Stars in Photographic Emulsions Initiated by Alpha-Particles

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A study has been made of stars in photographic emulsions initiated by alpha-particles from the 184-inch Berkeley cyclotron. These stars are similar to stars initiated by deuterons, which were described in an earlier paper. Eastman NTA plates were used. Plates from the emulsion number used will record alpha-particles of energy about 200 Mev and lower and protons of about 10 Mev and lower. The contribution of the high energy protons may be missing from the results given. The average number of prongs observed is close to 3. The ratio of the number of prongs in the three sectors in the forward direction of the beam to the number in the three backward sectors is about 6. The cross section for the formation of stars has been estimated by counting sections of alpha-particle tracks and the stars associated with these tracks. For alpha-particles of energy 130 Mev we obtain a value of the cross section, averaged over all of the atoms in the emulsion, of 3×10^{-25} cm^2 with an estimated uncertainty of 30 percent.

I. INTRODUCTION

A STUDY has been made of stars in photographic emulsions initiated by alpha-particles from the 184-inch Berkeley cyclotron.[1] The method of bombarding photographic plates in the cyclotron has been described in a paper on stars initiated by deuterons.[2] The stars initiated by alpha-particles are similar to those initiated by deuterons; however, in the case of the alpha-particle stars we were able to see the tracks of the initiating particles and, hence, to get an estimate of the cross section for the formation of stars.

The photographic plates used were Eastman NTA plates of emulsion thickness 35 microns. All were from the same batch, Emulsion No. 340,387, received February, 1947. This is the emulsion number used in a study[3] of alpha-particle and deuteron tracks, in which it was found that alpha-particles of 200 Mev and lower and protons of 10 Mev and lower can be followed easily. Tracks of higher energy protons may be missed. We are not able to tell from the experimental data how many proton tracks are missed for this reason. It is hoped that the data of the following sections will give useful qualitative information about the alpha-particle stars even though the contribution of the protons above 10 Mev is all, or in part, missing. Plates are now available which are much more sensitive than the plates used in this study. With the new plates it would be possible to see proton tracks at all energies which one would be likely to encounter in stars initiated by alpha-particles from the 184-inch cyclotron. Also it would be possible to extend the study to 380 Mev, the full energy output from the cyclotron. We hope at some time in the future to do a study of alpha-particle stars using the new Eastman NTB plates or one of the new Ilford types.

TABLE I. Composition of Eastman NTA emulsion.

Element	Percent composition	Weight (grams/cc)	Atoms/cc $\times10^{-23}$
Ag	47.1	1.700	0.0950
I	1.49	0.054	0.0026
Br	33.90	1.220	0.0920
O	4.80	0.173	0.0651
N	3.06	0.112	0.0482
C	8.47	0.305	0.1530
H	1.17	0.042	0.2509
Total		3.606	0.7067

II. NUMBERS AND DIRECTIONS OF STAR PRONGS

A group of stars initiated by alpha-particles of energy about 100 Mev is shown in Fig. 1. Stars

TABLE II. Average cross section for formation of stars by alpha-particles.

Energy (Mev)	No. of stars	Total path length (cm)	Mean path length (cm/star)	Average cross section (cm^2)$\times10^{24}$
50	12	2060	170	0.08
95	102	6870	67	0.21
130	138	6690	48	0.29
170	115	7650	67	0.21
210	99	9500	96	0.15

[1] W. M. Brobeck *et al.*, Phys. Rev. **71**, 449 (1947).
[2] E. Gardner and V. Peterson, Phys. Rev. **74**, 364 (1948).
[3] R. L. Brock and E. Gardner, Rev. Sci. Inst. **19**, 299 (1948).

