Powerboard Testing on Strip Modules

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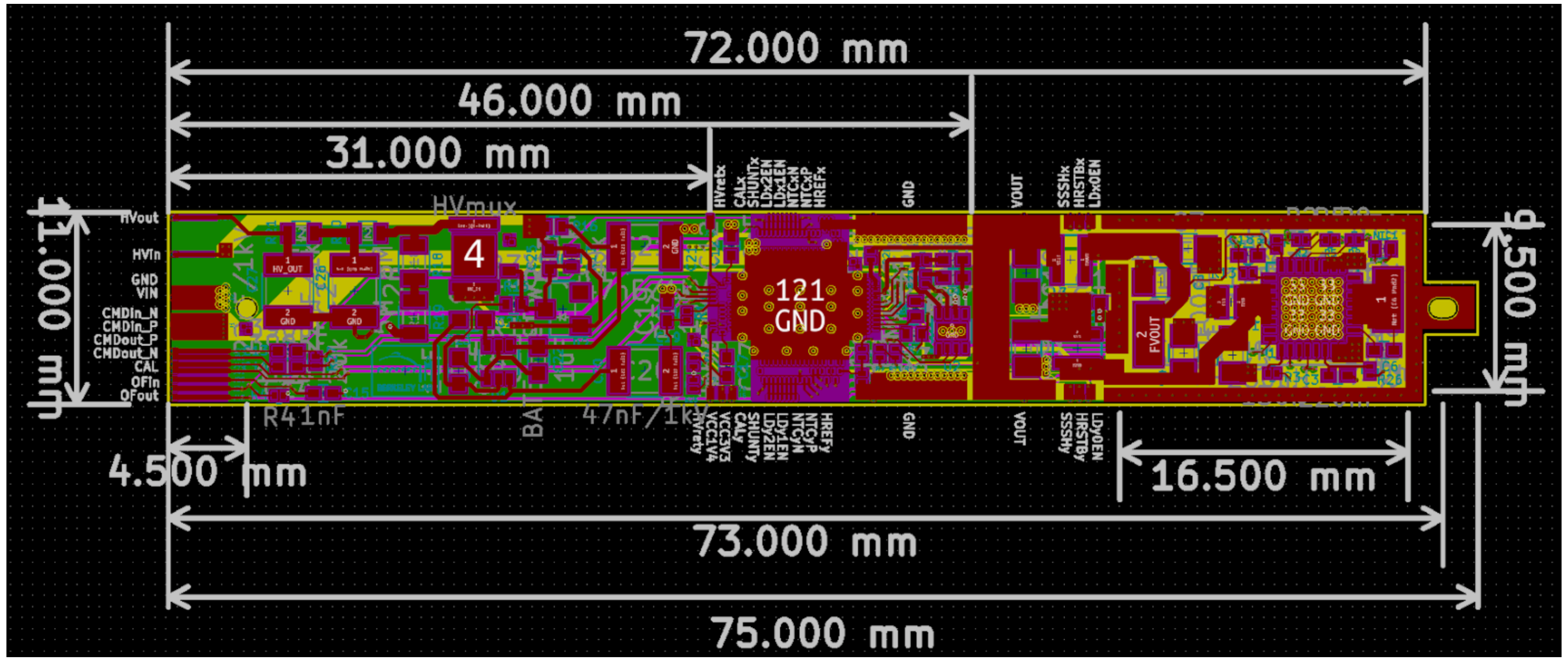
Introduction

- I am a graduate student at UC Berkeley, working on **ATLAS inner tracker (ITK) strips modules** for my qualification task



Powerboard schematic *(T. Heim et al)*

- My QT has consisted of two parts:

  1. Create an **external triggering** setup at LBL, and experiment with charge injection (September 2022 - May 2023)

  2. Implement powerboard-specific tests for **powerboards on modules**, which I will refer to as the “module powerboard QC routine” (May 2023 - present)

Deliverables

- These tasks each had one primary deliverable:

1. A **manual** for setting up a magnetic triggering test stand: available for comment **on CERNBox**

2. An automated module powerboard **test and analysis routine** integrated into ITSDAQ

This talk will showcase the module powerboard QC routine that I have developed, including

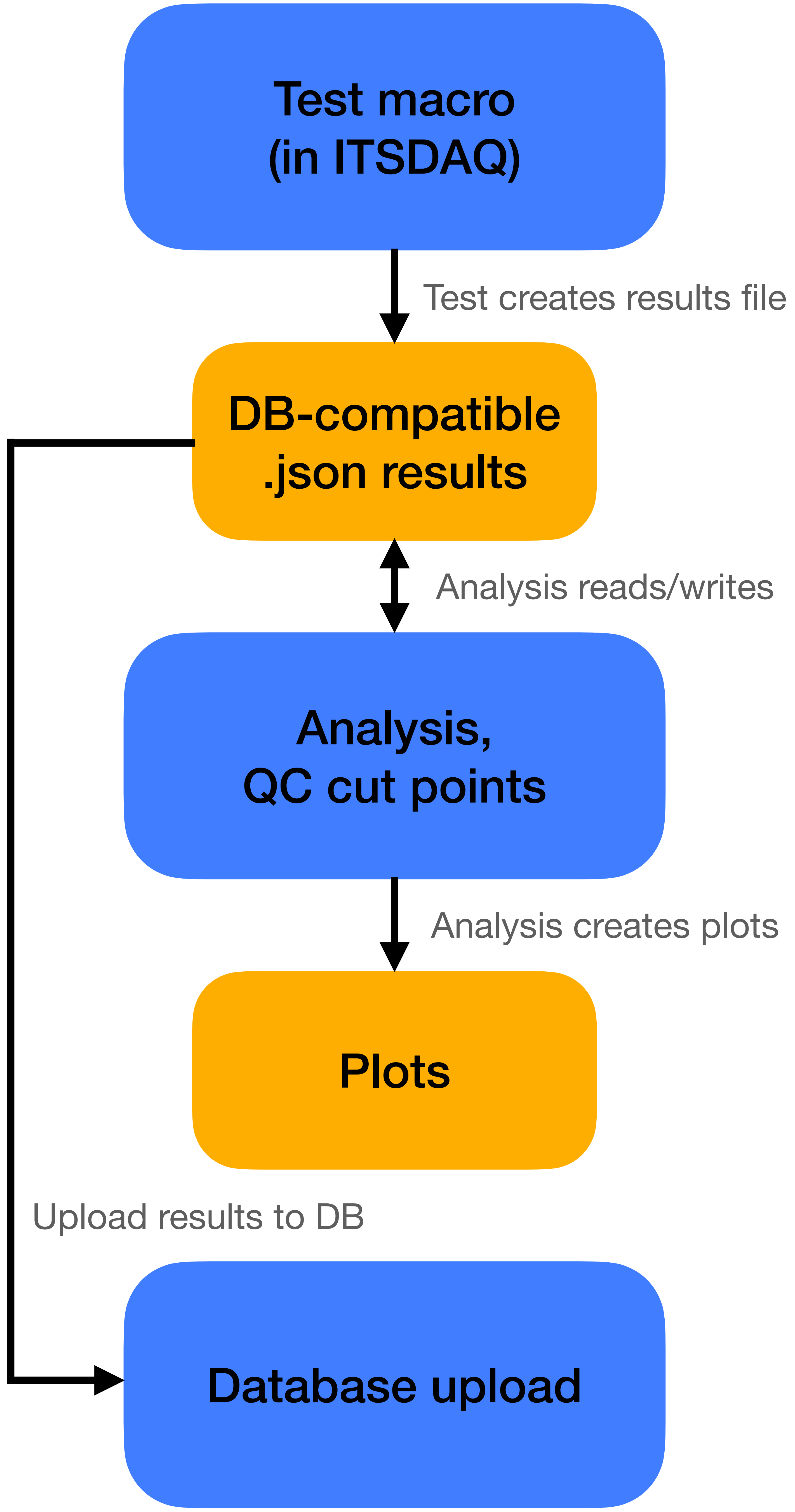
- The test structure and timing
- Data analysis procedure and QC cuts
- Support for various types of strips modules
- Defined steps for the post-QT work

Powerboard QC: Background

- Current powerboard QC is only being done **before** they are installed onto modules
- There was previously **no** QC procedure targeting the powerboards after they have been loaded onto a module
- This could mean…
  - Broken wire bonds
  - AMAC functionality issues
  - Broken/out of spec components such as NTCs
- The new QC procedure covers a majority of the electrical tests from the barrel powerboard production QC procedures, and includes some module-specific tests

Testing Procedure

- Tests are written into the Inner Tracker Strips Data Acquisition software (ITSDAQ-sw), for compatibility with experiment wide QC
- The test routine is modular, meaning that it is broken into **scans**, which each
  - generate their own results file and plots
  - target different parts of the powerboard functionality
  - invoke the same **"general QC cuts,"** which set thresholds for any AMAC readings which should not change per-test (e.g. 600/900 mV bandgap, ground voltages, etc.)



Dataset Definition

A few notes about the modules I have tested for this talk:

- “Warm” refers to room-temperature test conditions, i.e. module in an uncontrolled climate chamber. This corresponds to about **24 C**
- “coldbox” means the module was tested in our site QC box, where
  - “coldbox warm” means the temperature on the chuck was fixed at **20C**
  - “coldbox cold” means the temperature on the chuck was fixed at **-40C**
- **LS** refers to a long strip module, with 1 hybrid
- **SS** refers to a short strip module, with 2 hybrids
- In total, I tested 5 different modules - 3 in my own test setup, and 2 in the site QC coldbox

Test Types

There are currently two test types, which combined cover much of the AMAC functionality.

