Davis Cyclotron Irradiation of SiPM for EIC

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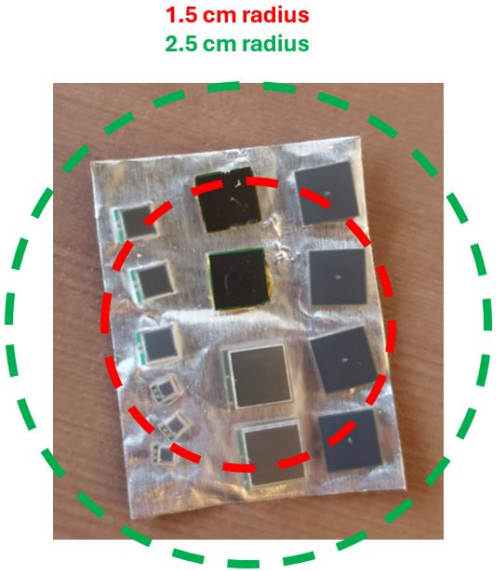
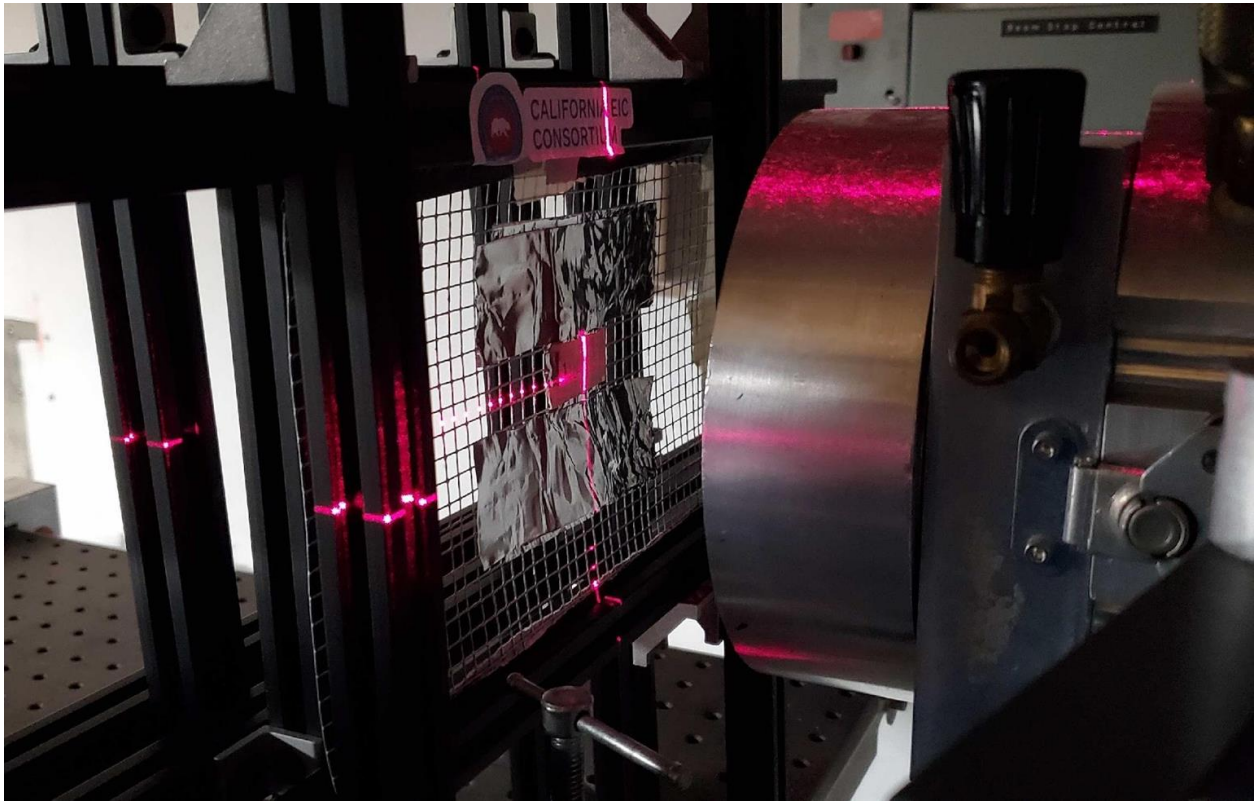
Introduction

- UC Davis cyclotron proton beam at 64 MeV kinetic energy
  - 1.5x damage factor compared to 1 MeV neutron
- 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, and annealing at 120 C

Irradiation Setup

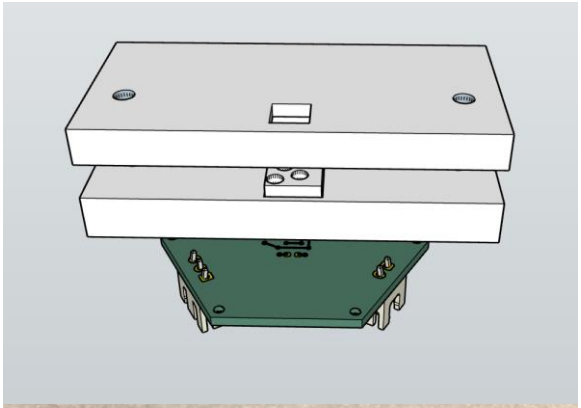


SiPM taped to aluminum tape within uniform beam radius, centered using laser.


