Radiation Detector 2018/19 (SPA6309), Tutorial 4

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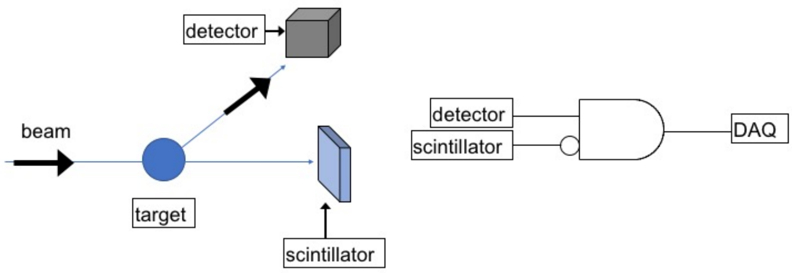
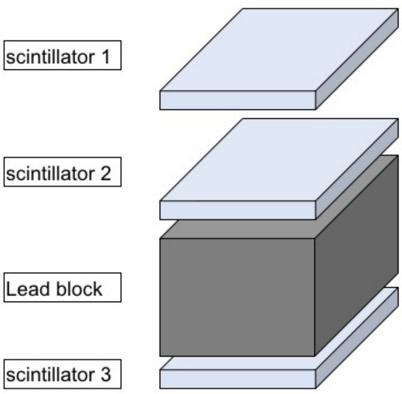
Name:

ID:

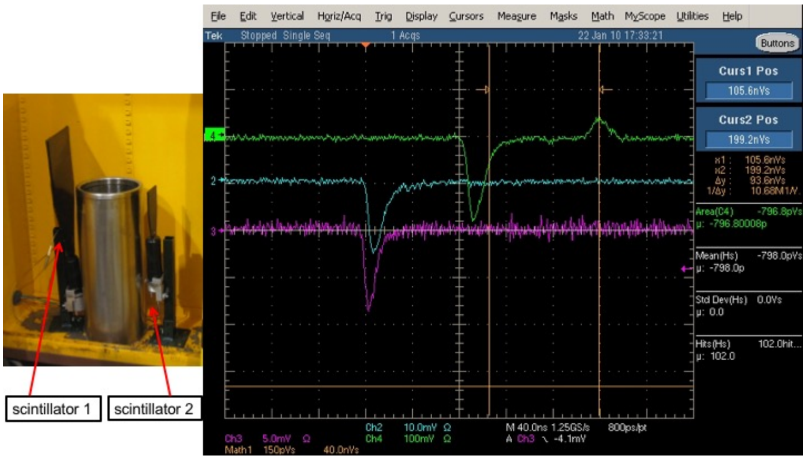
problem 1

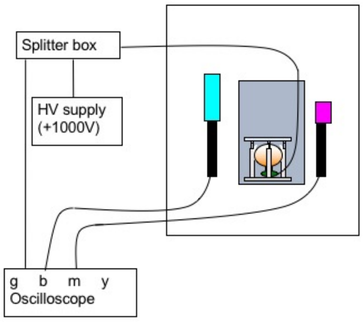


Above set up is a simple counting experiment using a scintillator and a detector. Now, we want to design the muon lifetime measurement experiment ($\mu \to \nu_\mu + \bar{\nu}_e + e$). There are 3 scintillator plates and 1 lead block. We want to detect the cosmic muon stopped in the lead block. The proposed set up looks following. Explain how to measure muon lifetime by this setting. Also, draw a diagram using logic symbols.



problem 2


scintillator 1
scintillator 2
File Edit Vertical Horiz/Acq Trig Display Cursors Measure Masks Math MyScope Utilities Help
Tek Stopped Single Seq 1 Acqs 22 Jan 10 17:33:21
Buttons
Curs1 Pos
105.6nVs
Curs2 Pos
199.2nVs
x1 : 105.6nVs
x2 : 199.2nVs
Δy : 93.6nVs
1/Δy : 10.68M1/V
Area(C4) -796.8pVs
μ: -796.80008p
Mean(Hs) -798.0pVs
μ: -798.0p
Std Dev(Hs) 0.0Vs
μ: 0.0
Hits(Hs) 102.0hit...
μ: 102.0
Ch2 10.0mV Ω
Ch4 100mV Ω
Ch3 5.0mV Ω
Math1 150pVs 40.0nVs
M 40.0ns 1.25GS/s 800ps/pt
A Ch3 ⍀ -4.1mV


