CONSTRUCTION AND OPERATION OF A STRAW TUBE PROPORTIONAL GAS FLOW COUNTER (PART II)

Abhishek

Roll No. 1911007

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Acknowledgments

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(Dated: April 27, 2023)

Abstract: A Proportional Counter is a detector that uses gas multiplication to detect particles of ionizing radiation and always operates in the pulse mode. It measures the energy the detector absorbs from ionization events caused by charged ion pairs in the gas. One useful application of this detector is detecting low-energy X-rays. We designed and built a Single-wire Proportional Counter and determined its operating region using I-V characteristics. We used it to detect low-energy X-rays from Iron-55. We built a Straw Tube Proportional Counter using OHP Sheet and aluminium tape; it does not need any window. More details are in the following sections.

I. INTRODUCTION

A Proportional Counter is a type of gas-filled detector that relies on gas multiplication, which occurs when ionizing radiation ionizes the gas under appropriate conditions. Gas multiplication arises due to the increasing electric field within the gas, which must reach a sufficiently high value. At lower electric field values, the charged particles created by the incoming radiation - electrons and ions - drift toward the oppositely charged electrodes. During this process, they undergo numerous collisions, primarily with neutral gas molecules. Since the energy imparted by the field is low, these particles acquire only minimal energy. However, the electric field can easily accelerate free electrons and acquire significant kinetic energy. If an electron collides with a neutral gas molecule and its kinetic energy exceeds the ionization energy of the molecule, an additional charged ion pair can be created, resulting in secondary ionization. This is a fundamental concept related to the operation of a Proportional counter.

When a strong electric field is present, gas multiplication causes an electron avalanche and ion drifts, known as the Townsend Avalanche. Each free electron generated by this collision can create more free electrons through the same process. The characteristics of the Proportional Counter depend on various factors, including the strength of the electric field and the counter's geometry. We used the GECO2020 and MAESTRO software for this experiment to observe the I-V characteristics and spectrum analysis, respectively. More details on this are provided in the later sections of the report.

II. THEORETICAL BACKGROUND

The proportional counter works efficiently in the proportional region since, in this region, the voltage is high enough to provide the primary electrons with sufficient acceleration and energy for them to ionize the gas molecules. Due to Townsend Avalanche caused by the secondary electrons, we observe a single large electrical pulse. Normally, proportional counters achieve typical amplification factors of 10^6 V /m. Since the number of ionization is proportional to the incident radiation energy, the electrical pulse generated in the output is also proportional to the radiation energy. Since the amplification factor is strongly dependent on the applied voltage, the output pulse is also dependent on the applied voltage and hence we require a constant voltage.

A. Working of Proportional Counter

When ionizing radiation passes through a gas, the energy from the radiation is transferred to gas molecules, resulting in ionization. In addition, accelerated charged particles can also create ion pairs by interacting with gas molecules. The resulting ionization can lead to the creation of more ion pairs through secondary collisions. This process is known as the Townsend Avalanche and creates electric charges that can be observed as an output signal proportional to the energy of the incident radiation. To ensure that the output pulse is proportional to the incoming ionizing energy, it is necessary to confine the multiplication region to a small cylindrical volume and ensure that each ionizing event creates only one avalanche. Our Single-wire proportional counter is designed to meet these requirements by using a cylindrical wall as the cathode and a very thin anode wire centred along its central axis. The electric field within the proportional counter is designed to vary with distance from the central anode wire, which results in a very confined avalanche region, ensuring that only a single electron avalanche occurs within it.

B. Gas Multiplication

The Proportional Counter has a strong electric field near the central axis, which is due to the anode wire. This region is known as the Avalanche region, where the gas multiplication occurs. As this device operates in the Proportional region of the I-V characteristic plot, which we have calculated later, the generated electrons due to the incident radiation are accelerated to such an extent that the kinetic energy of the primary electrons are sufficient to ionize other gas molecules while they are drifting towards the anode (i.e. the central wire). The secondary ion pairs are generated due to the ionisation by the primary electrons. These secondary electrons are further accelerated by the strong electric field, and while its drifts away towards the anode; it collides with other neutral gas molecules and further ionizes them, and this process continues within the counter. Finally, instead of some electrons, a substantial number of electrons are collected on the anode, as represented in Fig.(1) and this cascade of multiplication is called Townsend Avalanche. This process occurs above a threshold value of the electric field on the order of 106 V /m for a typical gas under normal atmospheric pressure. As this value is very high

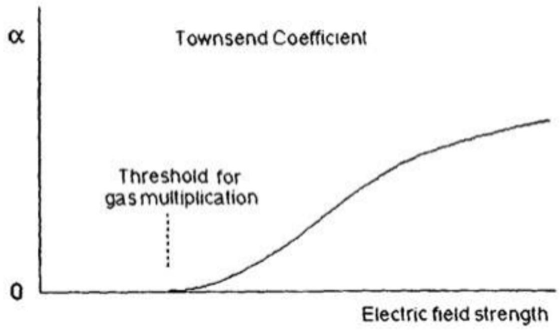


FIG. 1: Plot of the first Townsend coefficient as a function of electric field for a typical gas.

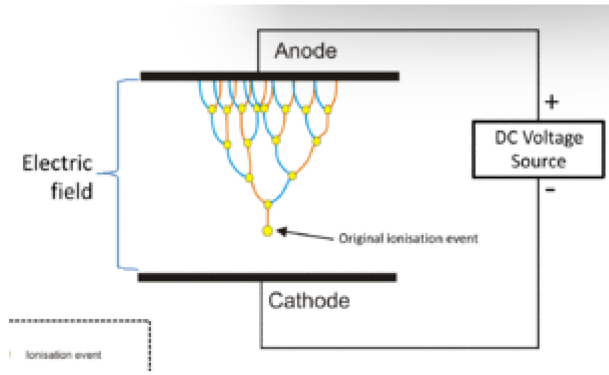


FIG. 2: *Charge multiplication in uniform electric field*

to achieve, very low pressure is maintained inside the gaseous chamber of the proportional counter where we use the P-10 gas, which is a a mixture of 90% Argon (filling gas) + 10% Methane (quenching gas).

