Proportional Counter

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1. Introduction

The proportional counter is a type of gas-filled detector that was introduced in the late 1940s, in common with the Geiger-Müller tubes. Proportional tubes are almost always operated in pulse mode and rely on the phenomenon of gas multiplication. This last is a consequence of increasing the electric field within the gas to a sufficient high value. One important application of these counters has been in the detection and spectroscopy of low-energy X- rays. Below in Figure 1, schematics of such a device is shown.

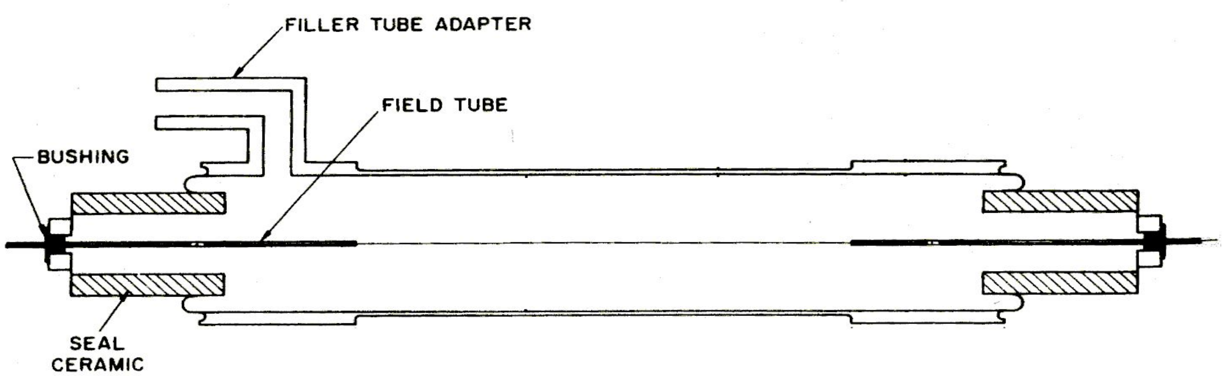

Fig. 1 Cross-sectional view of a Proportional Counter

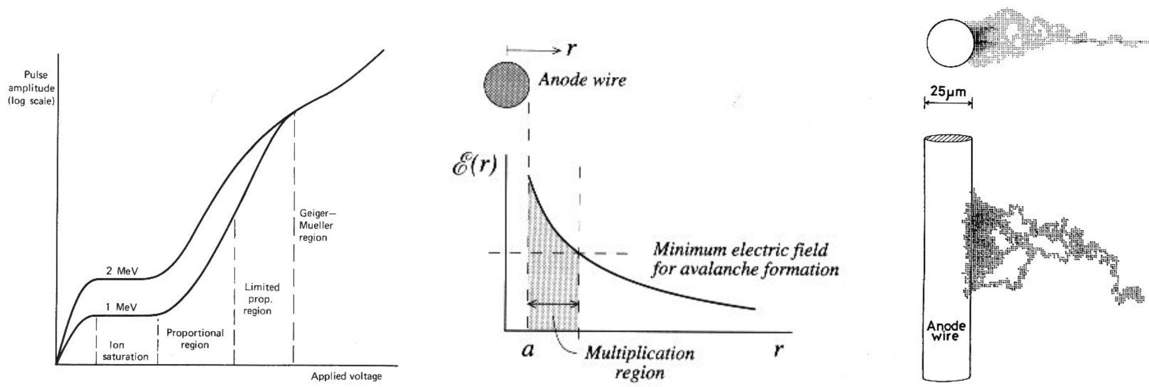

Fig. 2 Principles of Proportional Counter operation: proportional operation region (left), electric field strength (center) and electron avalanche (right)

The thin axial wire anode is supported at either end by insulators that provide a Vacuum-tight electrical feed through for connection to the high voltage. The outer cathode is conventionally grounded, so that positive high voltage must be applied to ensure that electrons are attracted toward the high field region in the vicinity of the anode wire. In Figures 2, the proportional operation region, the electric field strength and the electron avalanche are shown.

