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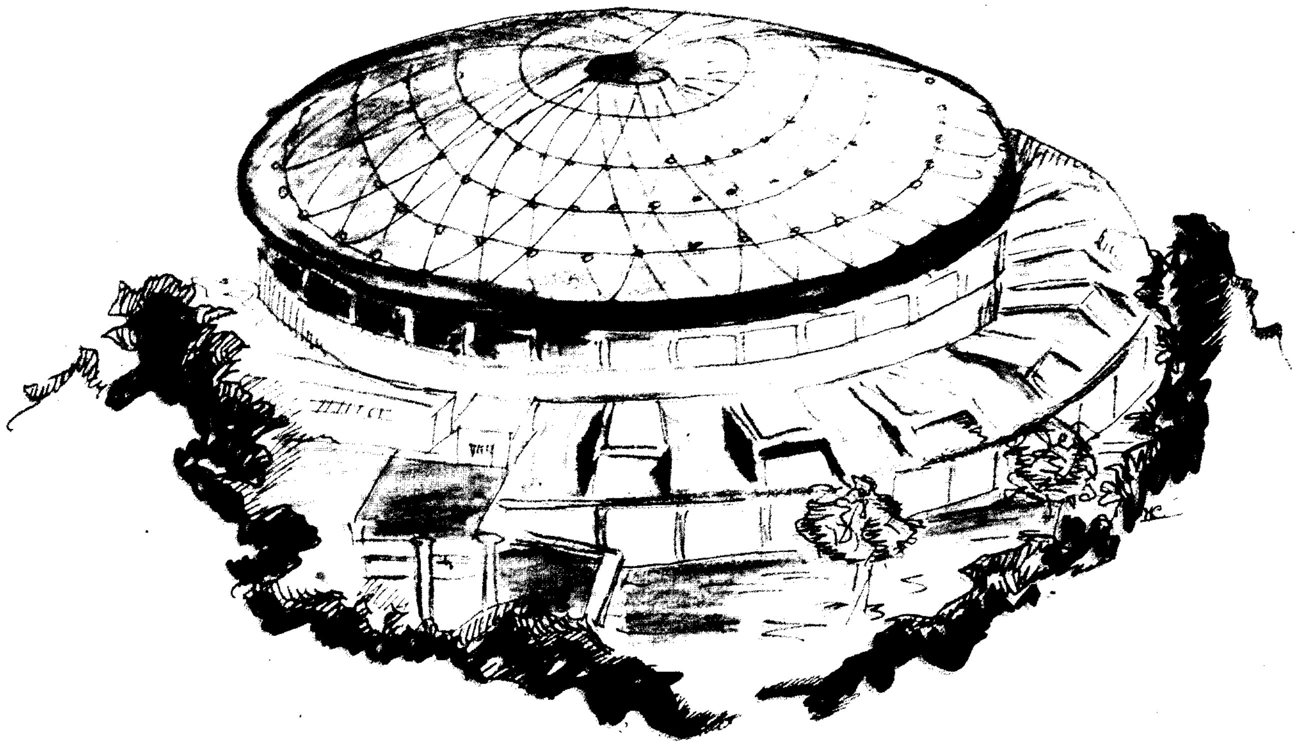

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A MODULAR DESIGN FOR GLASS SPARK COUNTERS

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ABSTRACT

In this paper a fully redesigned Glass Spark Counter is described. The detector exhibits noiseless operation and a time resolution less than 1 ns. The performance make this detector a good candidate for large area cosmic ray experiments. The simple assembling procedure allows large sensitive area at low cost.

INTRODUCTION

Spark gaps with resistive electrodes are usually named spark counters. These detectors can reach very high time accuracy and good space resolution at the same time. The first spark counters were developed by a group at Novosibirsk [1]. The electrodes of this detector are made out of semiconductive glass, the gas gap is of the order of 100 μm and the device is operated at high pressure (~10 bar). With this detector time resolution of several tens of picoseconds have been reached.

In order to reduce the cost and some technological difficulty, a group at Rome developed a large ($2m^2$) detector named Resistive Plate Counter (RPC) [2]. In this detector the gap is 2 mm and the electrodes are made out of phenolic resin called bakelite. The device, operating at atmospheric pressure, has a time resolution of the order of 1 ns. However, in spite of the electrode surface treatment, this device exhibits noisy operation, making difficult the calibration and monitoring of the detector.

