PLASTIC STREAMER TUBE CALORIMETERS

G.Battistoni, G.Bologna, P.Campana, V.Chiarella, U.Denni, B.D'Ettorre-Piazzoli, E.Iarocci, G.Mannocchi, G.P.Murtas, G.Nicoletti and P.Picchi.
LNF-INFN, Frascati (Italy)

## Abstract

We present the results of a preliminary test on an e.m. calorimeter test module using Plastic Streamer Tubes with external pad readout. We have measured energy response and resolution between 2 and 10 GeV, and $\pi$/e discrimination at 10 GeV.

## 1. Introduction

Plastic Streamer Tube devices (PLA.S.Tubes in the following) are based on the use of resistive cathode[1] and are operated in the limited streamer mode[2]. PLA.S.Tubes have a high resistivity cathode (f.i. graphite coated plastics) which is transparent to transients and external electrodes (strips, pads, delav lines) are used to pick-up induced pulses.This device has been or is being used in several experiments(see f.i. ref.[3,4,5]) as the sensitive device of tracking calorimeters with simple digital (yes/no) readout of individual projective elements. The digital readout allows to record the detailed spatial pattern and is convenient in those experiments, such as proton decay[4] and neutrino detectors[5], where tracking is of relevance. Good shower energy measurement is limited to relatively low energies[6], due to track pile-up on the same readout element, the limit depending on the granularity and density of the calorimeter.

Here we present the results of a preliminary test performed with a PLA.S.Tube calorimeter with streamer charge readout by pick-up pads, which shows its possible use as e.m. shower calorimeter in the energy range of interest for high energy colliders. The idea of measuring shower energy by measuring the total charge collected in a saturated mode device has been already used in the Limited Geiger e.m. calorimeter of PEP-4 [7]. Total charge measures the total number of elementary discharges, which is equivalent to count tracks and so to measure energy. The response is linear and resolution varies as $1/\sqrt{E}$, up to energies (several GeV) for which track pile-up occurs in the elementary Geiger cell. Limited streamer mode allows to operate in an analogous way. Now the elementary cell area is given by the

