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A MICROSTRIP GAS AVALANCHE CHAMBER WITH TWO-DIMENSIONAL READOUT

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A microstrip gas avalanche chamber with a 200 μm anode pitch has been built and successfully tested in our laboratory. A gas gain of 10^4 and an energy resolution of 18% (FWHM) at 6 keV have been measured using a gas mixture of argon–CO_2 at atmospheric pressure. A preliminary measurement of the positional sensitivity indicates that a spatial resolution of 50 μm can be obtained.

1. Introduction

The introduction of the Multiwire Proportional Chamber (MWPC) in 1968 by Charpak and coworkers [1] has drastically changed the field of gas radiation detectors, starting a completely new approach to the old problem of neutral and charged-particle detection. The MWPC is not only the most widely used detector type in high-energy physics experiments, but it also plays a significant role in several other fields of research such as X-ray crystallography, biomedicine, astrophysics, etc. Nevertheless the MWPC, at least in its standard design, has two major limitations: (i) the spatial resolution in the direction orthogonal to the anode wires is limited by the wire spacing (≥ 1 mm); (ii) the rate capability is limited by the long positive-ion collection time to $\cong 10^4$ particles (s^{-1} mm^{-1}) [2]. To improve on these two limitations, one can try to reduce the anode wire spacing and so improve the accuracy and reduce the incoming particle flux per wire and one can also try to reduce the anode–cathode gap to shorten the ion collection time, thus avoiding the space charge buildup around the anode wires. However, below 1 mm wire spacing and below 2 mm anode–cathode gap, the MWPC becomes difficult to operate because of the electrostatic instabilities arising from the mechanical tolerances. In a recent paper [3], Oed suggested the use of photolithographic

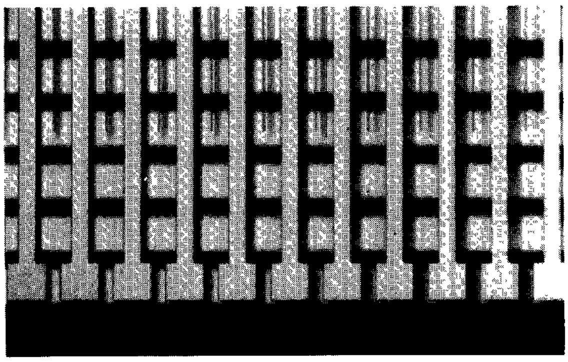

Fig. 2. A magnified view of the detector amplifying plane.

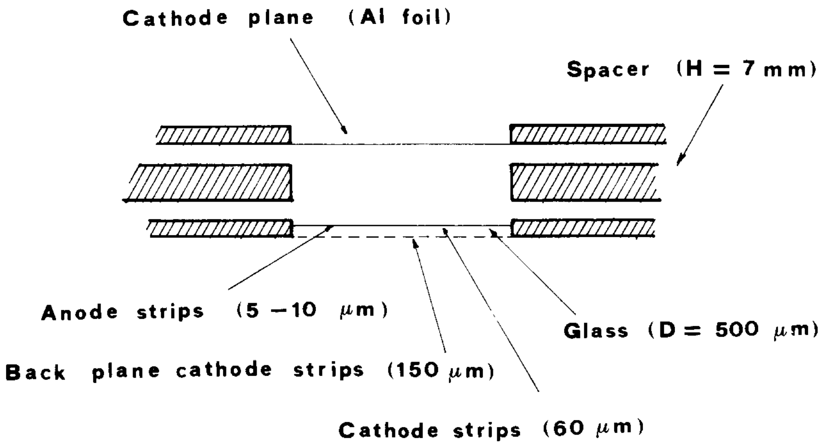

Fig. 1. A cross section of the detector assembly.

