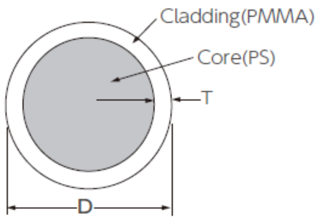
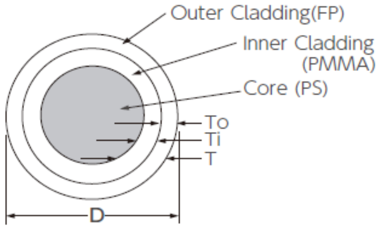
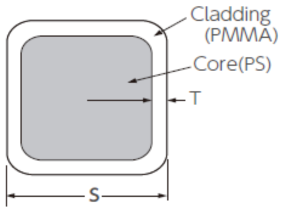
WLS fiber Study

Jae Min Choi

Trapping Efficiency

Trapping Efficiency

Cross-section and Cladding Thickness

	Single Cladding	Multi-Cladding (M)
Round Fiber (D)	 Cladding Thickness[1]: T=2% of D Numerical Aperture : NA=0.55 Trapping Efficiency : 3.1%	 Cladding Thickness[2] : T=2%(To)+2%(Ti) =4% 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

1) In some cases, cladding thickness T is 3% of D. 2) In some cases, cladding thickness T is 6% of D, To and Ti are both 3% of D.

<Properties table of Y-11>

Critical Angle for total reflection in WLS fiber

- Refractive Index of core : 1.59
- Refractive index of cladding : 1.49

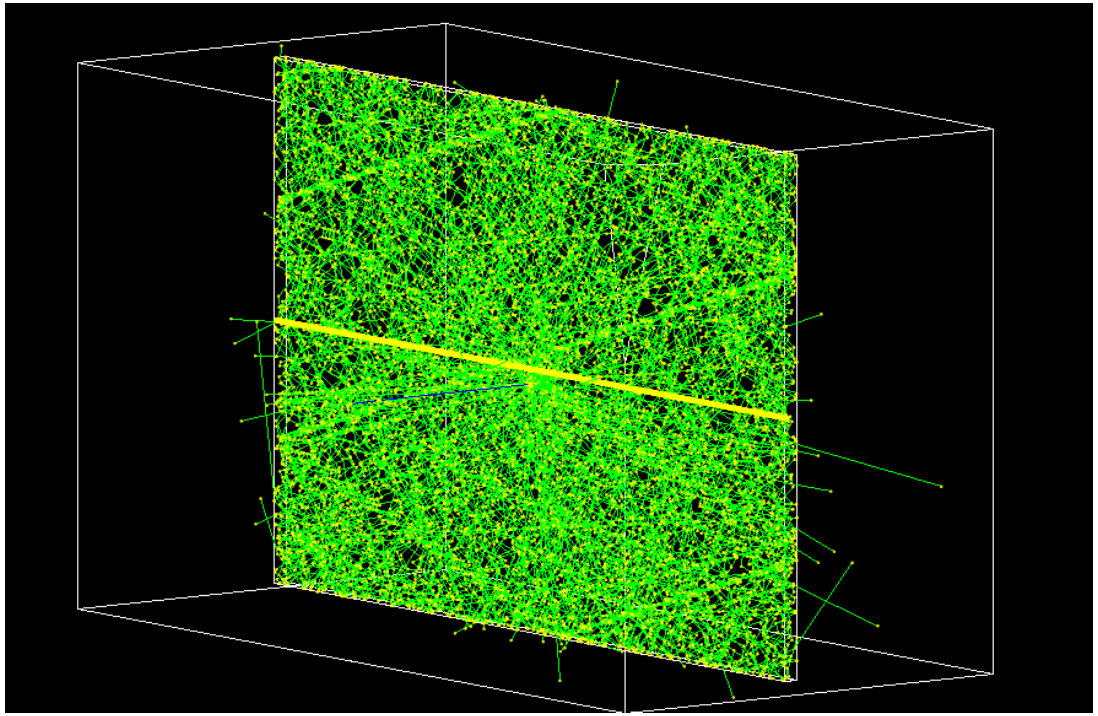
critical angle $\theta_c = \sin^{-1}\left(\frac{1.49}{1.59}\right) = 69.57^\circ$

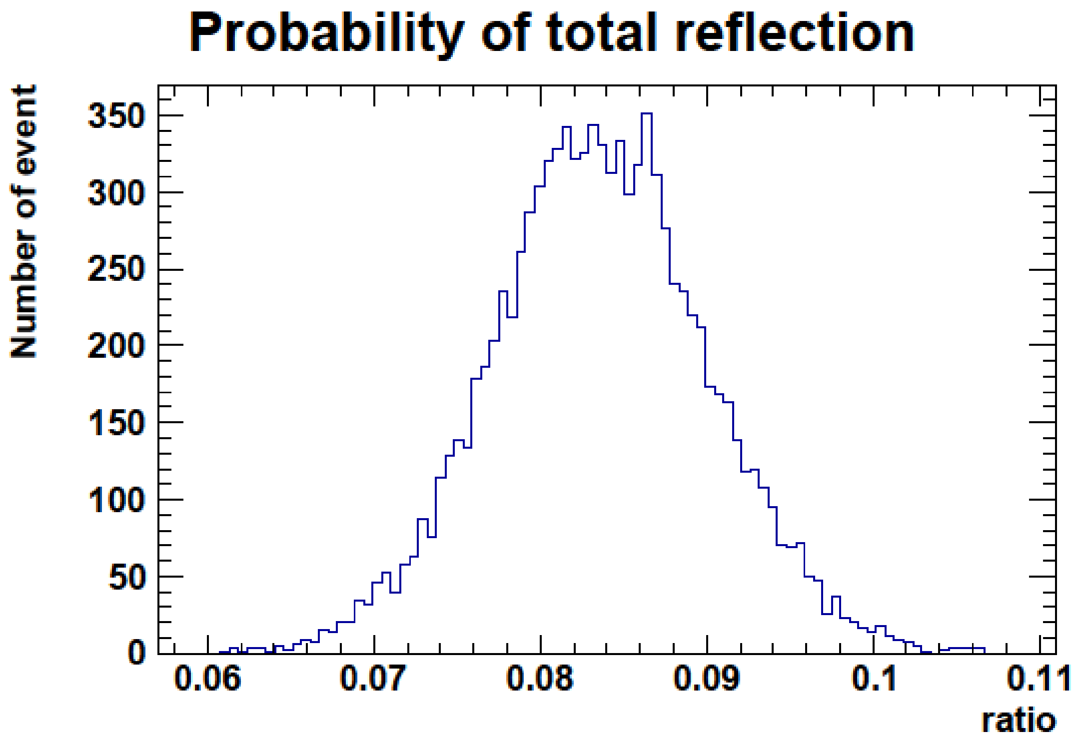
Assume that there is no attenuation and emission occurs isotropically. Probability for total reflection is

$$P = \frac{2 \times \int_0^{2\pi} \int_0^{20^\circ} \sin\theta \, d\theta \, d\phi}{\int d\Omega} = \frac{2 \times 0.06}{2} = 6\%$$

<Calculated results of Trapping Efficiency>

Probability for total reflection





Ratio between the number of WLS process and the number of photon arrived at MPPC

Average of absorption ratio 0.084 is larger than our calculation 0.06.

New Calculation

Equation for total reflection

- As a results

$$\sin\theta = \frac{\cos\psi_c}{1 - \frac{a^2}{R^2} sin^2\varphi}$$

Probability for total reflection in (a, 0, 0)

- And by using that

$$P=\frac{1}{2}-\frac{1}{\pi}\int_0^{\frac{\pi}{2}}\sqrt{\frac{\sin^2\psi_c-(\frac{a}{R})^2\sin^2\phi}{1-(\frac{a}{R})^2\sin^2\phi}}\,d\phi$$

(this result is for one direction)

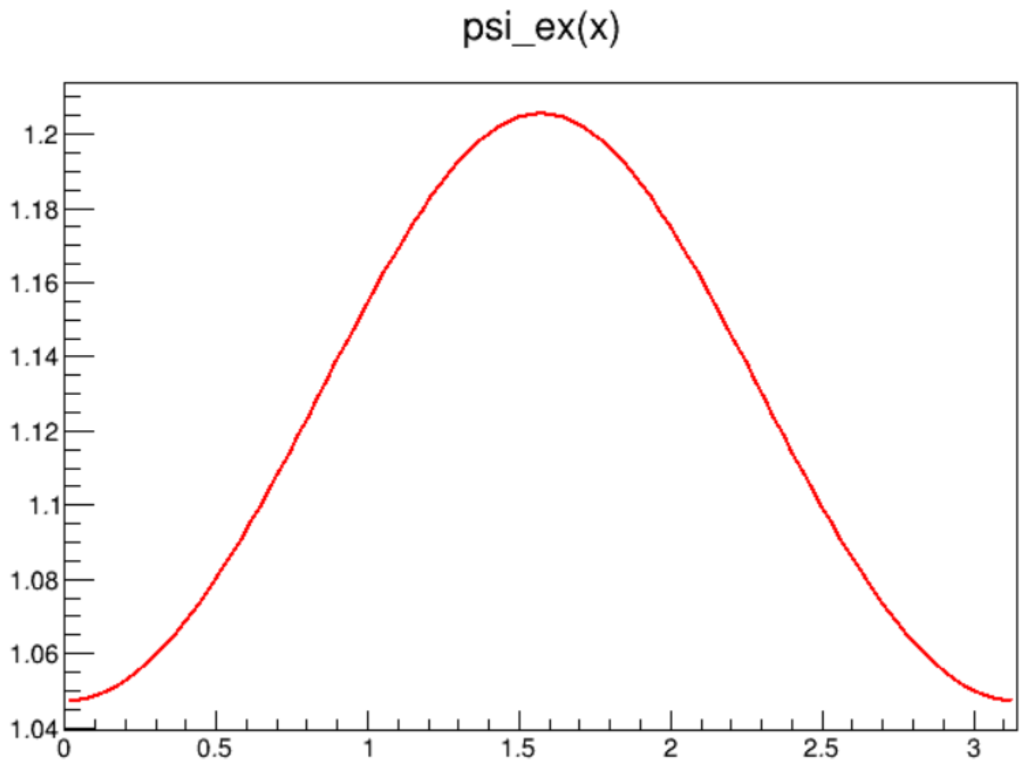
Value of a	Value of $P=\frac{1}{2}-\frac{1}{\pi}\int_0^{\frac{\pi}{2}}\sqrt{\frac{\sin^2\psi_c-(\frac{a}{R})^2\sin^2\phi}{1-(\frac{a}{R})^2\sin^2\phi}}\,d\phi$
0.1 R	0.03161
0.2 R	0.03212
0.3 R	0.03302
0.4 R	0.03443
0.5 R	0.03652
0.6 R	0.03959
0.7 R	0.04479
0.8 R	0.05414
0.9 R	0.07899

