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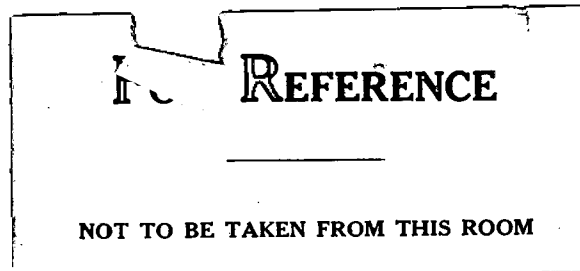
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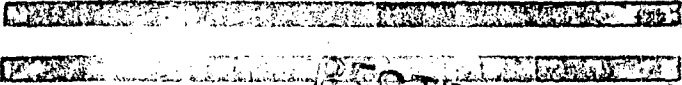
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STARS IN PHOTOGRAPHIC EMULSIONS INITIATED BY ALPHA-PARTICLES

Eugene Gardner

June 16, 1948

Berkeley, California

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ABSTRACT

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  $3 \times 10^{-25}$  with an estimated uncertainty of 30 per cent.

STARS IN PHOTOGRAPHIC EMULSIONS INITIATED BY ALPHA-PARTICLES

By: Eugene Gardner, Radiation Laboratory, Department of Physics, University of California.

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STARS IN PHOTOGRAPHIC EMULSIONS INITIATED BY ALPHA-PARTICLES

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1. Introduction

A study has been made of stars in photographic emulsions initiated by alpha-particles from the 184-inch Berkeley cyclotron<sup>1</sup>. The method of bombarding

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<sup>1</sup>W. M. Brobeck, E. O. Lawrence et al., Phys. Rev. 71, 449 (1947)

photographic plates in the cyclotron has been described in a paper on stars initiated by deuterons<sup>2</sup>. The stars initiated by alpha particles are similar to those initiated

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<sup>2</sup>E. Gardner and V. Peterson, Phys. Rev. (to be published)

by deuterons; however, in the case of the alpha-particle stars we were able to see the tracks of the initiating particle, 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. This is the emulsion number used in a study<sup>3</sup> of alpha-particle and deuteron tracks, in which it was found

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<sup>3</sup>R. L. Brock and E. Gardner, Rev. Sci. Inst. 19, 299 (1948)

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.

## 2. 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 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<sup>2</sup>. 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<sup>2</sup>.

### 3. 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. 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.

### 4. 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 per cent 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

Table I. Composition of Eastman NTA Emulsion

<u>Element</u>	<u>Per Cent Composition</u>	<u>Weight (Grams/cc)</u>	<u>Atoms/cc x 10<sup>-23</sup></u>
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

which differ by 30 per cent. 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.

