our latest half-lives and energies for the members of the previously reported[1] Pa^{227} and Pa^{228} collateral chains. The radioactive properties of ThC, RaE, AcC, Po^{213}, and daughters are the accepted values taken from the literature.[8]

The cooperation of Professor R. L. Thornton, Mr. J. T. Vale, and the 184-inch cyclotron group is gratefully acknowledged. This paper is based on work performed under the auspices of the Atomic Energy Commission.

[1] A. Ghiorso, W. W. Meinke, and G. T. Seaborg, Phys. Rev. **74**, 695 (1948).
[2] See Ghiorso, Jaffey, Fobinson, and Weissbourd, "An alpha pulse analyzer apparatus," Plutonium Project Record **14B**, 17.3 (1948), to be issued.
[3] English, Cranshaw, Demers, Harvey, Hincks, Jelley, and May, Phys. Rev. **72**, 253 (1947).
[4] Hagemann, Katzin, Studier, Ghiorso, and Seaborg, Phys. Rev. **72**, 252 (1947).
[5] G. T. Seaborg, Chem. Eng. News **26**, 1902 (1948).
[6] I. Perlman, A. Ghiorso, and G. T. Seaborg, Phys. Rev. **74**, 1730 (1948).
[7] I. Perlman, A. Ghiorso, and G. T. Seaborg, unpublished work.
[8] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. **20**, 585 (1948).

Correction and Addendum: Scattering of Particles by the Gas in a Synchrotron*

[Phys. Rev. **74**, 140 (1948)]

NELSON M. BLACHMAN AND ERNEST D. COURANT
Brookhaven National Laboratory, Upton, Long Island, New York

CORRECTION: The formula for P in the title of Fig. 1 should read like the right side of Eq. (18).

For the word "half" in the title of Table I, read "10 percent of."

For b in the second-last line of page 143, read B.

For $-A$ in Eq. (18) read 0.

For $\frac{1}{2}\pi$ at the end of the fourth-last paragraph of the article, read $1/2\pi$.

More accurate calculations show that for a 10 percent loss of particles, $\eta=0.0855$ rather than 0.089.

Addendum: This note considers the effect of an initial betatron oscillation on the probability of surviving scattering of a particle being accelerated in a synchrotron or betatron. Let β be the amplitude of this initial oscillation. With appropriate choice of $t=0$, this oscillation contributes to both sine and cosine oscillations the amplitude $\beta/2^{\frac{1}{2}}$. Thus, $(1/2)\beta^2$ should be added to the right sides of Eqs. (7) and (8), and $(1/2)\beta^2(T_i/T_f)^{\frac{1}{2}}$ to the right side of (10). The maximum value of $\eta=\langle b^2\rangle/2A^2$ now occurs when

$$T/T_1=4/(1+\beta^2/2A^2\eta_0)^2,$$

in which η_0 is the maximum value η would have if $\beta=0$; it is

$$\eta=(\eta_0+\beta^2/16A^2)^2/\eta_0$$
$$\approx\eta_0+\beta^2/8A^2$$

for small β/A.

For example, for 10 percent loss, $\eta_0=0.086$. If $\beta=2.5$ cm and $A=8$ cm, then $\eta=0.0982$. The higher loss can be read from Fig. 1—14.5 percent—or compensated for by a reduction in pressure of $\beta^2/8A^2\eta_0=14$ percent.

This calculation underestimates the loss by tacitly assuming not that the initial amplitude is β, but that the initial amplitudes obey a Rayleigh distribution with β the r.m.s. initial amplitude. It overstimates the loss by including that (small) loss which would have occurred while the amplitude of betatron oscillation was building up to initial value.