Range of φ

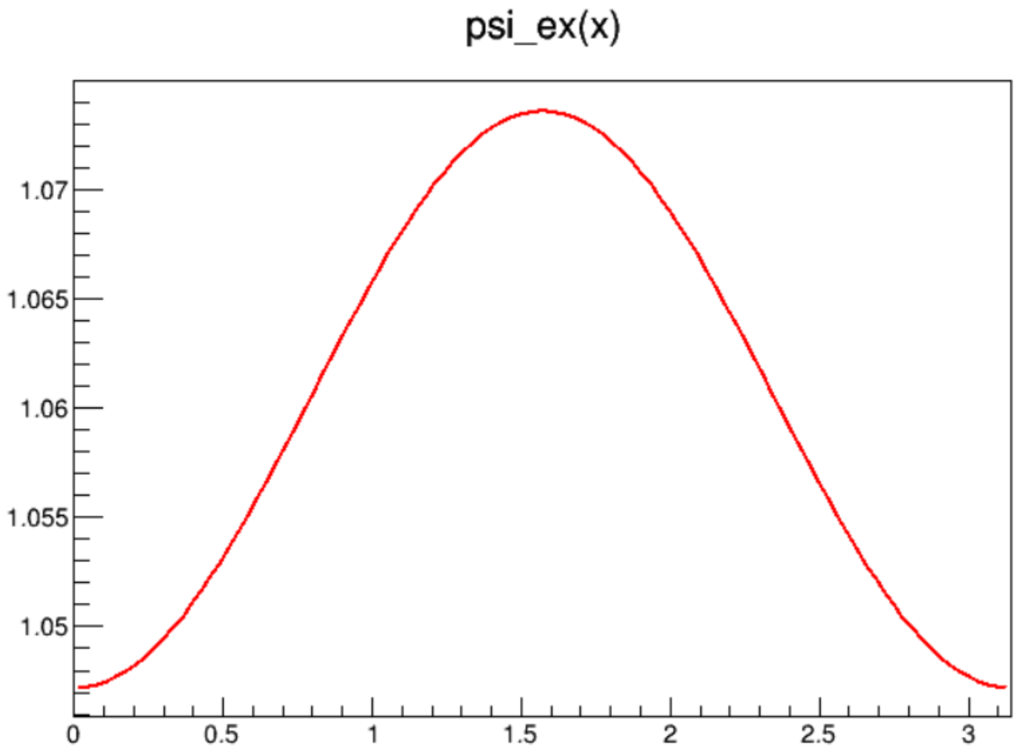
- When a->R and φ -> $\pi/2$, the value of integration goes to infinity.
- To avoid this, let's specify the range of φ, that is, setting upper bound of φ as a function of a.

$$-\frac{R}{a} sin\psi_c \leq \sin\phi \leq \frac{R}{a} sin\psi_c$$

Angle with normal vector of cylinder

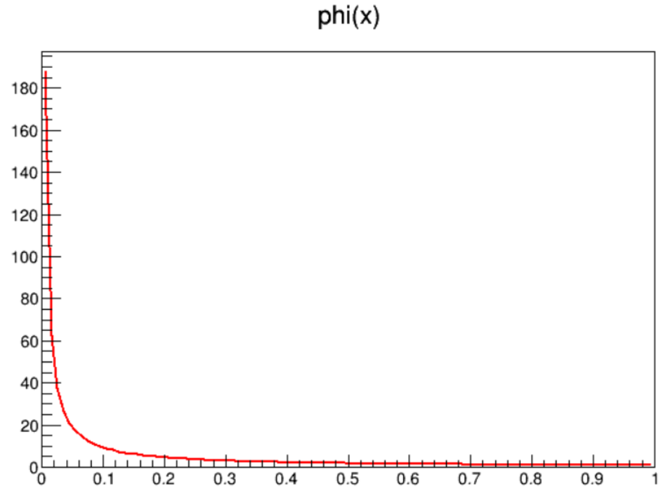


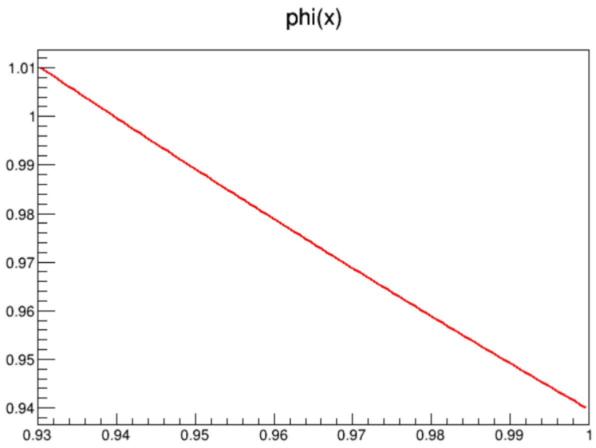
When a = 0.7R, θ = 30*deg



When a = 0.4R, θ = 30*deg

Even if the polar angle is the same, the value at the peak changes depending on the position a.
Critical angle is about 1.2217.


phi(x)
180
160
140
120
100
80
60
40
20
0
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1


phi(x)
1.01
1
0.99
0.98
0.97
0.96
0.95
0.94
0.93
0.94
0.95
0.96
0.97
0.98
0.99
1

Integration

- However, we cannot get results of indefinite integral.

Reflectivity

Fresnel's Equation

- Reflectivity can be calculated by Fresnel's equation.
- If direction of polarization is parallel to incident plane, transmittance and reflectivity is as follows

$$R = (\frac{\alpha-\beta}{\alpha+\beta})^2 \quad \text{and} \quad T = \alpha\beta(\frac{2}{\alpha+\beta})^2$$

$$(\alpha = \frac{\cos\theta_t}{\cos\theta_i} \quad \text{and} \quad \beta = \frac{\mu_1 n_2}{\mu_2 n_1})$$

Fresnel's Equation

- If direction of polarization is perpendicular to incident plane, transmittance and reflectivity is as follows

$$R = (\frac{1-\alpha\beta}{1+\alpha\beta})^2 \quad \text{and} \quad T = \alpha\beta(\frac{2}{1+\alpha\beta})^2$$
$$(\alpha = \frac{\cos\theta_t}{\cos\theta_i} \quad \text{and} \quad \beta = \frac{\mu_1 n_2}{\mu_2 n_1})$$

- Anyway, when total internal reflection occurs, α goes to 0, so R is equal to 1.
- That is, reflectivity is equal to 1.

Fresnel’s Equation

- By previous slide, we can check that Reflectivity is function of incident angle, refractive index of two medium.
- In Geant4, total reflection is realized as G4OpBoundaryProcess, and it means that we don’t have to set refractivity.
- Reflectivity will be determined automatically.

Mail from Kuraray

Osamu.Shinji@kuraray.com
Naoya.Sato, Yuuki.Imamiya, Shota.Moriyama, 나, Katsuhiro.Fujita에게

2019. 7. 16. 오후 6:10 (16시간 전)

영어 > 한국어 메일 번역 영어 번역 안함

Dear Jae Min Choi-san,

Thank you for your interesting for our fibers and your questions.
I am one of technicals of KURARAY's schintillating fiber for a long years.
I am trying to answer here to your questions, too.

Q1.
I cannot understand the meaning of your 'coating'.
Usually we uses 'coating' as a white coat or a black coat, for example, mainly in order to block and remove a cross-talk light from the neighbor fibers laying side-by-side.
If you must interested in our multi-cladding Y-11 fiber, our multi-cladding fiber has two cladding layers that have lower refractive indexes than the core polystyrene.
Therefore, our fiber can be an optical fiber in which optical rays can propagate by total reflection (reflection ratio is 100% thioretically) based on refractive index difference between core and cladding. The claddings here are not called as 'coating', as you know.
If you means 'coating' as a white paint or a aluminum spattering, both of them will be almost no use to increase light yield or fiber NA, although it is not easy to explain the reasons. .