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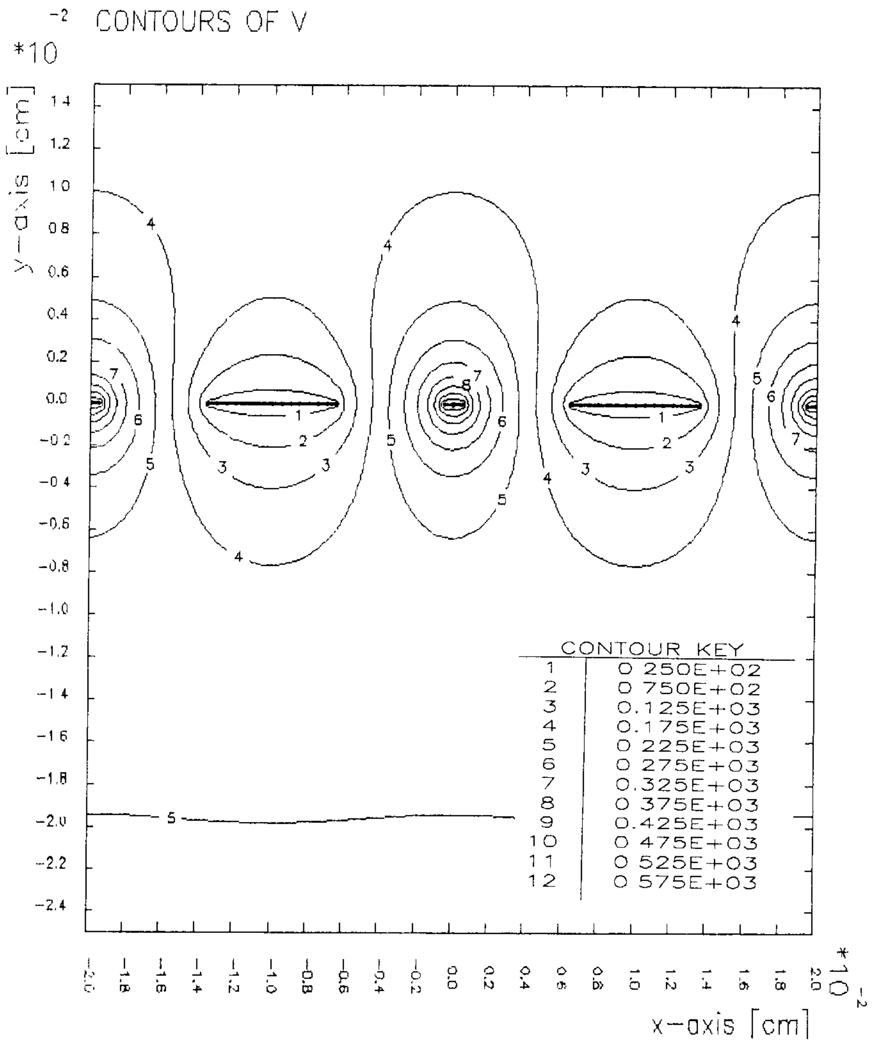

Fig. 3. A detail of the equipotential lines in a region close to the anode strips.

techniques, which have 0.1–0.2 μm accuracy, to drastically reduce these tolerances enabling the reduction of the anode pitch and the anode–cathode distance. In his paper he showed that a multiplying structure, with a 200 μm pitch made with photolithographic techniques, was able to detect heavily ionizing particles like αs, neutrons and high-energy γs with a gas gain below 10^3. The gas filling was isobutane at low pressure (300 mbar). The aim of this work is to further develop this idea to include the detection of minimum ionizing particles (this means increasing the gas gain at least to 10^4), to study the possibility of working with a standard gas mixture (argon–CO_2, argon–isobutane, at atmospheric pressure), to measure the energy and spatial resolution for low-ionizing particles and to study the possibility of two-dimensional readout with just one amplifying structure.

2. The detector structure

The detector is made of two parts: a low-electric-field drift region, followed by a high-electric-field amplification region (see fig. 1). Primary electrons, created in the drift region by the incoming radiation, drift toward the anode and are multiplied in the amplification region. The high electric field is obtained by interleaving, on the same plane, anode and cathode strips which were engraved with photolithographic techniques onto a 0.5 mm thick glass substrate *. The aluminium anode strips have a 5 or 10 μm width and are 2 μm thick; the anode pitch is 200 μm. The precision of the photolithographic

* Made by CSEM, Neuchatel, Switzerland.

