(111)(111) component greater than ϵ_c; (2) those in the vicinity of which the strain tensor is negligible; (3) other antimony atoms. We attribute the "new" resonance to donors of class (1) and the resonance of Wilson and Feher[3] to donors of class (2). The g factors of the donors of class (3) will form a continuous distribution and will not give rise to an observed line.

Our model explains the following features of the results of Pontinen and Sanders[1]: (1) The fact that the g values of the new resonance are exactly the same and the g tensors have the same shape as those found by Wilson and Feher[3] in strained germanium. (2) The absence of the new resonance in arsenic-doped germanium. Δ_c is about an order of magnitude smaller for an arsenic atom than for an antimony atom; consequently the critical strain ϵ_c is an order of magnitude larger. The relative volume of crystal in which the strain ϵ_c may be attained will therefore be at least one and more probably two or three orders of magnitude smaller in a crystal of comparable perfection. (3) The weaker temperature dependence of the intensity of the new resonance. The intensity of the resonance observed for antimony donors not subject to strain decreases rapidly with increasing temperature because the resonance is due to electrons in the singlet ground state of the donor[2] and electrons are thermally excited out of the singlet into the triplet ground state. In the donors subject to the saturation strain, the energy difference between the lowest state and the next higher state is considerably greater than the separation of the singlet and triplet of the unstrained donor.[4] Consequently, much larger temperatures are required to excite electrons out of the lowest state, in which they produce the observed resonance.

None of these features is explained by the models suggested by Pontinen and Sanders.[1]

According to our explanation of the new resonance the relative intensities are expected to be a structure-sensitive feature of the crystal. Thus we would not have anticipated the approximate constancy of the intensity ratio for the various samples studied by Pontinen and Sanders. The resolution of this point will require studies of the new resonance in crystals of controlled and known perfection.

[1]R. E. Pontinen and T. M. Sanders, Jr., Phys. Rev. Letters 5, 311 (1960).

[2]G. Feher, D. K. Wilson, and E. O. Gere, Phys. Rev. Letters 3, 25 (1959).

[3]D. K. Wilson and G. Feher, Bull. Am. Phys. Soc. 5, 60 (1960).

[4]P. J. Price, Phys. Rev. 104, 1223 (1956).

[5]H. Fritzsche, Phys. Rev. 115, 336 (1959); Phys. Rev. 120, 1120 (1960).

QUANTITATIVE EVIDENCE OF ONE-PION EXCHANGE EFFECTS IN p-p SCATTERING*

Peter S. Signell
Physics Department, The Pennsylvania State University, University Park, Pennsylvania
(Received September 26, 1960)

Only a short time ago it was possible to write of the (π) meson theory of nuclear forces, "On the one hand, no one seriously doubts that the meson theory is at least qualitatively correct, but on the other hand, not a single quantity has yet (1958) been calculated and measured with sufficient accuracy to constitute a convincing confirmation of its quantitative correctness."[1] Soon after that statement was published, however, the well-known work of Moravcsik and co-workers was reported,[2] in which a new kind of phase-shift analysis was performed on the 310-Mev proton-proton scattering data. The nine lowest angular momentum phase shifts were searched on: The higher angular momentum phase shifts were computed from a meson-theoretical one-quantum exchange force. The theoretical quantum-nucleon coupling constant was treated as another search parameter, while the theoretical virtual quantum mass was taken to be that of the physical π meson. Since the numerical value of the quantum-nucleon coupling constant turned out to be in the neighborhood of values obtained from analysis of experimental pion-nucleon data, also using meson theory, it was strong quantitative evidence for the theory.

The present author felt that the significance of the results in the work just described was considerably marred by the appearance of two strikingly different low angular-momentum phase-shift sets, both of which have approximately the same desirable behavior[3] under variations of the theoretical coupling constant. It seemed advisable to analyze the data further, now treating the virtual quantum mass as an additional search parameter. It was assumed that if one of the sets was correct, only that one would show a behavior similar under quantum-mass variation to the behavior observed for both sets under variations in the coupling constant. This would clear away the doubt in the coupling constant prediction as well as provide a prediction for the vii tual quantum mass. The latter, when compared with the well-known physically-measured mass of the pion, would provide another and perhaps more direct piece of quantitative evidence for this application of the theory.

The coupling constant was fixed at $g^2 = 12.0$, and 9-parameter searches were carried out, starting with sets 1 and 2 of MacGregor et al.[2] Contours of the goodness-of-fit parameter[2] χ^2 could have been determined in the g^2-quantum mass plane, but the profiles seemed sufficient in view of the results shown in Fig. 1. The two solutions exhibit an exceedingly poor behavior under variations of the quantum mass: The curves are far from parabolic and the minima are far from the physical value.

