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SPARK CHAMBER IN MEASUREMENTS OF DIRECTION. -

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1. - INTRODUCTION.

We were brought to investigate the precision attainable in reconstructing the path of a ionizing particle by means of a wide gap spark chamber, by the need of information of our group which is preparing an experiment to be done on Adone about the e^+e^- annihilation into two bosons ($\pi^- \pi^+; K^- K^+$)(1).

The problem has various aspects; it's important for instance to know the accuracy attainable in angular measurements; the value of the lateral displacement of the spark from the path of the particle (shift); the angular efficiency in detecting particles; the best working conditions for what concerns the type and pressure of the gas; the value of the applied electric field; the dimensions of the chambers, etc. This paper is intended to give the first results we got in measurements of the shift; measurements on angular efficiency, in different working conditions, are in progress.

2. - THE EXPERIMENTAL APPARATUS.

Fig.1 shows the typical components of the apparatus.

The S_1 and S_2 scintillation counters give the master trigger when passed through by a cosmic ray. C_1 and C_2 are the wide gap chambers.

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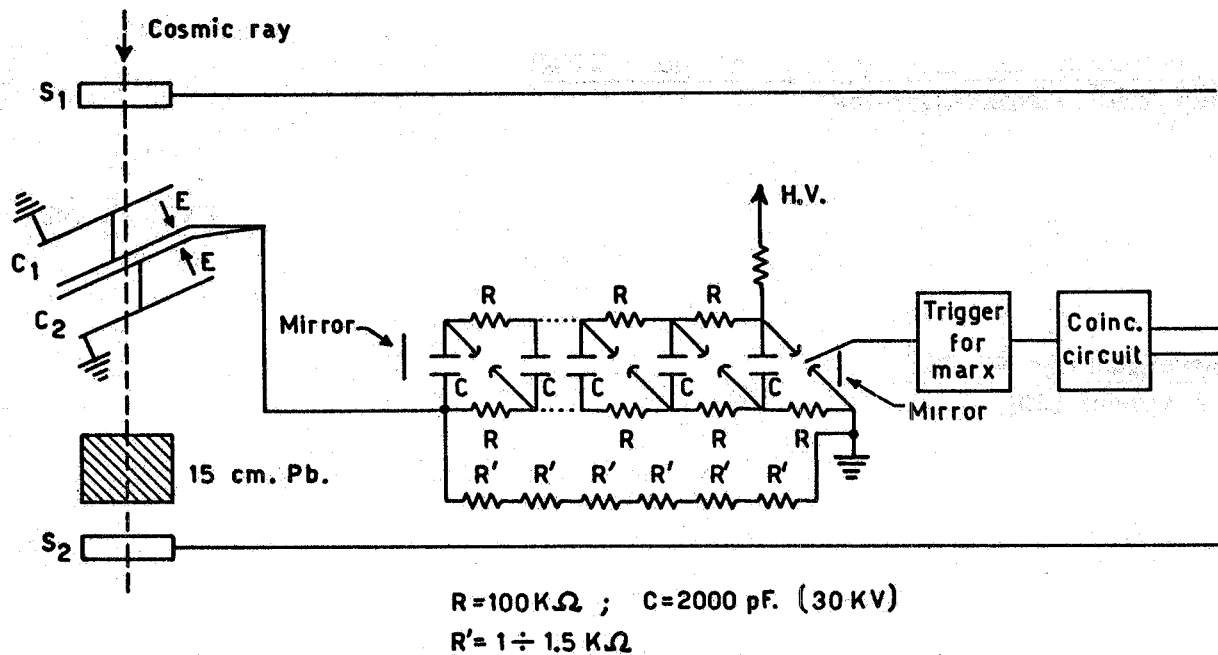


FIG. 1 - Schematic of the wide gap spark chamber system.

2.1. - The wide gap chambers.

We employed two identical chambers $10 \times 10 \times 23\text{ cm}^3$. Of very simple construction, they consist of a mylar box continually fluxed with pure Helium, at atmospheric pressure. As the electrodes of the chambers 2 mm Al plates were used, shielded from the gas by 1 mm sheet of plexi glas, and the boxes were held between them.

2.2. - The Marx generator.

