Simulation study for the Scintillator Properties of DCV

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Motivation

- Downstream Charged Veto(DCV) detects π^+ and π^- to reject $K_L \rightarrow \pi^0 + \pi^+ + \pi^-$ decay.
- DCV is composed of 4 long scintillator and Each scintillator has 1460mm length and 5 X 173.5 mm^2 cross section.
- In one scintillator, there are 18 grooves for WLS fibers which are guided to aluminum light-collecting box.
- Since DCV operates in narrow membrane, it is in form of pipe and receives signal by MPPC.
- At this time, WLS fibers collect the photons and shift it into wavelength of high efficiency for MPPC.
- The purpose of this simulation is to understand detection process of DCV which is how detect π^+ and π^- and how does photon propagate

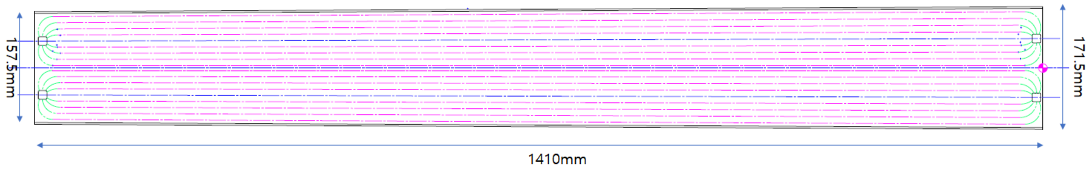


Fig 2–a. blueprint of DCV1

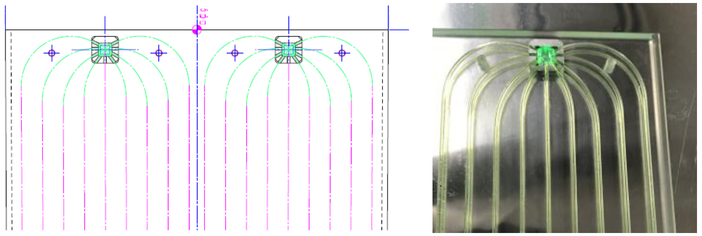
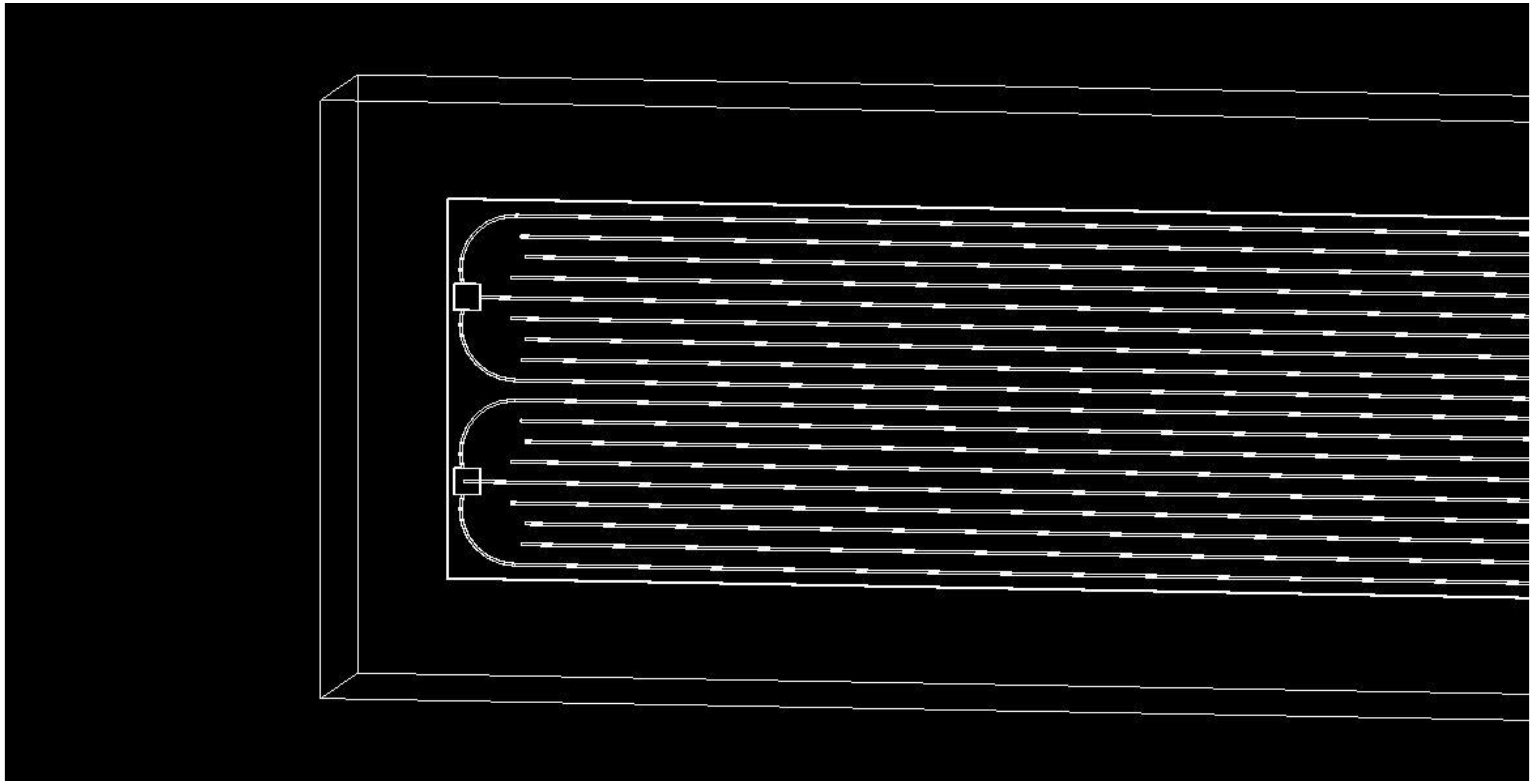


