Radiation Measurement with Geiger-Meuller Tubes

Advanced Lab 2023

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Abstract

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Introduction

Intro about radiation?

The three main kinds of radiation are alpha, beta, and gamma radiation. Alpha radiation is a helium nucleus, two protons and two neutrons. It has a +2 charge, is relatively heavy, and is easily shielded by paper. Beta radiation comes in two varieties, β^+ and β^-. β^+ radiation occurs when a neutron decays into a proton, an electron, and a neutrino. β^- radiation occurs when a proton decays into a neutron, a positron, and a neutrino. Both beta radiations are charged and can be shielded by thin metal sheets. Finally, gamma radiation is high energy photons, in the MeV range and higher. Gamma radiation is electrically neutral and needs heavy shielding, as it can penetrate lead in high enough concentrations.[?] In our experiment, we will be using Cobalt-60 and Cesium-137, both of which are gamma sources.

In this experiment, we will be using Geiger *Müller* tubes to measure radiation. Geiger *Müller* (GM) counters are the most widely used tool for radiation detection because of their accuracy and simple design. A GM counter is able to detect alpha, beta, X-ray, and gamma radiation, giving it high versatility. Their internal construction is a cylindrical tube with a rod running down the center. The tube is filled with a gas, usually neon, argon, or helium, that will be ionized by radiation. A potential is applied between the tube and the inner rod, so that when radiation enters the chamber and ionizes the gas, there is a current flow between the tube and the rod. This current flow is detected by further circuitry and marked as a radiation detection event.[?] In addition to the GM counter, we will be using a ST360 Radiation Counter to count and track radiation detections.

We will go through a four step process in this lab. First, we will determine the operating voltage of the GM counter, which we will use for the rest of the experiment. Second, we will measure the background radiation to subtract from our later radiation rate measurements. Third, we will calculate the dead time of the GM counter using the two source method. Finally, we will calculate the shielding coefficient of lead with a gamma ray source and the relationship between the shielding thickness and the radiation attenuation.

We expect the radiation attenuation to follow an exponential decay as a function of lead shielding thickness. The intensity (I) after passing through a lead shield of thickness X is given by the equation

$$I = I_0 e^{-\mu X}, \tag{1}$$

where I_0 is the initial intensity and μ is the attenuation coefficient. To solve this equation for μ, we set the final intensity equal to half the initial intensity, which will occur after a thickness $X_{1/2}$, the half thickness:

$$1/2I = I_0 e^{-\mu X_{1/2}}. \tag{2}$$

Solving Equation (2) for μ gives

$$\mu = ln(2)/X_{1/2}. \tag{3}$$

We will measure and calculate μ and $X_{1/2}$ for Cobalt-60 gamma radiation attenuation through lead, expecting an exponential relationship between the shielding thickness and the radiation attenuation.[?]

Citations for later SpecTech Student Manual Some radiation source Centric Geiger Muller Tubes Manual

Methods

To run the experiment, we first had to determine the operating voltage for high sensitivity for the Geiger-*Müller* tube. This was done by sweeping the operating voltage from 0V - 1200V in 20V increments for 30 seconds. This data was then plotted to determine a range in which the operating voltage would be sensitive enough without causing dialectric breakdown and damaging the equipment. As seen in figure [], the operating voltage for high sensitivity is within the 800V-1100V range. Thus, 900V was chosen as it was within this range at a convenient point and agreed with the value provided by the manufacturer.

Once the operating voltage was determined, the background radiation count was measured to account for noise in the count rate. This was done by running the Geiger-*Müller* counter for 1000 runs at 1s intervals with no radioactive samples. This background count rate was then subtracted from each data set for count rate measured to minimize noise and gain more accurate results.

Another method in reducing the uncertainty for our experiment was calculating the dead time for the Geiger-*Müller* tube. Dead time is the period of time in which the positive ions take to reach the cathode and the tube becomes insensitive to radiation. Because count rates for radioactive samples are essentially random, we can attempt to correct this random statistical process to determine a true count rate of a substance. Since the decay of radioactive nuclei can be described by a Poisson distribution, we relate the true count rate as

$$r = Re^{-RT}, \tag{4}$$

where r is the measured rate, R is the true count rate, and T is the dead time. If we take an approximation of this true count rate with a second-order Taylor Series approximation we see that

$$r \approx R(1 - RT). \tag{5}$$

Rearranging this for true count rate, we have that

$$R \approx \frac{r}{1 - rT} \tag{6}$$

By accounting for the dead time in our experiment, we can calculate the true count rate of a radioactive sample. This is done by implementing the two-source method.

