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LARGE MULTIWIRE PROPORTIONAL CHAMBERS FOR
EXPERIMENT NA3 AT THE CERN SPS.

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ABSTRACT

A description is given of large multiwire proportional chambers (sensitive area of about 8 m²) designed and built for the experiment NA3 at CERN. The novel features of these chambers like the use of graphite coated cathode planes, spacers with compensating field wires and fast electronics are discussed. Details of the fabrication procedure and performances in test beam and experiment are also given.

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1. INTRODUCTION

The multiwire proportional chambers described in this paper were developed and built at CERN as a part of the NA3 spectrometer which is installed in a secondary beam of the CERN Super Proton Synchrotron. In its present configuration, the spectrometer is used for the study of the production of muon pairs in hadronic collisions⁽¹⁾. The chambers, denoted by PC3 and PC4 in the layout of the experiment, are placed downstream of the magnet and cover the acceptance of the apparatus. The choice of multiwire, rather than drift chambers is due to the higher particle flux the multiwire chambers can stand and the better pattern recognition efficiency for multitrack events.

There are three types of wire planes corresponding to a different orientation of the wires : horizontal, vertical and inclined at 14.5° with respect to the vertical direction. Each chamber is composed of six planes, two of each type (fig. 1). This structure is determined by the requirements on momentum resolution and pattern recognition.

We report here on the results of the development, design, and the fabrication of the proportional chambers, as well as on results of tests and experience in operation.

Special features of these chambers are :

- the large sensitive surface,
- the novel mechanical design of the frames and of the cathode planes,
- the use of spacers ("garlands") with field restoring wires placed between the cathodes and the sense wires,
- the subdivision of the cathode surface into electrically separated sections, allowing the central region of the chambers to be made insensitive when a high-intensity beam (10^7 - 10^8 part/sec) is sent through the apparatus,
- the compactness and reliability of the associated electronics,
- the test facility of the amplifiers and read-out system,
- the chamber monitoring system.

2. GENERAL DESCRIPTION OF THE CHAMBERS

The chambers, three of which have been built, have a rectangular useful surface of $3.1 \times 2.6 \text{ m}^2$. A chamber is composed of two identical halves which are mounted face to face thus providing two independent inclined coordinates u and v .

The anodes are made of $20 \text{ }\mu\text{m}$ diameter, gold plated, tungsten wires, with 3 mm spacing. They are supported by a frame made of printed circuits and reinforced epoxy resin (Stesalit⁽²⁾) bars. The total number of sense wires in a plane is 1024 for the vertical and inclined planes and 864 for the horizontal ones. Each sense wire is connected at one end to an amplifier connector placed on the printed board outside the chamber volume. The wire electronics, described in section 4, plugs into these connectors (fig. 1a).

The cathodes are made of $25 \text{ }\mu\text{m}$ thick plastic (Hostaphan⁽³⁾) foils which are glued on Stesalit frames (fig. 1b) and painted on one side with a colloidal suspension of graphite in isopropyl alcohol. The gap between the sense wire and the cathode planes is 6 mm wide.

The frames of the electrodes are not self-supporting. They are therefore assembled between a pair of support frames (fig. 1c), made of steel plates stiffened by a U-shaped profile. Twelve holes, precisely drilled in the support frames and equipped with hollow bronze cylinders (fig. 1d), fix the position of each plane with respect to the chamber reference system. One of the support frames was carefully adjusted in its geometry and then used as basic reference throughout the whole chamber fabrication.

The chamber is assembled by means of twelve hollow precision steel pins (fig. 1e) which are passed through the bronze cylinders. The clamping is done by means of twelve bolts going through these pins. This system allows the chamber to be easily opened and to have direct access to any of the electrodes with a minimum of dismantling operations. To do this, the ends of the reference pins in the center of each side of the support frame are pushed to the position where the chamber is to be opened by four identical spare pins and an extraction tool. The pin pairs are then clamped together through the holes. The axial centering is obtained by the spherical shape of the pin ends. The remaining eight pins are then

extracted and replaced by expandable dowels to retain the desired number of electrodes to each steel frame. The two halves can now be separated by releasing the four bolts in the center pins. The chamber is closed by a procedure inverse to the one described above. Both operations are done with the chamber in vertical position.

