Daily report

13 November, 2019

Submission of the proceeding

A new charged particle detector for the KOTO experiment at J-PARC

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Abstract. We report the performance of a new scintillator array Downstream Charged Veto (DCV) for the J-PARC KOTO experiment to suppress the $K_L \to \pi^+\pi^-\pi^0$ decay background. Since the background originates from undetected charged pions passing through the beam hole of the electromagnetic calorimeter, the DCV detector was installed in vacuum downstream of the calorimeter. The DCV is composed of two plastic scintillator pipes read out by Multi Pixel Photon Counters (MPPCs) through wavelength shifting (WLS) fibers. The light yield was found to be 60 photoelectrons/0.8 MeV in a test bench when cosmic-rays pass through the center of the DCV. Energy calibration was performed using cosmic-rays after installation.

1. Introduction

The KOTO experiment at J-PARC aims to study the $K_L \to \pi^0\nu\bar{\nu}$ decay, which is one of the most sensitive probes to new physics beyond the standard model (SM). Its signature is a pair of photons from a π^0 decay without any additional activity in the hermetic detector system surrounding the decay region. To detect this highly suppressed decay, expected at 3×10^{-11} in the SM, it is important to reject background events related to other kaon decay modes. At the single event sensitivity of 1.30×10^{-9} achieved with 2015 data by KOTO, the number of $K_L \to \pi^+\pi^-\pi^0$ background events was estimated to be 0.05 [1], which corresponds to 2 events at the SM sensitivity. The decay becomes background when charged pions passing through the beam hole are undetected due to their interaction with non-active materials. A Monte Carlo simulation shows that most of π^+ and π^- particles disappear in three sections, as illustrated in Fig. 1. One is the membrane which separates the 10^{-5} Pa decay region and the 0.1 Pa detector region. Another source is square pipes made of 0.5-mm-thick G10 plates placed inside the calorimeter and the CC04 separately, which prevents the membrane from drooping toward the beam axis. The last one is a beam pipe made of 10-mm-thick aluminum for extending the vacuum region downstream.

To suppress the $K_L \to \pi^+\pi^-\pi^0$ background, such charged pions should be detected before they interact with those non-active materials. In this respect, we decided to install a new charged particle detector, named DCV, inside the high vacuum region downstream of the electromagnetic calorimeter. To maximize the detector performance, the DCV should be placed as close as possible to the calorimeter. Since the DCV is able to support the membrane, we do not need the G10-pipe inside the CC04 anymore. The G10-pipe placed inside the calorimeter is still needed, though its length can be shortened.

Writing the thesis

Chapter 1

Introduction

KOTO(K0 at TOkai) 실험은 중성 케이온의 희귀 붕괴모드 중 하나인 $K_L \to \pi^0 \nu \bar{\nu}$의 붕괴 갈래비를 측정하는 실험으로 일본 J-PARC(Japan Proton Accelerator Research Complex)에서 진행되고 있다. 현재 표준모형을 바탕으로 계산된 $K_L \to \pi^0 \nu \bar{\nu}$의 붕괴 갈래비는 $(3.00 \pm 0.30) \times 10^{-11}$이다. KOTO에서 2015년에 수집한 데이터를 분석한 결과 $K_L \to \pi^0 \nu \bar{\nu}$의 붕괴 갈래비는 $(1.30 \pm 0.01_{\text{stat}} \pm 0.14_{\text{syst}}) \times 10^{-9}$까지 측정되었다 [1]. 의 측정은 에서 붕괴된 두 개의 광자를 CsI 열량계에서 검출함과 동시에 중성 케이온의 다른 붕괴 및 중성자 반응에서 발생하는 광자 및 하전입자를 배제 검출기에서 배제함으로써 이뤄진다. 그림 1.1은 KOTO 검출기의 단면도를 보여준다.

CsI 열량계에서 측정된 두 광자 신호의 에너지 및 위치를 통해 π^0를 재구성 할 수 있으며, π^0의 z-축 붕괴 지점과 z-축에 수직한 방향의 운동량을 계산할 수 있다. $K_L \to \pi^0 \nu \bar{\nu}$에서 발생한 π^0의 붕괴 지점 및 수직방향 운동량 범위를 예측할 수 있으며 이를 신호영역(Signal region)이라한다. 그림 1.2는 2015년 데이터에서 재구성된 π^0의 붕괴지점과 수직방향 운동량을 기록한 그래프다.

신호영역 내에 측정된 사건 중 $K_L \to \pi^0 \nu \bar{\nu}$에서 발생한 것이 아닌 임의의 다른 사

3

Introduction 한글 > Latex

Design of the DCV 한글 > Latex

Fabrication Process

Energy Calibration

Conclusion

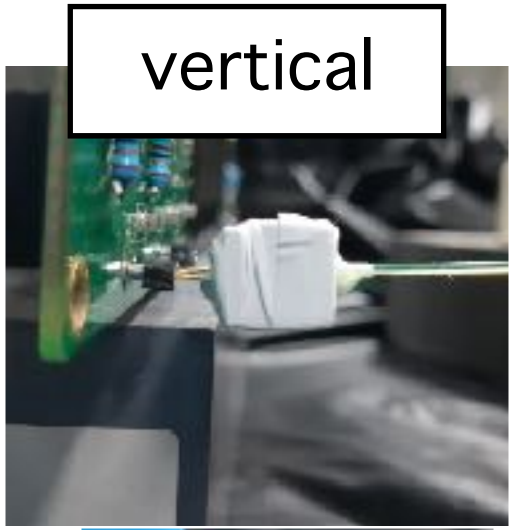
Rearrangement of contents

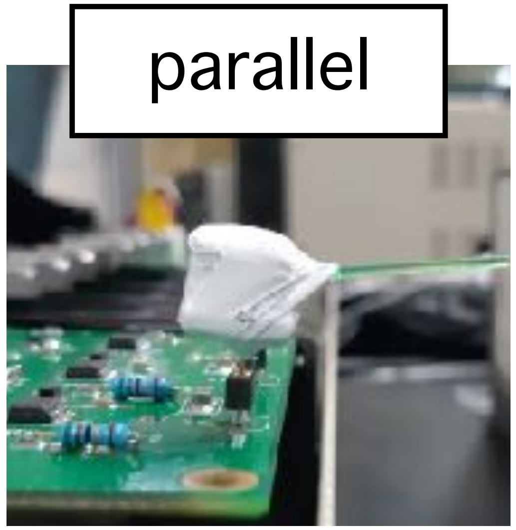
- Introduction
  - KOTO Experiment & 2015 data.
  - MC simulation
  - Motivation
- Design of the DCV
  - Scheme of the DCV
  - Bending radius
  - **R&D? Semi-final test?**

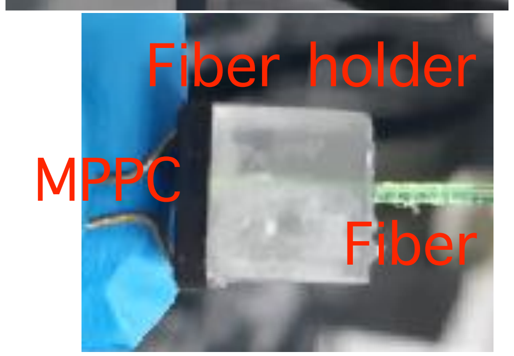
Rearrangement of contents

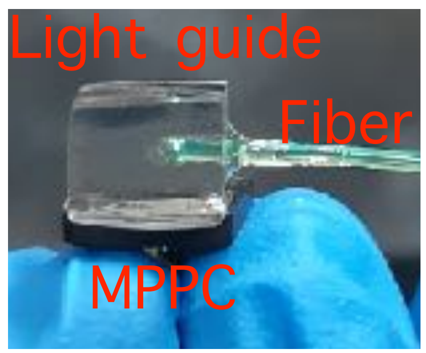
- Fabrication Process
  - Grouping the MPPCs
  - Fiber test
  - Making the scintillator pipes
  - Cosmic ray test
  - Installation(DCV1, DCV2), Configuration(DCV map)
- Energy calibration
- Conclusion

