Fabrication, Assembly and Testing of Multiwire Proportional Counters

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Abstract— Multiwire Proportional Counter (MWPC), a particle studied under this project is an indispensable part of all nuclear physics experiments involving the study of compound nucleus and fission fragments. The work done under this project involves the fabrication, assembly and testing of a MWPC. The experimental work has been done at Inter University Accelerator Center (IUAC), New Delhi. The MWPC fabricated at IUAC had an active area of 16x11 cm^2. Timing resolution and gain of the fabricated MWPC was made to improve over that of already available MWPCs at IUAC by reducing the anode wire pitch and using a ten micrometer diameter wire for anode frame. The fabricated MWPC was thoroughly tested with an alpha source and it was observed that the detector could handle heavy count rate exceeding 20 KHz without any breakdown. Fabricated MWPC was also used in a nuclear physics experiment in the NAND experimental set up of IUAC to extract information about mass, kinetic energy and angular distribution of fission fragments. All the detailed investigations done with the detector were part of the M.Sc. Dissertation work of the first two authors. During under graduation and post-graduation, students study about proportional counters with emphasis on their construction and basic principle of operation. However, this project work provided the first two authors with a unique opportunity of getting a practical experience on how these proportional counters are fabricated and their importance in the field of nuclear physics. Thus, project based learning leaves a larger impact on the mind of the students as far as understanding of concepts of science is concerned

Key words: Multiwire Proportional Counters, Fabrication, Detector

I. INTRODUCTION

A multi wire proportional counter is simply a gas filled wire chamber consisting of a large number of anode wires stretched in a plane for position measurement. The original motivation of developing such detectors came from the need to track particles in high energy physics experiments. The wire chambers, thus developed worked amazingly well and helped scientists make great discoveries at particle accelerators. Although these chambers are still used in some laboratories, but since the advent of high resolution silicon detectors their utility has somewhat diminished. Fig.1 shows the sketch of a typical multi wire proportional chamber [1]. The closely spaced thin anode wires are stretched in a plane that is midway between two cathode planes. The cathodes are kept at negative potential with respect to anode wires that are kept at ground potential. Each of the anode wires acts as an independent proportional counter and must therefore be read out independently [2].

The spacing between the anode wires, also called pitch, determines its position resolution. A pitch of 2 mm to 3 mm is typical of most wire chambers. It should, however, be remembered that the position resolution is generally better than this spacing. The cathode planes are generally separated by a distance of approximately six times the pitch. A point worth noting here is that the cathode plane can also consist of closely spaced wires or strips to enhance the position resolution.

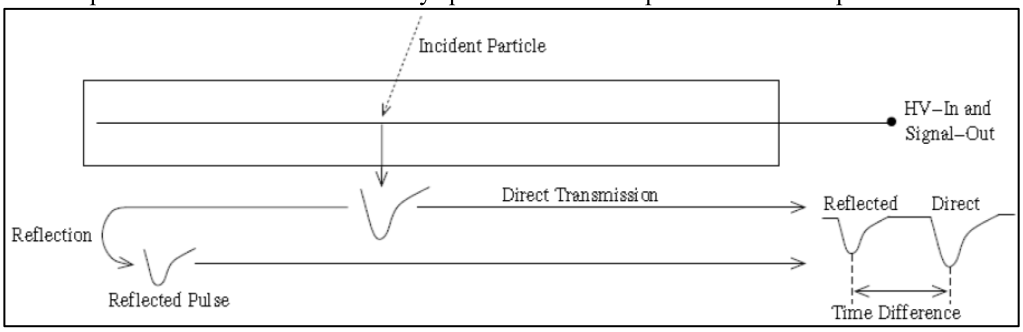

Fig. 1: Position sensitive detection from a timing device. The signal generated in the central anode wire is transmitted in both directions. The direct and reflected pulses arrive at the processing electronics (such as an oscilloscope) at different times. The time difference is then used to determine the position of the pulse generation provided the system has been calibrated.

