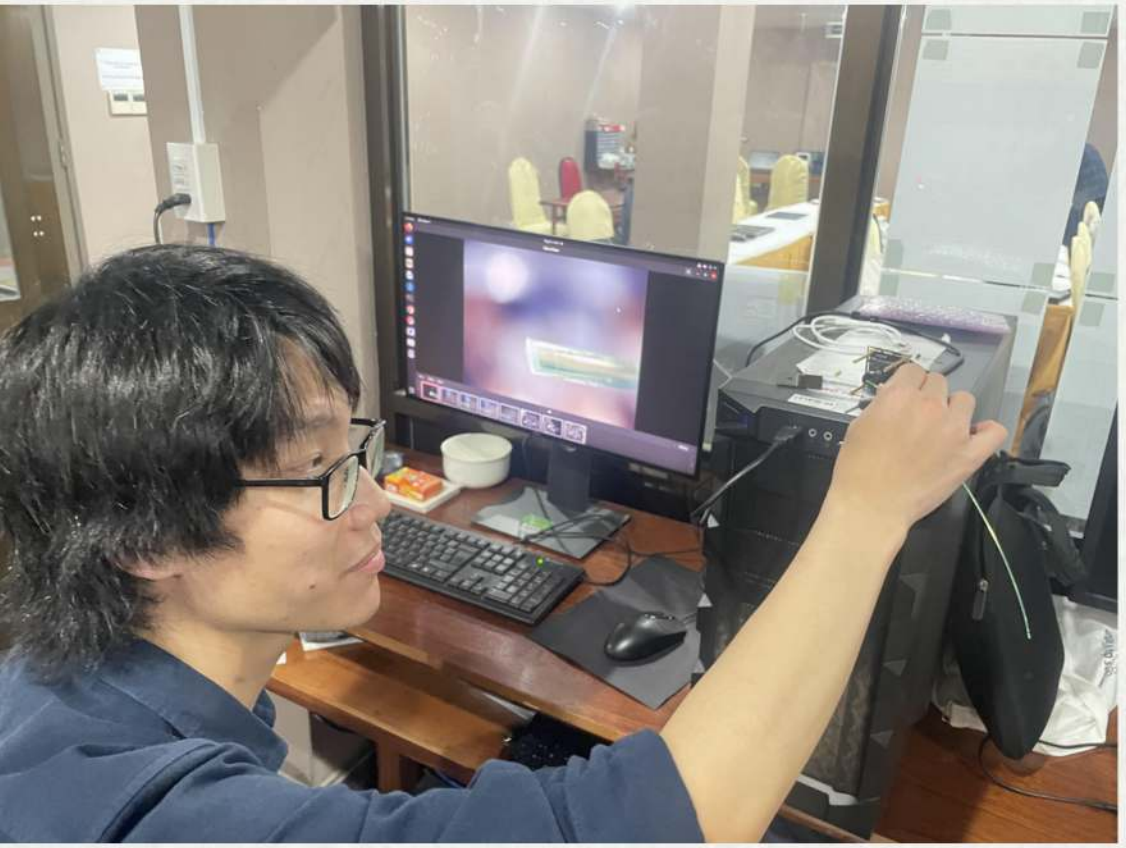
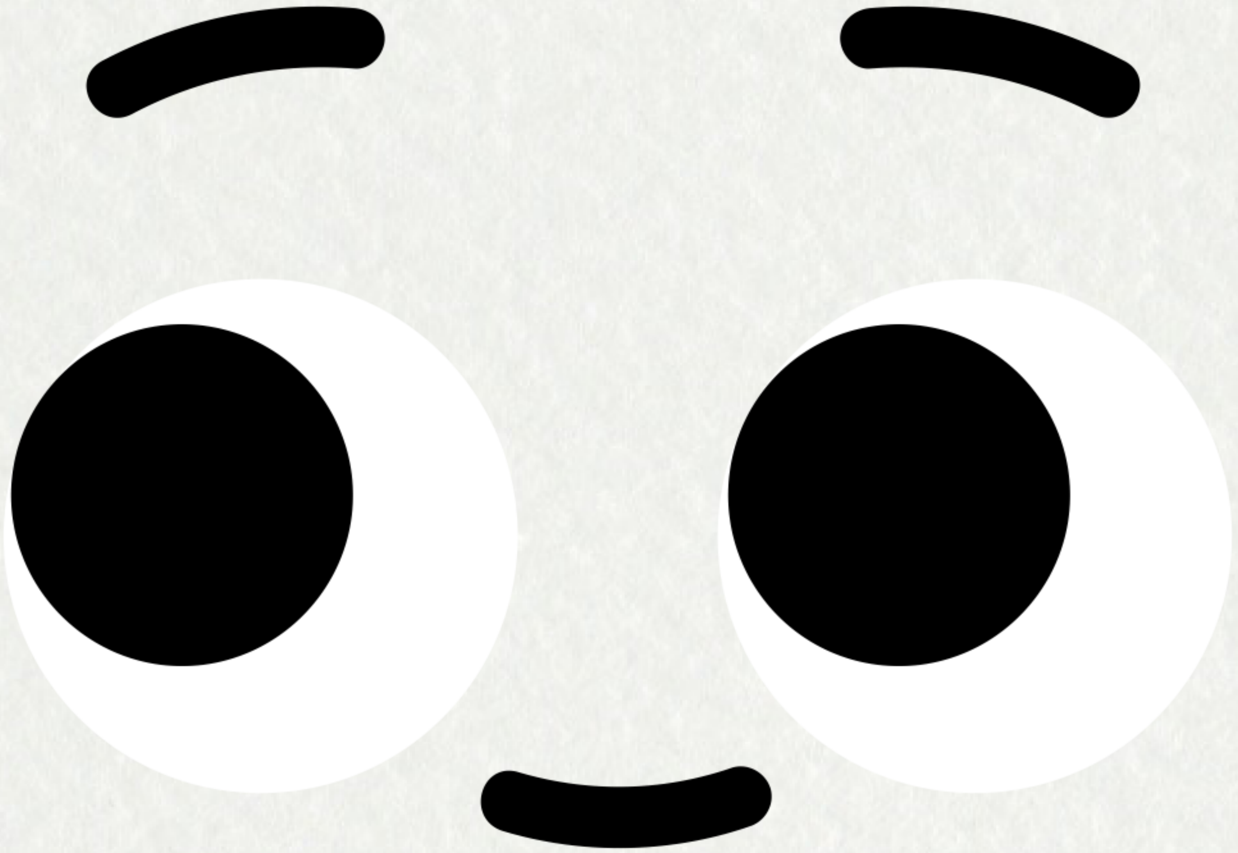
SINGLE MPPC




Trung Tin | Quang Minh | Quang Anh | Alex Sells | Thien Nga
Instructors - Dr. Thanh Dong | M.Sc. Thanh Nguyen | M.Sc. Shouvik Mondal

AGENDA

1. Overview
2. Experimental Setups
3. Results
4. Discussion



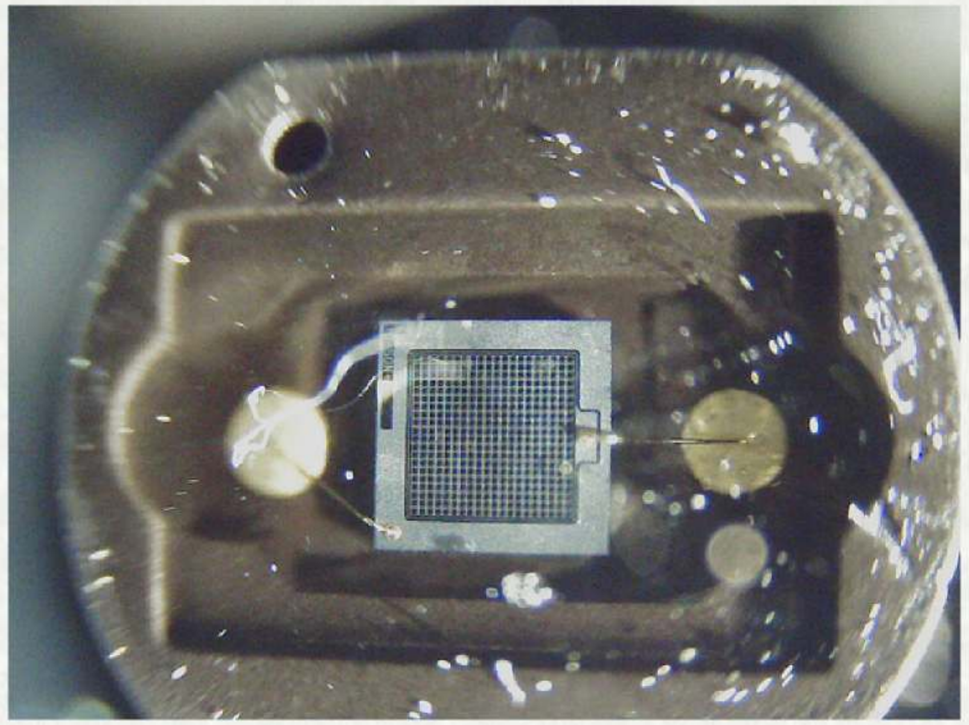
OVERVIEW

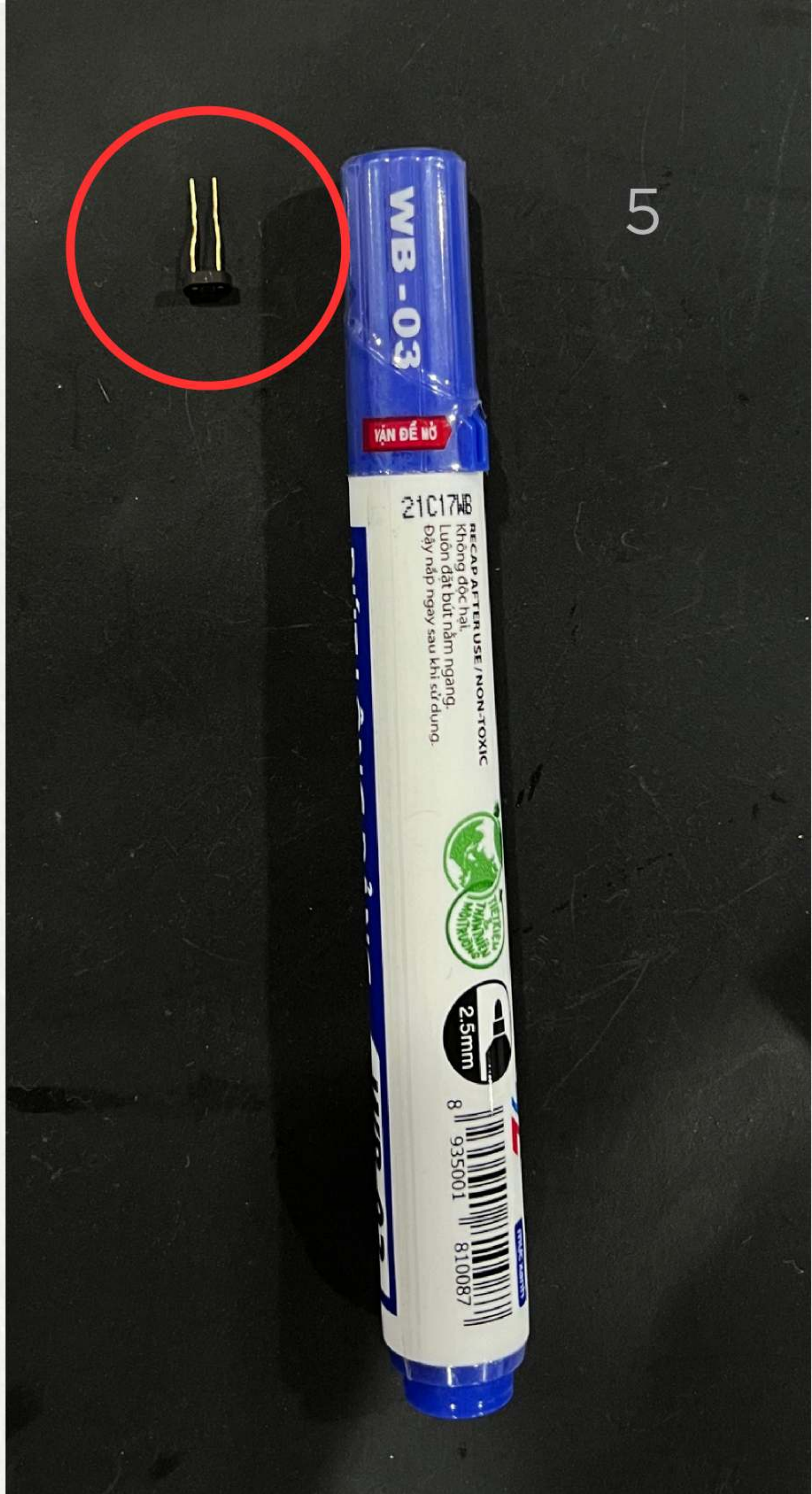
Objectives

- **MPPC Characteristics**
  - Dark noise
  - Crosstalk
  - After pulse
- **ToF method**
  - Speed of electrical signal in LEMO cables
  - Speed of light in optical fibers
- **Cosmic ray muons**
  - Rate (muon flux)
  - Zenith angle

Single Multi-Pixels Photon Counters

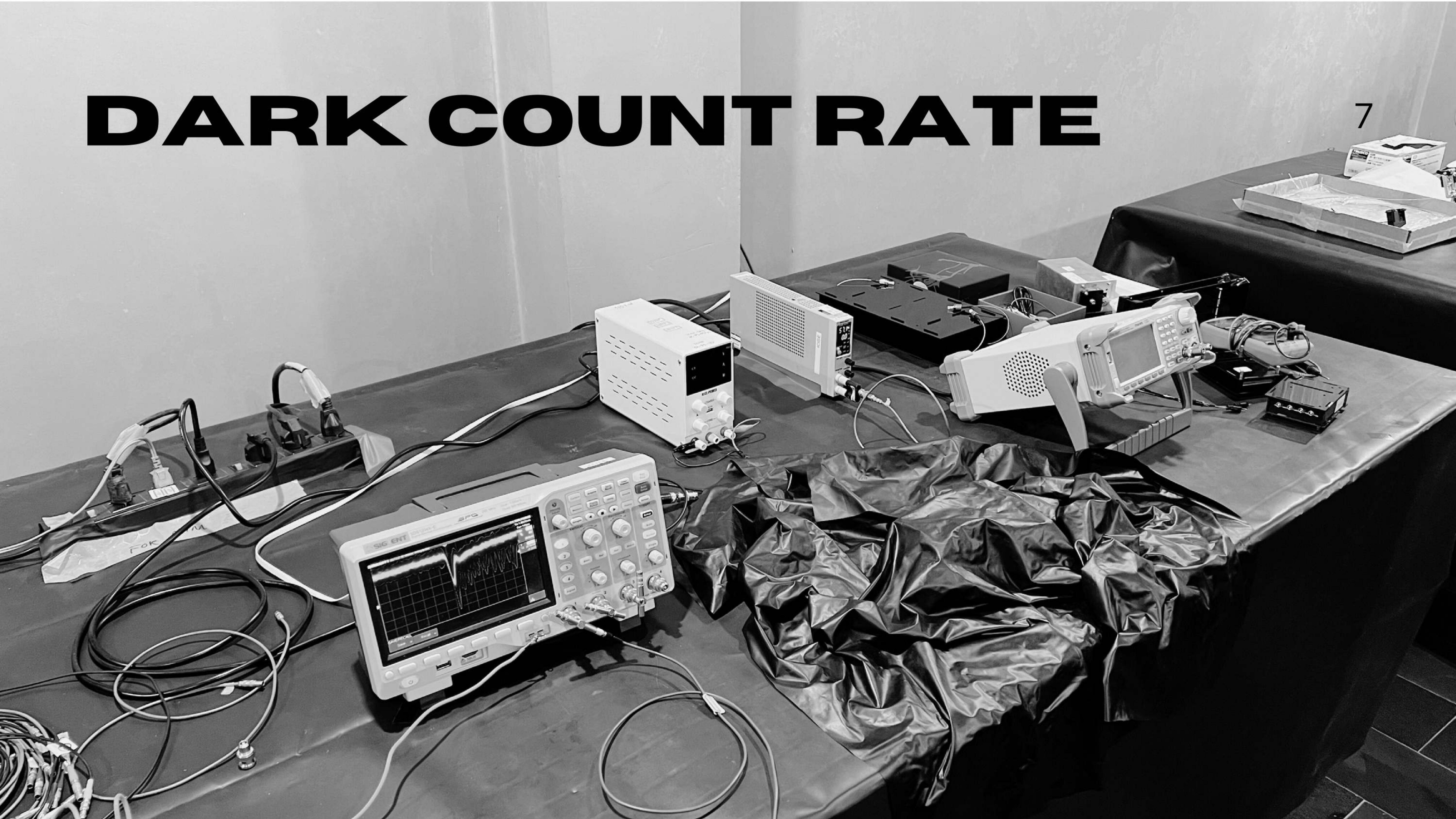
Pixel pitch - 25 µm
Effective photosensitive area - 1.3 x 1.3 mm
Number of pixels - 2668
MPPC model - S13360 - 1325CS





