The Question of the Existence of Varitrons

by Vernov et alii
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THE QUESTION OF THE EXISTENCE OF VARITRONS

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The question as to the existence of "elementary" particles with different properties (mass, life, etc.) is one of the acutest problems of modern physics. Hence the great interest which has been aroused by the work of A. I. Alikhanyan, A. I. Alikhanov et al, concerning the study of the nature of particles which are constituents of cosmic rays.

As is known, as far back as 1944 [1, 2] A. I. Alikhanyan and A. I. Alikhanov on analyzing the different properties of the soft component (ratio of the number of particles constituting the soft and hard components, measured by means of counters and ionization chamber, nature of absorption of the soft component and transition effect) have arrived at the conclusion [2]: "that aside from electrons there are present in the soft component, other charged particles also, the properties of which differ sharply from the properties of electrons, and which cannot be identified with the usual mesotrons... It was found that they constitute about 10 - 15 percent of the intensity of the hard component at an altitude of 3250 meters."

To confirm this conclusion, A. I. Alikhanyan, A. I. Alikhanov, et al, have conducted an extensive series of investigations devoted to studies of the nature of soft component particles, utilizing the method of deflection in a magnetic field as well as the method of determining ionization caused by particles of the soft component. Subsequently the method of magnetic deflection has become predominant

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in the research conducted by A. I. Alikhanyan, A. I. Alikhanov and their co-workers on the nature of cosmic ray particles. Data obtained by this method proves, according to the views of these researchers, that there exist at an altitude of 3250 meters "a considerable number of new particles having different mass values, ranging within the limits from 100 up to tens of thousands of electron masses" [3]. A. I. Alikhanyan, A. I. Alikhanov, et al, have named these particles varitrons. Investigations analogous to the experiments of Alikhanyan, Alikhanov, et al, and concerned with studies of the general properties of the soft component [1], as well as the study of the ionization spectrum produced by cosmic rays particles [4], and constituting one of the initial premises of the entire concept of varitrons, were also carried out by associates of the Cosmic Rays Laboratory of the Physical Institute imeni P. N. Lebedev of the Academy of Sciences USSR [5-7]. These investigations have shown the fallacy of conclusions arrived at by A. I. Alikhanyan, A. I. Alikhanov, et al.

The authors of the present article have repeatedly criticized the experiments of Alikhanyan, Alikhanov, et al, and had considered that the conclusion as to the existence of varitrons, reached on the basis of these experiments, is an erroneous one, and, as will be shown below, is due entirely to a lack of critical analysis of experimental conditions.

In the present article we will consider in detail only the series of researches by A. I. Alikhanyan, A. I. Alikhanov, et al, devoted to measurement of the mass of cosmic ray particles by the magnetic deflection method.

SECTION 1. DATA ON THE NUMBER OF VARITRONS OBTAINED BY A. I. ALIKHANYAN, A. I. ALIKHANOV ET AL, IN THE COURSE OF WORK CONDUCTED OVER THE PERIOD 1947 - 1949

In this paragraph we will show that from the data derived by A. I. Alikhanyan, A. I. Alikhanov and their co-workers from work conducted during 1947 - 1949 (and entirely contradictory with results of their own work carried out in 1950), it follows that the number of varitrons stopped within a given filter is not less than the number of protons stopped within the same filter. The number of varitrons at an altitude of 3250 meters, according to data of Alikhanyan, Alikhanov, et al, constitutes in any case not less than 1 - 2 percent of the number of particles of the hard component of cosmic rays.

In the 1947 - 1949 work the deflection (δ) of particles in the magnetic field was determined by means of three rows of hodoscopic counters (two rows were placed above the gap of a permanent magnet, and one below), while the range of the particles was determined by means of a system consisting of lead filters between which were disposed rows of hodoscopic counters (see for example description of units in papers [2, 8, 9]).

From an analysis of the spectrum of impulses (deflections) of the particles made in the 1948 paper [2], A. I. Alikhanyan, A. I. Alikhanov, et al, arrive at the conclusion that among the stopped single particles of non-electronic nature there are present particles of either sign having a mass greater than the mass of a meson. The total number of such particles according to the direct experimental estimate of Alikhanyan, Alikhanov et al, constitutes 5.3 percent of the number of particles of the hard component. A. I. Alikhanyan and A. I. Alikhanov point out that among the stopped particles heavier than the mesons, one-third has a negative charge and only one-fifth has impulses corresponding to impulses of protons, and, consequently, not less than 3 percent of the hard component intensity is composed of particles of neither proton nor meson nature. Further, as A. I. Alikhanyan and A. I. Alikhanov [2] point out as regards such particles "not more than one quarter can be electrons. Actually, however, the number of electrons among the single soft particles is considerably below this maximum estimate." At the same time "the effect of scattering from the poles is so small that it cannot be detected" [2].

The conclusion as to the existence of particles different from mesons and protons is arrived at by A. I. Alikhanyan, A. I. Alikhanov, et al, also in other papers (see for example [8, 9]). Moreover the use of a large mass spectrometer with coordinate counters of small diameters and of a magnet having a magnetic field intensity of about 7000 Gauss has made it possible, in the opinion of A. I. Alikhanyan, A. I. Alikhanov, et al, to solve the problem relative to the nature of particles having impulses falling within the interval excluding mesons and protons having the given ranges. "With this variety of mass, the number of varitrons was found to be considerably higher than was reported in the first investigations" [8].

Let us consider the data of A. I. Alikhanyan et al, concerning particles having a range of 2.4 - 3.6 centimeters Pb [9]. A summary of the results obtained is given in figures 1 - 3 of the present article taken from the corresponding figures of paper [9] and from Tables 4 and 5 of the same paper.

The number of particles, stopped within 1.2 centimeters Pb, for different deflection intervals, obtained by us on summation of the corresponding figures of Tables 4 and 5 [9], is shown in Table 1.