C. Townsend Avalanche & Equation

When incident radiation enters the gas chamber it ionizes the gas and produces electrons and ions. At low values of the field, electrons and ions simply drift to their respective collecting electrodes. Now gas multiplication is a consequence of increasing the electric field within the gas to a sufficiently high value. During the migration of the charges, many collisions occur with neutral gas molecules. Positive ion has low mobility that's why they achieve very little average energy between collisions, but electrons are easily accelerated by the applied field and may have significant kinetic energy when undergoing such collision. If the energy is greater than the ionization energy of the neutral gas molecule, it will produce another set of ion pairs. Because the average energy of the electron between collisions increases with increasing electric field, there is a threshold value of the field above which this secondary ionization will occur.

The electron liberated by this secondary ionization process will also be accelerated by the electric field. During its subsequent drift, it collides with other neutral gas molecules and thus can create additional ionization. In that way, the gas multiplication process, therefore, takes the form of a cascade, which is known as the Townsend avalanche. The Townsend equation gives the fractional increase in the number of electrons per unit path length [**?**]:

$$\frac{dn}{n} = \alpha dx$$

where α is the first Townsend coefficient. This coefficient is a function of the electric field.

The solution of the above equation is given by:

$$n(x) = n(0)e^{\alpha x}$$

Here we have considered that α is constant with the electric field. This equation predicts that the density of electrons grows exponentially with distance as the avalanche progresses.

Now mean free path for ionization is given by

$$\lambda = \frac{1}{N\sigma}$$

where N = molecules per cm^3, and Townsend coefficient is given in terms of the mean free path given by

$$\alpha = \frac{1}{\lambda}$$

1. *Proportional Counter's Performance*

If the single electron response is known, the amplitude properties of pulses produced by many original ion pairs can be deduced.The total charge Q generated by n_0 original ion pairs is

$$Q = n_0 eM$$

where, M = average gas multiplication factor, which characterizes the counter's operation. Here in this analysis, it was considered that there is no space charge effect.

$$\ln M = \int_{E(a)}^{E(r_c)} \alpha(E) \frac{dr}{dE} dE$$

where r = the radius from the center of the anode wire. The integration is carried out over the entire range of radii over which gas multiplication is possible or from the anode radius a to the critical radius r_c beyond which the field is too low to support further gas multiplication[**?**].

Now we will introduce the electric field of the cylindrical geometry.

$$E(r) = \frac{V}{r \cdot \ln\left(\frac{b}{a}\right)}$$

Then we will get this expression.

$$\ln M = \frac{V}{\ln\left(\frac{b}{a}\right)} \int_{E(a)}^{E(r_c)} \frac{\alpha(E)}{E} \frac{dE}{E}$$

By assuming linearity between α and E (electric field) Diethorn derived the equation for multiplication factor(M) [**?**]

$$\ln M = \frac{V}{\ln\left(\frac{b}{a}\right)} \frac{\ln 2}{\Delta V} \left[\ln \frac{V}{pa \ln\left(\frac{b}{a}\right)} - \ln K \right]$$

where $M =$ gas multiplication factor.
V = Applied voltage
$a =$ anode radius
b = cathode radius.
p = gas pressure
$\Delta V =$ The potential difference through which an electron moves between successive ionizing events.
K = the minimum value of $\frac{E}{P}$, below which multiplication cannot occur. The expression given above is known as the Diethorn Equation. Both ΔV_λ and K values should be constants for any given fill gas and for $P-10$ gas the values are: - $K = 4.8 \times 10^4$ V/cm atm. - $\Delta V_\lambda = 23.6$ V.

For a given proportional counter at constant gas pressure, the above equation shows that the gas multiplication increases rapidly with applied voltage V. Neglecting the slowly varying logarithmic term, the multiplication M varies primarily as an exponential function of V.Proportional counters must therefore be operated with extremely stable voltage supplies to prevent changes in M throughout measurement.
Maximum avalanche size before discharge is

$$Q_{\max} \approx 10^7 e$$

(Raether limit) .
Raether limit is the physical limiting value of the multiplication factor (M) or gas gain in an ionization avalanche process (Townsend avalanche).

D. Fe-55 X-ray Source

Fe-55 decays via electron capture in the following way,

$$^{55}Fe_{26} \leftarrow {}^{55}Fe_{25} + \nu_e + \text{X} - \text{ ray}$$

In the process, one electron is captured[2] from the K orbital and another electron from L jumps to K orbital either by emitting an X-ray or by exchanging the energy to another electron. The latter effect is called the Auger effect. The emitted X-ray has energy 5.9KeV.

III. CHARACTERISTICS OF PROPORTIONAL COUNTER

The operation of a gas-filled detector depends on the electric field's strength. The current signal generated will be a function of applied voltage which the detector's characteristics curve can show.

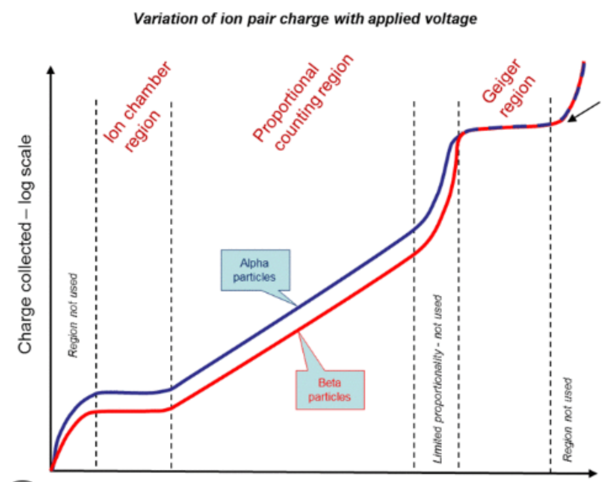


FIG. 3: *I-V characteristic curve of ionization detector*

- Recombination Region: No charges are collected in this region as the ion-electron pairs recombine due to coulomb interaction.

