PERFORMANCE OF A LARGE SYSTEM OF PROPORTIONAL DRIFT
TUBES FOR A FINE-GRAIN CALORIMETER

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ABSTRACT

The features of proportional counters and of drift chambers have been combined in a single detector element. For a fine-grain calorimeter used in a neutrino experiment a system of 13,000 counters has been built. The performance and long-term stability of the proportional drift tubes and the electronics is discussed.

1. INTRODUCTION

A fine-grain calorimeter has been designed for a neutrino experiment at CERN¹⁾. The detector consists of a target calorimeter, composed of 78 equal subunits, surrounded by a frame of magnetized iron for muon identification at large angles, and is supplemented by a muon spectrometer. A schematic view is shown in Fig. 1.

A subunit of the target calorimeter consists of a $3\text{ m} \times 3\text{ m} \times 8\text{ cm}$ marble plate sandwiched between a plane of scintillators and a plane $4\text{ m} \times 4\text{ m}$ of 128 proportional drift tubes. These sample the particle shower as it develops in the target plates and measure the shower energy and direction. The small cross-section of only $2.9\text{ cm} \times 2.9\text{ cm}$ makes the proportional drift tubes especially suited for measuring the direction of the energy flow.

Making use of the drift-time information, one measures, in addition, the direction of muons and their deflection in magnetized iron. The proportional drift tubes cover also the iron frames and allow one to sample that part of the hadron shower which may escape from the target calorimeter into the iron frame or the muon spectrometer, which is equipped with 18 planes of proportional drift tubes.

In this contribution, we restrict ourselves to aspects of technical reliability of the proportional drift tube system. The aspects of pattern recognition, energy flow measurements and the system of scintillation counters are discussed elsewhere^{1,2,3)}.

2. PROPORTIONAL DRIFT TUBES

The proportional tubes are required to locate muon tracks with an accuracy of 1 mm (r.m.s.)²⁾ and to sample particle showers by recording the ionization loss of the secondaries in the marble and in the iron. This double purpose requires a dynamic range of about 20 and a good stability of the gas amplification, implying close mechanical and electronic tolerances³⁾ and a stabilization of the gas amplification.

2.1 Construction and mechanical reliability

Sixteen extruded aluminum tubes of internal cross-section $29 \times 29 \text{ mm}^2$ and 4 m in length are glued together with epoxy. As sketched in Fig. 2, a 50μ stainless steel wire is placed inside narrow slots in cylindrical brass rods, one on each end, stretched with a tension of 1N and crimped with a specially designed tool. The supporting rods are held by insulator pieces; they centre the wire to within $\pm 0.2 \text{ mm}$ at the ends. A hole in the insulator pieces allows for gas flow and insertion of the wire. The extruded aluminum pieces, which cover the ends of the tubes, have 16 holes which allow access to each wire *in situ*. Rubber seals and aluminum cover plates assure gas-tightness. Nine-hundred-sixty such units, called chambers, have been built by a space-craft firm^{*)}.

Due to the rigid construction, the deviation from flatness was better than 2 mm, the leak rate less than 10^{-2} Torr l/sec for 1 atmosphere pressure difference. The mechanical precision resulted in a good uniformity of the gas gain. The average pulse heights, moving a ^{106}Ru source to five positions along each of the 16 wires of a chamber, were measured for 400 chambers. The average variance around the mean was 5%, as expected from the variation in thickness of the sense wire.

From the nine-hundred-sixty chambers, eight-hundred have been mounted and in use for about two years. The remaining chambers have been stored temporarily and will be installed during the summer of 1980 to fill the gaps in the iron frame (Fig. 1).

During the two years of operation, a total of 10 wires out of 12,600 broke or had to be disconnected, which can be done without disturbing adjacent tubes. It is planned to replace the broken or disconnected wires *in situ* during the next shutdown. Mechanically, the system has proved to be extraordinarily satisfactory.

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2.2 Gain control

To meet the requirements, the gain of the proportional drift tubes has to be monitored and adjusted. Keeping the high voltage fixed, a fluctuation of the atmospheric pressure and hence the pressure in the chambers as well of 50 mbar would change the gas amplification by $\Delta A/A \approx 60\%$ for the mixture 95% argon, 5% propane. Figure 3 schematically shows the distribution of the gas and the gain control.

