

Yale

LFHCal SiPM QC

ORNL + Yale contribution to-date

Isaac Mooney [isaac.mooney@yale.edu] (Yale / BNL / CFNS), on behalf of Yale Relativistic Heavy-Ion Group, with contributions from Oskar Hartbrich (ORNL)
10/6/2025



First batch of Hamamatsu SiPMs at BNL

- BNL received ~50000 S14160-1315PS SiPMs from Hamamatsu
 - Need to QC 5% sample for acceptance
 - Yale + Debrezen SiPM tester device not yet available
- ORNL has automated wafer probe station + parametric analyzer
 - Can automate tray scans of 23x20 SiPMs at a time
 - In clean room...
- Extract V_{bd} from I-V curve in (close to) dark conditions.



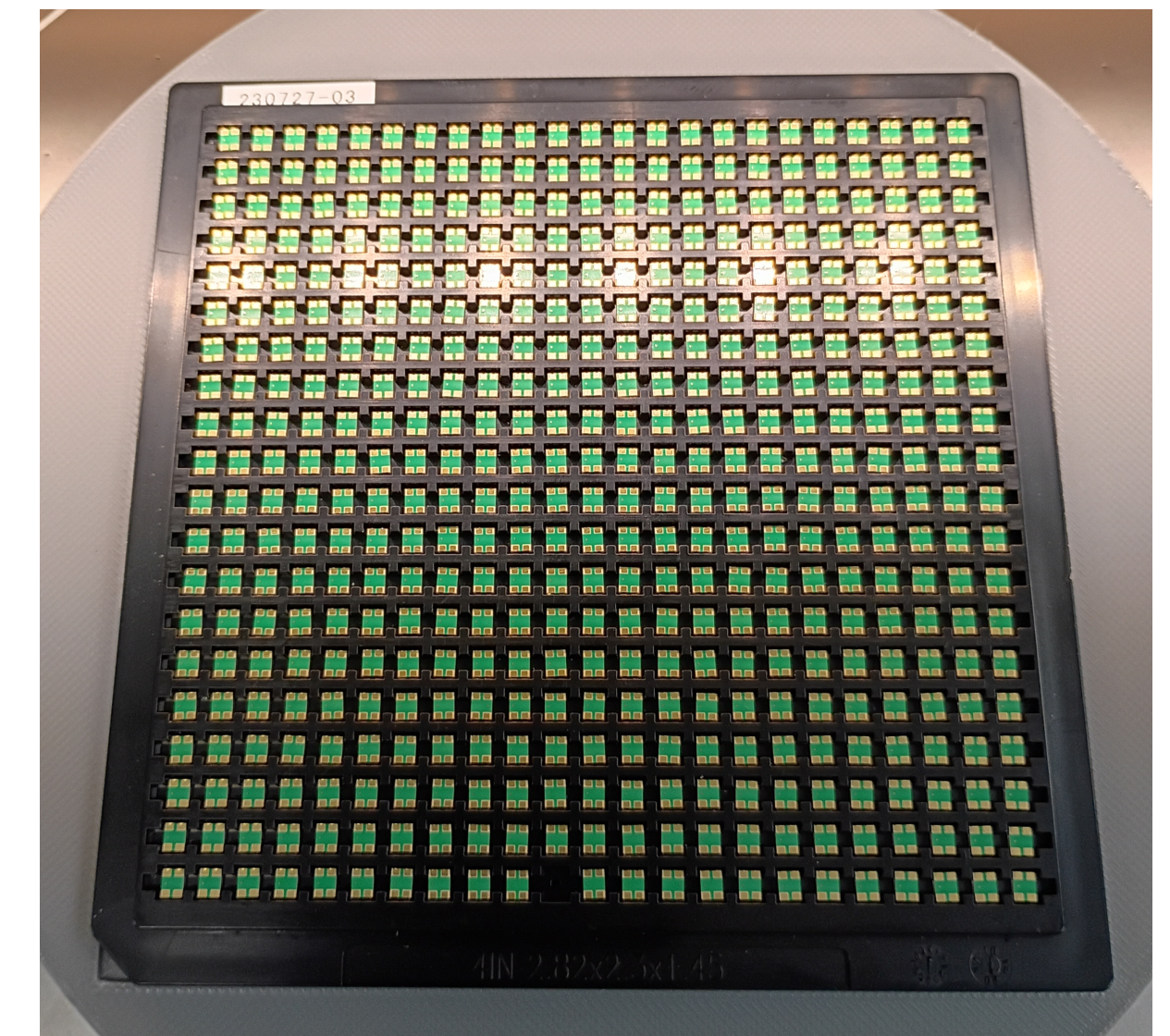
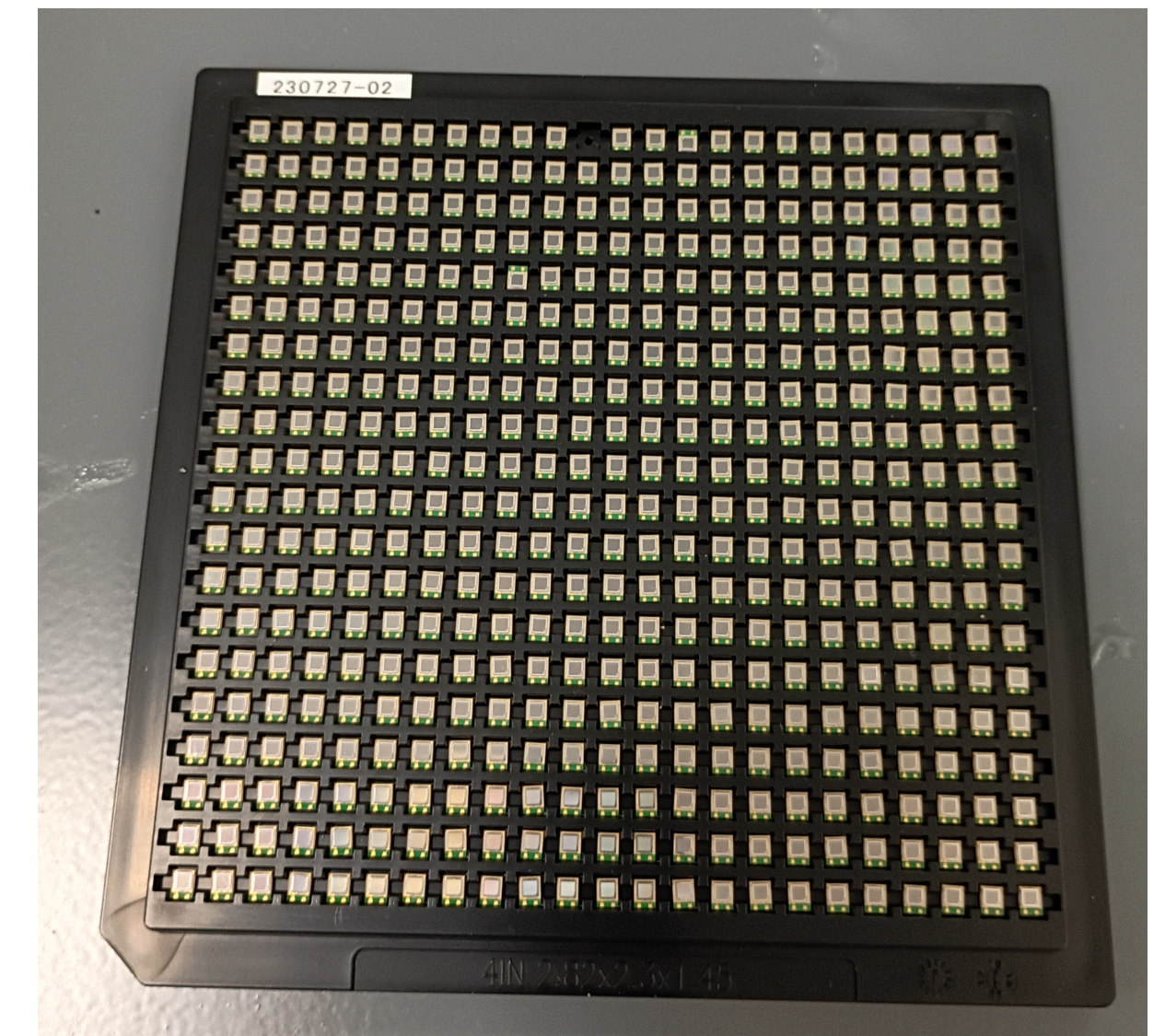
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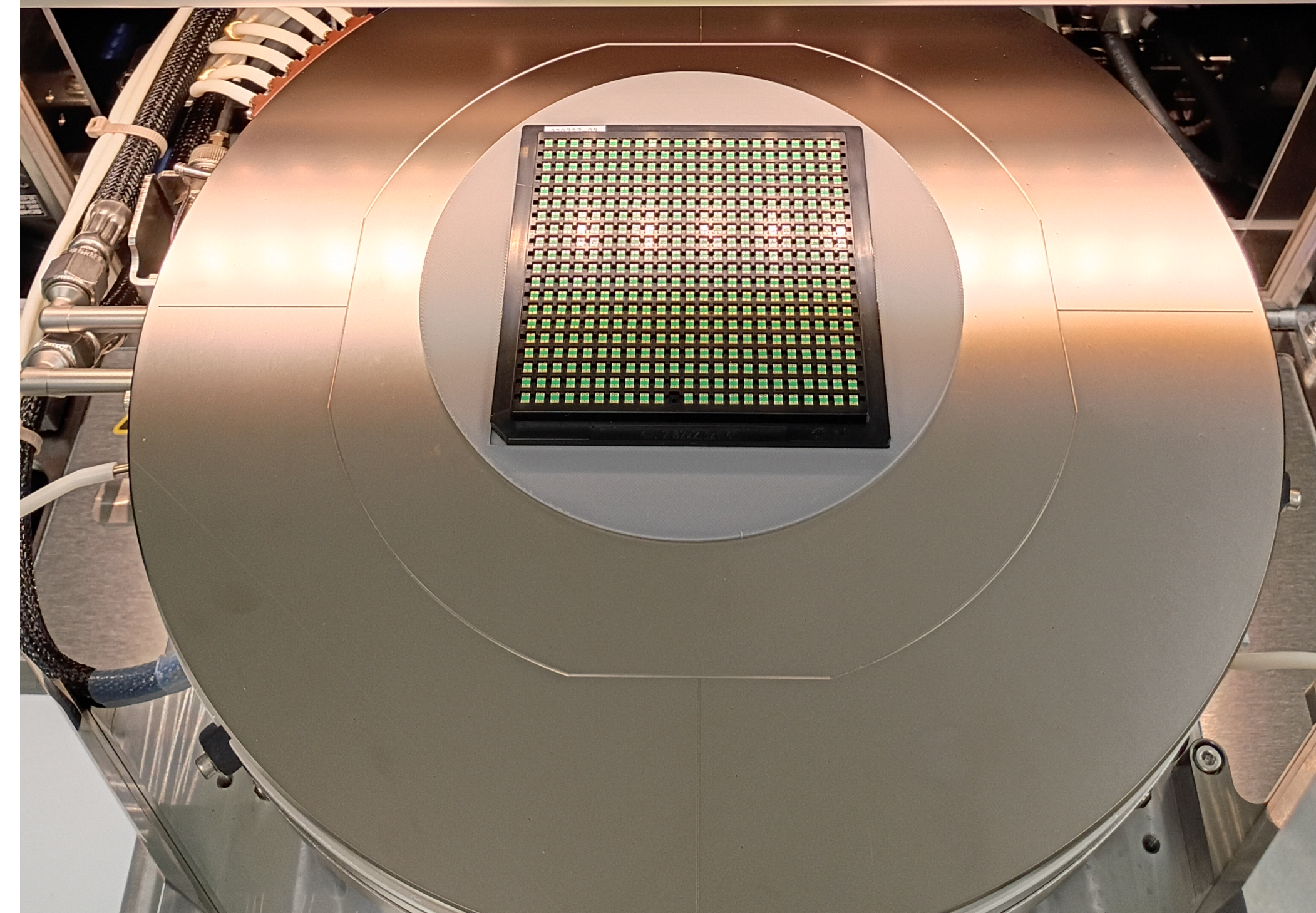
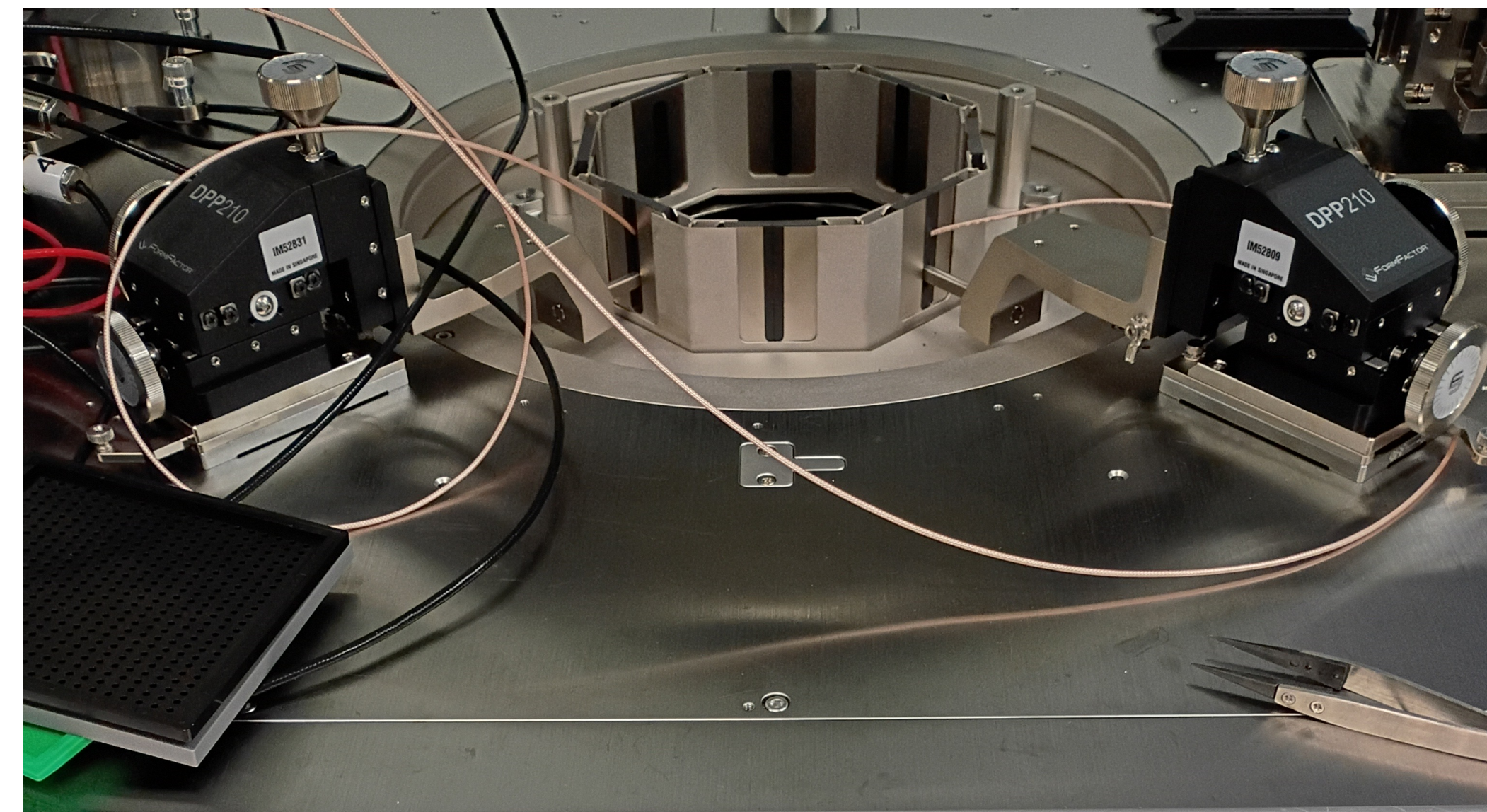
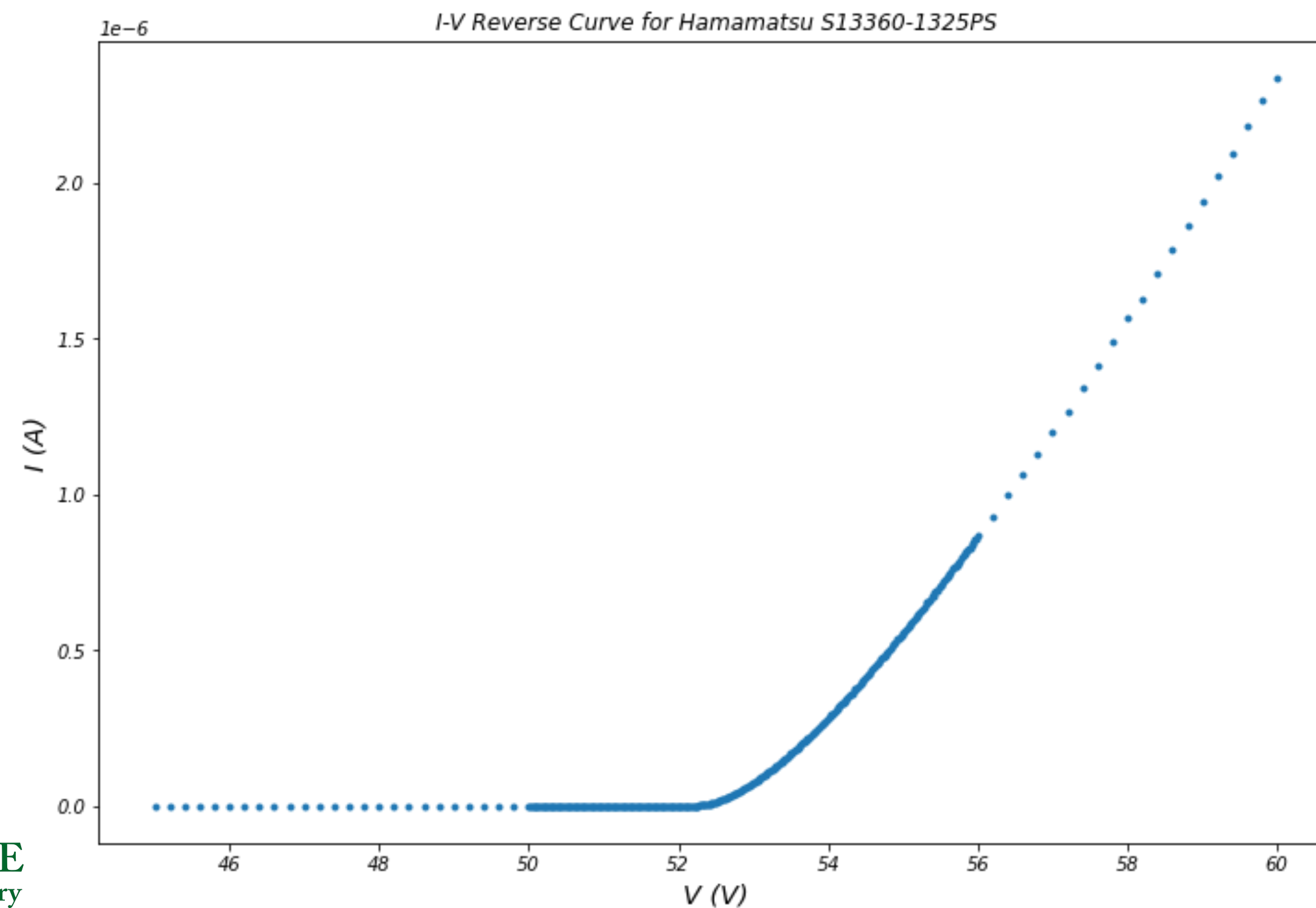
Practice: A tray of “old” SiPMs

