DUNE CE Testing @ Cincinnati

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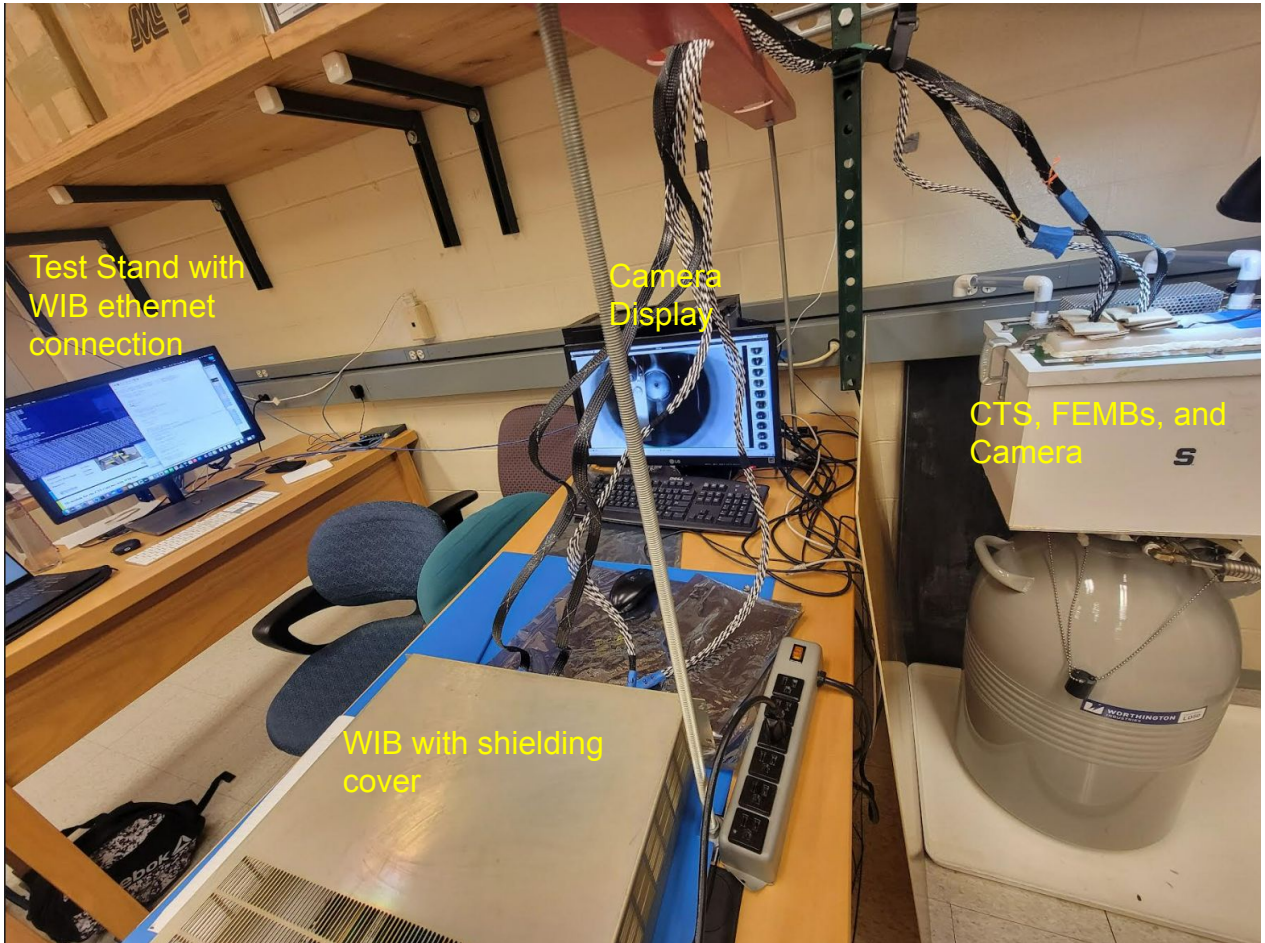
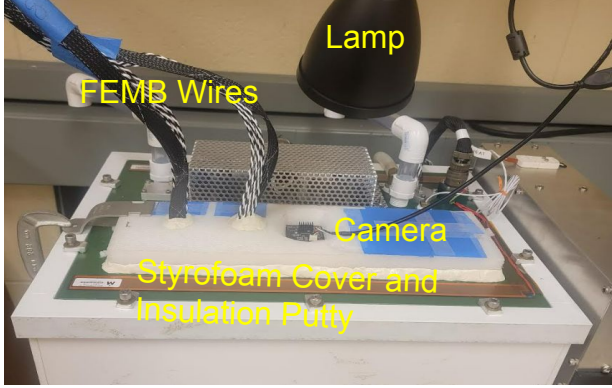
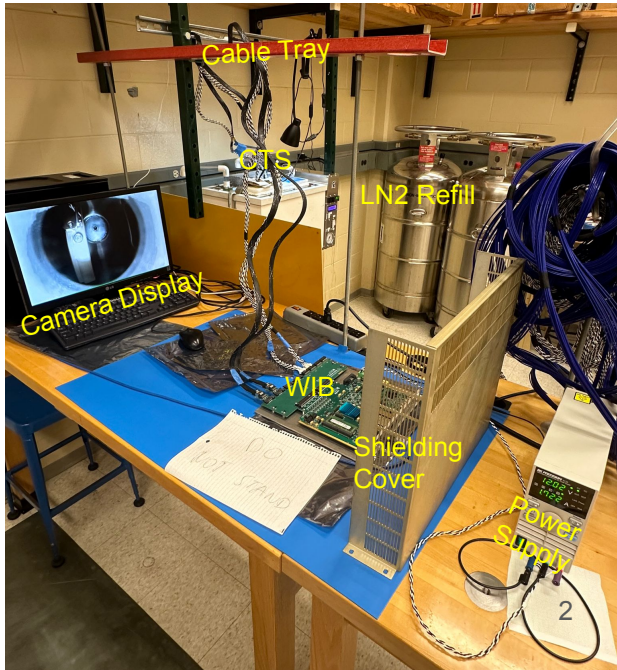
Thanks to Cheng-Ju Lin, Roger Huang, and Shanshan Gao for their help!

