HRPPD aging studies at JLab

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Motivation

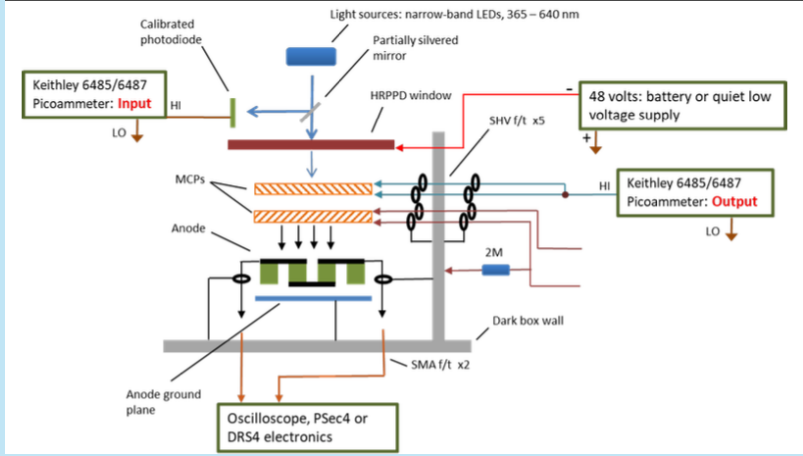
- **Assess Long-Term Stability**: Monitor potential degradation in photocathode
QE and MCP gain over time.

- **Optimize Operating Conditions**: Understand how voltage and light settings affect aging, then adjust them to reduce lifetime.

- **Ensure Reliable Performance**: Maintain consistent detector response for extended use.

- **Extend Detector Lifetime**: Prevent early failure by understanding degradation mechanisms.

Aging studies plan



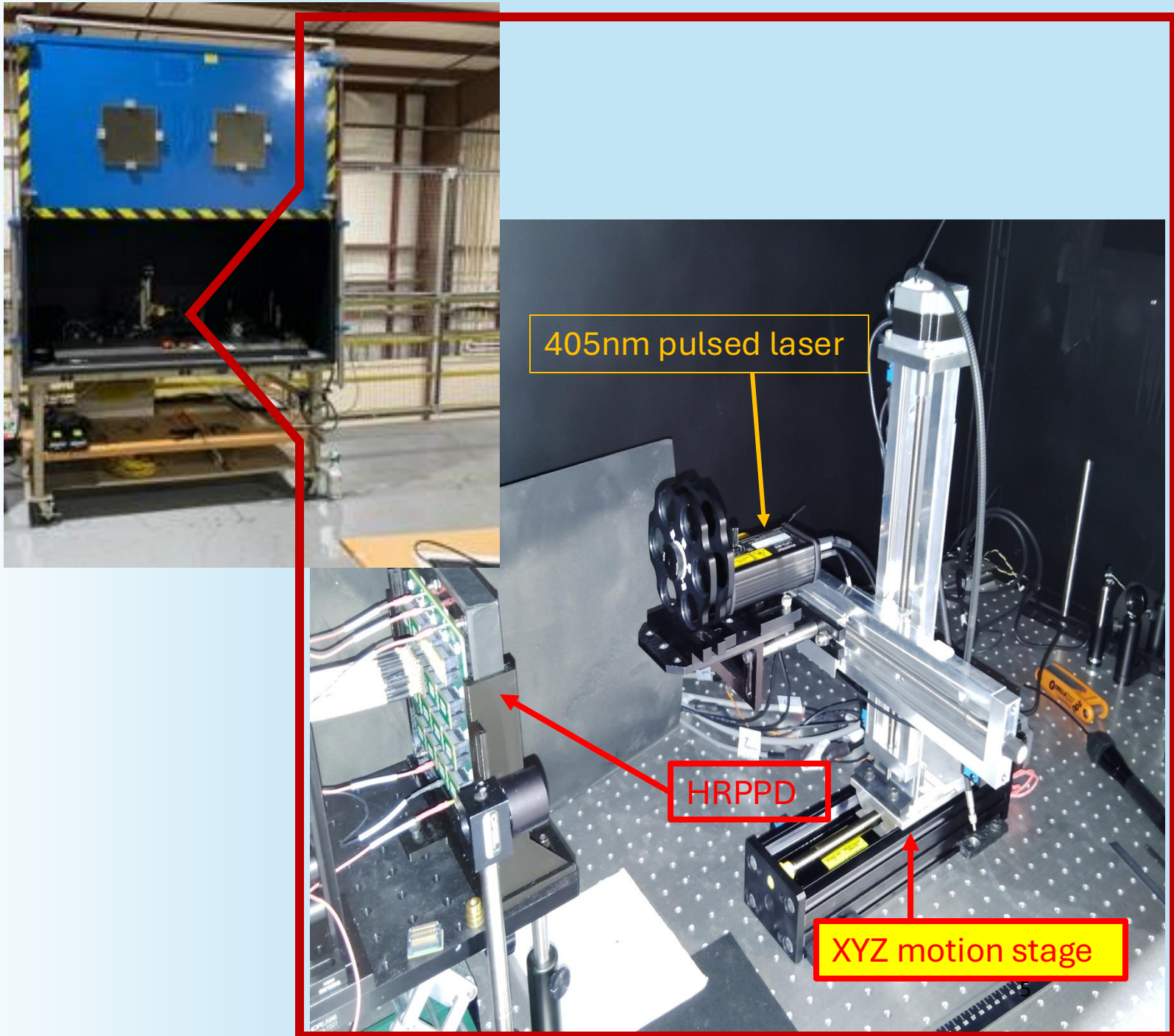
During aging, the following parameters were monitored continuously:

- ✓ Gain, ~10^6 gain
- ✓ **D**ark **R**ate (Hz/cm^2),
- ✓ **T**ransit **T**ime **V**ariation (TTV),
- ○ **P**hoton **D**etection **E**fficiency (PDE),
- ○ **A**fter **P**ulsing **R**ate
- ✓ Biasing voltages between Entry-MCP, Exit-MCP and PC
  - ○ The biasing voltages between MCP-1 and MCP-2 will be adjusted for gain control and safe operation with the HRPPD longevity in mind and to reduce the impact of aging.
- ✓ **Q**uantum **E**fficiency (QE)
  - ○ This measurement requires some changes in setup so that this measurement will be performed after some time e.g. 2-3 days

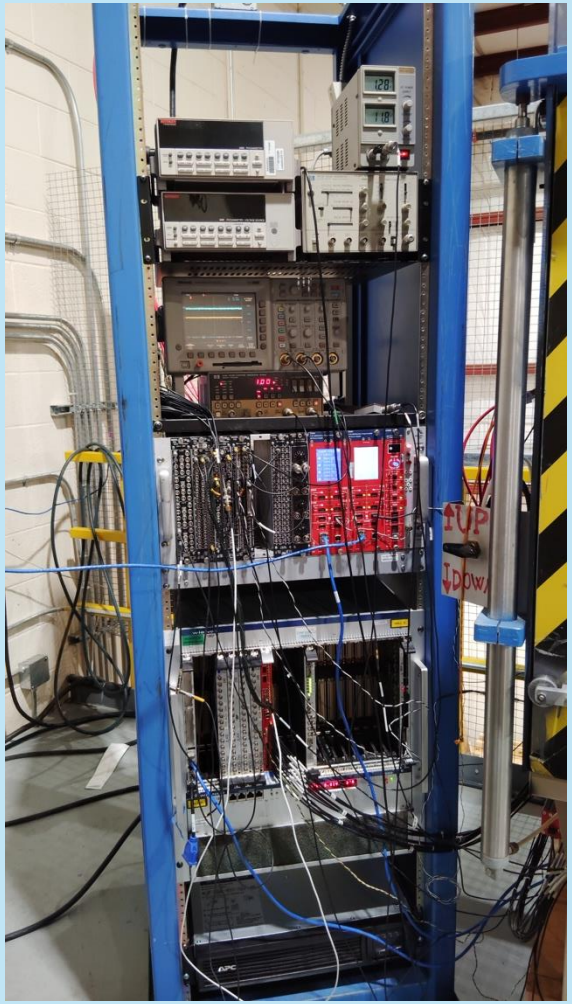
The goal is to reach ~$10^{14\text{-}15}$ photon flux per cm^2 during these measurements

Dark box and readout electronics at JLab

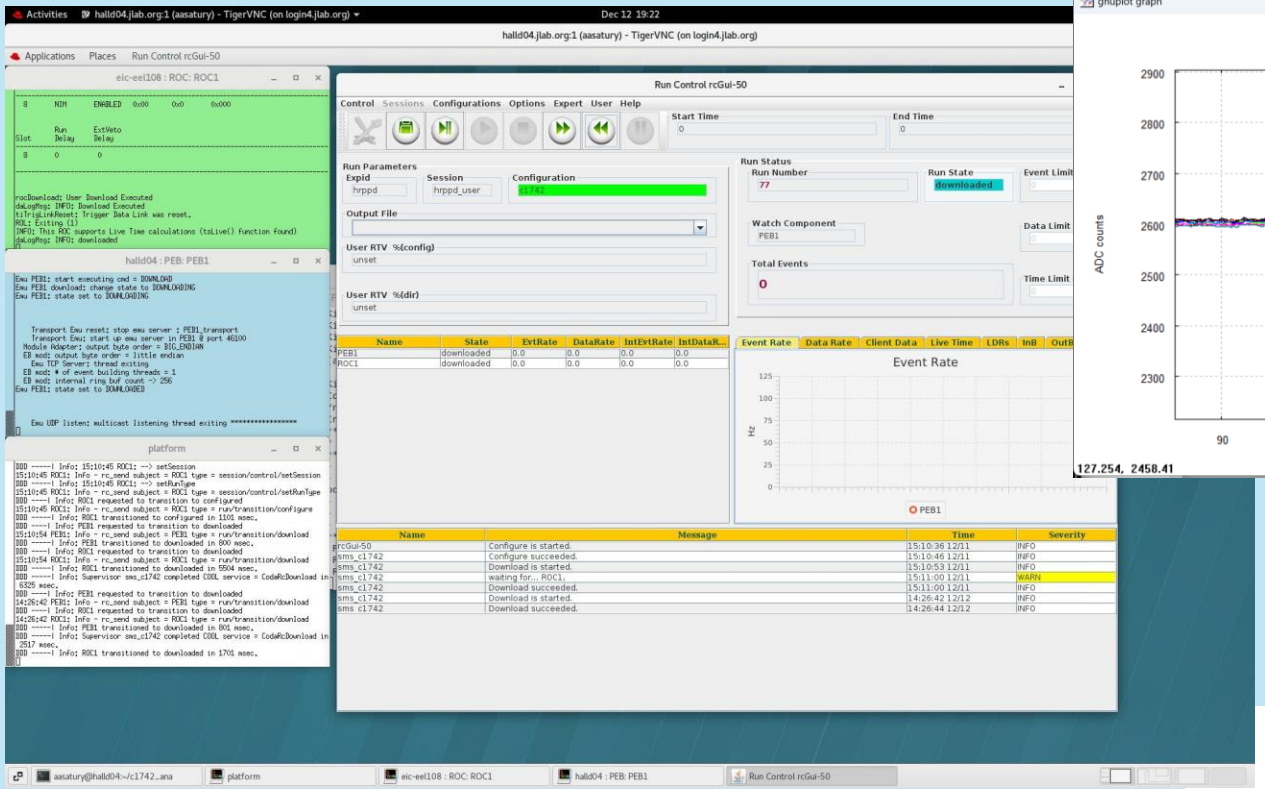
- 405nm pulsed laser
- continuously monitoring reference photodiode
- 2x sets of ND filters for light attenuat
- VELMEX XYZ motion stage