The windows of the chamber are made of a mylar-aluminum sandwich foil glued on to the steel frames. The aluminum foil is necessary to prevent water vapor to penetrate the chamber, and to screen the anode wires from high-frequency noise.

The gas tightness system was designed to leave access to the chamber electronics. A simple solution was adopted which consists of using rubber foam and steel strips. The rubber strips (fig. 1f) are glued on the borders of the steel frames and on both sides of the printed circuits. The steel strips (fig. 1g) are positioned by means of small permanent magnets fixed to the frames. They close the gap between the rubber strips when the chamber is assembled. The supply of high-voltage is done by multipin plugs which are mounted in the steel strips. This system has proven to be reliable and very easy to control by the gas leak detector as all joints are directly accessible.

Due to the chamber size, intermediate supports are necessary to keep the anode wires stable against electrostatic forces and the electrode spacing uniform. These spacers, referred to as garlands⁽⁴⁾, are made of a plastic strip⁽⁵⁾ bent into a zig-zag shape which is placed on the cathode plane in a direction perpendicular to the sense wires (fig. 2). Field restoring at the anode wires is provided by an insulated conductor in the form of a thin electric wire⁽⁶⁾ which is stretched on the top of the garland and set at an appropriate voltage. When the chamber is assembled, the garland and the electric wire attached to it by a very tiny nylon thread form a precise spacer between the electrodes. The separation between the garlands placed on the same half-gap is 40 cm. The garlands on the opposite sides of the wire plane are displaced by 3 cm in order to preserve high local chamber efficiency. Stability of the spacers against shocks is provided by silk threads stretched perpendicular to the garlands and attached to their support nylon wires.

The total thickness of each chamber is $\sim 0.4 \text{ g/cm}^2$ ($\sim 1\%$ of a radiation length), the largest part coming from the gas mixture.

3. THE CONSTRUCTION PROCEDURE OF THE CATHODE AND WIRE PLANES

The design of the cathode frames includes facilities for mounting the garlands and the high-voltage connections. Slots in the horizontal bars force the gas to flow vertically through all the gaps of the chamber in parallel. The frame bars are glued together and equipped with brass rings.

The Hostaphan foil was stretched to a tension of about 350 N/m on a light metallic frame, equipped with clips and springs and then glued to the Stesalit frame by Araldite.

Before painting, a mask was applied to the foil in order to define the conductive surface. The cathodes are divided into five electrically separated regions. The central region is a horizontal band of 6 cm width; the two adjacent regions are 9 cm wide. These bands can serve as "beam killers" if the corresponding voltage is lowered by about one kilovolt relative to the rest of the cathode. The separations between bands are obtained by glueing a 2 mm wide adhesive tape on the foil before painting it. The graphite⁽⁷⁾ was diluted by an equal volume of isopropyl alcohol and then sprayed by a compressed air gun mounted on an automatic scanner. Best results were obtained when the surface was painted twice using about 40 g/m² of mixture each time and the surface being polished after the first painting. A final polishing with soft paper resulted in a surface resistance of 5 to 50 k Ω . The foil then appears perfectly smooth and slightly transparent. Eventually the adhesive strips are removed, borders and separations polished and if necessary cleaned with a pencil eraser.

The choice of graphite as a conductive layer is determined by two basic requirements involved in the construction of large proportional chambers to be operated with high-intensity beams :

a) because of the large gap capacitance, a high resistance cathode plane is required in order to limit the electrical current drawn by the chamber in case of discharges across the gap ,

b) a chemically inert cathode surface is needed to allow the chamber to be exposed to large radiation doses without appreciable degradation of its characteristics.

The frames of the wire planes are made of four Stesalit bars and a number of printed circuits that are pinned and glued together after being assembled on the reference support frame. The wires are stretched to a tension of 0.35 N and positioned on a pair of combs which are mounted on the reference frame. The position, both of the combs and of a pair of precisely graduated rulers, is adjusted such that, when the combs are lowered to approach the printed circuit frame, the wires fall in the correct grooves of the rulers. They are then correctly positioned relative to the reference pins. The wires are soldered either automatically by a hot helium jet or manually by a small soldering iron. A 60/40 alloy without flux core was used. Before soldering, the wires and the solder points on the printed circuit are wetted by a liquid flux⁽⁸⁾. The residual flux is removed by distilled water, alcohol and freon. Dust is removed by an ionized compressed air jet before assembling.

