2014.05.08-09

Development of AC2 for E36 experiment /TREK J-PARC

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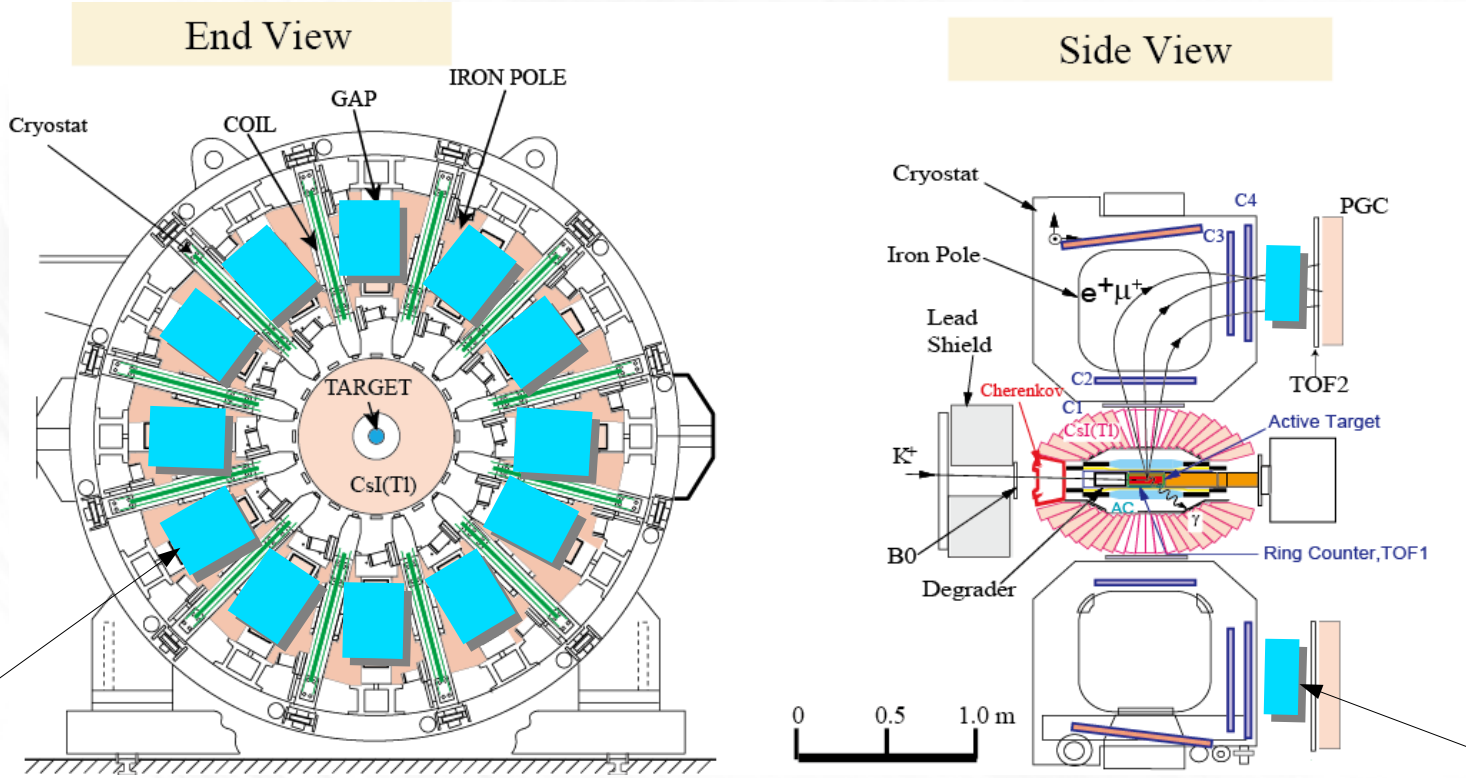
Specification of AC2 Requiring for E36



e^+/μ^+ identification

Effective area	: 20 x 20 [cm^2]
Efficiency	:>90%
Mis-id	:<5%
Censor	:12
Cost	:low

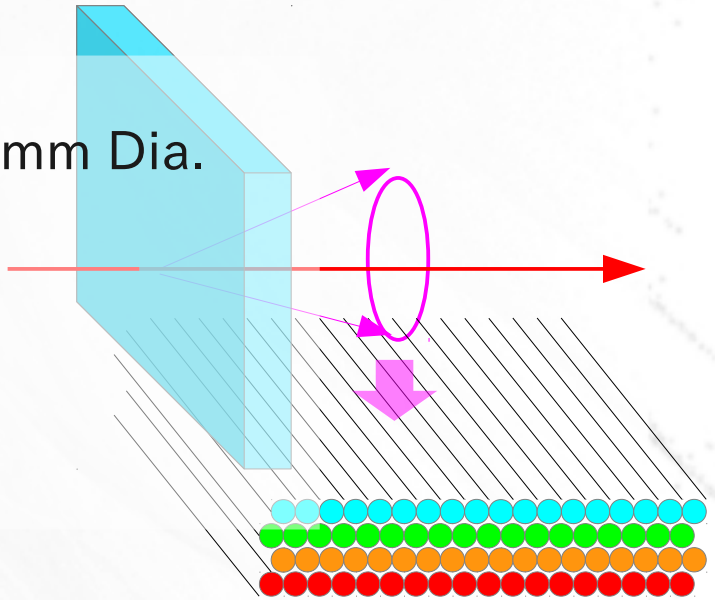
Aerogel

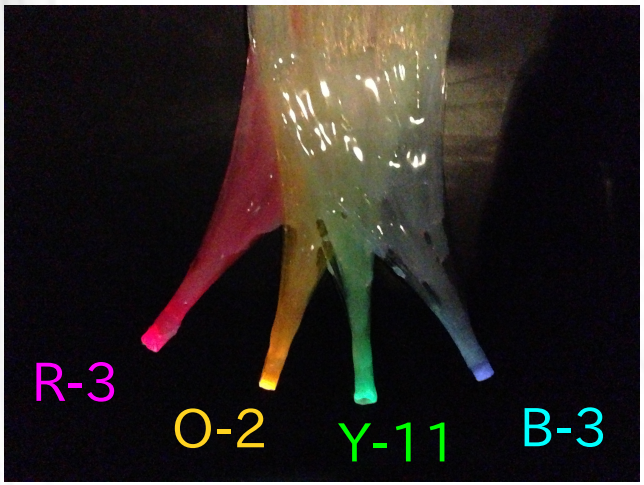
Index	: ～1.08
Thickness	:6 cm
WLSF	:4 kind Fibers
Photo Detect.	:MPPC

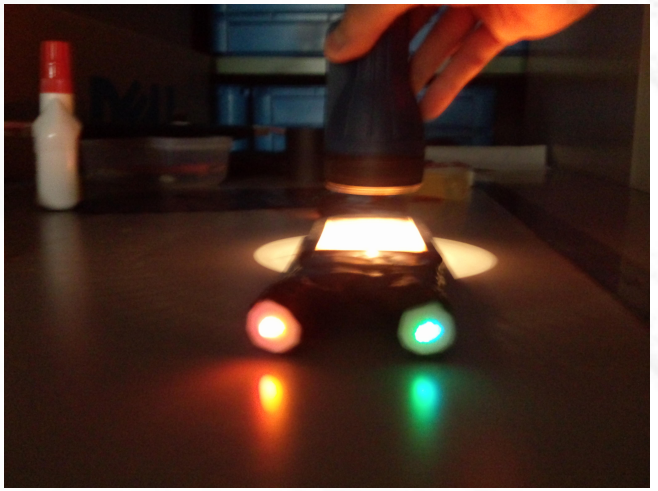
WLSF Light Guide

WLSF @Kuraray Co. Ltd.
(B-3, Y-11, O-2, R-3), double Cladding, 0.2 mm Dia.

Fiber Light Guide @ Chiba Univ.
Effective area : 10 x 20 cm^2 (x4)
Cross section : 175 mm^2
○ 15 mm Dia.
□ 14mm







Primary test of prototype

～Property of Prototype～

Effective area … 6 cm x 10 cm
(12 cm x 10 cm)
Cross section … ○8 mm Dia. (x4)
PMT … R9880U-210, -20
*see the data sheet after back up

1. Cosmic ray test

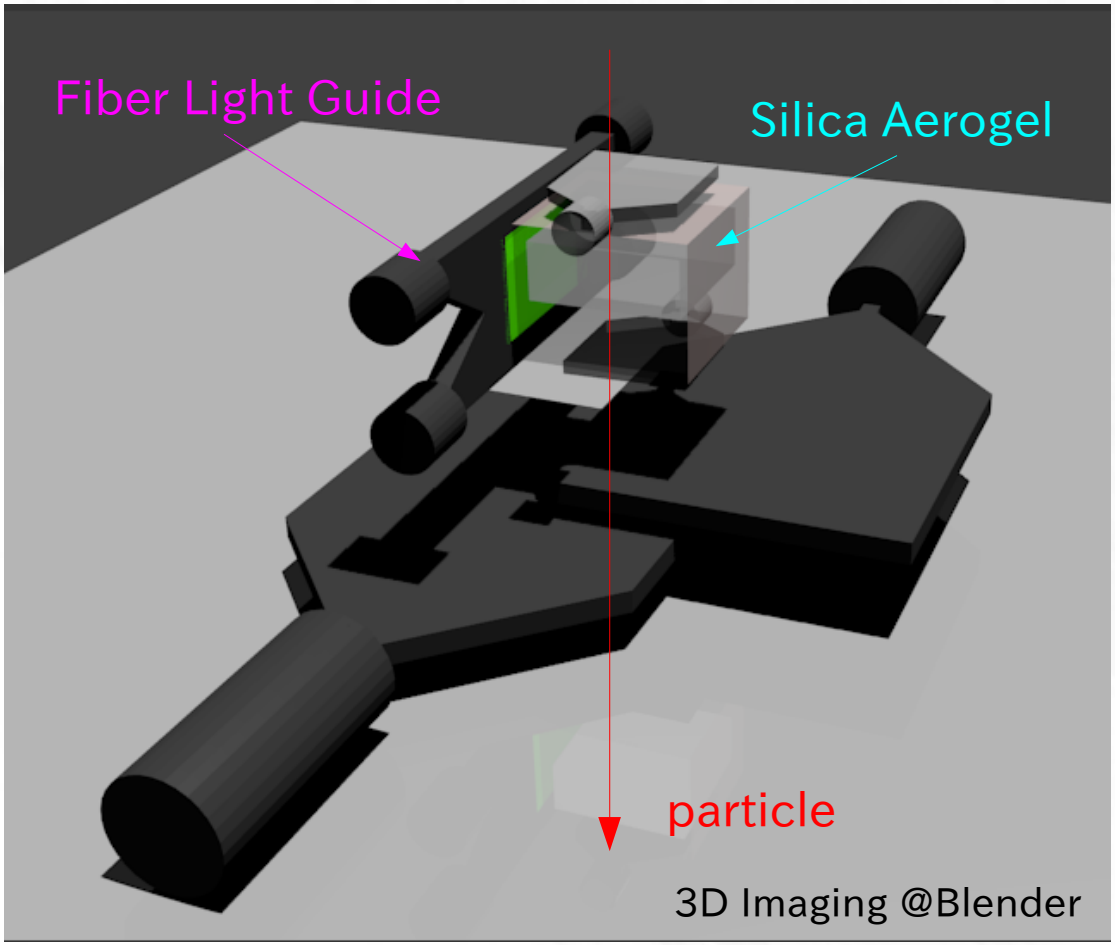
We have measured collection efficiency of fiber light guide for Cherenkov light, detection efficiency for thickness of aerogel and aptitude of WLSF kinds.

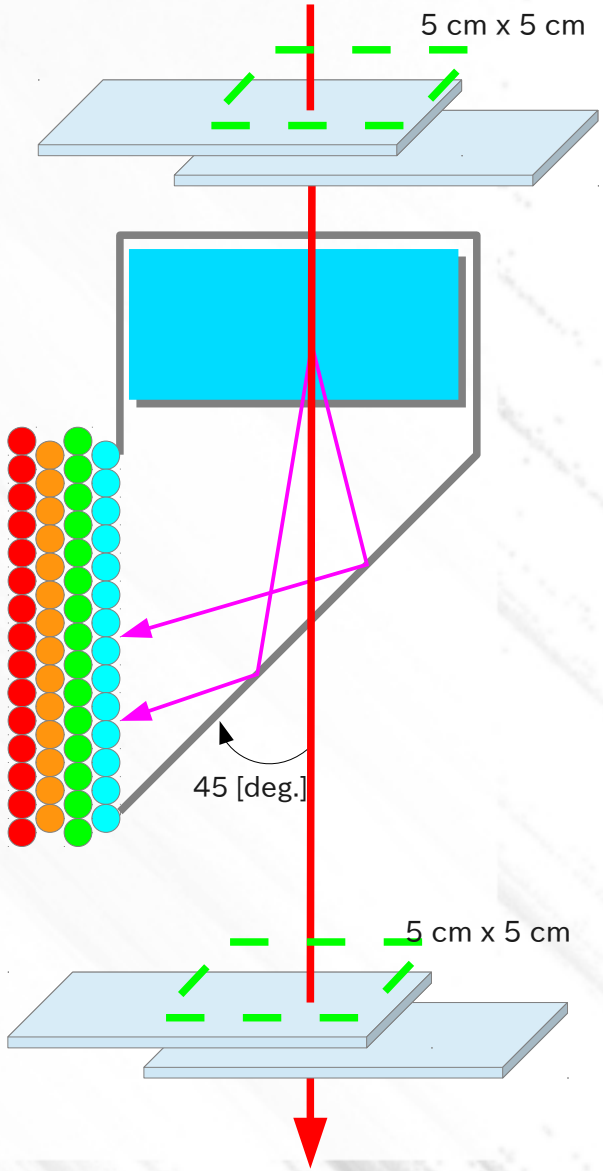
2. Beam test @Tohoku

In addition to the above, we have Measured detection efficiency by position dependence, fiber hit event, Comparison with the measurement using cosmic ray and difference of index of aerogel: 1.03, 1.05 and 1.08.

