

# Construction and operation of a small multiwire proportional chamber

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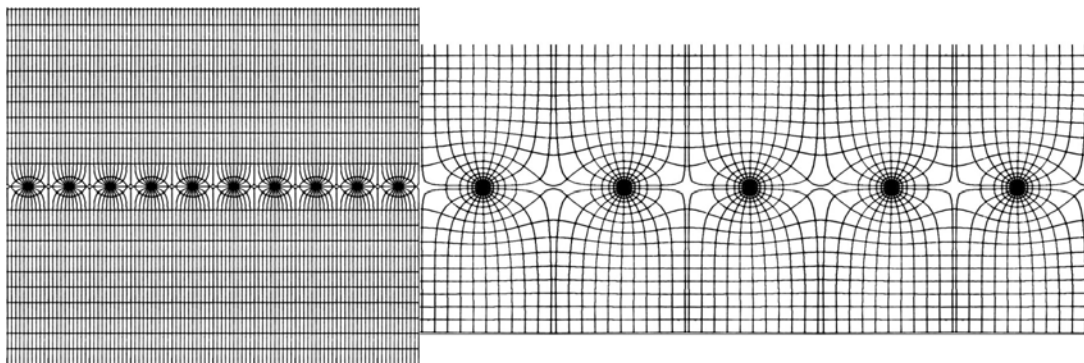
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**Abstract.** The aim of this laboratory session is to provide the basic ingredients for understanding the construction and operation of Multiwire Proportional Chambers (MWPC). The construction of a simple position sensitive MWCP is described. Only measurements requiring rather simple hardware (amplifiers, digital oscilloscope) are presented.

## 1. Principles of Operation

The principles underlying modern multiwire chambers were already shown around 1920 (Geiger-Müller counter); the first wire chamber used in high-energy physics was, in fact, a spark chamber whose electrode plates were replaced by grids of parallel wires in order to reduce multiple scattering, energy loss and secondary interactions, and to allow the localization of particle impact points without using photographic methods. Later, the idea of the Geiger-Müller counter was taken up again and developed into modern position detectors, more precisely into MWPC.

A MWPC in its simplest form essentially consists of thin parallel and equally spaced anode wires symmetrically sandwiched between two cathode planes. Cathode planes can be a set of thin equally spaced wires but also can be made of a continuous plane conductor. The gap between the plane of the anode wires and the cathode plane is normally a few millimeters. The chamber is filled with an appropriate mixture of gases depending on the desired mode of operation. On application of a high

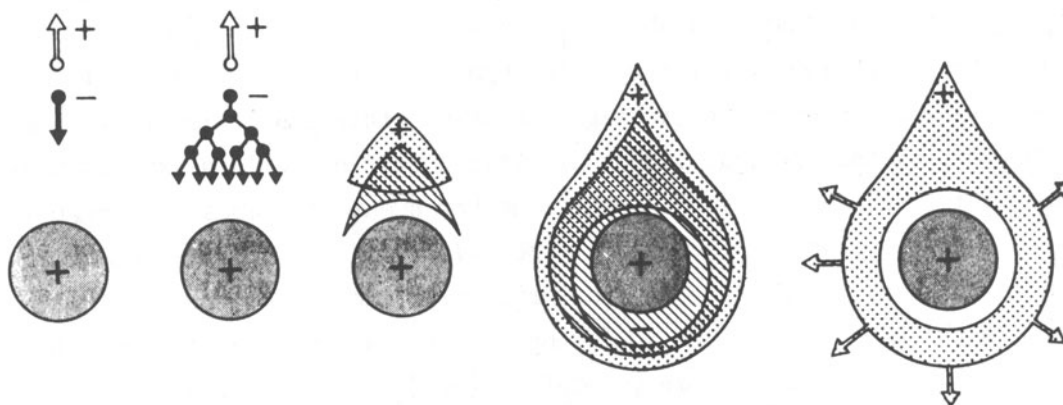


**Figure 1.** Typical Electric field and potentials lines in a MWPC

voltage (HV) between anodes and cathodes, the electric field takes the form shown in figure 1.

