CHIRAL THEORY OF NUCLEONS

D. I. Diakonov, V. Yu. Petrov, P. V. Pobylitsa

Several years ago it became clear that the spontaneous chiral symmetry breaking in QCD is of paramount importance to see how nucleons are 'built'. The mere fact that nucleons are rather heavy and that they are not degenerate with partners in parity (N*, 1535) demonstrates this very clearly /1/. The chiral theory of nucleons is a dynamical theory which emphasises exactly the spontaneous chiral symmetry breaking (SCSB).

At low energies two degrees of freedom remain significant in the strong interactions: quarks which obtained a dynamical mass $\sim$300 MeV due to the SCSB, and the pion field interacting with quarks /2/. (Similarly, in the 'low energy' solid state physics the essential degrees of freedom are electrons with an effective mass, and phonons). The nucleon in our approach can be viewed as a bound state of three quarks — bound by a self-consistent pion field. The quantum numbers (spin, isospin, strangeness) are determined by the quantization of the fluctuations of the self-consistent field.

It is interesting that the energy of the pion field coincides with the aggregate energy of the Dirac sea of quarks, i. e. of quarks with negative energies. Therefore, the nucleon's properties are determined not only by the three 'valence' quarks but also by the Dirac sea. (In the presence of the three valence quarks the sea naturally differs from the free one). For example, the nucleon mass ($\sim$1 GeV) is build up in the following way: about 2/3 of the original dynamical quark mass is 'eaten up' because the quarks are in a deep potential well which is due to the pion field, so that the valence quarks contribute around 300 MeV. The remaining $\sim$700 MeV are needed to create such a pion field that binds the valence quarks. Simultaneously, these $\sim$700 MeV is the shift of the aggregate energy of the Dirac sea in respect to the free vacuum. The shift is due to the presence of three valence quarks.

Using the suggested chiral theory, we have first calculated the mass and other characteristics of nucleons: the axial constant g_A, the pion interaction constant $g_{\pi NN}$ and $g_{\pi N\Delta}$, the magnetic moments, the electric formfactor, the splitting of N and Δ /3/, the nucleon σ term /4/. All the calculated quantities coincide with the experimental data within 10%. Then a double-strange dibaryon state (dilambda) was investigated /5/. We predict the mass to be 2300—2400 MeV. It is interesting that the state is nearly degenerate in P-parity, its decay width being of the same magnitude as the parity splitting.

Finally let us mention that the chiral theory of nucleons suggests new concepts to nuclear physics as well. In ref. /6/ a new condensed phase of nuclear matter has been investigated: Fermi solid or Fermi liquid state with a short-range order. Probably at high densities such a phase is energetically preferable as compared to the ordinary nuclear matter.

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