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Production of Mesons by the 184-inch Berkeley Cyclotron

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Physics-General

University of California
Radiation Laboratory
Berkeley, California

Contract No. W-7405-eng-48

PRODUCTION OF MESONS BY THE 184-INCH BERKELEY CYCLOTRON

by

Eugene Gardner and C. M. G. Lattes

March 2, 1948

Special Review of Declassified Reports

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Physics-General

ABSTRACT

PRODUCTION OF MESONS BY THE 184-INCH BERKELEY CYCLOTRON

Eugene Gardner and C. M. G. Lattes

March 2, 1948

Radiation Laboratory, Department of Physics
University of California
Berkeley, California

We have observed tracks which we believe to be due to mesons in photographic plates placed near a target bombarded by 380 Mev alpha particles. For a 10-minute exposure in the cyclotron, about 50 meson tracks are found along the 3-inch edge of a photographic plate. The mass has been determined by measuring the bending in the magnetic field and the range in emulsion. From the first 50 meson tracks measured we find a mass of 313 ± 16 electron masses. It is highly probable that these mesons are the heavy mesons described by Lattes, Occhialini, and Powell.

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PRODUCTION OF MESONS BY THE 184-INCH BERKELEY CYCLOTRON

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Radiation Laboratory, Department of Physics
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Berkeley, California

We have observed tracks which we believe to be due to mesons in photographic plates placed near a target bombarded by 380 Mev alpha particles. The identification of the particles responsible for these tracks was first made on the basis of the appearance of the tracks; they show the same type of scattering and variation of grain density with residual range found in cosmic ray meson tracks by Lattes, Occhialini, and Powell¹, and roughly two-thirds of them produce observable stars at

¹ C. M. G. Lattes, G. P. S. Occhialini, and C. F. Powell, Nature 160
453, 486 (1947)

the end of their range. Their appearance is sufficiently characteristic that a practiced observer can recognize them on sight. Later the identification was confirmed by a direct determination of the mass from $H\beta$ and range measurements (to be described below) which gave the value 313 ± 16 electron masses, showing that they are almost certainly the heavy mesons described by Lattes, Occhialini and Powell.

The experimental arrangement is shown in Fig. 1. The circulating beam of 380 Mev alpha particles inside the cyclotron passes through a thin target, producing mesons and other particles; the negative mesons are sorted out by the magnetic field and roughly focused on the edge of a stack of photographic plates placed as shown. All the measurements reported

here refer to negative mesons produced in a carbon target by full-energy alpha particles, although a few observations have been made with other targets and energies. Beryllium, copper, and uranium targets were bombarded with full energy alpha particles and gave mesons in numbers comparable to those from carbon; a carbon target bombarded with 300 Mev alpha particles gave a greatly reduced yield.

The photographic plates used are Ilford Nuclear Research plates, type C.2, with an emulsion thickness of 50 microns; the exposure times were about 10 minutes and the alpha particle current about 1/10 microampere. Each plate shows about 50 meson tracks along its edge, with about ten times as many heavy particle tracks in the same area. The latter are attributed to stars and recoils produced by neutrons and are found all over the plates. Fig. 2a shows a typical meson track which produces a star, and 2b shows one which does not.

The opportunity for making a mass determination is furnished by the magnetic deflection of the mesons. By measuring the point and angle of incidence of each track on the edge of the plate, the radius of curvature in the field is determined. The range in the emulsion is measured with an eyepiece micrometer, and to this is added the path through a one mil aluminum foil covering the plates. (The earlier observations were made with black paper covering the plates but these are not suitable for range measurements because of the uncertain thickness of the paper.) A total of 49 tracks have so far been measured in this way. There is no significant difference between the masses of the star and no-star particles, and the mean mass of all the particles is 313 ± 16 electron masses; the spread in individual values is probably within the errors of the measurements. The most important source of error is the scattering of the particles in

the aluminum foil and in the first 80 microns of the emulsion. The angle measurements could not be made closer to the edge than this because of the distortion of the emulsion on processing.

The mass value found would indicate that at least 160 Mev should be available in the collision to produce these particles, and furthermore it seems likely that this energy should be concentrated in a single nucleon-nucleon collision. The means for this concentration is provided by the internal motions of the nucleons in the colliding nuclei, as first suggested by M. Millan and Teller² and further developed by Horning and Weinstein³.

