First results for SiPM irradiation tests at the UC Davis Cyclotron

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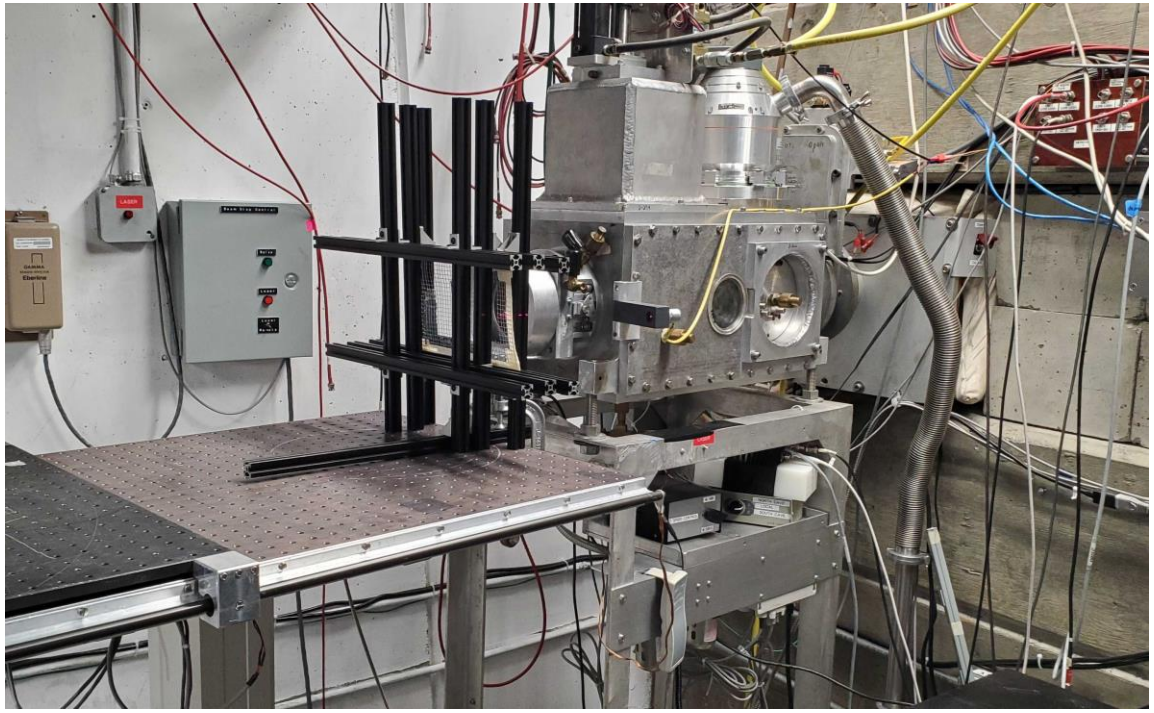
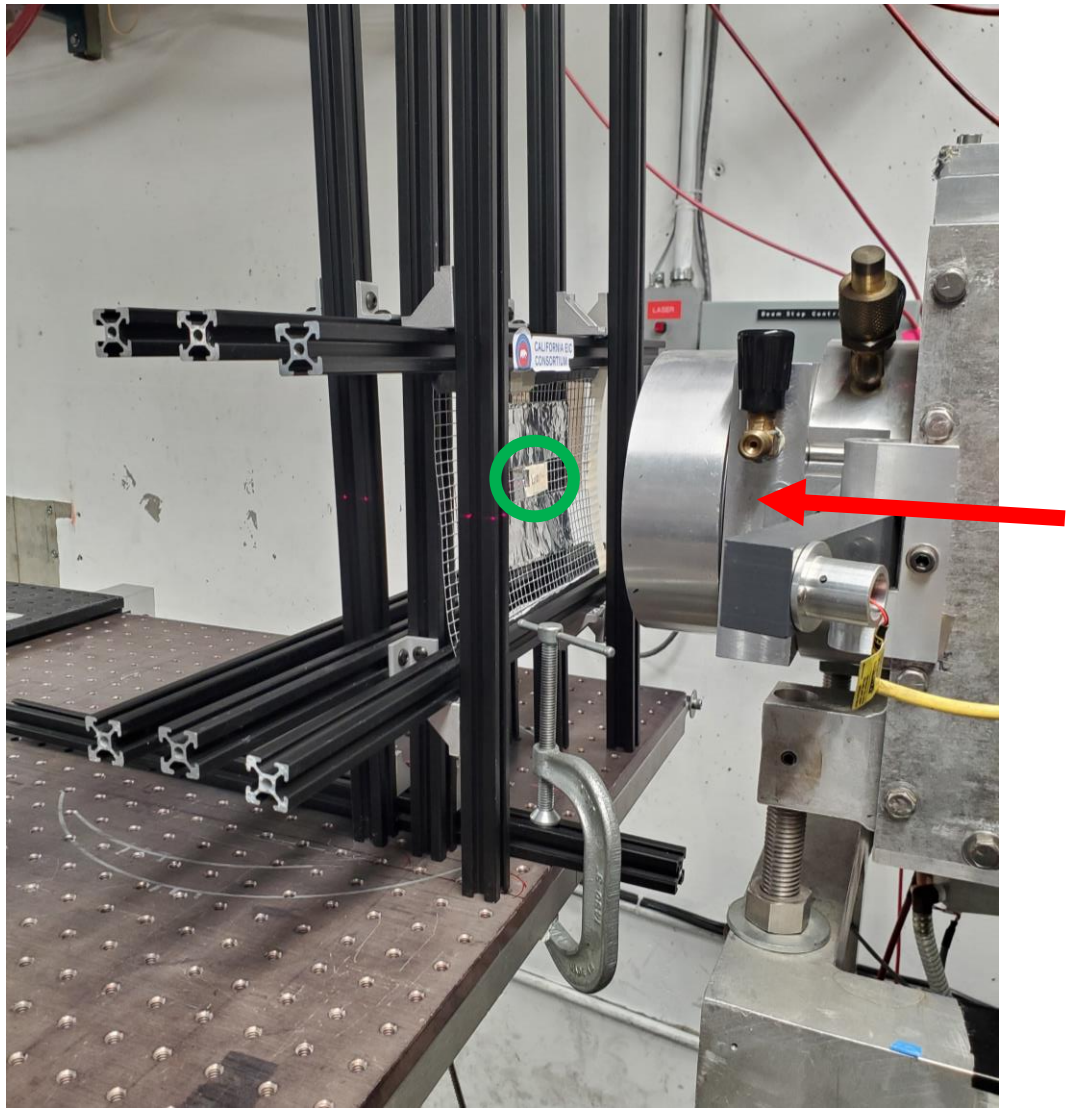
Overview

- The test was conducted on May 14th and 15th. The beam used was a 64 MeV proton beam.
- We irradiated 7 different types of SiPMs over a range of proton fluences between 10^8 and 10^{13} /cm^2.
- SiPMs attached to readout boards and scintillator tiles were irradiated as well.
- Additional tests on electronics were performed by the BNL group.
- The dark current vs. voltage characteristics of many of the irradiated SiPMs were measured several hours and 1 day after irradiation.
- A first set of measurements with cosmic events was also made.



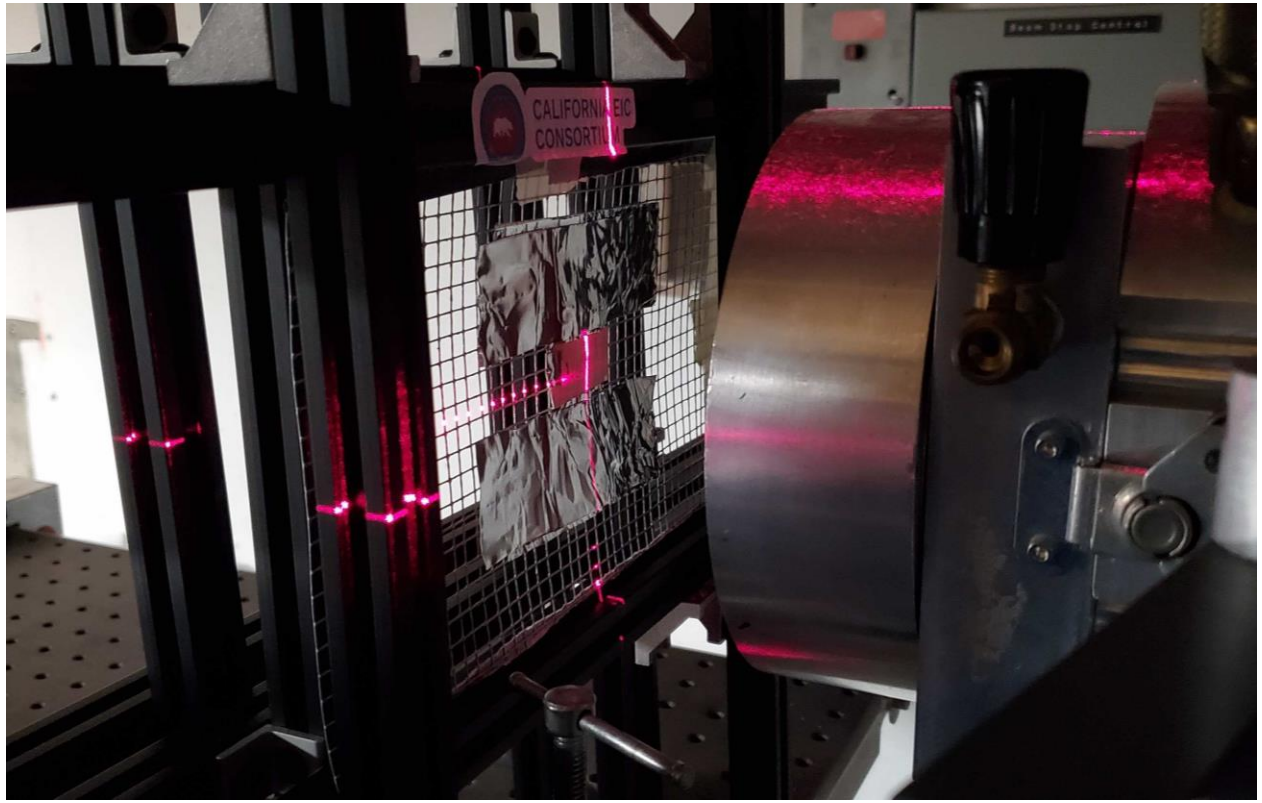
Setup – mount



The 64 MeV **proton beam** enters from the right.