Q2.
The trapping efficiency described in our web site is not observed value, but only one of simple calculations.
When one point at the center axe of WLS fiber emits green lights by a blue light irradiation from an outside scintillator,
the green light can be expected to spread spherically and isotropically.
Then the emitted lights between 0 and 26.7 degrees only can propagate to one fiber end.
This plus-minus 26.7 degrees of solid angle in circular cone vs. 4*PI (sphere) is correspond to 5.4% for our multi-cladding fiber.
This is our simple calculation as 5.4%.
If the emission point is not on the center of fiber axe, the value will be a different one.

Q3.
I guess you must need an information how the WLS Y-11 fiber can absorb the blue light that comes from outside of the fiber.
You can refer to the attached file, I believe it will be great helpful for you.

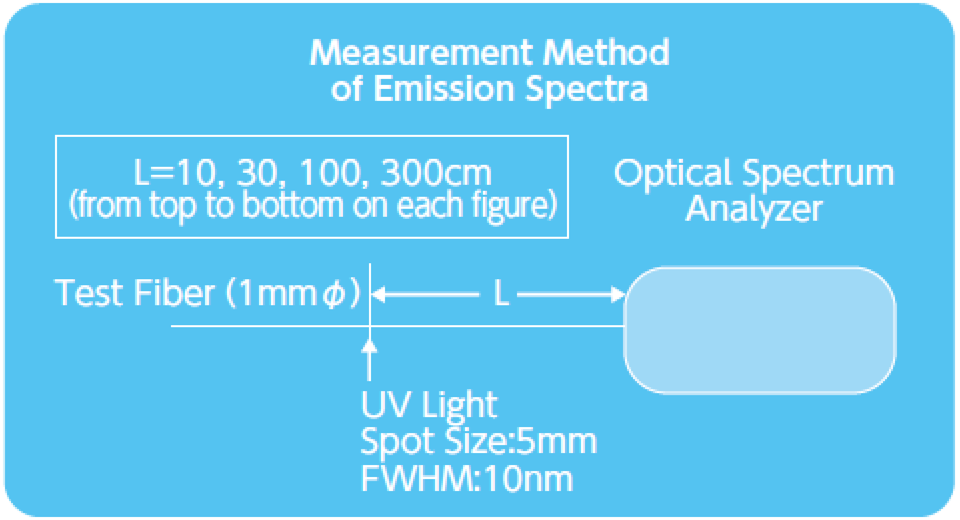
If any more questions or requests, please let me know.

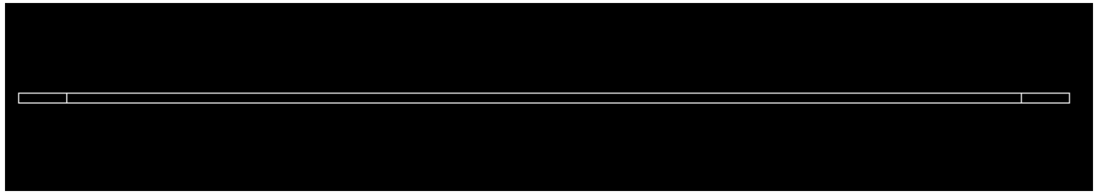
Thank you very much,

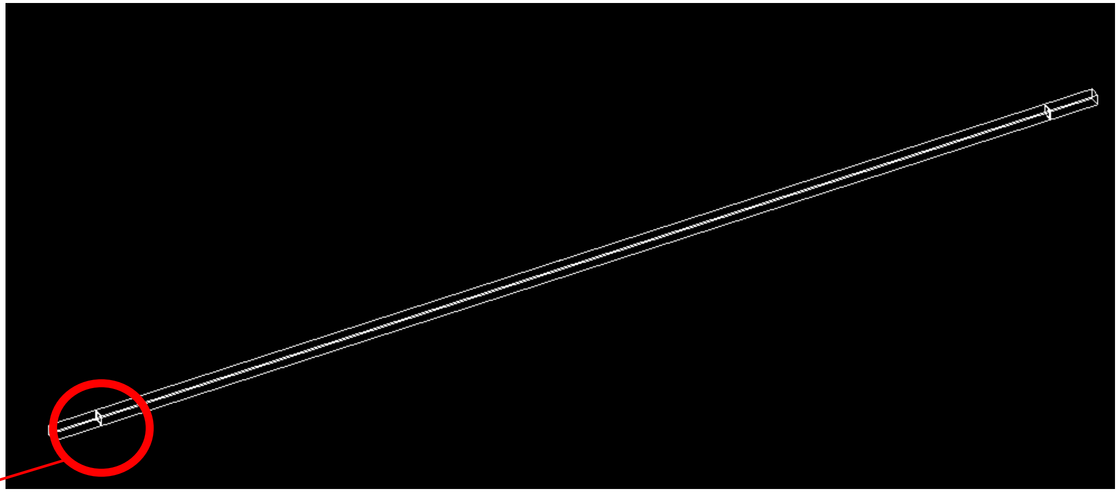
Osamu Shinji
KURARAY

- We can confirm this by mail from Kuraray.
- There is no white paint or aluminum spattering for increasing reflectivitiy.

