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EAS WITH PLASTIC STREAMER TUBES AND OTHER GAS DETECTORS

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EAS WITH PLASTIC STREAMER TUBES AND OTHER GAS DETECTORS

G. Battistoni, C. Gustavino, F. Ronga and S. Torres
INFN- Laboratori Nazionali di Frascati , P.O. Box 13, 00044 Frascati (Italy)

ABSTRACT

We discuss the feasibility of a very large array for extensive air showers using very cheap gas detectors such as plastic streamer tubes and resistive plate counters. The cost of these devices is a fraction of the cost of a scintillator.

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INTRODUCTION

As discussed widely during this conference the behavior of the possible sources of very high energy photons seems to be highly variable. In particular the emission of Cygnus X3 seems to have changed during the past years and stopped during 1985. It is clear that the only way to solve those kind of problems from the experimental point of view is to build bigger apparatus capable to follow the variation of the sources. An array of 1km^2 should be capable for detection of very large energy showers with statistically significant signals each day (assuming as correct the flux measured from the Kiel experiment(1)). In order to have good angular resolution and to have the possibility to measure the shower profile the coverage with detectors of this surface should be of the order of 1%.

The price for a such array will be prohibitive using the traditional scintillator counters technique. The cost per m^2 of a scintillator counter, is of the order of 1,200-4,500 U.S. dollars per square meter of surface (the big spread on the prices depends mainly on the performances required).

The cost of a plastic streamer tube detector is of the order of 65 U.S. dollars per square meter, this is the reason why we have started to investigate about the possible use of this technique for an extensive air shower array.

The detector array should be capable of:

1) measuring the direction of the shower axes;
2) measuring the energy and the profile of the shower.

The direction of the shower axes can be determinated using the arrival time of the electrons on each counter. The error on this determination depends on the time resolution of the detector and on the intrinsic time spread of the electrons of the shower front (that is of the order of a few nsec).

In order to measure the energy and the profile of the shower the detector should be capable of counting the number of particles arrived. From the profile of the shower it is possible to have information on the kind of primary, if hadron or photon. In fact photons will interact high in the atmosphere and will have preferentially broad showers.

MONTECARLO

We have used a very simple Montecarlo in order to study the array performances: showers having average properties were generated and a square array of 1 Km^2 was used.

The showers were generated randomly inside the array surfaces. The density of electrons Δ was generated according the well know Greisen expression(2):

$$\Delta(r) = N_e \quad C(s) \left(\frac{r}{r_1}\right)^{s-4} \left(\frac{r}{r_1} + 1\right)^{s-4.5} \qquad (1)$$

$$r_1 = \frac{73.5\,T}{273\ P} \quad (T \text{ in } {}^\circ K \text{ and } P \text{ in atmospheres})$$

In this formula there are only two parameters: the total number of electrons and the age parameter s. The age parameter s has been used to try to identify the primary of the shower. At sea level the average value of s is 1.3 and the R.M.S. is .18. C(s) is a function of s. In the Montecarlo the number of electrons given from this formula was distributed according the Poisson law.

The arrival time of the particles was generate according to the distribution taken from Hillas $^{(3)}$. The particles at more than 150 meters from the core were not considerd for timing, due to the lack of information on the time distribution. At this time spread was added the spread due to the detector supposed to be gaussian. The sigma of this gaussian was scaled according to the square root of the number of particles, if more than one particle was hitting the detector.

After the shower generation a standard maximum likelihood fitting algorithm was used in order to find the direction, the profile, the total number of electrons and the position of the core.

For the angular resolution we have found that the results of the Montecarlo can be well summarized by the following expression:

$$\sigma_\theta = \frac{3.5}{\sqrt{(N_e\, \varepsilon_a)}}\,(1+.11\,\sigma_d) \qquad (2)$$

where the angular resolution (in space) is in degrees, N_e is the total number of electrons in the shower, ε_a is the fraction of surface covered with detectors, and σ_d is the detector time resolution in nsec.

This shows that the relative position of the detectors is not inportant: the only important quantity is the fraction of surface covered with detectors. This means that an array with large detectors at high separation (up to 100 meters) have the same angular resolution that an array with smaller detectors at smaller separation, if the total active surface is the same. Clearly to build an array with a small number of large surface detectors is easier than to build an array with a big number of small surface detectors, especially concerning the site preparation .

Also, 2) shows that the time resolution of the detector is not constrained to be in the nsec range. An array with detectors having 10 nsec of time resolution will have angular resolution approximately 2 times bigger than an array with negligible time resolution.

