1.3 Muon Physics

Second Pre-lab:

- Background Information:

  In this lab session we will detect muons, generating and ejecting into scintillator, with PMT outputting signal to electronics box, such that we could read the decay time of Muons.

  - Muons, discovered by C. W. Anderson and S. H. Neddermeyer in 1937, is a fundamental particle, a lepton with electricity -1/2e and 1/2 spin. Muons will decay in, on average, τ = 2.2μs, in their own frame, with a simple exponential function, s.t. $N(t) = N_0 e^{-\lambda t}$, and we could calculate that $\tau = 1/\lambda$.
  - Detector is composed by scintillator and photomultiplier tube (PMT). Scintillator is used to slow down the muons ejecting into, stop them for decaying. While muons decaying, photons will be emitted during the process and hit into PMT, passing the signal to indicate how many muons decaying and decay time. Figure 1 shows the scale of detector.

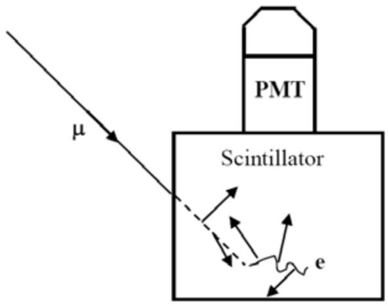


Figure 1

  - Readout electronics is the device changing the amplified signal, compared with the input signal of discriminator, to a readable wave signal and pass the signal to a FPGA timer to calculate the decay time of the muons. Figure 2 shows how Readout electronics works.

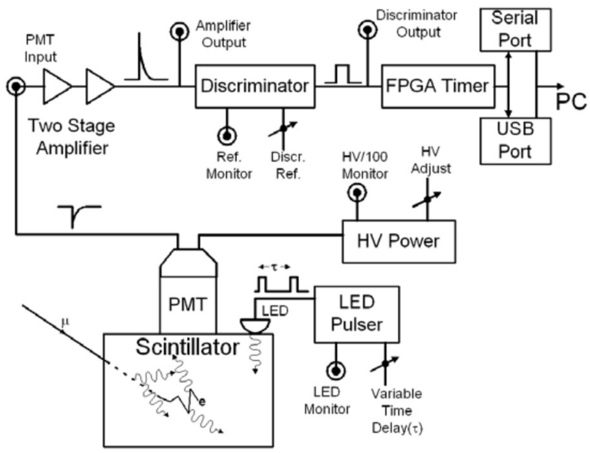


Figure 2

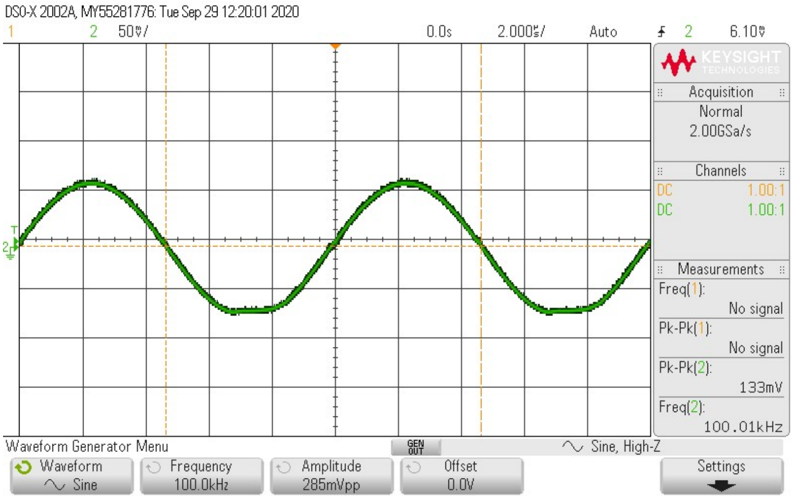
- Task:
  - Connect the electronics box with amplifier and test the saturated amplitude.
  - Connect the pulse output to electronics box and record the muons decay time with fixed repetition rate of 100Hz.
  - Connect the pulse output to electronics box with time adjusting, for steps between 20μs to 1μs of pulse pairs. Then calculate the decay time and plot with pulse pairs. It should be linear.
  - Find the timeout interval of the FPGA that FPGA will no longer record data.
  - By changing the time interval while detecting muons, obtain the resolution of the FPGA.
  - Discuss about the experiment.

In this lab session, we are going to use FPGA to detect muons. With such detection, we will finish the Exercise 3 and 4.

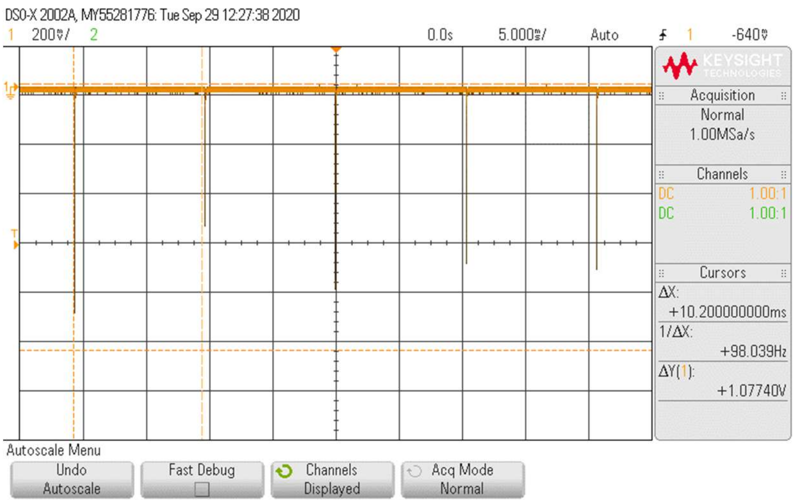
Second Lab session (29 September 2020, 12:05pm)