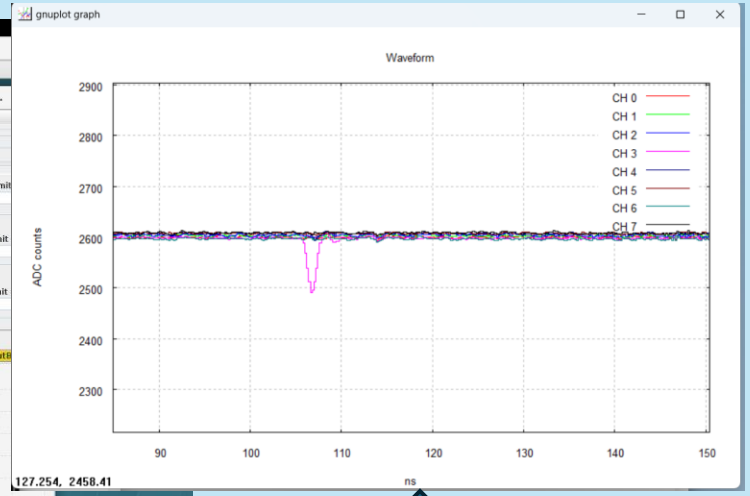


Existing electronics

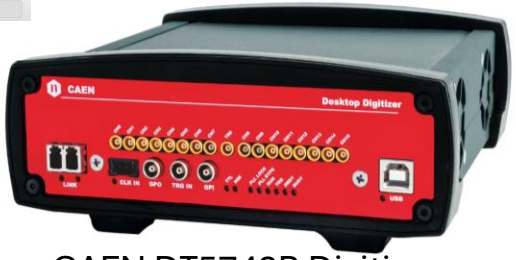


Electronics Rack



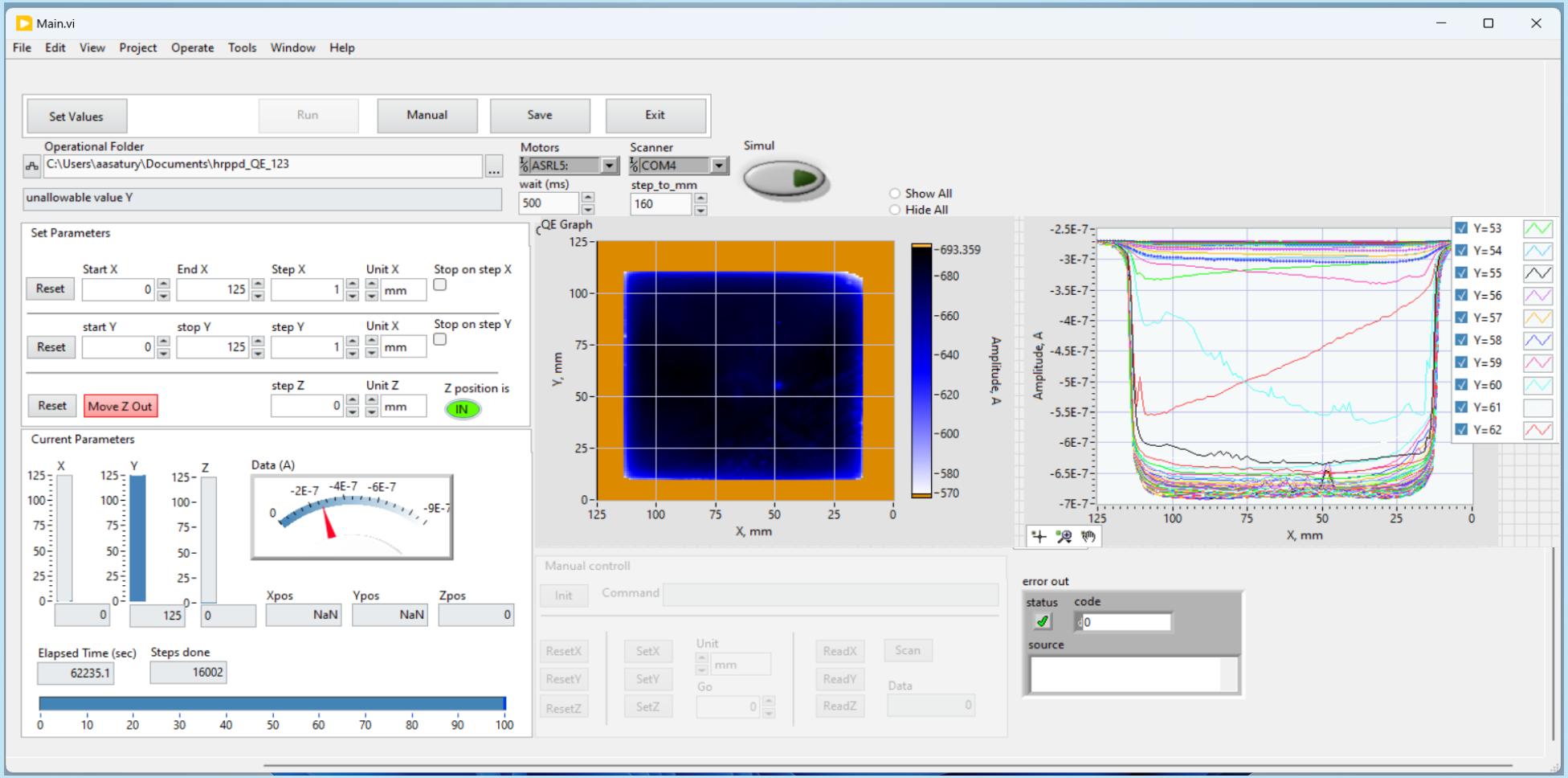


1. CAEN DT5742B digitizer
2. CAEN V1742 Digitizer with CODA DAQ and electronics
3. CAEN N1470 HV source for HRPPD
4. Light source pulsed 405nm
5. Calibrated Hamamatsu S2281 photodiode
6. XYZ motion stage Velmex



CAEN DT5742B Digitizer

XYZ motion stage controlling and readout GUI

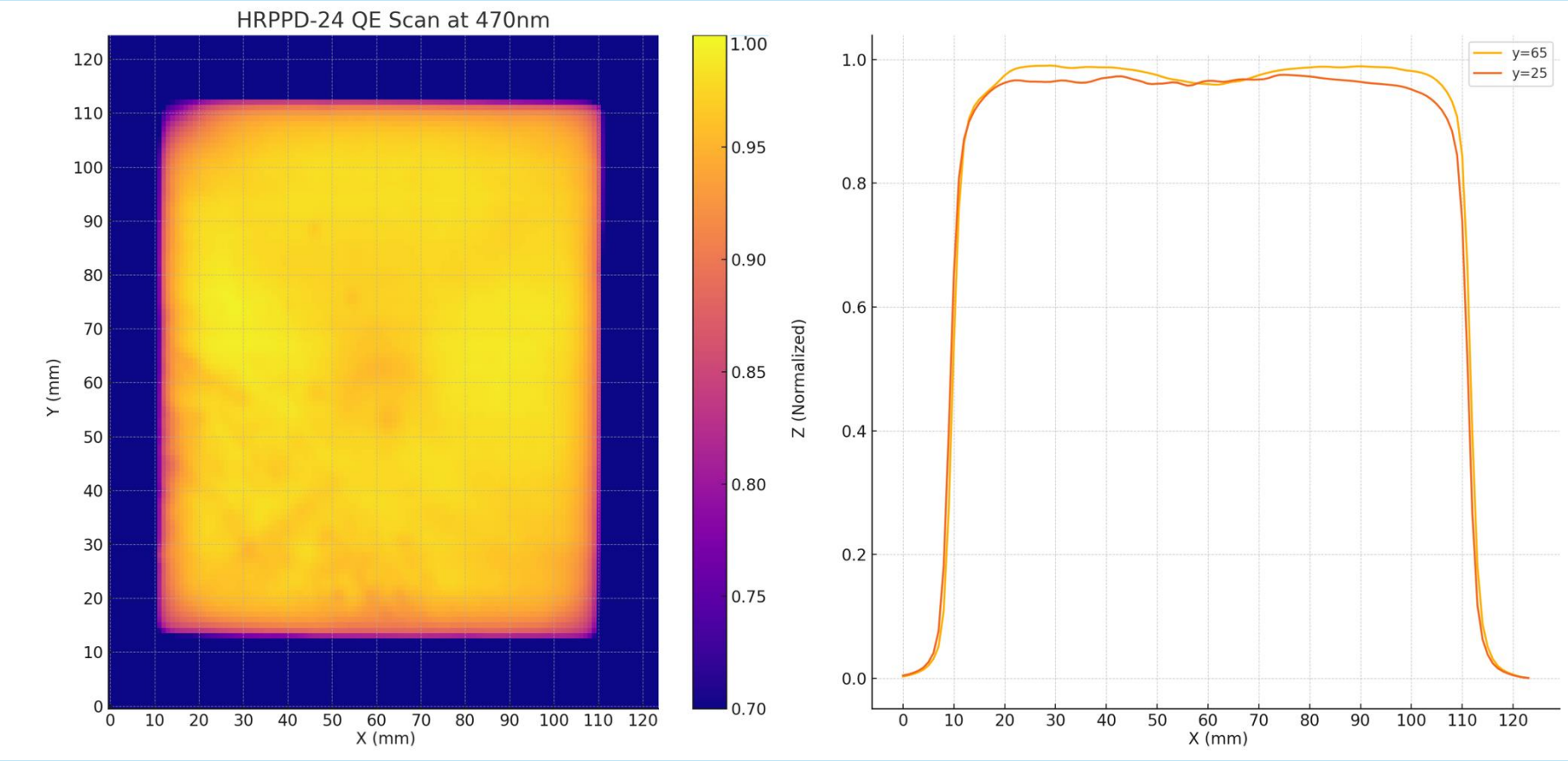


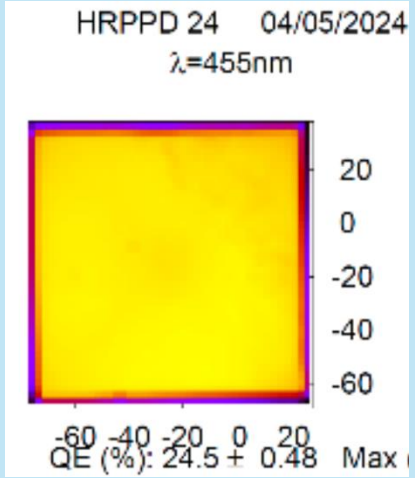
VELMEX

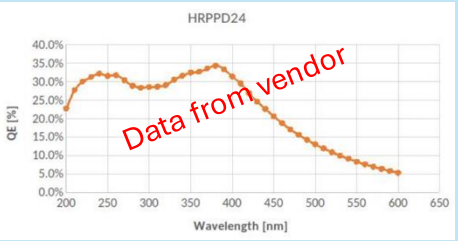
Keithley picoammeter

- LabView-based GUI to control 2x Desy chained VELMEX XYZ motion stage and Keithley picoammeter for data taking and in-situ readout

QE measurement results before aging





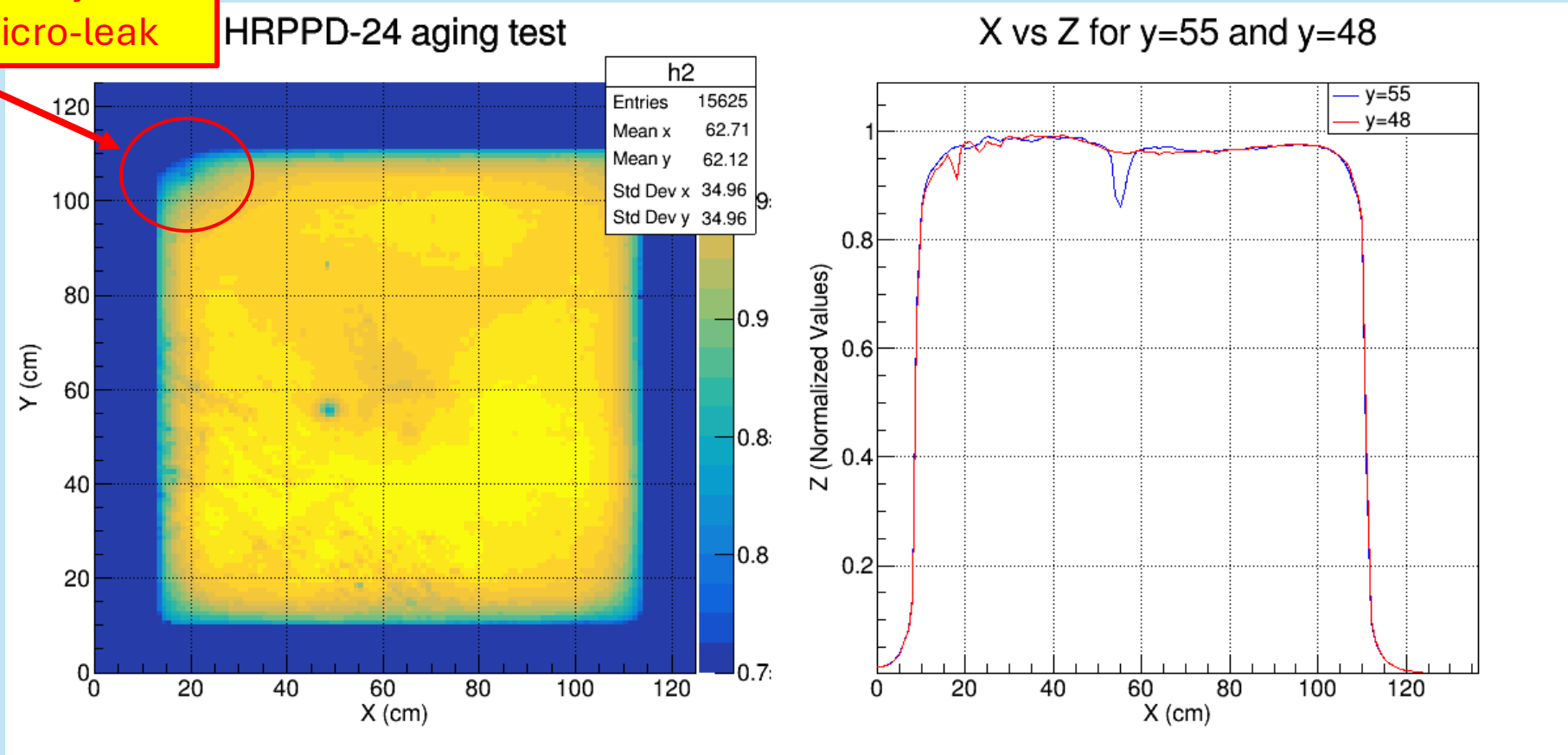


With no light source, the HRPPD current is -0.49950uA at 470-472nm, with light source the HRPPD measured current is -0.50296uA, the reference **calibrated** photodiode current is -14.9886nA, photosensitivity of photodiode at 470nm is ~237mA/W

With the given numbers the QE of the HRPPD-24 at 470-472 nm is approximately ~14.5-14.9%

QE measurement results after aging

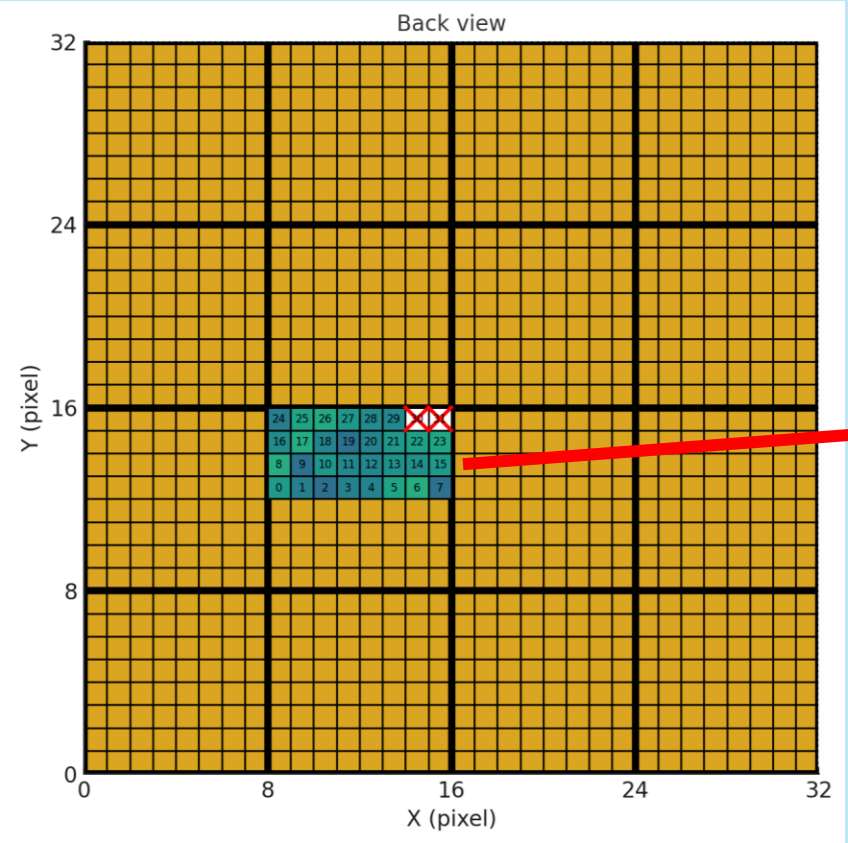
Possible or very small vacuum micro-leak

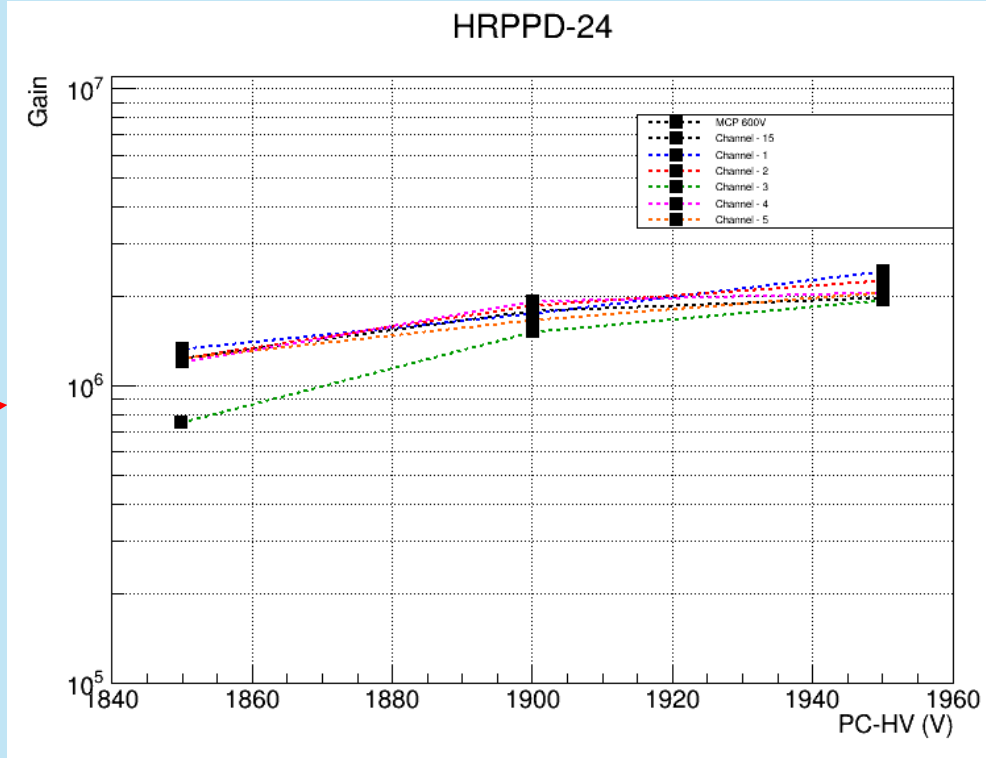


- The calculations show the total amount of charge collected over the illuminated area and time duration with a photon flux of ~5×10^{15}photons/s/cm^2 is <2 Columb/cm^2 with a beam diameter of ~1mm^2, and illumination time for ~300 mins, at a given 470-472nm wavelength.

