TABLE I. Energy values for columbium 95.

	35-day Cb^{95}	90-hour Cb^{95}
β-max.	0.146 ± 0.01 Mev	
γ	0.758 ± 0.02 Mev	0.216 ± 0.01 Mev (100% converted)
$\frac{\text{Conv. electrons}}{\text{Continuous beta-particles}}$	2.4×10^{-3}	1.4×10^{-2}

later a lead radiator. These data indicate the presence of one gamma-ray of energy 0.758 Mev, which is in good agreement with the energy value obtained from the conversion electron region in the beta-spectrum.

A summary of the results obtained in this investigation is shown in Table I.

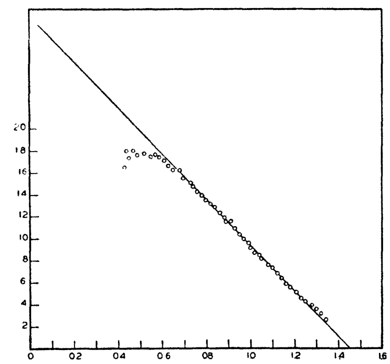

FIG. 2. Kurie plot of the beta-spectrum of Cb^{95}. (Kurie plot, $(N/FI^3)^{\frac{1}{2}}$ *vs.* energy E, where N is net counting rate, F is the Fermi function, and I is the coil current in amperes.)

This document is based on work performed under Contract No. W-7405 eng. 26 for the Atomic Energy Commission at the Oak Ridge National Laboratory.

[1] V. A. Nedzel, PPR Vol. 9B, 7.15.7 (1947). (The Plutonium Project Report (PPR) contains a complete report of Project information, Vol. 9B being entitled *Radiochemistry of the Fission Products*. This volume is in the process of being declassified and prepared for publication as part of the National Nuclear Energy Seiies under auspices of the United States Atomic Energy Commission.)

[2] J. S. Levinger, PPR Vol. 9B, 7.15.11 (1946).

[3] M. Deutsch, L. G. Elliott, and R. D. Evans, Rev. Sci. Inst. **15**, 178 (1944).

[4] E. P. Steinberg, PPR Vol. 9B, 7.15.10 (1946).

Observations on Large Cosmic-Ray Bursts at an Altitude of 3500 Meters*

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November 15, 1948

EXPERIMENTS on the frequency *versus* size of large bursts under great thicknesses of lead have been carried out at Climax, Colorado (altitude 3500 meters). The equipment used consisted of an ionization chamber (Carnegie Model "*C*" meter) filled to a pressure of 50 atmospheres of pure argon and surrounded by three different lead shields. These shields were (a) 10.7 cm Pb; (b) 26.7 cm Pb; (c) shield (b) plus a 30.5-cm lead slab covering a cone of approximately 45° semi-vertical angle with respect to the center of the ionization chamber. On a horizontal plane over the ionization chamber and the various lead shields was placed a number of Geiger-Müller counters which were connected to four different coincidence circuits. The Geiger-Müller counters were arranged relative to one another so that they would record large atmospheric showers of various spreads over the ionization chamber shield.

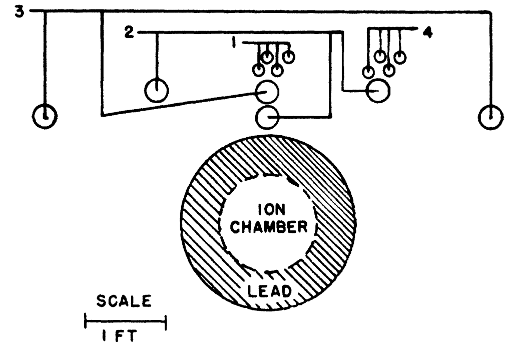

FIG. 1. A schematic drawing of the ionization chamber, 10.7-cm Pb shield and Geiger-Müller counters which are connected to four different coincidence circuits as shown.

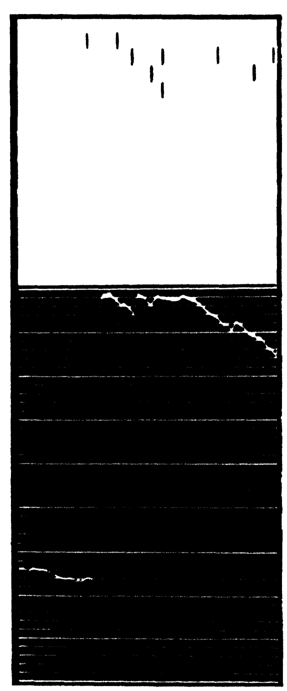

FIG. 2. Record of a burst which is equivalent to 3300 singly charged particles at minimum ionization passing through the ion chamber. The records of the recording lights of the coincidence circuits are above the electrometer trace. It can be seen clearly that this burst does not occur simultaneously with any of the four coincidences registering atmospheric showers.