R&D topics : Vertical vs Parallel



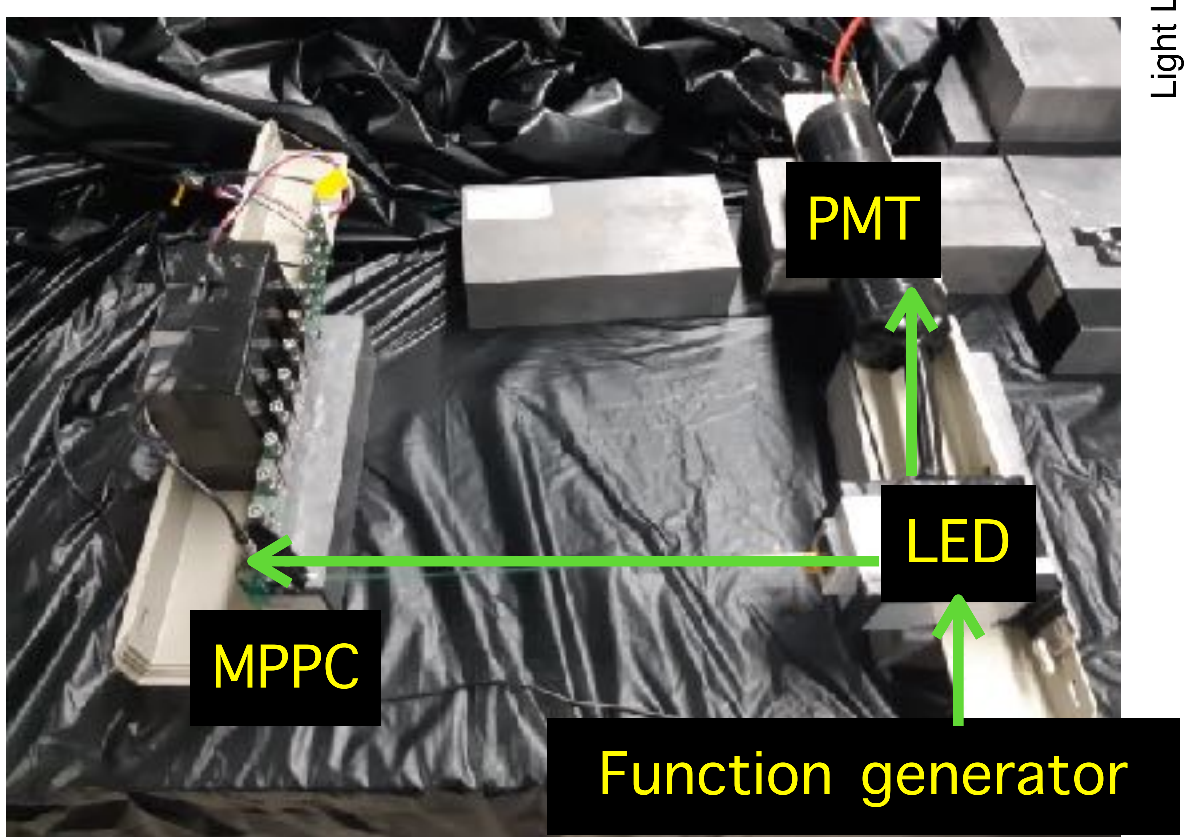


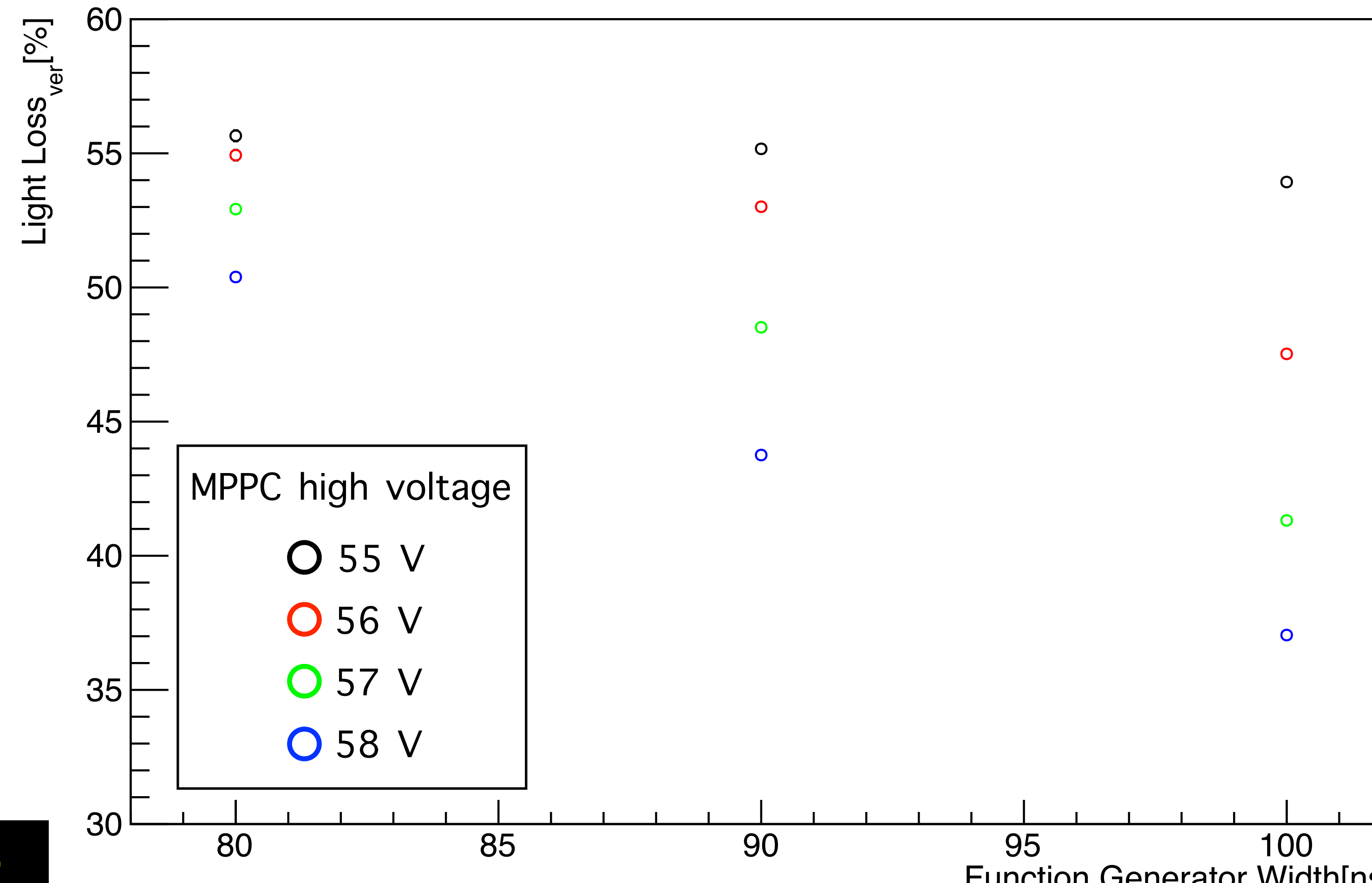




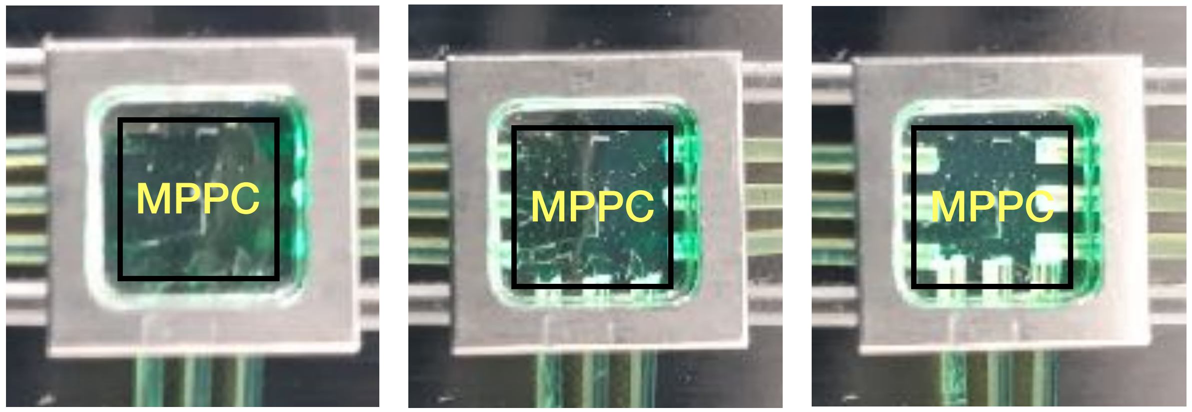
MPPC	HAMAMATSU S13360-6050CS
Fiber	Kuraray Y-11, 1mm
LED wavelength	~ 430 nm
Light guide size	8 mm * 8 mm * 6 mm
Light guide material	acrylic
Light guide suface	Polished #15000

$$Light\ Loss_{ver}[\%] = \{1 - \frac{mean(par.)}{mean(ver.)} \times \frac{PMTmean(ver.)}{PMTmean(par.)}\} \times 100$$



