EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

NP Internal Report 73-8
22 May 1973

THE "HONEY COMB", A HODOSCOPE OF HEXAGONAL PROPORTIONAL CHAMBERS

L. Baksay, B. Naroska and V. Telegdi

ABSTRACT

For future experiments on the ISR it is of interest to construct a counter hodoscope surrounding the intersect in almost 4π. It should be able to provide information on the multiplicity and geometrical configuration of an event.

One way of realizing such a hodoscope is to surround the intersect by one or possibly several layers of a honeycomb structure, in which each hexagonal cell is a proportional counter.

We describe the properties of a single honeycomb cell, which has been tested as a first step before building such a device.

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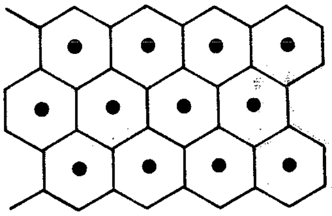
1. INTRODUCTION

In future experiments on the ISR it might be interesting to know the multiplicity and geometrical configuration of events over 4π in addition to the one or two particles measured exactly by a spectrometer.

There are several alternatives for constructing a hodoscope which surrounds the interaction region. For example, one might use a hodoscope of scintillation counters or conventional proportional chambers. These could, in addition, utilize the current-dividing method recently described by Foeth et al.$^{1)}$ to determine the position of a track along the wire.



One possible alternative is to surround the intersect by a layer of hexagonal cells, each of which is a proportional counter. The signal wires threading the hexagonal units should be connected to simple amplifiers and read into a computer.

This has the advantage of supplying the multiplicity and rough location of tracks quickly and without the elaborate reconstruction programs needed for conventional proportional chambers. Furthermore, it is a very compact device in comparison with a scintillator hodoscope. To investigate the properties of such a device, a series of tests was made on several single hexagonal cells.

2. THE PROTOTYPES

2.1 Dimensions

The following considerations apply to the dimensions of the honeycomb cell (HC). The diameter of the hexagon should be small enough to provide sufficient spatial resolution, while keeping the number of wires within reasonable limits. A counter in which the path of particles in the gas is long and the edge effects are consequently negligible, offers the advantage of high efficiency and stability. On the other hand, a long cell is very directional, and there is a high probability of particles traversing more than one cell.

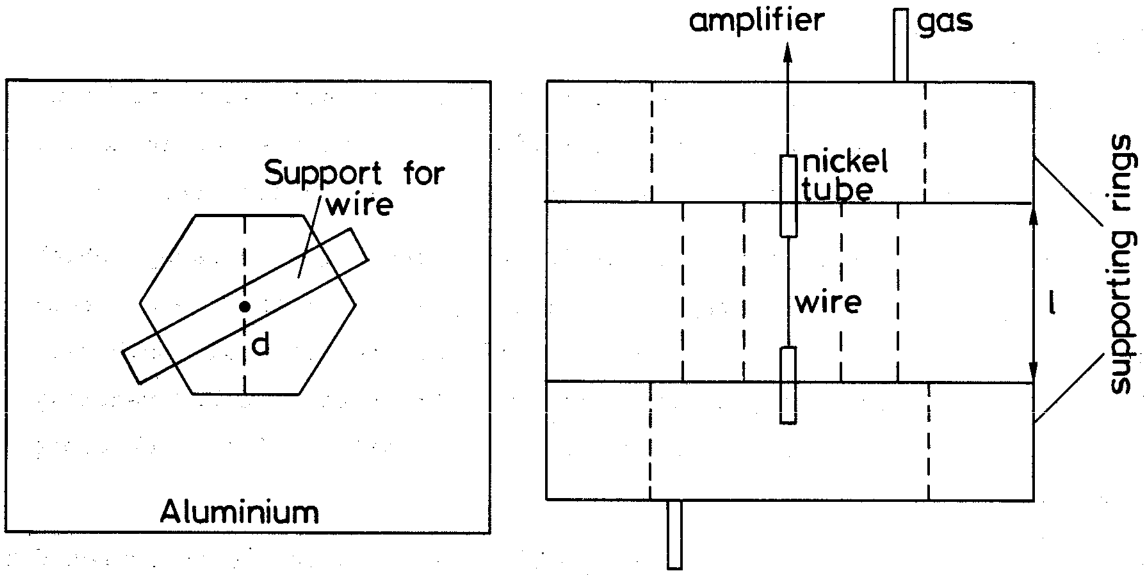


Fig. 1 Top and side view of HC prototype

We built several prototypes, each hexagon diameter being either 1.7 cm or 2.8 cm, and the depth between 2 cm and 5 cm (Fig. 1).