As with single wire proportional counters, the radiation passing through the chamber volume produces electron ion pairs. The ions move towards the cathode while the electrons rush toward the anode wires. The high electric potential at the anode causes the electrons to gain enough energy between collisions to produce secondary ionization and ultimately avalanche. The output of a multi wire proportional chamber depends on the associated electronics, which in turn depends on its mode of operation. In digital mode, in which only counting is performed and the information is binary, the electronics might consist of simple level crossing discriminators and counters [3]. However, if the pulse height is also to be measured, then the circuitry would become more complicated and involved. The MWPC described above can give only one dimensional position resolution. To obtain two dimensional event identification, one generally uses two such detectors with wires perpendicular to each other. A time coincidence unit can then tag the events in the two chambers as being from the same particle. An even higher resolution can be obtained by using several chambers in succession such that the wires of each of them are tilted at a different angle.

II. DESCRIPTION OF THE DETECTOR

The core of the MWPC consists of three wire frames with active area of 16x11 cm^2. Wire frames are shown in Fig.2.

- X-POSITION wire frame – It is made up of 100 parallel gold plated tungsten wires.
- CATHODE – It is made up of doubly aluminized mylar foil.
- Y-POSITION – It is made up of 100 parallel gold plated tungsten wires perpendicular to the X-POSITION wire frame.

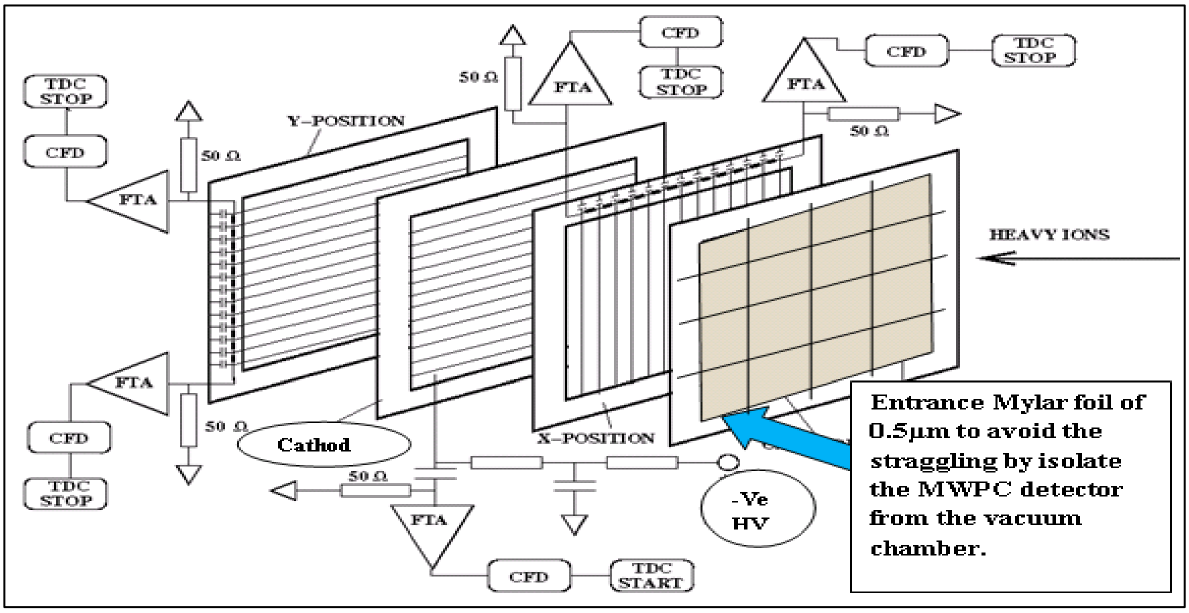

Fig. 2: Schematic arrangement of assembled electrodes

The distance between adjacent wire frames is 10 mm. Anode wire frames are made from gold plated tungsten wires of 10 µm diameter stretched on a 1.7 mm thick printed circuit board[4]. The separation between adjacent wires is 0.5 mm. The two anodes are grounded, whereas the cathode operates in a proportional region with a typical voltage of 450V. Position information from both X and Y planes are extracted using commercially available rhombus delay line integrated chips of model TZB12-5. The electrodes are housed inside a rectangular metal housing milled out from a solid aluminium block. The detector is operated with isobutane gas at constant volume with pressures varying from 1 to 5 Torr depending on the type of incident particle and count rates [5]. To avoid straggling, entrance foil used is 0.5 µm mylar thick. For improved resolutions, the preamplifier was placed next to detector inside the vacuum chamber.

