

CROSS SECTIONS FOR π - p INELASTIC COLLISIONS ACCORDING TO THE REGGEIZED MULTIPERIPHERAL MODEL

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The energy dependence of the cross sections for the inelastic π - p collisions is compared with the predictions of the Reggeized multiperipheral model. A good agreement is observed for many reactions. The observed deviations of the experimental points from the calculated curves may be attributed to the production of resonances.

It was shown recently that the multiperipheral Regge pole exchange model describes correctly distributions of secondary particles from high energy pion-proton and K^- -proton interactions [1]. In the present paper we compare the predictions of the model for the energy dependence of cross sections for inelastic pion-proton collisions with the existing experimental data [2].

In Figs 1-6 cross sections for different pion multiplicity reactions of negative and positive pions on protons are plotted as a function of laboratory momenta of incident pions. The curves show the predictions of the discussed model. They were calculated according to the formula:

$$\sigma = \frac{A}{P^* E^*} \int |S(p_1, p_2, \dots, p_n)|^2 \delta_4 \left(P^* - \sum_{i=1}^n p_i \right) \prod_{i=1}^n \frac{d\vec{p}_i}{E_i}.$$

Here A is a normalization constant adjusted for each of the considered reactions separately, P^* is the cms momentum of colliding particles, E^* — their total energy in cms, $p_i = (E_i, \vec{p}_i)$ is the four momentum vector of i -th secondary particle and $P^* = (E^*, 0)$ — the four momentum vector of the system.

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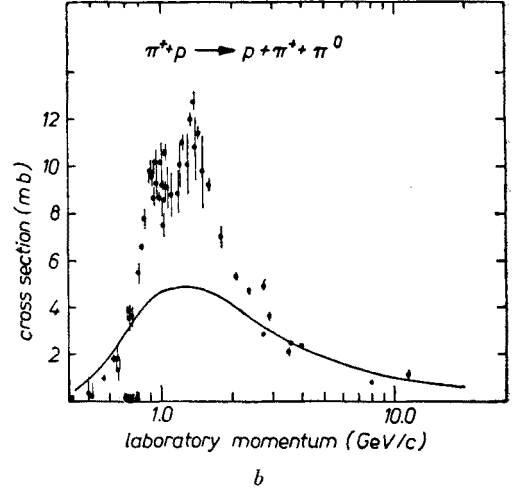
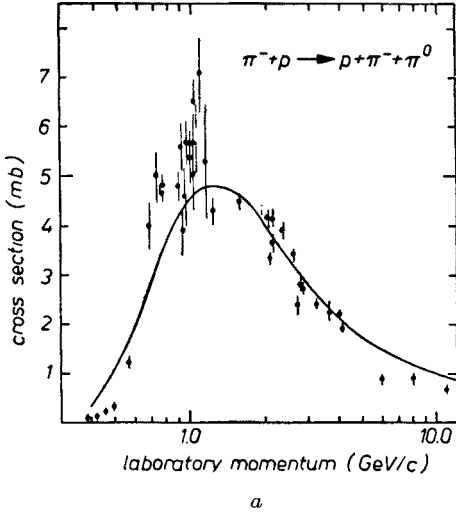


Fig. 1a, b

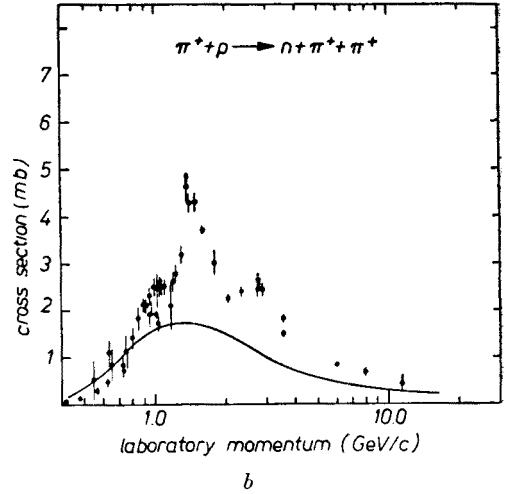
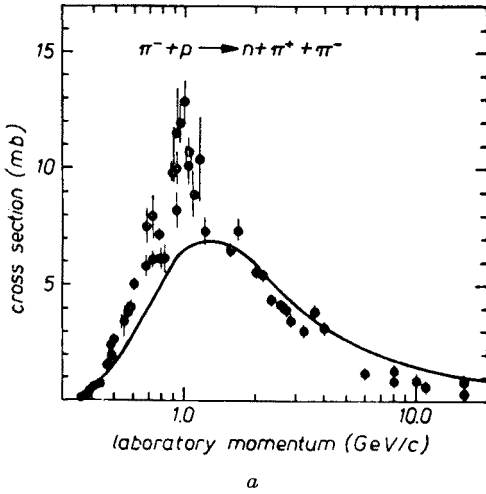
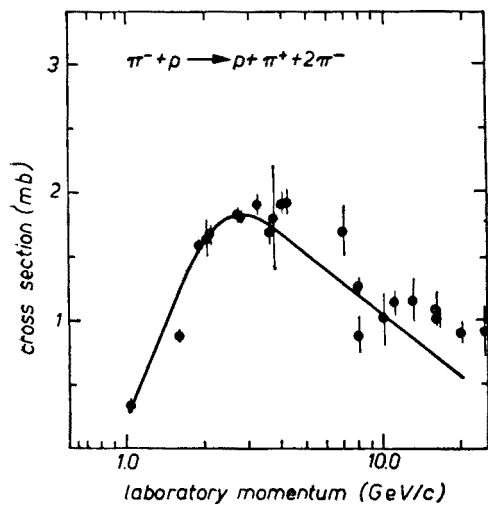


