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Electron diffusion in helium streamer chamber with 5 atm pressure *

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1. Introduction

In the contemporary elementary particle physics much attention is paid to the quality of the detection systems. A particularly important feature of the detector is its high resolution and the precision of the charge particle trajectory determination.

The resolution of the streamer chamber (SC) can be improved by decreasing streamer diameter and its length. Using the traditional photographic way of detection the respective streamer dimensions are 1–2 mm and 5–10 mm for parallel and for perpendicular direction of the electric field produced in SC with the high voltage pulse. One way of decreasing the streamer size is to increase the SC gas pressure. This way has been shown by Sandweiss [1] who applied a gas pressure of 24 atm and using the standard photographic method obtained streamer images of 45 μm (in diameter). Stabnikov and Tombak [2] suggested that the use of holographic technique might decrease then the diameter of recorded streamers. Indeed this has been demonstrated experimentally in [3–6] and later on in [7–11], and by applying both the high pressure and holographic techniques the streamer diameters were reduced down to 8 μm [10].

The latter authors applied a gas pressure of 35 atm and observed $100\ \mathrm{cm}^{-1}$ streamer density.

The fact that the detector system enables a precise determination of the particle trajectory becomes especially important when advantage is to be made of the achieved small streamer size. In this respect the deflection of streamers from the original particle trajectory caused by thermal diffusion of electrons is the disturbing effect.

In this work we present results of experimentally determined deflection of this streamer observed in helium streamer chamber (HSC) under 5 atm pressure.

2. Deflection of streamers

Uncertainty in determining the coordinates of charged particle trajectory is due to two effects. The first one is related to the measurement error of the streamer

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coordinates, which becomes negligible, as shown by KALIMOV et al. [12], when the holographic method is used.

The second effect is a deflection of streamers from the original trajectory, caused by physical factors. The primary electrons produced along the particle trajectory are first thermalized and then subjected to thermal diffusion. In both the processes the electron is deflected from its initial position before a streamer is produced. The total mean square deflection is

$$\sigma^2 = \sigma_{t_1}^2 - \sigma_D^2$$

where σ_{t_1} represents deflection in time t_1 of electron thermalization process, and

$$\sigma_D = \sqrt{2D t_2}$$

corresponds to thermal electron diffusion, D being diffusion coefficient, and t_2 – time of diffusion.

Typical values of σ_{t_1}, for the initial electron energy of 10 eV, were obtained by DAVIDENKO [13] and BRAGLIA [14]. These authors have also noticed that when H_2O vapour is used, the thermalization time is significantly shorter. This thermalization property of H_2O and other molecular gases was studied earlier [15], [16].

3. Apparatus

Figure 1 presents a block-diagram of the experimental apparatus used in the work. The electrons from the β-source of ^{90}Sr pass through the streamer chamber (1) and get into the scintillation counter (3) which generates the trigger signals. This signal is transmitted to the start-off electron circuit (4) from the output of which it comes to the input of the pulsed voltage generator PVG (5). The signal for starting the pulse nitrogen laser (7) is received from the second PVG cascade through the delay line (6). A high voltage pulse from the PVG output is transmitted to the high voltage electrode of the streamer chamber. The latter is a plexiglass cylinder of

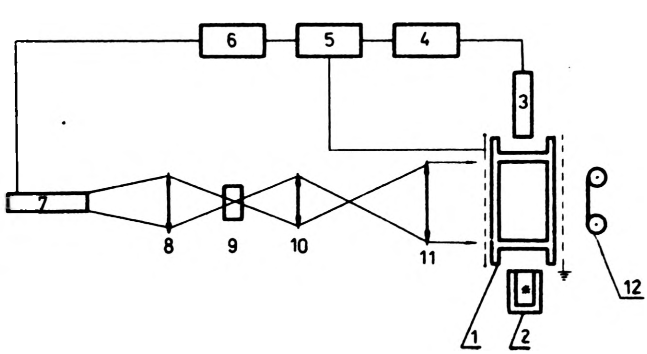

Fig. 1. Block diagram of the experimental setup. 1 – helium streamer chamber, 2 – source of electrons, 3 – scientillation counter, 4 – electronic triggering system, 5 – PVG, 6 – delay line, 7 – nitrogen pulse laser, 8 – quartz lens, 9 – cell with rhodamine 6G, 10, 11 – optical lenses, 12 – photographic film

