Performance Test of Thin Plastic Scintillators with Positron Beam

～for WAGSCI experiment～

Naruhiro Chikuma

University of Tokyo

竹馬 匠泰

東京大学

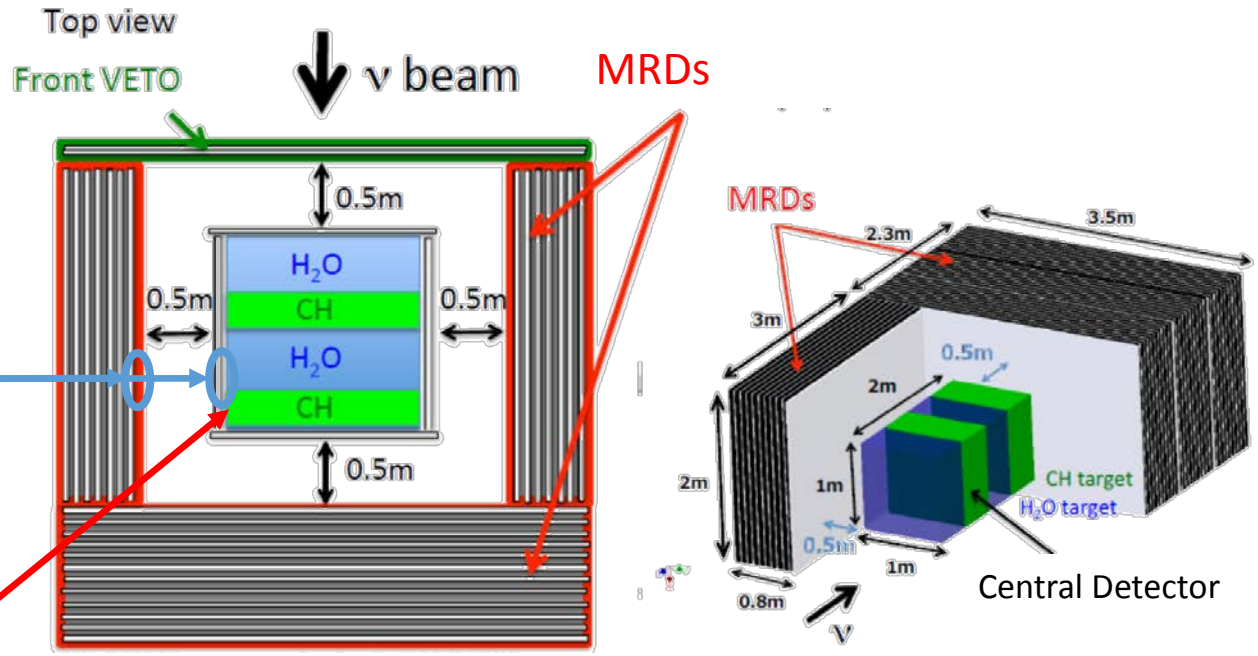
WAGASCI Experiment

- Aim to measure the cross section ratio of neutrino nuclear interaction b/w water and plastic.

  - Central Detector(Target part) + MRDs
  - H_2O target and CH target(1 ton, respectively)

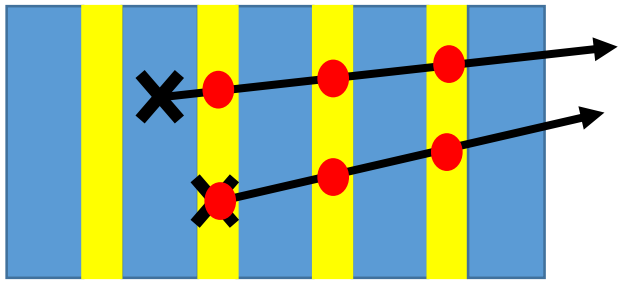
⇒**Plastic scintillator** is used to acquire light yield for the charged particles emitted by neutrino interaction.

※**TOF measurement** b/w Central Detector and MRDS.
⇒To eliminate the background coming in from the outside.



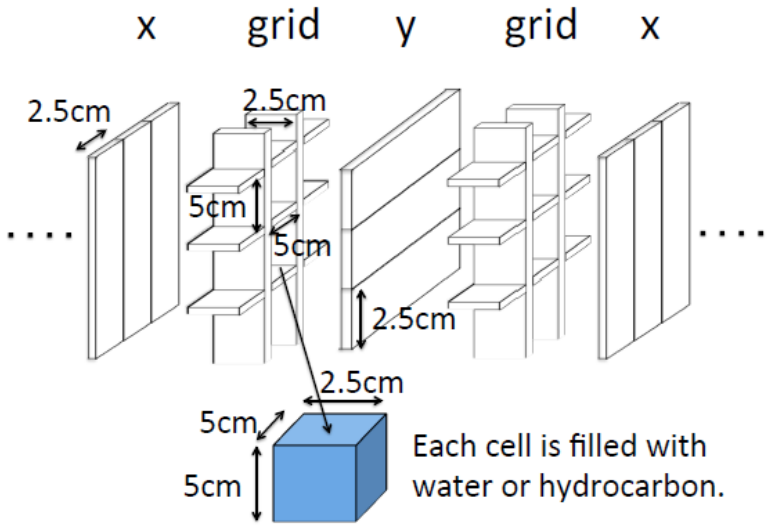
Central Detector (WAGASCI Detector)

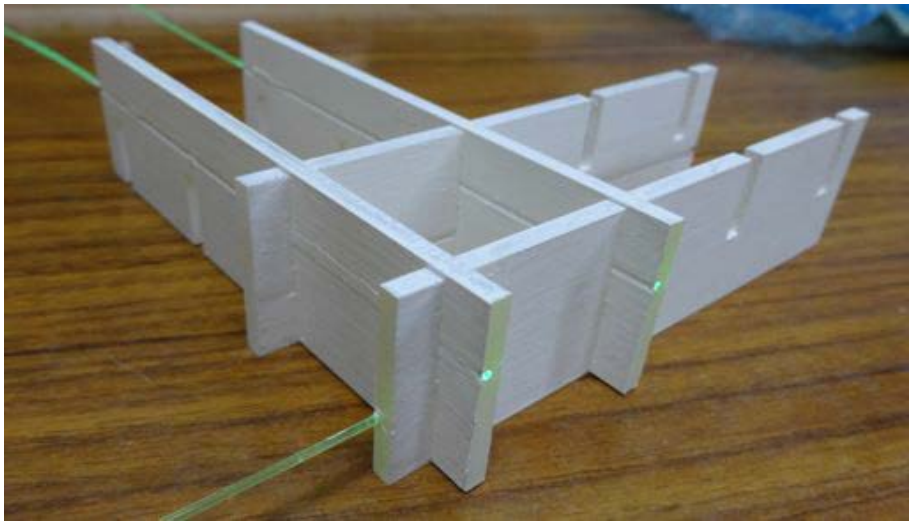
- Require a large ratio of the target mass to the scintillator's mass.
  - Because of no way to distinguish which of the target or scintillator the vertex is exactly on, and interactions on scintillators are to be background.



⇒**3mm thin scintillators** are used and 3D grid is constructed.

Target(water/plastic, Signal) : 79%, Scintillator(BG) : 21%





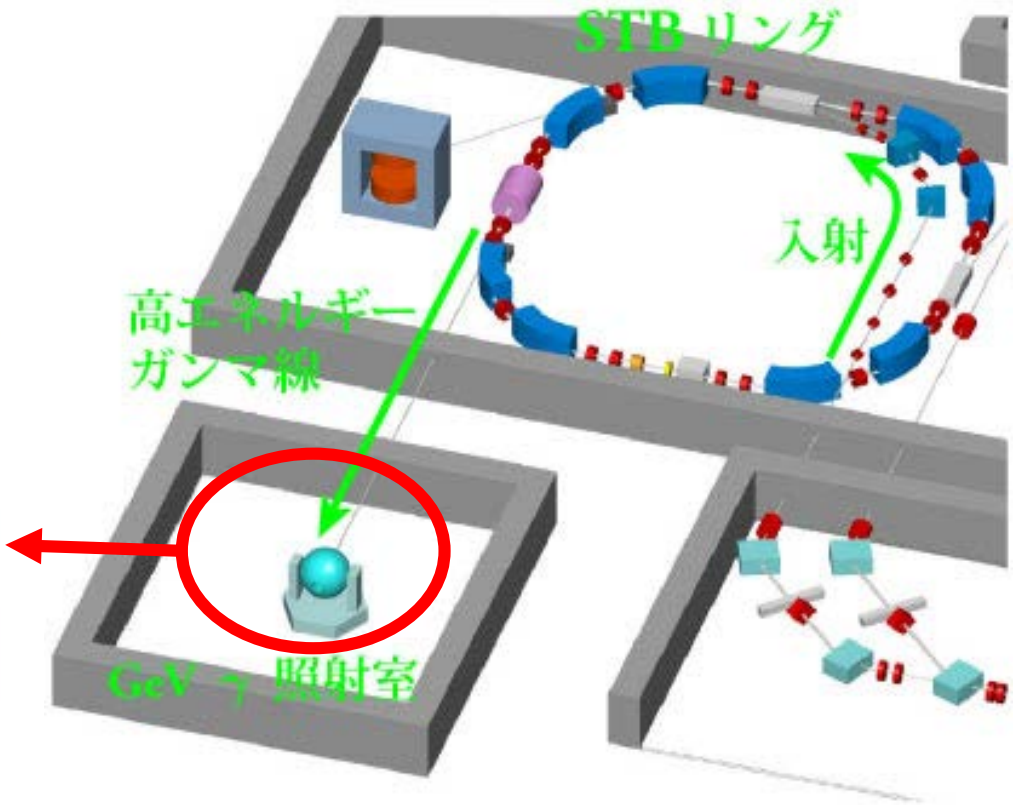
Schedule of Beam Test

- 19th ~ 21st Dec 2014
- Beam runs for 36 hours in all

Beam Facility

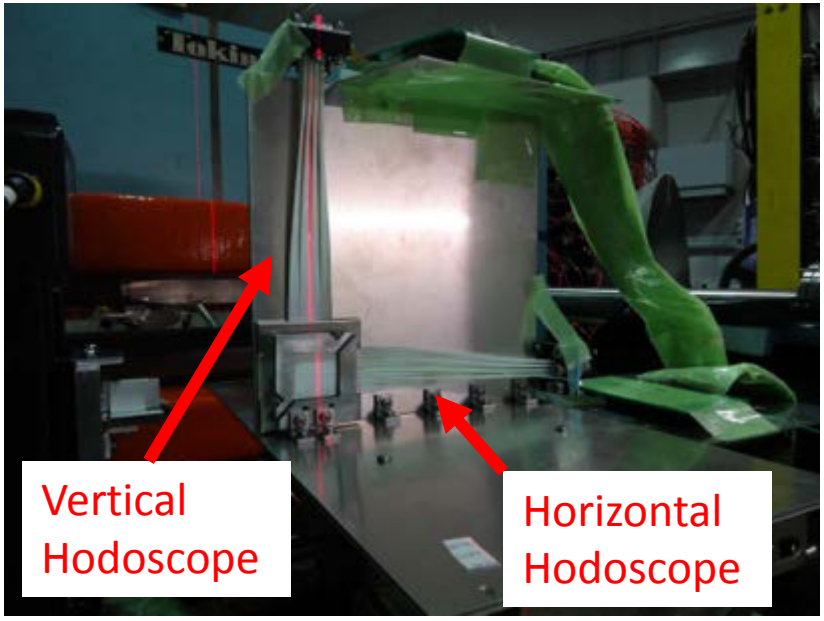
Positron beam at Research Center for Electron Photon Science, Tohoku University

Max Energy	**850MeV**
Dispersion of energy	**~1%**
Max Intensity	**3 kHz**

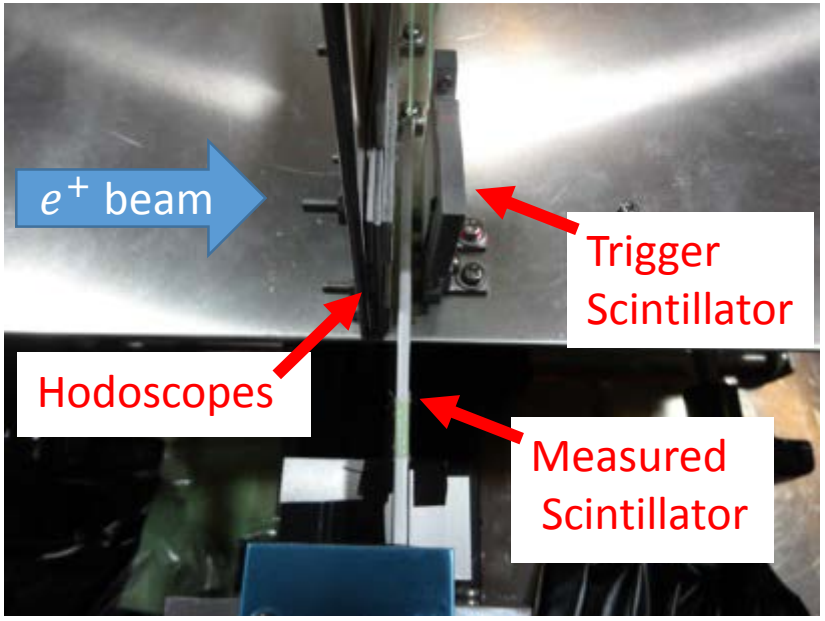


Setup : Test for 3-mm-thick Scintillator

- Each module is located from the beam upstream as the following:
  ①Hodoscope(horizontal) ②Hodoscope(vertical) ③Measured scintillator ④Trigger scintillator
- Coincidence is taken between these three:
  Hodoscope(horizontal), Hodoscope(vertical), Scintillator for trigger
- Readout flow:
  Scintillator → WLS fiber → MPPC → CAMAC ADC
  Hodoscope → MPPC array → easiroc