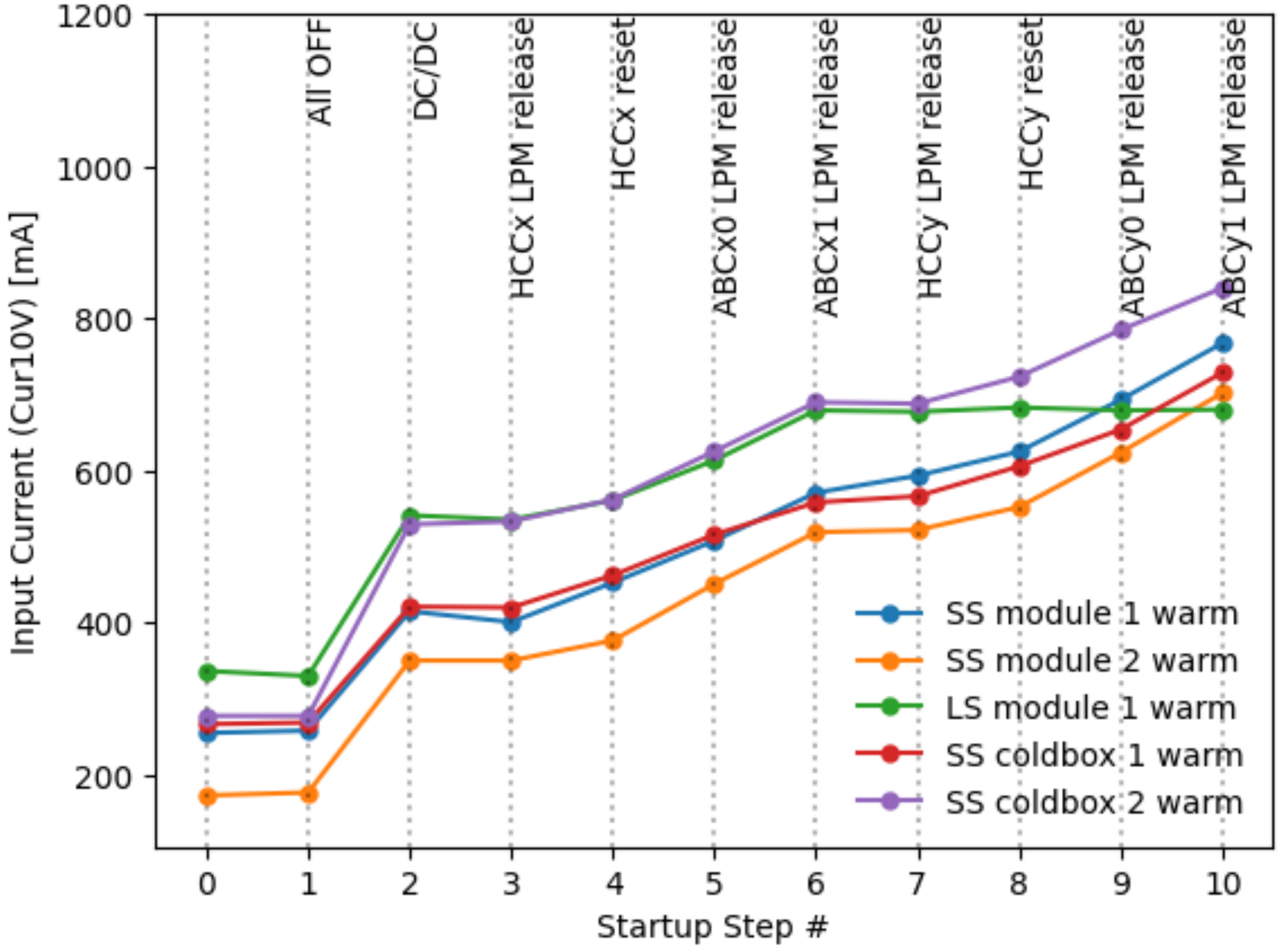
1. **DCDCStartupScan**
    - This test iterates through the **DCDC power-up sequence steps**, from fully off to fully on
    - It monitors AMAC variables as components are released from low power mode/ configured
2. **ShuntCalibrationTest**
    - This test ramps the **X/Y hybrid shunt voltages** to induce temperature changes
    - It monitors AMAC variables as current flow to the hybrids is changing

Test Types

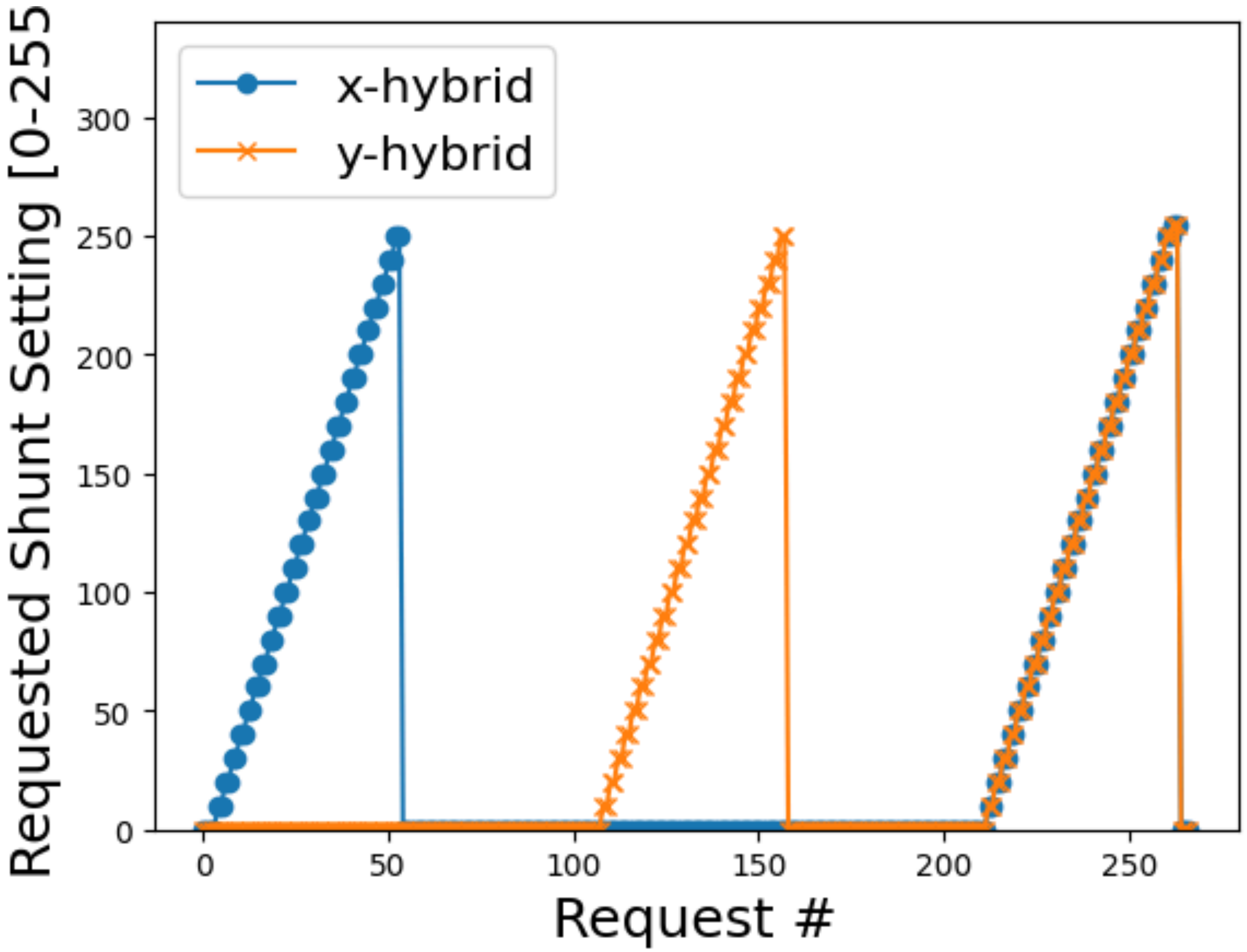
What does this look like practically?

(note that current measurements are not yet correctly calibrated in ITSDAQ, so we can consider them to be relative in the left plot)

