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A set of multigap plane proportional chambers with optimised sensitive surface area for a vertex detector

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Abstract. The construction and performance of multigap plane multiwire proportional chambers (MWPCs) 108 × 108 cm^2 are described. Relevant details on the construction procedure and the results of operating tests are reported. These chambers are operating in the NA1 experiment at SPS, CERN.

1. Introduction

We describe a set of MWPCs of 1.16 m^2 useful surface area, used in the NA1 experiment at SPS, CERN to measure the lifetime of charmed mesons in a purely electronic way (Albini *et al* 1982) for the first time. The apparatus consists of a forward spectrometer covering the angular region between 0° and 6° and a multilayer active silicon target surrounded by a vertex detector. The vertex detector is composed of a drift chambers box, a set of MWPCs and a segmented photon detector (figure 1).

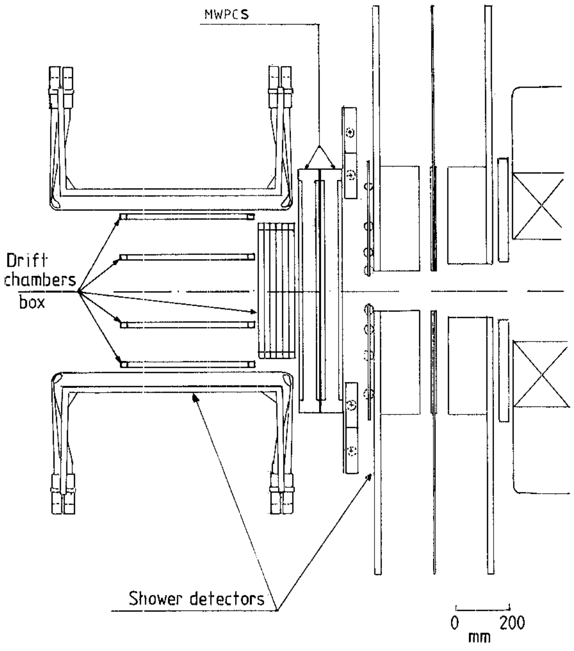

Figure 1. General layout of the NA1 vertex detector.

In the vertex detector design we had to solve the problem of getting the maximum amount of information whilst keeping the physical dimensions of the whole detector to a reasonable size. In a volume of less than 1 m^3 we installed ~200 drift cells, ~3000 proportional wires and ~500 PMs, ensuring complete coverage for charged particles up to 120° and the detection and energy measurement of photons up to 70°.

The MWPCs were used for triggering purposes and off line analysis. The main requirements on the MWPCs were that, independently of the drift chambers information, the interaction point should be reconstructed with a precision better than 2 mm in the direction perpendicular to the beam, and that the secondary vertices due to K and Λ decays should be identified. All these conditions had to be satisfied by a MWPC set less than 200 mm thick, since the compactness of the vertex detector did not allow a longer lever arm.

In the present paper we describe the characteristics of the MWPC design, the construction procedure and we report the performance of the MWPCs in the test runs and in the NA1 data acquisition runs.

2. Design and construction

The design was mainly influenced by the requirement of having minimum depth in the beam direction. Accordingly, we decided to build the chambers with three sense wires planes (instead of two, as usual) to reduce the total number of external support frames. In order to decouple optically the gaps, we used for the cathode planes aluminium foils 40 μm thick. Because of this choice we were forced to maintain the overall mechanical tolerance at the 1% level to prevent high-voltage breakdown in the chambers.

The main mechanical characteristics of the chambers are: (a) 108 × 108 cm^2 internal dimension, (b) 20 μm wires, (c) 2 mm pitch, (d) 8 mm gap. Each chamber is composed of eight Vetronite† frames (Stesalit 4411W), held together by two aluminium frames, ensuring the necessary mechanical rigidity. On the frames are glued two Aclar† foils 50 μm thick for gas enclosure (figure 2).

