CERN LIBRARIES, GENEVA

CM-P00071027

CERN-EP/80-57

29 April 1980

DEVELOPMENT OF LARGE PLANAR PROPORTIONAL CHAMBERS

S. Ferroni, V. Gracco, A. Santroni

Istituto Nazionale di Fisica Nucleare, Sezione di Genova

and

Università di Genova, Italy

R. Kiesler, K. Kirsebom, M. Macri^{*)}, B. Mouellic

CERN, Geneva, Switzerland

ABSTRACT

We describe a set of large multiwire proportional chambers used in an experiment at the CERN Super Proton Synchrotron. The sensitive area is $2320 \times 2320 \text{ mm}^2$, and four detecting planes, each with different orientation, are grouped together within the same mechanical frame. The number of wires for each module is 5000.

Very uniform efficiency over the whole area is achieved by means of a simple mechanical construction.

The chambers were operated for a long time without any damage under high particle flux.

(Submitted to Nuclear Instruments and Methods)

*) Present address: Istituto Nazionale di Fisica Nucleare, Sezione di Genova, Italy.

1. INTRODUCTION

A set of large multiwire proportional chambers (MWPCs) has been designed and built for use in an experiment at the CERN Super Proton Synchrotron (SPS). The experiment¹⁾ (CERN/SPS/WA7) was intended to measure exclusive processes (mainly elastic) at large p_T . The large acceptance required by the low magnitude of the cross-sections, necessitated using detectors with a large sensitive area (typically $2.5 \times 2.5 \text{ m}^2$). The use of proportional chambers with good spatial resolution ($\sim 1 \text{ mm}$) allowed acceptance of high incident particle fluxes, minimizing dead-time losses.

In this paper we describe the design characteristics and the behaviour of the chambers.

2. DESIGN SPECIFICATION

The useful detector size was determined by the aperture of the analysing magnet to be $2320 \times 2320 \text{ mm}^2$. In order to minimize the amount of material along the particle trajectories, the required detecting surface was provided by proportional planes covering the entire area.

The spacing between the signal wires was chosen to be 2 mm for all planes in order to provide adequate resolution. To speed up data processing, we introduced planes with rotated coordinates, thereby reducing the number of ambiguities caused by the presence of multiple hits in the chambers.

The detector length was kept as short as possible by grouping together in a "module", within the same mechanical frame, four sensitive planes [working in fact as four independent chambers sharing common gas circulation]. A metal frame provided rigidity, acted as a support for the whole module, and made it gas-tight.

The design parameters for the four planes of each module are summarized in Table 1.

The reason for choosing the unconventional value of 28.7° for the angles in the u and v planes is due to the fact that for such an angle both the "sin" and "cos" functions can be expressed as rational numbers; this simplifies the on-line data filtering (by means of dedicated hardwired processors)²⁾, thus avoiding floating-point calculations.

Since the MWPCs had to withstand high particle fluxes, particular care was taken to avoid performance deterioration with ageing due, for example, to deposits on signal and HV electrodes, observed and reported by many users³⁾.

Tests have been performed on the MWPCs using wire cathode planes and cathode planes made of graphite-coated stretched Mylar foils (which were the only mechanically feasible solutions over such large dimensions). The properties of the so-called "magic gas" and various Ar + CO₂ mixtures have been investigated.

After an integrated number of particles ($\sim 3 \times 10^{13}$ part./cm²) traversed a chamber with wire cathode planes, we definitely observed (as expected) a deposit on both the signal and the HV wires when operating with the "magic mixture"; some deposit was also suspected to be present with the Ar + CO₂ mixture. When the graphite-coated cathode planes were used, we observed no deposit on the HV planes, neither with the "magic mixture" nor with Ar + CO₂. However, a suspect deposit was present on the signal wires after using the "magic mixture", whilst the wires remained clean with Ar + CO₂.

The low cost and the absence of safety problems was an additional advantage which finally led us to choose the Ar + CO₂ gas mixture, which has proved to be very stable.

