PULSE ANALYSIS IN PLANPARALELL PROPORTIONAL DETECTOR

Karol KVETAN

Author: ***RNDr. Karol Kvetan, CSc.***
Workplace: ***Institute of Materials Science, Faculty of Materials Science and Technology, Slovak University of Technology***
Adress: ***ul. Jána Bottu 25, 917 24 Trnava***
Tel.: ***+421 33 5521007***
E-mail.: ***karol.kvetan@stuba.sk***

Abstract

In the last few years the multiwire gas filled detectors, acting in proportional or Geiger-Műller working region, has became an important element in a number experimental arrays set up for particle-physics experiments. They are used mainly for position sensing of radiation and they are widespread not only in nuclear physics, but also in other fields, such as crystallography, radiography, astronomy, biology, medicine etc., with the possible accuracy of position measurements in the range of millimeters.

We present the testing measurements for our planar proportional detector, designed and manufactured for radiographical experiments.

Key words

position measurements, multiwire chambers, ionization and drift processes, pulse analysis, induced pulses

Introduction

The present multiwire planparallel detectors are modern development based upon the properties of the old classical proportional or Geiger counters. A detail theory of these devices has been given by Charpak [1], Rice-Evans [2], Sauli [3] and others.

The most important feature is the ability to provide position information in a form that can be easily digitized for computer storage and manipulation. The standard arrangement of such device, with the corresponding electronics, is depicted in Fig. 1.

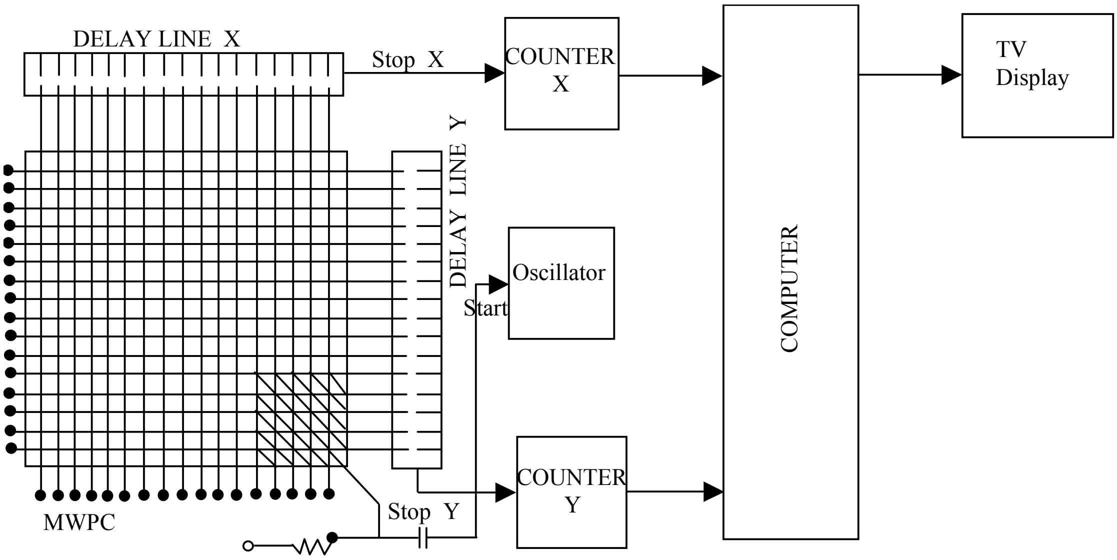

Fig. 1 *A typical scheme showing the operation of bidimensional planar multiwire, detector using the delay line method.* ***.*** *The main aim at position measurements consist in localisation of the wire nearest to the initiating charged particle. Direct signal from the anode plane starts a clock oscillator. The induced signals on cathode wires by means of delay lines stop the counters and two numbers proportional to the X and Y coordinates are fed to the controlling computer and imaged on TV-display.*

The most important parameter of multiwire detectors appears to be the shape of voltage pulses. The rise-time allows to obtain time and position information about traversing particle, and the pulse height permits their identification. Owing to the obtaining the appropriate knowledges of pulse properties of such appliance, we have constructed the simple one-dimensional model and performed its operation. The aim of our work was to investigate the dependence of pulse shapes on various parameters and to evaluate this effect in respect of position measurements.