*picuture from the downstream viewpoint

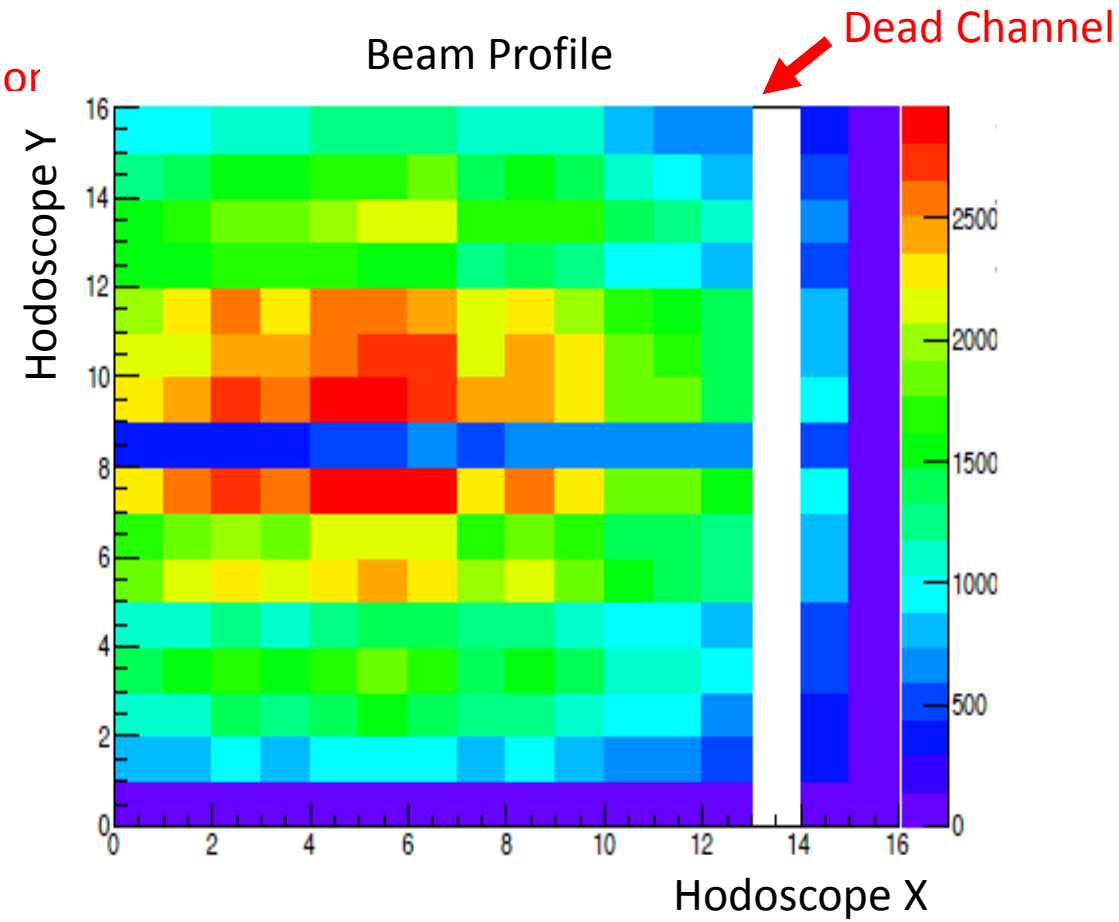


*picuture looking down the setup

Beam Profile

- The figure shows the view from the beam downstream.
- 589MeV positron beam.
- Shifted to the left for avoiding dead channel.

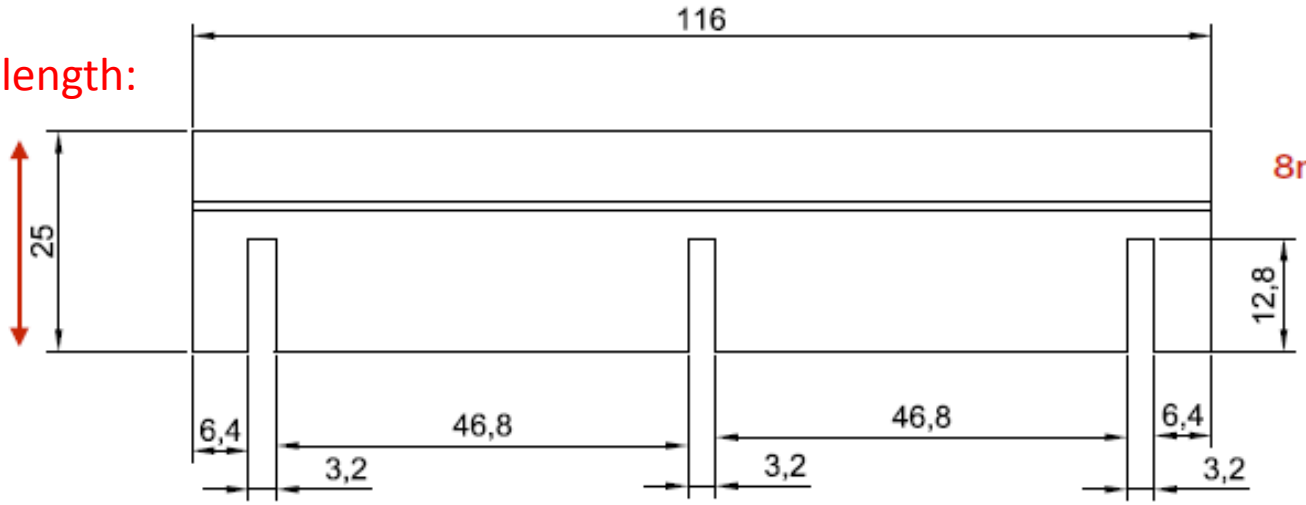
*Hodoscope's segmentation
1.5mm



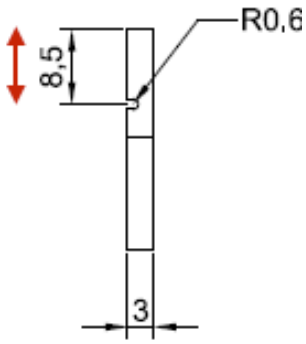
Scintillators

Drawing of scintillator processed by G-Tech

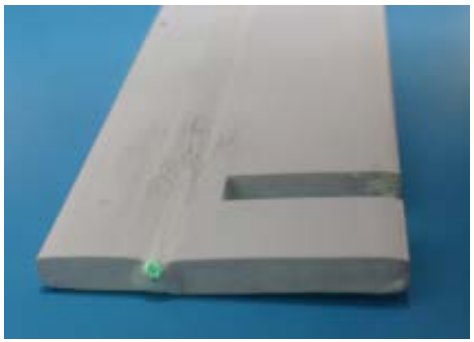
Actual length:
24mm



8mm



- Length of WLS fiber : 60cm
- The fiber is glued before coating it by reflector
- Edges and slits are also coated by reflector



Light Yield

Correction with crosstalk and afterpulse of MPPC

- “true light yield” = (measured light yield) / (1 + crosstalk & afterpulse rate)
- crosstalk & afterpulse rate is measured at Kyoto U. (ΔV=4.0V) ⇒ 5.18%

Efficiency

$$= \frac{(\#\ of\ events\ with\ both\ of\ condition\ ①\ \&\ ②\ )}{(\#\ of\ events\ with\ condition\ ①)}$$

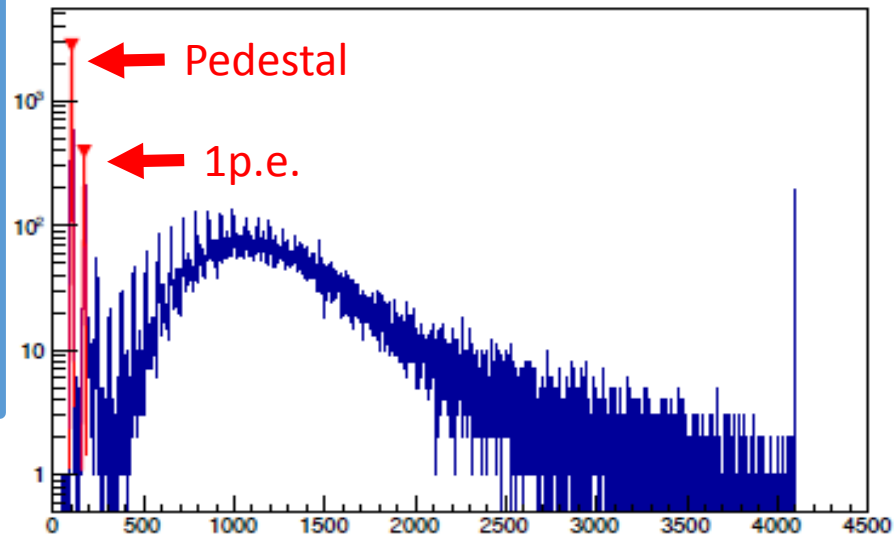
condition ① : ADC value of hit channel in hodoscope is over the threshold.

*Hit channel : with the largest ADC value in H/V hodoscopes(easiroc) respectively.

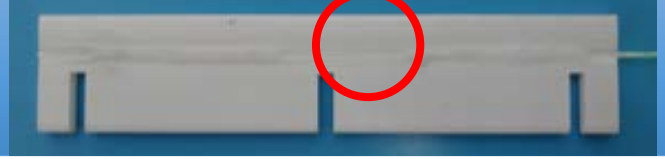
condition ② : Light yield of measured scintillator is over 1.5p.e.

*Pedestal and 1p.e peaks are measured every event (Figure).

ADC distribution of measured scintillator



Measurements

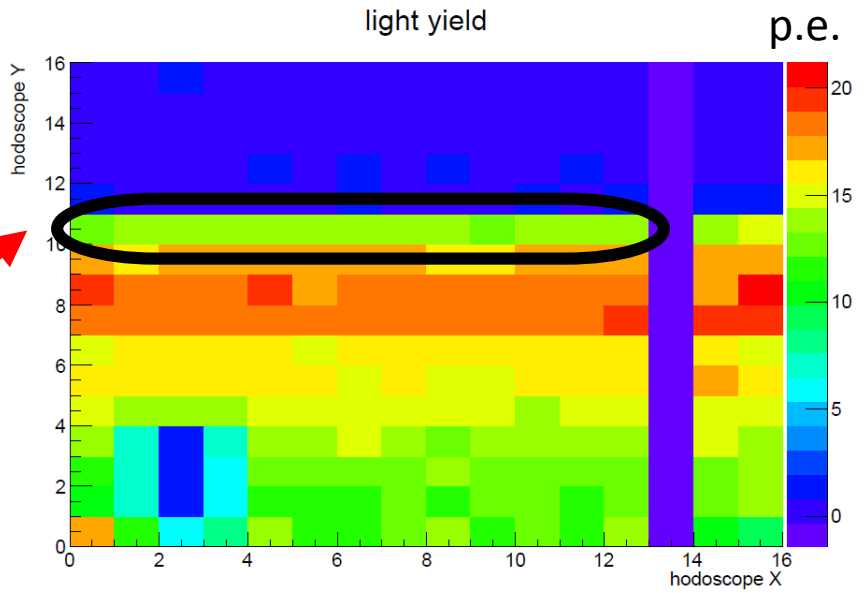


*Scintillators processed by G-Tech

Light Yield

The average for these 13 bins at the edge* :

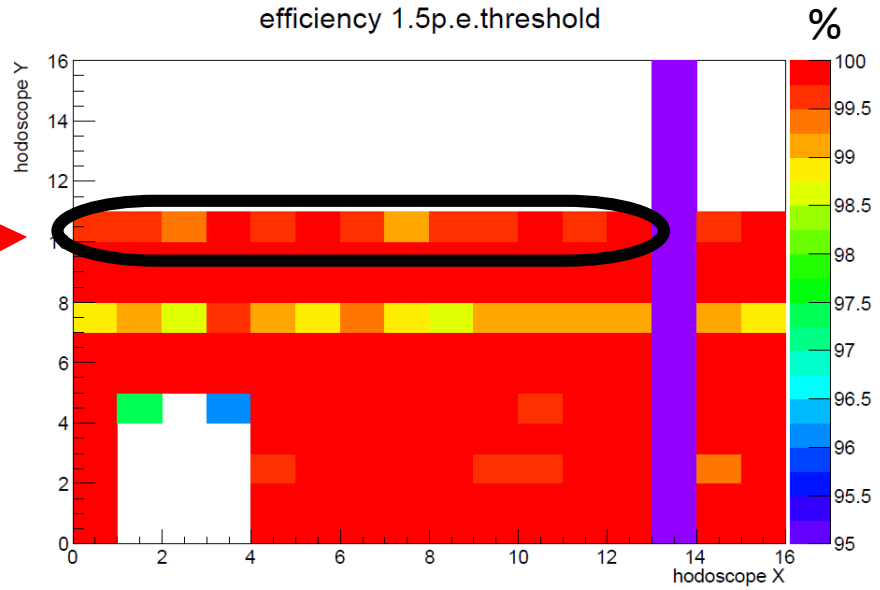
13.60 ± 0.14p.e.



Efficiency

The average for these 13 bins at the edge* :

99.65 ± 1.02%



* ch # is 0~12 in vertical, 10 in horizontal

Measurements

*Scintillators processed by G-Tech

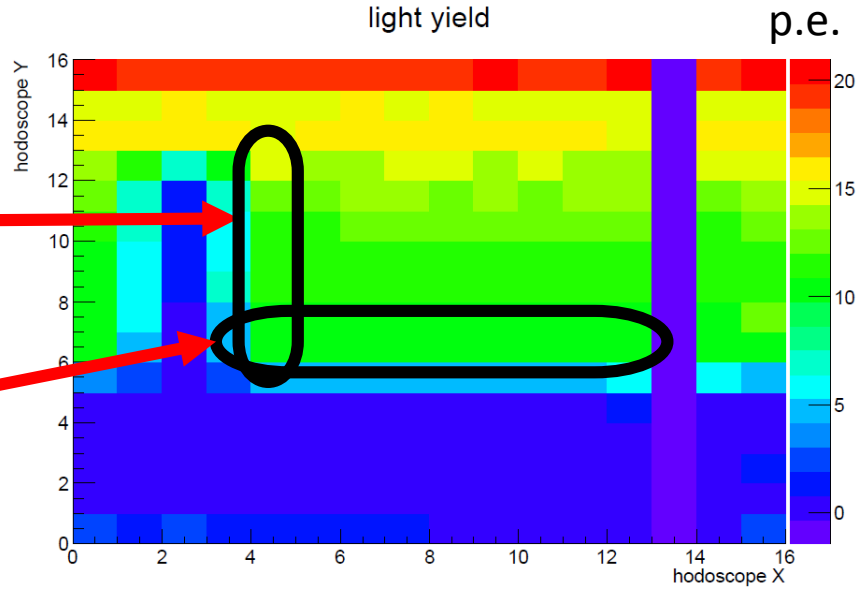
Light Yield

The average for these 7 bins at the edge*1 :

11.34 ± 0.11p.e.

The average for these 9 bins at the edge*2 :

10.41 ± 0.09p.e.



