Measuring the Timing Resolution of a WLSF

2021 Capstone Project 

Andrija Paurevic - February 16th, 2022

Presentation Outline

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What is Capstone?

- A semester long course offered at the University of Toronto
- Team of four work with a ‘client’ to complete a design project.
- The Engineering Physics division normally works with the laboratory co-ordinators to improve laboratory equipment/experiments
- Last semester, our team thought we would try something new and work with Professor Miriam Diamond and help get an experiment up and running
- Our design project was,

> To design and build an experimental set-up to facilitate the measurement of timing resolutions in WLSFs.

Our Team




- (Top-left): Ayse Ozdincer
- (Top-right): Andrija Paurevic
- (Bottom-left): Alexander Fogarassy
- (Bottom-right): Zhengbang Zhou

We are all undergraduate Engineering Physics students here at the University of Toronto.

Building a Dark Box 101

(Do not try this at home)

- Unfortunately, dark boxes that can house metres of WLSF are hard to come by
- So we put on our Engineering hats and got to work building one for the lab

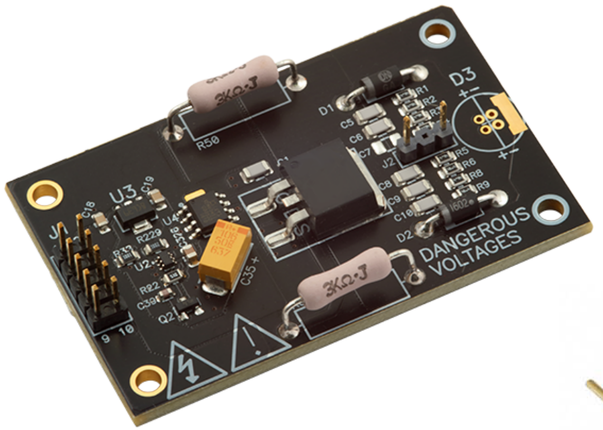
Building a Dark Box 101

(Do not try this at home)

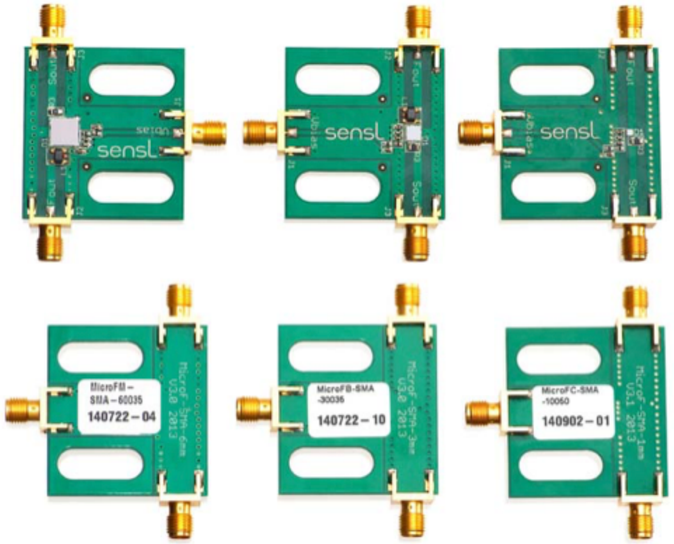
- After some time we had our final result!
- Key features: hinged lid, built in BNC-to-BNC through-hole connectors

Experimental Set-Up

Third-Party Components (links to documentation available)



PCO-7114 LED Pulser



SensL RB–Series SiPM

LED (405 nm)