CALIFORNIA EIC
CONSORTIUM

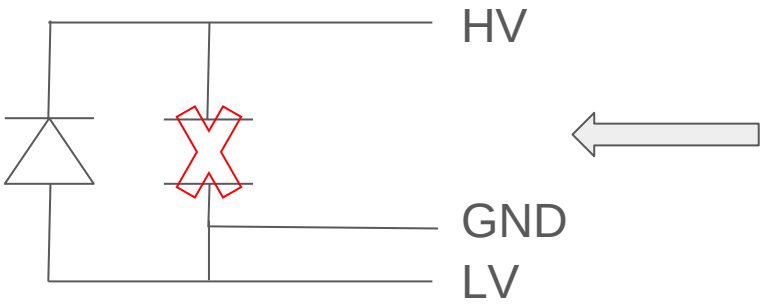
IV Setup

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.

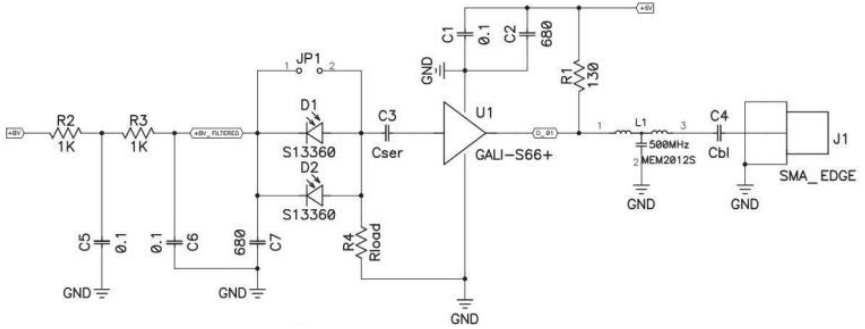


Board Electrical Diagram for IV

Hexagon Board IV Collection

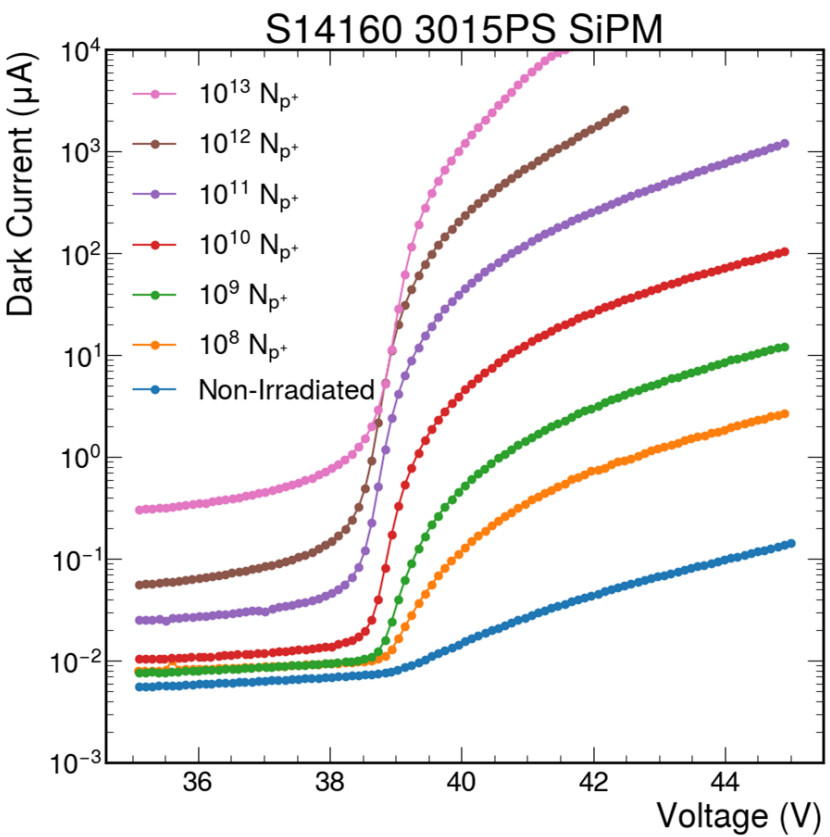


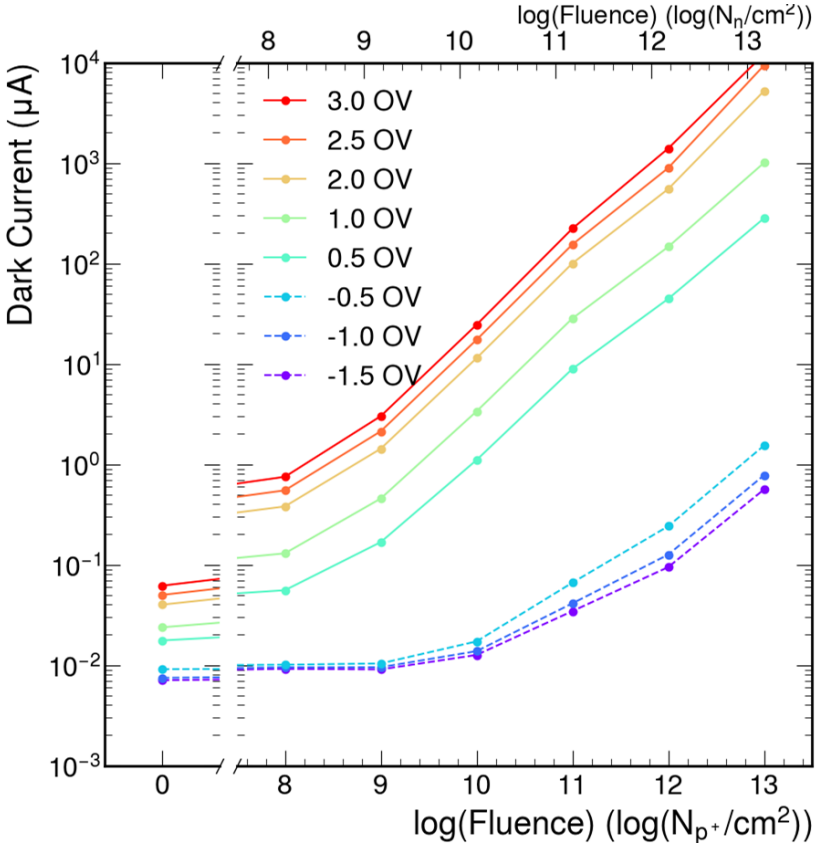
