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ABSTRACT

Predictions for $\bar{p}p$ annihilation, based on a quark model, are compared with experimental data. The model fails to give a quantitative description of the reaction.

Recently Rubinstein and Stern[1] derived predictions for nucleon-antinucleon annihilations based on a simple and interesting quark model. They assumed that in the annihilation process the three quarks and the three antiquarks that make up the initial state rearrange into three quark-antiquark pairs, i.e. three mesons.[2] They further assumed a one-to-one correspondence between the quarks in the initial and final states, including their charge, strangeness, and spin state.[3] In this note their predictions are compared with the experimental data on $\bar{p}p$ annihilations at rest.[4-10]

Prediction 1: Annihilation results in three and only three mesons.

Unfortunately only 38% of the annihilation events can be completely analyzed, and distributed among the various final states in hydrogen bubble chamber experiments.[4,9] (The remainder result in more than one unobserved neutral particle.) Of this 38%, $5 \pm 1\%$ correspond to two-meson,[5] $13 \pm 1\%$ to three-meson,[4,9,10] and $20 \pm 2\%$ to four-or-more-meson final states.[4,9] The findings are in serious disagreement with the prediction.

Prediction 2: No strange particles are produced.

Experimentally the fraction of all annihilations involving $\bar{K}K$ pairs is $6.82 \pm 0.25\%$.[8] The small rate for the associated production of strange-particle pairs, however, is a common feature of all elementary particle interactions.

Prediction 3: Because of its strange quark content, ϕ-meson production is severely limited.

Results of the Columbia experiment, as quoted in Table V of Ref. (11), give

$$\frac{\bar{p}p \to \pi^+\pi^-\phi}{\bar{p}p \to \pi^+\pi^-\omega} = 0.006 \pm 0.003,$$

in good agreement with the prediction. The same table shows, however, that a similar suppression of ϕ production exists in $\pi^{\pm}p$ interactions.[12]

Prediction 4: In Ref. (1) the annihilation products are predicted to be distributed among the various three-meson states as shown on line 2 of Table I.[13]

If we make the additional assumption that the singlet and triplet isotopic spin states contribute equally to the annihilation process, we must modify these predictions. The relative weights of the annihilation process in the available eigenstates of I^GJ^P become

$$0^+0^-: 1^-0^-: 0^-1^-: 1^+1^-: : 1/8: 1/8: 3/8: 3/8 .$$

With this plausible modification of the model we get the predictions shown on line 3 of Table I.[14] The experimental results shown on line 4 clearly disagree with either set of predictions.

To summarize, predictions 1 and 4 are not fulfilled; the agreement of the experiment with predictions 2 and 3 does not provide a strong argument for the model, since these predictions also hold true for reactions in which the assumptions of the model are inapplicable.

The overall picture indicates that the quark model in its simple intuitively appealing form used in Ref. (1) does not lead to a quantitative understanding of antiproton annihilation. A more sophisticated form will be necessary to obtain agreement with experiment.

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Table I. Distribution of final states in the reaction $\bar{p}p \rightarrow 3$ mesons.

Final state	$\pi^+\pi^-\pi^0$	$\pi^0\pi^0\pi^0$	$\rho^0\pi^+\pi^-$	$\omega\pi^+\pi^-$
Prediction of Ref. (1): % of all annihilations	8	12	25	28
Modified prediction (see text): % of all annihilations	4	6	30	24
Experiment: % of all annihilations	2.7 ± 0.7 3.5 ± 0.6 (a)	$< 3.2 \pm 0.5$ $< 3.5 \pm 0.4$ (b)	5.4 ± 0.3 (c)	3.1 ± 0.5 (c)

(a) Reference (6), (7)

(b) These values are given in References (9) and (15) respectively for annihilations with no charged prongs. They therefore constitute an upper limit for $\bar{p}p \rightarrow 3\pi^0$.

(c) References (4), (9)

REFERENCES

1. H. R. Rubenstein and H. Stern, Phys. Letters 21, 447 (1966).
2. Within the framework of the model only members of the pseudoscalar and vector meson nonets are considered quark-antiquark pairs. The term meson therefore is restricted to these objects.
3. This model was independently considered by E. Teller (Lawrence Radiation Laboratory), who calls it "quark chemistry" (private communication).
4. M. Cresti et al., Padova-Oxford collaboration; Proc. of the Sienna Int'l. Conf. on Elem. Part., Pg. 263 (1963).
5. C. Baltay et al., Columbia-Rutgers collaboration; Phys. Rev. Letters 10, 62 (1963).
6. G. B. Chadwick et al., Oxford-Padova collaboration; Phys. Rev. Letters 15, 532 (1965).
7. C. Baltay, P. Franzini, N. Gelfand, G. Lütjens, J. C. Severiens, J. Steinberger, D. Tycho, and D. Zanello, Phys. Rev. 140, B 1039 (1965), and Phys. Rev. 140, B 1042 (1965).
8. R. Armenteros et al., CERN - College de France - Ecole Polytechnique Collaboration; Proc. of the 1962 Int'l. Conf. on High Energy Phys. at CERN, Pg. 351. The quoted number depends on the assumption that annihilations leading to $K^+ K^-$, $K^- K^0$, $K^+ \overline{K^0}$, and $K^0 \overline{K^0}$ and equally probable.
9. C. Baltay, P. Franzini, G. Lütjens, J. C. Severiens, D. Tycho, and D. Zanello, Phys. Rev. 145, 1103 (1966).
10. N. Barash, L. Kirsch, D. Miller, and T. H. Tan, Phys. Rev. 145, 1095 (1966).
11. C. Baltay et al., Yale-Brookhaven collaboration, Phys. Rev. 142, 932 (1966).

12. Another recent compilation gives

$$\frac{\pi^- P \to \phi n}{\pi^+ n \to \omega p} \approx \frac{1}{50}$$

at equal c. m. momenta for the final states. R. I. Hess, Production of $K\bar{K}$ Pairs in $\pi^- p$ Interactions (Ph. D. Thesis) UCRL-16832, (in preparation).

13. In Table I we list only those channels for which experimental data are available. In Ref. (1) a more complete list of predictions is given.

14. The authors of Ref. (1) also predict that η production will be strongly limited. With the suggested modification in the model this prediction no longer holds; $\eta\pi^+\pi^-$ and $\eta\pi^0\pi^0$ become the dominant annihilation channels in the $I^G J^P = 0^+0^-$ state. Experimentally the $\eta\pi^+\pi^-$ final state is observed to account for only about 1% of all annihilations.[4,9]

15. J. G. Loken and M. Derrick, Phys. Letters 3, 334 (1963).