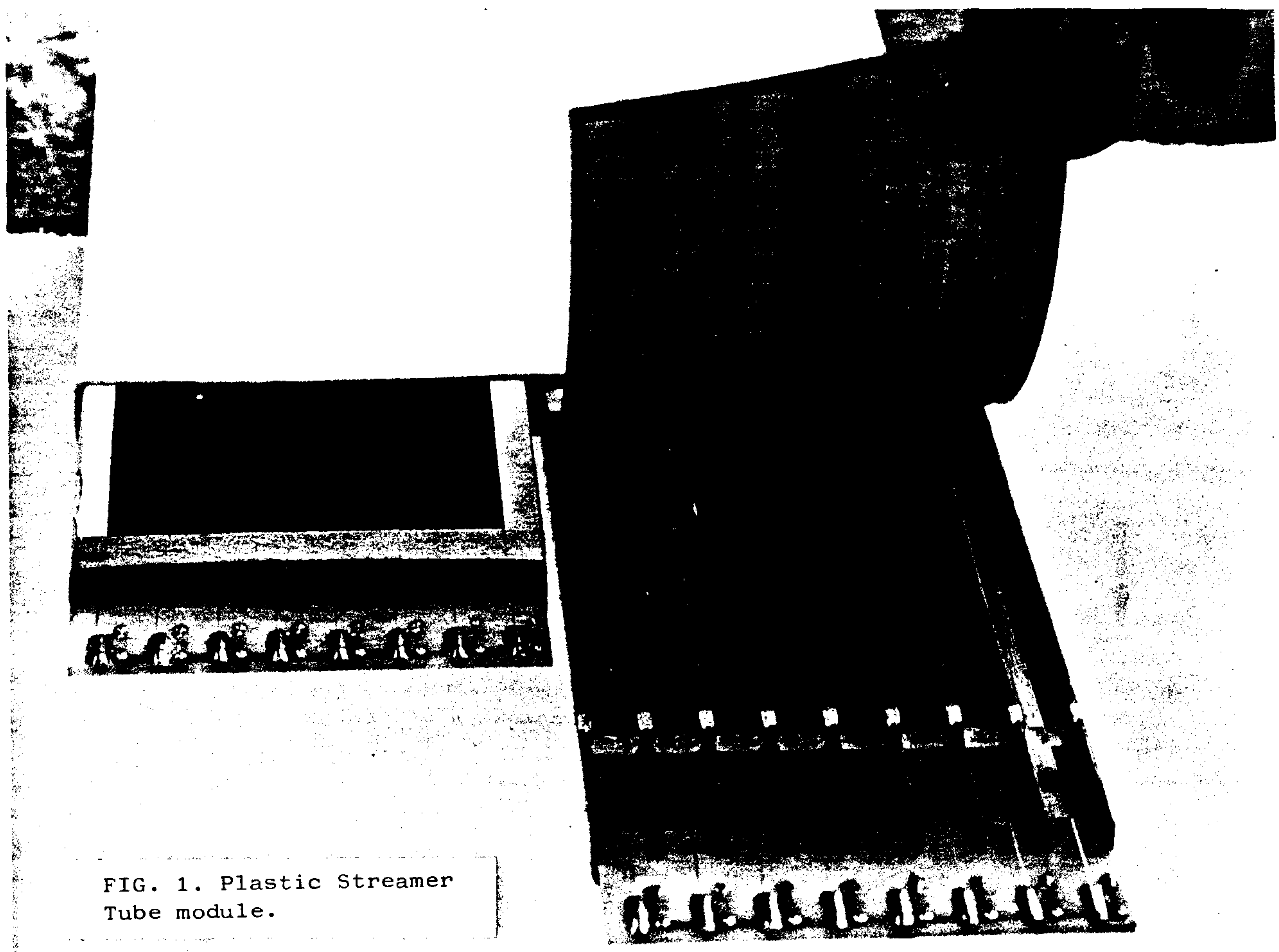

FIG. 1. Plastic Streamer Tube module.

tube width times the streamer obscuration length, i.e. the length of the dead wire region due to a single streamer. With respect to the Limited Geiger device, the mechanics of streamer tubes looks simpler, since they do not need a mechanical device to localize the discharge, and smaller elementary cells appear feasible, by acting on the gas mixture. The use of PLA.S. Tubes makes possible simple construction of both oriented tower and strip structures.

We have built the test module using tube modules of the Mont Blanc proton decay experiment. We will briefly describe their technology in par.2, before discussing the e.m. calorimeter test module and the experimental results.

## 2. Plastic Streamer Tubes

The Mont Blanc proton decay experiment (Frascati, Milano, Torino, CERN) makes use of about 50.000 PLA.S.Tubes equipped with about 100.000 x and y strips, for a total pick-up area of 3400 $m^2$. Details of the device structure are shown in fig.1 and 2. The constructive unit[8] is an 8-cell open profile, coated with graphite ($\gtrsim 5 \times 10^4 \Omega$/square). The 100 $\mu$m Be-Cu wires are kept in central position by PVC spacers every half a meter. A top cover, also coated with graphite ($\gtrsim 10^5 \Omega$/square), completes the tube structure. The tube element is $0.9 \times 0.9 \times 350$ $cm^3$. Two 8-tube units are inserted into a PVC bitube container.

Detection planes are made by simple juxtaposition of PLA.S.Tube modules and two-dimensional readout is performed by 16-strip units[8,9] facing the tube elements as shown in fig.2.

Modularity, thick sense wires, uncriticity of the streamer mode, splitting of pick-up and active element function, use of thermoplastics and their technology, make this detector cheap and simple to build and operate.

## 3. Test Module Description

The test module ($34 \times 50$ $cm^2 \times 50$ cm depth) consists of 16 lead sheets 5 mm thick (0.9r.1.) interleaved with the PLA.S.Tube modules described before. The total depth is 14.5 r.l. and the average distributed r.l. is 3.3 cm. The single element of the sandwich is shown in fig.3. The 100 $\mu$m thick wires are not read out being simply connected to the H.V. (fig.4).

