ISTITUTO NAZIONALE DI FISICA NUCLEARE

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G. Rivellini, L. Satta, P. Spillantini and A. Zallo: A COMPACT
LOW MASS SYSTEM OF FOUR CYLINDRICAL MULTIWIRE
PROPORTIONAL CHAMBERS.

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ABSTRACT.

Construction technique and performance of a system of four cylindrical MWPC are described. Low mass, uniform transparence and compactness are the main features of the system. The material crossed by a particle passing through one chamber is 0.024 g/cm^2.

1. - INTRODUCTION.

A system of four cylindrical multiwire proportional chambers (Fig. 1) has been built at Laboratori Nazionali di Frascati as the innermost part of the Vertex Detector of NA-1 Experiment at SPS. The aim of the experiment is the study of pseudoscalar meson photoproduction and hadronic fragmentation[1].

A large effort was made to build up a very low mass system by choosing light support materials and by reducing frames and spacers in order to minimize multiple scattering.

Each chamber is coaxial to the beam line and arranged in a concentric fashion around the target. The two cathodes consist of a thin film of copper on Kapton, with strips printed on in a helicoidal way. A high ouput density (12 coordinates between 2 and 13 cm radii) is obtained by adding to the digital readout of the four layers of wires, the

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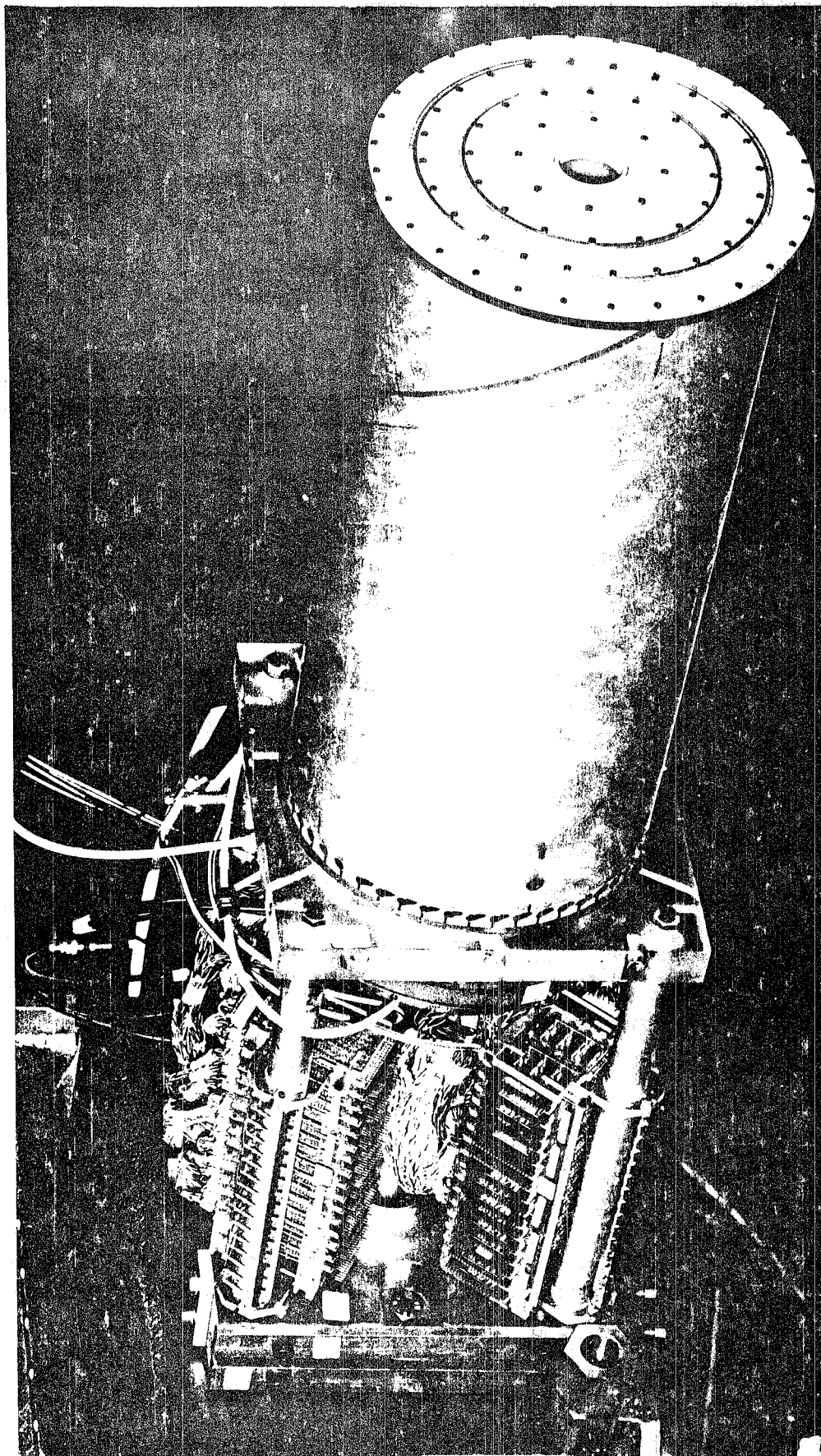(o) - Present address : CERN, Genève, Switzerland.

