MEASUREMENT OF THE MOMENTA OF FAST CHARGED PARTICLES (10^{10}–10^{12} eV/c) BY THE SPARK CHAMBER AND PHOTOEMULSION TECHNIQUE

M. I. DAĬON, V. B. ELISEEV, and M. A. KAZARYAN

P. N. Lebedev Physics Institute, Academy of Sciences, U.S.S.R.

Submitted to JETP editor September 13, 1965

J. Exptl. and Theoret. Phys. (U.S.S.R.) **50**, 376–378 (February, 1966)

Experimental data are presented on the probability of detecting the tracks of charged particles in a photoemulsion (thickness 200 μ) as indicated by a spark-chamber telescope.

1. IN connection with the problem of studying the interactions of cosmic-ray protons with matter, the possibility is again being discussed in the literature of measuring the momenta of fast charged particles (10^{11}–10^{12} eV/c) in a magnetic field by the spark chamber and photoemulsion method.[1] The essence of this method consists of first determining the location of a track in space by means of spark chambers and then, following the track, observing and identifying it in several layers of photoemulsion placed in a magnetic field. By this means it is possible to determine the coordinates of the track and its radius of curvature in the magnetic field with considerably improved accuracy.

The use of spark chambers to find interesting tracks in a photoemulsion was first suggested by us in 1959.[2] We considered the question of finding a given track in the photoemulsion, presented a calculation of the extreme momenta measurable, and discussed the possibility of measuring the momentum spectra of cosmic rays at mountain altitudes in the energy region 10^{10}–10^{12} eV. In the present note we report experimental results obtained in the same year on identification of particles in photoemulsion with the aid of a spark-chamber telescope. These data, which were presented in the thesis of M. A. Kazaryan (Nuclear Physics Scientific Research Institute, Moscow State University, 1959), have not been published previously.

2. In an electromagnet gap (60 × 20 × 10 cm) we placed three spark chambers at a distance of 28 cm apart in the form of a telescope. Each chamber measured 18 × 8 cm. The interelectrode spacing of the chambers was 2 mm. The chambers were filled with a mixture of air, argon, and organic vapors. A detailed description of the spark-chamber telescope in the magnetic field is given by Daĭon et al.[3] Under the lower spark chamber was placed a 200 μ photoemulsion on a glass backing. The emulsion was mounted in a special cassette which was positioned with respect to the coordinate grid of the lower spark chamber.

In a special experiment without a magnetic field, by recording single particles in the spark-chamber telescope, we obtained the distribution of the deviation of the sparks from the particle trajectory. For approximately 97% of the sparks, the value of the mean-square deviation from the trajectory turned out to be ~ 0.2 mm.[3]

3. We selected 26 straight tracks in the spark-chamber telescope. We computed the azimuthal angles α_i (the angle between a selected zero axis in the plane of the chamber and the projection of the trajectory in the plane of the chamber) and the corresponding angles of inclination of the trajectories from the vertical, β_i. From the angle of inclination β and the thickness of the photoemulsion we computed the length l of the projection of the trajectory in the plane of the photoemulsion. For 12 trajectories we computed the coordinates of the point of intersection of the trajectory with the photoemulsion from the coordinates of the spark in the lower chamber and the angles α and β, and then scanned a circular region of the photoemulsion 0.5 mm in radius around the calculated point, under a microscope with high magnification (~ 400 ×); the total number of tracks in this region was counted (the emulsion loading) and the azimuthal angles and length of the trajectory projection were measured. In 7 of the 12 cases we detected a single track in the scanned area of ~ 1 mm^2 with the given characteristics within the limits $\alpha \pm 4°$ and $l \pm 5\,\mu$. All of these events are listed in Table I.

To check the possibility of random coincidence of the trajectory direction in the emulsion with the given direction, we took 14 more trajectories at

Table I

From spark telescope		Number of tracks per mm² of emulsion	Number of tracks having azimuth $\alpha \pm 15°$	Number of tracks with $l \pm 5\,\mu$	Characteristics of tracks found in emulsion	
Azimuth α, deg.	Projected length l, μ				α, deg.	l, μ
151	23.6	18	1	1	155	23.3
92	15.7	29	4	1	93	17.5
10	14.4	16	—	—	—	—
208	37.7	17	2	—	—	—
76	7.7	28	1	—	—	—
182	27.5	24	3	1	182	22
51	24.3	17	1	1	52	22.4
69	12.5	36	3	1	66	13.6
181	22.4	39	2	—	—	—
192	27.5	23	2	1	193	29
?	19	30	2	1	73	22
152	11.4	21	2	1	150	17