Another approach eliminates both of these errors but is unable to take account of the damping of the initial oscillation, thus overestimating the loss. This is to use the solution of (17) satisfying the boundary condition

$$p(0,B)=\delta(B-\beta)\text{ for }0\le B\le A$$

rather than $\delta(B)$. This solution is

$$p=(2B/A^2)\sum_{s=1}^{\infty}J_0(\lambda_s\beta/A)[J_1(\lambda_s)]^{-2}\times J_0(\lambda_sB/A)\exp(-\lambda_s^2\xi/A^2),$$

whence

$$P(\xi)=\int_0^A pdB=2\sum_{s=1}^{\infty}J_0(\lambda_s\beta/A)\exp(-\lambda_s^2\xi/A^2)/\lambda_sJ_1(\lambda_s),$$

with $\xi=(1/2)\langle b^2\rangle$.

For $\eta=\xi/A^2=0.086$, $\beta/A=0.3125$, as before, this gives $P=18.9$ percent. For $\eta_0\ge0.3$, only one term of this series is significant, and it is seen that the number of protons surviving with $\beta=\beta$ is $J_0(\lambda_1\beta/A)$ times the number with $\beta=0$ ($\lambda_1=2.4048$, the first root of J_0); for $B/A=0.3125$ this ratio is 86.4 percent.

* Work done under the auspices of the Atomic Energy Commission.

The Beta-Ray Spectra of Cu^{64}

C. S. WU AND R. D. ALBERT
Columbia University, New York, New York

December 6, 1948

RADIOACTIVE Cu decays either by positron- or negatron-emission to Ni or Zn with a half-life of 12.8 hours. In 1945 Backus[1] reported disagreement between the observed ratio of the number of positrons to the number of

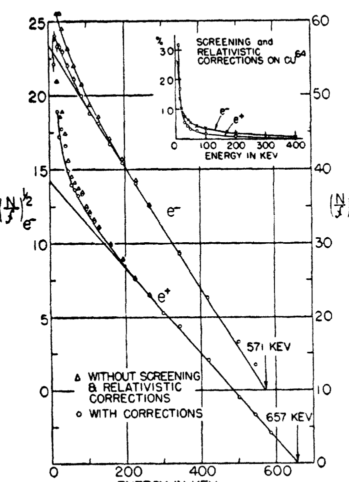

FIG. 1. Fermi plots of Cu^{64} negatron and positron spectra.

electrons in the region below 50 kev as compared to that predicted by the Fermi theory of beta-disintegration. Recently, Cook and Langer[2] investigated both the positron and negatron spectra from Cu^{64} over the entire energy region and found that both negatrons and positrons at low energies are too numerous to be accounted for by theory. Since the technical difficulties involved in the study of the beta-ray spectrum at very low energy are considerable, it is desirable to know how far the remaining discrepancies between experiment and theory at low energy can be reduced by improving experimental technique and employing a more rigorous Coulomb correction factor in interpreting the data.

The Columbia University solenoid β-ray spectrometer[3,4] was used in this investigation. In order to distinguish between electrons and positrons, a simple modified baffle system has been used and is found to transmit particles of one sign only, introducing no detectable scattering. The axis of the spectrometer is at least six feet away from any walls and is orientated along the earth's magnetic meridian. The vertical component of the earth's magnetic field is compensated by means of a pair of Thomson coils.

The radioactive Cu^{64} was prepared by intense deuteron bombardment of copper in the Columbia cyclotron. In carrying out the chemical purification and preparation, precautions for yielding high specific activity were particularly stressed. In the first few preliminary runs, the source was prepared by direct deposition of a drop of $CuSO_4$ solution on a collodion film. The deposit tends to crystallize at the edge of the drop and, therefore, forms a non-uniform source.

A more uniform source can be obtained by adding a trace of detergent to the $CuSO_4$ solution or from a colloidal suspension of $Cu(OH)_2$. The source backings used throughout this investigation were thin collodion film of about $4\mu g/cm^2$. The counter window consisted of 5 or 6 layers of collodion film of $3\text{–}4\mu g/cm^2$ each. Auxiliary experiments showed that this counter window should have negligible effects on the electron distribution above 20 kev.