² W. G. McMillan and E. Teller, Phys. Rev. 72 1 (1947)

³ W. Horning and M. Weinstein, Phys. Rev. 72 251 (1947)

According to this idea, there are three velocities to consider: the relative velocity of the two nuclei (corresponding to an energy per nucleon of 95 Mev), the velocity of a nucleon inside the alpha particle (corresponding to a maximum energy of about the Fermi limit, 25 Mev), and a similar internal velocity in the carbon nucleus. In the most favorable collision these can add together, giving an effective available energy of $1/2 (\sqrt{95} + \sqrt{25} + \sqrt{25})^2 = 195$ Mev in the center of mass system of the two nucleons concerned. Thus the observations are not inconsistent with a simple picture of meson formation by nucleon-nucleon collisions.

The measurements reported here are admittedly preliminary, and much more work is to be done, but it seems certain that this marks the beginning of meson study under controllable laboratory conditions. The large intensities, approximately 10^8 times those available in cosmic rays, mean that the rate of progress in this field can be greatly accelerated.

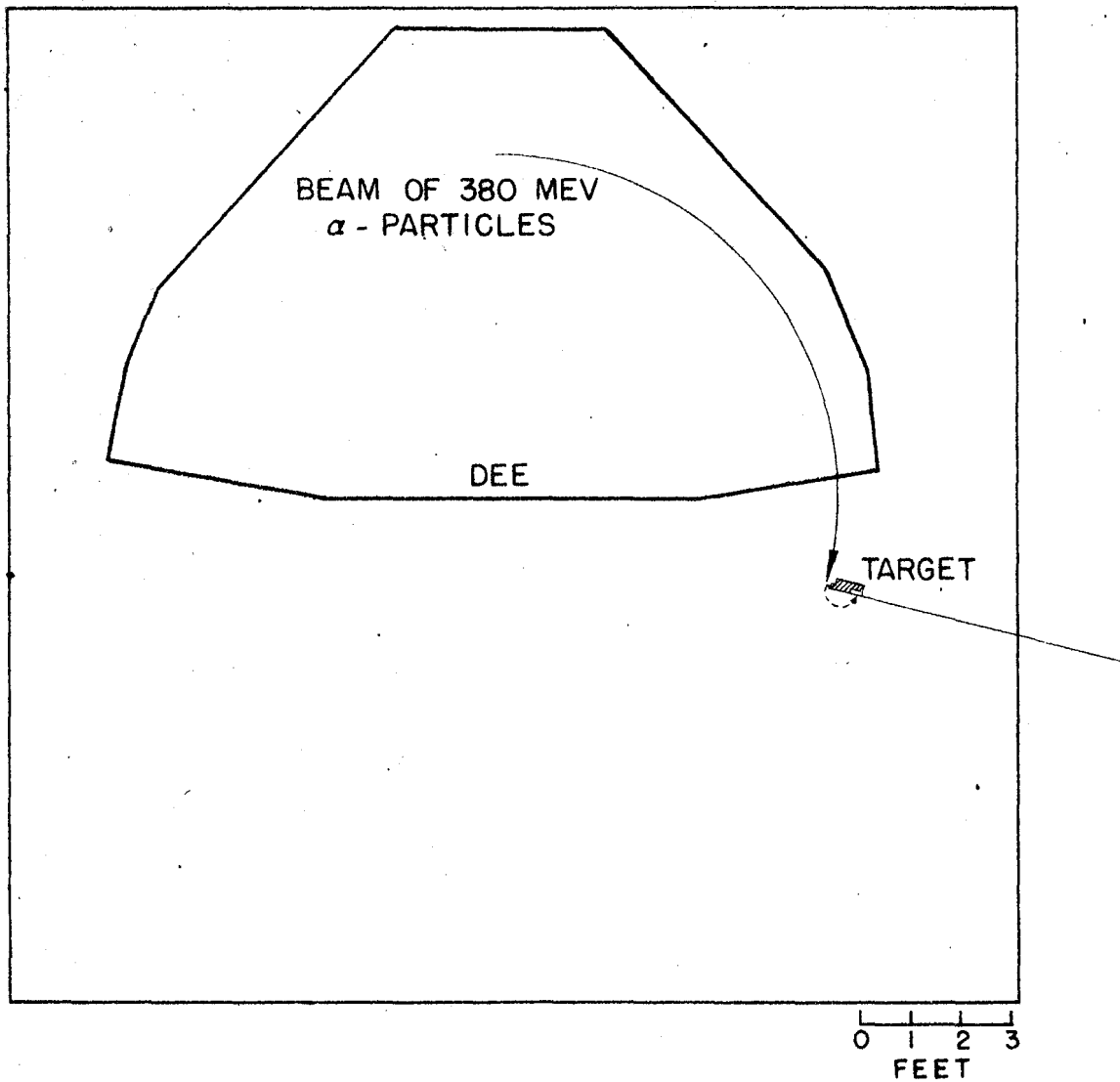
In conclusion, we wish to express our deepest appreciation to

