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)
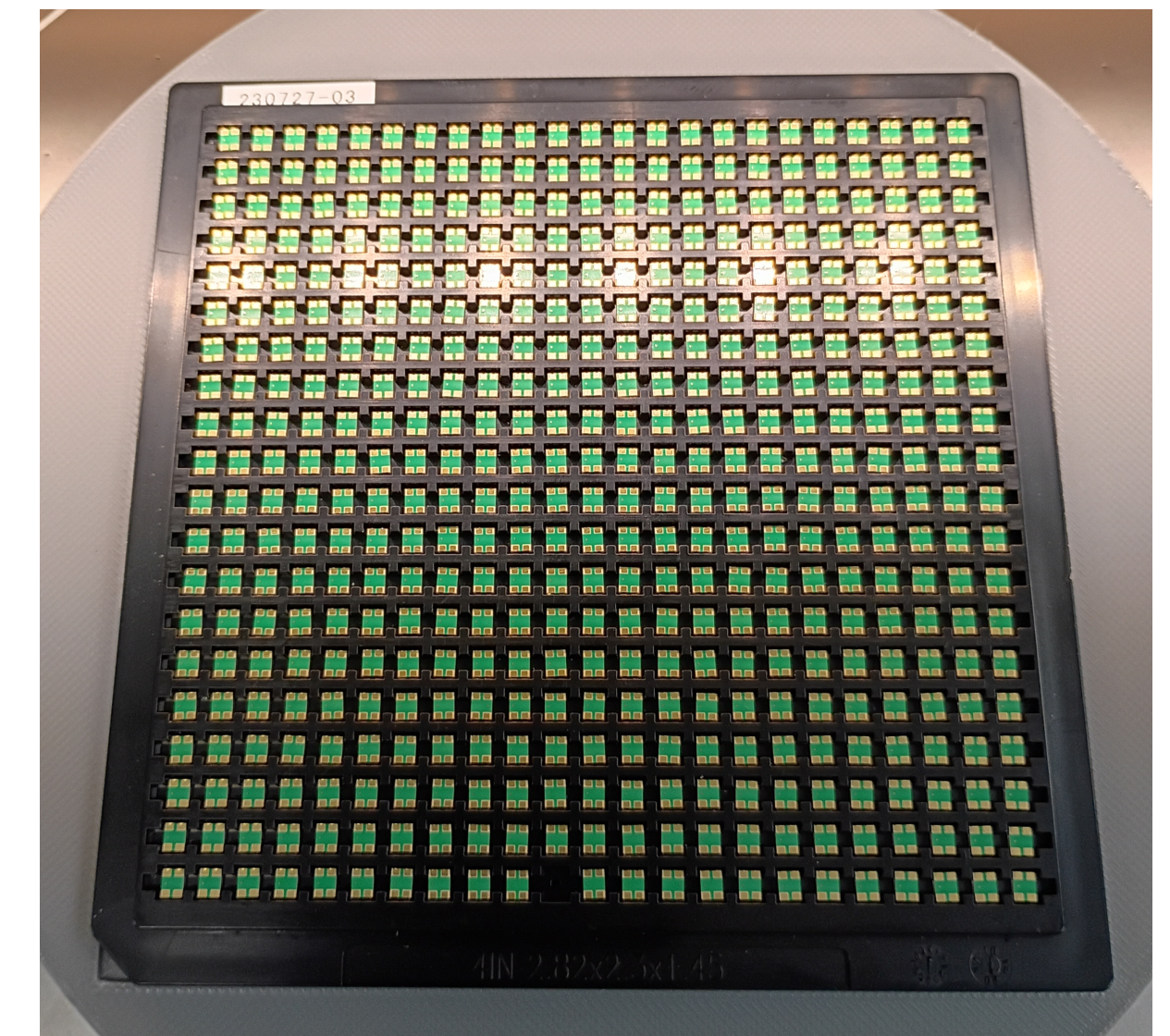**10/6/2025**

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.
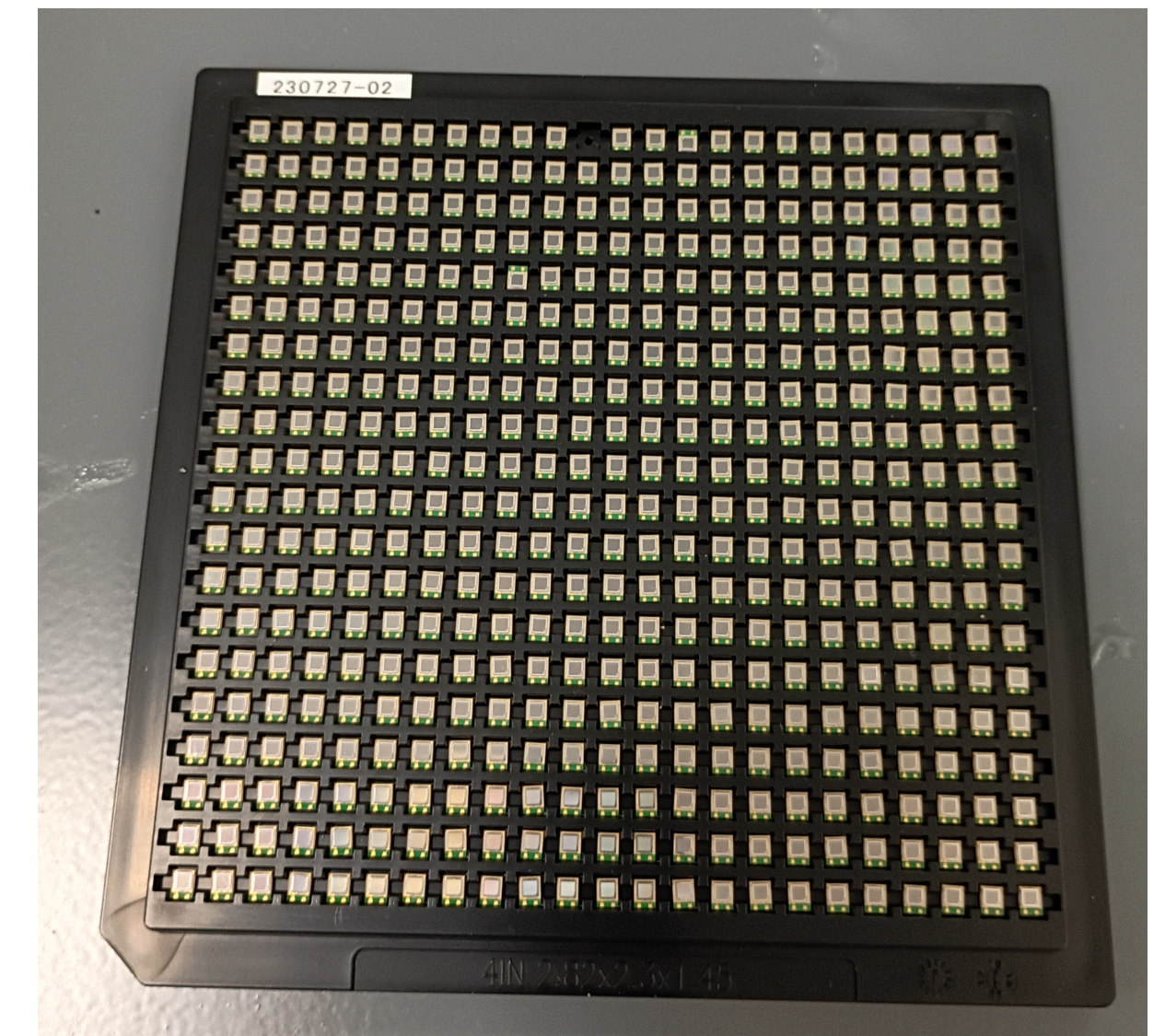
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OAK RIDGE
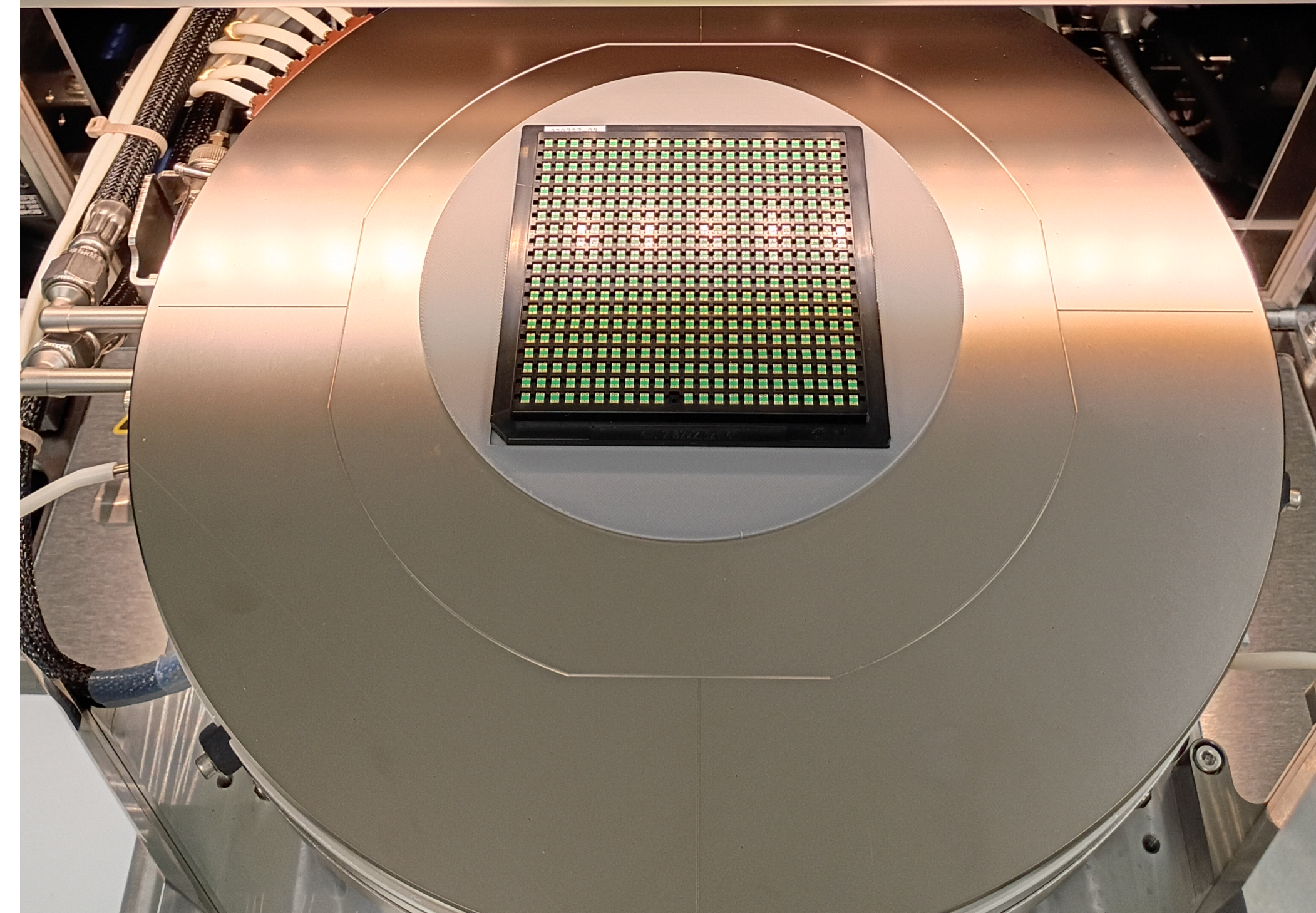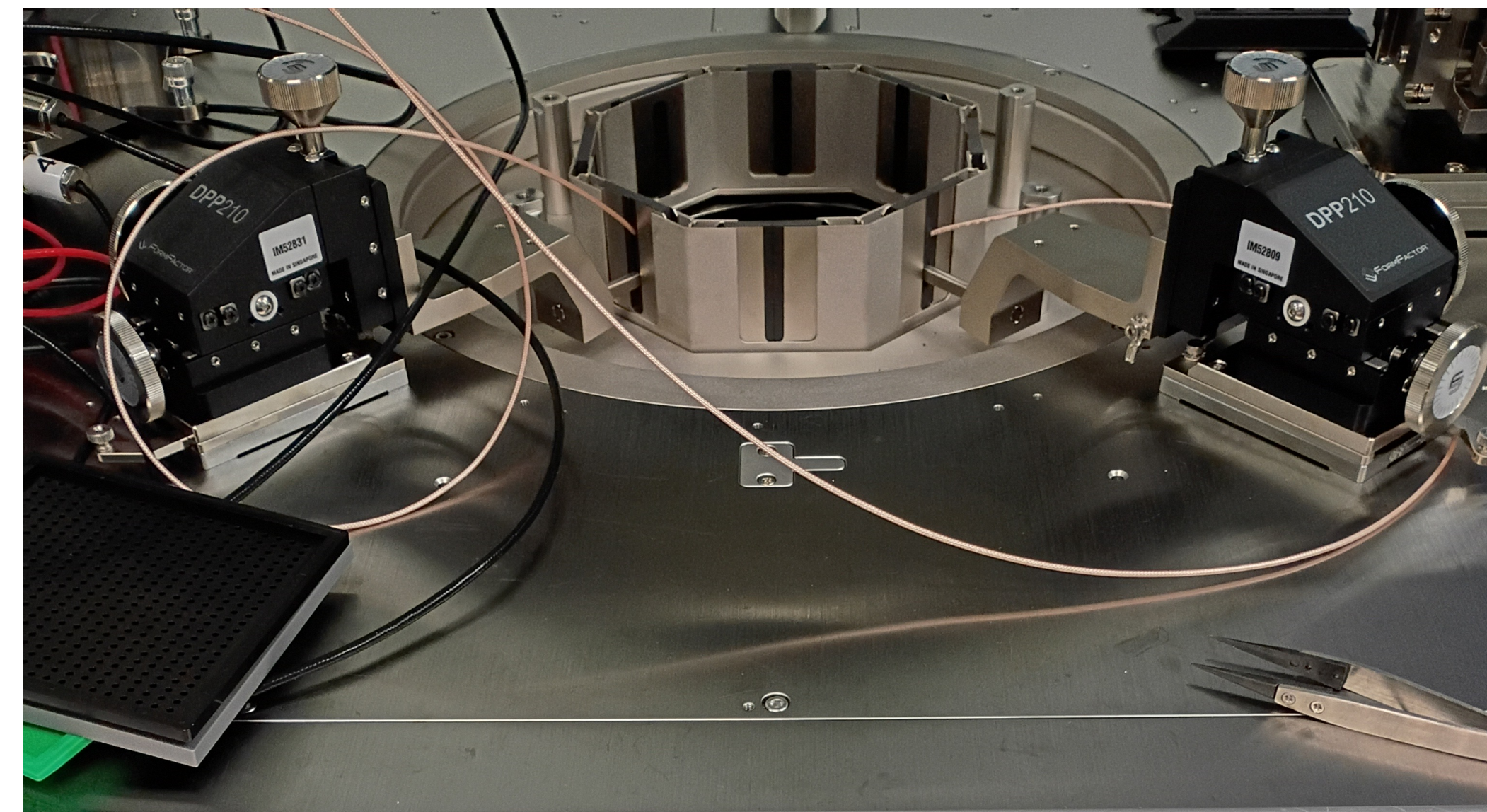National Laboratory

