Spectrum and Positive Excess of the Hard Component in the (9.3 – 17) x 10⁹ ev/c Momentum Range at an Altitude of 3250 Meters

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The spectral distribution of the positive excess in the hard component was measured in the $(0.3-17)\times 10^9$ ev/c momentum range. The measurements were performed on the large spectrograph of the Alagez Laboratory at an altitude of 3.25 km.

THE purpose of the present work is to continue into a region of significantly greater momenta, up to 1.7×10^{10} ev/c, the measurements of the momentum spectrum and positive component which were carried out in Ref. 1 in the region $(0.1-2.5)\times 10^9$ ev/c. At the present time interest in this problem has increased in connection with the fact that the study of the production of K-mesons in cosmic rays and especially in accelerators has disclosed a sharp asymmetry in the number of positively and negatively charged mesons produced. By this same fact, the proton character of the primary cosmic rays has ceased to be the only possible explanation of the positive component. Measurements were carried out in 1952 in the large magnetic spectrometer of the Alagez Laboratory at a magnetic field of magnitude 13,700 oe. At such a field the probable error in the measurement of a momentum of 1.7×10^{10} ev/c is close to 50%. The construction of the magnetic spectrometer and the methods of treating the data have been described briefly[2,3], and we will limit ourselves here to introducing only a sectional drawing of the distribution of the counters in the telescope and of the absorbers (Fig. 1).

A layer of lead of 7 cm thickness was placed over the entire apparatus. The total thickness of all the lead absorbers over the rows of counters $VI-X$ was equal to 5.8 cm. Under the row of counters X

TABLE Distribution of the particles of the hard component by momentum intervals.

	Momentum interval in units of 10^8 ev/c	3–5	5–6	6–8	8–10	10–15
$R>5,8$ cm	n_+	83	140	382	436	898
	n_-	88	114	261	318	667
	$k=n_+/n_-$	0,94±0,14	1,23±0,14	1,46±0,09	1,37±0,08	1,35±0,07
$R>19,8$ cm	n_+	32		99	152	490
	n_-	30		101	123	395
	$k=n_+/n_-$	1,07±0,25		1,12±0,10		1,24±0,08

(continuation of the table)

15–20	20–30	30–50	50–90	90–170	>170	3–170
611	880	765	582	309	211	5082
431	616	546	418	220		3669
1,42±0,08	1,43±0,07	1,40±0,07	1,39±0,08	1,47±0,09		1,39±0,02
371	588	551	422	224	141	2929
288	424	405	329	176		2271
1,29±0,09	1,39±0,08	1,36±0,08	1,28±0,08	1,27±0,12		1,29±0,03

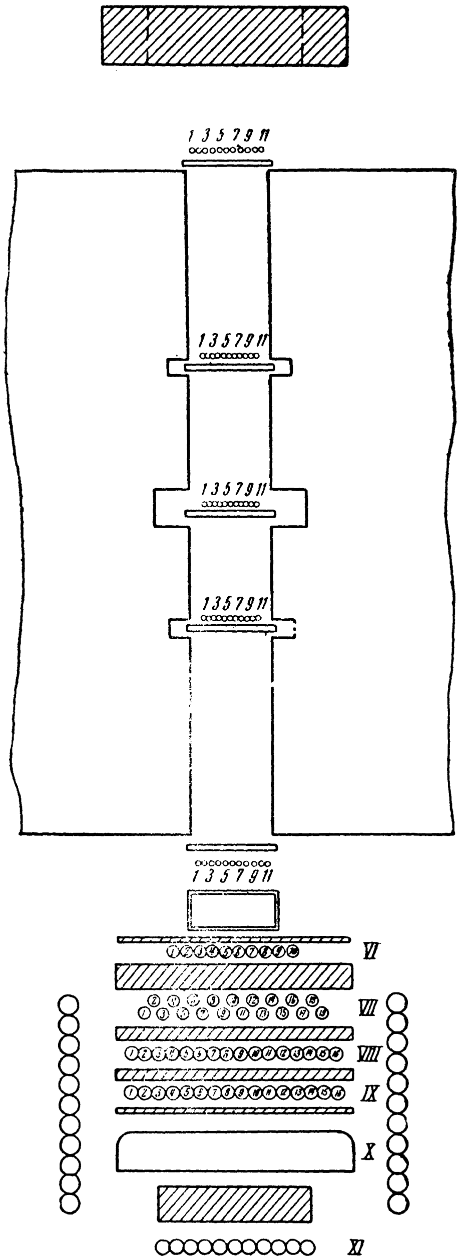

FIG. 1. Distribution of the counters in the telescope and of the absorbers.

was located a layer of lead of 14 cm thickness, under which was placed the row of counters *XI*. Particles which passed through all the rows of counters up to the tenth inclusively, and did not undergo multiplication, as determined by coordinated counters, were considered to belong to the hard component. The path of these particles was greater than 5.8 cm of lead. The path of those particles of the hard component which also passed through the row of counters *XI* was greater than 19.8 cm of lead.

