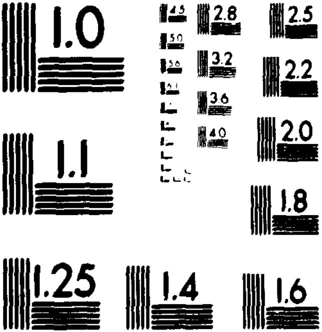

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS
STANDARD REFERENCE MATERIAL 1010a
(ANSI and ISO TEST CHART No. 2)

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PLASTIC SPARK COUNTERS WITH PVC ELECTRODES

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Abstract

The performance of a spark counter based on plasticized PVC is described. The relevant features of this detector match the requirements of surface and underground cosmic ray experiments. Its technological characteristics allow large area detector construction.

INTRODUCTION

In the framework of the study of new apparata for extensive air showers of cosmic rays, we have considered the application of spark counters. For this purpose a time accuracy of the order of only a few nanoseconds is required(1). Low cost, reliability and easy monitoring are of relevant importance.

So far the development of plate spark counters(2) with resistive electrodes has shown the possibility of reaching high time accuracies and good space resolution at the same time, but their use has been limited by the strict technological requirements due to the high gas pressure and to the degree of mechanical tolerances needed for gaps of 0.1~0.2 mm. They require electrode materials with volume resistivity in the range 10^9-10^{11} $\Omega \cdot$cm, with a sufficient degree of homogeneity; for this purpose some resistive glasses have been successfully proposed, but they are rather expensive and of difficult availability. In practice all these limitations become prohibitive for large area counters.

In order to reduce the technological difficulties it has been developed a new type of resistive plate counter (RPC)[3], to be employed whenever a time resolution of the order of hundreds of picoseconds is sufficient. In this detector the resistive electrodes are made out of a phenolic thermosetting resin denominated Bakelite. The counter gap is of the order of 1.5 ÷ 2 mm, and the gas circulation is at the atmospheric pressure. Anyway, the RPCs, as the other spark counters, exhibit a noisy operation, i.e. the production of spurious sparks, and the use of thermosetting materials is restrictive as far as the construction technology is concerned.

We describe here a new plastic spark counter based on plasticized PVC. While rigid (unplasticized) PVC has a volume resistivity of the order of 10^{15} Ω·cm, the addition of plasticizers to obtain the standard commercial soft PVC, lowers resistivity down to 10^{11}÷10^{12} Ω·cm[4]; by doping with ionic compounds, a volume resistivity around 10^8 Ω·cm can be easily achieved[5].We show that the use of commercial plasticized PVC allows the construction of spark counters with noiseless operation and time resolution of the order of 1 ns. Furthermore the use of a material such as PVC makes possible to exploit the thermoplastic material technology which allows to conceive easy construction procedures for large area counters.

PROTOTYPE DESCRIPTION

Fig. 1 shows the cross section of one prototype. The active volume containing the gas mixture is delimited by two parallel plate electrodes made of plasticized PVC, 1 mm thick. The volume resistivity is ~10^{11} Ω·cm. High voltage is supplied to the PVC electrodes by means of a graphite coating on the surface not in contact with the gas. The varnish is a commercial solution of graphite in methyl-isobutyl-ketone, and the surface resistivity is ~10kΩ/square. A copper strip provides the electrical contact with the high voltage. The graphite-coated surface of each electrode is glued to a rigid PVC plate, acting as insulator and mechanical support at the same time. A 2 mm gap between the two electrodes is provided by a rigid 2 mm thick PVC frame, which delimits an active surface of 20 x 20 cm^2, and by a PVC spacer, 2 mm thick, 10 mm in diameter, placed at the center of the active surface. The spacer is glued to both electrodes and prevents possible mechanical deformations of the structure. The gas flows through two connections in the PVC frame.