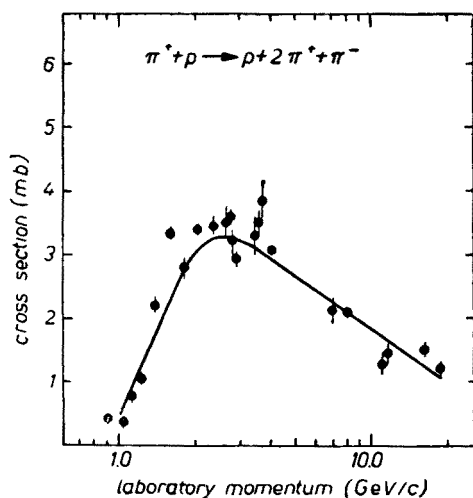
Fig. 2a, b

The matrix element $S(p_1, p_2, \dots, p_n)$ was taken according to the multiperipheral Regge exchange model in the form proposed by Chan Hong-Mo *et al.* [1]. The integration was performed by the Monte Carlo method using the program FOWL [3].

Comparing the obtained curves with experimental points we can notice that in spite of certain disagreements the general shape of the dependence of inelastic pion-proton cross

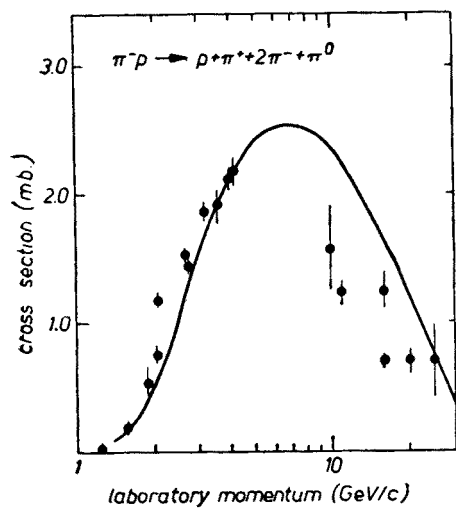


a

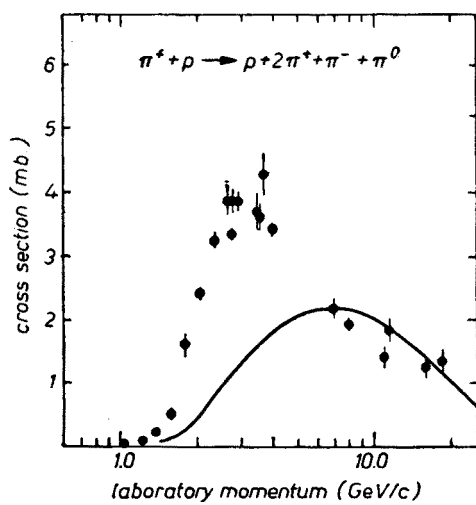


b

Fig. 3a, b



a



b

Fig. 4a, b

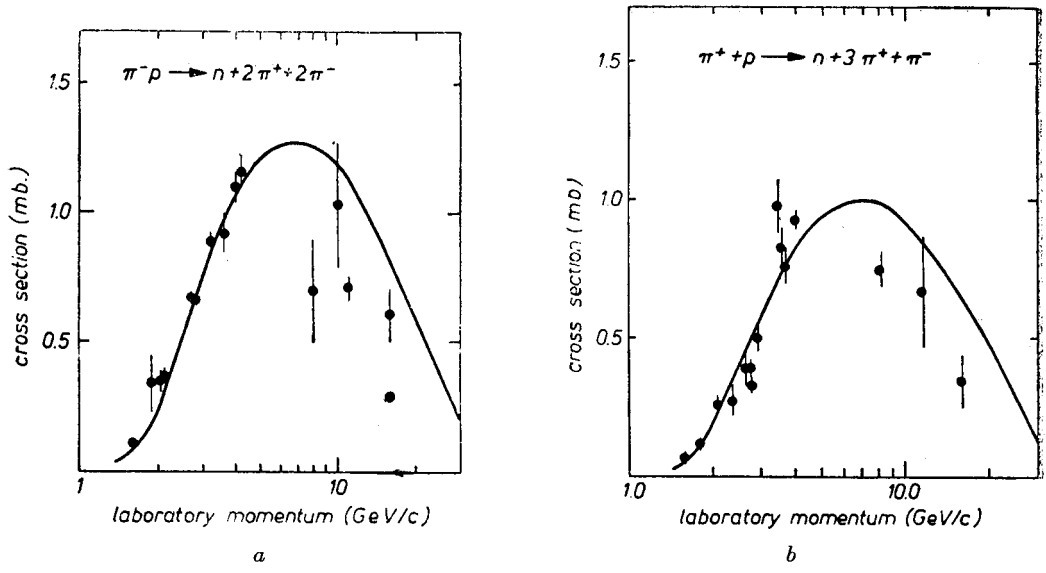


Fig. 5a, b

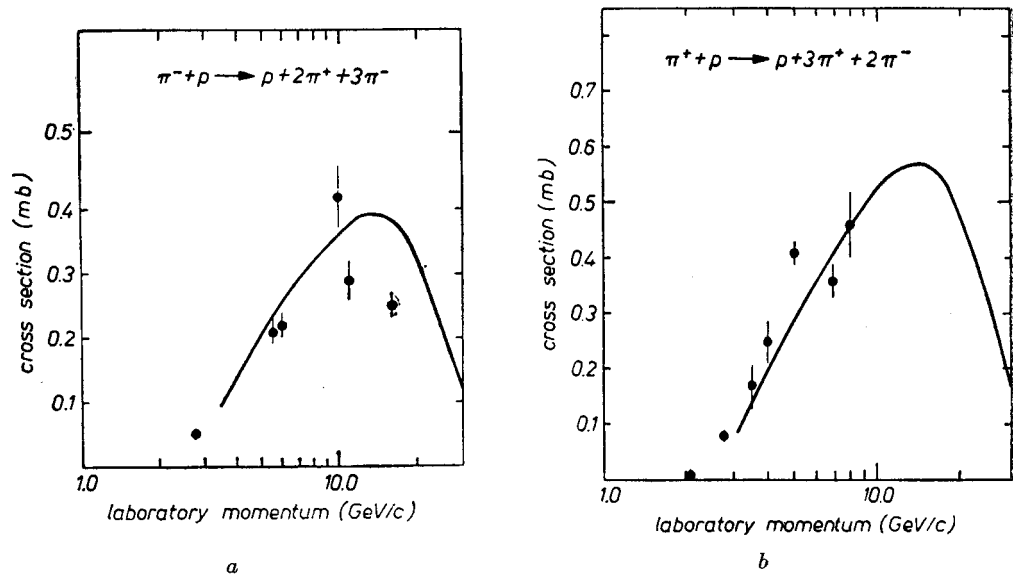


Fig. 6a, b

sections on the incident pion momentum is reproduced correctly. It should be noted that in the calculations only the normalization constants A were adjusted while all other constants entering into the matrix elements S were taken as fixed in [1] in order to describe secondary particle distributions in π - p interactions at 8 and 16 GeV/c.

The deviations of the experimental points from the calculated curves observed for some reactions in the low momentum region can be attributed to the production of resonances. This production is especially abundant in the reaction $\pi^+p \rightarrow p\pi^+\pi^+\pi^-\pi^0$ where strongest disagreement is observed (Fig. 4b). Also the maximum at 1 GeV/c in the measured cross sections for the reactions $\pi^-p \rightarrow p\pi^-\pi^0$ and $\pi^-p \rightarrow n\pi^+\pi^-$ is probably a reflection of the formation of $I = 1/2$ isobars in the mass regions 1600–1700 MeV (Figs 1a and 2a). The formation of isobars contributes also to the cross section for the reaction $\pi^+p \rightarrow p\pi^+\pi^0$ and $\pi^+p \rightarrow n\pi^+\pi^+$ as has been discussed by Galloway [4].

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APPENDIX

Compilation of inelastic $\pi^\pm$ -protons cross sections

Values of cross sections for inelastic collisions of positive and negative pions are collected in Tables I–VIII. Each table contains data for a given reaction. By a “reaction” we understand here a process with a given configuration of a nucleon and pions in the final state not taking into account short living resonances the decay of which could lead to the state considered. For example the reaction

$$\pi^+p \rightarrow p + \pi^+ + \pi^+ + \pi^- + \pi^0$$

contains also the following processes

$$\begin{array}{l} \pi^+p \rightarrow \Delta^{++}(1238) + \omega^0 \quad , \\ \quad \swarrow \quad \searrow \\ \quad p + \pi^+ \quad \pi^+\pi^-\pi^0 \\ \\ \pi^+p \rightarrow \Delta^+(1238) + \varrho^0 + \pi^+ \quad , \\ \quad \swarrow \quad \searrow \\ \quad p^+\pi^0 \quad \pi^+\pi^- \\ \\ \pi^+p \rightarrow p + B^+ \\ \quad \swarrow \\ \quad \pi^+ + \omega^0 \quad , \\ \quad \searrow \\ \quad \pi^+\pi^-\pi^0 \end{array}$$

etc.

In the present compilation all data available to the authors by January 1969 are included.