Data and Results

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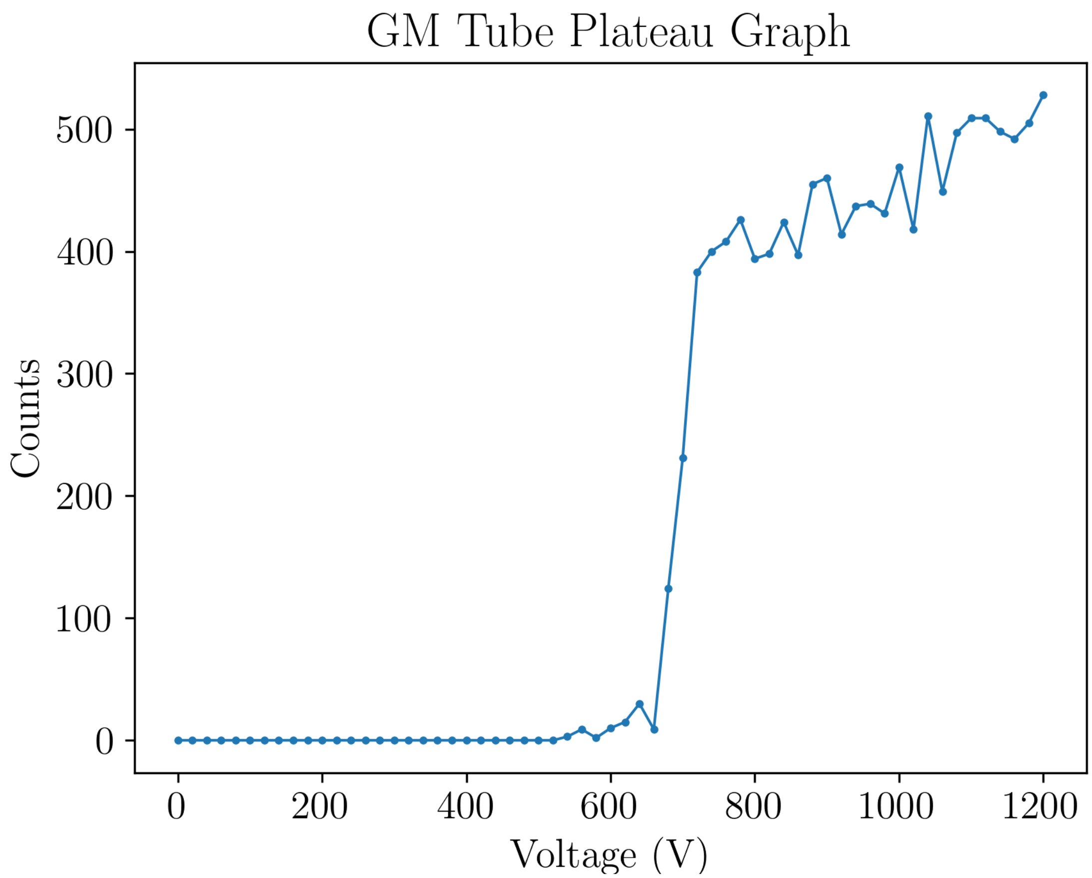

Figure 1: Counts vs. Voltage (V) for the plateau curve experiment, where the operating voltage of the Geiger-Muller tube was increased by 20 V from 0 V to 1200 V.

Discussion

We have presented the operating voltage and dead time for our Geiger Mϋller tubes, as well as the shielding coefficient for lead with gamma sources. More specifically, we presented the operating voltage as 900 Volts and the dead time as 0.0942 ± 0.02 seconds. We used two sources (Co-60 & Cs-137) and several methods to calculate the attenuation coefficient of lead shielding for gamma rays. Firstly, we calculated the attenuation coefficient for Co-60 as 8.63 ± 10 mm by taking the mean of the shielded data (attenuation data reference) and plugging it into our equation (attenuation equation reference). Secondly, we calculated the attenuation coefficient for Cs-137 as 9.72 ± 0.6 mm by fitting the data (attenuation data and plot reference). Lastly, we calculated the theoretical attenuation coefficient for Cs-137 as 14.994 mm by the equation (theoretical attenuation equation reference).

Operating voltage = 900 V
Dead time = 0.0942 ± 0.02 seconds Reported Background Count Rate = 0.424 ± 0.02 counts per second