The circuit of it is also shown in Fig. 1. It's a five stages marx with 5 spark gaps in air, which all see each other. The first one is triggered by a 4 KV pulse from the coincidence line.

mesons of more than 200 MeV from cosmic rays, e. e. minimum ionizing, were employed in the test; this we got by shielding S_2 with 15 cm of lead.

A total delay of about 250 nsec occurs between the passage of the particle and the application of the H. V. pulse to the chambers.

2.3. - Optical devices.

Aside of the chambers, at angles of 45 degrees with respect to them, a vertical mirror is placed, to give a perpendicular view of any

event in order to be able to do a spatial reconstruction of the track.

The camera used a xenar 1 : 3.5/100 lens. Under normal conditions TRI-X film with the lens opening set to f/8 was used.

3. - OPERATING CONDITION.

Three different values of the electric field (8, 10, 12 KV/cm) were applied to the chambers; for each value we did almost 2000 photographs of events, varying the angle between \vec{E} and the vertical direction, in the limits $0^\circ \pm 35^\circ$.

It's perhaps worthy to point at the devices we did use to have a good quality track for the tests i. e. a thin and straight, even if not so bright, one. On account of the fact that brightness and thickness depend, having fixed the value of the electric field, on the current flowing from the cathode to the anode through the discharge channel, previously formed by means of the streamers' progression, we did limit it in two ways:

a) shielding the conductive electrodes from the gas with a non conductive sheet of plexiglass;

b) introducing a new and shorter decay constant of the applied H. V. pulse, after a certain delay of time.

For what concerns point a), it's immediately clear that the only electrons flowing from the cathode to the anode through the previously formed discharge channel, are the ones robbed from the plexiglass, provided the sheet is thick enough.

Point b) was realized by putting in parallel to the chambers a spark gap, whose cathode was connected to ground through a convenient resistor, and whose electrodes could be adjusted to any distance.

The effects of the two devices are shown in the Fig. 2 and 3.

4. - MEASUREMENT OF THE SHIFT.

We define "shift" the distance between the track in the chamber and the path of the particle, as indicated in Fig. 4. Two identical chambers were used in our test (see Fig. 1). As the applied electric field E was equal, but pointing towards opposite direction, in such a way that the tracks in the chambers were shifted along opposing directions with respect to the path of the particle, the value δ of the shift is the half of the distance d (see Fig. 4).

The angle between \vec{E} and the vertical direction ($\psi_{\text{vert.}}^E$) could be modified by rotating the experimental set around the y axis of our coordinate system; (see Fig. 5) on this account we measured the values of the

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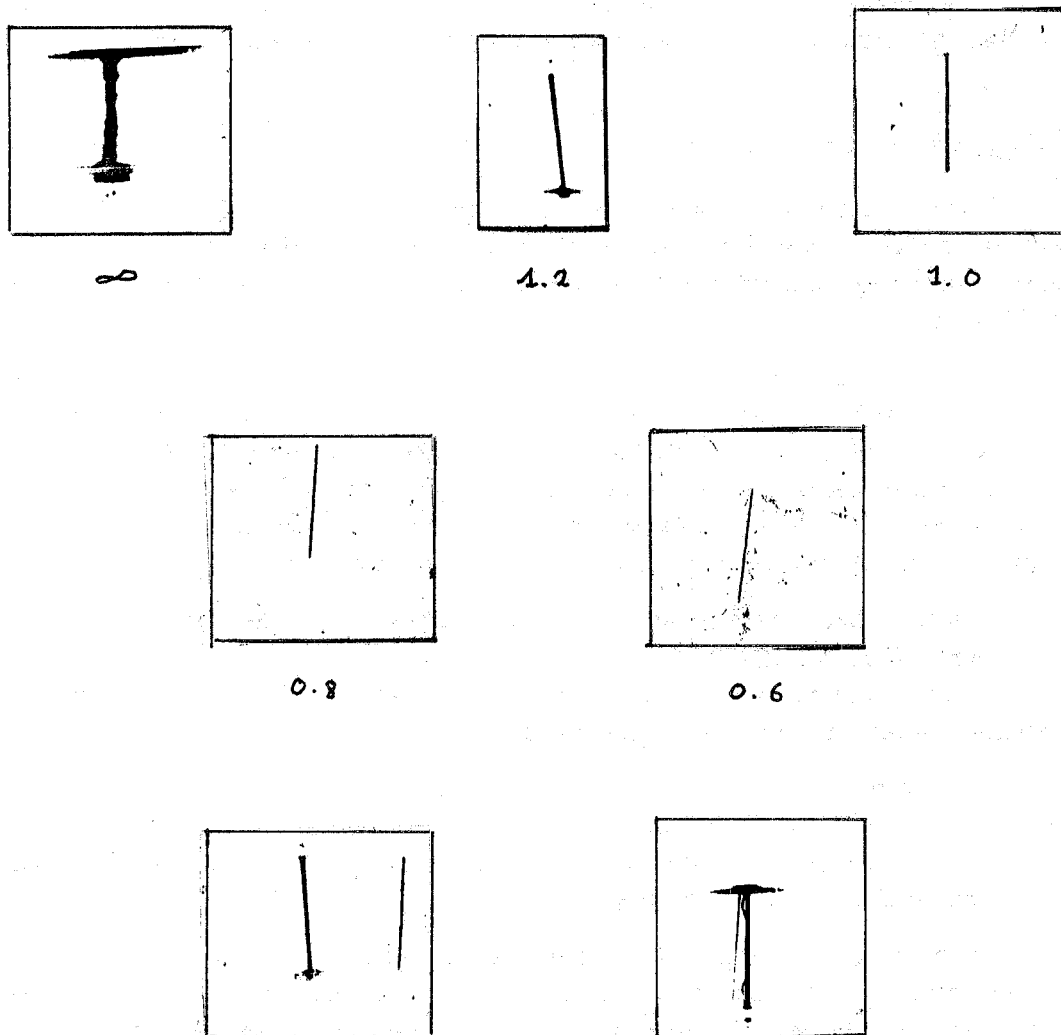