Design of simulation

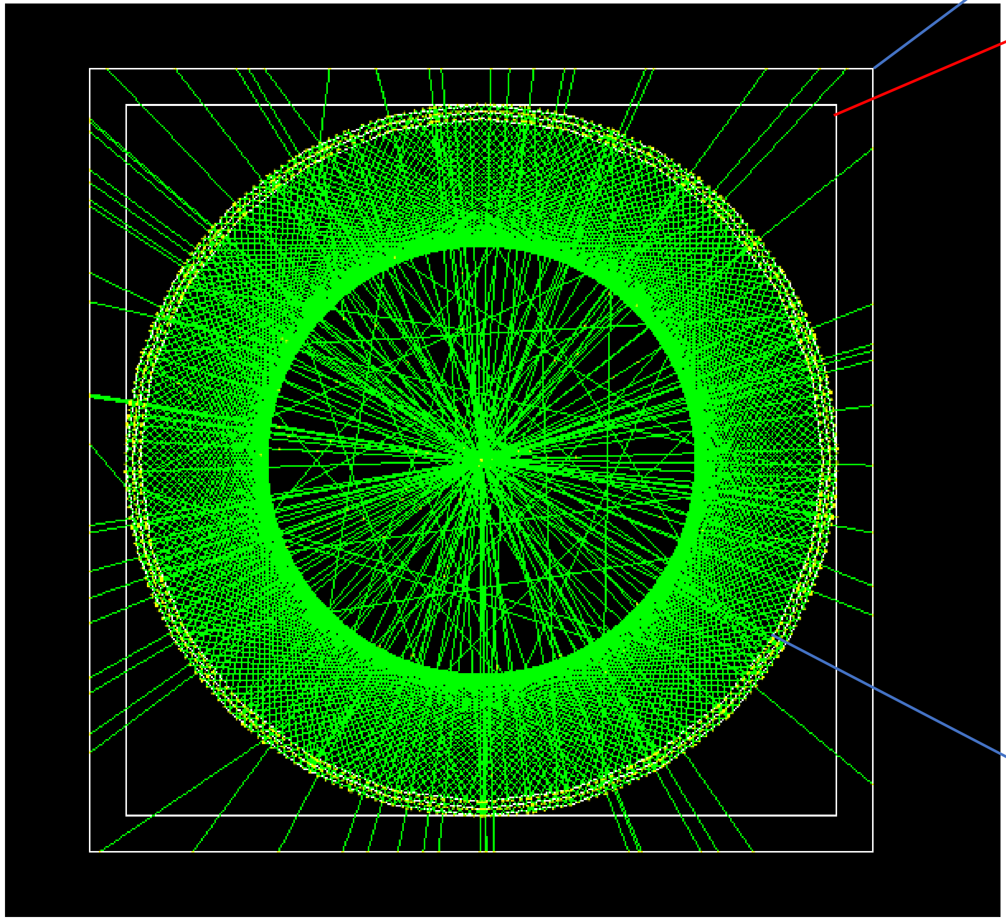


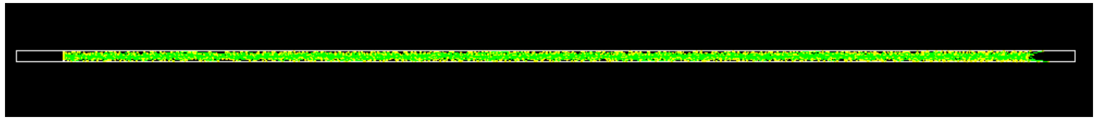


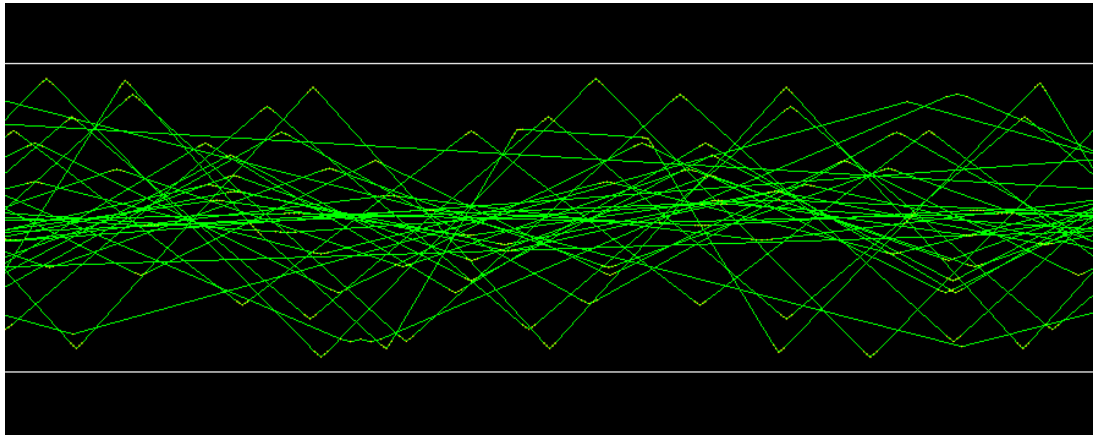


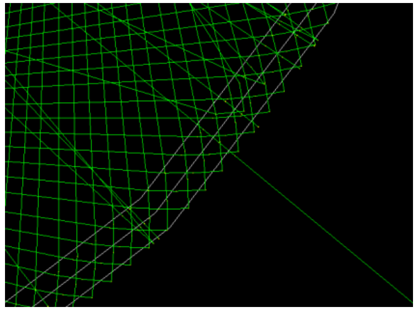
MPPC

Results of Simulation





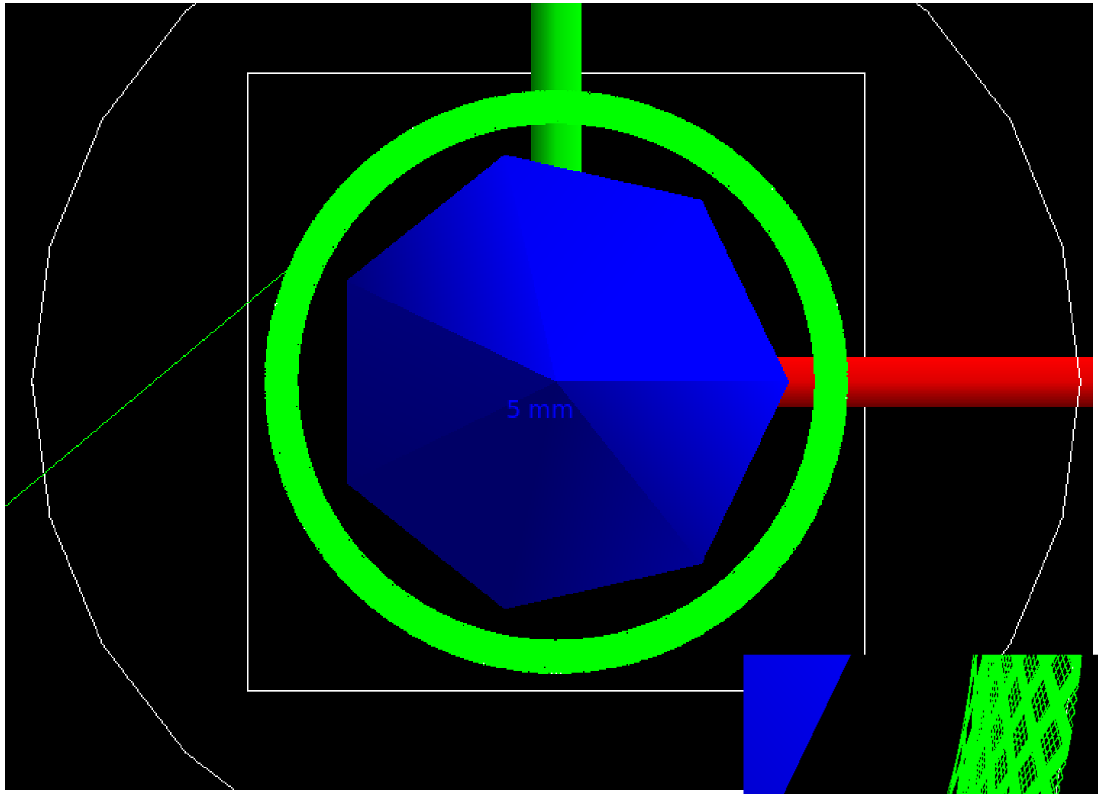


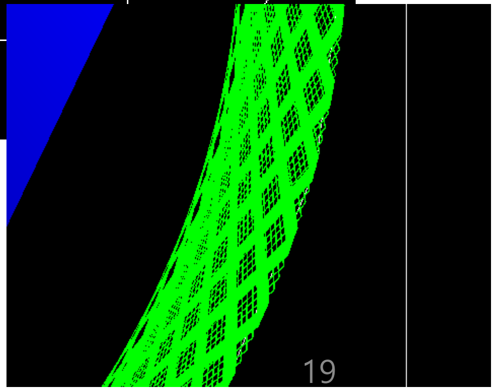


From the side near the center of the circle,
surface of core,
surface of cladding1(PMMA),
surface of cladding2(FP)

Visualization of example, WLS

- Compare the visualization results in previous slide, this is reasonable result.
- At least, total reflection work well.





Results of Simulation

- In visualization, photon looks like going out of fiber.
- However, by setting /tracking/verbose 2, we confirm that photon is reflected in WLS fiber.
- Some is between 1st and 2nd cladding and other is among core, 1st and 2nd cladding.
- Or going out of world.

```
*******************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 2,   Parent ID = 0
*******************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -49.9  2.88e-06        0        0         0 WLS_fiber_corePV initStep
    1        0        0    -35.8  2.88e-06        0     14.1      14.1 WLS_fiber_corePV OpWLS
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1), #SpawnTotal=  1 ---------------
    :         0         0     -35.8  2.41e-06      opticalphoton
    :----------------------------------------------------------------- EndOf2ndaries Info ---------------

*******************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 205,   Parent ID = 2
*******************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -35.8  2.41e-06        0        0         0 WLS_fiber_corePV initStep
    1    0.187   -0.442    -36.5  2.41e-06        0    0.871     0.871 WLS_fiber_cladding1PV Transportation
    2    0.191   -0.451    -36.6  2.41e-06        0    0.022     0.893 WLS_fiber_cladding2PV Transportation
    3    0.195    -0.46    -36.6  2.41e-06        0    0.028     0.921       World Transportation
    4    0.195    -0.46    -36.6  2.41e-06        0        0     0.921 WLS_fiber_cladding2PV Transportation
    5    0.191   -0.451    -36.6  2.41e-06        0    0.028     0.949 WLS_fiber_cladding1PV Transportation
    6    0.187   -0.442    -36.6  2.41e-06        0    0.022     0.971 WLS_fiber_corePV Transportation
    7   -0.187    0.442    -38.1  2.41e-06        0     1.74      2.71 WLS_fiber_cladding1PV Transportation
    8   -0.191    0.451    -38.1  2.41e-06        0    0.022      2.73 WLS_fiber_cladding2PV Transportation
    9   -0.195     0.46    -38.1  2.41e-06        0    0.028      2.76       World Transportation
   10   -0.195     0.46    -38.1  2.41e-06        0        0      2.76 WLS_fiber_cladding2PV Transportation
   11   -0.191    0.451    -38.2  2.41e-06        0    0.028      2.79 WLS_fiber_cladding1PV Transportation
   12   -0.187    0.442    -38.2  2.41e-06        0    0.022      2.81 WLS_fiber_corePV Transportation
   13    0.187   -0.442    -39.6  2.41e-06        0     1.74      4.55 WLS_fiber_cladding1PV Transportation
   14    0.191   -0.451    -39.7  2.41e-06        0    0.022      4.58 WLS_fiber_cladding2PV Transportation
   15    0.195    -0.46    -39.7  2.41e-06        0    0.028       4.6       World Transportation
   16    0.195    -0.46    -39.7  2.41e-06        0        0       4.6 WLS_fiber_cladding2PV Transportation
   17    0.191   -0.451    -39.7  2.41e-06        0    0.028      4.63 WLS_fiber_cladding1PV Transportation
   18    0.187   -0.442    -39.7  2.41e-06        0    0.022      4.65 WLS_fiber_corePV Transportation
   19   -0.187    0.442    -41.2  2.41e-06        0     1.74      6.39 WLS_fiber_cladding1PV Transportation
   20   -0.191    0.451    -41.2  2.41e-06        0    0.022      6.42 WLS_fiber_cladding2PV Transportation
   21   -0.195     0.46    -41.2  2.41e-06        0    0.028      6.44       World Transportation
   22   -0.195     0.46    -41.2  2.41e-06        0        0      6.44 WLS_fiber_cladding2PV Transportation
   23   -0.191    0.451    -41.2  2.41e-06        0    0.028      6.47 WLS_fiber_cladding1PV Transportation
   24   -0.187    0.442    -41.3  2.41e-06        0    0.022      6.49 WLS_fiber_corePV Transportation
   25    0.187   -0.442    -42.7  2.41e-06        0     1.74      8.24 WLS_fiber_cladding1PV Transportation
   26    0.191   -0.451    -42.7  2.41e-06        0    0.022      8.26 WLS_fiber_cladding2PV Transportation
   27    0.195    -0.46    -42.8  2.41e-06        0    0.028      8.29       World Transportation
   28    0.195    -0.46    -42.8  2.41e-06        0        0      8.29 WLS_fiber_cladding2PV Transportation
   29    0.191   -0.451    -42.8  2.41e-06        0    0.028      8.31 WLS_fiber_cladding1PV Transportation
   30    0.187   -0.442    -42.8  2.41e-06        0    0.022      8.34 WLS_fiber_corePV Transportation
   31   -0.187    0.442    -44.3  2.41e-06        0     1.74      10.1 WLS_fiber_cladding1PV Transportation
   32   -0.191    0.451    -44.3  2.41e-06        0    0.022      10.1 WLS_fiber_cladding2PV Transportation
   33   -0.195     0.46    -44.3  2.41e-06        0    0.028      10.1       World Transportation
   34   -0.195     0.46    -44.3  2.41e-06        0        0      10.1 WLS_fiber_cladding2PV Transportation
   35   -0.191    0.451    -44.3  2.41e-06        0    0.028      10.2 WLS_fiber_cladding1PV Transportation
   36   -0.187    0.442    -44.4  2.41e-06        0    0.022      10.2 WLS_fiber_corePV Transportation
   37    0.187   -0.442    -45.8  2.41e-06        0     1.74      11.9 WLS_fiber_cladding1PV Transportation
   38    0.187   -0.442    -45.8  2.41e-06        0        0      11.9 WLS_fiber_corePV Transportation
   39   -0.187    0.442    -47.3  2.41e-06        0     1.74      13.7 WLS_fiber_cladding1PV Transportation
   40   -0.191    0.451    -47.3  2.41e-06        0    0.022      13.7 WLS_fiber_cladding2PV Transportation
   41   -0.195     0.46    -47.3  2.41e-06        0    0.028      13.7       World Transportation
   42   -0.195     0.46    -47.3  2.41e-06        0        0      13.7 WLS_fiber_cladding2PV Transportation
   43   -0.191    0.451    -47.3  2.41e-06        0    0.028      13.7 WLS_fiber_cladding1PV Transportation
   44   -0.187    0.442    -47.4  2.41e-06        0    0.022      13.8 WLS_fiber_corePV Transportation
   45    0.187   -0.442    -48.8  2.41e-06        0     1.74      15.5 WLS_fiber_cladding1PV Transportation
   46    0.191   -0.451    -48.8  2.41e-06        0    0.022      15.5 WLS_fiber_cladding2PV Transportation
   47    0.195    -0.46    -48.8  2.41e-06        0    0.028      15.6       World Transportation
   48    0.195    -0.46    -48.8  2.41e-06        0        0      15.6 WLS_fiber_cladding2PV Transportation
   49    0.191   -0.451    -48.9  2.41e-06        0    0.028      15.6 WLS_fiber_cladding1PV Transportation
   50    0.187   -0.442    -48.9  2.41e-06        0    0.022      15.6 WLS_fiber_corePV Transportation
   51  -0.0975     0.23      -50  2.41e-06        0     1.32      16.9     MPPC2PV Transportation
   52   -0.111    0.261      -50  2.41e-06        0   0.0604        17       World Transportation
```

