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21 Luglio 1982

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THE GEIGER PROJECTION CALORIMETER

(Presented at the Summer Workshop on Proton Decay Experiments, Argonne National Laboratory, June 1982)

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ABSTRACT.

In view of a second generation p-decay experiment in the Gran Sasso Laboratory, a digital tracking calorimeter is being developed, based on the use of plastic tubes of the Mont Blanc detector type, which are operated in limited Geiger mode.

1. - INTRODUCTION.

The 150 ton Mont Blanc proton decay detector recently started into operation(1), will allow coverage of proton decay lifetimes up to 10^{31} years, with a rather uniform sensitivity to all decay modes producing charged secondaries in the detector.

Here we present the basic idea of a Geiger Projection Calorimeter for a second generation p-decay detector, with a ~2 Kton total mass to be installed in the Gran Sasso Laboratory(2), the excavation of which should start in a short time.

This new detector is an evolution of the Mont Blanc one, maintaining the basic character of a digital tracking calorimeter, but aiming at a substantial optimization of the detector technology, which is also required to afford further developement toward larger masses.

The Geiger Projection Calorimeter is based on the same Plastic Tube device of the Mont Blanc detector, but on the basis of the Mont Blanc experience aims at two substantial simplifying improvements. The first concerns the operation of the tubes in the limited Geiger mode, instead of limited streamer mode, which allows a cheaper readout. The second improvement concerns the assembly modularity of the detector, envisaged to be such to allow transportation and installation in the underground laboratory of $\sim$20 ton pre-assembled calorimetric units, already equipped with the readout and tested. It is also under study the possibility of using concrete as radiator-source medium.

Reduction of sampling thickness and average density with respect to the Mont Blanc detector would improve e. m. shower energy resolution, two track resolution, $\mu \to e$ detection efficiency, and the overall particle identification capability.

To improve track direction identification, the digital tracking detector can be implemented with a time of flight counter system.

2. - PLASTIC GEIGER TUBES.

The basic scheme of a Plastic Geiger Tube layer with two coordinate readout is shown in Fig. 1. The tube device is the same as used in the Mont Blanc detector(3): plastic tubes with a resistive graphite cathode, 100 μm anode wires, held in position every 50 cm by plastic supports, which ensure tube operation even for very long tube elements. With a classical A + Ethyl Bromide (a few percent) gas mixture, the tubes are operated in the Geiger mode.

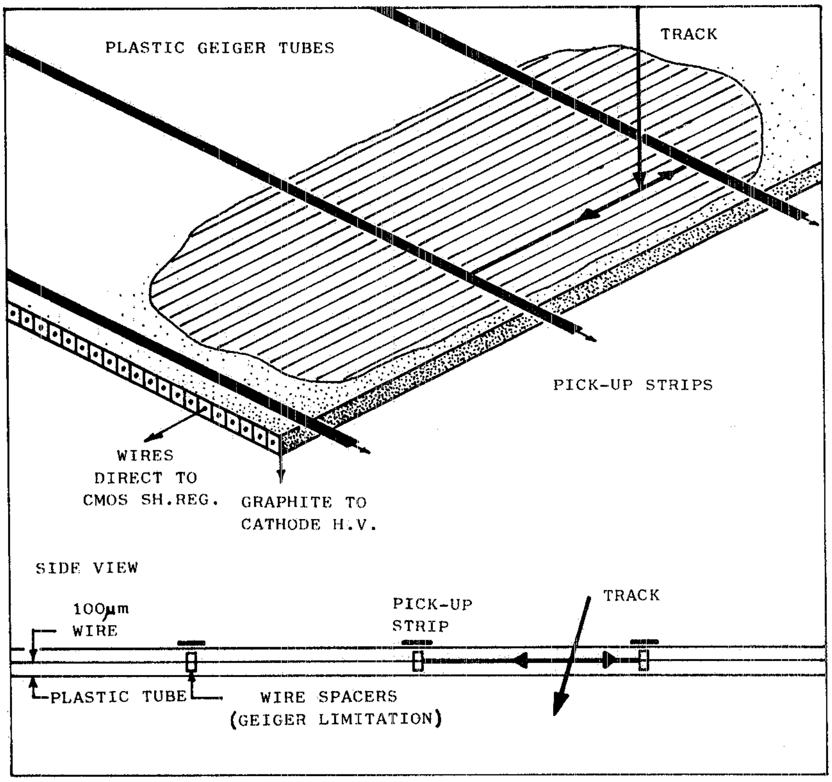

FIG. 1 - The Plastic Geiger Tube device, with strips to pick-up Geiger front.