FIG. 2 - The conductive plates are in contact with the gas. The numbers under the photos show the distance in cm between the electrodes of a spark gap in parallel to the chamber. Brightness and thickness of the tracks are growing smaller, while decreasing the distance. Note that brightness and thickness of two contemporary events, are different.

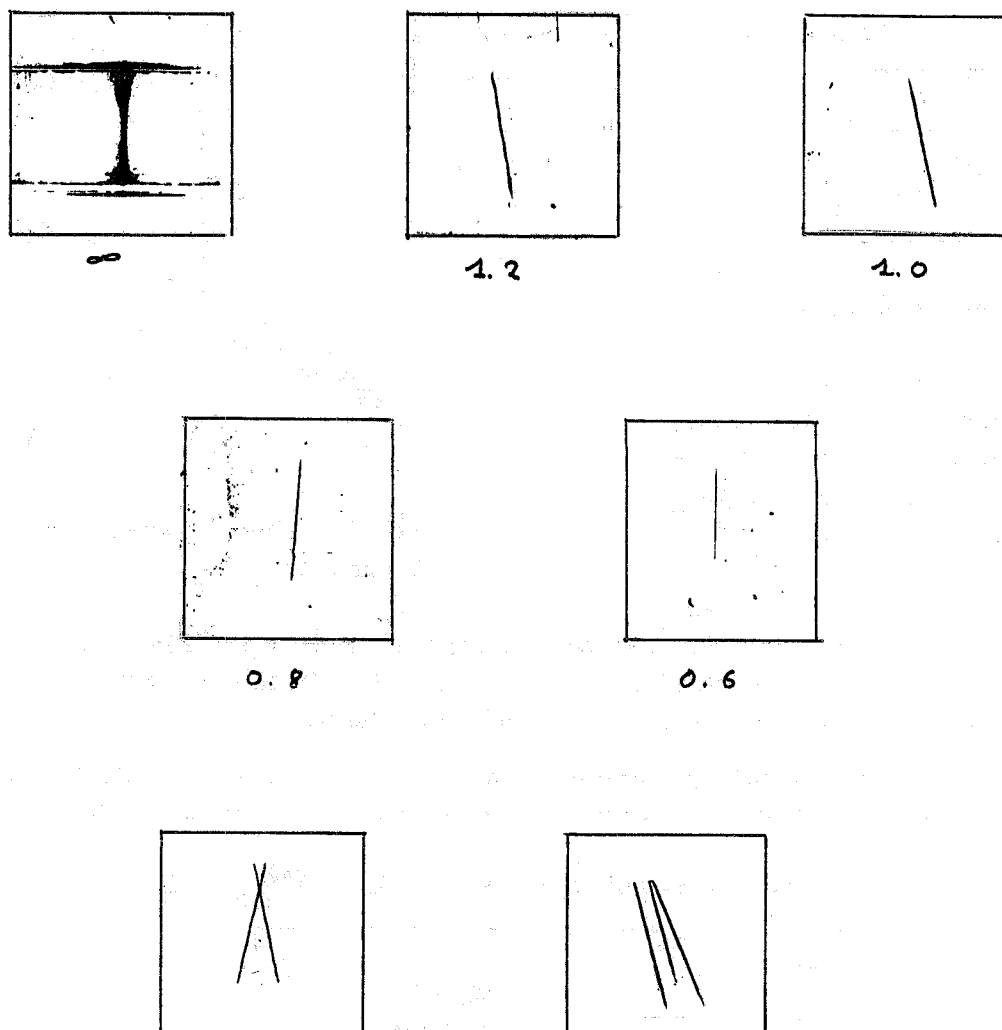


FIG. 3 - The electrodes are shielded from the gas with a non conductive sheet of plexiglas. Note the difference in size between the tracks shown in this series and the corresponding of series A. No difference can be detected between contemporary events.

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shift only in the x, z plane, i. e. the vertical plane containing the electric field E.

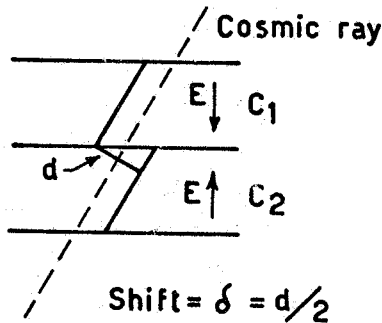


FIG. 4 - The tracks in the chambers are shifted along opposing directions with respect to the path of the particle. The value of the shift is $\delta = d/2$.

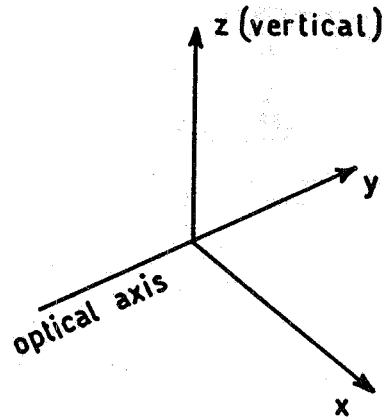


FIG. 5 - The reference frame of our test.

