DCV Simulation

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Introduction

- E14 KOTO is Experiment to find $K_L \rightarrow \pi^0 + \mathrm{v} + \mathrm{v}$ which is evidence of CP violation.
- However it is hard to search v, because it is neutral and too light to detect.
- For this reason, we decide to find π^0 from $K_L \rightarrow \pi^0 + \mathrm{v} + \mathrm{v}$ by veto the background K_L decay.
- Downstream Charged Veto(DCV) is detector for search and veto π^+ and π^- which is background of K_L decay, that is $K_L \rightarrow \pi^0 + \pi^+ + \pi^-$.

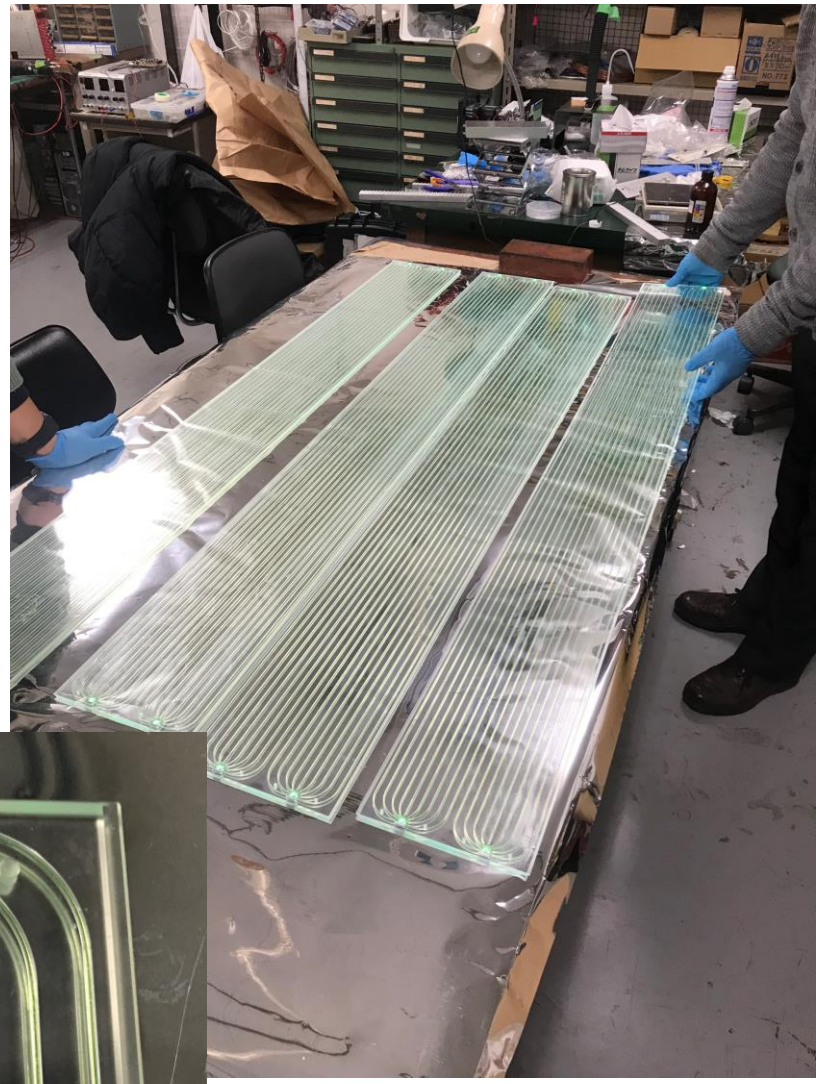
- And this simulation is for DCV.

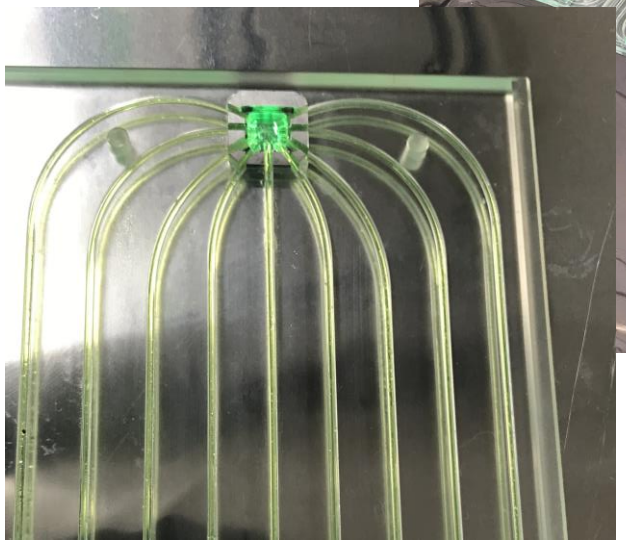
Downstream Charged Veto Construction

- One DCV has pipe form and each surface is plastic scintillator which is wrapped by aluminum reflector.