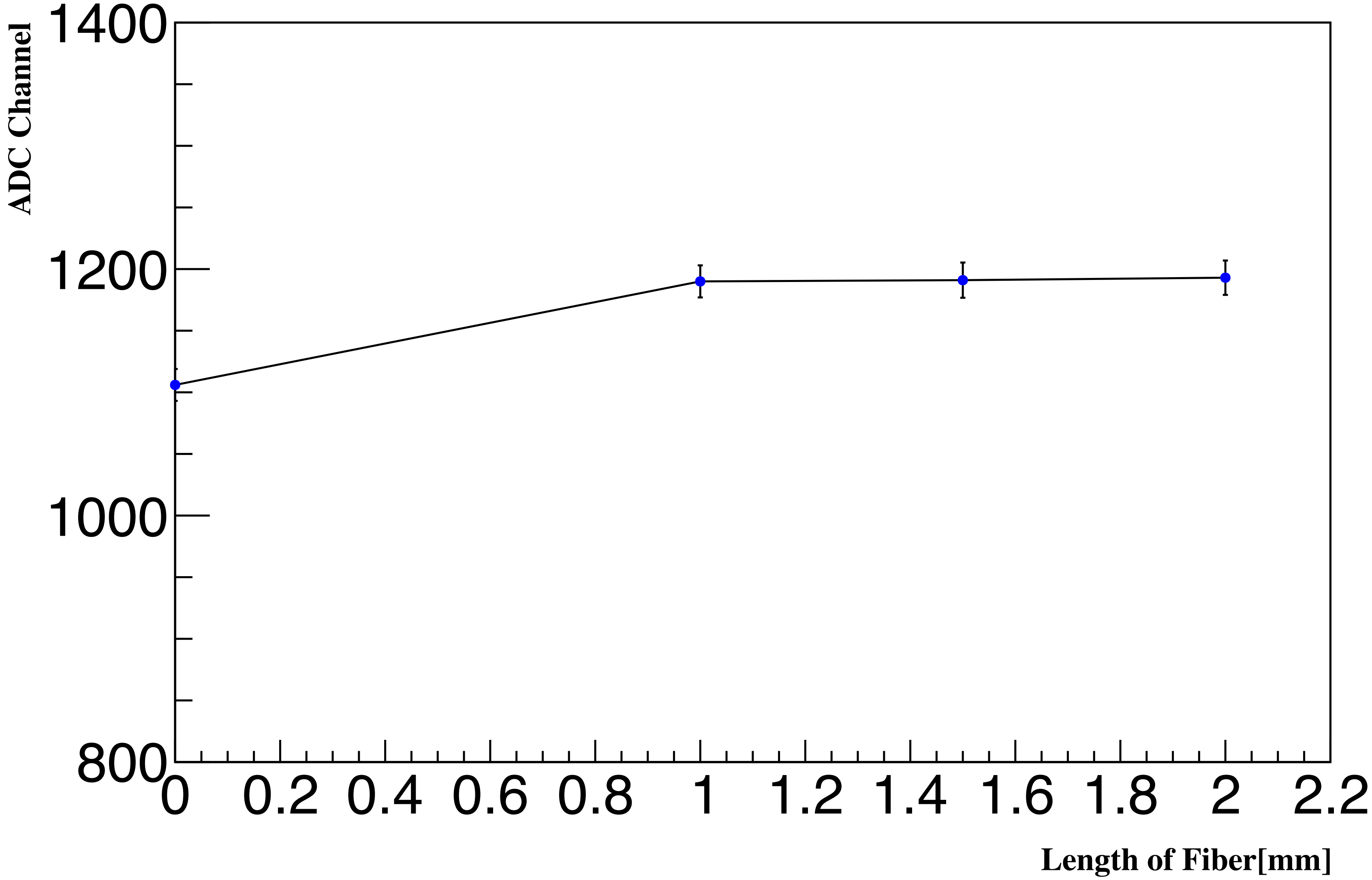


R&D topics : The length of the fiber in the light guide

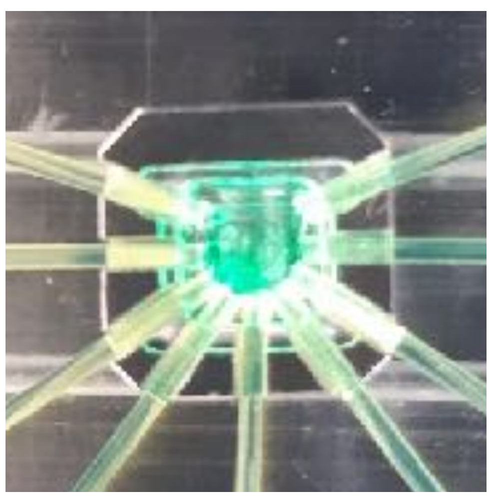


0 mm 1.0 mm 2.0 mm

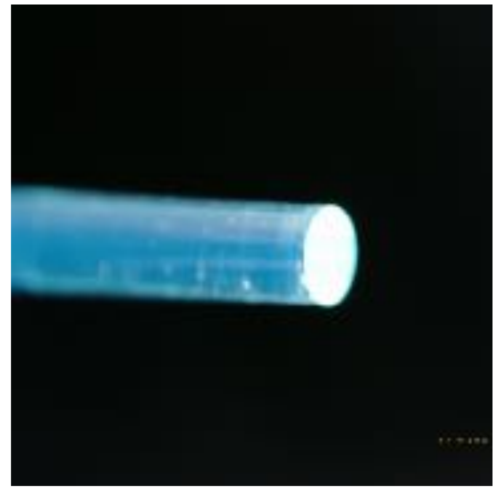
For MPPC region -1.0 mm 0 mm 1.0 mm

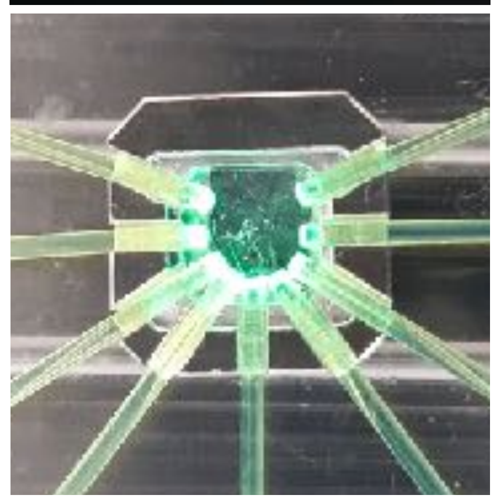


R&D topics : Fiber cut condition

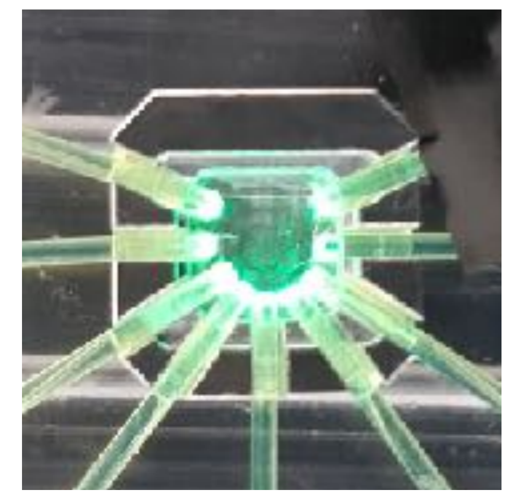


