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MULTIPLE PRODUCTION OF NONSTABLE PARTICLES IN PION NUCLEON COLLISIONS

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The statistical theory of multiple production of pions, nucleons, nonstable particles and antiparticles in (πN) — collisions is considered by using the method described in (1), (2). The deductions of the theory may be put into agreement with the experimental data if it is assumed that "strange" and "usual" particles are produced in different space volumes.

Introduction

In papers (1), (2) it was shown that in the case of (NN)-collisions the relative multiplicity which is predicted by the statistical theory of multiple production and the charge distribution of secondary particles agree well enough with experiment when we are dealing with pions and nucleons. But it is in sharp conflict with experiment in the case of strange particles. In order to bring the aforementioned into agreement with experiment it was suggested that introduce one more parameterradius of the space-region in which the "strange" particles are "crystallized" be introduced. It should be noted that the model under consideration is essentially different from that of Lepore and Neumann, (3) where the boundary of the space region is assumed to be diffuse although identical for different kinds of particles.

In this paper the model (1), (2) is applied to the multiple production of particles in (πN) — collisions.

2. Results of Fermi-Belenky Model

In Table 1 the theoretical and experimental values of the ratio σ_{st}/σ_0 of the probability of strange particle production to the probability of inelastic pion and nucleon production under the assumption that both strange $(S \neq 0)$ and usual $(S = 0)$ particles are produced in the same space volume with a radius equal to the Compton pion wave

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length[1]. As well as in case of (NN) — collisions the theoretical value of this ratio many times exceeds its experimental value. An analogous result may be obtained also for the case in which we assume that all these particles are produced in a volume with radius of the order of the K-meson Compton wave length. Let us consider the mechanism of the multiple production of strange particles in more detail.

3. *The Results of the "Compound Particle" Model*

Because of strong the interaction in a pion-nucleon collision a "compound particle" is originally produced. The fact that the nucleon "crystallization" starts simultaneuosly with pions from a volume whose radius is $\sim (\hbar/m_\pi c)$ is also accounted for in this strong interaction. Therefore only one parameter — the volume of the "crystallization" region[2] is included into the Fermi statistical theory. Quite another situation exists for strange particles. We must consider that the pion interaction with K-mesons is considerably smaller than with the nucleons (otherwise σ_{st}/σ_0 is much greater than the experimental value, as was shown above). Owing to this the "flying away" of free K-mesons will start from a smaller region with radius of the order of the K-meson Compton wave length. Then in the statistical weight formula the Fermi space factor V_1, undergoes a change for V_2 or V_3[3].

The first case corresponds to then Schwinger and Gell-Mann hypothesis on the global pion interaction with baryons (7), the second case will occur if the pion interaction with Λ—; Σ—; Ξ — particles is considerably less than with nucleons. As can be seen from Table 2 the calculation with the weight factor V_2 $(\pi\text{-}p)$ collisions is found to be closer to experiment (10)[4]. Since most of the strange particles are produced near the threshold one would not expect good agreement with experiment from the statistical theory. However, the minimum of the ratio σ_{st}/σ_0 in the region $\sim$ 1 BeV, which is often of the statistical character, is confirmed by the experiment (10).

In Table 3 the results are given of the calculation of the relative probability of possible reactions in $(\pi^-\text{-}p)$ and $(\pi^+\text{-}p)$ — collisions with the energy $E = 5$ BeV for the case of weight factors V_2 and V_3 ($W_2\%$ and $W_3\%$ respectively). In Table 4 the corresponding results are given for $(\pi^+\text{-}p)$ and $(\pi^-\text{-}p)$ — collisions with the energy $E = 7$ BeV. In both tables the probabilities W_i are expressed in percentages. The calculations are made under the same assumptions and using the same method as in (2).

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[1] In the cross-section of elastic production σ_0 the cases of "elastic production" of only one pair (πN) are not taken into account:

$$(N\pi):\ \sigma_0 = \sum_{n=\tau} \sigma(N\cdot n\pi) + \sum_{n=0} \sigma(\overline{N}\cdot 2N\cdot n\pi)$$

[2] This fact is also reflected in the anomolous core diffusion in the nucleon.

[3] We use the notation as in (1), (2).

[4] An anologous calculation for $(p—p)$ collisions at 3 BeV gives 16% for V_1 5.7% for V_2, 0.27% for V_3. The second event is also found to be the closest to experiment $\sim 3\%$.

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In conclusion, we wish to thank Professor D. I. Blokhintsev for discussions. We are also grateful to Duan-I-Shi, V. L. Evteev and G. N. Tentyukova for assistance in the numerical calculations.

