Report on the test run of the calibration system with SLArchetto Single Cube TPC

Jelena Maricic on behalf of

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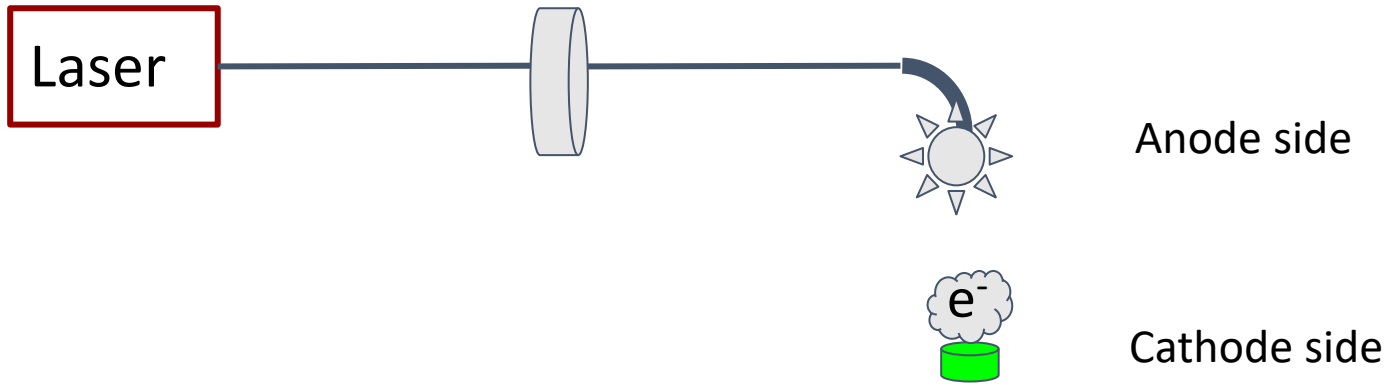
October 12, 2023

Role of the calibration system

- Must facilitate ND LAr to fulfill its physics goals by providing calibration function that will correct the reconstructed charge and vertex throughout the LAr TPC volume and module-to-module variation
- Photoelectron laser calibration system is designed to generate compact charge clouds at the specific locations on the cathode, where metallic targets are placed. Cathode is illuminated from the anode side, via laser pulses delivered via fiber to anode.

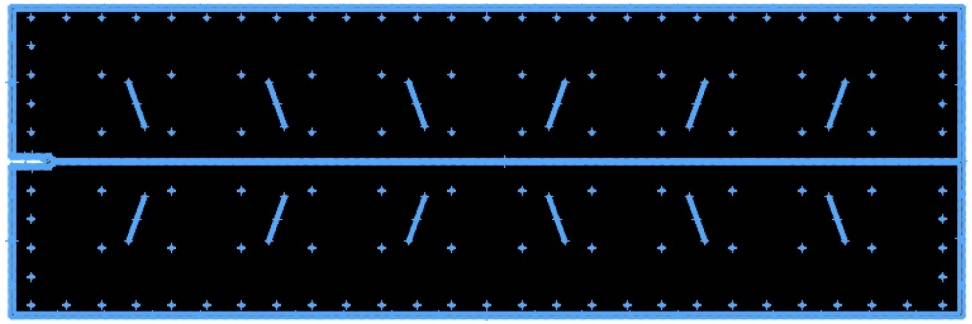


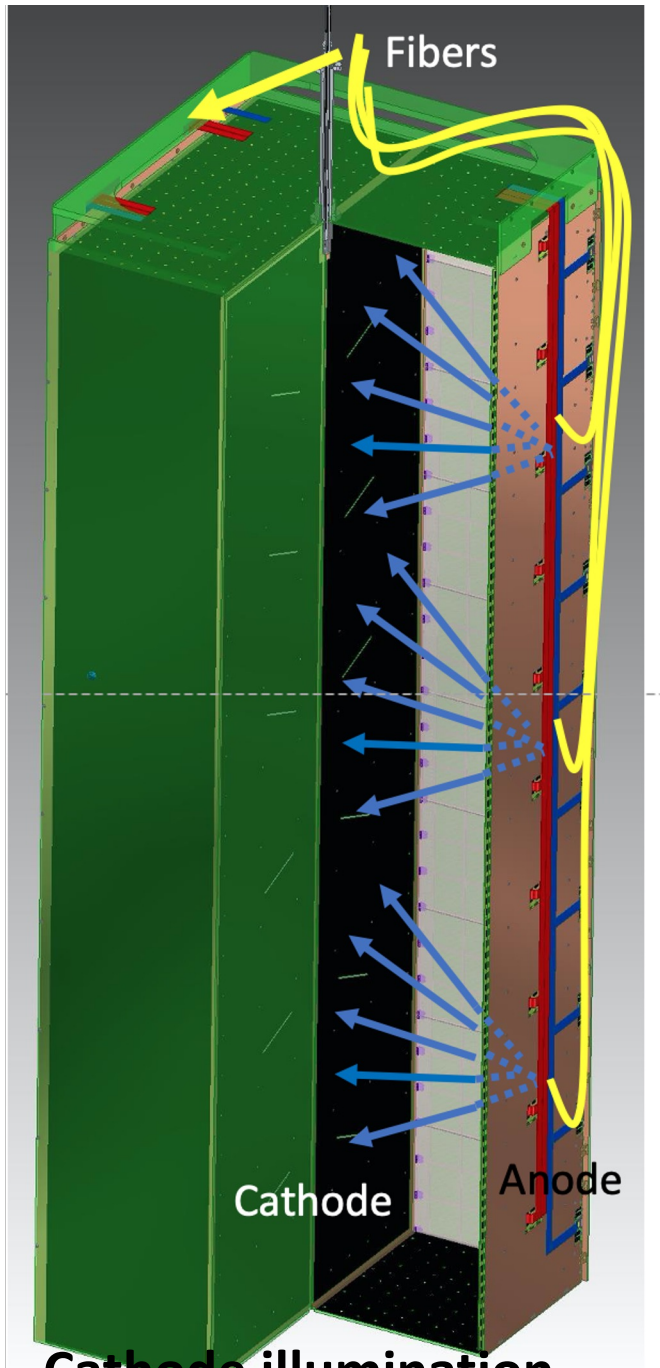
ND LAr TPC Calibration System Design

ND-LAr Calibration SubSystem Institutional Responsibilities

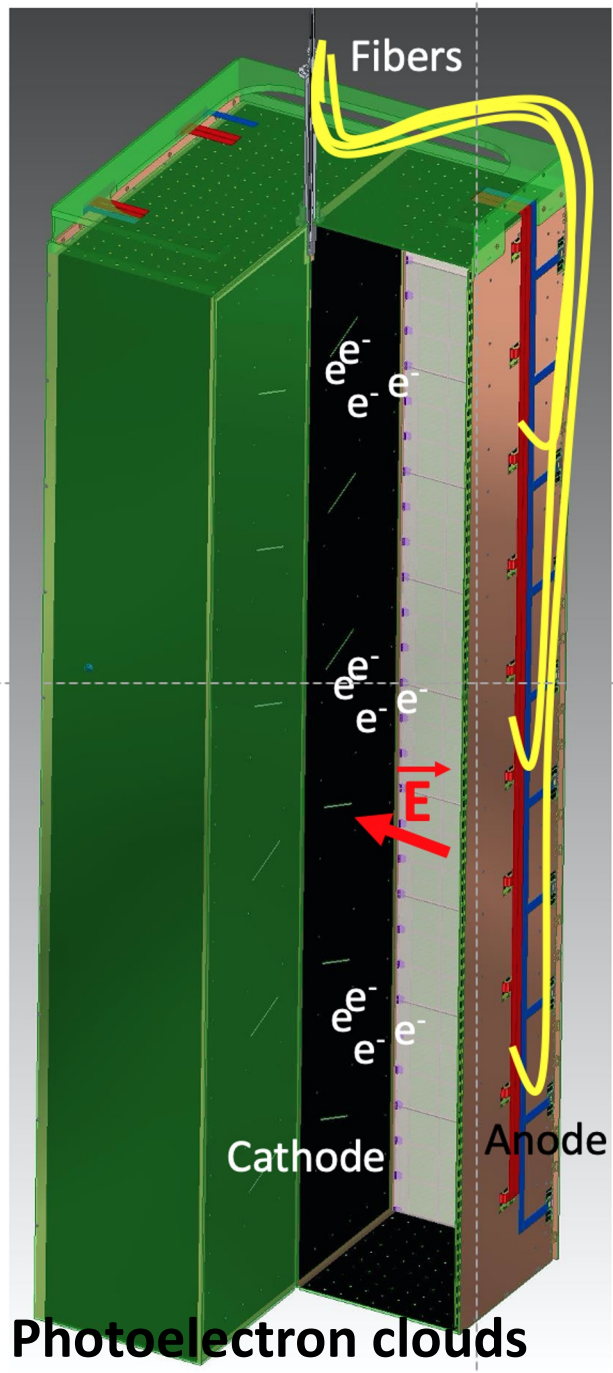
Task	Institutions
PE laser light delivery	UHawaii
Cathode photoelectric target production	MSU

Cathode targets





Cathode illumination



Photoelectron clouds

Test run

- Test run of the system was conducted in SLArchetto Single Cube TPC at SLAC.
- The test run took place from Monday night, October 2nd to October 9th and included calibration and cosmic ray runs.

