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James F. Miller

June 14, 1951

Berkeley, California

STARS PRODUCED IN NUCLEAR EMULSIONS BY CARBON IONS FROM THE CYCLOTRON

James F. Miller

Crocker Laboratory, University of California  
Berkeley, California

June 14, 1951

Carbon ions accelerated in the 60-inch cyclotron at Crocker Laboratory<sup>1,2,3,4,5</sup> have been used to expose nuclear emulsions, and a study of salient features is being made. This note states early results on the observation of inelastic nuclear events with the atoms of the emulsion. Ilford E-1 and D-1 nuclear emulsions were used. In the E-1 emulsion, the track of a carbon ion has a solid core, covered with electron spurs less than 2 microns long in the early part of the track and none in the later part. The track tapers appreciably and may have gaps near the end. In the D-1 emulsion the track is less dense and the tapering less noticeable.

The plates are exposed in the cyclotron vacuum to the external beam with nothing interposed between them and the beam. A set of three slits over a length of 26 inches serves to exclude all but a few extraneous charged particles. The plates are inclined so that the tracks dig into the emulsion at an angle of five degrees. Both  $C^{12}$  and  $C^{13}$  ions, completely stripped, have been used. Carbon<sup>12</sup> ions of 120 Mev energy have a range in the emulsion of 175 microns,  $C^{13}$  ions of 130 Mev have a range of 190 microns. Carbon ions ionized twice, rather than six times, can be accelerated in the cyclotron, using the cyclotron frequency as the third harmonic of their orbital frequency. These  $C^{2+}$  appear in great quantity in the internal cyclotron beam, and of these a small fraction is often found in the external beam. Their energy is one-ninth that of the  $C^{6+}$  and their range in the emulsion is about 2.5 microns.

Inelastic events in which charged particles are emitted are the only kind that can be definitely identified, and only these are included here.

From these events can be calculated a composite cross section for all the elements of the emulsion. In Ilford emulsions, the stated composition gives, out of 100 atoms, approximately 13 atoms each of silver, bromine, oxygen, and 17 of carbon, 41 of hydrogen, and 3 of minor constituents.

In calculating a cross section, the hydrogen atoms have been included here as capable of producing a star in contrast to the usual procedure when bombardment is with protons or neutrons. The full length of the carbon ion track has been used in the calculation. With  $C^{12}$  ions, 102 events have been found out of 181,000 tracks; with  $C^{13}$ , 108 events out of 188,000. These correspond to cross sections of  $0.40 \pm .03$  barns for  $C^{12}$ ,  $0.37 \pm .03$  barns for  $C^{13}$ . There follows a tabulation of the number of emergent prongs from the stars. Two-prong stars are included only when they could not have been elastic.

Prongs	2	3	4	5	6	7	Total
$C^{12}$	23	49	24	3	2	1	102
$C^{13}$	32	44	30	2	0	0	108

A feature of the stars is the high percentage of alphas emerging. Of protons emerging from carbon stars, the longest track lying wholly in the emulsion was 1046 microns, corresponding to an energy of 14.2 Mev. No "hammer tracks" from  $Li^8$  have as yet been observed.

The mosaic of Figure 1 shows a  $C^{12}$  ion stopped in Ilford 100 $\mu$ E-1 emulsion without a nuclear reaction and one which entered another nucleus, with seven emergent prongs. The  $C^{12}$  ion had traveled 63 microns when it entered the target nucleus and accordingly had about 90 Mev kinetic energy remaining. The seventh prong is hidden in the main mosaic since it is short and goes downward. Its presence is shown by the three pictures at the upper right, taken at increasing depths.

