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RESISTIVE CATHODE DETECTORS WITH BIDIMENSIONAL STRIP READOUT: TUBES AND DRIFT CHAMBERS

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Resistive tubes in the limited streamer mode with 1 cm granularity are described. Owing to resistive cathode transparency, both coordinates of a tube layer are readout by two sets of pickup strips. A graded cathode drift chamber with about 100 μm accuracy on both coordinates of the wire plane has been developed. It is again based on resistive cathode transparency, with external orthogonal strip readout, to which the charge centroid method is applied.

1. Introduction

The two wire detectors presented here make use of the resistive cathode technique, already described elsewhere [1]. We will briefly recall its basic idea. The ions drifting away from a sense wire after a multiplication process induce a charge flow into the surrounding cathode electrodes. If the cathode is a conductor, that simply describes its shielding effect. Now if the cathode is a high resistivity electrode, the induced charge flow is slowed down: it does not shield pulsed fields. In this condition if an electrode is placed outside the cathode enclosure and is connected to ground via a load resistor, at the start the induced charge flows into this electrode and a pulse can be collected. This makes possible readout arrangements that are completely equivalent to the usual kinds of cathode readouts (strips, pads, delay lines), with possible practical advantages coming from the physical separation between the cathode and readout elements.

However the basic advantage of this technique lies in the fact that the external pickup elements and the cathode of a given device can be designed independently, being two different physical elements. In fact structures can be designed which it would be impossible to realize in a cathode readout, where cathode and pickup elements are the same thing [1–3]. Such is the case of resistive cathode tubes, a detector we have already used in an experiment [4,5], where the second coordinate is measured with external orthogonal strips.

The first detector we will describe here is a development of that device. Now both coordinates are readout by two sets of pickup strips orhogonal to each other. This detector gas been proposed as the sensitive element of the calorimeter to be built for an experiment on nucleon stability to be performed in the Mont Blanc tunnel [6]. The tubes are operated in the limited streamer mode [7]. Their dimensions are $0.9 \times 0.9 \times 350$ cm^3, and will be arranged in 350×350 cm^2 planes, with 350 cm long x and y strips, for a total number of about 50 000 tubes and about 100 000 strips. Here we will describe the technical design and test work performed on the prototypes.

The second application to be described solves, in a similar way, an analogous problem. In a drift chamber cathode wires are needed parallel to the sense wires, to shape the drift field. This structure is clearly incompatible with an orthogonal cathode strip readout which on the other hand would provide, as in MWPC, an accurate method (the charge centroid method [8]) for measuring the second coordinate. Usual methods (current division, small angle stereo, delay lines) have an accuracy which in general is much lower than that achieved by drift time measurement in the wire coordinate.

To make our cathodes we coat a plastic support with a graphite varnish. As far as uniformity is concerned, it must be noticed that, provided the resistivity is above a lower limit to ensure unperturbed pulse transmission, and below an upper limit to avoid rate limitation, no uniformity is required. The minimum required resistivity depends on geometry and is in most cases $\lesssim 10^5$ Ω/square. The maximum in general is a few orders of magnitude higher.

2. Resistive tubes in the limited streamer mode

2.1. RS-tubes with x–y strip readout

An RS-tube (i.e. with resistive cathode and in limited streamer operation) module with strip readout for both the wire coordinat (x-strips) and the orthogonal one (y-strips) is shown in fig. 1. The RS-tubes are built using extruded PVC profiles coated on the inside with a resistive varnish [9]. The anode wires, 100 μm in diameter, are simply connected via impedance matching resistors, to a common HV bus. It must be noticed that the HV bus is equivalent, for each wire, to a large capacitance to ground, due to the large number of long wires in parallel.

Two sets of pickup strips are placed on the two sides of the RS-tube plane, outside the plastic multitube unit. In this arrangement the wires are used only as active elements to generate the detection process (the streamer), but not as readout elements; it presents relevant advantages: (i) the absence of a large number of HV decoupling capacitors, which would be the least reliable elements in a conventional wire readout; (ii) the physical separation of the HV-gas unit from the readout elements, leading to a very simple and safe structure.

The readout electronics is mounted directly at one end of the readout strip planes, to minimize connections.