EXPERIMENTS

DARK COUNT RATE

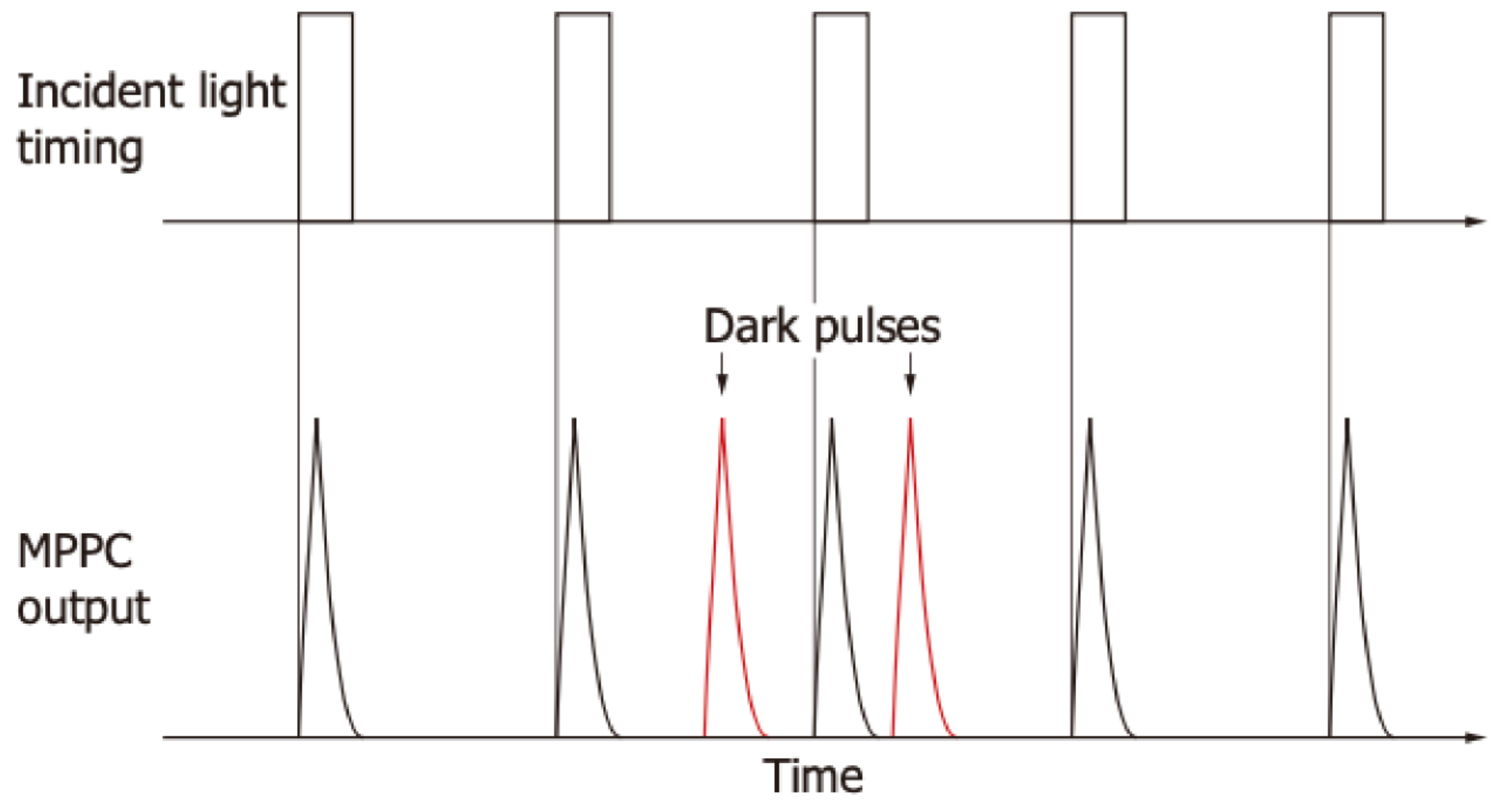


Theoretical background

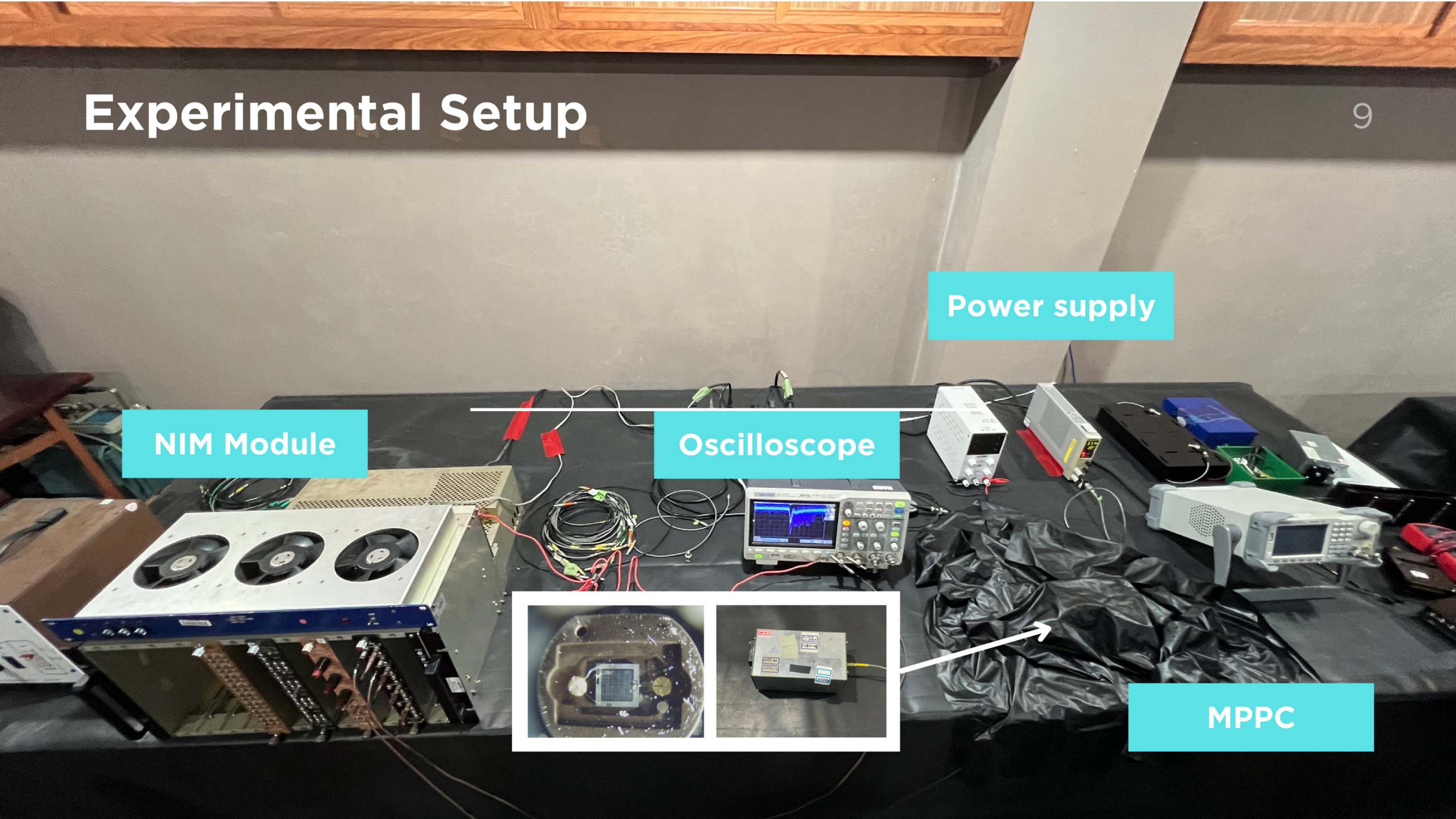
Dark count rate

- Photon-generated vs. thermally-generated carriers
- Dark pulses
- Dark count = # of dark pulses
- Dark count rate = dark pulses/second

[Figure 3-4] Dark pulses



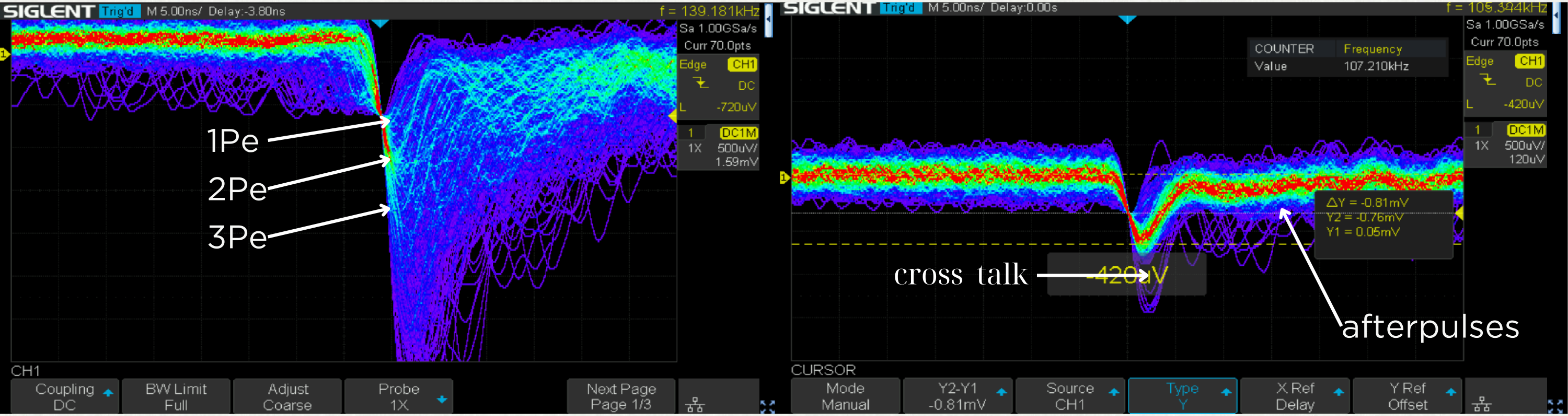
Experimental Setup



Procedure

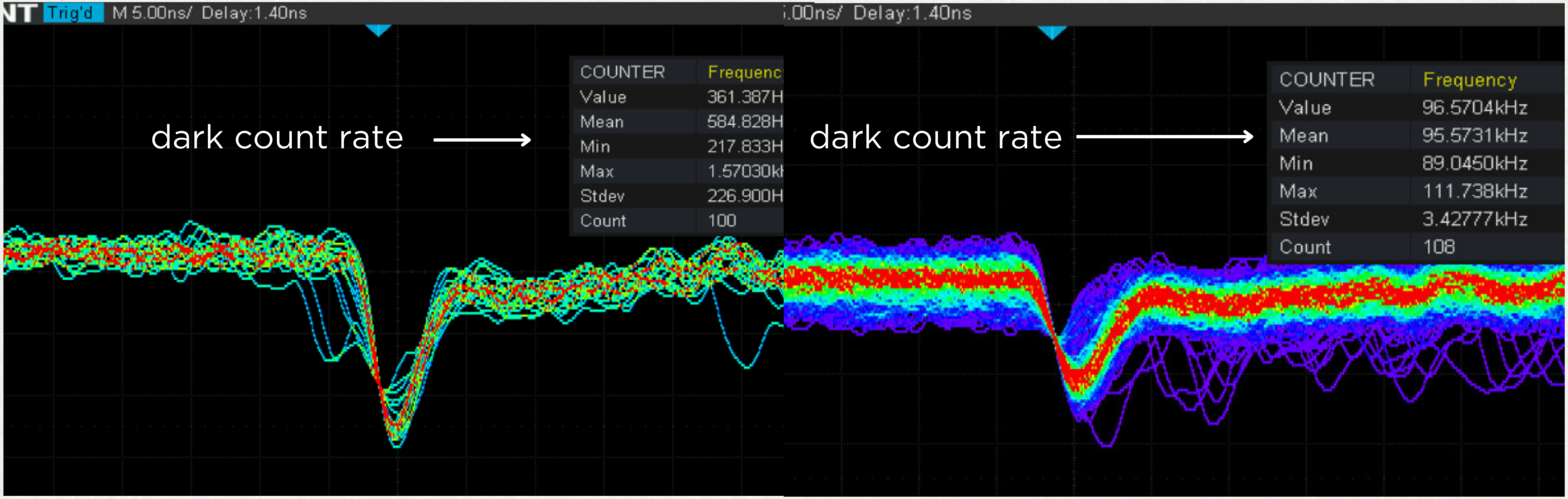
1. Cover MPPC with black cover after connecting
2. Turn on power supply
3. Observe oscilloscope and see if we need to amplify the signals
4. Amplification using NIM Module

