sive [de Swart, Marshak, and Signell, Nuovo cimento 6, 1189 (1957)].

[5]It is to be recalled that the Gartenhaus potential [S. Garthenhaus, Phys. Rev. 100, 900 (1955)] is based on a static-nucleon source theory so that it cannot be trusted at short distances.

[6]L. Goldfarb and D. Feldman [Phys. Rev. 88, 1099 (1952)] took over the "Thomas-Yukawa" shape of the spin-orbit potential for which K. Case and A. Pais [Phys. Rev. 80, 203 (1950)] had previously given arguments.

[7]The fit is fairly sensitive to V_0: e.g., if $V_0 = 17.7$ Mev, $\sigma(45°) = 3.75$ mb/sterad and $P(37°) = 0.19$ mb/sterad at 150 Mev. For $V_0 = 23$ Mev, $\sigma(45°) = 4.51$ mb/sterad at 150 Mev.

[8]The experimental cross-section and polarization curves are taken from Palmieri, Cormack, and Wilson, Ann. Phys. (to be published). The D curve is from A. E. Taylor (private communication).

[9]The Stapp No. 1 phase shifts [Stapp, Ypsilantis, and Metropolis, Phys. Rev. 105, 302 (1957)] yield an excellent fit of all the p-p measurements at 310 Mev.

[10]It is interesting to note that the shorter range is also preferable if one relates the spin-orbit force in nuclei to the two-nucleon spin-orbit force; for example a range of $\approx 0.7 \times 10^{-13}$cm is needed to explain the $p_{3/2} - p_{1/2}$ splitting in He^5 [J. P. Elliot (private communication)].

[11]This requires the measurement of five independent quantities [see Puzikov, Ryndin, and Smorodinski, J. Exptl. Theoret. Phys. (U.S.S.R.) 5, 489 (1957), and reference 3].

PARITY AND OTHER SYMMETRIES IN STRONG INTERACTIONS

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In recent times, the question whether the high degree of P-conservation in nuclear phenomena precludes any P-violation in strong interactions has been on many peoples minds. In this respect one has especially thought of the virtual role of the new particles in nuclear interactions. We do not as yet have the theoretical tools to tackle such problems quantitatively. However, qualitative tests have been devised[1] to check P-conservation directly in hyperon reactions. A first application[2] to

$$\pi^- + p \to \Lambda + K^0 \qquad (1)$$

yields no evidence of appreciable P-violation in this strong production reaction. Of course, this valuable information does not settle all issues quite definitely. Here we wish to comment further on this problem. Briefly the idea is the following: it has been shown previously[3] how possible deviations from invariance laws for nucleon and pion systems could be masked to a large extent if the baryon meson system can approximately be assigned a rather high symmetry, the doublet approximation (DA). In this note we shall explore the question of P-violation from the same viewpoint. This will lead to two qualitative questions which can be put to many tests.

In the DA the S-number splits[4] into two parts S_1, S_2 which are separately conserved. Thus in the DA we have one more selection rule. This added constraint forbids a small number of reactions, notably

$$\pi^+ + p \to \Sigma^+ + K^+, \ K^- + p \to \Sigma^+ + \pi^-,$$
$$\pi^- + n \to \Sigma^- + K^0, \ \bar{K}^0 + n \to \Sigma^- + \pi^+; \qquad (2)$$

but π-nucleon transitions and reactions like (1) are not forbidden. Thus as long as the DA is P-conserving[5] we have to this approximation neither P-violation in π-nucleon systems, not even due to virtual K-effects, nor in reactions like (1). But what about the reactions (2)?

As has been noted before[3,4] the very fact that the reactions (2) are so inhibited in a DA means either than a DA is just no approximation at all, or else that a "doublet perturbation" (DP) is needed to break the (S_1, S_2)-rules. What would happen if the latter alternative were true and if the DP would break the P-conservation of the DA? If the DP would only feed the channels (2) we would say that the DP leads to P-violations in those and only those reactions. But the DP may also contribute to (S_1, S_2)-allowed reactions of type (1) and may therefore add P-violating to the P-conserving contributions of the DA. Nevertheless, it seems reasonable to raise two questions.

(I) Are the production and absorption reactions which would be blocked by the (S_1, S_2)-rules[6] P-conserving to the same extent as the other channels? A marked difference would indicate that a DA is useful.

It should be emphasized that, even so, the applicability of a DA would be worse where the (Σ, Λ) mass difference can least be neglected. This is most prominently the case for Σ + nucleon $\to \Lambda$ + nucleon exchange at low Σ energies: these reactions are not forbidden by the (S_1, S_2)-rules but may be strongly distorted by the DP, just as $\pi^- + p \to \pi^0 + n$ at zero π^- momentum is not forbidden by isotopic spin but is strongly modified by electromagnetic and mass-difference effects.

The second question is mainly relevant only if a DA were to exist. In order to formulate it, we have to trace back previous arguments a few steps.