Tasks for the report:

- Report must include **abstract, introduction, theory, experimental setup, results and discussion** and **conclusions**
- Describe the operational principle of the detector

2. Building a Proportional Counter

Your task is to build a proportional counter from scratch using normal, accessible and affordable household items. Items such as empty beverage cans, water pipes and aluminum broomsticks have been used for the cathode tube. The important properties are electrical conductivity or insulation and dimensions. Remember to check the conductivity of the inner surface of your cathode tube (especially aluminum items often have insulating protective layer, that needs to be removed). Take measures of all of your parts.

Any dust and lipids on the surfaces will hinder the operation of the detector. Therefore all detector parts must be cleaned thoroughly using either dishwasher solution or isopropyl alcohol and ultrasonic bath. After cleaning, the detector will be assembled while avoiding surface contaminations by using rubber gloves.

Before assembling take some time to plan how you will put all the parts together and discuss your plan with the instructor.

When your detector is ready and the glue has dried, its air-tightness needs to be tested before measurements. Measure the gas flow from the gas supply. Connect the detector to the gas supply and after few minutes measure the gas flow out of the detector. If the gas flow in and out do not deviate significantly, the detector is good to go. A deviation of few ml/min is normal.

Tasks for the report:

- What parts did you use to build the detector? What were their dimensions? What is the purpose of each part?
- How did you clean the parts?
- How did you assemble the detector?
- Include at least one **photo** (more if possible)

3. Measurements

Before measurement a gas mixture is flushed through the detector for few hours. The gas has to replace all air in the detector before measuring. The suitable gas flow depends on how tight the detector is. As a rule of thumb the flow during flushing should be minimum 20 ml/min and during measurement maximum 20 ml/min.

The setup is described in Figure 3. High voltage source provides the detector operating voltage. The chain of the data acquisition consists of a preamplifier, a linear amplifier, a multichannel analyser (MCA) and an oscilloscope. The detector output is connected to the pre-amplifier and split into two cables. One cable is connected to the oscilloscope for online signal monitoring. Another cable is connected to the MCA for data storage and analysis. The radioactive source (Fe55 or Am241) is placed over the detector in order to test the detector performance. Data must be collected during several minutes in order to have enough statistics.