Results of Simulation

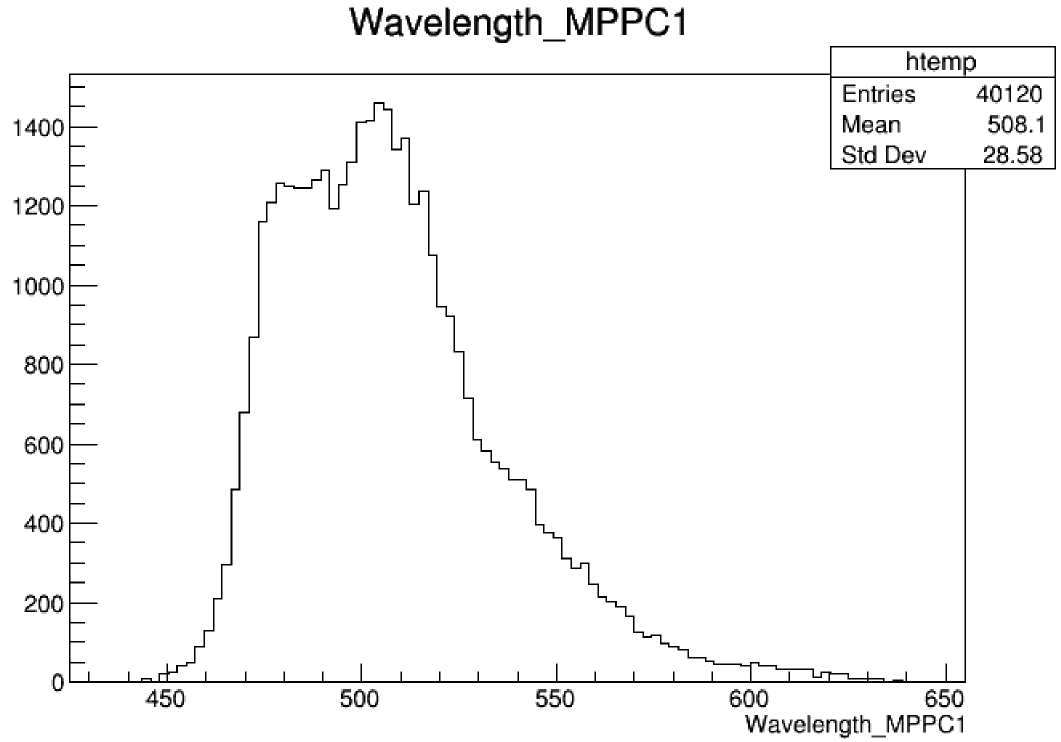
```
*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 26,   Parent ID = 0
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -49.9  2.88e-06        0        0         0 WLS_fiber_corePV initStep
    1        0        0    -43.3  2.88e-06        0     6.59      6.59 WLS_fiber_corePV OpWLS
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1), #SpawnTotal=  1 --------------
    :         0         0     -43.3  2.39e-06      opticalphoton
    :----------------------------------------------------------------- EndOf2ndaries Info ---------------

*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 180,   Parent ID = 26
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -43.3  2.39e-06        0        0         0 WLS_fiber_corePV initStep
    1   -0.449     0.17    -43.9  2.39e-06        0    0.799     0.799 WLS_fiber_cladding1PV Transportation
    2   -0.458    0.174      -44  2.39e-06        0   0.0192     0.818 WLS_fiber_cladding2PV Transportation
    3   -0.468    0.177      -44  2.39e-06        0   0.0224     0.841       World Transportation
    4   -0.468    0.177      -44  2.39e-06        0        0     0.841 WLS_fiber_cladding2PV Transportation
    5   -0.458    0.174      -44  2.39e-06        0   0.0224     0.863 WLS_fiber_cladding1PV Transportation
    6   -0.449     0.17      -44  2.39e-06        0   0.0192     0.882 WLS_fiber_corePV Transportation
    7    0.449    -0.17    -45.3  2.39e-06        0      1.6      2.48 WLS_fiber_cladding1PV Transportation
    8    0.458   -0.174    -45.3  2.39e-06        0   0.0192       2.5 WLS_fiber_cladding2PV Transportation
    9    0.468   -0.177    -45.3  2.39e-06        0   0.0224      2.52       World Transportation
   10    0.468   -0.177    -45.3  2.39e-06        0        0      2.52 WLS_fiber_cladding2PV Transportation
   11    0.458   -0.174    -45.4  2.39e-06        0   0.0224      2.54 WLS_fiber_cladding1PV Transportation
   12    0.449    -0.17    -45.4  2.39e-06        0   0.0192      2.56 WLS_fiber_corePV Transportation
   13   -0.449     0.17    -46.7  2.39e-06        0      1.6      4.16 WLS_fiber_cladding1PV Transportation
   14   -0.458    0.174    -46.7  2.39e-06        0   0.0192      4.18 WLS_fiber_cladding2PV Transportation
   15   -0.468    0.177    -46.7  2.39e-06        0   0.0224      4.2        World Transportation
   16   -0.468    0.177    -46.7  2.39e-06        0        0       4.2 WLS_fiber_cladding2PV Transportation
   17   -0.458    0.174    -46.7  2.39e-06        0   0.0224      4.23 WLS_fiber_cladding1PV Transportation
   18   -0.449     0.17    -46.7  2.39e-06        0   0.0192      4.25 WLS_fiber_corePV Transportation
   19    0.449    -0.17      -48  2.39e-06        0      1.6      5.84 WLS_fiber_cladding1PV Transportation
   20    0.458   -0.174      -48  2.39e-06        0   0.0192      5.86 WLS_fiber_cladding2PV Transportation
   21    0.468   -0.177      -48  2.39e-06        0   0.0224      5.89       World Transportation
   22    0.468   -0.177      -48  2.39e-06        0        0      5.89 WLS_fiber_cladding2PV Transportation
   23    0.458   -0.174    -48.1  2.39e-06        0   0.0224      5.91 WLS_fiber_cladding1PV Transportation
   24    0.449    -0.17    -48.1  2.39e-06        0   0.0192      5.93 WLS_fiber_corePV Transportation
   25   -0.449     0.17    -49.4  2.39e-06        0      1.6      7.53 WLS_fiber_cladding1PV Transportation
   26   -0.449     0.17    -49.4  2.39e-06        0        0      7.53 WLS_fiber_corePV Transportation
   27  0.00652 -0.00247      -50  2.39e-06        0    0.811      8.34     MPPC2PV Transportation
   28   0.0427  -0.0162      -50  2.39e-06        0   0.0632       8.4       World Transportation
```

