It is of interest that the fluctuations by which the data deviate from smooth curves can be correlated with the distribution of stable isotopes present in the natural elements used as targets, together with the variations in excitation energy required for reaction of the different isotopes. The excitation energies were estimated with the assumption that alpha-particles are favored over other charged particles in their evaporation from excited nuclei, and the agreement obtained affords some support for this hypothesis.

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* Present address: Department of Chemistry, Washington University, St. Louis, Missouri.

[1] B. B. Cunningham *et al.*, Phys. Rev. **72**, 739 (1947); H. H. Hopkins, Jr. and B. B. Cunningham, Phys. Rev. **73**, 1406 (1948).
[2] W. M. Good, D. Peaslee, and M. Deutsch, Phys. Rev. **69**, 313 (1946).
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## Variation of Meson Intensity with Height

P. H. Barker
*Dominion Physical Laboratory, New Zealand*
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During January and February of this year, flights have been made with an airborne cosmic ray recorder at Ohakea, New Zealand (magnetic latitude 45°S). The array used in these experiments is essentially similar to that of Bhabha *et al.*[1] using 5.25 cm of lead as an absorber. The major difference is in the filling of the counters, ether being used as the quenching gas to improve the low temperature performance. This equipment was mounted in the cannon compartment of a "Mosquito" aircraft and on the two successful flights a height of 30,000 feet was achieved. Pressure, time, and counts were recorded by a 16 mm ciné camera and the records when analyzed gave the results shown in Table I.

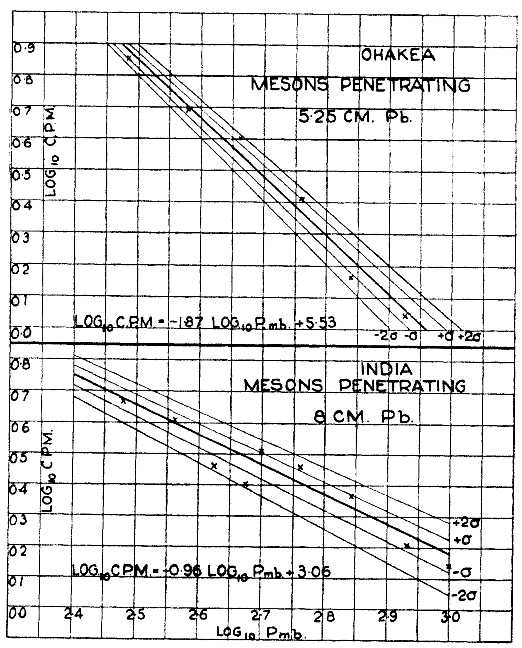


FIG. 1. (a) Mesons penetrating 5.25 cm Pb at Ohakea, New Zealand. (b) Mesons penetrating 8 cm Pb in India.

TABLE I. Analysis on all data from two flights.

| Height in feet | Pressure in mb | Counts per min. |
|---|---|---|
| 30,000 | 305 | 7.85 ±0.35 |
| 25,000 | 380 | 4.85 ±0.29 |
| 20,000 | 465 | 4.00 ±0.25 |
| 15,000 | 575 | 2.57 ±0.29 |
| 10,000 | 695 | 1.45 ±0.18 |
| 5,000 | 845 | 1.10 ±0.12 |

From the relationship between the integral momentum and range spectra, it is known that, for heights lying in the range represented by pressures between 250 mb and 1000 mb, the variation of meson intensity with height can be represented adequately on a double logarithmic plot by a straight line with a slope of approximately −2. Logarithms of counts per minute and pressure in millibars were accordingly taken and a least squares fit of a straight line was made to the points. The resultant line was found to be:

$$\log_{10} \text{C.P.M.} = -1.87 \log_{10} P_{\text{mb}} + 5.53, \tag{1}$$

and this is shown in Fig. 1a, together with the observed points. A similar procedure was carried out for the data obtained by P. S. Gill[2] for mesons penetrating 8 cm of lead; this equation is:

$$\log_{10} \text{C.P.M.} = -0.96 \log_{10} P_{\text{mb}} + 3.06, \tag{2}$$

and this line with its associated points is plotted in Fig. 1b. The limits for 1 and 2 times the standard deviation of the observations are also shown for both these equations. It will be seen that none of the observed points fall outside these limits and hence by the criteria suggested by Jánossy[3] we are not able to regard any such deviations from the straight line as statistically significant. From neither of these experiments, therefore, are we entitled to draw any conclusions as to the anomalous production of mesons and the present evidence for the existence of the anomaly suggested by P. S. Gill, must be regarded as inadequate.