Primary test of fiber light guide

1. Cosmic ray test

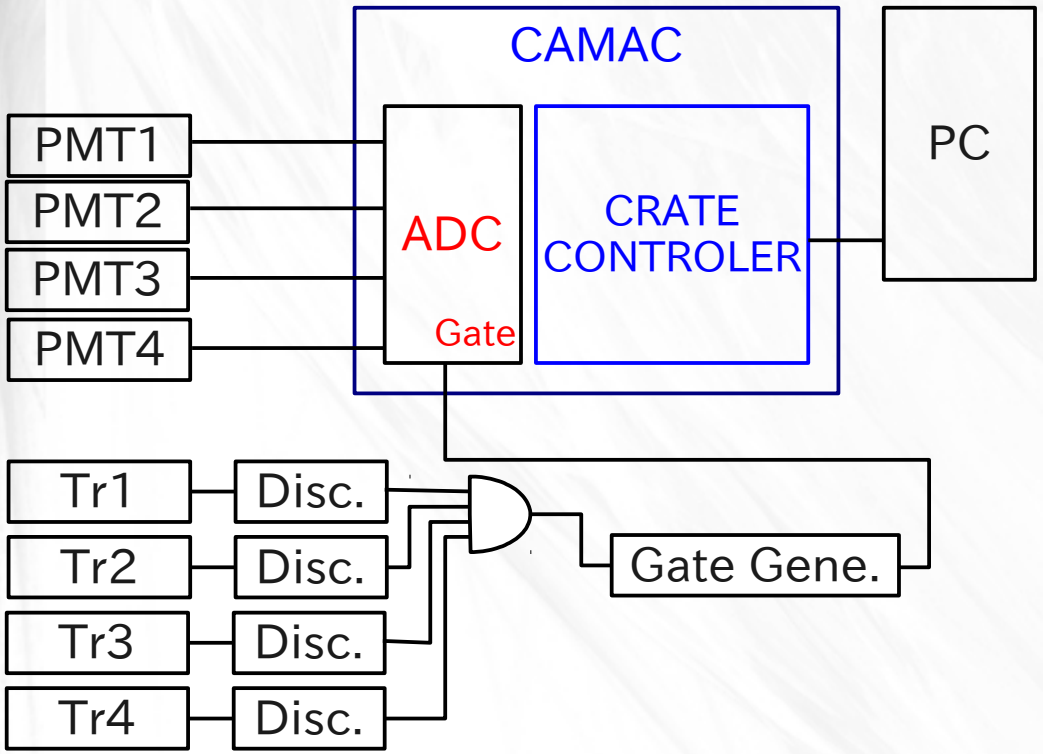


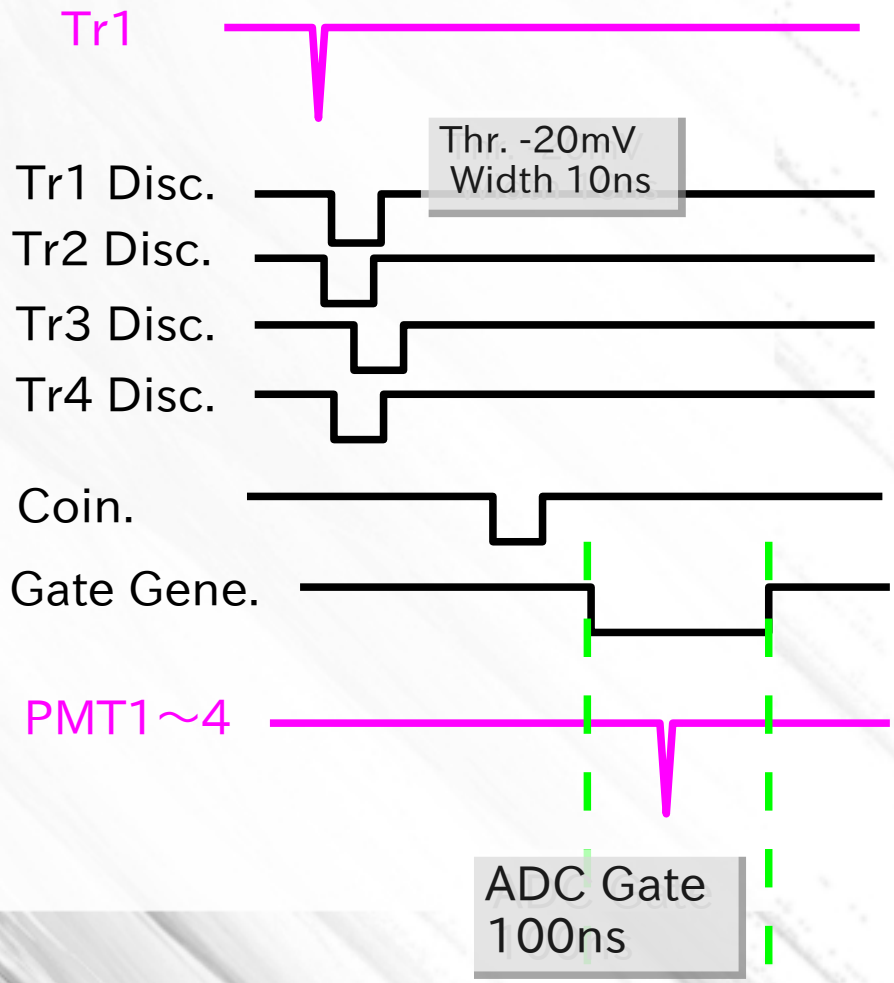


Primary test of fiber light guide

1. Cosmic ray test

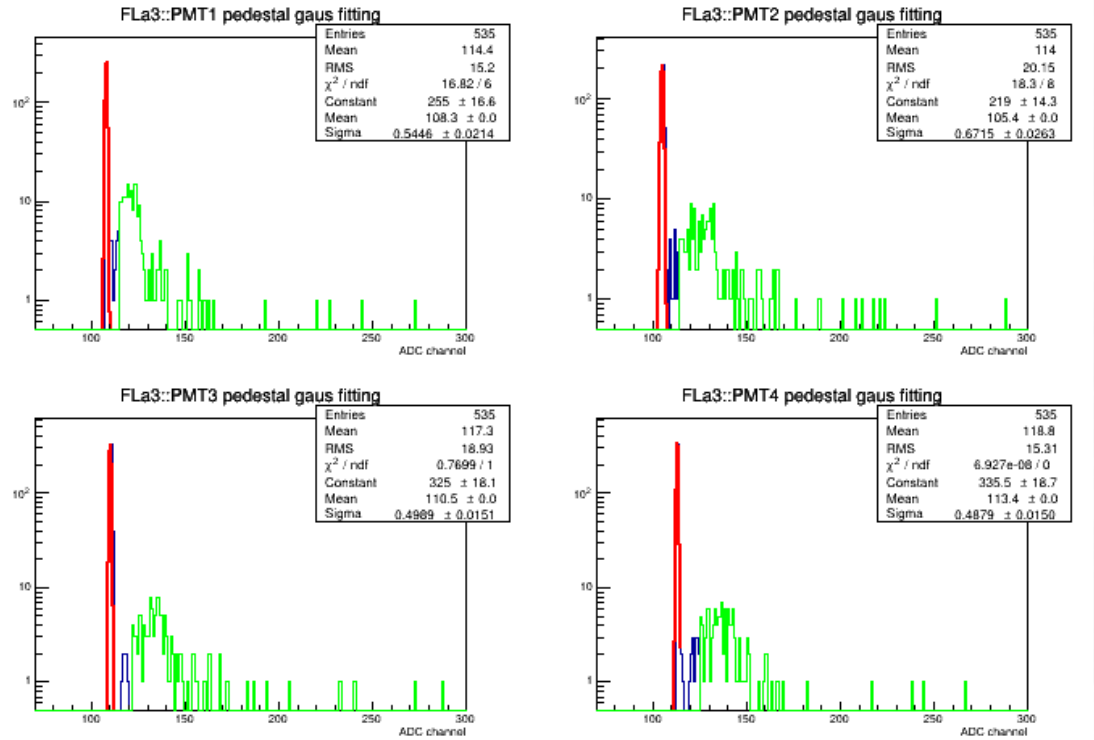
DAQ System





Primary test of fiber light guide

1. Cosmic ray test



		PMT1	PMT2	PMT3	PMT4	Logic
Gain		1.80E+07	2.57E+07	3.55E+07	3.41E+07	OR
0.5p.e.thr.	**eff**	**0.318**	**0.284**	**0.217**	**0.194**	**0.626**
	error	0.014	0.012	0.009	0.008	0.027
	p.e.	**0.38**	**0.33**	**0.24**	**0.22**	**0.984**
	error[p.e.]	0.02	0.02	0.01	0.01	0.072
Ped 3σ thr.eff	**eff**	**0.348**	**0.310**	**0.228**	**0.222**	**0.658**
	error	0.015	0.013	0.010	0.010	0.028
	p.e.	**0.43**	**0.37**	**0.26**	**0.25**	**1.073**
	error[p.e.]	0.02	0.02	0.01	0.01	0.083

Detection efficiency is decided from the ADC distribution of the PMT respectively. Gaussian fits to the pedestal (red line). Detection event is defined as an event has photoelectrons more than 0.5 p.e. threshold (green).

Mean number of photoelectrons was calculation to approximation of Poisson distribution with detection efficiency.

We analyzed the detection efficiency of M-ACC by all of the PMT connected the fiber light guide. It is a combination of the "or" logic:

1ch ∪ 2ch ∪ 3ch ∪ 4ch,

of the detection event of each the PMT.

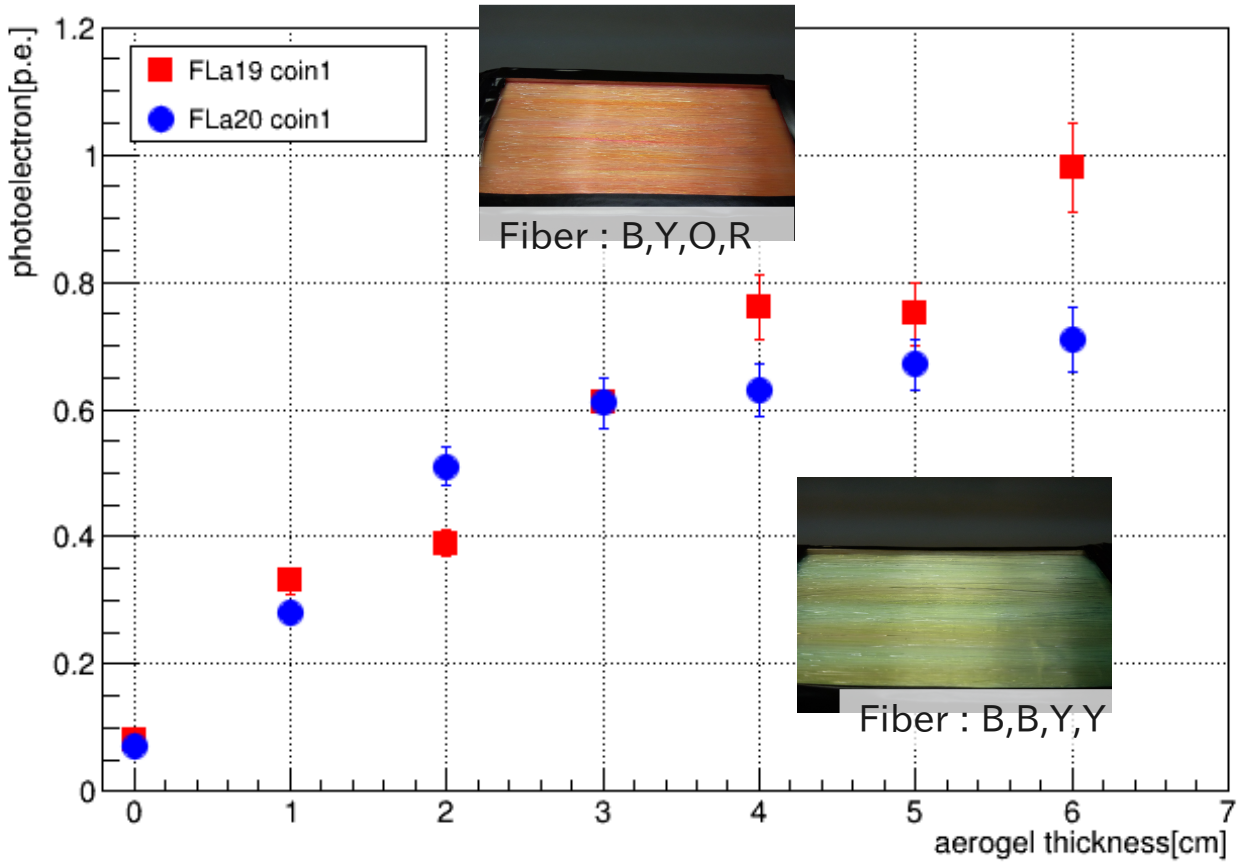
$$N_{p.e.} \cong -\ln(1 - efficiency)$$

Primary test of fiber light guide

1. Cosmic ray test

Result

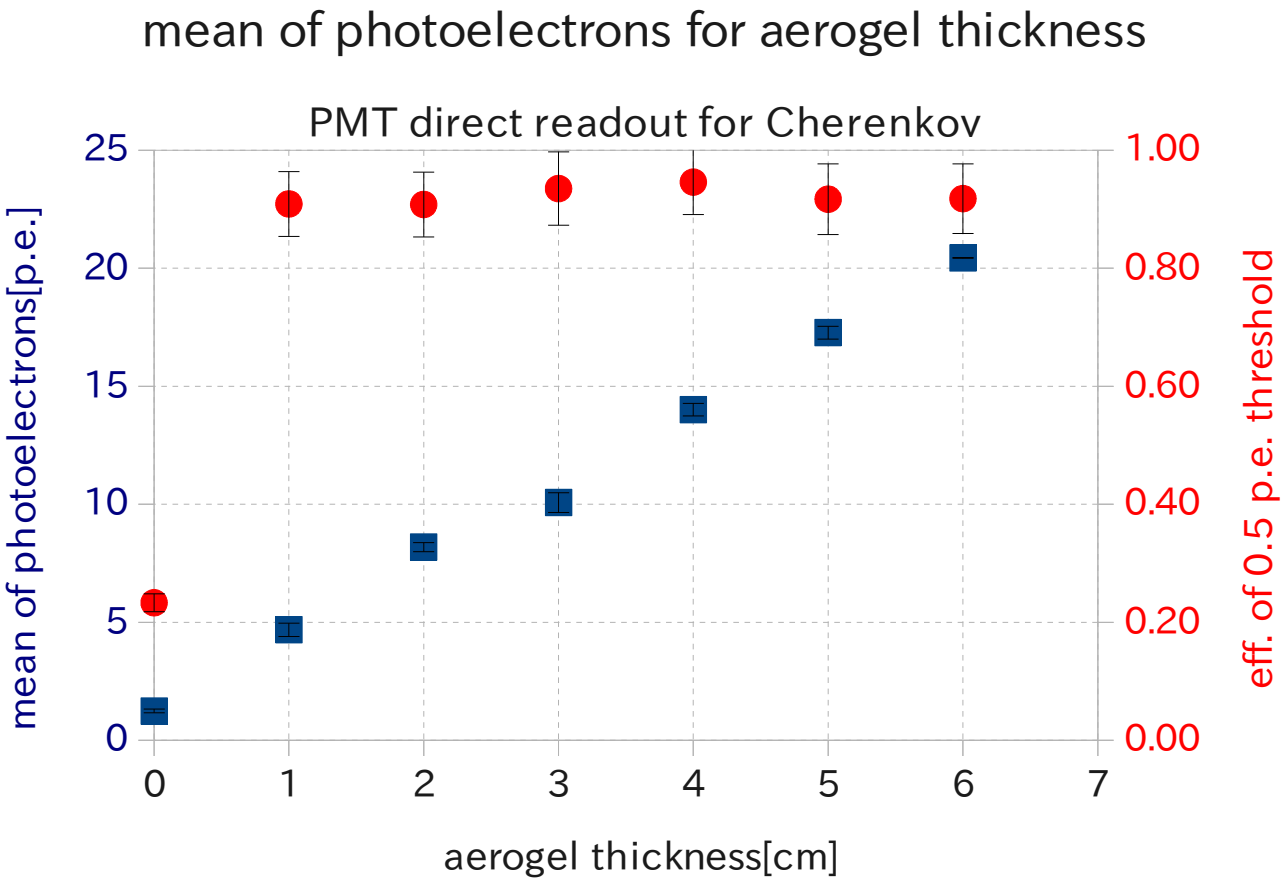
Photoelectrons of aerogel thickness (n=1.05)



Primary test of fiber light guide

1. Cosmic ray test

PMT direct reading Cherenkov light



Primary test of fiber light guide

1. Cosmic ray test

summary

4 PMTs have read a Cherenkov light through WLSF. Photoelectrons have been estimated “or” logic of PMT's detection. Cosmic ray tests were obtained the following results.

