DEVELOPMENT OF A MULTIWIRE POSITION SENSITIVE PROPORTIONAL COUNTER

by

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Preliminary measurements in a proportional counter with two independently counting wires have shown that counting rates up to 10^6 counts/s per wire can be reached without critical loss in the "true versus measured" linearity relation. In this paper, a gas-flow multiwire proportional counter designed and constructed in Iran, is presented. Results obtained with a fabricated detector, containing 32 Ni-chromic anode wires, are shown. Each wire is associated with a fast pre-amplifier and a discriminator channel. Counting rates of over 10^7 events per second are measured. The diameter, length, and resistance per unit length of anode wires are 35 μm, 3 cm and 10 /m, respectively. The cathode is constructed of two fiber glass printed sheets of 4 12 cm^2 dimensions. In this detector, P_{10} gas (10% of methane and 90% of argon) is used. The volume of the detector sensitive area is 24 cm^3. Detector signals are analyzed carefully through data acquisition systems (MCA, amplifier and preamplifier). Our study indicates that the present detector is a position sensitive detector and that the obtained position sensitivity resolution of this instrument is 3.5 mm.

Key words: proportional counter, position sensitivity, ionization, gas multiplication, charge division

INTRODUCTION

The multiwire proportional chamber, introduced and developed by Charpak, has multiple applications in elementary particle physics and astrophysics [1]. Position detection of radioactive rays enables us to measure the space distribution of radioactive and other materials absorbed by the human body (radio-medicine). Among other possible applications of the said detector are the distribution measurements of X-ray/neutron diffraction patterns [2-7]. The technology for the fabrication of multiwire proportional counters (MWPC) has been developed recently, based on Charpak's invention and the development of the multiwire proportional chamber for which he was awarded the Nobel prize in 1992 [8]. In the field of gas detectors, it is known that the space charge resulting from exposure to high fluxes ultimately limits their counting rate capability by reducing the electric field in the active region. Some of the issues of by-passing this limitation have been addressed, essentially based on the reduction of the drift path for electrons and ions: namely, concerning microstrip [9], microgap [10], and microdot [11] detectors. Very high counting rates may be achieved in a MWPC by the appropriate choice of geometry parameters, gas filling, and signal processing electronics [12, 13].

POSITION SENSITIVE DETECTORS

In position sensitive detectors (PSD), the position of the source can be determined using two methods: the charge division and rise time method. Since the charge division method is used more often [8], in the present investigation, the charge division method has been applied. Because, due to certain specific reasons, electromagnetic or particle rays may diffract, this detector seems to be a proper instrument for the measurement of diffracted rays. The multiwire proportional counter contains many thin sheets acting as anodes and cathodes. Each anode sheet was placed exactly and symmetrically between two cathode sheets. The electrode system was situated in a gas (P_{10}) con-

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tainer. Electrons formed by the ionization of the gas drift toward the plane of anode wires, initially in a nearly uniform field. As they approach, they are accelerated toward the nearest wire and into its surrounding high-field region where avalanches are formed [8, 14]. In the proportional counter, the total collected charge is proportional to initial electrons and, therefore, its constant proportionality is called the multiplication coefficient. In the common cylindrical geometry, electrons drift inwardly from their place of formation, along radial field lines, so that the position of the avalanche is a good indicator of the axial position at which the original ion pair was formed. If the track of incident radiation extends for some distance along the length of the tube, then multiple avalanches will also be distributed along the anode and only an average position can be deduced. The most common method of position sensing in proportional tubes is based on the principle of the charge division method [6]. The anode wire is fabricated to have a significant resistance per unit length, so that the collected charge is divided between amplifiers placed at both ends of the wire in a proportion that is simply related to the position of the interaction. By summing the output of the two amplifiers, a conventional output pulse with an amplitude proportional to the total charge is produced. A position signal is generated by dividing the output of a single amplifier by summed signals to give a pulse that indicates the relative position along the anode wire length. This division can be carried out either by the analog method or by digital techniques. An alternative to the charge division method, capable of excellent spatial resolution, has been developed by Borkowski and Kopp [15].

DETECTOR SIMULATION

The MWPC contains thin planes with equidistant and symmetric anode wires placed between several cathode plates. The optimum distance between the anode and cathode was measured within the selected voltage region, by the Garfield_7 code [16], and the obtained value was almost 5 mm. The electric field and equipotential surfaces in the presence of electric potential, deduced by the Garfield_7 code, are shown in fig. 1.

INVESTIGATION PROCEDURE

The investigation procedure in the present study has been divided into two sections: assembly and experimental procedures.