The situation with the total number of electrons and the age parameter s is different. An array with big detector at high separation has a worse performance than an array of small detectors at small separation. Fig 1a) and 1b) shows the errors on the age parameter s, and on the number of electrons, as a function of counter separation. The conclusion is that for the profile determination alone a detector at small separation (less than 50 meters) and a good coverage (of the order of a 1% or more) should be used.

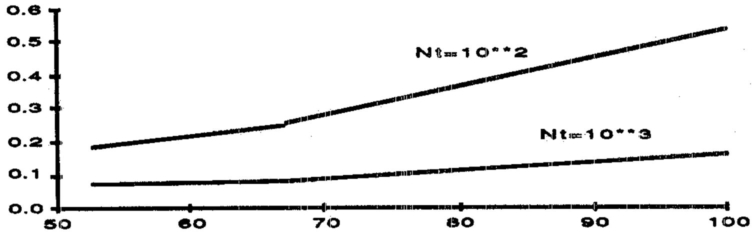


FIG. 1a - Fractional error on the number of particles as a function of the counter separation in meters; Nt= $N_e \varepsilon_a$.

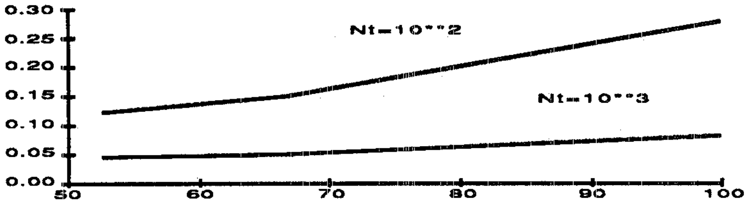


FIG. 1b - Error in the age parameters as a function of the counter separation in meter; Nt= $N_e \varepsilon_a$.

PLASTIC STREAMER TUBE

The plastic streamer tube device, of the kind used in the NUSEX(3) detector, is described in detail in references (4,5). The basic ideas of this device are the operation in an almost saturated regime, denominated self quenching streamer mode, and the use of resistive cathode. Streamer operation mode is obtained by using thick wires and highly quenching gas mixtures, and is characterized by big pulses (~1 mA peak current); this allows the use of a cheap readout electronics. The wire thickness gives an improved mechanical reliability. Fig. 2 shows the structure of the plastic streamer tubes of the NUSEX experiment. The construction of the detector is very simple because of the use of plastic material (PVC) as main component. The cathode function is obtained by a graphite coating of the PVC profiles. The use of resitive cathode is advantageous in many aspects, because it allows an external readout by pick-up electrodes, decoupled from the high voltage, thus permitting a bidimensional readout on the same wire plane, if needed.

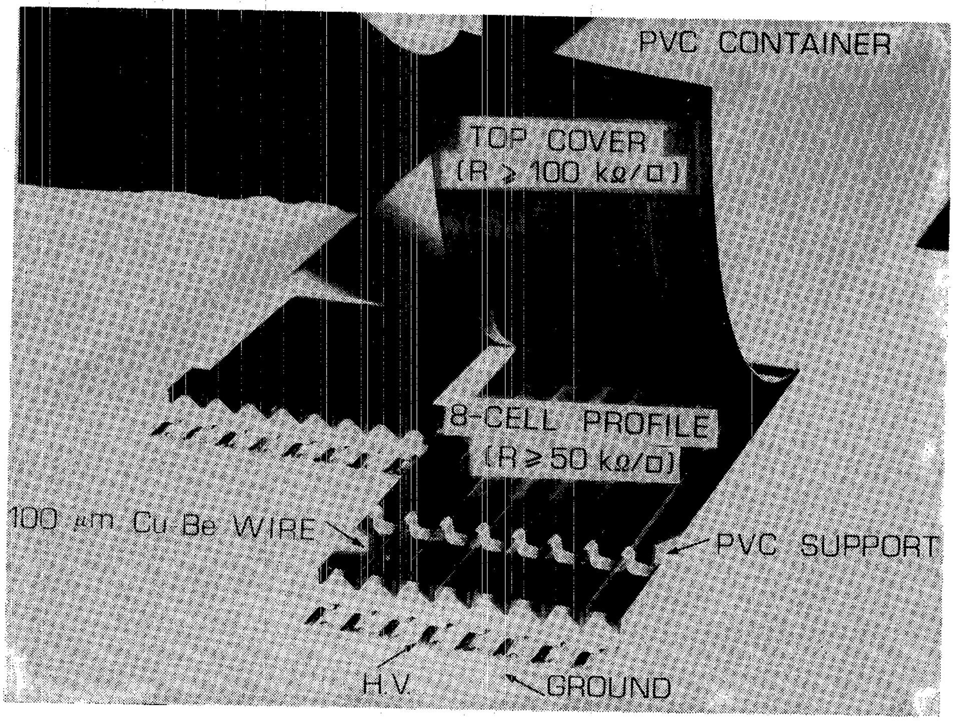


FIG. 2 - The plastic streamer tubes of the NUSEX experiment.

