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HIGH ACCURACY, TWO-DIMENSIONAL READ-OUT
IN MULTIWIRE PROPORTIONAL CHAMBERS

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CONTENTS

	<u>Page</u>
1. INTRODUCTION	1
2. PROPERTIES OF THE INDUCED PULSES	1
3. LOCALIZATION BY THE RATIO OF INDUCED PULSES	2
4. SPACE RESOLUTION	2
4.1 Strips orthogonal to the sense wires	2
4.2 Strips parallel to the wires	2
5. TWO-DIMENSIONAL READ-OUT OF CHAMBERS	3
5.1 In small chambers	3
5.2 In large chambers	3
6. CONCLUSION	4
REFERENCES	4
FIGURES	5

1. INTRODUCTION

In most applications of proportional chambers, especially in high-energy physics, separate chambers are used for measuring different coordinates.

For some applications, such as for X-ray or neutron mappings, this is almost impossible and it is necessary to read out two coordinates from a single-gap chamber¹⁾.

In general one coordinate is obtained by recording the pulses from the anode wires around which avalanches have grown. Several methods have been imagined for obtaining the position of an avalanche along a wire. One type of approach relies on the finite impedance of the amplifying wire; either the amount of charge or the rise-time of the pulse flowing at one end of the wire is position-dependent. The best accuracy obtained in small chambers by the rise-time method²⁾ has been 150 μm , using very high resistivity anode wires. An important field of applications for X-ray crystallography seems to be open for chambers with such accuracies, even if they are limited to one direction only, the accuracy in the orthogonal direction being given by the wire spacing.

Another type of approach, developed by the Perez-Mendez group^{3,4)}, is based on external delay lines coupled to cathode wires, orthogonal to the sense wires. These are capable of locating the centre of gravity of the induced pulse with an accuracy of 150 μm . Chambers for X-ray mappings have been successfully built by this method.

In this article we propose another method, which leads to the same range of accuracies and may be preferred in some cases. We also discuss the problem of accurate measurements for large-size chambers.

2. PROPERTIES OF THE INDUCED PULSES

When an avalanche occurs around a wire, positive pulses are induced on the cathode; they are coincident with the negative pulses collected on the sense wires. Some of the properties of these pulses have been extensively studied at an early stage of the multiwire chambers' development.

It was shown that one can determine the orthogonal coordinate by using, for the cathode, wires whose directions are perpendicular to the sense wires¹⁾. In contrast to the situation existing for the anode wires, the pulse is not localized at the wire facing the avalanche but is spread over large distances.

Figure 1 shows the pulse-height distribution of the induced pulses as a function of the distance from the avalanche (from Ref. 1) under very different conditions: gaps of 2 mm and 7 mm; pulse in a single wire or in groups of wires. The striking fact is the extension of the induced pulses over one or a few centimetres.

Similar observations have been made by Fischer and Plch⁵⁾ who have studied the localization of the induced pulses on wide bands of 5 cm width, and have shown that simple calculations agree with the observations.

In order to obtain the accurate position of an avalanche, it is necessary to measure the centre of gravity of this distribution. We will show that the shape of the distribution is so sensitive to the avalanche position that it is sufficient to measure the ratio of the pulses induced on two adjacent pick-up electrodes to get the centre of gravity of the avalanche with a high accuracy.

3. LOCALIZATION BY THE RATIO OF INDUCED PULSES

This method was experimented on in a chamber having the following characteristics:

chamber gap	:	8 mm
anode wire diameter	:	30 μ m
anode wire spacing	:	3 mm
cathode wire diameter	:	100 μ m
cathode wire spacing	:	1 mm

The wires of one cathode plane were parallel to the sense wires, and those of the other cathode plane were orthogonal to them. The gas filling was argon + isobutane + methylal (75%, 21%, 4%), and the chamber operated at a high voltage between 3 and 4 kV. For all measurements we used a well-collimated ^{55}Fe source emitting 5.9 keV X-rays. Sets of several consecutive wires on the cathode plane were connected together and used as pick-up electrodes for the induced pulses. We have tried several different dimensions and distances for the strips, but the best results were obtained with strips of 4 mm, 8 mm apart. The positive pulses were amplified by a simple fast amplifier ($R_{in} \approx 2 \text{ k}\Omega$), and the ratio of their pulse height was obtained in a fast divider^{*)}.