To make sure that the two sparks shift in a parallel way to each other, we did a spatial reconstruction of both the tracks, and measured the spatial angle, $\psi_1^E - \psi_2^E$, between them.

This was done by means of a Fortran program, supplied with the coordinates of 4 points taken on the direct and lateral view of each event(x).

Fig. 6 shows the results we got. When $\psi_{vert}^E = 20^\circ$ the distribu

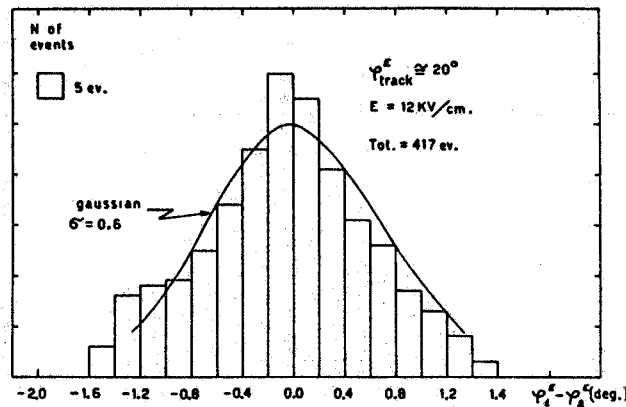


FIG. 6 - Number of events vs. $\psi_1^E - \psi_2^E$. $\psi_1^E - \psi_2^E$ is the difference between the two spatial angles of the tracks in the chambers. The mean angle is coherent with zero.

(x) - The scanning was carried out by means of a "Digitalizzatore KORISTKA - G.I.O. 500 b \square ".

tion, as expected, is a Gaussian, centered on zero.

In Table I we report similar results corresponding to different angles, and to different E values.

ψ_{track}^E

TABLE I

ψ_{track}^E	$l_1^E - l_2^E$	E(KV/cm)
0°-5° 20°-25° 30°-35°	0°+0.8° 0°+0.8° -0.2°+0.8°	8+9.5
20°-25° 30°-35°	0°+0.6° -0.2°+0.8°	12

The mean angle is always coherent with zero, and the standard deviation doesn't seem to change significantly for different E values.

