Davis Cyclotron Irradiation of SiPM for EIC

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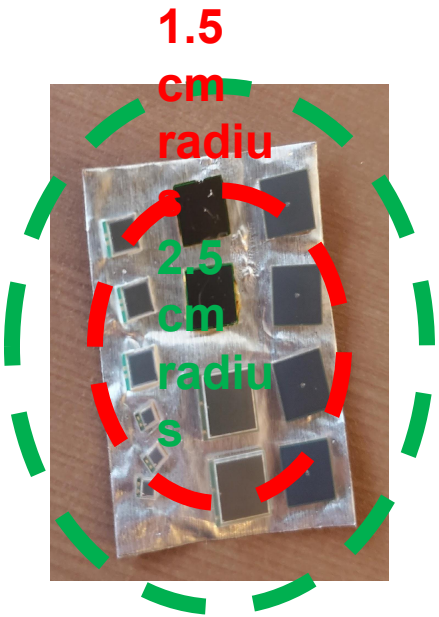
U.S. DEPARTMENT OF ENERGY

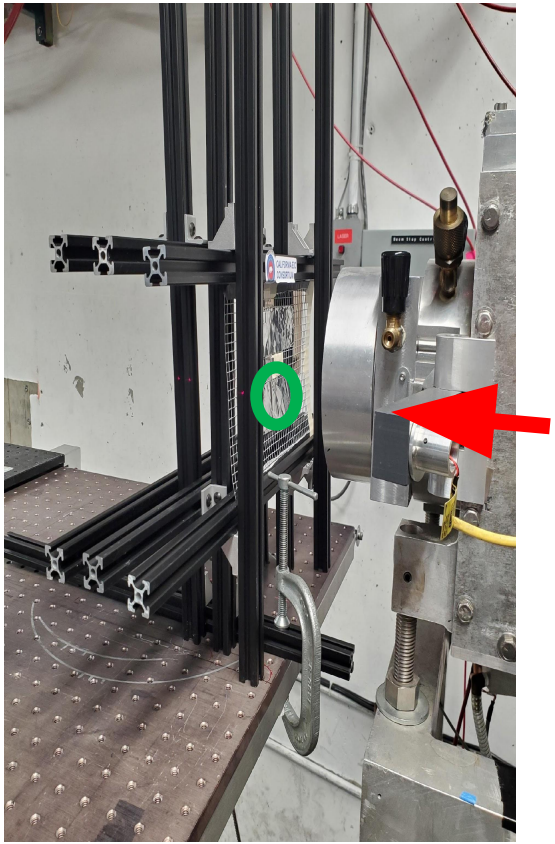
Introduction

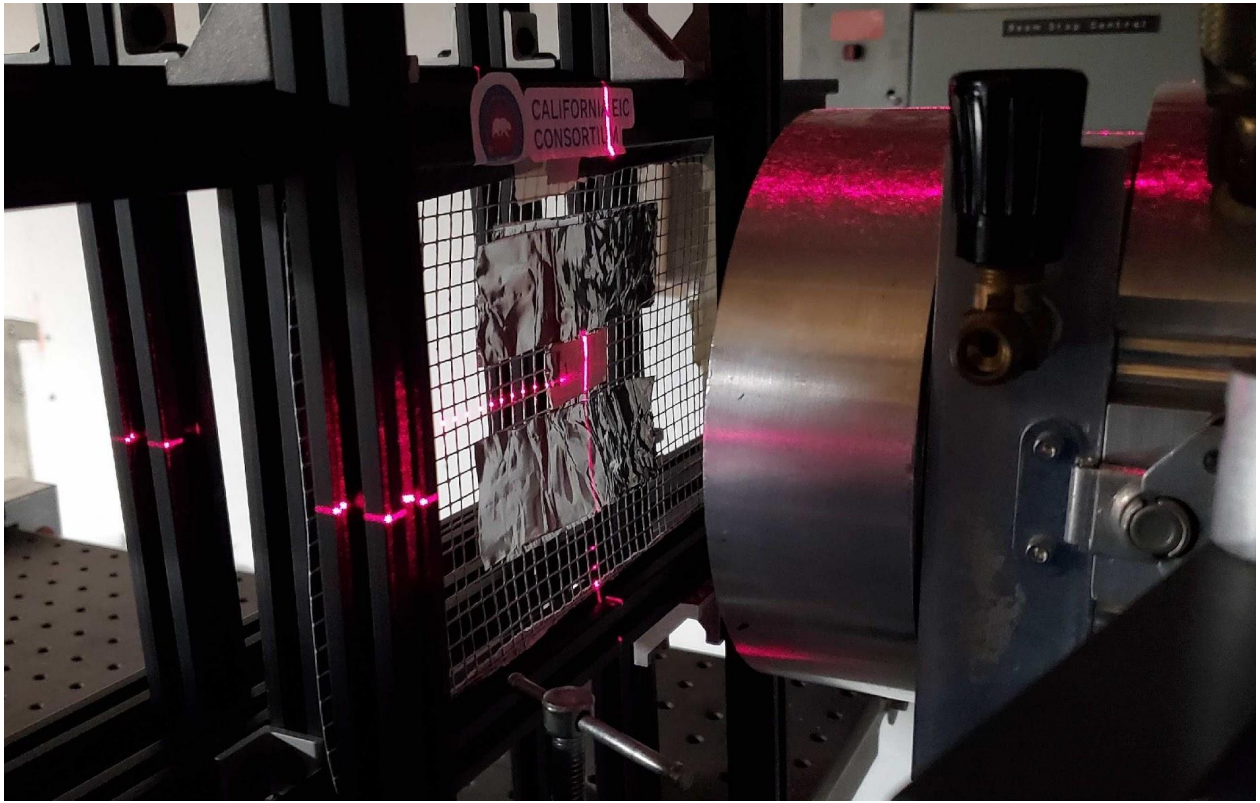
- UC Davis cyclotron proton beam at 64 MeV kinetic energy
- SiPM: S14160-6050, S14160-6015, S14160-3015, S14160-1315, S13360-6050
- Fluence range: 10^8 - 10^{13} p^+/cm^2
- Characterization includes taking IV from various time, pedestal / signal from SiPM readout, dark counts

Irradiation Setup



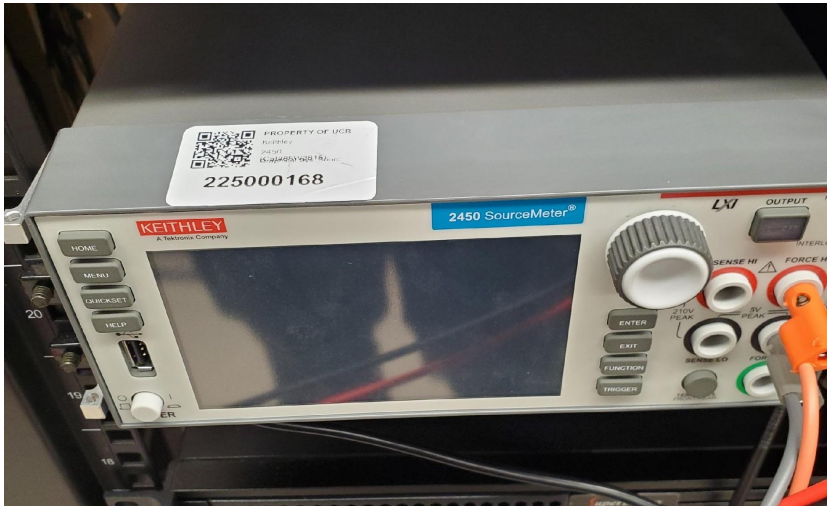
SiPM taped to aluminum tape within uniform beam radius, centered using laser.