Briefly the main steps of the construction are:

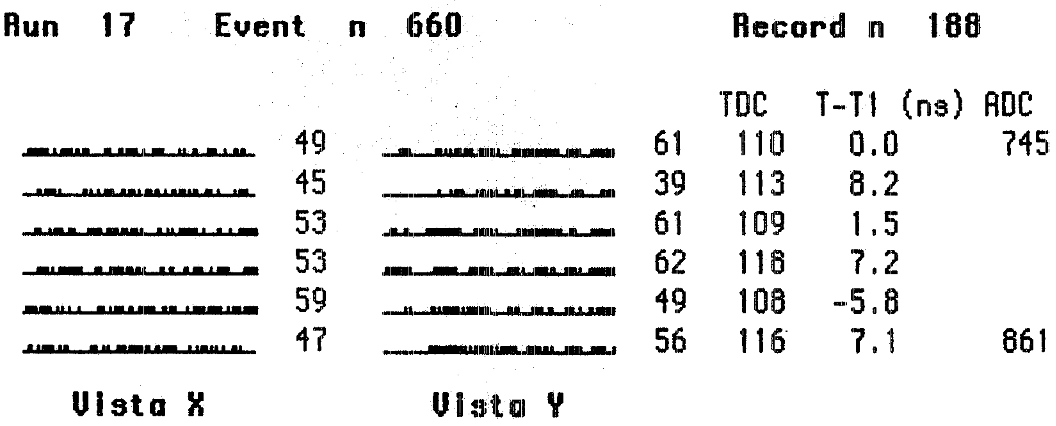
1) extrusion of the PVC;
2) painting with graphite based conductive paint;
3) wiring;
4) assembling.

These devices exhibit a stable, noiseless, and fully efficient operation in a wide high voltage range, for tube diameters down to to a few mm, and wire diameters in the range 40 ÷ 220 μm. The reliability in experimental conditions has shown to be extremely high(4).

There are now various high energy particle physics laboratories that have equipment for building such devices. In Frascati the typical building speeds are about 80 m^2 per day for the painting and 25 m^2 per day for the wiring (lenght=5 meters). The cost of a such device is about 65 U.S. dollars per m^2 for a profile lenght of 5 meters (the cost is a linear function of the length plus a constant).

Usually these devices are used as tracking detectors (NUSEX) or for calorimetric applications, in which many channels of electronics must be provided and strip or pad must be be put on the plastic streamer tubes, in order to pick up the signals. For E.A.S. the situation is simpler because for each detector we need to know only the arrival time and the charge collected. The time resolution of this kind of device is limited from the time necessary to collect on near the wires the ions left from an ionizing particle.

In order to study the performances of this kind of detector for E.A.S. we have used a telescope of streamer tubes (1 cm^2 cell size) consisting of 6 planes of 1.8 m^2 of surface. Each planes had a TDC for the time recording. The first and last plane had an ADC for recording the charge. Each plane had also digital readout in both views (this is not necessary for E.A.S.).



```
Run  17    Event  n  660             Record n  188

                                  TDC   T-T1 (ns)  ADC
           49             61      110     0.0      745
           45             39      113     8.2
           53             61      109     1.5
           53             62      118     7.2
           59             49      108    -5.8
           47             56      116     7.1      861
   Vista X        Vista Y
```

FIG. 3 - An example of atmospheric shower in the telescope.

In FIg. 4 is reported the distribution of the average arrival time of 6 planes for single particles, obtained when triggering with cosmic muons. The time resolution is of the order of 25 nsec (R.M.S. of a single plane). The charge resolution is of the order of 25%.

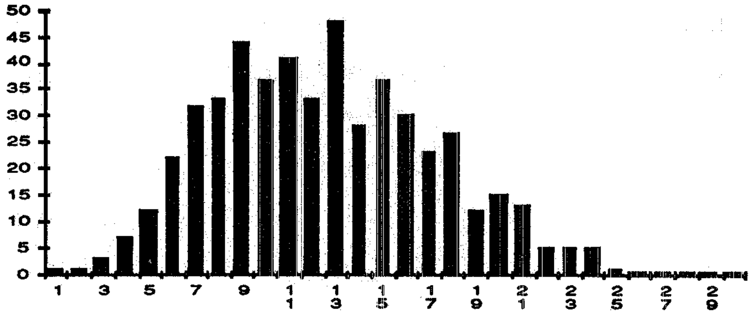


FIG. 4 - Distribution of time-plane – average time of 6 planes; 1 ch = 5 nsec the R.M.S. of the arrival time on one plane is 25 nsec.

