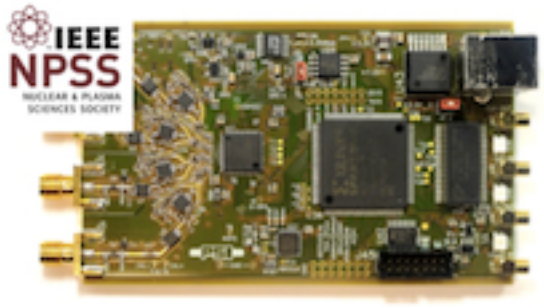
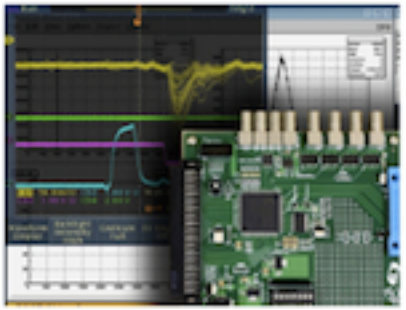
9-November-2019

International school on Real-time systems in Kuala Lumpur

Exercises

NOMACHI Masaharu






Students will work in smaller groups (4 people) on hands-on laboratory exercises.

There are 6 exercises in total.

Each exercise is a half day exercise. you will be able to do 4 of them.

1. Time of Flight measurement

2. Pulse shape discrimination

3. Timepix detector

4. EasyPET

5. Image reconstruction

6. Photon Counting

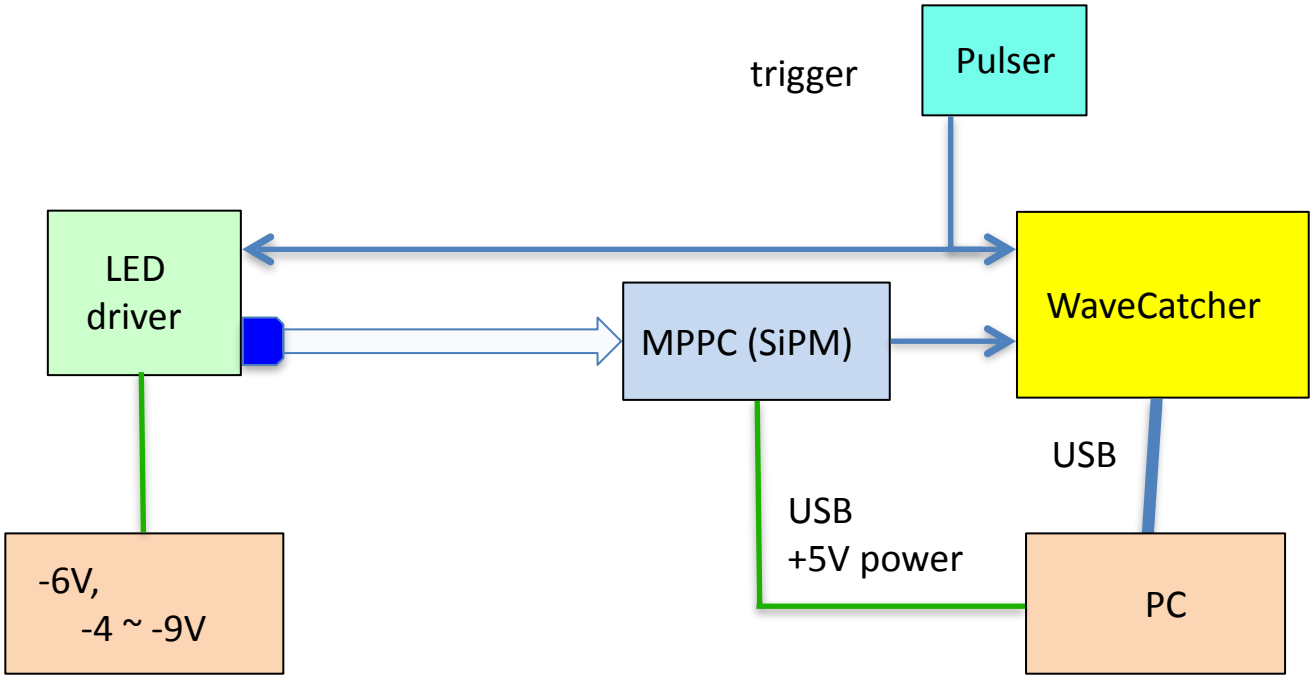
Light / Photon

- Light is electro-magnetic wave.
- Intensity of light
  - Intensity of wave is determined by Amplitude
  - Amplitude can be infinitely small.
    - Energy density of light can be infinitely small
    - How can we see the light of star at far distance?
  - Energy is quantized.
    - Single photon can excite
  - Intensity of light is the number of photon.