In a paper by Gill, Schein and Yngve,[4] the change of latitude effect of the hard component with height is considered and the suggestion made that the null result obtained by Bhabha is due to differences between the geometry of the various equipments compared. The geometry of the apparatus with which the Ohakea results have been obtained is identical with one used by Bhabha and so enables a check on this assumption. The following method was adopted. Straight lines were fitted by the method of least squares to the results obtained by Bhabha and by Gill and Schein. In the latter set the points above 250 mb have been omitted as these are beyond the region for which linearity can be assumed. If we take:

$$y = \log_{10} \text{C.P.M.}, \quad x = \log_{10} P_{\text{mb}},$$

we obtain the following equations.

$$\left.\begin{array}{lll} y=-1.89x+5.40 & \text{India } \lambda=3°\text{N} & (3) \\ y=-1.87x+5.53 & \text{Ohakea } \lambda=45°\text{S} & (1a) \end{array}\right\} \text{O.I.}$$

$$\left.\begin{array}{lll} y=-1.08x+3.59 & \text{Gill and Schein } A\lambda=0° & (4) \\ y=-1.10x+3.76 & \text{Gill and Schein } B\lambda=40°\text{N} & (5) \end{array}\right\} \text{A.B.}$$

From the coefficient of $x$ in these equations it will be seen that the change of latitude effect with height is very small for either pair and it would seem as if the null result obtained by Bhabha is correct. These lines however represent only the least squares fits for one particular sample and there is no guarantee that if further flights were to be made a different slope of line would not be obtained. To estimate the probable limits within which the change of latitude effect may lie, the appropriate values of the standard deviations of the observed points were applied as corrections to the least square lines at 250 mb and 1000 mb in such a way as to minimize the slope of the equatorial line and maximize that of the high latitude line. The values so obtained for the change of latitude effect with height are O.I. = 28 percent, A.B. = 11 percent. These agree reasonably well and we can therefore say that it is probable that the change of latitude effect with height lies between 0 and 11 percent, i.e., if the latitude effect at 1000 mb, is $x$ percent then the latitude effect at 250 mb will be $(x+11)$ percent. If no change of latitude effect with height is assumed then the sea level latitude effect is found to be 41 percent for O.I. and 49 percent for A.B. These values do not agree at all well with those actually observed at sea level, the maximum value found being known to be of the order of 10 percent. It seems therefore that some change of latitude effects with height occurs. An unknown absolute difference exists between the data in O.I. due to a possible difference in sensitivity, but this should not occur for A.B. This difference, however, will not affect the slope of the lines obtained. It appears that further work, using equipment giving results with a statistical error of $<1$ for a recording period of 60 minutes would be necessary to clarify the situation.

These experiments have been carried out as part of the research program of the Dominion Physical Laboratory with the assistance of the R.N.Z.A.F. whose help is gratefully acknowledged.

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## Evidence for the Photo-Fission of Uranium into Three Charged Fragments

E. W. Titterton and F. K. Goward
*Atomic Energy Research Establishment, Harwell, Berks, England*
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ILFORD type $D_1$ plates 100-$\mu$ thick have been impregnated with a saturated solution of uranium acetate and irradiated with 23-Mev $\gamma$-rays from the A.E.R.E. synchrotron. Exposures of up to 300R have been employed and photo-fissions are observed at approximately the rate to be expected from the cross section given by Baldwin and Klaiber.[1]

In the course of examining the plates 4 cases of photo-fission into three charged fragments have been found, a photomicrograph of one of which is given in Fig. 1. Details of the four events are given in Table I. We believe these events to be the first observed cases of this phenomenon in photo-fission. A tentative value for the rate of occurrence of this mode of fission can be given as 1 per $400\pm200$ binary photo-fissions.

