Shower Production in Small Thicknesses of Lead and Other Elements

It is generally assumed that the increased frequency of "shower coincidences," associated with the disposition of increasing thicknesses of lead above a set of Geiger-Müller counters, is a linear function of the thickness of the lead above such counters.[1]

As part of a general program of investigation of cosmic-ray shower production we have had occasion to make observations on the production of showers by relatively small thicknesses of material above the counters. These observations were undertaken primarily on account of the probable simplification of results due to the diminished importance of absorption for small thicknesses of material.

In the experimental arrangement of Fig. 1 it will be noted that at least three particles must be involved in a coincident discharge of the three counters, since no single particle from the lead can pass directly through more than one counter.

In Fig. 2 we have plotted the observed increase in counting rate ($\Delta C/T$) in counts per hour as a function of material thickness t in cm. A dotted curve, proportional to t^2, is also plotted for comparison purposes. The data indicate that the increase in such observed "triples" is definitely not a linear function of thickness, and is, for small thicknesses, considerably faster than the first power of t. One would expect that any correction of such observed counting rates for the absorption of shower particles in the producing material would become of relatively greater importance as t increases.

In view of the fact that other data in the literature, as well as observations made in this laboratory, indicate a linear increase of counting rate ($\Delta C/T$) with t where a minimum of two particles from the lead can cause a coincident discharge of the counters, we have also recorded "doubles" using only the two outside counters (1 and 3, of Fig. 1). In this case the data of Fig. 3 were obtained. This indicates an approximately linear relation between increase in coincidences and thickness of material for "two-particle" coincidences.

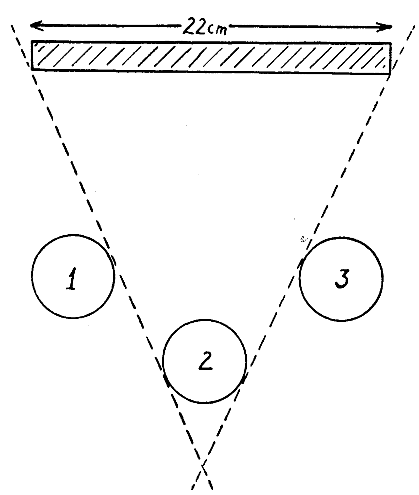

Fig. 1.

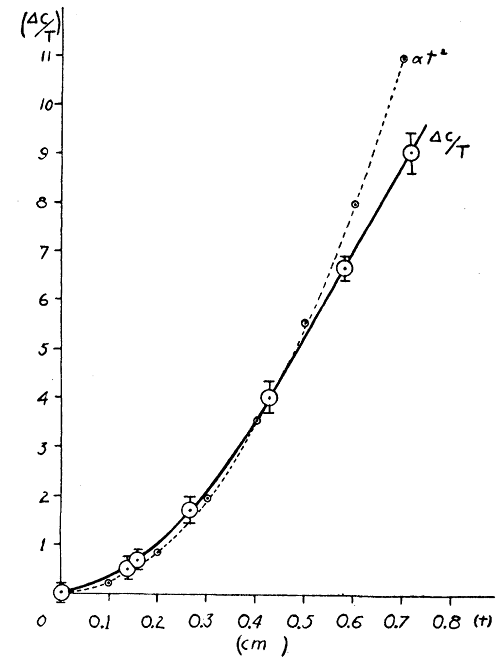

Fig. 2.

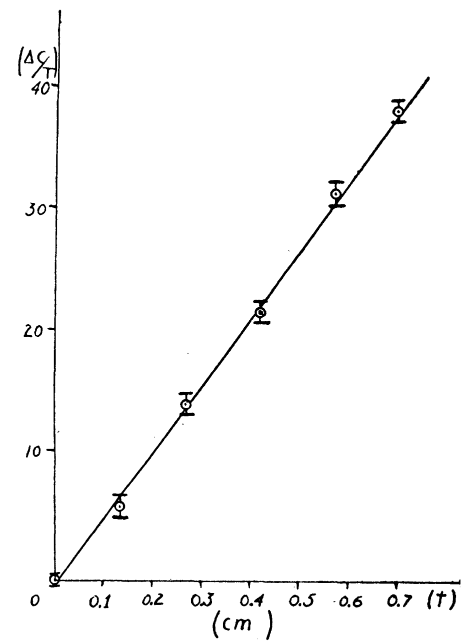

Fig. 3.

It must be emphasized that the above observations pertain to lead only. Our data on other materials (carbon, aluminum, copper and tin) show that the departure from linearity for "triples," as in Fig. 1, is a function of the atomic number of the element concerned, and indicate that for the elements of lower atomic number the increase in counting rate is more nearly a linear function of t.

