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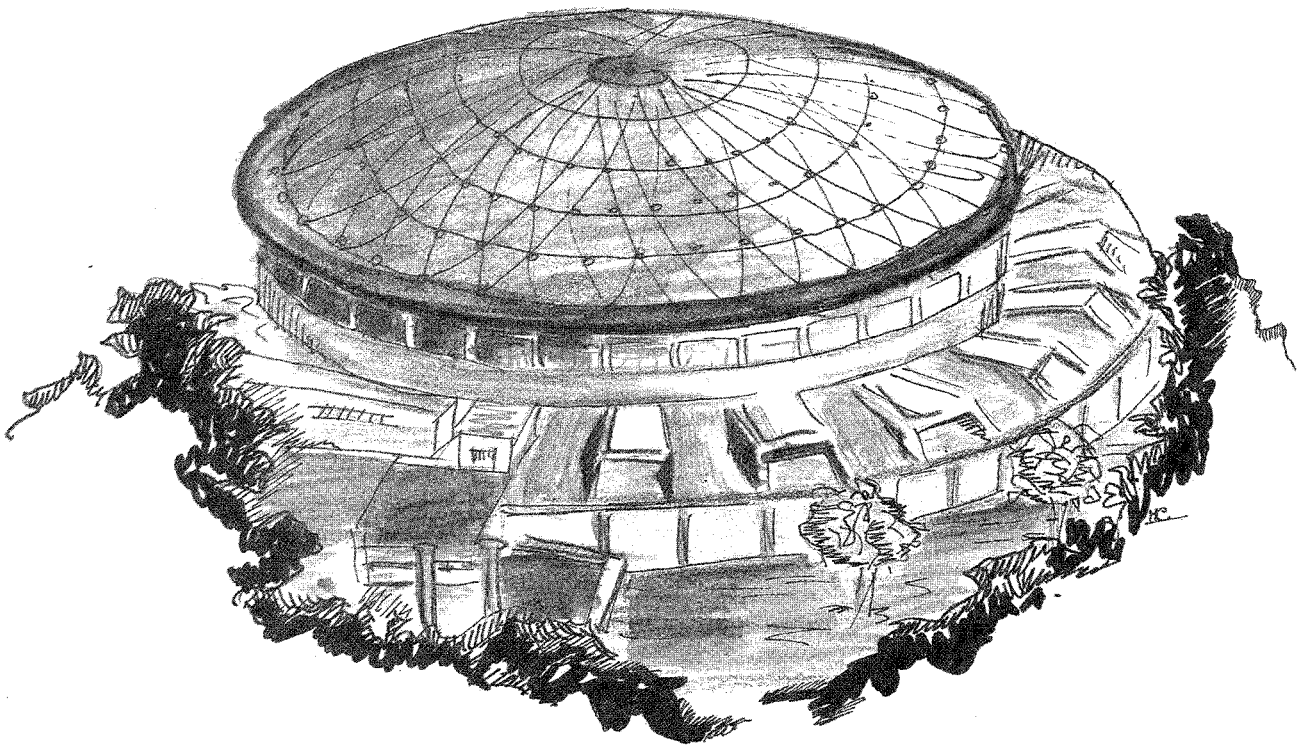

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USE OF LARGE SIZE STREAMER TUBES IN COSMIC RAY EXPERIMENTS

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Abstract

The influence of gas composition on charge distribution and stability of operation of streamer tube chambers with 3x3 cm^2 cell size has been studied. The possibility of using these chambers without continuous gas circulation has also been investigated in view of their use in large arrays operating in cosmic ray experiments.

Introduction

The use of a large system of streamer tubes as tracking detectors was achieved for the first time in the NUSEX proton decay experiment at Mt. Blanc[1]. Other cosmic ray experiments either in underground laboratories or at surface will use streamer tubes for tracking purpose in order to identify the muon component of extensive air showers. In both cases, due to the particular operation environment, the proposed detectors must have a minimum request of operation monitoring, and uncritical conditions concerning high voltage and gas mixture supply.

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For these reasons large cell size plastic streamer tubes offering a noticeable mechanical and electrical reliability have been developed in Frascati[2]. These tubes are being installed in the MACRO experiment[3] at the Gran Sasso Laboratory and in the EAS-TOP air shower array[4] on the top of the Gran Sasso mountain.