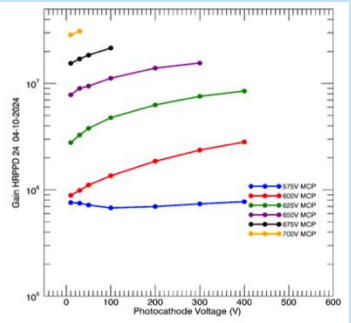
- Some sign of vacuum micro-leak? The vendor was notified and got the answer, “In any case first thing to do is to measure dark rates locally and globally. Usually, a leaking tile shows global increase in the dark rates.”

Sketch of the back side of HRPPD



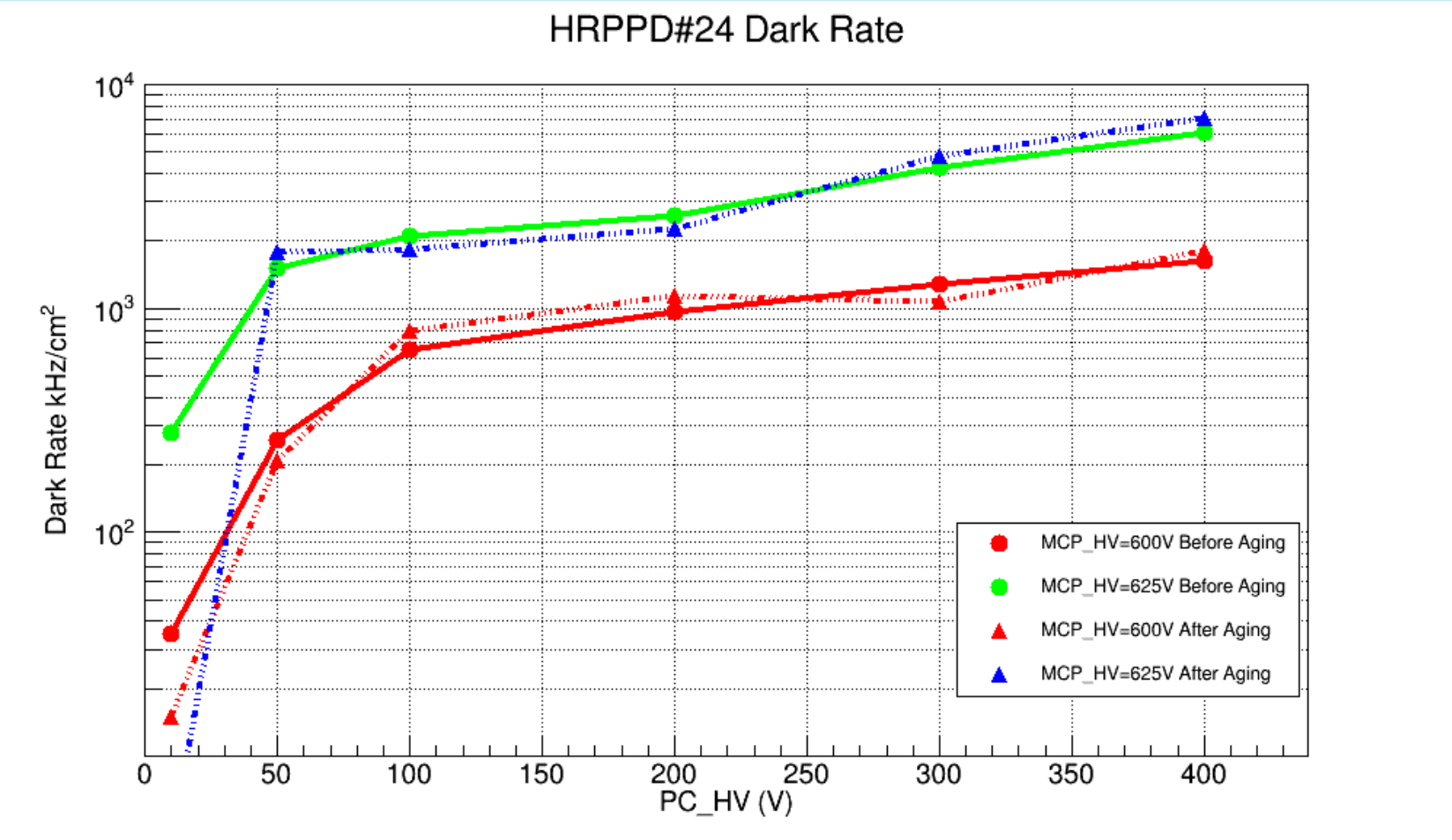


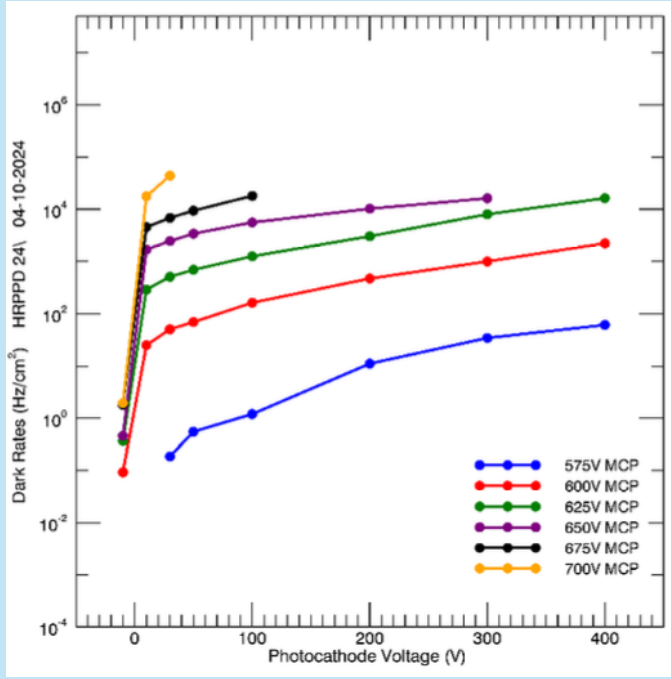
- The colored region where all measurements were performed
- The color code indicates Gain variations for different channels ~2x10^6 for ROP voltages
- The Gain for these channels are in the range of 7-12%, except for one channel
- Due to broken connectors, no data was collected from channels 30 and 31.



Vendor results

Dark Rates BEFORE and AFTER

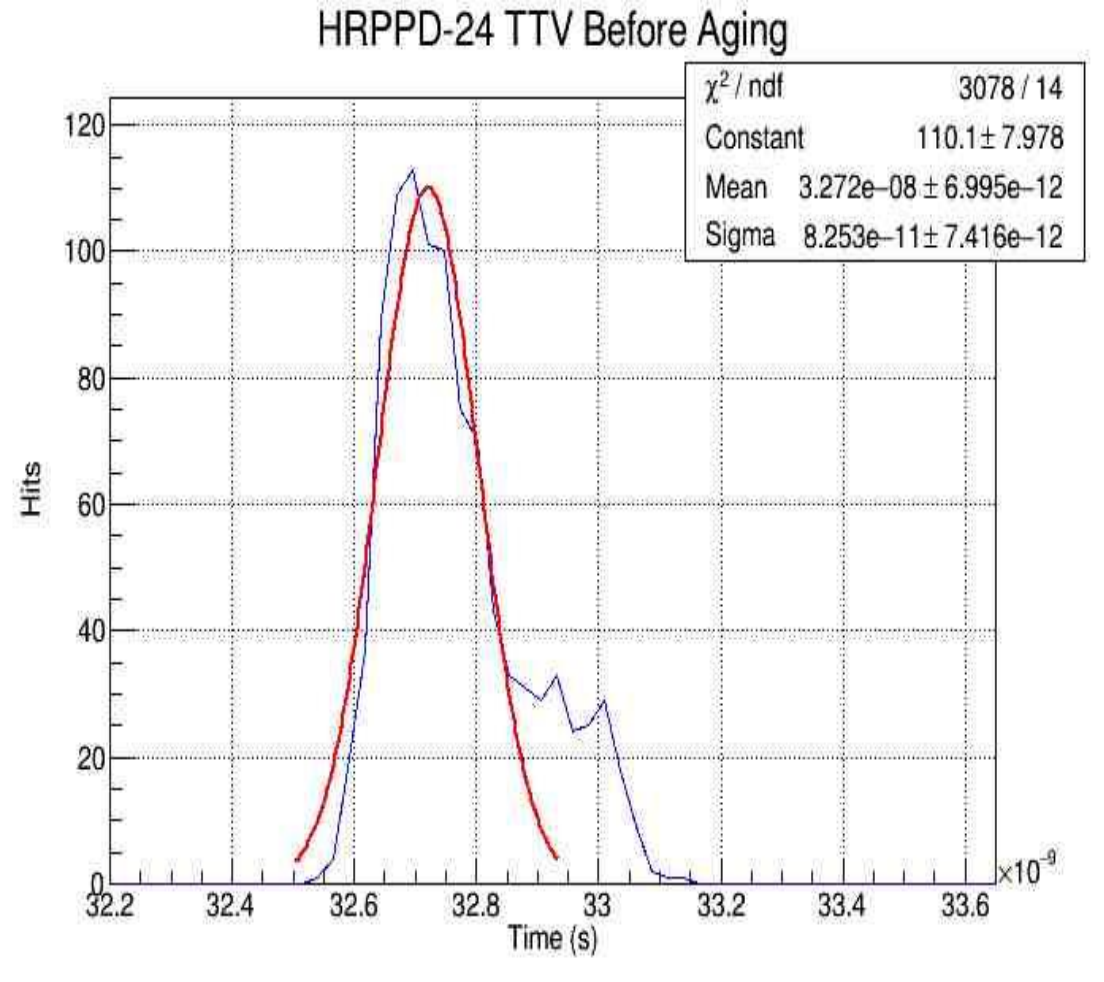


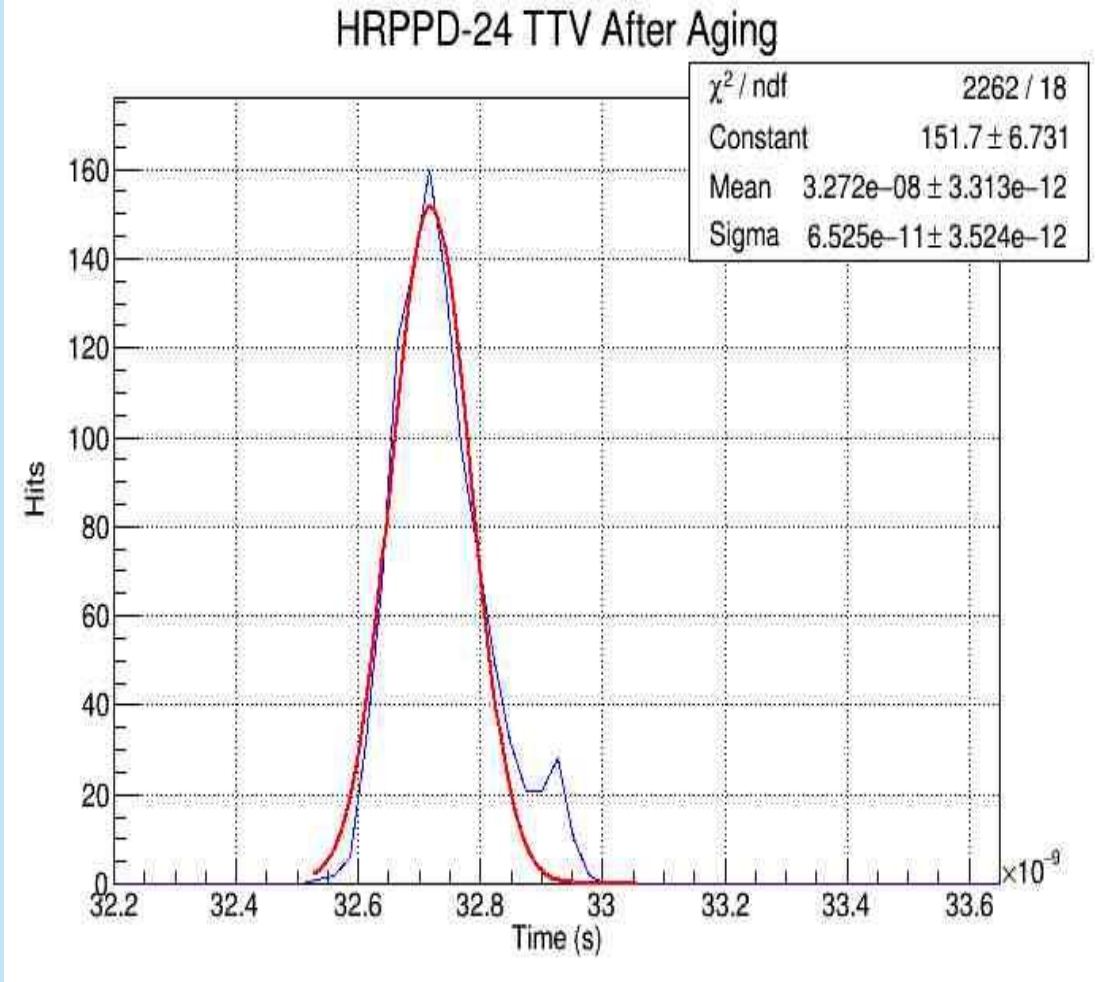


Dark rate results from vendor

- Dark rates for different PC and MCP biasing voltages were measured
- Solid lines are results before aging, dashed lines for after aging
- There is some negligible difference between the two measurements, but can't say it is due to aging