Several runs with sources varying from $0.3\ mg/cm^2$ to $\sim 0.1\ mg/cm^2$ showed a gradual but consistent reduction of deviation *versus* the source thickness at low energy region. Therefore, the importance of preparing extremely thin and uniform sources can never be over emphasized. With the thinnest source ($\sim 0.1\ mg/cm^2$) prepared with the present facilities, the deviation was found to be much less than previously reported.

In comparing the experimental data with the Fermi theory, the Coulomb correction factor has been reexamined and modified. Longmire and Brown[5] recently calculated the screening effect due to atomic electrons and the relativistic effect (which has often been neglected for $Z<29$) for Cu^{64} electrons and positrons. These corrections are considerable for electrons of energies below 200 kev and for positrons of energies below 100 kev (Fig. 1). Applying these corrections, the observed electron distribution (Fig. 1) agrees with the theory from upper energy limit down to ~ 70 kev. At least part of the remaining discrepancy could very well be due to the finite thickness of the source. The deviation in the case of positron appears to start at a much higher energy ~ 200 kev (Fig. 1). If these deviations are due to the scattering of electrons or positrons into the low energy region, the effect would be much more pronounced in the case of positrons because there are so few positrons at low energies. This can better be illustrated by comparing the area under the momentum distribution curves (Fig. 2) where the difference between the experimental and theoretical distribution for both positrons and electrons is about 1-2 percent of the total emission, while the previous work[2] reported an excess of 9 percent for positrons and 6 percent for electrons.

In view of the large decrease in the deviation resulting from the use of thinner and more uniform sources and the use of a more rigorous Coulomb correction factor, it seems probable that the remaining small observed deviation is instrumental and the Cu^{64} spectra are actually of the allowed type.

We wish to thank Professors W. W. Havens, Jr., L. J. Rainwater, and J. R. Dunning for their constant interest and valuable discussions. This document is based on work performed under Contract AT-30-1-Gen 72 with the Atomic Energy Commission and Columbia University.

1 J. Backus, Phys. Rev. **68**, 59 (1945).
2 C. S. Cook and L. M. Langer, Phys. Rev. **73**, 601 (1948).
3 C. M. Witcher, Phys. Rev. **60**, 32 (1941).
4 C. S. Wu, W. W. Havens, Jr., R. Albert, and G. Grimm, Phys. Rev. **73**, 1259(A) (1948).
5 C. Longmire and H. Brown, in press.

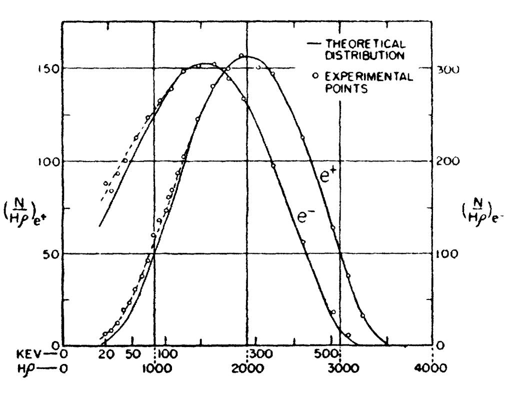

FIG. 2. Momentum spectra of Cu^{64} negatrons and positrons.

Additional Ferromagnetic Resonance Absorption Measuremets on Supermalloy

W. A. YAGER
Bell Telephone Laboratories, Murray Hill, New Jersey
November 24, 1948

THE results of a ferromagnetic resonance absorption experiment at 24,050 megacycles on a specimen of annealed Supermalloy were compared with theory[1] in a previous letter.[2] The λ in the relaxation term, $-\lambda[\mathbf{M}-\chi_0\mathbf{H}]$, was assumed constant in this analysis. It is now found that better agreement between theory and experiment is obtained by setting $\lambda \alpha H_z$. Furthermore,