The **SiPM sample** is placed about 15 cm away from the Kapton exit window (located in the metal cylinder).

Setup – beam centering



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The **SiPM sample** is placed about 15 cm away from the Kapton exit window (located in the metal cylinder).

The sample is centered on the beam spot using the laser system.

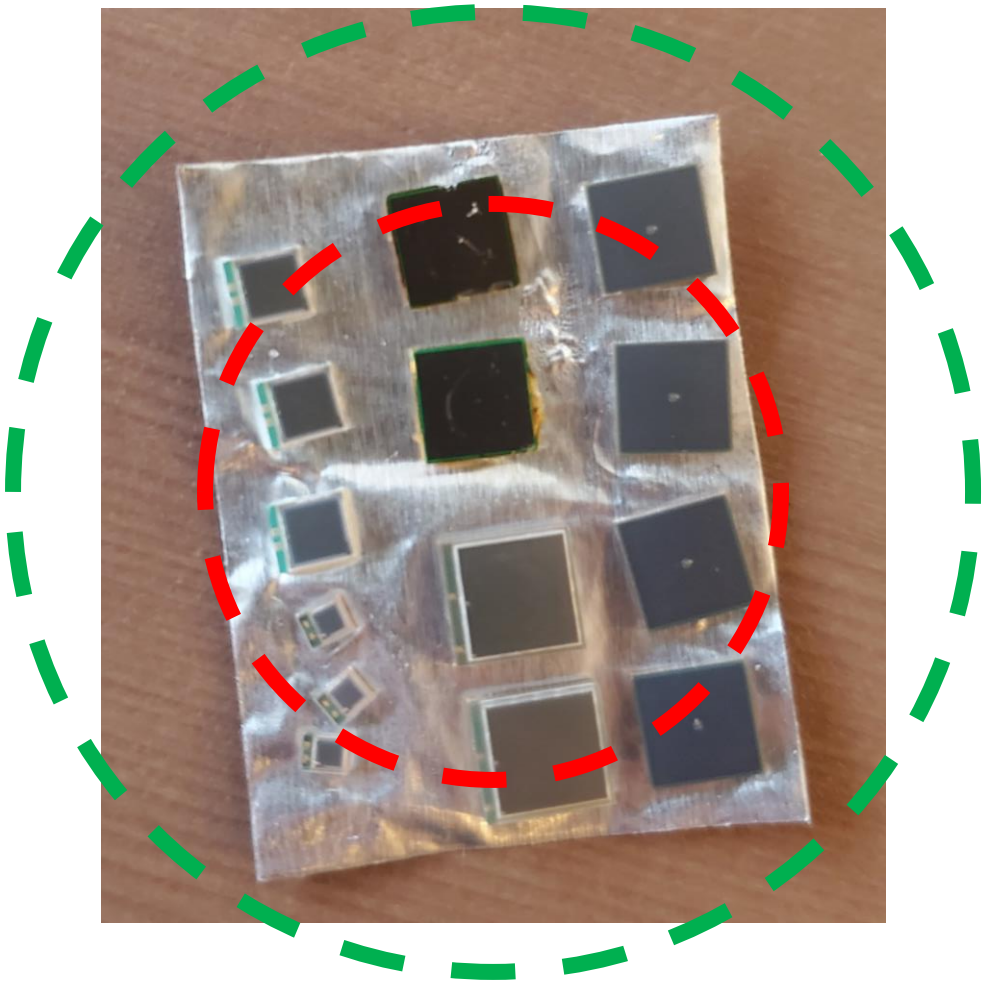
Setup – SiPM and layer ID

- Each SiPM had a unique ID.
- Each layer was labelled based on the radiation dose.

L12		
3015A12	S13A12	6050A12
3015B12	S13B12	6050B12
3015C12		6050C12
		6050D12
1315A12	6015A12	
1315B12	6015B12	
1315C12		

Accumulated fluence

1.5 cm radius
2.5 cm radius



Run info for 10^{12} fluence setting

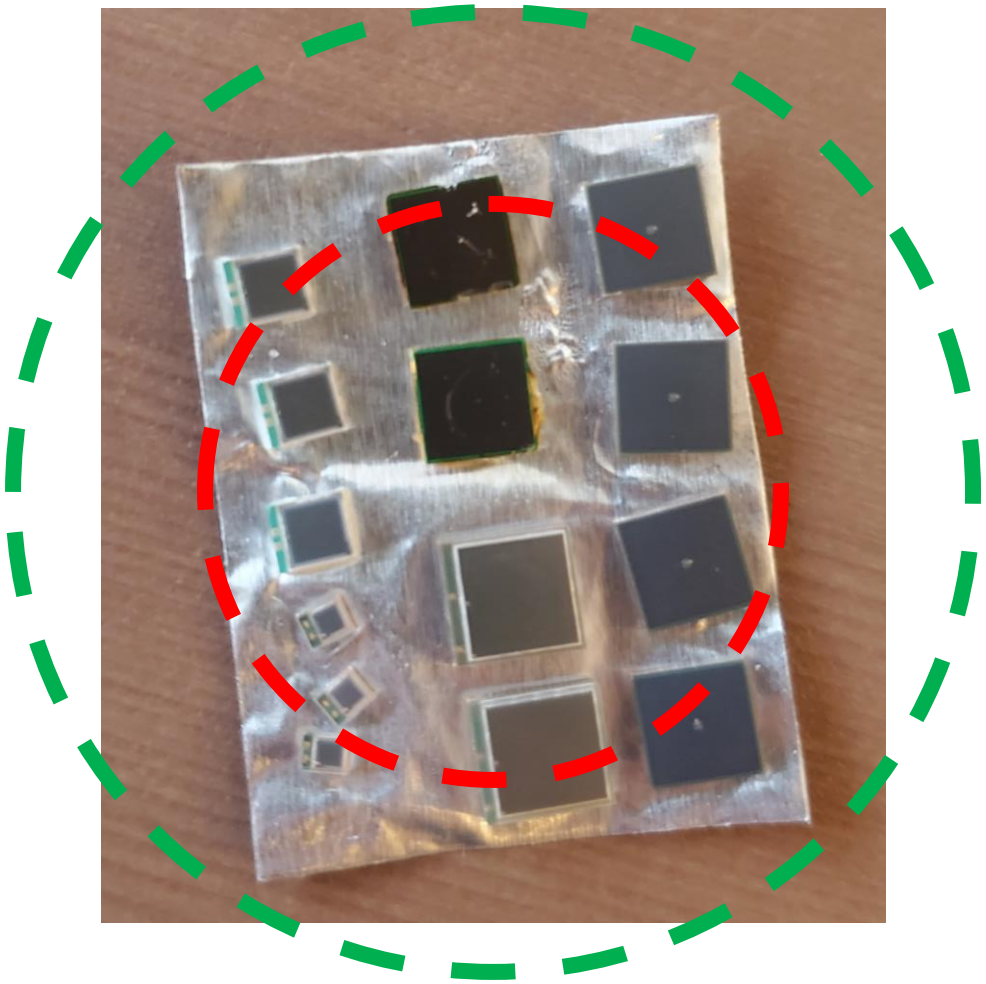
Beam Type: Proton **Target:** Si **File Name:**
Beam E (MeV): 64.0 **dE/dx (MeV·cm²/g):** 8.334 c:\ref_user\UC Riverside\UC-Riverside_5-14-24.html
Date: 5/14/2024

5/14/2024 **FC Lkg (A):** -4.800E-13 ± 1.056E-13
8:46:03 **SEM Lkg (A):** 1.299E-11 ± 1.328E-12
8:47:05 **FC/SEM Ratio:** 1.8896E+00 ± 4.0255E-03

	Run Time (s)	Mean Current (A)	Std Dev <I> (A)	Incr Dose (rad)	Acc Dose (rad)	Incr Fluence (p/cm²)	Acc Fluence (p/cm²)	Avg Dose Rate (rad/s)	Beam Profile
Run #1									
9:00:35	789.401	1.016E-08	1.751E-09	1.336E+05	1.336E+05	1.001E+12	1.001E+12	1.693E+02	0 - 0.5 cm
L12				1.329E+05	1.329E+05	9.957E+11	9.957E+11	1.684E+02	0.5 - 1.5 cm
				1.303E+05	1.303E+05	9.757E+11	9.757E+11	1.650E+02	1.5 - 2.5 cm

Accumulated fluence

1.5 cm radius
2.5 cm radius



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Between 1.5 and 2.5 cm radius, the total fluence relative decreases by ~2.5% compared to r = 0.

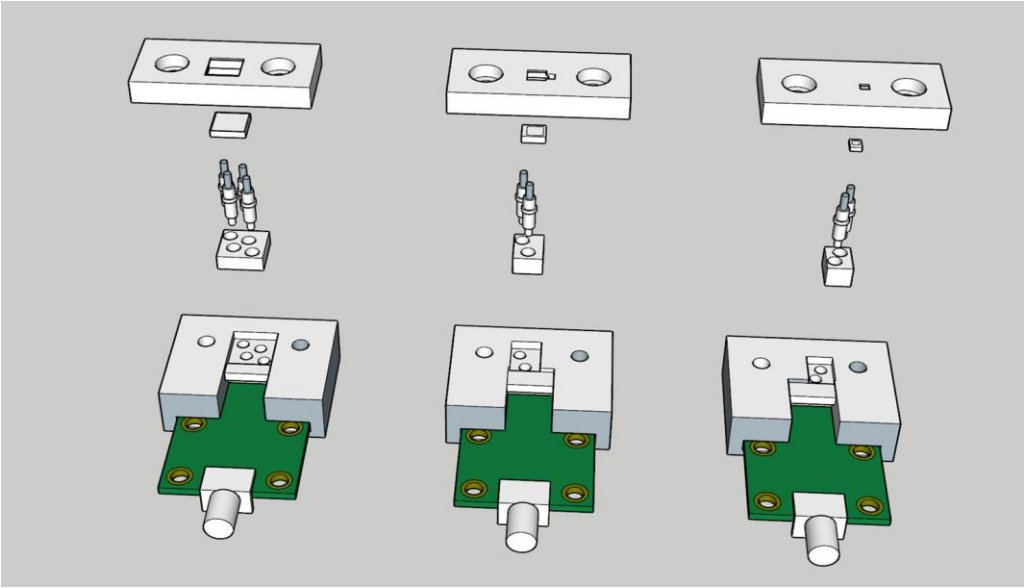
The absolute beam fluence is measured to about 2% precision.

