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Search for Optimum Electric Pulses to Obtain Tracks in Isotropic Monogap Chambers.

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An experimental layout has been realized in order to find the best conditions of pulsing an isotropic monogap chamber. In particular rectangular pulses and damped oscillating pulses have been analised and width, luminosity and brilliance of tracks and number of streamers per unit length have been measured.

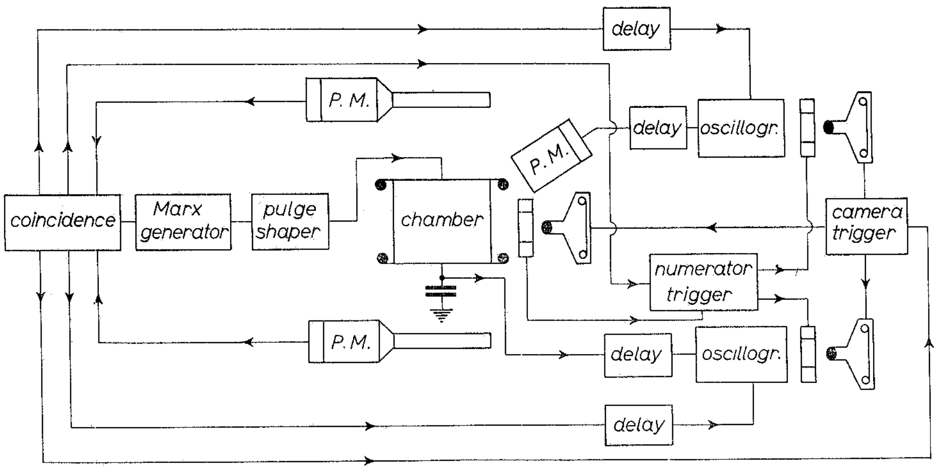

Fig. 1. – Block scheme of the experimental layout.

The block scheme of the experimental layout is sketched in Fig. 1. A fast coincidence, operated by a telescope of two scintillators, triggers a pulse generator of Marx type, followed by a convenient pulse shaper in order to give the chamber electrodes a rectangular voltage pulse with adjustable amplitude and duration or a damped oscillating pulse with adjustable amplitude, frequency and damping-time constant. The tracks and the shapes of the voltage pulses applied to the electrodes and those of a pulse (obtained by a multiplier phototube) proportional to the total light emitted from the track are photographed by means of three automatic cameras. The voltage pulses are delayed so that they are not superposed on the noise due to induction and radiation of the pulse delivered by the Marx generator. A number indicated by a numerator is photographed in order to associate the correspondent photographs of tracks, triggering pulse and emitted light. The advancement of the films and of the numerator is obtained by means of a camera trigger and a numerator trigger, both operated by the fast coincidence.

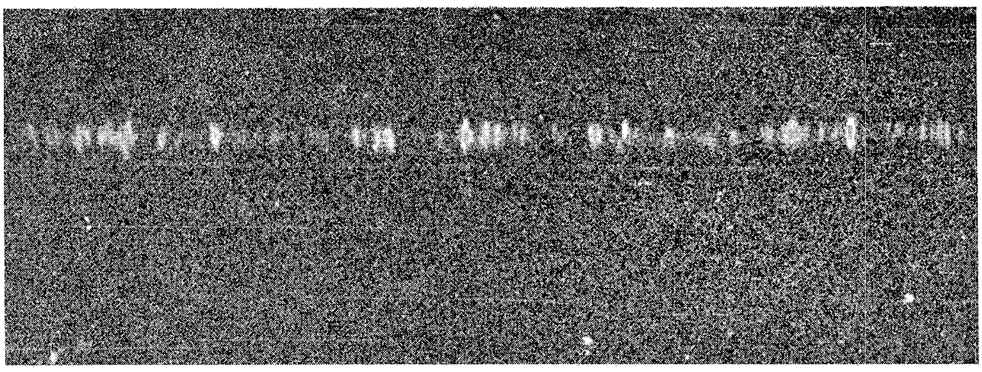

Fig. 2. – Track photograph in a direction perpendicular to the electric field, obtained by a rectangular pulse of 11 kV/cm amplitude and 45 ns duration. Streamer mean length $\overline{\Delta l} = (2.3 \pm 0.5)$ mm. Track length 14.5 cm.

