Hardware camp

# Group C


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# Objectives

**Sensors characteristic** →

- Noise
- Raising Falling time
- Sensitivity
- Dynamic Range

**Filtered signal**

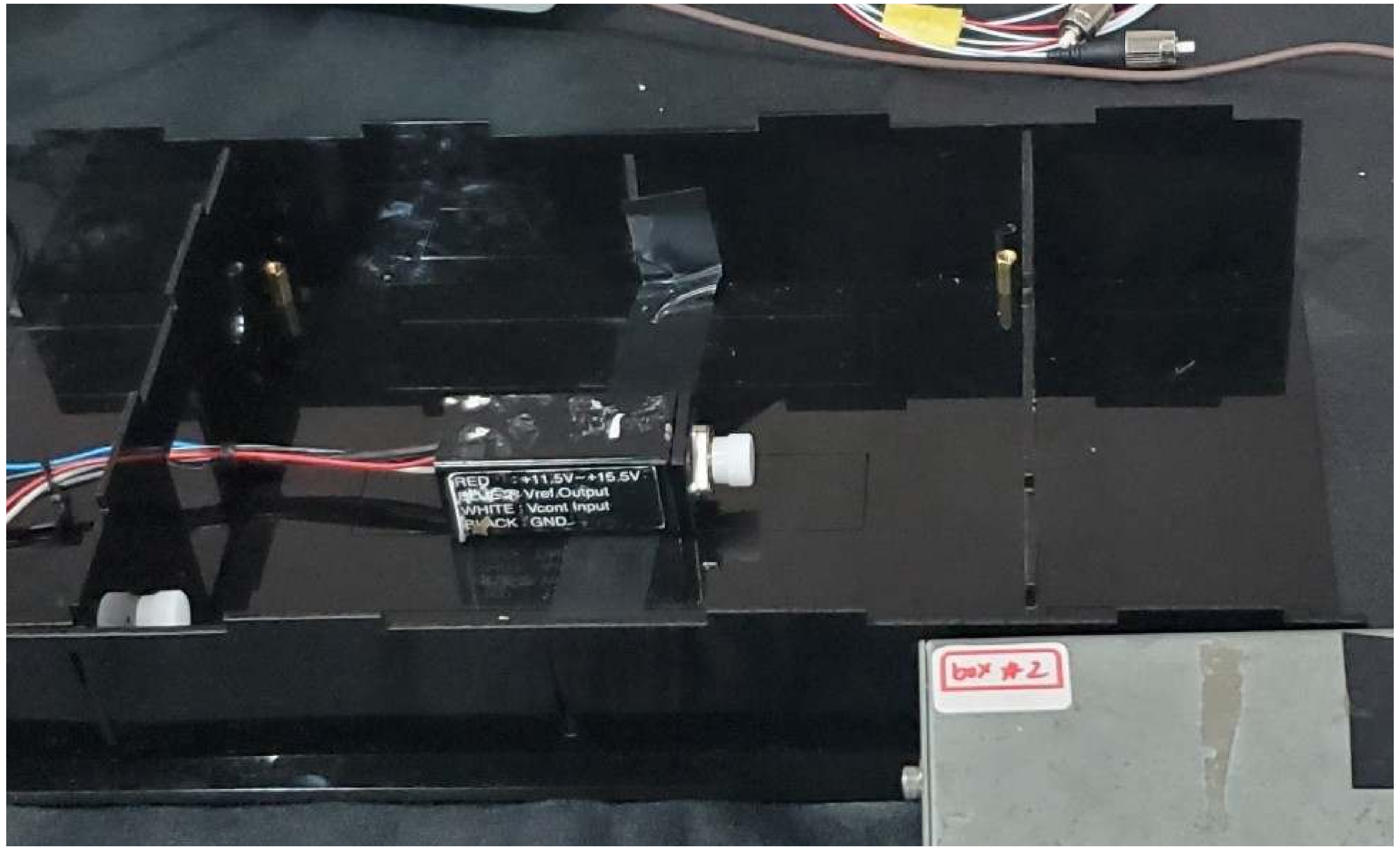
**Cosmic Ray** →

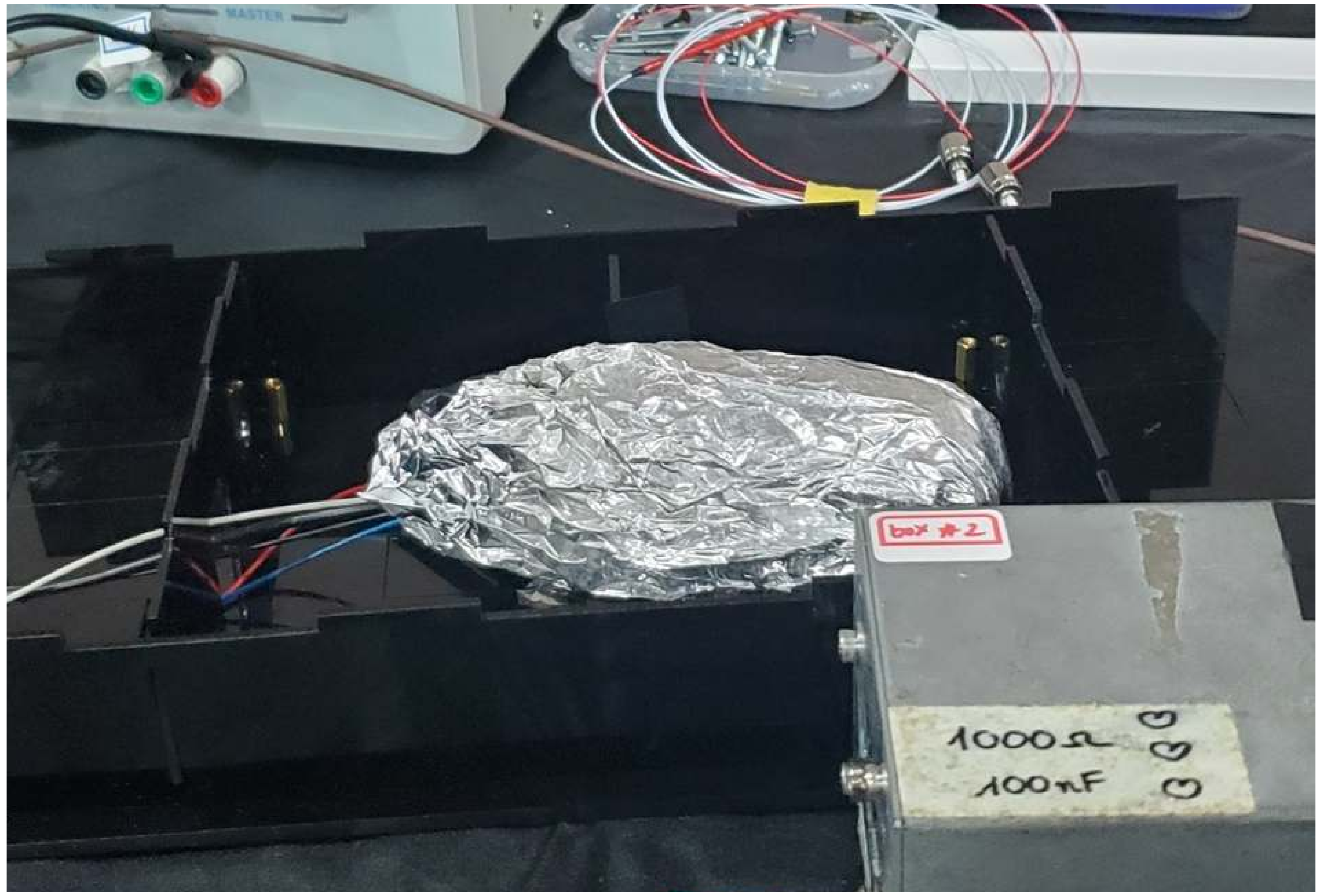
- Measuring Cosmic Muon Rate
- Optimizing Trigger Threshold
- Muon Decay Event

# NOISE RATE

## NOISE RATE

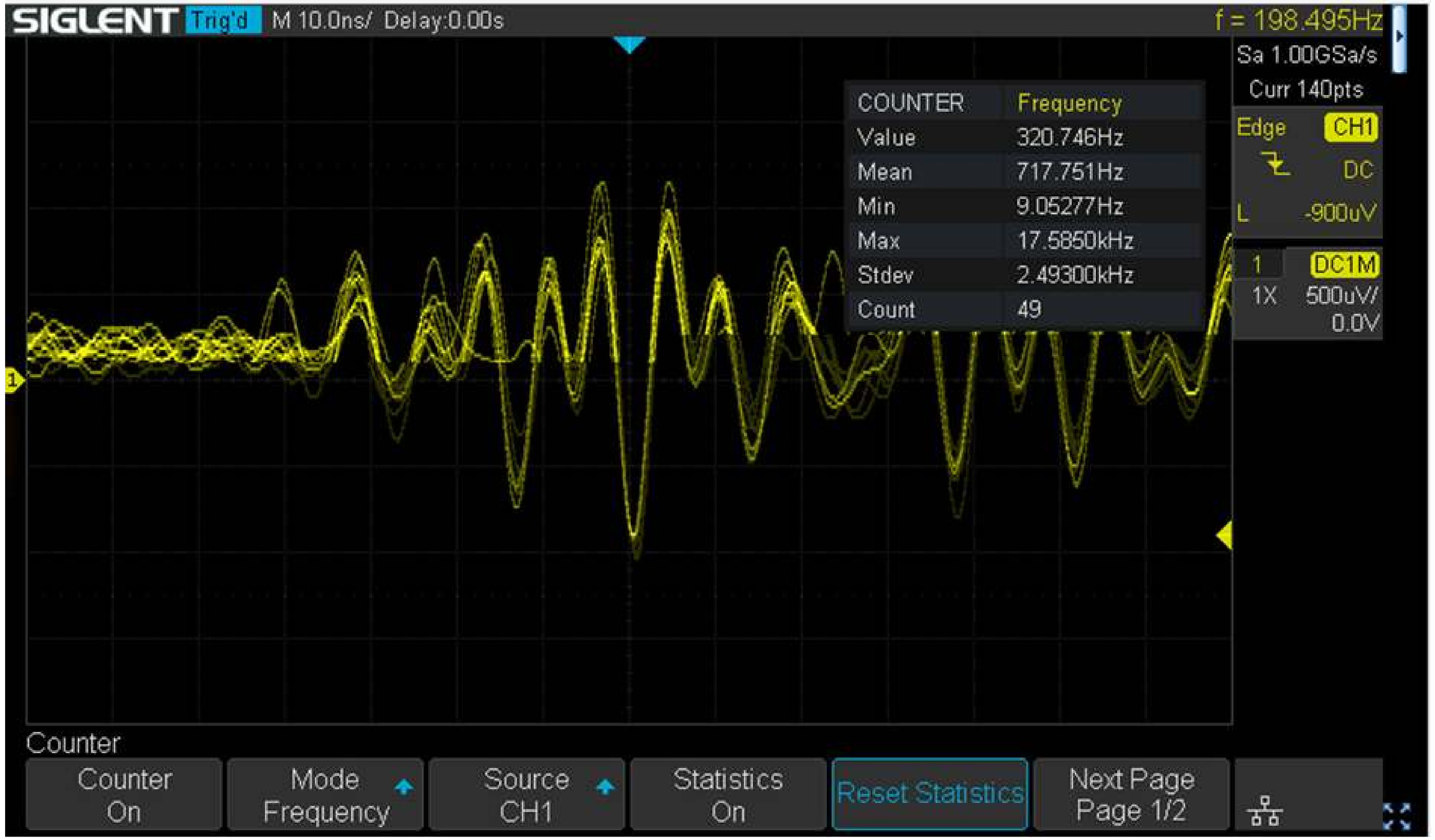
# Environmental setup



# NOISE RATE

## PMT signal




PowerOff

# NOISE RATE

## PMT signal


-0.9mV_PowerOn


-1mV_PowerOn

# MPPC Signal

| | 0.5 pe | | 1.5 pe | | 2.5 pe | |
|---|---|---|---|---|---|---|
| 56.07 V | -0.68mV | 23.9±6Hz | -1.25mV | 537±256Hz | -1.82mV | No signal |
| 57.06 V | -0.75mV | 56±4kHz | -1.46mV | 796±232Hz | -2.17mV | 30±60Hz |
| 58.05 V | -0.81mV | 71±6kHz | -1.66mV | 1.1±0.15kHz | -2.51mV | 15±6Hz |