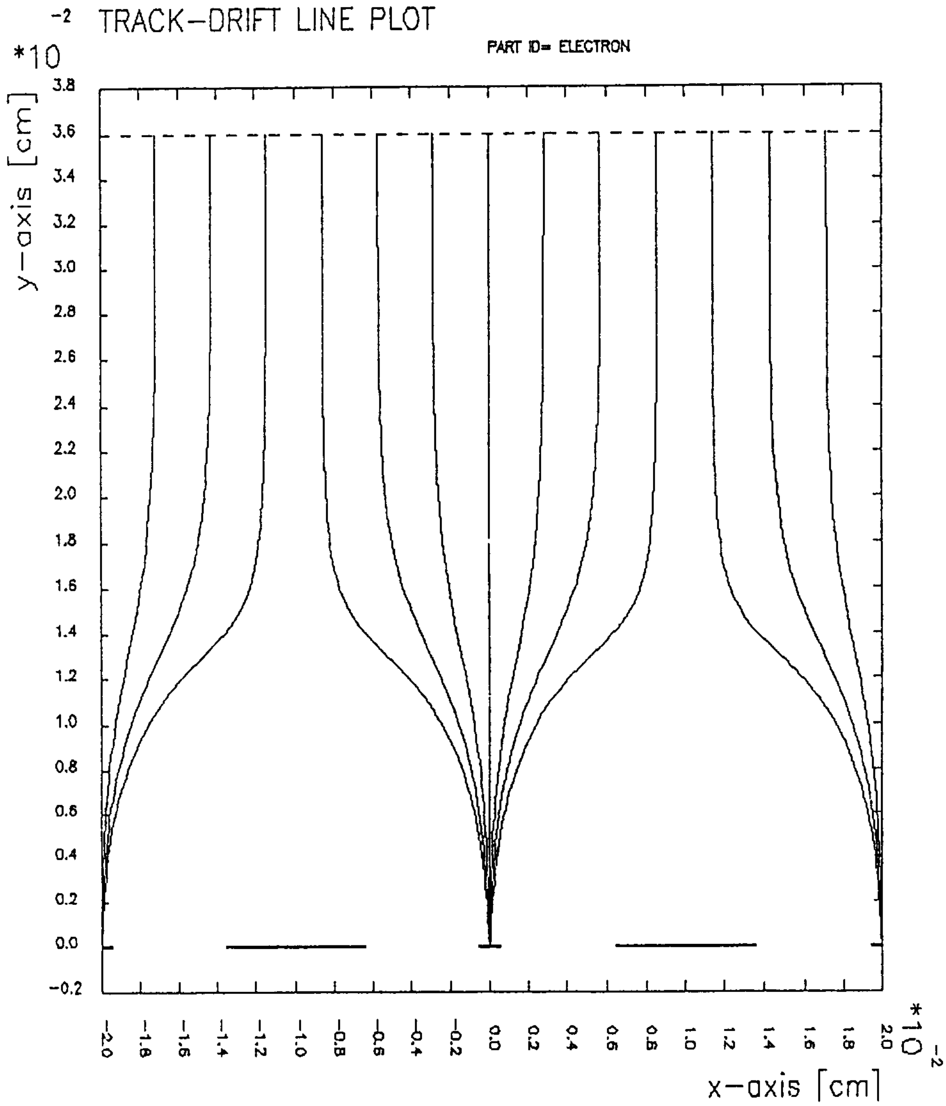

Fig. 4. The drift path for electrons toward the anode strips.

technique (electron beam) is 0.1 μm. The potential strips reinforce the field on the anode strips and collect the positive-ion cloud which is created around the anode wire during the avalanche process. The width and thickness of the anode strips were chosen to have a ratio as close as possible to one to minimize edge effects. The prototype we have built has a 60 mm × 60 mm active area and is ready for a two-dimensional readout. On the back of the glass substrate, a pattern of strips with a 200 μm pitch at 90° relative to the anode strips is deposited to collect some fraction of the charge induced by the positive ions drifting toward the potential strips. To increase this fraction, a very thin glass substrate was chosen. The back strips are at a positive potential to create an electric field penetrating through the non-metalized glass. This field is repulsive for positive ions. This avoids the positive charge buildup on the glass substrate [3]. Fig. 2 shows a magnified view of the detector plane onto which the anode and potential strips were engraved. It is also possible to see the strips deposited on the back.