Figure 2 is the photograph of a track obtained in a direction perpendicular to the electric field. The triggering pulse was rectangular with 11 kV/cm amplitude and 45 ns duration. The mean length of the streamers (in the direction of the electric field) is (2.3 ± 0.5) mm. The photograph of Fig. 3 is obtained by a rectangular pulse of 11 kV/cm amplitude and 56 ns duration. The mean streamer length is (6.1 ± 0.5) mm.

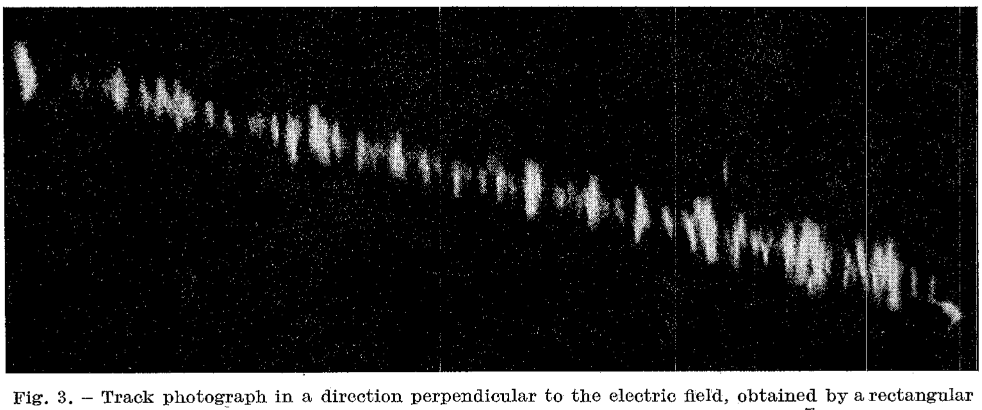

Fig. 3. – Track photograph in a direction perpendicular to the electric field, obtained by a rectangular pulse of 11 kV/cm amplitude and 56 ns duration. Streamer mean length $\overline{\Delta l} = (6.1 \pm 0.5)$ mm. Track length 15 cm.

By plotting the mean streamer length $\Delta\bar{l}$ as a function of the rectangular-electric-pulse duration Δt, the curve of Fig. 4 is obtained. The drift velocity, given by $\Delta\bar{l}/\Delta t$, increases rapidly for pulse durations longer than 60 ns, hence the further streamer development is mainly due to photoionization. This characteristic explains the statistical distribution of the streamer lengths. For mean lengths up to about 5 mm the distribution is rather symmetrical with respect to the mean value (see Fig. 5). The apparent asymmetry for low streamer length is due to the fact that the streamers having a length less than 1 mm emit a light insufficient to expose the film. For mean streamer lengths larger than 6 mm, many streamers « run away » because of the increasing value of the drift velocity and there is a considerable number of streamers with a length larger than the mean value (see Fig. 6). An important characteristic of a track is its brilliance (light emitted per unit apparent area of the track). Relative values of the brilliance have been obtained by dividing the area of the current pulse delivered by the multiplier phototube, by the total area of the corresponding 1:1 scale photograph of the track. The

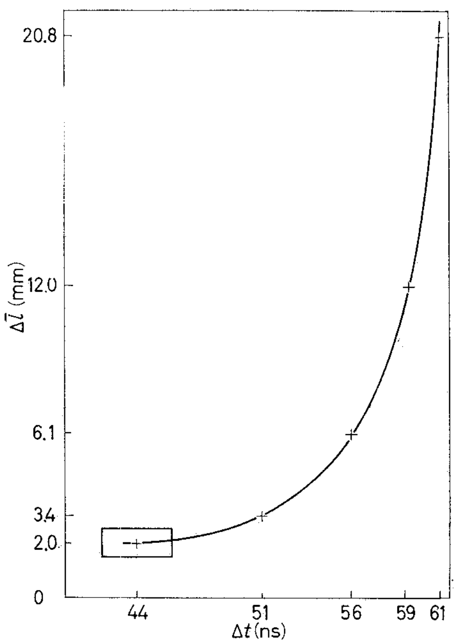

Fig. 4. – Mean streamer length $\Delta\bar{l}$ *vs.* duration Δt of a rectangular electric pulse.