Table 1

E BeV	Theory	Experiment
0.95	24%	~4%
1.3	19%	
5.0	134%	
7.0	201%	

Table 2

E BeV	σ_{st}/σ_0	
	V_2	V_3
0.95	13%	0.6%
1.3	9%	0.4%

Table 3

Reaction	$(\pi^+ p)$			$(\pi^- p)$	
	n	W_2%	W_3%	W_2%	W_3%
$N \cdot n\pi$	1	0.614	0.681	0,722	0,818
	2	8.68	9.67	10.2	11.6
	3	32.0	35.7	30.7	34.7
	4	31.7	35.3	30.0	34.0
	5	11.1	12.4	10.0	11.3
	6	1.42	1.58	1.26	1.42
$\Lambda k \cdot n\pi$	0	0	0	0.246	0.0127
	1	1.64	0.0820	1.94	0,0984
	2	1.41	0.0696	1.66	0,0835
	3	0.531	0.0260	0.536	0.0267
$\Sigma k \cdot n\pi$	0	0.284	0,0143	0,335	0.0172
	1	2.88	0.144	3.40	0.173
	2	2.81	0.139	2.84	0.143
	3	1.02	0.0499	0.987	0.0490
$Nk\bar{k} \cdot n\pi$	0	0.0753	0.0839	0.153	0.174
	1	0.415	0.463	0.418	0.473
	2	0.253	0,282	0.252	0.286
	3	0.0223	0.0249	0.0209	0.0237

Continuation of Table 3*

		$(\pi^+ p)$		$(\pi^- p)$	
	n	$W_2\%$	$W_3\%$	$W_2\%$	$W_3\%$
$2N \cdot \bar{N} n\pi$	0	1.37	1.52	2.77	3.15
	1	1.51	1.68	1.44	1.29
$\Xi \cdot 2k \cdot n\pi$	0	0.0176	0.0^3670	0.0357	0.0^2139
	1	0.0281	0.0^2107	0.0332	0.0^2129
	2	0.0^2175	0.0^4666	0.0^2185	0.0^4716
$\Lambda \bar{\Lambda} N \cdot n\pi$	0	0	0	0.0706	0.0^2126
$\Lambda \cdot 2k\bar{k} \cdot n\pi$	0	0.0^3178	0.0^5610	0.0^3361	0.0^4126
$\Sigma \cdot 2k \cdot \bar{k} \cdot n\pi$	0	0.0^3360	0.0^4123	0.0^3424	0.0^4148

Table 4**

Reaction		$(\pi^+ p)$		$(\pi^- p)$	
	n	$W_2\%$	$W_3\%$	$W_2\%$	$W_3\%$
$N \cdot n\pi$	1	0.144	0.172	0.170	0.209
	2	3.06	3.64	3.62	4.43
	3	16.2	19.3	15.7	19.2
	4	24.8	29.4	23.5	28.7
	5	13.8	16.4	12.5	15.2
	6	3.07	3.65	2.72	3.32
	7	0.363	0.432	0.316	0.386
$\Lambda \cdot k \cdot n\pi$	0	0	0	0.0595	0.0^2334
	1	0.622	0.0332	0.734	0.0403
	2	1.49	0.0785	1.75	0.0954
	3	0.959	0.0506	0.980	0.0526
	4	0.253	0.0131	0.245	0.0133
$\Sigma k \cdot n\pi$	0	0.0691	0.0^2373	0.0815	0.0^2453
	1	1.21	0.0648	1.43	0.0788
	2	3.25	0.172	3.29	0.178
	3	1.86	0.0972	1.80	0.0967
	4	0.253	0.0131	0.234	0.0125
$Nk\bar{k} \cdot n\pi$	0	0	0	0.0276	0.0342
	1	0.305	0,362	0.321	0.393
	2	0.545	0.648	0.550	0.669
	3	0.195	0.232	0.182	0.223
	4	0.0101	0.0120	0.0^2924	0.0113

* The quantity in brackets signifies the number of zeros for example: $0.0^23 = 0.003$

