

Module Electrical QC & LocalDB

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on behalf of module electrical QC and LocalDB team

Upgrade week, May 2023

<https://indico.cern.ch/event/1223748/>

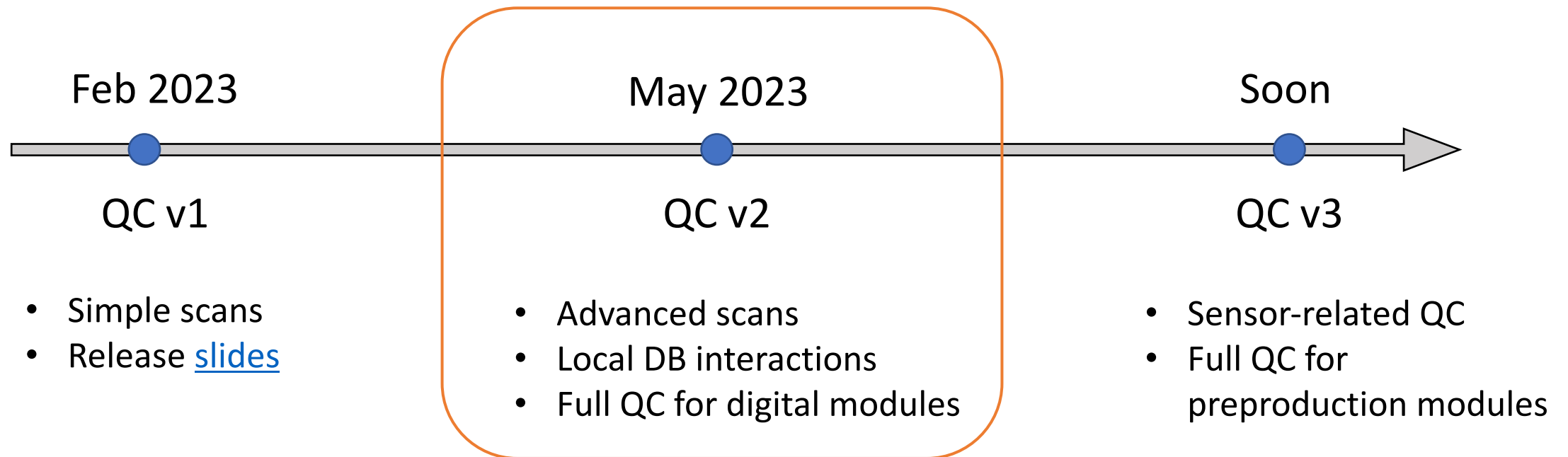


BERKELEY LAB




Module electrical quality control (QC): Define testing **procedures** and **specifications** to ensure that modules perform electrically well, providing **tools** for testing

LocalDB: intermediate aggregation place at testing sites of the of the QC data during production



Specifications and procedures are documented:

[AT2-IP-QA-0025 v.1](#) (latest version on [Gitlab](#))

	Electrical specification and QC procedures for ITkPixV1.1 modules		
Project Document No.: AT2-IP-XX-XXXX	Institute Document No.:	Created: 24th March 2022 Modified: 26th January 2023	Page: 1 of 29 Rev. No.: 0.1

For pre-production and production, **specifications will change** but electrical testing **procedure will stay the same**

We have currently defined specifications using the pre-production BoM. But all digital modules are using the LBL BoM → digital modules slightly out of some spec

Full suite of tests:

1. First power-up
2. ADC calibration + update chip configs
3. Analog readback + update chip configs
4. SLDO qualification
5. Vcal calibration + update chip configs
6. Injection capacitance + update chip configs
7. Low power mode
8. Over-voltage protection
9. Undershunt protection (QC v3: not ready)
10. Data transmission (QC v3: not ready)
11. Link sharing (QC v3: not ready)
12. Minimum health test
13. Tuning + update chip configs
14. Pixel failure analysis

Simple
scans

Advanced
scans

Section 3 of [electrical QC document](#)

Tools to aid in electrical QC procedure

The goal of these tools is to:

- Make electrical testing procedure easier and faster
- Standardize testing across different sites

<u>Measurement</u>	<u>Analysis</u>	<u>Database interactions</u>
module-qc-tools	module-qc-analysis-tools	module-qc-database-tools

Python-based packages with minimal requirements for use:

- Computer with [YARR](#) and \geq Python3.7
- Command-line control of lab equipment (i.e. labRemote)

Thank you to QC-v2 developers:

Kehang Bai, Timon Heim, Kosuke Itabashi, Marija Marjanovic, Lingxin Meng, Maria Mironova, Hideyuki Oide, Elisabetta Pianori, Giordon Stark, Emily Thompson, Connor Waits

Documentation in README's

 README.md

module-qc-tools v1.3.2rc0

A general python tool for running ITkPixV1.1 module QC tests

Table of contents

1. Requirements
2. Installation
3. Usage
4. Configuration and external commands
5. Measurements
 1. ADC calibration
 2. Analog readback
 3. SLDOVI
 4. VCal calibration
 5. Injection capacitance
 6. Low Power Mode
 7. Overvoltage protection
6. Output data
7. Schema check
8. Time Estimates
9. Upload results to localDB
10. For developer