Observation



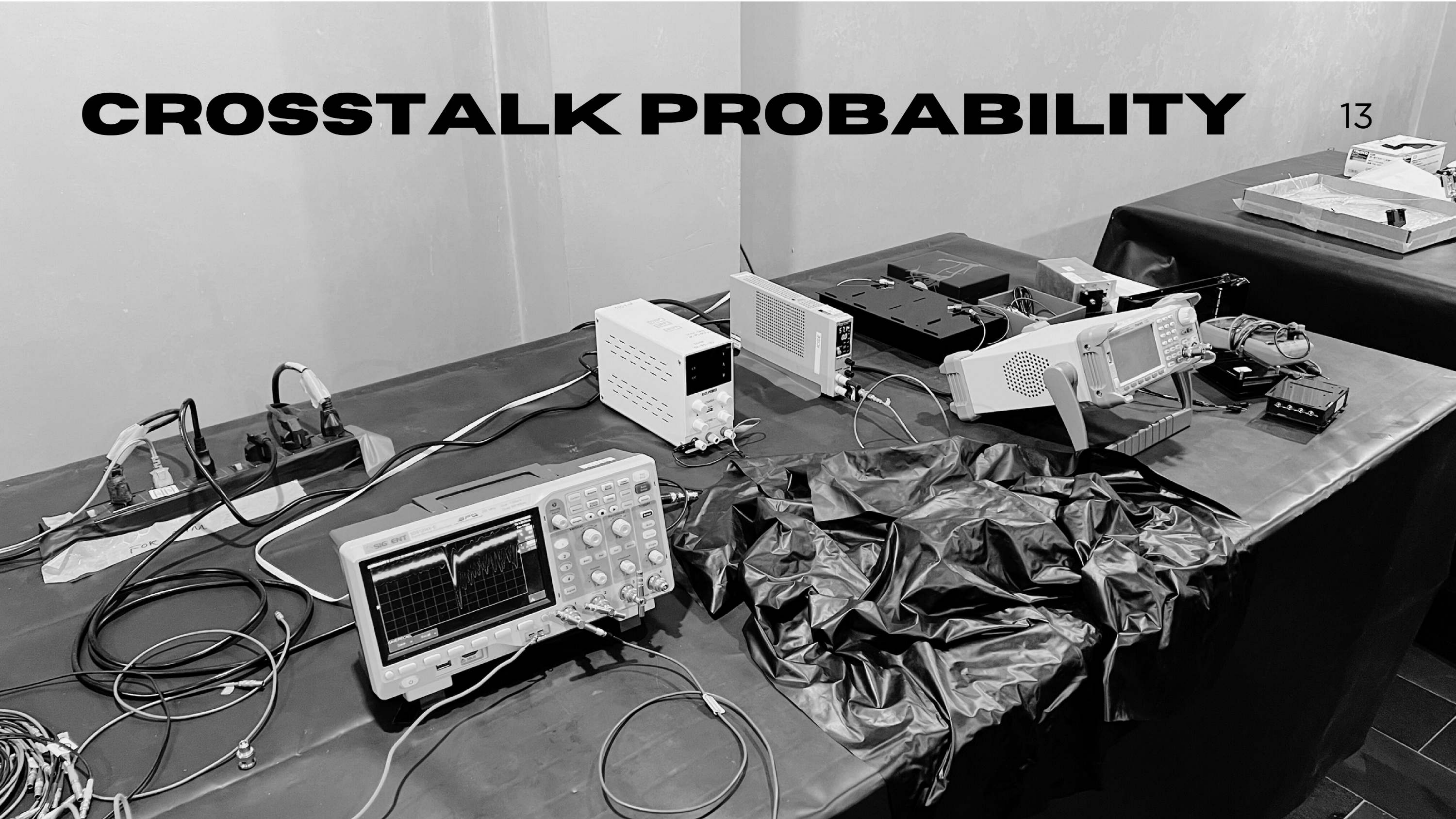
Using MPPC model S13360 - 1325CS

Measuring dark count rate



1.5Pe *0.5Pe*

CROSSTALK PROBABILITY

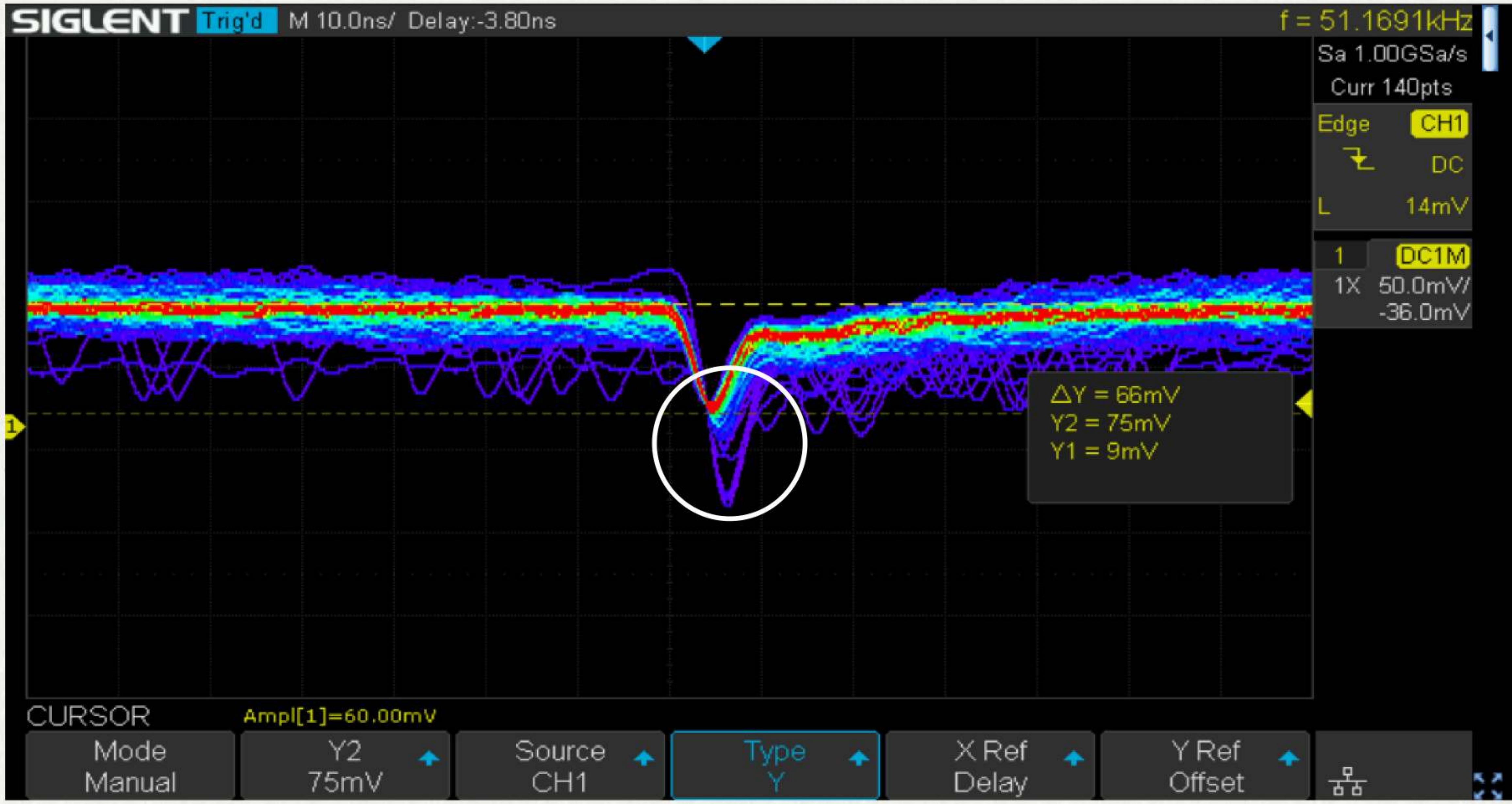


Theoretical background

Crosstalk Probability

- During thermal emission of single photon, there is a chance for a a signal to be detected from a neighboring channel
- Probability for crosstalk to occur can be estimated by:

$$P_{crosstalk} = \frac{N_{1.5\ p.e.}}{N_{0.5\ p.e.}}$$



Measuring $P_{crosstalk}$

	mean rate/kHz	1σ / kHz	Temp/Celsius	Amplitude/mV	Threshold/mV	no. counts
1pe	95.573	3.4278	25	1.25	0.63	100
2pe	0.584	0.226	25	1.9	1.26	100

$$P_{crosstalk} = 0.006 \pm 0.002$$

Measuring Pcrosstalk

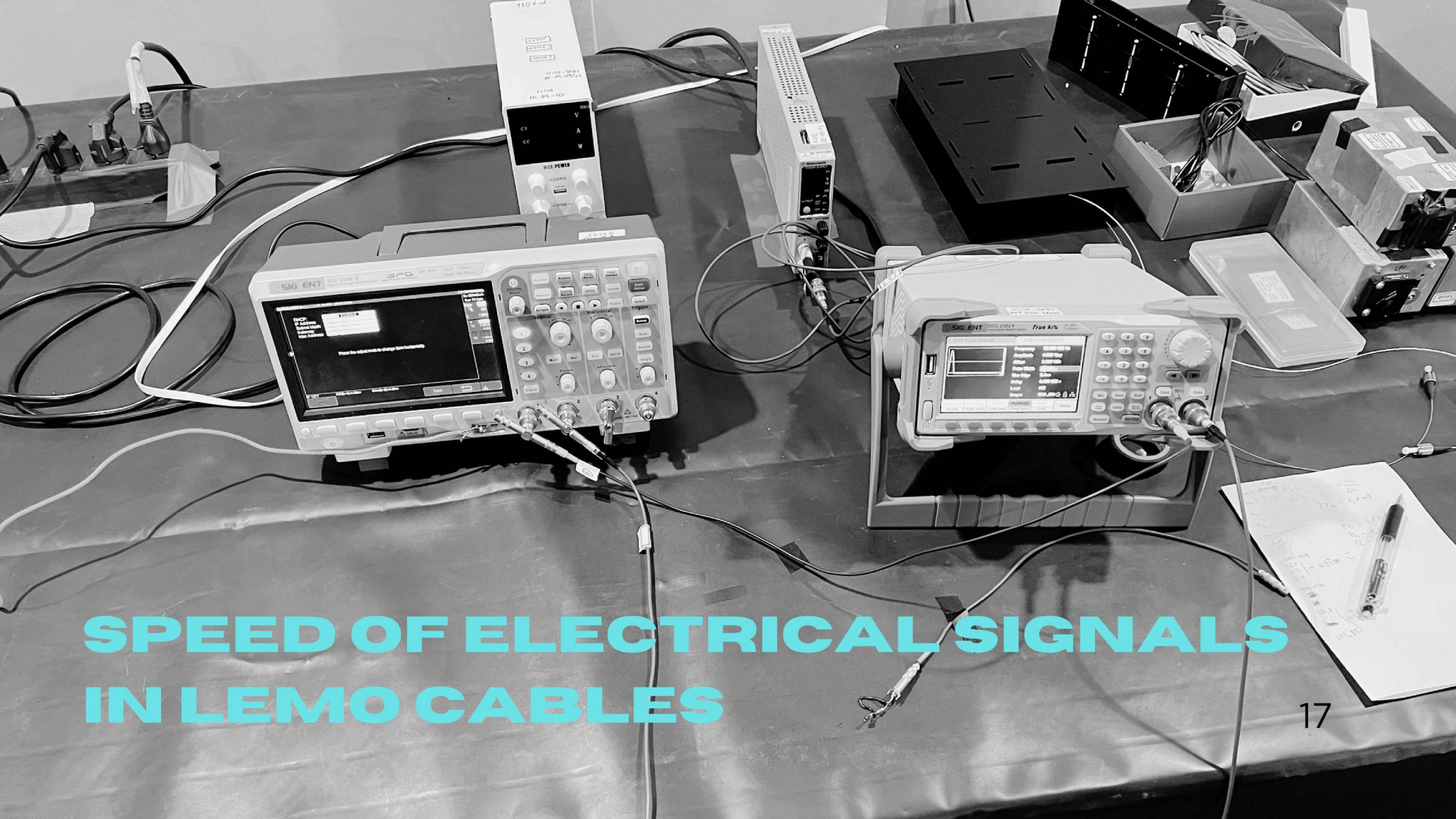
HAMAMATSU SPECIFICATION:

Sensitive area size :	**1.3x1.3 mm^2**
Number of pixels :	**667**
Pixel size :	**50x50 μm^2**
Gain :	**1.5 $x10^6$**
Operating voltage:	**~ 54.6 V**
Peak spectral sensitivity:	**450 nm**
Dark count :	**90 kHz** (typical)
Crosstalk:	**~ 1 %**
PDE at 450 nm:	**35 %**

