Table I. Characteristics of several meteorites.

Name of Bethany meteorite	Class	Ni %	U in 10^{-8} g/g	Th in 10^{-8} g/g	He in 10^{-6} cc/g	Age in 10^6 years calculated from Individual measurements	Average activity
Goamus	Of	8	1	4	0.15	60	75
Amalia (Foote)	Of	8			0.2		110
Gröndorn	Of	8			0.2		110
Lion River	Of	8			0.2		110
Amalia (Krantz)	Of	8	1	4	3.0	1100	1500

predicted difference would be 0.90×10^{-6} cc/g. The observed difference should not be greater than the predicted difference, though it may be less if the two points do not lie along a radial line.

If these two observations, (1) the difference in the helium content of different fragments and (2) the difference from point to point within the same fragment, are accepted as indicating that cosmic radiation has produced the helium in Bethany, then two important conclusions follow: 1. The time since the solidification of the metallic core of the parent planet, and also the time since the disruption of the parent planet, are both less than 60 million years. This upper limit can be established because the U and Th contents of Bethany Goamus are sufficient to produce all of its helium in only 60 million years. 2. The rate of production of helium in meteorites by cosmic radiation is more than 70 times the rate predicted from the values of the observational quantities used in my previous paper.[1] This is true because cosmic radiation has to produce the helium in 60 million years rather than in 4 billion years. This high rate of production of helium in meteorites, as compared to the calculated rate just outside the earth's atmosphere, may arise from the effect of the sun's general magnetic field, as suggested previously,[1] or from secondary helium-producing processes that have not been considered.

[1] C. A. Bauer, Phys. Rev. **72**, 354 (1947).
[2] F. A. Paneth, Nature **149**, 235 (1942).
[3] C. A. Bauer, Phys. Rev. **74**, 225 (1948).
[4] F. A. Paneth, Roy. Astr. Soc., Occasional Notes, No. 5, 57 (1939).

Shape of the Positron Spectrum of N^{13}

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In a recent letter,[1] we reported the results of an investigation of the shape of the positron spectrum of Cu^{61} (3.3 h). It was shown that the momentum distribution deviated markedly at low energies from that predicted by the Fermi theory for an allowed transition. In comparison with our earlier work on Cu^{64} (12.8 h),[2] it was noted that the deviation from the theoretical straight line Fermi plot began at an energy $W=2.0$ mc^2 for Cu^{61}, whereas the Cu^{64} plot was a straight line down to $W=1.53$ mc^2. The comparison between the Cu^{64} and Cu^{61} spectra is of interest because it involves two allowed transitions in isotopes having the same nuclear charge, Z, but different maximum energies, i.e., $W_0=3.36$ mc^2 for Cu^{61} and 2.29 mc^2 for Cu^{64}.

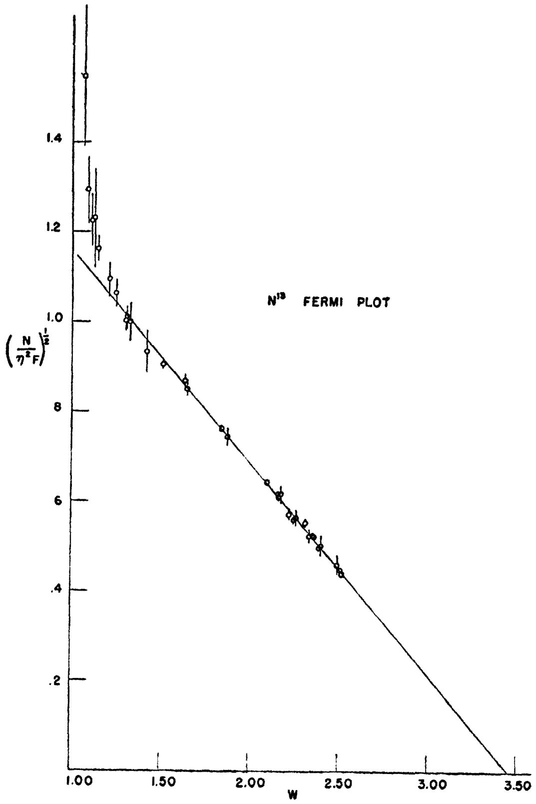

Fig. 1. Fermi plot of the positron momentum spectrum of N^{13}.

Our interest in the spectrum of N^{13} stems mainly from the fact that it is the result of an allowed transition with an energy release almost exactly the same as that in Cu^{61}, but in an isotope of much lower Z. The results of Siegbahn and Slätis[3] indicate that the N^{13} spectrum begins to deviate from theory at about the same energy as our data for Cu^{61} (i.e., 2.0 mc^2). However, since their data were obtained with a relatively thick source, it was thought desirable to investigate the N^{13} distribution under more ideal conditions.

In the present experiment, the N^{13} was produced by $C^{12}(d,n)$ in the cyclotron. The sample was activated in such a form that it could be transferred directly to the spectrometer without further preparation. The source consisted of a uniform layer of 0.6-mg/cm^2 colloidal graphite (Aquadag) on a 0.18-mg/cm^2 aluminum backing. For bombardment, the sample, mounted on a skeleton aluminum ring support, was clamped against the water-cooled target plate of the cyclotron. An aluminum mask served to confine the 12-Mev deuteron bombardment to the region of the graphite desired for the spectrometer source, i.e., 0.4 cm wide by 2.5 cm long. Individual bombardments were for twenty minutes with a target current of from 100 to 130 microamperes of deuterons. The source, prepared in this way, was then transferred to the 40-cm radius of curvature, shaped field magnetic spectrometer,[4] and readings were begun within six minutes. No trouble was encountered from other activities present, since they are all negatron emitters and since, because of the large size of the spectrometer and the absence of scattering, the background of the G-M detector was not increased by the presence of the source. The Zapon window counter transmits electrons down to 2.0 kev. The detecting slit width was 0.4 cm.

