

PHY 252 Lab 8: The Geiger Counter

Spring 2007

Introduction

This experiment has two main objectives. First, we will become familiar with the characteristics of the Geiger-Müller (GM) tube, including the properties of threshold, starting and operating voltages, GM plateau region and plateau slope. Then we will use the GM tube to perform a simple statistical experiment for the purpose of studying some of the techniques of statistical analysis.

Apparatus

The basic GM circuit diagram is shown in Fig. 1. The power supply and the counter are one unit. The GM tube itself consists of a cylindrical outer shell, which serves as a cathode, and is at the ground potential. In the center it has an axially mounted wire serving as an anode. The cylinder is filled with an inert gas (typically Argon) at a low pressure, plus a small amount of “quenching” gas (for example, ethyl alcohol).

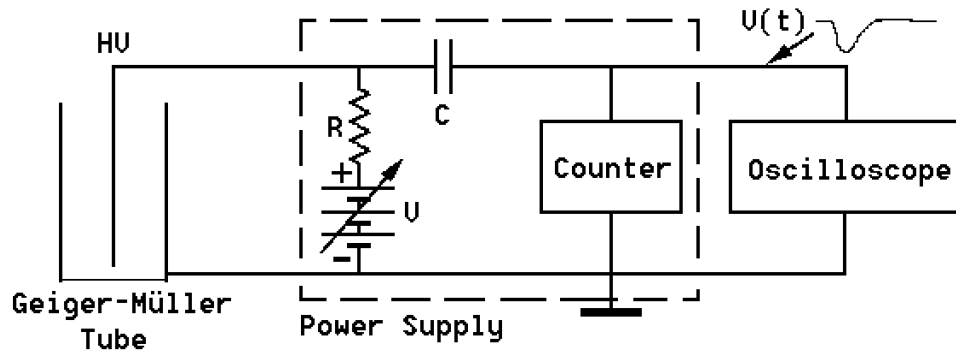


Figure 1. The Geiger-Müller apparatus.

A DC power supply provides a voltage across the tube in the range of a few hundred to over a thousand Volts, depending on the requirements of the particular tube. Caution: The front window of the tube is very thin and delicate and should never be touched.

Radiation entering the tube can ionize some of the gas atoms, thereby freeing electrons which are accelerated towards the center wire by the electric field. The electrons gain enough energy to cause further ionizations. The result is a “cascade” or “avalanche” effect, which produces a current pulse through the tube. This current pulse causes a voltage pulse across the resistor R , and then is fed through the DC blocking capacitor C to the counter. The pulse is used to trigger the counter, which records the number of pulses. We are thus able to count the number of ionizing particles entering the tube. There is, however, no information about the initial particle energy. An oscilloscope is connected to the system to allow us to visually observe the pulses from the tube. The purpose of the quenching additive gas is to effectively absorb UV-photons emitted from the electrodes when the ions produced in the multiplication process impact on the electrodes. Such photons may otherwise liberate secondary electrons (via the photo-electric

effect), which may initiate the avalanche process all over again, thereby leading to catastrophic breakdown of the tube (that is, a spark).

Measurement

1. Place a radioactive source near the GM tube. Note the operating voltage listed on the tube. Make an exploratory study of the effect of turning up the voltage across the tube. *Do not exceed the operating voltage by more than 100 V!* Note the appearance of the pulses on the oscilloscope and the behavior of the counter.
2. Systematically increase the voltage in steps of about 50 V, starting at 500 V. Decrease the step size, if necessary to see well the shape of the pulse you are plotting. For each voltage setting, record and plot the counting rate (counts/second) and the pulse height as seen on the oscilloscope. Determine the GM tube “threshold voltage”, that is, the voltage at the beginning of the GM plateau (see Fig. 2). Also measure the *slope* of the plateau (increase in counting rate per 100 V).
3. Arrange a source to give about 5-6 counts per 10 sec time interval (perhaps just the room background radiation will give you sufficient counting rate). Record the number of counts N per 30 sec interval for as many intervals as you reasonably can. Plot in a graph: the number of counts per 30 sec interval as the abscissa, and the number of times that number of counts occurred as the ordinate.