A systematic study of the performances of these tubes operated with different Argon/Isobutane gas mixtures has been performed. Results concerning the high voltage working point, the plateau width and the shape of the charge distribution are presented. Moreover in order to meet the request of minimizing the operation monitoring the possibility of running with sealed chambers has been investigated.

Streamer tube design

The basic unit, schematically shown in Fig. 1a, is an 8-cell extruded PVC open profile. The single cell cross section is 3x3 cm^2, and the wire diameter is 100 μm. The anode wires are stretched along the cells, being fixed in a central position every half meter by plastic spacers, and soldered at both ends on printed circuit boards, where they are connected to a common high voltage bus. The tube walls are coated with graphite (R~1÷2 KΩ/square) and the whole system is inserted in an uncoated PVC container 1.5 mm thick. After the application of the high voltage the positive ions charge up in a short time the uncoated wall until the stable field configuration shown in Fig. 1b is reached.

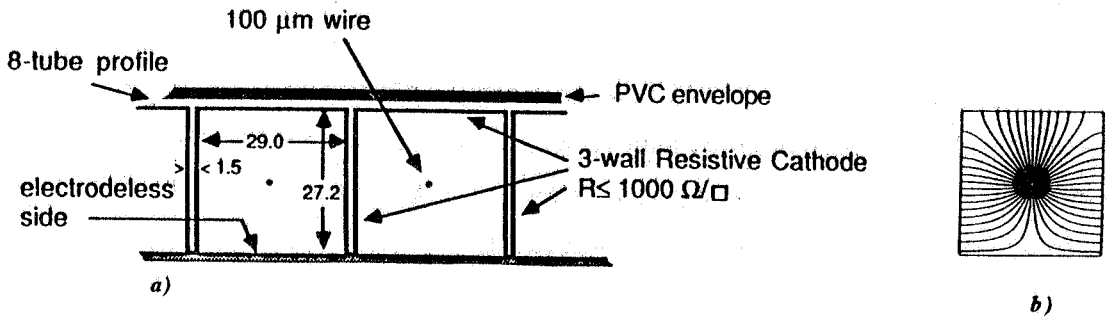

FIG. 1 - a) geometrical structure of 3 x 3 cm^2 cell size streamer tube,the dimensions are given in mm; b) configuration of electric field lines for the coverless streamer tube.

This design allows a bidimensional readout. Signals are collected from individual wires by means of a decoupling capacitor. Pulses induced on external strips at angle with the wires provide the information of the second coordinate.

A great care has been devoted to guarantee the tightness of the tube. The envelope is closed at both ends by PVC caps where the gas flow connectors are embedded. One of the two caps has also the external connections to the wires and the graphite. The end caps are soldered to the chamber envelope just by melting the plastics around the edge. Finally, the surface where the

closing plugs are joined to the container are varnished by means of a silicon resin[5]. The same varnish is distributed at the contact suface between gas and HV connectors and the PVC caps. After the construction all tubes are submitted to the gas tightness test which guarantees against any possible misfailure in the whole sealing procedure or other imperfections, as microholes, of the container. The gas tightness is measured by means of a vacuum test. A vacuum pump draw gas out a streamer tube chamber for a time ranging between 15 and 30 minutes until a residual pressure of the order of 0.2 ÷ 0.5 mb is found. After the pump is closed the gas pressure rises quickly up to about 1 ÷ 1.5 mb, then increases slowly according to the curve of Fig. 2 which is representative of the typical behaviour of a gas tube.

A pressure of about 6 mb is reached after about two hours, due to the outgassing from internal walls and PVC permeability. Tubes with non perfect endcap soldering or having bad tightness in correspondance of the connectors embedded in the plastic exhibit a well distinct behaviour characterized by a continuous increasing of the pressure with time[6].

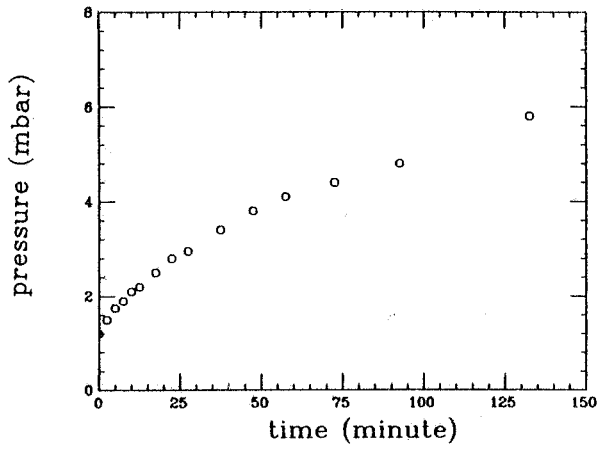

FIG. 2 - Residual pressure in function of the scaling time. The origin of the time scale is set after the quick gas pressure increase (a few seconds) following the stop of the vacuum pump.