** The quantity in brakets signifies the number of zeros.

Continuation of Table 4

Reaction	n	$(\pi^+ p)$ $W_2\%$	$(\pi^+ p)$ $W_3\%$	$(\pi^- p)$ $W_2\%$	$(\pi^- p)$ $W_3\%$
$2N\bar{N}\cdot n\pi$	0	1.47	1.75	2.98	3.67
	1	10.3	12.3	8.55	10.4
	2	8.81	10.5	9.91	12.1
	3	0.486	0.431	0.204	0.249
$\Xi 2k\cdot n\pi$	0	0.0^2990	0.0^3405	0.0201	0.0^3850
	1	0.0495	0.0^2202	0.0584	0.0^2245
	2	0.0239	0.0^3969	0.0253	0.0^2106
$\Lambda 2k\bar{k}n\pi$	0	0.0^3239	0.0^5873	0.0^3485	0.0^4183
	1	0.0^3104	0.0^5378	0.0^3122	0.0^5459
$\Sigma\cdot 2k\cdot\bar{k}\cdot n\pi$	0	0.0^3377	0.0^4137	0.0^3444	0.0^4167
	1	0.0^3171	0.0^5622	0.0^3181	0.0^5677
$\Lambda\bar{\Lambda}N\cdot n\pi$	0	0	0	1.05	0.0204
	1	0.844	0.0149	0.433	0.0^2719
$\Sigma\bar{\Sigma}N\cdot n\pi$	0	1.43	0.0267	1.69	0.0324
	1	0.690	0.0^2251	0.662	0.0^2295
$\Lambda\cdot\bar{\Sigma}N\cdot n\pi$	0	0.960	0.0179	1.13	0.0217
	1	0.572	0.0^2974	0.675	0.0118
$\bar{\Lambda}\cdot\Sigma N\cdot n\pi$	0	0.960	0.0179	1.13	0.0217
	1	0.572	0.0^2974	0.675	0.0118
$\bar{\Xi}\cdot 2\Lambda$	0	0	0	0.0741	0.0^4494
$\bar{\Xi}2\Sigma$	0	0.0192	0.0^4123	0.0226	0.0^4149
$\bar{\Xi}\Lambda\Sigma$	0	0.0783	0.0^4502	0.0925	0.0^4610
$\bar{\Xi}\Xi N$	0	0.130	0.0^2241	0.263	0.0^2506
$\Lambda N\bar{N}k$	0	0.0139	0.0^3732	0.0281	0.0^2154
$\bar{\Lambda}2N\bar{k}$	0	0.0^2693	0.0^3366	0.0141	0.0^3768
$\Sigma N\bar{N}k$	0	0.0157	0.0^3828	0.0185	0.0^2101
$\bar{\Sigma}2N\bar{k}$	0	0.0^2784	0.0^3414	0.0^2926	0.0^3503

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КРАТКОЕ СОДЕРЖАНИЕ

В. С. Барашенков и В. М. Мальцев, *Множественное рождение нестабильных частиц при столкновении пионов с нуклонами.*

Статистическая теория множественного рождения пионов, нуклонов, нестабильных частиц и античастиц в (πN) — столкновениях рассматривается методом, описанным в работах (1), (2). Выводы теории можно согласовать с экспериментальными данными, если предположить, что „странные" частицы и „обыкновенные" частицы рождаются в разных пространственных объёмах.

REFERENCES

1. V. S. Barashenkov, B. M. Barbashev, E. G. Bubelev, V. M. Maksimenko, *Nucl. Phys.* (in print) *GETP* (in print).
2. V. S. Barashenkov, B. M. Barbashev, E. G. Bubelec *Nuovo Cimento* (in print).
3. I. V. Lepore, M. Neumann, *Phys. Rev.* **98**, 1484, (1955).
4. S. Z. Belenky, *Nucl. Phys.* **2**, 253, (1956).
5. C. Z. Belenky, A. I. Nikishev, V. M. Maksimenko, I. L. Rosental, *Uspekhi Fis. Nauk* **62**, N 6, (1957).
6. B. M. Maksimenko, I. L. Rosental, *GETP* **32**, N 5, (1957).
7. D. I. Blokhintsev, *Uspekhi Fis. Nauk* **61**, 137, (1957).
8. Gell-Mann, *Phys. Rev.* **106**, 1296, (1957).
9. M. M. Block at al., *Phys Rev* **103**, 1484, 1956
   W. Fowler et al., *Phys. Rev.* **103**, 1489, (1956).
   Harris et al., *Phys. Rev.* **101**, 1214, (1956).
   V. Votruba, M. Danys, F. Low, *Reports about* **7** *Rochester Conference*, May 1957, Dubna.
10. S. I. Brown et al., *Bull. Amer. Phys. Soc.* **2**, N 1, 19, (1957).
    E. P. Eisler et al., *Bull. Amer. Phys. Soc.* **2**, N 2, 222, (1957).
    L. B. Leipuner et al., *Bull. Amer. Phys. Soc.* **2**, N 1, (1957).
    M. Chretien et al., *Bull. Amer. Phys. Soc.* **2**, N 1, 185, (1956).
    Fowler et al., *Phys. Rev.* **98**, 121, (1955).
    R. Budde et al., *Phys. Rev.* **103**, 1827, (1956).

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