FIG. 1 - Complete system of the four chambers. Electronic readout and support structure are concentrated at one end of the system. The sensitive region is 50 cm long. Other characteristics and mechanical dimensions are summarized in Table I.

analogic one of the pulses induced on strips of each chamber[2]. The system covers the polar angular range $5^{\circ} \leq \theta \leq 160^{\circ}$. The main purpose of the device is a fast determination of charged particle multiplicity in special trigger configurations at large angle. The chamber radii are integer multiple of the smallest one to make fast hardware pattern recognition easier (Fig. 2). Uniform transparency and lightness to the charged particles is achieved using self supporting rolled foam-Kapton cathodes, avoiding spacers and concentrating all the read-out printed boards and other services (gas and H. V.) in the upstream frame of the chambers.
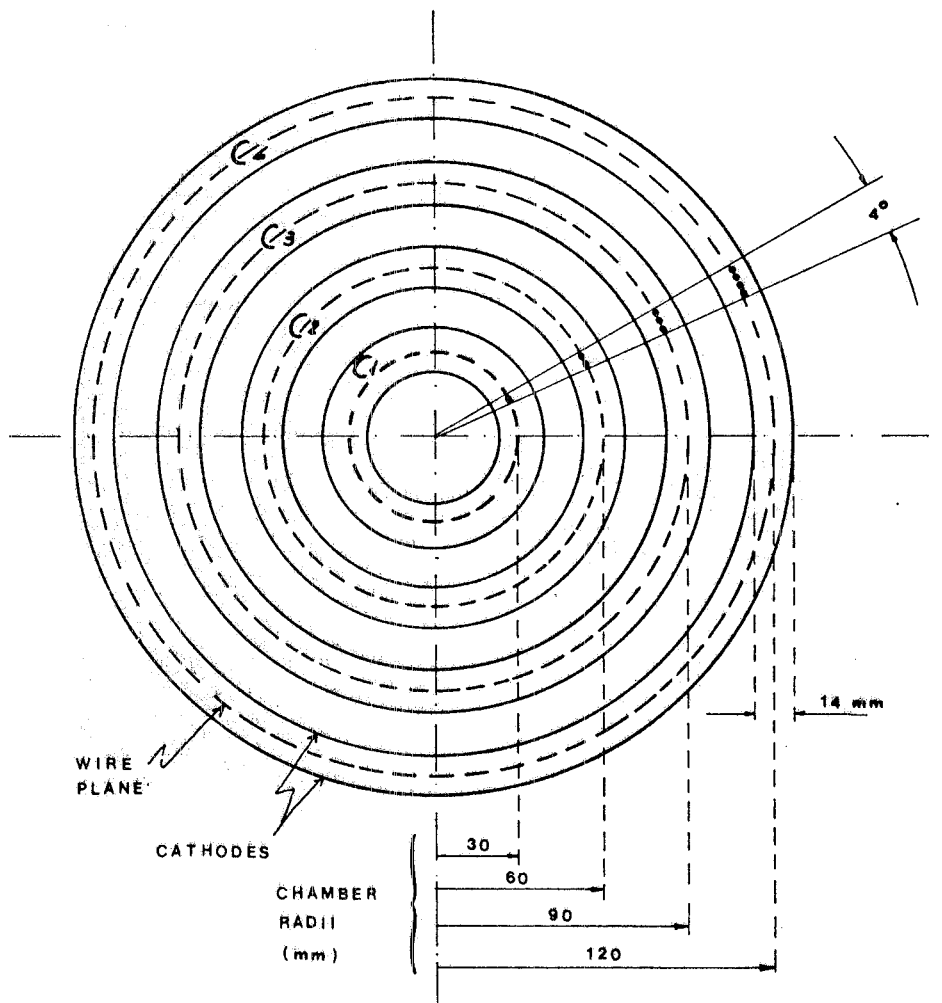

FIG. 2 - Cross view of the system. The number of the wires of the chamber C2, C3 and C4 is integer multiple of the number of wires of chamber C1. The resulting wire spacing for all chambers is 2.1 ± 0.1 mm.

2. - MECHANICAL STRUCTURE AND CHARACTERISTICS OF THE CHAMBERS.

