It is felt that further refinements of the method presented here, in which the energy corresponding to electron capture decay to identified excited states of the product nuclei are correlated with corresponding partial half-lives, will lead to more meaningful information as to the nature of the electron capture decay process. Until more complete information is available on the gamma-rays associated with each transition, and until more is known about the ratio of K to L capture in the decay of each isotope, this relationship must be regarded as provisional.

I am indebted to Professor Glenn T. Seaborg for many interesting and helpful discussions on this subject.

This work was performed under the auspices of the U. S. Atomic Energy Commission.

[1] G. T. Seaborg and I. Perlman, Rev. Mod. Phys. 20, 585 (1948).
[2] L. B. Magnusson and G. T. Seaborg, unpublished work (Jan., 1949).
[3] Perlman, Ghiorso, and Seaborg, Phys. Rev. 74, 1730 (1948).

Magnetic Deflection of Cosmic-Ray Mesons Using Nuclear Plates*

IAN BARBOUR
University of Chicago, Chicago, Illinois
June 1, 1949

A METHOD has been described[1] in which two nuclear plates are exposed with an air gap separating their parallel emulsion surfaces, in a perpendicular magnetic field (see Fig. 1). Using a permanent magnet weighing 65 lbs., field strength 13,300 gauss, two balloon flights were carried out with Ilford C2 emulsions, one above 90,000 ft. for 1 hour with 100-μ emulsions, the other for 3 hours with 200-μ emulsions. After development, positions of particles, stopping in the emulsion, relative to the x-ray registration dots, is plotted by means of a pantograph attached to the microscope stage,[2] and the azimuth of the track on emergence measured with an eye-piece protractor. Matching of track segments due to a single particle in the two plates is ascertained by the equality of the following quantities: (a) the dip angles, q_T and q_B in Fig. 1, between emerging track and emulsion surface, accurately measured with a tilting stage;[2] (b) grain counts, (c) estimates of scattering, and most important, (d) the two deflections, Δ_T (obtained by projecting the bottom track) and Δ_B (from projecting the top track). Where a $\pi-\mu$-decay occurs in one plate and the μ-meson crosses the air gap to stop in the other plate, the total μ-meson range gives additional certainty in matching. The magnetic radius is computed from the two independent deflection measurements, Δ_T and Δ_B. Assuming singly-charged particles, and that the energy-loss is a function of velocity only, it can be shown that $R/m=f(R/H\rho)$, where R (range), H (field), and ρ (curvature) can be experimentally determined, but m (mass) is unknown. From range-energy curves[3] for protons in an Ilford emulsion, the function f was graphed, allowing determination of the mass of other particles. The probable error in each angular deflection is the sum of: (a) theoretical average scattering angle,[4] for a particle of the range and mass determined, (b) emulsion distortion (measured "deflections" of a control series of 60 protons with *no* field approximated a Gaussian curve with standard deviation $\frac{1}{2}°$, excluding emulsion areas less than 8 mm from plate edges), (c) instrumental errors (these will be negligible when positions are re-measured with micrometer-thread stage motions readable to 1μ). As scattering introduces the greatest uncertainty, measurements on particles with range 500μ or greater are desirable. Since for a given curvature, the deflection angle will increase with the path length in the air gap, particles with small dip angles will have smaller percent errors. Events have occurred with measured deflection angles 10 times the total probable error in angle, but cases of at least twice this accuracy can be anticipated.

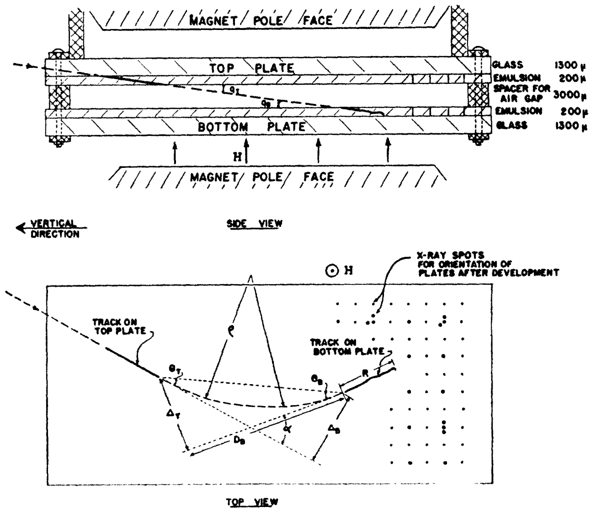

FIG. 1. Side and top view of plate assembly for magnetic deflection experiment.

