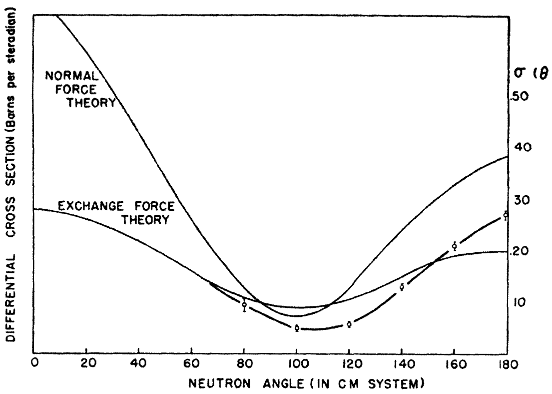

FIG. 1. Neutron-deuteron scattering at 4.5 Mev.

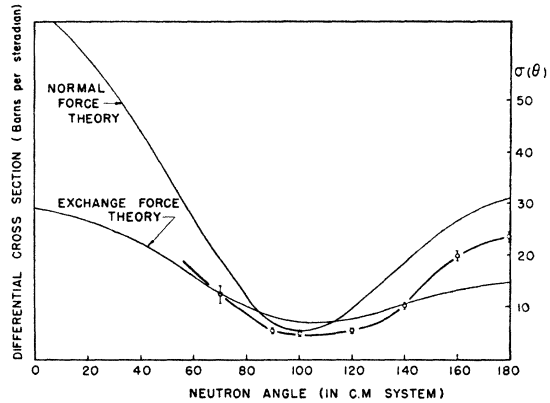

FIG. 2. Neutron-deuteron scattering at 5.5 Mev.

Absolute values of neutron-deuteron differential scattering cross sections were calculated from the known yield of the source, the amount of scattering material, and the geometry of the apparatus.

A measurement of neutron-proton scattering at these energies gave, within five percent statistical errors, the expected isotropic distribution in the center-of-mass system. The total $n-p$ cross section determined from this data agrees with the published values of Bailey and Bennett *et al.*[2]

Neutron-deuteron scattering measurements were compared with the theory of Buckingham and Massey.[3] Their calculations of the scattering phases in the region 0 to 11.5 Mev were interpolated for the energies used here.

Figures 1 and 2 show the results. The total cross sections, if one assumes a reasonable extrapolation to the angles where no experimental data could be obtained, are in acceptable agreement with experimental total cross sections obtained by Nuckolls and Bailey *et al.*[4] The ratio of the differential cross section at 180° to the value at the minimum is approximately 5:1 at both energies which is much larger than the ratio predicted by the exchange force theory (2:1). A full report will be published.

It is a pleasure to acknowledge the aid and the many helpful suggestions of Dr. N. P. Heydenburg at the Department of Terrestrial Magnetism, and to thank Dr. E. O. Salant for suggesting this problem and for critical discussions.

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Intensity and Lateral Distribution of the *N*-Component in the Extensive Showers of the Cosmic Radiation*

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DURING the summer of 1949 an experiment was performed (Echo Lake, Colorado, 3260 m elevation) to study the intensity and the lateral distribution of the *N*-component[1] present in the extensive air showers.

The general layout of the experiment is sketched in Fig. 1A. C_1, C_2, C_3, C_4 and C_5 (core selectors) are the same as used in a previous experiment on the lateral structure of the extensive showers.[2] The cross section of one of them is drawn in Fig. 1B. As shown in reference 1, the fivefold coincidences (*abcde*) are mostly produced by showers whose cores hit within a distance of 10 to 20 meters from the selectors. Such coincidences generated master pulses, *C*, which were sent to the other parts of the apparatus; namely, to the density detector and to the *N*-component detector. Both these detectors were located at the center of a circle (of radius *d*) on which the core selectors were arranged, five meters from one another.