The hexagonal cell was cut out of a block of aluminium, to the top and bottom of which two aluminium rings were fastened. To these was glued the mylar which kept the gas inside the cell; all necessary cable connections as well as the amplifier were mounted on the rings.

2.2 Wire

The signal wire threading the cell was of gold-plated tungsten, standard for proportional counters. We used a thickness of either 50 μ or 100 μ. The wire was held in the axis of the cell by two nickel tubes (outer diameter 0.5 mm), which were glued into a vetronite bridge fastened to the top and bottom of the cell.

2.3 Gas

The gas filling of the HC should be chosen so that the counter is efficient and fast; this means that it should have high specific ionization and high drift velocity.

We used isobutane/argon and methane/argon mixtures, the percentage of argon varying from 10% to 70%.

2.4 Signal

The wire was kept on a positive potential with respect to the counter. An ionizing particle passing through the gas of the counter gives rise to a small current signal in the wire. In the tests we used a proportional amplifier (μA 733 by Fairchild) because it was readily available. Its input impedance was ∿ 2000 and its amplification factor ∿ 50. The output signal was limited to 2 V.

A large percentage of the HC pulses saturated the amplifier, which means they are ≳ 20 μA. To measure the efficiency of the cell, the amplifier pulses were fed into a NIM discriminator. The dependence of efficiency on the threshold setting is shown in Fig. 2. The threshold used in the tests was 450 mV.

Eventually this proportional amplifier is to be replaced by a simpler one (RCA CA 3046/7112), as the HC is to be operated as a counter, neglecting the analogue information.

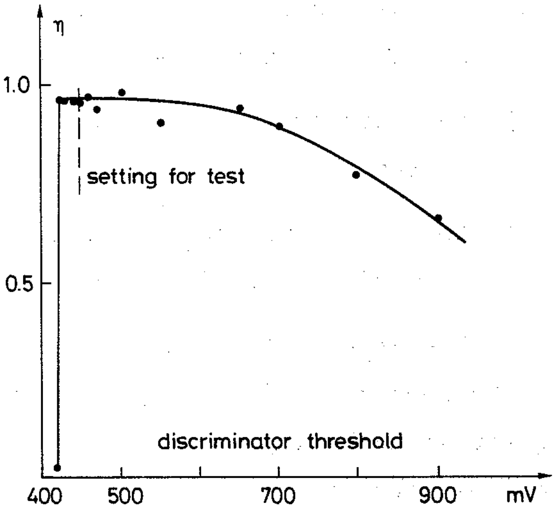


Fig. 2
Efficiency η of HC as function of discriminator threshold (ℓ = 2 cm, HV = 6 kV, isobutane : argon = 9 : 1)

3. THE TEST SET-UP

The test was done on the PS in a parasitic beam in the South Hall. Most measurements were made with a closed beam stopper, so that one had essentially μ's of a few GeV. The beam was diffuse and divergent, its properties being changed several times by the main user. Over an area of 1 cm^2 one had ∿ 300 particles/burst.

To measure the efficiency of the HC, two crossed scintillation counters were used which defined an area of 2 × 2 mm^2. To measure the over-all drift-time distribution they were replaced by two scintillation counters of 4 × 4 cm^2. In addition to this twofold coincidence there was an anticoincidence of a large scintillation counter with a hole of 5 mm diameter. (In the following these counters are referred to as "telescope".)

The cell was placed between the two telescope counters, so that the beam passed parallel to the wire. In this set-up we measured high-voltage curves for different gas fillings, the efficiency distribution, pulse heights, and drift-time.

3.1 High-voltage curves

For the test, positive high voltage was applied to the wire. All cells showed a plateau, the position of which was determined by:

a) the dimensions of the counter -- the longer the counter the lower was the inset of the plateau;

b) the thickness of the wire -- a thinner wire requires less high voltage;

c) the gas -- methane/argon mixtures decreased the high voltage in comparison with isobutane/argon.

The length of the HV plateau was determined by the gas mixtures, isobutane/argon mixtures giving the longest plateaus, which means greatest stability. At the end of the plateau the length of the HC pulses becomes several times longer than at lower voltages, probably due to the onset of the Geiger region.