Splitter box
HV supply
(+1000V)
g b m y
Oscilloscope

This is a cosmic ray test of a PMT (in the dewar). 2 scintillator signals (blue and magenta signals) are used to make a "trigger" signal of DAQ. Cosmic muons create Cherenkov radiation with liquid in the dewar, and that light is detected by the PMT sitting at the bottom of the dewar. All of them are displayed by an oscilloscope with 50 Ω termination. The green line shows the PMT signal. Notice the PMT signal shows a reflection (110ns later from the main signal), which is most likely happens at the "splitter box" (device located between PMT to an oscilloscope). The time takes to process signals by any devices are negligible.

[1] What is the trigger signal?

[2] How much the cable from PMT to the oscilloscope is longer than cables of scintillators to the oscilloscope?

[3] How long the cable between PMT to the splitter box?

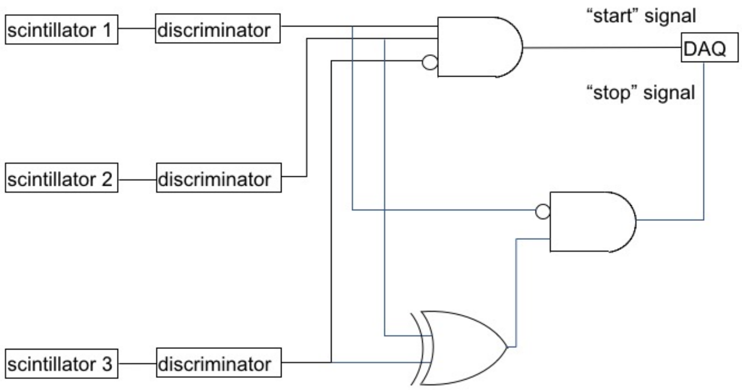
[4] PMT is a device to generate electrons from photons using photo-electric effect, then electrons are "multiplied" to make an observable big pulse. The PMT we study has 10^7 multiplication (called "gain"). Estimate how many electrons are generated originally by photons, then they are multiplied to make this pulse. (This is called "photo-electron", and closely related how many photons hit the PMT)

solution, problem 1

How to measure the lifetime of a muon? First, muon doesn't get old until it's going to stop, so to measure the lifetime you don't need to measure from the time particle was produced, but measure the time only when the particle become slower or start to slow down. This makes it possible to measure lifetime with small set up.

Scintillator 1 and scintillator 2 are used to defines incoming muon track from above and stop in the lead block. To removing through going muon, we require anti-coincidence from scintillator 3. This signal is used to define the "start" of recording the time. Then if the muon decays it will emit an electron. This electron can go either direction and detected by scintillator 2 or 3. This gives the "stop" signal and time between these 2 signals corresponds to muon lifetime.

For the logic diagram, first, we require the coincidence of scintillator 1 AND 2, and NOT 3. This signal is sent to the DAQ to be used to define "start". Then, the signal from either scintillator 2 or 3 can be used to define "stop" signal. To eliminate the possibility this stop signal may be made by another incoming cosmic ray, now we can use anti-coincidence with scintillator 1.



solution, problem 2

[1] Trigger signal tells DAQ to start and to stop to take data.

[2] Since Green signal is delayed roughly 80ns, it is roughly 16m longer than other cables.

[3] The reflected signal travels 3 times longer pass between PMT and splitter box, and it takes 110ns delay (=22m). So this difference comes from the round trip between PMT and splitter box.

2a=22

And we find cable a is 11 m. Usually, this works in the opposite way. By knowing cable length, we can diagnose where has impedance mismatching.

[4] Starting from $V = IR$, by multiplying time for both sides, $V \cdot s = Q \cdot R$. Approximating the pulse with a triangle, it is roughly 180mV height and 40ns width, so the area is $3.6 \times 10^{-9} V \cdot s$. Here, charge Q is photo-electrons × gain × Coulomb.

$$3.6 \times 10^{-9} V \cdot s = PE \cdot 10^{7} \cdot 1.6 \times 10^{-19} C \cdot 50\Omega$$

Thus $PE = 45$ and there are roughly 45 photo-electrons originally generated by incident photons.

In [4]:
```
import numpy as np
C=1.6E-19
g=1E7
Vs=0.5*180E-3*40E-9
PE=Vs/g/C/50
print PE
```

```
45.0
```