Production of Mesotrons by Penetrating Non-Ionizing Rays

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IN an attempt to obtain information as to the nature of the secondary processes giving origin to the cosmic-ray mesotrons, an experiment has been recently performed at 4300 m above sea level (Mt. Evans, Colorado) with the counter arrangement schematically represented in Fig. 1. The 2 counters F and likewise the 5 counters A were connected in parallel. The counter battery A completely covered and extended beyond the solid angle subtended by counters B, C, D and E. By means of a circuit which will be described by one of us (V. H. R.) on a later occasion, the following events were simultaneously recorded: (1) fourfold coincidences ($BCDE$), (2) fourfold coincidences ($BCDE$) not accompanied by a pulse in any of counters A (anticoincidences ($BCDE$–A)), (3) fivefold coincidences ($BCDEF$), (4) fivefold coincidences ($BCDEF$) not accompanied by a pulse in any of counters A (anticoincidences ($BCDEF$–A)). Ten cm of lead were permanently placed in position S_1 and 5 cm of lead in position S_2, so that only particles penetrating 15 cm of lead could give rise to fourfold coincidences ($BCDE$). Measurements were taken with 5 additional centimeters of lead either in position R_1 or R_2 and with various absorbers in position Σ. The experimental results are summarized in Table I.

The anticoincidences ($BCDE$–A) recorded with 5 cm of lead in R_2 and no lead either in R_1 or in Σ are only 0.4 percent of the fourfold coincidences ($BCDE$). They represent a "zero effect" caused by lack of efficiency of the counter battery A, by chance coincidences, and possibly by scattering and by showers coming from the side, which discharge counters B, C, D and E without striking counters A. The last effect is probably responsible for the few anticoincidences ($BCDEF$–A) recorded in the same condition. By moving the lead from R_2 to R_1, when no absorber is present in Σ, the numbers of anticoincidences ($BCDE$–A) and ($BCDEF$–A) increase considerably. This result can be interpreted as indicating the existence of non-ionizing rays traversing the counter battery A un-

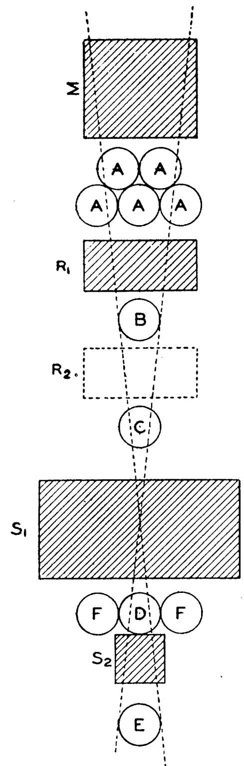

FIG. 1. Arrangement of counters.

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TABLE I. *Various coincidence and anticoincidence counts.*

EXPERIMENTAL CONDITION	TIME OF EXPER. (HOURS)	$BCDE$	$BCDE$–A	$BCDEF$	$BCDEF$–A
$R_1=0$, $R_2=5$ cm Pb, $\Sigma=0$	20.00	198 ± 3.1	0.8 ± 0.2	7.7 ± 0.6	0.15
$R_1=5$ cm Pb, $R_2=0$, $\Sigma=0$	120.70	198 ± 1.3	2.83 ± 0.15	10.6 ± 0.3	0.86 ± 0.09
$R_1=5$ cm Pb, $R_2=0$, $\Sigma=$ 2.5 cm Pb	108.38	192 ± 1.4	2.37 ± 0.15	10.1 ± 0.3	0.75 ± 0.08
$R_1=5$ cm Pb, $R_2=0$, $\Sigma=10$ cm Pb	127.06	176 ± 1.2	1.75 ± 0.12	8.8 ± 0.3	0.68 ± 0.07
$R_1=5$ cm Pb, $R_2=0$, $\Sigma=20$ cm Pb	24.00	162 ± 2.7	1.75 ± 0.27	8.5 ± 0.6	0.71 ± 0.17