DCDCStartupScan:
Iterate through startup steps



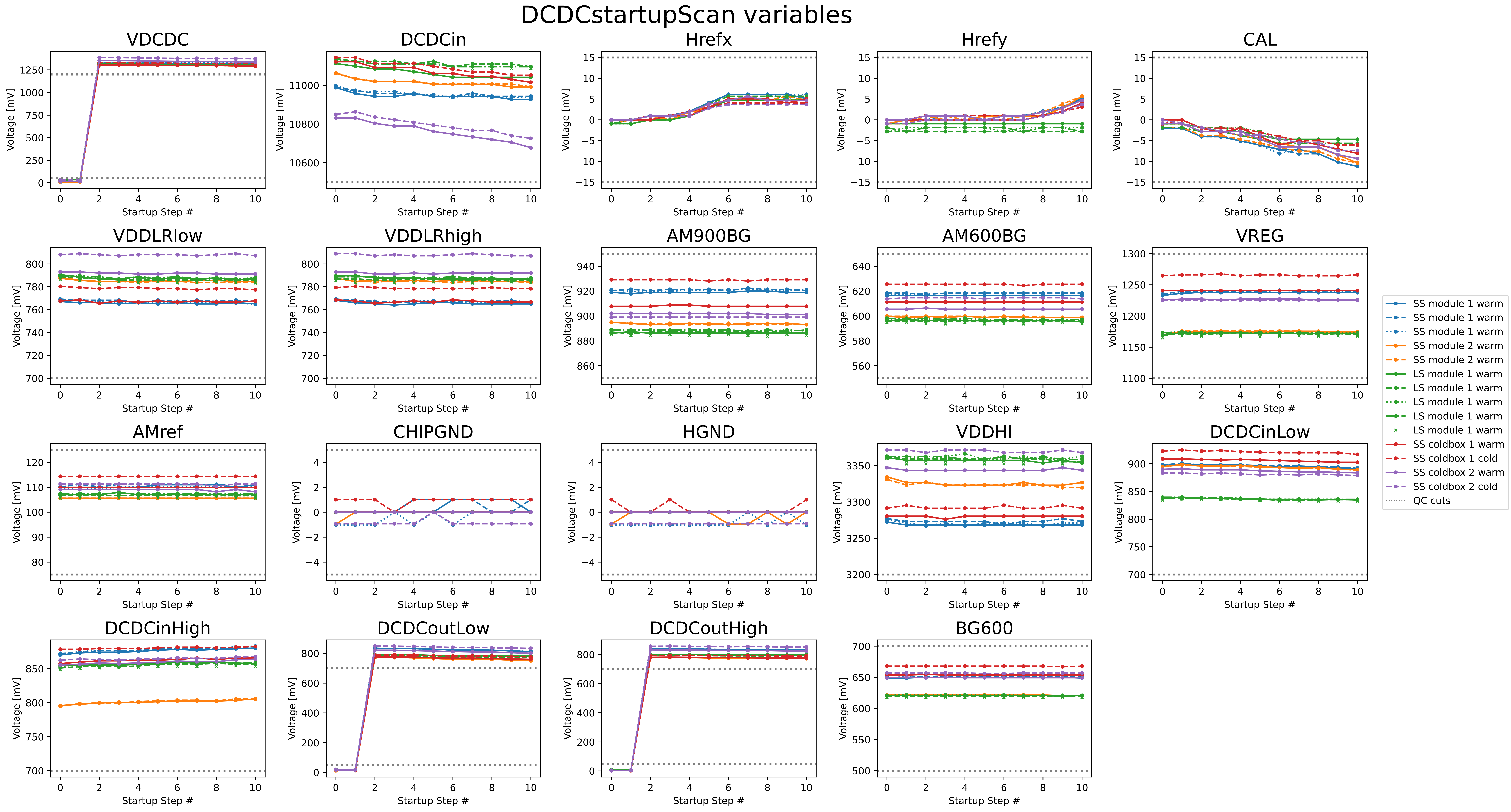
ShuntCalibrationTest:
Iterate through shunt settings



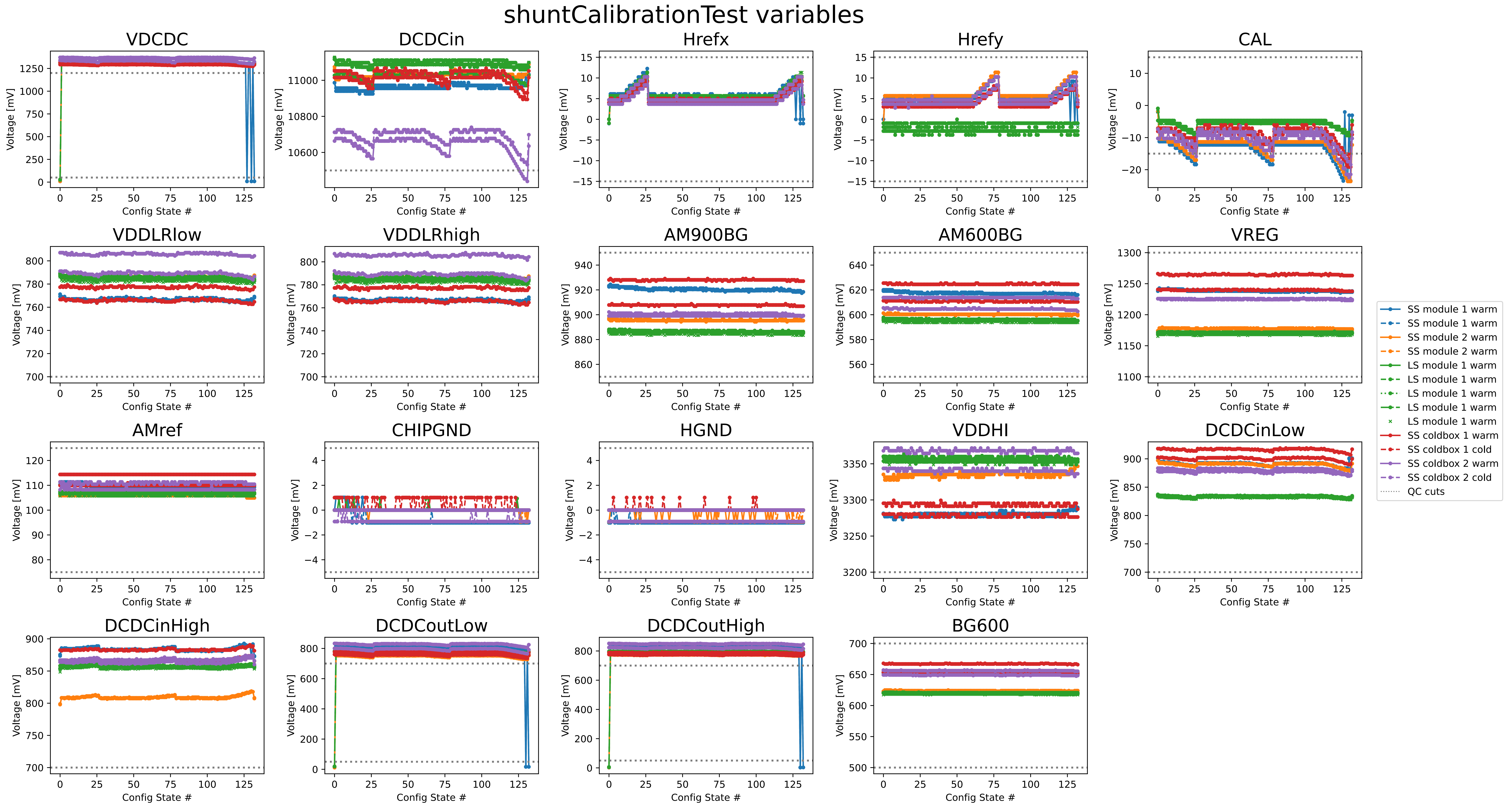
General QC Cuts

- Throughout both test, there are certain measurements that we expect to stay constant
- These are called **general QC cuts**. Failing such a cut generally indicates a broken or missing wirebond.
- For some of these cuts, the thresholds may be derived from theoretically expected values
  - I.e. ground measurements such as HGND and CHIPGND should be at or around 0
- For others, we can infer their values statistically
- On the next slide, some of these values are plotted during the DCDCStartupScan against test time

General QC Cuts: DCDCStartupScan example



General QC Cuts: ShuntCalibrationTest example



General QC Cuts

- Using statistics/theoretical expectation values, we apply the **currently implemented** general QC cuts shown at right
- They are required for **every measurement** in **every test**
- These cuts are **independent of the number of hybrids**, meaning they apply evenly to SS, LS, and (hopefully) EC modules
- Ground voltages, register voltages, and input voltages are defined **theoretically**, while other values are statistical