Y-11(200) WLSF

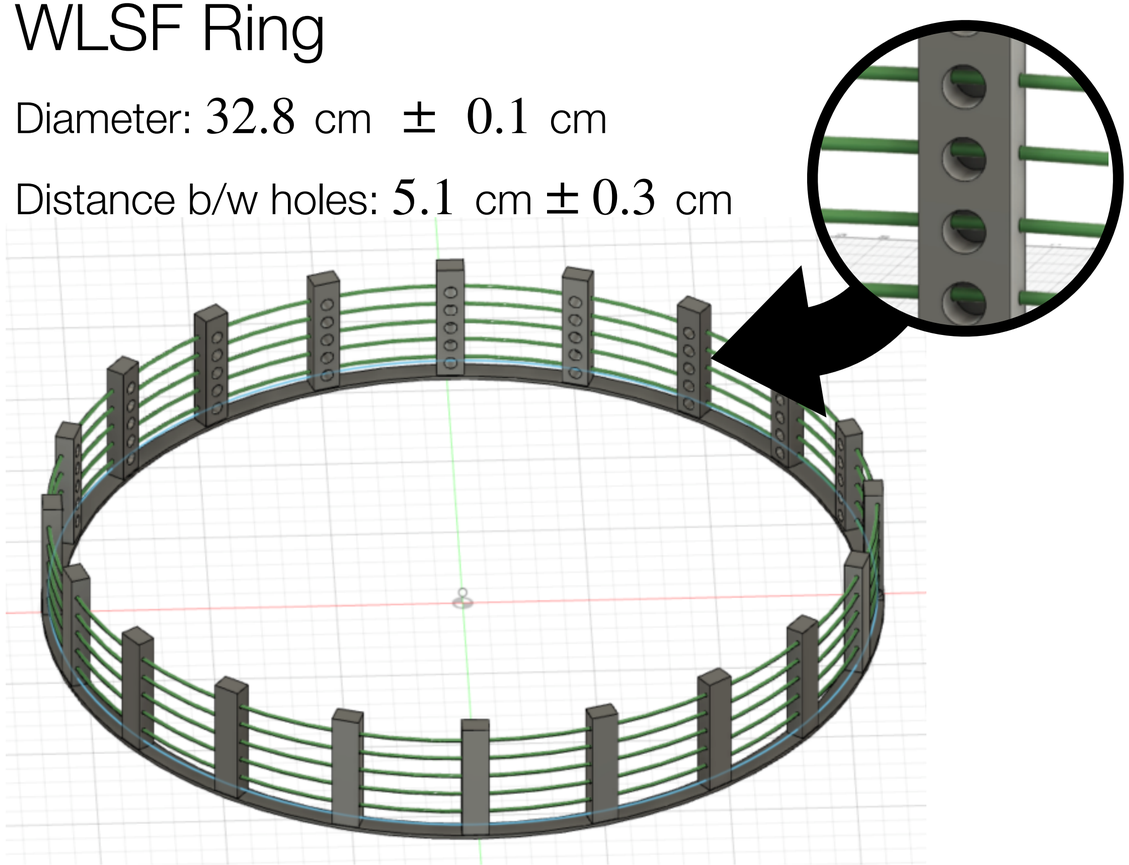
Experimental Set-Up

Custom Mechanical Components

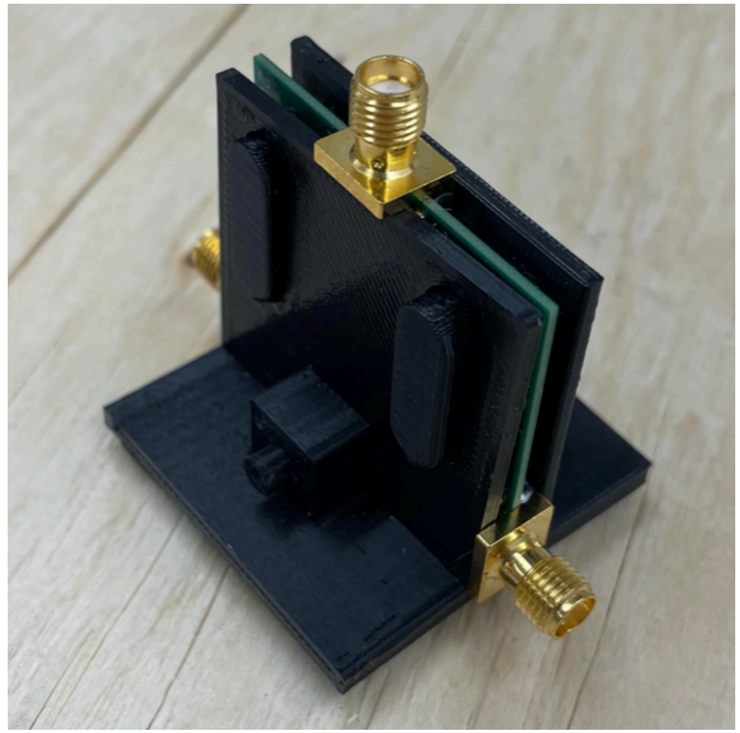