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)
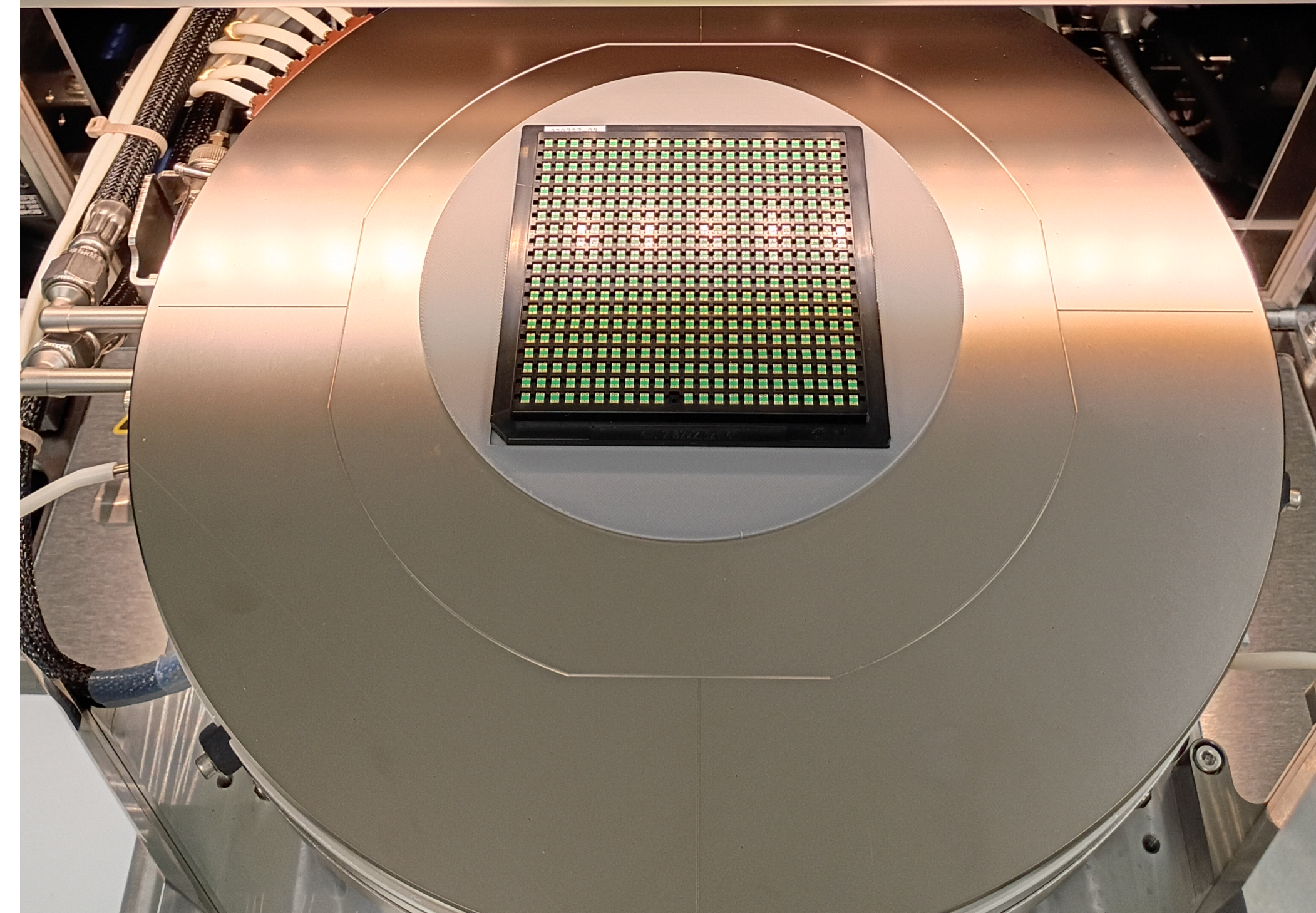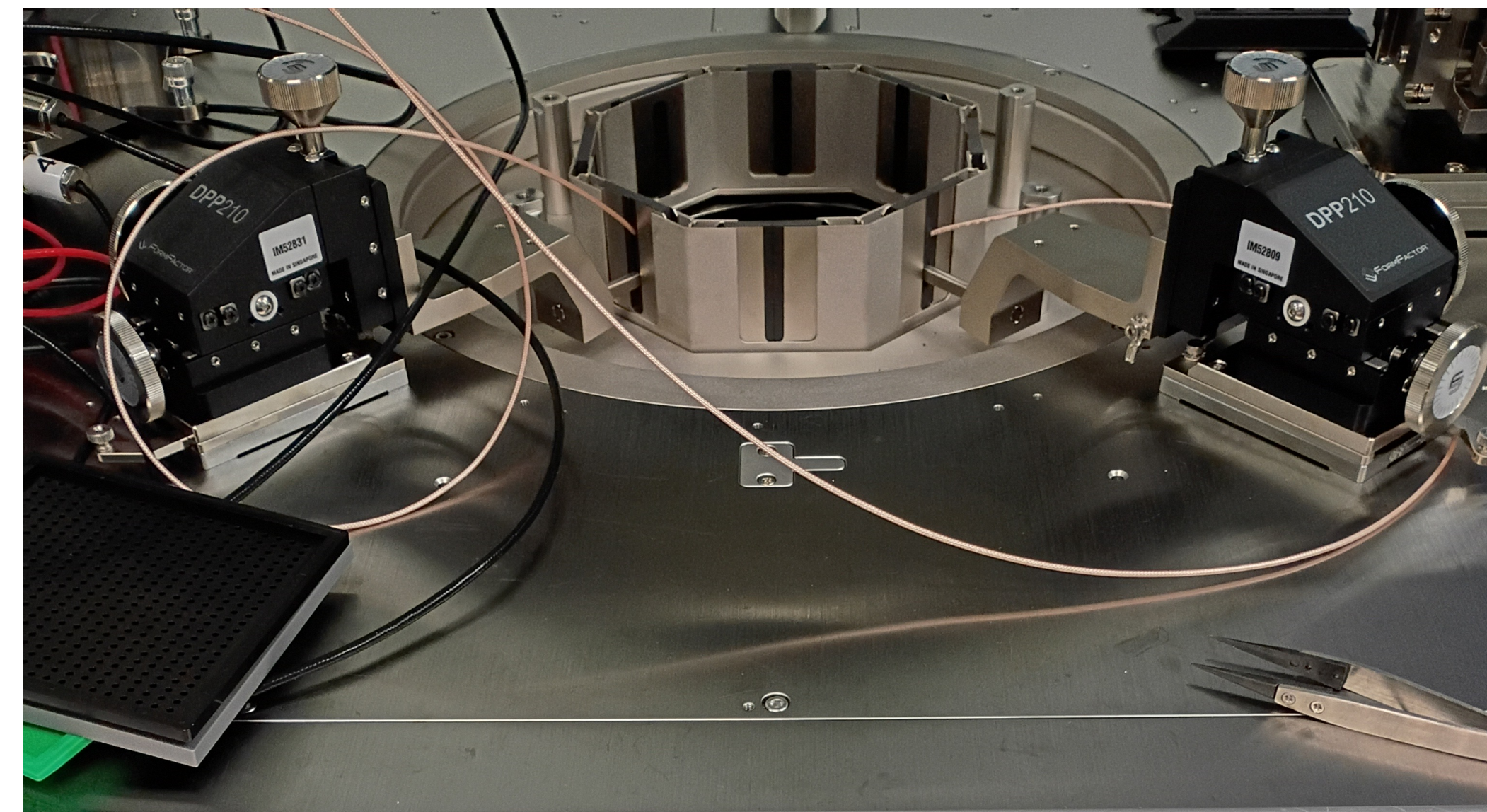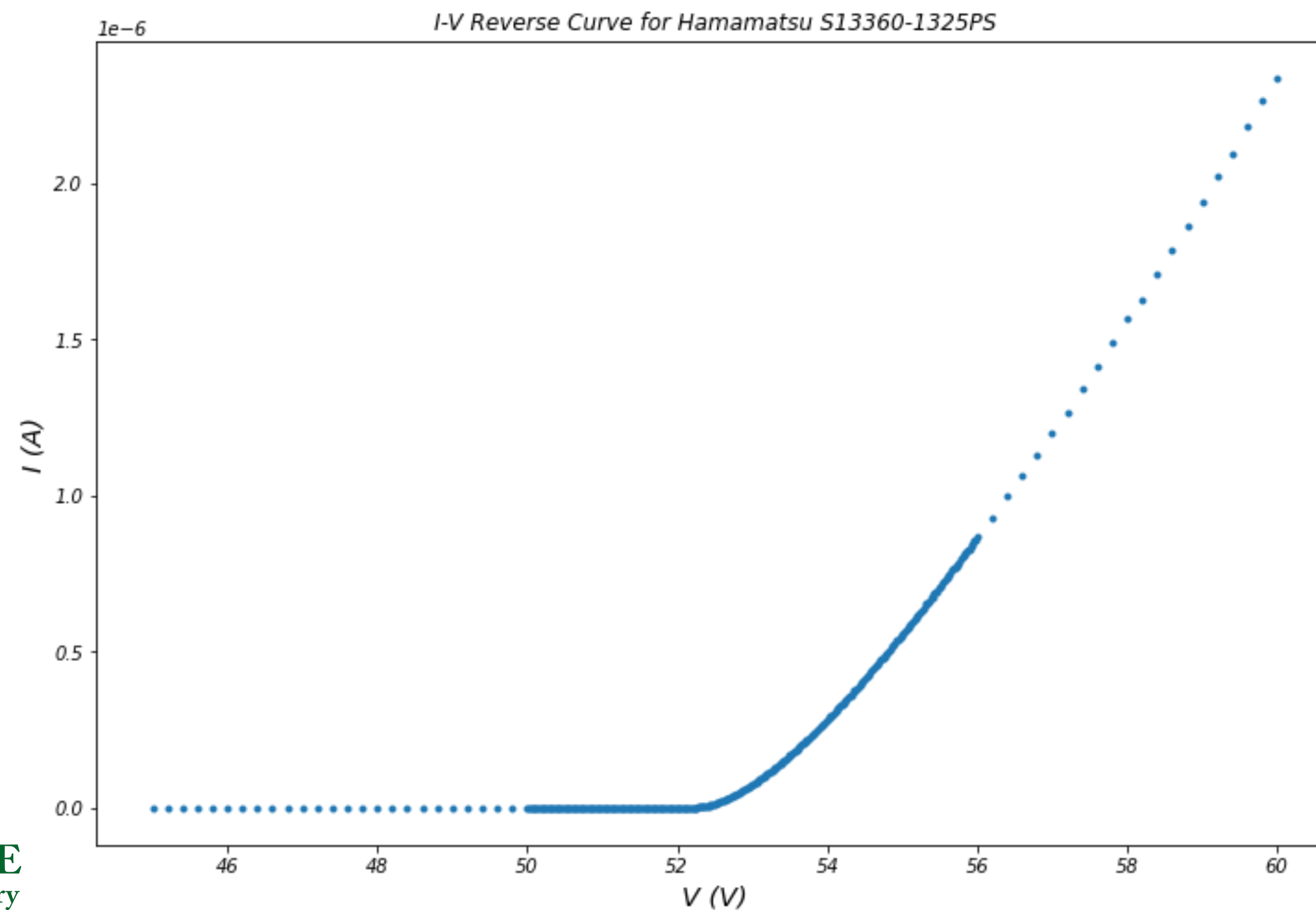

OAK RIDGE
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Into the prober

- 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)