- Ionization Region: As the voltage is raised, the recombination forces are overcome, and the current begins to increase as more and more electron-ion pairs are collected before they can recombine. At some point, all created pairs will be collected, and a further increase in voltage shows no effect. So we get a flat, known as an ionization region.

- Proportional Region: A further increase in voltage beyond this region shows an increase in current again. The electric field is strong enough to accelerate the free electron to energies capable of ionizing gas molecules in the cylinder. These electrons are known as secondary electrons and can also be accelerated to produce more ionization. As the number of electron-ion pairs in the avalanche is directly proportional to the number of primary electrons, this region is known as the Proportional region.

- Limited proportional region: If the voltage is now increased beyond this region, the total amount of ionization created through multiplication becomes sufficiently large that the space charge created distorts the electric field about the anode. This region is known as a limited proportional region.

IV. INTRODUCTION TO STRAW-TUBE DETECTORS

Straw tube proportional counters are gas-filled detectors used to detect and measure charged particles produced in high-energy physics experiments.

They consist of a thin-walled straw-shaped tube made of a dielectric material such as mylar, kapton or polycarbonate and filled with a gas such as argon, helium or a mixture of the two. An anode wire is placed in the center of the tube, and a high voltage is applied across the wire and the outer wall of the straw.

When a charged particle passes through the gas in the straw, it ionizes the gas molecules, producing electrons and positive ions. The electrons are accelerated towards the anode wire, producing a signal that can be detected and recorded. The resulting signal is proportional to the energy the charged particle deposits, allowing for precise measurements of particle energy and momentum.

Straw tube proportional counters offer several advantages over other types of particle detectors, including high spatial resolution, low material budget, high rate capability, low cost, and resistance to radiation damage.

In the context of *Open Lab*, we chose the *straw-tube design* over the conventionally build proportional using a hollow metal cylinder and a particle capture window. This was done *to improve upon the previous designs, which had higher operational voltages and costlier to build*.

V. ADVANTAGES OF “STRAW-TUBE" DESIGN OF PROPORTIONAL COUNTER OVER CONVENTIONAL DESIGNS

Straw tube proportional counters and regular cylindrical proportional counters are two types of gas-filled detectors commonly used in nuclear and particle physics experiments. While both types of detectors serve the same general purpose, there are several advantages of straw tube proportional counters over regular cylindrical proportional counters:

- **Spatial resolution:** Straw tube proportional counters have a much better spatial resolution than regular cylindrical proportional counters. This is because the straws in a straw tube could be made very thin (typically 0.5-1 mm in diameter), allowing for precise localization of the position of ionization events along the straw axis. This is important in experiments where it is necessary to track the trajectory of charged particles.

- **Reduced dead time:** Dead time is when a detector cannot detect additional events because it is still processing the previous event. Straw tube proportional counters have a lower dead time than regular cylindrical proportional counters due to the shorter distance the electrons travel in the straw. This is important in experiments where high particle rates are expected, such as in high-energy physics experiments.

- **Low material budget:** The amount of material a detector contains can affect the detection efficiency and produce unwanted secondary interactions. Straw tube proportional counters have a low material budget because they consist mainly of thin-walled metal tubes and thin wires. This is important in experiments where minimizing the amount of material is critical, such as in experiments that search for rare events, such as dark matter detection.

- **Reduced electronic noise:** The small diameter of the straw tubes in straw tube proportional counters allows for a reduced electronic noise compared to regular cylindrical proportional counters. This is because the signal from the straw is less affected by external noise sources.

- **High gas gain:** Straw tube proportional counters can achieve a high gas gain (up to 10^5) due to their small diameter and high voltage operation. This is important in experiments where a high signal-to-noise ratio is necessary, such as in experiments that search for rare events.

- **Easy to construct and operate:** Straw tube proportional counters are relatively easy to construct and operate compared to other detectors. This is because they consist of a simple structure of metal tubes and wires, and the gas used in the detector is typically a simple mixture of argon and carbon dioxide.

- **No Window required:** A detector made of aluminium pipe requires a window since Fe-55 gamma particles are not very energetic and cannot cross a thick aluminium. At the same time, it can easily pass OHP sheets and thin aluminium tape.

Overall, straw tube proportional counters offer several advantages over regular cylindrical proportional counters in terms of spatial resolution, dead time, material budget, electronic noise, gas gain, and ease of construction and operation. These advantages make them an ideal choice for many nuclear and particle physics experiments.

A. Fe-55 X-ray Source

Fe-55 decays via electron capture in the following way,

$$^{55}Fe_{26} \rightarrow {}^{55}Fe_{25} + \nu_e + \mathrm{X-\ ray}$$

In the process, one electron is captured[2] from the K orbital and another electron from L jumps to K orbital either by emitting an X-ray or by exchanging the energy to another electron. The latter effect is called the Auger effect. The emitted X-ray has energy 5.9KeV.

VI. DESIGNING THE PROPORTIONAL COUNTER

FIG. 4: Straw Tube detector without any window.

