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ON LIMITED STREAMER OPERATION

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STREAMER OPERATION

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ABSTRACT

A systematic study on limited streamer tubes  $8 \times 8 \text{ mm}^2$  in cross section has been performed, testing different gas mixtures and cathode materials. A discussion concerning the set of gas mixtures allowing streamer operation is presented. Plastic tubes with graphite cathode are found to exhibit a wider operation range than aluminum tubes.

1. - INTRODUCTION

In preceding papers on limited streamer tubes<sup>(1, 2, 3)</sup> various tube geometries and gas mixtures which allow streamer mode operation have been shown. The basic requirement for fully efficient, uncritical and noiseless streamer operation, is that highly quenching gas mixtures must be used and, furthermore, the quenching action must be increased as the tube dimension is decreased. In practice the useful set of gaseous components and mixing proportions is found to be a very small subset of those useful for the proportional mode. The stringent requirement on the gas mixture, is a consequence of the streamer generation mechanism. As directly shown by pictures of the multiplication process<sup>(4, 5)</sup>, the streamer is started by the primary proportional multiplication on the wire, and propagates toward the cathode, perpendicularly to the wire. Therefore the stringent condition on the gas mixture comes from the fact that not only the streamer

process must be started on the wire (for which a good fraction of the standard proportional mode mixtures are useful), but that it must extinguish itself at some distance from the cathode. Self-quenching of the streamer occurs due to two factors: the electric field decreasing with the inverse distance from the wire axis, and the strong U. V. absorption due to the quenching component of the gas mixture, which controls the secondary gas ionization at the base of the streamer propagation mechanism. Actually for optimal tube operation the streamer must extinguish itself at some distance from the cathode to avoid that ultraviolet photons extract electrons from the cathode, which drift to the wire and generate another streamer (afterpulse) in the nearest region of the wire outside the dead region due to the primary streamers. In conclusion the reason for which the smaller the tube the higher must be the quenching action of the gas<sup>(2,6)</sup>, is to reduce the radial streamer length according to the reduced tube radius.

Afterpulse generation is easily recognized since it occurs at a constant time after the primary streamer and the delay coincides with the drift time over the cathode-wire distance. Afterpulse generation may be iterative and trains of streamer pulses may be observed. A similar afterpulse generation process had been already observed in proportional tubes<sup>(7)</sup>. In case of a simple digital (yes/no) readout of streamer tubes, and at operation rates far from the maximum, afterpulse generation does not affect detector performance. On the other hand there are two cases where afterpulses cannot, in general, be tolerated: i) when the coordinate along the tubes is readout; ii) when charge is readout to measure shower energy in streamer tube calorimeters<sup>(8)</sup>. We have developed plastic streamer tubes with graphite cathode which when used with the proper gas mixture do not exhibit appreciable afterpulse generation. Since afterpulses are due to electron extraction from the cathode surface by ultraviolet photons, one may expect some influence in tube operation due to cathode material.

In this respect tests had been performed with  $2 \times 2 \text{ cm}^2$  tubes, for a given gas mixture and for various cathode materials, without observing any appreciable difference<sup>(2)</sup>. Subsequently with smaller tubes ( $\sim 1 \text{ cm}^2$ ) we made qualitative observations showing a higher sensitivity of aluminum tubes for afterpulse generation. Here we present a systematic comparative test between aluminum and graphite cathodes, with  $8 \times 8 \text{ mm}^2$  tube dimension and different gas mixtures.

## 2. - EXPERIMENTAL RESULTS

To test the influence of cathode material on afterpulse generation in streamer tube operation we have used two model tubes which are identical but for the cathode material, one being an aluminum tube, the other a PVC tube with graphite cathode. The inner cross-section of the tubes is  $8 \times 8 \text{ mm}^2$ , the length 20 cm, the wire  $40 \mu\text{m}$  in diameter.

Both tubes were exposed to a non collimated  $^{90}\text{Sr}$  source, which illuminates a few centimeter length and generates a singles counting rate between 100 and 250 Hz.

In order to evidenciate afterpulse generation, we have used a very simple method. For each model tube, the singles counting rate as a function of the H. V. is simultaneously measured with two discriminators, which have different shaping times : a short-shaping discriminator, which will count afterpulses, and a long-shaped one, which will not (but in extreme cases). Each tube is connected to a non updating discriminator with  $10 \text{ mV}/50 \Omega$  threshold, and 200 ns shaping plus recovery time. This discriminator triggers another discriminator with a long time shaping of  $1 \mu\text{s}$ . Both discriminators go to scalers, to measure the singles counting rate as a function of H. V.