Fig 2–b. blue print and photon around MPPC

Fig 2–c. DCV assembly

Geometry



- This corresponds to one side of the DCV.

Important process and headerfile

- Scintillation Process

- The scintillation process is a process in which a particle passes through a material and deposits energy, and the excited electrons fall back to the ground state and generate photons.

- In this simulation, we used G4Scintillation.hh.

- WaveLength Shift(WLS) Process

- WLS Process Process is a process in which light is absorbed and then re-emitted, and the wavelength is shifted because the wavelength absorbed and the wavelength emitted are different.

- In this simulation, we used G4OpWLS.hh.

Scintillator EJ-200

- Scintillator used in DCV is EJ_200 of Eljen Technology.
- The properties used for the simulation are shown in the table on the right.
- The important thing is that when energy is deposited on scintillator, 10,000 of photons will be emitted.

Properties of EJ-200	
Scintillation Efficiency (photons/ 1 MeV)	10,0000
Wavelength of Maximum Emission (nm)	425
Light Attenuation Length (cm)	380
Decay Time (nm)	2.1
Number of H Atoms per cm^3	5.17
Number of C Atoms per cm^3	4.69
Density (g/cm^3)	1.023
Refractive Index	1.58

Fig 6. Properties of EJ-200

Scintillation Process

- The wavelengths of the produced photons by scintillation process were based on the emission spectrum of EJ-200.
- When we shoot a pion with 1 GeV, we can confirm that emission process works well.