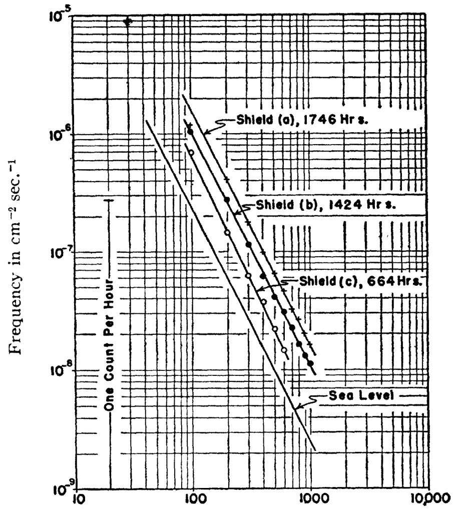

FIG. 3. Frequency *versus* size curves for large cosmic-ray bursts under several lead shields at an altitude of 3500 meters. The number of hours data obtained with each shield is shown in the figure. The sea level curve was obtained with a 10.7-cm Pb shield.

A schematic drawing of the ionization chamber, the 10.7-cm Pb shield, and the Geiger-Müller counters is shown in Fig. 1. This arrangement corresponding to the 10.7-cm Pb shield is similar to that used by Lapp[1] at sea level. Both the electrometer trace from the ionization chamber, which registers the cosmic-ray intensity and the bursts, and the recording lights of the coincidence circuits were recorded on the same 5-inch wide photographic paper as shown in Fig. 2.

By means of this arrangement, it was found that, within experimental error, less than 5 percent of the bursts were caused by air showers even with shield (a). It is very difficult to see any mechanism by which an atmospheric shower of very high energy could produce more than 100 particles below 10.7-cm Pb without tripping the shower recording arrangement. If we should assume that these bursts are produced by μ-mesons of energies greater than 10^{10} ev,[2,3] then we would expect that the burst producing radiation would exhibit no detectable absorption in lead and, also, that there would be very little, if any, absorption in the atmosphere from Climax to sea level. The experimental data in Fig. 3 shows that this is not the case, however. For burst sizes of more than 300 particles, corresponding to an energy of 4.5×10^{10} ev of the burst producing radiation,[3] there is clearly a decrease in frequency by a factor of approximately 6.7 on going from Climax to sea level. This fact demonstrates that these large bursts at high altitude are not produced by μ-mesons. The burst producing radiation is absorbed by a factor of 1.52 on increasing the lead shield from 10.7-cm to 26.7-cm Pb. This figure corresponds to a mean free path of 434 g/cm^2 in lead, assuming that the burst producing radiation is absorbed exponentially. This value is considerably larger than the mean free path of a high energy nucleon which is absorbed according to a cross section equal to the geometrical cross section of a lead nucleus which can be estimated to correspond to a mean free path of about 160 g/cm^2 in lead.

Some indication regarding the zenith angle dependence of the intensity per steradian of the burst producing radiation can be obtained from the data with shield (c). This shield is not hemispherically symmetrical and, therefore, the absorption in it, expected according to the above measured mean free path of 434 g/cm^2 in lead, is a function of the zenith angle dependence of the particles initiating the bursts. At 300 particles it can be seen from Fig. 2 that the burst frequency was changed by 1.83 on going from shield (b) to shield (c). Furthermore, this change in a spherical shield of 30.5-cm Pb, according to the mean free path of 434 g/cm^2, should be 2.22. This means that only 0.83 of the burst producing radiation encountered the flat absorber of shield (c). In order to make this so, it is necessary for the intensity per steradian of the radiation producing more than 300 particles to vary as between $\cos^5\theta$ and $\cos^6\theta$. This strong zenith angle dependence is further evidence for the fact that the burst producing radiation exhibits a strong absorption in the earth's atmosphere.

We wish to express our thanks to Dr. M. A. Tuve, Department of Terrestrial Magnetism, Carnegie Institution, for putting the Model "*C*" meter at our disposal.

* Assisted by the joint program of the Office of Naval Research and Atomic Energy Commission.

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[3] R. F. Christy and S. Kusaka, Phys. Rev. **59**, 414 (1941).

Erratum: Nuclear Spins and Quadrupole Moments of B^{10} and B^{11}

[Phys. Rev. **74**, 1191 (1948)]

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November 10, 1948

IN the above letter the nuclear quadrupole couplings of B^{10} and B^{11} in borine carbonyl were erroneously listed with negative signs. These constants are both positive.

Rock Magnetism as a Clue to Earth's Magnetic History

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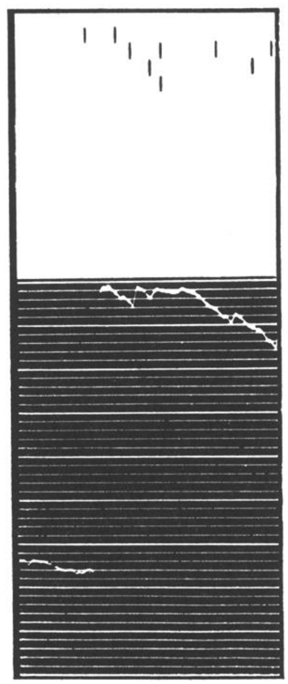
November 15, 1948

DURING June, July, and August this past summer, an expedition to the western United States made measurements of the magnetization of rocks in several localities.



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