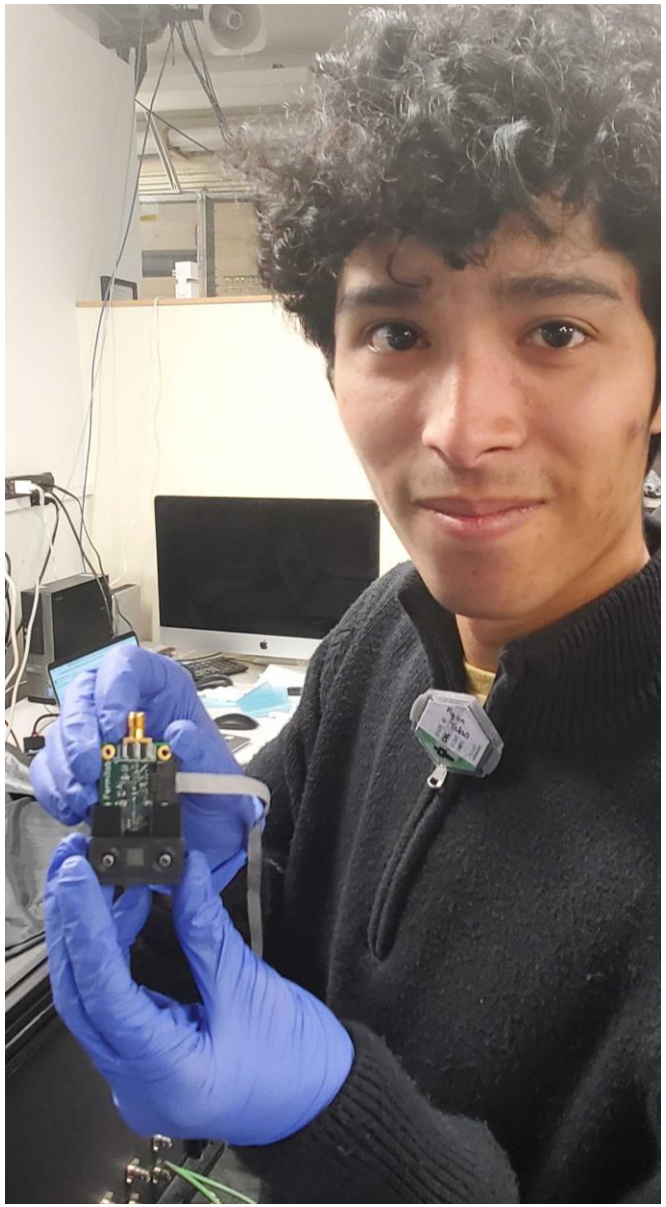
List of irradiated SiPMs

SiPM type	Number Irradiated	Proton fluence range ($1/cm^2$)	Under consideration for which ePIC Calorimeter(s)
S14160-6050HS	20	$10^8 – 10^{13}$	PECal, FHCal(Insert), ZDC, BECal
S14160-6015PS	16	$10^8 – 10^{13}$	PECal, EEEMC, BECal
S13360-6050VE	10	$10^8 – 10^{12}$	BEMC
S14160-3015PS	18	$10^8 – 10^{13}$	FHCal(Insert), ZDC, EEEMC
S14160-3010PS	8	$3.5x10^8 – 5.4x10^{10}$	EEEMC
S14160-1315PS	15	$10^8 – 10^{13}$	FHCal(Insert), ZDC
S13360-1350CS	6	$10^9 – 10^{11}$	None (comparison)

I-V test setup

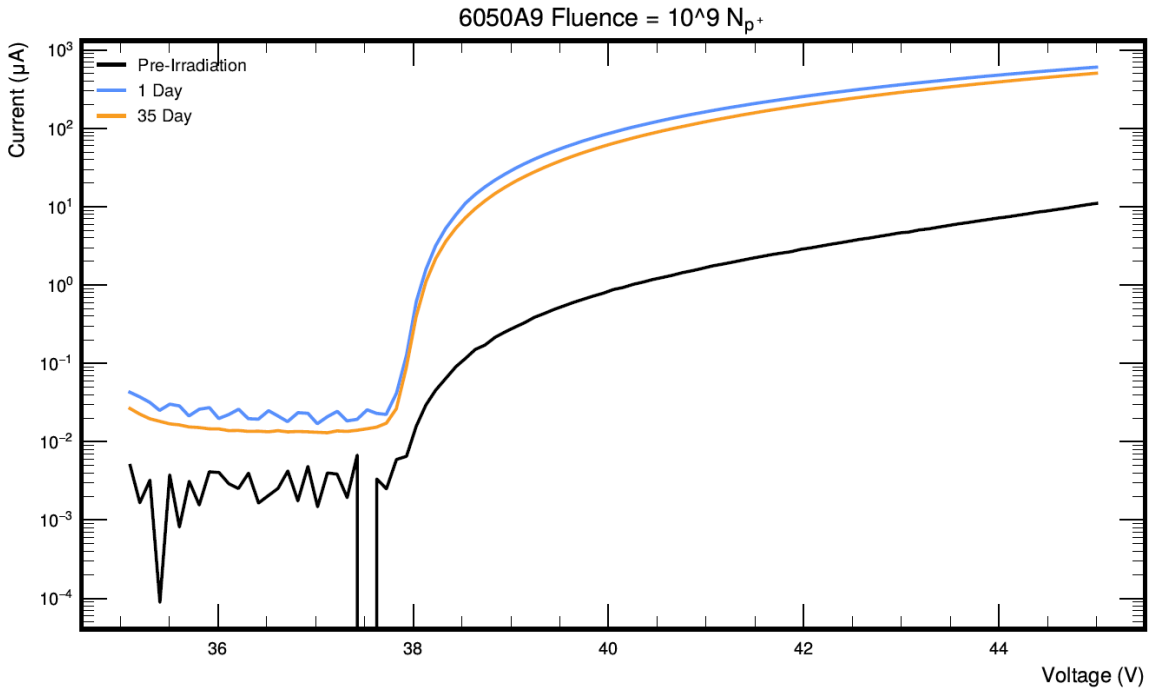
“Non-destructive” test, in which we use pogo pins to perform measurement before and after irradiation (i.e no soldering). Also allows to quickly test a variety of SiPMs.

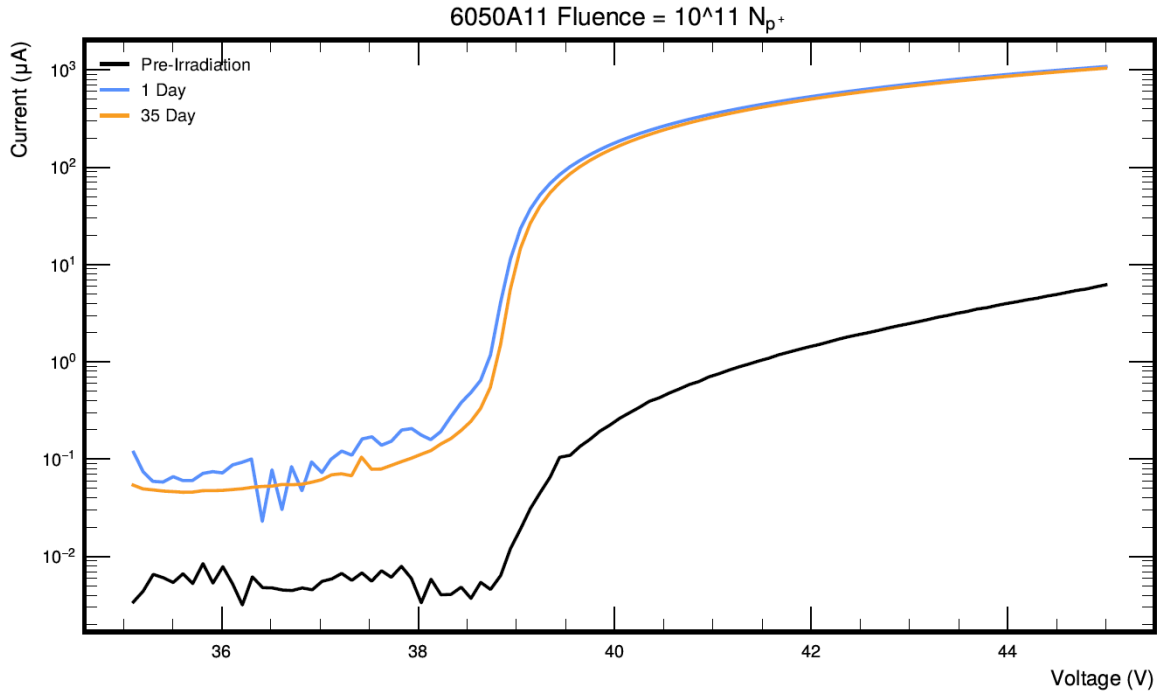




Results for S14160-6050HS

I-V scans taken in a dark box pre-irradiation, several hours after irradiation, and one day after irradiation. All SiPMs have been tested and stored at room temperature.