- Have a full 23x20 tray of S13360-1325PS SiPMs available at ORNL
 - Same package, same footprint, same tray as S14 series
 - Hamamatsu provided V_{bd} for each sensor -> excellent crosscheck of method
- Step 1: Flip SiPMs
 - 3D-printed alignment jig + courage + percussive adjustments (+ manually fixing bad flips)



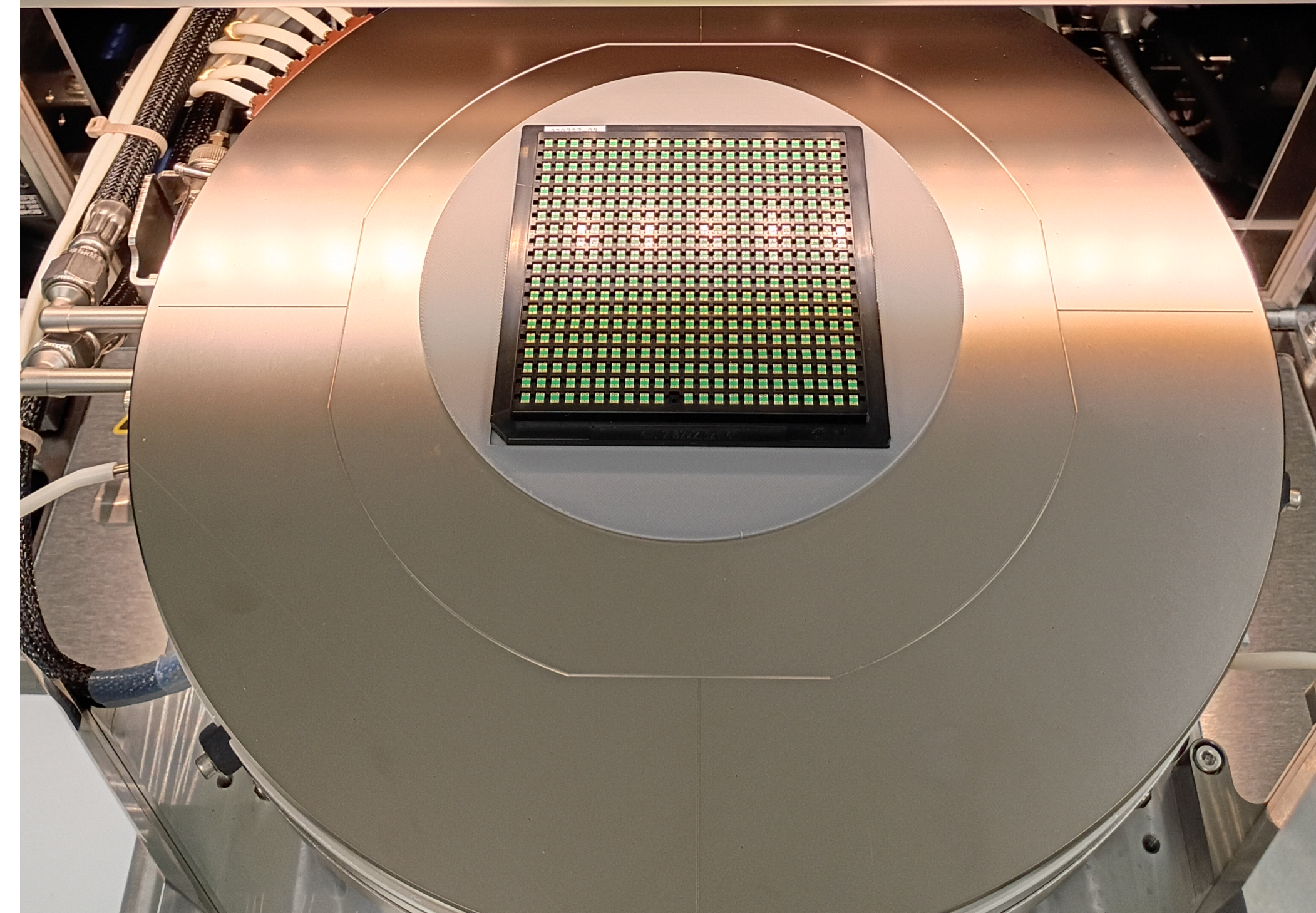
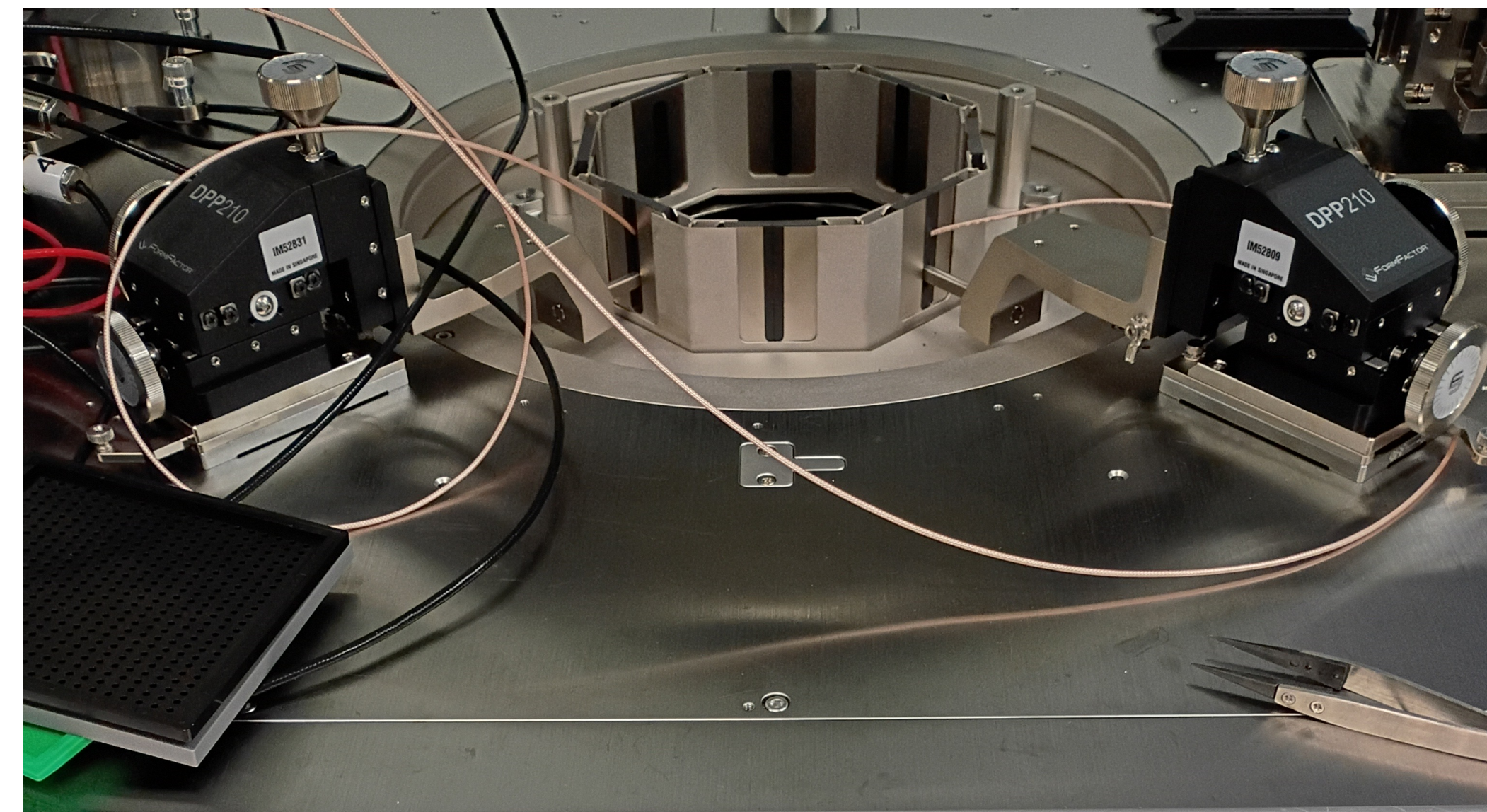
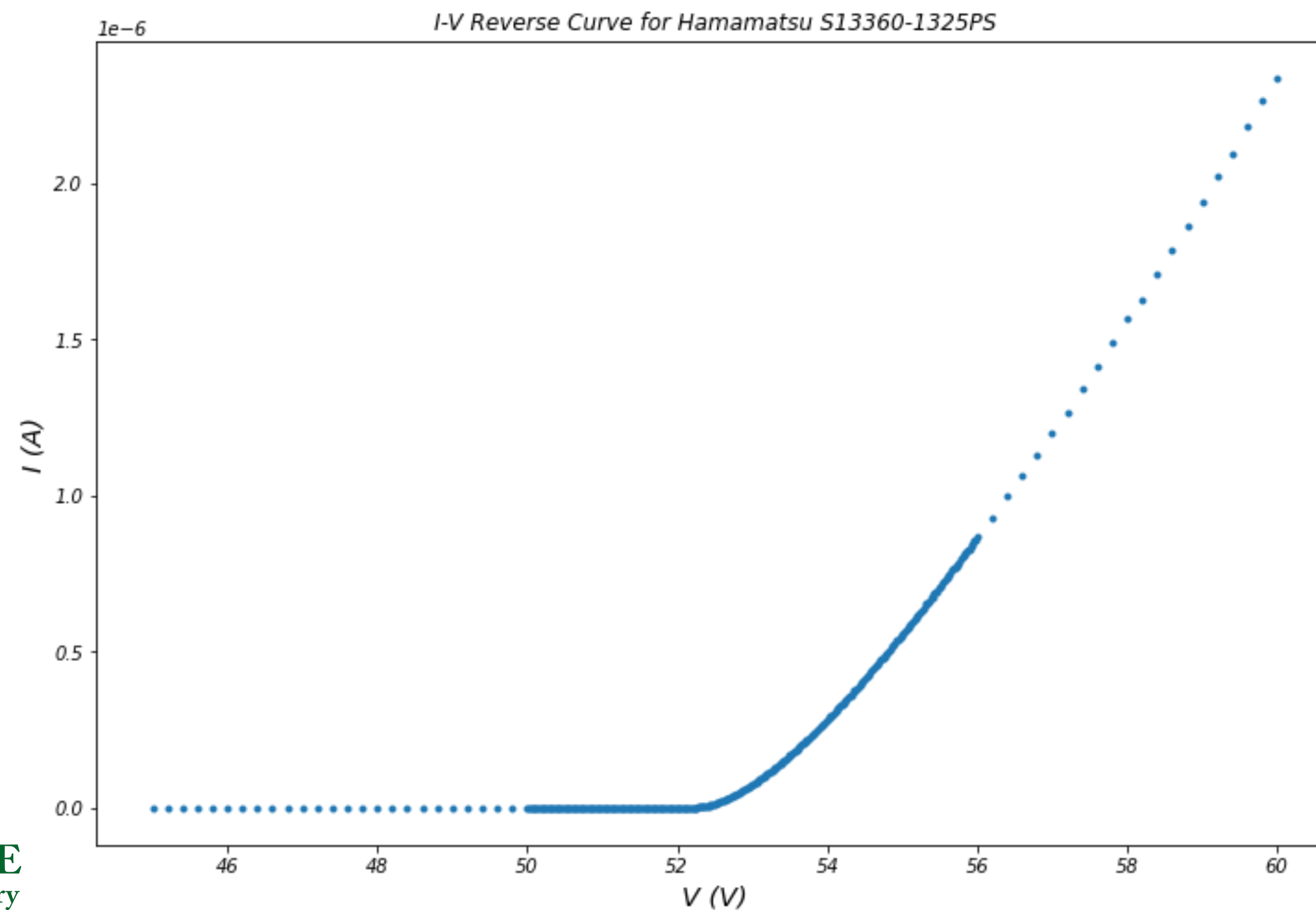
Into the prober

