was believed to be $\sim$0.2 microampere, but the effective bombarding current may have been severalfold greater because of multiple traversals of the target. On the basis of comparative yields, the cross section appears to be $\sim 10^{-4}$ barn.

Sheline and Johnson have mentioned the potential significance of Mg^{28} as a tracer, particularly in photosynthesis and general biochemistry. It should also be of value in the investigation of metallurgical systems, of geochemical problems, and of organomagnesium compounds such as Grignard reagents. While the above yield is not great, it is ample for producing a tracer for experiments of several days duration. We plan to seek target materials and conditions that will give higher yields and to develop chemical procedures for isolating Mg^{28} in carrier-free condition.

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The Density Distribution within Two Meters of Large Air Shower Axes*

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DETAILS of the lateral structure of individual air showers have been observed[1] by using a 20-channel electron-pulse ionization chamber which took 20 density samples from each shower. The geometry is shown in plan in Fig. 1, where each area represents the region from which an individual collecting wire gathered electrons. The pulses were separately amplified, displayed on 20 cathode-ray tubes, and photographed. The last stage of amplification was made nonlinear so that a large range of densities could be accurately measured. Amplifier calibrations were made by pulsing the shell of the chamber and stability of gain proved satisfactory. The absolute value of ionization was determined in the customary manner from Po α-particle ionization. Precautions such as purification of the argon, experimental and theoretical evaluation of the pick-up between detection areas, etc., were taken. The recording system was actuated by a fourfold coincidence in a simple Geiger-counter array.

During 109 hours of operation at an altitude of 280 meters, events were recorded in which the density distributions over the array of wires in the chamber were of the following types: (1) flat with only small fluctuations from the average (consistent with those expected from the statistics of independent events) (events 3 and 4); (2) increasing or decreasing functions (event 9); (3) markedly peaked (events 5 and 8); and (4) flat with rather marked and systematic fluctuations from the average (event 13) (see Figs. 2 and 3). These events have been interpreted, respectively, to be the result of showers whose axes hit (1) relatively far away from the chamber; (2) near the end of the chamber with small

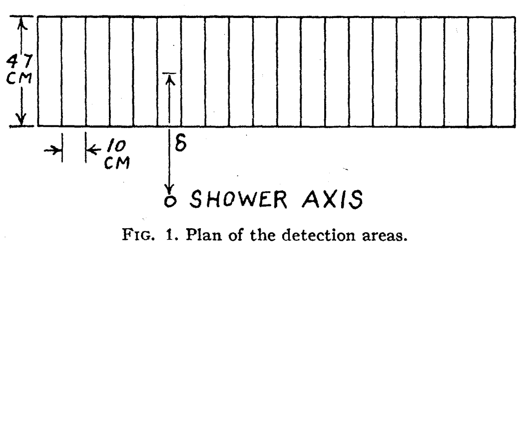

FIG. 1. Plan of the detection areas.

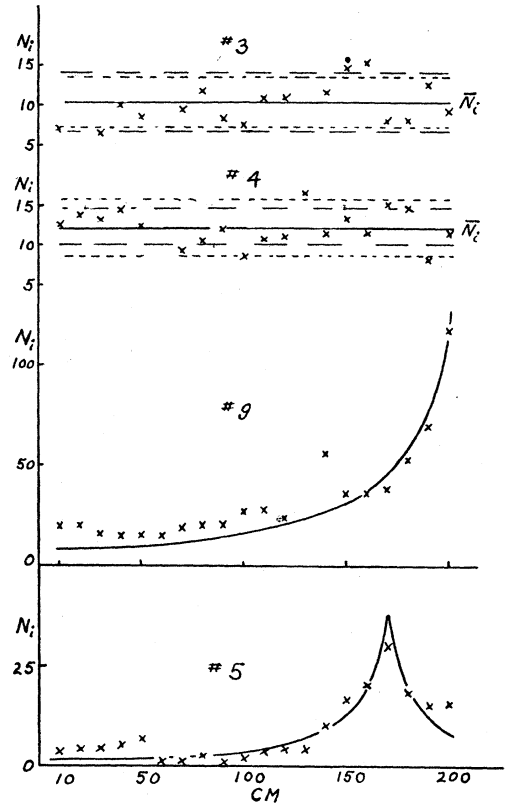

FIG. 2. Individual showers; number of electrons N_i within the detection areas *versus* position of the areas. In 3 and 4 the dotted lines represent $(\bar{N}_i)^{\frac{1}{2}}$ and the dashed lines σ, the rms deviation from the average. The curve in 9 represents a shower of local size $\Pi=3.5\times10^4$ electrons with $\delta=28.5$ cm. The curve in 5 represents $\Pi=5.6\times10^3$ with $\delta=23.5$ cm.