(To determine the intervals of deflections (δ) for particles having different mass values, we ascertained the interval of impulses, corresponding to the given interval of ranges for particles of given mass. Conversion from impulses to deflections is made according to the formula given in the papers of A. I. Alikhanyan, A. I. Alikhanov, et al, $pc = (k/\delta)$ eV [8, 9], where k is a coefficient having different values for different experimental units (thus in paper [9] $k = 6 \cdot 10$ eV $\cdot$ cm).

In so doing we also took into account the maximum error in impulse value, due to terminal dimensions of counters in accordance with the formula of A. I. Alikhanov and A. I. Alikhanyan.

$$(\Delta pc/pc)_{max} = \alpha/\delta \quad [8, 9].$$

The obtained limits of deflections for protons and particles of mass $\sim$ 300 m_e are shown in Figures 1, 2 and 3 of t[illegible] resent article.)

Results analogous to those shown in Table 1 can be obtained from data published at an earlier date [8]. According to this data within the interval range of 1.2 - 3.6 centimeters Pb, the number of varitrons of mass greater than 300 m_e but smaller than the mass of a proton is about equal to the number of protons stopped within the same filter. A. I. Alikhanyan and A. I. Alikhanov et al, have discovered varitrons also among particles which pass through all the

TABLE 1

Interval of Deflections of Particles in Magnetic Field δ in cm.	0-8.5	9-13	13.5-30	30.5-40	Total
Particle Masses in m_e	$m > m_{pr}$	Protons	$m_{pr} > m > 300$	$m < 300$	
N+	671	568	536	174	1949**
N-	280	117	573	173	1143
α*	1.03	1.1	1.45	3	
Taking into account luminosity N_o^+	690	625	778	522	2615
Taking into account luminosity N_o^-	288	129	832	519	1768
Number of varitrons of different mass in percent of protons — positive	110		124		
Number of varitrons of different mass in percent of protons — negative	46		133		
Number of varitrons of both signs ($N_o^+ + N_o^-$) in percent of protons	156		257		
($N_o^+ + N_o^-$) in percent of particles with $R > 3.6$ centimeters Pb	0.9	0.6	1.6		

*α - correction for luminosity taken from Figure 11 [9].

** The number 2049 appearing in Table 4 of the paper by A. I. Alikhanyan et al [9] is apparently a typographical error.

filters (the hard component) and came to the conclusion that a large number of varitrons is present in the air. Thus in paper [8] A. I. Alikhanyan, A. I. Alikhanov, et al, estimate, "in percent the content of varitrons found in the air as a result of disintegration of stopped heavier varitrons. To do so there was determined from the curves (Figures 21 and 22) (correspondingly Figure 4 of our article) the ratio of area occupied by the maxima, projecting above the smooth course of the spectrum, to the entire area of the spectrum, and thus it was found to be equal to 0.1 - 0.12. This estimate gives the lower limit of percentage content of varitrons in the constituents of cosmic rays." [8]

The occurrence of a large number of trajectories in the region of deflection values, which exclude mesons and protons having the given ranges, could be caused by a number of parasitic effects: influence of electrons, background of showers coincidences, scattering from magnet poles and within counter walls, etc. Hence, before making any far-reaching assertions concerning discovery of a great number of new elementary particles -- varitrons, one ought to present a painstaking analysis of all possible parasitic effects. Even though in individual papers [2, 9] attempts are being made to present such an analysis, in none of the papers is there taken into account the sum total of all the effects. In paper [2], as we have mentioned before, there is discussed the possible background caused by the presence of electrons, and indications are given that since such background does not exceed one quarter of the effect observed it will not alter the basic conclusions. The same conclusion is reached by A. I. Alikhanyan, et al, in paper [9], in which the background, caused by false stops and false trajectories, is taken into account, but no mention is made of the role of the electrons. For noting that the background in impulse spectra, obtained in the course of the 1949 work, constitutes 20 - 25 percent of the effect, the authors write that "at such a correlation of effect and background the results are fully reliable" [9].

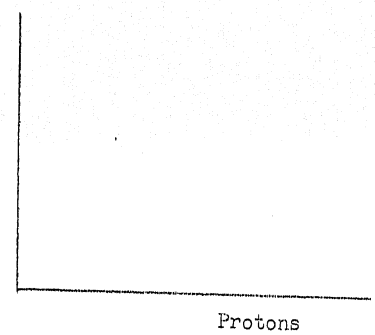

Figure 1. Spectrum of deflections in the magnetic field of stopped particles. Dotted lines added by us.

Figure 2. Spectrum of deflections in the magnetic field of stopped particles. Dotted line added by us.

From the quoted citations and figures of the work of A. I. Alikhanyan, A. I. Alikhanov, et al, it follows directly that the number of varitrons, though it changed greatly in different investigations [2, 8, 9], constituted in any case 1 - 2 percent of the number of particles of the hard component (see Tables 1 and 4 of the present article), while the number of particles, the mass of which was intermediate of that of a proton and the mass value 300 m_e, was not less than the number of protons stopped within the same filters. The number of varitrons of mass greater than the mass of a proton is also of the same order as the number of protons (see Table 1 and Figures 1 - 4 of the present article). However, as will appear below, such a conclusion is completely without foundation.

Figure 3. Spectrum of deflections in the magnetic field of stopped particles. Dotted line added by us.

Figure 4. Spectrum of impulses of stopped particles.