Streamer tube operation

Two 1m long streamer tubes placed at a vertical distance of about 2m from each other have been put in coincidence to select an approximately orthogonal ($\vartheta \leq 25^{o}$) cosmic ray beam crossing a 5m long test tube. The lowest triggering tube was shielded on three sides by a Pb box 5cm thick, in order to cut out most of the soft component.

Pulses from the eight contiguous wires of the test tube are OR-ed together. This output is split, one signal being directly fed into the input of a FASTBUS LeCroy ADC model 1885N gated (1.5 μs integration time) by the coincidence, while the other one is shaped to 5 μs by means of a nonupdating discriminator with 10 mV/50 Ω threshold. In this way charge spectra and singles counting rates have been measured simultaneously.

The singles rate plateaux, and the charge distributions as a function of high voltage are shown in Fig. 3a,b,c for three different Ar/Isobutane relative concentrations, 40/60 - 50/50 - 60/40. As expected the knee of the singles rate plateau decreases with increasing Argon concentration and, due to the worsening of the quenching action of the mixture, after-pulses are

copiously produced at increasing voltages. As a consequence the width of the singles rate plateau (defined as the voltage range corresponding to a singles rate increase ≤ 5%) decreases from ~1000 V for Ar/Isobutane=40/60 to ~800 V for Ar/Isobutane=60/40, and the charge distribution broadens.