The density detector (i.e., the apparatus for measuring the density of the ionizing particles in the showers) consisted of three groups of three counters each: $L_1L_2L_3$ (effective area 0.15 m²), $M_1M_2M_3$ (effective area 0.02 m²) and $S_1S_2S_3$ (effective area 0.003 m²) (see Fig. 1C). Coincidences $(L_1L_2L_3C)=(LC)$, $(M_1M_2M_3C)=(MC)$ and $(S_1S_2S_3C)=(SC)$ were recorded.

The *N*-component detector (see Fig. 1C) consisted of a Pb-absorber Σ (4 in.×25 in.×45 in.), surrounded by paraffin in which 16 BF_3 proportional counters were embedded. On the basis of the results obtained in previous experiments,[3] the detection of the *N*-component was accomplished by recording the neutrons of moderate energies released in nuclear interactions of the *N*-component with nuclei of the lead. The detector recorded neutrons in the energy range between 1 and 20 Mev, with an over-all efficiency $E=0.04\pm0.01$. The pulses of the neutron counters, *n*, were put in coincidence with the coincidences (*LC*), (*MC*) and (*SC*) delayed 7 μsec. and shaped in a 200 μsec. square pulse. Coincidences (*nLC*), (*nMC*) and (*nSC*) were recorded. Chance coincidences were negligible.

Four series of measurements were made, with the distance *d* between the core selectors and the other detectors equal to 10, 18, 50, and 95 meters.[4] The results are given in Table I.

For the interpretation of the results we considered the ratios:

$$P_{LM}=\frac{(nLC)-(nMC)}{(LC)-(MC)} \quad \text{and} \quad P_{MS}=\frac{(nMC)-(nSC)}{(MC)-(SC)},$$

namely, the probability that a shower, which produced a master pulse *C* in one of the core selectors and struck the density detector

TABLE I. Experimental results with their standard errors. Δ_{LM} (and Δ_{MS}) are the average densities of the showers which struck a core selector and counters *L*, but not counters *M* (or *M* but not *S*). R_{LM} and R_{MS} are the intensities of the *N*-component, relative to the intensity of all the ionizing particles, in the showers whose average densities are $\bar{\Delta}_{LM}$ and $\bar{\Delta}_{MS}$.

		$d=10$m	$d=18$m	$d=50$m	$d=95$m
C	(h^{-1})	6.25±0.15	6.32±0.15	6.25 ±0.14	6.10 ±0.14
(*LC*)	(h^{-1})	4.38±0.13	4.67±0.13	1.80 ±0.08	0.507±0.04
(*MC*)	(h^{-1})	2.07±0.09	1.62±0.08	0.29 ±0.03	0.048±0.012
(*SC*)	(h^{-1})	0.37±0.04	0.28±0.03	0.029±0.01	0
(*nLC*)	(h^{-1})	1.40±0.08	0.96±0.06	0.15 ±0.02	0.025±0.009
(*nMC*)	(h^{-1})	1.02±0.06	0.58±0.05	0.061±0.013	0.006
(*nSC*)	(h^{-1})	0.25±0.03	0.21±0.03	0.016±0.007	0
$\bar{\Delta}_{LM}$	(m^{-2})	42	38	24	19
$\bar{\Delta}_{MS}$	(m^{-2})	195	168	115	115
$R_{LM}\times100$		1.42±0.17	1.15±0.15	0.79 ±0.15	0.66 ±0.30
$R_{MS}\times100$		1.06±0.2	0.64±0.15	0.46 ±0.20	~0.35

