

G.Battistoni, G.Bologna, P.Camparè, V.Chiarella, A.Ciocio,  
B.D'Ettore-Piazzoli, E.Iarocci, G.Mannocchi, G. Nicoletti,  
F.Picchi

Laboratori Nazionali di Frascati - INFN - Italy

M.De Palma, G.Maggi

Istituto di Fisica dell' Università and Sezione INFN - Bari -  
Italy

P.Strolin

Istituto di Fisica Sperimentale dell' Università and Sezione  
INFN - Napoli - Italy

#### ABSTRACT

We report the results obtained with a hadron calorimeter test module made of Plastic Streamer Tubes, with external pads to readout induced charge. We have measured energy response and resolution between 20 and 100 GeV.

Here we present results obtained with a Plastic Streamer Tube (P.S.Tube) hadron calorimeter test module where streamer charge was readout with pad electrodes outside the resistive cathode.

Making use of the results of the previous tests made with e.m. P.S.Tube calorimeters [1,2] one could infer that, due to the reduced track density in hadron showers, the linear energy response range of an hadron calorimeter, for the same granularity and operation conditions, would be largely extended. In this respect we have built the test module using P.S.Tubes of the same geometry as in the M. Blanc proton decay detector [3].

The test has been performed within the work to prepare proposals for LEP [4].

#### THE TEST MODULE

The test module consists of 26 iron plates  $120 \times 65 \text{ cm}^2$ , 4 cm thick, 1.7 cm apart, interleaved with P.S.Tubes, for a total depth of  $\sim 6 \text{ L}$ . The average distributed interaction length is  $\sim 25 \text{ cm}$ . The single sandwich element is shown schematically in fig. 1; each plane contains 64 streamer tubes, each one with

a  $9 \times 9$  mm<sup>2</sup> active cell, a separation wall of 1 mm and 100  $\mu$ m BeCu wire. Induced pulses are picked up by external pads which are  $60 \times 60$  cm<sup>2</sup> printed circuit boards with copper on both faces as signal and ground electrodes. Pad signals are summed 4 by 4 and all together by means of linear fan in-fan out and sent, through attenuators, to individual ADC channels to readout induced streamer charge. The wires are not readout and are connected to ground. A negative high voltage is applied to the resistive cathode (see fig. 2). The tubes are operated in the streamer mode, with an Arson+Isobutane (1+3) mixture. The working voltage (4.5 KV) is just above the knee of the efficiency plateau (fig. 3) for streamer production by minimum ionizing particles.

Single streamer pulses as detected on one pad are shown in fig. 4. Pulse shape is determined by pad capacitance (8 nF) discharging through 50 Ohm termination with 400 ns time constant.

Streamer charge distributions for single tracks, at different angles with respect to tube axis, are shown in fig. 5, as measured on a single wire. While for orthogonal incidence mostly single streamers are produced, for increasing angle the average number of streamers also increases. Charge peak differs of about a factor of two between 0 and 45 degrees.

The test module was exposed to muon and pion beams at CERN-SPS at six different energies : 20,25,40,50,80 and 100 GeV.

In fig. 6 the total charge distribution collected on pads for 25 GeV pions is shown, together with the muon spectrum. The number of streamers corresponding to the pion peak is ~280.

In fig. 7 is plotted the total charge readout as a function of pion energy. The experimental points have been corrected for longitudinal shower leakage. The response of the calorimeter is linear up to ~50 GeV while at higher energies non linearity starts to become effective ( 9% non linearity at 100 GeV).

In fig. 7 is also plotted the energy resolution as a function of energy. The experimental points are compatible, within the range of linear response, with a  $78\%/ \sqrt{E}$  law. In computing energy resolution, at the highest energy points, non linearity has been taken into account.

The measured resolution is within 10% that of plastic scintillator calorimeters with the same sampling [5], and the range of linearity is adequate to match LEP energies.

Furthermore, as stressed elsewhere [1,2], this result does not appear as a limit, given the possibility of making smaller tubes and acting on the streamer operation conditions.

The P.S.Tube calorimeter can be equipped with a projective digital readout (for instance strip electrodes on the tube side opposite to the pad) allowing muon trackings through iron, which can simplify the muon identification system.

#### REFERENCES

- 1) G.Battistoni et al., LNF 82/16 (1982), presented at the "Inter. Conf. on Instrumentation for Colliding Beam Physics", Stanford, February 17-23, 1982.
- 2) G.Battistoni et al., 'Pls.S.Tube e.m. calorimeter', these Proceedings.
- 3) Proposal for a Nucleon Stability Experiment, Frascati-Milano-Torino, preprint (1979).