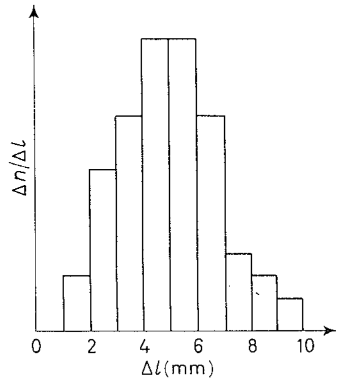

Fig. 5. – Streamer distribution $\Delta n/\Delta l$ *vs.* streamer length Δl, where Δn is the number of streamers having a length between Δl and $(\Delta l+1)$ mm. The track observed had 14.5 cm length and 52 streamers with a mean length $\Delta\bar{l}\simeq 4.9$ mm.

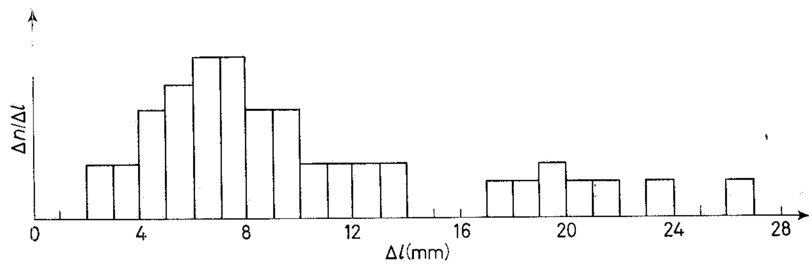

Fig. 6. – Streamer distribution $\Delta n/\Delta l$ *vs.* streamer length Δl for a track having 14.5 cm length and 49 streamers with a mean length $\Delta\bar{l}\simeq 9.4$ mm.

area of the track has been computed by adding the areas of all the streamers of the track considered. The relative brilliance values so obtained are plotted in Fig. 7 *vs.* streamer mean length, varied by changing the pulse duration at constant voltage amplitude. The resulting linear behaviour is in agreement with the following elementary interpretation. As soon as the free-electron number of a streamer reaches a value, in correspondence of which the emitted light is at the threshold to be photographed, the electric field is strongly reduced inside and strongly increased outside the electron avalanche because of the spatial charge. The further development of the streamer occurs on the leading edge of the electron avalanche (and on the streamer's ion tail) at about a constant electric-field value. This is given, schematizing the electron avalanche by a sphere of radius R and uniform charge density ϱ, by $E=\frac{4}{3}\pi R^3\varrho/4\pi\varepsilon_0 R^2 = \varrho R/3\varepsilon_0$. A constant value of E implies a constant (ϱR), which is proportional to the streamer brilliance (and the latter quantity is proportional to the excited-atom number and to the thickness of the streamer, characterized by R).

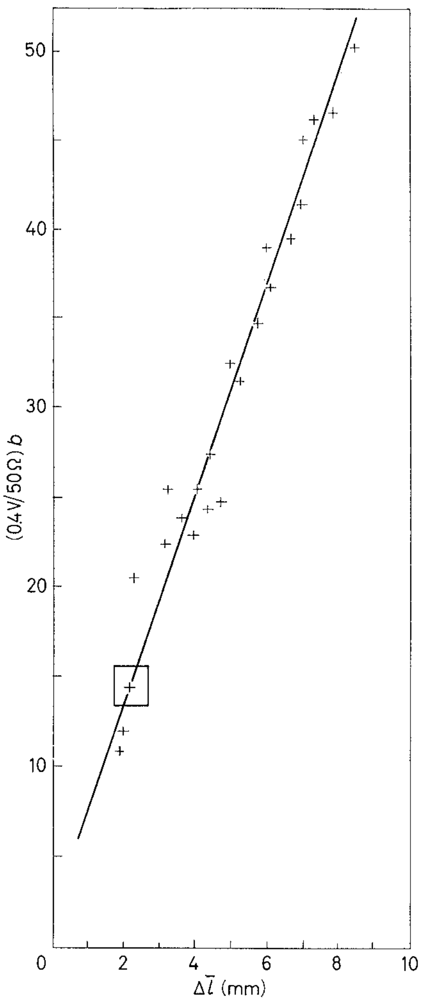

Fig. 7. – Relative brilliance values b *vs.* streamer mean length $\Delta\bar{l}$.

