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RADIATION LABORATORY

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EVIDENCE CONCERNING THE REACTION $P + P \rightarrow \pi^+ + D$

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The mesons produced by protons on protons have been reported[1,2] by various observers. The strong forward high energy peak in the cross section found in the early work indicated that a deuteron may be produced in the reaction. The shape of the peak and the energetics of the reaction have given further evidence that this is the case.[3,4]

We have observed the reaction $P + P \rightarrow \pi^+ + D$ by coincidence counting technique. By using a magnetic field to determine the momentum of the particles and finding the range of both in aluminum, we have essentially identified the reaction products by measuring the masses of both the meson and deuteron.

The arrangement is shown in Fig. 1. The 340 Mev external proton beam of the Berkeley cyclotron strikes a 1-inch thick polyethylene target. Typical trajectories are shown for the meson and deuteron in the forward direction. The orbits were located by using a wire with known current and tension. Each counter telescope consists of four liquid scintillators, 4 x 5 x 3/4 inch in size, viewed by photomultipliers. The outputs were mixed using conventional electronics. The events recorded require both

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[1] W. F. Cartwright, C. Richman, M. N. Whitehead, and H. A. Wilcox, Phys. Rev. 78, 823 (1950).

[2] Vincent Z. Peterson, Phys. Rev. 79, 407 (1950).

[3] W. F. Cartwright et al., Bull. Am. Phys. Soc. Vol 25, No.6, E-5, Los Angeles meeting, December 1950, private communication.

[4] V. Z. Peterson, Bull. Am. Phys. Soc. Vol 25, No.6, A-2, Los Angeles meeting, December 1950; private communication.

particles to have range large enough to enter the third counter of each telescope but to stop before the fourth. Range was varied with absorbers in the position shown. The integral range spectrum for the coincident events is shown as a function of range in the deuteron telescope in Fig. 2. The slope of the spectrum between 110 and 130 Mev corresponds to the variation of measured deuteron energy for production at various target depths due to its energy loss in passing through the rest of the target. Protons from the reaction $P + P \rightarrow \pi^+ + n + P$ of approximately the same velocity as the deuteron would not appear at ranges greater than the deuteron range of 90 Mev. The lowest energy point on Fig. 2 corresponds to zero absorber.

The momentum of the deuteron was measured by shifting the position of the deuteron telescope. See Fig. 3. Deuterons produced at the front and back of the target are expected to have momenta 630 and 710 Mev/c respectively. The cone of the coincident deuterons was defined by the meson telescope to be ~2-1/2 inches in diameter. Protons from the reaction $P + P \rightarrow \pi^+ + P + n$ for which we would have detected the meson would appear at a maximum momentum of about 450 Mev/c (~12 inches from the center of the deuteron telescope). The main proton beam appears at 855 Mev/c 8.5 inches from the deuteron telescope. The deuteron mass calculated from this data is $2.2 \begin{smallmatrix} +0.6 \\ -0.4 \end{smallmatrix}$ proton masses. The meson mass was obtained by varying the magnetic field and measuring the range spectrum in the meson telescope. We obtain $270 \begin{smallmatrix} +80 \\ -90 \end{smallmatrix}$ electron masses. The errors in the masses correspond to the limits of uncertainties in the momentum and range resolution of the deuteron and meson telescopes.

Mesons produced by 340 Mev protons on carbon in the same solid angle do not appear to be accompanied by correlated deuterons (see Table I). The

meson telescope counts are approximately 90 percent mesons and our high background appears to be accidental coincidences between the meson deuteron events and the excessive singles rates of the final deuteron telescope counters.

Measurements of the absolute cross section are in progress.

We wish to thank Professor W. K. H. Panofsky for encouragement and generous assistance throughout the measurements, Dr. E. Martinelli and Mr. L. Neher for their discussions and assistance, Mr. R. Hildebrand for loan of the counters used, Mr. A. J. Stripeika and the electronics group for maintenance of the electronics and Mr. J. Vale and the crew for the proton bombardments.

This work was performed under the auspices of the Atomic Energy Commission.

TABLE I

Typical data taken with same geometry and beam intensity for equivalent number of protons. Probable errors are given.