Construction of Detector

Multiwire proportional or Geiger-Műller computers consist essentially of a set of thin, parallel and equally spaced anode wires, symetrically sandwiched between two cathode planes; we have used a proportional computer with typical structure, that a cross-section is given in Fig.2.

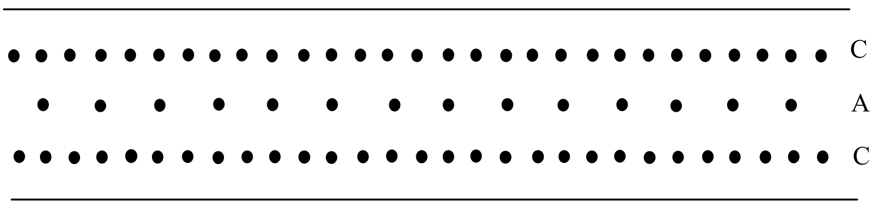

Fig. 2 *A cross-section of typical planar multiwire proportional chamber C – cathode wires, A – anode wires*

We have constructed one-dimensional multiwire detector with the dimensions of sensitive volume of 150 x 85 x 16 mm^3, using a plexiglass for the frames. There are three demontable frames with the positive-charged central plane, consisting of 30 μm diameter gold plated molybdenum wires with 2 mm spacing. The wires were soldered on a printed board. The cathode planes consisted of 2 mm spaced, 100 μm diameter wires; anode-cathode gap was 8 mm. Detector was filled with 94 % Ar + 6 % CO_2 gas mixture under normal pressure.

The measurements were performed using the ^{241}Am alpha-source and the ^{55}Fe X-ray source collimated to 250 μm wire diameter. The signals were fed to low noise preamplifier with a voltage gain of 7, and with an input impedance of 1 kΩ. The minimum detectable pulses were 0.5 mV, which is adequate - with the discrimination treshold around one tenth of pulse height - to ensure high efficiency. The preamplifier was followed by an amplifier with a gain of 10, and the pulse shapes were analysed from oscilloscope with a nanosecond scale. To measure induced pulses, the same read-out was connected to cathode planes.

Time Analysis of Pulses

It would be emphasized that it is a motion of positive ions away from the anode which plays the most important role in the time development of pulses. The detected signals, negative on the anode and positive on the cathode, are then the consequence of the change in energy of the system due to movement of charges.

Fig. 3 shows the pulse shapes differentiated with the time constant equal to 10^{-6} seconds for ^{241}Am alpha-source and ^{55}Fe X-ray source, too.