3. Modeling of the detector with the GARFIELD program

To investigate and predict the detector characteristics (electrostatic field and equipotential lines, electron and ion drift lines, signals on the electrodes and so on), the GARFIELD program has been used. GARFIELD [4] has been developed at CERN by R. Veenhof and its

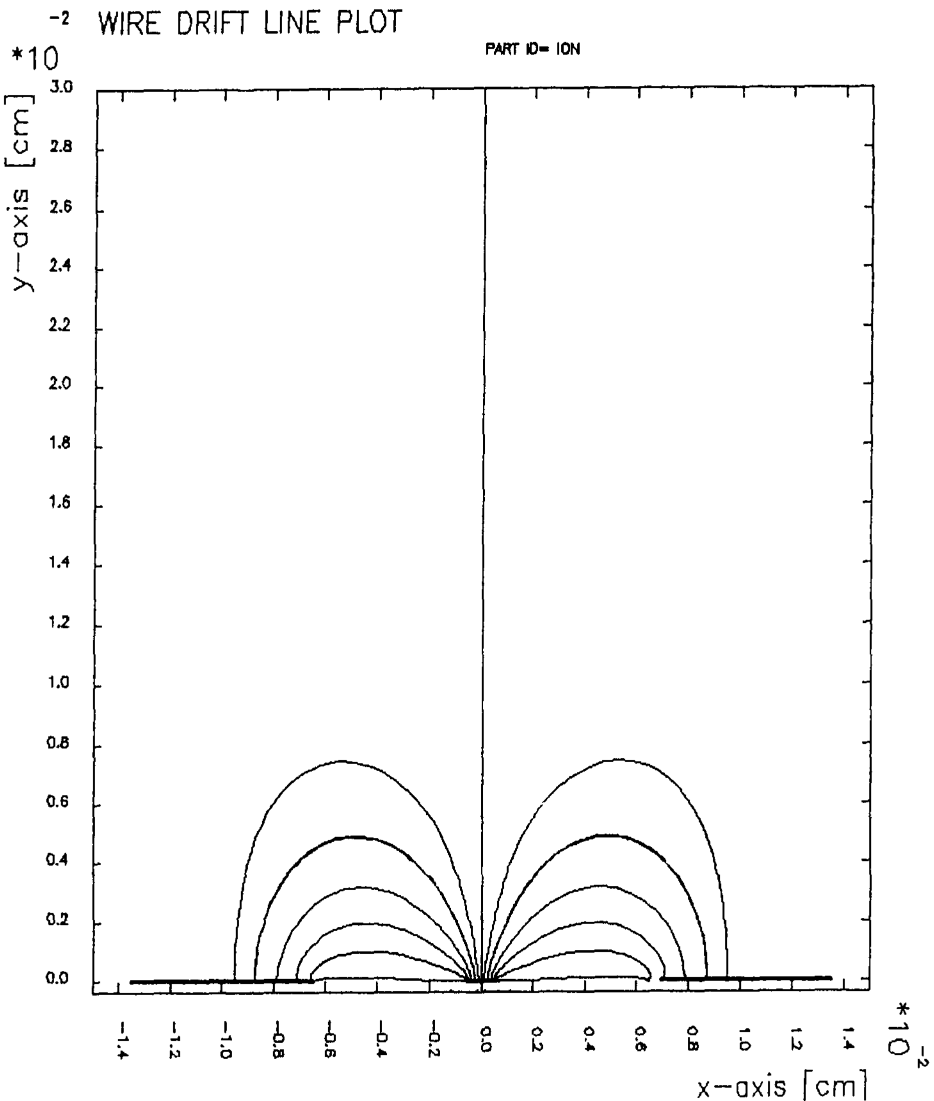

Fig. 5. The drift path for positive ions.

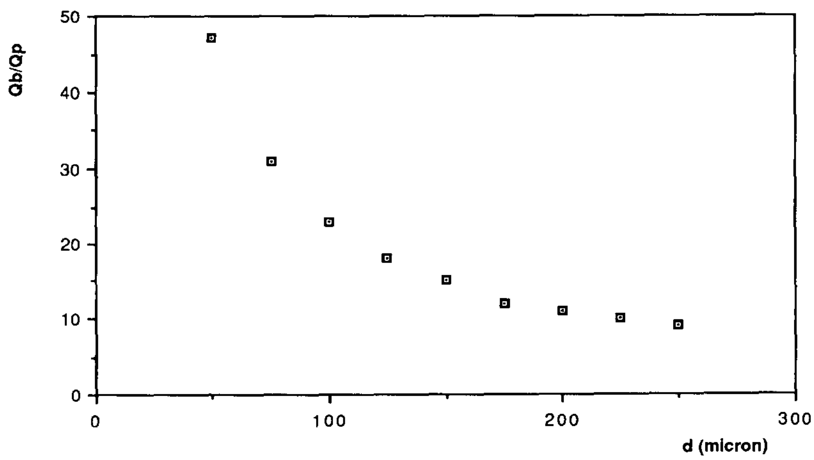

Fig. 6. The ratio between the charge induced on the back strips and the charge induced on the front cathode strips as a function of the effective detector thickness d.