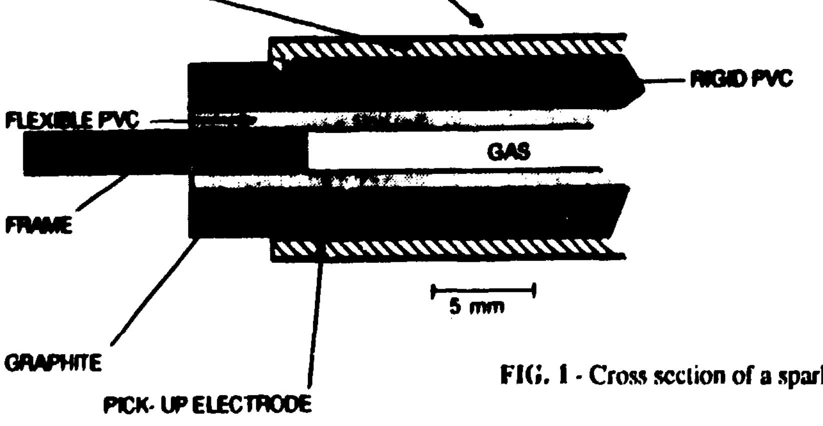

FIG. 1 - Cross section of a spark counter prototype.

A pad (20 x 20 cm^2) made of a printed circuit board with copper on both faces is placed on each PVC plate in order to pick-up the induced pulses. The surface resistivity of the graphite coating provides good transparency[(6)]. The outer faces of the pads act as reference electrodes.

The structure of the counter is symmetrical, and balanced electrical connection and readout is possible, as shown in Fig. 2. The H.V. acrcss the counter is supplied by two H.V. power supplies, symmetrically with respect to ground. The two pads give pulses of opposite sign.

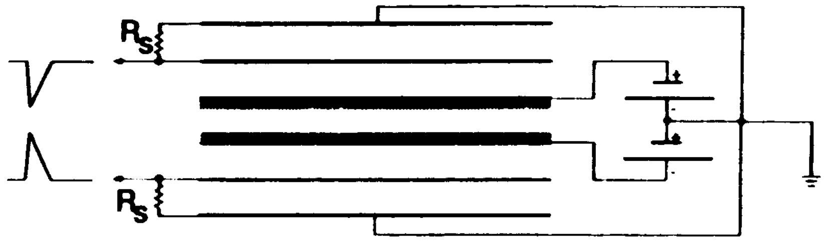

FIG. 2 - Layout of the electrical connections

EXPERIMENTAL TEST

The test counters have been flowed with an Argon (60%) + isobutane (38%) + Freon 13B1 (2%) gas mixture, at atmospheric pressure. A minimum ionizing particle crossing the gap at normal incidence is expected to give ~7 primary ion pairs in the average. The spark regime is achieved above ~7 kV. The two pads are readout on a 50 Ω impedance; Fig. 3 shows the induced pulses on one pad at 9 kV. The pulses exhibit a definite threshold in amplitude at about 50 mV/50 Ω, thus reflecting the threshold behaviour of the breakdown mode. Their shape is triangular, with a base width of about 100 ns. We expect a fast rise time: the pulses in the picture are slightly integrated by the pad capacitance (1.4 nf). Peak amplitude varies slowly with high voltage (~5%/100V).

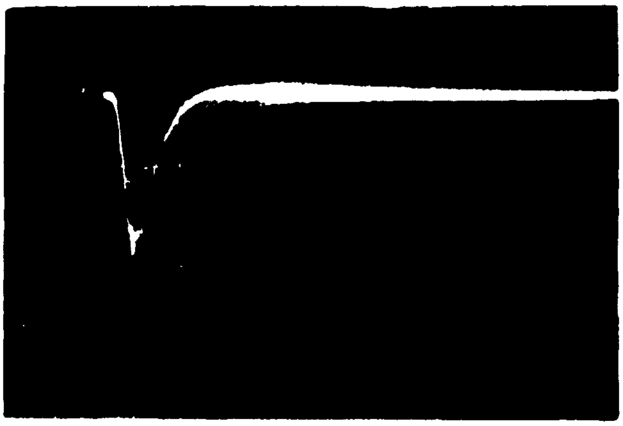

FIG. 3 - Induced pulses as detected on one pad at 9 kV, termination on 50 Ω. Vertical scale 50 mV/div, horizontal scale 100 ns/div.

A test counter has been inserted in a scintillator telescope, selecting cosmic ray muons, around the vertical direction, within the active area of the counter. The spark counter pulses are discriminated with a 20 mV/50 Ω threshold, and the coincidence rate with the trigger telescope is measured. Fig. 4 shows the resulting detection efficiency of the spark counter as a function of high voltage. A plateau is reached, at about 8 kV, at a level of ~98%. The efficiency loss due to the PVC spacer is less than 1%.