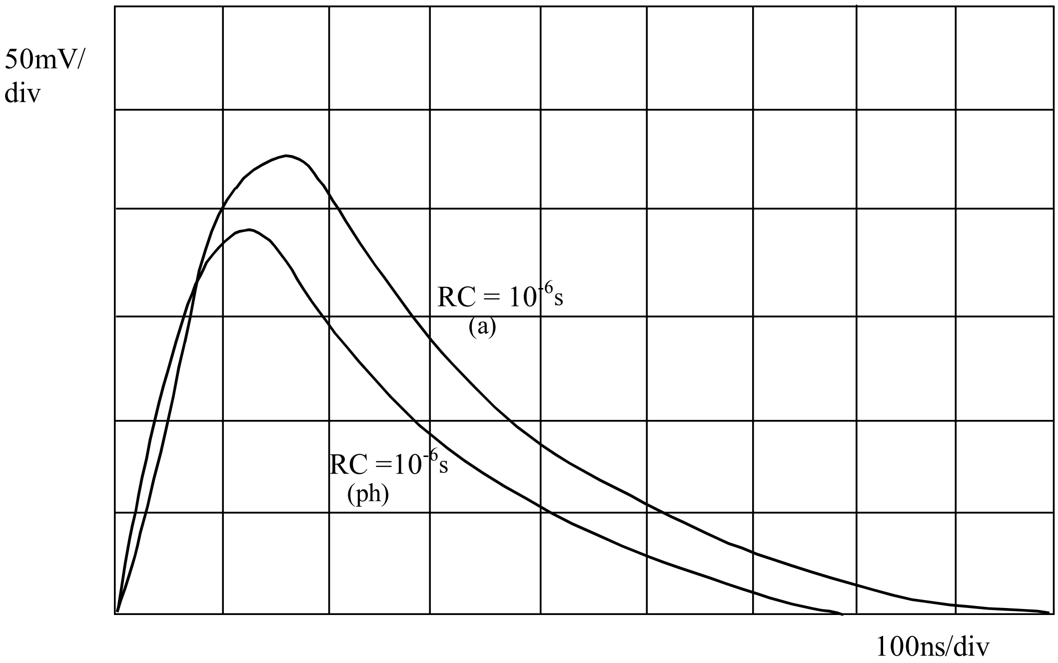

Fig. 3 *Pulse shapes of 5.5 MeV alpha-rays (a) and 5.9 keV X-ray photons (ph), differentiated with time constant RC =* 10^{-6} *s. Horizontal scale – 100 ns/div., vertical scale – 50 mV/div*

The rise-times of pulses are less than 180 and 120 ns, respectively. These values include small contribution from our electronic circuits (~ 30 ns), which were not designed to make such fast time measurements. The observed difference of both alpha- and X- ray pulses can be understood on the basis of various times necessary for collecting of electrons. The collection time depends on the range between the lowest and the highest arrival time at the wire of electrons liberated in the gas by the same incident particle. In the case of photons the conversion electrons have arrange only of millimeter or so, and they will all arrive within a few nanoseconds of each other. In the case of charged particles, however, they are distributed throughout the depth of chamber, and the time for collecting all the electrons is sufficiently larger.

We have measured the rise-time fluctuations of pulses, too, that reflect the distribution of electron arrivals from equally positioned ionizing tracks. They were found to be about 30 and 20 ns, respectively, as observed from oscilloscope screen.

As resulting from these considerations, the rise-time of voltage pulses is also the function of the distance of source from a detection wire, and of the applied voltage. These dependences are shown in Fig. 4. The rise-time increases by a factor of about 1.4, when the drift distance is varied from 10 to 80 mm. This phenomenon is currently used for obtaining of spatial coordinates of ionizing track (so-called the rise-time method of Borkowski and Kopp [4]).