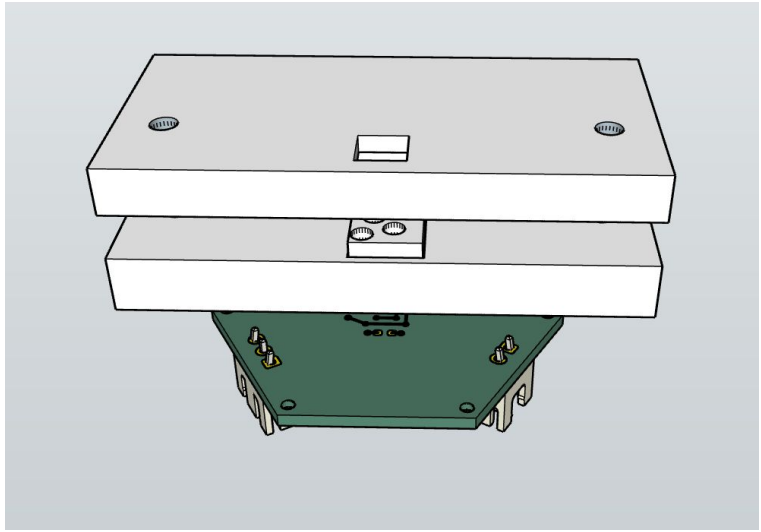


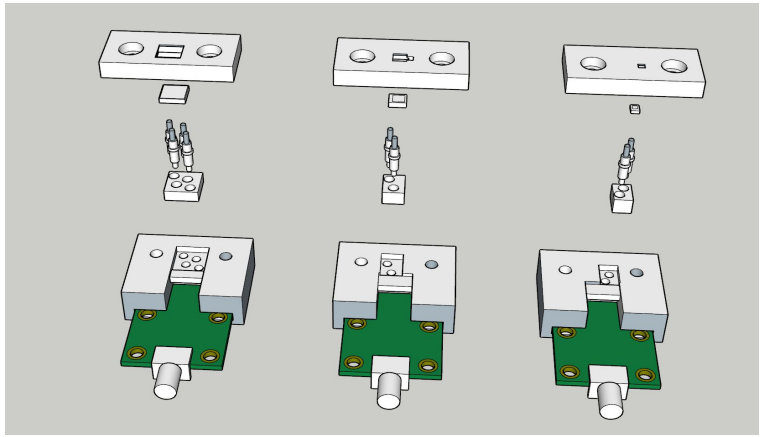

CALIFORNIA EIC
CONSORTIUM

IV Setup

Non-soldering contact base setup with pogo pins measures IV source meter control by Labview. The boards used for measurement only has sipm onboard and no other components.

