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OBSERVATIONS OF MULTIPLE PION PRODUCTION IN n-p COLLISIONS AT THE BEVATRON

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OBSERVATIONS OF MULTIPLE PION PRODUCTION IN n-p COLLISIONS AT THE BEVATRON*

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More than 500 events showing pion production in n-p collisions have been obtained by exposing a hydrogen-filled diffusion cloud chamber[1] to high-energy neutrons from the Bevatron. The neutrons were produced by bombarding an internal Cu target with 6.2-Bev circulating protons. The cloud chamber was placed 75 feet from the target along a line tangent to the proton beam, and was in a pulsed magnetic field of 15,300 gauss. The beam at the chamber was collimated to 5/8-inch by 2.5 inches. A 19-inch paraffin filter was inserted into the beam 55 feet from the cloud chamber to reduce the number of low-energy neutrons; and a 2-inch Pb filter, followed by a small sweeping electromagnet, was inserted 40 feet from the cloud chamber to remove the γ rays. The energy distribution of the neutrons undoubtedly extended from a few Mev up to 6.2 Bev. However, since no events were recorded with fewer than three outgoing prongs, neutrons below 280 Mev did not contribute.

One event had seven outgoing prongs (Fig. 1). Measurements of momentum and relative ionization of the prongs are given in Table I. A reasonable assumption is that all the prongs are either pions or protons, and there is no evidence to indicate otherwise. Track 1 ionizes slightly more than minimum and is therefore an identified proton. Tracks 2 and 6 are minimum ionization and, therefore, are identified as positive pions. Tracks 3, 4, and 7 are negative and, therefore, are negative pions. Track 5 is unidentified from ionization and momentum. Since the transverse momentum can be balanced within the errors of measurement there is

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

+ Also at the University of San Francisco.

[1] Elliott, Maenchen, Moulthrop, Oswald, Powell, and Wright, Rev. Sci. Instr. 26, 696 (1955).

probably no neutral particle leaving the collision; and since all the particles are identified except Track 5 we know that under these conditions it must be a proton. The reaction is therefore believed to be

$$n + p \rightarrow p + p + \pi^+ + \pi^+ + \pi^- + \pi^- + \pi^- ,$$

where five pions have been produced in a nucleon-nucleon collision. The kinetic energy of the incoming neutron is approximately 4.7 Bev for this case. We are unable to rule out six-meson production, i.e. pp++ ---0 or pn +++ ---, but both these possible reactions are considered less probable. The total charge of +1, the relatively high momentum of all the positive tracks, and the absence of a recoil blob at the origin make it highly unlikely that the event is a rare carbon-oxygen star from the methyl alcohol in the cloud chamber.

Table I

Data on seven prong event

Track	sign	Measured momentum (Bev/c)	Ionization density (Relative)	Momentum used for momentum balance (Bev/c)	Particle identification
1	+	0.85 ± 0.05	~1.5	0.90	Proton
2	+	0.67 ± 0.04	Minimum	0.71	π^+
3	-	$0.74 \begin{smallmatrix}+0.10\\-0.09\end{smallmatrix}$	Minimum	0.83	π^-
4	-	1.19 ± 0.06	Minimum	1.19	π^-
5	+	$3.0 \begin{smallmatrix}+0.3\\-1.5\end{smallmatrix}$ (a)	Minimum	1.56	Proton
6	+	$0.63 \begin{smallmatrix}+0.15\\-0.10\end{smallmatrix}$	Minimum	0.53	π^+
7	-	0.065± 0.003	~3	0.065	π^-

(a) The total energy of the outgoing particles is limited by the energy of the original protons in the Bevatron. The upper limit here is obtained in this way rather than from direct measurement.

Of the remaining events, 48 have five-prongs and 473 have three-prongs. Table II shows the events classified according to the number of visible prongs and the number of pions produced in the collision. A preliminary analysis of the five-prong events indicates that 16 of these have one or more neutral

Table II

Relative frequencies of multiplicities of pion production in n-p collisions

Observed type of event	3-prong			5-prong			7-prong		
Identified No. of pions	1	1 or more	2 or more	3	3 or more	4 or more	5	5 or more	6 or more
No. of events	-	473	-	3	29	16	1	0	0

outgoing particles, indicating the production of four or more pions. Identification of these events is based on (a) ionization and momentum measurements showing that two of the positive particles are pions (six cases), (b) lack of transverse momentum balance within the errors of measurement (seven cases), or both (a) and (b) (three cases). Production of three pions is indicated in three of the five-prong events that show transverse momentum balance. Because it is easier to establish the absence than the presence of momentum balance, 3:16 can only be considered within statistics as a lower limit to the ratio of three-pion to four-or-more-pion production in the five-prong events. The group of five-prong events listed as " 3 or more" pion production consists of those events for which the presence or absence of one or more neutral outgoing particles has not been established. The grouping of the three-prong events into the "one or more" pion-production classification reflects the lack of analysis of this group.

