TRACK SPARK CHAMBERS IN A MAGNETIC FIELD

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The present paper deals with large-gap spark chambers in which the discharge develops along the true trajectory of the particle. Such chambers have undergone in recent years a particularly intense development in the Soviet Union [1–14]. The investigations show that track chambers have a number of important advantages over the usual spark chambers and yield much more data on the processes taking place in the sensitive volume of the chamber.

Various types of track spark chambers have been created and developed, all of which can be classified according to three groups:

1. Chambers with an interelectrode distance of several tens of centimeters, in which the particles pass from one electrode to the other.
2. Projection chambers, in which the particles pass parallel to the electrodes and where the interelectrode distance is several tens of centimeters.
3. Streamer chambers, which will be dealt with at greater length in other reports of the same authors [12, 13].

One of the main factors determining the suitability of track chambers is the accuracy with which the sparks coincide with the true trajectory of the particle. A detailed investigation of this question was carried out by V. N. Bolotov et al. [14].

It was shown that for particles passing through the central part of the chamber at an angle of 0–8° to the electric field, the angular accuracy with which the spark follows the true trajectory of the particle is $5 \cdot 10^{-4}$ radian [14].

We performed similar measurements in the angular interval of 0–5° for all particles passing through the chamber independent of the place of the passage. The angular accuracy was found in this case to be about 10^{-3} radian (Fig. 5).

The recording efficiency of single particles in two-electrode chambers with a large discharge gap is very high, and it may be assumed with certainty to be close to 100%. In standard spark chambers the efficiency decreases as the number of simultaneously recorded particles increases.

The recording efficiency curve of showers in track chambers, obtained in the study of V. N. Bolotov et al. [10], shows that the efficiency is close to 100% in the case where the number of particles ~ 50.

In 1962 it was shown in our experiments that the sparks in a large-gap two-electrode spark chamber placed in a magnetic field are curved [5]. Cosmic ray observations have established that within the limits of the measurement accuracy the curvature of the tracks corresponds to the true trajectory of the particle in the magnetic field [6–8]. Accordingly, it was established that track spark chambers can be used for detecting charged particles and measuring the momenta of fast particles.

Our preliminary estimates indicated that for a track length of $l = 50$ cm in a magnetic field of 10,000 oersted the maximum measurable momentum may reach ~ 100 GeV/c.

Experiments conducted by the present authors on the synchrophasotron of the Joint Institute for Nuclear Research were aimed at determining the practically attainable accuracy in measuring the momentum of charged particles in track spark chambers and establishing the sources of errors in momentum measurements.

A beam of π^- mesons with a momentum of 4.1 ± 0.08 GeV/c passed through a chamber placed in a magnetic field of $H = 13500$ oersted. The spark chamber, having a gap $l = 40$ cm ($40 \times 40 \times 30\,\mathrm{cm}^3$) and filled with pure neon under a pressure of 520 mm Hg, was fed a high-voltage pulse with an amplitude of 130 kV from an Arkad'ev-Marx oscillator.

Photographs were taken with a stereoscopic camera. The curvature of the tracks on the film was measured by the method of coordinates. A photograph of a track obtained in this chamber is shown in Fig. 1.

The momentum distribution obtained for 52

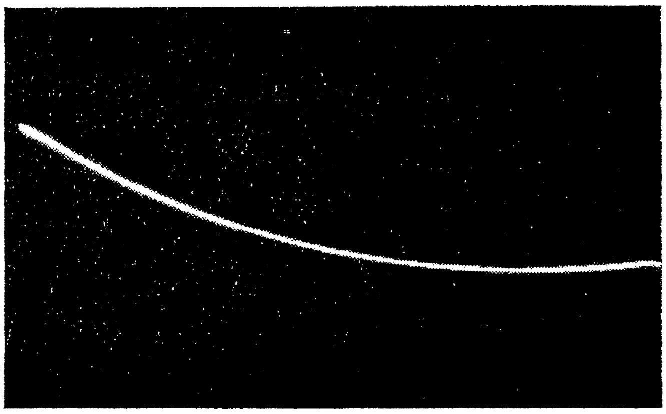

Fig. 1. Photograph of a track in a track spark chamber.

particles is given in Fig. 2. The average momentum was $p = 4.08 \pm 0.05$ GeV/c, and the rms error of an individual measurement $\Delta p = 0.4$ GeV/c.