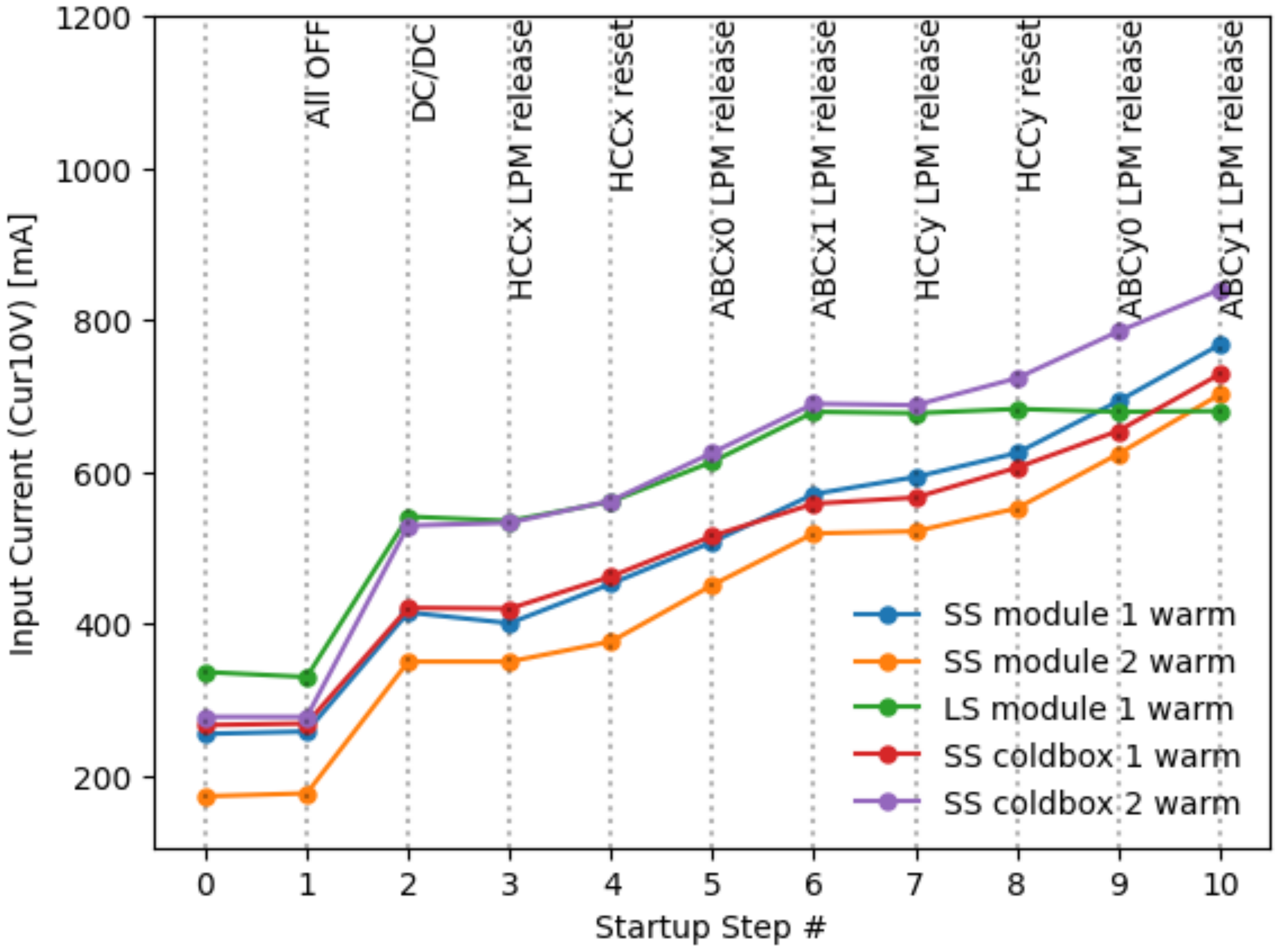
Variable (ITSDAQ)	Threshold	Result if failed
VDCDC	DCDC fully off: < 50 mV DCDC fully on: > 1200 mV	DCDC output voltage. Should be in the 1.4V to 1.5V range, when calibrated
DCDCin	> 10500 mV	Input DCDC sense. If incorrect check wire bond/ sense resistor
HREF(x,y)	0 +/- 15 counts	Ground reference for x/y hybrids. Should be 0. Check HREF wirebonds
CAL	0 +/- 15 counts	Should be 0, can drift by ~15 counts per test. check CAL wirebonds
VDDLR(low, high)	> 700 counts	LinPol current sense. If this is too low, check VDD1V4/VDD3V3 wire bonds
AM900BG	900 +/- 50 counts	900mV band gap. Should not drift
AM600BG	600 +/- 50 counts	600mV band gap. Should not drift
VREG	1200 +/- 100 counts	1.2V constant output (1200 counts)
AMref	All times: 100 +/- 25 counts	Reference voltage for ADC measurement
CHIPGND	0 +/- 5 counts	Chip ground measurement. Should be 0. Check wire bonds
HGND	0 +/- 5 counts	HV ground. Should be 0. Check wire bonds
VDDHI	> 3200 counts	MOSFET bias. if this is low/zero, check VDD1V4/VDD3V3 wire bonds
DCDCin(Low,High)	Above 700 counts	?
DCDCout(Low,High)	DCDC fully off: < 50 counts DCDC fully on: > 700 counts	?
BG600	600 +/- 100 counts	600mV band gap. Should not drift, but has a wider range than the other 600BG

DCDCStartupScan Cuts

- This test targets **current** response to changing AMAC **configuration** state

- We will also expect to see the increase in AMAC output current reflected by changes in powerboard temperature (NTCpb, PTAT)

- If a component in this test is not functioning properly, we will see no change in current
  - See e.g. the LS module in blue, at right - flat current for y-hybrid configuration steps



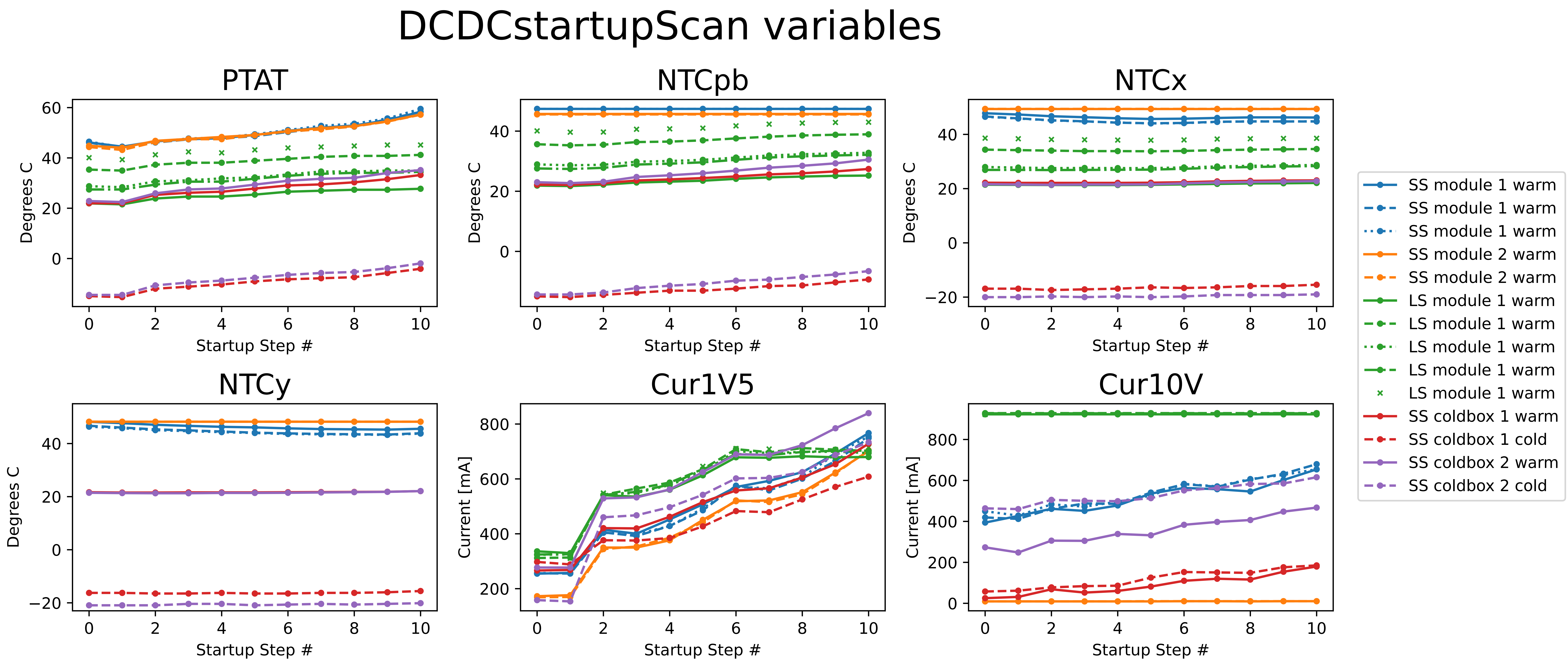
Current response to changing AMAC configuration state, for a variety of strip modules

DCDCStartupScan QC Cuts

- **Implemented cuts** for this QC scan are shown at right:
- Some theoretical estimate for input/output current correspondence can also be applied
- Plots for this test include
  - Input vs. Output current
  - Efficiency
  - Temperature

Variable (ITSDAQ)	**Threshold**	**Note**
AMAC Efficiency	> 60% at all points after startup	Check Cur10V/Cur1V5 wirebonds
PTAT	Start to finish change > 10 C, unless we are at a maximum	Check PTAT wirebond / component
NTCpb	Start to finish change > 5 C, unless we are at a maximum	Check NTCpb wirebond / component
Cur1V5	DCDC off: < 200 mA Total change from start to finish: > 300 mA Startup step current requirements: - > 100 mA for DCDC on - > 10 mA each for HCC(x,y) resets - > 50 mA each for ABC(0,1)(x,y) resets	Check bPol enable wirebond Check respective component wirebond/ function: HCC, ABC0, ABC1
Cur10V	Total change from start to finish: > 150 mA	If no change, problem with wirebond or component in TuneCurrentMirror
LV Supply Current	If present, require consistency within +/- 100 mA with Cur10V measurement for ON and OFF DCDC steady state (no shunts)	Check LV supply & Cur10V wirebond