With our usual gas mixture for  $\sim 1 \text{ cm}^2$  tubes (Argon-Isobutane: 1+3), the plateau curves for the graphite and aluminum cathodes, with both the short and long time shaping are shown in Fig. 1. The long time shaping gives for both cathodes a rather wide singles rate plateau. The short time shaping gives a slightly deviating curve for the

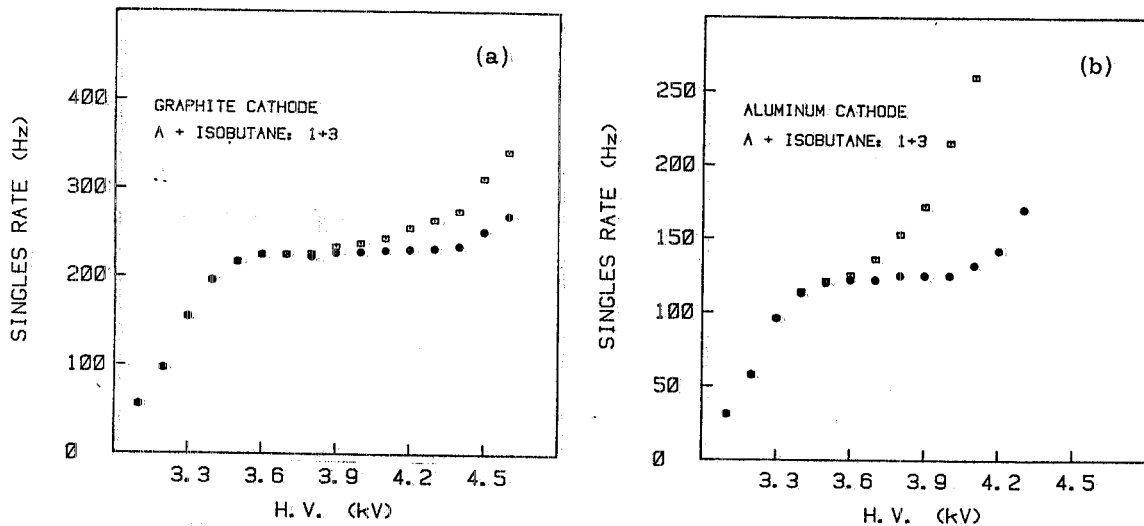


FIG. 1 - Singles rate plateaux for graphite (a) and aluminum (b) cathode;  $8 \times 8 \text{ mm}^2$  tube size,  $40 \mu\text{m}$  wire. Dots:  $1 \mu\text{s}$  time shaping; squares: 200 ns shaping plus recovery time.

graphite, but a rapidly increasing one for the aluminum. In Fig. 2 the pictures of the wire pulses at different H. V. 's also show the different behaviour of the two model tubes, with afterpulse generation clearly visible for the aluminum cathode at increasing H. V. .

