and Greisen[6] have verified that the mean life measured in Berkeley[7] has about the best value to fit the underground intensity curve.

We wish to remark that the hypotheses of Barnothy and Forro and of the writer are exactly equivalent in respect to the means of obtaining the proper form of the vertical intensity *vs.* depth relation, and to point out that the necessary parts of both hypotheses are the following: (1) An unstable particle of type A is produced high in the atmosphere with an energy spectrum $\sim E^{-1-\gamma}$, and decays into a particle of type B that is capable of penetrating to great depths; (2) essentially no particles of type A are capable of penetrating to great depths—or $I_A\epsilon_A \ll I_B\epsilon_B$, where I and ϵ represent respectively the intensity and the efficiency of detecting the components at large depths; (3) particles of type B lose energy at an approximately constant rate in traversing matter—mainly in small units instead of transferring large fractions of their energy in single interactions; and (4) $\gamma c\tau_0 = kL$, where γ is the Lorentz factor for particles of type B just capable of penetrating to the depth where the kink occurs, τ_0 is the mean life at rest of particles of type A, L is the distance (6.4×10^5 cm near the top of the atmosphere) in which the atmospheric pressure decreases by a factor ϵ, and k is a factor varying from about $\frac{1}{2}$ to 1.5 depending on the cross section for absorption of particles of type A by processes other than decay.

All conditions 1 to 4 are met by the pi-mu-meson explanation, provided that pi-mesons of high energy have cross sections for nuclear interaction greater than 1/1000 of the geometric cross section of the nucleons. The hypothesis of neutral penetrating particles can of course be made to account for conditions 1, 3, and 4 because we have practically no independent information about the energy loss of the neutral particles in the ground. However, it is also necessary in this case to explain the absence of mu-mesons at great depths; i.e., one must assume either that the meson spectrum is sharply cut off at high energies, or that a new process of energy loss sets in. The cut-off must be so complete that the mesons become less than 1/400 as abundant as is predicted by extrapolation of the known part of the meson energy spectrum with the assumption of no new absorption processes.

Further information on the origin of the penetrating particles is obtainable from the zenith angle dependence of the underground intensity, but here again the hypotheses of Barnothy and Forro and of the writer predict identical results, again with the necessary assumptions 1 to 4 listed above. In inclined directions, the unstable component A is produced at greater altitudes than in the vertical direction, so that the probability of decay is greater by a factor $\sec\theta$ (because of the reduced density of the air, in case A is subject to other strong absorption processes, or because of the longer path to sea level in case A is not a strongly interacting particle). Therefore, if the dependence on depth h goes as $h^{-\gamma}$ above the kink and $h^{-(\gamma+1)}$ below the kink in the curve, the zenith dependence underground should go as $(\cos\theta)^\gamma$ both above *and* below the kink.* This is in agreement with the experimental results of Barnothy and Forro.[3] If they are indeed correct, they constitute clear proof not that the hypothesis of Barnothy and Forro or that of the writer is correct, but that the conditions 1 to 4 listed above are met by the penetrating particles and their parents.

Direct information about the ionizing or neutral nature of the rays found underground, and about the penetrating character or local origin of the charged rays observed, can be obtained in principle from accurate absorption curves. The data available at this date are however somewhat confusing. Barnothy and Forro have presented evidence that most of the rays are neutral. Miesowicz, Jurkiewicz, and Massalski,[8] however, have apparently shown that the neutral rays are simply low energy gamma-rays of local radioactive origin. The absorption curves that have been measured of the ionizing component underground[3, 9–11] contain large statistical errors, irregularities that have required artificial explanations, and disagreements with each other. If the charged particles are those that have traversed all the earth above the counters, a meter of lead should only succeed in stopping 6 percent of the particles at 300 m.w.e., $2\frac{1}{2}$ percent at 1000 m.w.e., and one percent at 3000 m.w.e. The absorption measured by Wilson[9] at 300 m.w.e. is small enough (though the statistical errors are large); but the absorption measured by Nishina and Miyazaki[11] at 3000 m.w.e. is much too great; and the ups and downs of the curves of Barnothy and Forro at 1000 m.w.e., if not due to statistical and unknown systematic errors, are also too great.

It seems impossible, therefore, to draw a specific and reliable conclusion about the nature and origin of the rays underground from the data now available.

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* Of course, for particles of type A with low energy, the probability of decay is practically 1 regardless of the zenith direction. The factor $\sec\theta$ applies only to high energy particles that have small probabilities of decaying.
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Radiation from Zn^{65}

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SOME preliminary measurements have been made in this laboratory on the energies of the beta- and gamma-radiations from Zn^{65}, using a beta-ray spectrometer of the thin lens type. The spectrometer has been equipped with a spiral baffle placed in the center of the spectrometer tube. A proper choice of the focusing magnet's current direction thus makes possible the selection for analysis of either positrons or negatrons. The source was in the form of a small square of zinc metal of surface density 25 milligrams/cm², irradiated with slow neutrons in the pile at Chalk River, Ontario. The total activity was one millicurie. Positron, negatron, and gamma-ray spectra were run. In the latter case, measurements were made of the energies of photoelectrons expelled from a uranium radiator of density 50 milligrams/cm². The resolution of the instrument is of the order of 3.5 percent in momentum. The energy calibration used both the F line of thorium B and the annihilation radiation of Zn^{65}. The estimated error on the basis of this calibration is thought to be about 0.5 percent in momentum. No corrections have been made for the finite thickness of the source or radiator, the importance of which has been discussed recently by Jensen, Laslett, and Pratt[1] and by Hornyak, Lauritsen, and Rasmussen.[2]