The big advantage of operating the current division on the cathode electrodes is that high-impedance amplifiers could be used.

The intrinsic noise of the system was measured, connecting the same pick-up electrode to the two amplifiers; it was always about 30% of the measured peaks' width (see next section) and was not subtracted from the data.

4. SPACE RESOLUTION

4.1 Strips orthogonal to the sense wires

Figure 2 shows the separation of the ratios of the pulse heights as the source, well-collimated, is displaced by a step of 2 mm in the region between two neighbouring strips. The FWHM of the distribution corresponds to an accuracy of $\sigma = 200 \mu\text{m}$.

In Fig. 3 the results of a complete scanning are shown. The ratio A/B of the pulse heights on the two strips, whose centres lie 8 mm apart, is given on the left scale together with the FWHM of the peaks. On the right scale, the equivalent standard deviation in millimetres is presented. The width of the source ($\approx 100 \mu\text{m}$) and the noise (30%) have not been subtracted.

4.2 Strips parallel to the wires

We observe two phenomena:

- The sense wires are clearly separated from one another. Figure 4 shows the ratio A/B provided by two pick-up electrodes, 8 mm apart, when the source was collimated on two anode wires 3 mm apart. The resolution corresponds to about 150 μm .
- There is a clear right-left effect, depending on the source position in respect to the anode wire. Figure 5a shows the measured ratio A/B for two source positions, 1 mm at the left and 1 mm at the right of the same anode wire; the result of a complete scanning is shown in Fig. 5b.

*) Developed at CERN by J. Olsfors.

This proves that the avalanches do not surround the wire in a uniform way. Walenta et al.⁶⁾, have observed that a right-left effect exists in the time of the appearance of an induced pulse in the adjacent wires; notice that a difference in pulse height could simulate a difference in time when threshold circuits are used. The accuracy in position determination is such that one could clearly separate two wires only 0.5 mm apart by current division on the induced pulses, and perhaps interpolate between them.

5. TWO-DIMENSIONAL READ-OUT OF CHAMBERS

5.1 In small chambers

For small-size chambers of the order of 10 cm, one can adopt the following read-out scheme. The cathodes are made of two layers of strips orthogonal to each other, the strips being 5 mm wide and separated by a 5 mm spacing. The pulse height in each of the 20 strips can be digitized to a reasonable accuracy, say a few per cent; the central wires can be connected together and give the pulse gating the system. The position of an ionizing event is given roughly by the centre of the distribution, while the ratio of the pulse heights in two adjacent strips -- or better, a best fit to the distribution -- gives the accurate position. The attractive feature of the method is that the high accuracy is obtained with a very inaccurate measurement of the pulse heights. In this respect it is easier to operate than any current division method.

5.2 In large chambers

Recently we have discussed the properties of drift chambers providing one coordinate with a very high accuracy (of the order of $100 \mu\text{m}$ ⁷⁾). It is clear that a method giving the localization of the avalanche along the wires has the considerable advantage of avoiding the ambiguities arising when many particles are detected and two independent orthogonal coordinates are measured.

Current division was discussed as a possible solution. For fast measurements required by high rates, the current division has to be done on wires with a low resistance.

Accuracies of the order of 3 mm have been obtained by us and by other authors under such conditions for wire lengths of the order of 30 cm. For lengths of the order of metres the accuracy would be about a centimetre.

The method we describe offers the possibility of a vernier method (Fig. 6).

Suppose that in a chamber such as the one described, the pick-up strips orthogonal to the anode wires are connected together alternately and provide the pulse heights A and B. The ratio A/B gives then, as before, the fine position between two strips, and the normal current division on the anode wire provides the gross coordinate.