In extensive air shower arrays and high energy neutrino experiments [3,4,5] detectors with a time resolution of 1 ns and good tracking performances (~1 cm) are often required. Taking into account the dimension of such apparata, it is of extreme importance to use detectors easy to calibrate and to monitor, inexpensive and easy to construct.

Some of us showed the possibility to use commercial glass as electrode to realize a noiseless device (Glass Spark Counter – GSC) with good performance [6,7,8].

In this paper we describe a modular design for the GSC. This design allows the realization of large sensitive planes at low cost, because of the simple assembly and the cheap material used. A gap uniformity of the order of 1% is obtained, allowing a time resolution less than 1 ns.

In the following we discuss the detector design, glass electrode properties, detector performances and long term tests.

1 - GSC DESIGN

A sketch of the GSC design is shown in Fig. 1. It consists of two glass electrodes 2 m long, 8 cm wide and 2 mm thick. The 2 mm distance between the electrodes is ensured by PVC spacers inserted without gluing at the edges of the plates. The spacers are 1 cm long, 5 mm large and are placed 20 cm apart. The high voltage is applied to the electrodes by means of a coating of water–based graphite, with a surface resistivity of about 100 kΩ/square. The detector is inserted in an extruded PVC envelope, which acts as a gas container. The H.V. connections to the graphite are located in one of the two end caps which close the GSC module. The gas flows along the module through inlets on the end caps. External pick–up electrodes (not shown in Fig. 1) are used to detect the induced pulses, transmitted through the resistive graphite coating applied to the electrodes.

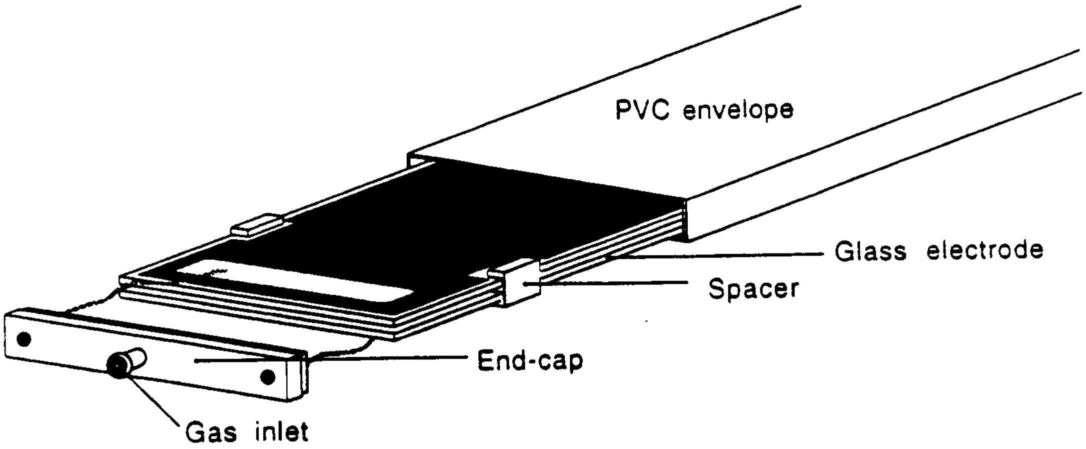

FIG. 1 – Sketch of a GSC module.

The advantages of this design with respect to the one of standard RPC are manifold:

- The gas containment is ensured by the external PVC envelope and not by the electrodes themselves. This solution allows uncritical gas pressure operation, avoiding any change of the distance between the electrodes.
- The use of a discrete number of spacers instead of a continuous frame minimizes the geometrical dead zone.
- The "E" shaped spacers sustain both the electrodes such that the curvature of the glass is the same for both plates, thus maintaining the gap uniformity. Fig. 2 shows that the maximum glass sagitta for spacers 20 cm apart is less than 100 μm. However, as shown in Fig. 3, the measured gap uniformity is about 20 μm.
- The long structure of the modules optimizes the gas flowing.

- The simple assembling minimizes the manpower; a preliminary estimate of the costs for a large production is of the order of 100 \$/m^2 [9].