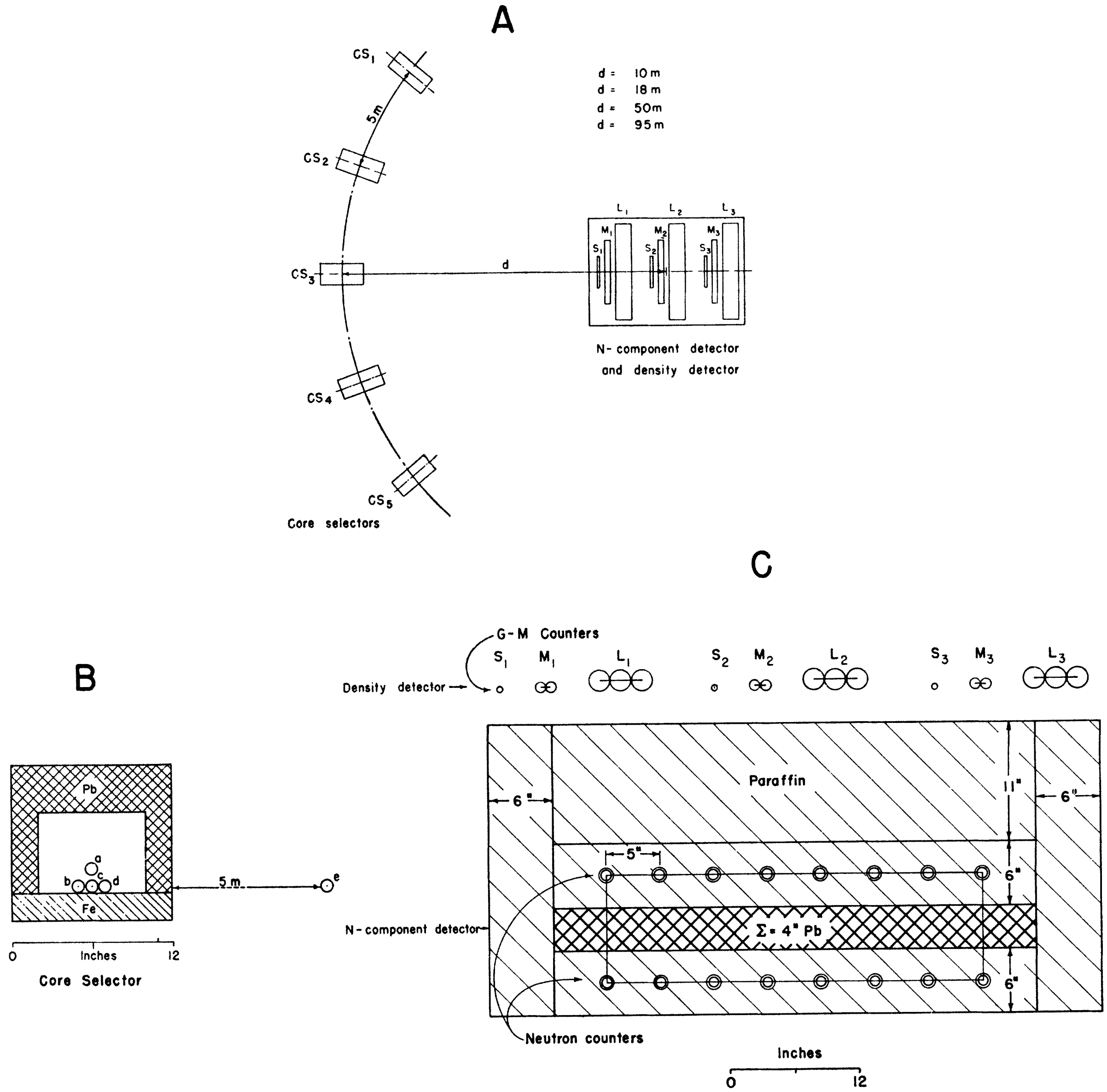

FIG. 1. General layout of the experiment (Fig. 1A). In Fig. 1B is given the cross section of one of the core selectors and in Fig. 1C the cross section of the detectors of the density of the showers and of the N-component.

with a density such as to trigger counters, L, but not M (or M but not S), contained a particle of the N-component which interacted in the absorber Σ and produced at least one neutron recorded by our apparatus. One can write:

$$P_{LM}=1-\exp\{\bar{\Delta}_{LM}\cdot\sigma\cdot(1-e^{-x/\lambda})\cdot[1-(1-E)^{\nu}]\cdot R_{LM}\}$$

(and a similar expression for P_{MS}), where $\bar{\Delta}_{LM}$ is the average density of the ionizing particles in the showers which triggered both one or more of the core selectors and counters L, but not counters M; σ is the surface of the lead Σ and x its thickness; λ the interaction mean free path in lead of the N-component; ν the average multiplicity of the neutrons produced in lead in a nuclear disintegration; and R_{LM} the density of the N-component relative to the total density of ionizing particles in the showers considered.