In Fig. 3 the high voltage plateaus for four different gas mixtures are shown.

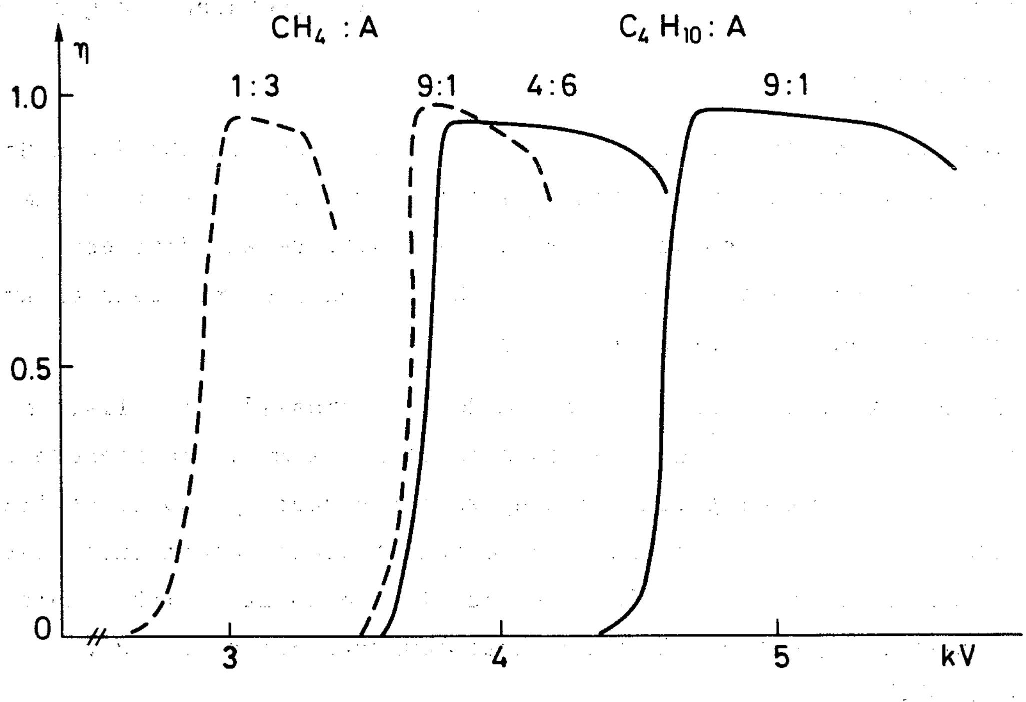


Fig. 3 High-voltage plateaus for four different gas mixtures (ℓ = 5 cm)

Within the limits of accuracy the efficiency does not depend on the type of gas used (see Fig. 3).

The efficiency was also measured with a collimated β-ray source (SR 90), which gave a rate in the HC of 450 e$^-$/sec. At this rate the HC was 100% efficient.

By moving the HC relative to the telescope counters the efficiency was measured over the area of the cell. In Fig. 5 the efficiency distributions in the horizontal and vertical directions are plotted for cells of various lengths. The efficiency is constant from near the wire to a certain distance from the wire; this distance seems to depend on the length of the cell. The decrease in efficiency is due to the finite resolution of the telescope counters and back-scattering effects in the aluminium block which surrounded the cell.

To eliminate this back-scattering, a counter was built which consisted of two cells, separated by a foil of 0.2 mm aluminium. The result of the scan of this double cell is in Fig. 6. The efficiency stays constant even when crossing the separating wall (full curve).