Plastic Scintillator in DCV

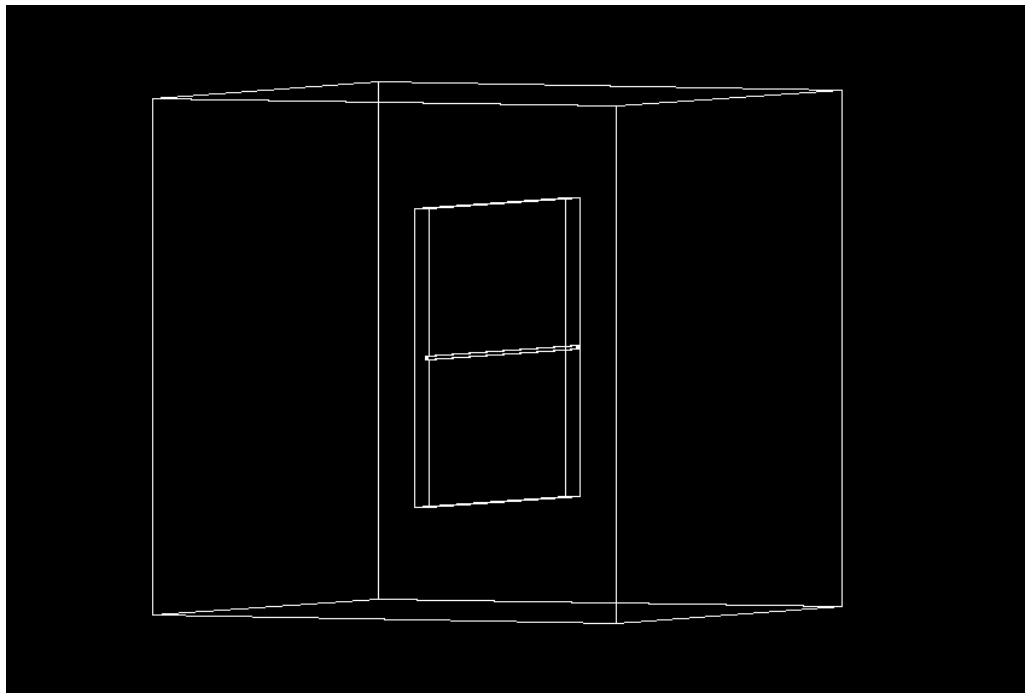
- DCV consist of four plastic scintillator, EJ-200, which is 1410mm long with a cross section $5 * 171.5\ mm^2$
- Each Scintillator has 18 grooves for wavelength shifting fibers, which are guided to Al light-collection boxes at both ends.

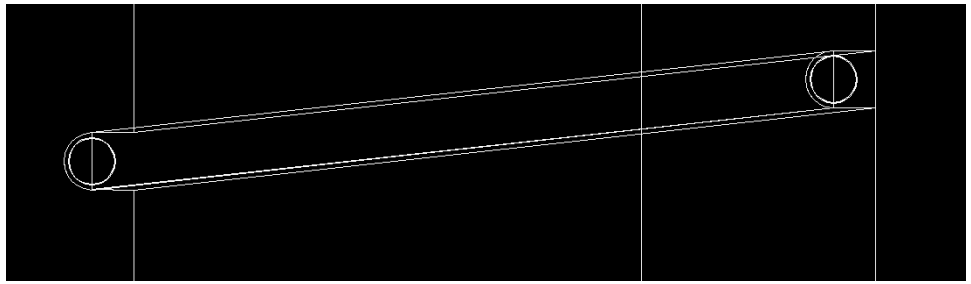




Simulation of Scintillator

- To simulate one plastic scintillator in DCV, we make one groove in plastic scintillator.
- And put wavelength shifting fiber which consist of core and cladding in groove, and fill groove with with optical cement.