We operated at 57V

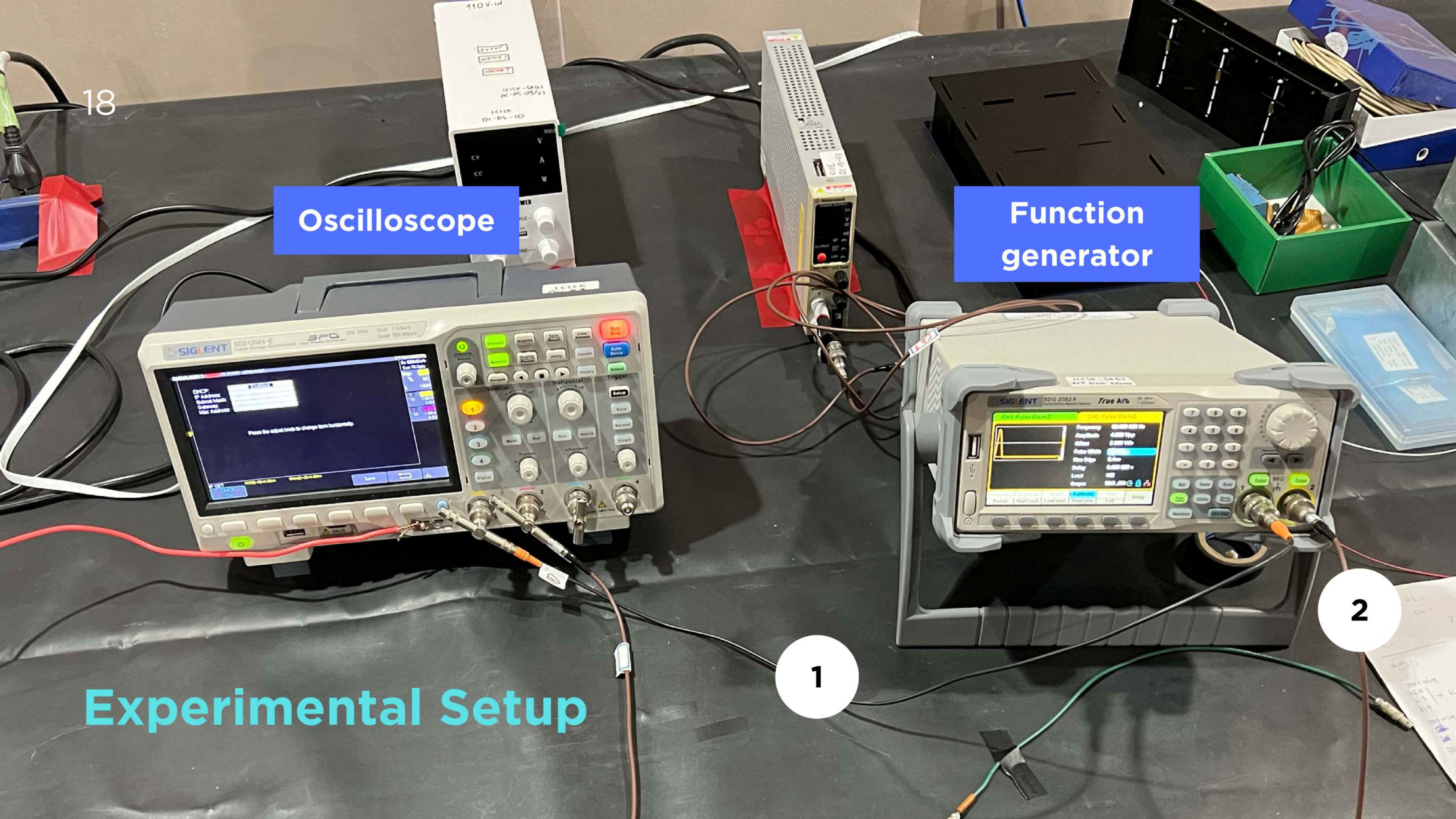
Our rate is similar for 0.5Pe threshold

→ Crosstalk result matches datasheet



SPEED OF ELECTRICAL SIGNALS IN LEMO CABLES

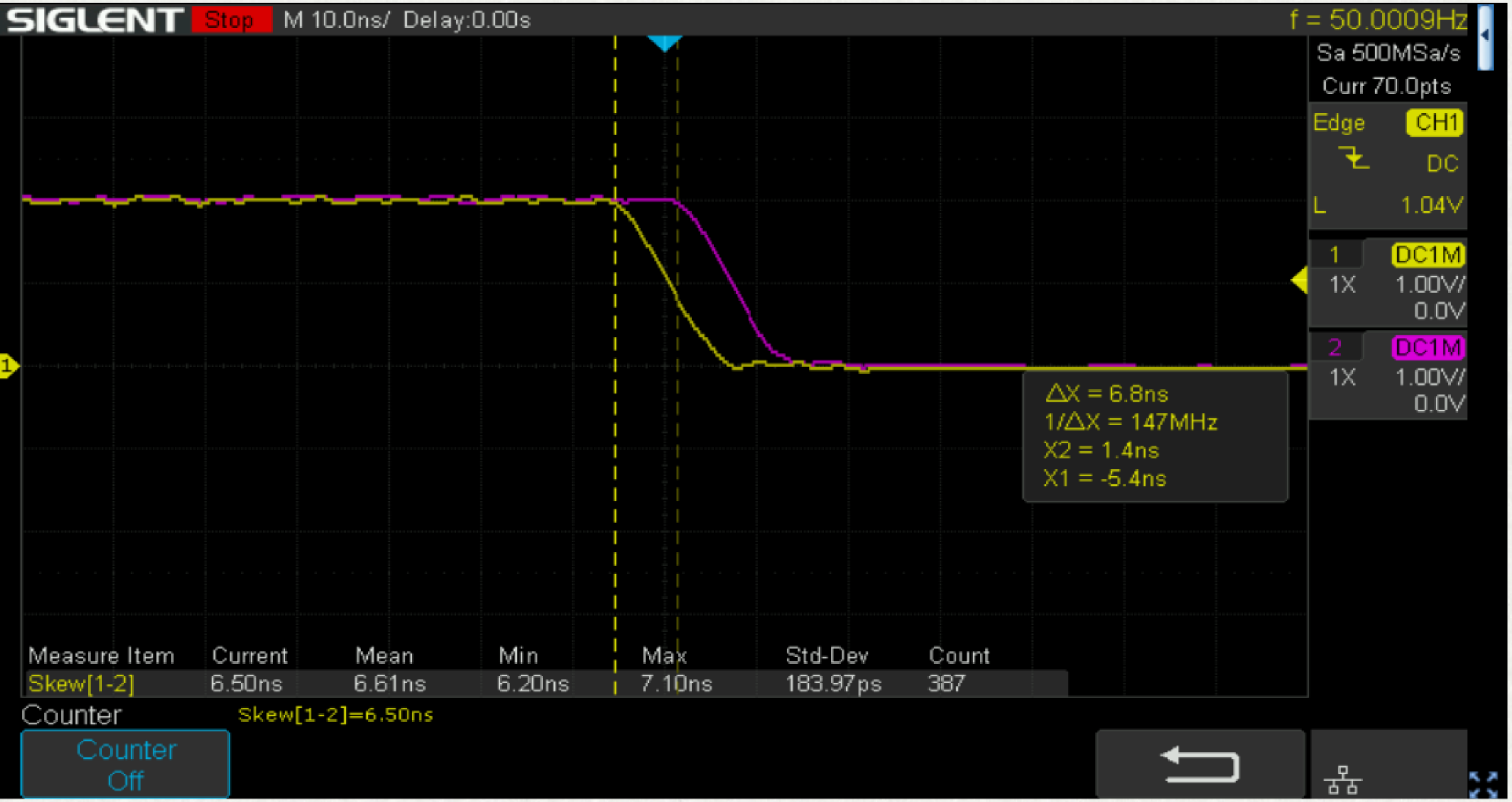
Experimental Setup



Measurements

Δt

ΔL



Results

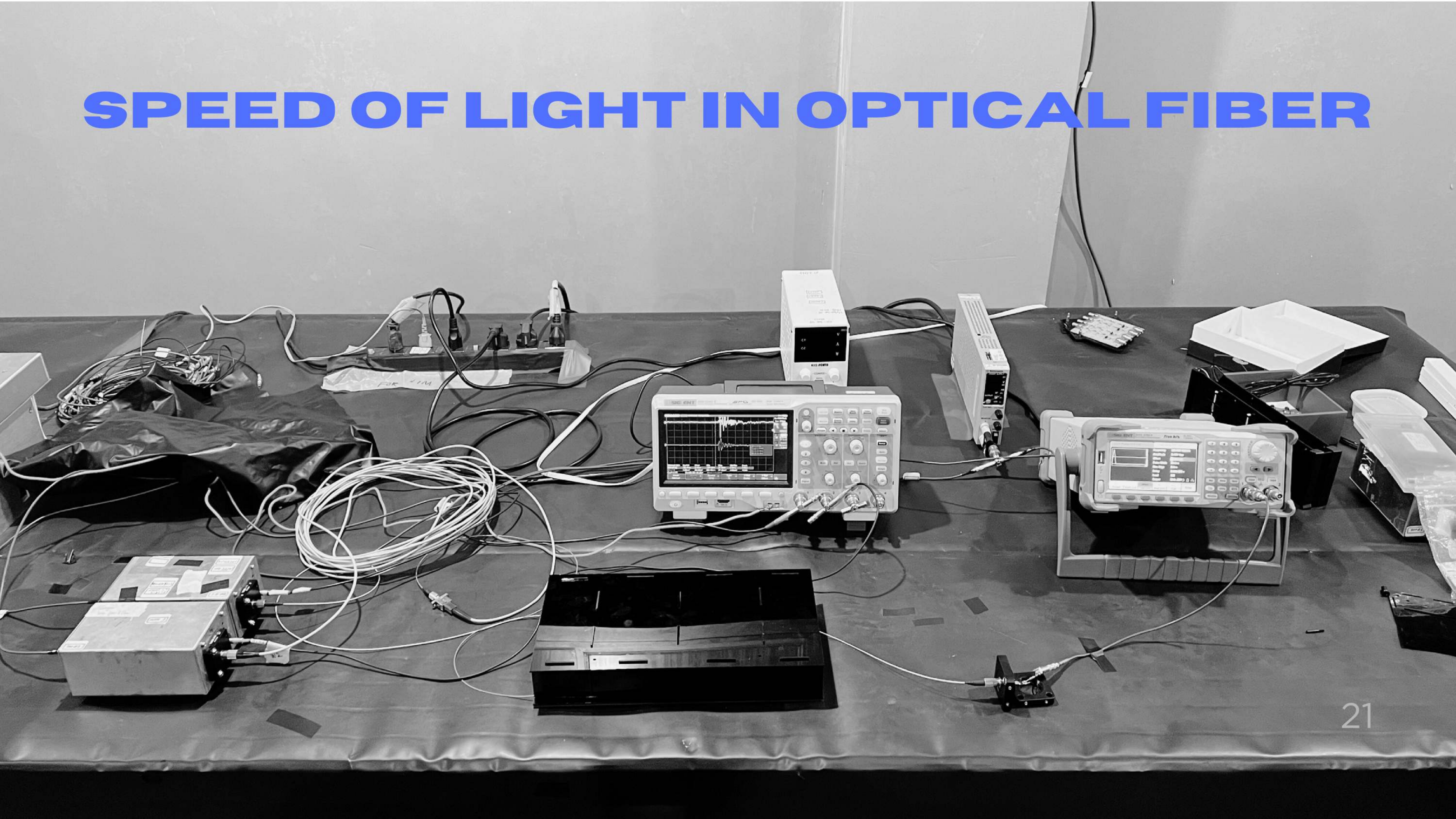
Llong (m)	Lshort (m)	ΔL (m)
2.018	0.62	1.39895
2.0185	0.619	
	0.619	
2.01825	**0.6193**	

t (ns)	Δt (ns)
6.8	6.7
6.6	

v ≈ 218,880,000 ± 10,000 m/s

expected v = 2E8 m/s

SPEED OF LIGHT IN OPTICAL FIBER



Theoretical background

ToF

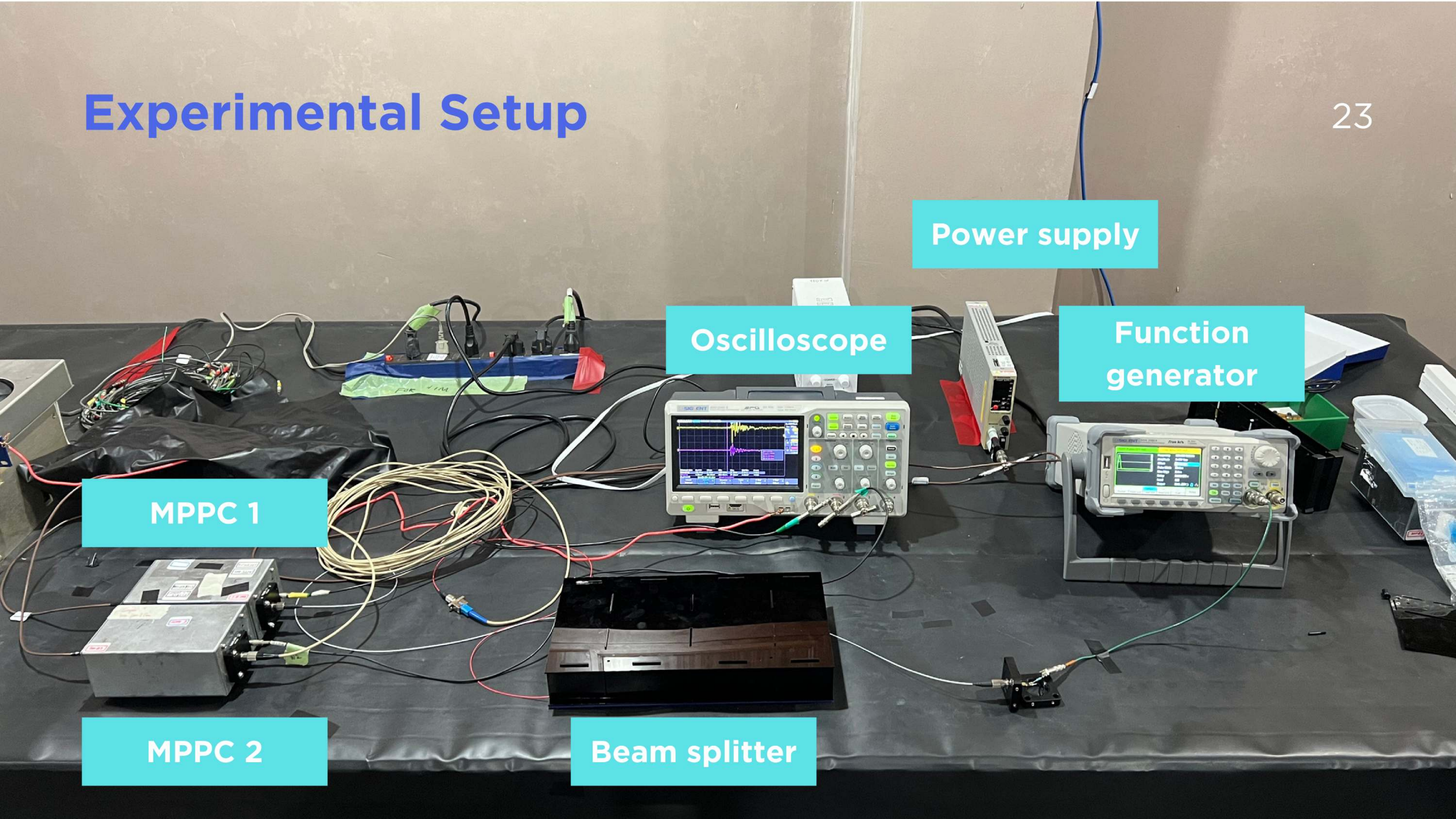
Measurement of **time** taken by an object to travel over a **distance** through a **medium**

Index

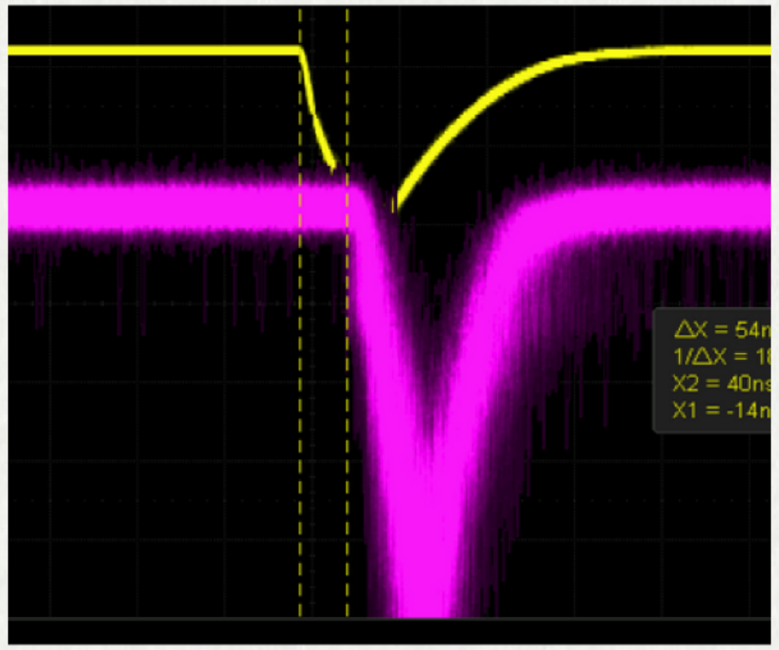
n = c/v

- **c** = 3E8
- **n** = 1.57 - 1.67 (optical fiber)
- **expected** speed of light in optical fiber = 2E8

Experimental Setup



Procedure

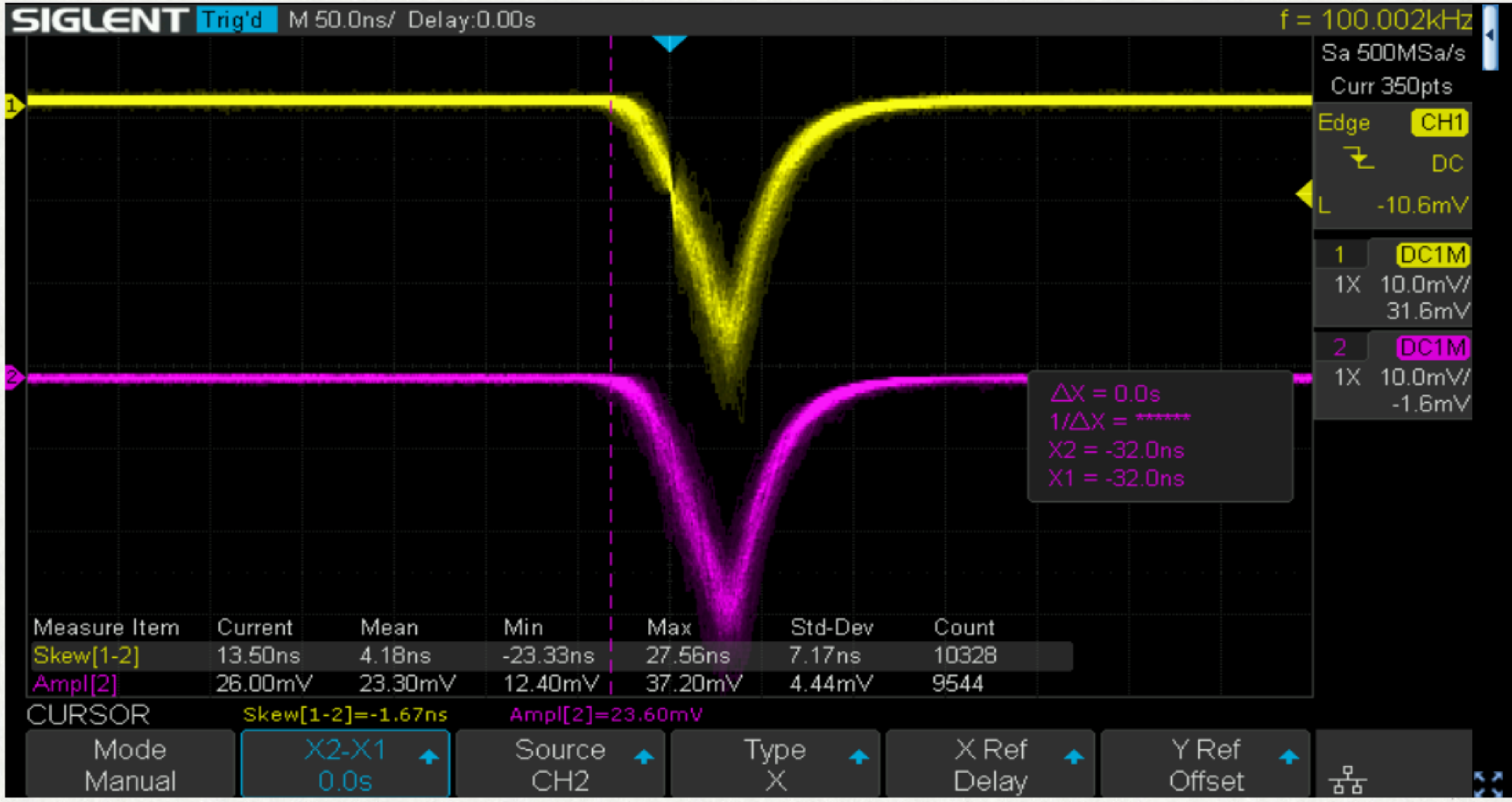


1. Finding the offset for precision
2. Measure our cables for ΔL value
3. Observe oscilloscope and find Δt
4. Calculate speed of light in optical fiber

Execution

1

Finding the offset for precision



Offset = 0

Execution

2

Measure our cables for ΔL value

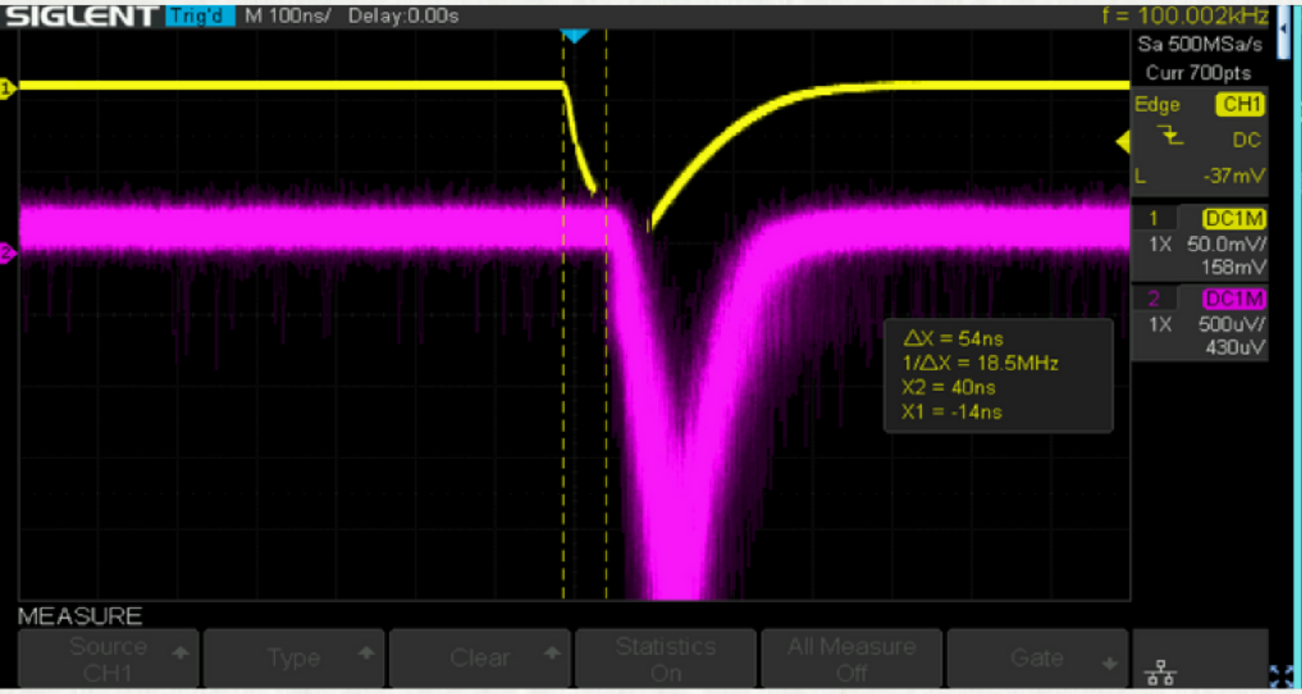
Cable	ΔL (m)
1	10.270 ± 0.05
2	4.243 ± 0.05
3	10.140 ± 0.05