WLSF Ring

Diameter: 32.8 cm $\pm$ 0.1 cm

Distance b/w holes: 5.1 cm $\pm$ 0.3 cm



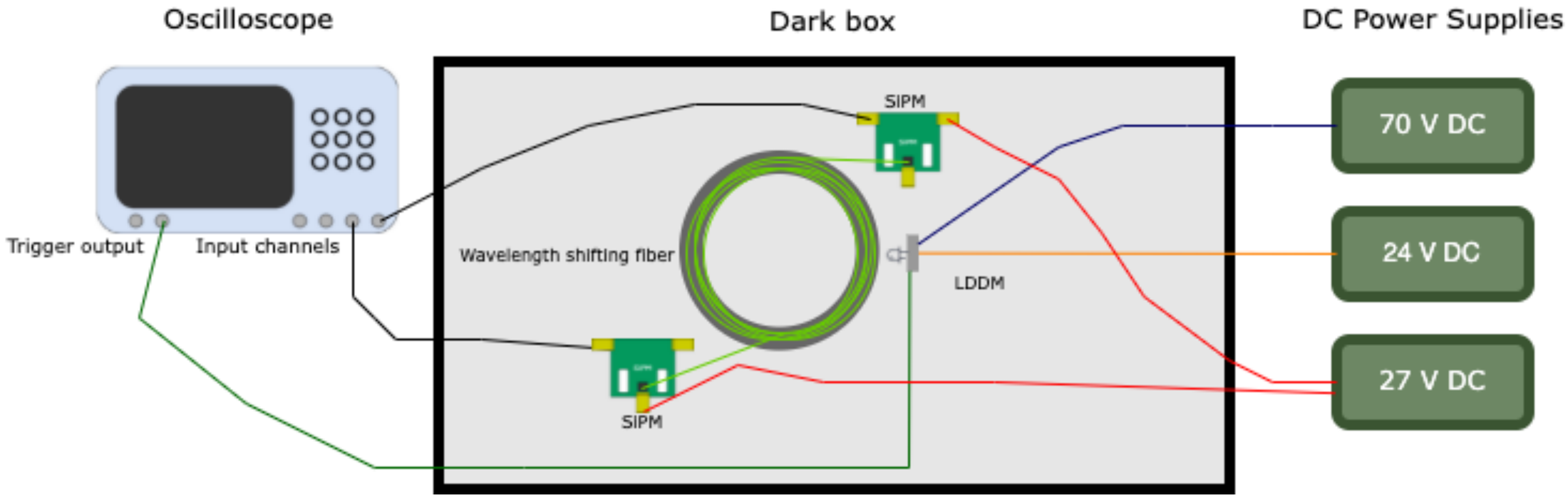
SiPM Holders