The Table gives the experimental results — the number of positively and negatively charged particles (n_+ and n_-) the momenta of which lie within the indicated intervals (the tabulated numbers being given without correction for the magnetic aperture ratio of the apparatus). These data were obtained as a result of measurements of the momenta of 8966 particles. They give the momentum spectrum and the distribution of the positive component in this spectrum. The last column of the table gives the values of the positive excess for the entire momentum interval investigated, this excess is $k = 5082/3666 = 1.39 \pm 0.08$ for the particles with path length $R > 5.8$ cm of lead. In order to explain how an excess of this magnitude is concerned with mesons, let us consider the average value of the excess for particles with a path greater than 19.8 cm of lead. Because of ionization braking, protons of momentum less than 1.05×10^9 ev/c do not occur among these particles. Protons of greater momenta must be strongly absorbed in the supplementary 14 cm block of lead, the thickness of which is equivalent to a single "geometrical" nuclear absorption path. The positive excess for particles with a path greater than 19.8 cm of lead is given by $k = 2929/2271 = 1.29 \pm 0.03$.

The spectrum of the positive excess was measured in Ref. 1 up to 2.5×10^9 ev/c. It is of interest to obtain the value of the positive excess for larger momenta. From the data of the table it follows that for momenta greater than 3×10^9 ev/c the positive component is equal to:
$k = 1656/1174 = 1.41 \pm 0.05$ for particles with path $R > 5.8$ cm; $k = 1197/910 = 1.31 \pm 0.5$ for particles with path $R > 19.8$ cm.

These results, in agreement with Ref. 1, indicate that in each measured spectrum as well as in the region of larger momenta a significant part of the positive excess is produced by μ mesons. Since a part of the protons of high energy produces penetrating particles in the lead and thus "passes" into the hard component, it follows from the results introduced that the positive excess arising from the meson component itself is, in any event, less than 1.30.

The spectral distribution of the positive excess is shown in the table and in Fig. 2. In these results it is to be noted that the positive excess in the region of small momenta, where protons are known to be absent (momenta less than 0.6×10^9 and 1.0×10^9 ev/c for mesons with paths greater than 5.8

and 19.8 cm of lead, respectively), is near unity. This fact, which appears as a consequence of the local generation of slow mesons by the neutron component, is well known at the present time[4,5].

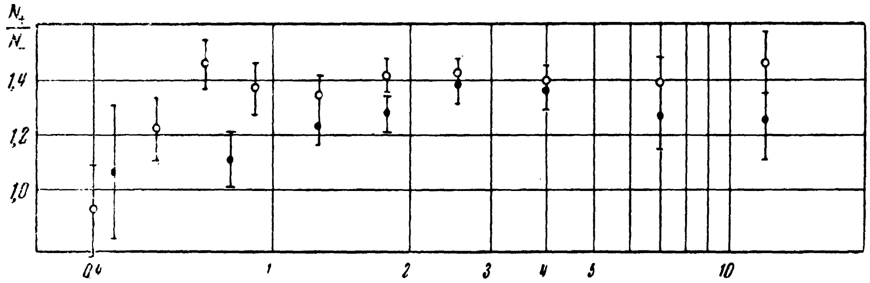

FIG. 2. o— positive excess for particles with $R > 5.8$ cm Pb; o—the same with $R > 19.8$ cm Pb. Momenta in units Bev/c are plotted as abscissa.

The separation of the positive excess into a proton part and a meson part which has been carried out in this and the preceding work[1] allows the possibility of determining the vertical intensity of the proton component under the conditions of our experiment, that is, under a layer of lead of 7 cm thickness. Subtracting the spectrum of the negative particles, increased by the magnitude of the mesonic positive excess, from that of the positive particles, and carrying out a summation over the momentum intervals, we obtain the number of protons with momenta of interest to us. The results obtained above show that the upper limit of the positive excess for mesons is near 1.30. On the other hand, measurements at sea level, where the intensity of the proton component is of a smaller order than at a height of 3250 m, show that the positive excess of the mesonic part of the spectrum, k_μ, in our momentum interval, measured with high statistical accuracy[6], is near 1.25. Just such a value of k_μ was obtained in Ref. 1 for the mesonic part of the spectrum in the momentum region $(2.4 - 7.7) \times 10^8$ ev/c at a height of 3250 m. Taking $k_\mu = 1.25$, therefore, we find the intensity of the proton share of the hard component by the formula

$$N_p = \sum_i (n_+^i - 1{,}25\, n_-^i) \Big/ \sum_j \left(n_+^j + n_-^j\right).$$

The summation in the numerator is carried out beginning with the fifth momentum interval ($p > 10^9$ ev/c), while that in the denominator is carried out over all the tabulated momentum intervals. Thus, from the intensity of the total hard component registered by the apparatus, we obtain $N_p = 4.8 \pm 0.05\%$.

In conclusion we note that in the region of momenta greater than 5×10^9 ev/c the integral μ meson spectrum, constructed according to the table for paths greater than 19.8 cm of lead, is satisfactorily described by a power function $\sim p^{-\gamma}$ with exponent $\gamma = 2.45 \pm 0.05$.

LITERATURE

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