FNAL Board IV Collection



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

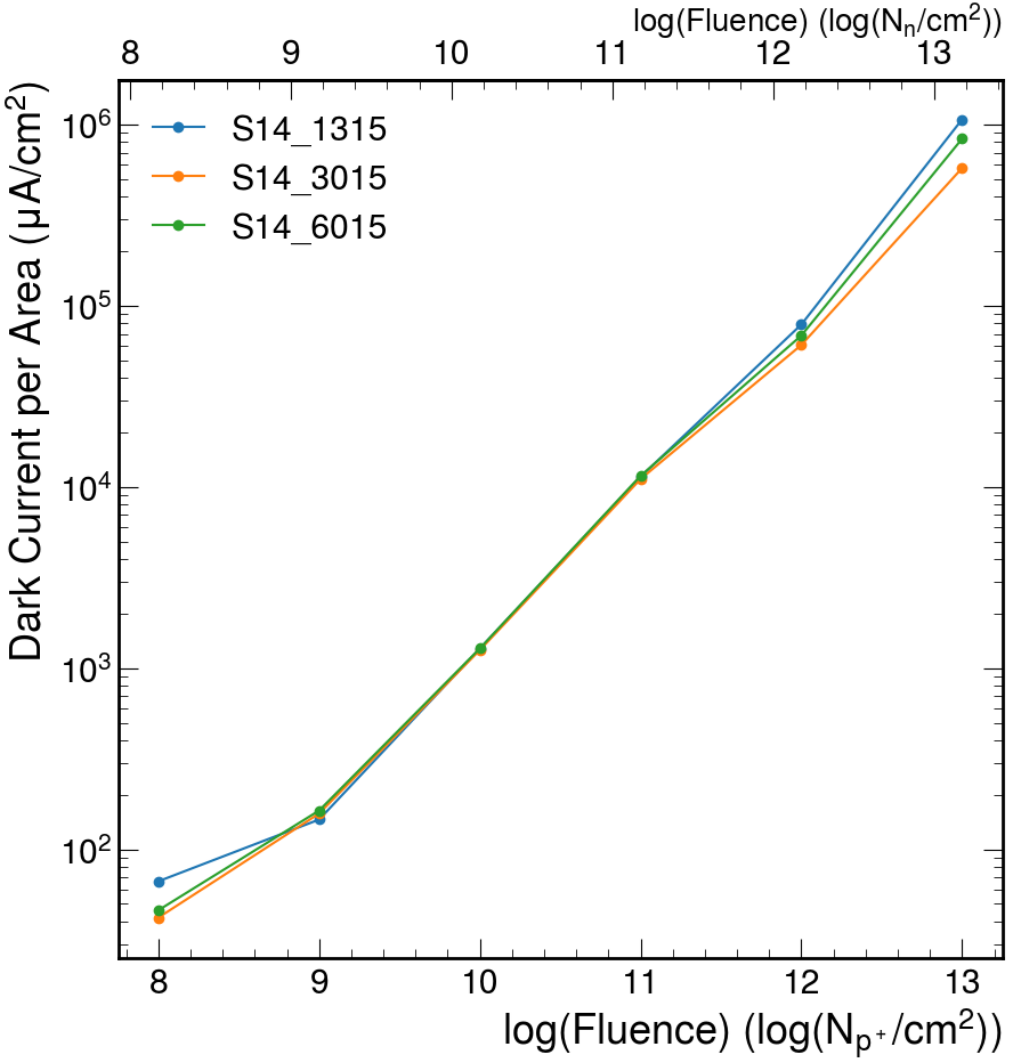
S14160-3015PS Irradiation IV





Area Scaled Current

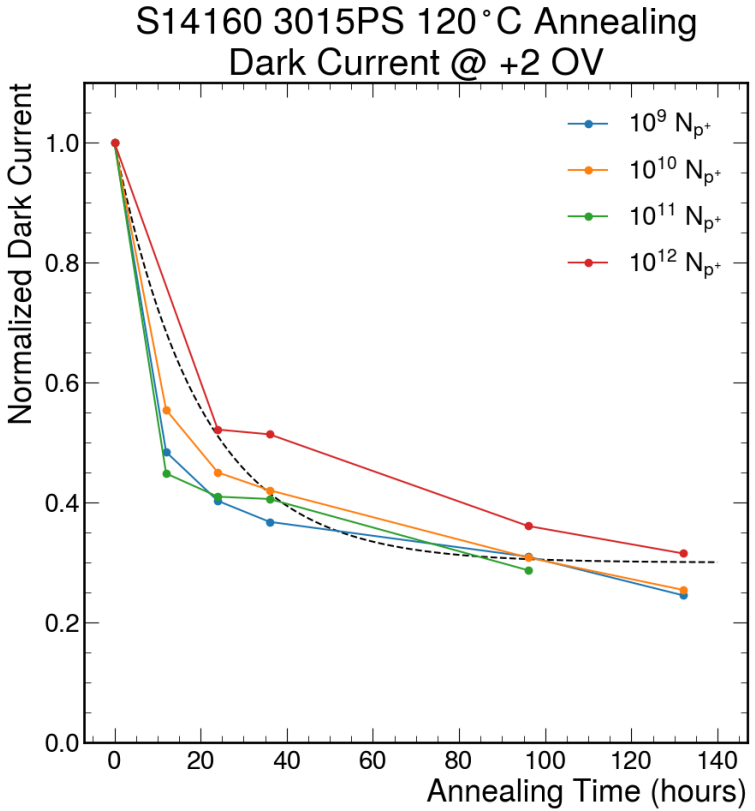
Area factor accounted dark current comparison between 3015, 6015, 1315 at +3 OV.