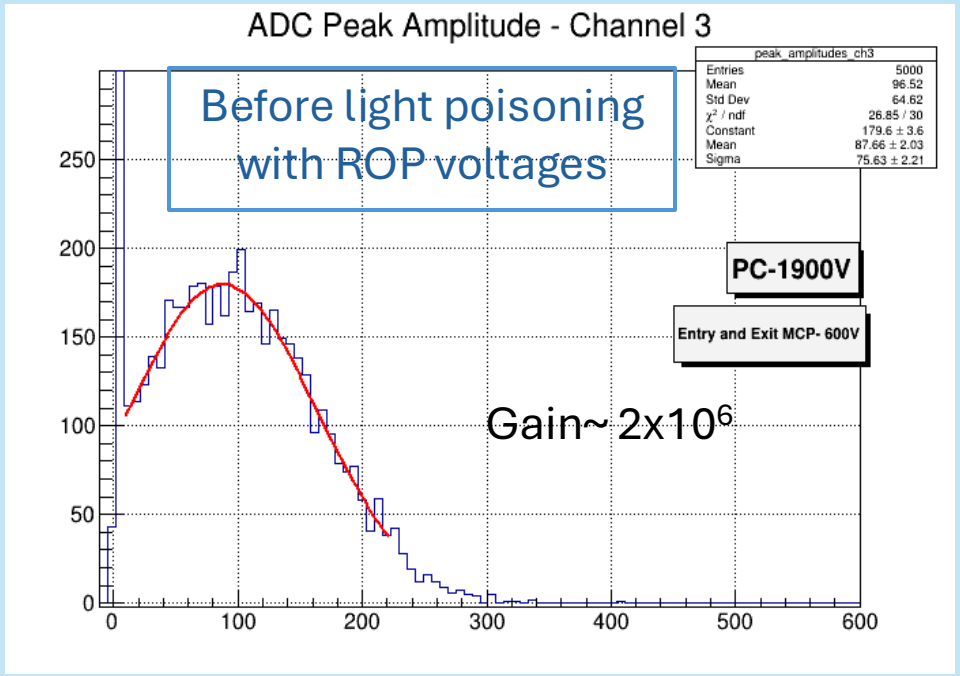
Transit-Time-Variation Studies

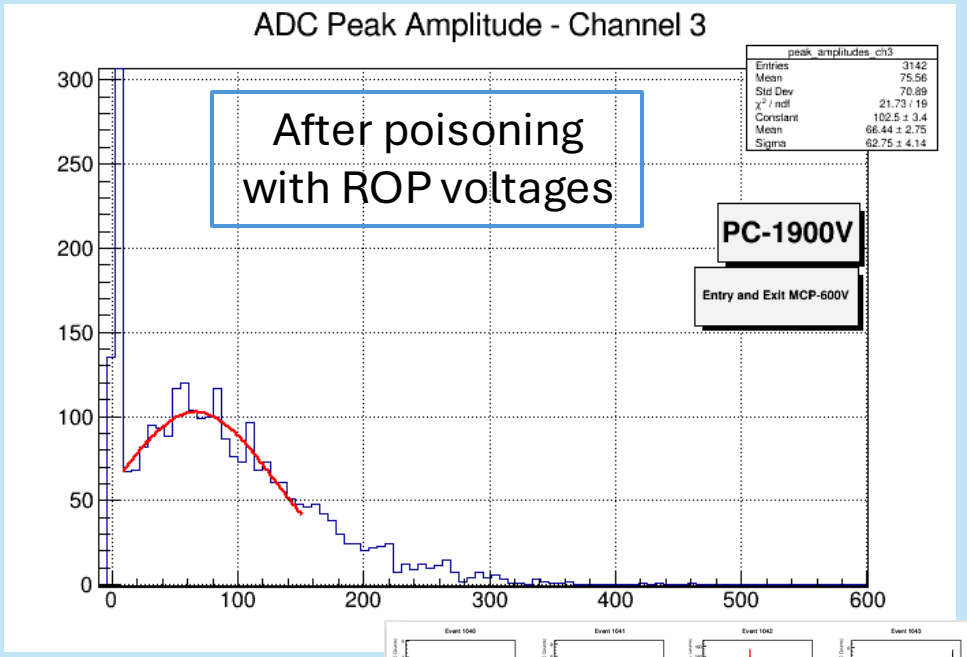


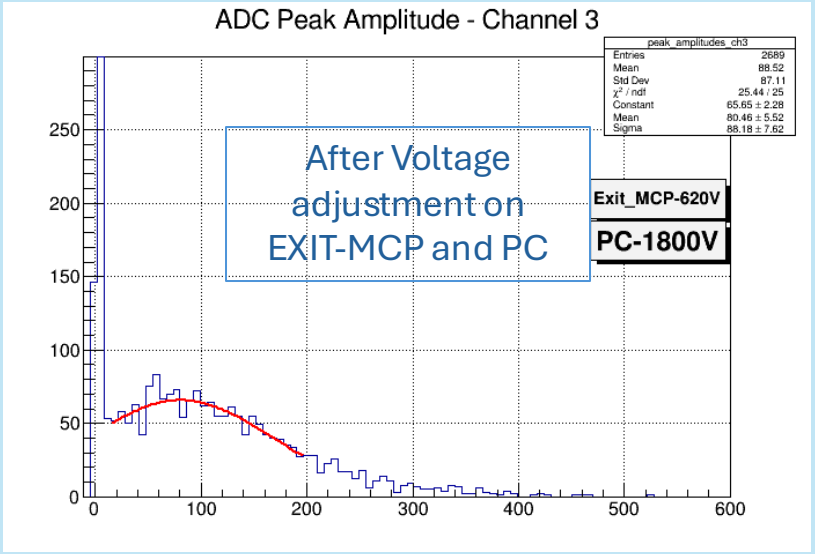


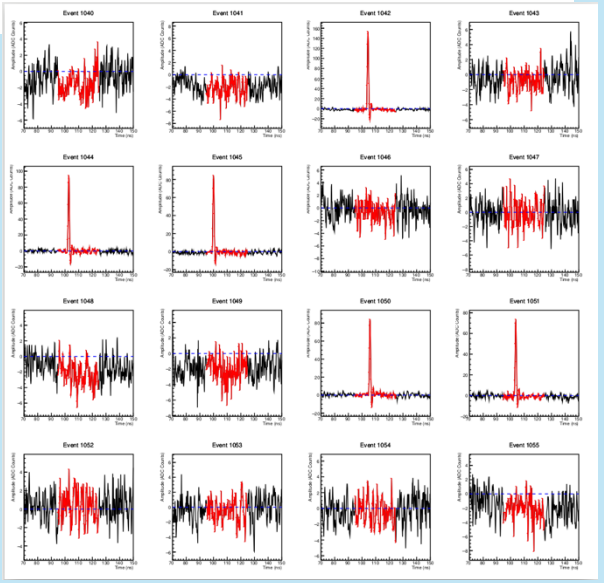
- Unexpected TTV Improvement: Could be from environmental temperature variations

Single-PhotoElectron peaks









Summary:

- Prepared setup for Aging studies

✓ **QE measurement and studies:**

- After excessive light poisoning ~20% degradation was observed

✓ **Dark Rates:**

- No noticeable degradation was seen that can be improved

✓ **Transit Time Variation:**

- Strange behavior; need to do more neat and deep studies

✓ **SPE detection efficiency**

- Cleary observed a change in SPE detection(not quantified yet !!!)

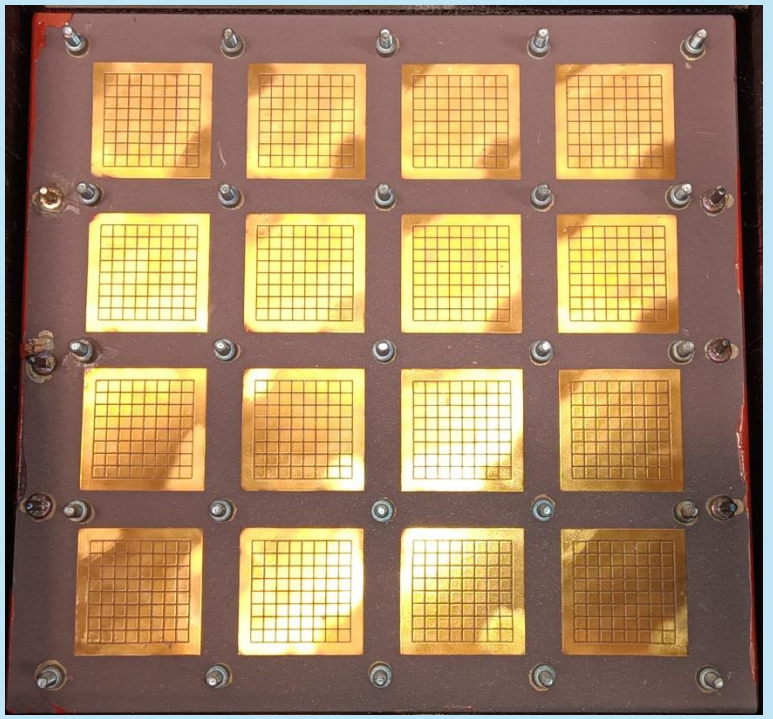
❑ **P**hoton **D**etection **E**fficiency (PDE) for higher rates and flux is ongoing.

- These **preliminary** results show that biasing Exit-MCP voltage to higher gain and reducing Entry-MCP and PC voltages can potentially recover SPE detection and extend lifetime

THANK YOU

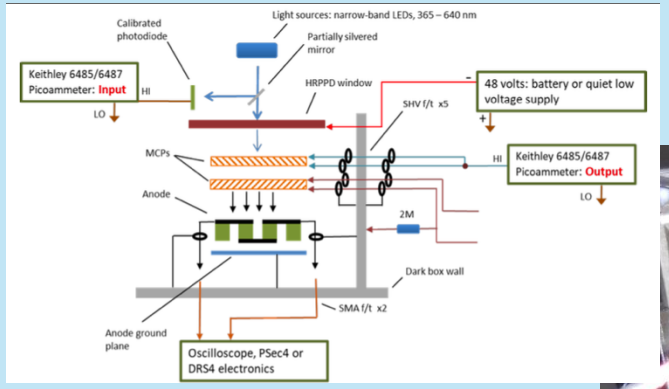
Back up

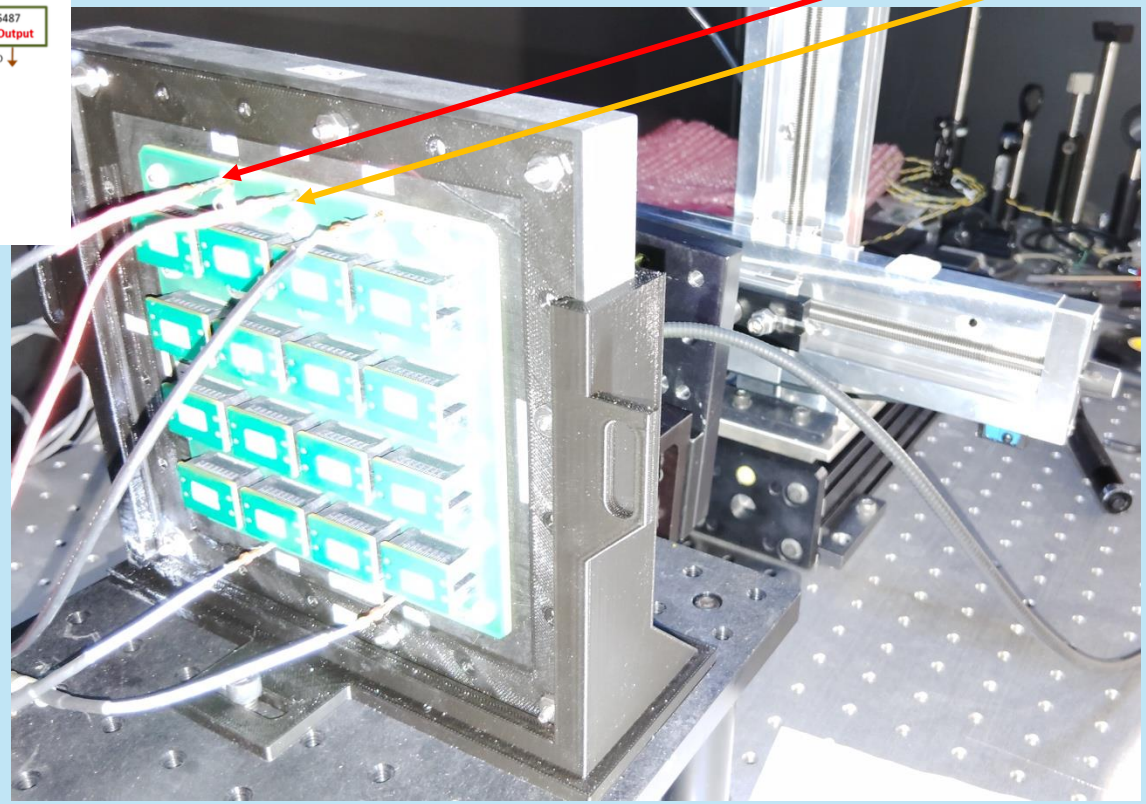
Front

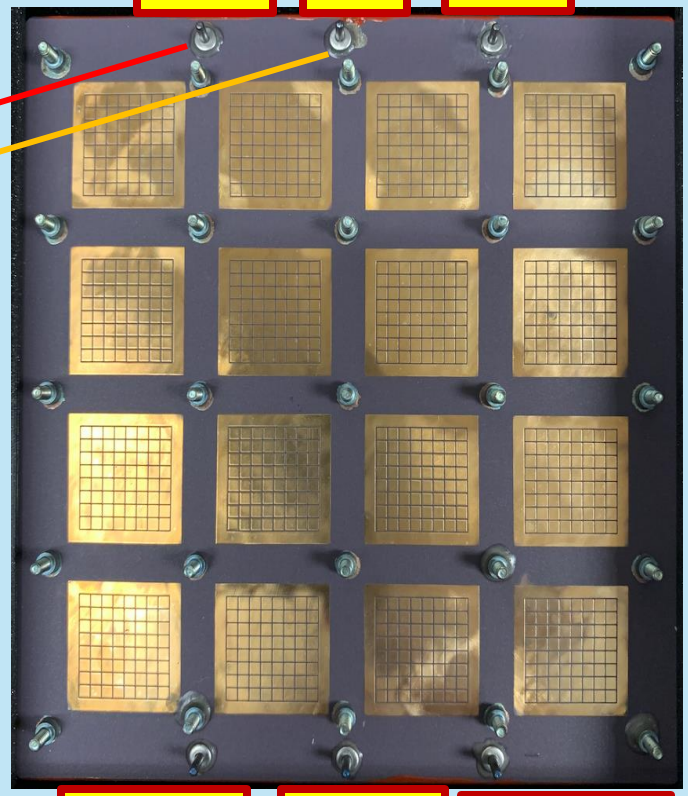


Back

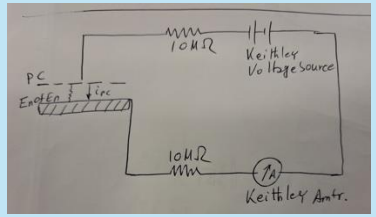
QE measurements test setup and HRPPD readout schematics