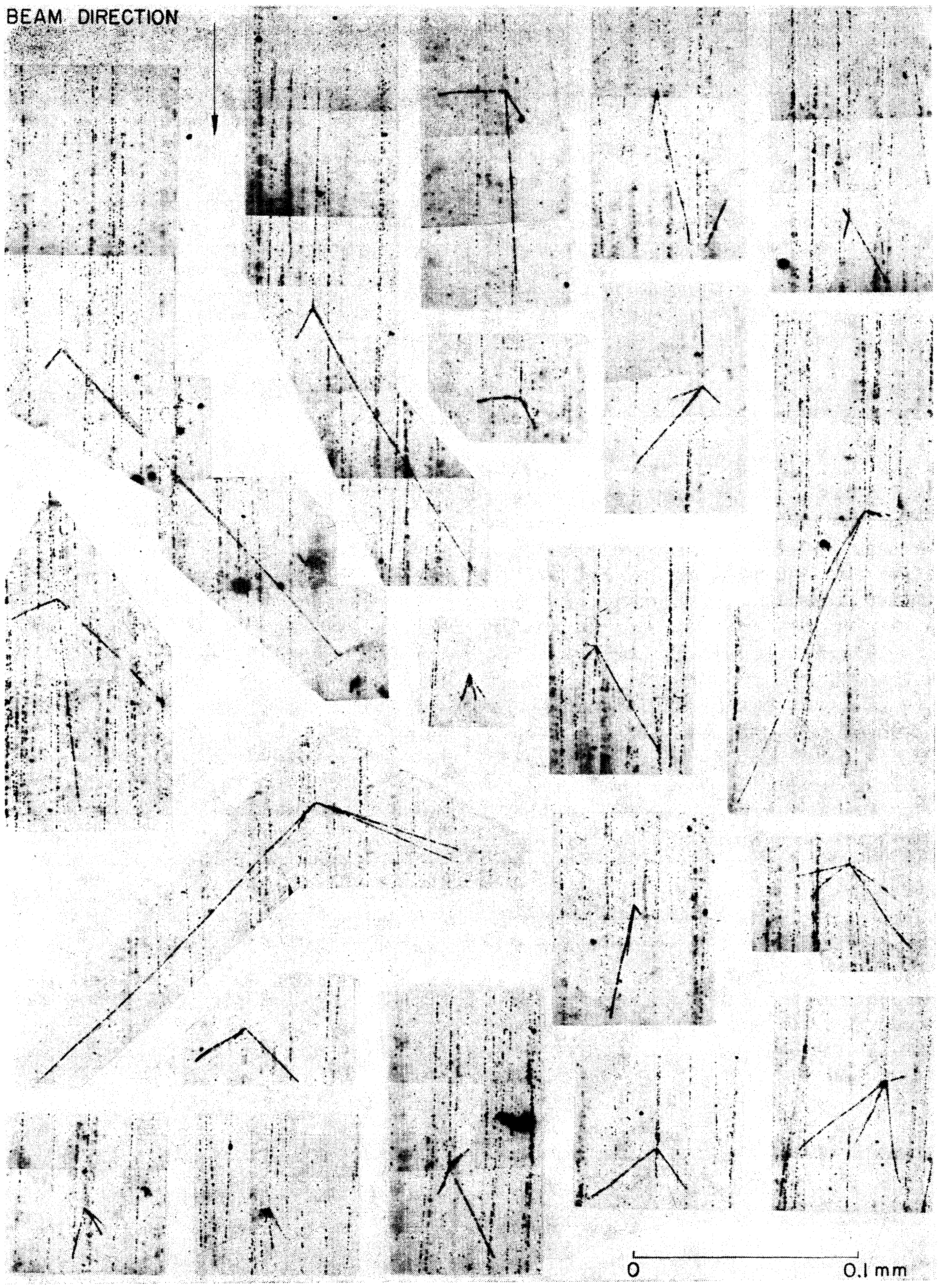

FIG. 1. Group of stars initiated by alpha-particles of energy about 100 Mev. (Photomicrographs made with 3-mm apochromatic objective lens.)

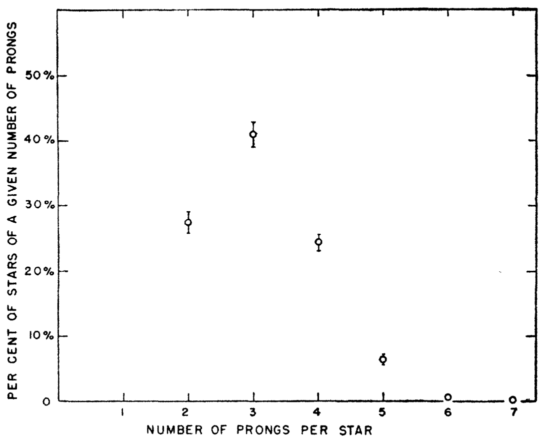

FIG. 2. Frequency distribution of stars of various numbers of prongs. Graph gives percent of stars of a given number of prongs as a function of the number of prongs. Stars from all energies (about 50 to 200 Mev) have been lumped together. Errors shown are statistical probable errors.