The results are shown in the accompanying figures. In all cases, the "normal" background, measured with the source in position in the spectrometer, and zero current in the focusing coils, averaged about 20 counts per minute, and this has been subtracted before plotting. Figure 1, (a) and (b), shows the positron distribution obtained and the calculated Fermi plot. Extrapolation of the latter leads to an end point of 0.325 ± 0.002 Mev which is in good agrement with the spectrometer measurements of Peacock.[3] Only one recognizable positron group is evident, although the effects of source thickness and scattering in the spectrometer would make difficult the detection of weak positron groups below say 0.15 Mev. Figure 2 shows the result obtained with the magnet

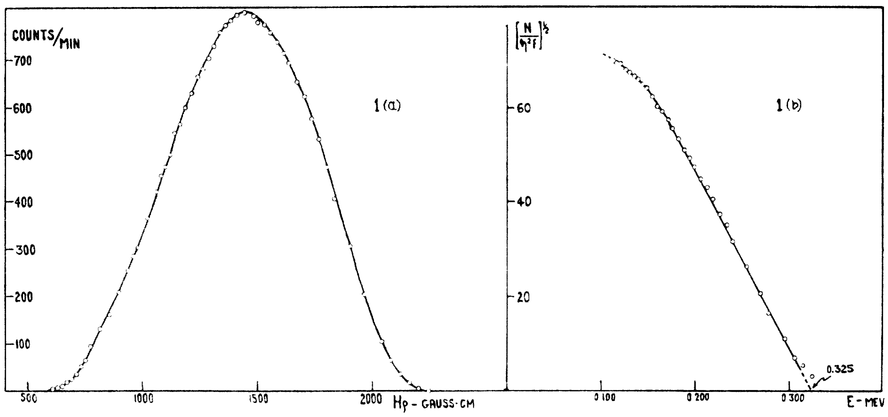

FIG. 1. (a) Positron spectrum and (b) Fermi plot of positrons from Zn^{65}.

current adjusted to transmit only negatrons. The strong conversion line corresponds to a 1.120±0.005-Mev transition. The continuous background can be attributed to Compton recoil electrons generated in the thick source. A Fermi plot failed to reveal any negatron group. It is therefore probable that orbital electron capture and positron emission are the only modes of decay of Zn^{65}. By extrapolating the continuous distribution to intercept the momentum axis, we obtain for the maximum energy of the Compton recoils the value of 0.92^8 Mev from which the energy of the responsible gamma-ray may be calculated to be 1.14±0.02 Mev. Therefore, we may assume with reasonable assurance that the transition giving rise to the conversion line also ejects the gamma-ray responsible for the Compton distribution.

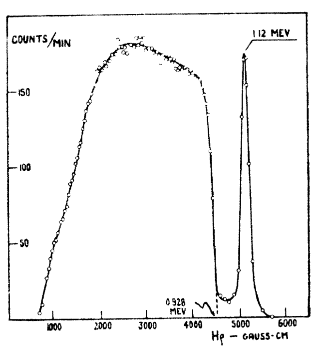

FIG. 2. Negatron spectrum of Zn^{65}.

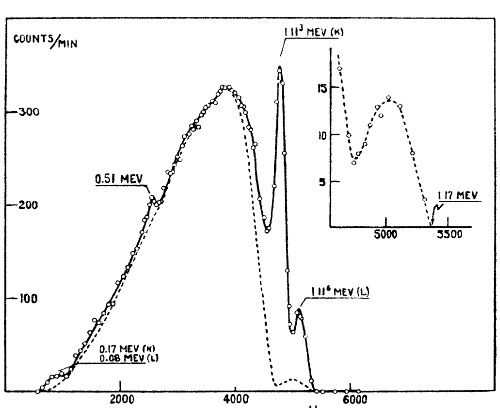

FIG. 3. Gamma-ray spectrum of Zn^{65}.

Figure 3 shows the gamma-ray spectrum taken with the uranium radiator. The solid curve is a composite curve of photo-electrons and Compton electrons combined. The broken curve is the Compton background alone, taken with the radiator removed. The measured energies of the photo-electrons plus the shell-binding energies of uranium (0.114 Mev and 0.020 Mev for K and L shells, respectively) lead to energies of 1.11^4±0.005 Mev (a weighted average of 1.11^3 Mev for K shell and 1.11^6 Mev for L shell), 0.510±0.003 Mev which can be identified as annihilation radiation, and a somewhat weak peak at about 0.17±0.02 Mev or 0.08±0.02 Mev depending upon whether we assume their origin to be in the K or the L shell. The 1.11^4-Mev gamma-ray can be identified with the conversion electron line of 1.12 Mev and is in good agreement with the work of Jensen, Laslett, and Pratt whose revised value for this transition has been reported as 1.11^8 Mev.[4] It id definitely lower than the value 1.14 Mev proposed by Deutsch, Roberts, and Elliott,[5] although the values are probably consistent within the error limits. The lowest energy gamma-ray has not been reported previously, and it is certainly near the limit of detection.

Examination of the Compton background curve in Fig. 3 shows a distinct distribution at the high energy end. This has been plotted on an expanded scale in the inset. It would appear to be caused by a gamma-ray of too low an intensity to produce a detectable photo-electron line. The maximum energy of the Comptons is at 1.17 Mev. The gamma-ray then has an energy of 1.38±0.03 Mev.

Further experiments are proceeding to make reasonably certain that these gamma-rays of low intensity are really those of Zn^{65} since the possibility of minute amounts of radioactive impurities cannot yet be discounted. We hope to be able to make a more detailed report in the near future.

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Neutron-Proton Scattering

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IN order to account for the coherent scattering of slow neutrons by para- and orthohydrogen molecules, as well as the observed binding energy of the deuteron, assuming a square well interaction,