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TEST OF PROTOTYPE HADRON CALORIMETER FOR THE L3 EXPERIMENT

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A fine sampling, tracking hadron calorimeter operating with limited streamer tubes and using a copper absorber has been tested with pions from 1 to 10 GeV/c. The energy resolution measured is consistent with the one expected from empirical formulae obtained for scintillator calorimeters, thus demonstrating that streamer tubes bring little or no loss in resolution. Our laboratory tests have demonstrated that chambers using tubes as small as 3.5×4.5 mm^2 can operate satisfactorily in limited streamer mode.

1. Introduction

We present tests performed at the CERN PS of a prototype fine sampling hadron calorimeter. These measurements, performed with pions of 1 to 10 GeV/c, were intended to gain knowledge to design the L3 LEP hadron calorimeter, for which operation in a 5 kG magnetic field precludes the use of a magnetic absorber and of photomultipliers. Space and cost limitations prevent also the use of liquid argon. Therefore we had to limit ourselves to gaseous detectors and since previous experience [1] showed that limited streamer tubes can be reliably mass produced and yield better resolution than proportional chambers, we chose the former type. To match the L3 space limitation, thinner chambers than for previous set-ups [2] were built and laboratory tests on very thin and metallic chambers were also performed.

2. Calorimeter test at the CERN PS

2.1. *The set-up*

Fig. 1 shows how the limited streamer tube chambers are interleaved with 12 mm thick copper absorber plates. The overall thickness of the 47 sampling planes was 3.75 neutron interaction lengths. A chamber (fig. 2) consists of 48 graphite coated PVC tubes each 6×9 mm^2 acting as the cathode. The wire diameter is 60 μm. We operated the chambers at -4000 V with a 1:4 argon isobutane mixture. In a separate test, we studied ^{55}Fe spectra at different high voltages and found that 4.0 kV corresponds to the best resolution in the single streamer mode. Strips parallel to the wires are glued on a separate board, which together with the pad circuit board

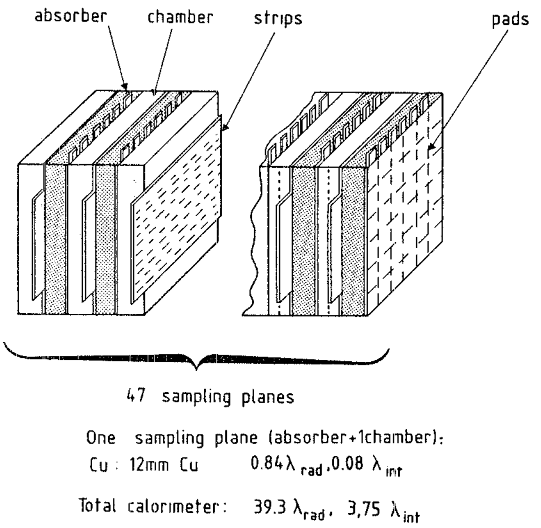

Fig. 1. Hadron calorimeter prototype used for the test at the CERN PS.

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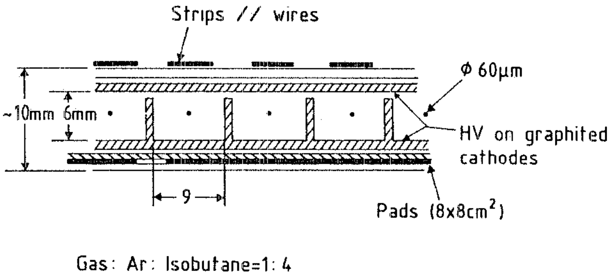

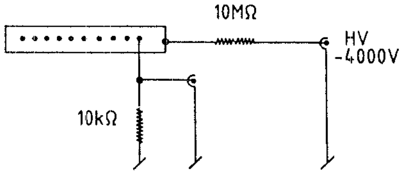

Fig. 2. Chamber structure.

are mounted on each side of the chambers. For each chamber, the OR signal of the 48 wires is fed into an ADC. The addresses of hit strips are also read. The results presented here were obtained with the wire signals and the patterns were controlled with the strip signals.

2.2. Beam and trigger

The apparatus was operated from August till December 1982 in the t6-beam line at the CERN PS. The beam momentum was adjustable between 1 and 10 GeV/c ($\Delta p/p \simeq 1\%$). In this momentum range, the beam contained essentially pions, electrons and some muons. Electrons were flagged by two gas Cherenkov counters and rejected in the off-line analysis. Scintillator signals gave two different trigger conditions (see fig. 3); going through particles ("muon" runs) and interacting particles ("pion runs"). Pedestal runs were taken between normal runs to check the ADC stability.