New in QC-v2

Analysis of advanced scans has been integrated into QC-tools framework



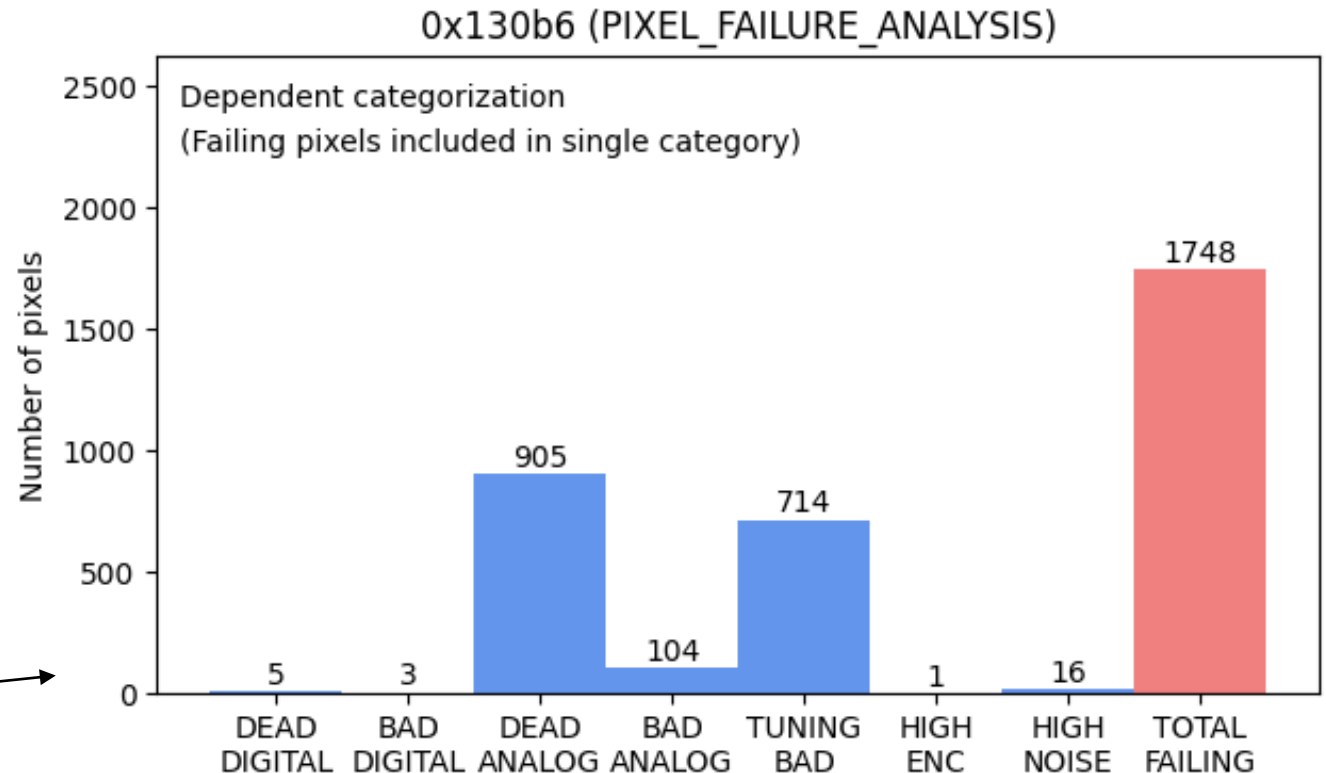
Advanced scans: minimum health test, tuning, and electrical pixel failure analysis

Each advanced scan requires user to run YARR scans – see [Appendix B.9](#) for details

Example: electrical pixel failure analysis

- Digital scan
- Analog scan
- Threshold scan
- Noise scan
- ToT memory scan

Analysis takes as input all YARR scans and produces electrical pixel failure summary



Implemented full QC flow with QC-tools and LocalDB / prodDB communication



(screenshot of simple scan analysis output)

The screenshot displays the 'Attachments' section of a software interface. It contains several items related to a scan analysis for '0x130bc':

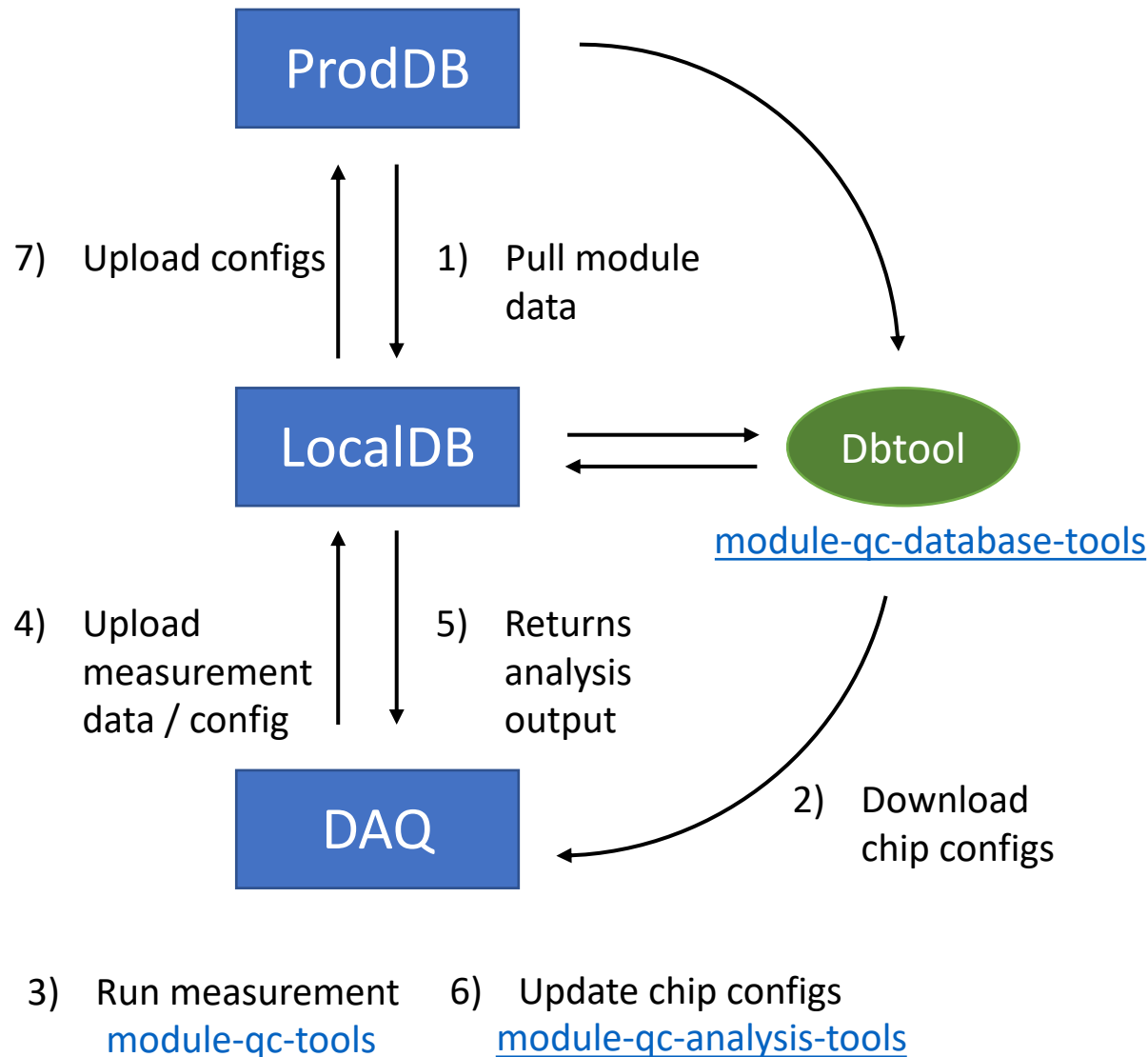
- 0x130bc_classification.png**: A bar chart titled '0x130bc (MIN_HEALTH_TEST)'. The y-axis is 'Number of pixels' (0 to 35). The x-axis categories and their values are: DEAD DIGITAL (0), BAD DIGITAL (0), DEAD ANALOG (23), BAD ANALOG (1), THRESHOLD FAILED FITS (8), HIGH ENC (3), and TOTAL FAILING (35).
- 0x130bc_summary.png**: A table titled 'MIN_HEALTH_TEST for 0x130bc' with the following data:

Parameter	Analysis result	QC criteria	Pass
BAD_ANALOG_INTEGRATED	24	[0, 153.6]	True
THRESHOLD_FAILED_FITS_INDEPENDENT	32	[0, 1536]	True
HIGH_ENC_INDEPENDENT	3	[0, 1536]	True
- 0x130bc.log**: A log file with a 'Download' button.
- output.log**: An output log file with a 'Download' button.
- 20UPGFC0078012_MODULE_INITIAL_WARM_MIN_HEALTH-TEST.zip**: A zip file with a 'Download' button.

Red arrows point to the bar chart with the text 'Plots from analysis'. Another red arrow points to the table with the text 'QC results'. A third red arrow points to the log files with the text 'Analysis logs'. A fourth red arrow points to the zip file with the text 'Scan results'.

New in QC-v2: Communication with LocalDB

QC-v2 workflow:



Major change since QC-v1: **analysis of QC data performed in LocalDB**

We have tested this workflow at LBNL – it works!

All steps except first and last are bash-scriptable ([example from LBNL](#))

Notes:

Step 2: The Dbtool will obtain chip configs from previous stage or if not present, will generate from wafer probing

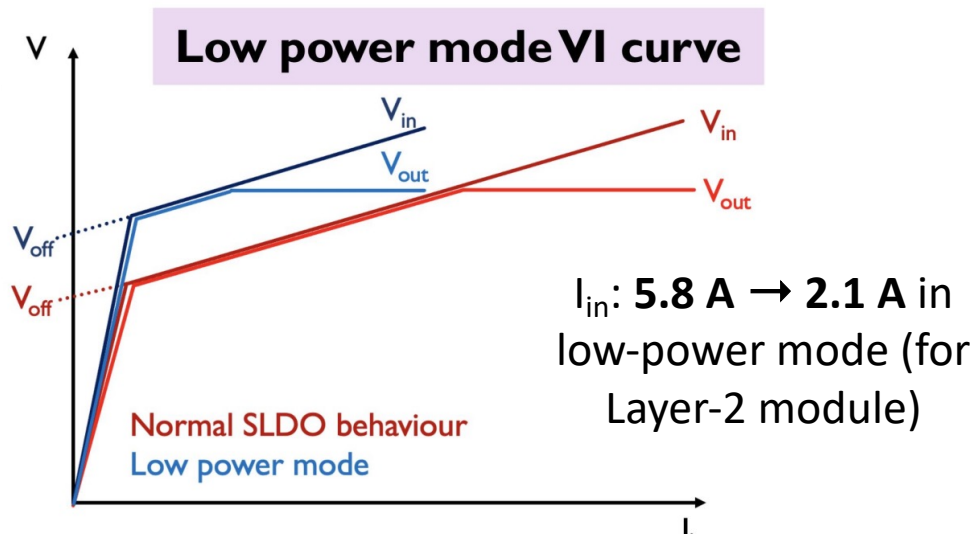
Steps 4-5 performed together: on upload LocalDB performs analysis and returns results when finished

Steps 3-6 repeated for each simple scan. Advanced scan workflow differs slightly (see backup)