If an ionizing process occurs in the gas, the produced electrons (primaries) will drift toward an

anode wire. Far away from those wires ( $\sim 20$  times the wire-diameter) the electric field is basically constant, however, near them the electric field becomes inversely proportional to the square of distance ( $r$ ) to the wire, therefore the primary electrons can gain enough kinetic energy so that inelastic collisions with the gas molecules can lead to new ionizations, with the generation of secondary electrons. The latter can undergo further inelastic collisions, eventually resulting in what is called “an electron avalanche” or “charge multiplication” figure 2. If the total collected charge is proportional to the number of primary electrons, then the chamber is said to operate in the “proportional mode”. The proportionality constant is called “multiplication factor” and depends exponential on the applied HV.



**Figure 2.** Ionization process around a wire.

The electron avalanche is rapidly ( $\sim$ nsec) collected by the wires, the positive ions leftover in the trail of multiplying electrons move in opposite direction toward the cathode. In their motion, they induce image charges in all surrounding electrodes and these results in a negative signal on the wire where the avalanche originated (figure 2). So, in principle, each wire could act as an individual detector

If it is possible to decode on which of the wires the signal originated, then the MWPC is said to be “position sensitive”. The easiest, but most expensive, way to read those electric signals is to connect each wire to a circuit which includes an amplifier, a discriminator and digitizer (ADC or QDC). However, handling a high number of electronic channels is often not affordable. In those cases, cheaper (interpolation) methods such as delay line, or charge division, are recommended

## 2. Experimental Procedure

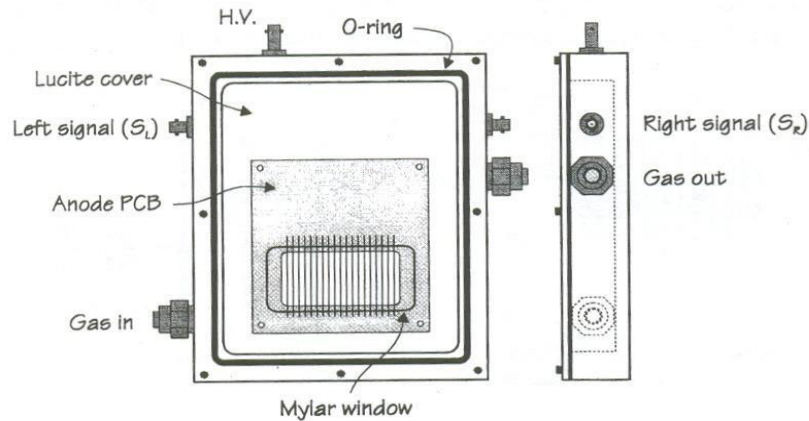
The multiplication factor, efficiency and other operating characteristics of a MWPC depend on both, the mechanical parameters (wires diameter and distances, electrode's gap, etc), and on the gas used. Since my aim here is that the students could build their own position sensitive MWPC, the chambers to be described here have a design and an electronic read out that is easy to assemble, and is sufficient to demonstrate position sensing capabilities. The mechanical parameters here can be considered as typical for a small size MWPC (Ref [1,2]).

### 2.1 Mechanical construction

Our chamber consists of a central anode wire plane placed between two cathodes. The anode was formed by a 17 Tungsten Au-plated wires (25 microns diameter and 3 cm long) with a 2.5 mm separation between them (the “pitch”). They were soldered to a 1/16"-thick fiberglass printed circuit board (PCB). The cathodes were made from a single 4x4 cm Cu strip laid down on a PCB.

The electrodes were enclosed in a 10x12x2.5 cm<sup>3</sup> gas-tight, high-density, polyurethane container (see figure 3). For pedagogical reason the box had a transparent acrylic cover to show the inner parts

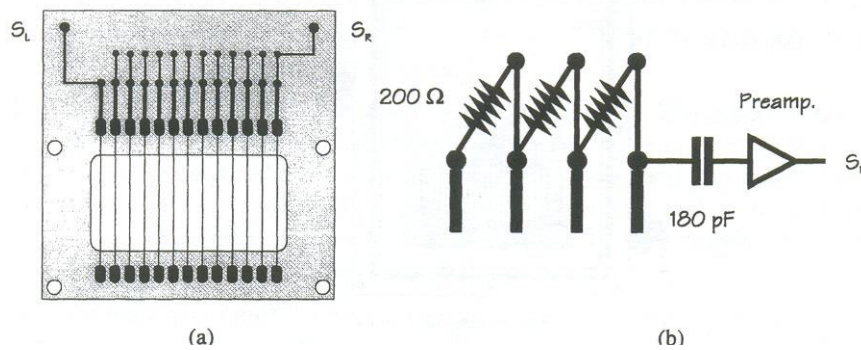
of the chamber. A  $5 \times 3 \text{ cm}^2$  entrance window made of 1.5 microns thick Mylar was also necessary to allow a calibration using alpha particles from a radioactive source.