Figure 7 shows the results of the measurement for a repetitive structure such as the one described. Here the pick-up electrodes were groups of four cathode wires, 8 mm apart, connected alternately to lines A and B. The accuracy is of course rather poor when the source is just in front of a strip, and improves to about $200 \mu\text{m}$ in the centre of the separation. As before, noise and source width were not subtracted.

In a drift chamber of the type we have proposed⁷⁾ it is not possible to have cathode wires perpendicular to the anode wires. However, one could imagine a long, thin, metallized strip facing the anode wires repeating the alternative pick-up electrodes structure we have described.

6. CONCLUSION

This report describes a method of allowing the localization, with a very high accuracy, of the position of avalanches in an MWPC. The accuracy is of the order of $\sigma = 150 \mu\text{m}$ and has so far been shown to be limited only by the electronics. For small chambers of the order of 10 cm, as required for applications as X-ray crystallography, moderately simple systems based on our method can be envisaged. Although at this stage it does not pretend to be more accurate or more simple than the other existing methods, it may be preferable in some cases -- for instance when non-delayed analogue information is needed, giving the position of a particle with the highest precision.

* * *

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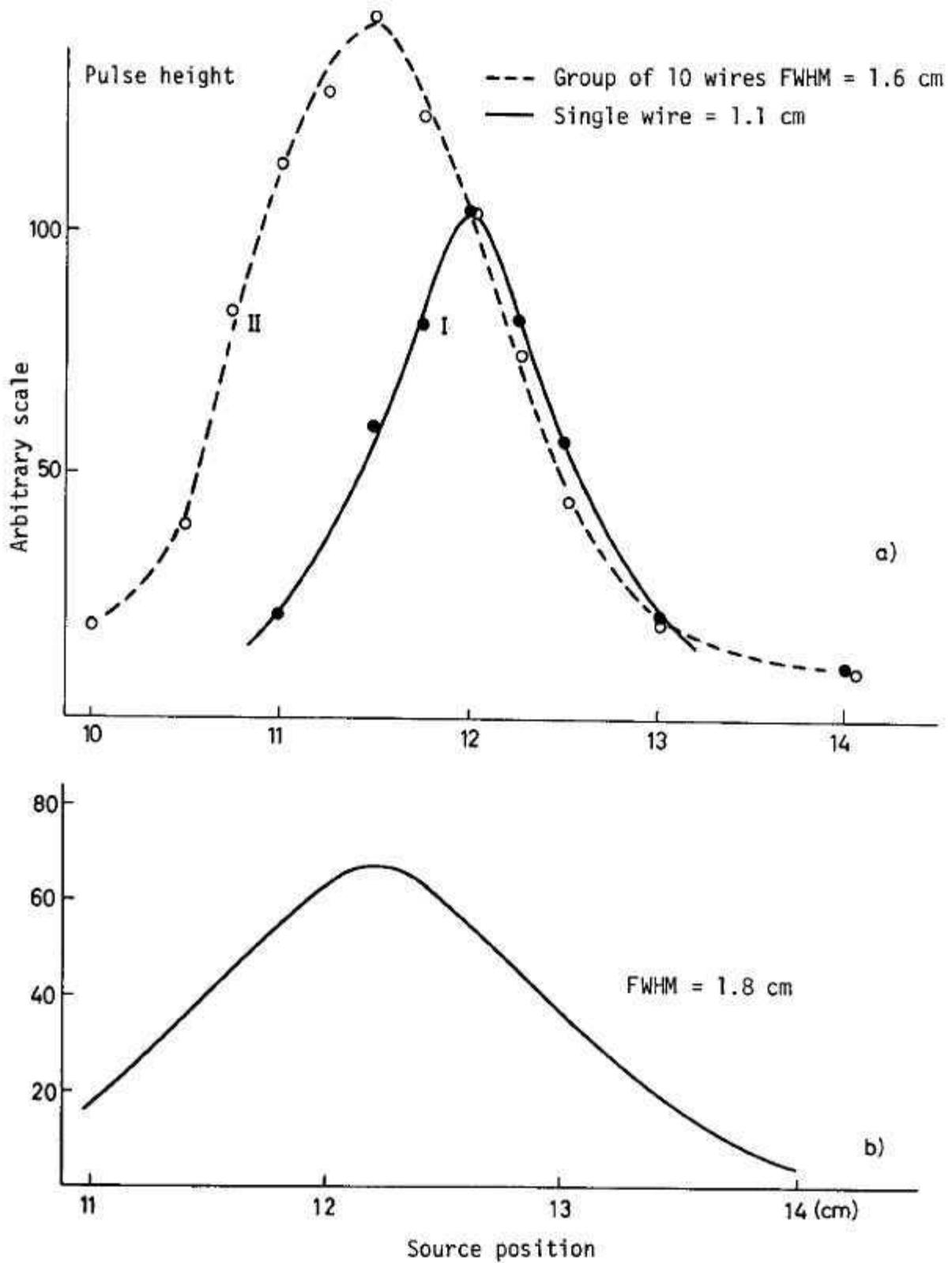