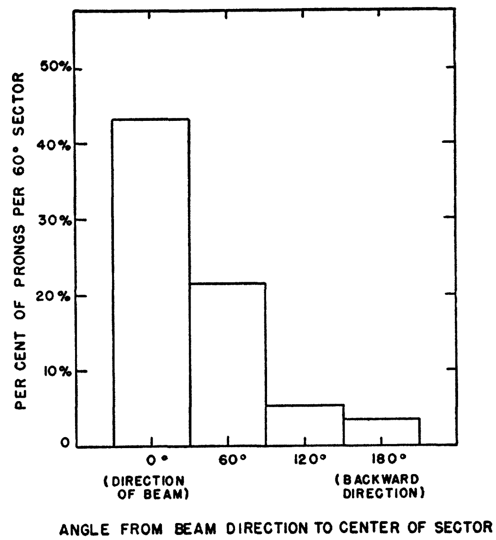

FIG. 3. Angular distribution of prongs. Histogram gives percent of prongs per 60° sector as a function of angular position of sector. Stars from all energies (about 50 to 200 Mev) have been lumped together.

initiated by alpha-particles at other energies were also observed; the full study included about 450 stars at energies from about 50 to 200 Mev. The numbers of prongs per star and the directions of the prongs with respect to the beam direction were remarkably similar for all energies studied, no differences being observed which were significantly larger than the statistical probable errors. In presenting the data here, stars from all energies have been lumped together. The frequency distribution of stars of various numbers of prongs is shown in Fig. 2. It is similar to the corresponding curve for stars initiated by deuterons.[2] The direction of the prongs with respect to the beam direction is shown in Fig. 3. The directions do not refer to the directions in three dimensions as the stars are originally formed in the emulsion, but to the projected directions as seen through the microscope. The field of view of the microscope was divided into 60° sectors, and a tabulation was made of the number of prongs in the various sectors. The ratio of the number of prongs in the three sectors in the forward direction of the beam to the number in the three backward sectors is about 6. This is to be compared with a ratio of 3 found for stars initiated by deuterons.[2]

III. CROSS SECTION FOR FORMATION OF STARS

In the photomicrographs shown in Fig. 1 the tracks of the direct alpha-particle beam can be seen as straight sections which are approximately parallel. Occasionally one of the tracks terminates in a star. By counting sections of tracks and the stars originating on these tracks, it is possible to get an estimate of the mean path length for formation of stars. The number of sections of tracks was found by counting tracks in sample areas. The number of sections actually counted was about 10 times the number of stars. The length of track was found by multiplying the number of sections of track by the diameter of the field of view of the microscope.

Since we have not been able to tell which elements in the emulsion were responsible for the stars observed, we are not able to find the cross sections associated with the different elements.

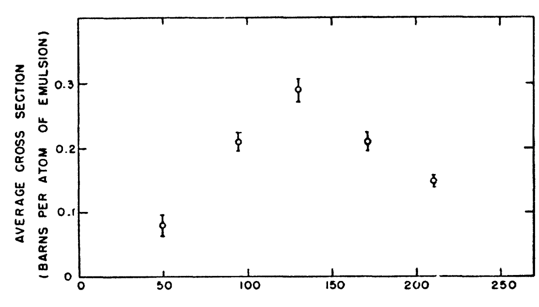

FIG. 4. Average cross section for formation of stars by alpha-particles as a function of the energy of the initiating alpha-particle.

All that we are able to give is an average over-all of the elements in the emulsion, calculated by using the total number of atoms per cc. The number of atoms per cc, as found from the chemical composition of the NTA emulsion, is shown in Table I. The figures given in Table I apply to the dry emulsion, no correction having been made for moisture picked up by the plates. The average cross section is shown in Table II and in Fig. 4.

IV. DEUTERON CONTAMINATION

One factor which prevented us from making a more accurate determination of the cross section was the presence of deuterons in the alpha-particle beam. Even after helium has been run into the ion source continuously for several days it is still possible to find deuterons in the beam. The number of deuteron tracks in the photographic plates varied from a few percent of the number of alpha-particle tracks to approximately as many as the number of alpha-particle tracks. Although deuteron tracks are not ordinarily seen at the energies at which we were working, they seemed to contribute enough developed grains so that there was some uncertainty in the count of the alpha-particle tracks. Different observers counting the same tracks have reported alpha-particle track counts which differ by 30 percent. This introduces an uncertainty in the cross sections given in Table II and Fig. 4. There is little confusion between stars initiated by alpha-particles and stars initiated by deuterons since it is ordinarily easy to tell whether an alpha-particle track ends at the star.

V. ACKNOWLEDGMENTS

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Positive Mesons Produced by the 184-Inch Berkeley Cyclotron

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Positive mesons produced by 380-Mev alpha-particles in the 184-inch Berkeley cyclotron have been detected by means of photographic plates. The experimental arrangement is similar to that used for detecting negative mesons except that the plates are placed in a position to receive positive instead of negative particles from the target. Heavy positive mesons are observed to decay into secondary mesons in the manner described by Lattes, Occhialini, and Powell. Relative numbers of positive and negative mesons coming from a target are found by placing plates symmetrically on opposite sides of the target. Preliminary results indicate that for a $\frac{1}{16}$-inch carbon target there are about one-fourth as many heavy positive mesons as heavy negative ones for meson energies of 2–3 Mev in the laboratory system.