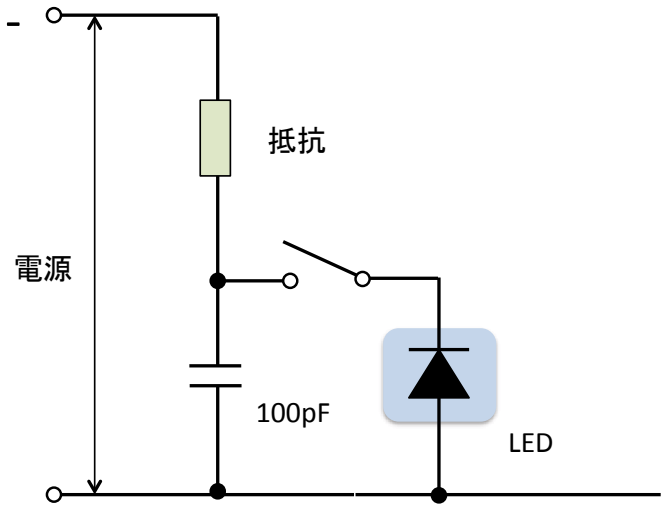
6. Photon Counting

Marc-Andre Tetrault

- Photon counting using MPPC(SiPM).
  - Learn MPPC(SiPM)
  - Learn Histogram
  - Learn Poisson distribution