In the usual case the proportional counters are constructed with cylindrical geometry. The anode is made up of thin wire along the axis of the hollow tube, where the hollow tube is considered a cathode. This kind of structure has also some significance, such as:

Gas multiplication requires a large electric field.In cylindrical geometry,the electric field at a radius r is given by [?] :

$$E(r) = \frac{V}{r \cdot \ln\left(\frac{b}{a}\right)}$$

where $V =$ voltage applied between anode and cathode

a = anode wire radius

b = cathode inner radius,

Large values of the electric field, therefore, occur in the immediate vicinity of the anode wire where r is small. A key design goal is that each original ionizing event due to incident radiation produces only one avalanche. This is to ensure proportionality between the number of original events

- If uniform multiplication is to be achieved for all ion pairs formed by the original radiation interaction, the region of gas multiplication must be confined to a very small volume compared with the total volume of gas. Under these conditions, almost all primary ion pairs are formed outside the multiplying region, and the primary electron simply drifts to that region before multiplication takes place. Therefore, each electron undergoes the same multiplication process regardless of its original position of formation, and the multiplication factor will be the same for all original ion pairs.

for Townsend avalanche to occur, the required electric field is as high as 5.18×10^6 V/m, for parallel plate design, where the separation between the plates is around 1 cm requires 51,800 V, which is too high to generate with available instruments. In a cylindrical proportional counter, such a huge electric field can be generated, by applying merely $2000-3000$ V.

A. Cathode Tube

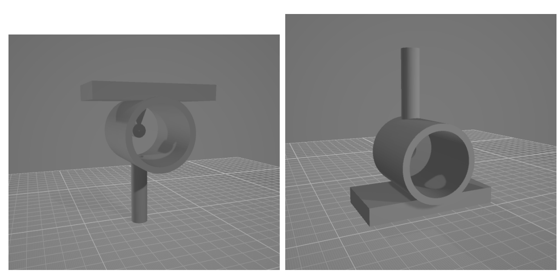
For making the cathode, we have chosen an aluminum pipe of a small radius smaller radius, which provides the required electric field at less voltage and is also cost-effective.Length of tube is 15 cm and diameter 1.7 cm.

B. Anode Wire

Anode wire must be chosen wisely as the dimension of the anode wire is crucial for the operation of the counter. For that, we used copper wire collected from the regular covered wire. The copper wire's diameter is approximately 0.15 mm.

C. Lid of the Proportional Counter

To close the cathode tube, we had to design a lid with a Safe High Voltage (SHV) connector and an inlet and outlet for gas flow. We used Lid Caps which was made by previous group.



(a) Open End (b) Closed end

FIG. 5: Frequency measurements at a constant velocity (v1)

VII. EXPERIMENTAL SETUP

FIG. 6: Rack containing NIM Bins and oscillator((also used for grounding purpose)

Apart from the detector, we used several electronic modules to perform the experiment. The setup which was used for conducting the experiment is given below.

- High voltage source
- Preamplifier
- Amplifier
- Multi-channel analyser (MCA)

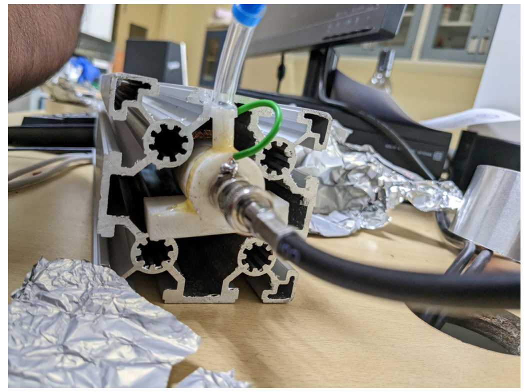


FIG. 7: Straw Tube detector inside aluminium box

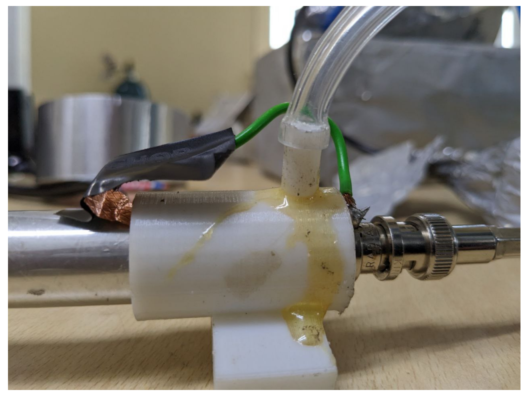


FIG. 8: Straw Tube Detector connected with gas flow and power supply

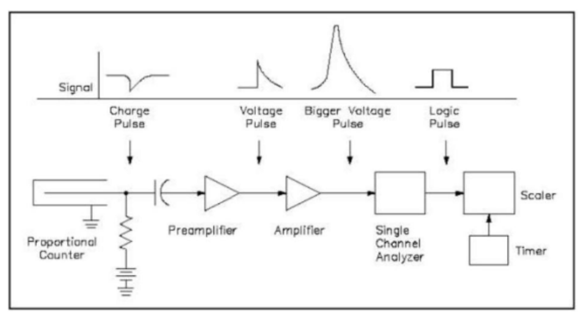


FIG. 9: *circuit diagram*

A. High voltage source

A 4-channel High Voltage power supply which is capable of providing DC voltage up to 8kV has been used to provide the required voltage to the proportional counter using SHV cable. The voltage level and current are monitored using the CAEN GECO software provided by the manufacturer.

B. Preamplifier

FIG. 10: The ORTEC-142 Pre-Amplifier was covered with Aluminium foil during the Experiment to reduce Noise due to external influence)

The preamplifier is used for providing enough gain to use the signal as input for the amplifier. In this case, the preamplifier also converts the signal that comes as current to a voltage pulse. The low current generated due to any ionization event is transformed into a voltage pulse by passing the signal through a $100M\Omega$ resistor.