3. CHAMBER CONSTRUCTION

Figures 1 and 2 show respectively a cross-sectional and an exploded view of an MWPC module. Figure 3 gives an over-all view of the module. Each module is made of 4 signal planes and 8 high-voltage planes; the frames are made of Vetronite^{*)}, a fibre-glass reinforced epoxy resin.

*) Stesalit No. 4411.

The HV planes are prepared by epoxying directly to a fibre-glass frame a Mylar foil (67 μm thick) stretched under a linear tension of ~ 50 kg/m. After the epoxy has hardened, the Mylar foil is stretched still further by heating it uniformly. The surface is then sprayed with several layers of graphite paint^{*)} and carefully polished to produce a shiny, smooth electrode surface.

This construction satisfies both economy and simplicity. Another advantage is that it facilitates the carrying out of minor repairs to the electrodes.

The signal sense wires were made of 20 μm gold-plated tungsten wires spaced by 2 mm, stretched with a tension of 50 ± 5 g, and soldered to the pads of a printed-circuit board glued to the fibre-glass frame. A precision of ± 0.1 mm was achieved on the position of the soldered wires over all the plane length.

For the x and y planes, the last three wires on both sides were replaced by guard wires having larger diameters (40, 70, 150 μm). No such guard wires have been used on the u and v planes.

All the mechanical stresses from the signal and HV planes are supported by two identical Al frames, carrying a precision-placed dowel system by means of which the individual planes are assembled. This construction ensures automatic positioning of all planes with an accuracy of ± 0.05 mm. After the module is assembled, the relative coordinates of each plane are completely determined by the construction only. Absolute coordinates are obtained from an external survey of only the four corner dowels.

The Al frames provide rigidity and also form the main body of the gas-tight enclosure. The two external windows, glued directly to the Al frames, are made of Mylar-Aclar^{**)} foils 50 μm thick. The sides of the module are made of Plexiglas windows through which the connections to the PC boards protrude. Gas-tightness along the PC boards is provided by soft rubber-cord "O" rings (see Fig. 1).

*) Graphite-loaded paint, type Acheson 502, diluted with 50% methy-butyl ketone.

**) Mylar-Aclar 33 type Kel-ef.

4. WIRE STABILITY AND ELECTROSTATIC FORCES

The signal wires are exposed to electrostatic forces. In our case the maximum free wire length compatible with sufficient stability is around 70 cm ⁴⁾. Since this is much less than the actual wire lengths (cf. Table 1), some mechanical support had to be devised.

Moreover, the electrostatic attraction of the HV electrodes towards the anode plane tends to reduce the gap width, mainly in the centre of the chamber. As a result, the efficiency is not uniform across the sensitive area, and electrical breakdown could occur.

The maximum inwards sagitta Δy for a plane (assuming, for simplicity, a squared shape) of surface H^2 , stretched with a linear tension T and subject to a pressure P (due to electrostatic attraction) is ⁵⁾

$$\Delta y = \frac{P}{T} \frac{H^2}{8}, \quad P = \frac{C^2 V^2}{8 \epsilon_0 s^2}; \quad s = \text{wire spacing}, \quad C = \text{chamber capacity}.$$

For the present chambers typically $V \sim 4$ kV and $P \sim 0.8$ N/m²; hence to keep $\Delta y < 0.1$ mm, the tension T should be $> 4 \times 10^3$ N/m.

Stretching the Mylar foil with such a tension would pose complicated constructional problems. In an attempt to solve the two above-mentioned problems simultaneously, we placed suitably spaced-out corrugated Kapton strips on both sides of the signal wires (Fig. 4) ⁶⁾. With regularly alternated strips spaced by about 27 cm, it is easy to counteract the forces trying to pull together the anode and cathode planes, as well as to prevent wire displacement and the resulting instabilities. The corrugation allows the strip to remain vertical when laid on a plane. A nylon wire (diameter = 0.3 mm) is stretched tightly parallel to the longitudinal direction of the Kapton strip half-way between the sense wire and high-voltage planes. This wire traverses the Kapton strip through appropriate holes, once for each lateral deflection of the strip. Hence the lateral rigidity of the entire garland structure is ensured (especially important for x, u, and v-planes, where the garlands are horizontal). Also, by the use of

