MPPC Characterization Experiments

Study the Speed of Light in Cable & Muon Rate at Distinct Angles

Group Members

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Presentation Overview

etoolbox

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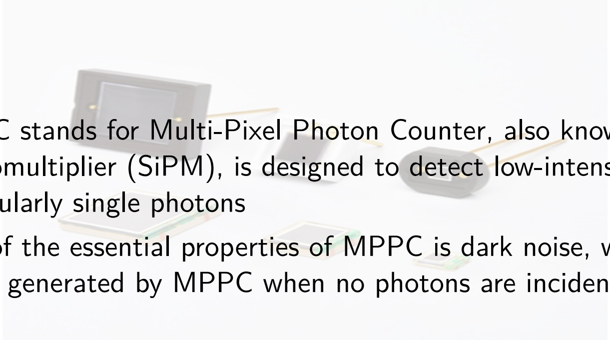
Objectives

- Create a simple yet proper cosmic ray muon detector using scintillators and Multi-Pixel Photon Counter (MPPC).
- Create a simple system to study the speed of light in optical fibers using MPPC.

Definition



- MPPC stands for Multi-Pixel Photon Counter, also known as Silicon Photomultiplier (SiPM), is designed to detect low-intensity light signals, particularly single photons
- One of the essential properties of MPPC is dark noise, which is the output signal generated by MPPC when no photons are incident on the detector.

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Setup

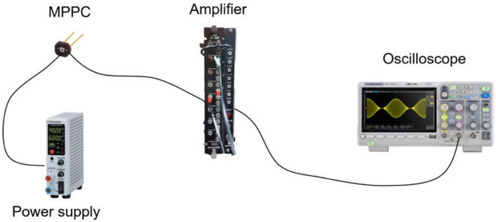
Instrument

- Power Supply
- MPPC
  - Type: S13360-1325CS
  - Serial: 12482
  - $V_{breakdown}$ from manufacturer: 51.85V
  - $V_{operator}$: 56.85V (=$V_{breakdown}$ + 5V)
- Oscilloscope

Setup

Setup

- MPPC & a low-pass filter is placed inside a dark box, electrically connected.
- A power supply is linked to the box to generate electricity.
- The circuit will then send signal to an oscilloscope.
- We analyze the data coming on the oscilloscope in this setup.



Examination of $V_{breakdown}$

Procedure

- Provide power with the source supply.
- Use the *Vertical & Horizontal Scale*, as well as the *Trigger* button to adjust and find the pulse shape.
- Measure the distance from the base to the peak.

- There are mostly pulse of 1 p.e, sometimes 2 p.es, and rarely 3 p.es.

Examination of $V_{breakdown}$

Purpose

- Determining the V_{BR} of MPPC initially is practically beneficial and recommendable.
- Most MPPC characteristics are dependent on V_{over}.

Note

Recommended to compare or calibrate the characteristics of MPPCs at the same V_{over}.

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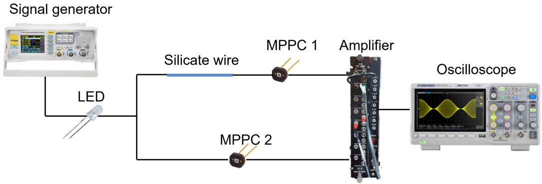
Setup

- A signal generator is connected to an LED.
- The LED then be covered and linked by a cable which will be divided into 2 paths.
- Two MPPCs are joined at the end of two cables, respectively.
- MPPCs are bonded to the amplifier to augment signals.
- Signals then be transmitted to the oscilloscope for analysis purpose.



Procedure

- Turn on the generator to provide electricity for the LED.
- Observe the received signals on the oscilloscope.
- Change the length of the fiber of one path. Then, observe the alternative signals.

Purpose

- Determine the speed of light in a given optical fiber.
- From the obtained data, find the *Refractive Index* of that material.

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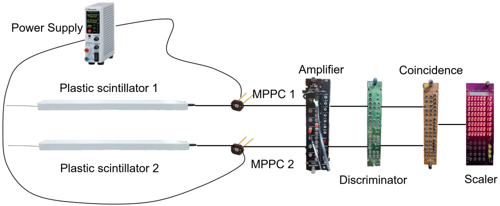
Setup

- MPPC
- Scintillators connected with optical fibers
- Power supply
- Connect the optical fibers to the MPPC



Setup

MPPC board:

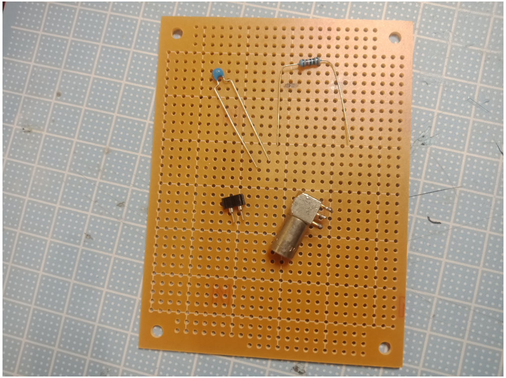


Fig. 1: LED board with components

Setup

MPPC board:

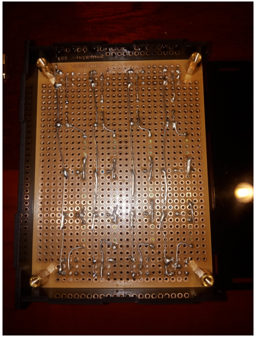


Fig. 2: LED circuit board's front face.