The mixing station supplies nine modules. Each module consists of 128 to 196 chambers. The gas in a module is pumped once around in about three hours to homogenize the gas mixture and the outgassed impurities. Needle valves regulate the intake of fresh gas and the outlet of used gas to one complete exchange per week.

In the gas outlet of each module is a stabilizer, consisting of a 30 cm long proportional tube and a $20\mu\text{Ci } ^{90}\text{Sr}$ source. The gas amplification is kept constant in this tube by adjusting the high voltage via a feedback system. This high voltage is used for all the chambers in this module.

To control these stabilizers there is an additional stabilizer which directly uses pure gas from the mixing station. Figure 4a shows the control voltage of this stabilizer, which is proportional to the required high voltage to keep the gain constant, as a function of time. The rise in required high voltage corresponds to a gain loss of about $\Delta A/A = 1.6\%/ \text{day}$. The irradiation was about 160 particles/cm/sec at a gas gain of $\sim 10^5$. Inspection of the sense wire showed an insulation layer of a few microns on the wire. None of the other stabilizers filled with impurity enriched gas showed this gain reduction. It seemed, therefore, logical to add 5×10^{-3} of water vapour to the gas mixture. As Fig. 4b shows, since this was done we have not encountered any similar problems for a new wire in the same stabilizer. (The jump on 15 October 1978 corresponds to a change of the load on the platform, where the mixing station is located, indicating the sensibility of the system.)

Figure 5 illustrates the effect of the gain stabilization over a period of one year. The mean pulse heights in the modules for cosmic ray tracks under 22.5 degrees were recorded. Figure 5 shows the distribution of these measurements around the mean during one year. The spread of $\sigma = 5\%$ is very satisfactory.

2.3 Electronics

The moderate requirements for the accuracy of the drift-time measurements and the slow drift velocity of the argon/propane mixture allows the use of Transistor-Transistor-Logic integrated circuits. The high degree of integration available in this logic family made it possible to build an eight bit ADC and an eight bit TDC per wire with a maximal deadtime of less than 15 μ sec. The principle is sketched in Fig. 6. More details can be found in Ref. 4).

At the output of a charge amplifier, a comparator starts the fast time measurement. The charge is sampled for 800nsec and held on a storage capacitor. After the time measurement is stopped by a late-time reference (end of the GATE) the analogue comparator starts to compare the voltage on the storage capacitor with a ramp. The clock frequency is 20 MHz. This complicated electronics, for 16 wires (one chamber), including the necessary memories and line drivers and receivers, is built on two cards. Sixteen cards are read by a single slot CAMAC unit. With a complexity of about 1.7×10^5 IC's, 6.5×10^5 passive components and $\approx 5 \times 10^6$ soldered points, failures were to be expected.

Each electronic set was tested before and after an initial burn-in period of 24 hours. The infant mortality was 12.5%. After installation about 30% of the sets failed during the first two months. Thereafter, the reliability increased enormously. Twelve per cent of the sets failed in the following four months. Now, after about two years, the average failure rate is below five sets per week ($< 2.5\%$ per month) from 800 installed; this corresponds to a mean time between

failure of 5×10^5 hours per IC. A broken electronic set can be detected during data taking quite easily and can be replaced without interruption in about 10 minutes (this includes a test of the replacement). In addition, with the redundancy built into the experiment, one faulty electronic set does not usually affect the data acquisition.

3. CONCLUSIONS

A system of 12,600 proportional drift tubes with the associated electronics has been in operation for two years. The reliability and performance has been very satisfactory. The rest of the system, another 2,400 wires, will be installed in the summer of 1980.

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Figure captions

- Fig. 1 : Side view of the CHARM neutrino detector. Only 12 out of 78 target planes and the first two toroidal magnets are shown. The last two toroidal magnets are identical to the last shown.
- Fig. 2 : Details of the mechanical design of the proportional drift tubes.
1) sense wire, 2) aluminum tube, 3) wire support, 4) gas inlet/outlet, 5) insulator, 6) tube support and manifold, aluminum, 7) cover plate.
- Fig. 3 : Gas and gain control system.
- Fig. 4 : Control voltage as a function of time: a) old wire, b) new wire, water vapour added.
- Fig. 5 : Deviation of the mean pulse height for a cosmic ray from the mean taken over a period of one year.
- Fig. 6 : Block diagram of the electronics.

FIG 1

FIG 2

FIG 3

FIG 4

FIG 5

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FIG 6