July 12th 2024

Updated UC Testing Setup

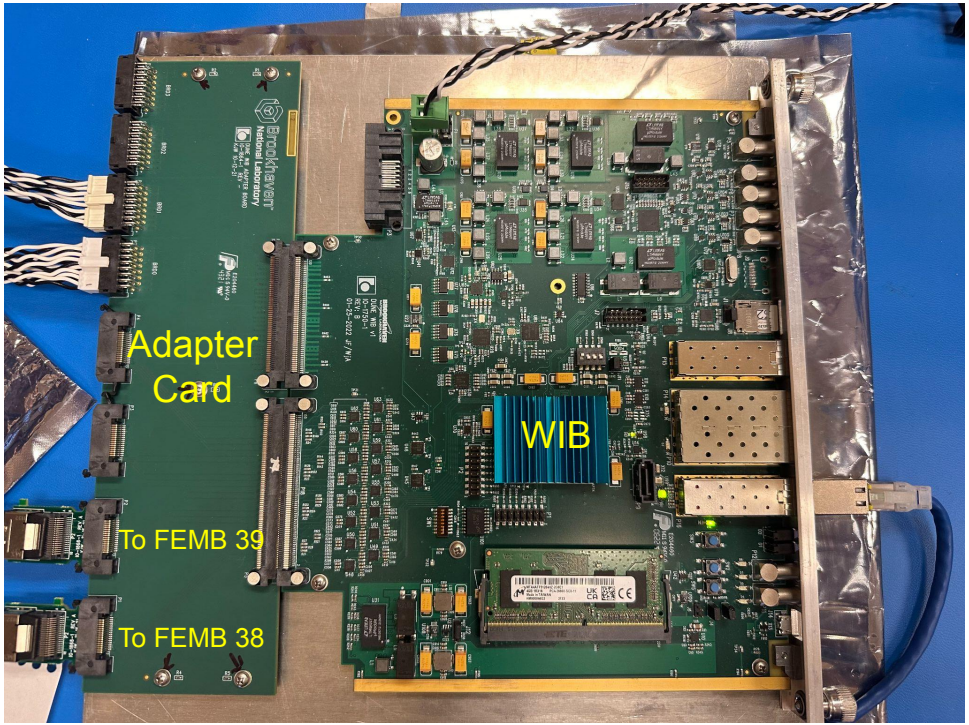


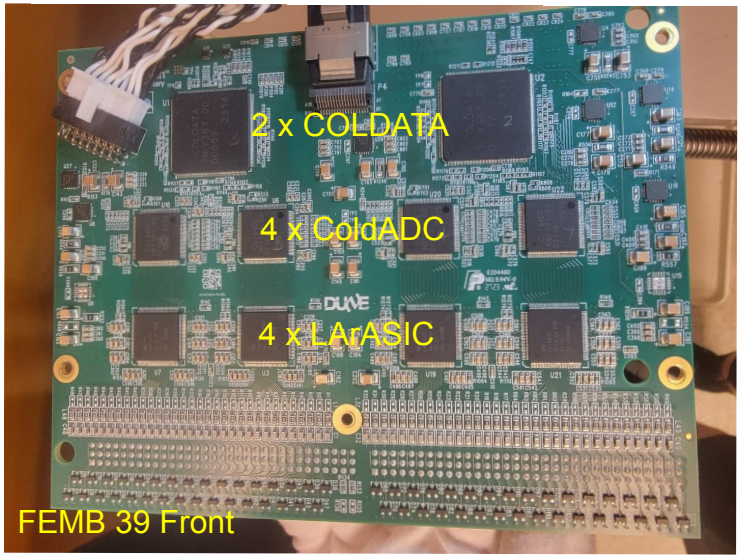


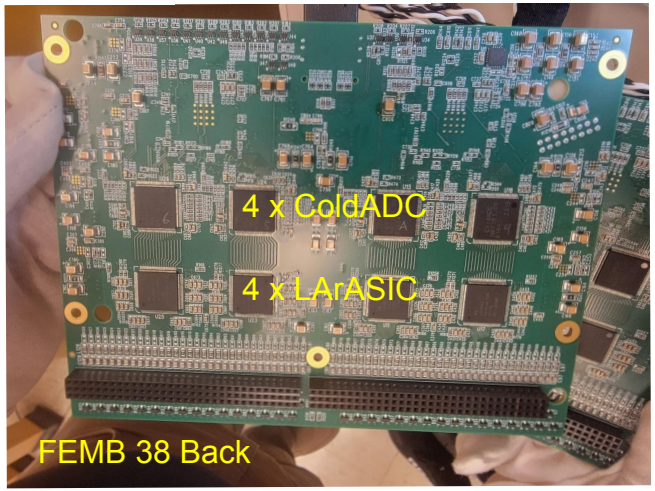


Components Being Tested

- WIB Firmware as reported by `wib_startup.py`:
  WIB FW generated at 2023-9-24 55:8:9

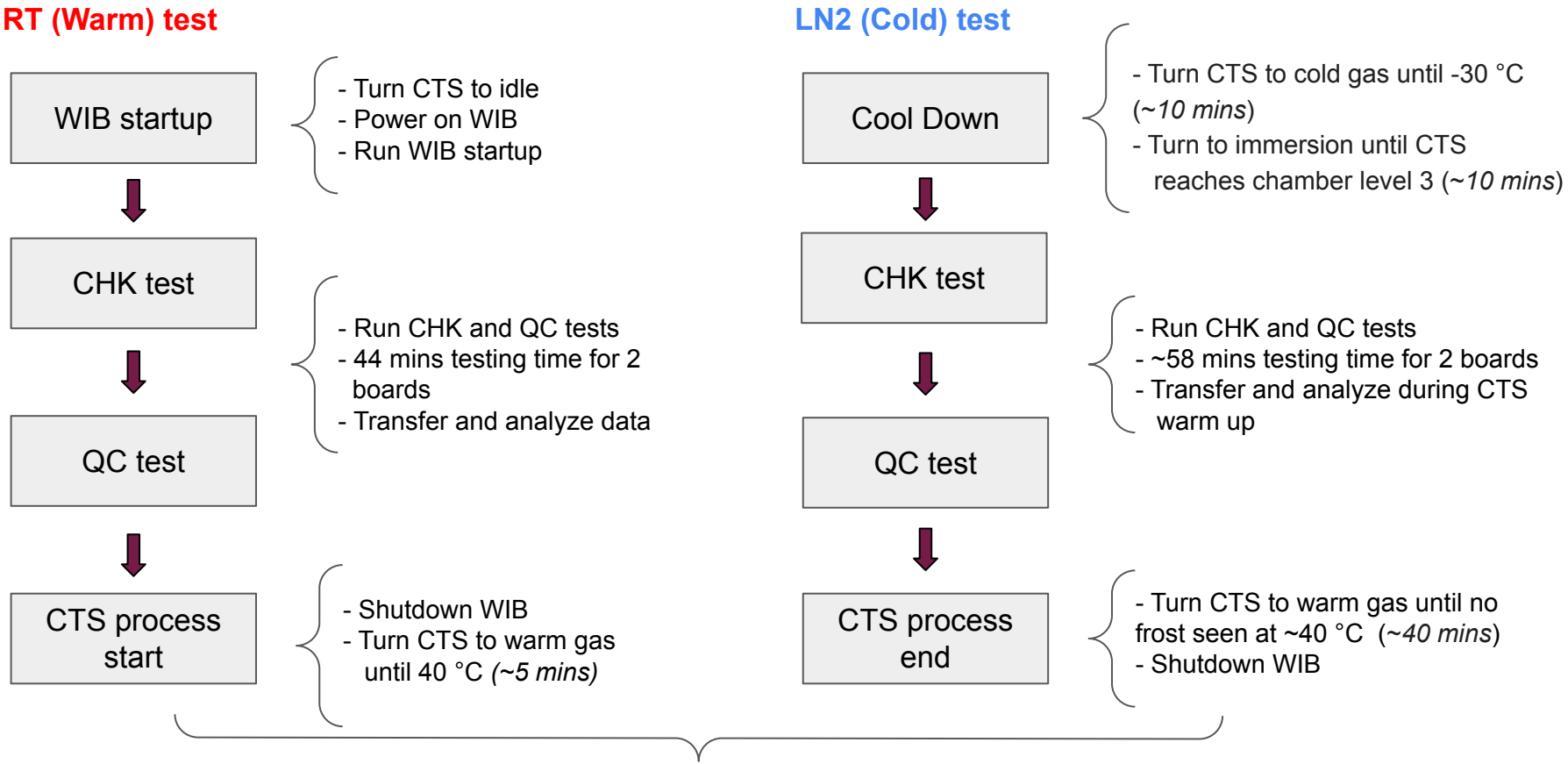






- Note: ToyTPC not available for our testing

Typical Testing Cycle



Testing Monitoring and Metadata

- Created spreadsheet where various useful metrics during testing are recorded and monitored.
  - Test and CTS process duration are computed automatically (see bottom figure)
  - Also kept track of environment, current drawn, and CTS dewar volume (see right figure)

Room Temp	Humidity	PS Avg. Currrent Drawn During Test (A)	Dewar Starting Vol (CTS Process)	Dewar Vol (Immersion L3 Start)
22.2 °C	73.10%	3.04	N/A	N/A
22.4 °C	73.20%	3.1	N/A	N/A
22.8 °C	72.60%	2.45	1590	1570
22.9 °C	72.60%	3.25	1590	1570
23.2 °C	72.00%	3	N/A	N/A
23.2 °C	71.80%	3.13	N/A	N/A
23.2 °C	69.30%	2.7	1411	1383
23.2 °C	69.10%	3.17	1411	1383