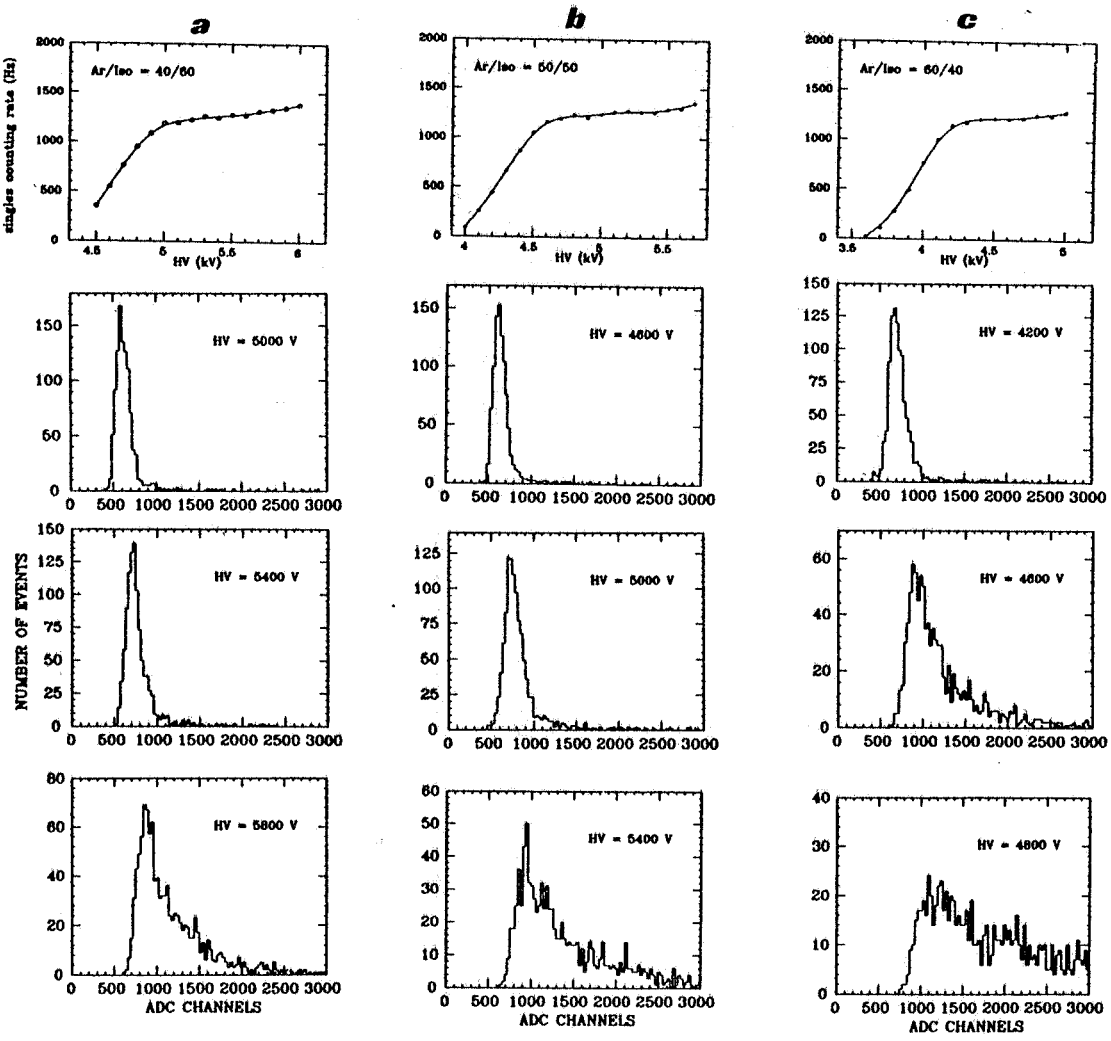

FIG. 3 - Singles rate plateaux and charge distributions at different voltage for: a) Ar/Isobutane=40/60; b)Ar/Isobutane=50/50; c)Ar/Isobutane=60/40.

The typical single wire signal at a voltage near the knee of the plateau is shown in Fig. 4. The amplitude is ≥ 40 mV/50 Ω, the rise time about 10 ns, the width at the base about 100 ns.

The dependence of the peak of the charge distribution on the potential follows the exponential behaviour $Q \sim e^{KV}$, Fig. 5a. The peak charge at the knee of the plateau grows from 40 to 70 pC with the increase of the Argon concentration. The value of K in the range of the tested mixtures depends very sligthly on the Ar/Isobutane relative fraction:

Ar/Isobutane	$K(V^{-1})$
40/60	$(17 \pm 2)\cdot 10^{-4}$
50/50	$(17 \pm 2)\cdot 10^{-4}$
60/40	$(20 \pm 1)\cdot 10^{-4}$

showing that the collected charge changes of about 18% for 100 V increasing potential.

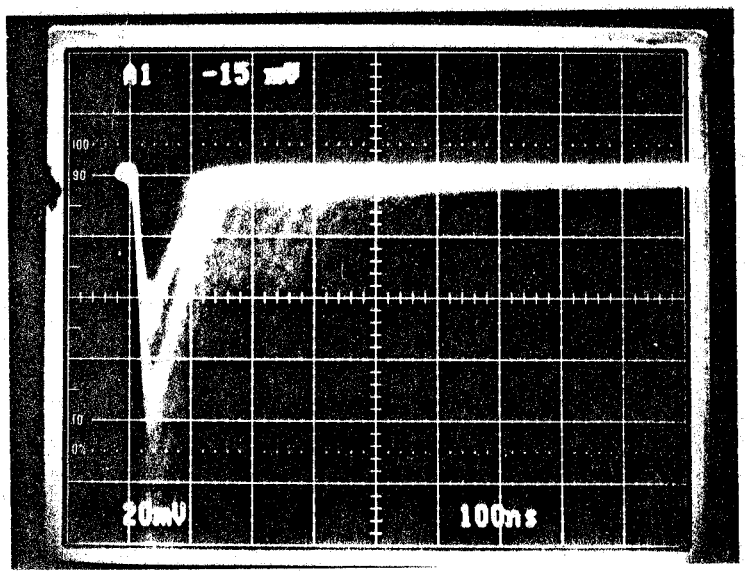

FIG. 4 - Typical single wire singnal, obtained with uncollimated β source, for Ar/isobutane = 50/50, HV = 4900 V. The horizontal scale is 100 ns, the vertical scale 20 mV. The occurrence of single and multistreamer discharges if due to the angular spread of the ionizing tracks.