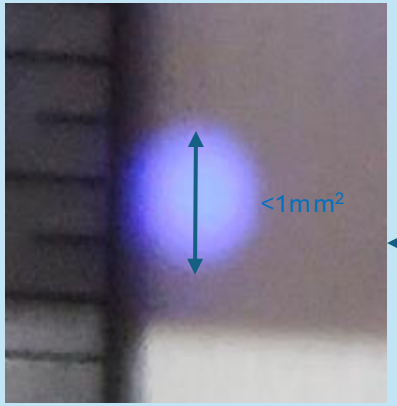
- Tests were done by applying -100V on PC
- Readout from MCP-ENT
- All other connectors were terminated



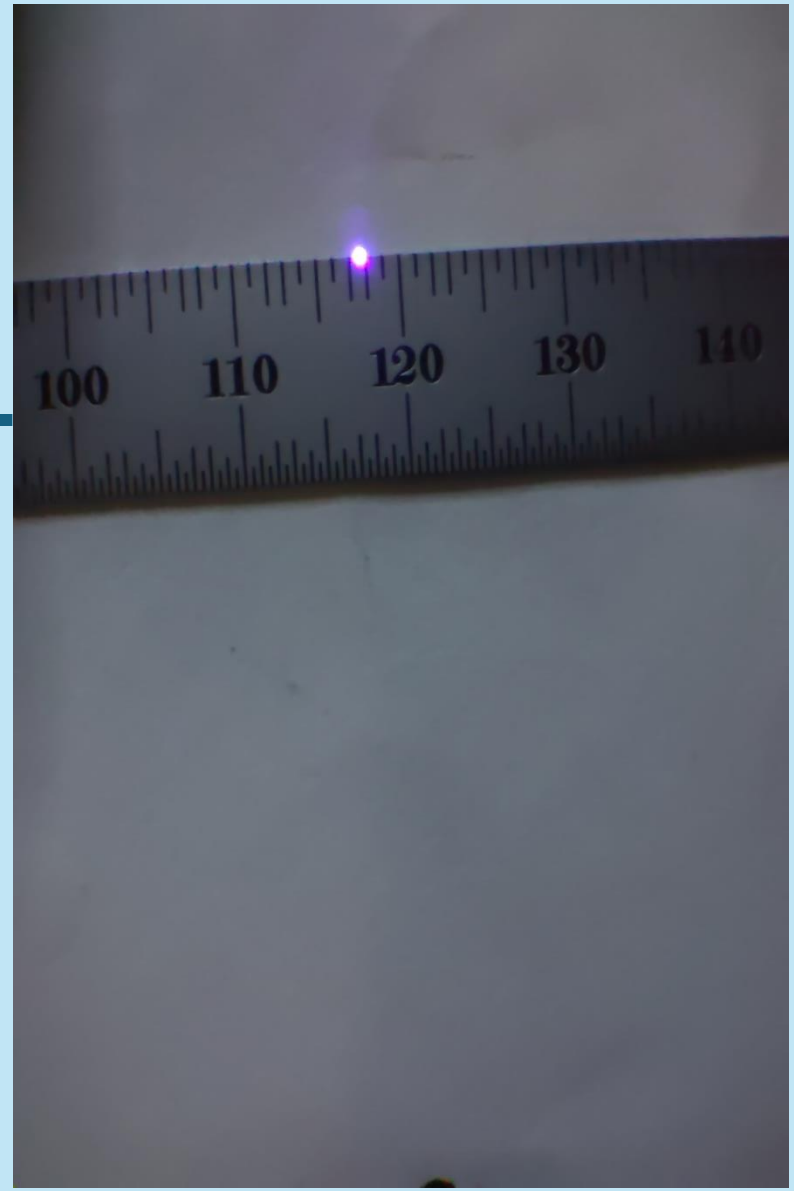
Connection schematic
Thanks to Chandra and Alexander

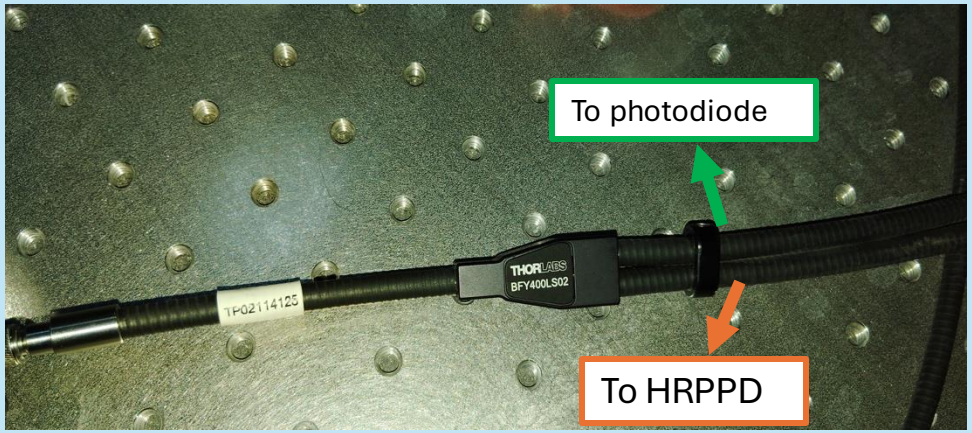
Light source and shape for QE measurements

- As a light source 470-472nm LED was used and delivered via 400um Y-shape 50/50 fiber
- Focused by lens
- Beam diameter on HRPPD is <1mm^2

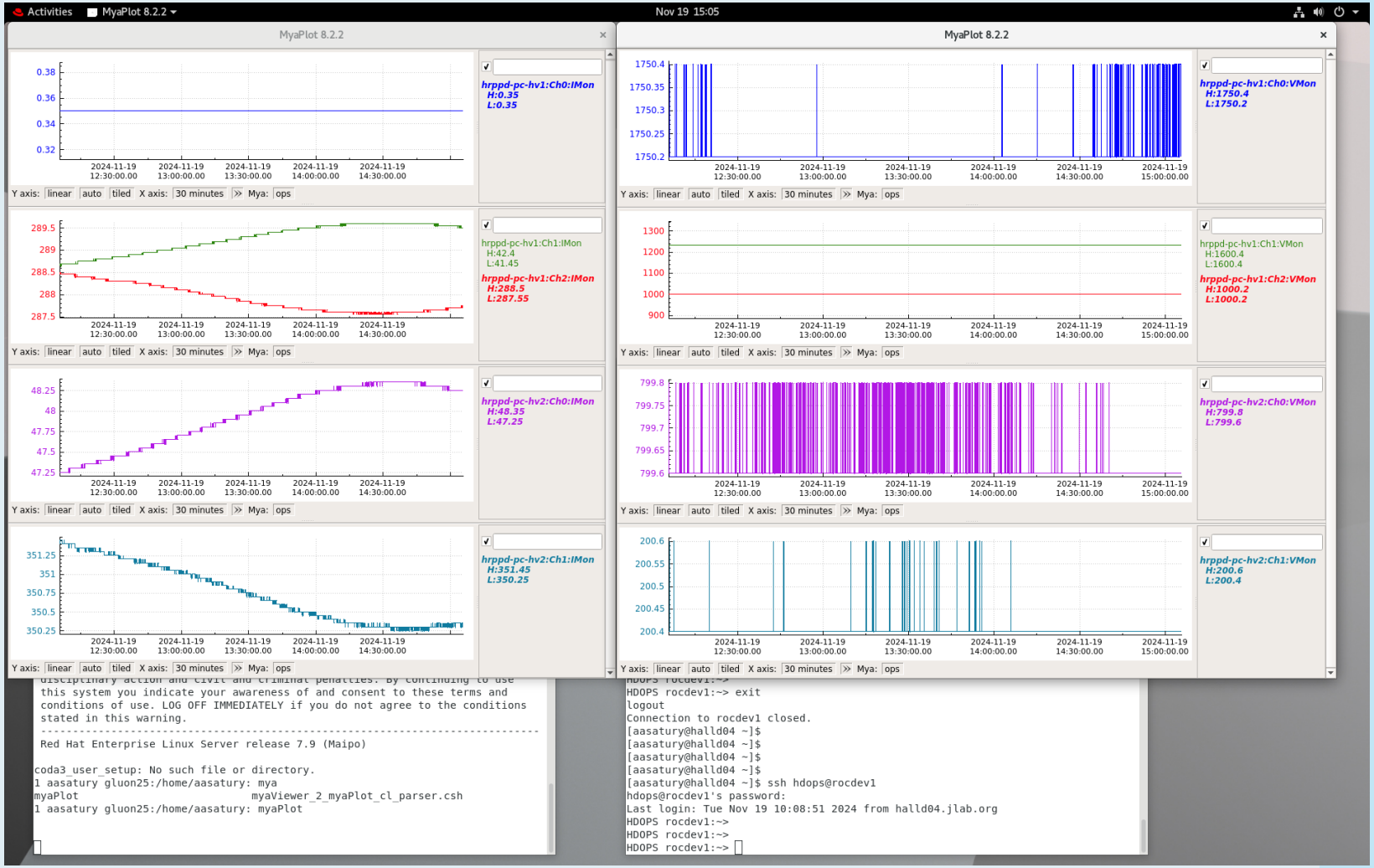


<=1mmX1mm





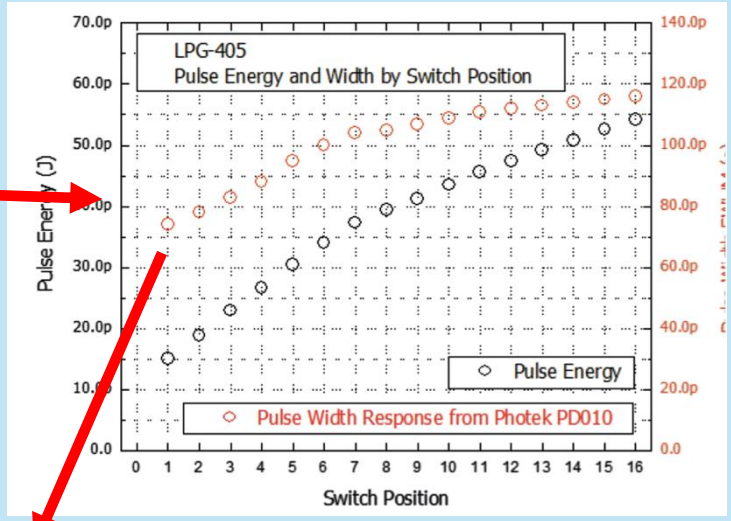
Used during QE scan measurements

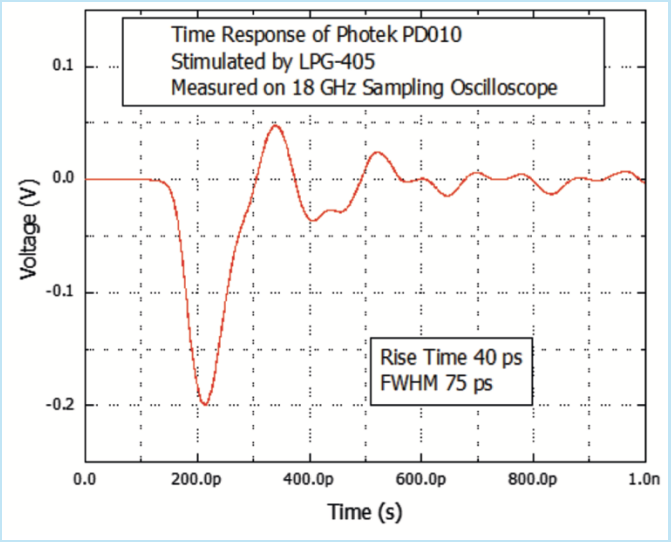


HVs in EPICS Environment

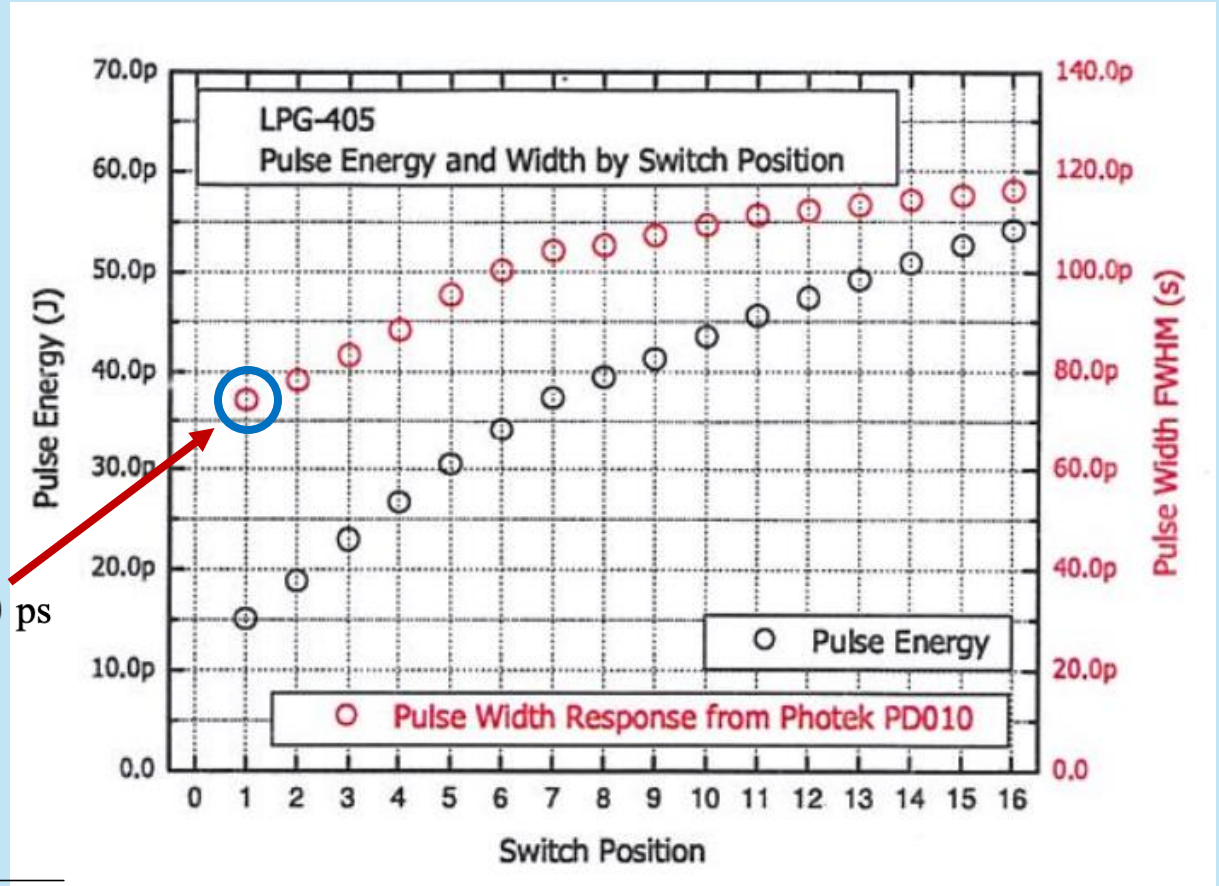
- Integrated to JLab EPICS environment for monitoring and controlling the HVs