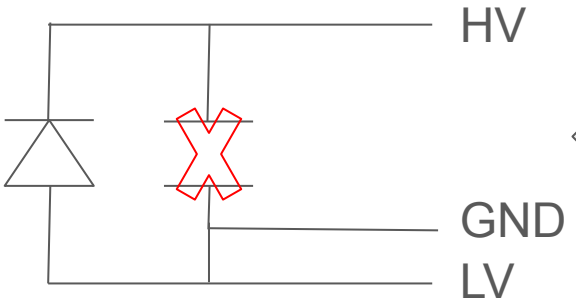




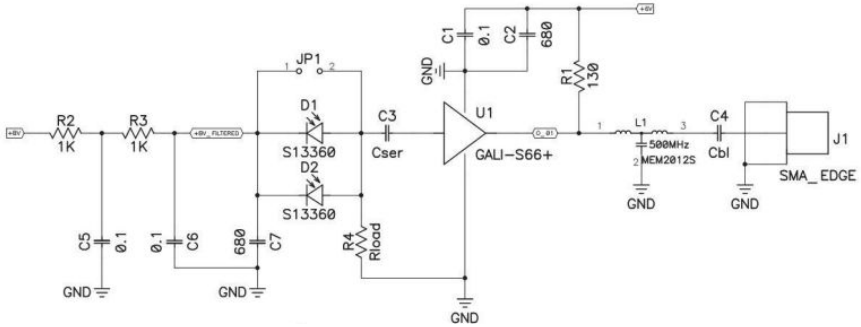


Board Electrical Diagram for IV

Hexagon Board IV Collection

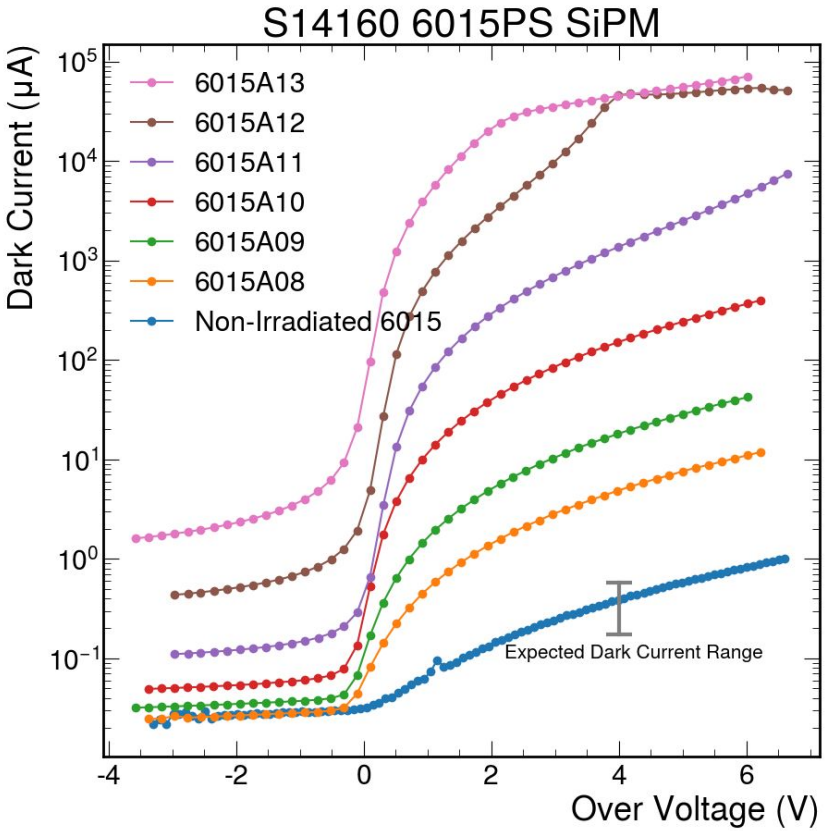


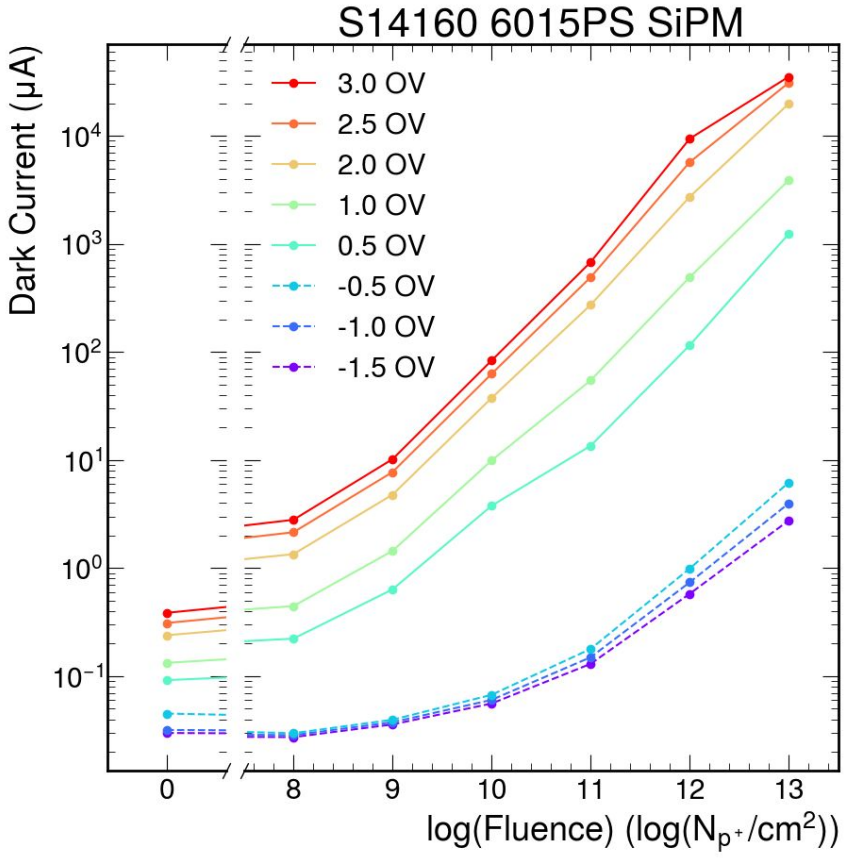
FNAL Board IV Collection



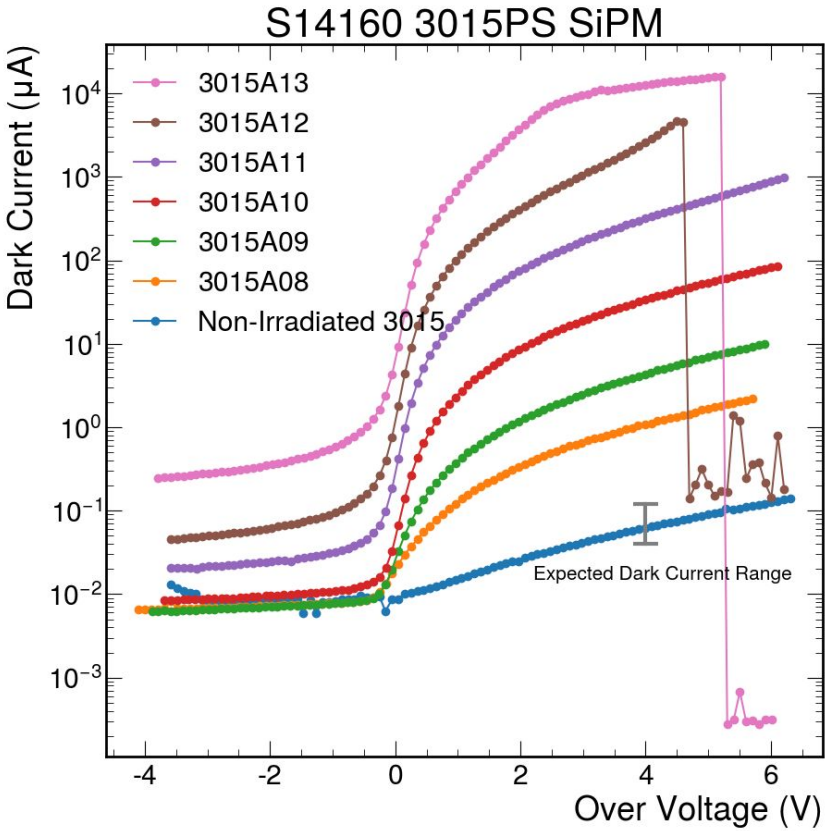
Unknown leakage at high fluence and current form FNAL Board, thus changing to a simple readout circuit to determine dark current with direct measurement.