Nipper



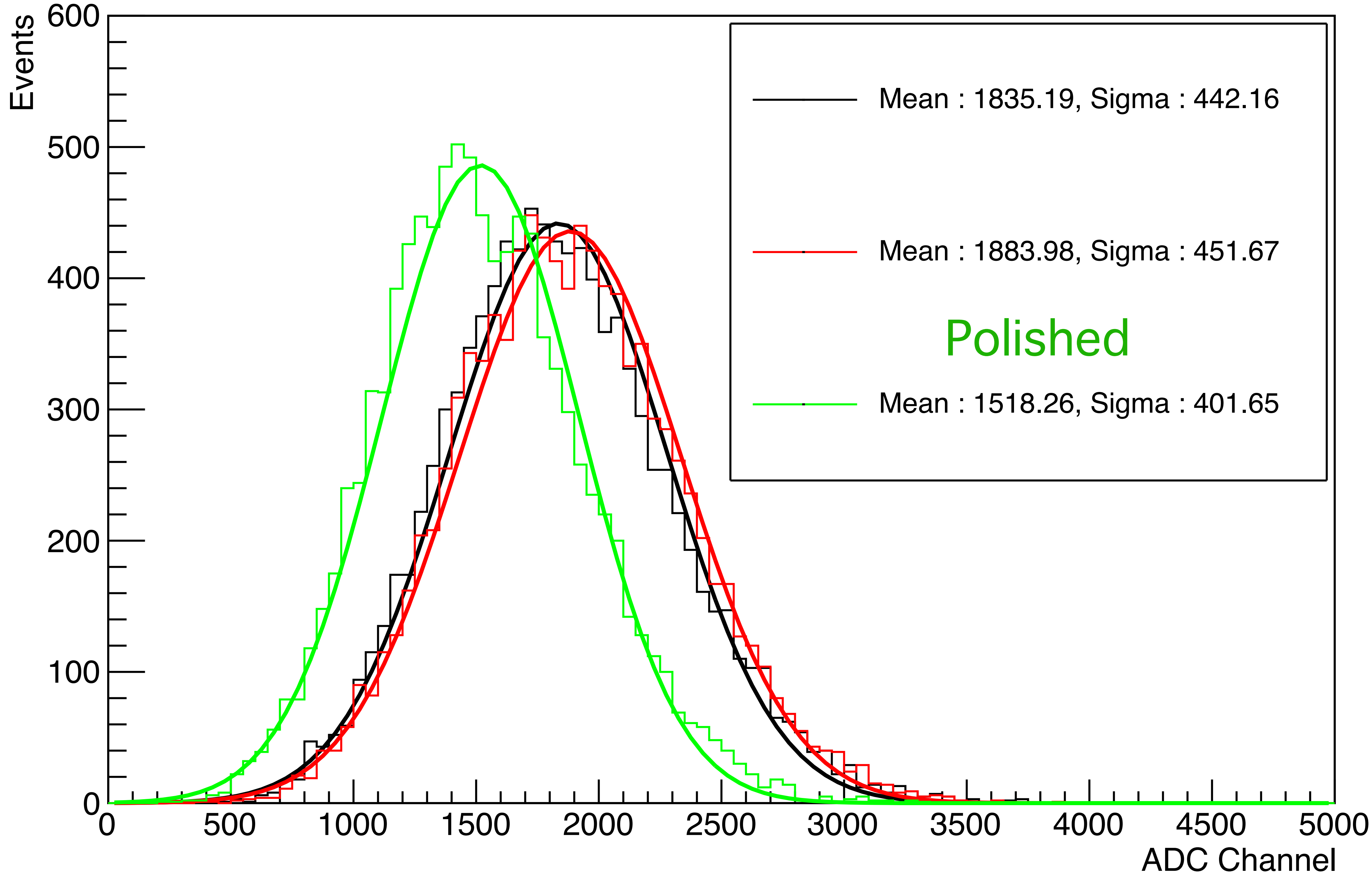


Diamond
cut machine



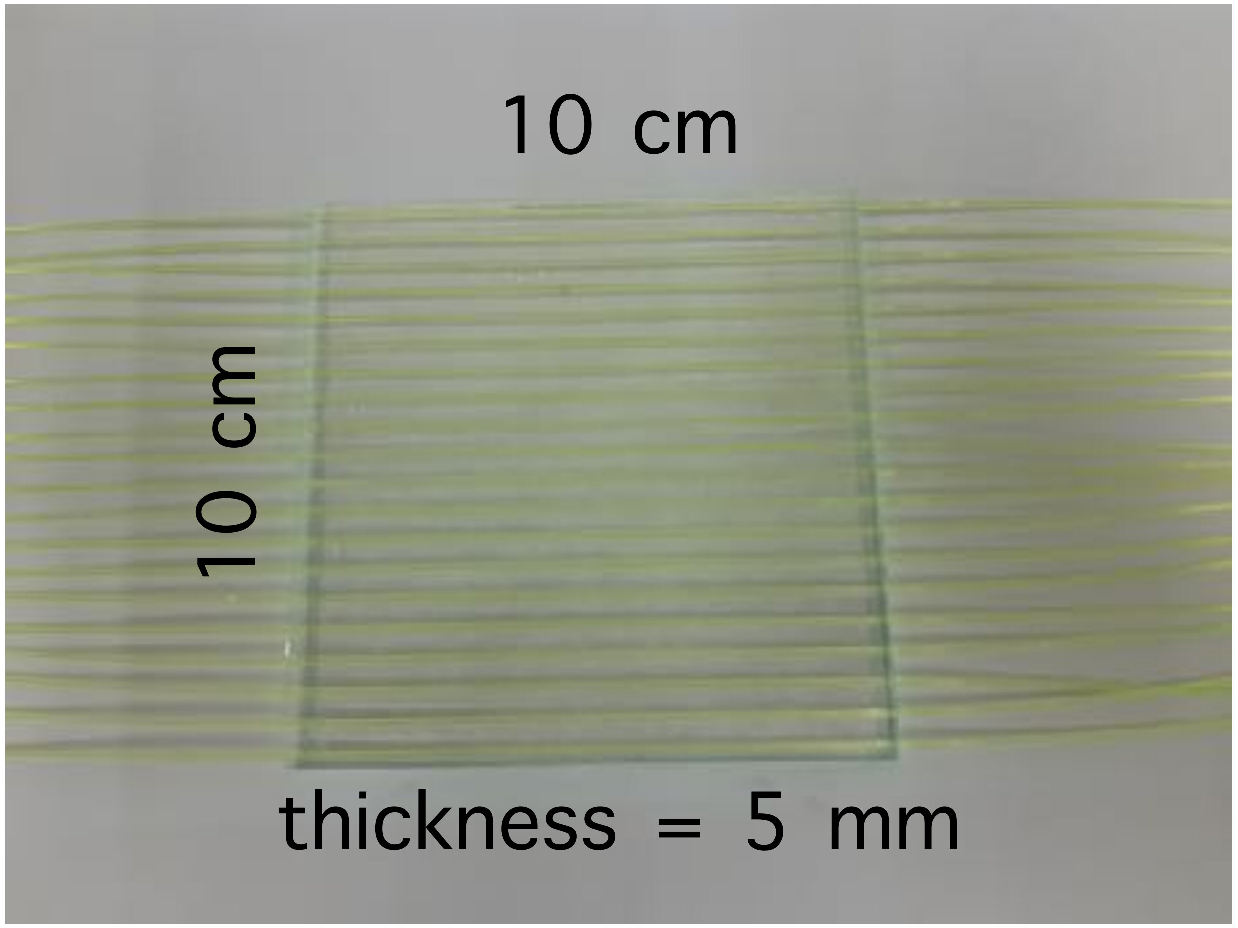
Polish the edge
(10cycles #1200)
after diamond cutting

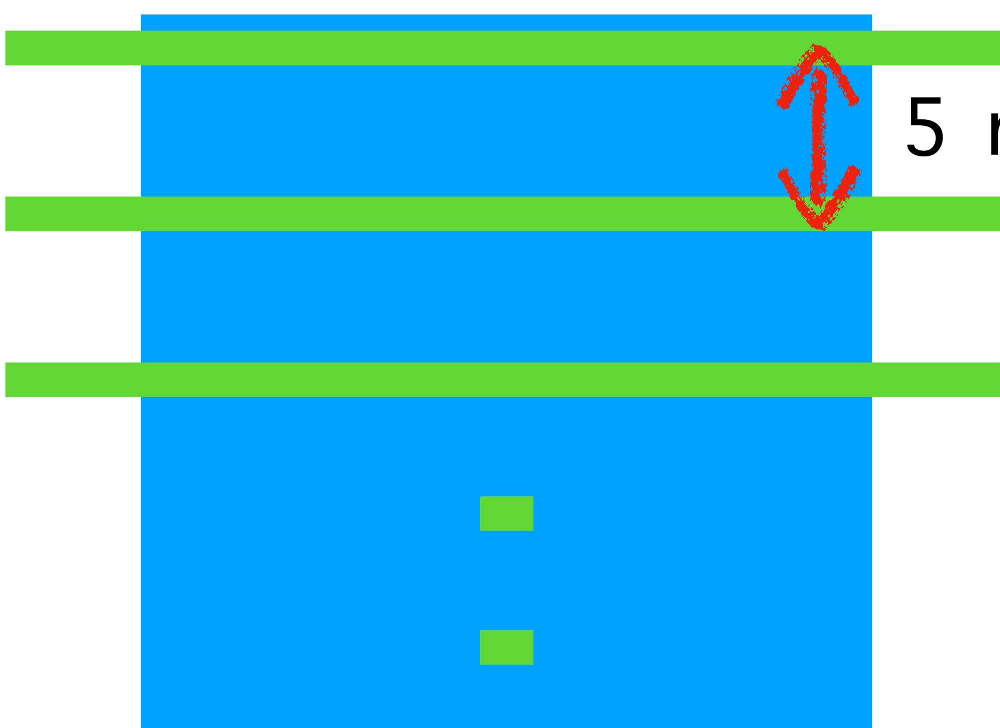
R&D topics : Fiber cut condition



- For consistency and sufficient light yield, It is recommended to choose a diamond cut method.