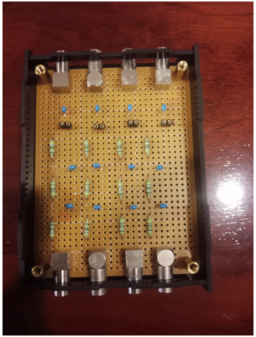


Fig. 3: LED circuit board's back face.

Setup

MPPC board

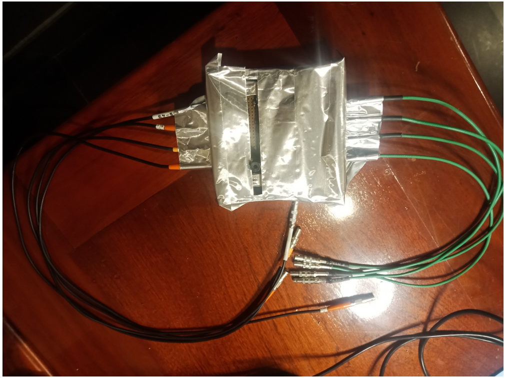


Fig. 4: Complete MPPC Circuit

Setup

The scintillators & MPPC boards are coupled as the following figure:

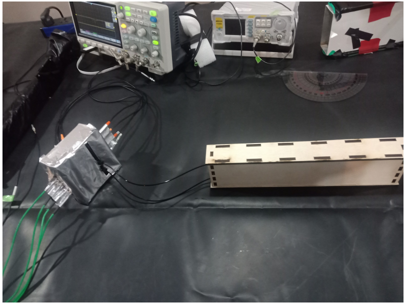
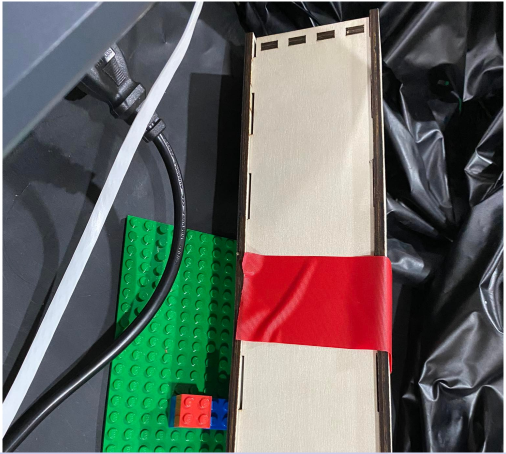


Fig. 5: MPPC & Scintillators setup for Muon Detection

Setup

The scintillators at different angles



Procedure

- Provide power with the source supply.
- Use the *Vertical & Horizontal Scale*, as well as the *Trigger* button to adjust and set the threshold.
- Cover the scintillators & MPCC boards system to ensure that no incidence external photon could disturb and cause unwanted false signal.
- Record the muon counts for around 15 minutes on a measurement of an angle.
- Analyze the data acquired to have the muon counts distribution.

Cosmic Ray Detection (Muon Rate)

Purpose

- Calculate muon rate in different scintillator's angle.
- Obtain the muon counts distribuiton.

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Outcome

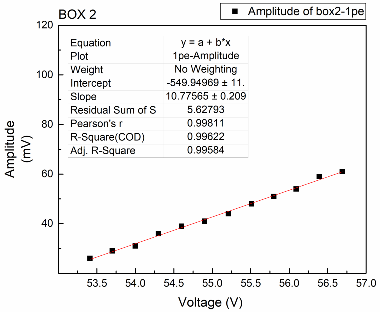

Fig. 6: Box 2 - The Relation between Supply Voltage and Pulse Amplitude - 1 p.e

Discussion

- Our findings indicate that the breakdown voltage of the MPPC depends on the applied voltage. The higher the applied voltage, the higher the breakdown voltage.
- The result of the breakdown voltage that we obtained has an approximation error of about 3% and the standard deviation is not significant.
- limitations of our study are we only examined the breakdown voltage of one type of MPPC and under a limited range of conditions.
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Outcome

- For 2 same length of fibers:

- For 2 same length of fibers:

Discussion

- The time for light travel is linearly proportional to the optical fiber's length. The slope corresponds to the velocity of light in optical fiber and it is 0.1867 m/ns. From this, we can calculate the refractive index.
- The refraction index is nearly the same in different wire lengths.