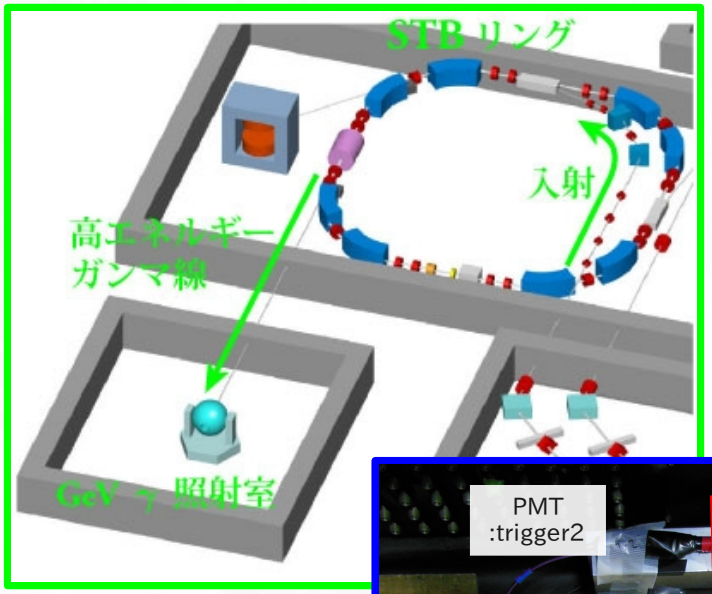
- WLSF Ligth guide kinds *BYOR* $\gtrsim$ *BBYY*
- Number of photoelectrons ~1 *p.e. (n=1.05, 6 cm)*
- Collection efficiency ~5%

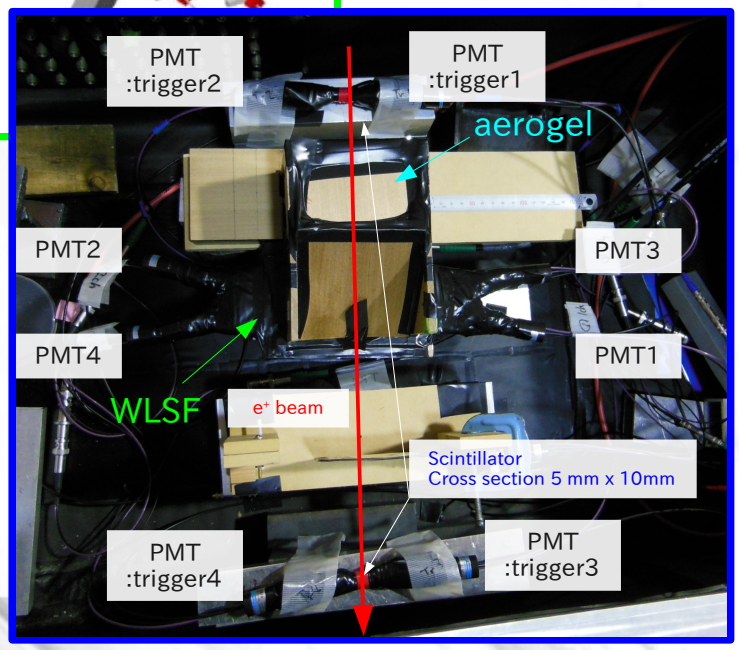
Comparison with reading direct PMT : 1 p.e./20 p.e.

In the test, it was found a rough performance of prototype and evaluation method has been established.

Primary test of fiber light guide

2. Beam test @Tohoku





Primary test of fiber light guide

2. Beam test @Tohoku

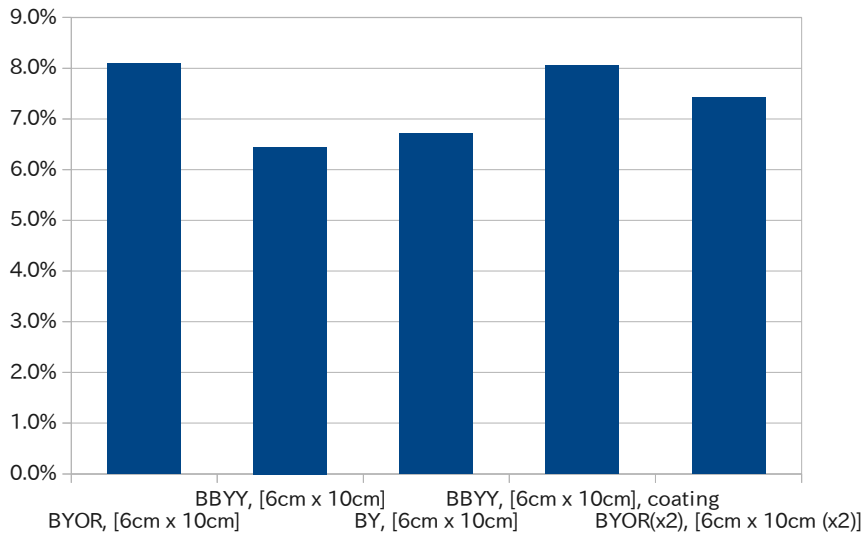
Measurement items

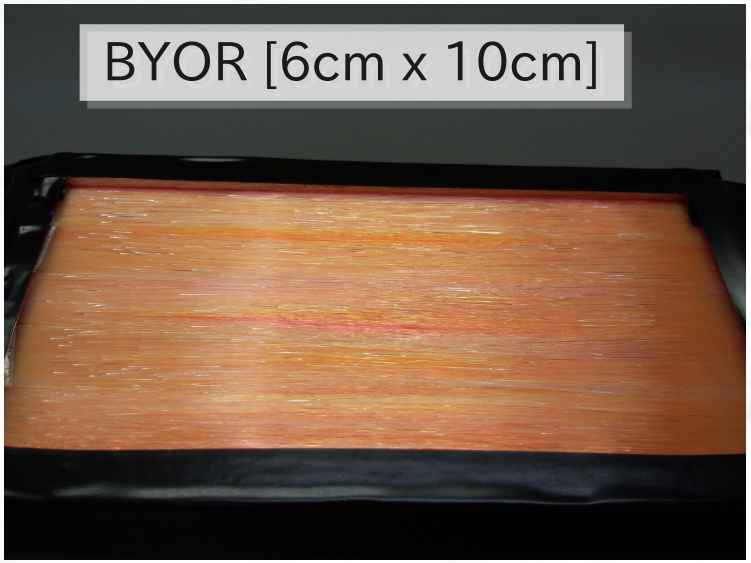
- Collection efficiency of fiber light guide
  ⋯ Comparison with reading direct large PMT(5 inch)
- Number of photoelectrons with thickness of the aerogel
- Number of photoelectrons with refractive index of the aerogel
- Position dependence of incident e^+ beam
- Position dependence of incident e^+ beam for 2 face light guide type

Collection efficiency of fiber light guide

Comparison with reading direct large PMT(5 inch)

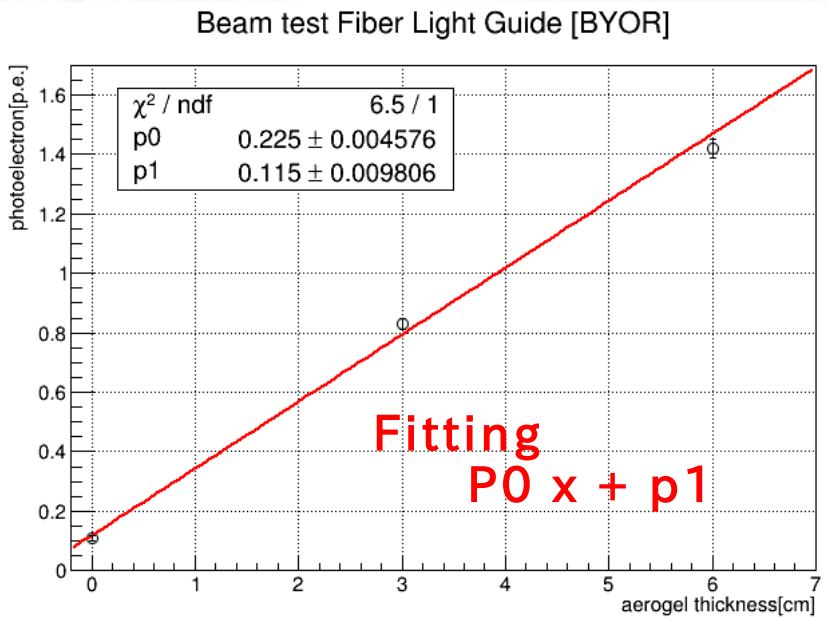
Reading Cherekov	Aerogel	eff	error	p.e.	error	coll. Eff.
BYOR, [6cm x 10cm]	6cm, (1.05)	0.76	0.02	**1.43**	0.03	**8.1%**
BBYY, [6cm x 10cm]	6cm, (1.05)	0.68	0.02	**1.14**	0.03	**6.4%**
BY, [6cm x 10cm]	6cm, (1.05)	0.70	0.02	**1.19**	0.03	**6.7%**
BBYY, [6cm x 10cm], coating	6cm, (1.05)	0.76	0.02	**1.42**	0.03	**8.0%**
BYOR(x2), [6cm x 10cm (x2)]	6cm, (1.05)	0.73	0.01	**1.31**	0.03	**7.4%**
PMT direct	6cm, (1.05)	1.00	0.00	**17.71**	0.06	





Number of photoelectrons with thickness and refractive index of the aerogel

Incident beam position	aerogel	eff	error	p.e.	error
[BYOR], 6cm x 10cm	0	0.10	0.01	**0.11**	0.01
	3	0.56	0.01	**0.83**	0.02
	6	0.76	0.02	**1.42**	0.03



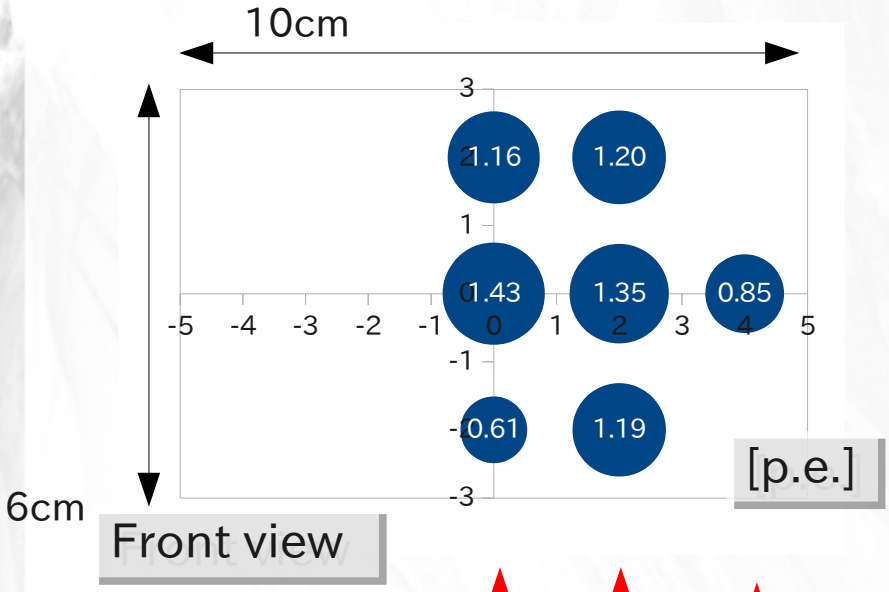
Estimate of umber of photoelectrons with the index

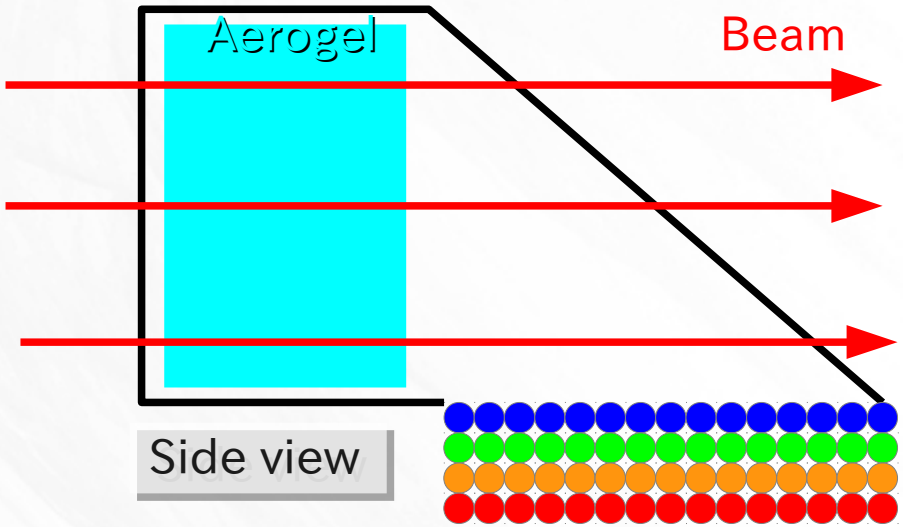
$$N_{p.e.} \propto 1 - \frac{1}{(n\beta)^2}$$

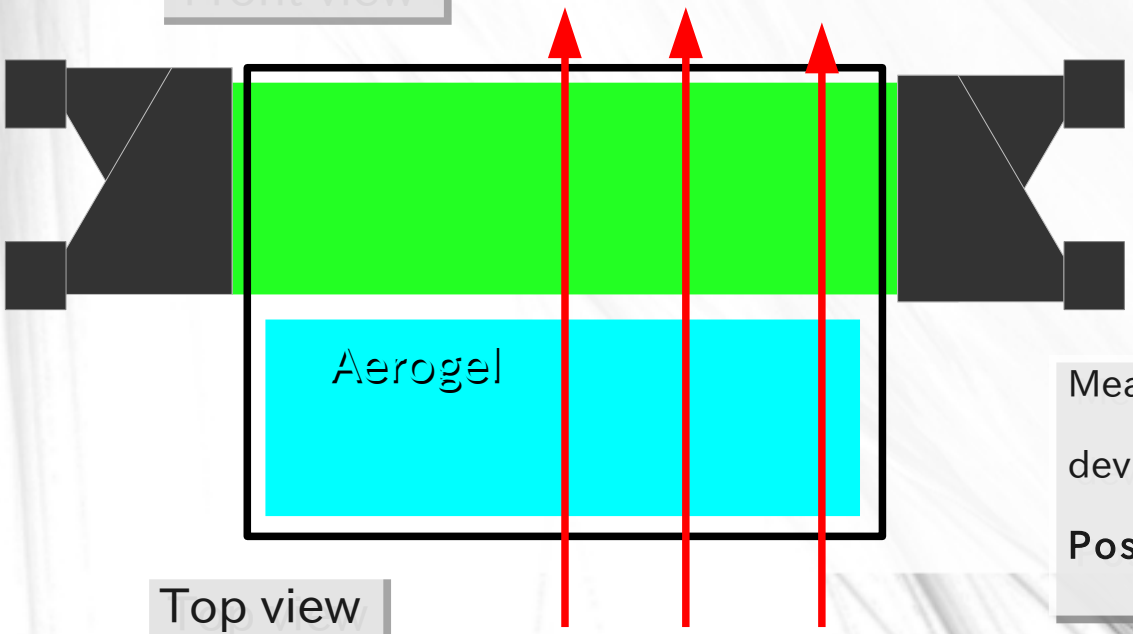
	1-(1/nβ)^2	rate of 1.05
1.03	0.0574	0.6
1.05	0.0929	1
1.08	0.1427	1.53

Incident beam position	aerogel	eff	error	p.e.	error	ratio of 1.05
[BYOR], 6cm x 10cm	1.03	0.39	0.01	**0.49**	0.01	0.6
	1.05	0.56	0.01	**0.83**	0.02	1.0
	1.08	0.64	0.01	**1.02**	0.02	1.2