Experimental Set-Up

Inside the Dark Box

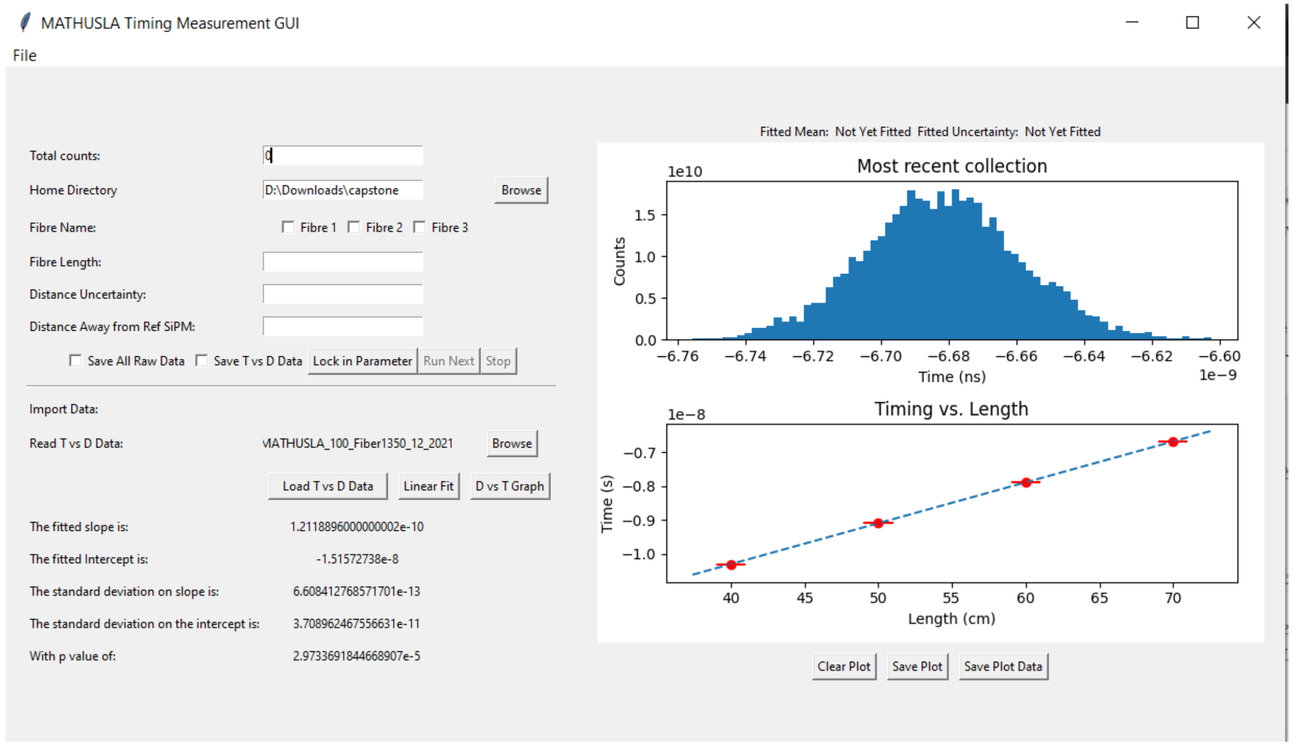
- We had the following high-level set-up in the dark box