The mean value of the spurious curvature for 49

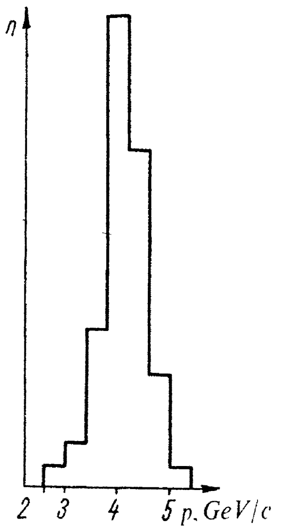

Fig. 2. Momentum distribution obtained for 52 particles.

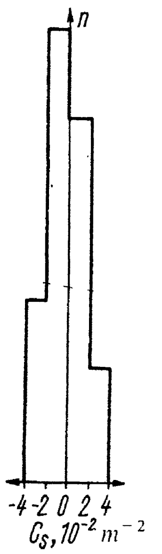

Fig. 3. Mean value of the spurious curvature for 49 particles.

particles (Fig. 3) was found to be $C_s = (-0.44 \pm 1.03) \cdot 10^{-2}\ m^{-1}$, which in a field of $13.5 \cdot 10^3$ oersted corresponds to a maximum measurable momentum of 40 GeV/c and gives a relative rms error $\Delta p/p = 0.1$ for a momentum $p = 4$ GeV/c in accordance with the distribution of Fig. 2.

A characteristic of spark chambers is the error due to the distortion of the true curvature of the particle as a result of the inhomogeneity of the electric field in the chamber. When the electric and magnetic fields are homogeneous, the drift of electrons in crossed fields | $\mathbf{E} \perp \mathbf{H}$ results in a displacement of the spark track relative to the real trajectory of the particle without changing its curvature.

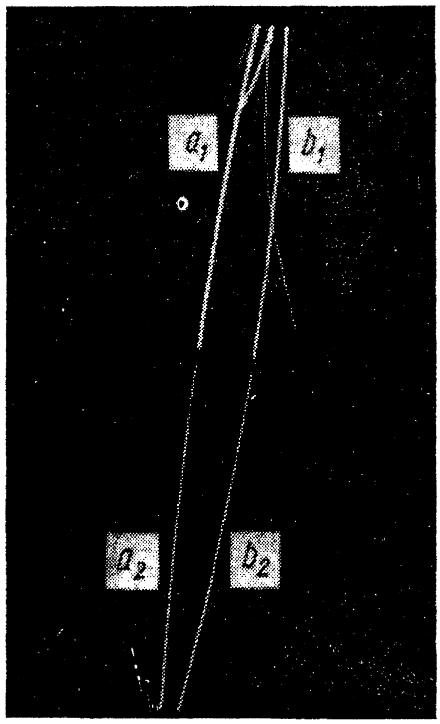

Fig. 4. Photograph of a pair of particles, obtained in a two-section chamber:
$a_1 = 0.92$; $a_2 = 1.05$;
$b_1 = 0.83$; $b_2 = 0.84$.

The overall rms error due to the error in the measurement of the track curvature (the rms coordinate spread of the measured points $\rho_y = 0.25$ mm) and to the distortions introduced by optical dispersion amounts to 7 %.

This is less than the error in the distribution of the curves of Figs. 2 and 3. This and the nonzero mean value of the spurious curvatures are due to the inhomogeneity of the electric field. The accuracy we obtained is far from the maximum attainable accuracy.

Fig. 4 gives the photograph of a pair of particles obtained in a two-section spark chamber. The intermediate electrode is an aluminum foil 40 μ thick. The discharge gap of each section is 25 cm.