The mechanical structure of each chamber consists of two light coaxial continuous cylinders connected by ring-shaped frames at their ends (Fig. 3). To the inner cylinder are fixed the ring-shaped frames between which the wires are stretched at 60 ± 1 g tension. The external cylinder assures the gas enclosure of the chamber.
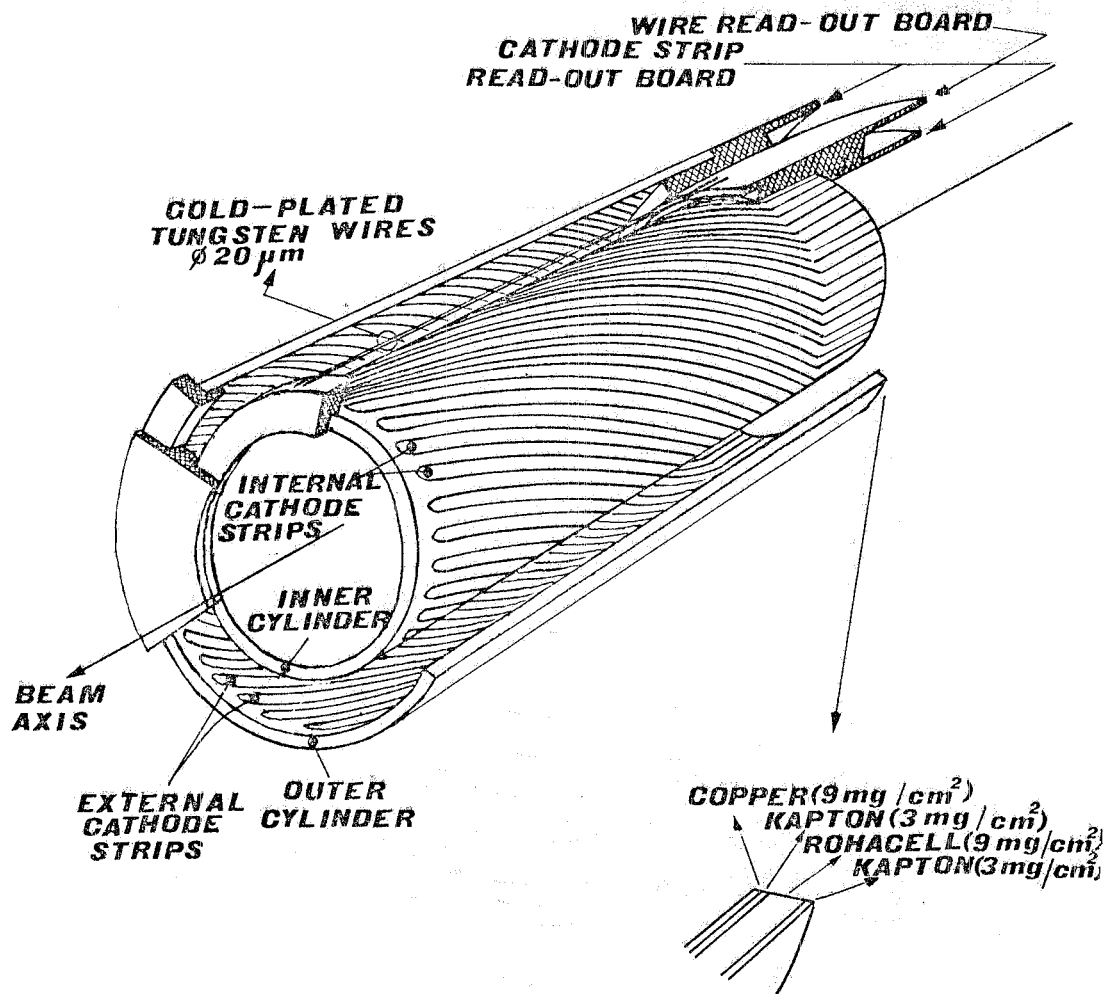

FIG. 3 - Artistic view of a chamber.

The cylinder structure had to be such to guarantee the necessary mechanical precision ($\Delta R \leqslant 100 \ \mu$m) and the rigidity, preserving the maximum possible lightness. The best solution we have obtained, is to build the support cylinders by polymethacrylimid plastic foam, whose components are methacrylic acid and methacrylomitrile. We used the product "Rohacell 31" whose density is 30 Kg/m^3 [3]. It is characterized by a high resistance to solvents, heating and mechanical actions. Test on mechanical rigidity were made for a 20 cm radius cylinder. A sufficient mechanical rigidity is assured by a layer of 2 mm of plastic
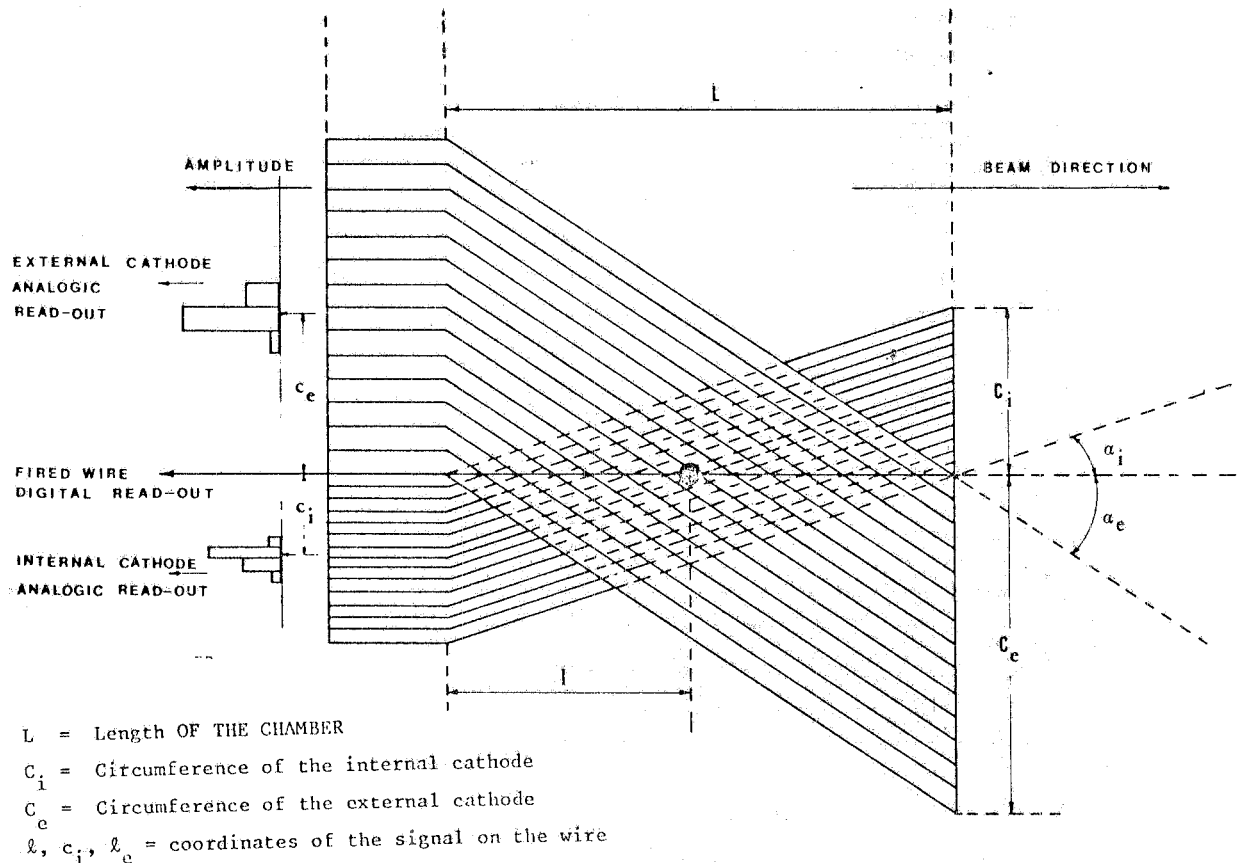
foam glued between two 25 μm Kapton sheets. For diameters less than 10 cm the plastic foam layer can be reduced to 1 mm.

