Production of Secondary Electrons by Cosmic Ray Particles

SOME early measurements of Anderson and Neddermeyer[1] show that the number of single secondary electrons ejected by cosmic ray particles from a metal plate is in reasonable agreement with that to be expected from direct elastic collisions. In a series of photographs we have observed the traversal of a 2 cm. plate of gold by about 900 particles, all of which may be assigned to the penetrating group. With this gold plate, which has a thickness of 8·5 in the units of the cascade theory, the behaviour of electrons can be immediately distinguished from that of the penetrating particles, and so the behaviour of the penetrating rays can be examined separately. On the assumption that these penetrating rays have a mass greater than that of electrons, Bhabha[2] has calculated the number of ordinary secondary electrons knocked on by collision and the subsequent cascade showers that the latter produce. The particles are considered in two energy groups, above and below 3×10^9 e. volts, previous measurements of the energy spectrum for the magnetic field and counter arrangement used having shown that 44 per cent of the observed rays have an energy greater than 3×10^9 e. volts. For convenience of the comparison with theory, the secondary electrons have been classified into those with energy greater and less than the critical energy of the cascade theory, for gold, 10^7 e. volts.

In the group of particles with energy greater than 3×10^9 e. volts, the total number of secondaries observed with energy greater than 10^7 e. volts was 4·4 per cent of the number of primary particles. The corresponding number of secondaries for the energy range below 3×10^9 e. volts was 0·4 per cent.

The table below shows the frequency of occurrence as a percentage of the penetrating particles of (*a*) single secondary, (*b*) two secondaries, (*c*) three or more secondaries.

	Energy of Primary (e.v.)	(*a*) 1	(*b*) 2	(*c*) >2
All observable secondaries	$> 3 \times 10^9$	3·3	0·3	0·3
	$< 3 \times 10^9$	0·8	—	—
Secondaries of energy $> 10^7$ e. volts	$> 3 \times 10^9$	2·8	0·3	0·3
	$< 3 \times 10^9$	0·4	—	—

We observe relatively few slow secondaries, with energy less than 10^7 e. volts, but this is due, at least in part, to the strong scattering of these particles.

The measurements give a rough indication of the mass of the main penetrating component of the rays. In Fig. 1 the total number of secondary particles of energy greater than 10^7 e. volts to be expected from the calculations of Bhabha[2] for penetrating particles of 10 and 100 times the electron mass and for protons is shown, and the measured values for the two groups of particles are plotted. These values are probably low, in comparison with the theoretical curves, since the theory does not take account of scattering, but they are sufficient to indicate a mass of the penetrating particles at least 100 m_0 and probably greater.

Thus these results show that the observed number of secondary electrons can be explained by the elastic collisions of the penetrating rays with electrons, assuming that the former have a mass rather greater than 100 m_0. The energy loss corresponding to this process can be seen from Bhabha's calculation to be of the order of one third of the ionization loss alone.

Now for energies between 10^9 and 2×10^9 e. volts, direct measurement[3,4] has shown a much larger energy loss, of the order of ten times the ionization loss. It follows that the main part of this energy loss must occur without producing observable secondaries.

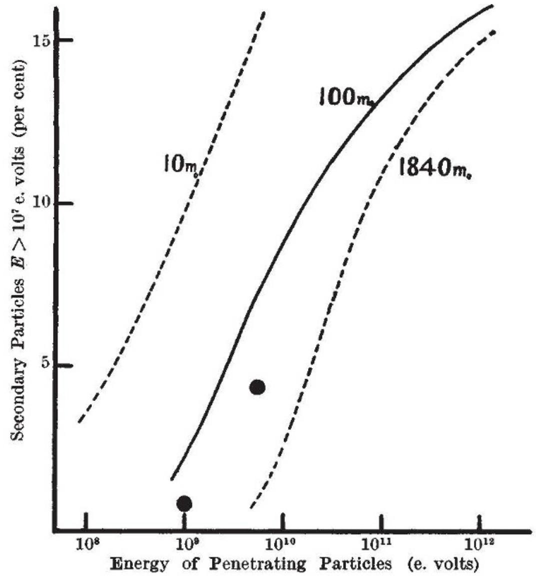

Fig. 1.

Fig. 2 shows the production of a small shower of four electrons by a penetrating particle of high energy. The fastest electron has an energy of about 3×10^7 e. volts. A similar photograph has been reported by Ehrenfest[5].

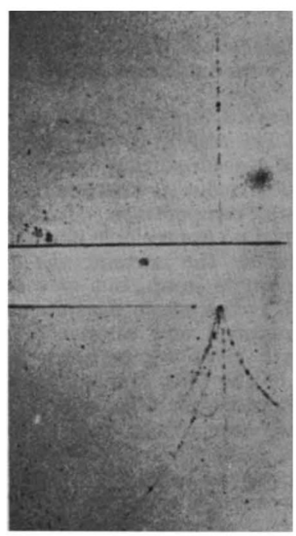

Fig. 2.

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[1] Anderson and Neddermeyer, *Int. Conf. Phys. Lond.*, 182 (1934).
[2] Bhabha, *Proc. Roy. Soc.*, A, **164**, 257 (1938).
[3] Blackett and Wilson, *Proc. Roy. Soc.*, A, **160**, 304 (1937).
[4] Wilson, *Proc. Roy. Soc.*, A (in the Press).
[5] Ehrenfest, *Comptes rendus*, **206**, 428 (1938).