- Reflected among core, 1st and 2nd cladding

```
*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 28,   Parent ID = 0
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -49.9  2.88e-06        0        0         0 WLS_fiber_corePV initStep
    1        0        0    -43.8  2.88e-06        0     6.13      6.13 WLS_fiber_corePV OpWLS
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1), #SpawnTotal=  1 --------------
    :         0         0     -43.8  2.61e-06      opticalphoton
    :----------------------------------------------------------------- EndOf2ndaries Info ---------------

*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 178,   Parent ID = 28
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -43.8  2.61e-06        0        0         0 WLS_fiber_corePV initStep
    1   -0.422   -0.229    -43.8  2.61e-06        0    0.481     0.481 WLS_fiber_cladding1PV Transportation
    2   -0.431   -0.234    -43.8  2.61e-06        0     0.01     0.491 WLS_fiber_cladding2PV Transportation
    3    -0.44   -0.238    -43.8  2.61e-06        0     0.01     0.501       World Transportation
    4    -0.55   -0.298    -43.8  2.61e-06        0    0.126     0.627  OutOfWorld Transportation

*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 27,   Parent ID = 0
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -49.9  2.88e-06        0        0         0 WLS_fiber_corePV initStep
    1        0        0    -43.3  2.88e-06        0     6.62      6.62 WLS_fiber_corePV OpWLS
    :----- List of 2ndaries - #SpawnInStep=  1(Rest= 0,Along= 0,Post= 1), #SpawnTotal=  1 --------------
    :         0         0     -43.3  2.56e-06      opticalphoton
    :----------------------------------------------------------------- EndOf2ndaries Info ---------------

*******************************************************************************************
* G4Track Information:   Particle = opticalphoton,   Track ID = 179,   Parent ID = 27
*******************************************************************************************

Step#    X(mm)    Y(mm)    Z(mm) KinE(MeV)  dE(MeV) StepLeng TrackLeng  NextVolume ProcName
    0        0        0    -43.3  2.56e-06        0        0         0 WLS_fiber_corePV initStep
    1    0.163    0.451    -43.5  2.56e-06        0    0.541     0.541 WLS_fiber_cladding1PV Transportation
    2    0.167    0.461    -43.5  2.56e-06        0   0.0115     0.553 WLS_fiber_cladding2PV Transportation
    3     0.17     0.47    -43.5  2.56e-06        0   0.0117     0.564       World Transportation
    4    0.199     0.55    -43.6  2.56e-06        0    0.125     0.689  OutOfWorld Transportation
```

- Going out of World

Result of Simulation



- However, trapping efficiency obtained by simulation, is far larger than we expected.
- Also, the shape of graph differ from we expected.
- There be more problem.

Absorption Length

Experiments for absorption length

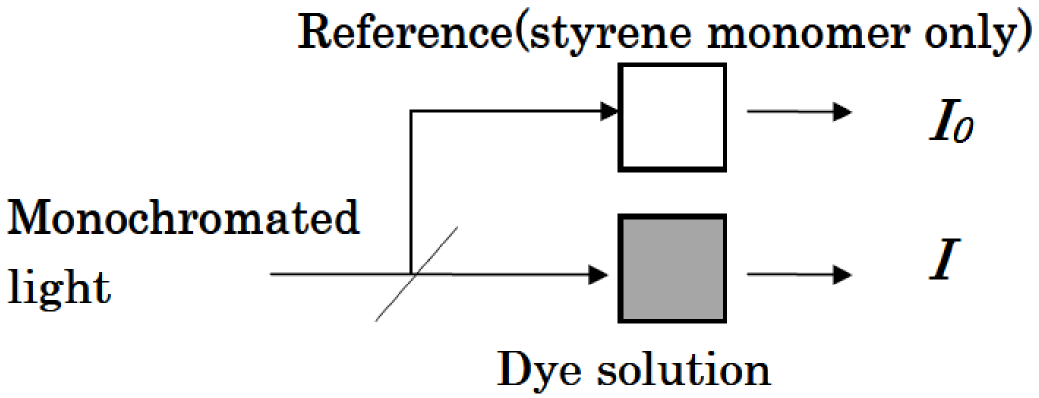
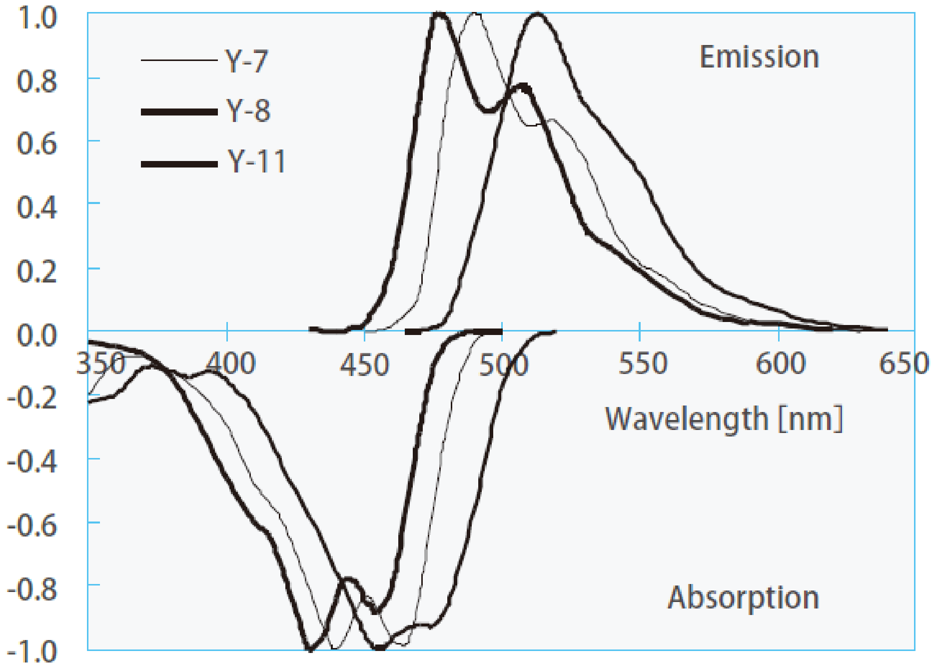


Fig.1 Absorbance measurement
by d=10mm path cell

Y-7, Y-8, Y-11



Absorbance

- Mathematically, probability of finding a particle at depth x into the material in calculated by Beer-Lambert Law

$$P(x) = e^{-x/\lambda}$$

- And λ is attenuation(absorption) length, and it depend on material and energy.
- Definition of absorbance is as follow.

$$\text{ABS} = k(\lambda)Cd = log_{10}\{\frac{I_0(\lambda)}{I(\lambda)}\} \qquad \text{when d = 10 mm}$$

- For reference, C is equal to 18.2 ppm and k_p(k at peak of abosorption) is equal to 0.00638 in Y-11 of Kurarary

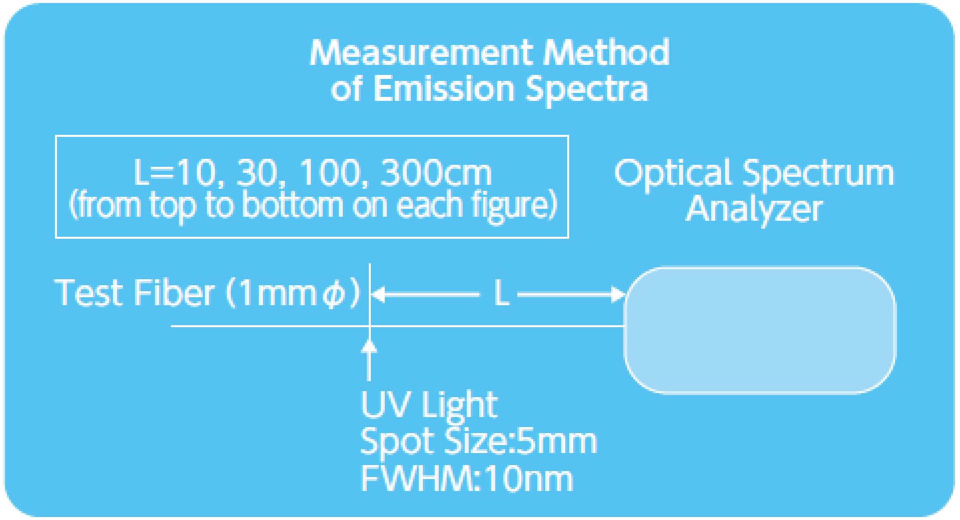
Changing parameter used in Geant4

- If assume that y-axis of absorption spectrum is k, absorption(attenuation) length of Y-11 is as follow.

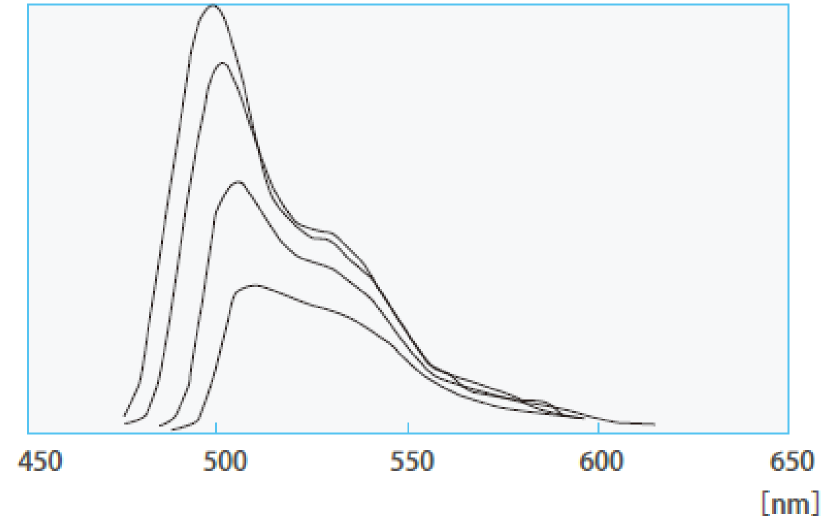
$$\lambda = \frac{1}{kC * ln10}$$

- C is concentration of dyne used in Y-11 and k is constant which is function of wavelength.