Properties of EJ-200

PROPERTIES	EJ-200	EJ-204	EJ-208	EJ-212
Light Output (% Anthracene)	64	68	60	65
Scintillation Efficiency (photons/1 MeV e^-)	10,000	10,400	9,200	10,000
Wavelength of Maximum Emission (nm)	425	408	435	423
Light Attenuation Length (cm)	380	160	400	250
Rise Time (ns)	0.9	0.7	1.0	0.9
Decay Time (ns)	2.1	1.8	3.3	2.4
Pulse Width, FWHM (ns)	2.5	2.2	4.2	2.7
No. of H Atoms per cm^3 ($x10^{22}$)	5.17	5.15	5.17	5.17
No. of C Atoms per cm^3 ($x10^{22}$)	4.69	4.68	4.69	4.69
No. of Electrons per cm^3 ($x10^{23}$)	3.33	3.33	3.33	3.33
Density (g/cm^3)	1.023	1.023	1.023	1.023
Polymer Base	Polyvinyltoluene			
Refractive Index	1.58			
Softening Point	75°C			
Vapor Pressure	Vacuum-compatible			
Coefficient of Linear Expansion	7.8 x 10^{-5} below 67°C			
Light Output vs. Temperature	At 60°C, L.O. = 95% of that at 20°C No change from 20°C to -60°			
Temperature Range	-20°C to 60°C			

- The properites of EJ-200 which is used to realize are below.

- Material properties

Composition, Density(1.023g/cm3)

- Scintillation Process

Scintillation efficiency(10,000/1MeV), Decay time(2.1ns)

- Cerenkov Process

Refractive index(1.58)