Our detector contains a central anode surface placed between two cathode plates. The assemblage was placed in an aluminum box acting as the chamber of the detector. The anode surface contains 32 Ni-chromic wires. The diameter, length, and resistance per unit of length of the anode wires are 35 μm, 3 cm, and10 /m, respectively. A chain resistance of 1 k has been constructed using these wires, all of them connected to a fiber glass sheet of 8 19 cm^2 dimensions. The cathode is made of two fiberglass printed sheets of 4 12 cm^2 dimensions. From top to bottom, at a distance of 5 mm, the anode circuit is surrounded by a cathode circuit. The detector chamber has a hole of 2 12 cm^2 atop of it. The hole is covered by 0.8 mg/cm^3 thick Mylar, so as to allow incident radiation with less attenuation to enter the Mylar chamber. The door is made of plexiglas and tightened with O-ring and screws. The schematic presentation of the detector is shown in fig. 2.

ASSEMBLING AND CONNECTING

The detector contains a printed board circuit (PBC), 5 mm spacers, isolation screws, an O-ring, and resistances. The detector chamber was connected to a high voltage power supply (SHV jack) on two sides. Tensional force was applied to the Ni-chrome wires before connection because, due to the increase in temperature, the wires might fall. After soldering the

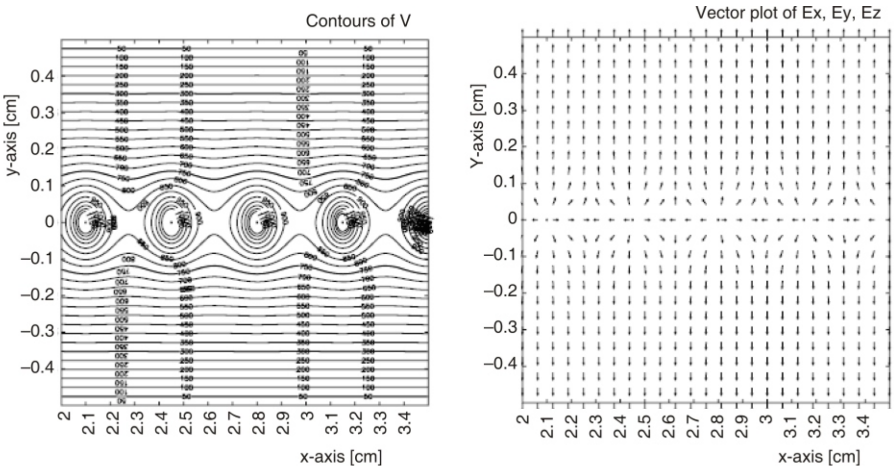

Figure 1. Equipotential surfaces of the electric field deduced by the Garfield_7 code

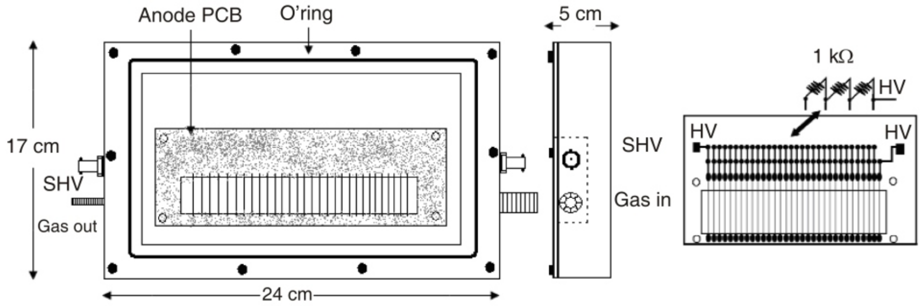

Figure 2. Schematic presentation of the detector chamber and its constituent parts (left) and the anode PBC (right)

wires to the PBC, it is necessary to dissociate the wires from it with utmost precision. In order to avoid electrical leakage and electric sparks at sharp points, we had to cover these points with special isolators. After washing the electronics and the detector chamber with acetone, the system was assembled with electronic items, spacers and screws. The assembled system was then placed on two plexiglas stands, connecting the cathode surfaces to the ground and, from two sides, the anode wires to the SHV jack. After connecting the O-ring and ensuring isolation, the detector door was closed and all screws fastened. In this stage, the detector has to be filled with gas (P_{10}). Therefore, in order to remove the dust and unwanted gases, the outlet was opened for some time. The exhaust was put in water to measure gas Debby. In this stage, the system is ready for applying voltage. Due to the sensitivity of the electronic devices, the voltage has to be applied slowly. The final appearance of fabricated multiwire proportional detector (MWPD) is shown in fig. 3(b).