this wire, one obtains an even spacing of the lateral deflections along the garlands (important for the vertical garlands in the y-planes). The electric field modification around the strip, because of its dielectric rigidity, would result in a rather wide inefficient region (~ 2 cm) (Fig. 4). To correct for this unwanted effect, we stretched a PVC-insulated copper wire (0.9 mm external diameter) along the Kapton strip: the signal wires therefore are orthogonal to the PVC wires in the x and y-planes and make a 61.3° angle with the PVC wires in the u and v-planes. By applying a negative voltage to the wire, one can compensate for the field distortion and restore good efficiency nearly everywhere around the strip (Fig. 4).

5. PERFORMANCE OF THE CHAMBERS

As already mentioned in Section 2, the gas mixture used consisted of Ar + CO₂ + freon. Compared to the standard one, the use of this mixture introduced a small reduction in the gas amplification under normal operating conditions, and a shortening of the plateau length⁷⁾.

With an electronic threshold level of 2 mV on the signal wires, a mixture containing 25.0% CO₂ + 74.25% Ar + 0.75% freon gives a plateau (Fig. 5) extending over ~ 300 V, somewhat shorter than what is obtained with the "magic mixture" (Fig. 6), but quite sufficient for correct operation. We stress that all the MWPCs exhibited exactly the same behaviour: the start of the plateau region for different gaps or chambers never departed from the average value by more than 50 V. Even more important, a careful scanning over the whole area of each plane showed a remarkably uniform efficiency at each voltage. No spurious sparking or discharge -- which could eventually lead to a wire breakdown -- has been observed during about two years of operation.

The dark current in the chamber has been observed to decrease in time, and after a few days of operation the current had a typical value of ~ 0.5 μ A, i.e. about 0.1 μ A/m² at 4.0 kV; this behaviour was consistent in all planes. When the field-correcting wires along the strips are brought to a negative potential

of 2.0 kV, the dark current is seen to increase from 0.5 to about 4 or 5 μA , probably because of the high field gradients created. However, after a few days the current falls again to much lower values (about 1 μA). It should be remarked that no particular care was taken during the assembly (such as operating in a dust-free room), as this would have been impractical for a chamber of such large dimensions.

The chamber efficiency has been measured in detail in the region around the strips. Without applying any voltage to the correction wire, the efficiency drops drastically (as would be expected) over a rather wide (~ 2 cm) region on both sides of the strips. The inefficient region is, however, reduced when the wire is brought to a negative potential (Fig. 7).

The transverse size of the corrugation must be chosen carefully.

If the strip extends transversely more than ~ 10 mm, a satisfactory recovery in the efficiency cannot be obtained. For narrower strips, on the contrary, the efficiency is almost entirely recovered (Fig. 8).

6. THE ELECTRONICS AND THE SAFETY SYSTEM

The read-out electronics used for the chambers has been described in detail elsewhere⁸⁾. Because of the high rates expected, this read-out system had to be fast (which it also is) so as to minimize dead-time losses⁹⁾. The solution adopted consisted in storing the signals from the sense wires into twisted-pair delay lines (one line per wire). A delay of 450 ns was long enough to allow the trigger electronics to decide whether the event was a possible good candidate and to generate a strobe signal which latched the signals from the chamber into memory registers.

The amplitude attenuation after 85 m of cable was 30%, with negligible time slewing.

On the chamber side there is only a preamplifier, which acts as a line driver; its input impedance was chosen to be rather low ($400\ \Omega$) in order to minimize the time duration of the pulse^{*)} over threshold. The latter can be adjusted at the receiver end to between 1.2 and 5 mV, typical values being about 2 mV.

The amplitude variation between the ends of the long sense wires is negligible.

Because of the large number of wires involved (~ 5000 in each module and a total of about 20 000 wires) it was important to provide a testing facility simulating the behaviour of the chamber. To this end, on each signal plane an Al strip, 1 cm wide, was laid across the pads of the PC boards, separated by a 100 μm thick Mylar insulator. By injecting a suitable pulse along the strip, the signals induced through capacitive coupling to the wires could simulate real pulses from ionizing particles.