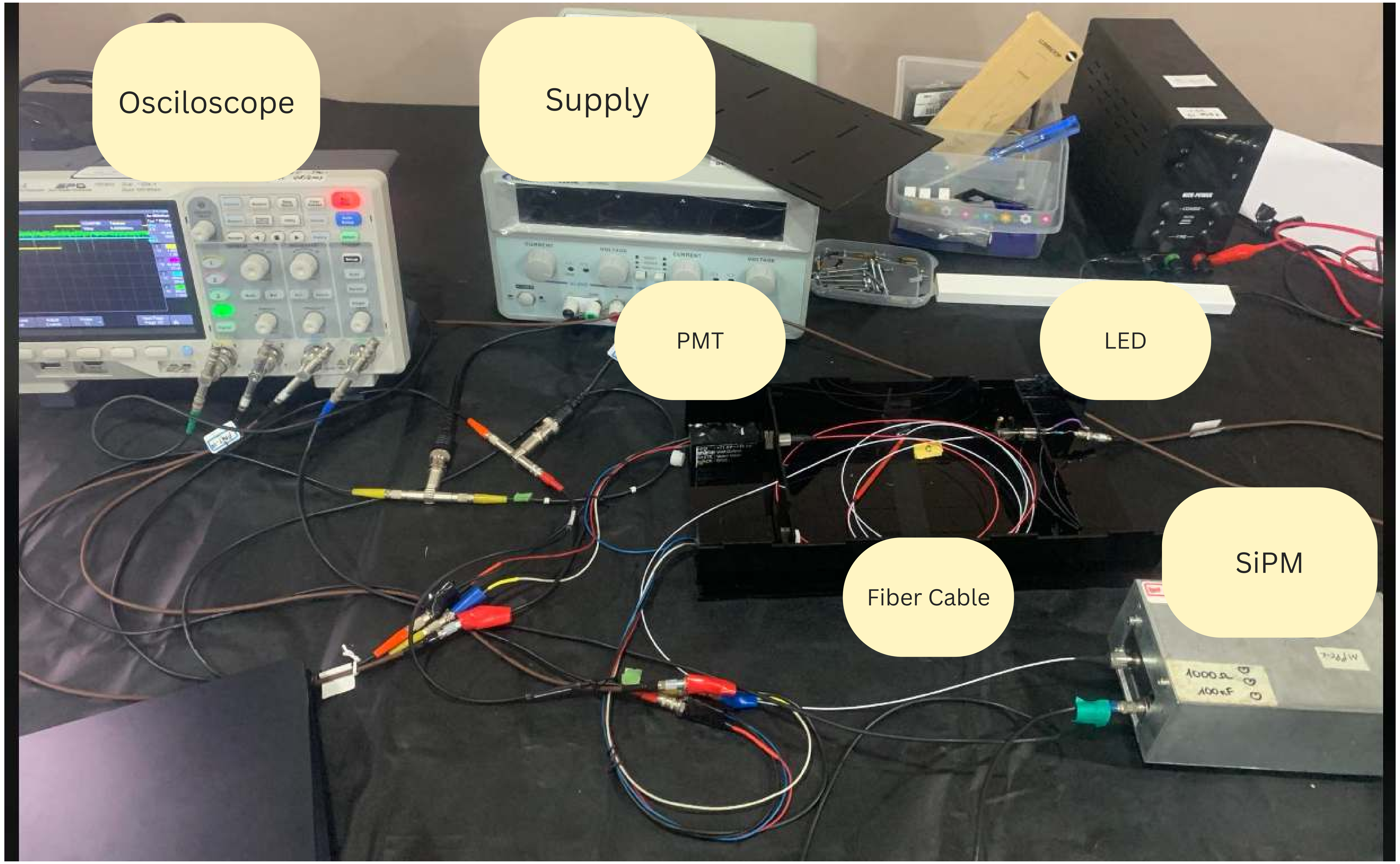
# Comparison

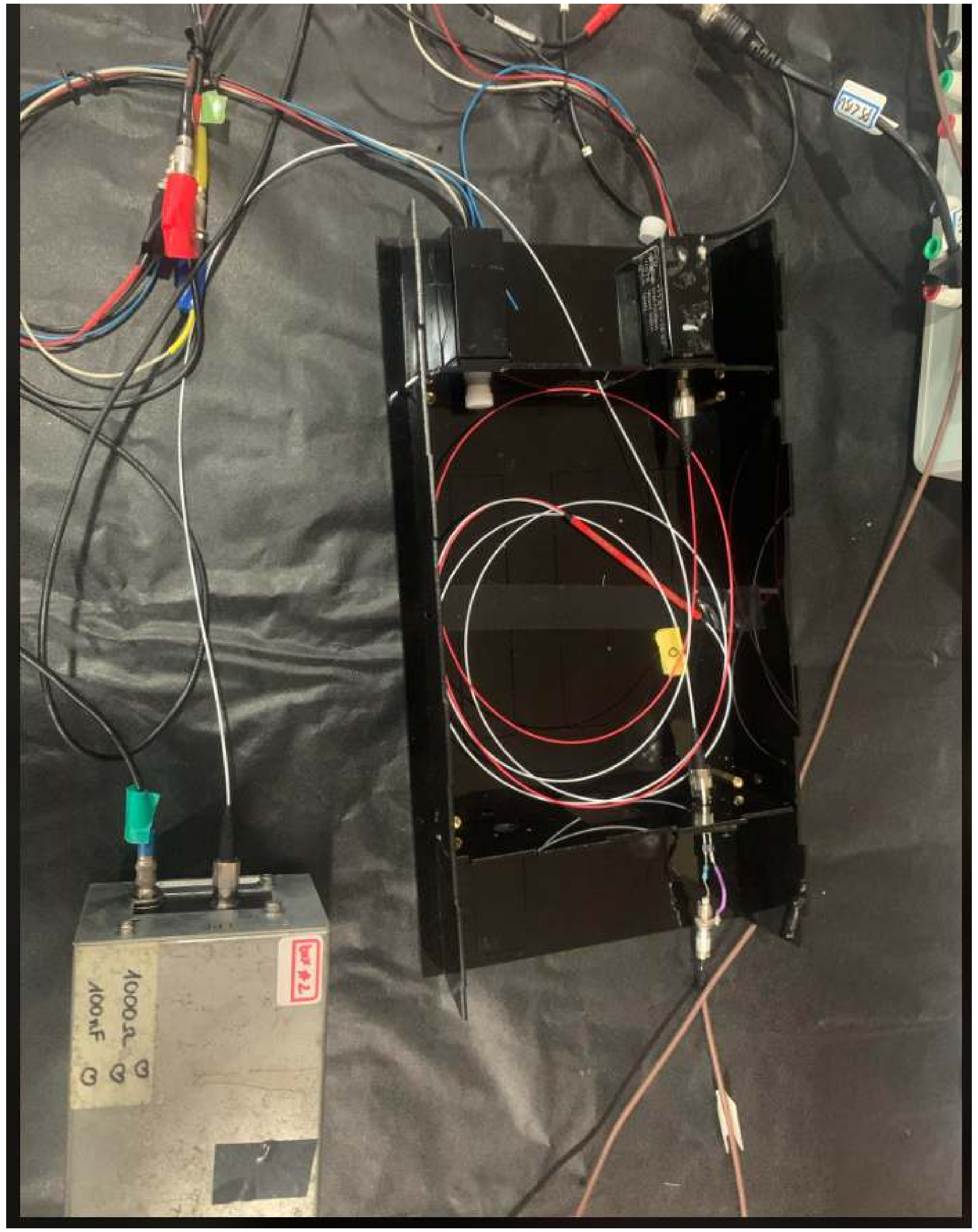
- The case with 57.06 voltage and 0.5 PE threshold level gives us a good MPPC noise rate.

- For both PMT and MPPC results, the MPPC at the 0.5 PE threshold is more stable than the PMT with less uncertainty.