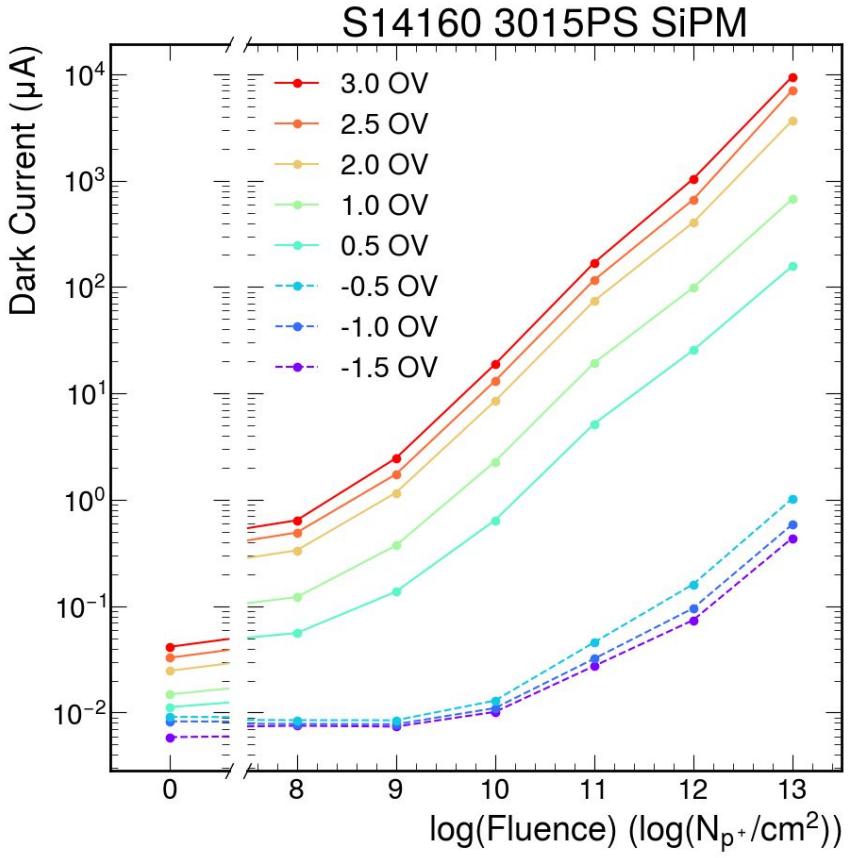
S14160-6015PS Irradiation IV





S14160-3015PS Irradiation IV

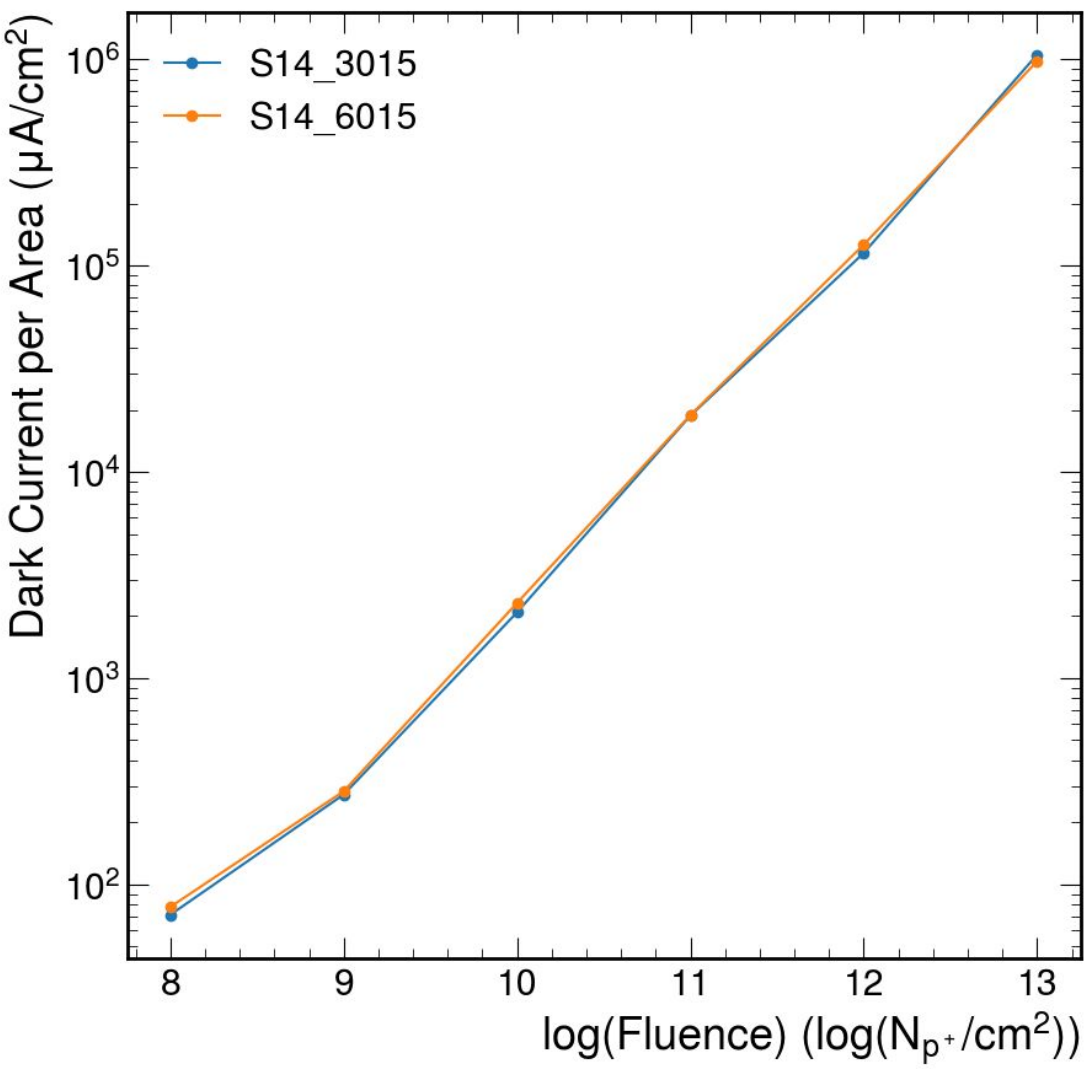




Area Scaled Current

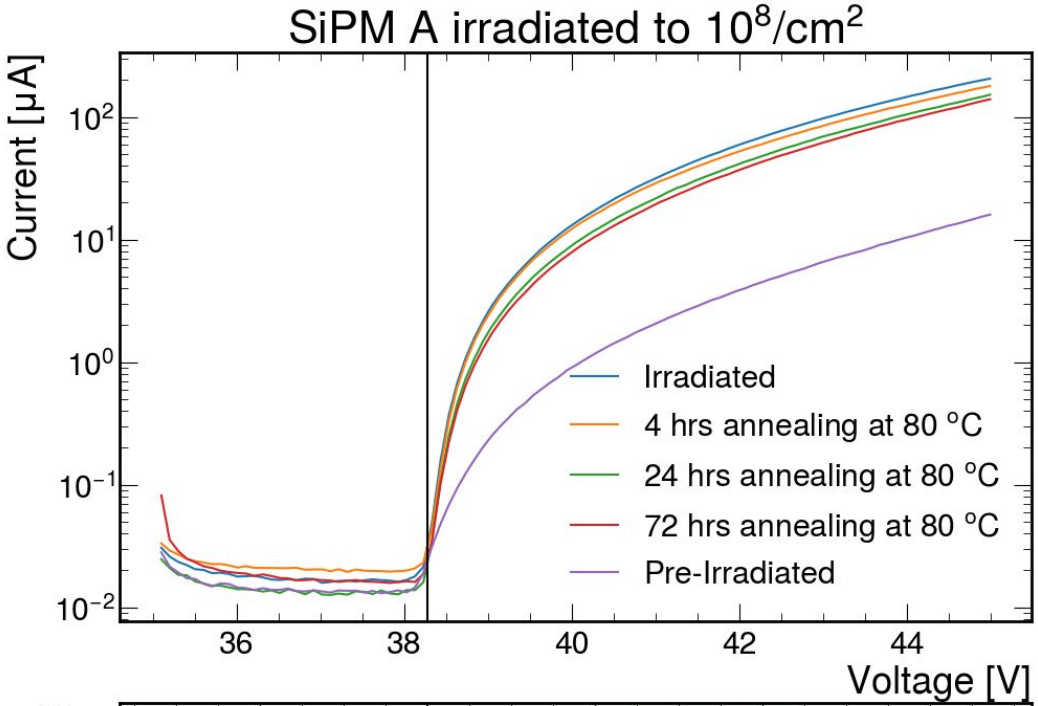
Area factor accounted dark current comparison between 3015 and 6015 at +3 OV.

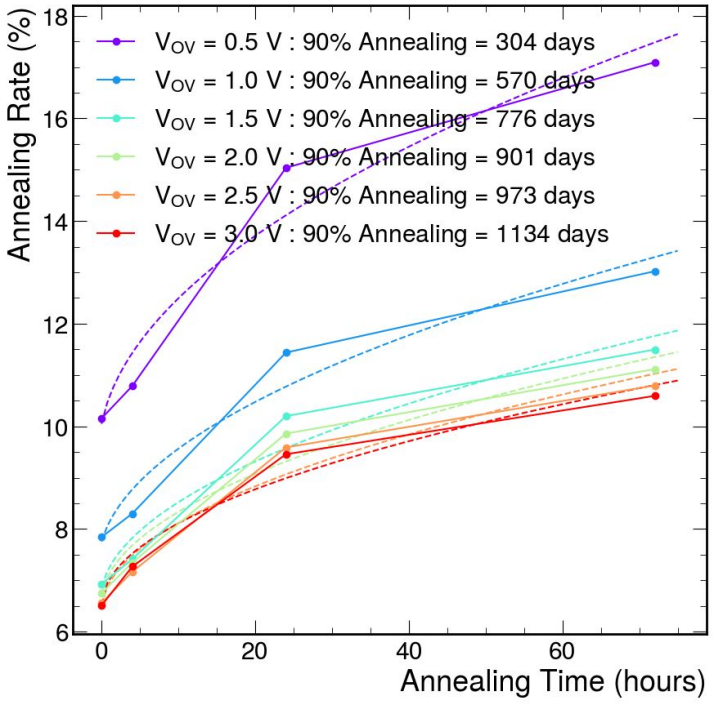
Proof we don't have current saturation using the HEX board.