Position dependence of incident e^+ beam

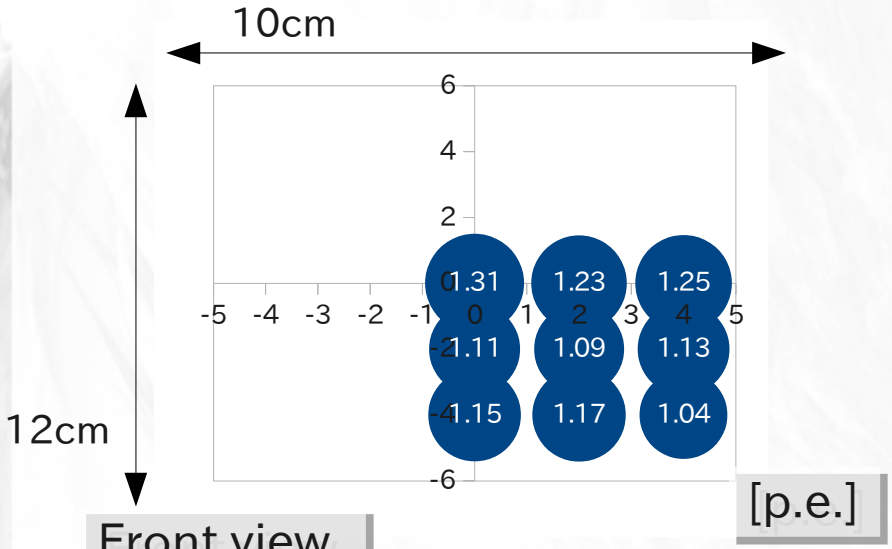


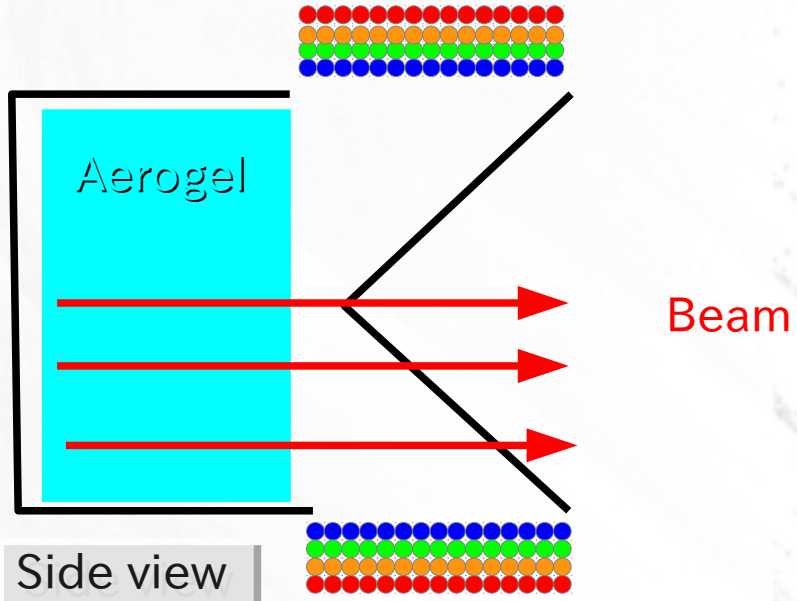


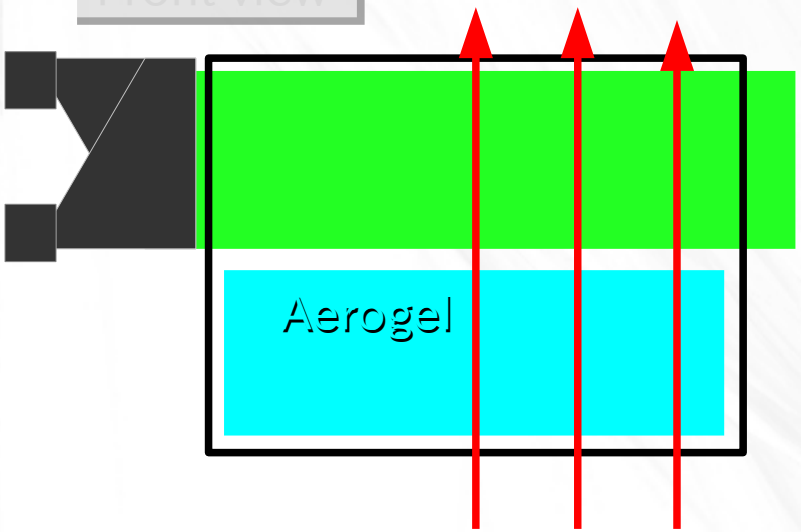


Mean of photoelectrons
1.11 p.e.
deviation
0.29 p.e.
Position dependence
～26%

Position dependence of incident e^+ beam for 2 face light guide type







Mean of photoelectrons
1.16 p.e.
deviation
0.09 p.e.
Position dependence
~7%

Primary test of fiber light guide

2. Beam test @Tohoku

performance of prototype

- Size of prototype : 12 x 10 cm^2
- Reading by WLSF & PMT
- Aerogel : index(1.05), thickness 6cm

WLSF coll. eff.	~ 8%
Detection eff.	~ 72%
Mean Photoelectrons	~ 1.3 p.e.
Position dependence	~ 7%

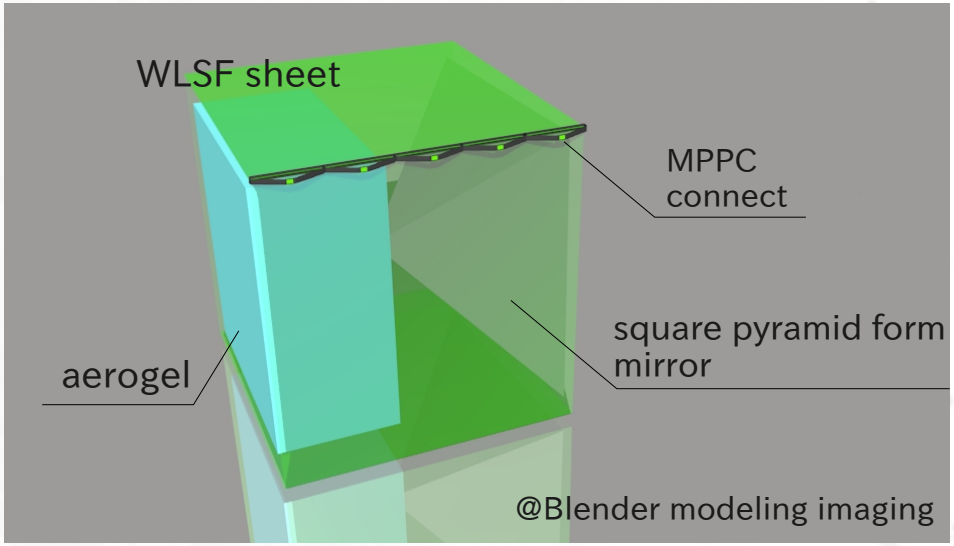
- Rate of index 1.08/1.05 = 1.2 times
- Timing resolution ~0.14 ns

Discussion

According to the primary test

Prototype :12 x 10 cm^2
Reading by WLSF & PMT
Aerogel : index(1.05), thickness 6cm
- WLSF coll. Eff. ～ 8%
- Position dependence ～ 7%
- Detection eff. ～ 72%
- Mean Photoelectrons ～ 1.3 p.e.

Rate of index 1.08/1.05 = 1.2 times

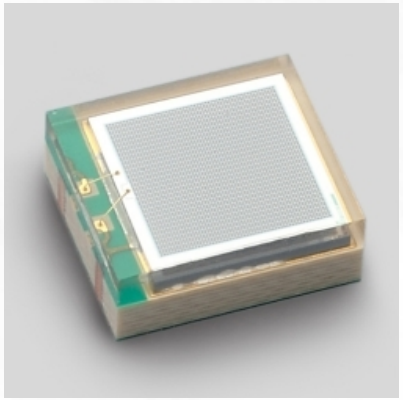


Development of AC2

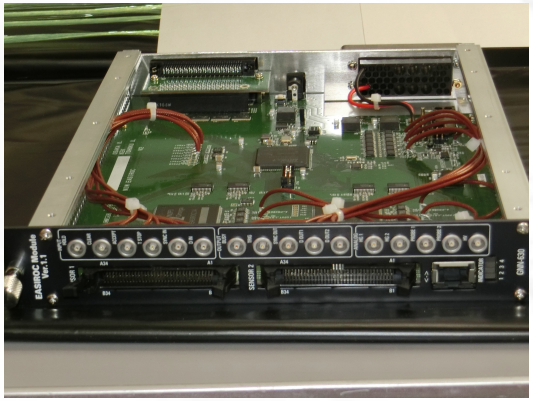
Aerogel (n=1.08) 20 x 20 x 4 cm^3
WLSF (2800 fibers)
- Sheet width : 14cm
- Cross section : 176mm^2

Reflector : square pyramid form
MPPC (6 x 6 mm^2) x5
- Reading by **EASIROC** module

Efficiency : ～90%
Number of photoelectrons : ～2 p.e.
*PMT → MPPC
position dependence : a few %



MPPC



EASIROC module

Discussion

plan1

Aerogel 20 x 20 x 4 (x12)	…	1000 k¥	Kakenhi
WLSF 2800 fibers (2m)			
Cross section : 176mm^2	…	400 k¥ (x4)	kakenhi of last year
MPPC (6 x 6 mm^2)	…	16 k¥ (x60)	
Module EASIROC(64ch)	…	400 k¥	Kakenhi
Total	…	**960 k¥**	

Plan2

Aerogel	…	1000 k¥	Kakenhi
WLSF 2800 fibers (2m)			
Cross section : 176mm^2	…	400 k¥ (x4)	kakenhi of last year
PMT (□18 mm)	…	120 k¥ (x24)	
Total	…	**3280 k¥**	

Plan3

Aerogel	…	1000 k¥	Kakenhi
5 inch large PMT	…	500 k¥ (x24)	
Total	…	**12000 k¥**	

Schedule

April

May

Finish

Prototype:6 x 10
n=1.05, PMT
Cosmic ray (Lab.)
Beam test (Tohoku)

Finish

12 x 10
n=1.05, PMT
Cosmic ray (Lab.)
Beam test (Tohoku)

20 x 20
n=1.05, PMT
Cosmic ray (Lab.)

June

20 x 20
n=1.05, 1.08, MPPC
Cosmic ray(Lab.)

July

20 x 20
n=1.05, 1.08, MPPC
Beam test e/ μ (J-PARC?)

TIPP 2014
@Amsterdam

August

Decided for installed AC2

September

Produce & Performance estimate
& Calibration for AC2

JSP 2014
@Saga

October

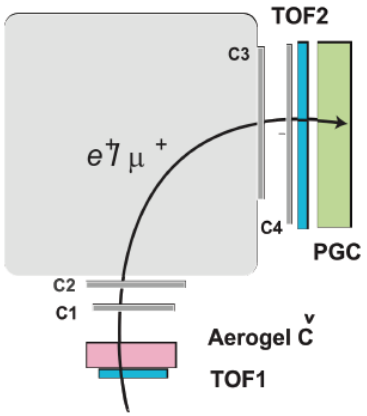
E36 Physics Run start

IEEE NSS 2014
@ Seattle

Back Up

Particle Identification for e/ μ

Calibration of PID performance



- Particle identification by
  a) TOF
  b) Aerogel Cherenkov (AC)
  c) Lead Glass (PGC)
- Efficiency calibration with the "sandwich method" using real K_{e2} data.

Element for check	Tracking elements	PID
AC	C1, C2, C3, C4	TOF⊗PGC
TOF	C1, C2, C3, C4	AC⊗PGC
PGC	C1, C2, C3, C4	TOF⊗AC

- PID efficiency limited by K_{e2} statistics
- We may also use K_{e3} events at reduced field

PID performance will improve if AC2 will be installed.

Element for check	Tracking elements	PID
AC	C1,C2,C3,C4	TOF⊗PGC⊗AC2
TOF	C1,C2,C3,C4	AC⊗PGC⊗AC2
PCG	C1,C2,C3,C4	AC⊗TOF⊗AC2
AC2	C1,C2,C3,C4	AC⊗TOF⊗PGC

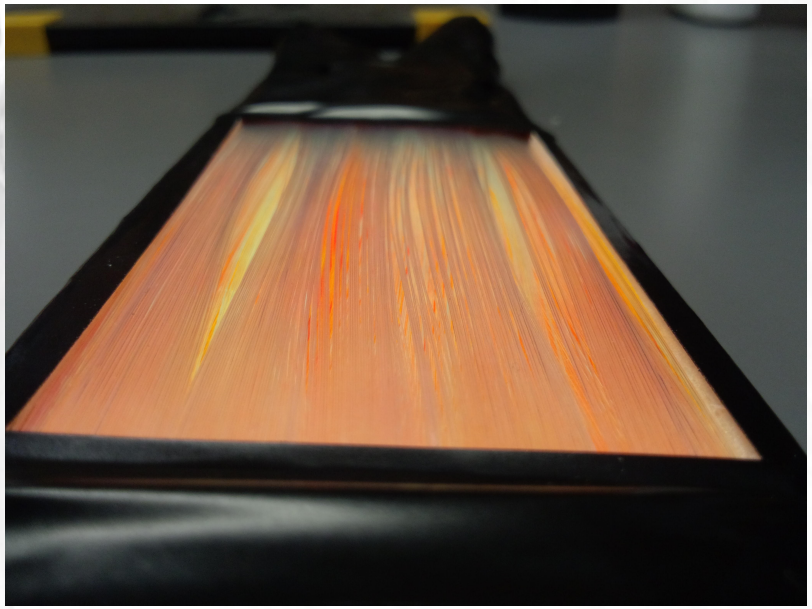
P_e = 247 MeV/c,
P_μ = 236 MeV/c

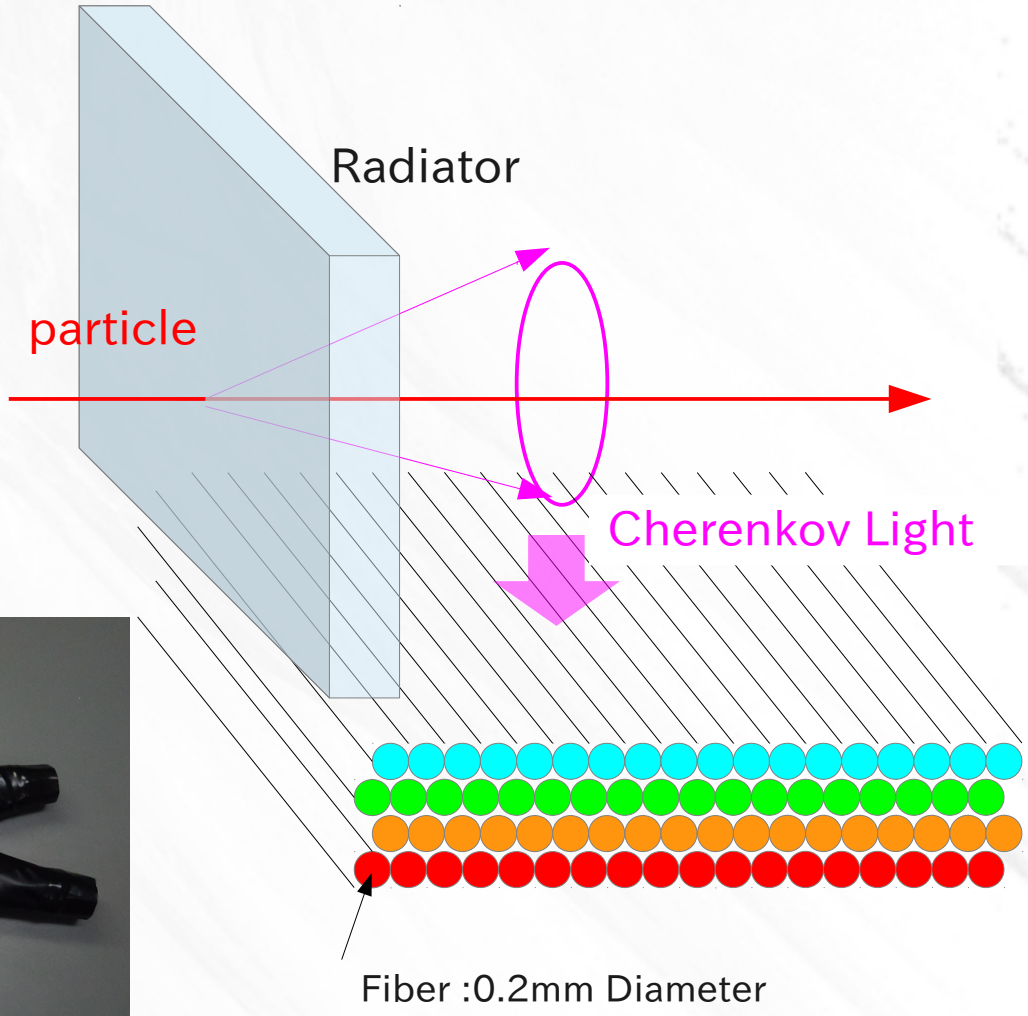
Condition of particle identification for e/ μ