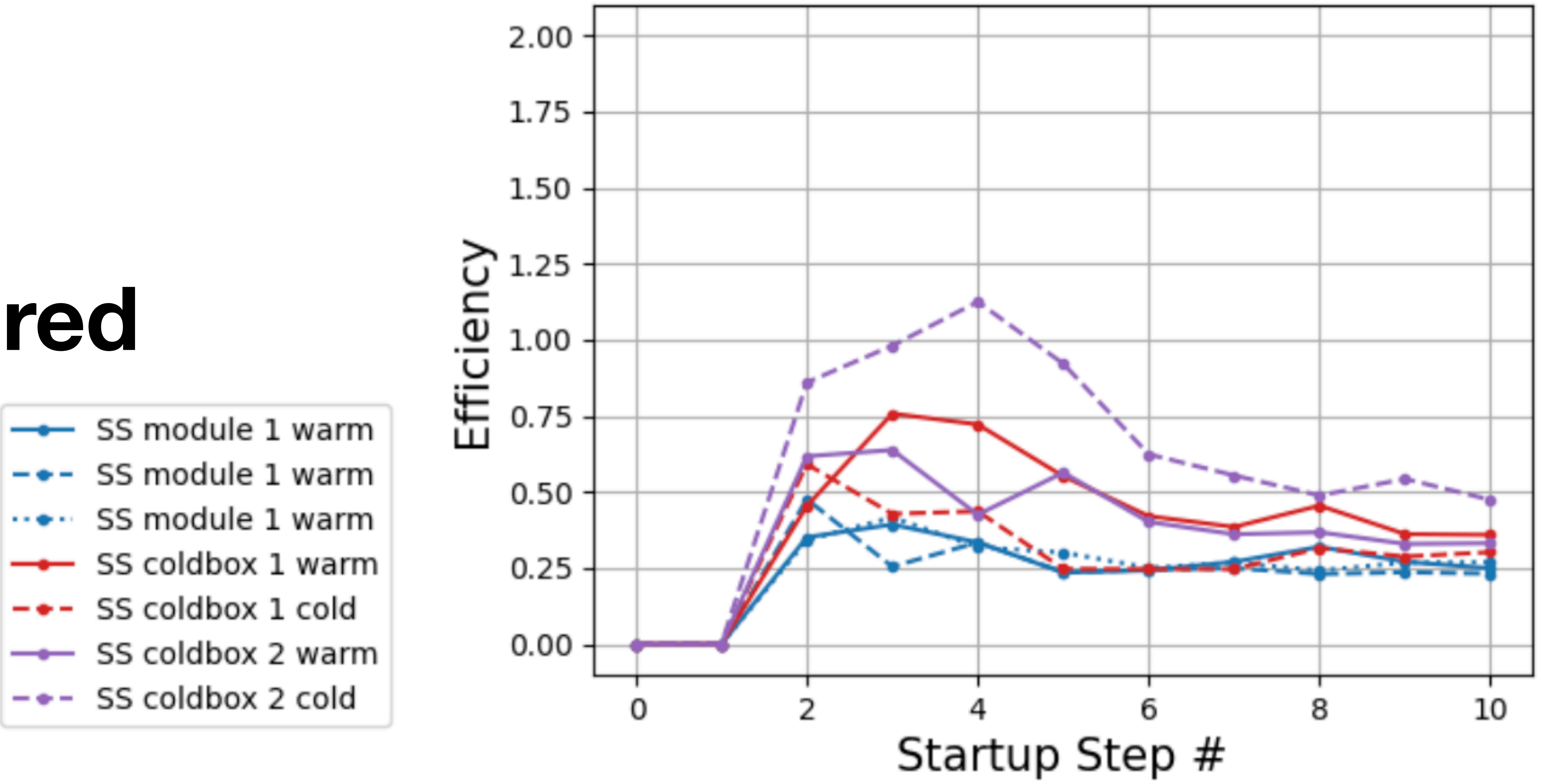
DCDCStartupScan QC Cuts

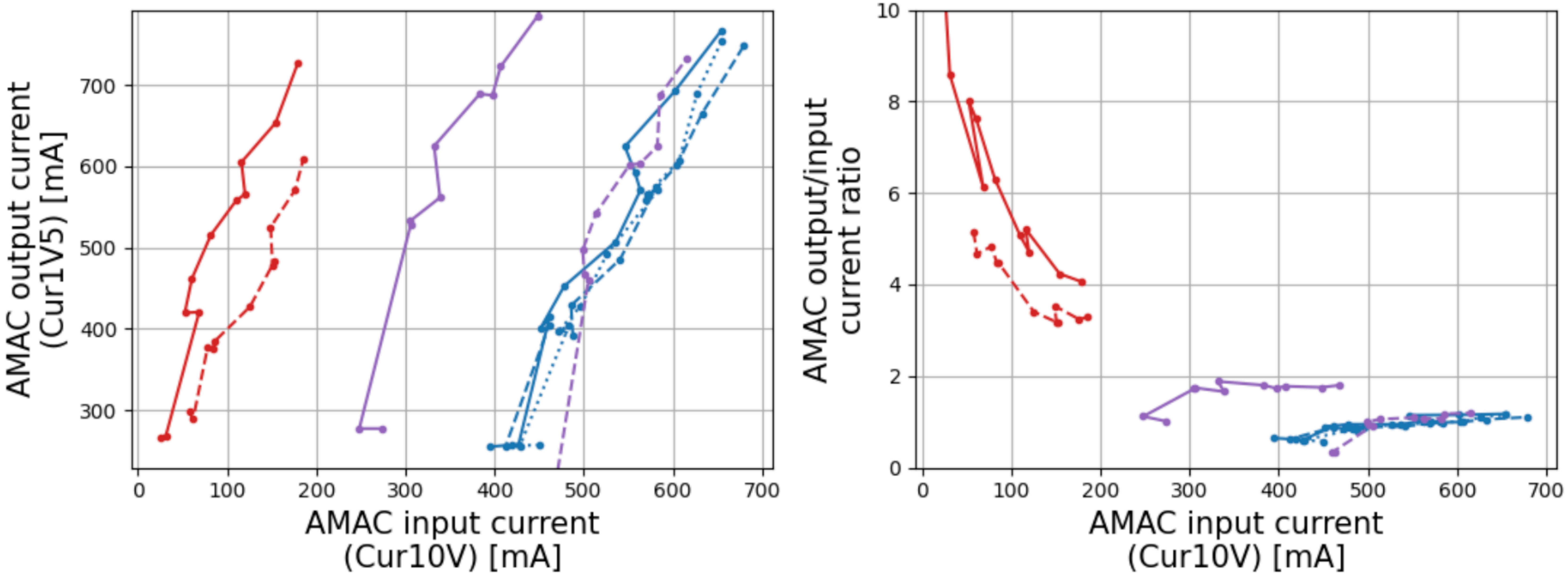


- As expected, NTCpb/PTAT rise slightly, while x/y NTCs are stable

DCDCStartupScan Cuts

- Currently, efficiency cuts/plots are **hampered by calibration** of input/output current
  - See plot at right
- Other measurements are also possible, including **comparing output/input current linearity directly**
- This is also dept. on calibration, but current analysis makes the plots

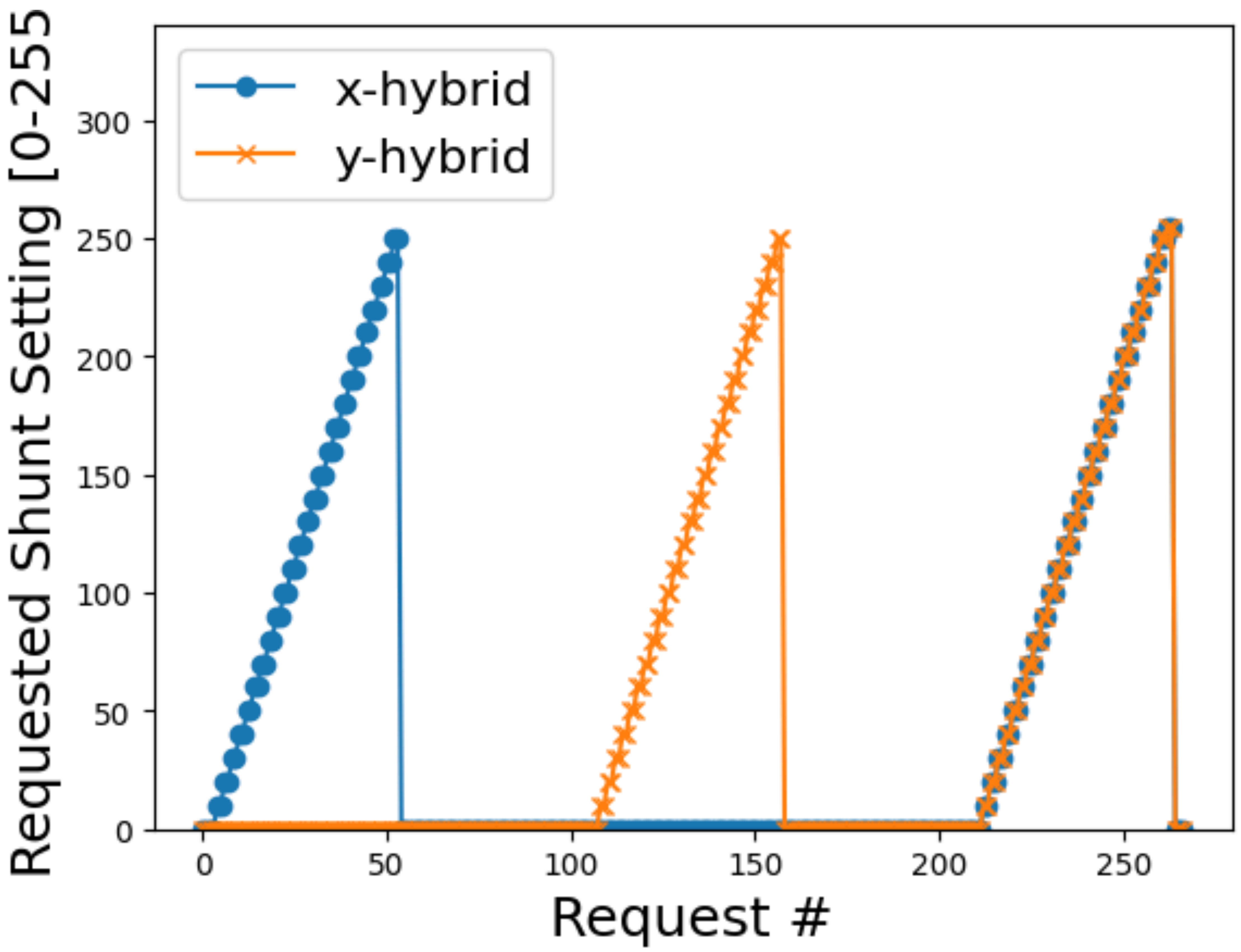




input/output current comparisons + efficiency plots, with bad Cur10V modules removed

ShuntCalibrationTest QC cuts

- This test targets **temperature** response to changing x/y hybrid shunts
- We expect changes in all temperature sensors as shunt load is increased
- We can also test here the **shunt(x,y)** and **cal(x,y)** wirebonds