To ensure the required mechanical precision the following constructive procedure was used : a sheet of Kapton was rolled on a metallic rectified cylinder, the plastic foam was glued on the Kapton and rectified at a lathe ; finally on the "Rohacell 31" the other Kapton sheet was glued. One of the sheets (the internal one for the external cylinder and the external one for the internal cylinder) was laminated with 17 μm of copper, on which the cathode strips were printed by usual photographic techniques. A conservative choice of 2 mm plastic foam support was made in building the four chamber system, also for the innermost chamber. The total thickness of a cylinder is 0.015 g/cm^2 to which an average 0.009 g/cm^2 thickness for the copper strips must be added. Indeed the total thickness of one chamber is 0.048 g/cm^2. If necessary the transparence of the system to the produced particles can be improved (from 0.024 g/cm^2 to 0.013 g/cm^2 per chamber) substituting the copper laminated Kapton with aluminized Kapton. To minimize the total mass, the down-stream frame was composed by rings turned from pieces of a mixture of two araldites (7% of Araldite D and 93% of Araldite XG55). Density of the mixture is 1.5 g/cm^3 and the frame is 1 g/cm^2 thick in average, including the O-rings for gas enclosure and the contacts for the wires. Chamber characteristics are summarized in Table I.

TABLE I - Geometrical characteristics of the chambers.

Chamber		Radius (mm)	Number of elements : (wires/strips)	Strip width (mm)	Angle between strips and wires (rad)
C_1	wire plane	30	90	----	---
	internal cathode	23	50	1.50	0.281
	external cathode	37	50	3.00	0.438
C_2	wire plane	60	180	----	---
	internal cathode	53	50	3.54	0.586
	external cathode	67	50	4.42	0.698
C_3	wire plane	90	270	----	---
	internal cathode	83	50	5.22	0.806
	external cathode	97	50	5.73	0.864
C_4	wire plane	120	360	----	---
	internal cathode	113	50	6.17	0.957
	external cathode	127	50	6.44	1.005

Wires are made of gold-plated tungsten with 10 μm radius. Spac
ing is 2.1 $\pm$ 0.1 mm. The upper and lower cathodes are printed in heli
coidly shaped strips having a defined angle with respect to the cham-
ber axis (see Table I). This arrangement makes each strip turn through
360° from the upstream side to the downstream one of the chamber (Fig.
4). Such a wire and cathode strip disposition provides 3 coordinates for
a charged particle traversing a semichamber; the hit wire number pro-
vides one coordinate (digital outputs) and the pulses induced on strips on
both cathodes provide the other two coordinates (analogic outputs). Pro
cessing the analogic outputs from strip cathodes a spatial resolution of
$\pm$ 1 mm can be obtained[4]. Such a precision was decided to be satisfac
tory for the cylindrical chambers of the Vertex Detector. In fact, a bet
ter resolution (200 μm rms) is obtained by the drift chamber system lo
cated around the cylindrical chambers. The wire number related to the

L = Length OF THE CHAMBER

C_i = Circumference of the internal cathode

C_e = Circumference of the external cathode

ℓ, c_i, ℓ_e = coordinates of the signal on the wire

$$\frac{\ell}{L} = \frac{c_i}{C_i} = \frac{c_e}{C_e} \qquad \alpha_{i(e)} = \text{arctg} \frac{c_{i(e)}}{L}$$

FIG. 4 - Flat envelope of cathode planes of one cylindrical
chamber (schematic and not in scale) : θ_1 and θ_2 are the in-
ternal and external angles between strips and wires as spe-
cified in Table I. C_i and C_e are the centroids of pulses indu
ced on internal and external cathode strips respectively. Re
dundant information for z could be used to remove ambigui
ties arising from multiple tracks.

azimuthal angle of the charged particles, as hinted before, is the out-standing information to be used for trigger purposes from the cylindri cal chambers. For this reason accurate tests were performed on digi tal outputs.