- 4) ALEPH collaboration, letter of intent, unpublished. 5) S.Iwata, report DPNU-3-79 (1979).
- 6) G.Battistoni et al., Nuclear Instr. and Meth. 176,297(1980).

## FIGURE CAPTIONS

- Fig. 1. Geometry of one layer of the test module.
- Fig. 2. H.V. and readout scheme.
- Fig. 3. Single tube layer efficiency as a function of H.V. for orthogonal tracks.
- Fig. 4. Single streamer pulses as detected on a pad (50 Ohm load).
- Fig. 5. Streamer charge distributions for single tracks at 0, 30, and 45 degrees with respect to wire axis; 9x9 mm\*\*2 tube size, 100 um wire, A + Isobutane 1+3 gas mixture, H.V. = 3.5 kV.
- Fig. 6. Total collected charge distribution for pions and muons at 25 GeV.
- Fig. 7. Total collected charge and energy resolution (multiplied by  $\sqrt{E}$ ) as a function of pion energy. The points are experimental data while the solid line comes from corrections due to longitudinal leakage.

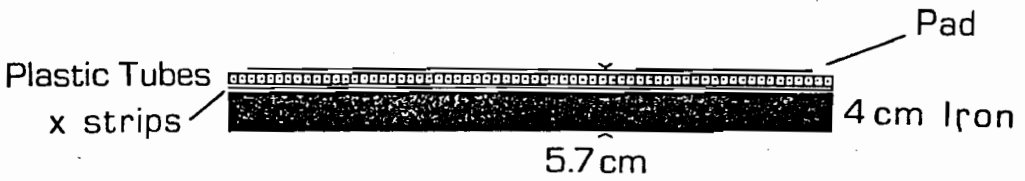


Fig. 1

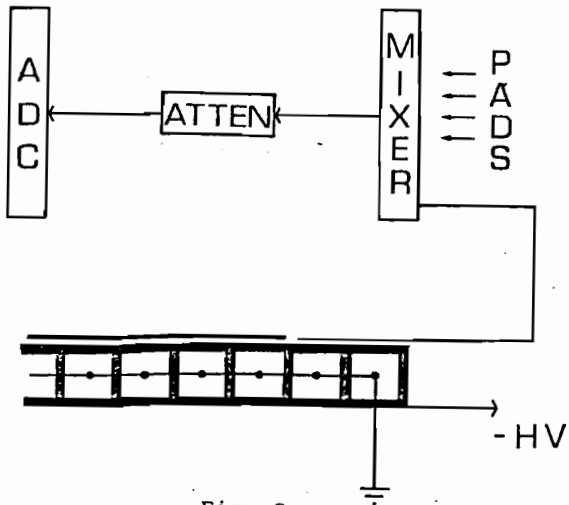


Fig. 2

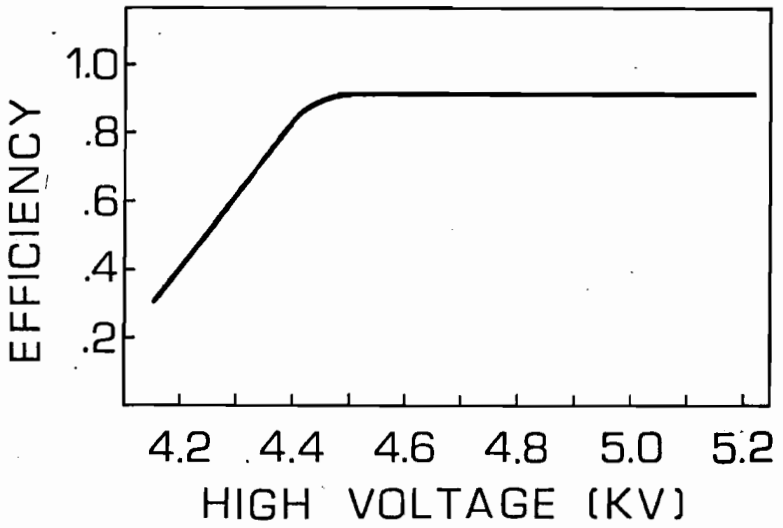


Fig. 3

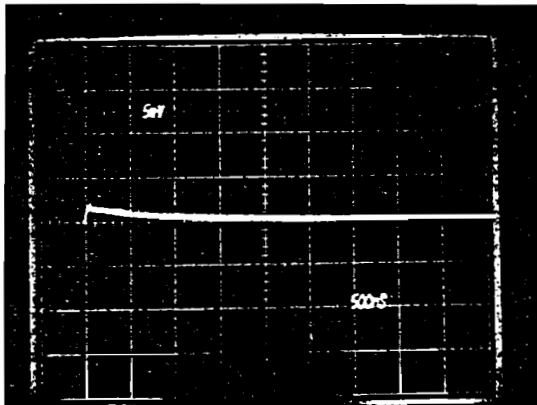


Fig. 4

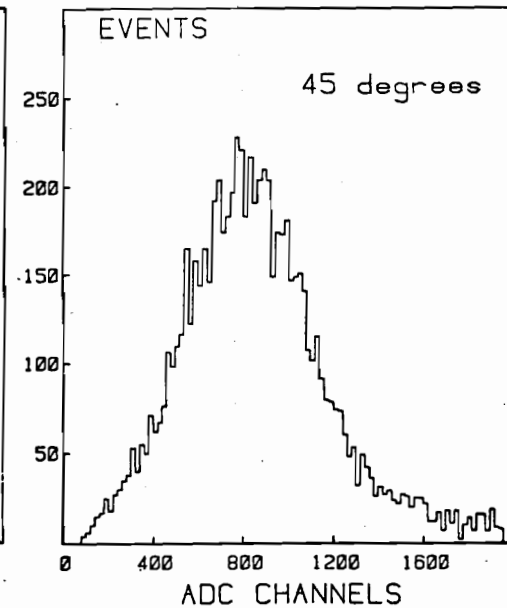
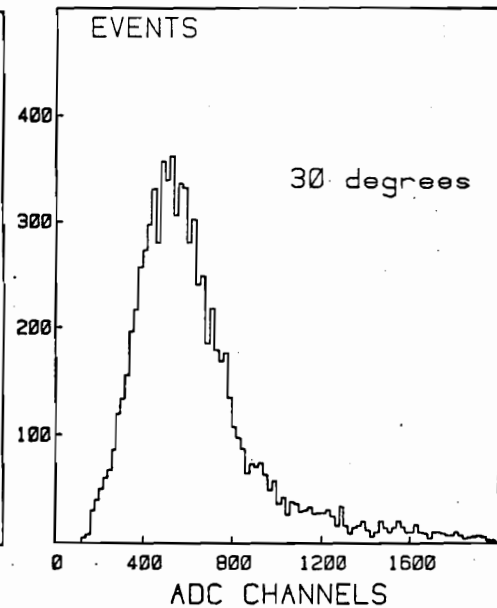
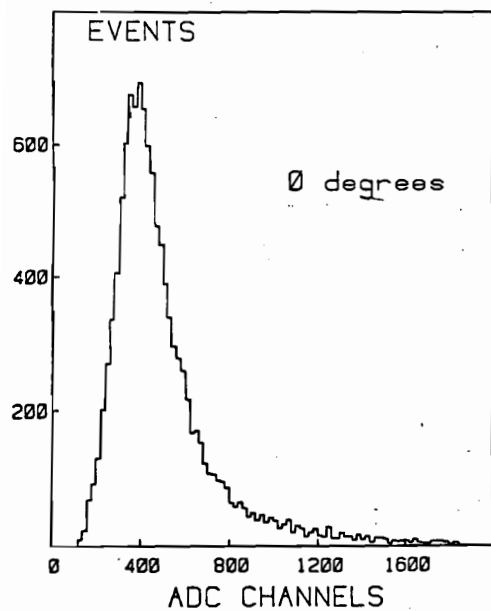


