Title
FURTHER EVIDENCE CONCERNING THE REACTION P t P-*D n+ +

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June 5, 1951

Berkeley, California

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Radiation Laboratory, Department of Physics
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The energy spectrum of π^+ mesons produced in collisions of 340 Mev protons with stationary protons has been shown[1,2] to be strongly peaked near the upper energy limit. The strong suspicion on energetic grounds that this peak was due to the reaction $p + p \rightarrow d + \pi^+$ has been confirmed recently by counter experiments.[3] This letter is primarily concerned with further absolute meson production cross section measurements at laboratory angles of 18°, 30°, and 64°.

Figure 1 shows the meson spectrum observed at $18.0 \pm 0.9°$, using a "point" source of liquid hydrogen bombarded with nearly monoenergetic protons. Meson energies and the incident proton beam energy were determined by range in absorbers, using the tables of Aaron, et al[4] with slight corrections required by the absolute proton range-energy measurements of Segrè and Mather.[5] The width of the observed peak (3.6 Mev) corresponds very nearly to that expected from a "line broadened by the 0.5 percent[6] inhomogeneity in the incident

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* Now at the California Institute of Technology

1 Cartwright, Richman, Whitehead, and Wilcox, Phys. Rev. 78, 823 (1950); Phys. Rev. 81, 652 (A) (1951)

2 V. Z. Peterson, Phys. Rev. 79, 407 (1950); Peterson, Iloff and Sherman, Phys. Rev. 81, 647 (A) (1951)

3 Crawford, Crowe, and Stevenson, Phys. Rev. 82, 97 (1951)

4 Aaron, Hoffmann and Williams, UCRL-121 (2nd Rev.) (1941)

5 R. L. Mather and E. Segrè, UCRL-1089

6 C. J. Bakker and E. Segrè, Phys. Rev. 81, 489 (1951)

proton beam.

The peak meson energy of 63.5 $\pm$ 0.3 Mev and incident proton energy (342 $\pm$ 1 Mev) may be used to calculate a mass value for the π^+ meson of 279.0 $\pm$ 1.5 m_e. The integrated spectrum corrected for absorption is $(1.6\,^{+0.3}_{-0.2})$ x 10^{-28} cm^2-steradian^{-1}, based on 885 mesons. The partial yields of the $p + n + \pi^+$ and $d + \pi^+$ reactions may be estimated by resolving the spectrum of Figure 1 into a continuous distribution up to 60.0 Mev plus a line separated by 3.5 Mev. Since the energy resolution half-width is 1.8 Mev the position of the peak and the higher energy side of the curve are only slightly affected by the presence of the continuous spectrum. Good agreement with the experimental curve is obtained if the "line" contains 55 $\pm$ 10 percent of the mesons observed.

The preliminary measurement made at 30° using a line source geometry[2] has been repeated with the point source and better statistics (482 mesons). The integrated cross section at this angle, corrected for absorption, is $(5.8\,^{+1.2}_{-0.6})$ x 10^{-29} cm^2-steradian^{-1}. However, the energy resolution of this spectrum, taken previous to the 18° run, is not sufficient to separate the partial reactions.

The cross section at 64° $\pm$ 8° has also been determined, although the low yield and poor angular resolution make it difficult to obtain a significant energy spectrum. A value of $(7\,^{+4}_{-2})$ x 10^{-30} cm^2-steradian^{-1}, based on 22 mesons, is calculated from the emulsion-target geometry and proton flux. An independent check of this value may be obtained by determining the yield of elastically scattered protons in the same emulsion. Using the known P - P scattering cross section of 5.5 $\pm$ 1 mb/ster [7] (c.-m. system) the meson/proton

[7] O. Chamberlain and C. Wiegand, Phys. Rev. 79, 81 (1950)

yield ratio gives a meson cross section of $11 {}^{+6}_{-4} \times 10^{-30}$ cm^2-steradian^{-1}.