values of δ; (3) inside the chamber collecting area; and (4) inside the chamber with multiple shower cores due to more than one initiating π^0 meson. These four classifications are not sharply defined and showers of intermediate types were observed.

The first interest in these events is that of viewing for the first time a detailed "display" of an air shower. The scientific interest is twofold: (a) what is the shape of the lateral distribution function for a single cascade shower, and (b) what is the evidence for a multiplicity of cores, especially a multiplicity attributable to a multiplicity of π^0 mesons? In answering (a) we are forced to assume a distribution and look for consistency because of the finite detector areas, the transition effect in the top of the chamber, and the variation in δ (see Fig. 1) from event to event. As a first approximation, the chamber response curves fitted to each event were constructed (including transition effect) from lateral distribution functions that were obtained from existing shower theory results. The distributions were obtained as functions of electron and photon energies for air and for distances within 10 meters of the shower axis.[1] The electron distributions are perhaps dependent upon better approximations than those used by Molière, (e.g., the number of low energy electrons is certainly treated better) but the resultant total distribution function was the same as that found by Molière.[2] The experimental results appear to require no drastic revision of our total distribution function.

In answering (b) it is necessary to consider the expected non-Poissonian fluctuations in the density distribution near the axis of a single-cored shower and also the effect of π^0 decay. It has been demonstrated[1] that neither of the two considerations provides a likely explanation of the auxiliary peaks in events 5 and 9. Events

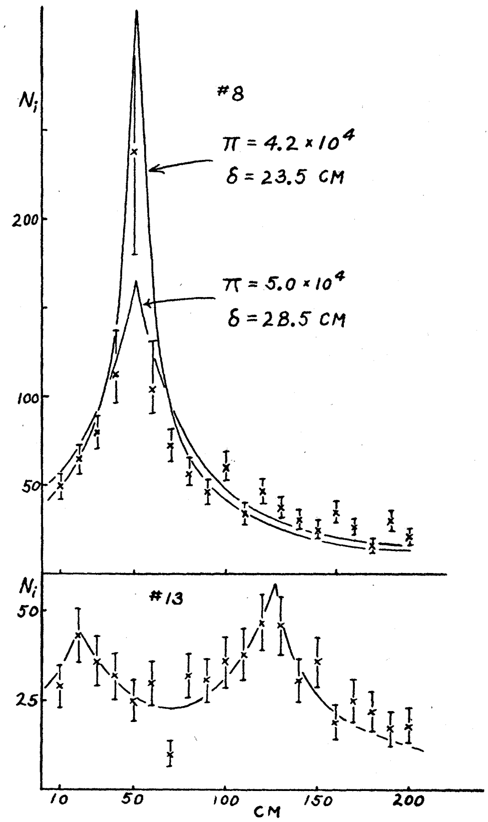

FIG. 3. Individual showers. Event 8 is the largest event observed. In 13, a curve compounded from two showers indicates the effect of superposition; this event is believed to be a close hit because of its size, the fact σ is nearly twice $(\overline{N_i})^{\frac{1}{2}}$, and the systematic character of the "fluctuations."

3 and 4 were the largest of their type and confirm (at least in the case of distant events) the prediction[1] that the fluctuations in N_i expected in this experiment are $1.15\sqrt{N_i}$ (the 1.15 arises from the transition effect).

An event such as 13 is particularly difficult to interpret except in terms of separated cores generated by different π^0 mesons.