3. - CHAMBER CONDITIONING AND TEST PROCEDURES.

Before setting the chambers in operation, sense wires and high voltage electrodes have been cleaned sequentially with amylacetate, methilethilketone, ethyl alcohol and liquid freon.

The chambers were flushed and operated with a "magic gas mix ture" 25% Isobutane, 5% Methilal, 0.1% - 0.46% Freon 13B1 in Argon.

Negative high voltage was applied to the cathodes, the initial dc current level was different for each chamber but, as a general condi-tioning procedure, the voltage was increased when the noise was de-creased below 5-6 μA. After proper conditioning at operating HV $\simeq$ $\simeq$ 4.3 KV all the chambers of the system reached a noise level of abo ut 1 Hz/wire. The corresponding stationary current was less then 1.5 μA for each chamber.

All the chambers were tested in laboratory with a Sr^{90} β-ray source and with cosmic rays. The results were consistent with those obtained on a prototype chamber using 250 MeV electrons of the 1 GeV electronsychrotron at Laboratori Nazionali di Frascati[5].

In the following we refer to the results of a complete and accura te test made on the chambers using a π, μ beam of the PS at CERN ($E_{\pi,\mu}$ = 5-10 GeV, divergence $\simeq$ 1 mrad). The chamber system was positioned transversally to the beam (10^5 particles/sec on a spot of $\simeq$ 60 cm^2) and data analysis was carried out for each chamber inde-pendently).

The signals from the wires were processed through a suitable electronic chain[6]. The differential output of the preamplifier loca-ted near the chamber is carried by a twisted pair cable over a distan ce of 50 m to the processing chain (receiver-trigger-memory module, encoder system and control unit). This chain was interfaced through CAMAC to a HP 2100 computer equipped by 32 K memory and a magne tic tape unit.

4. - METHOD OF ANALYSIS.

Each chamber was software divided in two semi-chambers. The refore when in an event a wire or a group of contiguous wires (hereaf ter referred to as "cluster" of wires), are fired in a semi-chamber, one wire or a cluster of wires are expected to be fired in the other one (see Fig. 5).
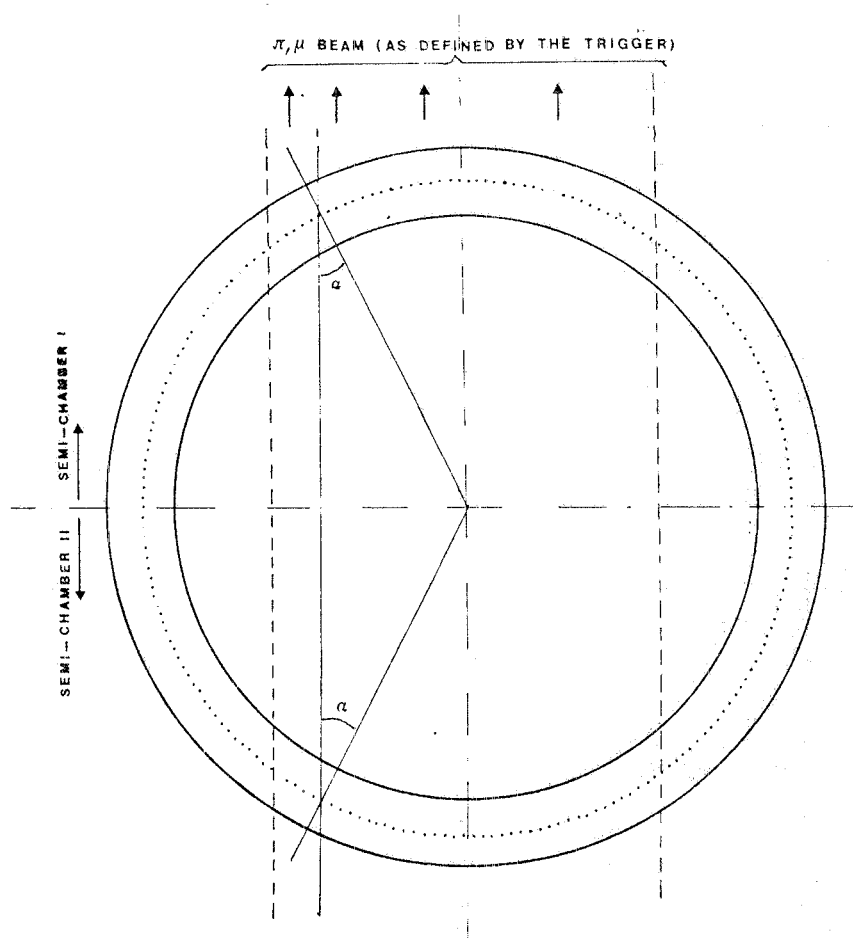
FIG. 5 - Each chamber has been software divided in two semi-
chambers. Performances were studied as a function of the an-
gle between the local normal to the chamber and the projection
of the track on a plane perpendicular to the wires.