We have built and tested RS-tubes about 3.5 m long, with cathode resistivity about 100 kΩ/cm along the tube. A typical singles rate versus HV curve is shown in fig. 2, with a 700 V wide plateau. The tube

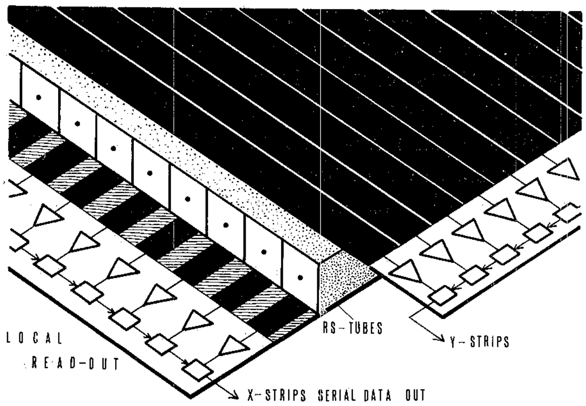

Fig. 1. Schematic structure of a multitube module with x–y strip readout.

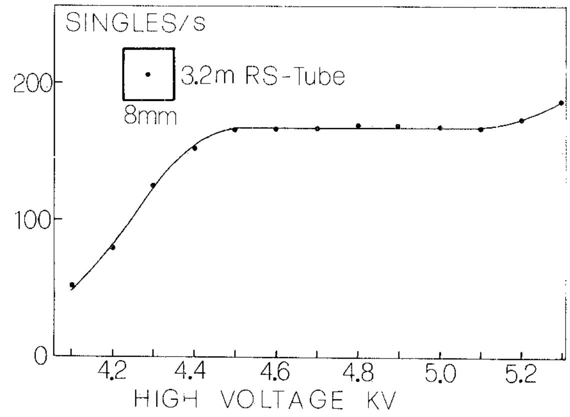

Fig. 2. Sigles rate versus HV for an 0.8 × 0.8 × 320 cm^3 RS-tube with 100 μm sense wire. Gas: argon–isobutane (1 + 3).

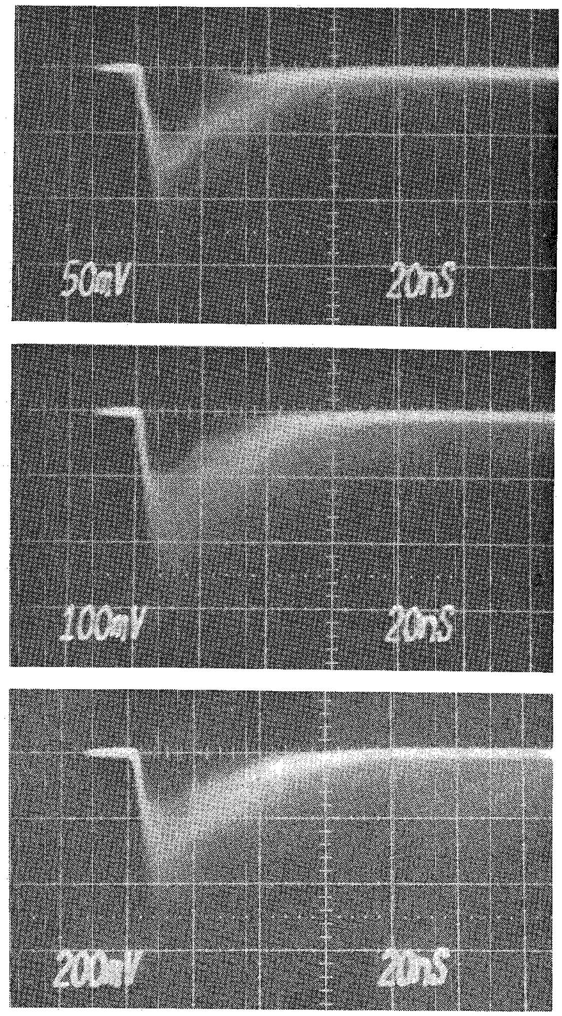

Fig. 3. Wire pulse shapes for the tube of fig. 2, at (a) 4.5, (b) 4.85 and (c) 5.2 kV.

