Experiment: 03

Objective: To study the random nature of nuclear radiations (counting statistics) using G-M counter.

Apparatus:

- Geiger-Müller tube
- Shelf stand
- High voltage supply
- Scalar, counter and timer setup
- Radioactive source
- Source holder

Theoretical Background

Radioactive decay is a random process. Consequently, any measurement based on observing the radiation emitted in nuclear decay is subject to some degree of statistical fluctuation. These inherent fluctuations represent an unavoidable source of uncertainty in all nuclear measurements and often can be predominant source of imprecision or error. The term counting statistics includes the framework of statistical analysis required to process the results of nuclear counting experiments and to make predictions about the expected precision of quantities derived from these measurements. This is true for the background radiation also. Therefore the theory presented here can be tested with or without a source.

The value of counting statistics falls into two general categories. The first is to serve as a check on the normal functioning of a piece of nuclear counting equipment. Here a set of measurements is recorded under conditions in which all aspects of the experiment are held as constant as possible. Because of the influence of statistical fluctuations, these measurements will not all be the same but will show some degree of internal variation. The amount of this fluctuation can be quantified and compared with predictions of statistical models. If the amount of observed fluctuation is not consistent with the predictions, one can conclude that some abnormality exists in the counting system. The second application is deals with the situation in which we have only one measurement. We can then use counting statistics to predict its inherent statistical uncertainty and this estimate an accuracy that should be associated with that single measurement.

The statistical nature of the phenomenon can be seen by recording counts for a large number of one-minute intervals. Assume that we are using a radiation source of constant activity (large half-life) so that the number of counts during a time t has a mean value m. Then P(N) the probability that N particles are registered during the one minute interval is given by

$$P(N) = \frac{m^N e^{-m}}{N} \quad \text{... (4)}$$

This is the Poisson's distribution. Also, the mean standard deviation σ is

$$\sigma = \sqrt{m}$$

Or when m differs only slightly from N

$$\sigma = \sqrt{N}$$

The relative mean standard deviation is $\frac{\sqrt{N}}{N} = \frac{1}{\sqrt{N}}$ and the percentage deviation is therefore $\frac{1}{\sqrt{N}} \times 100$. In order to obtain 2% relative error, 2500 counts must be registered; for 1% relative error, 10000 counts must be registered. You can see that the counting time is not important.

For large values of m, Poisson's law, using Stirling's formulae, can be shown to approach a normal distribution having the same mean value and mean deviation, i.e.

$$P(N)\,dN = \frac{dN}{\sqrt{2\pi m}} \exp\left[-\frac{(N-m)^2}{2m}\right]$$

$$= \frac{dN}{\sigma\sqrt{2\pi}} \exp\left[-\frac{(N-\sigma)^2}{2\sigma^2}\right] \quad \text{... (5)}$$

The distribution is hereby approximated by a continuous distribution.

For this experiment, 200 independent measurements will be taken on the long lived isotope ^{137}Cs (Half life = 30y) and with this data the predictable behavior of the measurements has to be shown. This has to be done with a strong source as well as with a weak source.

Procedure:

1. Set the G-M detector at the operating voltage.
2. Place a strong ^{137}Cs source at a distance such that the count rate is about 4000.
3. Set the preset time as 30 seconds and take the uncorrected counts for 200 times.
4. Repeat the step-3 using a weak source.

Table-2:

Source and its activity: Background counts=

Run No.	N	$N-\overline{N}$	$\frac{N-\overline{N}}{\sigma}$	$\frac{N-\overline{N}}{\sigma}$ (rounded)
1				
2				
3				
4				
5				
6				
. . .				

Data Analysis:

Calculate the average of these 200 counts N. Tabulate $N-\overline{N}$ in the table. Note, the number $N-\overline{N}$ can be positive or negative. If you will add up all $N-\overline{N}$ values in the table, the answer should be zero. If it is not, a mistake has been made. Calculate σ which is $\sqrt{N}$. This is called the standard deviation. Sixty-eight (68) percent of the observed data should lie within the range. In the above case, 136 of these measurements should fall within this range. Does the data fit?

Calculate $\frac{N-\overline{N}}{\sigma}$ and tabulate it in the data table. Now round off the value for each entry to the nearest 0.5. For example, if $\frac{N-\overline{N}}{\sigma} = +1.11$, the rounded off figure would be +1, etc. Plot the frequency of rounded off events versus σ and a Gaussian distribution curve should be seen. Fig-6 shows a normal distribution curve that should be similar to your calculations.

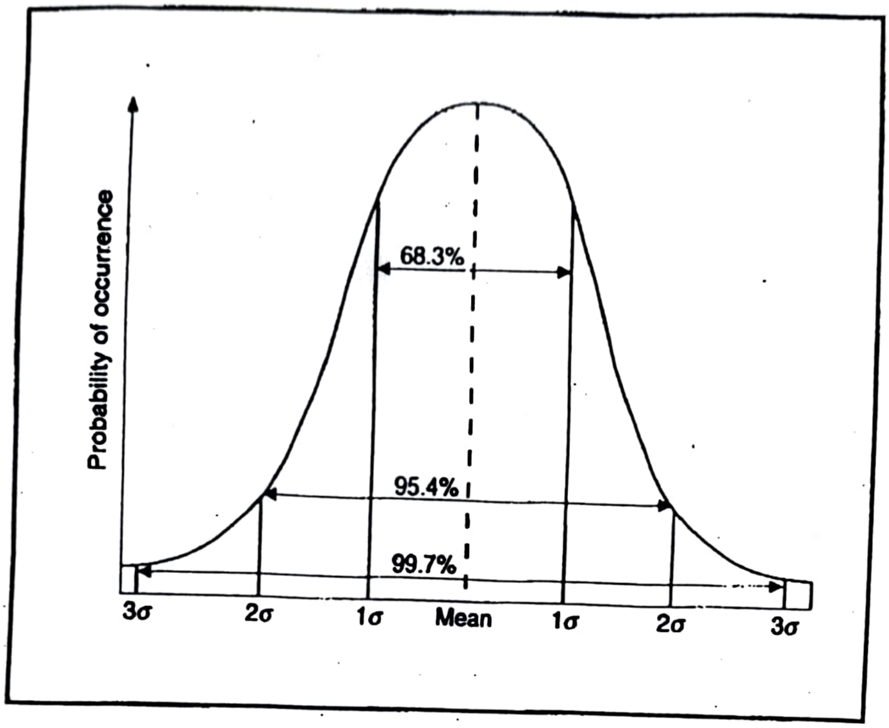

Figure 6: Normal distribution curve

Results:

Mean =

Standard deviation =

Variance =