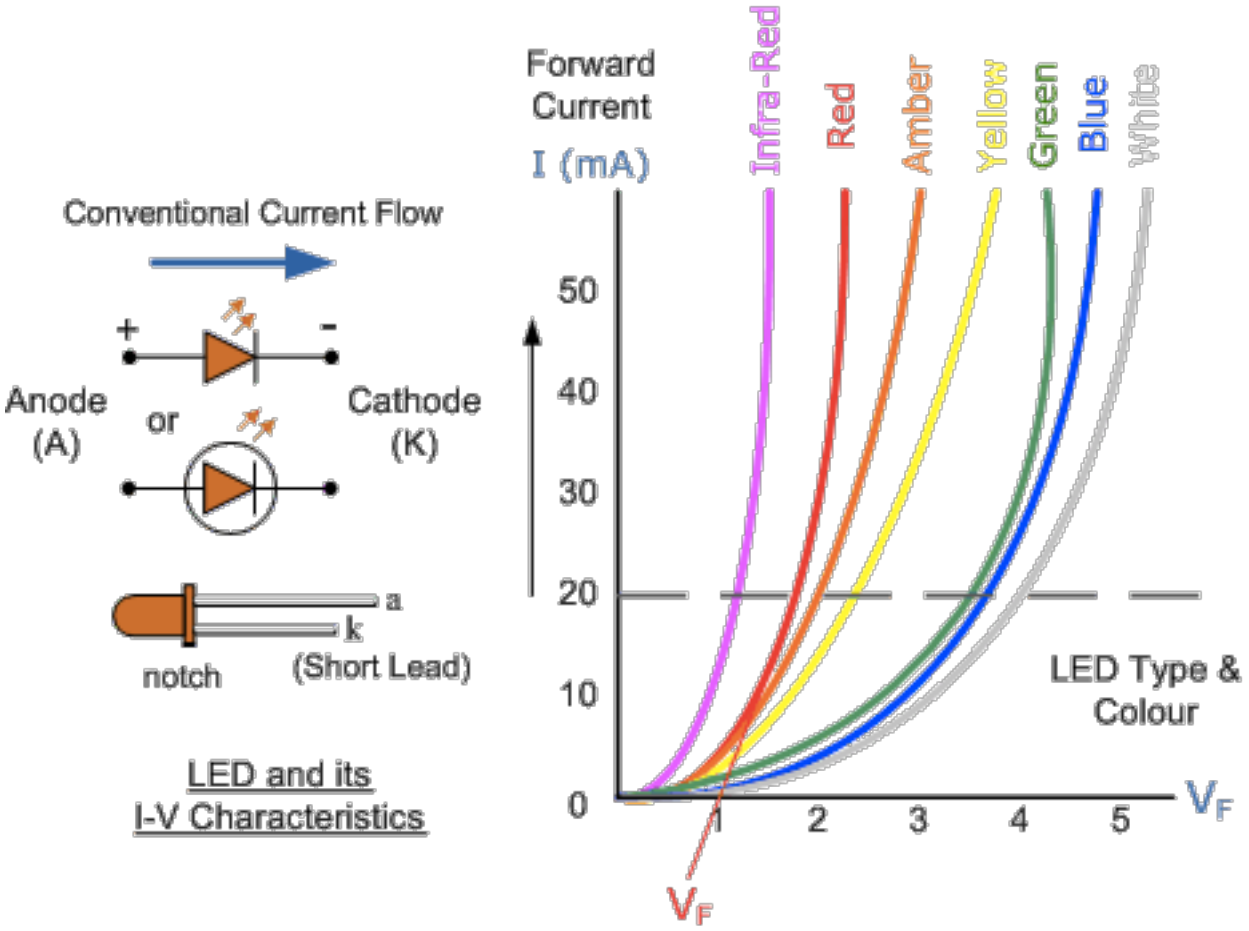
LED driver



Pulser switch ON to discharge.
Discharge can be an order of nano second.

The number of photon is controlled by the amount of charge.

Charge is proportional to Voltage.



Do you know why Blue needs higher voltage?
Do you know the energy of “blue” ph

https://www.electronics-tutorials.ws/diode/diode_8.html

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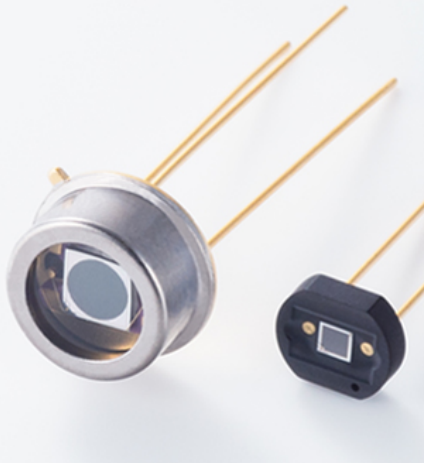
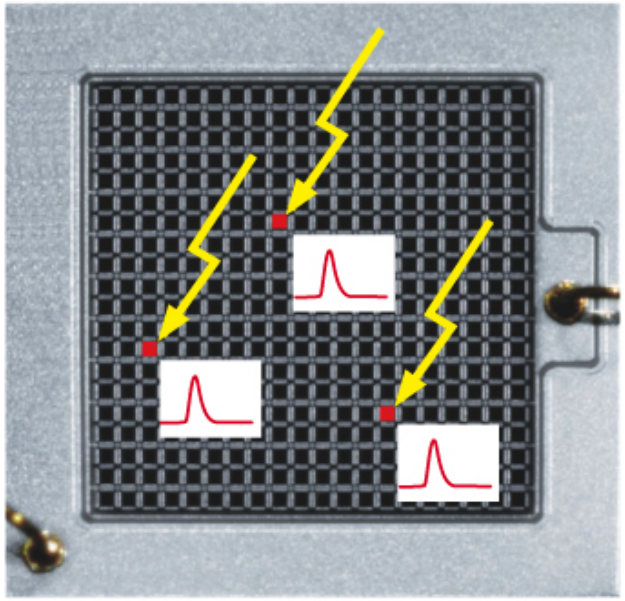
Home > Products > Optical sensors >

Multi-Pixel Photon Counters (MPPCs/SiPM)



https://www.hamamatsu-news.de/hamamatsu_optosemiconductor_handbook/

- Three exercises use MPPC.
- MPPC is short for Multi-Pixel Photon Counter, and this detector is also known as silicon photomultiplier (SiPM). It is a solid state photodetector that uses multiple avalanche photodiode (APD) pixels operating in Geiger mode.



Each pixel is a photo sensor (Geiger mod).
Geiger mode is high gain but cannot distinguish the number of photon.
Just ON or OFF.
Since each pixel is small, the probability of multi photon is small.
Increasing the number of incoming photon, linearity can be worse.

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Poisson distribution

N photon is emitted. Probability to be observed is p for each photon.
Probability of finding n is binomial distribution.

