is made that the number-size distribution of stars is the same for the three materials measured. The cross section is then proportional to the product of the counting rate in the chamber and the relative atomic stopping power, S, of the wall material for the fragments. Using the values of 1.45, 2.3, and 4.4 for S and 1.0, 1.5, and 1.6 for the measured counting rates at 2 Po-α, the cross sections are in the ratio 1:2.4:4.9. Since the integral bias curves are exponential with nearly equal slopes for the three chambers, the relative cross sections are quite insensitive to the choice of bias at which calculations are made.

A logarithmic plot of these cross sections against atomic weight is given in Fig. 2, together with a line of slope $\frac{2}{3}$ to indicate a power-law variation with that exponent. The relative cross sections for the two heavier materials are consistent, within the limits of error, with an $A^{\frac{2}{3}}$ law. If the somewhat low value of the aluminum cross section is real, it may be due to a smaller average star size in aluminum, resulting in fewer bursts above a given bias than for the heavier elements. The values of the relative atomic stopping power used in the above calculations are those for alpha-particles from radioactive materials.[2] If one uses the recent values of Teasdale[3] for 12-Mev protons, the copper and lead cross sections are closely consistent with $A^{\frac{2}{3}}$, but the aluminum cross section deviates even more from this power law. We conclude that the results are not inconsistent with a cross section proportional to the $\frac{2}{3}$ power of the atomic weight. Several experiments[4–6] with nuclear emulsions under various absorbers have indicated that the absorption cross section for the star-producing radiation is proportional to the nuclear geometrical cross section. The emulsion tracks and stars were used as indicators of the star-producing radiation. Our results, based on measurements of nuclear-type bursts, are consistent with this conclusion.

* This investigation was supported by the ONR.
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[6] Bernardini, Cortini, and Manfredini, Phys. Rev. **74**, 1878 (1948).

A Correction to Be Applied to the Activity of Neutron-Activated Cadmium-Covered Indium Foils

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ONE common method of measuring a slow neutron flux involves the use of foils of some material having a high neutron activation cross section in the resonance region. A necessary part of the technique is the activation by neutrons of one known energy. This is most easily done by the use of cadmium covers on the foils, since cadmium is transparent to neutrons in the resonance region above the 1 ev, and is effectively black in the 1/v region below about 0.4 ev (Table I). The low energy end of the resonances of some elements, notably indium, extends below the cadmium cut-off,[1] and a correction depending on the cadmium thickness used must be applied to the calculated activity to account for those neutrons normally captured by the resonance, but which are absorbed by the cadmium.

TABLE I. Correction factors on indium activity and other data as a function of the thickness of the cadmium cover.

Cadmium thickness—in.	Correction factor	99% black region—ev	% absorption at 0.6 ev	1.0 ev
0.010	0.90[a]	0.11–0.23	11	0.2
0.020	1.072	<0.26	21	0.5
0.030	1.111	<0.28	30	0.7
0.040	1.150	<0.30	38	0.9
0.050	1.191	<0.32	45	1.2
0.060[b]	1.236	<0.34	51	1.4
0.070	1.28	<0.35	56	1.6
0.080	1.32	<0.36	61	1.9
0.100	1.42	<0.38	69	2.3

[a] Calculated from curve.
[b] Equation (1) is probably not valid at greater thicknesses because of abrupt changes in the shape of the cross-section curves in the energy region above about 0.6 ev. Correction factors given for greater thicknesses are therefore only approximations.

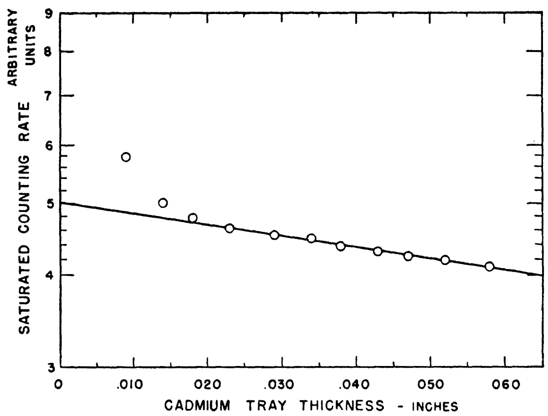

FIG. 1. The saturated activities of neutron-activated indium foils surrounded by cadmium is shown as a function of the cadmium thickness. The errors are less than the size of the circles.