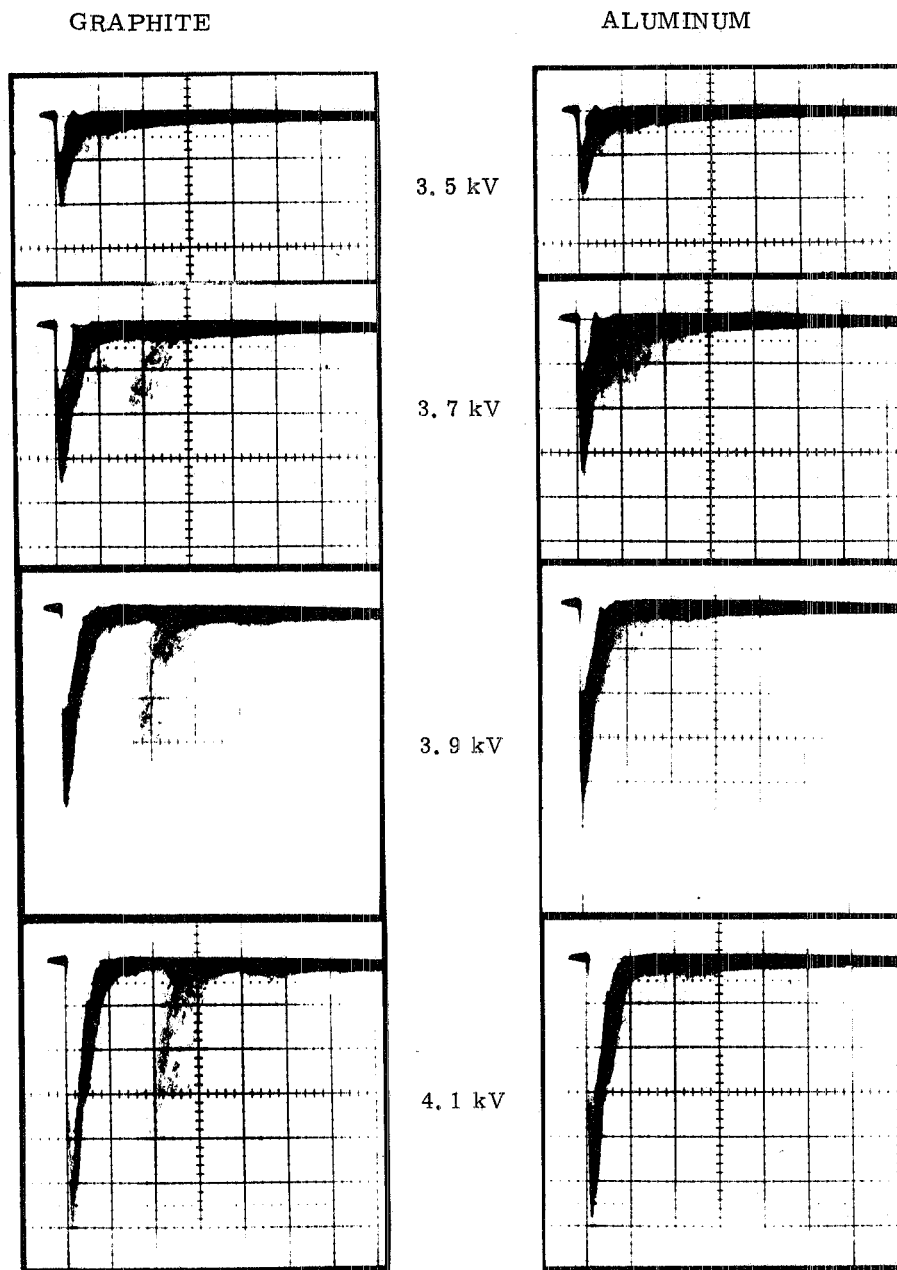


FIG. 2 - Wire pulses at different H. V. 's for graphite and aluminum cathode;  $8 \times 8 \text{ mm}^2$  tube,  $40 \mu\text{m}$  wire; gas mixture: A + Isobutane: 1 + 3. Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

The charge distributions (500 ns time integration) for the two tubes are shown in Fig. 3 as measured at 3.8 kV. Due to afterpulse generation, the aluminum cathode gives a peak amplitude about 60% higher than the graphite cathode, and a broader distribution.

By lowering the Isobutane concentration down to the 1+1 mixture with Argon, the plateau with the long time shaping discriminator becomes shorter, and the difference between graphite and aluminum increases (Fig. 4).

This behaviour of aluminum with respect to graphite cathodes, can be easily attributed to its lower electron work function. Actually the operation of an aluminum streamer tube is impaired if light can enter it. Let us give a qualitative figure: the light from a standard 100 Watt incandescence lamp flowing through a 1 mm hole in the tube, kept 50 cm apart, is enough to bring the tube to its saturated local rate ( $\sim 10^4/s$ ). By inserting U. V. filters, we have verified that the aluminum surface is sensitive to the U. V. component. All observations quoted above refer to the particular commercial aluminum we have tested. However qualitative observations with a few different types of aluminum, showed the same behaviour.

The effect of varying the quenching component concentration in the gas mixture is visible in Fig. 5, where wire pulses from the plastic tube are shown for different Isobutane fractions, always generated by the non collimated  $^{90}\text{Sr}$  source. The pictures were taken at corresponding H. V. 's with respect to the singles rate plateaux: inside the full efficiency region,  $\sim 150$  V above the 90% level. The peak amplitude is practically unaffected while pulse duration decreases as the fraction of Isobutane increases. This can be explained with the propagation of the streamer process over shorter distances. It is worthwhile noticing that even at the highest Isobutane concentrations, the pulses maintain the characteristic fast rise time and shape due to the electron signal, which is an indication that no change occurs in the basic (streamer) generation mechanism.