Efficiency

The average for these 7 bins at the edge*1 :

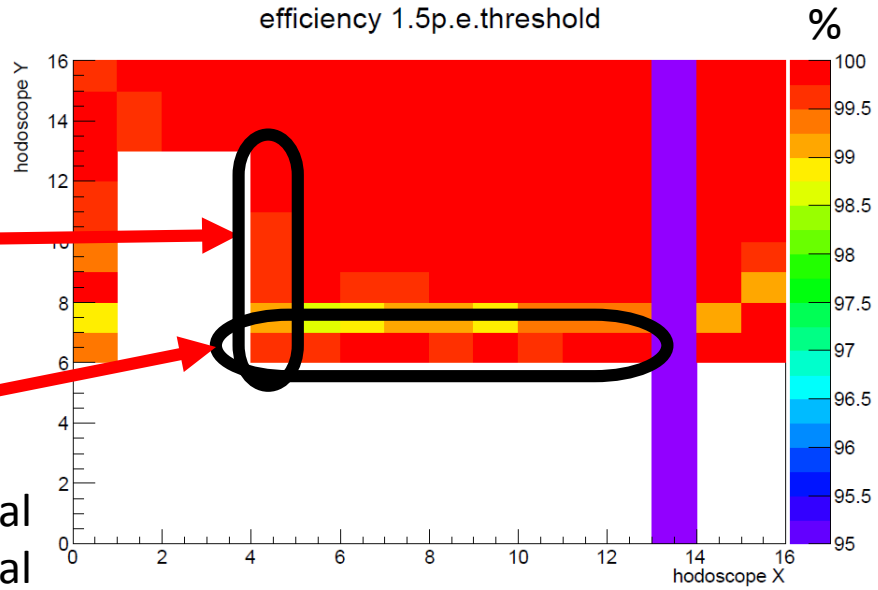
99.60 ± 0.94%

The average for these 9 bins at the edge*2 :

99.78 ± 0.91%

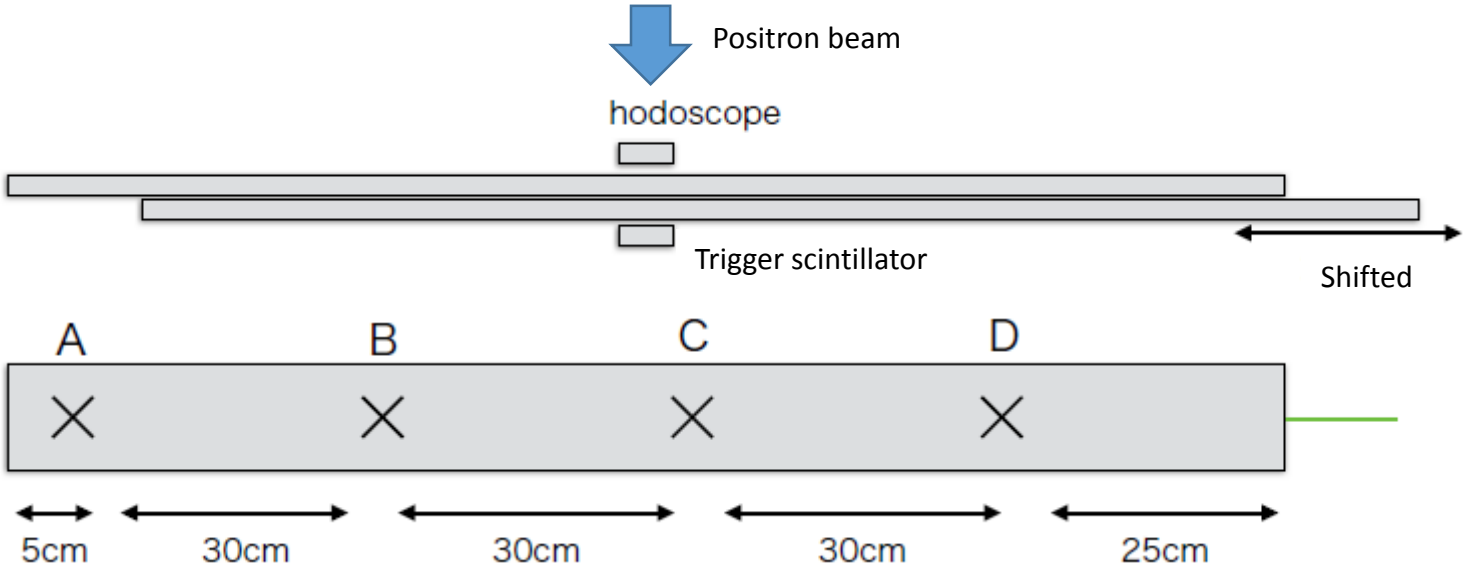
*1 ch # is 4 in vertical, 6~12 in horizontal

*2 ch # is 4~12 in vertical, 6 in horizontal



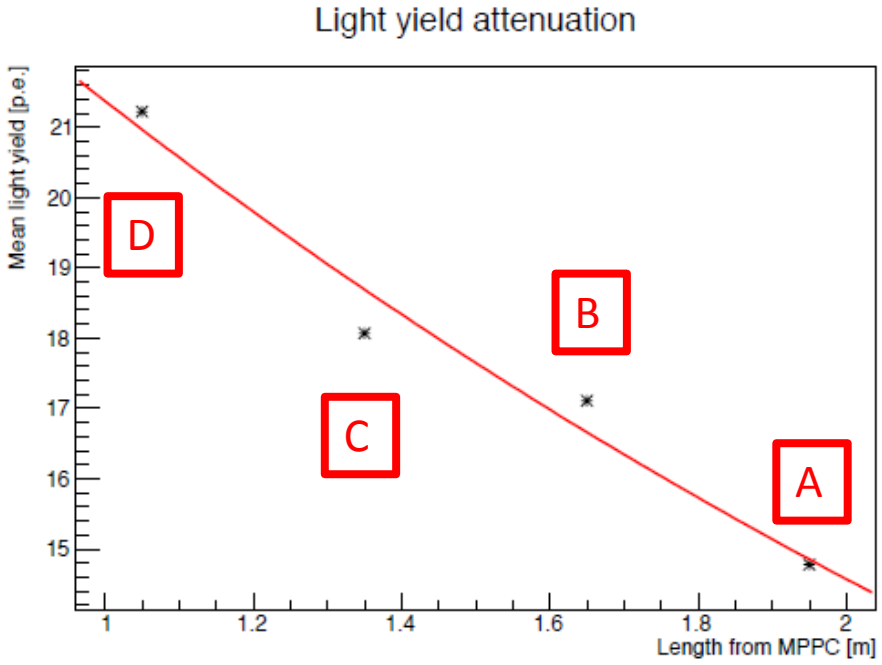
Setup for TOF Measurement

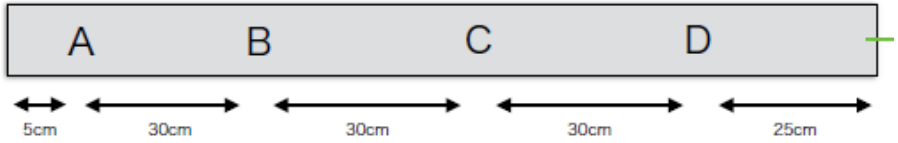
- Each module is located from the beam upstream as the following:
  ①Hodoscope ②INGRID scintillator1 ③INGRID scintillator2 ④Trigger Scintillator
- INGRID scintillator2 is shifted for each measurement(see bottom figure).
- The length of the WLS fiber is 2m.
- “New type” MPPC(crosstalk suppression type sample) is used for INGRID scintillator.



Attenuation in the WLS Fiber

- Mean light yield is plotted as the **function of distance from MPPC**, and fitted with **exponential** function.





Mean Light Yield

	A	B	C	D
P.E.	14.78	17.11	18.07	21.22

Fitted result:

$$y_{[p.e.]} = 31.4 \times \exp(-0.383 * x_{[m]})$$

Suppose no attenuation at 0m from MPPC, half reduction length is:

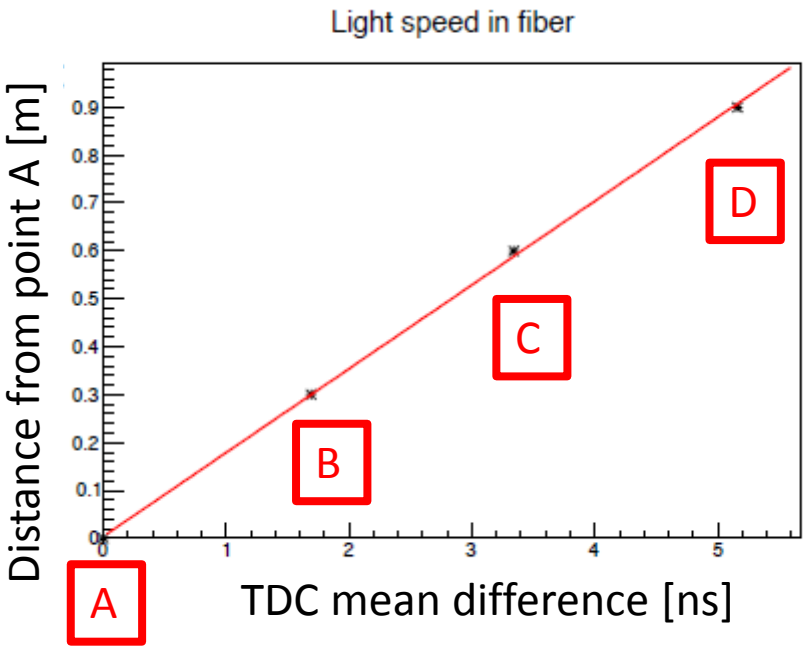
"attenuation length" = 2.61[m]

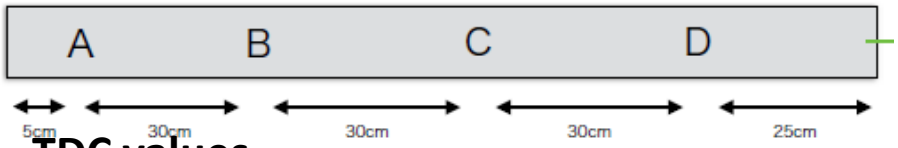
Time Resolution & Speed of Light in the WLS Fiber

- The average of time resolution of INGRID scintillator is measured as: 2.55 [ns] (1σ of gauss fitting.)

  ⇒Too bad to measure TOF in WAGASCI. This is going to be measured again, and one more scintillator layer for TOF would be added as a temporary solution.

- "The distance from point A" and "the difference in TDC mean" are plotted, and are linearly fitted.





TDC values

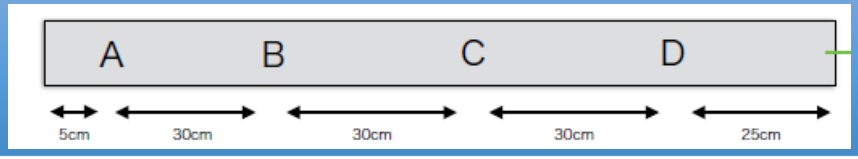
	A	B	C	D
Mean[ns]	55.87	54.18	52.53	50.71
Sigma[ns]	2.572	2.592	2.503	2.550

Fit results shows:

"Speed of light in fiber"

$= 1.75 \times 10^8$ [m/s]

Summary

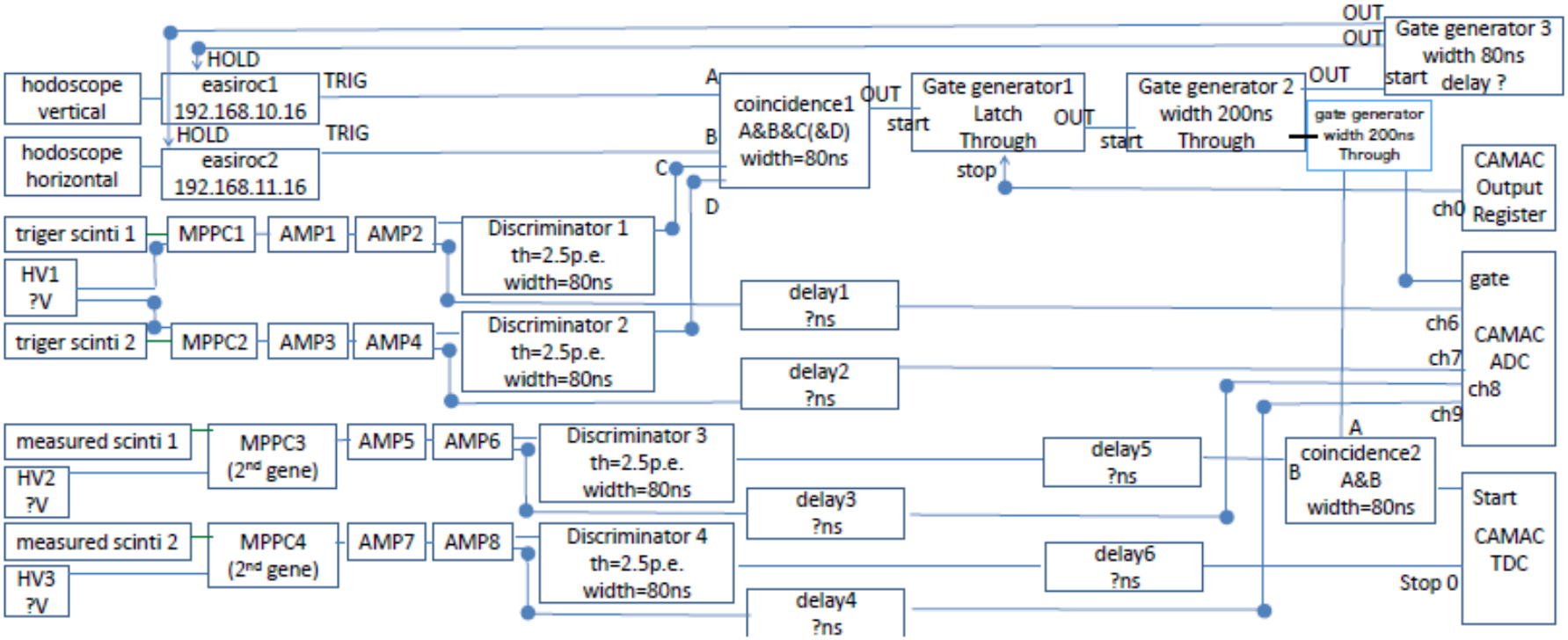


- Efficiency is better than 99% with accuracy of 1% error for the whole region of scintillator.
- Light yield in average is 20~25[p.e.] near the fiber, 10~12[p.e.] at the bottom edge(the farther one from the fiber), and about 13[p.e.] at the top edge(the nearer one).
  - Large enough to set threshold at 1.5[p.e.]
- Attenuation length in fiber : 2.61 [m]
- Time resolution of INGRID scintillator : 2.55 [ns] ⇒ Too bad.
- Speed of light in fiber : 1.75×10^8 [m/s]