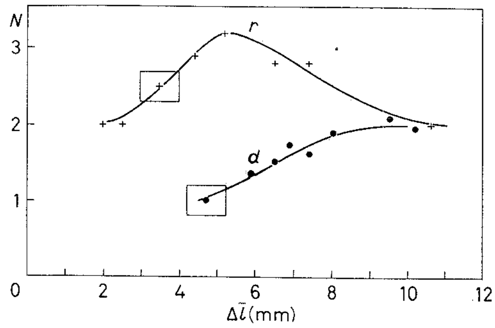

Fig. 8. – Streamer number N per track unit length *vs.* streamer mean length $\Delta\bar{l}$. Curve r is obtained by rectangular electric pulses of amplitude 11 kV/cm and variable duration Δt. Curve d is obtained by damped oscillating pulses of frequency 40 MHz, damping-time constant 200 ns and variable amplitude.

Another important parameter for the track definition is the streamer number per unit length of a track. The ion-electron pairs produced by a minimum-ionization particle in our working conditions (neon at atmospheric pressure) are about 57 per unit length, but only 2 or 3 streamers per unit length are actually observed. Namely, because of spatial-charge effects, the biggest electron avalanches suppress all others (1). We have found that the

(1) K. STRAUCH: *IEEE Trans. Nucl. Sci.*, NS-**12**, 1 (1965).

streamer number N per unit length depends on the streamer mean length $\Delta\bar{l}$. Plotting N *vs.* $\Delta\bar{l}$ in the case of rectangular electric pulse of constant amplitude and variable duration, curve r of Fig. 8 is obtained. For any electric-pulse amplitude there is an optimum pulse duration in order to obtain the maximum streamer number per unit length. For the example quoted in Fig. 8, the maximum of curve r corresponds to $E = 11$ kV/cm and $\Delta t \simeq 52$ ns (mean streamer length $\Delta\bar{l} \simeq 5.1$ mm: see Fig. 4).

We have performed an analogous search by using a damped oscillating pulse ([2]). Up to the maximum frequency ($\simeq 40$ MHz) obtainable with concentrated parameter and the actual chamber dimensions (20 cm diameter and 10 cm height) the track brilliance is less than that obtained by rectangular pulses. The streamer number N per unit length is given by curve d of Fig. 8. The mean streamer length $\Delta\bar{l}$ has been changed by varying the amplitude (from 10 to 12 kV/cm for the first elongation), whereas frequency (40 MHz) and damping-time constant ($\simeq 200$ ns) are maintained invariant. The streamer number N per track unit length obtained with damped oscillating pulses reaches the value obtained by rectangular pulses only for $\Delta\bar{l} > 1$ cm. We think, however, that a good improvement (by using oscillating pulses) may be obtained working with baked chambers filled with a noble gas of spectral purity. Namely the photoionization due to the photons emitted by the same gas cannot occur. Moreover the successive overlapping due to reversions of the electric field reduces the spatial-charge effects. Consequently an increase of brilliance and streamer number per unit length should be obtained.

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We thank Prof. E. Gatti for his encouragements, suggestions and critical discussions during the development of this work.

([2]) For details on the damped oscillating pulse and the relevant best gas mixture see: G. Cavalleri, E. Gatti and G. Redaelli: *Nuovo Cimento*, **25**, 1282 (1962); F. T. Arecchi, G. Cavalleri, P. Principi and G. Redaelli: *Energia Nucleare*, **9**, 713 (1962); G. Cavalleri, E. Gatti, R. Habel, E. Iarocci, T. Letardi and R. Visentin: *Nuovo Cimento*, **41 A**, 289 (1966).