Table I. Branching ratios r for incident pion kinetic energies E.

E (Mev)	810[a]	905	960[b]	960[c]	1020[d]	1100[e]
r	2.5 ± 0.4	1.70 ± 0.17	1.25 ± 0.16	1.56 ± 0.19	2.0 ± 0.5	1.67 ± 0.13

[a]L. Baggett, Lawrence Radiation Laboratory Report UCRL-8302, 1958 (unpublished); L. Baggett and B. McCormack, 1958 Annual International Conference on High-Energy Physics at CERN, edited by B. Ferretti (CERN Scientific Information Service, Geneva, 1958), p. 68.
[b]V. Alles-Borelli, S. Bergia, E. P. Ferreira, and P. Waloschek, Nuovo cimento 14, 211 (1959).
[c]E. Pickup, F. Ayer, and E. O. Salant, Phys. Rev. Letters 5, 161 (1960).
[d]I. Derado and N. Schmitz, Phys. Rev. 118, 309 (1960).
[e]E. Pickup, D. K. Robinson, and E. O. Salant (to be published).

in emulsions indicated $r = 0.7 \pm 0.3$. However, the uncertainties involved may not rule out consistency with the bubble-chamber value.

The Carruthers-Bethe model for the reactions (1) and (2), considering the amplitudes a_0, a_1, a_2 of final pion-pion isospin states $t = 0, 1, 2$, predicts that

$$|a_1|^2/|a_0|^2 = (r - \tfrac{1}{2})^{-1},$$

if the $T = 3/2$ state is excluded (so that $a_2 = 0$). By inserting the low emulsion value of r at 900 Mev, a sharp maximum in $|a_1|^2/|a_0|^2$ at that energy was obtained, indicative of a resonant $t = 1$ state. Clearly the new measurement of r at 900 Mev contradicts this conclusion. However, it does not necessarily follow that some other model would not give a dominant $t = 1$ state, even with the branching ratios observed.

We take pleasure in acknowledging our indebtedness to Dr. F. R. Eisler, Dr. N. I. Samios, and Dr. M. Schwartz for preparation of the pion beam, to the BNL Bubble Chamber Group, to the Cosmotron crew, and particularly to our scanners for their unstinting work.

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†On leave of absence from the Florida State University, Tallahassee, Florida.

‡On leave of absence from the National Research Council, Ottawa, Ontario, Canada.

[1]P. Carruthers and H. A. Bethe, Phys. Rev. Letters 4, 536 (1960).

[2]This value is not corrected for scanning losses at small angles.

[3]W. D. Walker, F. Hushfar, and W. D. Shephard, Phys. Rev. 104, 526 (1956).

ELECTRONS IN THE PRIMARY COSMIC RADIATION*

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The question of the presence of electrons in the primary cosmic radiation has frequently been discussed in the literature.[1] Attempts to identify such a component have so far been negative. Critchfield, Ney, and Oleksa[2] quote an upper limit of 0.076 (min cm^2 sr)$^{-1}$ for electrons with energies exceeding 1 Bev. In this note we report an experiment which forces us to conclude that there exists a flux of primary electrons which enters the top of the atmosphere.

Three balloon flights were carried out in August and September, 1960 from Fort Churchill, Manitoba which has a calculated geomagnetic cutoff rigidity for vertically incident particles of about 100 Mv (Quenby and Webber[3]). Data were obtained in each flight during the ascent and for approximately 10 hours under 3 to 5 g/cm^2 of residual atmosphere. A cross section through