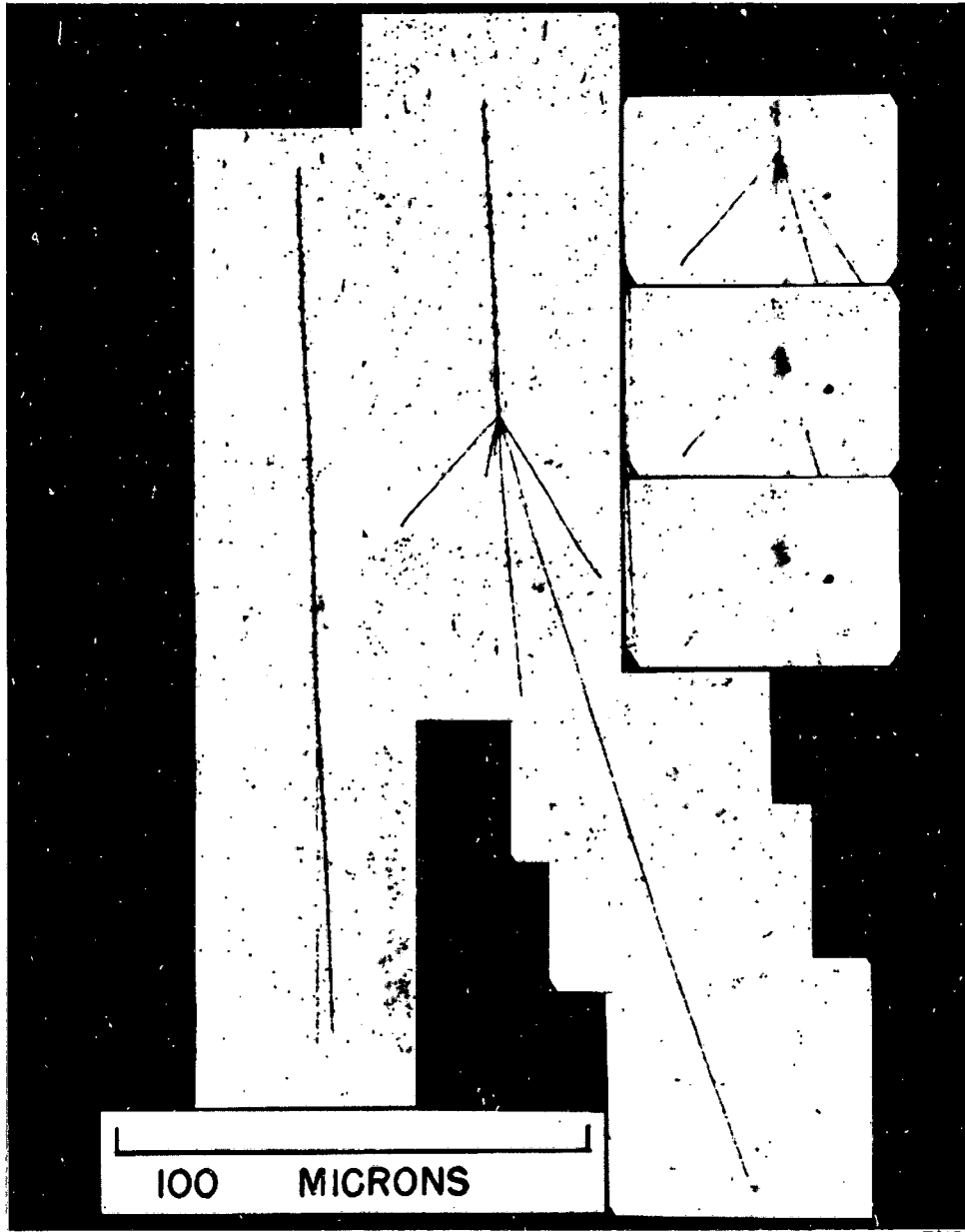


Fig. 1

$C^{12}$  ion tracks in Ilford E-1 emulsion. One stopped without nuclear event, the other produced a seven-pronged star.

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References

1. L. W. Alvarez, Phys. Rev. 58, 192 (1940).
2. C. A. Tobias, Ph. D. Thesis, University of California, Berkeley, (1941).
3. R. I. Condit, Ph. D. Thesis, University of California, Berkeley, (1942) and Phys. Rev. 62, 301 (1942).
4. H. York, R. Hildebrand, T. M. Putnam, and J. G. Hamilton, Phys. Rev. 70, 446 (1946).
5. J. F. Miller, J. G. Hamilton, T. M. Putnam, H. R. Haymond, G. B. Rossi, Phys. Rev. 80, 486 (1950).