For such large chambers it is also extremely important to ensure that the wires do not break during the course of operation, as this would result in unacceptable loss of experimental time because of the long period needed for disassembly and repair.

The usual dark-current monitoring and disconnection of the chamber HT in case of excessive current was not quite efficient, probably because of the long delay between detection and switch-off (by relay contact).

Using a small test chamber, we got some indication of how one could possibly protect the chamber. It was seen that, whilst normal current pulses (due to traversing particles) were of short duration and were irregularly spaced in time, bursts of current pulses with very regular pulse spacing and high rate occasionally occurred; in some cases the dark current increased by several orders of magnitude after particularly long bursts of this type. This was interpreted as a pre-warning of a larger discharge, and we decided to base a prototype protection system on this observation.

*) A typical time over threshold at full efficiency is ~ 240 ns.

We designed a current transformer to be inserted into the HV line, and a Crytron^{*)} switch was connected, in parallel, to the chamber. The transformer had to integrate the current pulse burst with a time constant of $\sim 0.25 \mu\text{s}$, and the resulting pulse fired the Crytron switch via a current comparator and amplifier. With this system the HV across the chamber could be lowered to less than 10% of the operating voltage within $0.5 \mu\text{s}$ after the detection of one of the current pulse bursts. A full-scale chamber equipped with the system and exposed to a test beam proved capable of providing full protection against wire breaks over a long period of time.

During this test run we were able to prove that even with high-intensity beams traversing the chamber a clear distinction could be made between current pulses due to normal proportional operation and the occasional regularly spaced current pulse bursts considered as a "warning" of possible discharges.

In addition to the current pulse burst detection, the final system (shown in Fig. 9) also housed a d.c. current monitor which acted upon the Crytron switch when the current was considered as dangerous for the chamber. Remote control of comparator bias and some timing circuitry for automatic slow recovery of chamber voltage after switch-off was added, as well as a status output for use in the on-line experimental data acquisition system.

During two years of uninterrupted operation of the 12 gaps we had only one wire break, which must, however, be attributed to an error in the gas filling of that chamber, as pure argon was erroneously used. In this case the spark formation time was much too rapid for the protection system to react.

7. CONCLUDING REMARKS

The operation and results described above demonstrate the feasibility of constructing proportional detectors with a very large sensitive area working

*) Crytron type KN6, manufactured by EG & G.

reliably, with good and uniform efficiency and low dead-time, in the presence of high particle fluxes.

Our experience has shown that these goals can be obtained at a reasonable price using a simple construction and operating the chamber with a safe and inexpensive Ar + CO₂ + freon mixture.

Acknowledgements

We thank all the technical staff of the INFN Section in Genova, and in particular G.C. Barisone, S. Bianconi, F. Conforti, G. Massari, A. Morelli, P. Poggi and L. Trapedini, as well as D. Ploujoux and P. Anzoli from CERN.

We are particularly indebted to G. Trucco for her enthusiastic help during the construction of the detectors and to M. Bozzo and A. Buzzo for their help in the early stage of the work.

We also acknowledge useful conversations with A. Michelini and R. Lorenzi.

