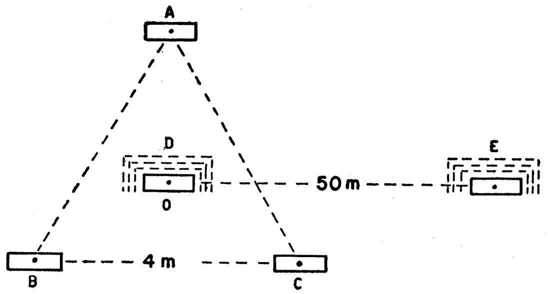

FIG. 1. Horizontal arrangement of counters A, B, C, D, E.

measurements were performed to study how this adjustment had to be made. Because of the condition $S_E\Delta_E$=constant, the probability that showers producing coincidences T hit also counter E, is practically independent of the absorber thickness t.

Assuming for the showers an integral density spectrum $F(\Delta)=K\Delta^{-\gamma}$,[1] it is possible to deduce from the values of S, S_E, T, $T+D$, and $T+E$ the density, in the showers, of the particles capable of crossing the thickness t, both near the core and about 50 m from it.

The absorption curves in H_2O, where practically no transition effect for the electrons and photons from the air is expected, show in all cases an exponential decrease followed by a plateau; the latter is interpreted as due to the penetrating component (nucleons and μ-mesons) of the extensive showers.

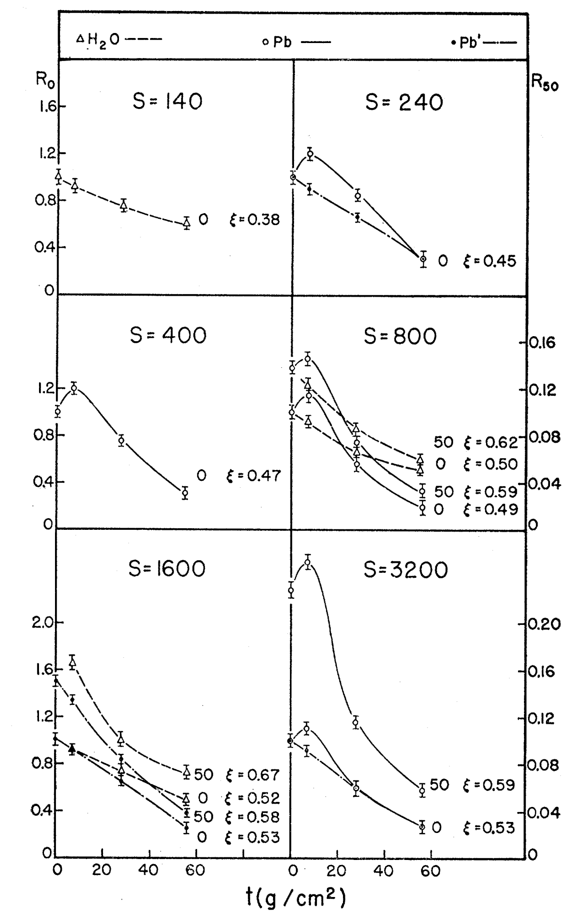

FIG. 2. R_0 and R_{50} are the fractions of particles in the showers, capable of crossing the thickness t of absorber at 0 and 50 m from the core.

In lead, instead, a transition curve has been found due to the conversion of the photons in the absorbers. The true absorption has been measured in this case by registering, besides the coincidences $T+D$ and $T+E$, the coincidences $T+D+D'$ and $T+E+E'$, where, D' and E' were counters placed at the top of the absorbers above counters D and E respectively. The results of these measurements are labeled Pb′ in Fig. 2. All curves in Fig. 2 give the results of the measurements after subtraction of the tail due to the penetrating component. These curves are interpreted as representing the absorption of the soft component of the extensive showers.

Both in H_2O and in Pb the curves are well described by the expression

$$I(t)=I_0(E+E_C)^{-\xi}, \tag{1}$$

where ξ is a constant, E_C is the characteristic energy of air, and E is the energy for an electron to cross the thickness t. The energy-range relation used is that given by Clay[2] which fits well the experimental data thus far available. The values of ξ which fit our results are given in Fig. 2.

The theoretical expressions for the energy spectrum in an electron shower, calculated by several authors,[3] are of the same form as Eq. (1). However, assuming that the showers are produced near the top of the atmosphere by a primary electron or photon of $10^{14}-10^{16}$ ev (which is the energy required to generate at sea level the showers detected by our apparatus) the theory predicts $\xi=1.6$ to 1.7. These values are in strong disagreement with the experimental values ($\xi=0.5$ to 0.6). Besides, at 50 m from the cores, the cascade theory predicts less than 1 percent of the electrons to have energies 10^9 ev, while our measurements show that there, 25 percent of the electrons satisfy this condition.