III. FABRICATION OF THE DETECTOR

MWPC has been made by three electrodes which are given below:

- X-POSITION WIRE FRAME: It has been made by soldering the 100 parallel gold plated tungsten wires of 10µm in diameter with a step of 0.5 mm stretched onto a 1.7 mm thick printed circuit board with an active area of 16x11 cm^2. It measures the horizontal (X) position signals.
- CATHODE WIRE FRAME: It has been made by 1.3 µm thick doubly aluminized Mylar foil. Fig.3 shows the cathode wire frame fabricated at IUAC.

Fig. 3: Cathode Wire Frame.

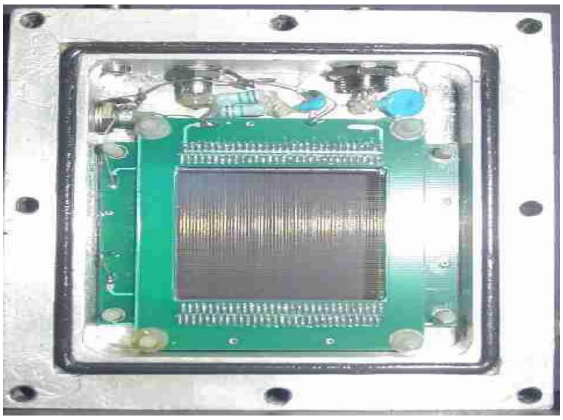

Fig. 4: Y Position Wire Frame

- Y-POSITION WIRE FRAME: It has been made by soldering the 100 parallel gold plated tungsten wires of 10μm in diameter with a step of 0.5 mm stretched onto a 1.7 mm thick printed circuit board perpendicular to the wire of the X-POSITION WIRE FRAME with an active area of 16x11 cm^2. It was used to measure the vertical (Y) position signals. Fig.4 shows the Y position wire frame fabricated at IUAC [6].

A. *Steps of Fabrication*

- The separation distance between adjacent wire frames was kept 2.4 mm.
- For extracting the position information from X and Y wire frames, commercially available rhombus delay line integrated chip (model TZB 12-5) were used in anode wire frames. Each chip has 10 taps with a delay of 2ns/tap and a characteristic impedance of 50Ω.
- In position electrode (X and Y), wires were shorted in pair and connected to one tap of delay line chip. End to end delay in X and Y position frame was 100ns. There were 5 delay line chips in each anode frame (X and Y position wire frame).
- On the front side of the detector, one Mylar foil of 0.5 μm was used to isolate the gas detector from the vacuum chamber. The foil was supported by crossed 0.5mm nylon wire at 20mm separation.
- The electrode assembly was mounted inside a rectangular metal housing milled out from a solid aluminium block.

IV. TESTING OF THE DETECTOR

A. *Experimental Set Up*

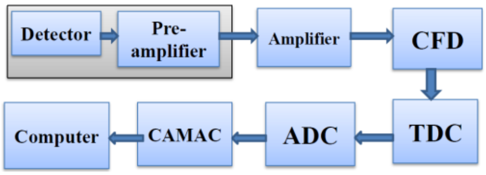

Fig. 5: Schematic representation of experimental setup

The analog signal pulse produced as a result of passage of radiation through a detector usually has a very narrow width and amplitude and therefore cannot be directly digitized or even counted. Unless the detector signal has enough strength, it must be preamplified before transporting it to other processing units [7]. A preamplifier is a simple but efficient amplifier. As can be seen in the block diagram shown in Fig.5, the preamplifier was directly connected to the detector output. Then the signal was amplified by 16-channel spectroscopy amplifier and all timing signals, positions and central anode signals were sent to constant fraction discriminators (CFD) for generating NIM logic pulse for timing measurements. Then the timing signal was changed to an analog signal by TDC (time to digital converter) and then the analog signal was changed to a digital signal by Analog to Digital converter (ADC). CAMAC is an acronym of Computer Automated Measurement and Control [8]. The standard CAMAC backplane is called DATAWAY, which was directly interfaced to a computer. By using 'freedom software' we got the position spectrum of the charged particle.