Date	Test #	Test Type	CHK or QC	Board #'s	CTS Process Start	Test Start	Test End	CTS Process End	Test Duration	CTS Process Duration
06/17/2024	1	Warm	CHK	38,39	N/A	9:47	9:48	N/A	00:01	N/A
06/17/2024	2	Warm	QC	38,39	N/A	9:51	10:33	N/A	00:42	N/A
06/17/2024	3	Cold	CHK	38,39	10:41	11:06	11:07	12:43	00:01	02:02
06/17/2024	4	Cold	QC	38,39	10:41	11:08	12:08	12:43	01:00	02:02
06/17/2024	5	Warm	CHK	38,39	N/A	12:50	12:52	N/A	00:02	N/A
06/17/2024	6	Warm	QC	38,39	N/A	12:54	13:36	N/A	00:42	N/A
06/17/2024	7	Cold	CHK	38,39	13:36	14:03	14:05	15:40	00:02	02:04
06/17/2024	8	Cold	QC	38,39	13:36	14:06	15:01	15:40	00:55	02:04

Improved testing procedures

Procedure Checklist

- Created checklist to ensure various steps in the testing procedure are not skipped, are followed in the correct order, and all bookkeeping data is recorded

- Assigned one student as Test Manager for each day of testing

UC DUNE COLD ELECTRONICS TESTING
Testing Checklist

Date:
Daily Cycle Number:

Test Manager:

#	Procedure	Initials	Comments
1	WIB is turned on: 12 V @ ~1.6V		
2	Ssh to WIB, get into script directory		
3	Ran `wib_startup.py`?		
4	Checked disk space in WIB (< 80%)? If more space needed, run clear_data.py		
5	Record **date, test number, test type, CHK or QC, board #, room temp, room humidity,** and **construction.**		
6	Start CHK Warm Test; Record **Test Start time** and the **average current.**		
7	If CHK test completed, record **Test End Time.**		
8	Begin QC Warm testing: **Repeat step 5,** record **Test Start Time** and the **average current.**		
9	If QC test completed, record **Test End Time.**		
10	Turn on "Warm Gas" for 10 minutes (40-50°C) and record the **CTS Process Start** and the **Dewar Starting Volume.**		
11	Turn the CTS to "Cold Gas"		
12	Once the CTS reaches -30°C, turn to "Immersion" and record the **Dewar Vol (Immersion L3 start).**		
13	Once the chamber level reaches L3, start the CHK Cold Test, **repeat step 5,** record **Test Start** and **avg current.**		
14	If CHK test completed, record **Test End Time.**		
15	Begin QC Cold testing: **Repeat step 5,** record **Test Start Time** and the **average current.**		
16	If QC test completed, record **Test End Time.**		
17	Transfer data from WIB to test stand using `get_ana_data.sh`		
18	If testing is completed, CTS back to "Warm Gas"		
19	Once no frost or condensation are visible inside the CTS, record the **CTS Process End** time.		
20	If testing done for the day, shutdown WIB, turn off CTS camera and light, turn off CTS. Otherwise, start new.		

Improved testing procedures

Workflow Streamlining using Python and Bash Scripts

- Modified certain scripts to simplify bookkeeping for each test
- Wrote bash scripts to automatically run processes to reduce human error and save time
- Summarized all relevant commands into procedures document

4. Open a new terminal (this will be your WIB terminal)
   `ping 192.168.121.123`, get response, ctrl-c to terminate
   `ssh wib`
5. `cd BNL_CE_WIB_SW_QC/`
6. `python3 wib_startup.py` (once every time WIB is turned on)
   a. Note that this script will sync WIB date/time with the server (no passwd input required)
7. Open another new terminal on the side to use for later (this will be your test stand terminal)

Run a checkout test

1. To run a CHK test (in the WIB terminal):

```
python3 femb_assembly_chk.py 0 save 5
```

(If you need to run more than one FEMB, add the slots separated by a space
e.g `python3 femb_assembly_chk.py 0 1 save 5`)

2. To transfer data from WIB to test stand and analyze it (in the test stand terminal):

```
get_ana_data.sh
```

Run QC test

3. To run a QC test (in the WIB terminal):

```
python3 QC_top.py 0 1
```

4. To transfer data from WIB to test stand and analyze it (in the test stand terminal):

```
get_ana_data.sh
```

Workflow Streamlining using Python and Bash Scripts

Changes made to existing *python* scripts and new *bash* macros written:

WIB startup (`wib_startup.py`)
- Updates date and time on WIB
- Checks if WIB storage usage is greater than 80% and encourages tester to run **`clear_data.sh`** macro

Clear data (`clear_data.sh`)
- Checks whether all data folders on WIB have been transferred to test stand
- Clears all data off the WIB (if data hasn't been transferred, tester is requested to run data transfer)

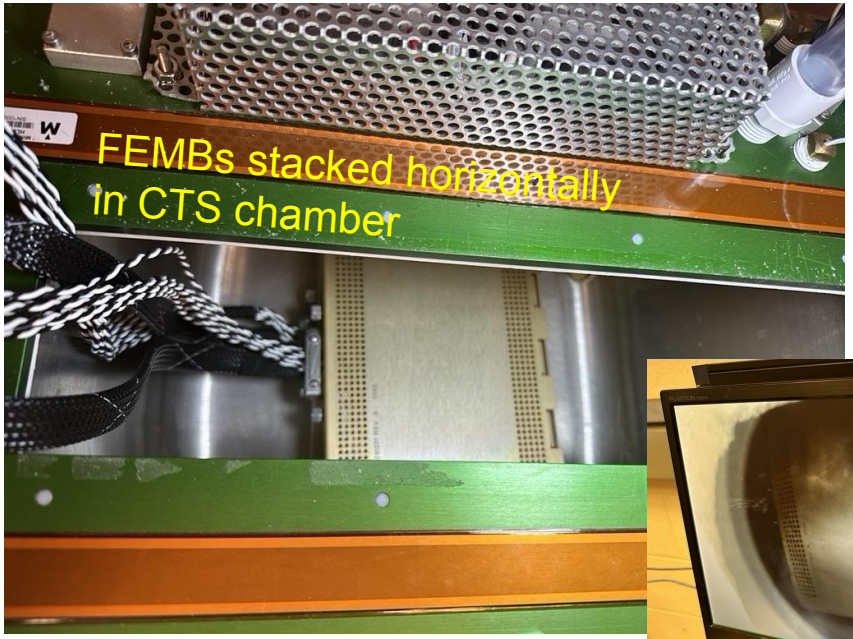
Data collection (`femb_assembly_chk.py` or `QC_top.py`)
- Automatically records date and time of test
- Requests run # from tester
- Labels *raw_data* folder with format: **`femb#_date_run#_env`**

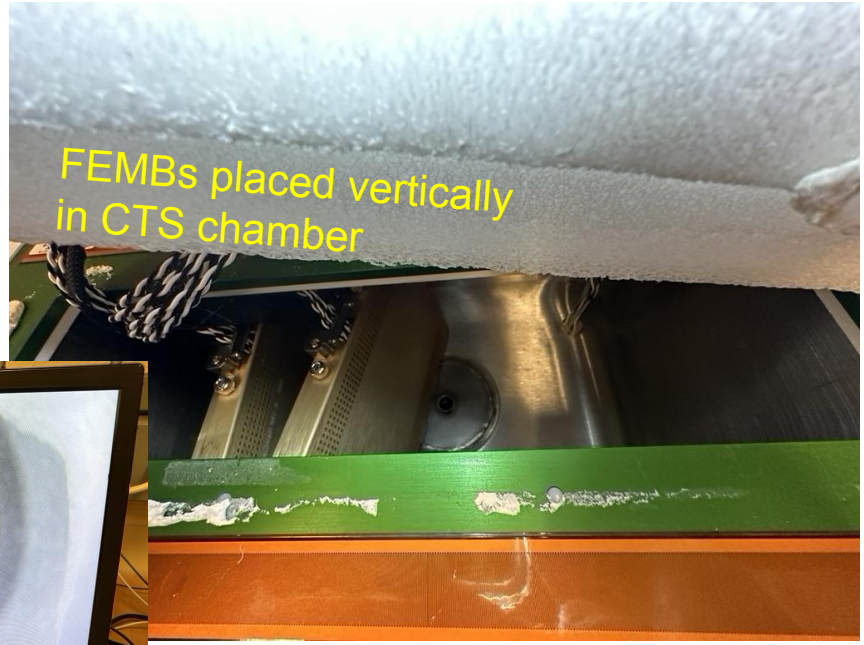
Data transfer and analysis (`get_ana_data.sh`)
- Automatically transfers data from WIB to test stand and analyzes it immediately (Tester has option to perform analysis or transfer data only)
- Labels *reports* folder with results with same format: **`femb#_date_run#_env`**