Photek LPG-405 pulsed laser
405 nm - pulse width = 75 ps
Freq range = single shot to 300 kHz
Class 1(!!!) – inherently eye safe





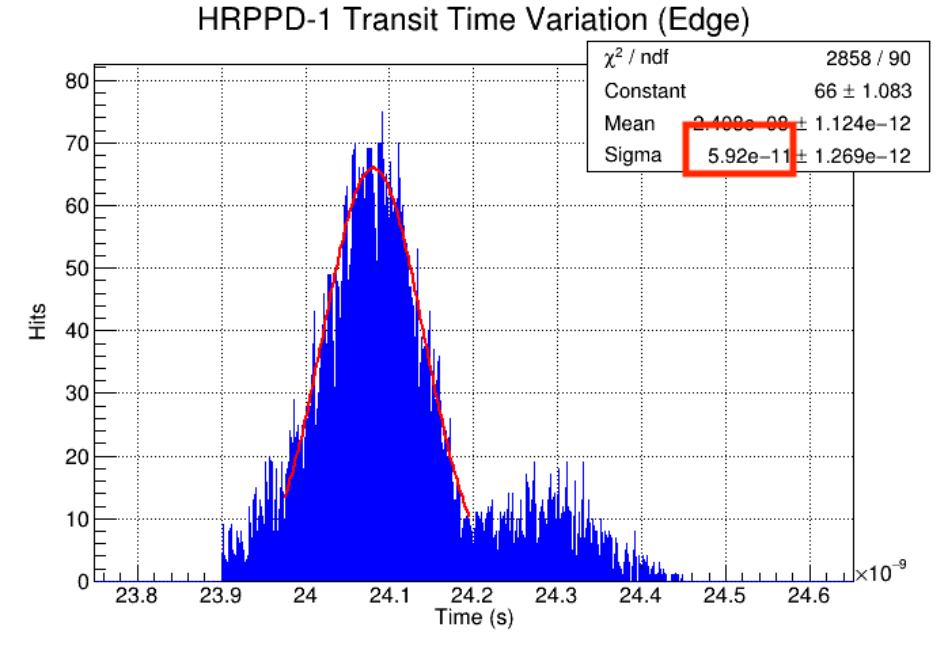
C.Zorn

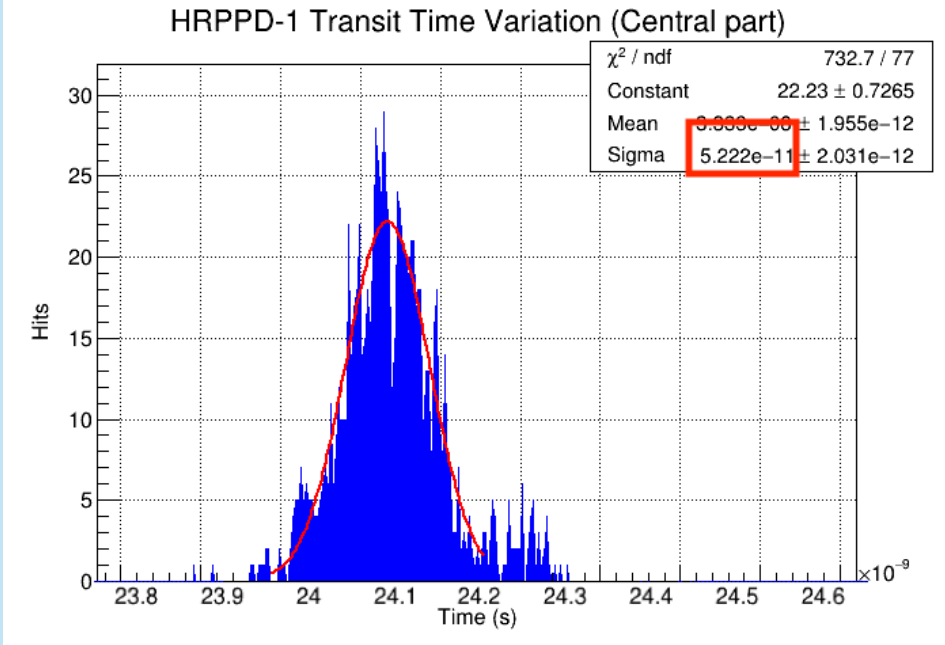


$\sigma = 30$ ps

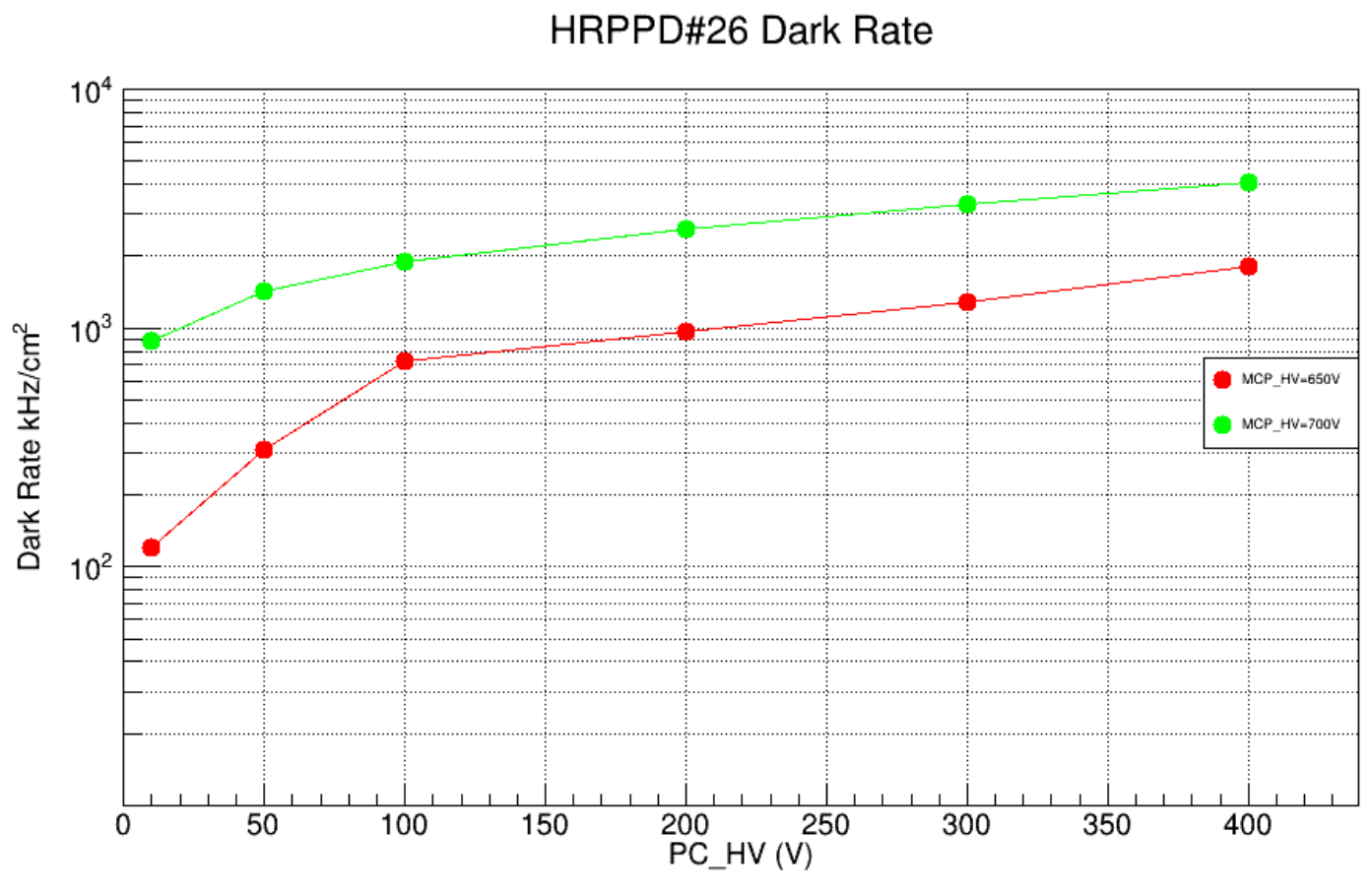
$$\mathrm{FWHM} = 2\sqrt{2\ln 2}\,\sigma \approx 2.355\,\sigma$$