REFERENCES

- 1) R. Almas, C. Baglin, R. Böck, E.T.C. Borggaard, K. Brobakken, L. Bugge, T. Buran, A. Buzzo, P. Carlson, L. Causton, C. Caverzasio, M. Coupland, D.G. Davis, J.D. Hansen, B.G. Duff, A. Eide, S. Ferroni, I. Gjerpe, V. Gracco, K. Guettler, J.P. Guillaud, J. Haldorsen, P. Helgaker, F.F. Heymann, D.C. Imrie, T. Jacobsen, K.E. Johansson, K. Kirsebom, S. Kooijman, R. Lowndes, A. Lundby, G.J. Lush, M. Macri, R. Møllerud, J. Myrheim, M. Poulet, L. Rossi, A. Santroni, B. Schistad, H. Schwartz, G. Skjeving, S.O. Sørensen, J. Tavernier and M. Yvert, Large-angle elastic scattering of charged pions on protons at 20 and 30 GeV/c incident momenta, Submitted to Physics Letters B.
- 2) M. Letheren, B. Martin, J. Joosten and I. Gjerpe, A specification of the hard-wired processor for experiment WA7 (Version 2), Internal note, SP section DD, 26.11.1976.
- 3) G. Charpak, H.G. Fisher, C.R. Gruhn, A. Minten, F. Sauli, G. Plch and G. Flügge, Submitted to Nucl. Instrum. Methods 99 (1972) 279-284.
P. Le Dû, P. Borgeaud, G. Burgun, R. Hammarström, R. Lorenzi and A. Michelini, CERN EP Internal Report 77-11 (1977).
- 4) T. Trippe, CERN NP Internal Report 69-18 (1969).
- 5) A. Michelini and K. Zankel, CERN Internal Report OM/SPS/75-5 (1975).
- 6) S. Majewsky and F. Sauli, CERN NP Internal Report 75-14 (1975).
A. Michelini: private communication.
- 7) F. Sauli, CERN NP Internal Report 77-09 (1977).
- 8) J.B. Lindsay, C. Millerin, J.C. Tarlé, H. Verweij and H. Wendler, Nucl. Instrum. Methods 156 (1978) 329.
- 9) B. Sadoulet and B. Makowski, CERN Internal Report DPH/11/PHYS 73-3 (1973).

Table 1

Chamber parameters

	Plane type			
	x	v	y	u
Angle with vertical direction (degrees)	0	-28.7	90	28.7
Wire spacing (mm)	2	2	2	2
Wire diameter (μm)	20	20	20	20
Longest signal wire (mm)	2320	3000	2320	3000
Gap thickness (mm)	6	6	6	6

Figure captions

Fig. 1 : Cross-sectional view of a module:

- (1) Plexiglas side windows
- (2) Printed-circuit boards
- Vetronite frame and spacers (hatched).
- (S) Sense wires
- (HV) High-voltage electrodes
- (M) Mylar-Aclar window.

Fig. 2 : Exploded view:

- (1) Al main frame and Mylar-Aclar gas window
- (2) Vetronite spacers
- (3) HV plane with supporting garlands
- (4) Sense plane.

Fig. 3 : Over-all view of a chamber module.

Fig. 4 : Garland details:

- (1) Corrugated Kapton strip
- (2) PVC-insulated copper wire
- (3) Sense wires
- (4) HT electrodes.

Fig. 5 : Efficiency and dark current versus HV for Ar + CO₂ + freon mixture.

Fig. 6 : Efficiency and dark current for Ar + isobutane + freon mixture.

Fig. 7 : Efficiency along an axis (x) orthogonal to the corrugated Kapton strip. $x = 0$ corresponds to the PVC-insulated copper wire position.

V_{ch} : chamber high voltage

V_{thr} : electronic read-out threshold

V_G : correcting voltage applied to PVC insulated wire.

Fig. 8 : Efficiency versus correcting-wire voltage at the wire position
($x = 0$).

Fig. 9 : Electronic diagram of the safety system.

Fig. 1

Fig. 2

Fig. 3

Fig. 4

Gas Mixture	Ar	74.25%	$V_{\text{thr}} = 2 \text{ mV}$
	Freon	0.75%	
	CO ₂	25.0 %	

Fig. 5

Gas Mixture	Ar	83.8 %	$V_{\text{thr}} = 2 \text{ mV}$
	Freon	0.8 %	
	Isobutane	15.4 %	

Fig. 6

Gas Mixture	Ar	74.25 %	$V_{thr} = 2 \text{ mV}$
	Freon	0.75 %	
	CO ₂	25.0 %	$V_{ch} = 4.1 \text{ KV}$

Fig. 7

Gas Mixture	Ar	74.25 %	$V_{thr} = 2\text{mV}$
	Freon	0.75 %	
	CO ₂	25.0 %	$V_{ch} = 4.1\text{ kV}$

Fig. 8

[illegible]

T1: 250 turns
on potore 4C4

T2: 4 : 120 turns
Ferrite 3E1
primary H.V. insulated