Better agreement between theory and experiment can be reached if one assumes that the primary electron hypothesis is wrong and that instead the electrons found in an extensive shower near sea level are produced mainly in the air not far (a few radiation lengths) above the apparatus.

The present results then suggest that the development of the extensive showers in the air is mainly due to the cascade multiplication of the nucleonic component; this is in agreement with the results of other experimenters (presence in the extensive showers of the N component, observation of locally produced soft showers). A more detailed account of these experiments is going to appear in *Nuovo cimento*.

[1] With $\gamma=1.31+0.038\log(1/s)$, ($S$ in m²), after G. Cocconi and V. Cocconi Tongiorgi, Phys. Rev. **75**, 1058 (1949).
[2] J. Clay, Physica **14**, 499 (1948).
[3] H. J. Bhabha and S. K. Chakrabarty, Proc. Roy. Soc. (London) **A181**, 267 (1943).

Natural Radioactivity of Lanthanum-138†

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WE have sought beta-particles and x-rays from natural lanthanum with the large proportional counter used in the study of neodymium.[1] The search was prompted by the discovery of the rare (0.089 percent) La^{138} isotope in natural lanthanum[2] and stimulated by the discovery of gamma-radiation from this nuclide.[3] This was presumed to follow electron capture decay to Ba^{138}, and K x-rays of barium were subsequently found.[4] Early searches for beta-particles[5] were inconclusive because of insensitive detectors or incomplete purification. Recently reported upper limits to the number of hard betas per second per gram of lanthanum are ~1,[2] 0.4,[3] and 0.2.[4]

Commercial lanthanum oxide (98 percent pure, Lindsay Light and Chemical Co., West Chicago, Illinois) was purified by three passages through a cation exchange resin column[1] and by numerous scavenging precipitations of zirconium iodate, barium sulfate, and copper sulfide. The first column purification removed a great deal of activity and the second removed a small amount in addition, whereas after the third purification the activity was unchanged. This residual activity, 54 ± 1 counts per minute for a 10-gram sample spread over 1650 cm^2, is thus attributable to lanthanum.

An aluminum absorption curve was obtained with aluminum foils rolled inside the sample foil. Because of the considerable activity of the aluminum (5 to 80 counts/min), a separate background count had to be taken with each absorber over a bare copper sheet. From the differences, curve *A* of Fig. 1 was obtained. This shows a hard component, which was fitted with a theoretical absorption curve[6] for Ba *K* x-rays in 50 percent geometry, curve *B*. This extrapolates to 10 counts/min at zero absorber, but since about 2 counts/min are expected from the gamma-radiation,[4] we ascribe 8 counts/min to *K* x-radiation. We estimate our counting yield for these x-rays to be 1.5 percent, giving a specific activity of 1.0 *K* x-rays per second per gram of lanthanum. This is somewhat greater than the value 0.4 reported previously[4] and, if correct, would indicate appreciable electron capture to the ground state of Ba^{138}.

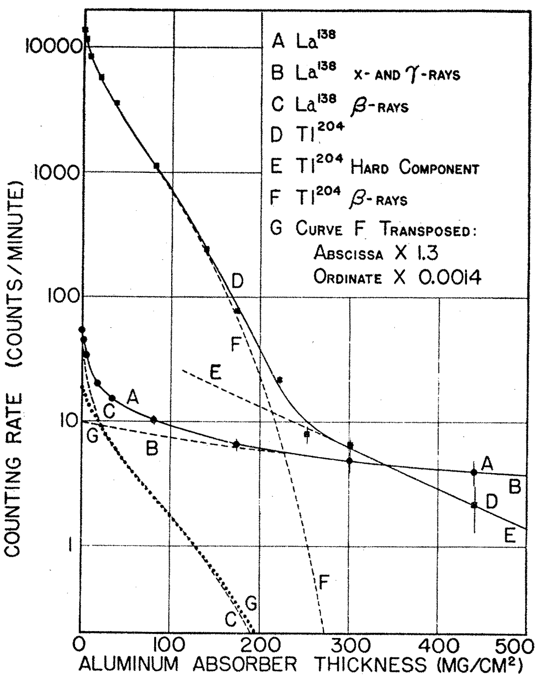

FIG. 1. La^{138} absorption curve and its analysis.