# Rising and Falling time

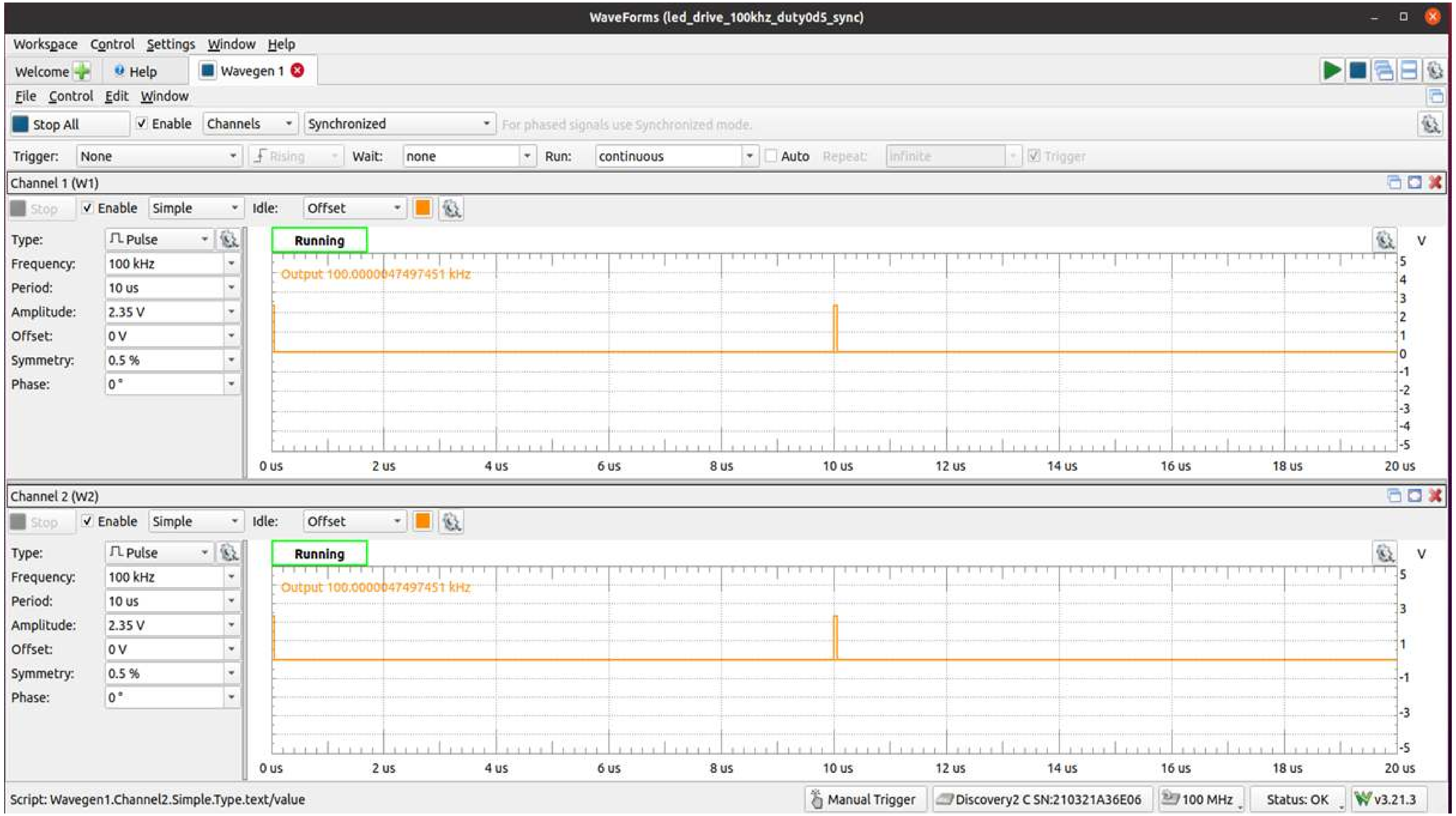
# SETUP



## RISING AND FALLING TIME

# Waveform generator

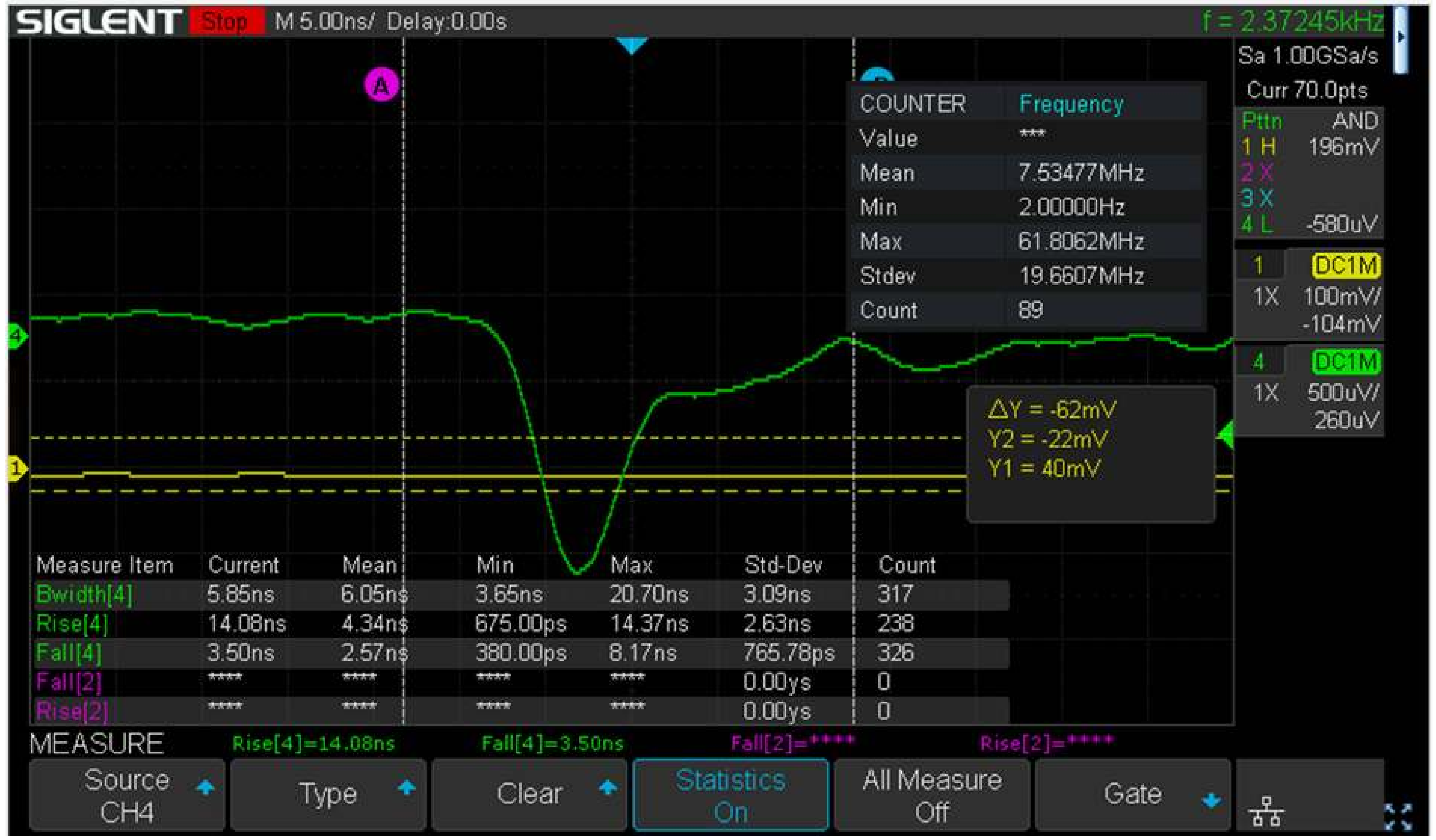



**f:100k(hz)**

**symmetry: 0.5%**

# PMT Measurement

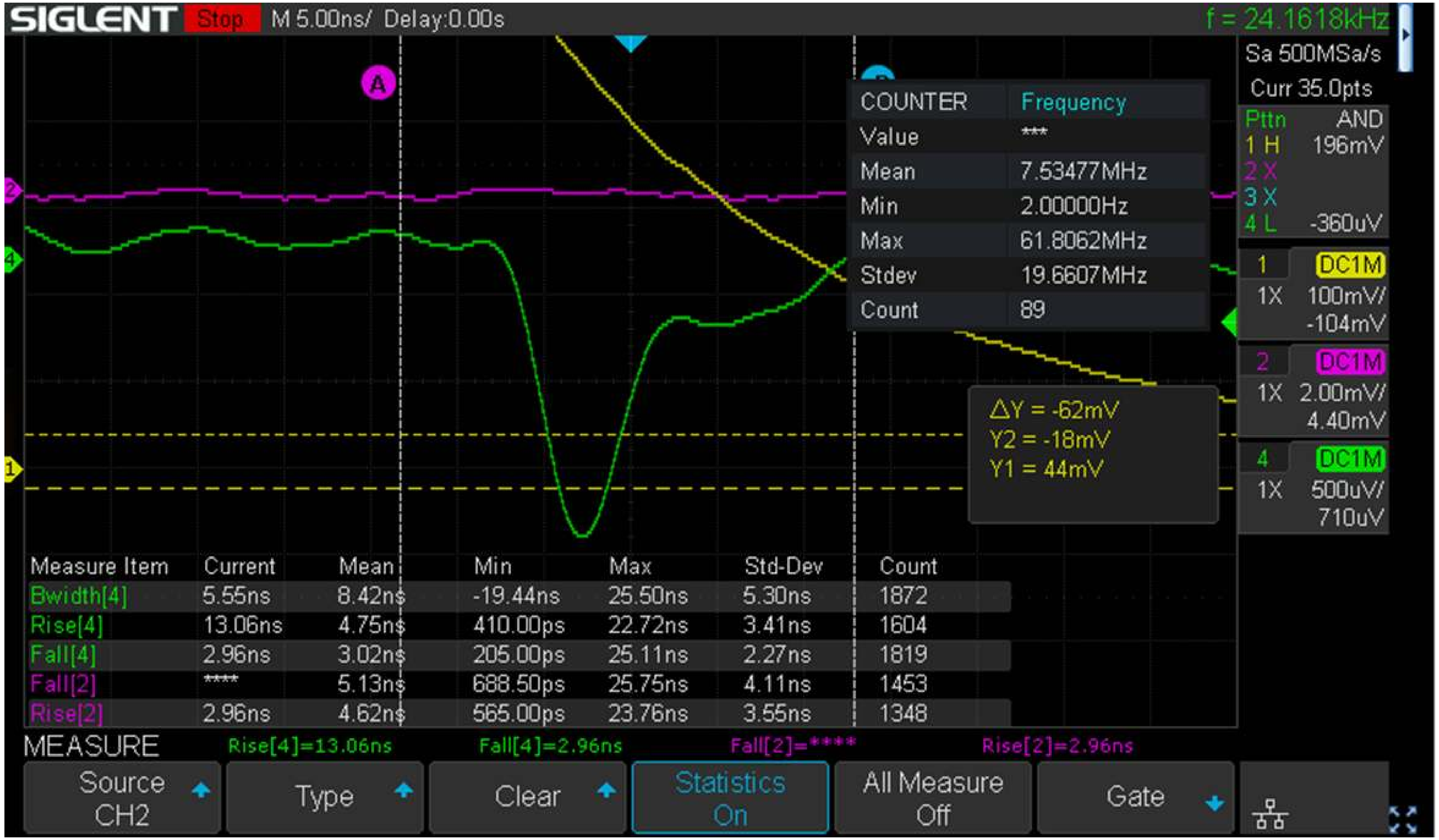

**Rising time: 2.98 ± 0.81 ns**
**Falling time: 2.35± 0.53 ns**




**Rising time: 14.08 ± 2.63 ns**
**Falling time: 8.17± 0.77 ns**

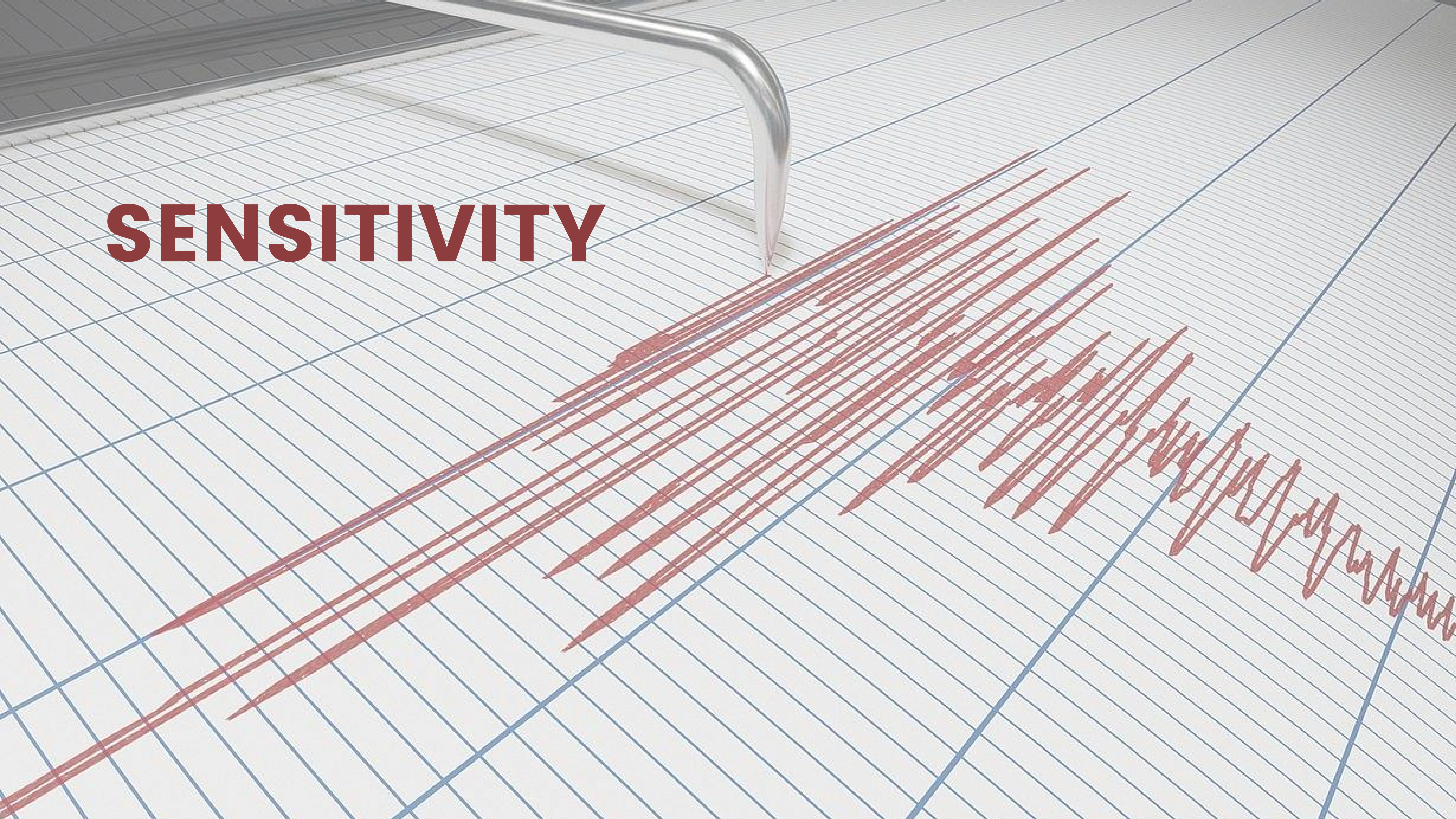
## RISING AND FALLING TIME

# PMT Measurement

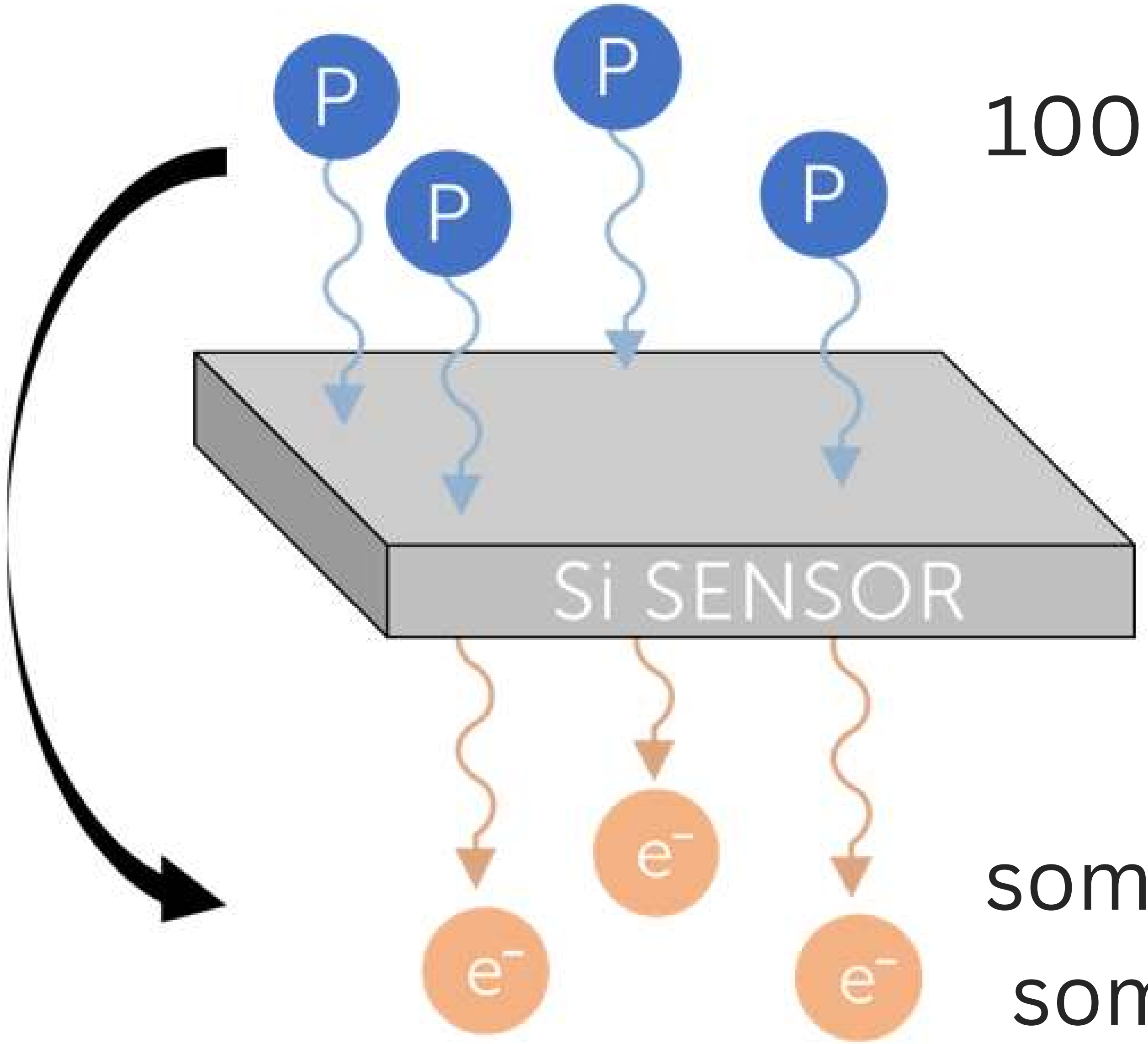


- **Both the rising time and falling time of PMT are smaller than SiPM.**
    - **With a tiny standard deviation, PMT allows us to experiment with better results.**
- **When we measure PMT and SiPM simultaneously, their rising time and falling time are similar. Thus, we have fundamental to compare the results of us in other experiment later.**

# SENSITIVITY



# Theory and Method

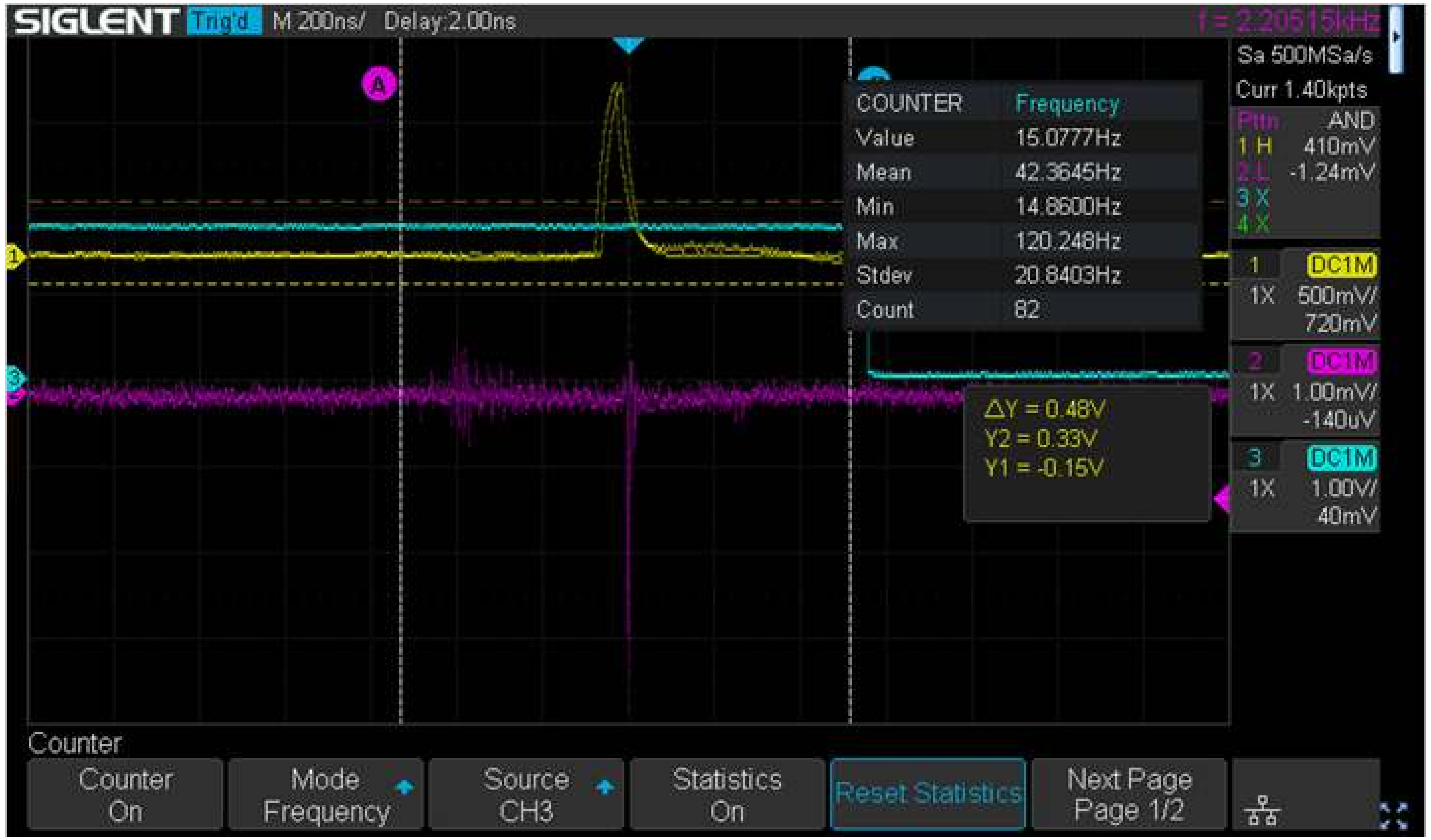



100 Photons

some received
some will not

Make a 100khz signal
Count numbers of received signal each
seconds

# PMT




| Supply voltage | Receiving freq (Hz) |
| --- | --- |
| 2.3V | 40±20 |
| 2.31V | 60±17 |
| 2.32V | 100±21 |

# SiPM


| Supply voltage | Received freq |
|---|---|
| 2.3V | 1200±213 |
| 2.31V | 1450±183 |
| 2.32V | 1700±250 |

# SENSITIVITY

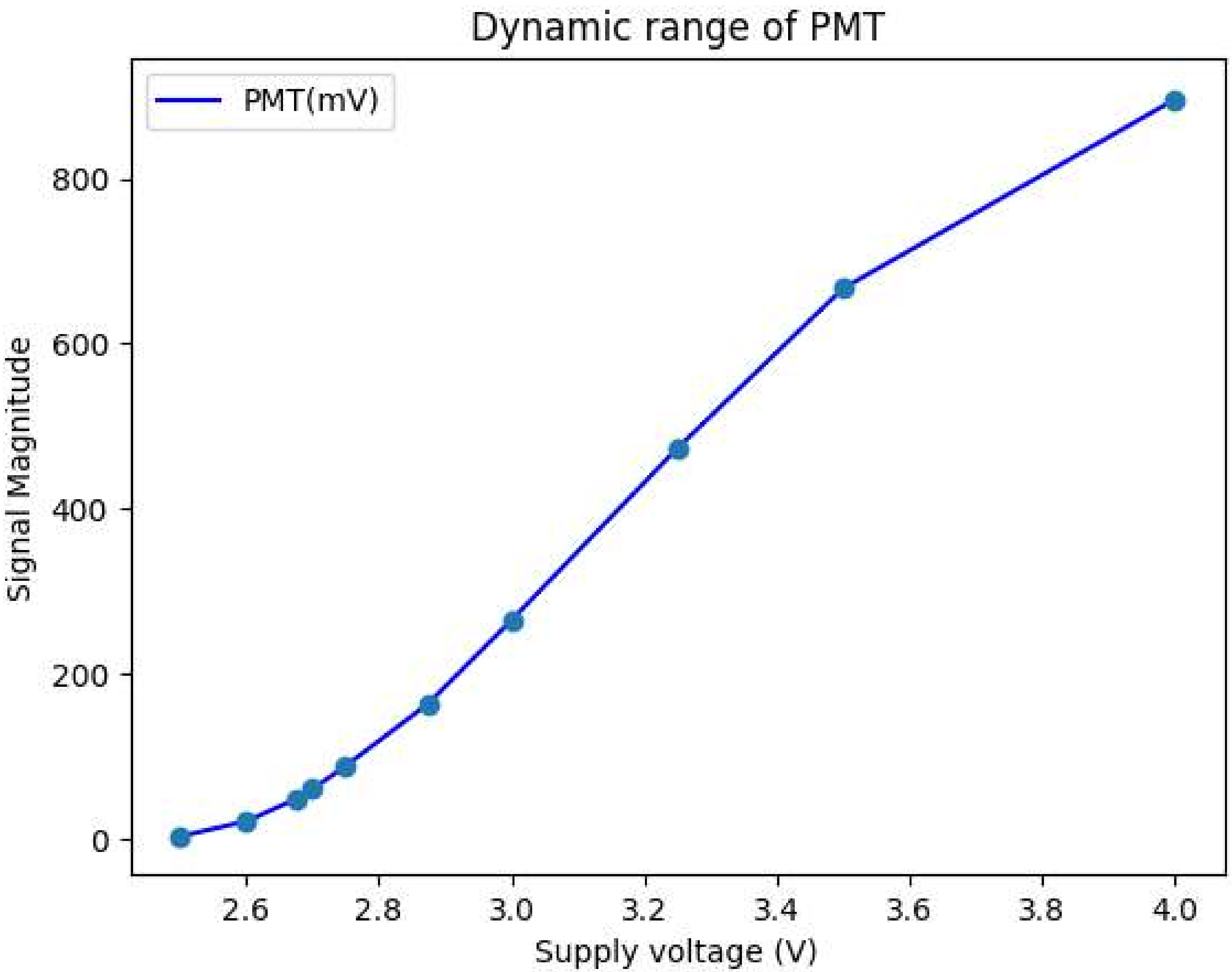
- **In term of this measurement, SiPM has a better sensitivity results**

- **Although the measure result show that SiPM is better, SiPM are designed to catch more wavelength than PMT, as a result it has more chance to catch photon**

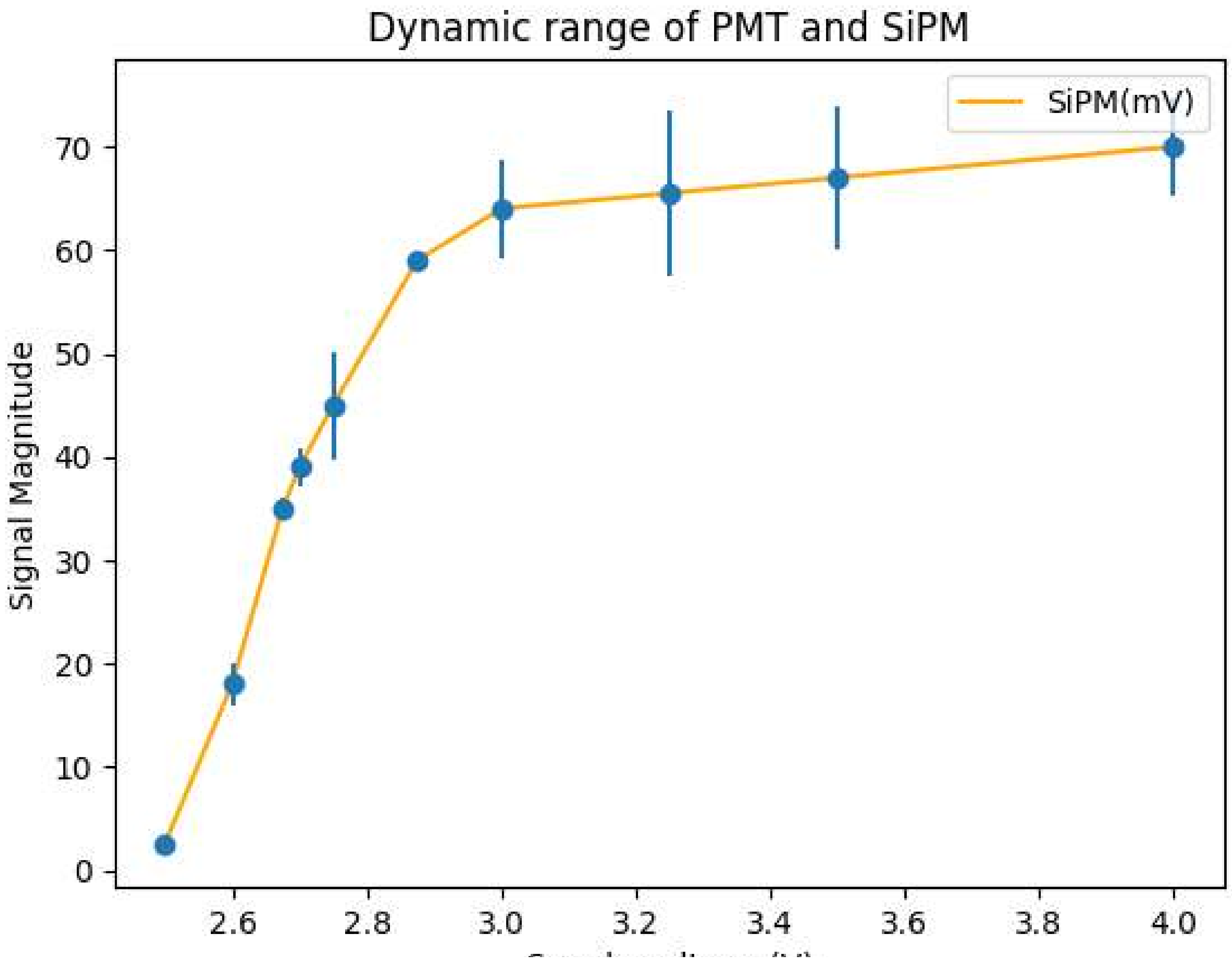

DYNAMIC RANGE
box #2

# Measurement Method

- We want to increase the intensity of photon until the signal is saturated
- Checking the linearity of the PMT sensing