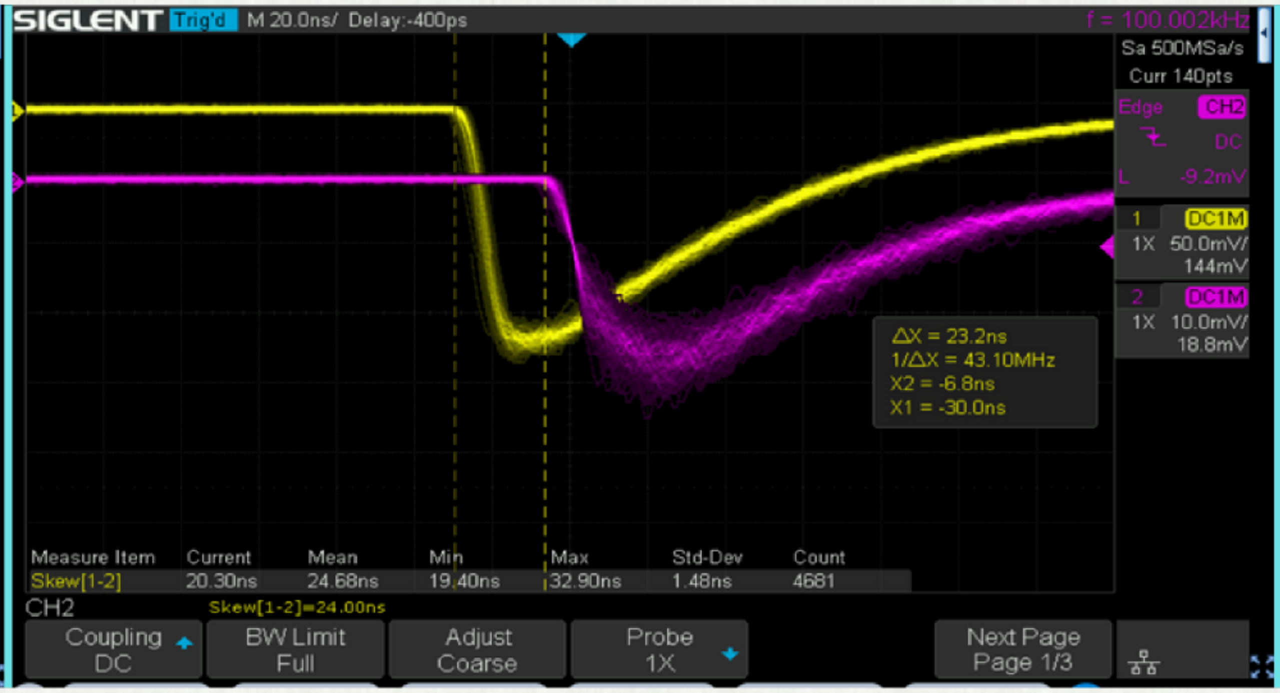
Execution

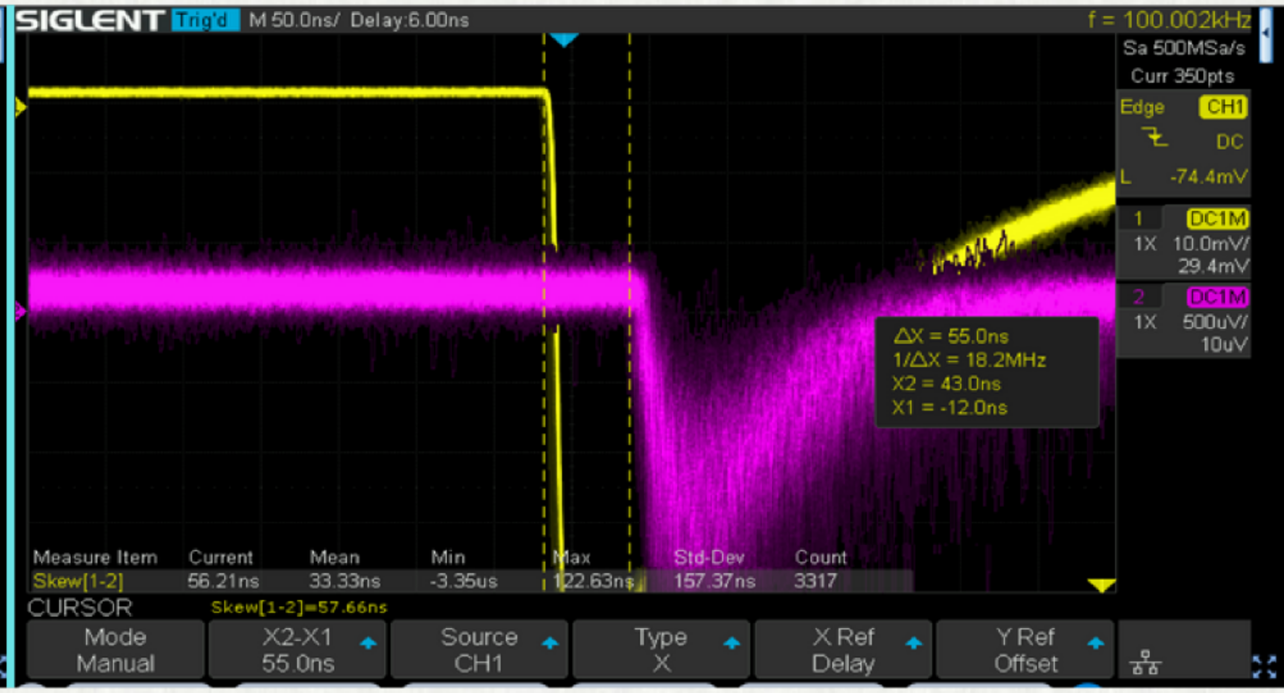
3

Observe oscilloscope and find Δt

Cable	Δt (ns)
1	54.0 ± 0.05
2	23.7 ± 0.05
3	55.0 ± 0.05







Execution

Error since 2 cables have roughly similar lengths

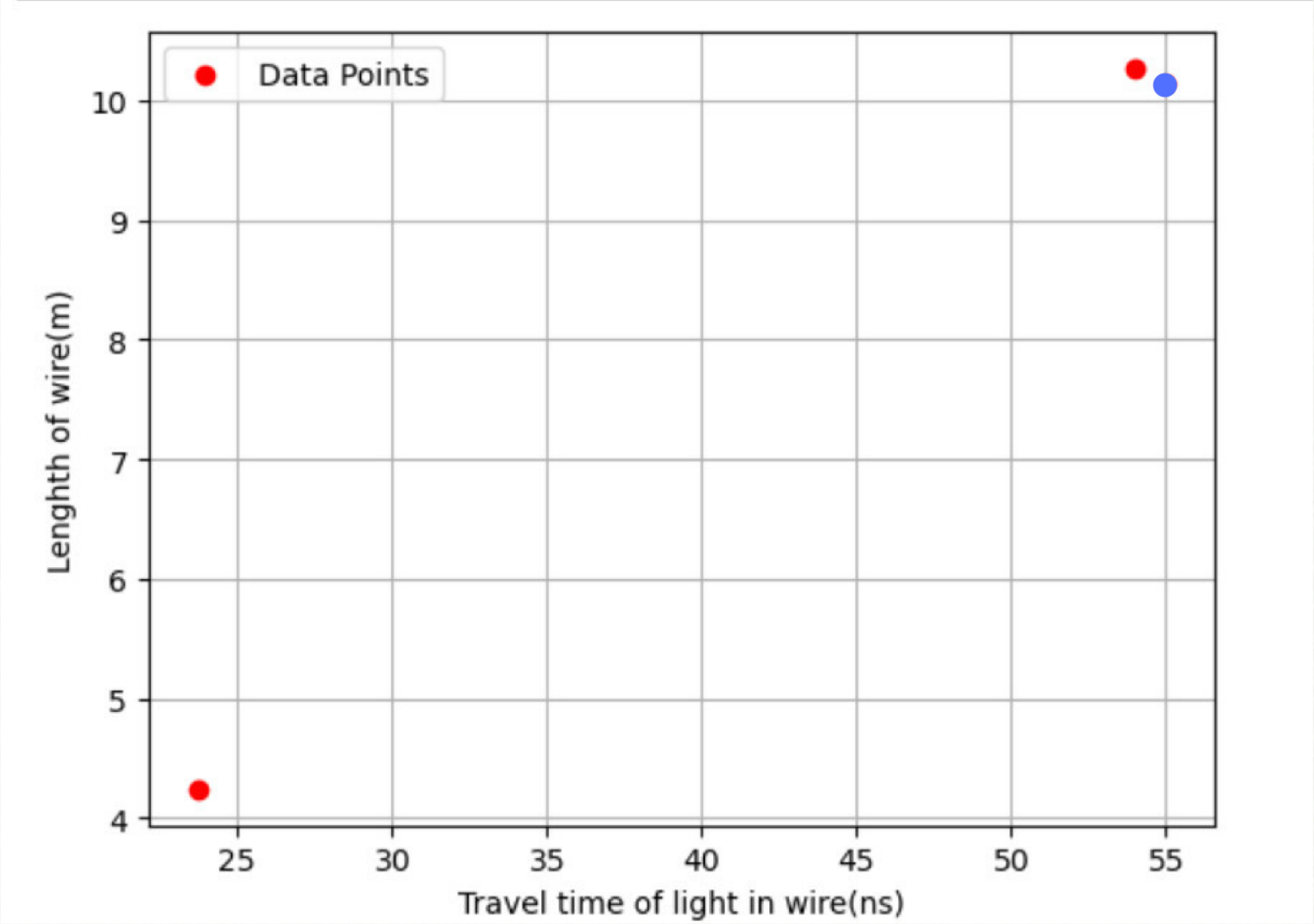


Figure 2B.4a The travel time of light in optical fiber for different wire lengths

Result

$$\delta V = \frac{\delta L}{\delta t}(m/s)$$

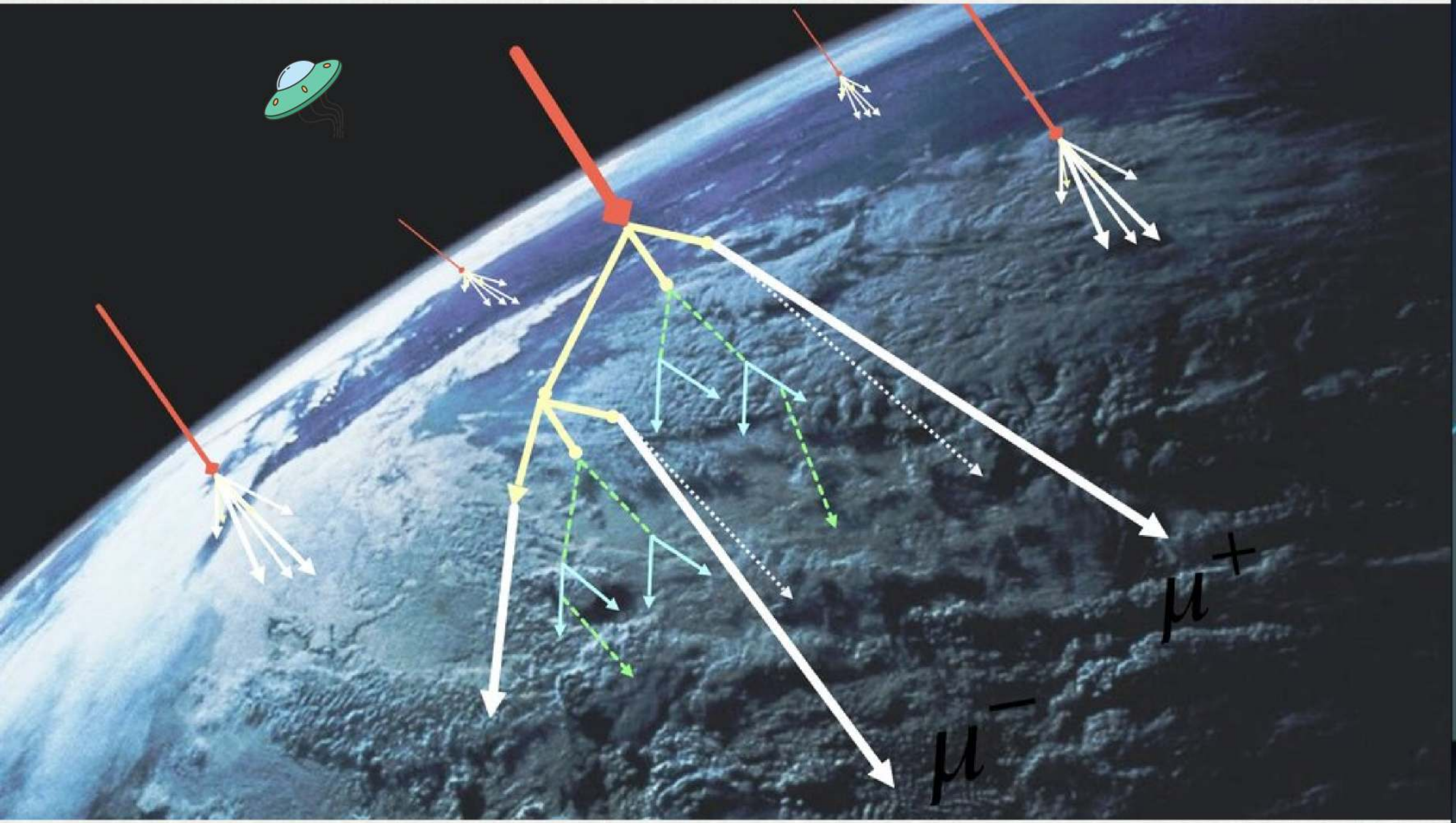
$$V_n = \frac{c}{n}$$

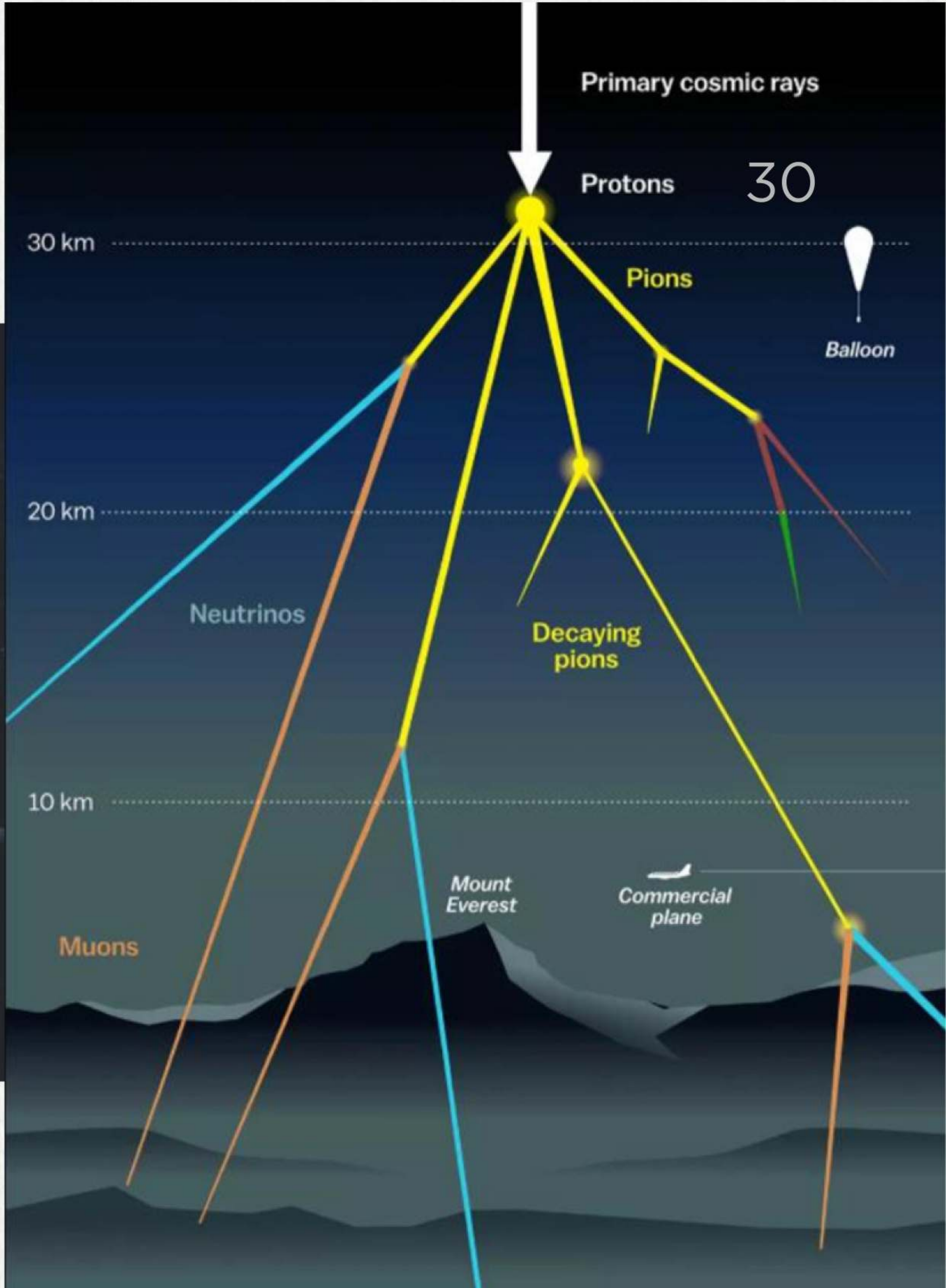
ΔL (m)	Δt (ns)	Speed (m/s)
10.270 ± 0.05	54.0 ± 0.05	190,185,185.2 ± 3,521,996
4.243 ± 0.05	23.7 ± 0.05	179,057,665.3 ± 7,554,011
10.140 ± 0.05	55.0 ± 0.05	184,363,636.4 ± 3,352,115