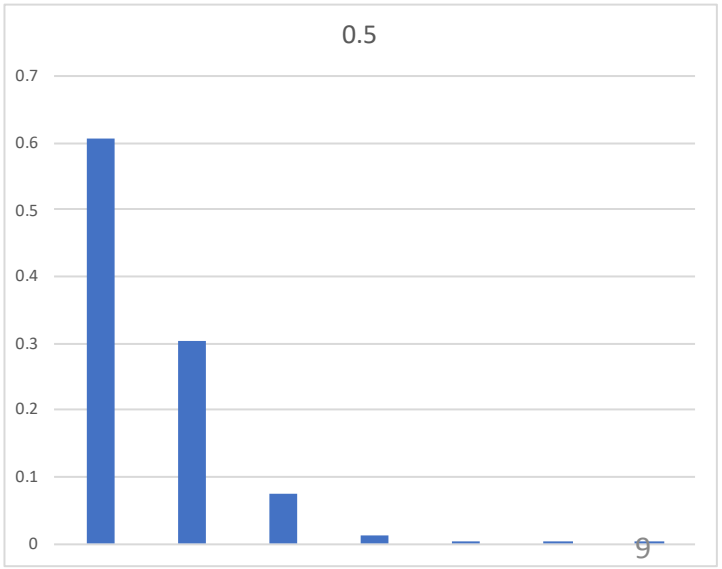
$$P_n = {}_N\mathrm{C}_n p^n (1-p)^{N-n}$$

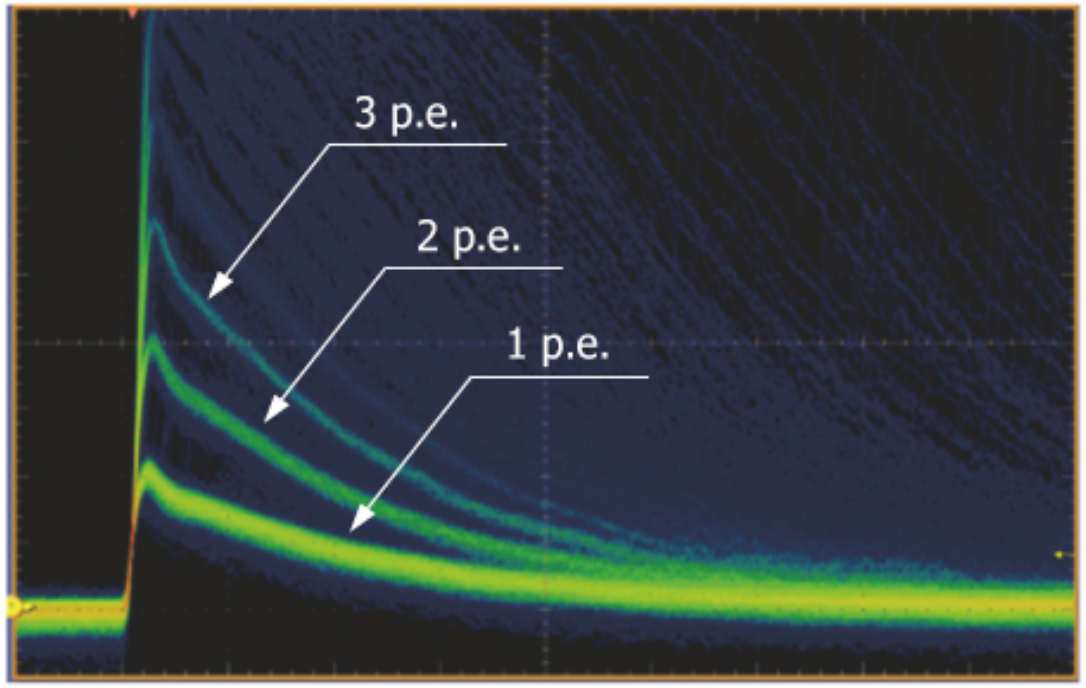
N is large but p is small. Average Np = λ is finite.

$$\begin{aligned} P_n &= \lim_{N\to\infty} {}_N\mathrm{C}_n p^n (1-p)^{N-n} = \lim_{N\to\infty} \frac{N!}{n!(N-n)!}\left(\frac{\lambda}{N}\right)^n \left(1-\frac{\lambda}{N}\right)^{N-n} \\ &= \frac{\lambda^n}{n!} \lim_{N\to\infty} \frac{N!}{(N-n)!}\frac{1}{N^n}\left(1-\frac{\lambda}{N}\right)^{-n}\left(1-\frac{\lambda}{N}\right)^{N} \end{aligned}$$

Consequently

$$P_n = \frac{\lambda^n}{n!} e^{-\lambda}$$





MPPC signal has a rich of information

1) Pulse height or Charge integration tells the number of photon.
2) Signal timing

