Fiber Attenuation Measurement Test

ePIC BIC Meeting
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Fiber Attenuation Measurement

Scintillating fiber Attenuation test

Purpose

- To check how attenuation length affect in calorimeters.

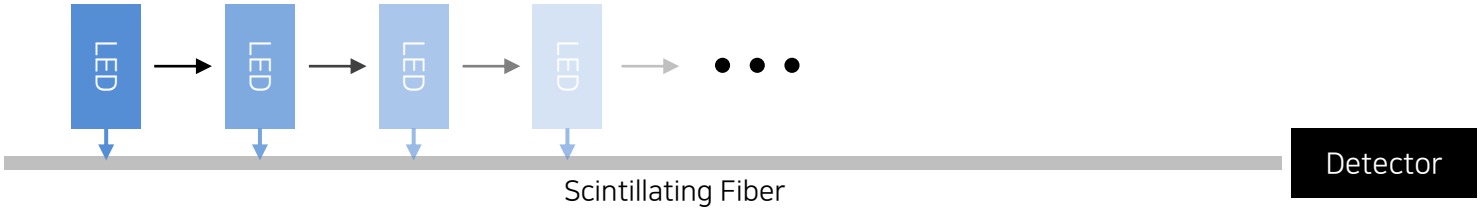
- Quality checking of fibers used in calorimeters.

- Comparing some different conditions as fiber types (single | double cladding), w/ w/o filter, ···

General Measurement Methods

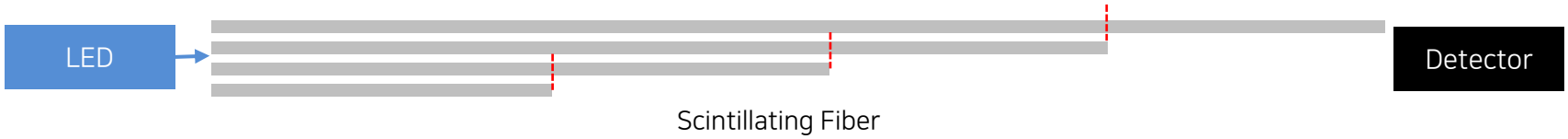
1. Side Illumination Fluorescence method (current method)

- Fiber & Detector is fixed, moving source of light and induce light on side of fiber.



2. Cut-Back method

- Measure light yield of fiber from end to end by cutting & polishing fiber in several lengths.



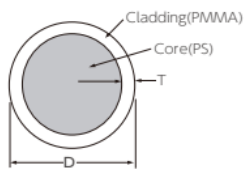
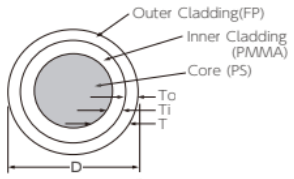
Fiber Attenuation Measurement

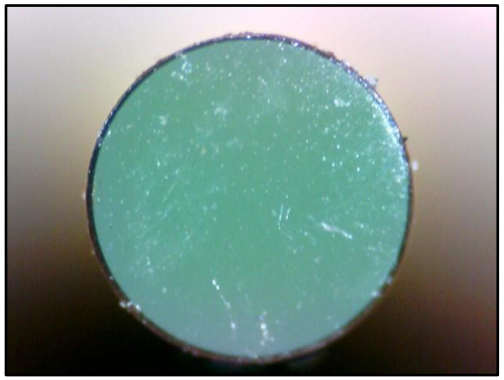
Scintillating Fiber specification

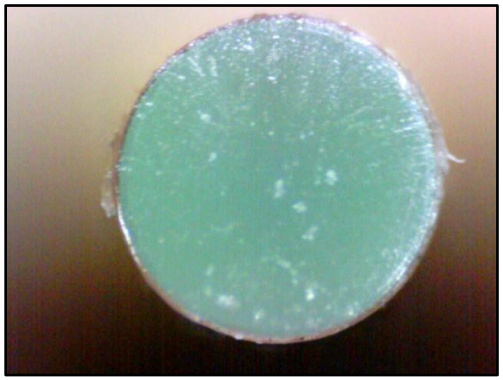
Materials

		Materials	Refractive index	Density (g/cm³)	No. of atom per cm³
Core		Polystylene(PS)	n_D=1.59	1.05	C: 4.9x10²² H: 4.9x10²²
Cladding	for single cladding inner for multi-cladding	Polymethylmethacrylate (PMMA)	n_D=1.49	1.19	C: 3.6x10²² H: 5.7x10²² O: 1.4x10²²
	outer for multi-cladding	Fluorinated polymer (FP)	n_D=1.42	1.43	

Cross-section and Cladding Thickness

	Single Cladding	Multi-Cladding (M)
Round Fiber (D)	 Cladding Thickness[3]: T=2% of D Numerical Aperture: NA=0.55 Trapping Efficiency : 3.1%	 Cladding Thickness[3]: T=2%(To)+2%(Ti) =4% of D Numerical Aperture : NA=0.72 Trapping Efficiency : 5.4%





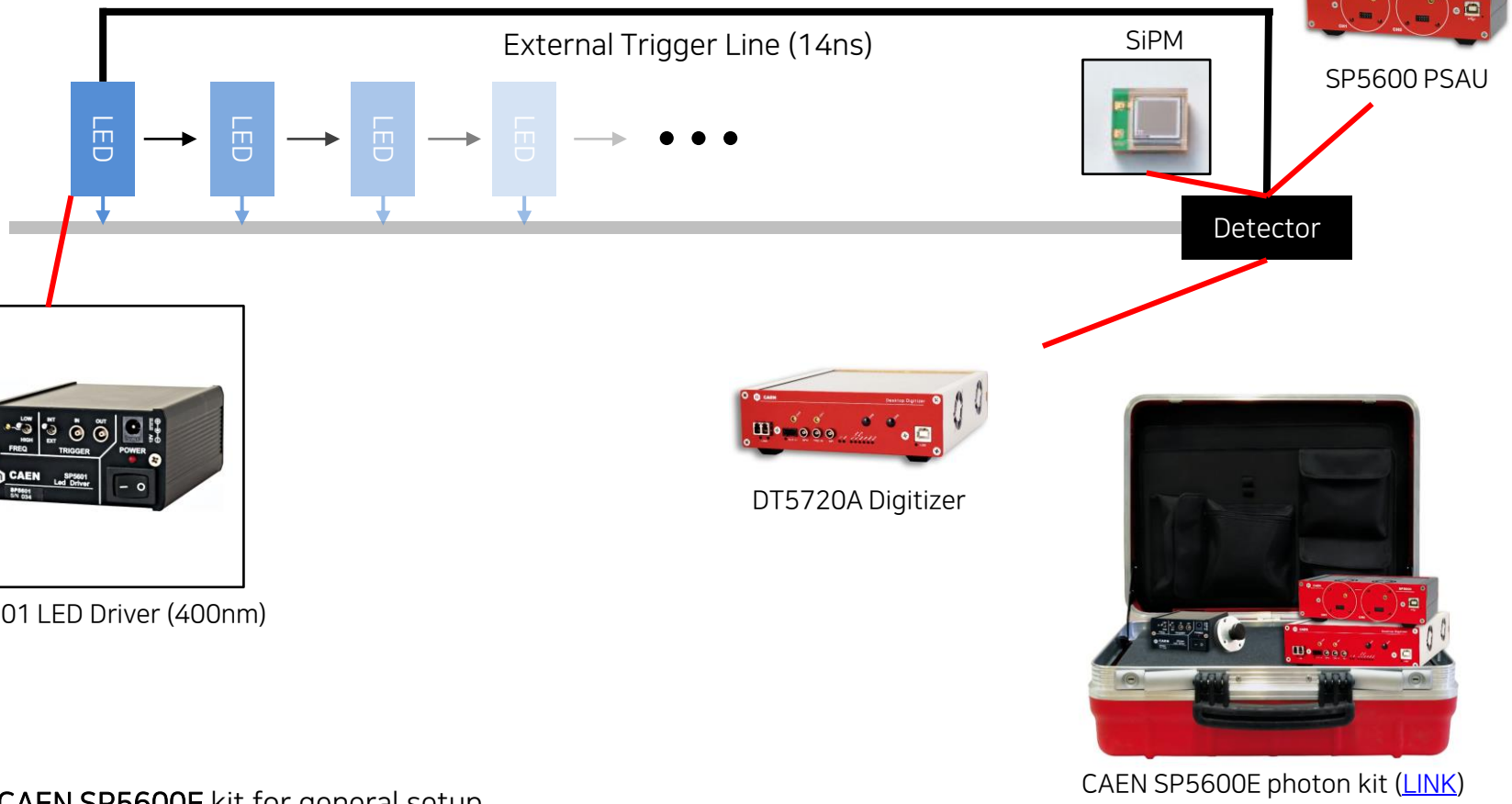
Polished Single Cladding (Left) | Double Cladding (Right)