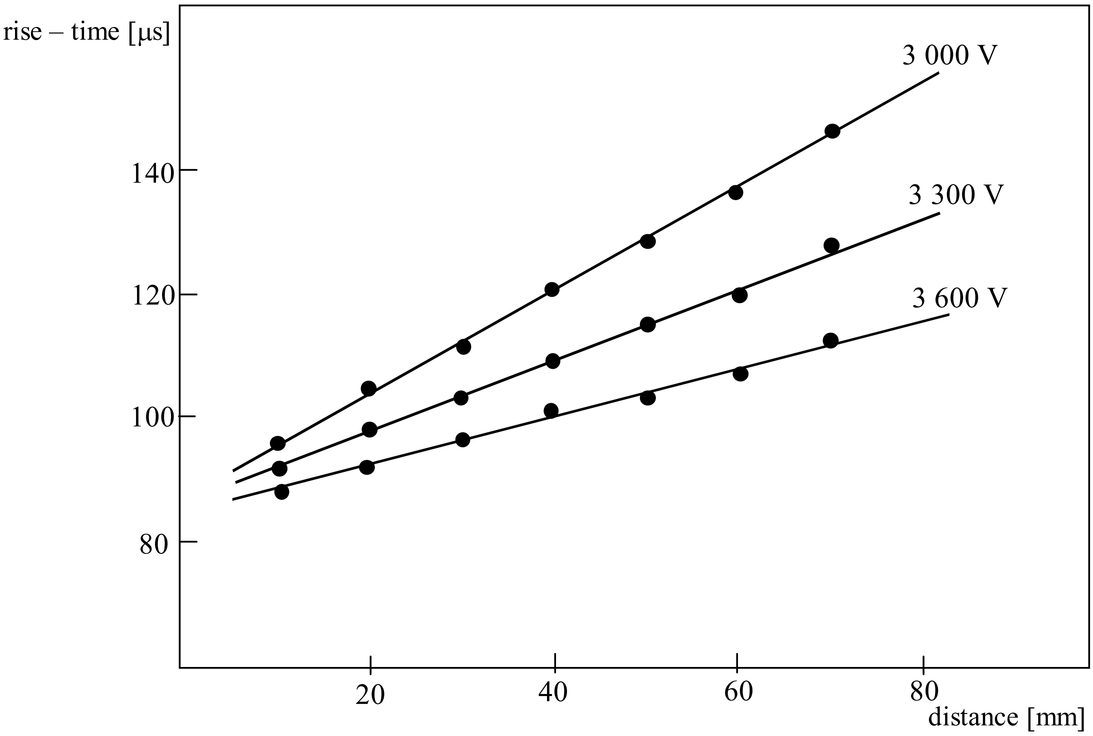

Fig. 4. *Rise-time of the pulse as a function of drift field and position (5.9 keV X-rays)*

Next important parameter is the direction of ionizing particle. We measured a change in rise-time to be from 180 to 250 ns, when the angle of incidence varied from 0 ° to 45 ° (0 ° corresponds to perpendicular incidence). The longer rise-time at inclined tracks is also a consequence of the difference in the time arrivals of primary electrons coming to anode wires from different positions along the track.

Induced Pulses

It is known that the motion of the positive ions is responsible for pulse creation. A negative pulse is obtained on an anode wire due to drift of positive ions away from wire. Complementary to this will be the similar but opposite (i.e.positive) pulse produced on the cathode. In addition, there will be positive pulses produced on the anode wires adjacent to the wire on which the avalanche concentrates. The timing of both the induced and the anode signals is identical, they differ only in polarity.

If the ion cloud (or avalanche) were produced mainly on the side of a wire, one would expect the adjacent wire on the other side to have a negative signal. Instead we saw positive pulses everywhere. Therefore it seems that the ion cloud is essentially symmetric about the central wire. A precise theory of creation of induced pulses was given by Fischer and Plch [5].

The total positive and negative charges are of equal amounts; however, whereas the negative charges are all concentrated on the central wire, the positive ones are in principle spread over all other electrodes. We have measured the amplitude of the pulses induced in cathode as a function of the applied voltage. Also recorded was the amplitude of the anode pulses; the results are shown in Fig. 5. We have seen that about 40 % of the positive charge is found on the neighboring sense wires, compensating negative signals, created by capacitive coupling between the central wires. The rest of positive charge – about 30 % per plane – is found on the cathode plane. Therefore the pulses on the cathode electrodes are smaller than on the sense wires.

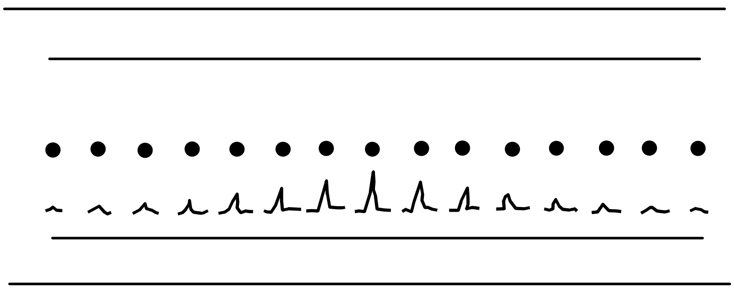

Fig. 5. *Pulse height as a function of high voltage using* ^{55}*Fe X-ray source*
Resistance load - 1 kΩ

We will not find a sharp localization of the induced signal on the cathode wires, but rather a broad charge distribution. His spatial extent is comparable to the anode-cathode gas spacing, with the maximum centered at the position of the avalanche (Fig. 6).