- Formfactor CM300xi probe station with Keithley 4200A-SCS parameter analyzer
 - Simple I-V curve scan around V_{bd} @20C
 - Achievable point resolution is near infinite, limited by time and light tightness of setup
- Two main methods:
 - V vs. \sqrt{I} (“the standard”)
 - V vs. $d(\log(I))/dV$ (“Hamamatsu V_{peak} ”)
 - (gain from SPS vs. voltage not feasible on this scale)



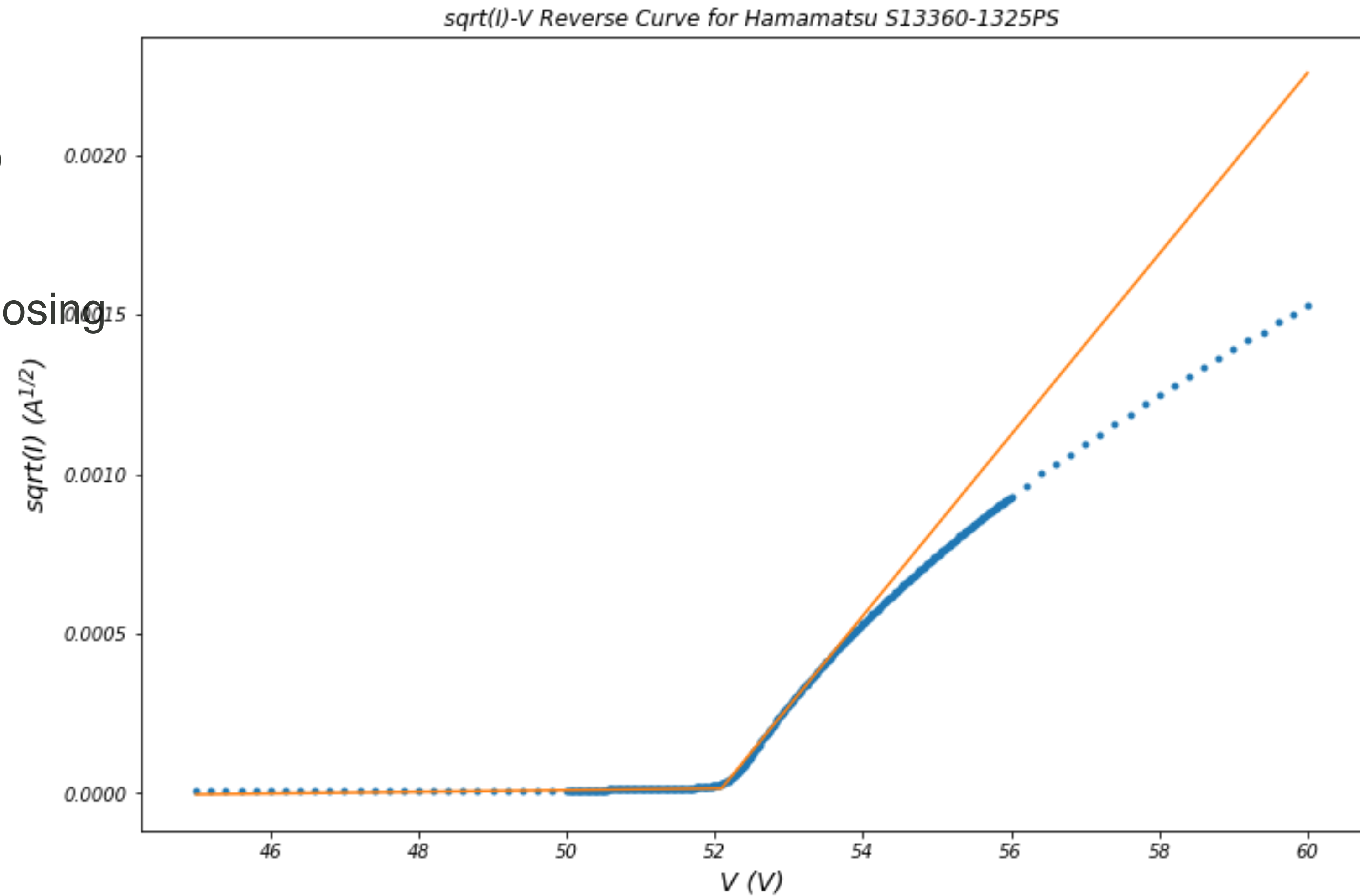
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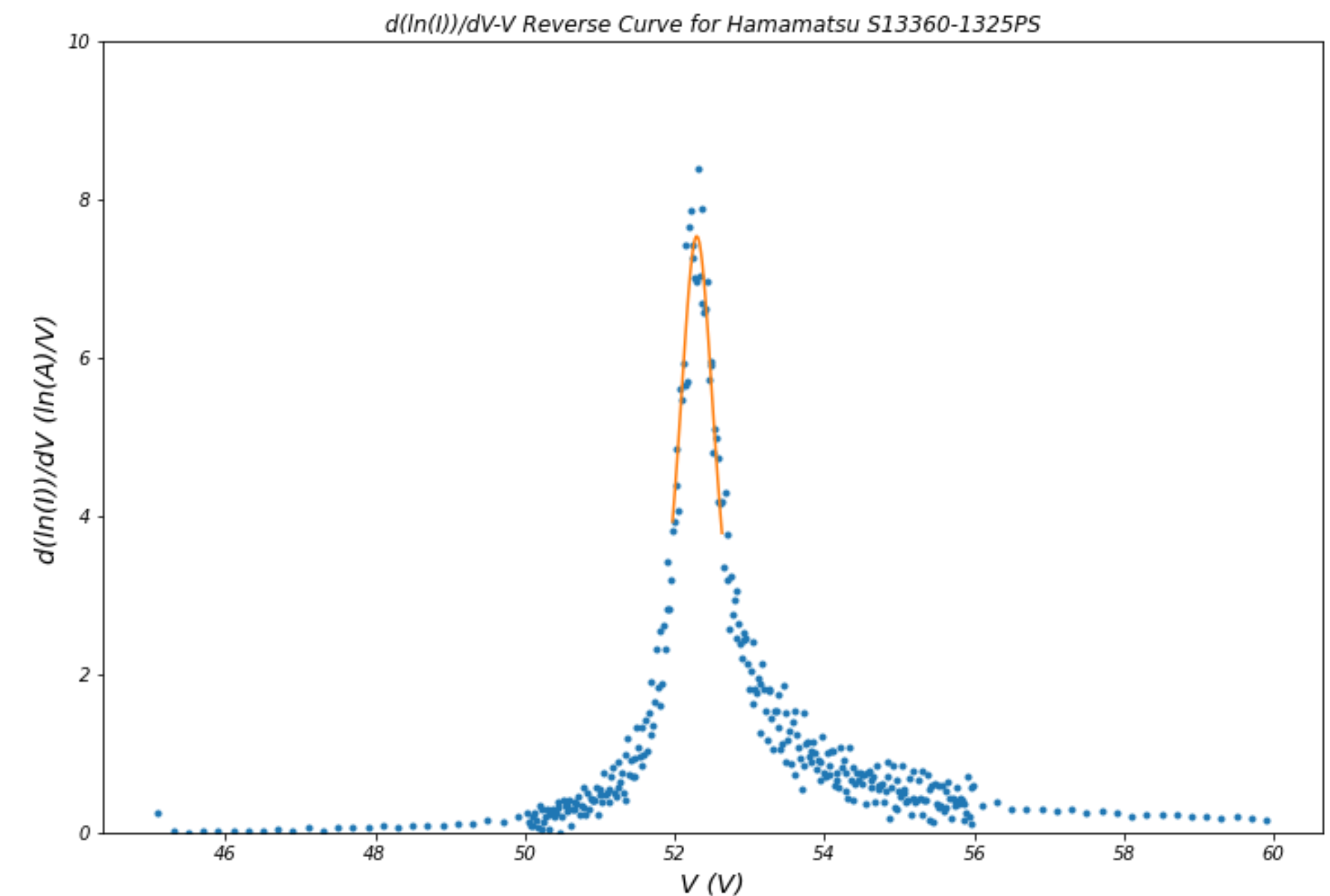
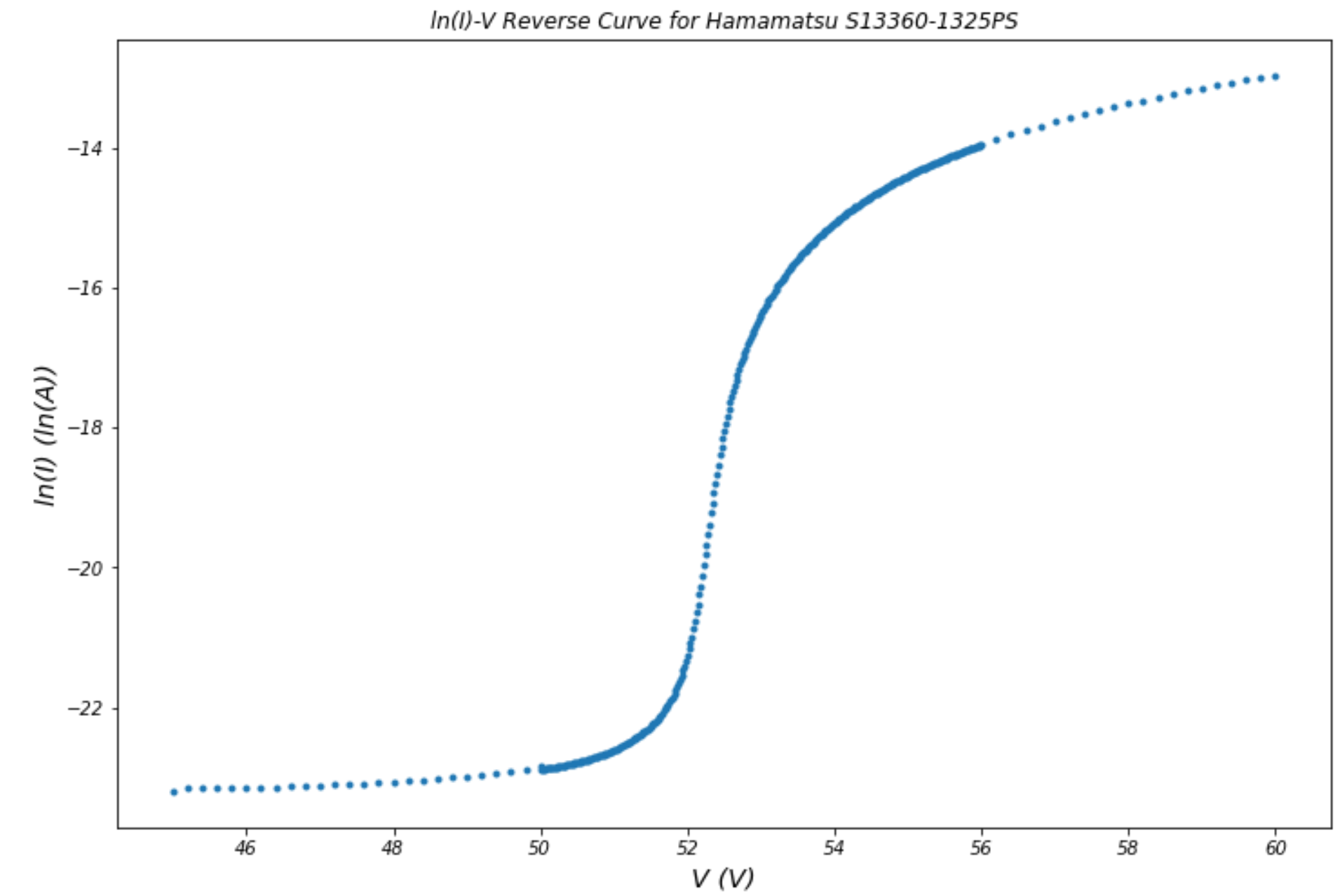
Method 1: V vs. sqrt(I)

- Intersection of two linear fits to V vs. sqrt(I)
 - Described e.g. [here](#)
- Looks like significant systematics from choosing fit range
 - Likely stray light in prober
 - Didn't pursue further