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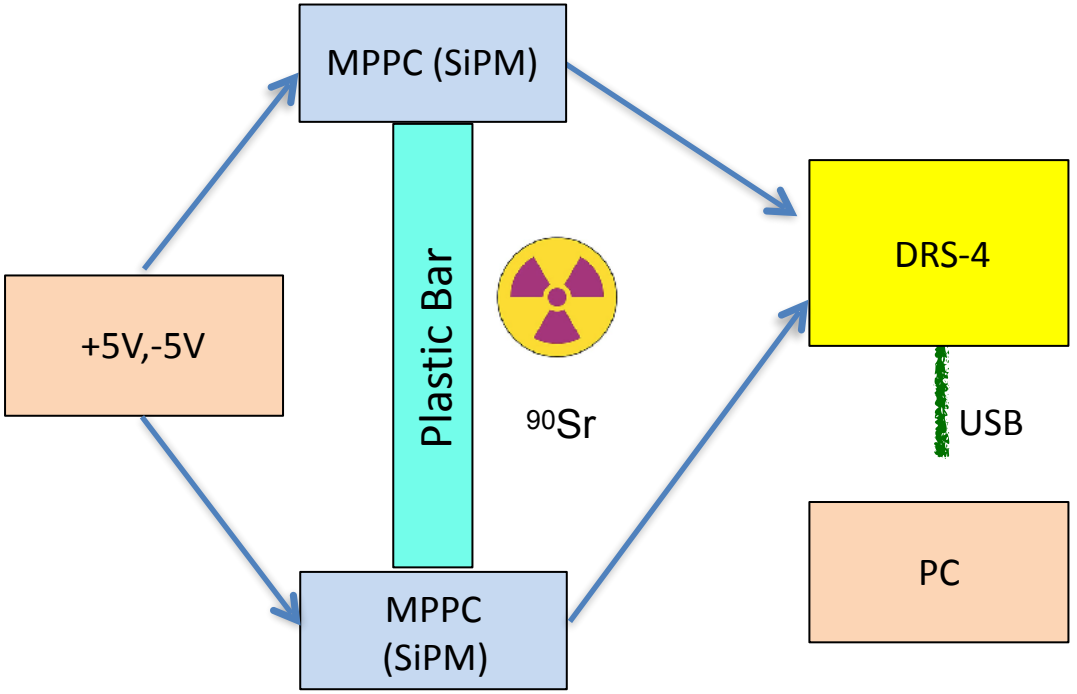
1. Time of Flight measurement

- Position measurement by time difference.
  - Propagation time is proportional to the distance
  - Position is measured by the arrival time difference.
  - Propagation speed is also measured.

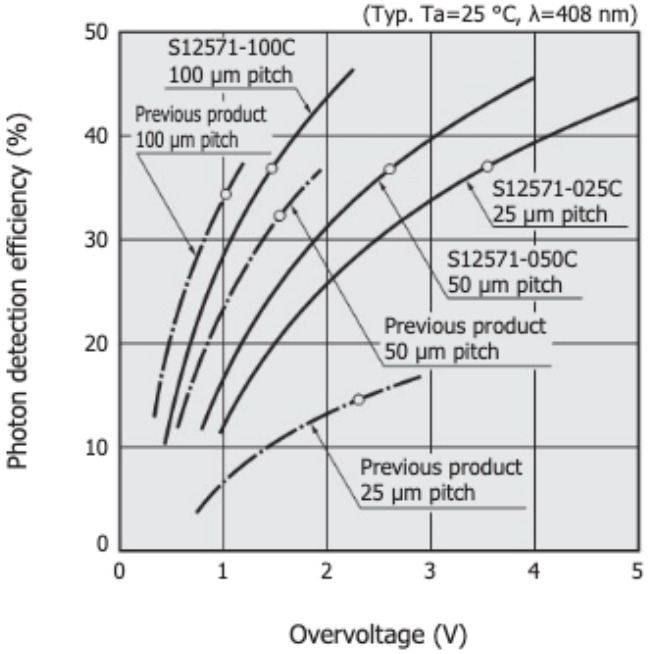


$T_L < T_R$

$T_L > T_R$

・Practice of MPPC bias control

[Figure 2-8] Photon detection efficiency vs. overvoltage



Photon detection efficiency does not include crosstalk and afterpulses.