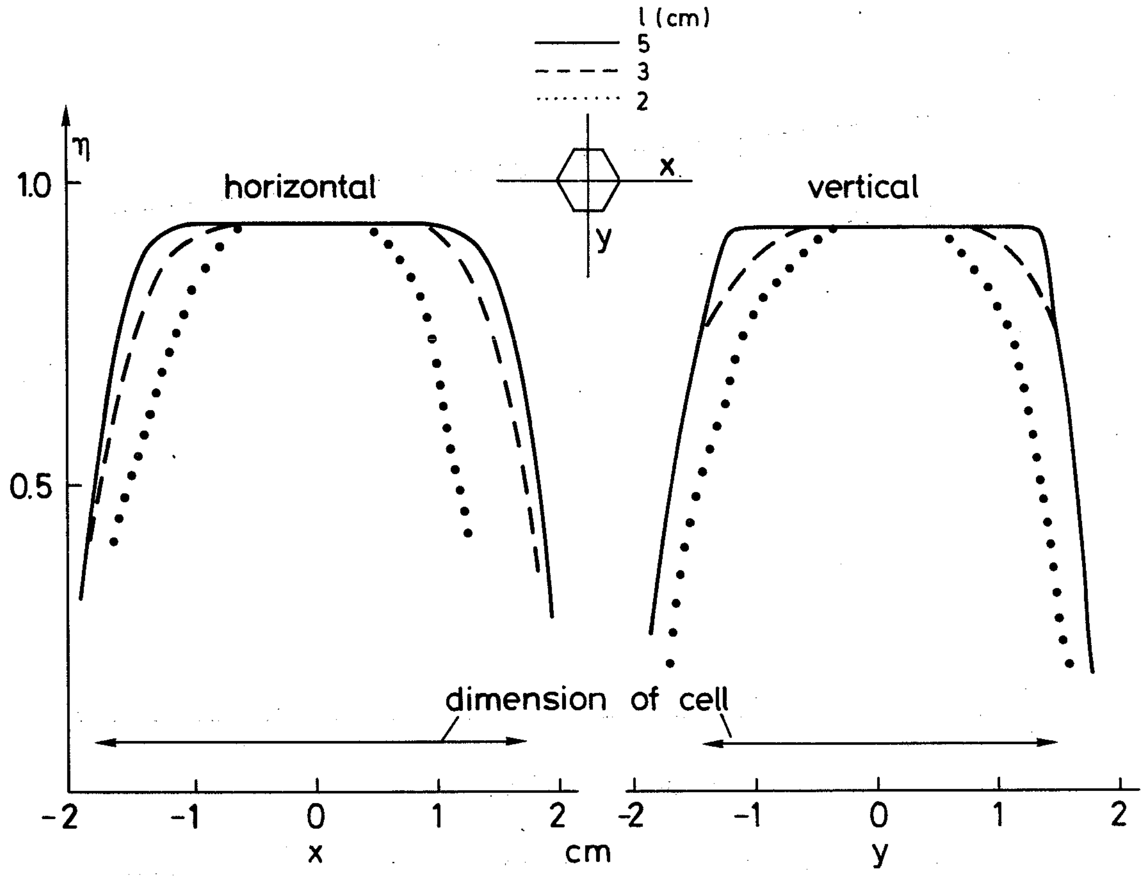


Fig. 5 Efficiency distributions in horizontal and vertical directions x and y (see insert) for HC cells of various lengths

3.2 Efficiency

The main question was, What was the efficiency of the HC and was it the same at different distances of the wire? The efficiency of the HC cell is given by the ratio

$$\eta = \frac{\mathrm{HC} \cdot \mathrm{telescope}}{\mathrm{telescope}} \; .$$

The telescope of scintillation counters defines an area of $2 \times 2\ \mathrm{mm}^2$, which is small compared to the HC cross-section. The beam went parallel to the wire.

The efficiency was found to be rate-dependent under beam conditions which gave an instantaneous rate of 3000 to 60,000 particles/burst (Fig. 4). Owing to the total length of the HC pulse which went up to several microseconds, the probability of two pulses falling on top of each other was not negligible at this rate. A simple calculation shows that with an effective length of the beam pulse of 320 msec and HC pulse of 2.5 μsec at a rate of 6×10^4 part/burst one expects the inefficiency to be ∿ 15%.