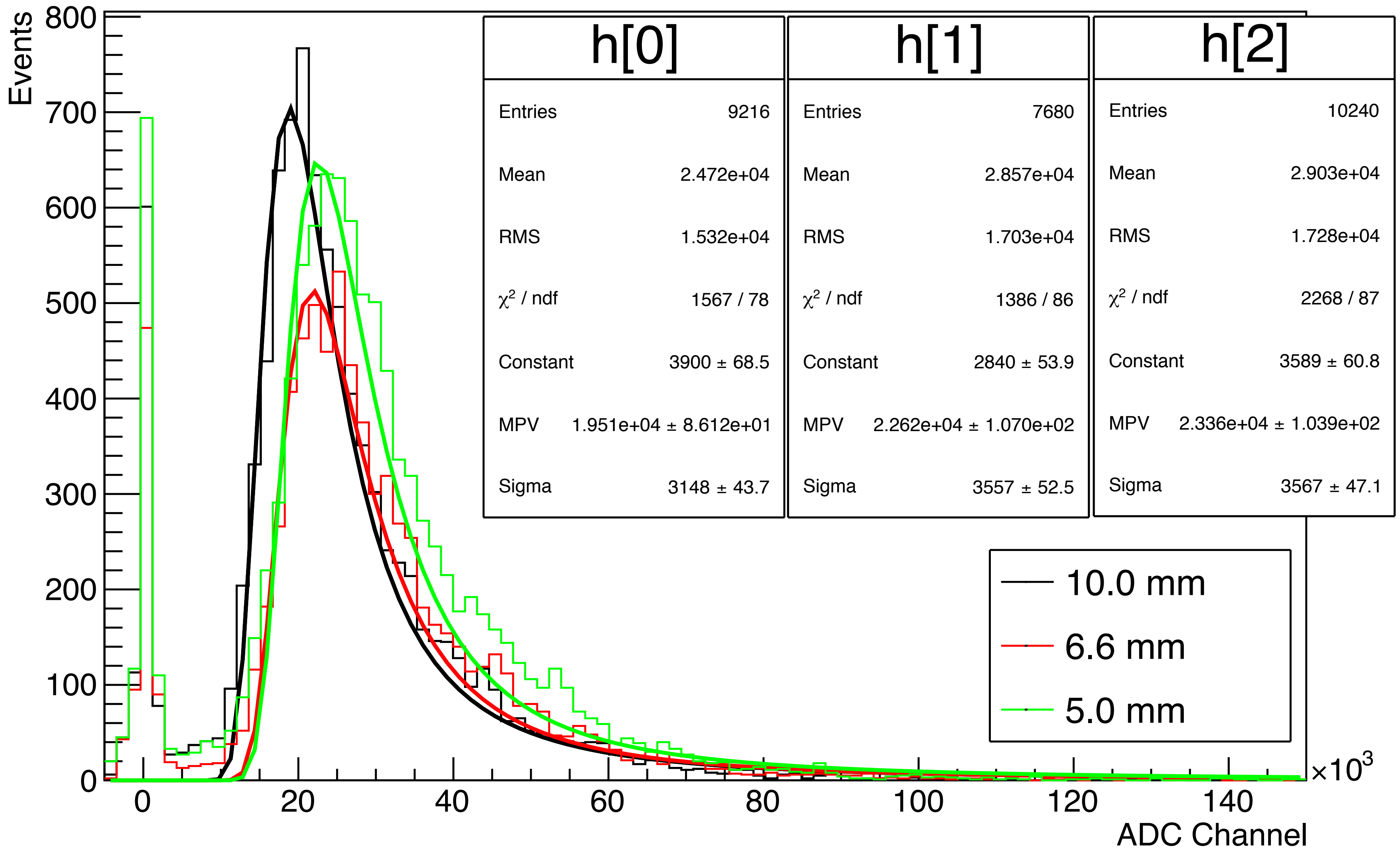
R&D topics : Pitch dependence





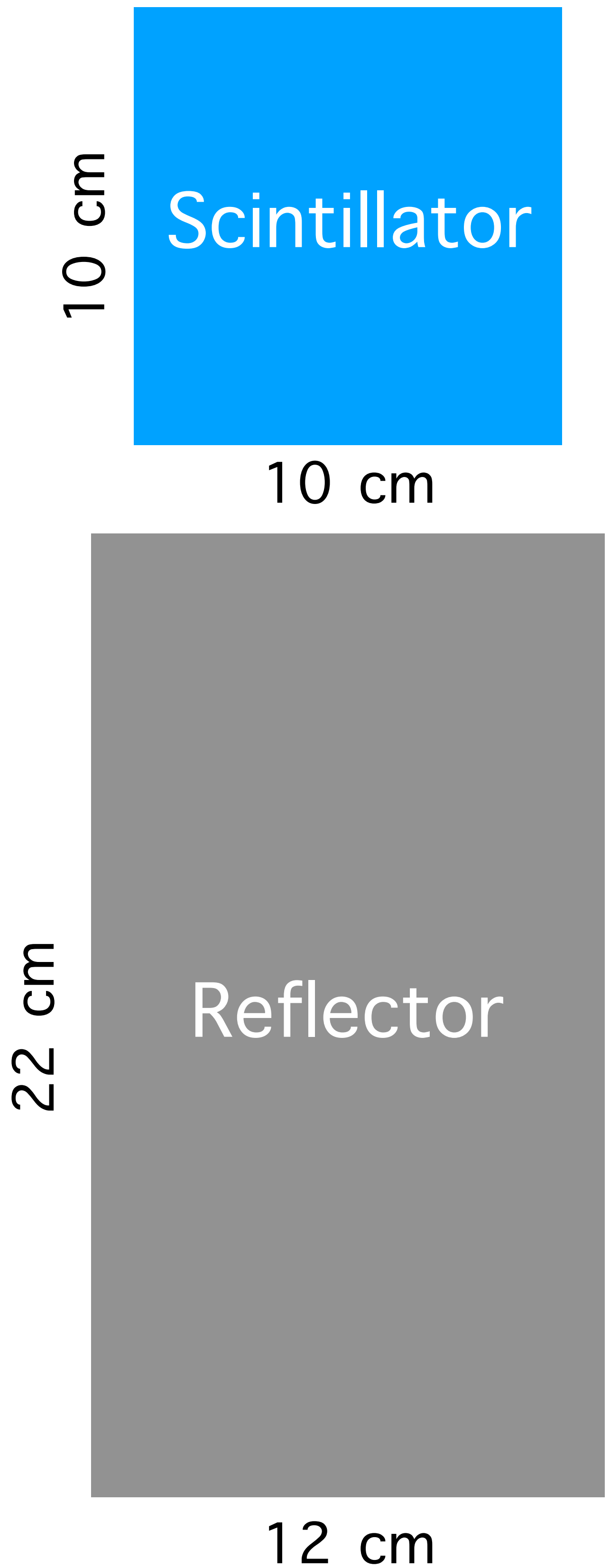
5 mm(20 fibers), 6.6 mm(15 fibers), 10 mm(10 fibers)

