaa" "4e6a" "566c" "5671" "5672" "2e74" "aaaa" "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" "aaaa" "566a" "566c" "5671" "5672" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "aaaa" "63a6" "a66a" "6a6a")
```

This can be used temporarily for running other scans with FELIX.

Scan results (1/2)

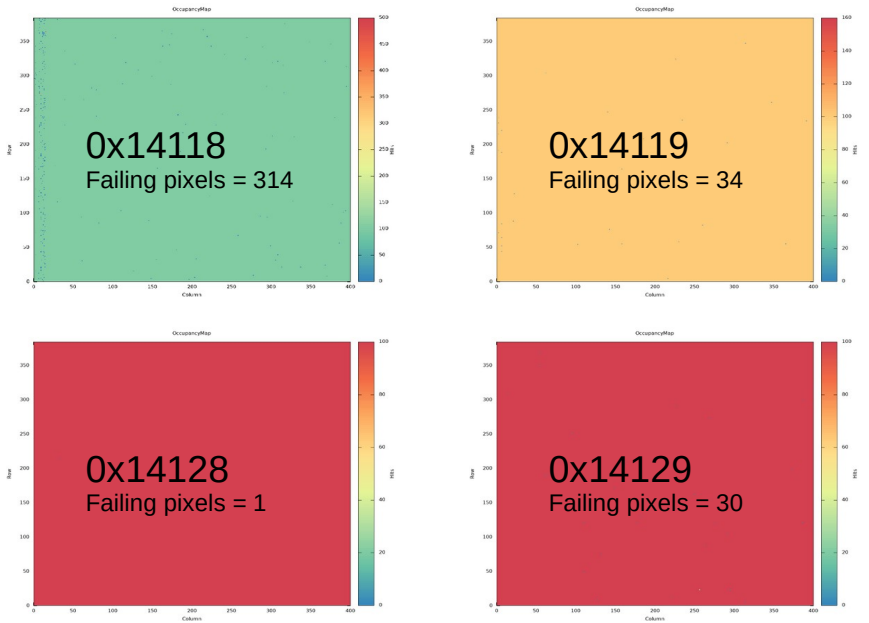
Digital Scan



User time: 46.5 s
Analysis: 740 µs
Configuration: 620 µs
Processing: 0 µs
Scan: 39198 µs

Trigger frequency = 5 KHz
Injections = 100

Analog Scan

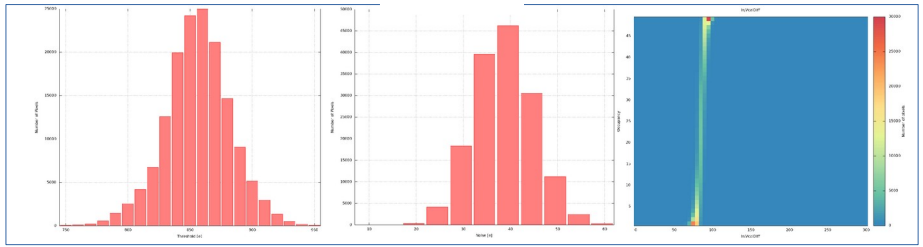


User time: 46.3 s
Analysis: 729 µs
Configuration: 703 µs
Processing: 0 µs
Scan: 43065 µs

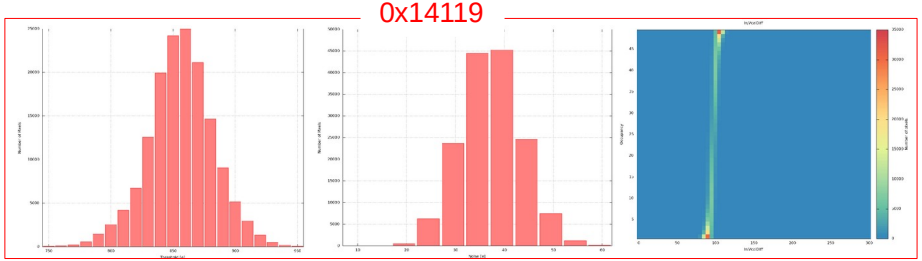
Scan results (2/2)

Threshold Scan

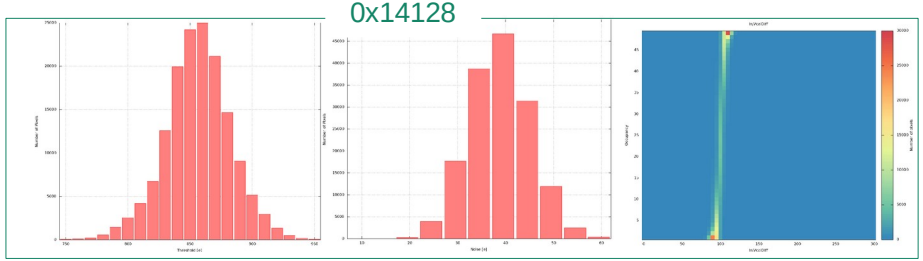
0x14118



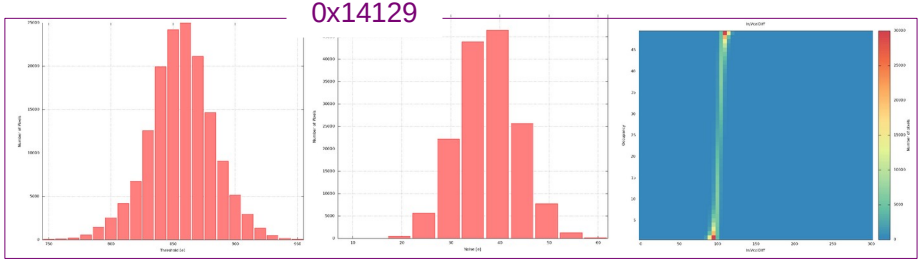
0x14119



0x14128



0x14129



```
[ info ][ StdAnalysis ][20872]: [1][0x14128][0] Threshold Mean = 978.6095947752412 +- 30.810425680406215
[ info ][ StdAnalysis ][20869]: [0][0x14118][0] Threshold Mean = 855.4551088958542 +- 29.785273598132484
[ info ][ StdAnalysis ][20878]: [3][0x14119][0] Threshold Mean = 945.6960709171823 +- 25.520117177133592
[ info ][ StdAnalysis ][20872]: [1][0x14128][0] Noise Mean = 38.77379065992978 +- 6.260338252076129
[ info ][ StdAnalysis ][20872]: [1][0x14128][0] Number of failed fits = 4
[ info ][ StdAnalysis ][20875]: [2][0x14129][0] Threshold Mean = 963.3372355625197 +- 25.759518161537752
[ info ][ StdAnalysis ][20869]: [0][0x14118][0] Noise Mean = 38.55561013224672 +- 6.336692879729476
[ info ][ StdAnalysis ][20869]: [0][0x14118][0] Number of failed fits = 123
[ info ][ StdAnalysis ][20878]: [3][0x14119][0] Noise Mean = 37.25460401490792 +- 6.102259783450186
[ info ][ StdAnalysis ][20878]: [3][0x14119][0] Number of failed fits = 24
[ info ][ StdAnalysis ][20875]: [2][0x14129][0] Noise Mean = 37.52114141691696 +- 6.063402691153536