The significance of these observations and other data will be discussed after the completion of a series of rather lengthy experiments on the absorption of shower particles in the shower producing material.

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[1] C. W. Gilbert, *et al.*, Proc. Roy. Soc. **A144**, 559 (1934).

Absorption and Detection of Slow Neutrons

Attempts to explain the capture of neutrons have generally included the assumption that the capture probability varies inversely as the velocity of the neutron. Accordingly the various reactions used as detectors should be velocity sensitive.

As the disintegrations[1] of boron and lithium according to the reactions[2]

$${}_5B^{10} + {}_0n^1 = {}_3Li^7 + {}_2He^4$$

and

$${}_3Li^6 + {}_0n^1 = {}_2He^4 + {}_1H^3$$

are among the most useful detectors of neutrons, we have made a comparison of these in terms of the absorption observed in B, Li, and Cd.

The "slow" neutrons in these experiments are those from a paraffin sphere of 6 cm radius enclosing a Rn-Be source, and more specifically, are those that are stopped by cadmium, 0.9 g per square centimeter.

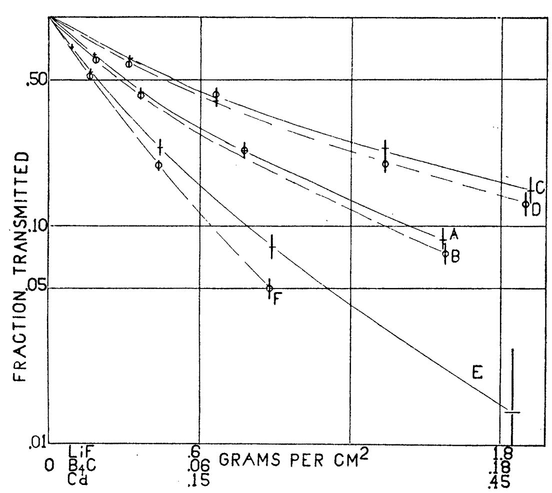

FIG. 1. The absorption of slow neutrons.

Curve	*Absorber*	*Detector*
A	boron	boron
B	boron	lithium
C	lithium	boron
D	lithium	lithium
E	cadmium	boron
F	cadmium	lithium

Identical ionization chambers were constructed except that the collector and all walls of one were coated with powdered boron with a little Aquadag (carbon) as binder, and the other with lithium foil. The details of such a chamber and the geometric arrangement of the source, sample and chamber were as previously described[3] except that in this case the distance from the source to chamber was 18 cm.

The data obtained in these experiments are disclosed in the accompanying plot, Fig. 1, of the logarithm of the fraction of slow neutrons transmitted against the mass per square centimeter of the absorbing sample. The vertical lines indicate the statistical error on the basis of the square root of the number of counts.

The cadmium was in the form of pure metal sheet, the lithium in LiF, and the boron in B_4C mixed with talc. The mass per unit area is the effective mass, account having been taken of the obliquity of part of the beam and the variation in intensity from different zones of the paraffin sphere. These correction factors have little effect on the result; e.g., in the case of B_4C, 0 at large transmissions to 3 percent at 0.08 transmission.

In order to get a reasonably large number of counts, these chambers were built with three successive, separate layers of B or Li. This arrangement permits the use of a total thickness sufficient to absorb most of the slow neutrons while at the same time permitting the detection of many disintegration particles produced by neutrons captured in the first layers. Such chambers should be relatively insensitive to neutron velocity. That the sensitiveness does not vary much with velocity seems to be borne out by the fact that the curves for the same absorber observed with Li and B as detectors are not very different.

Although the cadmium absorption curve by boron detection diverges more from the exponential than the earlier[4] curve by lithium detection, this divergence is of the same order as the experimental error. The departure of the B and Li absorption curves from the exponential form is outside the estimated experimental error. With the type of

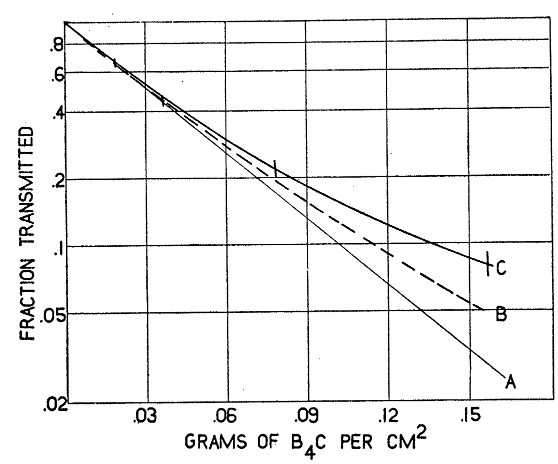

FIG. 2. *A*, the exponential form; *B*, the theoretical $1/V$ curve; *C*, observed for B with B detector.