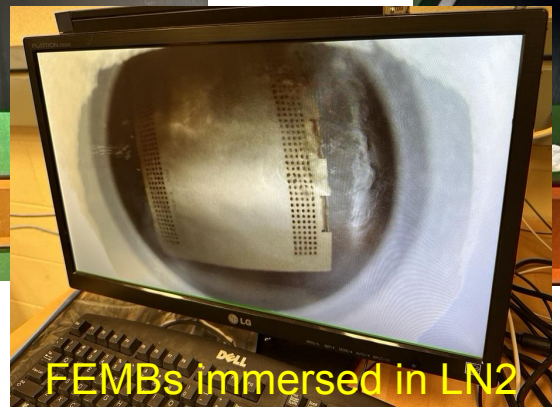
```
janus:BNL_CE_WIB_SW_QC uc_dune$ get_ana_data.sh
Transfer CHK or QC: CHK
Analyze the data y/n: y

These are the available CHK files:
femb38_femb39_07_09_2024_run08_RT_0pF

Now transferring
PWR_SE_200mVBL_14_0mVfC_2_0us_0x00.bin
Raw_DIFF_900mVBL_14_0mVfC_2_0us_0x10.bin
logs_env.bin
Mon_200mVBL_14_0mVfC.bin
MON_PWR_SE_200mVBL_14_0mVfC_2_0us_0x00.bin
MON_PWR_DIFF_200mVBL_14_0mVfC_2_0us_0x00.bin
Raw_SE_900mVBL_14_0mVfC_2_0us_0x10.bin
Raw_SE_200mVBL_14_0mVfC_2_0us_0x00.bin

Transfer of CHK files complete
Now Analysing...
/Users/uc_dune/Library/Python/3.11/lib/python/site-packages/fpdf/__init__
  warnings.warn(
./tmp_data/CHK/femb38_femb39_07_09_2024_run08_RT_0pF/
```

Testing Observations and Problems

- Ran 3 consecutive cold cycles with 2 FEMBs stacked horizontally, and 4 consecutive cold cycles with them placed vertically
- The following slides summarize observations and problems encountered during testing.

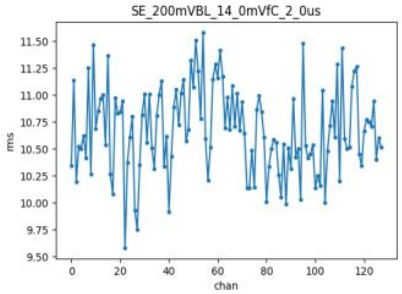


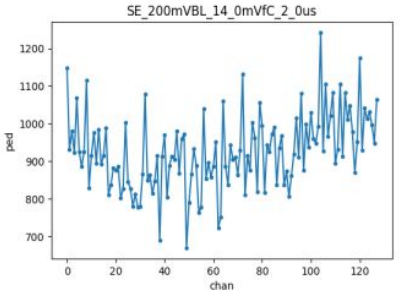


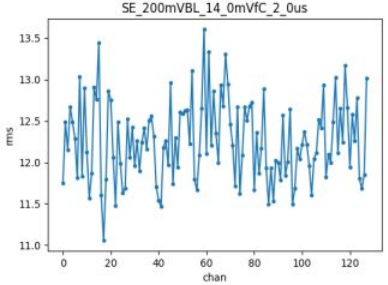


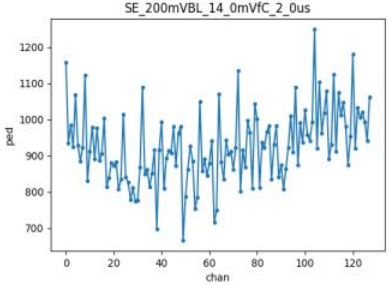
CHK Warm Results

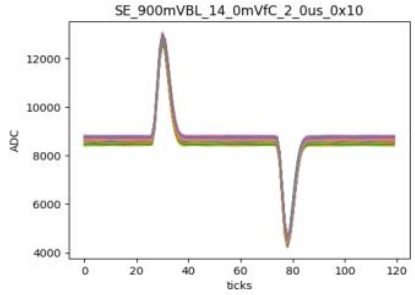
Typical example of "reasonable" CHK tests