KAPDB0217EB

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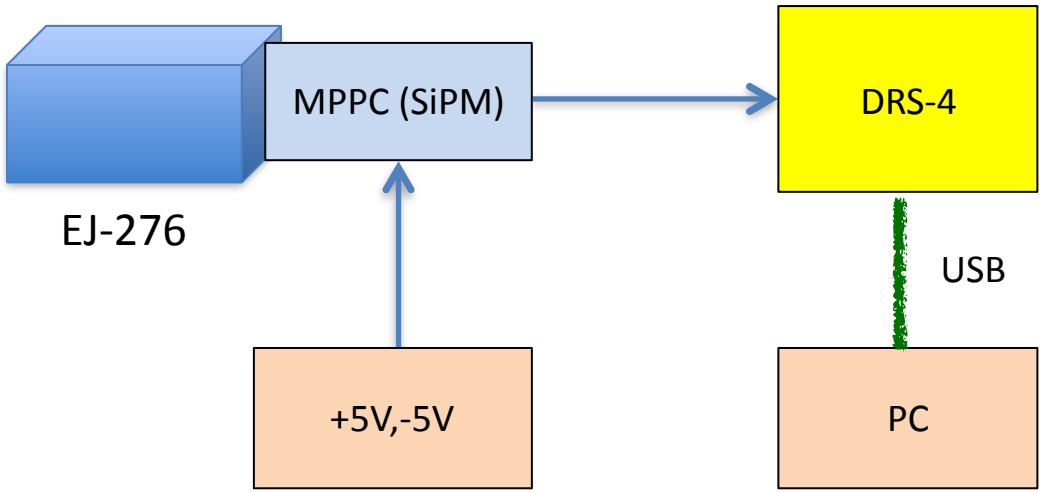
2.Pulse shape discrimination

Vo Hong Hai

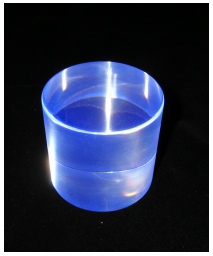
- Particle discrimination by pulse shape.
  - Accumulate Radon daughters in the air.
  - (Vacuum cleaner + Filter paper)
  - Select alpha events from gamma background



ELJEN TECHNOLOGY

PULSE SHAPE DISCRIMINATION
EJ-276 & EJ-276G

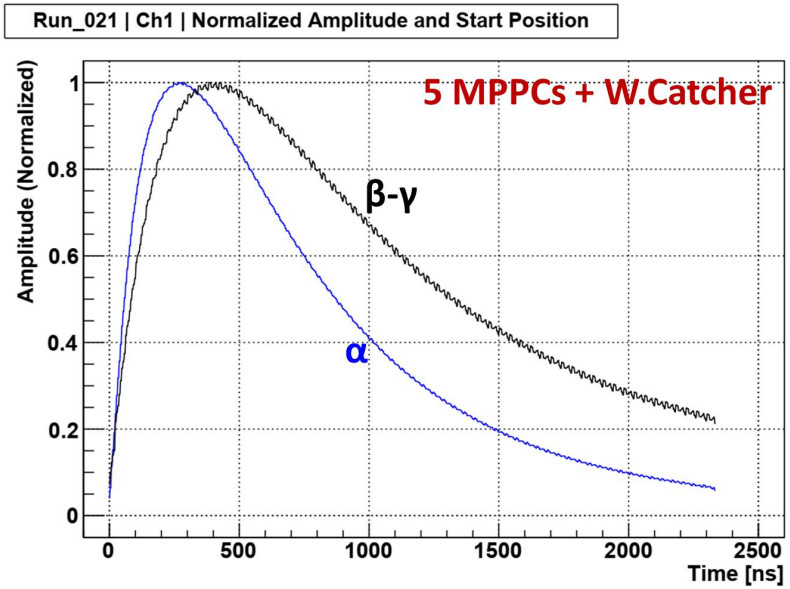
(Formerly EJ-299-33A, EJ-299-34)