2.1. *Cathode planes*

Due to the electrostatic attraction between the electrodes, the cathode planes tend to dish in. Although this problem applies mainly to the outside cathode planes, for proper chamber operation, the inflection of all cathodes must be limited to less

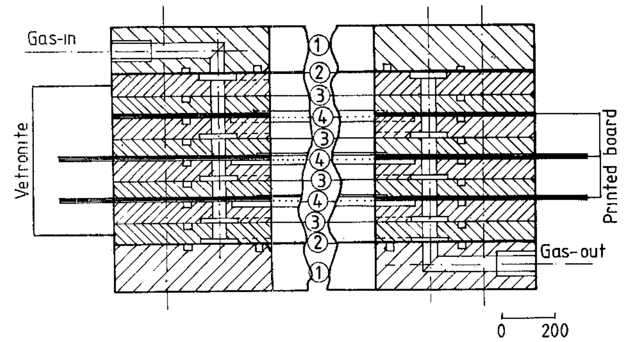

Figure 2. Cross view of a single multiwire proportional chamber. (1), external aluminium frame; (2), Aclar window; (3), cathode aluminium foil; (4), sense wires. The sense wires are indicated by dots on the three planes.

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† Vetronite and Aclar are commercial names of a compound of fibreglass saturated by epoxy resins, and of a polychlorotrifluoroethylene film, respectively.

than 0.1 mm. This is obtained by stretching the aluminium foils of the cathodes before gluing them to the frames. The minimum necessary stretching tension is determined from the solution of the differential equation describing a membrane deformed by a distributed force. In our case at the centre of the cathode plane, the sagitta derived from this equation is

$$u(0,0)=\frac{pL^2}{8T}\left(1-\frac{32}{\pi^3}\sum_{k=0}^{\infty}\frac{(-1)^k}{(2k+1)^2\cosh(2k+1)(\pi/2)}\right)$$

$$\approx 7.37\times 10^{-2}\frac{P}{T}L^2$$

where p is the electrostatic pressure, L^2 the area of the aluminium foil, and T the tension. By imposing that the sagitta be less than 0.1 mm one gets a lower bound for the tension T. This tension is applied to the aluminium foils by the combined action of atmospheric pressure and heat. To this purpose the foils are laid out on a specially designed table, equipped with heating resistors, and where a groove of semicircular cross section has been milled along the whole rim. On this table the foils are brought to 40 °C and stretched by a moderate vacuum made in the groove. The sum of the tensions due to thermal dilation and to vacuum (given by the product of the atmospheric pressure and the radius of the groove cross section) is equal to the calculated tension, in order to ensure the proper stretching of the cathodes. Once the aluminium foils are prepared this way, the Vetronite frames are glued on them in a relatively short time, since at 40 °C the glue we used (60% of Araldite AY103 and 40% of hardener HY991) polymerises rapidly.

Finally, to provide additional path length for surface discharges, Mylar strips 10 mm wide and 250 μm thick (not shown in figure 2) are inserted over and under the cathode in a slot cut in the inner perimeter of the Vetronite frames.

2.2. *Wire planes*

The wires are stretched to 50 ± 0.5 g. They are soldered on the printed board and glued with Araldite for maximum safety. The three sense planes are oriented in different directions: two of them scan the horizontal and vertical coordinates, while the third one is oriented at 45° for ambiguity resolution. Owing to the dimension of the chamber, the wires have to be supported. To avoid inefficiencies in the central region we stretched for each plane two copper wires, insulated by a Teflon sleeve of 1 mm diameter, in a direction normal to the sense wires, at +200 mm and −200 mm with respect to the centre of the chamber. The copper wires over and under the sense wires are tied together every 100 mm by means of a thin nylon thread. The fastening details of the copper wires are reported in figure 3. To smooth the electric field at the edge, the last three sense wires have increasing diameters: 40, 75 and 100 μm respectively.

2.3. *Gas flow*

For space reasons, the gas inlet and outlet are drilled in the aluminium frame in the direction of the wire planes. Since the three gaps do not communicate due to the cathode foils, the gas is brought to the gap through holes in the Vetronite frames. The entrance to each gap is obtained by milling several rectangular openings in the Vetronite, to obtain a gas flow as uniform as possible.

It is to be noted that the Vetronite frames are not sufficiently rigid to support the stress of the wire planes or the aluminium foils without severe deformations.