An investigation of this correction as applied to indium was made in a constant and well-known flux or graphite moderated neutrons from a 1g Ra-Be source. The foils were irradiated at a point about 20 inches from the source, where there is a mixture of neutrons of varying energies. The foils used were made from high purity indium, measured 4.00×6.35 cm, and weighed 2.4000±0.0030 g. Cadmium plates the size of the foils were made in about 5, 10, and 30-mil thicknesses, and trays were made in 10 and 30-mil thicknesses. A particular thickness was made up of a sandwich of appropriate plates and tray. The actual thicknesses ran from 0.009″ to 0.058″ in about 0.005″ steps. The points obtained for those thicknesses which were black to thermals lie in a straight line on a logarithmic plot (Fig. 1). A least-squares fit gives an equation of the form

$$C' = Ce^{3.507t}, \tag{1}$$

where C is the observed activity, C' is the true activity, and t is the thickness of cadmium in inches. A tabulation of correction factors for various thicknesses and other data is given in Table I.

The errors involved in all measured quantities were less than 1 percent, with the exception of the cadmium thicknesses, where the error was ±0.0005″. Because of the exponential form of Eq. (1), however, the error in the correction factors given in Table I is estimated at less than 0.5 percent for the thicknesses between 20 and 60 mils.

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The Intensity of Primary Heavy Nuclei in the Stratosphere at Night*

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FREE balloon flights in the stratosphere have been conducted in order to investigate the flux of primary heavy nuclei and the rate of production of nuclear disintegrations during the night. The elevation and duration of these flights are given in Table I.

Ilford G-5 type photographic emulsion plates, 200μ in thickness, were arranged with emulsions in contact and the plane surfaces parallel to the zenith direction. The total matter per sq. cm. of the

TABLE I. Data on balloon flights.

Time of launching Day	Hour	Average ceiling elevation in cm of Hg pressure	Time at average ceiling elevation
July 22, 1949	5:30 A.M.	1.0	6.2 hr.
August 3, 1949	5:36 A.M.	3.5	5.0 hr.
October 31, 1949	10:17 P.M.	3.3	7.8 hr.
November 30, 1949	10:08 P.M.	6.4	6.9 hr.

upper hemisphere of the gondola covering the plates was in all cases negligible compared to the mass of the atmosphere directly above the plates.

The plates were carefully examined for heavy nuclei tracks and cosmic-ray stars. The intensity of cosmic-ray stars is given in Fig. 1 for the day flight of August 7 and the night flight of October 31. The rate of production of stars with more than n prongs is given in units of the number of stars per cc per day.

In order to be sure that the lower temperature of the plates at night did not affect the interpretation of this experiment the grain density as a function of ionization energy-loss was determined on the plates used during the night flights and those used during the day. For corresponding energy-losses the grain densities were reduced by less than 10 percent by the lower temperatures during the night, which would make a negligible difference in the intensity of delta-rays between day and night.

The number of delta-rays extending 1.1μ from the center of the heavy nuclei tracks was measured in each case, and the tracks grouped according to their intensity of delta-rays per 100μ (Fig. 2). The relationship between the delta-ray intensity of primary heavy nuclei tracks and the type and velocity of the particles has been shown by previous investigations.[1,2]

Since the night balloon flight of October 31 leveled off at a slightly lower elevation than did the day flight, and in order to correct for the contribution of heavy nuclei during the time of rise and fall, it is necessary to know the altitude dependence of the heavy nuclei tracks.

For the investigations reported in this paper it is sufficient to know the variation of all tracks, with a given number of delta-rays per 100μ, with the altitude. This is shown in Fig. 3, where the number of tracks with more than 12 delta-rays per 100μ is given as a function of the pressure-altitude.

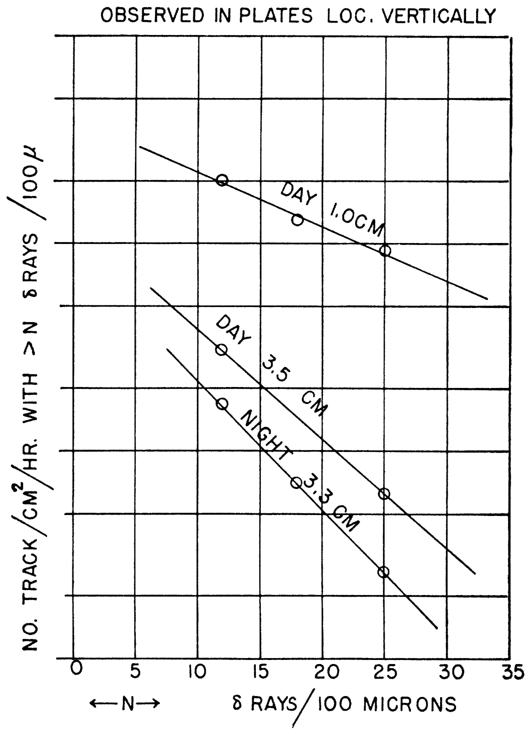

FIG. 2. Distribution of delta-rays on the heavy particle tracks. (The ordinate scale is the same as that for Fig. 3.)