V = 184,535,495.6 ± 2,994,517 m/s ⟶ **Mean Index Refraction = 1.626 ± 0.027**

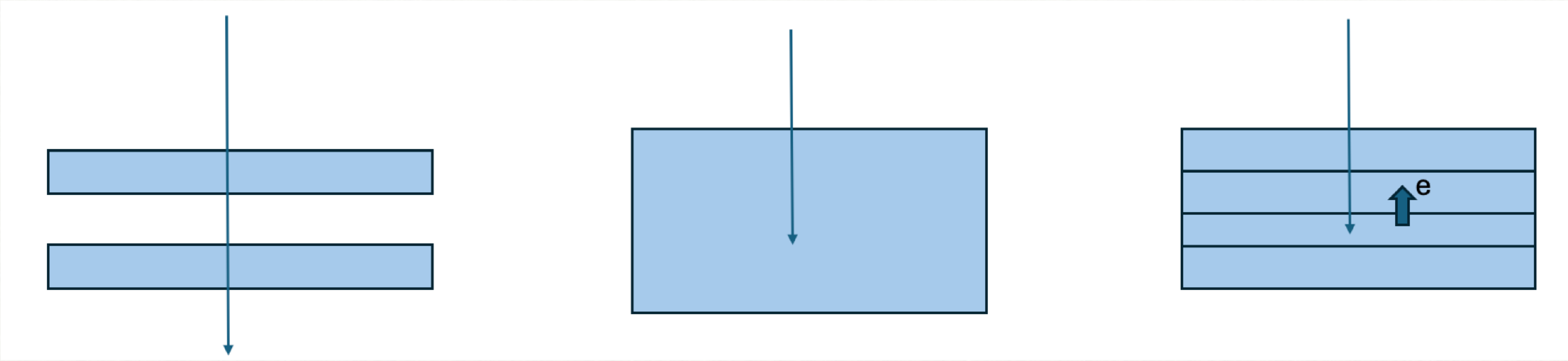
Expected n = 1.57 ~ 1.67

MUON COUNTING





Why measure Cosmic Ray Muons



Flux Measurement

- Important for calculating backgrounds for other experiments as muons are very penetrating

Decay Rate

- Muon lifetime can be used to calculate Fermi coupling constant i.e. the strength of the weak interaction

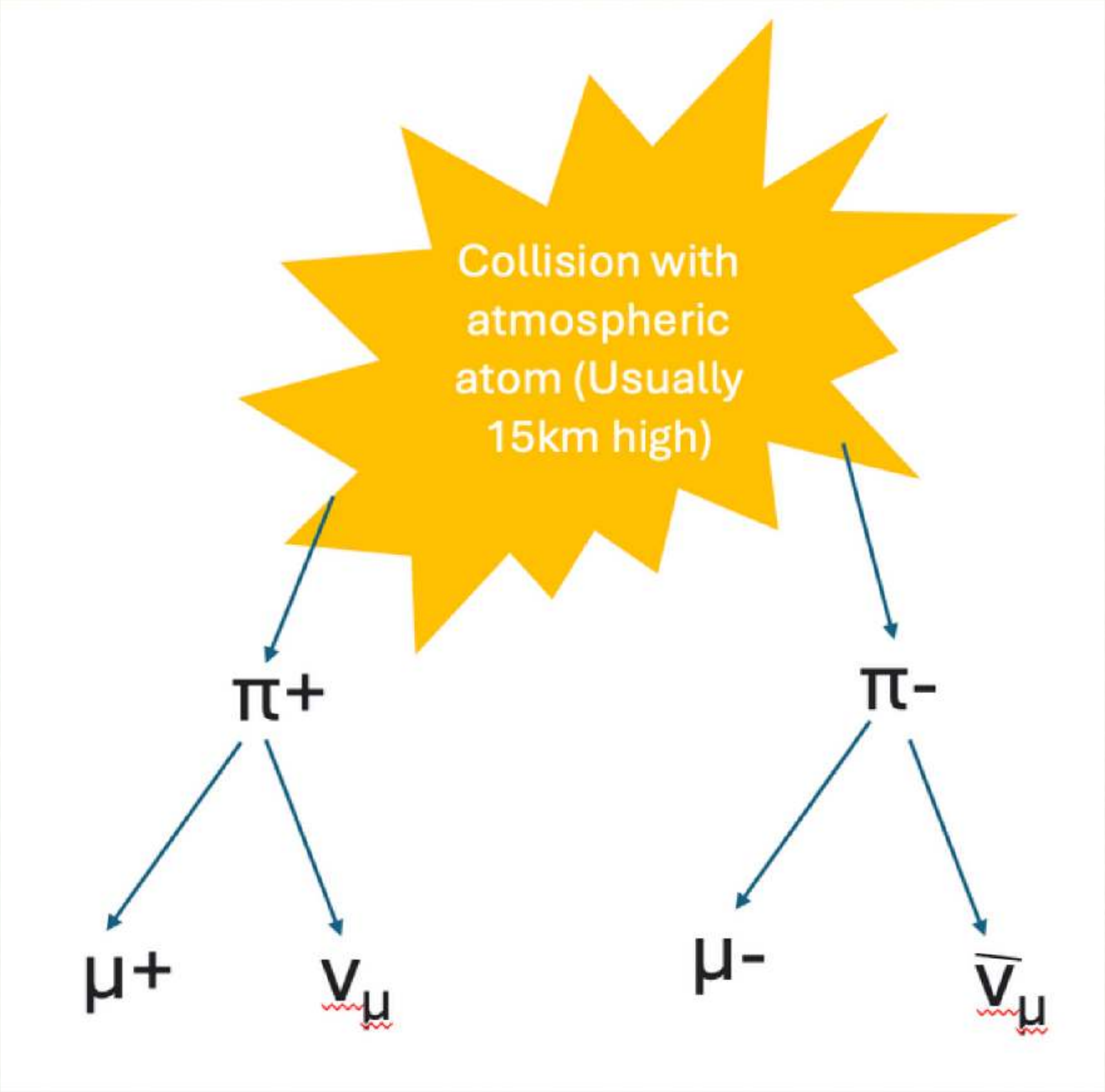
Direction of Decay

- Can find evidence of Parity violation

What are cosmic ray muons?

Cosmic rays are constantly colliding with matter in the atmosphere

- **Pions** are the predominant product of the interaction
- Due to the muons travelling at relativistic speeds and length contraction, they can be detected at the Earth's surface before decaying into electrons



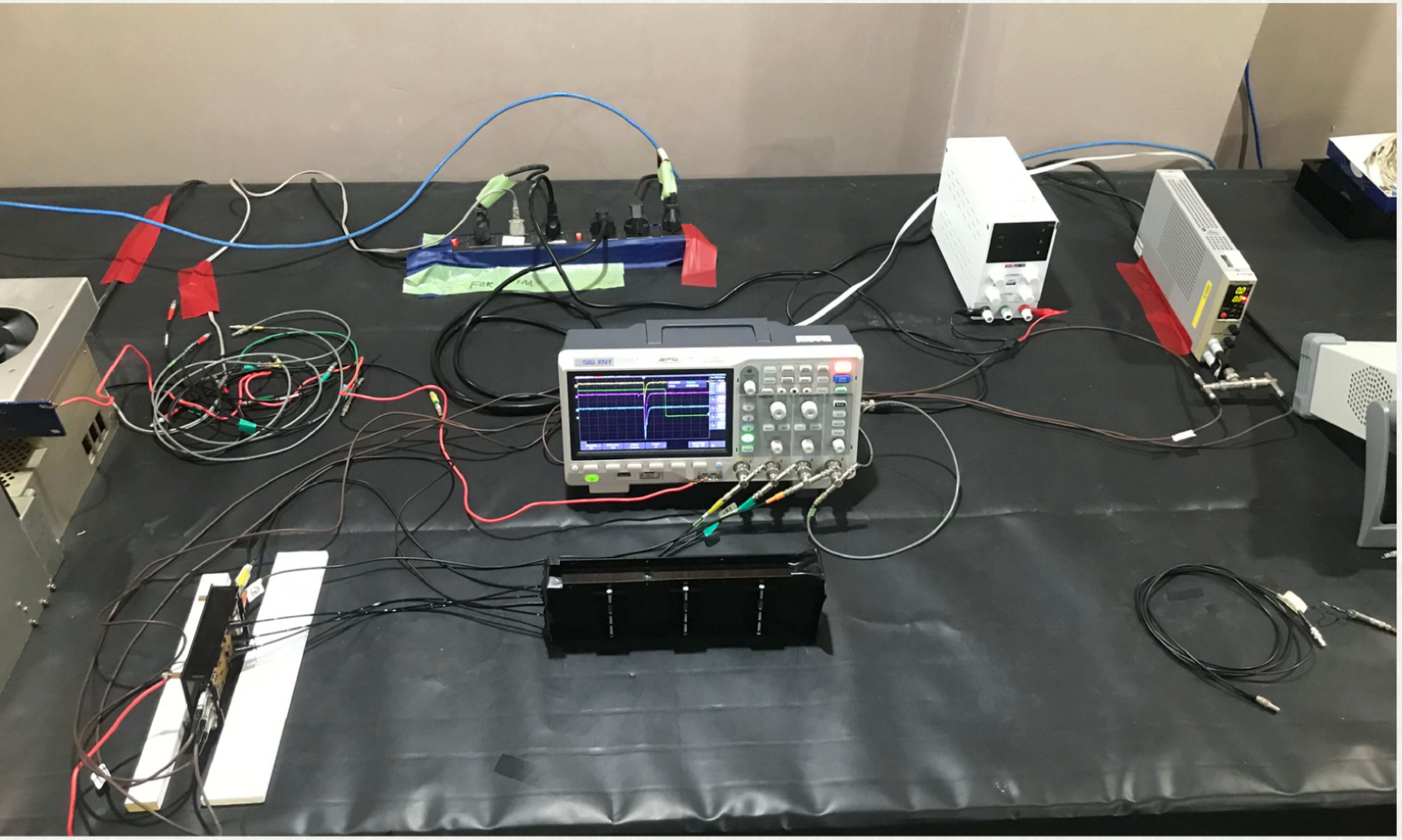
$$L = L_0\sqrt{1 - \frac{v^2}{c^2}}$$

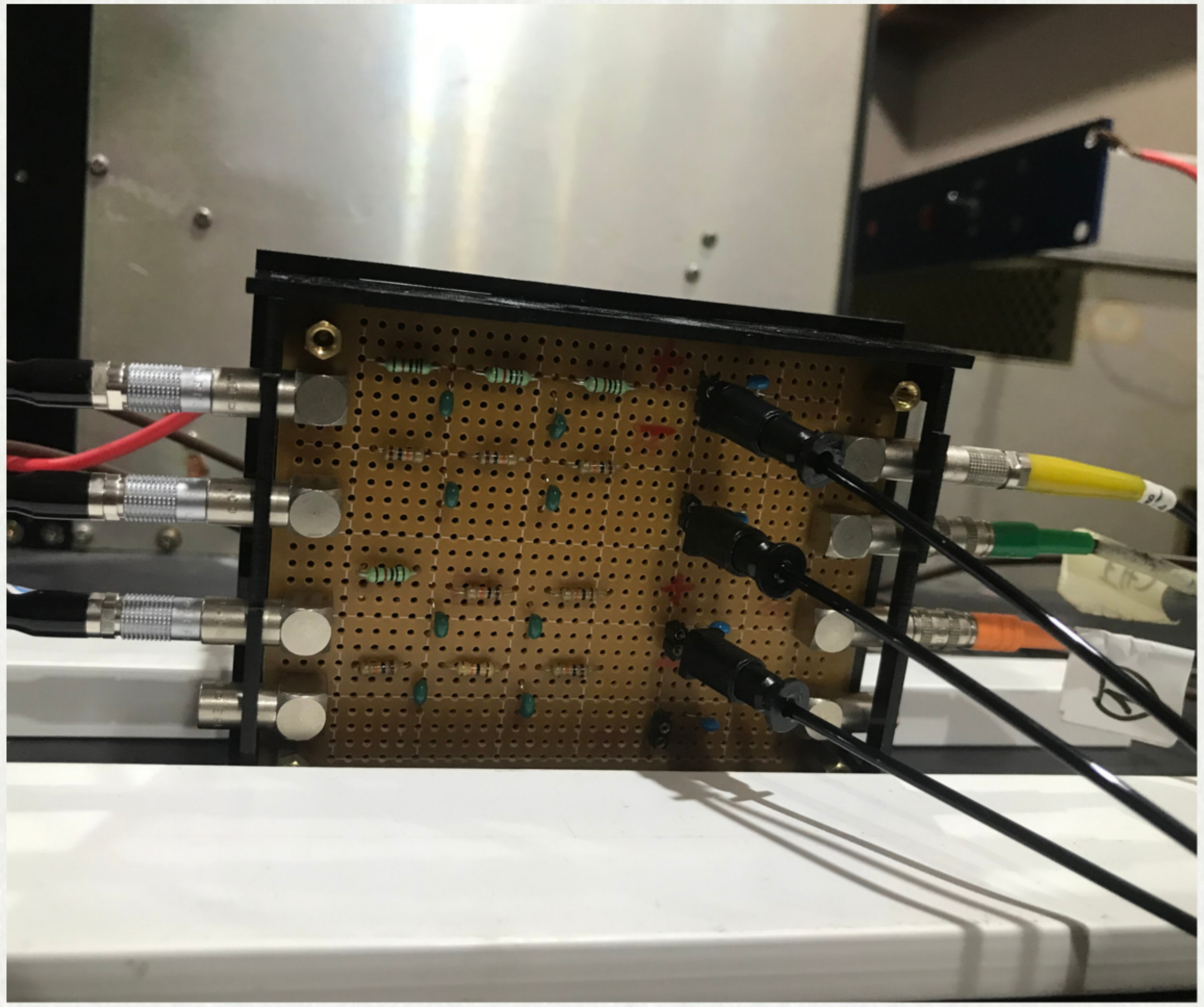
Theoretical background

How to measure muon count?