ShuntCalibrationScan x/y shunt scan schematic

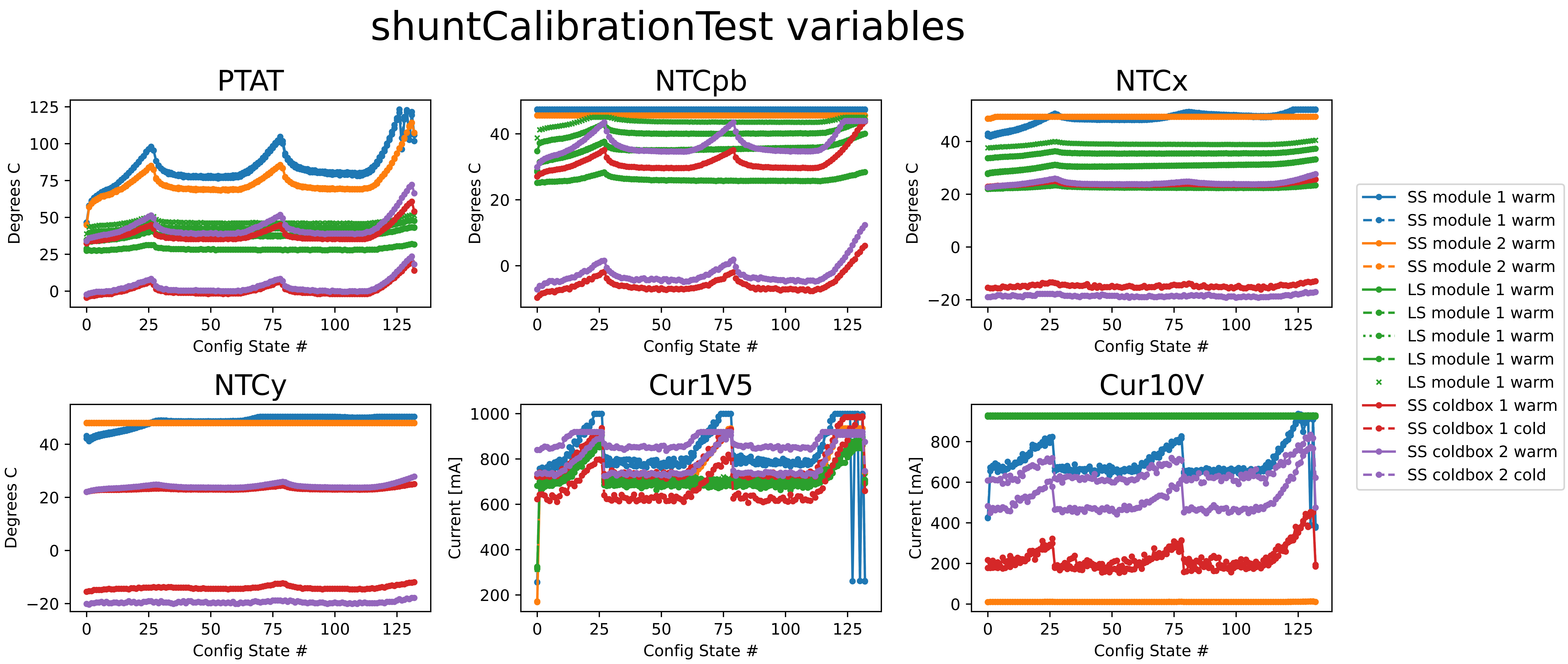
ShuntCalibrationTest QC cuts

- **Implemented cuts** for this scan are shown at right
- Efficiency plots, current, temperature, and voltage plots are generated with each analysis
- With the inclusion of this test, we have tested all of the standard AMAC readings in ITSDAQ

Variable	**Threshold**	**Note**
AMAC Efficiency	> 60% at all points after DCDC turn on	Check Cur10V/Cur1V5 wirebonds
PTAT	Start to finish change > 15 C, unless we are at a maximum	Check PTAT wirebond / component/ solder pin
NTC(x,y)	Start to finish change > 2 C, unless we are at a maximum	Check NTC wirebond/ component
NTCpb	Start to finish change > 2 C, unless we are at a maximum	Check NTCpb wirebond / component
Cal(x,y)	Require Cal(x,y) set to 0 to be < 10 mV Require Cal(x,y) set to 1 to be > 900 mV	Check Cal(x,y) wirebonds
Shunt(x,y)	Require any Shunt(x,y) change > 10 mV Require total Shunt(x,y) change > 750 mV Require Shunt(x,y) = 0 to be < 10 mV	Check AMAC to pb bonds Check shunt component/power shortage Check ground voltages

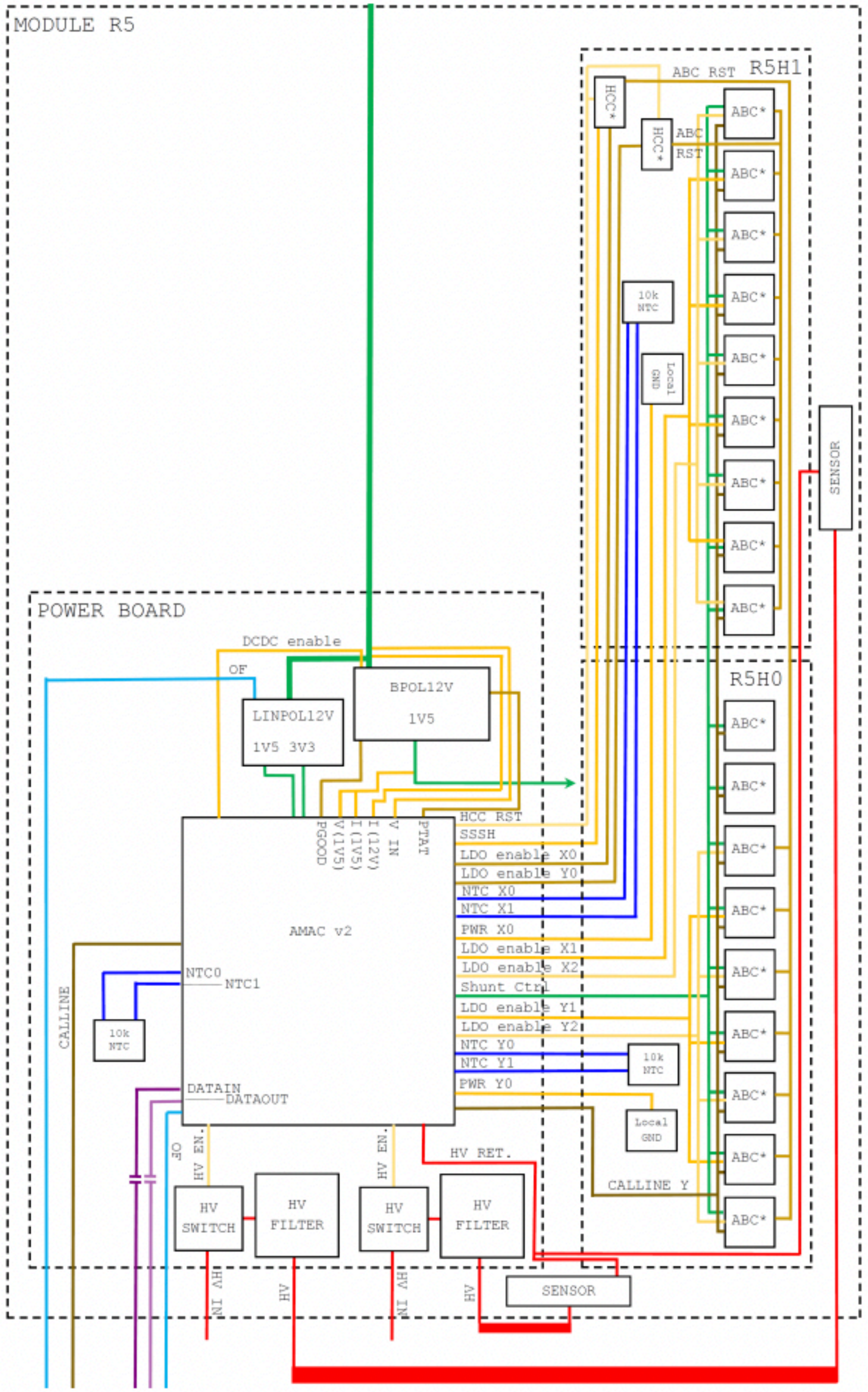
ShuntCalibrationTest QC cuts

- Once again, cut points are extracted statistically:



Barrel and Endcap Compatibility

- **Barrel compatibility:**
  - We have only LS and SS modules. Support for both is integrated into the analysis.
  - Because all barrel modules have only 1 AMAC per module, the tests run identically on all barrel modules.
- **Endcap compatibility:**
  - From the **endcap module document**, there are no endcap modules with more than 2 hybrids per AMAC
  - Cole has offered to **run these tests on EC modules** when he has more, but we agree that they should work out of the box
  - The analysis has a natural flow for including the different **current/NTC** readings in endcap modules



(b) End-cap R5 modules.

