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NUCLEON - ANTINUCLEON ANNIHILATION AT REST

IS NOT A SIMPLE QUARK REARRANGEMENT

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A B S T R A C T

Shortcomings of the quark re-
arrangement model are exposed.

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Recently, Rubinstein and Stern ¹⁾ have proposed a quark model for nucleon-antinucleon annihilation. It consists in the assumption that the three spin one half quarks making up the nucleon and the three spin one half antiquarks making up the antinucleon rearrange themselves into three quark-antiquark $L = 0$ pairs, without annihilation or creation of pairs, and without exchanging spin, charge or hypercharge. The final state therefore contains three non-strange pseudoscalar and/or vector mesons. Because there is no simple way of treating spin-orbit coupling, the consequences of this model are most easily drawn for annihilations at rest ²⁾ in which the reaction proceeds overwhelmingly from an s state ³⁾ and the final mesons may emerge without relative angular momenta ⁴⁾.

We want to show that the predictions of quark rearrangement in the sense just described are in strong disagreement with the experimental data ⁵⁾. The model predicts that antiproton-proton annihilation at rest leads to the three-meson states given in Table I in the proportions shown ⁶⁾. The decays and the branching ratios of the resonances being known, it is straightforward to transform Table I into a set of predictions for the distributions of annihilations among the eight readily distinguishable topological categories. Table II compares this theoretical distribution with experiment. It is seen that the discrepancies are great and distributed over the whole range of multiplicities. Furthermore, the following points may be mentioned.

- 1) - The model predicts zero rate for two-body final states. If the rate for $\pi^+ \pi^-$ is indeed low, the rate for $\rho \pi$ is appreciable : $(4.3 \pm 0.6)\%$ accounting for more than half of the decays into the $\pi^+ \pi^0 \pi^-$ channel ; the agreement of the theoretical and experimental rates for the $\pi^+ \pi^0 \pi^-$ topology is therefore fortuitous.

2.

- 2) - The rate for the $3\pi^0$ channel is predicted as 11% whereas the experimental rate for all zero-prong events is $(3.2 \pm 0.5)\%$.
- 3) - The production of vector mesons in three-body states is seriously overestimated. The theoretical rates for $\omega^0 \pi^+ \pi^-$ and $\rho^0 \pi^+ \pi^-$, 24 and 26% respectively, are to be compared with the experimental figures : (3.8 ± 0.4) and $(5.8^{+0.3}_{-1.3})\%$, the 5.8% figure being in fact the total rate into four charged pions.

The quark rearrangement model has some of the basic ingredients of any future theory of $p\bar{p}$ annihilation, namely a set of weights for the various decay modes and a prescription for how phase space is to be taken into account. The extraction of the experimental consequences of this relatively simple theory meets with a number of problems which other theories will almost surely encounter as well. Accordingly, in spite of the obvious shortcomings of the quark rearrangement model in its present form, a detailed comparison of the model with experiment for annihilations at rest and in flight will be presented elsewhere ⁷⁾.

REFERENCES AND FOOTNOTES

- 1) H.R. Rubinstein and H. Stern - Phys.Letters 21, 447 (1966).
- 2) For annihilation at rest the model reproduces the U(12) predictions.
 N.P. Chang and S. Shpiz - Phys.Rev.Letters 14, 617 (1965) ;
 R. Delburgo, Y.C. Leung, M.A. Rashid and J. Strathdee - Phys.Rev. Letters 14, 609 (1965).
- 3) a) R. Armenteros, L. Montanet, D.R.O. Morrison, S. Nilsson, A. Shapira, J. Vandermeulen, Ch. d'Andlau, A. Astier, J. Ballam, G. Ghesquière, B.P. Gregory, D. Rahm. P. Rivet and F. Solmitz - Proceedings of the International Conference on High-Energy Nuclear Physics, Geneva 1962, edited by J. Prentki, CERN, 351 (1962).
 b) C. Baltay, N. Barash, P. Franzini, N. Gelfand, L. Kirsch, G. Lütjens, D. Miller, J.C. Severiens, J. Steinberger, T.H. Tan, D. Tycko and D. Zanello - Phys.Rev.Letters 15, 532, 597 (1965).
- 4) The considerations of annihilations in flight are complicated by the fact that the final states must involve angular momentum : an upper bound of 0.3 millibarns may be placed on the s wave contribution to $p\bar{p}$ annihilation at 5.7 GeV/c on the basis of a simple unitarity argument - this is less than 2% of the annihilation cross-section at this energy (22 mb).

- 5) a) C. Baltay, P. Franzini, G. Lütjens, J.C. Severiens, D. Tycko and D. Zanello - Phys.Rev. 145, 1103 (1966).
- b) M. Cresti, A. Grigoletto, S. Limentani, A. Loria, L. Peruzzo, R. Santangelo, G.B. Chadwick, W.T. Davies, M. Derrick, C.J.B. Hawkins, P.M.D. Gray, J.H. Mulvey, P.B. Jones, D. Radojicic and C.A. Wilkinson - Proc. of the Siena Conference on Elementary Particles, p. 263 (1963).

The two sets of results do not show any significant disparities. We consistently quote figures from Baltay et al. which are based on larger statistics.

- 6) Table I is the result of a recalculation according to the procedure suggested in Ref. 1). The discrepancies are of no consequence for the arguments given here.
- 7) J. Harte, R.H. Socolow and J. Vandermeulen (to be published).

- Table I -

Predicted distribution of final states
for $p\bar{p}$ annihilation at rest, in percent

$\pi^+\pi^-\pi^0$	7.4	$\pi^+\pi^-\rho^0$	25.6	$\pi^0\rho^+\rho^-$	2.9
$\pi^0\pi^0\pi^0$	11.2	$\pi^0\pi^0\rho^0$	4.7	$\pi^+\rho^0\rho^-$	1.4
$\pi^+\pi^-\eta$	1.4	$\pi^+\pi^0\rho^-$	1.0	$\pi^-\rho^0\rho^+$	1.4
$\pi^0\pi^0\eta$	0.7	$\pi^-\pi^0\rho^+$	1.0	$\pi^+\rho^-\omega^0$	1.0
$\pi^+\pi^-\chi$	1.0	$\pi^+\pi^-\omega^0$	24.0	$\pi^-\rho^-\omega^0$	1.0
$\pi^0\pi^0\chi$	0.5	$\pi^0\pi^0\omega^0$	12.2	$\pi^0\omega^0\omega^0$	0.5

- Table II -

Predicted and observed distribution of
final states among eight topological cate-
gories, for $p\bar{p}$ annihilation at rest.
The experimental percentages sum to 95.4%
the remainder being kaonic annihilations.

Category	1	2	3	4	5	6	7	8
0 prong	$\pi^+\pi^-$	$\pi^+\pi^-\pi^0$	$\pi^+\pi^-\pi^0$	$\pi^+\pi^-\chi^0$	$2\pi^+ 2\pi^-$	$2\pi^+ 2\pi^-\pi^0$	$2\pi^+ 2\pi^-\chi^0$	6 prong
Predicted (%)	12.9	0	7.4	22.3	25.6	28.5	3.1	0.1
Observed (%)	3.2 ± 0.5	0.5 ± 0.1	7.3 ± 0.9	34.8 ± 1.2	5.8 ± 0.3	18.7 ± 0.9	21.3 ± 1.1	3.8 ± 0.2