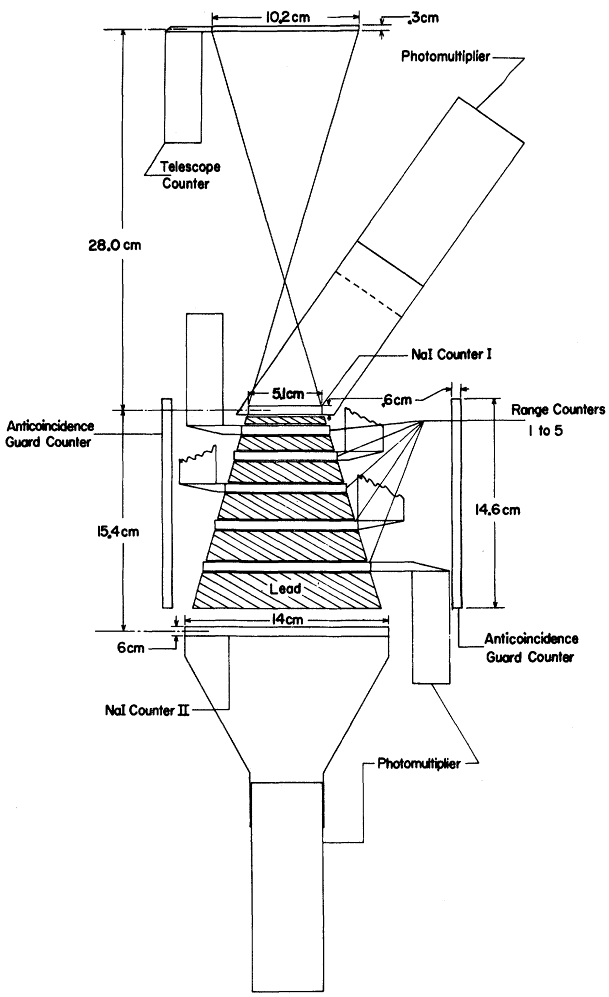

FIG. 1. Cross section of the detector system.

the detector is shown in Fig. 1. The telescope counter and the top NaI counter define the solid angle of acceptance for vertically incident particles. Their range in lead is measured by determining the number of range counters that were triggered in sequence by at least one ionizing particle. The pulse heights from the NaI counters I and II are measured and give the energy loss of particles prior to entering the lead absorber and the energy loss of those particles able to penetrate the entire absorber thickness. This method discriminates against all upward moving charged particles except for those that have minimum energy loss in both NaI counters. The detector system is surrounded on four sides by plastic scintillation counters in anticoincidence.

Protons which come to rest in the lead through ionization are readily identified by their range and the corresponding energy loss in Counter I.

In addition to these protons (and α particles) many events are observed which have minimum ionization loss in Counter I but end within the stack of lead absorbers. These events cannot be attributed to protons losing their energy by ionization only, since they would penetrate to counter II, but may be due to (a) high-energy protons making a nuclear collision, (b) mesons, or (c) electrons entering the detector and producing a soft shower in the lead plates.

The altitude dependence of those events is shown in Fig. 2. Near the transition maximum the intensity follows the altitude dependence for secondary electrons (dashed line), while at high altitude it begins to level off or even increase. The dashed line gives the approximate altitude dependence of the secondary electron intensity in air originating from π decay and was arrived at by assuming that the number of π mesons created at any depth in the upper atmosphere is proportional to the flux of high-energy protons present at this depth. It is normalized to the observed intensity at the transition maximum. Obviously, the observed altitude dependence cannot be explained on the basis of secondary electrons.

In Fig. 3 we plot the observed differential range spectrum of the events under discussion at 3 to 4 g/cm^2 atmospheric depth. The dashed line gives

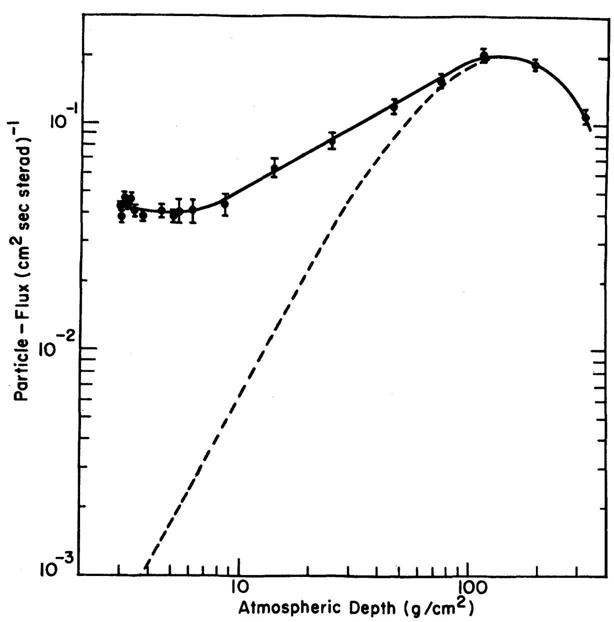

FIG. 2. Intensity versus atmospheric depth. ——— Mimimum-ionizing particles with range between 0 and 120 g/cm^2 of lead (error limits shown are standard deviations). - - - Secondary electrons (computed).