During the operation of the chambers the mechanical rigidity is provided by the external aluminium frames, on which each plane is fixed in the assembling procedure. When a chamber is opened each plane is screwed to an independent supporting frame which sustains the mechanical stress. In this way the assembly procedure is rather cumbersome, but it guarantees the requested tolerance.

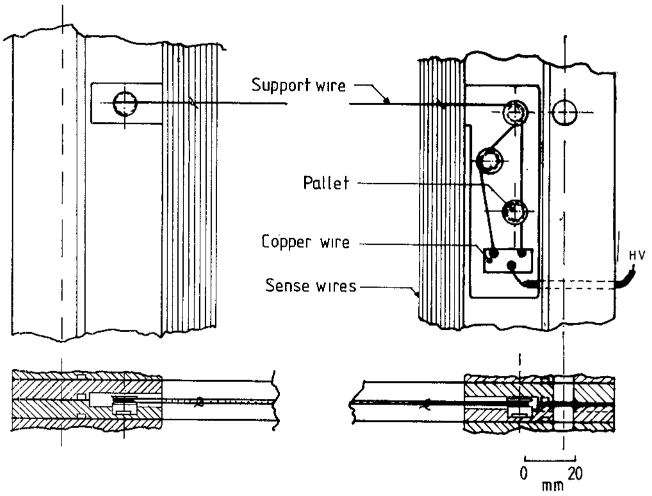

Figure 3. Fastening details (top and cross sectional views). The pallet where the copper wire is anchored is glued in a hole drilled in the Vetronite frame. The small slab where the copper wire is soldered is made of copper and the correcting voltage is fed through a cable running to the exterior.

3. Electronics and tests

The readout we used was originally designed by Lindsay *et al* (1974). We had to redesign the preamplifiers to have the possibility of stacking them on the chambers. They are protected against sparks by 1.8 kΩ resistors soldered on the printed board circuit of the chamber.

The high-voltage generator has been especially designed for the NA1 vertex detector chambers and was described elsewhere (Bologna *et al* 1980). Its main features are that it is located near

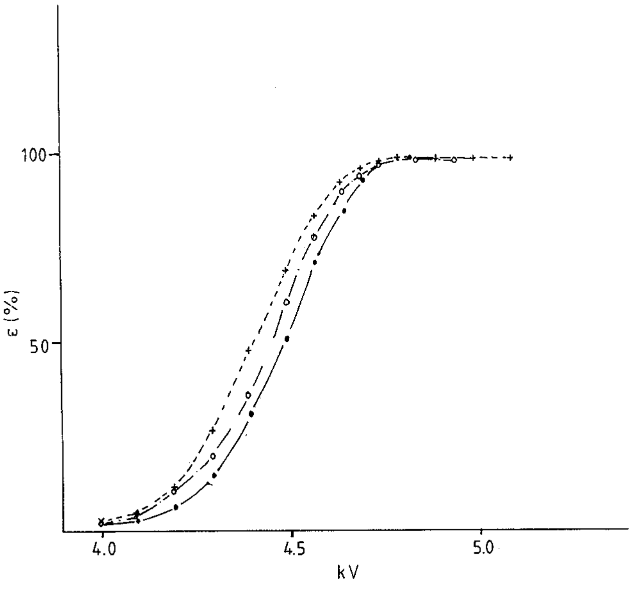

Figure 4. Efficiency against high voltage for the three planes separately.