- Procedure:

  1) The oscillator generator is set to 100Hz. And we connect the generator with PMT input and connect the amplifier output with ch.2. The initial pk-pk voltage was 100mV, and we increased it until there was mutant of the sine wave pattern. Then we took a screen shoot of the oscillator. The mutant point is around 285mV. (As Figure 3)



  2) We connected the pulse output to ch.1. The supposed frequency is 100Hz and the actual value was 98.039Hz. (As Figure 4) By obtaining data from electronics box, we could get the decay time of muon is around 558.88ns. Standard deviation is 41.02.



  3) Then, with the same setting as step1 and step2, such that connecting pulse output to pulse input of electronics box, we adjusted time interval trough 20µs

to 1μs and got total 11 groups of data. By plotting the records of FPGA and scope results, we obtained a nearly perfect line. (Figure 5 & 6)

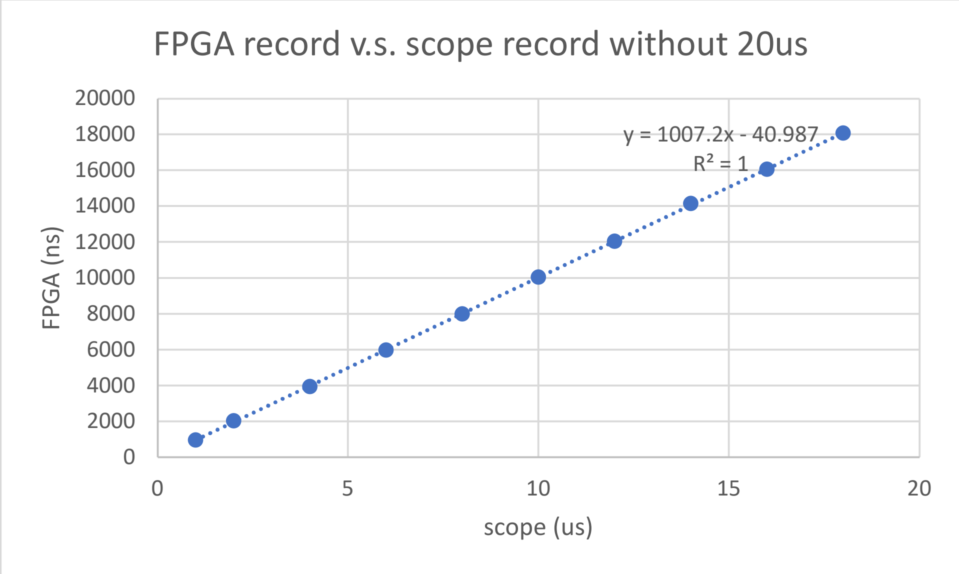


Figure 5

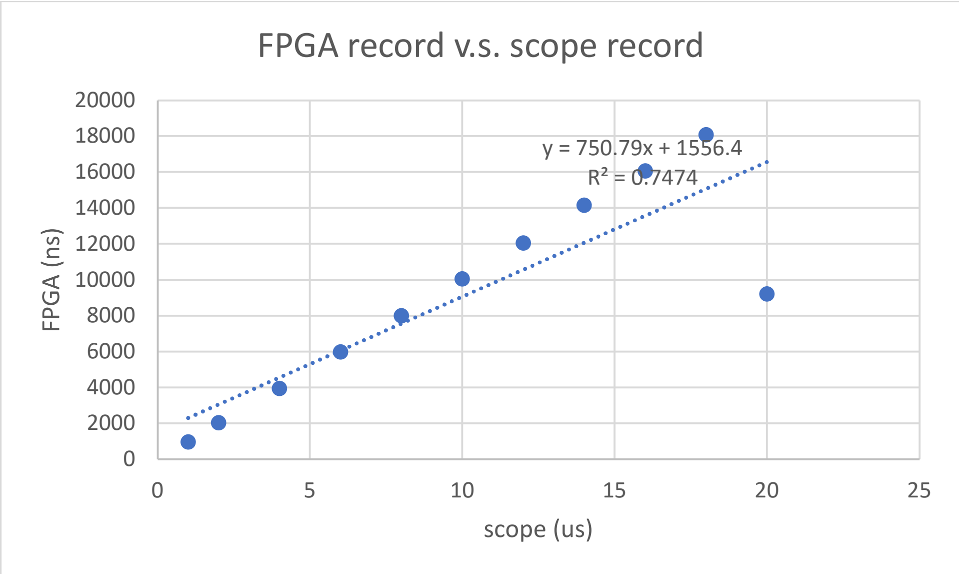


Figure 6

4) With same setting, we increased the time interval and we found that over 20μs, FPGA would hardly receive records.

5)Keep rotating the pulser time adjust knob, and use the software to record data, we can find that the minimum change between every value is 20ns. Therefore, the resolution of the timing is 20ns.

- Summary:

During this lab session, I learned to how people operate the electronics box and PMT. As we spent some time on incorrect operation, we find the background noise of the electronics box is 60ns as decay time. In our data, there will appear some error values around 40μs. Detailed data analysis will in post lab.