SECTION 2. DETERMINATION OF THE MASS OF VARITRONS

A characteristic peculiarity of deflection spectra shown in the investigations of A. I. Alikhanyan, A. I. Alikhanov, et al, is the presence of many maxima (Figures 1 - 6 of the present article). In the opinion of A. I. Alikhanyan, A. I. Alikhanov, et al, [8, 9] the presence of maxima and their nature make it possible to determine the masses on the assumption that the range of particles is determined only by energy losses due to ionization. (In paper [9] A. I. Alikhanyan, et al, state that "formation of breaks and steps is by no means connected with absorption of the particles in lead, but is the result of processes of disintegration taking place in the air". Thus A. I. Alikhanyan, et al, weaken their own method of determining the mass of the particles.) We shall show in the present paragraph that the majority of maxima in the spectrum of deflections are fictitious. At the same time assertion as to their presence in the spectrum of impulses of the hard component necessitates the introduction of completely artificial assumptions.

Let us show first of all the values of varitron mass in accordance with the work of A. I. Alikhanyan, A. I. Alikhanov, et al.

In paper [8] we find the statement: "In Table 3 (Table 2 of our article) is shown a summary of all measurements of varitron mass according to determinations made by means of a large and a small instrument. Values of mass of those particles, the existence of which can be considered as being established with the greatest degree of certainty are shown in the last column of the table... The good agreement of data obtained by means of two different instruments, again confirms the conclusion as to the multiformity of the mass spectrum of particles of cosmic rays." In [9] it is stated: "In the present work it is shown that in cosmic rays at an altitude of 3250 meters above sea level are present varitrons having the following masses:

$$300 \mp 10,\ 380 \mp 20,\ 450 \mp 20\ (650),$$
$$730 \mp 20,\ 970 \mp 30,\ 1300 \mp 70\ m_e.$$

In addition the great resolving power of the instrument has made it possible better to determine the mass of the heaviest varitrons. Among them those most reliably determined were the following:

$$2500 \mp 200,\ 4000 \mp 500,\ 5500 \mp 500,\ 800 \text{ and } 12000\ m_e$$

In Figure 5 of our article (Figure 14 of paper [8]) is shown a characteristic "mass spectrum" of negative particles which are stopped in 3.6 - 5.6 centimeters Pb. In the other papers of A. I. Alikhanov, A. I. Alikhanyan and their co-workers, describing work using this method, are shown a great number of analogous "spectra".

TABLE 2

TABULATED VALUES OF

(Reprinted fr

Instrument	Large Mass Spectrometer								Small Mass			
Number of the Experiment	1 and 2								3			
Filter Over the Unit	None								None			
Interval of Ranges	3.6 > R > 1.2		5.6 > R > 3.6		R > 5.6		1.85 > R > 0.8		3 > R > 1.85		R > 3	
Sign of Particle Charge	+	-	+	-	+	-	+	-	+	-	+	-
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13]
									110	110	115	
							150	140	140	150	140	130
	210		200	210	190	190	200	200		200	200	200
	250		250	250		250					250	250
		300		300	300	300	310	310	310	320		300
		370	350	350								
	450	460	440	440	430	430						420
	530		550	550	530	530						

THE VARITRON MASSES

om paper [8]

Spectrometer

4						5				6				Value of Particle
None						Carbon 64g/cm^2				Lead 113g/cm^2				Mass From All Data in Mass of Electrons
2.4 R	0	5.4 R	2.4	R	5.4	5.4 R	0	R	5.4	3 R	1.85	R	3	
+	−	+	−	+	−	+	−	+	−	+	−	+	−	
[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]
110	110	110	110			110						115		110
140		140				140						140	140	140
180		210	190			220				200	200			200
260			270									250	250	250
330	300									330	320		320	300
														350
400			450											450
													520	550

[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]	[10]	[11]	[12]	[13
	650	680		680	680					630	650	
	850	840					820					
	1000	1000				1000	950				1000	
	1300	1400		1400		1300				1400		
	1840		1840				1840		1840			
		2700		2400		2600		2200				
		3800	3500	3800			3600	3600	3800			
	9500	8000	11,000									
			30,000	25,000				20,000	20,000			

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[14]	[15]	[16]	[17]	[18]	[19]	[20]	[21]	[22]	[23]	[24]	[25]	[26]	[27]	[28]
												600		680
830						830					800			850
												1000		1000
	1300	1100	1400										1200	1300
1840						1840						1840		1840
														2500
3500										3500				3800
8000														8000
										20,000	20,000			25000

On analysis of these spectra one is struck first of all by the fact that the usual mesons having a mass of $\sim 200\ m_e$ are by no means separated, predominant particles. Usual μ-mesons, as they are now being called, are "drowned" among particles having other mass values, according to data of the papers under consideration. (The fact that data shown in Figure 5 does not include correction for luminosity of the instrument, by no means alters this conclusion, since the curve of luminosity [8] is a uniform curve and on passing from a mass $\sim 200\ m_e$ to a mass $\sim 400\ m_e$ is changed only twofold, and in the "mass spectrum" of Figure 6 there are present particles having a mass of 300 and 400 m_e, their number being not less than the number of usual mesons.)

The authors of the papers under consideration find maxima in the impulse spectrum even for particles which are not stopped within the filters of the unit (hard component).

A characteristic impulse spectrum of particles with R > 5.6 centimeters Pb is shown in Figure 4 of the present article (corresponding to Figure 21 of paper [8]). In order to explain the presence of these maxima, A. I. Alikhanyan, et al, resort to the extremely artificial assumption that in the air there are present particles having impulses within a definite interval of values. Such particles can occur only as a result of disintegration of stopped particles. According to data of A. I. Alikhanyan, A. I. Alikhanov, et al, the number of such slow varitrons is very considerable, since the number of secondary varitrons formed as a result of disintegration within the air of the arrested heavier particles constitutes about 10 percent of the hard component (see quotation from [8] on page 1049 of our article [page 10 of the translation]).