Cross sections for reaction $\pi^-p \rightarrow p\pi^-\pi^0$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.39	1.30	0.08 ± 0.13 -0.05	Blokhintseva 1963
0.43	1.32	0.13 ± 0.06	Barish 1964
0.46	1.34	0.23 ± 0.04 -0.07	Blokhintseva 1965
0.50	1.37	0.31 ± 0.07 -0.04	Barish 1964
0.58	1.42	1.22 ± 0.13	Poirier 1966
0.68	1.49	4.0 ± 0.5	Burnstein 1965
0.73	1.52	4.98 ± 0.54	Vittitoe 1964
0.77	1.54	4.65 ± 0.17	Olivier 1966
0.78	1.54	4.79 ± 0.26	Femino 1967
0.90	1.62	4.8 ± 0.3	Bertanza 1966
0.92	1.63	5.6 ± 0.5	Cason 1966
0.93	1.63	3.9 ± 0.5	Gensollen 1963
0.94	1.64	4.6 ± 0.6	Baggett 1958
0.96	1.65	5.7 ± 0.5	Cason 1966
1.00	1.67	5.4 ± 0.5	Cason 1966
1.03	1.68	5.7 ± 0.6	Gensollen 1963
1.03	1.69	6.5 ± 0.5	Pickup 1963
1.03	1.69	5.0 ± 0.7	Massimo 1964
1.09	1.72	7.1 ± 0.8	Alles-Borelli 1958
1.15	1.75	5.3 ± 1.2	Derado 1960
1.23	1.80	4.3 ± 0.3	Pickup 1963
1.59	1.97	4.48 ± 0.15	Alitti 1963
2.05	2.18	4.15 ± 0.2	Jacobs 1968
2.10	2.20	3.33 ± 0.06	West 1966
2.14	2.22	3.7 ± 0.2	Hagopian 1966
2.17	2.23	4.15 ± 0.2	Jacobs 1968
2.36	2.31	3.9 ± 0.2	Jacobs 1968
2.60	2.41	3.4 ± 0.2	Jacobs 1968
2.70	2.44	2.4 ± 0.2	Miller 1967
2.75	2.46	2.8 ± 0.1	Baton 1965
2.86	2.51	2.7 ± 0.15	Jacobs 1968
3.22	2.64	2.4 ± 0.15	Jacobs 1968
3.63	2.78	2.23 ± 0.18	Lee 1967
4.00	2.90	2.21 ± 0.10	Bondar 1964
4.16	2.95	1.88 ± 0.05	Eisner 1967
6.00	3.49	0.89 ± 0.13	Crennell 1968
8.00	3.99	0.88 ± 0.15	Allard 1967
11.00	4.64	0.7 ± 0.1	Caso 1968
16.00	5.56	0.40 ± 0.27	Honecker 1968
25.00	6.92	0.3 ± 0.1	Erwin 1968

TABLE IIa

Cross sections for reaction $\pi^- p \rightarrow n\pi^+\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.32	1.25	0.015 ± 0.003	Batusov 1965
0.33	1.26	0.027 ± 0.005	Batusov 1965
0.34	1.26	0.03 ± 0.02	Deahl 1961
0.35	1.26	0.53 ± 0.013	Batusov 1965
0.36	1.27	0.10 ± 0.04	Batusov 1960
0.36	1.27	0.125 ± 0.028	Batusov 1965
0.37	1.28	0.14 ± 0.10	Perkins 1960
0.38	1.29	0.16 ± 0.08	Batusov 1965
0.39	1.30	0.4 ± 0.2	Blokhintseva 1963
0.40	1.31	0.38 ± 0.09	Batusov 1965
0.41	1.31	0.61 ± 0.13	Batusov 1960
0.44	1.33	0.71 ± 0.17	Perkins 1960
0.46	1.34	1.5 ± 0.1	Blokhintseva 1965
0.49	1.36	2.4 ± 0.2	Barish 1964
0.49	1.36	1.93 ± 0.18	Kirz 1963
0.49	1.36	1.93 ± 0.37	Perkins 1960
0.49	1.37	2.8 ± 0.2	Barish 1964
0.54	1.40	3.3 ± 0.3	Barish 1964
0.55	1.40	3.36 ± 0.74	Perkins 1960
0.55	1.40	4.0 ± 0.2	Barish 1964
0.56	1.41	3.7 ± 0.3	Kirz 1963
0.58	1.42	3.98 ± 0.37	Poirier 1966
0.58	1.42	3.8 ± 0.4	Barish 1964
0.59	1.43	4.0 ± 0.3	Kirz 1963
0.60	1.44	5.0 ± 0.3	Kirz 1963
0.68	1.49	7.5 ± 0.8	Burnstein 1965
0.69	1.49	5.8 ± 0.5	Kirz 1963
0.73	1.52	7.87 ± 0.91	Vittitoe 1964
0.74	1.52	6.1 ± 0.4	Kirz 1963
0.77	1.54	7.14 ± 0.23	Olivier 1966
0.78	1.54	7.05 ± 0.34	Femino 1967
0.81	1.56	6.1 ± 0.6	Kirz 1963
0.90	1.62	9.8 ± 0.5	Bertanza 1966
0.92	1.63	10.1 ± 0.8	Cason 1966
0.93	1.63	8.2 ± 0.8	Gensollen 1963
0.94	1.64	11.5 ± 2.0	Baggett 1958
0.96	1.65	12.0 ± 0.9	Cason 1966
1.00	1.67	12.9 ± 1.0	Cason 1966
1.03	1.69	10.1 ± 0.9	Gensollen 1963
1.03	1.69	10.7 ± 0.6	Pickup 1963
1.15	1.75	10.4 ± 1.8	Derado 1960
1.09	1.72	8.9 ± 1.0	Alles-Borelli 1959
1.23	1.80	7.3 ± 0.6	Pickup 1963
1.59	1.97	6.45 ± 0.17	Alitti 1963