I. INTRODUCTION

THE mesons first observed[1] at the 184-inch Berkeley cyclotron[2] were known to be negatively charged, since the photographic plates used for detecting them were placed in a position to receive negative but not positive particles from the target. We have now detected positive mesons by placing plates in a position to receive positively charged particles from the target. As with the exposures to negative mesons, the target

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[1] E. Gardner and C. M. G. Lattes, Science **107**, 270 (1948).
[2] Brobeck, Lawrence, MacKensie, McMillan, Serber, Sewell, Simpson, and Thornton, Phys. Rev. **71**, 449 (1947).

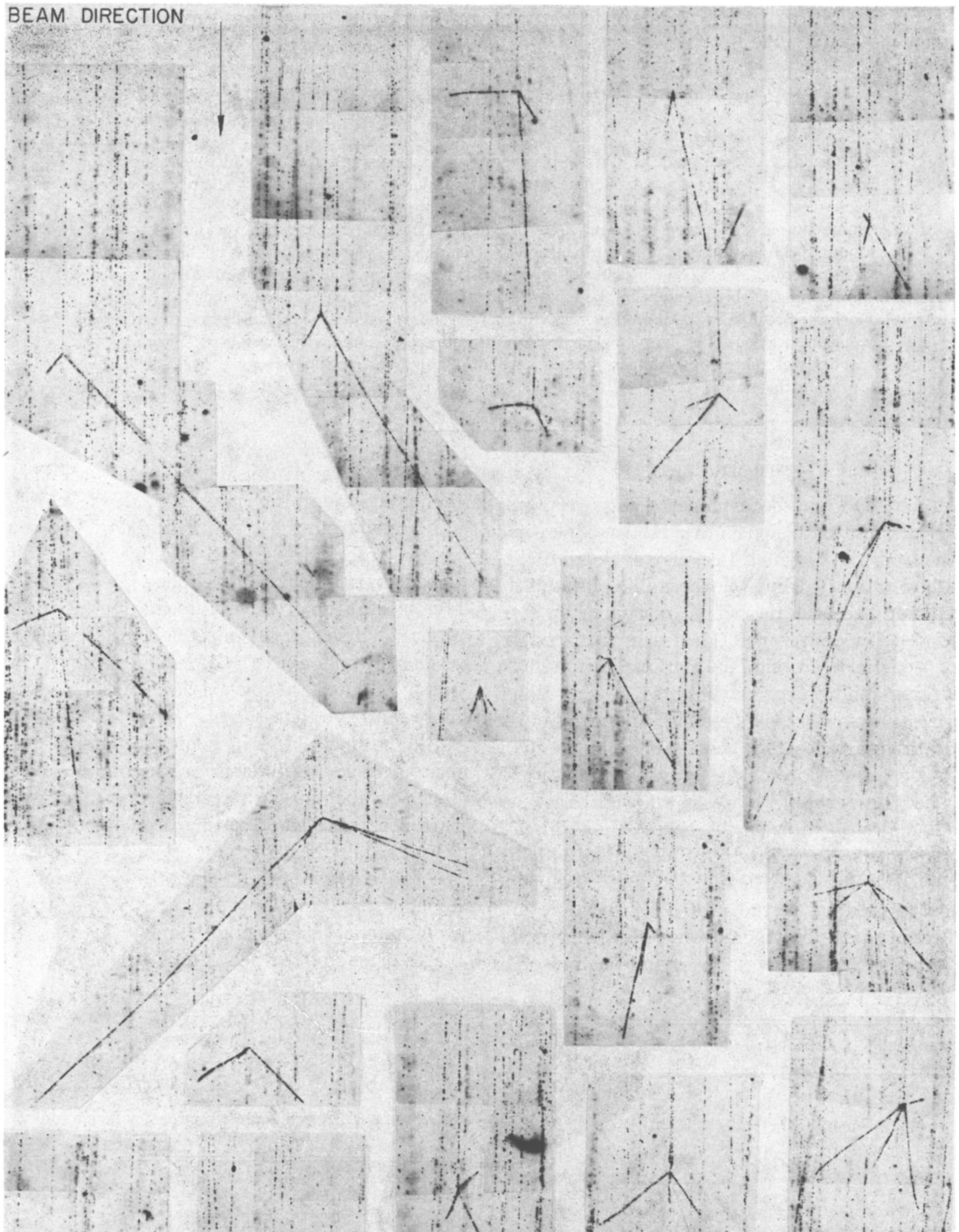

FIG. 1. Group of stars initiated by alpha-particles of energy about 100 Mev.
(Photomicrographs made with 3-mm apochromatic objective lens.)