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Outcome

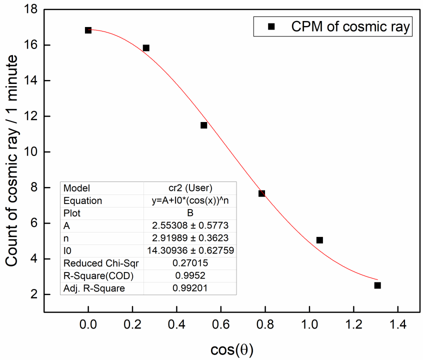

Fig. 13: Relation between the angle of scintillator and counts of cosmic rays per time

Outcome

Cos(θ)	Count/mins	Error
1.308	2.50	0.00
1.047	5.04	0.23
0.785	7.67	0.00
0.523	11.49	0.57
0.262	15.83	0.64
0.000	16.82	0.68

Fig. 14: Data table

Cosmic Ray Detection (Muon Rate)

Outcome

- From the plot, we can see that the bigger the angle between the scintillator and the horizontal axis, the larger the recorded cosmic ray count.
- From the experiment, the cosmic ray counts per time along the angle of the scintillator form a Gaussian distribution.

Discussion

- The errors occur due to the fact that we take the mean of measurements over a small time interval. If we consider a longer period of time, the counts of cosmic rays maybe more stable, thus reducing the error.

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Project Hindrance:

- Room temperature affects the natural properties of material.
- Noise from the other instruments.
- Could not create a total Faraday cage.
- Other sub-particles than Muon can be detected by scintillator, especially electron.
- Time limited to perform enough long experiments for stable measurements.
- Instrument errors.
- The **Biggest** hindrance is our own inexperience

What have we learnt?

- How to use oscilloscope system, MPPC and some type of experiments related to it.
- Understand the principles of scintillation detectors, trigger DAQ, cosmic ray detection, etc.
- Know how to solder MPPC circuit, arrange measurement system, and polish optical fibers

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Bonus

As requested, this is our assignment for the homework of Prof. Suzuki.

Simple experiment (2)

Exercise

1. Particle decay follows the following formula:

$$N = N_0 e^{-t/\tau},$$

where N and N_0 are the numbers of events at time t and 0, respectively, and τ is the lifetime.

The right side table is a result of the experiment.

(a) Make a plot of the number of events as a function of the decay time (use log scale as a vertical axis).

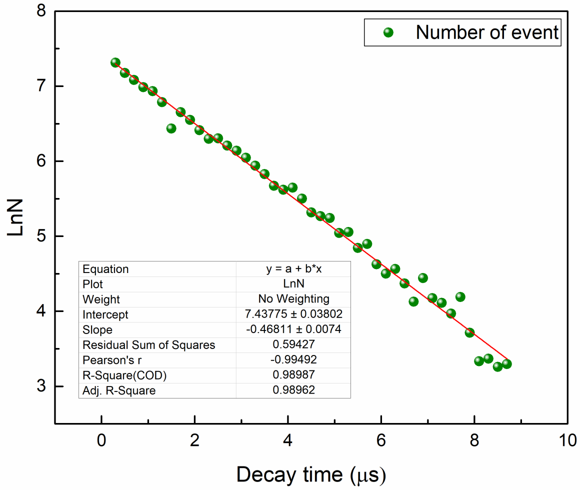
(b) Get the muon lifetime.

2. Some events show no 2nd signal which corresponds to decay electron. What are those events ?

Decay time t [μ sec]	Number of events	Decay time t [μ sec]	Number of events
0.3	1501	4.7	194
0.5	1308	4.9	189
0.7	1191	5.1	155
0.9	1082	5.3	157
1.1	1024	5.5	127
1.3	886	5.7	134
1.5	823	5.9	102
1.7	775	6.1	90
1.9	700	6.3	96
2.1	610	6.5	79
2.3	544	6.7	62
2.5	547	6.9	85
2.7	497	7.1	65
2.9	463	7.3	61
3.1	422	7.5	53
3.3	380	7.7	66
3.5	340	7.9	41
3.7	291	8.1	28
3.9	276	8.3	29
4.1	283	8.5	26
4.3	245	8.7	27
4.5	204		

* ex. "0.3" means $0.1 \leq t < 0.4$ [μ sec]

Bonus


Number of event
LnN
Decay time (μs)
8
7
6
5
4
3
0
2
4
6
8
10
Equation
y = a + b*x
Plot
LnN
Weight
No Weighting
Intercept
7.43775 ± 0.03802
Slope
-0.46811 ± 0.0074
Residual Sum of Squares
0.59427
Pearson's r
-0.99492
R-Square(COD)
0.98987
Adj. R-Square
0.98962

- For the first question:

$$N = N_0 e^{\frac{t}{T}}$$

$$\Rightarrow ln(N) = ln(N_0) - \frac{t}{T}$$

$$\Rightarrow ln(N) = (-\frac{1}{T})t + ln(N_0)$$

From the plot, we have the regression line function.

We have

$$\Rightarrow -\frac{1}{T} = -0.47 \Rightarrow T = 2.13 = \text{Muon lifetime}$$

Bonus

- For the second question:
  The events that show no second signal correspond to muons that did not decay within the detector. Muons are unstable particles and will decay into an electron, a muon neutrino, and an electron antineutrino with a certain probability within their lifetime. However, some muons may travel through the detector without decaying and will not produce a second signal.