B. *Testing of the Detector with an Alpha Source*

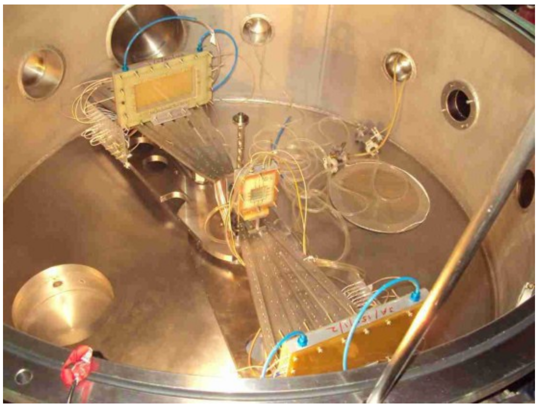

Fig. 6: Schematic arrangement of MWPC detector in GPSC chamber.

The detector was thoroughly tested with ^{241}Am alpha source for determining its position and timing resolution, as well as detection efficiency. Fig.6 shows the position of two MWPCs inside the GPSC chamber during the testing of the detector [9]. An alpha source test is considered to be the benchmark test in terms of detection efficiency as the alpha-particles deposit very small amount of energy (<50 KeV) at low gas pressure in the active volume.

For alpha particle detection, the detector was operated using isobutane gas at a pressure of 5 Torr with an operating voltage of 450 V on cathode and anodes were grounded [10]. Rise times were about 10 ns. The actual position of the incident particles was obtained by taking the difference between the two position measurements in software for both horizontal X = XL-XR and vertical Y = YU-YD positions [11].

Fig.7 shows the one dimensional spectrum of X frame of MWPC which tells about the horizontal position of the detected particle while Fig.8 shows the one dimensional spectrum of Y frame of MWPC which tells about the vertical position of the detected particle.

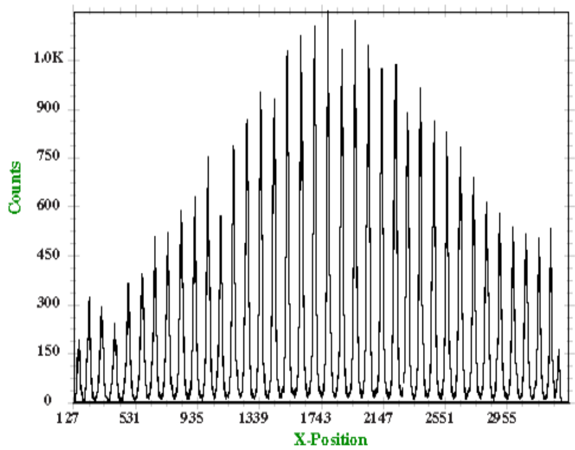

Fig. 7: X-position spectrum.

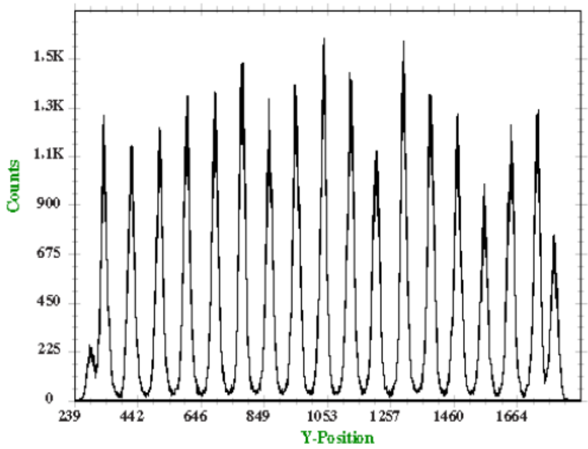

Fig. 8: Y-position spectrum.

The sum of the position signals XL+XR and YU+YD is equal to the total delay of the delay line and thus should remain constant. It gives a single peak during the experiments [12]. This was used to eliminate events arising from reactions and pickups in delay lines and transmission cables, weak signals which were triggered by CFD on one side but not on the other side and multiple hit events [13].