As said before the only effect limiting the time resolution is due to the finite drift velocity of the ions. If more than one particle hit the planes of streamer tubes the time recorded will be the time of the particle nearest to the wire. So the time resolution will become better: it will scale approximately with the square root of the number of particles. This has been proved triggering the telescope with atmospheric showers (in Fig. 3 a typical shower event is shown).

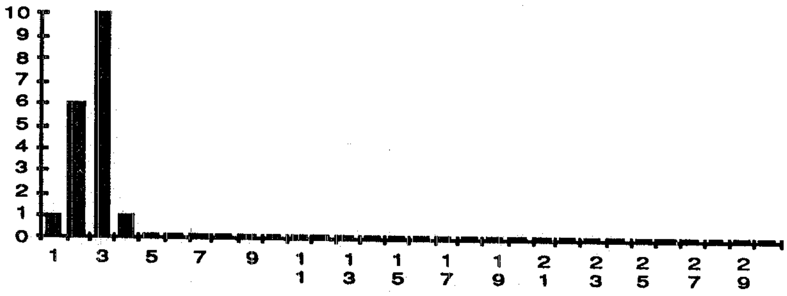


FIG. 5 - Distribution of time-plane – average time of the 6 planes for ≈ 40 particles. The R.M.S. of time-plane is 3.3 nsec.

For an average number of 40 particles per planes (evaluated from the digital readout and the ADC's) we have obtained 3.3 nsec of time resolution (Fig. 5).

A big advantage of this detector for a possible use in EAS is that it is a noiseless device. This means that all the counts are due only to ionizing particles: this is very useful for a continuous monitoring of the device.

Usually these devices have been used with a continuous flow of gas, but sealed counters have been tested in laboratory. This kind of device could have problems at temperature near zero with the standard mixtures, because of the isobutane condensation. A part from this, no strong requirement on the temperature are required.

The mechanics of this detector is very simple and in particular the weight is very small. This will simplify the building of an EAS array.

RESISTIVE PLATE COUNTER

This kind of device$^{(6)}$ is a cheaper and simpler version of the Pestov and Fedovitch device. It consists of a 2 mm gap between two bakelite parallel plate electrodes. A dc high voltage of the order of 10 Kv is applied. When a particle crosses the gap a spark is generated. The discharge, however, is prevented from propagating through the whole gas because of the high resistivity of the electrodes, the electric field is suddenly switched off in a limited area around the point where the discarge occurred.

Due to the parallel plate geometry the drift times are all equal. So the time resolution is very good, less than 1 nsec.

This kind of device until now has been used only for the Nadir neutron antineutron experiment. The device is not noiseless; this means that in order to have a noiseless device two counters must be operated in coincidence. The noise increases with the temperature and this could be a problem for E.A.S. if conditioning is not provided. For very low temperature they have the same limitations of the plastic streamer tubes.

The estimated cost is of the order of 260 U.S. dollars per m^2.

PLASTIC STREAMER DETECTORS AND EAS ARRAYS

The main advantage of a plastic streamer detector is its low price that is more than a factor 20 cheaper than a scintillator counter. Another big advantage is the easiness of calibration and monitoring due to the noiseless operation of the devices.

The time resolution at a first look seems not good for an E.A.S.; but for a very big array this is only partially true, because of the big number of particles hitting the detectors.

As we have said before If we want to know the profile of the shower we need to have large active surfaces, of the order of 1% of the total surface. For example for an array having 1Km^2 of surface and a coverage of 1% 41024 counters each having 9.8 m^2) we have :

N_e	σ_θ	σ_s
10^4	1°	.12
10^5	.31°	.05

The cost of the detectors for this array is of the order of 700.00 U.S. dollars. Using scintillator the cost will be at least a factor 20 higher with the same resolution for the age parameter s and a gain in the angular resolution of a factor 3. To this cost should be added the cost of the electronics and of the site preparation.

Increasing the surface by a factor 10 the streamer tube arrays will have the same angular resolution of the scintillator arrays but still at a price a factor 2 below that of the scintillator array.

In conclusion plastic streamer detector arrays seems to have better performance/cost ratio with respect to scintillator counters and it is interesting to have in mind this kind of solution for the next generation of EAS array.

The resistive plate counters have a good chance to become another valid alternative to the scintillator counter technique if some problems, due to the stability and to the still higher price, will be solved.

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