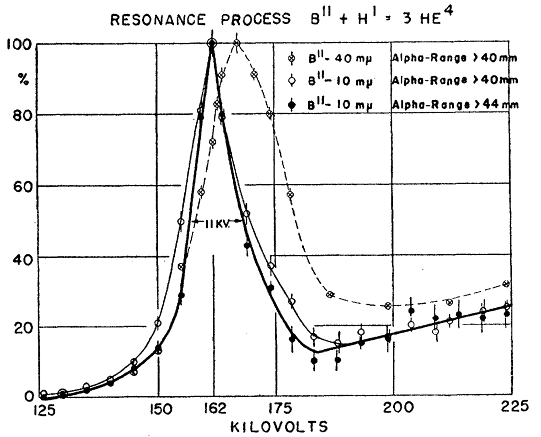

FIG. 1.

The present data are offered in corroboration of the data of Kanne, Taschek, and Ragan[1] on the position of the resonance peak, and of Jacobs and Whitson[2] on the shape of the yield curve. Data on the width of the resonance are offered, in which constancy of the voltage is not a factor. (Figure 1.)

The resistance controlled transformer-kenotron condenser set[3] was used to supply voltage up to 225 kilovolts. Ripple of approximately 4.5 kilovolts[4] was reduced to about 100 volts by loading the set with five condensers of capacity 0.5 mf each, tapped onto the potential divider. Voltage was monitored manually with a deviation of less than ± 1 kilovolt. Voltage was measured with a high resistance voltmeter, calibrated in sections with the aid of a potentiometer and standard cell to an accuracy of 0.5 percent.

Targets were of boron (11), on a polished copper button, prepared by Hoff Lu[5] with a high intensity mass spectrograph. One target had boron deposited to a thickness of 10 millimicron (mμ) and another a thickness of 40 mμ. Heating of the targets, as recommended by Bowersox,[6] prevented deposition of carbon on the 10 mμ target. The 40 mμ target had some abuse before the present experiment, but no further deposition occurred after it was heated. Thus, the yield curves remained constant during the course of the experiment.

Alpha-particles were observed at 90°, with the targets at a 45° angle. A shallow ionization chamber was used. Observations were made at ranges of 40 and 44 millimeters to make certain the long range alpha-particles appearing at energies of over 180 kilovolts could not be accounted for by the slight increase in range of the continuous group of alpha-particles from the second alternate reaction due to the greater kinetic energy of the bombarding protons. That the two curves for 40 and 44 millimeters range agree settles this point. Slight deviations are noted, however, in the region of 175 kilovolts.

The yield curves indicate, as shown by Jacobs and Whitson, a sharp resonance superimposed on an exponentially increasing background. The theoretical aspects of this phase of the problem have been discussed by Wheeler.[7]

The proton energy required at the resonance peak is 162 ± 1 kilovolts. This value agrees with that of Kanne, *et al.* (163 ± 6 kilovolts). Other values given have varied from 159 to 165 kilovolts. Higher values than these have been shown to be in error because of deposition of carbon on the targets.

The experimental half-width at half-maximum of the resonance for the 10-mμ target is 5.5 kilovolts. This width cannot be a broadening of the resonance due to variation in the voltage. Ripple was 100 volts, and variation in voltage for other reasons was held to ± 1 kilovolt. Half-width for the 40-mμ target is 10.5 kilovolts. This agrees with the value of 1.6 kilovolts for the stopping power of the 10-mμ target. The third factor in the experimental broadening of the resonance is the presence of scratches in the polished copper button. Heidenreich and Matheson[8] have utilized the electron microscope for the study of polished steel surfaces. They have demonstrated the presence of scratches of depth 13–50 mμ. The presence of such scratches would give an apparent thickness to the target which would readily account for the observed width of the resonance. It seems reasonable to conclude, therefore, that the width of the resonance is considerably less than the minimum measured width.

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[3] J. H. Williams, W. H. Wells, J. T. Tate, and E. L. Hill, Phys. Rev. **51**, 434 (1937).
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[5] Hoff Lu, unpublished.
[6] R. B. Bowersox, Phys. Rev. **55**, 323 (1939).
[7] J. A. Wheeler, Phys. Rev. **59**, 27 (1941).
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Electron Beams in Strong Magnetic Fields

J. R. PIERCE
Bell Telephone Laboratories, New York, New York
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In a recent paper,[1] Brillouin derives some types of electron flow in beams and states several conclusions. It should be emphasized that these conclusions do not apply to beams derived from a cathode of finite size located in the magnetic field unless the cathode is everywhere parallel to the magnetic field.

Consider, for instance, a circular disk cathode and axially symmetrical accelerating electrodes, the whole system immersed in a strong uniform magnetic field perpendicular to the cathode. Assuming no component of electric field in the θ direction we have from the angular momentum equation

$$\dot{\theta} = \frac{\omega_0}{2}(1-(r_0/r)^2). \tag{1}$$

Here $\omega_0 = (e/m)B$ and r_0 is the radius at which the electron leaves the cathode. We have also

$$\ddot{r} - r\dot{\theta}^2 = -(e/m)E_r - \omega_0 r\dot{\theta}. \tag{2}$$

Here E_r is the radial field, which may be due to space charge or to the accelerating voltages applied to the electrodes.