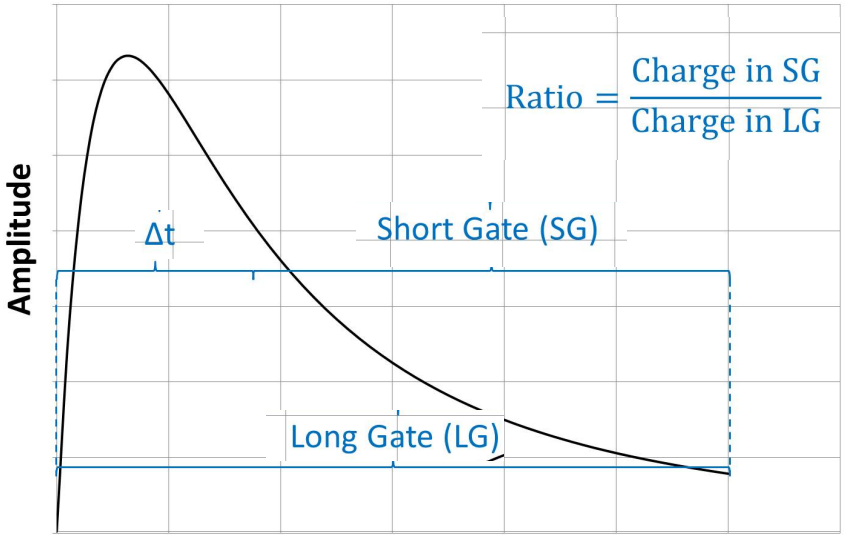


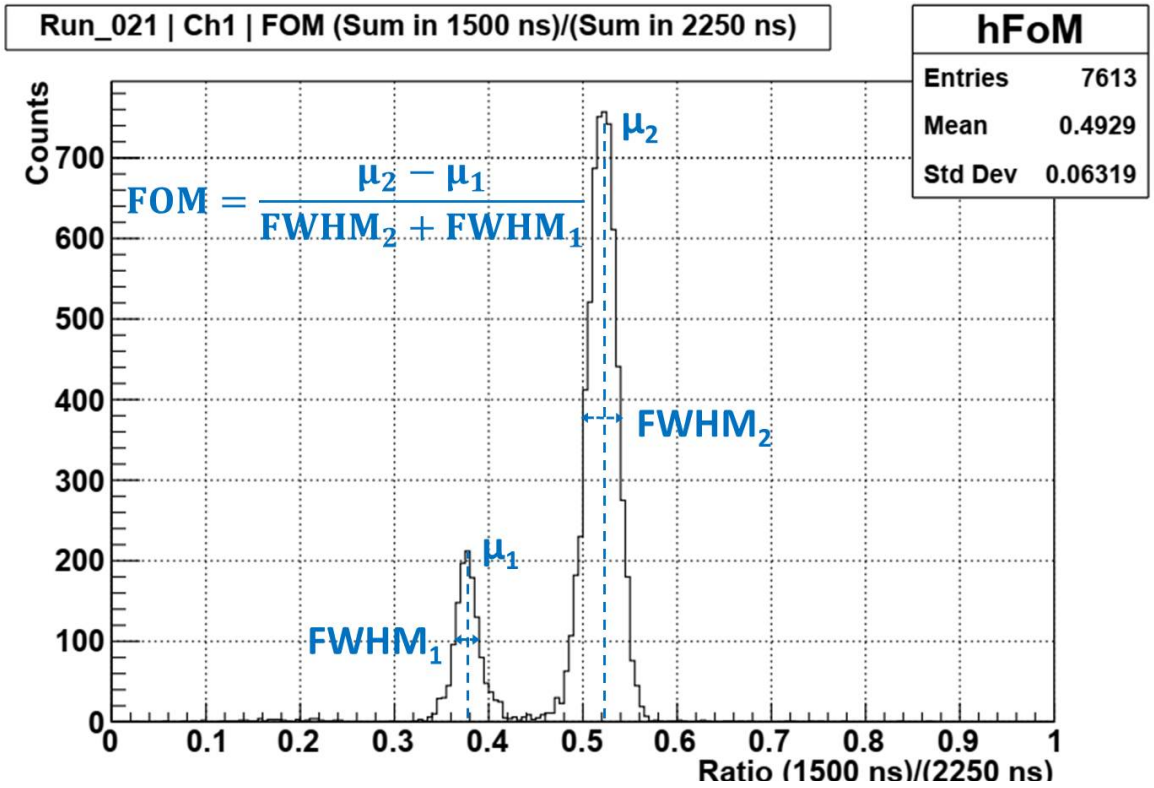
PROPERTIES		EJ-276
Light Output (% Anthracene)		56
Scintillation Efficiency (photons/1 MeV e^-)		8,600
Wavelength of Maximum Emission (nm)		425
No. of H Atoms per cm^3 ($x10^{22}$)		4.546
No. of C Atoms per cm^3 ($x10^{22}$)		4.906
No. of Electrons per cm^3 ($x10^{23}$)		3.533
Density (g/cm^3)		1.096
Approx. Mean Decay Times of First 3 Components (ns)	Gamma Excitation	13, 35, 270
	Neutron Excitation	13, 59, 460

Alpha particle and beta ray excite different state.