Software Development

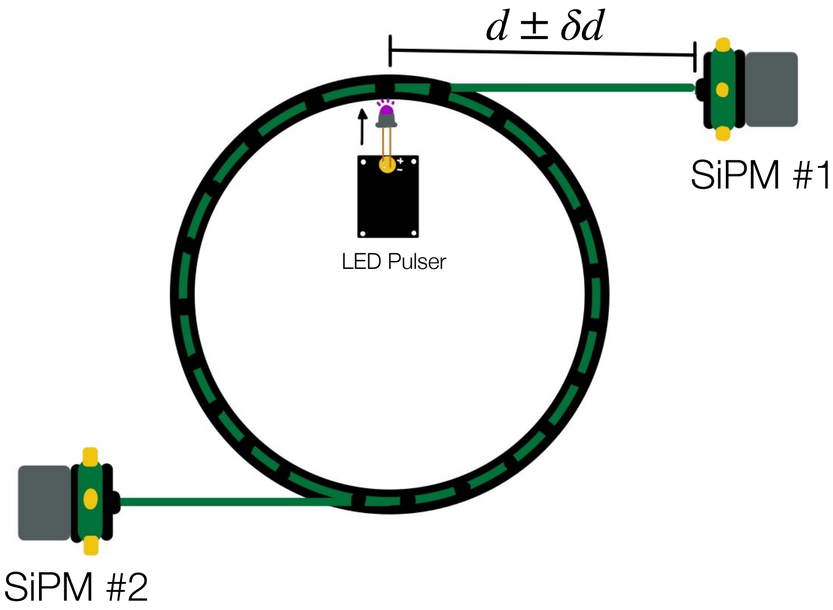
Custom GUI and Data Analysis Script

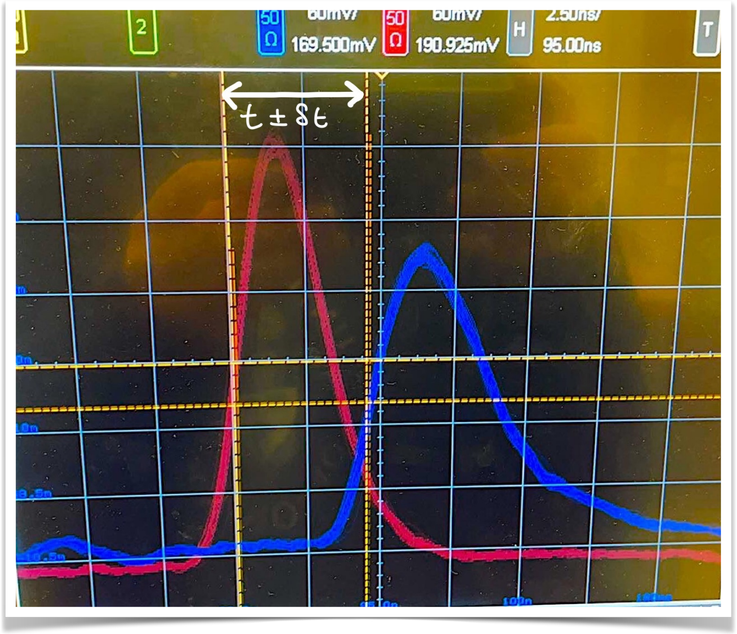
- Key features: live plots, live curve-fitting, robust data storage and collection, modular (can be upgraded/modified easily)



Experimental Procedure

- Once the WLSF fibre has been cut to the desired length, the ends are polished to a mirror finish and then it is carefully coiled into the ring
- The SiPM's are then cleaned and the LED is positioned in the desired slot at the desired distance $d \pm \delta d$ from one of the SiPM sensors
- The Oscilloscope measures the timing delay between the two successive fast channel output signals from the SiPMs for $'N'$ counts (see figure on the right)
- Resulting histogram is then curve fit to a Gaussian function with fit parameters σ_{fit} and μ_{fit}
- Record the data point as $(\Delta d, \Delta t) \mapsto \left(d \pm \delta d, \mu_{fit} \pm \sigma_{fit}\right)$
- Once sufficient data points have been collected, fit to linear equation and invert it to get distance as a function of timing delay.