Muon excites electrons in scintillator → Electrons de-excite and emit photon → Photo sensor collects and converts photon into electrical signals

Experimental Setup



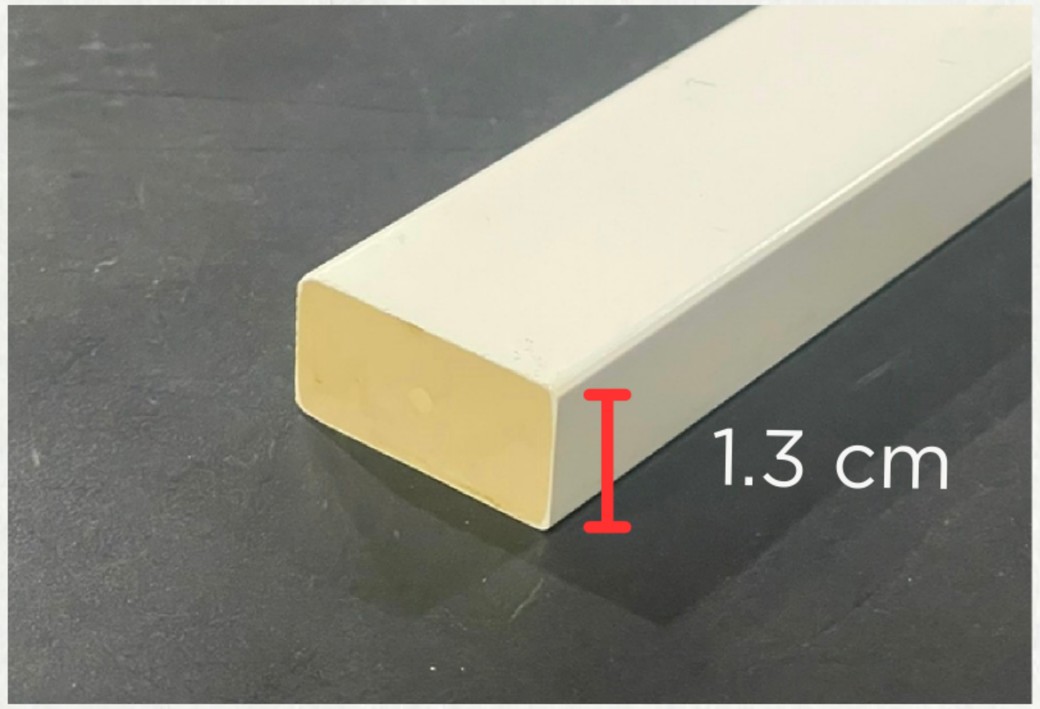


Experimental Setup

Single plastic scintillator

2.55 cm

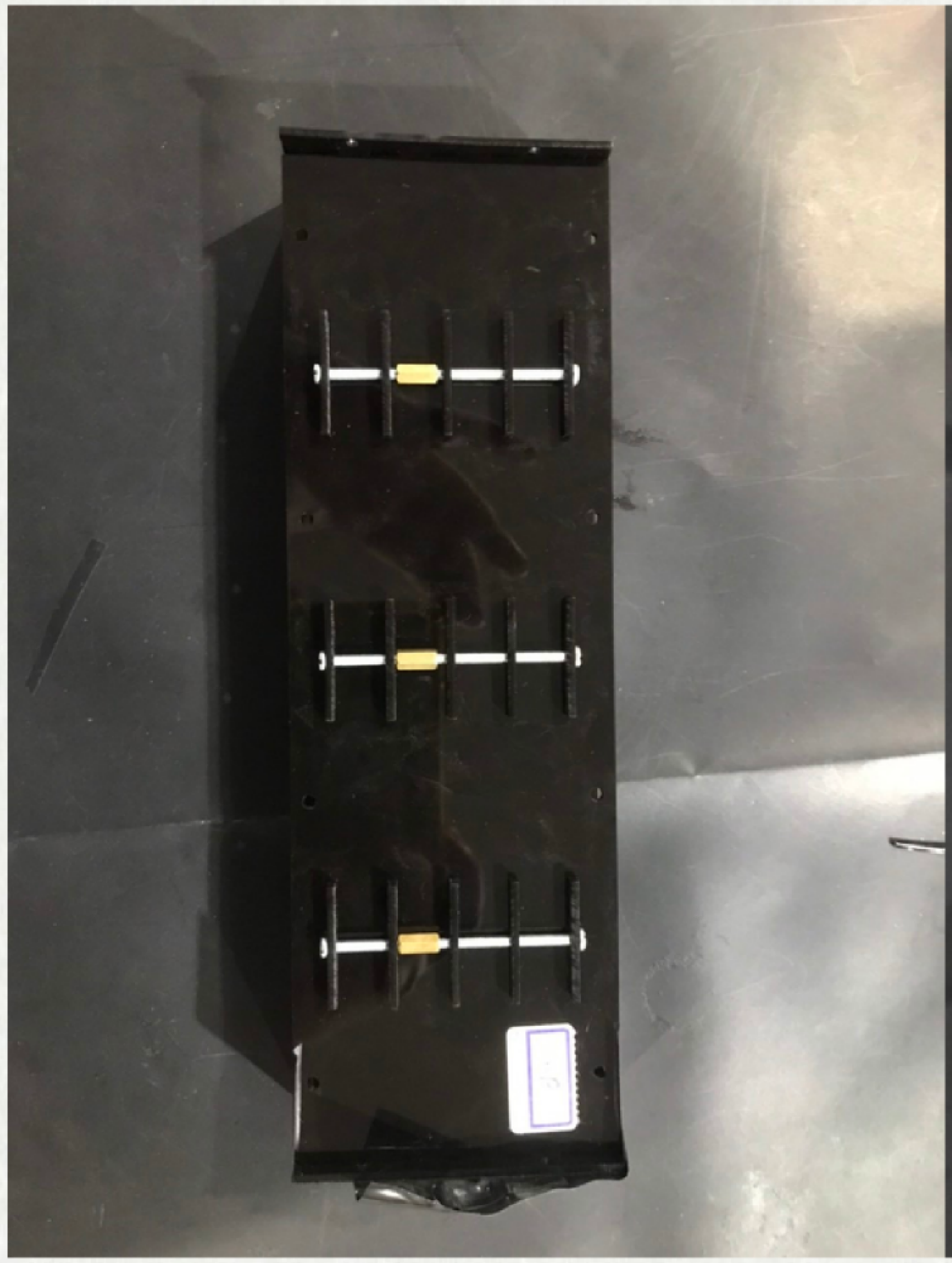
25 cm

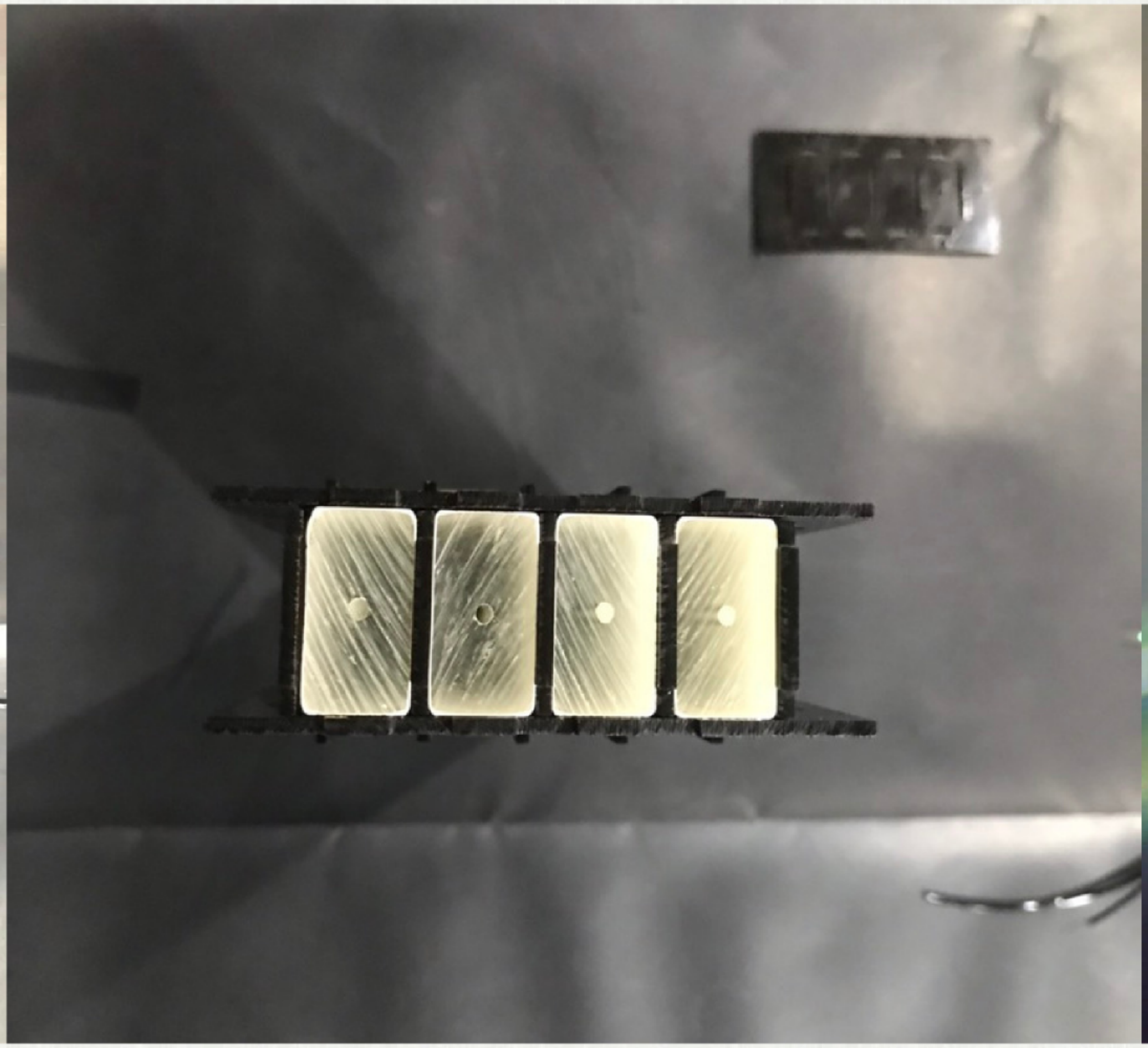


x4

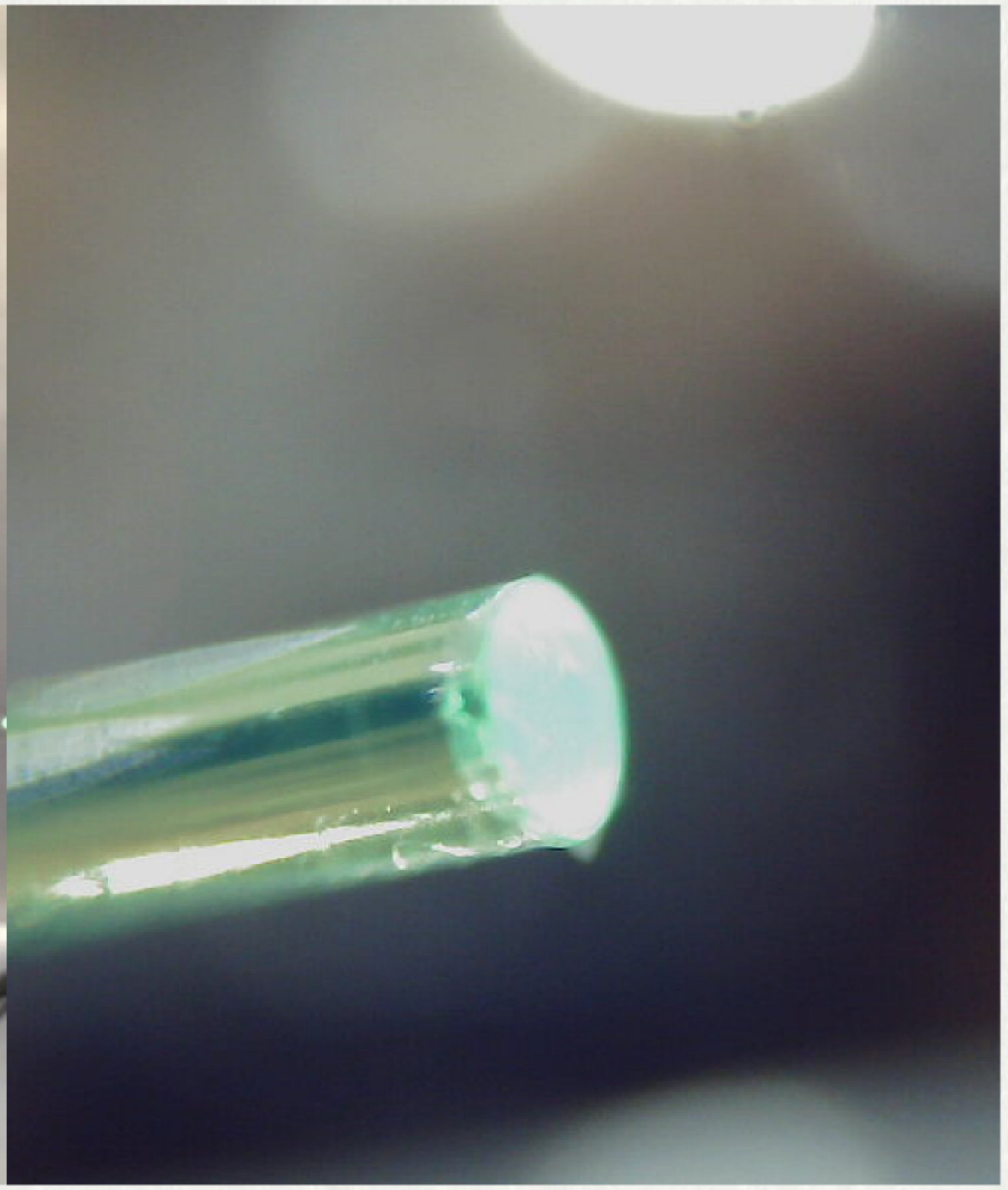
Area = 63.75 cm^2

Experimental Setup





plastic scintillator box

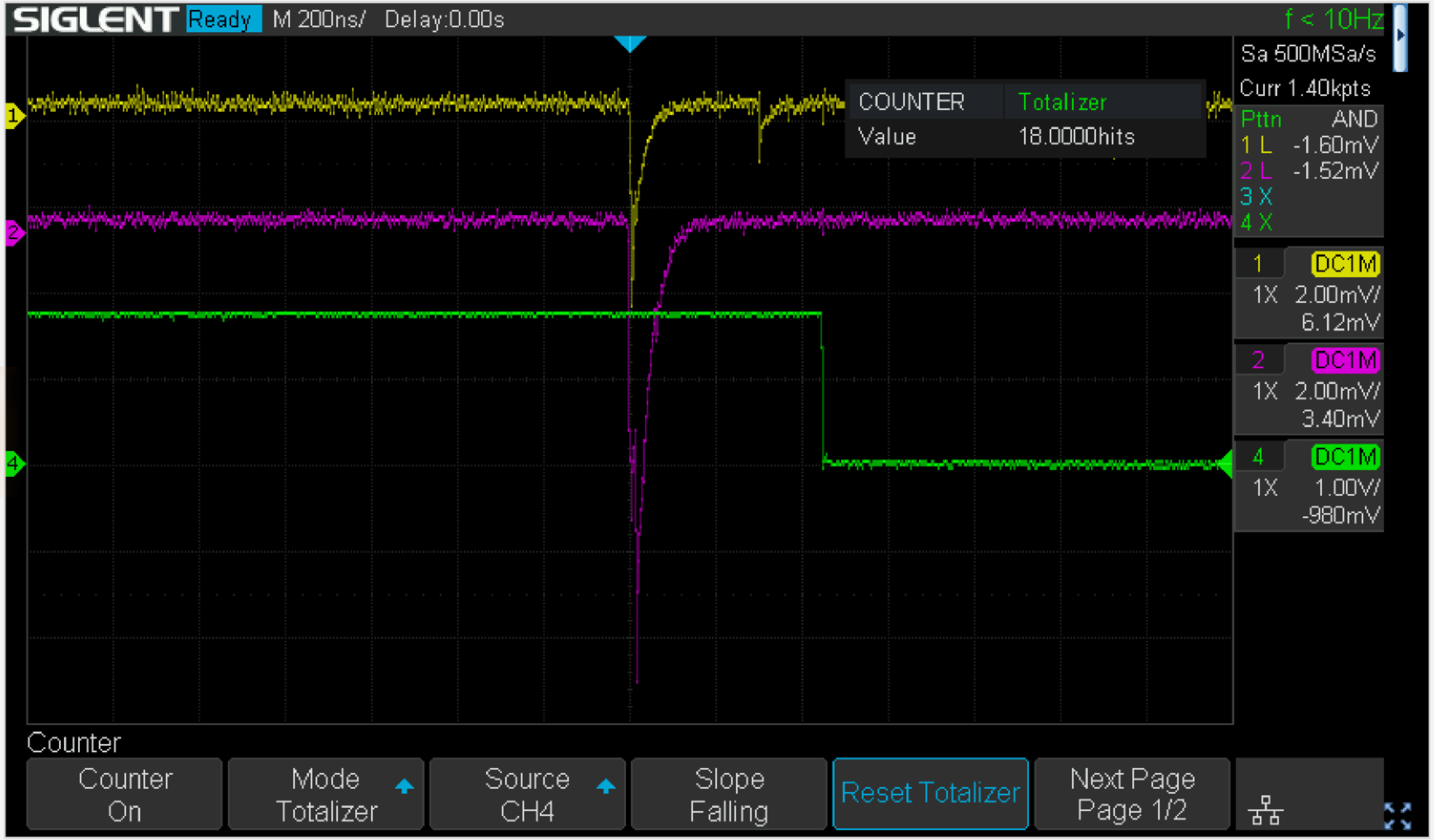


wavelength shifting fiber

Observations

The formula to calculate the **rate of muons**

$$r_\mu = \frac{hits}{time.Area}(min^{-1}cm^{-2})$$



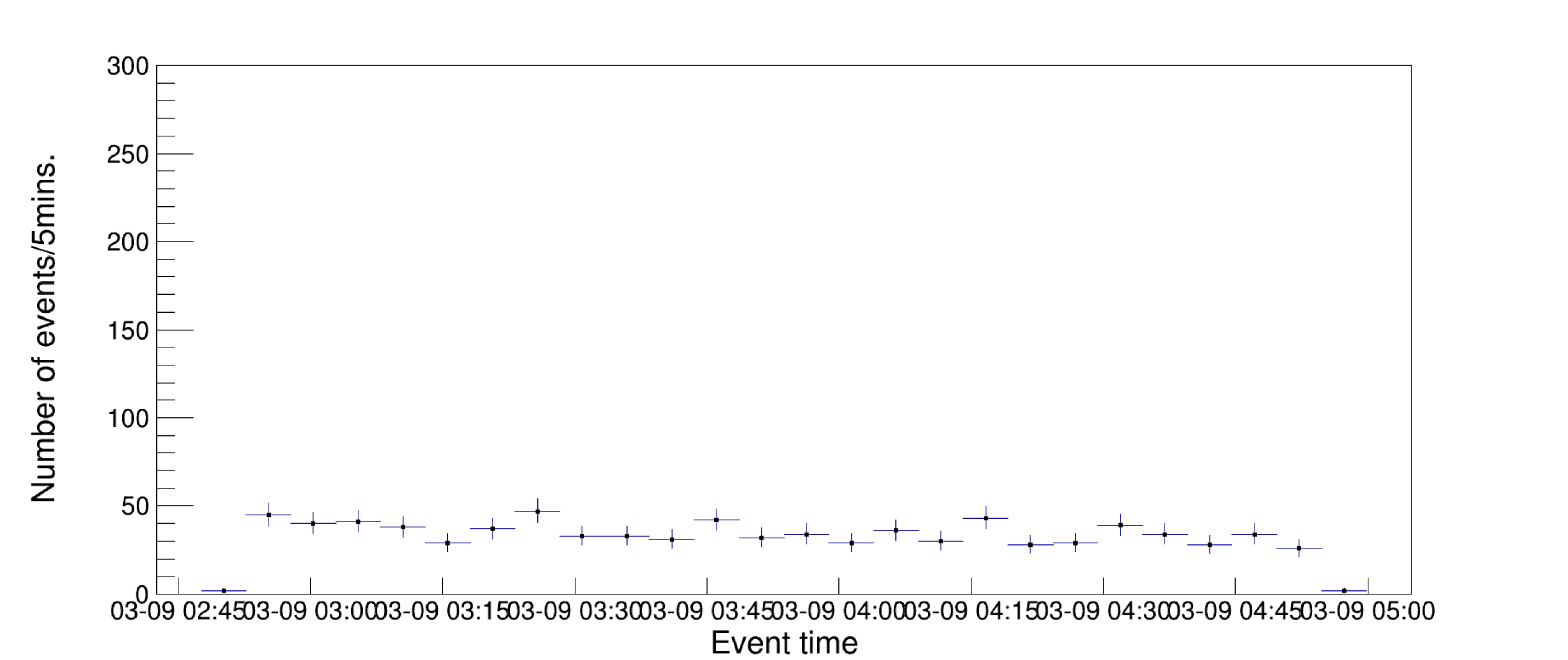
The moun signal coming from the two plastic scintillators

Results

Time measurement	Hits	Time (min)	Rate of muon (1/min.cm^2)
1	129	5	0.4047058824
	248	10	0.3890196078
2	123	5	0.3858823529
	246	10	0.3858823529

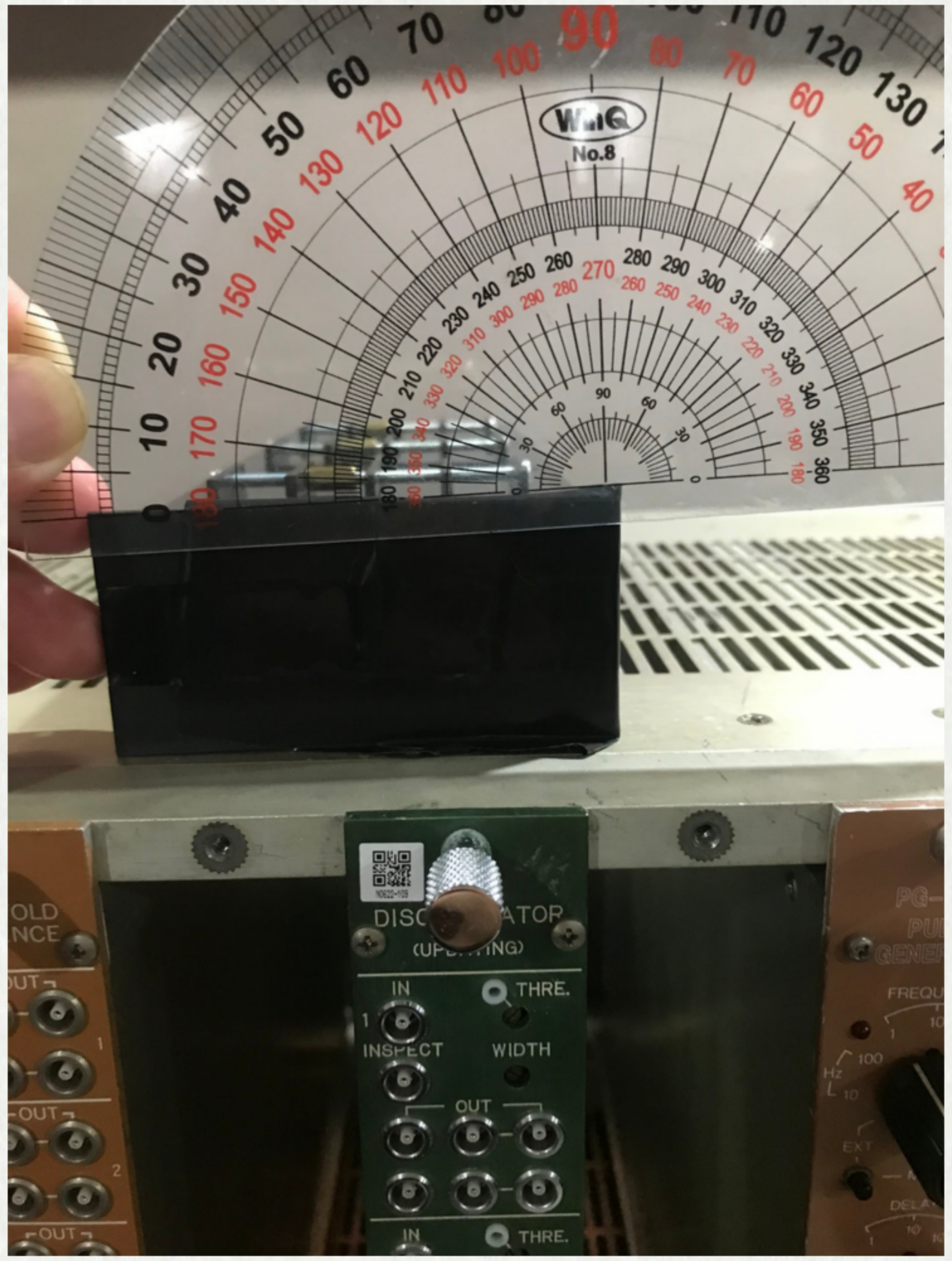
Rate of muon with 2 plastic scintillators

Results

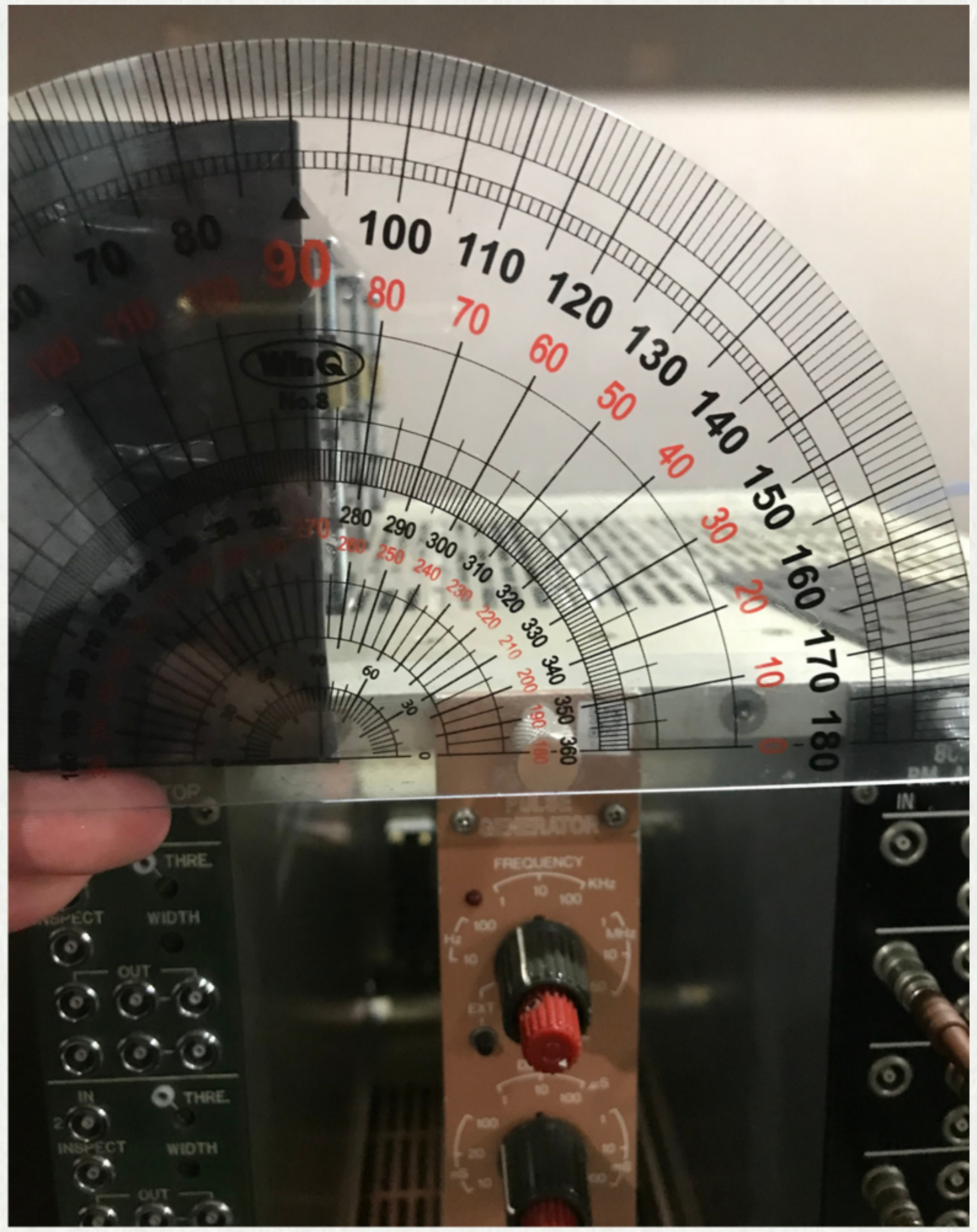


Rate of muon with 3 plastic scintillators

Experimental Setup