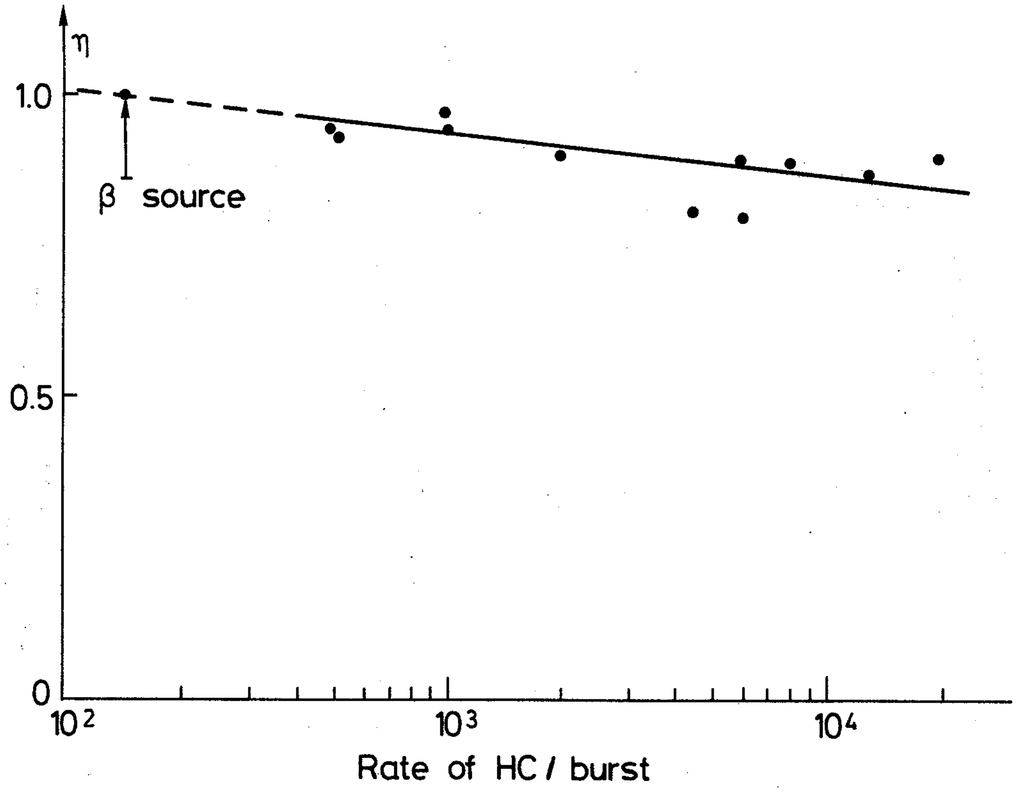


Fig. 4 Efficiency η as a function of the single HC rate

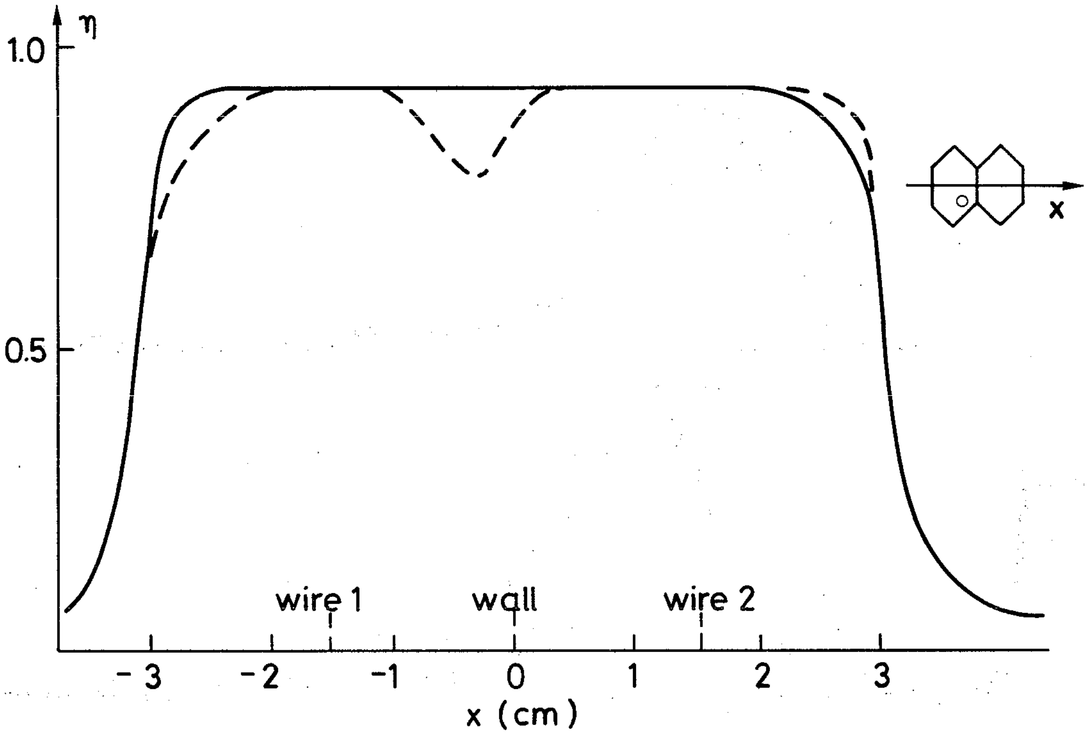


Fig. 6 Efficiency distribution for a double cell, separated by a wall of 0.2 mm aluminium