Table IIa (continued)

Incident Pion Lab.Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.70	2.03	7.35 $\pm$ 0.5	Bacon 1965
2.05	2.18	5.5 $\pm$ 0.3	Jacobs 1968
2.10	2.20	5.67 $\pm$ 0.10	West 1966
2.14	2.22	5.4 $\pm$ 0.3	Hagopian 1966
2.17	2.23	5.3 $\pm$ 0.3	Jacobs 1968
2.36	2.31	4.3 $\pm$ 0.3	Jacobs 1968
2.60	2.41	4.1 $\pm$ 0.2	Jacobs 1968
2.70	2.44	3.9 $\pm$ 0.2	Miller 1967
2.75	2.46	3.9 $\pm$ 0.1	Baton 1965
2.86	2.51	3.4 $\pm$ 0.2	Jacobs 1968
3.22	2.64	3.0 $\pm$ 0.2	Jacobs 1968
3.63	2.78	3.79 $\pm$ 0.24	Lee 1967
4.0	2.90	3.16 $\pm$ 0.13	Bondar 1964
4.16	2.95	2.85 $\pm$ 0.07	Eisner 1967
6.0	3.49	1.16 $\pm$ 0.18	Crennell 1968
8.0	3.99	1.25 $\pm$ 0.21	Allard 1967
8.0	3.99	0.96 $\pm$ 0.05	Poirier 1967
10.0	4.44	0.85 $\pm$ 0.12	Fleury 1962
11.0	4.64	0.7 $\pm$ 0.1	Caso 1968
16.0	5.56	0.8 $\pm$ 0.18	Bellini 1966
16.0	5.56	0.26 $\pm$ 0.19	Honecker 1968
25.0	6.92	0.5 $\pm$ 0.2	Erwin 1968

TABLE IIIa

Cross section for reaction $\pi^-p \rightarrow p\pi^+\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.77	1.54	0.08 $\pm$ 0.02	Olivier 1966
0.78	1.54	0.05 $\pm$ 0.02	Femino 1967
1.03	1.69	0.33 $\pm$ 0.04	Colley 1963
1.59	1.97	0.88 $\pm$ 0.04	Alitti 1963
1.89	2.11	1.58 $\pm$ 0.3	Christian 1966
2.03	2.17	1.64 $\pm$ 0.15	Carmony 1962
2.10	2.20	1.67 $\pm$ 0.08	Satterblom 1964
2.70	2.44	1.83 $\pm$ 0.05	Klein 1964
2.75	2.46	1.81 $\pm$ 0.05	Alitti 1965
3.21	2.63	1.91 $\pm$ 0.08	Chung 1968
3.63	2.78	1.68 $\pm$ 0.17	Lee 1967
		— 0.09	
3.70	2.80	1.8 $\pm$ 0.4	Ching-Chu Shen 1967
4.00	2.90	1.91 $\pm$ 0.08	Bondar 1964
4.16	2.95	1.92 $\pm$ 0.10	Chung 1968

Table IIIa (continued)

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
7.00	3.75	1.7 ± 0.2	Cason 1966
8.00	3.99	0.88 ± 0.15	Allard 1967
8.00	3.99	1.27 ± 0.07	Lamsa 1968
10.00	4.44	1.01 ± 0.21	Biswas 1964
11.0	4.64	1.14 ± 0.11	Caso 1968
13.0	5.03	1.14 ± 0.15	Ioffredo 1968
16.0	5.56	1.08 ± 0.15	Ballam 1966
16.0	5.56	0.99 ± 0.05	Honecker 1968
20.0	6.20	0.89 ± 0.08	Ioffredo 1968
25.0	6.92	0.9 ± 0.2	Erwin 1968

TABLE IVa

Cross sections for reaction $\pi^- p \rightarrow p\pi^+\pi^-\pi^0$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.03	1.69	~ 0.004	Colley 1963
1.59	1.97	0.184 ± 0.017	Alitti 1963
1.89	2.11	0.52 ± 0.14	Christian 1966
2.03	2.17	0.74 ± 0.08	Carmony 1962
2.10	2.20	1.17 ± 0.06	Satterblom 1964
2.70	2.44	1.53 ± 0.04	Klein 1964
2.75	2.46	1.44 ± 0.05	Alitti 1965
3.21	2.63	1.86 ± 0.08	Chung 1968
3.63	2.78	1.91 ± 0.14	Lee 1967
4.00	2.90	2.11 ± 0.09	Bondar 1964
4.16	2.95	2.18 ± 0.11	Chung 1968
10.00	4.44	1.77 ± 0.35	Biswas 1964
11.0	4.64	1.23 ± 0.11	Caso 1968
16.0	5.56	1.24 ± 0.15	Ballam 1966
16.0	5.56	0.70 ± 0.04	Honecker 1968
20.0	6.20	0.7 ± 0.1	Ioffredo 1968
25.0	6.92	0.7 ± 0.3	Erwin 1968

TABLE Va

Cross sections for reaction $\pi^- p \rightarrow n\pi^+\pi^+\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.03	1.69	~ 0.002	Colley 1963
1.59	1.97	0.12 ± 0.02	Alitti 1963
1.89	2.11	0.34 ± 0.11	Christian 1966
2.03	2.17	0.35 ± 0.04	Carmony 1962

