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MAGNETIC FIELD INFLUENCE ON THE SELFQUENCHING STREAMER DISCHARGE

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This work was performed within the frame-work of methodical investigations connected with the elaboration of the hadron calorimeter of the detector DELPHI /1/ for LEP.

The DELPHI hadron calorimeter consists of iron layers in gaps of which there are plastic streamer tubes /2/ operating in the selfquenching streamer mode. In addition the calorimeter is a yoke of the superconducting solenoid and hence the magnetic field can influence its work for at least two reasons: 1) influence of the field on development of showers in the calorimeter; 2) influence of the field on characteristics of the streamer mode itself.

The first aspect was investigated in the paper /3/. With the help of the Monte-Carlo simulation it was shown that due to distortion of particle tracks in a shower the response of the calorimeter increases by 20-30% in a magnetic field about 12 kG and the value of the effect depends both on the field magnitude and direction. The aim of the present work is to investigate influence of a magnetic field on the selfquenching streamer discharge characteristics.

The measurements were made with a short (about 30 cm) plastic streamer tube (Fig. 1). The diameter of the anode wires was 75 μm, inner dimensions of tube cells were 9x9mm^2.

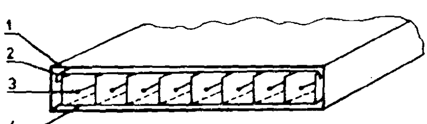


Fig. 1. The schematic view of plastic streamer tube: 1 - envelop; 2 - cover; 3 - anode wire ; 4 - profile.

All four sides of cells were covered with a resistive graphite paint with typical resistivity in the range 50-2000 kOhm per square. To screen, the tube was wrapped up in a thin aluminium foil. To increase the gap in a charge characteristic between the limited-proportional and streamer modes we have chosen the gas mixture with a relatively small organic component (the mixture was argon + isobutane = 1 + 1). This allows one to investigate in more details the influence of a magnetic field on the limited-proportional, transition and streamer modes. The tube was irradiated with X-ray of energy about 8 keV (K-series in Cu). Giving point-like ionization in a gas, X-rays provide good conditions for charge characteristic measurements.

The DELPHI hadron calorimeter consists of a barrel and end-caps. In the barrel the streamer tubes are placed in gaps between iron layers parallel to a magnetic field and hence the magnetic field in the tubes is small (about 10 G). Such a small field does not perturbate on the streamer discharge. But in the end-caps there are large regions where the magnetic field has a large component which is perpendicular to the streamer tubes and hence the magnetic field in tubes may be quite large - up to 12 kG. So, the attention was paid to the case of a perpendicular field.

Fig. 2 represents the counting and charge characteristics of the tube without a magnetic field.

The influence of the magnetic field on the charge spectra for different voltages applied to the tube is shown in Fig. 3. The magnetic field is perpendicular to the anode wires.

Fig. 3 a shows the charge spectrum modification in the region of the limited-proportional mode. The spectrum modification in the region of the selfquenching streamer mode is shown in Fig. 3 c,d. From these spectra it is clear that the

magnetic field decreases the total charge both in an avalanche and in a streamer.

The interesting fact is that in spite of a decreasing avalanche charge in the magnetic field the probability of avalanche developing into a streamer (under the high voltage

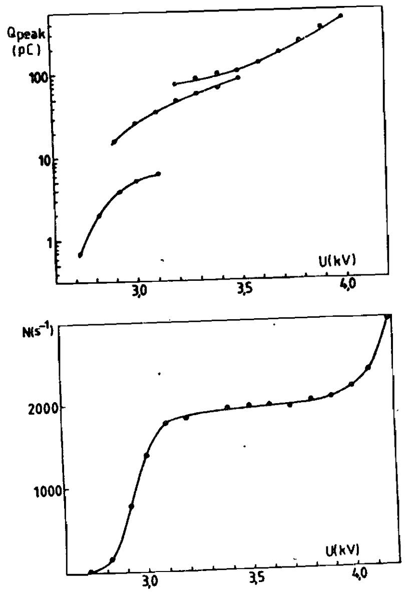


Fig. 2. The charge (up) and counting (down) characteristics of streamer tube in absense of a magnetic field.