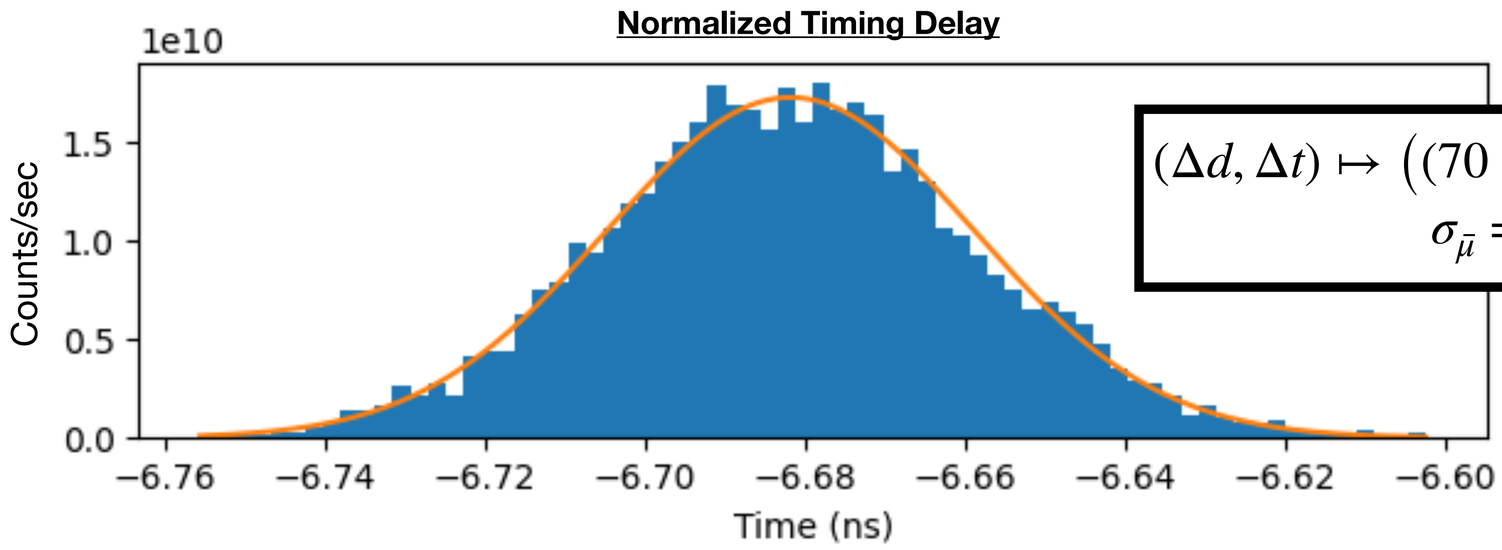


Sources of Error

- Micro-fractures inside the WLSF are common (even if it’s a fresh sample)
- SiPM Sensor to WLSF coupling isn’t optimal; fibre is fitted snuggly into the slot but is **not** adhered to the surface of the SiPM
- Since the SiPMs live outside the ring, error is introduced in measuring that initial distance from the SiPM to the first ring hole
- The ring shape is a spiral and so there is technically some change in height for every adjacent hole. For now, the lateral error from hole to hole along with the initial distance measurement were considered as the sources of error for the LED distance measurement

Experimental Results

- Most of the course was spent iterating and improving upon the experimental set-up
- However, near the end of the last term our team managed to collect some data during the final demonstration
- Below is an example of a timing delay histogram for 5000 counts

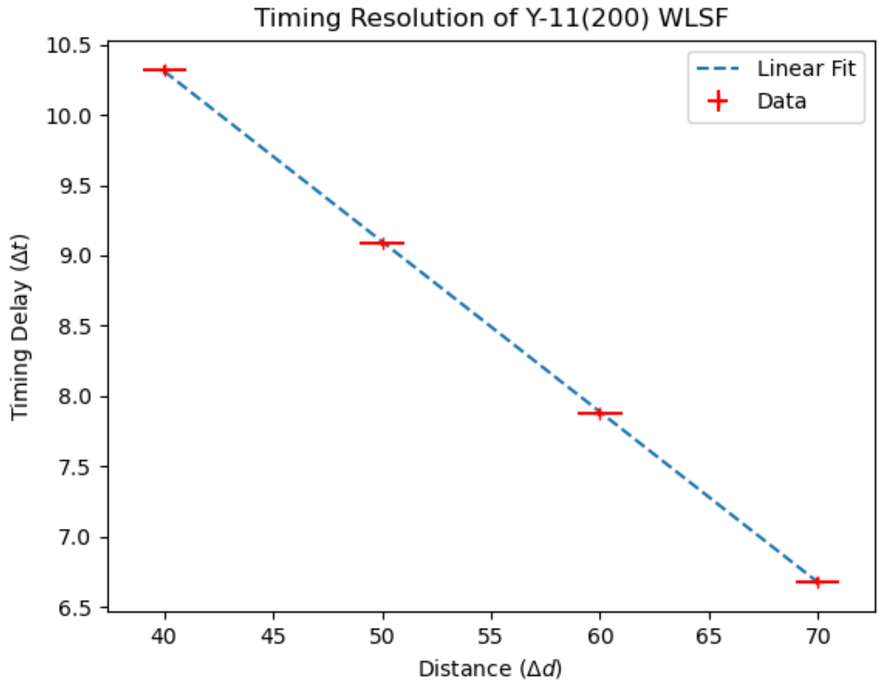


$$(\Delta d, \Delta t) \mapsto \big((70 \pm 1)\ \text{cm}, (6.68 \pm 0.03)\ \text{ns}\big)$$
$$\sigma_{\bar{\mu}} = 4.24 \times 10^{-5}\ \text{ns}$$

Experimental Results

- Plotting the following data points resulted in the linear fit below $\left(L_{wlsf} = (3.0 \pm 0.1)\ \text{m}\right)$
- Note: timing errors are on the graph they're just too small to see