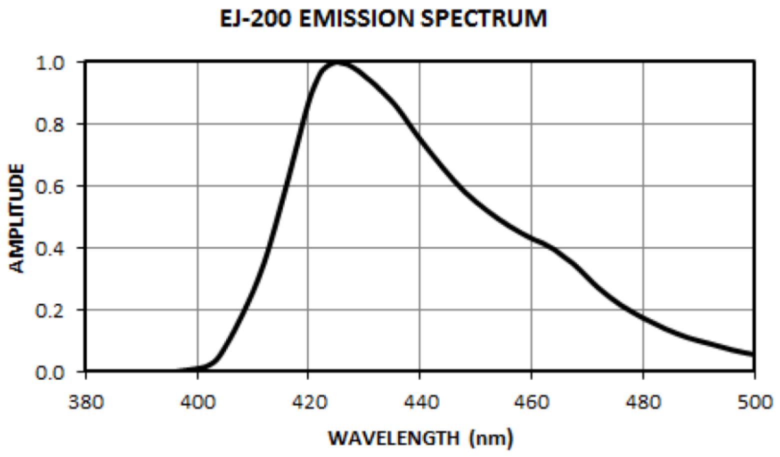


Fig 8-a. Input Emission spectra of EJ-200

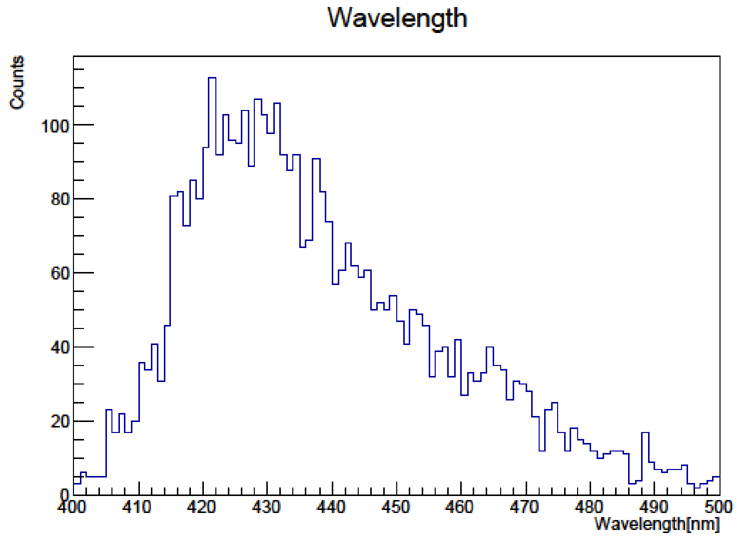


Fig 8-b. The resulting emission spectrum of simulation

Energy Deposit on the Scintillator

- For 10000 events, it can be seen that deposit on scintillator take the form of Landau distribution

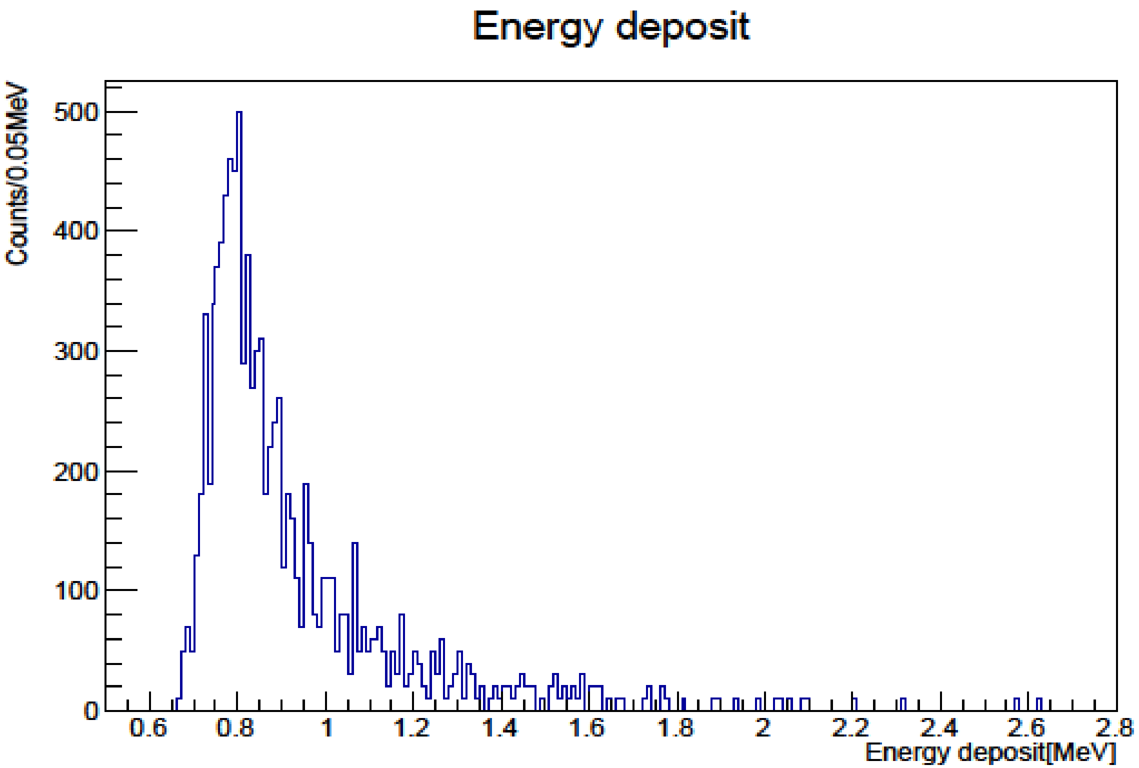


Fig 7–a .Energy deposit on plastic scintillator

WLS-Fiber Y-11

- WLS-fiber used in DCV is Y-11 of Kuraray.
- The properties used for the simulation are shown on the right.
- The point to note in properties of WLS-fiber is that re-emission occurs from 350 nm to 500 nm are absorbed, not for greater than 500 nm.
- For this reason, we set WLSCOMPONENT from 450 nm to 640 nm, WLSABSLENGTH from 350 nm to 500 nm, and ABSLENGTH for more than 500 nm.