* Supported in part by the joint program of the U. S. Office of Naval Research and the U. S. Atomic Energy Commission.
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The Neutron-Electron Interaction*

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AFTER it was pointed out by Foldy[1] that approximately 4000 ev (well depth for e^2/mc^2 range) of the neutron-electron interaction could be attributed to the neutron moment, it was clear that more accurate measurements were necessary in order to isolate the electrostatic dissociation effect arising from the meson charge distribution. At this time an experiment was already under way at Brookhaven designed to increase the experimental accuracy by means of mirror reflection of neutrons. Previous measurements had utilized the variation of scattering cross section with angle[2] or with wavelength[3] to detect the form factor behavior of the electron scattering. The observed effects in each case were small and of the same order of magnitude as various corrections. Since the form factor is exactly unity for mirror reflection, however, the neutron-electron scattering is observed at its maximum value. Fortunately, the use of a balancing technique makes the critical angle for total reflection a sensitive measure of the neutron-electron interaction.

The experimental arrangement used was one in which the critical angle is measured for total reflection of long wavelength neutrons at the interface of bismuth and liquid oxygen. As the nuclear scattering (per unit volume) of oxygen and bismuth differ by only two percent while the electron scattering is much stronger in bismuth, the index of oxygen relative to bismuth is to a large extent determined by the electron scattering amplitude. A highly collimated neutron beam, Fig. 1, filtered through graphite, was incident on the interface at an adjustable angle of the order of a few minutes of arc. The critical angle was measured by techniques developed for other mirror experiments.[4] The measurement consists essentially of an observation of the incident angle at which the reflected intensity drops suddenly, this angle being the critical angle for the cut-off wavelength (6.7A) of the incident filtered neutrons. In order to determine the critical angle accurately, the experimental points (Fig. 1) are compared to a calculated curve that takes into account the finite reflectivity beyond the critical angle and the resolution of the incident neutron beam (about 0.25 minutes of arc). The final value, based on several measurements similar to that illustrated in Fig. 1, is 3.64±0.04 minutes.

The equation relating the critical angle to the coherent bound scattering amplitude a is

$$\frac{\pi}{\lambda^2}\theta_c^2 = N_{\mathrm{Bi}}a_{\mathrm{Bi}}\left\{\frac{N_{\mathrm{O}}a_{\mathrm{O}}}{N_{\mathrm{Bi}}a_{\mathrm{Bi}}}-1\right\}+\{N_{\mathrm{Bi}}Z_{\mathrm{Bi}}-N_{\mathrm{O}}Z_{\mathrm{O}}\}a_e, \qquad (1)$$

where N is the number of nuclei per cm^3, λ the neutron wavelength, and the subscripts O, Bi, and e refer to oxygen, bismuth, and the electron. This equation consists of three parts: the first involving the measured critical angle, the second the coherent amplitudes, and the last the neutron-electron interaction. Since the nuclear amplitudes of oxygen and bismuth are nearly equal, the two terms on the right-hand side of the equation are of the same order of magnitude. In order to reach reasonable accuracy in the electron amplitude, the coherent nuclear amplitudes must be measured with much higher accuracy. These amplitudes are obtained from the free atom cross sections by application of the reduced mass factor and subtraction of incoherent scattering.

It is not necessary to measure the absolute values of the free atom cross sections of oxygen and bismuth, for it is only the ratio that enters into the result in a sensitive way. This ratio was measured by transmission for neutrons of average energy 8 ev: these neutrons being produced by a boron difference measurement for a pile neutron beam. Two nearly identical beams were

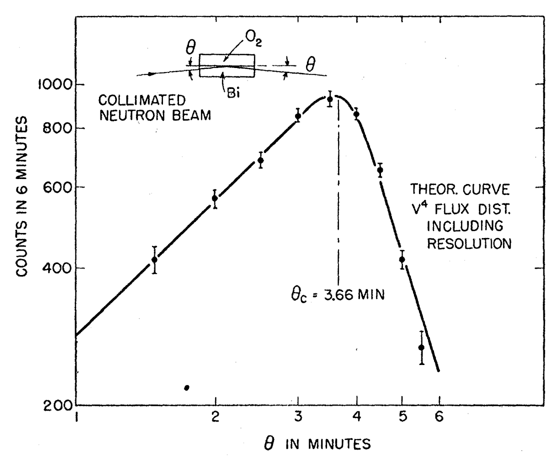

FIG. 1. Intensity of neutrons reflected from oxygen-bismuth interface as a function of incident angle.