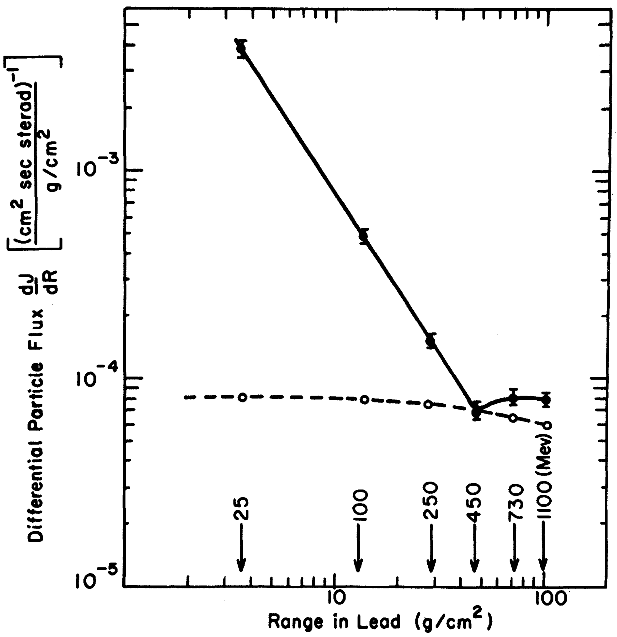

FIG. 3. ——— Differential range spectrum of minimum-ionizing particles in lead under 3 to 4 g/cm^2 of air (error limits are standard deviations). - - - Possible contribution by protons and mesons.

the range spectrum that could be caused by protons and pions under assumptions (a) and (b). A comparison of the curves shows that these particles cannot alone produce the observed range spectrum. Therefore, a substantial fraction of these events is attributed to primary electrons.

We then estimate the energy and flux of the electrons which appear to enter the top of the atmosphere. In particular, we wish to find out whether a portion of the electrons has energies exceeding the geomagnetic cutoff at Fort Churchill for vertical incidence and must, therefore, be of interplanetary or galactic origin. Particles below the geomagnetic cutoff may originate as secondaries from the southern hemisphere. The electrons which enter the lead absorber will in general produce soft showers. We shall have to relate the "range" of the shower to the energy of the incident electron. Greisen and Thom[4] have, for several electron energies, determined the average range in lead at which all ionizing tracks of a shower have disappeared. From their data and Monte Carlo calculations of Wilson[5] we have derived the energy scale in Fig. 3.

We see that primary electrons above the calculated geomagnetic cutoff of 100 Mv are present. All data presented are from a flight on September 8, 1960, at a time of normal solar activity. Measurements on other days lead to the same conclusions.

We here restrict ourselves to deducing a lower and upper limit for the primary electron flux. The lower limit must be derived by subtracting the largest possible contribution of secondary electrons, stopping protons, and mesons. This contribution was obtained by making the extreme assumption that in the range interval with lowest intensity, all the events are due to protons and mesons. The dashed line in Fig. 3, which gives the calculated proton and meson spectrum, is normalized at that point. The difference between the two curves, therefore, represents a lower limit for the electron flux. The possible contribution of secondary electrons to this flux was obtained from Fig. 2 and also subtracted. For reasons not discussed here the effect of upward moving neutrons and γ rays is estimated to be less than 10% of the lower limits.

The upper limits for the electron flux are given by the observed values without subtraction of a possible contribution by protons, mesons, or secondary electrons. This leads to the limits for the vertically incident electron flux that are shown in Table I.

These are preliminary results and detailed calculations of the electron flux and energy spectrum, its time variations, and the implications to the problem of the origin and modulation of cosmic radiation will be published elsewhere.

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Table I. Flux of vertically incident electrons (cm^2 sec sr)$^{-1}$.

	$25 < E < 100$ (Mev)	$100 < E < 1300$ (Mev)	$E > 1300$ (Mev)
Lower limit	28×10^{-3}	3.5×10^{-3}	0
Upper limit	31×10^{-3}	11×10^{-3}	8×10^{-3}

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[1]See, e.g., V. L. Ginzburg, Progress in Elementary Particles and Cosmic Ray Physics (North Holland Publishing Company, Amsterdam, 1958), Vol. 4, p. 337.