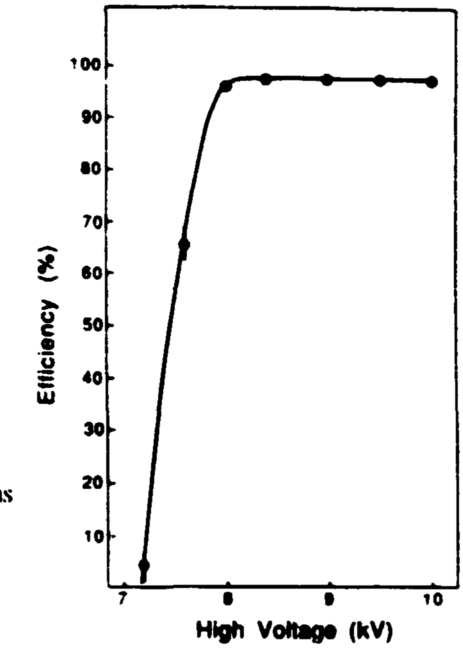

FIG. 4 - Detection efficiency as function of high voltage, as measured with cosmic ray muons.

Fig. 5 shows the singles counting rate as a function of high voltage. A plateau region 1 kV wide is clearly visible, in correspondence of the maximum efficiency region. This shows that this spark counter has a wide noiseless operation range, i.e. where only particles are counted. An instability region is reached above 9.2 kV. Cosmic rays and local radioactivity contribute to the counting level (~600 Hz/m^2). The plateau is also obtained at higher counting rates, for instance when a non collimated ^{90}Sr source illuminates the counter.

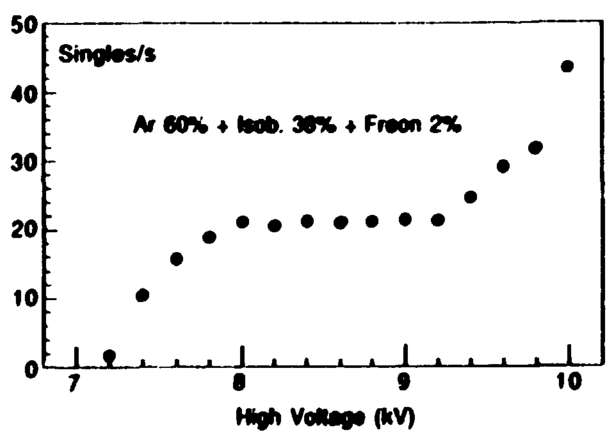

FIG. 5 - Singles counting rate as a function of high voltage.

The singles rate plateau characteristics (position of the knee, width, and counting level) are reproducible in the different prototypes. The knee of the plateau, i.e. the beginning of the maximum efficiency region, and the plateau width are dependent on the gas mixture. A detailed investigation is in progress in this respect.

We have measured the time resolution of the spark counters with cosmic rays, using a telescope in which two identical counters are used. The time difference between the leading edges of the pulses from the two counters (5 mV/50 Ω threshold) have been measured by a CAMAC TDC. Fig. 6 represents the time difference distribution at 9 kV. In the hypothesis that the two counters give the same time dispersion, the time resolution s is obtained from the measured resolution σ_{exp} by:

$$\sigma^2 = \frac{\sigma^2{}_{EXP}}{2}$$

Fig. 7 shows the time resolution obtained as a function of high voltage. No corrections have been introduced to take into account the slewing due to the amplitude jitter. In the operation range corresponding to the plateau region, a time resolution of the order of 1 ns is easily achievable. The worsening at higher voltages is due to unstable operation conditions, where spurious sparks are generated. The obtained resolution is largely within the requirements of an apparatus for extensive air showers, where an angular resolution of ~ 1 degree is achievable with a few ns time resolution. Anyway it must be noticed that the counter performance can be considerably improved requiring a better uniformity in the gap: in our prototypes we only asked for a tolerance of ~10% of the gap.