EXPERIMENTAL PROCEDURES

The assembly of electronic devices, without the divider circuit and collector, is shown in fig. 3(a). So as to amplify the output pulses of the MWPC, the ORTEC-142 PC charge sensitive preamplifier and amplifier were used in the present work. The output pulses of the amplifier are analogue pulses which are converted to digital pulses by passing through the analogue-to-digital converter (ADC) unit, so that the digital pulse height has been obtained by the multi-channel analysis (MCA) unit.

As is clear from fig. 3(a), the data acquisition procedure is as follows: a standard source is placed in a particular are on the detector window during the creation of the photo peak. With the displacement of the standard source, the channel number of the photo peak will decrease. The shape of the photo peak on the oscilloscope indicates that, after the displacement of the source, due to the increase in the resistance of anode wires as compared to the earlier position, the pulse height on the same channel number decreases. In the present experiment, the high voltage, amplifier gain, gas Debby and pressure were constant at 1700 V, one bubble per second and 1.3 atmospheres, respectively. The typical X-ray spectrum of the MWPC is shown in fig. 4. In the present experiment, ^{241}Am was used as a

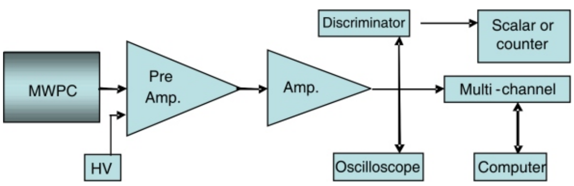

Figure 3(a). Block diagram of experiment set-up

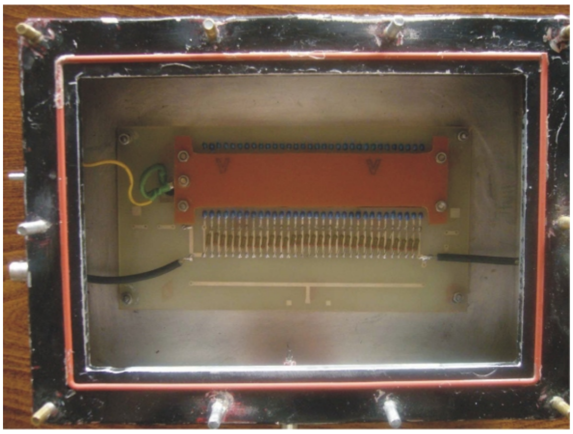

Figure 3(b). Final appearance of the fabricated MWPD

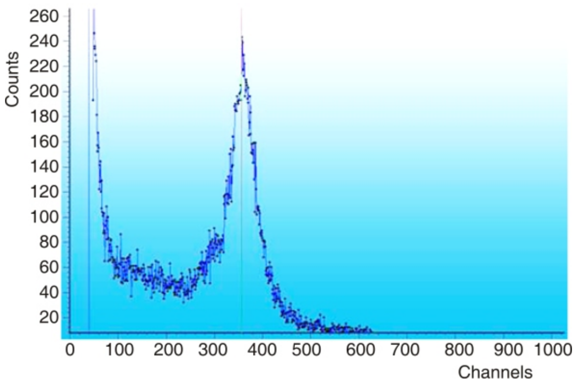

Figure 4. X-ray spectrum of silver obtained with MWPD

variable X-ray source and generator of the main source (excited Ag). Silver (Ag) was excited through a 60 keV X-ray beam of a ^{241}Am source. The k_{α} -X-ray of silver (22.4 keV) was selected as entrance radiation in the present investigation. As was indicated in fig. 4, due to reasons listed below, the MWPC photo peak width of 22.4 keV is larger than the above photo peak width of solid state detectors [17].

(1) Due to the small distance of the X-ray source from the MWPC main circuit (2 cm) and the X-ray source diameter (3 mm), the falling X-ray on the anode wires is not a plane wave, so that it may, at the same time, interact with many anode wires and create many pulses with various heights, too.

(2) Due to multiple collisions of the mono-energy X-ray with the sensitive material of the MWPC (P_{10} gas), a lot of ionization will take place, and may therefore, create many pulses with various heights.

The avalanche effect in an ideal gas (inert gas) takes place at low voltages, as compared to other gas combinations; so, one of the basic components of gas-flow detector sensitive materials are ideal gases. The operation region of the present detector (counts *vs*. applied voltage) and pulse height *vs*. applied voltage curve, are shown in figs. 5 and 6, respectively.

As shown in fig. 5, the plateau length of the present detector is 300 V, indicating that along with the increase in the applied voltage, the multiplication coefficient also increases. Our results show (fig. 6) that, with the increase in pulse height at the end of the proportional region (V > 1800), pulse height also increases rapidly, starting the Geiger region, ultimately. As fig. 7 shows, the relationship between source position and the channel number is linear. It also indicates that the effective length of this detector is 8 cm, which is the maximum displacement of the source, as the pulse height will obey the sensitivity of this detector. The minimum displacement of the source, which makes a change in the channel number of the photo peak by unit, is known as position sensitivity resolution of the PSD. In the present measurement, the obtained position sensitivity resolution of the MWPC was 3.5 mm.