[2]C. L. Critchfield, E. P. Ney, and S. Oleksa, Phys. Rev. 85, 461 (1952).

[3]J. J. Quenby and W. R. Webber, Phil. Mag. 4, 90 (1959).

[4]K. Greisen and H. Thom (unpublished). (We wish to thank these authors for making their results available to us prior to publication.)

[5]R. R. Wilson, Phys. Rev. 86, 261 (1952).

DIRECT Ξ DECAY AND MUONIUM-ANTIMUONIUM TRANSITIONS

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It now seems certain that the mass difference between $K_{(1)}^0$ and $K_{(2)}^0$ is quite small ($|\delta m| < 10^{-5}$ ev with 95% confidence[1]). Okun' and Pontecorvo[2] discuss a connection between δm and the existence of $\Delta S = 2$ weak interactions. They show how such an interaction, if as strong as the $\Delta S = 1$ weak interactions, might lead to a mass splitting of the order of electron volts. Indeed, if the $\Delta S = 2$ interaction were absent, a mass difference between the neutral K mesons arises only at second order in the weak interaction and the theoretical estimate, $\delta m^{(2)} \approx 10^{-5}$ ev, agrees with experiment. But suppose L_w (the weak-interaction Lagrangian) includes a $\Delta S = 2$ term (which would permit direct decays of cascade hyperons, i.e., $\Xi^- \to n + \pi^-$, $\Xi^0 \to n + \pi^0$, and $\Xi^0 \to p + \pi^-$). The first order mass splitting, $\delta m^{(1)}$, is equal to twice the matrix element, $M = \langle K^0 | L_w | \bar{K}^0 \rangle$. Noting that $M = \langle \bar{K}^0 | L_w | K^0 \rangle = \langle K^0 | C^{-1} L_w C | \bar{K}^0 \rangle$, where C is the charge-conjugation operator,[3] we find that only the part of the $\Delta S = 2$ coupling which is even under C contributes to $\delta m^{(1)}$. Hence, a $\Delta S = 2$ weak interaction which is odd under C does not lead to a large $K_{(1)}^0$, $K_{(2)}^0$ mass splitting. The small measured value of δm implies nothing about the $\Delta S = 2$, C-odd interaction, but only requires that the $\Delta S = 2$, C-even interaction is no more than 10^{-5} as strong as $\Delta S = 1$ weak interactions.

Assume that a $\Delta S = 2$ interaction odd under C exists with similar strength as ordinary $\Delta S = 1$ weak interactions [the four-Fermion coupling, $G(\bar{\Lambda}\gamma_\lambda n)(\bar{\Lambda}\gamma_\lambda\gamma_5 n) + \text{H.c.}$, is one example[4]]. From CP invariance it follows that any such interaction is also odd under P. Consequently, the effective interaction responsible for direct decay of Ξ into a nucleon and a pion is invariant under space reflection for some assignment of relative Ξ, n parity. The absence of a large δm, although failing to forbid direct Ξ decay, implies that such modes (if they occur at all) cannot display asymmetries (i.e., they "conserve parity"). No direct decays of Ξ have yet been seen. However, existing experimental evidence that direct decay is absent is exceedingly slight.

An identical argument relates the appearance of muonium-antimuonium transitions to the possible existence of interactions permitting $e^- + e^- \to \mu^- + \mu^-$.[5-7] At first sight, looking for spontaneous transitions between muonium and antimuonium seems a more sensitive experiment than the direct search (utilizing, for example, the clashed electron beams soon to be available at Stanford University). But transitions between the 1S states of muonium and antimuonium are generated only by that part of the ($e^- + e^- \to \bar{\mu} + \bar{\mu}$ permitting) interaction which is even under C. To prove this, merely read for $\langle K^0|$ and $\langle \bar{K}^0|$ in the first paragraph, the 1S state of muonium and of antimuonium. The interaction $(\bar{\mu}\gamma_\lambda e)(\bar{\mu}\gamma_\lambda\gamma_5 e) + \text{H.c.}$, odd under C, could hardly be detected by looking for the muonium-antimuonium transitions it fails to induce. It could be found directly (by charge-exchange scattering of muons on electrons, or by $e^- + e^- \to \mu^- + \mu^-$), or possibly, by searching for nondegenerate transitions between states of muonium and antimuonium in the presence of external electromagnetic fields.

We wish to thank Professor M. Gell-Mann for