Distance to closest SiPM (cm)	Timing Delay (ns)	Error in Distance (cm)	Error in Timing Delay (ns)
40	10.32	1	0.03
50	9.08	1	0.02
60	7.88	1	0.03
70	6.68	1	0.03

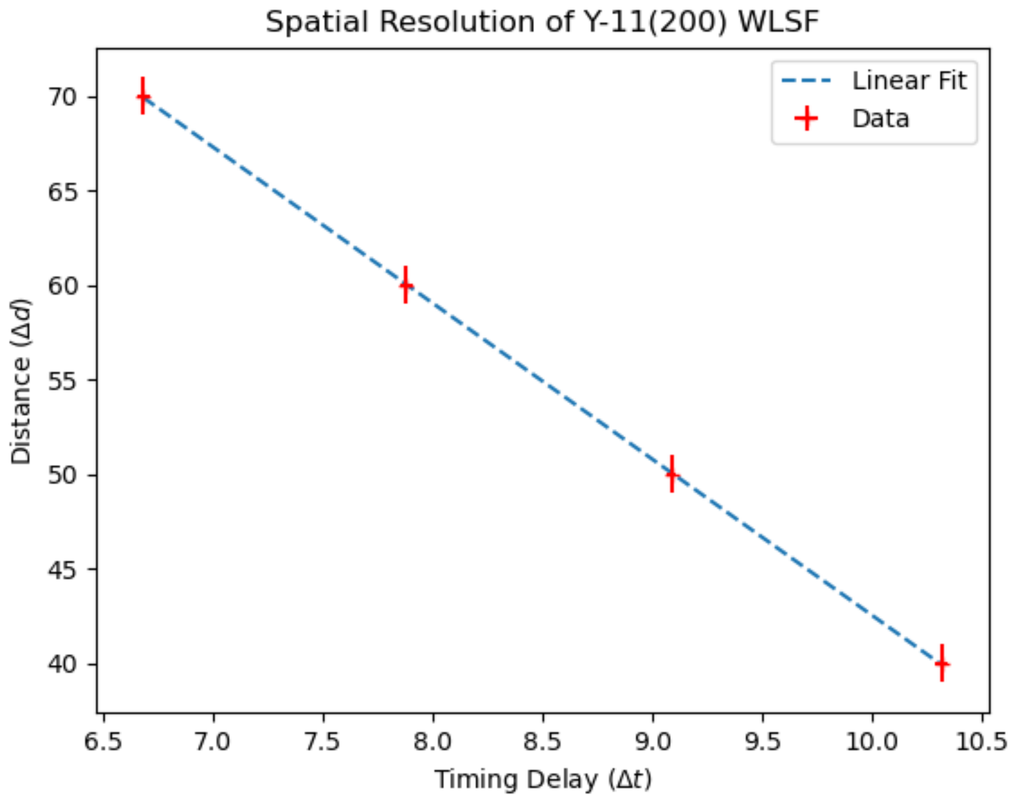


Fit Parameter	Value	Error
Slope	-0.1213 ns/cm	0.0005 ns/cm
Intercept	15.16 ns	0.03 ns

Experimental Results

- With this information, we can invert the linear fit to obtain a spatial resolution for the WLSF.

Fit Parameter	Value	Error
Slope	-8.24 cm/ns	0.03 cm/ns
Intercept	125 cm	0.28 cm



Discussion and Conclusions

- We can check the validity of the fit by looking at the linear intercept b and rearranging the kinematics equation $\Delta t = \frac{n}{c}(L_{wlsf} - 2\Delta d)$
- The index of refraction of Y-11(200) is 1.59
- $L_{wlsf} = \frac{cb}{n_{Y-11(200)}} = \frac{(1ft/ns)(15.16ns)}{1.59} = 9.53ft \approx 2.86m$
- Close to the measured WLSF length
- More measurements are needed in order to see if relation remains linear due to imperfections in the fibre

Next Steps

- Some next steps for this initiative would include the following,

Priority 1

Integrate Scintillating Tiles with the Set-up

Collecting More Data

Priority 2

Develop holders for other SiPM models

Priority 3

Develop a better/more automated way of data collection

Questions?