- SLAC Single Cube test ((UH + MSU) goals:
  - measure PE yield from targets in LAr
  - exercise the entire PE laser calibration chain
  - validate simulations with actual cosmic ray data
  - test alternative calibration sources (deployed UV LED)
  - Validate light distribution from the J-pipe

Laser system certification

- Laser system was subjected to strict scrutiny by the SLAC Laser Safety Office to gain approval, because it is a class 4 UV (invisible) laser.
- Ranjan, Yun-Tse and Jelena went through extensive laser training (2 online courses, one hands-on training) to become Qualified Laser Operators (QLO).
- Standard Operating Procedure document for laser approval has been produced and approved for four different modes of operation:
  - Standard running – class 1 system operation (1 QLO)
  - Alignment mode – class 4 operation mode (3 QLOs and no excess for others) used to align laser optics (mirrors and lenses)
  - Power measurement – class 1 modified system operation (2 QLOs)
  - Cathode illumination pattern with green laser – class 1 modified system operation (2 QLOs) – not useful

    (We need measurement with UV laser.)

SLAC NATIONAL ACCELERATOR LABORATORY

Standard Operating Procedures and Laser Safety Contract: Liquid Noble Test Facility (LNTF), BLDG 620

(PEP Interaction Region 2)

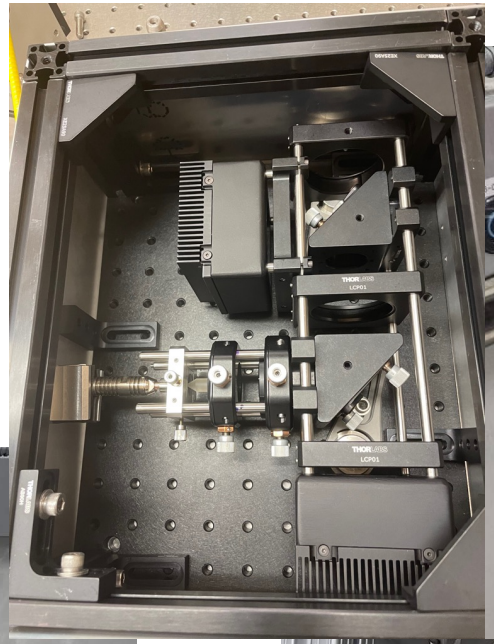
Author: Jelena Maricic, Ranjan Dharmapalan
Department: FPD DUNE
Location: BLDG 620
Version: 1.0
Date: September 14, 2023
Laboratory Phones: x5406

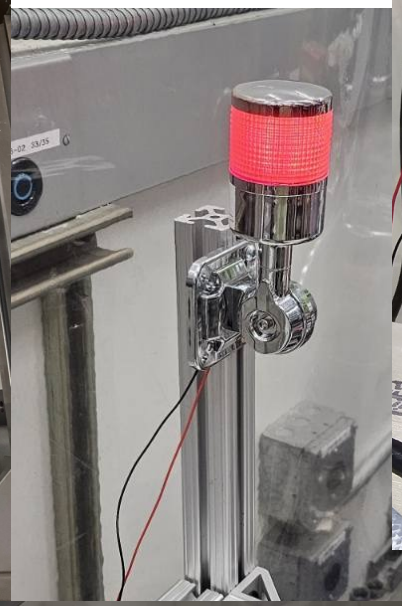
APPROVAL OF SOP AND LASER SAFETY CONTRACT DESCRIBED HEREIN:

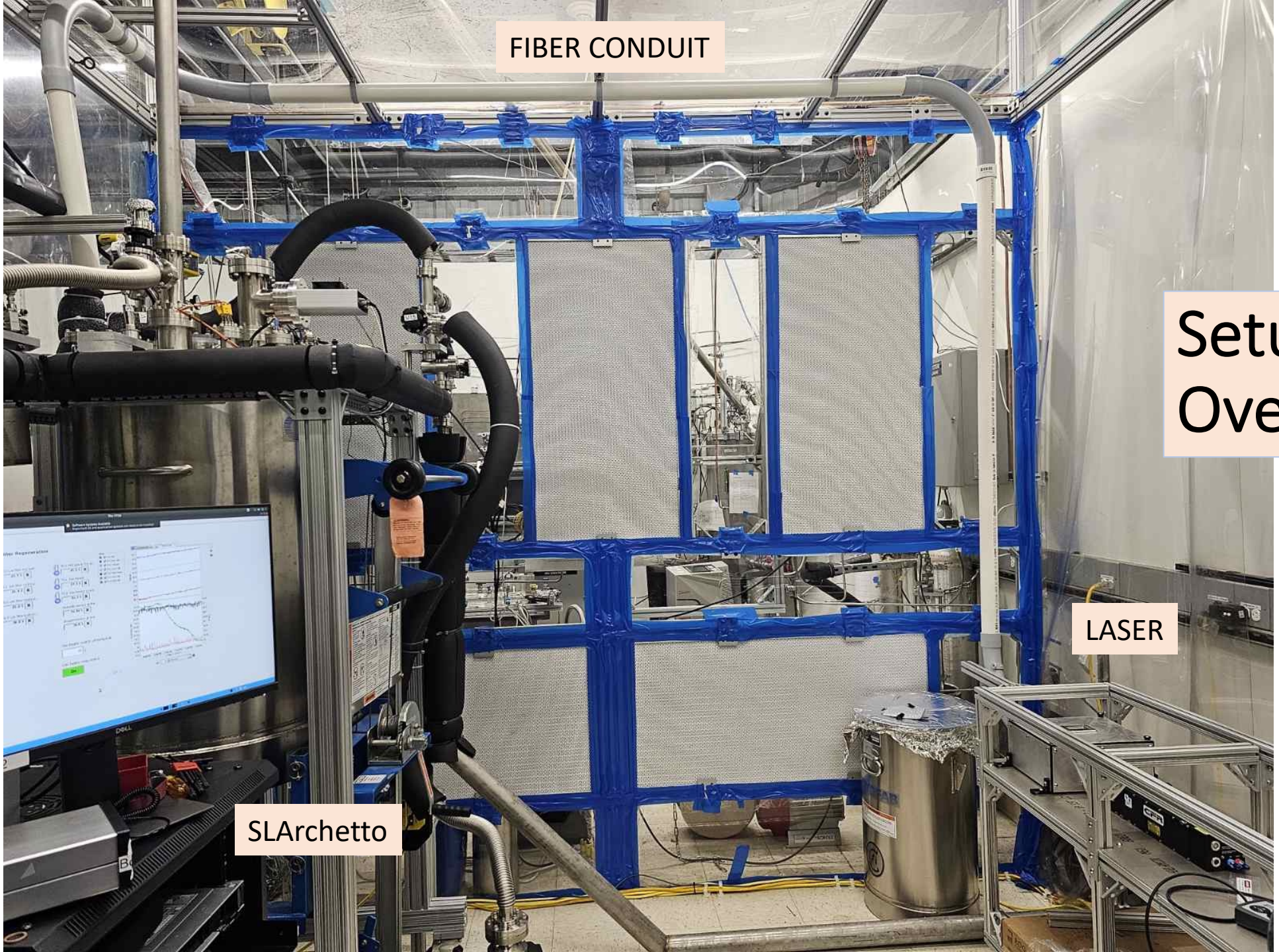
Tsai, Yun-Tse, System Laser Safety Officer (SLSO)	Date
Tanaka, Hirohisa, Program Manager	Date
Norm Picker, Division ESH Coordinator	Date
Mike Woods, SLAC Laser Safety Officer (LSO)	Date

Laser System Overview

Safety features include interlock, warning light, Secured key, warning labels.