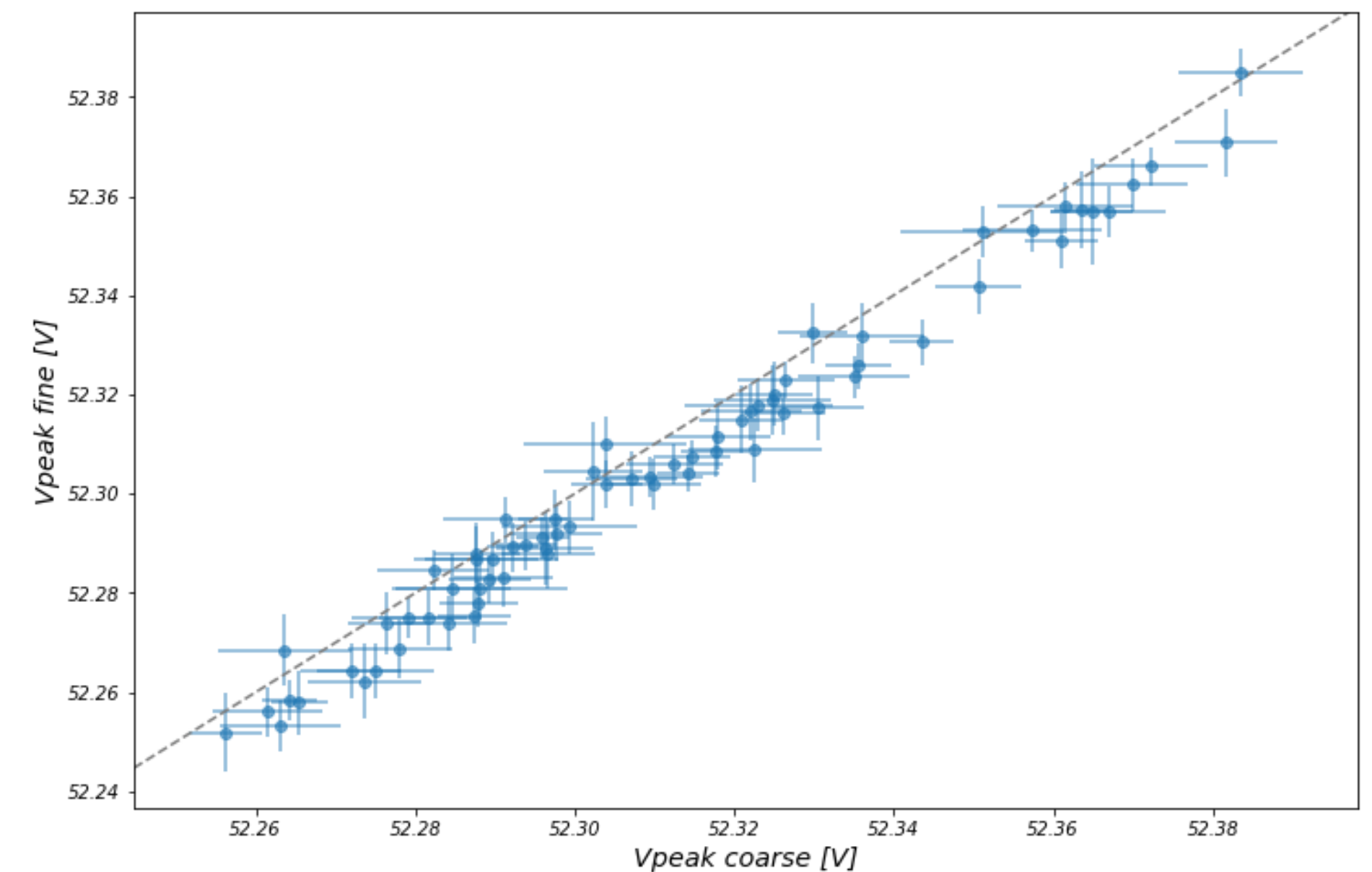
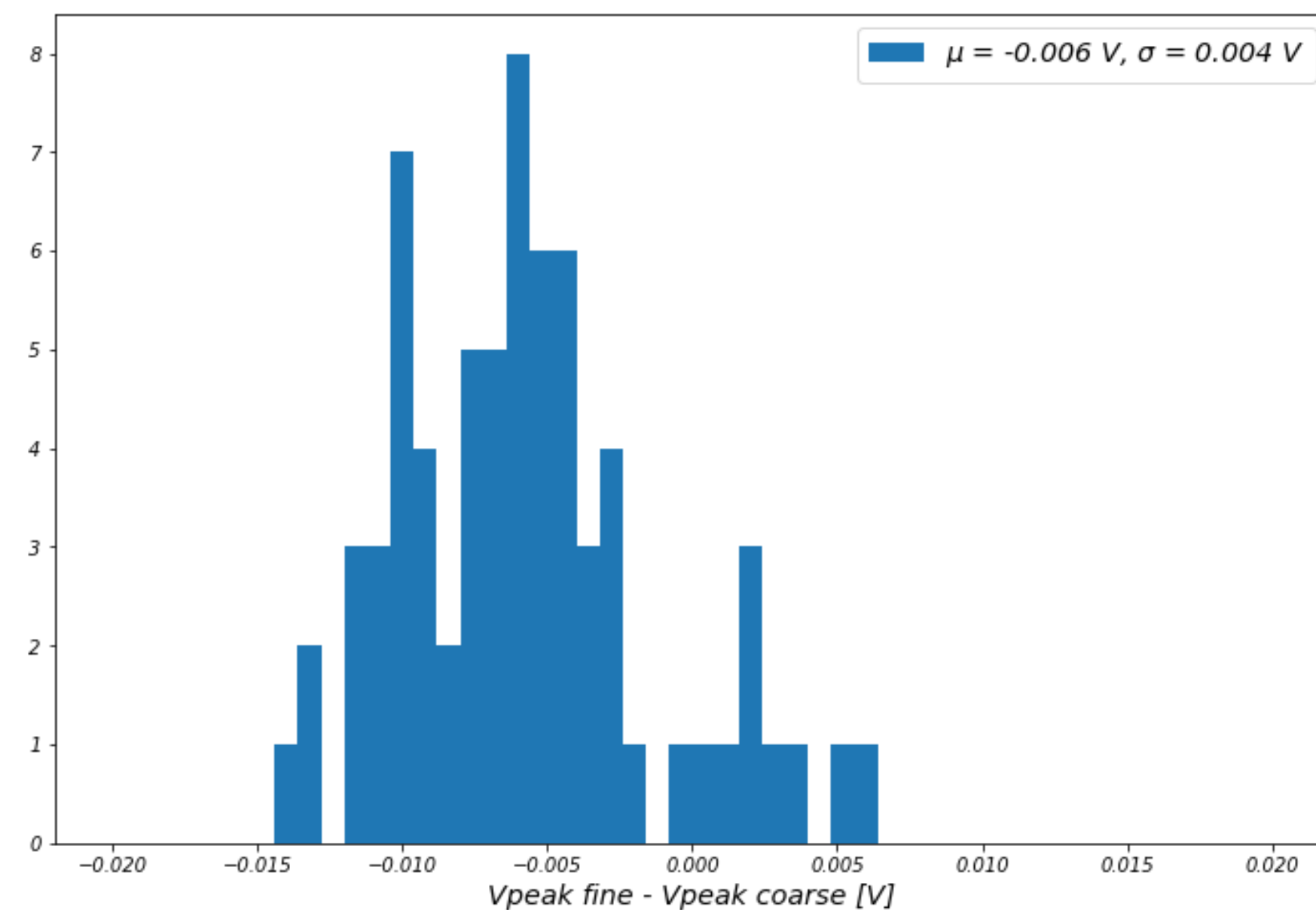
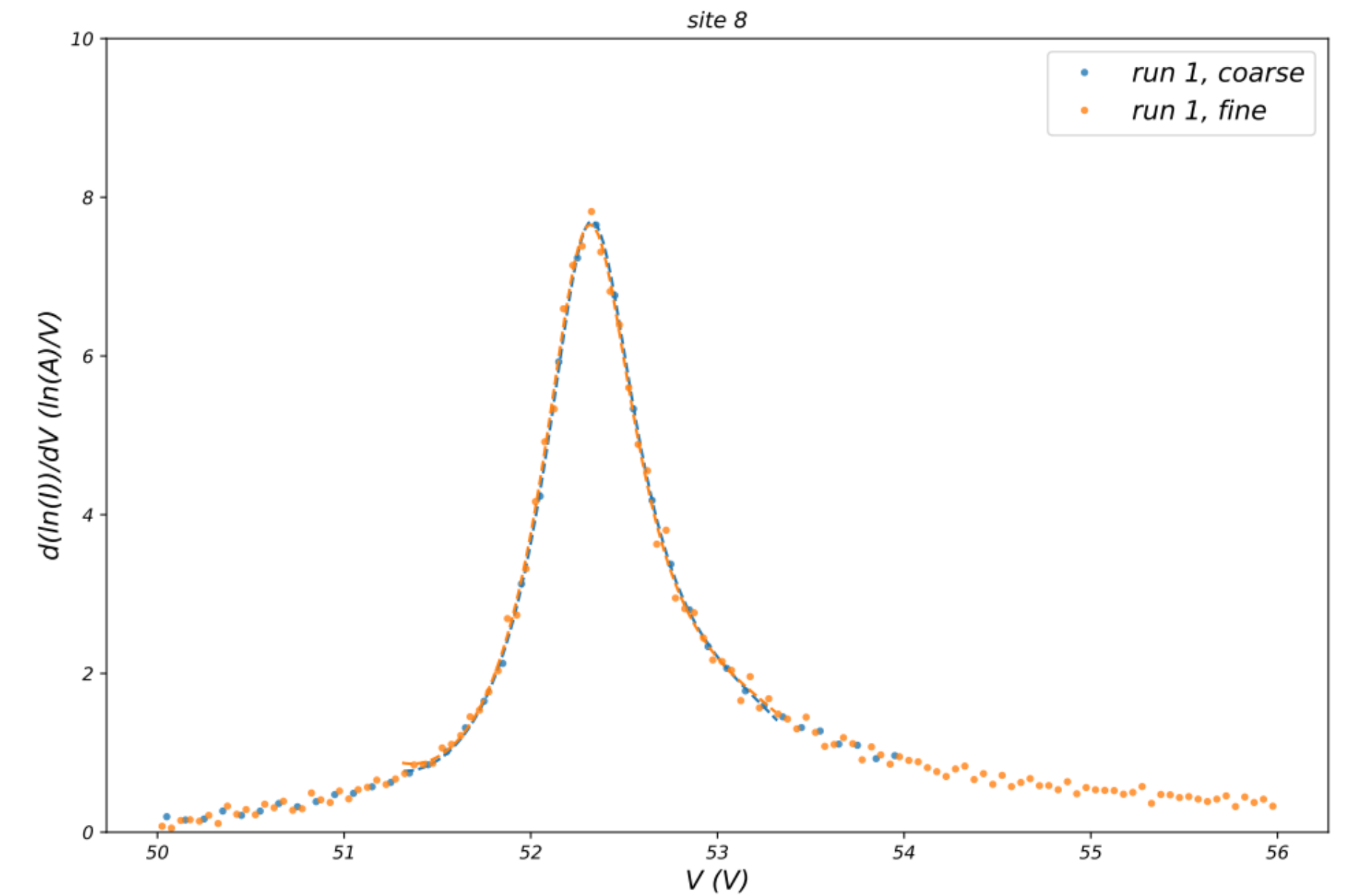
Method 2: Hamamatsu V_peak

- Inflection point of $\ln(I)$ under low light
 - Described [here](#)
 - Very tightly correlated to V_{bd} with fixed (small) offset
 - (exact offset depends on SiPM model?)
- Very stable extraction



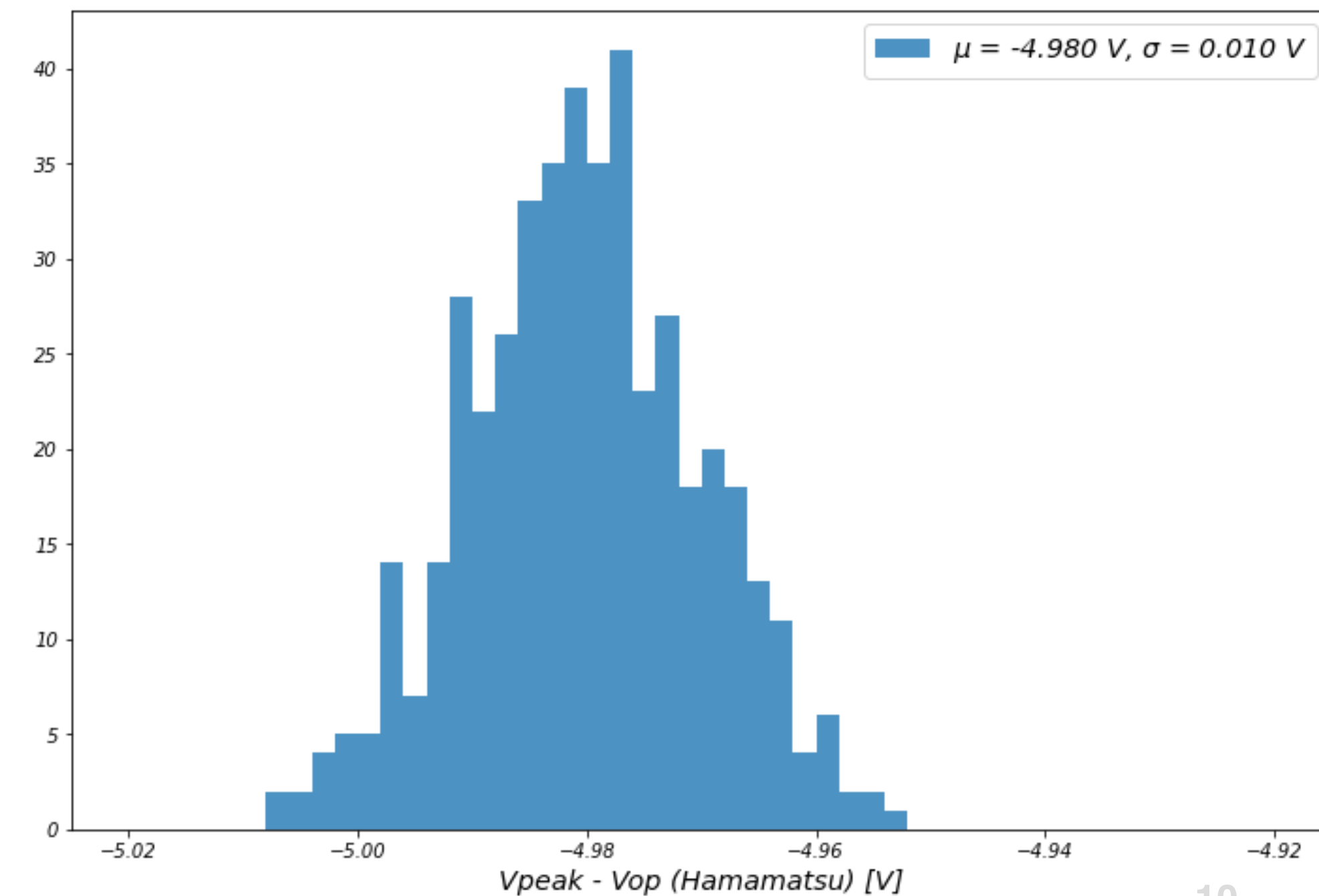
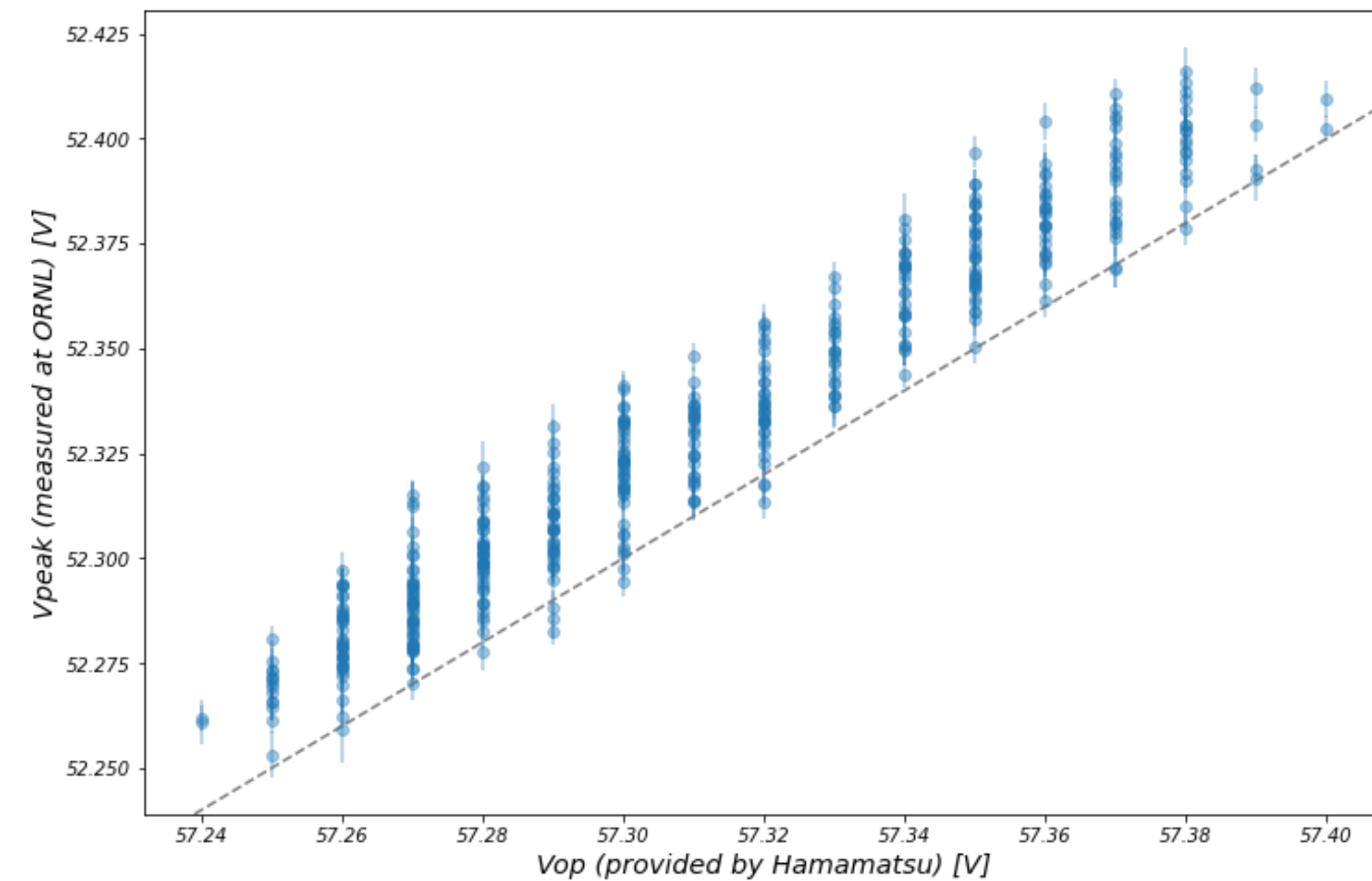
Validation Sample I