For the analysis only events where a single wire was fired in a
semi-chamber are considered, and correspondingly the number and
position of the fired wires in the other semi-chamber are registered.
In this way the two semi-chambers are managed as two independent
detectors, allowing the following peculiarities :

a) The efficiency, the size of the clusters and the H. V. plateau can be
   measured, by scanning wire by wire or in a very limited region of
   the chamber (given the small angular divergence of the beam).
b) Owing to the easy identification of secondary interactions originat-
   ing outside the chamber (amounting to a 5-7 % of the registered e-
   vents) the size of a cluster is surely due to one single track.
c) Given the small angular divergence of the beam, correlating the hit
   wires on the two semi-chambers to the α angle (see Fig. 5) detai-
   led measurements of the chamber parameters (efficiency, cluster-
   ing, multiplicity) can be obtained as a function of α angle.

d) Cross talk between not contiguous wires, products of interaction on the chamber material and noise can be well separated and suppressed in the analysis.

5. - RESULTS.

Because all four chambers behave in the same way, test results of chamber C2 only are reported.

In normal working condition the maximum current in the chamber was 10 μA for a beam of 10^5 particles/sec. The background immediately after a beam burst was less than 5 Hz/wire.

In Fig. 6 the efficiency for tracks quasi-normal to the field chamber ($a \lesssim 6°$) are reported as a function of the H.V. applied to the cathodes for different Freon 13B1 contents in the gas mixture, with a stroble signal of 85 ns.
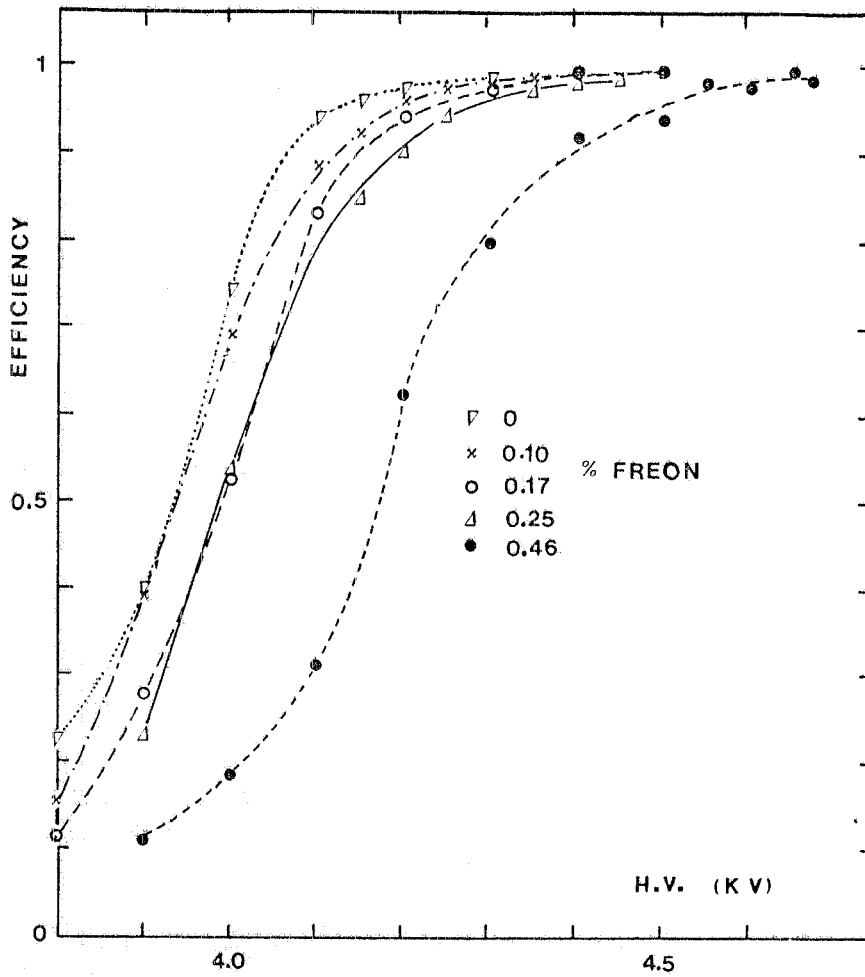

FIG. 6 - Efficiency versus H.V. for various Freon contents.

We chose to operate the chambers with 0.17 % of Freon 13B1, to which correspond an average 98.5 % efficiency of the chamber system and a plateau length of about 300 V for noise level not exceeding 3 Hz/wire.