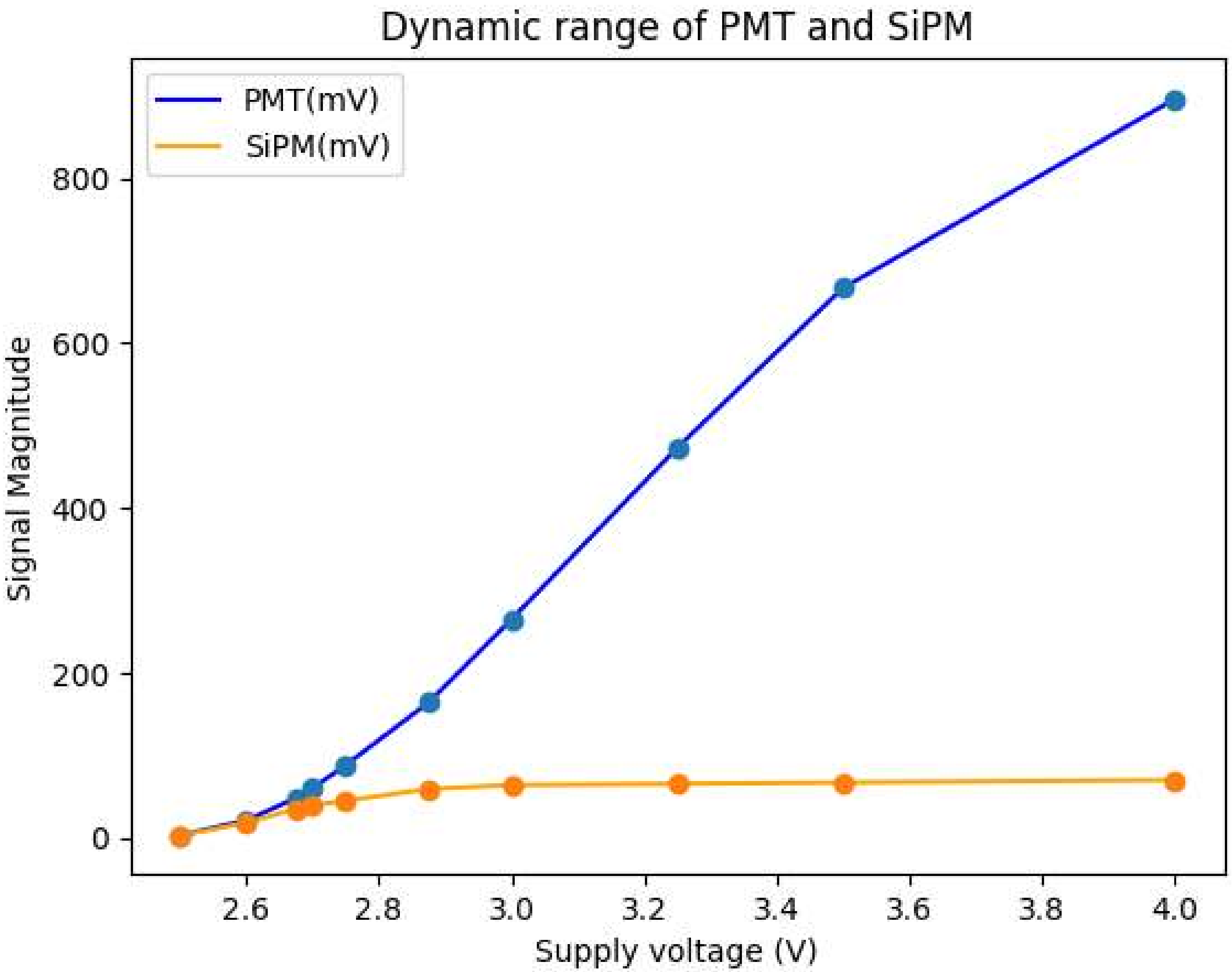



PMT response is linear unitl saturated




SiPM response is linear unitl saturated

# Dynamic Range



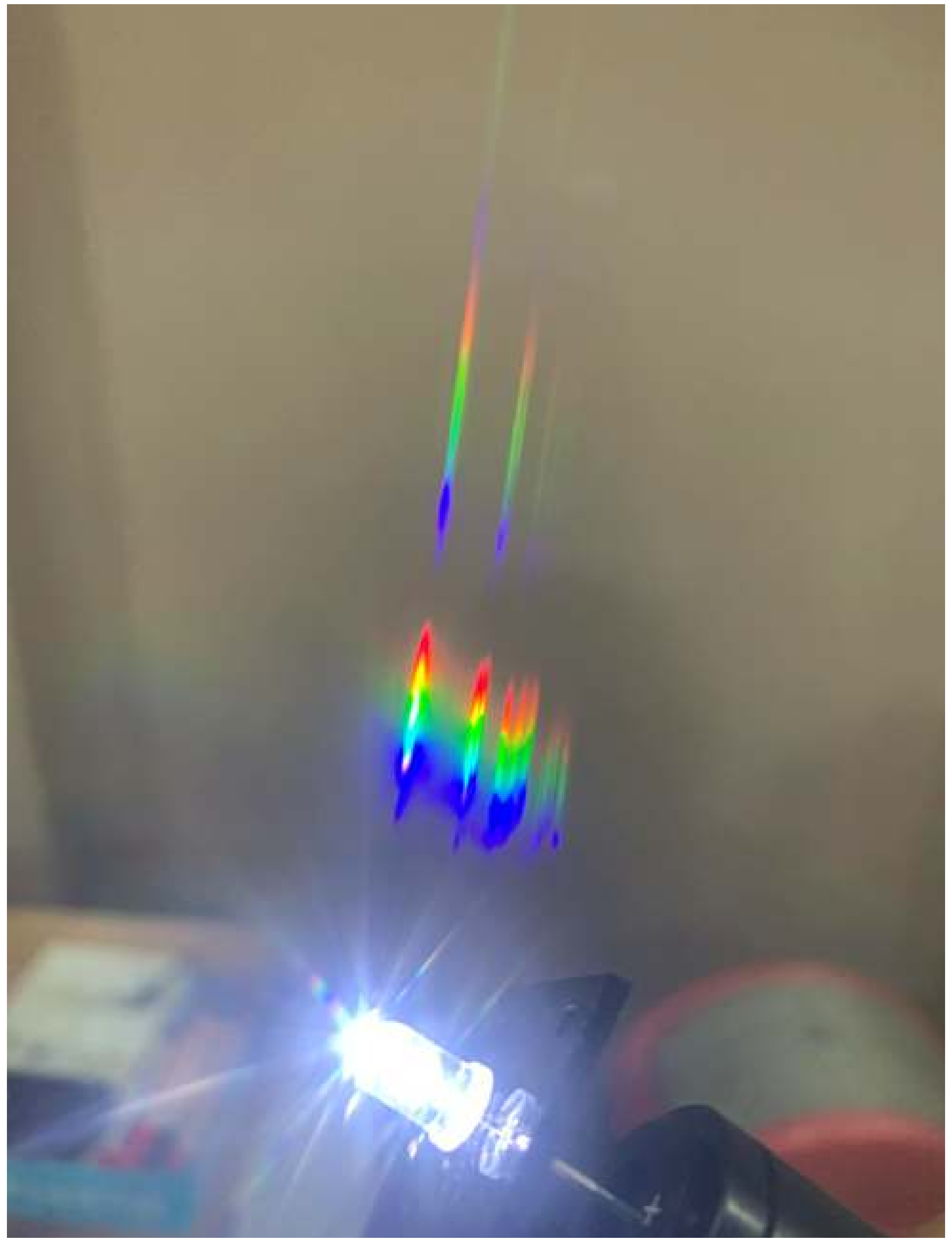

- PMT gives stronger response signal
- PMT have wider dynamic range
- PMT is quietly linear

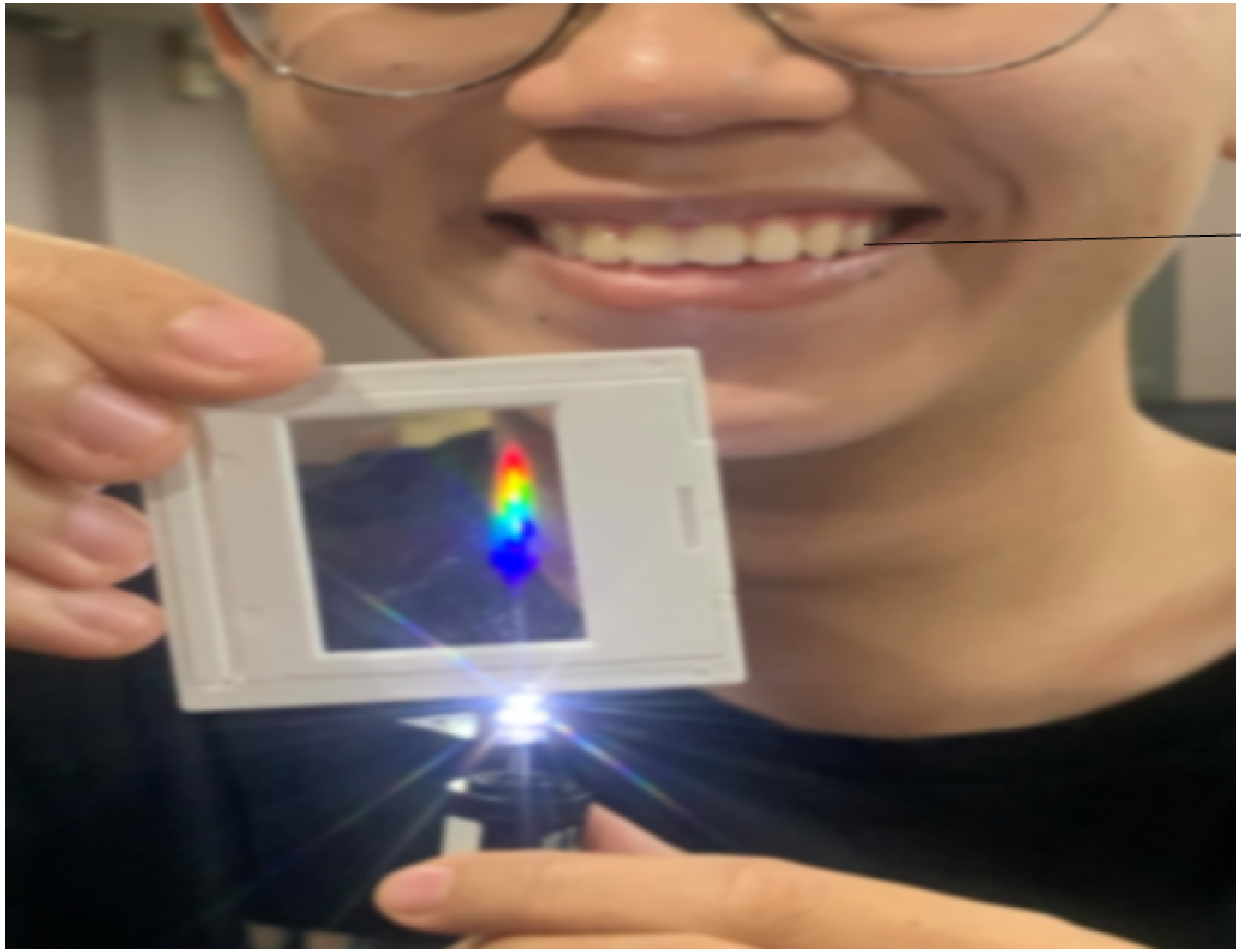
# Characteristic summary

| PMT | SiPM |
| --- | --- |
| Faster rising and falling time | More stable |
| Have a wider dynamic range | more sensitive to photon |