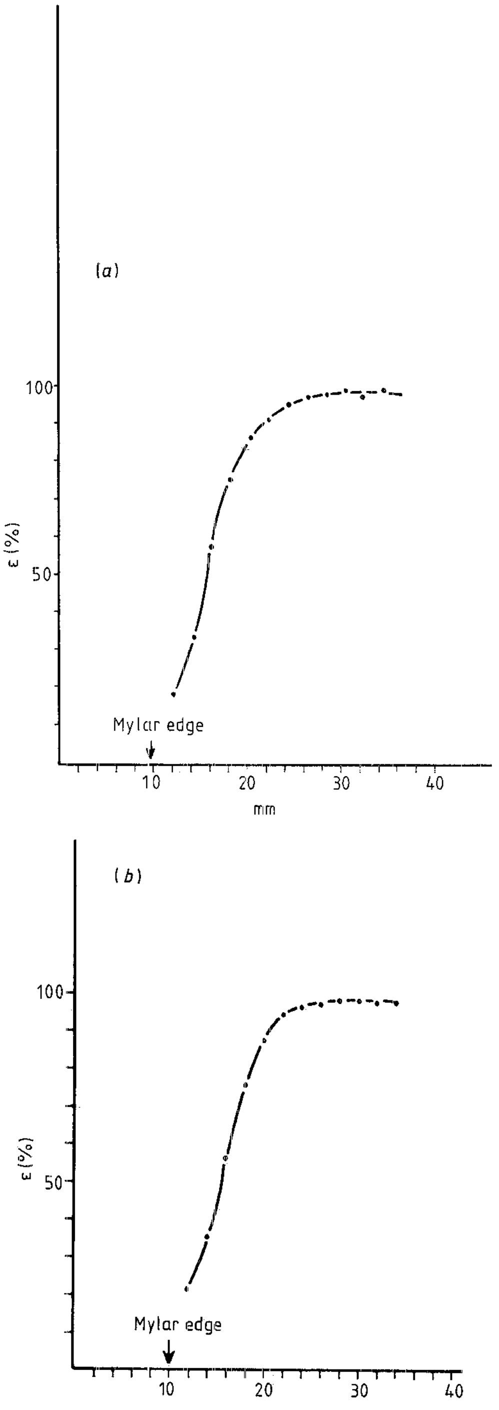

Figure 5. Efficiency against distance from the edge. (a), Abscissa is the distance from the edge in a direction along the sense wires; (b), abscissa is the distance from the edge in a direction perpendicular to the sense wires.

the chambers and is remotely controlled by the on-line computer. The maximum current it can draw is hardware prefixed to a value depending on the beam intensity. If a voltage breakdown occurs in the chamber, the generator automatically drops the high voltage in nearly one ms to a point where the current falls below the fixed value. This way the chambers are protected against multiple sparking.

During tests and data taking we always used the so-called magic gas mixture (isobutane 25%, freon 13Bl 0.1%, methylal 5% in argon). In nearly one year of operation we did not observe any deterioration of chamber performance. We only noted a white spot in the beam region on the cathode planes.

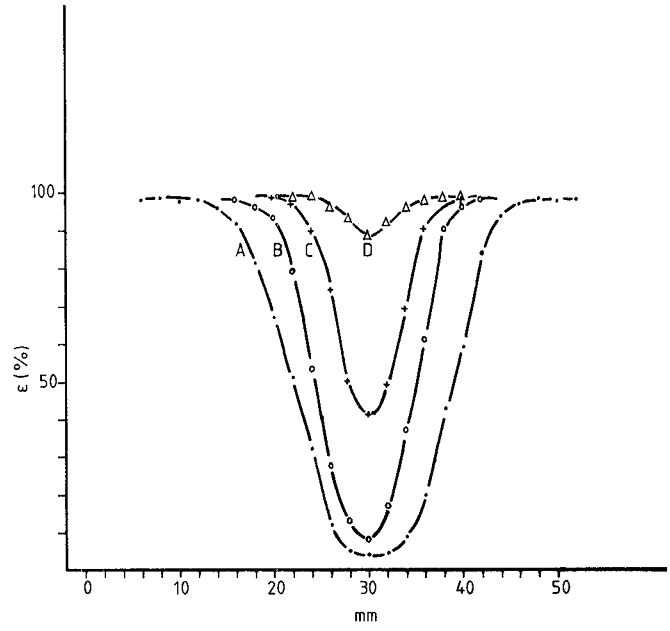

Figure 6. Efficiency around the support wires for various correcting voltages. A, 0 V; B, –800 V; C, –1000 V; D, –1200 V.