Equivalent results are obtained with different wire diameters. In Fig. 6 the single streamer charge is plotted versus Isobutane fraction, for a  $9 \times 9 \text{ mm}^2$  cell and  $100 \mu\text{m}$  thick sense wire. Here the tube was exposed to a 10 GeV pion beam orthogonal to the wire. In the same figure the charge distributions for two different Isobutane fractions are shown. They are about 60% FWHM wide. The small tail on the right of the gaussian-like distribution is consistent with  $\delta$  rays produced in the material in front of the sensitive volume of the tube (tube material plus trigger counters).

Different gaseous components have been tested. Ethane exhibits a lower quenching action with respect to Isobutane. With Argon+Ethane (1+8), the situation is shown in Fig. 7. Propane exhibits an intermediate behaviour between Ethane and Isobutane. With Methane we could not achieve streamer operation. With  $\text{CO}_2$  we could obtain streamer operation but not good efficiency and tolerable afterpulse generation at the same time.

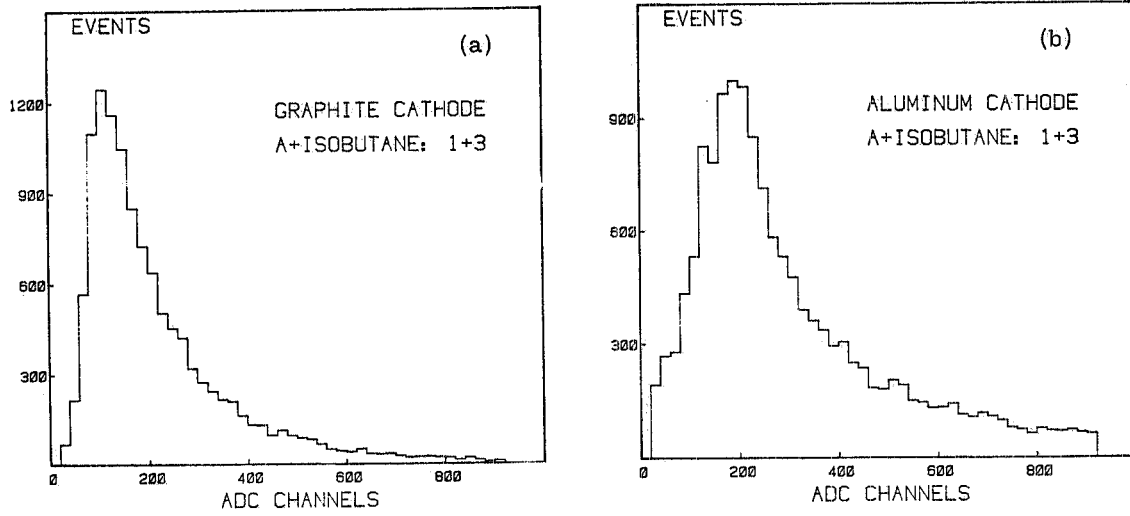


FIG. 3 - Charge distributions for graphite (a) and aluminum (b) cathodes;  $8 \times 8 \text{ mm}^2$  tube size,  $40 \mu\text{m}$  wire, HV = 3800 V.