	A	B	C	D
Fiber Length from MPPC [cm]	195	165	135	105
Light yield (mean) [p.e.]	14.78	17.11	18.07	21.22
TDC mean [ns]	55.87	54.18	52.53	50.71
TDC sigma [ns]	2.572	2.592	2.503	2.550

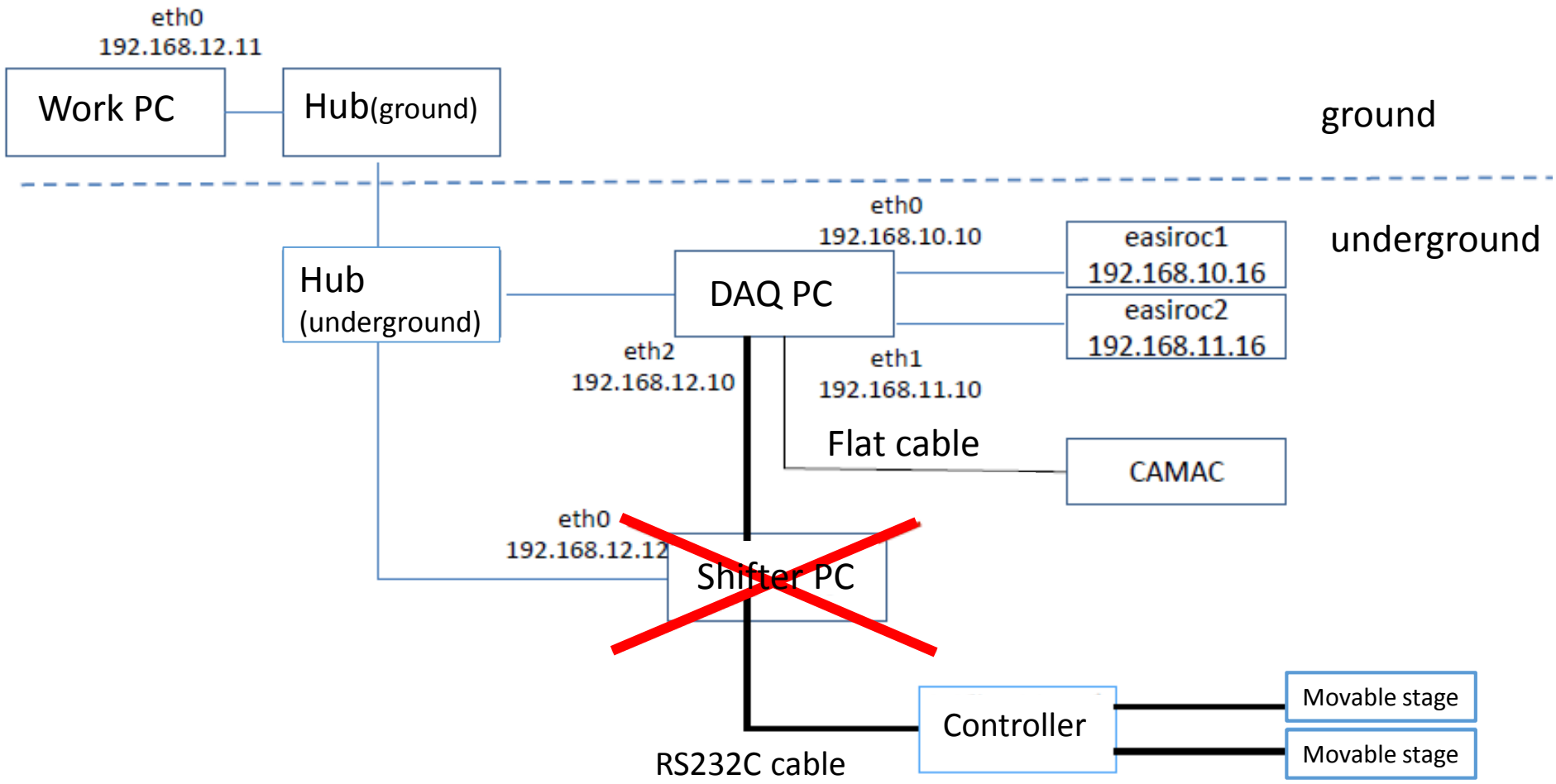
Backup

Wiring diagram

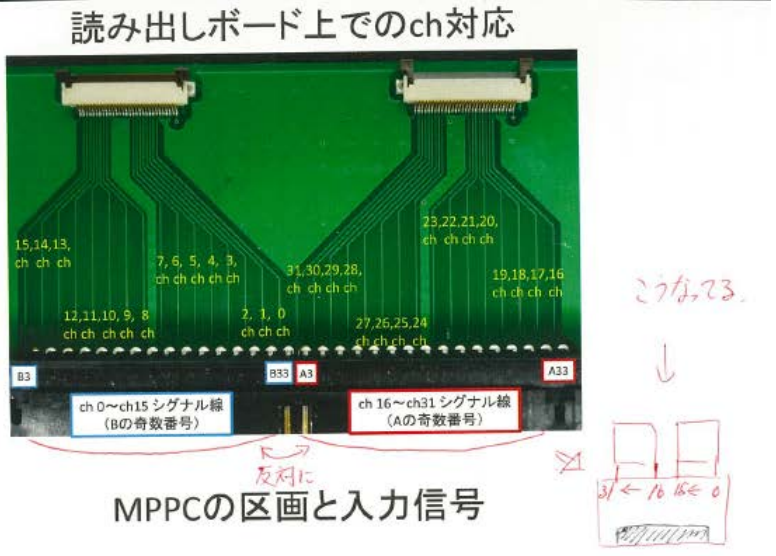


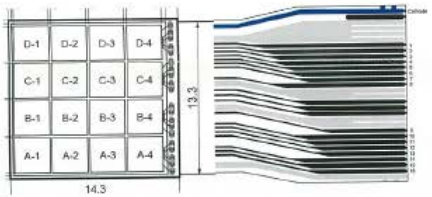
- ADC signal is set within “gate signal”.
- TDC signal is set to come after “start signal”.
- The peak of easiroc signal is adjusted to “falling edge of hold signal”.

PC


eth0
192.168.12.11
Work PC
Hub(ground)
ground
underground
eth0
192.168.10.10
easiroc1
192.168.10.16
easiroc2
192.168.11.16
Hub
(underground)
DAQ PC
eth2
192.168.12.10
eth1
192.168.11.10
Flat cable
CAMAC
eth0
192.168.12.12
Shifter PC
Controller
Movable stage
Movable stage
RS232C cable

MPPC Array





FPC Pin No.	Element No.
1	D1
2	D2
3	D3
4	D4
5	C1
6	C2
7	C3
8	C4
9	B4
10	B3
11	B2
12	B1
13	A4
14	A3
15	A2
16	A1

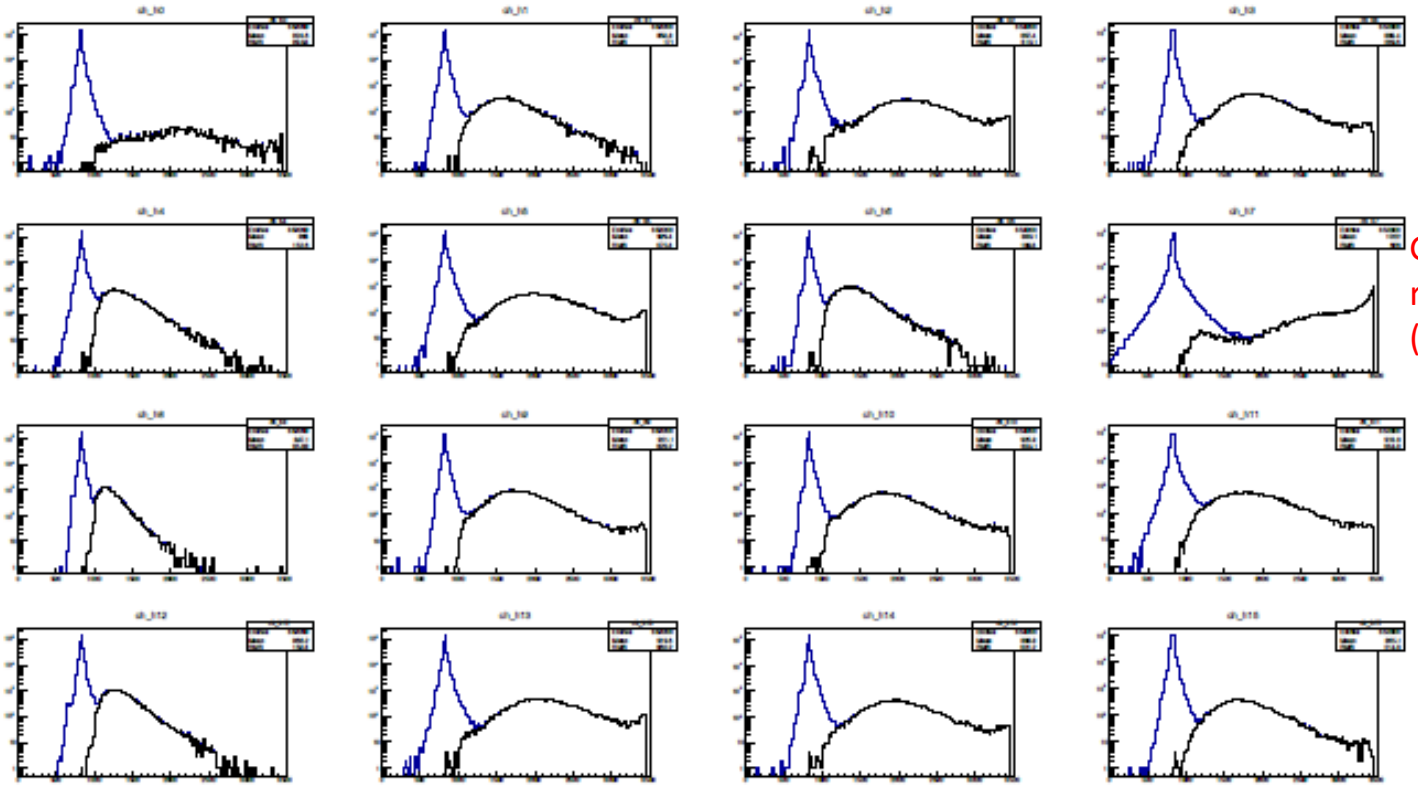
これをもとに今回の場合の割り当てを計算

easiroc threshold

- Threshold is defined for each hodoscope channel.
- The value at the valley between pedestal and signal is set as the threshold.

Blue : whole events
Black : Triggered events

hodoscope horizontal ch



Growing to the right (cause unknown)

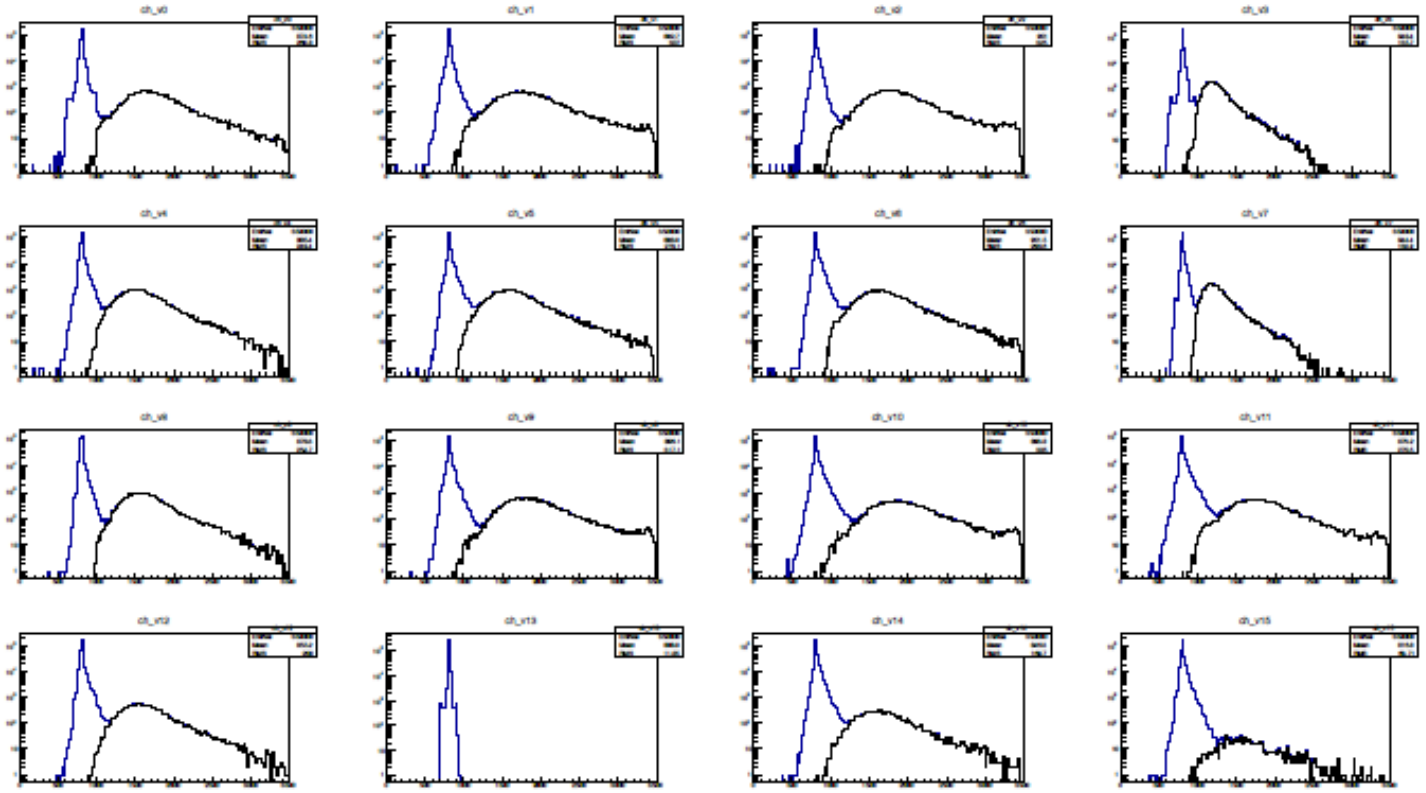
Small ΔV (usual value did not work)

