Instructions on Calibrating Your Counters

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Introduction

Before you can start taking data, you'll need to calibrate your counters. That means setting the high voltage of the photomultiplier tubes (PMT's) to the proper values. You want the voltage to be high enough so that the counter has a high efficiency for detecting cosmic ray muons that pass through it. That means that for essentially all traversing muons the signal size should be large enough so that it exceeds the threshold of the compartor. On the other hand, you don't want the voltage on the PMT to be so high that it gives a lot of noise signals. Each phototube/scintilator combination has its own characteristics so we can't tell you beforehand what voltage to set. You'll have to determine it experimentally. The next few pages give instructions on how to do that.

Setting Voltages

1. First, stack your counters so that they lie on top of each other and completely overlap each other. We'll label the counters 1 to 4 from top to bottom

2. Set the thresholds of the compartors on all four channels to 300 mV. This is the default setting so when you power up the DAQ board this is what they should be. We'll show you during the workshop how you can use the GUI program to check their values and to set them to different values if you like. One note, although the setting says 300 mV, there is a factor of 10 gain before the comparator so it's actually a threshold of 30 mV on the output signal of the PMT.

3. Using the GUI panel:
   a) Enable counter 1 only
   b) Set for singles (no coincidence)
   c) set counting time to one minute

4. We'll adjust the voltage of counter 1 so that we get about a 15 Hz rate, that is, so that the count rate is about 1000 counts per minute. Try an initial voltage of 750 V and adjust it up or down until you get approximately 1000 counts per minute. This doesn't have to be precise. Anything from 800 to 1200 counts per minute will be fine. A rate of 15 Hz is about twice the rate of cosmic ray muons through the counter but that's fine. We're trying to make sure we have close to 100% efficiency. We'll get rid of the noise contribution when we take data by taking counters in coincidence.

5. Now repeat steps 3 and 4 for the other three counters.

Congratulations! Your counters should now be set. Now let's check that they really are nearly 100% efficient.

Checking Efficiencies

1. Using the GUI panel:
   a) Enable counters 1 and 2
   b) Set for two-fold coincidence
   c) Record number of coincidences in one minute.
2. Repeat the above procedure for the counter pairs 2-3 and 3-4.
3. Since you're now taking coincidences, there will essentially be no noise counts. You'll only get noise counts if there is an accidental coincidence between a noise signal in each of the two counters. That will be very rare since the noise rate is low (provided you didn't set the voltage way too high). The noise rate is probably around 10 Hz and the coincidence overlap time is about 100 ns. Use that to calculate the expected noise coincidence rate. Since the noise coincidence rate is very low, the rate you're measuring must be real. It's the rate of cosmic ray muons passing through the counters. That rate should be the same for all three pairings that you measured assuming you have all counters overlapping in the same way.
4. If the rate for any pairing differs significantly from the other two, try adjusting the voltage settings to bring up the rate that's low. But remember statistics. If you record N counts the error on that is $\sqrt{N}$. So, if you record, for example, 400 counts, the error on that number is 20. If you want higher statistics count for longer but remember that the error only decreases as the square root of the time.
5. Now measure the rate for the pairing of counters 1 and 4. This rate is probably a bit less than that of the three pairings above. Can you explain why?
6. As a final measure, record the rate for the 4-fold coincidence using all four counters. It should be essentially the same as the 2-fold coincidence rate of counters 1 and 4. Why?

Congratulations! You're ready to do some experiments. But first let's have some lunch!