2.3. Analysis

"Muon" runs were collected in order to check correct operation of our system. The individual chambers gave a nearly Gaussian shaped signal distribution (one streamer) with a small tail (more than one streamer) (fig. 4). The mean individual chamber resolution σ/peak-position found for muons is $(40 \pm 8)\%$. The muon signal distribution for the total calorimeter (fig. 5) was found to be Gaussian with a resolution of 14%, in agreement with the formula

$$\frac{\sigma}{\text{peak position}} = \frac{1}{\text{peak position}} \sqrt{\sum_{i \atop \text{all chambers}} \sigma_i^2}$$

The mean charge of one streamer was 15.5 pC. We used a Le Croy ADC, type 2249A, with 10 bit and 256 pC full scale.

To get a clean pion data set, several off-line criteria were applied [3]. The shower energy resolutions obtained from the wire charge readout, after visual scanning of the strip pattern, are given in table 1. The

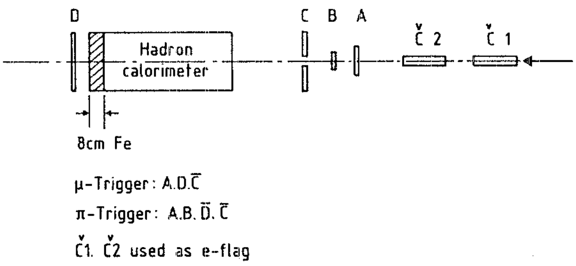

Fig. 3. Set-up and trigger definitions.

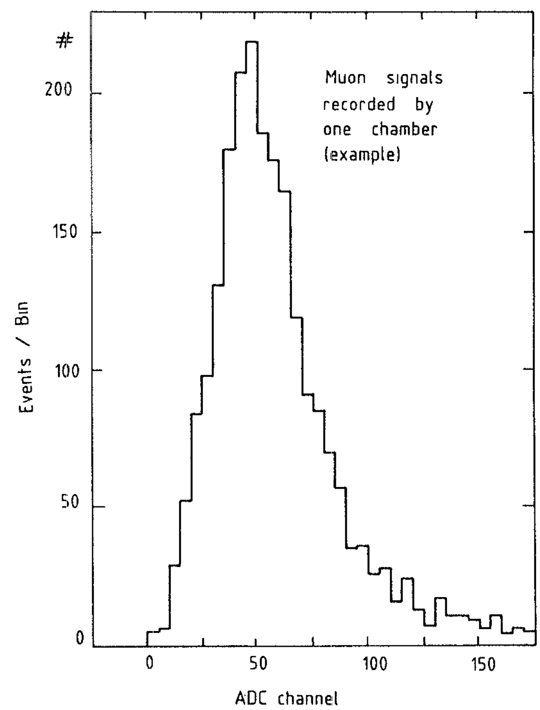

Fig. 4. Pulse height spectrum due to muons crossing one single chamber (example).

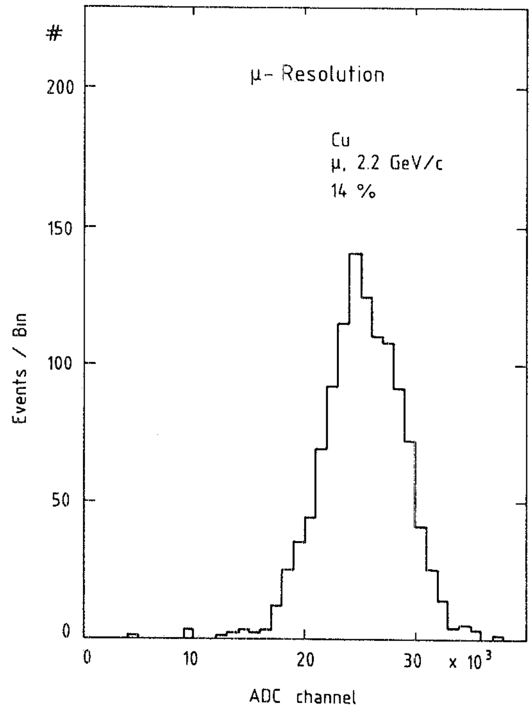

Fig. 5. Total pulse height spectrum for 2.2 GeV/c muons going through the calorimeter.

quoted errors include statistics, systematics (determined by varying off-line cuts) and errors due to ADC saturations. These results are shown in fig. 6 and compared with the expected trend calculated from the empirical formulae fitting experimental scintillator calorimeter resolutions [4,5]. A quite good agreement is observed. Therefore, we can state that streamer tubes perform as well as scintillators in what concerns the energy resolution of our calorimeter.

