μ Lifetime

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You should read this in full before beginning and use it as you plan your work. I expect you to complete this lab in the format of an original science experiment and **not** *as a "cookie cutter" lab. In particular, that means your lab notebook must make sense to someone reading it without access to this document or the lab manual.*

1 Purpose

The purpose of this lab is to make a measurement of the muon lifetime and directionality. All of your measurements will be quantitative though your directionality conclusions will be qualitative. Everything else you do should be in support of these goals, and as you do things you should always understand how that task relates back to this.

2 Goals

At the end of this lab you should have a response to the following:

1. What is the charge species averaged muon lifetime inside scintillator? You will use the boxed system and mostly follow the lab manual for this, note that the included software is for taking data only, you must do the analysis "off-line" with the software package(s) of your choice (subject to the restrictions of this class).
2. What is the directional distribution of the local muon flux (this will be fairly qualitative)? There is no "magic box" for this part, you will be using NIM electronics just like in actual research labs. There is a bin, collection of modules, and PMT available to you. You must design, debug, and run the coincidence circuit for yourselves (there is documentation for the various modules available online).
3. Why should your results be considered reliable? (I'll expand on this in a later section)

3 Theory/Background

I'm not going to write this for you here. You should read whatever is available in the manual. Most of the concepts will have come up at some point or another in course work. You should understand:

1. Where do the muons we measure come from and how are they produced?

2. When a charged particle moves through the scintillator, it produces blue light (exactly what the PMT needs). How does light produced in the scintillator become an electrical signal on the PMT output? Can you predict anything about the size and polarity of the PMT pulses (and/or how the relate to the energy or other properties of whatever causes them)?

3. If the muons take time to get to us, how is it they haven't all decayed before they get here? Also if they are produced elsewhere and at an unknown time, how is it that we are able to measure their lifetime?

4. What are the expected sources of background? What can we do "in hardware" (ie with our settings) to reduce them? What can we do "in software" (ie as part of our analysis)?

5. What is the expected time structure of a signal?

You may (and should) also include any other topics you feel are important.

4 Why should I believe you?

You need to respond to two different issues here. First, this is a class, so you need to convince your TA that you have an understanding of how things work. In general, these are the sort of things that people will assume you know and do correctly if it were professional research. Second, even if you were an established member of the field, detectors can be very complicated and often something subtle can cause a very big mistake (see the recent arXiv.org post regarding faster than light neutrinos). To that end you must:

1. Be able to describe the output from the PMT. You should save or sketch a scope trace and describe what you see and why it is that way.

2. Determine the optimal PMT bias (or range of biases) for this work (see "suggested exercise" 6 in the manual).

3. Be able to describe the amplifier output and its relation to the pmt output. (again a meaningful sketch or scope dump (see "suggested exercises" 1 and 2 in the manual).

4. Be able to describe the discriminator... as above (see "suggested exercises" 3 and 5).

5. Understand the FPGA timing properties and how the potential impact of the above (see "suggested exercise" 4).

6. Understand the distribution of muon energies (ie. pulse heights). Set the scope threshold to something relatively low (maybe 75 to 100 mV amplitude) and, using the single acquisition mode, measure many (150-200) pulse heights. Histogram those values, do you observe anything interesting?

7. Understand how the NIM electronics work. You'll achieve this by keeping good records of your debugging process in your lab notebook.