4. THE CHAMBER ELECTRONICS⁽⁹⁾

The electronics system, a block diagram of which is shown in fig.3, consists of :

- a) amplifier cards carrying amplifiers, electronic delays and logic circuits for 16 channels which plug into the connectors on the chamber board,
- b) readout cards for decoding and for distribution of control and timing signals which plug into connectors at the four corners of the chamber,
- c) Camac readout modules in the data acquisition system, one for each chamber plane,
- d) power supplies located outside the experimental area,
- e) control and test modules in a dedicated Camac system.

The board of a chamber plane is divided in two halves which contain up to 32 amplifier and 4 readout connectors. On the amplifier card connector 16 pins are used for the sense wires, the other ones for the chamber bus. The chamber bus printed on the board (fig. 1i) carries the power and control lines and the fast signals, while the address and memory-OR lines are

wire wrapped. All fast signal lines are interlaced with a.c. grounded lines, to provide a good $50\ \Omega$ transmission line. The fast ECL signals are terminated in the middle of each chamber board. The signal propagation delay is about 11 ns/m. The power lines are reinforced by copper bars.

4.1 Amplifier and read-out system

Each amplifier card contains eight thick-film hybrids of the type PC-800⁽¹⁰⁾, ECL/TTL level translators, filter and test circuits and one data output connector. Each hybrid contains two channels of the following basic elements : a differential amplifier with input protection, a discriminator with variable threshold, a dual one-shot, a dual D-type flip-flop and an open connector output gate capable of driving the external data-bus. The input signal threshold I_{th} may be varied linearly from $\sim 1\ \mu A$ up to $10\ \mu A$ by means of the external control voltage V_{th} . The one-shot delays T_d are set by means of the control voltage V_d (fig. 4). Useful range of T_d is from 330 up to 750 ns. The voltages V_{th} and V_d are common to all hybrids on one half of a chamber plane. The dispersion of the one-shot delays for all channels in a plane is less than 18 ns. Other relevant parameters of the hybrids are the double pulse resolution $T_{dpr} \approx 35\ ns$ and the time slewing $T_{slew} \approx 5\ ns$.

The amplifier signals are gated into the flip-flops by the strobe signal, which is generated by the trigger of the experiment. To improve the timing of the strobe signals, they are sent from each corner of a plane towards the middle.

The reading out of the data in a chamber is controlled by a set of six JCF20⁽¹¹⁾ Camac readout modules, one per plane. When an amplifier card is addressed, it opens the 16 output gates and puts the contents of the 16 flip-flops on the external data-bus. The data so received in the JCF20 are instantaneously coded and the corresponding addresses of the wires hit are stored in the data buffer. Each JCF20 may store up to 16 data words of 16 bits. The data words contain the address of the center, and the width of the cluster of the wires being hit. The reading of a complete chamber plane takes about 60 μs . All planes are read simultaneously. The read-out cycle can be repeated to handle events of high multiplicity.

Additional features of the on chamber electronics are fast OR and fast CLEAR. To allow for easy testing of all channels, each card contains a special test-circuit which makes use of a capacitive coupling of a test signal to the amplifier inputs. The amount of charge induced into all amplifiers is controlled by an appropriate d.c. level.

Using a special CAMAC module in the monitoring system, one can address each amplifier card individually. This permits a quick and easy verification of all components.

4.2 Low and high-voltage system

The low voltage system for the above described chambers consists of twelve power modules, one control data-bus and a special control module. Each module generates six different voltages at a max. power of 320 W which are controlled and regulated by individual cards, using remote sensing techniques. Switching supplies are used for ± 5 V while series regulation is used for the control voltage. The voltages are electrically floating in the module itself and grounded only at the chamber plane, avoiding in this way serious noise and ground loop problems.