- Optimize scan parameters for speed vs. accuracy
- Slight bias between settings ~10mV
 - Have to live with this?
- Final settings: Full tray scan in ~1h25min



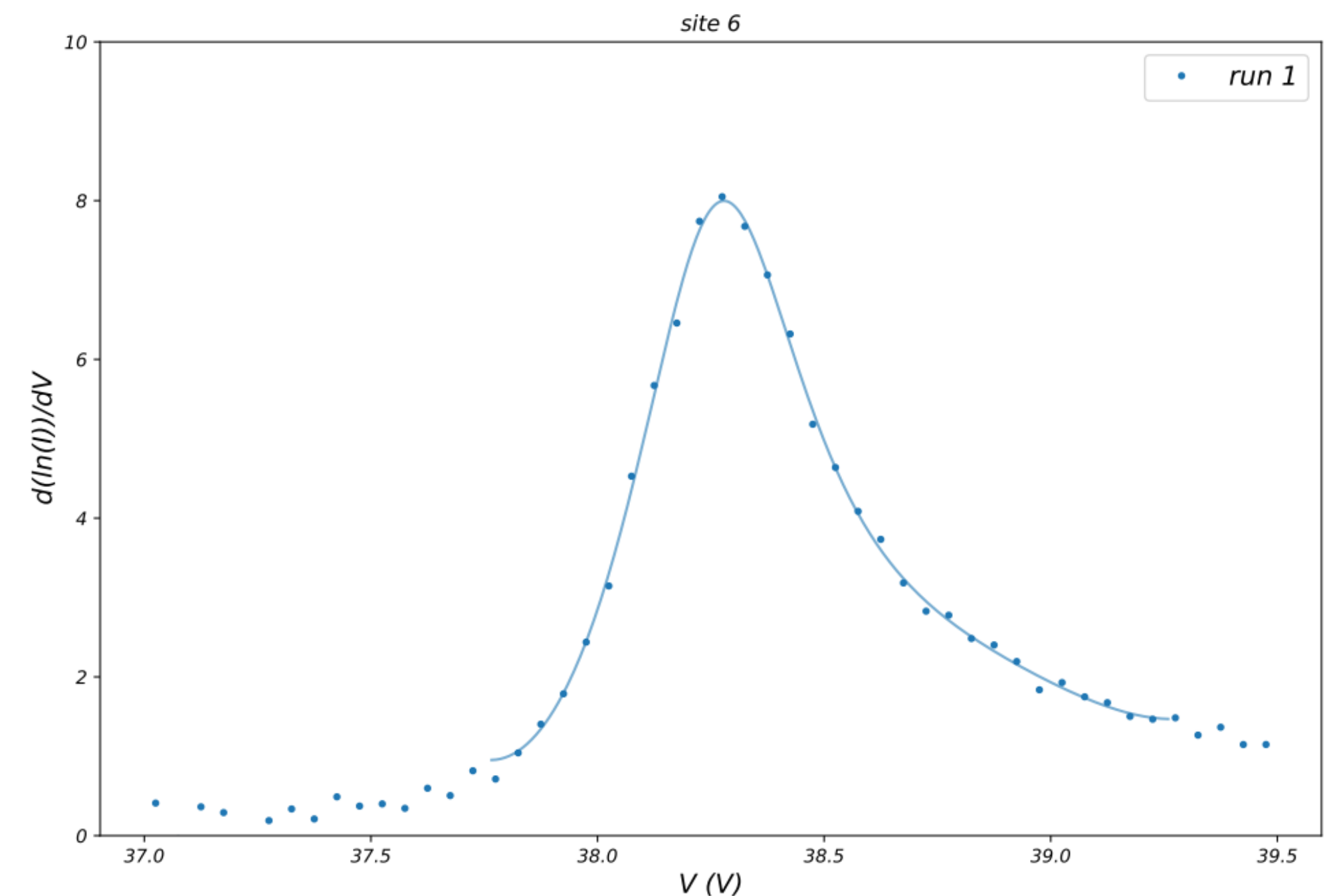
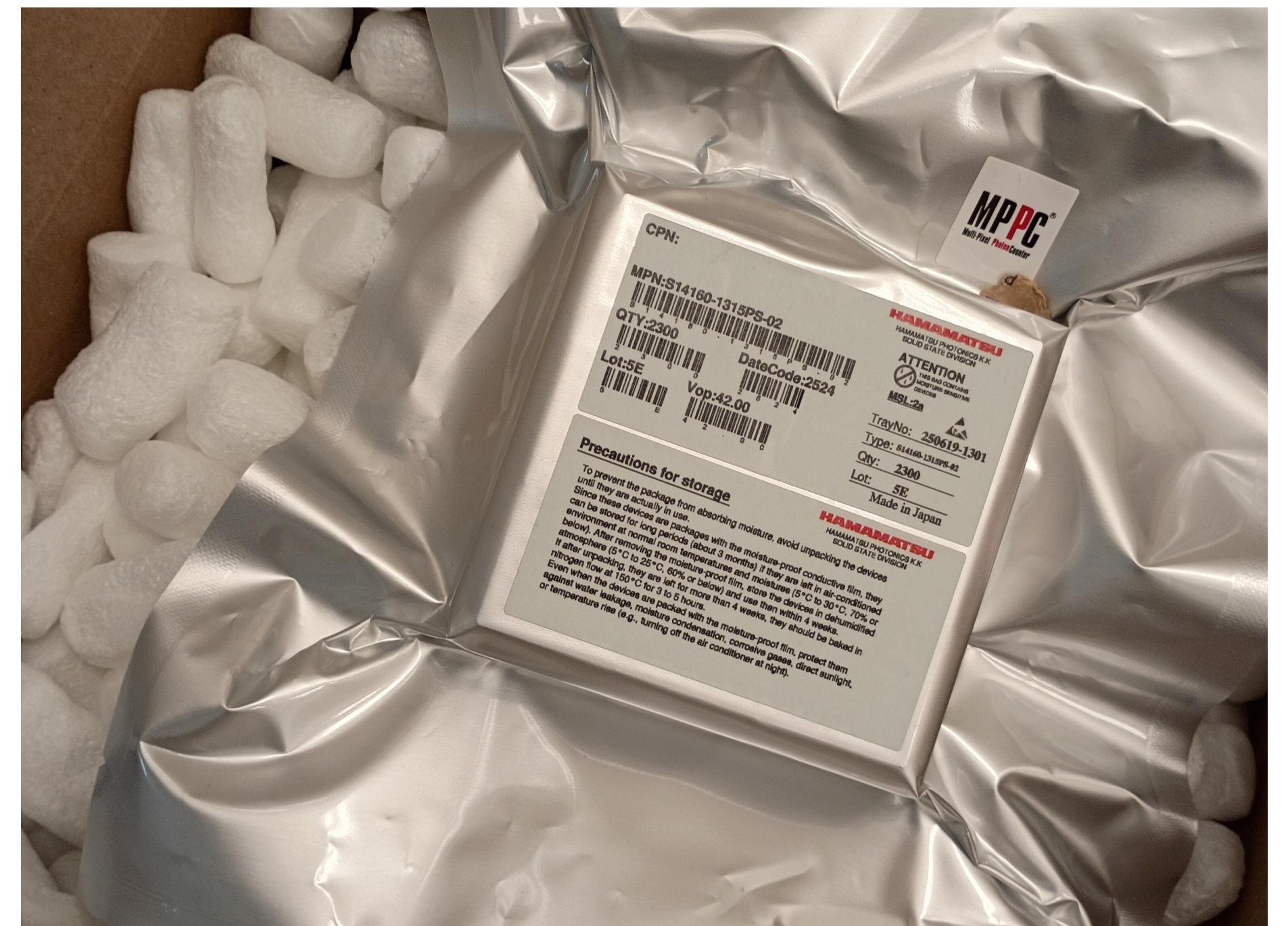
Validation Sample II

- Full tray scan compared to Hamamatsu V_op table
 - (V_op is V_bd+5V)
- 20mV offset, 10mV spread
 - Coarse vs. fine scan is only 5mV spread
- Conclusion: This works.



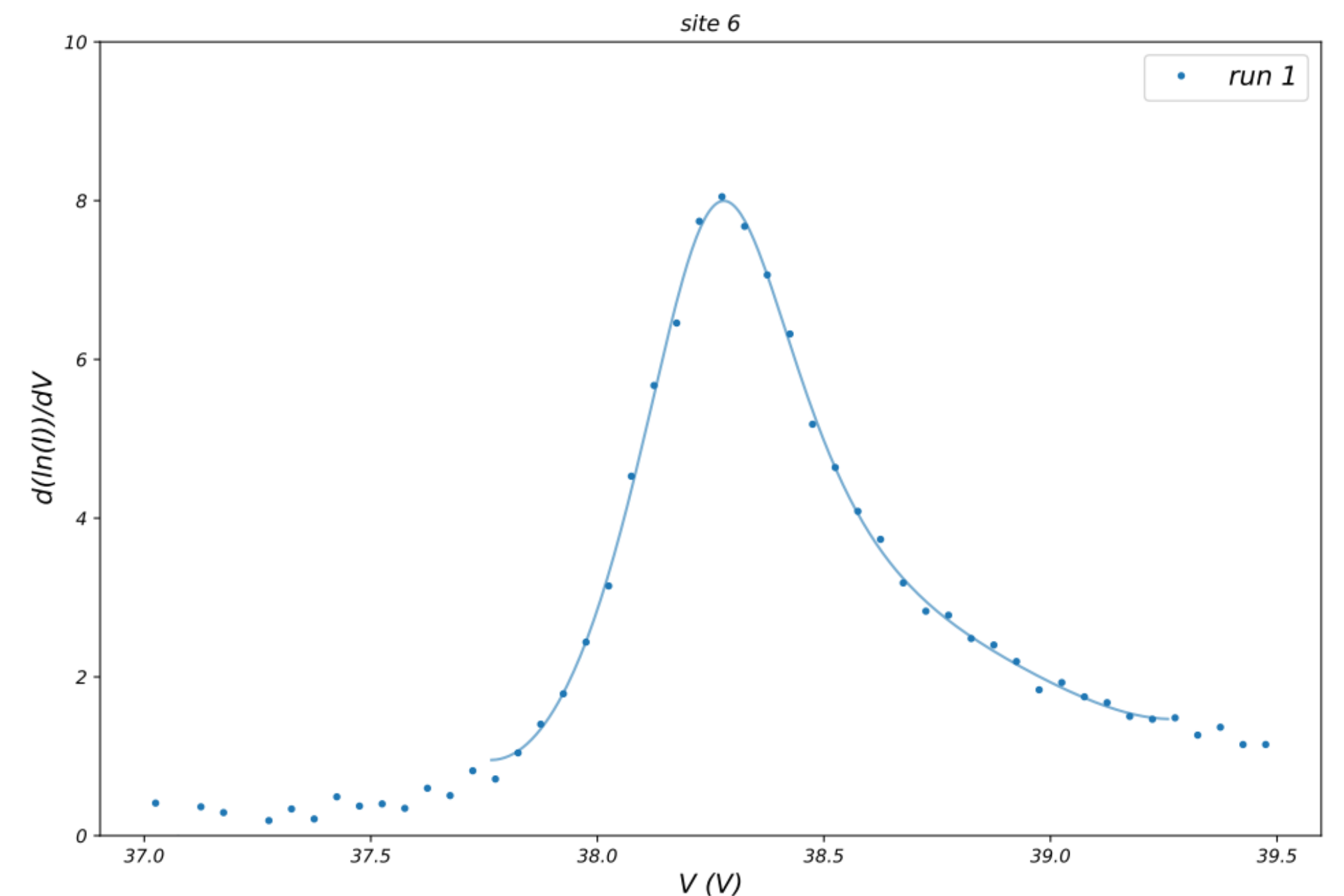
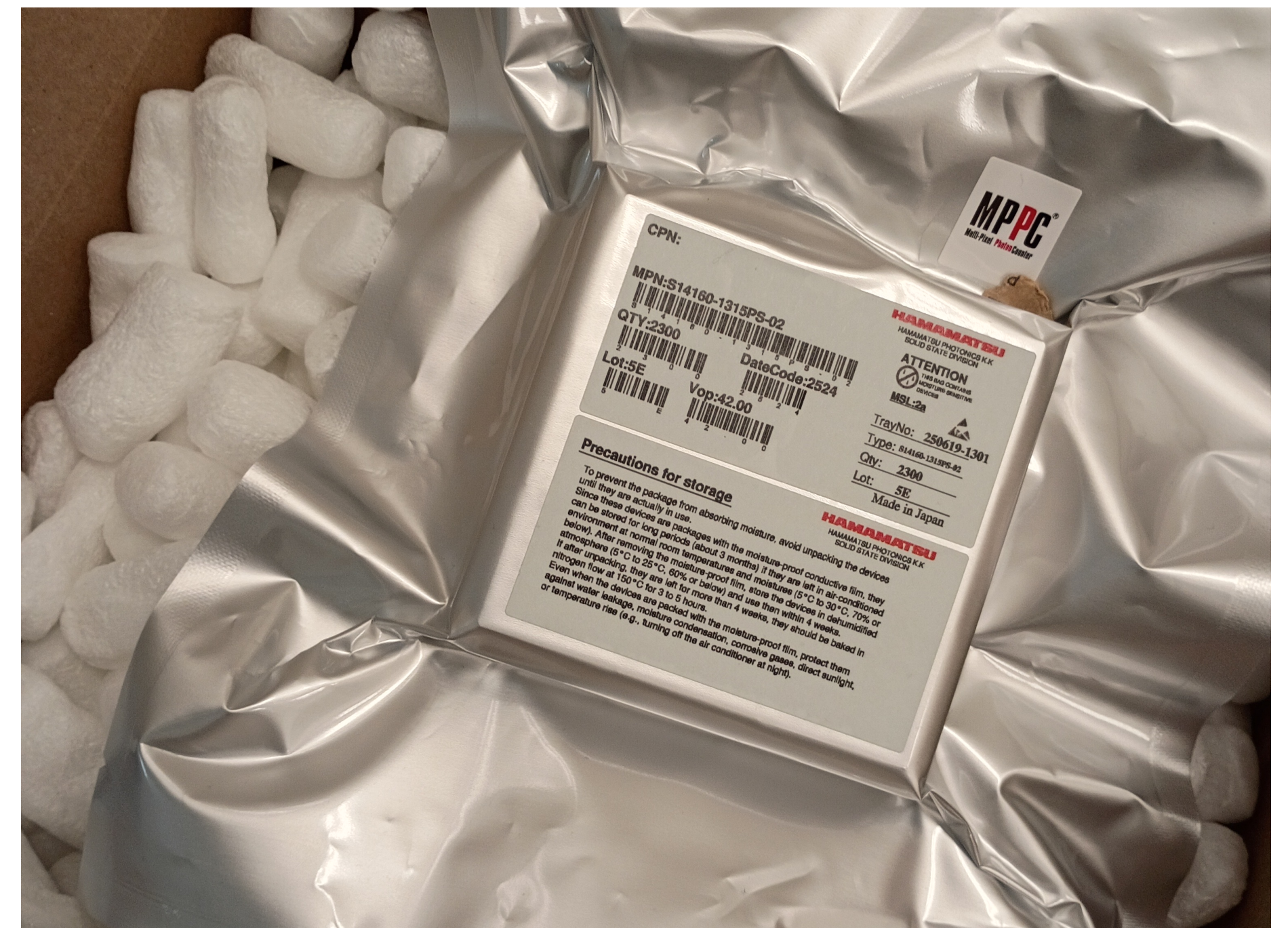
The QC Sample