It can be shown, however, that almost all the maxima appearing in spectra given in the papers under consideration are within the limits of statistical errors. We have plotted smooth curves without any maxima from data of several deflection spectra [8, 10] (Figures 4, 5, 6 of the present article). It is readily apparent that distribution of experimental points along the smooth curves is in good agreement with the expected statistical distribution of fortuitous deflection (in accordance with Poisson's formula) (see Table 3 of the present article). And consequently, the fact that A. I. Alikhanyan, A. I. Alikhanov, et al, plot not a smooth curve, but a curve having many maxima is completely unjustifiable and arbitrary.

A fully analogous situation obtains also insofar as other spectra given by A. I. Alikhanov, A. I. Alikhanyan, et al, are concerned.

Almost all maxima of the curves of impulse (deflection) spectra of particles of soft and hard components are fictitious, and consequently conclusions as to the great variation in varitron mass and their properties, as for example disintegration, which are based on the existence of maxima, are completely without foundation.

[See following page for Table 3]

Figure 5. Spectrum of deflections in the magnetic field of stopped particles. Dotted curve added by us.

TABLE 3

	According to paper [8], page 688, Figure 14 (Figure 5 of the present article)		According to paper [8], page 696, Figure 21 (Figure 4 of the present article)		According to paper [10] page 1321, Figure 5 (Figure 6 of present article)	
	Experimental	Expected From Law of Errors	Experimental	Expected From Law of Errors	Experimental	Expected From Law of Errors
Total number of experimental points	37		32		38	
Number of points within limits of single error	25	26	23	22	24	26
Number of points beyond limits of single error	12	11	9	10	14	11
Number of points beyond limits of two-fold error	3	2	2	1.6	3	2

SECTION 3. DATA ON VARITRONS OBTAINED BY A. I. ALIKHANYAN AND HIS CO-WORKERS BY OTHER METHODS

Data of other work conducted at the same laboratory is also in "accordance" with results obtained using mass spectrometers. In the paper of S. Ya. Nikitin on studies of the ionization spectrum of soft component particles [4] a conclusion is drawn as to the existence of three groups of particles having masses of 300 - 500, 700 - 1100 and 2000 - 3500 m_e. The erroneousness of data derived from this work, due to insufficiently clear separation of showers, is discussed in detail by Dobrotin, et al, in their paper [6], and therefore we will not consider it here. A similar situation exists in the study of the nature of particles by means of photographic plates [11]. In this work were found six groups of particles having masses of 180 - 200, 320 - 350, 650 - 700, 950 - 1000, 3500 - 4000 and 8000 - 10,000 m_e, which in general is in agreement with masses obtained by using a mass spectrometer. The number of particles of intermediate mass constitutes according to this data 63 percent of the number of slow protons, while the number of particles heavier than protons is about 10 percent. A detailed study at the Cosmic Rays Laboratory of the Physical Institute imeni P. N. Lebedev, Academy of Sciences USSR, using the same plates by means of which the varitrons were discovered, has shown that A. Alikhanyan, D. Samoilovich, et al, [11] grossly overestimate the accuracy of particle mass determination by the method of grain counting, a fact which has led to erroneous conclusions regarding the existence of a great number of particles distinct in their nature from mesons and protons. (The authors wish to express their gratitude to Professor I. M. Frank for his advice and discussion of data on thick-layer photographic plates.)

Figure 6. Spectrum of deflections in the magnetic field of stopped particles. Dotted curve added by us.

It should be noted that in the numerous investigations using photographic plates, which have been published in recent years [12], particles with a mass of $\sim$ 1000 m_e have been detected only rarely and in isolated instances. An estimate of the possible value for the upper limit of the number of such particles, derived from statistical errors of the experiment, for instance according to data of [13], gives 2 percent of the number of protons stopped within the emulsion of the photographic plates. Hence the assertion made in the publications of A. I. Alikhanyan, A. I. Alikhanov, et al, relative to the "agreement" of data obtained by means of a mass spectrometer with those derived by other methods has no factual basis. (In this connection attention must be called to Table 2 of the present article. As is readily apparent from this table, A. I. Alikhanov, A. I. Alikhanyan, et al, [8] have asserted that results of experiments on mass determination of particles, conducted on different apparatus, are fully in agreement with one another. However, now [14] these authors themselves have repudiated the assertion relative to the existence of an overwhelming majority of values of the varitron mass.)

It is necessary to emphasize once more that the results of Alikhanyan, Alikhanov, et al, on the determination of mass of cosmic rays particles, which we have considered above, are in sharp disagreement with the results of all known investigations devoted to this problem [15]. In the course of work [16] conducted by associates of the Physical Institute imeni P. N. Lebedev, of the Academy of Sciences USSR, during 1950 at an altitude of 3860 meters, it was found that even if cosmic rays do contain particles of a mass intermediate of those of a proton and a π-meson, their number is not greater than 10 percent of the number of protons within the same range interval (30 - 105 grams/cubic centimeter Pb).

In their 1950 paper A.I. Alikhanov and A. I. Alikhanyan refer to the previous publication of Brode, et al, [17] as confirming their conclusions, but fail to indicate that Brode had subsequently admitted the erroneousness of his results [18].

SECTION 4. COMPARISON OF THE RESULTS OF STUDIES CONDUCTED BY A. I. ALIKHANYAN, A. I. ALIKHANOV, ET AL, IN 1947 - 1949 WITH RESULTS OF THEIR WORK IN 1950

Up to now we have analyzed the results of studies published by A. I. Alikhanov, A. I. Alikhanyan, et al, in 1947 - 1949. In the present paragraph we will show that results of the 1950 work, shown in the paper of A. I. Alikhanyan, and A. I. Alikhanov [14], refute their prior results. To do so let us compare the number of varitrons and the form of observed mass spectra given in the 1950 paper with those of their earlier publications.

