TABLE II

Target nucleus	E_{bind}, Mev	E_B, Mev	σ, cm^2	Reference
Li^7	2.5	5.0	$1.8\cdot10^{-26}$	Present work
Be^9	2.2	6.4	$1.0\cdot10^{-25}$	[3]
B^{10}	4.4	7.9	$6.5\cdot10^{-27}$	[4]
C^{12}	7.4	9.2	$1.0\cdot10^{-27}$	[2]
N^{14}	11.6	10.5	*	
O^{16}	7.2	11.7	$1.5\cdot10^{-27}$	[4]
Al^{27}	10.0	17.4	**	

* Activity due to F^{18} production is not observed.[5]
** Activity due to F^{18} production is observed but the value of σ is not given.[6]

action mechanism of this kind a larger value of the F^{18}-production cross section will be observed when the nitrogen ions bombard nuclei with smaller α particle binding energies (E_{bind}). In Table II we compare nitrogen-ion induced F^{18}-production cross sections and values of α particle binding energy in light nuclei. In order to compare the results, the values of σ are taken for collision energies equal to the height of the Coulomb barrier.

It was obvious from Table II that σ decreases as E_{bind} increases.

[1] L. D. Wyly and A. Zucker, Phys. Rev. 89, 524 (1953).
[2] H. L. Reynolds and A. Zucker, Phys. Rev. 96, 1615 (1954).
[3] H. L. Reynolds and A. Zucker, Phys. Rev. 100, 226 (1955).
[4] Reynolds, Scott, and Zucker, Phys. Rev. 102, 237 (1956).
[5] H. L. Reynolds and A. Zucker, Phys. Rev. 101, 166 (1956).
[6] Webb, Reynolds, and Zucker, Phys. Rev. 102, 749 (1956).
[7] J. P. Lonchamp, J. phys. et radium 14, 89 (1953).

Translated by H. Lashinsky
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A STUDY OF SLOW μ MESONS IN THE STRATOSPHERE BY THE METHOD OF DELAYED COINCIDENCES

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A study has been made of the altitude dependence of μ mesons of ~ 100 Mev up to altitudes of about 25 km at 51° and 31° N latitude. The μ-meson production spectrum in the atmosphere has been measured at these latitudes.

EXPERIMENTS on the altitude dependence of slow μ mesons by the method of delayed coincidences were carried out by Sands[1] and Conversi[2] in airplanes at altitudes up to ~ 10 — 11 km. In the present experiment the altitude dependence of slow μ mesons has been studied using that method in balloon flights up to the altitude of ~ 25 km at 51° and 31° N geomagnetic latitude.

The counter arrangement used is shown in Fig. 1. The counter trays T_1 and T_2, separated by a Pb absorber 5 cm thick, formed a telescope. The two groups of counters marked "del" detected delayed particles. The counters of the groups A and B were connected in parallel and the anti-coincidences (A-B) were recorded. The mesons stopped in the graphite block C 7 cm in thickness.

The array detected μ mesons with kinetic energies of 100 — 115 Mev. The "del" counters were oper-

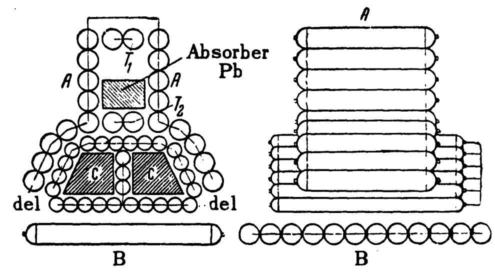

FIG. 1. Schematic diagram of the apparatus

ated in the following way: the high voltage was set at 40 – 50 v below the counting threshold, and the appearance of the master pulse (coincidence T_1T_2) caused a voltage pulse of ~ 180 — 200 v to be applied to the counters for ~ 3 μsec.

The pulsed operation of the delay counters increased the efficiency of the decay-electron detection. In the ordinary method of delayed coincidences it is necessary that the pulse width of the counters detecting decay electrons be less than the chosen delay. A considerable narrowing of the counter pulse necessitates, however, a much more elaborate electronic circuitry, increases the dissipated power and the total weight of the apparatus, etc. It is therefore necessary to increase considerably the delays in experiments sent into the stratosphere, which reduces the detection efficiency of decay electrons. The background cosmic radiation is a further reason for reduced efficiency of the decay electron detection in the conventional counter connection. The total time of counter insensitivity due to dead time becomes appreciable at high altitudes, thus reducing the efficiency. The pulsed operation of counters eliminates all those deficiences of the delayed coincidence method.

The measurement of chance coincidences recorded during the flight was carried out as follows: after each operation of the delay counters due to the master pulse trigger, the counters were operated again about 100 μsec later, when chance coincidences only could be detected. All data obtained during flight were relayed by a radio transmitter, displayed on an oscilloscope, and recorded photographically.

The experiments on the altitude dependence of slow μ mesons were carried out during 1953 — 1955. Two flights were made at each latitude, 51° and 31° N. The results of corresponding flights were consistent. The number of chance coincidences was subtracted from the measured number of delayed coincidences. At high altitudes chance coincidences amounted to ~ 40 — 50% of all recorded events. The detection efficiency η of stopping μ mesons was then accounted for. The efficiency was determined in the course of an auxiliary experiment at sea-level by comparison of the measured number of delayed coincidences with the absolute intensity of μ mesons at sea-level;[3] it was found that $\eta = 0.23 \pm 0.02$.