- Received 4600 (10 trays) S14160-1315PS SiPMs for LFHCAL beam test prototype construction
 - Hand delivered by N. Novitzky ☺
- 5% sample to be measured for V_{bd} + visual inspection before assembly into LFHCAL modules
- $d(\ln(I))/dV$ peak shape slightly different than S13
- Adjusted some measurement details, 1h30min per tray.



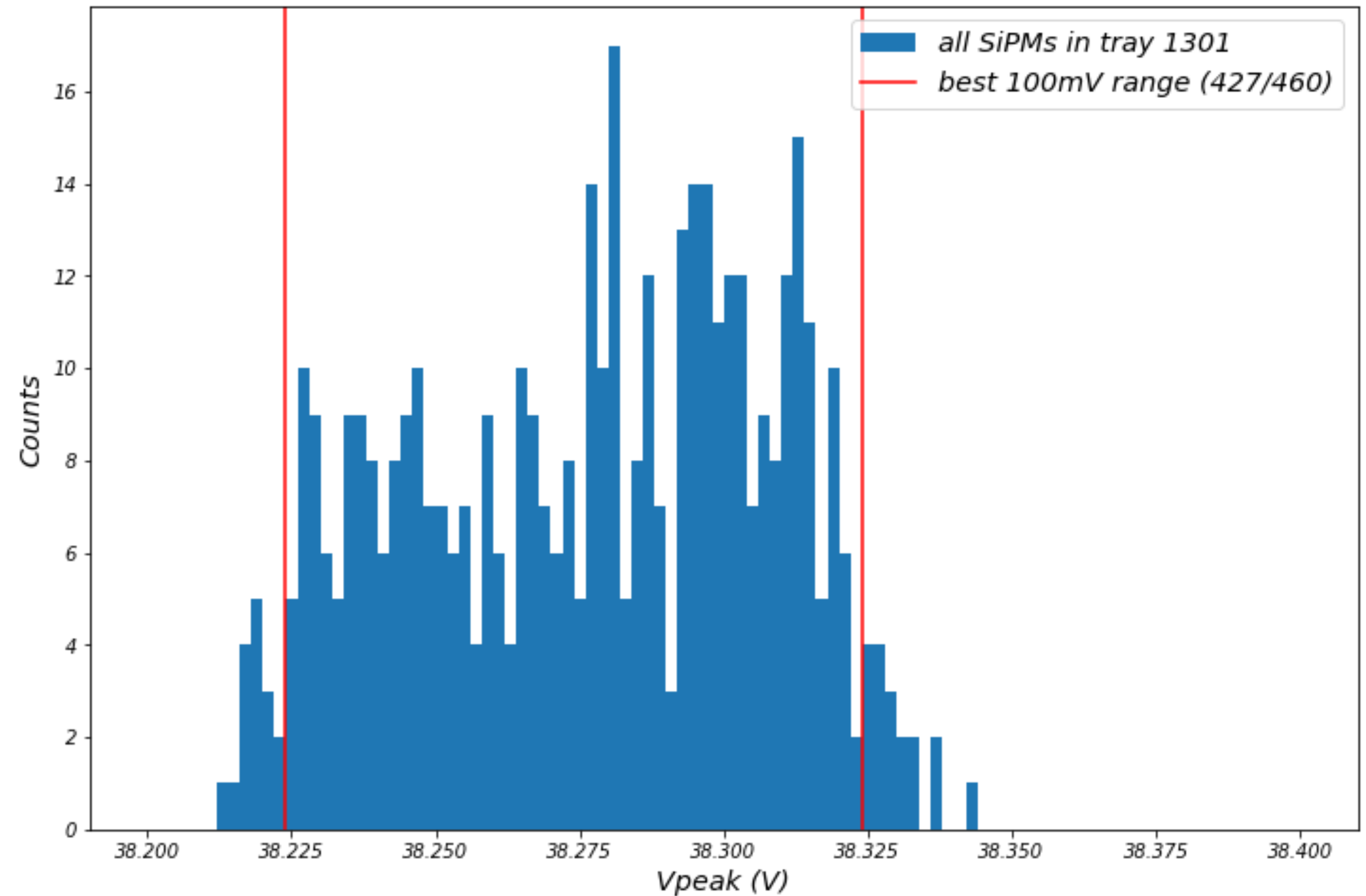
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First Tray Data

- Package is labeled “V_{op} = 42.0V”
 - Mean V_{bd} per tray should be 37.9-48.1V
 - Spread per tray should be 100mV max
- V_{peak} mean/median 38.28V
- Min/max spread 130mV
- 427/460 SiPMs within 38.27V +- 50mV



Conclusion

- ORNL will provide QC for ~3000 SiPMs from first Hamamatsu production batch
- Method developed and validated
 - Works very well on S13360 reference sensor set
- (Too) large deviation from V_{bd} specs on first tray of S14160 QC batch
 - Is $(V_{bd} - V_{peak})$ larger for S14 types than S13 types?
 - Only Hamamatsu example is for large size, large cell S13 type and way different than our S13 measurement
- Had some alignment issues (user error) on the next scanned tray...
 - Will have the rest by the end of this week.

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Yale contribution

QC of ~30k of the S14 Hamamatsu SiPMs from BNL

The team



Helen Caines



Prakhar Garg



Isaac Mooney



Emily Pottebaum



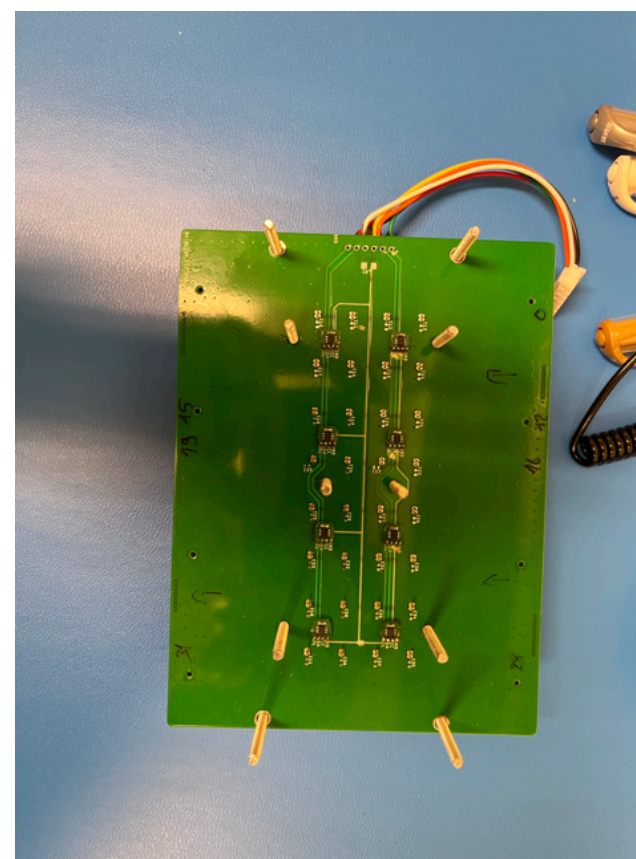
Ryan Hamilton



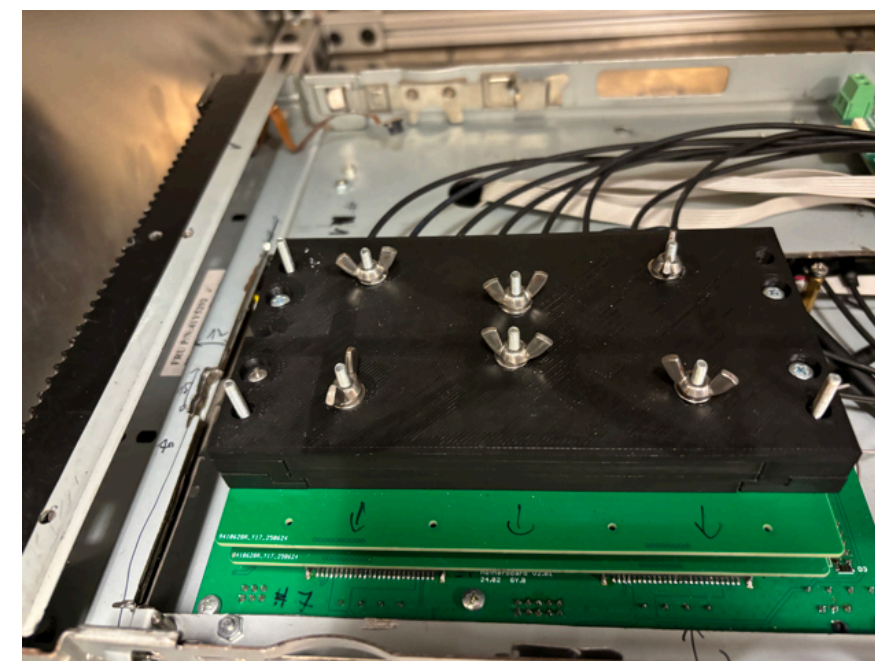
Langdan Zhu

Week 1

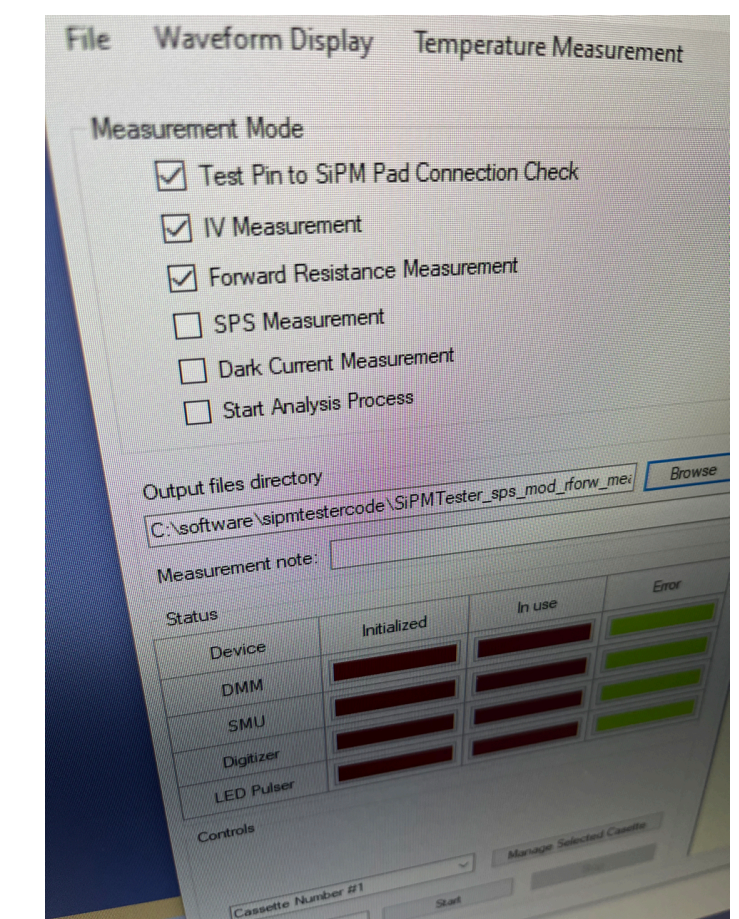
9/22 - 9/26



- A section of the lab was prepared, including Linux machines sent in advance from Debrecen
- Debrecen team visited, brought hard drives on the machines, hardware for the testing setup, a PXIe, etc.
- Software, including GUI for running tests of 32 SiPMs per cassette, working with minor memory issues