Comparison of simulation



Y-11(200)

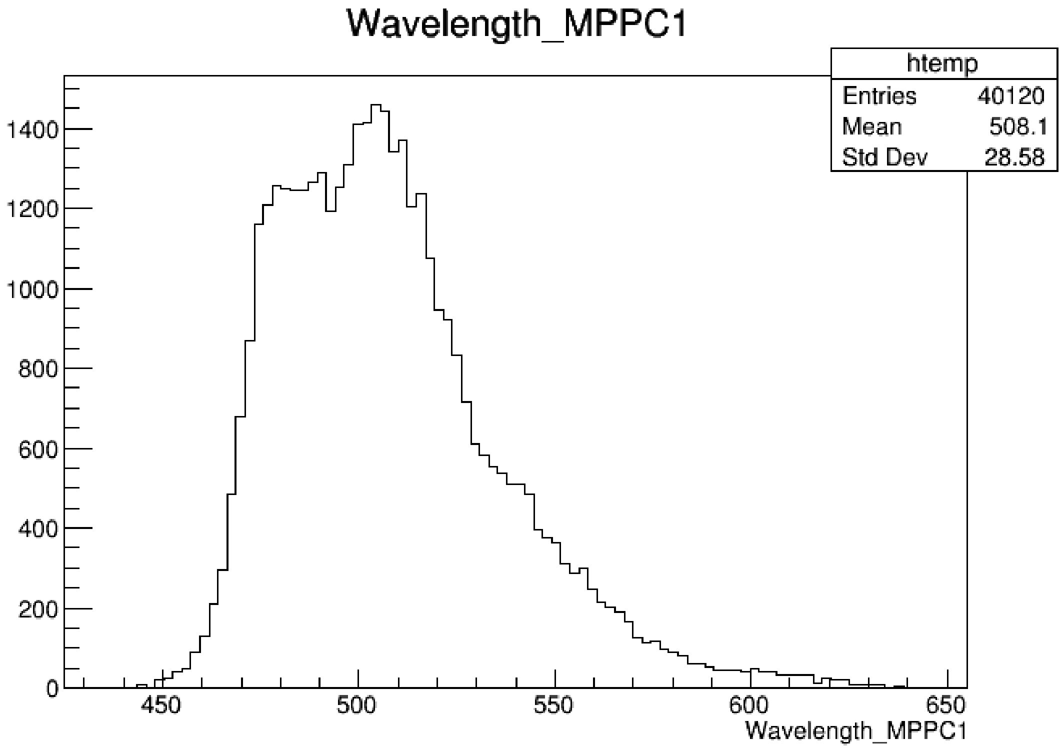


Exiting Wavelength:430nm

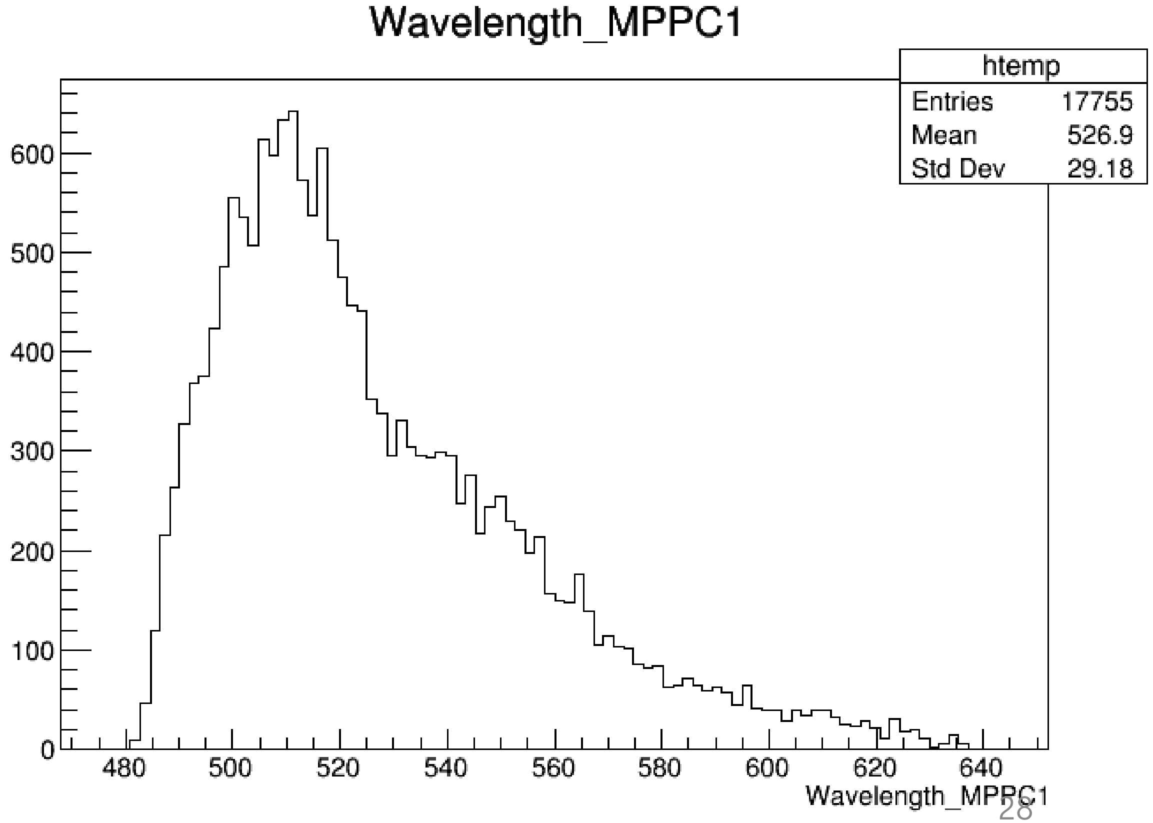
When photon of a wavelength of 430nm shoot in the end of fiber, the emission spectrum should be same as the right.

