Relative Yield Functions for π^--Mesons from Carbon*

STANLEY B. JONES AND R. STEPHEN WHITE
Radiation Laboratory, Department of Physics, University of California, Berkeley, California
(Received December 28, 1949)

This paper describes determinations of the relative yield curves for π^--mesons generated by alpha-particle and proton beams striking carbon targets. The mesons counted had energies of 2–10 Mev and angles to the beam direction up to about 45°.

THE artificial production of mesons has made possible the determination of meson yield as a function of the energy of the bombarding particle. This paper reports such determinations for π^--mesons generated by the Berkeley 184-inch cyclotron with both proton and alpha-particle beams incident upon a carbon target with the restriction that only mesons of energies 2–10 Mev and of angle to the beam up to about 45° were counted. A preliminary report of this study has been published in abstract form.[1]

The beam energies were selected by placing the targets at predetermined distances from the center of the cyclotron. As indicated in Fig. 1, the π-mesons produced at the target move approximately in circular orbits in the magnetic field. In particular, the π^--mesons circulate in the counterclockwise direction as illustrated. Some of the low energy ones are slowed down and stopped in stacked photographic plates placed from four inches to seven inches from the leading edge of the target as shown in Fig. 2. These plates are then examined for meson tracks over an area corresponding to meson energies of 2–10 Mev by means of a microscope with a traveling stage.

The bombardments were made by using the carbon targets illustrated schematically in Fig. 2. The target dimensions in the plane perpendicular to the beam direction are 1 inch by 3 inches. The thickness for the alpha-particle beam was $\frac{1}{16}$ inch with an exposure time of 20 minutes and for the proton beam, $\frac{1}{32}$ inch with an exposure time of 30 seconds. Most of the mesons originate from the small target area, measuring 1 inch along the leading edge by $\frac{1}{8}$ inch perpendicular to the edge, which first intercepts the beam, since this region is most intensely bombarded by the cyclotron beam. This was found by monitoring the target with thin polystyrene.

The integral of the beam-current was obtained by observing the relative amounts of C^{11} formed in the $C^{12}(\alpha,\alpha n)C^{11}$ and $C^{12}(p,pn)C^{11}$ reactions for the alpha-particle and proton bombardments, respectively, through measurement of the positron activity of C^{11} which has a half-life of 20.5 minutes. A correction was made for the decay of the C^{11} activity in the target during the bombardment by alpha-particles. A correction for the variation of the cross section for $C^{12}(\alpha,\alpha n)C^{11}$ [2] and $C^{12}(p,pn)C^{11}$ [3] with energy was also included.

For this work, Ilford 50 micron C-2 and Eastman 100 micron NTB nuclear emulsions on standard 1-inch by 3-inch glass plates were used for the alpha-particle and proton exposures, respectively. At each beam energy, a single plate from the center of a stack of at least five plates was selected for study. Each plate was scanned to a depth of 2 mm from the leading edge for a measured distance along the edge. Nearly identical areas were scanned on the plates for the various beam energies and meson density over the scanned and adjacent areas did not change rapidly. The number of mesons counted in each case was corrected for the corresponding integrated beam current, plate thickness, and area scanned.

The apparatus was selective for π^--mesons. However, positive mesons might possibly have entered the plates

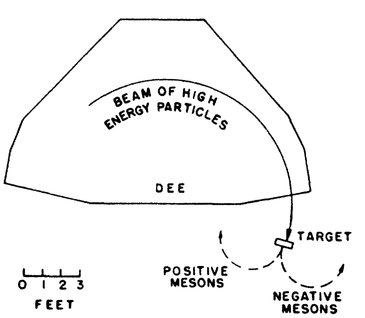

FIG. 1. Plan view of cyclotron (meson trajectories enlarged).

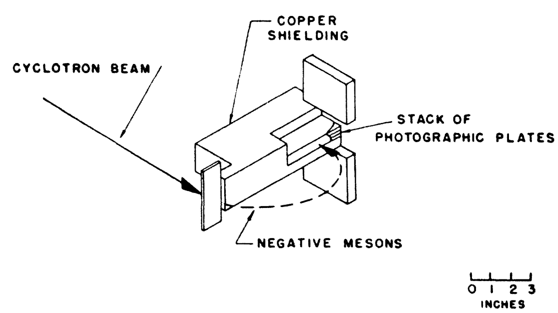

FIG. 2. Schematic diagram of plate holder.

* This paper is based on work performed under the auspices of the AEC.
[1] S. B. Jones and R. S. White, Phys. Rev. 75, 1468 (1949); Phys. Rev. 76, 588 (1949).
[2] R. L. Thornton and R. W. Senseman, Phys. Rev. 72, 872 (1947).
[3] Aamodt, Peterson, and Phillips (to be published).