**Figure 3.** Schematic diagram of the MWPC

## 2.2 Assembling

Each chamber were designed like a ready-made kit, which includes housing, anode and cathode PCBs, anode wires, spacers, plastic screws, resistors, capacitors and soldering equipment. The detector housing was fitted with the appropriate feed-troughs for the HV, signal outputs and gas connectors (figure 3). In order to simplify the construction, the students were provided with PCB frames on which the tensed (90 g) Tungsten wires had already been soldered. In this way, the anode plane could be quickly built, by just placing the wired frame directly on top of the PCB anode, and soldering the wires using the anode tracks as guidelines (figure 4).



**Figure 4.** Schematic of the anode plane and resistive network implemented in the charge division readout method

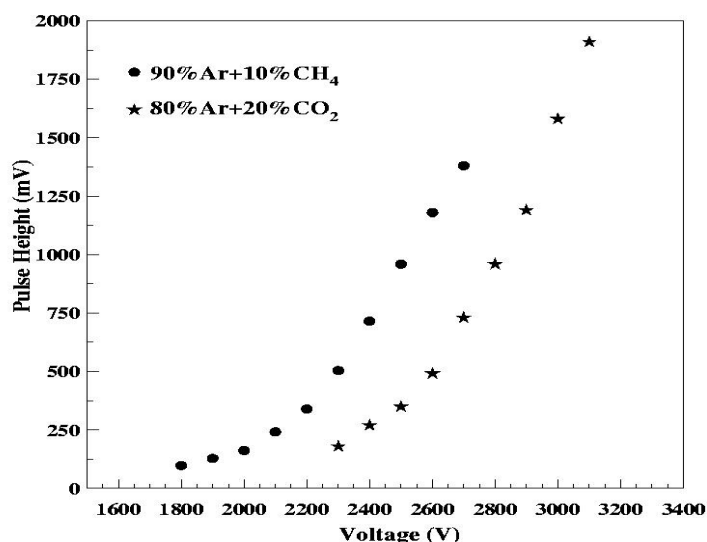
After soldering the anode wires, it was necessary to cut (very carefully) the wires from the PCB frame. A sharp cutter or single edge knife was found to work just fine. In order to make the resistive chain, a series of resistor (220 ohm each) is placed in the back-side of the PCB anode. Once in place, they were soldered by the students.

The next step was to assemble the anode, and the cathode, planes using the plastic screws and spacers. At this point, it was possible to try different spacers and work with different cathode-anode distances ( $D$ ), just keeping in mind that for large  $D$ 's the chamber needed

higher voltages to produce the same charge. The chamber was assembled using only one cathode plane to allow a see-through environment. Finally, the chamber was mounted on the plastic box, and each end of the resistive chain was connected through a 180 pF high voltage capacitor to their respective signal outputs (labeled SL and SR in figure 3). The anode wires were connected to the HV through a 10 Mega-ohm resistor to decrease parasite currents. The cathode was connected to a common electric ground. Final testing of electrical connections was made before placing the acrylic cover of the detector box, with the corresponding O'ring acting as a gas-tight seal. After this procedure, the MWCP was ready to be filled with gas.