I-V Reverse Curve for Hamamatsu S13360-1325PS

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I-V Reverse Curve for Hamamatsu S13360-1325PS
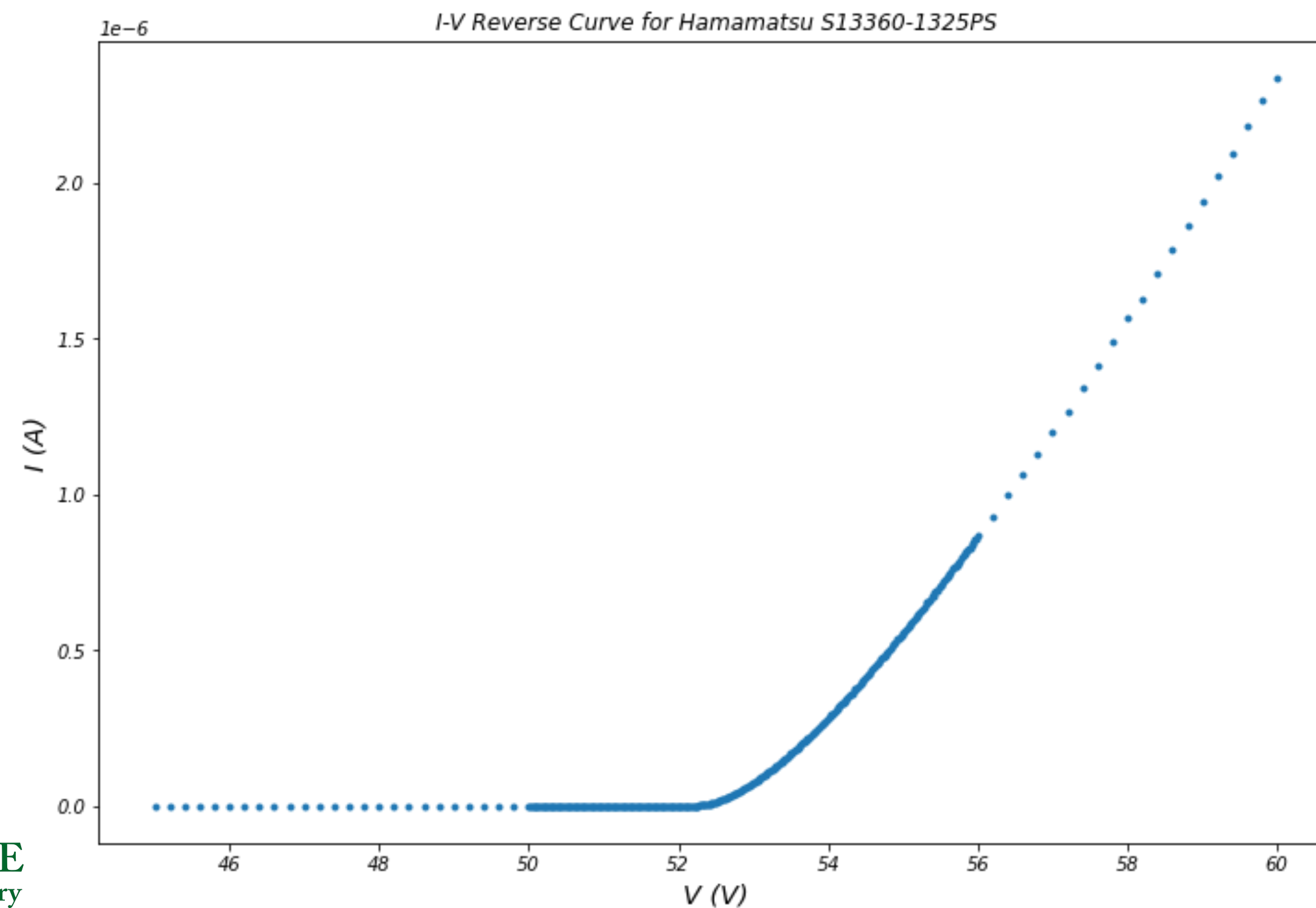
Method 1: V vs. sqrt(I)

- 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



sqrt(I)-V Reverse Curve for Hamamatsu S13360-1325PS
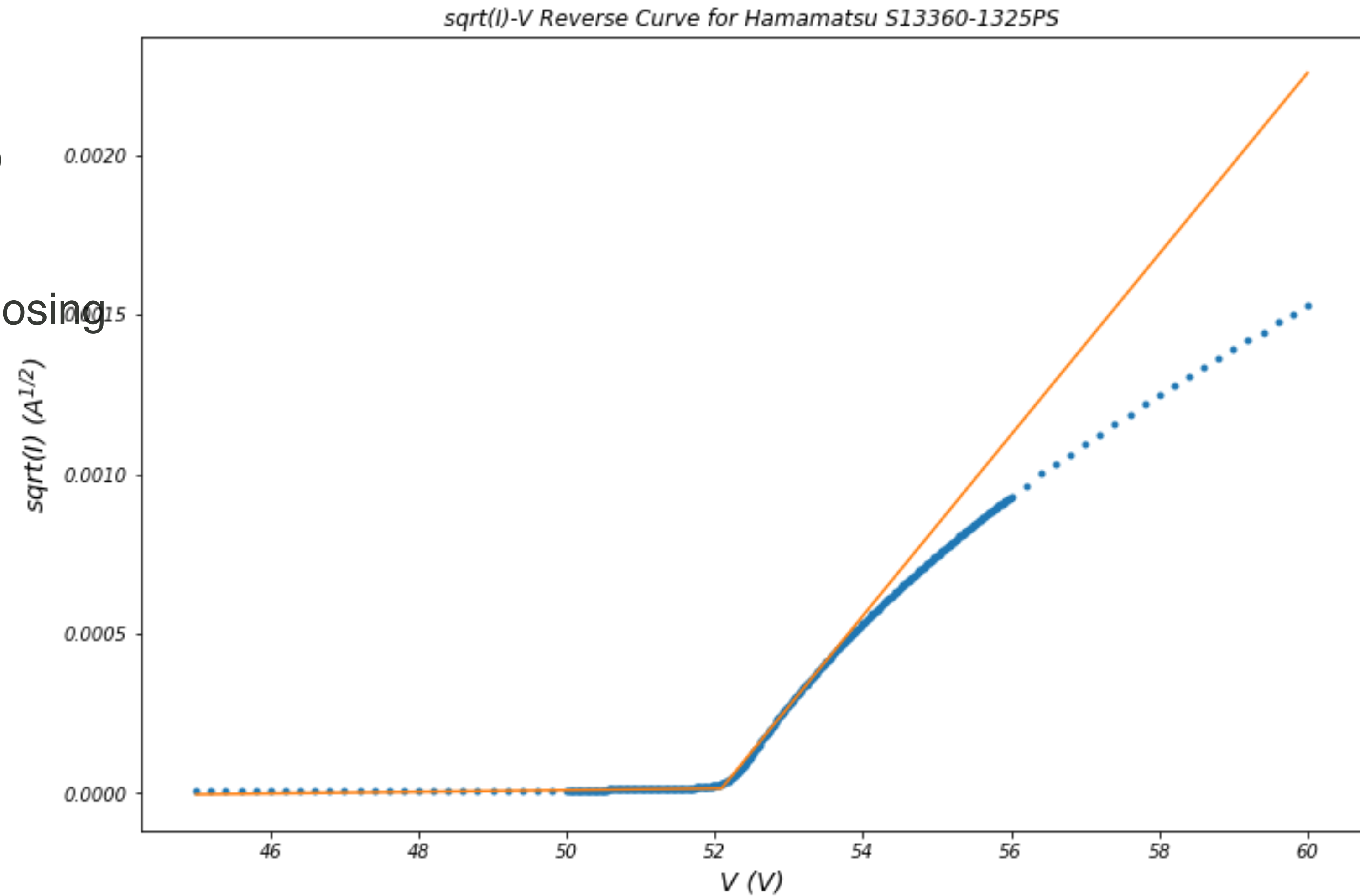
Method 2: Hamamatsu V_peak