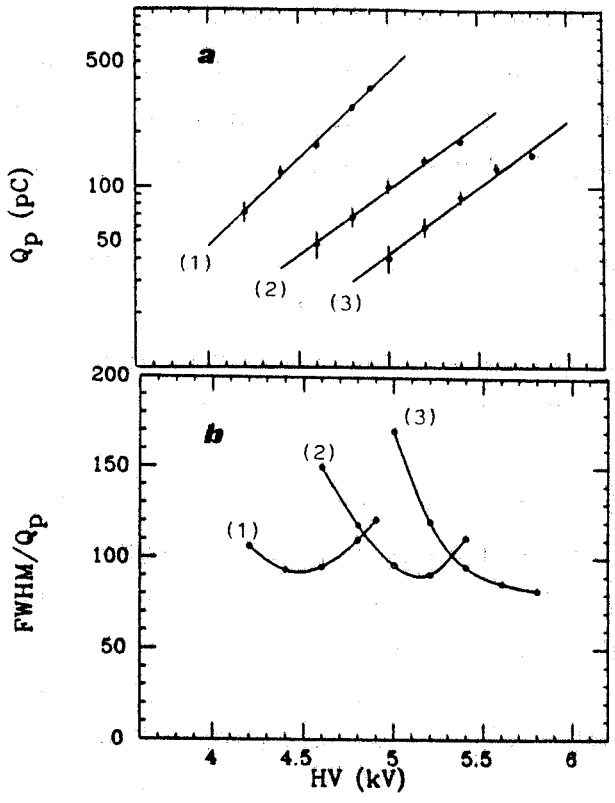

FIG. 5 - a) Peak of the charge distributions and b) charge resolution as a function of the high voltage for the three different Ar/Isobutane relative concentrations (1) = 60/40; (2) = 50/50; (3) = 40/60.

In Fig. 5b the dependence of the charge resolution (FWHM/Q_P, Q_p = peak charge) on the high voltage is shown. At increasing voltage the resolution (100÷120% near the knee of the efficiency plateau) decreases, but, once after-pulse generation becomes considerable, the resolution worses. This effect is more evident at low isobutane concentrations. We note that the

resolution obtained at the onset of the efficiency plateau is better for mixtures with larger fraction of Argon. This result is a consequence of the fact that the resolution improves with increasing charge when the afterpulse generation is negligeable.

Test with sealed streamer tubes

The possibility of using these chambers without continuous gas circulation has been investigated using a few 5m long streamer tube chambers, sampled randomly from the mass production satisfying the gas tightness test. Before sealing, the chambers have been flowed with an Ar/Isobutane=40/60 mixture.

In the operation of proportional or streamer chambers the gas circulation is usually required to avoid the deterioration of the performances due to the addition of bad impurities. These have a twofold origin:

i) contamination of the original mixture by other gases due to outgassing from the internal walls or to selective diffusion of the air gases through the plastic. These effects depends on the nature of the internal surface and on the nature and thickness of the container walls;

ii) formation of polymers on the anode surface which slowly drift toward the cathode and deposit on it if not blown away by a large gas flow. These cathode deposits can be very photosensitive, allowing even very low energetic photons to liberate electrons from the cathode and generate afterpulses[7].

In order to separate the different contributions to the gas contamination two different tests have been performed: the first with the high voltage switched off, and the second one with a continuous voltage applied. The measurements consist of a continuous monitoring of the singles rate plateau and charge distributions for a period of time ("sealing time") of order of 1÷2 months.

Fig. 6 shows the singles counting rate as a function of high voltage measured with cosmic rays and local radioactivity on the 8-wires of one test tube sealed and left out for two months with high voltage switched off (but for the periodical measurements). The curve "a" is obtained just after the sealing, curve "b" after a sealing time of one month, and finally the curve "c" after a sealing time of two months. In doing this comparison the counting rate of the trigger streamer chambers has been used for normalization in order to prevent any apparent variation induced by fluctuations in the cosmic ray flux or local radioactivity. It is possibile to notice that after two months two effects are evident: an efficiency loss of about 10%, at voltages near the knee of the plateau (~5000 V); and, at higher voltages (~6000 V), a noticeable rise of about 20% in the singles counting rate, due to the increase of after-pulse generation.