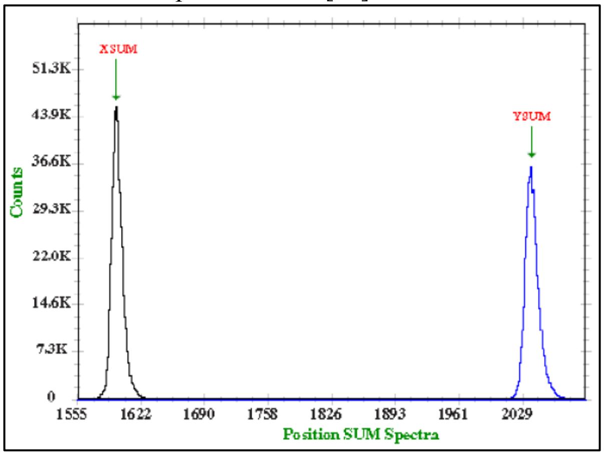

Fig. 9: Spectrum of sum position of X and Y

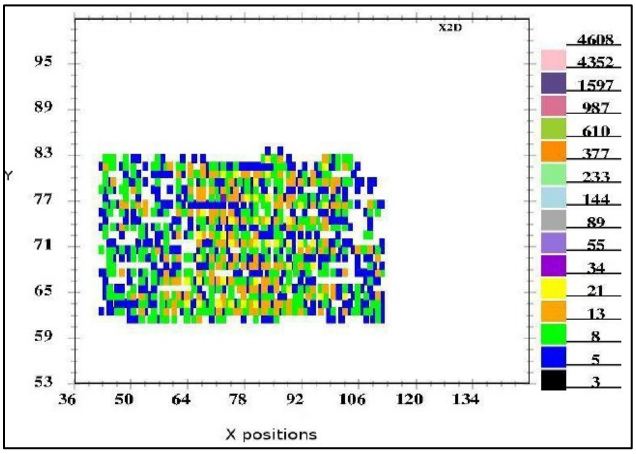

Fig. 10: Two dimensional spectrum of X-Y position

Spectra of X-position and Y position are shown in Fig.9. The width of these peaks is a measure of the time dispersion in the detector as well as electronics setup. Fig.10 shows the two dimensional spectra of X-Y position [14]. In this spectrum the whole wire frame of MWPC is retraced.

V. RELEVANCE OF MWPC AT IUAC

The relevance of fabrication and study of MWPCs lies in the fact that they are an indispensable part of all nuclear physics experiments performed at the Inter University Accelerator Center. MWPC is used in the following experiments at IUAC.

- A compact parallel plate detector for heavy ion reaction studies.
- A detector system for the study of low energy heavy ion reaction using the kinematic coincidence technique.
- To analyze the formation of compound nucleus and a generation of fission fragments specially in the National Array of Neutron Detectors (NAND) set up of IUAC.

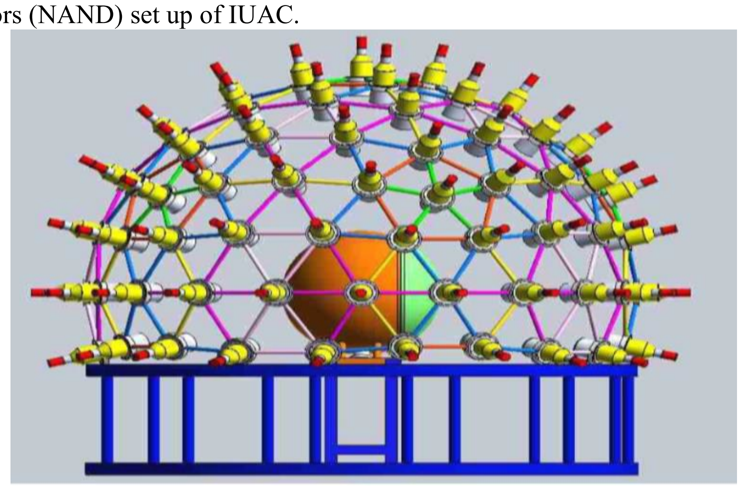

Fig. 11: Schematic diagram of NAND set up of IUAC

VI. Conclusion

The project involved the fabrication, assembly and testing of multi wire proportional counters which are basically gas detectors working in the proportional region. The design of MWPC was modified to increase the timing resolution and gain which are the efficiency defining characteristics of any position sensitive detector. The timing resolution was increased by reducing the anode wire pitch and using a ten micrometer diameter wire for anode frame. Detailed analysis of a typical proportional counter (MWPC) helped the first two authors to understand the relevance of gas detectors in nuclear physics experiments and how the various parameters should be varied so as to increase the overall efficiency of the gas detectors. The project emphasizes the importance of project based learning for under graduate and post graduate students.

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