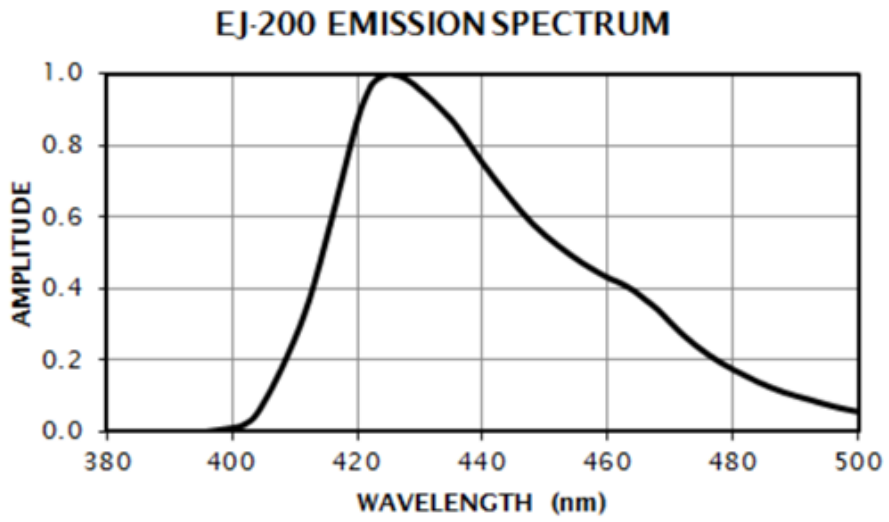
- Absorption Process

Light attenuation length

Cf) Property which cannot be used

Rise time(0.9ns) in Scintillation

Emission spectrum of EJ-200



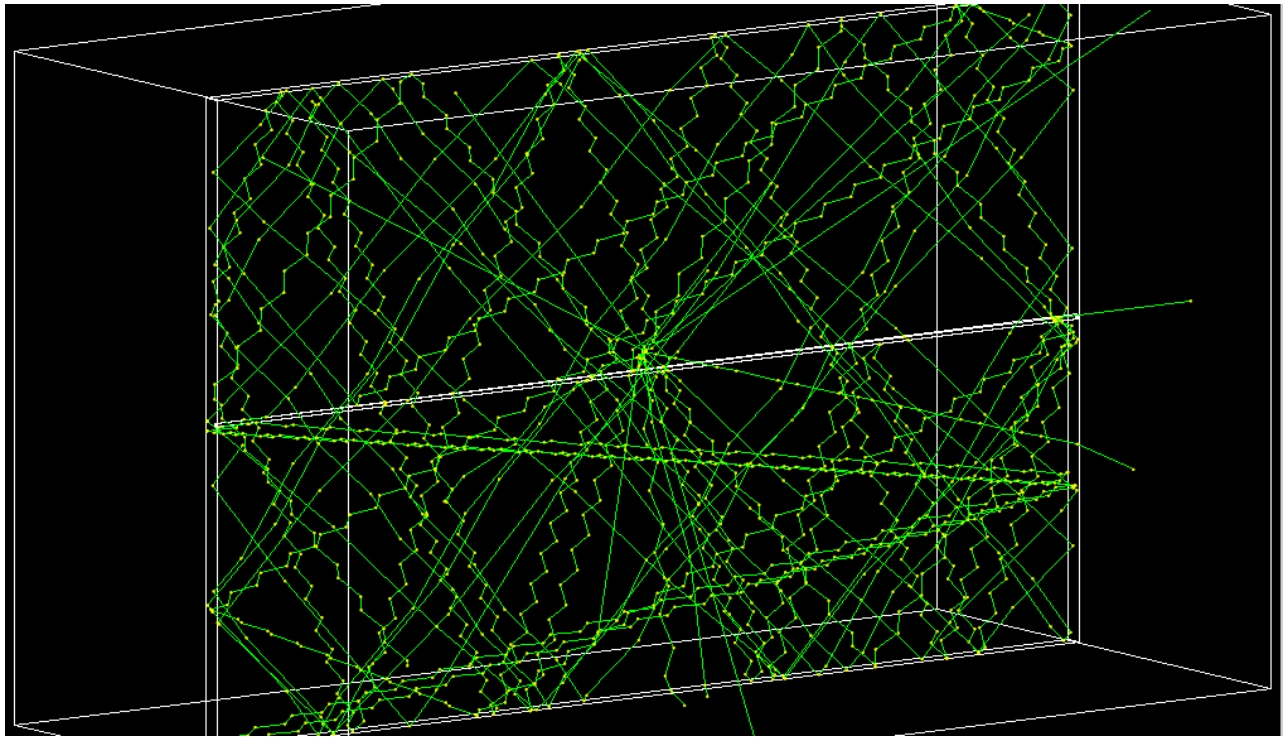

```
G4double PhotonEnergy[] =
  {
    3.100*eV, 3.061*eV, 3.024*eV, 2.988*eV,
    2.952*eV, 2.917*eV, 2.883*eV, 2.850*eV,
    2.818*eV, 2.786*eV, 2.755*eV, 2.725*eV,
    2.695*eV, 2.666*eV, 2.638*eV, 2.610*eV,
    2.583*eV, 2.556*eV, 2.530*eV, 2.505*eV,
    2.480*eV
  };
G4double Scintillation_EJ200[] =
      {
              0, 0.17, 0.21, 0.5,
              0.88, 1.0, 0.91, 0.83,
              0.77, 0.62, 0.5, 0.47,
              0.42, 0.37, 0.31, 0.21,
              0.18, 0.14, 0.1, 0.09,
              0.08

      };
```

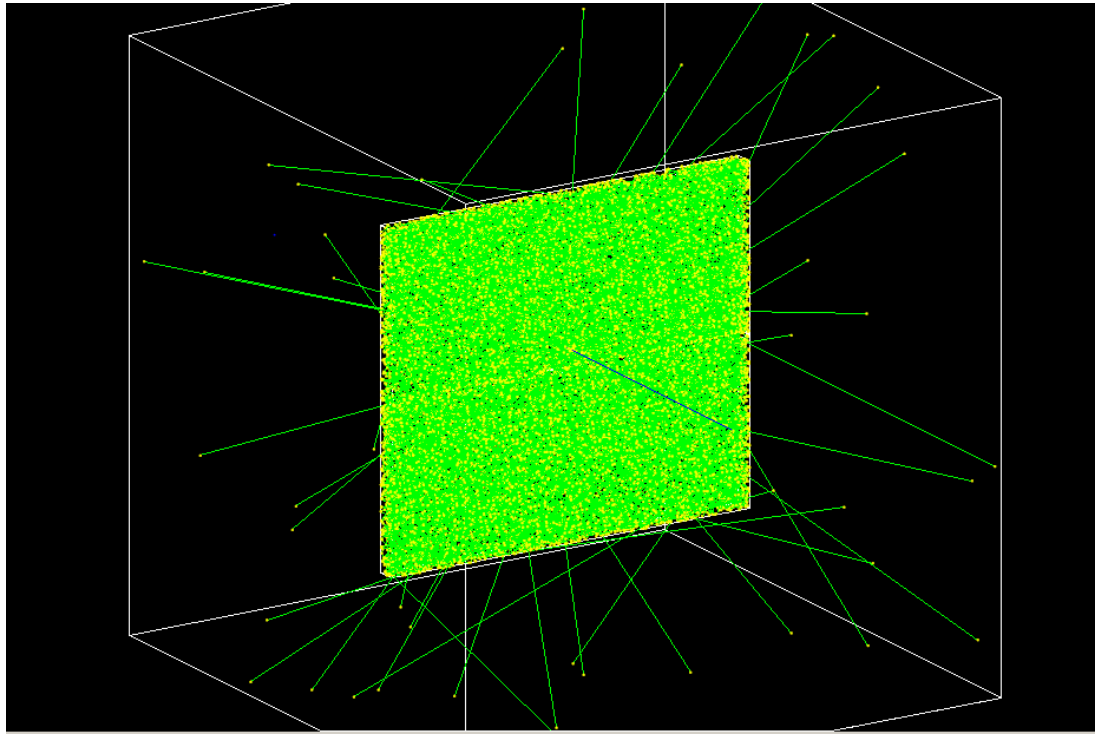
- Emission spectrum of scintillation process of EJ-200 is above.
- Explain how simulation is operated, first of all shoot particle deposit energy on scintillator.
- And then by emission spectrum, how much energy will be emitted in some wavelength is determined.
- In last, the number of photon in some wavelength is calculated by equation energy/ h*frequency.