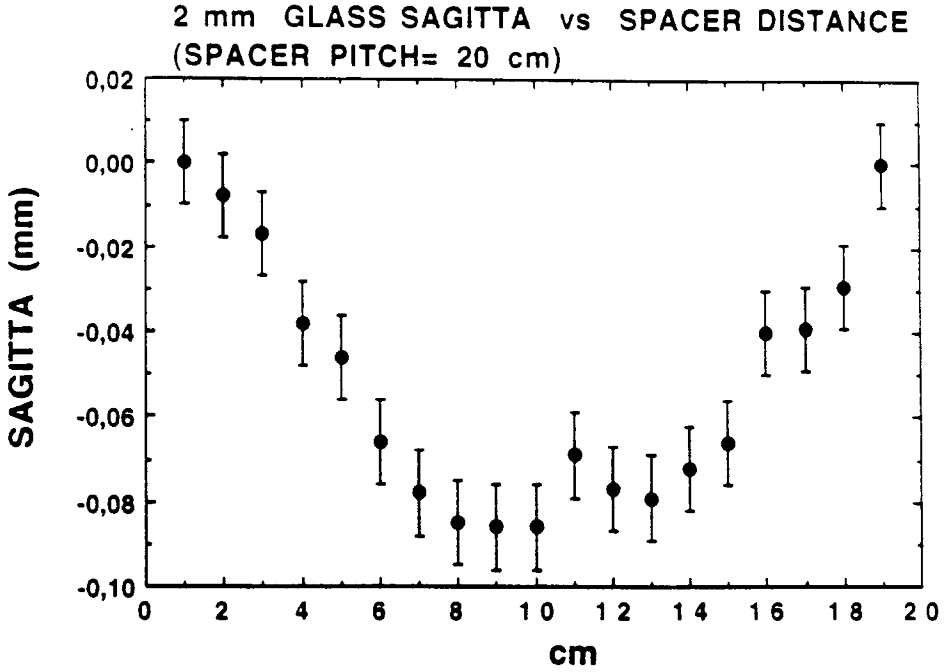

FIG. 2 – Glass sagitta as a function of the distance for spacers 20 cm apart.

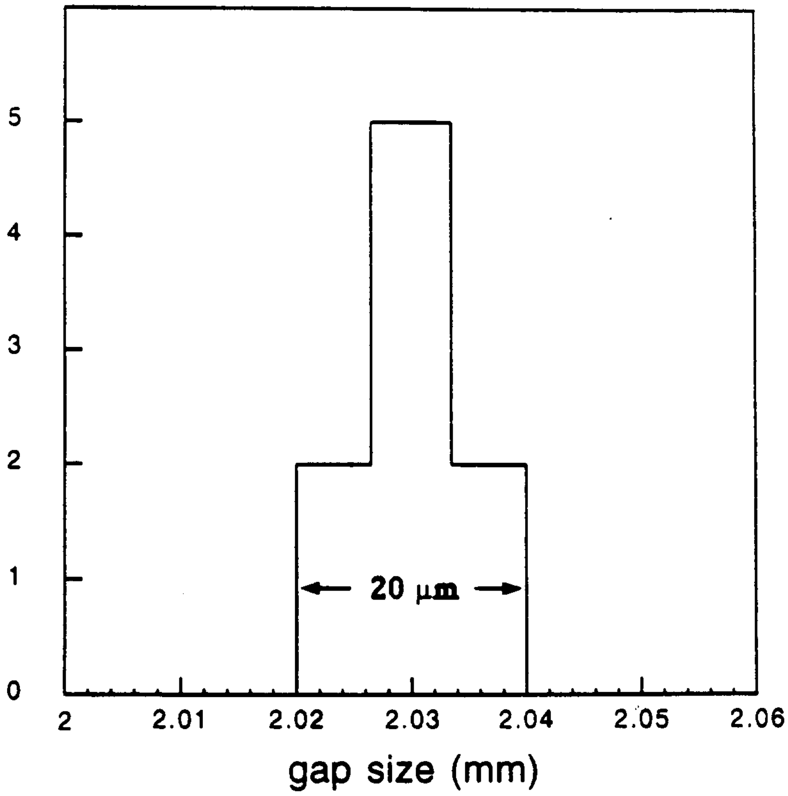

FIG. 3 – Distribution of the distance between the electrodes.

In Fig. 4 is shown the high voltage connection side of a module, before the insertion in the PVC envelope. Fig. 5 shows a 0.5x2 m^2 plane obtained by placing 6 GSC modules one next to the other.