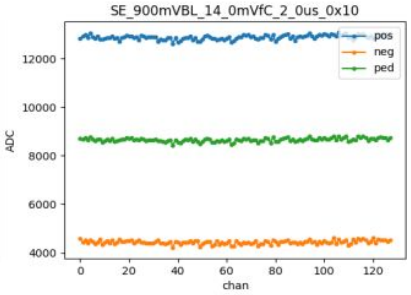


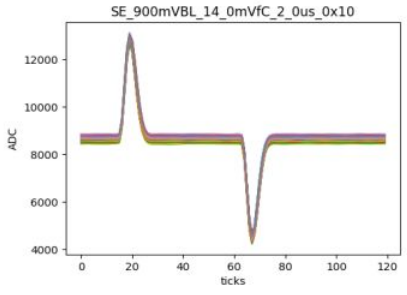


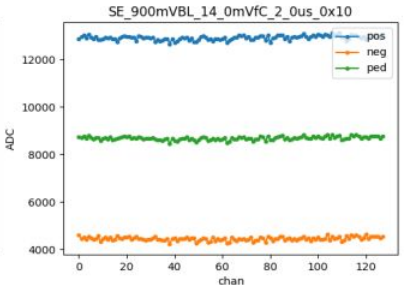


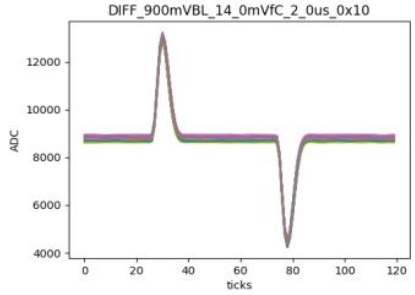


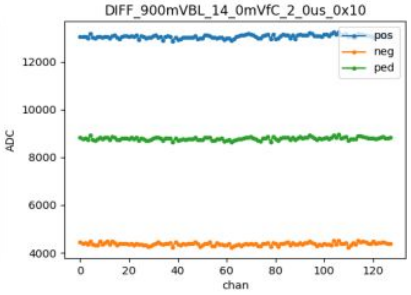


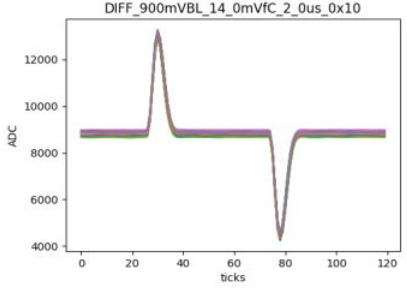


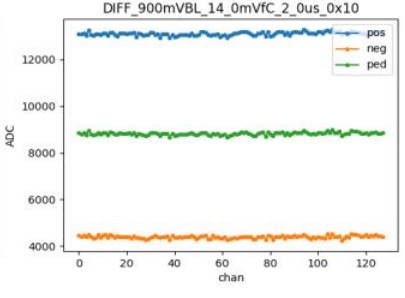






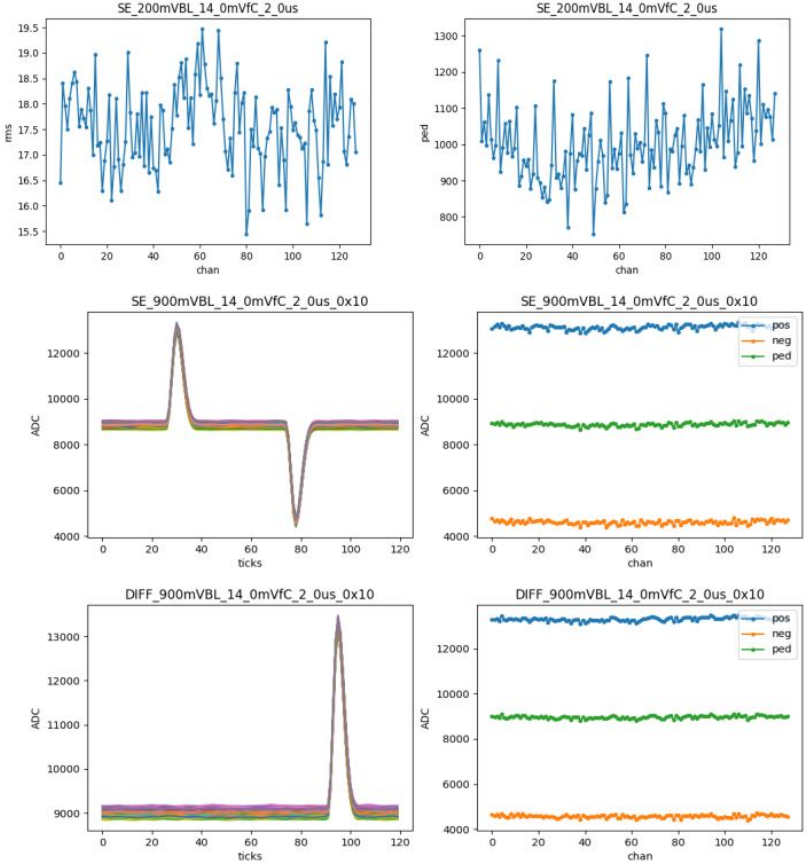




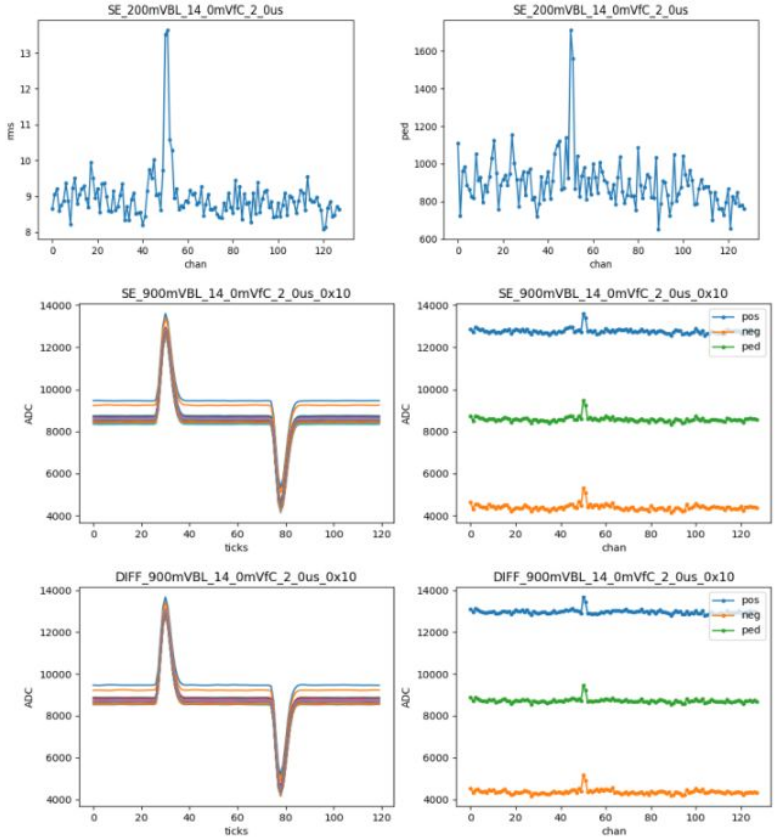


CHK Warm Results

Example of "problematic" CHK Reports



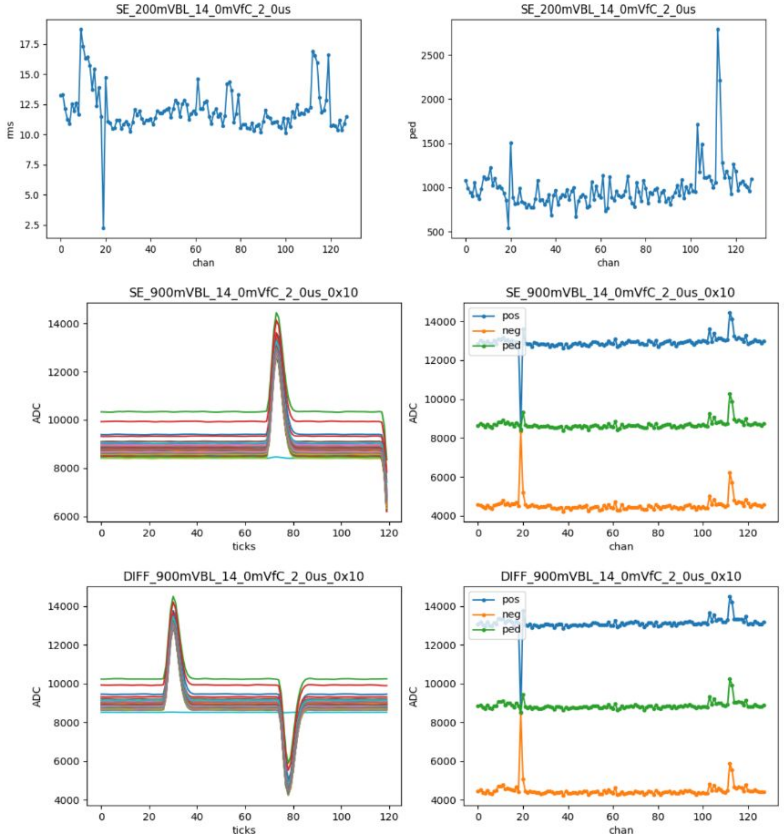
I2C error (waveform trigger not synced)



Anomalous channel(s) response

CHK Warm Results

Example of "problematic" CHK Report



I2C error and Anomalous Channel(s)

CHK Warm Test FEMB 38 Scorecard (abridged)

- Pink run numbers denote I2C errors

Date	6/17	6/17	6/18	6/18	6/20
Run Number	1	5	1	6	1
Time	9:47	12:50	9:23	12:19	9:37
Power Measurement	P	P	P	P	P
Temperature	P	P	P	P	P
BGP	P	P	P	P	P
RMS	F	P	P	P	P
200mV baseline	F	F	F	F	F
Pulse_SE	F	F	F	F	F
Pulse_DIFF	P	P	F	P	F
ADC Monitoring	P	P	P	P	P