Fig. 1 Variation of the height of the induced pulses as a function of source position:
a) Distance from the central wire to sensing wires = 2 mm. Curve I: pulse on a single wire. Curve II: pulse on a group of 10 wires connected together.
b) Distance from central wire to sensing wire = 7 mm. (From Ref. 1.)

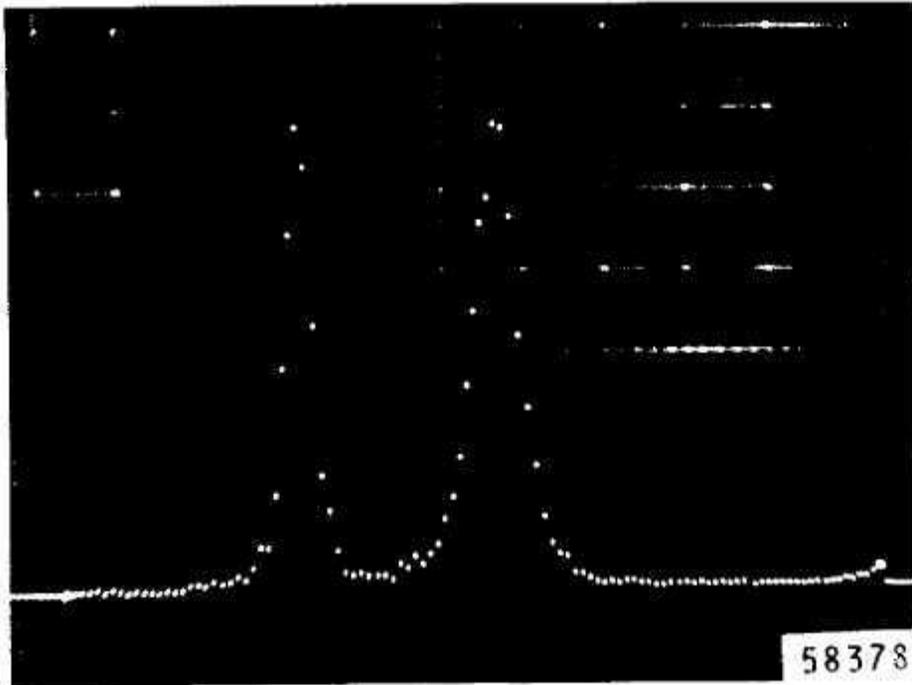


Fig. 2 Localization by the ratio of induced pulses. Pick-up strips of 4 mm, 8 mm apart. Chamber gap $L = 8$ mm. Collimated source of ^{56}Fe , separated by a step of 2 mm along the sense wires in the region between the two strips.