The GSC design is open to further developments. A possibility is the use of larger electrodes, say 20 cm wide, in order to minimize the geometrical dead zone of a plane. A production of about 150 modules (8 cm wide, 1 m long), is now in progress, to realize a sampling calorimeter prototype.

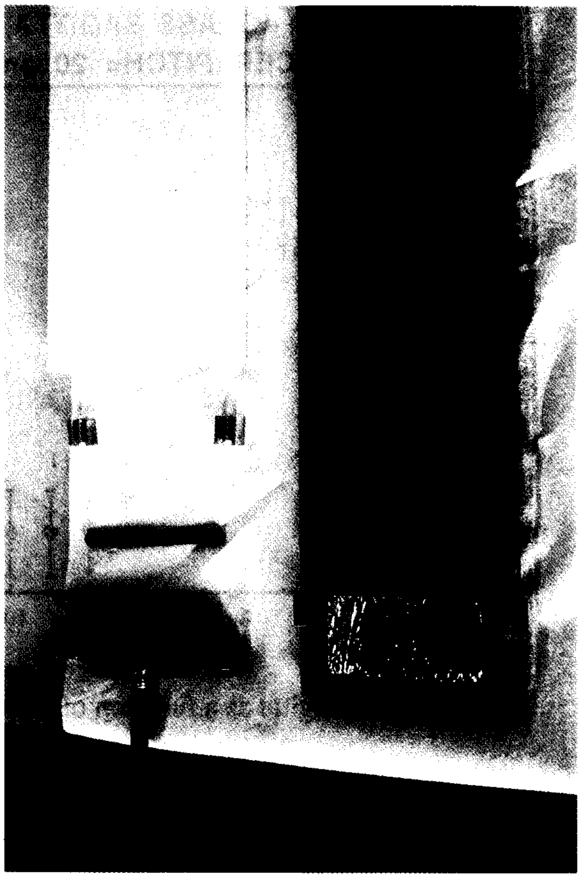

FIG. 4 – H.V. connection side of a GSC module.

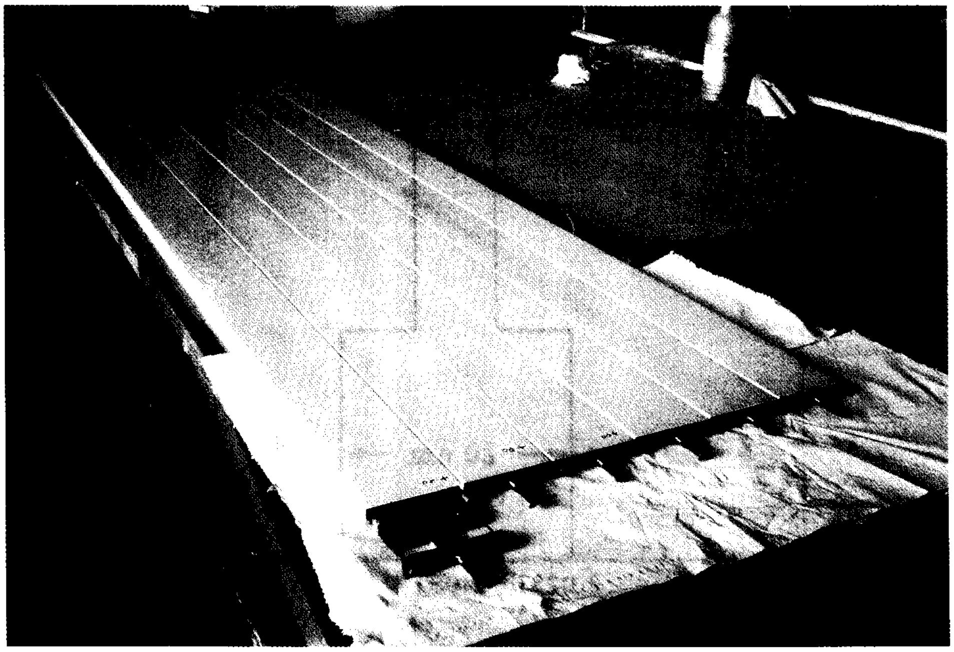

FIG. 5 – A 0.5 x 2 m GSC plane.