The Geiger process initiated by the primary proportional multiplication, propagates along the wire on both sides of the track crossing point, and extinguishes itself in correspondence of the wire supports, which act as a Geiger limitation device. The Geiger current pulse is ~1 mA high and ~10 μs in duration and is sufficient to charge-up the capacitance of wires as long as 10 m or more, to a several volt amplitude. Therefore one coordinate of the tube can be read-out by direct connection of wires to a CMOS shift register. To provide the second coordinate measurement, external pick-up strips are placed across the tubes in correspondence of the Geiger limitation devices (one strip every 50 cm), where they pick-up the arrival and extinction of the Geiger front. The measurement of the delay time gives the track position along the wires. This possibility has been pointed out by G. Charpak and F. Sauli for MWPC operated in the Geiger mode(4).

We have tested in the limited Geiger mode the Mont Blanc plastic tubes (9×9 mm^2 cross section, 100 μm wires). They exhibit, as for the streamer mode, a singles counting rate plateau (negligible noise), as shown in Fig. 2.

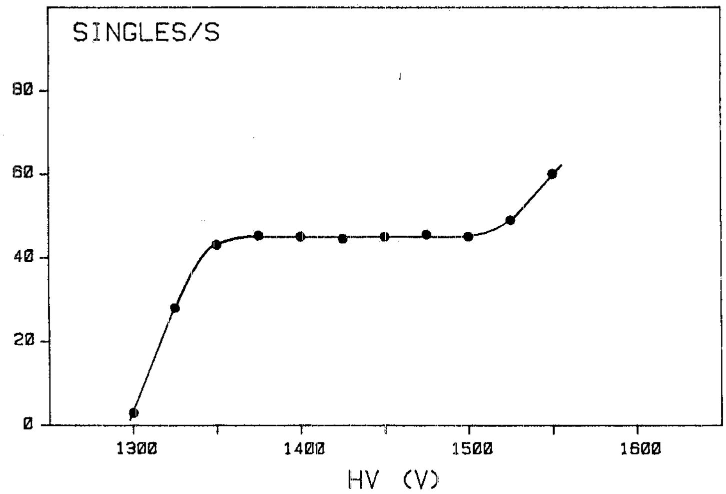

FIG. 2 - Singles rate vs. HV for a Geiger tube module with 100 μm wires; gas mixture: A + 2.6% Ethyl Bromide; the wires are connected to a CMOS GATE, with a 10 kOhm termination.

That was obtained with the gas mixture A + 2.6% Ethyl Bromide, and by connecting 8×1 m wires directly to a CMOS gate with a 10 kOhm termination. The typical wire pulse shape is shown in Fig. 3.

In that condition the Geiger characteristic propagation time is ~300 ns/cm. The typical pulse as picked-up by a cross strip (50 Ohm termination) at the Geiger limitation point is shown in Fig. 4. The useful portion of the pulse is the fast trailing edge.

Preliminary measurements show that a space accuracy of ~5 mm can be obtained. The leading edge of the Geiger pulse on wires, picked-up via a small capacitance on a 50 Ohm bus,

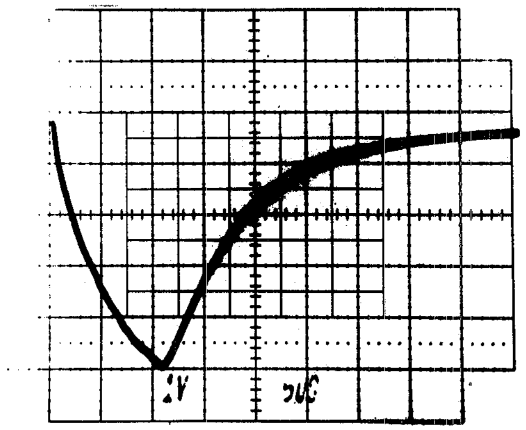

FIG. 3 - Typical Geiger pulse as detected on wires with 10 kOhm termination. Vertical scale 1V/div; horizontal scale 5 μs/div.

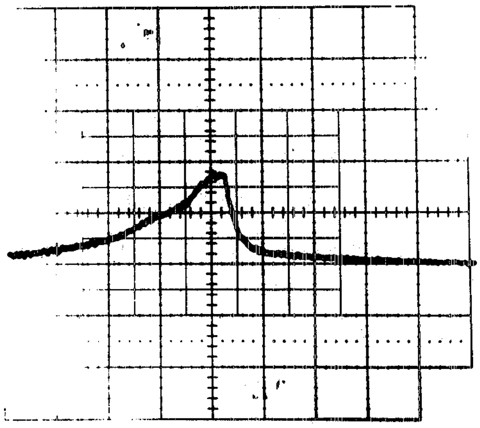

FIG. 4 - Geiger front pulse as detected on a cross strip facing the Geiger limitation point, on 50 Ohm termination. Vertical scale 10 mV/div; horizontal scale 500 ns/div.

can be used as timing signal and trigger element. Fig. 5 shows the time resolution for cosmic muons of a Geiger tube module, measured using a scintillation counter hodoscope as start signal.