- 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?)
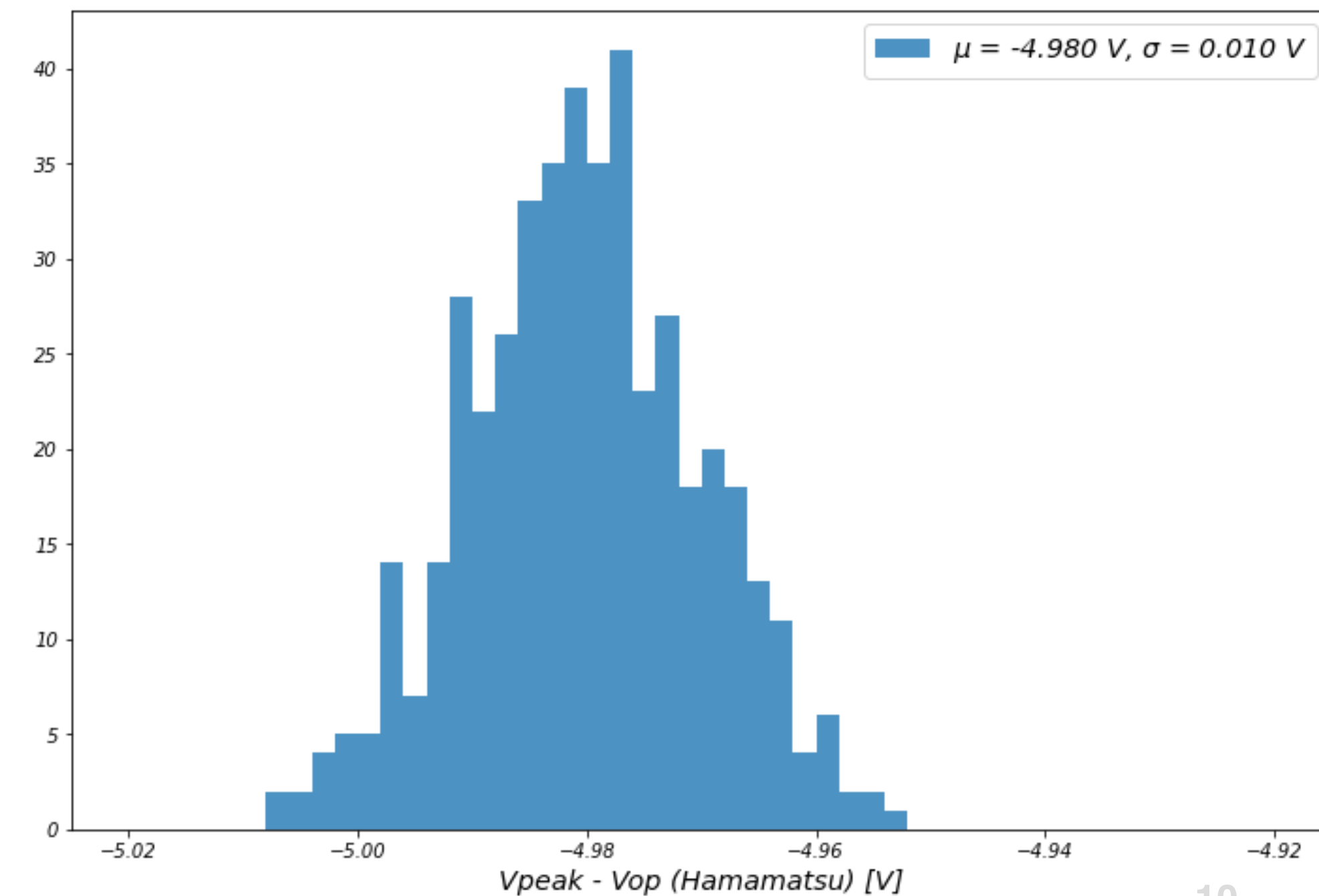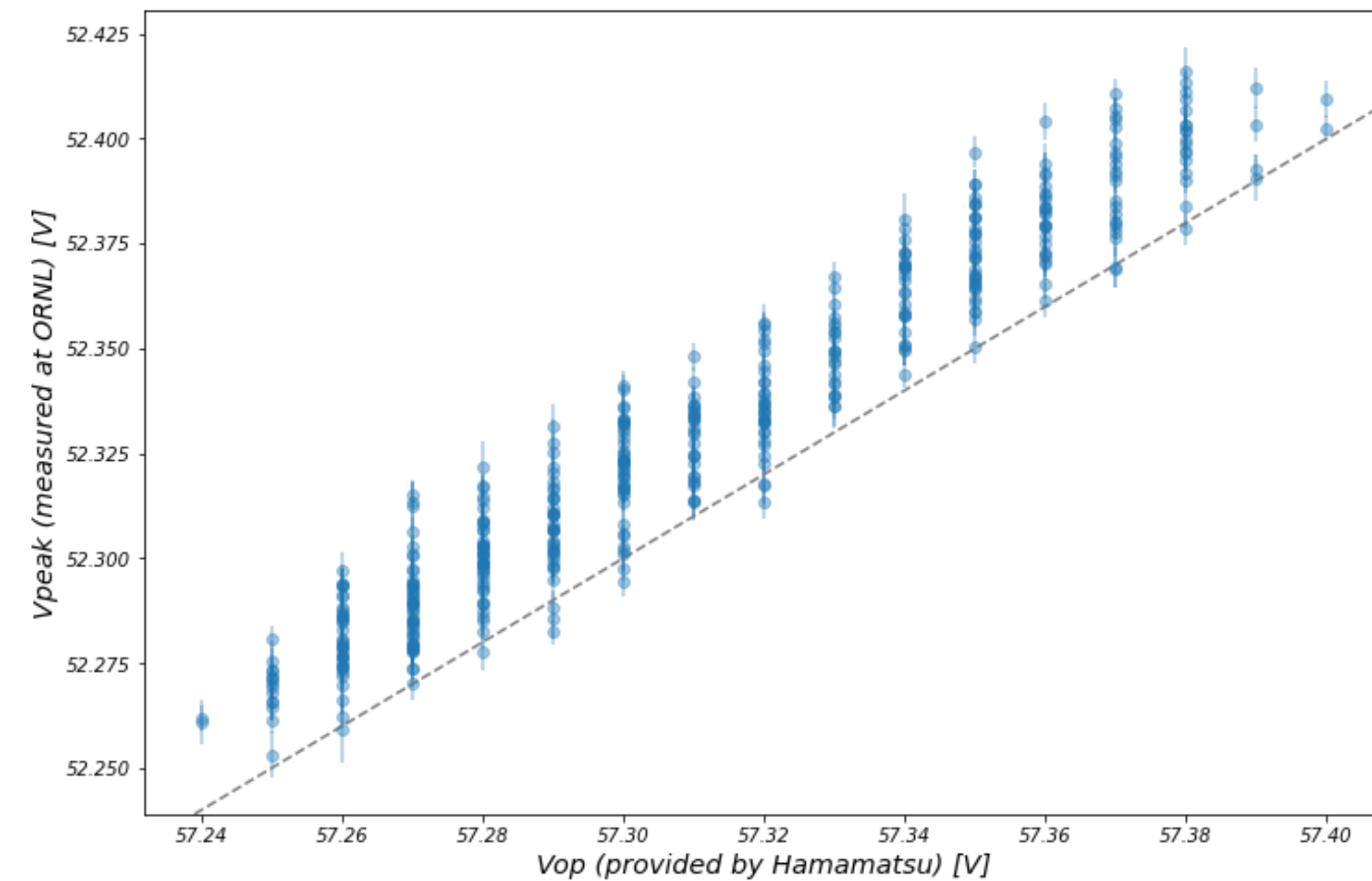
- Very stable extraction
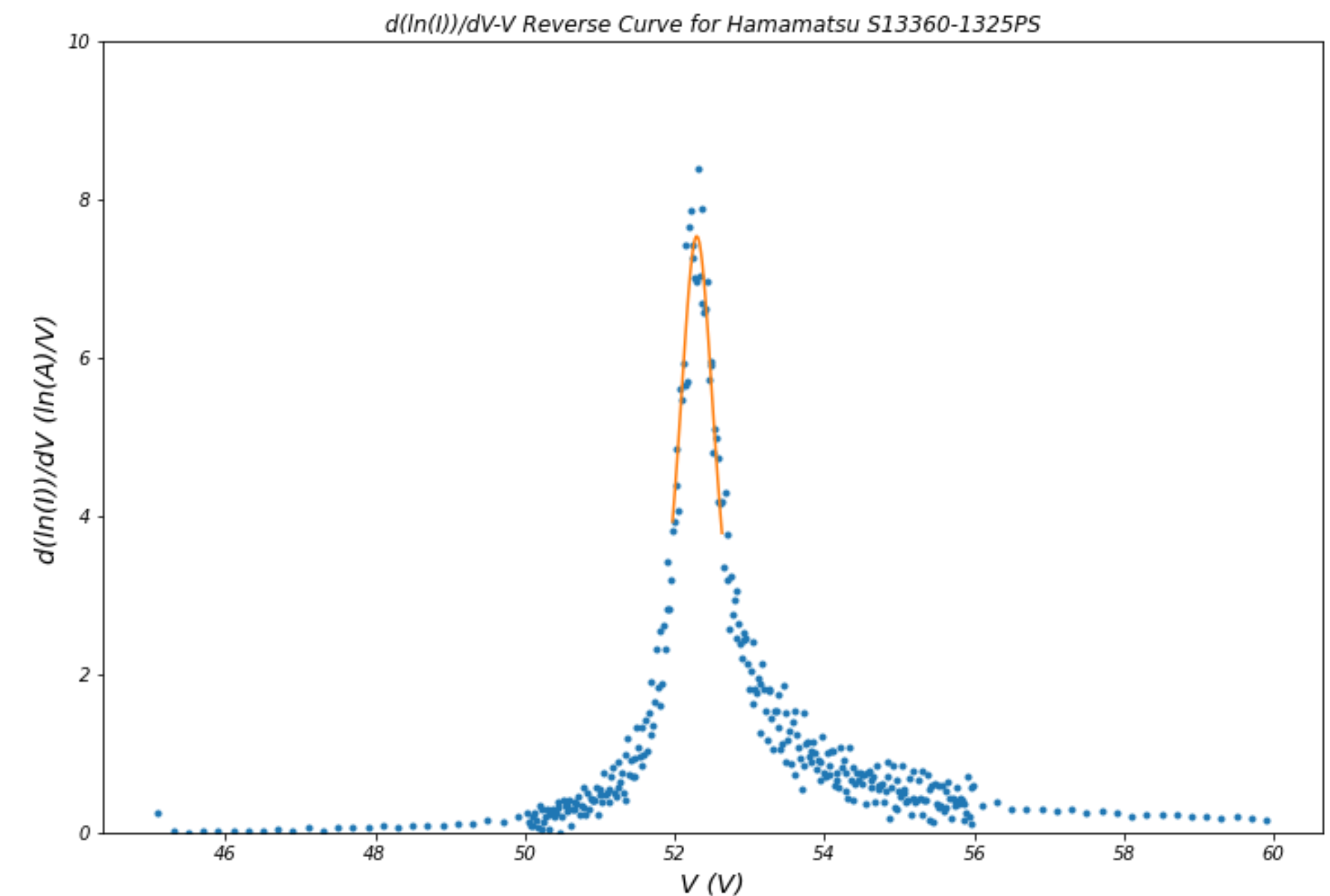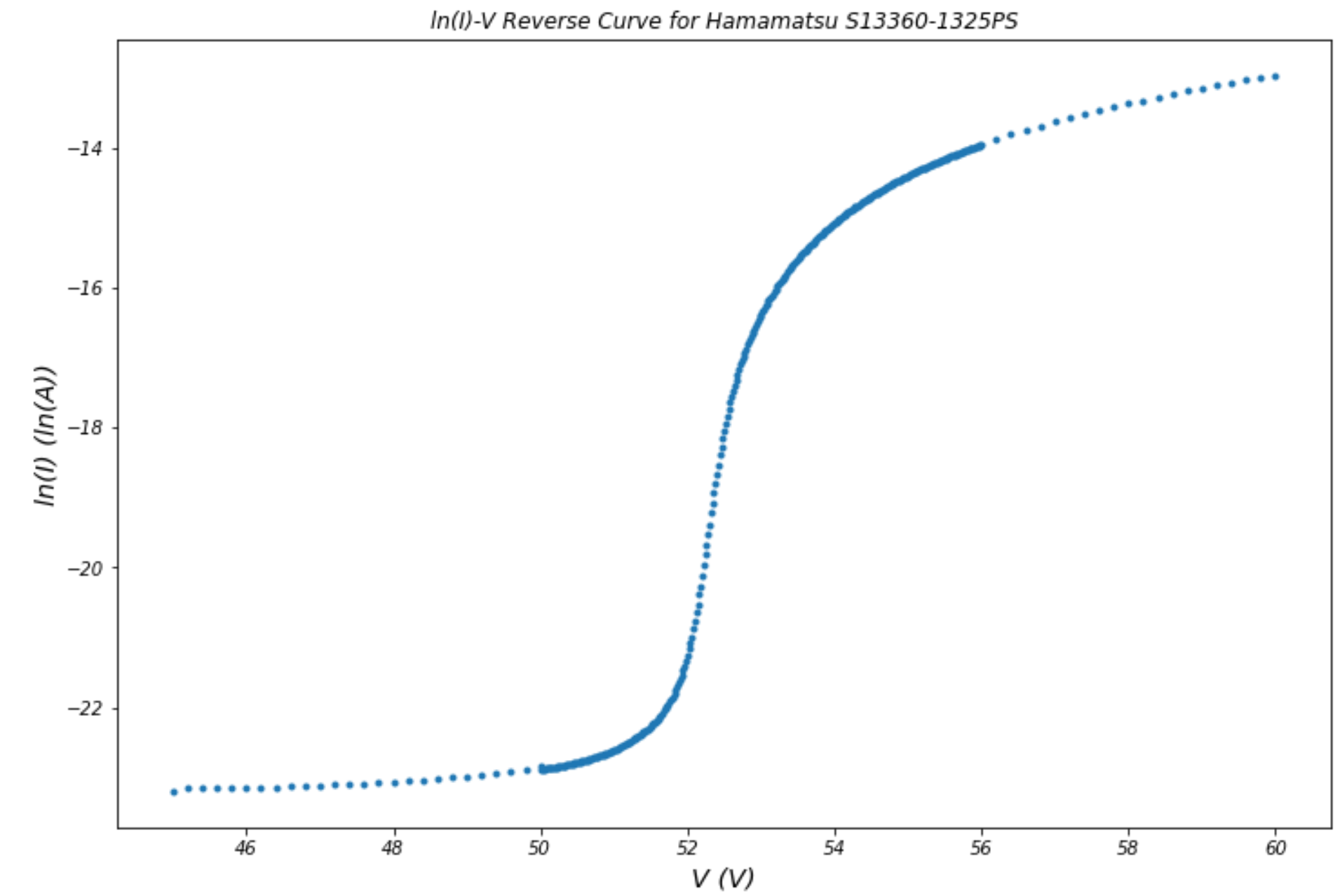
Validation Sample I

- Optimize scan parameters for speed vs. accuracy

- Slight bias between settings ~10mV

  - Have to live with this?