These data, normalized to the 0^{o} cross section measured by Cartwright, et al,[8] can be used to plot the angular distribution. The relative cross sections as a function of laboratory angle are plotted in Figure 2. The angular distributions to be expected from pure isotropic or $\cos^2 \theta$ production are also shown, for the case $p + p \rightarrow d + \pi^+$. A direct comparison of these curves to the experimental data assumes that most of the mesons are emitted with maximum energy at all angles. This assumption is supported by the energy spectra at 0^{o} [8] and 18^{o}. Comparison of curves in Figure 2 shows a strong preference for $\cos^2 \theta$ emission.

If the angular distribution were strictly $\cos^2 \theta$, the total cross section for π^+ production may be estimated to be $(2.3 {}^{+0.4}_{-0.2}) \times 10^{-28}$ cm^2.

This work was sponsored by the Atomic Energy Commission.

[8] F. Cartwright, private communication

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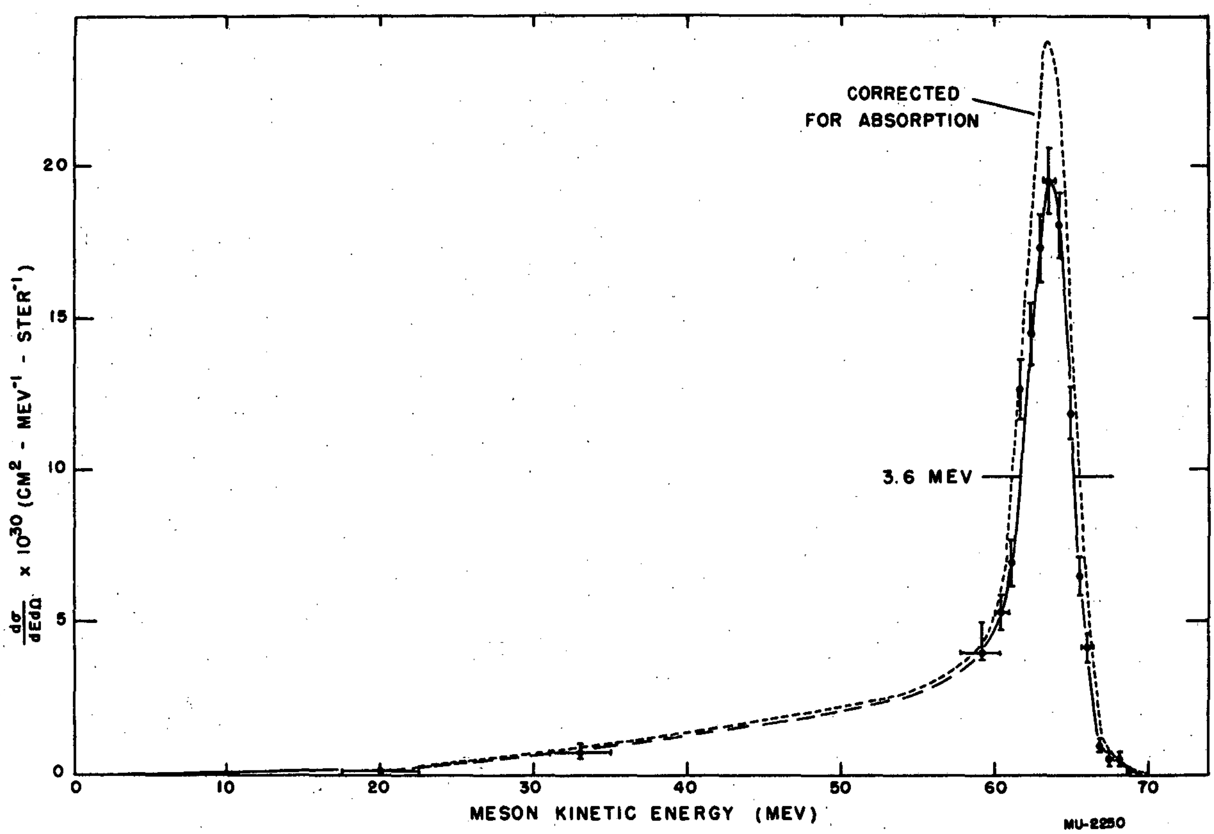
Figure Captions