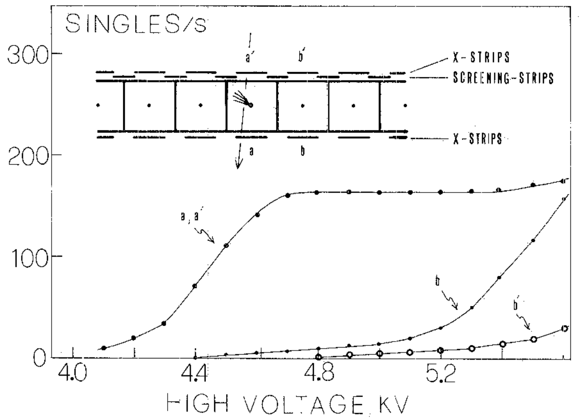

Fig. 4. Singles rate versus HV for (a, a′) the strip near the hit wire, (b) the adjacent strip without screening strips, (b′) the same with the screening strips.

was irradiated with a ^{90}Sr source. The shape of the curve does not change if measured with cosmic rays and radioactivity alone, and a plateau level of about 30 Hz is obtained. This level if measured in the underground laboratory in Mont Blanc [6], with an iron shield to absorb radioactivity from the rocks, drops below 1 Hz, showing that the noise of the streamer mode is negligible even in this limit situation.

Wire pulses as observed at the beginning, middle, and end points of the plateau are shown in fig. 3.

The detection efficiency of a layer of tubes of this type, with 1 mm thick separation walls, is 96%, when measured with cosmic rays.

2.2. Strip multihits

An intrinsic feature of orthogonal strip readout due to the induction width and amplitude spread, is that a single track produces on average more than one hit. We can rely on the data obtained with the RS-tube inner detector of the $\gamma\gamma 2$ experiment (Adone, 1978) [4,5]. It consisted of 20 mm RS-tubes with 20 mm orthogonal strips. The average strip hit multiplicity for tracks perpendicular to the wire plane was

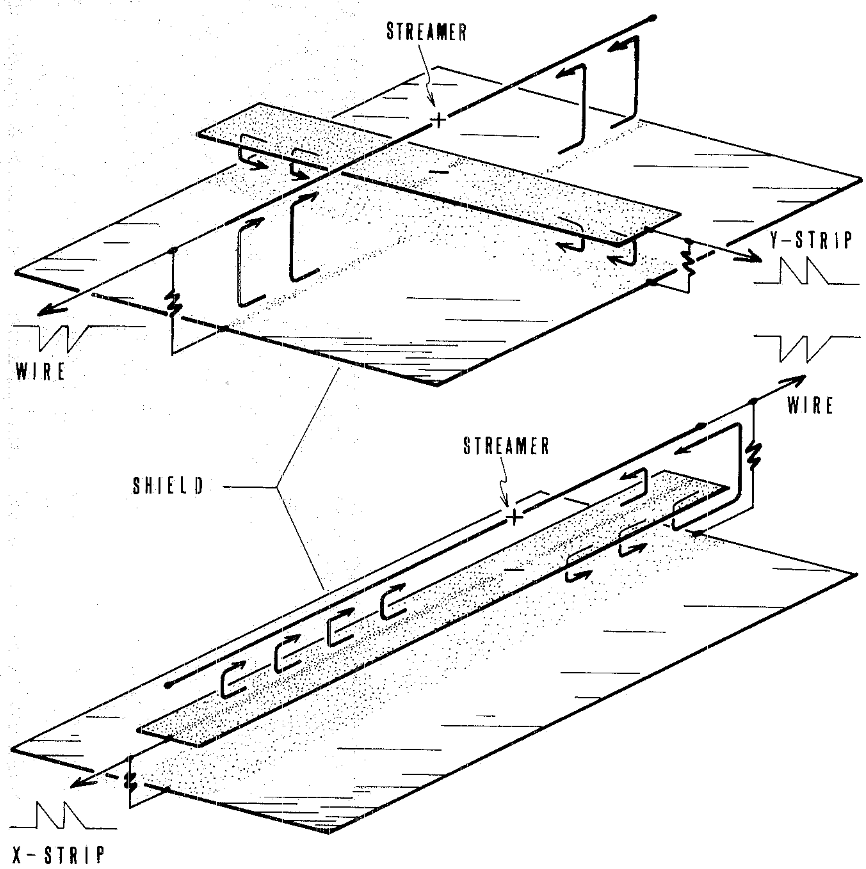

Fig. 5. Schematic drawing to show the propagation of pulses on strips: (a) orthogonal and (b) parallel to the wires.