# Filtered Signal Measurement

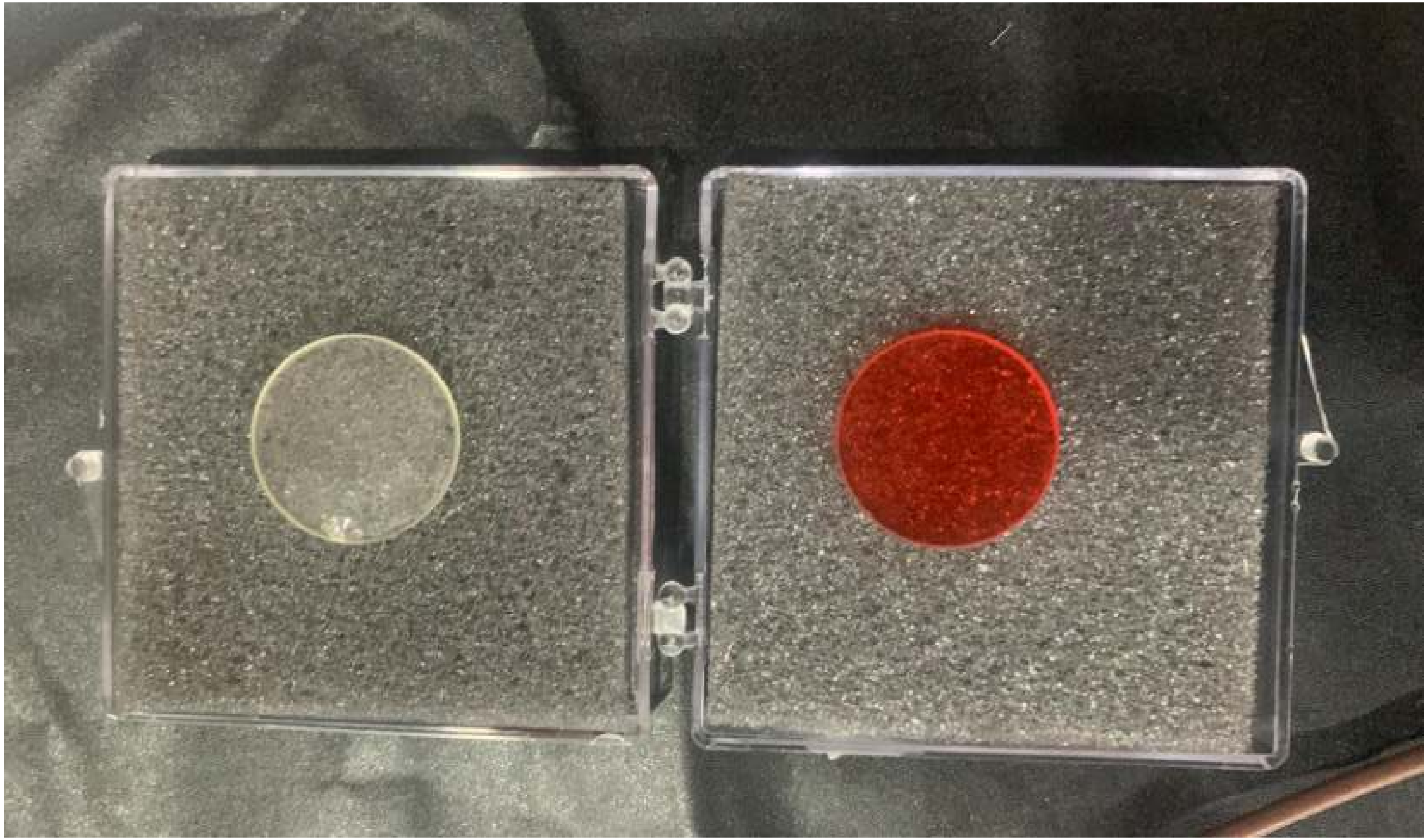
# Filtered Signal Measurement





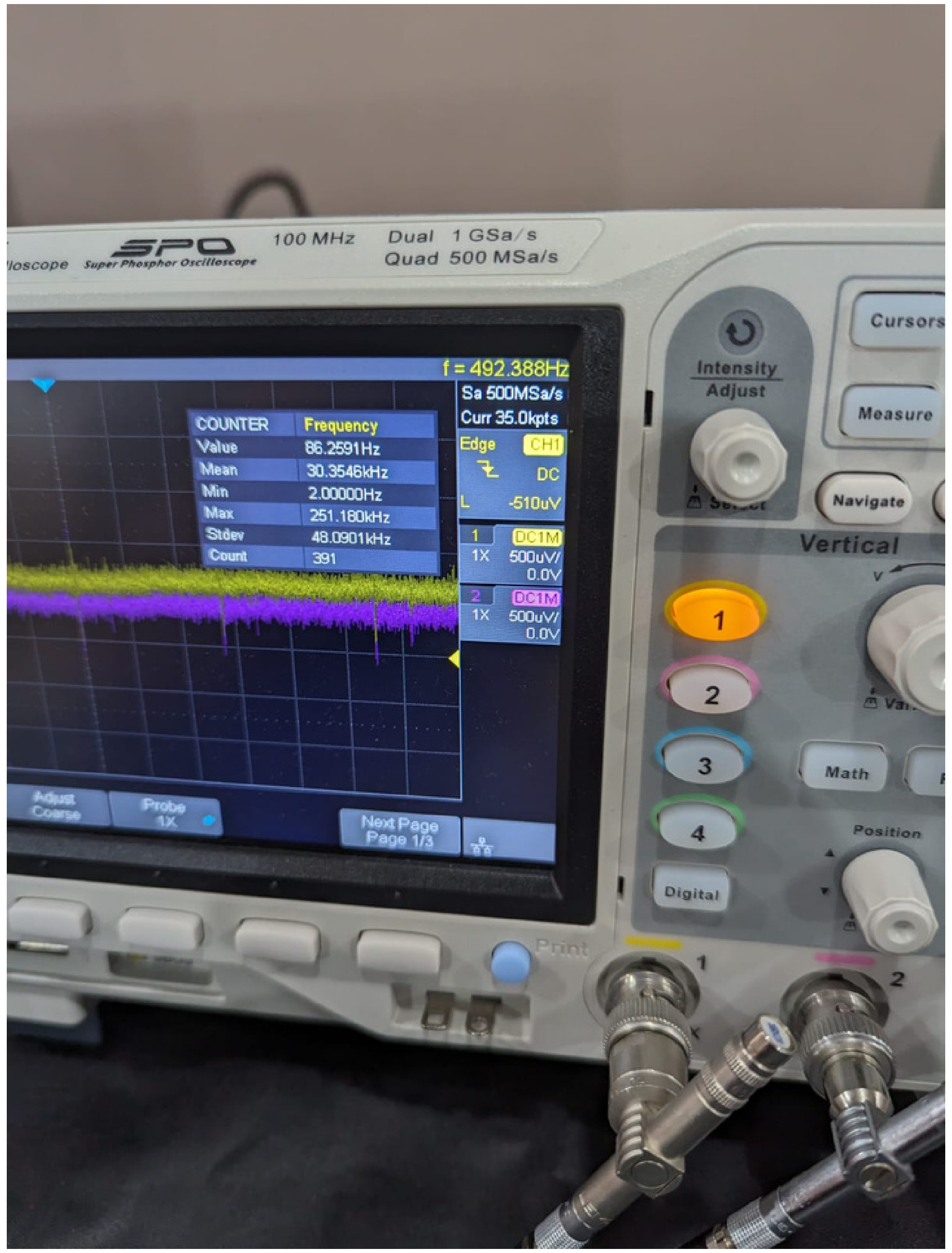
Full bright

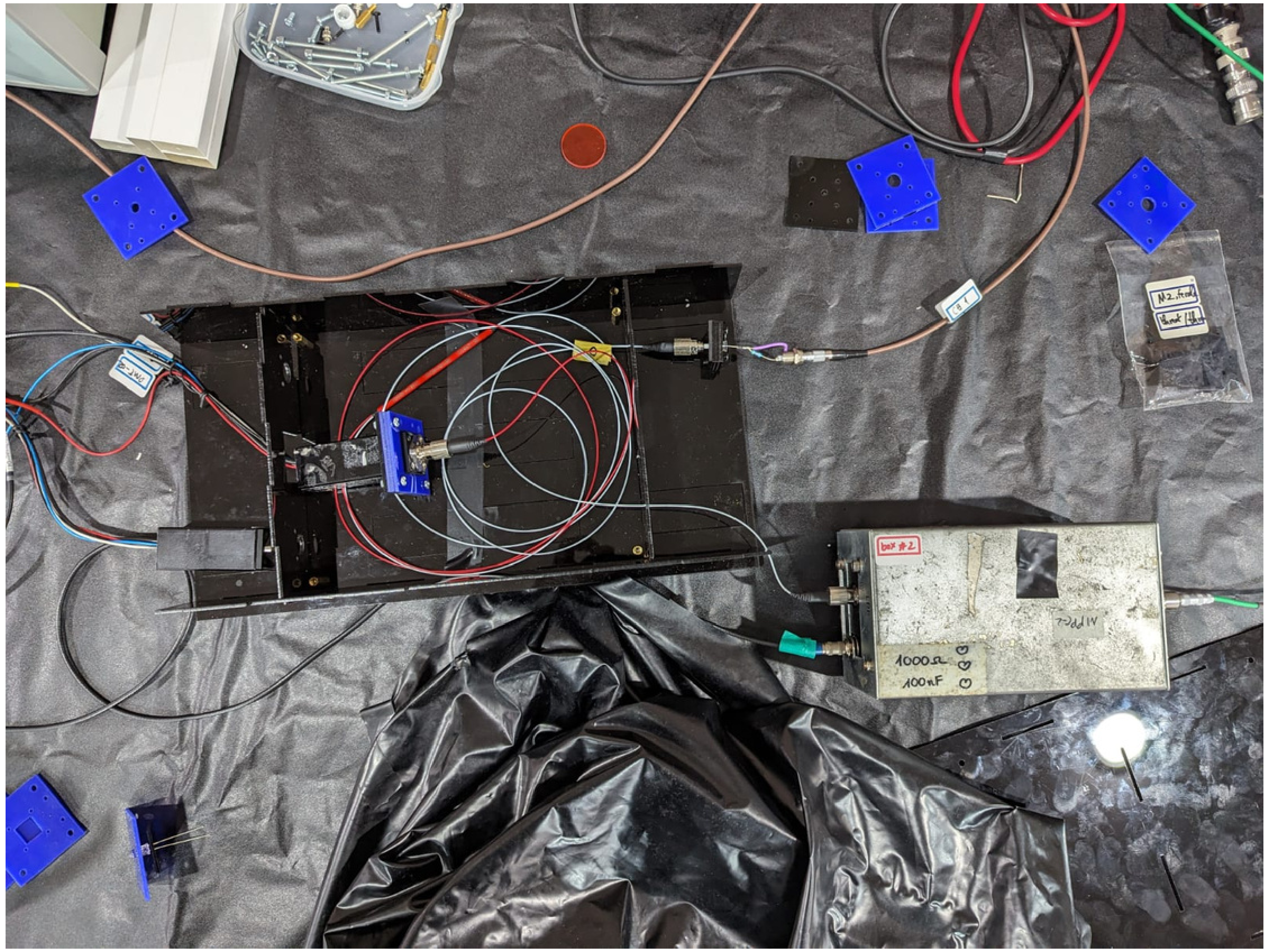
# Filter



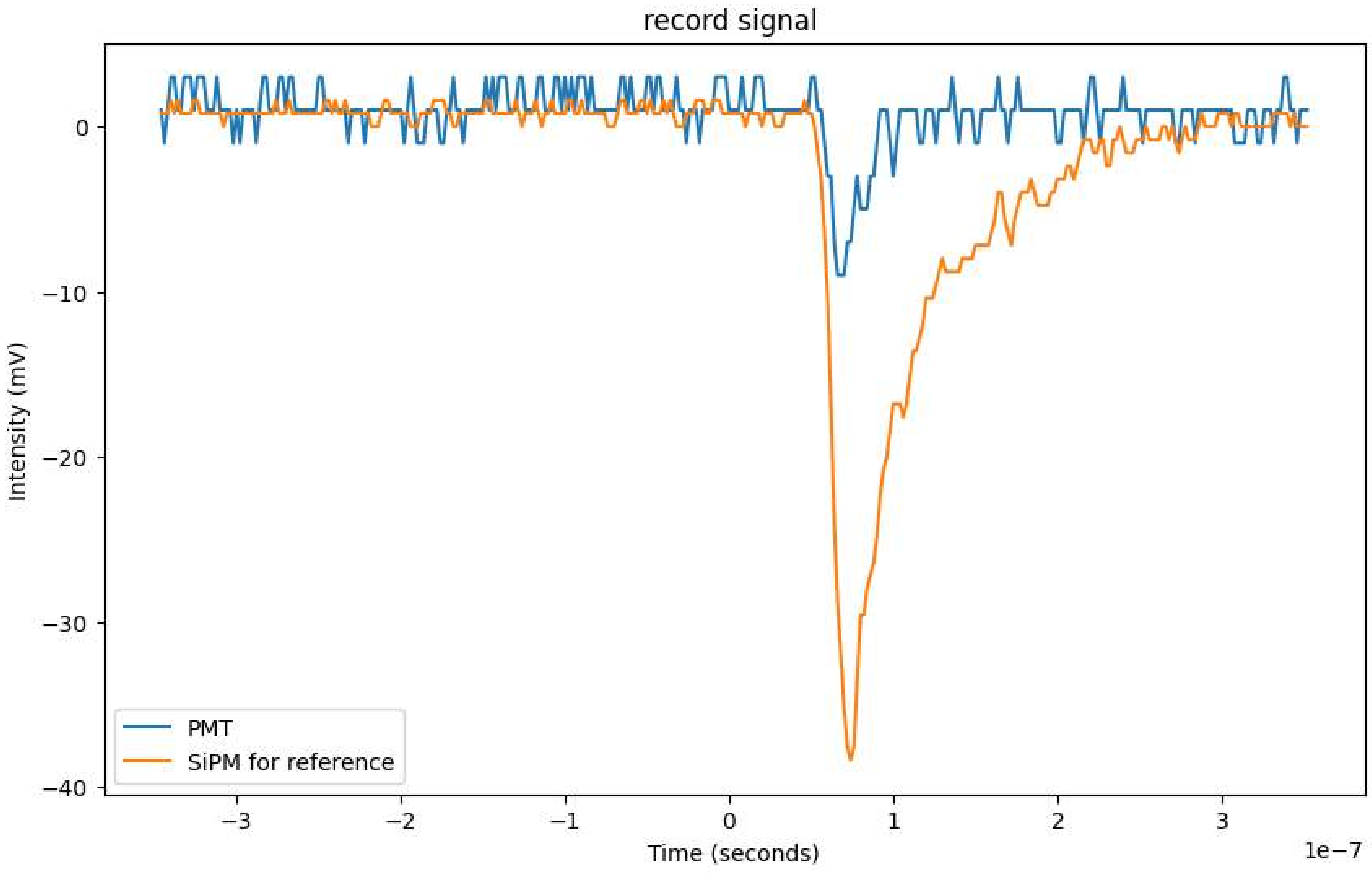
# Set up


56.03
0.000
0.000


Super Phosphor Oscilloscope
100 MHz
Dual 1 GSa/s
Quad 500 MSa/s
f = 492.388Hz
Sa 500MSa/s
Curr 35.0kpts
COUNTER Frequency
Value 86.2591Hz
Mean 30.3546kHz
Min 2.00000Hz
Max 251.180kHz
Stdev 48.0901kHz
Count 391
Next Page Page 1/3
Intensity Adjust
Cursors
Measure
Navigate
Vertical
Math
Position
Digital