To obtain data on electron drift in crossed electric and magnetic fields, spark deviations in the presence and in the absence of a magnetic field for different incidence angles of the charged particles into the chamber were measured (Fig. 5).

For a field intensity of $E = 3$–4 kV/cm the root-mean-square spark displacement relative to the true trajectory in the absence of a magnetic field varies from 0.2 to 0.4 mm, depending on the angle at which the charged particle enters the chamber. In the presence of a magnetic field and for an incidence angle of 10°, the rms spark displacement is 0.5 mm in accordance with the estimated electron drift in crossed electric and magnetic fields.

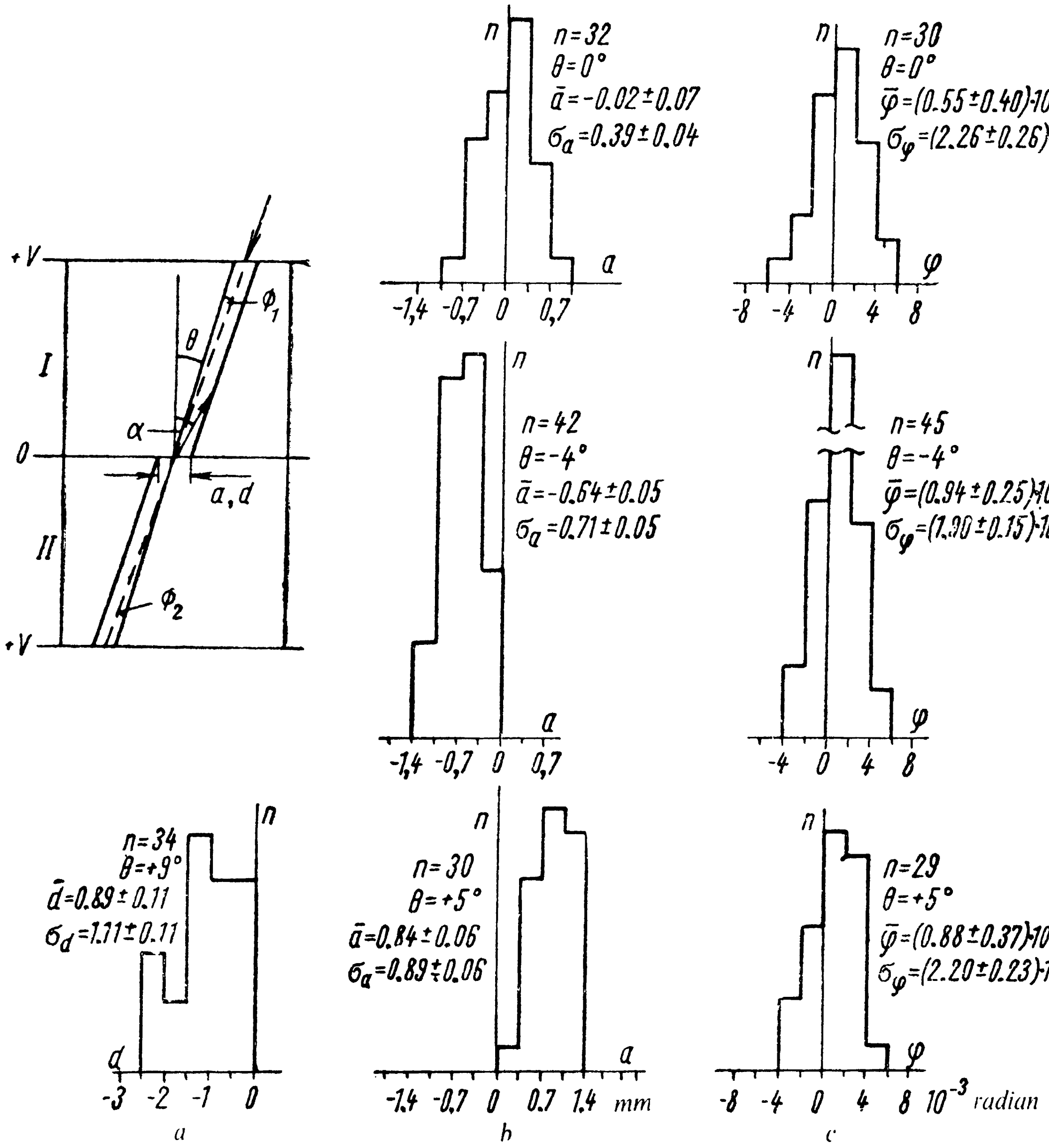

Fig. 5. Experimental data on electron drift in crossed electric and magnetic fields: θ is the angle between the particle trajectory and the direction of the electric field; ϕ and a are respectively the angle and displacement between the sparks in sections I and II in the absence of a magnetic field; α and d are respectively the electron drift angle and spark displacement in crossed fields ($E \perp H$).