First of all we must note that the apparatus used in the most recent work [14] differs from the previously utilized mass spectrometers. This difference resides in the following: (1) the magnetic field is created by an electromagnet, which makes it possible to conduct measurements in the magnetic field as well as without it. (In various discussions we had indicated repeatedly, the necessity of such control experiments.) (2) Trajectories of particles in the magnetic field are determined in a plane perpendicular to the magnetic field as well as in a plane parallel thereto. A total of 10 rows of coordinated counters was utilized. All this has increased the reliability of each individual trajectory as well as the resolution power of the instrument, and has also made it possible to eliminate scattering from poles of the magnet; (3) All measurements were conducted under a 10 centimeter lead filter, which has greatly decreased the number of electrons among particles of the soft component.

A comparison of the number of varitrons having masses whose values are within the interval from 300 to 1840 m_e, according to data found in various publications of A. I. Alikhanov, A. I. Alikhanyan and their co-workers, is shown in Table 4 of our article.

Data of column 2, Table 4, are taken from Table 1 of our article. It is also shown there in detail how they have been derived. In column 3 are shown data taken from publication [10], since they are used in the paper of A. I. Alikhanov and A. I. Alikhanyan [14] (see Table 3 of their paper). It must be noted that in determining the number of particles having a mass $>$ 300 me, Alikhanyan and Alikhanov for some reason confine themselves to values of their deflection in the magnetic field amounting to 21 centimeters. Utilization of the aforesaid criterion for separating deflection intervals of particles of different mass, which we have mentioned before (Section 1), shows that on determination of the number of particles having a mass $>$ 300 m_e, the area should be taken which is limited by the curve (Figure 6) up to deflections amounting to 23 centimeters. At the same time as the determination of the number of protons, summation should be made of only the trajectories within the deflection interval of from 12 to 6.5 centimeters. These conditions lead to the fact that the number of particles having a

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mass intermediate of that of a meson and that of proton according to data [10] is actually greater than 85 percent and is equal to 130 percent of the number of protons.

[See following page for Table 4]

Table 4 shows that the number of varitrons having a mass from 300 to 1840 m_e, which were found in the most recent work [14] is many times smaller than their number according to results of earlier investigations by the same authors, namely 8.5 times less than in the 1947 work, 16 times less than in the 1949 work (actually the discrepancy is even greater, since the criterion used by us in determining the deflection limits decreases the relative number of varitrons in the studies of 1947 - 1949), and even as estimated by Alikhanyan and Alikhanov is 5.5 times less than in the 1947 publication. (The fact that in the 1950 experiments a study was made of the impulse spectrum of particles under 10 centimeters Pb does not alter this result, since, even according to data of A. I. Alikhanyan and A. I. Alikhanov [14] the number of varitrons under 10 centimeters Pb decreases only 40 percent. Actually this decrease must be attributed to a weakening of the electron background.)

A. I. Alikhanyan and A. I. Alikhanov contend that the recent publication [14] shows no substantial discrepancy, in the number of particles, with data of prior work. They consider that in the 1947 experiments there were found only twice as many particles having a mass 300 $m_e < m <$ 1840 m_e as in the 1950 experiments. The twofold difference in the number of varitrons observed in 1947 and 1950, respectively, is derived by A. I. Alikhanyan and A. I. Alikhanov solely on the basis of a spurious operation. Namely, from the figures obtained in 1947 they now subtract, as an afterthought, the background

TABLE 4

Comparison of the Number of Particles with a Mass $300 < m < 1840\ m_e$ According to Data of Various Papers by A. I. Alikhanov and A. I. Alikhanyan Taking into Account the Luminosity

		1	2	3	
		Paper [16] of 1950 (according to values of Table 4) $16 < R < 24$ cm C	Paper [9] of 1949 Tables 4 and 5 $2.4 < R < 3.6$ cm Pb	Paper [10] of 1947* page 1323 $3.6 < R < 5.6$ cm Pb	
				According to Our Calculations	According to Calculations of Alikhanyan and Alikhanov [14]
		[1]	[2]	[3]	[4]
Number of particles with mass	(N_o^+	--	778		
$300 < m < 1840\ m_e$	(N_o^-	--	832		
(corrected for luminosity)	($N_o^+ + N_o^-$	45	1610	450	346
Number of protons		280	625	340	400
Number of particles having $300 < m < 1840\ m_e$ in percent of protons		15	257	130	85
in percent of hard component		0.15	1.6	1.1	0.9

	[1]	[2]	[3]	[4]
Number of protons in percent of hard components	0.9	0.6	0.85	1

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* Analogous results are also obtained in the 1948 paper [8]

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caused by (a) electrons, (b) scattering from poles of the magnet, (c) non-rigorous selection of trajectories on interpretation. In the 1947 - 1949 publications, however, [8 - 10], it was contended that all these factors have no appreciable effect (see Section 1 above). The fact that taking into account of these factors decreases the number of varitrons 2.5 times is merely additional proof that up to the recent work of 1950, the mass spectrometer had recorded essentially the background. This has been demonstrated by the recent work conducted under more rigorous conditions. Even on assuming, in accordance with 1950 results [14], that varitrons actually exist in an amount constituting 15 percent of the number of protons having the same range values (whether one is justified in making such an assumption will be discussed in Section 5), then the background in spectra of impulses (deflections) of the 1947 - 1949 work constituted at least 80 percent (and probably considerably more than 80 percent) of the observed effect. It is quite obvious that under such conditions there was no justification for announcing the discovery of newparticles having different mass values, or even of one mass value different from the mass values of a meson and a proton. The nature of the impulse spectrum obtained in the course of the recent investigations is also entirely dissimilar from all spectra shown in previous publications (see Figure 15 [14]). In lieu of a continuous "forest" of maxima in the recent publication there has appeared, in addition to the maximum of μ-mesons, a very pronounced maximum also for the π-mesons. This is in accordance with expectations inasmuch as measurements were conducted under lead using a device of greater resolving power than that utilized before. In addition, particles heavier than protons have completely disappeared in the new spectrum, although according to data of the 1949 paper [9] (see Table 2 of our article) their number previously had been of the same order as that of the varitrons within the mass interval from 300 to 1840 m_e.