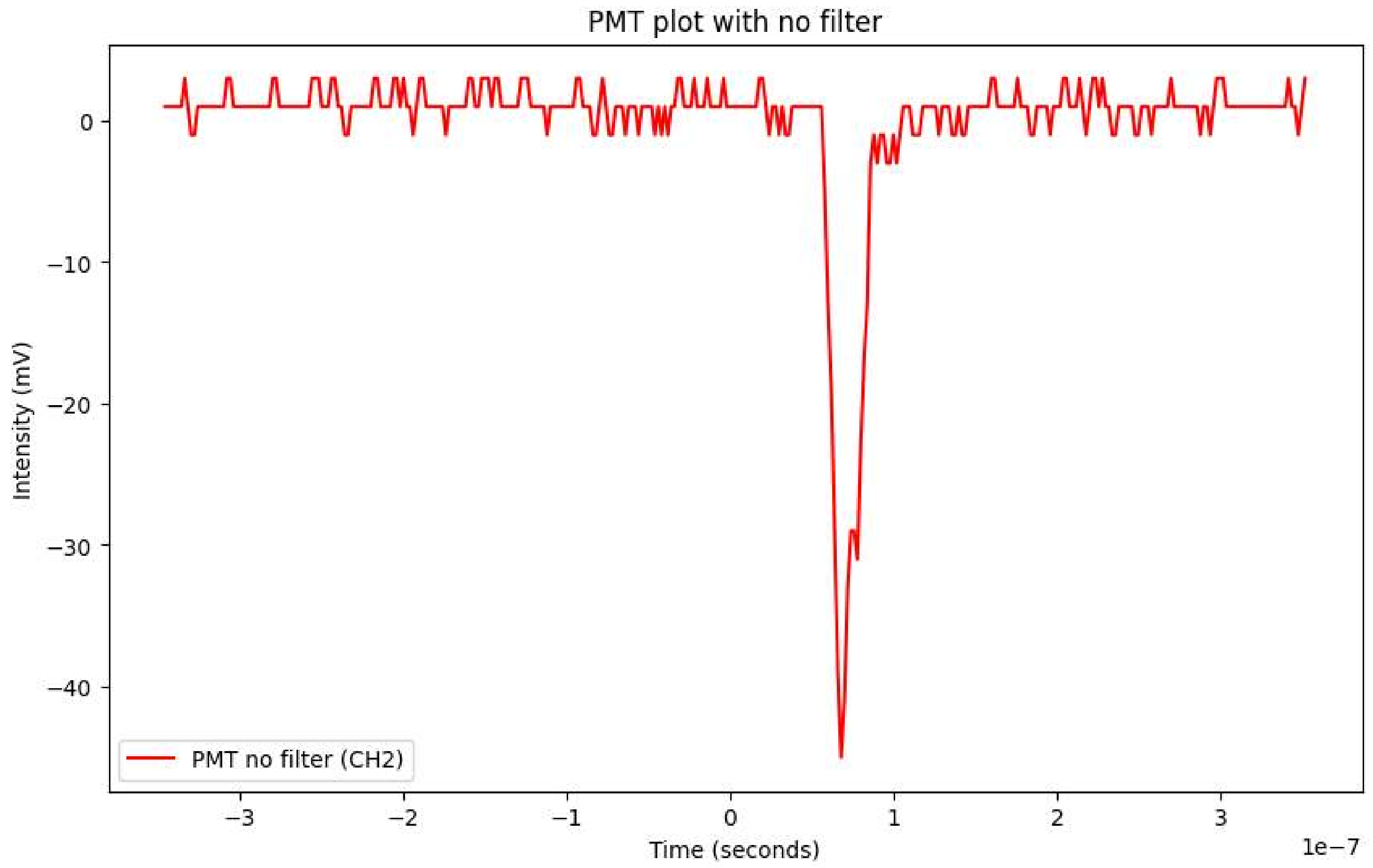

1000Ω
100nF

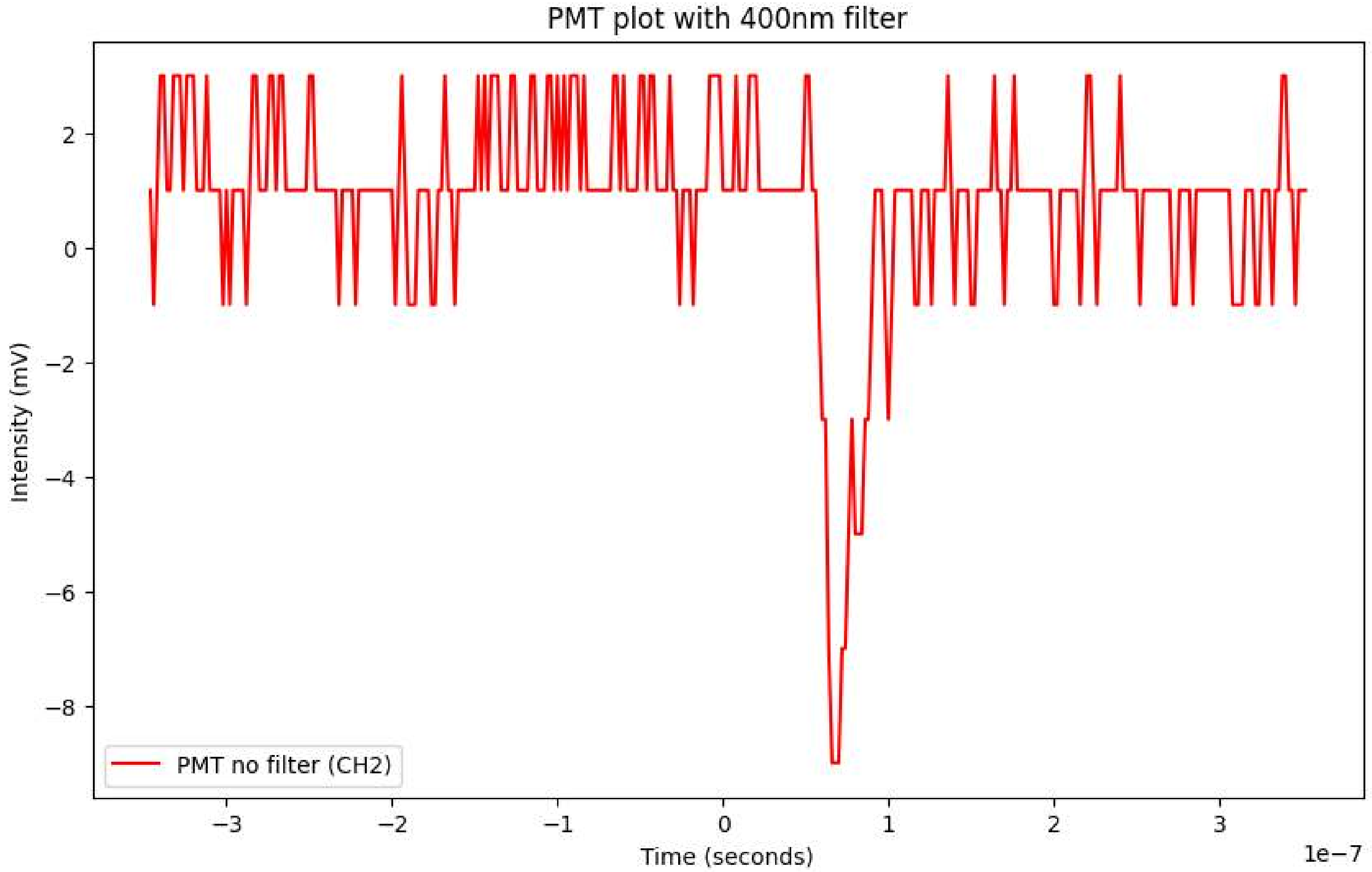
# Measurement method

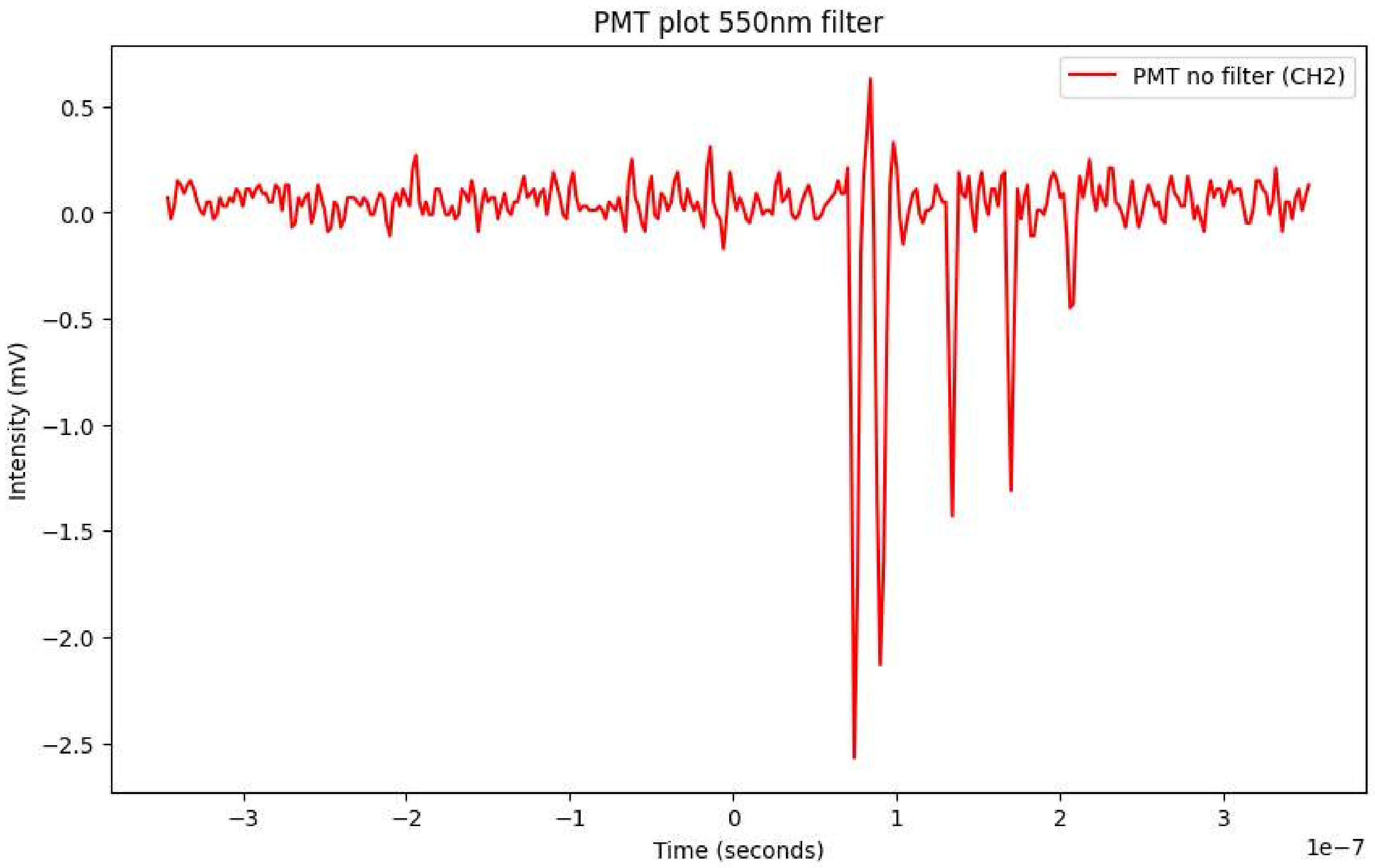


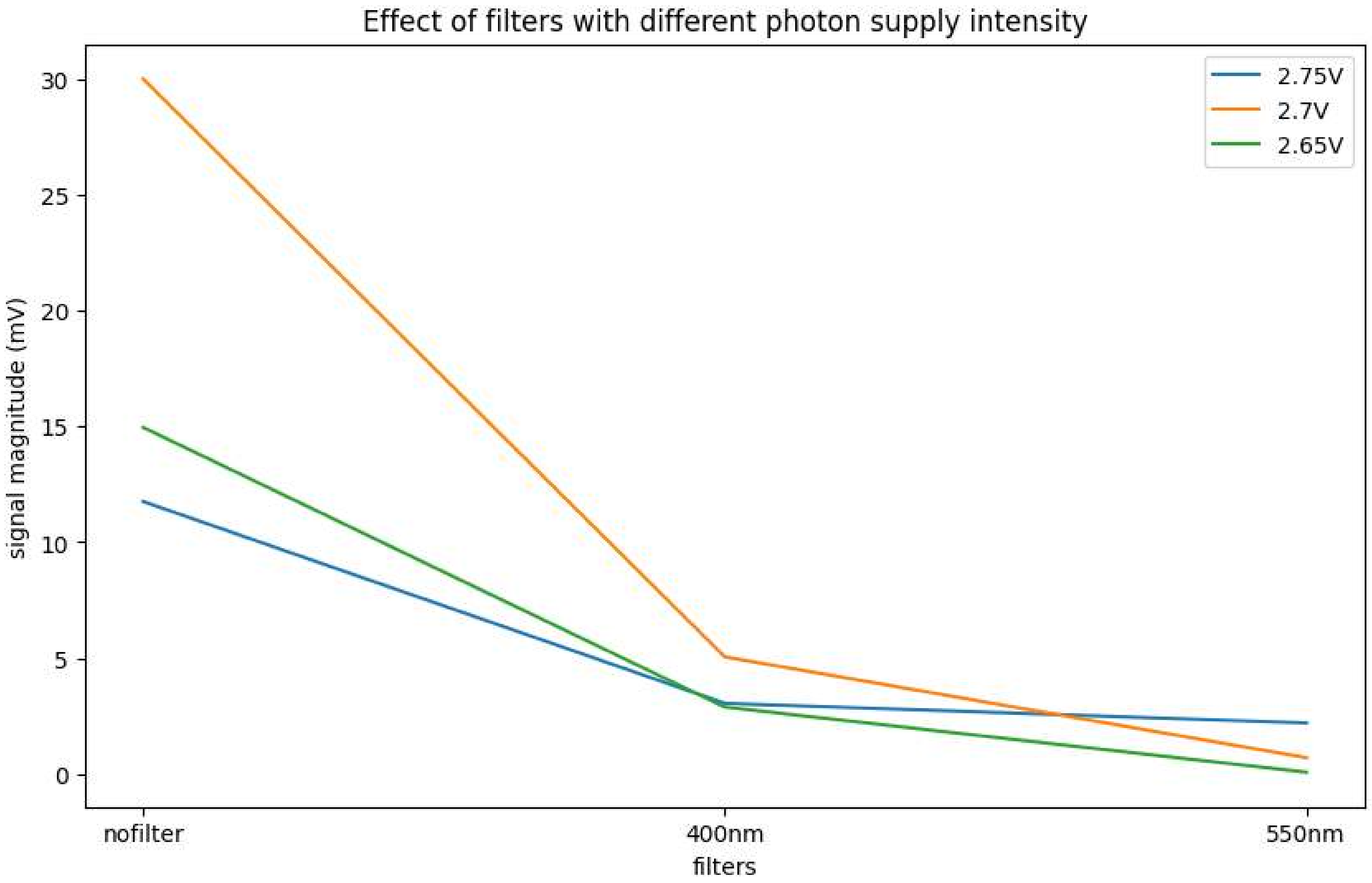

- Adding filter only on PMT
- Measuring SiPM for normalization references
- Estimate intensity of signal using integral

# PMT plot


PMT plot with no filter
0
−10
−20
−30
−40
Intensity (mV)
PMT no filter (CH2)
−3
−2
−1
0
1
2
3
1e−7
Time (seconds)

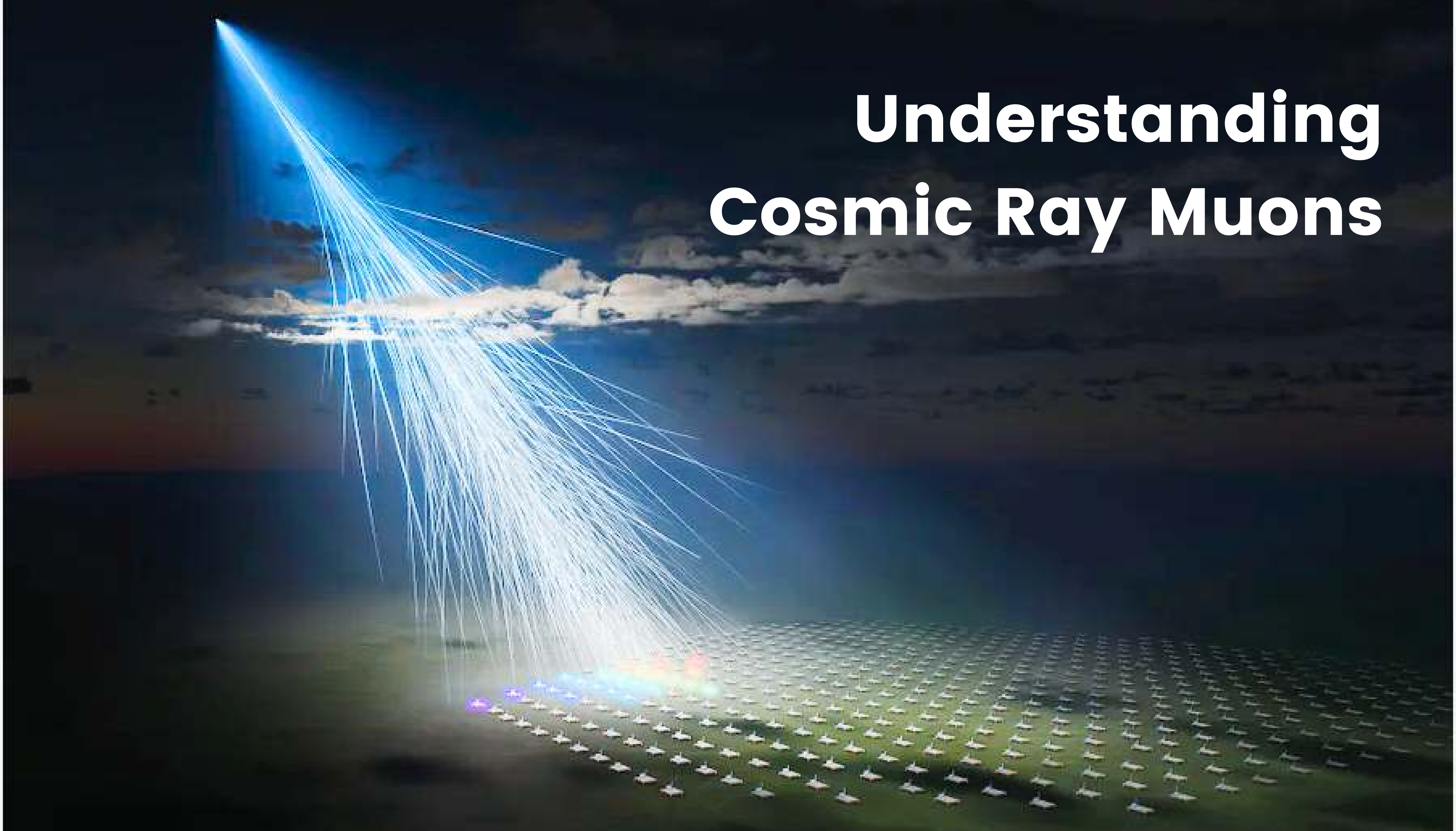

PMT plot with 400nm filter
2
0
−2
−4
−6
−8
Intensity (mV)
PMT no filter (CH2)
−3
−2
−1
0
1
2
3
1e−7
Time (seconds)


PMT plot 550nm filter
PMT no filter (CH2)
0.5
0.0
−0.5
−1.0
−1.5
−2.0
−2.5
Intensity (mV)
−3
−2
−1
0
1
2
3
1e−7
Time (seconds)