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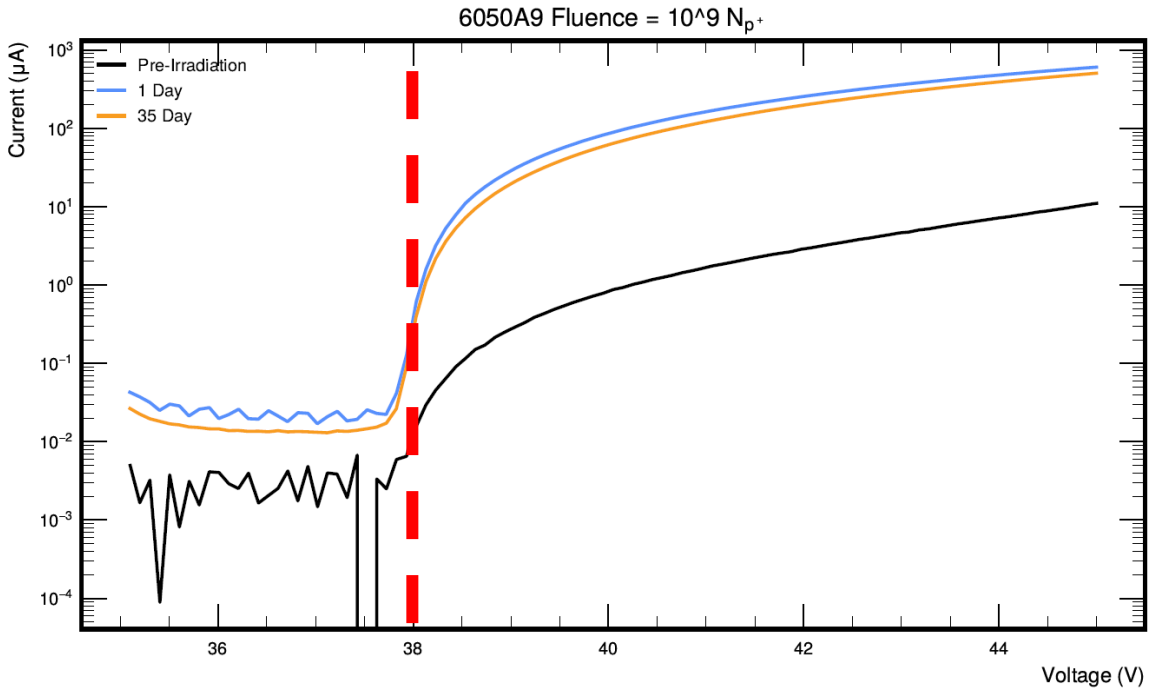
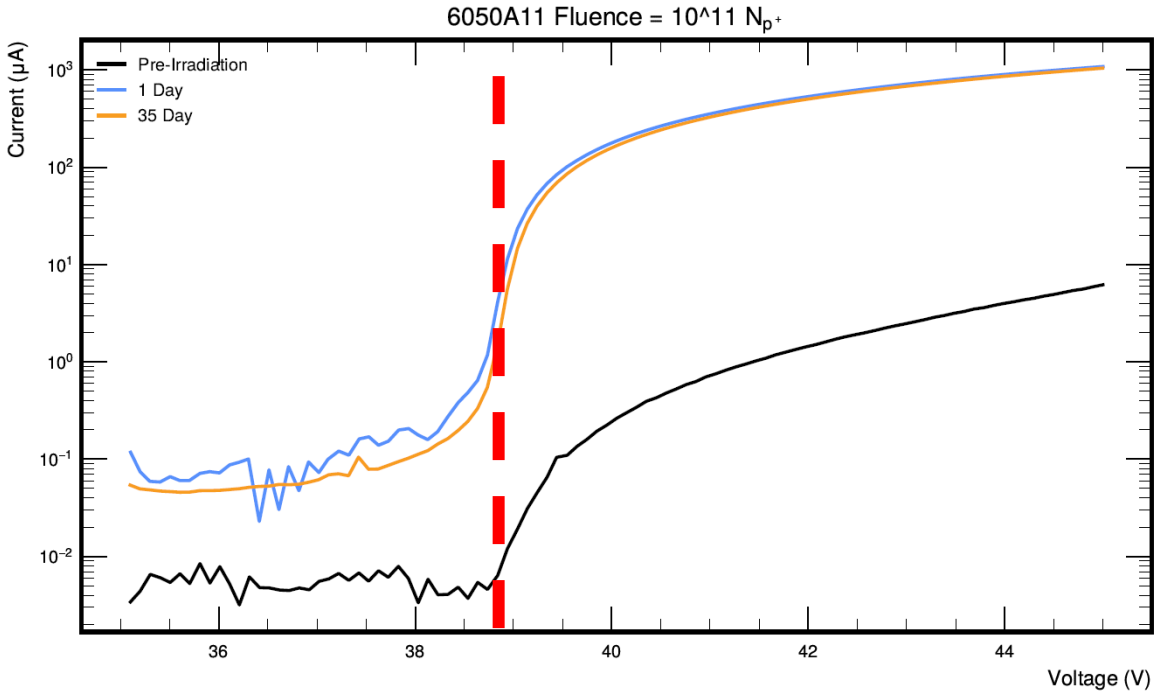
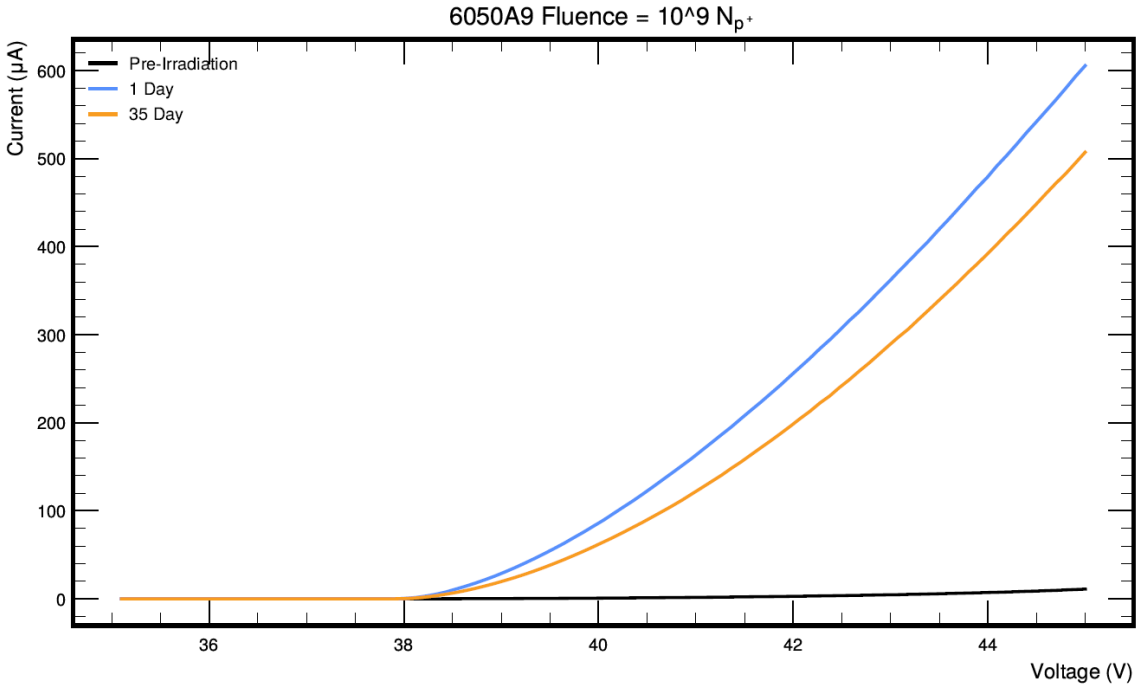


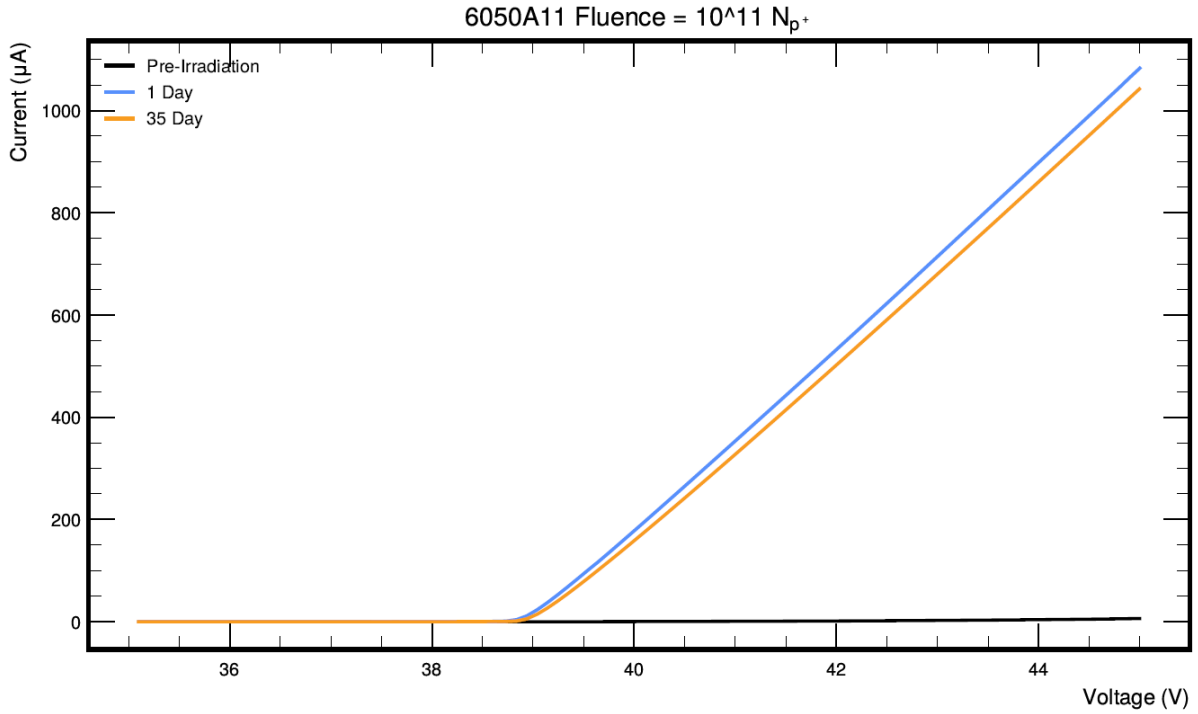


Results for S14160-6050HS

Same plots with linear y scale. Some room-temperature annealing (up to 10%) observed over the course of a month.