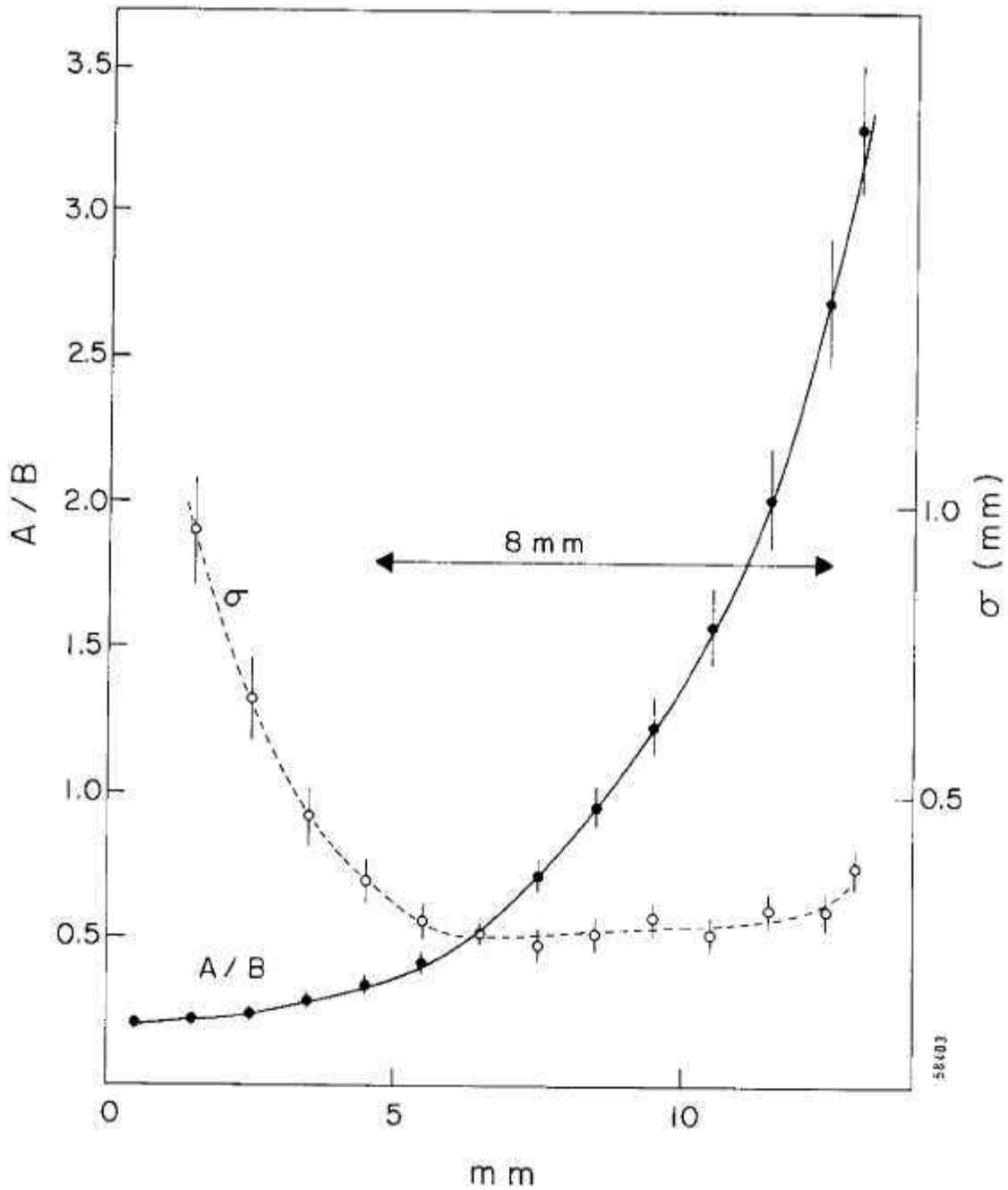


Fig. 3 Variation of the ratio of induced pulses. Full curve: ratio as a function of the avalanches along the sense wires; the error bars represent the FWHM of the peaks. Dashed curve: the equivalent standard deviation as a function of position. The width of the source (≈ 0.1 mm) and the noise ($\approx 30\%$ of the peak width) are not subtracted.