C. Amplifier

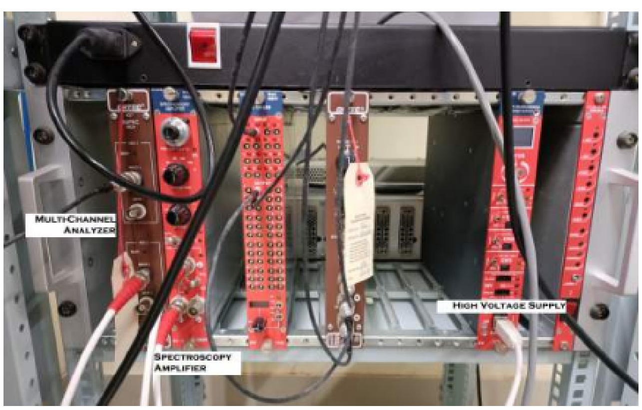


FIG. 11: The Spectroscopy Amplifier and Multi-Channel Analyser used in this Experiment.

Spectroscopy Amplifier: We used the **CAEN-N968** Spectroscopy Amplifier, as shown in Fig.(13), which was implemented in a one-unit-wide NIM module. It accepts the typical outputs generated from either optical feedback or resistor feedback Pre-Amplifiers connected with the detector. It amplifies the signal according to the set gain and it increases the Signal Noise Ratio. The spectral amplifier also shapes the pulse to a partially Gaussian shape and decreases the width time of the pulse which improves the noise performance. We fixed the Coarse gain at 20 with a Shaping time of 2µsec in uni-polar pulse mode.

Multi-Channel Analyzer: We used the ORTEC ASPEC927 Multi-Channel Analyzer which was used to convert the analog output pulse signal to digital energy value according to the pulse height and determine the radiation spectrum of the given radioactive source. The MCA has a 14-bit Analog to Digital converter (ADC) and the spectrum was recorded on computer using the MAESTRO software. It was connected to the output of the Amplifier.

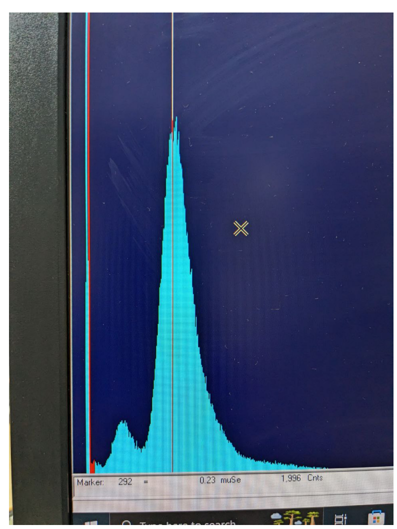
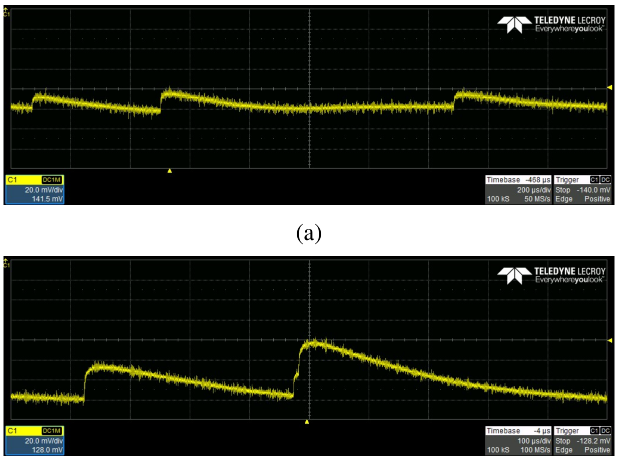


FIG. 12: Spectra obtained from Fe-55 source using MAESTRO software

VIII. OBSERVATIONS AND CALCULATIONS

A. Preamplifier's Output in Oscilloscope

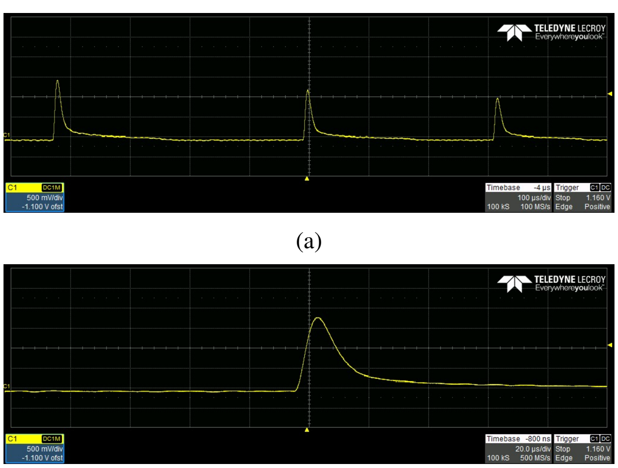


(a)

(b)

FIG. 13: Preamplifier's output in presence of X-ray source

B. Amplifier's Output in Oscilloscope



(a)

(b)

FIG. 14: Amplifier's output in presence of X-ray source

C. Inverse Square Law

D. Current variations with Bias Voltage

TABLE I: TABLE FOR OPERATIONAL VOLTAGE VS CURRENT hhh

Operational volage (V)	Current in (micro Ampere)
2600	0.05
2610	0.1
2620	0.1
2630	0.15
2640	0.25
2650	0.35
2660	0.5
2670	0.61
2680	0.9
2690	1.15
2700	1.5
2710	1.75
2720	2.0
2730	2.5
2740	3
2750	3.3
2760	3.8
2770	4.25
2780	4.7
2790	5.05
2800	5.6
2810	6.05
2820	6.65
2830	7.45
2840	8.4
2850	9.65
2860	11.65
2870	14.8
2880	18.55
2890	22.8
2900	26.7
2910	30.7
2920	33.65
2930	37.35
2940	40.5
2950	43.5