Target	Meson Counts	Coincidence Counts	Background	Difference	Meson Deuteron Coincidences / Meson Counts
Polyethylene	1085 ± 18	144 ± 7	46 ± 4	98 ± 8	-----
Carbon	288 ± 11	3 ± 1	6 ± 2	- 3 ± 2	- .010 ± .007
Hydrogen (Equivalent)	797 ± 31	141 ± 7	40 ± 4	101 ± 8	+ .127 ± .010

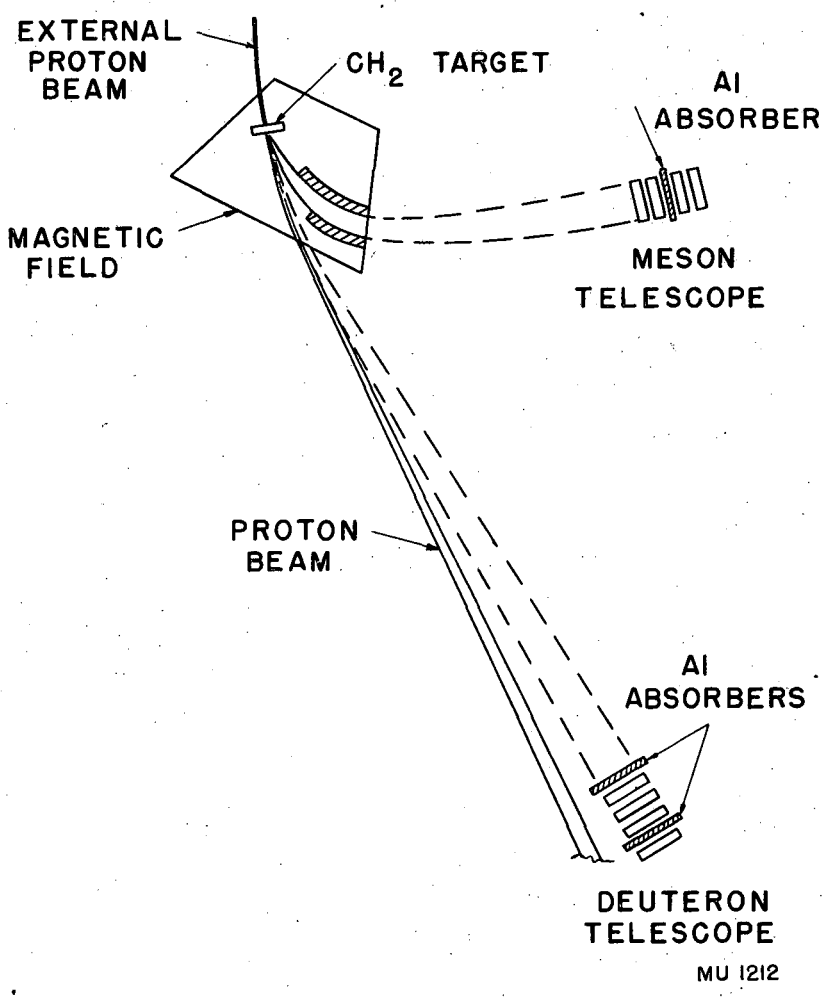

Fig.1

The geometry of the experiment.