S14160-3015PS Annealing at 120 C

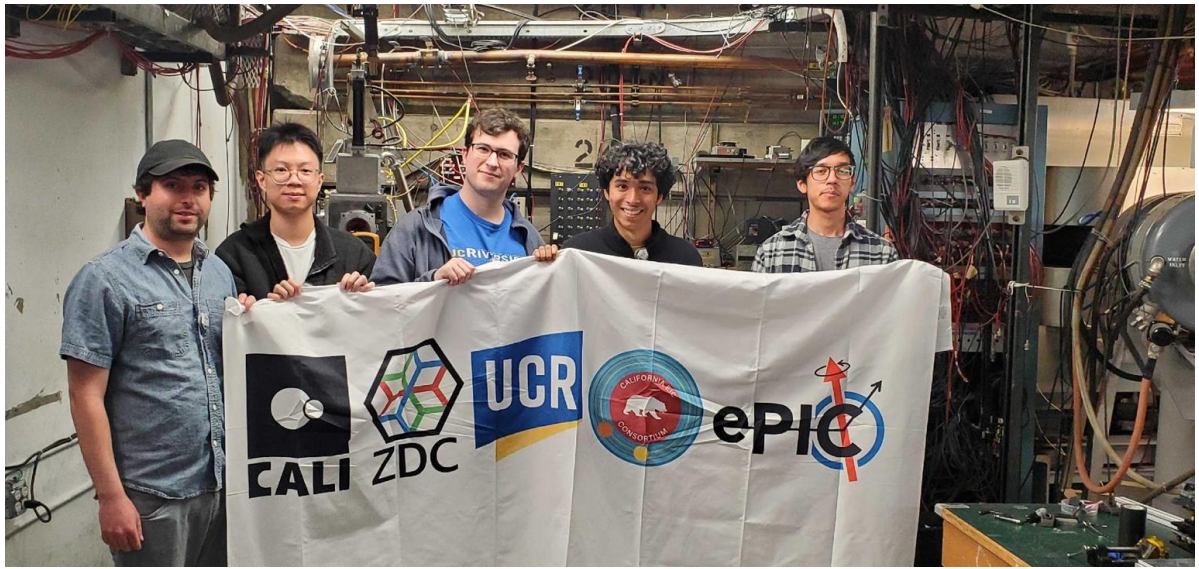
High temperature annealing at 120C does not damage SiPM and PCB board

Comparing to initial irradiated dark current, an expected exponential decay trend shows annealing of half of dark current around 19 hours