The 1950 work of A. I. Alikhanov and A. I. Alikhanyan fully shows the erroneousness of their work published in 1947, 1948 and 1949 in which, as is now fully apparent, the background had a determinant effect. The conclusion arrived at on the basis of data presented in these publications, relative to the existence of new particles is completely unjustified.

SECTION 5. CONCLUSIONS REACHED BY A. I. ALIKHANYAN AND A. I. ALIKHANOV ON THE BASIS OF THEIR 1950 WORK

Let us consider now the essential conclusions which have been drawn by A. I. Alikhanyan and A. I. Alikhanov on the basis of data obtained in their recent work utilizing a new mass spectrometer [14]. We have already noted that in the new unit a number of defects have been eliminated which in the past had induced the appearance of a very pronounced background in the observed spectrum of impulses (deflections) of the particles, and also that the resolving power of the device has been increased. These two conditions have allowed the investigators to separate for the first time μ - and π -mesons and to show that π-mesons are actually generated within 10 centimeters Pb. Qualitatively this was to be expected in view of the sum total of work on electron-nuclear showers conducted at the laboratory of the Physical Institute of the Academy of Sciences over a number of years [19]. From the new data of A. I. Alikhanov and A. I. Alikhanyan it follows that in their apparatus under 10 centimeters Pb there are observed three types of particles: μ -mesons, π -mesons and protons.

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In addition, A. I. Alikhanov and A. I. Alikhanyan consider that their data proves also the existence of particles having a mass of 500 - 600 and 900 - 1000 m_e, and in this recent work both groups of particles together constitute 15 percent of the number of protons stopped within the same absorber. We will show in the present paragraph that this conclusion cannot be considered as justified.

First of all it is necessary to emphasize that in the recent work of Alikhanov and Alikhanyan the number of trajectories attributed to varitrons is but a small multiple of ten in lieu of the several thousand varitron trajectories which were considered in prior work.

In a case where the proof of the existence of a small number of new particles is involved one cannot disregard the possible causes producing an apparent occurrence of anomalous particles. (As shown before the lack of such an analysis has led A. I. Alikhanyan and A. I. Alikhanov to the erroneous assertion that there exists a large number of varitrons having a mass from 100 to 20,000 me.)

In the 1949 paper A. I. Alikhanov, A. I. Alikhanyan, et al, [9] have carried out a control experiment wherein the filters in which the particles stopped were removed. Thus it was found that the number of cases of false "absorption" (stopping without filters) is only 4 - 5 times smaller than the number of cases of stopping with the filters. However in the course of the 1950 investigations of A. I. Alikhanov and A. I. Alikhanyan, according to paper [14], this very important control experiment has not been performed. It is readily apparent that if in the 1950 experiments the background has been considerably decreased in comparison with the 1949 work [9], still this effect of "false absorption" by itself would be fully sufficient to account for the occurrence of all the varitrons. The control experiments must be conducted systematically throughout the entire duration of measurements.

Even if the occurrence of anomalous trajectories is not attributed to the effects induced by the apparatus used, a number of causes can be pointed out which induce an apparent occurrence of varitrons. We will enumerate some of these causes:

1. Nuclear absorption of π-mesons must induce an apparent occurrence of particles heavier than the π-mesons. A rough estimate can be made of the number of such instances of nuclear absorption. To do so it is necessary to know the number of π-mesons within the impulse interval $3 - 4.5 \cdot 10^8$ eV/c, that is within that interval which corresponds to the anomalous particles. From Table 6 of paper [14] by A. I. Alikhanyan and A. I. Alikhanov it follows that the number of π-mesons within the range interval of 16 - 24 centimeters C, that is within the impulse interval $1.95 - 2.3 \cdot 10^8$ eV/c, is equal to 146.

According to data obtained on using thick-layer photographic plates [20] it can be assumed that the energy spectrum of the π-mesons formed has the form: $N(E)\,dE \sim dE/E^{1.5}$, where E -- total energy of π-meson, and, consequently, the number of π-mesons passing through the apparatus within the impulse interval $3 - 4.5 \cdot 10^8$ eV/c, which is the number with which we are concerned, must be ~ 400. It can be assumed that the effective section of interaction of π-mesons with the nucleus approximates the geometric section of the nucleus (there exists a quantity of experimental data which supports the correctness of such an assumption [20]). In such a case on

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passing 14 grams/cubic centimeter of carbon, one-fifth of all the π-mesons must sustain interaction with atomic nuclei (free path of particle within the carbon corresponding to geometric section of the nucleus, being $\sim$70 grams/cubic centimeter). Consequently it may be expected that about 80 π-mesons will undergo nuclear collisions within the carbon filters of the apparatus used by A. I. Alikhanov and A. I. Alikhanyan, and due to nuclear energy losses a portion of them will imitate single particles of a mass $> 300\ m_e$.

Altogether these authors have found, after making the correction for luminosity, 45 anomalous particles. Thus it is apparent that the occurrence of at least a considerable portion, and possibly of all such particles, is caused by the above-described process.