original scope is to model drift chambers made up of thin wires. To simulate our detector strips, the line electrodes were replaced by rows of wires of appropriate diameter. The computation of the electrostatic field and potential is carried out in two steps: first GARFIELD computes the charge (per unit length) on all the wires, then it adds the contribution of each wire to the field (at any given position). Fig. 3 shows details of the

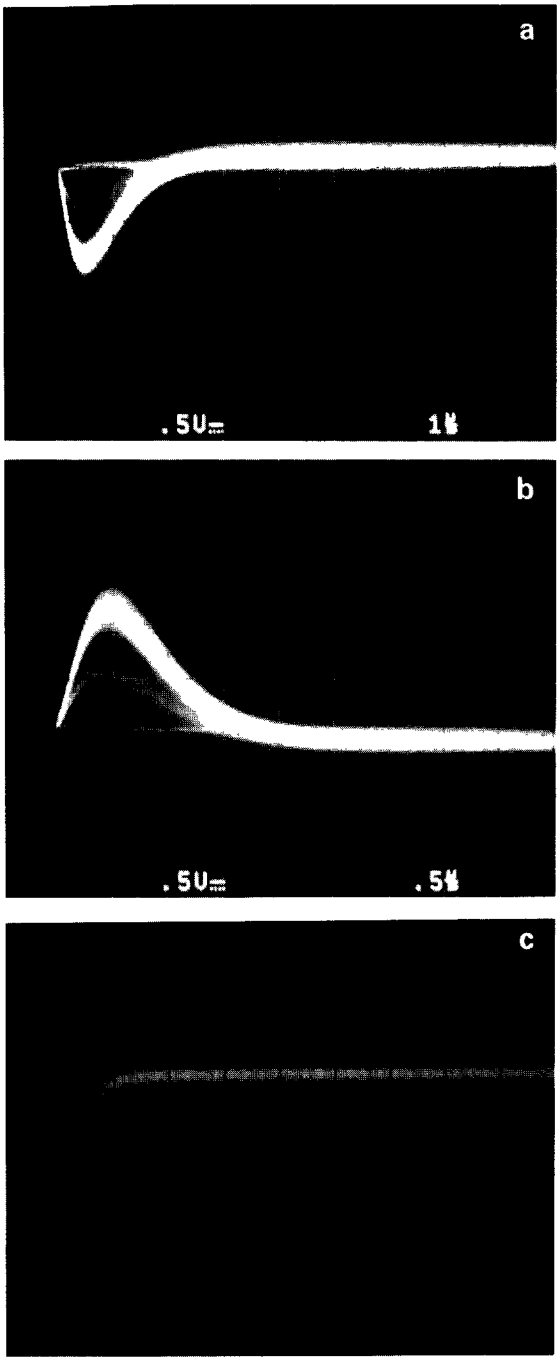

Fig. 7. (a) The anode signal, (b) the cathode signal, (c) the back-strips signal. The source was ^{55}Fe and the gas filling was argon–CO_2 at atmospheric pressure.

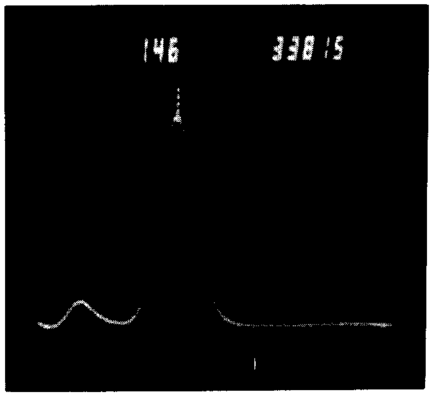

Fig. 8. The pulse height spectrum of the signal of fig.7a. The FWHM of the 6 keV peak is 18%.