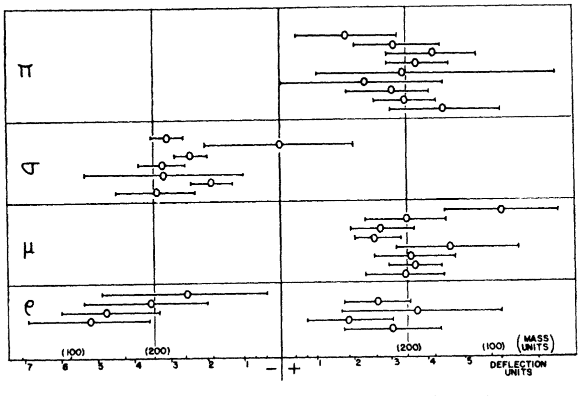

FIG. 2. Preliminary deflection measurements of cosmic-ray mesons, using nuclear plates.

After analyzing plates from the short flight, plus $\frac{1}{4}$ the emulsion area of the second flight, preliminary measurements have been obtained on 33 mesons, shown in Fig. 2. There is confirmation of the positive charge of π and μ-mesons, and the negative charge of σ (star-producing) mesons, concerning which there is no possibility of direct evidence on cosmic-ray mesons from other emulsion techniques like scattering, grain counting, etc. ρ-mesons (stopping with no visible interaction) appear about equally divided between + and −. Mass and probable error values are plotted on a "deflection unit" scale[5] and give, combining μ and ρ, 219±26; for π and σ, 270±23. There is no evidence in these experiments so far for the presence in appreciable abundance of "heavy" mesons, which could usually be differentiated from protons if they were negative or interacted visibly. The possible presence of "light" mesons cannot yet be excluded, as there are several tracks still "unmatched" (since a meson of mass less than $40m_e$ would experience a very large deflection, a much larger area of the opposite plate must be scanned for a possible matching segment from such a particle). After completion of analysis of the remaining $\frac{3}{4}$ of these plates, another flight is planned in which longer exposure and use of larger plates should give better statistics and accuracy.

The cooperation of Dr. Marcell Schein in this experiment is gratefully acknowledged.

* Assisted by a fellowship from the DuPont Company, and by the joint program of the ONR and the AEC.

[1] C. F. Powell, Nature **161**, 473 (1948); I. Barbour, Phys. Rev. **74**, 507 (1948).

[2] I. Barbour, Rev. Sci. Inst. **20**, 530 (1949).

[3] Lattes, Fowler, and Cuer, Proc. Phys. Soc. **59**, 883 (1947).

[4] E. J. Williams, Phys. Rev. **58**, 292 (1940); Goldschmidt-Clermont, King, Muirhead, and Ritson, Proc. Phys. Soc. **61**, 183 (1948).

[5] For any range or path length, a given increment in deflection angle is essentially represented by the same number of deflection units in all parts of the scale. Mass values are averaged, weighted as the inverse squares of probable errors, on this scale.

A Large Nuclear Disintegration Produced by a Very High Energy Alpha-Particle of the Cosmic Radiation*

J. J. Lord, Marcel Schein, and M. Vidale
Department of Physics, University of Chicago, Chicago, Illinois

May 31, 1949

INFORMATION regarding the manner in which extremely high energy nuclei interact with other nuclei is so limited that the following event of this nature is described as has been observed on an Eastman NTB-3 photographic plate, 150 microns in thickness, exposed in the stratosphere through the use of free balloons. The nuclear collision, as indicated by the tracks of the onizing particles involved, is shown in Fig. 1.

The method of grain counting has been employed in order to obtain information as to the possible nature of each track. Since the grain density is a function of the energy loss per micron, this quantitative relationship was obtained by measuring the grain densities of several long proton and meson tracks ending in the emulsion, and tracks due to single charged particles at minimum ionization. The relationship between grain density and energy loss will not be given, since it was within statistical error the same as that published by Powell and his collaborators[1] for the Kodak NT-4 emulsion.

Track A, Fig. 1, extends from the nuclear disintegration throughout the emulsion for 38,000 microns to a point in the glass backing of the plate. The measured grain densities at points 0.0, 1.5, and 3.6 cm from the disintegration are respectively 0.99, 0.98, and 0.98 grains per micron, as given by counting at each point about 500 grains.