In general form the events are similar to those observed in the ternary fission of $U^{235}$ by slow neutrons[2–4] and, as in that case, the appearance of the tracks is compatible with the long range particles being $\alpha$-particles.

The possibility that the observed fissions were induced by the neutron background and not by $\gamma$-rays has been considered. Calculations and measurements comparing the fission rates in and out of the $\gamma$-ray beam both show that the observed rate of binary fission is at least fifty times as great as could be accounted for by the slow and fast neutron backgrounds. In addition,

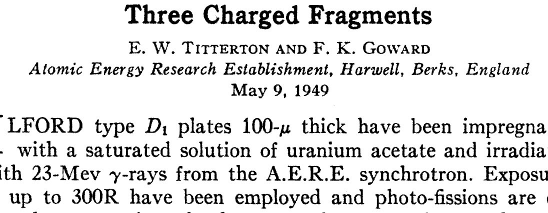

Fig. 1. Photomicrograph of event 2. Observer: Mrs. B. D. Mathieson. The long range light particle leaves the emulsion at the surface. The heavy fission fragments are wholly contained in the emulsion.

Table I. Details of four events indicating fission into three charged particles.

| Event | Observer | Range of short fragment microns | Range of long fragment microns | Range of $\alpha$-particle microns | Energy of $\alpha$-particle Mev | Angle of emission of $\alpha$-particle relative to long fragment (degrees) |
|---|---|---|---|---|---|---|
| 1 | Miss A. M. Graham | 10.7 | 13.2 | 177 | 19.0 | 54 |
| 2 | Mrs. B. D. Mathieson | 8.9 | 12.8 | 143* | 16.6* | 105 |
| 3 | Mrs. B. D. Mathieson | 9.2 | 9.7 | 240 | 21.8 | 85 |
| 4 | Mrs. B. D. Mathieson | 12.5 | 13.8 | 100* | 14.0* | 76 |

* Track leaves emulsion.

(1) Experiments on the slow neutron ternary fission of $U^{235}$ indicate a rate of occurrence of ternary events in which the $\alpha$-particle has an energy exceeding 14 Mev as about 1 per 1000 binary fissions.[4]

(2) According to Tsien *et al.*,[2] the fission of $U^{238}$ with fast neutrons does not give rise to tri-partition with a third fragment of range greater than 5-cm, air equivalent.

Combination of these results provides strong evidence that the 4 events are examples of the photo-fission of uranium in which a long range light particle is emitted in addition to the heavy fission fragments.

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## On the Penetrating Component of Cosmic Ray Air Showers*

Frank L. Hereford
*Bartol Research Foundation of the Franklin Institute, Swarthmore, Pennsylvania*
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RECENT experiments, carried out by Cocconi, Cocconi-Tongiorgi, and Greisen[1] have shown that the particles associated with extensive cosmic ray air showers which are capable of penetrating 17.5 cm Pb are thereafter absorbed very slowly with a mean range of approximately 3600 g/cm² Fe. This fact was cited as evidence that the penetrating particles are mainly $\mu$-mesons. However, evidence has also been presented for the existence of penetrating nuclear particles in extensive showers.[2,3]

In the experiment to be described the detection of such heavy particles was attempted through the measurement of the counting efficiency of a tray of low pressure G-M counters under 18.5 cm Pb (200 g/cm²) for single penetrating shower particles. The presence of an appreciable fraction of nuclear particles more heavily ionizing than $\mu$-mesons would be indicated by an increase of counting efficiency for penetrating shower particles over that for the total penetrating radiation at sea level. This latter radiation is known to consist predominantly of $\mu$-mesons with very nearly minimum specific ionization.

The apparatus (Fig. 1) contained three trays (E, 1, 3) of argon-ether counters filled at a sufficiently high pressure (90 mm Hg) to yield an efficiency of very nearly 100 percent. In tray 2 were placed alternately a set of thirteen similar argon-ether counters and a set of helium-amyl acetate counters of identical geometry