The spread due to the scanning errors was determined by repeated measurements of an event and has been unfolded from the results reported in Table I.

Fig. 7 shows one of the distributions we got, in measurements of the distance d, i. e. of the displacement of the two spark tracks from each other.

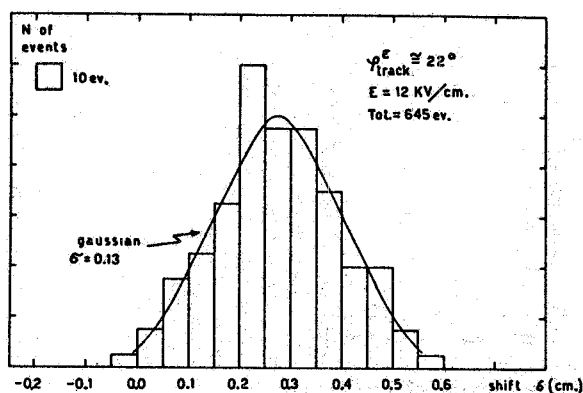


FIG. 7 - Number of events vs. δ , for $l_1^E, \text{ track} \approx 22^\circ$ and $E = 12 \text{ KV/cm}$.

The spread of the values is due to scanning errors and to the fluctuations which arise during the development of the track itself.

Similar distributions were plotted for different values of E, and of the angle between the track and the electric field.

The results we got for δ are summarized in Fig. 9, 10 and Table II.

TABLE II

E track (xz plane)	δ : shift (mm)	E(KV/cm)	Gas
5° 15° - 20° 20° - 25° 30° - 35°	0.5 \pm 0.5 1.25 \pm 0.5 1.50 \pm 0.6 1.85 \pm 0.6	9.5	Helium at atmospheric pressure
15° - 20° 20° - 25° 30° - 35°	1.00 \pm 0.5 1.20 \pm 0.5 1.50 \pm 0.5	8	Helium at atmospheric pressure
15° - 20° 20° - 25° 30° - 35°	1.20 \pm 0.5 1.35 \pm 0.5 1.80 \pm 0.5	12	Helium at atmospheric pressure

Every point on the plots of Fig. 9 and 10 is based on about 700 events. The spread due to scanning errors, as previously done, has been unfolded from these results. (See Fig. 8).

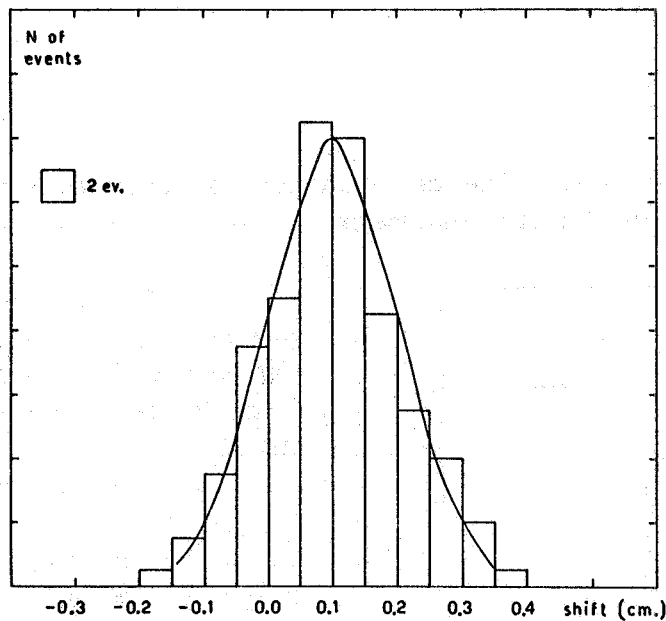


FIG. 8 - The plot shows the distribution around the mean value of 150 repeated measurements of the shift on one event. (Scanning error).

From the results reported in Fig. 9 and 10, we can argue that the shift is approximately independent of the value of the electric field E , in the limits $8 \leq E \leq 12$ KV/cm, when operating in Helium at atmospheric pressure.