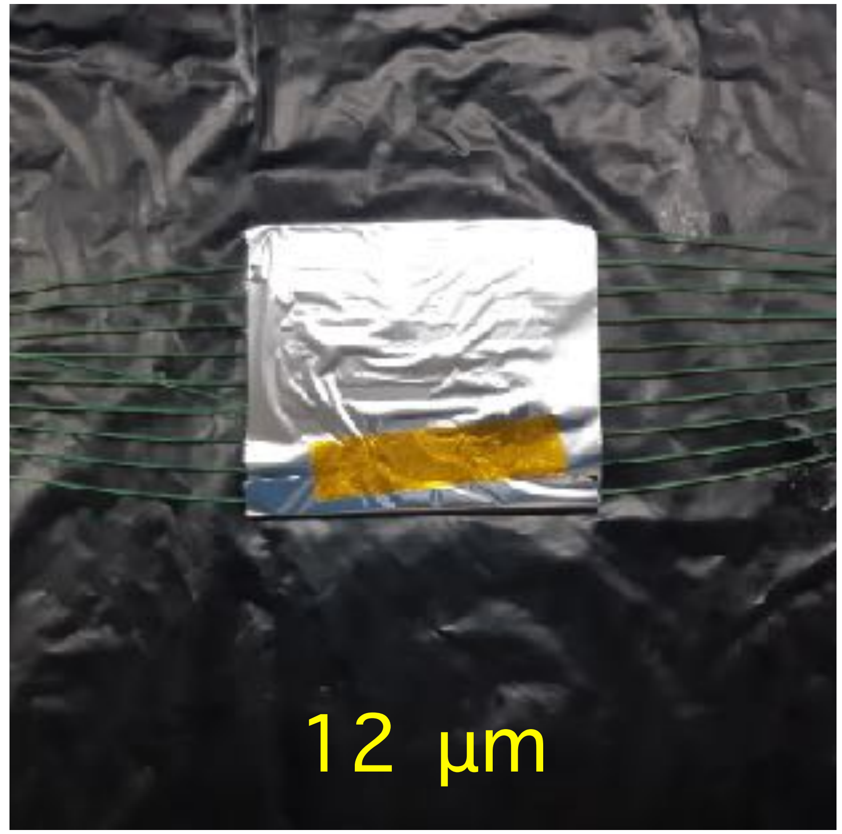
R&D topics : Pitch dependence

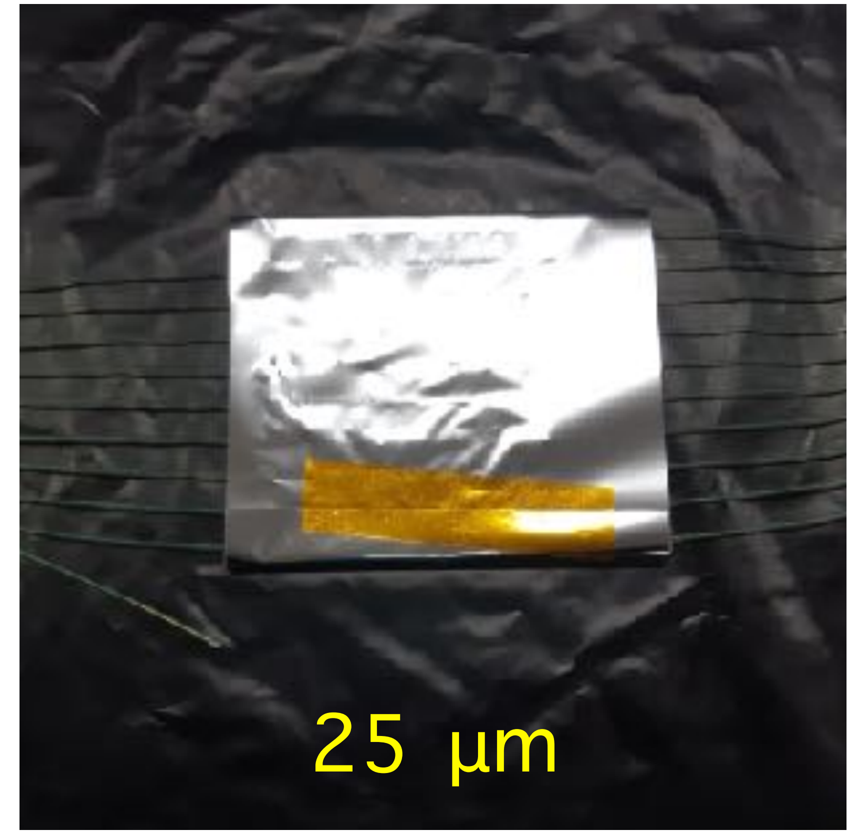


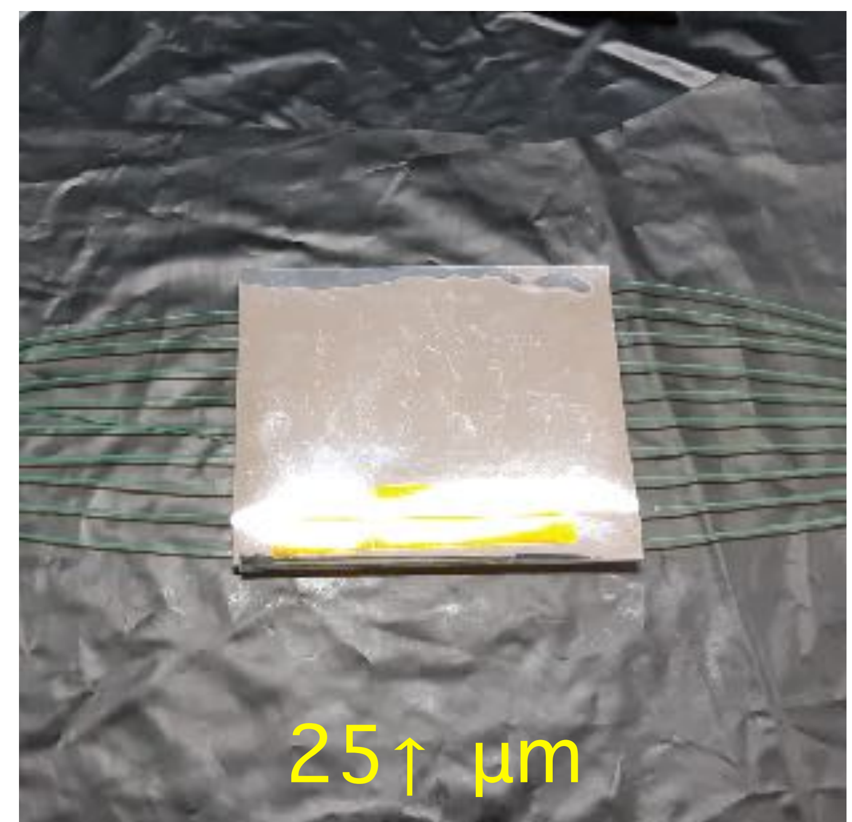
Pitch length	5 mm	6.6 mm	10 mm
Number of fibers	20	15	10
Number of p.e.	~ 55	~ 53	~ 46