In a similar experiment using neutrons from 2.2-Bev protons at the Brookhaven Cosmotron, no five-prong events were found among 185 three-prong events.[2] The mean available energy in the center-of-mass system in the Brookhaven experiment was determined to be 720 Mev, whereas in this experiment the available center-of-mass energies extend up to 2 Bev.

Similar evidence for high multiplicities has been found in π^--p collisions[3] and p-p collisions. Negative pions with an average kinetic energy

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[2] Fowler, Shutt, Thorndike, and Whittemore, Phys. Rev. 95, 1026 (1954).
[3] Maenchen, Powell, Saphir, and Wright, Phys. Rev. 99, 1619 (1955).

of 4.5 Bev yielded three cases of four-or-more meson production in 145 interactions; 5.3-Bev protons gave two cases of four-or-more meson production in 39 interactions.

The cloud chamber pictures were scanned by Alfred S. Fischler, Mrs. Marjorie E. Isitt, Arthur A. Kemalyan, and Joseph H. Wenzel. They were all scanned at least three times.

We are indebted to the members of the Bevatron staff for their kind cooperation.

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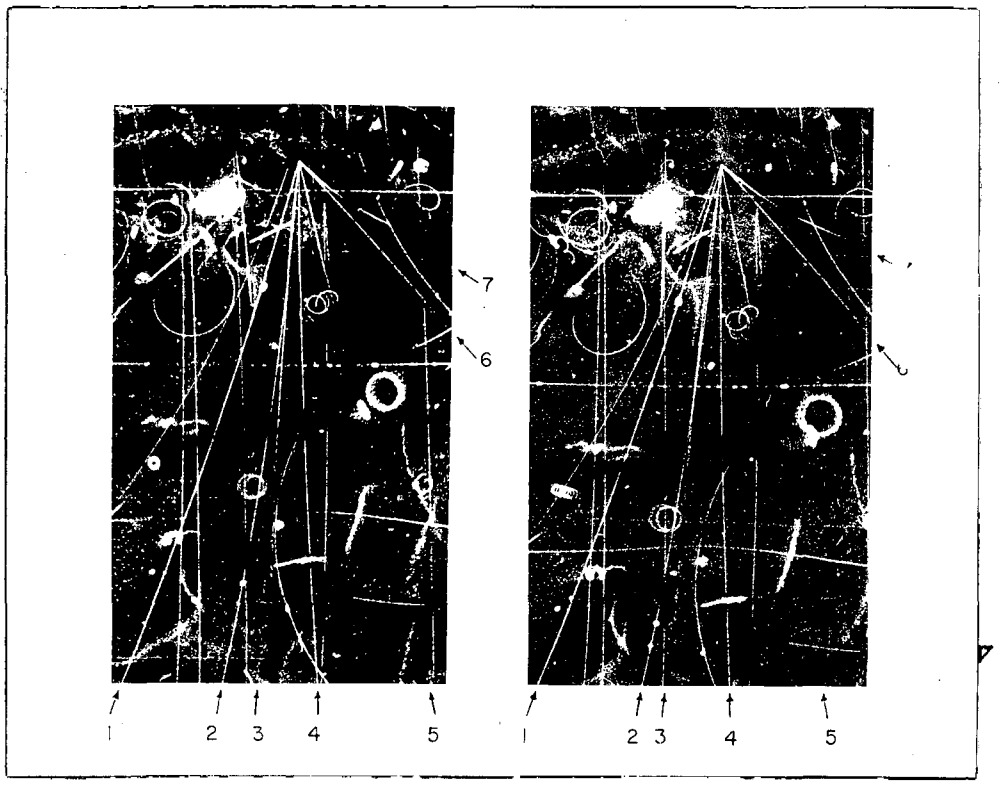
Fig. 1. Photograph of seven-prong event interpreted as production of five pions in an n-p collision.