Aerogel : refractive index
n<1.094

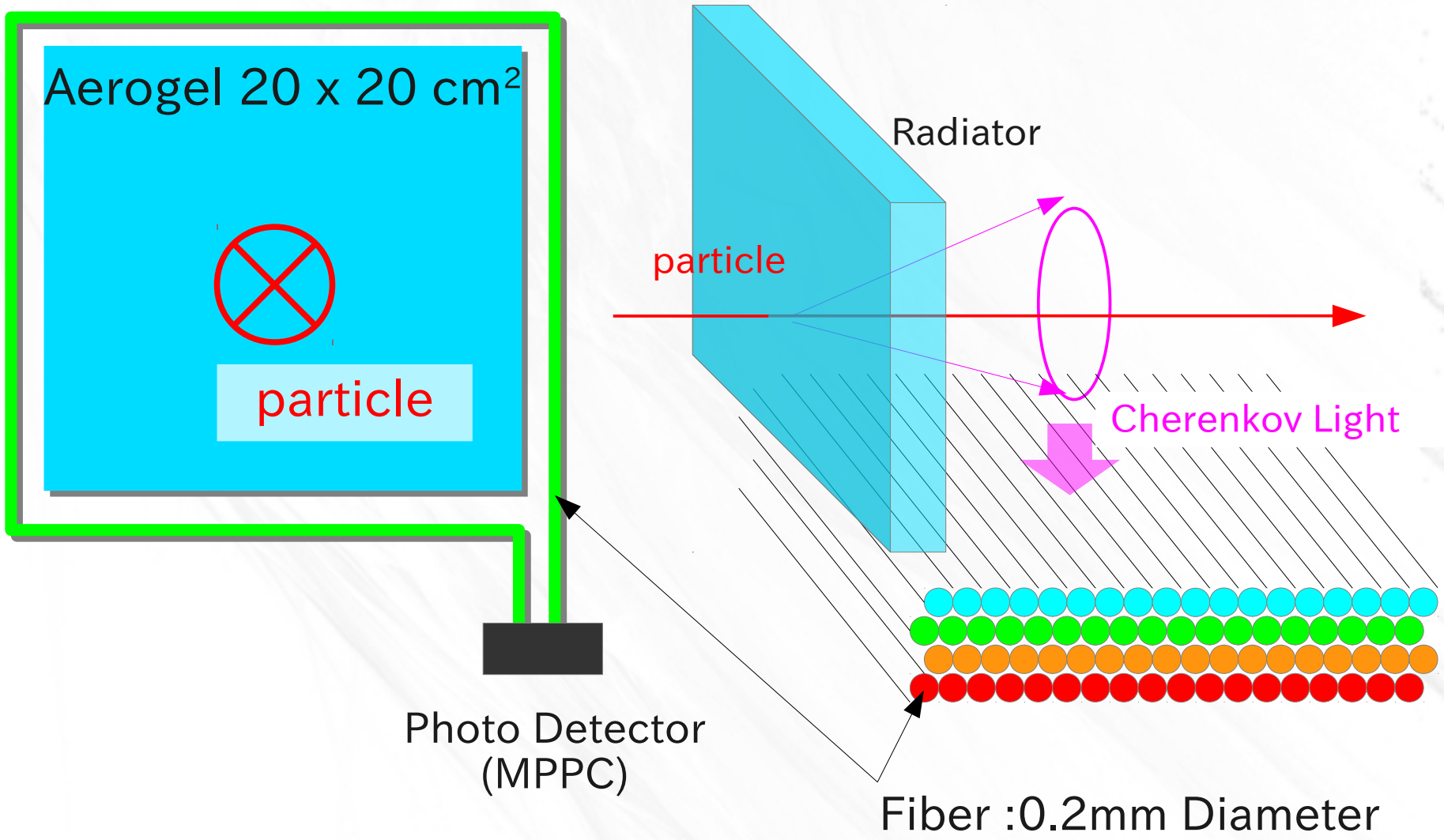
This experiment requires precise e+/ μ+ identification. The will install aerogel Cerenkov (AC) counter, time-of-fright (T counter, and lead glass counter (PGC) so that it is possible particle identification to achieve less than 10^{-6} mis-identifi challenge to add aerogel Cerenkov (AC2) counter betweer chamber and TOF2 for higher identification. For the above the detector will be obtained less than 10^{-8} mis-identificati

Cherenkov Light Guide for WLSF





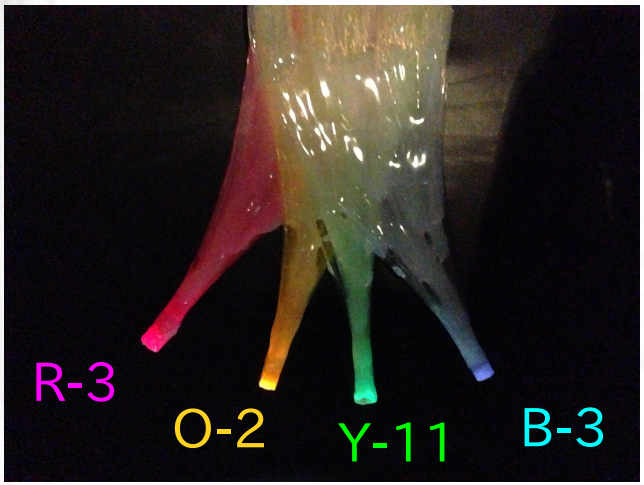
AC2 Dsign

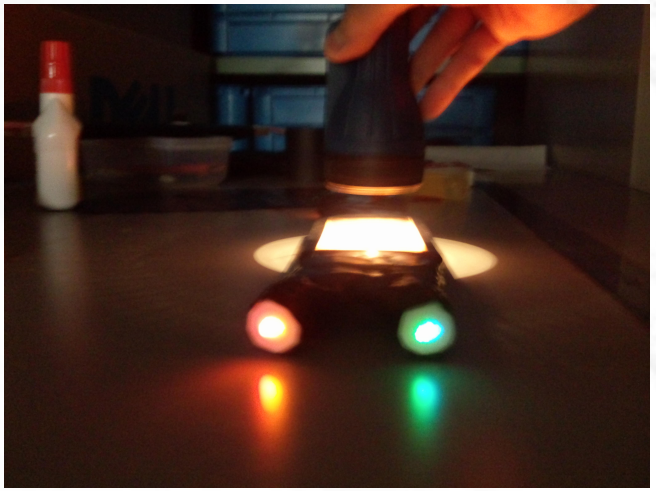

Aerogel 20 x 20 cm²
particle
Radiator
particle
Cherenkov Light
Photo Detector
(MPPC)
Fiber :0.2mm Diameter

Making for WLSF Light Guide

WLSF @Kuraray Co. Ltd.
(B-3, Y-11, O-2, R-3), double Cladding, 0.2 mm Dia.

Fiber Light Guide @ Chiba Univ.
Effective area : 100 x 200 mm^2 (x4)
Cross section : 320 mm^2
○ 20 mm Dia.
□ 18 mm



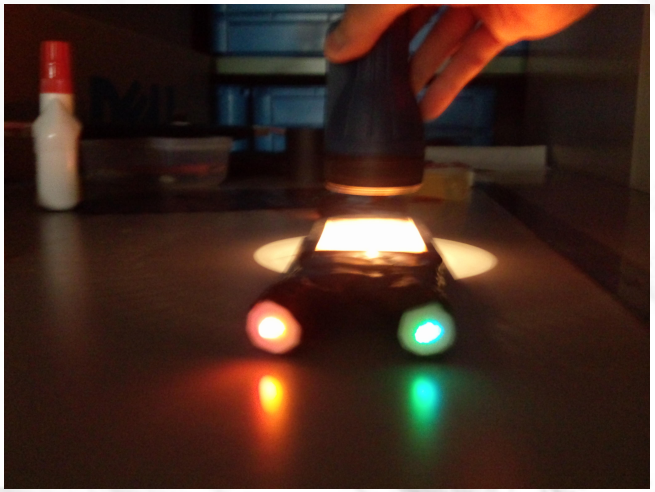


Making Fiber Light Guide (FLa series)

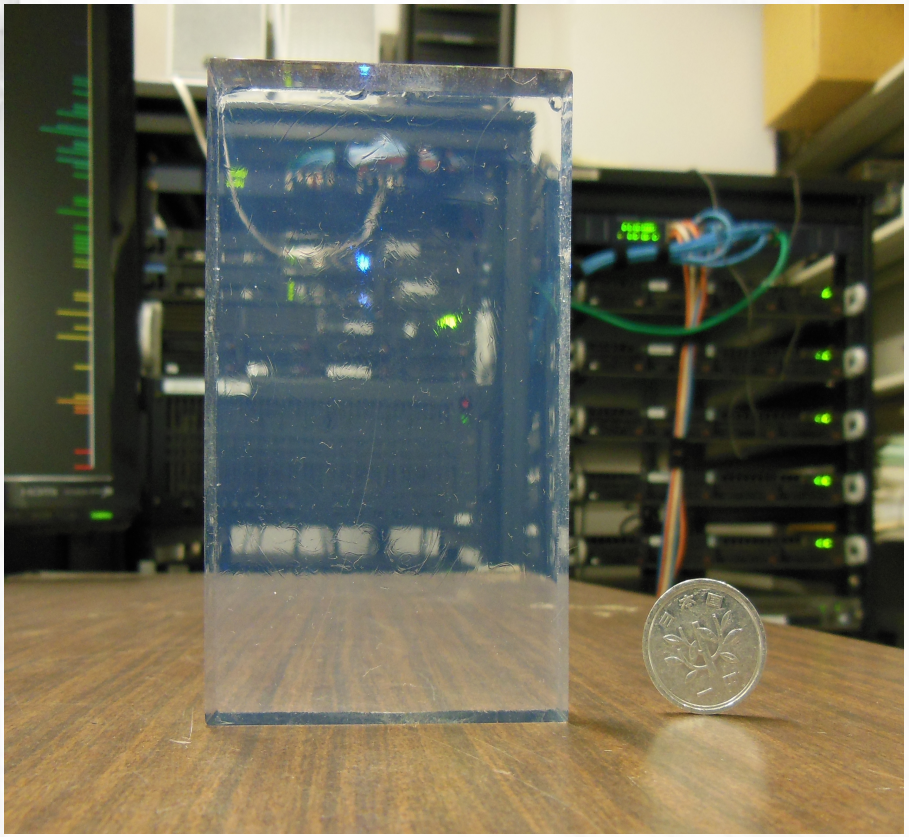
波長変換ファイバー(直径0.2 mm)をシート化して層状にする。

Problem for method of making fiber sheet

- Attend for effective area　:max of making now … 30 x 5 cm^2
- Connected Adhesive　:Aron Alpha solve fiber → PVAL、vinyl ester resin
- 断面処理・研磨処理　:研磨方法を改善中
- 受光面表面コーティング　:稲玉さんのライトガイド用のジェルは使えるのか
- 下地反射材　:アルミマイラーに表裏がある、ESフィルムはどうか



Silica Aerogel



- SiO_2 + 空気の混合
- 低密度、低屈折率、透明
- 製作時に屈折率を決定可能

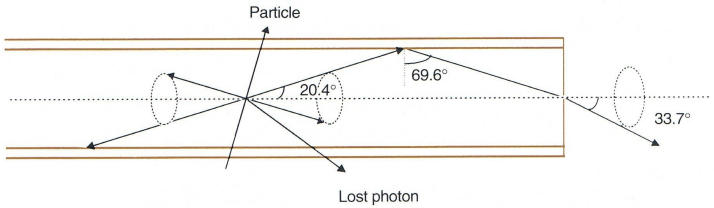
  $1.002 < n < 1.3$

n = 1.049
TL= 40 mm
Size 60 x 90 x 10[mm^3]

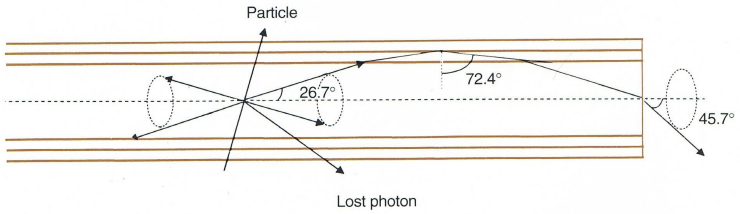
Wavelength Shifting Fiber

Cladding and Transmission Mechanism

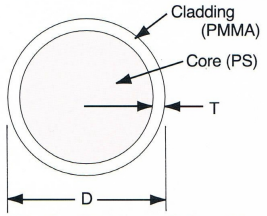
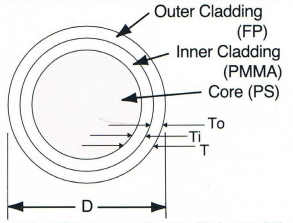
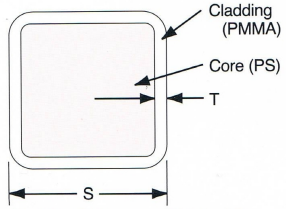
Single Cladding
Single cladding is standard type of cladding.



Multi Cladding
Multi cladding fiber (M) has 50% 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.



Cross-section and Cladding Thickness

	Single Cladding	Multi Cladding (M)
Round Fiber (D)	 Cladding Thickness : T=3% of D Numerical Aperture : NA=0.55 Trapping Efficiency : 3.1%	 Cladding Thickness : T =3% (To)+3% (Ti) =6% of D Numerical Aperture : NA=0.72 Trapping Efficiency : 5.4%
Square Fiber (SQ)	 Cladding Thickness : T=2% of S Numerical Aperture : NA=0.55 Trapping Efficiency : 4.2%	Not available

Materials

		Material	Refractive index	Density [g/cm³]	No. of atom per cm³
Core		Polystyrene (PS)	n_D=1.59	1.05	C : 4.9×10^{22} H : 4.9×10^{22}
Cladding	for single cladding inner for multi cladding	Polymethylmethacrylate (PMMA)	n_D=1.49	1.19	C : 3.6×10^{22} H : 5.7×10^{22} O : 1.4×10^{22}
	outer for multi cladding	Fluorinated polymer (FP)	n_D=1.42	1.43	

Wavelength Shifting Fiber

Cladding and Transmission Mechanism

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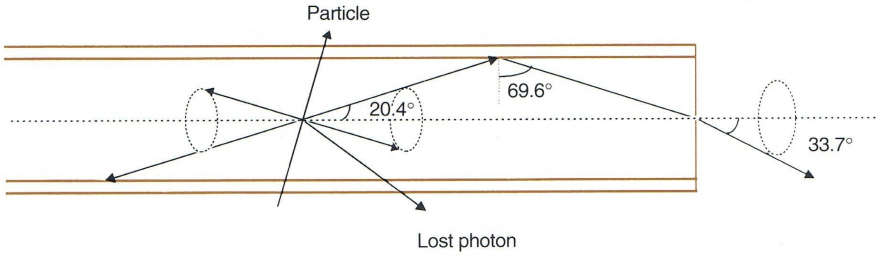
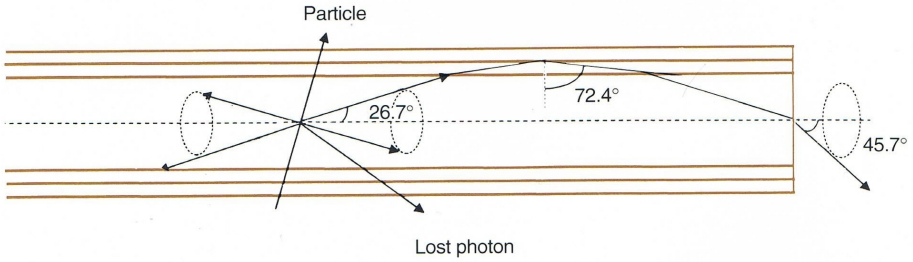
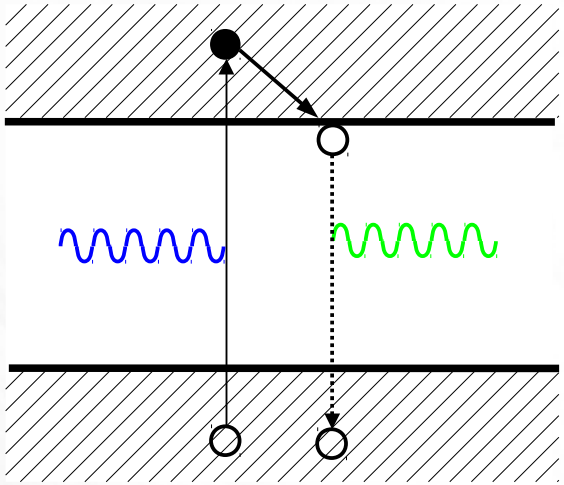
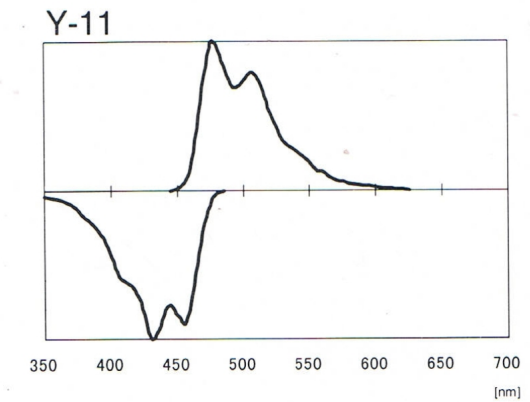
Single cladding is standard type of cladding.