Curve *C*, the activity remaining after subtraction of the hard component, indicates an energetic beta-radiation. For a comparison analysis absorption measurements were taken under identical conditions on Tl^{204} mixed with pure Nd_2O_3, giving curve *D*. Subtraction of the weak hard component *E* leaves curve *F* with a range of 300 mg/cm^2. It was found that curve *F* could be fitted to curve *C* beyond about 30 mg/cm^2 by multiplying its abscissa by 1.3 and its ordinate by a suitable factor, giving curve *G*. Thus we take the range of the La^{138} particles to be $1.3\times300=390$ mg/cm^2, corresponding to a maximum energy of 1.0 ± 0.2 Mev. The extrapolated intensity for zero absorber is 19 counts/min. From the estimated counting yield of about 53 percent, the specific beta-activity is 0.07 particle per second per gram lanthanum. Their intensity relative to the γ-rays is too high for conversion electrons without isomerism, which is never observed in even-even nuclides. Their intensity relative to the x-rays is probably too high for positrons, and it would be difficult to reconcile the observed gamma-spectrum[4,7] with annihilation radiation of the requisite intensity. Thus, we believe they are negative beta-particles. The excess radiations below 30 mg/cm^2 are probably compounded of *L* x-rays, *K* Auger electrons, and background enhancement,[1] although a weak soft beta-component may also be present.

Assuming a fluorescence yield of 86 percent for barium[8] and neglecting *L*-capture, we calculate an electron-capture partial half-life of 7×10^{10} years and a negatron partial half-life of 1.2×10^{12} years. The net half-life is essentially the same as for electron capture. The $\log ft$ for the β^- transition is 21.3, which seems consistent with a fourth-forbidden transition from ${}_{57}La_{81}{}^{138}$ in a $g_{7/2}-d_{3/2}$ configuration with spin 5 and even parity.

† This work has been supported by the AEC. A detailed description of it and that on neodymium (reference 1) is contained in an unpublished AEC Report NYO-3228. Tl^{204} was obtained from the Isotopes Division of the AEC.

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Ionization Loss at Relativistic Velocities in Nuclear Emulsions*

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SINCE 1949, when nuclear emulsions sensitive to particles at minimum ionization became available, conflicting results have been reported on the variation in *I*, the rate of energy loss by ionization with velocity in the emulsion, as measured by grain density *g* at total energies $\gamma>4$ rest mass units.[1-8] Analysis of important high energy phenomena requires a knowledge of this variation; yet the very existence of a relativistic rise in *g* above its minimum value g_{min} has been controversial. Ionization theories predict a minimum rate of loss I_{min} at $\gamma\approx4$, and a rise in *I* with increasing energy to a limiting value determined by the polarization of the medium.[9-11] The saturation of *I* sets in at different energies in the various theories (e.g., $20<\gamma<100$ in iron), but Fermi's plateau value I_{pl} remains essentially unaltered in the multifrequency theories of Wick and of Halpern and Hall.

In calibrating a set of 400 micron Ilford G.5 emulsions exposed to the cosmic radiation at an altitude of 100,000 ft, we have found evidence for a relativistic rise in *I* and measured its magnitude in the following way. In plates from the same batch, exposed and developed[12] together, a preliminary value g_{min}' was first obtained. Then *g* was measured for two groups of tracks: (a) thin shower tracks ("*s* tracks" with $g<1.25\ g_{min}'$) emerging from nuclear explosions; each was $>2000\mu$ long, and contained 400 to 1400 grains; and (b) "*p* tracks," provisionally attributable to incident star-producing particles, i.e., thin upper-hemisphere tracks approximately collinear with the shower axis. These were required to have an associated shower multiplicity $n_s\geq5$, and a length $>500\mu$. (The *s* tracks were not restricted in multiplicity; they originated in stars with $n_s\geq1$.) Altogether, some 10^5 Ag grains were counted in this study.

Figure 1 shows our experimental frequency distribution in *g* for 43 *s* tracks and 48 *p* tracks. We shall show that the former group can be used for precise evaluation of g_{min}, and the latter for estimation of g_{pl}, the "plateau" grain density corresponding to I_{pl}. Since *g* is proportional to *I* at low grain densities,[2,12] the observed g_{pl} and g_{min} determine at once the ratio I_{pl}/I_{min} in AgBr.

The *s* tracks are known to be due predominantly to pions.[2,13] We have used their energy spectrum[13] and ionization theory[10] to calculate their expected distribution in ionization in the region