The Fermi Proton Effect

E. Fermi and his co-workers[1] have recently discovered the remarkable effect of proton containing substances in *increasing* the yield of artificial radioelements during neutron bombardment. We had an opportunity to study this effect and some of our results are communicated below.

A silver cup was irradiated for 15 minutes with neutrons, from a Be-tube with 200 mC Rn, (1) in air, (2) filled to the rim with pure water and (3) filled and surrounded with water. The increase in activity depends to a great extent on the geometry of irradiation. The dimensions in case 3 are shown in Fig. 1.

The emitted electrons were counted by means of a He-filled Geiger-Müller tube and a thyratron operated counter. The results are plotted on logarithmic paper, as given in Fig. 2.

Filling the cup with water increases the silver activity three-fold and by surrounding it with water the activity is still further increased by a factor of 3–4. This increase is also produced in about the same degree by *n*-pentane (n-C_5H_{12}), while the effect of carbon tetrachloride (CCl_4) and carbon disulfide (CS_2) is practically negligible.

The addition of 5 percent uranyl nitrate to the water reduces the effect of pure water, as does boric acid.[1] The introduction of an Al-cylinder of 0.03 mm wall thickness between source and cup has practically no effect.

This Fermi phenomenon was also observed with iodine and aluminum cylinders. One should expect the same effect with neutrons produced by artificially accelerated ions.

In agreement with Fermi and as expressed by one of us in discussions previously, we believe that as the neutrons loose their energy by collisions they are more and more easily captured by nuclei with the production of stable or radioactive isotopes. The protons of the water absorb the energy of the neutrons by elastic collisions and the probability of capture of neutrons by protons (deutons will be investigated) is evidently small, since a large quantity of neutrons are reflected backwards (see case 3).

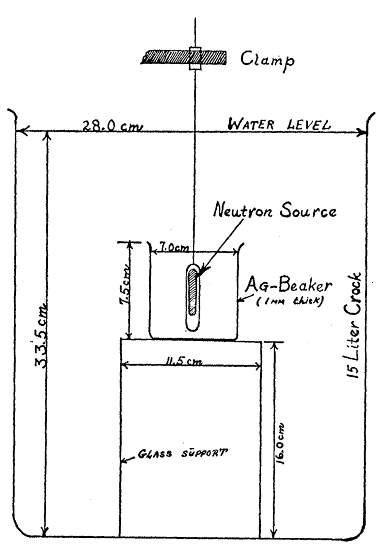

FIG. 1. Method of irradiating.

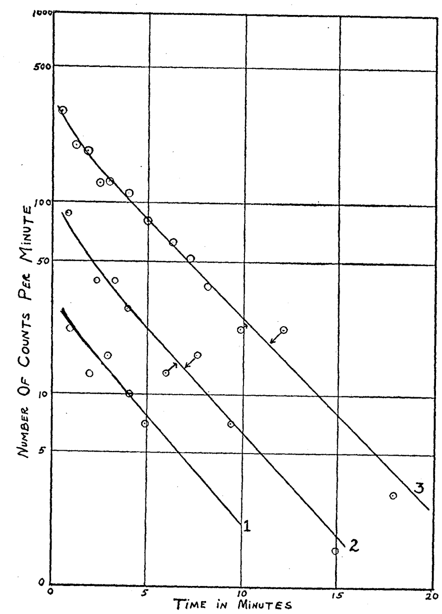

FIG. 2. Variation of the activity produced by bombarding silver with neutrons. (1) *AG*-beaker in air; (2) *AG*-beaker with water inside; (3) *AG*-beaker filled with and surrounded by water.

It would be interesting to determine the neutron capture probability of different elements or isotopes placed between the source and the silver (or any other suitable material) and as indicated by the activity of the latter.

It is a pleasure to acknowledge our indebtedness to Dr. M. Cutler, of Michael Reese Hospital, for our sources and to Dr. W. D. Harkins for the loan of metallic beryllium.

A. v. GROSSE
M. S. AGRUSS

Kent Chemical Laboratory,
University of Chicago,
December 10, 1934.

[1] E. Fermi, E. Amaldi, B. Pontecorvo, F. Rasetti and E. Segrè, La Ricerca Scientifica **2**, No. 7–8, No. 9–10 (1934).

North-South Asymmetry of the Cosmic Radiation in Mexico

During a recent survey of cosmic-ray angular distributions, northern and southern intensities were compared at six different zenith angles in the plane of the local magnetic meridian. Measurements were made at two elevations in geomagnetic latitude 29°. The first station, referred to by the name Copilco, was on a ranch near Mexico City at an elevation of 2280 m. The second station was a camp on the summit of Nevado de Toluca, a volcano in the State of Mexico, elevation 4300 m.