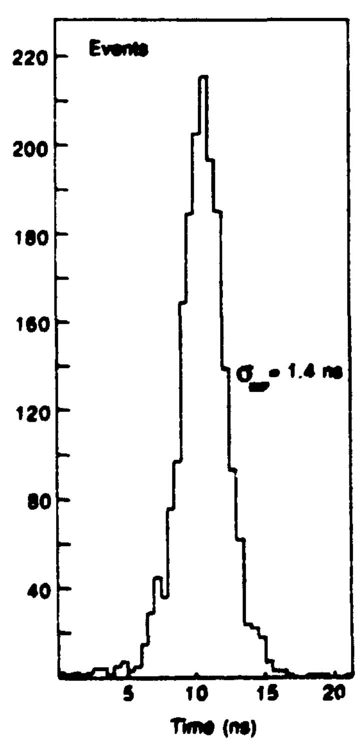

FIG. 6 - Distribution of the time differences between two identical spark counters.

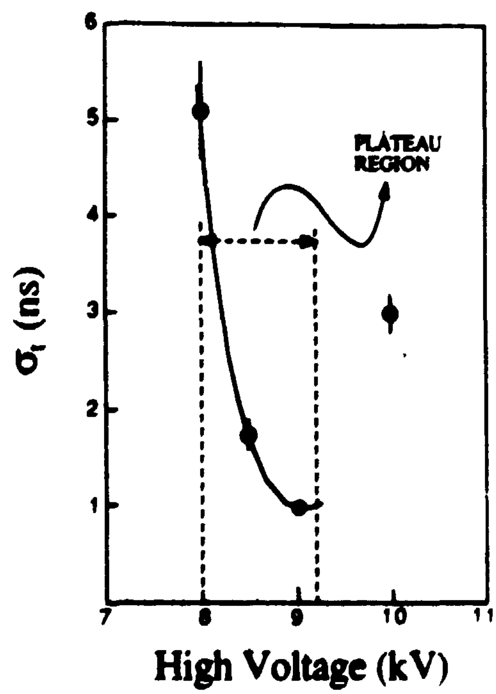

FIG. 7 - Time resolution as a function of high voltage.

CONCLUSIONS

The obtained results show that commercial plasticized PVC can be successfully used as resistive electrode in spark counters with localized discharge. At resistivities of $\sim 10^{11}$ $\Omega\cdot$cm the spark counters can be operated up to background rates of 10^3 counts/s·m^2 without any appreciable saturation(7). The local counting rates due to ambient radioactivity and cosmic rays are below this limit in most of the sites dedicated to EAS arrays.

The detector here described is also well suited for large area underground experiments, where a time-of-flight system can be used to discriminate the upward going muons, produced by neutrino interactions in the surrounding rock, from the downward going atmospheric muons. The same detector can also provide two-coordinate localization, by means of strip readout, with an expected resolution of ~ 2 mm on both views.

The noiseless operation exhibited by the PVC spark counters is of extreme importance in a large area apparatus, because it allows easy monitoring and calibration.

If lower resistivities are necessary, in order to operate the spark counters at higher local counting rates, the electrical properties of PVC can be adjusted by proper doping, without altering the mechanical characteristics. However, further work is needed in this respect.

AKNOWLEDGEMENTS

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REFERENCES

1) G. Battistoni et al., *EAS with Plastic Streamer Tubes and Other Gas Detectors*, LNF-86/4(P), and Proc. of the Workshop on HE-UHE Behaviour of Accreting X-Ray Sources, Vulcano (Italy) 1986, ed. by F.Giovannelli.
2) W. Braunschweig, Physica Scripta, 23 No. 4:1 (1981) 383; P.J. Carlson, Physica Scripta, 23 No. 4:1 (1981) 392; G.V. Fedotovich, Yu.N. Pestov and K.N. Putilin, Proc. of the In. Conf. on Instrumentation for Colliding Beam Physics, Stanford 1982.
3) R. Santonico and R.Cardarelli, Nucl. Instr. and Methods, **187** (1981) 377.
4) W.V. Titow, *PVC Tecnology*, Elsevier, Amsterdam 1984.
5) R. Galeazzi, European Vynil Corporation, Laboratori di S.Donato Milanese (Italy), private communication.
6) G. Battistoni et al. Nucl. Instr. and Methods **202** (1982) 459.
7) C. Gustavino, Thesis, University of Rome, 1987, unpublished.