##### 5. Acknowledgements

We wish to express appreciation to Professor Ernest O. Lawrence for his continued interest in this study. The program was greatly helped by discussions with Professors R. L. Thornton, R. Serber, E. M. McMillan, and L. W. Alvarez. We wish to thank Mr. D. J. O'Connell for making the alpha-particle track and star count, Mr. A. J. Oliver for the preparation of Fig. 1, Mr. Duane Sewell and the cyclotron crew for bombarding the plates, and the Eastman Kodak Company for information regarding Eastman NTA plates. 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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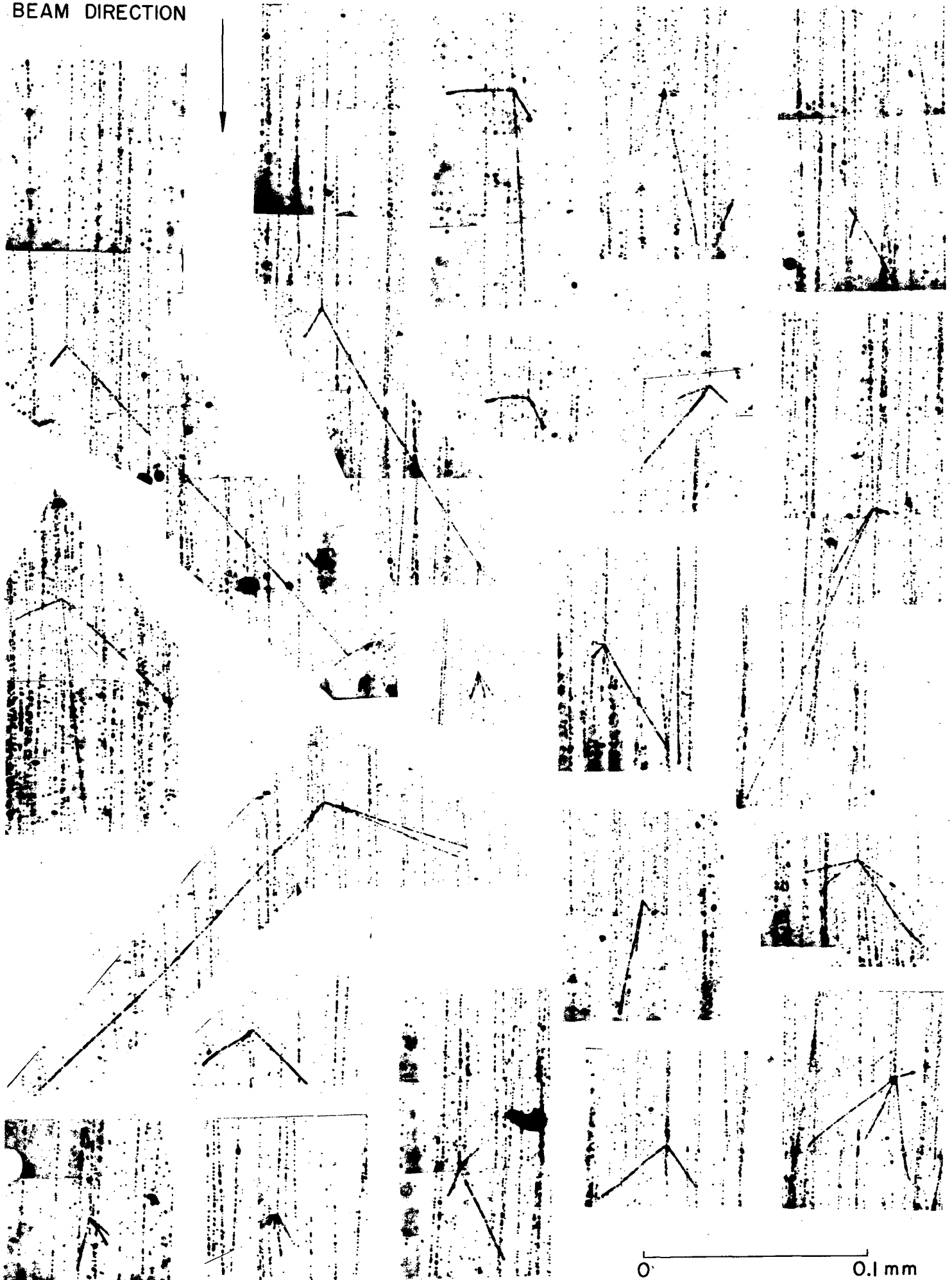
Table II. Average Cross Section for Formation  
of Stars by Alpha-Particles

<u>Energy (Mev)</u>	<u>No. of Stars</u>	<u>Total Path Length (cm)</u>	<u>Mean Path Length (cm/star)</u>	<u>Average Cross Section (cm<sup>2</sup>) x 10<sup>24</sup></u>
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

Figure Captions

- Fig. 1. Group of stars initiated by alpha-particles of energy about 100 Mev.
- Fig. 2. Frequency distribution of stars of various numbers of prongs. Graph gives per cent 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 per cent of prongs per  $60^\circ$  sector as a function of angular position of sector. Stars from all energies (about 50 to 200 Mev) have been lumped together.
- Fig. 4. Average cross section for formation of stars by alpha-particles as a function of the energy of the initiating alpha-particle.