2 - FLOAT GLASS ELECTRICAL PROPERTIES

Fig. 6 shows the volume resistivity at room temperature of a sample of commercial float glass. The resistivity, around $\rho \approx 10^{12}\Omega$cm, allows the use of this kind of glass to realize GSC for low rate application [8].

The float glass stability was tested by applying a 2kV voltage to a glass sheet for several tens of days. The result is shown in Fig. 7. We note that, apart from temperature fluctuations, the resistivity does not change with the time. After 52 days, the total integrated charge flowed through the glass sheet is about 10 mC/cm^2. The same charge would flow through the device in a time greater than 10 years, at an incident particle rate of 600 Hz/m^2.

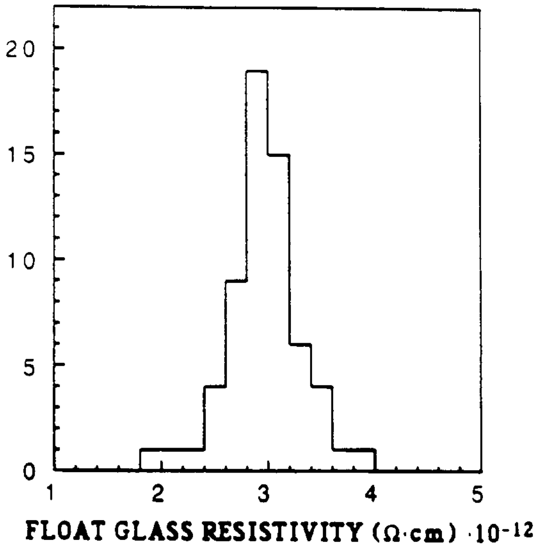

FIG. 6 - Distribution of the volume resistivity of a float glass sample.

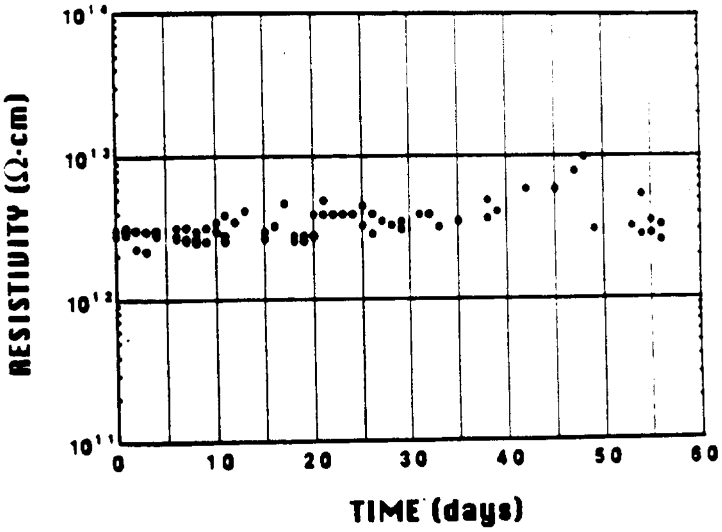

FIG. 7 – Float glass volume resistivity as a function of the time. The supplied voltage is 2 kV.

3 - FLOAT GSC PERFORMANCE

In Fig. 8 is shown the single counting rate as a function of the high voltage for a GSC plane of 1 m^2. The gas mixture is Ar+Iso–C_4H_{10}+Freon 13B1 = 60%+35%+5%. A wide plateau is visible, the counting level is essentially due to the cosmic rays and ambient radioactivity. The noiseless operation exhibited by GSCs is very important in a large area apparatus, as it allows easy monitoring and calibration. The efficiency of a GSC as a function of the high voltage is shown in Fig. 9. Fig. 10 shows the time resolution (rms) as a function of the high voltage. A safe region with a time resolution less than 1 ns is obtained.