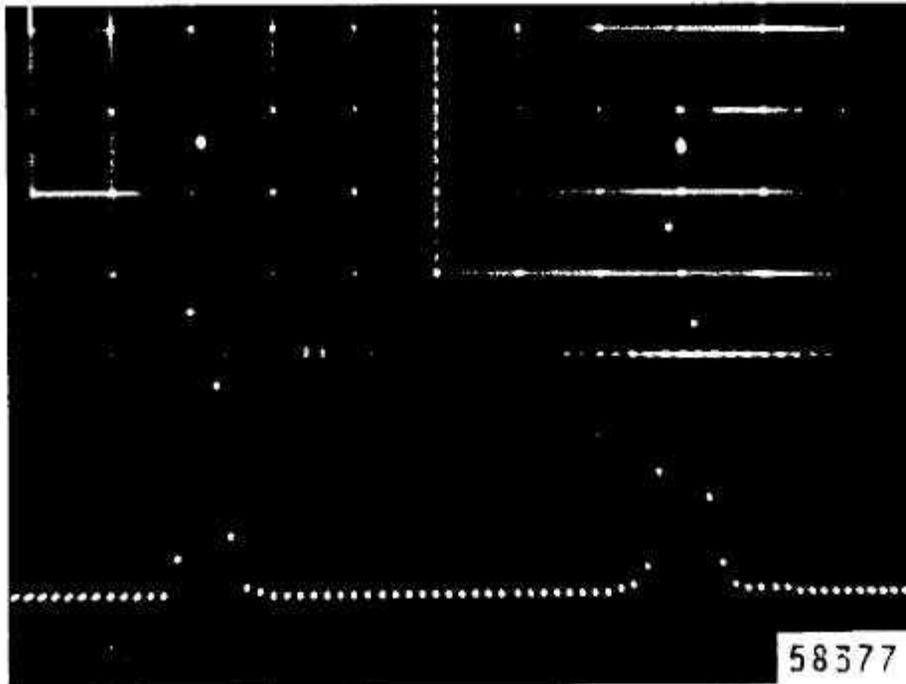
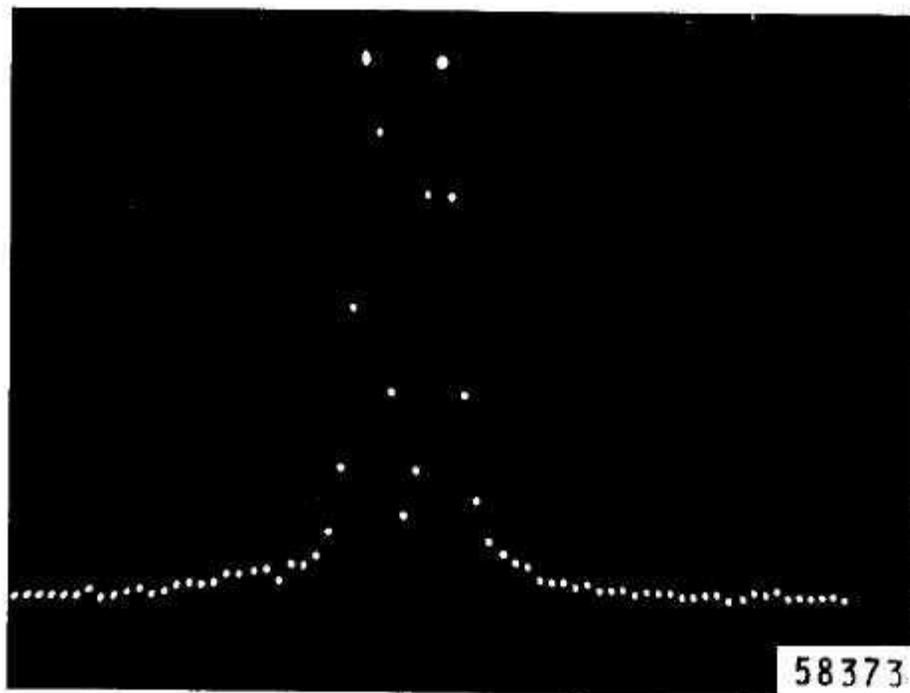
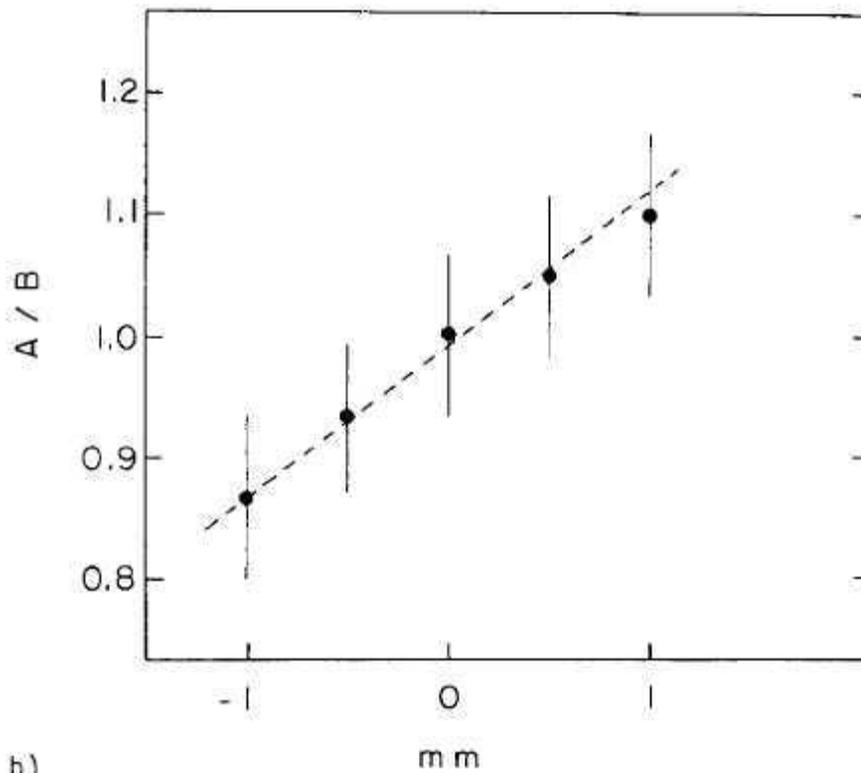