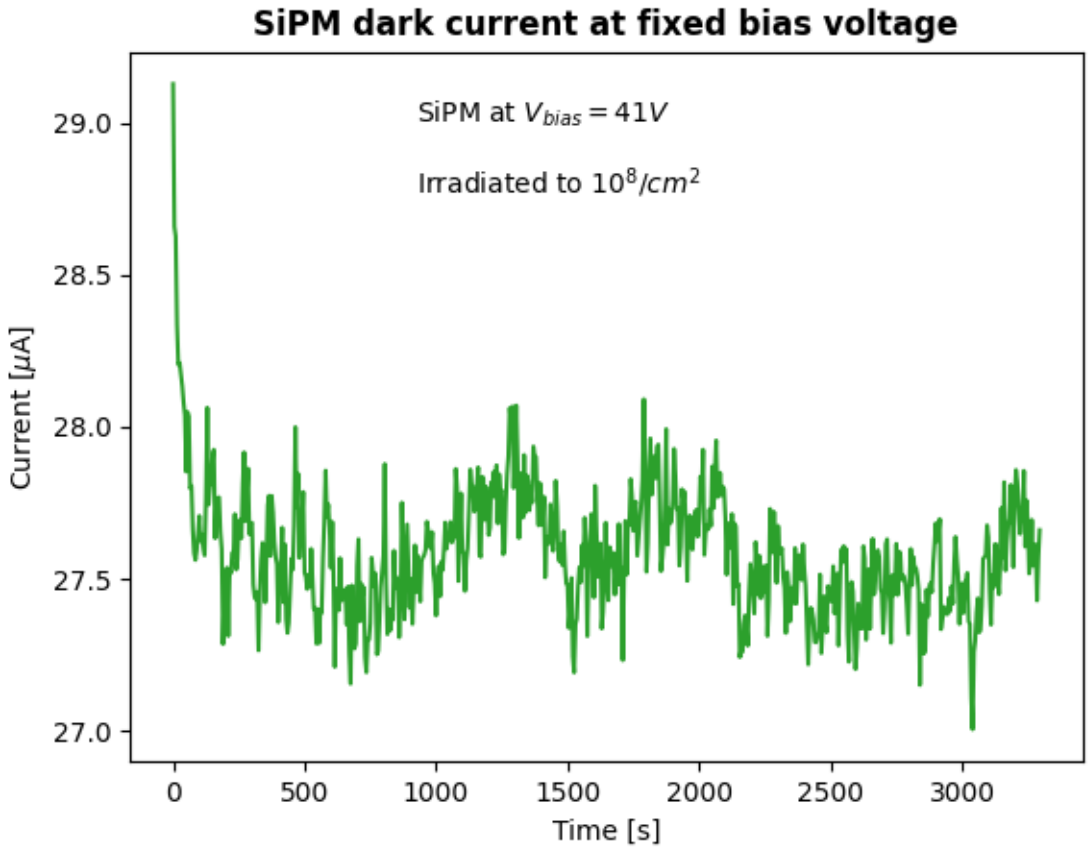
IV curves become more linear at higher radiation doses.



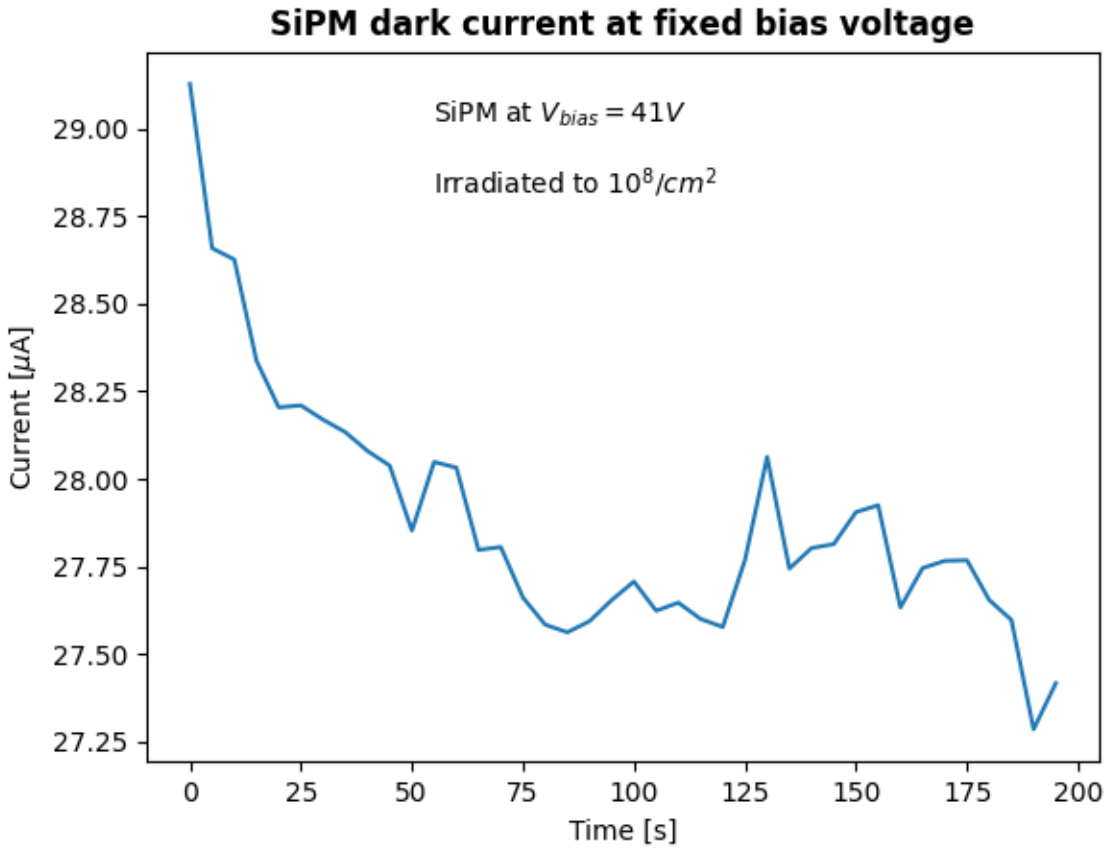


Time dependence of SiPM signal at fixed voltage

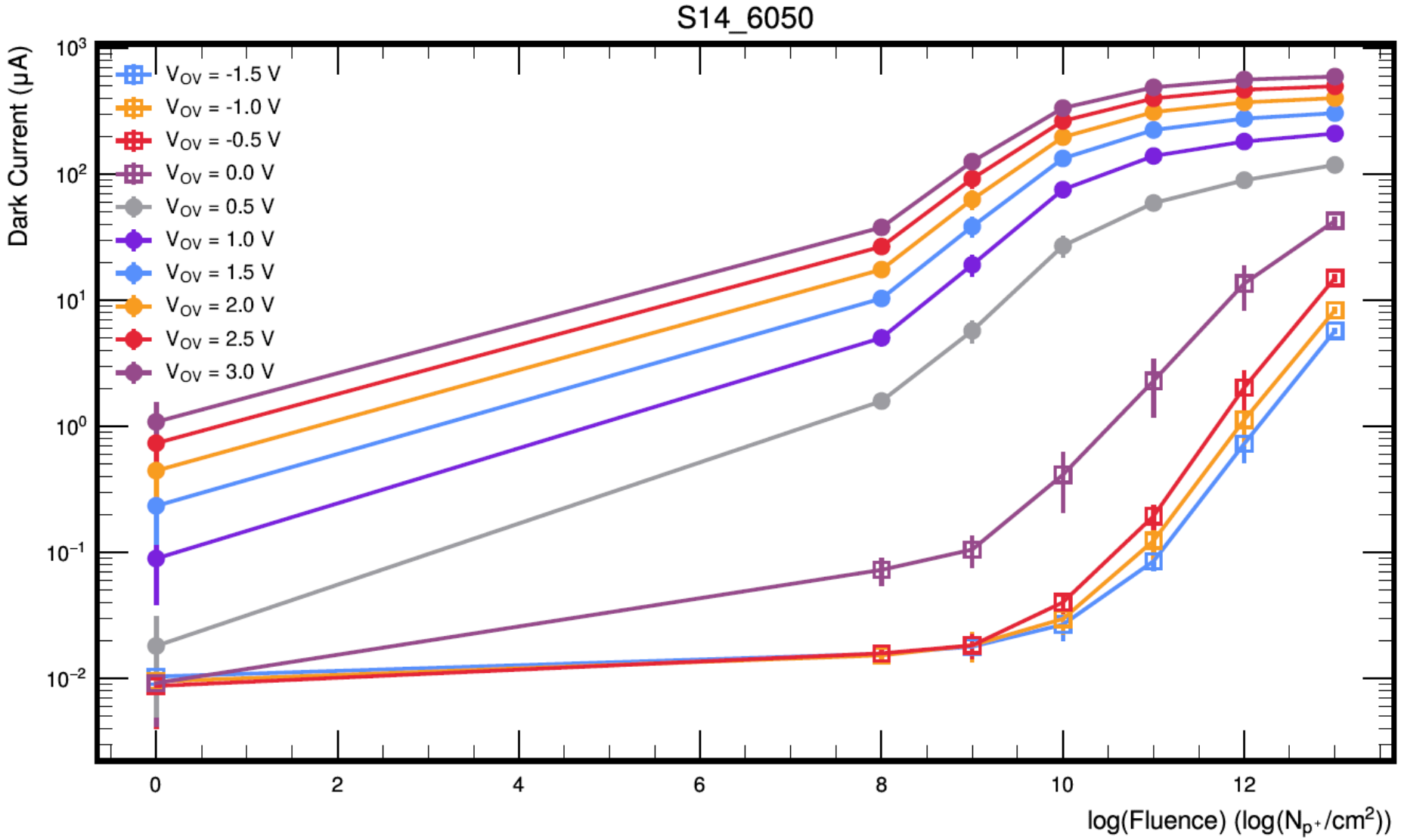
When making the IV curve studies, we wait ~2s after each voltage change before measuring the current. The current can ‘relax’ by up to 5% over the first 20s.