S14_6050 Annealing at 80C

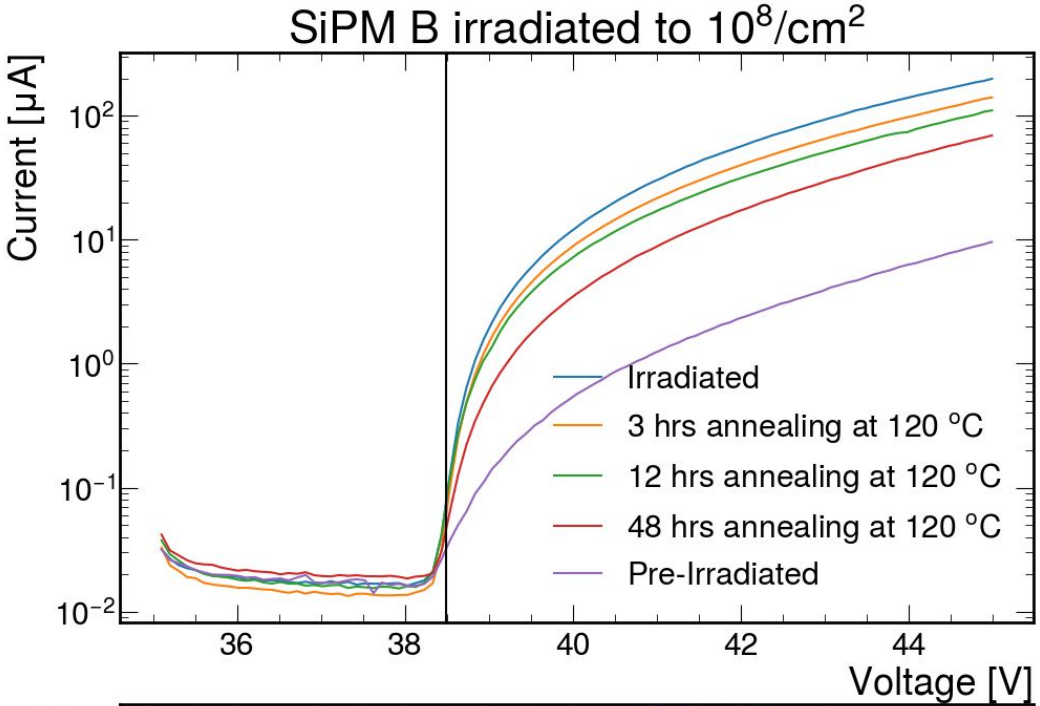
Results are still not confirmed without further data taken.

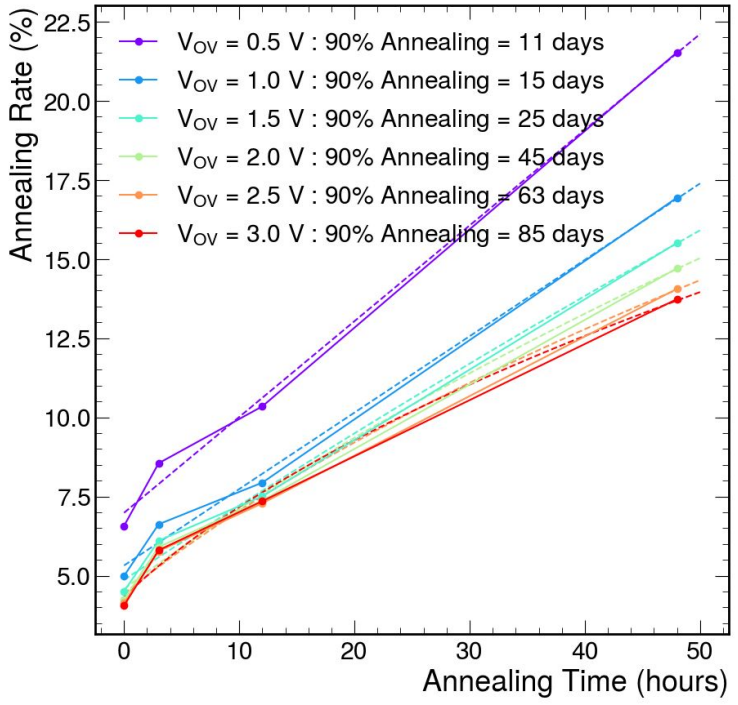




S14_6050 Annealing at 120C

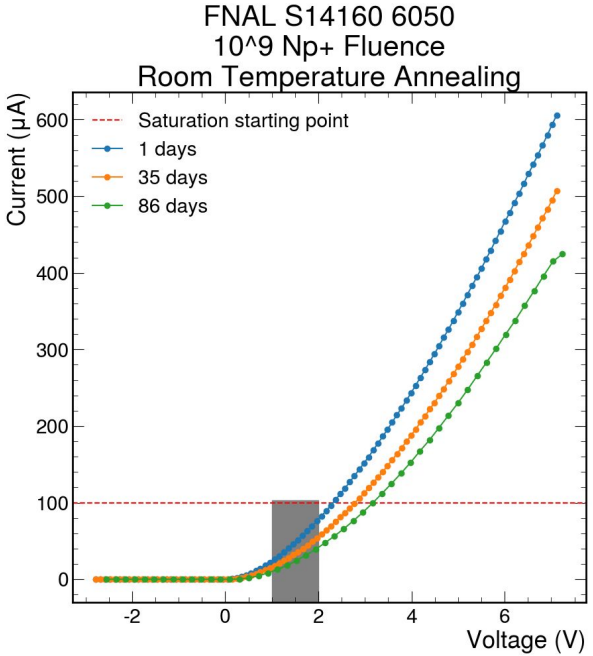
Results are still not confirmed without further data taken.

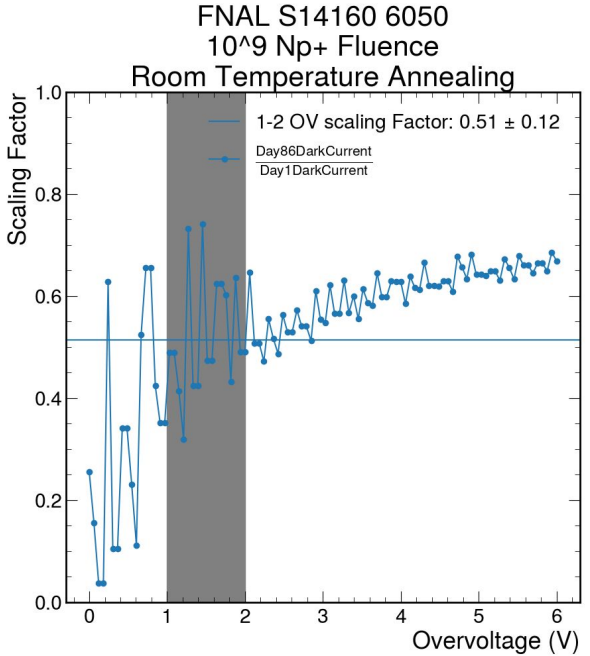




Annealing at Room Temperature

IV of 6050A9 at various times, but there is know dark current saturation at 100 uA.
The averaged annealing factor for day 86 from day 1 will be *2 using the +1-2 OV.