Table Va (continued)

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
2.10	2.20	0.37 ± 0.02	Satterblom 1964
2.70	2.44	0.67 ± 0.02	Klein 1964
2.75	2.46	0.66 ± 0.03	Alitti 1965
3.21	2.63	0.89 ± 0.04	Chung 1968
3.63	2.78	0.92 ± 0.08	Lee 1967
4.0	2.90	1.10 ± 0.06	Bondar 1964
4.16	2.95	1.16 ± 0.06	Chung 1968
8.0	3.99	0.69 ± 0.12	Allard 1967
10.0	4.44	1.03 ± 0.24	Biswas 1964
11.0	4.64	0.71 ± 0.05	Caso 1968
16.0	5.56	0.62 ± 0.10	Ballam 1966
16.0	5.56	0.29 ± 0.02	Honecker 1968

TABLE VIa

Cross sections for reaction $\pi^-p \rightarrow p\pi^+\pi^+\pi^-\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
2.75	2.46	0.056	Alitti 1966
5.48	3.35	0.21 ± 0.02	Bomse 1967
5.97	3.48	0.22 ± 0.02	Alyea 1968
10.0	4.44	0.42 ± 0.05	Bardadin 1964
11.0	4.64	0.29 ± 0.03	Daronian 1968
16.0	5.56	0.25 ± 0.02	Honecker 1968

TABLE VIIa

Cross sections for reaction $\pi^-p \rightarrow p\pi^+\pi^+\pi^-\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
5.48	3.35	0.34 ± 0.03	Bomse 1967
5.97	3.48	0.30 ± 0.03	Alyea 1968
11.0	4.64	0.71 ± 0.07	Daronian 1968
16.0	5.56	0.55 ± 0.03	Honecker 1968

TABLE VIIIa

Cross sections for reaction $\pi^-p \rightarrow n\pi^+\pi^+\pi^-\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
5.48	3.35	0.12 ± 0.01	Bomse 1967
5.97	3.48	0.12 ± 0.03	Alyea 1968
11.0	4.64	0.30 ± 0.03	Daronian 1968
16.0	5.56	0.19 ± 0.01	Honecker 1968

TABLE Ib

Cross sections for reaction $\pi^+p \rightarrow p\pi^+\pi^0$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.42	1.32	0.11 ± 0.04	Barnes 1963
0.49	1.36	0.3 ± 0.8	Detoeuf 1964
0.55	1.40	0.1 ± 0.6	Detoeuf 1964
0.57	1.42	1.00 ± 0.13	Poirier 1966
0.63	1.45	1.8 ± 0.2	Debaisieux 1965
0.64	1.46	1.7 ± 0.8 -0.3	Willis 1959
0.65	1.47	1.3 ± 0.5	Detoeuf 1964
0.73	1.52	3.55 ± 0.53	Barloutaud 1962
0.73	1.52	3.8 ± 0.3	Newcomb 1963
0.73	1.52	3.56 ± 0.15	Chavanon 1968
0.75	1.53	3.6 ± 0.5	Heuhebaert 1962
0.80	1.56	5.5 ± 0.5	Detoeuf 1964
0.83	1.58	6.54 ± 0.17	Chavanon 1968
0.85	1.59	7.8 ± 0.5	Detoeuf 1964
0.90	1.62	9.8 ± 0.5	Detoeuf 1964
0.91	1.62	9.6 ± 0.5	Tilger 1966
0.93	1.63	8.7 ± 0.4	Chavanon 1968
0.95	1.64	10.2 ± 0.5	Detoeuf 1964
0.95	1.64	9.3 ± 0.8	Barloutaud 1963
0.98	1.66	8.7 ± 0.2	Chavanon 1968
1.00	1.67	10.2 ± 0.9	Detoeuf 1964
1.02	1.68	9.2 ± 0.2	Metzger 1967
1.03	1.69	7.5 ± 0.5	Gensollen 1963
1.03	1.69	8.6 ± 0.8	Barloutaud 1963
1.04	1.69	10.6 ± 0.4	Foelsche 1962
1.05	1.70	9.1 ± 0.9	Detoeuf 1964
1.08	1.71	8.1 ± 0.1	Chavanon 1968
1.10	1.73	8.8 ± 1.0	Detoeuf 1964
1.18	1.77	8.9 ± 0.9	Barloutaud 1963
1.20	1.78	10.1 ± 1.0	Detoeuf 1964
1.22	1.79	11.0 ± 0.3	Foelsche 1962
1.23	1.79	8.8 ± 0.2	Chavanon 1968
1.30	1.83	10.1 ± 1.3	Detoeuf 1964
1.33	1.85	12.0 ± 0.3	Chavanon 1968
1.39	1.88	12.8 ± 0.4	Foelsche 1962
1.40	1.88	10.8 ± 1.4	Detoeuf 1964
1.45	1.91	11.4 ± 0.25	Chavanon 1968
1.50	1.93	9.8 ± 1.6	Detoeuf 1964
1.60	1.98	9.2 ± 0.2	Daronian 1966
1.80	2.07	7.0 ± 0.5	Johnson 1964
2.08	2.19	5.29 ± 0.13	James 1966
2.35	2.31	4.7 ± 0.2	Alf 1966
2.75	2.46	2.79 ± 0.10	Armenise 1965