1.8, and the standard deviation in the longitudinal coordinate measurements was $\frac{1}{5}$ of the strip width. Since in the present case the geometry is equivalent except for an ineffective factor, we expect the same performance.

As far as the parallel strips are concerned, this effect is much reduced because the streamer always occurs at the center of the strips. However to fully minimize this effect we have introduced an additional set of strips between the x-strips and the tubes, as shown in fig. 4. These strips produce a screening effect which reduces the amplitude on the central strip (i.e. facing the hit wire) by a factor of two, while for the adjacent strips the reduction factor is four. The result is summarized in fig. 4, where the x-strip singles rate is plotted in three cases: (a, a′) central strip, (b) adjacent strip without screening strips, (b′) the same with screening strips inserted. The discriminator threshold was 6 mV/50 Ω for the curves a′ and b′ and twice as high for the curves a and b. The addition of the screening strips reduces the multihits to a negligible level throughout the entire HV operation range.

2.3. Strip pulse propagation

A pickup strip plane consists of a 1 mm thick PVC sheet with Al strips on one side and an Al shield on the other, both 40 μm thick. At our lengths both wires and strips exhibit a transmission line behaviour. In our modules two lines are of interest: the wire-ground (Z_0 = 330 Ω) and the strip-ground line (Z_0 = 25 Ω for 1 cm strips, τ = 6 ns/m). Pulse propagation for strips orthogonal to (or at an angle with) the wires is schematically shown in fig. 5a. The wire and y-strips signals propagate simultaneously and independently on the wire-ground and strip-ground lines respectively. In particular the strip pulse shape is independent of the wire load.

The situation is quite different when the strips are parallel to the wires. Now (fig. 5b) only the wire-strip line is excited, the strip–ground gap being shielded by the strip itself, and the current generated in the streamer process must reach one end of the wire–strip line before being injected into the strip–ground line. In this case the strip current is nothing else than that coming out of the wire and therefore the strip pulse shape depends on the wire load. This propagation mechanism can be observed by looking at the relative delays between the wire and strip pulses shown in fig. 6, for the 3.2 m long RS-tube with both x- and screening-strips (6 mm and 4 mm respectively). In fig. 6a the negative wire pulse (detected on a 50 Ω load in series with the total matching load of 330 Ω) is shown together with the corresponding strip pulse (25 Ω load) as obtained with a ^{90}Sr source placed in relation to the strip readout end. For both signals the wire triggered the oscilloscope. In fig. 6b the source was placed at the open end of the strip line, and the reflected pulses at the open wire end are visible.

The minimum pulse height available on both x and y strips is always several millivolts on a 25 Ω load. Due to the low attenuation of the transmission lines