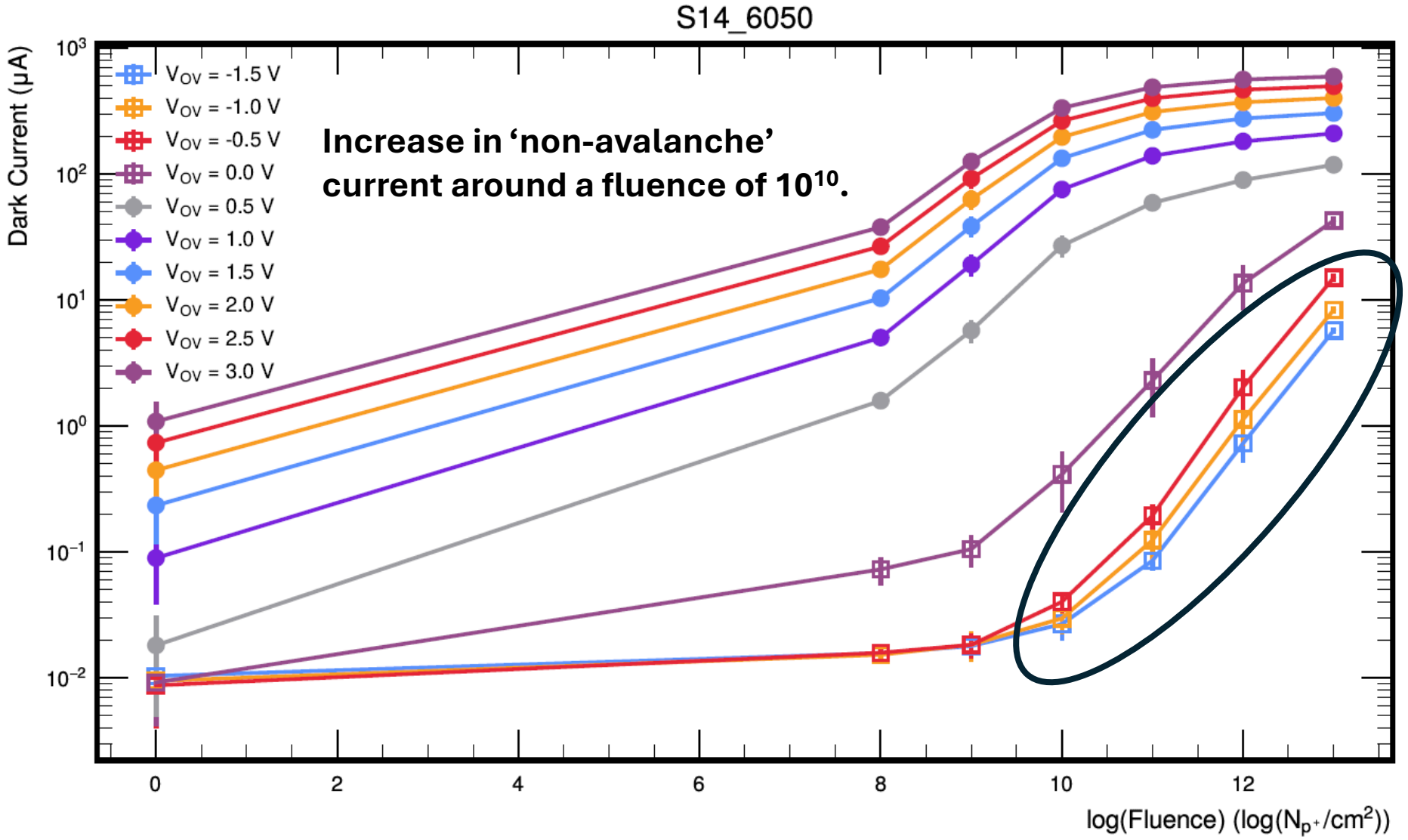
Zoomed in to first 200s



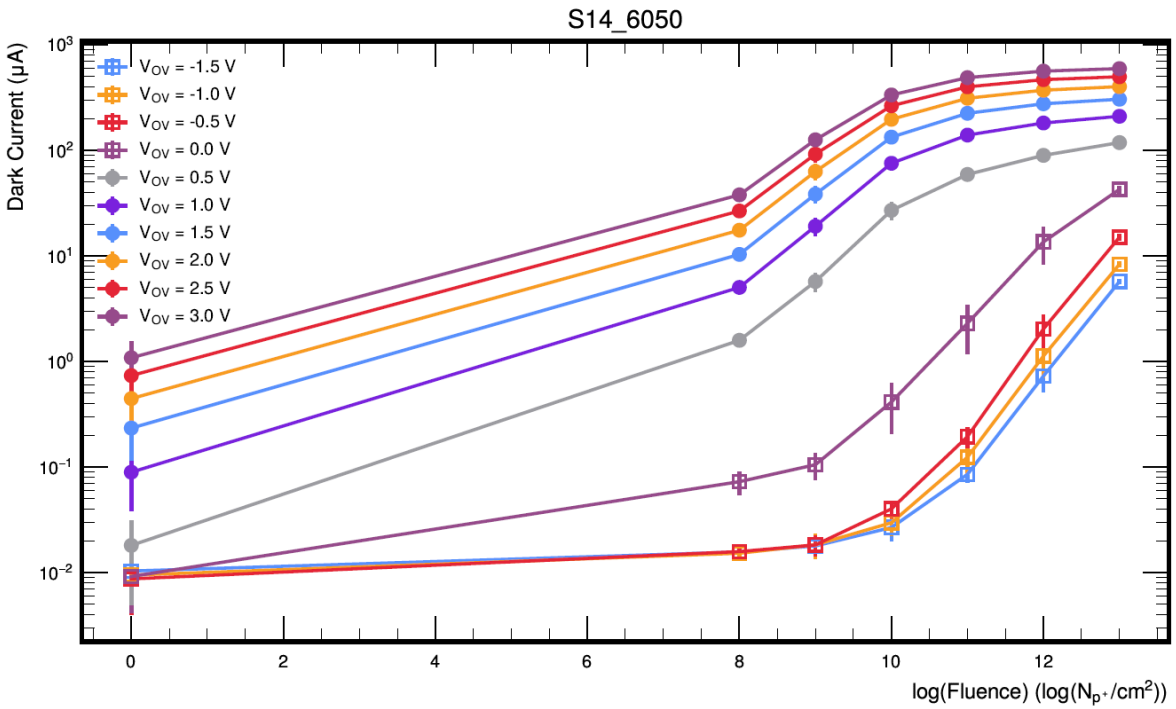
Results for S14160-6050HS

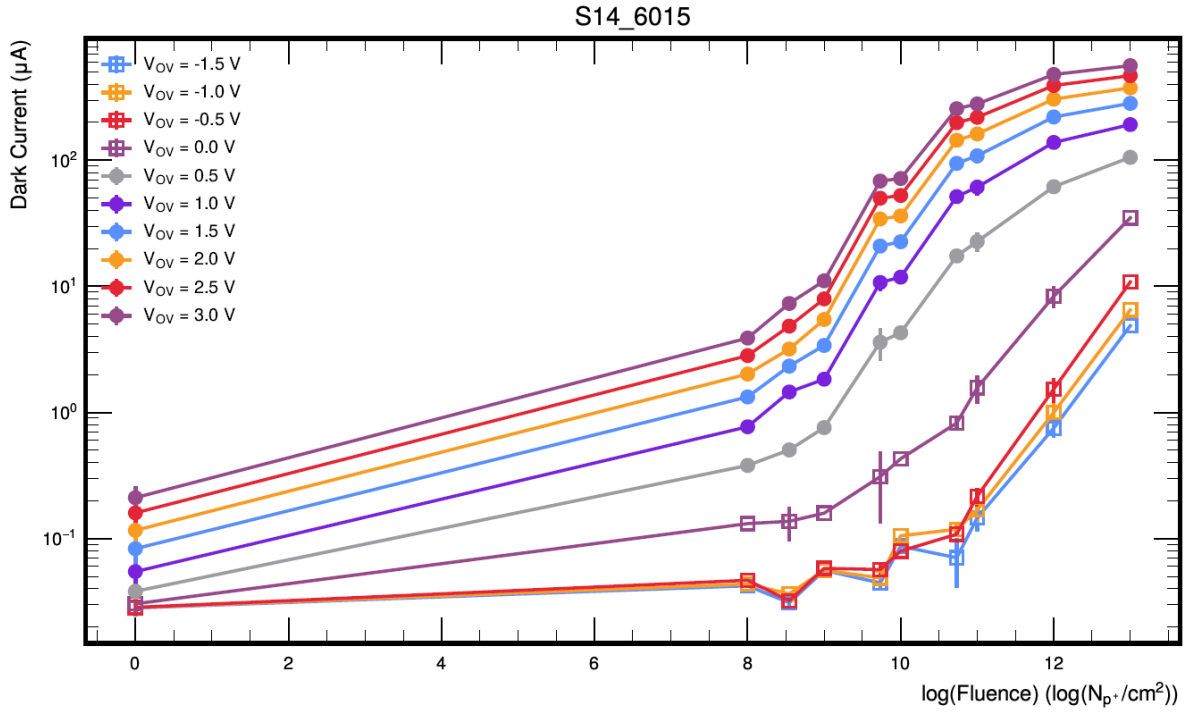


Results for S14160-6050HS



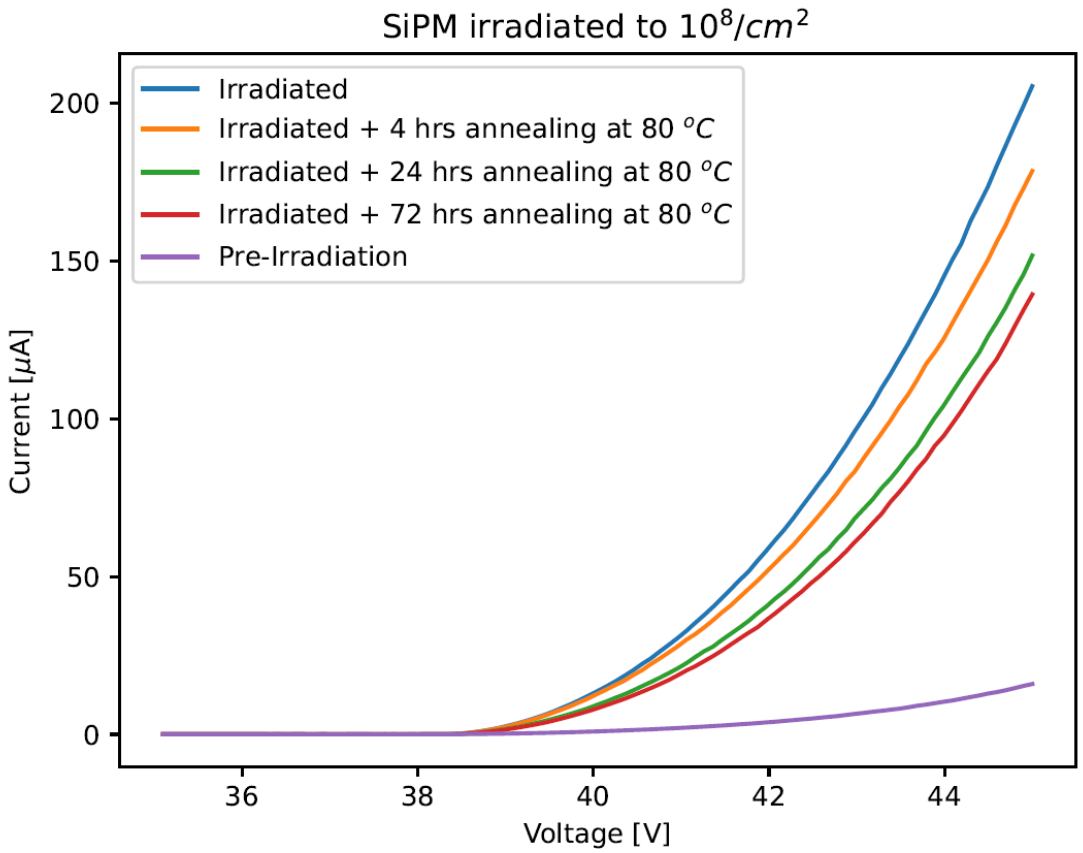
