Stars Induced by 350- to 400-Mev Protons*

G. BERNARDINI, E. T. BOOTH, AND S. J. LINDENBAUM
Columbia University, New York, New York
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ILFORD G5 plates with emulsions 400 microns thick were exposed to the 385-Mev proton beam of the Nevis cyclotron. The exposures were made inside the vacuum chamber at maximum orbit radius. Very brief exposures with the ion source off, yielded about 2×10^5 proton tracks per cm^2 in the emulsion, and the average length of each track was greater than 10 mm. These tracks were parallel, on the average, to $\pm 1°$.

Four hundred and four stars induced by the protons in the emulsion have been analyzed. The star prongs are classified as "gray" for grain densities less than three times minimum, "sparse black" for grain densities between three and six times minimum, and "black" for grain densities greater than six times minimum. These ranges correspond approximately to proton energies greater than 100 Mev, between 30 Mev and 100 Mev, and less than 30 Mev, respectively. In Fig. 1 is shown the distribution of the number of stars with various numbers of black plus sparse black prongs. In Fig. 2 is plotted the percentage of stars with at least one outgoing gray prong. The incoming proton tracks were observed in all cases but have not been counted in any of the prong statistics.

For 219 of the stars, the distribution of black, sparse black, and gray prongs are summarized in Table I.

The mean free path for the production of stars with one or more black prongs by 350- to 400-Mev protons has been determined by measuring by sampling, the total track length in the emulsion scanned, and dividing by the number (404) of stars found. In this way, a mean free path of 56 ± 9 cm was found. This corresponds to a nuclear cross section for the production of stars in G5 emulsion of 45 ± 6 percent of geometric, indicating considerable nuclear transparency.

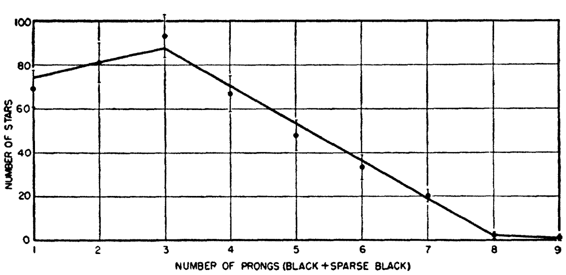

FIG. 1. The distribution curve for number of stars as a function of number of prongs (black+sparse black) with grain densities greater than three times minimum.

The angular distribution of prongs in the different energy ranges was determined for one hundred stars. The gray and sparse black prongs were peaked markedly in the forward direction with respect to the primary proton. The mean angle for these prongs was about 30°. The black prong angular distribution can be interpreted as consisting of $\frac{2}{3}$ isotropic prongs and $\frac{1}{3}$ projected in the forward 90°.

The Wouthuysen[1]-Goldberger[2] model for the interaction of nucleons with the nucleus predicts considerable transparency and

TABLE I. Properties of 219 stars as a function of the number of black (grain density greater than 6 minimum) prongs.

No. of black prongs	0	1	2	3	4	5	6	7	8	9
No. of stars	6	47	47	48	34	23	10	3	0	1
No. of stars with gray prongs	5	30	20	20	10	5	3	0	0	0
No. of stars with a gray or sparse black prong	6	35	31	32	20	13	3	0	0	0

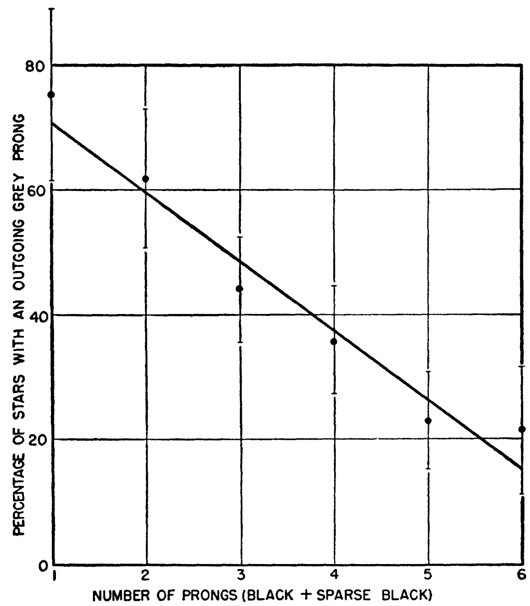

FIG. 2. The percentage of stars with an outgoing gray prong as a function of the number of prongs (black+sparse black) with grain densities greater than three times minimum.

the immediate ejection of sharply projected fast nucleons and some slower less collimated knockons before the evaporation process. All of these features are in agreement with our results.

Figure 2 shows that as the number of black prongs increases, the percentage of stars with gray prongs decreases, gray prongs were not observed in stars having more than six black prongs. This is interpreted to mean that for the 7-, 8-, or 9-prong stars most of the primary proton energy was absorbed by the nucleus. In these cases, the average energy associated with a black prong is 50 Mev, in approximate agreement with values measured in stars produced by cosmic rays.[3]

Reference to Table I shows that for stars between 2 and 5 (inclusive) black prongs, the percentage of stars which have a gray or sparse black prong is approximately constant and equal to 60 percent. Furthermore, less than 7 percent of all stars have two or more outgoing gray or sparse black prongs. Allowing for the fast neutrons which are not visible, the inference is that in nearly all stars there is at least one outgoing fast nucleon.

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1 S. A. Wouthuysen, Phys. Rev. 75, 1329 (1949).
2 M. L. Goldberger, Phys. Rev. 74, 1269 (1948).
3 Brown, Camerini, Fowler, Heitler, King, and Powell, Phil. Mag. 40, 862 (1949); Bernardini, Cortini, and Manfredini, Phys. Rev. 79, 952 (1950).

The Nuclear Spin of $_{43}Tc^{99}$

KARL G. KESSLER AND WILLIAM F. MEGGERS
National Bureau of Standards, Washington, D. C.
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THE emission spectrum of Tc^{99} has been investigated in this laboratory,[1] the wave-lengths of the principal lines have been reported[2–4] and an analysis of the spectrum has now been prepared.[5]

A 2.1-mg portion of the Tc^{99} sample was used in making a series of interference spectrograms with a liquid-nitrogen-cooled beryllium hollow cathode discharge tube filled with helium gas at about 1 mm pressure. Fabry-Perot interferometers having 3.75