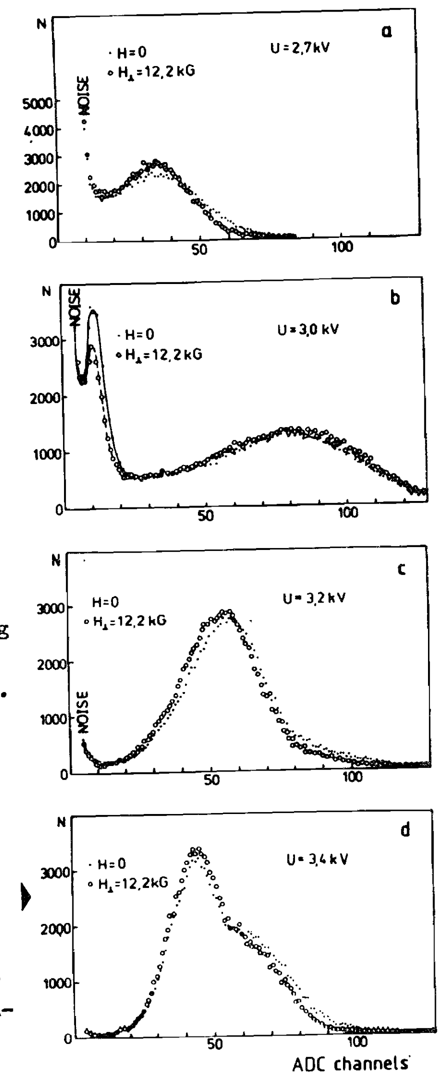


Fig. 3. Charge spectra of the signals with and without the field at different voltages: a) limited-proportional mode, 0.02 pC/channel b) transition region, 0.3 pC/channel; c) streamer mode, 0.5 pC/channel; d) double-streamer mode, 1.3 pC/channel.

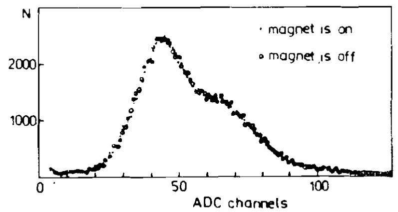


Fig. 4. The contral charge spectra with the magnet on and off; the tube is out of the field.

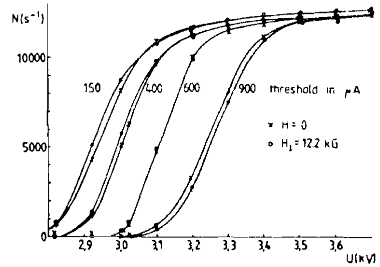


Fig. 5. The counting characteristics with and without the field at the different registration thresholds.

of the transition region) is greater than without a magnetic field (Fig. 3b). The consequence of this is that the mean charge in the transition region is greater in the magnetic field.

The observed effect being small, measures were taken to minimize possible systematic errors. To exclude apparatus drift, the time intervals between measurements with and without the field under a certain high voltage were not larger than 10-15 min (two spectra measured in equal conditions with a time interval 15 min differ from each other within statistical errors). Agreement of the results from different sets of measurements was also checked. To check if there was any influence of the large magnetic field on the apparatus and the X-rays source which were near the magnet, the tube was taken out of the field and the charge characteristic was measured with the magnet on and off while all components of the apparatus were on their places. Fig. 4 shows the result of this measurement. The shape of the spectrum is not changed and mean values of the collected charge differ within the statistical error. Thus the observed effect is completely due to the influence

of the magnetic field on development of an avalanche and a streamer.

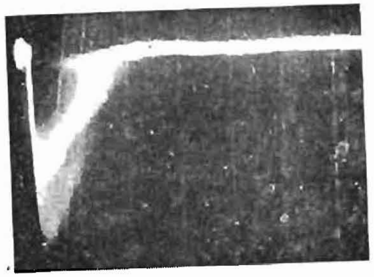
The counting characteristics measured in the magnetic field and without it under different thresholds (Fig. 5) show the following.

When the threshold level is lower than the amplitudes of streamer signals but higher than the amplitudes of limited-proportional signals, the rise of a counting rate curve begins earlier in the magnetic field. This corresponds to an earlier beginning of the streamer mode in the magnetic field.

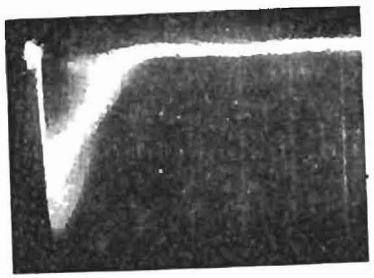
When the threshold level is not in the gap between two modes and hence when only sufficiently large pulses are registered, the effect is reverse. This corresponds to smaller amplitudes of pulses in the region of streamer mode in the magnetic field.

Thus one may conclude that the streamer charge decrease in the field is due to the decreasing amplitude of the current signals rather than to any change of time duration of the signals. The photographs of the pulses (Fig. 6) confirm this. It is also seen that the time dynamics of the streamer formation (shape of the pulse) at a different field value and direction does not practically change.

