LETTERS TO THE EDITOR

Prompt publication of brief reports of important discoveries in physics may be secured by addressing them to this department. Closing dates for this department are, for the first issue of the month, the eighteenth of the preceding month, for the second issue, the third of the month. Because of the late closing dates for the section no proof can be shown to authors. The Board of Editors does not hold itself responsible for the opinions expressed by the correspondents.

Communications should not in general exceed 600 words in length.

Multiple Scattering of Fast Electrons

We have made cloud-chamber measurements of the scattering of electrons of 2 to 8 Mev energy in lead and in carbon, under such conditions that the observed deflections are mainly due to multiple scattering. The scattering material was placed across the center of the chamber, and a magnetic field was applied to determine the energy of each electron both upon entering and upon leaving the scatterer. The lead and carbon sheets were made of such a thickness that NtZ^2 was the same for both, to within about three percent. (N=number of nuclei per cc; t=thickness of lamina; Z=atomic number.) Theoretically the scattering should be the same for two laminae, except possibly for a difference of about three percent in the average angle due to a difference in screening.

The results of the measurements are shown in Fig. 1. The projected angle of scattering, for each electron, is multiplied by the mean $H\rho$ value which it had inside the lamina. This allows tracks having a wide range of $H\rho$ values to be plotted together, since in multiple scattering the average deflection is supposed to be proportional to $1/H\rho$. The validity of this was checked by splitting the data into two groups, 2 to 5 Mev and 5 to 8 Mev. The $H\rho\theta$ plots were the same for these two groups, within the statistical fluctuations. The data for lead and carbon give the same value for the average $H\rho\theta$, to well within the accuracy of the experiment. Since all conditions in the experiment remained identical in the measurements with the two laminae, the result gives a clear confirmation of the dependence of scattering upon Z^2, in going from $Z=6$ to $Z=82$. The values for the average (projected) $H\rho\theta$ have been compared with theoretical values computed for our experimental conditions by E. J. Williams.[1] The experimental values are only 58 percent as high as the theoretical values. This discrepancy is in the same direction and of roughly the same amount as that found by Fowler and Oppenheimer[2] and Fowler,[3] for lead at about 10 Mev.

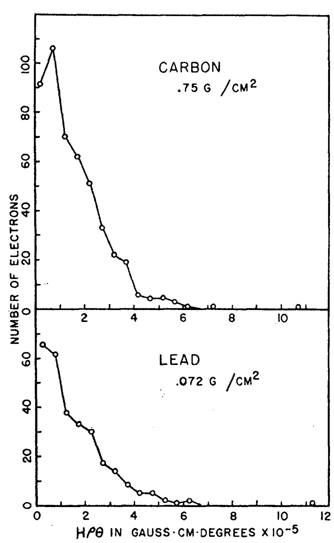

FIG. 1. Scattering of electrons in lead and carbon.

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[1] E. J. Williams, Proc. Roy. Soc. **A169**, 531 (1939).
[2] W. A. Fowler and J. Oppenheimer, Phys. Rev. **54**, 320 (1938).
[3] W. A. Fowler, Phys. Rev. **54**, 773 (1938).

Sommerfeld's Fine Structure Constant and Born's Reciprocity

Sommerfeld's fine structure constant $2\pi e^2/hc=1/137$ appears in the following connection. If a particle is considered as a Gaussian distribution ψ of matter of radial width Δq, then the same particle represents a Gaussian distribution of momenta of width Δp where Δq and Δp are related by the formula

$$\Delta q\Delta p=h.$$

With a certain degree of arbitrariness $\frac{1}{2}\Delta q$ can be identified with the radius and Δq with the diameter D of the particle. Using the customary value for an electric particle we have

$$\Delta q=D=4e^2/3m_0c^2 \tag{1}$$

and

$$\Delta p=h/\Delta q=m_0c\tfrac{3}{4}(2\pi)137=645.6m_0c. \tag{1'}$$

Both Δq and Δp are considered to be measured by an observer at rest outside the particle. We may ask, however, what is the invariant *proper* increase Δp^0 for an observer who himself is accelerated from $p=0$ to a momentum whose value to an observer at rest is Δp? The answer is that Δp^0 is much smaller than the corresponding

Δp, namely [see Eq. (6)]

$$\Delta p^0 = 7.163 m_0 c. \tag{2}$$

Similarly, the *proper* value Δq^0 of the diameter for an inside observer is [see Eq. (8)]

$$\Delta q^0 = 0.881 D. \tag{2'}$$

Whereas (1)(1′) give the product

$$\Delta q \Delta p = 2\pi D m_0 c (\tfrac{3}{4}\, 137), \tag{3}$$

(2)(2′) give the product of order

$$\Delta q^0 \Delta p^0 = 2\pi D m_0 c \tag{3'}$$

in which the factor $(\frac{3}{4}\, 137)$ has disappeared. *Thus, an electric particle can be characterized as a distribution in space and momentum space such that the product of the widths (uncertainty product) $\Delta q \Delta p = h$ reduces to a proper uncertainty product $\Delta q^0 \Delta p^0 = h_0$ which is of the order of 137 times as small.* The arbitrariness in assuming a certain value for the "diameter" of the particle has been removed by a more consistent calculation to be published later.