Of independent interest is the measurement of charged particle momenta in a projection spark chamber. This has a number of advantages, of which the principal ones are the absence of electron drift ($\mathbf{E} \parallel \mathbf{H}$) and the long track in the case of a fairly uniform electric field.

Fig. 6 shows a photograph of charged particles, which we obtained in a projection spark chamber with a discharge gap $l = 18$ cm ($18 \times 60 \times 40$ cm^3) placed in a magnetic field.

After attaining the streamer conditions for operation in the spark chamber of G. E. Chikovani et al. [12] and B. A. Dolgoshein and B. I. Luchkov [13], in which it is possible to obtain high-quality tracks

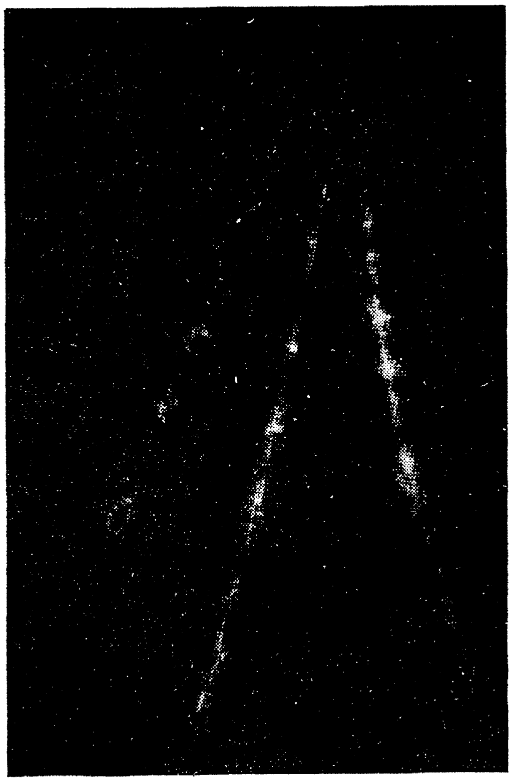

Fig. 6. Photograph of a charged particle obtained in a projection spark chamber.

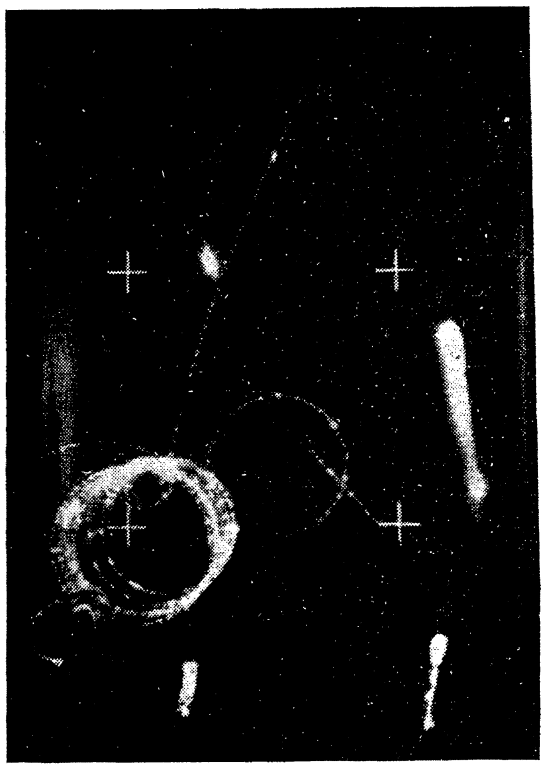

Fig. 7. Photograph of charged particle tracks in a streamer chamber.

of charged particles, we replaced the projection conditions of the chamber by streamer conditions.