diameter 70 mm and height 10 mm [4]. The edges of the cylinder are closed with 12 mm thick glass windows. The structure of the chamber enables its operations at gas pressures of up to 5 atm. The electrons pass through the chamber via two specially made mylar windows. The electrodes, in the form of a system of parallel wires ($\varnothing = 100$ μm) are 3 mm spaced and positioned in the immediate vicinity of (close to) the chamber glass windows.

The high-voltage pulse generator assembled according to the standard scheme of Arkadyev–Marx type consists of seven sections. The shock capacitance of the PVG is 3000 pf. The amplitude of the high voltage pulse is 127 ± 5 kV. The output signal delay against the (triggering) signal from the phototube multiplier is 1–2 μs. The laser was started by a signal from the output of the second PVG section through the cable delay line. The delay time of the signal during the work varied from 125 ns to 3 μs.

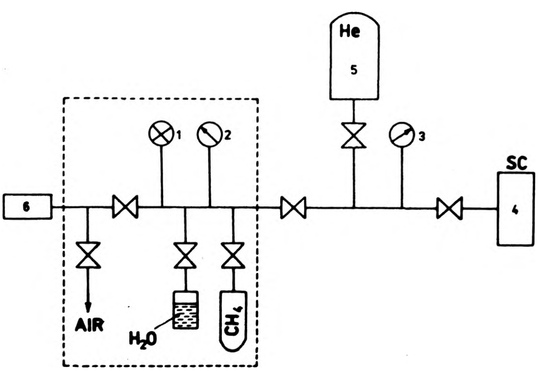

Fig. 2. Vacuum system. 1 – lamp, 2 – reference vacuum gauge (300 divisions), 3 – manometer (up to 10 atm), 4 – streamer chamber, 5 – helium bottle, 6 – pump

A vacuum system (Fig. 2) allowed us to fill the streamer chamber with helium, methane and water admixtures in the required proportions. The admixtures were controlled by means of a vacuum-gauge. The initial vacuum was 10^{-2} Torr. In order to clean thoroughly the chamber the time of its employing was prolonged and the chamber washed with helium. In a well cleaned streamer chamber the electron tracks can be detected on the shadowgrams at 0.01–1% methane and 0.3–0.9% water admixtures. Such small amount of admixtures enables the laser detection in a helium streamer chamber. In spite of the presence of the admixtures the helium streamer chamber may be treated as a practically pure helium target.

4. Results of the experiment

In the work the deflection of streamers from the charged particle trajectory in a helium streamer chamber was measured. The experiment was performed at 5 atm pressure with various quantities of H_2O vapour and methane admixtures (Tab. 1). The streamers were recorded on the Mikrat–300 film of 200 lines/mm resolution. The laser pulse retardation 125 ns with respect to the high voltage pulse was

Table 1

CH_4 [%]	0.02	0.05	0.1	0.5	0.9	0.02	0.05	0.1	0.5	0.9
H_2O [%]	0.3	0.3	0.3	0.3	0.3	0.9	0.9	0.9	0.9	0.9

varied till 3.2 μs. According to the changing retardation the diameter of streamers was varied from 80 to 400 μm. The high voltage pulse was retarded by 1 μs with respect to the time of the charged particle passage through the streamer chamber.

The results obtained did not show a clear dependence of the streamer deflection on the quantity of admixture in the investigated range.

The percentage distribution of the streamer deflection within 0–1.2 mm deflection range is shown, as an example, in Table 2, for the admixture of 0.5% and 0.9% admixtures of methane and H_2O vapour, respectively.

Table 2

Δx [mm]	0–0.1	0.1–0.2	0.2–0.3	0.3–0.4	0.4–0.5	0.5–0.6
$N(\Delta x)$ [%]	41.6	20.8	13.6	8.4	2.5	4.4
Δx [mm]		0.6–0.7	0.7–0.8	0.8–0.9	0.9–1.0	
$N(\Delta x)$ [%]		1.9	2.5	1.5	2.5	

N – total number of the streamer deflected, Δx – deflection range, $N(\Delta x)$ – number of the streamers deflected in the range.