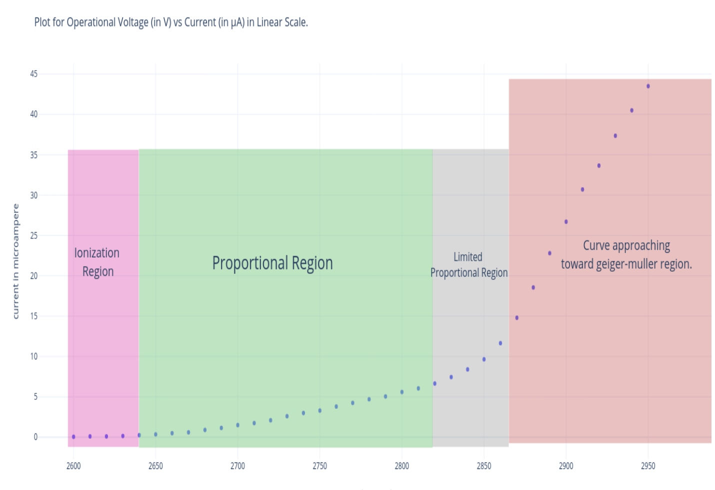


FIG. 15: Plot for Operational Voltage (in V) vs Current (in μA) in Linear Scale

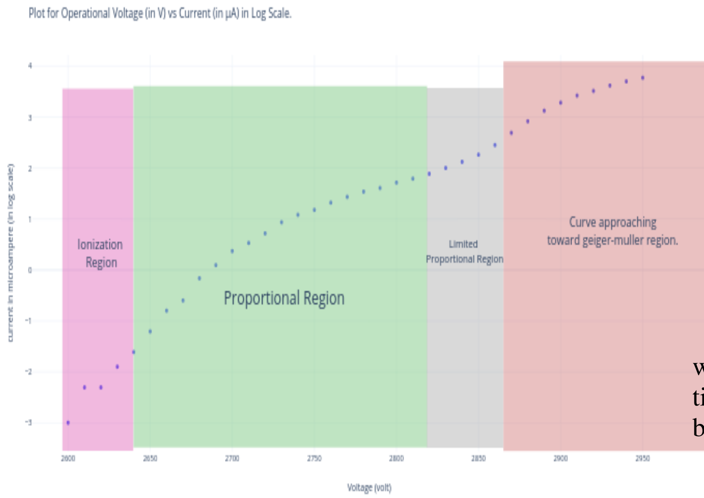
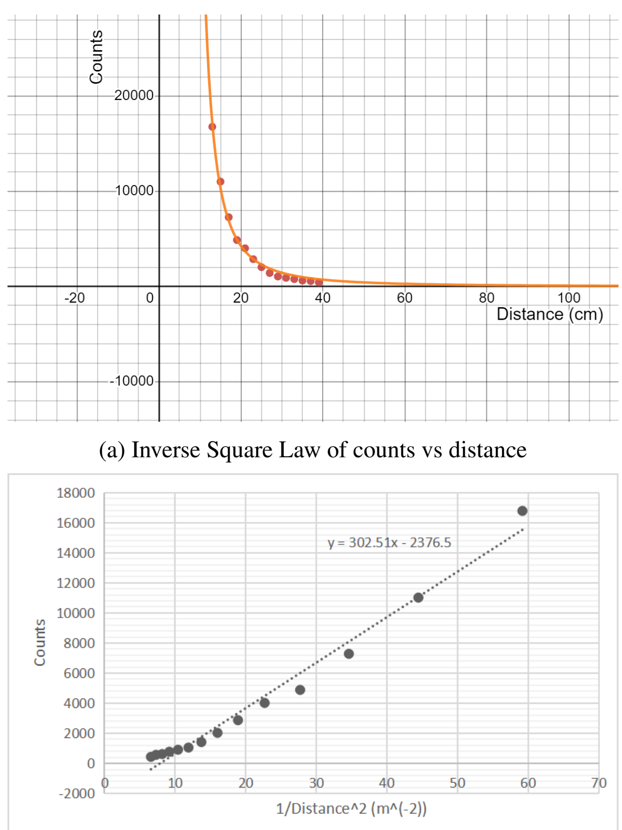


FIG. 16: Plot for Operational Voltage (in V) vs Current (in µA) in Logarithmic Scale.



(a) Inverse Square Law of counts vs distance

(b) Linear Plot of counts vs inverse square of distance

FIG. 17: Inverse square law

E. Energy resolution

$$\text{Resolution} = \frac{\text{FWHM}}{\text{Energy corresponding to max peak}} \tag{1}$$

$$= \frac{2.35\sigma}{\text{mean}} \tag{2}$$

where σ is the standard deviation of the fitted Gaussian function. The relationship between voltage and resolution has been plotted for the setup.

TABLE II: Energy Resolution

Voltage	Mean	Sigma	Resolution
2200	148.2	27.37	0.4340
2250	179.9	28.9	0.3775
2300	244.2	33.7	0.3243
2350	411.8	58.8	0.3356
2400	472.7	61.8	0.3072
2450	624.32	79.119	0.2978
2500	835.3	114.8	0.3230
2550	975.5	137.6	0.3315

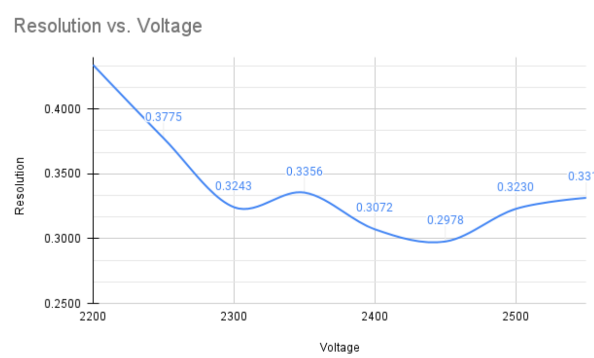


FIG. 18: *Plot for Resolution vs Applied Bias Voltage (minimum resolution value at 2450 V).*