Fig. 4 Localization of the sense wires by the ratio of induced pulses. Ratio of the pulses induced on two strips 8 mm apart, parallel to the sense wires. Wire distance: 3 mm.



a)



b)

Fig. 5 Localization of the right-left side of an avalanche development. With the two pick-up strips on each side of a sense wire the ratio is sensitive to the position with respect to the wire. a) Ratio of the pick-up pulses for the two positions of the source at 1 mm from the wire. b) Ratio as a function of the distance to the wire.

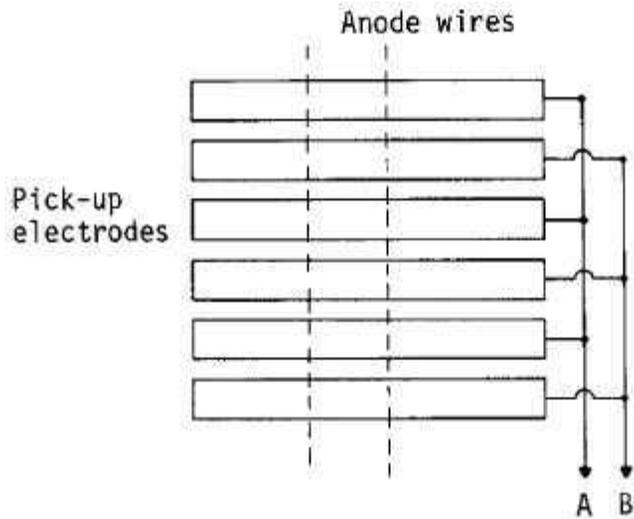


Fig. 6 Principle of a vernier method for high-accuracy measurements along a wire.