Proposed Testing Deliverables

- At this point, a **robust powerboard electrical test routine** has been developed, which functions for all ITK strips barrel modules

- I propose the following to be delivered after the official end of this QT:

  1. Include support for EC modules, with help from Cole

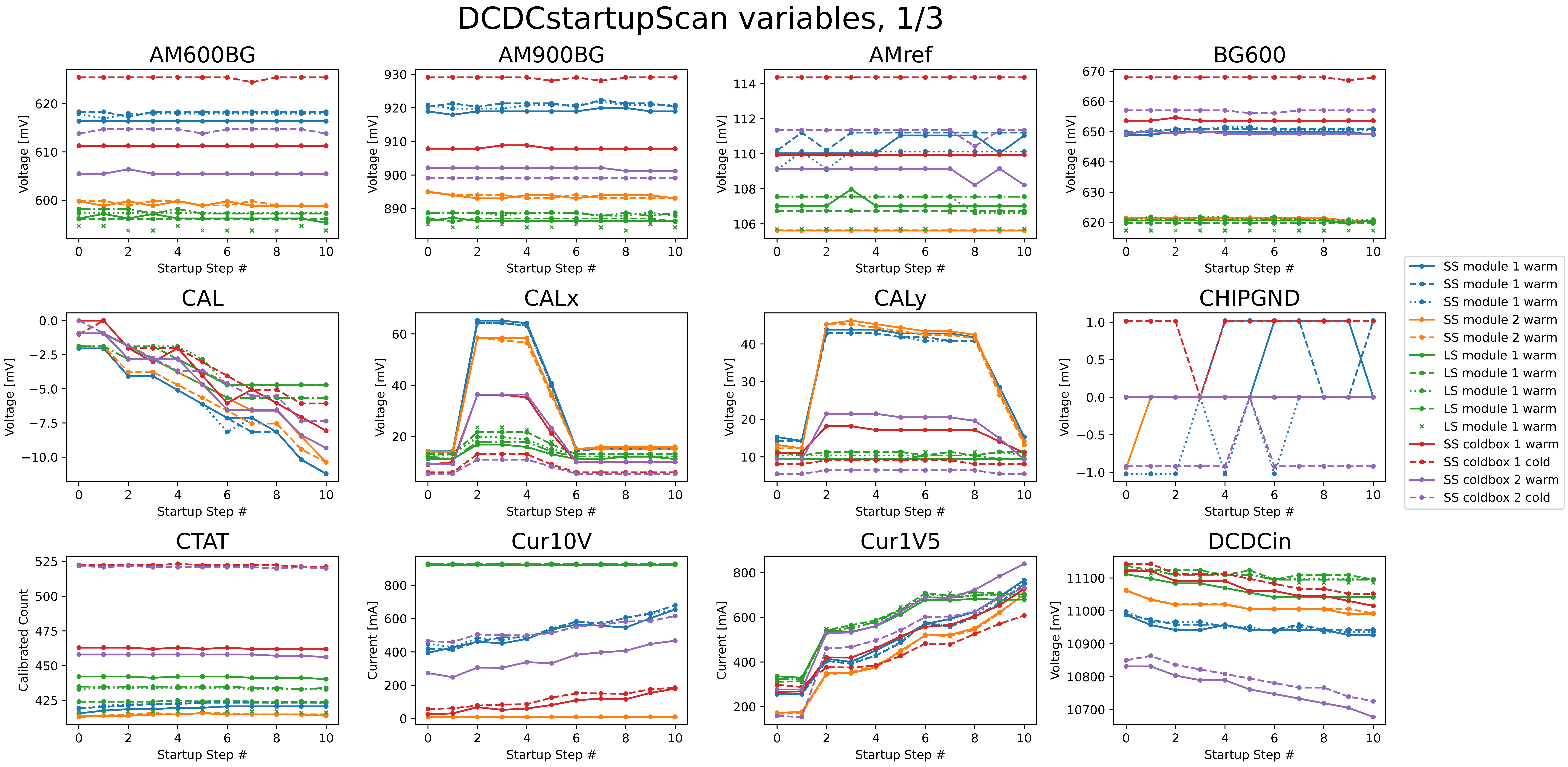
  2. Merge currently open PR of this code to ITSDAQ so that other users can run/aggregate statistics

  3. Update cut points when enough stats have been collected

  4. Adding tests to the database?
     - This must be done carefully, due to on-going production
     - For this reason I think it is best for someone else to follow up on it, with technical help from me.