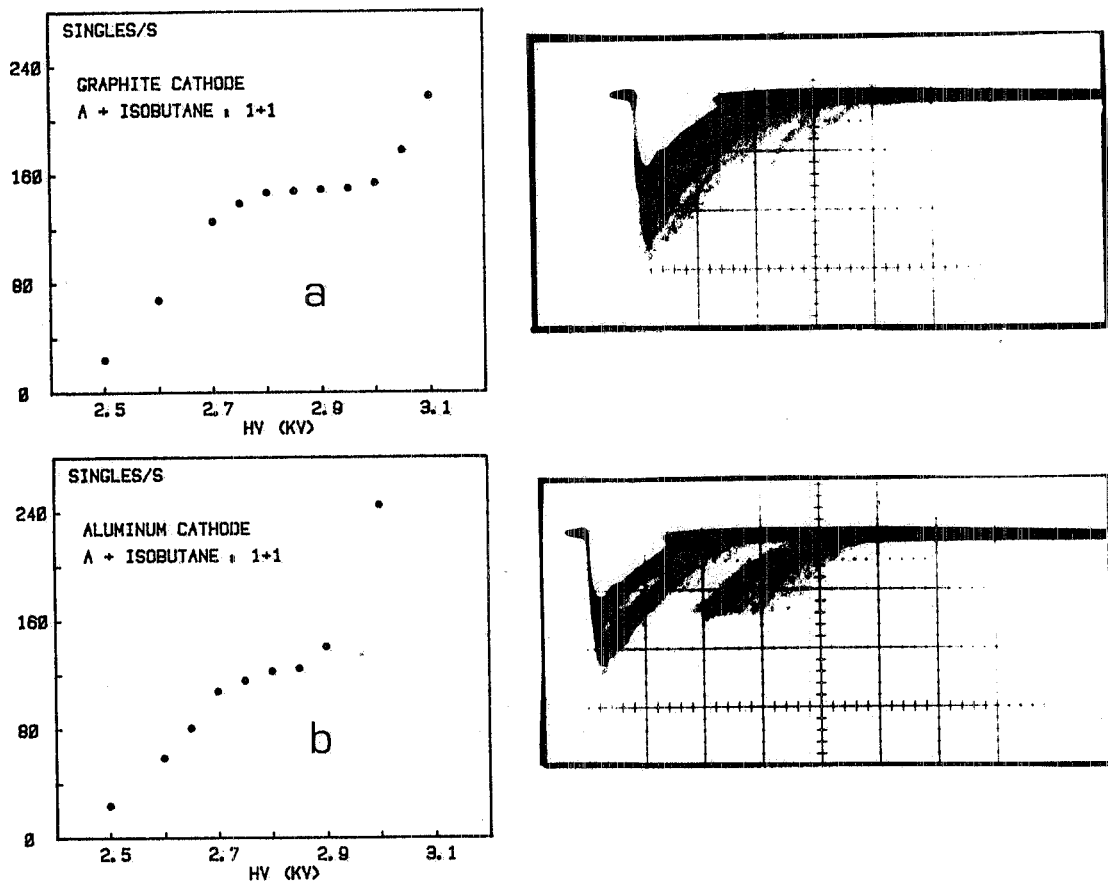


FIG. 4 - Singles rate plateaux and wire pulses (at 2.9 kV), for graphite (a) and aluminum (b) cathode;  $8 \times 8 \text{ mm}^2$  tube,  $40 \mu\text{m}$  wire; gas mixture: A+isobutane: 1+3. Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

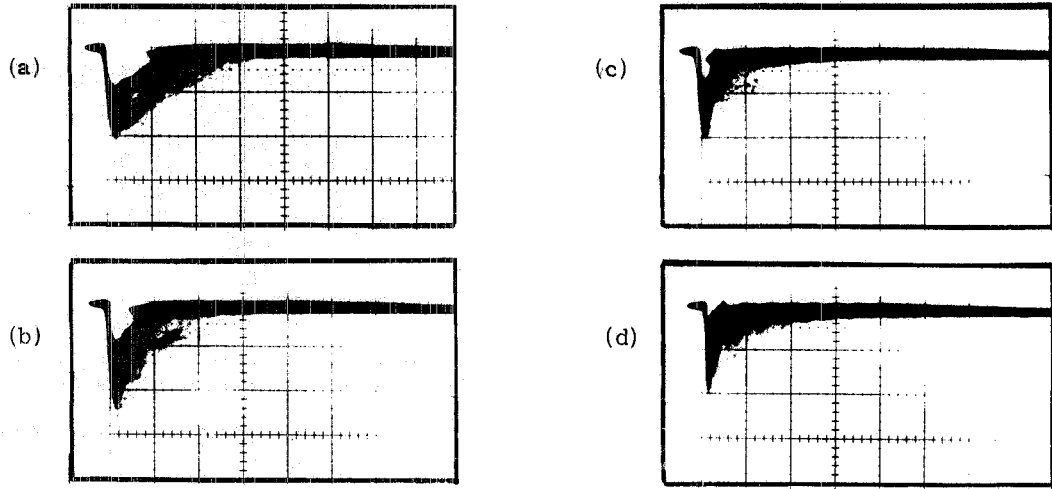


FIG. 5 - Wire pulses for different Isobutane fractions;  $8 \times 8 \text{ mm}^2$  tube,  $40 \mu\text{m}$  wire, graphite cathode: a) 50% Isobutane, 2.8 kV; b) 60%, 3.1 kV; c) 70%, 3.3 kV; d) 80%, 3.7 kV. Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