The chambers were tested in a laboratory with a ^{106}Ru source and with a pion beam at the CERN PS. Figure 4 shows the efficiency curve of the three wire planes in the central region,

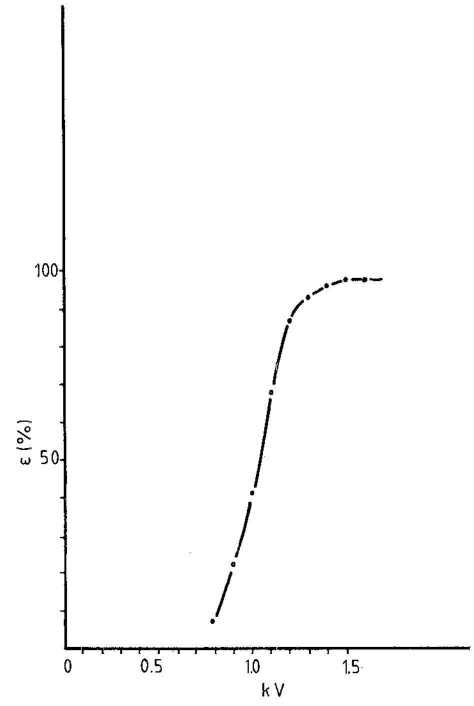

Figure 7. Efficiency curve around the support wire as a function of the correcting voltage at an operating voltage of 5 kV.

obtained with 10 GeV/c pions. The point of inflection of the curves lies in a ~100 V range, and the plateau extends for a few hundred volts. Inside the plateau zone the mean multiplicity for normal incidence varies between 1.1 and 1.2 for the three planes. Similar results were obtained with the ^{106}Ru source, and we also noted the existence of a plateau in the singles counting rate of the planes. After a careful conditioning of the chambers, carried out by increasing the high voltage in such a way that the dark current is limited to 5 μA, and waiting for it to return to zero before a new voltage increment, the final noise rate, 100 V after the highest plateau knee, was a few hertz per wire.

Concerning the efficiency uniformity over the whole chamber surface, the measurements performed are within 3% of the value of the central region.

Figures 5(*a*) and (*b*) show the efficiency variation near the edge of the chambers, in a direction perpendicular and parallel to the wires, respectively. The arrows indicate the position of the Mylar strips. The two curves are rather similar, and the full efficiency is reached about 12 mm from the Mylar strips. In figure 6 the efficiency around the support wire, for various correcting voltages, is reported. The measured points are spaced by 2 mm. At 1.4 kV the width of the inefficiency zone is reduced below the sensitivity of the measurement procedure. In fact, if the FWHM of these zones is plotted against the high voltage, the extrapolation of the resulting straight line to 1.5 kV gives a width of less than one millimetre. The efficiency of a sense wire on the support wires, is reported in figure 7 against the high voltage, and shows that a plateau zone is slowly reached.

Hereafter we report some results in the analysis of data of the NA1 experiment obtained with these chambers. One of the most important items where the chambers are essential is the determination of the primary and secondary vertexes of the events. Figure 8 shows the X and Y vertex projections for a sample of ~5000 events, determined by using all the straight lines reconstructed in the MWPCs. If one rejects, event by event, all traces which pass at a distance from this vertex greater than a suitable cut, the remaining ones define the primary vertex. In the hypothesis that the rejected traces are mainly due to neutral kaons decaying into two charged pions, for each pair of lines a secondary vertex is defined, by which a new momentum determination is obtained. Figure 9 shows the invariant mass distribution for such pairs of tracks. A clean signal centred at the K^0 mass is evident.