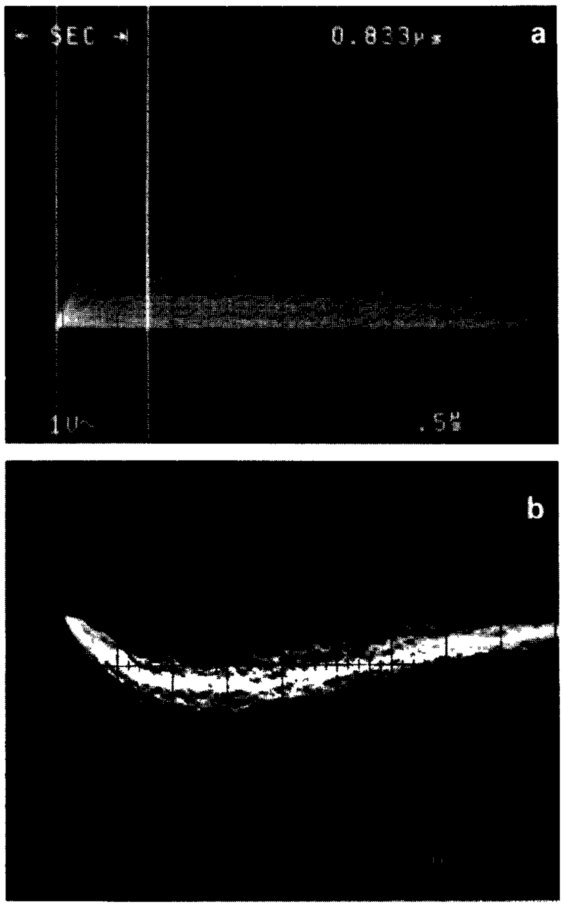

Fig. 9. (a) The signal from the microstrip anodes with a ^{90}Sr source and a very long ($\equiv 50$ μs) differentation time constant to avoid the problem of ballistic deficit; (b) the corresponding signal from the standard MWPC.

equipotential lines in a region close to the anode strips. Fig. 4 shows the drift line for the electrons released by an ionizing track crossing the detector, while fig. 5 shows a detailed view of the drift path for positive ions in the region between the anode and the potential strip. Almost all of the positive charge is collected by the two closest (60 μm) potential strips. With GARFIELD, it is also possible to compute the charge induced on all the electrodes when a point or line charge is put somewhere in the active volume. It is then possible to evaluate the ratio between the charge induced on the back plane (Q_b) and the charge induced on the potential strips (Q_p) as a function of the effective thickness of the substrate (fig. 6). Because dielectrics cannot be handled by GARFIELD, it has been assumed that the effective thickness of the substrate is obtained from the physical thickness scaled by the ratio of the dielectric constants of glass and gas ($\epsilon_{glass}/\epsilon_{gas} \cong 4$).

4. The detector signals

The detector was first studied by connecting together all the anode and cathode strips as well as the back strips. Fig. 7 shows the three signals coming from the detector when it was exposed on an area of several cm^2 to a ^{55}Fe source. The gas filling was argon–CO_2 at atmospheric pressure, the anode width was 5 μm, and the potential difference between anode and cathode strips was 600 V. While anode and cathode signals have roughly the same amplitude, the signals on the back are about 15% of the signals on the front strips. Fig. 8 shows the pulse height spectrum of the signals of fig. 7a. The FWHM of the 6 keV peak was 18%. The good gain uniformity is due to the precision of the photolithographic techniques and to the fact that the anode wires are isolated from each other by the potential strips. Fig. 9a shows the signals from the cathode strips obtained when the detector was exposed to a ^{90}Sr source. The shaping time of the amplifier was set to 50 μs, to avoid any problem of ballistic deficit. This signal can therefore be used to estimate the ion drift time which is much less than 1 μs. Fig. 9b shows the corresponding signal coming from a standard MWPC processed with exactly the same electronics. The time to collect all the positive charge for the standard MWPC is two orders of magnitude higher. A further factor of 10 comes from the pitch reduction, therefore the microstrip detector should be three orders of magnitude faster than the standard MWPC. Fig. 10 shows the gas gain versus the potential difference between anode and cathode strips when using an argon–CO_2 mixture at atmospheric pressure and ^{55}Fe source illumination. The maximum gas gain is $\cong 1.2 \times 10^4$ and it is limited at present by occasional sparking at the cathode end. The gain can be further increased by rounding off this edge.