Table Ib (continued)

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
2.77	2.47	4.88 ± 0.23	Yamamoto 1968
2.90	2.52	3.6 ± 0.2	Alff 1966
3.54	2.75	2.05 ± 0.2	Abolins 1964
3.54	2.75	2.47 ± 0.08	Hoa 1966
4.0	2.90	2.31	Aderholz 1965
8.04	4.00	0.74 ± 0.06	Aderholz 1968
11.5	4.74	1.1 ± 0.2	Evans 1968

TABLE IIb

Cross sections for reaction $\pi^+p \rightarrow n\pi^+\pi^+$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.42	1.32	0.025 ± 0.018	Barnes 1963
0.48	1.36	0.12 ± 0.01	Kirz 1961
0.55	1.40	0.5 ± 0.5	Detoef 1964
0.57	1.42	0.28 ± 0.07	Poirier 1966
0.63	1.45	0.46 ± 0.10	Debaisieux 1965
0.64	1.46	1.1 ± 0.3	Willis 1959
		-0.7	
0.65	1.47	0.8 ± 0.4	Detoef 1964
0.73	1.52	0.78 ± 0.17	Barloutaud 1962
0.73	1.52	0.7 ± 0.1	Newcomb 1963
0.75	1.53	1.1 ± 0.4	Heuhebaert 1962
0.80	1.56	1.4 ± 0.3	Detoef 1964
0.85	1.59	1.8 ± 0.3	Detoef 1964
0.90	1.62	2.1 ± 0.2	Detoef 1964
0.91	1.62	2.10 ± 0.17	Tilger 1966
0.95	1.64	2.3 ± 0.2	Detoef 1964
0.95	1.64	1.9 ± 0.3	Barloutaud 1963
1.00	1.67	2.5 ± 0.2	Detoef 1964
1.02	1.68	1.9 ± 0.1	Metzger 1967
1.03	1.69	1.7 ± 0.2	Gensollen 1963
1.03	1.69	2.4 ± 0.4	Barloutaud 1963
1.04	1.69	2.5 ± 0.2	Foelsche 1962
1.05	1.70	2.5 ± 0.2	Detoef 1964
1.10	1.73	2.5 ± 0.2	Detoef 1964
1.18	1.77	2.3 ± 0.5	Barloutaud 1963
1.20	1.78	2.6 ± 0.2	Detoef 1964
1.22	1.79	2.8 ± 0.2	Foelsche 1962
1.30	1.83	3.2 ± 0.2	Detoef 1964
1.39	1.88	4.6 ± 0.3	Foelsche 1962
1.40	1.88	4.3 ± 0.2	Detoef 1964

Table IIb (continued)

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.49	1.93	4.3 $\pm$ 0.3	Fortney 1964
1.60	1.98	3.7 $\pm$ 0.1	Daronian 1966
1.80	2.07	3.0 $\pm$ 0.3	Johnson 1964
2.08	2.19	2.25 $\pm$ 0.09	James 1966
2.35	2.31	2.38 $\pm$ 0.14	Alff 1966
2.75	2.46	2.41 $\pm$ 0.15	Armenise 1965
2.77	2.47	2.59 $\pm$ 0.15	Yamamoto 1968
2.90	2.52	2.42 $\pm$ 0.14	Alff 1966
3.54	2.75	1.79 $\pm$ 0.07	Hoa 1966
3.54	2.75	1.48 $\pm$ 0.05	Abolins 1964
4.0	2.90	1.44	Aderholz 1965
6.0	3.49	0.80	Crennell 1968
8.04	4.00	0.61 $\pm$ 0.06	Aderholz 1968
11.5	4.74	0.4 $\pm$ 0.2	Evans 1968

TABLE IIIB

Cross sections for reaction $\pi^+p \rightarrow p\pi^+\pi^+\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
0.63	1.45	$\sim$ 0.02	Debaisieux 1965
0.63	1.45	$\sim$ 0.03	Willis 1959
0.91	1.62	0.43 $\pm$ 0.06	Broderick 1966
1.04	1.69	0.34 $\pm$ 0.06	Foelsche 1962
1.12	1.74	0.78 $\pm$ 0.14	Kopp 1961
1.22	1.79	1.04 $\pm$ 0.05	Foelsche 1962
1.39	1.88	2.18 $\pm$ 0.14	Foelsche 1962
1.60	1.98	3.3 $\pm$ 0.1	Daronian 1966
1.80	2.07	2.9 $\pm$ 0.2	Johnson 1964
2.08	2.19	3.40 $\pm$ 0.11	James 1966
2.34	2.31	3.44 $\pm$ 0.16	Alff 1966
2.62	2.41	3.49 $\pm$ 0.25	Alff 1966
2.75	2.46	3.60 $\pm$ 0.10	Armenise 1965
2.77	2.47	3.19 $\pm$ 0.17	Yamamoto 1965
2.90	2.52	2.95 $\pm$ 0.14	Alff 1966
3.43	2.71	3.3 $\pm$ 0.3	Abolins 1963
3.54	2.75	3.5 $\pm$ 0.2	Abolins 1963
3.65	2.79	3.85 $\pm$ 0.30	Goldhaber 1964
4.00	2.90	3.09 $\pm$ 0.1	Aderholz 1965
6.95	3.73	2.1 $\pm$ 0.2	Forman 1966
8.04	4.00	2.05 $\pm$ 0.06	Aderholz 1968
11.0	4.64	1.27 $\pm$ 0.16	Brucker 1968
11.5	4.74	1.39 $\pm$ 0.16	Evans 1968
16.00	5.56	1.28 $\pm$ 0.15	Ballam 1967
18.5	5.97	1.19 $\pm$ 0.12	Cason 1968