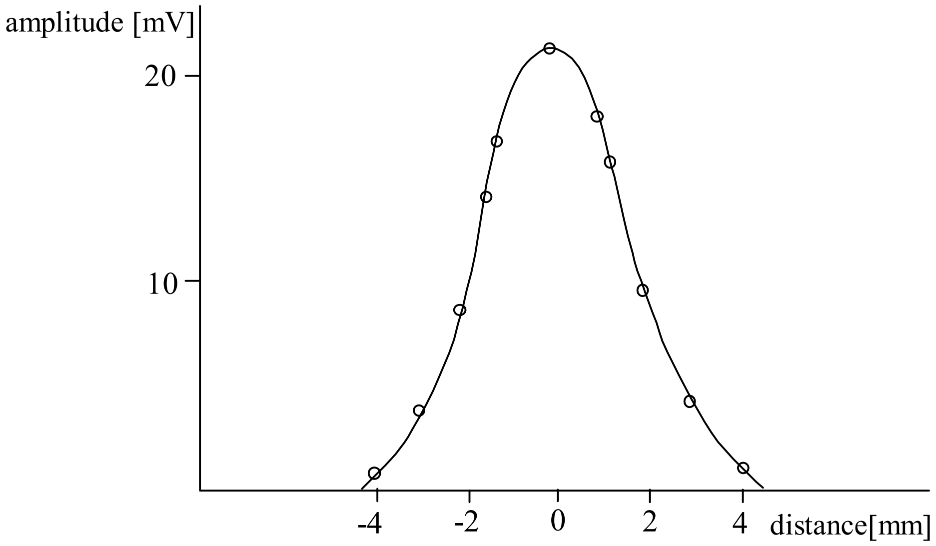

Fig. 6 *Pulse height distribution of induced pulses along the cathode plane*

The position of this centroid can be calculated by means of recorders and computers. This fact is often used to measure the location of the avalanche along the wire. There exist various methods to determine the position of the centroid [6]. In this way, spatial resolution of multiwire detectors is more better than the cathode wire spacing. Perez-Mendez et al {7] have shown that with cathode wires spaced at distances of 1 mm they determine the center of gravity of the avalanches to an accuracy 50 µm.

If the cathode electrodes are made of wires perpendicular to each all, a distribution of induced pulses can be observed on both cathode planes. This feature is essential for the detection of low-energy particles, X-rays or neutrons, since the two coordinates have to be extracted from a single gap.

When the electrons from the primary ionization process are shared among several adjacent wires, as for example when one is dealing with an inclined tracks, then one wire will receive electrons as the first, and the first avalanche will start there. This will induce positive signals on the neighbouring wires. As the electrons from further out drift in, they in turn will start avalanche on some of these neighbors, thus turning a pulse that originally started out positive into a negative one. In general when there is such a superposition of induced and normal pulses, it is the negative “normal” pulse which dominates.

Conclusions

We have presented and discussed time measurements and some other properties of planar multiwire detector. The experiments described above has confirmed that these devices can be a reliable tool for various applications.

The scope pictures of pulses show that rise-times are in the range of $10^1 - 10^2$ ns; it results in good time resolution of the chamber. As results from the physical principle of the pulse creation, a pulse from the cathode wires is in time coincidence with the negative one on the sense wires, and may differ only in the amplitude and in the polarity. The study of the induced pulses shows that two coordinates can be measured from a single gap (this principle is used in bi-dimensional devices).

As it can be concluded from these facts, multiwire gas-filled detectors can be used to fast time measurements; two-dimensional detectors are reliable device for radiographical applications.

References:

[1] CHARPAK, G., BOUCLIER, R., BRESSANI, T., FAVIER, J., ŽUPANČIČ, Č. *Nucl. Instr. and Meth.,* 1998, 62, 235.

[2] ERSKINE, G.A. *Spark, Streamer, Proportional and Drift Chambers*. London: Richelieu Press, 1984.

[3] SAULI, F. *CERN Int. Rep*. 77-09, 1997.

[4] BORKOWSKI, C.J., KOPP, M.K. *Rev. Sci. Instr*., 1999, 46, 951.

[5] FISCHER, G., PLCH, J. *Nucl. Instr. and Meth*., 1993, 100, 515.

[6] See, for example RITSON, D. *Techniques of High Energy Physics.* New York: Interscience, 1991.

[7] PEREZ-MENDEZ, V., STETZ, A.W. *Lawrence Berkeley Laboratory Int. Rep.* LBL-2064, 2003.