This track, A, cannot be due to a meson, proton, or deuteron, since with this grain density, their corresponding ranges would all be less than 38,000 microns. In addition, for the above mentioned particles, including the triton, the grain density should show a considerable change along the track. The remarkable constancy of the grain density along the 38,000 microns is, however, in perfect agreement with that due to an alpha-particle close to its maximum ionization.

An alpha-particle with this grain density, which is very close to the minimum for double charged particles, would have to have an energy in excess of 3 Bev. In the plane of the plate, which was located vertically, the track A makes an angle of about 15° with the vertical. These facts strongly indicate that the alpha-particle was most likely a part of the primary cosmic radiation.

Track A' is of interest, since the measured grain density along its 3550 micron range within the emulsion is constant, and is within statistical error, the same as that of track A. This grain density corresponds either to that of a 70 Mev proton (and other singly charged particles of correspondingly low energies), or an alpha-particle of at least 3 Bev. A consideration of the sum of the energies of the particles causing the tracks other than A and A' and an assumption of an equal energy for neutrons emitted leads to a total energy release in the star of roughly 1 Bev. Thus, since A carries a momentum corresponding to at least an alpha-particle of 3 Bev energy, and since the other tracks, excluding A and A', do not show any preferential direction, momentum can be conserved only if track A' is also assumed to be due to a very high energy alpha-particle. This is in perfect agreement with the measured grain density of A'.

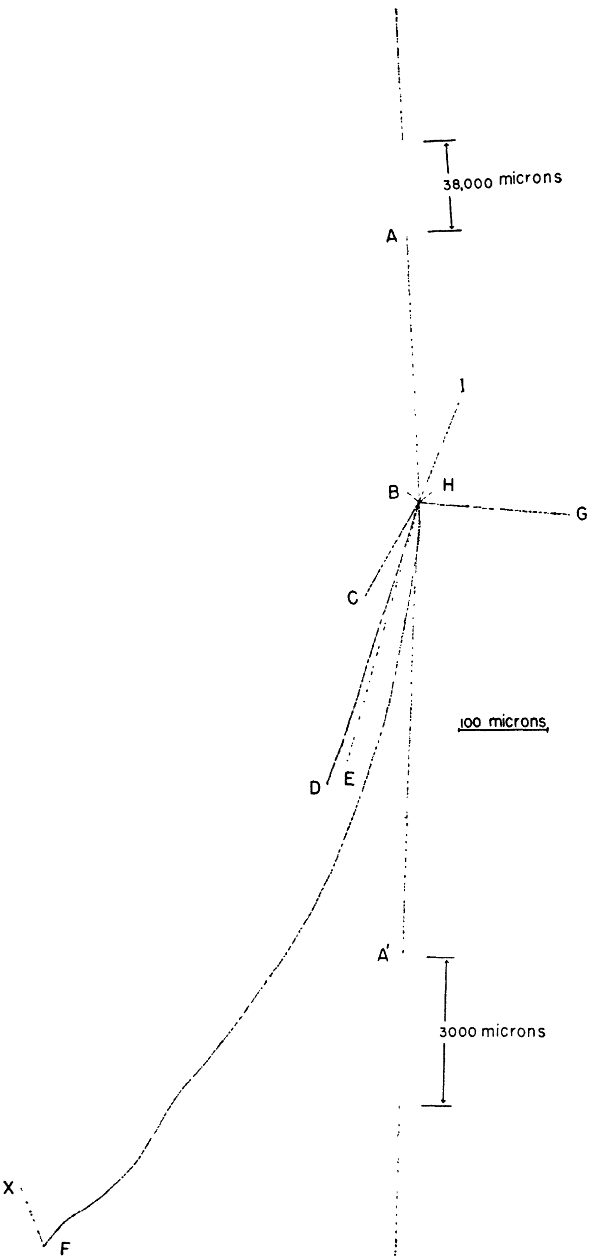

FIG. 1. Reproduction of a photograph showing a π-energy nuclear collision.

Tracks F and D end in the emulsion and were identified, respectively, as due to a π-meson and a proton. At the end of track F, a single track, X, of low grain density originates and passes into the glass backing after traversing 76 microns of emulsion. From its measured grain density track X could either be due to a μ-meson of energy, 4 Mev, or a proton of 31 Mev. The former view, which is more probable, would mean that tracks F was due to a positive π-meson undergoing the familiar decay to a μ-meson. The less likely alternative is that F could be due to a negative meson which, after stopping, is captured and produces a disintegration with the emission of a single ionizing particle with ionization which corresponds to that of a 31 Mev proton. However, it would be somewhat unusual if, as in this case, no other fragments of heavier nuclei occurred in the star.