- Final settings: Full tray scan in ~1h25min
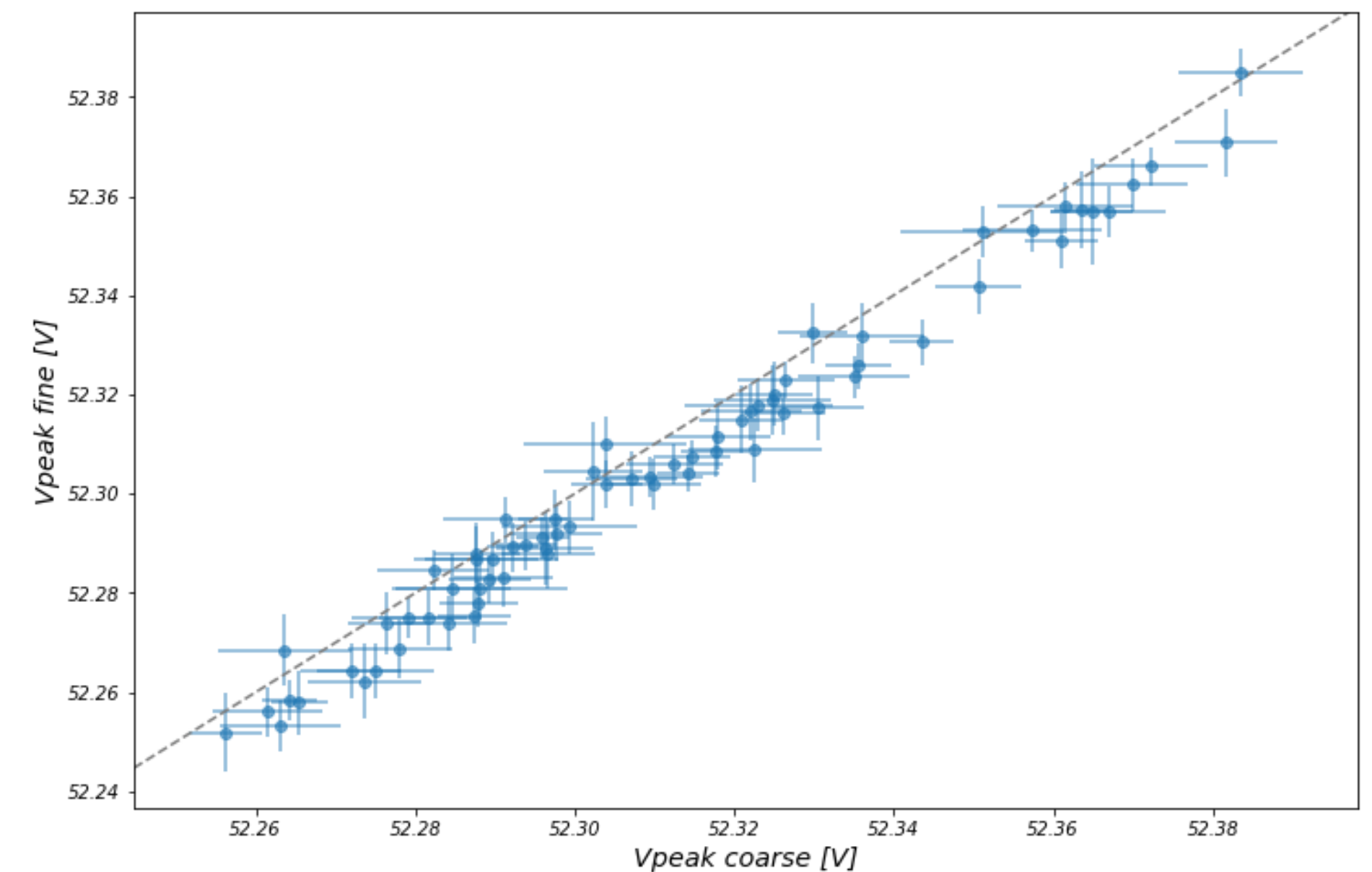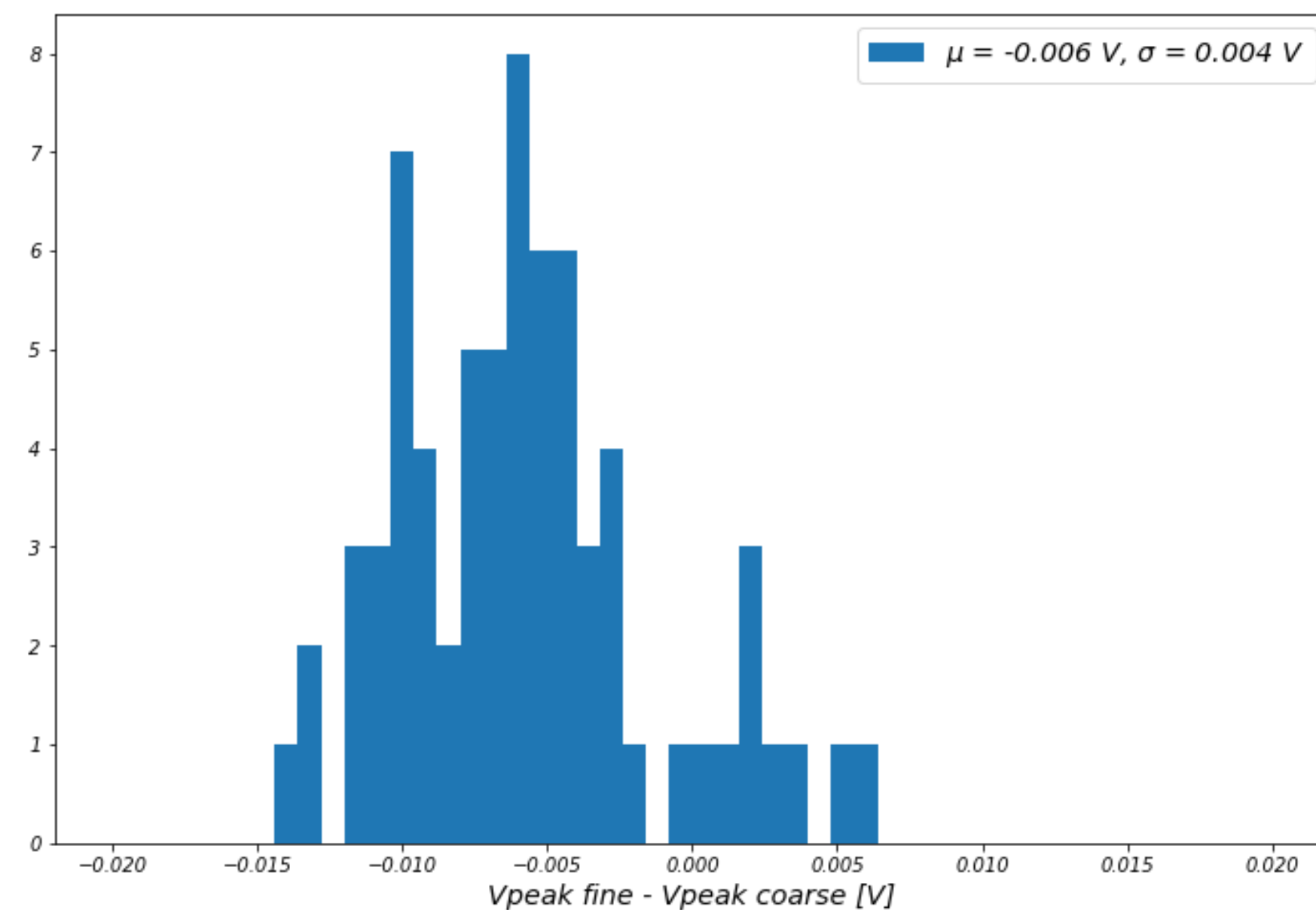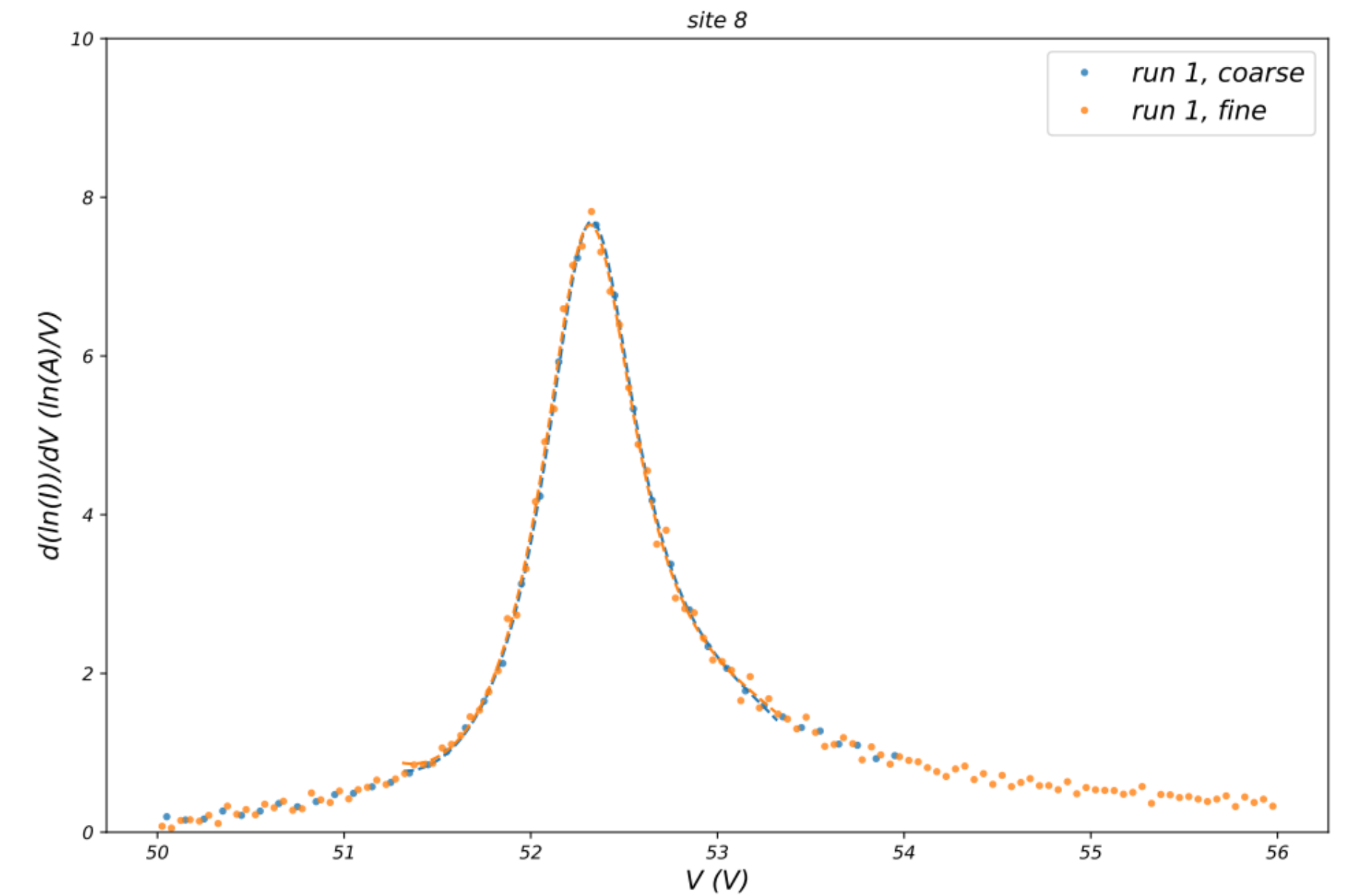
Validation Sample II

- 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.