Analysis

Determine the *mean number* of counts \bar{N} and the standard deviation σ . Results of your measurements should approximate the Poisson distribution, which describes the probability of observing N counts in a given time interval:

$$P(N) = \frac{e^{-\bar{N}} \bar{N}^N}{N!}, \text{ with } \sigma = \sqrt{\bar{N}}.$$

The Poisson distribution assumes the source of the detected radiation emits it at random times. Compare your graph with this expression. Also compare your results with Fig. 2.

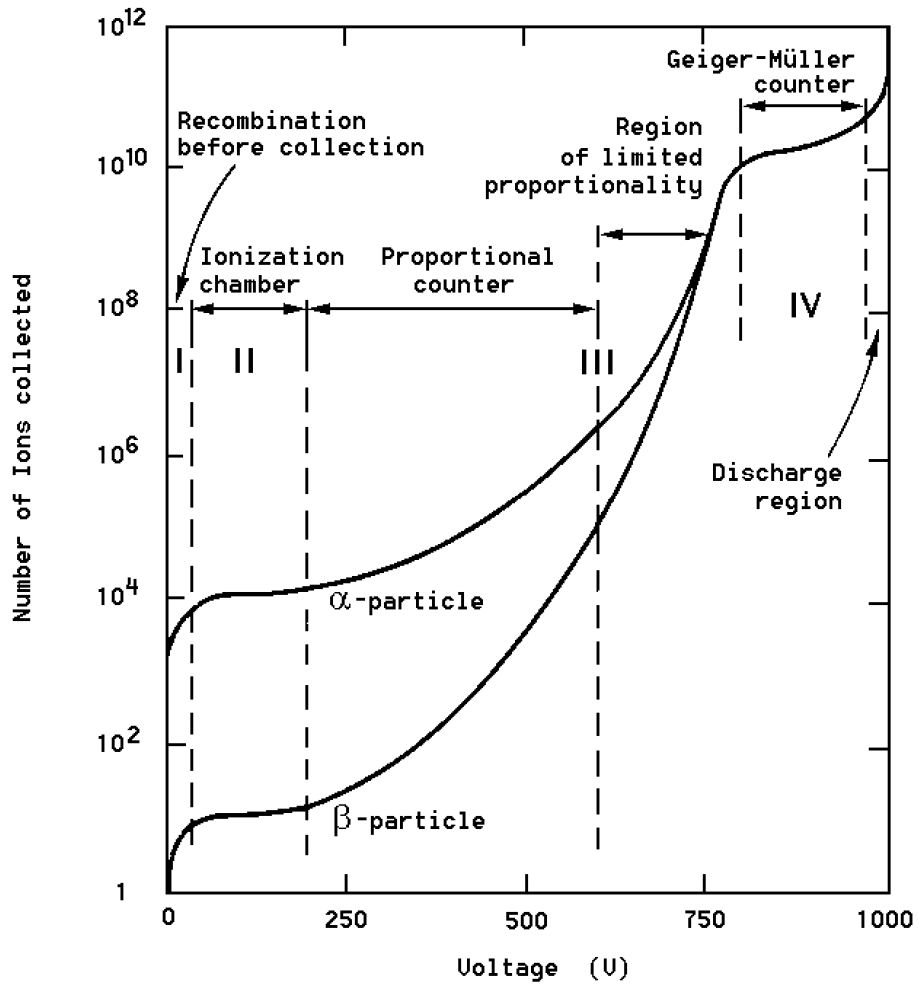


Figure 2. The number of electron-ion pairs collected when a charged particle traverses a gaseous counter of average size, plotted against the voltage applied between the electrodes. The curves are for α -particles (He nuclei) and β -particles (electrons). Note the three regions of operation: (II) as an ionization counter, (III) as a proportional counter, and (IV) as the Geiger-Müller counter.