Kuraray SCSF-78, Single Cladding (SC) & Double Cladding (DC) LINK

- Used Kuraray SCSF-78 scintillating fiber, both single cladding & double cladding.
- Fibers are ~3m length, 1mm diameter, non-S type.
- Polished one side manually, with sandpaper (400, 1000, 2000 grit) & polishing film (3μm, 1μm). (Detail in Backup)

Fiber Attenuation Measurement

Overall test setup



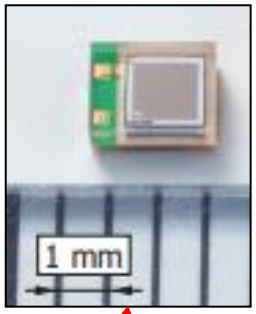
- Used CAEN SP5600E kit for general setup.
- Attached our SiPM on SP5600 Power Supply and Amplification Unit & DT5720A waveform digitizer.
- Used SP5601 LED driver (400nm wavelength) as exciting light, connected its trigger to DAQ system.

Fiber Attenuation Measurement

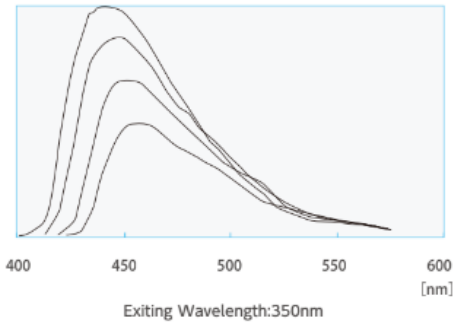
SiPM specification

Structure

Parameter	Symbol	S14160 -1310PS	S14160 -3010PS	S14160 -1315PS	S14160 -3015PS	Unit
Effective photosensitive area	-	1.3 × 1.3	3 × 3	1.3 × 1.3	3 × 3	mm
Pixel pitch	-	10		15		μm
Number of pixels	-	16663	89984	7284	39984	-
Geometrical fill factor	-	31		49		%
Package	-	Surface mount type				-
Window	-	Silicone resin				-
Window refractive index	-	1.57				-

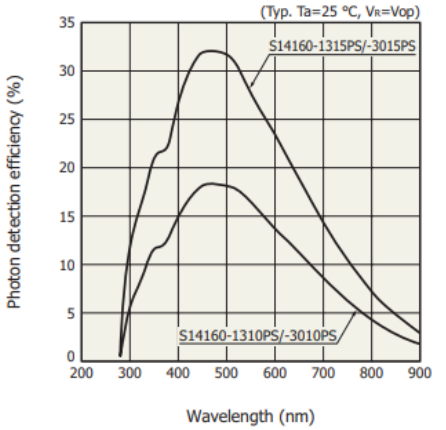


SCSF-78

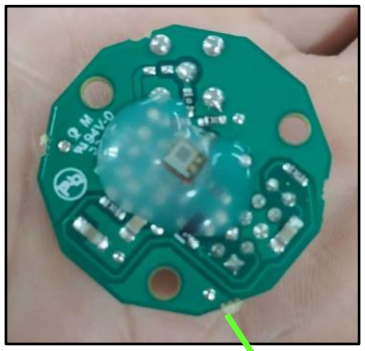


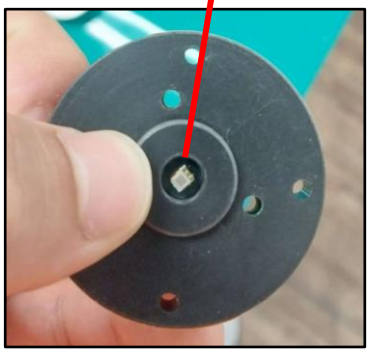
Fiber emission spectra LINK

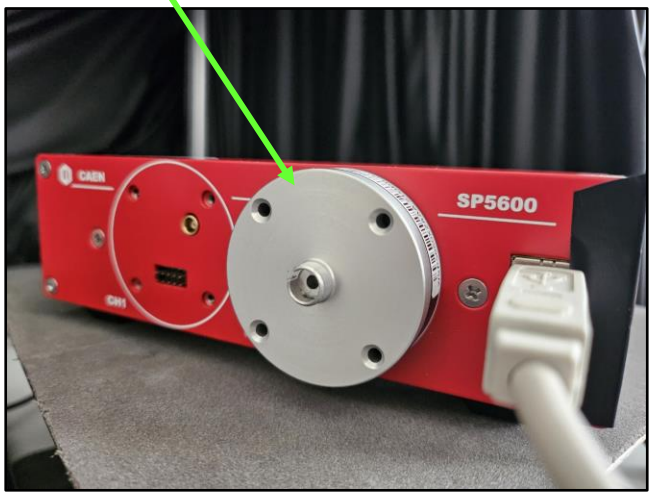
Photon detection efficiency vs. wavelength



SiPM detection efficiency







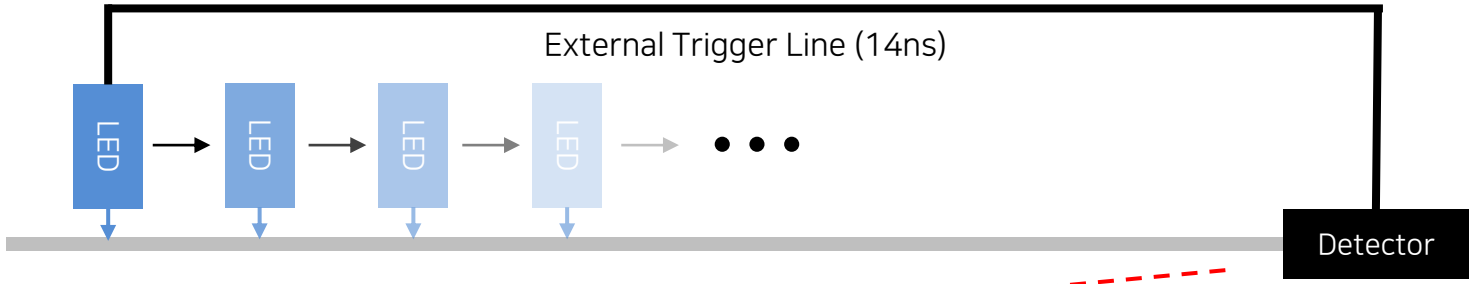
- Used SiPM as detector, Hamamatsu S14160-1310PS. (Spec. LINK)