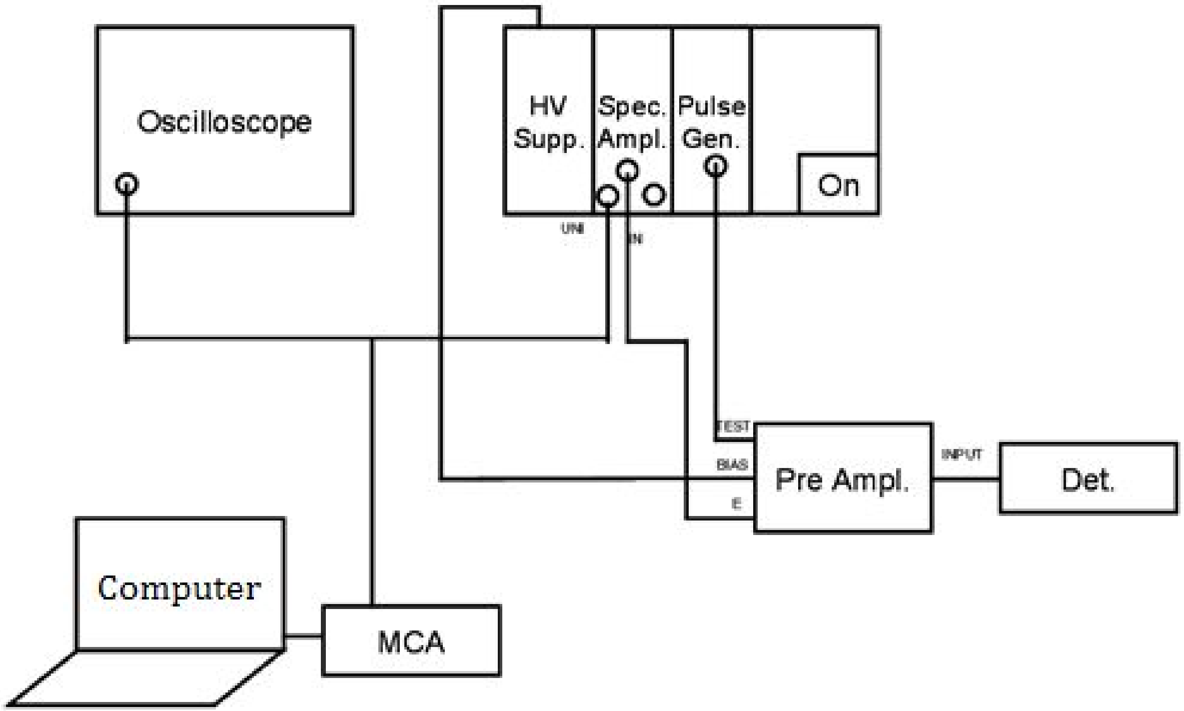

Fig 3: Schematic drawing of the setup. Note: Power cables are not included in the drawing.

The MCA software starts and pauses measurement by pressing F3. The histogram is cleared by pressing the button A and time is reset to 0 by pressing the button T. The region of interest (ROI) is cleared by pressing the button R.

3.1. Calibration

In the calibration a test pulse with known pulse height is fed through the electronics. You need to measure the electronics response with six different pulse heights. You can use for example 20, 50, 70, 100, 120 and 150 mV pulses, with spec. amplifier gain = 10 or use your own set of pulse heights. The calibration pulse height is measured using the oscilloscope, while the corresponding MCA channel is discovered by saving a single histogram with all the calibration points and fitting eg. a Gaussian[1].

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[1] Check the software preferences that the centroid/ FWHM detection mode is set to Gaussian mode.

3.2. Measurement with Radiation Sources

Two radiation sources, Fe55 and Am241, are used to measure the charge multiplication of the detector. Before measuring check that you can see a signal in the oscilloscope. Take one measurement of the background without radiation source.

It is recommended to start with Fe55 using the highest amplifier gain (100) and (slowly) ramp up voltage until a signal is seen in MCA. The voltage is ramped up in suitable steps and amplifier gain adjusted when signal goes outside MCA range. Take at least four measurements per amplifier gain. Paint the region of interest in the MCA software and take notes on **voltage, gain, centroid** and **FWHM**. Remember to SAVE the measurement data. With Am241 it is then convenient to ramp down from the voltage you were left with in previous measurement.

During the measurement the rate should not exceed 200 cps. If the rate is high, the source needs to be collimated. Make also sure that the low channel background is excluded using threshold before taking note on the rate.

Tasks for the report:

- Describe the test setup
- What gas did you use?
- How did you calibrate the electronics?
- What equipment did you use for it?
- Establish relationship between collected charge Q and calibration pulse height (in Volts). Hint: you can use the preamplifier input capacitance C = 1 pF.
- Plot the **collected charge vs. MCA channel**.
- Fit a straight line in the plot to obtain a calibration constant.
- Show the spectra of the two radiation sources Fe55 and Am241
- At what voltage, using which gain did you first see the signal (for both radiation sources)?
- At which voltage did you stop measuring and why?
- Did you use collimator with either source?
- Calculate the collected charge using the calibration results.
- Plot the **charge multiplication vs. Voltage** and **Resolution vs. Voltage**, both sources in same graph, if possible
- At which point does the detector reach the proportional region?
- What software did you use in the data-analysis?

- Did you use any special functions in the software for fitting?
- Remember to do **error analysis**!

Bibliography

[1] Glenn F. Knoll (2000 or 2010): *Radiation Detection and Measurement,* Wiley