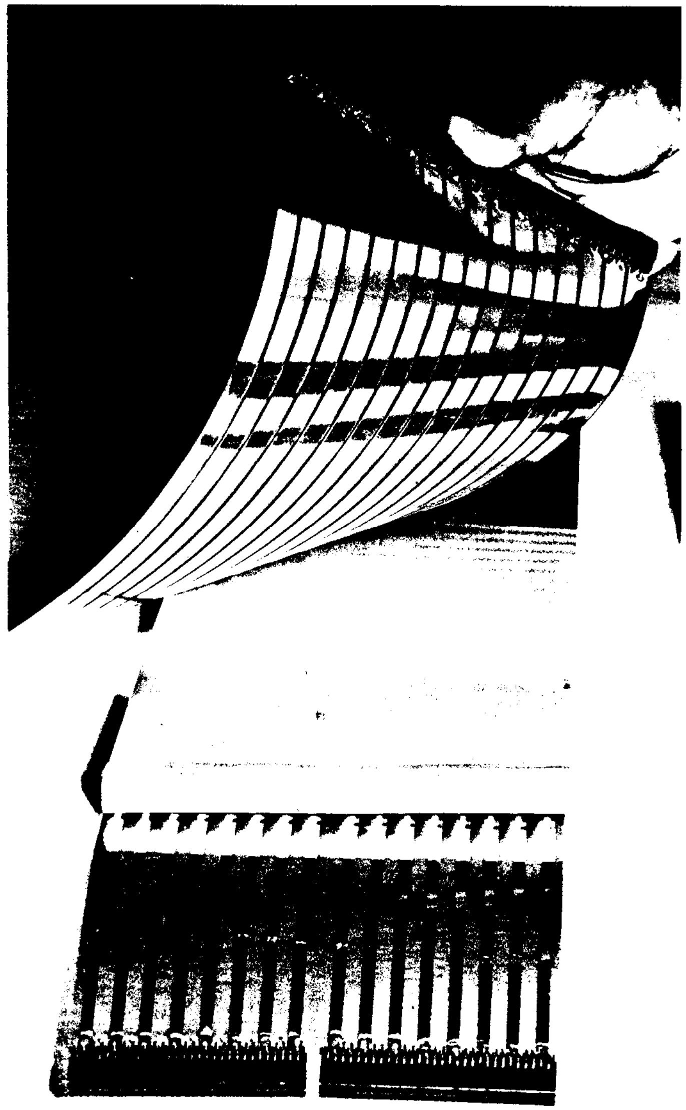

FIG. 2. Plastic Streamer Tube module with x and y pick-up strips.


FIG. 3. Geometry of one sampling layer of the test module.

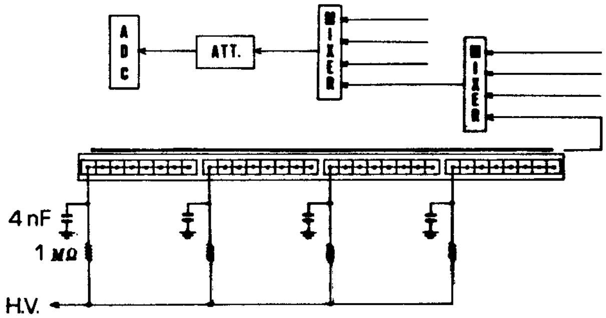


FIG. 4. H.V. and readout scheme.

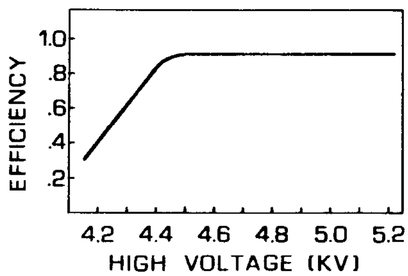


FIG. 5. Single tube layer efficiency as a function of H.V. for orthogonal tracks.

Streamer induced pulses are picked-up by external pads which are 34 x 50 $cm^2$ printed circuit boards, with copper on both faces as signal and ground electrodes. On the tube side opposite to the readout pad, there is a grounded aluminium sheet. The 16 pads are connected through linear mixers and attenuators, to one or more ADC circuits (fig.4), to read out induced streamer charge.

The tubes are operated in the streamer mode with an Argon + Isobutane (1+3) mixture. The working voltage (4.6 KV) is about 100 V above the knee of the efficiency plateau for streamer production by minimum ionizing particles (fig.5). A typical single streamer pulse as detected on wires (50 Ohm termination) is shown in fig.6: the shape is triangular, with $\sim$1 mA peak current and 40 ns duration. Typical single and double streamer pulses as detected on a pad are shown in fig.7: the pulses are integrated by the large pad capacitance ($\sim$ 4000 pF), which discharges through the 50 Ohm termination with a 200 ns time constant.

The induced charge distribution on the pad facing one tube layer for tracks at normal incidence, is shown in fig.8. The distribution is substantially due to single streamers. It peaks at 14 pC, with a 50% FWHM.

## 4. Experimental Results

The test module was exposed to electron and pion beams at CERN-PS, at four different energies: 2,4,7,10 GeV. In fig.9 the total charge distribution collected on the pads is shown for 10 GeV electrons: the narrow peak near the origin is due to residual pions in the electron beam trigger.