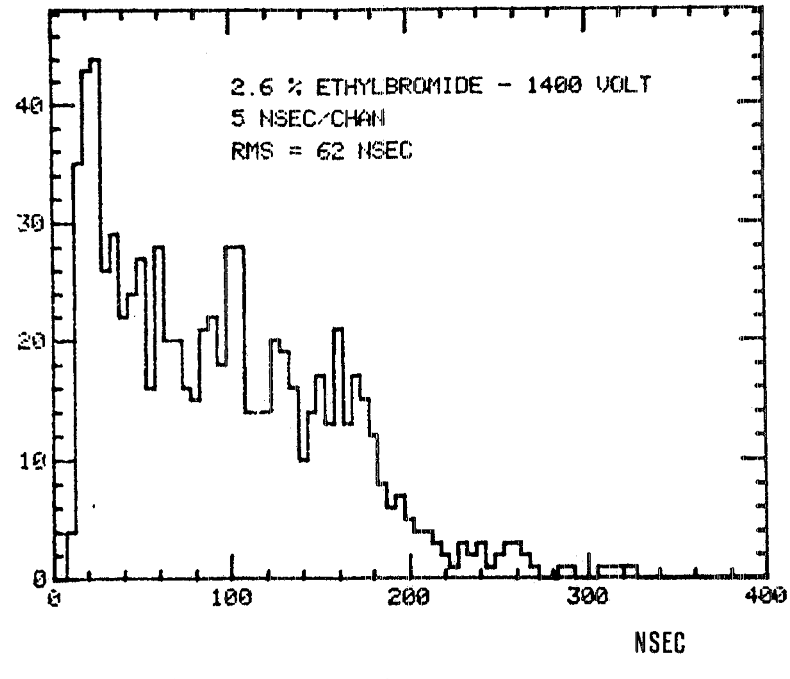

FIG. 5 - Time distribution on a Geiger tube module for cosmic muons.

The cost/m^2 for the Geiger projection readout is of the same order of the simple Shift Register readout on wires, for equal lengths of wires and strips.

Two features of this Geiger device are worth of mention, concerning reliability and operation simplicity: the non flammable gas mixture and the very low operation voltage (~1500 V).

3. - MODULARITY OF THE GPC.

Existing or proposed proton decay calorimeters, in the very large scale perspective, show two problems. The first one concerns the use of iron, which is expensive and difficult to assembly in the form of thin and large plates. The second one, actually the major one, concerns the lack of the proper kind of modularity; they typically consist of alternate layers of crossed elements. Due to the very large detector cross section, that implies the very individual components (sensitive elements, iron slabs, readout cards) to be put together in the underground laboratory, which is expensive. The point is that these p-decay calorimeters are big and finely textured buildings, to be built-up in an unconfortable place. The idea under study is to build-up the full detector by combining together large calorimetric modules: GPC modules (see Fig. 6) consisting of Plastic Geiger tubes embedded in a concrete block, with all active terminations (x-y signals, gas, H. V.) on one single face of the module. This structure is made possible by the fact that the second coordinate readout of the GPC is based on the use of a small number of passive elements (1 strip/50 cm).

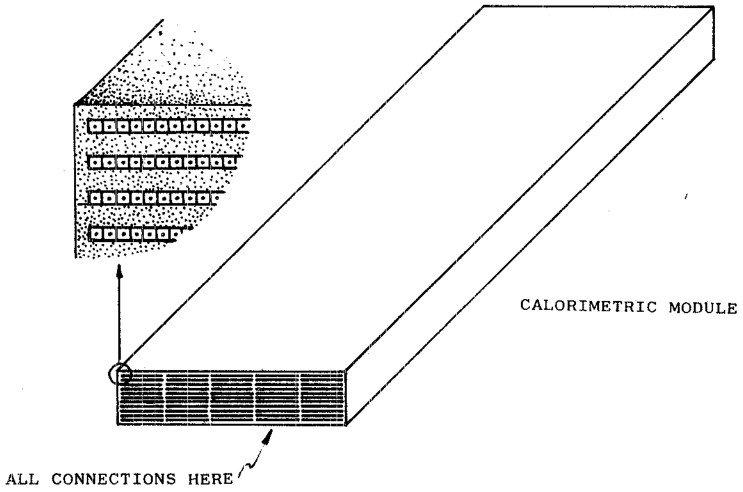

FIG. 6 - Sketch of the Geiger Projection Calorimeter module.

