## ON THE EXISTENCE OF PARTICLES WITH A MASS INTERMEDIATE BETWEEN THOSE OF MESOTRON AND PROTON *

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Investigations carried out by us since 1942 up to 1946 (1) reveal in the soft component at an altitude of 3250 m above sea level besides electrons the presence of particles sharply differing in their properties from the electrons and the mesotrons. The existence of this particle group has been proved directly by means of the ionization telescope. This group was called by us "the third component".

It was observed (2) that these particles produce ionization 2—3 times stronger than a relativistic

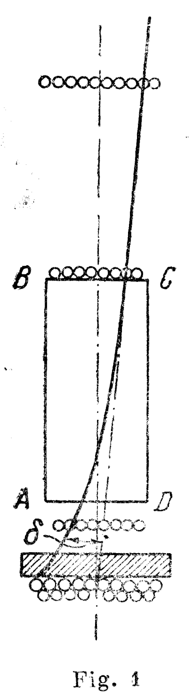


Fig. 1

particle and are absorbed completely by 4—5 cm of lead. The number of these particles constitutes about 15 per cent of the hard component intensity.

In 1945 on Mt. Alagez, passing the narrow beam of cosmic rays through a strong and extensive magnetic field, we have observed (3,4) that in the transmitted beam there remains a considerable number of particles which are little deflected by the magnetic field, but are absorbed completely by 5 cm of lead. This brought us to the idea that these particles are heavier than the mesotrons and are probably protons.

In the summer of 1946 we have continued our experiments in order to examine the nature of these particles. For this purpose we have built a system of counters which permitted us to measure simultaneously both the curvature of the path of the particle and its range (Fig. 1).

Our arrangement was a telescope constituted from three trays of counters. Each tray included 10 counters of a small diameter. The first two trays separated by 50 cm were placed above the slit of the large magnet. The third tray was placed under the slit. Separation between the poles of the magnet was 8 cm, the width of the pole 12 cm, the extension of the field 50 cm and the field strength was equal to 3860 Oe.

Under the third tray of counters lead blocks of different thickness were placed. Under the lead there was a fourth group of counters which permitted us to record the particles that had traversed the lead.

Each counter of the first three groups was connected with a separate neon tube. Thus photographing the flashings of the neon tubes on the motion-picture film we have been able to determine the coordinates of each separate particle*. The fourth group gave one mark on the film.

The first two groups, placed above the magnet, determine the direction of the incident particle and the third permits us to measure the deflection of the particle in the magnetic field.

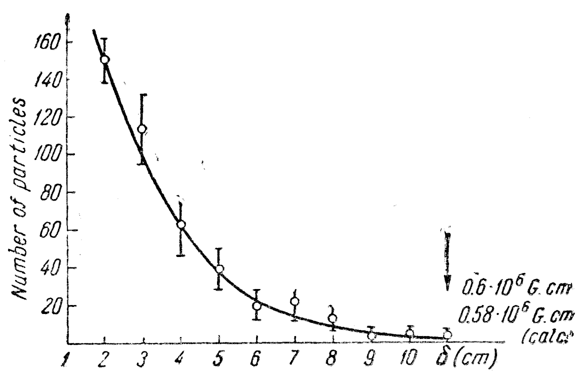


Fig. 2. Spectrum of mesotrons deflections (δ)

Under the conditions of our experiments a particle with a momentum $1 \cdot 10^6$ G · cm was deflected by 5 cm. The error in the determination of the momentum did not exceed 20 per cent. First of all, we have measured the spectrum of particles which penetrate 5.4 cm of lead. In Fig. 2 the deflection spectrum of mesotrons, which have traversed 5.4 cm of lead, is shown. The maximum deflection of mesotrons traversing the plate does not exceed 10 cm which corresponds to $0.6 \cdot 10^6$ G·cm.

The calculated value of the minimum momentum of the mesotron still able to penetrate 5.4 cm of lead is $0.58 \cdot 10^6$ G · cm. This figure excellently agrees with the observed one. This result serves as a good

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* This method of registering the deflections of particles was suggested by S. Nikitin.

proof that the chosen scheme can be used for the measurement of the spectrum of fast cosmic rays particles.

Analysing the results further we find that there is observed a large number of particles absorbed in 5.4 cm of lead and deflected in the magnetic field as little as mesotrons which penetrate this absorber. Considering the curvature of the path of these particles together with their range, we find that they possess a mass considerably larger than that of a mesotron. The number of these particles constitutes at an altitude of 3250 m 10—12 per cent of the number of mesotrons. The deflection spectrum of these particles is shown in Fig. 3. When the thickness of the

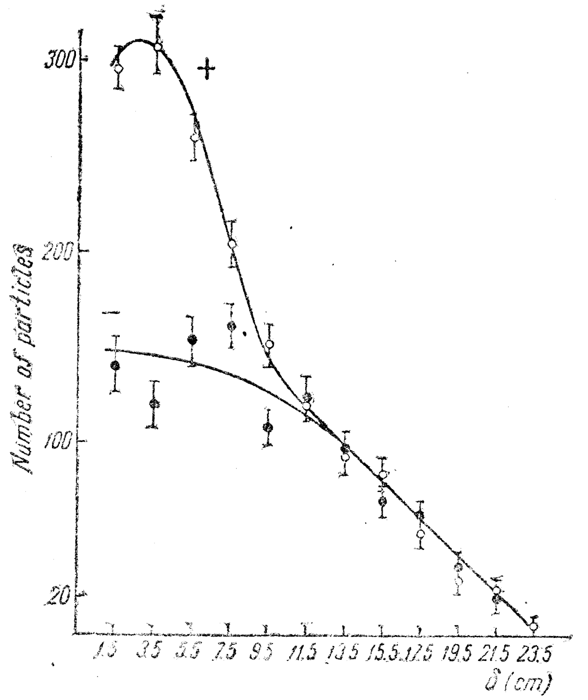


Fig. 3

lead absorber was reduced from 5.4 to 3.8 cm, the number and the spectrum of the absorbed particles did not alter appreciably.