It has been recently reported[4] that a search of the 95-Mev Harvard data[5] has yielded a unique set of phase shifts. In an attempt to clarify the situation at 310 Mev, a new analysis was made of the 95-Mev data. The result of varying the coupling constant and virtual quantum mass, using a 5-parameter search, is shown in Figs. 1 and 2. The results at 95 Mev and 310 Mev are seen to be strikingly different.

The similar but poor behavior of the two 310-Mev sets in contrast to that of the 95-Mev set suggests that neither 310-Mev set is much more nearly correct than the other. That is, better 310-Mev experimental[6] data might be expected not to lead to one or the other of these, but rather to a third unique set which would have a theoretical behavior similar to that of the 95-Mev data.

We conclude that (a) the 95-Mev Harvard proton-proton scattering data sharply exclude the numerical values of the theoretical coupling constant and virtual quantum mass from being very different from the corresponding values for the real pion, thus providing quantitative evidence of the one-pion exchange force used by MacGregor et al.[2]; and (b) conclusions previously deduced from the 310-Mev data are made uncertain, probably due basically to a lack of good enough data.

The phase-shift searches reported here were

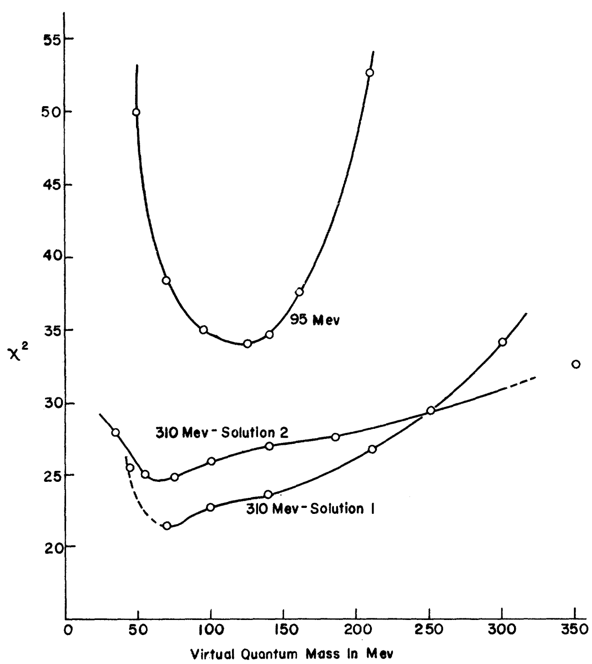

FIG. 1. The "goodness-of-fit" parameter χ^2 vs the virtual quantum mass, for the Harvard 95-Mev data and for sets 1 and 2 of MacGregor et al.[2] at 310 Mev. The 95-Mev minimum is at quantum mass ~ 125 Mev. The mass of the pion is ~ 135 Mev.

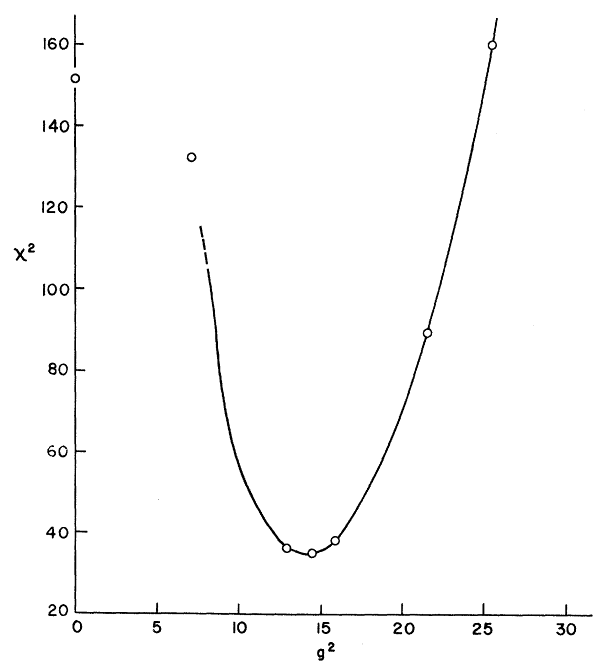

FIG. 2. χ^2 vs the quantum-nucleon coupling constant, for the Harvard 95-Mev data. The minimum is at $g^2 \sim 14$.

carried out on the IBM 704 in the U. S. Atomic Energy Commission Computation Center at New York University.