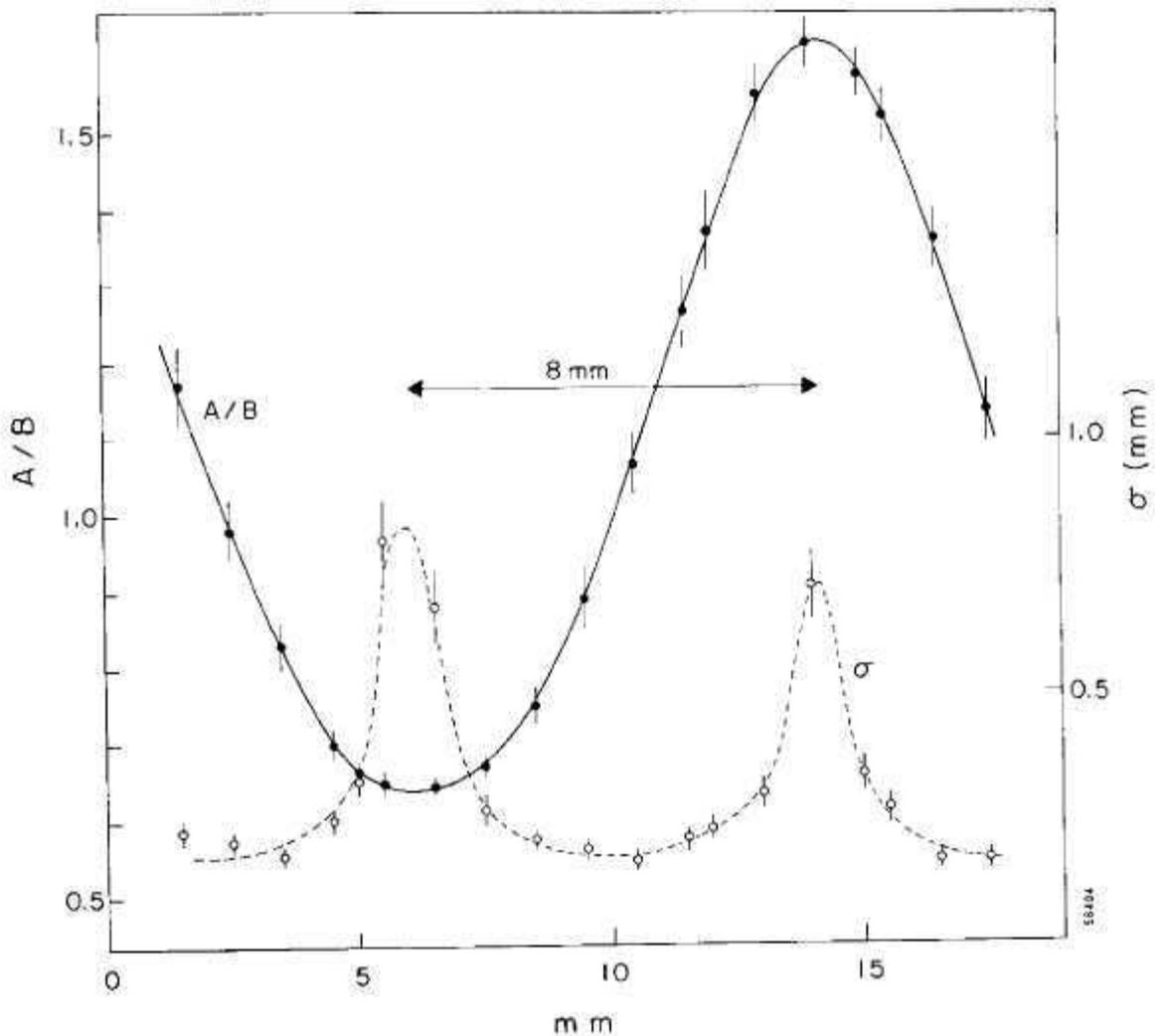


Fig. 7 Ratio of the pulses induced in groups of alternate strips. Full curve: ratio as a function of the avalanches along the sense wires; the error bars represent the FWHM of the peaks. Dashed curve: the equivalent standard deviation as a function of position. The width of the source (~ 0.1 mm) and the noise ($\sim 30\%$ of the peak width) are not subtracted.