### 3 Initial operation

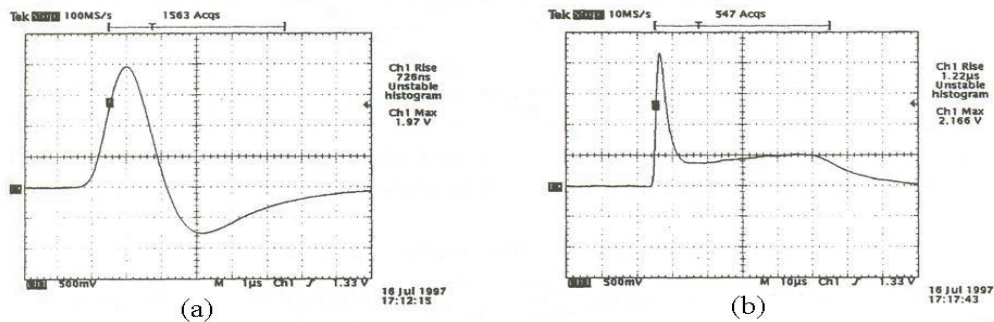
As with all gaseous detectors, the choice of gas depends on the multiplication factor, among other experimental requirements. It was found that the avalanche process occurs in noble gases at much lower voltages than in complex molecules. Thus, the gas used in a MWPC usually has noble gas as main component. As an example of how much the operational voltage and the avalanche size can vary, in figure 5 we present the pulse-height measured with a chamber (identical to the one built in the School) but filled with two different gases 80%Ar+20%CO<sub>2</sub> and 90%Ar+10%CH<sub>4</sub>. During the laboratory session the gas used was Ar+CO<sub>2</sub> mixture which is non explosive.



**Figure 5.** . Pulse height variation as function of the voltage for two different gasses

#### 3.1 Turning on the voltage

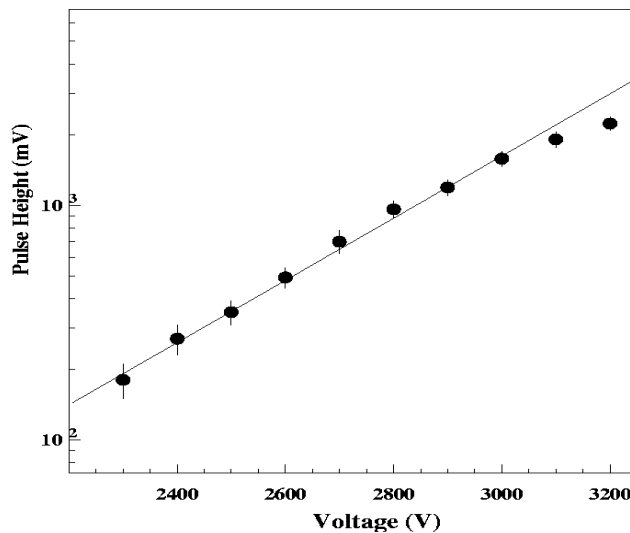
For simplicity, the chamber was operated under a steady gas flow at atmospheric pressure. A <sup>241</sup>Am radioactive source, producing 5.48 MeV alpha-particles, was used for testing purposes. This source was mounted on a holder with a collimator of 0.5 mm and placed directly on front of the Mylar entrance window of the chamber. The collimator was used to improve the position resolution as well as to control the counting rate. The MWPC output was connected to an ORTEC 142C charge-sensitive preamplifier, followed by a shaping amplifier ORTEC 855 operated with a shaping time of 0.5 microseconds. After flushing the chamber for several minutes with the gas, the HV power supply was switched on, and the bias slowly increased making sure to start from 0 V, and not to exceed 3.5 kV. After reaching 2.3 KV, the signals were clearly visible in the oscilloscope (1 μs/div, 50 mV/div). figure 6 shows a typical pulse. It is possible to use either the unipolar or bipolar outputs of the amplifier.



**Figure 6.** Typical signal outputs (256 sample mean) as seen on a digital oscilloscope, bipolar (a), and unipolar (b).

**4. Pulse height Measurements**

One of the first things to measure in a gas detector is the relationship between operational HV and pulse height (PH). This measurement was carried out by placing the <sup>241</sup>Am source near the center of the chamber and setting the HV to 100 Volts less that the minimum voltage (≈ 2,200 V) at which the signal is observed for first time. In such conditions, the scope’s trigger level is set just above the electronic noise, and kept at the same level from then on. In order to measure the PH, the HV was increased and our digital oscilloscope was set in an “averaging mode” (64 samples, or higher). Under this condition, a very clean and stable pulse can be observed and measured. The PH was registered for different HV values figure 7 shows a log-linear plot of the results obtained while operating one of the chambers. mode.).