$\bar{\Delta}_{LM}$ (and $\bar{\Delta}_{MS}$) were deduced from the density spectra obtained in the experiment quoted in reference 1, and from the probabilities of showers of different densities striking counters L, M, and S. The values used for $\bar{\Delta}_{LM}$ and $\bar{\Delta}_{MS}$ are given in Table I.

The mean free path λ was assumed to be equal to 160 g cm^{-2}.

The multiplicity ν has been measured[2] for 2 in. Pb at the average distance of about 10 meters from the core of the showers, and found to be about 60, which gives $1-(1-E)^{\nu}=0.92$. The approximation $1-(1-E)^{\nu}=1$ was used, which implies the assumption that ν does not vary strongly with the distance from the core of the showers.

The results obtained for R_{LM} and R_{MS} are given in Table I. Owing to the large statistical errors in the results and to the uncertainty of the assumptions introduced, particularly for ν, we do not attribute much quantitative significance to the variations of R with the distance from the core and with the average density of the shower. However, the following conclusions can be drawn:

(1) the intensity of the N-component capable of producing nuclear disintegrations is of the order of one percent of all the

ionizing particles present in the extensive showers, at 3260 m elevation;

(2) the value of the ratio R does not vary strongly with the distance from the core of the showers. Hence the lateral distribution of the N-component does not differ strongly from that of the electrons.

These results rule out the possibility that most of the N-component observed near the core of a shower is produced far above the apparatus. The peaked lateral distribution observed, and the fact that the particles of the N-component in a single shower can be as many as 10^6, suggest that the mechanism of production of the N-component inside an extensive shower is similar to that of the electrons. The N-component must be the result of a nuclear cascade process which develops throughout the atmosphere. The core of the shower contains the most energetic particles of the N-component and keeps on supplying less energetic particles to the outer regions of the shower.

* The authors are grateful to the Research Corporation for a grant which covered the expense of performing this experiment. The funds for constructing the apparatus were provided through a contract with the ONR.

[1] The term *N-component* is used here in the sense defined by B. Rossi [Rev. Mod. Phys. **20**, 537 (1948)]; namely, the N-component consists of all of the particles capable of producing nuclear disintegrations (high energy neutrons and protons, π-mesons, etc.).

[2] Cocconi, Tongiorgi and Greisen, Phys. Rev. **76**, 1020 (1949).

[3] V. Cocconi Tongiorgi, Phys. Rev. **75**, 1532 (1949).

[4] We want to point out that the geometrical distances, d, between the core selectors and the N-component detector are to be taken only as an indication of the order of magnitude of the average distances of the particle of the N-component from the core of the showers. As a matter of fact, the true average distances are somewhat smaller than d, since the requirement of the N-component hitting the detector favors the showers whose core lies in between the core selectors and the N-detector.

Spectral Emission from Scintillation Solutions and Crystals*

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June 19, 1950

WE have investigated the spectral emission of several solutions that have been used as scintillation counters.[1] Some of the results are presented in the figures. The following emission spectra are shown, with a mercury spectrum superimposed on each one for calibration.

Figures (1A) and (1B): Crystalline terphenyl excited by 50 kv x-rays and the mercury line 2537A, respectively. (1C): A solution of terphenyl in benzene irradiated with 50 kv x-rays. (1D), (1E) and (1F): Solutions of terphenyl in benzene, xylene, and toluene excited by the 2537A line, the light falling on the side of the cell opposite to the slit. (1G): A solution of terphenyl in benzene excited by the 2537A line, the light falling on the side of the cell nearest the slit.