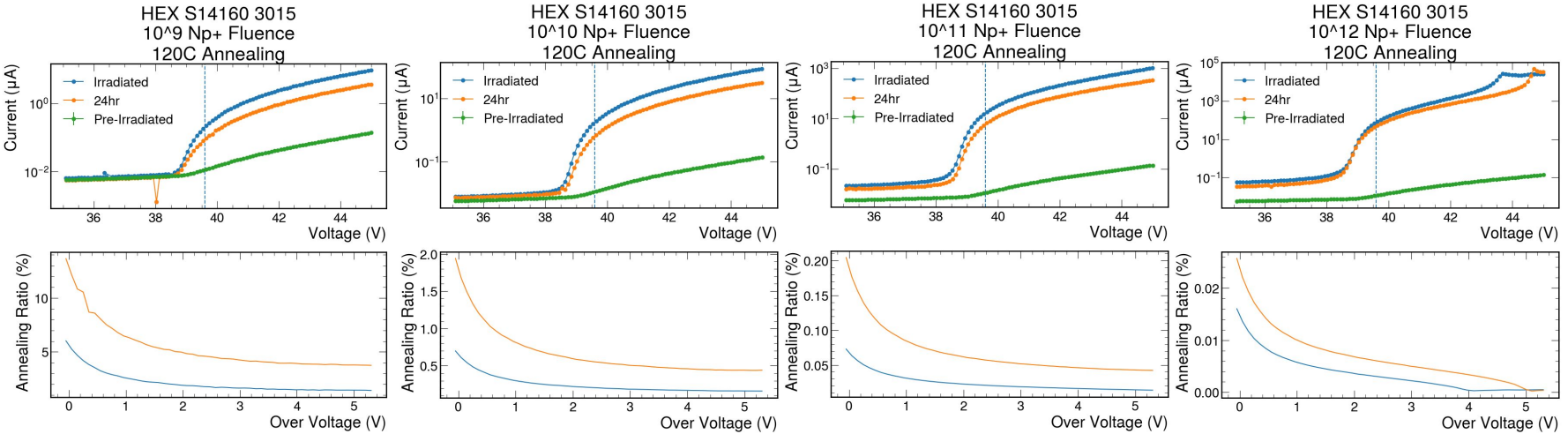


S14-3015PS Annealing At 120C

$$Ratio = \frac{Pre-IrradiatedCurrent}{AnnealedCurrent}$$

Annealing fluence 10^9 - 10^12 at 120C for continues time, recovery rate decreasing with increasing fluence damage.

Recovery compared to non-irradiated sample measured in lab all using HEX board.

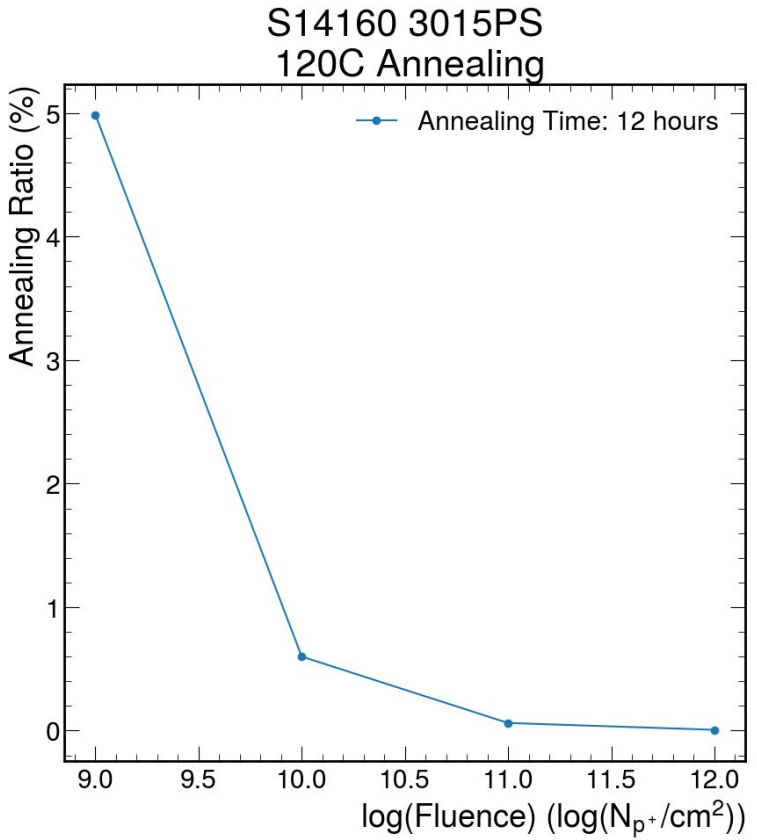


S14-3015PS Annealing At 120C cont.

More annealing currently processing.

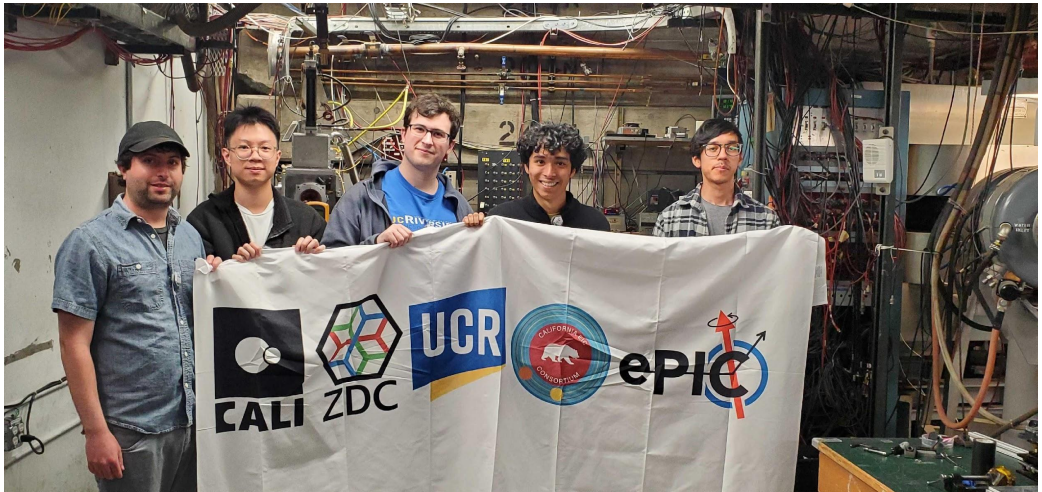
Expecting faster annealing at lower fluences, with exponential decay annealing rate trend for each fluences.

