INVESTIGATION OF THE POLARIZATION OF COSMIC-RAY μ^+ MESONS

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The polarization of cosmic-ray μ^+ mesons was measured underground for a mean (with respect to the angular distribution) minimum momentum of 2.3 BeV/c. The polarization was found from the asymmetry in the angular distribution of positrons emitted in the decay of the μ^+ mesons stopped in a copper absorber. Altogether, 16290 decay events without a field and 14920 events in a depolarizing magnetic field of 80 Oe were observed. The polarization was found to be $P = 0.25 \pm 0.03$, so that the exponent of the π meson production spectrum could be determined.

VARIOUS experiments have shown that cosmic ray μ mesons are partially polarized.[1-9] The polarization depends on the energy spectrum of the π mesons and also on the ratio of the K^+ mesons to the π^+ mesons, in whose decay the μ^+ mesons are produced. Therefore, by studying the polarization and its dependence on μ-meson energy, we can obtain information on the spectrum of the π mesons and on the ratio of the number of the K^+ and π^+ mesons. The dependence of polarization on the μ-meson momentum was studied in [10], and it was shown there that the polarization increases with increasing momentum. This could be explained by the increase in the fraction of μ mesons produced as a result of the K-meson decay. However, our preliminary data [10] did not possess a high statistical accuracy. In order to confirm the results obtained, we have constructed an improved and more efficient array.

In the present experiment we have studied the polarization of cosmic-ray μ mesons underground. For vertical μ mesons, the layer of earth above the array amounted to a minimum momentum of 2.1 BeV/c. The mean momentum, taking the angular distribution of decaying μ mesons into account, was 2.3 BeV/c.

The polarization was determined by studying the asymmetry in the angular distribution of positrons from the decay of μ^+ mesons stopping in the copper absorber. The diagram of the array in two views is shown in Fig. 1. The counter tray IV consisted of copper counters with diameter $d = 2$ cm and length $l = 45$ cm, and all other trays of MS-9 counters with $d = 3$ and $l = 28$ cm. Trays I and III were connected in coincidence and tray IV in anticoincidence. The pulse of the anticoincidence

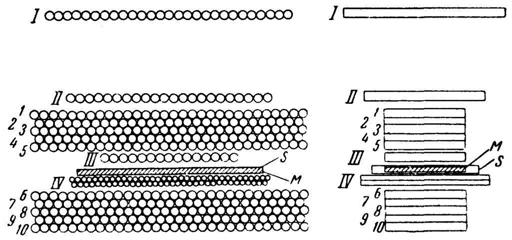

FIG. 1

I + III − IV selected the μ mesons stopped in the copper absorber M ($52 \times 28 \times 2$ cm). The resolving power of the coincidence circuit was 5×10^{-7} sec.

The counters of trays I, II, and III were connected to a permanent hodoscope in order to determine the direction of the μ mesons. The pulse from the anticoincidence I + III − IV caused a high voltage pulse to be applied to the thyratron TGI I-35/3, to whose anode a shaping line was connected. A high voltage pulse of about 2 keV amplitude with a ≤ 0.15 μsec rise time and total duration $\tau = 3.5$ μsec was fed, with a delay of 1.2 μsec, to counters 1—5 and 6—10, which served to detect the decay positrons emitted upwards and downwards respectively. The anodes of the counters of the trays 1—10 were connected to a pulsed hodoscope operating on cold-cathode thyratrons MTKh-90 working as neon lamps. The cathodes of these counters were connected to a constant voltage of −100 V to remove the primary ions produced by the passage of μ mesons prior to the arrival of the high-voltage pulse. Thus, the pulsed hodoscope recorded the decay positrons within the 1.2—4.7 μsec time interval after the stopping of a μ meson, and during this time it was insensitive to the passage of

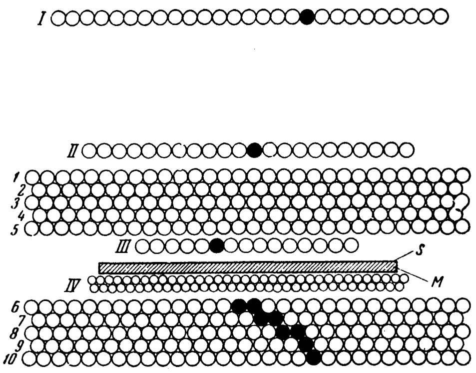

FIG. 2

μ mesons. A typical decay event is shown in Fig. 2. Both hodoscopes were photographed with an FR-2 recording camera, whose shutter was opened only when the pulsed hodoscope recorded at least three discharged counters. The discharges in the cells of the constant and pulsed hodoscopes were quenched by a circuit triggered by the anticoincidence I + III − IV.

In order to determine the asymmetry of the instrument with respect to the absorber, a solenoid S was set up which produced a depolarizing magnetic field of 80 Oe inside the absorber. An automatic device switched the magnetic field on and off every 30 min.

The reduction and selection of the events was carried out by reconstructing each event on a scaled diagram of the array. Such a reduction increased the reliability of the results obtained greatly, since it was easy to select decays which occurred inside the copper absorber. The measurements were carried out on two similar arrays which, after selection, together gave about 150 events per day. As a result of the measurements without the field (index 0) and with the field (index H), we have obtained from N decay events the following values of the ratio R of the number of positrons emitted upwards to the number of positrons emitted downwards, and of the polarization P:

N_0	N_H	R_0	R_H	R_0/R_H	P
16290	14920	1.35 ± 0.017	1.12 ± 0.018	1.20 ± 0.03	0.25 ± 0.03

The obtained value of R_H shows the existence of an instrumental asymmetry. Since the counter trays 1—5 and 6—10 were not interchanged among each other, a possible difference in their efficiency could produce such an instrumental asymmetry. Setting the parameter of the two-component neutrino theory $\xi = -1$, we can calculate the polarization from the formula $P = K(R-1)/(R+1)$, where K is a coefficient depending on the geometrical parameters of the experimental array and on the spectrum of the decay electrons. The coefficient K of our array was calculated using the computer of the Computing Center of the Academy of Sciences, Armenian S.S.R., and was found to be $K = 2.243$. In order to find the true value of the polarization, we have substituted the ratio $R = R_0/R_H$ into the formula used for the calculation. The value of the polarization, $P = 0.25 \pm 0.03$, was obtained with account of the angular distribution of the μ mesons and their polarization before entering the copper absorber. The calculation carried out according to Gol'dman[1] gives the value of the π meson production spectrum $\gamma = 1.87 \pm 0.37$ for the polarization obtained. We can conclude that the obtained data do not indicate any appreciable admixture of μ mesons as a result of the $K_{\mu 2}$ decay, within the limits of statistical error.

It should, however, be mentioned that the value obtained can be considered as absolutely exact only after determining the coefficient K of the array by means of an accelerator. Consequently, our conclusion cannot be considered as final, at least not until the data will have been compared with the result on the polarization obtained using the same array with low-energy μ mesons.

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