The apparatus used was a new multidirectional coincidence counter which simultaneously recorded the intensities from seven different zenith angles. (Because of high horizons the data for the lowest of these have not been used.) Frequent rotations of 180° about a vertical axis at regular intervals gave data for comparing the intensities from opposite azimuths at each of the zenith angles without relying upon long-time constancy of the instrumental sensitivity, nor upon knowing the relative sensitivities of different coincidence groups. The operation and recording were wholly automatic and it was only necessary to set up the apparatus and then afterwards to read the records.

The results of the north-south comparisons represent but a small part of the data obtained on the expedition, but since they present some new and unusual features they are reported in advance of the complete account of the work. A definite southern excess was found at most zenith angles and at both stations. These are represented in Fig. 1, by the ratios of the differences of the south and

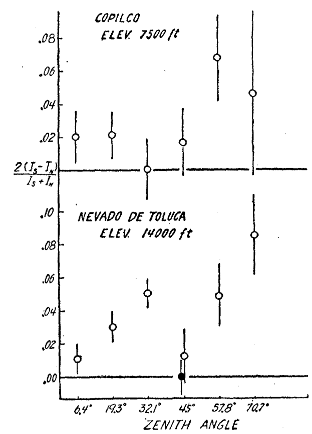

FIG. 1. Ratios of the difference to the average of south and north intensities at two stations in Mexico.

north intensities to their average value. Each point in the figure is the average of many independent determinations, and from the dispersion of the individual data the probable errors can be determined with considerable accuracy. These are represented by the vertical lines. Data for angles near the horizon are characterized by a small number of counts and the probable errors are correspondingly large. The point represented by the full dot was obtained in the same latitude at an elevation of 11,000 ft. in 1932.

A north-south asymmetry of this general character was first predicted by Lemaitre and Vallarta, though the excluded region diagrams of Störmer give a basis for the qualitative explanation. If attention is limited to rays of a particular energy which arrive from a direction parallel to the plane of the meridian this fixes the scale on which to represent the radius of the earth and it fixes the shape of the excluded regions. The component of the motion of a charged corpuscle resolved parallel to the meridian plane which rotates so as to always contain the corpuscle, is similar to that of a small ball rolling in the horn-shaped potential valley, a portion of which is represented in Fig. 2.

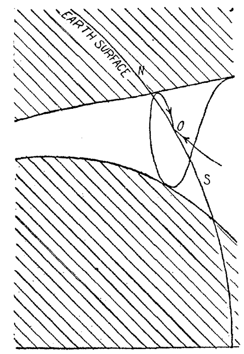

FIG. 2. Portion of the Störmer excluded region diagram for rays incident in the magnetic meridian in the latitude of Mexico, showing typical orbits incident from the north and from the south at the same zenith angle.

To be incident from the polar side of the observer at angles close to the horizon, rays would have to first pass through the earth as is indicated by the diagram, whereas from the equatorial side the orbit comes directly from external space. A lower northern intensity can thus be interpreted as a shadow effect. Since other energies are also to be taken into consideration the shadow is only a partial one. These considerations seem to account for the asymmetry at angles close to the horizon but the asymmetry near the zenith would seem to require more complicated orbits which first enter the horn on the opposite side of the equator where they penetrate the earth, thence passing out again, crossing the equator, and arriving at the point *O*. Recent calculations by Lemaitre and Vallarta have indicated the existence of such orbits and it is possible that they may account for the observed asymmetry at angles close to the zenith. It would also seem possible to account for a dip in the asymmetry such as is observed at 45° by a consideration of these same orbits. However, it is possible, though not probable in view of the similar results at both stations, that this dip is due to statistical fluctuations.

If the north-south asymmetry is to be attributed to shadow effects, along the lines indicated, it should depend upon the sum of the positives and negatives, and not upon their difference as in the case of the east-west asymmetry. The effect should disappear at the equator and should appear as a northern excess in southern latitudes.

I am indebted to M. S. Vallarta for urging me to make these further studies of the north-south intensities, as well as for his cooperation in carrying out the work. I also wish to acknowledge my gratitude to Dr. C. S. Margain for the use of his facilities at Copilco, to the Federal Government of Mexico for assistance on Nevado de Toluca, and to Mr. Lewis Fussell, Jr., for his help with the measurements and reduction of data. The work was carried out under a grant from the Carnegie Institution of Washington, administered by the Cosmic Ray Committee and the Department of Terrestrial Magnetism.

THOMAS H. JOHNSON

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