We are now going to report the calculations that have led to the proper values Δp^0 and Δq quoted in (2)(2′). In the dimensionless quantities

$$P = p/m_0 c \quad \text{and} \quad E = \epsilon/m_0 c^2, \tag{4}$$

the Einstein energy-momentum equation reads

$$E^2 = 1 + P^2 \quad \text{with} \quad E dE = P dP. \tag{5}$$

A line element dP is the projection of a line element $(dP^2 + dE^2)^{\frac{1}{2}}$ on the hyperbola (5). Its proper length is obtained by dividing it by the proper unit of length which is its distance $(P^2 + E^2)^{\frac{1}{2}}$ from the zero point. Integrating we obtain the proper increase

$$\Delta P^0 = \int \left(\frac{dP^2 + dE^2}{P^2 + E^2} \right)^{\frac{1}{2}} = \int_0^{\Delta P} \frac{dP}{(1+P^2)^{\frac{1}{2}}}$$
$$= \ln \{ \Delta P + (1 + \Delta P^2)^{\frac{1}{2}} \} = \mathrm{Sinh}^{-1}\, \Delta P. \tag{6}$$

Substituting ΔP from (1) we obtain the result (2). *Born's idea of reciprocity has led us to consider a similar reduction in space.* Starting from the equation

$$(ct)^2 = D^2 + q^2, \quad \text{hence} \quad dq/dt = c \cdot [1 + (D/q)^2]^{\frac{1}{2}}, \tag{7}$$

and introducing the dimensionless coordinates

$$Q = q/D \quad \text{and} \quad T = ct/D \tag{7'}$$

we obtain in the same way as in (6)

$$T^2 = 1 + Q^2 \quad \text{and} \quad \Delta Q^0 = \mathrm{Sinh}^{-1}\, \Delta Q. \tag{8}$$

Then, using $\Delta q = D$ or $\Delta Q = 1$ we obtain the result of (2′). The Eq. (7) is the mathematical formulation of an important result of *Dirac's* that a signal traveling from infinity to the center of the electron saves time as against a signal traveling with velocity c.

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On the Collimation of Fast Neutrons

Several experiments[1,2] have been carried out with a beam of neutrons produced by placing a thick wall of water in front of a neutron source and using a hole through the wall as a collimator. It has been observed with cloud chambers[1] that while there are large numbers of hydrogen recoils produced with the chamber in the beam, the number and length are both greatly diminished if the chamber is moved out of the beam. It has also been observed[2] that such a collimating system supplemented by lead shields to cut down γ-radiation from the collimating screen, gives little ionization current when the chamber is taken out past the edge of the beam, compared to that produced in the beam.

The effects of neutron collimation are rather clearly indicated in the accompanying photographs which show the proton recoils produced in a cloud chamber filled to atmospheric pressure with CH_4. The neutrons were produced by the bombardment of lithium or beryllium with 1.2-Mev deuterons accelerated by a cyclotron. A wall of water which was about 75 cm thick in the region of the hole served as the collimator. This hole was about 10 cm in

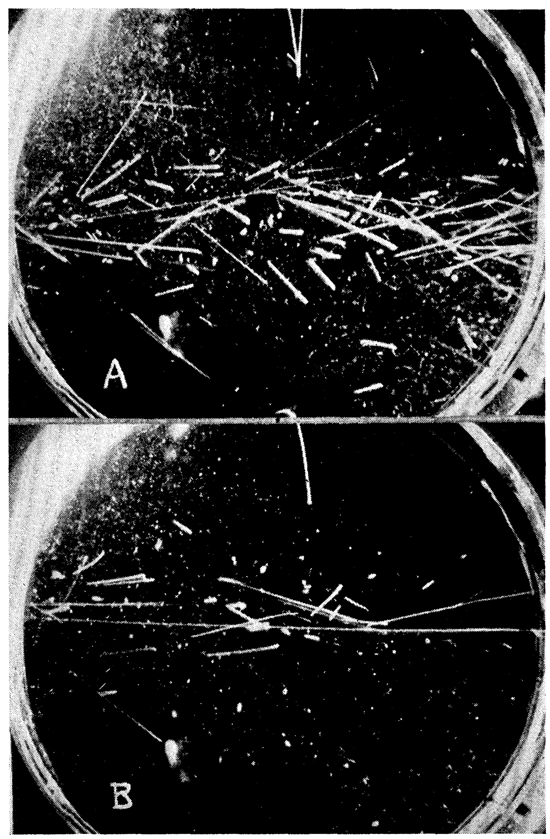

FIG. 1A. Tracks of the recoils in CH_4 produced by a collimated beam of neutrons which passed from left to right through the cloud chamber. Left edge of chamber about 4 cm from collimator. B. Tracks of recoils produced when the nearest edge of chamber was 30 cm from the collimator.