A SPURION MODEL OF THE Ξ-PARTICLE

H. P. Dürr

Max-Planck-Institut für Physik und Astrophysik, München

J. Géhéniau

Université Libre de Bruxelles, Bruxelles

(presented by H. P. Dürr)

In the nonlinear theory of elementary particles by Heisenberg and co-workers it was suggested that the observed deviations from the isotopic spin symmetry in the interactions of elementary particles may result from a degeneracy of the vacuum with respect to isotopic spin. The vacuum in this formalism can be imagined as an infinite Lorentz, CPT and GP invariant sea of spurions and antispurions which, in particular, carry isotopic spin $\frac{1}{2}$ and have certain parity properties. Strange particles then may occur in such a theory in the form of fermions which are closely coupled to one or more of these spurions of the vacuum.

To test this hypothesis about the vacuum, especially with respect to its group theoretical assumptions on the spurions, a nucleon Dirac equation was studied which was modified through the addition of nucleon-spurion interaction terms which are possible under the stated symmetry requirements. The model leads to definite predictions as to the existence and mass sequence of possible strange particle states, and their relative intrinsic parities.

The nucleon-one-spurion solutions are identical with the solutions studied earlier by Dürr and Heisenberg, and correspond to the baryons of strangeness one. They are characterized by two—in this phenomenological treatment arbitrary—coupling parameters α and η which are related to the Λ-N- and the Σ-Λ-mass splitting, respectively. The nucleon-two-spurion solutions can be related to particles of strangeness two (Ξ-type solutions). They consist of an isodoublet as a lowest state (with even parity, by definition) which is identified with the Ξ-particle; two heavier isoquartets (with even and odd parity, respectively), and a still heavier isodoublet (with odd parity). All particles have Dirac spin $\frac{1}{2}$.

The masses of the various nucleon-two-spurion states depend only on the coupling parameters α and η, if the mass of the Ξ is known. The mass ratio m_Ξ/m_N however, contains a constant N which depends on the spurion-spurion interaction.

If one assumes that the coupling parameter can be approximated by constants and be fixed so as to give the correct Λ and Σ mass, and that the spurion-spurion interaction is the same as the nucleon-spurion interaction, then the masses of the Ξs can be calculated. The Ξ gets a mass which is about 15% above the experimental value.

DISCUSSION

MARSHAK: It looks as if the package of opposite parity for Λ and Σ and spin $^1/_2$ for Y_1 might not be correct. The experimental evidence seems to go the other way. What can you do in that case?

DÜRR: Then we can throw the whole thing away. The whole group theoretical basis has to be changed to make the Λ-Σ parity even. If we have a particle with spin $^1/_2$, let's say a nucleon, then a whole family of other particles exist which are one-spurion and two-spurion states. Now of course one can do the same thing with, let's say, a particle of spin $^3/_2$; one can bind one-spurion and two-spurions to it and then find out where the other spin $^3/_2$ levels lie. But of course we need a particle with spin $^1/_2$, an isotopic triplet. It may not be Y_1^*, but somewhere it has to be, and it has to show up with lower mass than the Λ^* ($\tau = 0$, spin $^1/_2$).

Nambu: I ask Professor Heisenberg, is there another particle coupled with the form $^1/_2\ (\tau_3 - \Lambda_3)$ to the baryons?

Heisenberg: This other particle would, if it existed, probably have a finite rest mass and therefore not contribute to electrodynamics.

Nambu: Is the electromagnetic charge universal?

Heisenberg: You can only get integer multiples of the unit charge, which is the same for all types of particle.

Van Hove: You have often stressed the analogy between the isospin carrying groundstate of your theory and the groundstate of a ferromagnet. In a ferromagnet there are spin waves which must be regarded as excitations of mass zero. Are there analogous " isospin waves " of mass zero in your theory, and, if so, what is their role?

Heisenberg: I think one main difference is that the isospin particles (the spurions) have no Lorentz properties, no position and no momentum. So the analogy is not complete. One could of course say that we attach spurions to particles as one can attach spin waves to electrons. Perhaps we can turn it round. I could imagine that even in a ferromagnet there are electron excitations with spin one instead of one half. This would be quite natural because already in the Ca atom we have, so to speak, an electron of spin one.

Blokhintsev: I ask Prof. Dürr, how many parameters do you use to fit the experimental data for the masses of the baryons?

Dürr: We start out assuming that there exists a nucleon and introduce the nucleon mass as the basis. In the one-spurion equation two parameters enter. These two parameters may be fixed in such a way as to reproduce the Λ and Σ masses. This allows us to predict the masses of two other particles. In the two-spurion case the addition of essentially one new parameter fixes all the levels because the parameters in the two-spurion case are related to those in the one-spurion case. This new parameter N contains the unknown spurion-spurion interaction. We may fix it by the Ξ mass and predict the three higher levels. That would be in the ideal situation that the parameters do not depend on the momentum squared, which of course I do not know to be so.

Källén: I should like to ask Professor Heisenberg: In 1957 or 1958 there was another paper in which you also beautifully explained electromagnetism. Would you comment on the differences and similarities of these two papers? And, in particular, on why the last one is more reliable than the first?

Heisenberg: The first theory used a model not containing the isospin group. Later on, Pauli and I found a similar, very simple, equation which did contain the isospin group. The calculations were now repeated with the new equation. Since the two equations were very similar, with regard to the Lorentz group, the Lorentz part of the old paper is very similar to the Lorentz part of the new. The isospin part is now, of course, entirely different.

Källén: If I remember correctly, you were at the time prepared to take the old calculation rather seriously. In particular you computed the electromagnetic charge, from a Tamm-Dancoff approximation, and got fairly close to 1/137. Do you now imply that the value of the electric charge is mainly connected with the Lorentz group?

Heisenberg: I think that the value could easily change by a factor two or four, but I have not done the calculation. The order of magnitude should be more or less the same; in the old calculation the value has been roughly 1/250. However, the Tamm-Dancoff method is very probably unreliable for the value of the coupling constant, whereas the mass-eigenvalues should come out with better accuracy, estimated in the first paper at roughly $\pm 15\%$. I do not hope for quick and good results on coupling constants.

Källén: Would you then accept that the qualitative agreement between the result of a Tamm-Dancoff calculation and the data is not absolute evidence for the correctness of the underlying physical idea?

Heisenberg: The Tamm-Dancoff approximation can never prove anything about the mathematical correctness or incorrectness of a theory. If the theory is mathematically a sensible theory, and not a divergent theory (which of course would not make any sense at all) then one can hope that the Tamm-Dancoff method gives reasonable results. We know that this is so, e.g. for superconductivity and for the anharmonic oscillator. If a Tamm-Dancoff approximation predicts mass eigenvalues which are later on found experimentally, I would consider this as supporting the underlying ideas. But of course such agreement might also be accidental.