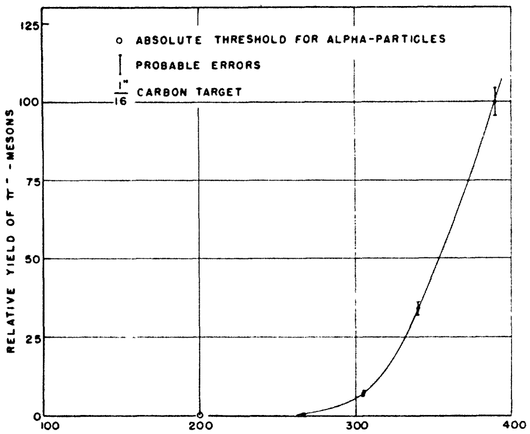

FIG. 3. Meson excitation curve for alpha-particles normalized to 100 at 390 Mev with a meson energy interval of 2–10 Mev.

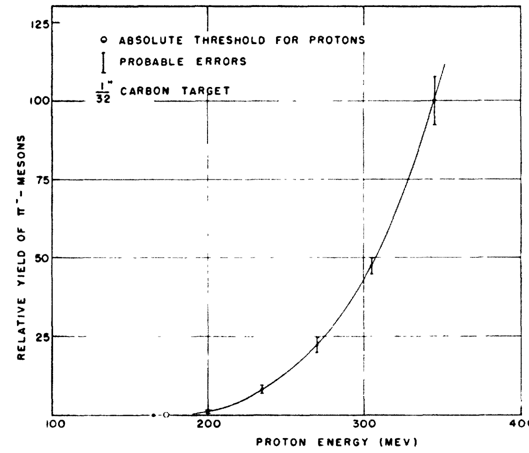

FIG. 4. Meson excitation curve for protons, normalized to 100 at 345 Mev with a meson energy interval of 2–10 Mev.

and it is certain that some μ-mesons entered the plates. In order to include only π^--mesons, we counted only σ-mesons (star forming mesons). Since few, if any, μ^--mesons form stars,[4,5] the total number of π^--mesons in the energy interval examined will then be proportional to the number of σ-mesons since a fixed fraction of π^--mesons form stars.[6]

The data are given in Table I.

Plots of the data in the tables are given in Figs. 3 and 4. W. H. Barkas, by the method of energy and momentum balance, has calculated the absolute minimum threshold for meson production using the most favorable reactions.[7] These are indicated in the figures.

It should be emphasized that this study does not give the relative total cross section for π^--meson production but only the relative yields in a particular meson energy interval. V. Peterson[8] measured an absolute differential cross section for π^--mesons produced by 390-Mev alpha-particles on a $\frac{1}{4}$-inch carbon target. For π^--mesons of energy 2–5 Mev and of angles with the beam direction up to about 45° he found a value of $3.0\pm0.8\times10^{-32}$ cm^2 Mev^{-1} steradian^{-1} per carbon nucleus. Richman and Wilcox[9] measured a value of $2.1\pm0.6\times10^{-28}$ cm^2 steradian^{-1} per carbon nucleus at 90 degrees to the beam direction for the combined cross section for both π^--mesons and π^+-mesons produced by 345-Mev protons on carbon.

The authors are indebted to Professor Ernest O. Lawrence for his continued interest in this work. We also wish to thank Professor R. L. Thornton and Drs. Eugene Gardner, C. M. G. Lattes, and Hugh Bradner for much helpful discussion. We are very grateful to James Vale and the cyclotron crew for making the bombardments.

TABLE I. Data on mesons from carbon.

Beam energy	No. σ-mesons observed	Relative volume scanned	Relative integrated beam current	Corrected relative yield
		I. Alpha-particle beam		
390	241	1.00	1.00	100 percent
340	109	0.740	1.80	34
305	24	0.797	1.87	7
265	4	0.806	3.85	0.5
		II. Proton beam		
345	75	1.00	1.00	100 percent
305	126	1.08	3.30	47
270	46	0.794	3.57	22
235	19	0.944	3.46	8
200	3	1.12	3.76	1
165	0	1.23	1.97	0

[4] W. Y. Chang, Rev. Mod. Phys. **21**, 166 (1949).
[5] Goldschmidt, Clermont, King, Muirhead, and Ritson, Proc. Phys. Soc. London **61**, 183 (1948).
[6] F. L. Adelman and S. B. Jones, Phys. Rev. **75**, 1468 (1949).
[7] W. H. Barkas, Phys. Rev. **75**, 1109 (1949).
[8] V. Peterson, private communication.
[9] C. Richman and H. Wilcox, Phys. Rev. **78**, 85 (1950).