As shown in Fig. 10 a simple formula relates the shift to the angle between the track and the electric field:

$$\delta = c \sin \psi_{\text{track}}^E$$

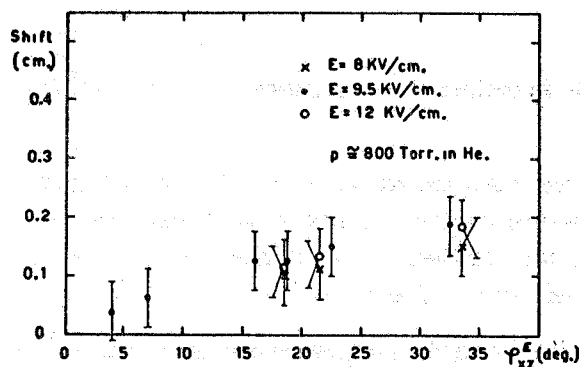


FIG. 9 - The shift, in different experimental conditions, is plotted against the angle ψ_{track}^E . The errors are unfolded of the scanning ones.

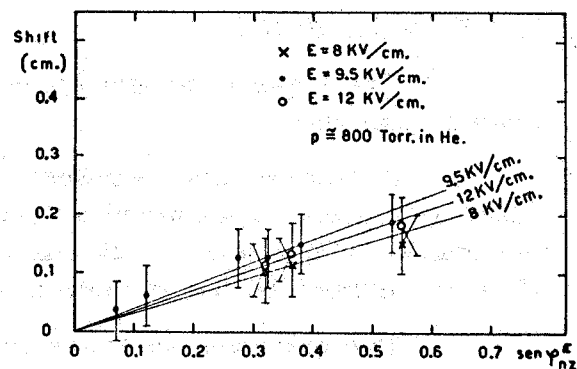


FIG. 10 - The shift is plotted against $\sin \psi_{\text{track}}^E$. There is a definite linear dependence $\delta = c \sin \psi_{\text{track}}^E$.

The physical interpretation of the results we got, may be the following: during the rising portion of the H. V. pulse applied to the chambers, and before space charge effects become important, the ionization electrons, on the path of the particle move along the lines of the applied electric field, creating while proceeding, electron avalanches according to the Townsend law^(2, 3)

$$n(x) = e^{\alpha x}$$

Space charge effects, however, become rapidly more and more important because of the exponential growth of electrons in the heads of the avalanches. Let's suppose that the path of the particle makes an angle with the E direction; then, when the electric field E' on the surface of the head, due to the electronic space charge of the head itself, is approximately equal to E ^(2, 4), the electronic cloud of the avalanche interacts so strongly with the ions could of the advanced nearby avalanche, that streamers are not allowed to develop along the E direction; they are, on the contrary, compelled between the two nearby heads, that means, along a direction

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which is parallel, but not superimposed, to the path of the particle⁽⁴⁾.

This effect (shift) is supposed to grow with the angle between the track and E, until a certain value of it ($\sim 45^\circ$), when E' is no more competitive⁽⁴⁾ with E, and streamers can develop along the lines of the applied electric field.

Beyond that angle, the path of a particle is defined by a succession of dots^(5, 6, 7) and we won't speak of shift any more.

5. - CONCLUSIONS.

The results we got agree with similar measurements of the following authors:

a) Bolotov and Devishev⁽⁹⁾ using two chambers of 20 cm of gap, filled with Neon, measured a displacement of the spark with respect to the track, of 0.3 mm, when the particle's trajectory, made an angle of 4° with respect to the direction of the electric field.

The distance d_c travelled by the spark in the direction of E, turned out to be of 4 mm.

This result is in agreement with the $d_c = 3.5$ mm we can get from our own measurements.

b) Strauch et al.⁽¹⁰⁾, found values for d_c , of 3 and 5 mm, with maxima fields of 22 and 4.5 KV/cm, respectively.

c) We also have agreement with Miyamoto's calculations⁽⁸⁾; he finds out for d_c the values of ~ 3.5 mm, in pure Helium, with a field of 9 KV/cm.

Slightly larger than ours, are Brookes'⁽¹¹⁾ results of the shift. He used a 15 cm chamber, filled with 98% Neon and 2% Helium; the applied field was of 8.6 KV/cm; the shift turned out to be ~ 4 mm, when $\psi \frac{E}{\text{track}} \sim 30^\circ$.

The difference, we think, may be explained in terms of the different values of Townsend's first coefficient α , in Helium or in Neon.

6. - ACKNOWLEDGMENTS.

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