Figure (2A): An anthracene crystal excited by 50 kv x-rays. (2B) and (2C): Anthracene crystals excited by 2537A light shining on the side farthest from and nearest to the slit respectively. (2D): A solution of anthracene in xylene irradiated with 50 kv x-rays. This was taken with the spectroscope slit wide open, so that the spectrum is displaced about 100A toward shorter wavelengths. (2E): The same solution excited by 2537A light.

The spectra obtained with particle bombardment (Compton electrons from the x-rays) appear to be the same as the fluorescent spectra caused by ultraviolet light. From Figs. (1D), (1E) and (1F) we see that the light emitted is characteristic of the terphenyl molecule and is the same with different solvents.

There is evidence that some of the light emitted is reabsorbed, both in the solutions and in the crystals. Since the ultraviolet light used to excite the fluorescence is very strongly absorbed by the solutions, the emitted light must travel about 5 mm through the solution if we irradiate the side away from the slit, and only a very short distance if we irradiate the part nearest the slit. In

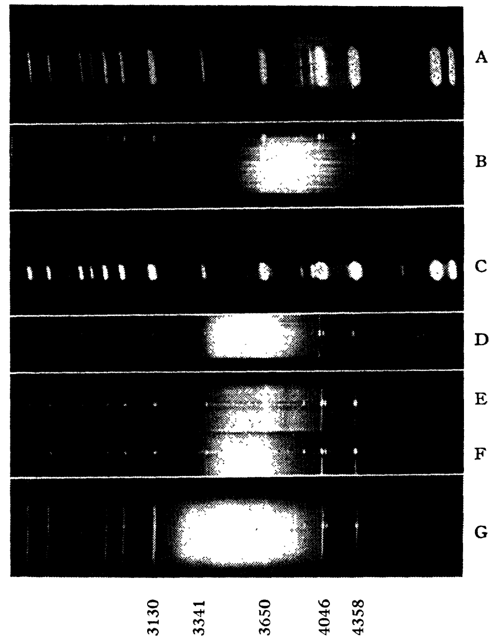

FIG. 1. Emission spectra of terphenyl.

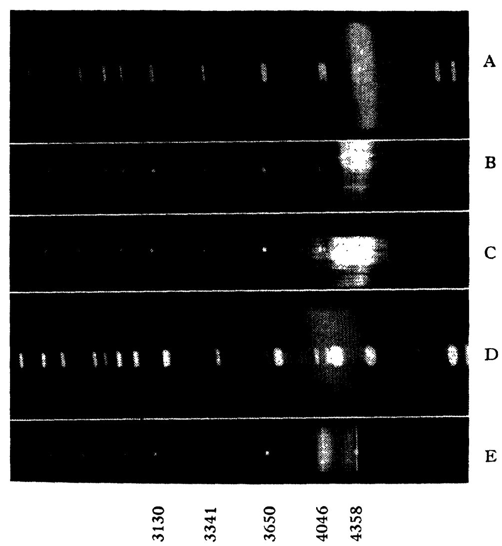

FIG. 2. Emission spectra of anthracene.

Fig. 1 the solution reabsorbs the band at 3280A, and the crystal, which has a much higher density of terphenyl molecules, reabsorbs the 3450A band. The 3720A band is weaker in (1A) than in (1B) because the crystal was thicker. In the same way, as we go from (2A) to (2E) the bands at about 4740A and 4460A disappear and one appears at 4050A.

The 5819 end-window photo-multiplier tube will favor anthracene crystals over terphenyl solutions because of its spectral sensitivity. Observations with this tube show that the pulse height from the terphenyl solutions due to the Cs^{137} 630-kev electron is about 35 percent of the pulse height from an anthracene crystal. When a 1P21 photo-multiplier is used this ratio is about 50 percent; and with a 1P28, which favors the solutions, the ratio of pulse heights is approximately 65 percent.

* Assisted by the joint program of the ONR and AEC.

[1] Reynolds, Harrison, and Salvini, Phys. Rev. **78**, 488 (1950).