$$Ratio = \frac{Pre-IrradiatedCurrent}{AnnealedCurrent}$$



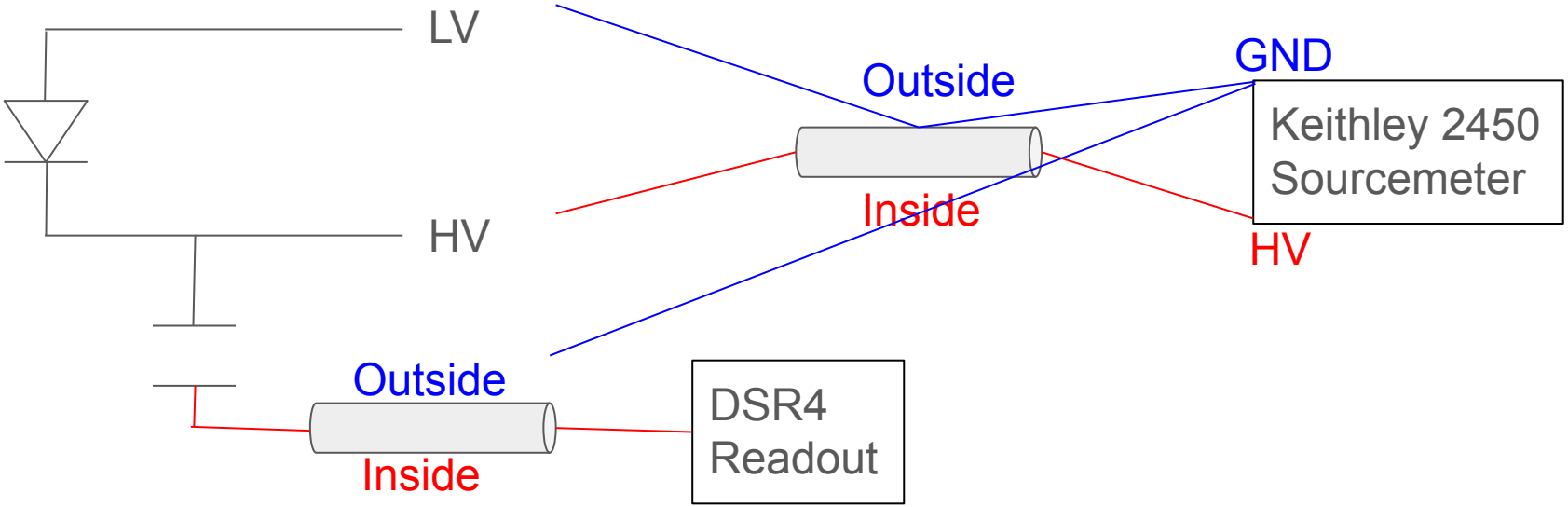
Summary

- We collected IV curve over a range of fluences for S14-6015 and S14-3015
- We collected IV for 6050 at low fluences for annealing properties
- More SiPMs still to be measured: S14-6050, S13-6050, S14-1315
- We will annealing at more temperature time to quantify recovery rate
- Additional measurements include: pedestal, LED signal/noise, dark count



backup

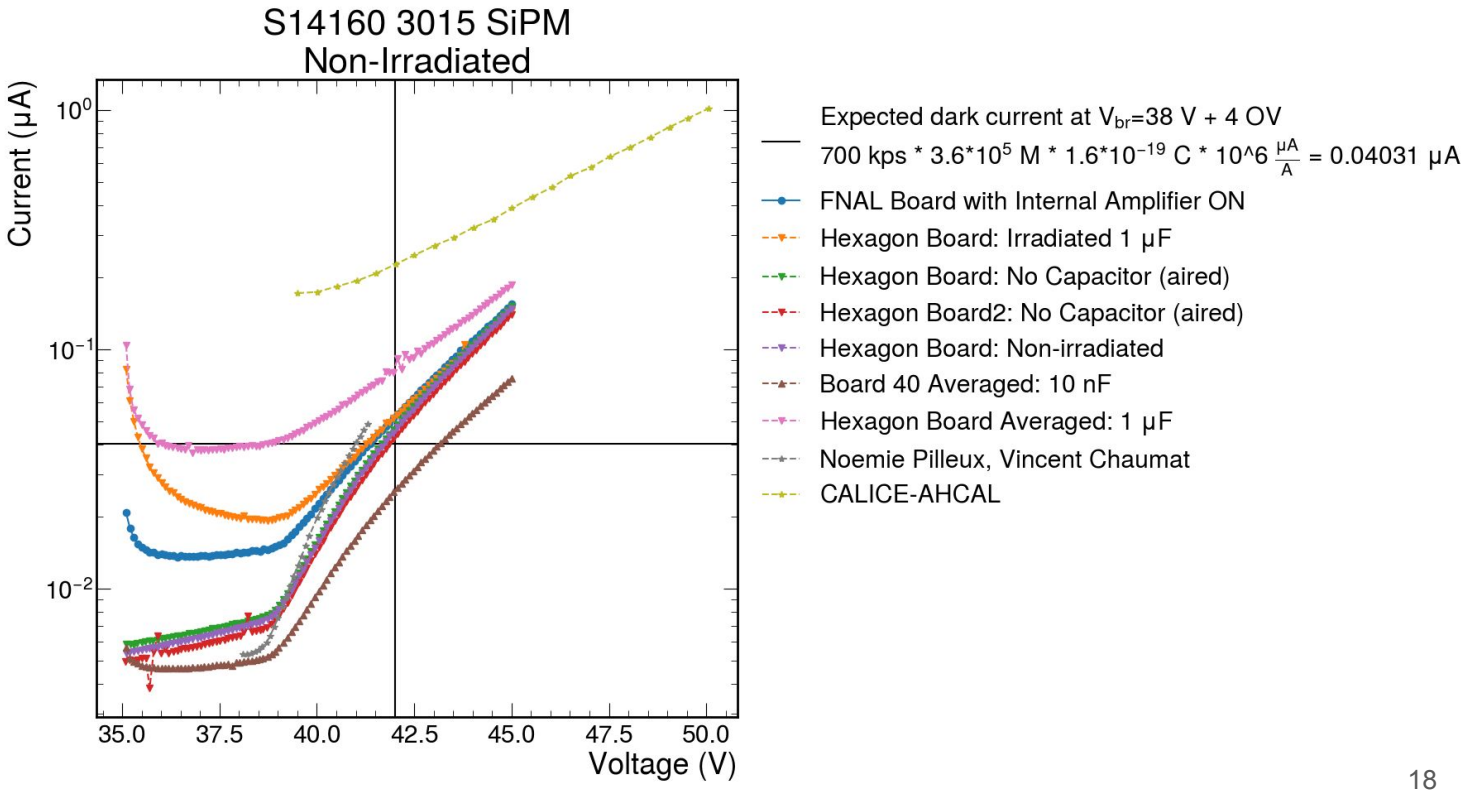
Board Electrical Diagram for Readout and Noise



Measurement for FNAL readout at high fluence is unknown, two DAQ system available for testing: DRS4, CITIROC.