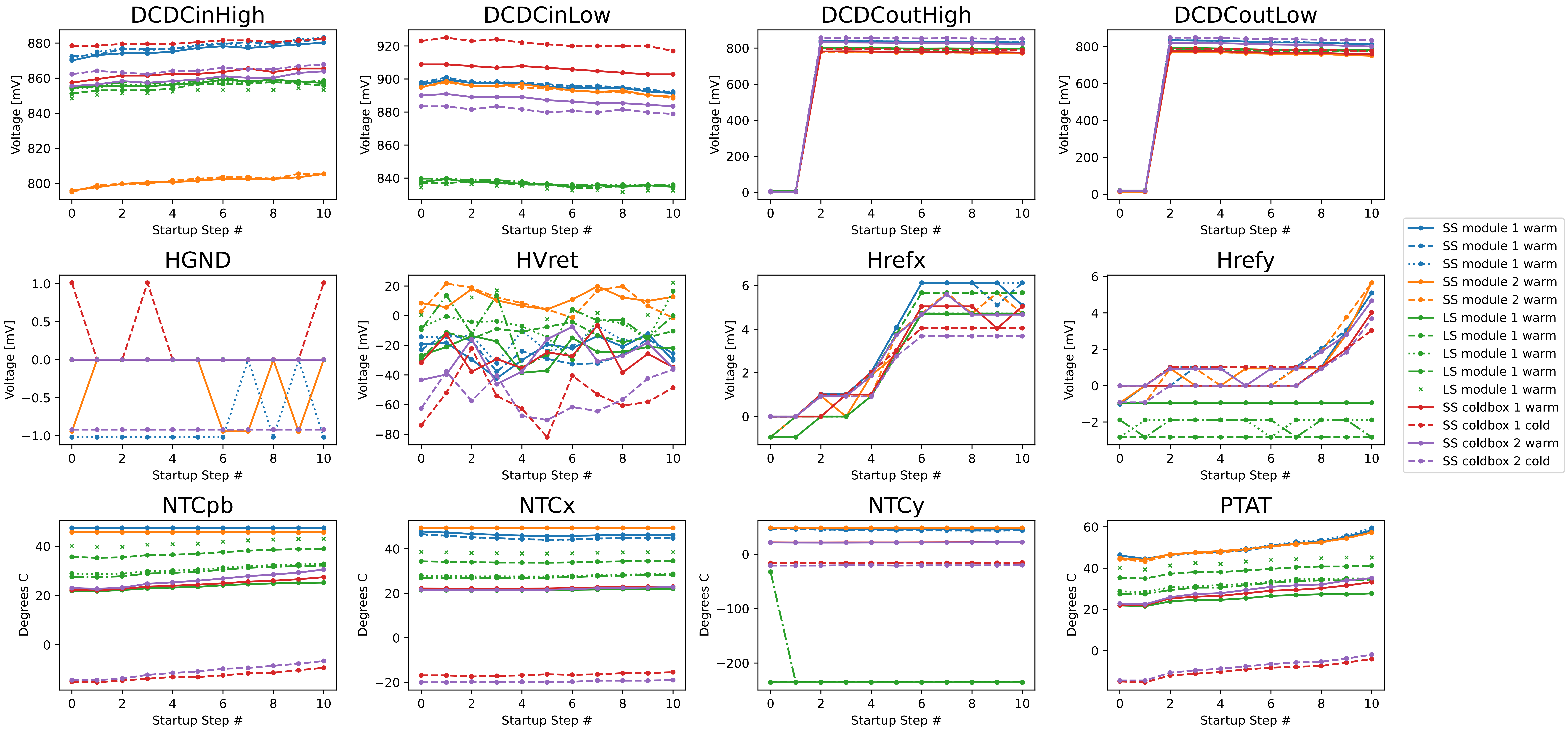
Questions

Backup

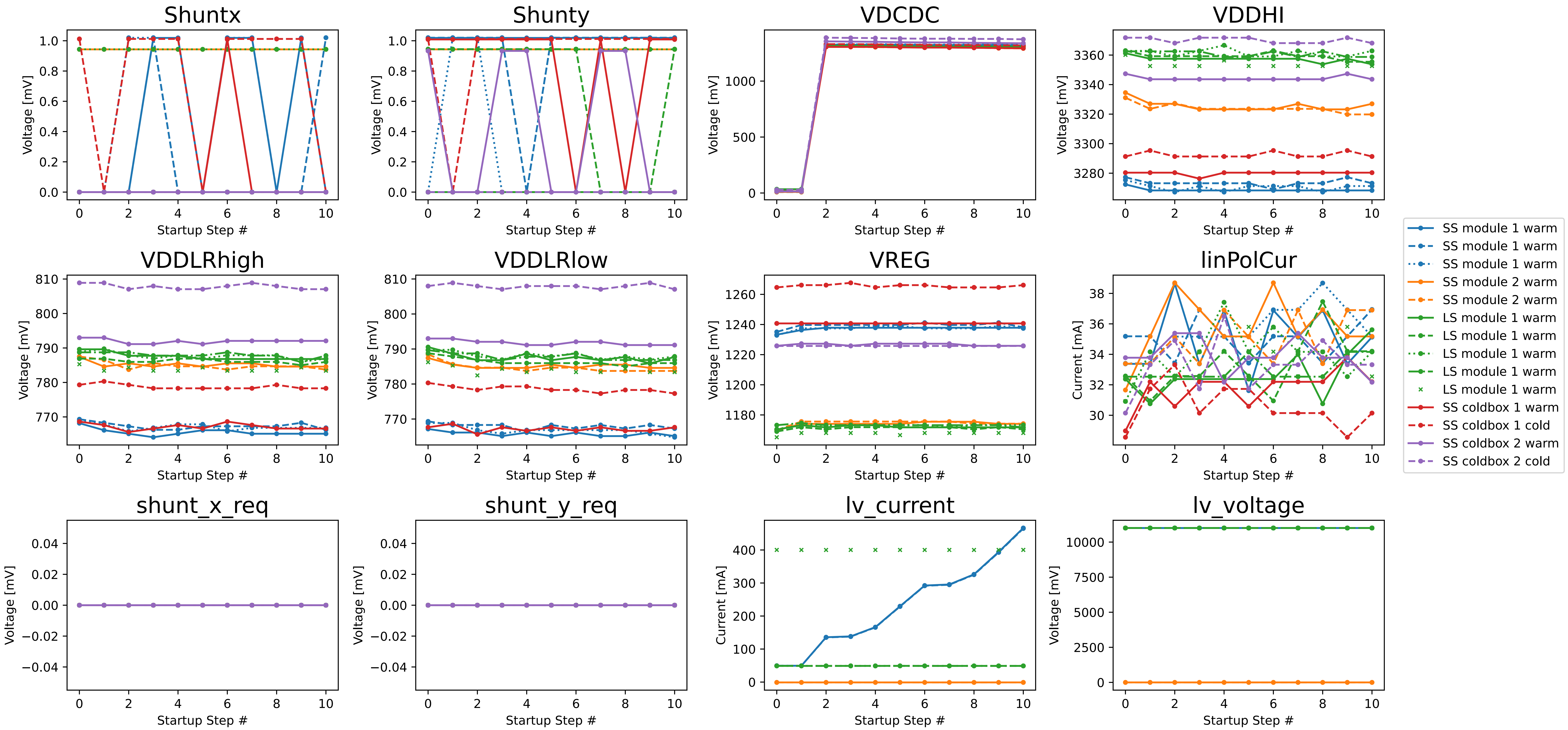


DCDCstartupScan variables, 1/3
AM600BG
AM900BG
AMref
BG600
CAL
CALx
CALy
CHIPGND
CTAT
Cur10V
Cur1V5
DCDCin
Voltage [mV]
Calibrated Count
Current [mA]
Startup Step #
SS module 1 warm
SS module 1 warm
SS module 1 warm
SS module 2 warm
SS module 2 warm
LS module 1 warm
LS module 1 warm
LS module 1 warm
LS module 1 warm
LS module 1 warm
SS coldbox 1 warm
SS coldbox 1 cold
SS coldbox 2 warm
SS coldbox 2 cold

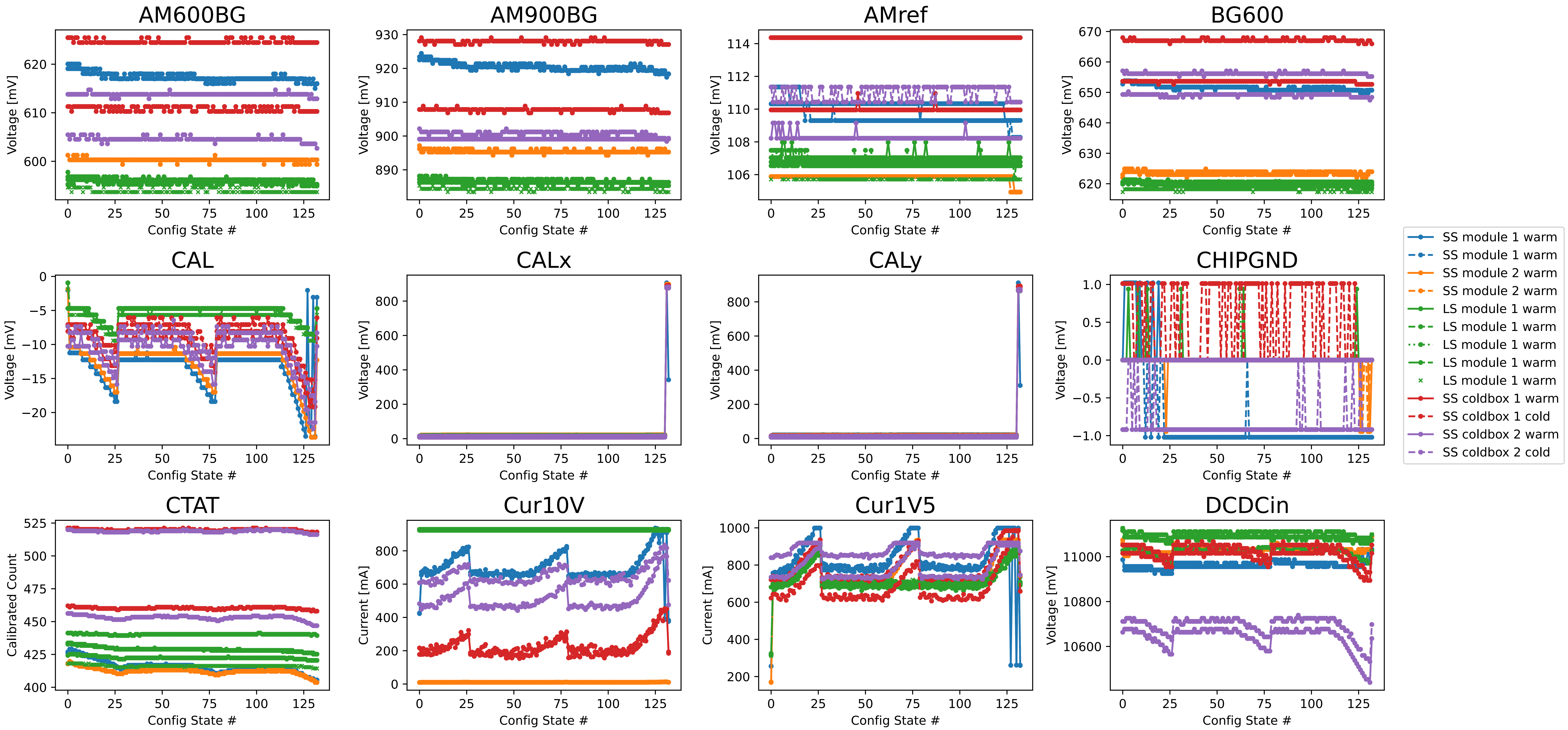
DCDCstartupScan variables, 2/3



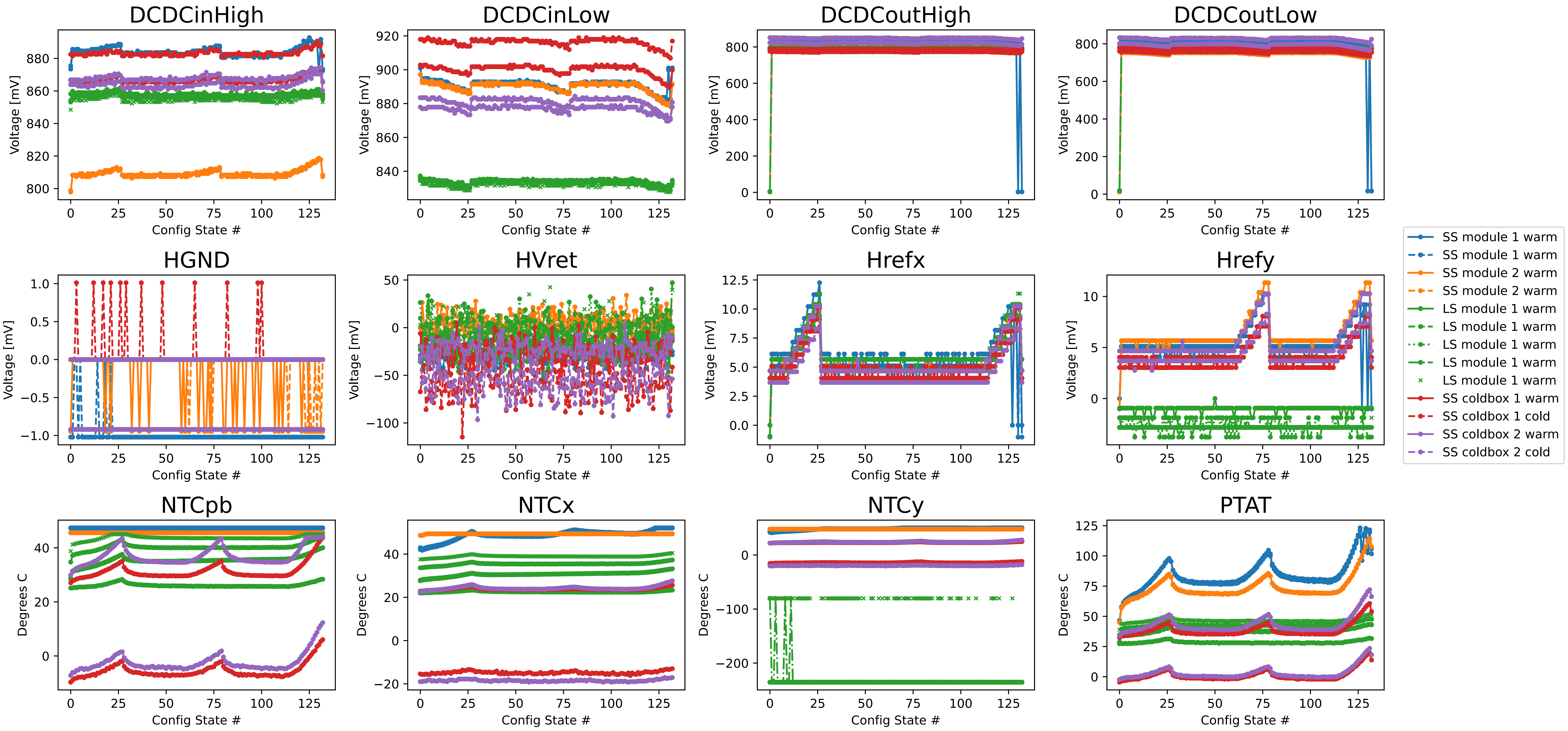
DCDCstartupScan variables, 3/3



shuntCalibrationTest variables, 1/3



shuntCalibrationTest variables, 2/3



shuntCalibrationTest variables, 3/3