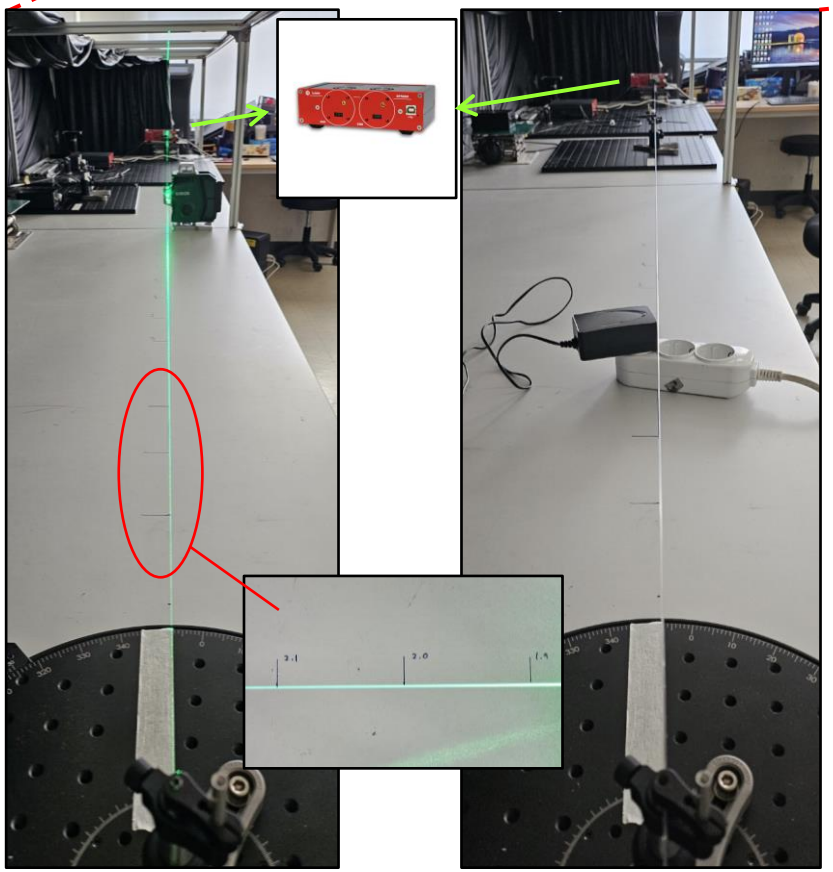
- Peak wavelength of fiber's emission & peak of SiPM's **detection efficiency is almost same.**

- Attached SiPM on PCB board, mounted it on SP5600.

Fiber Attenuation Measurement

Test Setup



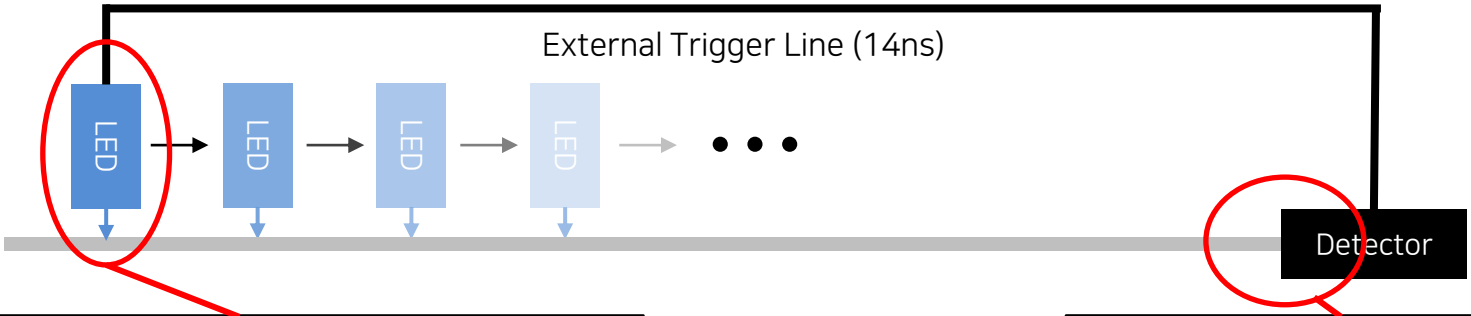


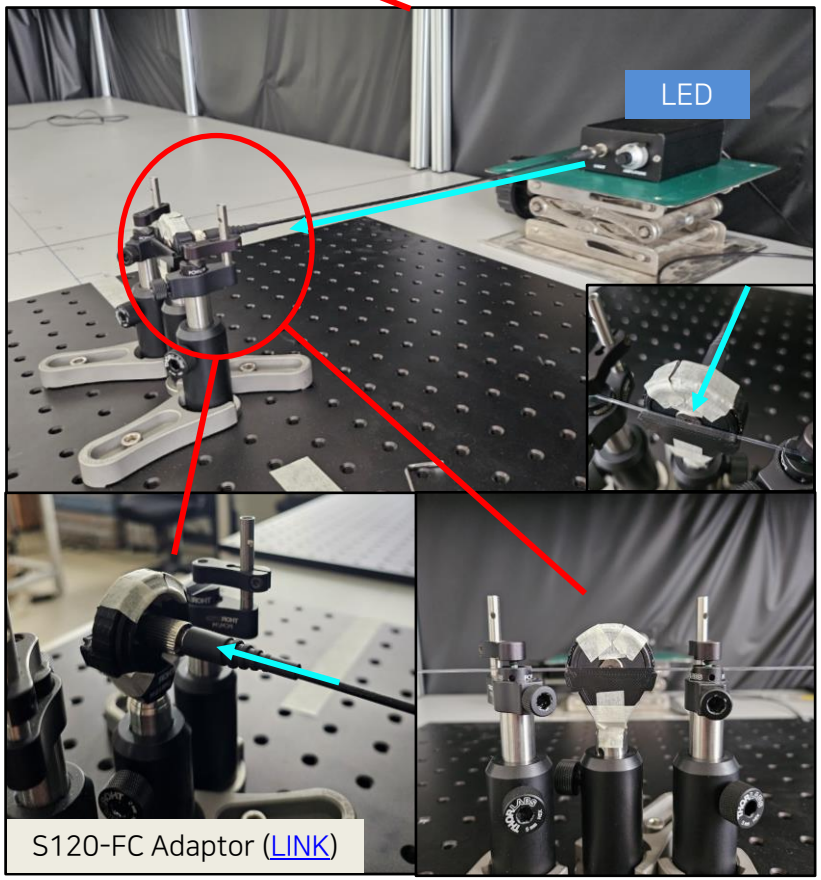
Thorlabs Compact V-mount (LINK)

- Aligned setup & fiber with laser guide, draw measure points on table.
- Used V-shape optical mounts to hold fibers on air.
- Covered whole setup with blackout curtain (Performance on backup)