Comparison of S14160-6050HS and S14160-6015PS results



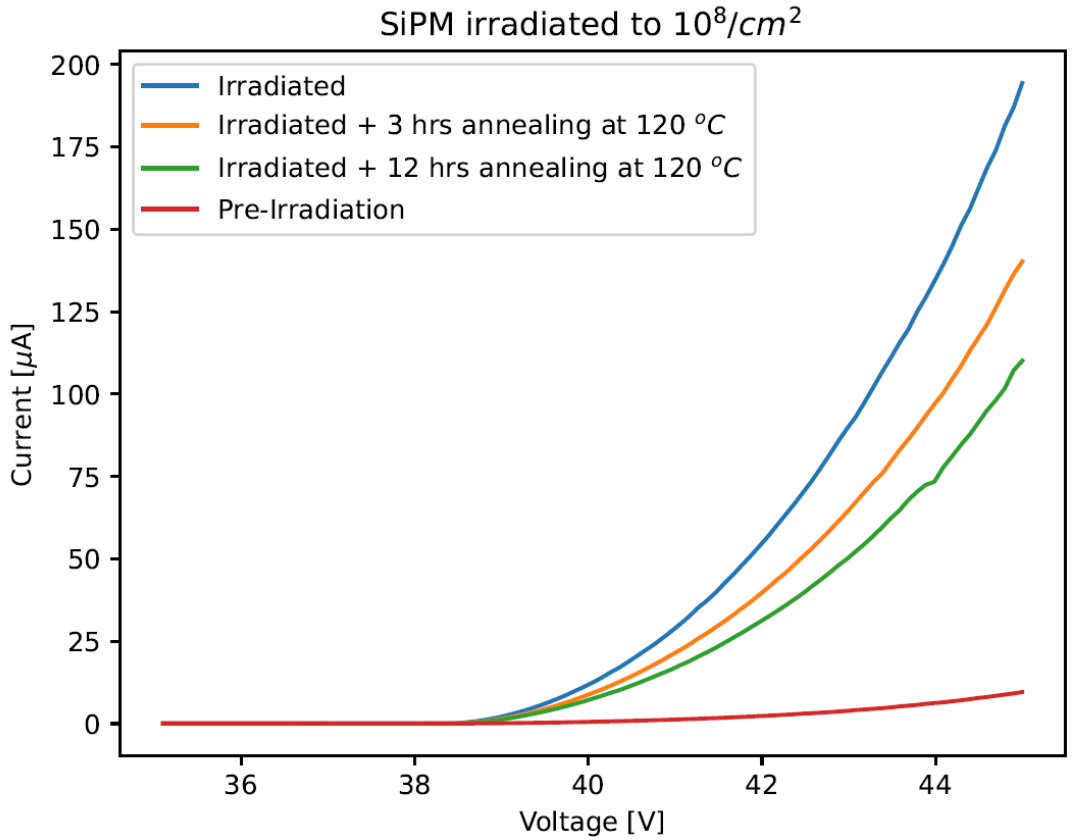


First high-temperature annealing results for S14160-6050HS

80C



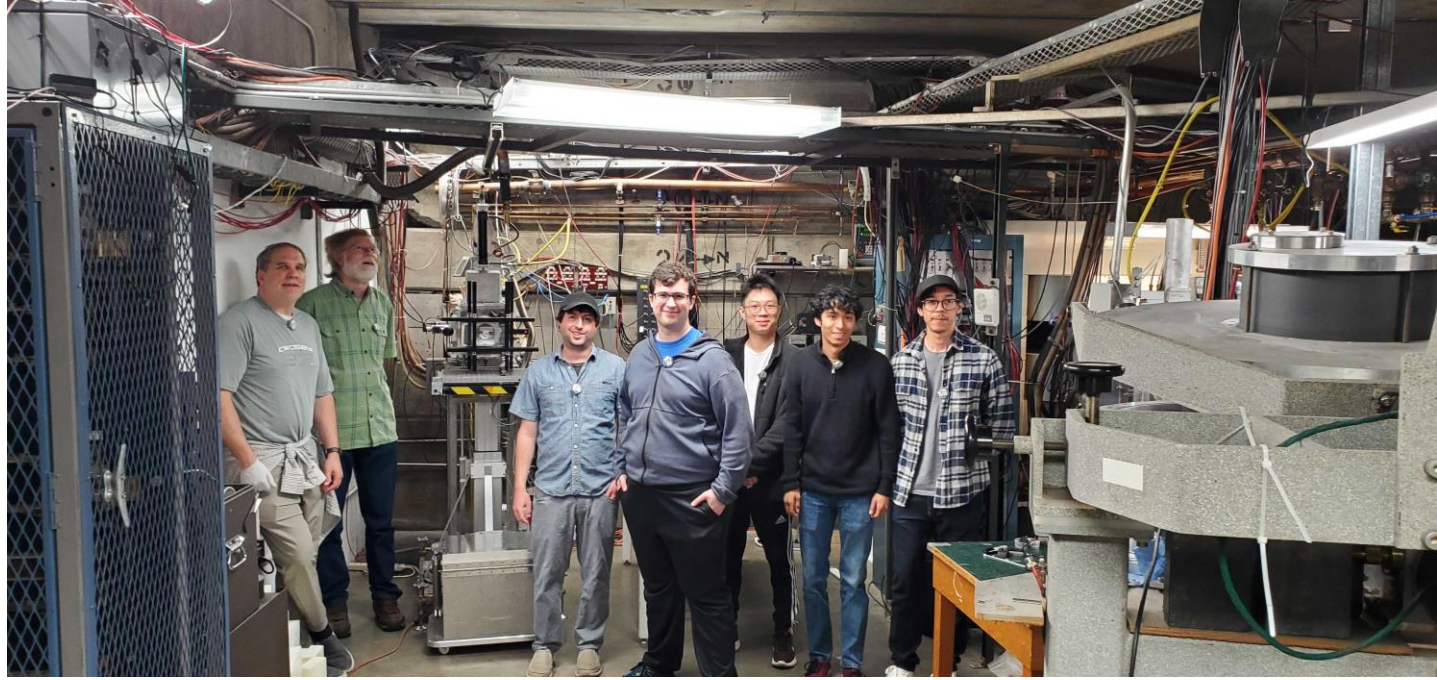
120C – Data for longer annealing times coming