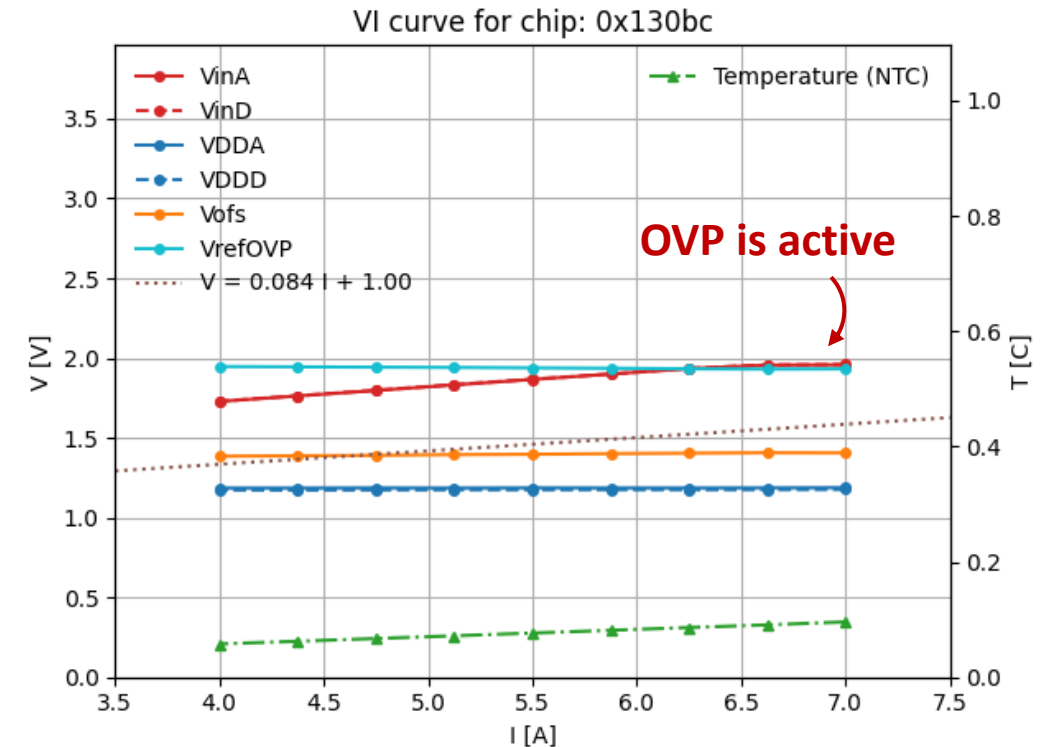
More simple scans have been integrated into QC-tools framework



Low-power mode increases V_{offset} , allowing for chip to become operational for testing at lower I_{in}



Over-voltage protection (OVP) prevents V_{in} from exceeding 2V. OVP is tested in low-power mode.



- [Low-power mode](#) switch implemented in [firmware](#)
- Requires special low-power chip configs

How long does it take to perform electrical QC on a quad module?

Time to perform scans (minutes)	Measurement	Analysis
ADC calibration		
Analog readback		
SLDO		
VCal calibration		
Injection capacitance		
Low-power mode		
Over-voltage protection		
Undershunt protection	TBD	TBD
Data transmission	TBD	TBD
Minimum health test		
Tuning		
Electrical pixel failure analysis		
Full pixel failure analysis	TBD	TBD
Total time		

We have some ideas for speeding up simple scans

- re-write scans to reduce number of times needed to upload configs
- reduce granularity
- remove duplicate measurements of GND

Next steps for module electrical QC (QC-v3)

Next steps for QC

We have made significant progress in previous 3 months, and we have a clear path forward on missing items:

Step	Stage 1 (digital module) warm				Stage 2(full QC)	spec	procedure	measurement	analysis	local db	database
	1	2	3	4							
Low level	first power-up					✓	✓	NA	NA	NA	NA
		config from DB (Wafer probing)				NA	NA	✓	NA	NA	✓
			ADC calibration			✓	✓	✓	✓	✓	✓
			Analog readback			✓	✓	✓	✓	✓	✓
			SLDO VI			✓	✓	✓	✓	✓	✓
			Vcal calibration			✓	✓	✓	✓	✓	✓
			Injection Capacitance			✓	✓	✓	✓	✓	✓
		Simple scans		config from DB (elec QC)		NA	NA	✓	NA	NA	□
				LP mode		✓	✓	✓	✓	✓	✓
				Undershunt protection		□	□	□	□	□	□
			Data Transmission		□	□	□	□	□	□	
			Overvoltage protection		✓	✓	✓	✓	✓	✓	
High level		Min. health test			✓	✓	✓	✓	✓	✓	
		Tuning			✓	✓	✓	✓	□	✓	
		(Elec) Pixel Failure 1.0		Pixel Failure 2.0	✓	✓	✓	✓	□	✓	
		Sensor-related QC	source scan		□	✓	✓	□	□	✓	
			disc bump		□	✓	✓	□	□	✓	
	0-bias			□	✓	✓	□	□	✓		

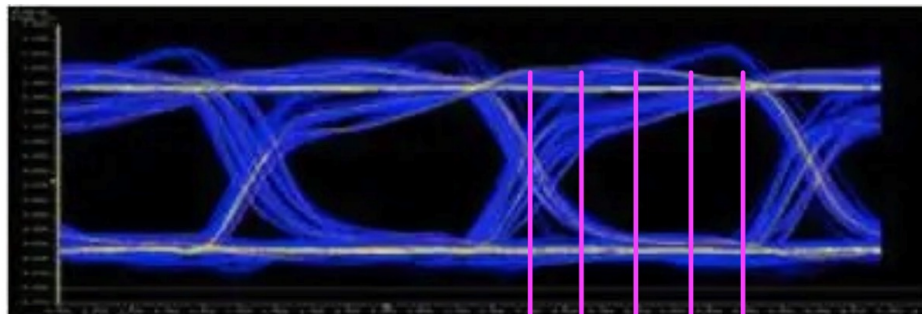
Only two remaining simple scans needs to be integrated:

1. Under-shunt protection – Lowers V_{ref} to reduce I_{load} if I_{load} approaches I_{in}

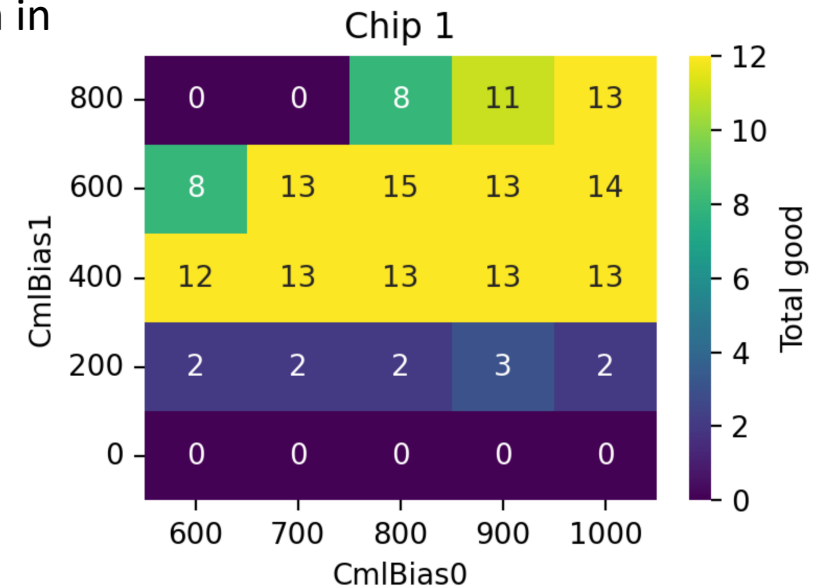
- Testing procedure has been proposed – specifications and integration into tools still needed
- See recent [update](#) from Konstantin Mauer

2. Data transmission

- Operation at 1.28 Gbps is more stable after adding new deserialiser in YARR firmware, allowing for manual varying of sampling delay (see recent [update](#) from Maria Mironova).
- Next step is to release new firmware, implement eye-diagram scan in QC-tools, consider data merging

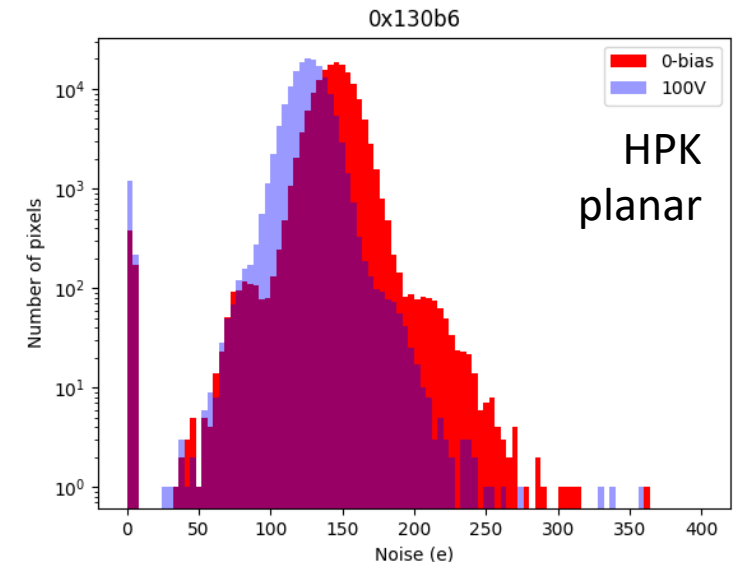
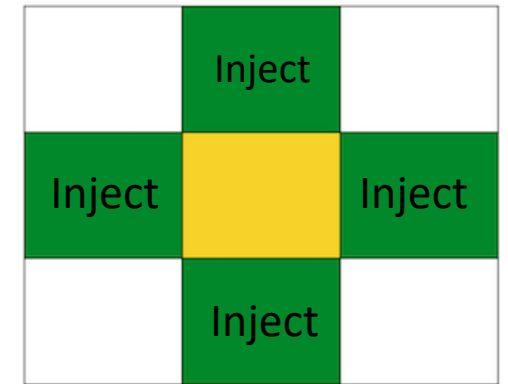