Multi Cladding
Multi cladding fiber (M) has 50% 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.



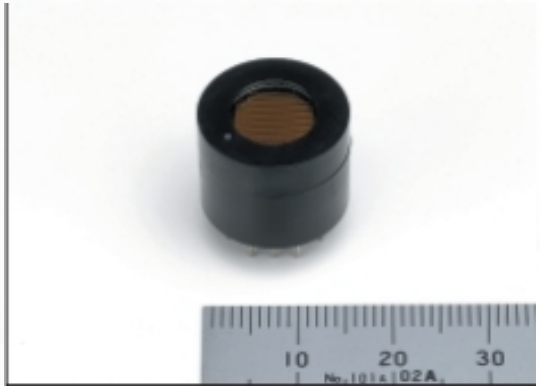


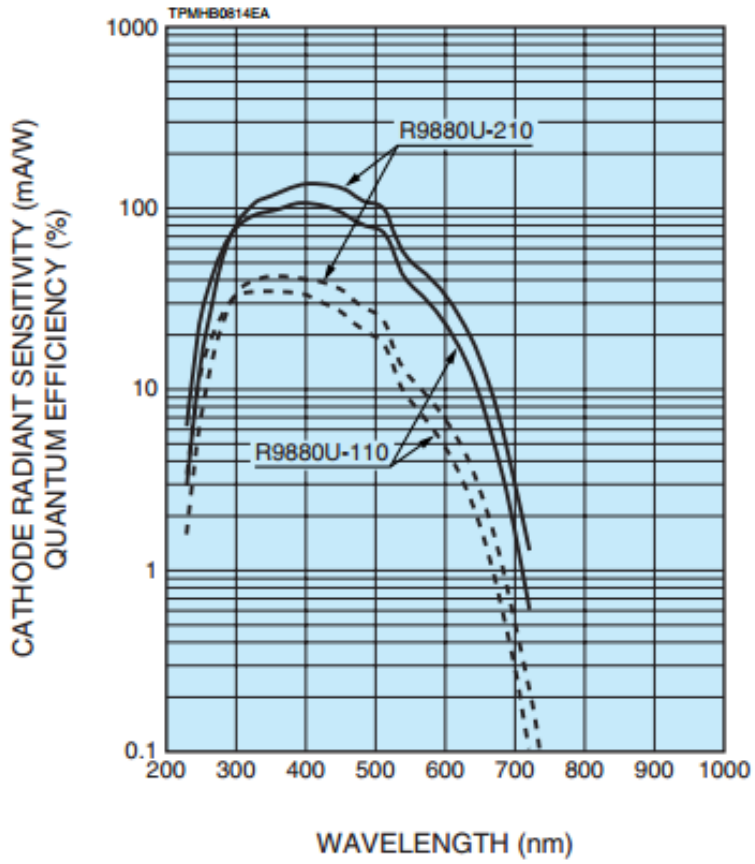


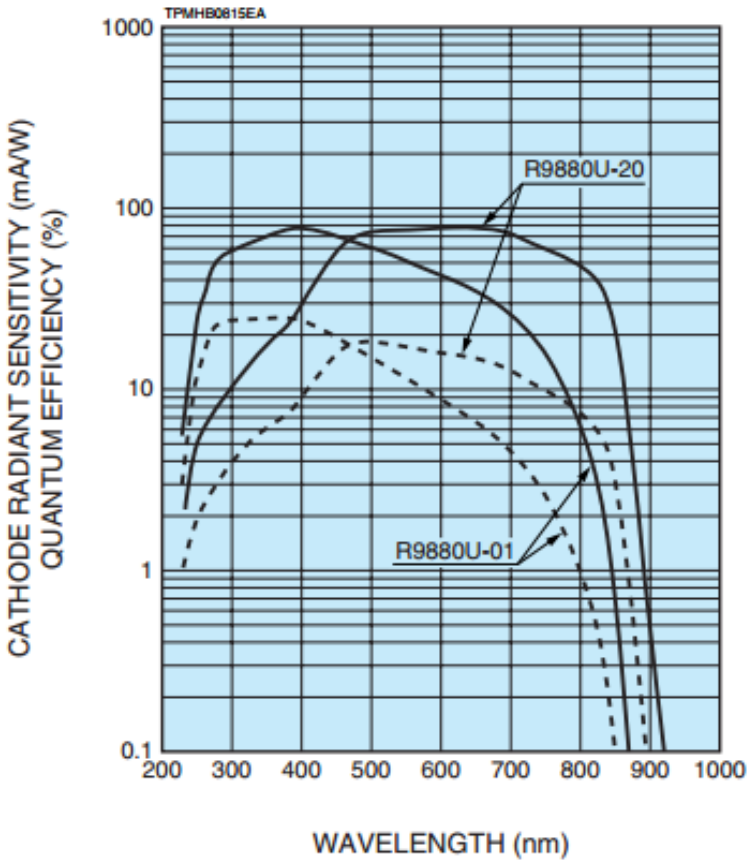
Photomultiplier Tube

R9880U-210 : (B-3,Y-11)
-20 : (O-2, R-3)

effective area; 8 mm Dia



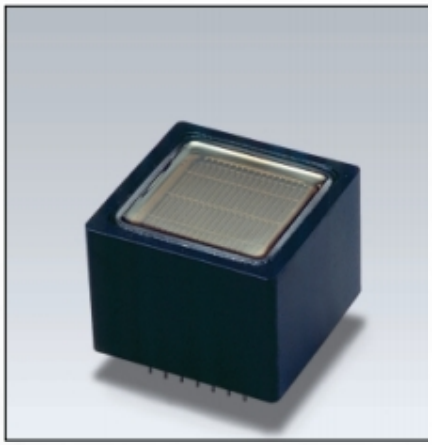


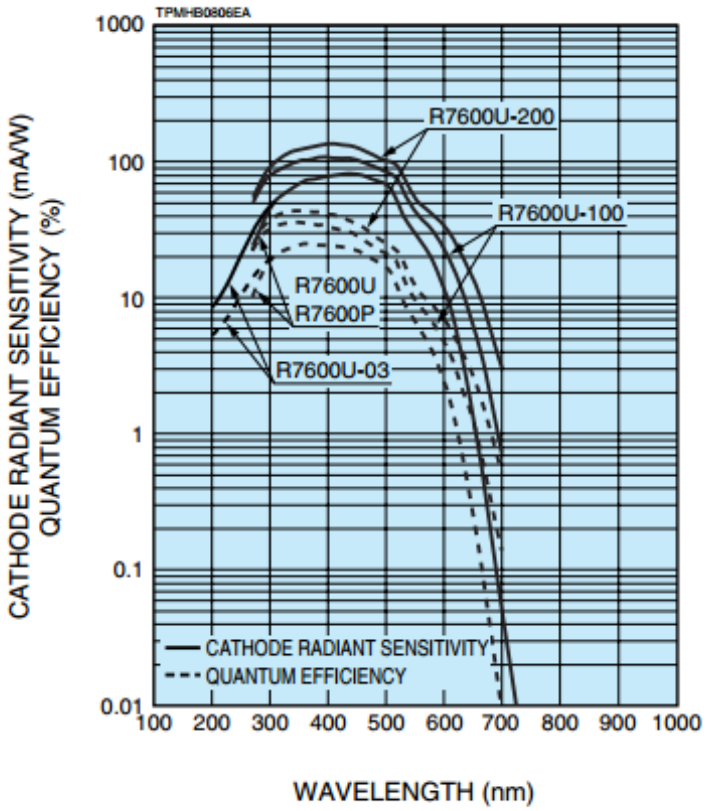


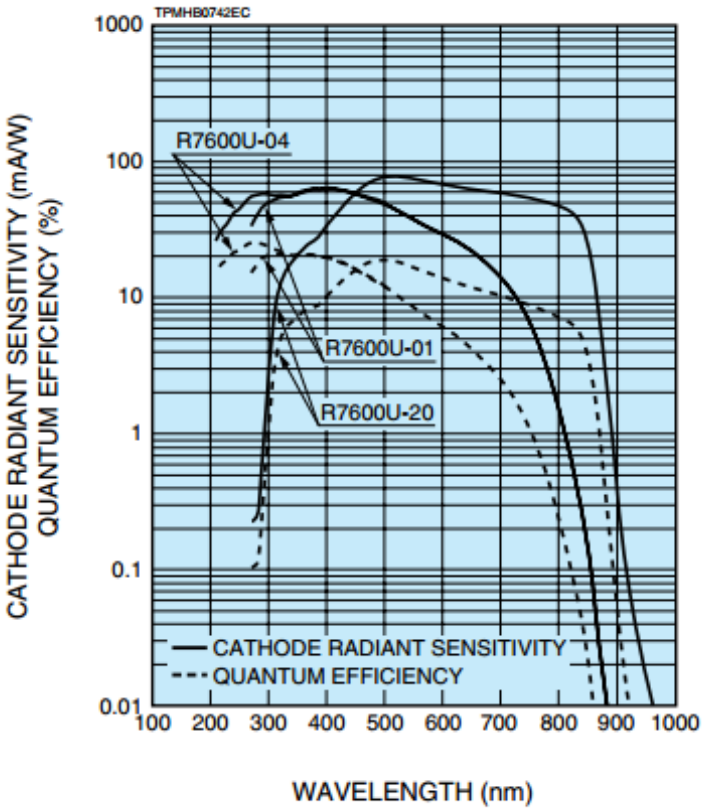
Photomultiplier Tube

R7600U-200 : (B-3,Y-11)
-20 : (O-2, R-3)