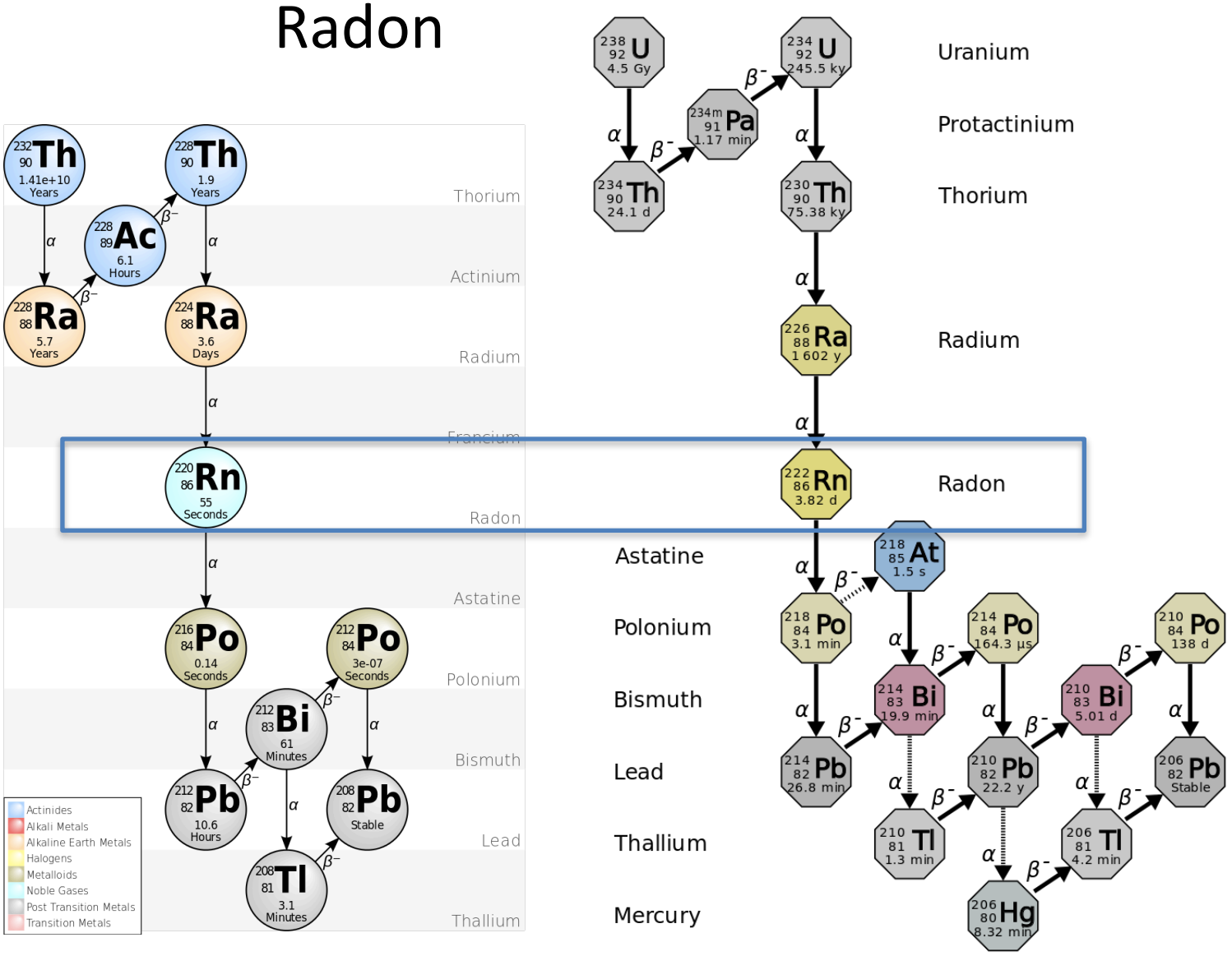
Pulse shape is different.






Run_021 | Ch1 | FOM (Sum in 1500 ns)/(Sum in 2250 ns)
hFoM
Entries 7613
Mean 0.4929
Std Dev 0.06319
Counts
$FOM = \frac{\mu_2 - \mu_1}{FWHM_2 + FWHM_1}$
μ_2
$FWHM_2$
μ_1
$FWHM_1$
0 100 200 300 400 500 600 700
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
Ratio (1500 ns)/(2250 ns)

Radon



https://en.wikipedia.org/wiki/Decay_chain