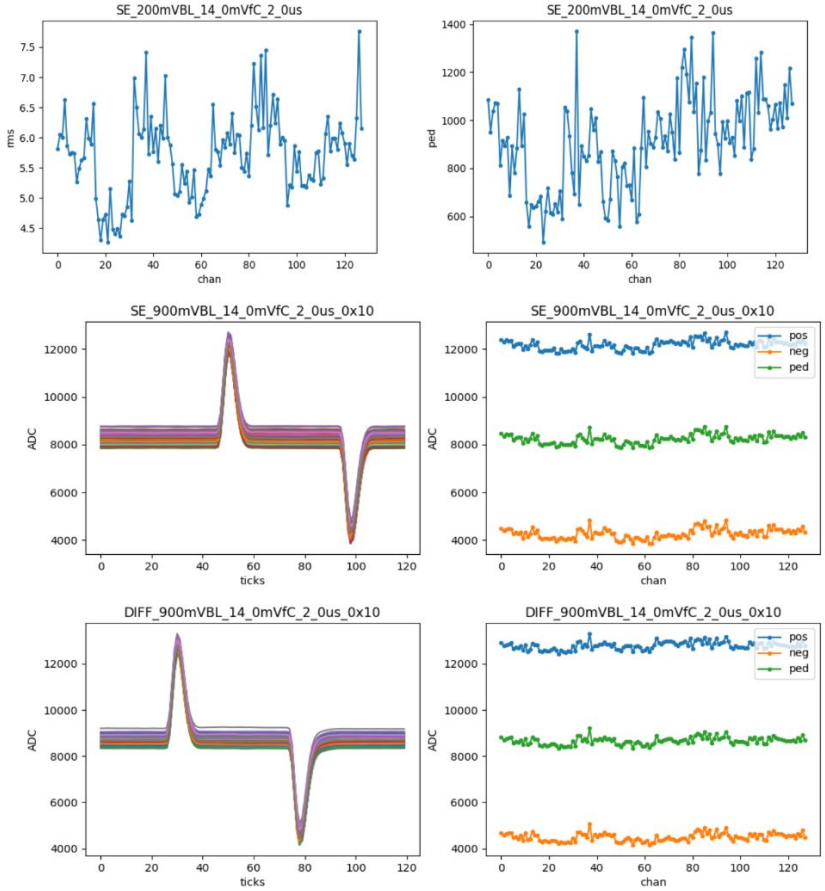
Passed for FEMB 39 in some tests

Failed for all warm tests

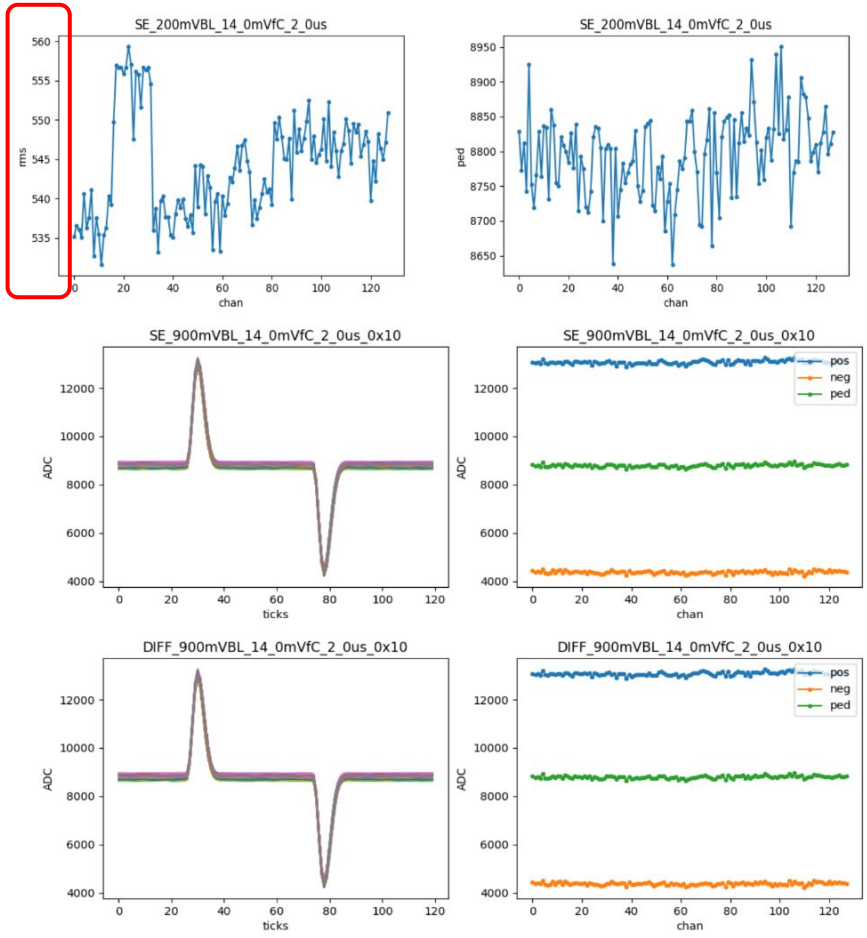
- 18 / 42 reports showed I2C errors, 42.9%.
- 5 / 42 reports showed anomalous response, 12%.
- 1 / 42 reports showed both, 2.4%.

CHK Cold Results

Example of Reasonable-looking Reports

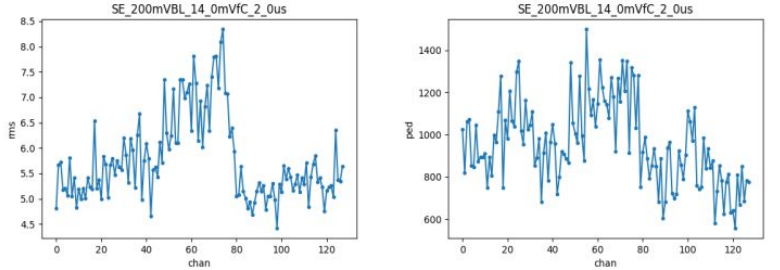


Note very large RMS scale in this run

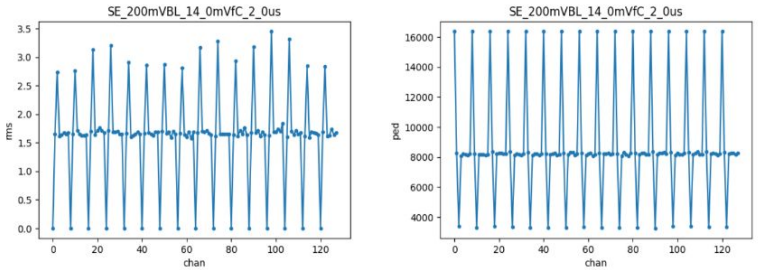


CHK Cold Results

Examples of "Problematic" Reports



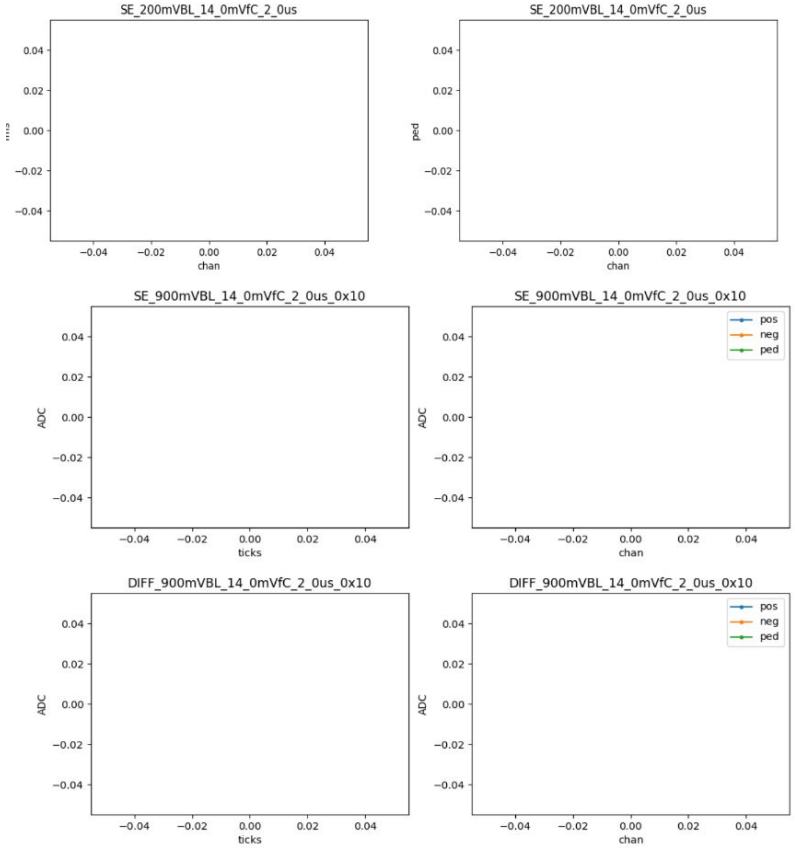
I2C error (waveform trigger not synced)