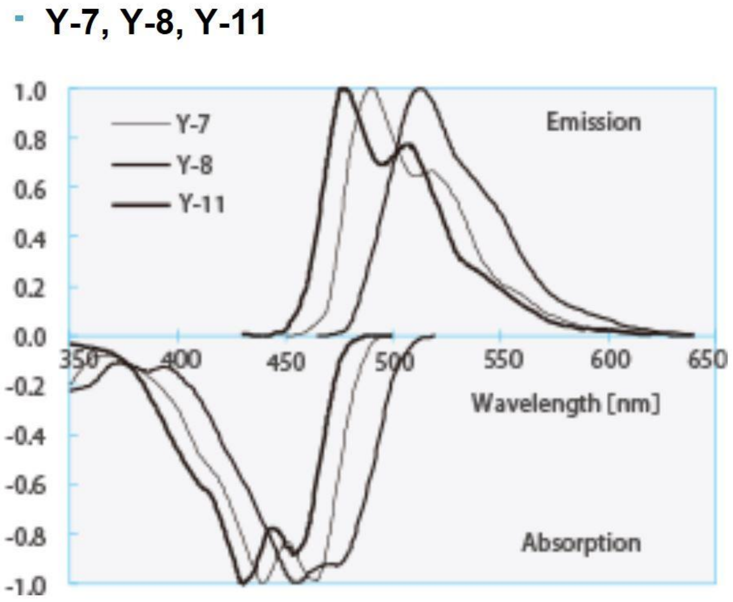


Fig 9-a. emission and absorption Spectrum of Y-11

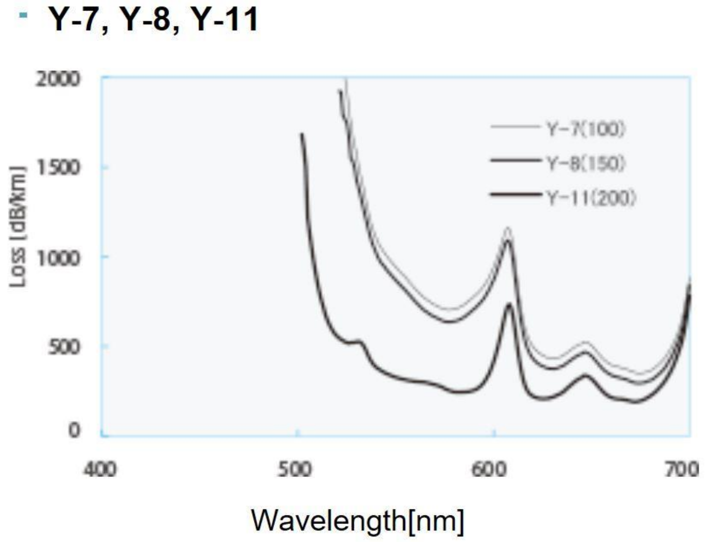


Fig 9-b. Transmission Loss of Y-11

OpWLS Process

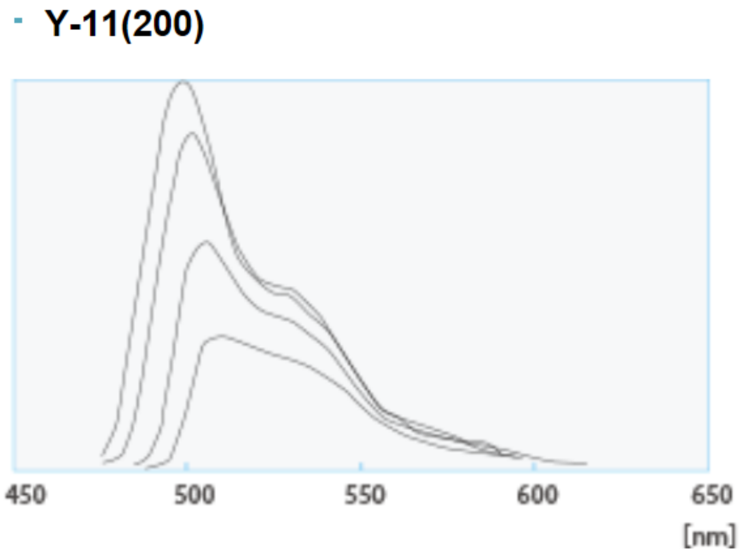
- In G4OpWLS process, the emission is put into amplitude, but in case of absorption, the absorption length should be input.
- Therefore, When we set absorption length l_0 at the wavelength which absorption amplitude 1, we can calculate absorption length at the other wavelengths that absorption amplitude c.