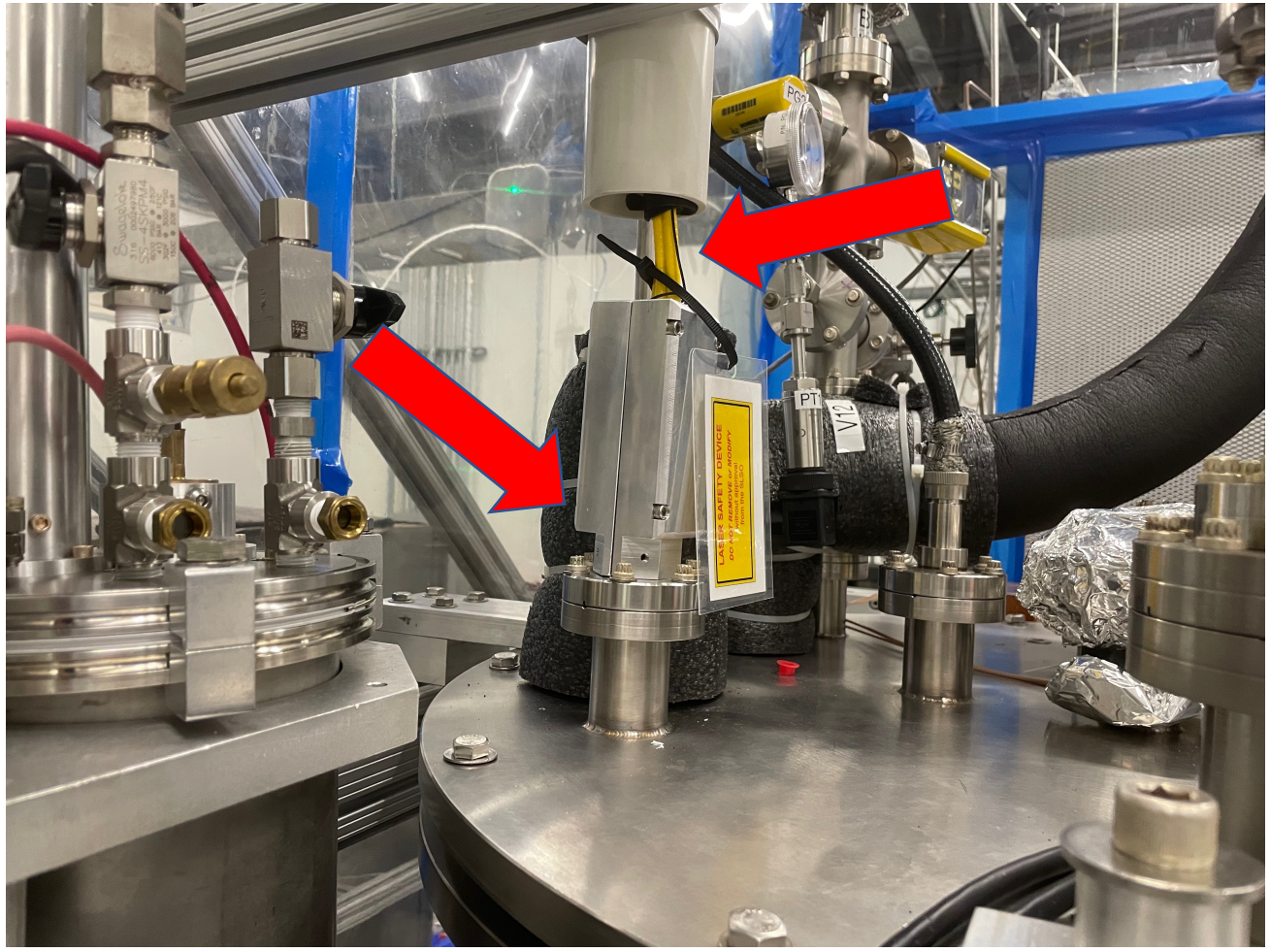






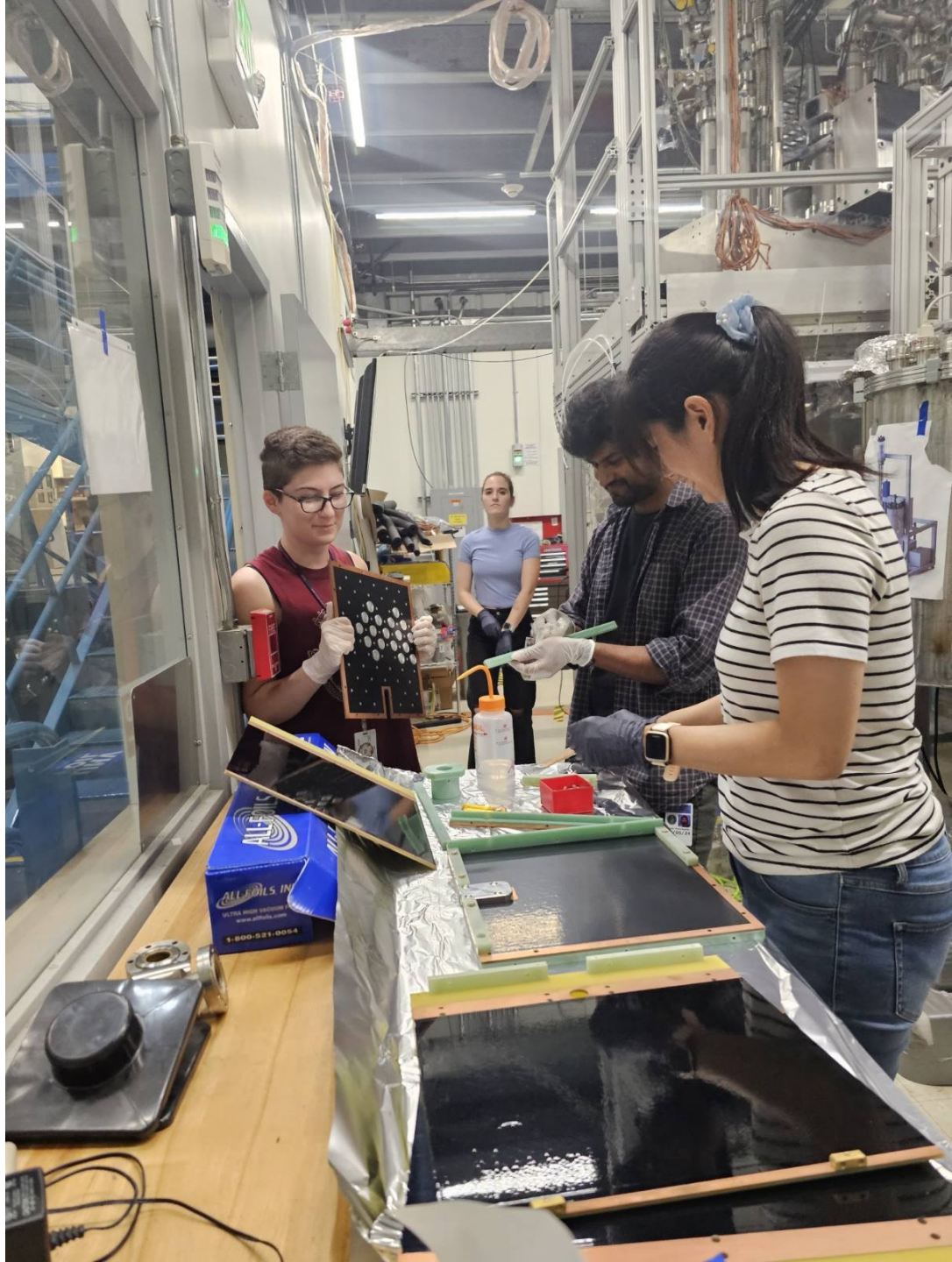
Setup Overview

SLArchetto – optical fiber interface



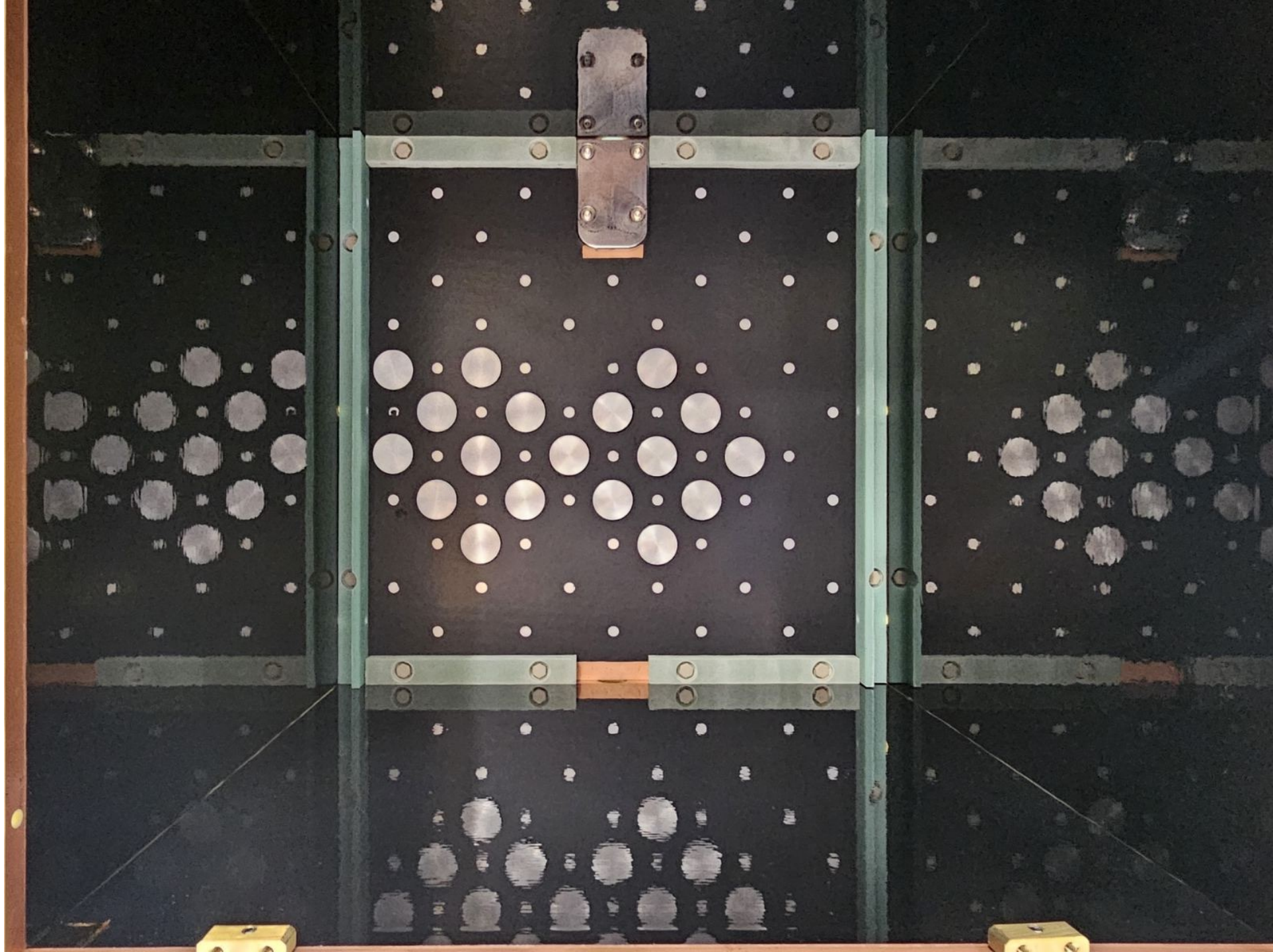
Upgrades to SLArchetto Single Cube