As a proof of the fact that nuclear absorption of π-mesons does not take place in their apparatus, A. I. Alikhanyan and A. I. Alikhanov adduce two reasons:

(a) of all the particles which constitute the group of particles having the masses ~ 500 and $\sim 1000\ m_e$, there were registered light particles of negative sign the impulses of which are within the interval $3 - 4.4 \cdot 10^8$ eV/c whereas in the impulse interval $4.4 - 6 \cdot 10^8$ eV/c there were observed only three particles. A. I. Alikhanov and A. I. Alikhanyan are of the opinion that this constitutes a proof of the fact that nuclear energy losses of π-mesons cannot cause an apparent occurrence of particles with a mass of 500 and 1000 m_e because such energy losses within both impulse intervals should have been observed about equally often. This is not to say that the observed number of particles (8 ∓ 2.7

and 3 ∓ 1.7) does not permit any conclusions, but the very deduction is an incorrect one, since, if within the impulse interval 3 - 44 • 10^8 eV/c there are eight particles, then assuming the spectrum to be of the form $dE/E^{1.5}$, in the impulse interval 4.4 - 6 • 10^8 eV/c there must be five particles and not eight particles as is supposed by A. I. Alikhanyan and A. I. Alikhanov. With increase of the π-meson impulse there must also increase the energy transmitted to particles emitted on interaction of the π-meson with the nucleus and consequently the probability increases that secondary particles are registered in the hodoscope. This may lead to such a condition that the track of such a π-meson will not be considered as being a single one and will be totally omitted from consideration.

(b) As is being pointed out by A. I. Alikhanyan and A. I. Aliklanov, among the negative particles with impulses within the interval 3 - 4.5 • 10^8 eV/c, that is among particles of intermediate mass, there are observed seven particles stopped in a graphite layer of 4 - 12 centimeters, and 28 particles stopped within 12 - 24 centimeters, whereas in a case of nuclear energy losses 20 particles should have stopped in the first absorber.

However, a process can be indicated which in the case of nuclear energy losses will result in stopping of π-meson essentially in the lower layers of absorbents.. Assuming that on interaction with the nucleus the π-meson loses only a portion of its energy or transfers a portion of that energy to a relatively rapid proton, emitted on nuclear fission. Then the secondary particles will be braked due to ionization losses. As a result the main portion of π-meson stopping due to nuclear energy losses which leads to formation of particles with masses $> 300\ m_e$, will occur in the lower filters. The presence of unpropagated electrons will also result in registration of stops, essentially, within the lower filter.

The two reasons refuting the contention that nuclear energy losses of π-mesons may account for the apparent occurrence of particles heavier than π-mesons are found to be inadequate and consequently π-mesons detected in large number under the lead must necessarily induce the apparent occurrence of particles heavier than the π-mesons.

2. To estimate scattering within counter walls A. I. Alikhanyan and A. I. Alikhanov utilize the value of the probable angle of multiple scattering. However to demonstrate the existence of a small number of particles with intermediate masses on a background of a large number of protons and mesons, this procedure cannot be used. In such a case it is indispensable to determine the experimental deflection curve for the stopped particles in the absence of the magnetic field. This was done by Alikhanyan and Alikhanov for the first time in the course of the 1950 work, but with entirely insufficient statistical material. It was found that for 58 trajectories (Figure 12 [14]), corresponding to a straight line, there is present one instance of deflection by 4 diameters of the counter, which corresponds to a radius of curvature of 10 meters. Such an additional deflection in the magnetic field would make it possible to mistake a proton for a particle having a mass of $\sim 1200\ m_e$.

If conclusions are being based on such scanty statistical material, then even on the basis of the cited data it follows that of 100 protons, ~ 2 can have a curvature corresponding to a particle with a mass of $\sim 1200\ m_e$, whereas only 15 varitrons are observed for 100 protons. In addition occurrence of trajectories imitating particles of greater mass will also be caused by scattering of mesons.

3. Installation of lead over the apparatus has considerably decreased the number of electrons being registered. It is known, however, the process of π-meson and proton generation within lead is accompanied by formation of soft component particles (electronic-nuclear showers). Electrons formed within the lead, passing through graphite can lose a considerable portion of their energy on formation of photons and stop thereafter due to ionization losses of energy, thereby simulating the trajectory of a single stopped particle (and such stops will occur mainly in the lower layers of the absorber). This may result in an apparent occurrence of particles with an intermediate mass.

The fact that particles with intermediate masses are distributed among two groups as this is shown in Figure 14 of the paper by A. I. Alikhanyan and A. I. Alikhanov [14] can hardly constitute by itself a confirmation of the existence of varitrons. Most likely the presence of definite groups is due to errors in interpretation. In this connection it must be noted that in earlier work of A. I. Alikhanyan, and A. I. Alikhanov [2, 8, 9] mention was made repeatedly of maxima, beyond the limits of statistical errors of the experiment, in the impulse spectrum of particles, corresponding to particles heavier than the protons. However, A. I. Alikhanyan and A. I. Alikhanov have repudiated their conclusion as to the existence of varitrons having a mass greater than that of a proton. In their paper [14] it is stated: "Further experiments have shown that particles of negative sign with impulses greater than $6 \cdot 10^8$ eV/c, to which we had attributed such masses (referring to masses greater than the mass of a proton) are detected very seldom, if more rigorous conditions are adhered to in observations and selection of trajectories."

Summarizing the results of Section 5, it becomes necessary to reach the conclusion that the question of the existence in cosmic rays of two groups of particles having a mass of 500 - 600 and 900 - 1000 m_e, and a life such as to render them recordable by means of a unit like the mass spectrometer of A. I. Alikhanyan and A. I. Alikhanov, remains at present a moot question. Since even the recent experiments of Alikhanyan and Alikhanov cannot be considered, for reasons enumerated above, as constituting a proof of the existence of such particles.

Isolated references which have appeared in recent years in the literature [12, 21], regarding the existence in cosmic rays of particles having masses distinct from those of protons, π- and μ-mesons, testify that their number is completely insignificant in comparison with that of protons and mesons. In addition these particles apparently have a life of less than 10^{-10} seconds [21]. Both these facts render it practically impossible to observe them by means of the mass spectrometer of A. I. Alikhanyan and A. I. Alikhanov.