Light yield Ratio	100%	96%	84%
Fiber length	70 cm (from center of scintillator to MPPC)		

R&D topics :Thickness of the aluminum mylar



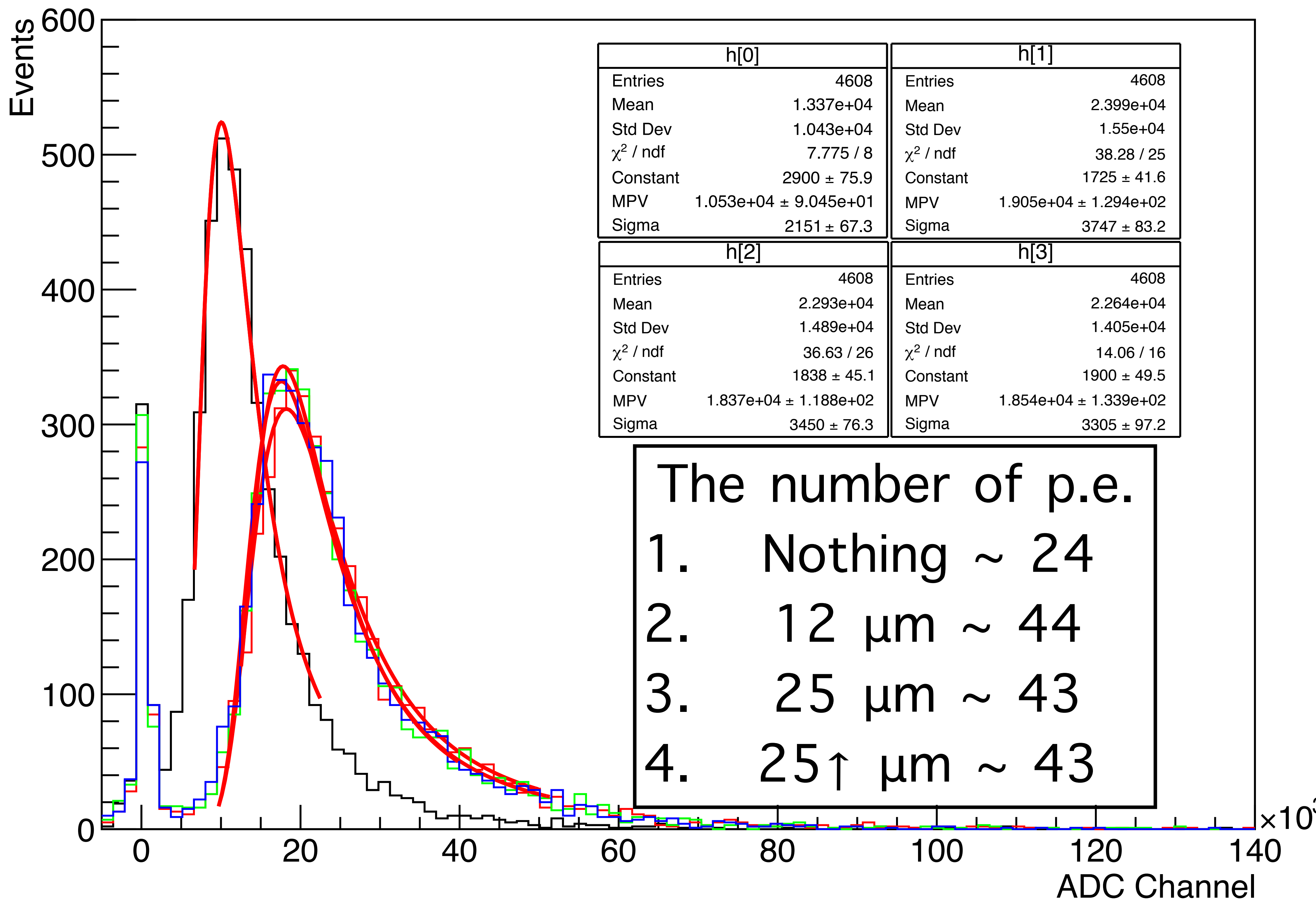






*One fiber was broken for all cases.