**Figure 7.** Pulse height vs. HV applied between the anode and the cathode. The straight line represents an exponential ( $Ae^{(bx)}$ ) fit

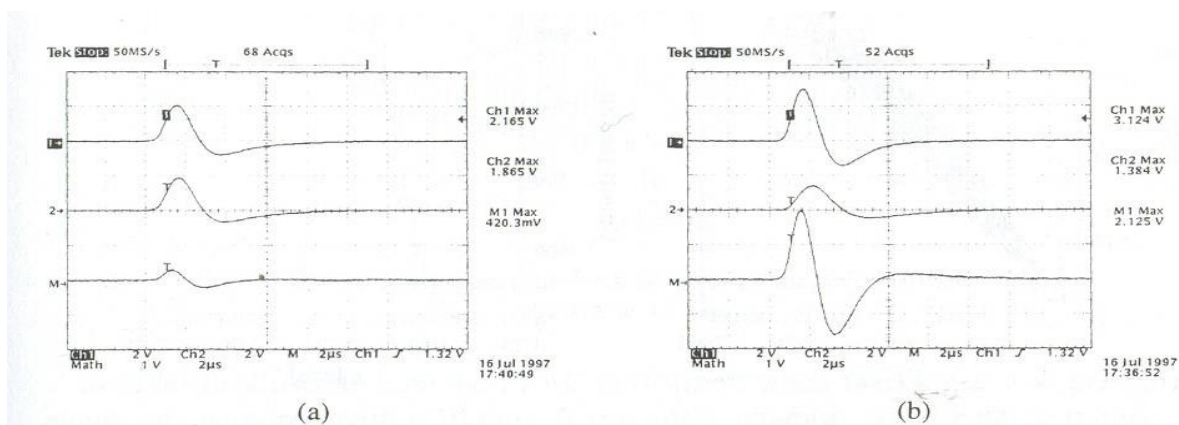
The straight line showed in this plot is the prediction of a simple avalanche growth theory [3]. This exponential growth is also a signature that the chamber is working in the proportional region. The deviation from linearity at highest HV value indicates the beginning of the Geiger regime, where chamber starts to discharge (sparks).

## 5. Position Sensing Capability

The use of digital oscilloscope also helped to illustrate, at least qualitatively, the position sensing capability of the MWPC. Since the charge division method is used, it is expected that the output signals SL and SR (figure 3) should show a correlation with the position of the source.

In order to verify that any difference between SL and SR was due to a change in the position of the source, each read out line has to be calibrated with a pulse generator (for example a 419 Ortec pulser), in such a way that both read out lines produced the same output for a single given input signal. Then each output of the detector was connected to the oscilloscope using the amplifier in fast bipolar mode. Each signal was averaged at least 128 times in order to reduce noise, and the resulting waveforms were subtracted from each other using the Math channel of the oscilloscope. figure 7 shows two screenshots of the oscilloscope when the 241Am source was placed in two different positions.

By placing the source at the middle of the chamber both signals should have approximated the same height (figure 7 a). Then as the source is moved closer to the right (left) the SR (SL) increases while SL (SR) decreases, as shown in figure 7 b. This behavior is more notorious when we look at the math channel (bottom wave form in figure 7 a and b). This reveals charge conservation, i.e., the SR, SL are proportional to the charge collected at either the end of the resistive chain, so the total signal for a single event has to be proportional to (SL+SR). Thus,  $SR/(SR+SL) = (1-SL)/(SR+SL)$ , therefore whenever SR (SL) increases, SL (SR) has to decrease. In fact this ratio is also proportional to the position X of the traversing particle [4] as measured at the left-end of the chamber, and it is given by  $X = L SR/(SR+SL)$  where L is the total active length of the chamber along X (in our case 4 cm).



**Figure 7.** Position determination using a digital oscilloscope. In (a) the radioactive source is near the center of the MWPC. In (b) the source is closer to the right of the chamber. The signal output order is: right (top), left (middle), subtraction right-left (bottom).

## 6. Summary

In this laboratory session the students built from scratch a MWPC. This MWPC was operated in the proportional mode and shown to have position-sensing capabilities. Of course, time permitting, once the chamber is ready and working, it is possible to demonstrate to the students other features such as rise time, energy resolution, position resolution etc.

## References

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- [2] Charpak, G and Sauli F., *Nuc. Inst. and Meth* **162**, 405 (1979)
- [3] Rose M. A. and Korff, S.A. *Phys. Rev.* **59**, 850 (1941)
- [4] Albrei J.L. and Radenka V., *IEEE Trans. Nuc. Sci.* 23-1, 251 (1976).