- SLArchetto was dismounted from cryostat and dismantled.
  - Installed cathode with photoelectric targets
  - Replaced the backplate with the new one that has a cut out for UV LEDs.



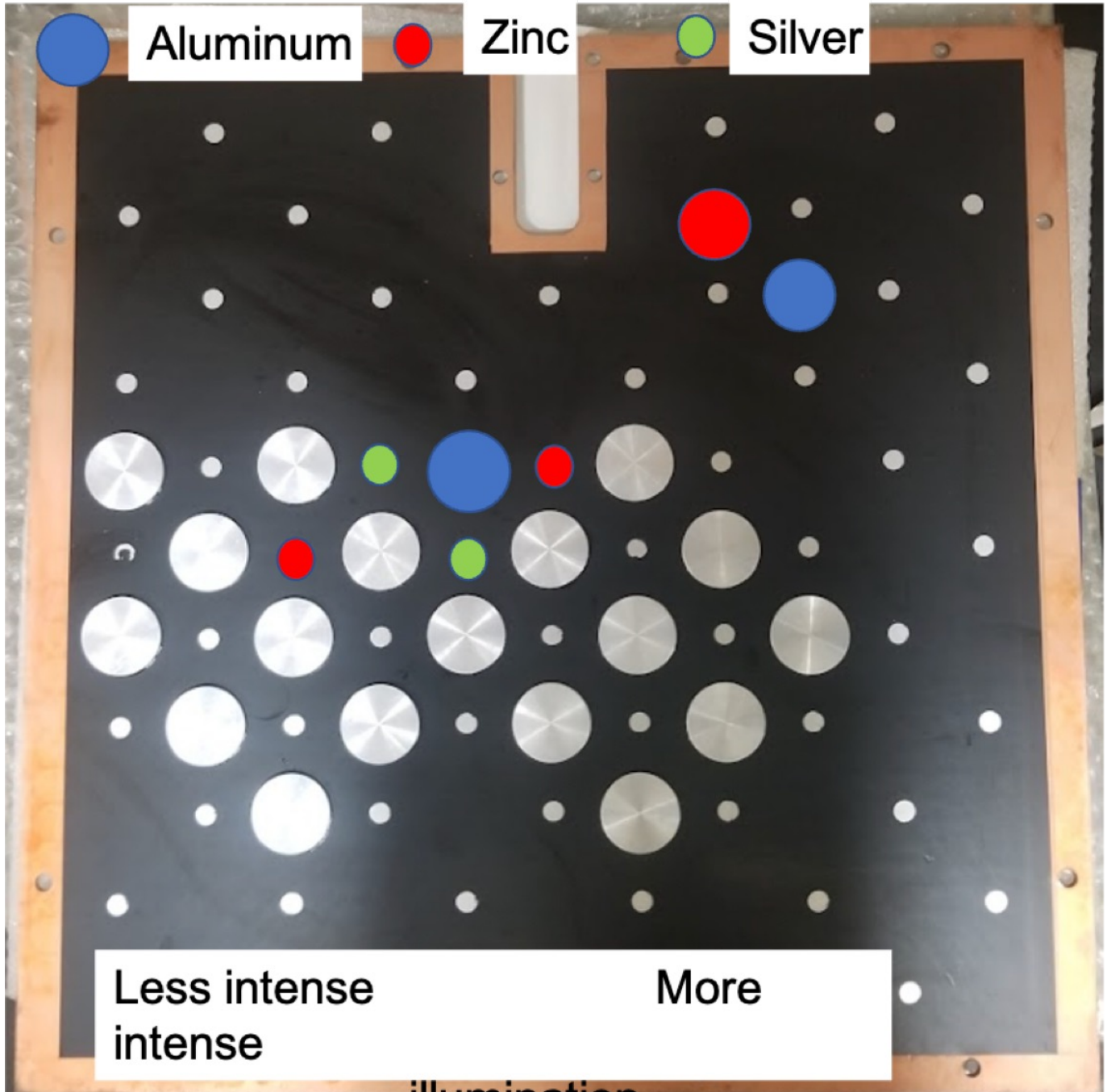
Cathode with Targets:

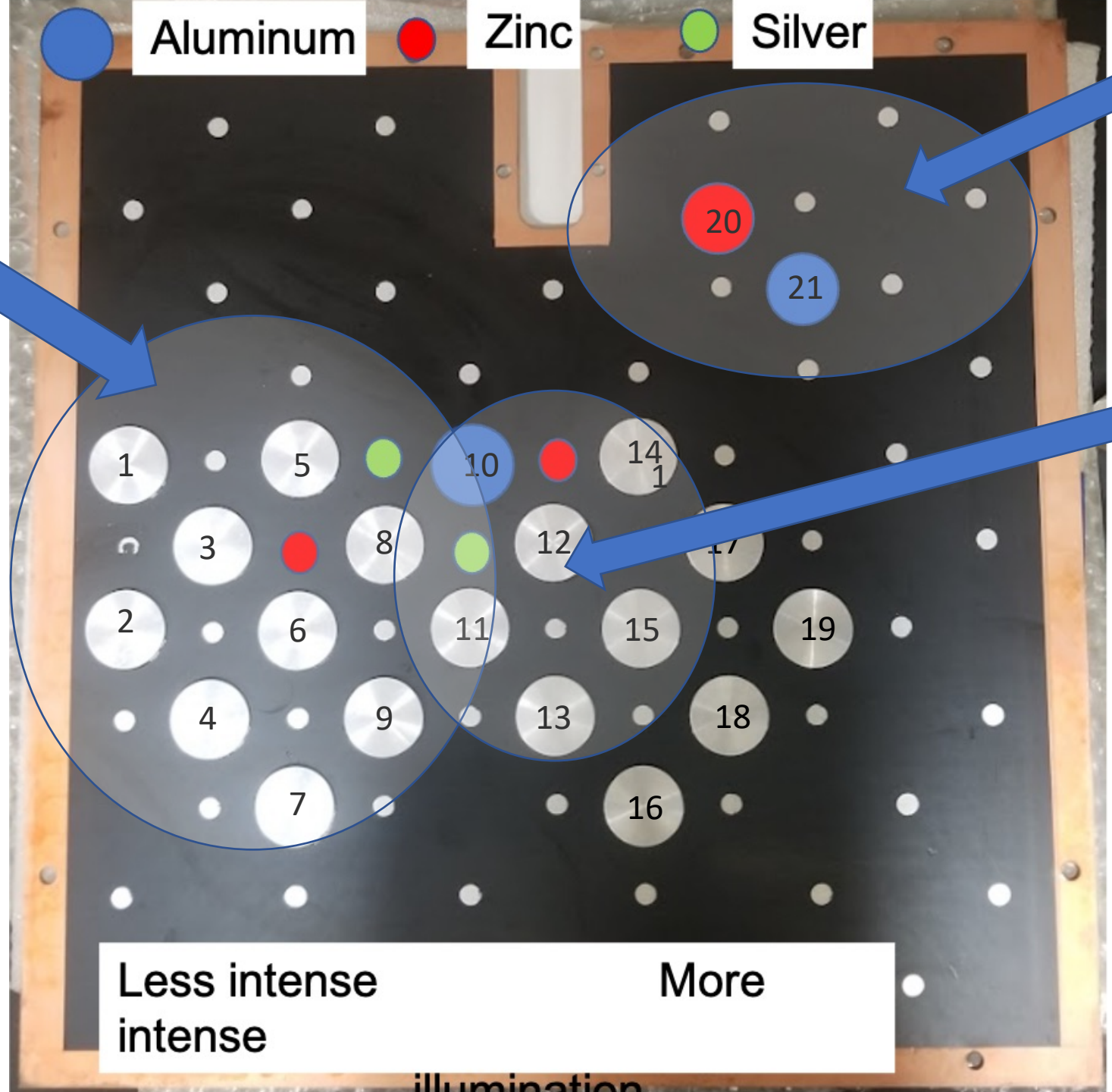
glued (large) and deposited (small)



Additional Targets

- We decided to add additional zinc and silver targets for comparison QE measurement
- We added a couple additional large Al targets for better coverage.





Short fiber

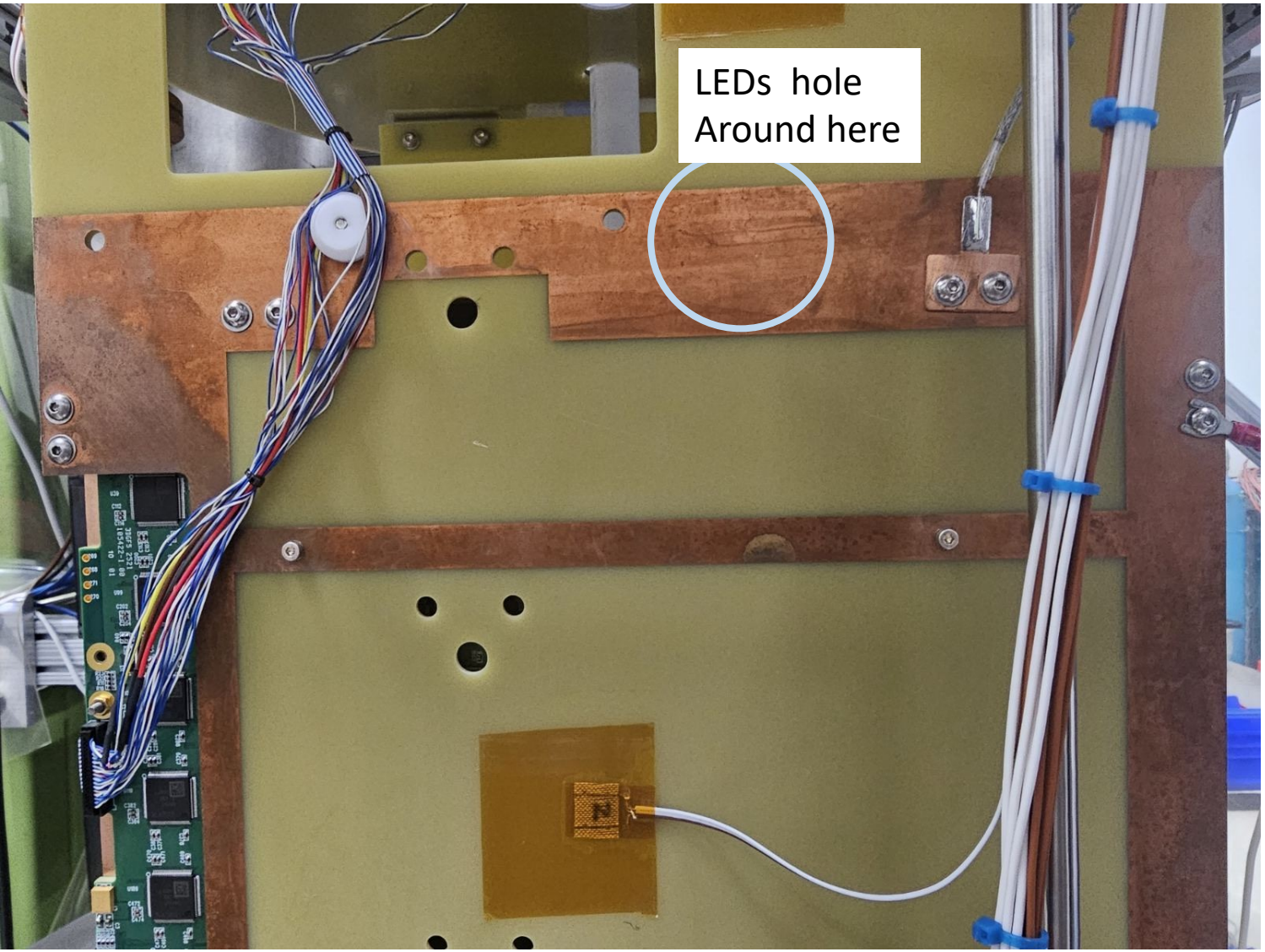
UV LED

Long Fiber

J-pipe Entire cathode

Backplate Modification

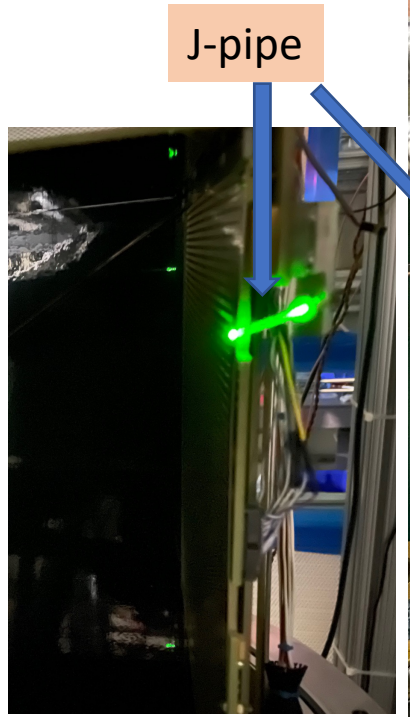
- We had to modify TPC backplate to make a cutout for UV LED insertion.