Different sampling delays



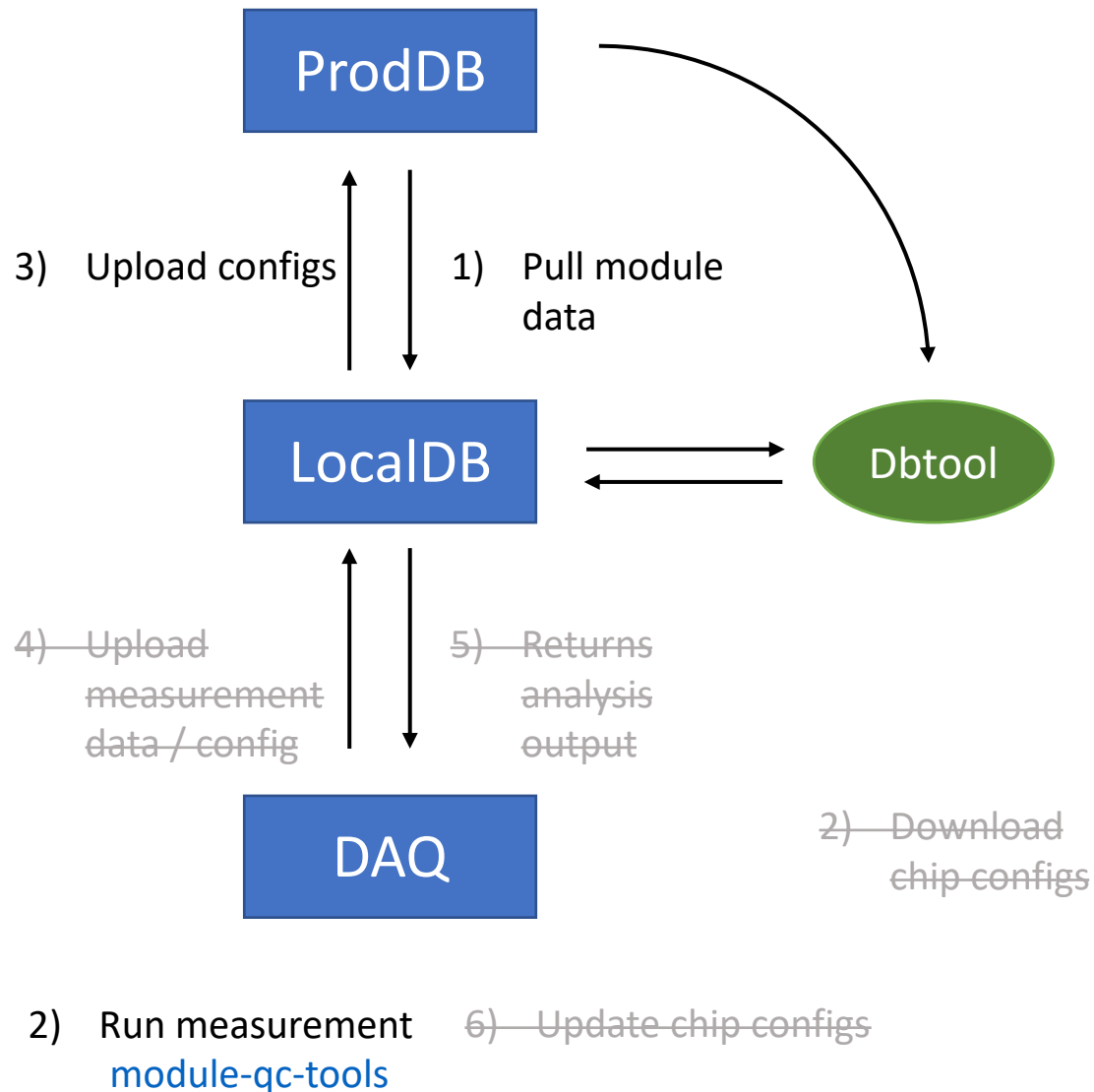
Full pixel failure test – following scans have been partially **implemented into QC-tools framework**, but **missing procedure / specifications** – we need all module / sensor types to converge quickly

- Merged bump scan
 - Inject moderate charge into neighboring pixels, do not expect cross-talk unless merged
- Disconnected bump scan
 - Inject very high charge into neighboring pixels, expect cross-talk if connected
- Zero-bias scan
 - Compare noise from threshold scan with and without sensor biased
- Source scan
 - Run source scan, expect hits if connected



We will develop procedure and specifications based on what we have available at LBNL (currently two modules, one HPK planar and one Advacam micron)

QC-v3 workflow:



For QC-v3 (full QC flow), we envision:

Simplified workflow, further automation

- No handling of chip configs in local file system
- YARR communicates directly with localDB, obtaining chip configs when running measurements
- Update of chip configs happens in localDB with analysis
- Wrap in GUI: no need to open terminal

Site qualification update

Qualification for blocks 11.1-11.3 is progressing

We will release qualification for block 11.4 (advanced scans) soon, and am working towards what is needed for sensor-related QC with pre-production modules

Mention how many sites have qualified?

Review team:

Electrical QC coordinators + Abhishek Sharma, Jon Taylor, Yannick Dieter, Anastasia Kotsokechagia, Emily Thompson

Email us:

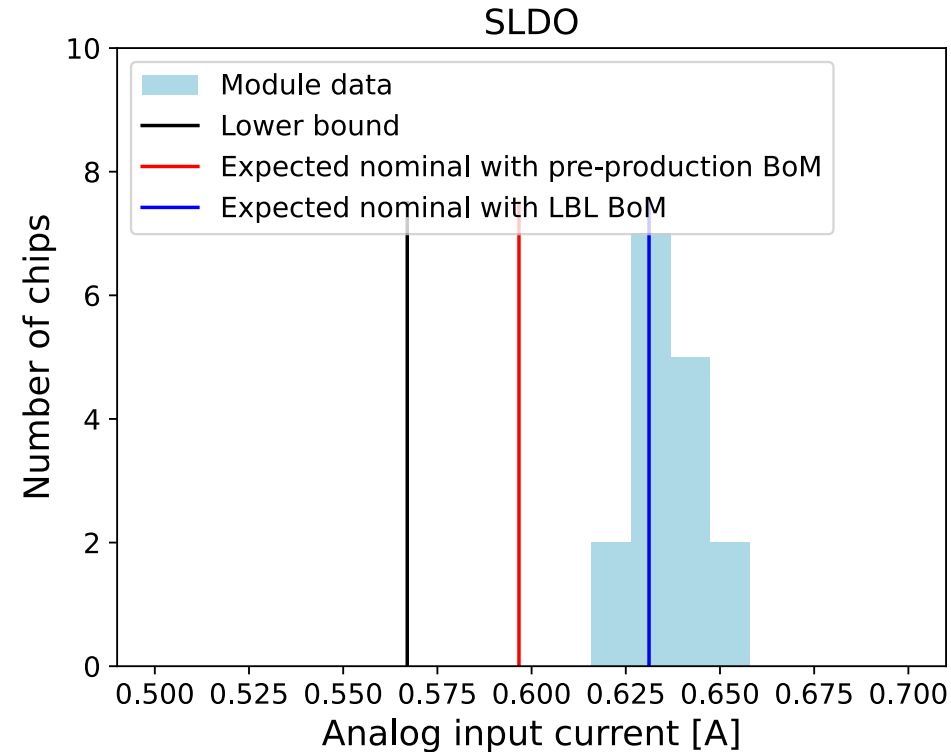
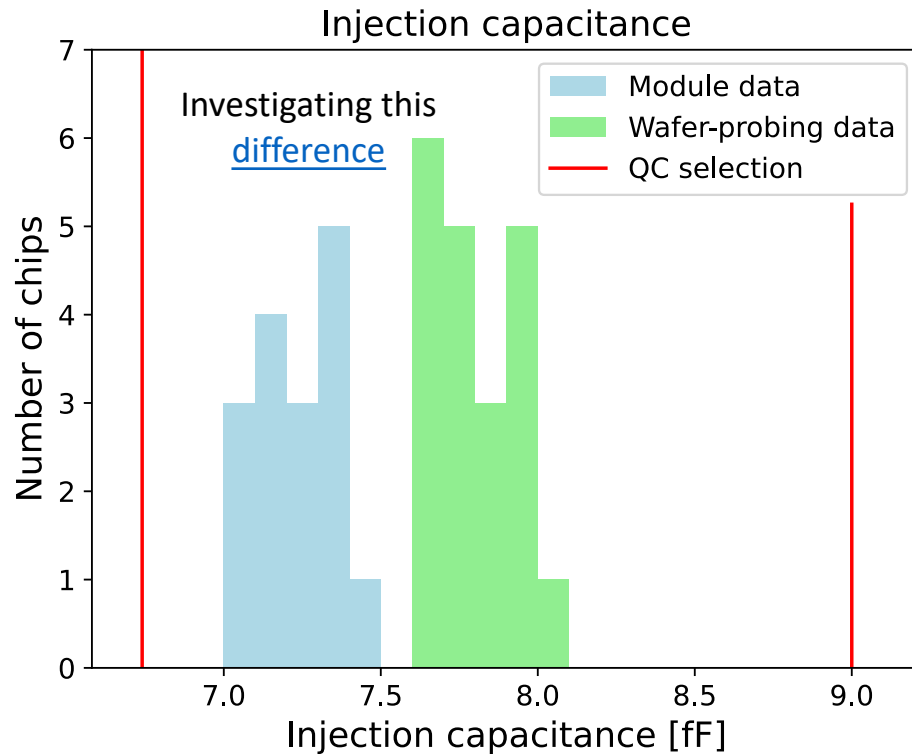
itk-pixel-module-electricalQCreview@cern.ch

11	Digital module tests			
		11.1	First power-up	TRUE
		11.2	Minimal tests	TRUE
		11.3	Simple scans	TRUE
		11.4	Advanced scans	FALSE
		11.5	Swapping module	FALSE
		11.6	Quad & Triplet Complementary stage	FALSE

From [Module Site Qualification](#)

Update this

Analysis of 5 digital modules tested at LBNL:



Chips may fall out of spec for this QC criteria (expected)

Next steps: More in-depth analysis, perform analysis from data in prodDB, allow comparison of module QC results at different stages.

- We have **framework for full workflow in place** – including simple scans, advanced scans, and communication with LocalDB
- Adding / changing electrical tests will be significantly easier now that we have framework in place
- Our focus in the next few weeks:
 - Finishing up simple scans
 - Sensor-related QC
 - Releasing remaining site qualification blocks
 - Improving / speeding up workflow

Electrical QC Documentation:

- Module electrical QC document ([EDMS](#), [Gitlab](#))
- [Module QC Stages and Tests](#)
- [Module Site Qualification](#)
- Template for module QC qualification (11.1-11.3): [template](#)

LocalDB useful links:

- [Local Database User Support mattermost](#)
- [LocalDB documentation](#)
- [LocalDB issue tracker](#)
- [LocalDB demo videos](#)

Support:

- [Electrical testing meeting](#): **Tuesdays, 5 pm CET**
- Follow regular updates from electrical QC in [Module WG meeting](#): **Thursdays, 4 pm CET**
- The [Mattermost](#) Electrical Testing channel
- Make an [issue](#) on gitlab : report problems encountered during testing, helps keep discussions in the same thread if mattermost gets too hectic
- Above support is sufficient so far, however module QC group will setup “office hours” if needed

<https://gitlab.cern.ch/atlas-itk/pixel/module>

atlas-itk > ... > module

M module [New project](#)

Group ID: 34875 [Leave group](#)

Recent activity Last 30 days

Merge Requests created	29	Issues created	35	Members added	4
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Subgroups and projects Shared projects Archived projects Updated

- > **I ITkPix_preprod** 0 2 1
- > **R rd53a_program** 0 2 1
- M module QC measurement tools** [Maintainer](#) ★ 3 16 hours ago
- M module QC analysis tools** [Maintainer](#) ★ 2 16 hours ago
This project contains the code used to analyze the data from electrical testing of...
- M module QC database tools** ★ 0 23 hours ago
- I itkpix-electrical-qc** ★ 2 1 day ago
- M module QC data tools** [Maintainer](#) ★ 0 3 days ago
this project contains the modules needed to write/read the data files used in the ...

So far we have received **positive and constructive feedback** – we encourage users to document their difficulties / questions in issues so we can develop in a transparent way

People can contribute! Get in touch with us if you want to help develop.

Follow technical discussion of tools at the [Electrical testing meeting](#) (Tuesdays, 5 pm CET)

Eventually we will use QC data from pre-production to optimize QC procedure in production

We are not there yet. At the moment we want to collect data to:

- Adjust QC specifications
- Understand what is the module yield driver
- How frequently do we need to re-perform tests? Do chip parameters change? If so, why?