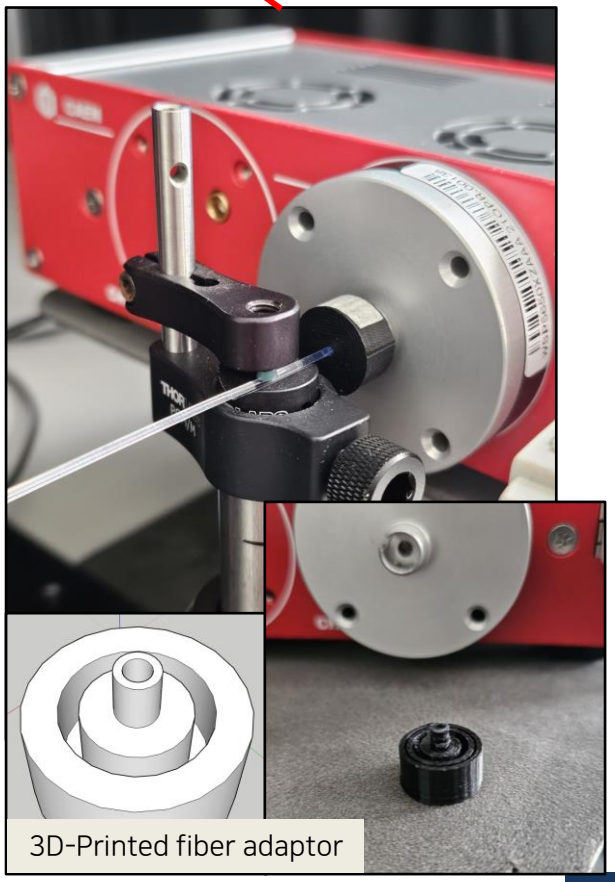
Fiber Attenuation Measurement

Test Setup



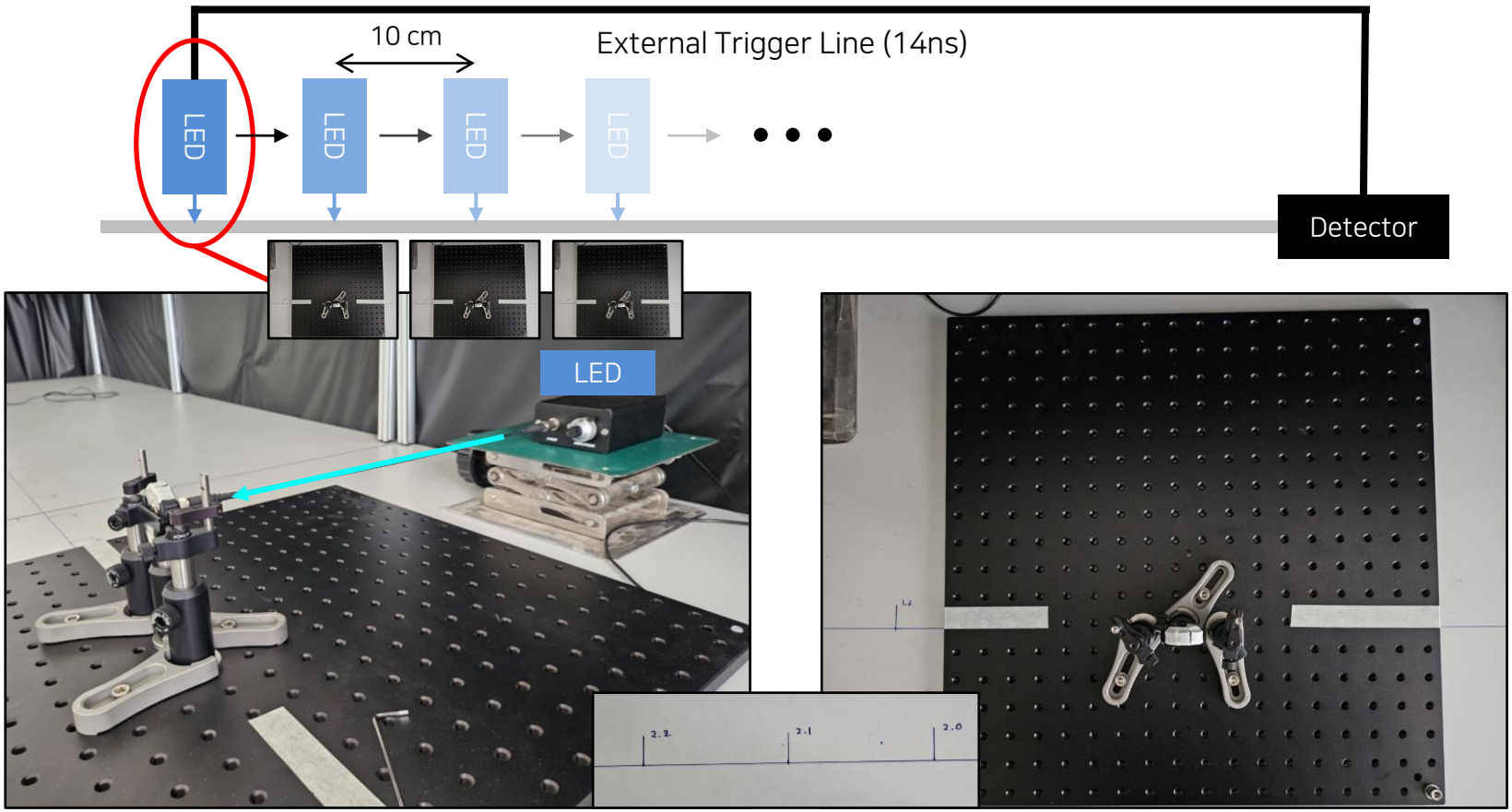


Controlled consistency
of incoming light yield
& optical contact



Fiber Attenuation Measurement

Test Setup

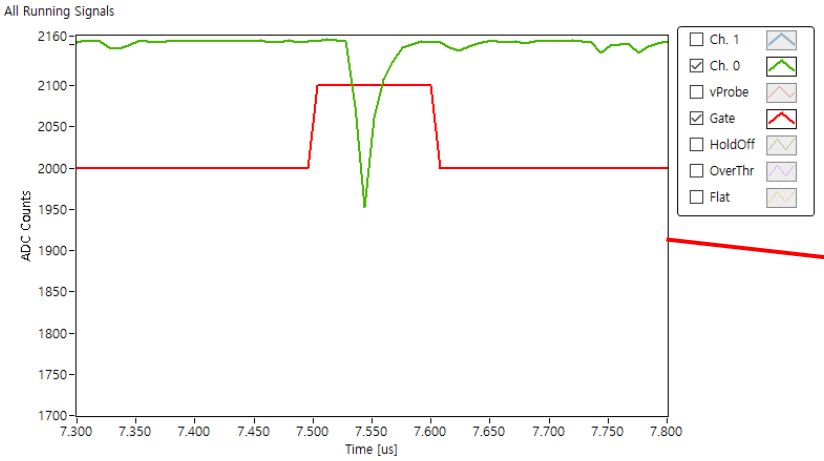


- Manually move the breadboard (which has incoming LED) along the guide line on table.

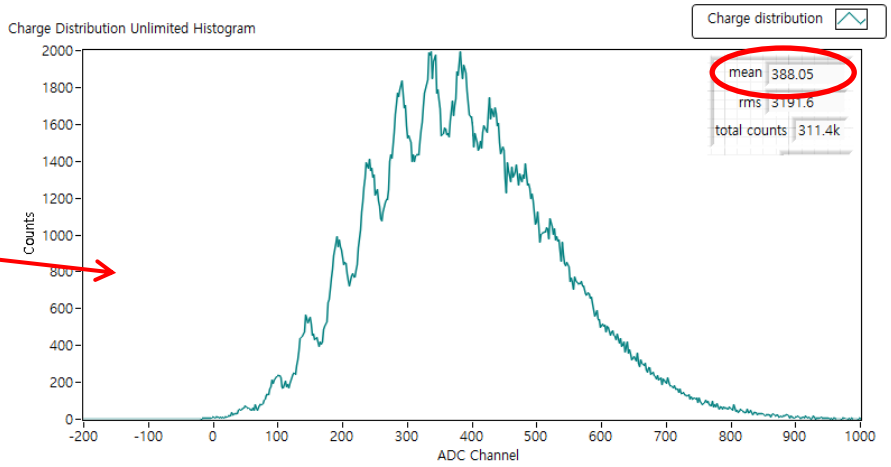
- Moved <u>10cm interval</u>, matching tape with guide line.

Fiber Attenuation Measurement

Data Acquisition



Single waveform using HERA (LINK)



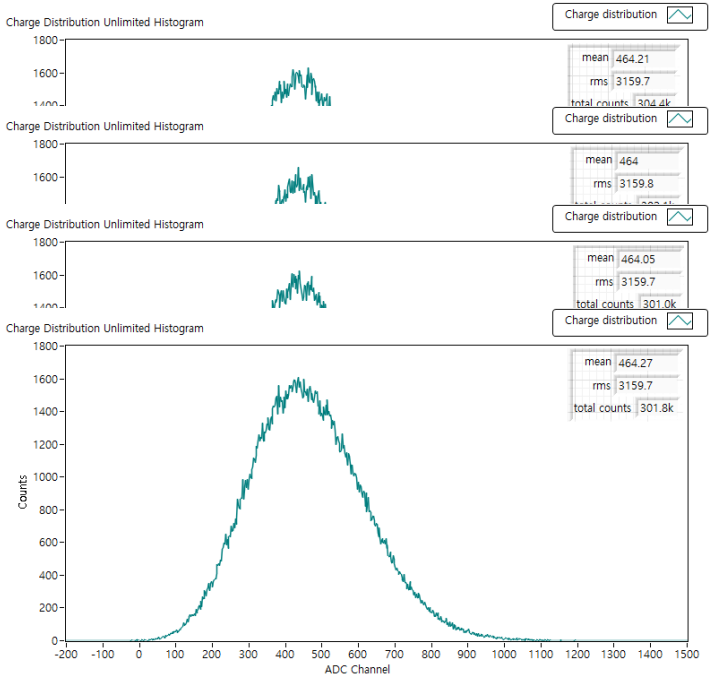
Integrated ADC Histogram

- Used CAEN software, HERA for controlling SiPM & data taking.
- Applied 45V, set gain 32 for all results.
- Got waveform data triggered by external trigger from LED driver.
- Used **average value** of integrated ADC histogram of run **as light yield** from fiber.