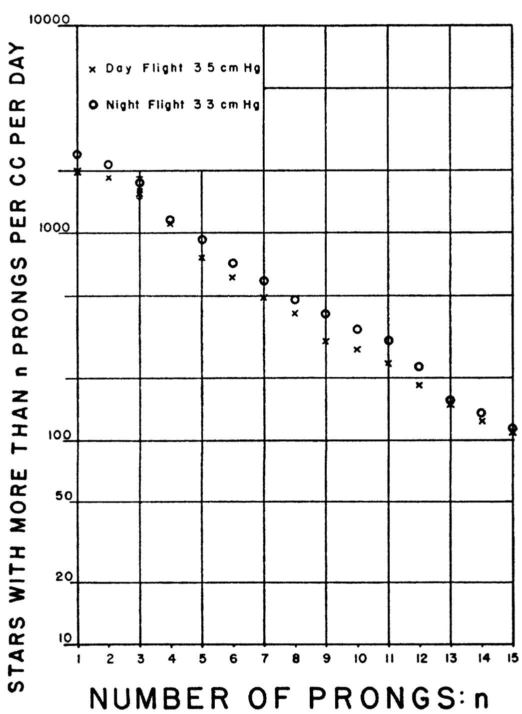

FIG. 1. Distribution of stars with respect to the number of their prongs.

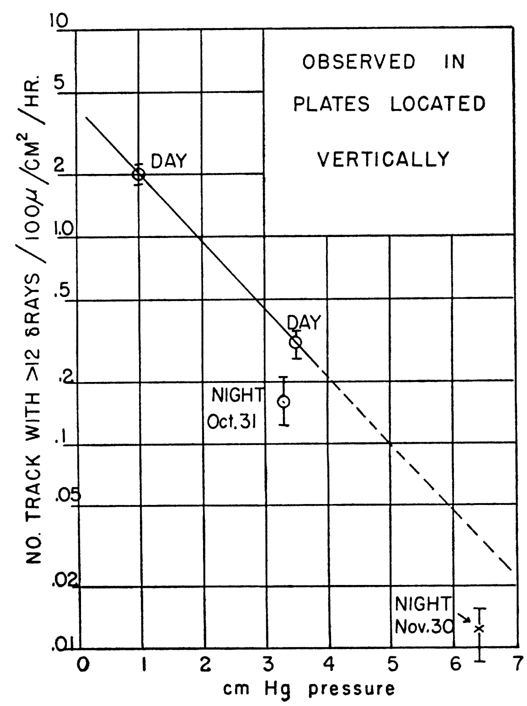

FIG. 3. The number of tracks with more than 12 delta-rays per 100μ as a function of the altitude.

It is to be noticed (Fig. 3) from the flight of October 31 that the ratio of the flux of the heavy nuclei tracks, which have more than 12 delta-rays per 100μ, during the day to those during the night is 2.1 ± 0.6. If it is assumed that the flux of heavy nuclei tracks is an exponential function of the atmospheric pressure between 1.0 and 6.4 cm of Hg, then the flight of November 30 gives a ratio of 3.0 ± 1.1 between the flux during the day to that at night.

Within experimental error of five percent the rates of production of stars given in Fig. 1 are the same during the day and the night, which strongly indicates that the proton and alpha-particle components of the cosmic radiation do not exhibit any appreciable diurnal variation.

The experimental evidence presented here indicates that there is a large change in the intensity of heavy nuclei between day and night. Since the measurements refer to tracks having more than 12 delta-rays per 100μ, the data refers to nuclei having, on the average, an atomic number greater than 10. It is not clear from this investigation whether or not this large diurnal variation applies only to heavy nuclei of relatively low energies. They could then possibly originate from the sun.

A more detailed study of the diurnal variation of heavy nuclei with the time of day and as a function of the energies of the particles may lead to a new approach regarding their origin.

We wish to thank Mr. J. Litwin for assistance in scanning the plates used in this experiment.

* Assisted by the joint program of the ONR and AEC.

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Detection of the π-μ-Decay with a Scintillation Crystal†

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THIS letter summarizes the preliminary results of an experiment from which it is hoped to obtain an accurate and direct measurement of the mean life of the π^+-meson. The experimental arrangement is shown schematically in Fig. 1.