F. MCA output

Now following figures are the spectra obtained from MAESTRO and we saved them in an ASCII file I Used CERN ROOT to fit the curves. Each spectrum was taken on a different voltage

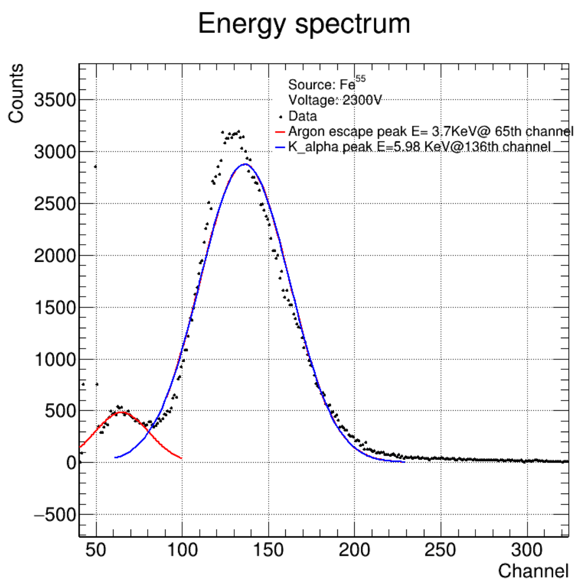


FIG. 19: *Fe - 55 radiation spectrum at Bias Operational Voltage 2300 V*

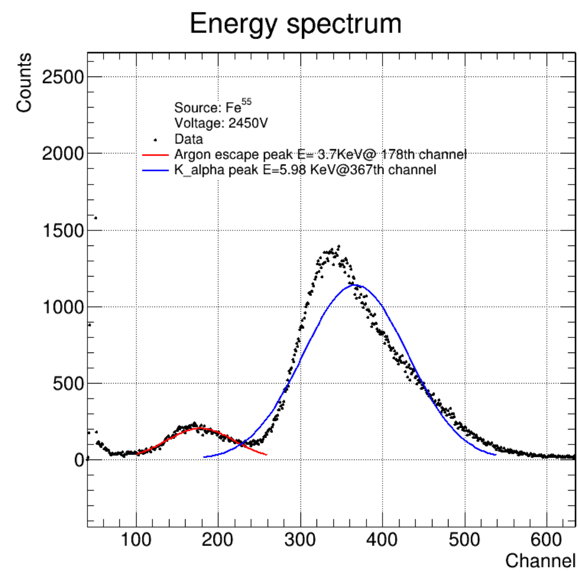


FIG. 21: *Fe-55 radiation spectrum at Bias Operational Voltage 2450 V*

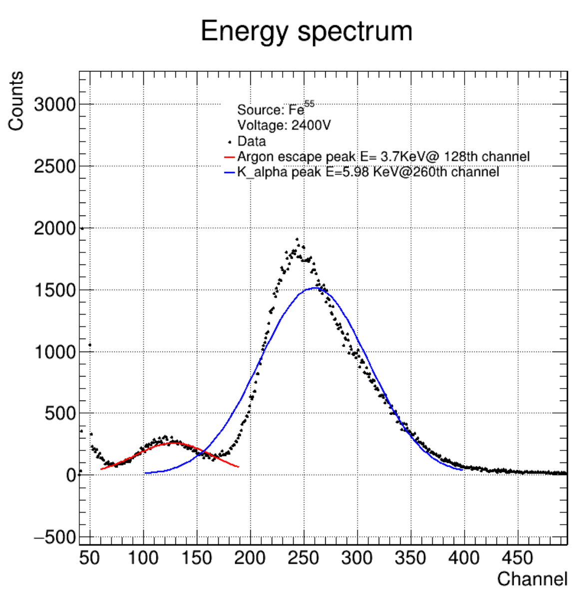


FIG. 20: *F e-55 radiation spectrum at Bias Operational Voltage 2400 V*

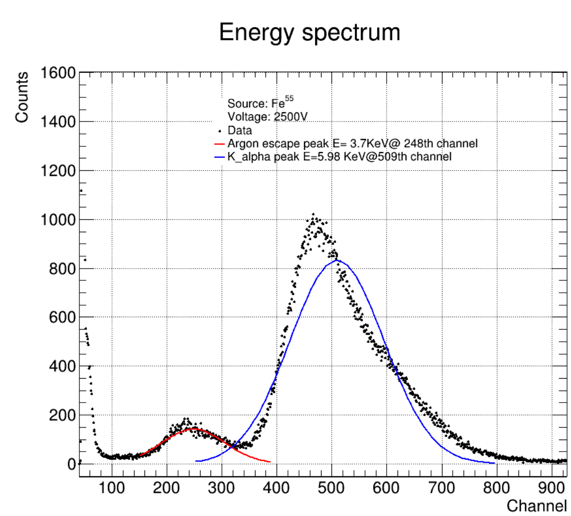


FIG. 22: *Fe-55 radiation spectrum at Bias Operational Voltage 2500V*

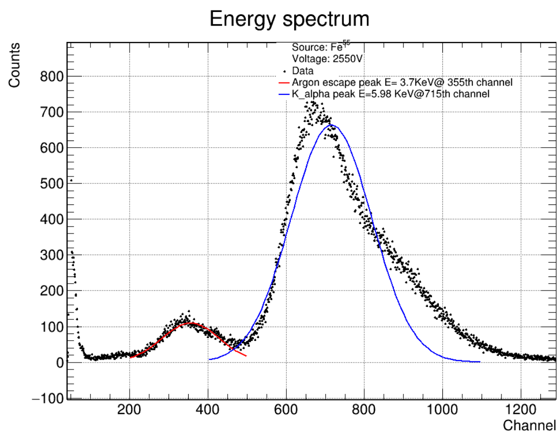


FIG. 23: *Fe-55 radiation spectrum at Bias Operational Voltage 2550V*

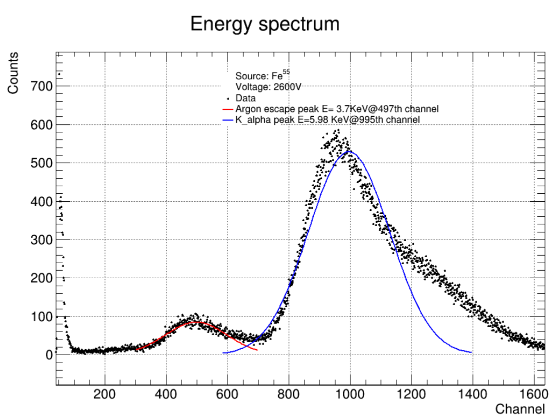


FIG. 24: *Fe-55 radiation spectrum at Bias Operational Voltage 2600 V*

IX. DISCUSSION

A. Efforts to remove errors

- A Faraday cage can be used to reduce noise by blocking external electromagnetic fields. In this case, a thick cuboid made of aluminum was found to be the perfect size for use as a Faraday cage, as it closely matched the dimensions of the detector. By enclosing the detector within the cage, the amount of noise was significantly reduced, from an initial level of perhaps 50

- Grounding is an essential technique for reducing noise, as it can help to stabilize the voltage and minimize the impact of electromagnetic interference. In the case described, a common ground was established by connecting the metal rack containing the nim modules to a non-painted area using a screw. By grounding the cage in this way, the amount of noise was reduced even further, to below 5

- The sensitivity of the preamp is an important consideration when trying to obtain accurate data. In this case, it was found that connecting the preamp directly to the shv connector with the anode wire produced the best results, as it minimized the impact of any noise or interference.

B. Results & Discussion

- As we increased the voltage in our experiment, we observed that the device started producing noisy and saturated results after reaching about 3000V due to its limitations. This prevented us from properly verifying the proportional region since we were not able to pass the μA current range.

- To investigate the behavior of the proportional counter, we plotted its V-I characteristics and noticed a sudden increase in current at 2900 V, indicating that the device becomes less useful above 2900V.

- We verified the inverse-square law by fitting a plot of current versus distance with an inverse square curve The plot showed that the current due to ionization and distance are inversely related as $I = \frac{1}{r^2}$.

- We also plotted counts versus $1/r^2$ and obtained a linear fit to further verify the inverse square law.

- To determine the optimum operating voltage for the detector's resolution, we plotted the spectrum curve and fitted it with the Gaussian function within the preamplifier limit of 3000V. We calculated the resolution and found that the voltage with the highest resolution (lowest FWHM) was 2400V.

- We further confirmed this by plotting the resolution for different voltages (as shown in Fig. 18) and found that the optimal voltage for further analysis was 2400V.

- An energy calibration was performed by fitting the highest peak in the Fe spectrum using a Gaussian function. The spectrum was then calibrated by assigning an energy value of 5.88 KeV to the channel corresponding to the peak.