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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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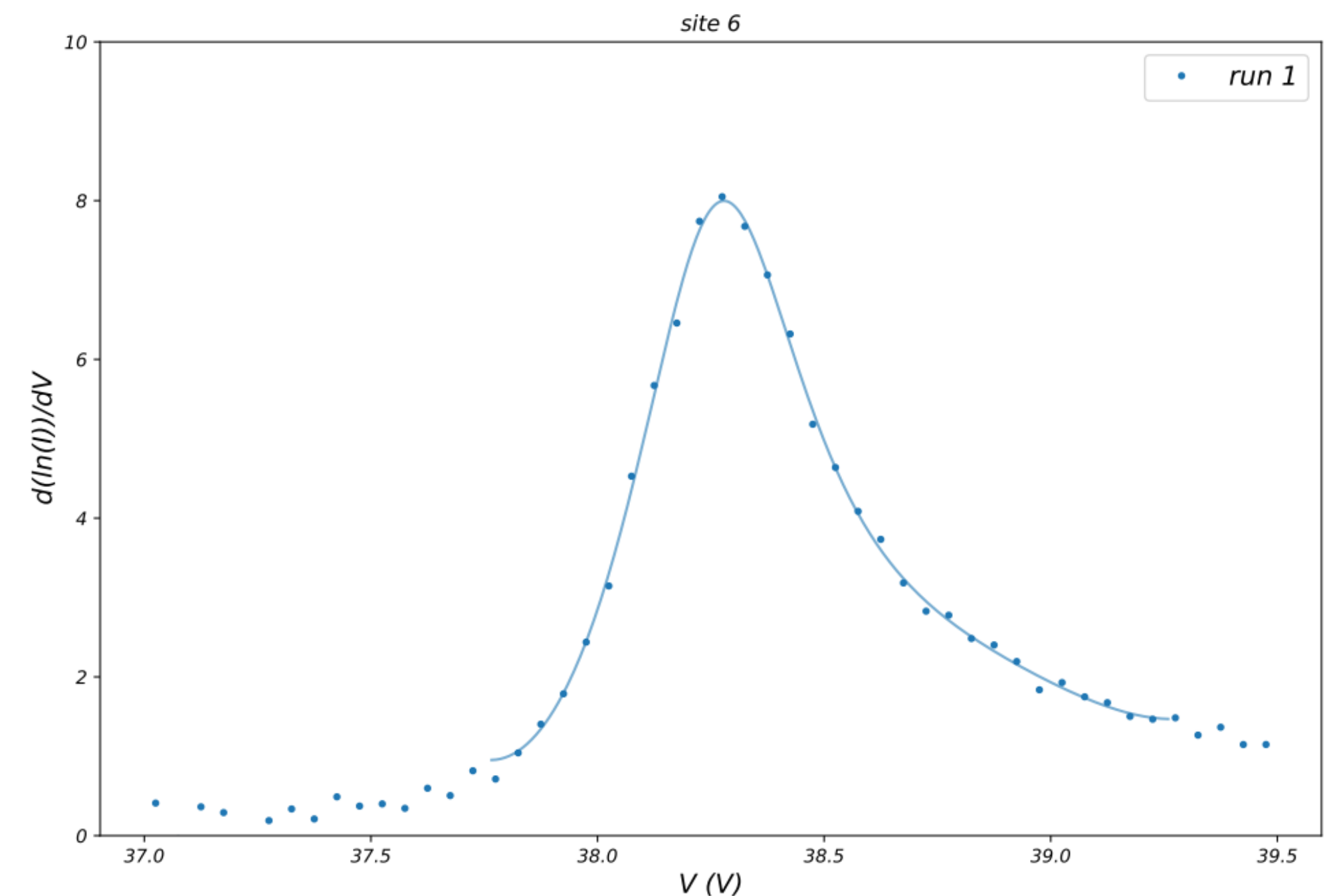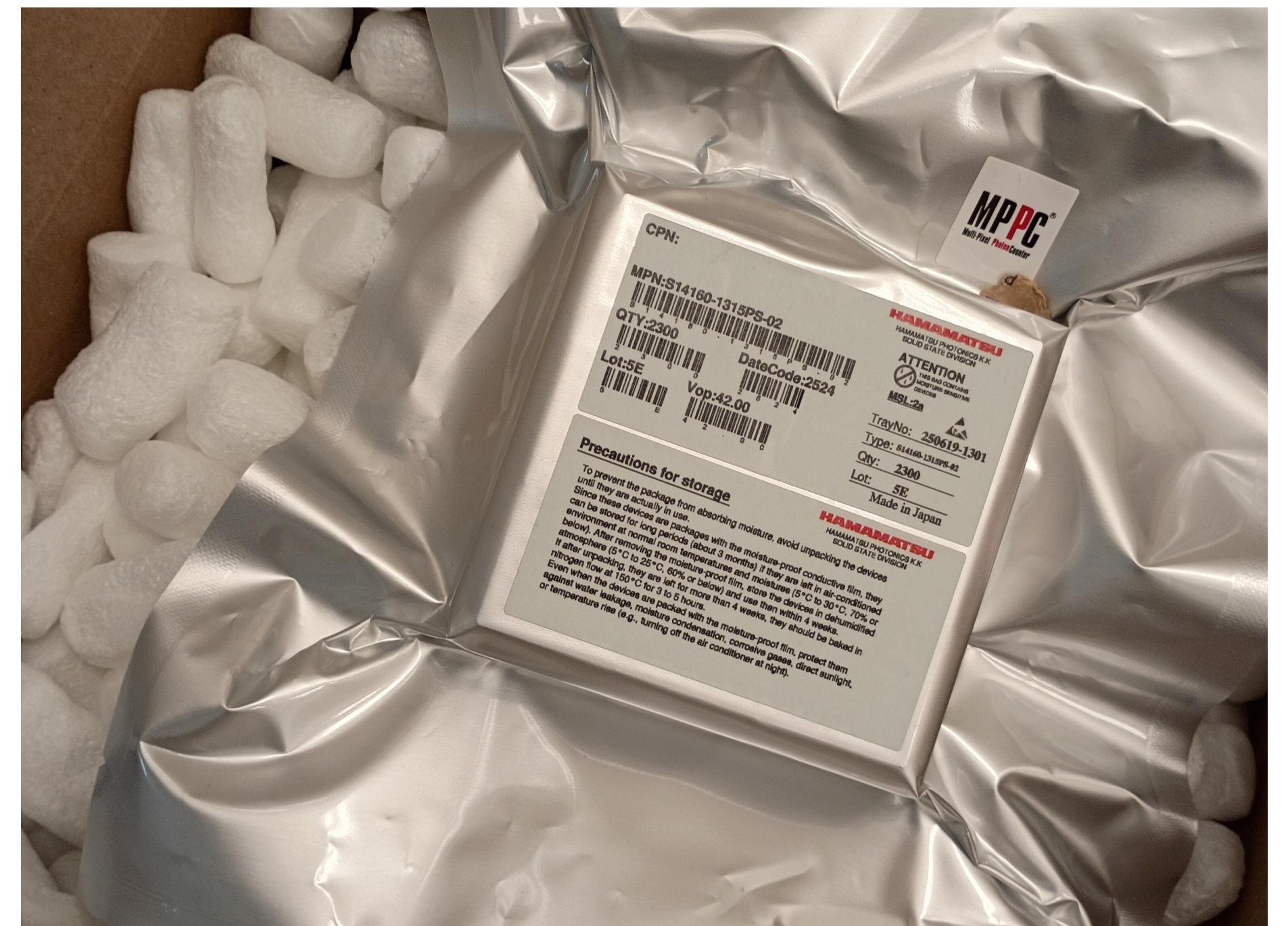
- Adjusted some measurement details, **1h30min per tray**.
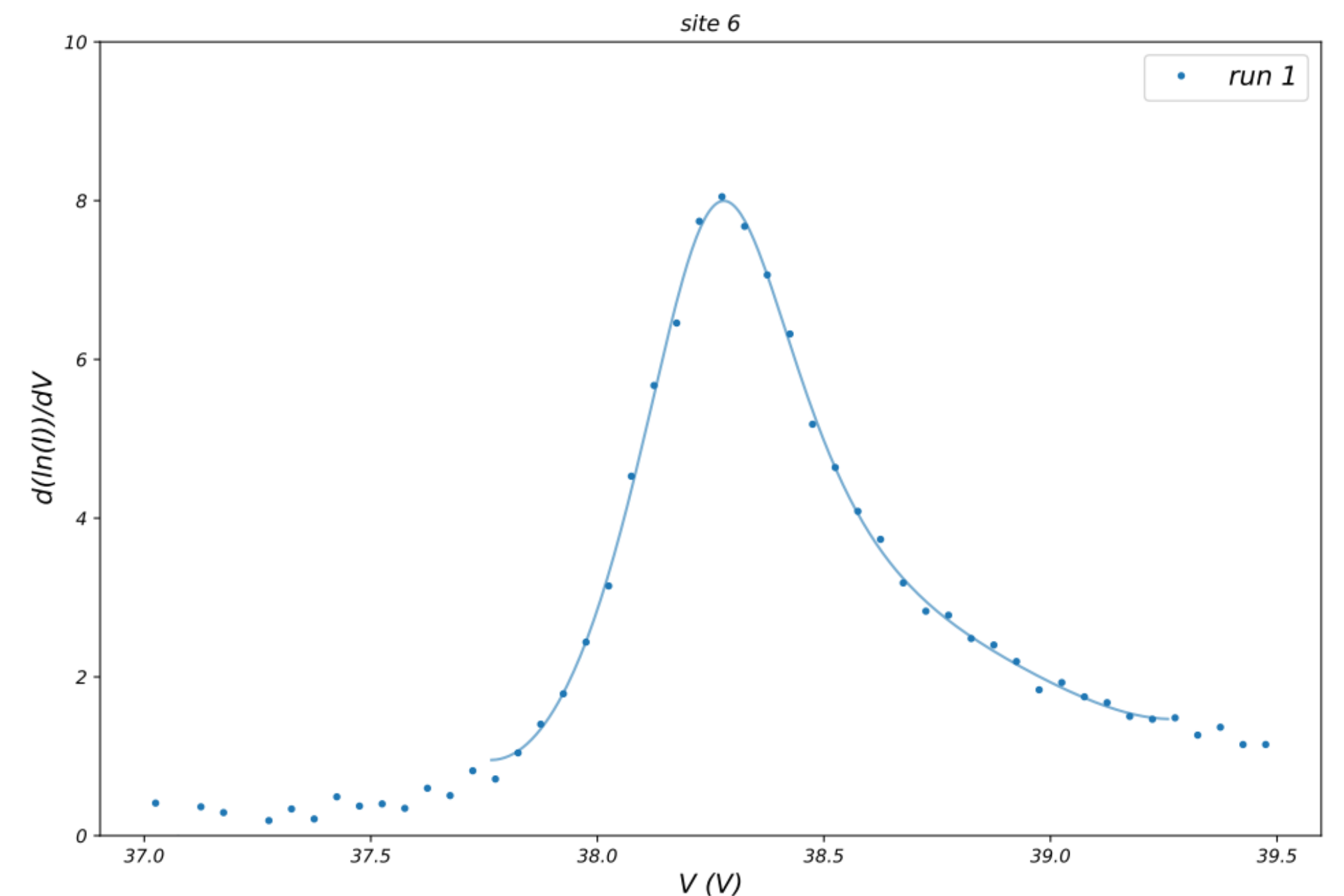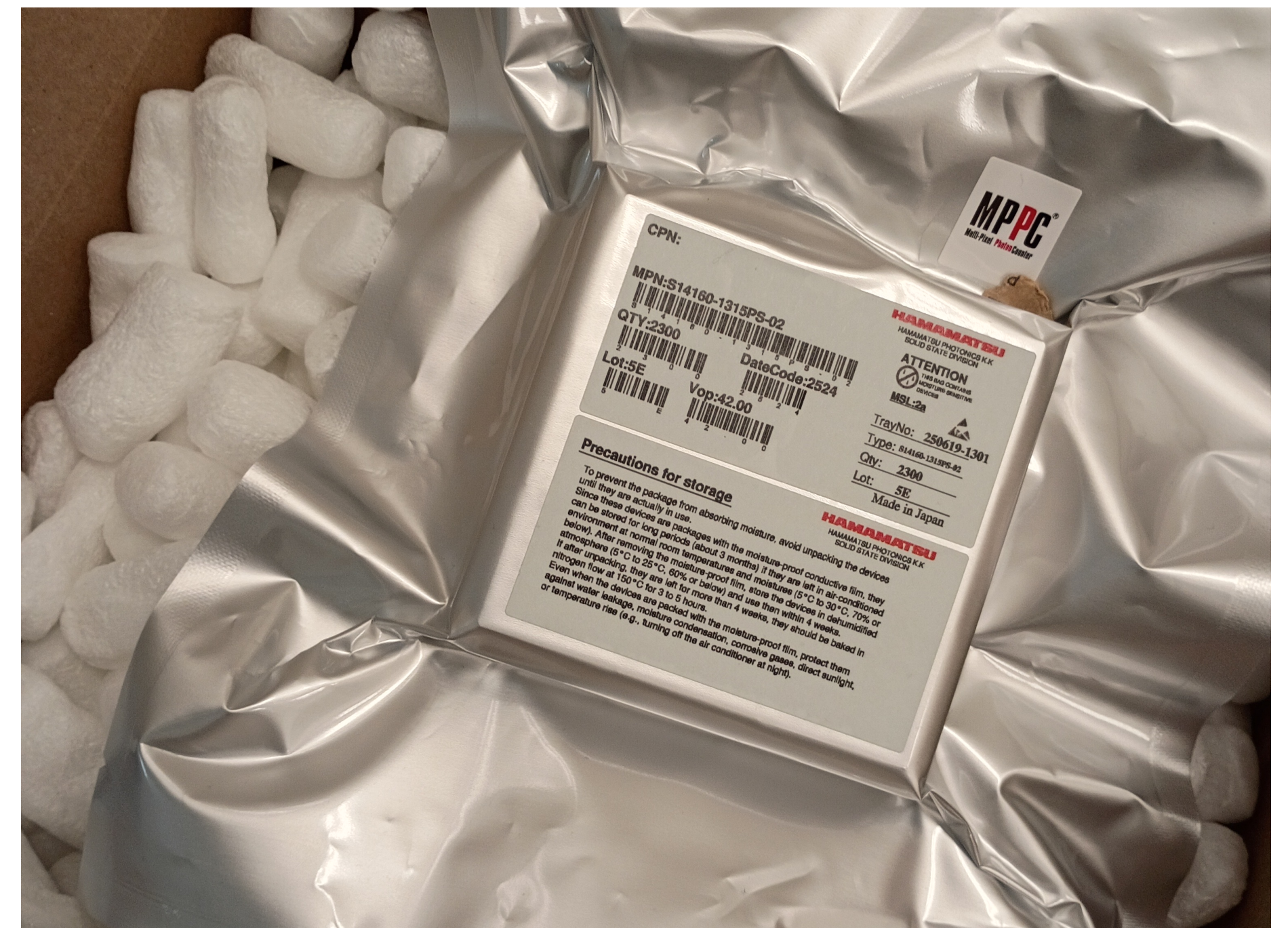
First Tray Data

- 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
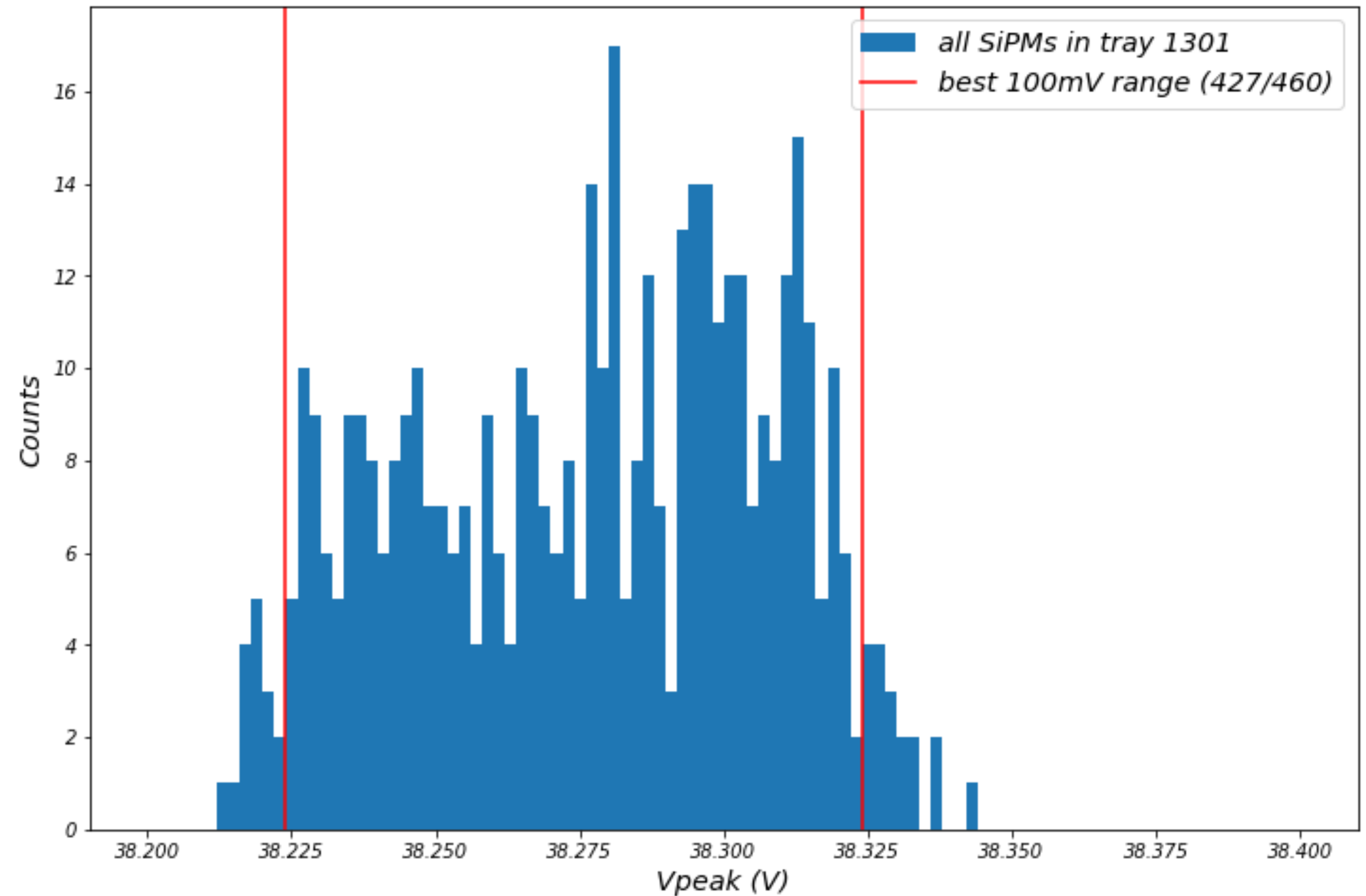
Conclusion