Fig. 5

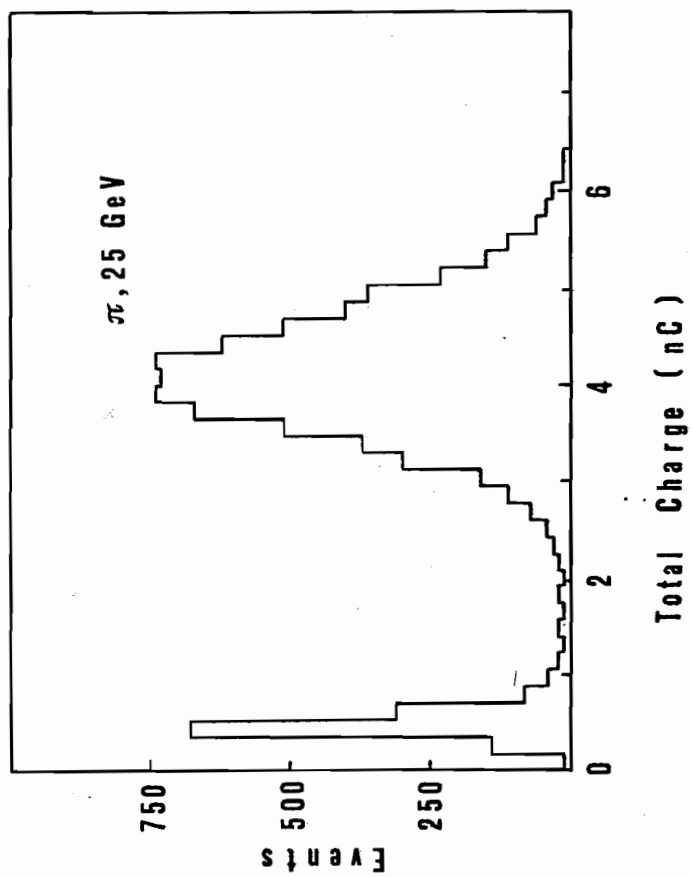


Fig. 6

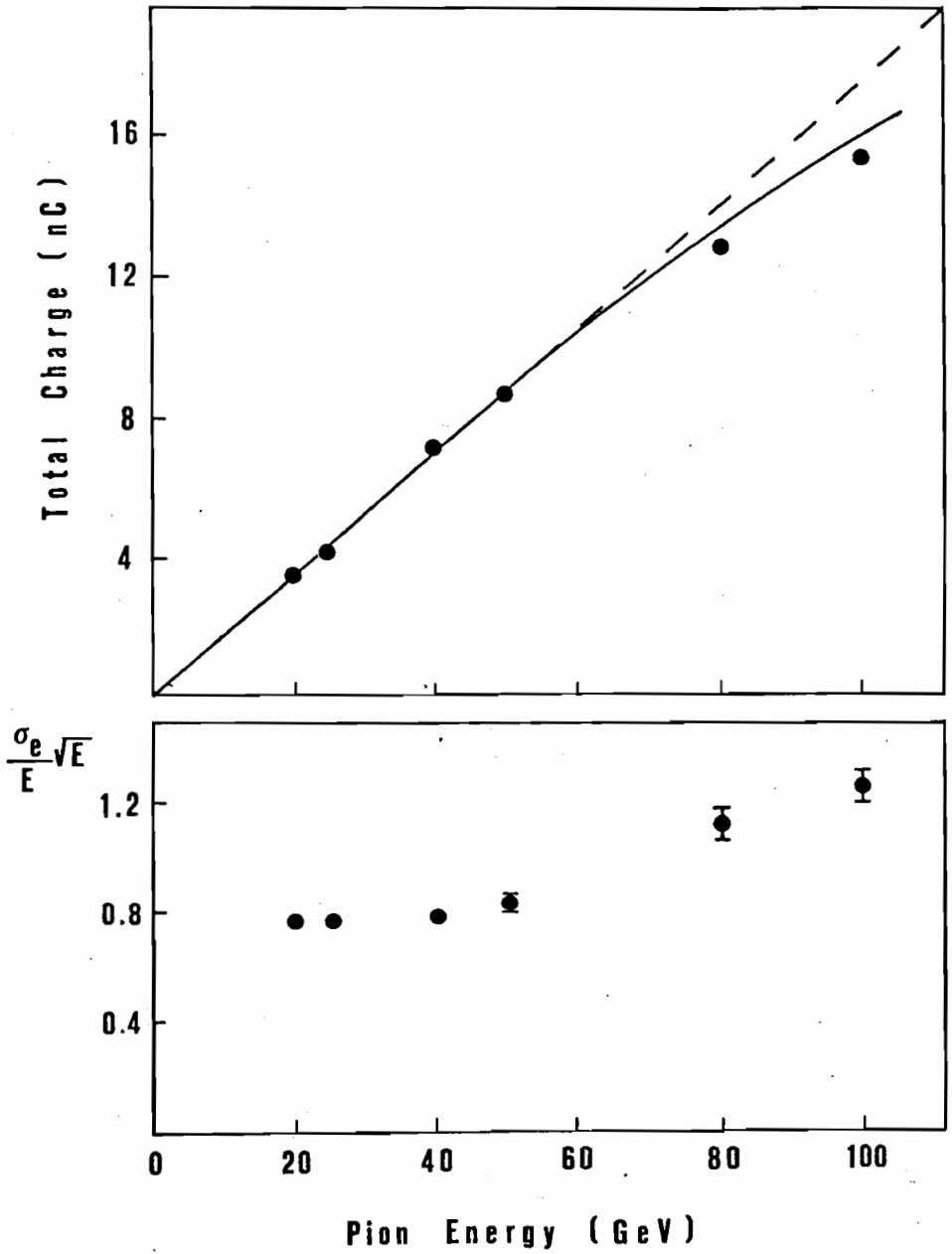


Fig. 7