The high-voltage system for one complete chamber contains one commercial four channel power supply⁽¹²⁾, one tracking unit, one distributor and two control units. The power supply receives four reference voltages from the tracking unit and generates the corresponding output voltages, which may be individually limited to any voltage or current value. High voltage is distributed to the chamber from a box which contains 24 current to frequency converters each one connected to a cathode section or a field wire, and also protection resistors⁽¹³⁾ mounted between adjacent cathode sections. The minimum sensitivity of the current to frequency converters is $\sim 0.1 \mu\text{A}$. The time interval between successive pulses is tested by the control unit for each channel and compared to a common preset value, the current limit. Should the interval be shorter than the limit set, an alarm is generated and sent to the tracking unit, which in turn will cut off the HV power supply. An inhibit signal on each control unit allows to gate off the current sensing circuitry during the accelerator bursts. The currents are visualized at the front panel by 24 LED's flashing at a frequency of 1 Hz per μA .

All voltages and currents of the low voltage power supplies as well as the current drawn by each chamber plane are continuously controlled by the monitoring system.

5. RESULTS OF TESTS AND PERFORMANCE IN THE EXPERIMENT

Before installation in the experiment, one complete chamber has been tested in a beam at the CERN Proton Synchrotron.

During the test the chamber was operated using the following gas-mixture : 27% isobutane and 73% argon (57% of the argon was bubbling through isopropyl alcohol kept at a temperature of 3-4°C). In the experiment, the chamber was operated with a mixture of 20% isobutane, 80% argon and 0.1% freon (all the argon is bubbling through isopropyl alcohol at a temperature of 7°C). We call these mixtures I and II respectively. Typical efficiency plateau measurements for both gas mixtures are shown in fig. 5a. These results were obtained with a 100 nsec strobe width and with a threshold setting of 2.6 μ A. A check of the chamber uniformity was done by measuring the efficiency plateau at various positions in each of the six gaps. The histogram in fig. 5b shows the distribution of the high-voltage values at which 50% efficiency was reached. The average value is 2.62 kV with a spread of only 10 - 20 V. Measuring the wire efficiency at various beam intensities has shown that the overall dead time of a single channel is $\sim$ 250 ns.

In fig. 6a we show the efficiency of one sense wire at various positions around the crossing with a garland and as a function of the field wire voltage. One can see that the inefficiency due to the presence of the garland is almost completely removed by putting the field wires at 1.8 kV. Fig. 6b shows the high voltage characteristics of the field wire.

In order to study possible ageing effects, one gap of the chamber was irradiated in a high intensity beam ($\sim 10^8$ particles per burst, spot-size $\sim 4 \times 3$ cm²). At this beam intensity the chamber was drawing a current of 1.1 mA. After a total irradiation of $\sim 10^{12}$ particles, we did not observe a significant change in the plateau curve; in addition accurate visual inspection revealed no damage to the wires and the cathode planes.

In the experiment the chambers have been operated with the cathodes at 2.65 kV and the garland wires at 1.7 kV. Given the timing of the experiment trigger, the length of the dual one-shot was chosen to be 750 ns while the strobe width was 75 ns. With the particle flux through the chamber being of the order of 10^7 part/sec, the overall efficiency of each plane was 99%.

Both chambers PC3 and PC4 have performed very satisfactorily during two years of operation without need for any intervention or repair.

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FIGURE CAPTIONS

Fig.1 Section of the chamber showing details of the frames, the pins, the printed boards with associated electronics, the gas tightness system, cooling and screening of the electronics.

- a) amplifier card
- b) Stesalit frames : 6 anodes, 12 cathodes and 1 spacer
- c) support frame
- d) hollow bronze cylinder
- e) position pin
- f) rubber strips
- g) steel strips
- h) ventilator unit
- i) chamber board and bus

Fig.2 Picture of the end of a garland showing the nylon wire which supports the garland running through holes in the garland itself. The field wire stretched on the top of the garland is also visible behind the sense wire plane.

Fig.3 Block diagram of the electronics.

Fig.4 One-shot delay characteristics of the PC-800 hybrids. The average and the r.m.s. values of the delays as measured on a large number of channels are also given.

Fig.5a) High-voltage plateau of the chamber for the two gas mixtures mentioned in the text.

- b) distribution of the high-voltage values for 50% efficiency measured in 25 points over the surface of the chamber and in all six gaps.

Fig.6a) Efficiency scan of a sense wire across the garland for different values of the field wire voltage.

- b) efficiency as a function of the high-voltage of the field wire.

FIG. 1

FIG. 2

FIG. 3

FIG. 4

FIG. 5

FIG. 6