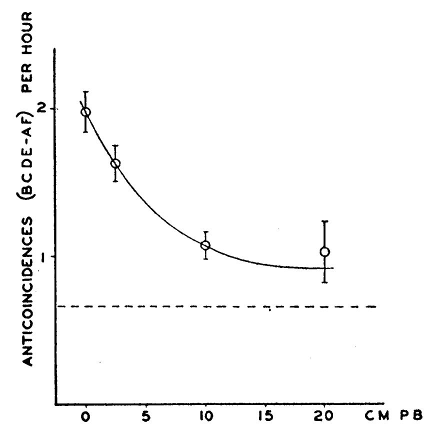

FIG. 2. Anticoincidence counts as a function of thickness of lead absorber.

detected and producing in R_1 ionizing penetrating particles (mesotrons), which discharge the counters underneath. A proof of the above interpretation is found in the fact that an absorber of sufficient thickness placed above counters A (position Σ) strongly reduces the number of anticoincidences ($BCDE$–A) recorded with lead in R_1. This is what one would expect if most of these anticoincidences are due to non-ionizing rays producing mesotrons in R_1. Indeed, a non-ionizing ray traversing Σ has a certain probability of generating a secondary ionizing particle which discharges A. In this case, no anticoincidence can be produced even if the non-ionizing ray survives the encounter. On the contrary, anticoincidences due to spurious phenomena like scattering, showers from the side, etc., should be equally frequent with and without the absorber Σ. The production of mesotrons by non-ionizing rays seems, thus, to be definitely established in agreement with results obtained by Schein and Wilson and by Schein, Jesse and Wollan in the high atmosphere.[1]

[1] M. Schein and V. C. Wilson, Phys. Rev. **54**, 304 (1939); M. Schein, W. P. Jesse and E. O. Wollan, *ibid.* **57**, 847 (1940). Other observations of the same kind had been previously reported: see B. Rossi, Zeits. f. Physik **68**, 64 (1931); D. S. Hsiung, Phys. Rev. **46**, 653 (1934); H. Maass, Ann. d. Physik **27**, 507 (1936). However, it has been shown recently by Rossi, Jánossy, Rochester and Bound (this issue, p. 761) that the observed effects were caused by spurious phenomena rather than by mesotron production. This only partially applies to the results of F. R. Shonka [Phys. Rev. **55**, 24 (1939)].

Valuable information on the nature of the mesotron producing rays is provided by the experimental data on the rate of decrease of anticoincidences with increasing thickness of the absorber Σ. In order to avoid anticoincidences due to side showers from being recorded, we shall consider only the coincidences ($BCDE$) unaccompanied by pulses either in counters A or in counters F (anticoincidences ($BCDE$–AF)). Side showers are unlikely to discharge counter D without hitting counters F.[2] The counting rate ($BCDE$–AF), which is equal to the difference between the counting rates ($BCDE$–A) and ($BCDEF$–A), is plotted against absorber thickness in Fig. 2. The dotted line represents the zero effect observed with $R_1 = 0$ and $R_2 = 5$ cm Pb. It appears that the non-ionizing mesotron producing rays have a large probability of traversing several centimeters of lead without generating secondary ionizing particles. In fact, about 10 cm of lead in Σ are needed to cut off most of the anticoincidences. This behavior is very different from that of photons, most of which materialize into electron pairs already in 1 cm of lead, as recently shown by Jánossy and Rossi.[3] We conclude that the non-ionizing rays which produce mesotrons are more penetrating than photons. They could be "neutrettos" (neutral mesotrons) or high energy neutrons. The last assumption would be in agreement with Johnson's arguments indicating protons as the primary origin of mesotrons.[4] Indeed, mesotron production by heavy particles could be accompanied by transitions from protonic to neutronic states and vice versa, so that the observed neutrons could arise from the transformation of primary protons.

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[2] It is still uncertain, however, how many of the anticoincidences ($BCDEF$–A), which we disregard, are caused by side showers rather than by multiple production of mesotrons.

[3] L. Jánossy and B. Rossi, Proc. Roy. Soc. **175**, 88 (1940). The experimental method used is very similar to that described in the present note.

[4] T. H. Johnson, Rev. Mod. Phys. **11**, 208 (1939).