Visualization of Simulation

- In the middle of simulation



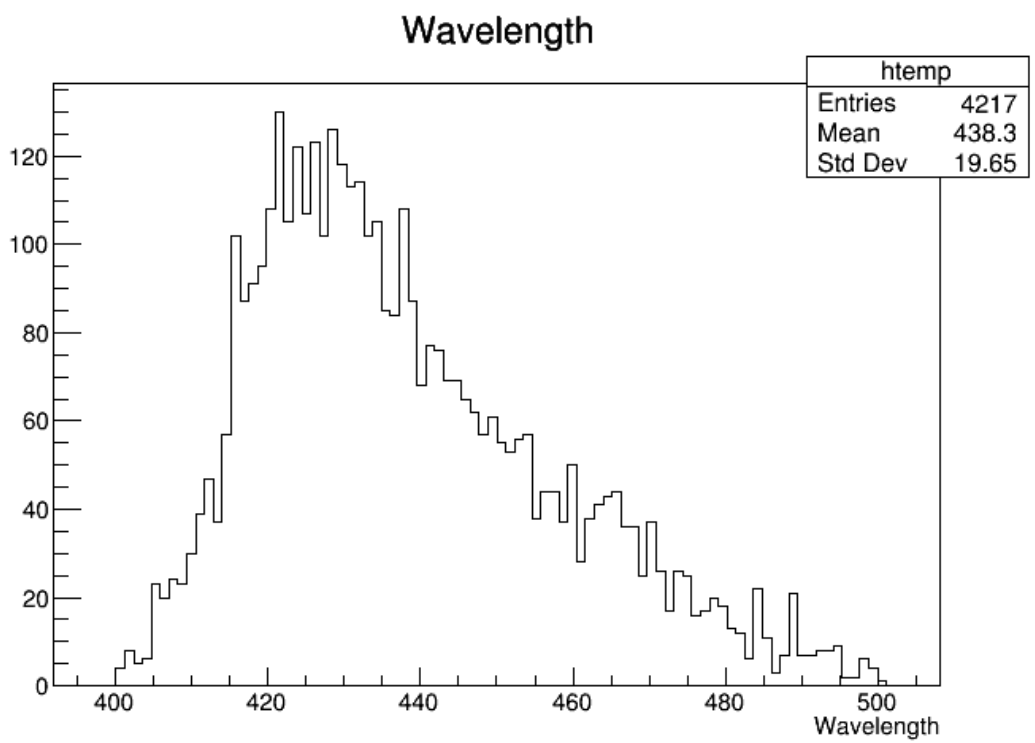
- After the end of simulation



- Result of simulation

(Even though scintillation yield of EJ-200 is 10,000/MeV, for releasing burden of computer set scintillation yield as 100/MeV)

Wavelength of photon



- Graph in left is wavelength of photon which is emitted by scintillation process.
- Compare with Emission spectrum, we can sure that this is reasonable result.

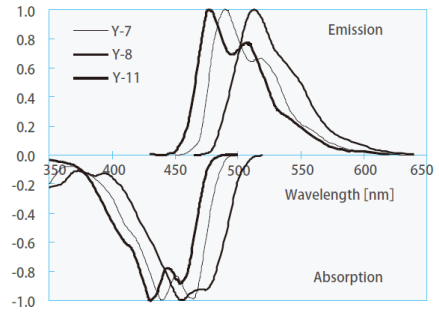
WLS-Fiber Y-11

Formulations [1]

Description	Emission			Absorption Peak[nm]	Att.Leng.[2] [m]	Characteristics
	Color	Spectra	Peak[nm]			
Y-7(100)	green	See the following figure	490	439	>2.8	Blue to Green Shifter
Y-8(100)	green		511	455	>3.0	Blue to Green Shifter
Y-11(200)	green		476	430	>3.5	Blue to Green Shifter (K-27 formulation) Long Attenuation Length and High Light Yield
B-2(200)	blue		437	375	>3.5	UV to Blue shifter
B-3(200)	blue		450	351	>4.0	UV to Blue shifter
O-2(100)	orange		550	535	>1.5	Green to orange shifter
R-3(100)	red		610	577	>2.0	Green to red shifter