BEAM DIRECTION



0 0.1 mm

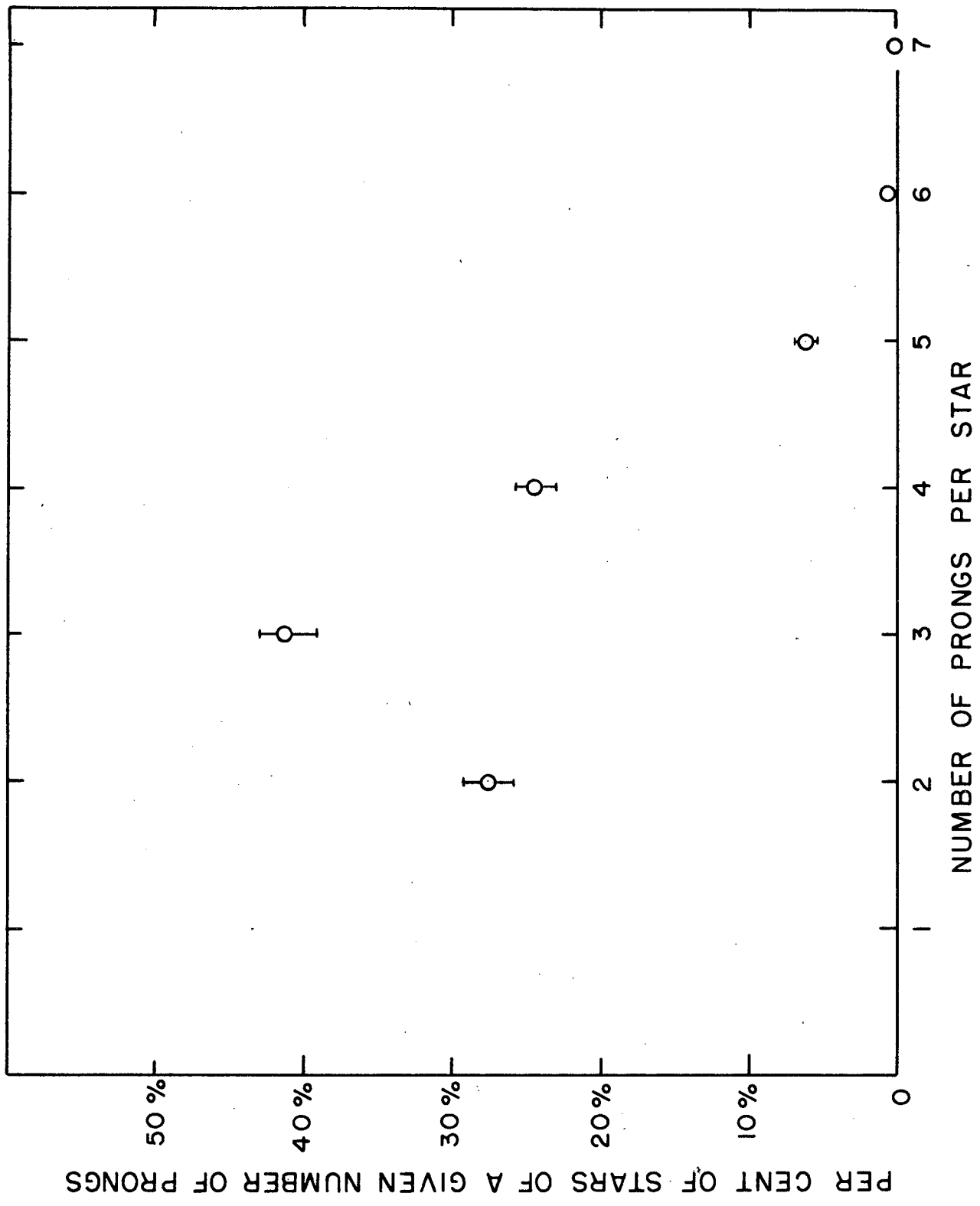