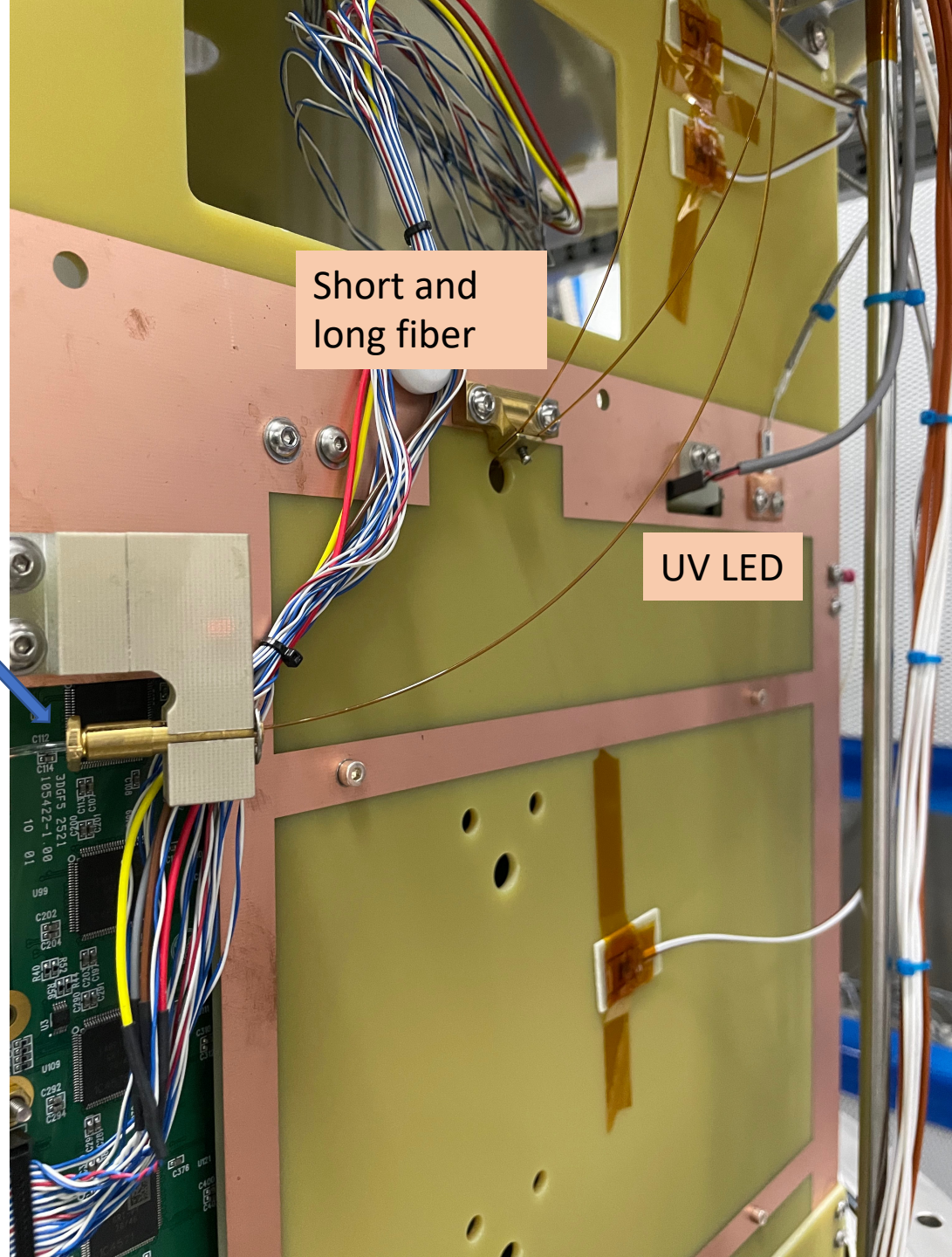


UV LED hole
And holder

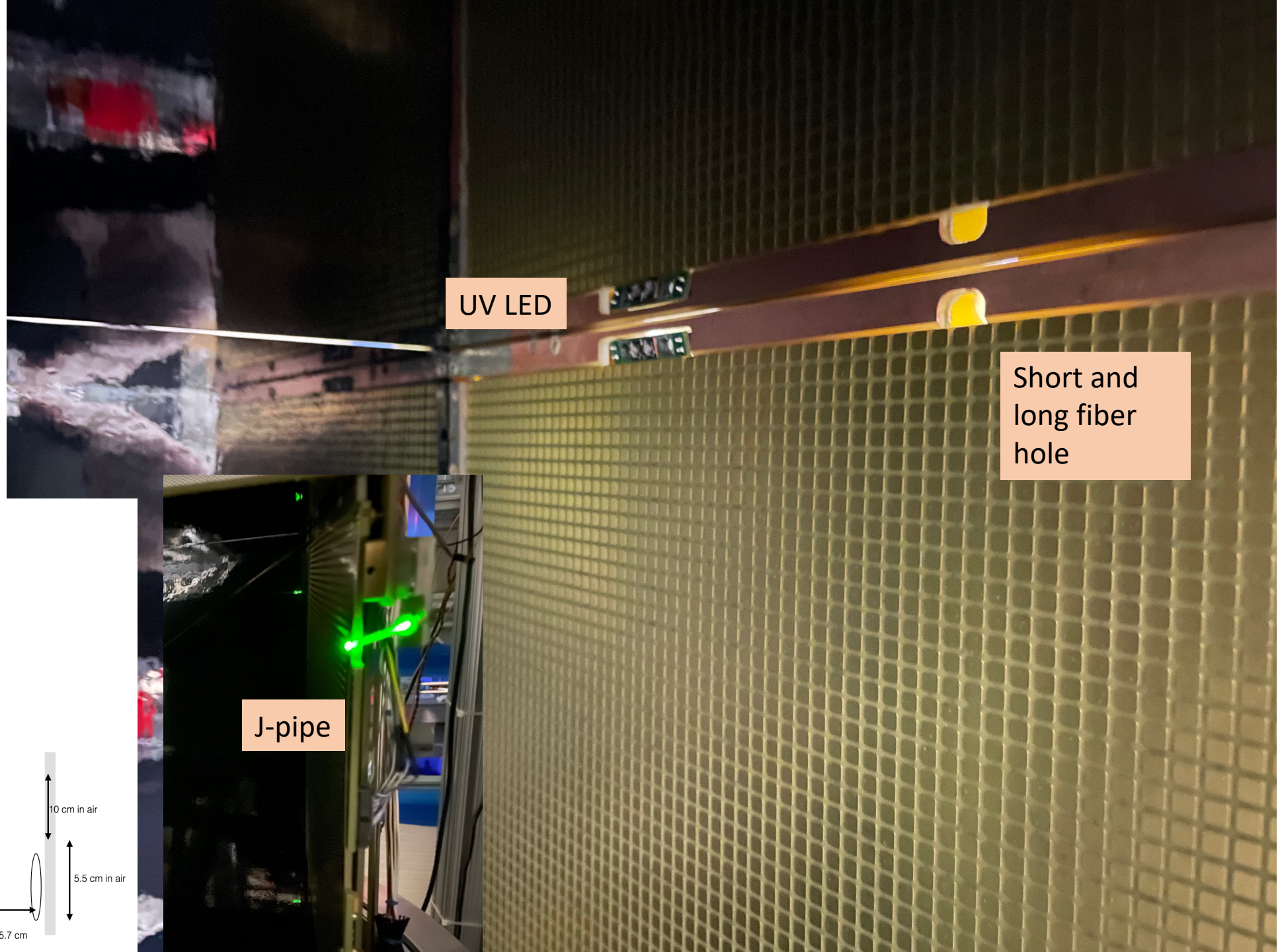
Illumination Sources

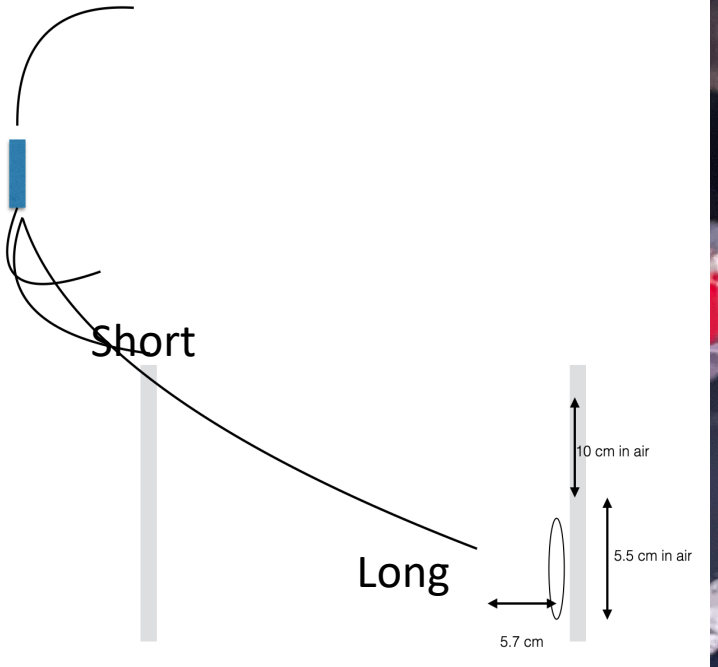
- Lack of measurement of reflective QE for metallic targets in argon means that we have a lot of uncertainty in the electron yield that needs to exceed noise level on LArPix.
- We tested 4 different illumination sources with different goals:
  - Long fiber (close to cathode) to maximize light intensity on targets
  - Short fiber to illuminate larger cathode area, and consequently more targets
  - J-pipe – illuminate even larger cathode area, albeit with reduced intensity
  - UV LED – test of alternative illumination source