No waveform shape for any channel

CHK Cold Results

Example of "Problematic" Report



Blank graphs

CHK Cold Test FEMB 38 Scorecard (abridged)

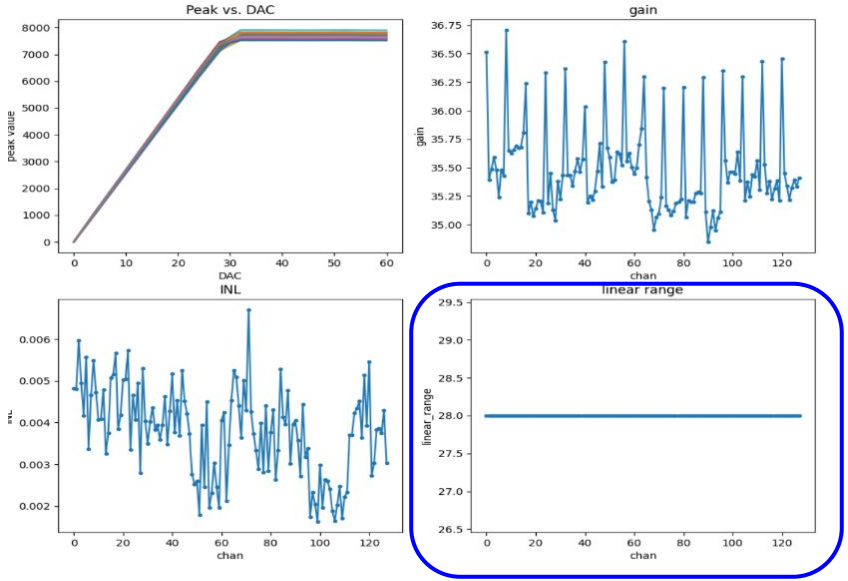
- Blue denotes No waveform shape for any channel
- Purple denotes blank graphs

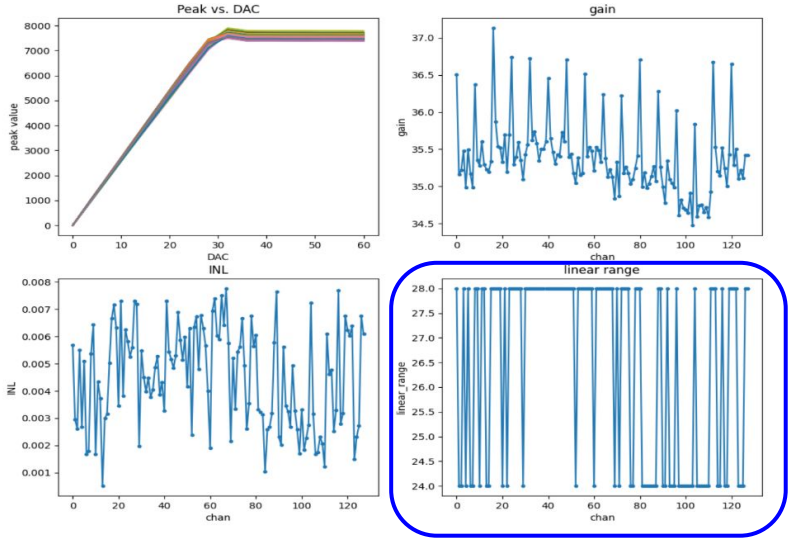
Date	6/11	6/11	6/11	6/12	6/12	6/12	6/12	6/12	6/12
Run Number	3	4	6	3	5	8	9	10	12
Time	12:07	12:13	13:31	10:42	11:56	15:00	15:03	15:09	16:11
Power Measurement	P	P	P	P	P	P	P	P	P
Temperature	F	F	F	F	F	F	F	F	F
BGP	P	P	P	P	P	P	P	P	P
RMS	F	P	P	P	P	P	P	P	P
200mV baseline	P	P	P	P	P	P	P	P	P
Pulse_SE	P	P	P	P	P	P	P	P	P
Pulse_DIFF	F	F	F	P	P	P	P	P	P
ADC Monitoring	F	F	F	F	F	F	F	F	F

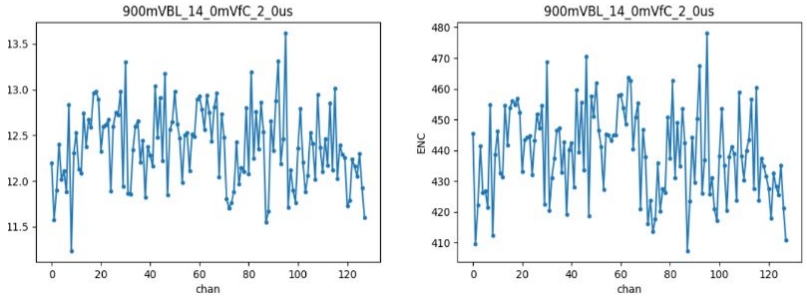
- Only 38 / 103 tests resulted in generated reports.
- 5 / 38 reports showed I2C errors, 13%.
- 12 / 38 reports showed graphs with straight lines only, 32%
- 9 / 38 reports had blank graphs, 23%

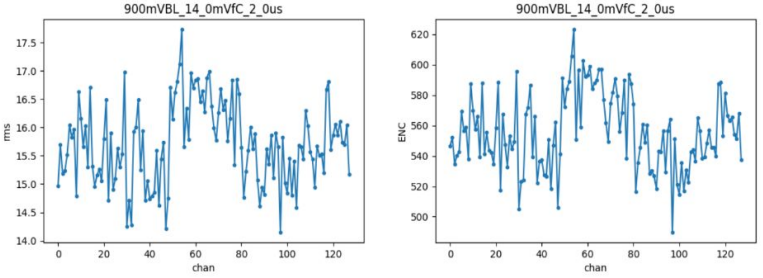
Examples of QC Warm Reports (CALI2)

- This portion of the QC test suite leads to channel saturation (expected), but variations seen in “linear range” plots









Summary of QC Warm Results for two FEMBs

FEMB 38 Scorecard (abridged)

Date	6/11	6/12	6/12	6/13
Run Number	2	2	7	2
Time	10:44	09:07	13:13	09:22
Power Consumption	F (ch 104, bchip 6)	F (ch 104, bchip 6)	F (ch 104, bchip 6)	X
Leakage Current	F (ch 104, bchip 6)	F (ch 104, bchip 6)	F (ch 104, bchip 6)	X
Pulse Check	F	F	F	X
RMS Check	F	F	F	X

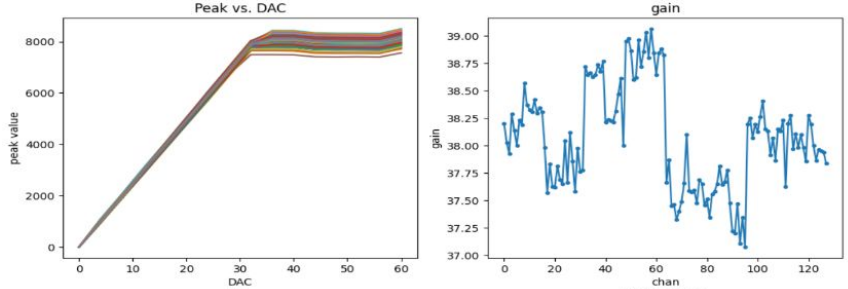
FEMB 39 Scorecard (abridged)