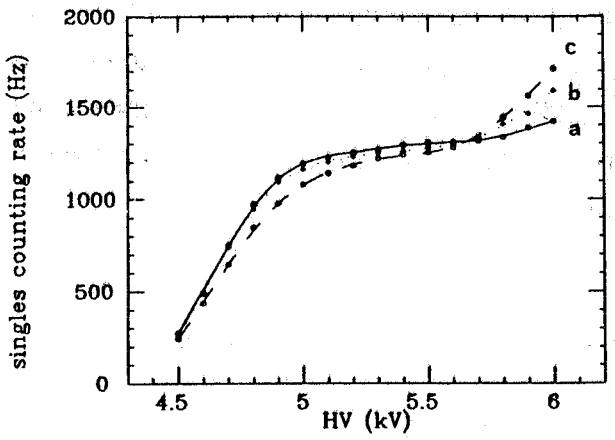

FIG. 6 - Singles counting rate as a function of high voltage for a sealed tube with the high voltage switched off: a) just after chamber sealing; b) one month after chamber sealing; c) two months after chamber sealing.

The lower efficiency at voltages near the knee is probably due to the presence of electronegative molecules as O_2 or H_2O entered at very slow rate during the test time in the gas volume through wall outgassing or PVC permeability. Other impurities, whose nature is not easy to asses from these measurements, should responsible of the increasing of afterpulses at high voltages. Only the last effect is pratically present at short times as shown by the curve b) in Fig. 6.

The shortening of the plateau is enhanced in normal operation conditions when the high voltage is continuously applied to the chamber. This test was performed over a period of 40 days keeping chambers at a voltage of 5200 V, about 200 V above the knee of the efficiency plateau. The results show a considerable acceleration in the degradation of the singles rate plateau, Fig. 7, with an increase $\geq 30\%$ of the counting rate at 6000 V after 40 days. This effect is likely due to the gas polimerization and, being correlated to the particle rate, is expected to be less relevant in underground experiments.

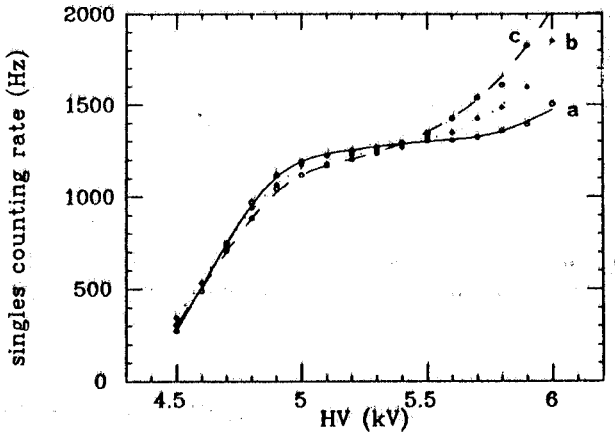

FIG. 7 - Singles counting rate as a function of high voltage for a sealed tube with a continous voltage applied: a) just after chamber sealing; b)twenty days after chamber sealing; c) forty days after chamber sealing.

On the other hand, the decrease of the efficiency at voltages close to the onset of the plateau seems to be not affected by the continuous application of the high voltage in such a way confirming the hypotesis of an effect related essentially to the presence of electronegative impurities.

On the whole the deterioration of the performances of the chambers appears rather moderate. As shown in Fig. 8 the charge distributions measured at different times remain

substantially unchanged also at a voltage of 5.8 kV, about 800 V beyond the knee of the efficiency plateau, where the rise of the counting rate is ~ 20%. Since the integration time is 1.5 μs while a shaping of 5 μs has been used for singles rate plateau measurements the absence of any appreciable changement of the charge distribution could indicate that the rate increase beyond the plateau is likely due to very delayed afterpulses.