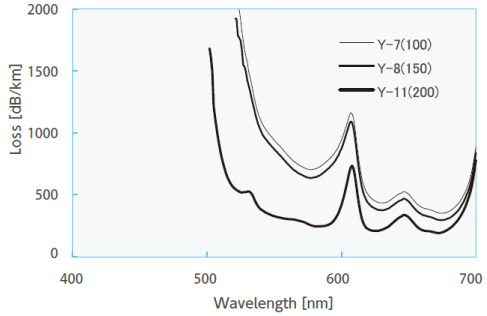
Absorption and Emission Spectra

Y-7, Y-8, Y-11



Transmission Loss

Y-7, Y-8, Y-11



- Properties which used to realize simulation is below

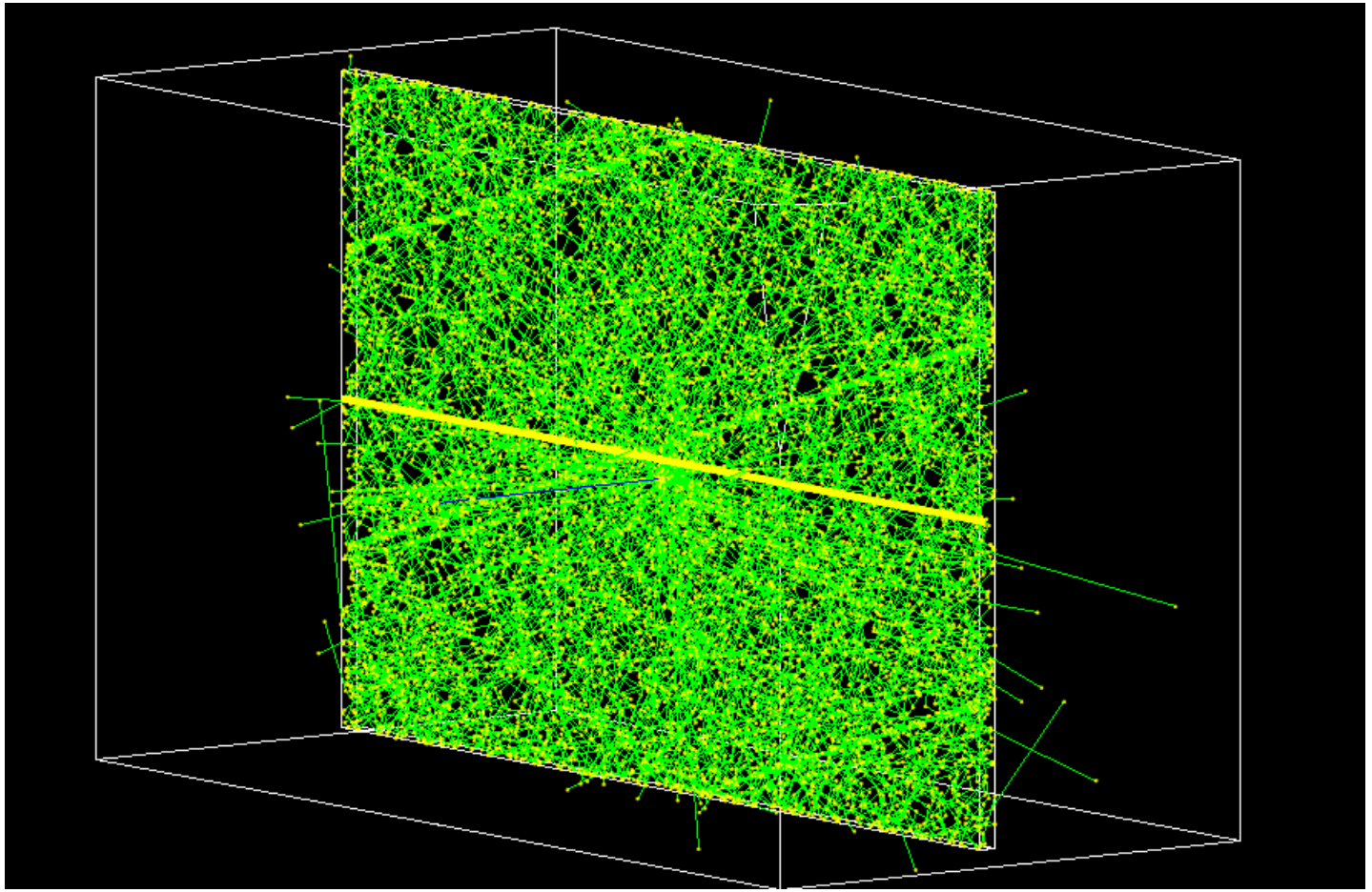
- Core

Composition, Density, Absorption spectra, Emission spectra, Refractive index