- 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
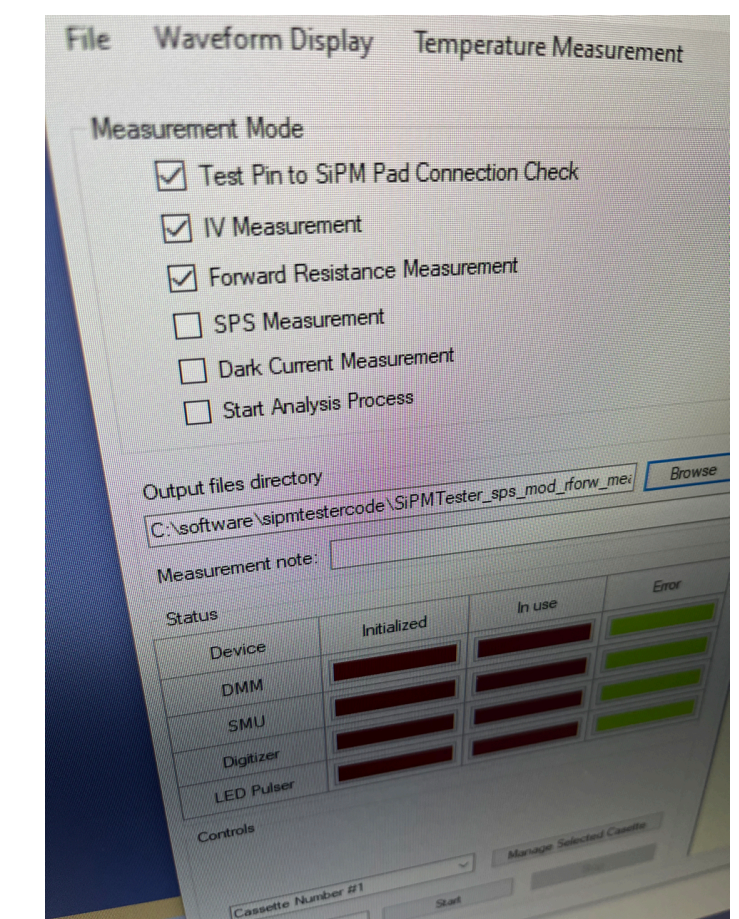
Ryan Hamilton

Langdan Zhu

Week 1
9/22 - 9/26
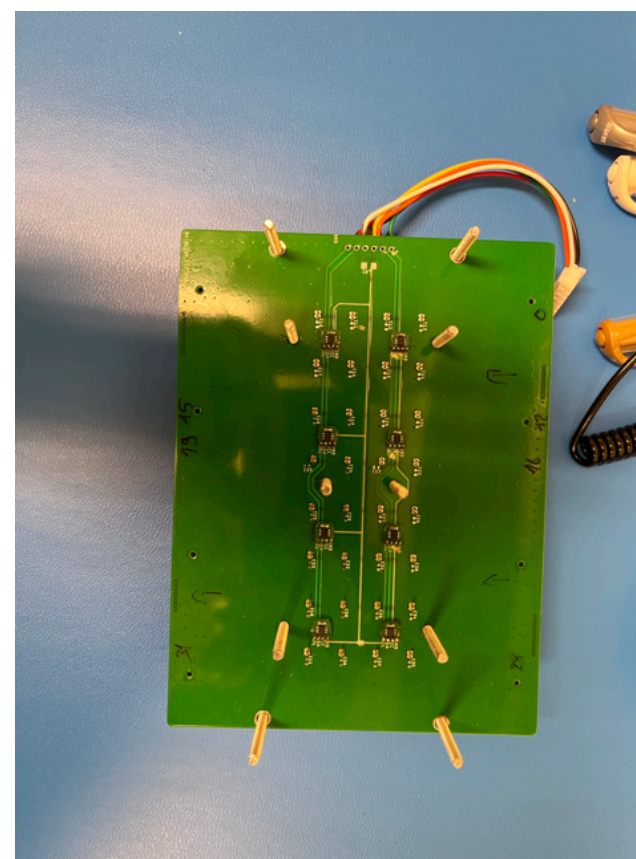
- A section of the lab was prepared, including Linux machines sent in advance from Debrecen

- 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
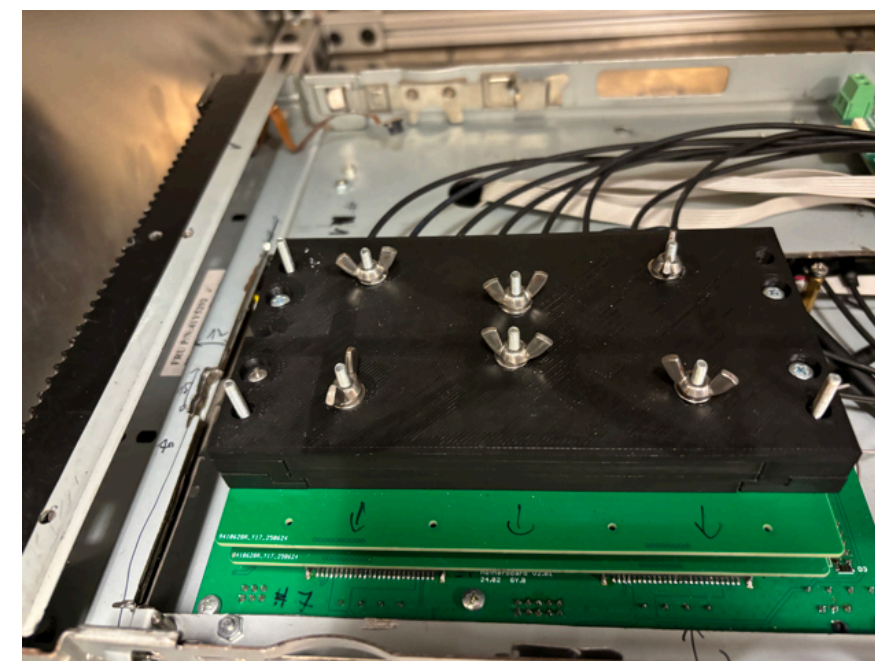
Isaac Mooney, Yale / BNL / CFNS

Week 2
9/29 - 10/3

- 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.

Good

Bad

Week 3
10/6 - 10/10

- 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.