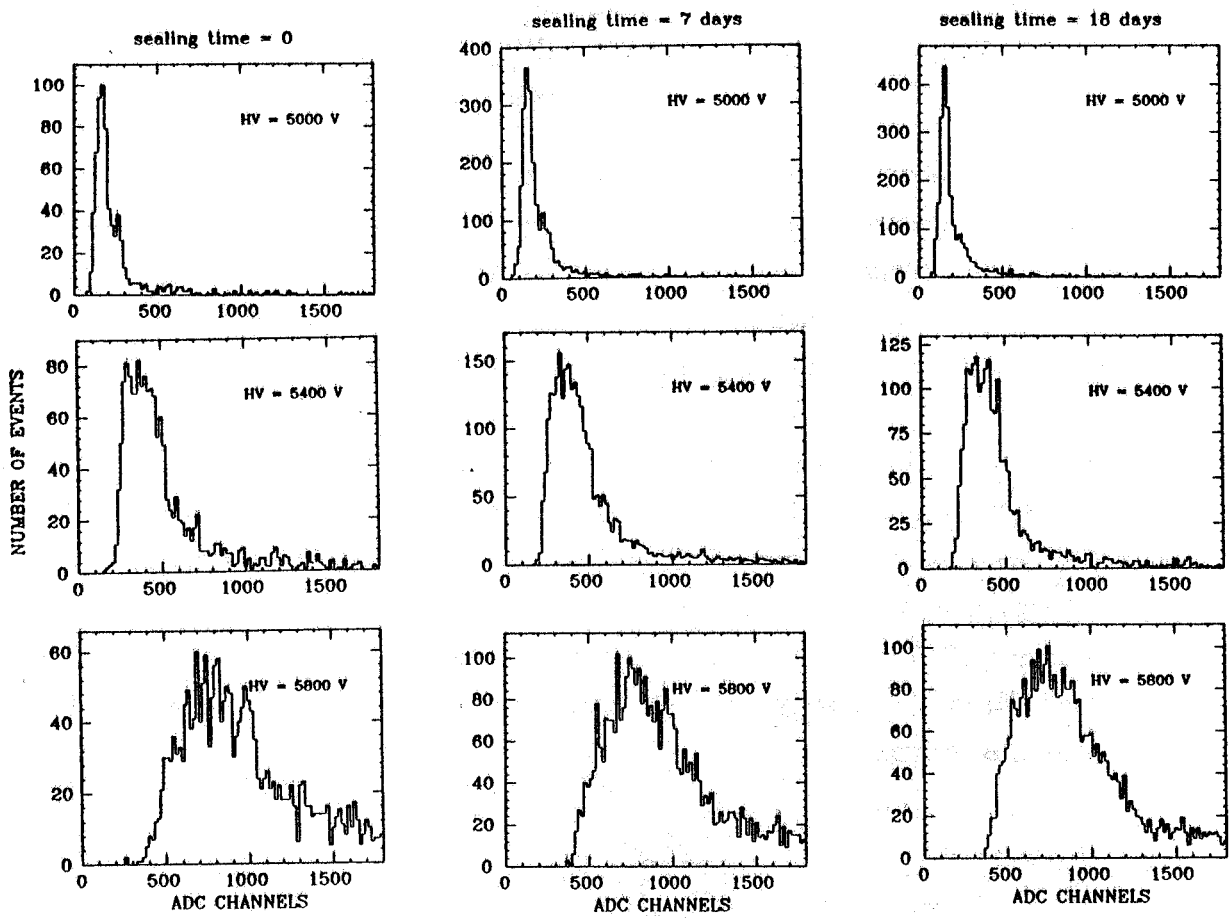

FIG. 8 - Charge distributions measured at different scaling times and at three different high voltages on the efficiency platean. A continuous voltage of 5200 V has been applied after sealing. The gas mixture is As/isobutane = 40/60.

These cannot be originated by electrons liberated from the cathode by UV photons, since the cathode anode drift time is about 400 ns, but are probably produced by heavy ions, whose drift velocity is remarkably lower. Delayed afterpulses are found in CO_2 gas mixtures[8]. In the present case CO_2 molecules could be originated by the reaction of atomic oxygen, produced in the gas either from O_2 or from molecules containing oxygen, with hydrocarbon radicals produced by the avalanche[9]. This mechanism could be alternative to the usual one invoked to explain the aging effects and related to the deposit of insulating material on the cathode.

A detailed investigation of these phenomena is beyond the aims of the present work. Nevertheless it is whort to remark that a flushing at normal flow rate quickly restored the normal shape of the plateau curve, thus showing that not irreversible conditions were produced by the operation without continuous gas circulation. That seems to favour the previously mentioned mechanism as origin of the slow deterioration of sealed tubes.

Conclusions

A study of the operation of 3x3 cm^2 plastic streamer tubes in different conditions has been performed. The results show that these tubes, routinely produced with industrial procedure, can be operated in very high current mode (Q_p>40pC) with good charge resolution (~80÷90%) and high stability (plateau width ≥ 800 V), at least in low radiation environments. The results concerning the tests with sealed tubes give good confidence about the possibility of running with a sporadic gas circulation (about every two or three weeks). This is clearly a relevant feature for a detector operated far from usual laboratory conditions.

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