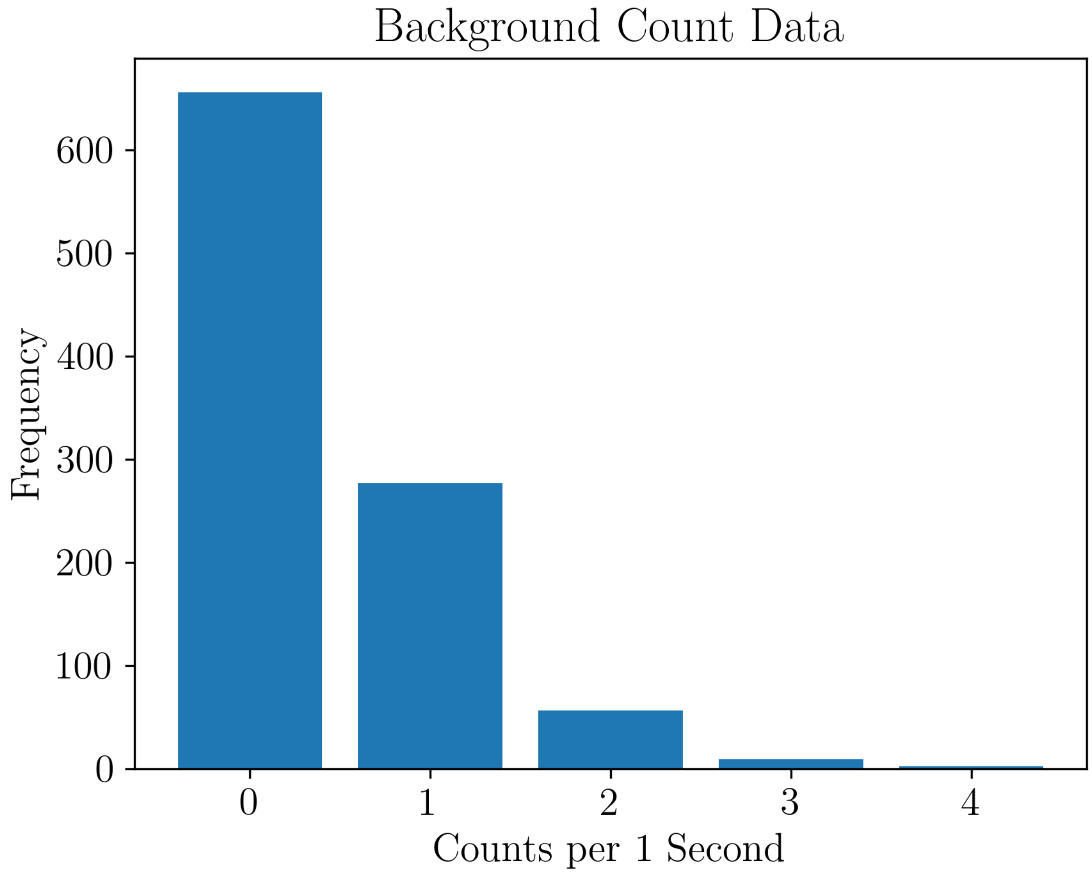

Figure 2: Count distributions over intervals of 1 second for the background measurement.

Mean attenuation coefficient for Co-60: 8.63 ± 10 mm (calculated by taking the mean of the shielded data)
Attenuation coefficient for Cs-137: 9.72 ± 0.6 mm (calculated by fitting the data)
Theoretical attenuation coefficient foor Cs-137: 14.994 (with our Co-60 source reported to emit between 1.17 MeV and 1.333 MeV, the average between the two was taken and used to calculate the theoretical attenuation coefficient. This mass-attenuation value is 1.25 MeV mm