Letting $r-r_0=y$, $|y|\ll r_0$ (later to be justified by the result), we obtain the approximate equation

$$\ddot{y}=-(e/m)E_r-\omega_0^2y. \quad (3)$$

As this is linear, the solution for $\dot{y}=y=0$ at $t=0$ is

$$y=-\frac{e}{m\omega_0}\int_0^t E_r(T)\sin\omega_0(t-T)dT. \quad (4)$$

Here $E_r(T)$ is the radial field the electron encounters a time T after it has left the cathode.

Equation (4) can be integrated by parts. Using the information that E_r is zero at the time $T=0$ when the electron leaves the cathode surface, we obtain

$$y=-\frac{e}{m\omega_0^2}\left\{E_r(t)-\int_0^t\cos\omega_0(t-T)d[E_r(T)]\right\}. \quad (5)$$

Now when $\omega_0=0$ (contrary to our assumption) the integral has the value $E_r(t)$. If $E_r(T)$ is a smoothly increasing function of T, as ω_0 is made larger and larger the integral will become smaller and smaller. For very large values of ω_0 the electron motion will be essentially a displacement outward (as E_r is negative).

$$y=-\frac{e}{m\omega_0^2}E_r(t), \quad (6)$$

and a rotation of angular velocity

$$\dot{\theta}=-\frac{e}{m\omega_0 r_0}E_r(t). \quad (7)$$

Thus the effect of making the magnetic field very intense is to make the electron paths approach straight lines normal to the cathode.

It is interesting to note that the electron optical equations for paraxial rays without space charge can be extended by means similar to those described by Meyer[2] and Condon[3] to give results similar to those of Brillouin but for focused beams in which the radius may change along the beam. Such a treatment would predict the final behavior of the beam in terms of the conditions under which it is generated.

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[3] Edward U. Condon, "Focusing of Space Charge Limited Electron Beams," talk in A.I.E.E. Electron Ballistics Symposium, Columbia University, May 23, 1945.

Ionization by Fission Fragments in Nitrogen, Argon, and Xenon

N. O. LASSEN
Universitetets Institut for Teoretisk Fysik, Copenhagen, Denmark
September 15, 1945

SEVERAL investigators using ionization chambers have determined the energy of fission fragments[1,2] by comparing the ionization produced by the fragments with that produced by α-particles and assuming proportionality between energy and ionization. This proportionality is known to be valid for α-particles, but as the fission fragments have much higher energies, masses, and charges than α-particles and as it is known,[3,4] that the mechanism of ionization is somewhat different for the two sorts of particles the assumption might seem to be a little problematic. Meanwhile, the results agree fairly well with other measurements of the energy,[5] as well as with the theory,[6] and thus we may consider the assumption to be correct, at least within some 10 percent. Nevertheless, it may be of interest to note that by measuring the ionization in different gases we get almost the same energy distribution of the fission fragments, which further confirms the correctness of the assumption.

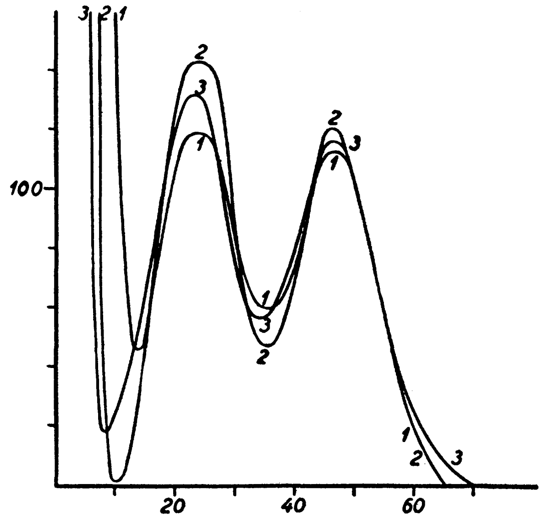

FIG. 1. Energy distribution of fission fragments having traversed 0.79 mg/cm² of mica+0.25 mg/cm² of aluminum. Measurements in nitrogen (curve 1), argon (curve 2), and xenon (curve 3).
Abscissa: Energy of Fragments in Mev
Ordinate Number of Fragments Per Unit Energy Range

Using the apparatus previously described[7] the ionization of fission fragments having traversed 0.79 mg/cm² of mica +0.25 mg/cm² of aluminum was determined. In Fig. 1, curve 2, the number of fragments is plotted against the size of the ionization pulses. The curve refers to 2,000 particles and is obtained with argon in the ionization chamber; in the previous letter[7] a second measurement was shown and there the experimentally found points were plotted. With nitrogen in the chamber we get a similar curve, but the pulses are much lower; this curve is transformed into curve 1 on the figure by multiplying the abscissae by 1/0.69 and the ordinates (in order to get the same area) by 0.69. In the same way curve 3 is obtained from the curve measured in xenon by multiplying the abscissae with 1/1.21 and the ordinates with 1.21. The figures 0.69 and 1.21 are chosen so as to make the end parts of the curves coincide; then, as seen, the curves almost coincide in the whole region occupied by fission fragments. The large number of small pulses represents the background in the ionization chamber produced by neutrons and especially by γ-rays.

The abscissae of the two peaks corresponding to the two groups of fission fragments and the valley between them are for all three curves very nearly the same and the