2.4. Effect of uranium absorbers

We made additional tests by substituting in each absorber plate part of the copper with uranium (see fig. 7). At 2.2 and 4 GeV/c, we obtained (38 ± 2)% (see fig. 8) and (26 ± 2)% respectively. The expected compensation effect due to the uranium [4,5] is small in this

Table 1
π-energy resolution.

$E\pi$ [GeV]	Resolution [%]
1.0	60 ± 5
2.2	40 ± 2
4.0	30 ± 2
10.0	21 ± 4

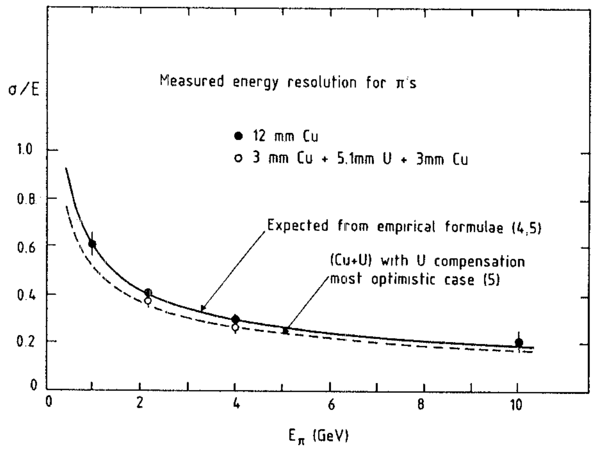

Fig. 6. Measured energy resolution for pions. The quoted errors are the total ones (statistics and systematics). The expected resolutions are obtained from empirical formulae [4,5] for Cu absorber plates (continuous curve) and Cu–U–Cu sandwiches (broken curve).

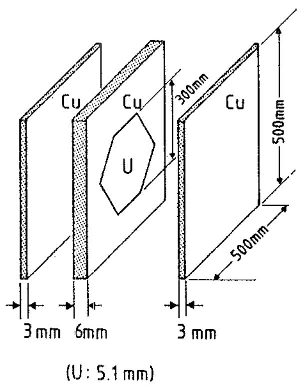

Fig. 7. Structure of a Cu–U–Cu sandwich absorber plate.

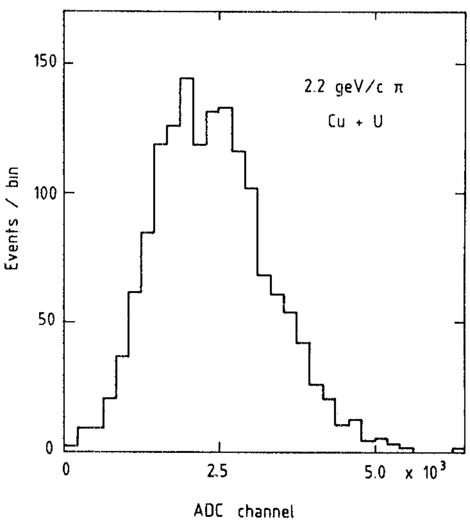

Fig. 8. Total pulse height spectrum for 2.2 GeV/c pions.

Table 2
Resolution of test chambers.

Wire-beam angle α[deg]	Tubes		
	Cross section wire-diameter	6×6 mm^2 50 μm	4×4 mm^2 30 μm
90		31%	46%
30		22%	38%

layout and cannot be resolved with our sensitivity, as the data shows. In any case, as foreseen [6], the 3 mm copper provided adequate shielding for proper chamber operation.