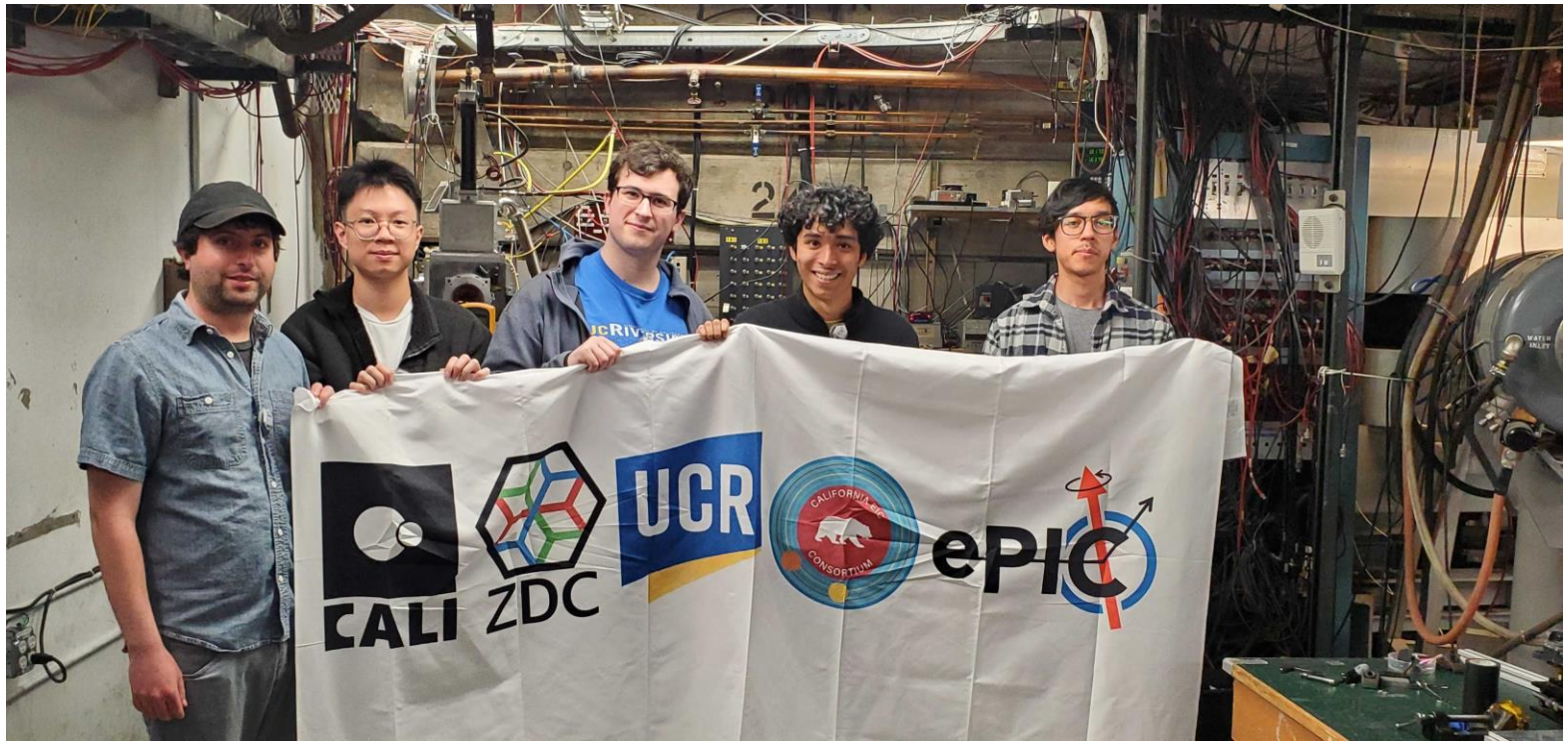


Summary and next steps

- We irradiated a variety of SiPMs over a range of fluences using a 64 MeV proton beam.
- We have presented results of dark current vs. overvoltage for these SiPMs. Results for additional SiPMs can be found in the backup slides.
- We have begun to study the effect of high-temperature annealing to recover some of the SiPM performance. More results will be available in the next few weeks.
- We plan to make a table (database) available to the collaboration which provides all the collected information on the irradiated SiPMs.

UC Davis beam test – May 14th - 15th, 2024

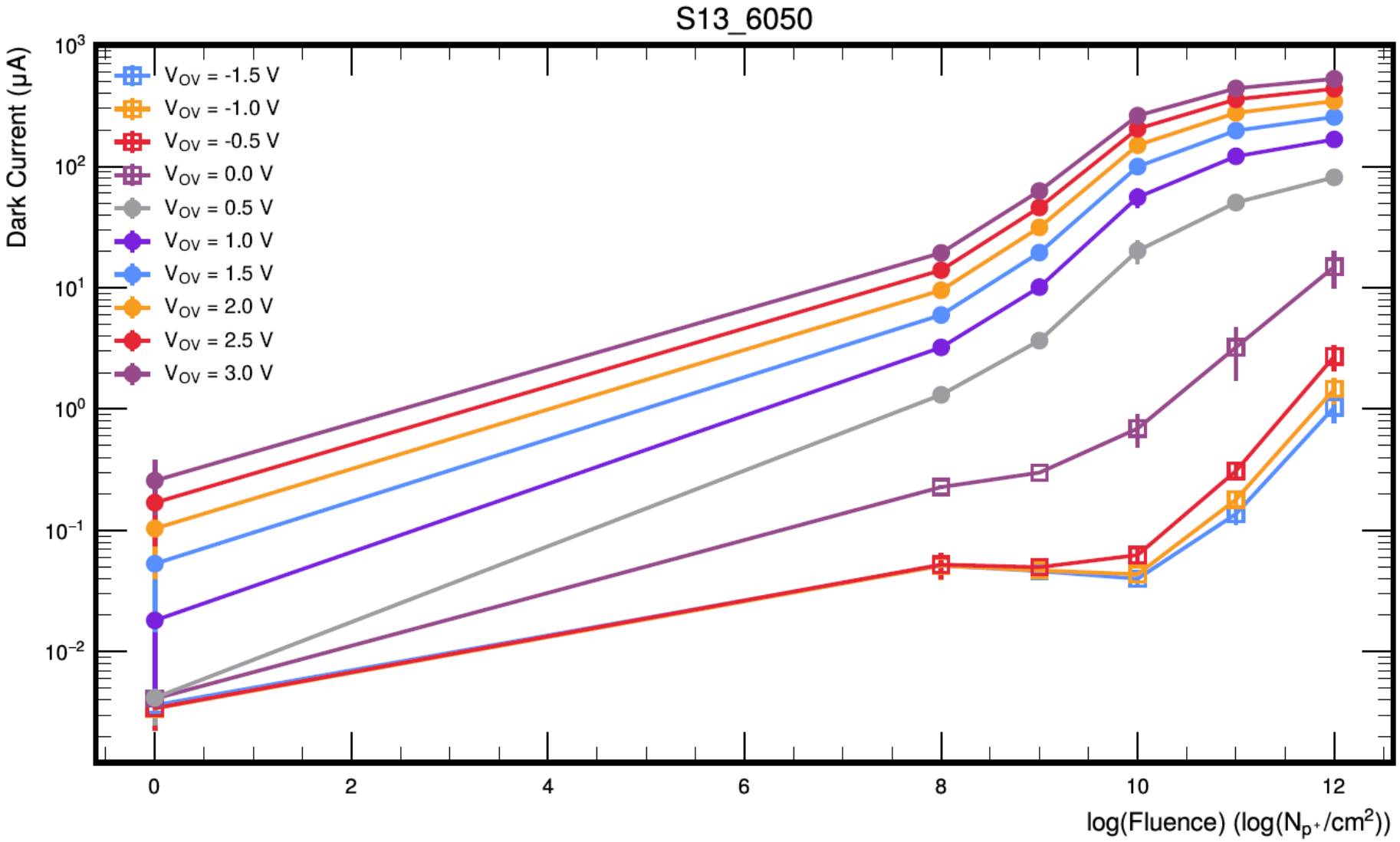




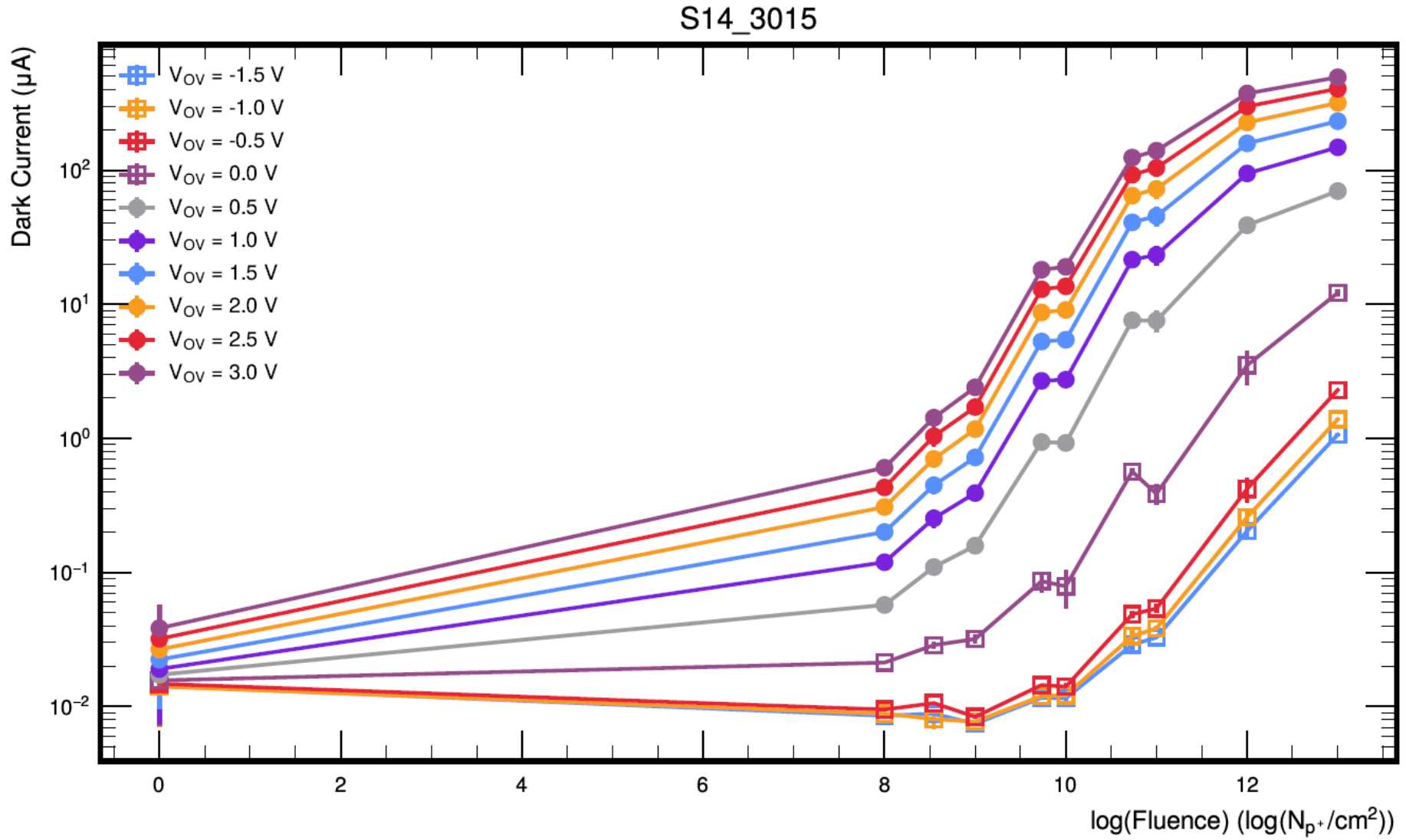
Additional photos

Backup Slides

Results for S13360-6050VE



Results for S14160-3015PS



Results for S14160-3010PS