Illumination sources: inside TPC





Power measurement after laser alignment

- We measured power output inside TPC in warm, prior to cryostat closing with power meter.
- We measured the output in increasing and decreasing steps, as there is hysteresis
- Power decreased by 20%-30% after 4 hours of continuous running
- Delivers up to 50 uJ per pulse in cold

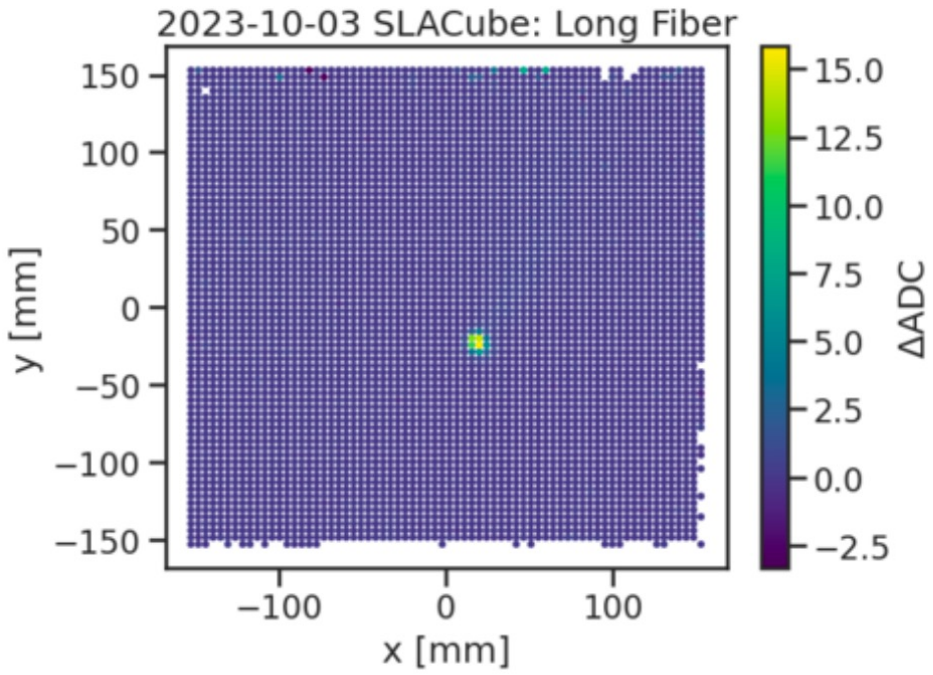
A	B	C	D
Transmi-ssion %	Warm (uJ)	sigma (uJ)	Duration (min)
0			
5			
10	10.3	0.7	3:00
15	14.6	0.8	3:00
20	18.9	1	3:32
25	23.8	1.2	3:00
30	30	1.3	3:00
35	33.9	1.4	3:00
40	38.6	1.6	3:00
45	43.5	1.6	3:00
50	47.6	1.8	3:00
40	32.4	1.4	3:00
30	22.5	1.1	3:00
20	14.9	0.8	3:00
10	8.6	0.8	3:00
50	47.8	2.6	3:00

Trigger conditions

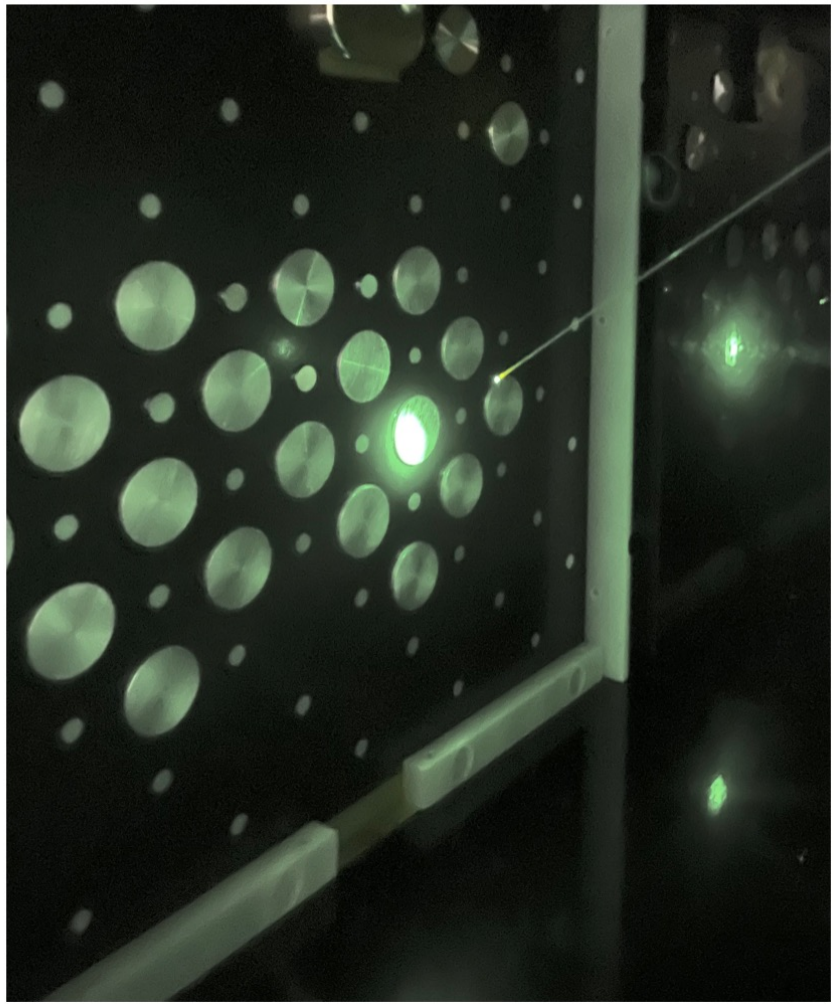
- Due to concern that the pulses may be too small to run DAQ in self triggering mode, special trigger conditions were used
- Specifically, external trigger was issued after laser pulse and UV LED flashed.
- Laser shutter was closed for part of the run for background subtraction.
- Dedicated meeting to discuss trigger options.
  - Use of analogue probe
  - **External trigger**
  - Periodic trigger
  - Periodic reset

Preliminary results with Long Fiber

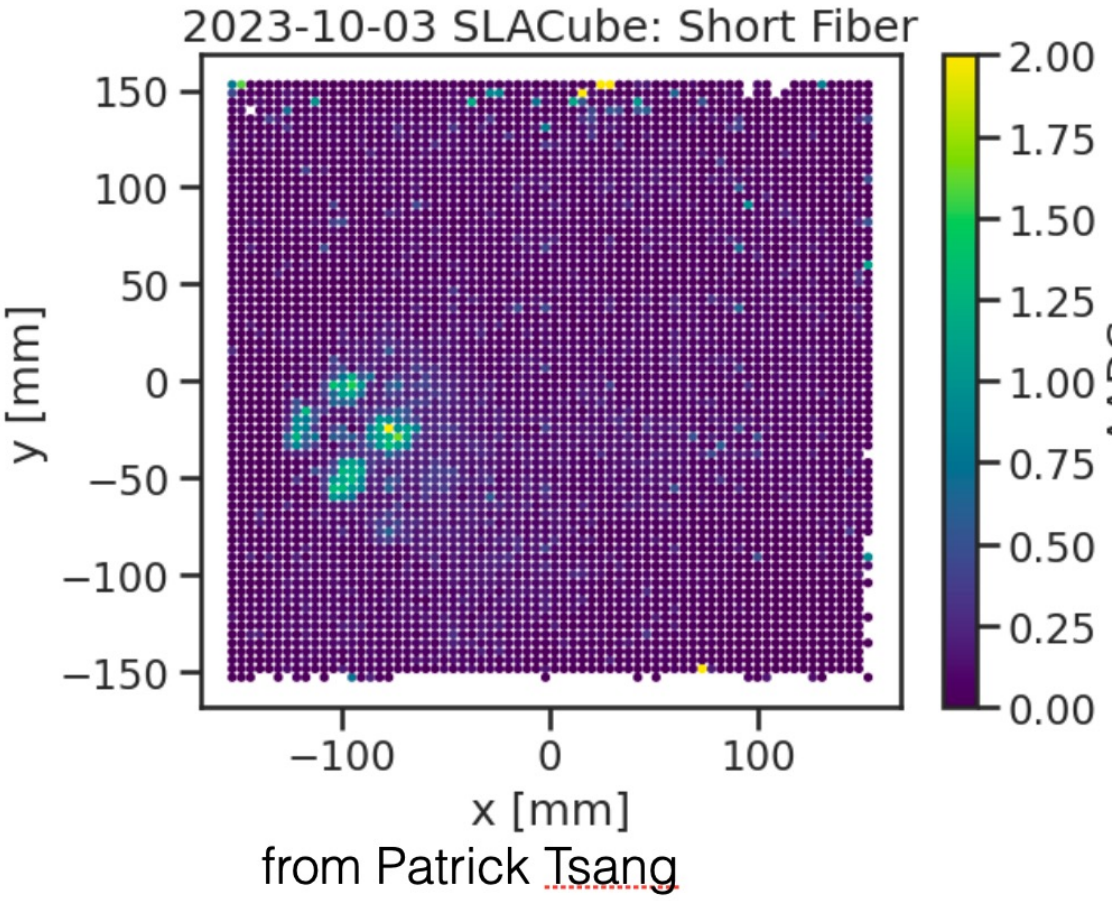
Note: fiber location and illumination may be different in LAr