At 0 degree angle



At 90 degree angle

Observations

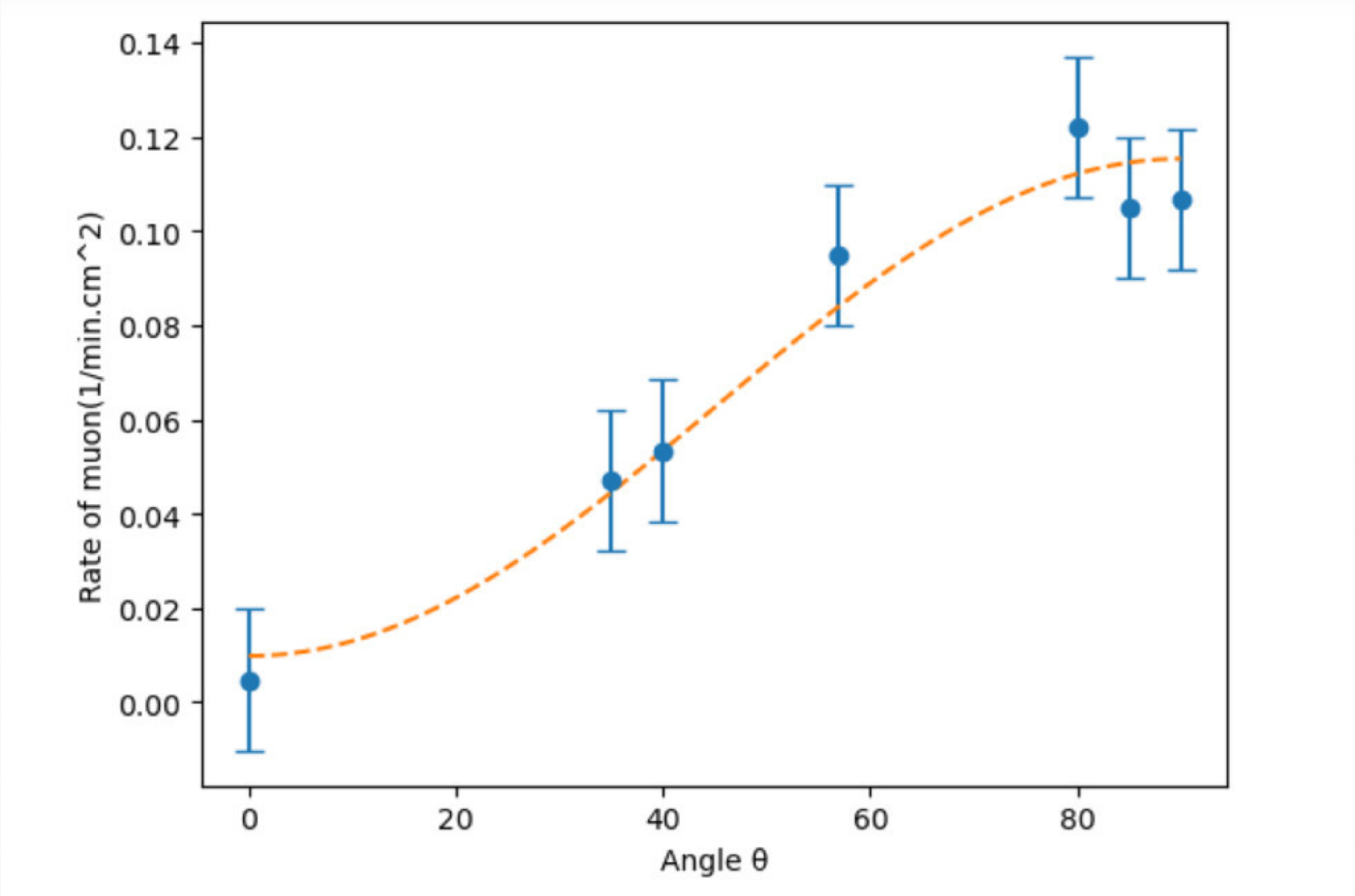
The muon signals coming from three plastic scintillators

Results

Time measurement	Angle (deg)	Hits	Time (min)	Rate of muon (1/min.cm^2)
1	0	3	10	0.004705882353
2	35	30	10	0.04705882353
3	40	34	10	0.05333333333
4	57	61	10	0.09568627451
5	80	78	10	0.1223529412
6	85	67	10	0.1050980392
7	90	68	10	0.1066666667

Rate of muon with 3 plastic scintillators changing of angles

Results



Rate of muon at different angles

SUMMARY

MPPC Characteristics

- Noise ✓
- Noise coincidence ✓
- Electric gain ✓

ToF method

- Speed of light in optical fibers ✓
- Speed of electrical signal in LEMO cables ✓

Cosmic ray muons

- Rate (muon flux) ✓
- Light yield (# of photons) ✓
- Zenith angle ✓

DISCUSSION & SIGNIFICANCE

- Most results **matched expectations** set by theory/datasheet
- Any small disagreement can be explained in terms of experimental setup or statistical error
- Improvements to experiment suggested


for Water break
Behind this Door
or Go to 1st floor
Please,
CLOSE the
DOOR after you




THANKS!

ANY QUESTIONS

"fancy"
phen xì