The increase in readout channels due to the shortening of the cross-strips, can be compensated by grouping together far apart strips (image overlap).

Permanent embedding of tubes in concrete implies a calculated risk approach, which is based on the possibility, specific of tube detectors, of getting rid of the single badly working wires, and on a supposed small probability of single wire failure ($< 10^{-3}$/year). The latter is consistent with the very early life of the Mont Blanc detector.

The dimensions of the GPC modules are fixed on the basis of full detector dimensions and transportation limits: the feasibility of 20 ton blocks, $10 \times 2.5 \times 0.4$ m^3 is being studied.

GPC blocks would be equipped with electronics and tested in the home laboratory. Various assembly configurations are possible: vertical or horizontal, crossed or parallel.

4. - DETECTION FEATURES.

The tube device granularity can be 8×8 mm^2, roughly equivalent on both views. Tracking capability with respect to the Mont Blanc detector would be improved by thinning the sampling thickness: ~ 0.2 instead of 0.6 r. l. The improvement would be not only due to finer longitudinal sampling, but also to the consequent reduction in density, which is equivalent to an improvement of the transverse granularity. Concrete density can be varied between 2.4 g/cm^3 (standard composition) to ~ 4.5 g/cm^3 (with a magnetite filling). At a constant sampling thickness of ~ 0.2 radiation length, the average detector density would be about 2 g/cm^3, roughly independent of concrete density. It is not clear which density is to be preferred, even ignoring technical aspects: fiducial/total mass, radiation/absorption length, nuclear effects, are differently influenced. Montecarlo studies are in progress in this respect.

Due to the sharp low edge of the time distribution of the wire pulses (Fig. 5), the effective time resolution is about 25 ns, when a likelihood fit is used. That is confortable for the $(K, \pi) \rightarrow \mu \rightarrow e$ decay identification, for which this detector actually exhibits a high efficiency (> 50%). It is worth of mention that for several meters deep detectors, that resolution is sufficient to determine the direction of flight of particles throughout the detector (identification of muons from very high energy neutrinos), see Fig. 7. However for efficient direction identification for relatively short tracks (p-decay, neutrino oscillations), counters with ~ 1 ns time resolution must be inserted in the concrete blocks. Very promising in this respect, for its low cost, is the spark counter device (Resistive Plate Counters) being developed in Rome by R. Santonico(5).

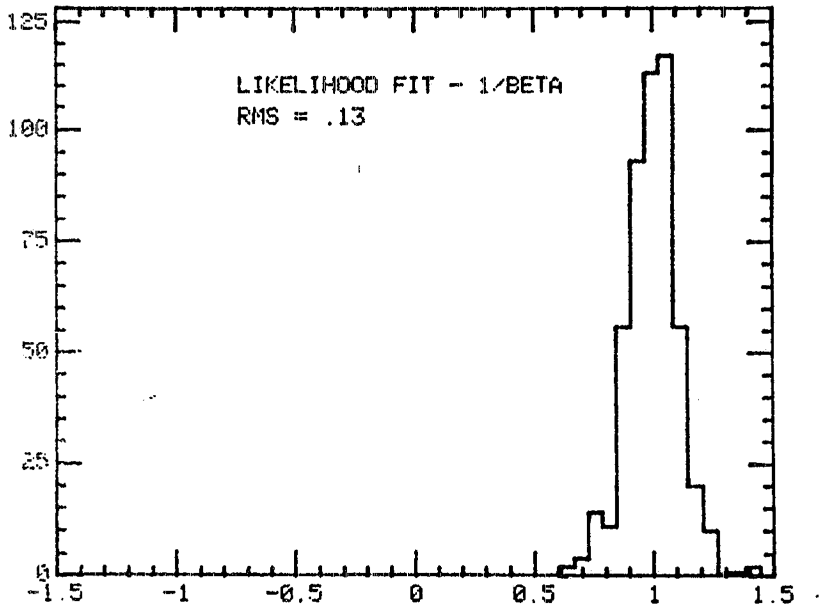

FIG. 7 - Expected velocity resolution for particles coming from the same direction, as obtained from Montecarlo calculations. Measured time distribution of Fig. 5 with likelihood fit has been used and 9.6 m long tracks with 320 time measurements have been generated. The minus sign on the horizontal scale indicates particles coming in the opposite direction.

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(4) - G. Charpak and F. Sauli, Nuclear Instr. and Meth. 96, 363 (1971).

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