The efficiency for a single wire is summarized in Fig. 7, where the percentage of wires whose efficiency exceeds a fixed value is repo_ rted.
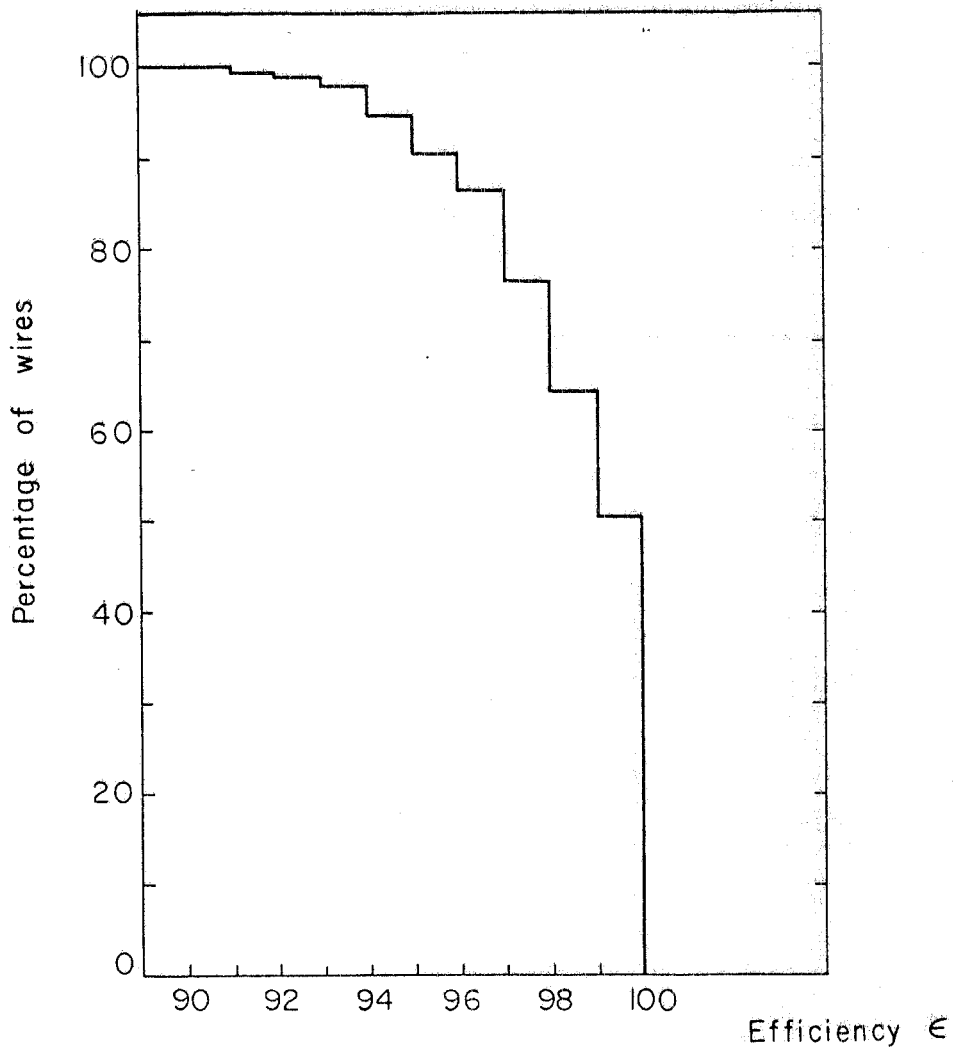

FIG. 7 - Efficiency distribution for a sample of wires. The histogram gives the percentage of wires having an efficien- cy greater than ε versus efficiency ε.