- Cladding

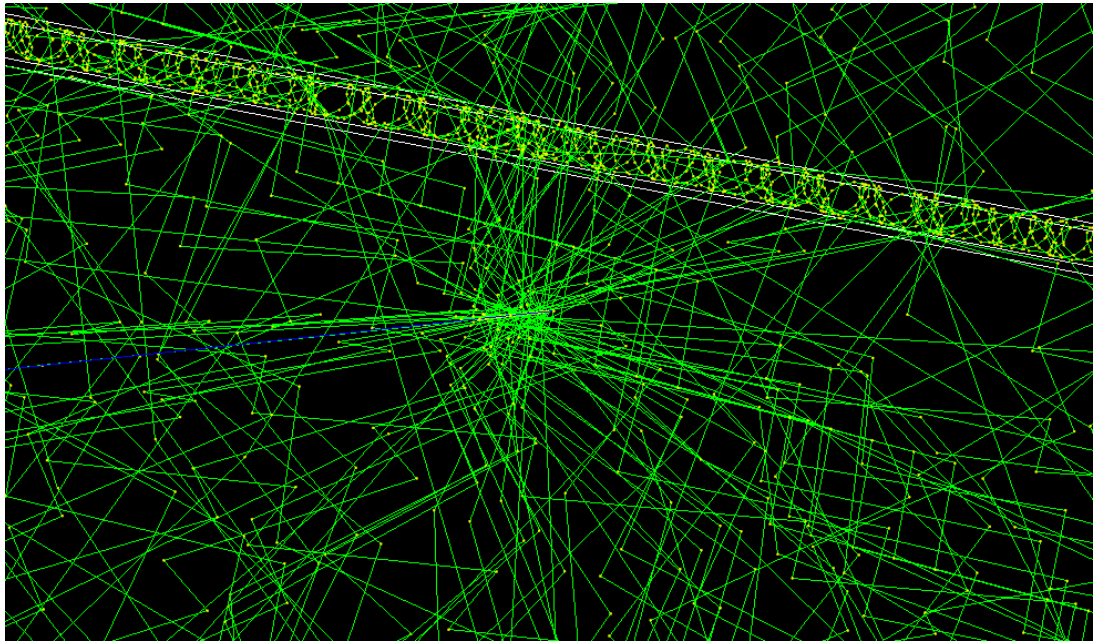
Refractive index

Simulation result with WLS-fiber



- The Result when scintillation yield is 100/MeV

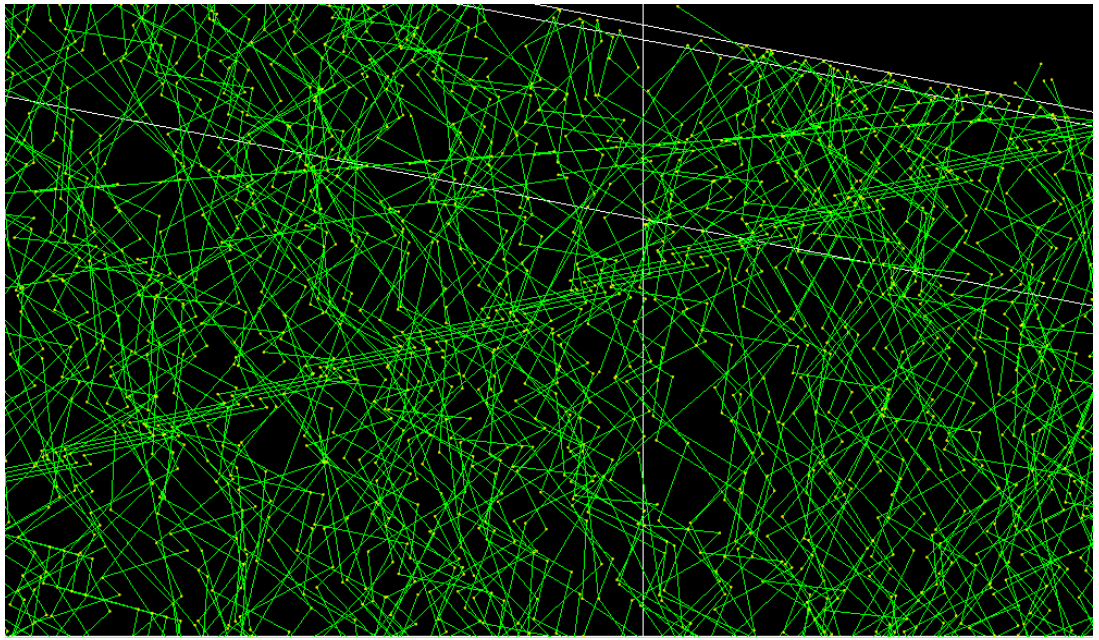
Simulation for Scintillation process



- Scintillation yield 100/MeV
- Shooted particle : mu+
- Energy of particle : 100GeV