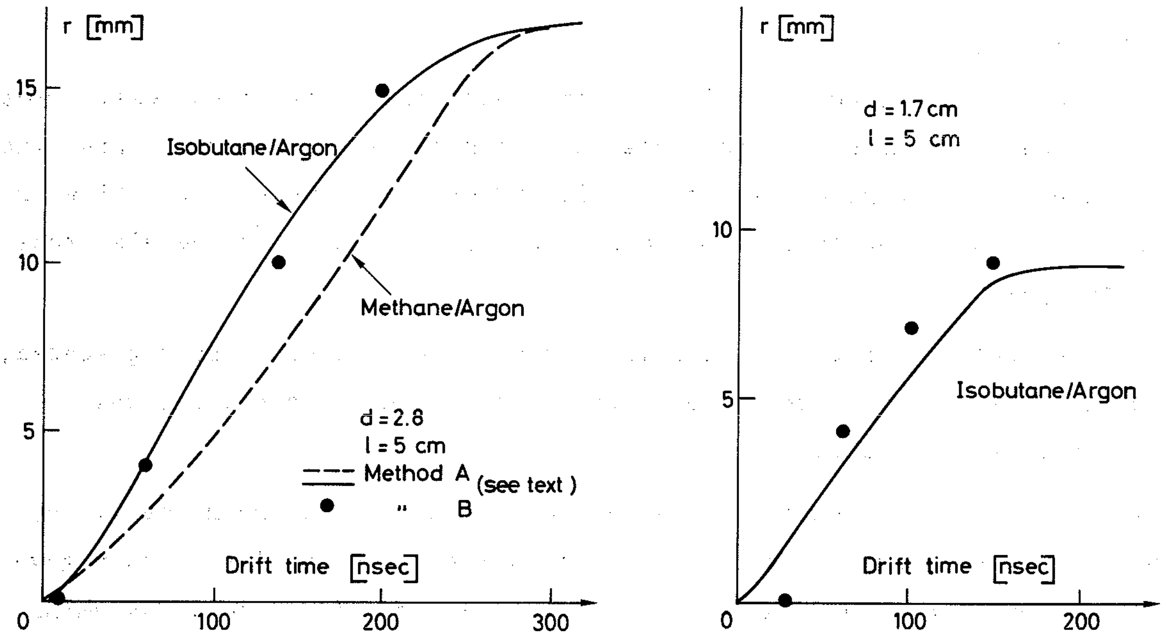
A slight misadjustment of the cell, which means that particles are traversing the cells at an angle, caused a dip in efficiency near the wall owing to the shortened ionization path (dotted curve in Fig. 6).

3.3 Pulse-height distributions

In order to investigate further the behaviour of the HC, especially with regard to the efficiency near the walls, its pulse-height distribution was measured. The counter showed a Landau distribution with clear separation from the peak at zero, which was due to inefficiency because of high rates (Fig. 7).

The maximum pulse-height was found to drop towards the ends of the counter (Fig. 8). The amount of decrease depends on the dimensions of the HC, getting larger with growing cell diameter and decreasing length of cell. But for the prototypes tested it never exceeded ∿ 30%, so that the remaining pulse height is still sufficient to be recorded.

The decrease is only slightly affected by the gas mixture used.



a) b)

Fig. 9 Distance r of a track from the wire as function of the drift-time for cells of (a) ∿ 2.8 cm and (b) ∿ 1.7 cm diameter, respectively

3.5 Effective length

The wire on both sides of the cell was held by nickel tubes at the same potential as the wire. As their diameter is five times that of the wire, a considerable field distortion is introduced. This and the fact that the cell has finite length result in a finite effective length λ of the HC -- that is, the length where the counter is fully efficient (see Fig. 10).

To measure the effective length the HC was turned by 90°, so that the beam went vertical to the wire. By moving the HC, a distribution of the efficiency along the wire was measured (Fig. 11) at various distances from the wire. It showed a steep drop at both ends. The effective length is defined to be the full width at half maximum.

To investigate the effect of the Ni tubes, their distance t was varied for the cell of 3 cm length. The result for three tube distances is plotted in Fig. 12.