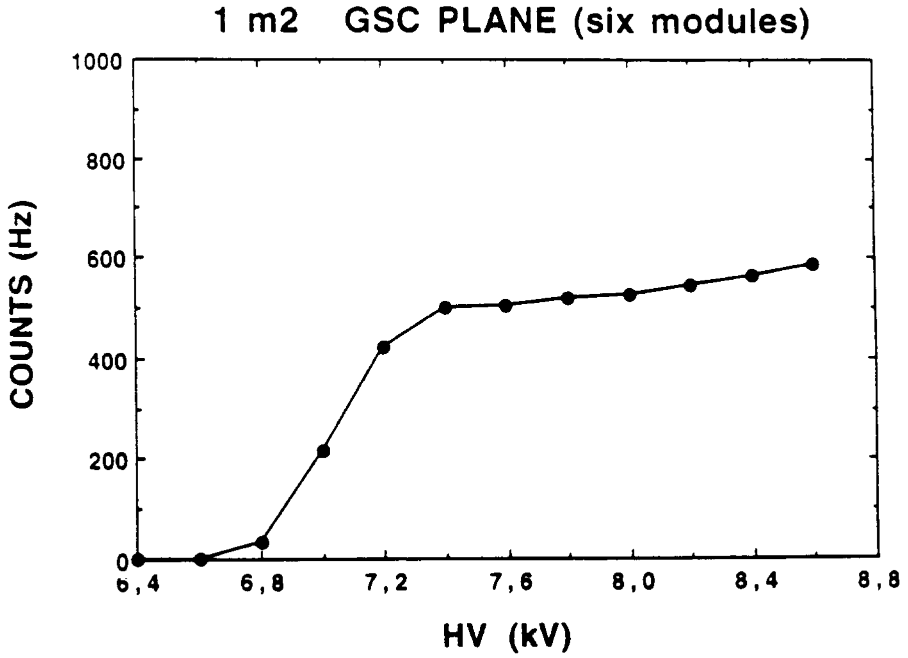

FIG. 8 – Single counting rate as a function of the high voltage for a GSC plane of 1 m^2.

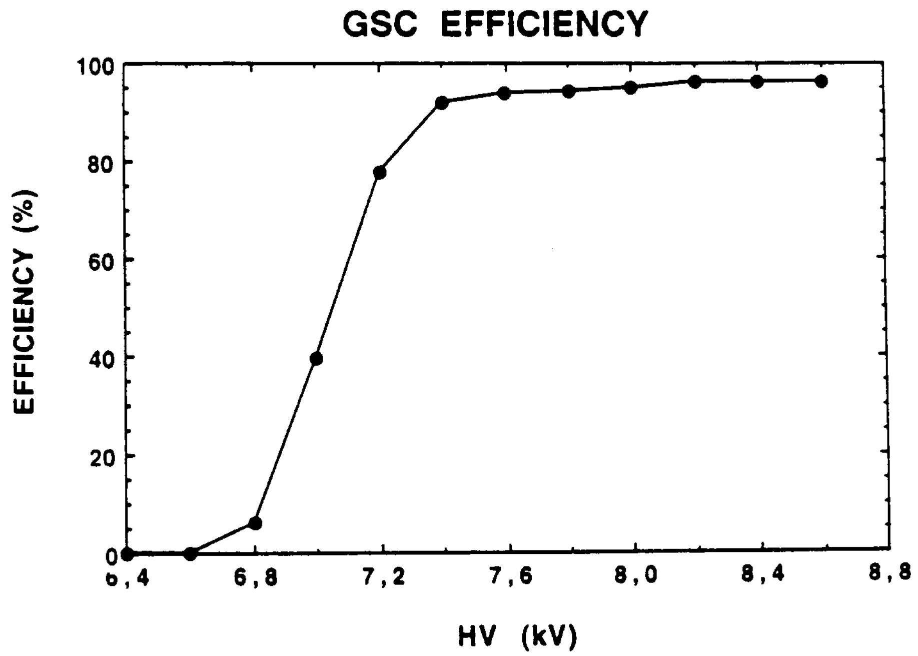

FIG. 9 – Detection efficiency as a function of the high voltage.