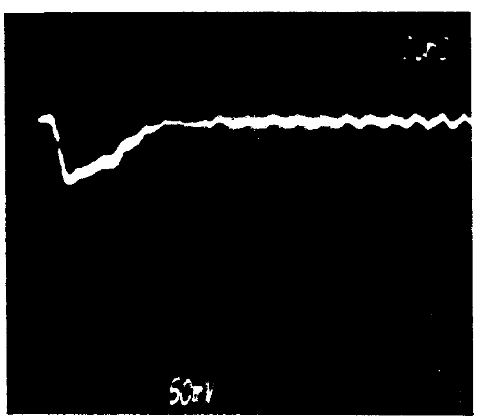

FIG. 6. A typical single streamer pulse as detected on the wire (50 $\Omega$ load).

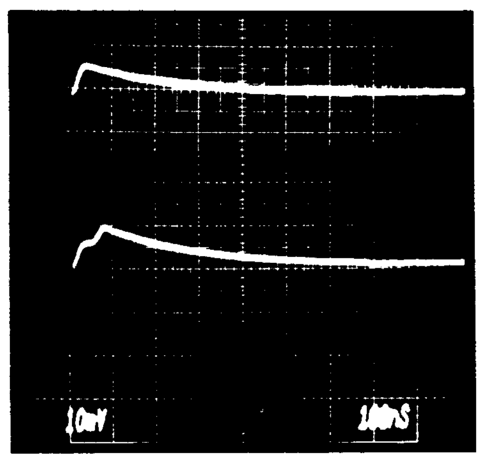

FIG. 7. Signals on a pad due to single and double streamers (50 $\Omega$ load).

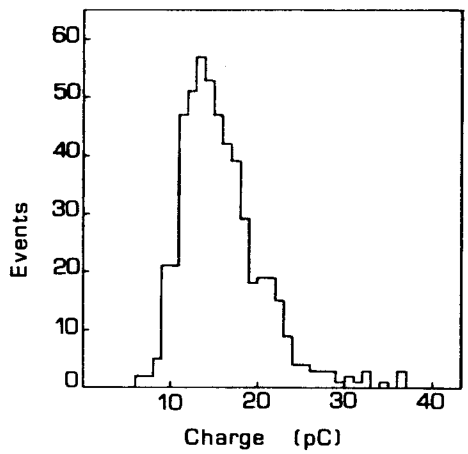


FIG. 8. Collected charge distribution on a single pad for single orthogonal tracks.

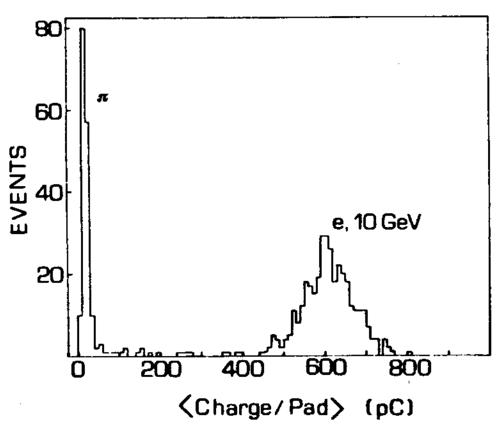


FIG. 9. 10 GeV electron spectrum together with residual pions, in units of the average charge induced on the 16 pads.

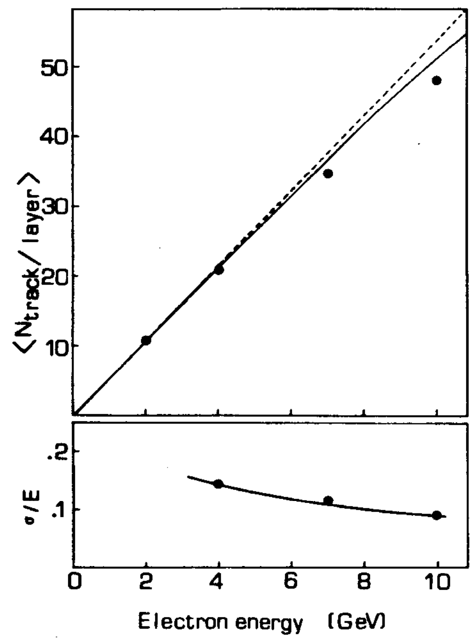


FIG. 10. Signal and energy resolution as a function of electron energy. The signal is in units of orthogonal track signal (non interacting pions).

The total collected charge at the electron peak corresponds to ~650 streamers: a 28 db attenuation was necessary to match the ADC operation range. Making use of transition curves for electron showers[10], from the total number of streamers we have estimated an average numebr of ~100 streamers on the plane at the depth of the shower maximum.

