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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A Process Aiding the Capture of Electrons Injected Into a Betatron

D. W. Kerst
Physics Department, University of Illinois, Urbana, Illinois

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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 circulating current in an accelerator the use of a contractor may prove to be valuable.

The magnetic and electrostatic fields of the beam also influence the focusing of electrons in the beam. Damping of oscillations about the equilibrium orbit results from decreasing electrostatic repulsion within the beam, as some of the circulating current is being lost to the walls. This damping is of the same order of magnitude as the orbit contraction in the example above.

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The Neutron Density in the Free Atmosphere up to 67,000 Feet*

LUKE C. L. YUAN
Princeton University, Princeton, New Jersey

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SINCE neutrons in cosmic rays cannot be considered as primary particles because of their short lifetime, a maximum in the intensity distribution of neutrons as a function of the altitude must exist. Considerable work[1–4] has been done in the past to determine the neutron distribution in the atmosphere, and the results obtained thus far show that at low altitudes the slow neutron intensity increases exponentially with the altitude up to about 20 cm of Hg, with an absorption depth, λ, of the order of 150 g/cm^2, where λ is given by the expression $N = N_0 \exp(-x/\lambda)$.

The following is a preliminary report on recent results obtained at high altitudes where a maximum in slow neutron intensity has been observed.

The measurements were carried out by sending aloft two identical BF_3 proportional counters to an altitude of 67,000 feet by means of free balloons. These counters were filled with enriched boron of 96 percent B^{10} to a pressure of 20 cm of Hg, and they were operated at a voltage plateau centered at 800 volts.

One counter was shielded with 0.030 inch of cadmium and the other counter was enclosed in a tin shield of the same thickness for the compensation of possible effects caused by stars produced in the cadmium shield. Both shields were sealed airtight and were maintained at atmospheric pressure throughout the flight, thus eliminating any possible effects caused by corona discharge at the high voltage terminals.

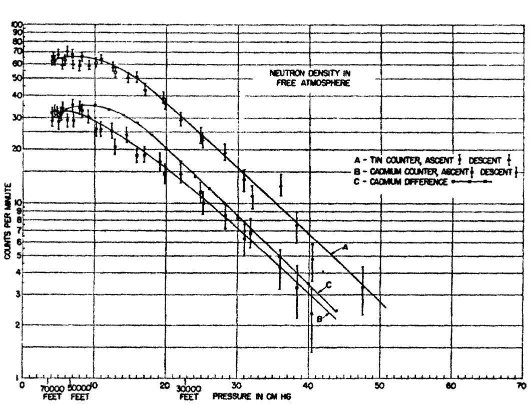

FIG. 1. Neutron density as a function of pressure in the free atmosphere.

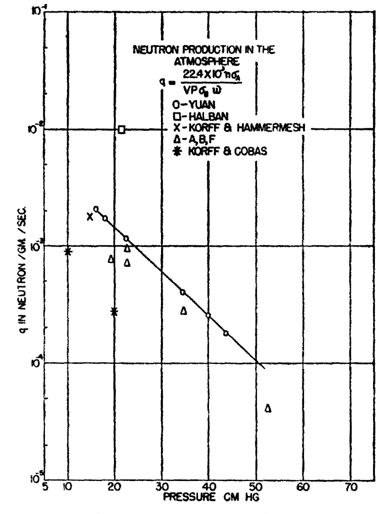

FIG. 2. Rate of neutron production in the atmosphere.

The measured neutron counts were radioed down by means of a frequency-modulated telemetering system.

A calibrated fixed signal of constant amplitude was switched on every 15 minutes for a period of 8 seconds. This served as a check on the constancy of the amplifier gain and the performance of the whole system.

The temperature and the pressure were measured by means of a thermal resistor and an aneroid barometer, respectively.

The measurements were recorded on a galvanometer-type oscillograph, as well as by a scaling circuit arrangement, whose readings were photographed automatically every minute.

The results of this flight are collected in Fig. 1. This shows the counting rate as a function of altitude. The upper curve (A) is for the tin-shielded counter and the lower one (B) for the cadmium-shielded counter. A maximum in the neutron intensity has been obtained for both counters at about 7 cm of Hg. The maximum intensity for slow neutrons, obtained by taking the cadmium difference ($E_n < 0.4$ ev), occurs at approximately 9 cm Hg (center curve, C).

Up to 18 cm of Hg the neutron intensity increases exponentially with the altitude, with an absorption depth of 156 g/cm^2, which is in agreement with our previous measurements at lower altitudes.

Our counter sensitivity was calibrated experimentally through the courtesy of the Argonne National Laboratory by using their standardized neutron source. The result of the rather elaborate calibrations is that the efficiency of our 20-cm Hg counter for thermal neutrons is 6.8 percent. By means of this calibration, the absolute values of the rate of production of neutrons in the atmosphere per gram per second are calculated from the expression given by Bethe,