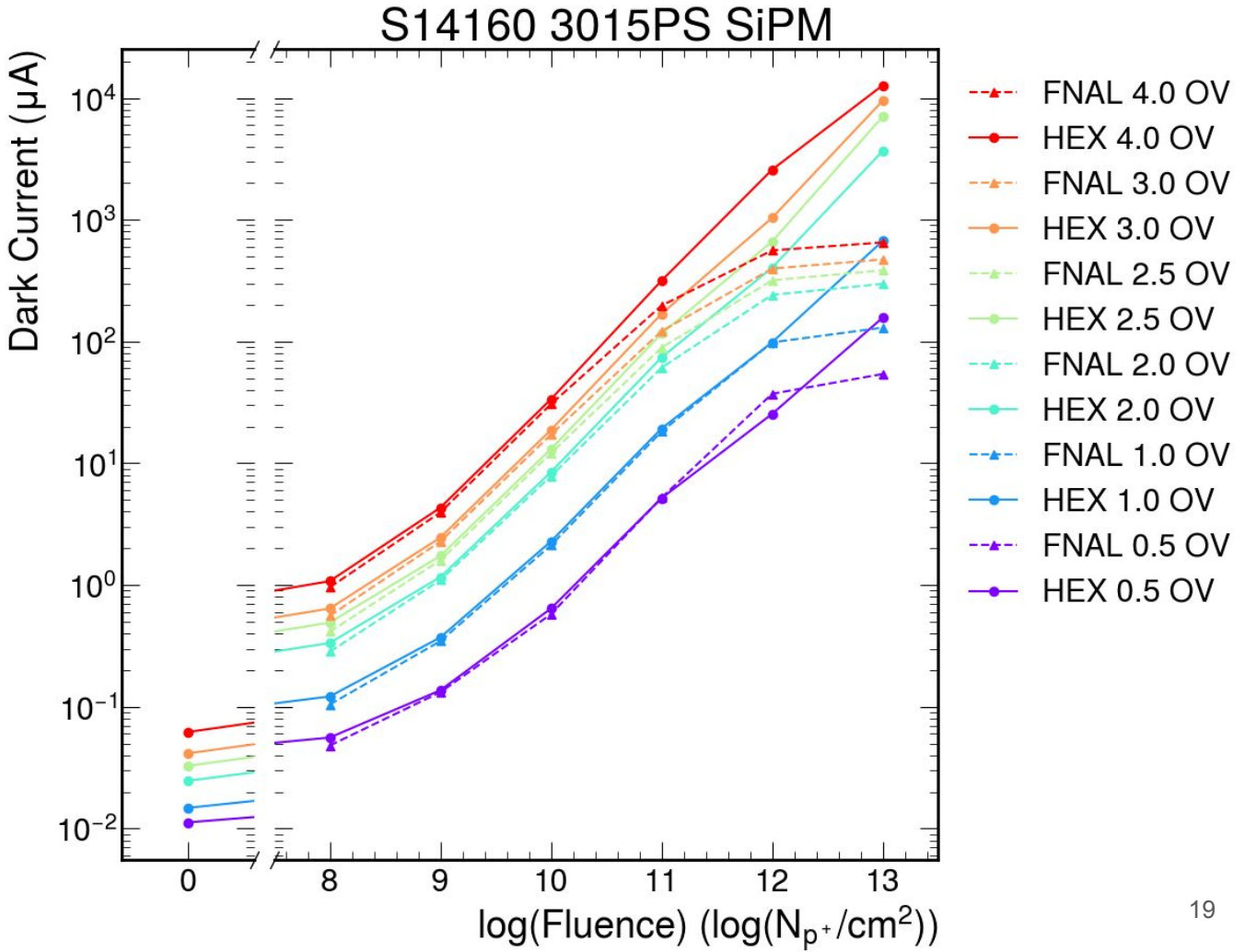
Setup Confirmation

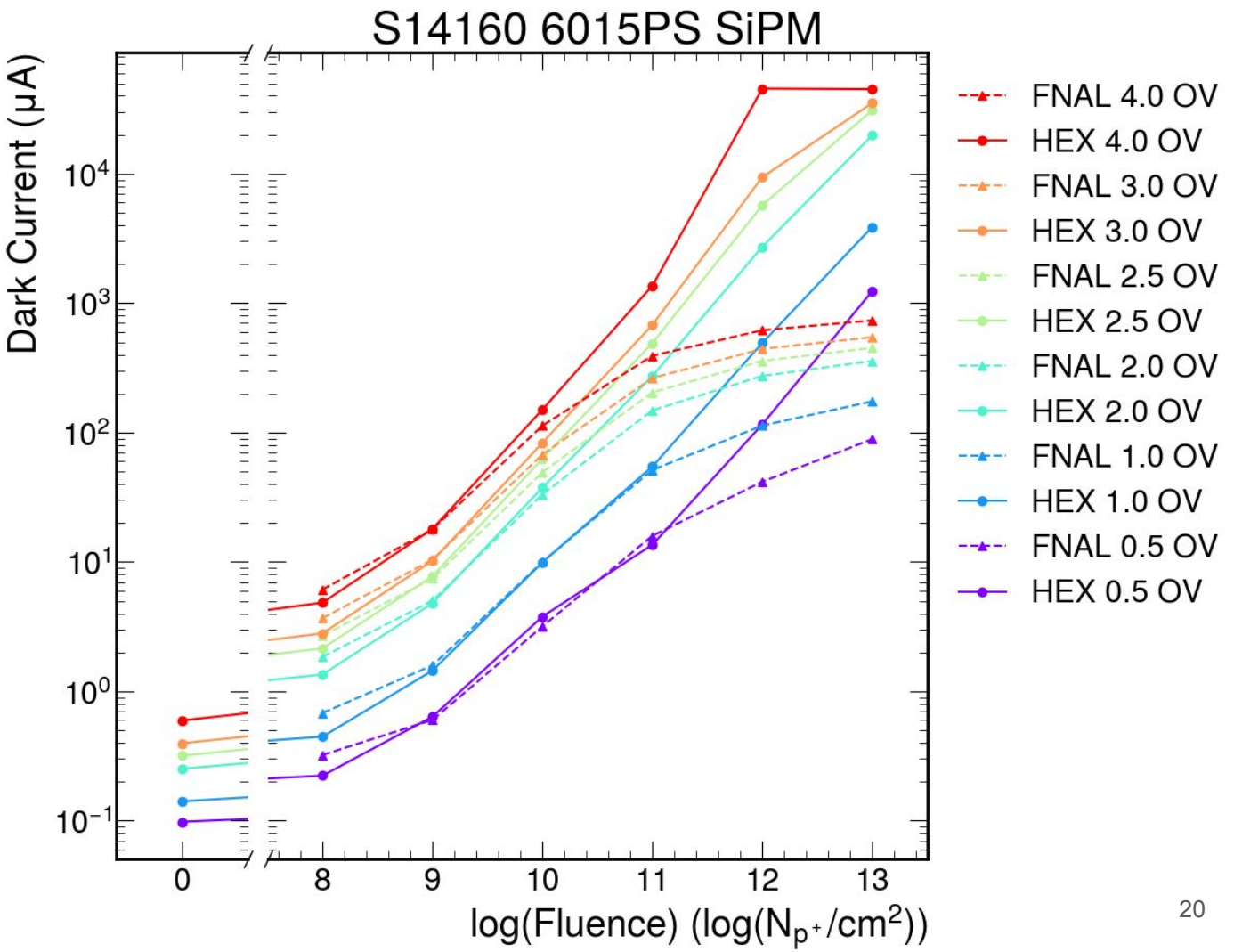
Looking at the rough calculation of expected dark current for typical data sheet value, the HEX setup seems to be the closes.



FNAL vs. HEX

Comparing the setup of FNAL and HEX, we can see that it branches off at about 10^10 fluence. So we can still use lower fluence IV.




S14160 6015PS SiPM
Dark Current (μA)
10^4
10^3
10^2
10^1
10^0
10^{-1}
0
8
9
10
11
12
13
log(Fluence) (log(N_{p^+}/cm^2))
FNAL 4.0 OV
HEX 4.0 OV
FNAL 3.0 OV
HEX 3.0 OV
FNAL 2.5 OV
HEX 2.5 OV
FNAL 2.0 OV
HEX 2.0 OV
FNAL 1.0 OV
HEX 1.0 OV
FNAL 0.5 OV
HEX 0.5 OV