R&D topics :Thickness of the aluminum mylar



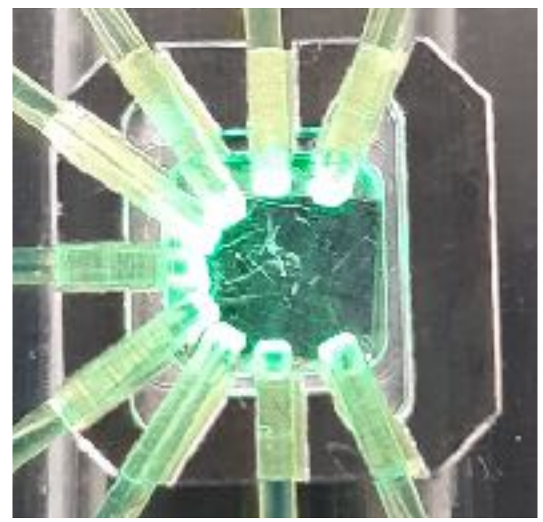
- A 12 μm thick of reflector is enough to reflect the light compared the other reflectors.

R&D topics : Reflector in the light guide

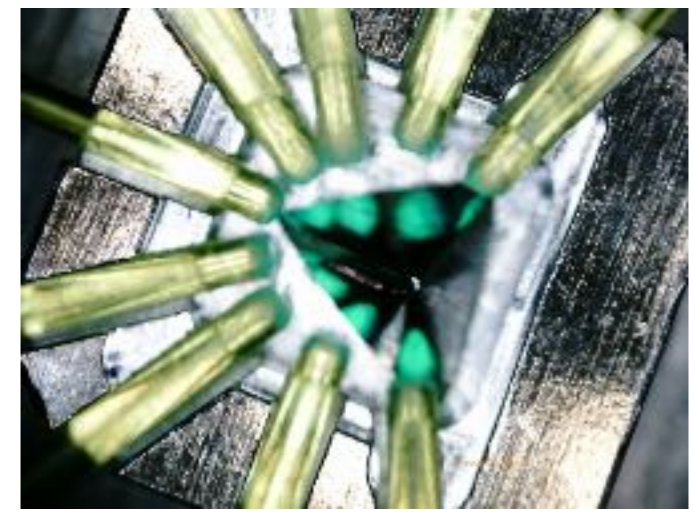
In previous polished fiber

Placement of
the tetrahedron-shaped
aluminized mylar

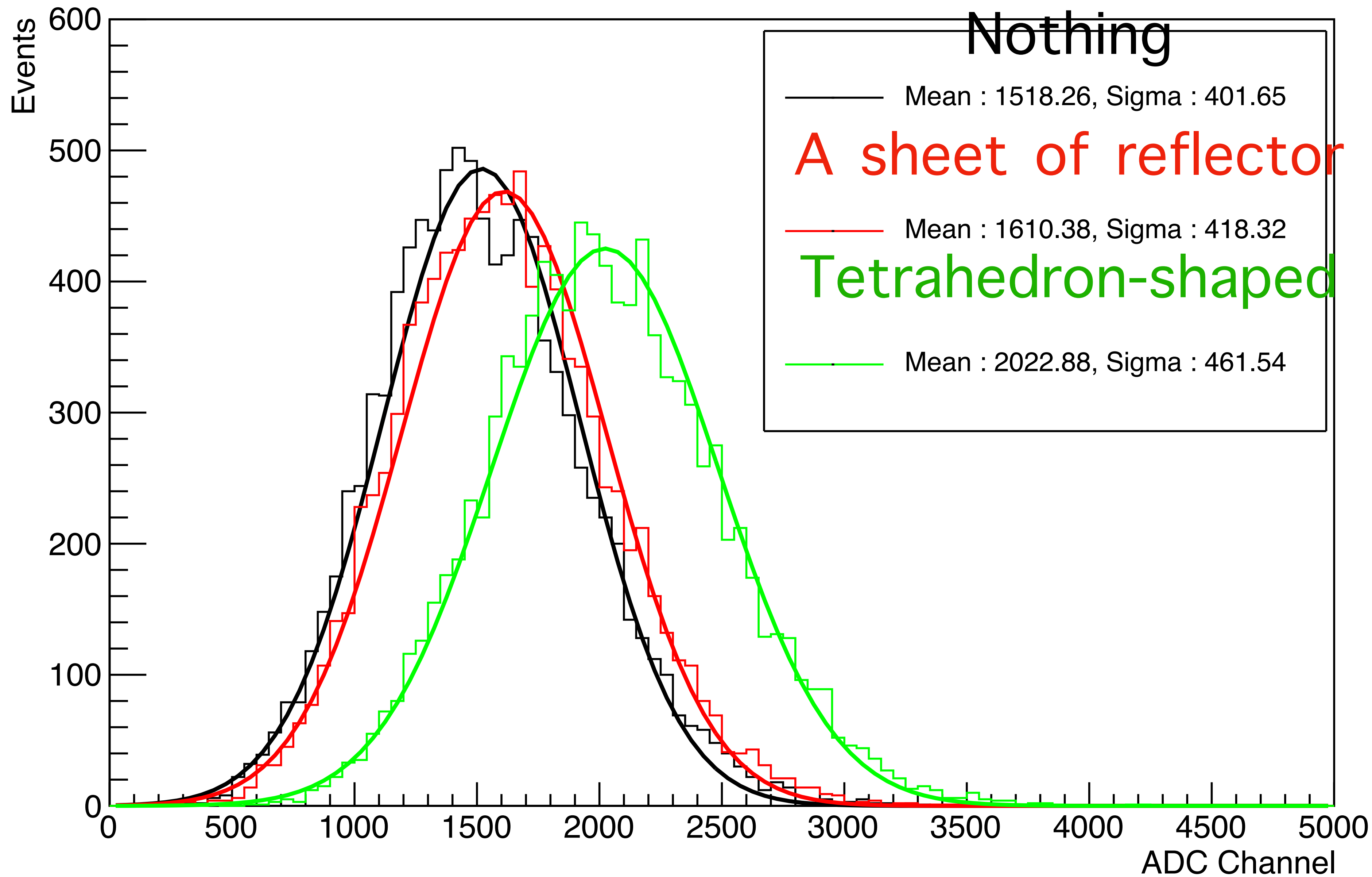
Nothing



Placement of
the aluminized mylar



R&D topics : Reflector in the light guide



- Tetrahedron-shaped reflector increased about 30% efficiency of light yield.

- The way to create a large number of tetrahedron-shaped reflector is currently under study.