In order to investigate the nature of these particles, we have made a large set of measurements with different arrangements of filters of different thickness, made from different materials. For instance, placing 2.4 cm of lead above the third group of counters and 3.0 cm of lead between the third and the fourth groups of counters (Fig. 4, *b*) we have found that the particles which penetrate the first filter are stopped in the second. The same result was observed in the case when a brass absorber 4 cm thick was placed instead of 3.0 cm of lead. The experiments performed according to the scheme 4,*b* show, that the particles with the momenta from $H\rho=1.7\cdot10^6$ G · cm and less are not protons, for the protons with the momenta less than $1.7\cdot10^6$ G · cm can not traverse 2.4 cm of lead. This conclusion can be made also from the fact of the presence of particles of both positive and negative charges.

In this range interval (2.4 — 5.4 cm) we have observed a considerable number of particles with a momentum of $0.7\cdot10^6 - 2.0\cdot10^6$ G. cm. It follows from this fact that the masses of the particles lie within the limits of 250—2000 electron masses*.

The particles of such masses and with a momentum within above mentioned interval must possess an ionization power 1.5—3 times stronger than that of the relativistic particles. In the previous experiments with an ionization telescope we have in fact observed in the soft component particles having the specific ionization 2—3**.

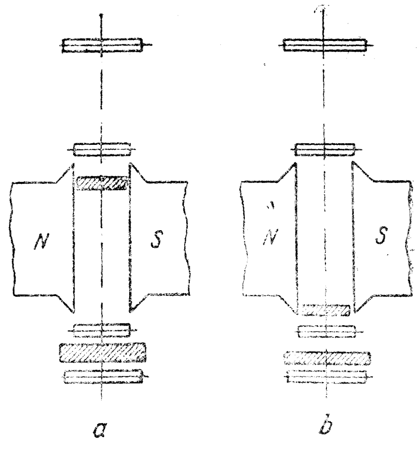


Fig. 4

In order to exclude the possible distortion of the results due to electrons with a momentum in the same interval we have performed many experiments which have proved that electrons do not distort the spectrum shown in Fig. 3.

If the particles observed by us with momenta from $0.7\cdot10^6$ up to $2\cdot10^6$ G · cm were electrons, then in the experiment shown in Fig. 4, *b* they would penetrate the 3 cm lead plate or 4 cm brass absorber and would be included into the hard component.

Besides we have found that the large majority of particles which penetrate 2.4 cm of lead but are stopped by 3.0 cm of lead are not multiplied. Per 100 particles which traverse the 2.4 cm lead absorber (in the experiment according to the scheme Fig. 4,*a*) and are stopped in the next 3 cm lead filter, there were only 10—12 cases with more than one particle emerging from the plate 2.4 cm thick.

* This is true if the energy losses are due only to ionization. In the opposite case, if there are also losses of other origin, one would obtain a smaller value of the mass. However, the measurements with the ionization telescope show, that the mass value cannot be decreased considerably. Hence, although the presence of non-ionization energy losses is not excluded, they cannot be considerable.

** The experiments with the ionization telescope were thoroughly repeated by S. Nikitin in 1946 and will be published in this journal. He obtained a differential ionization spectrum, which appeared to consist of three groups of different ionization power: 1) mesotrons, 2) electrons, 3) particles with a specific ionization 1.5—3 and with a range of ca. 4.5 cm of lead. This agrees well with the mass determination from the results of the magnetic analysis.

Finally, we have placed a lead plate 2.4 cm thick under the second group of counters in the initial region of the magnetic field (Fig. 4, *a*). In this case it can be shown that electrons with momenta of $0.7 \cdot 10^6$—$2 \cdot 10^6$ G · cm, which are present in air in a small amount in the large majority of cases are multiplied when traversing the plate and are slowed down to such an extent that they would be removed by the magnetic field. L. Landau has shown that the number of electrons in the interval, which is of interest for us, is decreased by such a plate at least 10—12 times. However, the experiment shows that the observed particles practically do not change in their number at all. This proves once more that these particles are not electrons.

It was also very important to prove that in our system do not play any rôle the extraneous particles, showers, which can enter the system from the outside, and to examine whether the results are not affected by the scattering of particles by the poles of the magnet. For this purpose we have placed 4 counters connected with one neon tube on each pole. The counters were placed in such a position that each particle striking the pole or being reflected by it would certainly traverse one of the counters and, therefore, would be recorded by a flash. Finally, in the third tray of counters in the telescope we have switched off three counters from each side of tray. With such a strongly canalized beam (passing through the central part of the magnetic field) we have observed the same spectrum of heavy particles as that shown in Fig. 3.

One more experiment is to be mentioned here. In the case when an absorber 4 cm thick was placed over the whole telescope the number of particles, stopped in the lower 5.4 cm lead filter was strongly decreased. Nearly all of the particles with momenta in the interval of $2 \cdot 10^6$—$0.7 \cdot 10^6$ G·cm are now able to pass through a 5.4 cm lead filter.

Considering all the obtained data we come to the conclusion that in the cosmic rays there are particles, having masses larger than that of a mesotron and some even exceeding that of a proton. We suggest to call these particles varytrons.

We have observed on the whole more than 4000 varytrons. The number of positive varytrons appears to be 1.7 times larger than the number of negative varytrons.

At an altitude of 3250 m above sea level the number of varytrons constitutes about 10 per cent of the number of mesotrons.

A more detailed paper will be published in this journal.

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