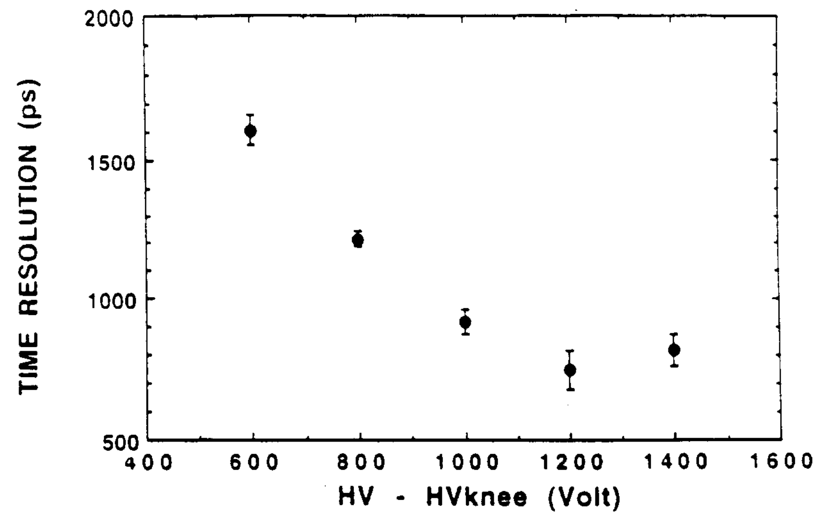

FIG. 10 – Time resolution as a function of the high voltage.

4 - LONG TERM MEASUREMENTS

Fig. 11 shows the counting level of a 0.5x2 m^2 plane as a function of the time. The applied voltage is 8 kV. We note that the counting level is stable during the 3 months of operation. Fig. 12 shows the current drawn by the plane as a function of the time. After about 20 days the current level stabilizes, at the level of about $0.4 mA/m^2$. This value is compatible with the one estimated from charge and counting measurements.

A lifetime test has been performed by irradiating an area of about 20 cm^2 with a ^{137}Cs source. In this measurement, the radiation level is 2 counts/cm^2·s, about 40 times greater than the level due to the cosmic rays and the ambient radioactivity. The applied voltage is 8.4 kV. After 6 months of irradiation, corresponding to more than 20 years of operation at normal conditions, we do not observe any change on the detector performance (i.e. efficiency and time resolution). In Fig. 13 a, b the efficiency and the time resolution, measured on the irradiated area, are plotted as a function of the time.

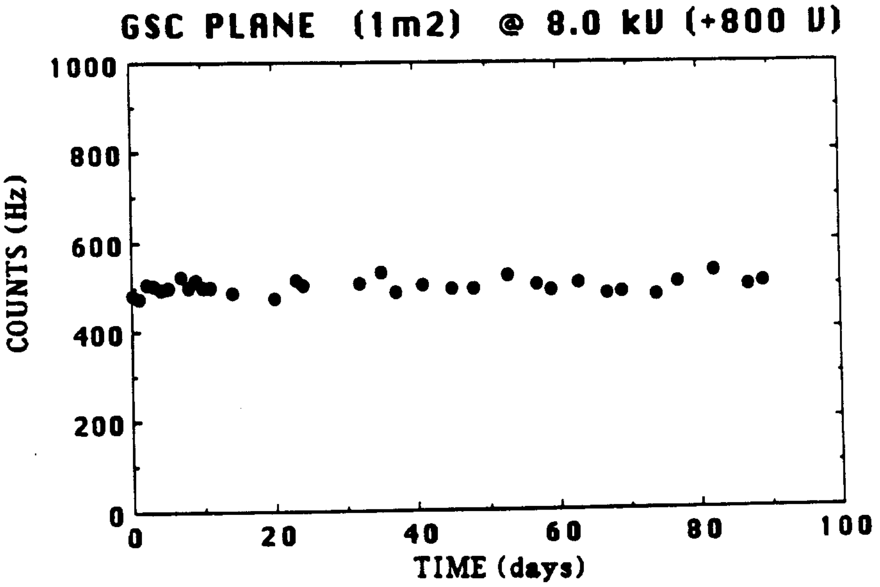

FIG. 11 – Single counting rate as a function of the time for a GSC plane of 1 m^2.