Mesons are produced in a carbon or beryllium target T by γ-rays from the M.I.T. synchrotron. Some of the π-mesons pass through an absorber A_1 ($\frac{1}{4}$ in.-Pb$+\frac{1}{4}$ in.-Al) traverse a 2 g/cm^{-2} stilbene crystal X_1 (facing a 1P21 photo-multiplier, PM_1), a 2 g/cm^{-2} bakelite absorber A_2, and stop in a 1 g/cm^{-2} stilbene crystal X_2 (facing a 5819 photo-multiplier, PM_2). Practically all of the μ-mesons (range 0.1 g/cm^{-2}) arising from the decay of the stopped π^+-mesons come to rest in the same crystal X_2 and subsequently decay, giving rise to positrons. The arrival of the π^+ meson, the disintegration of the π^+-meson, and the disintegration of the μ^+-meson produce light flashes that are detected by the photo-multiplier PM_2. The resulting pulses are amplified by a distributed constant amplifier, delayed 10^{-7} seconds by a coaxial cable, and displayed on a high writing-speed oscilloscope. The over-all resolution of the crystal and electronic equipment is sufficient to measure the time between arrival and decay of π^+ mesons when this time is $3\cdot10^{-8}$ seconds or greater. The pulses from PM_2 are also presented on a second slower oscilloscope for the purpose of observing the decay electron from the μ-meson. The sweeps of the two oscilloscopes are triggered simultaneously by coincidences between PM_1 and PM_2. The two oscilloscopes are photographed with the same camera on a continuously moving film.

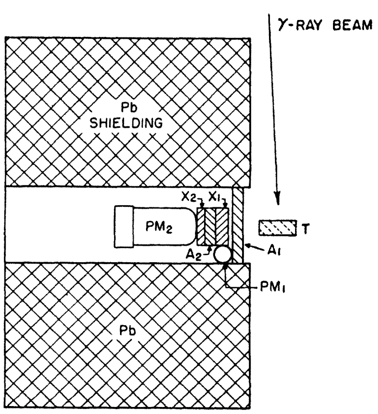

Fig. 1. Experimental arrangement for detecting the π-μ-e-decay.

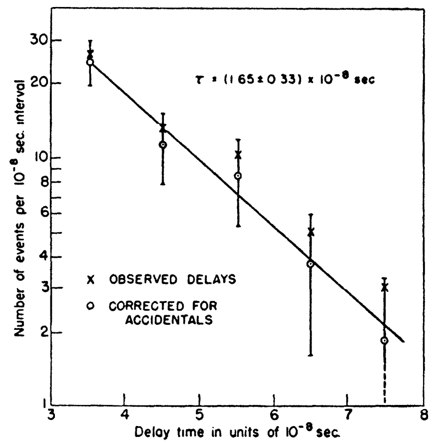

Fig. 2. Distribution of delayed events. The standard errors indicated are those for the data corrected for accidentals.

The synchrotron was operated at 315 Mev at a repetition rate of 2 pulses per second. Each pulse was about 100μsec. long, and produced an ionization of 0.025 roentgens in a Victoreen thimble r-meter surrounded by $\frac{1}{4}$ in.-Pb and placed in the beam 3 meters from the target.

In about 12 hours of operation some 25,000 pictures were taken, among which about 100 showed closely spaced double pulses. We selected a group of 57 satisfying the following criteria:

(1) time separation between 3 and $8\cdot10^{-8}$ sec.; (2) first pulse greater than $\frac{3}{2}$ and second pulse greater than $\frac{1}{2}$ of the average pulse produced by a minimum ionizing particle traversing 1 g/cm^{-2} of the crystal; (3) an additional pulse occurring within 5.7 μsec. which could be interpreted as being due to the electron from the decay of a μ-meson. The time distribution of these 57 double pulses is shown by the crosses in Fig. 2, in which the abscissa is the delay and the ordinate is the number of events per 10^{-8} sec. interval. We interpret these 57 events as being due mostly to π^+-decay processes. The following arguments confirm our interpretation:

(a) the time distribution (corrected for accidentals) of the additional pulses occurring within 5.7 μsec. is consistent with the known mean life of 2.15 μsec. for the μ-meson;

(b) events such as these plotted on Fig. 2 may occur by chance. However, the computed number of chance events over the period of observation is only 1.5 per 10^{-8} sec. interval. Measurements between $8\cdot10^{-8}$ sec. and $20\cdot10^{-8}$ sec. indicated the existence of a background of this magnitude. Sixteen events satisfying criteria (1) and (2) above, but not (3), (i.e., events *unaccompanied* by a third pulse) show a distribution of delays consistent with the hypothesis that most of these events are accidental. The absolute number is also consistent with this hypothesis.

(c) Delayed pulses might conceivably be produced by unexpected fluctuations in the light emission of the crystal or by some short-lived induced radioactivity. This, however, is ruled out by