PHY/ENS 119 EXPERIMENT NO. 11
GAMMA RAYS AND NUCLEAR DECAY

Purpose

A common radiation detector (a Geiger counter) to count γ-rays will be used in these experiments. Observations will be made on

1. Fluctuations in random counting rates from a ^{137}Cs sample.
2. The half-life of a γ-decaying excited state of the nucleus ^{137}Ba.

Introduction

The general principle of operation of a Geiger counter is quite simple: energy loss or absorption of any type of high-energy radiation that enters the gas in the Geiger tube results in free pairs of electrons and positive ions. Due to the voltage applied between the electrodes in the tube, electrons move toward the (positive) anode, and ions toward the (negative) cathode. The resulting transient charge pulses pass through a resistor R connected in series with the Geiger tube and appear as voltage pulses across the resistor. These pulses are then fed into a counting program in a computer, which keeps track of the number of pulses and the elapsed time. The pulses can also be fed through an audio amplifier, so that they can be heard.

It is important to understand in part 1 that measurements of random events are always subject to fluctuations in the numbers of counts actually measured in repeated trials, even though the experimental conditions are unchanged from one trial to the next. As discussed in lecture, nuclear decay is a random process, i.e., it is impossible to predict exactly when a given nucleus will decay. Only averages can be predicted, e.g., that in a particular sample, maybe 10 nuclei will decay every second *on average*. In part 2, you are going to measure the half-life $T_{1/2}$ of an excited state of the ^{137}Ba nucleus. The half-life is of the order of minutes, a convenient time for this experiment.

Part 1 -- Random Counting Fluctuations

In this part you use a long-lived radioactive source (^{137}Cs, $T_{1/2} = 30$ years) to study fluctuations in the results of repeated trials.

Procedure

1. Open the "Radiation" program on the desktop of the computer at your lab bench. A screen should open, showing two columns for acquisition of data on the left, and a grid for graphing on the right. If there is any old data showing, pull down the "data" menu and click "clear all data". The data columns and grid should now be empty, and the "collect" button above the grid should be green, awaiting the start of data collection.
2. Place the ^{137}Cs source far enough away from the Geiger tube to give roughly 1 count/sec.

3. Now press the green “Collect” button to record the number of counts observed every10 seconds (this should be approximately 10 counts on average, sometimes more, sometimes less). Continue this procedure for 20 minutes, so that the counts in 120 10-second intervals are recorded.
4. Plot a histogram in your lab book of your count data, while the data is being recorded by the computer program. Your TA will discuss how to do this.
5. According to the statistics of radiation processes such as the ones studied here, about 2/3 of the counting events on your histogram (i.e., about 80 out of 120) should fall within ± one standard deviation σ of the mean number of counts <N>, and that $\sigma = \sqrt{\langle N \rangle}$. Does your histogram data bear this out?
7. List a few examples of random number phenomena in everyday life.

Part 2 — **The half-life of ^{137}Ba***

1. Before starting this part of the experiment, clear all old data that you are finished with. When you are ready to start measurements on ^{137}Ba*, the TA will prepare a sample for you. **Be sure to start your measurements within seconds of getting your sample; don’t give it time to go “stale.”** Put the fresh ^{137}Ba* source on top of the Geiger tube and begin counting by clicking the green “Collect” button. The computer will then begin recording the number of counts in 10-second intervals. Continue recording for 10 minutes; i.e., 600 seconds.
3. Copy the data table into your lab notebook; there will be 60 points.
4. Plot your data on a graph. The y-axis should be the **natural log** of the count rate, the x-axis should be the total elapsed time in seconds. Determine the half-life $T_{1/2}$ of ^{137}Ba* from your graph. Roughly estimate the error (uncertainty) in $T_{1/2}$ from the scatter of your data points on the graph.

* The asterisk indicates that the Ba nucleus is in an excited state. It decays to the ground state by the emission of a γ ray, with a half-life of a few minutes. It is these γ rays that the Geiger counter responds to.

$$^{137}\text{Ba}^* \rightarrow {}^{137}\text{Ba} + \gamma$$