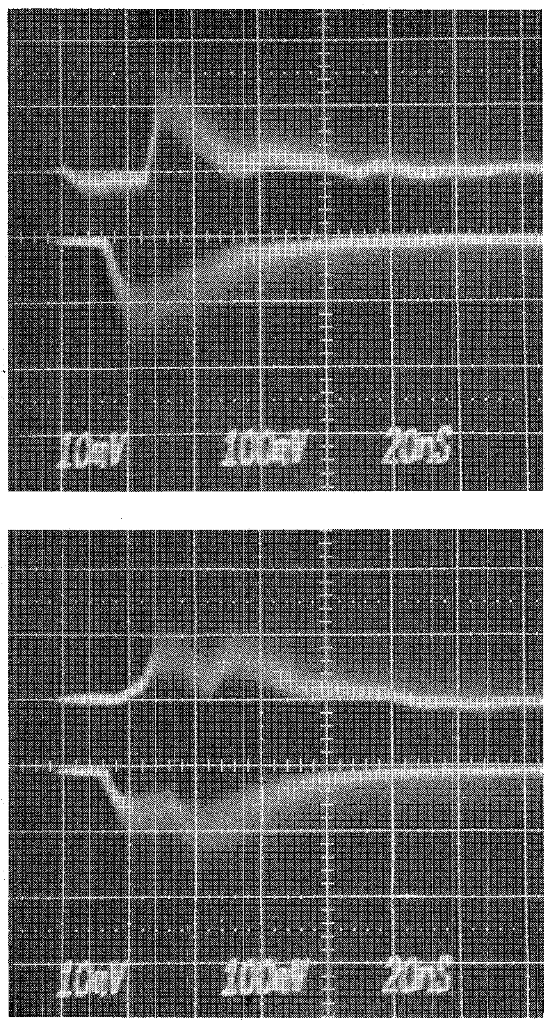

Fig. 6. Wire and strip pulses from the 3.2 m long tube with a ^{90}Sr source placed (a) at the strip readout end, (b) at the open end of the strip.

involved, these results can be extended to much longer tubes and strips.

To readout the RS-tube system of the Mont Blanc experiment, a dedicated monolithic is being developed by the Le Croy Research Corporation. It is a dual amplifier–discriminator with 50 Ω input impedance, ±30 μA minimum input threshold, and a power consumption <50 mW/channel. A single printed circuit board will service 32 strips, also containing a shift-register memory and a prompt OR stage for triggering.

2.4. Construction details

Figure 7 shows a scheme of the RS-tube module assembly and of the final arrangement with the readout strips. To make the tubes we will start with an open profile to simplify many construction operations. A PVC 8-cell profile is coated with a felt-pen built for the purpose and a graphite varnish [9]. 8-fold wire holders made out of thermoset PVC, are inserted at 50 cm intervals along the module. 100 μm Be–Cu wires are then stretched and soldered on two

