Passed date:	Grade	Return date:

Cosmic rays and the muon lifetime

Instructions and Questions

Part I contains questions that you should answer during the lab. Write down the answers on this question sheet, and hand in the sheet as an appendix to your lab report. Part II contains questions that you should answer during the analysis session. Put the answers (including figures as required) in the main body of your lab report.

Name:
E-mail:
Lab date:
Hand-in date:
Supervisor:

Part I
Setting up the experiment

The details of the electronics setup is shown in figure 7 in the manual.

1. Use the oscilloscope to look at one of the signals from the amplifier. How would you characterize the signal? Note the amplitude and the time scale and draw the shape. Is the width of the signal good enough for our purposes? Explain why the width matters.

2. Check the same signal after it has passed the discriminator. Note the amplitude and the time scale and draw the shape.

3. Look at the amplifier and discriminator signals at the same time. Try triggering on the signal from the amplifier. What happens to the discriminator signal when you use a low (50 mV) trigger level on the oscilloscope? What about when you use a high (200 mV) trigger level? Now try triggering on the signal from the discriminator. Do you still see the same category of signals from the amplifier?

4. Connect the remaining signals from the amplifier to the discriminator. Check that all the discriminator output signals have a width of 25 ns and that the thresholds are correct.

5. Connect the two upper scintillators to a coincidence unit (we will call it UP) and the two lower scintillators to another coincidence unit (we will call it DOWN). Display both the output and the anti-output of one of the coincidence units. Compare the signals and draw them with scales, noting the position of the null-level (0.0 volt). Confirm that the signals are 75 ns wide.

6. Look at the UP and anti-DOWN signals at the same time. These signals taken in coincidence should start the TPHC. Due to fluctuations in their arrival time, some of the start signals will be fake starts. Convince yourself of this by pressing the *Run/Stop* button on the oscilloscope until you find a fake start.

7. Connect the UP signal to a discriminator, and then connect the output of that discriminator back into the oscilloscope. Now the UP signal is much narrower than the anti-DOWN. Delay the UP signal (by adding extra cables) so that it always starts and stops within the time span of the anti-DOWN. This solves the problem of fake starts. Connect the UP and anti-DOWN signals to a coincidence unit in order to create the start signal for the TPHC.

8. Repeat the two previous points for the DOWN and anti-UP signals, making the DOWN signal more narrow in order to avoid fake stops. Use the DOWN and anti-UP signals to create the stop signal for the TPHC. In the end you should have the following coincidences:

$$\begin{array}{ll} \text{UP and anti-DOWN} & \text{(Start)} \\ \text{DOWN and anti-UP} & \text{(Stop).} \end{array}$$

Connect the start and stop signals to the TPHC.

9. If it is not already done, start the computer and connect its multi channel analyzer to the TPHC with a coaxial cable. Start up the program called Maestro and confirm that the x-axis of the histogram has 512 bins. If everything looks OK, start the data taking in order to confirm that your setup works. It shouldn't take more than a minute for the first count to appear.

10. Before you start collecting data for real, you have to calibrate the MCA. Take two identical signals, separate them by a known delay, and connect them to the start and stop of the TPHC. Ask the lab supervisor for help. Use 1, 2, 5, 10, 15 and 20 µs delays. What are the corresponding channel numbers?

11. Clear the spectrum and start collecting muon data.

Part II
Data analysis

The data file contains one column of numbers. They are the number of counts in each bin of the histogram you recorded during the lab. The first number corresponds to the first bin, the second number to the second bin, etc. Each bin represents a certain decay time.

12. Plot the calibration data that you obtained in Question 10. Find out how to transform bin numbers into decay times. You can use the MATLAB function *polyfit*.

13. Plot the muon data. Remember to apply your calibration so that the x-axis displays time rather than bin number.

14. Fit the muon data to an exponential function plus a constant background. The fit model can be written as

$$f = A \cdot e^{-t/\tau} + b$$

where A is proportional to the sample size, t is time, τ is the muon lifetime and b is the background level. You can fit by minimizing the χ^2 with the MATLAB function *fminsearch*. The χ^2 is given by

$$\chi^2 = \sum_{i=1}^{N_{\text{bins}}} \left(\frac{f_i - y_i}{\sigma_i} \right)^2$$

where y_i is the number of data counts in the i:th bin and σ_i is the uncertainty of that number. Plot the fit in the same figure as the data.

15. What is the χ^2 per degree of freedom? What is the chance probability Q? What does this tell you about the fit model and the data?

16. What is the experimental value of τ? Compare it to the theoretical value. Your most important task is to explain why they do not agree perfectly. Name as many sources of error as you can. Motivate why and in what direction they would affect the experimental value of τ.