Comparison with reference

For 10 cm

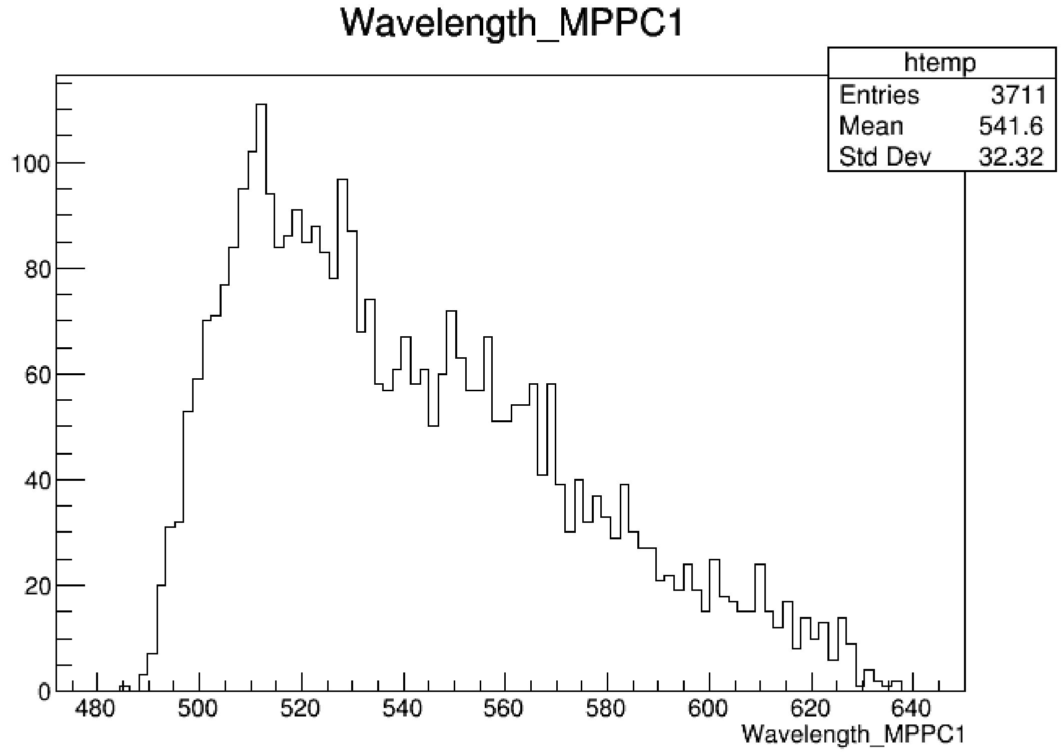


For 30 cm

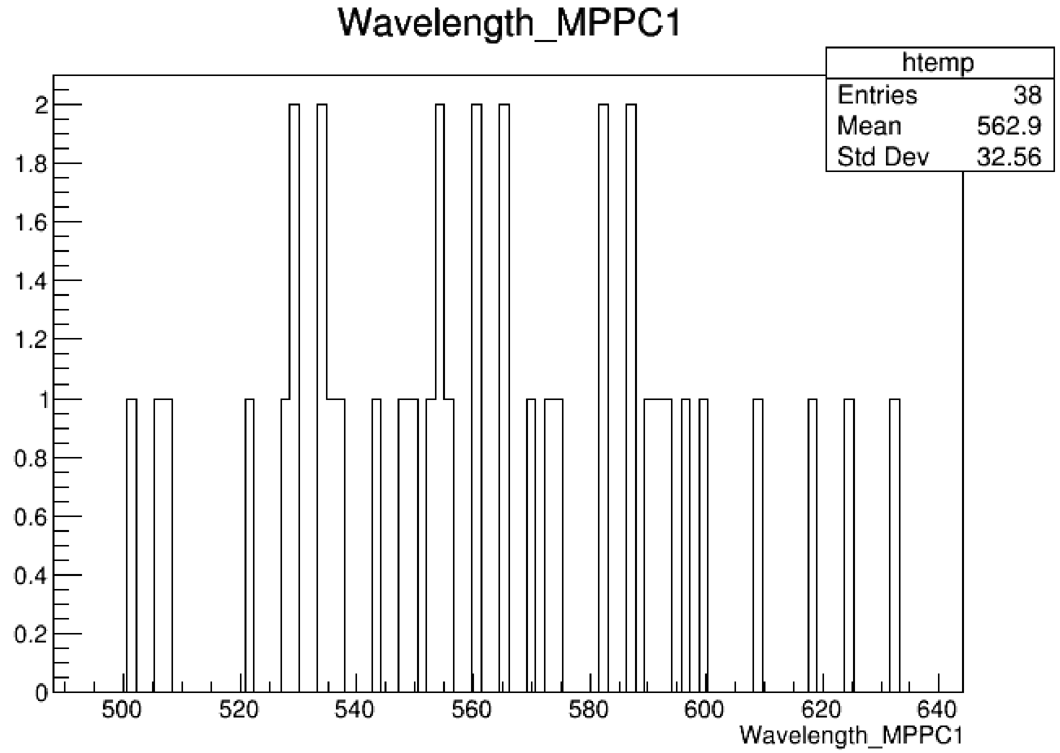


Comparison with reference

For 100 cm



For 300 cm

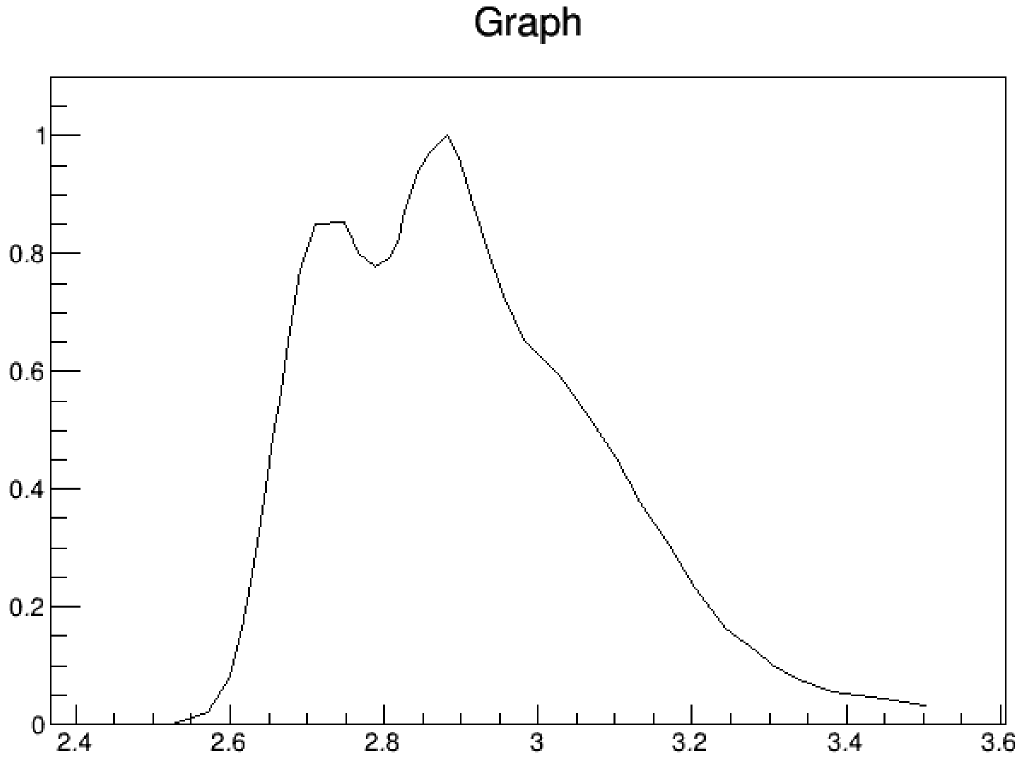


Problem

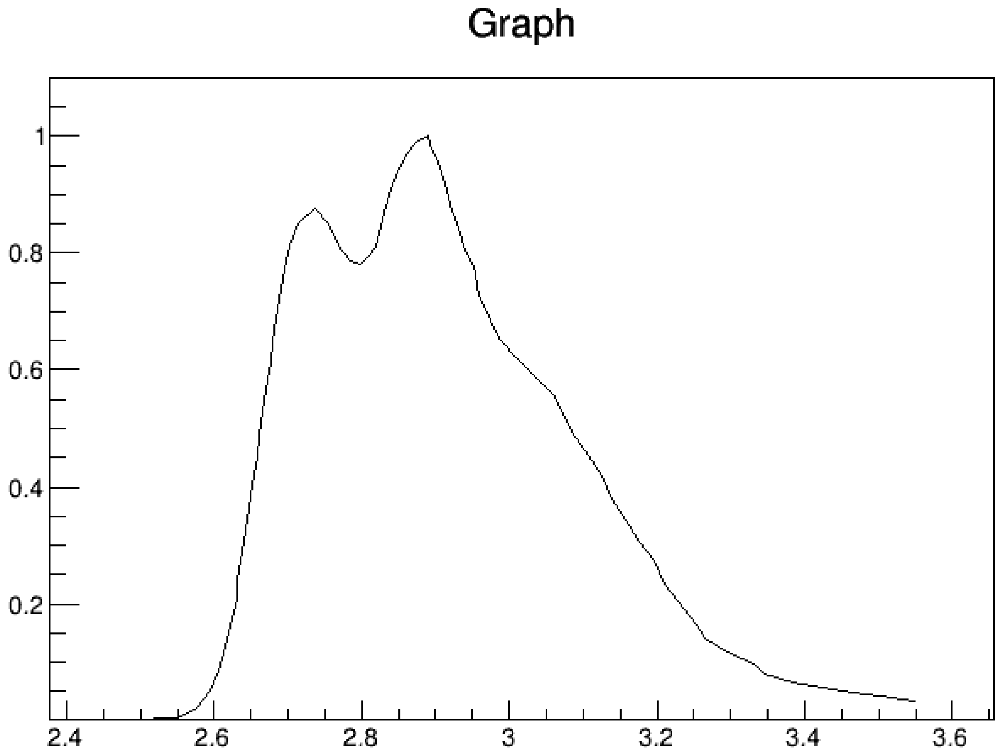
- However, the shape of graph is not exactly same with reference.
- Also, there is problem of trapping efficiency, that is, the value of probability is much higher than we expected, about 5 times.(in 10cm)
- According to mail from Kuraray, trapping efficiency is calculated only in axis. For this reason, we need to calculate trapping efficiency more detail.

Backup

Absorption spectrum used before



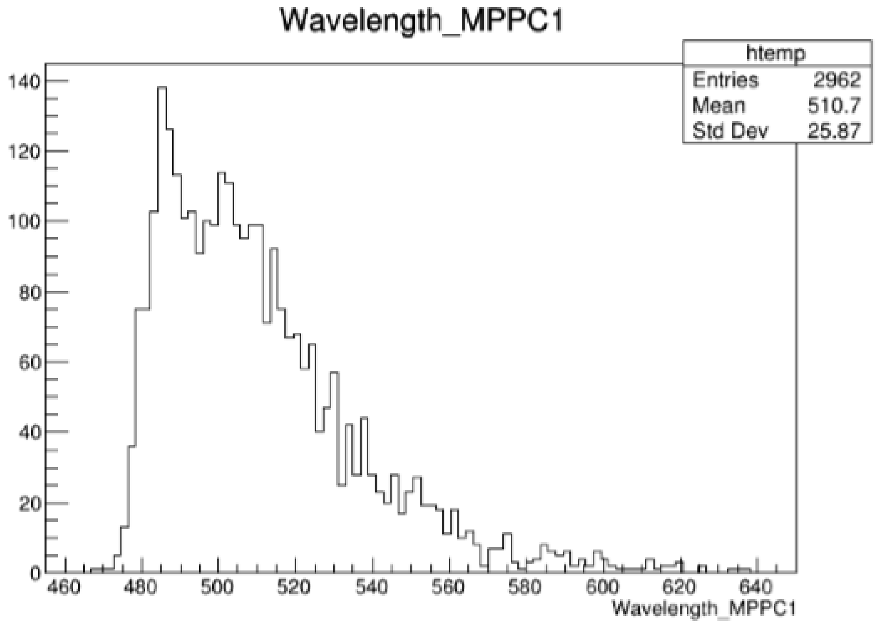
Absorption spectrum used after



Backup

Before

For 30 cm



After

For 30 cm