$$l = \frac{-l_0}{\ln\left(1 - c(1 - \frac{1}{e})\right)}$$

- By this equation, we can maintain the absorption spectrum.

OpWLS Process

- To verify that the OpWLS process works well, we checked the emission spectrum when photons with wavelength 430nm are shot in fiber.
- Comparing the spectrum obtained from the simulation with the spectrum provided by the Kuraray, we can confirm that the WLS process works well.



Exiting Wavelength: 430nm

Fig 11-a. emission spectrum with exciting wavelength 430 nm

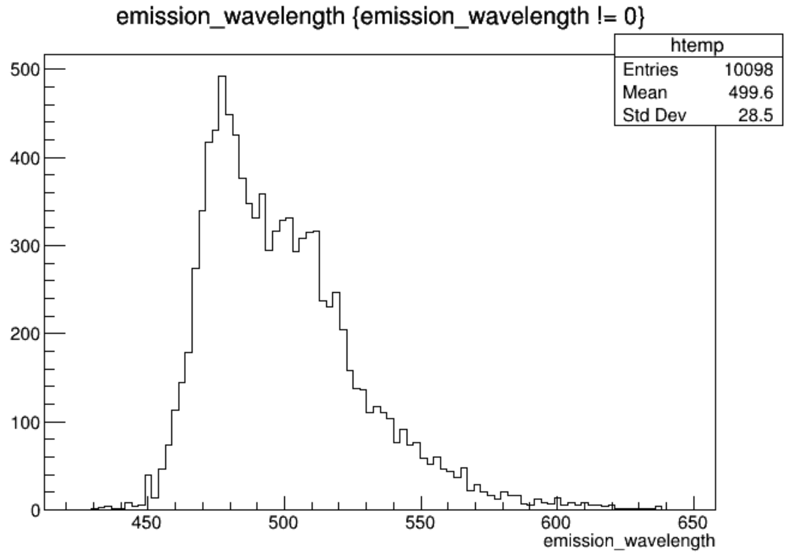


Fig 11-b. emission spectrum obtained from simulation

Aluminum mylar

- The thickness of aluminum mylar used in the DCV was 12 μm.
- Actually, DCV and mylar are not exactly attached, and there was space in the middle.
- For this reason, we made an air layer of about 1 * mm in simulation.
- By setting aluminum mylar, it can be seen that the photons that came out of the scintillator were reflected and came into scintillator by the aluminum mylar.
- As a results, when we set the aluminum mylar, the efficiency increased about 3/2 times.