Ext. Trigger from LED SP5601 LINK

Fiber Attenuation Measurement

Setup stability & consistency test



Run #	Mean ADC (AU)	Run #	Mean ADC (AU)
1	464.21	6	464.26
2	464.54	7	464.27
3	464.00	8	464.36
4	464.41	9	463.98
5	464.05	10	464.29

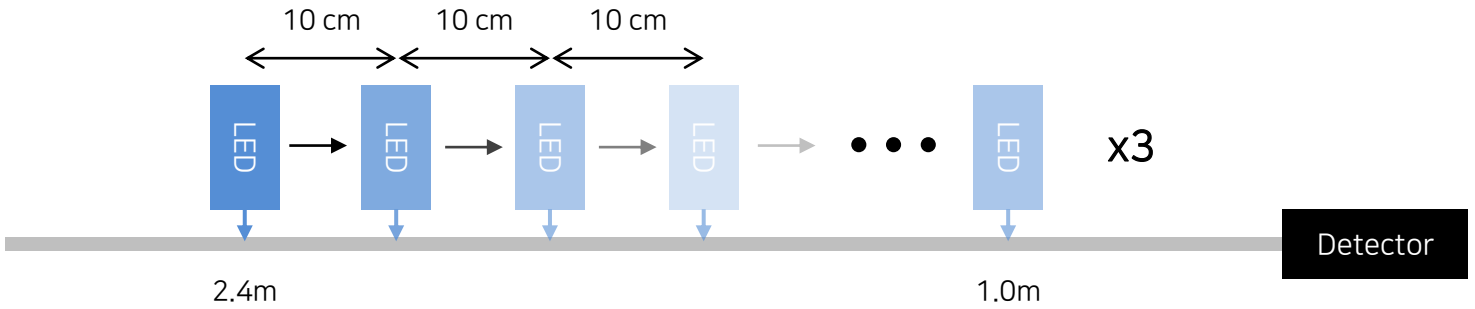
Average	Stdev
464.24	0.18 (0.04%)

Average value of 10 runs

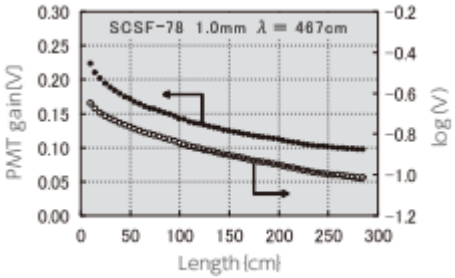
$0.04\ \% < \frac{1}{\sqrt{300k}} \cong 0.18\ \%$, under statistical fluctuation

- Checked stability & consistency of setup.
- Got data in same condition (1.1m from detector, Single Cladding) for 10 times, for each ~300k events.
- Confirmed result having agreement under statistical fluctuation.

Fiber Attenuation Measurement
Results



- Measured SCSF-78 scintillating fiber, single cladding & double cladding.
- Measured <u>1.0~2.4m, 10cm interval 15 points | 3 measurement per points</u>
- Made 3 iterations of measurement, each following through guide line.
- Used <u>average of 3 measurements as value, stdev as error of point</u>.



From fiber spec. sheet

- Fit points using <u>single exponential function</u> - $\text{Light Yield}(x) = \text{I}_0\exp(-\frac{1}{\lambda}x)$, ($\lambda$: Attenuation length)

Single Cladding (SC)
1. 4 Different SC fibers. (SC-1,2,3,4)
2. 1 SC fiber in different days. (SC-5)

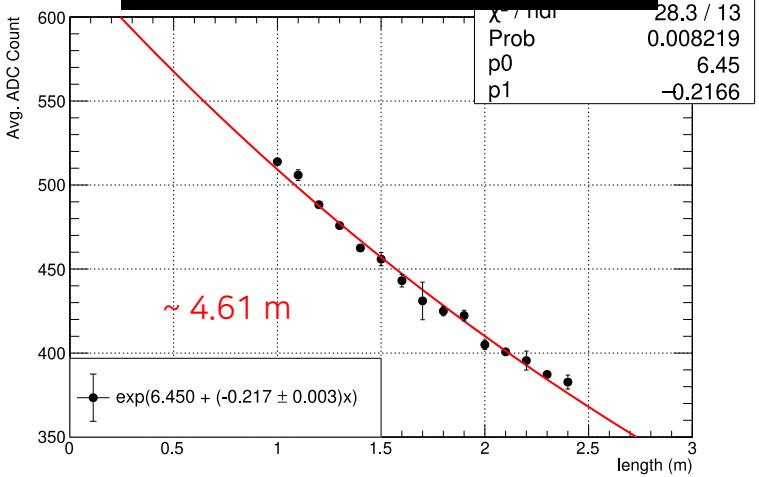
Double Cladding (DC)
1. 4 Different DC fibers. (DC-1,2,3,4)

Fiber Attenuation Measurement

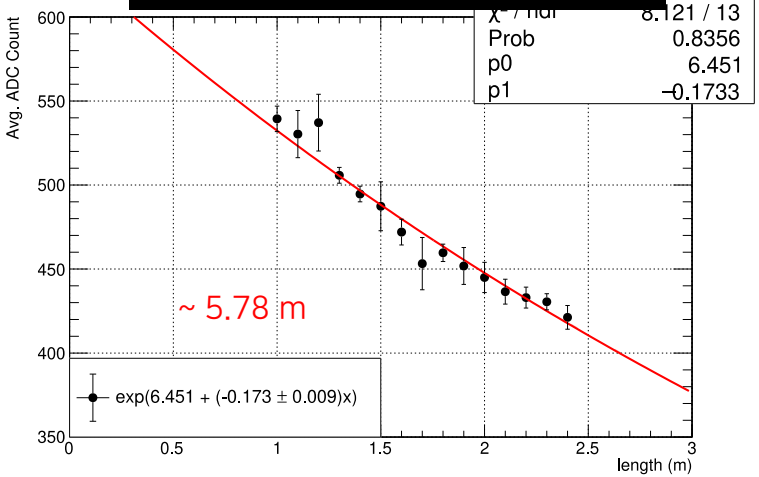
Results – Different Single Cladding fibers

Avg.	5.16 m
Stdev.	0.51 m (~10%)