- Aiming for another tray this week

Results from Tray 1

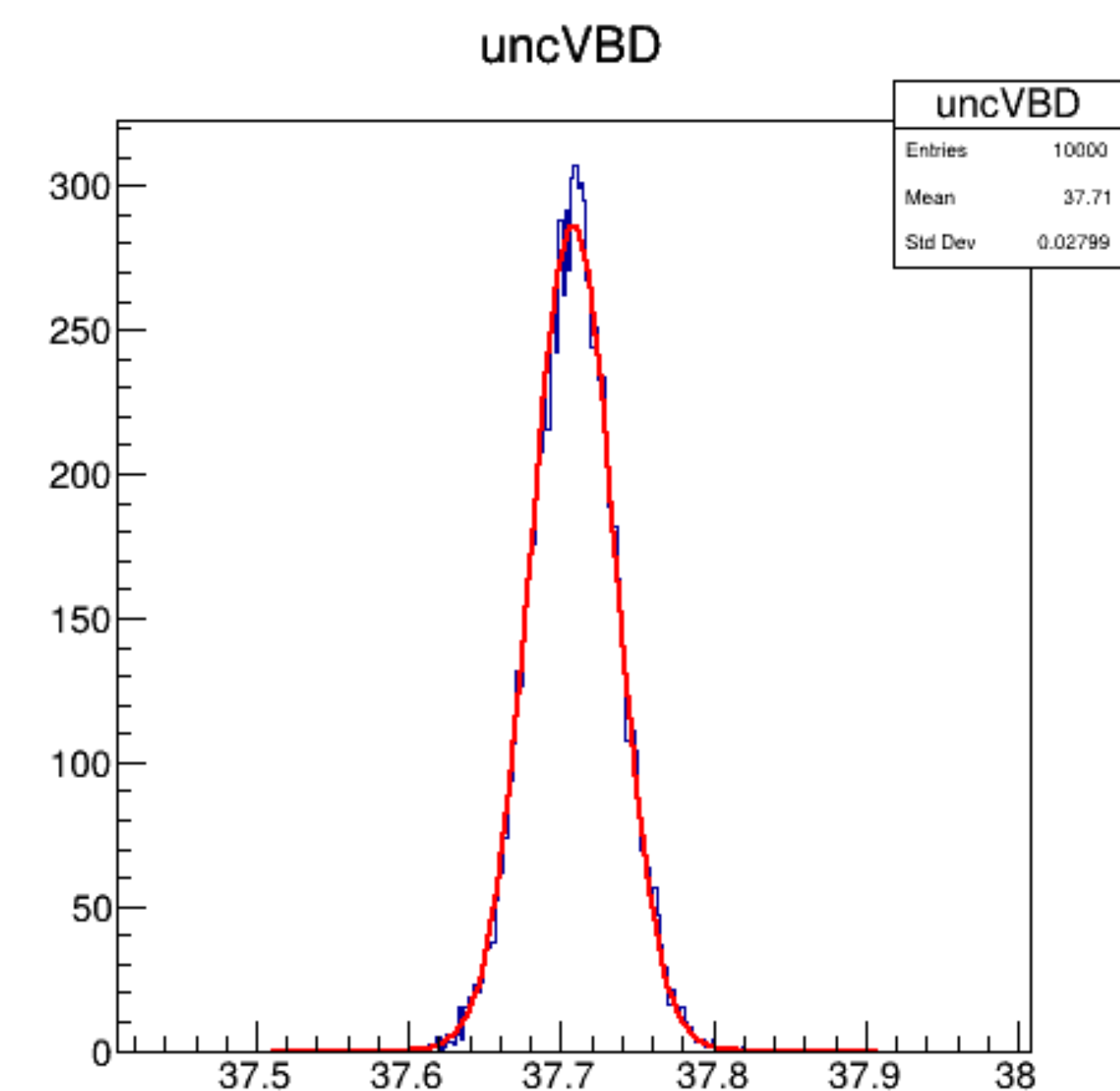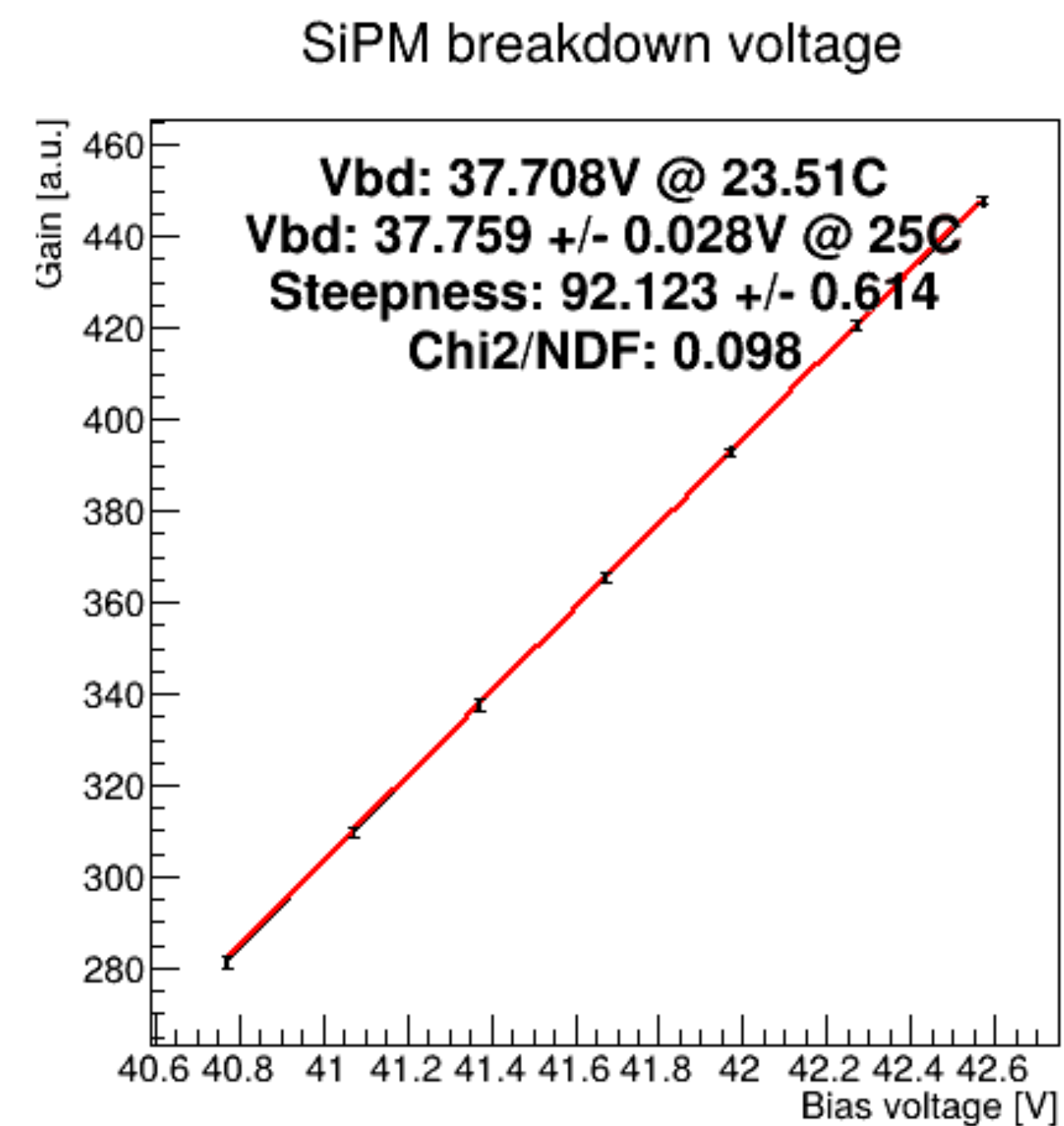# Single photon spectra (SPS)
Example: SiPM (0,10)
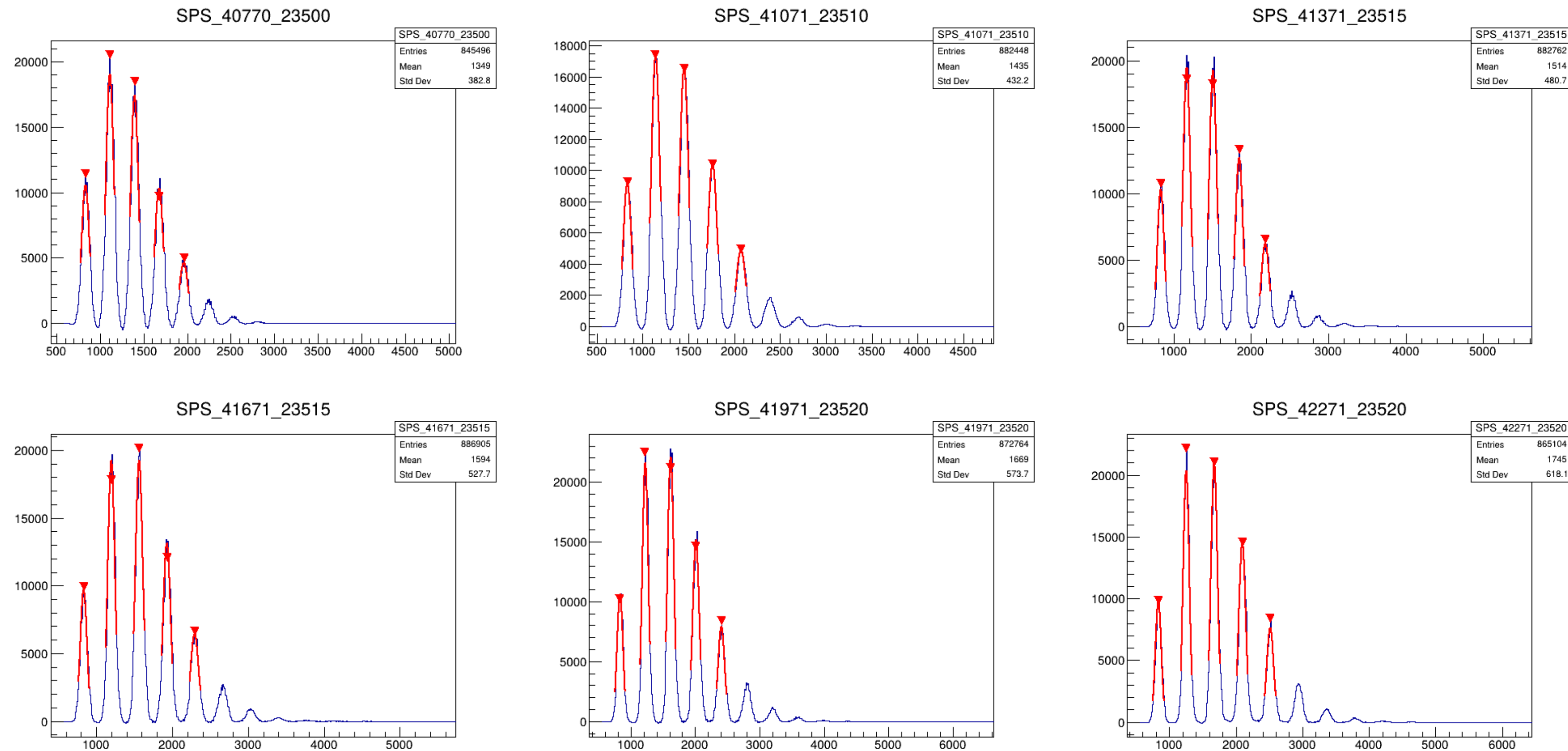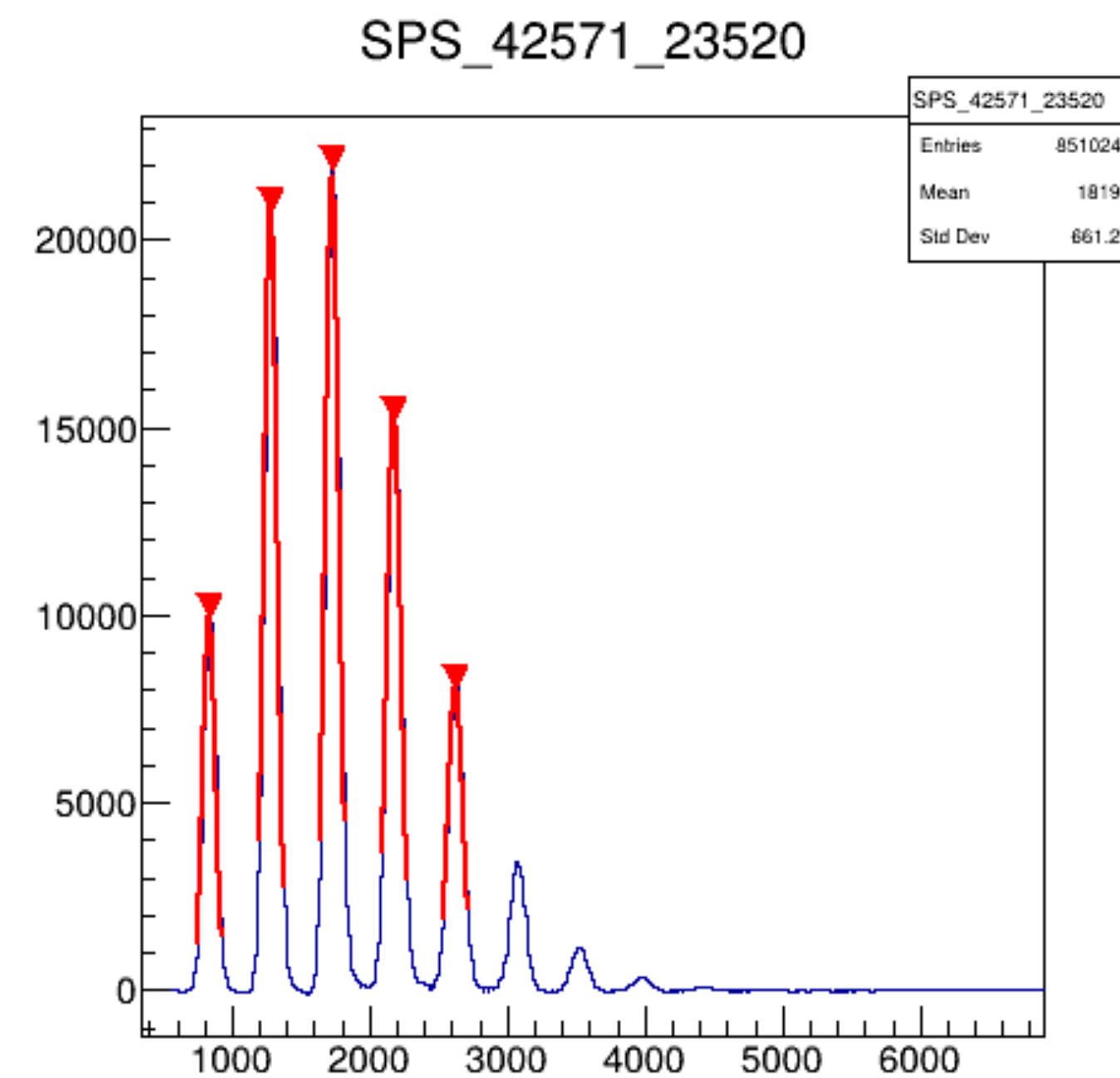

Each panel is a different voltage (in title). Increases from top left to bottom right (along with measured temperature, also in title).

Single photon spectra (SPS)
Example: SiPM (0,10)

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
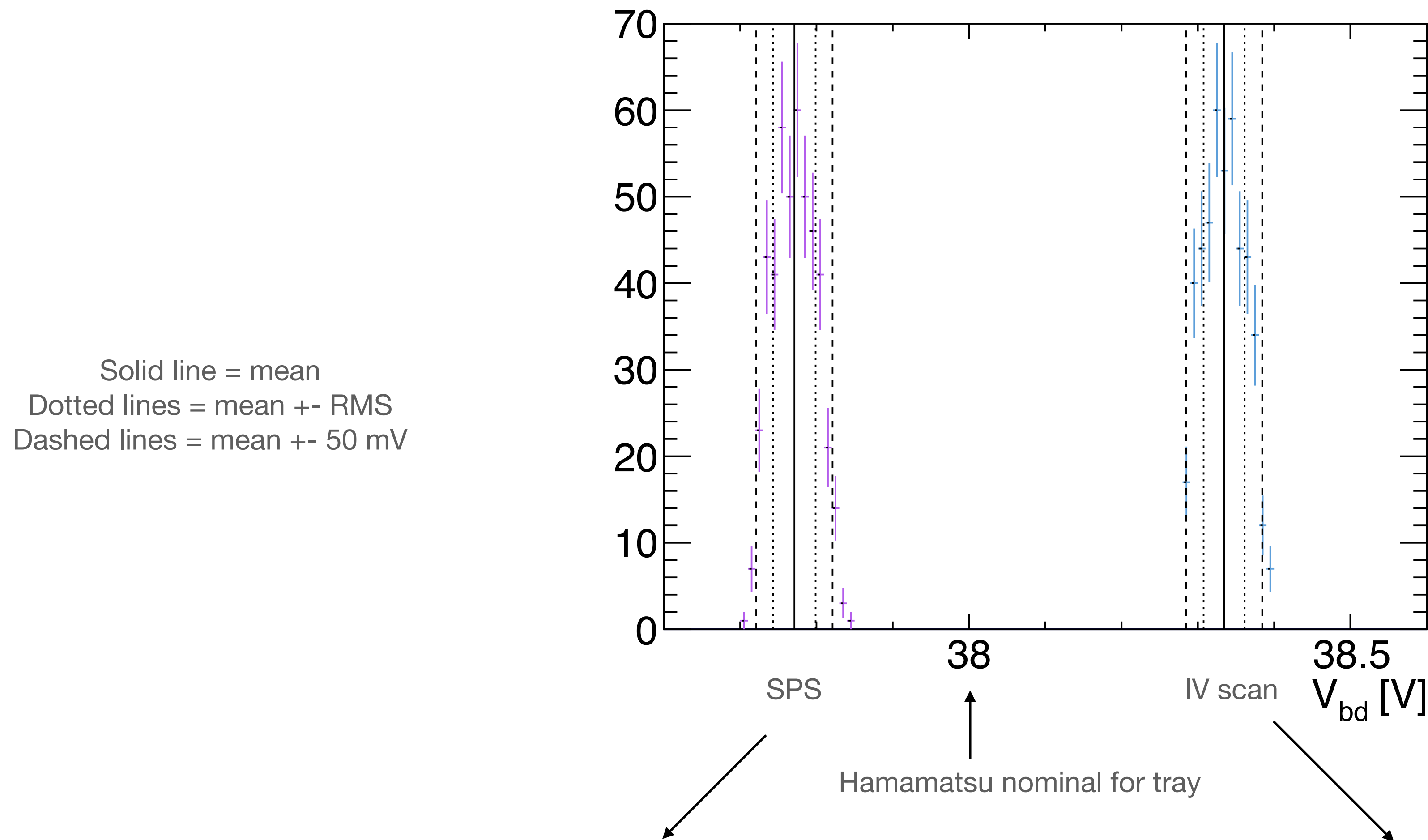## Example: SiPM (0,10)
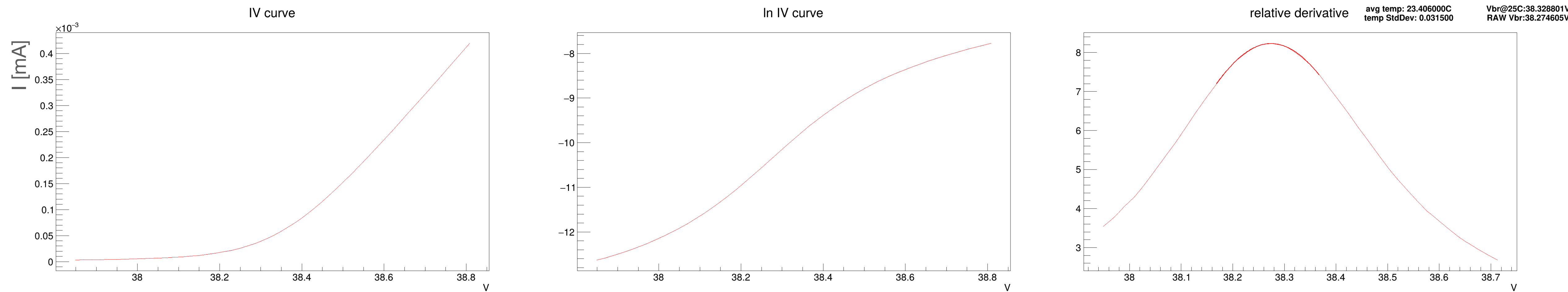
$$I(V_{peak}) \sim 30 \text{ nA}$$

Measurement made at 50 voltage steps

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

V_{peak} and V_{bd}

V_{peak} and V_{bd}

Solid line = mean
Dotted lines = mean +- RMS
Dashed lines = mean +- 50 mV

SPS

IV scan

38

V_{bd} [V]

Hamamatsu nominal for tray

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

From root integrals: **4.3%** outside 38.28 V +- 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