Reflected photons from the beveled edges of the front glass



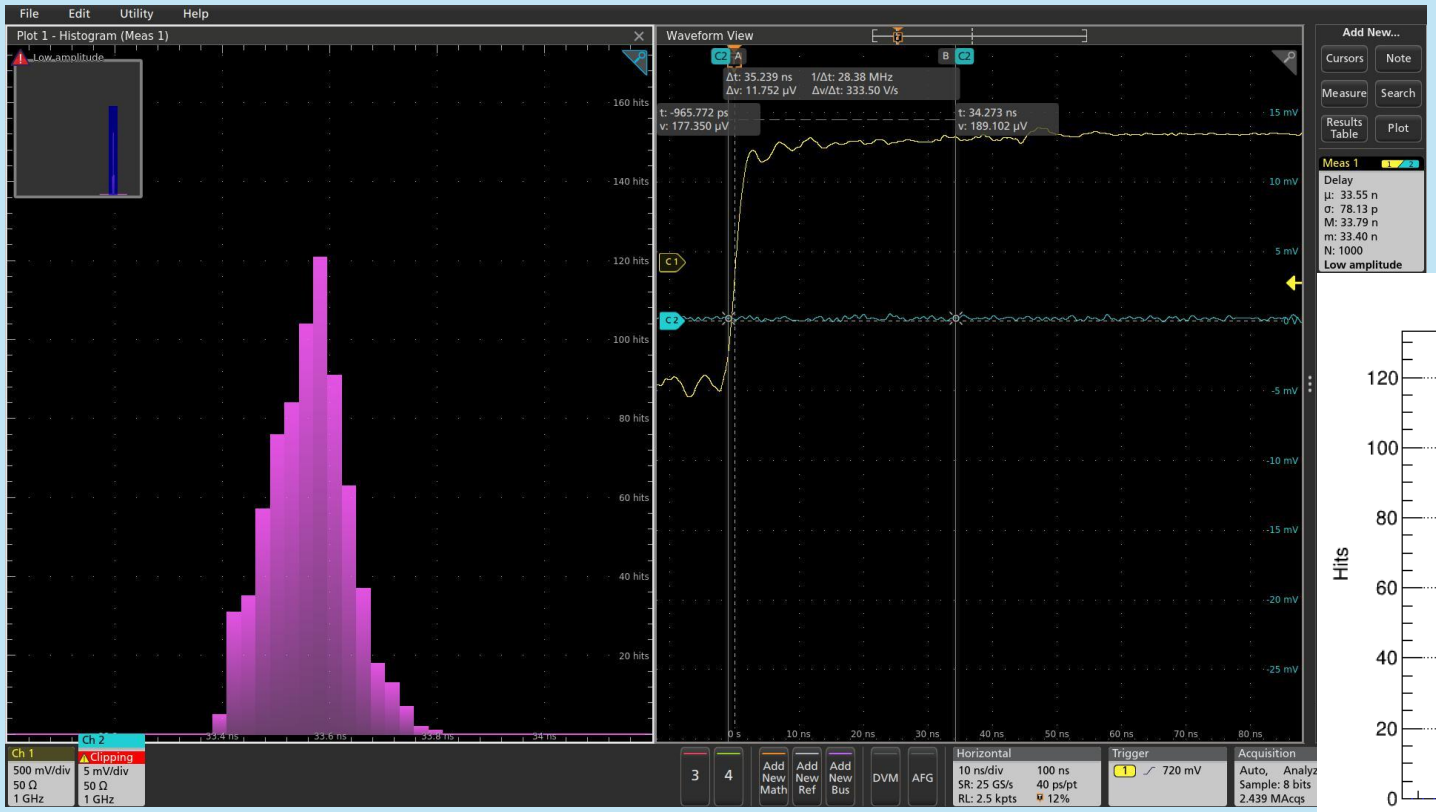


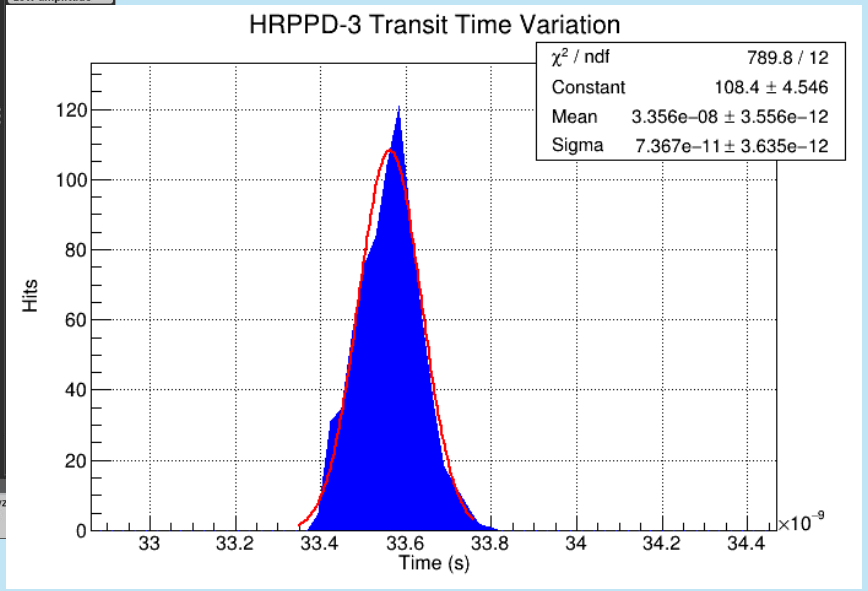
Dark Rate measurement



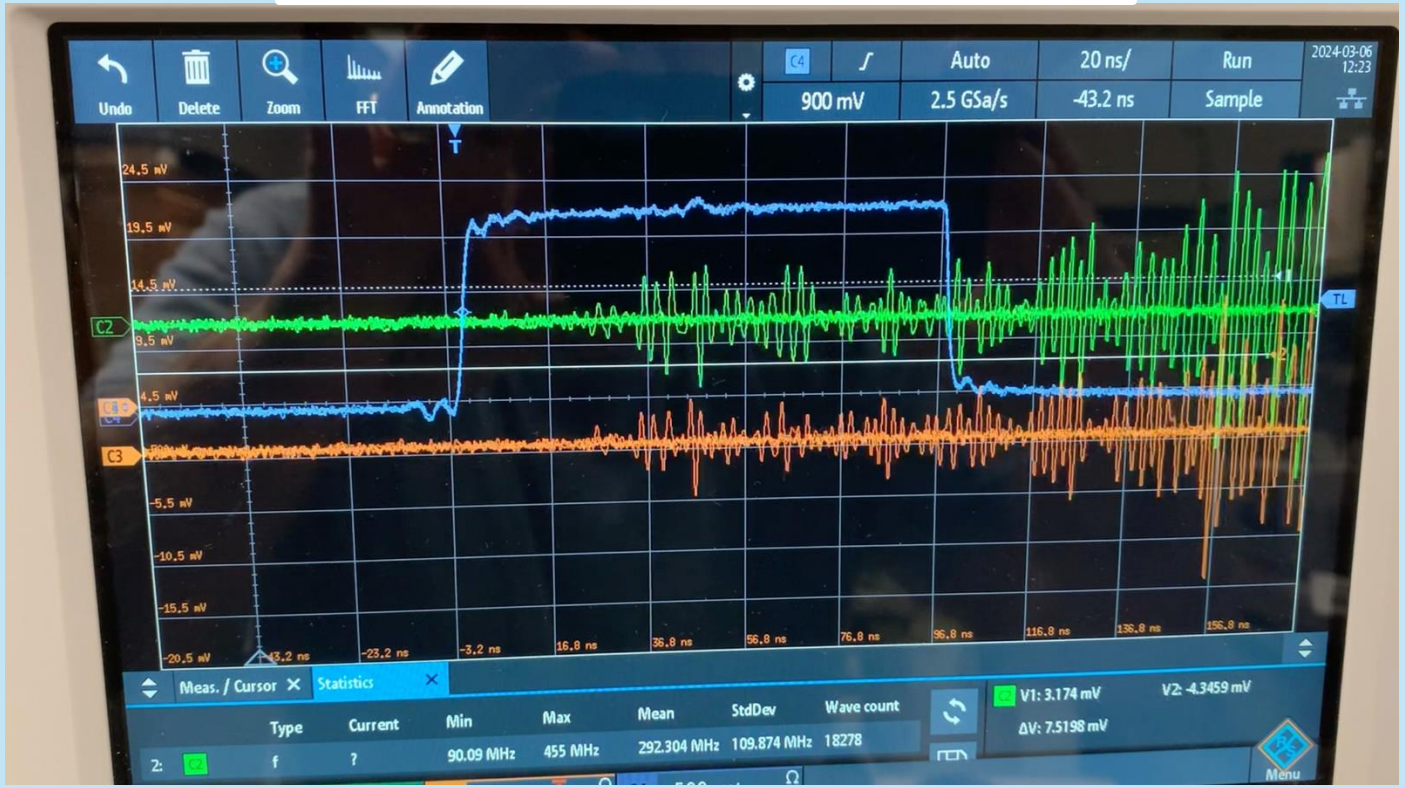
- Dark rates were measured at -650V and –700V on MCP
- 10V, 50V, 100-400V on PC

TTV(Transit Time Variation) for HRPPD-17

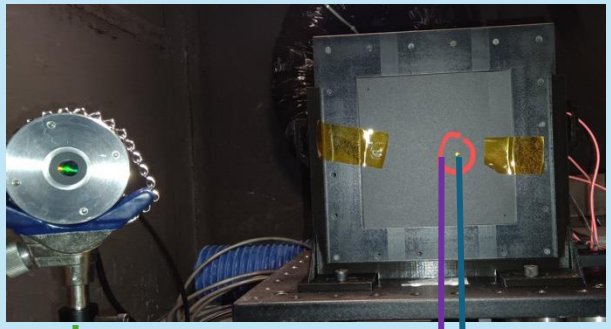




Examples of noisy signals
(The ground pin was broken)



Schematic of HRPPD TTV setup



HV

FAN-IN/OUT

Level Translator Discriminator

Amplifier

MSO64 Oscilloscope

CH 1

CH 2

Reference Oscilloscope

CH 1

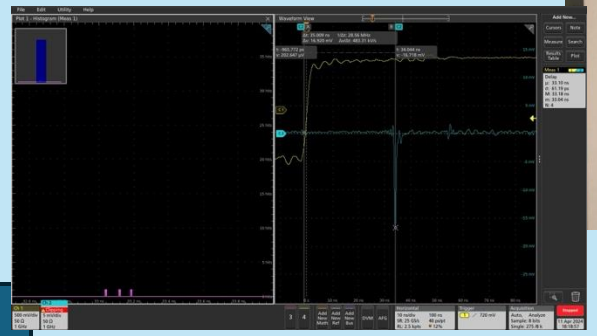
CH2/ 3

HRPPD CH-1...N

HRPPD CH-1...N

Laser is OFF in this case

Reference MCP



LASER trigger

Laser trig IN

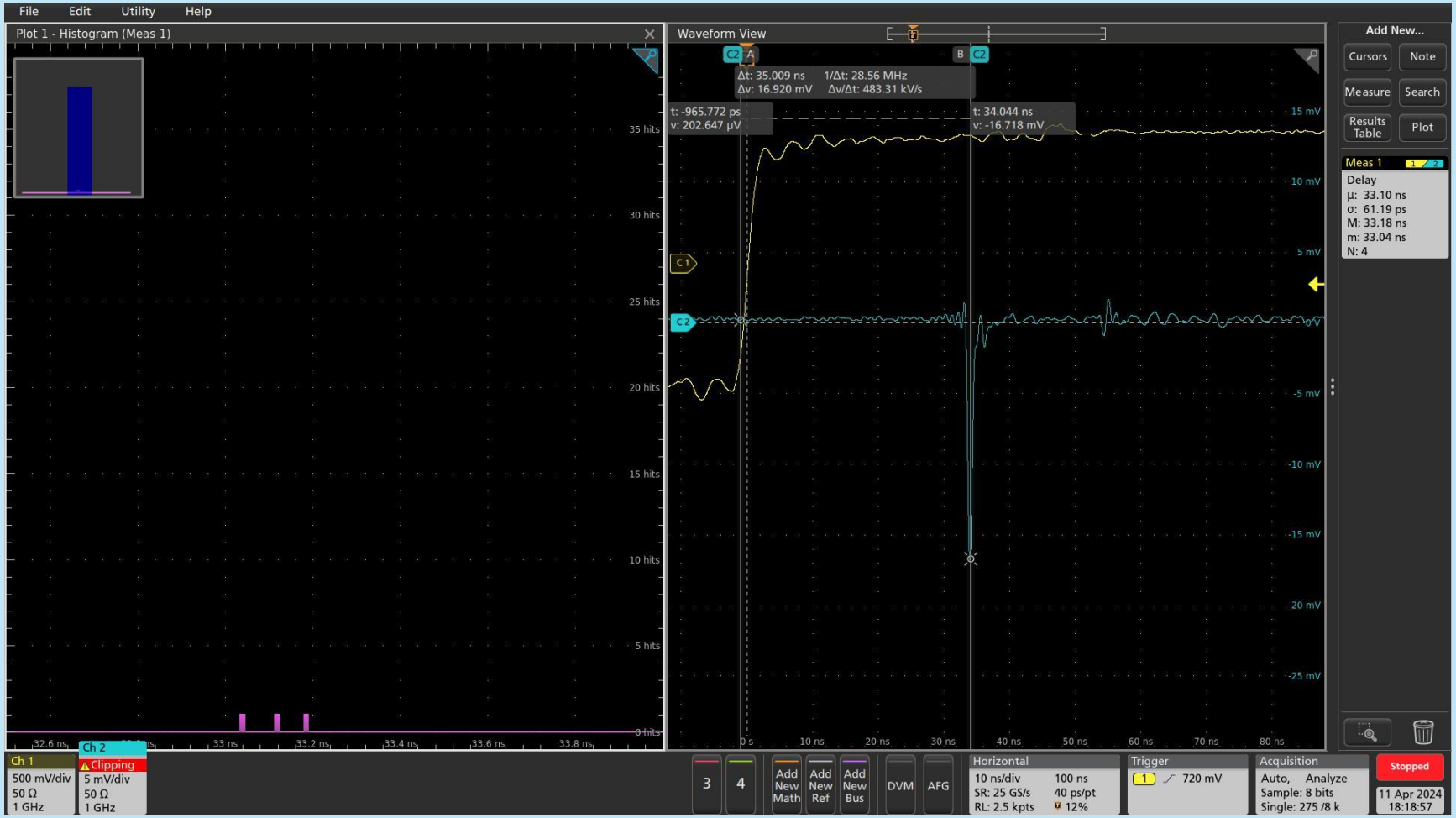
Laser trig OUT

Gate generator (3kHZ)