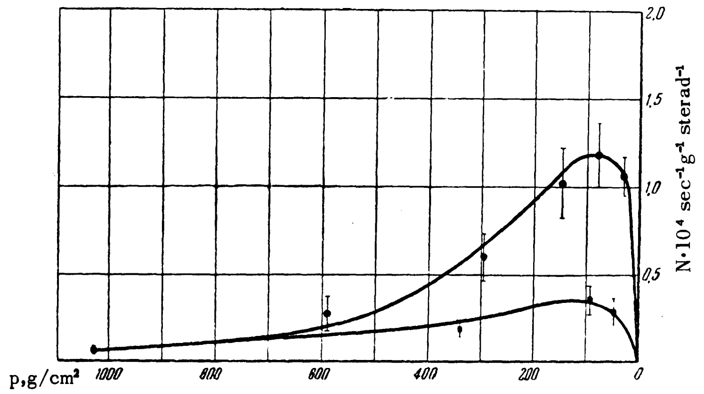

FIG. 2. Altitude dependence of slow mesons for 51° N latitude (upper curve) and 31° N latitude (lower curve)

The altitude dependence of slow μ mesons at the latitudes of 51° and 31° N is shown in Fig. 2. The x axis represents the pressure in g/cm^2, and the y axis — the number of mesons in $g^{-1}sec^{-1}sterad^{-1}$.

The measurements of the slow μ-meson intensity at high altitudes make it possible to correct the low-energy end of the production spectrum in the atmosphere averaged over the total flux of nuclear-active particles. The expressions for the μ-meson production spectrum in the atmosphere given in Refs. 1 — 4 are not accurate for low energies. This is due to the fact that the experiments[1,2] upon which the calculations are based were carried out at relatively low altitudes (up to 10 — 11 km) where the intensity of slow μ mesons is insensitive to the shape of the meson production spectrum in the low-energy region.

The data on the absolute intensity of slow μ mesons in the stratosphere at the altitude of ~ 30 – 50 g/cm^2 obtained in the present experiment were used for the determination of the μ-meson production spectrum in the low-energy region. The differential equation[5] expressing the balance of the number of mesons with total energy ϵ at any atmospheric depth was used. The chosen spectrum had, on one hand, to satisfy the measured intensity according to the equation of Ref. 5 and, on the other, to coincide with the known μ-meson production spectrum for energies $\geq 7\mu c^2$.[6] The obtained μ-meson production spectrum in the atmosphere at 51° N latitude can be written as follows:

$$\Pi_{51^\circ N}(\varepsilon) = \frac{360}{(B+\varepsilon)^{2.7}} (\mu c^2)^{-1} \quad \text{min}^{-1}\, \text{sterad}^{-1},$$

where $B = (2 \pm 0.3)\mu c^2$ and ϵ is the total energy of the μ mesons in units of μc^2. For the latitude of 31° N the expression for the spectrum is:

$$\Pi'_{31^\circ N}(\varepsilon) = \frac{2700}{(12+\varepsilon)^{2.7}}(\mu c^2)^{-1}\ \text{min}^{-1}\,\text{sterad}^{-1}\ \text{for}\ 2\mu c^2 < \varepsilon < 7\mu c^2;$$

$$\Pi''_{31^\circ N}(\varepsilon) = \frac{360}{(2+\varepsilon)^{2.7}}(\mu c^2)^{-1}\ \text{min}^{-1}\,\text{sterad}^{-1}\ \text{for}\ \varepsilon \geqslant 7\mu c^2,$$

under the condition

$$\Pi'_{31^\circ N}(7\mu c^2) = \Pi''_{31^\circ N}(7\mu c^2).$$

It can be easily seen that the observed spectrum exhibits a large latitude effect for slow mesons and that such an effect is absent (cf. Ref. 6) for mesons with energy $\geq 7\mu c^2$ between the latitudes of 51° and 31° N. It should be noted that the μ-meson production spectrum at 51° N latitude, obtained as the result of the present work, yields a slightly larger value for the number of mesons with energy between 2 and $7\mu c^2$ compared with Ref. 1.

In the present experiment, therefore,

(1) new apparatus has been developed for the study of slow μ mesons in the stratosphere by the delayed coincidence method;

(2) the altitude dependence of slow μ mesons has been measured at 51° and 31° north latitude;

(3) the meson production spectrum in the atmosphere at the latitudes of 51° and 31° N has been determined in the low-energy region ($E \gtrsim 100$ Mev).

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[1] M. Sands, Phys. Rev. **77**, 180 (1950).
[2] M. Conversi, Phys. Rev. **79**, 750 (1950).
[3] A. Fafarman and M. H. Shamos, Phys. Rev. **96**, 1096 (1954).
[4] G. M. Garibian and I. I. Gol'dman, J. Exptl. Theoret. Phys. (U.S.S.R.) **26**, 257 (1954).
[5] Hamilton, Heitler, and Peng, Phys. Rev. **64**, 78 (1943).
[6] T. N. Charakhch'ian, Dissertation, Moscow State Univ., 1954.

Translated by H. Kasha
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