CONCLUSIONS

On the basis of a detailed consideration of the entire work of A. I. Alikhanyan, A. I. Alikhanov and their co-workers, on varitrons we reach the following conclusions:

1. As a result of improved experimental conditions A. I. Alikhanyan and A. I. Alikhanov in the course of their 1950 work [14] obtain a number of particles with a mass intermediate of that of a π-meson and that of a proton, which is many times smaller than their number according to earlier work (in comparison with the 1947 paper it is at least 5.5 times smaller; in comparison with the

later, 1949 paper it is even 16 times smaller). It follows that in all prior work of A. I. Alikhanyan and A. I. Alikhanov at least an overwhelming portion of the observed effect was caused by parasitic background. In lieu of an entire system of elementary particles with masses from 100 to 20,000 m_e [14], of different values of varitron mass shown in Table 2 of the present article, A. I. Alikhanyan and A. I. Alikhanov now affirm only the existence of two groups of particles insignificant in their intensity with masses of 500 - 600 and 900 - 1000 m_e.

The results of their own 1950 work completely cancel all prior work of these investigators.

2. Numerous experiments conducted particularly at the Laboratory of the Physical Institute of the Academy of Science [16] also show that at least an overwhelming majority of trajectories, which A. I. Alikhanyan and A. I. Alikhanov had attributed in their prior papers to varitrons, are caused by various parasitic effects. Therefore on the basis of the work of these authors it is impossible to reach any conclusions on the existence of particles having a mass intermediate of that of a usual μ-meson and that of a proton.

3. Statistical examination of data on the basis of which the impulse spectra in the 1947, 1948 and 1949 papers of A. I. Alikhanyan, A. I. Alikhanov, et al, were developed shows that maxima in the impulse spectra are fictitious and arose solely as a result of inadmissible disregard of the rules of experimental data interpretation. Consequently conclusions reached on the basis of an existence of these maxima are completely erroneous.

4. New experiments conducted at the FIAN Laboratory on determination of "ionization spectra" of particles of the soft and hard components of cosmic rays [6] have shown the erroneousness of an analogous work of Nikitin [4] in which he arrived at the conclusion to the effect that ionization measurements confirm the existence of a large number of varitrons.

Interpretation of thick-layer photographic plates by means of which A. I. Alikhanyan, et al, have found varitrons [11] also shows that these authors, entirely without justification, have attributed the particle tracks found by them to the varitrons.

5. In the 1950 paper of A. I. Alikhanyan and A. I. Alikhanov there is still lacking a due analysis of already known effects which necessarily must result in an apparent occurrence of particles with masses intermediate of those of proton and π-meson. Therefore the conclusion of A. I. Alikhanyan and A. I. Alikhanov as to the existence of even an insignificant (in comparison with the prior work) number of varitrons, which they express in that paper, is also not substantiated.

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BIBLIOGRAPHY

[1] A. Alikhanov, A. Alikhanyan. Journ. of Phys., 8, 314, 1944.

[2] A. Alikhanyan, A. Alikhanov, A. Vaisenberg. ZhETF [Zhurnal eksperimental'noy i teoreticheskoy fiziki], 18, 301, 1948.

[3] S. Nikitin, A. Vaisenberg. Introductory article in the book of Yanossi Kosmicheskiye lychi (Cosmic Rays), IIL, 1949.

[4] S. Nikitin. ZhETF, 18, 577, 1948.

[5] N. Dobrotin. Journ. of Phys., 10, 207, 1946.

[6] N. Dobrotin, Ya. Grayevskaya, N. Grigorov, S. Nikol'skiy, I. Rappoport. DAN SSSR [Doklady Akademii Nauk SSSR], 77, 599, 1951.

[7] S. Azimov. Thesis. Tr. FIAN, 4, 317, 1949.

[8] A. Alikhanyan, A. Alikhanov, V. Morozov, G. Muskhelishvili, A. Khrimyan. ZhETF, 18, 673, 1948.

[9] A. Alikhanyan, V. Morozov, A. Khrimyan, G. Muskhelishvili, V. Kamalyan. ZhETF, 19, 1021, 1949.

[10] A. Alikhanyan, A. Alikhanov, V. Morozov, G. Muskhelishvili, A. Khrimyan. DAN SSSR, 58, 1321, 1947.

[11] A. Alikhanyan, D. Samoilovich, I. Gurevich, Kh. Babayan, R. Gerasimova. ZhETF, 19, 664, 1949

[12] J. B. Harding. Phil. Mag., 41, 405, 1950, L. Leprince-Ringuet. Rev. Mod. Phys., 21, 42, 1949.

[13] C. Franzinetti. Phil. Mag., 41, 86, 1950.

[14] A. Alikhanyan, A. Alikhanov. ZhETF, Present issue, page 1023.

[15] T. C. Merkle, E. L. Goldwasser, R. B. Brode, Phys. Rev., 79, 927, 1950.

[16] S. Azimov, N. Birger, N. Dobrotin, G. Zhdanov, Yu. Kokwin, S. Slavatinskiy. DAN SSSR, 78, 447, 1951.

[17] J. G. Retallack, R. B. Brode. Phys. Rev., 75, 1716, 1949.

[18] R. B. Brode, Phys. Rev., 78, 92, 1950.

[19] N. Birger, V. Veksler, N. Dobrotin, G. Zatsepin, L. Kurnosova, A. Lyubimov, I. Rozental, L. Eidus. ZhETF, 19, 826, 1949.

[20] U. Camerini, P. H. Fowler, W. O. Lock, H. Muirhead. Phil. Mag., 41, 413, 1950.

[21] A. J. Seriff, R. B. Leighton, C. Hsiao, E. W. Cowon, C. D. Anderson. Phys. Rev., 78, 290, 1950. K. Armenteros, K. H. Barker, C. C. Butler, A. Cachou, A. Chapman. Nature, 167, 501, 1951.