Professor E. O. Lawrence whose interest and encouragement have made this work possible. The program has been greatly aided by help from Professor R. L. Thornton, Professor E. M. McMillan, Professor R. Serber, and Professor L. W. Alvarez. The authors are indebted to John Burfening, Lt. Col., U. S. Army, for his work on methods of exposing plates in the cyclotron. We also wish to thank Mr. D. J. O'Connell and Mr. A. J. Oliver for microscope work and photography, and Mr. Duane Sewell and the cyclotron crew for making the bombardments. The construction of the 184-inch cyclotron was made possible by a grant from the Rockefeller Foundation. This paper is based on work performed under Contract No. W-7405-eng-48, with the Atomic Energy Commission, in connection with the Radiation Laboratory, University of California, Berkeley, California.

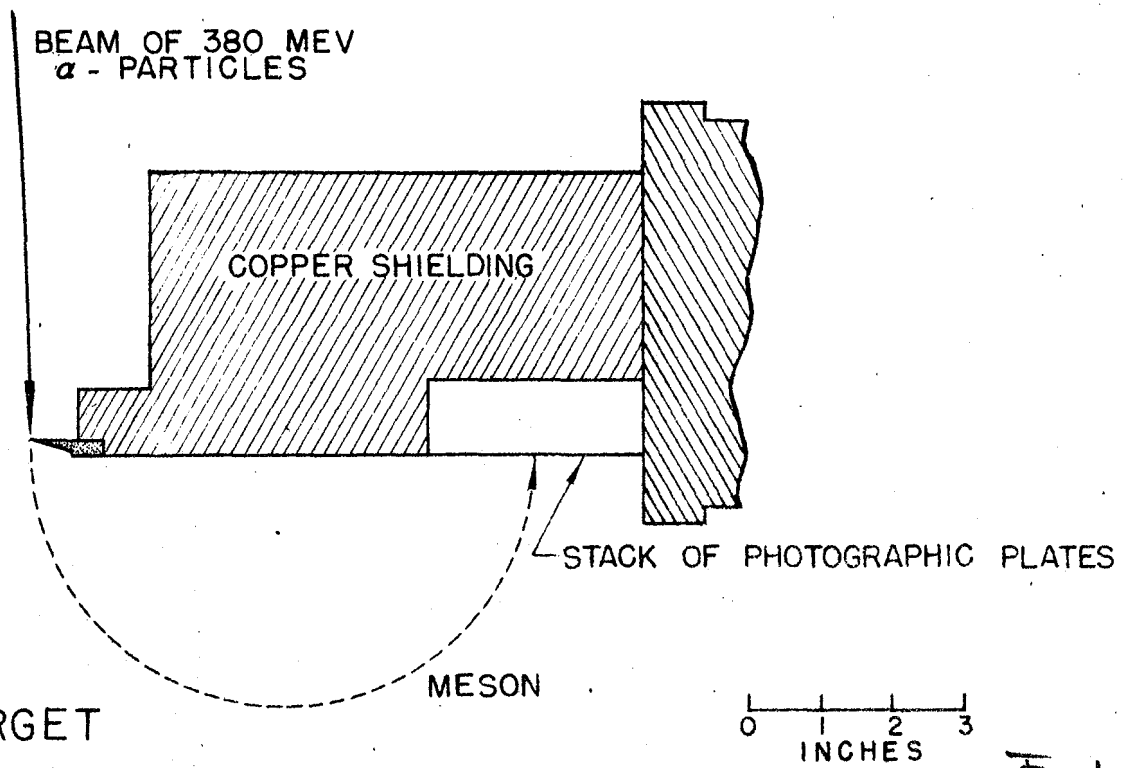
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Figure Captions

- Fig. 1. General arrangement of apparatus in the cyclotron. Top: Plan view of cyclotron, showing location of target assembly. Bottom: Detail view of target assembly showing position of stack of photographic plates.
- Fig. 2a. Track of meson which initiates a star. Meson enters plate on right and moves toward left, initiating star in upper left corner. Note scattering along track and increase of grain density toward star. The heavy dark line on the extreme right indicates the edge of the photographic plate.
- Fig. 2b. Track of meson which does not initiate a star. Meson enters plate on right and moves toward left. Note scattering along track and increase in grain density toward left.