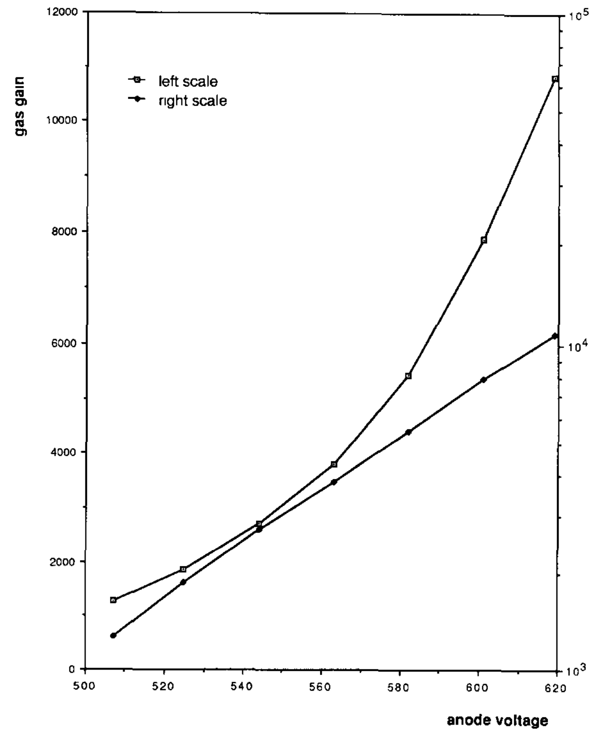

Fig. 10. The gas gain as a function of the potential difference between anode and cathode strips. The gas filling was argon–CO_2 at atmospheric pressure and the source was ^{55}Fe.

5. The positional sensitivity

To study the positional sensitivity, eight consecutive cathode strips, using a microbonding technique, were connected to eight charge preamplifiers and read out individually. Fig. 11 shows an example of the single-event charge distribution on the cathode strips (^{55}Fe source illumination, 7 mm drift space) while fig. 12 shows the histogram of the centroid of the distribution of fig. 11 when two slits 120 μm wide, 1 cm thick and

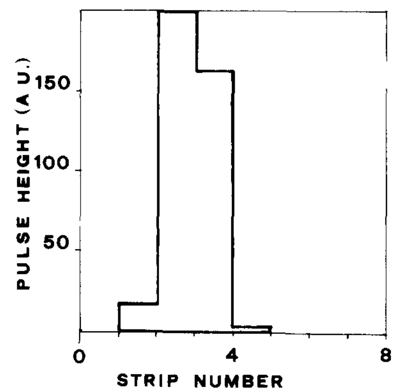

Fig. 11. A typical single-event pulse height distribution on the cathode strips (^{55}Fe).

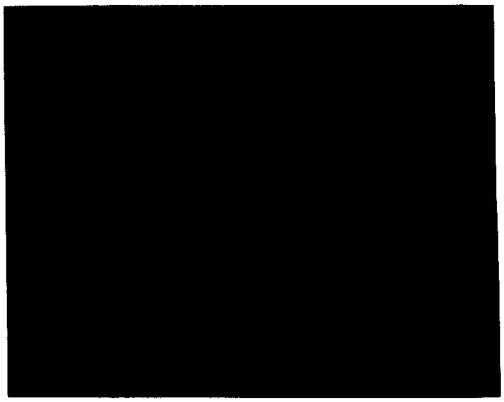

Fig. 12. The histogram of the centroid of the cathode charge distribution obtained with two slits 500 μm apart (^{55}Fe).

500 μm apart were uniformly illuminated with a ^{55}Fe source. The FWHM of the two peaks is less than 200 μm indicating that the major contribution to the width comes from the slit itself. The spatial resolution can be roughly estimated on the order of 50 μm (rms).

6. Conclusions

A simple, cheap microstrip detector with a 200 μm pitch having a gas gain of 10^4 has been built and successfully tested. Preliminary measurements indicate that two-dimensional readout is possible and the positional sensitivity in the order of 50 μm (rms) can be obtained. This kind of proportional gas detector should be faster than MWPCs by at least three orders of magnitude because of the denser sampling and because of the very short ion collection time.

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