The effective length is found to be ∿ 60% of the free wire length near the wire and decreasing towards the walls of the cell.

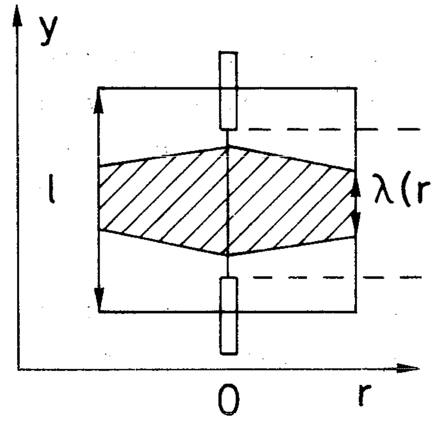


Fig. 10 Definition of the coordinate system for the measurement of the effective length

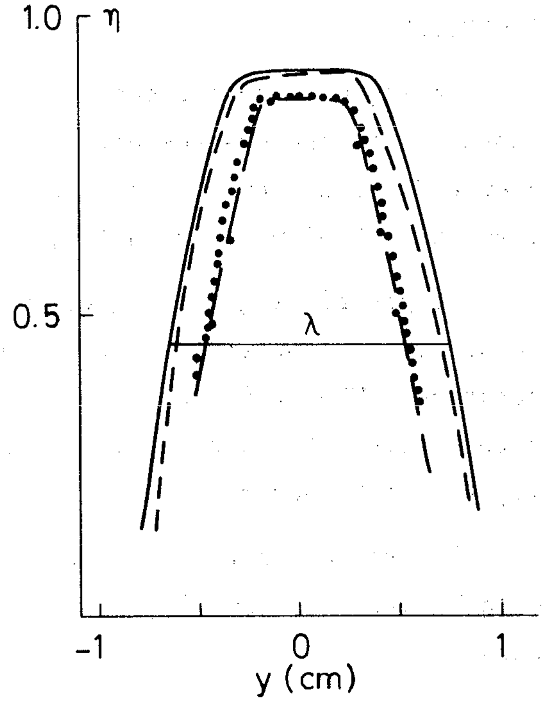


Fig. 11 Efficiency η along the wire at various distances from the wire

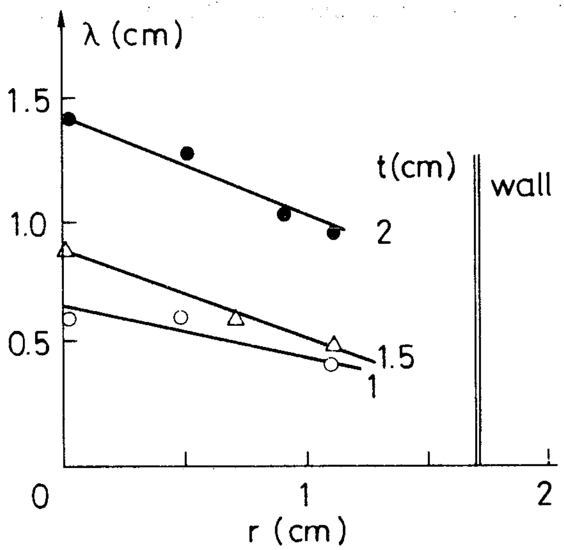


Fig. 12 Effective length λ as function of the distance r from the wire for various tube distances

4. CONCLUSION

A hexagonal proportional counter which is to be the element of a counter hodoscope was tested. It was found that a cell of ∿ 3 cm diameter and 2.5 cm length, which would be reasonable for a large device (leading to ∿ 3500 cells in 4π), would operate satisfactorily.

The gas filling which gives most stability is isobutane with 10% argon. This might still be replaced by a mixture which gives a faster operation. The efficiency of the cell is then uniform till very close to the walls. At rates of a few hundred per second it is 100%, dropping slightly at higher rates.

The typical time jitter would be ∿ 300 nsec. The effective length could be made 1 cm by holding the signal wire with appropriate metal tubes.

The signal is large enough to use simple, relatively cheap amplifiers.

Acknowledgement

We would like to thank Professor C. Rubbia for his support.

REFERENCES

1) H. Foeth et al., On the localization of the position of the particle along the wire of a multiwire proportional chamber, submitted to Nuclear Instruments and Methods, 1973.

2) H.W. Fulbright, Handbuch der Physik, Vol. 45, p. 19.