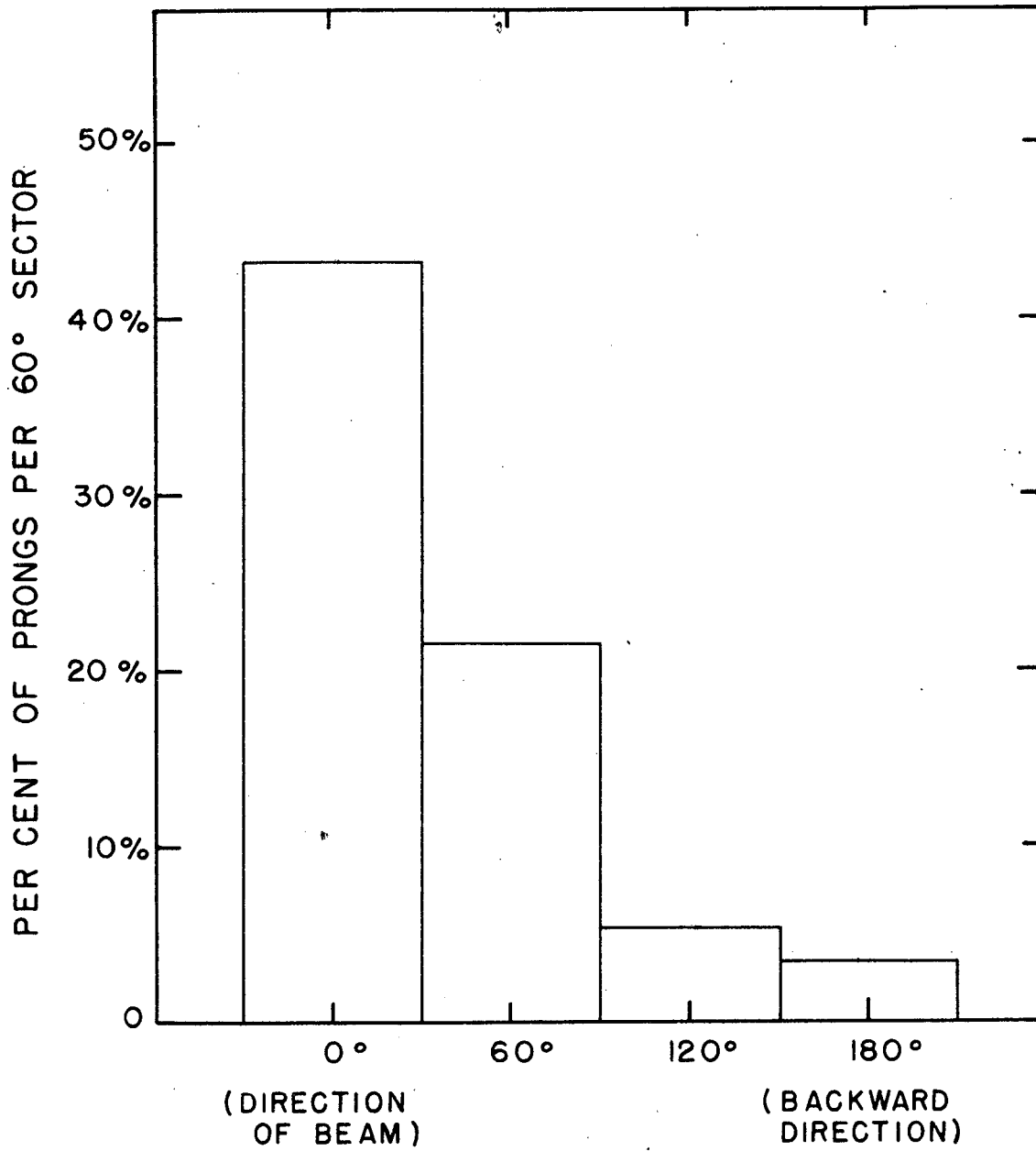