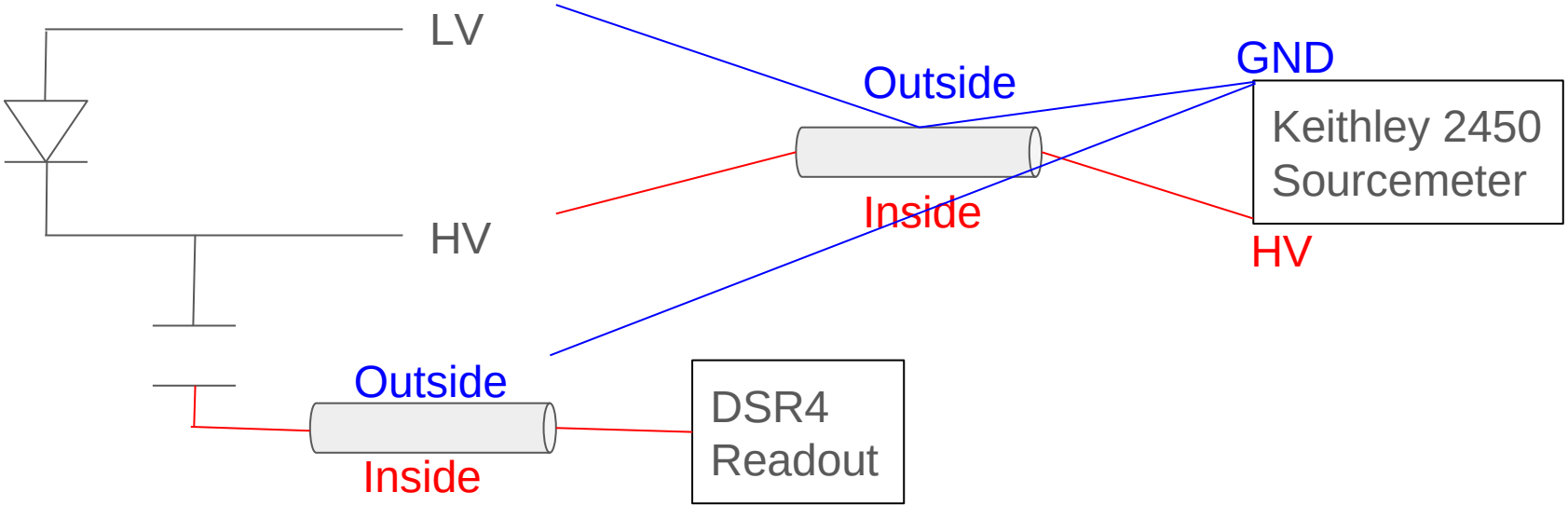
Summary

- We collected IV curve over a range of fluences for all irradiated SiPMs
  - Dark current expected to increase by 4 orders after one year of maximum EIC luminosity
- We annealed at more 120 C
  - Annealing dark current by halves with ~19 hours