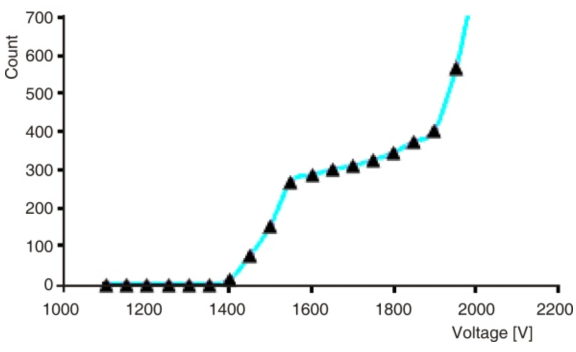

Figure 5. Plateau region of detector

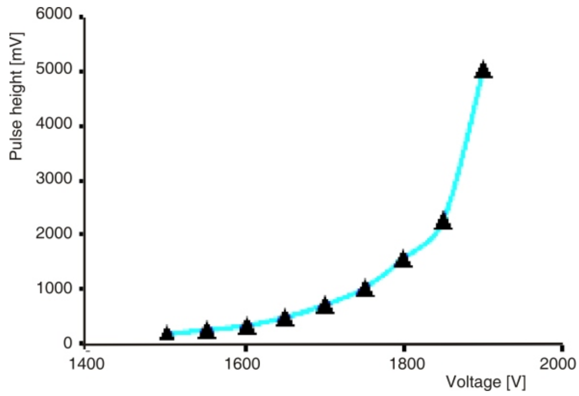

Figure 6. Pulse height *vs*. applied voltage

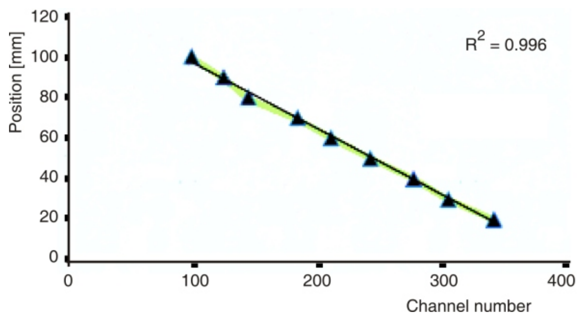

Figure 7. Linearity of position and channel number

DISCUSSION

This detector was designed and fabricated for the first time in Iran. Due to the sufficient thickness of its Myler windows, a complete spectrum of any X-ray and low energy γ-ray sources (channels and counts) can be obtained by use of advanced circuits (dividers and collectors) of our detector. Our investigation shows that the space resolution of this detector increases by using thin and long wires (anode wires), meaning that, for this purpose, the distance between anode wires needs to be decreased. The linear relationship between position sensitivity and the channel number of this detector was shown in fig. 7, demonstrating that by increasing the position resolution of the present detector, the slope of the linear curve will increase. The present study shows that accurate electronic devices and the high resistance of anode wires, as well as the best combination of gas materials, may foster further development in the industry.

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РАЗВОЈ ПОЗИЦИОНО ОСЕТЉИВОГ ПРОПОРЦИОНАЛНОГ БРОЈАЧА НА БАЗИ ВИШЕ СТРУНА

Прелиминарна мерења пропорционалним бројачем са две независне струне показала су да се могу достићи брзине бројања до 10^6 одброја у секунди по једној жици, без значајних губитака на линеарности односа "тачно – измерено". У раду је приказан гасни вишеструни пропорционални бројач, дизајниран и направљен, и изложени су резултати добијени фабричким детектором који садржи 32 никл-хромне анодне жице. Свака струна је повезана са брзим претпојачавачем и каналом за дискриминацију. Постигнуте су брзине бројања од преко 10^7 догађаја у секунди. Пречник, дужина и подужна отпорност анодних жица су 35 μm, 3 cm и 10 Ω/m, респективно. Катода је направљена од две штампане плоче од фибергласа димензија 4 cm 12 cm. Коришћен је гас P_{10} (10% метан и 90% аргон), а осетљива запремина детектора је 24 cm^3. Сигнали детектора пажљиво су анализирани помоћу система за аквизицију података (вишеканалног анализатора, појачавача и претпојачавача). Наш рад показује да је овај детектор позиционо осетљив и да је добијена резолуција осетљивости овог инструмента од 3.5 mm.

Кључне речи: пропорционални бројач, позициона осетљивост, јонизација, гасна мултипликација, расподела наелектрисања