easiroc threshold

Blue : whole events

Black : Triggered events

hodoscope vertical ch



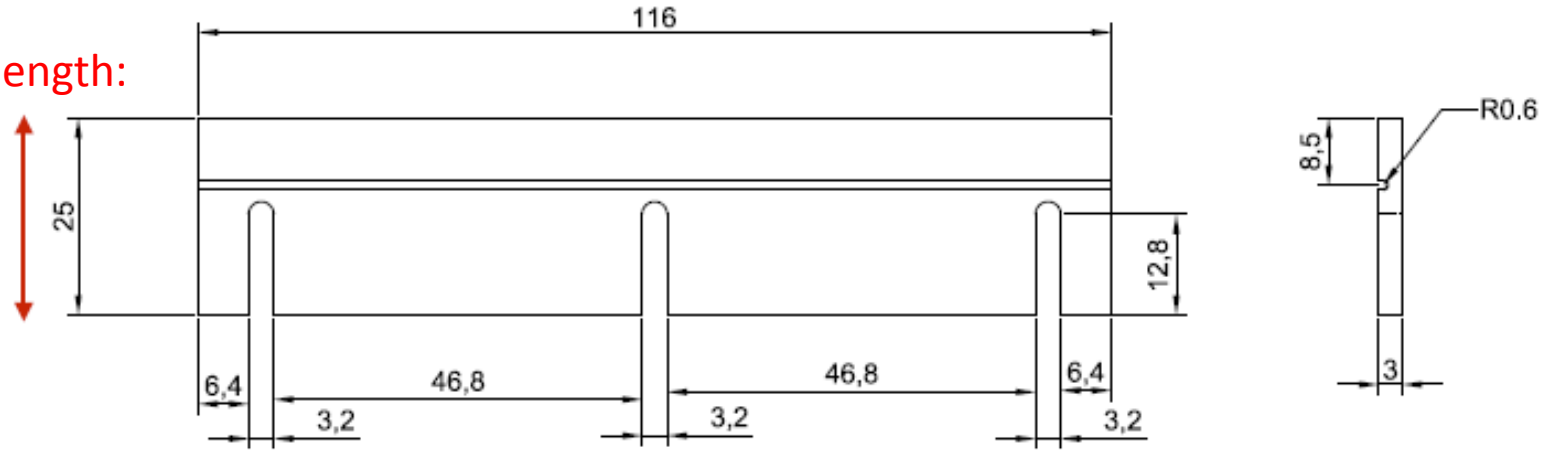
Did not breakdown
(dead channel)

Low number of events

Scintillators

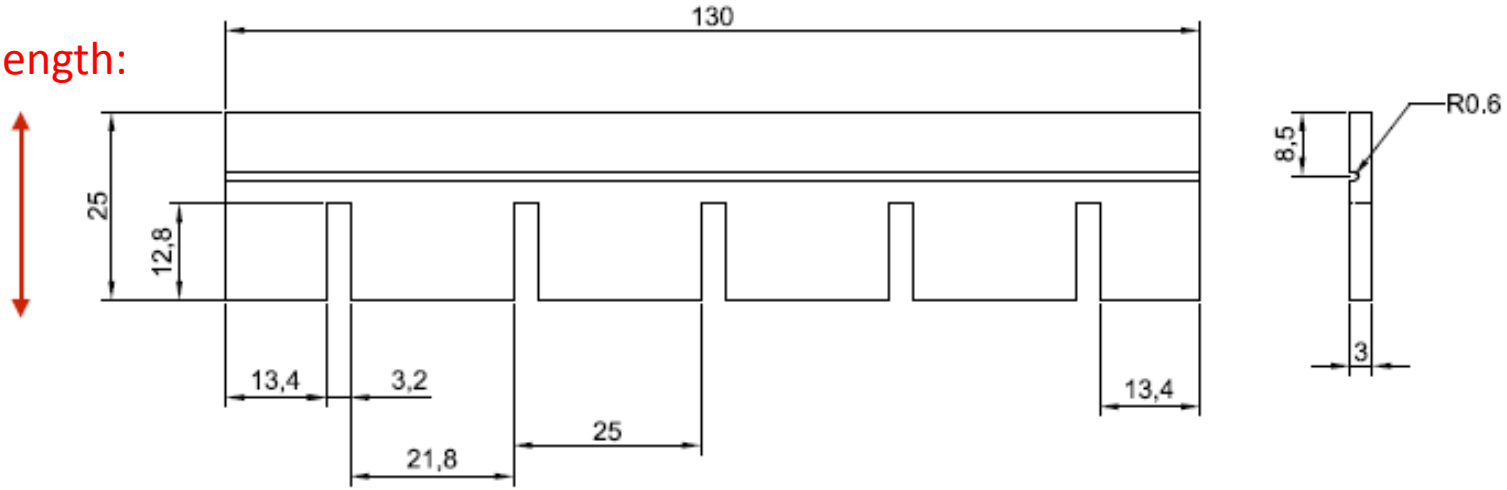
Processed at Kyoto University

Actual length:
24mm



Processed by NICHIREI

Actual length:
24mm

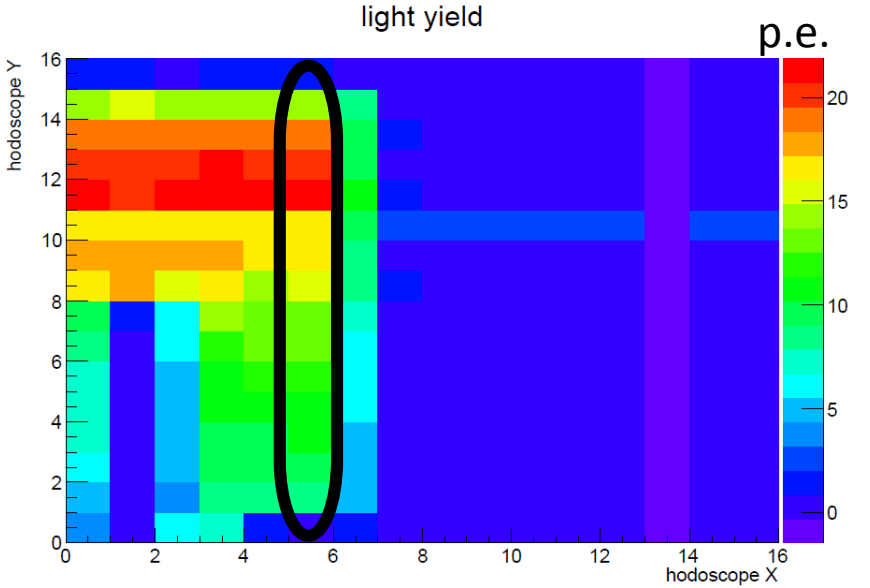


Scintillator processed by **G-tech**

Light Yield

The average for these 14 bins at the edge* :

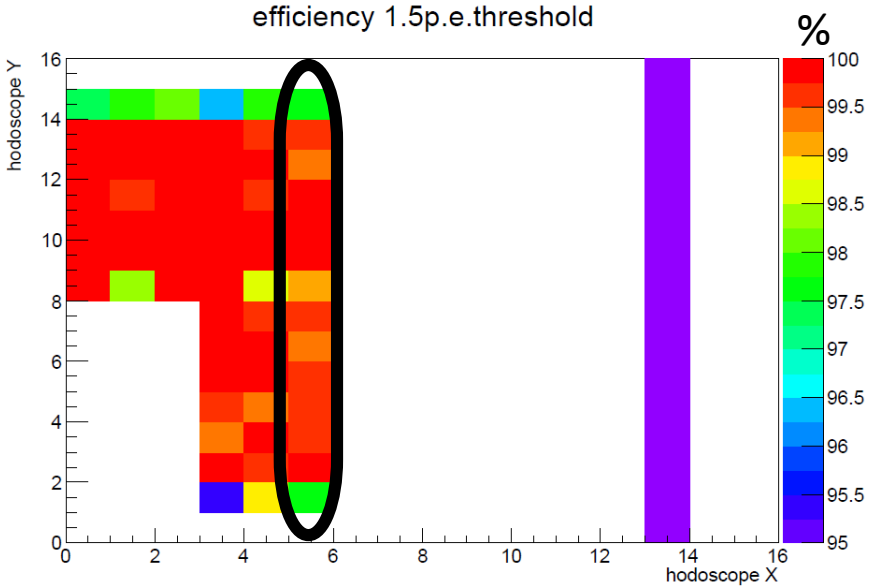
14.79 ± 0.17p.e.



Efficiency

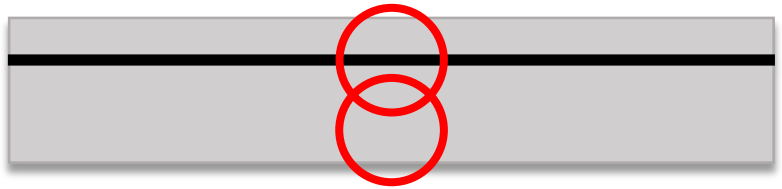
The average for these 14 bins at the edge* :

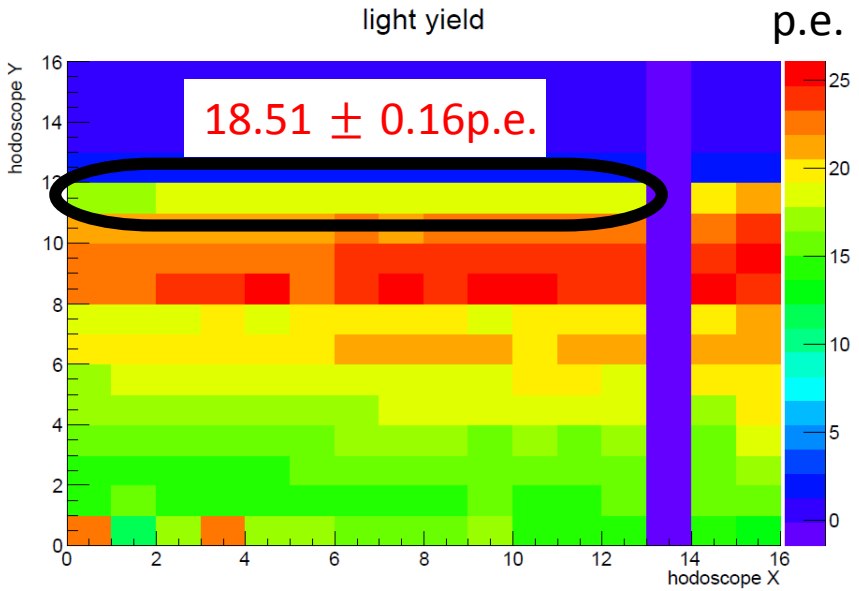
99.53 ± 1.14%

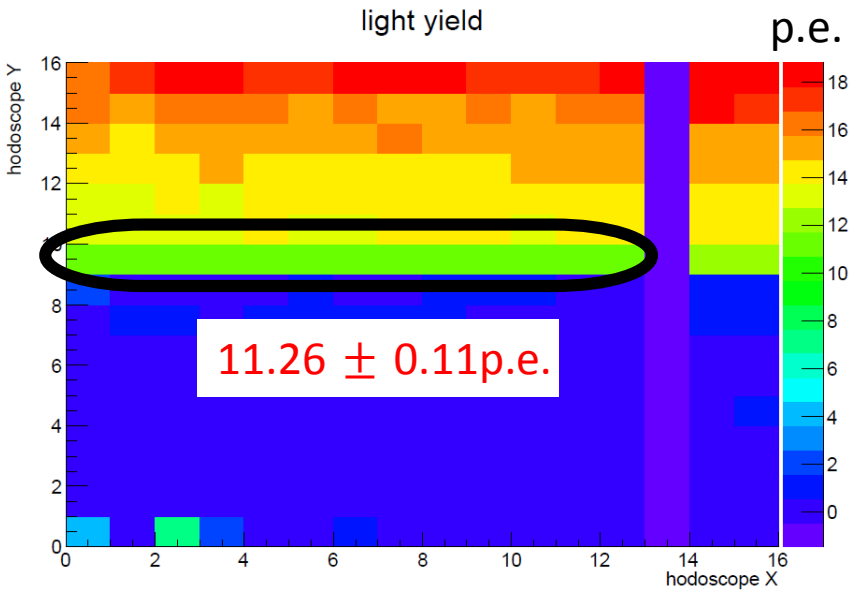


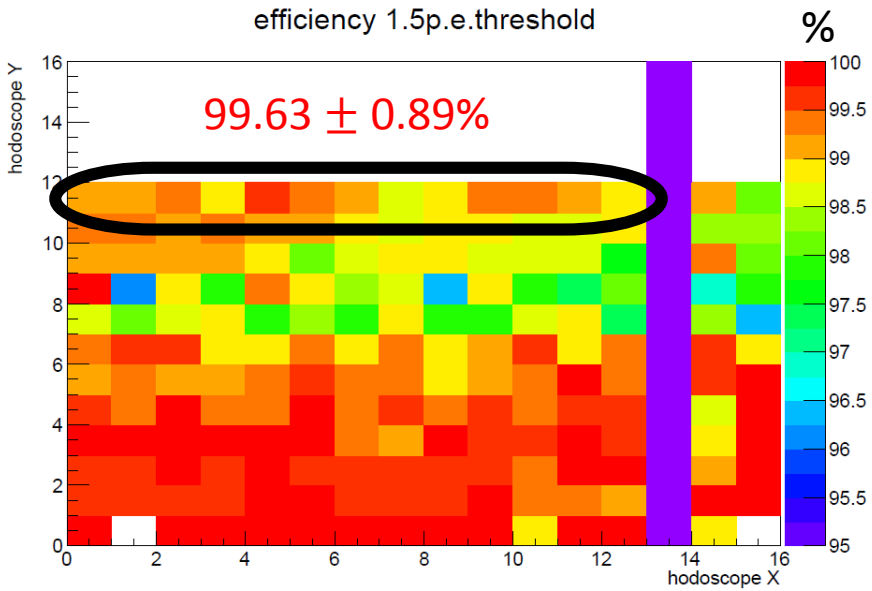
* ch # is 5 in vertical, 1~14 in horizontal