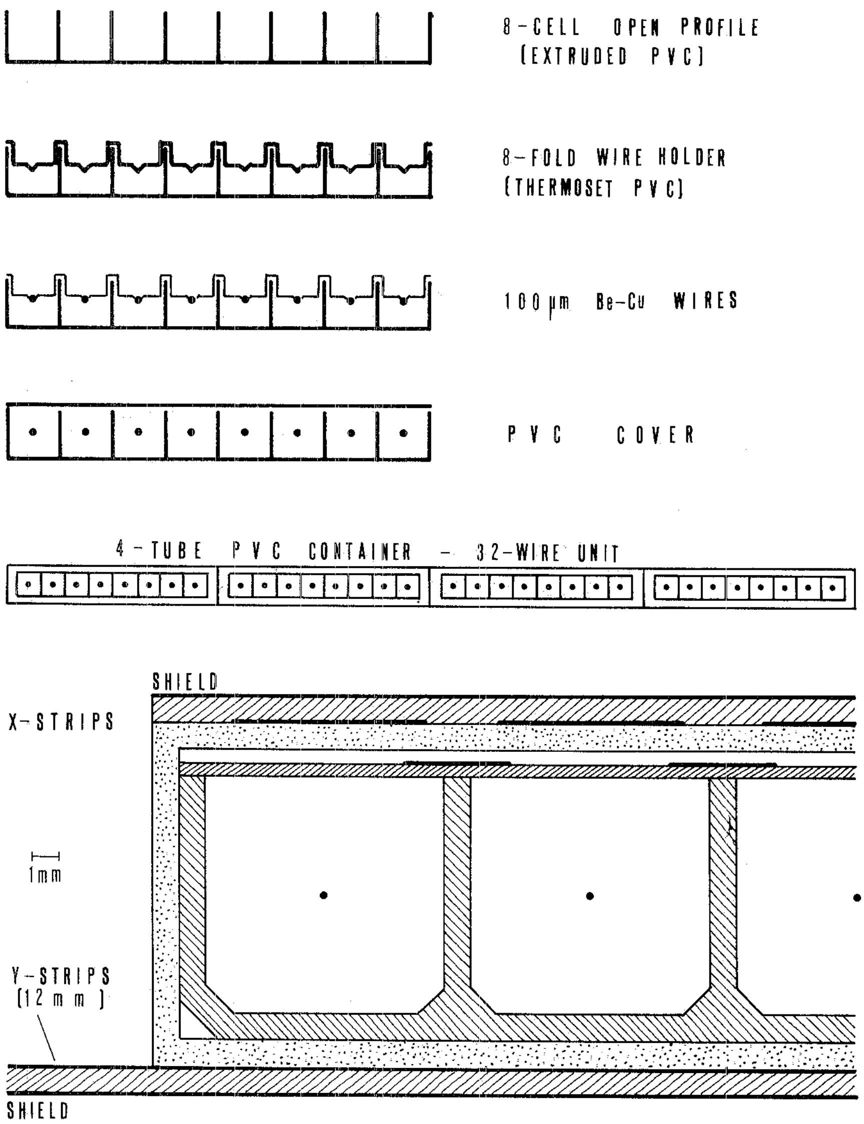

Fig. 7. Assembly details and final geometry.

printed circuit boards inserted at both ends of the profile. The wires are fastened to the holders by melting the PVC with a hot point. A PVC cover coated on one side with the same varnish is then placed on the module, which is inserted in a PVC tube container. The screening strips are mounted on the PVC cover.

2.5. Long term tests

We have irradiated with a ^{90}Sr source a region of about 1 cm along a test tube, filled with our usual gas mixture of argon–isobutane (1 + 3). After a charge of 2.7 C, corresponding to 2.8×10^9 pulses, was integrated, no appreciable effect on the tube behaviour was observed. This result shows the possibility of operating RS-tubes at relatively high rates for long periods.

As far as low operation rates are concerned, it is worthwhile noticing that they can be operated without continous gas flow. We have kept a test tube in continuous operation without any gas flow, under the normal cosmic ray and radioactivity background. After 2.5 months no difference in performance was observable.

3. A drift chamber with high X and Y accuracy

We have built a drift chamber of the conventional graded cathode type, where the field shaping wires consist of resistive lines drawn on a thin Mylar foil. The transparency of the resistive cathode makes it possible to place a set of strips orthogonal to the wires outside the chamber, to measure the second coordinate. A schematic drawing to show the chamber structure is shown in fig. 8a. This prototype chamber has a useful area of 10×20 cm^2, with a rather conventional drift cell geometry, as shown in fig. 8b. The chamber did not show any undesired effect due to the resistive cathode [10]. The orthogo-