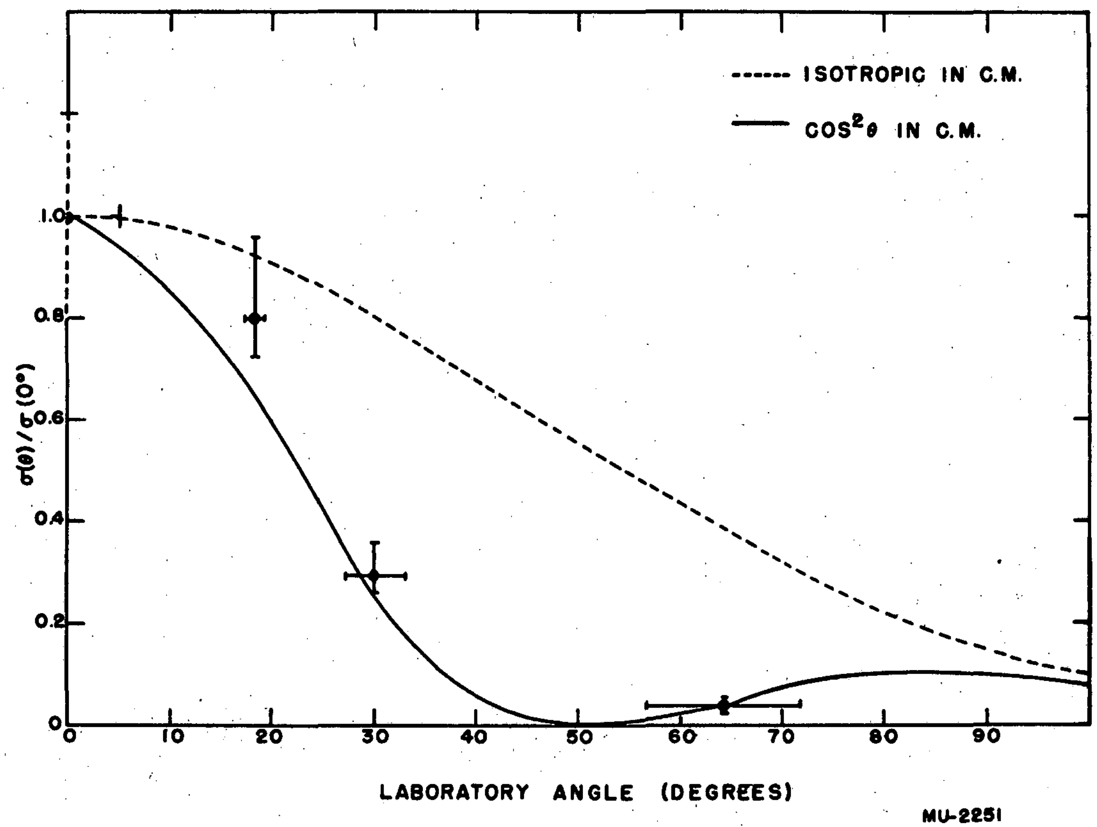
Figure 1. Energy spectrum of π^+ mesons at $18.0 \pm 0.9^{\circ}$. The peak occurs at 63.5 ± 0.3 Mev. The dotted curve includes a correction for nuclear absorption of mesons in slowing down. Base on 885 mesons.

Figure 2. Angular distribution of π^+ mesons in the laboratory system. The curves are calculated for the reaction $p + p \rightarrow d + \pi^+$ for 340 Mev protons



CORRECTED
FOR ABSORPTION
3.6 MEV
$\frac{d\sigma}{dEd\Omega}$ x 10^{30} (CM^2 - MEV^{-1} - STER^{-1})
0
5
10
15
20
0
10
20
30
40
50
60
70
MESON KINETIC ENERGY (MEV)
MU-2250

Fig. 1



------ ISOTROPIC IN C.M.
COS²θ IN C.M.
1.0
0.8
σ(θ)/σ(0°)
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
LABORATORY ANGLE (DEGREES)
MU-2251

Fig. 2