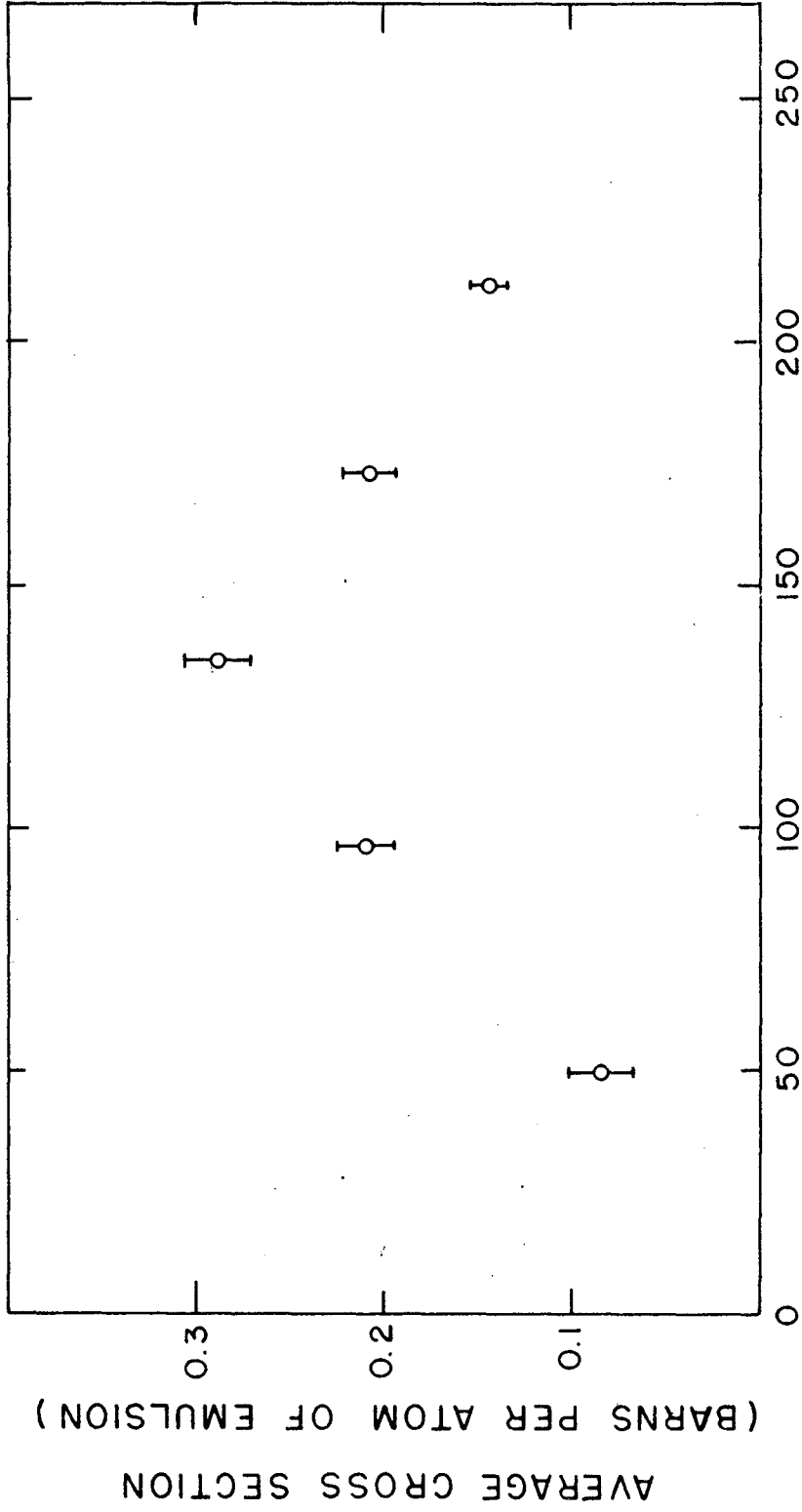
FIG. 2





ANGLE FROM BEAM DIRECTION TO CENTER OF SECTOR

FIG. 3



ENERGY OF INCIDENT ALPHA PARTICLE (MEV)

FIG. 4

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