Isaac Mooney, Yale / BNL / CFNS

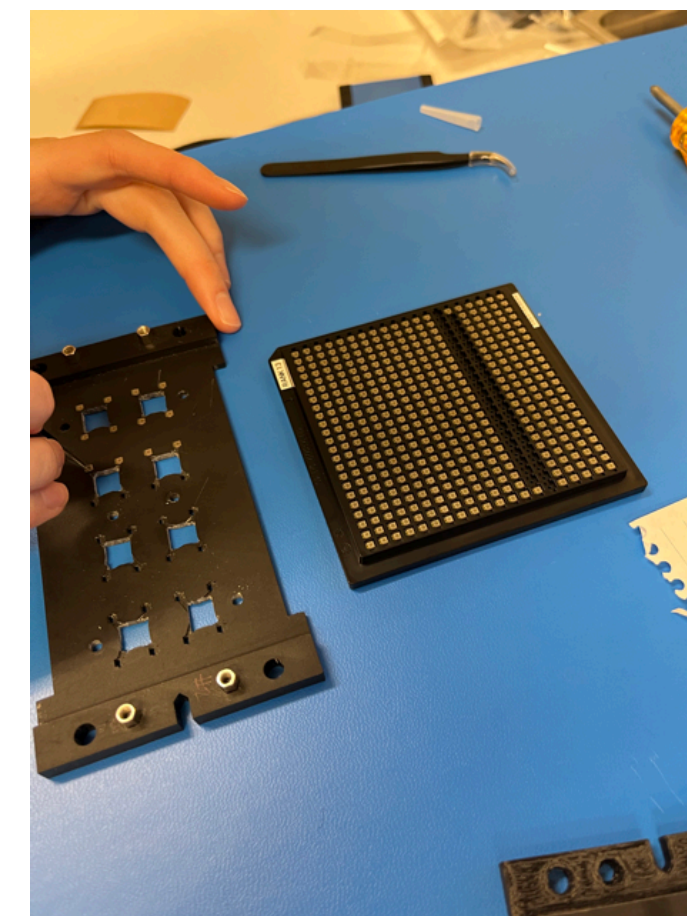
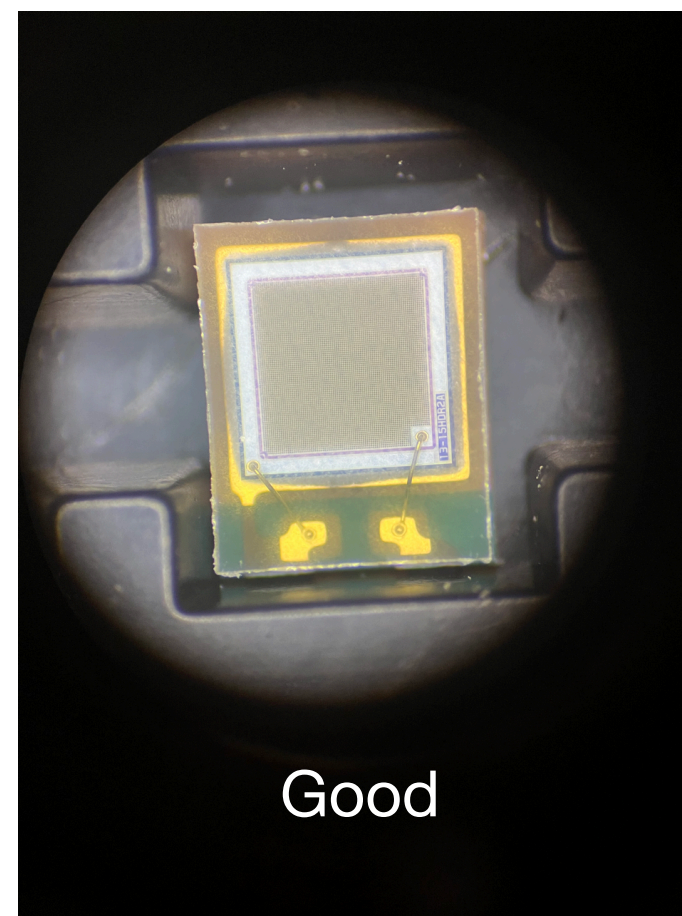
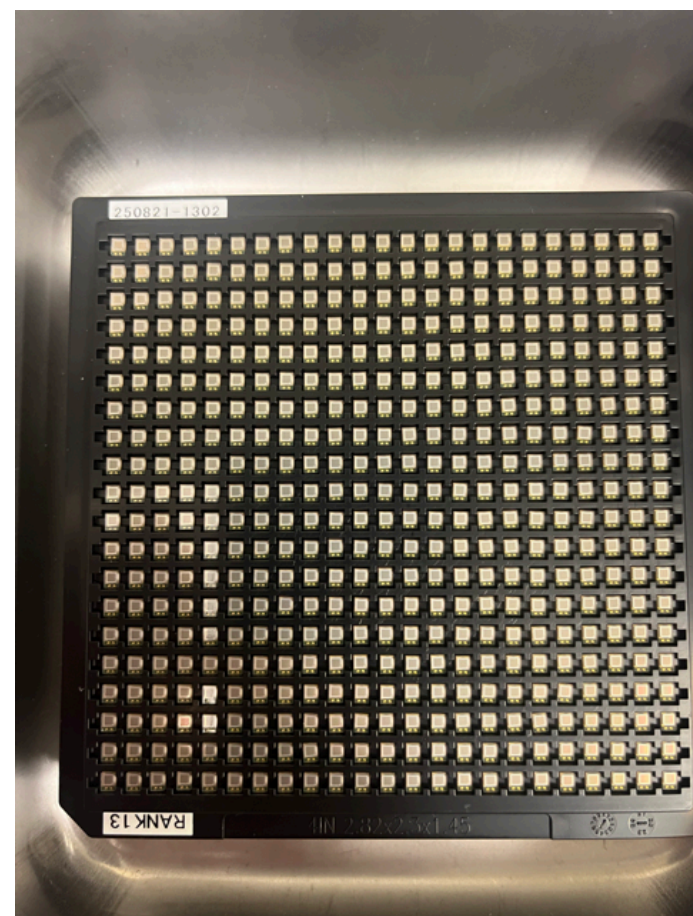


Week 2

9/29 - 10/3

Procedure for SiPM Shift Running	
1.	Check if computers are running: wake up monitor, check if lights are blinking on power supply.
a.	If not: press the button on the Linux box (on the bottom of the rack).
b.	Flip the switch on the bottom left of the PXIe.
c.	Flip the switch in the back of the power supply.
2.	If on the wrong machine (Linux box vs. PXIe) press the switch on the wall to change [To do: figure that out].
3.	Check previous shifter's e-log sign-out entry: https://elogs.physics.yale.edu/LFHCat-Yale/ . Figure out what cassettes, trays, etc. are where.
4.	Fill out the e-log sign in sheet, adding info in the yellow fields from the GUI and/or by observing the cassettes and manufactory trays. Note any alarming details if you find something out of the ordinary. As you follow the procedure below, you can edit the e-log and add any other details if relevant.
5.	Find the measurement panel GUI. If it is not present, open Microsoft Visual Studio. Open the "SiPMcharacterization" project in VS. Press "run," or the green play button in Visual Studio's upper taskbar. This should start up the measurement GUI.
6.	Check bottom left to see if previous measurement has completed. DO NOT proceed if the measurement is still in progress, as opening the dark box while a measurement is taking place can damage the SiPMs!!!
7.	Check visually that it seems the previous shift has left one cassette in the measurement circuit, and one cassette loaded with new SiPMs in the "next-in-queue" box.
8.	In that case, remove the just-tested cassette out of the dark box, following the "Removing completed measurement cassette" procedure below.
9.	Insert the next-in-queue alternate cassette into the circuit (left by the previous shifter in the next-in-queue box), following the "Preparing circuit for data-taking" procedure below.
10.	Ground yourself with the grounding cuff.
11.	Follow the "Removing SiPMs" procedure below for the cassette you just removed from

- Last week: wrote instructions for shifters, working on a manual with pictures. First week of testing, just finished testing first of five trays (460 SiPMs each) dropped off by Oleg Eyser in Week 1.
- Database for SiPM measurements/plots almost ready, mostly just needs to be hosted on a server.



Week 3

10/6 - 10/10

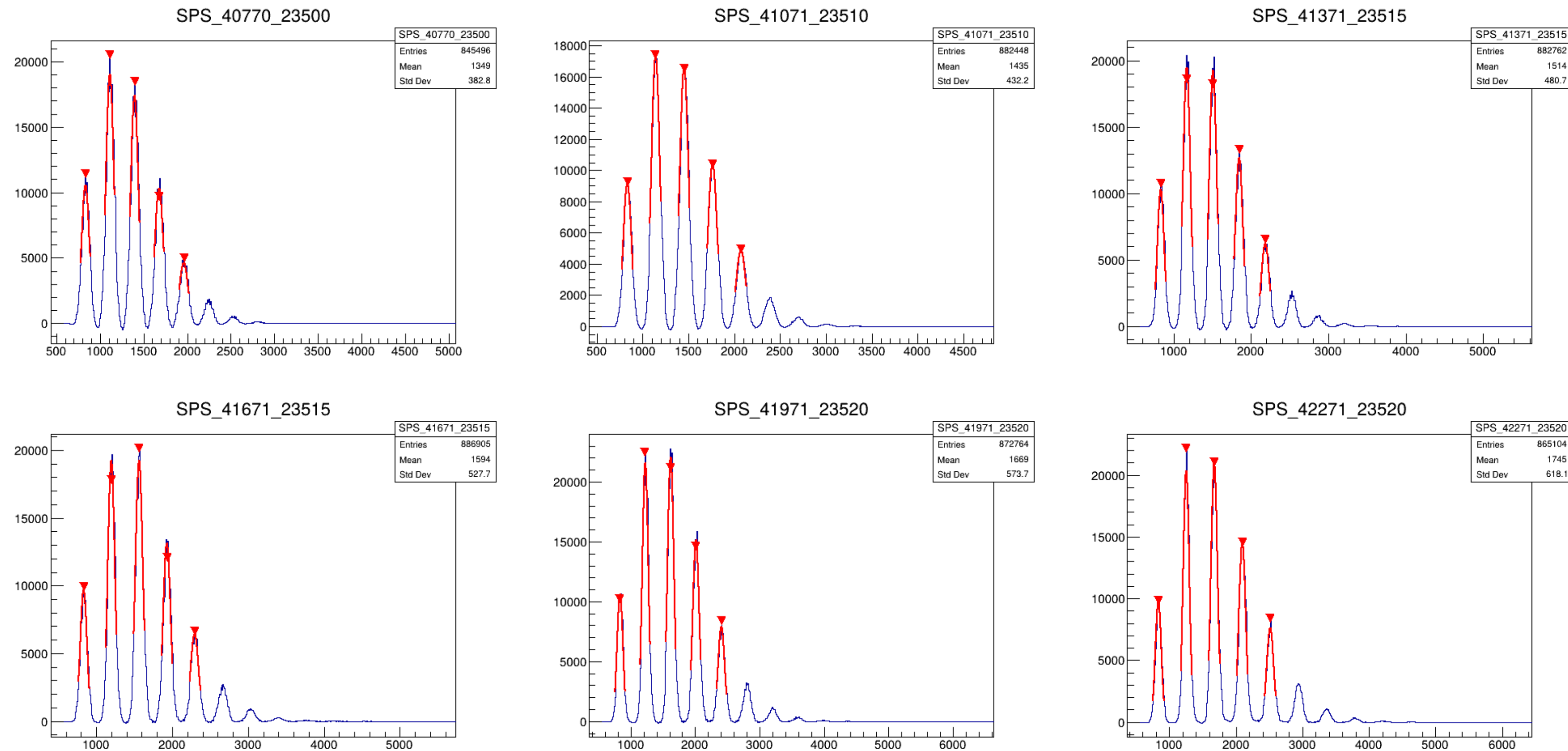
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- Aiming for another tray this week



Results from Tray 1

Single photon spectra (SPS)