effective area; 18 mm x 18 mm

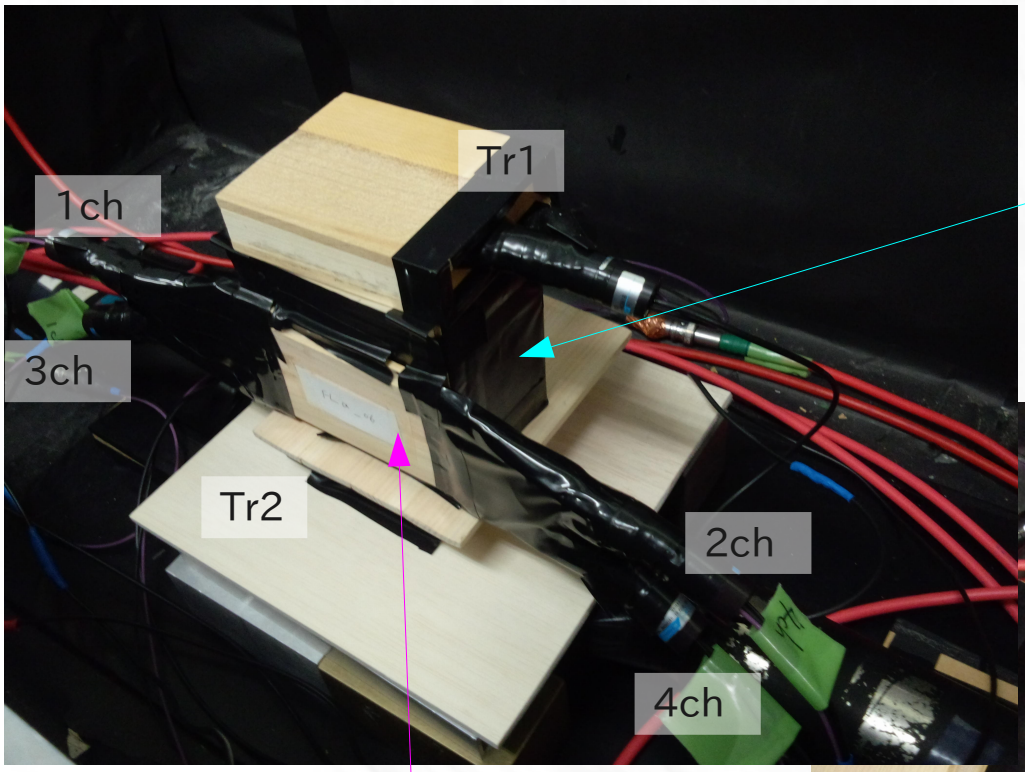






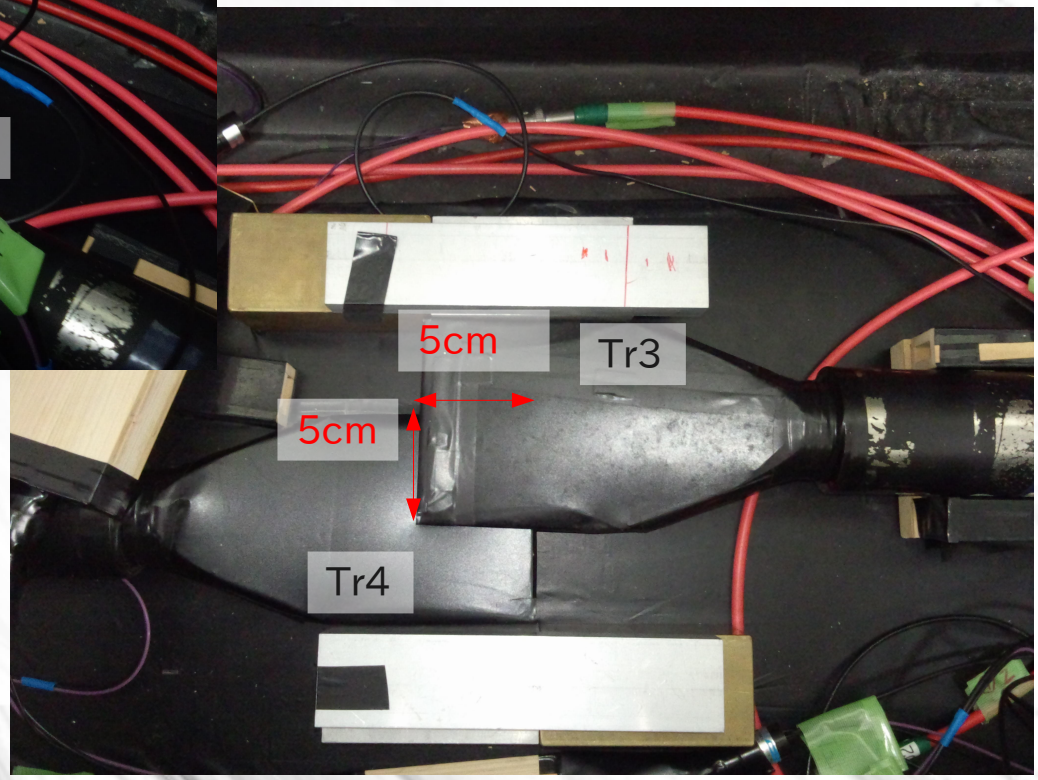
Primary test of fiber light guide

1. Cosmic ray test



Silica Aerogel

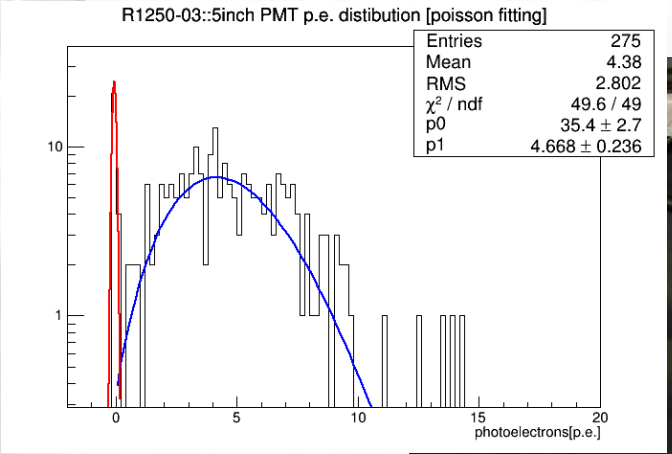
WLSF Light Guide

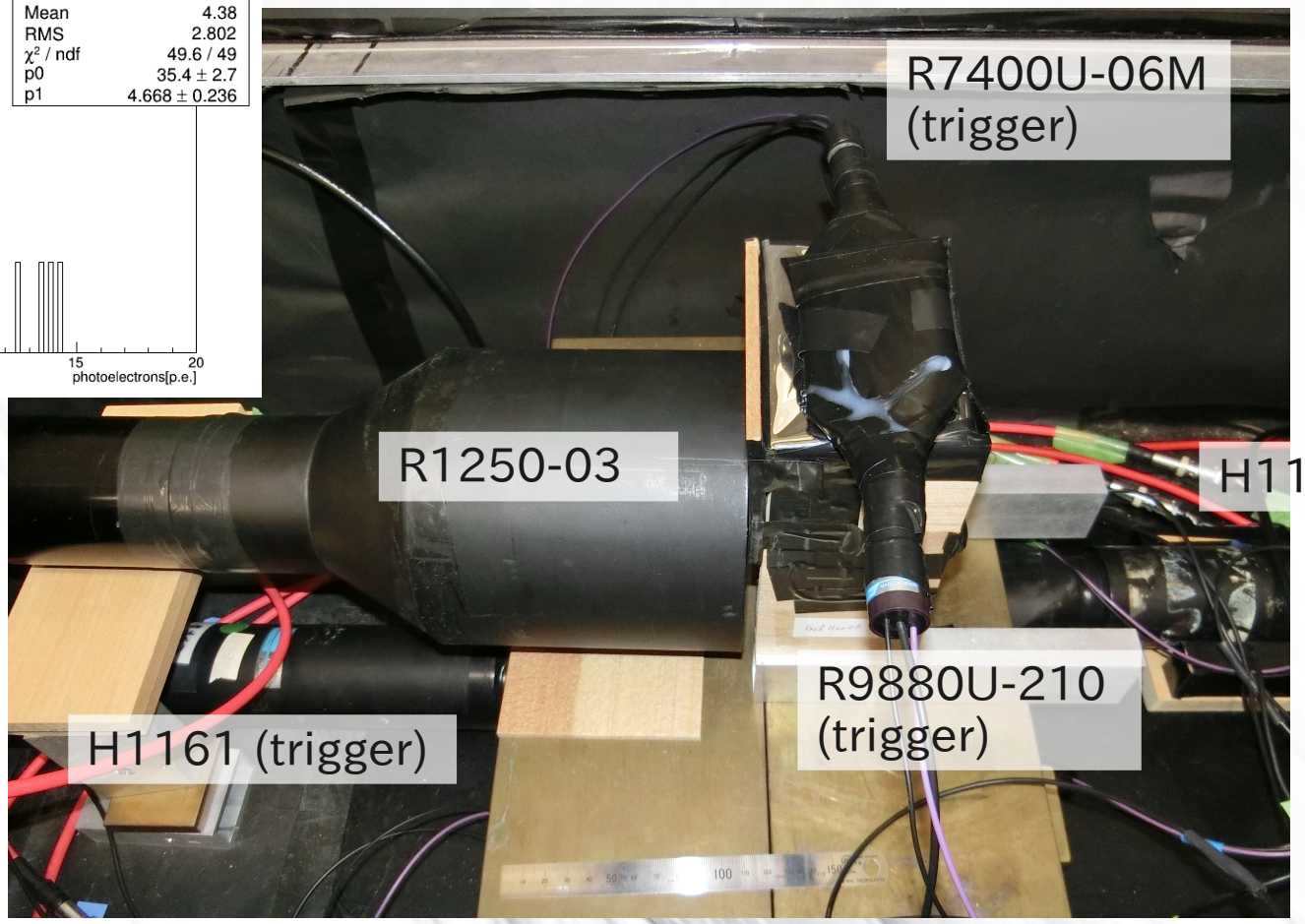


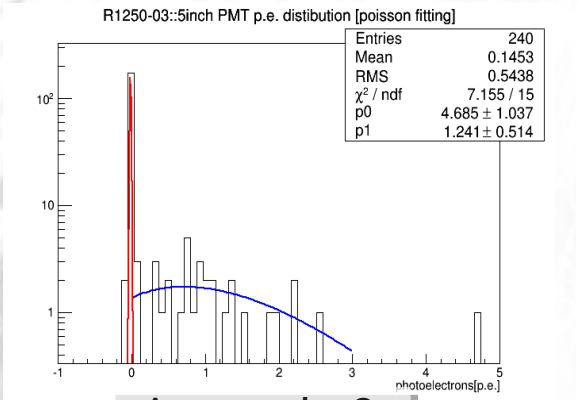
Primary test of fiber light guide

1. Cosmic ray test

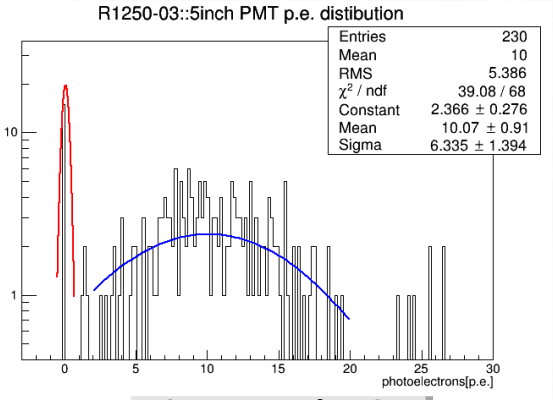
PMT direct reading Cherenkov test



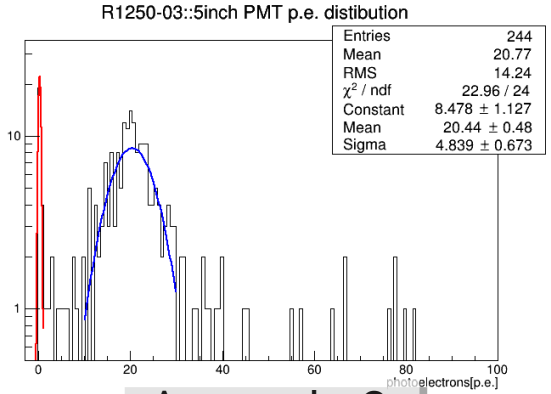




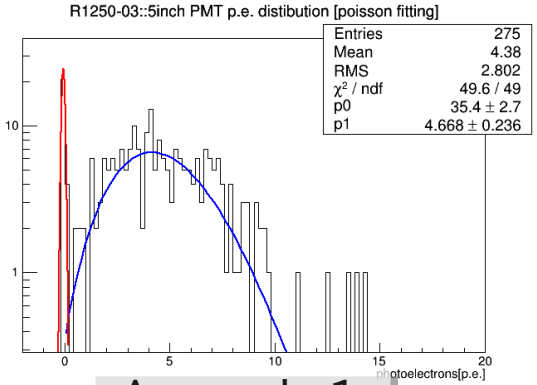
Aerogel x0



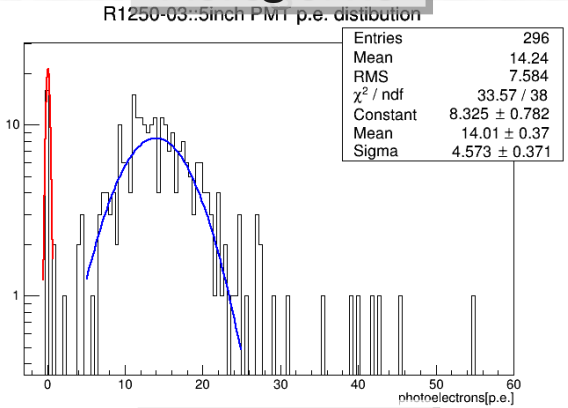
Aerogel x3



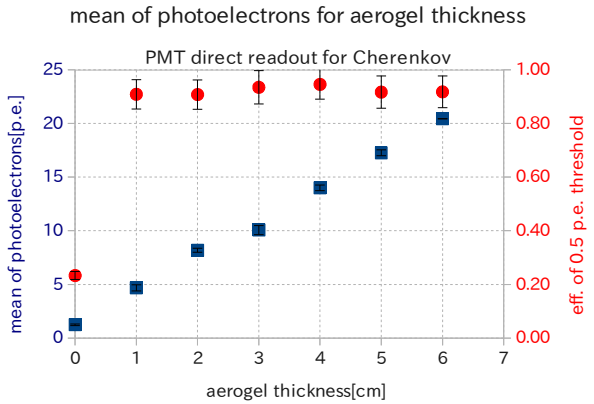
Aerogel x6

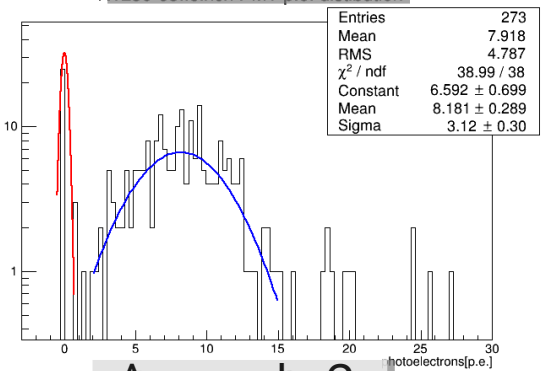


Aerogel x1

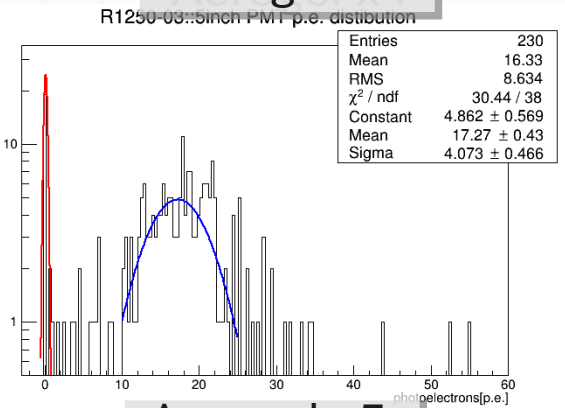


Aerogel x4





Aerogel x2

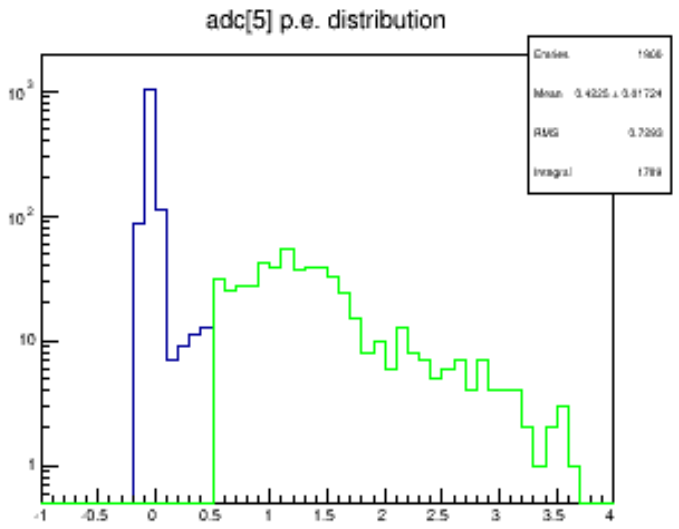


Aerogel x5

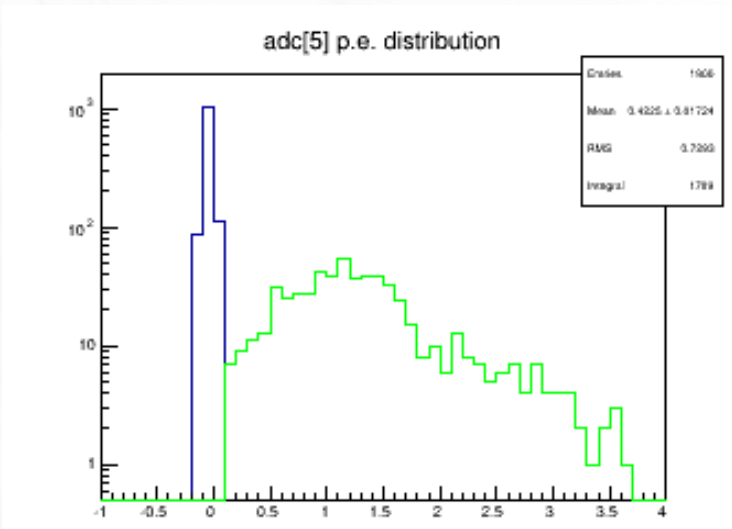
Primary test of fiber light guide

2. Beam test

解析手法



0.5 p.e. しきい値



ペデスタル3σ しきい値

0.5 p.e.しきい値と、ペデスタル3σでは検出効率
による光電子数が約0.1p.e.の差があった。

n=1.03

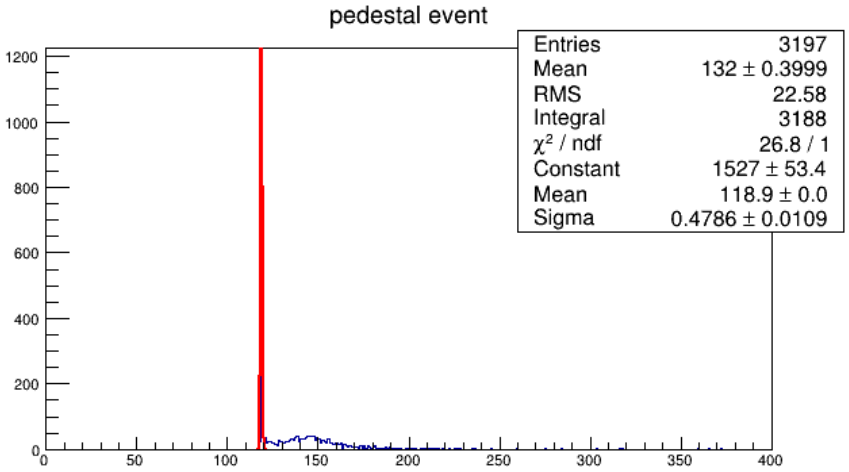
	index	trans. Length [mm]
JESU1-8a	1.0367	39.8
JESU1-7a	1.0369	43.5
JESU1-8b	1.0366	43.4
	1.0367	42.2
	0.0002	2.1