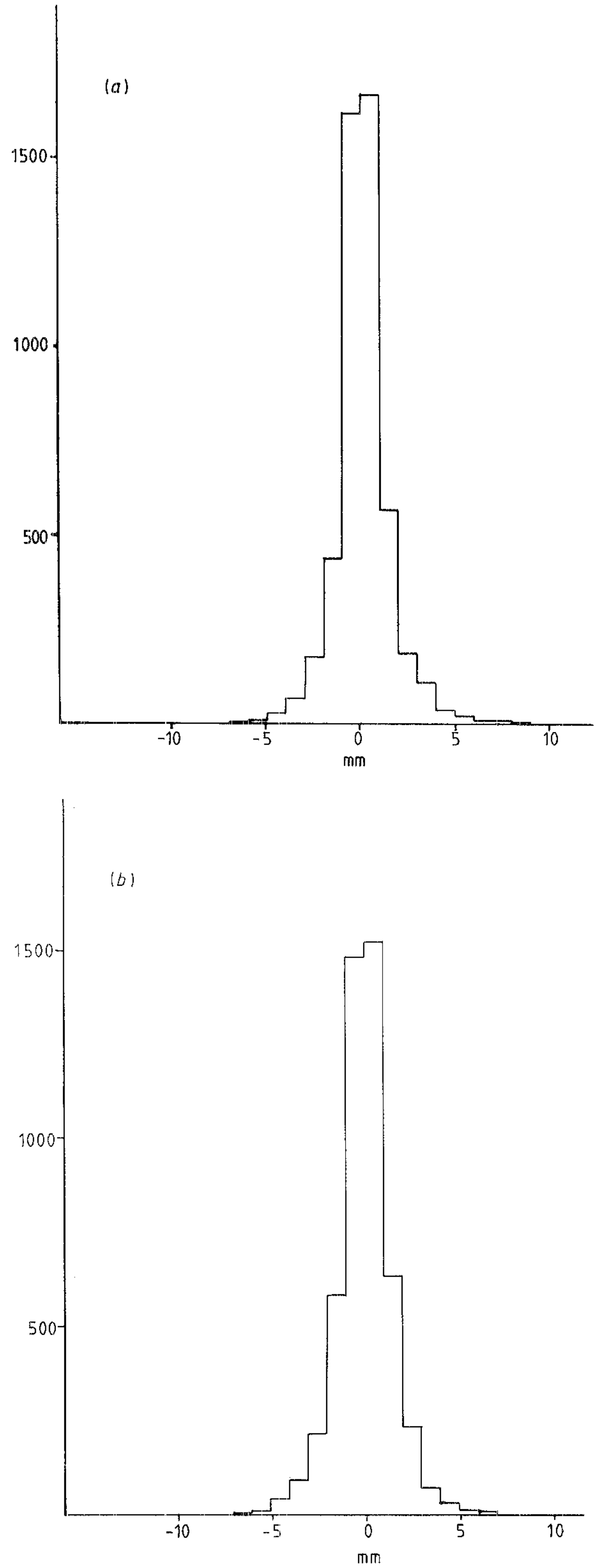

Figure 8. X (*a*) and Y (*b*) vertex projections determined by means of all traces reconstructed in the MWPCs.

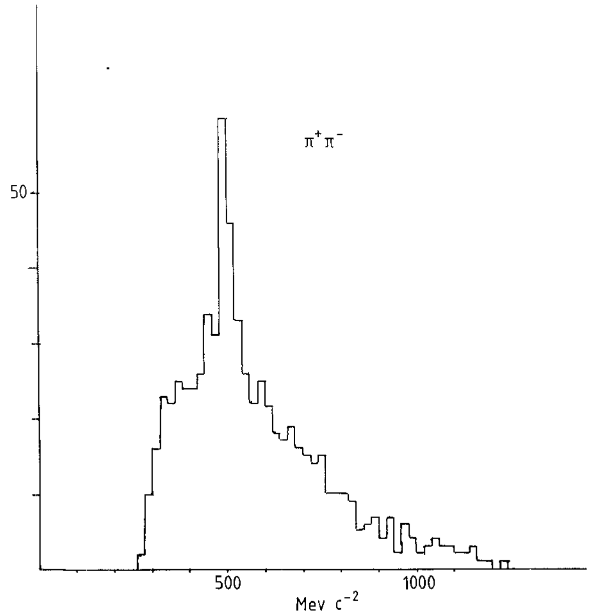

Figure 9. Invariant mass distribution of the reconstructed tracks pointing to the secondary vertexes.

4. Concluding remarks

We built MWPCs with three sense planes, such that a single module can give a point in space without ambiguities, and where the ratio of useful surface area to the total surface is maximised. The chambers proved very reliable over a period of nearly one year of running. We did not observe any degradation of their operative characteristics. In the same period we had only one wire failure in about 3500 wires simultaneously working.

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References

Albini E *et al* 1982 Electronic measurement of the lifetime of D$^{\pm}$ mesons
Phys. Lett. **110B** 339

Lindsay J, Millerin Cl, Tarlé J C, Verweij H and Wendle H 1974 A general purpose amplifier and read-out system for multiwire proportional chambers *Report CERN* 74–12

Bologna G *et al* 1980 A remotely controlled high voltage power supply system for multiwire and drift chambers
Nucl. Instrum. Methods **178** 587