[ info ][ StdAnalysis ][20875]: [2][0x14129][0] Number of failed fits = 6
```

User time: 1503.3 s
Analysis: 787 µs
Configuration: 696 µs
Processing: 0 µs
Scan: 1733258 µs

Timing vs N Front-Ends (FEs)

Scans	1 FE	2 FE	3 FE	4 FE (full quad)
Digital	User time: 11.81s "analysis": 563, "config": 191, "scan": 27788	User time: 23.71s "analysis": 770, "config": 401, "scan": 32795	User time: 37.25s "analysis": 800, "config": 569, "scan": 37742	User time: 47.92s "analysis": 740, "config": 775, "scan": 42364
Analog	User time: 12.05s "analysis": 556, "config": 206, "scan": 28238	User time: 25.02s "analysis": 465, "config": 377, "scan": 34853	User time: 37.10s "analysis": 496, "config": 548, "scan": 39639	User time: 48.34s "analysis": 800, "config": 748, "scan": 44799
Threshold	User time: 373.32s "analysis": 704, "config": 186, "scan": 1251930	User time: 768.90s "analysis": 734, "config": 399, "scan": 1430736	User time: 1195.37s "analysis": 621, "config": 538, “scan": 1594621	User time: 1544.56s "analysis": 886, "config": 704, "scan": 1743871

Configuration time scales with number of FEs, looks suspicious and obvious place for improvement.

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 time-based firmware-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 before sending the calibration injection and trigger sequence. All scans can be run successfully at 5KHz frequency. MR !659

Next steps

Future improvements:

- Firmware limitations (running scans above 5 KHz frequency, and for more than 100 injections) and FELIX SW wishlist items (such as setting FELIX registers for running various scan configurations through DAQ SW) to be communicated to the experts (ANL), hopefully at the upcoming ITk week.
- Better parallelization for configuring the module and other timing optimizations to be done in YARR.

- To switch to latest FELIX SW (FELIX-star) and FELIX-Client (for YARR).

- To setup the SP quad module chain readout with FELIX.