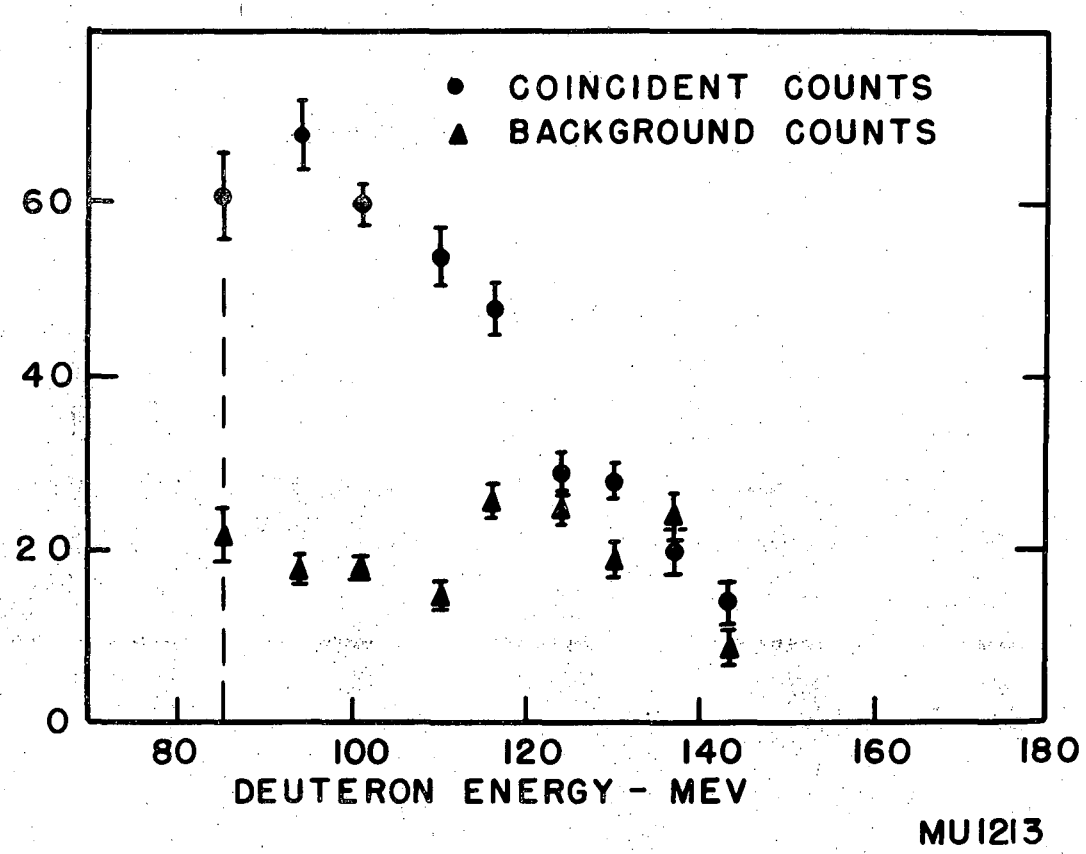

Fig. 2

The integral range spectrum of meson-deuteron coincidence counts as function of deuteron energy. Probable errors are shown.

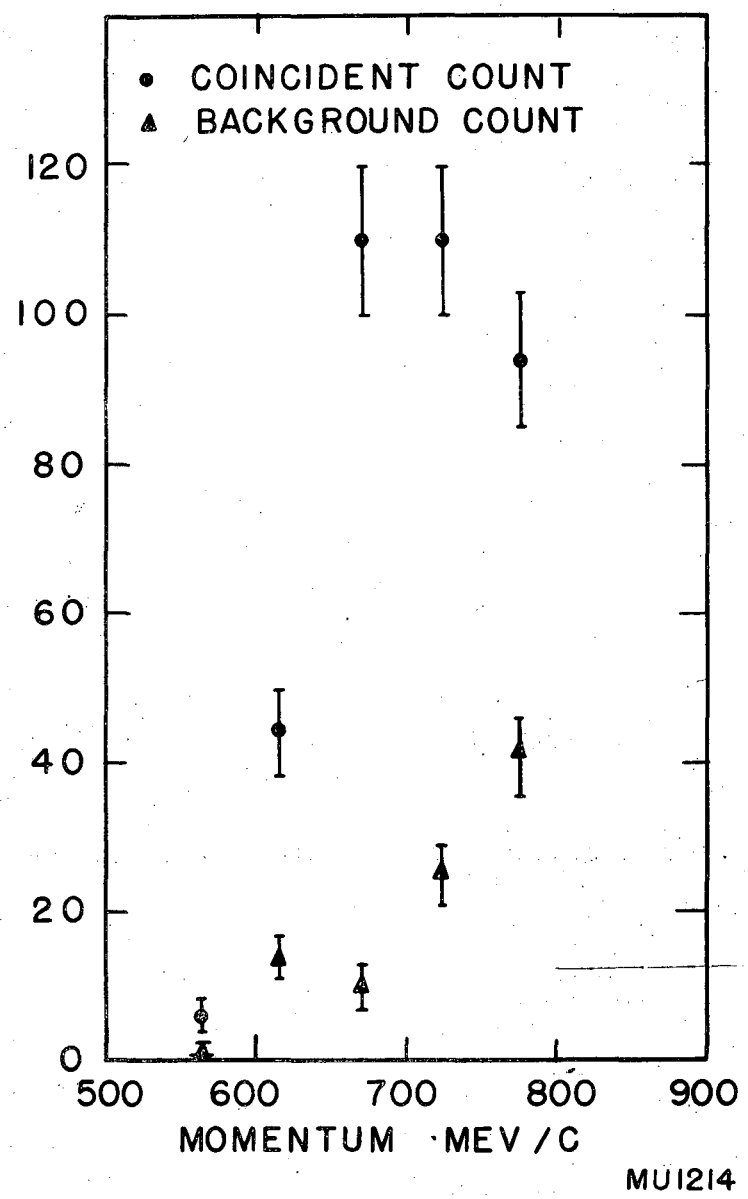

Fig. 3

Meson-deuteron coincidence counts as function of deuteron momentum. Probable errors are shown.