3. Behaviour of test streamer tubes as a function of the angle between the wire and the incident particle

During the last runs, we installed in front of the hadron calorimeter some tubes having a cross section of 6×6 and 4×4 mm^2, both made of graphite coated PVC [7]. We operated them with the same gas mixture used for the calorimeter (argon : isobutane = 1 : 4) and recorded their pulse height spectrum for different angles between the wire and the beam. The results reported in table 2 and fig. 9 show that the normalized peak position of the pulse height spectrum is proportional to the length of the track projection along the wire. From this it comes out that the length of the dead region L due to a single streamer is 3.1 mm for both tubes:

$$L = \frac{d \operatorname{ctg} \alpha}{\operatorname{Ampl}(\alpha)/\operatorname{Ampl}(90°)}, \quad d = \text{cell size.}$$

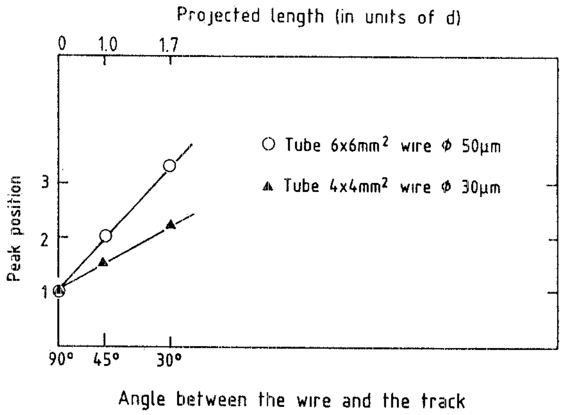

Fig. 9. Position of the peak in the pulse height spectrum versus α normalized to $\alpha = 90^3$.

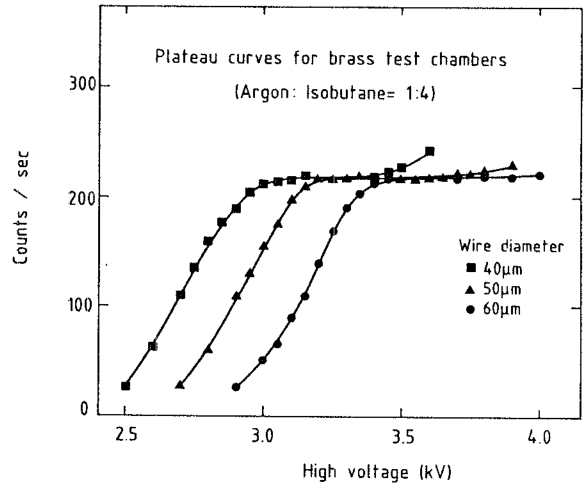

Fig. 10. Plateau curves for wires from 40 to 60 μm in diameter with a 1 : 4 argon isobutane mixture.

4. Performance of small brass tubes

Dense materials to replace graphited PVC cathode profiles were also tested and the possibility of scaling down the geometrical dimensions of the tubes was investigated [8]. Here we report results on brass tubes 3.5×4.5 mm^2 in cross section, equipped with wires from 40 to 60 μm in diameter. The tube profiles were obtained by means of a milling machine. Tests were carried out exposing tubes to an uncollimated Cs^{137} source. The gas mixture was argon + isobutane (1 : 4). The analogue signal from the wire was fed into an amplifier followed by a discriminator with a shaping time of 250 ns. The discrimination voltage was set to 100 mV/50 Ω (corresponding to 4 mV/50 Ω threshold for the chamber signal), in order to get rid of the proportional component, so as to be sure to work in the streamer mode. The plateau curves for different wires are shown in fig. 10. Using a second discriminator with

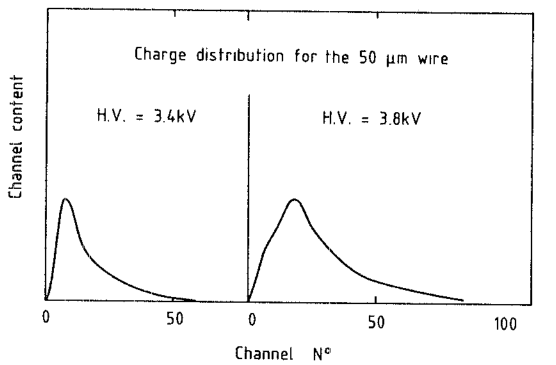

Fig. 11. Charge distribution for the 50 μm wire at 3.4 and 3.8 kV.

a shaping time of 25 ns allows us to count double pulses. We saw that the percentage of double streamers due to the photoionization process on the brass surface is less than 4% for all the length of the plateau. In fig. 11 we show the charge distributions for the 50 μm wire at a voltage well inside the plateau and at a higher one. The results show that such small brass tubes can work reliably.

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