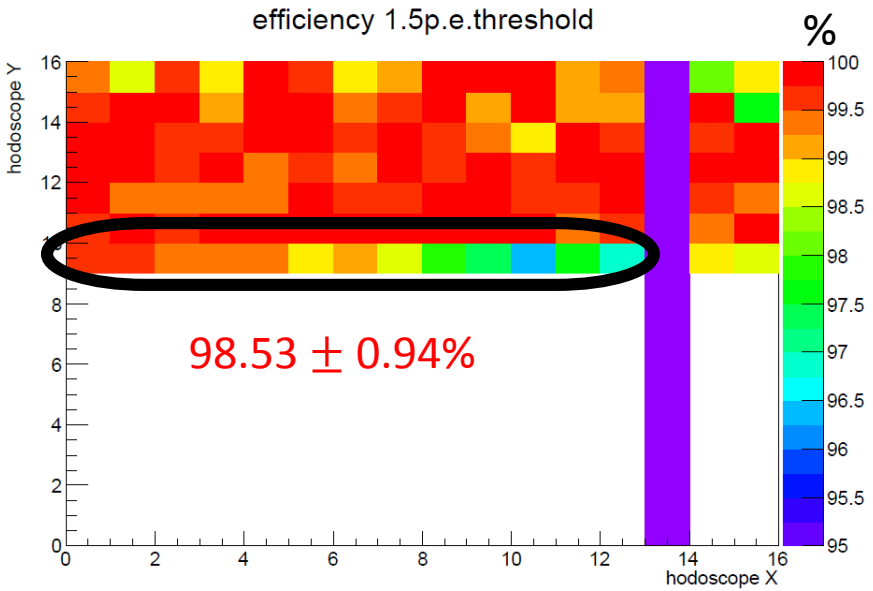
Scintillator **without slits**









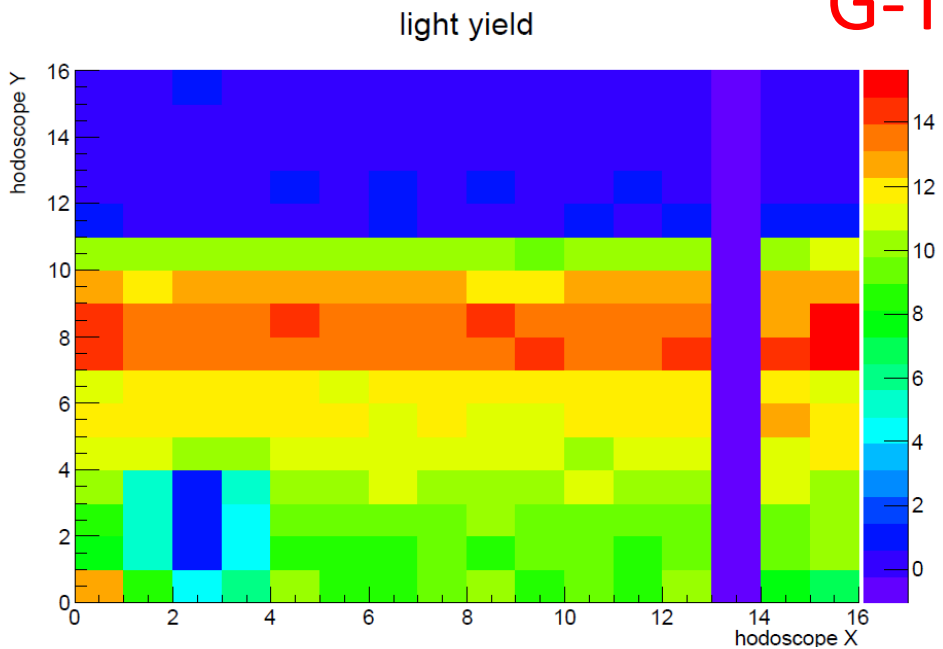


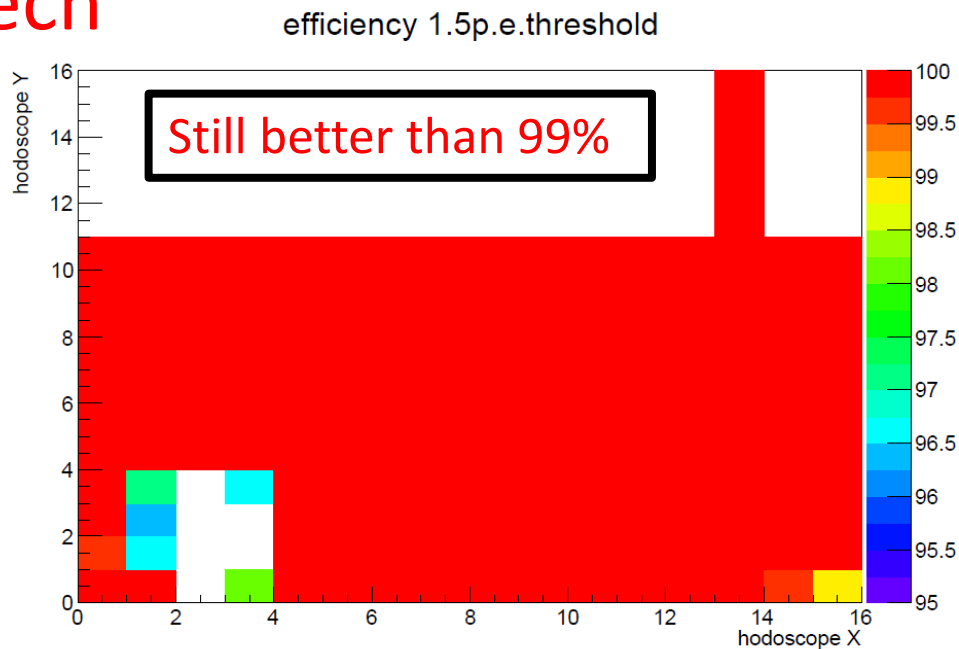
Calculation for 120cm fiber length

- Light yield and efficiency are calculated for **120cm** fiber case.
  (*__60cm__ fiber is used for this beam test.)
- The attenuation length is here **1.97m***.
  *The definition of this length will be explained later.
  *3.5m is reported by Kuraray.
- Efficiency is re-calculated by using light yield with 1.2m fiber.

$$\textbf{(LightYield)}|_{x=1.2} = \textbf{(LightYield)}|_{x=0.6} * \exp(-0.6 / 1.97)$$