The average size of the clusters for quasi-normal tracks ($\alpha \lesssim 6^{\circ}$) is very small (1.04) but increases with α (see Figg. 8 and 9 were the cluster size is shown as function of α). The average multiplicity for tracks out of clusters is 0.1 and does not depend on α.
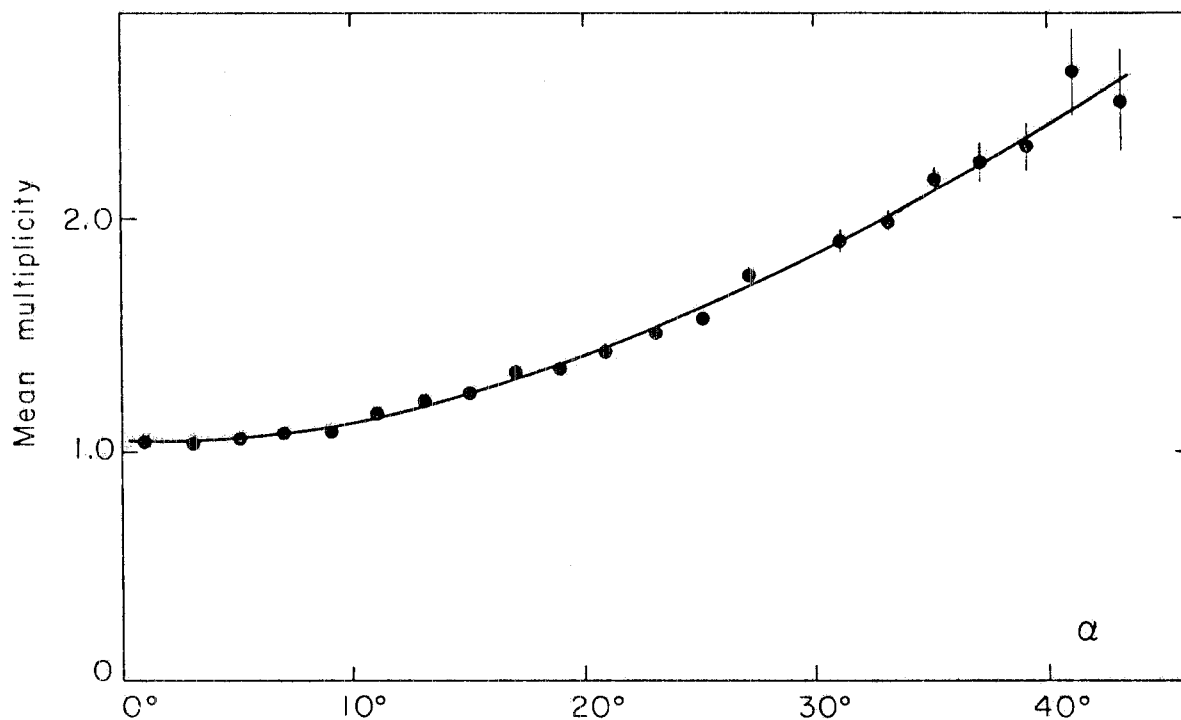
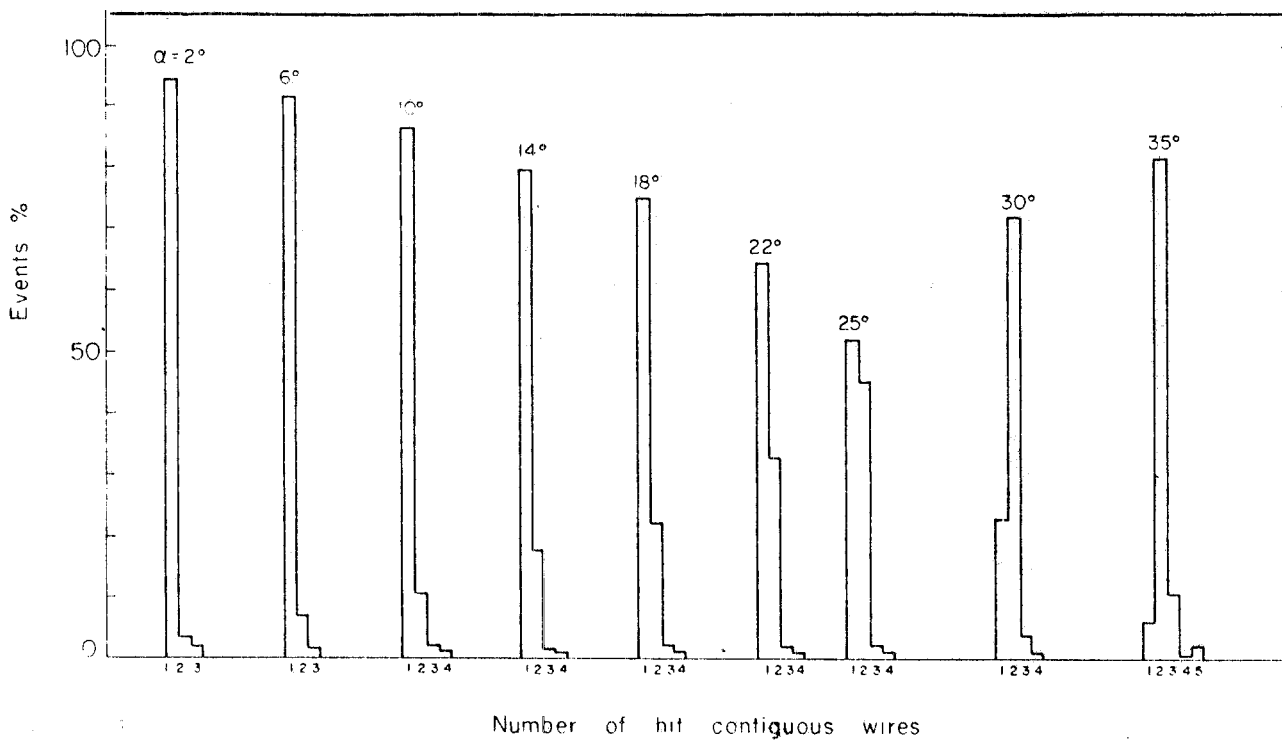FIG. 8 - Mean multiplicity in one semi-chamber as a function of α angle for a single opposed hit.

FIG. 9 - Cluster distribution at various α angles. Percentage of events versus number of contiguous fired wires.

6. - CONCLUSIONS.

The cylindrical chamber system we described has been built up by using self supporting rolled foam-sandwiches. The previously explained construction technique is easily managed and offers the possibility to stack together many sensitive sheets with high output density preserving lightness and uniform trasparency. In exaustive tests the chamber behaved reliably and met the requirements of our experiment. For the particular attention given to the choice of the geometrical parameters (ratio between the chamber radii, position of the helicoidal strips of the cathodes, etc.), the chamber system could be easily provided with fast hardware processing systems.

We stress that such a system of cylindrical chambers is the ideal one, not only around a target in a high rate, high multiplicity and large solid angle experiment, but also to cover the centrol region around the interaction point of a storage ring machine, either in e^+e^- experiments[7] or for the study of the pp or $p\bar{p}$ interactions in the colliding beam.

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