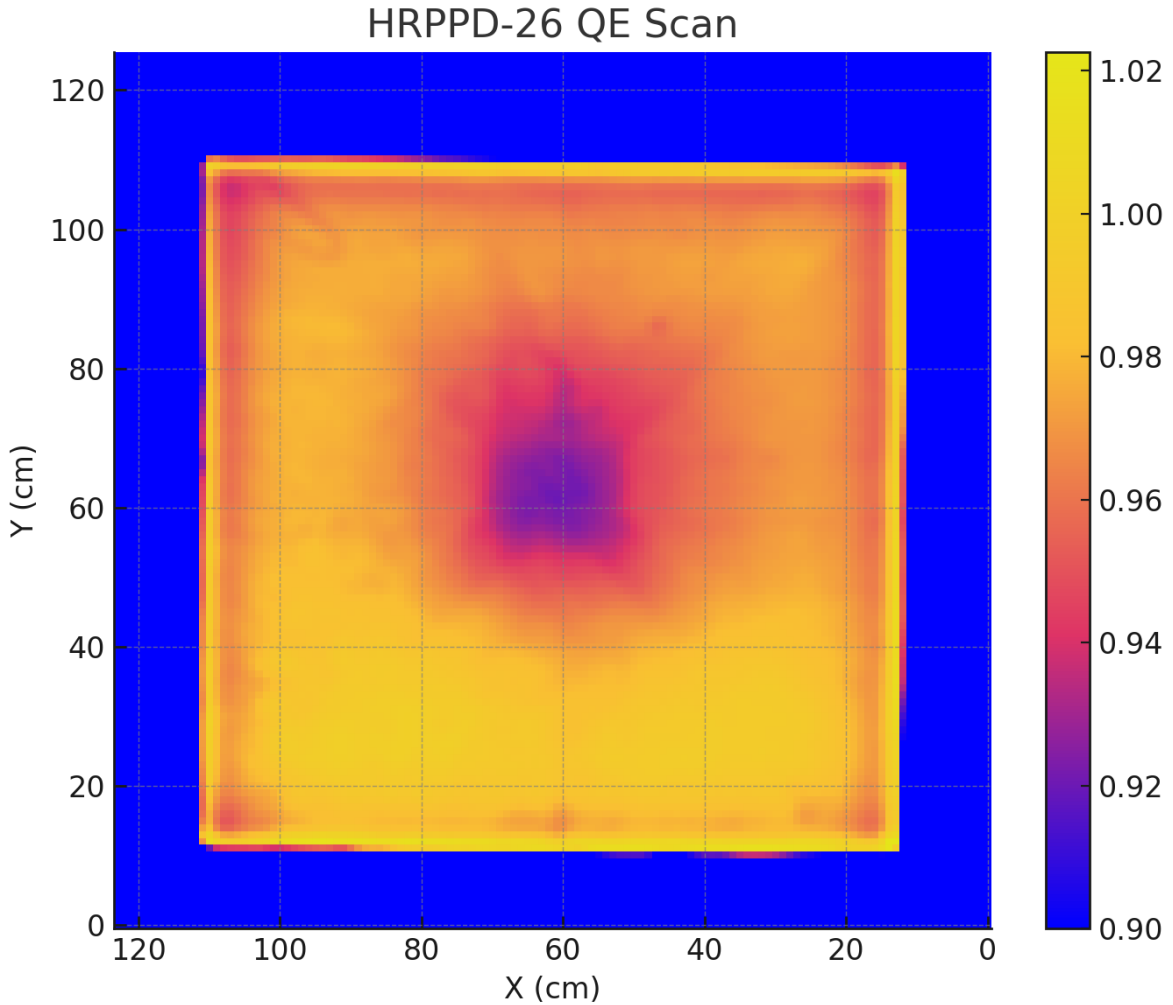
Scaler

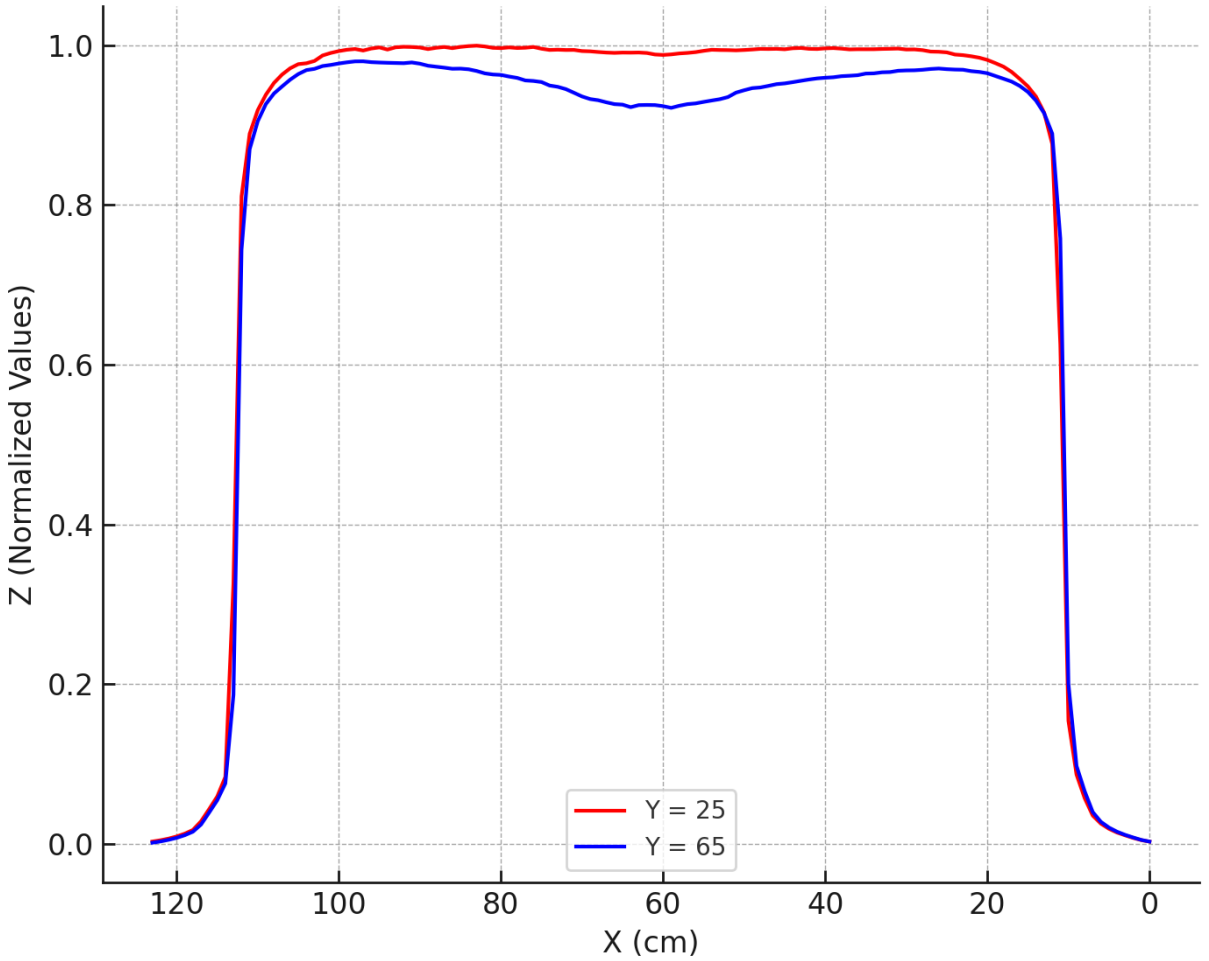
Dark Rate measurement

SPE amplitude example

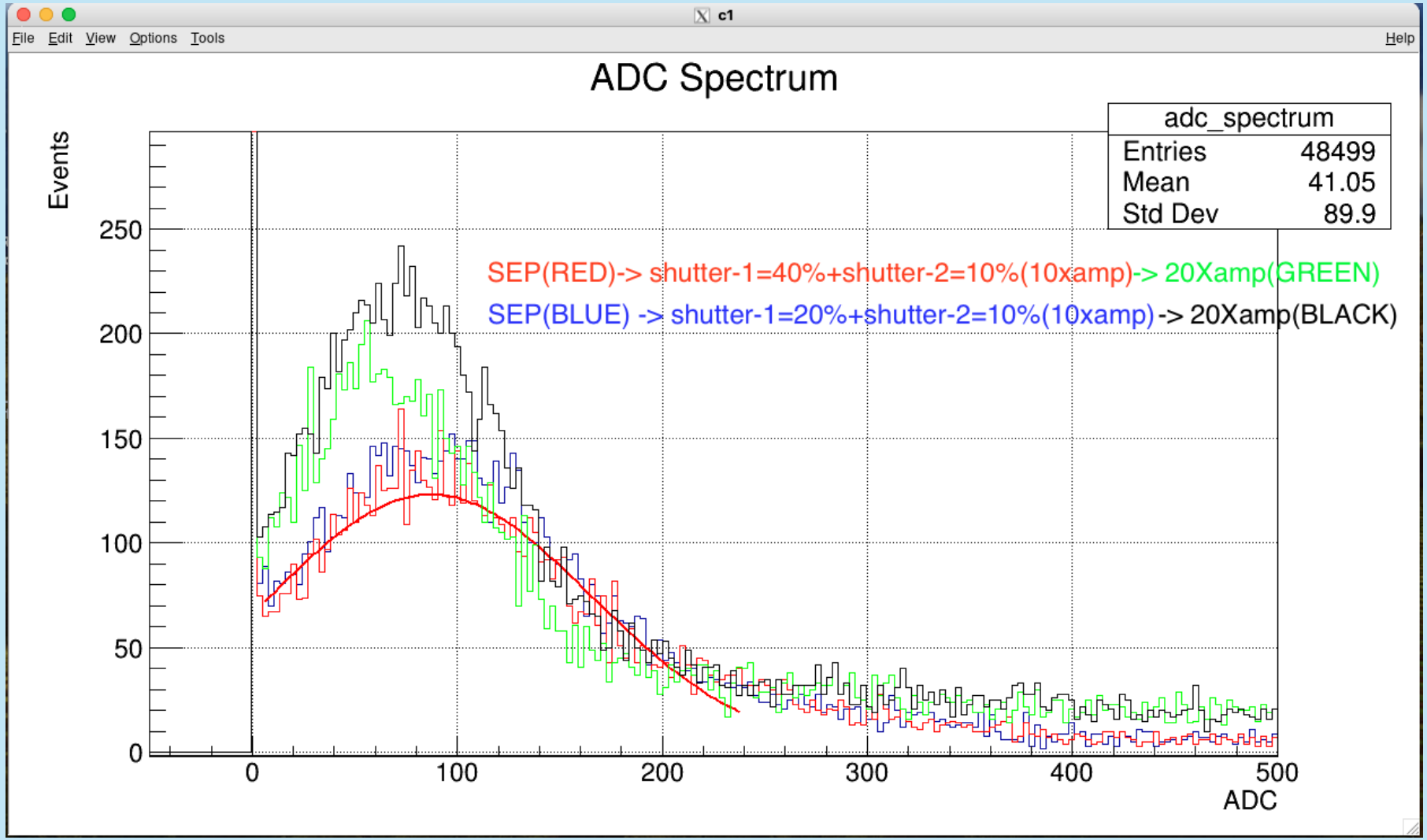


Amplitude example for one SPE event between 15mV and 20mV


HRPPD-26 QE Scan
Y (cm)
X (cm)
120
100
80
60
40
20
0
1.02
1.00
0.98
0.96
0.94
0.92
0.90

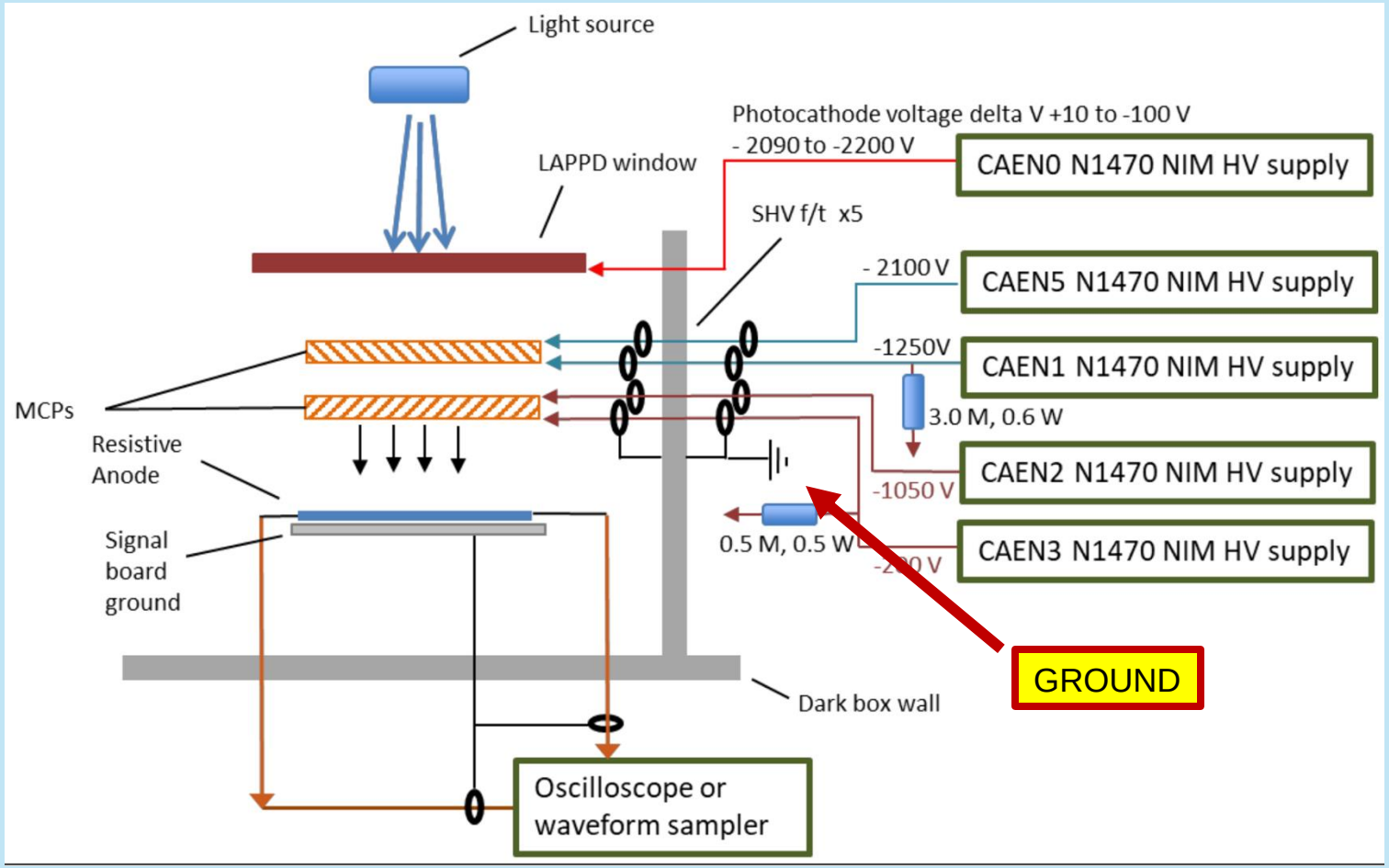

Z (Normalized Values)
X (cm)
1.0
0.8
0.6
0.4
0.2
0.0
120
100
80
60
40
20
0
Y = 25
Y = 65

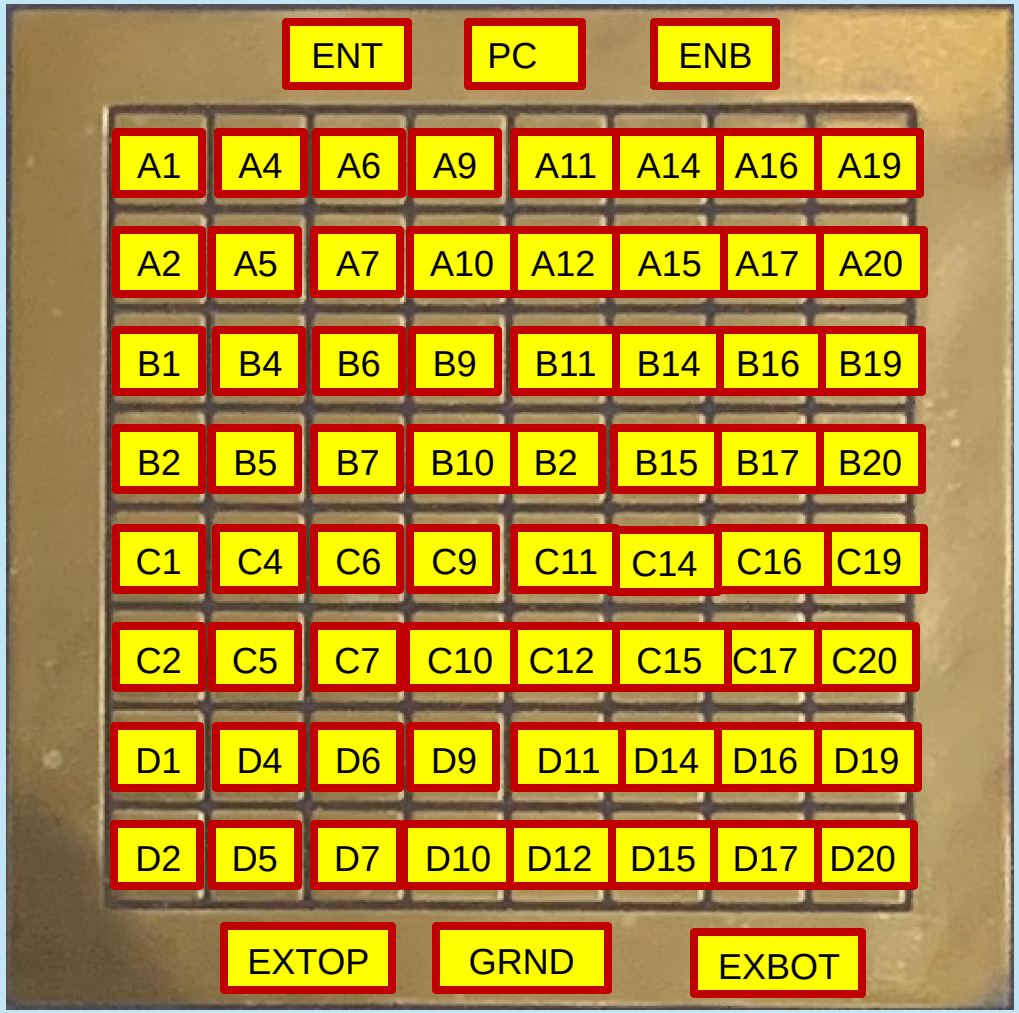
Single Electron Peak

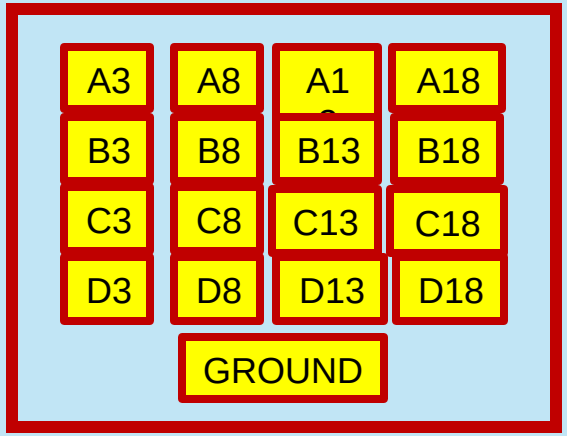


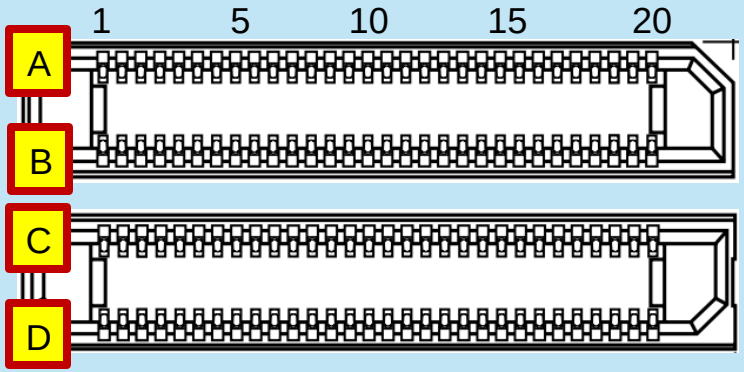
Results from ARC building test setup

HV connection schematic
(provided by INCOM)




ENT
PC
ENB
A1 A4 A6 A9 A11 A14 A16 A19
A2 A5 A7 A10 A12 A15 A17 A20
B1 B4 B6 B9 B11 B14 B16 B19
B2 B5 B7 B10 B2 B15 B17 B20
C1 C4 C6 C9 C11 C14 C16 C19
C2 C5 C7 C10 C12 C15 C17 C20
D1 D4 D6 D9 D11 D14 D16 D19
D2 D5 D7 D10 D12 D15 D17 D20
EXTOP
GRND
EXBOT


A3 A8 A1 A18
B3 B8 B13 B18
C3 C8 C13 C18
D3 D8 D13 D18
GROUND


1
5
10
15
20
A
B
C
D

Readout Map