- The spectrum plot (Figure 19) revealed two prominent peaks and a small bulge next to the major peak. The first peak corresponded to the argon escape peak, the second and most prominent peak was attributed to the $K\alpha$ X-ray line of Fe^{55}, which had an energy of 5.88 KeV. The third peak was due to the $K\beta$X-ray line of Fe^{55}, but was not clearly visible due to the poor resolution of the detector.

- It should be noted that the detector used had very low resolution. Further investigations are required to optimize the detector and obtain more accurate results.

- Building the detector took up most of the allocated time, which limited the ability to further study the Ba and Co spectrum. However, a well-insulated and near 0-level noise-reduced compartment was successfully constructed for the detector.

X. CONCLUSION

A Single-wire straw tube Proportional Counter was successfully constructed using readily available materials such as Copper wire, and OHP sheet covered with Aluminium tape. In addition, some basic $3-D$ parts were available pre-designed and printed using Onshape to be used in the construction of the detector. The Gas Amplification factor was calculated for each operating voltage, and the Diethorn Equation was validated.

Using an X**-ray source** $Fe-55$, the $I-V$ characteristics curve of the detector was measured, and the Proportional region was identified. The radiation spectrum obtained from the Multi-Channel Analyzer was analyzed, and the detector was calibrated with the aid of known energy of the K_α peak and Argon escape peak, after Gaussian fitting of the peaks, and correlation with the corresponding Channel numbers.

The Full Width at Half Maximum (FWHM) for the most significant peak, i.e., the K_α peak of $Fe-55$ decay, was computed for different Operating Bias voltages using Gaussian fits. The operating voltage that yielded the best resolution detection was determined, and the optimal operating voltage was found to be 2400 V. This value is in excellent agreement with the calculated theoretical value of 2425.29 V. This method of constructing a Single-wire Proportional Counter, combined with the use of an X-ray source and Multi-Channel Analyzer, can also be adapted for the construction and calibration of a Straw Tube detector.

In addition, **it was observed that the peaks, such as the K_α and Argon escape peaks, were shifting towards higher channel numbers as the voltage to the detector were increased**. This phenomenon is due to the fact that higher-voltage particles produce more ionization in the gas, leading to a greater number of electrons being collected by the detector wire. Consequently, the increased number of collected electrons results in a higher voltage pulse being generated by the detector, which leads to a larger signal being recorded by the Multi-Channel Analyzer at higher channel numbers.

This observation has significant implications for the use of Straw Tube Proportional Counters. Since the channel number is proportional to the energy of the detected particle, different energy sources can be distinguished by the channel number at which their corresponding peaks are observed. This property is particularly useful in high-energy physics experiments, where it is necessary to detect and distinguish between particles with a wide range of energies. Therefore, Straw Tube Proportional Counters can be utilized to measure and analyze the energy spectrum of various radiation sources in a range of scientific and technological applications.

XI. REFERENCES

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