Total charge readout as a function of electron shower energy is plotted in fig.10. The solid line comes from the experimental points, corrected for shower losses on the back of the calorimeter. The linear behaviour below 2 GeV has been somewhat arbitrarily assumed. However it appears a reasonable assumption from the $1/\sqrt{E}$ behaviour of energy resolution. This is reported also in fig.10. The experimental points have been corrected for shower loss fluctuations (the maximum correction was at 10 GeV, from 10% to 9%). The solid line corresponds to $28\%/\sqrt{E}$. Due to tight beam schedule we have not explored operation conditions (gas and H.V.) different from those quoted above, which are the standard ones for the digital readout of the Mont Blanc detector. However in one electron run at 10 GeV we have operated the tubes at 4.5 KV, measuring a spread corresponding to $26\%/\sqrt{E}$. The measured energy resolution is equivalent to that obtained with the Limited Geiger calorimeter quoted above, when scaled with $\sqrt{t}$.

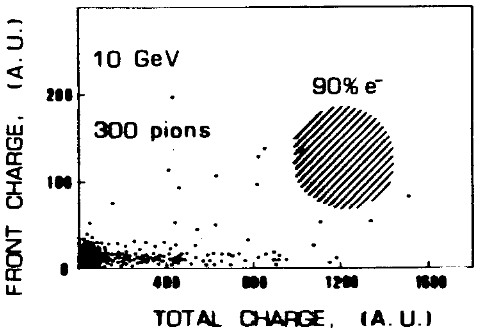


FIG. 11. Scatter plot of the charge collected on the first three pads vs. total charge, for 10 GeV pions.

By comparison of non linearity at 10 GeV, between our calorimeter and the Limited Geiger one, and correcting for different densities ( $\overline{X}_0$ = 3.3 and 5 cm respectively), we have estimated a streamer obscuration length of $\sim$1.5 mm. We have assumed a negligible effect on linearity due to the high resistivity cathode.

The test module was exposed to a 10 GeV pion beam, to measure $\pi$/e discrimination. In both the electron and pion tests in addition to the total charge, the charge collected on the first three pads was measured. The scatter plot in fig.11 shows the front-radiator vs. total charge distribution for a sample of 300 pions. Only one event gives an amplitude in the 90% acceptance region (shown dashed in the figure) for 10 GeV electrons.

## 5. Future Development

The results obtained concerning the energy response do not appear as a limit. They can be improved by reducing the tube width (PLA.S.Tubes down to $4 \times 4$ mm$^2$ have been operated[11], and the streamer obscuration length (by increasing the quenching fraction in the gas mixture, to reduce streamer charge).

Due to reduced track density in hadron showers with respect to e.m. showers, from the results with the e.m. calorimeter one can infer[12] a comparatively larger linear range for PLA.S.Tube hadron calorimeters.

The PLA.S.Tube device allows simple arrangement of oriented towers and strip geometries for optimal spatial information (shower vertices and profiles, $\mu$-tracking through iron[12]).

The use of a saturated mode simplifies controls and stability problems.

Within the work to prepare proposals for LEP, tests will be performed with both e.m. and hadron calorimeter PLA.S.Tube test modules, with fine sampling, tower and strip arrangement.

## REFERENCES

1) G.Battistoni et al. Nucl.Instr.Meth. 152 (1978) 423

2) G.Battistoni et al. Nucl.Instr.Meth. 614 (1979) 57

3) J.E.Augustin et al. Physica Scripta vol.23 (1981) 623

4) M.Jonker et al. Physica Scripta vol 23 (1981) 677

5) Proposal for a Nucleon Stability Experiment, Frascati-Milano-Torino (1979) unpublished.

6) G.Battistoni et al. Study of neutrino induced background for the proton decay experiment in the Mont Blanc tunnel, to be published on the proceedings of the 1981 EPS Conference on High Energy Physics, Lisbon.

7) Presented by A.Barbaro-Galtieri at the General Meeting on LEP, Villars-on-Ollon, 1981.

8) G.Battistoni et al. Nucl.Instr.Meth. 176 (1980) 297

9) G.Battistoni et al. LNF-82/6, submitted to Nucl.Instr.Meth.

10) U.Amaldi, Physica Scripta vol.23 (1981) 409; S.Iwata, Calorimeters for High Energy Experiments at accelerators, DPNU-3-79.

11) G.Battistoni et al. Limited Streamer Tubes with Resistive Cathodes, to be published on the proceedings of the 1981 EPS Conference on High Energy Physics, Lisbon.

12) ELECTRA collaboration, Letter of intent to study $e^+e^-$ annihilation at LEP, January 1982, unpublished.