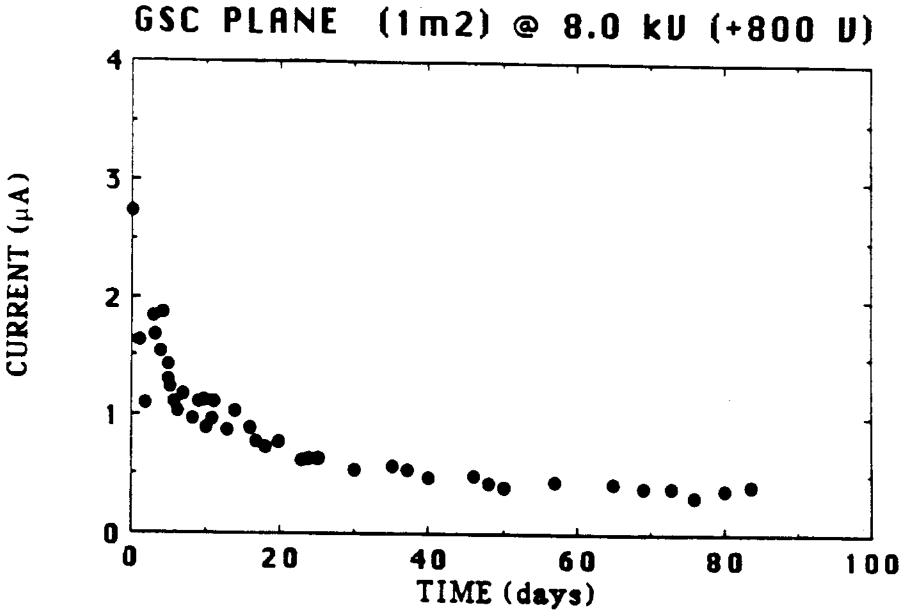

FIG. 12 – Current drawn by a GSC plane of 1 m^2 as a function of the time.

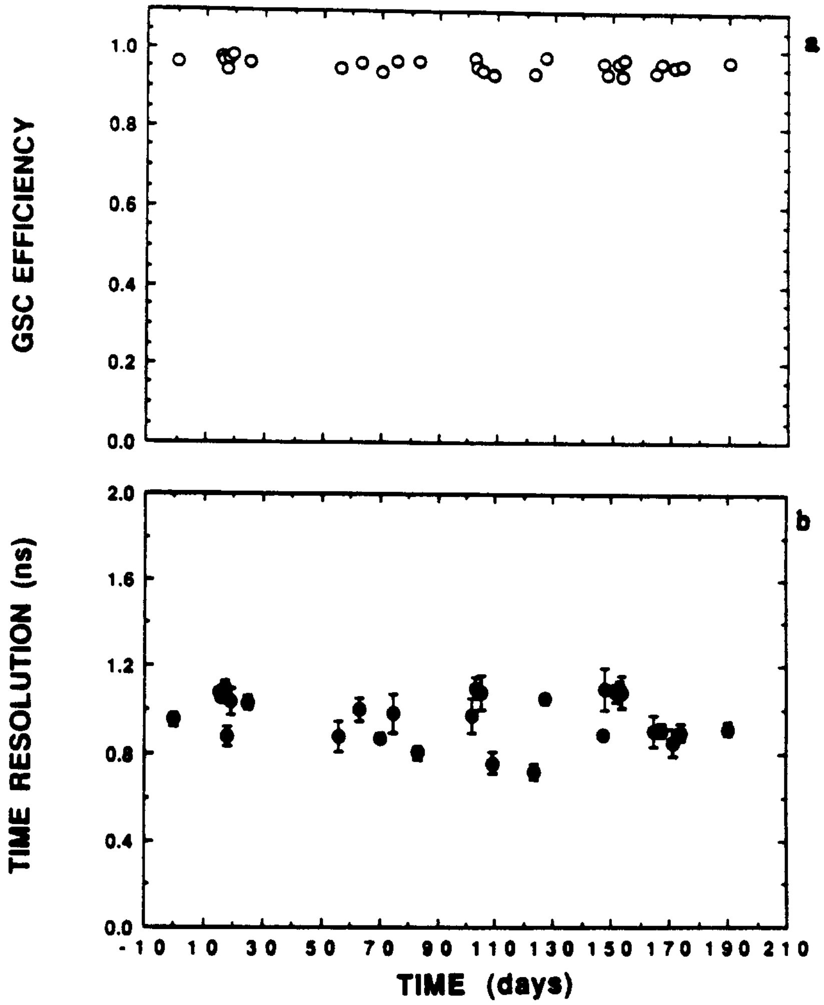

FIG. 13 – a) GSC efficiency and b) time resolution behaviour measured on the irradiated area. The measurements have been performed removing the ^{137}Cs source.

CONCLUSIONS

Float GSC for cosmic ray experiments is ready for a large industrial production at low cost. Glass electrodes do not need extra surface treatments and allows the realization of noiseless detectors. The modular design proposed ensures simple assembling and a good gap uniformity.

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