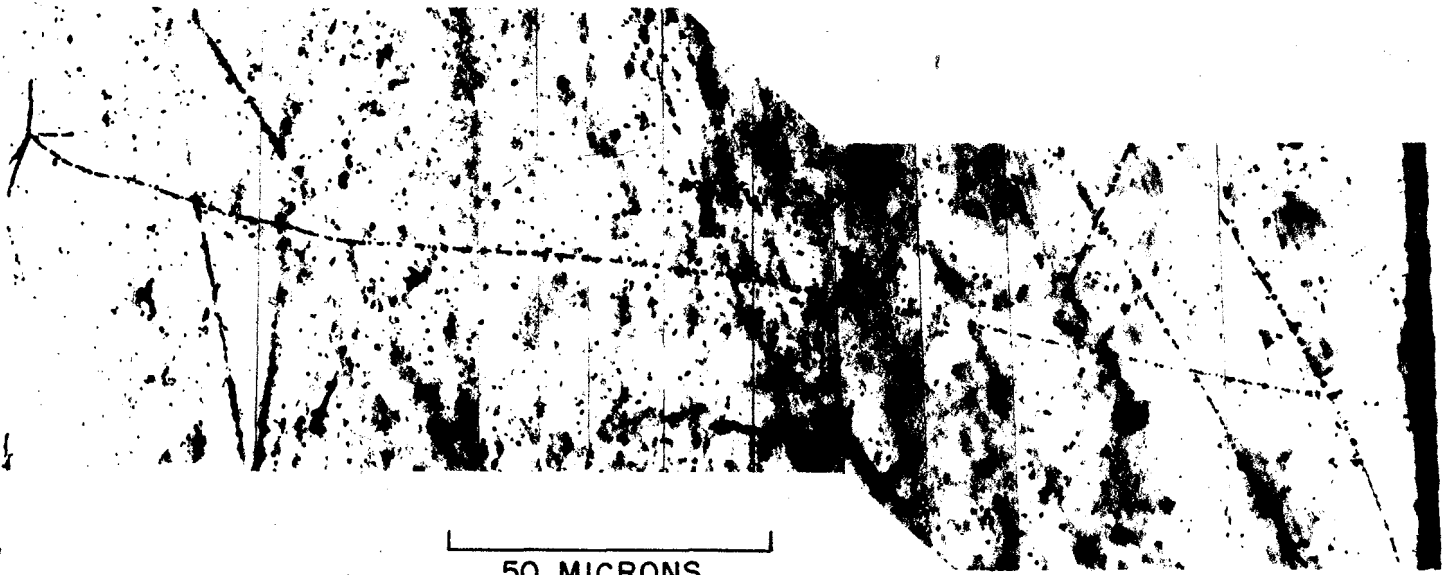


PLAN VIEW OF CYCLOTRON



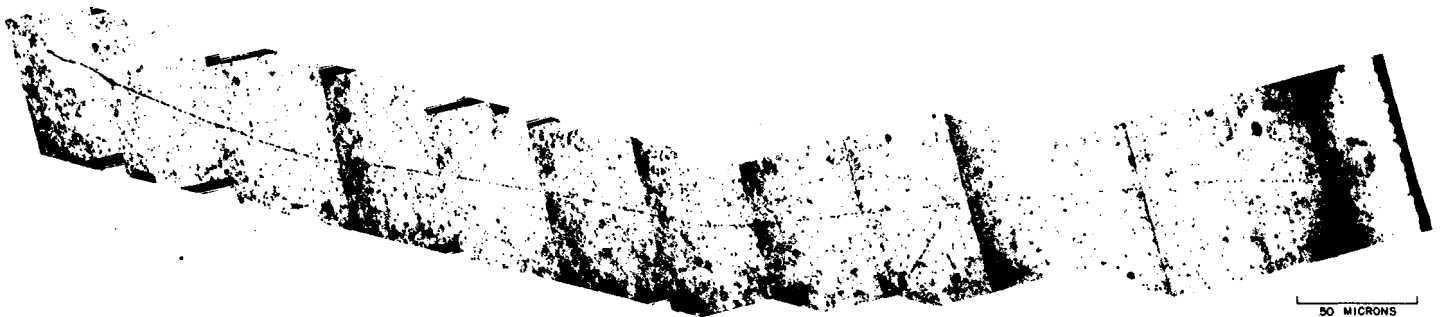
DETAIL OF TARGET

Fig. 1



50 MICRONS

2A



50 MICRONS

2B