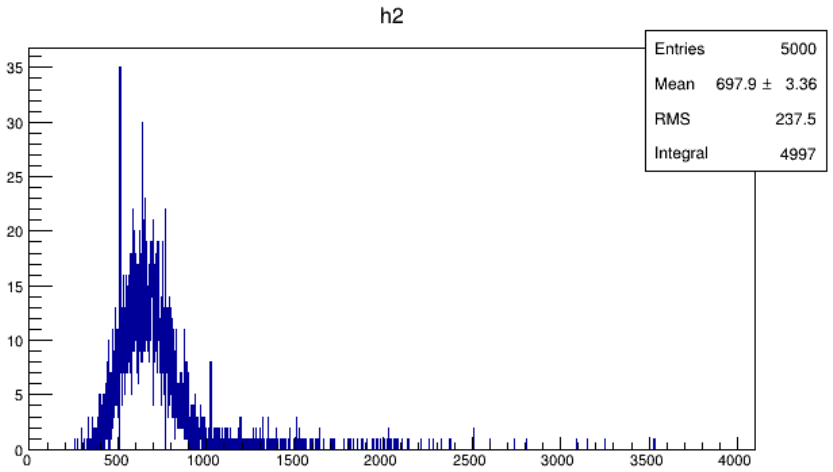
n=1.05

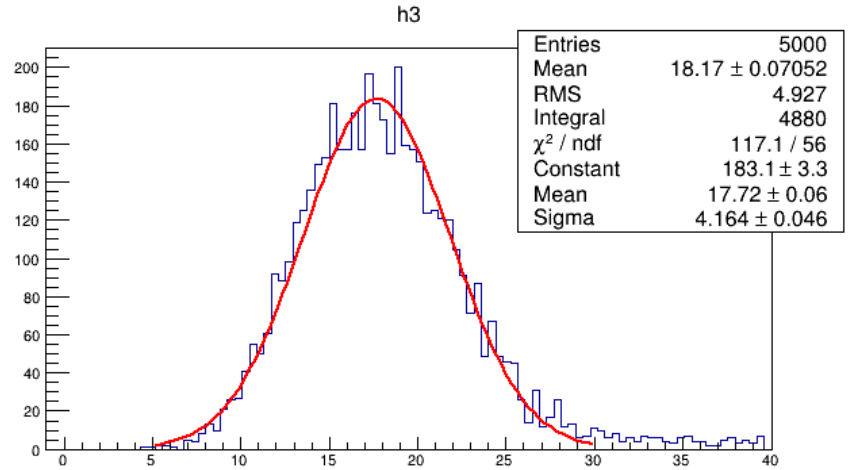
	index	trans. Length [mm]
9a-k	1.0479	40.1
8a-l	1.0496	40.5
8a-h	1.0494	38.3
	1.0490	39.6
	0.0009	1.2

n=1.08

	index	trans. Length [mm]
PDR8-6b	1.0749	42.4
PDR8-5b	1.0753	40.6
PDR8-4b	1.0762	42.1
	1.0755	41.7
	0.0007	1.0







run::data018

PMT direct aerogel(x6), pedestal 3sigma threshold

PMT::R1250-03 RA1908

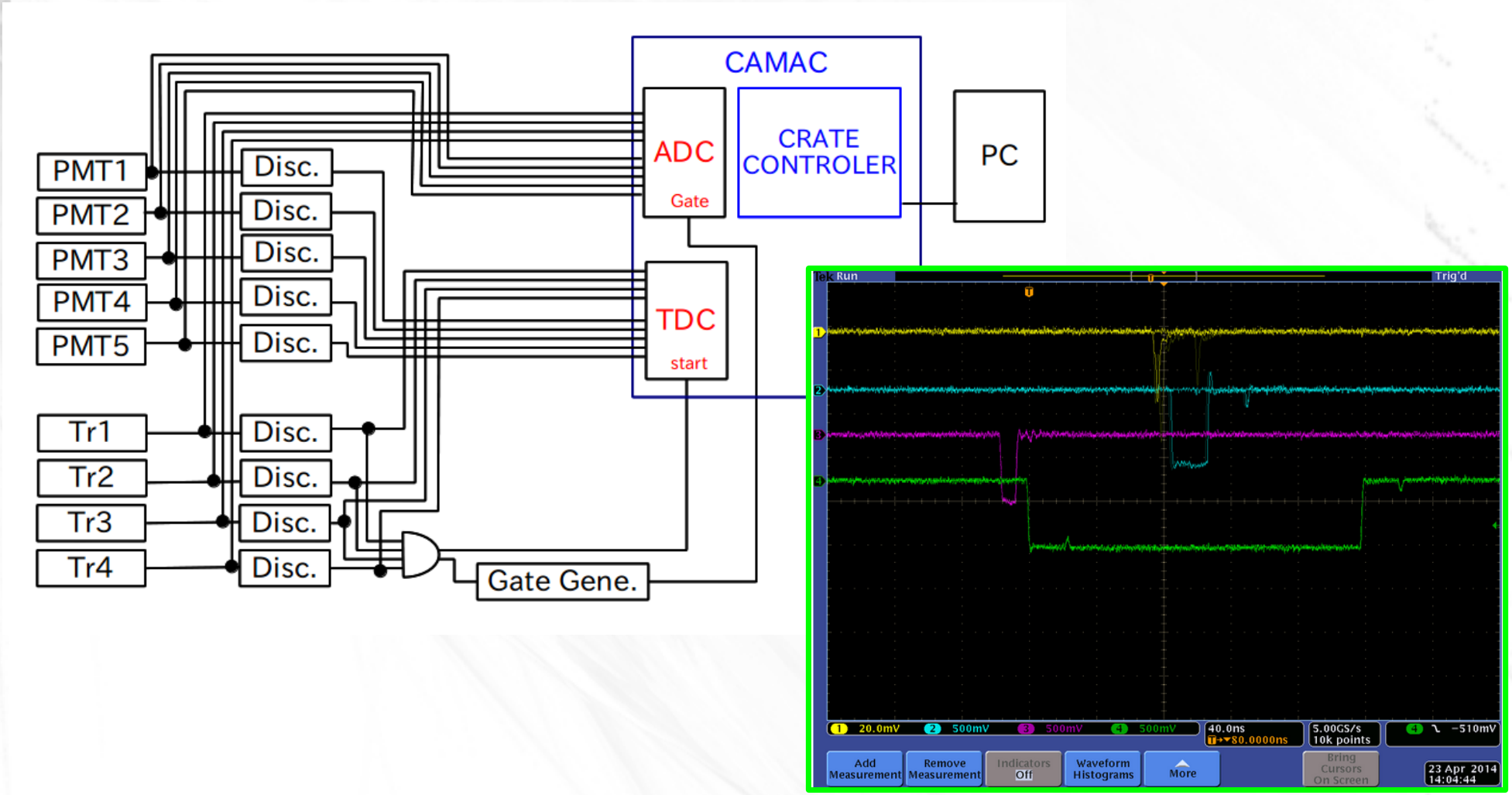
ADC 1ch pedestal mean::118

eff::1.000000

photoelectrons::17.718329

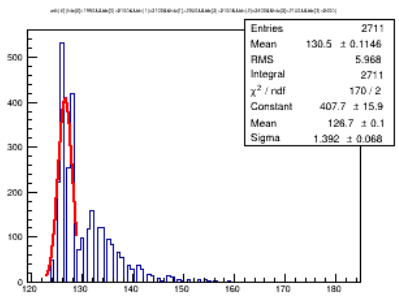
Primary test of fiber light guide

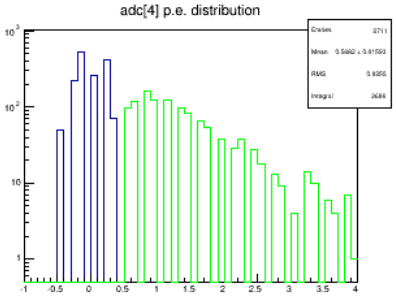
2. Beam test @Tohoku

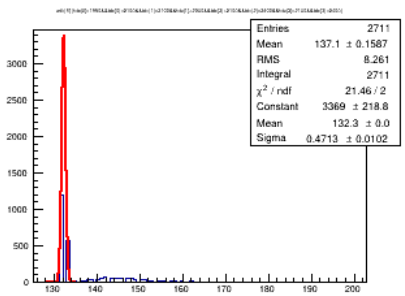


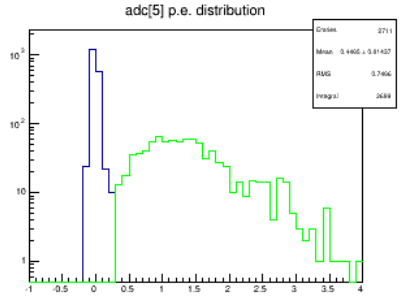
Primary test of fiber light guide

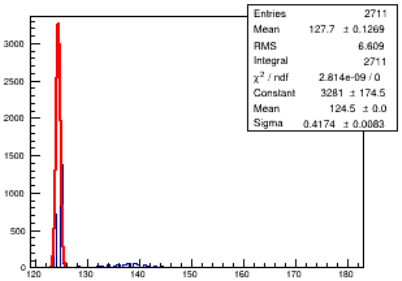
2. Beam test @Tohoku

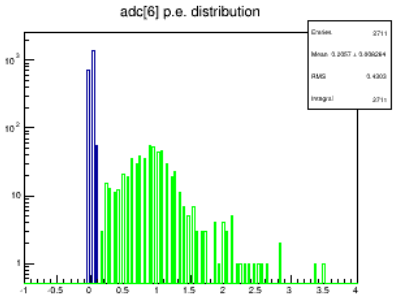


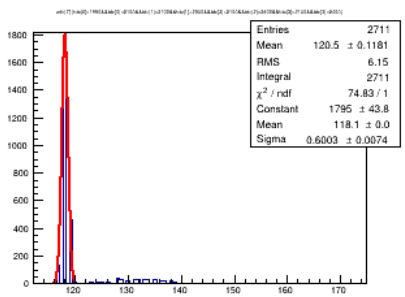


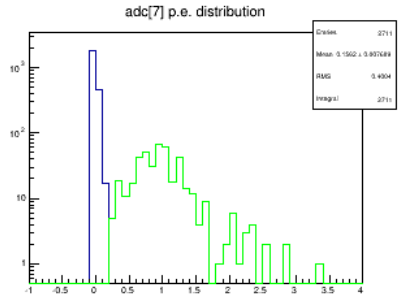


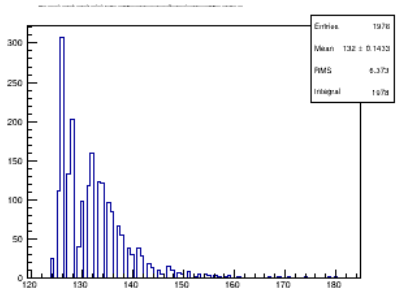










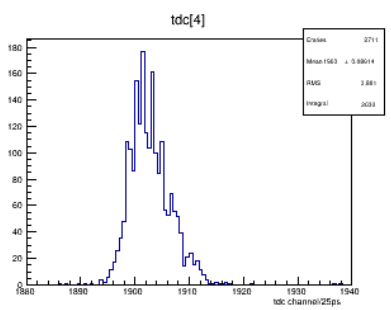


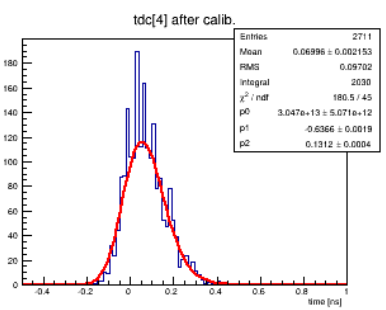
ADC 1ch pedestal mean::126
eff::0.428255
photoelectrons::0.559063
ADC 2ch pedestal mean::132
eff::0.322390
photoelectrons::0.389184
ADC 3ch pedestal mean::124
eff::0.209517
photoelectrons::0.235111
ADC 4ch pedestal mean::118
eff::0.156400
photoelectrons::0.170077

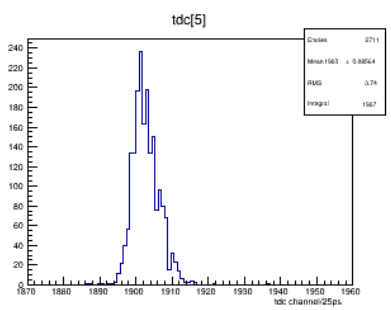
run::data032
position::center middle
pedestal 3 σ threshold
Trigger TDC cut analysis
ADC 1 or 2 or 3 or 4ch
eff::0.729620
photoelectrons::1.307927

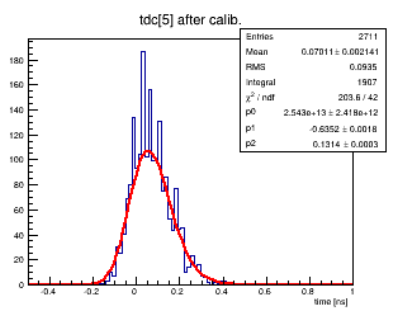
Primary test of fiber light guide

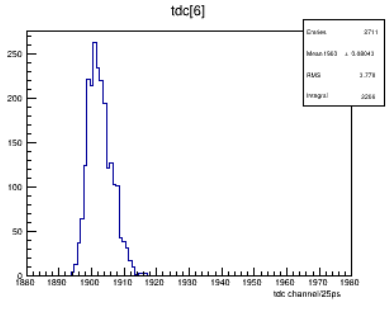
2. Beam test @Tohoku

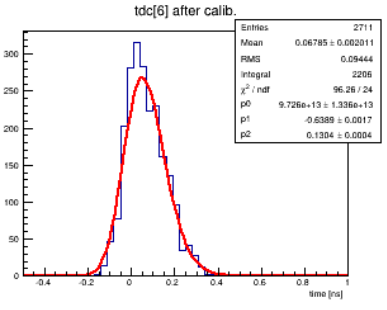


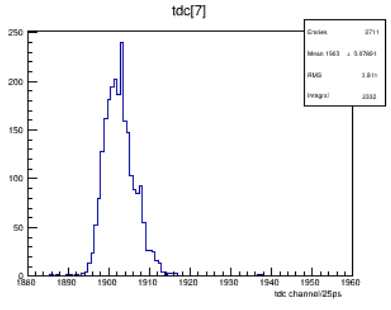


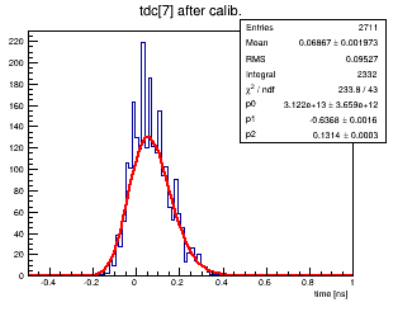












run::data032
FLa32[BYOR(x2)]6 cm x 10 cm(x2)
TDC timing resolution
Trigger TDC cut analysis

PMT :: R9880U-210 BAC0996
PMT :: R9880U-210 BAC2397
PMT :: R9880U-20 BCA6347
PMT :: R9880U-20 BAC9435

start fructuation considering

$$tdc = tdc[4] - \frac{tdc[0]+tdc[1]+tdc[2]+tdc[3]}{4}$$

TDC 1ch timeing ::0.131173 ns

TDC 2ch timeing ::0.131420 ns

TDC 3ch timeing ::0.130394 ns

TDC 4ch timeing ::0.131393 ns

Fitting fanction::Landau distribution

$$F(t,t_0) = \frac{1}{\sqrt{2\pi\sigma^2}} \exp\left[\frac{t - t_0 - e^{-(t-t_0)}}{2\sigma^2}\right]$$

parameter:: t_0 ... mean

parameter:: σ ... deviation