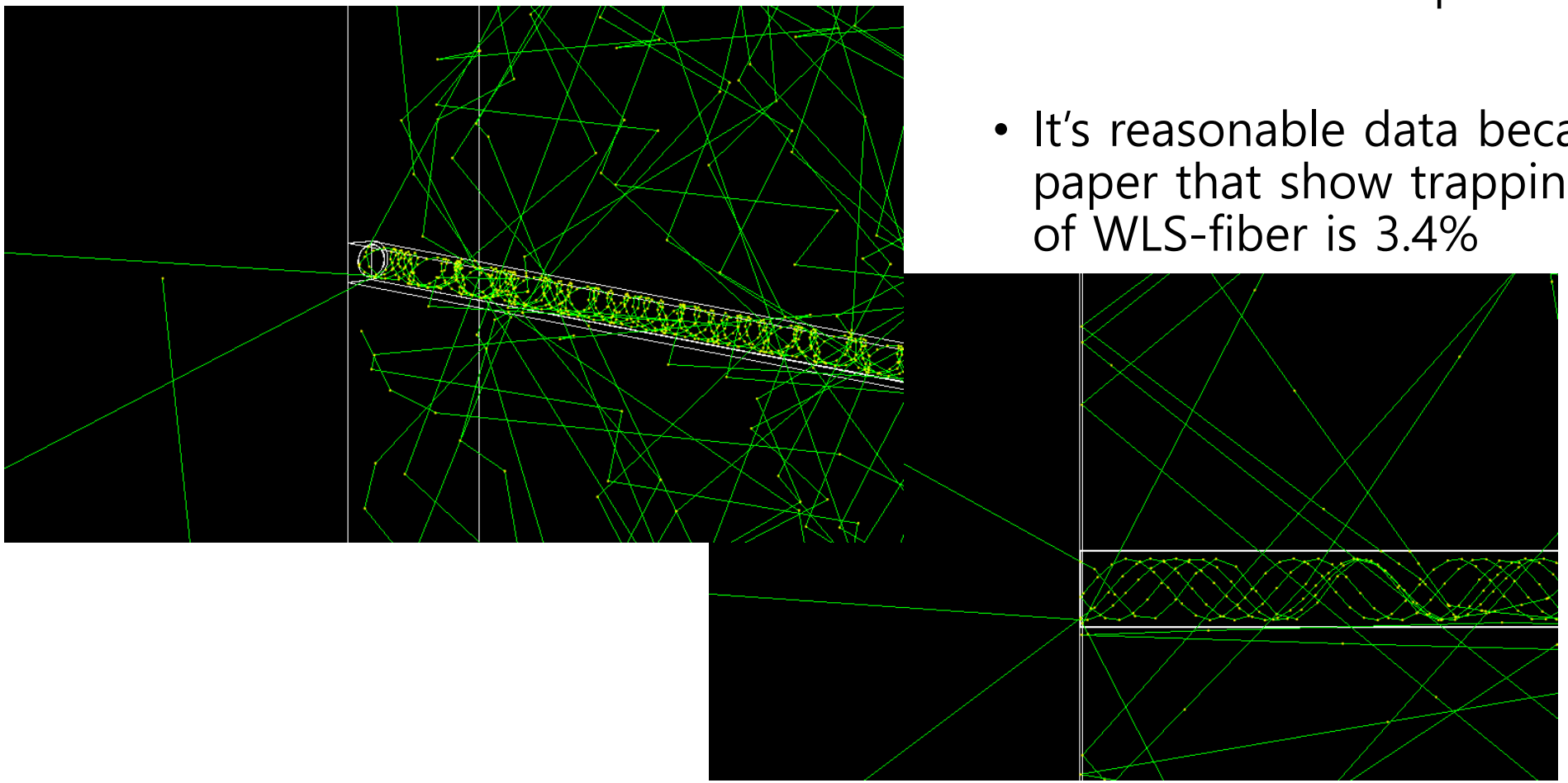
- Scintillation process : 65
- Cerenkov process : 30

Total Reflection



- Considering of refractive index of Plastic Scintillator 1.58, incident angle should be larger than 39.27.
- The probability of total reflection is 0.766

Simulation



- The number of Captured photon : 3
- It’s reasonable data because there is paper that show trapping efficiency of WLS-fiber is 3.4%

Capture in WLS-fiber