To facilitate analysis of QC results prior to prodDB-readiness, we have setup submission to google sheets via module-qc-analysis-tools

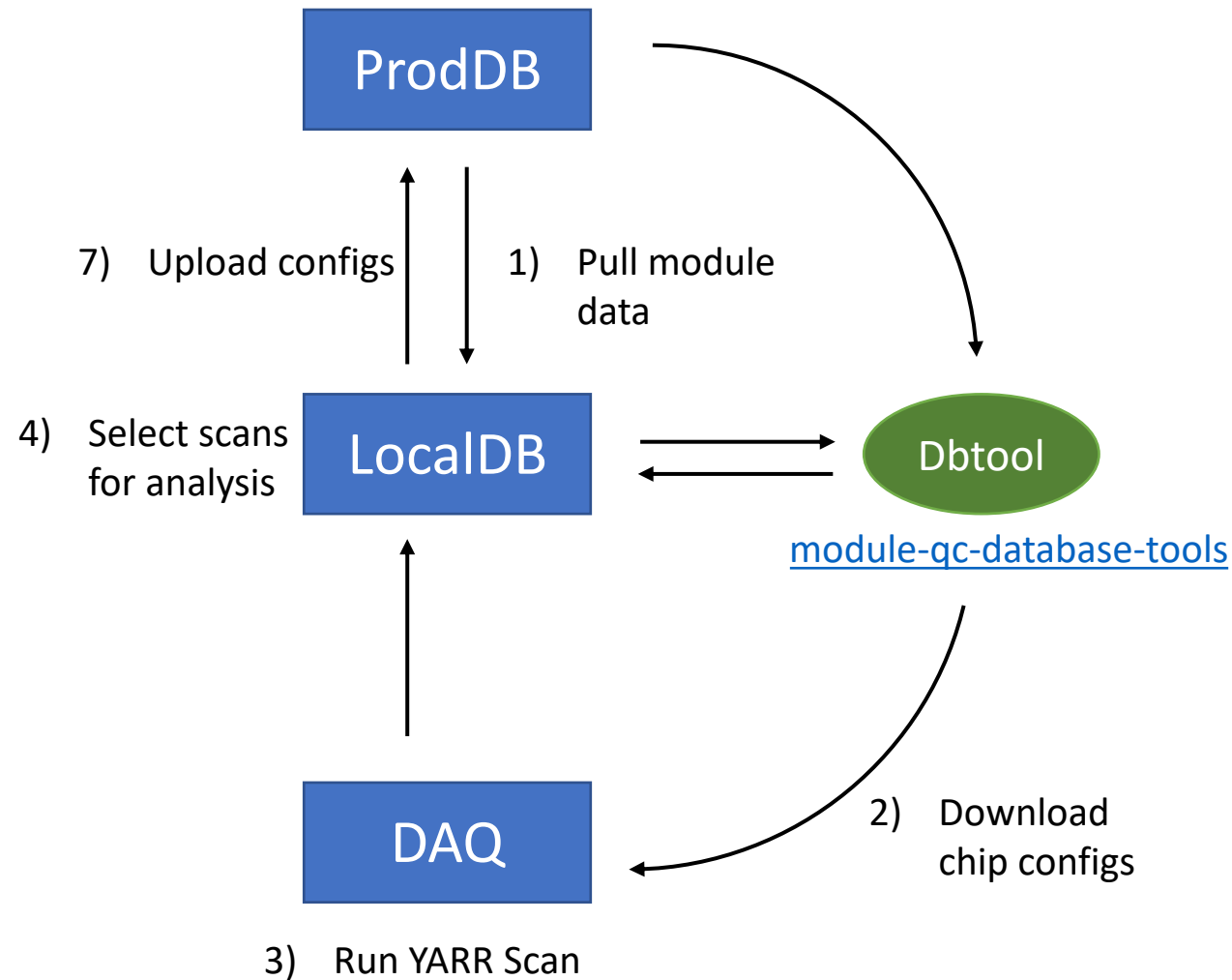
- Module-qc-analysis-tools will produce URL's (1 / chip / test), and user needs to copy/paste URL into browser to submit results (details in [SQ template](#))
- View submitted results [here](#)

Failure	Scan type	Criteria
Digital Dead	Digital Scan	Occupancy < 1% of injections
Digital Bad	Digital Scan	Occupancy < 98% or > 102% of injections
Analog Dead	Analog Scan	Occupancy < 1% of injections
Analog Bad	Analog Scan	Occupancy < 98% or > 102% of injections
Tuning Bad	Threshold Scan	$ \text{Pixel threshold} - \text{Mean threshold distribution} > 5 \times 40e^*$
High ENC	Threshold Scan	Mean pixel noise < 200e (L0) or < 300e (L1/L2)
Noisy	Noise Scan	Occupancy > 10^{-6} hits per BC
ToT Memory Failure	ToT Memory test	Occupancy < 100% of injections

Table 10: Electrical pixel failure categories

From [electrical QC document](#)

QC-v2 workflow (**advanced scans**):



Notes:

Step 2: The Dbtool will obtain chip configs from previous stage or if not present, will generate from wafer probing

Steps 3: YARR runs scan, updates chip configs locally, and uploads scan results and updated chip configs to LocalDB

Step 4: User selects YARR scans on LocalDB viewer to perform complex analysis

Steps 3, 4 is repeated for each advanced scan.

Qualification for blocks 11.1 – 11.3 released, coming soon: 11.4 - 11.5 and 12.2

How does qualification work?

1. Sites follow directions in [electrical QC document](#)
2. Sites are required to use some tools (database, analysis) and strongly encouraged to use measurement tool
3. Sites get help via [mattermost](#), creating an issue in [gitlab](#), or by attending [electrical QC meeting](#)
4. When ready, they prepare slides following [template](#)
5. Upload slides + material to cernbox, use SQ webapp to upload link, send an email to electrical QC coordinators