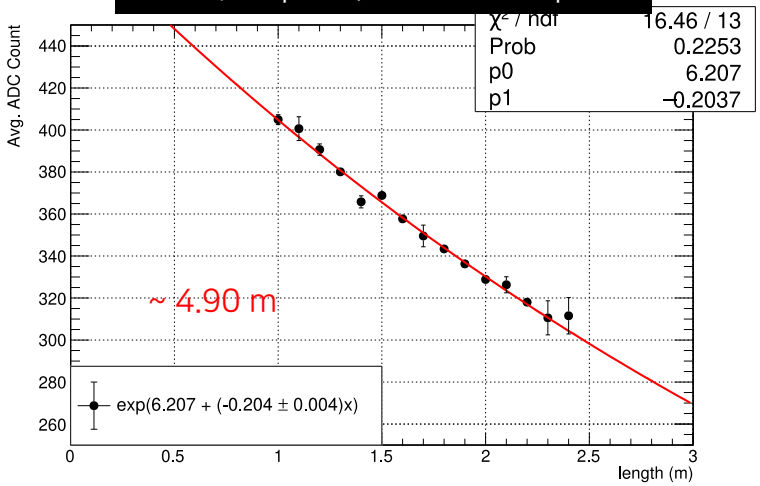
SC-1 | 15 point, 3 measure / point



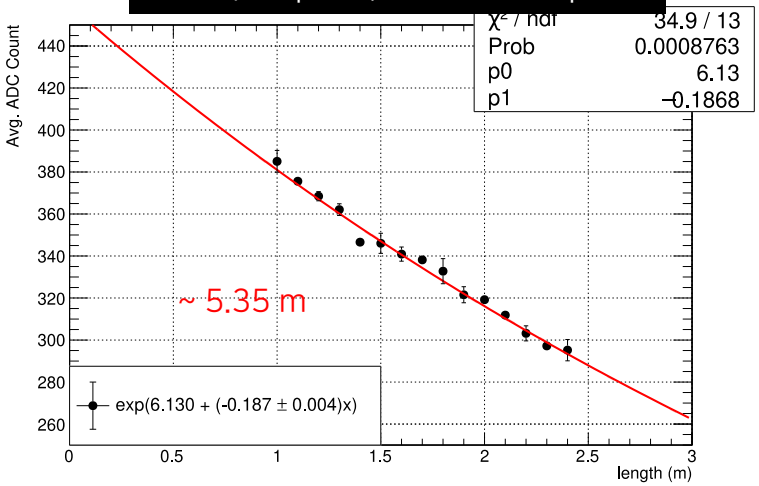
SC-2 | 15 point, 3 measure / point



SC-3 | 15 point, 3 measure / point



SC-4 | 15 point, 3 measure / point



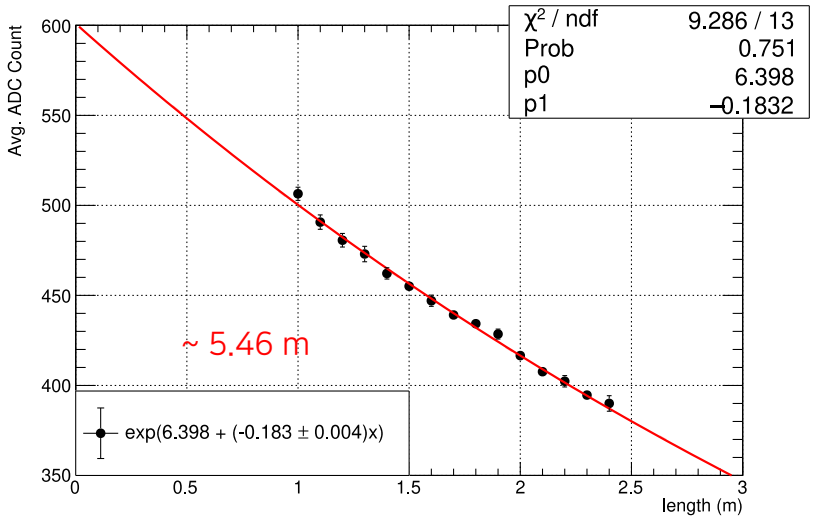
Used different polishing method between SC-1,2 & SC-3,4, so light yield value differ

Fiber Attenuation Measurement

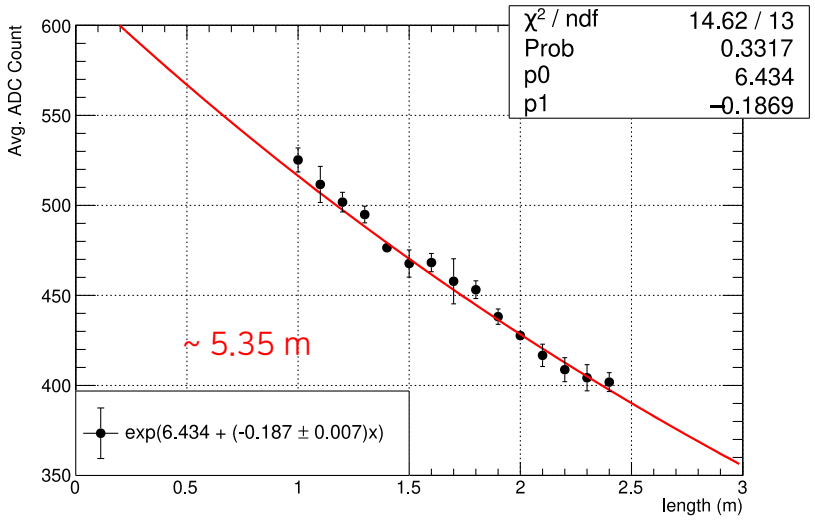
Results – Same Single Cladding fiber

Avg.	5.29 m
Stdev.	0.21 m (~4%)

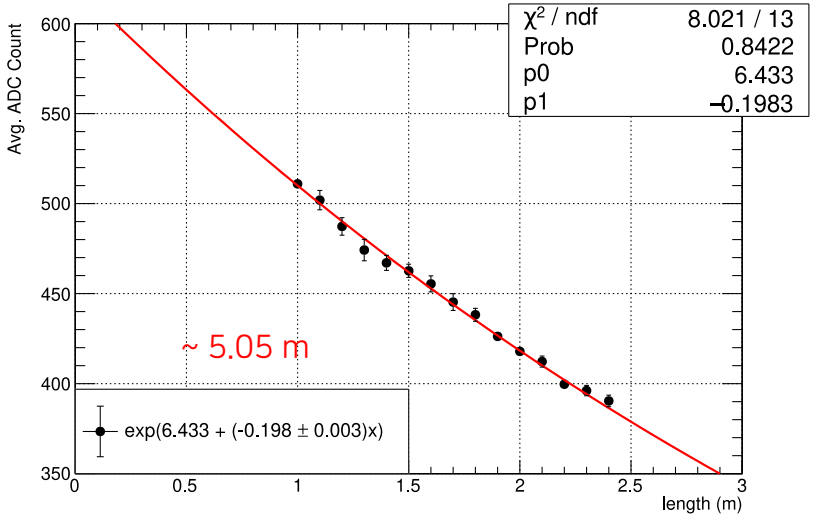
SC-5 | 15 point, 3 measure / point, Day 1



SC-5 | 15 point, 3 measure / point, Day 2



SC-5 | 15 point, 3 measure / point, Day 3



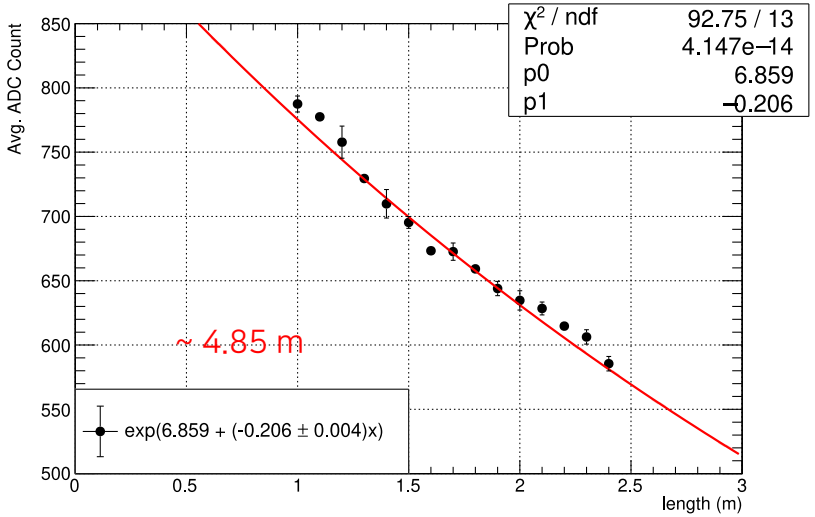
Same fiber, measured different days.

Fiber Attenuation Measurement

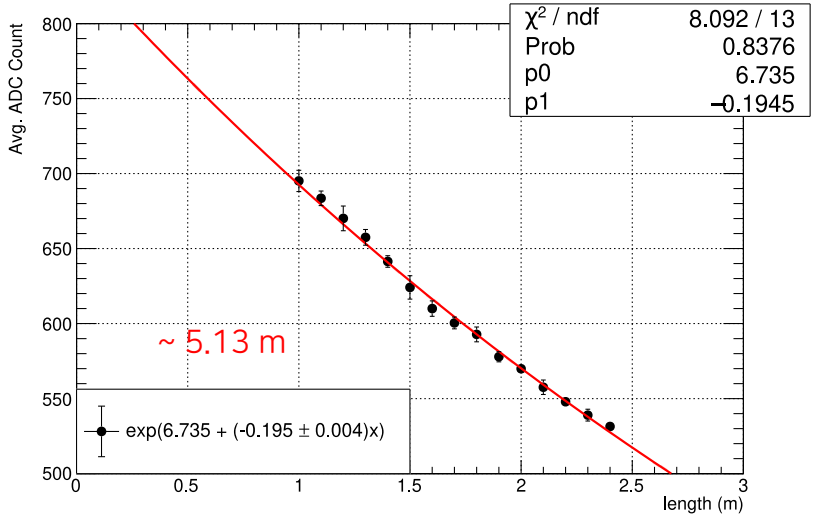
Results – Different Double Cladding fibers

Avg.	4.87 m
Stdev.	0.18 m (~4%)