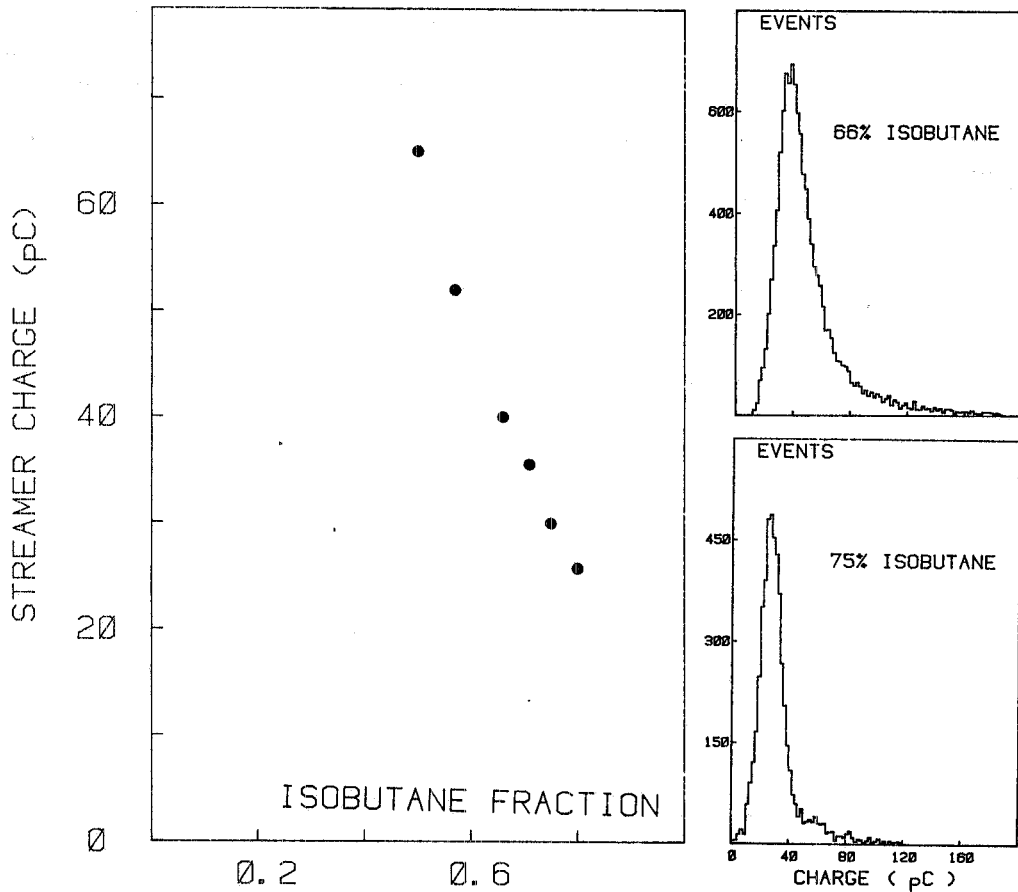


FIG. 6 - Single streamer peak charge vs. Isobutane fraction together with the charge distributions at two different Isobutane concentrations, for  $9 \times 9 \text{ mm}^2$  tube and  $100 \mu\text{m}$  wire.