If the reactions (2) were to show appreciable P-violation, the concepts of $\Sigma\Lambda$-parity, of relative parity $p(K)$ of charged and neutral K's, and of Ξ-nucleon parity may cease to be meaningful. However, up to the DA stage they are supposed to be well defined. Even so, there remains an ambiguity in the DA, namely whether $p(K)$ is even or odd.[3] In either case one can introduce a DP which violates the separate (S_1, S_2) conservation.[7] In the present spirit it could also violate P; but we shall require CP-invariance for it.[8] Further we may require that the DP conserves the conventional isotopic spin T. If the DA comprises all couplings linear in π and K to baryons, it is easily shown for either $p(K)$, that under the stated conditions the simplest DP is of the four-baryon types; it can have the (V, A) form. The influence of the DP on nucleon-nucleon interactions is then quite short ranged, as it comes about via virtual hyperon pairs.

In a previous study of the case of odd $p(K)$ we had explored the logical alternative for the DP: the simplest interaction was considered under the explicit assumption of P-conservation.[9] This coupling had to violate isotopic spin.

For odd $p(K)$, the present alternative – T-conservation, P-violation – would largely restore the isotopic spin conservation in K^--d reactions. It is easy to see that in this way no new deviations for the branching ratios in K^- absorption can occur[10] to the extent that the charged and neutral K-couplings of the DA do not interfere. Where then lies the test for odd $p(K)$? In general the most sensitive tests lie where one compares the reaction rates involving charged and neutral K particles. First of all this occurs in the verification of the triangle inequalities in (πp)-production reactions.[3] A more decisive test comes from situations where the possible oddness of $p(K)$ could produce a clash with charge symmetry: (II) Is charge symmetry valid in the comparison of production (or absorption) rates of charged and neutral K particles? Thus one asks for a comparison of K^+ production in (π^+, X) collisions with K^0 production in (π^-, X) collisions, where X is a self-conjugate nucleus like d, He. Or one compares channel by channel the absorption of K^- and $\bar{K}^0$ (or K_2^0) on X, etc.

To recapitulate: (I) can give further guidance concerning P-conservation; (II) is addressed to the structure of a possible DA.

Finally it may be observed that the possible existence of a DA would hold out a promise that CP-invariance is the truly universal reflection principle, since it has been shown that a DA is necessary[11] for extending symmetries to K couplings of such a nature that CP-invariance leads to separate conservation of C and P. Indeed, the requirement of minimal interactions only[12] and of CP-invariance provide sufficient constraints for restricting possible P-violations to the DP in addition to the weak interactions.

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[1]V. Soloviev, Nuclear Phys. 6, 618 (1958); Drell, Frautschi, and Lockett (to be published).

[2]Crawford, Cresti, Good, Solmitz, and Stevenson, Phys. Rev. Lett. 1, 209 (1958).

[3]A. Pais, Phys. Rev. 112, 624 (1958). The invariance specifically discussed in this paper is the charge independence of π-nucleon systems.

[4]A. Pais, Phys. Rev. 110, 574 (1958). The quantum numbers S_1, S_2 mentioned below are defined in Table I of this paper.

[5]It is not impossible to formulate a DA with indefinite K-parities. But then one cannot strictly require CP-invariance to hold in the presence of all electromagnetic interactions.

[6]Also various Ξ-reactions are of this type: $\pi^- + n \to \Xi^- + 2K^0$, $\pi^+ + n \to \Xi^- + 2K^+$, $K^- + p \to \Xi^- + K^+$, etc. Note also the possibility of using $\pi^- + p \to \Sigma^- + K^0 + \pi^+$; $K^+ + p \to K^0 + p + \pi^+$; etc. for measuring up-down asymmetries in production. The importance of K-exchange scattering, forbidden by (S_1, S_2) conservation, becomes emphasized once more.[3]

[7]It is sufficient that this interaction couples charged to neutral K particles and/or N_2 to N_3 states, as defined in reference 4, Eqs. (14), (15).

[8]This guarantees a null electric dipole moment for the neutron, see L. Landau, Nuclear Phys. 3, 127 (1957). For experimental aspects see Smith, Purcell, and Ramsey, Phys. Rev. 108, 120 (1957).

[9]This is the $KK\pi$-interaction of reference 3, Sec. IV.

[10]See also reference 3, Sec. VI, remark 2.

[11]But not sufficient; further degeneracies are necessary. These questions are discussed by J. Sakurai, University of California Radiation Laboratory Report UCRL-8440 (to be published); G. Feinberg and F. Gürsey (to be published). These papers contain full

references to earlier work on CP-invariance.

[12]That is, fermion-fermion-boson interaction without derivatives. For the bearing of this condition on electromagnetism, see Ia. Zel'dovitch, J. Exptl. Theoret. Phys. (U.S.S.R.) 33, 1531 (1957) [translation: Soviet Phys. JEPT 6, 1184 (1958)].

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OPTICAL MODEL OF INELASTIC SCATTERING. T. K. Fowler [Phys. Rev. Lett. 1, 371 (1958)].

In Table I, the number in the fourth line of column 2 should be 12.5 instead of 12.6.