*Supported in part by the U. S. Atomic Energy Commission.

[1]R. B. Leighton, Principles of Modern Physics (McGraw-Hill Book Company, Inc., New York, 1959) p. 622.

[2]M. H. MacGregor, M. J. Moravcsik, and H. P. Stapp, Phys. Rev. 116, 1248 (1959).

[3]See reference 2, p. 1248, Fig. 1.

[4]M. H. MacGregor, M. J. Moravcsik, and H. P. Noyes, Bull. Am. Phys. Soc. 4, 268 (1960).

[5]E. H. Thorndike and T. R. Ophel, Phys. Rev. 119, 362 (1960); J. N. Palmieri, A. M. Cormack, N. F. Ramsey, and R. Wilson, Ann. Phys. 5, 229 (1958).

[6]The lower values of χ^2 for the 310-Mev sets are caused in part by the large errors assigned to the experimental data at that energy.

POSSIBLE EXISTENCE OF $\Delta Q = -\Delta S$ DECAYS

R. E. Behrends*
Brookhaven National Laboratory, Upton, New York
and Physics Department, University of Pennsylvania, Philadelphia, Pennsylvania

and

A. Sirlin†
CERN, Geneva, Switzerland
(Received October 13, 1960)

The possible existence of isotopic spin $I=3/2$ strangeness-changing currents, which lead to decays that satisfy $|\Delta S| \leq 1$ and to the $|\Delta I| = \frac{1}{2}$ rule for processes involving only strongly interacting particles, has been discussed recently.[1-3] In particular, it has been shown[1] that the quasi-conservation of the vector part of the $I=3/2$ currents in the presence of both the strong π and K interactions of the Yukawa type requires a lower symmetry of the strong couplings (the 14-parameter group $G2$) than the $I=\frac{1}{2}$ currents (the seven-dimensional rotation group). For this and other theoretical reasons,[2,3] it is worthwhile to examine in more detail the experimental implications of such currents.

As has been noted,[1] the existence of $I=3/2$ currents of strongly interacting particles which are coupled to the leptonic currents permits, but does not demand, the presence of leptonic modes of decay with $\Delta Q = -\Delta S$ (while still preserving the rule $|\Delta S| \leq 1$ for all decays). On the other hand, for pure $I=\frac{1}{2}$ currents, these decays are forbidden.

It follows from the existence of the K_{l2} decay that $I=\frac{1}{2}$ currents must be present in the space-time vector and/or axial vector part. For example, if the K were pseudoscalar (scalar), K_{l2} could occur through the axial vector (vector) part. However, this still allows one of the space-time parts to be composed of dominant, or even possibly "pure" $I=3/2$ currents through which the K_{l3} modes of decay could proceed. As the predictions of pure $I=\frac{1}{2}$ currents on the K_{l3} decays have been already given,[4] we will now examine the other "pure" case; namely, the possibility that the space-time part governing these decays consists of pure or dominant $I=3/2$ currents. It is the purpose of this note to discuss the implications of such an assumption with regard to the $\Delta Q = -\Delta S$ modes of decay. We shall also assume time-reversal invariance.

Let us consider the K_{l3} decays. The first interesting consequence is that we can obtain exact lower and upper bounds for the $\Delta Q = -\Delta S$ decays $K^0 \to \pi^+ + l^- + \nu$ in terms of observed lifetimes. For "pure" $I=3/2$ currents, neglecting electromagnetic effects, we obtain

$$\sqrt{2}M(K^0 \to \pi^- + l^+ + \nu) = -M(K^+ \to \pi^0 + l^+ + \nu). \quad (1)$$

By using Eq. (1) and the relation $K_2{}^0 = (K^0 - \bar{K}^0)/\sqrt{2}$, we get the following triangular inequalities for the total rates R:

$$R^{1/2}(\bar{K}^0 \to \pi^- + l^+ + \nu) + \frac{1}{\sqrt{2}}R^{1/2}(K^+ \to \pi^0 + l^+ + \nu) \geq \sqrt{2}R^{1/2}(K_2{}^0 \to \pi^- + l^+ + \nu), \quad (2)$$

and cyclically. These inequalities hold exactly for the e^+ and μ^+ modes and for the total rates for positive leptons, electron plus muon. The TCP theorem tells us that $R(\bar{K}^0 \to \pi^- + l^+ + \nu) = R(K^0 \to \pi^+ + l^- + \nu)$ and CP invariance implies