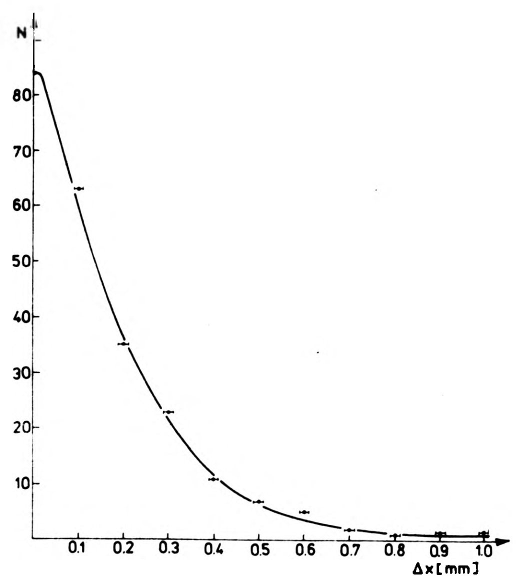

Fig. 3. Deflections of the streamers vs the charged particle trajectory

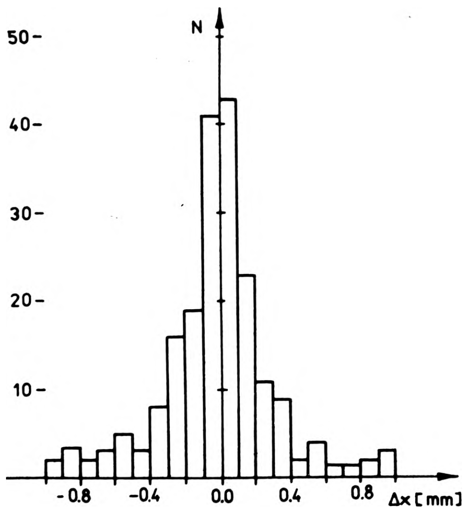

Fig. 4. Histogram of streamers deflections

It is worth noticing that after a prolonged work of the streamer chamber the number of the streamers deflected in the range 0.8–1.2 mm increased to $9^0/_0$. Due to the prolonged work of the streamer chamber the temperature of the gas and thereby the diffusion coefficient increase.

The experimental curve of the number (N) of deflected streamers vs the distance between one streamer and the particle trajectory is shown in Fig. 3 for $0.5^0/_0$ of CH_4 and $0.9^0/_0$ of H_2O vapour. The average deflection of the streamers is ± 0.14 mm. Figure 4 shows the histogram of the streamers deflected from the charged particle trajectory.

5. Conclusion

The streamer deflection value (0.14 mm) obtained in the holographic streamer chamber under 5 atm the pressure is smaller than the reported in [12], for 1 atm pressure with holographic recording. This result shows that with increasing pressure in the chamber the streamer deflection decreases. A large streamer deflection deteriorates the accuracy of the measurement of the particle trajectory in the streamer chamber. The streamer deflection can be reduced by:

1. Decreasing in the high voltage pulse retardation with respect to the time of the charged particle passage through the streamer chamber. Till now due to technical conditions this time is limited to 0.5 μs.

2. Reducing the time of electron thermalization. In the case of the streamer chamber filled with He this time is of ns range. Thus, the thermal electron diffusion determines the streamer deflection value.

3. Reduction of the thermal electron diffusion. To this effect the admixture of the gas with a high cross-section to the dissociative attachement of the electrons is added. The electrons resulting from ionization along the charged particle trajectory are attached by admixed gas molecules and the negative ions are produced. The

velocity of ions is smaller than that of thermal electrons so their deflection caused by thermal diffusion is in μm range.

The information about the charged particle trajectory (before the high voltage pulse from PVG is applied to the streamer chamber) is obtained from the negative ions [7], [10], [17]. Just before the high voltage pulse is applied to the streamer chamber the electrons, necessary to create streamers, are detached from the negative ions by the special light impulse.

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