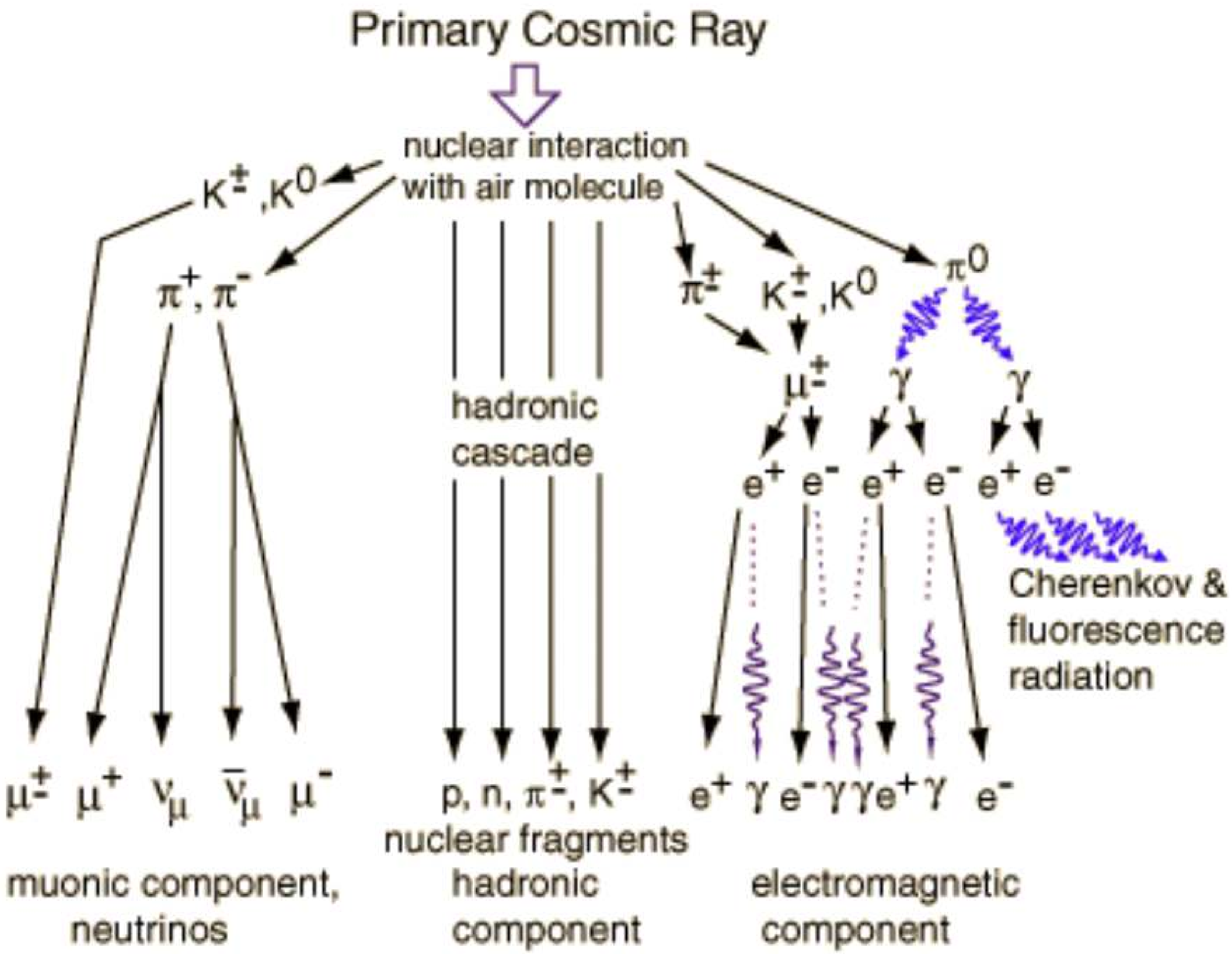



Power transmission over different wavelength filter

# Understanding Cosmic Ray Muons



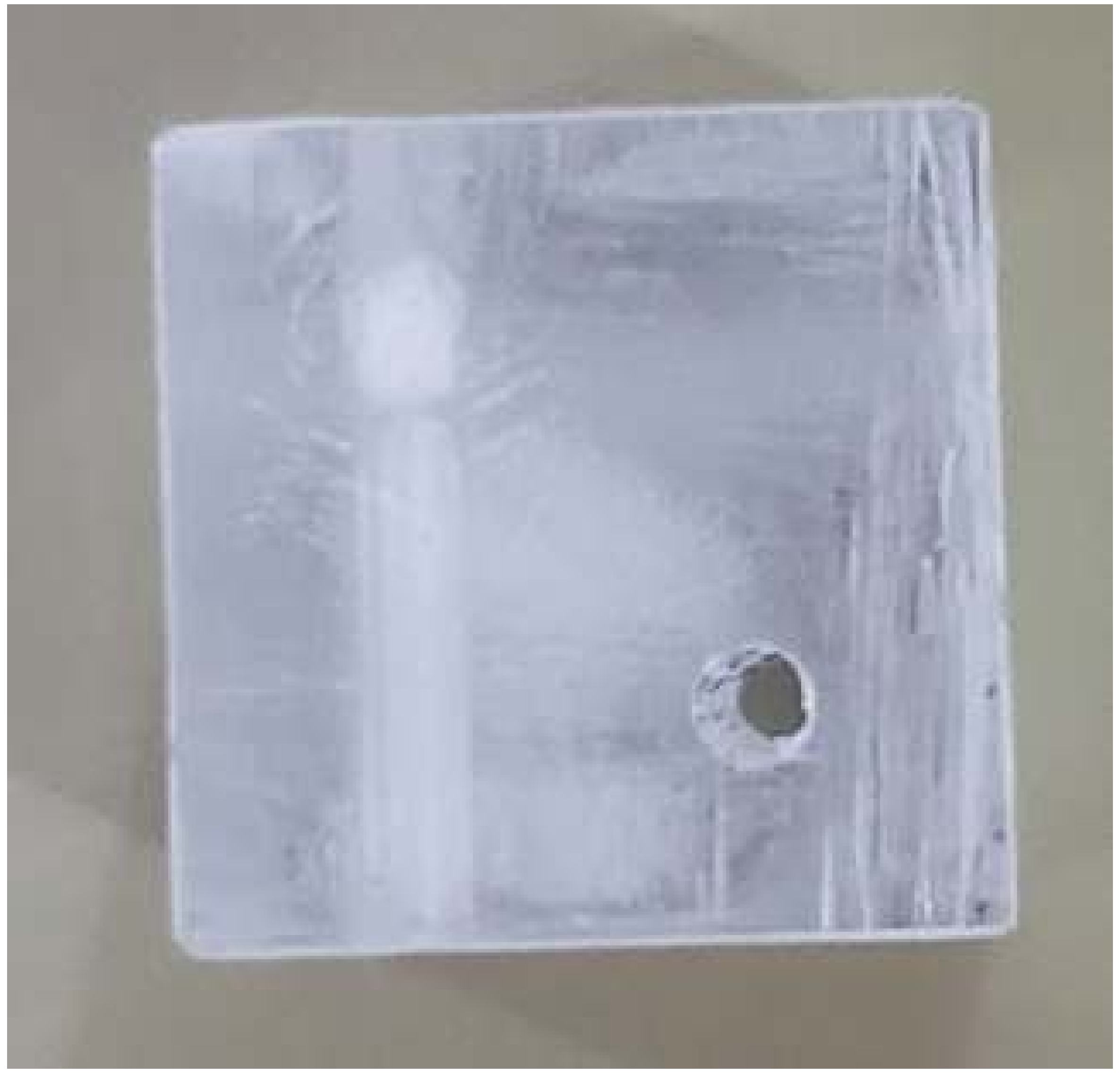
# Muon Production Phenomenology




*Source is C. R. Nave, Cosmic Rays, HyperPhysics.*

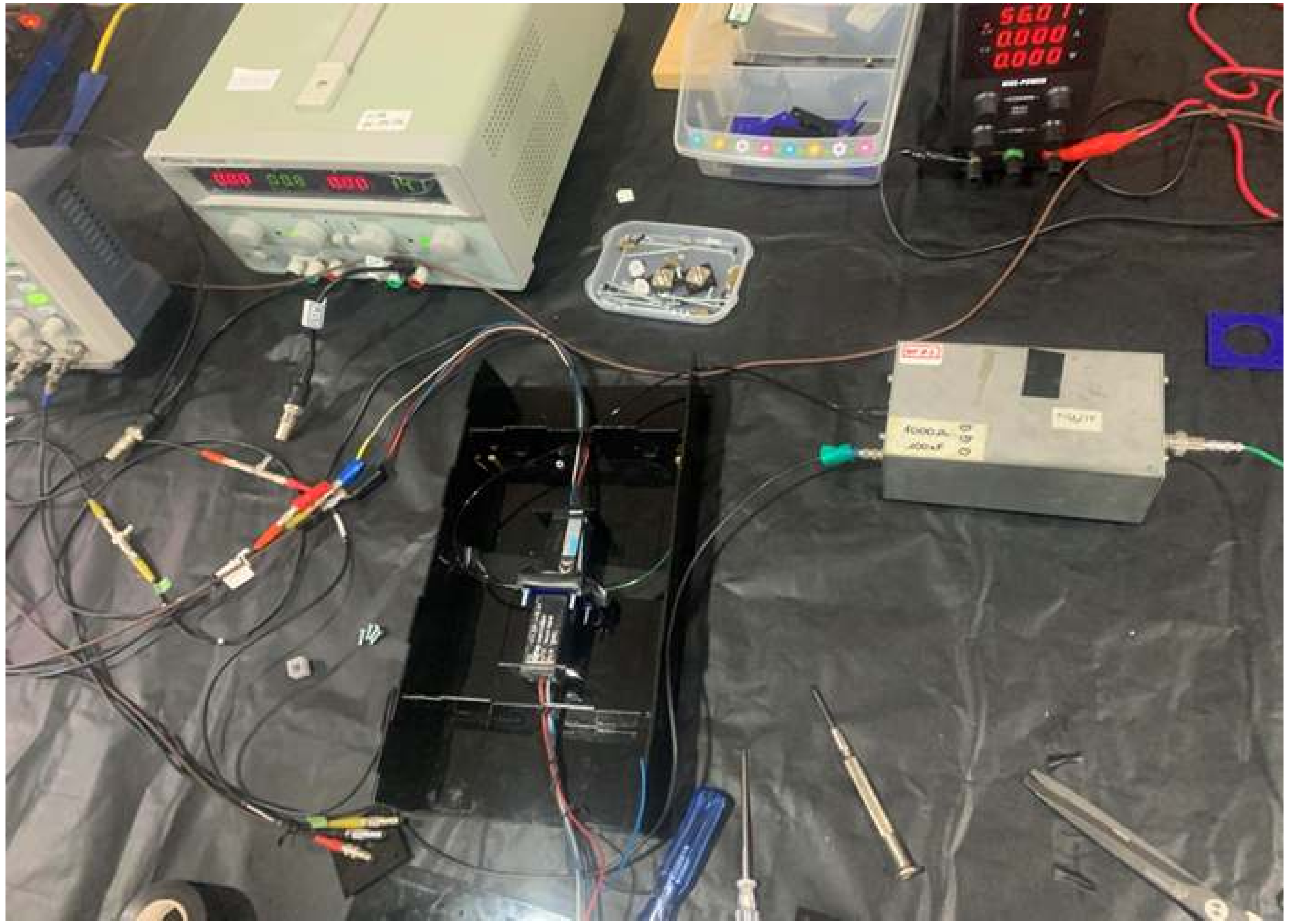
# Scintillator Cube (Thanks DAT)