backup

Board Electrical Diagram for Readout and Noise

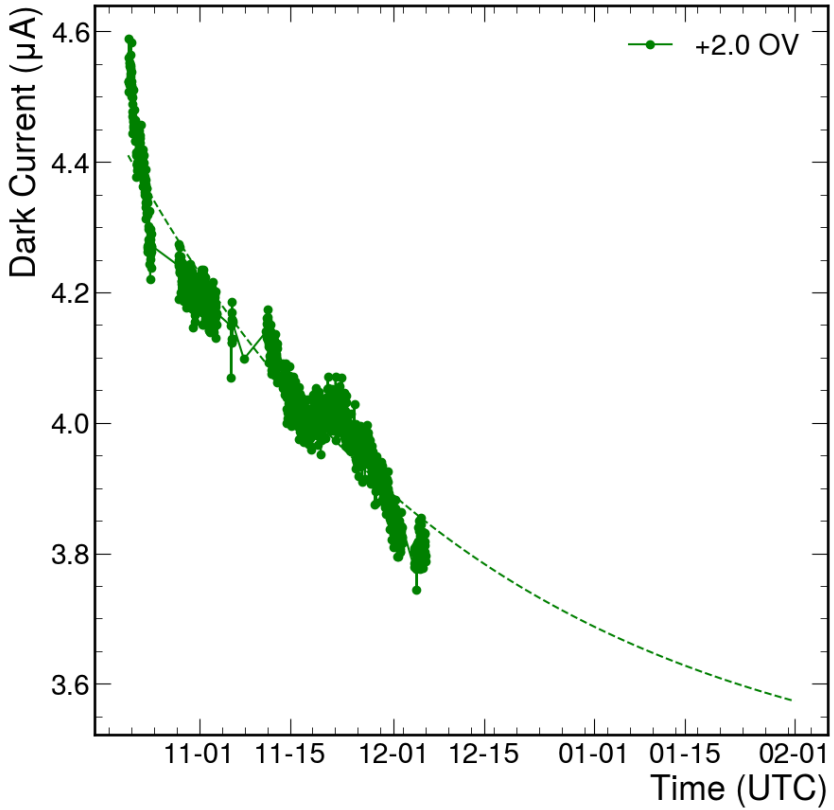


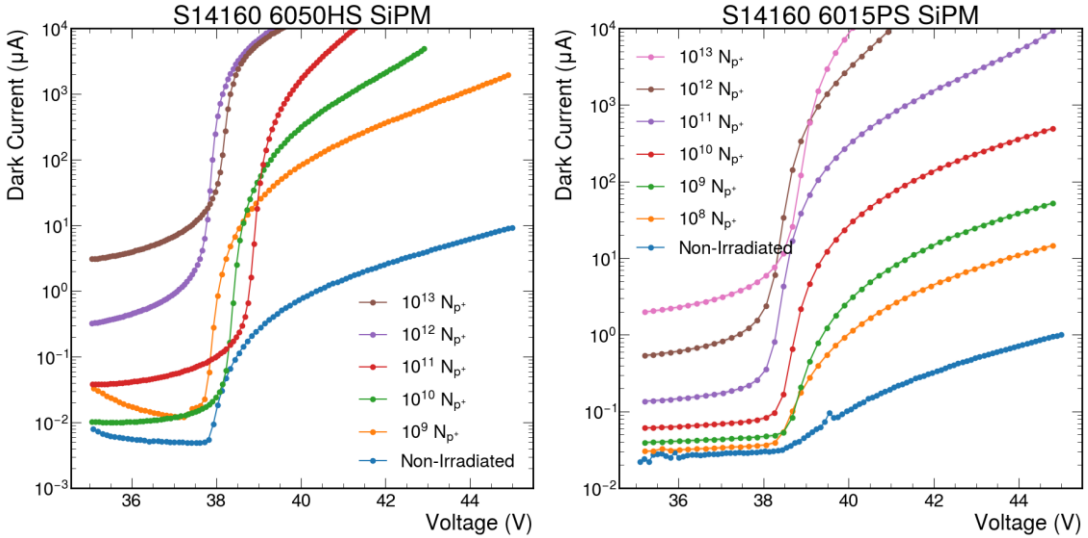
Measurement for FNAL readout at high fluence is unknown, two DAQ system available for testing: DRS4, CITIROC.

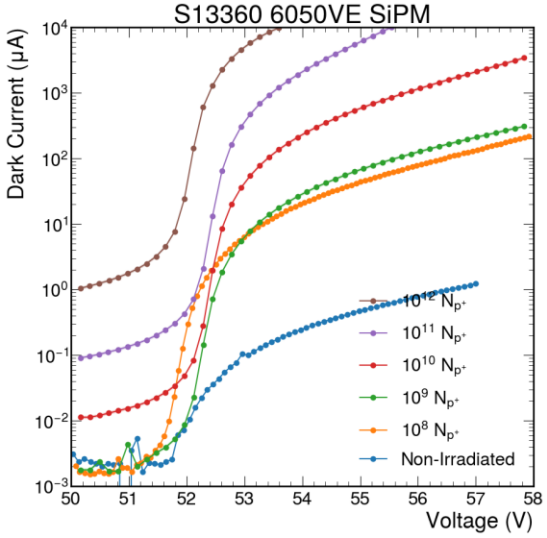
Room Temperature Annealing

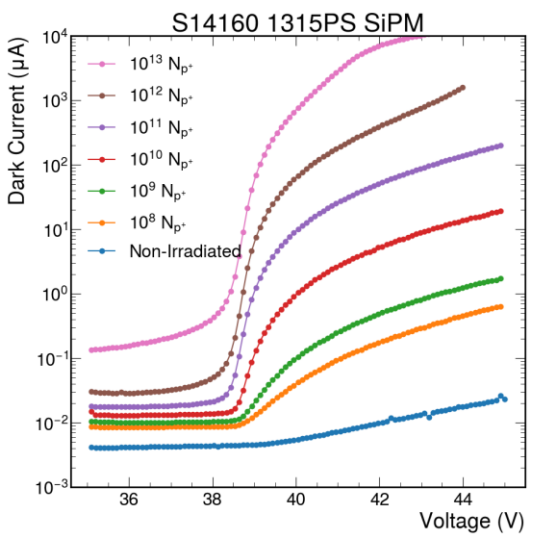
We have a IV collection setup using hexagon board with capacitor in BNL

After Au-Au run of the STAR experiment, IV decay trend were recorded and calculated for the factor of 1.24 +- 0.05 after three month of room temperature annealing applied to Davis IV data





