We have made similar calculations for the lateral spread of high energy nucleons in lead and find, for example, that under a block of 56-cm thickness the root-mean-square distance from the shower axis of particles with energy above 10 Bev is 6.4 cm. Owing to the constant density of the medium, the maximum spread is not attained within several meters of lead.

It is hoped to present a more detailed account of this work shortly.

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The Drift Mobility of Electrons in Silicon

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The mobility of electrons injected into *p*-type silicon has been determined by measuring transit times between the emitter and collector points with single crystal rods.

The techniques used to measure the drift mobility of injected carriers in germanium[1] were altered in these measurements not only because the shape of the advancing wave front of injected carriers in silicon is affected by a temporary trapping but also because of the much higher impedance of voltage probe points.

A schematic diagram of the circuit used successfully with silicon is shown in Fig. 1. Electrons are injected at the time of the current pulse and flow down the crystal under the influence of the electric field. When the pulse of electrons arrives at the collector point, a signal is produced.[2] A sketch of the oscilloscope pattern obtained is shown in Fig. 2. The dots represent 10-μsec marker intervals. The current pulse used to inject the electrons produces a corresponding voltage pulse at the start of the oscilloscope trace as a result of the resistance of the silicon rod between the collector point and ground. After this initial pulse the voltage remains constant for some 40 microseconds. During this time the injected electrons are moving down the silicon crystal from the emitter point which was placed a centimeter away from the collector. When the electron pulse arrives at the collector, the voltage pulse shown is observed. The transit time, *t*, for the injected electrons is the time represented by the distance from the center of the voltage pulse to the maximum signal produced by the arrival of the electron pulse.

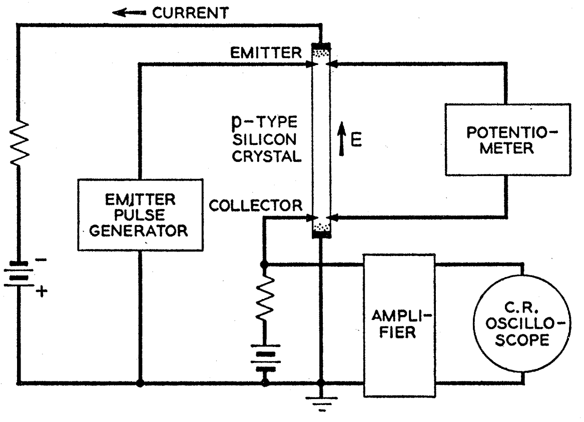

Fig. 1. Schematic of circuit used to measure the drift mobility of injected electrons in silicon.

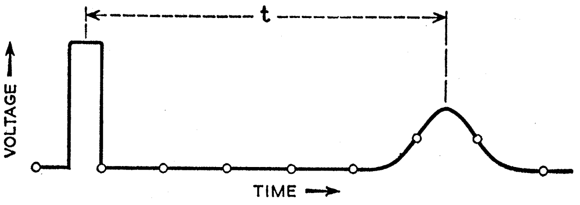

Fig. 2. Drawing of oscilloscope trace showing time of injection pulse and subsequent electron arrival.

It is found that the transit time measured in this way is a function of the amplitude of the current pulse as a result of conductivity modulation of the silicon rod. As the amplitude of the current pulse is continuously decreased, the signal arrival time becomes earlier, at first rapidly and then more slowly. The transit time corrected for conductivity modulation could therefore easily be obtained visually by extrapolating the locus of arrival time points to zero signal.

The drift mobility μ_D of electrons in silicon was calculated from the relation $\mu_D=L^2/Vt$, where t is the transit time, L is the distance from emitter to collector, and V is the voltage difference in silicon between emitter and collector.

Representative values of L and V used are shown in Table I together with the resultant measured transit time. The corresponding value of μ_D has been corrected for nonuniformity of electric field and temperature rise produced by the dc current.[1] The average value of mobility obtained for all data is 1210 cm²/volt sec.

Table I. Representative values of electron drift mobility data.

Sample No.	L(cm)	V(volts)	t(μ sec)	μ_D(cm²/volt sec)
I	0.537	5.70	43.9	1204
I	1.10	12.3	84.0	1248
I	1.12	29.5	41.8	1194
II	0.64	5.56	63.3	1190
II	0.64	11.8	32.6	1162
II	0.64	4.49	73.8	1283

This value is more than four times as large as the mobility of electrons in silicon reported by Pearson and Bardeen[3] (300 cm²/volt sec for electrons, 100 cm²/volt sec for holes). Their values, however, were obtained from Hall effect data in multicrystalline samples, and their extremely low values were most probably caused by inhomogeneities produced by crystal grain boundaries.

In view of the experience with germanium, it is felt that even though only two samples have been examined, the drift mobility of electrons in silicon is within 10 percent of 1200 cm²/volt sec. Preliminary measurements with injected holes in *n*-type silicon indicate a drift mobility for holes in the neighborhood of 250 cm²/volt sec giving a ratio of electron to hole mobility of 4.8.

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Photomeson Production in Carbon and Hydrogen*

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Cylindrical targets of paraffin, heavy paraffin, and graphite were exposed simultaneously to the x-ray spectrum produced by 330-Mev electrons in the M.I.T. synchrotron. The