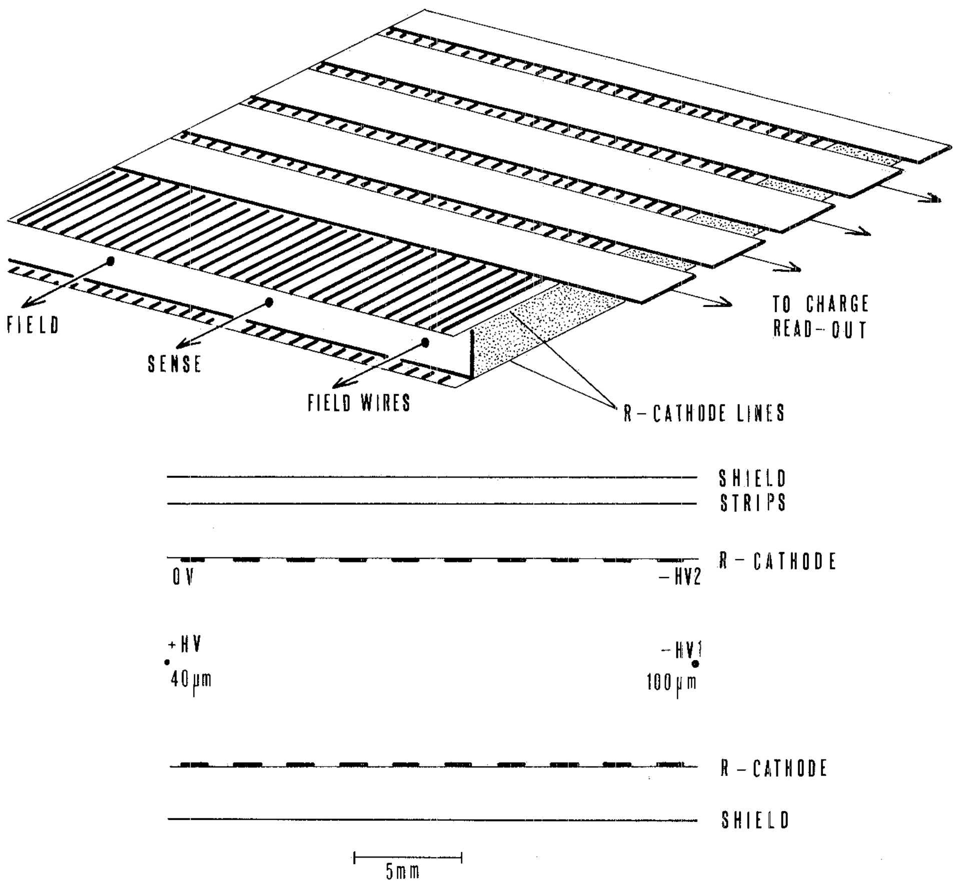

Fig. 8. (a) Schematic drawing of a resistive cathode drift chamber with orthogonal readout strips; (b) drift cell geometry.

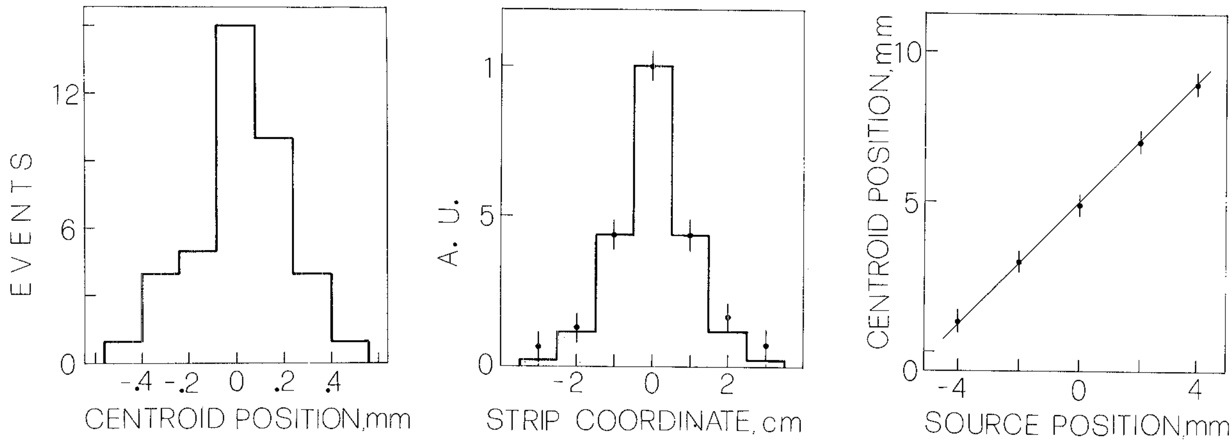

Fig. 9. (a) Charge centroid distribution as obtained with a collimated ^{55}Fe source; (b) relative charge distribution over the strips; (c) average centroid position for different source positions.

nal strips have a 1 cm spacing. They were connected to a charge readout to measure the coordinate parallel to the wires by means of the charge centroid method. A collimated ^{55}Fe source was placed in the middle of one of the pickup strips, amplitudes were recorded, and for each event the charge centroid was calculated. We obtained the centroid spatial distribution shown in fig. 9a, while the average charge distribution on the strips is shown in fig. 9b, compared with the expected distribution in the hypothesis of full transmission through the resistive cathode. The slight discrepancy on the tails of the distribution is due to the relatively low resistivity of the cathode lines (160 kΩ/cm): it disappears for resistivities $\gtrsim$500 kΩ/cm along the lines. However even in this non-optimized condition the resulting spatial accuracy is high: the centroid distribution in fig. 9a has a standard deviation of 200 μm, including the source spread which had about the same nominal width. Thus the accuracy of the chamber is better than that. Fig. 9c shows the centroid position when the source is moved in small steps over one strip width: deviations from linearity turn out to be negligible.

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