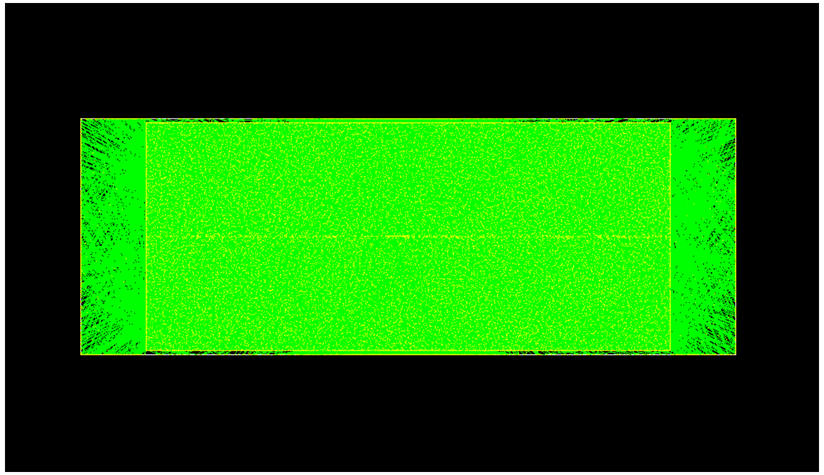


Fig 12-a. Visualization without aluminum mylar

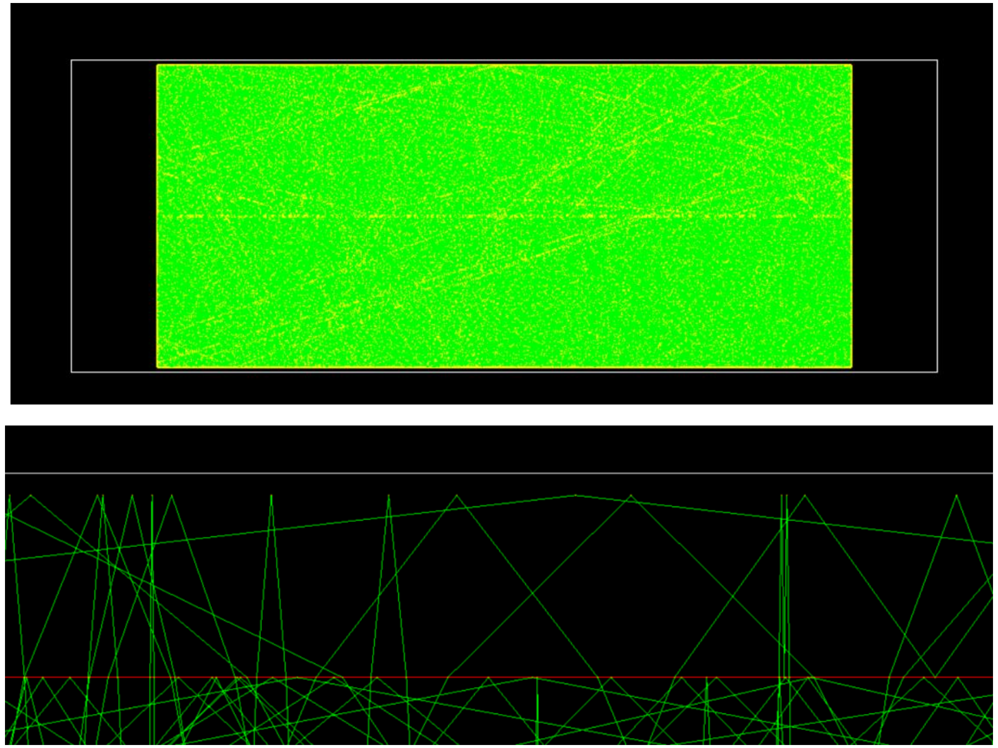


Fig 12-b. Visualized effect of aluminum mylar

Signal of MPPC

- Finally, every time when photons reach MPPC, we generate the MPPC signal on right.
- As a results, we can get the MPPC signal shown right.

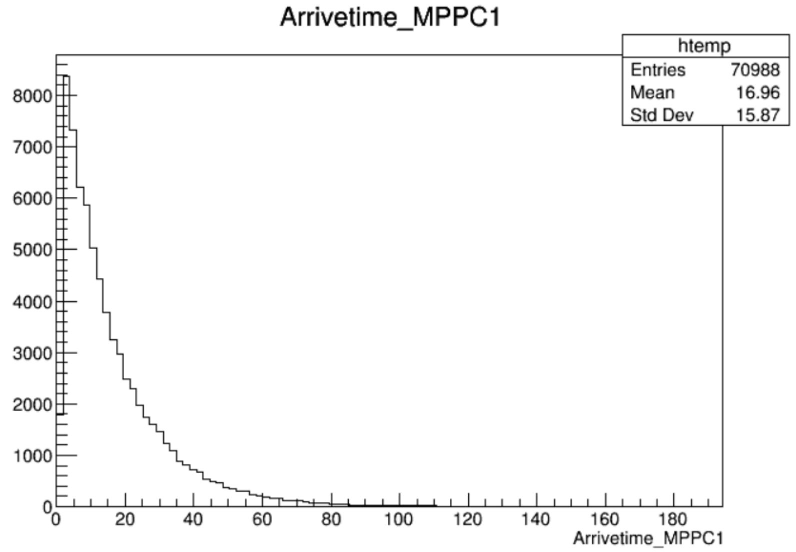


Fig 13-a. The time photons arrive at the MPPC

Conclusion

Backup

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			

Fig . Full properties of Scintillator EJ-200