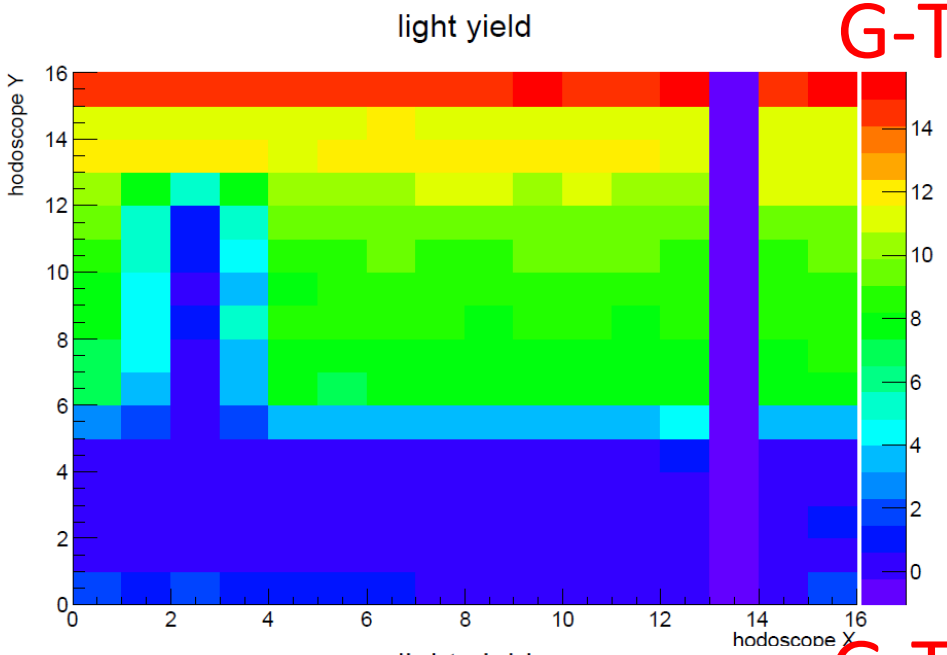
G-Tech

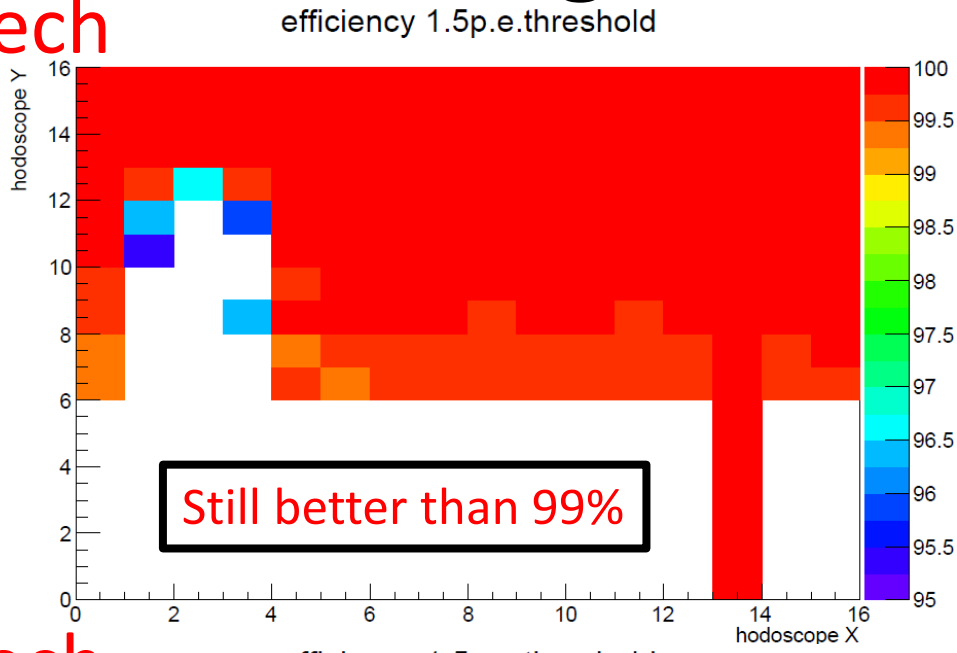




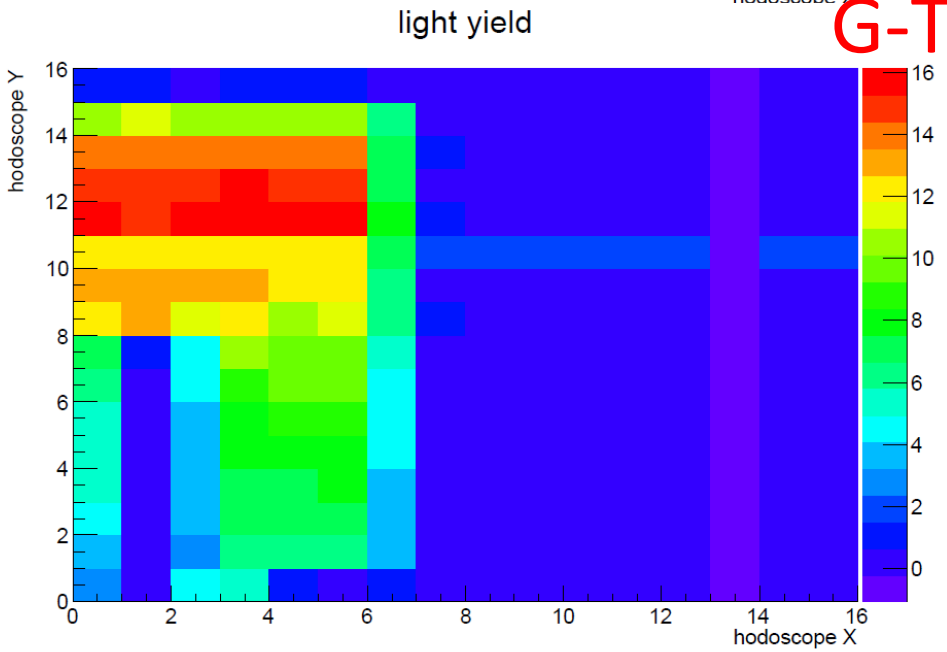
Calculation for 120cm fiber length

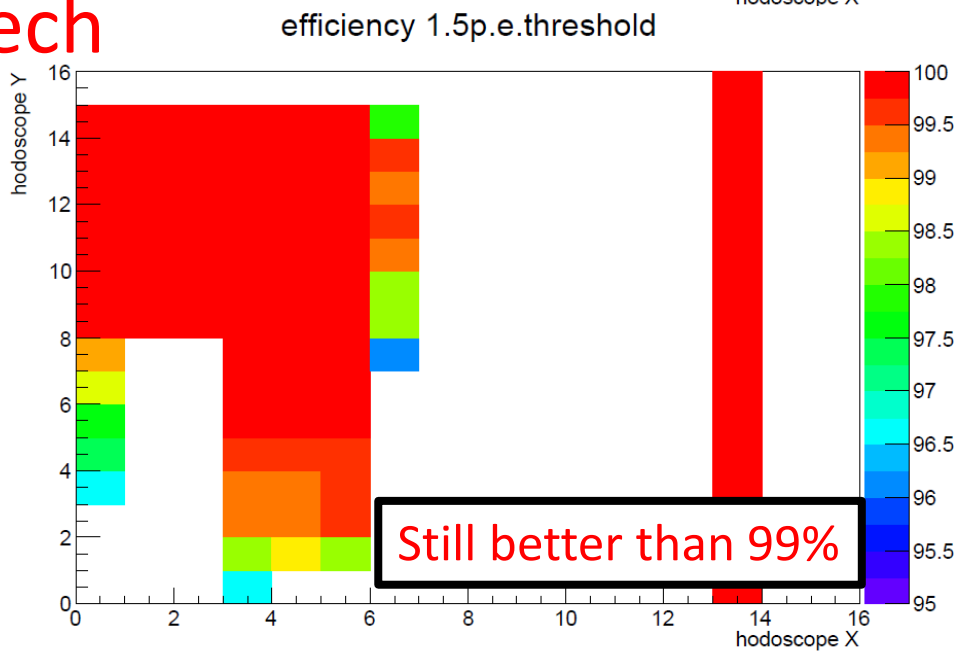
G-Tech





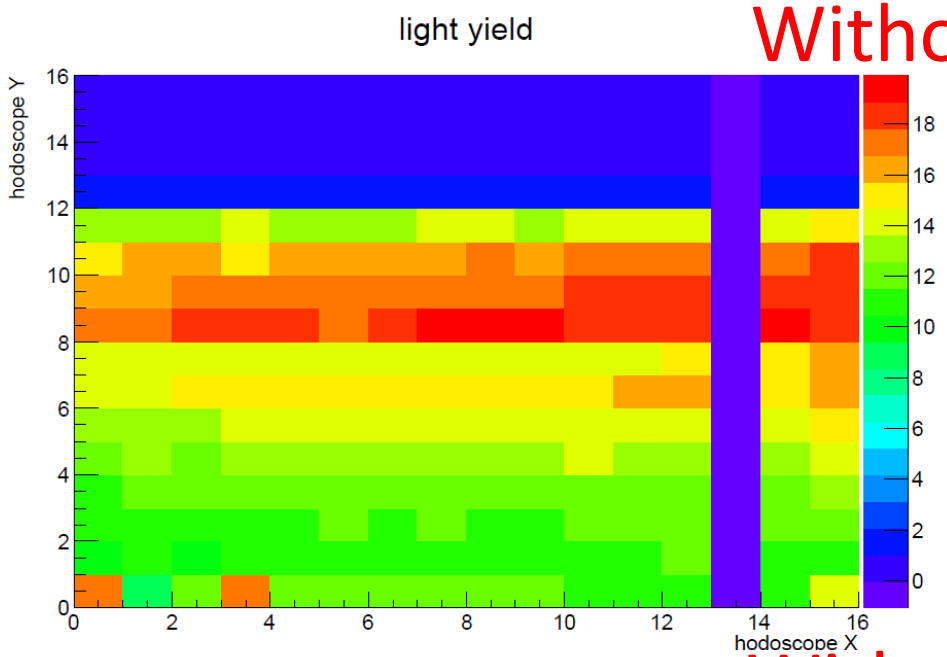
G-Tech

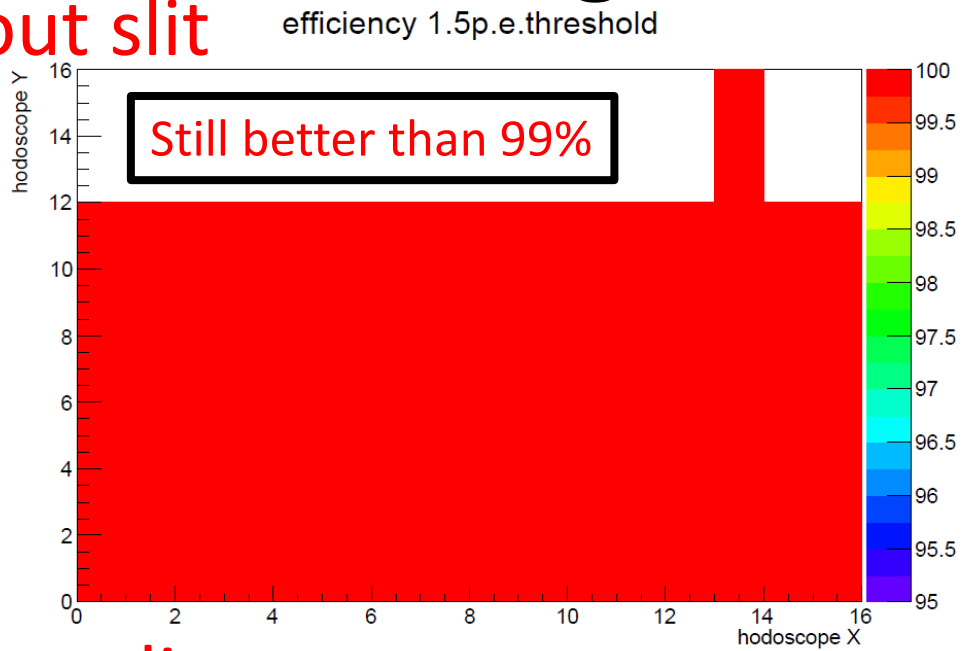




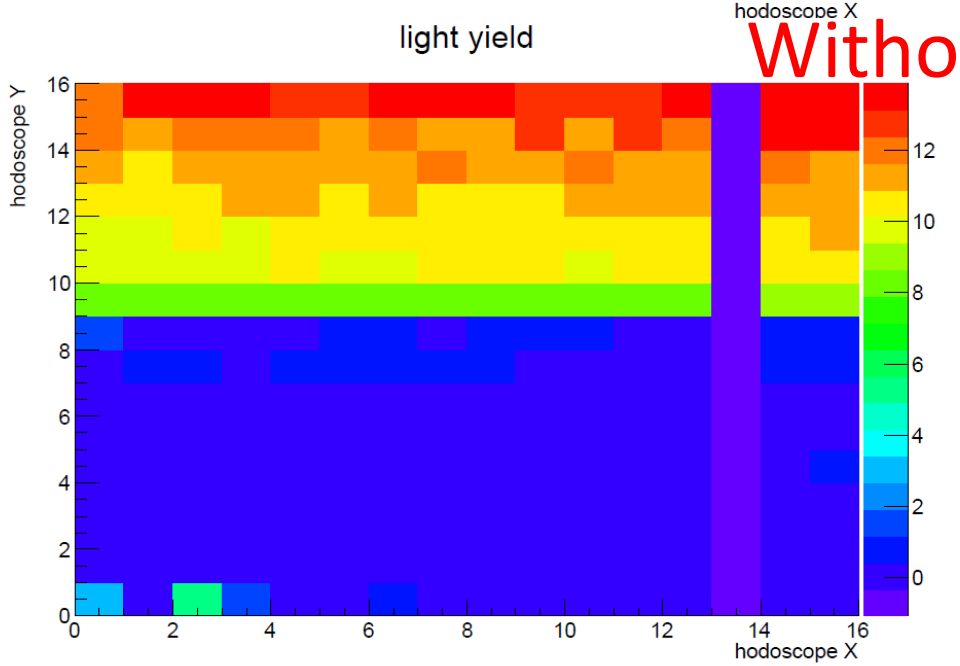
Calculation for 120cm fiber length

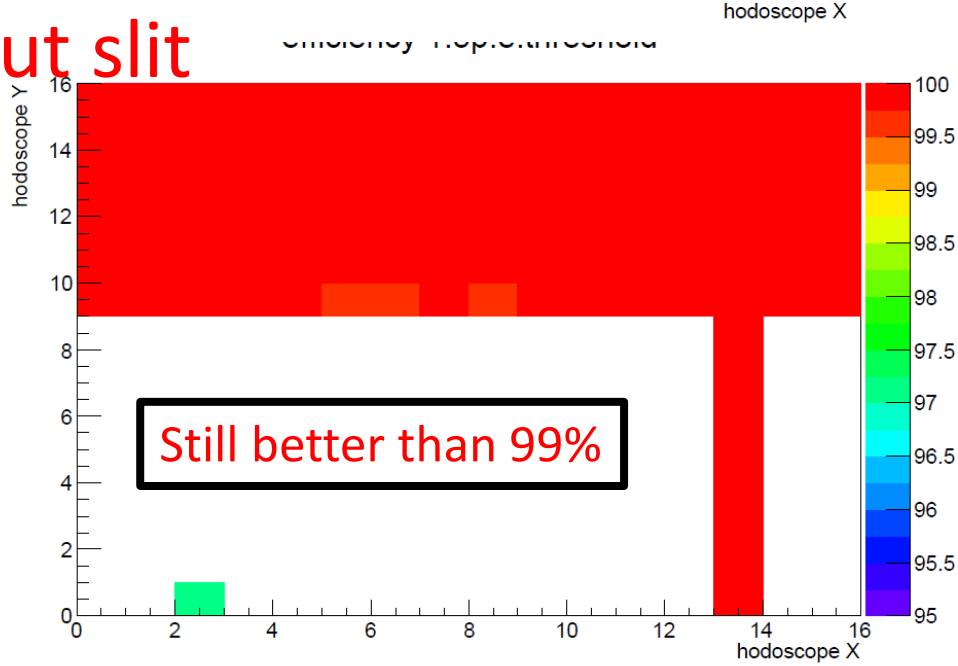
Without slit





Without slit

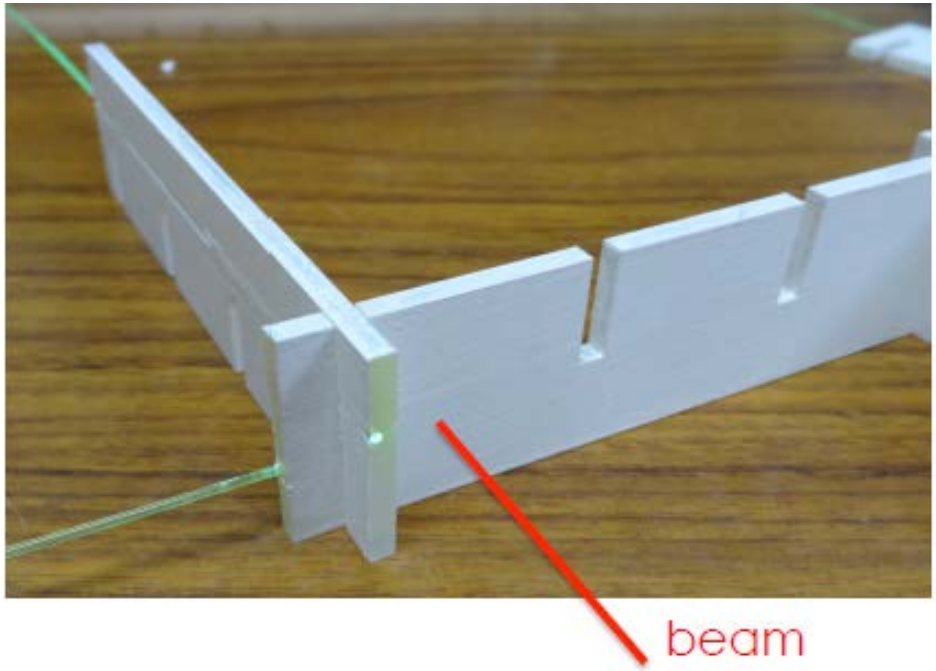


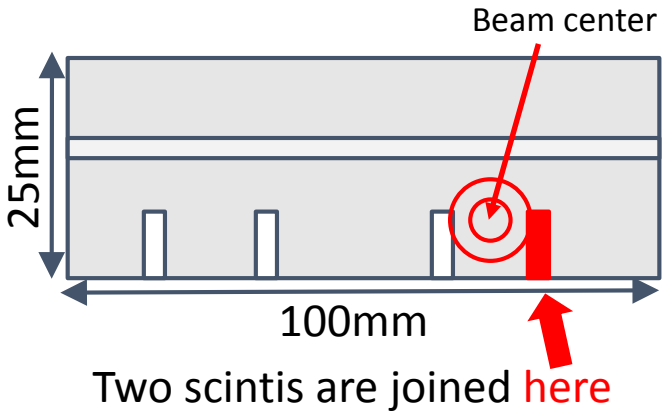


Cross Talk Measurement

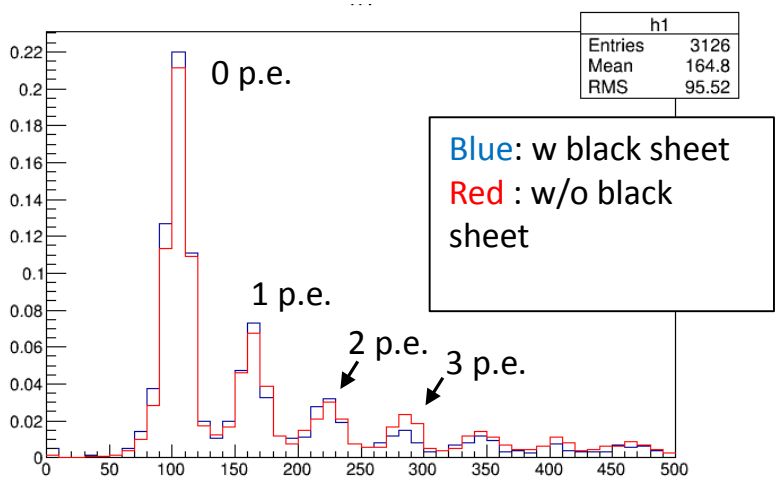
We measured two differenet setup:

1. Black sheet is put between two scintillators as optical cut.
2. Black sheet is removed.

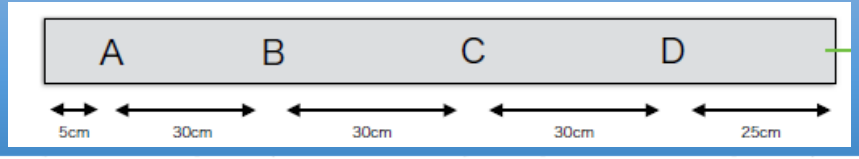


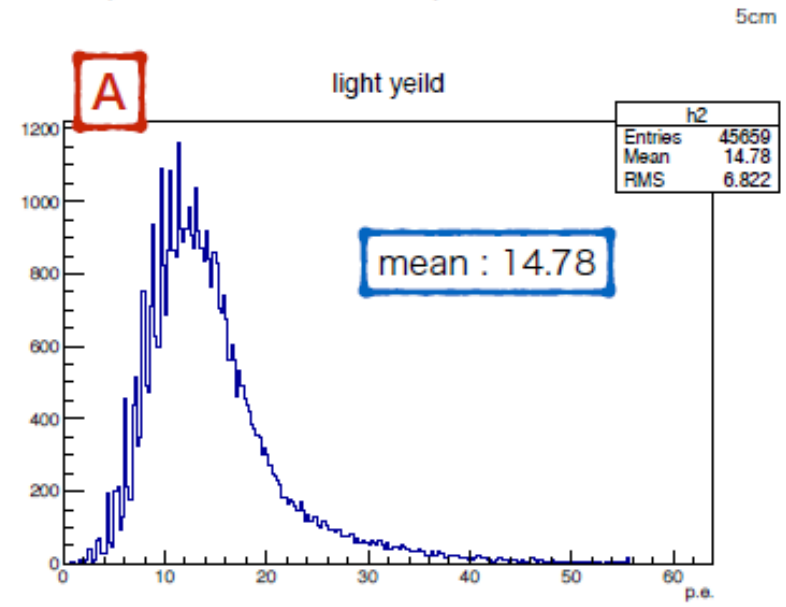


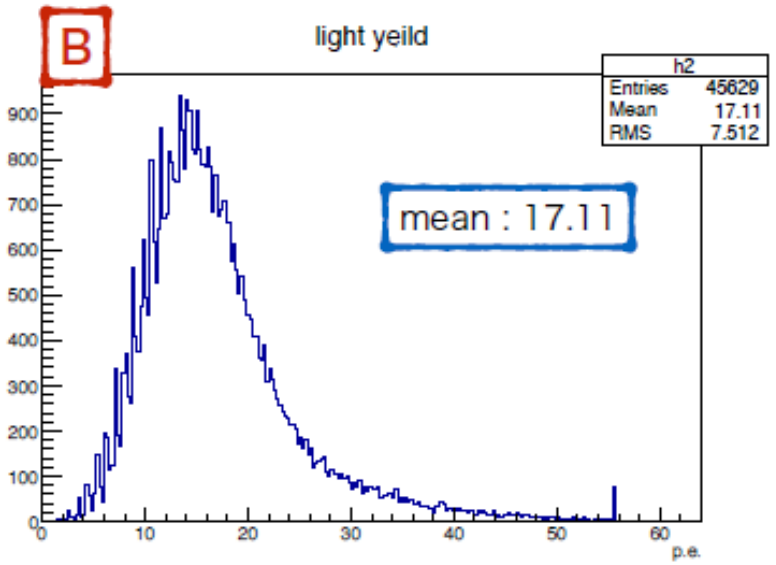
Two scintis are joined here

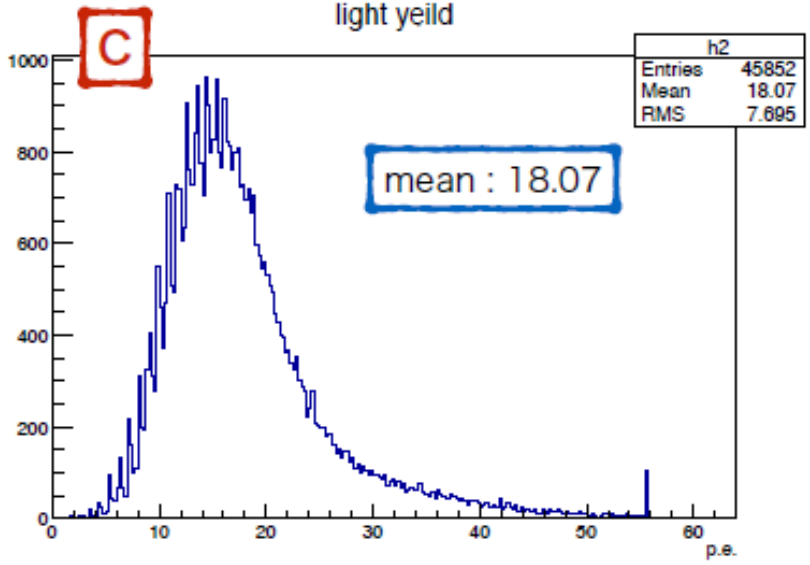


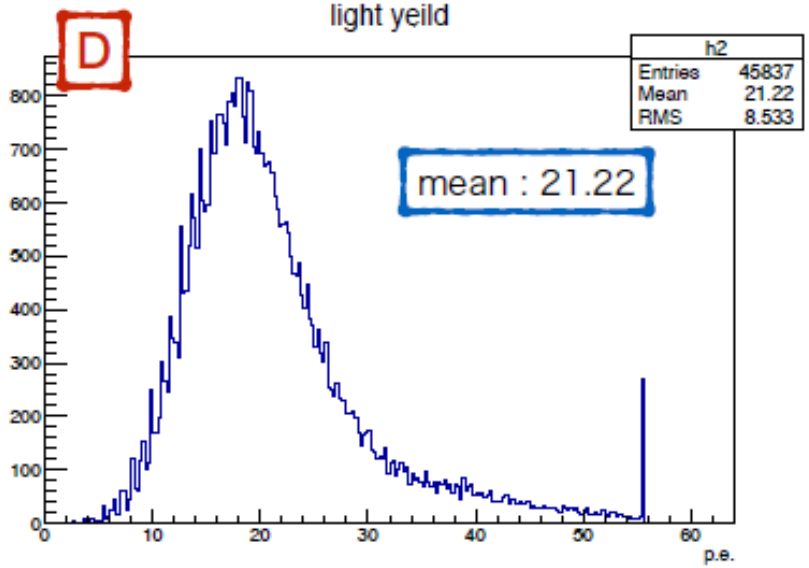
Light yield


A
B
C
D
5cm
30cm
30cm
30cm
25cm

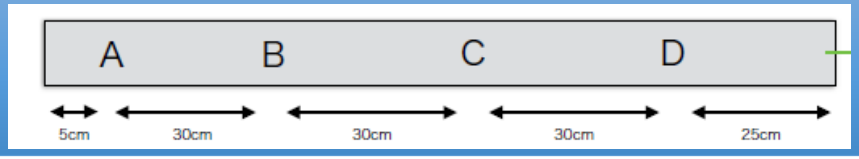

A
light yeild
h2
Entries 45659
Mean 14.78
RMS 6.822
mean : 14.78
p.e.

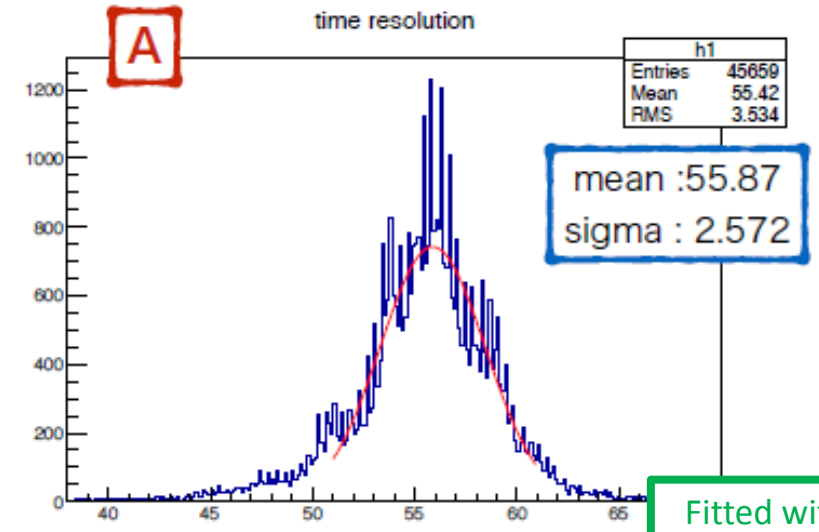

B
light yeild
h2
Entries 45629
Mean 17.11
RMS 7.512
mean : 17.11
p.e.

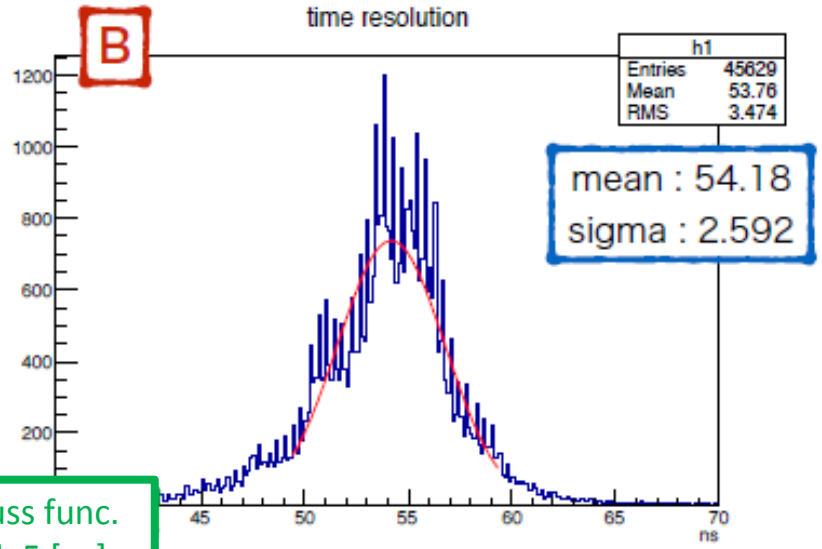

C
light yeild
h2
Entries 45852
Mean 18.07
RMS 7.695
mean : 18.07
p.e.


D
light yeild
h2
Entries 45837
Mean 21.22
RMS 8.533
mean : 21.22
p.e.

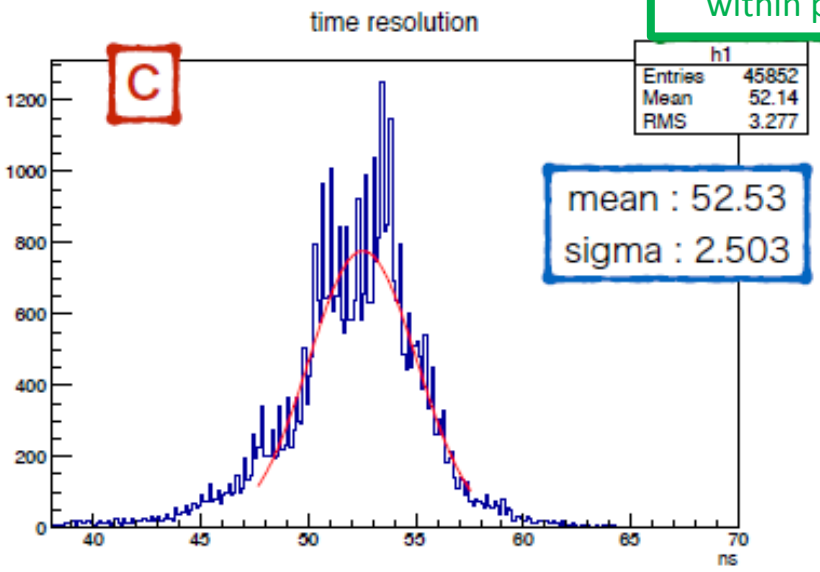
Time Resolution

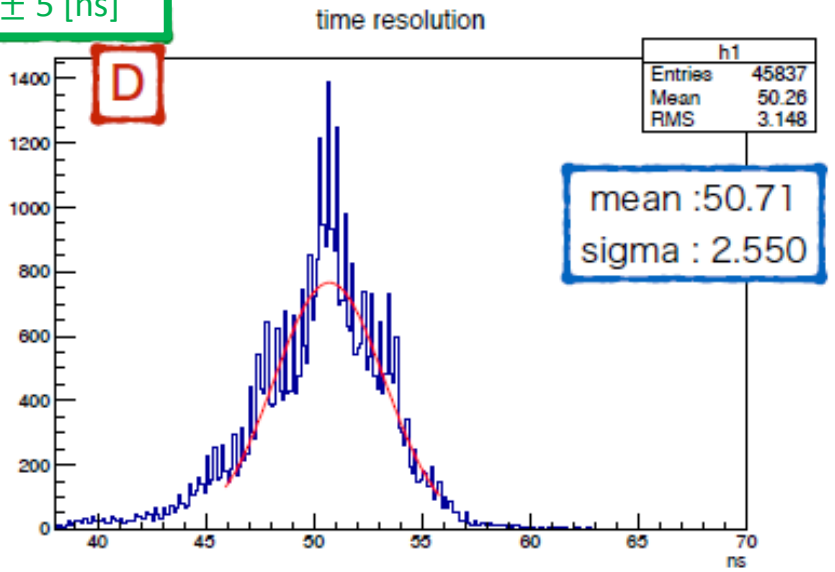






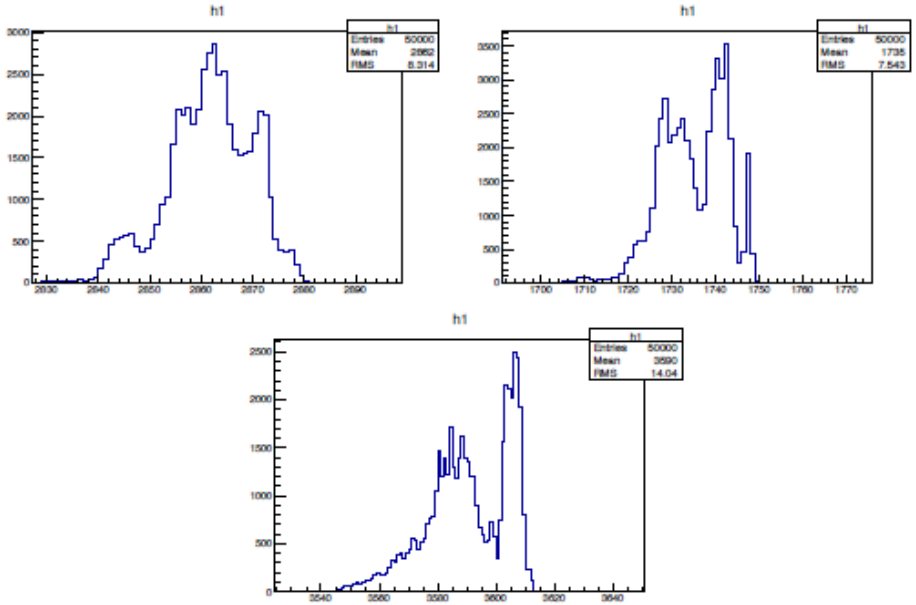
Fitted with gauss func.
within peak $\pm$ 5 [ns]

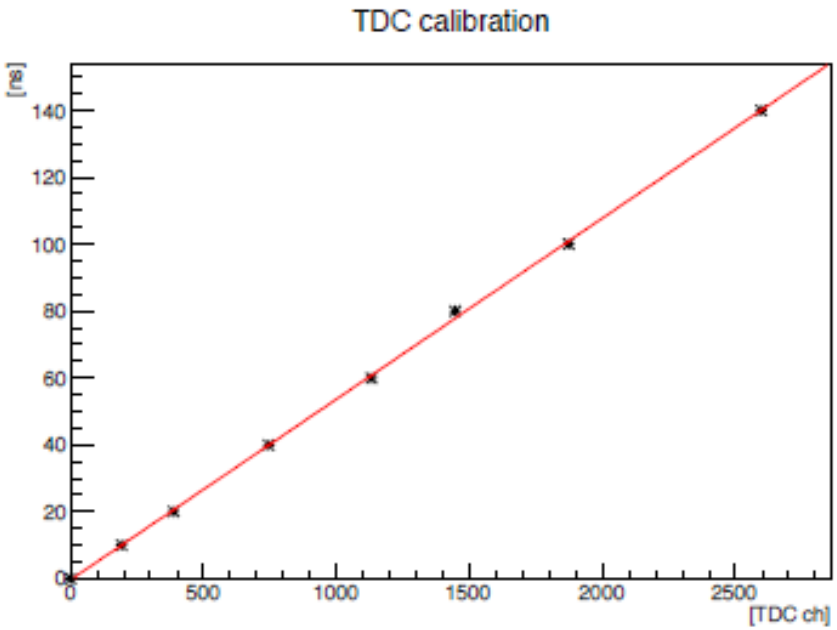




TDC calibration (measured@Kyoto U.)

- Signal from clock generator is delayed and measured by TDC.
- The time difference is checked by oscilloscope.





Several peaks appeared(with 50sec data). *cause unknown.

↓

- This might be the cause of peak ugliness at beam test.
- Fitted data in all.

Fitted results shows:

1 [TDC ch] = 54.05 [pc]

pedestal = 6.27 [TDC ch]