A decay curve of the positron activity taken over five half-lives in the spectrometer at an $H\rho = 2487$ gauss-cm shows a simple decay with a half-life of 10.2 ± 0.1 minutes. All parts of the spectrum were found to decay with a period consistent with this value.

In taking the data, counts were recorded at each field setting for three successive two-minute intervals. For each bombardment, a few points were taken in the lower energy region, and several points were taken at the high energy region of the spectrum. The individual runs were corrected for decay, and then all the runs were adjusted to the same intensity level at one energy, $W = 2.1$ mc^2.

Figure 1 shows the Fermi plot of the momentum distribution. It is seen that the experimental data are fitted by a theoretical straight line down to about $W = 1.3$ mc^2. This energy, at which the deviation from the Fermi theory begins, is much lower than the value indicated by the data of Siegbahn and Slätis and is indeed lower than that found by us for either Cu^{61} or Cu^{64}.

In the light of these measurements, it would appear that the deviation from theory depends on *both* the nuclear charge, Z, and the maximum energy, W_0, and may therefore be explainable in terms of Coulomb effects on the positron.

Our end point for N^{13}, determined from the straight-line extrapolation, is $E_0 = 1.25 \pm 0.03$ Mev, in good agreement with the value given by Siegbahn and Slätis.

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[1] C. S. Cook and L. M. Langer, Phys. Rev. **74**, 227 (1948).

[2] C. S. Cook and L. M. Langer, Phys. Rev. **73**, 601 (1948).

[3] K. Siegbahn and H. Slätis, Arkiv. f. Mat., Astr. o. Fys. **32A**, No. 9 (1945).

[4] L. M. Langer and C. S. Cook, Rev. Sci. Inst. **19**, 257 (1948).

A Process Aiding the Capture of Electrons Injected Into a Betatron

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EARLY experience with the operation of a betatron showed that electrons could be trapped by the magnet although they were injected at energies far above that allowed by the early theory.[1] At these high injection energies the electrons should strike the electrode structure from which they came after completing a few revolutions around the magnet. A particle oscillating with amplitude a about the equilibrium orbit experiences a decrease of amplitude per revolution $da = adE/4E$ where E is the injection energy and dE is the energy gain per revolution. With the values taken from our 22-Mev betatron $a = 1$ cm, $E = 60{,}000$ volts, $dE = 90$ volts/turn; thus, $da = 0.0004$ cm per revolution. In several revolutions this damping is not sufficient to allow the electrons to pass the injector, which in practice can protrude several millimeters beyond the point of injection toward the equilibrium orbit. By tracing groups of electron paths around the machine R. A. Becker, N. Dimitriadis, L. Bess, and J. S. Blair of this physics department have shown that it is not possible to account for passage of the smallest injectors we have used.

The effect I wish to describe depends upon the electromagnetic energy associated with the electron beam circulating between the poles of the betatron. This electromagnetic energy is withdrawn from the kinetic energy of the beam after it leaves the injector. This causes the radius of the orbit to shrink. Since the energy in the electromagnetic field is proportional to the square of the circulating orbit current, the loss of energy per electron will be proportional to the circulating current.

The magnitude of the shrinkage in our 22-Mev betatron can be calculated from the fact that a wire placed at the position of the orbit has about 4×10^{-6} henries inductance mainly as a result of the large central flux. The injection current from the gun is 1 ampere. The voltage per turn is LdI/dt, neglecting retardation, and if one ampere circulating was established in the time for one revolution, 10^{-8} second, the loss per turn would be $4 \times 10^{-6} \pm 10^{+8} = 400$ electron volts. If several revolutions are required to establish this circulating current, the energy lost by the electrons is still 400 electron volts. The electrostatic energy associated with an ampere of circulating current is about 150 electron volts, making the total loss 550 electron volts.

The shift in the orbit radius, r, produced by this loss is $dr = rdE/(1-n)2E = 4$ mm with $r = 20$ cm, $E = 60{,}000$ volts, $dE = 550$ volts, and $n = \frac{3}{4}$. We know that we retain only 0.1 ampere in the beam,[2] but it is very likely that electrons destined to strike the wall or the injector rotate a few times about the magnet and build the current up to one ampere for a while.

The resistance of the tube coating and the time for penetration of magnetic flux into iron should influence the time dependence of this orbit contraction.

Injection from a gun placed at a radius smaller than the orbital radius works well. This also may be aided by the same effect. In this case electrons injected at about the time the circulating current has reached its maximum will increase in energy and orbital radius as the main part of the circulating current is lost by striking the injector.

Since this action described depends on the current circulating in the beam, it might be expected that the yield of x-rays from a betatron would increase more rapidly than the emission current from the injector. However, it is known that yield sometimes increases and sometimes decreases as the emission is decreased. The characteristics on the injector hinder a simple interpretation of an emission measurement.

It is frequently found that a so-called orbit contractor greatly assists the capture of electrons. It consists of one wire above and one wire below the orbit in which a rising current at injection time contracts the orbit.[3] This helpful action is very similar to the action of the beam on itself, and in cases where it is impossible to build up a high circu-