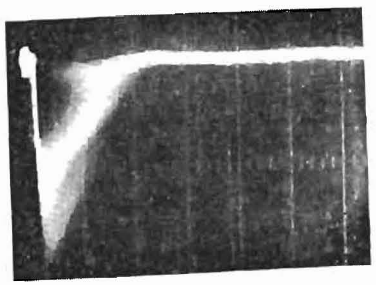
Concerning the calorimeter operation it is interesting to know the magnetic field influence on the mean value of a collected charge. Fig. 7 represents the change of the charge mean value against the magnetic field tension for the case of a perpendicular field and for the case of an inclines field (the angle between the direction of the magnetic field and the anode wires $\alpha = 48^{\circ}$). The high voltage is chosen in the beginning of the plateau of the counting characteristic, which corresponds to the single streamer mode. In both cases sufficiently linear dependence upon the field is observed. It should



a)



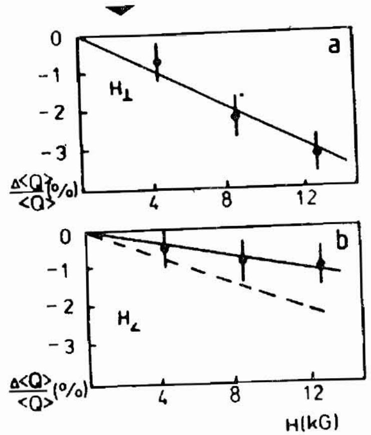
b)



c)

Fig. 6. The photography of the signals ($U = 3.3$ kV; 400 A/div.; 50 ns/div.); $H_{\perp}$ - component of the magnetic field which perpendicular to anode wires; $H_{\parallel}$ - parallel component. a) $H = 0$
b) $H_{\perp} = 12.2$ kG, $H_{\parallel} = 0$
c) $H_{\perp} = 9.1$ kG, $H_{\parallel} = 8.1$ kG.

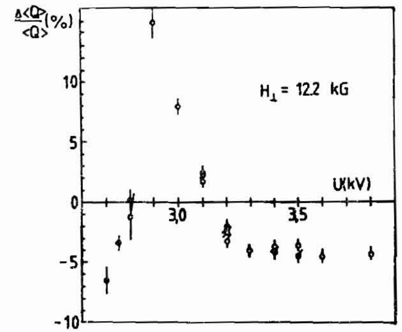
Fig. 7. The collected charge mean value shift versus the magnetic field magnitude and direction: a) $H_{\perp}$; $H_{\parallel} = 0$
b) $H_{\angle}$, $\angle\alpha = 48^{o}$.



be noticed that in the case of an inclined field the effect is smaller than it could be expected if only a perpendicular component of the field had influence on the discharge (dotted line which is obtained from the line in Fig. 7a by multiplying by sin 48^{o}).

Fig. 8 represents the change of a mean value of a collected charge in the large high voltage range. It is seen that in the region of the limited-proportional and streamer modes

Fig. 8. The collected charge mean value shift versus applied voltage for the perpendicular field. Open and closed points represent the different sets of measurements.



the value of the effect is rather small. But in the transition region the effect is considerable (10-15%). Thus the preferable operational high voltage for the streamer tubes of the hadron calorimeter will be the voltage for the single streamer mode for the majority of the shower particle, i.e., in the vicinity of the beginning of the plateau of a counting rate curve. In this case the systematic shift in responses of the barrel and the end-caps of the calorimeter will be negligible.

To avoid confining to the chosen gas mixture it was checked if there is any effect in another one (argon + isobutane = 1 + 3) in the streamer mode. The similar result was observed.

Thus the magnetic field influences the development of an avalanche and a streamer, and the effect is about several per cent in the field about 10 kG. This effect seems to be negligible for the hadron calorimeter, but it is certainly interesting for the understanding the mechanisms of avalanche and streamer development.

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Алексеев Г.Д., Корытов А.В. E13-87-175
Влияние магнитного поля на характеристики самогасящегося стримерного режима

Изучено влияние магнитного поля на характеристики самогасящегося стримерного режима. В полях порядка 10 кГс заряд в стримере уменьшается на несколько процентов (изменение заряда обусловлено уменьшением амплитуды сигнала). В переходной области напряжений от пропорционального режима к стримерному магнитное поле приводит к увеличению вероятности перерастания лавины в стример.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

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Alekseev G.D., Korytov A.V. E13-87-175
Magnetic Field Influence on the Selfquenching Streamer Discharge

The incluence of the magnetic field on the selfquenching streamer discharge characteristics is investigated. In the field about 10 kG streamer charge is decreased several per cent (change of charge is due to amplitude decreasing of signal). In the transition region from limited-proportional to streamer mode magnetic field results in increasing of probability of avalanche developing into a streamer.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

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