TABLE IVb

Cross sections for reaction $\pi^+p \rightarrow p\pi^+\pi^+\pi^-\pi^0$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.04	1.69	< 0.004	Foelsche 1962
1.22	1.79	0.074 ± 0.008	Foelsche 1962
1.39	1.88	0.220 ± 0.045	Foelsche 1962
1.60	1.98	0.5 ± 0.1	Daronian 1966
1.80	2.07	1.7 ± 0.2	Johnson 1964
2.08	2.19	2.41 ± 0.09	James 1966
2.34	2.31	3.26 ± 0.16	Alff 1966
2.62	2.41	3.86 ± 0.25	Alff 1966
2.75	2.46	3.35 ± 0.1	Armenise 1965
2.77	2.47	3.87 ± 0.21	Yamamoto 1965
2.90	2.52	3.87 ± 0.17	Alff 1966
3.43	2.71	3.7 ± 0.3	Abolins 1963
3.54	2.75	3.6 ± 0.2	Abolins 1963
3.65	2.79	4.31 ± 0.35	Goldhaber 1964
4.00	2.90	3.43 ± 0.1	Aderholz 1965
6.95	3.73	2.2 ± 0.2	Forman 1966
8.04	4.00	1.91 ± 0.08	Aderholz 1968
11.0	4.64	1.39 ± 0.16	Brucker 1968
11.5	4.74	1.8 ± 0.2	Evans 1968
16.00	5.56	1.28 ± 0.17	Ballam 1967
18.5	5.97	1.34 ± 0.18	Cason 1968

TABLE Vb

Cross sections for reaction $\pi^+p \rightarrow n\pi^+\pi^+\pi^+\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
1.6	1.98	0.07 ± 0.02	Daronian 1966
1.80	2.07	0.12 ± 0.02	Johnson 1964
2.08	2.19	0.26 ± 0.03	James 1966
2.34	2.31	0.28 ± 0.04	Alff 1966
2.62	2.41	0.39 ± 0.07	Alff 1966
2.75	2.46	0.39 ± 0.03	Armenise 1965
2.77	2.47	0.33 ± 0.03	Yamamoto 1965
2.90	2.52	0.50 ± 0.05	Alff 1966
3.43	2.71	0.98 ± 0.10	Abolins 1963
3.54	2.75	0.83 ± 0.07	Abolins 1963
3.65	2.79	0.76 ± 0.07	Goldhaber 1964
4.0	2.90	0.93 ± 0.04	Aderholz 1965
8.04	4.0	0.74 ± 0.07	Aderholz 1968
11.5	4.74	0.67 ± 0.2	Evans 1968
16.0	5.56	0.35 ± 0.10	Ballam 1967

TABLE VIIb

Cross sections for reaction $\pi^+p \rightarrow p\pi^+\pi^+\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
2.08	2.19	~ 0.01	James 1966
2.75	2.46	0.079 ± 0.010	Hamzeh 1965
3.5	2.73	0.165 ± 0.040	Carmony 1964
4.0	2.90	0.249 ± 0.036	Bondar 1966
5.0	3.21	0.41 ± 0.02	Drevermann 1967
6.95	3.73	0.36 ± 0.03	Slattery 1966
8.04	4.0	0.40 ± 0.03	Bardadin 1968

TABLE VIIIb

Cross sections for reaction $\pi^+p \rightarrow p\pi^+\pi^+\pi^-\pi^-\pi^0$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS, GeV	Cross Section mb	References
2.75	2.46	0.025 ± 0.006	Hamzeh 1965
3.5	2.73	0.104 ± 0.025	Carmony 1964
4.0	2.90	0.253 ± 0.036	Bondar 1966
5.0	3.21	0.610 ± 0.030	Drevermann 1967
6.95	3.73	0.760 ± 0.100	Slattery 1966
8.04	4.00	0.84 ± 0.06	Bardadin 1968

TABLE VIIIb

Cross sections for reaction $\pi^+p \rightarrow n\pi^+\pi^+\pi^+\pi^-\pi^-$

Incident Pion Lab. Mom., GeV/c	Total Energy in CMS GeV	Cross Section mb	References
2.75	2.46	0.004 ± 0.002	Hamzeh 1965
3.5	2.73	0.022 ± 0.007	Carmony 1964
4.0	2.90	0.040 ± 0.009	Bondar 1966
5.0	3.21	0.110 ± 0.010	Drevermann 1967
8.04	4.00	0.33 ± 0.04	Bardadin 1968

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