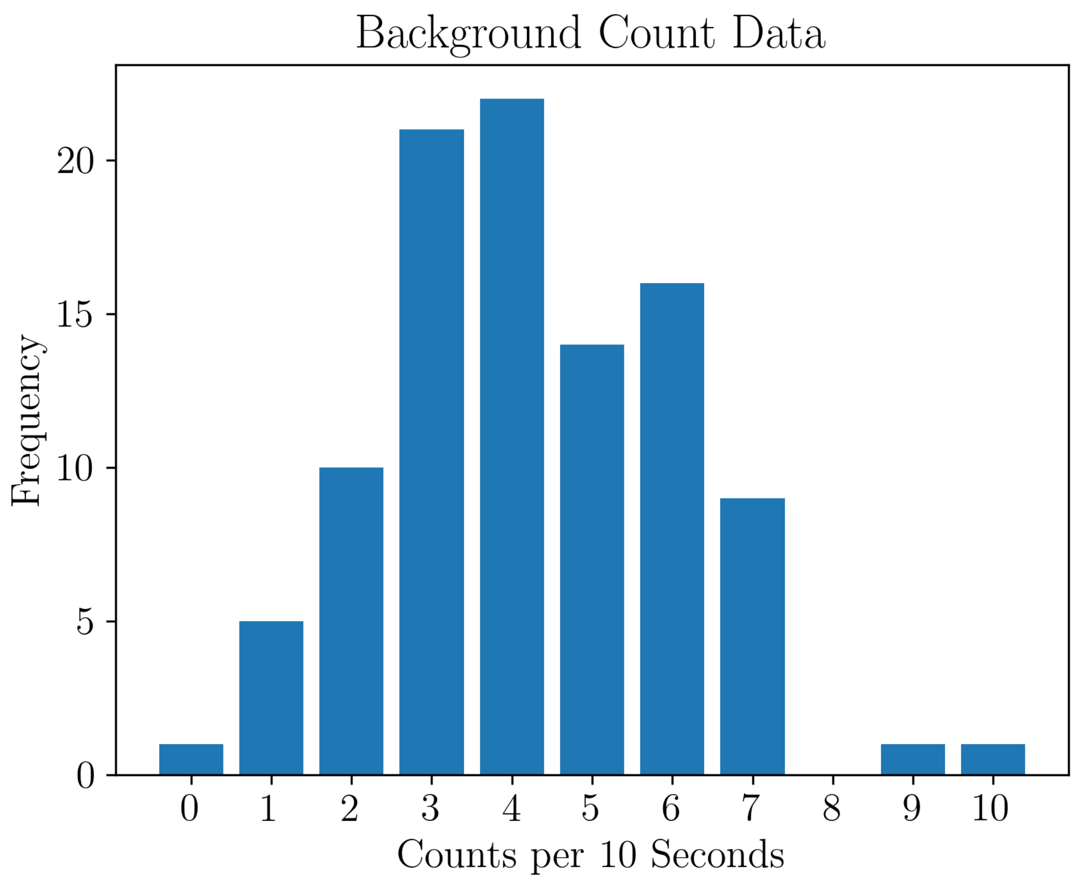

Figure 3: Count distributions over intervals of 10 seconds for the background measurement.

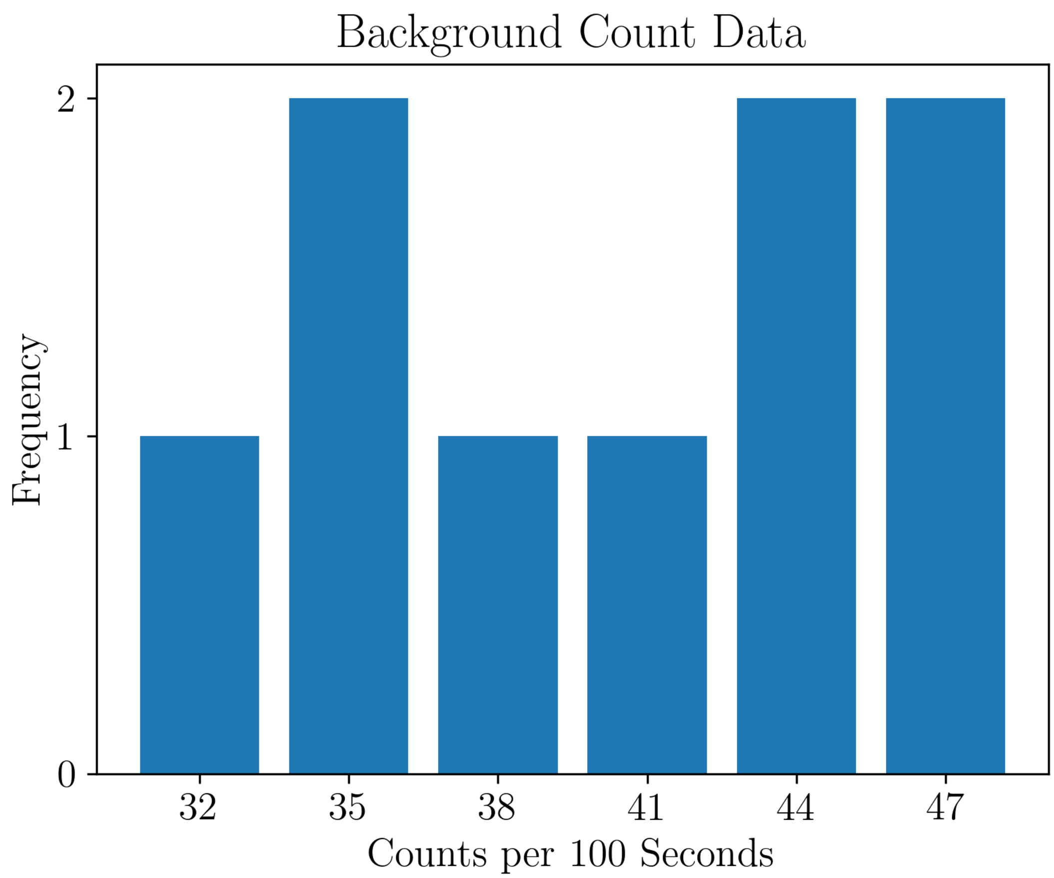

Figure 4: Count distributions over intervals of 100 seconds for the background measurement.