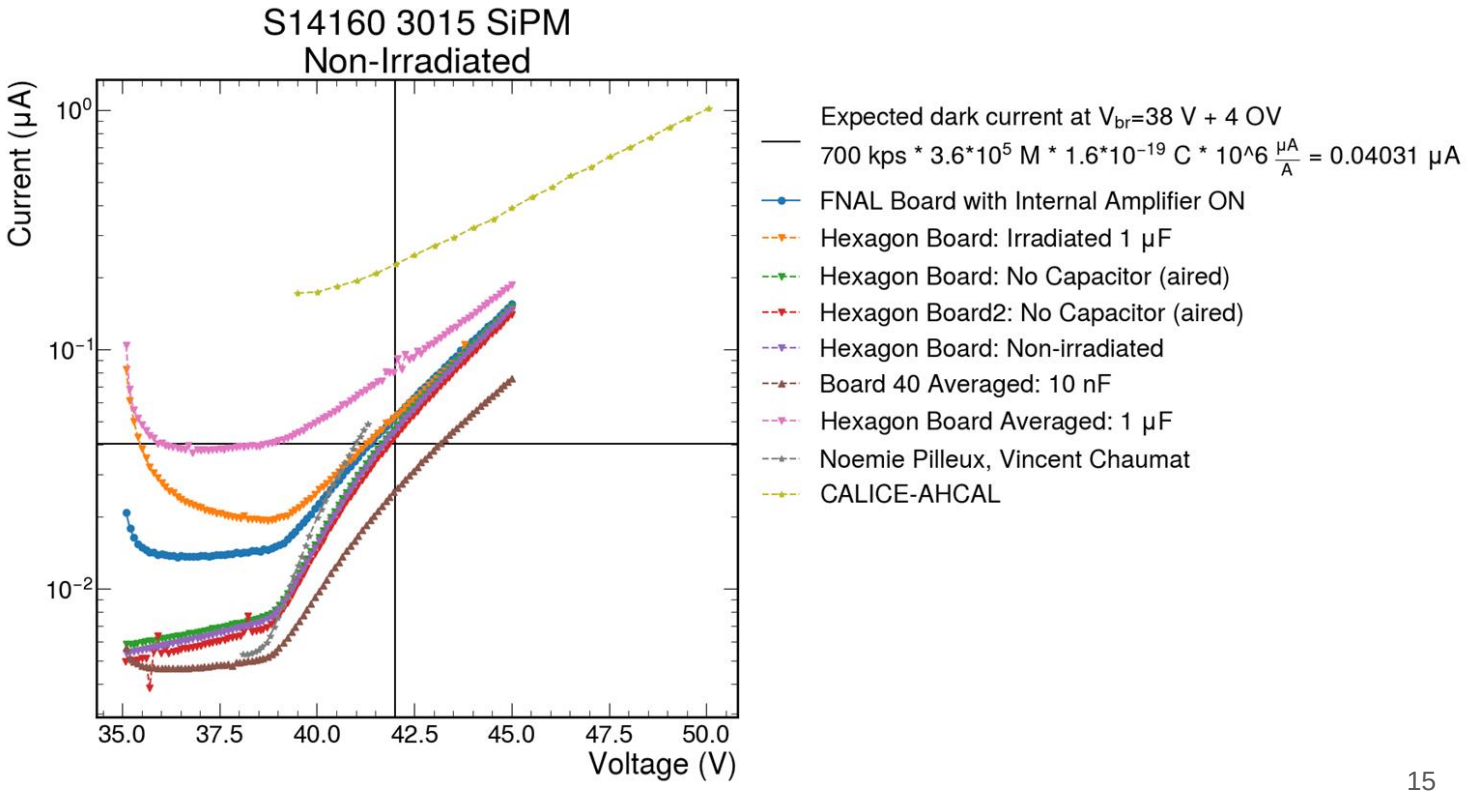




Other Models

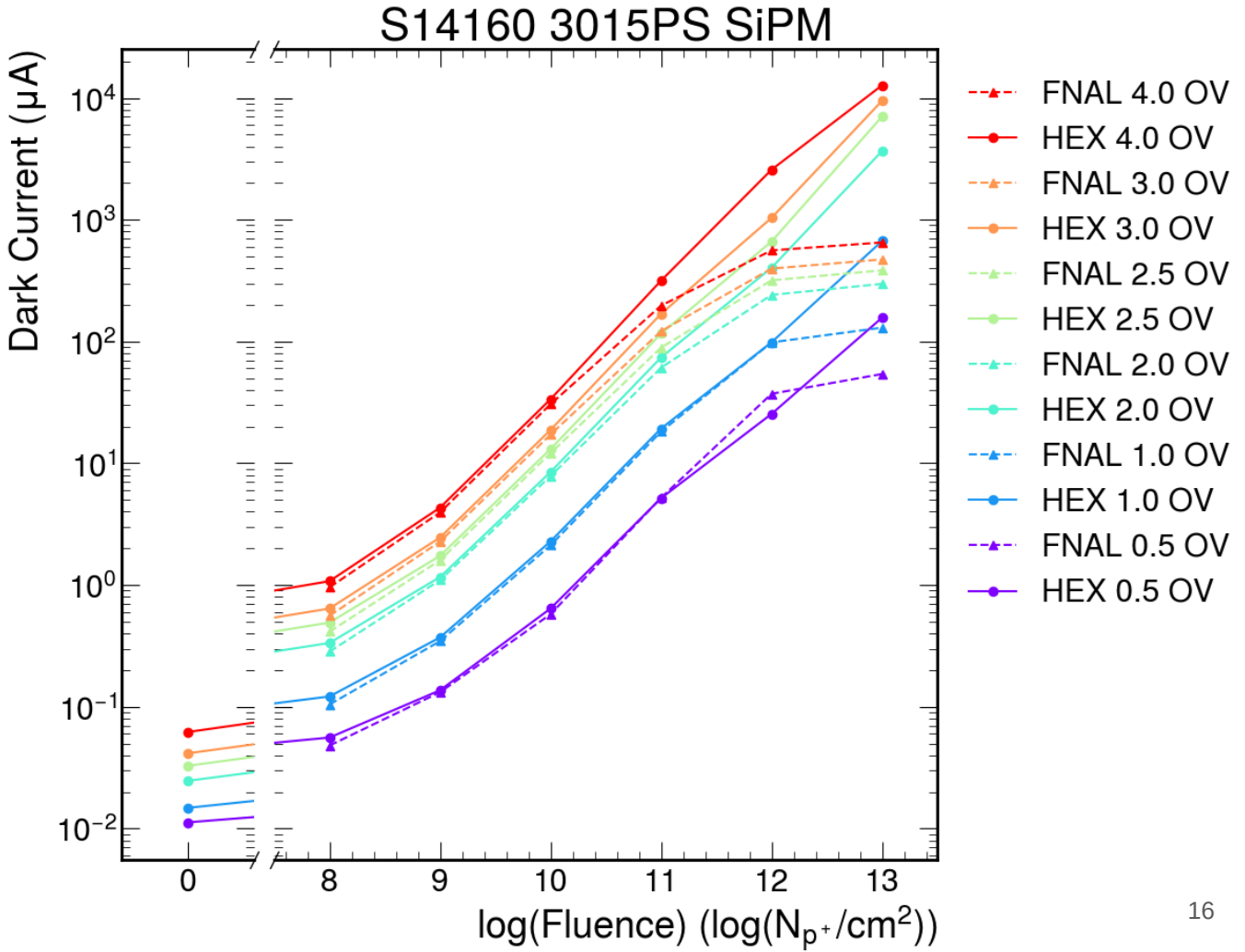
Setup Confirmation

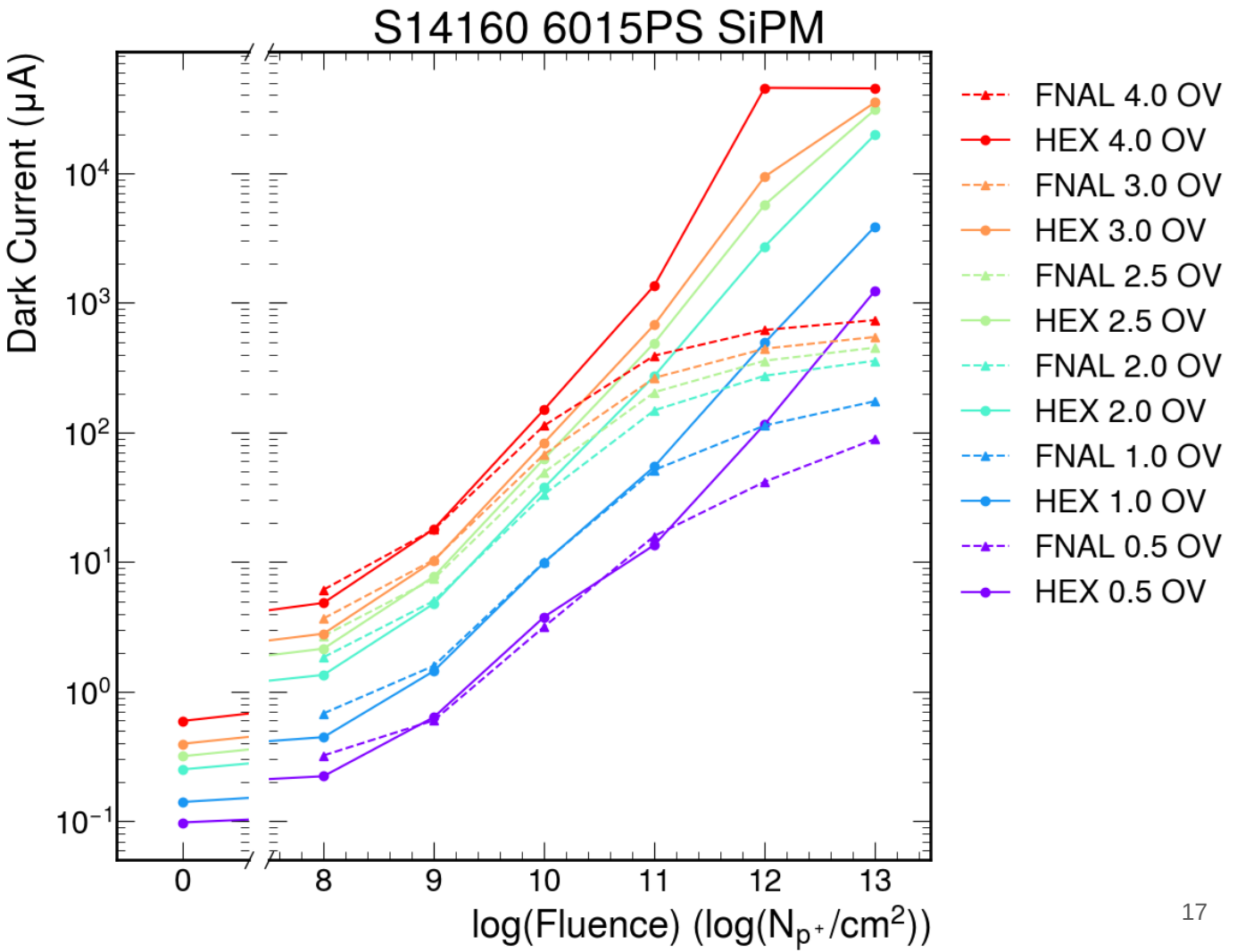
Looking at the rough calculation of expected dark current for typical data sheet value, the HEX setup seems to be the closes.



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