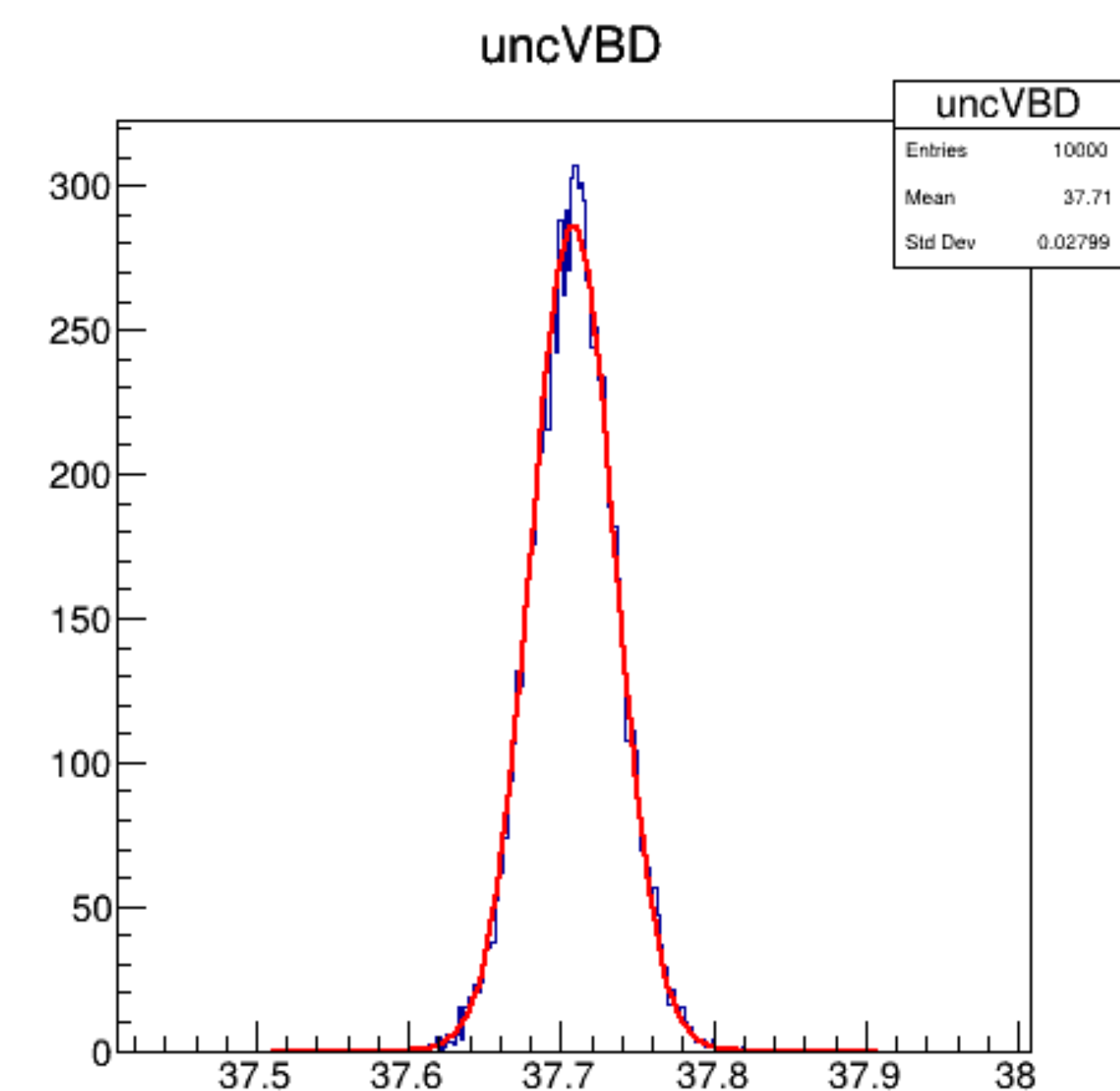
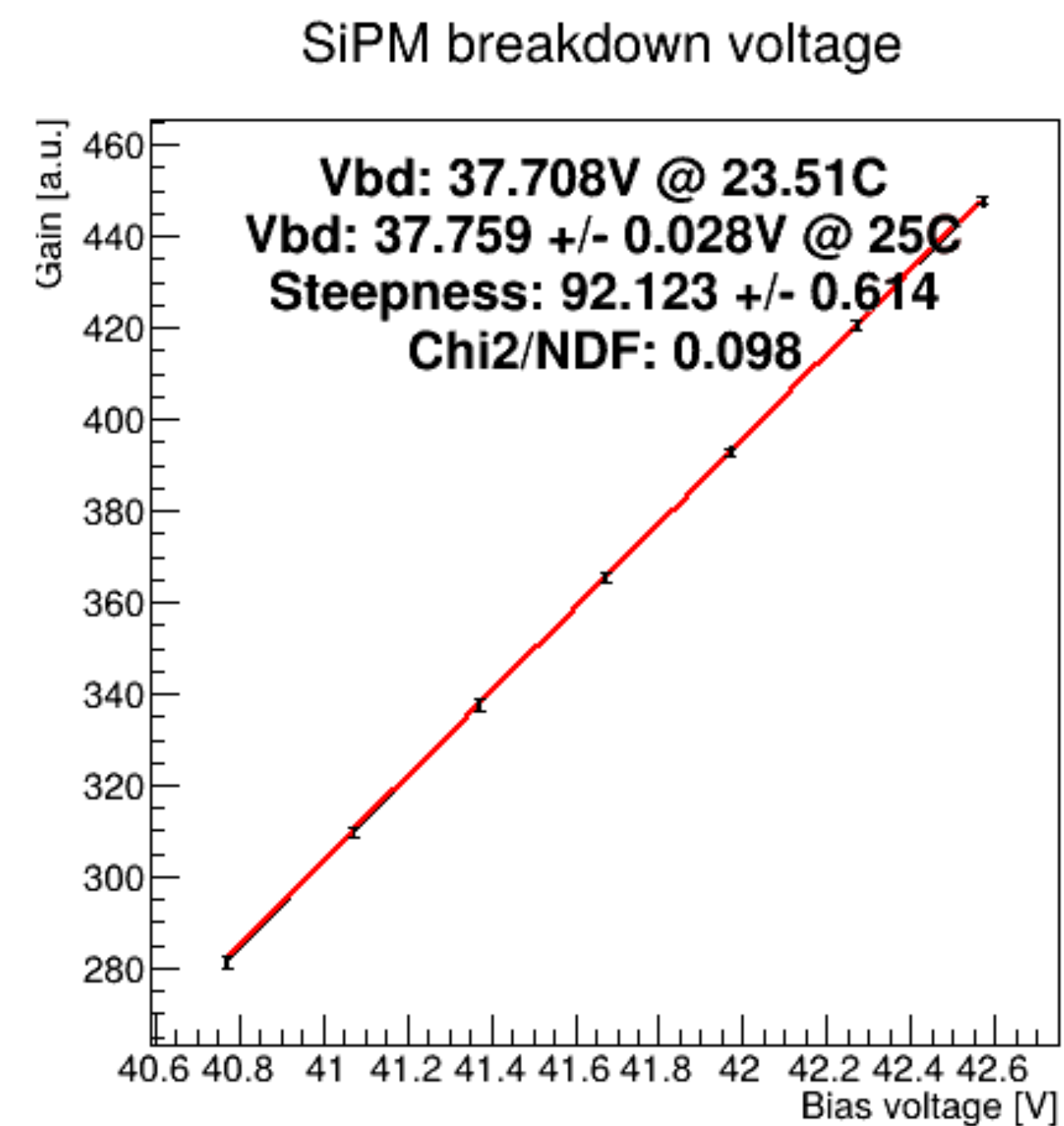
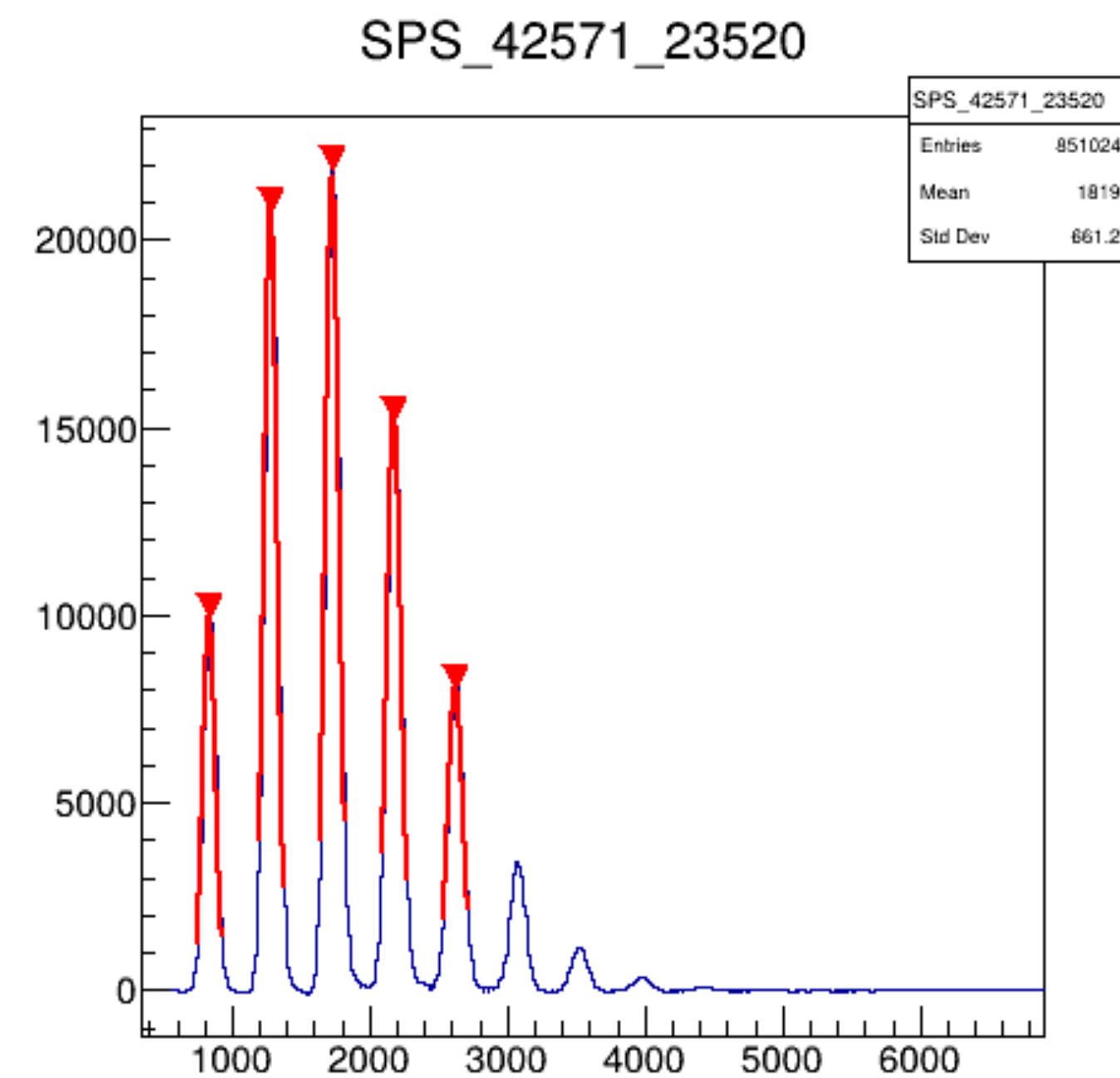
Example: SiPM (0,10)



Each panel is a different voltage (in title). Increases from top left to bottom right (along with measured temperature, also in title).

Single photon spectra (SPS)

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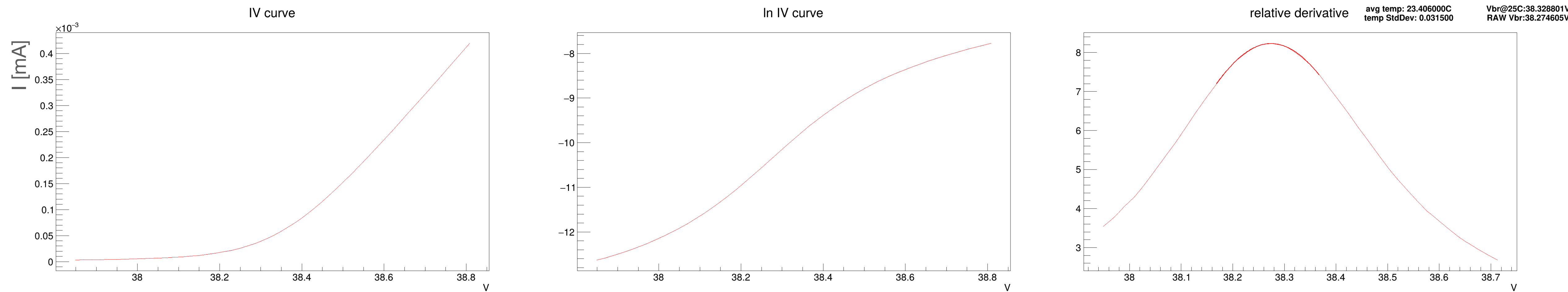


Each SPS plot gives us one datapoint in the middle figure, after fit and inter-peak distance extraction.

V_{bd} linearly extrapolated to zero gain, with temperature correction: **~37.76 V**

IV curves

Example: SiPM (0,10)

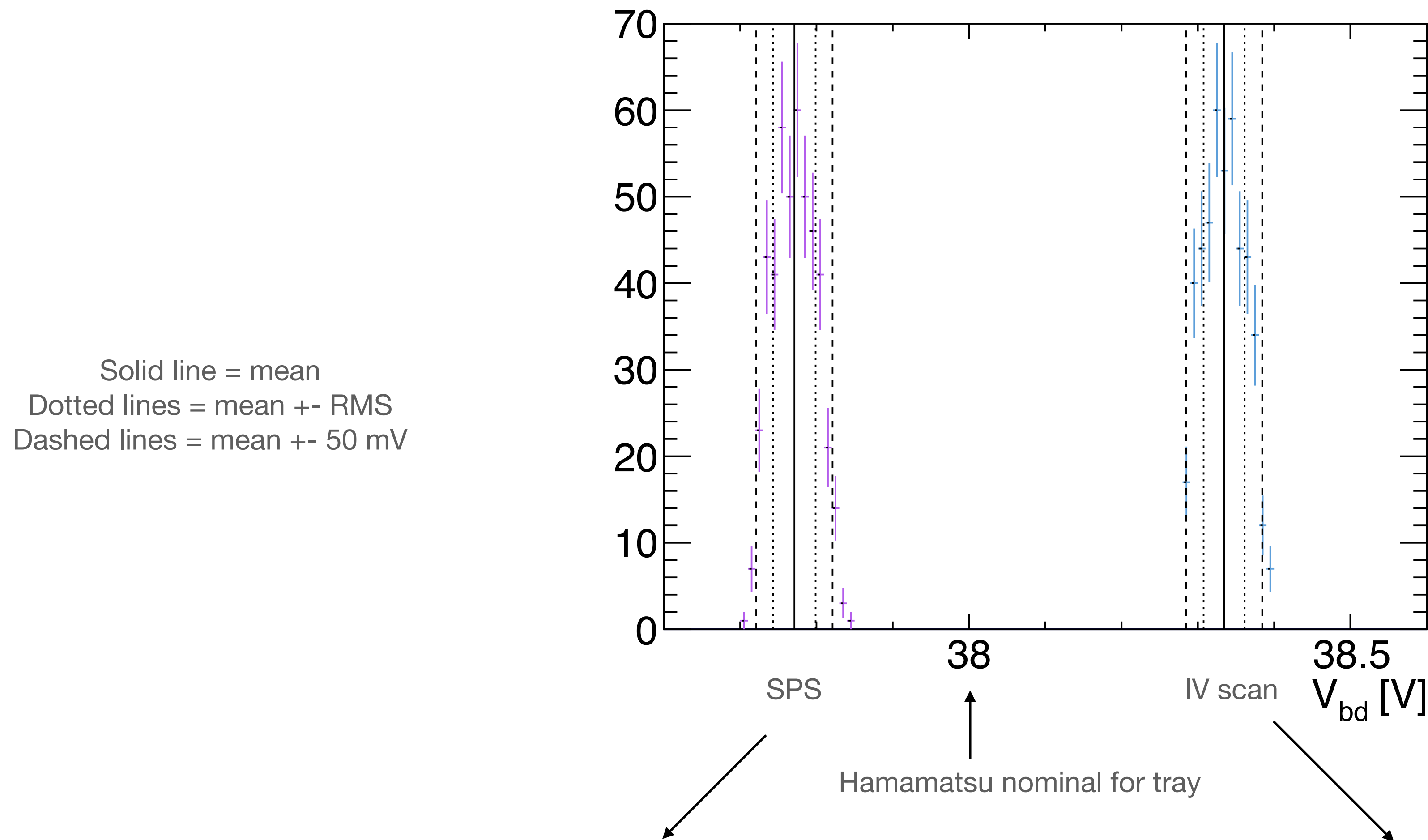


$I(V_{\text{peak}}) \sim 30 \text{ nA}$

Measurement made at 50 voltage steps

$V_{\text{peak}} \sim 38.275$ cf. $V_{\text{bd}} \sim 37.71$
Corrected to 25C: $V_{\text{peak}} \sim 38.329$ cf. $V_{\text{bd}} \sim 37.759$
 $V_{\text{diff}} \sim 0.57 \text{ V} \rightarrow$ seems large?

V_{peak} and V_{bd}



From root integrals: **6.0%** outside 37.72 V \pm 50 mV. By eye/hand: 25/459 = 5.4%

From root integrals: **4.3%** outside 38.28 V \pm 50 mV. By eye/hand: 7/459 = 1.5%

Outlook

- Setup seems to be working, takes about 1+ hr/32 SiPMs
- Need to look further into temperature correction; difference between determinations of V_{bd} from IV and SPS; whether small amount of light is pulsed during IV measurement as specified by Hamamatsu.
- Are outliers the same between both methods? SiPM flaws vs. procedure.
- Further smooth data-taking expected, aiming for ~1 tray/week going forward.
- Cataloguing with database