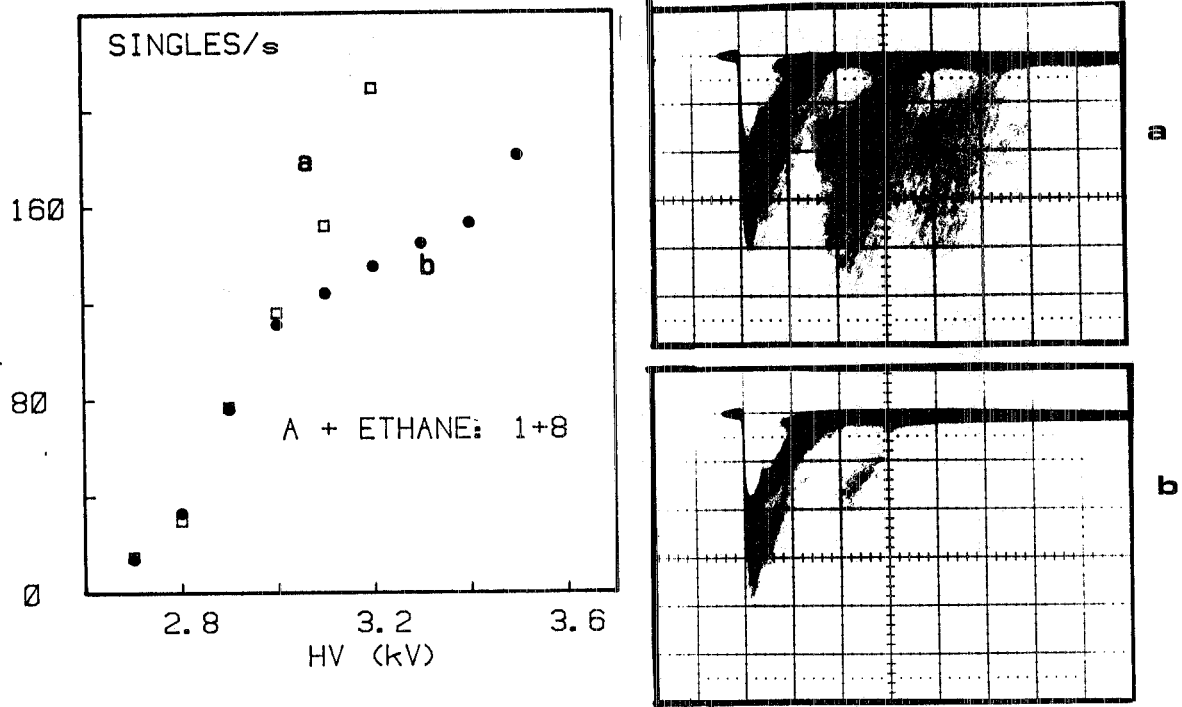


FIG. 7 - Singles rate plateaux and wire pulses (at 3.2 kV) for aluminum (a) and graphite (b) cathodes;  $8 \times 8 \text{ mm}^2$  tube,  $40 \mu\text{m}$  wire; gas mixture: A + Ethane: 1 + 8, Vertical scale: 50 mV/div; horizontal scale: 50 ns/div.

The three component gas mixture A + CO<sub>2</sub> + n-Pentane (1 + 2 + 1), gives a streamer tube performance which is practically equivalent to that of the A + Isobutane (1 + 3) mixture. This mixture is presently used for the streamer tube calorimeter of the Mont Blanc proton decay experiment<sup>(9)</sup>.

### 3. - CONCLUSIONS

We have pointed out that streamer operation mode in practice can be obtained only with a well definite set of gas mixtures, depending also on tube dimensions. Nature and percentage of quenching component must be chosen according to detector characteristics and operation conditions. When using aluminum cathodes, gas choice is even more stringent, to avoid undesired afterpulse generation. On the other hand, once the right mixture is used, there is no criticality at all in tube operation.

REFERENCES

- (1) - G. Battistoni et al. , Nuclear Instr. and Meth. 152 (1978), 423.
- (2) - G. Battistoni et al. , Nuclear Instr. and Meth. 164 (1979), 57.
- (3) - G. Battistoni et al. , Nuclear Instr. and Meth. 176 (1980), 297.
- (4) - G. D. Alexeev et al. , Lett. Nuovo Cimento 25 (1979), 157.
- (5) - M. Atac and A. V. Tollestrup, Self Quenching Streameres in Drift Tubes, Proceedings of INS Intern. Symposium on Nuclear Radiation Detectors, Tokyo 1981.
- (6) - G. Battistoni et al. , Limited Streamer Tubes with Resistive Cathode, Proceedings of the 1981 EPS Conference on High Energy Physics, Lisbon 1981.
- (7) - P. J. Campion, Nuclear Instr. and Meth. 112 (1973), 75.
- (8) - G. Battistoni et al. , Plastic Streamer Tube Calorimeters, Proceedings of the Intern. Conference on Instrumentation for Colliding Beam Physics, SLAC, Stanford 1982; Frascati Report LNF-82/16 (1982).
- (9) - G. Battistoni et al. , Phys. Letters 118B (1982), 461.