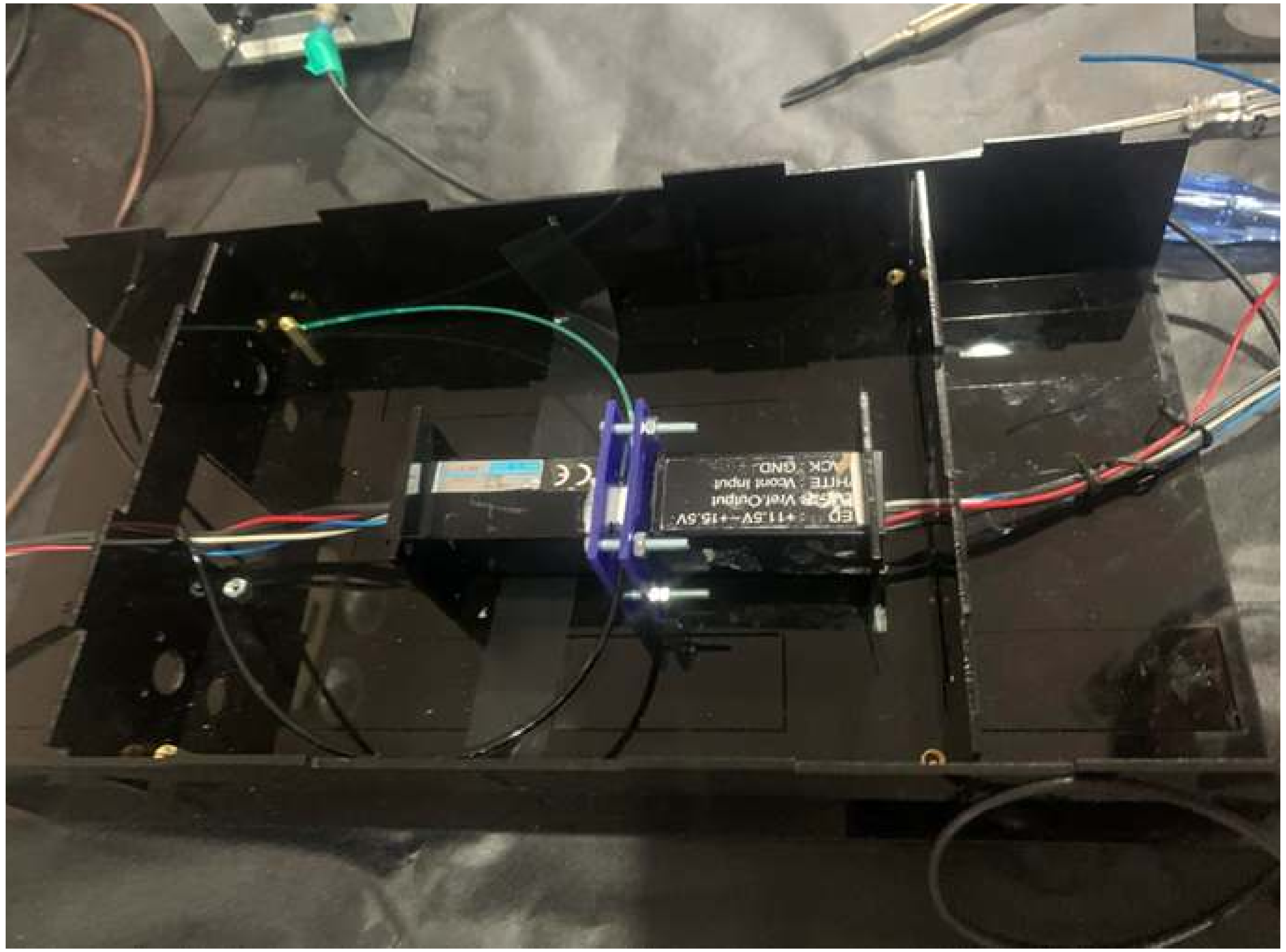
**Before sanding**



**After sanding**

# Experimental Setup:

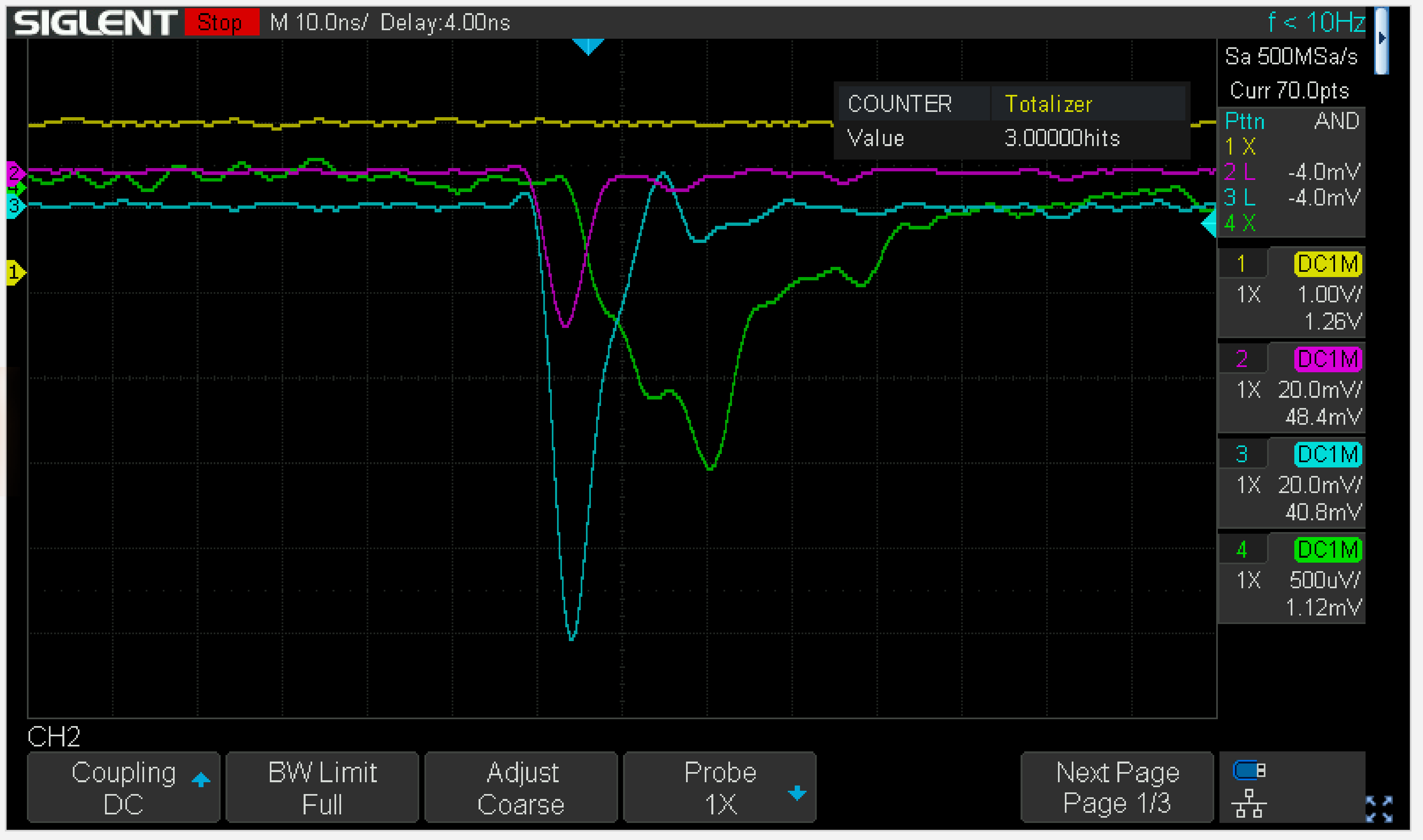




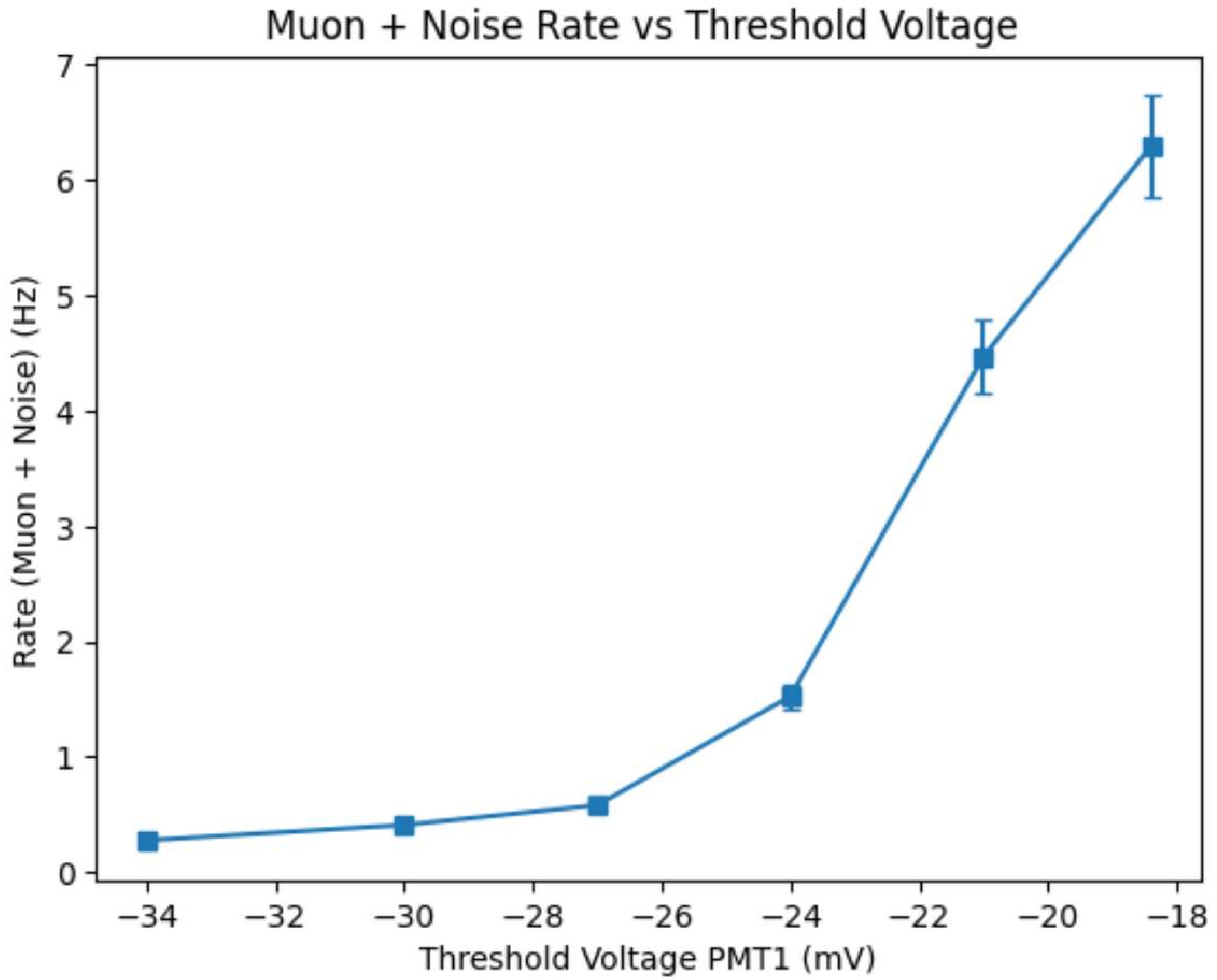
# Measuring Cosmic Muon Rate

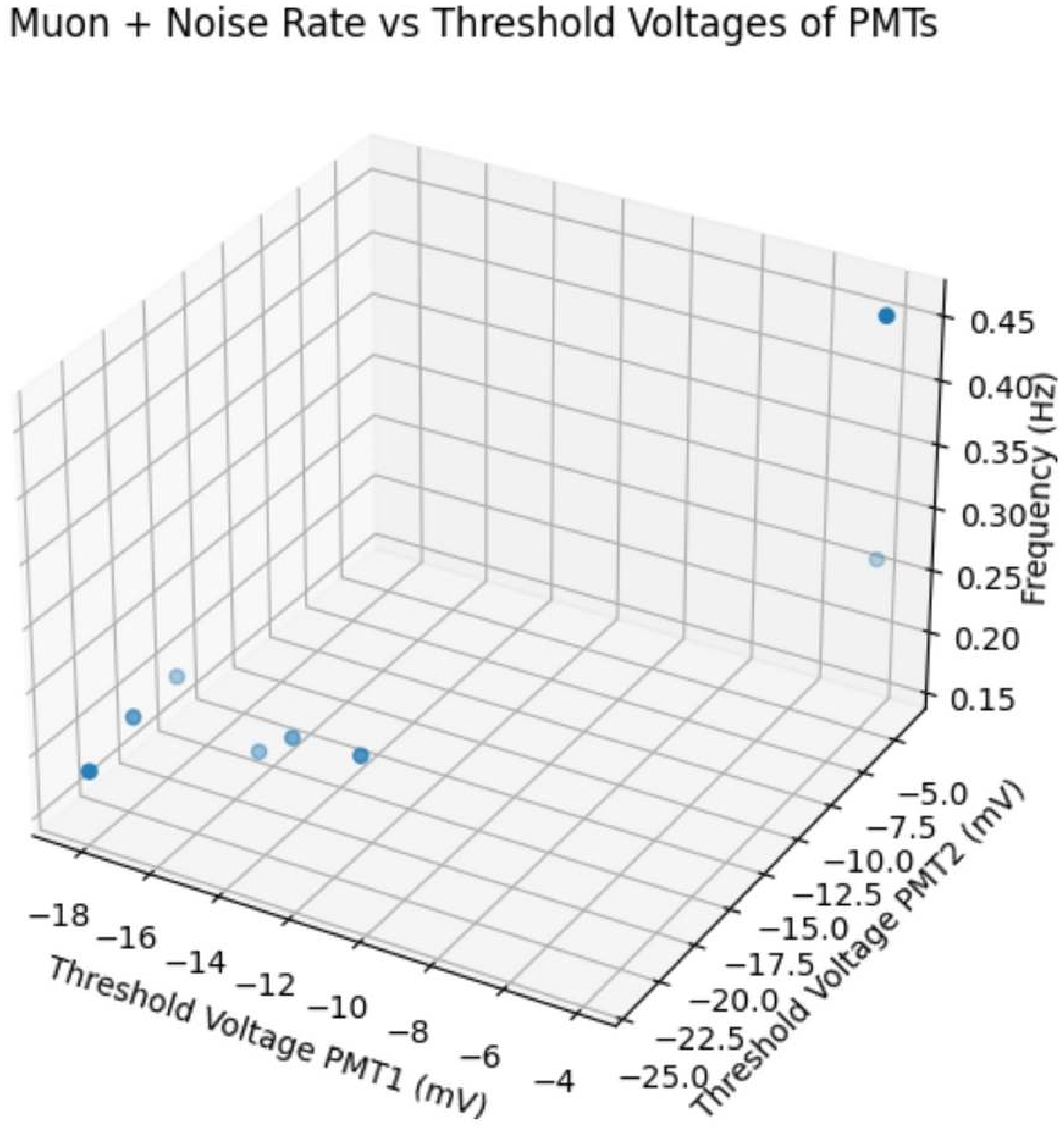
1. Triggering at the Falling Edge of PMT1
2. Triggering at the Coincidence of PMT1 and PMT2

# Coincidence of  Signals  for a Cosmic Muon



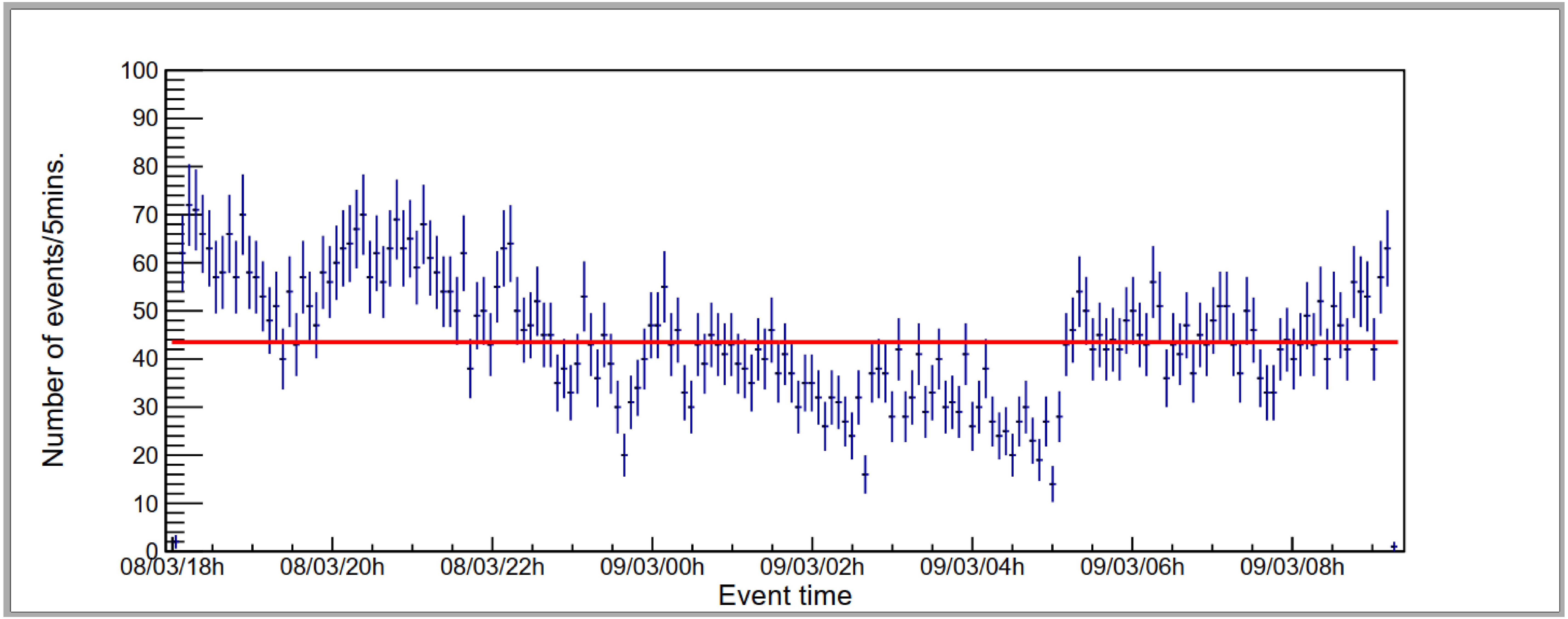

- **Ch1 – Coincidence Trigger (Yellow)**
- **Ch2 – PMT1 (Pink)**
- **Ch3 – PMT2 (Blue)**
- **Ch4 – SIPM (Green)**


Muon + Noise Rate vs Threshold Voltage
Rate (Muon + Noise) (Hz)
Threshold Voltage PMT1 (mV)
7
6
5
4
3
2
1
0
−34
−32
−30
−28
−26
−24
−22
−20
−18

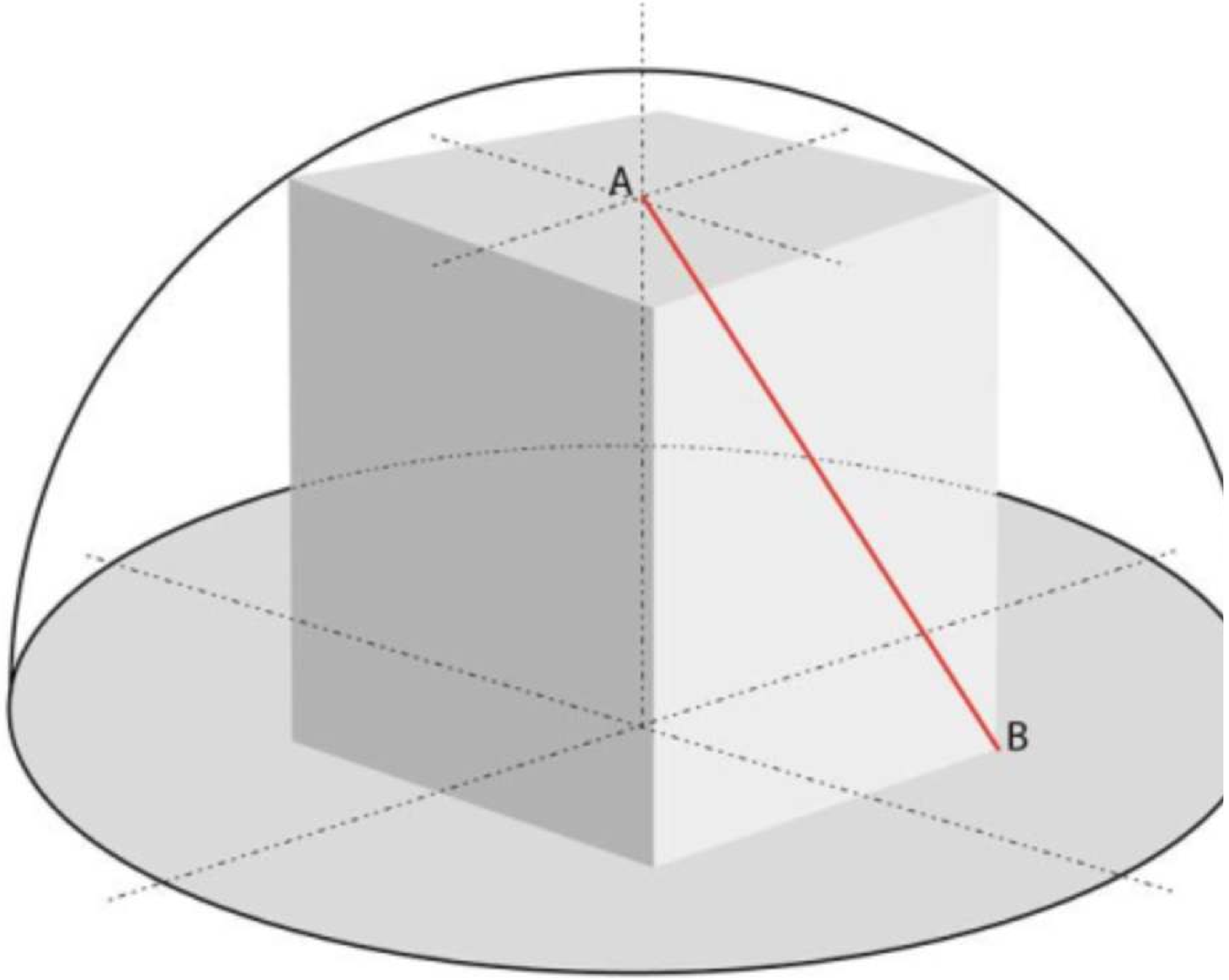

Muon + Noise Rate vs Threshold Voltages of PMTs
Frequency (Hz)
0.45
0.40
0.35
0.30
0.25
0.20
0.15
Threshold Voltage PMT1 (mV)
−18
−16
−14
−12
−10
−8
−6
−4
Threshold Voltage PMT2 (mV)
−5.0
−7.5
−10.0
−12.5
−15.0
−17.5
−20.0
−22.5
−25.0

# Muon Rate measured for the whole Night

**Rate (Avg) = 0.146 Hz**



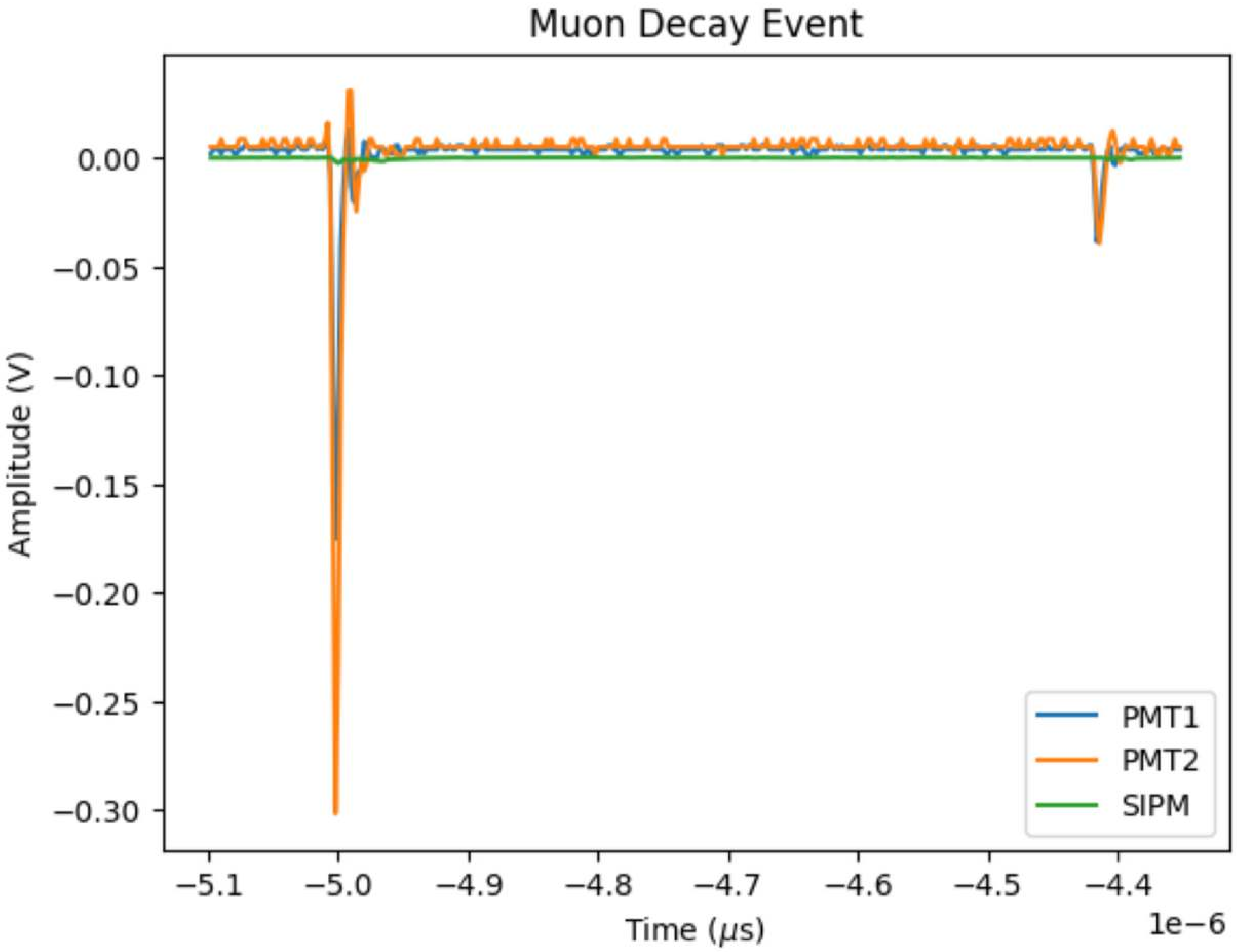
## Comparision with Theoretical Expectation




**Assuming Muon Flux = 1 muon / cm^2 / min**
**The lower bound = 5 / 60 = .084 Hz.**

**To calculate the upper bound of muon rate, the muons passing through the half sphere should be more than muons passing the cube. Therefore the upper bound is 2*pi*R^2 = .15 Hz.**

**The measured average rate .146 Hz is consistent with the theoretical bounds.**



Muon Decay Event
Amplitude (V)
0.00
−0.05
−0.10
−0.15
−0.20
−0.25
−0.30
−5.1
−5.0
−4.9
−4.8
−4.7
−4.6
−4.5
−4.4
1e−6
Time (μs)
PMT1
PMT2
SIPM


**Any question?**
**Ask Gia Minh**

# Thank you!