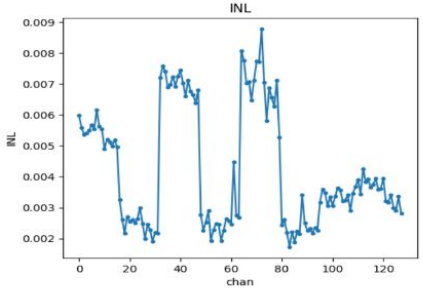
Date	6/11	6/12	6/12	6/13
Run Number	2	2	7	2
Time	10:44	09:07	13:13	09:22
Power Consumption	F (ch 24, bchip 1)	F (ch 24, bchip 1)	F (ch 24, bchip 1)	X
Leakage Current	F (peak: ch 112, bchip 7) (base: ch 48, bchip 3)	F (peak: ch 112, bchip 7) (base: ch 48, bchip 3)	F (peak: ch 112, bchip 7) (base: ch 48, bchip 3)	X
Pulse Check	F	F	F	X
RMS Check	F	F	F	X

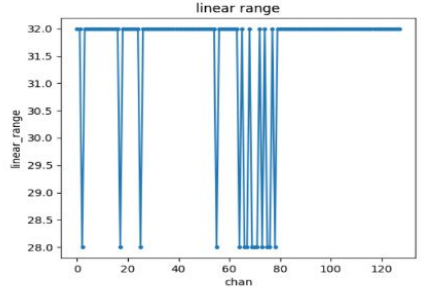
- Different channels fail between the two FEMBs, but neither of the FEMBs pass any of the reported QC tests (for CALI2)

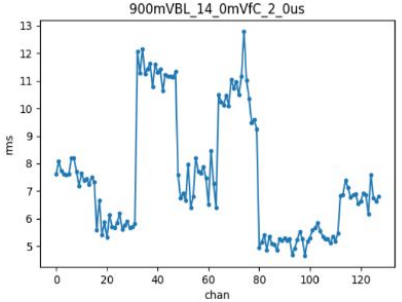
Examples of QC Cold Reports (CALI2)

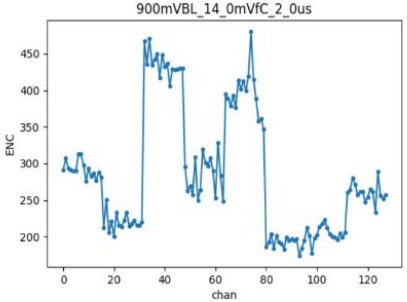
- Same observations as for Warm results

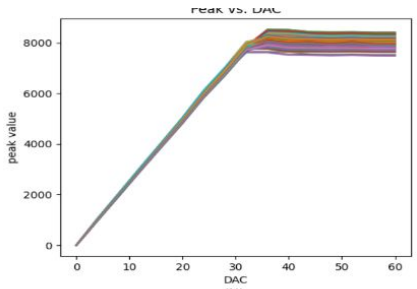


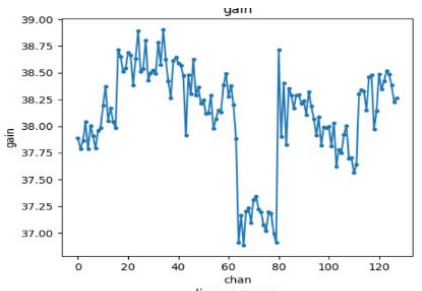


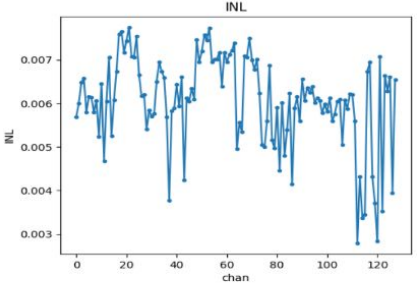


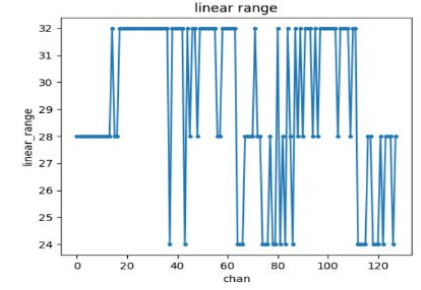


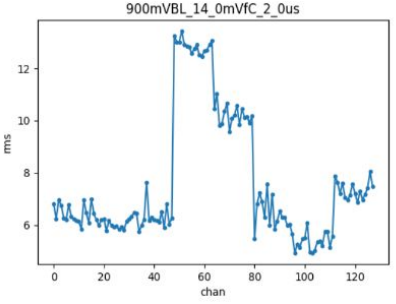


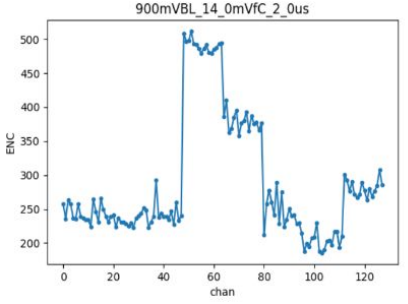












Summary of QC Cold Results for two FEMBs

FEMB 38 Scorecard (abridged)

Date	6/11	6/12	6/12
Run Number	5	4	11
Time	12:21	10:47	15:15
Power Consumption	F (ch 64,67,72,74,79, bchip 4)	P	P
Power Cycles	F (ch 64,67,72,74,79, bchip 4)	F (PWR_DIFF, PWR_SE_SDF)	F (PWR_DIFF, PWR_SE_SDF)
Leakage Current	F (base: ch 94, bchip 5)	P	P
Pulse Check	F	P	P
RMS Check	F	P	P

FEMB 39 Scorecard (abridged)

Date	6/11	6/12	6/12
Run Number	5	4	11
Time	12:21	10:47	15:15
Power Consumption	P	F (PWR_DIFF, PWR_SE_SDF, PWR_DIFF)	P
Power Cycles	F (PWR_DIFF, PWR_SE_SDF)	F (PWR_cycle0_SE, PWR_SE_SDF, PWR_DIFF)	F (PWR_DIFF, PWR_SE_SDF)
Leakage Current	F (ch 61, bchip 3, ch 25, bchip 1)	F (ch 61, bchip 3, ch 25, bchip 1)	F (ch 61, bchip 3, ch 24/25, bchip 1)
Pulse Check	F	F	F
RMS Check	F	F	F

- Different channels fail between FEMBs, as observed for Warm tests
- However, for some of the cold tests, FEMBs now pass some of the QC variables (CALI2)
- 7 out of 18 reports had blank graphs only, 38.9%
- Full suite of test results and complete scorecards can be perused in these **132 slides**!

Summary of Observations

- No obvious differences seen in test results between vertical and horizontal orientation of the FEMBs inside the CTS

- Apparently random failure modes during warm testing not understood, including no waveforms for all channels and blank graphs in reports
  - No obvious correlation with environment, CTS behavior, or which FEMB was being tested

- Majority of CHK and QC cold tests did not run or did not produce reports
  - FEMB 38 more affected than FEMB 39, but otherwise no obvious reasons found for this behavior

- Given the random behavior seen between Pass/Fail in Warm and Cold testing scorecards, it is unclear to us what we would classify as a successful CHK/QC test for a given FEMB
  - Perhaps these FEMBs 38 and 39 were known to have this random behavior from their testing at BNL?
  - Have the 17/25 FEMBs tested successfully at BNL been subjected to multiple cold cycles and behaved consistently well for all cycles?

- During this week, ran cold cycles on FEMBs without boxes, results are consistent with the above so far

- Suggestions for additional studies or different warm testing configurations are welcome!
  - Have removed CTS lid and will be shipping to BNL early next week