Table II

From spark telescope		Number of tracks per mm² of emulsion	Number of tracks having azimuth $\alpha \pm 10°$	Number of tracks with $l \pm 8\,\mu$
α, deg.	l, μ			
146	23	10	—	—
146	23	30	2	—
146	23	12	—	—
215	26	23	1	—
215	26	31	—	—
215	26	17	2	—
338	19	15	—	—
10	14.4	44	1	—
10	14.4	28	1	—
208	37.7	37	4	—
208	37.7	41	1	—
226	20.6	21	—	—
258	8.5	21	1	—
275	6	35	2	—

random (Table II). In these 14 mm^2 we did not detect a single case of coincidence with trajectories with the given characteristics and with tolerances even larger than in the basic event: a tolerance of $\pm 8\,\mu$ in l and $\pm 10°$ in α. Incidentally, in the main series (Table I) for an increase of the interval widths from $l \pm 5\,\mu$, $\alpha \pm 4°$ to $l \pm 8\,\mu$, $\alpha \pm 15°$, no additional trajectories were observed.

Thus, the 7 cases of matching of the trajectories in the spark-chamber telescope and the photoemulsion are not random coincidence; they show that from the indication of the spark-chamber telescope we can observe an interesting track in the photoemulsion.

The detection efficiency obtained of ~60% is rather large if we consider that the experiment was very preliminary in nature. In particular, the photoemulsion was not positioned particularly accurately, and for the small area scanned (in our case 1 mm^2) even a small shift of the emulsion gives a loss of trajectories. Furthermore, in our spark chambers, in contrast to chambers with neon filling, "tails" were observed in the distribution of deviations of sparks from the trajectory, i.e., sometimes the sparks occurred to the side, at a large distance from the trajectory.

A similar means of target designation with a spark-chamber telescope on a photoemulsion stack for identification of particles produced by a given event in the photoemulsion has been accomplished by Basova et al.[4] and by Duff et al.[4]

We note that air-argon chambers are convenient for operation in a magnetic field, since displacement of the sparks does not occur here even for large clearing fields.[5] However, because of their large memory time and the low shower efficiency, their field of application is very limited. To find interesting tracks in photoemulsion, it is possible to use neon spark chambers with sonic location of the sparks, or wire chambers. The speed and efficiency of track detection in the photoemulsion can be considerably increased by machine analysis of the spark-chamber data and automatic scanning of the emulsion. If wide-gap spark chambers are used, it is necessary to take into account the shift of the trajectory along the field, which can reach several millimeters (see Bolotov et al.[6]).

In the measurement of fast particle momenta, in addition to the problem of identifying tracks in an emulsion, which, as our work has shown, can be solved quite successfully (see also the work of Basova et al.[4]), a more complicated problem arises of the accurate measurement of the relative coordinates of tracks in several emulsions located at a distance of several tens of centimeters. For large emulsion areas of the order of hundreds of square centimeters, to achieve and preserve over a period of time a relative alignment within 1–2μ, on the basis of our tests, turns out to be a very complex technical problem, and it is hardly possible to think in terms of this accuracy in estimating the resolving power of the apparatus. A value of 3–4μ is apparently realistic. However, this question remains open to direct experimental verification.

The authors thank V. Kh. Volynskiĭ for major assistance in this work.

[1] L. Alvarez and W. Humphrey, Proc. Conf. on the Interaction Between Cosmic Rays and High Energy Physics, Cleveland, September, 1964.

[2] M. I. Daĭon and V. Kh. Volynskiĭ, JETP **37**, 906 (1959), Soviet Phys. JETP **10**, 648 (1960).

[3] M. I. Daĭon, V. Kh. Volynskiĭ, and L. I. Potapov, PTÉ, No. 2, 47 (1961).

[4] E. S. Basova, A. S. Vovenko, U. G. Gulyamov, V. G. Kolesnik, T. Sanevska, L. V. Sil'vestrov, É. Skrzypczak, Hsui Yung-Ch'ang, and M. S. Khvastunov, JINR preprint No. 1942, 1965; PTÉ, No. 1, 1966. B. G. Duff, D. A. Garbutt, and W. T. Toner, Nucl. Instr. Meth. **29**, 351 (1964).

[5] M. I. Daĭon, V. M. Knyazev, and G. A. Marikyan, PTÉ, No. 1, 54 (1965).

[6] V. N. Bolotov, M. I. Daĭon, M. I. Devishev, L. F. Klimanova, B. I. Luchkov, and A. N. Shmeleva, PTÉ, No. 2, 57 (1964).

Translated by C. S. Robinson
52