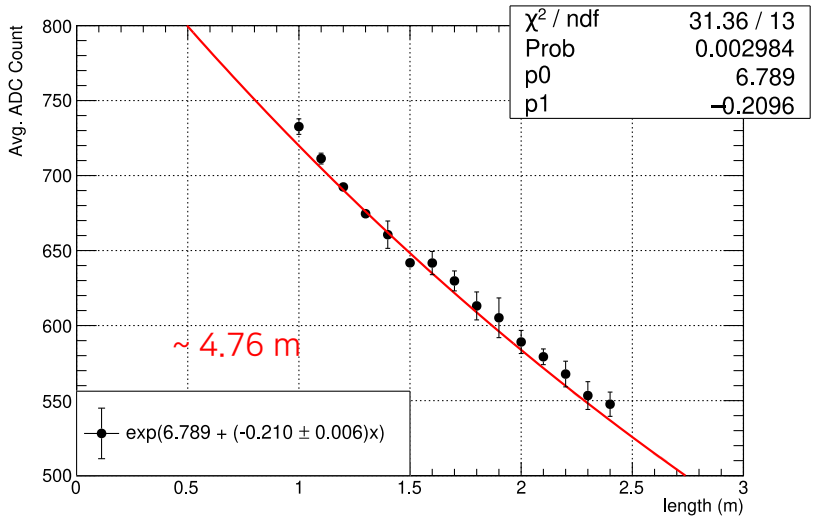
DC-1 | 15 point, 3 measure / point



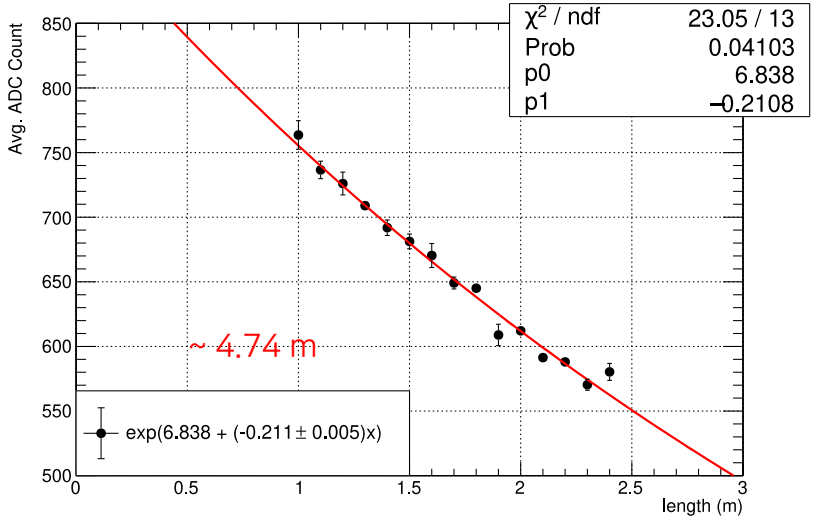
DC-2 | 15 point, 3 measure / point



DC-3 | 15 point, 3 measure / point



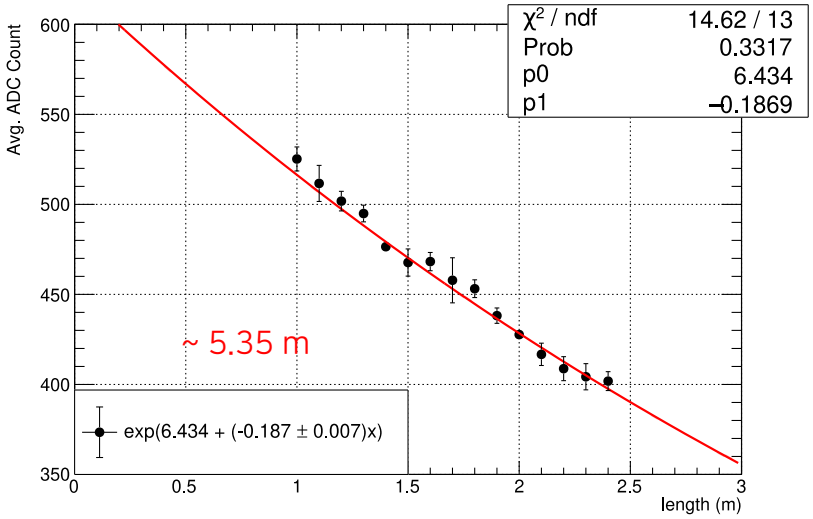
DC-4 | 15 point, 3 measure / point



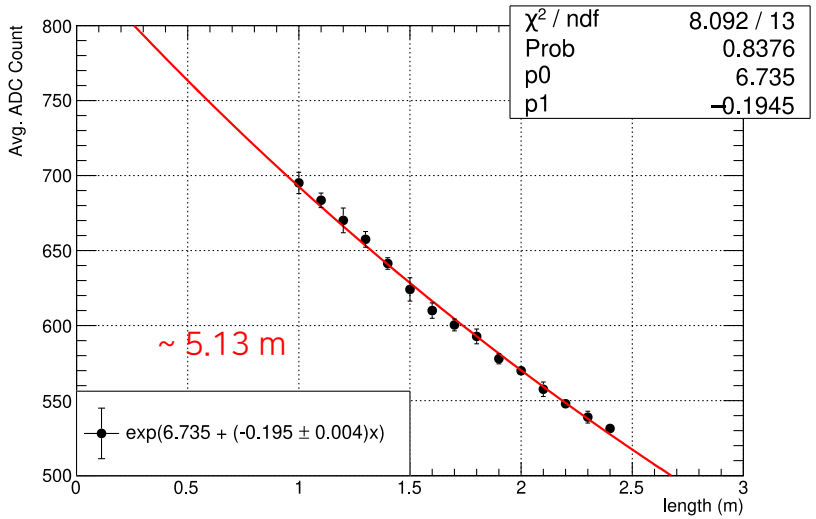
Fiber Attenuation Measurement

Results – SC vs DC

⑤ | Single Cladding (45V 32 Gain)



② | Double Cladding (45V 32 Gain)



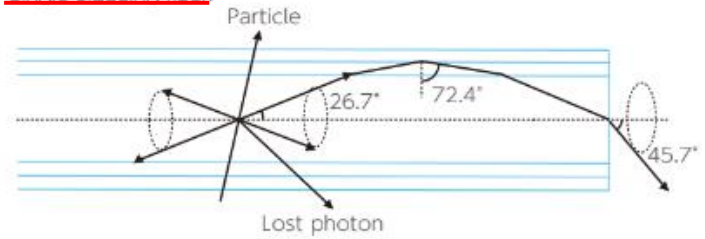
	SC	DC
Avg.	5.19 m	4.87 m
Stdev.	0.45 m (~9%)	0.18 m (~4%)

Measured Attenuation length

Spec LINK

Multi-cladding

Multi-cladding fiber(M) has higher light yield than single cladding fiber because of large trapping efficiency. Clear-PS fiber of this cladding has extremely higher NA than conventional PMMA or PS fiber, and very useful as light guide fiber. Multi-cladding fiber has long attenuation length equal to single cladding fiber.

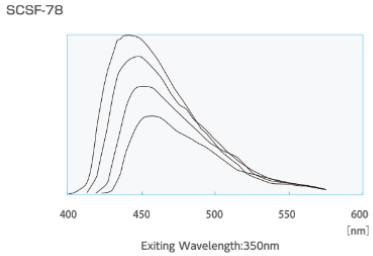


- Need more stats for accurate result, but it shows consistency with information in spec. sheet

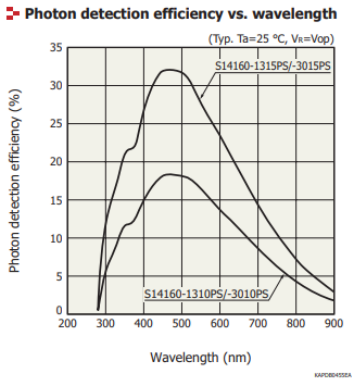
Fiber Quality Test
Summary & Plan

Fiber	Atten. Length (m)	Fiber	Atten. Length (m)	Fiber	Atten. Length (m)
SC-1	4.61	SC-5 (1)	5.46	DC-1	4.85
SC-2	5.78	SC -5 (2)	5.35	DC-2	5.13
SC-3	4.90	SC -5 (3)	5.05	DC-3	4.76
SC-4	5.35			DC-4	4.74

	SC	DC
Avg.	5.19 m	4.87 m
Stdev.	0.45 m (~9%)	0.18 m (~4%)



- Measured attenuation length of scintillating fibers, using SP5600E kit with SiPM (S14160-1310PS).
- Result has ~7% fluctuation for single cladding, ~4% for double cladding.
- Result showed consistency with information in spec. sheet, DC > SC (light yield), DC ≅ SC (atten.)