Photographs of charged particle tracks in a streamer chamber placed in a magnetic field are given in Fig. 7.

The rms coordinate spread of the measured points relative to the approximating straight line for 125 muons with a momentum $p \geqq 0.6$ GeV/c was found to be 200 ± 90 μ, which gives a maximum mea-

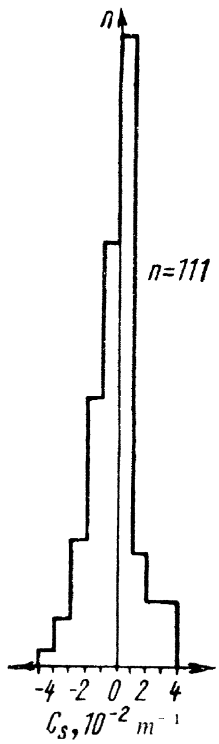

Fig. 8. Distribution of spurious curvatures.

surable momentum in a field of 10^4 oersted of 100 GeV/c in accordance with the Chikovani-Dolgoshein data. For a more reliable determination of the maximum measurable momentum, we determined the spurious curvature of the same tracks. The distribution of the spurious curvatures (Fig. 8) indicates a non-vanishing mean value of the spurious curvatures.

$$C_s = (1.67 \pm 9.6) \cdot 10^{-3}\ \mathrm{m}^{-1},$$

which gives a value $p_{max} = 30$ GeV/c.

However, these data are preliminary and the measurements are being continued.

REFERENCES

1. Borisov A. A. et al. Pribory i Tekhnika Eksperimenta. No. 1, 49 (1962).
2. Govorov A. M. et al. Pribory i Tekhnika Eksperimenta, No. 6, 170 (1961).
3. Borisov A. A. et al. Pribory i Tekhnika Eksperimenta, No. 2, 170 (1962).

4. Mikhailov V. A. et al. Fifth Conference on Nuclear Electronics. M., 1961.
5. Alikhanyan A. I. et al. JETP, **44,** 113 (1963).
6. Alikhanyan A. I. et al. Phys. Lett., **4, 5,** 295 (1963).
7. Alikhanyan A. I. et al. Phys. Lett., **7, 4,** 272 (1964).
8. Alikhanyan A. I. In "Voprosy fiziki elementarnykh chastits". Erevan, 1963.
9. Daion M. I., Leksin T. A. Uspekhi Fiz. Nauk, **2,** 281 (1963).
10. Bolotov V. N., Devishev M. I., JETP 45, 1680 (1963); **46,** 1990 (1964).
11. Lyubimov V. A., Pavlovskii F. A., JETP, **46,** 1143 (1964).
12. Chikovani G. E. et al. JETP, **46,** 1228 (1964).
13. Dolgoshein B. A., Luchkov B. I., JETP, **46,** 392 (1964).
14. Bolotov V. N. et al. Pribory i Tekhnika Eksperimenta, **2,** 51 (1964).

DISCUSSION

M. G. Meshcheryakov

If I correctly understood you, in your experiments the spurious track curvature was not equal to zero. What are the reasons for spurious track curvatures and what are the methods of eliminating them?

T. L. Asatiani

The non-vanishing value of the spurious curvature should be attributed to the inhomogeneity of the electric field, all the more so because in the absence of a magnetic field the beam was displaced toward the edge of the chamber. A higher degree of homogeneity can be achieved either by using a distributed resistance (Lyubimov, Institute of Theoretical and Experimental Physics), or by using a circuit of series-connected capacitances (Strauch, Harvard).