from Patrick Tsang



Preliminary Results with Short Fiber



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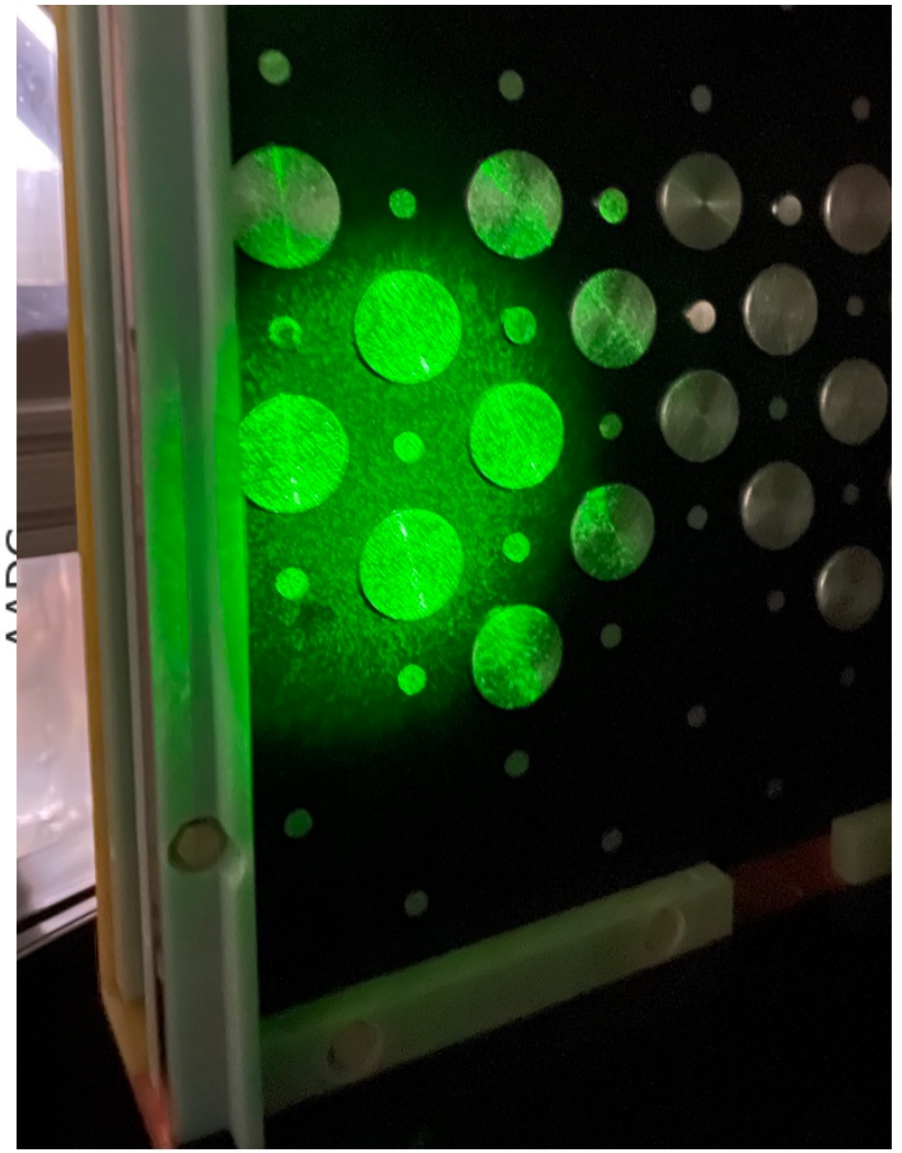
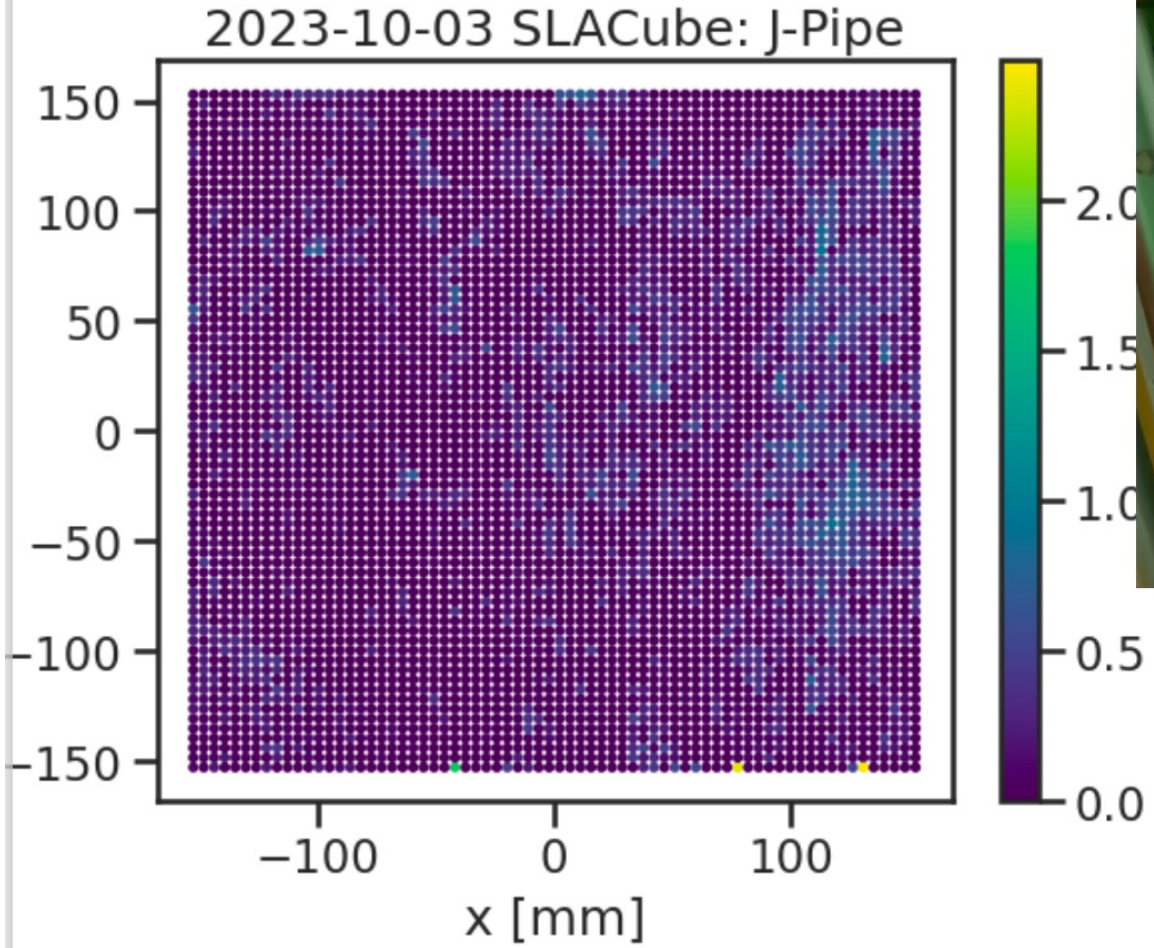


Preliminary results with J-pipe



from Patrick Tsang

Summary and Next Steps

- First test of the calibration system in LAr TPC completed.
- Detected signals from short and long fiber with external trigger.
- Signal from J-pipe too low – not distinguishable from background.
- Did not get the signal from UV LED: light more dispersed, but unsure if the delays have been setup correctly → improvement in next run
- Crude analysis points to QE of the order of 10^{-8} for the illuminated targets → rather low.
- Next steps:
  - Need a better QE calculation, comparison between targets and proper analysis that takes into account purity changes as well.
  - Purity measurement to adjust for changing purity conditions
  - Light detector inside TPC and power detector inside laser box.
  - New SOP that will allow illumination measurement with UV laser.
  - Testing in warm for UV LED flashing and set up of the time delays.