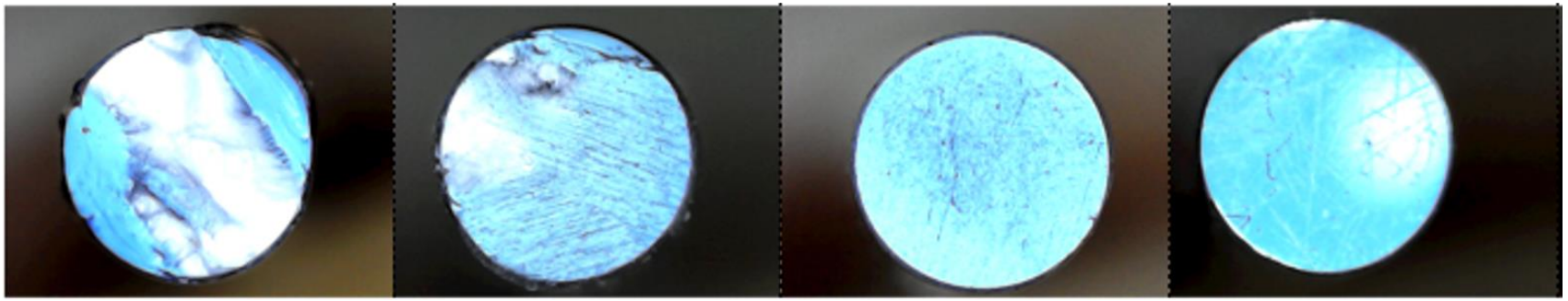
Next Plan

- Make more statistics for accurate results. (Automating measure process research in UoS)
- Measure fibers in different conditions – applying optical filter on fibers
- Cross-check result by changing measuring method – Cutback method

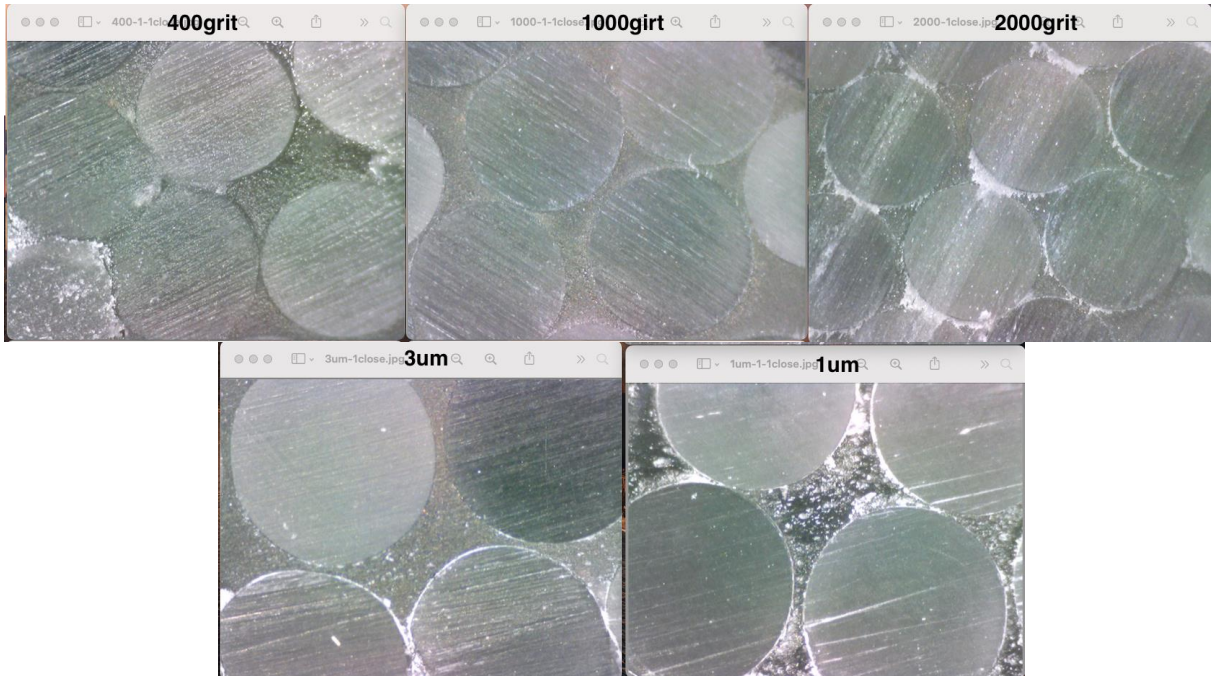
Backup

Fiber Attenuation Measurement

Polishing Fiber

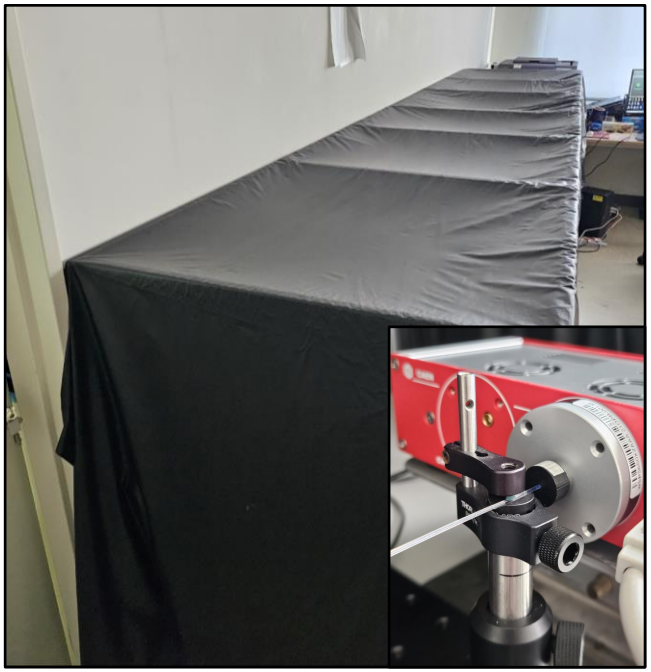


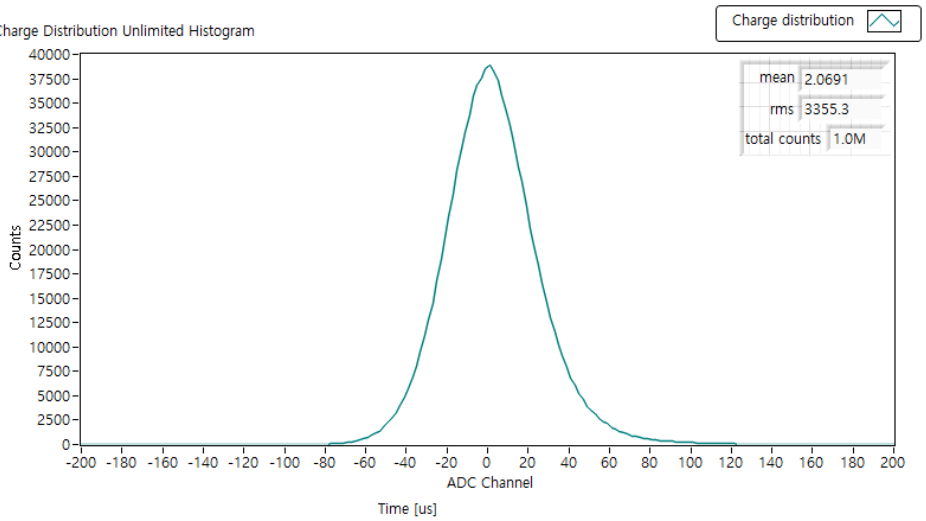
Before Polishing | Sandpaper | 3μm Film | 1μm Film



Fiber Attenuation Measurement

Dark Case test





Int. ADC w/o LED source

- Checked if light leakage occurs through blackout curtain.
- Fiber was connected to SiPM without LED source.
- Got ~1 million events, but no significant leakage seems to occur.